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Budker Institute of Nuclear Physics

Book of Abstracts
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Timing detectors / 0

High precision time measurements in future experiments
Dr. VA'VRA, Jerry

1 SLAC

New experiments are attempting to measure time together with position. The aim is to reach single photon timing resolution at a level of 100ps for RICH detectors and 20-30ps for minimum ionizing particles in TOF detectors. The talk discusses present limits and judges what is realistically achievable. Detector examples discussed use of MRPCs, MCP-PMTs, Diamond detectors, SiPMTs, Low and high gain Avalanche diodes (LGADs) and Micromegas. We specifically discuss issues such as single pixel vs. multi-pixel tests, small test vs. large physics system results and hidden problems people usually do not want to talk about.

Electronics, Trigger and Data Acquisition / 2

Development of the ATLAS Liquid Argon Calorimeter Read-out Electronics for the HL-LHC
LIQUID ARGON CALORIMETER, Group

1 ATLAS

To meet new TDAQ buffering requirements and withstand the high expected radiation doses at the high-luminosity LHC, the ATLAS Liquid Argon Calorimeter readout electronics will be upgraded. The triangular calorimeter signals are amplified and shaped by analogue electronics over a dynamic range of 16 bits, with low noise and excellent linearity. Developments of low-power preamplifiers and shapers to meet these requirements are ongoing in 130nm CMOS technology. In order to digitize the analogue signals on two gains after shaping, a radiation-hard, low-power 40 MHz 14-bit ADCs is developed using a pipeline+SAR architecture in 65 nm CMOS. Characterization of the prototypes of the frontend components show good promise to fulfill all the requirements. The signals will be sent at 40MHz to the off-detector electronics, where FPGAs connected through high-speed links will perform energy and time reconstruction through the application of corrections and digital filtering. Reduced data are sent with low latency to the first level trigger, while the full data are buffered until the reception of trigger accept signals. The data-processing, control and timing functions will be realized by dedicated boards connected through ATCA crates. Results of tests of prototypes of front-end components will be presented, along with design studies on the performance of the off-detector readout system.

Calorimetry / 3

ATLAS LAr Calorimeter Performance in LHC Run-2
LIQUID ARGON CALORIMETER, group ; Mr. MAHON, Devin

1 ATLAS
2 Columbia University

Liquid argon (LAr) sampling calorimeters are employed by ATLAS for all electromagnetic calorimetry in the pseudo-rapidity region \( |\eta| < 3.2 \), and for hadronic and forward calorimetry in the region from \( |\eta| = 1.5 \) to \( |\eta| = 4.9 \). In the first LHC run a total luminosity of 27 fb\(^{-1}\) has been collected at center-of-mass energies of 7-8 TeV. After detector consolidation during a long shutdown, Run-2 started in 2015 and about 150fb-1 of data at a center-of-mass energy of 13 TeV have been recorded.

In order to realize the level-1 acceptance rate of 100 kHz in Run-2 data taking, the number of read-out samples recorded and used for the energy and the time measurement has been modified from five to four while keeping the expected performance.

The well calibrated and highly granular LAr Calorimeter reached its design values both in energy measurement as well as in direction resolution.
This contribution will give an overview of the detector operation, hardware improvements, changes in the monitoring and data quality procedures, to cope with increased pileup, as well as the achieved performance, including the calibration and stability of the electromagnetic scale, noise level, response uniformity and time resolution.

Electronics, Trigger and Data Acquisition / 4

The Phase-I Trigger Readout Electronics Upgrade of the ATLAS Liquid Argon Calorimeters

LIQUID ARGON CALORIMETER, group\(^1\) ; Mr. FORTIN, Etienne\(^2\)

\(^1\) ATLAS
\(^2\) CPPM

Electronics developments are pursued for the trigger readout of the ATLAS Liquid-Argon Calorimeter towards the Phase-I upgrade scheduled in the LHC shut-down period of 2019-2020. Trigger signals with higher spatial granularity and higher precision are needed in order to improve the identification efficiencies of electrons, photons, tau, jets and missing energy, at high background rejection rates, already at the Level-1 trigger. The LAr Trigger Digitizer system will digitize the 34,000 channels (SuperCells) at a 40 MHz sampling frequency with 12 bit precision after the bipolar shaping of the front-end system. The data will be transmitted to the LAr Digital Processing system in the back-end to extract the transverse energies and perform the bunch-crossing identification. A demonstrator has been installed during Run-2, and the results of the data-taking have helped to validate the chosen technology. Results of ASIC developments including QA/QC and radiation hardness evaluations, performance of the pre-production boards, results of the system integration tests, QA/QC test of final production boards will be presented along with the overall system design and status of the installation and commissioning.

Timing detectors / 5

A High-Granularity Timing Detector for the Phase-II upgrade of the ATLAS Calorimeter system: detector concept, description and R&D and beam test results

Dr. CASTILLO GARCIA, Lucia\(^1\)

\(^1\) Institut de Fisica d’Altes Energies (IFAE)

The increase of the particle flux (pile-up) at the HL-LHC with luminosities of \(L \simeq 7.5 \times 10^{34}\) cm\(^{-2}\)s\(^{-1}\) will have a severe impact on the ATLAS detector reconstruction and trigger performance. The end-cap and forward region where the liquid Argon calorimeter has coarser granularity and the inner tracker has poorer momentum resolution will be particularly affected. A High Granularity Timing Detector (HGTD) is proposed in front of the LAr end-cap calorimeters for pile-up mitigation and for luminosity measurement.

It will cover the pseudo-rapidity range from 2.4 to 4.0. Two Silicon sensors double sided layers will provide precision timing information for MIPs with a resolution better than 30 ps per track in order to assign each particle to the correct vertex. Readout cells have a size of 1.3 mm \(\times\) 1.3 mm, leading to a highly granular detector with 3 millions of channels. Low Gain Avalanche Detectors (LGAD) technology has been chosen as it provides enough gain to reach the large signal over noise ratio needed.

The requirements and overall specifications of the HGTD will be presented as well as the technical proposal. LGAD R&D campaigns are carried out to study the sensors, the related ASICs, and the radiation hardness. Laboratory and test beam results will be presented.

Tracking and vertex detectors / 6

Silicon pixel-detector R&D for CLIC
The physics aims at the proposed future CLIC high-energy linear e-e+ collider pose challenging demands on the performance of the detector system. Precise hit-time tagging with ~5 ns resolution is required for the vertex and tracking detectors, to mitigate the impact of beam-induced background on the measurement accuracy. Moreover, a low mass of ~0.2% X0 per layer for the vertex and ~1% X0 per layer for the tracker is needed, combined with a single-plane spatial resolution of a few micrometers. To address these requirements, an all-silicon vertex and tracking system is foreseen at CLIC. To this end, a broad R&D program on new silicon detector technologies is being pursued. For the ultra-light vertex detector, different small pitch (25 um) hybrid technologies with innovative sensor concepts are explored. A dedicated 65 nm readout chip (CLICpix2) has been developed and interconnected via fine pitch bump-bonding to thin planar sensors. Furthermore, alternative interconnects such as bonding using anisotropic conductive films (ACF) are explored. Various Silicon On Insulator (SOI) test chips are also under study. For the large-scale silicon tracker, fully monolithic CMOS technologies are considered. CMOS sensors with a large collection electrode have been extensively studied in various test-beam campaigns. Based on 3D TCAD simulations and previous test results, innovative concepts for CMOS sensors with a small collection electrode have been developed and implemented in various prototype chips targeting CLIC and other future projects. The CLICTD tracker prototype chip has recently been produced using two variants of a modified 180 nm CMOS process with a high-resistivity epitaxial layer. The design includes an innovative sub-pixel segmentation scheme and first samples are currently under evaluation. To predict and further optimise the performance of the various prototype technologies, a fast and versatile Monte Carlo Simulation Tool (Allpix-Squared) has been developed. This contribution gives an overview of the R&D program for the CLIC vertex and tracking system, highlighting new results from measurements and simulations of recent prototypes.

Particle Identification / 7

Identification of ultrahigh energy extensive air showers with Taiga-Muon installation

Author(s): Mr. VAIDYANATHAN, Arun1
Co-author(s): Dr. KRAVCHENKO, Evgeniy 2

1 PhD Student
2 BINP/NSU

The TAIGA astroparticle observatory is under the construction at Tunka valley close to the Baikal Lake. Up to now it consists of 2 imaging air Cherenkov telescopes, about 100 wide-angle optical detectors, and 19 stations with 342 scintillation detectors. In 2019, the existing system of scintillation detector stations was extended with 3 stations of the new type Taiga-Muon counters. Each station contains 16 counters, with 8 surface and 8 underground counters. The counter and station positioning has been studied using specially developed Monte Carlo simulation program based on of CORSIKA and GEANT4 software packages. This simulation study is concentrated on the ultrahigh energy extensive air showers (EAS) induced by gamma-quanta or proton in the range from 1 PeV to 10 PeV and zenith angle ranging 00 - 450. The simulation results are analyzed with the help of neural network. For this work, a set of air showers was created by CORSIKA. The list of useful secondary particles at the ground level is produced using the COAST library package. The interaction of secondary particles with the soil and detectors was simulated with GEANT4 package. It is known, that the lateral distributions of particle density in gamma-quanta and proton EAS are different at the ground level. Also the density of muons is different. To use both these characteristics for separation of gamma-quanta from proton we suggest using a neural network. The method called binary cross entropy was studied. Amplitudes in surface and underground counters of each station were given as input data. The air shower having energy ranging 2.25 - 3.5 PeV shows more than 90% of identification efficiency for proton by keeping identification efficiency of gamma around 50%.
Calorimetry / 8

CMS ECAL monitoring and its upgrade for High-Luminosity LHC

Mr. OVTIN, Ivan

1 NSU, BINP

The Compact Muon Solenoid (CMS) detector is a large general-purpose detector at the Large Hadron Collider (LHC). The Electromagnetic Calorimeter (ECAL) is an important part of CMS to accurately measure the energies of electrons and photons. The ECAL is made of 75848 lead-tungstate (PbWO4) scintillating crystals. The ECAL response changes over time mainly because of crystal transparency variations due to radiation damage and recovery. The laser monitoring system is designed to measure the transparency changes for each ECAL crystal over time. High-Luminosity running at the LHC, which is planned for 2025 and beyond, will imply an order of magnitude increase in radiation levels and particle fluences with respect to the present LHC running conditions. The mitigation of aging is an important goal for the upgrade of the laser light monitoring system. This talk describes the evolution the transparency of the ECAL crystals in Run 2 data, the components of the ECAL monitoring system, and its proposed upgrade.

Poster Session - Board: 69 / 9

The phase-1 upgrade of the ATLAS level-1 calorimeter trigger

Dr. SHAW, Savanna

1 University of Manchester

The ATLAS level-1 calorimeter trigger (L1Calo) is a hardware-based system that identifies events containing calorimeter-based physics objects, including electrons, photons, taus, jets, and missing transverse energy. In preparation for Run 3, when the LHC will run at higher energy and instantaneous luminosity, L1Calo is currently implementing a significant programme of planned upgrades. The existing hardware will be replaced by a new system of feature extractor (FEX) modules, which will process finer-granularity information from the calorimeters and execute more sophisticated algorithms to identify physics objects; these upgrades will permit better performance in a challenging high-luminosity and high-pileup environment. This talk will introduce the features of the upgraded L1Calo system and the plans for production, installation, and commissioning. In addition, the expected performance of L1Calo in Run 3 will be discussed.

Electronics, Trigger and Data Acquisition / 10

The ATLAS Electron and Photon Trigger Performance in Run 2

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ATLAS electron and photon triggers covering transverse energies from 5 GeV to several TeV are essential to record signals for a wide variety of physics: from Standard Model processes to searches for new phenomena in both proton-proton and heavy ion collisions. Main triggers used during Run 2 (2015-2018) for those physics studies were a single-electron trigger with ET threshold around 25 GeV and a diphoton trigger with thresholds at 25 and 35 GeV. Relying on those simple, general-purpose triggers is seen as a more robust trigger strategy, at a cost of slightly higher trigger output rates, than to use a large number of analysis-specific triggers. To cope with ever-increasing luminosity and more challenging pile-up conditions at the LHC, the trigger selections needed to be optimized to control the rates and keep efficiencies high. The ATLAS electron and photon performance during Run-2 data-taking is presented as well as work ongoing to prepare to even higher luminosity of Run 3 (2021-2023).
TAIGA - an advanced hybrid detector complex for astroparticle physics and high energy gamma-ray astronomy in the Tunka valley.

Prof. BUDNEV, Nikolay

1 Irkutsk State University

The physics motivations and advantages of the new TAIGA (Tunka Advanced Instrument for cosmic ray physics and Gamma Astronomy) array are presented. TAIGA aims to address gamma-ray astronomy at energies from a few TeV to several PeV, cosmic ray physics from 100 TeV to several EeV, as well as for search for axion-like particles, Lorentz violations and another evidence of New Physics. In 2020 year a one square kilometer TAIGA setup should be put in operation. It will consist of a Cherenkov timing array TAIGA-HiSCORE with the 120 wide angle detectors distributed on area 1 km$^2$ about with spacing 106 m, three a 4-m class Imaging Atmospheric Cherenkov Telescopes of a TAIGA-IACT array of FoV of 10x10 in the vertexes of triangle with sides 300 x 400 x 500 m about as well TAIGA-Muon and Tunka-Grande scintillation arrays.

Tracking and vertex detectors / 12

Novel focal plane detector concepts for the NSCL/FRIB S800 spectrometer

Dr. CORTESI, Marco

1 NSCL

The NSCL/FRIB S800 superconducting spectrograph is used for studying nuclear reaction induced by high-energy radioactive beams. The spectrometer was designed for high-precision measurements of small scattering angles (within ±2 mrad), combined to large acceptance of the solid angle (20 mrad) and momentum (6%). The high-resolution (1/10,000) is optimized for energies up to 200 MeV/u. The S800 has been an indispensable apparatus for the wide physics program of the NSCL with fast rare isotope beams, being the most heavily-used experimental device at NSCL. The S800 spectrograph will continuous to serve the nuclear physics/astrophysics community for experiments with rare isotope beams also during FRIB operation. A crucial component for the performance of the S800 spectrometer is the focal plane detector system, which consists of an array of various detector technologies for trajectory reconstruction as well as particle identification (PID). This includes two x/y drift chambers for tracking, an ionization chamber for atomic number identification by energy loss measurement, and a plastic scintillator for timing (as well as energy loss). Downstream the plastic scintillator, a CsI(Na) hodoscope is deployed to identify atomic charge states of the implanted nuclei via total kinetic energy (TKE) measurement. In this work, the operational mechanism and performance of a novel detector concepts planned for the upgrade of the S800 focal plane are described for the first time. In particular, we will present the design of the new drift chamber (DC) readout based on a hybrid Micro-Pattern Gaseous Detector structure. Performance evaluations under irradiation with small lab source (5.6 MeV alpha–particle emitted by an Am-241 source) as well as with test heavy-ion beams will be presented and discussed in detail. In the latter case we the detector was irradiated by a 78Kr+ beam at around 150 MeV/u, as well as by a heavy ion fragmentation cocktail produced by the 78Kr beam impinging on a Be target. In addition, we will present the development of a heavy-ion particle identification (PID) device based on an energy-loss measurement (ΔE) within a novel optical scintillation scheme. The new instrument consists of a multi-segmented optical detector (OD) filled with high-luminescence yield gas (e.g. pure Xenon). Its operational principle is based on recording the fast scintillation light emitted along an ion’s track. This developing technology allows for high-resolution ΔE measurements at high counting rate, unlike traditional ionization chambers. Both high energy resolution and high counting rate capabilities are needed to take full advantage of the future FRIB’s rare-isotope beam portfolio and anticipated high intensity. The proposed detector presents a significant advance in both instrumentation and capabilities in the field of experimental nuclear physics, providing new opportunities for experiments with rare isotope beams.
Calorimetry / 13

Performance of the ATLAS Tile Calorimeter

TILE CALORIMETER SPEAKERS COMMITTEE, on behalf

1 Tile Calorimeter

The Tile Calorimeter (TileCal) is a sampling hadronic calorimeter covering the central region of the ATLAS experiment, with steel as absorber and plastic scintillators as active medium. The scintillators are read out by wavelength shifting fibres to photomultiplier tubes (PMTs) at the back of each wedge-shaped calorimeter module. The analogue signals from the PMTs are amplified, shaped, and digitised on the detector every 25 ns, and stored on detector in digital pipeline buffers until a trigger decision is received. The data are then read out to the off-detector systems for further processing.

TileCal employs several calibration systems that, together with the collected collision data, provide the basis for response equalisation and monitoring at each stage of the readout path; from scintillation light production to energy and time reconstruction. Furthermore, the calorimeter performance has been established with large samples of proton-proton collision data during LHC Run 1 and Run 2. The high-momentum isolated muons have been used to study and validate the electromagnetic scale, while hadronic response has been probed with isolated hadrons. The calorimeter time resolution has been studied with multi-jet events.

We present and summarise results of the calorimeter calibration and performance.

Timing detectors / 15

The MIP Timing Detector for the CMS Phase II Upgrade

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The Compact Muon Solenoid (CMS) detector at the CERN Large Hadron Collider (LHC) is undergoing an extensive Phase-II upgrade program to cope with the challenging conditions of the future High-Luminosity LHC (HL-LHC). There will be a significant increase in the expected number of simultaneously occurring, separate events (pile-up) at the HL-LHC. The new CMS timing detector will enable us to measure minimum ionizing particles (MIP) with a time resolution of 30-50 ps with a hermetic coverage up to a pseudo-rapidity of $|\eta|=3$ during its lifetime. Such a high precision timing information will be used to mitigate the impact of the pile-up events by employing four dimensional reconstruction algorithms. It will also extend the physics reach of the detector by enabling searches for the long-lived particles predicted in different beyond the Standard Model scenarios. The MIP timing detector consists of a single layer LYSO crystals readout with SiPMs in the central region (barrel) and two Low Gain Avalanche Diode detector layers in both end-caps of the CMS detector. This talk is organized in four parts: the physics case for the MTD will be discussed in the first part of the talk, which will be followed by the description of the barrel and endcap timing layers, the final part will be dedicated to the distribution of the timing synchronization (LHC clock) and the data acquisition system of the MTD.

Electronics, Trigger and Data Acquisition / 16

FPGA-based algorithms for feature extraction in the PANDA shashlyk calorimeter

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PANDA is one of the four experimental pillars of the upcoming FAIR facility in Darmstadt, Germany. In PANDA, an antiproton beam with an energy between 1.5 and 15 GeV/c will interact in a hydrogen or nuclear target, allowing for studies of various aspects of non-perturbative
QCD. Motivated by the high interaction rates and the diverse physics goals of the experiment, a triggerless readout approach will be employed. In this approach, each detector subsystem will be equipped with intelligent front-end electronics that independently identify signals of interest in real time. In order to detect the most forward-directed photons, electrons and positrons in PANDA, a shashlyk-type calorimeter is being constructed. This detector consists of 1512 individual cells of interleaved plastic scintillators and lead plates, and has been optimised to have a relative energy resolution of approximately $3%/\sqrt{\text{GeV}}$ and a time resolution of approximately $100 \text{ ps}/\sqrt{\text{GeV}}$. The signals from this detector will be digitised by sampling ADCs and processed in real time by FPGAs. As part of the triggerless approach, these FPGAs will perform so-called feature extraction on the digitised signals, where the pulse-height and time of incoming pulses are extracted in real time. A substantial pileup rate is expected, and it is foreseen that the chosen algorithm should enable reconstruction of such events. The work presented here has consisted of developing a detailed Geant4-based model of the shashlyk calorimeter and readout system, calibrating this model against testbeam data, and using it to evaluate potential feature-extraction algorithms for the PANDA shashlyk calorimeter.

Timing detectors / 17

Precise charged particle timing with the PICOSEC detection concept

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Precise timing at the level of a few 10ps is a key requirement for unambiguous 4D track reconstruction in future high-luminosity HEP experiments. The PICOSEC detection concept developed in the context of the RD51 collaboration aims to provide precise charged particle timing with a Micromegas detector coupled to a Cherenkov radiator with a photocathode. An excellent timing resolution of 24ps for MIPs was achieved with this concept with a single-pad prototype with a CsI photocathode. Muon beam tests, laser studies as well as detailed simulations have been used to understand the timing characteristics of this detector. Ongoing developments towards larger detectors capable of operating in high particle flux environments include multi-channel PICOSEC modules, resistive Micromegas and robust photocathode materials. Multi-pad prototypes have been shown to preserve the timing capabilities even for the case of signal sharing across multiple pads and spark-resistant resistive Micromegas have been operated in particle beams achieving comparable timing performance. Alternative photocathode materials including diamond-like carbon (DLC), boron carbide and pure metals are studied to replace CsI in harsh ion backflow conditions. The progress and developments towards robust large-area PICOSEC detectors for precise timing applications in future experiments will be presented.
Calorimetry / 20

The Phase 2 Upgrade of the LHCb Calorimeter system.
Dr. GUZ, Yury

The purpose of the Phase 2 LHCb Upgrade is to make it able to work at luminosity of $(1..2) \times 10^{34} \text{cm}^{-2}\text{s}^{-1}$. The plan is to collect ~300 $\text{fb}^{-1}$ of data during 3-5 years. The Phase 2 Upgrade will require a major revision of the LHCb Calorimeter system.

The increased instantaneous and integrated luminosity will result in very high particle density and radiation doses in the central area of the detector. In these conditions, ECAL has to provide high quality energy and position measurement for electromagnetic showers, as well as separation of two closely lying showers.

The choice for the central part of ECAL can be a sampling scintillation calorimeter with dense tungsten-based converter. The radiation hard crystal scintillators, like GAGG:Ce or YAG:Ce, can be used as active elements. The peripheral areas with moderate radiation doses can be instrumented with calorimeter modules based on plastic scintillator.

Another requirement for the LHCb Phase 2 Upgrade ECAL is the ability to measure the time of arrival of the photon or electron with an accuracy of few tens of picosecond. At high luminosity, such time measurement is a powerful tool helping to correctly assign electromagnetic showers to primary vertices. A dedicated timing layer in front of ECAL can be used for time measurements; another option is to use the “intrinsic” time resolution of the ECAL modules.

An R&D campaign was started to optimize the Upgrade 2 ECAL structure. It includes: - studies of scintillating materials, in particular irradiation measurements; - beam test studies of the performance of various ECAL module prototypes, both for central and peripheral areas; - simulation studies to find the optimal detector layout.

In this talk we present the R&D results and the current status of the LHCb Calorimeter upgrade.

Poster Session - Board: 70 / 23

Improvements in the NOvA Detector Simulation based on JINR stand measurements

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NOvA is a long-baseline neutrino experiment aiming to study the neutrino oscillation phenomenon in the muon neutrino beam from complex NuMI at Fermilab (USA). Two identical detectors have been built to measure the initial neutrino flux spectra at the near site and the oscillated one at an 810 km distance, which significantly reduces many systematic uncertainties. To improve electron neutrino and neutral current interaction separation, the detector is constructed as a finely segmented structure filled with liquid scintillator. Charged particles lose their energy in the detector materials, producing a light signal in a cell that is recorded by readout electronics. The simulation models this using the following chain: a parameterized front-end simulation converts all energy deposits in active material into scintillation light, the scintillation light is transported through an optical fiber to an avalanche photodiode, and the readout electronics simulation models the shaping, digitization, and triggering on the response of the photodiode.

Two test stands have been built at JINR (Dubna, Russia) to measure the proton light response of NOvA scintillator and the electronic signal shaping of the NOvA front-end electronics. The parameters measured using these test stands have been implemented in the custom NOvA simulation chain. Further improvements are possible with detailed studies on Cherenkov light at a new test stand.
Micropattern gas detectors / 25

Review on the R&D activities within the RD51 Collaboration
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University of Virginia

Recent advances in photolithography and micro processing techniques have enabled the emergence of Micro Pattern Gaseous Detectors (MPGDs) such as Gas Electron Multipliers (GEMs) or Micro Mesh Gaseous Structures (Micromegas) and many other more recent technologies. These new technologies combine the gas amplification principle of gaseous detectors with micro-structure printed circuits technologies to provide a wide variety of high rate particle tracking detectors with excellent space and time resolution, high radiation tolerance, low material and large material capabilities. The RD51 collaboration is a CERN based international collaboration dedicated to the development and advancement of the MPGDs technologies for application in both basic and applied research and beyond. The RD51 collaboration, which aims at bringing the experts in the field together, is structured into working groups that cover several R&D areas including the emergence of new structures, technologies and applications, detector characterization, large scale production and test facilities, simulations studies, software development and most importantly the development of associated readout electronics. In this talk, we will give a brief and comprehensive overview of the RD51 collaboration and MPGDs-related detector development and R&D. In a second part of the talk, we will be present the newly emerging US-based MPGD communities and the ongoing R&D activities for future colliders and fixed target experiments. Finally, future RD51 projects and plans will be summarized.

Status of facilities / 27

The reserach activity of the Frascati Laboratory
Dr. GIANOTTI, Paola

INFN - LNF

The Frascati National Laboratory (LNF) is the largest and the oldest among the National Laboratories of the Italian Institute for Nuclear Physics (INFN). Since its foundation in 1954, it has been devoted to two main activities: the development, construction and operation of particle accelerators; the design and construction of forefront detectors for particle, nuclear and astro-particle experiments. The focus of the scientific program carried out at LNF has always been in the field of high energy physics, but interdisciplinary research has grown of importance along the years, with a perfect balance between internal activities, carried out on site, and external ones taking place in the major laboratories all over the world. In the presentation, an overview of the research program carried out at the Laboratory will be presented.

Calorimetry / 28

Performance study of a compact LumiCal prototype in an electron beam
Dr. GOSTKIN, Mikhail

JINR

The FCAL collaboration is preparing large-scale prototypes of special calorimeters to be used in the very forward region at a future electron-positron collider for a precise and fast luminosity measurement and beam-tuning. LumiCal is designed as silicon-tungsten sandwich calorimeter with very thin sensor planes to keep the Moliere radius small, facilitating such the measurement of electron showers in the presence of background. Dedicated FE electronics has been developed to match the timing and dynamic range requirements. A partially instrumented prototype was investigated in a 1 to 5 GeV electron beam at the DESY II synchrotron. Sixteen thin detector planes fully assembled with readout electronics were installed in 1 mm gaps between
tungsten plates of one radiation length thickness. High statistics data were used to perform sensor alignment, and to measure the longitudinal and transversal shower development in the sandwich. In addition, Geant4 MC simulations were done and compared to the data.

Particle Identification / 29

Forward RICH detector for the PANDA experiment

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The PANDA detector at the international accelerator Facility for Antiproton and Ion Research in Europe (FAIR) in Darmstadt (Germany) will address fundamental questions of hadron physics in high-energy antiproton collisions with fixed hydrogen and nuclear targets. The PANDA Forward RICH (FRICH) is intended for identification of charged particles with forward polar angles below 5°–10° and momenta from 3 to 15 GeV/c. PANDA FRICH will feature a multilayer focusing aerogel radiator, photon detection by Hamamatsu H12700 MaPMTs and DiRICH front-end electronics. Precisely aligned flat mirrors will collect Cherenkov light on the photon detector. Results of optical measurements of the detector components are presented.

The PANDA Forward RICH prototype was tested at 3-GeV electron beam at the Budker INP in 2019. Single photon resolution was obtained that agrees with expectations.

Poster Session - Board: 30 / 30

Ion detector for Accelerator Mass Spectrometry based on low-pressure TPC with THGEM readout

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A new technique for ion identification in Accelerator Mass Spectrometry (AMS) has been proposed by measuring the ion track ranges using a low-pressure time projection chamber (TPC). As a proof of principle, the low-pressure TPC with charge readout using a THGEM multiplier was developed. The tracks of alpha particles from various radioactive sources were successfully recorded in the TPC. The track ranges were measured with a high accuracy, reaching the 2% resolution level. Using this results and the SRIM code simulation, it is shown that the isobaric boron and beryllium ions can be effectively separated at ten sigma level. It is expected that this technique will be applied in the AMS facility in Novosibirsk for dating geological objects, in particular for the geochronology of Cenozoic Era.

Electronics, Trigger and Data Acquisition / 32

Electronics Performance of the ATLAS New Small Wheel Micromegas wedges at CERN

ATLAS, Muon Coll.; Dr. TZANIS, Polyneikis
The LHC accelerator plans to have a series of upgrades to increase its instantaneous luminosity to $7.5 \times 10^{34} \text{cm}^{-2}\text{s}^{-1}$. The luminosity increase drastically impacts the ATLAS trigger and readout data rates. The present ATLAS small wheel muon detector will be replaced with a New Small Wheel (NSW) detector which is expected to be installed in the ATLAS Underground cavern at the end of 2020. With the series-production micromegas (MM) quadruplets (modules) already produced, the activities concerning the integration of the modules into the final, fully equipped MM wedges, that will then be installed on the wheel structure on surface, are currently in full swing at CERN. One crucial part of the integration procedure concerns the installation, testing, and validation of the on-detector electronics & readout chain for a very large system with a more than 2.1 M electronic channels in total. These include ~4K MM Front-End Boards (MMFE8), custom printed circuit boards each one housing eight 64-channel VMM Application Specific Integrated Circuits (ASICs) that interface with the ATLAS Trigger and Data Acquisition (TDAQ) system through ~1K data-driver Cards (ADDC & L1DDC, respectively). The readout chain is based on optical link technology (GigaBit Transceiver links) connecting the backend to the front-end electronics via the Front-End Link eXchange (FELIX), a newly developed system that will serve as the next-generation read out driver for ATLAS. Experience and performance results from the first large-scale electronics integration tests performed at CERN on final MM wedges, including system validation with cosmic-rays, will be presented.

Micropattern gas detectors

The Micromegas chambers for the ATLAS New Small Wheel upgrade

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The ATLAS collaboration at LHC has chosen the resistive Micromegas technology, along with the small-strip Thin Gap Chambers (sTGC), for the high luminosity upgrade of the first muon station in the high-rapidity region, the so called New Small Wheel (NSW) project. After the R&D, design and prototyping phase, the series production Micromegas quadruplets are being constructed at the involved construction sites in France, Germany, Italy, Russia and Greece. At CERN, the final validation and the integration of the modules in Sectors are in progress. These are big steps forward for the installation of the first NSW, the NSW-A foreseen for the LHC long shutdown in 2020. The construction of the four types of large size quadruplets, all having trapezoidal shapes with surface areas between 2 and 3 m², will be reviewed. The achievement of the requirements for these detectors revealed to be even more challenging than expected, when scaling from the small prototypes to the large dimensions. We will describe the encountered problems, to a large extent common to other micro-pattern gaseous detectors, and the adopted solutions. Final quality assessment and validation results on the achieved mechanical precision, on the High-Voltage stability during operation with and without irradiation will be presented together with the most relevant steps and results of the modules integration into sectors.

Tracking and vertex detectors

Small-Strip Thin Gap Chambers for the Muon Spectrometer Upgrade of the ATLAS Experiment

ATLAS, Muon Coll.¹; Mr. PUDZHA, Denis²

¹ ATLAS
² PhD student

The instantaneous luminosity of the Large Hadron Collider at CERN will be increased by about a factor of five with respect to the design value by undergoing an extensive upgrade program over the coming decade. The largest phase-1 upgrade project for the ATLAS Muon System is
the replacement of the present first station in the forward regions with the New Small Wheels (NSWs) during the long-LHC shutdown in 2019-2021. Along with Micromegas, the NSWs will be equipped with eight layers of small-strip thin gap chambers (sTGC) arranged in multilayers of two quadruplets, for a total active surface of more than 2500 m². To retain the good precision tracking and trigger capabilities in the high background environment of the high luminosity LHC, each sTGC plane must achieve a spatial resolution better than 100 µm to allow the Level-1 trigger track segments to be reconstructed with an angular resolution of approximately 1 mrad. The basic sTGC structure consists of a grid of gold-plated tungsten wires sandwiched between two resistive cathode planes at a small distance from the wire plane. The precision cathode plane has strips with a 3.2 mm pitch for precision readout and the cathode plane on the other side has pads for triggering. The sTGC design, performance, construction and integration status will be discussed, along with results from tests of the chambers with nearly final electronics with beams, cosmic rays and high-intensity radiation sources.

Electronics, Trigger and Data Acquisition / 35

Upgrade of the Muon Drift Tube (MDT) electronics for the ATLAS Phase-II upgrade

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² LMU

The ATLAS monitored drift tube (MDT) chambers are the main component of the precision tracking system in the ATLAS muon spectrometer. The MDT system is capable of measuring the sagitta of muon tracks to an accuracy of 60 µm, which corresponds to a momentum accuracy of about 10% at pT=1 TeV. To cope with large amount of data and high event rate expected from the High-Luminosity LHC (HL-LHC) upgrade, ATLAS plans to use the MDT detector at the first-trigger level to improve the muon transverse momentum resolution and reduce the trigger rate. The new MDT trigger and readout system will have an output event rate of 1 MHz and a latency of 6 us at the first-level trigger. A new trigger and readout system has been proposed. Prototypes for two frontend ASICs and a data transmission board have been designed and tested, and detailed simulation of the trigger latency has been performed. We will present the overall design and focus on latest results from different ASIC and board prototypes.

Poster Session - Board: 3 / 37

Precision survey of the readout strips of small-strip Thin Gap Chambers using X-rays for the muon spectrometer upgrade of the ATLAS experiment

ATLAS, Muon Coll.¹ ; Dr. LEFEBVRE, Benoit²

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² TRIUMF

The instantaneous luminosity of the Large Hadron Collider (LHC) will be increased by a factor of 5 following a series of upgrades of the CERN accelerator complex. In anticipation to the increased collision rate at the interaction point, the muon end-cap inner station of the ATLAS detector will be replaced by the so-called New Small Wheels (NSWs) during the LHC shutdown of 2019/2021. The NSWs combine the Micromegas and small-strip Thin Gap Chambers (sTGC) technologies. The sTGC detector modules are arranged in trapezoid wedges of 4 detector planes with fiducial areas varying between 3 and 6 m²{2}. Up to 1000 azimuthal cathode strips are read out on each plane for precise muon trajectory measurements. The positioning of individual strips must be known to within 100 microns to satisfy the performance targets of this ATLAS upgrade. Non-conformities of the sTGC strip-pattern are therefore measured on finished wedges using an X-ray gun precisely positioned at reference points. The working principles and experimental procedure of this technique will be shown as well as validation studies based on measurements carried out on sTGC wedges of the early production.
Construction and geometrical precision assessment of the Micromegas detectors for the ATLAS New Small Wheel upgrade

ATLAS, Muon Coll.¹ ; Mr. MINASHVILI, Irakli²

¹ ATLAS  
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The upgrade of the Large Hadron Collider (LHC) to the High Luminosity LHC (HL-LHC) is required to probe the physics beyond Standard Model. After the ongoing long shutdown (LS2), the accelerator luminosity will be increased 2 to 3 times as compared to designed luminosity value i.e. $1 \times 10^{34}$ cm$^{-2}$s$^{-1}$. To meet the requirements of higher rates environment of HL-LHC era, the muon system of ATLAS detector needs to be upgraded. Therefore, the small wheel comprised of Cathode Strip Chambers (CSC) and monitored Drift Tubes (MDT) chambers will be replaced by the new small wheel (NSW). The NSW will be constituted by Micromesh Gaseous Structure (Micromegas) detectors and small-strip Thin Gap Chambers (sTGC). Micromegas detectors will be used for tracking as well as triggering purpose. In each of the NSW (A&C), 16 modules will be installed in 16 sectors i.e. 8 large sectors and 8 small sectors; covering total area of $\sim 1200$ m$^2$. Micromegas are ionization-based gaseous detectors made up of parallel plates, having a thin amplification region separated from the conversion region via thin metallic mesh. The production of Micromegas detectors as well as methods adopted to achieve required geometrical precision are presented. Specific measurement devices have been developed in the last few years to determine the quality of Micromegas chambers required for NSW. Planarity measurements of drift, readout panels as well as modules after assembly are done with a specific CMM (co-ordinate measuring machine), results are shown for drift, readout panels as well as modules. Results of in-plane measurements (XY co-ordinate), performed using Rasnik masks etched on the PCBs are also reported. Modules constructed using the dedicated tools and methods are validated using cosmic muons, results of one such module are shown.

Micropattern gas detectors / 42

Production and installation of first GEM station in CMS

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In December 2018 the Large Hadron Collider (LHC) entered the LS2 phase (Long Shutdown 2), which will last until beginning of 2021: in this period a maintainance program of LHC and of the other smaller accelerators is scheduled. In 2017 and during the whole 2018 LHC has reached the record beam luminosity $2 \times 10^{34}$ cm$^{-2}$s$^{-1}$, around a factor of 2 beyond the LHC design.  
To cope with this and also looking at the following LHC phase, in which the luminosity will be further increased up to a factor 5-7, the same LHC experiments must be upgraded. In this context and concerning the muon subsystem, the CMS experiment began installing the first GEM based detectors station (GE1/1) in July 2019 almost 5 meters from the point of interaction and covering the pseudorapidity region $1.6 < \eta < 2.15$.  
GE1/1 will consist of 144 Triple Gas Electron Multiplier detectors (GEM): this station is designed to work together with the Cathode Strip Chamber (CSC) station ME1/1, improving tracking and triggering of muons produced with the pseudorapidity covered by these stations.  
The installation in CMS is now underway at a good pace: the first 72 chambers have been installed together with their services (gas, cooling, low voltage and high voltage), while the completion of the station is foreseen in spring 2020. This contribution will analyze the detector design, moving then to all the steps a detector must pass before being approved for the installation in CMS. The status of the operations will be presented, together with the tools developed to monitor the detector parameters during installation. Finally the plans for the installation and commissioning of the entire project will be outlined.
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Results of ultra-high-energy cosmic rays from the Telescope Array

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The Telescope Array is the largest ultra-high-energy cosmic ray (UHECR) observatory in the Northern Hemisphere. It consists of 507 surface scintillator detectors covering approximately 700 square kilometers and three fluorescence telescope sites overlooking the surface array. The aim of the Telescope Array is to explore the origin and nature of UHECR by measuring the energy spectrum and the distribution of arrival directions and mass composition of UHECR. Here the recent results of the Telescope Array are presented. In addition, we have two ongoing extensions: one is the extension for the highest-energy cosmic rays towards four times the Telescope Array and the other is the Telescope Array Low-energy Extension to explore the transition from galactic to extragalactic cosmic rays. The prospects of these extensions are presented.

Poster Session - Board: 4 / 45

The STAR detector upgrades for the BES-II and at forward rapidity

YANG, Chi

1 for the STAR Collaboration

The Beam Energy Scan phase II program (BES-II) at the Relativistic Heavy Ion Collider (RHIC) is examining the center-of-mass collision energy region from 7.7 GeV to 19.6 GeV which was determined from the results of BES-I. Key measurements such as the net proton kurtosis, the directed flow and the dilepton production are possible during BES-II with an order of magnitude better statistics due to the Low Energy RHIC electron Cooling (LEReC) upgrade of RHIC and the STAR detector upgrades. The BES-II upgrades comprise the inner Time Projection Chamber (iTPC), endcap Time Of Flight (eTOF) and Event Plane Detector (EPD), which are all fully commissioned and operational since beginning of 2019.

Beyond BES-II, the STAR Collaboration is currently designing, constructing, and installing a suite of new detectors in the forward rapidity region (2.5 < η < 4), enabling a program of novel measurements in pp, pA and AA collisions. To fully explore this physics, the forward upgrade needs superior detection capability for neutral pions, photons, electrons, jets and leading hadrons by adding charged-particle tracking and electromagnetic and hadronic calorimetry to STAR’s capabilities at forward rapidity.

In this talk, we will present the details of the STAR detector upgrades for the BES-II and beyond. The scientific opportunities enabled from these detector upgrades will be discussed.

Instrumentation for Astroparticle and Neutrino physics / 46

Observation of unusual slow components in electroluminescence signal of two-phase argon detector

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Proportional electroluminescence (EL) in noble gases is used in two-phase detectors for dark matter search to record ionization signals in the gas phase induced by particle scattering in the
liquid phase (S2 signals). In this work, the EL pulse shapes in a two-phase argon detector have for the first time been studied systematically in a wide electric field range varying from 3 to 9 Td. The pulse shapes were studied at different readout configurations and spectral ranges: using cryogenic PMTs and SiPMs, with and without a wavelength shifter (WLS), in the VUV and visible range. We observed the fast component and two unusual slow components, with time constants of about 5 µs and 70 µs. The unusual characteristic property of slow components was that their contribution increased with field. We also show that the fast component may be used to measure the EL gap thickness with sub-mm resolution. The results obtained can have practical applications in DarkSide dark matter search experiment.

Particle Identification / 47

The Barrel and Endcap Disc DIRC at PANDA

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1 GSI Helmholtzzentrum GmbH

The PANDA experiment of the FAIR facility will address open questions in hadron physics using antiproton beams in the momentum range of 1.5-15 GeV/c. The antiprotons are stored and cooled in the High Energy Storage Ring (HESR) and allow high precision spectroscopy in the energy range of closed and open charm. Two Cherenkov detectors using the principle of Detection of Internally Reflected Cherenkov light (DIRC) will provide excellent PID in the PANDA target spectrometer. The Endcap Disc DIRC separates pions from kaons better than $3\sigma$ up to momenta of 4 GeV/c in the forward direction, for polar angles from 5° to 22°. It uses a fused silica radiator disk, consisting of four optically isolated quadrants. The Cherenkov photons are imaged on Microchannel-Plate PMTs (MCP-PMTs) by focusing lightguides. The Barrel DIRC cleanly separates pions from kaons for polar angles in the range of 22° - 140° and momenta up to 3.5 GeV/c. The barrel is formed by 16 sectors, each comprising three narrow fused silica radiator bars, with a flat mirror attached to one end and a spherical lens attached to the other, and a large fuse silica prism, coupled to each group of three lenses. The Cherenkov light is focused on the back side of the prism, where an array of lifetime-enhanced MCP-PMTs detects the photons. The designs are simulated and validated in test beams with prototypes and the Technical Design Reports of both devices have recently been completed. While mass production of some of the components has already started, the R&D for other important items, like the readout electronics or the shape and materials of the mechanical support, is still ongoing. This talk describes the status of the two DIRC projects and will discuss the remaining R&D activities.

Electronics, Trigger and Data Acquisition / 49

Current and Future FPGA-TDC Developments at GSI

Dr. TRAXLER, Michael1 ; Dr. KNITTEL, Günter1

1 GSI Helmholtzzentrum für Schwerionenforschung GmbH

High precision time measurements as well as pulse width encoded charge measurements are a crucial element in particle identification detectors. FPGA based time-to-digital converters have been proven to be very useful devices for this task. The design efforts at GSI lay special emphasis on providing low and lowest cost platforms for TDCs. This is due to the fact that in particle physics, massive amounts of TDCs are used in detector facilities. Therefore, we target absolute low cost devices such as Lattice ECP5, while keeping the timing performance on the already achieved level and still improving many more aspects. Two different second generation architectures are currently under development: Eraser and Eins11!. For Eraser, the target specs are: 10ps time precision RMS with 48 channels on ECP5, and 64 channels on ECP3. Eins11! can provide 64 channels in the ECP5, but with a lower precision in the order of 100ps. Further features of both architectures are:
• Channels can be combined pairwise under program control in order to increase precision or decrease deadtime
• ToT measurements in any channel using a stretcher, or using two channels
• Increased resolution by having two edges in the TDL at any time (Wave Union type A)
• 40-bit timestamps
• Single-cycle encoder with 100% efficiency running at 290MHz
• Pipelined trigger operation: up to 16 triggers can be issued before the first one needs to be returned
• Freely positionable trigger window relative to trigger signal
• Per-channel trigger window comparator for fast read-out (high trigger rate)
• On-the-fly elimination of hits that drop out of the trigger window (on each channel) to lower internal data rate
• Additional deadtime-free Sampling-TDC on each channel with a sampling rate of 1.16GS/s
• Logic Analyzer Memory for all channels, variable sampling rate, maximum trace length 28us
• High-performance 32-bit pulse counter on each channel
• On-the-fly fine-time calibration using per-channel lookup tables
• Protection against overflow conditions and corrupted input signals

On ECP3, a preliminary implementation achieved a precision of 11ps mean. The current target platforms are the proven systems TRB3, TRB3sc, DiRICH as well as the new low-cost ECP5 system TRB5sc.

**Poster Session** - Board: 52 / 50

**Study of the Water Cherenkov Detector with High Dynamic Range for LHAASO**

Dr. JIANG, Kun

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A Large High-Altitude Air Shower Observatory (LHAASO) is building at Haizi mountain, Sichuan, China at an elevation of 4410 m. One of its main goals is to survey the northern sky for very-high-energy (above 100 GeV) gamma ray sources via its ground-based Water Cherenkov Detector Array (WCDA). WCDA is 78000 m² in dimension and consists of 3120 water detector cells divided into 3 water ponds. A hemispherical 8-inch photomultiplier tube (PMT) CR365 from Beijing Hamamatsu Photon Techniques INC. (BHP) is installed at the bottom-center of each cell of the first water pond to collect the Cherenkov light produced by air shower particles crossing water. In this presentation, technical design details of WCDA is introduced. The design of a high dynamic range base for CR365 will be presented. The batch test system for PMTs and test results of about 1000 PMTs will also be included.

**Poster Session** - Board: 5 / 51

**Time Projection Chamber as Inner Tracker for Super Charm-Tau Factory at BINP**

Mr. KUTTIKATTU VADAKEPPATTU, VIJAYANAND; Mr. SOKOLOV, Andrey; Mr. SHEKHTMAN, Lev; Mr. MALTSEV, Timofei

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At present time, Budker INP is developing a charm-tau factory project, which consists of a high-luminosity collider with the luminosity of $10^{35} \text{cm}^{-2}\text{c}^{-1}$ and a universal magnetic detector. The tracking system of the detector will comprise of an internal tracker and a drift chamber. One of the options for internal tracker is Time Projection Chamber (TPC). The advantages of the TPC are high spatial resolution and particle identification capabilities by registration of dE/dx losses. However, using a time-projection chamber implies serious challenges. For example, the TPC have to simultaneously deal with tracks from several thousand events and maintain the enormous data rate. This work describes the results of the Monte-Carlo studies of the transport characteristics and spatial resolution in various gas mixtures proposed for TPC. Besides of this, the simulation of the ion back flow and its effect on spatial resolution will be given as well as the results of the background simulation studies.

**Poster Session - Board: 53 / 52**

**Observation of primary scintillations in the visible range in liquid argon doped with methane**

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Neutron veto detector based on liquid scintillator containing hydrogen atoms is an integral part of any underground experiment for dark matter search. So far, a flammable mixture of liquid hydrocarbons was used as a liquid scintillator. A safe alternative would be a liquid scintillator based on liquid argon doped with methane. In this work, we have studied the primary scintillations in pure liquid argon and its mixtures with methane, the CH4 content varying from 100 ppm to 10%. The primary scintillations in these mixtures have for the first time been observed in the visible and NIR range and their relative light yields have been measured as function of the CH4 content.

**Poster Session - Board: 71 / 53**

**Development of the light collection module for the Liquid Argon TPC**

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A modular liquid-argon (LAr) TPC with pixelated charge readout is considered as a part of the near detector for the DUNE experiment. Such the TPC is developing by ArgonCube collaboration. To provide a trigger for the neutrino event the LAr scintillation light detection is proposed. The light is a vacuum ultraviolet with 128 nm wavelength, thus, it is a challenge to register it. The main requirements imposed on the light detection system are: a good performance at cryogenic temperatures, nonconductive materials, compact dimensions, detection efficiency at a level of percent. A light collection module (LCM) as a candidate for the system is developed at JINR (Dubna, Russia). The LCM is based on the WLS-fibers that are coated with TPB and readout by silicon photomultipliers(SiPM). Also, a full readout chain for the light detection system is being developed at JINR that contains the front-end electronics, SiPMs power supply, DAQ. A cryogenic test setup has been built at JINR to study the performance of the LCM in the...
LAr. A similar study was carried out in the cryogenic laboratory of Bern University with highly purified LAr. These studies have shown that the detection efficiency of the LCM for the LAr scintillation light is about 1%. Further tests in the ArgonCube TPC prototype will provide us the real performance of LCM-system with a full readout chain.

Instrumentation for Astroparticle and Neutrino physics / 54

Measurements of argon-scintillation and -electroluminescence properties for low mass WIMP dark matter search

Author(s): Mr. KIMURA, Masato¹
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An argon scintillation detector has several features that make it attractive for use in various physics projects such as WIMP dark matter search. The detector observes scintillation and/or electroluminescence signals. The main features of the detector are: efficient conversion of energy deposition into observables: powerful particle identification by use of scintillation pulse shape and ionization to scintillation ratio: and scalability and cost efficiency due to the availability of argon. In these projects, comprehensive understanding of the detector property is crucial to reduce systematic uncertainties and improve the physics sensitivity.

This talk covers the recent measurements of the argon properties, with a primary focus on the electroluminescence signal. Basic properties of the gas argon luminescence signal are measured using a dedicated gas argon time projection chamber. Based on this measurement, we discuss the luminescence process of the signal, such as a theoretically predicted mechanism called “neutral bremsstrahlung”. In addition, we present several measurements of the liquid argon response, namely, scintillation and ionization yields under high electric field and energy dependence of the argon response. Recent development of the liquid argon scintillation detector for low mass dark matter search is also introduced, which is relatively small but achieves the world-highest light collection efficiency.

Particle Identification / 55

The Upgrade of the LHCb RICH System for the LHC Run 3

Dr. PAPANESTIS, Antonios¹

¹ STFC - RAL

The RICH detectors of the LHCb experiment have provided particle identification with excellent performance during Run 1 and 2 of the LHC. Currently the LHCb experiment is undergoing an upgrade to allow, starting from 2021, data collection at 5 times the instantaneous luminosity of the period 2010-2019 (up to $2 \times 10^{34} cm^{-2} s^{-1}$) with the aim to collect 50 fb$^{-1}$. The required upgrades to detectors and electronics are significant, with the RICH system changing all of the photon detectors and a full replacement of the upstream RICH detector. The existing Hybrid Photon Detectors (HPD) are being replaced by two types of Multi-Anode Photomultiplier Tubes (MaPMT) plus electronics capable of recording data at the full LHC collision frequency of 40 MHz. The required 3072 MaPMTs have been received from the manufacturer and have undergone detailed characterisation, measuring gain and uniformity across channels plus quantum efficiency on a smaller sample. The MaPMTs and associated electronics are currently being mounted on their mechanical support structures, and about half are ready for installation in the early part of 2020. The upstream RICH detector is also ready for the installation of the new optical elements. The status of the project will be presented.
Data Acquisition System for Belle II Electromagnetic Calorimeter
Mr. REMNEV, Mikhail

1 BINP

Belle II experiment is conducted in KEK institute, at the SuperKEKB B-factory, with all detector subsystems taking data since March 2019. One of the primary detector subsystems is an electromagnetic crystal calorimeter (ECL) that consists of 8736 CsI(Tl) scintillation crystals. This report describes data acquisition (DAQ) system that has been developed for ECL. Front-end electronics of ECL DAQ consists of several hundred highly configurable FPGA-controlled modules that utilize pipeline readout architecture and are able to handle up to 30 kHz trigger rate. ECL front end electronics are initialized, configured and monitored by ECL DAQ software. Initialization software library can work with several transport protocols, internally optimize requests to the electronics and perform caching of the configuration data. Configuration software manages and monitors more than 50'000 electronics parameters and updates them based on the calibrations. Continuous monitoring of ECL data quality is also implemented. ECL DAQ software is integrated with Network Shared Memory 2, slow control system used in Belle II experiment.

Calorimetry / 57

Performance of the Belle II Electromagnetic Calorimeter in First Data
LONGO, Savino

1 DESY

The Belle II experiment at the SuperKEKB electron-positron collider in Tsukuba, Japan began physics data taking in 2019 and will search for new physics in the flavour sector of the Standard Model as well as for dark sectors. The Belle II electromagnetic calorimeter plays a central role in photon, neutral pion and neutral hadron reconstruction, in addition to enabling advanced triggering techniques to give Belle II improved sensitivities to unique signatures of potential new physics. The calorimeter is constructed from 8736 CsI(Tl) scintillator crystals which have been equiped with new waveform sampling electronics to maintain high performance while operating in the intense beam background environment produced by SuperKEKB. This talk will present measurements of the photon and neutral pion reconstruction performance during the first physics data-taking runs of Belle II in addition to results of the first application of CsI(Tl) pulse shape discrimination at a B-Factory experiment. Through the application of pulse shape discrimination, it will be demonstrated that improvements are achieved in challenging and important areas of particle identification such as neutral hadron vs. photon identification and low momentum charged particle identification.

Poster Session - Board: 72 / 58

The Readout system of the CBM Projectile Spectator Detector at FAIR

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1 INR RAS

The Projectile Spectator Detector (PSD), a sampling lead/scintillator forward hadron calorimeter with transverse and longitudinal segmentation and with MPPCs photodetectors, will be used at the Compressed Baryonic Matter (CBM) experiment at FAIR to measure the centrality and orientation of the reaction plane in nucleus-nucleus collisions. After amplification in the FEE, signals from the MPPCs are readout with LMT9011 ADCs with 14 bit digitization and up to 125 Msps rate which has been developed for the ECAL of the PANDA experiment at FAIR. The Kintex 7 FPGA is used for signal processing and data collection. The trigger-less readout is based
on the GBT-FPGA. Clock source switching from onboard generator to the RX clock transmitted via GBT has been implemented to integrate the ADC board into the CBM DAQ system. One PSD module has been integrated into the mCBM experiment at the SIS18 facility of GSI/FAIR joining the FAIR Phase-0 program. Details of the PSD readout electronics and first results of the data processing and transmission within the common, synchronized mCBM data transport taken during the data campaign in November/December 2019 will be presented.

Tracking and vertex detectors / 59

The ATLAS Strip Detector System for the High-Luminosity LHC

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The ATLAS experiment at the Large Hadron Collider is currently preparing for a major upgrade of the Inner Tracking for the Phase-II LHC operation, scheduled to start in 2026. The radiation damage at the maximum integrated luminosity of 4000/fb implies integrated hadron fluencies over $2 \times 10^{16}$ $n_{eq}/cm^2$ requiring a complete replacement of the existing Inner Detector. An all-silicon Inner Tracker (ITk) is under development with a pixel detector surrounded by a strip detector. The current prototyping phase, targeting an ITk Strip Detector system consisting of four-barrel layers in the center and forward regions composed of six disks at each end. With the production of modules scheduled to begin in 2020 and after successfully passing the Final Design Review, a thorough understanding of the current prototype modules is critical.

In this contribution, we present the design of the ITk Strip Detector and outline the current status of R&D and prototyping on various detector components as well as reports on tests of prototype end-cap strip modules at DESY test beam facilities.

The modules under study in test beams are irradiated and unirradiated so-called R0 modules, designed for the innermost region of end-cap wheels where radiation and occupancy conditions are the most severe. An R0 module is comprised of a sensor with glued-on readout hybrids and a power board. We will also present results from the first double-sided R0 prototype module, built using a carbon-fiber core with integrated services. The results focus on the detection efficiencies and spatial resolution of the modules, both in general and for specific regions of each module and to beam positions within or in between strips. The overall performance of the prototypes will also be discussed, for example relating detection efficiencies to noise occupancies.

Comparative aging studies on a Single Wire Proportional Chamber

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In order to extend previous studies and test additional variables playing a role in the aging processes, a Single Wire Proportional Chamber (SWPC) was specially designed. In this contribution, the authors will present the result of two couples of tests performed on this SWPC. During the first test, the SWPC was irradiated with X-rays and alpha particles sources with the same hit rate until the same integrated charge (1.4 mC/cm) was reached. Nevertheless, the performance loss during the X-ray irradiation was larger, traces of polymers were found on the wire only in the case of alpha irradiation. The second test was performed irradiating the SWPC with alphas and X-ray, but this time with the same anodic current i.e. very different hit rate. The irradiation continued until the wire chamber lost half of the initial gas gain. As expected, in the case of alpha irradiation the integrated charge needed for the goal was lower with respect to the one needed during the X-ray radiation: 9.5 mC/cm and 33 mC/cm respectively. However, the electron microscope analysis revealed, once again, a large polymer deposit on the alpha irradiated wire while no deposit was found on the X-ray irradiated one.
The Phase-2 Upgrade of the Hardware Trigger of CMS at the LHC

JEITLER, Manfred

The CMS experiment uses a two-level triggering system consisting of the Level-1, instrumented by custom-design hardware boards, and the High Level Trigger, a streamlined version of the offline reconstruction software running on a computer farm. The upgrade of the collider to the “High-Luminosity LHC” that will deliver a luminosity of $5 \times 10^{34} \text{ cm}^{-2} \text{ s}^{-1}$, corresponding to 140–200 pile-up events, also necessitates a substantial upgrade of the trigger system to make optimal use of the data. An important difference from the present system will be that after the upgrade, information from the silicon strip tracker will be available already for the Level-1 Trigger. This will allow CMS to use so-called “particle flow” objects, i.e. signals seen not only in one subdetector but put together from all available subdetectors, resulting in much sharper cuts on trigger objects. Also, trigger rates will rise both at Level-1 (from 100 kHz to 750 kHz) and at the High-Level Trigger. At the same time, more sophisticated algorithms will be available at Level-1. To make this possible, the latency - the processing time available for arriving at the Level-1 trigger decision - will increase significantly. Machine-learning techniques such as Boosted Decision Trees have already started to be implemented in the trigger electronics and will occupy a more important place in the future. The use of High-Level Synthesis (HLS) tools will allow physicists to formulate trigger requirements in a language closer to that of data analysis. To avoid missing unexpected signatures from New Physics, studies are underway to employ anomaly detection using autoencoders.

Amplitude and time parameters of modules for hadron calorimeter at MPD/NICA.

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The parameters of Forward Hadron Calorimeter (FHCal) for MPD experiment at heavy ion collider NICA (Dubna, Russia) are discussed. The calorimeter will measure a geometry of heavy-ion collisions and also will be used for the trigger of the most peripheral events. FHCal consists of two equivalent parts placed left/right respective the beam collision point. Each FHCal part consists of 44 individual modules. This is a lead–scintillator compensating calorimeter with the light readout provided by WLS-fibers embedded in the grooves in the scintillator tiles. The longitudinal segmentation of the calorimeter modules requires 7 compact photodetectors in each module. The silicon photomultipliers, SiPMs are used for the readout. The results of the tests with cosmic muons are presented. The procedure of the absolute light yield evaluation in each longitudinal section is elaborated. The light yield of about 45-50 photoelectrons is obtained for the minimum ionizing particles crossed a single FHCal module section. While the electronic noise contribution is estimated of about very few photoelectrons. The time resolution of about 1 ns was measured for cosmic muons crossed one FHCal module. The obtained parameters of FHCal ensure the reliable trigger for detection of the hadrons with the energies 1- 5 GeV.
Cosmic Ray Imaging System Based on Scintillator Detector with SiPM Readout

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Incident cosmic ray particles can interact with atmosphere molecule, which can produce plenty of muons. Due to high penetration ability, muons can be substituted to detect materials that traditional methods, like X-rays, cannot detect. Detectors that measure deviation angle of in-coming and out-coming tracks can give a 3-D density distribution amid in detectors.

We’ve built a muon imaging system prototype based on scintillator position detectors with SiPM readout. The detector is composed of plastic scintillators with wavelength shift (WLS) fibers inside and SiPM readout modules. When cosmic ray muon penetrates through, scintillator will produce photon. Yielded photons can be collected by WLS fibers and then transmitted to SiPM. Charge of SiPM signal will be recorded by the readout electronics and can be used to infer deposit energy in scintillator.

A test system and a GEANT4 simulation program has been set to estimate position resolution of 3 kinds of scintillator structure. The first one is square cross section strip plastic scintillator, coated with reflective paint so as to reflect photons. It’s the most popular structure, and its resolution should be 2.9mm if side length of square is 10mm. The second one is triangle cross section strip scintillator, which is also coated with reflective paint. Position resolution should be better, due to measurement of deposit energy in different strips. Simulation result shows 50% better than square situation. The last one is a whole plate without any cutting and coating. This is the simplest and most economic structure. But shows the worst position resolution and detect efficiency. Experimental data from the test system is close to GEANT4 simulation. After measurement of detector’s position resolution, we build a muon imaging system. Point of Closest Approach (PoCA) algorithm is used to calculate density distribution.

Particle Identification Algorithms for the Panda Barrel DIRC

**Mr. ALI, Ahmed**

1 GSI

The PANDA experiment at the international accelerator Facility for Antiproton and Ion Research in Europe (FAIR) near GSI, Darmstadt, Germany will address fundamental questions of hadron physics. Excellent particle identification is required to achieve the PANDA physics goals. Hadronic particle identification (PID) in the PANDA target spectrometer will be delivered by two DIRC (Detection of Internally Reflected Cherenkov light) counters. The Barrel DIRC will cover the polar angle range of 22°–140° and is designed to provide pion/kaon separation for momenta between 0.5 GeV/c and 3.5 GeV/c with a separation power of at least 3 standard deviations. Several reconstruction algorithms have been developed to determine the performance of the detector. The “geometrical reconstruction” determines the Cherenkov angle relying primarily on the position of the detected photons. The “time imaging”, however, utilizes both position and time measurements by directly performing the maximum likelihood fit. GEANT4 simulations and experimental data from prototype tests at the CERN PS were used to optimize the performance of the algorithms. We will discuss detailed aspects of both reconstruction approaches.

Performances of a resistive MicroMegas module for the Time Projection Chambers of the T2K Near Detector upgrade

**JESÚS-VALLS, César**

1
In view of the J-PARC program of upgrades of the beam intensity, the T2K collaboration is preparing towards an increase of the exposure aimed at establishing leptonic CP violation at $3\,\sigma$ level for a significant fraction of the possible $\delta_{CP}$ values. To reach this goal, an upgrade of the T2K near detector ND280 has been launched, with the aim of reducing the overall statistical and systematic uncertainties at the appropriate level of better than 4\%. We have developed an innovative concept for this neutrino detection system, comprising the totally active Super-Fine-Grained-Detector (SuperFGD), two High Angle TPC (HA-TPC) and six TOF planes. The HA-TPC will be used for 3D track reconstruction, momentum measurement and particle identification. These TPC, with overall dimensions of 2x2x0.8 m$^3$, will be equipped with 32 resistive Micromegas. The thin field cage (3 cm thickness, 4\% rad. length) will consist of composite material with a Kapton foil with copper strips as inner layer. The 34x42 cm$^2$ resistive bulk Micromegas will use a 500 kOhm/square DLC foil to spread the charge over the pad plane, each pad being appr. 1 cm$^2$. The front-end cards, based on the AFTER chip, will be mounted on the back of the Micromegas and parallel to its plane. The first resistive MicroMegas modules have been tested in a test beam at CERN and at DESY. Results of these test beams will be shown in this talk.

Tracking and vertex detectors / 68

The Drift Chamber of the MEGII experiment

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The MEG experiment at the Paul Scherrer Institut searches for the charged Lepton Flavor Violating $\mu^+ \rightarrow e^+\gamma$ decay. MEG has already determined the world best upper limit on the branching ratio: $\text{BR} < 4.2 \times 10^{-13}$ at 90 \% C.L.

An upgrade (MEG II) of the whole detector has been approved to obtain a substantial increase in sensitivity. Currently MEG II is completing the upgrade of the various detectors, an engineering run and a pre-commissioning run were carried out during 2018 and 2019. The positron tracker is a unique volume, cylindrical drift chamber, with the axis parallel to the muon beam. The external radius (30 cm) of the chamber is constrained by the available space inside the COBRA magnet, while the internal radius (17 cm) is large so that low energy positrons, less than 45 MeV/c, are swept out of the magnet by the gradient field without crossing the sensitive volume.

With the new tracking system layout the main advantages are that the positrons with a momentum greater than 45 MeV/c will be tracked as close as possible to the Timing Counter system (TC) by using a very small amount of material, 1.45 $10^{-3}$ X$_0$, allowing to increase: the positron reconstruction efficiency, the positron momentum and vertex resolutions and to the positron timing matching resolution. The single drift cell is approximately square, with a 20 \mu m gold plated W sense wire surrounded by 40 \mu m silver plated Al field wires in a ratio of 5:1. For equalizing the gain of the innermost and outermost layers, two guard wires layers (50 \mu m silver-plated Al)
have been added at proper radii and at appropriate high voltages. The total number of wires amounts to 11904.

Due to the high wire density (12 wires/cm$^2$) and the stringent precision requirements on the wire position and uniformity of the wire mechanical tension (better than 0.5 g) impose the use of the classical feed-through technique as wire anchoring system could hardly be implemented and therefore it was necessary to develop new wiring strategies. The basic idea is to create a multi-wires plane, by soldering the wires between two 40 µm thick custom wire-PCBs. Despite to the conceptual simplicity of the building strategies, to ensure the electrostatic stability of the drift cells and meet the requirements on the uniformity of the wire mechanical tension for all the multi-wires plans necessary for the construction of the CDCH. All these constraints require the use of an automatic wiring system (called wiring robot). The CDCH is the first drift chamber ever designed and built in a modular way, in fact, it is built by overlapping along the radius, alternatively, multi-wires plane and PEEK spacers, to set the proper cell width, in each of the twelve sectors, between the spokes of the rudder wheel shaped end-plate. A carbon fiber support structure guarantees the proper wire tension and encloses the gas volume. At the innermost radius, an Al Mylar foil separates the drift chamber gas volume from the helium filled target region.

We describe the CDCH design and construction (wiring procedure and assembly procedure). The wiring phase at INFN-Lecce, the choice of the wires, their mechanical properties and a material budget estimation are presented. The assembly and sealing at INFN-Pisa are then describe, before the preparation of the endcaps services.

Status of facilities / 70

New challenges for distributed computing at the CMS experiment
Ms. KRAMMER, Natascha$^1$

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The Large Hadron Collider (LHC) experiments soon step into the next period of run-3 data-taking with an increased data rate and high pileup requiring an excellent working computing infrastructure. In the future High-Luminosity LHC (HL-LHC) data-taking period, the compute, storage and network facilities have to be further extended by large factors and flexible and sophisticated computing models are essential. New techniques of modern state-of-the-art methods in physics analysis and data science, Deep Learning and Big Data tools, are crucial to handle high-dimensional and more complex problems. Beside flexible cloud computing technologies the usage of High Performance Computing (HPC) at the LHC experiments are explored. In this presentation, I will discuss the LHC run-3 and future HL-LHC runs computing technologies and the utilisation of modern physics analysis and data science methods for the increasing and complex demands of large scale scientific computing.

Poster Session - Board: 45 / 71

New veto hodoscope ANTI-0 of the NA62 experiment at CERN

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The NA62 experiment is a fixed-target experiment at CERN SPS. The main goal of the experiment is to measure branching ratio of ultra-rare kaon decay $K^+ \rightarrow \pi^+ \nu \bar{\nu}$. The NA62 detector allows also to study other rare kaon decays and processes such as search of very weakly coupled particles of MeV-GeV mass-scale. The new veto hodoscope has been proposed and designed to veto events with halo particles entering the decay volume. The ANTI0 detector is under assembling at CERN now. The detector design, performance simulation and measurements with cosmic rays and test beams for the individual counters are presented. The commissioning and the first run of data-taking scheduled after LS2 (April 2021).
Poster Session - Board: 32 / 72

Novel triple-GEM mechanical design for CMS-ME0 detector and preliminary performance

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In the framework of the High-Luminosity Large Hadron Collider project (HL-LHC), the LHC experiments will require upgrades to their detectors to cope with the new accelerator performance. The upgrade of the CMS Muon Spectrometer foresees the installation of three new muon stations based on the Gas Electron Multiplier (GEM) technology, referred to as GE1/1, GE2/1 and ME0 detectors. While the installation and commissioning of the GE1/1 detectors is currently underway, the GE2/1 and ME0 detectors are expected to be installed between 2023 and 2025. The CMS GEM Collaboration has developed a novel construction design of large-area, trapezoidal-shaped GE1/1 triple-GEM detectors; in particular, a new self-stretching technique has been introduced to mechanically stretch the GEM foils without using spacer grids or glue inside the gas volume in order to avoid dead regions (several %) or possibly outgassing contaminants which could trigger premature aging processes. As has been observed, the PCB boards, which define the gas enclosure of the detector, get deformed (inflate) under the internal gas overpressure, introducing irregularities in the planarity of the GE1/1 detector, which could potentially affect the uniformity of the detector performance. Therefore, the collaboration has established a set of tests and quality controls in order to quantify these irregularities and mitigate their impact on detector performance. Additionally, new solutions and design upgrades have been implemented to prevent such effects in future GE2/1 and ME0 upgrade projects. We will focus in particular on the novel design solutions based on the PCB distance holders (pillars), which the collaboration adopted for realization of the latter projects, and their impact on the performance of the detector, with a summary of the ongoing R&D activities.

Poster Session - Board: 7 / 73

The sTGC Prototyping and Performance Test for the STAR Forward Upgrade

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The STAR experiment at RHIC is upgrading the Forward Tracking System (FTS) which consists of Forward Silicon Tracker (FST) and Forward sTGC Tracker (FTT). The small-strip Thin Gap Chambers (sTGC) at STAR are designed to provide precision position measurement at about 100um level for the charged particles in high luminosity, covering forward rapidity region (2.5 < eta < 4). This extended rapidity coverage on particle identification enables lots of physics opportunities in pp, pA and AA programs beyond 2020 at STAR. Two size of sTGC prototypes have been designed and produced at Shandong University. The final designation will be finished by Feb.2020. In this poster, the sTGC prototype R&D details and some performance test results, such as position resolution and detection efficiency, will be presented. Current status and future plan of the FTT upgrade will also be discussed.

Poster Session - Board: 73 / 74

COMET CRV SiPM readout prototype board performance

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The COMET experiment (J-PARC E21, Japan) is under development now. Cosmic ray muons can decay in flight or interact with the materials around the matter of the muon-stopping target and produce “fake” signal-like electrons in the detector region. In order to have control over this background, a Cosmic Ray Veto (CRV) system is required for COMET experiment. In accordance with our plan the CRV system consists of 6 panels located along the perimeter and roof of the COMET detector. The panels consist of “strip” plastic scintillator counters with SiPM readout. A special readout and signal processing electronic board is designed to prototype analog and digital paths. So the performance data and some specific details are presented. The obtained performance is in accordance with specification and satisfy the CRV system requirements.

Colliders and detector integration / 75

Simulation of physics background in Super c-tau factory detector

Mr. SHEKHTMAN, Lev

Simulation of background particle fluxes generated by colliding beams is performed with FLUKA package for the Super C-Tau factory Detector (SCTD). Two processes are considered as main sources of luminosity generated background: two-photon production of electron-positron pairs and Bha Bha scattering with bremsstrahlung photon emission (radiative Bha Bha). The SCTD geometry is described corresponding to the last version of the Conceptual Design Report. The magnetic field based on the calculation in ANSYS is introduced in the model. Main results of the simulation for beam energy of 3 GeV, luminosity of $10^{35}$ cm$^{-2}$s$^{-1}$ and 1.5 T magnetic field are the following: charged particle fluence in the region of the Inner Tracker (radius 5cm – 20 cm, Z between -30cm and 30 cm) is between $10^{5}$ particles/(cm$^2$ x s) and $\tilde{1}10^{3}$ particles/(cm$^2$ x s); 1-MeV neutron equivalent fluence for Si in the regions corresponding to electronics of the Inner Tracker and the Drift Chamber is below $10^{11}$ n/(cm$^2$ x y) and absorbed dose is below 100 Gy/y in the hottest regions of the detector.

Operation of silicon microstrip detector with integrating readout for fast time-resolved experiments

Mr. SHEKHTMAN, Lev

New detector prototype is developed for the “Plasma” scattering station on the eighth beamline of the VEPP-4 synchrotron radiation source at the Budker Institute of Nuclear Physics. The prototype is based on p-in-n silicon microstrip sensor with metal strips galvanically coupled to the p-implants. Each strip is connected to the input of low-noise integrator with 32 analogue memory cells. This approach allows to record time evolution of one-dimensional image of diffraction pattern with frame rate up to 10 MHz, spatial resolution of 130 $\mu$m (FWHM) for 70 keV photons and maximum photon flux about 100 photons/channel.

Development of a silicon microstrip detector prototype for ultra-fast imaging at a synchrotron radiation beam

Mr. SHEKHTMAN, Lev

This approach allows to record time evolution of one-dimensional image of diffraction pattern with frame rate up to 10 MHz, spatial resolution of 130 $\mu$m (FWHM) for 70 keV photons and maximum photon flux about 100 photons/channel.
A method of imaging of ultra-fast processes, like explosions or fast combustion, at a synchrotron radiation beam is being developed at the Siberian Synchrotron and Teraherz Radiation Center (SSTRC). Two stations are equipped with the detector for imaging of explosions, DIMEX, based on high pressure ionization chamber, and allowing to record up to 100 one dimensional images with a frame rate of 8 MHz. However the maximum flux that DIMEX can detect is limited as well as the spatial resolution and the frame rate because of the gas technology used. In view of the significant increase of SR flux at the VEPP-4M beam line due to the new 9-pole 2 T wiggler, a new detector is being developed for this beam line, based on Si microstrip sensor. The first Si microstrip detector prototype has been mounted with a new specially developed front-end ASIC that allows to record data with a rate up to 40 MFrames/s. The first measurements with this prototype demonstrated significant improvement of all critical parameters of the detector compared to the gaseous version. The maximum detected photon rate before saturation is increased by a factor of 10. The spatial resolution is improved from 240 \( \mu m \) to \( \approx 50 \mu m \) (FWHM) and the frame rate is increased by a factor 5.

Calorimetry / 78

Upgrade of the ATLAS Hadronic Tile Calorimeter for the High Luminosity LHC

TILE CALORIMETER SPEAKERS COMMITTEE, on behalf\(^1\); Ms. ZAKAREISHVILI, Tamar\(^2\)

\(^1\) CERN \\
\(^2\) High Energy Physics Institute of Tbilisi State University

The ATLAS hadronic Tile Calorimeter (TileCal) will undergo major upgrades to the on- and off-detector electronics in preparation for the high luminosity programme of the LHC (HL-LHC) in 2026. The system will cope with the HL-LHC increased radiation levels and out-of-time pileup. The on-detector electronics of the upgraded system will continuously digitize and transmit all photomultiplier signals to the off-detector systems at a 40 MHz rate. The off-detector electronics will store the data in pipeline buffers, reconstruct cell energy, produce digital hadronic cell sums of various granularity and send it to the Level-0 calorimeter trigger system, finally read out selected events. The modular front-end electronics feature radiation-tolerant commercial off-the-shelf components and redundant design to minimise single points of failure. The timing, control and communication interface with the off-detector electronics is implemented with modern Field Programmable Gate Arrays (FPGAs) and high speed fibre optic links running up to 9.6 Gb/s. The TileCal upgrade program has included extensive R&D and test beam studies using the beams from the Super Proton Synchrotron (SPS) accelerator at CERN, and a Demonstrator module equipped with the novel electronics for the HL-LHC upgrade and compatible with the existing ATLAS read-out chain inserted in ATLAS in August 2019 for testing in actual detector conditions. We present the status of the upgrade program, the results using muon, electron and hadron beams at various incident energies and impact angles collected in 2015-2018 , combined results of Demonstrator tests and calibration runs to evaluate the readiness of the new design.

Poster Session - Board: 74 / 79

Design of Prototype Front-End Electronics for the Gamma-Gamma Collider

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ABSTRACT:

The Gamma-Gamma collider is a scientific facility proposed in China to observe two unique interactions composed of [U+1D6FE][U+1D6FE] scattering and electron-positron pairs at the
1-2 MeV cross section. In the experiment, two $[\U+1D6FE]$ beams generated by the Compton back-scattering of high-energy electron beams ($\sim 200$ MeV) and high-intensity laser beams collide at the interaction point, and the products are collected by CsI(Na) scintillators and plastic scintillators, and then converted into electric signals by silicon photomultiplier (SiPM) detectors.

In this paper, the Front-End Electronics card (FEE) is designed to read out all electric signals from the SiPM detectors, with the feature of high sampling rate and low power consumption. There are 180 differential drivers, 45 low-power switch capacitor array (SCA, DRS4) chips with 8 input channels per chip, 6 ADCs with 8 channels per chip implemented on one FEE. The input signals are firstly stored in DRS4 chips for time stretching, then digitized by ADCs, and finally sent to back-end electronics via an optical link after packaged in an FPGA chip. The noise (RMS) of each readout channel on the FEE version 1 is less than 3 mV after the offset correction, and the ENOB of the channels is better than 6.7 bit when the frequency of input signals is less than 70 MHz. Therefore, the performance of the FEE v1 meets the requirements of the Gamma-Gamma collider.

**1. INTRODUCTION**

The Gamma-Gamma collider is under discussion in China proposed by Institute of High Energy Physics (IHEP). The high-energy electron beams ($\sim 200$ MeV) generated by a linear electron accelerator are divided into two arcs, and then brought into a head-on collision at the interaction point (IP). A high-intensity laser beam is illuminated to the electron beams at the conversion points (CP) shortly before they cross the IP, and the process can generate target gamma beams (1-2 MeV) based on Compton back-scattering. Finally, the $[\U+1D6FE]$ beams collide at the IP.

The planned structure of the Gamma-Gamma collider facility is shown in Fig. 1.

![Fig.1. A planned structure of the Gamma-Gamma collider facility.](image)

**2. DESIGN OF THE FRONT-END ELECTRONICS**

*Readout requirements*

In the Gamma-Gamma collider, there are thousands of electric signals to be read out from all SiPM detectors. The detectors are placed in the vacuum cavity to collect the light signals. And technical restrictions of vacuum wall penetration cause the front-end electronics to be placed in the cavity. Due to the compact vacuum area, the front-end electronics requires high integration, which results that each board with the size of 50 cm × 25 cm processes 180-channel analog signals from detectors. The power consumption of the front-end electronics is as low as possible to reduce the heat dissipation in vacuum.

Based on the selected type of detectors, the pulse width of $[\U+1D6FE]$ signals is 2 $\mu$s with 600 ns rising edge, the pulse width of electron signals is 30 ns with 10 ns fast rising edge, and the characteristic of positron signals are the superposition of 2 $\mu$s slow pulses and 30 ns fast pulses. In order to distinguish the type of particles, the waveform digitizing technology is applied on the readout electronics. Based on the Shannon sampling theory, the analog bandwidth is required better than 50 MHz. The sampling time window requires to reach at least 2 $\mu$s to acquire the whole pulse of particle signals. The target time resolution of detection system is 100 ps (RMS), and the time resolution is composed of the time precision of the detectors and the contribution of the readout electronics. According to the error transfer formula

$$N_{\text{whole-system}} = \sqrt{N_{\text{detector}}^2 + N_{\text{electronics}}^2}$$

(1)

($N_{\text{whole-system}}$ represents the time resolution of the detection system, $N_{\text{detector}}$ is the time precision of the detectors, and $N_{\text{electronics}}$ is the time resolution of the readout electronics), the time resolution of the electronics is required better than 70 ns on the condition that these factors are independent and the resolution of both is equal. Thus the waveform sampling rate needs to be set 1 GSPS based on the time fitting simulation with the same equivalent noise voltage, as shown in Table 1. The noise standard deviation of the readout system is required less than 3 mV at 1 V input range. Therefore, it is a good challenge to achieve the design of low noise, high sampling rate and low power consumption.

Table 1. The time resolution of different sampling rate based on the time fitting simulation.

<table>
<thead>
<tr>
<th>Sampling rate/GSPS</th>
<th>0.2</th>
<th>0.5</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time resolution/ps</td>
<td>131.6</td>
<td>82.5</td>
<td>50.8</td>
</tr>
</tbody>
</table>

*Basic Structure*

A readout electronics system composed of front-end electronics and back-end electronics has been put forward for the Gamma-Gamma collider, as shown in Fig. 2. The front-end electronics...
is comprised of several Front-End Electronics cards (FEEs) with 180 channels on each board. The back-end electronics is one Data Acquisition board (DAQ).

Calorimetry / 80

SND electromagnetic calorimeter time measurement and its applications
MELNIKOVA, Natalya

1 BINS

The SND is a non-magnetic detector deployed at the VEPP-2000 e+e- collider (BINP, Novosibirsk) for hadronic cross-section measurements in the center of mass energy region below 2 GeV. The important part of the detector is a three-layer hodoscopic electromagnetic calorimeter (EMC) based on NaI(Tl) counters. Until the recent EMC spectrometric channel upgrade, only the energy deposition measurement in counters was possible. A new EMC signal shaping and digitizing electronics based on FADC allows us to obtain also the event time structure. The new electronics and supporting software, including digital signal processing algorithms, are used for data taking in the ongoing experiment. We discuss the amplitude and time extraction algorithms, the new system performance on experimental events and physical analysis applications.

Poster Session - Board: 33 / 81

Spatial resolution of the detectors based on Gas Electron Multipliers
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Coordinate detectors based on Gas Electron Multipliers (GEM) are used in experiments at many high energy physics centers and at Budker Institute of Nuclear Physics particularly. Spatial resolution of these detectors is known to be in tens microns scale. Also the detectors possess a rate capability up to $10^7 cm^{-2}s^{-1}$. Consequently, the precise study of best possible coordinate resolution, achieved with GEM-detectors, is a significant task. The experimental data, collected by the moment, provides the possibility to compare it with the results of the simulation. The simulation of the detector performance includes transport of electrons through the detector medium, tracking of an avalanche evolution inside the working volume, as well as registering of the signal distribution on the readout strips. The simulation of individual detector shows that its spatial resolution is considerably better than the experimental results with the difference about two standard deviations. In order to find out possible reasons of the contradiction between measurements and the simulation of the individual detector, the simulation of complete experimental set-up (including tracking detectors) is performed. The results of complete set-up and individual detector simulations are determined to coincide in general.

Instrumentation for Astroparticle and Neutrino physics / 82

Development of a 3D highly granular scintillator neutrino detector for the T2K experiment
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2 Institute for Nuclear Research of the Russian Academy of Sciences

The long baseline neutrino experiment T2K has launched the upgrade project of its near detector ND280, crucial to reduce the systematic uncertainty in the prediction of number of events at the far detector to less than 4%. An essential component of this upgrade is a highly segmented
scintillator detector, acting as a fully active target for the neutrino interactions. We adopt a novel design, called SuperFGD, with dimensions of \(200 \times 180 \times 60\) cm\(^3\) and a total mass of about 2 tons. It consists of about 2x106 small scintillator cubes each of 1 cm\(^3\). Each cube is covered by a chemical reflector and has three orthogonal cylindrical holes of 1.5 mm diameter. The signal readout from each cube is provided by wavelength shifting fibers inserted in these holes and connected to micro-pixel avalanche photodiodes MPPCs. The front-end electronics will be based on the CITIROC chip designed for the multi-channel readout of SiPM. The total number of channels will be \(60,000\). We have demonstrated that this detector, providing three 2D projections, has excellent tracking performance, including a \(4\pi\) angular acceptance, especially important for short proton and pion tracks. Prototypes of this detector have been tested in a beam of charged particles at CERN in 2017-2018 and recently with a neutron beam at LANL in 2019. The project has been approved by CERN as part of the Neutrino Platform (NP07). In this talk, we will report on the design of this detector, its expected performance, the results of the test beams and the plan for the construction.

**Poster Session - Board: 10 / 83**

**Commissioning of the MEGII tracker system**

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The aim of MEG experiment is looking for the \(\mu^+ \rightarrow e^+\gamma\) at the Paul Scherrer Institute (PSI) near Zurich in Switzerland. The decay \(\mu^+ \rightarrow e^+\gamma\) is an extremely rare process of the violation of the flavour of charged-leptons and it is forbidden in the Model Standard that foresees an experimentally unattainable branching ratio \(\text{BR} \approx 10^{-55}\). Anyway some Super-Symmetric extensions to the Standard Model predict the decay \(\mu^+ \rightarrow e^+\gamma\) in the range \(10^{-11} - 10^{-14}\). MEG has already determined the world best upper limit on the branching ratio: \(\text{BR} < 4.2 \times 10^{-13}\) at 90\%CL with the full data set collected in the years 2009-2013.

The new positron tracker is a high transparency single volume, full stereo cylindrical Drift Chamber (CDCH), filled with a gas mixture of helium-isobutane. It is composed of 9 concentric layers, divided in 12 identical sector, each layer consisting of a sense wires plane between two field wires planes at alternating signs stereo angles. Each layer is composed of 192 drift cells (16 for sector), the single drift cell is approximately square, with a 20 \(\mu\)m gold plated W sense wire surrounded by 40 \(\mu\)m silver plated Al field wires in a ratio of 5:1. For equalizing the gain of the innermost and outermost layers, two guard layers have been added at proper radii and at appropriate high voltages. The total number of wires amounts to 11904.

We will present the CDCH commissioning operations performed at PSI after that it was moved from INFN-Pisa. The HV tests and conditioning of the chamber are presented, aiming at reaching the HV working point, as obtained from gas gain simulations. The first signals with cosmics rays are shown, before the description of the CDCH integration into the MEG II experimental apparatus.

Finally we will talk about the 2018 engineering run with CDCH fully integrated in the experimental apparatus for the first time. The subsequent the CDCH re-opening operations during the first half of 2019 to find the final stable working point configuration and of the pre-commissioning run of this year. Starting from a description of the read out configurations, the HV scans with cosmics and Michel positrons and the \(\mu^+\) beam intensity scans are shown.

**Poster Session - Board: 11 / 84**

**An automatic system for Drift Chambers wiring in modern High Energy Physics experiments**

Dr. TASSIELLI, Giovanni Francesco\(^1\); Mr. CHIARELLO, Gianluigi\(^2\)

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Modern experiments for the search of extremely rare processes require high momentum resolutions (order of 50-100 keV/c) tracking systems for particle momenta in the range of 50-100 MeV/c, dominated by multiple scattering contributions. A typical tracking detector with high precision and ability to withstand high rates is a full stereo, high granularity Drift Chamber. Due their high wire density, the use of the classical feed-through technique as wire anchoring system can hardly be implemented and therefore it is necessary to develop new wiring strategies. To this purpose, a wiring robot has been designed and built: for monitoring the solder quality of the wire to the supporting Printed Circuit Boards; for applying mechanical a pre-defined tension to the wires and maintaining it constant and uniform through the whole chamber; for monitoring the wire positions and their alignments within a few tens of $\mu$m; for anchoring the wires to their support with a contactless soldering system. The wiring robot consists of:

- List item **WIRING SYSTEM**: a semiautomatic wiring machine with a high precision on wire mechanical tensioning ($<0.05$ g) and on wire positioning ($<20$ $\mu$m) for a simultaneous wiring of multi-wire frames;
- List item **SOLDERING SYSTEM**: a contact-less infrared laser soldering tool for anchoring the wires to the supporting PCB;
- List item **EXTRACTION SYSTEM**: an automatic handling system for removing the multi-wire frames from the wiring system and for storing them and wit adjustable wire tension.

All subsystems of the wiring robot are managed and synchronized with a real-time system, based on a National Instrument CompactRIO platform. The wiring robot has been used for the wiring phase of MEG II Drift Chamber.

**Poster Session - Board: 66 / 85**

**Experience in computer design of microchannel amplifiers**

Dr. IVANOV, Valentin\(^1\)

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The experience of computer-aided design of micro channel amplifiers as fast photo detectors of modern charged particle accelerators is generalized. All aspects of the design of devices from the photo cathode to the collector are considered, including the issues of thermal stability, the influence of noise, saturation effects, the influence of edge fields, dark currents and the operation of amplifiers in strong magnetic fields. A review is given of modern analytical, numerical and mixed mathematical models used in modeling amplifiers that detect signals in a wide range of radiation - from infrared to x-ray. Comparison of simulation results with experimental data for four major Russian and foreign projects in which the author participated.

**Poster Session - Board: 67 / 86**

**On the focusing of ion beams using micro- and nanoporous structures**

Dr. IVANOV, Valentin\(^1\)

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Recently, many publications [1–5] have appeared, in which the mechanism of focusing of ion beams in porous dielectric structures is experimentally investigated. This self-organizing charge-up mechanism is called the capillary guiding effect. It consists in the fact that the ion beam induces a layer of surface charges on the walls of such structures, which forms an analog of the wave guide that reflects the beam from the walls. Thus, the initial ion beam is not only focused inside the channel, but also is able to change the direction of its movement in the direction along
the axis of the channels, if these channels are located at an angle to the direction of the initial
movement of the beam. A detailed study of this mechanism is possible only on the basis of a
meaningful theoretical model that takes into account the probabilities of elastic reflections and
charge exchange of ions when they collide with pore walls, depending on the parameters of the
initial beam and the properties of the material of the porous structure. The author’s experience in
numerical modeling of charged particle beams in micro channel plates [6] allowed him to develop
algorithms and programs for modeling guiding effects of ion beams and to carry out calculations
to study the details of the guiding mechanism and compare numerical results with experimental

Poster Session - Board: 34 / 87

Positive ion suppression with untriggered Bi-polar grid in the magnetic field

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High precision gaseous detectors such as Time Projection Chambers (TPC) are widely used in
high energy physics for many years. Recent progress in electronics allows operating TPC readout
in a continues mode, significantly increasing TPC readout capability. Further increase in the
TPC data taking rates is impeded by the space charge formed in the sensitive volume of the
TPC which distorts the electric field uniformity. The main contribution to the space charge is
generated by the TPC amplification elements emitting gas ions back into the detector volume.
To resolve this problem, a significant effort is undertaken by several large collaborations, utilizing
the amplification devices themselves as ion filters.

A new opportunity opens up for the sPHENIX experiment operating TPC in the magnetic field of
1.4 T. A combination of a strong magnetic field and electric fields makes it possible to construct
a static grid with different transparencies to primary electrons and back-flowing positive ions.
This well-known effect is described in the detector text-book published back in ‘90 [1], however,
it has not been implemented in any real detector. In this talk, I will present results showing
that the bi-polar grid operated at a constant voltage can have a practical effect on reducing
the space-charge problem of a real TPC. Results will be presented for several gas mixtures and
compared to the Monte Carlo simulations.


Status of facilities / 88

KEK and its plans

UNO, Shoji¹

¹ KEK

There are two campuses in KEK, Tsukuba and Tokai. In the Tsukuba campus, the operation of
the SuperKEKB accelerator just started with the full Belle II detector from March 2019.
SuperKEKB and Belle II had been upgraded from KEKB and Belle, respectively. The present
luminosity exceeded more than $10^{34}$ cm$^{-2}$s$^{-1}$ with lower total beam current as compared with
KEKB due to smaller vertical focusing length at the interaction point ($\beta^*$). It indicates that the upgrade accelerator can provide higher luminosity with higher beam current in the near future after sufficient vacuum scrubbing. The Belle II detector is basically working. Some demonstration plots will be shown in the conference.

In the Tokai campus, the high intensity proton accelerator (J-PARC) has been operated for 10 years. The facility provides us various particles (pion, kaon, neutrino, neutron and muon). Several nuclear experiments has carried out using pion and kaon. The T2K experiment provides some results for the CP violation in the neutrino sector using neutrino and anti-neutrino. The status of new project (HK) and the status of the COMET experiment (the search for the charged lepton flavor violation) will be mentioned in the conference. Also, the material and other science have been performed utilizing neutron and muon.

Poster Session - Board: 19 / 89

**Time of Flight system of the BM@N/NICA experiment.**

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BM@N (Baryonic Matter at Nuclotron) is the first experiment at the accelerator complex of the NICA. The Nuclotron will provide variety of beams from protons to gold ions with the kinetic energy of ions ranging from 1 to 6 GeV per nucleon. The main goal of the experiment is studying of baryonic matter at high density and temperature within collisions of relativistic heavy ions. The experiment combines high precision tracking with high performance time-of-flight measurements for particle identification. First physical data were obtained in spring 2018. The setup registered particles from collisions of Ar and Kr beams with the targets C, Al, Sn, Cu, Pb. The performance of the detectors and preliminary result of particle identification are presented in the poster.

Poster Session - Board: 46 / 90

**Particle identification with Cherenkov detector in VES experiment**

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Cherenkov detector is a key element of particle identification system in the VES fixed target experiment at IHEP(Protvino). It consists of a 1.6 m R-22 gas radiator and a system of 28 spherical mirrors with photomultipliers(PMT) as a photon detector. We present in this talk description of detector design, its model, particle identification algorithm, and discuss procedures of obtaining calibration constants. Detector performance in terms of identification efficiency and purity is demonstrated with the Monte-Carlo and experimental data analyses.

Timing detectors / 91

**Time-of-flight system of the MultiPurpose Detector at NICA**

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**Co-author(s):** Mr. RUMYANTSEV, Mikhail

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The time-of-flight method of particle identification in the MPD multi-purpose detector is one of the main methods for identifying charged hadrons in the momentum range up to 3 GeV. It is necessary that the time-of-flight system detectors have the best time resolution with an efficiency close to 100% for highly efficient registration and separation of kaons and pions with a limited
time-of-flight base. A multi-gap resistive plate chamber (MRPC) with 15 gas gaps was developed for this purpose. The best time resolution of the MRPC with front-end and digitizing electronics reached 40 ps with a detection efficiency of 99%. Such a detector is fully satisfied with the technical and physical requirements of the MPD experiment. The report will present the testing results of the MRPC prototype and the results of the simulation of the properties of the time-of-flight system assembled from these detectors.

Poster Session - Board: 22 / 93

Development of A SPIROC2E-Based Scintillator Test Platform for CEPC AHCAL prototype

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The Circular Electron Positron Collider (CEPC) is one of the next generation colliders aim at huge amount of the Higgs, W and Z bosons generation and its 70 cm × 70 cm × 40 layers AHCAL (Analog Hadron Calorimeter) prototype is under construction. The prototype AHCAL is a sampling calorimeter with steel as the absorber and scintillator tiles and SiPM (Silicon Photomultiplier) as sensitive medium and contains about 12,000 40 mm × 40 mm scintillators. The uniformity of scintillator light yield is a vital factor which greatly influences the energy linearity and resolution of the calorimeter. This paper describes a test platform which can measure the light yield of every scintillator used in the AHCAL prototype. The test platform which runs in a dark box to shield environmental light consists of a PC, a readout electronic system, and a 90Sr radioactive source on a stepping motor. The whole test platform is designed based on 4 SPIROC2E chips, a low-noise front-end chip with 36 SiPM readout channels. There’re 144 scintillator positions on the test platform, each of which contains a SiPM and an electronic readout channel. The stepping motor is programmed to move above the scintillators by a self-written software. When a test is started, each channel is ready to collect, sample, digitize the incident signal and then sends the charge and timing information to PC, while the 90Sr radioactive source is controlled to stay on the top of the first tested scintillator. After a fixed interval, 10 minutes for example, charge information is enough to extrapolate the light yield of the current scintillator and the source is moved to the next scintillator for another test unless all scintillators tested. Since the valid digital data from SPIROC2E chips is characterized with a “hit” signal, offline analysis is easy to be carried out and the light yield of every scintillator is obtained. In that way the whole test process for all scintillators will work out automatically without redundant intervention. SiPM gain difference, which could result from production and using damage, should be controlled strictly in order to test the light yield of scintillators. Even the same type SiPMs have distinctive gain, and are strongly dependent on temperature. So temperature monitoring system is established based on temperature sensors located evenly in all SiPM cells. Thanks to the internal DAC of SPIROC2E chip, the bias voltage for each SiPM can be tuned to minimize the gain difference according to the feedback from the temperature monitors.

Calorimetry / 94

AMoRE- an experiment searching for neutrinoless double beta decay using molybdate crystals and cryogenic detectors

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The AMoRE (Advanced Molybdenum based Rare process Experiment) is an experiment searching for neutrinoless double beta decay of Mo-100 in molybdate based crystal scintillators using a cryogenic detection technique. The crystals are equipped with metallic magnetic calorimeter (MMC) sensors for detection of both phonon and photon signals at temperatures of few tens of mK. Simultaneous measurements of thermal and scintillation signals produced by a particle interaction in crystals by the MMC sensors provide high energy resolution and efficient particle
discrimination. The AMoRE-pilot, an R&D phase with six 48deplCa100MoO4 crystals and a total mass of ~1.9 kg in the final configuration, was running at the 700-m-deep Yangyang underground laboratory (Y2L). After completion of the AMoRE-pilot run in the end of 2018, the AMoRE-I is being prepared with ~6 kg of crystals, thirteen 48deplCa100MoO4 and five Li2100MoO4, to be installed at the Y2L by January 2020. We have secured 110 kg of Mo-100 isotopes for production of the AMoRE-II crystals. The AMoRE-II with ~200 kg of molybdate crystals will be running at the Yemilab, new underground laboratory located ~1,100 m deep at Handeok iron mine and being excavated from March 2019 for a completion by the end of 2020. The AMoRE-II is expected to improve upper limit of effective Majorana neutrino mass down to the level of inverted hierarchy region of the neutrino mass, 20-50 meV, when no such decays are observed. Results of the AMoRE-pilot and progress of the AMoRE-I and AMoRE-II preparation will be presented.

Colliders and detector integration / 95

C.M.S. Energy Calibration in BES-III and VEPP-2000 experiments
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Inverse Compton scattering of laser radiation was implemented as a tool for accurate beam energy measurement at BEPC-II and VEPP-2000 colliders. The report summarizes the operation principles, performance and results obtained with beam energy measurement systems in these experiments.

Electronics, Trigger and Data Acquisition / 96

Front-End Electronics development for TPC/MPD detector of NICA project
Mr. VERESCHAGIN, Stepan1

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Time Projection Chamber is the main tracker of the Multi-Purpose Detector. The detector will operate at one of beam interaction points of the collider NICA and it is optimized to investigate both hot and dense baryonic matter. The TPC Front-End Electronics will operate with event rate up to 7 kHz at average luminosity 10^{27} cm^{-2}s^{-1} for gold collisions at \sqrt{sNN} = 9 GeV/n. The electronics is based on the novel ASIC SAMPA, FPGAs and high-speed serial links. Each of 24 readout chambers will serve by 62 Front-End Cards and one Readout and Control Unit. The whole system will contain 1488 FECs, 24 RCUs which gives us 95232 registration channels. The presents current status of the FEE development and results of the FEC testing.

Poster Session - Board: 75 / 97

Design and Optimization of the CSA-based Readout Electronics for STCF ECAL
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Super Tau-Charm Facility (STCF) is one of the important options for accelerator-based particle physics after Beijing Electron-Positron Collider (BEPC-II) in China, which aims at ultra-precise measurement and new physics search in tau-charm energy region with about 100 times higher luminosity. The electromagnetic calorimeter (ECAL), as an important part of the spectrometer, needs to meet demand of high-efficiency and high-resolution gamma detection, electron and
hadron discrimination, etc. Pure CsI (pCsI) is selected as the scintillation crystal for STCF ECAL owing to its fast response (30 ns decay time), high mass density and adequate radiation hardness. Due to the relative low light yield of pCsI crystal and the strong magnetic environment in the experiment, avalanche photodiode (APD) is proposed to convert the scintillation light into current signal with an internal gain of about 50 at the recommended operating voltage. Charge sensitive amplifier (CSA) which has the feature of low noise and high charge measure performance has been used to read the APD signal. Considering the large capacitance of APDs (tens to hundreds of picofarads) which may result in poor noise performance, a low noise field effective transistor (FET) input stage is adopted. Then, a CR-(RC)^2 shaping circuit is employed to improve the signal-to-noise ratio (SNR), and the shaped analog signal is digitalized by an ADC chip. Digital data are pre-processed by FPGA and transmitted to the upper computer via Ethernet. The circuit block diagram and PCB (Front End Board and Back End Board) pictures are shown in figure-1.

Under high event rate and large dynamic range conditions, it is difficult for CSA to achieve extremely low noise, especially with an input capacitance of hundreds of picofarads. In this paper, a noise equivalent circuit containing eleven noise sources is established. Based on this, the optimization for large input capacitance is carried out, applying different types and numbers of JFETs. The result shows that the 3-JFET (2SK715) input stage CSA has the best noise performance at large input capacitance. Optimization of shaping time is also conducted to meet a balance between shot noise and thermal noise, thereby minimizing system noise. The result indicates that the system noise can reach minimum level at a shaping time of about 100 ns. Under above conditions, an equivalent noise charge (ENC) of 675 electrons of electronic noise and 1025 electrons with S8664-0505 APD is realized. Furthermore, optimization of the APD operating voltage to achieve best SNR is also under development.

Instrumentation for Astroparticle and Neutrino physics / 98

The RED-100 experiment.
Dr. AKIMOV, Dmitry

1 ITEP and MEPhI

The RED-100 is a two-phase xenon emission detector built to study the recently discovered rare process of coherent elastic neutrino-nucleus scattering CEvNS. The detector contains ~200 kg of liquid xenon inside a cryostat, with ~100 kg in fiducial volume. The detector is sensitive to the very small level of ionization, down to single ionization electrons. First laboratory tests of the RED-100 detector has been carried out. The results are presented. The detector is planned to be installed at the Kalinin Nuclear Power Plant.

Instrumentation for Astroparticle and Neutrino physics / 100

The COHERENT experiment with LAr
Mr. KUMPAN, Alexander

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Coherent elastic neutrino-nucleus scattering (CEvNS) is recently discovered process by the COHERENT collaboration at the SNS accelerator facility (ORNL, USA). A short overview of the COHERENT multi-detector experiment, with the focus on the liquid argon CENNS-10 detector, is given. Data analysis of CENNS-10 science run is presented. Further LAr program at SNS is discussed.

Tracking and vertex detectors / 101

MPD TPC status
Mr. MOVCHAN, Sergey

1
In the frame of the JINR scientific program on study of hot and dense baryonic matter a new accelerator complex Ion Collider Facility (NICA) based on the Nuclotron-M is under realization. It will operate at a luminosity up to 10^27 cm^{-2} s^{-1} for ions up to Au^{79+}. Two interaction points are foreseen at NICA for two detectors which will operate simultaneously. One of these detectors, the Multi-Purpose Detector (MPD), is optimized for investigations of heavy-ion collisions. The Time-Projection Chamber (TPC) is the main tracking detector of the MPD central barrel. It is a well-known detector for 3-dimensional tracking and particle identification for high multiplicity events. The conceptual layout of MPD, TPC design and its parameters, the current status of the readout based on multiwire proportional chamber (MWPC) and readout electronics based on SAMPA chip as well as the status of TPC subsystems are presented.

Instrumentation for Astroparticle and Neutrino physics / 102

Neutrinoless double beta decay searches: gearing up for the tonne-scale era
Dr. ARAZI, Lior

The nature of the neutrino, namely whether it is a Dirac or Majorana fermion, is a key question with far-reaching implications in particle physics and cosmology. The most sensitive experimental probe in this respect is the search for neutrinoless double beta decay ($\beta\beta_0\nu$), which can only occur if the neutrino is its own antiparticle. A positive detection will provide a first demonstration of lepton number violation, as well as support for theories beyond the Standard Model explaining the origin and smallness of the neutrino mass, and the generation of matter-antimatter asymmetry in the Universe via leptogenesis. The importance of $\beta\beta_0\nu$ detection on the one hand, and the availability of promising experimental schemes with already proven results on the other, motivate an international, well-funded, multi-isotope approach. A number of experiments have already constrained the $\beta\beta_0\nu$ half-life to $10^{25} - 10^{26}$ years, employing masses of $\beta\beta_0\nu$ isotopes of tens to hundreds of kg. If one assumes that the underlying mechanism for $\beta\beta_0\nu$ is the exchange of light Majorana neutrinos, this corresponds to excluding effective Majorana neutrino masses slightly above the inverted mass-ordering band in the neutrino mass parameter space. The next generation of experiments aims to fully explore the inverted mass ordering region, which requires sensitivities to half-lives of the order of $10^{27} - 10^{28}$ years. This, in turn, necessitates tonne-scale masses of the $\beta\beta_0\nu$ isotopes and an order-of-magnitude improvement in background rejection. This talk will review the different technologies employed by the main $\beta\beta_0\nu$ experiments, their present status and plans for tonne-scale searches, discussing, in particular, their key merits and respective challenges.

Status of facilities / 103

The Experimental Program at IHEP CAS
Prof. WANG, Jianchun

The Institute of High Energy Physics (IHEP) of the Chinese Academy of Sciences (CAS) is a comprehensive research center for the study of particle physics in China. IHEP hosts or manages a number of key China based facilities in operation or under construction, including Beijing Spectrometer (BES III) at Beijing Electron Positron Collider (BEPC II), Daya Bay Reactor Neutrino Experiment, China Spallation Neutron Source (CSNS), Yangbajing Cosmic Ray Observatory, Hard X-ray Modulation Telescope (HXMT), Jiangmen Underground Neutrino Observatory (JUNO), Large High Altitude Air Shower Observatory (LHAASO), etc. It plays a major role in planning future research in this field, e.g. the proposed Circular Electron Positron Collider (CEPC) project. The institute is also a member of the LHC experiments, Belle II, and a few other important international collaborations. In this presentation status and plan of the IHEP experimental program will be described. A few selected detector research work will be introduced.
Poster Session - Board: 55 / 104

Development of a compact-size, novel wide Field of View VHE Gamma-Ray Imaging Air Cherenkov Telescope with a SiPM-based camera for energies above 10 TeV for operation in the TAIGA installation.

Dr. CHERNOV, Dmitry

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D. Chernov for the TAIGA collaboration.

The TAIGA complex-detector is designed to study gamma and cosmic rays in the energy range above 30 TeV. We are developing a novel wide-angle telescope with a SiPM-based imaging camera of a FoV of 15-20° and of an aperture of not more than 1 m2. In this report we intend to present the design of such a camera (optical system and DAQ), based on 1000-1200 SiPMs. The prototype of such a camera, based on 49 SiPMs, is operating at the TAIGA's site in Tunka valley since September 2019. The design of the prototype and the preliminary results of data analysis will be presented.

Poster Session - Board: 23 / 105

Study of the fast calorimeter prototype for modern $e^+e^-$ factories

Ms. PROKHOROVA, Ekaterina

1 Sergeeva

Modern $e^+e^-$ factories with high luminosity require a fast response time of the detector subsystems to suppress severe beam background. The prototype of the electromagnetic calorimeter based on the counter with pure CsI crystal, novel wavelength shifter with nanostructured organosilicon luminophores and avalanche photodiodes Hamamatsu S8664-55 is discussed. The results of cosmic particle signals registration by such prototype will be reported.

Poster Session - Board: 76 / 106

Design of Temperature Compensation System for SiPM based on SPIROC2E

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1 INTRODUCTION 1) CEPC and ECAL With the discovery of Higgs boson in LHC, basic physics has come to one of the most exciting crossroads in its history. CEPC (Circular Electron-Positron Collider) is the first phase of CEPC-SPPC. The main purpose is to generate positive and negative electron pairs with a centroid energy of up to 240 GeV, which collide in the ring at a time interval of about 3.5 us, with a brightness of $2^* [U+3016] 10 [U+3017] -34 [U+3016] cm [U+3017] -(-2) s^{-1}$, and generate a large number of Higgs particles and Z particles. ECAL (Electromagnetic Calorimeter) s an important part of CEPC concept detector. The electromagnetic energy meter mainly measures 30% of photons in jet. To achieve this goal, the pre research technical scheme adopts the way of scintillator array + SiPM stack, and forms a sampling type energy meter with tungsten plate absorber. 2 Design of the Temperature Compensation System 1) Basic structure A readout electronics system including ECAL base unit (EBU) and data interface board (DIF) was built to acquire the output of SiPMs. SiPMs and Scintillators are set on the EBU board. We use the SPIROC2E as the acquisition ASIC in this system. This chip can acquire the signal from the SiPMs, and do the A/D conversion with the ADC embedded. So we can get digital signal directly from SPIROC2E. There are 6 SPIROC2Es on each EBU board. EBU board is under the control of the DIF board. The detection results are transmitted to PC through the DIF board. 2) Design of the Temperature Compensation System We chose to use SiPM as the
detector of the ECAL prototype, but SiPM has some features which could be the limitation of the improvement of the performance of the prototype. The Gain of SiPM is sensitive to the environment temperature. According to the datasheet of SiPM by HAMATSU the gain nonlinearity of SiPM could reach 10% per degree Centigrade. To solve this problem we designed an automatic temperature compensation system based on the function of the readout chip we used on the EBU board. 16 temperature probes were set on the EBU board according to the simulation result. Some of the temperature probes are located near the SPIROC2E while the others are located around the SiPMs. We ran the readout system and acquired the output of every temperature probe. The result shows that the maximum temperature difference can reach about 1 degree Centigrade. The gain of SiPM increases linearly with the operation voltage, so we can change the operation voltage according to the temperature to compensate the nonlinearity. Each one of the SPIROC2E’s 36 channels is embedded with an output DAC for SiPM high voltage adjustment on 5V to tune gain channel by channel. There is an 8bit DAC connected to each input pin of the SPIROC2E which could be configured manually. The whole temperature compensation system is under the control of the FPGA on the DIF board. During every slow control period FPGA will acquire and analyze the temperature information from the temperature probes. FPGA will configure the DAC embedded to each output pin of the SPIROC2E according to the temperature. If the temperature near a SiPM is higher than the average level FPGA will improve the output of the DAC connected to it, while the temperature is lower FPGA shall do the opposite. 3 Work Situation of Temperature Compensation System To see if the system works as well as we expect, we did the optical calibration of SiPM. There are 210 SiPMs on each EBU board. We can see the single photoelectron spectrums of the SiPMs. A certain degree of distortion happens in the single photoelectron spectrums between different SiPMs before the temperature compensation, while after the temperature compensation, the result was corrected.

4 Summary In order to solve the problem that SiPM is sensitive to environment temperature, we built a temperature compensation system. This system could adjust the operation voltage of each SiPM to maintain gain consistency. The test result we got proved that our system works as well as we expected.

Calorimetry / 107

**Final design of the mu2e crystals calorimeter**

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The Mu2e experiment at Fermilab will search for the charged-lepton flavour violating neutrino-less conversion of a negative muon into an electron in the field of an aluminum nucleus. The Mu2e detector is composed of a tracker and an electromagnetic calorimeter and an external veto for cosmic rays. The calorimeter plays an important role in providing excellent particle identification capabilities, a fast online trigger filter while aiding the track reconstruction capabilities. The calorimeter requirements are to provide a large acceptance for ~100 MeV electrons and reach: 1) a time resolution better than 0.5 ns; 2) an energy resolution O(10%); 3) a position resolution of 1 cm. The calorimeter consists of two disks, each one made of 674 pure CsI crystals readout by two large area 2x3 array of UV-extended SiPMs of 6x6 mm^2 dimensions. A large scale prototype has also been constructed and tested at the beam test facility in Frascati. It consists of 51 pre-production crystals readout by a 102 SiPM. All the test and progresses done to define the calorimeter design, the satisfying results obtained with the test beam of the prototype as well as the current production phase will be presented. At the moment, all the components for the first disk has been characterized. The construction starting is planned for spring 2020.

Particle Identification / 108

**GlueX DIRC at JLab**

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The GlueX experiment at Jefferson Laboratory aims to perform quantitative tests of non-perturbative QCD through hadronic spectroscopy (mainly using light-quark mesons and baryons). The recently installed Detection of Internally Reflected Cherenkov light (DIRC) detector is an important addition to the particle identification (PID) package of GlueX and is a crucial element for carrying out the full GlueX physics program. The DIRC is designed to provide clean pi/K separation up to 4 GeV/c momenta in the forward region (theta<11 deg from the beam). This capability will enable us to explore the s-sbar hybrid meson states which decay into final states with charged kaons. The DIRC system is constructed using long quartz radiators from decommissioned BaBar experiment combined with new compact photon sensors based on SuperB FDIRC concept. This system was fully installed in Oct 2019, and commissioned with beam during 4 weeks in Dec 2019. In this presentation we will be discussing the construction and commissioning of the DIRC system, as well as the performance of the detector compared to expectation.

**Poster Session - Board: 24 / 109**

Methods for centrality determination in nucleus-nucleus collisions with forward hadron calorimeters at the BM@N experiment.

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The BM@N (Baryonic Matter at Nuclotron) is the fixed target experiment at NICA-Nuclotron (JINR, Dubna, Russia) accelerator complex. The main goal of the BM@N experiment is studying properties of dense nuclear matter produced in the ion-ion collisions. First experiments were done for carbon, argon and krypton ions beams with C, Al, Cu and Pb targets at beam energies up to 4.5 AGeV. The methods of central events selection on event-by-event base with old ZDC (Zero Degree Calorimeter) for these reactions will be presented. The new Forward Hadron Calorimeter (FHCAL) with transverse and longitudinal segmentation will be used to measure the collision centrality in heavy ion experiments after the BM@N upgrade. The FHCAL has the beam hole in the center due to expected high beam intensities. New forward quartz hodoscope is developing to be placed in the beam hole to measure the charge of fragments. New methods of centrality determination with the FHCAL and forward quartz hodoscope will be discussed.

**Poster Session - Board: 77 / 110**

Design features and Data Acquisition System of the TAIGA-Muon scintillation array

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The TAIGA-Muon scintillation array is located in the Tunka Valley and is a part of the single TAIGA experimental complex. Its construction started in the summer of 2019. By the autumn of 2019, the first three clusters were installed, consisting of 8 ground and 8 underground scintillation detectors each. Now the equipment is being adjusted and customized. TAIGA-Muon scintillation detectors were developed by scientists of Novosibirsk State University specifically for the harsh temperature conditions of the Tunka Valley. They will expand the capabilities of the current Tunka-Grande scintillation array and increase the efficiency of the search for ultra-high-energy
gamma rays. The report describes the design of the TAIGA-Muon array, the reading, data acquisition and control system.

**Poster Session - Board: 78 / 111**

**Testing the first cluster of the TAIGA-Muon array**

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The energy of gamma rays, which are planned to be studied in the TAIGA-Muon experiment, is not less than 100 TeV. Such particles come from space very rarely, so you need arrays that can detect them over an area of one to thousands of square kilometers. Large-area muon detectors developed specifically for this experiment by scientists at Novosibirsk State University will help reliably select gamma rays from the flow of primary cosmic particles and see our Universe in the spectrum of ultra-high-energy gamma rays. In the future, it is expected that several hundred such detectors will be deployed and they will work together with other arrays of the TAIGA gamma-ray observatory. Currently, 48 such detectors are produced, established and ready for use. They are combined in three clusters – 16 detectors in each. In the autumn of 2019, the first TAIGA-Muon cluster was equipped with electronics, connected to the data acquisition system and entered into operation in test mode. The report presents an analysis of the results of testing and calibration of signals from its 8 ground and 8 underground detectors.

**Micropattern gas detectors / 112**

**Pixelated Resistive Micromegas for Tracking Systems in High Rate environment**

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Started few years ago, the goal of this R&D project is to develop a new generation of single amplification stage resistive MPGD based on Micromegas technology with the following characteristics: stable and efficient operation up to 10 MHz/cm2 particle flows; high granularity readout with pixels (or small pads) of order mm2; fully integrated electronics; reliable and cost-effective production process. The miniaturization of the readout elements and the optimization of the spark protection system, as well as the stability and robustness under operation, are the primary challenges of the project.

Several micromegas detectors have been built with similar anode planes, segmented with a matrix of 48x16 readout pads with a rectangular shape (0.8x2.8 mm2) and with a pitch of 1 and 3 mm in the two coordinates. The active surface is 4.8x4.8 cm2 with a total number of 768 channels, routed off-detector for readout. With this anode/readout layout, the spark protection resistive layer
has been realized with two different techniques: a pad-patterned embedded resistor with screen printing (series-1), and a uniform DLC (Diamond Like Carbon structure) layer by sputtering (series-2). For each technique different configurations and resistivity values have been adopted. Characterization and performance studies of the detectors have been carried out by means of radioactive sources, X-Rays, and test beam. Conclusive results and a comparison of the performance obtained with the different resistive layout and different configurations are presented, in particular focusing on the response under high irradiation and high rate exposure.

Instrumentation for Astroparticle and Neutrino physics / 113

The DarkSide project, its past, present and future steps.
Dr. SUVOROV, Yury

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The DarkSide is a scientific project based on the dual-phase Liquid Argon Time Projection Chamber technology with the goal of direct search for the WIMP dark matter. This talk will give an update of the present status of the project and its future steps. Latest results from the DarkSide-50, the fist detector of the DarkSide family dedicated to the scientific run will be briefly described. The detector was built at Gran Sasso Underground Laboratory (LNGS, Italy), filled with 150kg of low radioactivity underground argon and is in data taking since mid of 2015.

The next step of the DarkSide program is a new generation experiment, Darkside-20k, lead by a global collaboration formed by the present Argon based direct DM detection experiments and will also be located at LNGS. The DarkSide-20k, is a 20-tonne fiducial mass acrylic TPC with SiPM based photosensors, is designed to have a background well below that from coherent scattering of solar and atmospheric neutrinos and heading to explore the region of a WIMP-nucleon cross section of $10^{-47}$ cm$^2$ for a WIMP mass of 1TeV/c$^2$ in a 5 yr run.

The ReD experiment is a lab scale new type TPC containing all technical solutions to be implemented in Darkside-20k was assembled in Naples University of Federico II with the goal of the directionality study in LAr. Its current status and plans will also be presented in this talk.

Poster Session - Board: 12 / 114

Fast Interaction Trigger for MPD Experiment at NICA
Mr. ROGOV, Victor; Dr. YUREVICH, Vladimir; Dr. SEGUEEV, Segey

1 JINR

The fast triggering of nucleus – nucleus collisions and the precise TOF measurement with picosecond time resolution are important features of all high-energy heavy ion experiments at colliders. The fast interaction trigger system of the Multi-Purpose Detector (MPD)experiment is developed for study of Au + Au collisions in energy interval $4 \leq \sqrt{s_{\text{NN}}} \leq 11$ GeV of the NICA collider. The main aims of the trigger system are fast and effective triggering of collision events in the center of MPD setup and the generation of start pulse for the TOF detector. For realization of this goals a two-arm modular Cherenkov detector based on MCP-PMTs, a system of special electronics and a laser calibration system are developed. The required time resolution of the detector is 50 ps (sigma). The detector and electronics concept and design, results of test measurements and MC simulation are presented and discussed.

Poster Session - Board: 79 / 115

The CMD-3 Detector’s Final Decision Block.
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In 2017, the luminosity at the VEPP-2000 collider at the Budker Institute of Nuclear Physics SB RAS, Novosibirsk, has increased. In this regard, it was decided to upgrade the trigger system of the CMD-3 detector. For this, the development of a device called the “Final Decision Block” was started. The task of this unit is to formulate a final decision on recording the current event in the detector based on the data received from the Charged and Neutral triggers. In this paper, we consider the designing and debugging process of the created block, as well as its implementation in the Data Acquisition System of the CMD-3 detector. The test results are presented both at the test bench and directly as part of the Data Acquisition System on the detector.

Colliders and detector integration / 116

Superconducting solenoid for PANDA detector

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BINP presents the design of the 2T superconducting solenoid for PANDA detector at FAIR. Since PANDA is a fixed target experiment, the main technical challenge is the insertion of a warm target pipe vertically to the solenoid axis in correspondence with the interaction point located at 1/3 of the length of the solenoid. The solenoid consists from three interconnected coils. The paper describes the design of the cryostat with cold mass, calculations of mechanical and thermal loads of the solenoid and status production of the magnet.

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Background evaluation at SuperKEKB and Belle II

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The SuperKEKB asymmetric electron-positron collider is the upgrade of the KEKB machine and it is expected to achieve the instantaneous luminosity of $8 \times 10^{35} \text{ cm}^{-2}\text{s}^{-1}$, 40 times higher than the record of KEKB. With the increased luminosity, the beam background is expected to grow significantly with respect to KEKB, leading, among other effects, to possible radiation damage of detector components and to performance deterioration of the Belle II detector. SuperKEKB started operating in 2018, with a stepwise reduction of the beam size at the interaction point that has been done in the last two years, studying the evolution of background conditions. We present the studies performed in 2019 to evaluate the contributions of single beam and luminosity background sources, the conditions in which the Belle II detector has been operated so far and the perspective for the future run.

Instrumentation for Astroparticle and Neutrino physics / 118

Hyper-Kamiokande

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Hyper-Kamiokande is a next generation large-scale water Cherenkov detector. Its fiducial volume will be about an order of magnitude larger than Super-Kamiokande and the detector performance is significantly improved with newly developed photo-sensors. Combination of the Hyper-Kamiokande detector with the upgraded J-PARC neutrino beam will provide unprecedented
high statistics of the neutrino and antineutrino signals to measure the CP violation and reveal a full picture of neutrino mixing with high precision. A set of upgraded and new near detectors will be used to control the systematic uncertainties. In addition to detecting the neutrino beam from J-PARC, the Hyper-Kamiokande detector will be used to search for proton decays, to study atmospheric and solar neutrinos, and to detect supernova and other astrophysical neutrinos. The construction of Hyper-Kamiokande is going to start in early 2020, with expectation of starting operation in 2027. The design and expected performance of the detectors and the status of project will be presented.

**Poster Session - Board: 80 / 119**

**The X-ray scanning technique application for sTGC detectors quality control**

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Gas detectors operated under harsh radiation conditions like the one foreseen at the HL-LHC, must fulfill a list of stringent quality control criteria. Based on current response, an X-ray scanning technique has been developed for detection of various defects prior to the installation of readout electronics. The later usually happens at the last stage of detector assembly. Thus, it allows testing the quality of the chambers, identified defects and when possible fix them already at an early stage.

**Poster Session - Board: 13 / 120**

**Cathode boards defects detection method for sTGC chambers**

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The harsh radiation conditions, including the ones expected for the operation with High-Luminosity LHC, require detailed and careful quality control of any gas detector from the very beginning stage of assembly. The existing probe methods for cathode boards QC are able to find shorts to ground, shorts between pads and breaks in the readout line at the initial stage of manufacturing. The cosmic test requires fully assembled detectors and reveals pads with absent or low amplitude analog signals associated with resistance in the readout trace line. In current work we propose the direct method for such defect recognition for both bare cathode boards and fully assembled detectors and demonstrate the examples of a successful cure.

**Micropattern gas detectors / 121**

**Gaseous Detector Studies with the VMM3a ASIC and the SRS**

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The developments in particle and nuclear physics experiments show four main requirements on the performance of gaseous detectors: large area coverage, high rate capability, excellent time resolution and good spatial resolution. As consequence new requirements for the readout electronics are defined.

In the particular case of the ATLAS New Small Wheel Upgrade, the VMM3a ASIC has been developed and optimised for tracking and triggering detectors. The ASIC provides many features, making it interesting for other applications. Thus it has been recently implemented into RD51’s Scalable Readout System (SRS), enabling the usage of the VMM3a in small R&D laboratory set-ups and mid-scale experiments.

In this talk the capabilities of the VMM3a within RD51’s SRS are presented by showing results obtained with a triple-GEM detector and X-ray sources. Preceded by an introduction to VMM3a/SRS, it will be shown, that with the VMM3a’s features, in particular the nanosecond time resolution and the continuous readout, deeper measurements for the understanding of a detector can be performed. The rare case of fluorescence X-rays, also known as ‘escape photons’, interacting in the gas volume of the detector can be resolved and used to determine the electron drift velocity in a dedicated set-up. The MHz rate capability of the VMM3a enables fast continuous X-ray imaging applications. First results of these measurements are presented, including an investigation of the neighbouring logic on the position reconstruction. This hardware feature should allow to gain additional information on the signal distribution, taking below-threshold hits into account.

Commissioning of the New ALICE Inner Tracking System

Mr. IDDON, James1; ALICE ITS, Collaboration1

1 CERN

The upgrade of the Inner Tracking System (ITS) of the ALICE detector will extend measurements of heavy-flavour hadrons and low-mass dileptons to a lower $p_T$ and increase the read-out capabilities to incorporate the full interaction. Furthermore, the tracking efficiency will be improved at low $p_T$. Some of the new measurements of heavy-flavour probes possible after the ITS upgrade and with an integrated luminosity of $10$nb$^{-1}$ include the nuclear modification factor and anisotropic flow down to $p_T$ of 2 GeV/c and 3 GeV/c respectively for the $\Lambda_c$ baryon.

To achieve this, the new ITS is comprised of 7 layers of a custom monolithic active pixel sensor design known as ALPIDE. The use of the ALPIDE-based detector design will reduce the material budget to 0.35%$X_0$ per layer for the inner most three layers, and to 1.0%$X_0$ per layer for the outer most four layers, compared to 1.14%$X_0$ per layer in the previous ITS. The readout rate will be improved to 100 kHz for Pb-Pb interactions, which is the double of the upgrade requirement. In addition, the radius of the first layer of the ITS will be reduced from 39mm to 23mm and the pixel size reduced to $\Omega(30\mu m) \times \Omega(30\mu m)$.

The effort in over 10 construction sites has resulted in a fully assembled and connected detector, which is currently under going on surface commissioning before it will be installed in the ALICE cavern in July 2020. This contribution will discuss the current status of the commissioning of the new ITS, including the methods used to characterise the detector and the results obtained so far.

ATLAS Forward Proton Time-of-Flight Detector - LHC Run2 performance and experiences
The performance of the ATLAS Forward Proton Time-of-Flight (ToF) Cherenkov detector is shown using the ATLAS collaboration data collected in the 2017 running period of the LHC Run2. The detailed analysis of the results, including detector efficiency and time resolution of the ToF is performed. The detector construction and its expected performance based on beam tests results are briefly summarized at the beginning of the first part of the talk. Operational experiences, problems caused due to attempts to operate MCP-PMTs in the vacuum and leading to the change of the detector construction, the request for R2D2 like construction of a new, future, MCP-PMT due to the observed gain drop for high rates and its non-recoverability are described. Also, other tested hardware changes are presented – the effect of the replacement of non-monolithic by monolithic crystal bars, the change of the MCP-PMT back-end electronics based on simulation to reduce signal cross talk resulting in further detector time resolution improvement. The second part of the talk is devoted to the achieved time resolutions, $20 \pm 4$ ps and $26 \pm 5$ ps, of two installed ToF detectors. Despite of their very low efficiencies (below 10%) in major parts of the analyzed data, this represents a superb time resolution for detectors operating a few millimeters from the LHC beams and making them, from the time resolution point of view, the best ToF detector among those operated by the different LHC experiments in the forward regions during the LHC Run2. At the end the possibility of reconstruction of $z$-coordinate of the ATLAS interaction region using the ToF detectors is shown.

SciFi - The new Tracker of the LHCb experiment

Dr. MASSAFFERRI RODRIGUES, André

The LHCb Collaboration is currently in the final step of an upgrade that will allow the experiment to operate at much higher luminosities and with a triggerless readout. The main tracking stations which originally were subdivided in an Inner Tracker made from silicon strip sensors and an Outer Tracker built from straw-tubes is being replaced by single detector, the Scintillating Fibre Tracker (SciFi).

The SciFi covers a total detector area of 340 m2 by using more than 10,000 km of scintillating fibre with 250 $\mu$m diameter, enabling a spatial resolution of better than 100 $\mu$m for charged particles. It is built from individual modules (0.5 m $\times$ 4.8 m) comprised of 8 scintillating fibre mats with a length of 2.4 m as the active detector material. The 13 cm wide fibre mats consist of 6 layers of densely packed blue emitting scintillating fibres. The scintillation light is detected with arrays of multi-channel silicon photomultipliers (SiPMs) cooled to -40C to minimize the expected high dark noise from neutron radiation. The readout of 524k channels occurs through custom-designed front-end electronics.

Since it is the first time that this technology is been used as a large tracker and with a small granularity many challenges has to be overcome. The talk will give an overview of the SciFi detector design, production, performance and the status of the detector assembly.

Multipurpose scintillation materials

Prof. KORZHIK, Mikhail

To date, more than 200 scintillation materials has been developed, however only a few of them are widely used for detectors design and construction [1]. A general trend is to use for detectors the elements produced from the selected top-quality grade scintillation materials instead of expensive novel chemically not stable halides. Another trend, which came in the last few years, is to apply
new achievements from the theory of scintillation materials to engineer the properties of the materials for a particular application [2]. From that point of view, the complex oxides with garnet structure is a family of materials, for which properties can be tuned for the best price/performance ratio for a particular application.

The combination of the scintillation properties, particularly the high light yield and high time resolution of garnet crystals with modern SiPM photosensors, with outstanding radiation hardness and chemical and mechanical stability make the complex garnet oxides the candidates of choice for a range of various applications in HEP experiments. Doped with Ce, the yttrium Y or Gd-based garnets could be produced by the well-established Czochralski crystal growth technique and can be produced at a quantity to equip detectors consisting of thousands and thousands of heterogeneous cells. Garnet crystals with a large quantity of Gd could be utilized for neutron detection in a large energy range. Due to its cubic crystalline structure, the garnet may be obtained as a polycrystalline ceramic using various techniques, including 3D-printing [3]; this further widens the range of the possible applications.

Here we report on the series of developments, in lines with the Grant No. 14.W03.31.0004 of Russian Federation Government and Crystal Clear Collaboration at CERN, on multicationic garnet structure scintillation materials. Their prospects for an application in “shaslyk”, “spaghetti”, neutron and “mip” detectors at future HEP experiments are discussed.

3. G.A. Dosovitskiy et. al, CrystEngComm 19 (2017), 4260-4264

**Poster Session - Board: 81 / 129**

**Study of application of the MWPCs of the LHCb MUON detector at very high rates**

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The muon detector of LHCb is one of the largest instrument of this kind worldwide, and one of the most irradiated. Currently we run at the relatively low instantaneous luminosity of $4 \times 10^{32}$ cm$^{-2}$s$^{-1}$, nevertheless the most irradiated MWPCs having the rates on the level $\sim 1$ MHz per FEB channel were $\sim 99\%$ efficient. Direct measurements shown that the hits in muon chambers dominated by signals from low energy background (LEB), presumably coming from reactions with thermal neutrons in the materials of chambers. Fraction of LEB hits exceeds 90% in inner regions of the MUON detector and it was one of the factor recovering an efficiency in four-gaps MWPCs strongly affected by deadtime of FE-electronics. Looking forward on future upgrade of LHCb aiming the run at luminosity of $2 \times 10^{34}$ cm$^{-2}$s$^{-1}$ where expected rate will reach $\sim 1$ MHz/cm$^2$ , a possibility of application of the multi gaps pad MWPCs assembled with FE-electronics able to reject LEB is presented. In addition, a test setup already constructed for GIF++ facility at CERN especially for the study of detectors and FE-electronics operating at very high rates is shown.

**Tracking and vertex detectors / 130**

**Current R&D and Future Trends in Silicon Detectors**

Mr. MUSSGILLER, Andreas¹

¹ DESY
With the LHC experiments preparing their upgrades for the High-Luminosity LHC (HL-LHC) there has been a natural emphasis on the R&D for their future tracking detectors. Beyond the HL-LHC developments new technologies and solutions have emerged that will pave the way for future tracking detectors. The presentation will review currently ongoing R&D activities and highlight future trends. It will not only focus on the silicon sensors and front-end electronics, but also cover engineering and integration aspects.

**Poster Session - Board: 1 / 131**

**THE STATUS OF THE DOUBLE POLARIZED DD-FUSION EXPERIMENT**

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1 PNPI
2 PNPI

A double-polarized dd-fusion experiment (PolFusion, PNPI, Gatchina) has been proposed to investigate the reactions \(d + d \rightarrow 3\text{He} + n\) and \(d + d \rightarrow t + p\) in the energy range of 10-100 keV. The possibility of using a vector and tensor polarized beam and target combination creates the opportunities to measure the asymmetry of the differential cross section and spin-correlation coefficients in the \(d + 3\text{He}\) and \(d + t\) reactions. Suggested measurements offer capabilities for determination of the quintet-state suppression factor for both reactions[1], one of the goals of PolFusion experiment program.

Status of experimental data and first test measurements are given. Overview of the experimental setup.


**Poster Session - Board: 47 / 132**

**FARICH detector beam test results**

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A high-performance particle identification (PID) system is essential for the successful realization of the broad physics program at the future Super C- Factory in Novosibirsk. The main requirements for the PID system are as follows: good \(\pi/K\)-separation in the entire operational momentum range and good \(\mu/\pi\)-separation in the momentum range from 0.3 to 1.2 GeV/c. The RICH detector based on focusing aerogel radiator (FARICH) meets all these requirements. The FARICH method is described, and the beam test results are presented.

**Calorimetry - Board: 25 / 133**

**ML-assisted versatile approach to Calorimeter R&D**
Advanced detector R&D for both new and ongoing experiments in HEP requires performing computationally intensive and detailed simulations as part of the detector-design optimization process. We propose a versatile approach to this task that is based on machine learning and can substitute the most computationally intensive steps of the process while retaining the GEANT4 accuracy to details. The approach covers entire detector representation from the event generation to the evaluation of the physics performance. The approach allows the use of arbitrary modules arrangement, different signal and background conditions, tunable reconstruction algorithms, and desired physics performance metrics. Being combined with properties of detector and electronics prototypes obtained from beam tests, the approach becomes even more versatile. We focus on the Phase 2 Upgrade of the LHCb Calorimeter under the requirements on operation at high luminosity. We discuss the general design of the approach, and particular estimations including occupancies and spatial resolution for the future LHCb Calorimeter setup at different pile-up conditions.

Micropattern gas detectors / 134

The $\mu$-RWELL for high rate applications

The micro-Resistive-WELL ($\mu$-RWELL) is a compact, simple and robust Micro-Pattern Gaseous Detector (MPGD) developed for large area HEP applications requiring the operation in harsh environment. The detector amplification stage, similar to a GEM foil, is realized with a polyimide structure micro-patterned with a blind-hole matrix, embedded through a thin Diamond Like Carbon (DLC) resistive layer with the readout PCB. The introduction of a resistive layer ($\rho \sim 50 \div 200 \, \Omega$/square) mitigating the transition from streamer to spark gives the possibility to achieve large gains ($>10^4$), while affecting the detector performance in terms of rate capability. Different detector layouts have been studied: the most simple one based on a single-resistive layer with edge grounding has been designed for low-rate applications (few tens of kHz/cm2); more sophisticated schemes have been studied for high-rate purposes ($\geq 10$ MHz/cm2). The single-resistive layer scheme, extensively tested and validated, is mature for the technology transfer towards the industry working into the rigid and flexible PCB photolithography. The high-rate version of the detector has been developed in the framework of the phase-2 upgrade of the LHCb muon system, where strong requirements on the robustness and rate capability are required. An overview of the different architectures studied for the high-rate version of the detector, together with their performance measured at the high intensity PiM1 beam of the PSI will be presented.

The presence of the resistive layer also affects the charge spread on the strips and consequently the spatial resolution of the detector: the results of a systematic study of the spatial resolution obtained with the charge centroid (CC) method for orthogonal tracks as a function of the DLC resistivity will be discussed. For non-orthogonal tracks the spatial resolution with CC method is compared with the performance obtained with the micro-TPC mode: a readout approach that exploiting the combined measurement of the ionization clusters time of arrival and the amplitude of the signals on the strips allows a fine estimation of the position of the track for a wide incident angular range.

The excellent performance together with the high flexibility of the technology suggests the use of such a detector as a high space resolution inner tracker in HEP.
A possible LHCb Luminosity Monitor based on the Muon System

KOTRIAKHOVA, Sofia

INFN Sezione di Roma

The Muon System of the LHCb experiment, after the ongoing upgrade, will be composed of 4 stations which comprise 1104 multi-wire-proportional-chambers (MWPC) with order of $10^5$ readout channels.

We are investigating the possibility of using the rates recorded on the Muon chambers to measure the luminosity.

A first study in this direction was performed analyzing the rates measured during special runs taken in 2012 at instantaneous luminosities up to $10^{33} \text{ cm}^{-2}\text{s}^{-1}$ and correlating them to the calorimeter-based measurements. After the correction for the dead time of the electronics the results were very promising allowing to estimate the correct values of luminosity with a precision better than 1%. The same method was also applied to a new set of runs taken in 2018 with a different LHC filling scheme necessary to achieve even higher values of instantaneous luminosity. Both the analyses will be presented to explore the possibility of using the muon system to monitor LHCb luminosity in future runs without the support of the calorimeter.

Silicon Vertex Detector and Data Quality Monitoring at the Early Start of the Belle II Experiment.

KODYS, Peter

Charles University

The Belle II experiment is a substantial upgrade of the Belle detector and will operate on the SuperKEKB energy-asymmetric $e^+e^-$ collider at KEK in Tuskuba, Japan. The accelerator successfully completed the first phase of commissioning in 2016 and the Belle II detector saw its first electron-positron collisions in April 2018. Belle II features a newly designed silicon vertex detector based on double-sided strip and DEPFET pixel detectors. A subset of the vertex detector was operated in 2018 to determine background conditions (Phase 2 operation); installation of the full detector was completed early in 2019 and the experiment started full data taking.

This talk will report on the final arrangement of the Belle II silicon vertex detector with focus on silicon vertex detector setup, its data acquisition workflow, online and offline monitoring of detector conditions and data quality, design and use of diagnostic and reference plots, and integration with the software framework of Belle II.
The Advanced Mo based Rare process Experiment (AMoRE) searches for neutrinoless double beta decay of 100Mo with the help of molybdate crystals operated as low-temperature scintillation bolometers. Currently, several molybdenum containing compounds, such as 40Ca100MoO4, Li2100MoO4 and Na2100Mo2O7, are considered as possible detectors for the final stage of the experiment, AMoRE-II. For such a rare event search experiment, the techniques for investigating and reducing radioactive background contaminants are extremely crucial. The first step in developing highly radiopure scintillating crystals is deep purification of raw materials used for growing them (MoO3 and carbonates of Ca, Li or Na), that is validated with precise and high-sensitivity radio-assay analyses. For the main component, MoO3, the developed purification technique consists of a sequence of vacuum sublimation, co-precipitation, and complete precipitation of polyammonium molybdates (PAM) from an acidic solution. By the end of 2021, ~100 kg of the 100MoO3 powder is going to be purified using this technique. In addition to the purification of the powder, the residual materials that remain after crystal production must be reconstituted and enriched molybdenum trioxide must be recovered and purified. The purified MoO3 powder has Th and U concentrations that are below the 10 pg/g detection limit for direct ICP-MS measurements. To reach this sensitivity, a sample prepared by an optimized microwave-assisted acid digestion method followed by the application of a solid phase extraction technique with UTEVA resin was used. Details of the radio purification and trace ICP-MS analysis of MoO3 powder performed at Center for Underground Physics (IBS, Korea) will be presented.

Poster Session - Board: 57 / 138

A Facility for mass production of ultra-pure NaI powder for the COSINE-200 experiment

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The COSINE experiment aims to reproduce DAMA/LIBRA’s observation of an annual modulation signal that can be interpreted as interactions of WIMPs (Weakly Interacting Massive Particles) dark matter. Ultra-low background NaI(Tl) crystal detectors are being developed for the next-phase experiment, COSINE-200. For the COSINE-200 experiment, all steps in the low-background detector production process, including the purification of ultra-pure powder, the growing of crystal, and the detector assembly, are being carefully developed. In this presentation, we discuss the purification of the ultra-pure powder, including the development of an instrument based on recrystallization for its mass production in our laboratory at the Center for Underground Physics, Daejeon, Korea. The COSINE-200 experiment’s goals require in total at least 500 kgs of NaI powder with contaminations from potassium (K) below 20 ppb and Pb-210 below 0.1 mBq/kg for the production of a 200 kg detector. To satisfy these requirements, a special clean facility that purifies NaI powder by means of fractional recrystallization from a water solution has been constructed. This facility consists of a dissolving tank, a recrystallization tank, a filter housing and a vacuum biconical dryer. The Maximum initial powder charge capacity is 70 kg and its recovery rate is typically ~45%. In normal operation, a single batch produces 30 kg of purified NaI powder in five days. To validate the purity of the produced product, the concentrations of K, Pb, Sr, Ba, Th and U were measured by ICP-MS method and these confirmed sufficient reduction of K concentration to below 20 ppb and those of all other radio-impurities as well. Details of the mass-production of purified NaI powder for the COSINE-200 experiment will be presented.

Poster Session - Board: 35 / 139

Development of the micro-resistive WELL discs for the CMD-3 tracking system.
Mr. SHEKHTMAN, Lev

1 Budker Institute of Nuclear Physics

Micro-pattern gas technology is planned for the upgrade of the tracking system of the CMD-3 detector at the VEPP-2000 electron-positron collider in Budker INP. The upgrade includes a new cylinder tracking and trigger detector that consists of two tracking layers at a radius of 32 to 33 cm with coordinate resolution close to 0.1 mm in Z (along the beam axis) and trigger segments of about 1 cm in phi. Another new coordinate subsystem includes two end-cap discs with active area between radius of 50 mm and 250 mm, that provides spatial resolution in R and in phi close to 1 mm as well as trigger signal from the phi segments. For these two subsystems we plan to use micro-RWELL technology because it allows much simpler assembling of large cylindrical detector and large discs as compared to the triple GEM technology. This technology was introduced by INFN Frascati group and the first tests demonstrated possibility of its application for particle detection at medium and low rates that satisfies the conditions of VEPP-2000 collider environment. Two full-size 50 cm diameter micro-RWELL discs were produced at CERN advanced PCB workshop. Two detectors based on these discs are assembled and preliminary test results will be presented at the Conference.

Poster Session - Board: 26 / 140

RADIATION HARDNESS OF GaAs:Cr AND Si SENSORS IRRADIATED BY ELECTRON BEAM

Mr. KRUCHONAK, Uladzimir

1 JINR

The interest in using the radiation detectors based on high resistive chromium-compensated GaAs (GaAs:Cr) in high energy physics and others applied fields has been growing steadily due to its numerous advantages over others classical materials. High radiation hardness at room temperature stands out and needs to be systematically investigated. In this paper an experimental study of the effect of 21 MeV electrons generated by the LINAC-200 accelerator on some properties of GaAs:Cr based sensors is presented. In parallel, Si sensors were irradiated at the same conditions, measured and analyzed in order to perform a comparative study. The target sensors were irradiated with the dose up to 1.5 MGy. I-V characteristics, resistivity, charge collection efficiency and their dependences on the bias voltage and temperature were measured at different absorbed doses. An analysis of the possible microscopic mechanisms leading to the observed effects is also presented in the article.

Poster Session - Board: 82 / 141

Processing of the Liquid Xenon Calorimeter’s signals for timing measurements.

Author(s): Mr. EPSHTEYN, Leonid
Co-author(s): Dr. YUDIN, Yury 1; Dr. MIKHAILOV, Kirill

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For identification of neutron-antineutron pair production events in the CMD-3 experiment (BINP, Russia) near threshold is necessary to measure the particles flight time in the LXe-calorimeter with accuracy of about 3ns. The duration of charge collection to the anodes is about 5mks, while the required accuracy of measuring of the signal arrival time is less than 1/1000 of that. Besides, the signal shapes differ substantially between events, so the signal arrival time is measured in two stages. To implement that, a developed special electronics performs waveform digitization and OnLine measurement of signals’ arrival times and amplitudes.
Performance of the Belle II Aerogel-Based Ring-Imaging Cherenkov counter system in SuperKEKB 2019 Phase 3 operation

Dr. LAI, Yun-Tsung

KEK

The Belle II experiment with SuperKEKB beam collision has started since 2018. The physics target of the experiment is to improve measurement of rare B meson decays with better and higher luminosity. An aerogel-based proximity focusing ring-imaging Cherenkov (ARICH) counter is utilized for charged particle identification (PID) in the forward end-cap region. For the study of CP violation involved in B decays, the goal is to separate kaons from pions up to and above $4\sigma$ for momenta up to 4 GeV/c. The counter is made of aerogel tiles to generate Cherenkov photons, and a 144-channel Hybrid Avalanche Photo Detector (HAPD) is adopted as a photo-detector. The HAPD signal is digitized by using the Application Specific Integrated Circuit (ASICs). Two different types of Field Programmable Gate Array (FPGA) boards are responsible for data processing and acquisition. In the Phase 3 (SuperKEKB beam collision from Apr. to Dec. 2019), the ARICH system have been operating smoothly, and software algorithm has been validated with the data as well. We will present the status of the entire hardware system during Phase 3 operation and the preliminary result of PID performance.

Development of the Level-1 track trigger with Central Drift Chamber detector in BelleII experiment and its performance in SuperKEKB 2019 Phase 3 operation

Dr. LAI, Yun-Tsung

KEK

The Level-1 trigger system (TRG) in the Belle II experiment is designed to summarize real-time sub-detectors information by using FPGA chips for the central data acquisition (DAQ) system, and it includes several sub-trigger systems for triggering various types of physics events in interest. The main focus in this talk is CDCTRG: the track trigger system with Central Drift Chamber (CDC) detector, which is responsible for the real-time trajectory reconstruction of charged particles with various algorithms: Track-segment Finder, 2D, 3D, Neuro-3D, and short tracking, etc. CDCTRG is necessary for specific types of physics, such as hadronic and mu-mu pair. This paper will introduce the design of the hardware system and algorithm implementation in FPGAs. Development, validation and performance of each CDCTRG module during SuperKEKB beam collision operation will also be discussed in detail.

High-level trigger for the upgraded LHCb detector

POLUEKTOV, Anton

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The LHCb experiment at the LHC collider at CERN is undergoing a major upgrade in 2019-2021. The goal is to be able to operate at an instantaneous luminosity of $2 \times 10^{33} \text{ cm}^{-2} \text{s}^{-1}$, which is 5 times higher than the luminosity in previous LHCb runs. This requires a major redesign of the trigger system due to outstanding rate of beauty and charm hadron production. In the upgraded trigger, the hardware (level-0) stage will be dropped and the detector will be fully read out at 30 MHz. A fully software trigger will be operating at the collision frequency, where a full offline-quality reconstruction will be performed. In this talk, I will cover the design aspects of the software trigger, and will present the computing and physics performance of the high-level trigger for upgraded LHCb.
Central Drift Chamber for the Belle II experiment

Dr. NAKAGIRI, Kota¹

¹ High Energy Accelerator Research Organization (KEK), Institute of Particle and Nuclear Studies (IPNS)

The Central Drift Chamber (CDC) is the main part of the tracking system in the Belle II experiment. It has a cylindrical shape with 2.3-m-length and 0.3(2.2)-m-inner(outer)-diameter, surrounding the $e^+e^-$ collision point. It consists of 9 super layers, which are composed of 8 (for the innermost super layer) or 6 (for the others) sub-layers. Axial and stereo super layers are alternately arranged to provide 3-dimensional tracking. The CDC was developed and installed in Oct. 2016, and it has been operated in the Belle II data taking since Mar. 2018. We will present the overview of the CDC, the operation status, and its performance with the cosmic-ray and $e^+e^-$ collision data.

Study of resistive materials for MPGD protection

Mr. DE OLIVEIRA, Rui¹

¹ CERN

CERN Micro Pattern Technologies workshop (CERN EP/DT/EF) is currently involved in one MPGD R&D project: “Study of resistive materials for MPGD protection”, this study is conduct in the framework of RD51 collaboration. A group of four institutes has been raised (Kobe, INFN Frascati, China and CERN) to address all the different aspects of this topic. The role of CERN MPT workshop in the group is the development and production of new MPGD devices based on DLC layers developed and produced in Japan (Kobe B/Sputter) and China (HEFEI). Several types of MPGDs have already been DLC-ied and characterized. A detailed production process for RGEM, THGEM, RMmegas and uRwell will be presented during this talk.

MPGD-based photon detectors for the upgrade of COMPASS RICH-1 and beyond

Dr. DASGUPTA, Shuddha Shankar¹

¹ Post Doc Researcher

After pioneering gaseous detectors of single photon for RICH applications using solid state Photo Cathodes (PC) within the RD26 collaboration and by the realization of the MWPCs with CsI PC for the RICH detector of the COMPASS experiment at CERN SPS, in 2016 we have upgraded COMPASS RICH by novel gaseous photon detectors based on MPGD technology. Four new photon detectors, covering a total active area of 1.5 square m, have been installed in order to cope with the challenging efficiency and stability requirements of the COMPASS physics programme. The new detector architecture consists in a hybrid MPGD combination: two layers of THGEMs, the first of which also acts as a reflective PC thanks to CsI coating, are coupled to a bulk Micromegas on a pad-segmented anode; the signals are read-out by analog F-E based on the APV-25 chip. These detectors are the first application in an experiment of MPGD-based single photon detectors.

Presently, we are further developing the MPGD-based PDs to make them adequate for setups at the future EIC collider. A compact collider setup imposes to construct a RICH with a short radiator length, hence limiting the number of photons. The last can be increased by detecting the photons in the far UV region. However, as standard fused-silica windows are opaque below 165 nm, a windowless RICH approach represents a possible choice. Another challenge is the need of improved space resolution, related to the shorter lever arm.
All aspects of the COMPASS RICH-1 Photon Detectors upgrade are presented, including R&D, engineering, mass production, quality assessment and performance as well as the on-going development for collider application.

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Design, Performance and Perspective of NA62-RICH at CERN
Mr. TURISINI, Matteo

NA62-RICH is the Ring Imaging CHerenkov detector of the NA62 experiment designed to measure the branching fraction of the ultra-rare decay of a charged kaon in a charged pion and two neutrinos. The experiment started in 2016 and is going to conclude the main measurement by 2025.

RICH sub-detector plays a fundamental role in NA62 by providing timing and multiplicity information to the global trigger system. It is also crucial for offline analysis with a single event time resolution of 70 ps and a muon misidentification of less than \(10^{-2}\).

NA62-RICH utilizes 1952 PMTs (Hamamatsu R7400) on a 1 squared meter photodetection surface. Single photoelectron signals are fed into custom frontend boards equipped with NINO ASICs and then to TDC cards within the TEL62 TDAQ system. Detector design and current performance are presented. In a long term prospect (>2026) NA62 is considering the possibility to increase the nominal beam intensity by a factor 4 and RICH time resolution must scale accordingly.

Timing detectors / 149

Timing characterization of 3D-trench silicon sensors
Dr. LAI, Adriano; Dr. CARDINI, Alessandro

Future tracking detectors have to be both space and time measuring devices at the single pixel level. This is strongly motivated by the extremely high interaction intensities foreseen in the collider experiments of the next couple of decades and possibly beyond. Presently, no satisfactory technical solutions are available and important development programs have started in this direction. Minimal requirements are: the capability to sustain fluences greater than some \(10^{16}\) 1 MeV neq cm\(^{-2}\) and radiation doses of some Grad, space resolutions around 10 \(\mu\)m and time resolutions below 50 ps.

3D silicon sensors are well known [1] for their very high radiation hardness (some \(10^{16}\) n/cm\(^2\) [2]) and have intrinsic characteristics which can be exploited for fast response. During last year, tests have been made by the TIMESPOT collaboration on developed 55-\(\mu\)m-pitch 3D-trench sensor prototypes, giving extraordinarily good results in terms of timing. The tests have been performed both in the laboratory under a 1030 nm pulsed laser beam and under minimum ionizing particle beam at the PSI laboratories (Paul Scherrer Institute, Villigen, Switzerland). The tests yield values of time resolution of the order and below 30 ps rms. Such results indicate that, as of today, these devices are possibly the only ones capable to satisfy the complete set of system requirements for a future vertex detector and can be considered a very interesting solution to be further developed and finalized. An optimized new batch of sensors is under development and will be submitted early 2020.

This paper will describe the characteristics of the developed sensors, the kind of measurements performed and will discuss the results obtained. The ongoing activity about further 3D sensor and fast front-end electronics developments will be also briefly illustrated.
DQM tools and techniques of the SND detector

Author(s): Mr. PUGACHEV, Konstantin
Co-author(s): Mr. KOROL, Alexander; Mr. KARDAPOLTSEV, Leonid

1 BINP

We describe data quality management system (DQM) for the SND detector operating at the VEPP-2000 collider (BINP, Russia). The system allows users to access and analyze data quality information with program API or in interactive session. It supports multiple presets for studying data quality by different criteria. The system provides easy user interaction and instruments for collected data cross-checking. It has been used since January of 2019. In this contribution the system architecture, implementation features and usage experience are presented.

Investigation of energy spectrum and chemical composition of primary cosmic rays in 1-1000 PeV energy range with a drone-borne installation.

Author(s): Dr. CHERNOV, Dmitry
Co-author(s): Dr. BONVECH, Elena; Prof. GALKIN, Vladimir; Dr. PODGRUDKOV, Dmitry

1 Skobeltsyn Institute of Lomonosov Moscow State University

This work is dedicated to the development of a project aimed at the implementation of a relatively new method of studying the PCR - the registration of optical Vavilov-Cherenkov radiation, often called “Cherenkov light”, from EAS (EAS CL), reflected from the snow surface. The objective of the project is to create an installation for the study of the cosmic ray mass composition in the energy range of 1-1000 PeV by detecting the reflected EAS CL. Silicon photomultipliers are planned to be used in the detector of the installation, and an unmanned aerial vehicle (UAV, drone) will be used to lift the measuring equipment over the snow-covered surface.

Belle-II Level-1 trigger

IWASAKI, Yoshihito

1 KEK

The Belle-II Level-1 trigger has been designed and constructed to select physics events of our interests for the Belle-II experiment at the asymmetric-energy electron-positron collider SuperKEKB. Our main physics target is a B-meson pair produced via Upsilon 4S, but also continuum event and a tau pair are important. To select those events with high efficiency, we use signals from the central drift chamber and the electromagnetic calorimeter. We describe our Level-1 trigger system and its performance during the operation of SuperKEKB in 2019.

Development of Compact, Projective and Modular Ring Imaging Cherenkov Detector for Particle Identification in EIC Experiments
Prof. HE, Xiaochun

1 Georgia State University, EIC PID Consortium - eRD14 Collaboration

The recent announcement of the construction of an Electron Ion Collider (EIC) at Brookhaven National Laboratory by the U.S. Department of Energy makes the reality of a long-sought experimental effort to explore the structure and properties of proton and nuclei in unprecedented precision and broad kinematic coverage. Particle identification (PID) of the final state hadrons is a key requirement for EIC. In order to meet the challenge of the confined volume of the electron endcap in EIC experiments, a compact, projective, and modular ring imaging Cherenkov (mRICH) detector is proposed for $K/\pi$ separation from 3 up to $10\overline{\text{GeV}}/c$. At the same time, the mRICH design has a significant potential for $e/\pi$ identification providing an important capability supplementing the electromagnetic calorimeters and other possible $e/\pi$ PID systems. The mRICH detector consists of an aerogel radiator block, a Fresnel lens, a mirror-wall and a photosensor plane. The first prototype of this detector design was successfully tested at Fermi National Accelerator Laboratory in April 2016 for verifying the detector working principles. This talk will highlight the recent advances and the beam test results of the second mRICH prototype in 2018. A future plan for the mRICH development will also be discussed in this presentation.

Poster Session - Board: 48 / 154

SEARCH STRUCTURES IN THE DISTRIBUTIONS OF PARTICLES FROM THE CENTRAL AREA OF EAS CONDUCTED AT THE “ADRON-55”

Author(s): Mr. ISKAKOV, Bakhtiyar
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Adron-55 with a field of scintillation detectors is used for research in the field of high energy gamma astronomy. The ionization calorimeter consists of two parts - the upper gamma block and the lower hadron block. The gamma block absorbs and registers the electron-photon component of cosmic rays, and the hadron component due to the small thickness of the gamma block passes without interaction through the gamma block and begins to interact and generate particles in the hadron block. The idea of the project is to select events when interactions in the gamma block are observed and there are no interactions in the hadron block. An analysis of the experimental results from the Adron-44 and Adron-55 installations showed that such events are $\sim 8\%$. The central part consists of gamma and hadron blocks of an ionization calorimeter, as well as a scintillation carpet. The peripheral part consists of 8 scintillation detectors located in circles with radius of 40 and 100 m. Over 4 years of operation, more than 120,000 events with energies above $10^{15} \, \text{eV}$ have been recorded.

Poster Session - Board: 14 / 155

Analysis of 2.7 GeV proton-beam measurements with the STS detector for the CBM experiment

Mr. PFISTNER, Patrick

1 KIT

The Compressed Baryonic Matter (CBM) experiment at the future Facility for Antiproton and Ion Research (FAIR) in Darmstadt, Germany, aims to explore the quantum chromodynamics phase diagram for highest baryon densities. CBM will measure rare probes with high statistics which requires fast and radiation hard detectors combined with free-streaming readout electronics. One of the core detectors of CBM is the Silicon Tracking System (STS). The STS is the key detector for measuring the momentum and tracks of up to 800 charged particles produced in Au+Au collisions happening at interaction rates of up to 10 MHz. In order to evaluate the detector performance, comprehensive tests have been performed with a minimum ionizing particle
An imaging hadron calorimeter with digital readout (DHCAL) using the micro-pattern gaseous detector (MPGD) technology is one of the hadron calorimeter options for the Circular Electron Positron Collider (CEPC). The sensitive detector of the CEPC DHCAL is required to be compact and highly efficient for MIPs with low number of hits per MIP track (hit multiplicity). GEM and WELL-THGEM detectors have been investigated as options for the DHCAL sensitive detector. A GEM detector with only two GEM layers (double-GEM) was proposed to make the detector more compact than the usual triple-GEM detector. A 30 cm x 30 cm double-GEM prototype was built with the self-stretching technique to study the performance of the double-GEM detector for application to the CEPC DHCAL. The double-GEM prototype was read out with the Microroc chip that has been developed specifically for the application of MPGDs to DHCALs, and was tested with cosmic-rays. The results of the test show a detection efficiency higher than 95% for MIPs was obtained, and hit multiplicity was about 1.2. However, the double-GEM detector made by the self-stretching technique has a dead area of about 10% at the four edges of the detector, which turned out to be hardly reduced. The WELL-THGEM detector is advantageous to the GEM detector in minimizing the dead area due to its simple assembly without stretching. In addition, it has a more compact structure than the double-GEM detector thanks to use of single-stage gas amplification and no induction gap. A 25 cm x 25 cm resistive WELL-THGEM prototype was developed with the DLC coating and thermal bonding techniques, where the former technique was used to make resistive layers for the prototype and the latter was used to bond the THGEM layer and the anode PCB together. Besides, a fast grounding circuit was designed on the anode to enhance the rate capability of the detector. Preliminary results from tests of the WELL-THGEM with X-rays show the gain of the detector could reach 8000 with a 20% uniformity, and the detector could maintain such a gain when irradiated with 8 keV X-ray at a rate of 300 kHz/cm². Based on these results, the WELL-THGEM detector looks a promising MPGD as the sensitive detector of the CEPC DHCAL, which merits further studies.
ηDAQ works by monitoring the state of involved system components and by keeping a track of the processed chunks of data. This metadata is logged and represented on a live dashboard. It also provides a single source of truth for all subsystems through an integrated REST API.

**Poster Session** - Board: 59 / 158

**Correction of angular sensitivity of the TAIGA-HiSCORE detectors for data processing**

Mr. PAKHORUKOV, Aleksandr¹ ; Mr. SAMOLIGA, Vladimir³

¹ Irkutsk State University

TAIGA-HiSCORE is an array of wide-angle air-Cherenkov detectors distributed on the area of 1 km². It is a part of a hybrid gamma-ray observatory TAIGA which combines imaging and timing methods to detect Cherenkov emission from extensive air showers. To collect Cherenkov light TAIGA-HiSCORE uses parabolic light guides - Winston cones, - combined with PMTs. We present the results of measurements of angular sensitivity of “PMT+cone” unit. This angular characteristic distorts a signal of initial event flux. To obtain an original signal we correct this distortion using weight functions. This corrections can be used for detection of gamma-ray sources.

**Poster Session** - Board: 85 / 159

**The high-resolution particle tracking triple-GEM detector for the test beam facility at VEPP-4M collider.**

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Co-author(s): Mr. SHEKHTMAN, Lev² ; Mr. BOBROVNIKOV, Viktor¹ ; Mr. MALTSEV, Timofei²

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Budker Institute of Nuclear Physics has a special installation for generation of test beams of electrons or photons in a wide range of energies at the VEPP-4M collider. This facility requires high resolution low-mass coordinate detectors to precisely determine particles trajectories. The specialized detector with high spatial resolution and low material content was developed. The detector consists of three cascades of gaseous electron multiplier (GEM), the orthogonal X-Y readout structure and detector electronics. Electronics is based on the APC128 ASIC (analog pipeline chip, 128 channels), six of these chips are used covering 768 channels in total. These channels are connected to the readout structure, which has two layers: 512 vertical strips and 256 horizontal strips, both directions have 0.25 mm pitch of the readout strips, thus the dimensions of the detector’s sensitive area are 128 x 64 millimeters. During 2016 the first detector prototype was manufactured (GEMs, flexible readout structures and electronics PCBs made at CERN Workshop, assembly finalized at the BINP). The spatial resolution of the prototype detector was measured to be 32 microns. The design of the detector was adjusted using the feedback taken during manufacture and operation. In the end of 2019 the new detector was manufactured with the improved design. The latest results on the performance of the improved detector will be reported at the conference.

**Timing detectors / 160**

**Timing Wall Detector Project for HF CMS**

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Co-author(s): Mr. DRUZHININ, Dmitry² ; Mr. STEFANOVICE, Roman³

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We propose Timing Wall Detector for HF CMS as the part of CMS Upgrade. The aim of this Detector is the suppression of pileup background and the improvement of spatial resolution of HF, which is important for HF performance in LHC high luminosity conditions. The spatial structure of Timing Wall corresponds to HF one. The element of Timing Wall consists of two parts, first part is designed for high precision timing and second is for spatial measurement with limited accuracy.

The timing part is the quartz trapezoid bar rotated be the angle of Cherenkov conus. PM MCP is used as photoreadout. The spatial measurement part is a set of scintillator (LSO/GAGG) pads with quartz fiber as a lightguide, with multianode PM as a photoreadout.

The time resolution better 30 ps was obtained in Test Runs. Different variants for scintillator are discussed. Special attention is paid to radiation resistance of the detector. The same approach can be applied for a detector in high pseudorapidity region for diffraction processes study.

Poster Session - Board: 36 / 161

The GEM-based detector for tracking the Compton-scattered photons in the Laser Polarimeter facility at VEPP4-M collider.

Author(s): Mr. KUDRYAVTSEV, Vasily
Co-author(s): Mr. SHEKHTMAN, Lev; KAMINSKIY, Viacheslav; Dr. NIKOLAEV, Ivan; Prof. MUCHNOI, Nikolai; Dr. NIKITIN, Sergey; Dr. BLINOV, Vladimir

The VEPP4-M collider has a unique system for energy measurement based on Resonance Depolarization technique. The existing system is working well using the Touschek effect for measurement of polarization at the energies below 2 GeV. For higher energies it is suggested to use the effect of asymmetry of reflected polarized laser photons back-scattered from polarized beam. For the measurement of polarization degree of the beam the coordinates of compton scattered photons are registered with different polarization of the laser. Since non-polarized beam does not produce asymmetry, thus difference in mean coordinate yields the information about polarization degree of the beam.

For registering of coordinates of reflected photons the special gaseous detector with triple-GEM was manufactured. The readout structure is a rectangular grid of 1120 pads, which are 2x1 mm sized in center and 4x2 mm on the edge where bigger pads are used for a rough alignment of the detector. In front of sensitive area the lead convertor is placed which converts the reflected photons into charged particles registered by the detector. The trigger for the detector, which is the same signal fed to laser, is generated by frequency division of VEPP4-M bunch crossing signal and is in the range of 1-4 kHz while the laser polarization can be switched on every flash. For the gathering of signals from the pads of the readout structure the DMXG64 front-end ASICs, which were developed at BINP, are used.

The prototype detector was tested and the principle was proved. The final detector is assembled and first results will be presented at the conference.

Poster Session - Board: 27 / 162

MPD/ECal – geometry and simulation
Large electromagnetic calorimeter (ECal) is now under construction for multipurpose detector (MPD) of the NICA project at JINR, Dubna to study a phase transition to QGP. ECal is placed in a cylindrical volume with an internal (external) diameter of 3.45(4.6) m and a length of 6 m. It is assembled from 38400 "shashlik"- type towers containing 210 alternating layers of 0.3 mm lead and of 1.5 mm plastic scintillator, pierced by 16 WLS fibers to collect light on a 6x6 mm2 silicon photomultiplier. At first, the towers are made as 4x4x41.5 cm3 boxes, which are later machined to truncated trapezoids of 64 types to densely fill the cylindrical volume and ensure that all axes of the towers are directed to the intersection point of the collider beams. Since a total weight of ECal towers is 60 tons, a power frame of almost 10 tones in weight has been designed on the basis of modern technology using carbon fibers. The power frame has added a passive material between and in front of the towers. The ECal simulation program was developed by the ITEP group using MpdRoot and FairSoft environment. Details of the program, which describe complicated geometries of both the calorimeter itself and the power frame, are discussed as well as an influence of the passive materials on the ECal performance. This work was supported by RFBR grant No. 18-02-40054.

Mechanics and Cooling for the PANDA Luminosity Detector

The PANDA-Experiment will be a fixed target experiment at the future FAIR-accelerator center at Darmstadt, Germany. As the experiment is designed for high precision measurements with an antiproton beam, especially in the charm sector of hadron spectroscopy, a precise knowledge of the luminosity is crucial. The determination of the luminosity will be done by measuring the angular distribution of elastically scattered antiprotons at very small scattering angles between 3 and 8 mrad. Therefore their tracks will measured by four layers of thinned HV-MAPS silicon sensors of 50µm thickness. To minimize the multiple scattering, the measurement is performed in vacuum. As the sensors will dissipate up to 7mW/mm², an active cooling is mandatory. To achieve this while maintaining a low material budget, the sensors will be glued on 200 µm thin CVD-diamonds which are clamped in an actively cooled aluminium heatsink outside of the acceptance. An excellent thermal contact to the stainless steel pipe for the coolant is ensured by melting the aluminium around the pipe before machining the heatsink. The poster will present the mechanical design and the cooling system.

High-Performance DIRC for the future Electron Ion Collider

The U.S. Department of Energy recently announced that the Electron-Ion Collider (EIC) will be the next major facility for nuclear science in the United States, located at the Brookhaven National Laboratory in Upton, NY. The EIC will answer fundamental questions about the role of gluons in nucleons and nuclei. The outcome of the EIC will provide unprecedented precision about the initial state properties in relativistic heavy ion collisions at RHIC and LHC, as well as the spin...
and spatial structure of the nucleon and light nuclei at low x. Particle identification (PID) of the final state hadrons is a key requirement for EIC. The EIC PID consortium (eRD14 Collaboration) has been developing PID detectors using ring imaging Cherenkov (RICH) techniques for EIC experiments covering the full kinematics coverage. In the ion-going direction, a dual-RICH (dRICH) is under development for $\pi/K$ separation up to 50 GeV/c. In the electron-going direction, a compact modular RICH (mRICH) has been developed for $\pi/K$ separation from 3 to 10 GeV/c. In the central rapidity region, a high-performance DIRC (hpDIRC) provides a compact and cost-effective way for $\pi/K$ separation up to 6-7 GeV/c. This talk will highlight the design, recent developments, and the prototype program of the EIC PID systems and discuss the performance of system prototypes in particle beams at FNAL and CERN.

Timing detectors / 165

Design and first performance results of waveform sampling readout electronics for Large Area Picosecond Photodetector

Dr. CROKER, Kevin; Prof. NISHIMURA, Kurtis; Mr. GLENN, Jocher; Dr. SHEBALIN, Vasily

1 University of Hawaii at Manoa
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Large Area Picosecond Photodetectors (LAPPD) are a new generation of microchannel plate photomultipliers being manufactured by Incom. These devices feature large sensitive area of 350 cm$^2$, high quantum efficiency ($\sim 20\%$), and tens of picosecond single photon timing resolution. LAPPDs use an anode structure with 28 striplines, allowing for spatial resolution of 1-3 mm while minimizing the number of readout channels. In this report, we present our design of integrated readout electronics for the LAPPD. These electronics read out all 2x28 channels of a stripline-anode LAPPD. Waveform sampling at up to $\sim5$GSPS is performed by 8 DRS4 switched-capacitor array ASICs. All DRS4 channels are digitized in parallel with two 32-channel ADCs. An on-board FPGA coordinates digitization and readout of waveforms, and could further be expanded to include some waveform processing. Data packages built in the FPGA are sent to a DAQ system via optical fiber, with a baseline Gigabit Ethernet interface implemented entirely on the FPGA. The electronics is designed to accommodate different triggering options: self-triggering using DRS4 transparent mode and external triggering, making event control very flexible. Further flexibility is enhanced with embedded software for an on-FPGA soft-core processor, as well as DAQ readout and control software. The device is plug and play with any existing IP network. An open-source ecosystem is being developed to provide full control of the device operation and an easy way to integrate it to any environment. In the report we describe the status of the electronics development, its firmware and readout software. Also the results of the first tests of the electronics with the LAPPD devices will be presented.

Particle Identification / 166

Operational Status of the Belle II Time-of-Propagation (TOP) Detector

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Data taking with the Belle II detector at the SuperKEKB electron-positron collider in Japan started in April 2018 with low luminosity. During the second stage of data-taking, which started in March 2019, SuperKEKB has reached the luminosity of $1.05\times10^{34}$ cm$^{-2}$s$^{-1}$ and Belle II collected about $10^{34}$ fb$^{-1}$ of integrated luminosity, moving towards the design luminosity of $5\times10^{35}$ cm$^{-2}$s$^{-1}$. Particle identification in the barrel region is provided by the Time-Of-Propagation(TOP) detector. The device consists of 16 bars of fused silica which serve as a source of Cherenkov photons and as a light guide at the same time. A unique feature of
the detector is that particle identification is based on the combined measurement of the time-of-flight and Cherenkov angle using the precise arrival times of detected photons and their spatial distribution. To achieve good pion-kaon separation the photon arrival times must be measured with a resolution of approximately 100 ps or better. Microchannel plate photomultipliers together with dedicated high-speed electronics for 2.7 GSa/s waveform sampling are used to achieve this timing resolution in a total of 8192 channels. In this report we give an overview of the TOP detector system, present the current status of its operation and plans toward the high occupancy conditions expected at the design luminosity of the SuperKEKB collider.

Calorimetry / 167

Change of SiPM parameters after very high neutron irradiation.

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Recently developed high dynamic range Hamamatsu and FBK SiPMs were irradiated with reactor neutrons at JSI (Ljubljana) up to $2 \times 10^{14}$ n/cm$^2$ (1 MeV equivalent). Parameters of the irradiated SiPMs were studied using continuous and pulsed light illumination. In this presentation we report about change of SiPMs PDE, gain, dark current, noise and breakdown voltage after irradiation.

Poster Session - Board: 37 / 168

Investigation and improvements of the mechanical structure of Cylindrical GEMs of the BESIII experiment

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Gas Electron Multipliers (GEMs) can be produced in large foils and molded in different shapes. The possibility to create cylindrical layers has opened the opportunity to use such detector as internal trackers at collider experiments. One crucial item is to have low material budget in the active area, so the supporting structure of anode and cathode must be light. KLOE2 collaboration has built the first Cylindrical GEM detector with honeycomb material with carbon fiber skins produced at high temperature. BESIII is preparing an innovative CGEM detector with charge and time readout. Among several innovative features, the mechanical structure was designed to be a sandwich of kapton and Rohacell, a PMI foam. After the transportation of the prototypes from the construction site in Italy to the Institute of High Energy Physics in Beijing, some malfunctions have been observed in some prototypes, compatible with GEMs deformation inside the detector. We have performed a detailed study by means of an industrial CT scan available in IHEP lab and autopsy to the damaged detectors. In this talk, we will review the construction process, the shipment, the findings of the investigation. A new supporting structure of carbon fiber and honeycomb, assembled at room temperature, has been designed and developed. The thickness of the carbon fiber is small enough to keep the material budget of a single detector layer below 0.5% of a radiation length, while the mechanical robustness results beyond the purpose of a detector for HEP. A first detector with such a mechanical structure has been built and shipped to IHEP, preliminary results from operation (e.g. current stability, discharges, temperature and humidity correlation) of the detectors will be also presented in this talk.
Micropattern gas detectors / 169

Preliminary results from the cosmic data taking of the BESIII cylindrical GEM detectors

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BESIII (Beijing Spectrometer III) is a multipurpose spectrometer optimized for physics in the tau-charm energy region. Both detector and accelerator are undergoing an upgrade program, that will allow BESIII to run until 2029.

A major upgrade is the replacement of the inner drift chamber with a new detector based on Cylindrical Gas Electron Multipliers to improve both the secondary vertex reconstruction and the radiation tolerance. The CGEM-IT will be composed of three concentric layers of cylindrical triple GEMs, operating in an Ar-ISO (90/10) gas mixture with field and gains optimized to maximize the spatial resolution using a charge and time readout. The new detector is readout with innovative TIGER electronics produced in 110 nm CMOS technology. The front end is a custom designed 64-channel ASIC featuring a fully digital output and operated in triggerless mode.

With planar prototypes, we measured an unprecedented spatial resolution below 150 microns in 1 Tesla magnetic field. It was measured in a wide range of incident angle of the incoming particle. Before the installation inside BESIII, foreseen in 2021, a long standalone data taking is ongoing at the Institute of High Energy Physics in Beijing; currently, the first two cylindrical chambers are available for the test, and are used to complete the integration between the detector and the electronics and to assess the required performance.

In this presentation a description of the CGEM-IT project, the TIGER features and performance, and the results of the analysis of first cosmic ray data taking will be presented. Focus will be given on the strip analysis, from which it is possible to measure the basic properties of the detector, and the cluster analysis, where a comparison with the results with planar prototypes will be discussed. The first preliminary results on efficiency and spatial resolution will be also presented.
100MoO3 powder (100Mo isotope ratio > 95%) were grown and their purities and composition were confirmed. We plan to carry out mass production of ~100 kg of crystal elements for the AMoRE in the future with three CZ growers at the CUP. In this study, we are going to present the growth of Li2MoO4 crystals at CUP and their purities.

**Poster Session - Board: 2 / 171**

**Status of Laser Polarimeter at VEPP-4M**

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Laser polarimeter facility at VEPP-4M accelerator is designed to calibrate the beam energy by resonance depolarization method in the energy region of the Upsilon meson. The laser trigger and laser polarization control system has been upgraded. A new water-cooled vacuum mirror is being developed.

**Poster Session - Board: 61 / 172**

**Development of a new type of hybrid photo-detector involving photocathode, scintillator and silicon photomultiplier**

**Author(s):** Dr. LEE, Jik

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We propose a new type of hybrid photo-detector that consists of photocathode, electrode, scintillator, and silicon photomultiplier in vacuum tube. This type of photo-detector with a large area of photocathode could be utilized in photo-detector array for neutrino detection. Photons incident onto the photocathode are converted to photo-electrons. Due to the electric field between photocathode and electrode, the photo-electrons accelerates toward the scintillator to produce scintillation lights. The scintillation lights, then, enters to the silicon photomultiplier SiPM to be converted to an electrical signal. The advantage of this type of photon-detector is that the scintillation lights contributes an extra gain in the order of tens to the total gain in addition to the base gain of at least 106 given from the silicon photomultiplier. We present the test result obtained with a demonstrator built to prove the principle of this type of photo-detector. We also present the design of experimental setup for fabrication of this type of detector.

**Status of facilities / 173**

**FAIR status and the PANDA experiment**

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The international accelerator Facility for Antiproton and Ion Research in Europe (FAIR) is the next generation accelerator complex for fundamental and applied research with antiproton and ion beams. FAIR will provide worldwide unique facilities enabling a wide spectrum of unprecedented forefront research in hadron and nuclear physics in atomic physics and nuclear astrophysics as well as in applied sciences like materials research, plasma physics and radiation biophysics. Key features of FAIR are intense beams of antiprotons and ions up to the heaviest and even exotic nuclei covering an energy range from rest up to 30 GeV/u. We present a brief overview on the current construction status of the FAIR accelerator facilities and the associated research pillars with emphasis on PANDA. PANDA (Antiproton Annihilation in Darmstadt), is the central experiment to fully exploit the physics research potential of the High Energy Storage Ring (HESR) with intense, phase-space cooled, antiprotons up to 15 GeV/c impinging on a variety of fixed targets. The PANDA detector features two spectrometers, the Target
Spectrometer with a SC solenoid magnet of 2 T and the Forward Spectrometer with a 2 Tm dipole magnet. In both spectrometers the PANDA collaboration employs a multitude of modern detector technologies to provide tracking, particle identification, calorimetry and muon identification, arranged hermetically close to 4π around the interaction region with additional detectors for coverage of the forward boosted particles. Focusing on the various PANDA detector systems we present an overview of recent developments, the detector construction progress and conclude with an outline for a phased deployment of PANDA at FAIR.

**Poster Session - Board: 86 / 174**

**Characterization of Hamamatsu 14160 series of Silicon Photomultipliers**

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Silicon Photomultipliers (SiPMs) are semiconductor-based photodetectors with performances similar to the traditional Photomultiplier Tubes (PMT). An increasing number of experiments dedicated to particle detection in colliders, accelerators, astrophysics, neutrino and rare-event physics, involving scintillators are using silicon Photo multipliers as photodetectors. They are gradually substituting PMTs in many applications, especially where low voltages are required and high magnetic field is present. Hamamatsu Photonics K.K. is one of leading producers of photodetectors and is continuously producing SiPMs of improved performances. In the last year Hamamatsu has introduced the 14160 series of SiPMs with improved performances. In the present work a characterization of these devices will be presented in terms of breakdown voltages, gain, noise and pulse shape. Particular attention will be devoted to the analysis of parameters as function of temperature. Finally a comparison with Hamamatsu SiPMs of the previous series and with devices produced by other companies will be presented.

**Poster Session - Board: 62 / 175**

**Measurement of amplitude distribution in Taiga-Muon Scintillator using cosmic particles.**

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The TAIGA experiment at Tunka valley, near to lake Baikal is enhancing the scintillation detector arrays with new type of scintillation detectors. This new type Taiga-Muon scintillator detector is tested with the help of particle tracking system using cosmic muons. The time difference technique has been applied to find the co-ordinates from streamer tubes which are connected in series. This type of detectors is already used in the muon system of the KEDR detector at the VEPP-4M collider, Budker INP. The amplitude distribution in the TAIGA-Muon scintillation detector is simultaneously analyzed with the co-ordinates of the incident particles. The ROOT software package and standard C++ program is used for this study. This results on the amplitude distribution will be used in data analysis of extensive air shower and for detailed Monte Carlo simulation.

**Poster Session - Board: 38 / 176**

**Influence of hole geometry on gas gain in GEM detectors**

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1
The Gas Electron Multiplier (GEM) technology is very popular among the high-energy physics community due to its excellent performance, even in high-rate environments; other striking features are strong resistance to aging as well as a flexible design. The core of the detector consists of thin foils with an etched pattern of holes. The detection principle relies on electron multiplication inside the holes, where a high electric field is apparent. New etching techniques have been used for the production of large-size ($0.3 \, \text{m}^2$ - $0.4 \, \text{m}^2$) GEM foils needed for high-energy physics experiments. The new techniques result in different hole geometries. To better understand the gas gain dependence on the hole geometry, several measurements have been performed, and have been complemented by GARFIELD++ simulations. The results are compared with other recent studies.

**Poster Session - Board: 63 / 177**

**NEVOD - experimental complex for multi-component investigations of cosmic rays and their interactions in the energy range $1 \, \cdot \, 10^{10} \, \text{GeV}$**

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Experimental complex NEVOD is located in the campus of the National Research Nuclear University MEPhI (Moscow) and is the only one in the world capable of carrying out the basic (particle physics and astrophysics) and applied (solar-terrestrial physics) studies by means of cosmic rays (CR) on the Earth’s surface in the entire range of zenith angles (0 to 180 degrees) and in a record energy range of CR primary particles ($1 \, \cdot \, 10^{10} \, \text{GeV}$). To provide solution of these tasks and to cover the very wide energy range, there were constructed a number of scientific facilities that have no analogues in the world: - large-volume Cherenkov water calorimeter (CWC) ($2000 \, \text{m}^3$) with a spatial lattice of quasispherical modules (QSM), which is a good homogeneous calorimeter with a $4\pi$ aperture capable of detecting both single muons and cascades in water in Cherenkov light with energies from 30 GeV to 100 TeV; - system of scintillation calibration telescopes (SCT) that allows to calibrate the response of QSMs and detect the electromagnetic and muon components of EAS with energies $10^{14}$-$10^{16} \, \text{eV}$; - vertically deployed around the CWC Russian-Italian coordinate-tracking detector DECOR (total area $70 \, \text{m}^2$) with a high spatial and angular resolution for the joint detection with CWD of multi-muon events at large zenith angles up to horizon for the generation of which particles of primary CR with energies in the range $10^{15}$ – $10^{18} \, \text{eV}$ are responsible; - muon hodoscope URAGAN with the total setup area $46 \, \text{m}^2$ continuously registering angular variations of muon flux in the range of zenith angles from 0 to 80 degrees, for generation of which the processes modulating CR flux with energies from 1 to 100 GeV in the heliosphere are responsible; - prototype detector for measurements of atmospheric neutrons PRISMA-32 which is represents an array of thermal neutron detectors located around the CWD and is designed to detect the hadron component of EAS with energies of $10^{14}$ – $10^{16} \, \text{eV}$; - NEVOD-EAS array of scintillation detectors deployed around the water detector over an area of $10^4 \, \text{m}^2$ for the detection of EAS with energies of $10^{15}$ – $10^{17} \, \text{eV}$ with a traditional technique. To extend the experimental capabilities up to the Mega-Science level, nowadays new large-scale detectors are being deployed around the EC NEVOD: - detector of atmospheric neutrons URAN, which is a development of PRISMA-32 facility on the area about...
10^3 m^2; - large-area vertical coordinate-tracking detector TREK (about 250 m^2) with a spatial resolution about 1 mm which allows to increase the upper limit of accessible for investigation primary energies up to 10^{19} eV. The description of experimental capabilities of the complex and first results of simultaneous detection of various EAS components are discussed.

**Poster Session** - Board: 20 / 178

**Investigation of Cherenkov radiation component in LYSO(Ce) crystals**

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Nowadays the measurements of time of registration in colliding beam experiments improves. LYSO(Ce) crystals could be used as fast counter of particle’s arrival time with accuracy better than 100 ps. There is the investigation of Cherenkov radiation influence on time of registration and its accuracy in LYSO(Ce). The result contains the data from the test beam experiment.

**Poster Session** - Board: 64 / 179

**The NEVOD-EAS air-shower facility**

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A new NEVOD-EAS array for detection of extensive air showers (EAS) in the energy range 10^{15} – 10^{17} eV is being created in MEPhI (Moscow, Russia) on the basis of the Experimental Complex NEVOD. It will operate in conjunction with the Cherenkov Water Detector NEVOD, coordinate-tracking detector DECOR and neutron detector URAN, as well as with detector TREK which is now being constructed. The NEVOD-EAS array is aimed at independent estimation of the size, axis position and arrival direction of extensive air showers (EAS) registered with other detectors of the Experimental complex NEVOD. This information will provide calibration of two novel perspective techniques developed in the Experimental Complex NEVOD: the method of local muon density spectra for studying inclined muon bundles, as well as investigation of EAS hadronic component via thermalized neutrons. Since the NEVOD-EAS array is being created at the densely built territory and detecting elements cannot be deployed in the same plane like in usual air-shower arrays, its registering system is organized in a cluster principle, and a newly developed cluster approach is used for experimental data analysis. Each cluster of the shower array is an independent system which includes 16 scintillation counters of EAS electron-photon component combined in 4 detector stations (DS) and registering electronics. Cluster electronics performs digitizing of analog signals, selection of local events according to intra-cluster triggering conditions, time-stamping of local events. Information on local events is transferred to the central DAQ post of control and synchronization of all clusters. The features of the distributed cluster type registering system of the NEVOD-EAS shower array, as well as the cluster approach to experimental data analysis are discussed. The main characteristics of the array important for EAS reconstruction which were obtained by simulation, as well as were measured during the data taking in conjunction with other detectors of the Experimental complex NEVOD, are presented.
Calorimetry / 180

CALICE highly granular calorimeters: imaging properties for hadronic shower analysis
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The CALICE collaboration pioneered the new trend in calorimetry - highly granular devices for high energy and particle physics applications. During the last fifteen years, several highly granular electromagnetic and hadron calorimeters based on different technologies were constructed and successfully tested. These comprise optical readout, signal collection with semi-conducting devices and gaseous detectors. All current CALICE prototypes address technological aspects such as embedded electronics. The results of beam tests with the various calorimeter prototypes will be presented. The MIP calibration and monitoring, calorimeter-based particle identification and comparison of different operation modes will be discussed.

Poster Session - Board: 87 / 181

The Front End Electronics for the Drift Chamber readout in MEG experiment upgrade

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Front End electronics plays an essential role in drift chambers for time resolution and, therefore, spatial resolution. The use of cluster timing techniques, by measuring the arriving times of all the individual ionization clusters after the first one, may enable to reach resolutions even below 100 µm in the measurement of the impact parameter. A high performance Front End electronics, characterized by low distortion, low noise and a wide bandwidth has been developed with the purpose to implement cluster timing techniques in the new drift chamber for the upgrade of the MEG experiment at Paul Sherrer Institut (CH).

Tracking and vertex detectors / 182

CYGNO: a gaseous TPC with optical readout for dark matter directional search
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The CYGNO project has the goal to use a gaseous TPC with optical readout to detect dark matter and solar neutrinos with low energy threshold and directionality. CYGNO will be part of the CYGNUS-TPC network with several underground laboratories around the world, that aim at reaching a total gas volume of about 1000 m³. The CYGNO demonstrator will have 1 m³ volume filled with He:CF₄ gas mixture at atmospheric pressure. Ionization electrons created by the particles interacting in the gas are drifted by the electric field to a three-layers GEM structure, and the light produced in the avalanche is monitored by sCMOS sensors providing a high granularity 2D track reconstruction. The 3rd coordinate is obtained using the time profile of light, simultaneously measured by photomultiplier tubes (PMT) with fast response. The combined readout of sCMOS sensors and PMTs provides a full 3D reconstruction, therefore allowing to infer the direction of the incoming particle. Such detailed reconstruction of the event topology gives also a powerful tool to discriminate signal from background, mainly represented by low energy
electron recoils induced by radioactivity. The high reconstruction efficiency with directionality of tracks down to energies of order 1 keV will give to CYGNO sensitivity to low mass dark matter and the potential to overcome the neutrino floor, that will ultimately limit non-directional dark matter searches.

**Poster Session - Board: 88 / 183**

**The FPGA Time-to-Digital Converter for the Large-Scale Detector TREK Based on Multi-Wire Drift Chambers**

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The new large-scale coordinate-tracking detector TREK is under construction in MEPhI. It is based on 264 multi-wire drift chambers (4000x508x112 mm³ size) developed in IHEP for experiments on the neutrino channel of the U-70 accelerator, and will have 250 m² of continuous effective area. The main goal of the project is the solution of so-called “muon puzzle”: the unpredicted by any theory excess of high multiplicity muon bundles generated by ultra-high energy primary cosmic rays. Besides of a set of field-forming wires, each multi-wire drift chamber has 4 signal ones. The current from these wires is processed by the shaper-amplifier AMP-4, mounted on the front of the chamber. It generates LVDS pulses that should be processed by multi-channel TDC that faces two main requirements: large matching window (more than 6000 ns) with LSD less than 10 ns and capability to hold more than 50 hits per channel in a single event. These conditions were fulfilled by the new time-to-digital converter developed on the basis of Cyclone V FPGA in MEPhI. This talk presents the design of the TDC, its main features and the first benchmarks of its performance.

**Poster Session - Board: 39 / 184**

**u-Rania: a neutron detector based on μ-RWELL technology**

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In the framework of the ATTRACT-uRANIA project, funded by the European Community, we are developing an innovative neutron imaging detector based on micro-Resistive WELL (μ-RWELL) technology. The μ-RWELL, based on the resistive detector concept, ensuring an efficient spark quenching mechanism, is a highly reliable device. The detector is composed of only two elements, i.e. a readout-PCB which comprises the amplification stage and a cathode. The amplification stage of the detector, realized by photolithography as a matrix of wells (with a pitch of 140 μm and a diameter of 60-70 μm) on a 50 μm thick polyimide substrate, is embedded in the readout board through a resistive layer realized by means of an industrial process with DLC (Diamond Like Carbon). The required surface resistivity, typically ranging from few tens to hundreds of MOhm/square, is clearly a parameter that must be optimized as a function of the detector performance, such as rate capability, spark amplitude quenching and maximum achievable gain. The cathode electrode defining the gas conversion-drift gap completes the detector mechanics: depositing few μm of Boron-10 on the copper surface of the cathode, will allow thermal-neutron detection through the release of an alpha particle, inside the active volume of the device, and a 7Li atom (10B + 1 n → 7Li + α). Boron-10 is one of the technologies being developed as an efficient and convenient alternative to the He-3 shortage. The goal of the project is to prove the feasibility of such a novel neutron detector by developing and testing small planar prototypes with readout boards suitably segmented with strip/mini-pad readout, equipped with existing electronics or readout in current mode.
The standard cathode PCB (18 micron of Cu layer on a 1.6 mm FR4 glass epoxy plate) of the \( \mu \)-RWELL has been coated with different thickness (1.5 – 2.0 – 2.5 – 3.0 – 4.3 microns) of 10B4C deposition by the ESS Coating Workshop in Linköping, Sweden. The thickness of the Boron layer is crucial for the conversion efficiency, a Geant4 simulation has been used to optimize the geometry of the detector.

A preliminary characterization of the prototypes has been done at the ENEA-HOTNES a calibrated 241Am-Be thermal neutron source placed in a cylindrical cavity delimited by polyethylene walls at the ENEA – Frascati Laboratory. HOTNES exploits a polyethylene shadow bar that prevents fast neutrons to directly reach the samples. The effect of the shadow bar and of the cavity walls, combine in such a way that the thermal neutron fluence is nearly uniform. The nearly uniform thermal neutron fluence rate at HOTNES reference irradiation plane is 758\( \pm \)16 cm\(^{-2}\)s\(^{-1}\).

For this test, the detectors, operated with the gas mixture Ar/CO\(_2\)/CF\(_4\) (45/15/40), have been read-out in current mode through a CAEN HV module A1561HDM. To extract from the current measurement the neutron detection efficiency, a detailed simulation of the thermal neutron detection process as well as a fine calibration of the gas gain of each detector used during the test has been performed.

The thermal neutron efficiency \( \epsilon \) is extracted from the measurement of the average current drawn by the irradiated detector through the formula: \( I = eN\epsilon G\epsilon R \), where \( e \) is electron charge, \( G \) is the gain of the detector and \( R \) is the thermal neutron fluence irradiating the detector, while \( N \), estimated with the simulation, is the average ionization generated in the gas gap by the alpha or Lithium ions coming from the interaction of the thermal neutron with 10B atoms. An overall neutron detection efficiency ranging between 1.5-2.0 (\( \pm \)0.2) % has been measured with 10B deposition in the range 1.5-4.3 micron thick. Systematic effects (measured and simulated) due to the absorption and back-scattering of the thermal neutron on the FR4 glass epoxy structure of the cathode PCB have been taken into account.

Further studies will be focused on the increasing of the detection efficiency and on the spatial resolution.

To increase the detection efficiency, a stack of Boron-coated aluminum mesh will be placed between the cathode and the readout PCB. Geometry optimization of the mesh and the spacing will be object of future studies with prototypes and simulation.

To achieve a spatial resolution of the order of 100 microns a combined charge and time readout will be used. A reconstruction software is being developed to allow exploiting the full potential of the readout electronics by means of processing charge and time information to estimate the position of the neutron interaction. Charge centroid and \( \mu \)TPC clusterization algorithms, developed for the BESIII Cylindrical GEM detector, will be adapted to the new detector configuration.

Preliminary results from the test with different prototypes, showing a good agreement with the simulation, will be presented together with construction details of the prototypes and the future steps of the project.

**Poster Session - Board: 40 / 185**

**Nanodiamond photocathode for MPGĐ-based single photon detectors at the future EIC**

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The construction of a Ring Imaging CHERenkov (RICH) detector for the particle identification in the high momenta range at the future Electron Ion Collider (EIC) is a challenging task. A compact collider setup imposes to construct a RICH with a short radiator length, hence limiting the number of photons. The last can be increased by detecting the photons in the far UV region. However, as standard fused-silica windows are opaque below 165 nm, a windowless RICH approach represents a possible choice. CsI is a widely used photo-cathode (PC) to detect photons in the far UV range, but because of its hygroscopic nature, it is very delicate to handle. Its Quantum Efficiency (QE) degrades in high intensity ion fluxes. These are the key reasons to quest for novel, less delicate PC with sensitivity in the far UV region. Layers of hydrogenated diamond nano grains have recently been proposed as alternative PC material and shown to have promising characteristics. The performance of nanodiamond PC coupled to THGEM-based detectors is the objects of our
ongoing R&D. The first phase of these studies includes the characterization of THGEMs coated with nanodiamond PC, the comparison of the effective QE in vacuum and in gaseous atmospheres, the hardness respect to the PC bombardment by ions from the multiplication process. The approach is described in detail as well as all the results obtained so far with this exploratory studies.

Poster Session - Board: 41 / 186

A GEM based TPC for beam monitoring

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In recent years Gas Electron Multipliers (GEMs) have proven to be reliable amplification stages at high beam rates, and can be used also in Time Projection Chambers (TPCs). Our group developed a double GEM based, finely segmented pad readout TPC for beam monitoring. The utilized GEMs and the custom-design FPGA data acquisition enables rate capability of 1 MHz for a 10 cm\(^2\) beam spot while providing excellent track-by-track position and angular information, better than 0.1 mm and 1 mrad respectively. The wide dynamic range of the system enables identification from \(^4\)He up to \(^{84}\)Kr using ionization measurement. The performance of the detector and the read-out was tested at the Institute of Modern Physics, Lanzhou, China, at the RIBLL beamline.

Poster Session - Board: 89 / 188

Towards an air-shower self-trigger for the sparse digital radio arrays

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The study of the ultra-high energy cosmic rays, neutrinos and gamma rays is one of the most important challenges in astrophysics. The low fluxes of these particles do not allow one to detect them directly. The detection is performed by measuring the cascades initiated by primary particles in the Earth atmosphere, namely air-showers. One of the perspective methods of the air-showers detection is the measuring of its radio emission. A radio detector is a cost-effective instrument which provides precise reconstruction of the parameters of primary particle and almost full duty cycle in comparison with other techniques. The main disadvantage of the modern radio detectors is the absence of established self-trigger technology due to high-level background and radio frequency interferences. In the most modern instruments the trigger is generated either by particle or by optical detectors. The development of the self-trigger for the radio detector will significantly simplify the operation of existing instruments and taking main advantages of the radio method as well as open the way to the construction of a new generation of radio detectors. In the present work we discuss the possible techniques for selection of air-shower signal from the background and our current progress on this problem.

Poster Session - Board: 90 / 191

A Readout System of the ALICE Fast Interaction Trigger

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The ALICE experiment at the CERN LHC will install Fast Interaction Trigger detector (FIT) during the ongoing second long shutdown of the LHC (2019-2021). The new FIT detector will serve as the main luminometer and trigger detector. It will also measure the precise collision
time, multiplicity, centrality and reaction plane. In order to cope with an increased interaction rate up to 1 MHz in proton-proton collisions and 200 kHz in Pb-Pb, a new readout system for the ALICE FIT detector has been designed. Event time will be measured by combined method with 13ps binning TDC THS788 and FPGA based TDC. The input charge will be integrated and measured by 12-bit 80Msps ADC. FIT readout system will allow to take data in continuous (trigger-less) and trigger (event selection by trigger) modes. Event readout selection as well as data processing done on Xilinx 7 FPGA. GBT-FPGA based readout allow to stream data up to 5.5 MHz event rate with 3.2 Mbps data rate. In this presentation we will discuss about the concept, features and performance of the digital readout system.

Tracking and vertex detectors / 192

Performance of the continuous ions suppression TPC prototype for circular collider
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The circumference of CEPC(Circular Electron Positron Collider) is 100km, with two interaction points available for exploring different detector design scenarios and technologies. Two common RF stations are deployed for the Higgs operation, which result in 286 beam bunches evenly distributed over a half ring. While for W and Z operations, independent RF cavities are used, 5220 and 10900 bunches are spreading in equal distance over the full ring, respectively. Therefore, the bunch spacing are about 500ns, 50ns and 30ns for Higgs, W and Z operations, respectively. Aiming for the CDR and TDR of the CEPC project, the feasibility study of TPC tracker detector was initiated for the purpose to identify feasible technology options and to gain expertise to build the detector units which meet the basic requirements of the CEPC detector design. The TPC detector at the proposed circular collider will have to be operated continuously and the backflow of ions must be minimized without the open/close time of a gating device technology. The gain of the selection detector module can be achieved up to about 5000 without any obvious discharge behaviour. The currents on the anode and drift cathode were measured precisely with an electrometer. The experimental results showed that IBF can be reduced to less than 0.1% at the specific gain. All update IBF results have been compared with ALICE TPC option and DMM(Double Mesh Micromegas) using 55Fe and X-ray tube. The future R&D has been mentioned to meet the high luminosity at Z.

Colliders and detector integration / 194

The luminosity detector at PANDA by HV-MAPS sensors
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The PANDA Experiment, which is located at the High Energy Storage Ring at the FAIR accelerator center in Darmstadt, Germany, is optimized for questions of hadron physics. With this detector it will be possible to discover new states and measure their line shapes as well as the line shapes of already known states very precisely. To normalize the energy scan measurements exact knowledge of the luminosity is required. The luminosity at PANDA will be determined from the angular distribution of elastic antiproton-proton scattering. In order to achieve an absolute measuring accuracy of 5%, the tracks of the scattered antiprotons will be measured by four planes of thinned silicon detectors (HV-MAPS). HV-MAPS are pixel sensors with integrated readout electronics. They will be operated with a reverse voltage of 60 volts to increase their radiation hardness. The four detector planes consist of CVD-diamonds on which the sensors are clued. To reduce the multiple scattering the detector is operated in a vacuum. The concept of the luminosity detector is presented and technical aspects such as the vacuum system, cooling, electronics, and sensors are discussed, as well as insights into data analysis.

Particle Identification / 195
Recent advances in particle identification methods
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The review will report on recent advances in particle identification methods in particle physics. We will discuss identification methods that are based on Cherenkov radiation and exploit the measurement of Cherenkov angle as well as the time of propagation of Cherenkov photons. We will also explore advances in transition radiation detectors and time-of-flight systems. We will discuss the detectors of the currently operating experiments and the research and development for future projects. Reference will also be made to developments that are potentially interesting for instrumentation in medical imaging.

Poster Session - Board: 28 / 196
Scintillation properties of zinc tungstate crystals
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Scintillation properties of several new zinc tungstate-based mixed crystals are studied. Measurements of their light yield at room temperature, decay time, maximum of spectral function and energy resolution at 662 keV are performed

Poster Session - Board: 65 / 197
Beam test characterization of a Plastic Scintillator Prototype for the space-based cosmic ray experiment HERD
Prof. CATTANEO, Paolo Walter

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The High Energy cosmic-Radiation Detector (HERD) detector is planned to go onboard Chinas Space Station, planned to be operational starting in around 2025 for about 10 years. The main scientific objectives of HERD are the search for signals of dark matter annihilation products, precise cosmic electron/positron spectrum and measurements of anisotropy up to 10 TeV, precise cosmic ray spectrum and composition measurements up to the knee energy (1 PeV), and high energy γ-ray monitoring and survey. HERD consists of a 3-D cubic crystals calorimeter (CALO) surrounded by microstrip silicon trackers (STKs) and scintillating fiber trackers (FIT) and by a Plastic Scintillator Detector (PSD) for γ-ray veto and ion charge measurement. A PSD prototype consisting of a scintillator tile readout by two arrays of SiPMs on opposite sides has been tested with proton and C ion beam at the CNAO (Centro Nazionale Adroterapia Oncologica) in Pavia (Italy). Preliminary results on charge and time resolution are presented.

Micropattern gas detectors / 199
Status of the GEM/CSC tracking system of the BM@N experiment
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Baryonic Matter at Nuclotron (BM@N) is a fixed target experiment at the NICA accelerator complex (JINR) aiming at studies of nuclear matter in relativistic heavy ion collisions. Triple GEM (Gas electron multiplier) detectors have been identified as suitable for the BM@N central tracking system, which is located inside the analyzing magnet. A cathode strip chamber (CSC) is mounted outside the magnet to improve the momentum resolution of the experimental setup.
Seven GEM detectors and one CSC are integrated into the BM@N experimental setup and data acquisition system. The structure of the BM@N GEM and CSC detectors and the results of the study of their characteristics are presented. The full configuration of the GEM/CSC tracking system is shortly reviewed.

Tracking and vertex detectors / 200

The Evolution of Drift Chambers at e+e- Colliders
Dr. GRANCAGNOLO, Francesco

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The overview of Drift Chambers detectors will be done.

Colliders and detector integration / 201

The PADME detector at LNF
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The Positron Annihilation into Dark Matter Experiment (PADME) aims to search for the production of a dark photon in the process e + e → A 0 γ. It exploits the 550 MeV positron beam provided by the DAΦNE LINAC impinging on a thin target. The primary beam crosses a diamond target and if it does not interact it is bent by a magnet in between the end of the spectrometer and the calorimeter, thus leaving the experiment undetected. If any kind of interaction causes the positron to lose more than 50 MeV of energy, the magnet bends it into the spectrometer acceptance, providing a veto signals against bremsstrahlung background. In case of annihilation, the accompanying ordinary photon is detected by the electromagnetic calorimeter regardless of the A 0 decay products. A single kinematic variable characterizing the process, the missing mass, is computed using the formula: M^2_{miss} = (P_{beam} + P_{e^-} - P_{\gamma})^2

Its distribution should peak at M_{A 0}^2 for A 0 decays, at zero for the concurrent e + e → γγ process, and should be smooth for the remaining background. To measure such a reaction, the PADME apparatus has been built at the Frascati National Laboratory of INFN. It consists of a small scale detector composed of the following parts:
• a diamond active target, to measure the position and the intensity of the beam in each single bunch;
• a beam monitor system consisting of two different silicon-pixel detectors. The first one, located at the beam entrance, can be inserted in place of the target to tune beam parameters; the second, located on the beam exit trajectory, monitors the beam spot during the data taking;
• a spectrometer, to measure the charged particles momenta in the range 50-400 MeV;
• a dipole magnet, to deflect the primary positron beam out of the spectrometer and the calorimeter and to allow momentum analysis;
• a vacuum chamber, to minimize the unwanted interactions of primary and secondary particles;
• a finely segmented, high resolution electromagnetic calorimeter, to measure 4-momenta and veto final state photons.

Each element has specific requirements that are stringent and sometimes at the limit of present technology. A commissioning run has been performed between 2008 and 2019, and in February 2020 the experiment is expected to take data for two months. The talk will give an overview of each detector component and a description of the chosen technical solutions implemented to accomplish the experiment needs. An insight of possible future upgrades will be given as well.

Electronics, Trigger and Data Acquisition / 202

Performance of the Belle II calorimeter trigger system at the SuperKEKB Phase 3 run
The Belle II experiment at the SuperKEKB electron-positron collider began physics data-taking in 2019 with full detectors. The main goal of the Belle II is to search for new physics beyond the Standard Model in heavy flavor sector.

In order to select events of interest efficiently under severe beam background environment from higher instantaneous luminosity run than the KEKB collider, we have upgraded a real-time hardware trigger system using the CsI(Tl) electromagnetic calorimeter. In this report, performance of the calorimeter trigger system under SuperKEKB Phase 3 operation will be described.

**Poster Session - Board: 50 / 203**

**New chemical approach to increase the refractive index, which is a key parameter of aerogels for Cherenkov radiators**

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Vavilov-Cerenkov radiation — glow caused by a charged particle in a transparent medium moving at a speed exceeding the phase velocity of light propagation in this medium. Such a glow allows detecting charged particles. The principle of operation of this detector is based on the detection of radiation that occurs when a charged particle moves in a transparent medium with a velocity greater than the speed of light $u$ in this medium. Since $u= c/n$, where the speed of light is in vacuum, and $n$ is the refractive index of the medium, the condition for the appearance of Cherenkov radiation has the form $> c/n$. Accordingly, for radiators of Cherenkov detectors, the most important characteristic is the index of light refraction. According to the refractive index ($1.13$-$1.007$), SiO2 aerogels occupy an intermediate position between liquids (water - $1.33$) and gases (freon $114$ - $1.00014$, CO2 $10$ atm - $1.0043$) [1]. This property of aerogels gives a number of advantages in use in Cherenkov detectors in front of liquids and gases, there is no need for high pressures, and the blocks are compact, convenient and easy to use. To increase the number of registered Cherenkov photons, as well as expand the range of particle identification in the direction of small pulses, it is necessary to obtain aerogel blocks with a refractive index higher than $1.07$ without deteriorating the optical properties (scattering length, light absorption length and uniformity of the refractive index in the layer).

Here we present a description of various approaches for increasing the refractive index using thermal sintering of blocks [2], the pinhole method (microholes) [3], including the original chemical approach developed by us based on the sol-gel method. The so-called chemical approach is based on the introduction of additives in SiO2 aerogel increasing the refractive index. For example, it is zirconium dioxide ($ZrO2$), the refractive index of which is $2.23$; for comparison, the SiO2 has a refractive index of $1.45$. The introduction of several mole percent can increase the refractive index by several hundredths of a unit.


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**Experimental setup for metallization of fiber and wire**

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Inverted cylindrical magnetron sputtering setup for fiber and wire metallization is being developed. Sputtering setup allow us to use magnetron target and wire from various materials. It can be useful for gilded wire production what is relevant for high-energy physics.

**The Well Electron Multiplier with DLC anode – a key element of the fast and robust position sensitive micro-pattern gaseous detector**

KASHCHUK, Anatoli

1 PNPI, Gatchina

Thin film of Diamond-Like Carbone (DLC) is used as a resistive anode in the Well Electron Multiplier – a key element of the fast and robust radiation detector. As shown, the DLC with thickness of 80 nm and surface resistivity of 25 MOhm/ certainty protects detector against discharges. DLC film in this test was deposited on a PCB above the copper mesh at cell size in range of 0.5-1 mm.

**Signal shapes in the Well Electron Multiplier with DLC anode**

KASHCHUK, Anatoli

1 PNPI, Gatchina

Thin film of Diamond-Like Carbone (DLC) was used as a resistive anode in the Well Electron Multiplier. The DLC film with thickness of 80 nm and surface resistivity of 25 MOhm/ was deposited on a PCB above the copper mesh at cell size in range of 0.5-1 mm. The shape of signals on various electrodes was studied. The new schematics of pole-zero cancellation is discussed.

**The KLOE-2 e+e- tagging for two-photon physics**

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One goal of the KLOE-2 experiment, at the Frascati φ–factory, is to study $e^+e^-\rightarrow\gamma\gamma^*e^+e^-\rightarrow\pi^0e^+e^-$ processes by tagging final state leptons with two scintillator hodoscopes installed, by means of roman pots, in the DAΦNE beam pipe. The High energy tagger (HET) counting rate is dominated by Bhabha scattering events without any associated signal in the KLOE detector. By comparison with the KLOE luminosity measurement, the effective Bhabha cross section per scintillator can be measured, in order to monitor detector performance and infer acceptance×efficiency of the HET. The $\pi^0$ production from two-photon fusion is tagged by requiring the coincidence between the HET detector and the KLOE calorimeter when two-cluster bunches are reconstructed, and evaluating the uncorrelated HET-KLOE time coincidences.
Data stability studies, based on very low angle Bhabha cross section measurement, and updates on $\gamma^*\gamma^* \rightarrow \pi^0$ search will be presented.

**Status of facilities / 208**

CERN activities and plans in HEP

**Status of facilities / 209**

Collider experiments at BINP

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**Poster Session - Board: 17 / 210**

Mechanical stability of wire structure of the KEDR new drift chamber

Mr. BASOK, Ivan

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The issues concerning mechanical stability of the wire structure and associated with the use of different materials in the making of a new drift chamber are discussed. The mechanical properties of aluminum cathode wire are investigated. The value of decline in wire tension as a result of material creep are measured. Topic of fixing security of wires is studied in detail.

**Poster Session - Board: 18 / 211**

Study of cathode aging and field emission in drift chambers

Mr. PRISEKIN, Vyacheslav

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Radiation aging of wire chambers and the effect exerted on it by various contaminants on the surface of a cathode wire are investigated. The threshold electric field strength that gives rise to autoelectronic emission has been measured for several cathode wire samples.

**Poster Session - Board: 29 / 212**

Simulation of the CsI crystal calorimeter of the detector of tau-charm factory in Novosibirsk

Mr. IVANOV, Vyacheslav

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The talk is devoted to the status of the simulation of the CsI crystal calorimeter of the detector of charm-tau factory in Novosibirsk. The calorimeter employs the scheme with the crystals focusing at the beams interaction point to obtain the optimal energy and coordinate resolutions. However, to avoid the «dead zones» effect, a slight defocusing in longitudinal and transversal directions is made. The description of the fully parametrized crystal geometry generator is presented. Using this generator the optimization of the calorimeter geometry parameters was done. The report also presents the results for the coordinate and energy correction functions calculation, as well as the estimation of the resulting energy and coordinate resolutions. Finally, the influence of the dead material in front of the calorimeter (including the option of «thin solenoid») was studied.
**Poster Session - Board: 51 / 213**

**Charged particle identification with the liquid Xenon calorimeter of the CMD-3 detector**

Mr. IVANOV, Vyacheslav

1 *Budker Institute of Nuclear Physics*

The talk is devoted to the procedure of the charged particle identification with the multilayer liquid Xenon calorimeter of the CMD-3 detector. The procedure uses the boosted decision trees classification method with specific energy losses of charged particles as input variables. The efficiency of the procedure is illustrated by an example of the measurement of the $e^+e^-\rightarrow K^+K^-$ process cross section in the center-of-mass energy range from 1.075 to 2.0 GeV. Special attention is paid to the detector response simulation and calibration issues.

**Poster Session - Board: 91 / 214**

**New Concepts for Light Mechanical Structures of Cylindrical Drift Chambers**

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New concepts, relevant to the design of a light mechanical structure for a cylindrical drift chamber, will be illustrated. A considerable reduction in the amount of material at the end plates can be obtained by the simple consideration of separating, in the mechanical structure, the gas containment function from the wire tension support function. According to this scheme, the wires are anchored to a self-sustaining light structure (“wire cage”) surrounded by a very thin skin (“gas envelope”) of suitable profile to compensate for the gas differential pressure with respect to the outside. The “wire cage” is schematically made of a set of radial spokes, constrained into a polygonal shape at the inner ends and extended to the outer endplate rim, thus subdividing the chamber in identical sectors. The drift chamber is, then, built by stacking up radially, in each of the sectors and between adjacent spokes, printed circuit boards, where the ends of the wires are soldered, alternated with proper spacers, to define the cell width. A system of adjustable tie-rods steers the wire tension to the outer endplate rim, where a rigid cylindrical carbon fibre support structure, bearing the total wire load, is attached. Two thin carbon fibre domes, free to deform under the gas pressure without affecting the wire tension and conveniently shaped to minimize the stress at the inner rim, contribute to the “gas envelope” and, together with an inner thin cylindrical foil and with the outer structural support, enclose the gas volume.

**Poster Session - Board: 92 / 215**

**A 10-3 drift velocity monitoring chamber**

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The MEG-II experiment searches for the lepton flavor violating decay $\mu \rightarrow e + \gamma$. The reconstruction of the positron trajectory uses a cylindrical drift chamber operated with a mixture of He and i-C4H10 gas. It is important to provide a stable performance of the detector in terms of its electron transport parameters, avalanche multiplication, composition and purity of the gas mixture. In order to have a continuous monitoring of the quality of gas, we plan to install a small drift chamber, with a simple geometry that allows to measure very precisely and in a promptly the electron drift velocity, the most sensitive parameter to the gas mixture. The monitoring chamber will be supplied with gas coming from the inlet and from the outlet of the detector to determine if gas contaminations originate inside the main chamber or in the gas supply system. The chamber is a small box with cathode walls, defining a highly uniform electric field in the volume of two adjacent drift cells. In the plane separating the two drift cells, 4 sense wires alternated with 5 guard wires collect the drifting electrons. The trigger is provided by two 90Sr weak calibration radioactive sources placed on top of a two thin scintillator tiles telescope. The whole system is designed to give a prompt response (within a minute) about drift velocity variations at the 10-3 level. Such a variation correspond to:

- +0.4% in i-C4H10 content (from 10.0% to 10.4%)
- -0.2% in i-C4H10 content (from 10.0% to 9.8%)
- $\pm 0.4\%$ in $E/p (\approx 6\%$ in gas gain) at gain $\approx 5 \times 10^5$
- $\pm 4$ V at $p \approx 1$ bar, $T \approx 25 ^\circ C$
- $\pm 4$ mbar at $V \approx 1500$V, $T \approx 25 ^\circ C$
- $-0.3 ^\circ C$ at $p \approx 1$ bar, $V \approx 1500$ V
- $\leq 100$ ppm variations in water vapor content around 3500 ppm.

Poster Session - Board: 93 / 216

The use of FPGA in drift chambers for data transfer rate reduction

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The widespread use in drift chambers of light helium-based gas mixtures is aimed at minimizing the multiple scattering contribution to the momentum measurement for low momentum particles. However, because of the limited number of ionization clusters produced, these gas mixtures introduce a substantial bias in the impact parameter estimate, particularly for short impact parameters and small drift cells. Recently, an alternative impact parameter reconstruction technique (Cluster Timing) has been proposed, which consists in using, with statistical considerations, the distribution of the drift times of all individual ionization clusters, to reduce the bias and, consequently, to improve the spatial resolution. An efficient application of Cluster Timing
techniques requires converting the sense wire signals from analog to digital, with at least 10 to 12 bits resolutions at sampling frequencies of at least 1-2 GSa/s. These constraints, together with the maximum drift time, of the order of several hundred nanoseconds, and with the large number of acquisition channels, typically of the order of tens of thousand in modern drift chambers at colliders, may require data transfer rates of the order of TB/s and, therefore, impose sizeable data reduction techniques. The amplitudes and the drift times of the peaks associated to the individual ionization clusters identified in the wire signal constitute the essential amount of data to be processed, transferred and stored and, to this purpose, fast readout algorithms, implemented within FPGA’s and executed in real time represent an attractive solution. The CluTim algorithm, described here, identifies in real-time the peaks corresponding to the different ionization cluster, stores each peak amplitude and time in an internal memory and sends the stored data to an external device when a specific trigger signal occurs. Such a quasi-on-line procedure results in data reduction factors of almost two orders of magnitude with respect to the raw digitized data. A hardware test of such an application is illustrated with the details of the applied algorithm.

**Poster Session - Board: 94 / 217**

**Muon system performance of the CMD-3 detector at VEPP-2000 collider**

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The Muon system of the CMD-3 detector is described. The Muon system is located around the CMD-3 detector. The Muon system is made from thin plates of plastic scintillators and is intended for measuring the time and position of particles passing through the detector. In particular to separate cosmic rays from products of antineutron annihilations in the calorimeters. Due to low velocities of antineutrons, the average times of annihilation in the calorimeters have a typical delay time about 4 − 10ns with respect to the beam collision. The time calibration procedure of Muon system and its efficiency measurement will be presented at this poster.

**Poster Session - Board: 95 / 218**

**Track finding with TMVA package for Muon g-2/EDM experiment at J-PARC**

Mr. SEMENOV, Aleksandr¹

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In this work we discuss the new way of the track finding procedure for g– 2/EDM experiment at J-PARC. This procedure implements the multivariate classification method on machine learning techniques with TMVA package and ROOT. The data from GEANT4 simulation are used for the training and testing the program. All simulated positron tracks were divided into three groups by the value of the transverse momentum for the better machine learning. Preliminary results of the new track finding method are presented.

**Poster Session - Board: 96 / 219**

**On-line luminosity measurements at Belle II**

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Belle II detector at SuperKEKB storage ring has started its operation in April 2018. We describe a system used at the Belle-II experiment for the on-line measurements of the luminosity provided by the SuperKEKB collider utilizing elastic e+e- Bhabha scattering and two-photon annihilation processes. Statistical accuracy of 2.3% is achieved at the luminosity of the order of $10^{34}$ with a
measurement rate of about 1 Hz. The overall systematic uncertainty is estimated to be at the level of 2%. Comparison with offline results is also presented.