Study of some aspects of straw tube detectors

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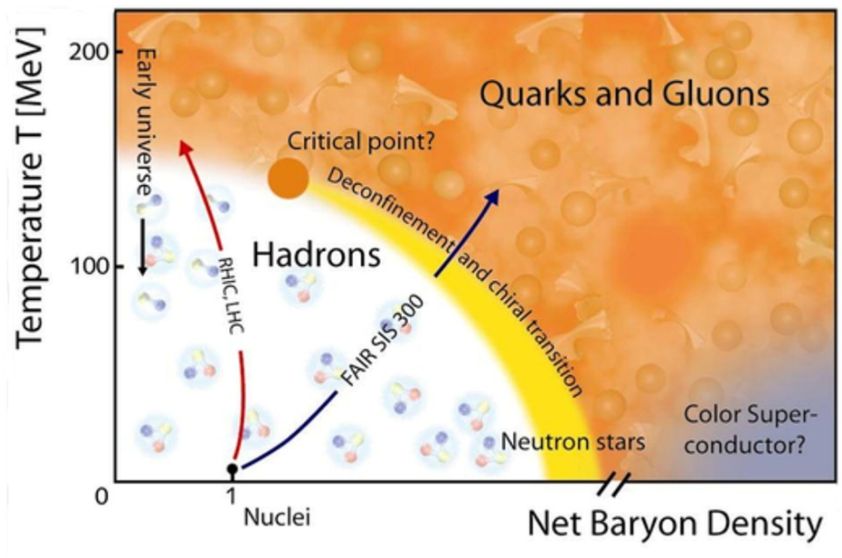
Outline

- CBM experiment @ FAIR
- CBM Muon Chamber
- GEM development
- R&D of Straw tube
- Summary and Outlook

Phase diagram of matter



- Main aim of relativistic heavy ion collisions is to study the phase diagram of strongly interacting matter.
- CBM @ FAIR, Darmstadt, Germany will explore the region at low temperature and moderate to high baryon densities.

The Compressed Baryonic Matter Experiment (CBM)@FAIR

- Fixed target heavy-ion experiment
- Energy range 2-45 GeV/u
- Expected to begin 2021

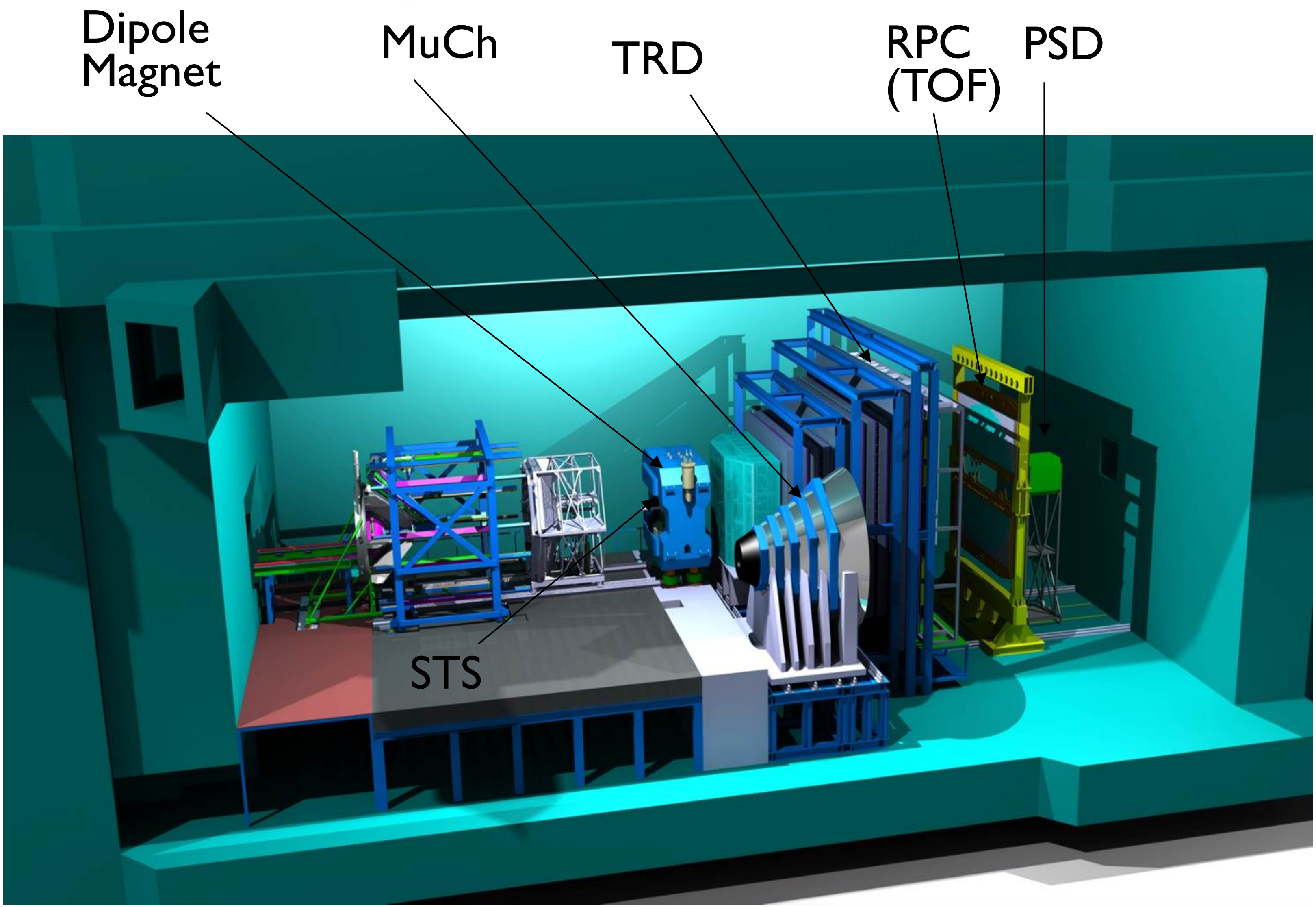
CBM physics program:

- Equation of state at moderate baryon density
- Deconfinement phase transition
- QCD critical endpoint
- Chiral symmetry restoration

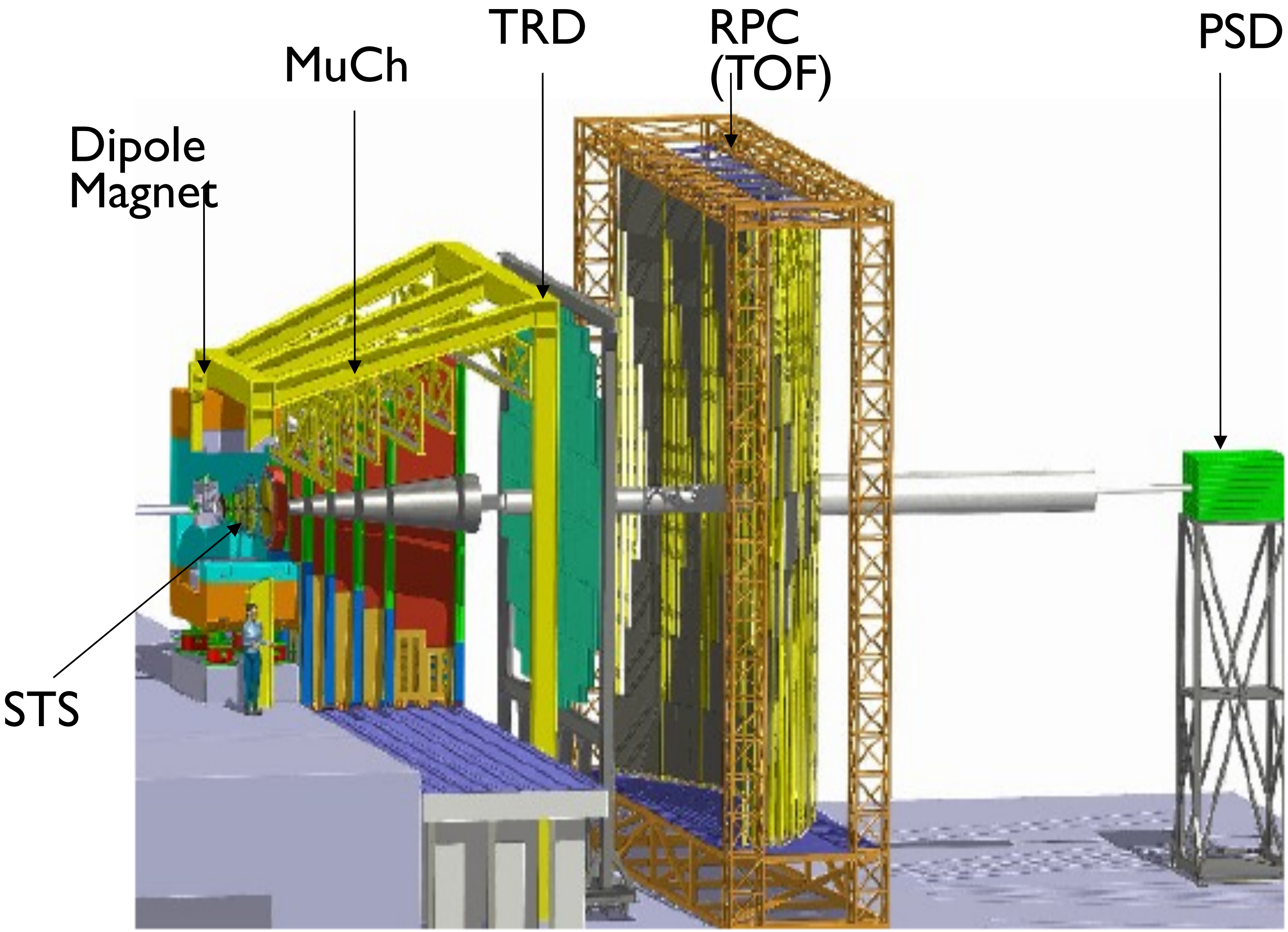
Diagnostic probes of the high-density phase:

- Open charm, charmonia
- Low-mass vector mesons
  - Rare probes
  - High interaction rates
  - Selective triggers
- Multi strange hyperons
- Flow, fluctuations, correlations

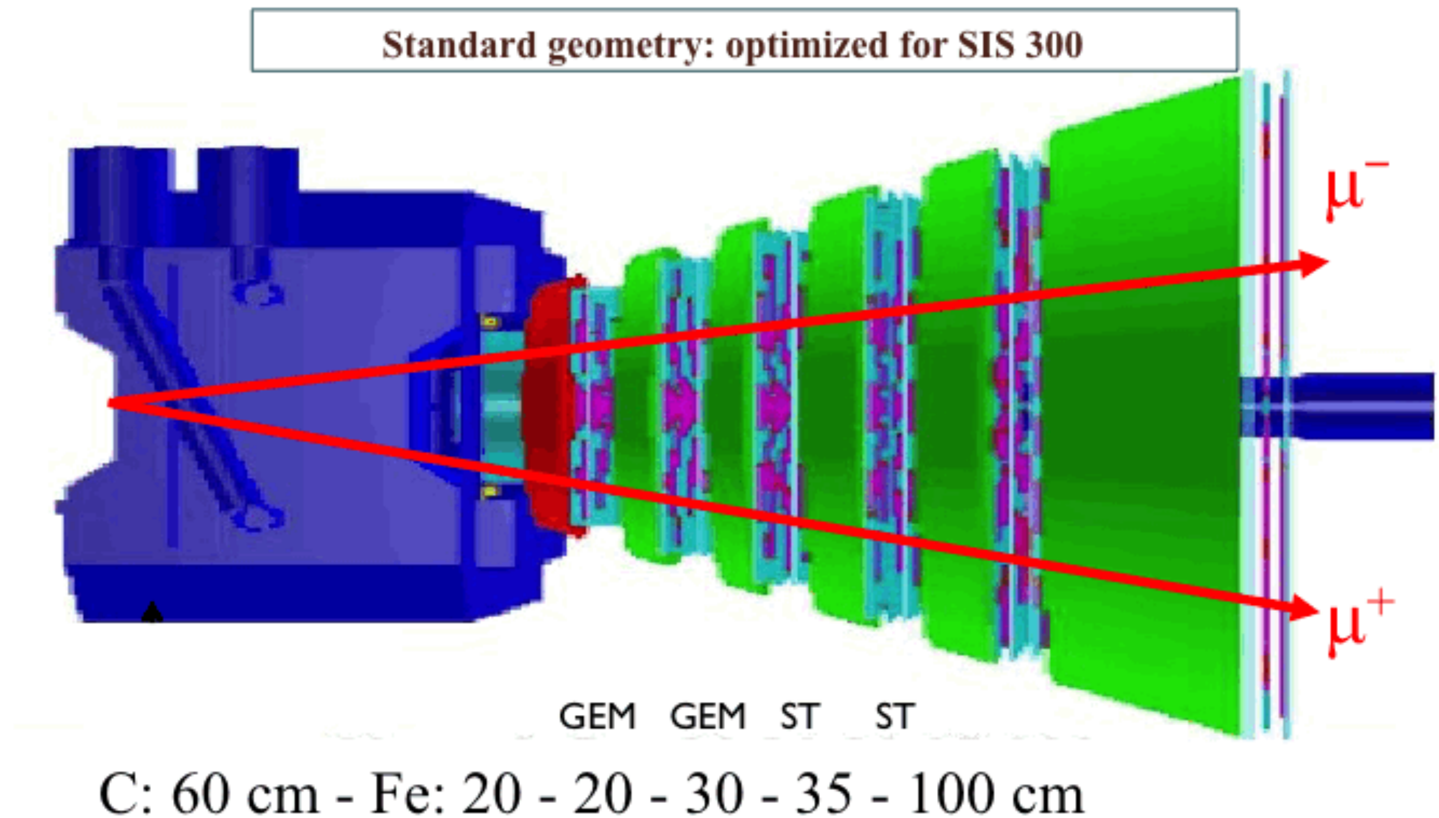
CBM experiment



CBM experiment : Muon set up



Muon detection system



All the GEM R&D has been carried out at VECC for CBM

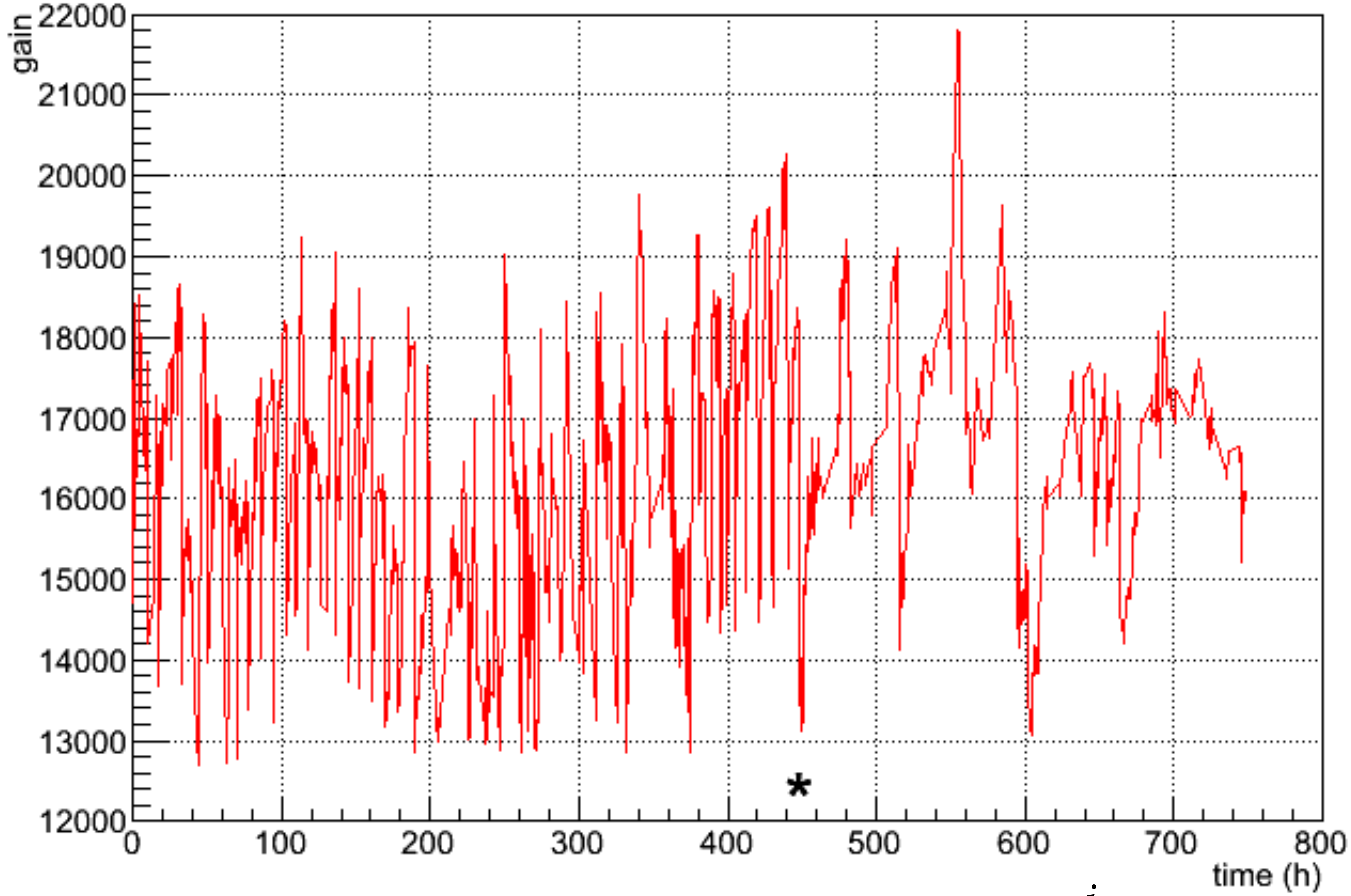
At Bose Institute, Kolkata an initiative has been taken for R&D of GEM detector (stability test) and Straw tube detector for the CBM Muon Chamber (MuCh)

Set-up at Bose Institute

Long term stability test

- Long term stability test is done with Fe^{55} source (100 mCi or 3.7 GBq)
- Gas: Ar/CO_2 70/30
- Constant applied voltage to the divider: -4300 V
- Anode current is measured with and without source continuously (using Keithley 6485 Pico-ammeter)
- Temperature, pressure and relative humidity are measured continuously

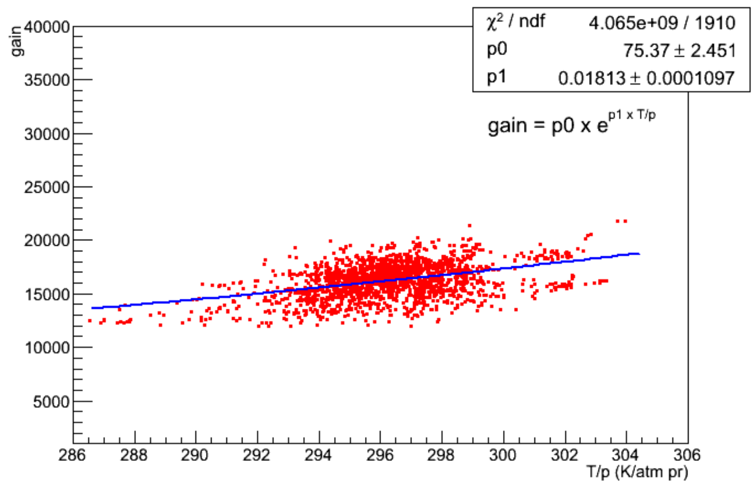
Gain Vs. time



The absolute gain of the detector is calculated from the formula: $\text{gain} = \dfrac{i_{\text{source}}}{r \times n \times e}$

r is the rate of the X-ray, n is the number of primary electrons and e is the electronic charge.

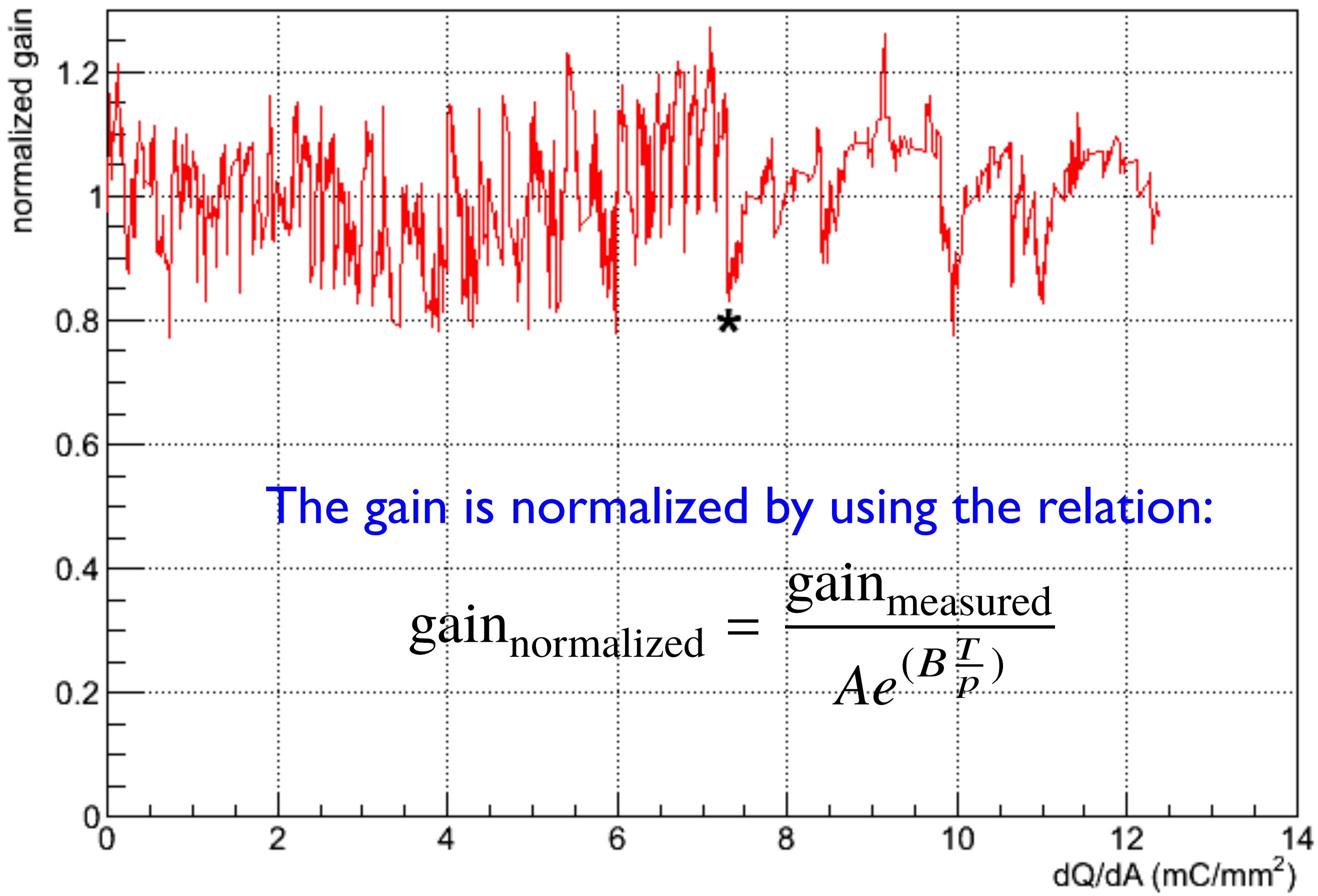
Correlation plot



- $g = G/Ae^{BT/p}$
- $G(T/p) = Ae^{BT/p}$
- G = measured gain
- g = normalized gain
- A & B fit parameter
- Townsend coefficient $\alpha \propto 1/\rho \propto T/p$
- ρ = mass density

Ref. M.C. Altunbas et al., NIM A 515 (2003) 249–254.

Normalized gain Vs. $\frac{dQ}{dA}$



The gain is normalized by using the relation:

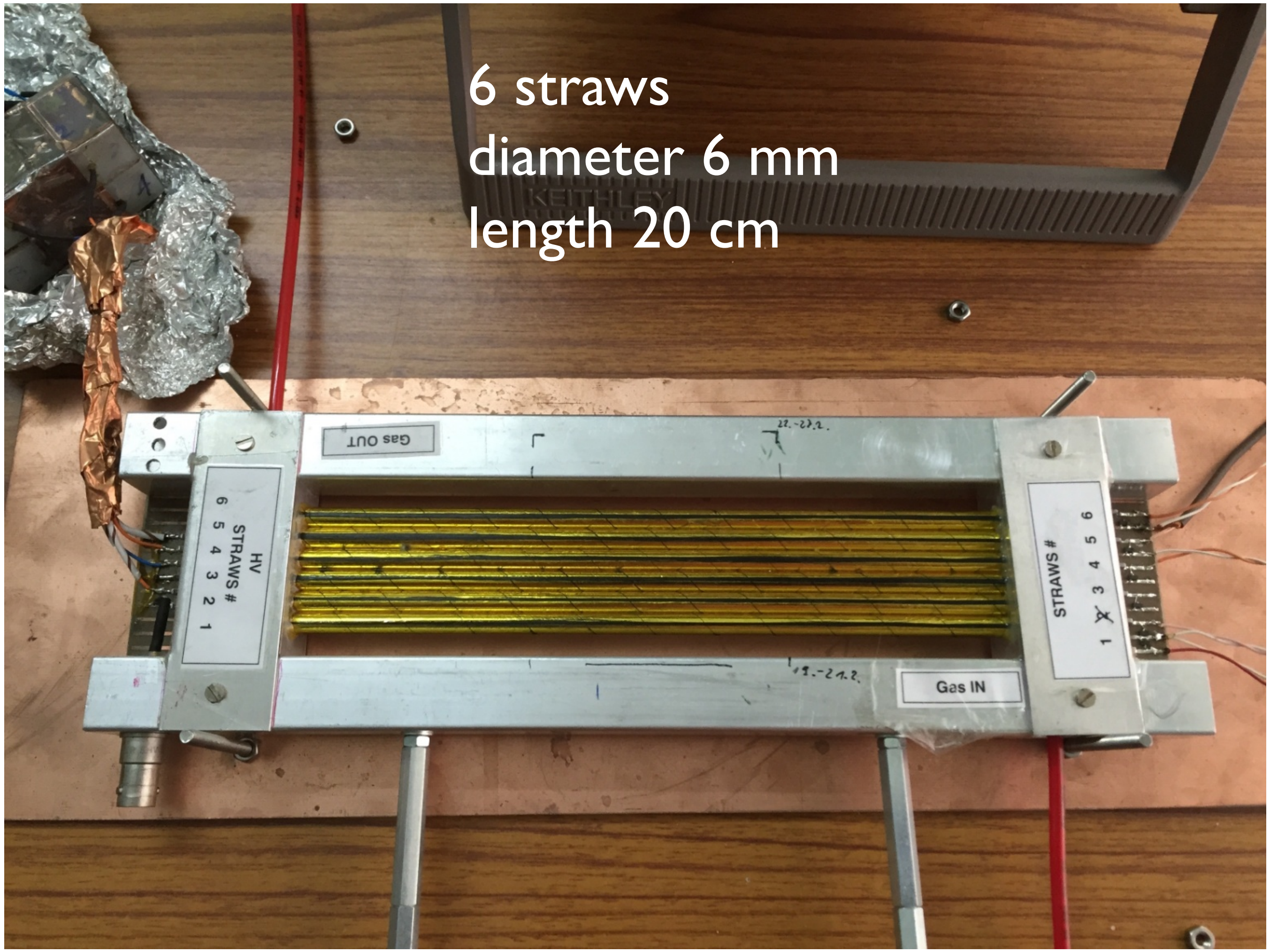
$$\text{gain}_{\text{normalized}} = \frac{\text{gain}_{\text{measured}}}{Ae^{(B\frac{T}{p})}}$$

2016 JINST 11 T10001 doi:10.1088/1748-0221/11/10/T10001. [arXiv:1608.00562]

Straw tube detector

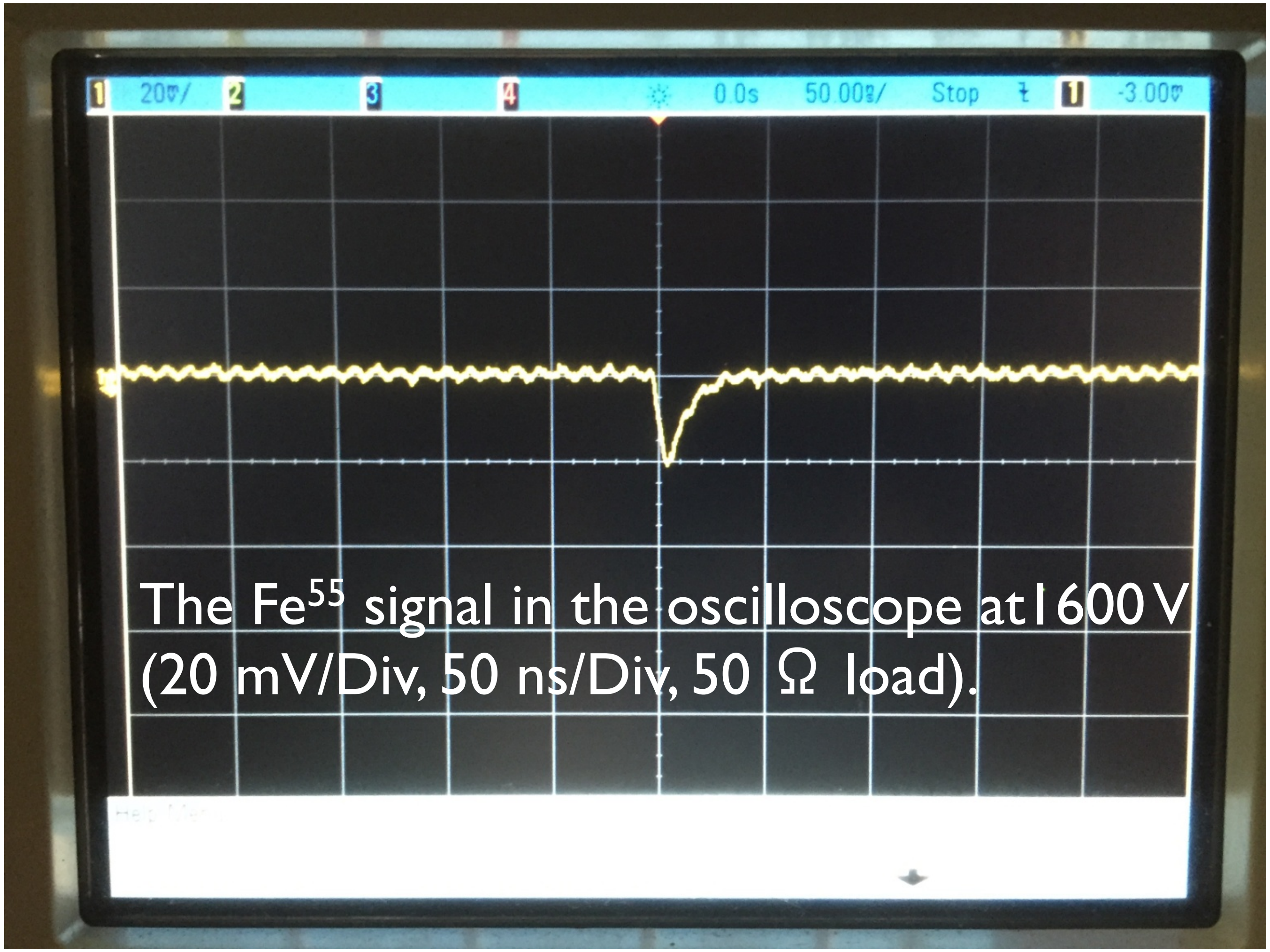
- Straw tube is typically prepared from a kapton film, one side containing a conductive layer of 1000-3000 Å Al + 4 μm carbon-loaded kapton and the other side containing a thermoplastic polyurethane layer of 3 μm.
- The thickness of the straw wall is around 60 μm.
- A straw tube detector is basically a gas filled single channel drift tube with a conductive inner layer as cathode and a wire stretched along the cylindrical axis as anode
- When high voltage is applied between the wire and the tube an electric field is generated in the gas filled region.
- The electric field separates electrons and positive ions produced by an incident charged particle along its trajectory through the gas volume.
- The wire is kept at positive voltage and collects the electrons while the ions drift towards the cathode. By choosing thin wires, with a diameter of a few tens of μm, the electric field strength near the wire is made high enough to create an avalanche of electrons.
- Depending on the high voltage and the gas composition a gain of about $10^4 - 10^5$ can be achieved

Straw tube for CBM



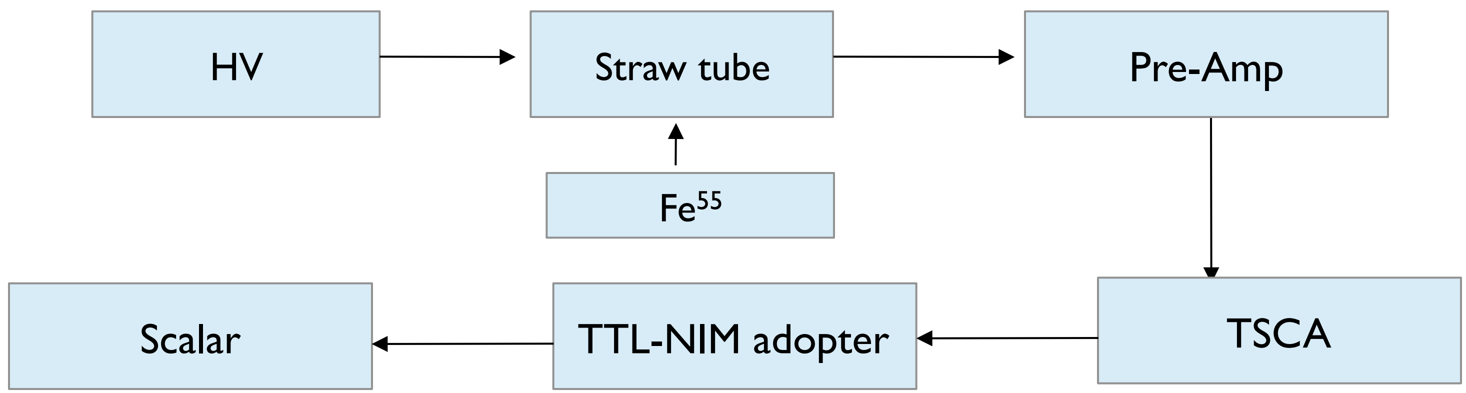
Detector courtesy: Late Prof. Vladimir Peshekhonov of JINR, Dubna

Signal from Straw tube



The Fe^{55} signal in the oscilloscope at1600 V (20 mV/Div, 50 ns/Div, 50 Ω load).

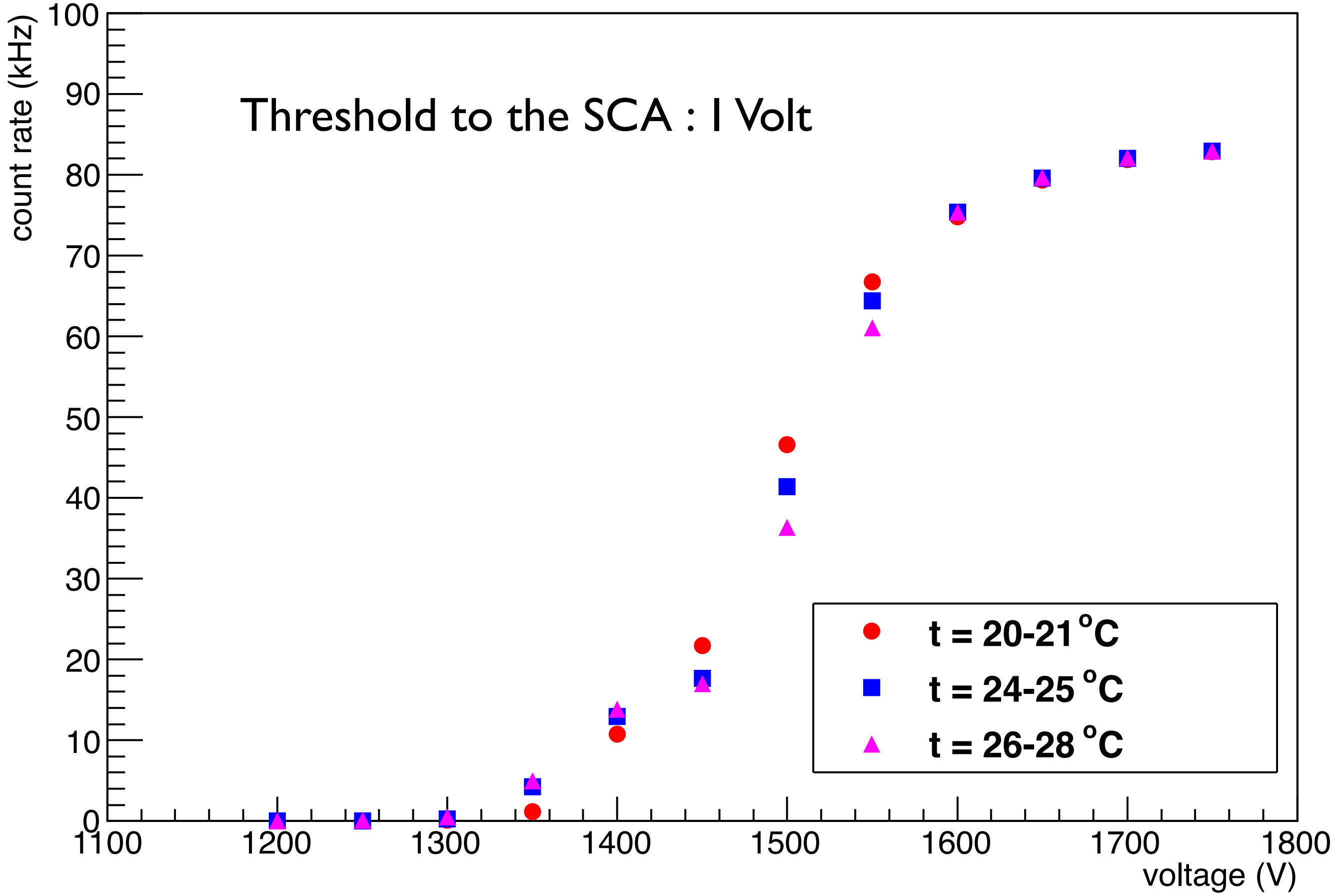
Block diagram



For count rate measurement

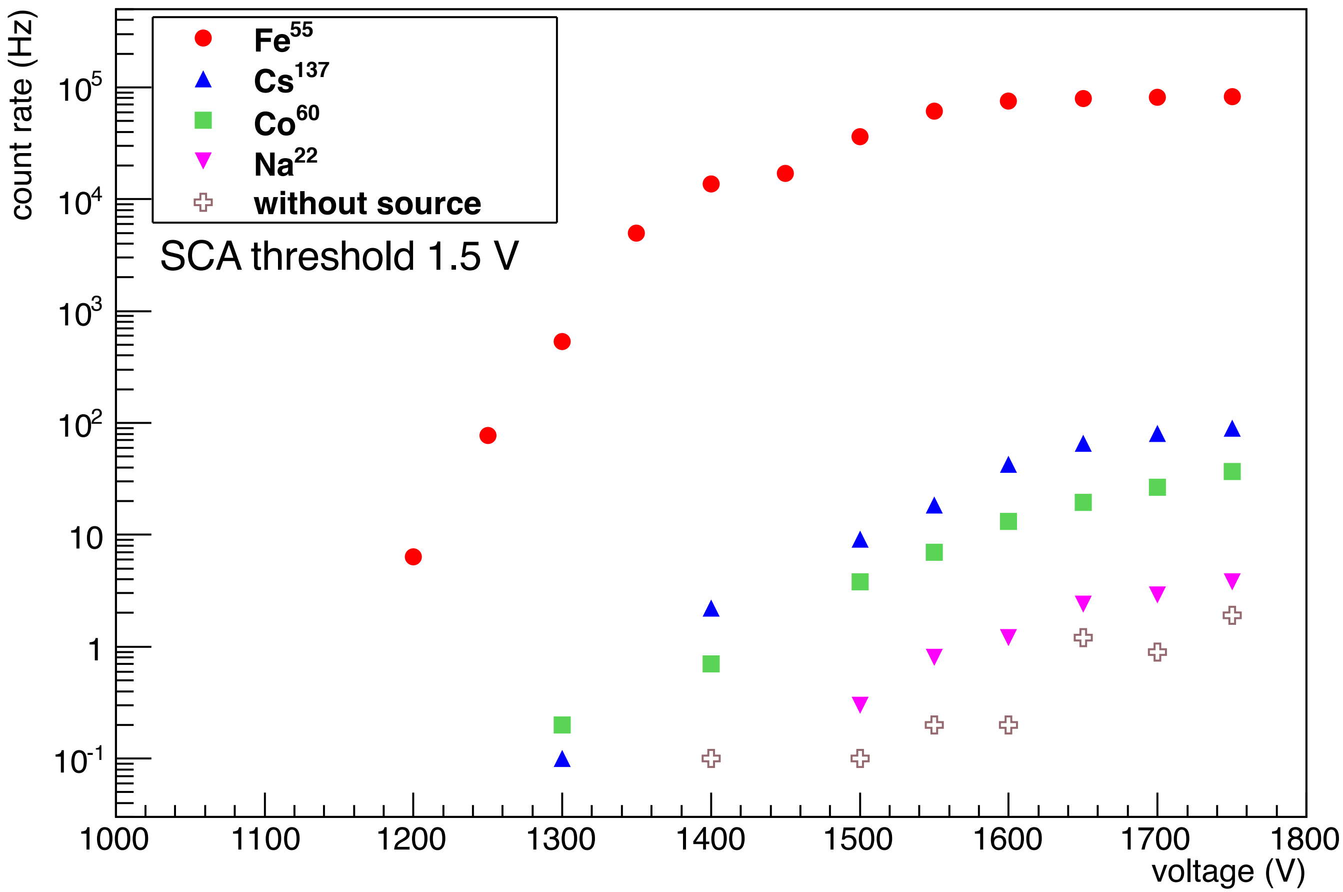
- Gas: Ar/CO_2 gas in 70/30
- Flow rate: 3 lt/hr
- Conventional NIM electronics

Count rate vs. voltage for Fe^{55}

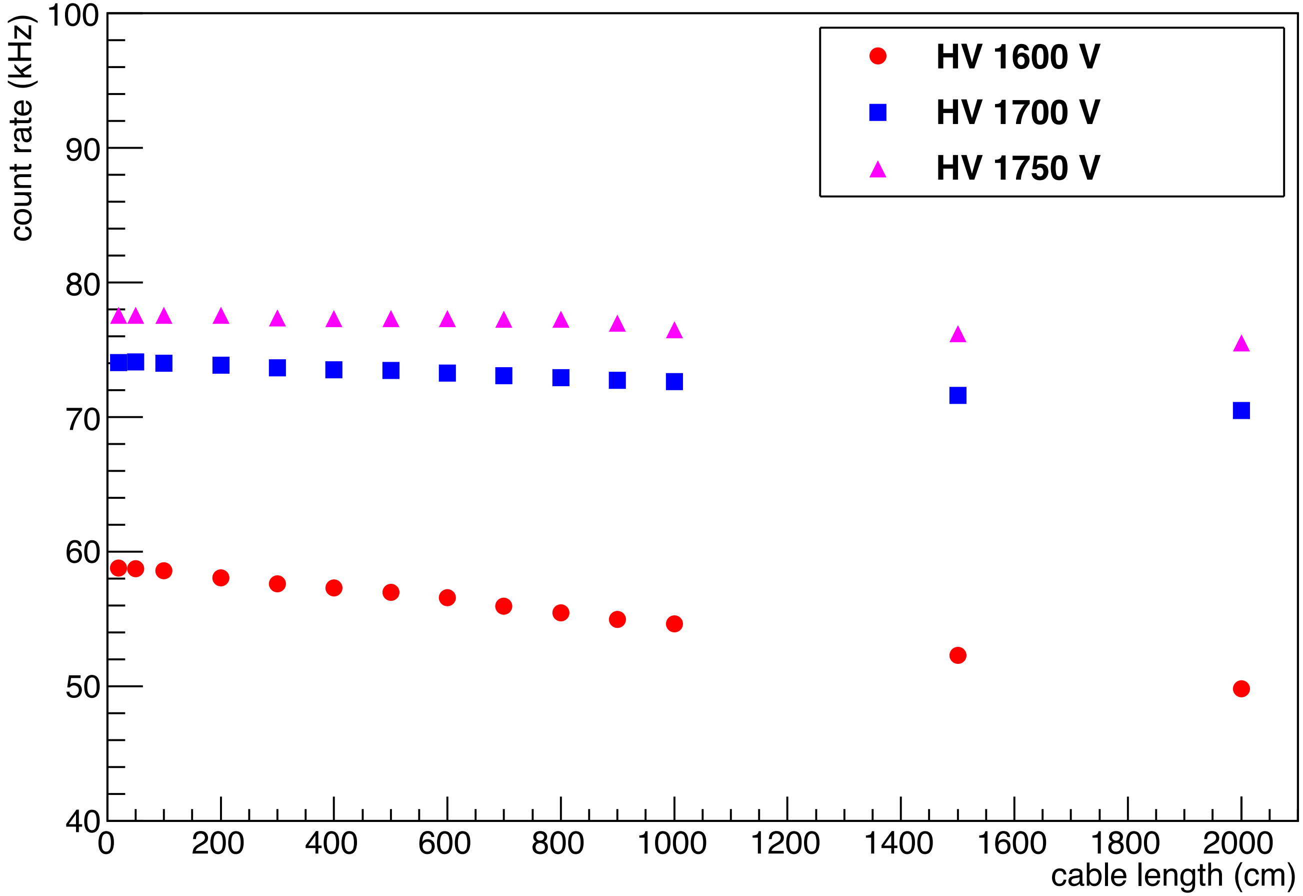


R. P. Adak, et. al. Proc. of the DAE-BRNS Symp. on Nucl. Phys. Vol. 61, (2016), 996-997.

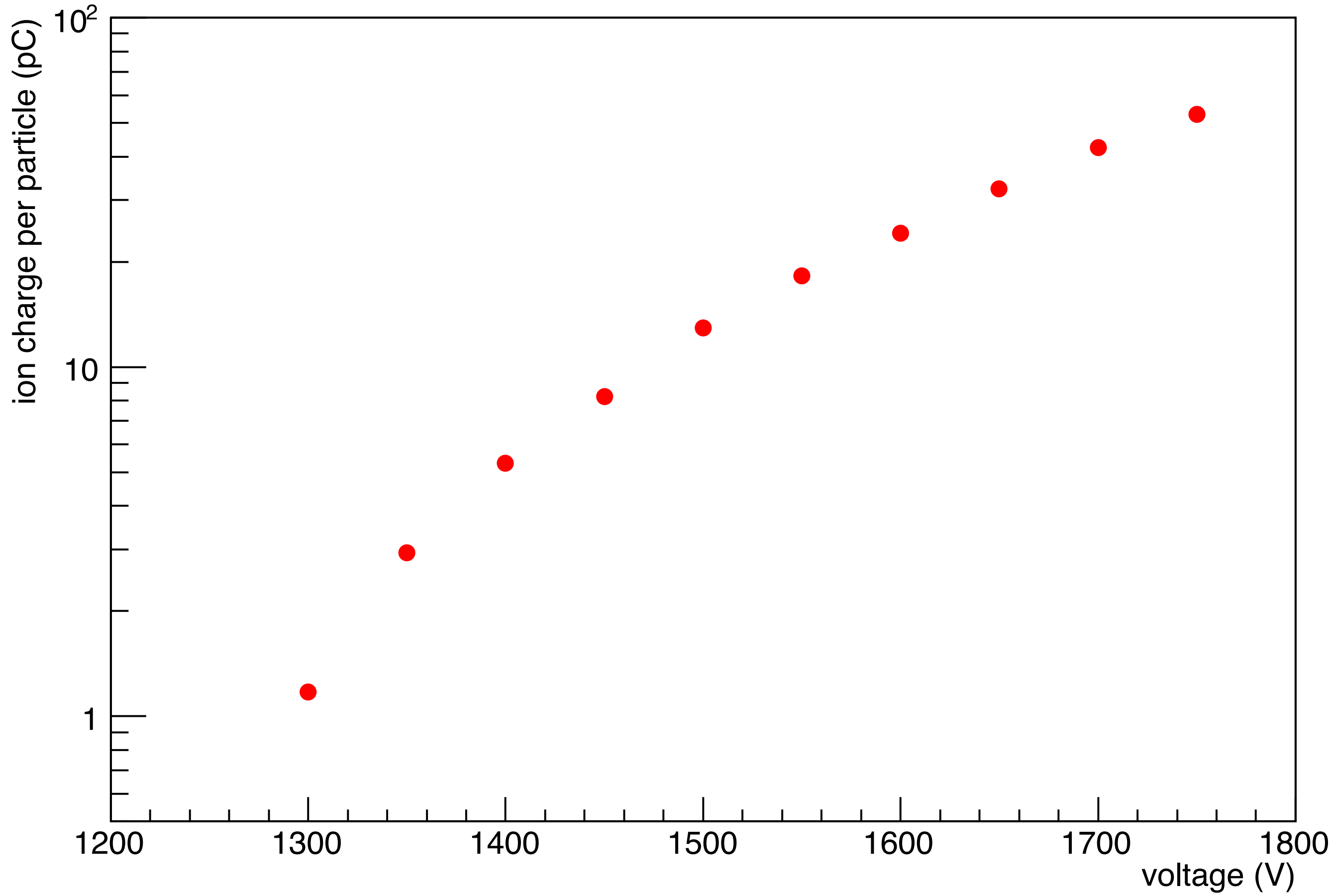
Count rate vs. voltage for different sources



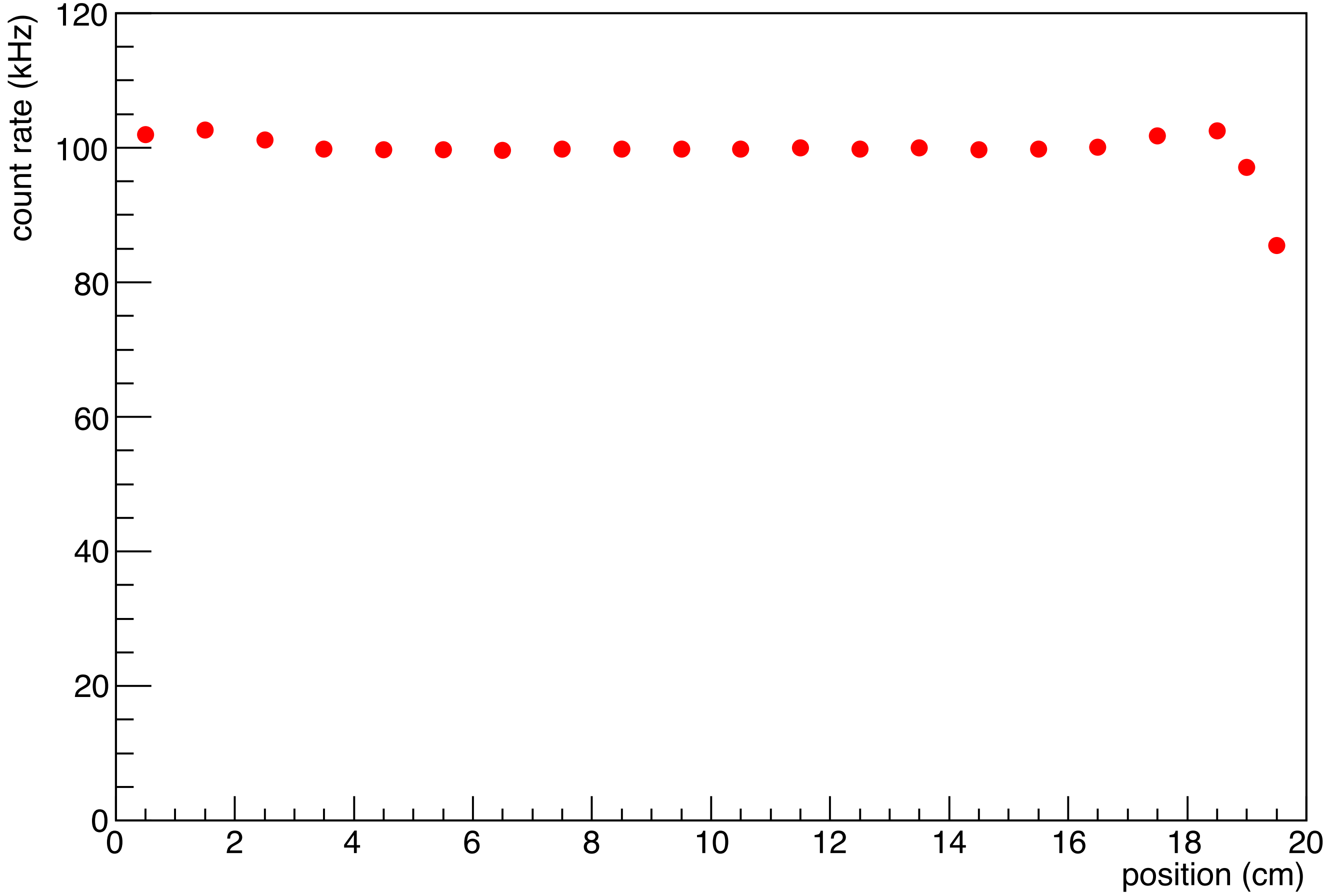
Test of signal attenuation



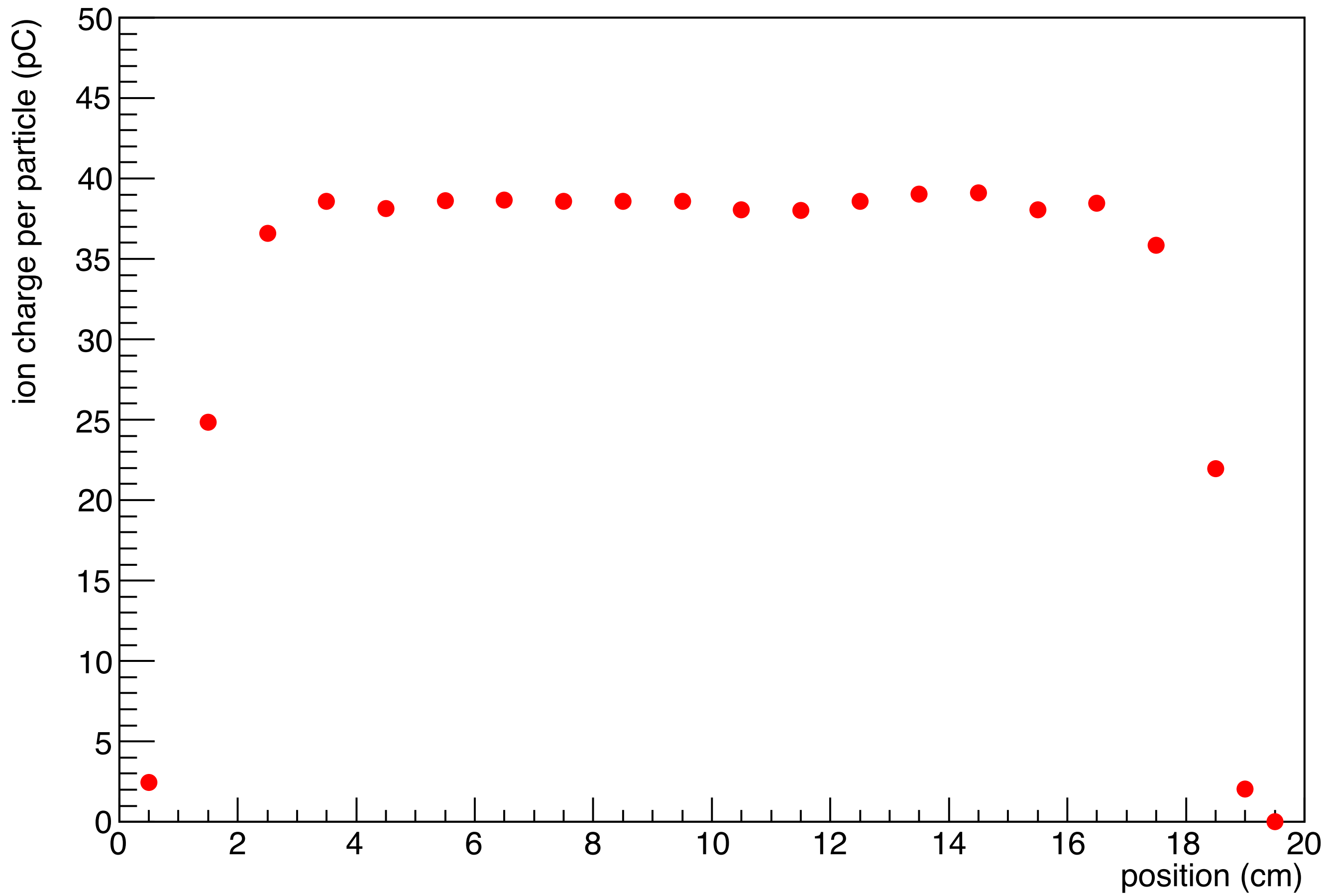
Gain vs. voltage



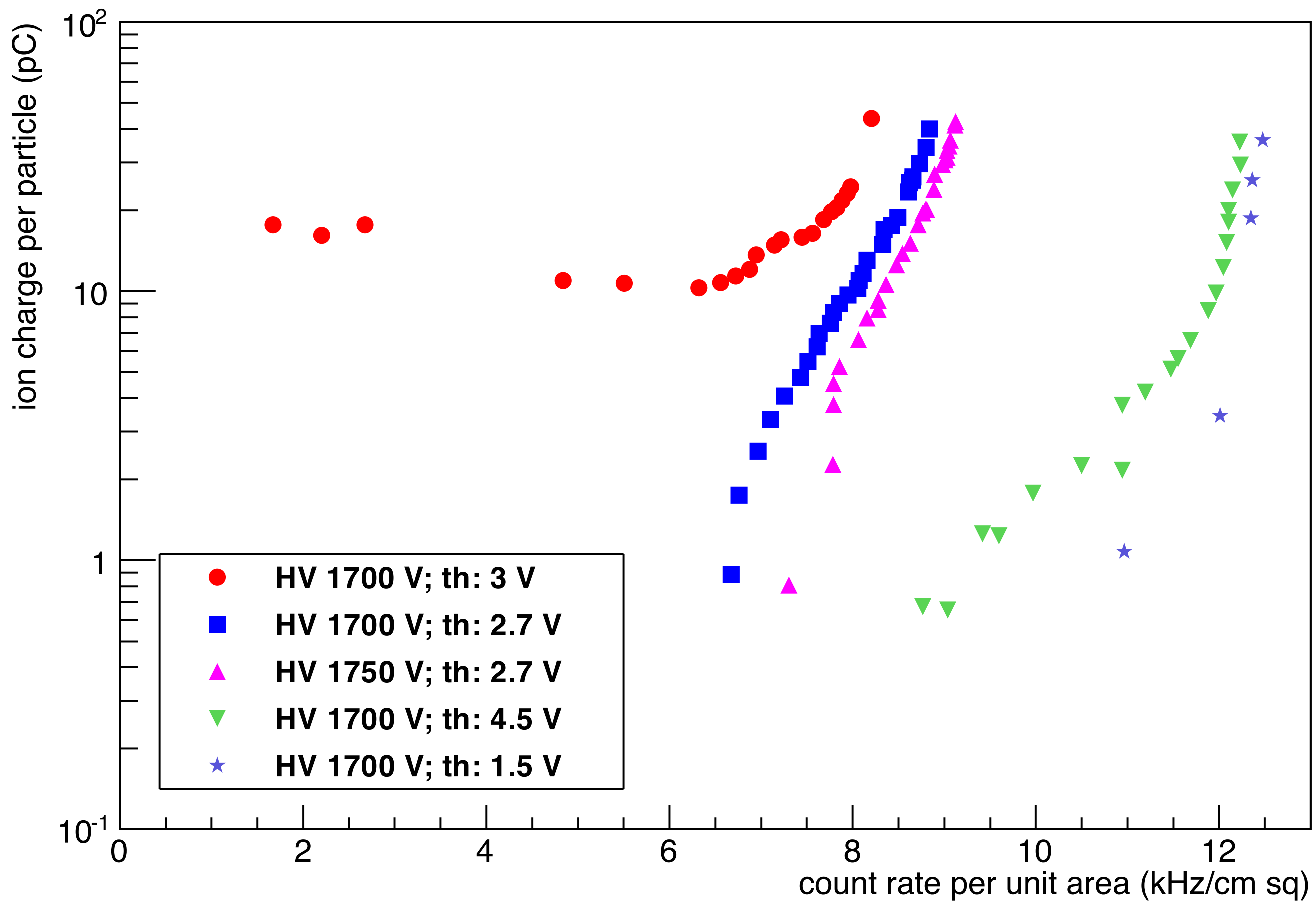
Uniformity of count rate along the length of the straw



Uniformity of gain along the length of the straw



Gain vs. rate



ion charge per particle (pC)
10^2
10
1
10^{-1}
0
2
4
6
8
10
12
count rate per unit area (kHz/cm sq)
HV 1700 V; th: 3 V
HV 1700 V; th: 2.7 V
HV 1750 V; th: 2.7 V
HV 1700 V; th: 4.5 V
HV 1700 V; th: 1.5 V

Summary and outlook

- Basic characteristic studies are performed for straw tube with Ar/CO_2 gas in 70/30 ratio using conventional NIM electronics.
- Count rate, gain, signal attenuation, uniformity are studied
- Dependence of rate on gain is observed
- Use of the straw tube in CBM MuCh is under investigation.

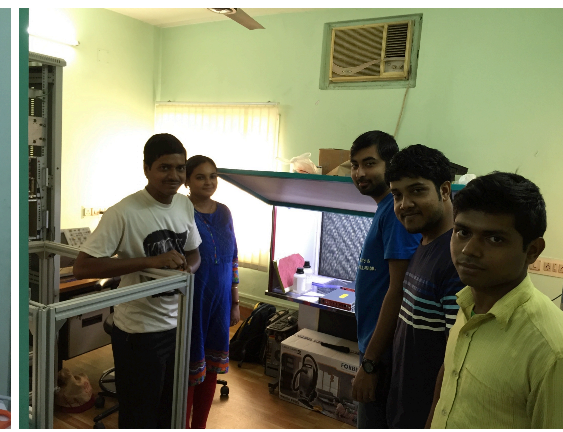
Acknowledgements

We would like to thank Late Prof. Vladimir Peshekhonov of JINR, Dubna for providing the straw tube prototype

and

Dr. Christian J. Schmidt of GSI Detector Laboratory for valuable discussions in the course of the study.

Workforce



Thank you for your kind attention !

Back-up slides

MUCH: Accumulated Charge

H	**hits/cm^2/event**	**~0.5 (first GEM Layer)**
R	**event rate [Hz]**	**10^7**
P	**primary electrons/track**	**~30**
G	**detector gas gain**	**10^3**
N_e	**=H×R×P×G (no. of electrons)**	**1.5×10^{11} cm^2/s**
Q_y	**=N_e×Q_e×y (acc. charge/year)**	**0.75 C/cm^2/y**
Q_{10y}	**acc. charge over exp. lifetime**	**7.5 C/cm^2**

Hysteresis