RPC Development for INO-ICAL

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Overview

- About the India-based Neutrino Observatory
- INO-ICAL Experiment and its Goals
- ICAL detector
- RPC development for ICAL
- Summary

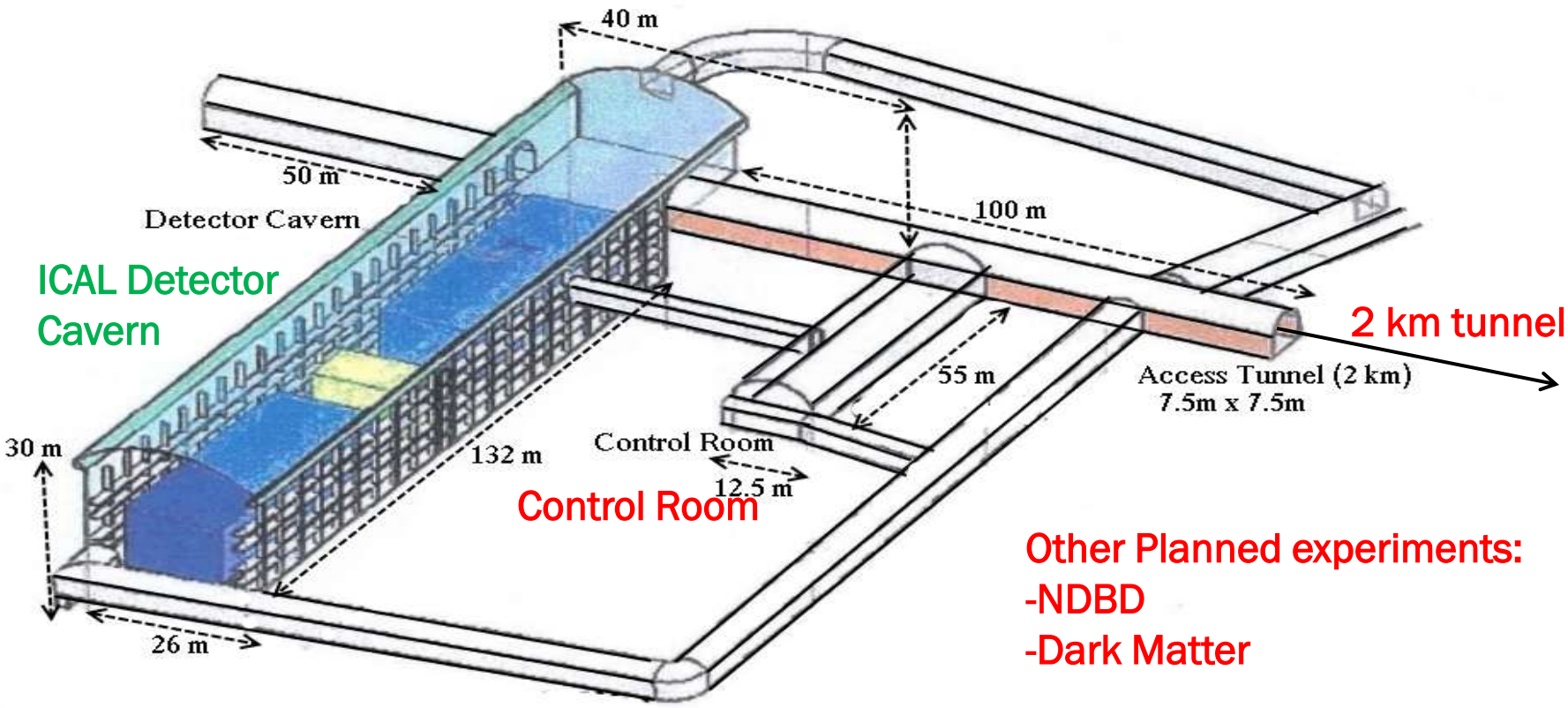
India-based Neutrino Observatory (INO)

- A mega science project of India (Cost: $ 300 M) with a national collaboration of over 20 institutions
- Primarily, a research lab for neutrino physics
  - construction of an underground laboratory and associated surface facilities,
  - construction of a Iron Calorimeter (ICAL) detector for neutrinos,
  - setting up of National Centre for High energy Physics (NCHEP)
- Site allotted and mandatory clearances received
- Project expected to be complete in 7 years

Site

Bodi west hills, Theni, Tamilnadu (South India)

Caverns for experiments



Other Planned experiments:
-NDBD
-Dark Matter

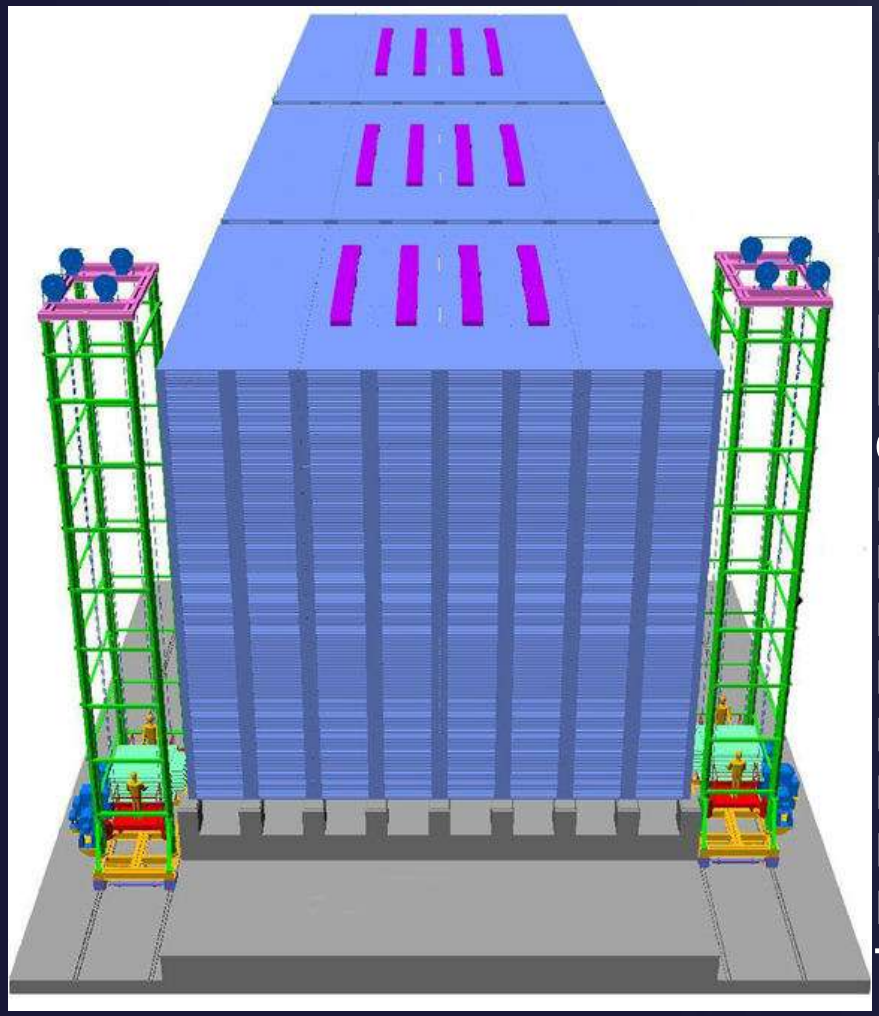
Main Physics Goals of INO-ICAL

- Reconfirmation with greater statistical significance the first oscillation dip in L/E of the atmospheric neutrinos, and measure precisely $|\Delta m^2_{32}|$ and $\sin^2 2\theta_{23}$
- Determine the sign of Δm^2_{32} and hence the neutrino mass hierarchy
- Distinguish $\nu_\mu \leftrightarrow \nu_\tau$ from $\nu_\mu \leftrightarrow \nu_s$ oscillation from muon-less events.
- Search for CPT violation

Detector Requirements

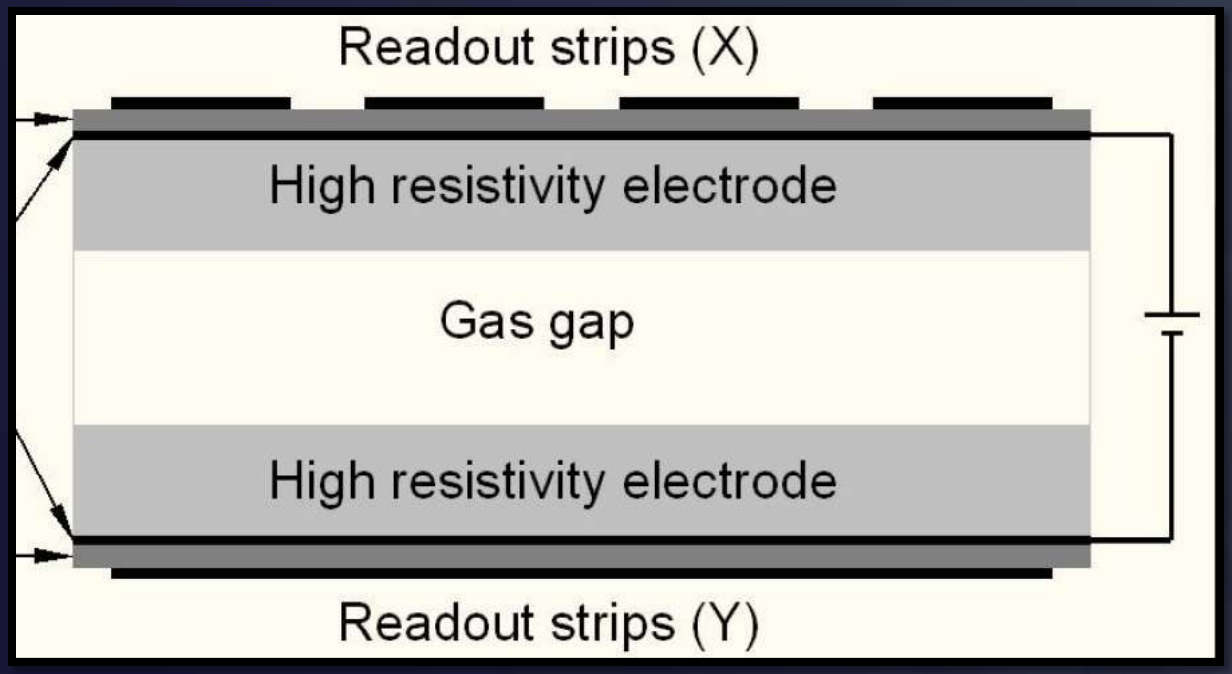
- Should have large target mass (50-100 kTons)
- Good tracking and energy resolution (tracking calorimeter)
- Good directionality (~1ns time resolution)
- Charge identification capability (magnetic field)
- Modularity and ease of construction
- Compliment capabilities of existing and proposed detectors
- Cost and time considerations
- Use magnetized iron as target mass and RPC as the active detector medium

ICAL Detector Parameters



No. of modules: 3
Module dimensions: 16m × 16m × 14.5m
Detector dimensions: 48.4m × 16m × 14.5m
No. of layers: 150
Iron plate thickness: 56mm
Gap for RPC trays :40mm
Magnetic field: 1.3 Tesla
RPC dimensions: 1,840mm × 1,840mm × 24mm
Readout strip pitch: 30mm
No. of RPCs/Road/Layer: 8
No. of Roads/Layer/Module: 8
No. of RPC units/Layer: 192
No. of RPC units: 28,800
No. of readout strips: 3,686,40
Total Mass: 50 kilo ton

Resistive Plate Chambers



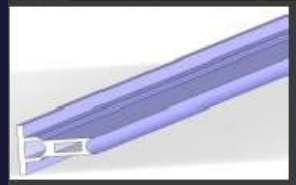
- Types of electrode (Glass and Bakelite)
- Modes of operation (Avalanche and Streamer)
- Types of construction (Single, double and multi gap)
- Types of application (Trigger and timing)

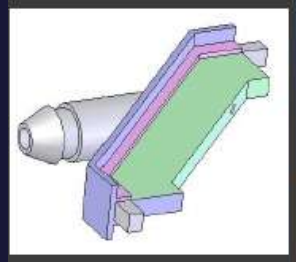
Tools Required for RPC Fabrication


Pickup panel


Paint plant


RPC Assembly jig






Gas system

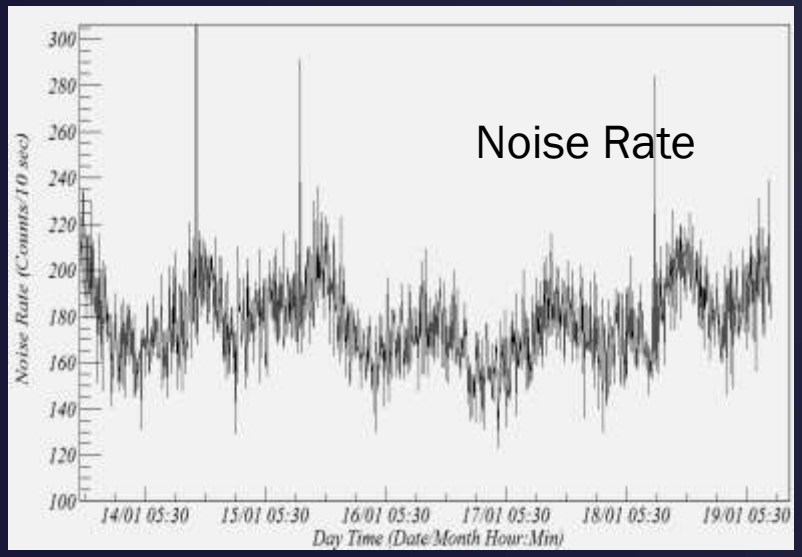
Fully assembled 1m × 1m RPC

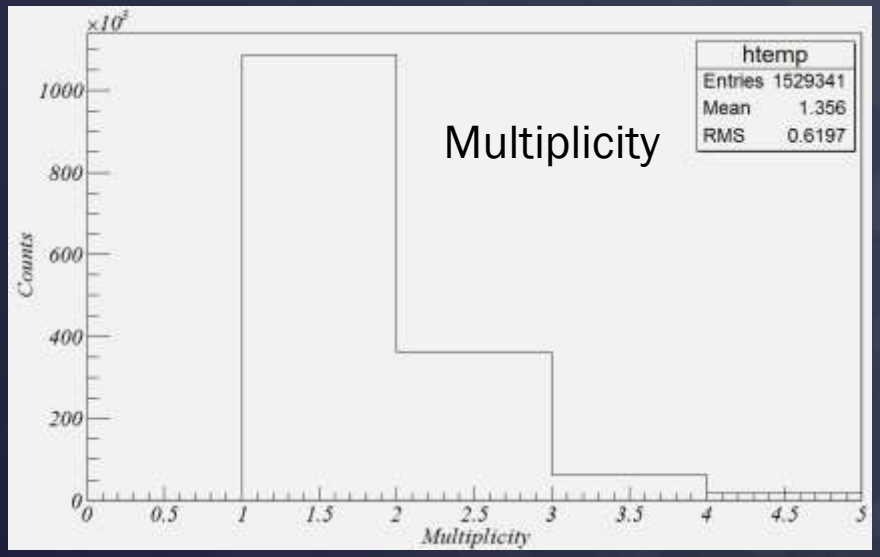
RPC R&D for INO: Prototype 1 (TIFR)

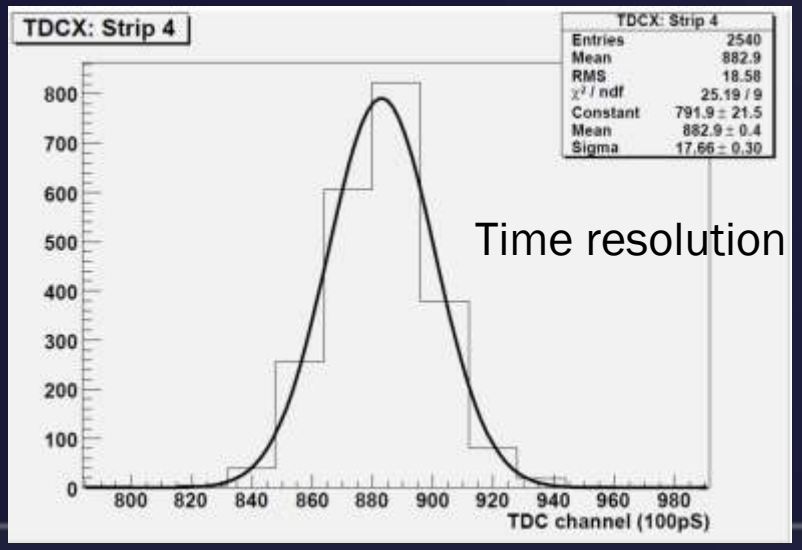
- 12 Glass RPC Layers [1m x 1m]
- 32 Strips per Plane
- 24 x 7 Cosmic Muon Tracking and Noise Rate Monitoring

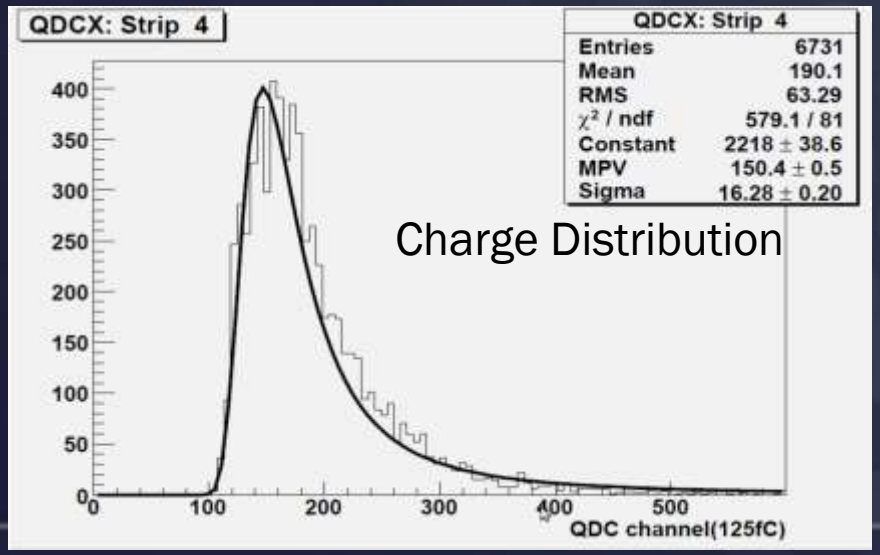
- Device level studies: Stability, Efficiency, Aging
- Electronics development
- Daq Development
- Gas System Development
- Other studies:
  - Zenith angle distribution of muons
  - muon directionality (up/down)
  - Sealed RPC studies

Basic studies on RPC Parameters

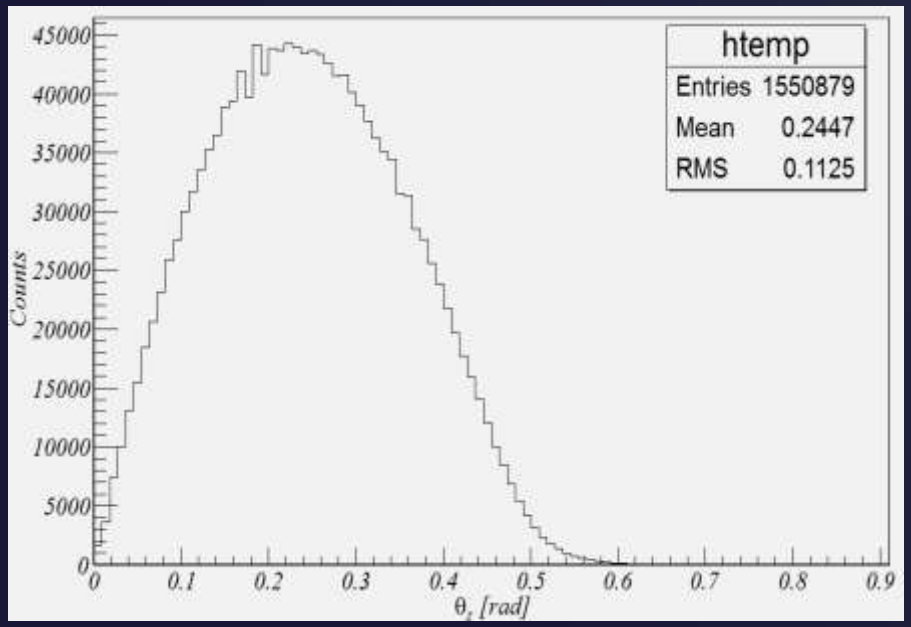




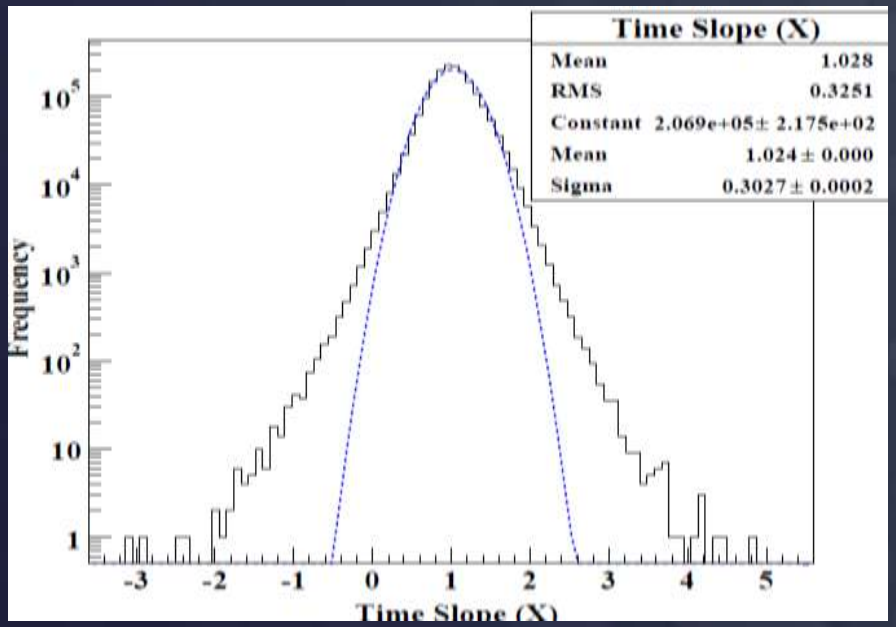




Other Studies

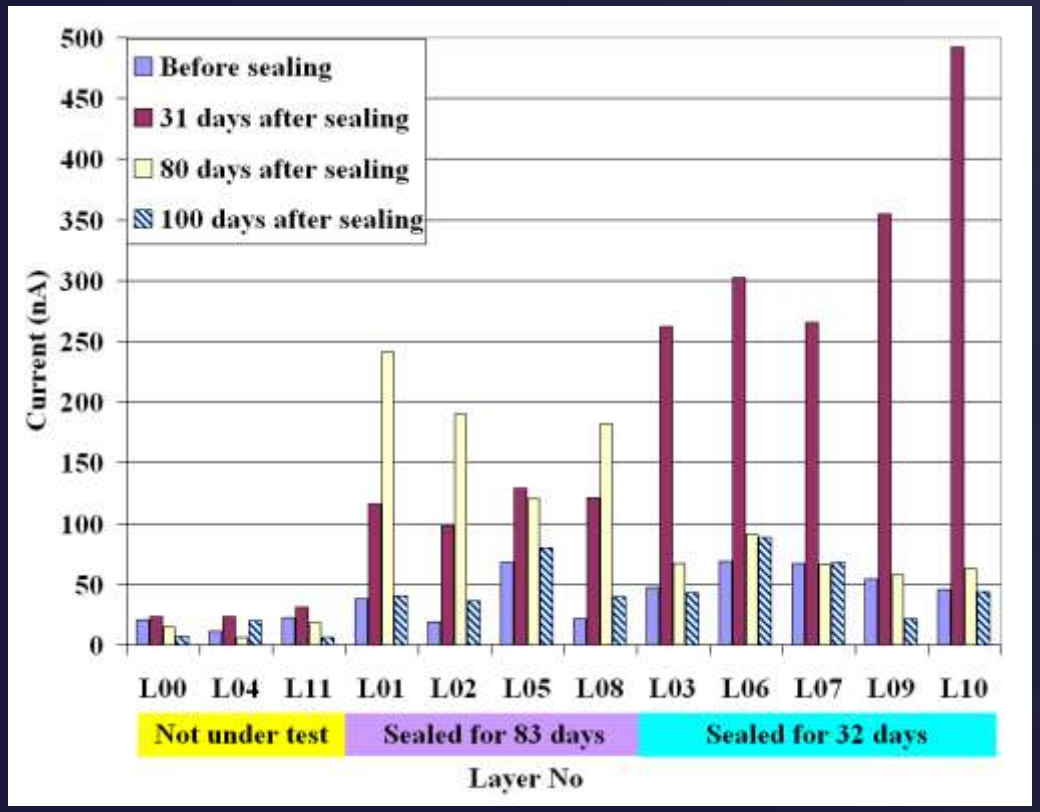


Zenith Angle Distribution



Directionality of muons

Sealed RPC Studies



- RPCs Gas inlet sealed
- Noise Rate, Current , Efficiency etc., monitored
- Encouraging results:
  - Satisfactory operation for 30 days without gas change
  - RPCs operation return to normalcy after gas change

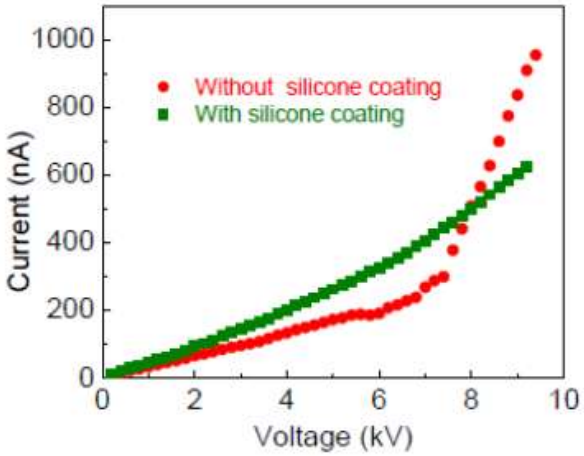
RPC: Device Level Simulation

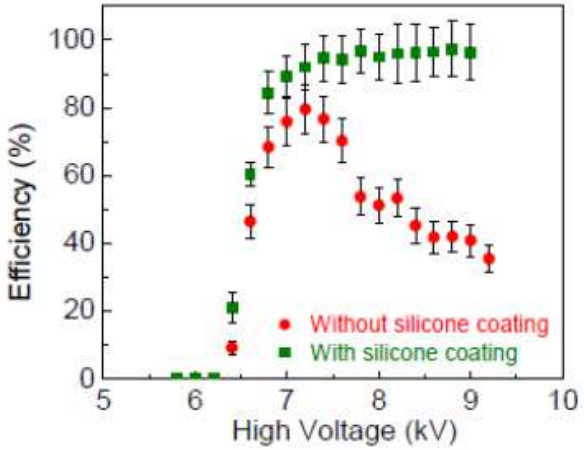
- HEED (Primary interactions in Gas Volume)
- MAGBOLTZ (electron transport)
- neBEM (Weighting Field / Electric Field)
- Ramo’s Theorem (induced signal)
- Current study: Comparison of effect of SF6 in signal development with experimental data

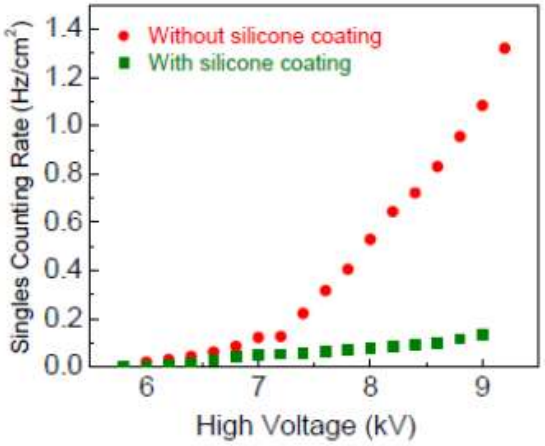
Bakelite RPC Development

- Groups involved: SINP & VECC
- The inner surfaces of the bakelite are coated with siliocone to make the surface smooth
- Efficiency plateau over 96% obtained with reduced noise rate and long term stability
- INO –ICAL experiment being modular in size, can use both glass as well as bakelite RPCs

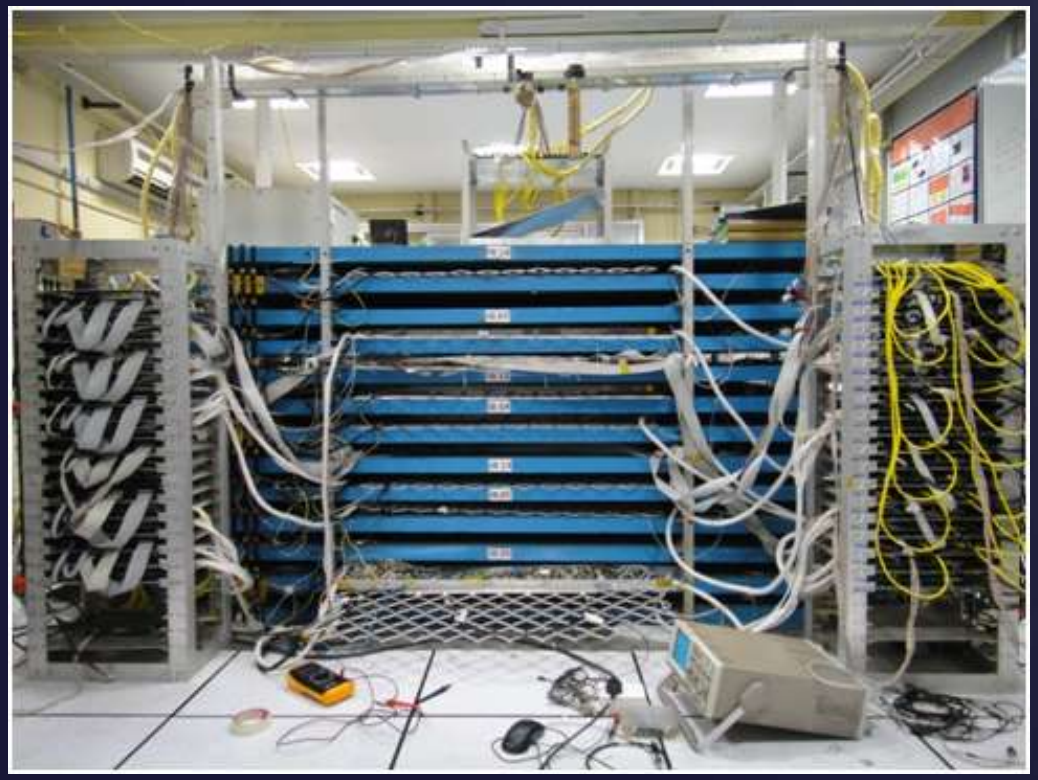
Effect of Silicone Coating:







RPC R&D for INO: Prototype 2 (VECC)



12 1m x 1m RPCs

- 4-Bakelite

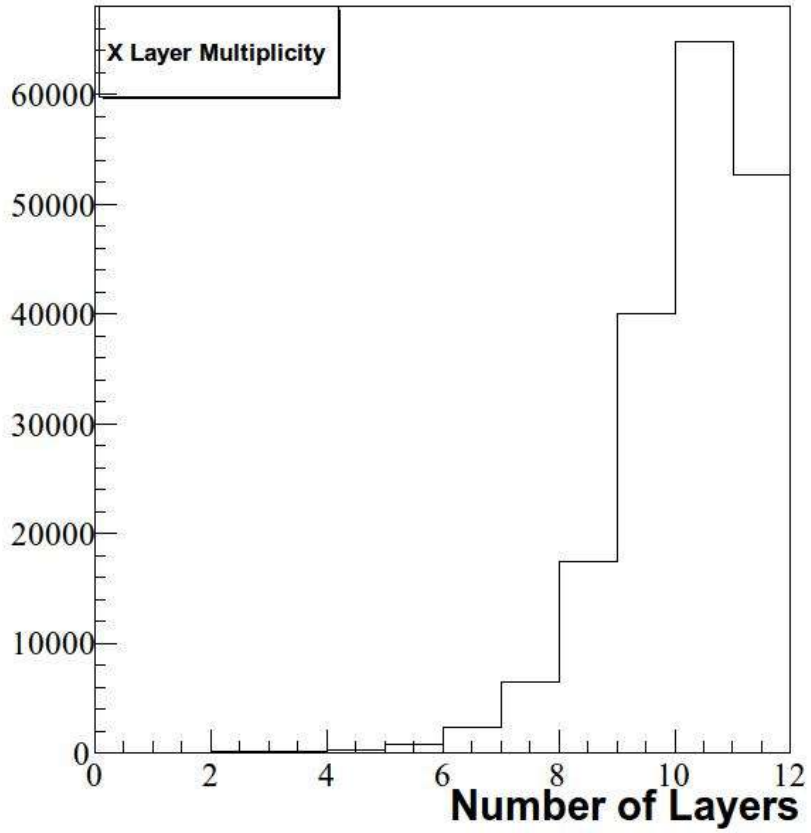
13 Iron Plates

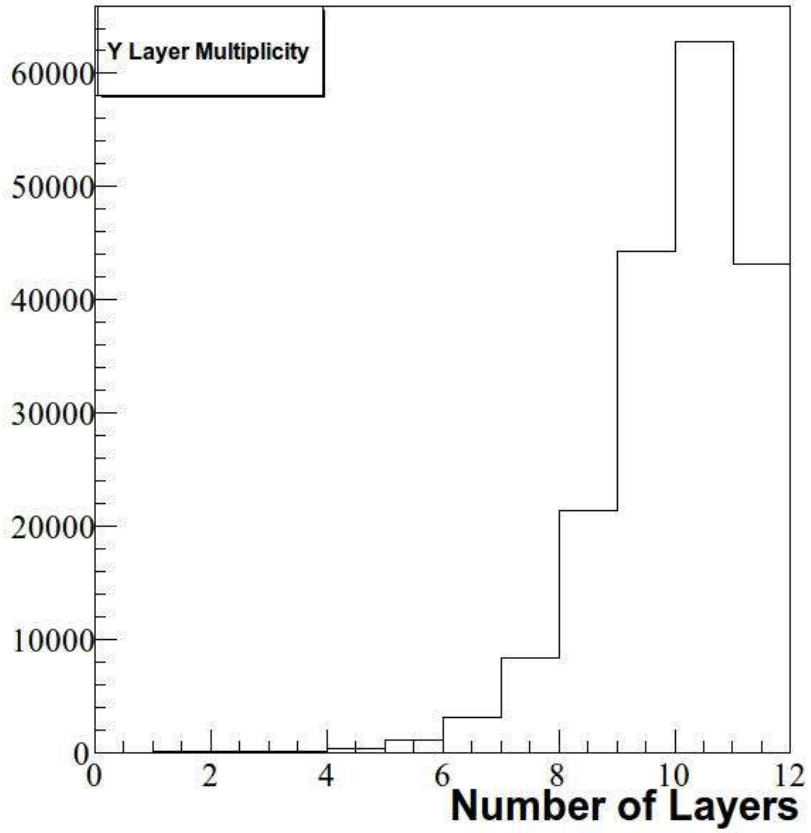
- ~ 5 cm Thickness

4 Coils, 5 turns each

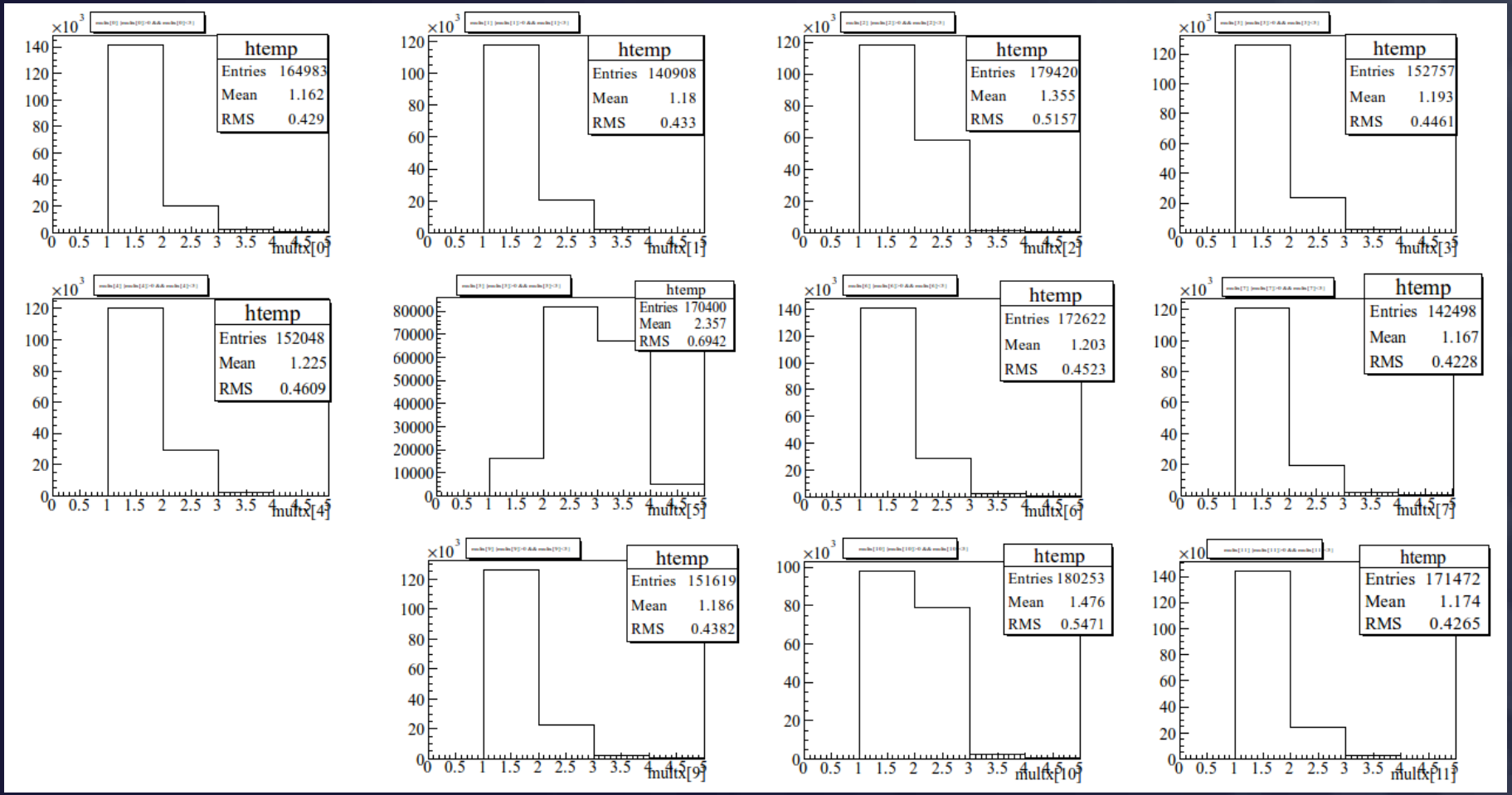
- 1.5 T Max
- Field along Y

Cosmic Muon Studies with VECC Prototype





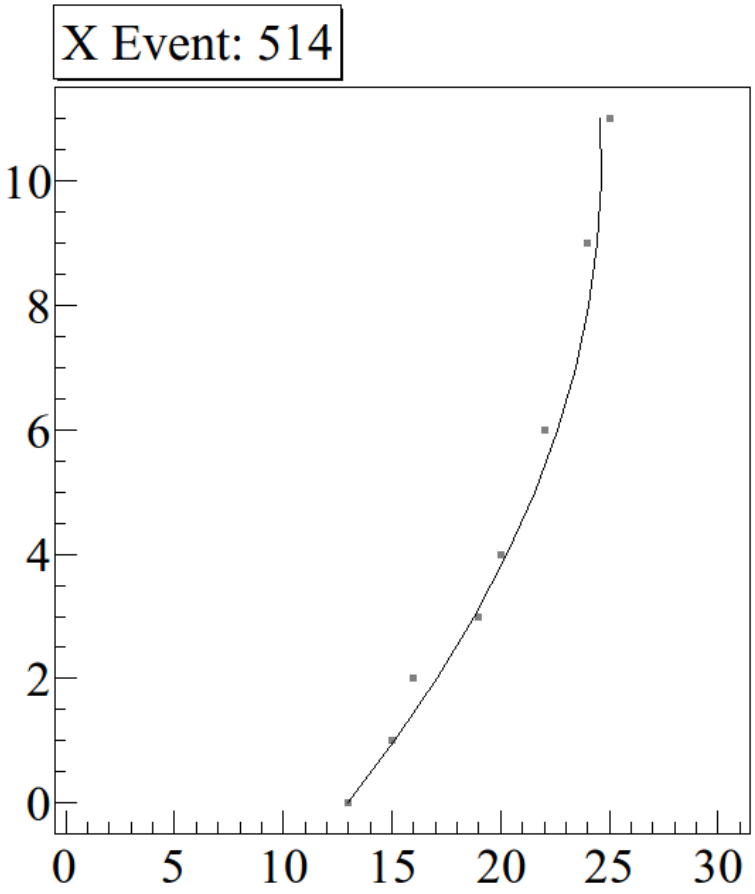
Cosmic Muon Studies with VECC Prototype

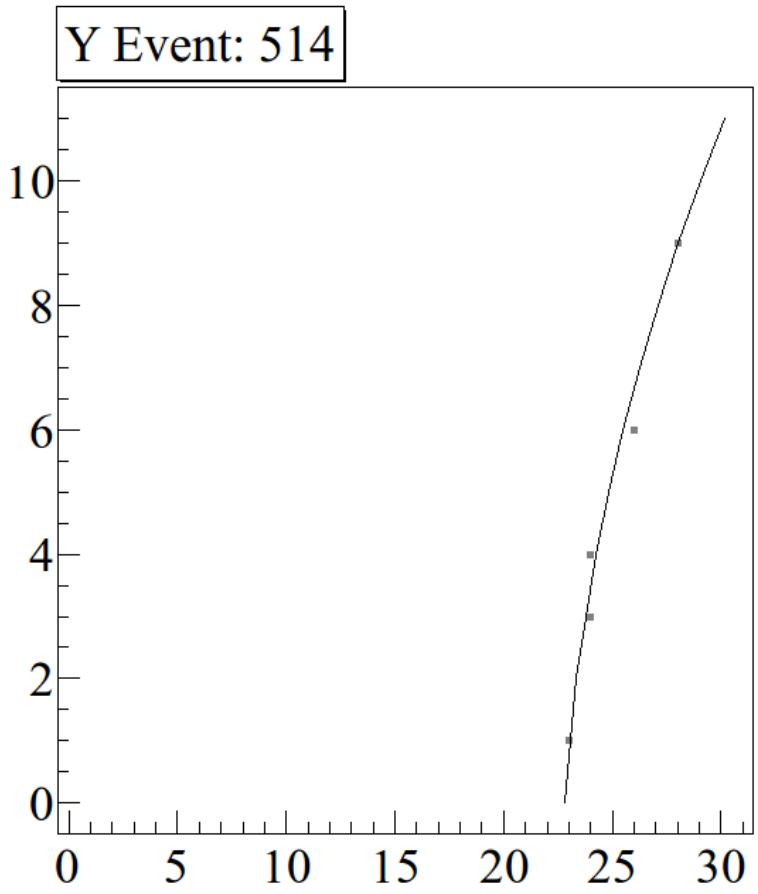


Data Analysis with VECC Prototype Data

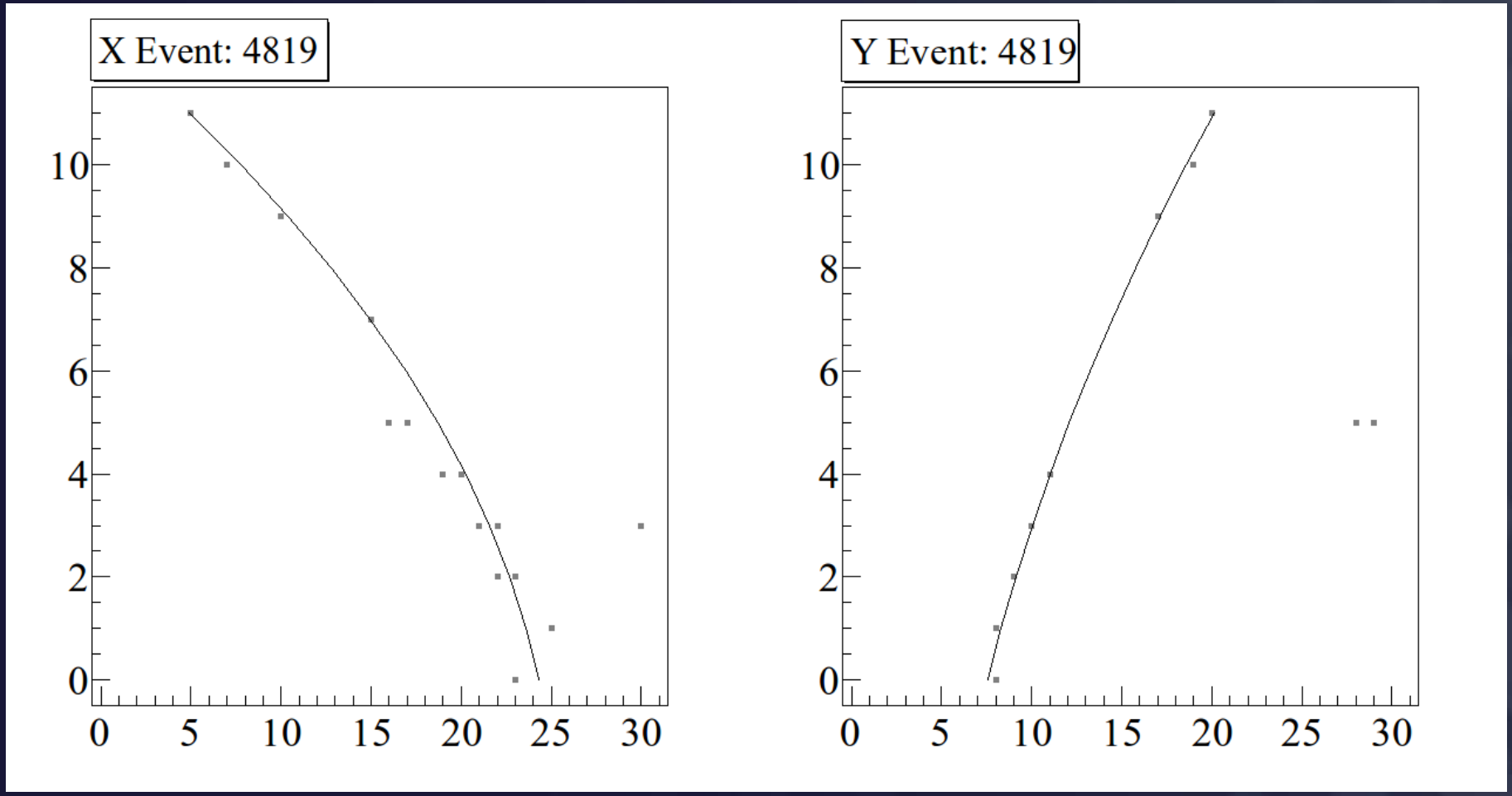
- 2011: proper data taking for almost 3 months
- Magnet Testing, Stabilizations
- Data taken with magnetic field could not be analyzed:
  - No ready made track fitting code available
  - Only noise rate and simple analysis was possible
- First Step:
  - Fitting with a second order polynomial:
  - $A+Bx+Cx^2$

Glimpses of curved tracks

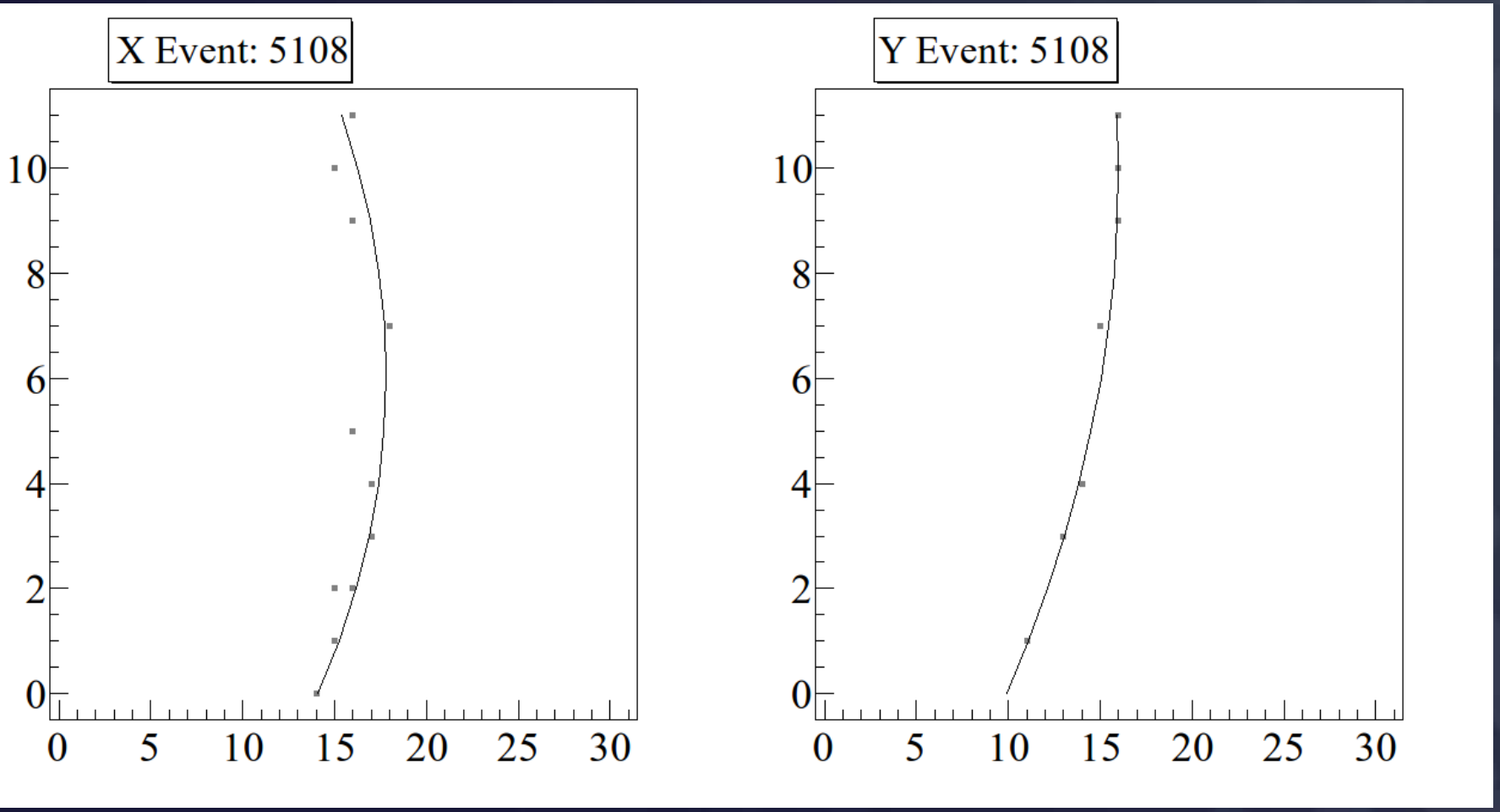




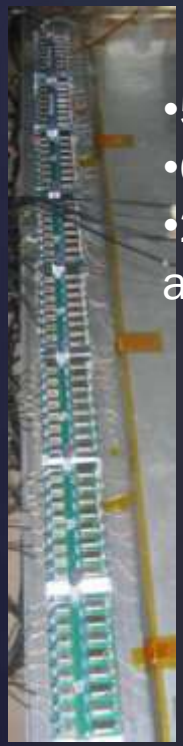
Glimpses of curved tracks



Glimpses of curved tracks



The 2m x 2m prototype at TIFR



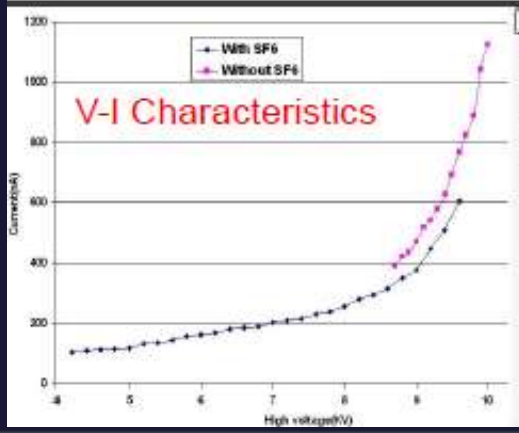
- 5 Glass RPC Layers [2m x 2m]
- 64 Strips per Plane
- 24 x 7 Cosmic Muon Tracking and Noise Rate Monitoring

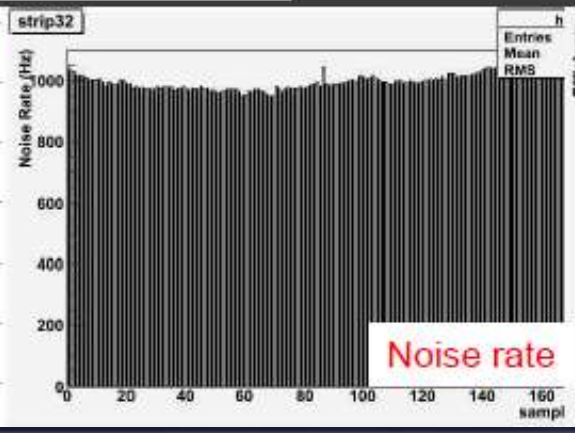
2m x 2m prototype: R&D and Studies

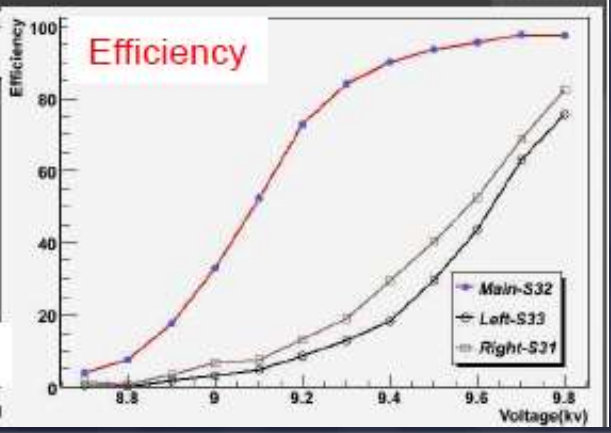

RPC fabrication stand


RPC test stand

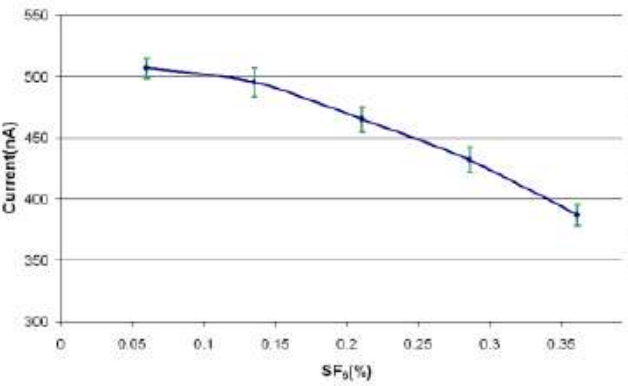
Basic characterisation of 2m × 2m RPCs



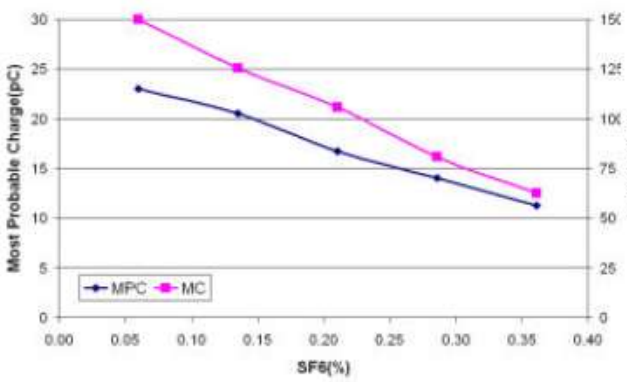




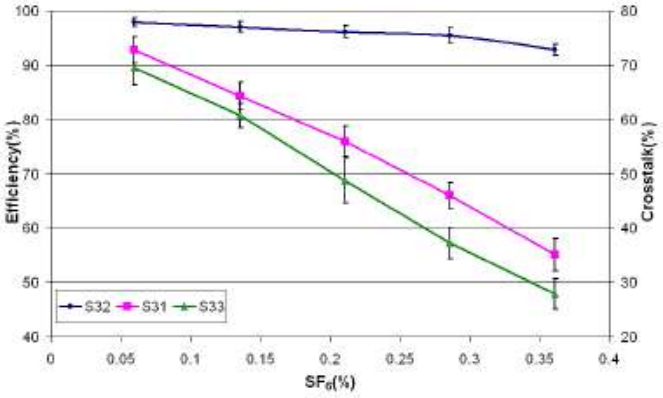
SF6 studies on RPC parameters



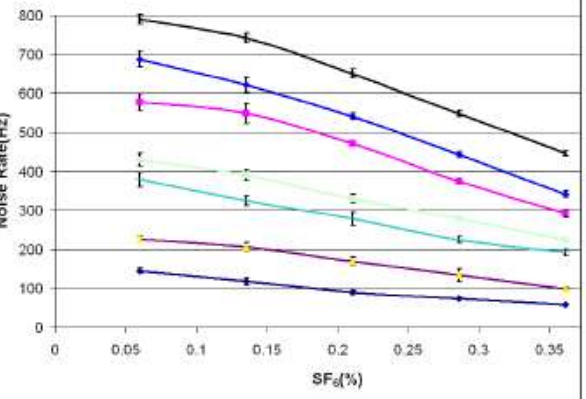
Chamber current



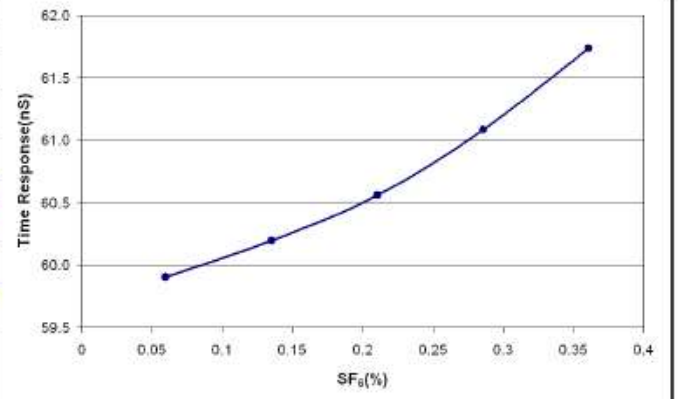
Signal charge



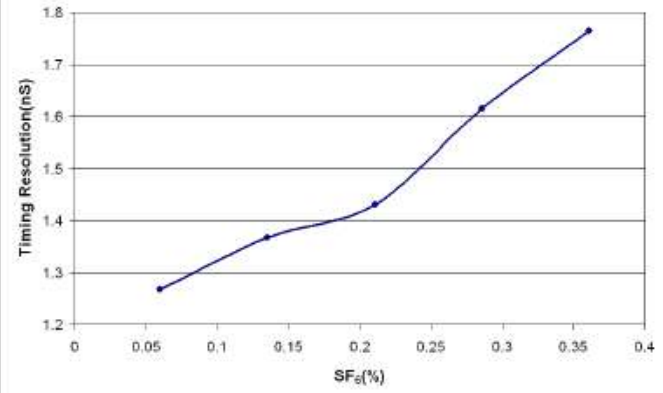
Efficiency



Noise rate



Time response



Time resolution

Industrialization: Glass Factory

Industrialization: Glass handling

Industrialization: Glass Storage

Industrialization: Glass Movement Trolley

Industrialization: Glass Vacuum Lifter

SCREEN PRINTING MACHINE

Name: Fully Automatic Glass Screen Printing Machine

Description: Working process: glass automatic pre-orientation conveying precise orientation printing detection and glass unloading conveying dryer (connective and fully automatic).

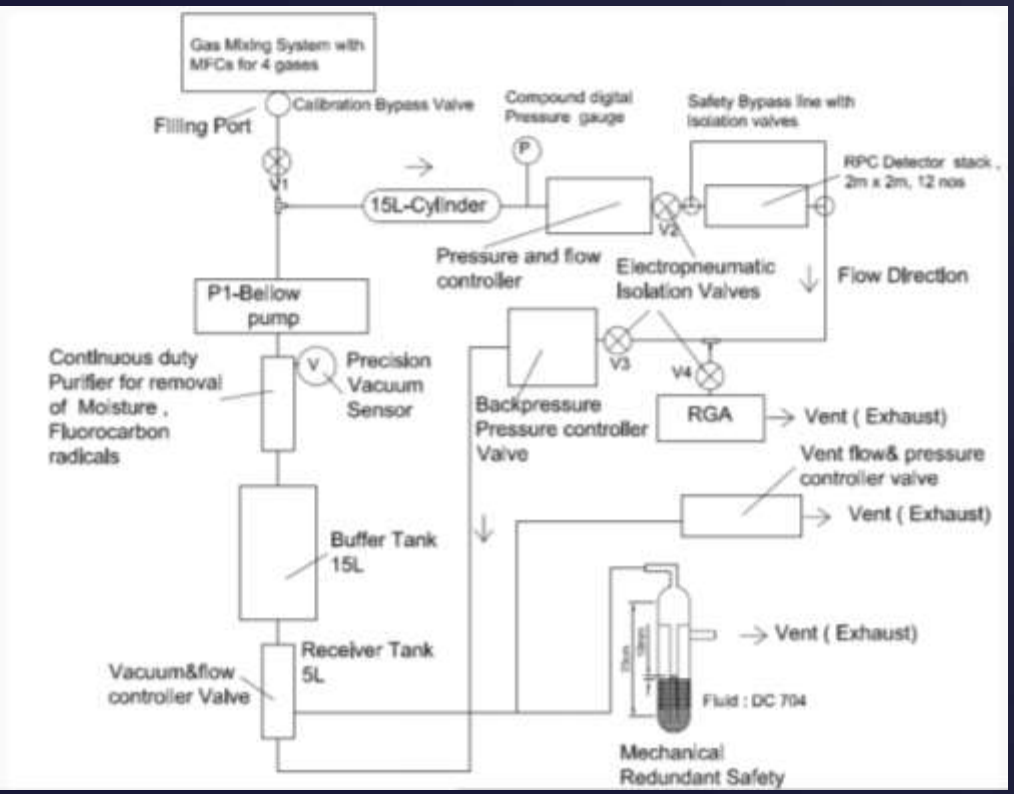
Special orientation system is very suitable for complex shapes of printing substrates such as the front and rear sector glass of automobiles. And the orientation precision is about ±0.5mm.

Due to easy scratched features of some printing substrates, we take the special treatment for the working table to prevent the printing substrates from scratching and make the table resistant to abrasion.

Machine is equipped with Japan MITSUBISHI PLC working system, friendly touch-on control panel, position adjusting system with high precision display function, error alarming system and photo electric protection device.

Industrialization: Robot for Button placing and Gluing

Gas Recirculation System



- 4 channel gas mixing module (filling/top-up of Iso-butane, Freon R134A, Argon and SF6
- Pressure balance system to maintain and control pressure within safe limits
- Total Capacity: 140 l
- Continuous duty gas purification system to remove moisture, and other radicals
- Contamination removal upto 2ppm.
- Dynamic pressure loss: Not more than 80 mbar

Summary

- Successful fabrication and characterization of large area RPCs required for INO's ICAL experiment
- Detector R&D almost completed
- Consultancy with industries in progress
- Industries are to convert lab scale work done so far to industrial scale
- Pilot production orders have been placed already and executed successfully
- Considering the amount of work to be done at least 6-8 industries have to be approached so that the work is shared and spread out.