RPC experience NISER

VARCHASWI K S KASHYAP

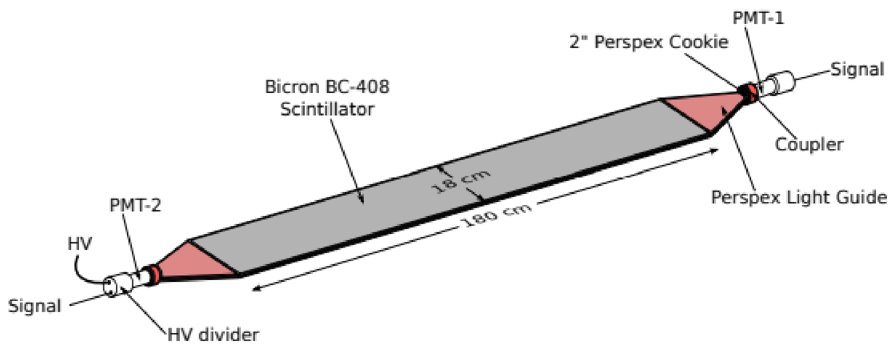
On behalf of NISER

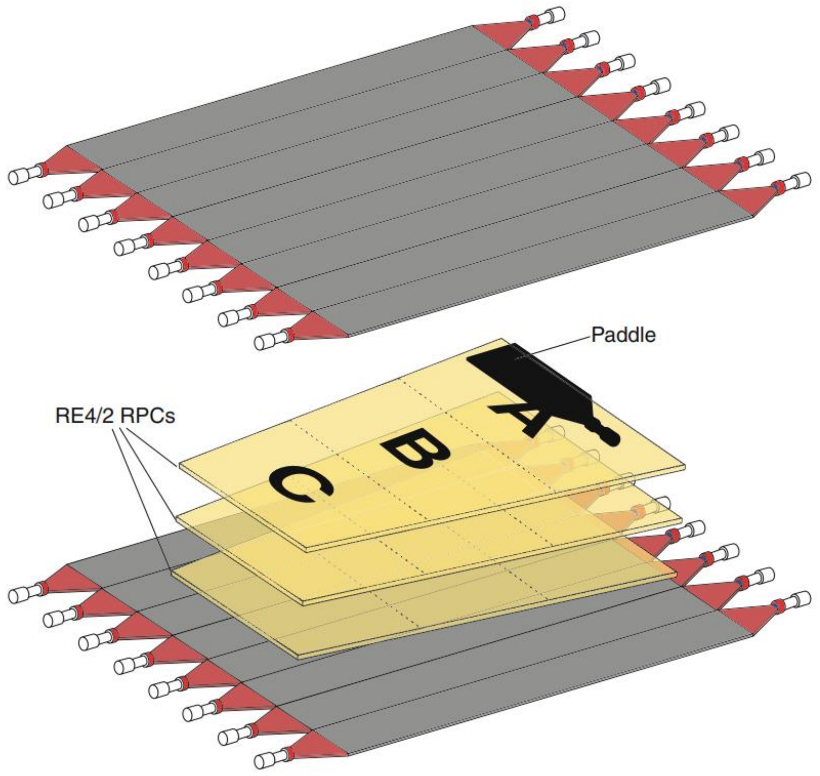
Outline

- RPC experience of NISER members
- RPC R & D for CBM
- ALICE-3 requirements
- RPC options and R & D foreseen

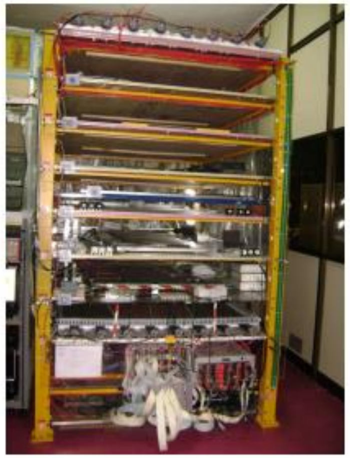
Work experience (RPCs)

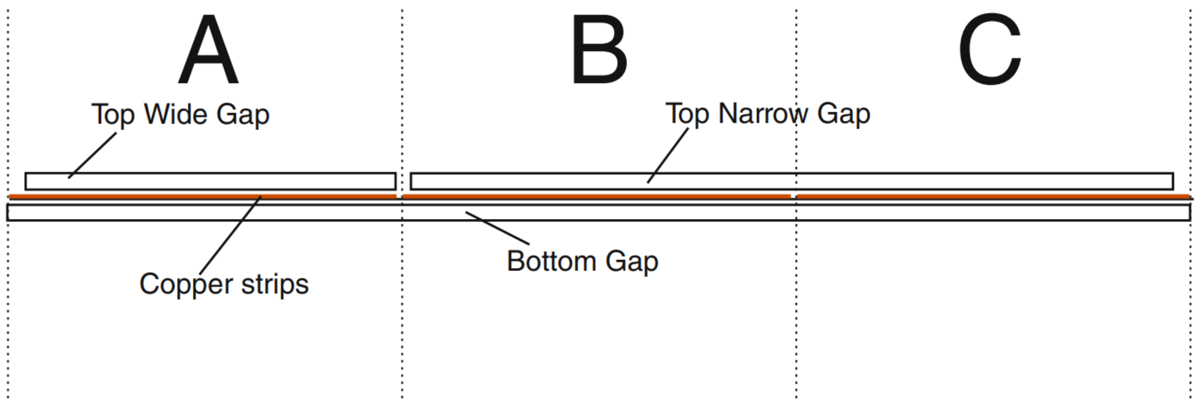
Varchaswi K S Kashyap





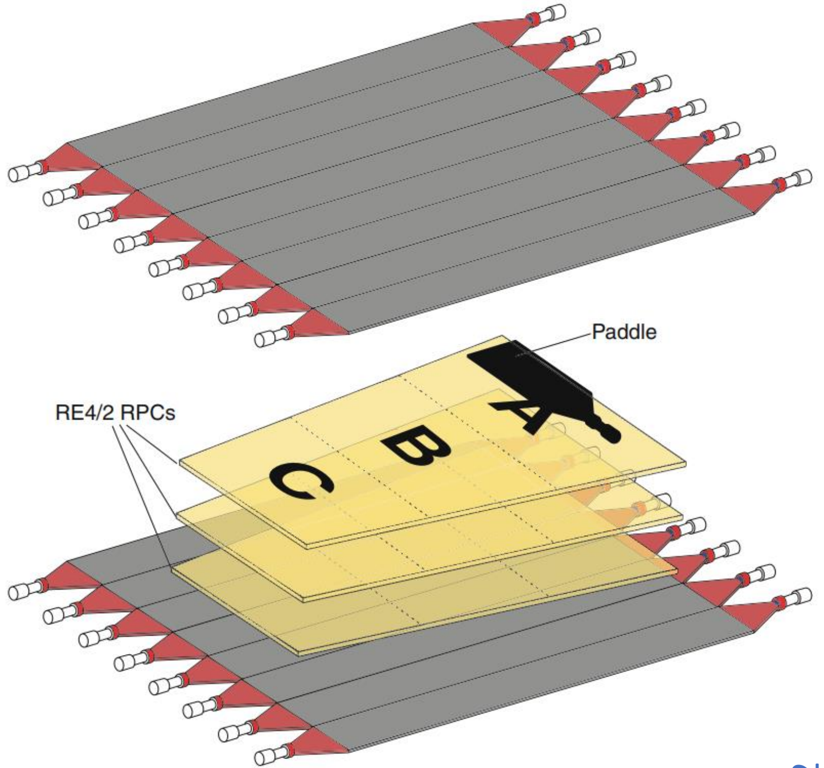
V. K. S. Kashyap et al , Pramana – J. Phys. (2016) 87: 92





Work experience (RPCs) contd.

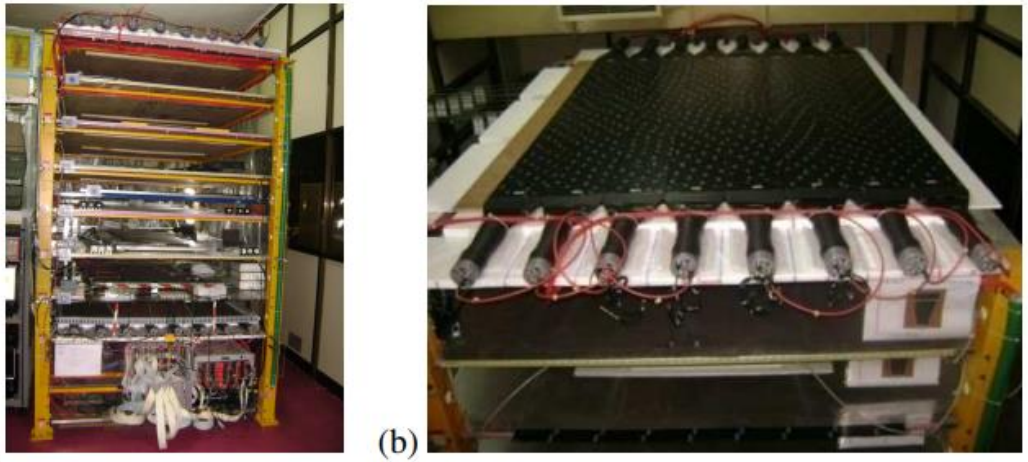
Varchaswi K S Kashyap

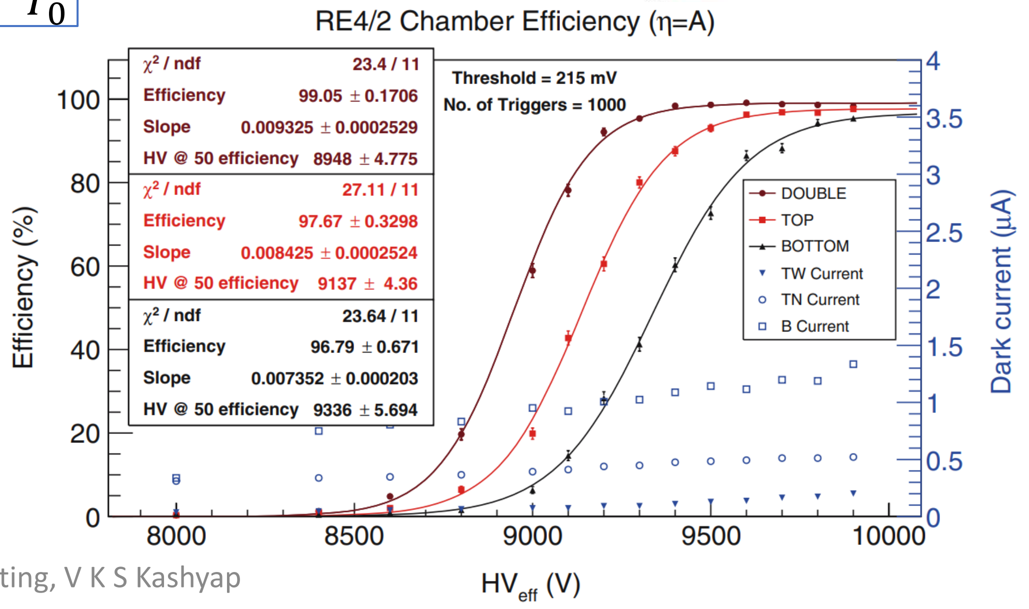


- **Bakelite electrodes**: 2 mm thick
- **Electrode spacing**: 2 mm
- **Surface resistivity of the conductive coating**: ~100 - 250 kΩ/square
- **Length**: ~1.6 m
- **Width (wide side)**: ~0.9 m
- **Width (narrow side)**: ~0.6 m

$$\text{Efficiency} = \frac{a}{1 + \exp[b(c - x)]}$$

$$HV_{\text{eff}} = HV_{\text{applied}} \times \frac{P_0}{P} \times \frac{T}{T_0}$$

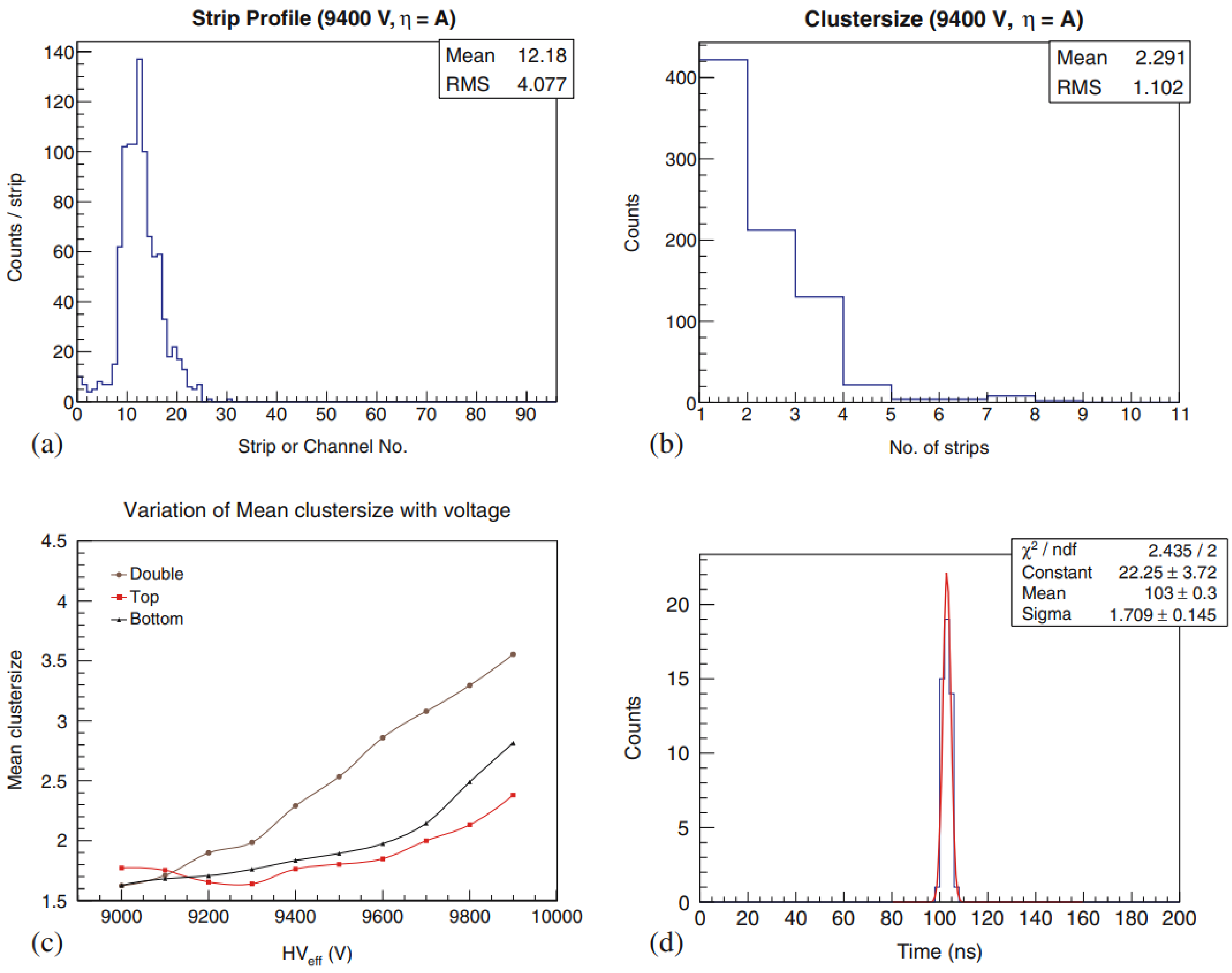

(a) (b)



V. K. S. Kashyap et al ,
Pramana – J. Phys. (2016) 87: 92

Work experience (RPCs) contd.

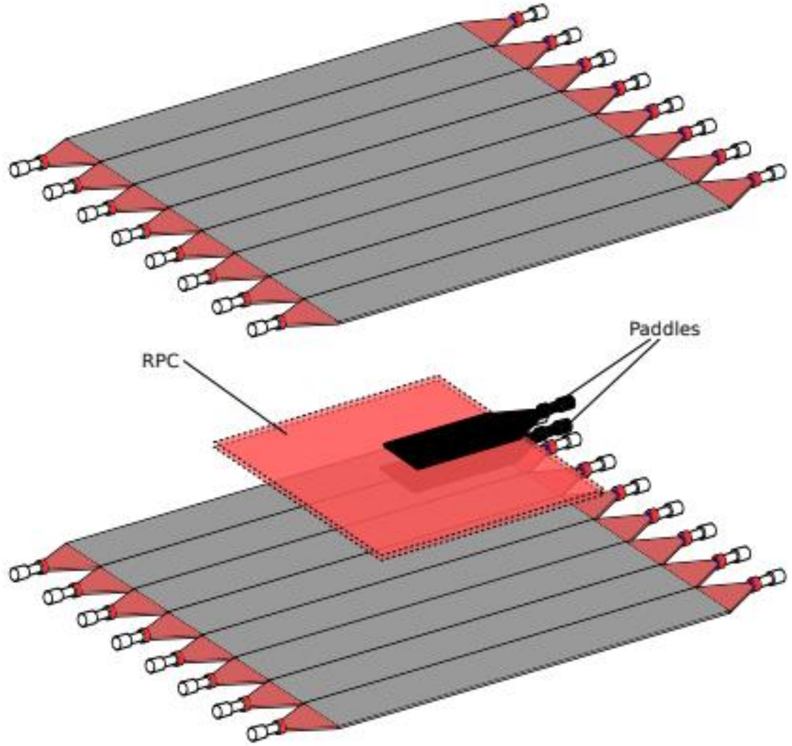
Varchaswi K S Kashyap



V. K. S. Kashyap et al ,
Pramana – J. Phys. (2016) 87: 92

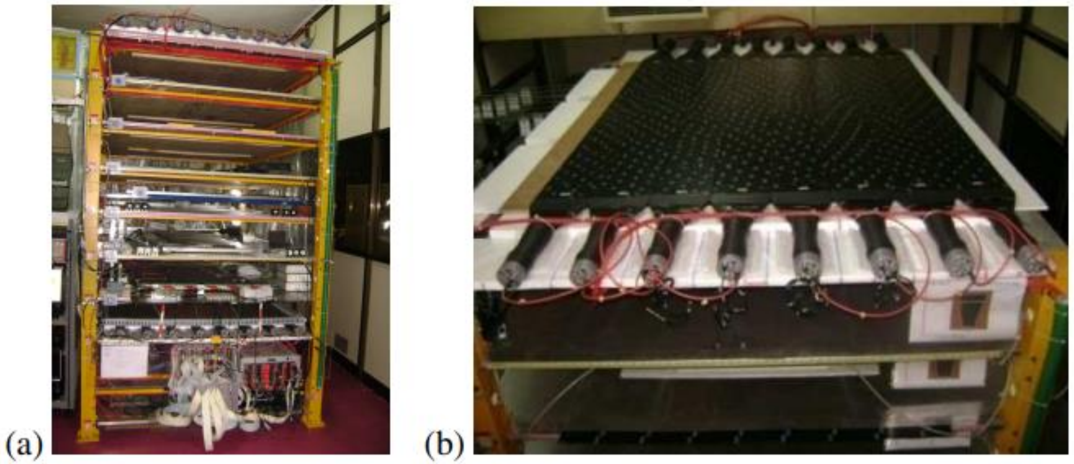
Work experience (RPCs) contd.

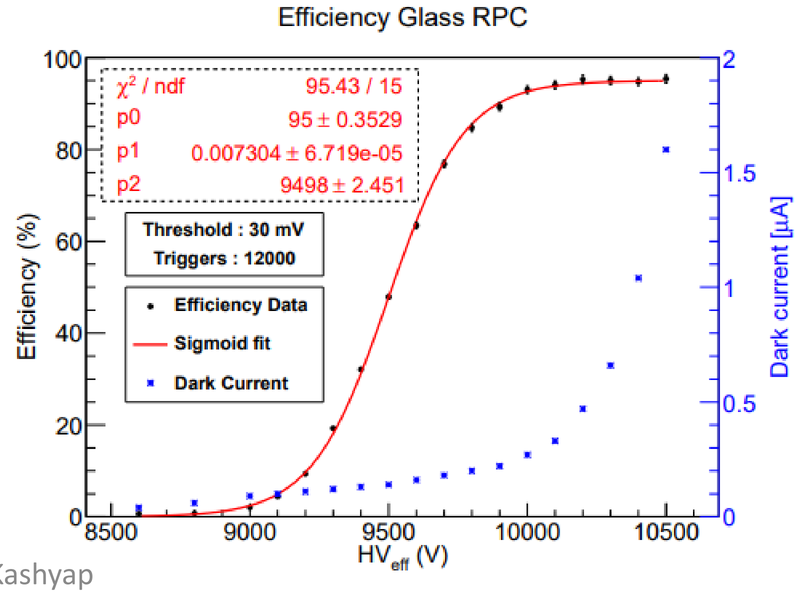
Varchaswi K S Kashyap



- **Glass electrodes**: 3 mm thick
- **Electrode spacing**: 2 mm
- **Surface resistivity of the conductive coating**: ~1 MΩ/square
- **Length**: 1 m
- **Width:** 1 m

V. K. S. Kashyap et al , Pramana – J. Phys. (2016) 87: 92



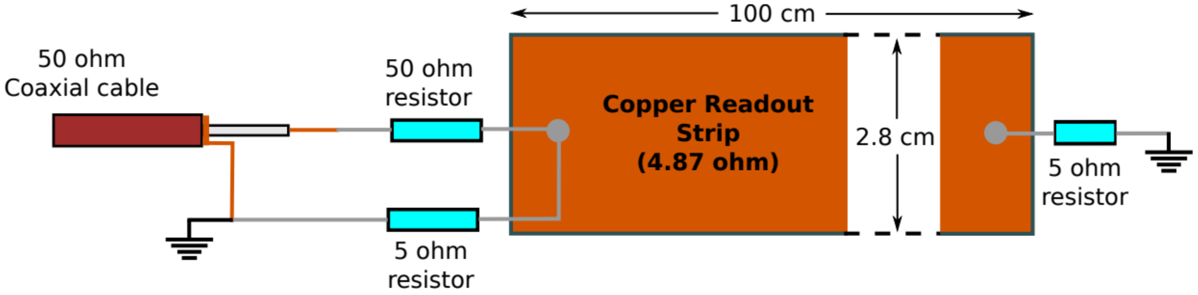


Work experience (RPCs) – contd.

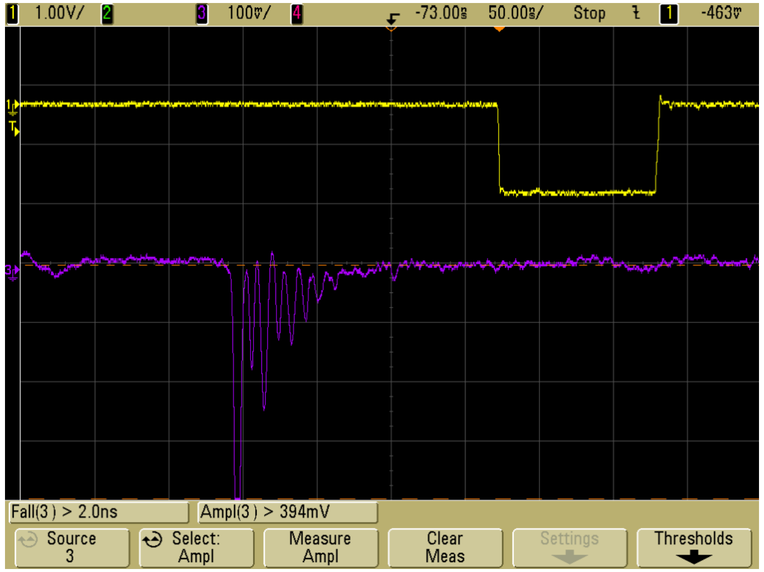
Varchaswi K S Kashyap

G10 readout

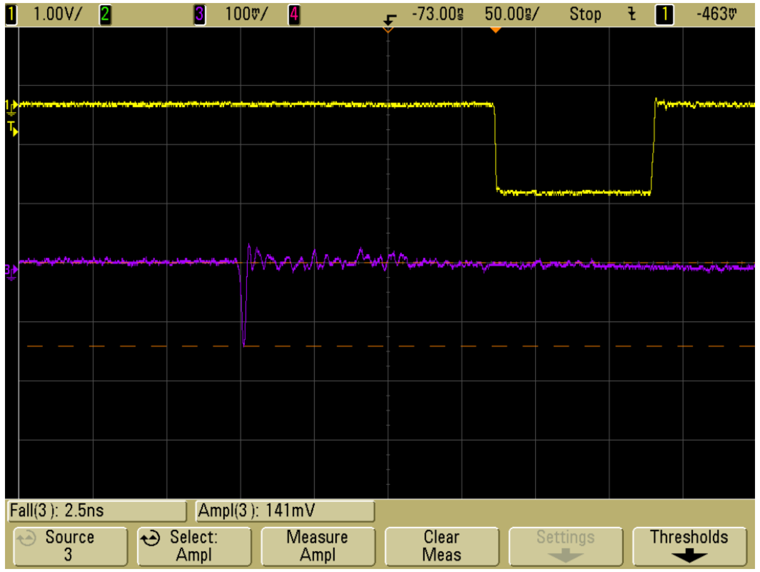
ANUSPARSH FE electronics



Impedance matching circuit



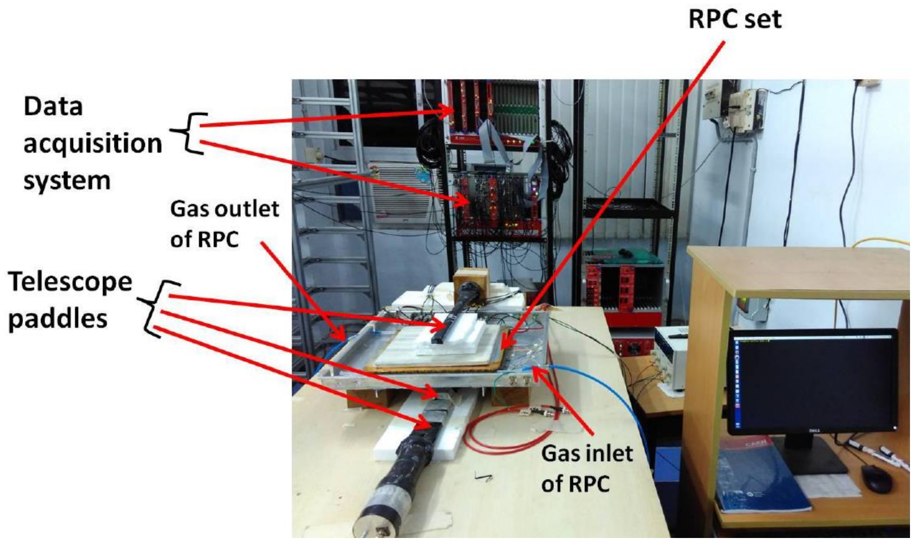
Signal before impedance matching



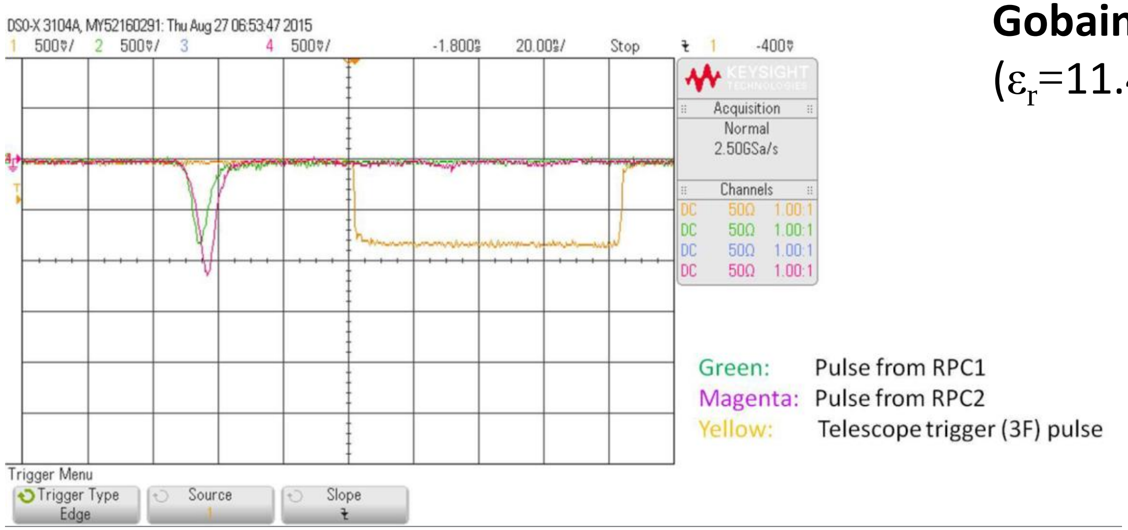
Signal after impedance matching

Work experience (RPCs)

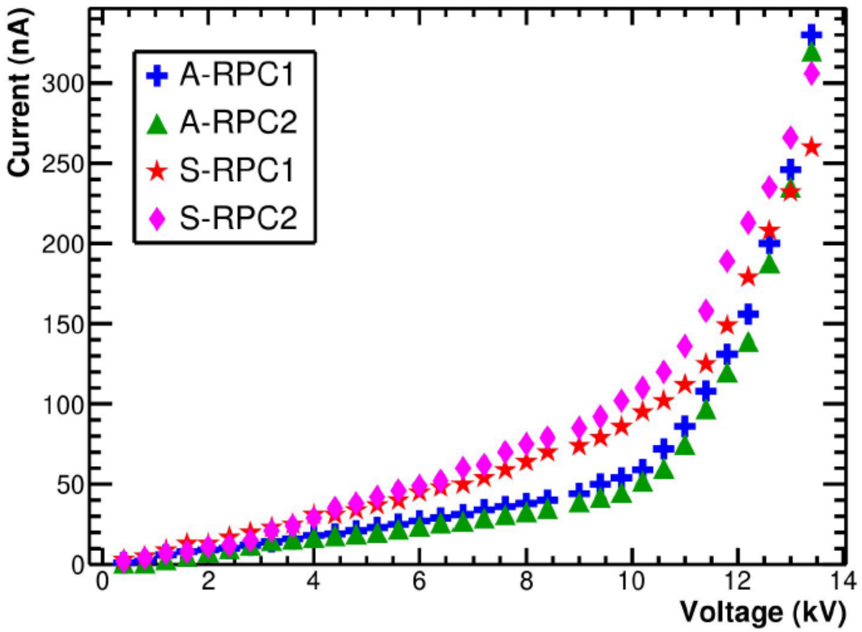
Raveendrababu Karnam

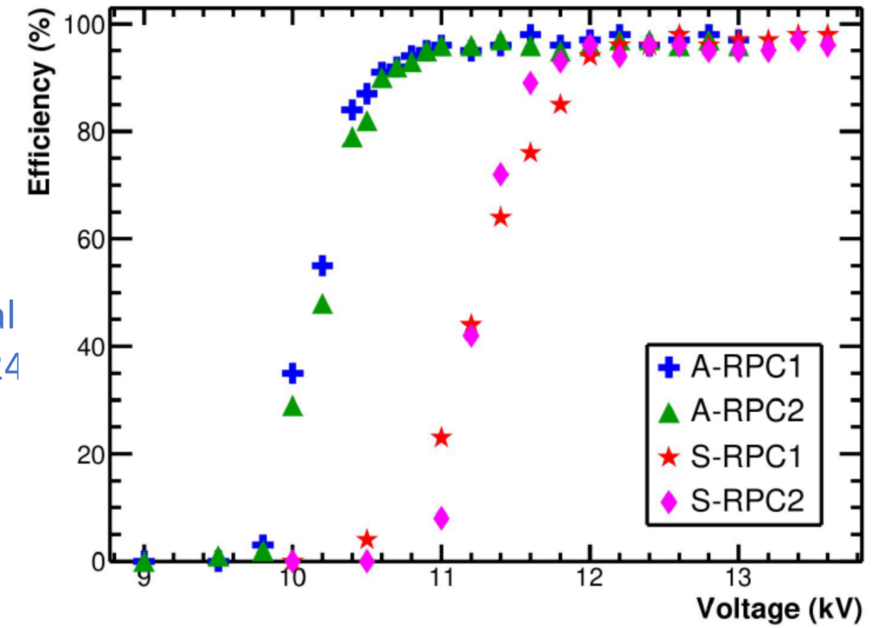


- 30 x 30 cm^2 RPCs
- 3 mm electrode thickness
- 2 mm gas gap
- 1 MΩ/square surface resistivity
- **Bulk resistivity of Asahi**: 4.73 x 10^{12} Ω.cm (ε_r=16.6)
- **Bulk resistivity of Saint-Gobain**: 3.65 x 10^{12} Ω.cm (ε_r=11.4)



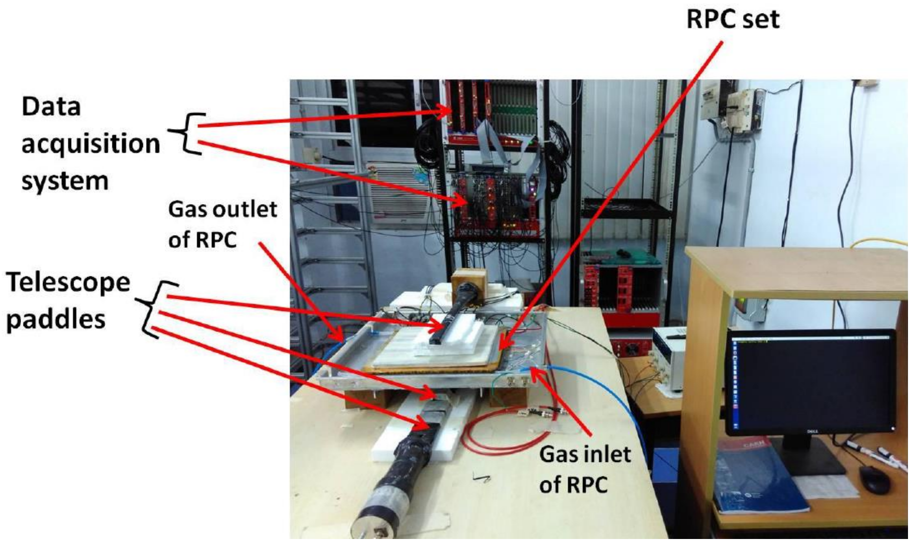
K. Raveendrababu et al
JINST, 2016, 11, P08024

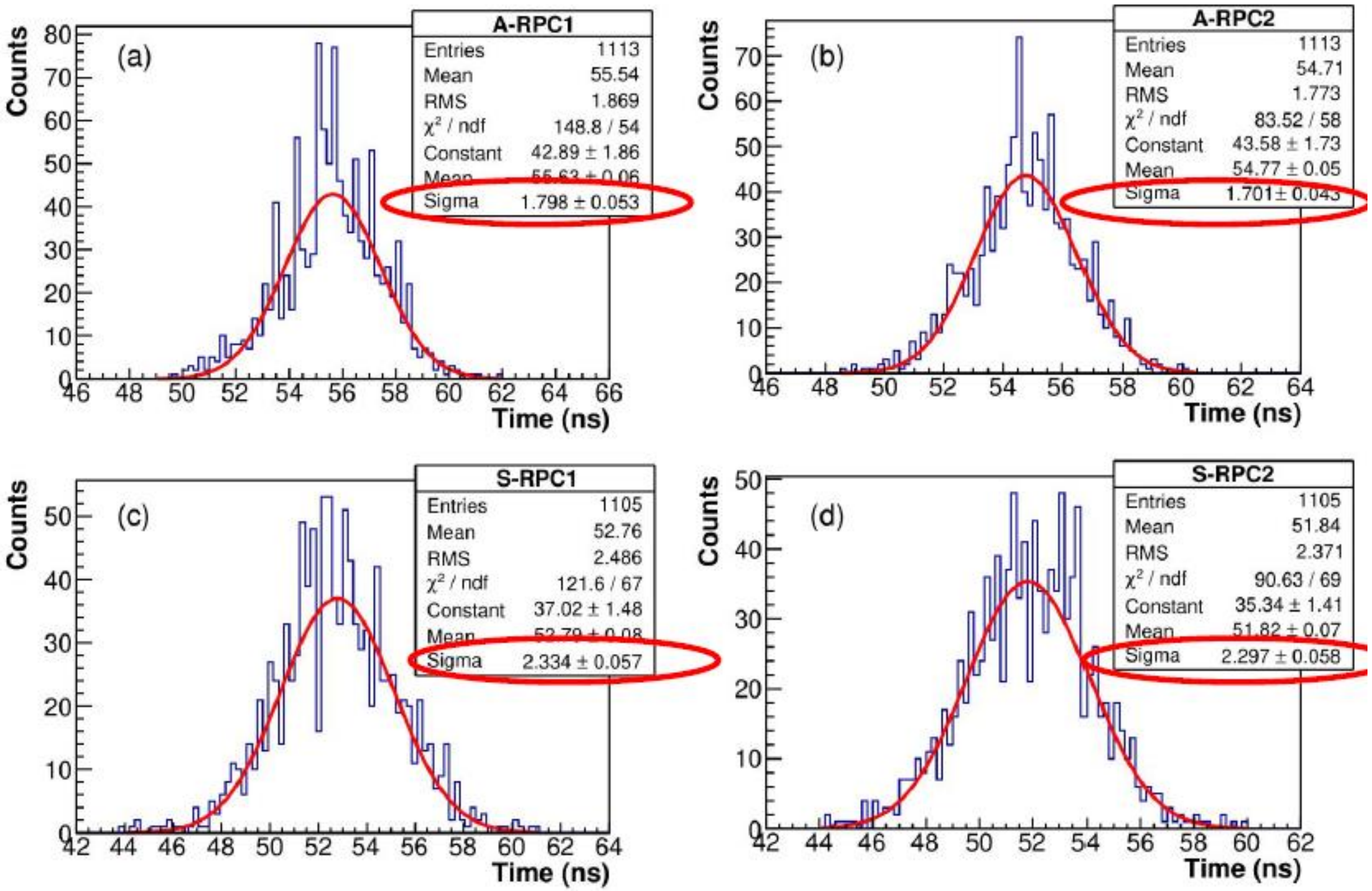




Work experience (RPCs)

Raveendrababu Karnam

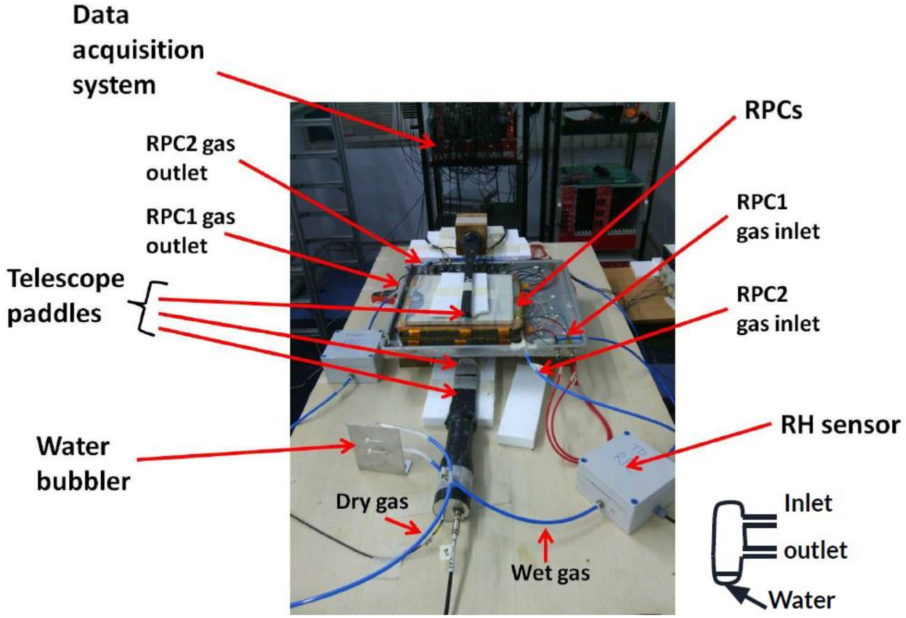


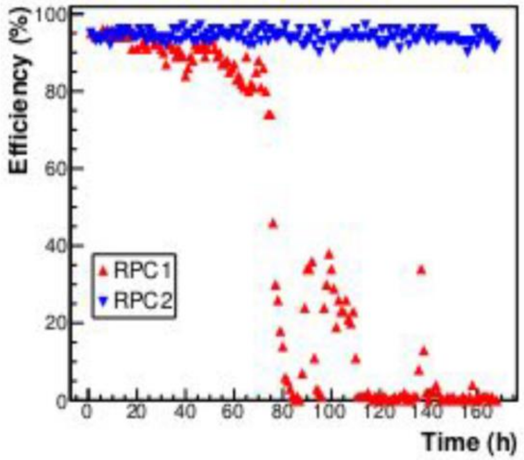


K. Raveendrababu et al., JINST, 2016, 11, P08024

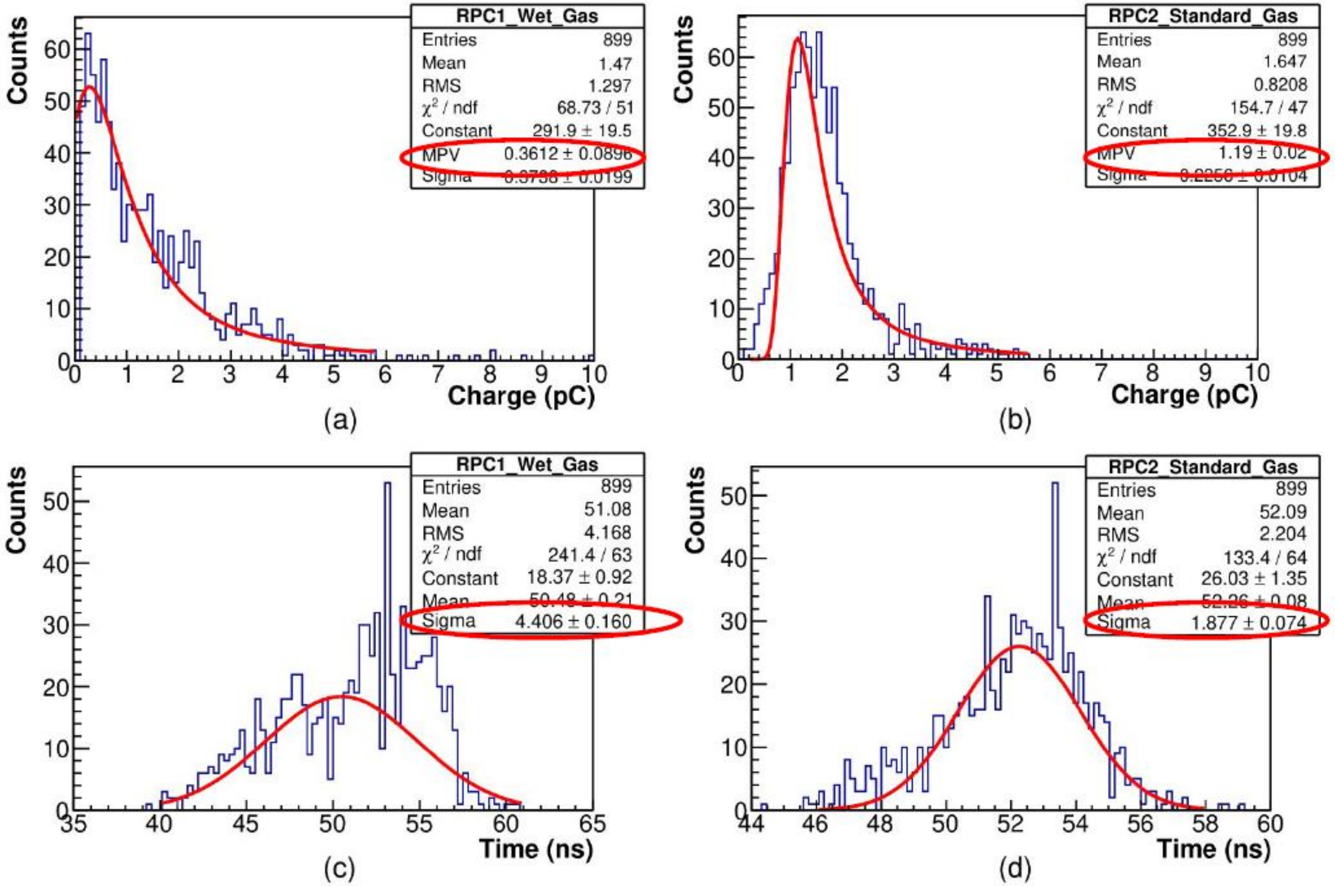
Work experience (RPCs)

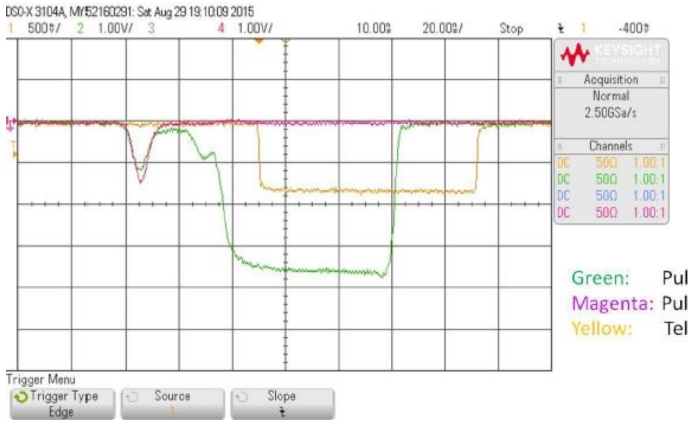
Raveendrababu Karnam





K. Raveendrababu et al., JINST, 2016, 11, C08001.

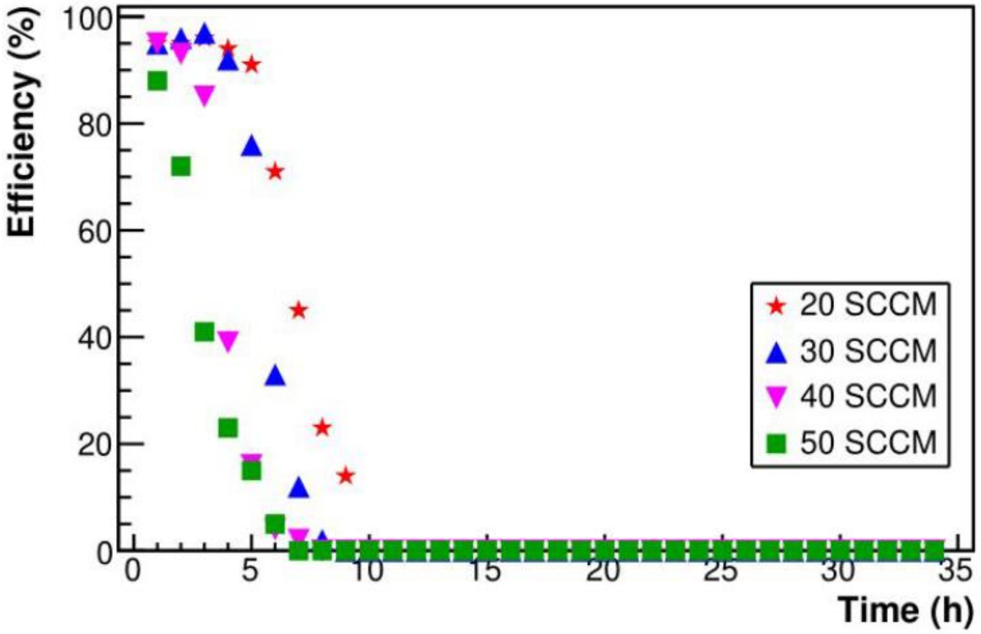


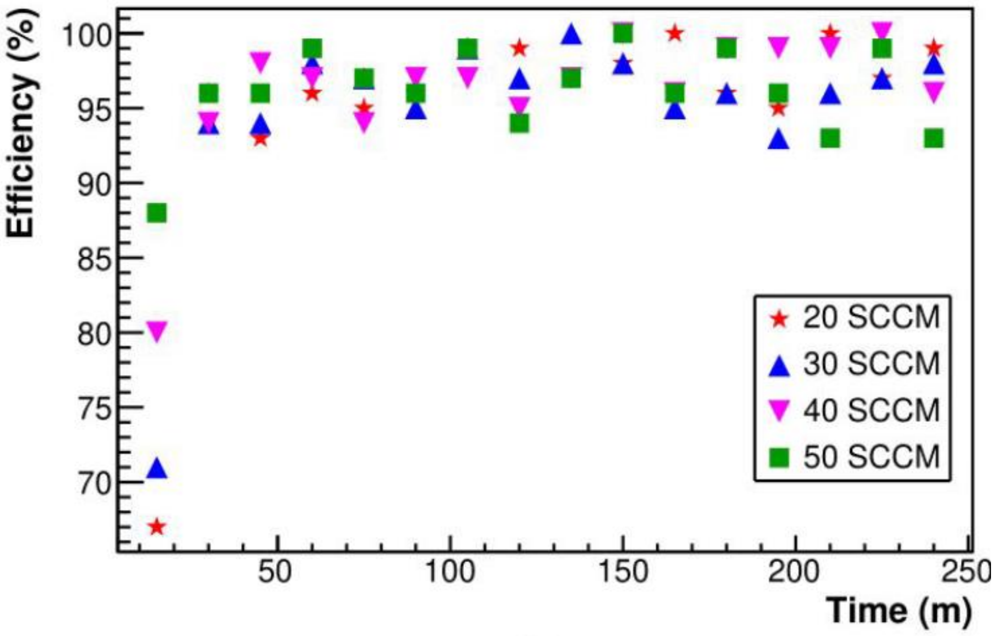


Green: Pulse from RPC1
Magenta: Pulse from RPC2
Yellow: Telescope trigger (3F) pulse

Work experience (RPCs)

Raveendrababu Karnam



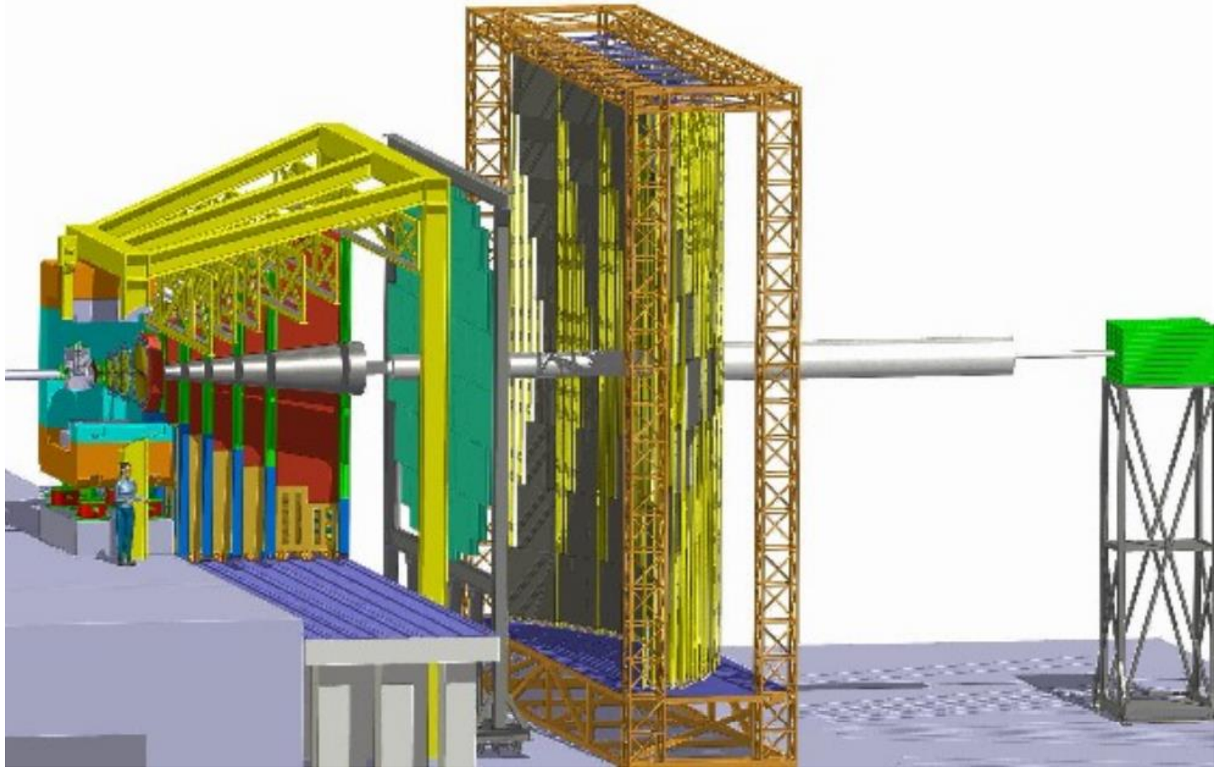


K. Raveendrababu et.al. JINST, 2016, 11, C08001.

Compressed Baryonic Matter experiment at FAIR

Muon Chamber (MuCh) System

- First 2 stations to be instrumented by GEM detectors
- RPCs proposed for 3^{rd} and 4^{th} stations
- Plan to use same electronics for GEM and RPCs
- R & D @ NISER for high rate capability RPCs



Picture from CBM-MUCH-TDR

High rate capability RPCs

The rate capability of RPC is defined as

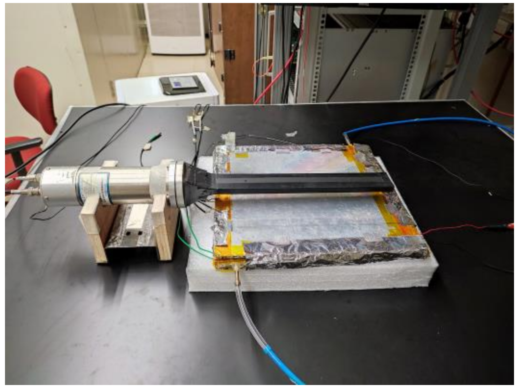
$$r_C = \frac{r}{V} = \frac{1}{\rho t \langle Q \rangle}$$

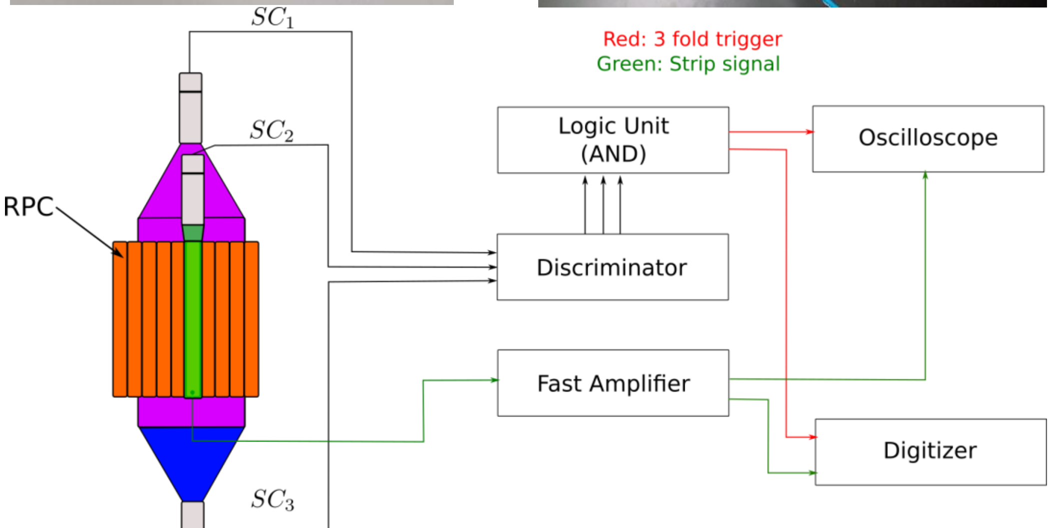
where $r_C = r/V$ is the rate per unit voltage drop, r is the particle (counting) rate, V is the voltage drop across the electrodes, ρ is the bulk resistivity of the electrodes, t is the total thickness of the electrodes and $\langle Q \rangle$ is the average charge produced in the gas for each count.

Avg. charge in gas gap <*Q*> (pC)	**Induced charge on readout (pC)**	**Total electrode thickness (mm)**	**Bulk resistivity (Ω.cm)**	**Rate ($kHz.cm^{-2}$)**	**Voltage drop (V)**
20	**1**	4	$3x10^{10}$	**1.25**	300
10	**0.5**	4	$3x10^{10}$	**2.5**	300
5	**0.25**	4	$3x10^{10}$	**5**	300

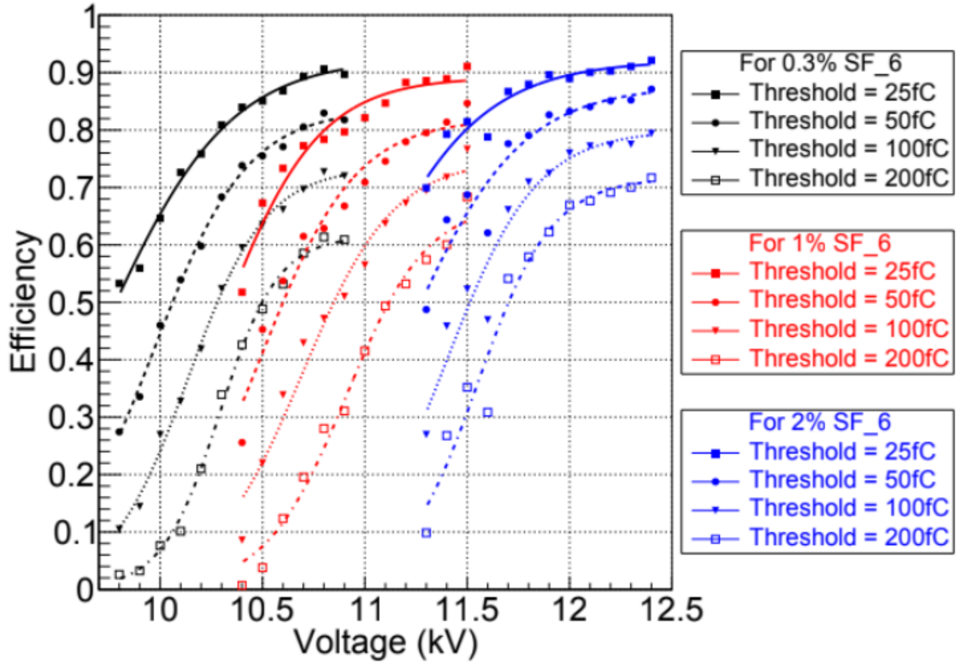
CBM MUCH requirement: 30 $kHz.cm^{-2}$ in 3^{rd} station and 10 $kHz.cm^{-2}$ in 4^{th} station !!

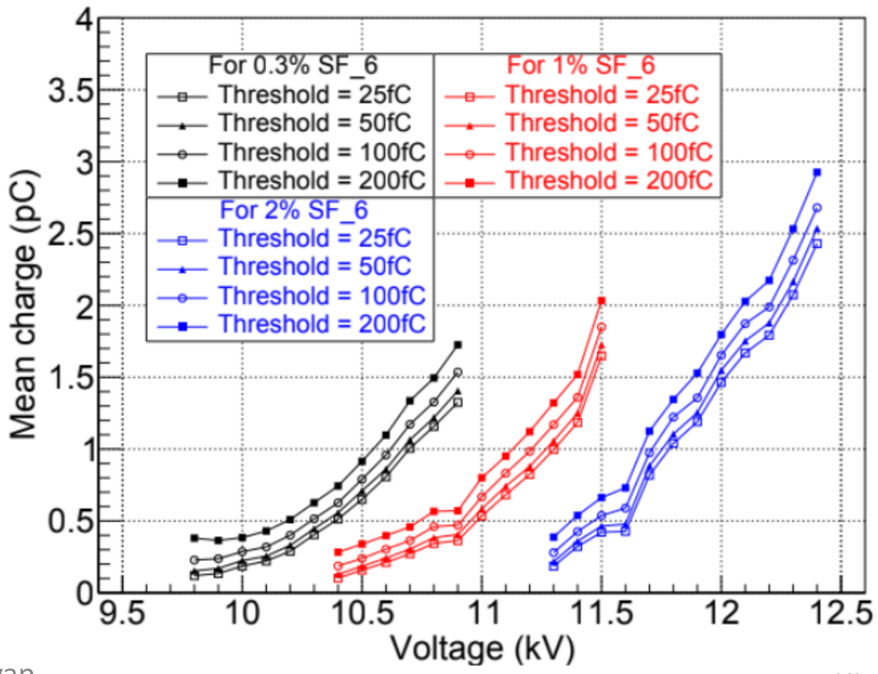
Semiconductive glass RPC





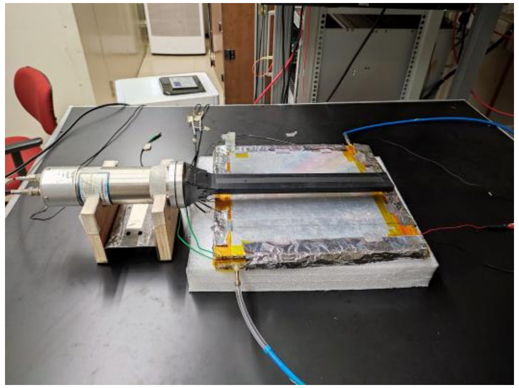
Glass bulk resistivity: $\rho \sim 10^{10}\ \Omega\text{cm}$

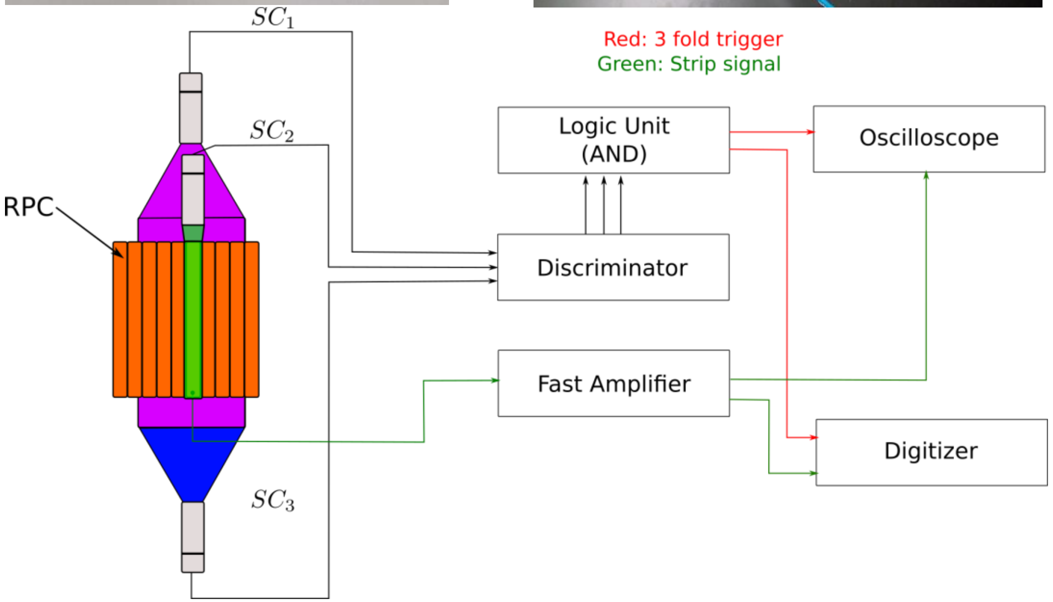




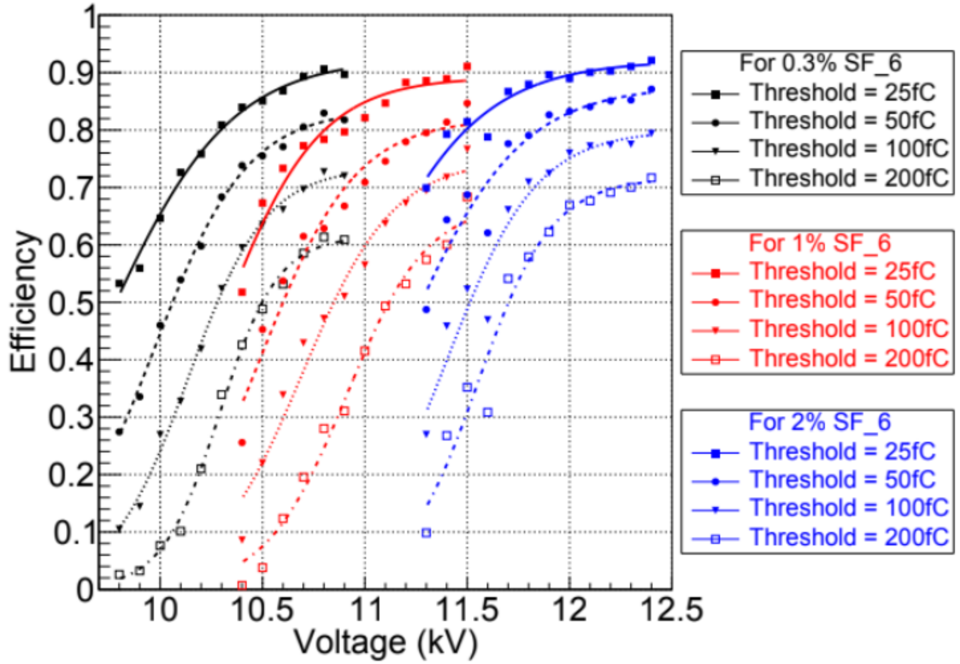
V. K. S. Kashyap et al, CBM Progress report, 2019

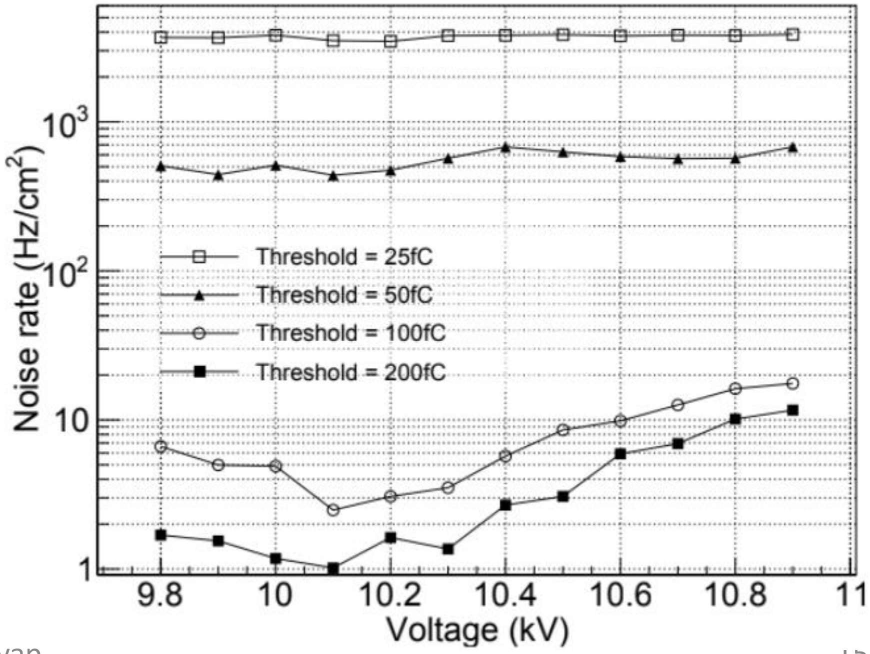
Semiconductive glass RPC



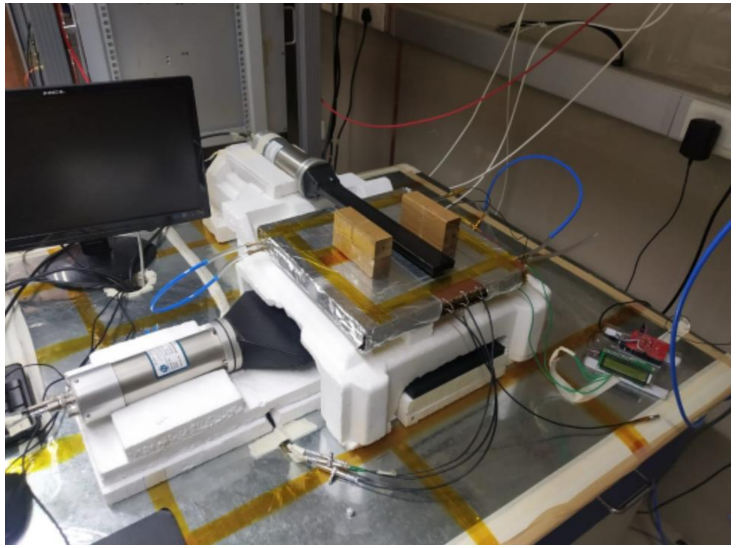


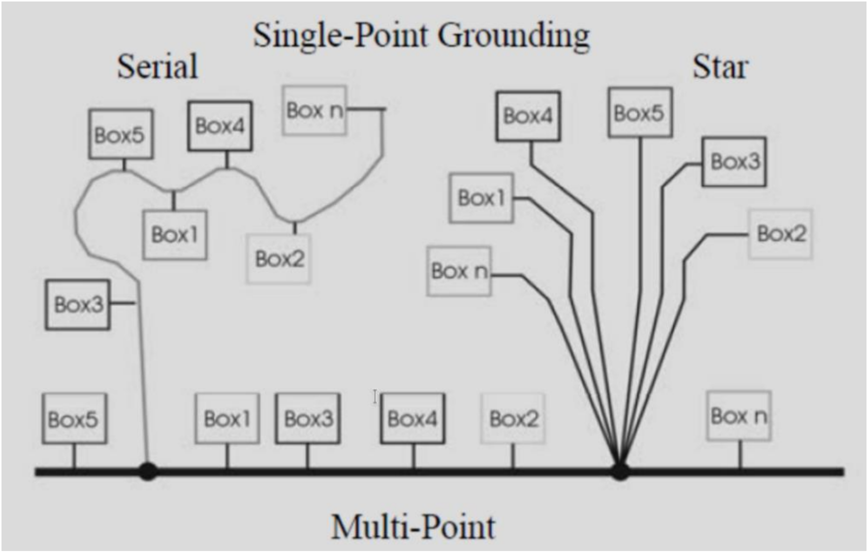
V. K. S. Kashyap et al, CBM Progress report, 2019

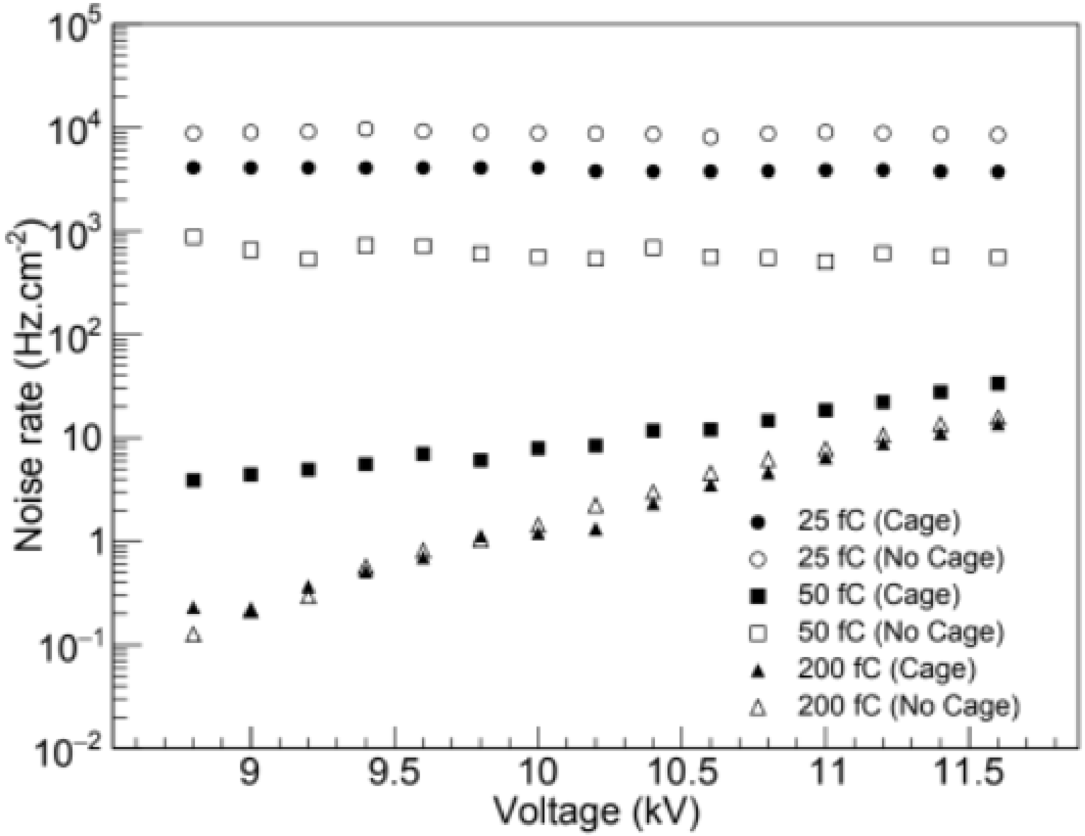




Normal glass RPC and noise reduction

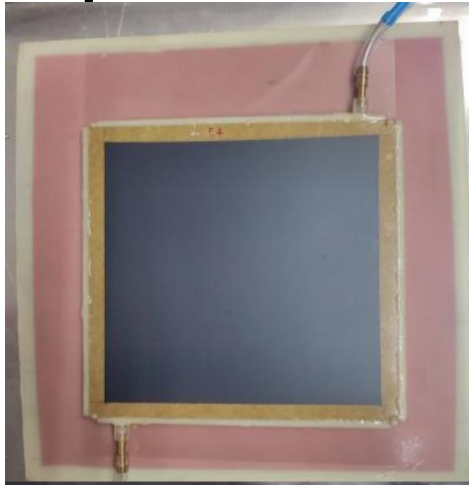


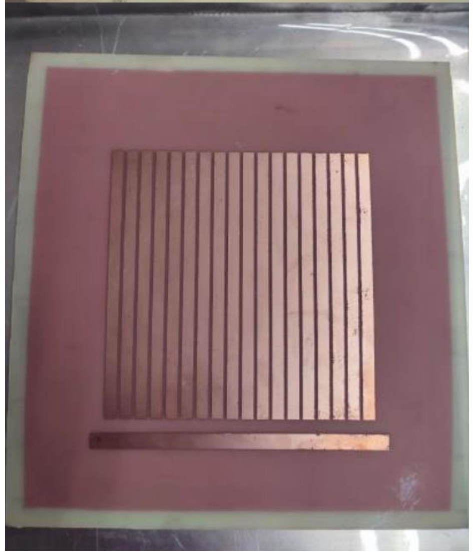


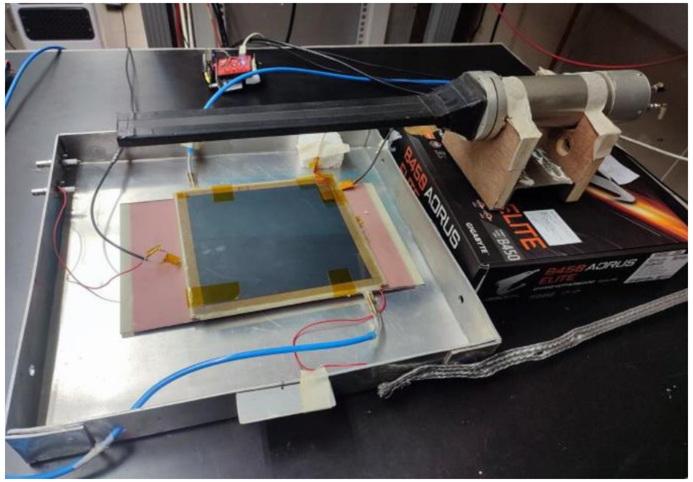


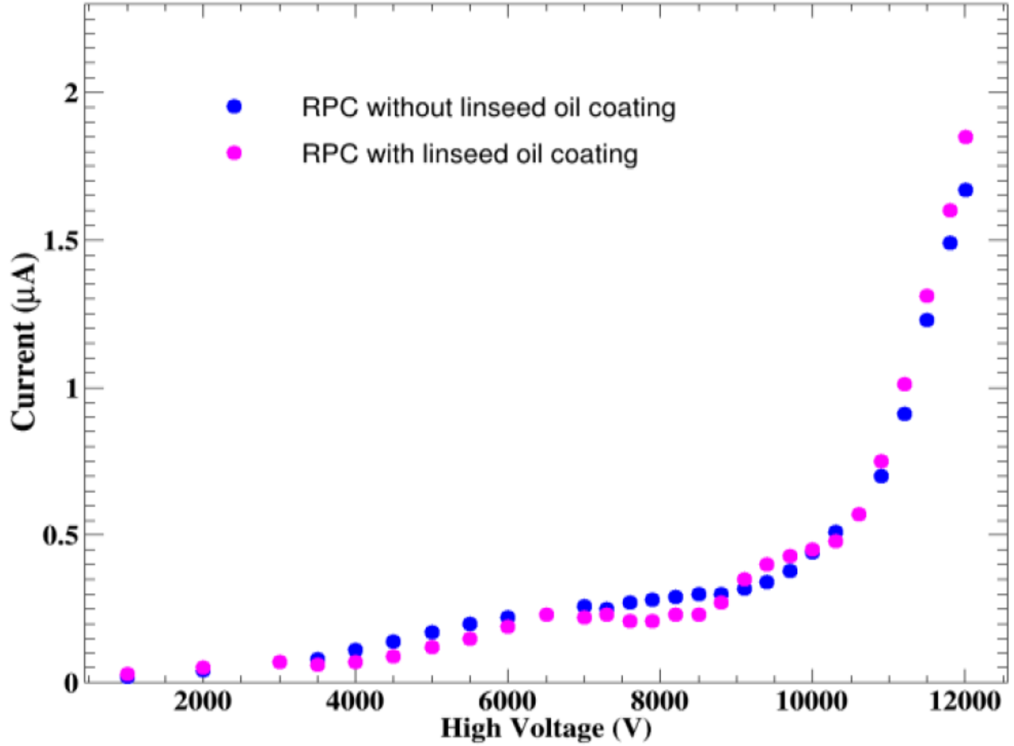
V. K. S. Kashyap et al, CBM Progress report, 2019

Bakelite RPC development for Muography and HEP experiments (Recent activity)

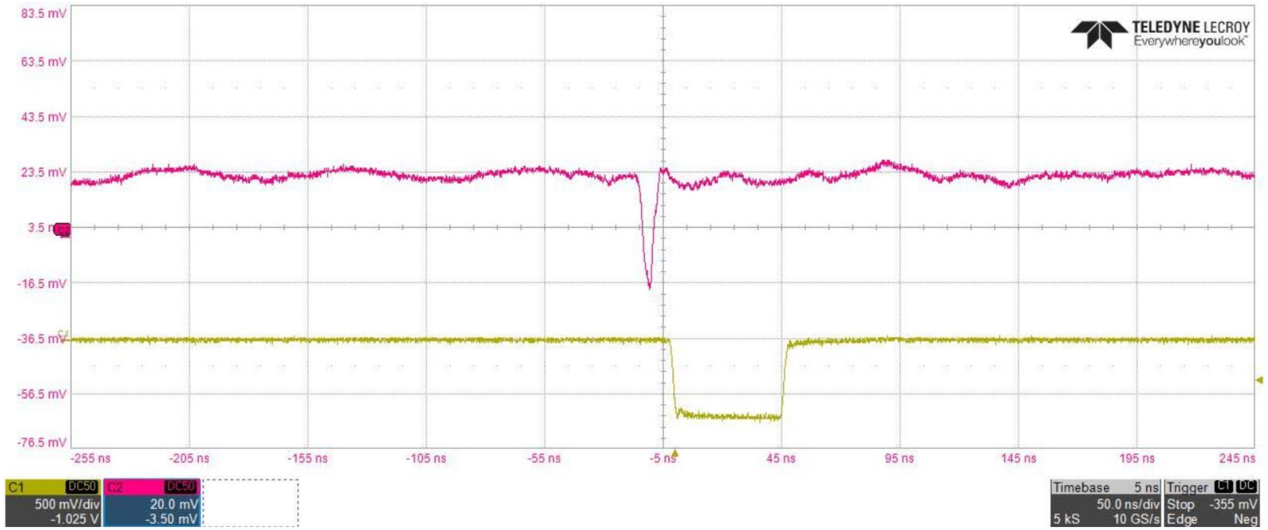




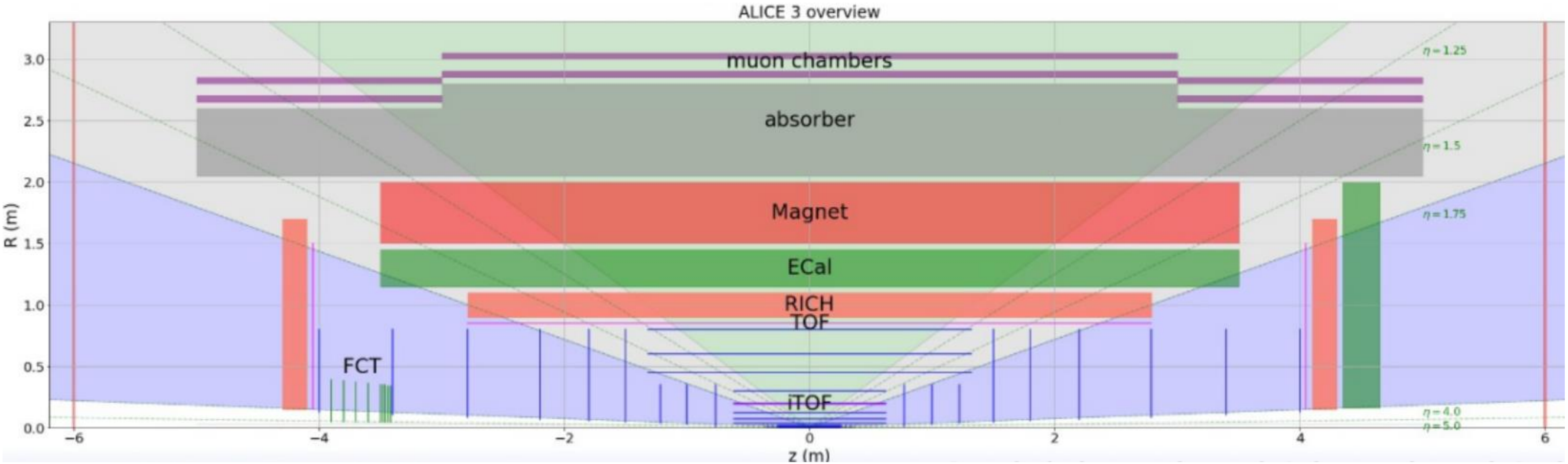




- Bakelite from Teknemika, Italy
- 20 x 20 cm^2 RPCs with and without linseed oil coating
- ~1 mm electrode thickness
- 2 mm gas gap
- 1 MΩ/square surface resistivity
- **Bulk resistivity**: ~10^{10} Ω.cm



ALICE-3 proposal



- Moderate charged particle rate of 3 Hz/cm^2
- Approximate area coverage needed: ~157 m^2
- Granularity of 6 x 6 cm^2 or 5 x 5 cm^2 pad size
- Readout channels ~ 40k

ALICE-3, Letter of Intent, 2021

Electrodes materials

Glass

- Hard and rigid
- Surface smoothness excellent
- Typical resistivity $\sim 10^{12} - 10^{13}\ \Omega\text{cm}$
- Semiconductive glasses can be produced with $\sim 10^{10}\ \Omega\text{cm}$ resistivity but are expensive
- Suitable mostly for low count rate or cosmic ray experiments
- Comparatively heavier

Bakelite

- Comparatively flexible
- Surface finish above average. Requires oil coating for better performance
- Typical resistivity $\sim 10^{10} - 10^{12}\ \Omega\text{cm}$
- Suitable for collider experiments
- Requires humidified gas mixture
- Needs R & D on rate capability for use in future collider facilities with increased luminosity and particle flux

Modes of operation

Avalanche Mode

- After ionization, charge multiplication reaches to an extent that its own field prevent further multiplication
- This is also known as the saturated avalanche
- Charge induced is ~1 pC
- Requires low-noise preamplification electronics
- Higher count rates are possible
- Better time resolution

Streamer Mode

- When the applied voltage is increased beyond the saturated avalanche regime a streamer or mild spark is created.
- A conductive channel is formed across the electrodes and the small discharge area remains inactive for a larger amount of time.
- Charge induced is ~10-100 pC
- Requires no preamplification electronics
- Cannot be operated in high count rate environment

Gas mixture and GWP

Gases used in RPC and Global Warming Potential (GWP)

Gas	Freon-r134a	i-butane	SF_6
GWP	1430	3	23900

- Freon r134a and SF_6 have high GWP
- Alternative gas candidates:

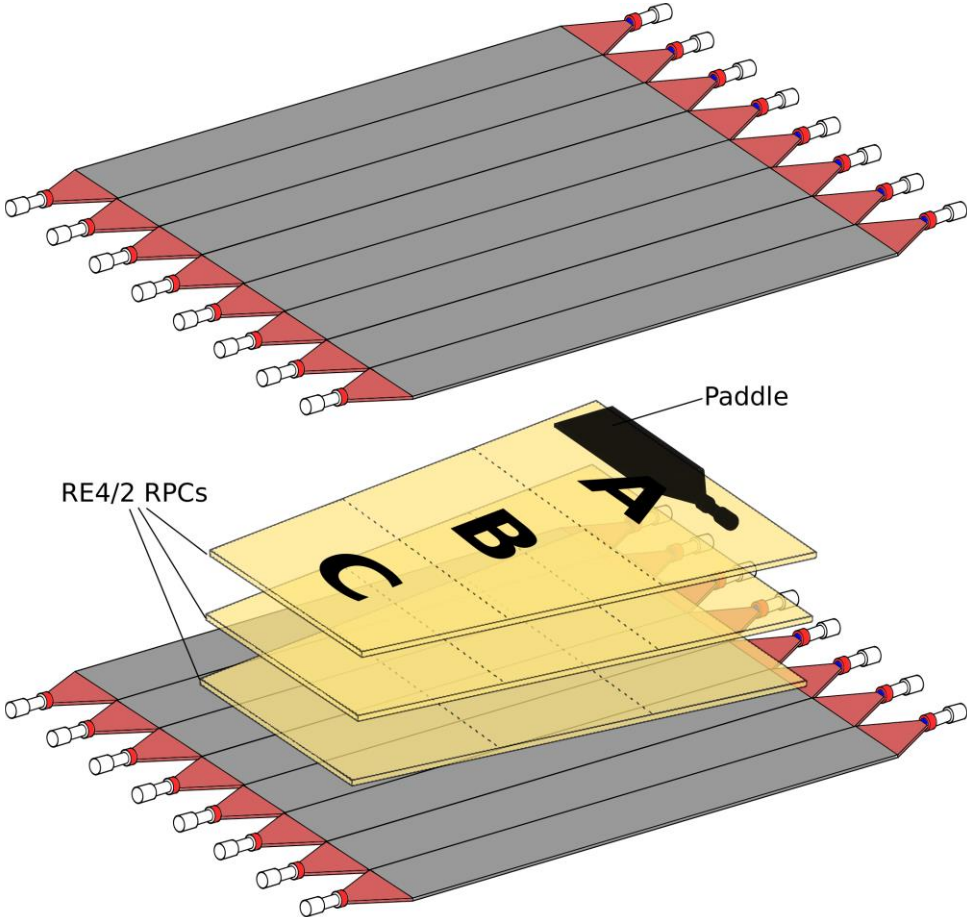
Gas	HFO-1234ze	HFO-1234yf
GWP	6	4

- These gases currently do not show performance similar to that of r134a mixtures in the avalanche mode and can be used as additional components to reduce overall gas mixture GWP
- More R & D ongoing to find good alternatives

1. M. Capeans et al, *2015 IEEE Nuc. Sci. Symp.and Med. Imag. Conf. (NSS/MIC)*, 2015, pp. 1-4
2. R. Guida et al, https://doi.org/10.1016/j.nima.2019.04.027

Quality control

- **Visual inspection** of gap and components
- **Mechanical tests** – leak tests of the gas gaps and pressure test of the spacers. Test of cooling systems for electronics
- **Electrical tests** – I-V characteristics of the gas gap. Connectivity tests of readouts and FE electronics after integration.
- **Uniformity and performance tests**- Cosmic muon characterization using hodoscope



Summary

- NISER group has expertise in RPC detectors and members have work experience related to INO, CMS and CBM experiments
- NISER is currently performing R & D on glass and bakelite RPCs for HEP experiments and societal applications
- The ALICE LoI requires that a muon chamber should have a rate capability of 3 Hz/cm^2 and granularity of 25 cm^2. RPCs could easily cater to the requirement
- R & D would be needed for RPC design and low GWP alternate gas mixtures

NISER RPC group

Prof. Bedangadas Mohanty
Experience: WA98@CERN, STAR@RHIC, ALICE@CERN
Interest and expertise: Physics analysis and simulations, QCD Critical Point and Phase Diagram
Current responsibilities: Part of STAR BES-II program, ALICE; Professor and Chairperson, Centre for Medical and Radiation physics, CBM@FAIR,

Dr. Varchaswi K S Kashyap
Experience: INO, ISMRAN and SuperCDMS
Interest and expertise: Gas detectors, neutron detectors and cryogenic detectors
Current responsibilities: R & D related to advanced gas detectors for EHEP experiments – GEM, RPC and detectors for rare event experiments, CBM@FAIR

Dr. Raveendrababu Karnam
Experience: INO. CMS Si tracker, ATLAS ZDC, Muography
Interest and expertise: Resistive plate chambers and gas detectors
Current responsibilities: Developing a portable muon radiography system for societal applications

Thank you !!