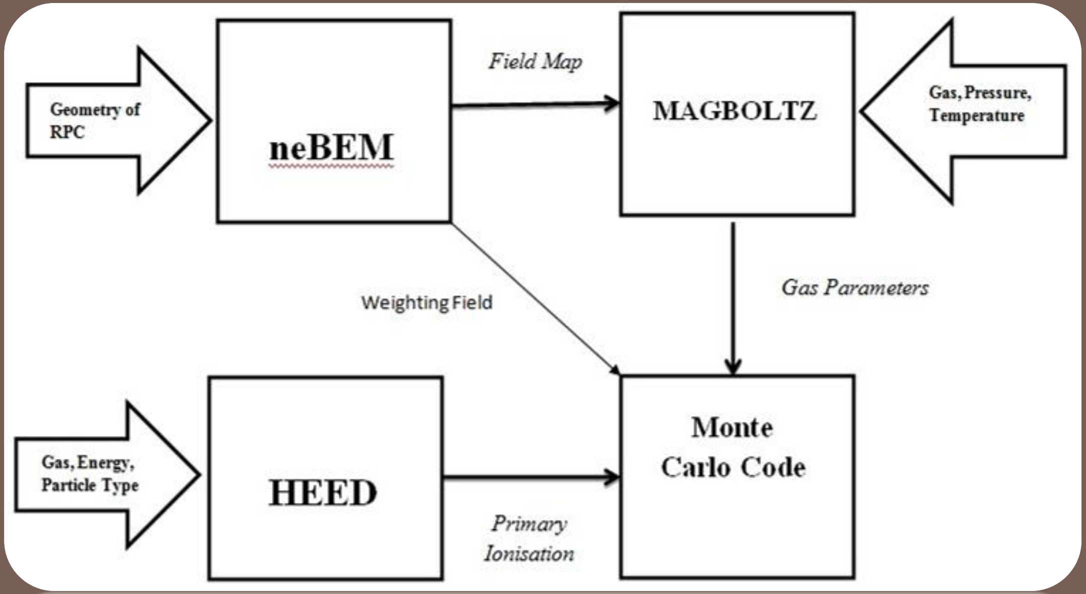

SIMULATION STUDIES ON THE EFFECT OF SF_6 IN THE RPC GAS MIXTURE

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RPC2012

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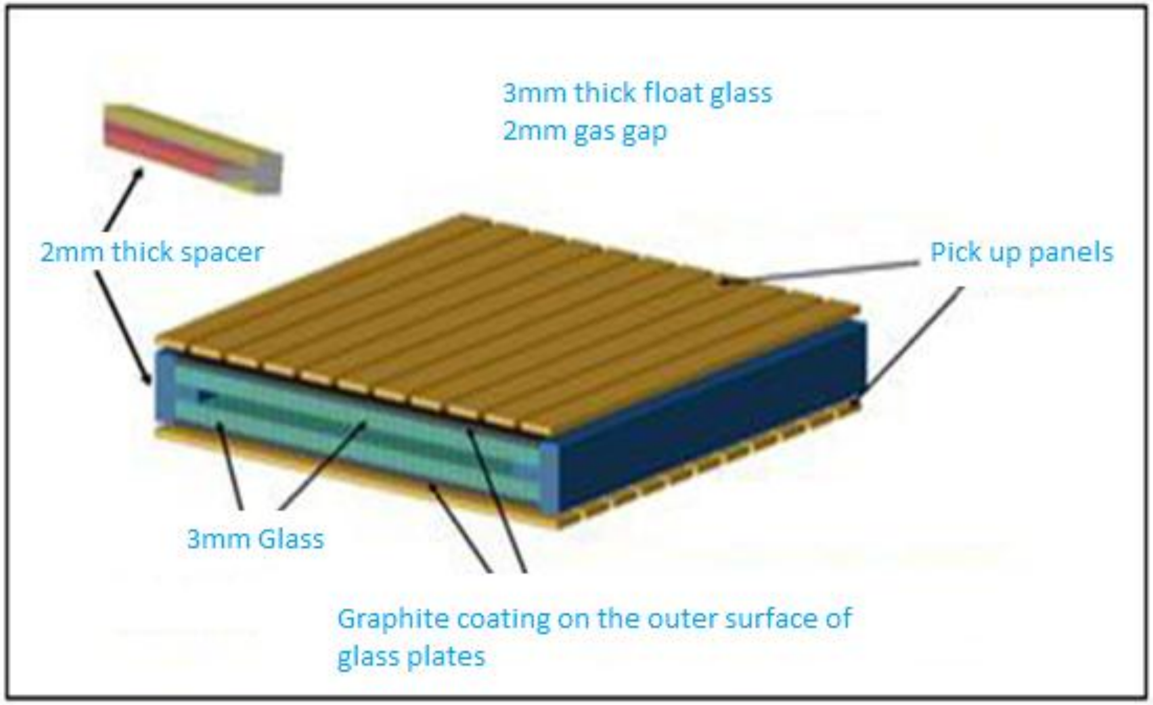
INO Experiment

- India-based Neutrino Observatory (INO) is a mega science project planned for studying the properties of atmospheric neutrinos in its first phase of operation [1].
- 50kton magnetized Iron CALorimeter (ICAL) is proposed as its main detector.
- About 28,800 Resistive Plate Chambers (RPCs) of about 2m×2m in area will be used as active detector elements in ICAL.

ICAL's RPC



- ICAL's RPC is made of two parallel electrodes (each 3mm thickness).
- Float glass with bulk resistivity of about $10^{12}\Omega$-cm is used.
- 2mm gas gap is provided by insulating (polycarbonate) spacers.
- Avalanche gas mixture R134A/Isobutane/SF_6 is used in the proportion 95.2/4.5/0.3
- A high voltage of about 10kV is applied.

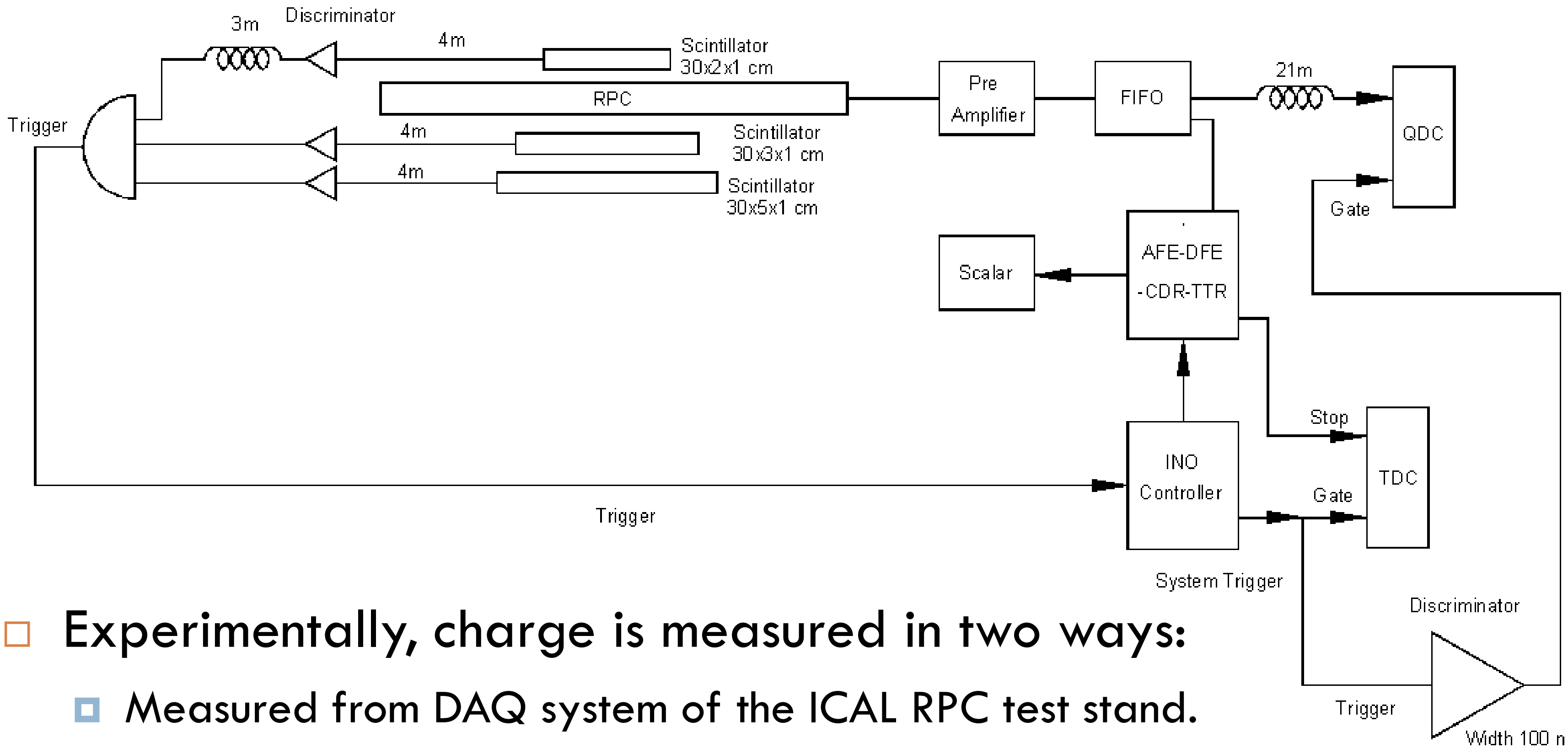
Modes of operation of RPC

- Streamer Mode
  - Electric field inside the gas gap will be high which results in a localised discharge.
  - Large signals (no need of preamplifiers).
  - Suitable for low-rate experiments (cosmic-ray experiments).
- Avalanche Mode
  - Electric field inside the gas gap is reduced and hence gas gain is low.
  - Smaller signals (preamplifiers are needed).
  - Suitable for high-rate experiments (accelerator experiments).

Effect of SF_6 on RPC performance

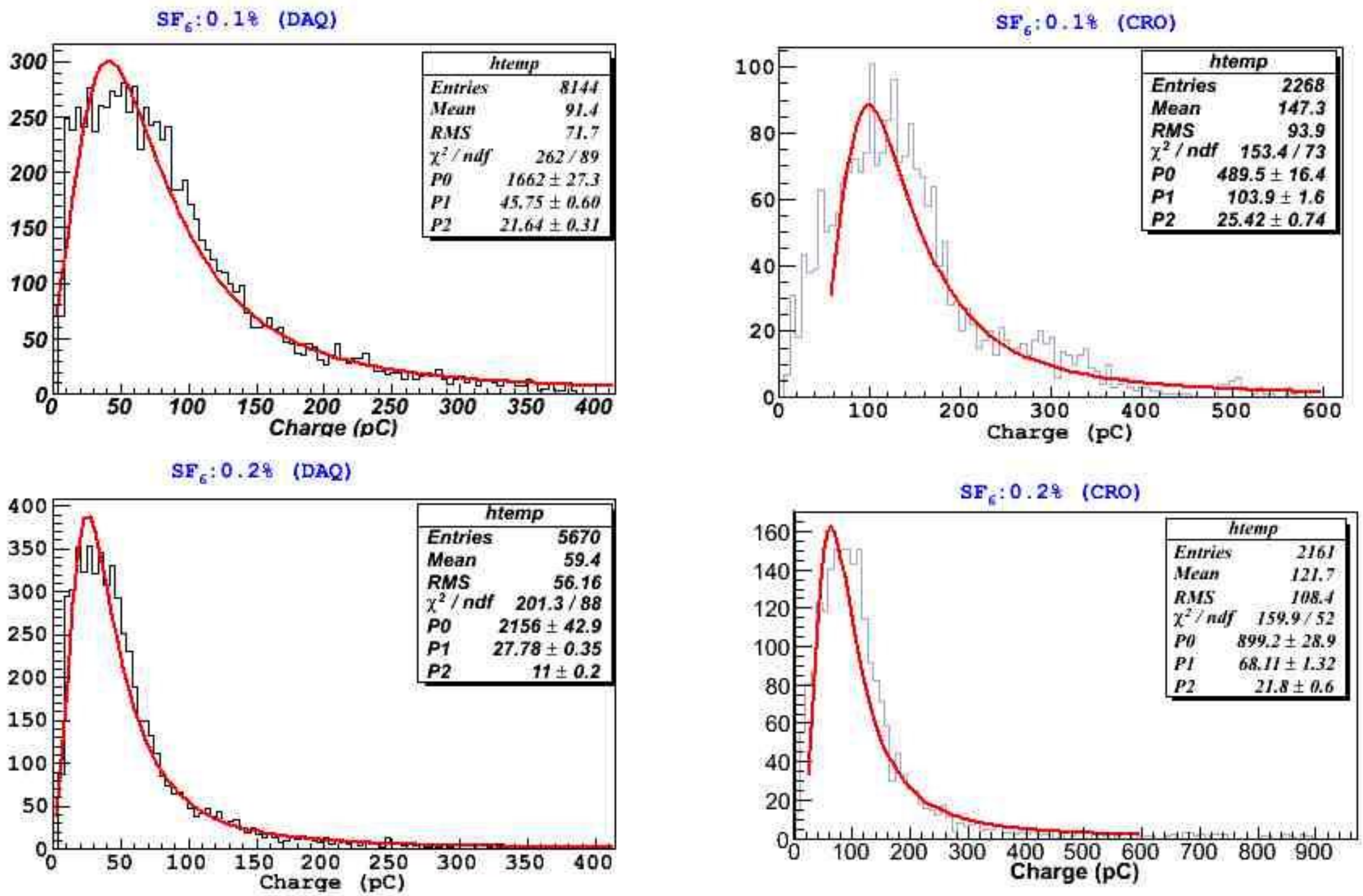
- Sulphur Hexafluoride (SF_6) is a strong quenching gas in the RPC gas mixture due to its high electron affinity.
- Adding SF_6 to $C_2H_2F_4/C_4H_{10}$ gas mixture will suppress streamer production in the RPC [2].
- This will result in the reduction of gas gain and hence charge developed on the pick-up strips is reduced.
- This is our first attempt to study and compare charge production on the RPC pick-up electrodes both experimentally and theoretically by varying SF_6 in small concentration in the RPC gas mixture.

Experimental setup

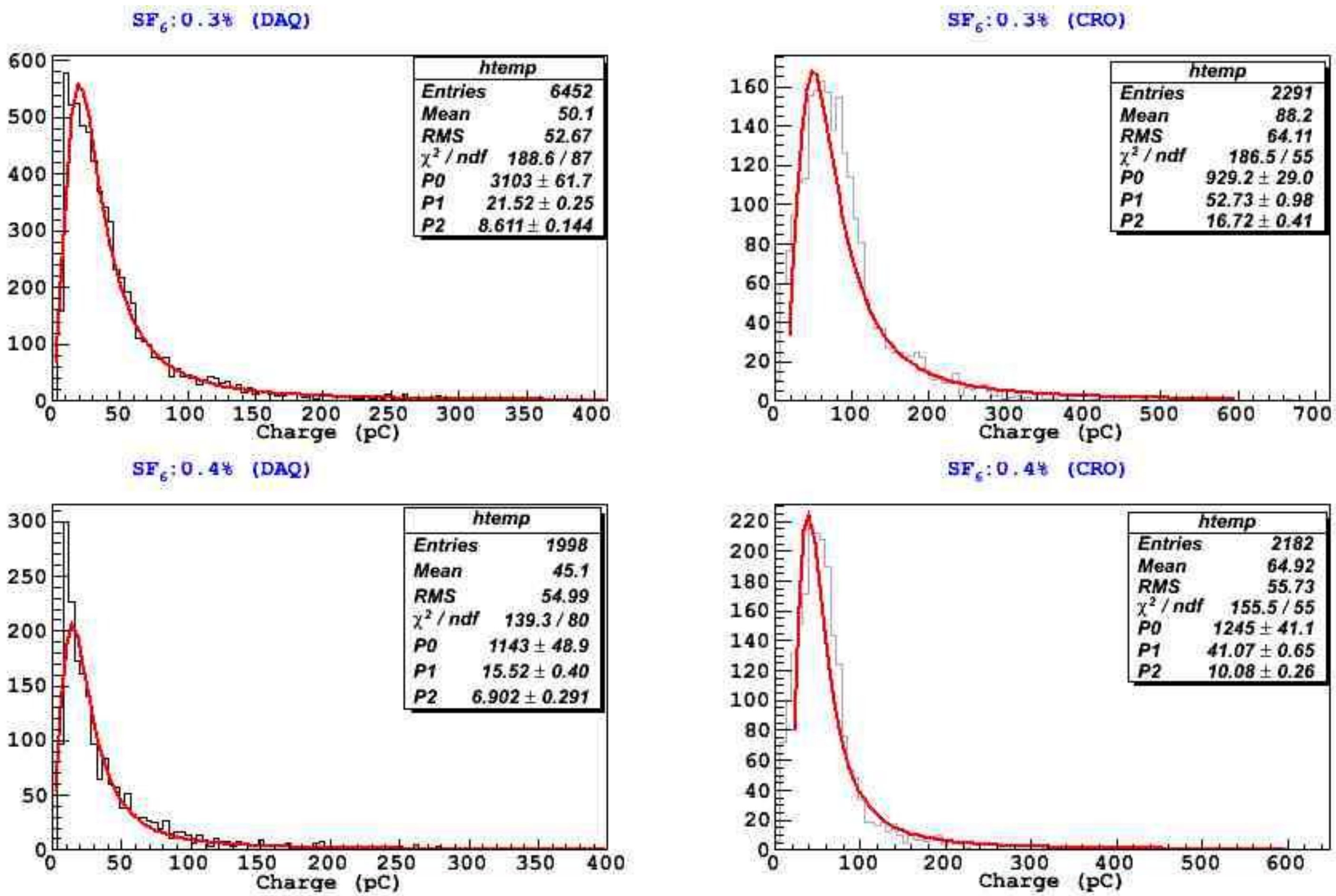


- Experimentally, charge is measured in two ways:
  - Measured from DAQ system of the ICAL RPC test stand.
  - Measured from the pulses captured on a digital oscilloscope.

Experimental results



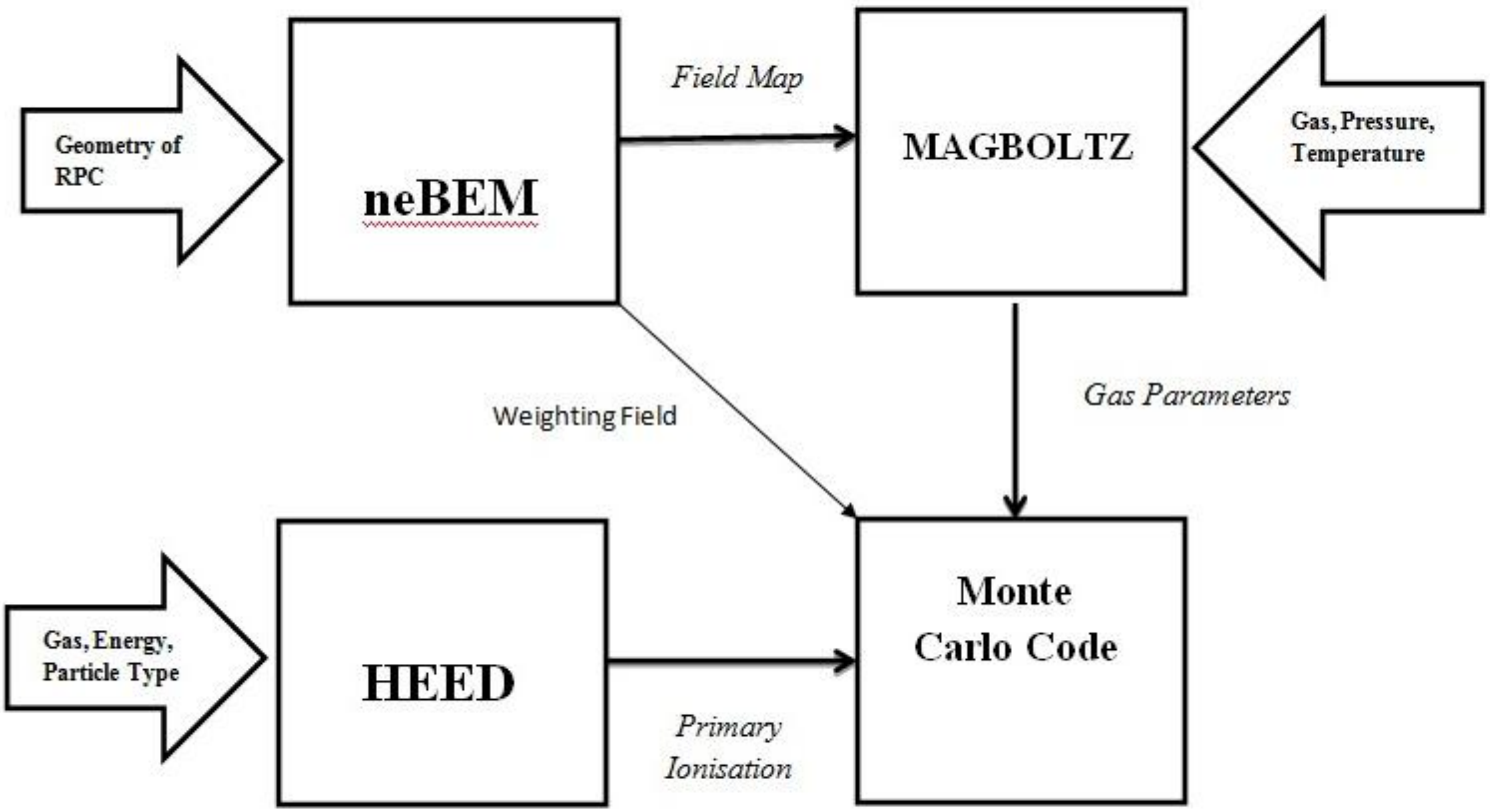
Experimental results



Experimental results

- In order to keep the signal in trigger window, a 21m long co-axial cable is used in the experimental setup. This will add an attenuation to the signal.
- Due to attenuation, charge measured by the DAQ is about 2.5 times lower than the charge measured by digital oscilloscope.

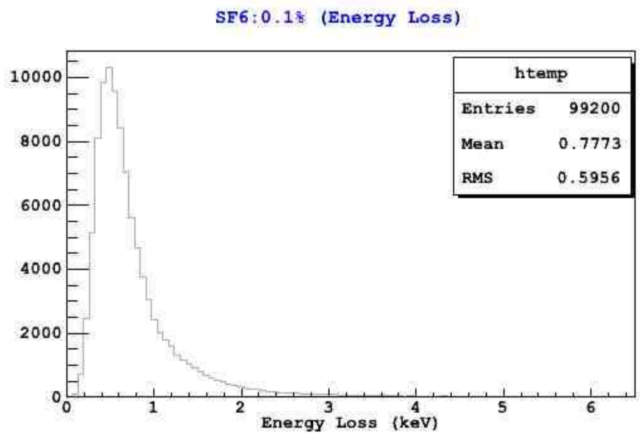
Simulation scheme

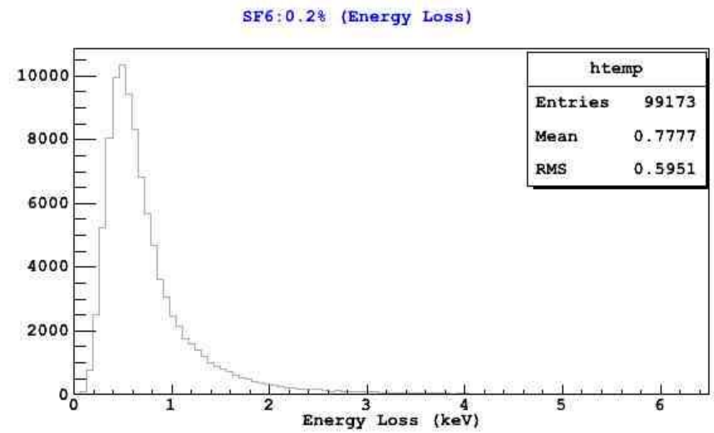


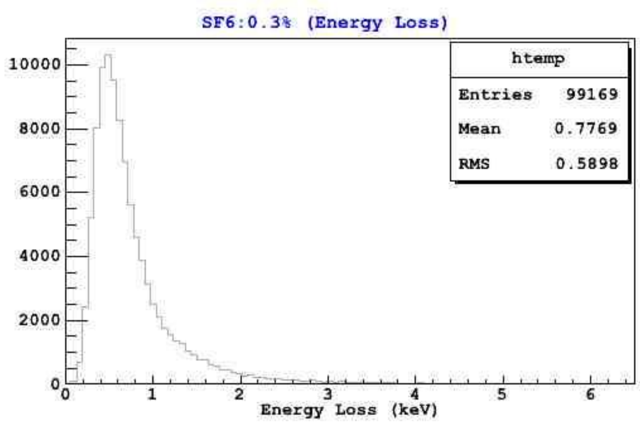
Simulation packages used

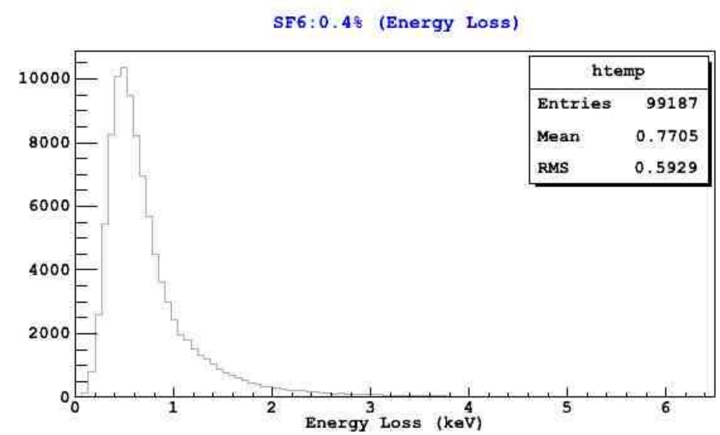
- HEED
  - Calculates the energy loss and ionisation produced by the particle traversing through the RPC [3].
  - Developed by I.Smirnov.
- neBEM
  - nearly exact Boundary Element Method (neBEM) is used for field calculation [5].
  - Developed by S.Mukhopadhyay and N.Majumdar
- MAGBOLTZ
  - Computes electron transport parameters [4].
  - Developed by S.Biagi.

HEED results



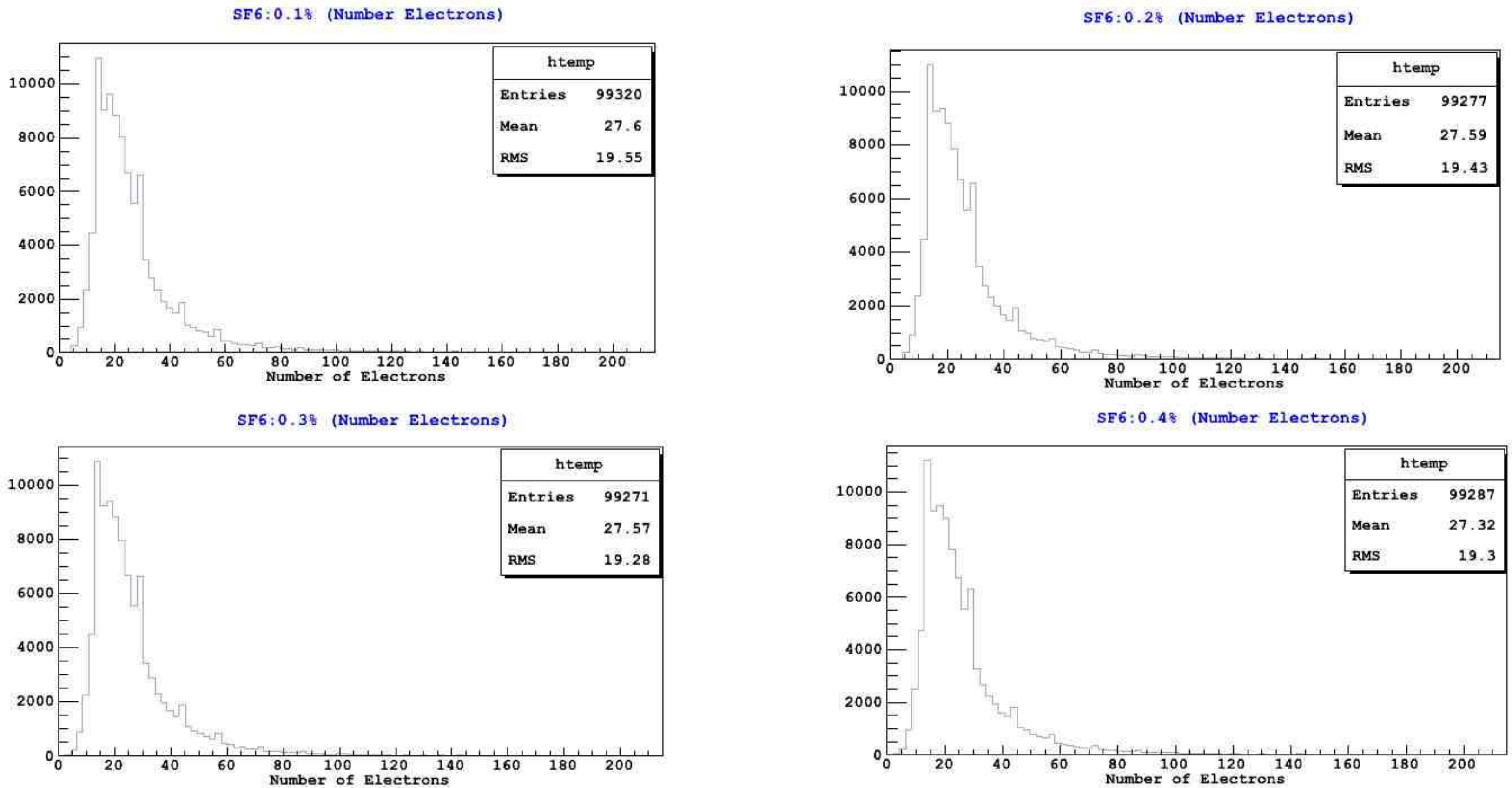






Particle = Muon (105MeV), Energy = 4GeV

HEED results

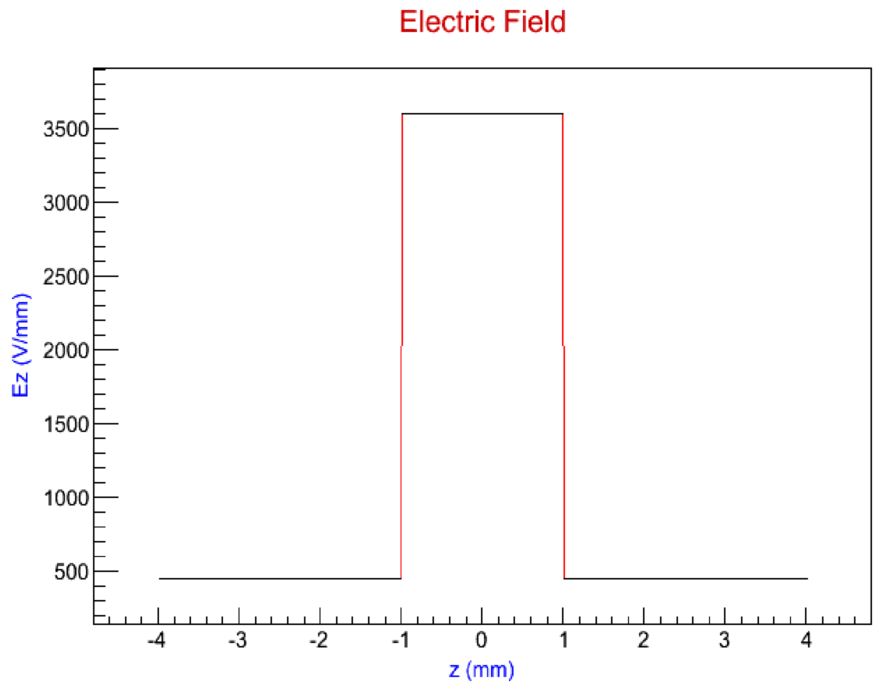


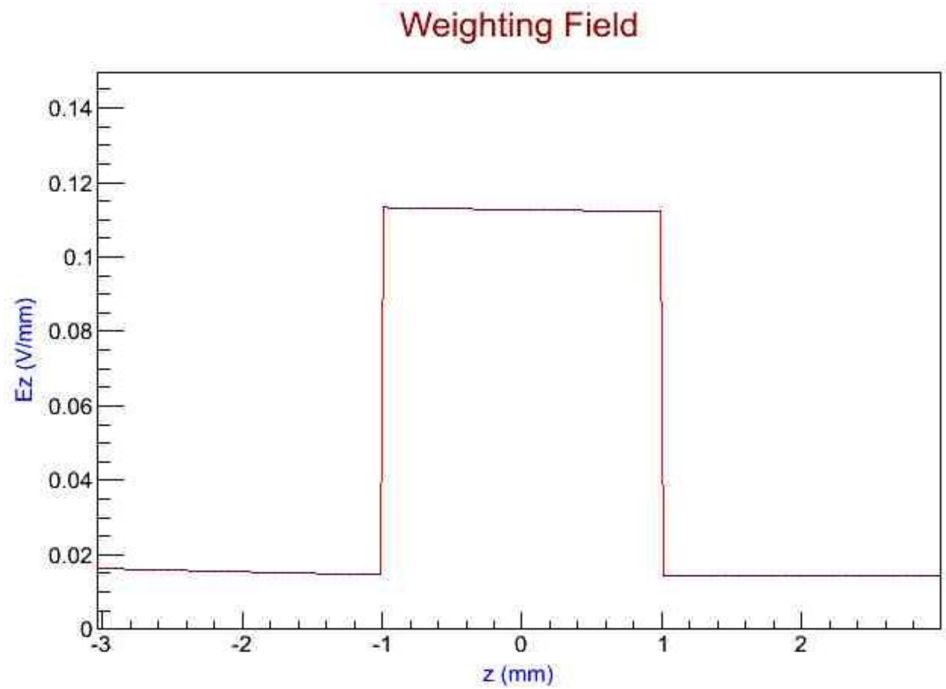
Cluster density obtained = 7.6/mm, Average number of electrons/cluster = 2.0

Parameters for neBEM calculations

Material	Dielectric	Dimension
Glass	7.75	3mm
Gas	1.000513 (equivalent to air)	2mm
Paint	12	20 micron
PET film	3	50 micron
Plasic HoneComb	1.000513 (Mostly air)	5mm

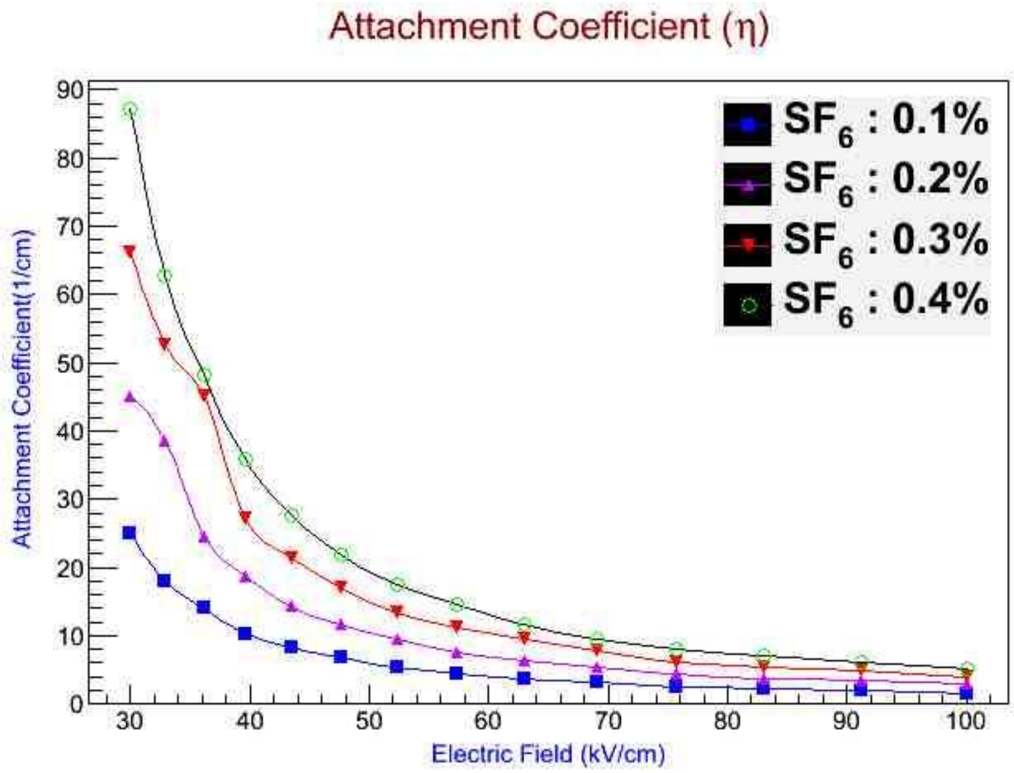
neBEM results (@9.9KV)

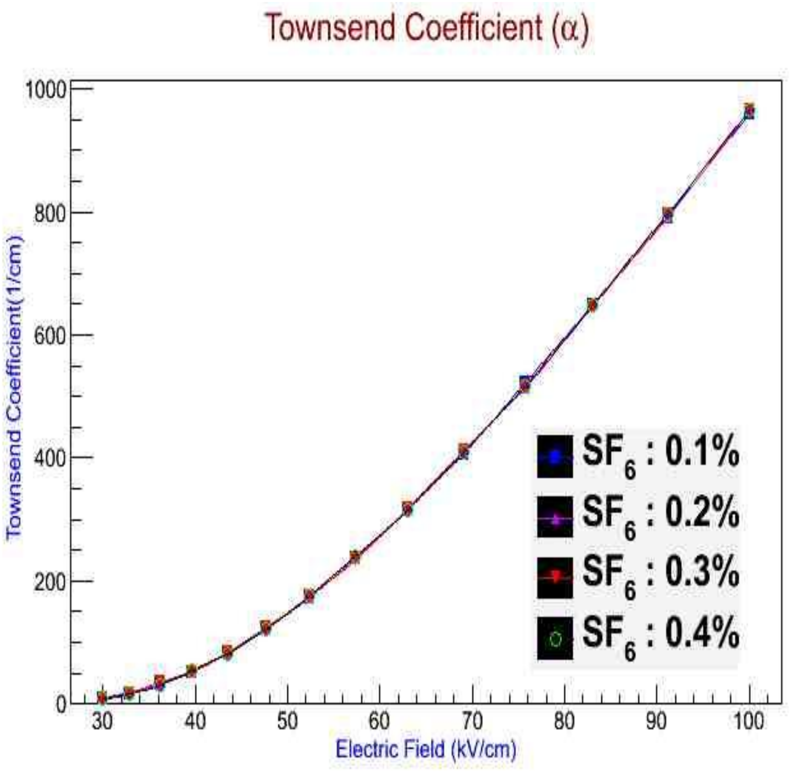




- Electric field in the gas gap is 3.6kV/mm
- Weighting field is 0.112V/mm

Magboltz results (@T=20 °C, P=1atm)





- Attachment coefficient increases with increase in SF_6 concentration.
- Townsend coefficient is almost the same in all gas mixtures.

Monte Carlo method

Following Ramo's theorem [6], the current induced by the drifting charge on the pick-up electrodes is given by:

$$i_{ind}(t) = v_d E_w q_e \, e^{(\alpha-\eta)v_d \Delta t} \sum_{j=1}^{n_{cl}} n_0^j M_j$$

Saturation limit set: $5*10^{10}$ electrons

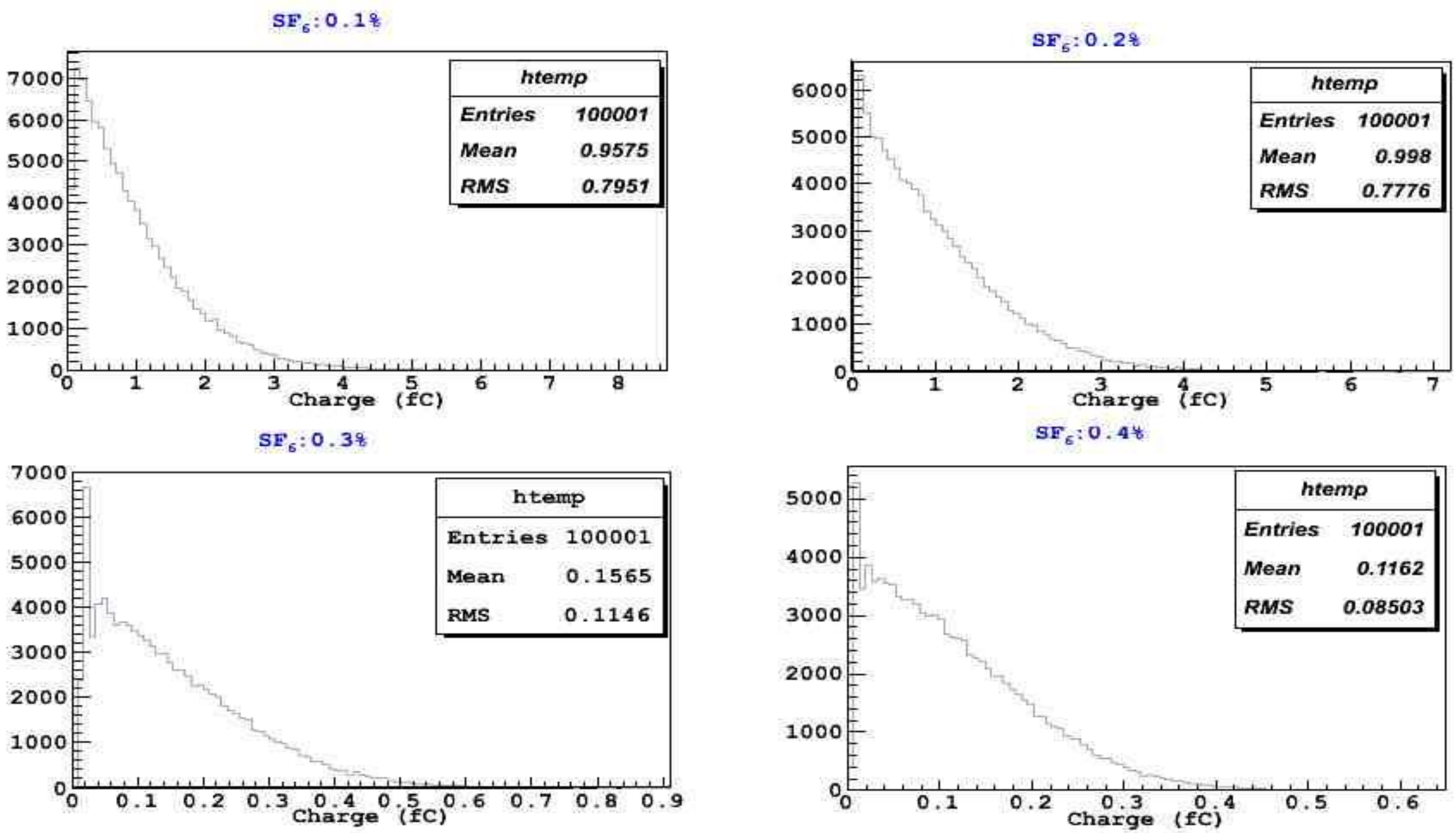
The charge induced on pick-up electrodes is calculated by direct integration of above relation:

$$q_{ind} = \frac{q_e}{(\alpha-\eta)d} \Delta V_W \sum_{j=1}^{n_{cl}} n_0^j M_j \left[e^{(\alpha-\eta)(d-x_0^j)} - 1 \right]$$

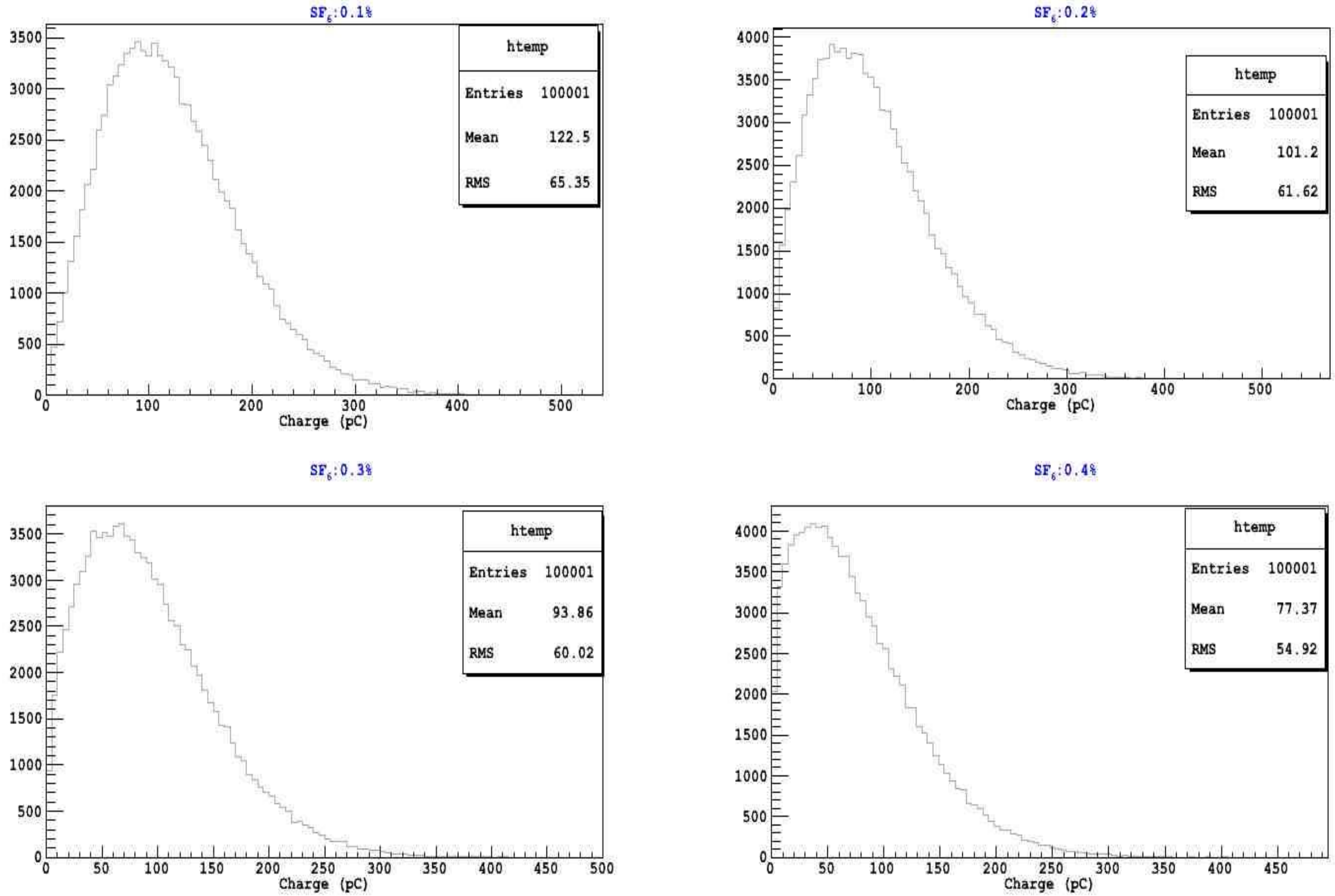
Fluctuations in the avalanche growth is taken care by the term, M_j which is obtained from the Polya distribution:

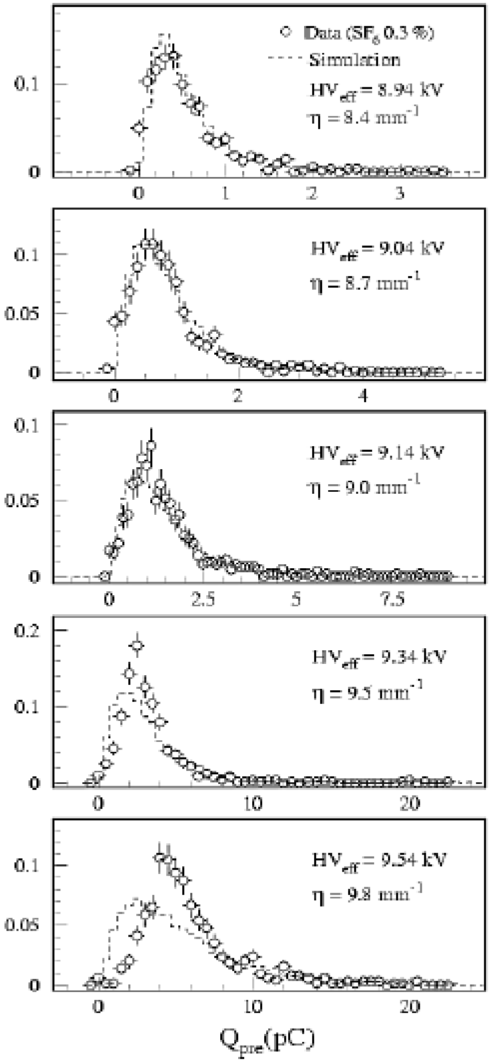
$$P_{Polya}(n) = \left\{ \frac{n}{N}(1+\kappa) \right\}^{\kappa} \exp\left\{ -\frac{n}{N}(1+\kappa) \right\}$$

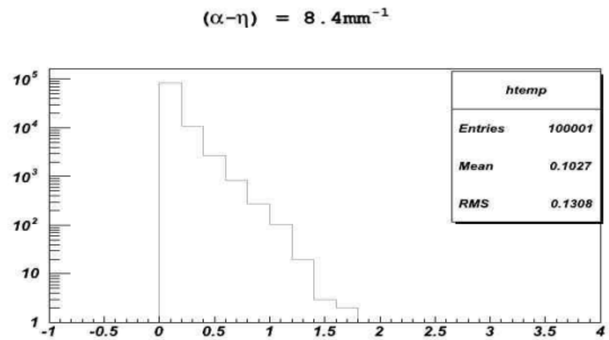
Simulated results (@3.6kV/mm)

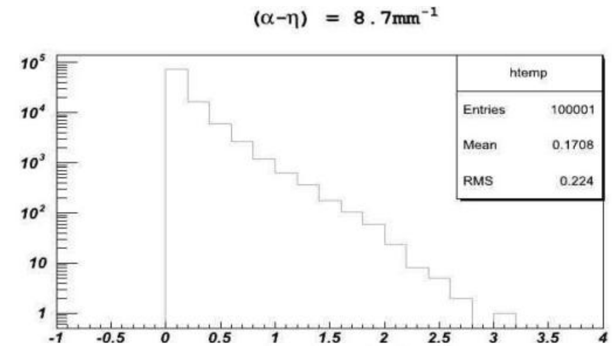


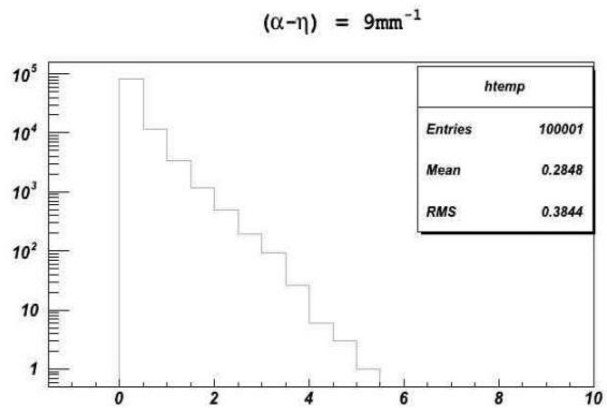
Simulated results (@5kV/mm)

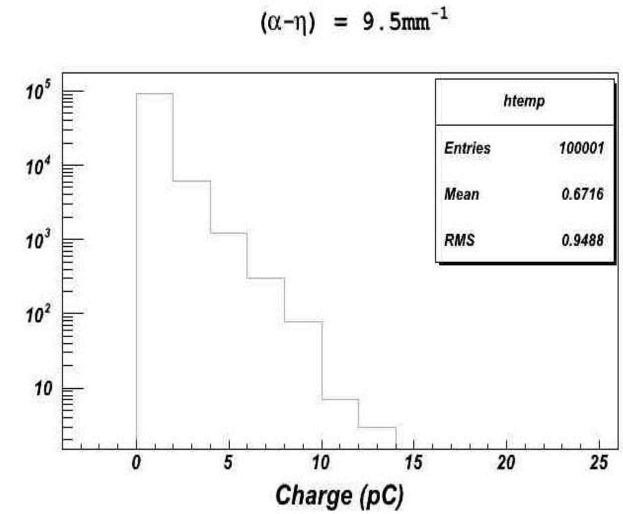


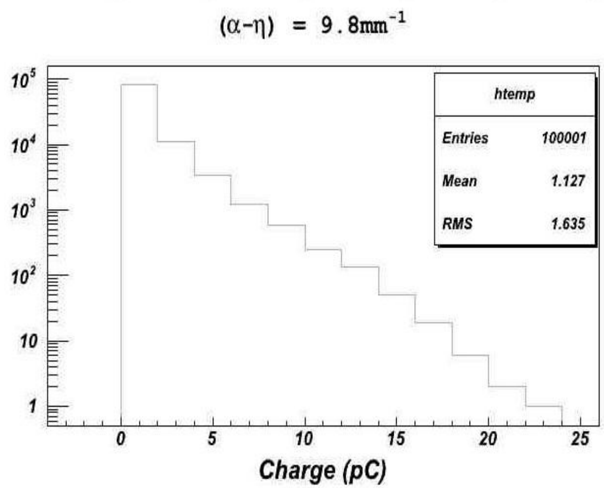












Dotted histograms are simulated by S.H.Ahn *et al.* [7]

Histograms are reproduced in these studies

Experimental Vs simulated results

SF_6 fraction (%)	With DAQ (pC)	With CRO (pC)	Simulated at 3.6kV/mm (fC)	Simulated at 5.0kV/mm (pC)
0.1	0.57	1.29	0.96	122.48
0.2	0.35	0.85	0.99	101.2
0.3	0.27	0.66	0.16	93.86
0.4	0.19	0.51	0.11	77.36

Conclusions and outlook

- Both experiment and model results follow the same trend. Charge induced on the pick-up electrodes of RPC decreases with increase in SF_6 concentration.
- Charge measured from experiment is in pico Columbs while the simulated charge is in femto Columbs (i.e. around 3 orders of magnitude smaller than the measured value).
- Why discrepancy in the order of charge?
  - Field is very low for the real RPC geometry which gives a low gas gain.
- The uncertainty in the electric field can arise from a small error in the geometry, effects of slight errors in the fabrication, error in the dielectric coefficient for the particular float glass we are using (needs to be measured).
- Slight error in the Townsend and attachment coefficients can result into significant deviations. This also needs to be looked into closely.
- We will look into all these factors as diligently as possible and try to improve our result and our understanding.

References

1. INO Project Report, INO/2006/01, May 2006.
2. P.Camarri *et al.*, NIMA 414 (1998), pp.317.
3. Igor Smirnov, HEED, Program to compute energy loss of fast particles in gases, Version 2.10, CERN.
4. S. Biagi, MAGBOLTZ, Program to compute gas transport parameters, Version 8.9.6, CERN.
5. N.Majumdar, S. Mukhopadhyay, NIMA 566 (2006), pp.489
6. S. Ramo, Proc. IRE 27 (1939), pp.584
7. S.H.Ahn *et al.*, JKPS Vol. 45, No.6, (2004), pp.1490

Thank you