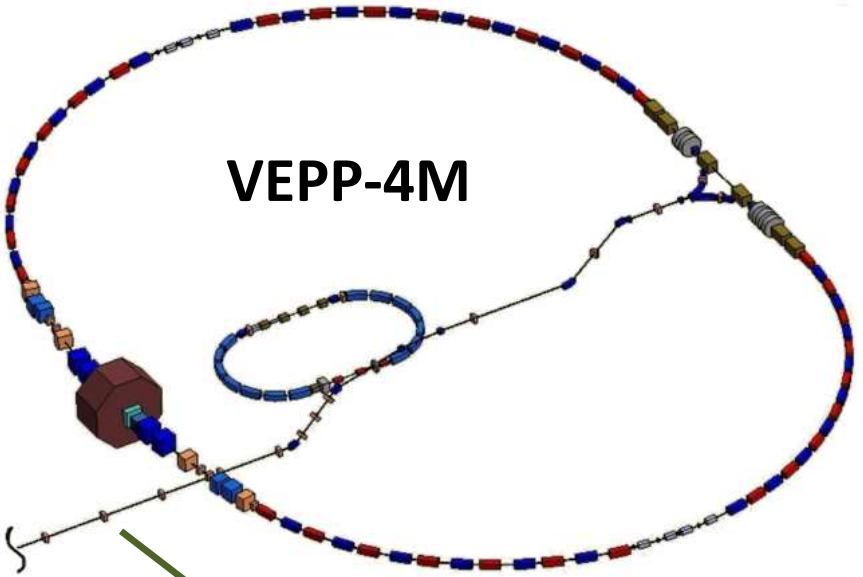
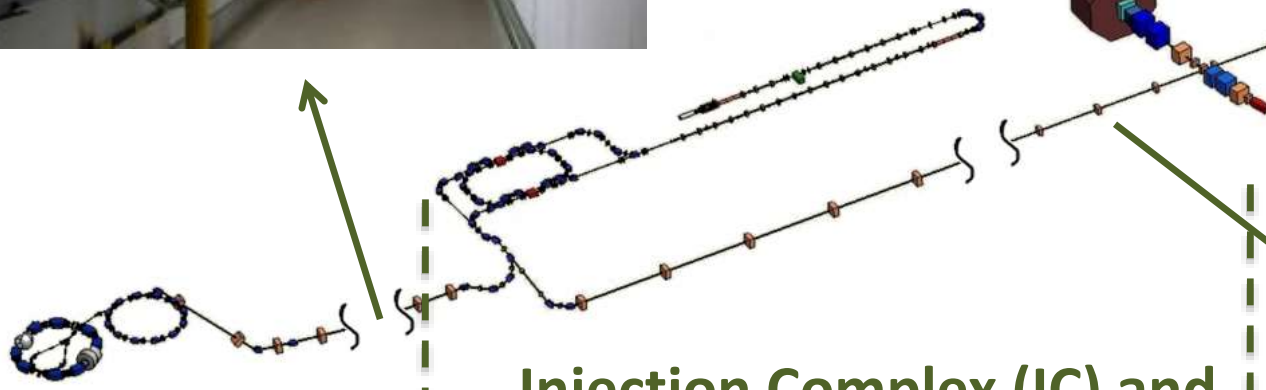
Collider experiments at BINP

Pavel Logachev
on behalf of
IC, VEPP-4M, VEPP-2000 teams

Feb 24, 2020
INSTR'2020, Novosibirsk.

BINP accelerator complex layout



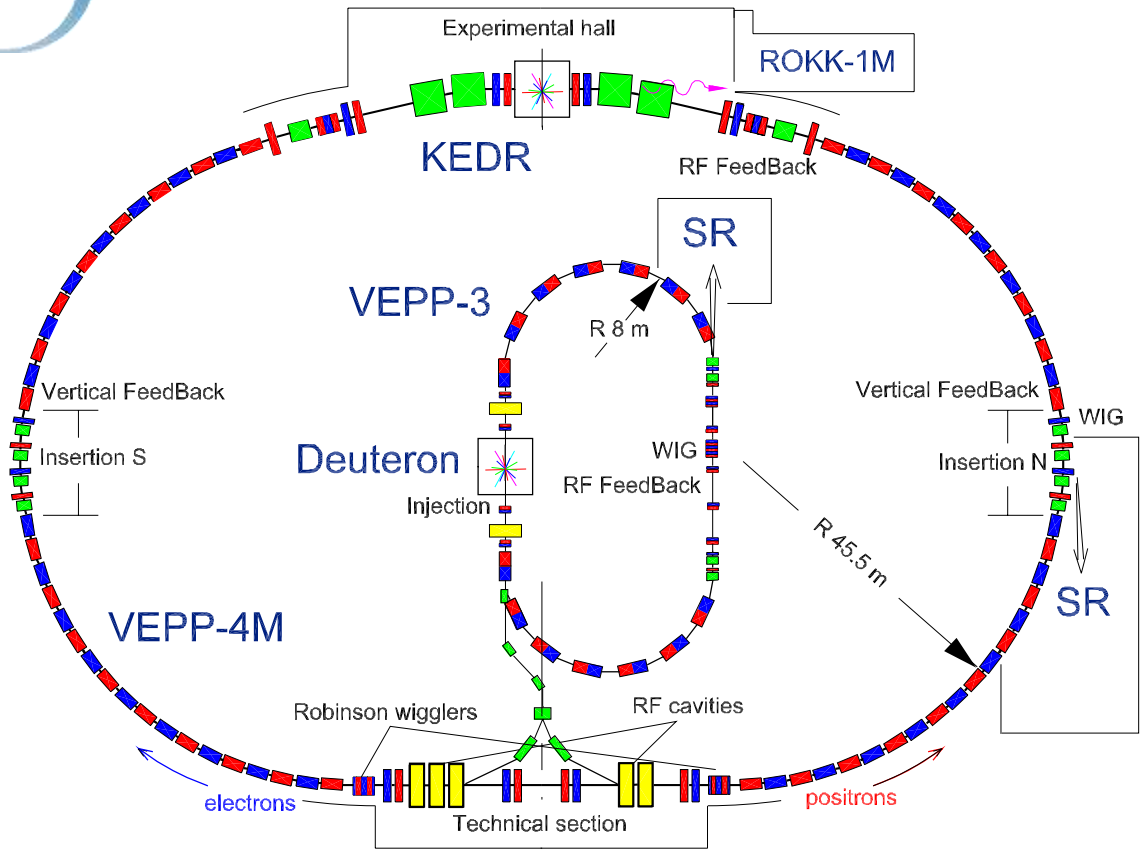


VEPP-2000

Injection Complex (IC) and beam transfer lines

IC Parameters (2019)	
Beam Energy:	**390 MeV**
Storage rate e^- @ 10.0 Hz:	**$1.8 \cdot 10^{10}$/s** (30 mA/s)
Storage rate e^+ @ 10.0 Hz:	**$1.8 \cdot 10^{9}$/s** (3 mA/s)

VEPP-4 facility



- ★ High energy physics at VEPP-4M with detector KEDR
- ★ Synchrotron radiation at VEPP-3 & VEPP-4M
- ★ Nuclear physics at VEPP-3 with Deuteron facility
- ★ Test beam facility at VEPP-4M
- ★ Accelerator physics activity

	VEPP-3	VEPP-4M	
Circumference	74.4	366	m
Energy	0.4÷2	1÷6	GeV
Bunches	2e±	2e+x2e-, 20e-	
Current	150	15	mA
Luminosity		$1 \cdot 10^{31}$	$cm^{-2} \cdot s^{-1}$

VEPP-4M BEAM ENERGY CALIBRATION

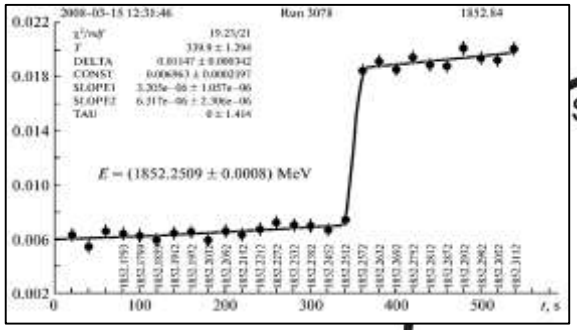
The main advantage of VEPP-4M in the HEP experiments is the high-precision beam energy measurement by resonant depolarization and beam energy monitoring by Compton backscattering

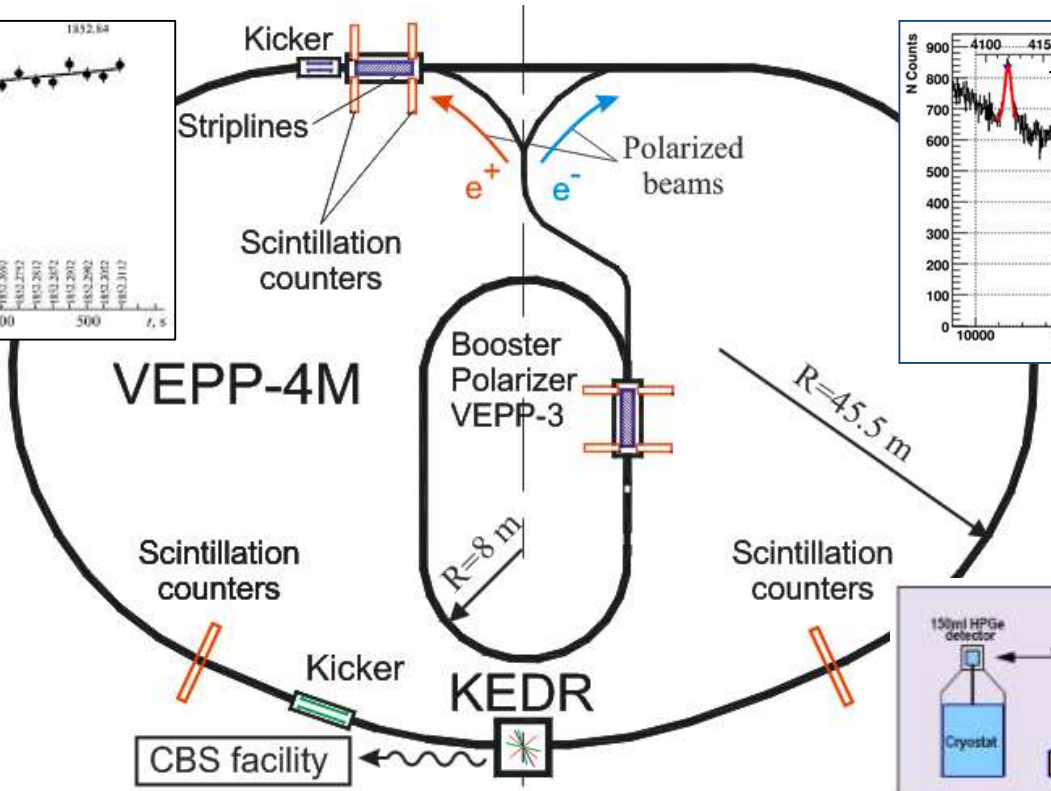
Resonance Depolarization

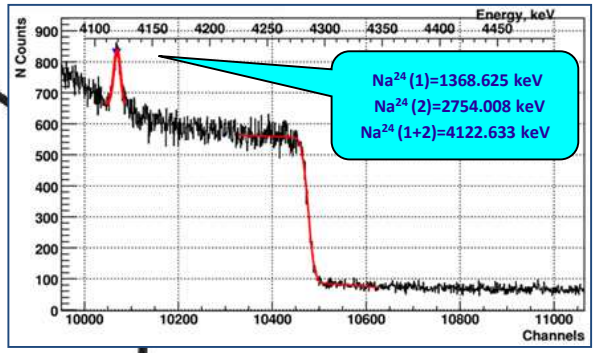
- **Accuracy ~ 10^{-6}**
- **Needs polarized beam**
- **Up to 2-3 serial measurements possible with the same beam**
- **Polarized beam obtained in ranges E = 1.5÷2 GeV and 3.8÷5 GeV**

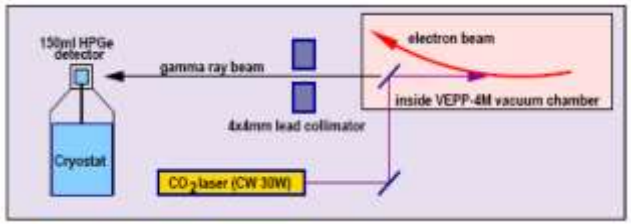
Compton Back Scattering

- **Accuracy ~ $5 \cdot 10^{-5}$**
- **Measurement time ~ 10 min**
- **Beam energy spread ~10%**
- **During statistics acquisition**
- **E < 3.5 GeV**







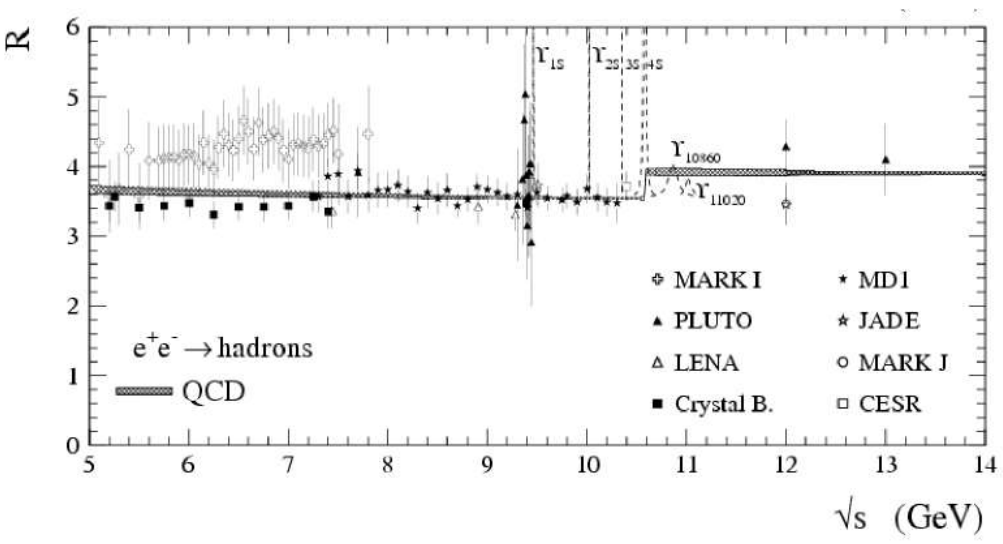


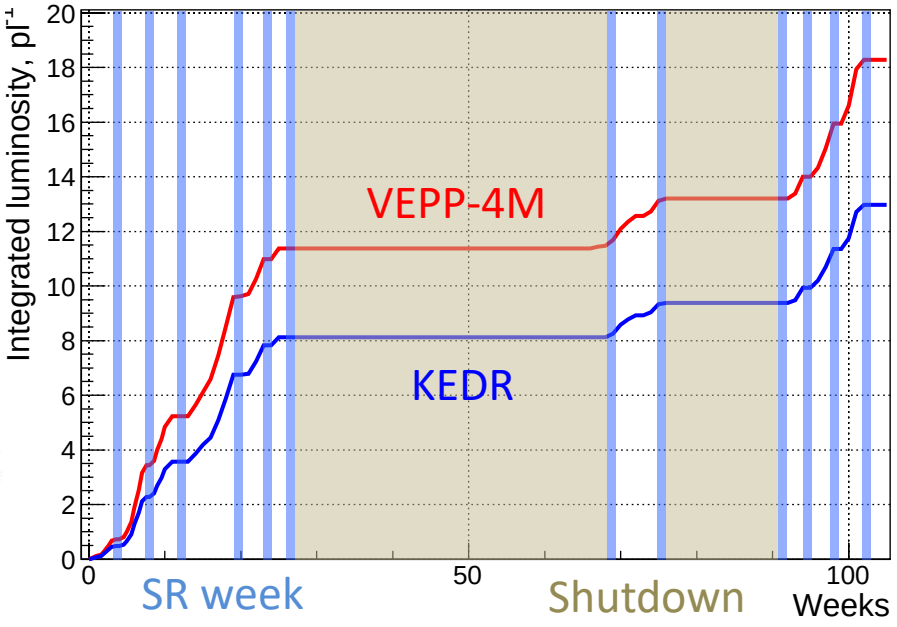
R-scan 4.5÷7 GeV

In 2018, at VEPP-4M experimental program in low energy range (2÷2.8 GeV) was finished. The next run concentrates on:

- hadronic cross-section measurement in the range of 2.3–3.5 GeV (~ 10 pb^{-1});
- Upsilon mesons study (~ 50 pb^{-1});
- gamma-gamma physics (~ 200 pb^{-1}).

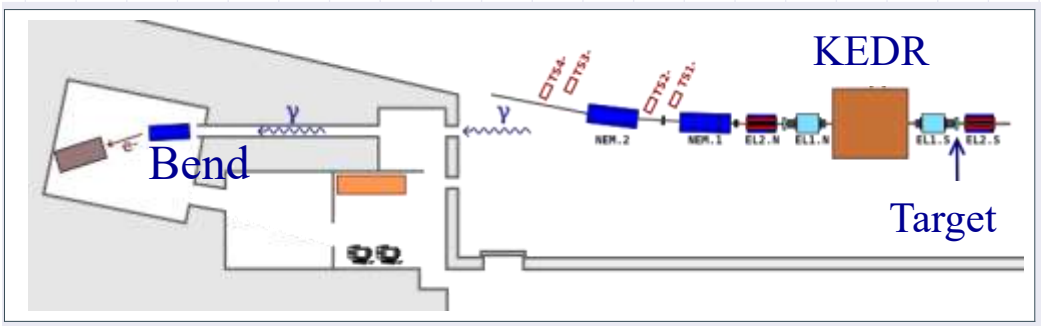
The first stage of this program is the hadronic cross-section measurement from 4.5 to 7 GeV in 17 points. Now we finished 15 points ~ 12 pb^{-1}.



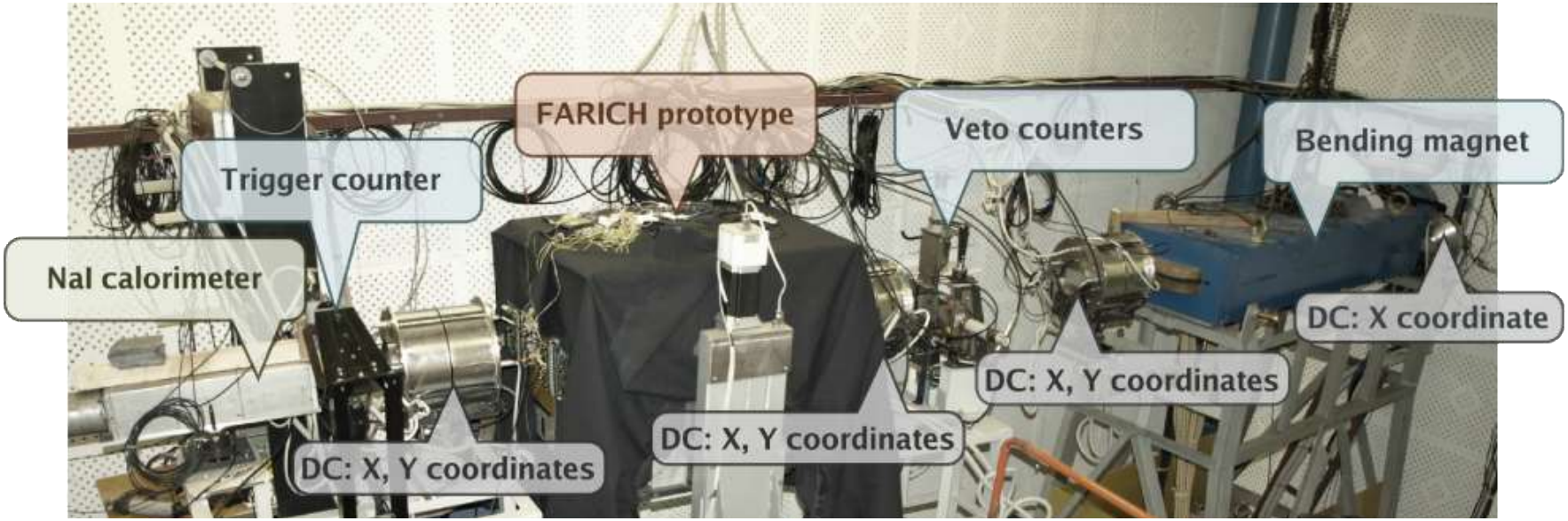


TEST BEAM FACILITY @ VEPP-4M

TBF is experimental facility of VEPP-4M uses bremsstrahlung gamma-rays from the movable beam scraper inserted in the halo of the circulating electron beam for test experiments with HEP detector components.

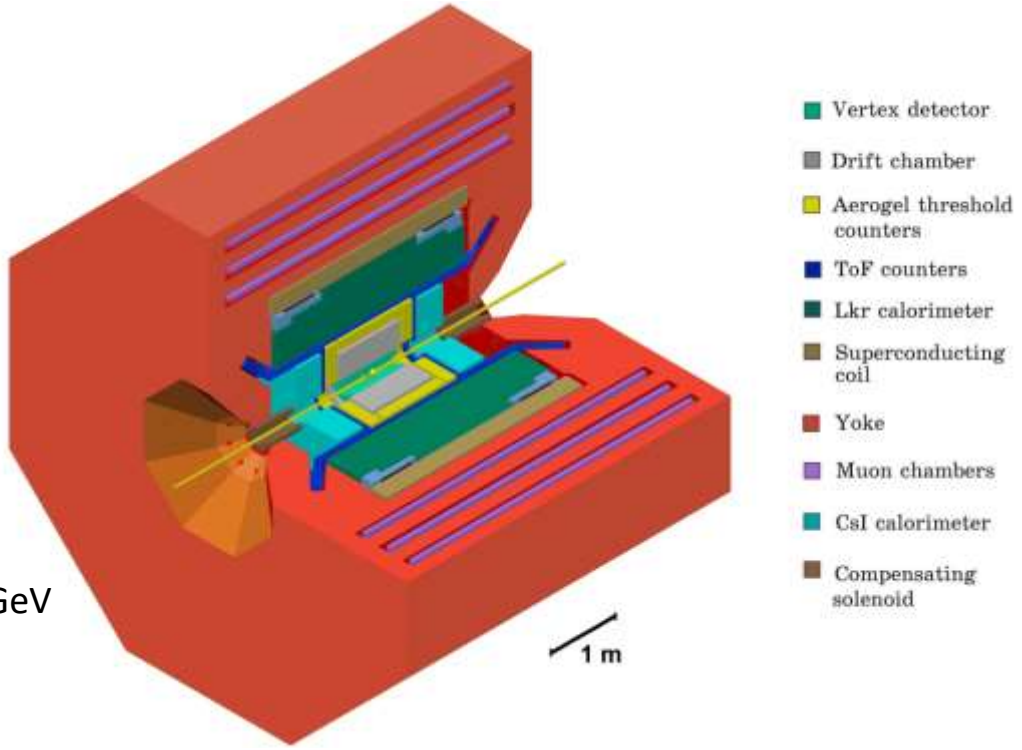


	e^-	gamma	
Energy	0.1÷3	0.05÷1.5	GeV
RMS dE/E	0.5÷1.5	~0.5	%
Intensity	10÷100	~1000	Hz



VEPP-4M & KEDR

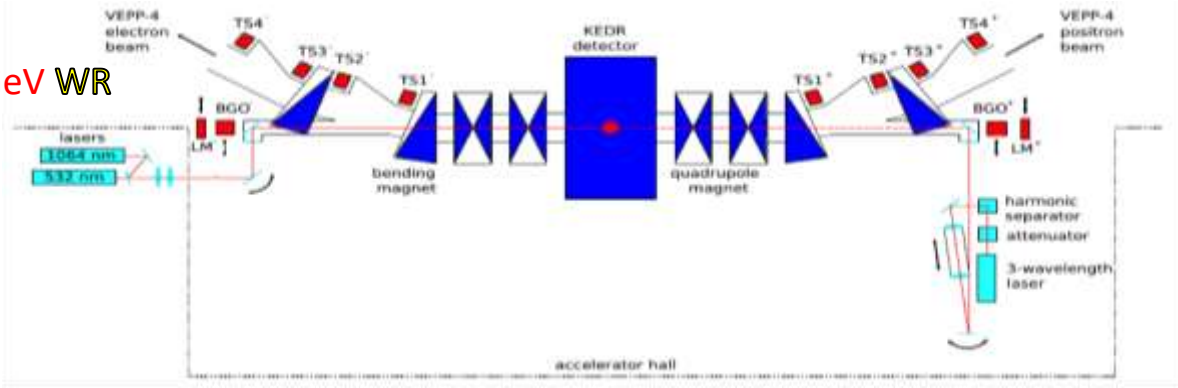
- ★ Universal magnetic detector KEDR
- ★ Electron-positron tagging system
- ★ Wide energy range 0.9÷6 GeV
- ★ Energy spread control
- ★ Precision beam energy calibration by resonance depolarization
- ★ First collider with beam energy monitoring by Compton backscattering



2001-2017 low energy luminosity run 2x(0.9÷1.9) GeV

- ✓ J/ψ, ψ' , ψ", ψ(3770) meson masses WR
- ✓ τ lepton mass ~~WR~~
- ✓ D^0 mesons masses
- ✓ $D^{\pm}$ mesons masses WR
- ✓ Search for narrow resonances 1.85÷3.1 GeV WR
- ✓ R-scan 1.85÷3.1 GeV WR
- ✓ Ruds- and R- scan 3.12÷3.72 GeV WR
- ✓ $J/\psi \to \gamma\eta_c$ WR
- ✓ ψ-mesons, η_c, … parameters WR

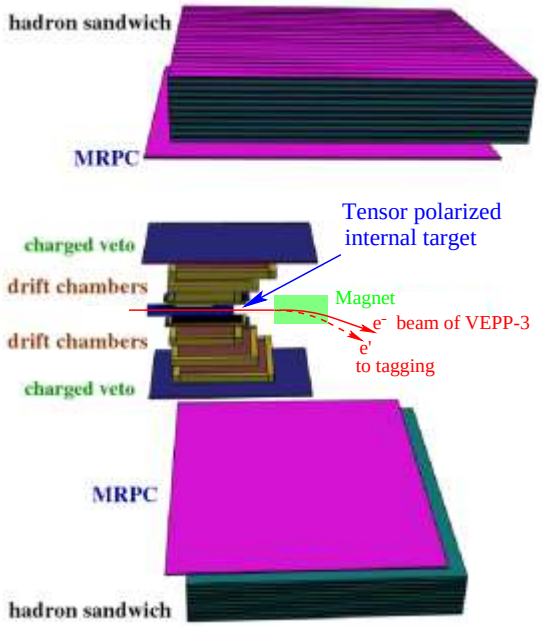
WR = World Record

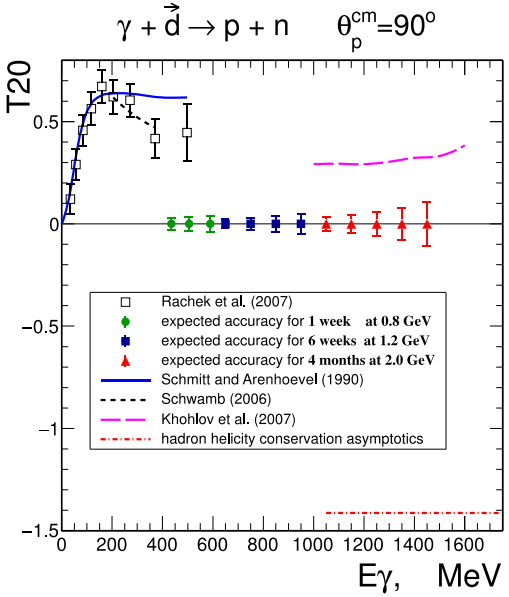


Deuteron VEPP-3

Tensor-polarized deuteron photodisintegration at the VEPP-3 storage ring

The two-body deuteron photodisintegration is one of the most studied process in nuclear physics. Tensor analyzing power T20 reaction will be measured in an unexplored region of the photon energy up to 1.5 GeV.





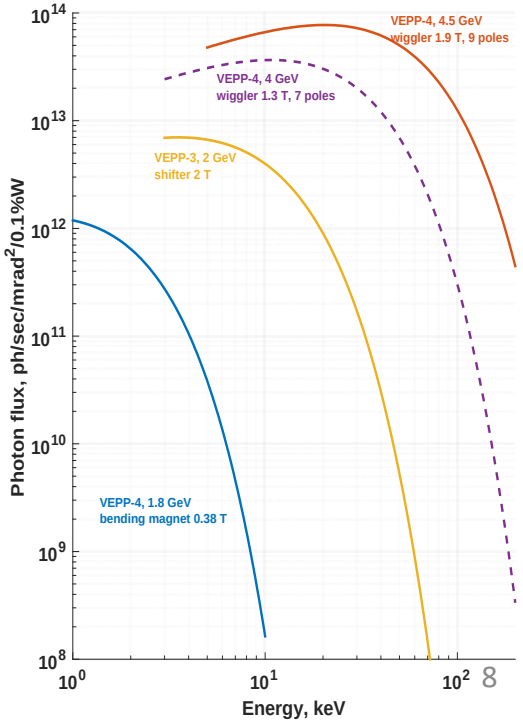
- ✓ SR @ VEPP-3 – 1.2 or 2.0 GeV with 2 T shifter
- ✓ SR @ VEPP-4M – 1.9 or 4.5 GeV with new 9-poles hybrid 2 T wiggler

VEPP-3

- LIGA-technology and X-ray lithography.
- Fast dynamic process.
- Precise diffraction and anomalous scattering.
- X-ray fluorescence analysis.
- High pressure diffraction.
- X-ray microscopy and micro-tomography.
- Time resolved diffraction.
- Time resolved luminescence.
- Precise diffraction.

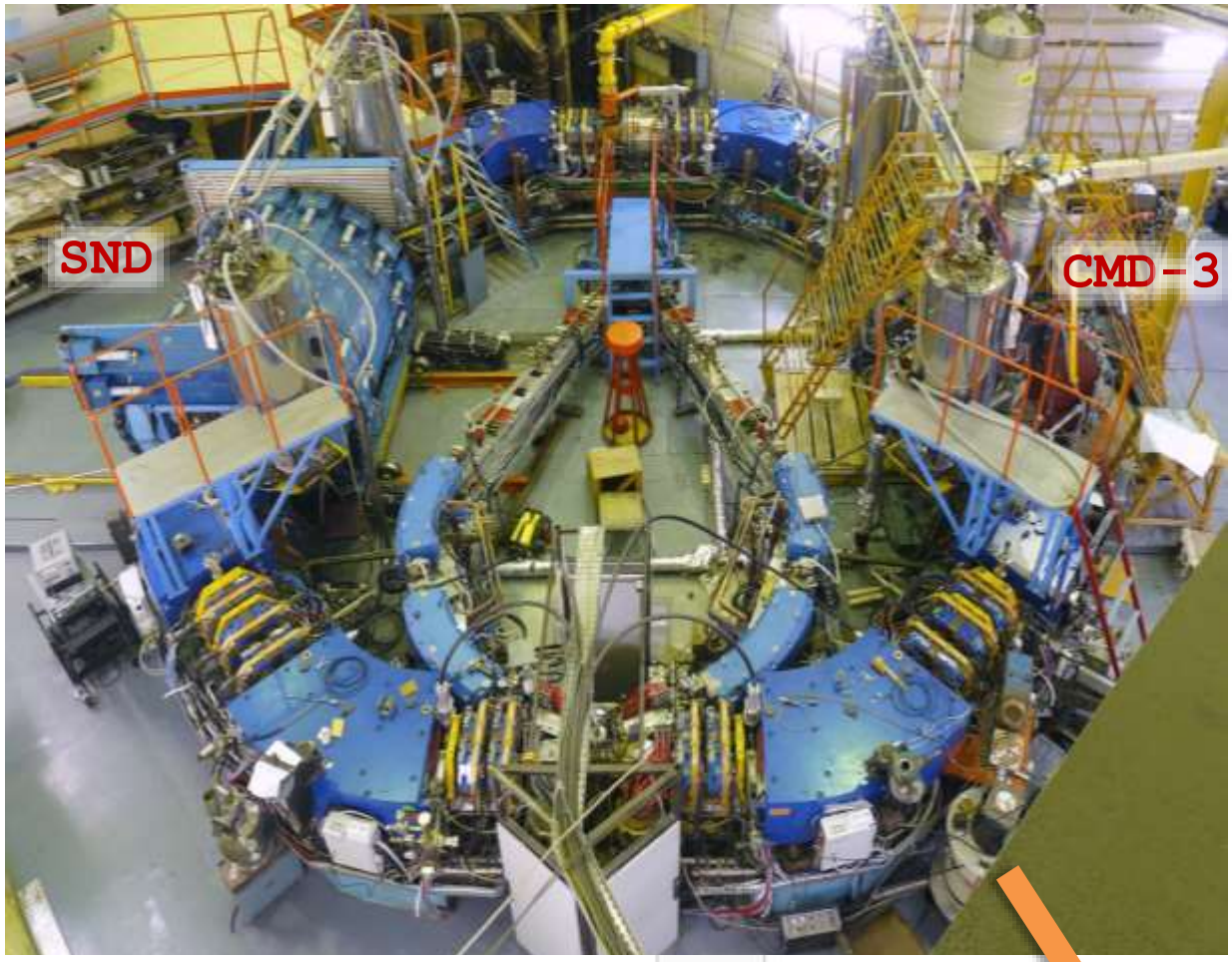
VEPP-4M

- Metrology experiments.
- Phase contrast microscopy, micro-tomography and hard X ray fluorescence.
- Nanosecond spectroscopy of fast processes.
- Material study under extremal conditions
- Material study for thermonuclear applications



VEPP-2000 overview

Design parameters @ 1 GeV	
Circumference	24.388 m
Beam energy	150 ÷ 1000 MeV
N of bunches	1×1
N of particles	1×10^{11}
Betatron tunes	4.14 / 2.14
Beta*	8.5 cm
BB parameter	0.1
Luminosity	1×10^{32} $cm^{-2}s^{-1}$



- Round beams concept
- 13 T solenoids for FF
- 2.4 NC dipoles @ 1 GeV
- CBS for energy control

Operating with IC#VEPP-5 since 2016

The concept of Round Colliding Beams

Axial symmetry of counter beam force + X-Y symmetry of transfer matrix IP2IP

⇩

Additional integral of motion (angular momentum $M_z = x'y - xy'$)

Particle dynamics becomes 1D; thinned resonance net; higher beam-beam threshold!

Lattice requirements:

- Head-on collisions!
- Small and equal β-functions at IP:
- Equal beam emittances:
- Equal fractional parts of betatron tunes:

$$\beta_x = \beta_y$$
$$\varepsilon_x = \varepsilon_y$$
$$\nu_x = \nu_y$$

Round beam

$M_x = M_y$

F.M. Izrailev, G.M. Tumaikin, I.B. Vasserman. Preprint INP 79-74, Novosibirsk,(1979).

L.M. Barkov, et. al, Proc. HEACC'89, Tsukuba, Japan, p.1385.

S. Krishnagopal, R. Siemann, Proc. PAC'89, Chicago, p.836.

V.V. Danilov et al., EPAC'96, Barcelona, p.1149.

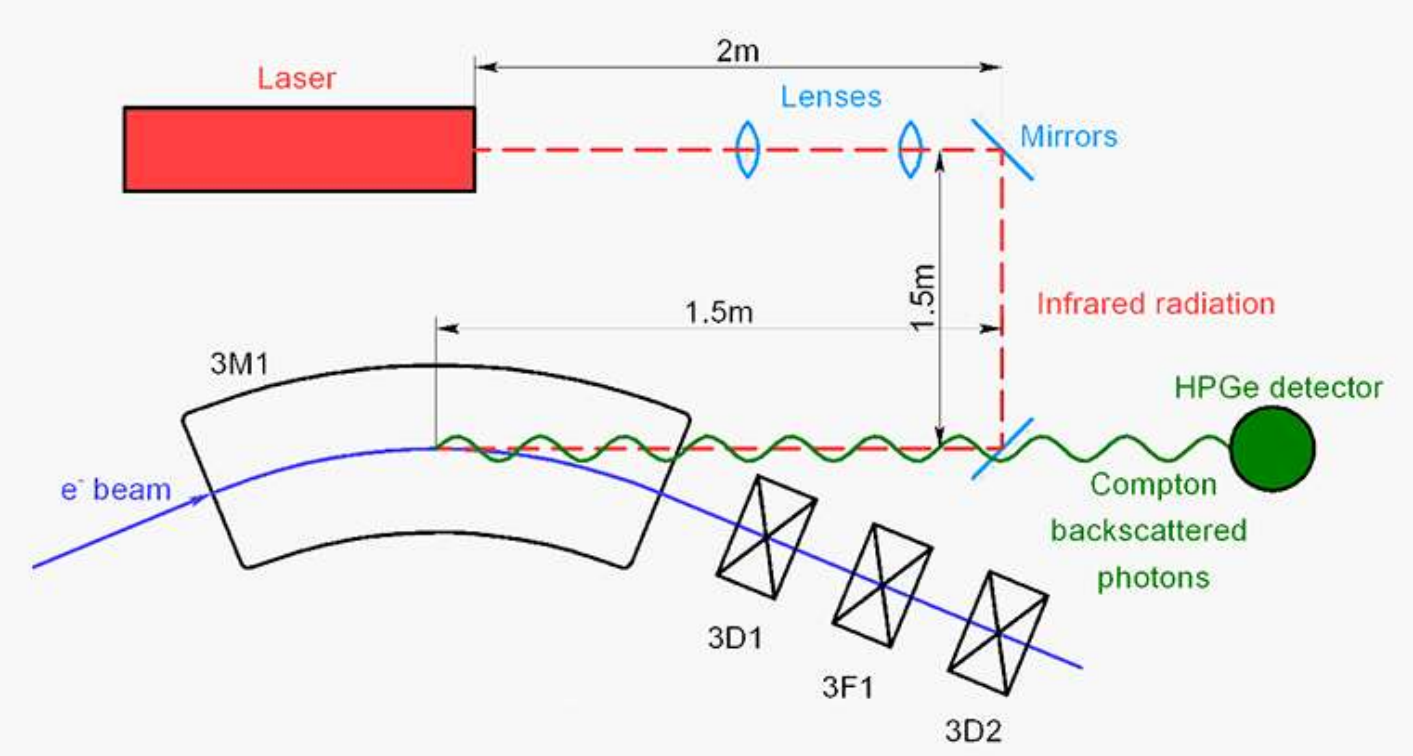
S. Henderson, et al., Proc. PAC'99, New York, p.410.

VEPP-2000. Experimental program

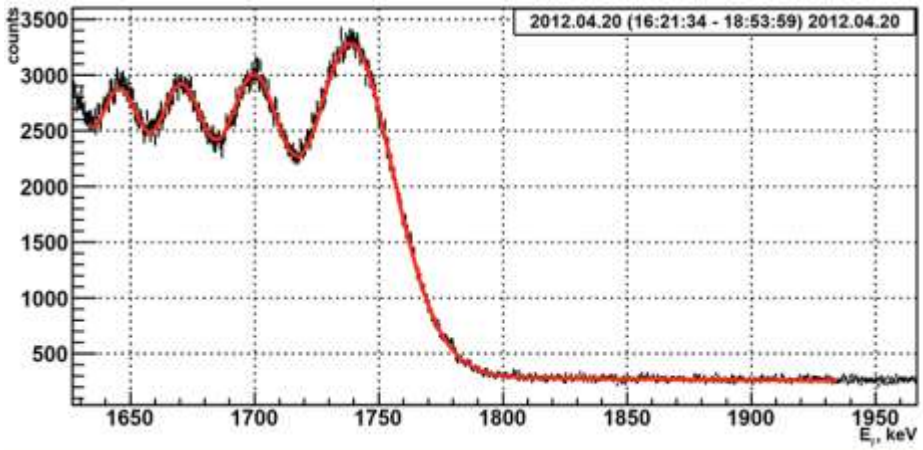
1. Precision measurement of $R = \sigma(e^+e^- \to hadrons)/\,\sigma(e^+e^- \to \mu^+\mu^-)$ exclusive approach, up to <1% for major modes
2. Study of hadronic final states:
$$e^+e^- \to 2h, 3h, 4h, \ldots \quad h = \pi, K, \eta$$
3. Study of vector mesons and theirs excitations:
$$\rho', \rho'', \omega', \varphi', \ldots$$
4. Comparison of cross-sections $e^+e^- \to hadrons$ with spectral functions of τ-decays
5. Study of nucleon electromagnetic formfactor at threshold
$$e^+e^- \to p\bar{p}, n\bar{n}$$
6. Measurement of the cross-sections using ISR
7. Study of higher order QED processes

Target luminosity integral is 1 fb^{-1} per detecor

Beam energy measurements: CBS system

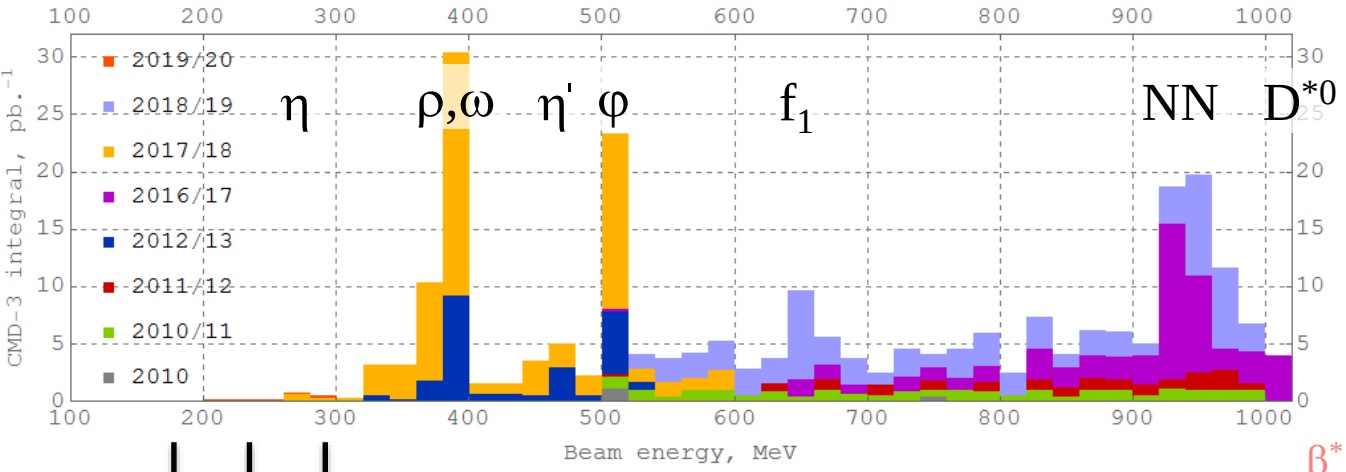


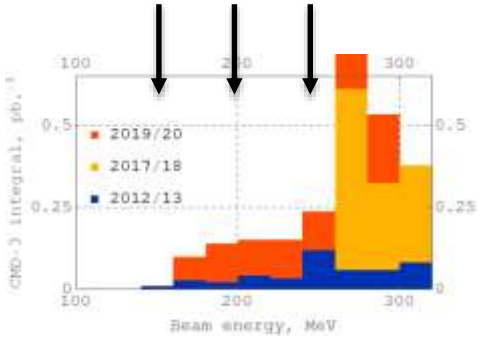
Backscattered photons spectrum edge:



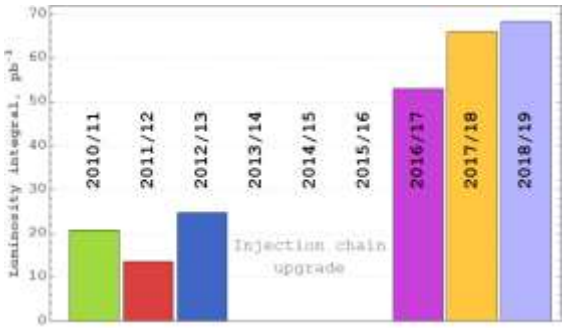
N.Muchnoi's talk, today at 14:30

Luminosity & data taking



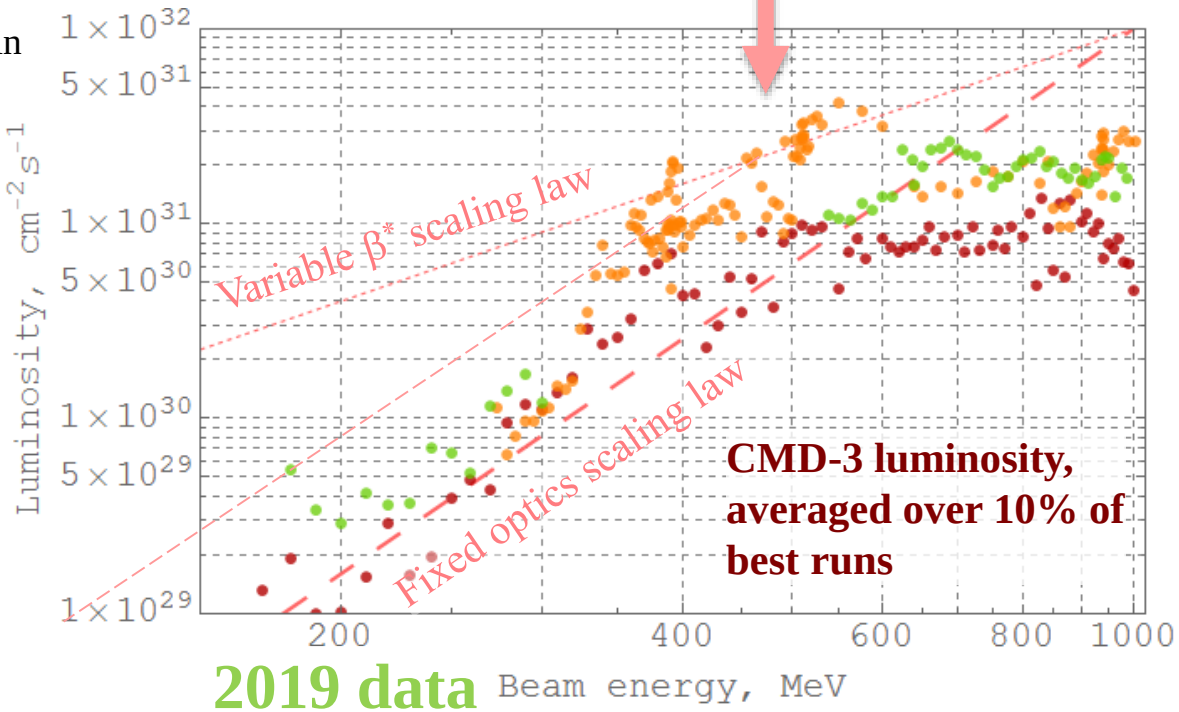


Lowest energy ever obtained in e^+e^- colliders



$\beta^* \sim 4$cm @ 475 MeV

2017-2018 data



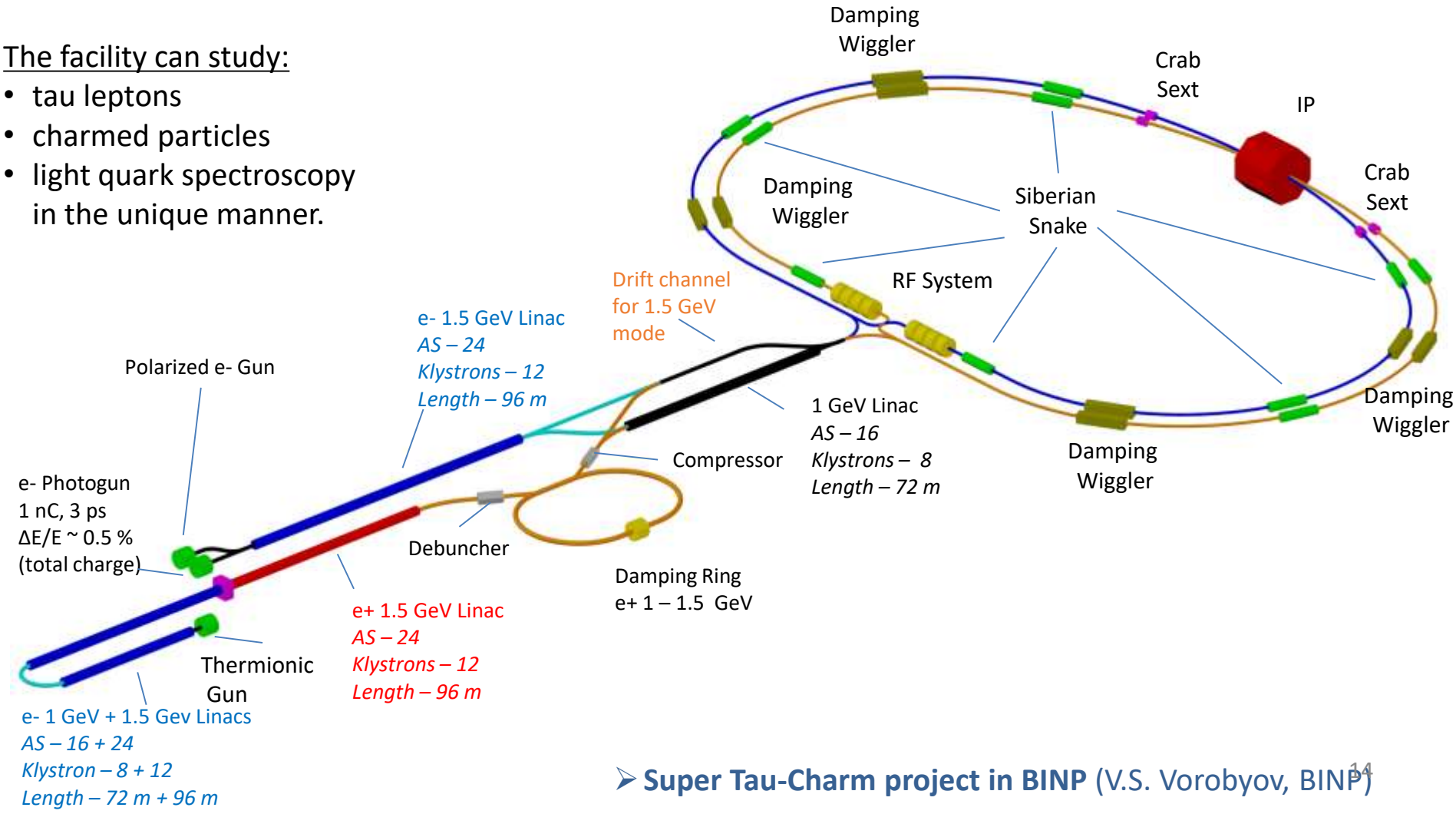
Future projects

Super-CT Project

- e+e- collider
- Beam energy range from 1 to 2.5 GeV
- Extremely high luminosity (~ 10^{35} $cm^{-2} \cdot s^{-1}$)
- Longitudinal polarization of electron beam at the IP.

<u>The facility can study:</u>

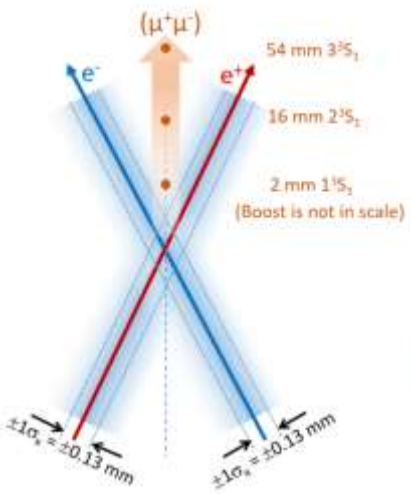
- tau leptons
- charmed particles
- light quark spectroscopy in the unique manner.

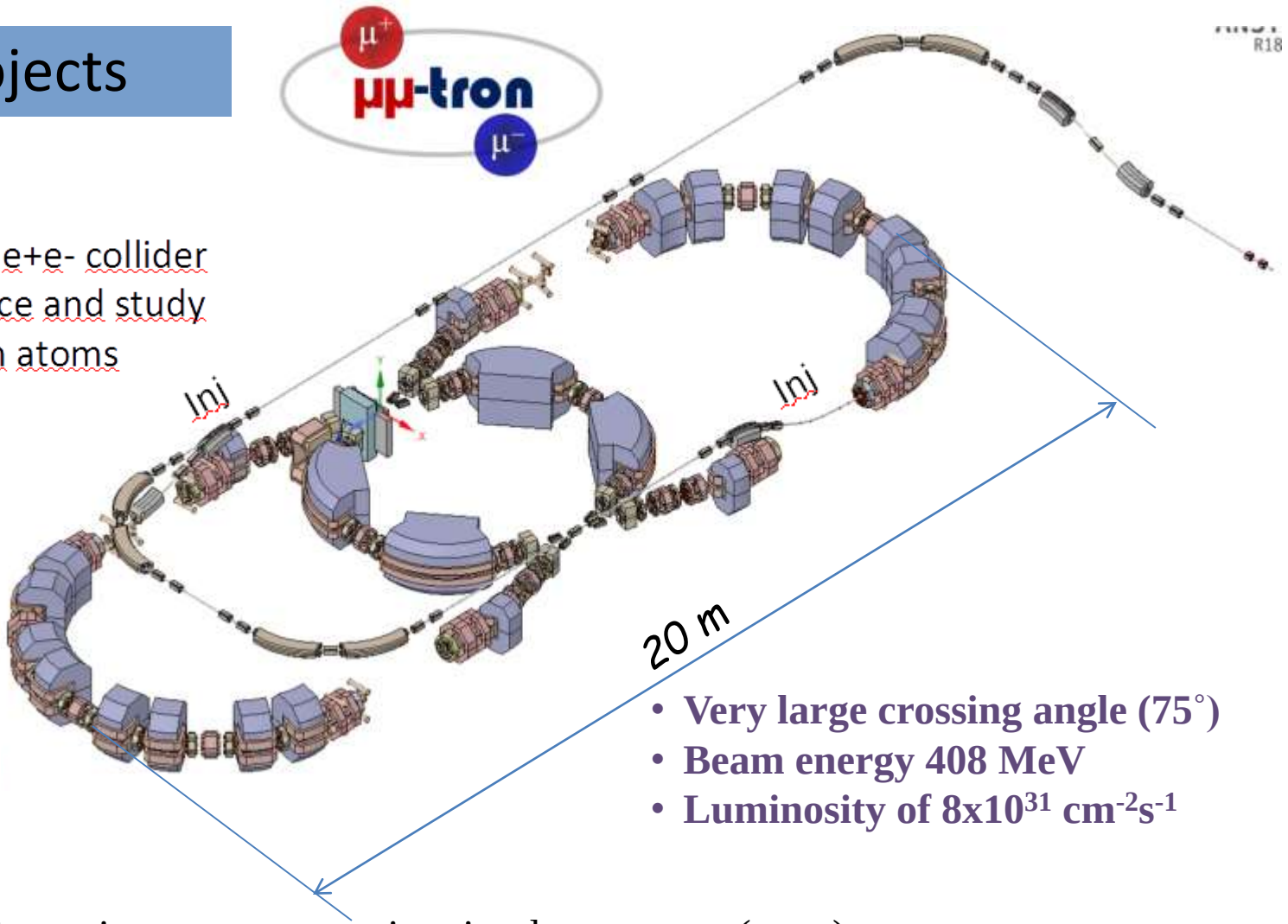


➢ **Super Tau-Charm project in BINP** (V.S. Vorobyov, BINP)

Future projects

New Budker INP e+e- collider project to produce and study dimuonioum atoms





- **Very large crossing angle (75°)**
- **Beam energy 408 MeV**
- **Luminosity of 8×10^{31} $cm^{-2}s^{-1}$**

- Dimuonium, bimuonium or true muonium is a lepton atom (μ+μ-).
- Dimuonium is pure QED system (no strong interaction, calculable).
- From 6 leptonic atoms (e^+e^-), (μ^+e^-), ($\mu^+\mu^-$), (τ^+e^-), ($\tau^+\mu$-), ($\tau^+\tau^-$) only two (e^+e^-), (μ^+e^-) were observed.
- Very compact (large m_μ), more sensitive to new physics than other exotic atoms.

Details are in: https://arxiv.org/abs/1708.05819

Thanks for your attention