Resistive Plate Chambers for Experiments at India-based Neutrino Observatory(INO)

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INO Collaboration

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Collaborating institutions/universities

AMU, BHU, BARC, CU, DU, HRI, UoH, HPU, IITB, IITKh, IGCAR, IMSC, IOP, LU, NBU, PU, PRL, SINP, SMIT, TIFR, VECC

Plan

- Physics motivations for INO
- India-based Neutrino Observatory (INO)
- INO Detector (ICAL)
- Resistive plate chamber (RPC) for ICAL
- Test results
- Future Plans

Physics Motivations for INO

- To reconfirm the oscillation through appearance and disappearance of neutrinos.
- To measure the neutrino oscillation parameters $| \ m^2_{31} |$, $\sin^2 2\theta_{23}$, θ_{13} more precisely.
- To determine neutrino mass hierarchy, whether normal ($m^2_3 > m^2_1$) or inverted ($m^2_3 < m^2_1$).

India-based Neutrino Observatory (INO)

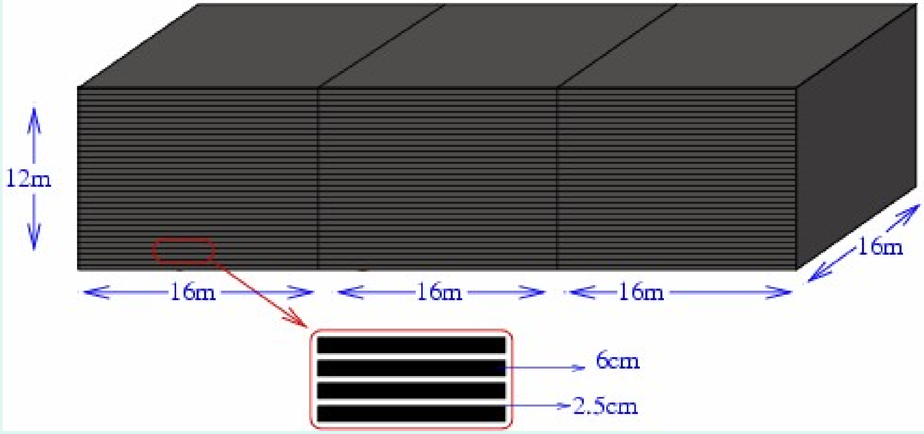
- A underground facility at PUSHEP in Nilgiri Mountains in South India, about 90 km from Mysore.
- A single 22 m wide, 120 m long and 30 m in height experimental hall will be constructed at the end of a 1.5 km long tunnel.
- At least 1 km of rock overburden in all directions.
- INO will have 50 kiloton Iron CALorimeter (ICAL) capable of detecting atmospheric ν_μ/ $\bar{\nu}_\mu$ interactions.
- May also host some other experiments (e.g neutrinoless double beta decay searches) which require low cosmic ray background environment.

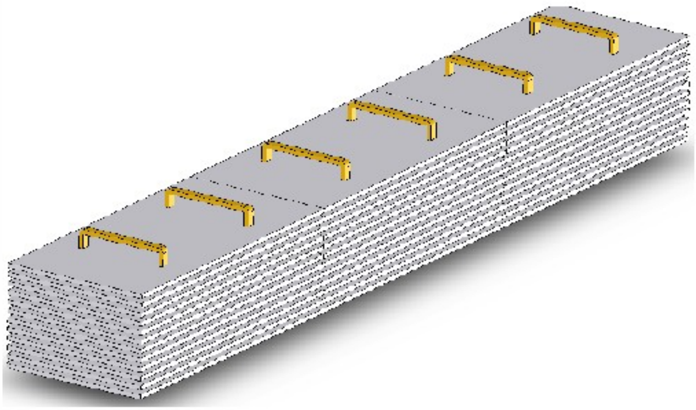
INO Detector :

A Magnetized Iron CALorimeter (ICAL):

- Three modules, each of the size $16m \times 16m \times 12m$ and of mass 17 kilotons.
- In each module 140 layers of iron plates and RPCs.
- 6 cm thick iron plates separated by 2.5 cm, with Resistive Plate Chambers (RPCs) as active element.
- Total mass of 51 kilotons.
- The cavern can accommodate another replica of the above detector so that if necessary, a 100 kiloton mass detector can be constructed.
- Magnetic field ~1 Tesla allows the determination of muon charge so that ν_μ and $\bar{\nu}_\mu$ can be studied separately.

Iron CALorimeter
(A detector for INO)





Mass : 51 kilo ton (or 100 kilo ton)

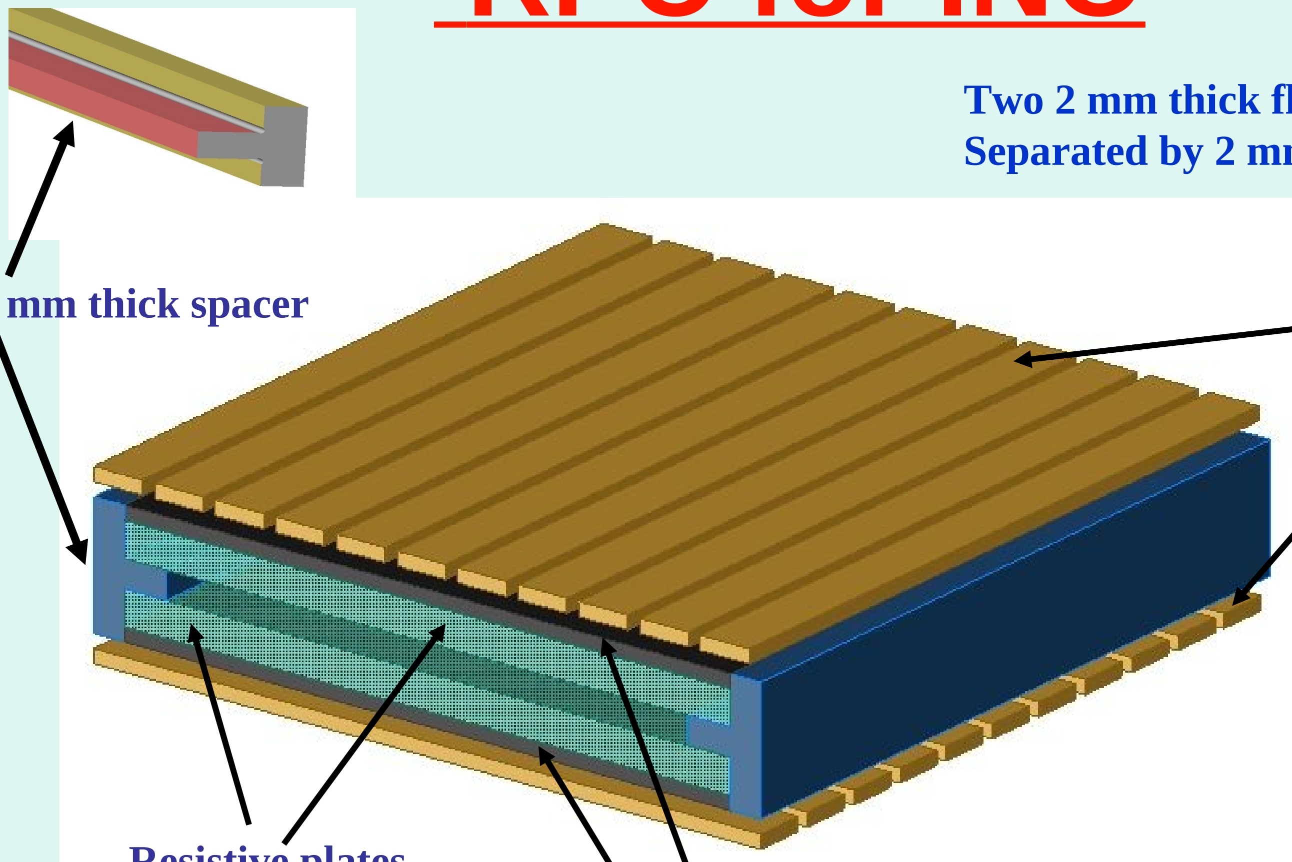
Magnetic field ~ 1 Tesla

Dimension : 48m × 16m × 12m

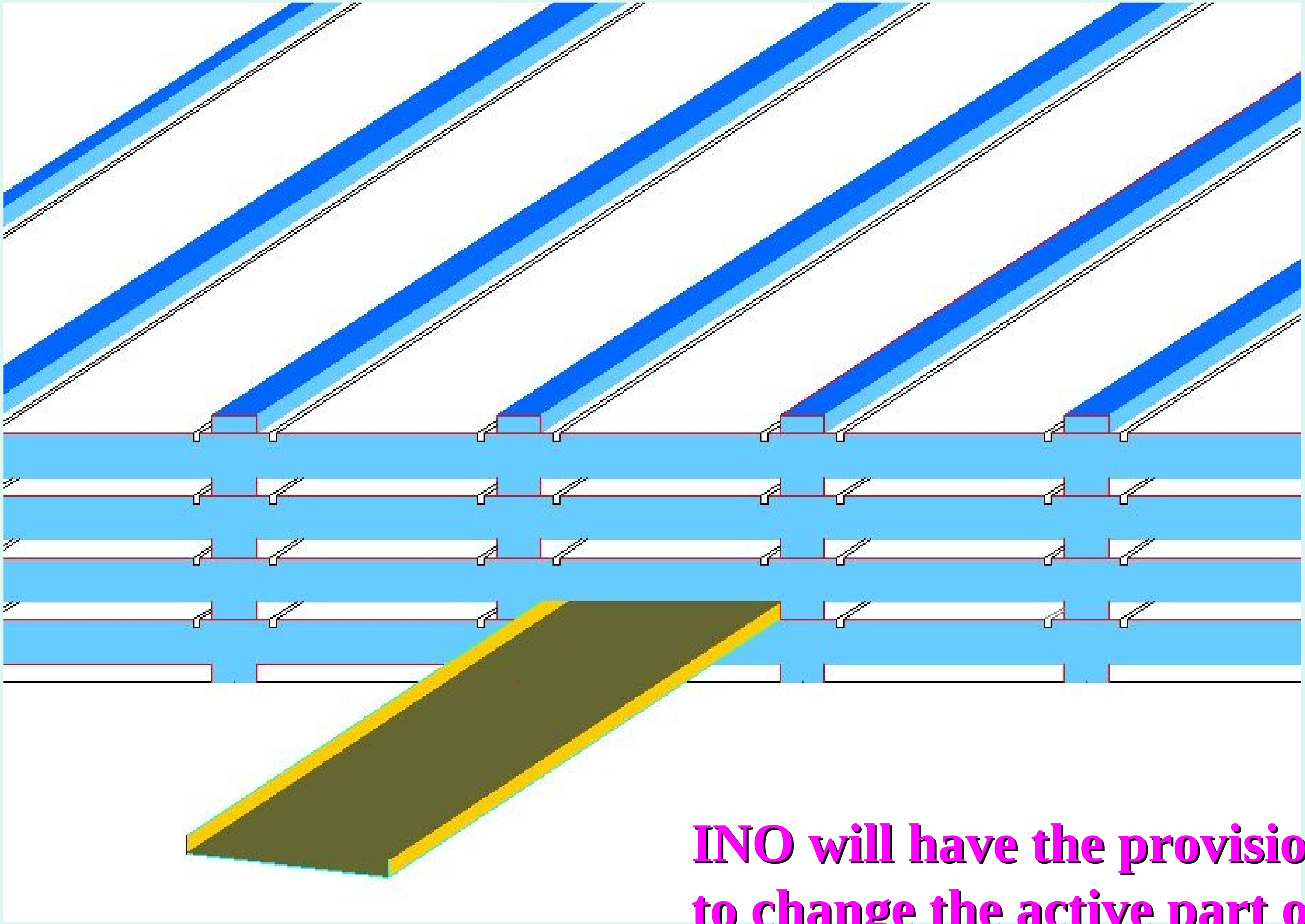
140 layers of iron plates

RPC for INO

Two 2 mm thick float Glass
Separated by 2 mm spacer



Complete RPC



INO will have the provision to change the active part of the detector.

Why RPC ?

- Built from simple and common materials.
- Low fabrication cost per unit area.
- Easy to construct and operate.
- Simple signal pick up and readout system.
- Large detector area coverage .
- High efficiency (>90%) and time resolution (~1ns).
- Particle tracking capability.

  Two dimensional (x and y) readout from the same chamber.
- Long term stability.

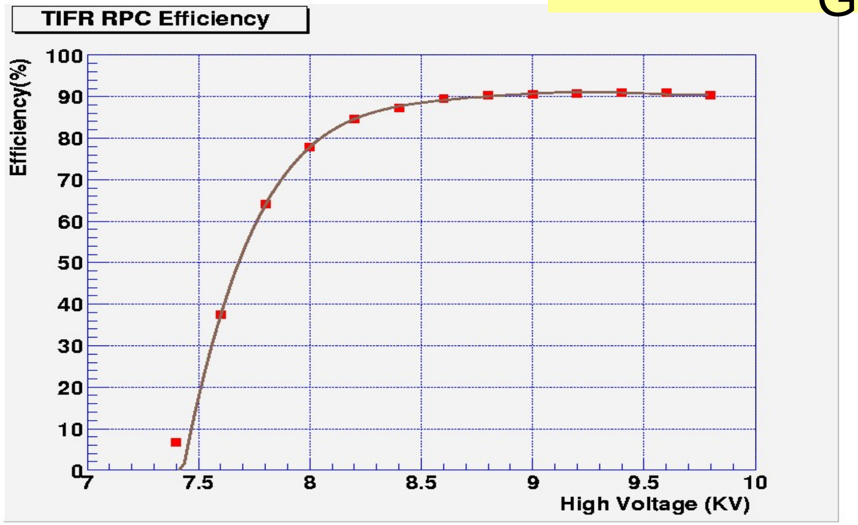
Resistive Plate Chamber (RPC) in INO

- RPC unit dimension : 2 m x 2 m
- RPC width : 6 mm
- Pick up strip width : 3 cm
- No. of RPC units / Road / Layer : 8
- No. of Roads / Layer / Module : 8
- No. of RPC units / Layer : 192
- Total no. of RPC units : ~26000

Test results of glass RPC

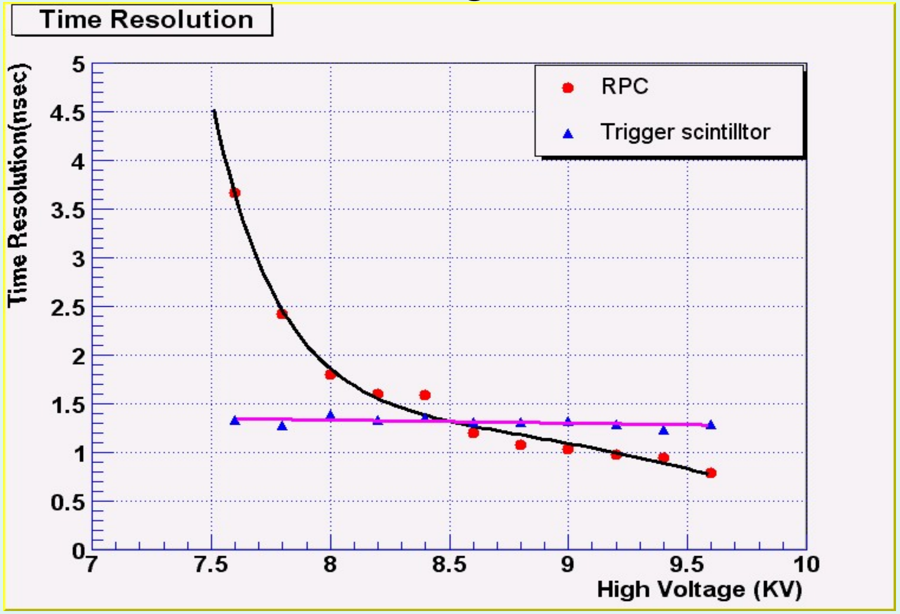
- Glass RPC s have been tested both in streamer and avalanche mode.
- 2 RPCs 30cm x 40cm are tested in avalanche mode for >14 months.
- Aging problem still not solved for glass RPCs in streamer mode.

Glass RPC Efficiency



Freon 134a : 62%
Argon : 30%
Isobutane : 8%

RPC Timing Studies



Why Bakelite RPC ?

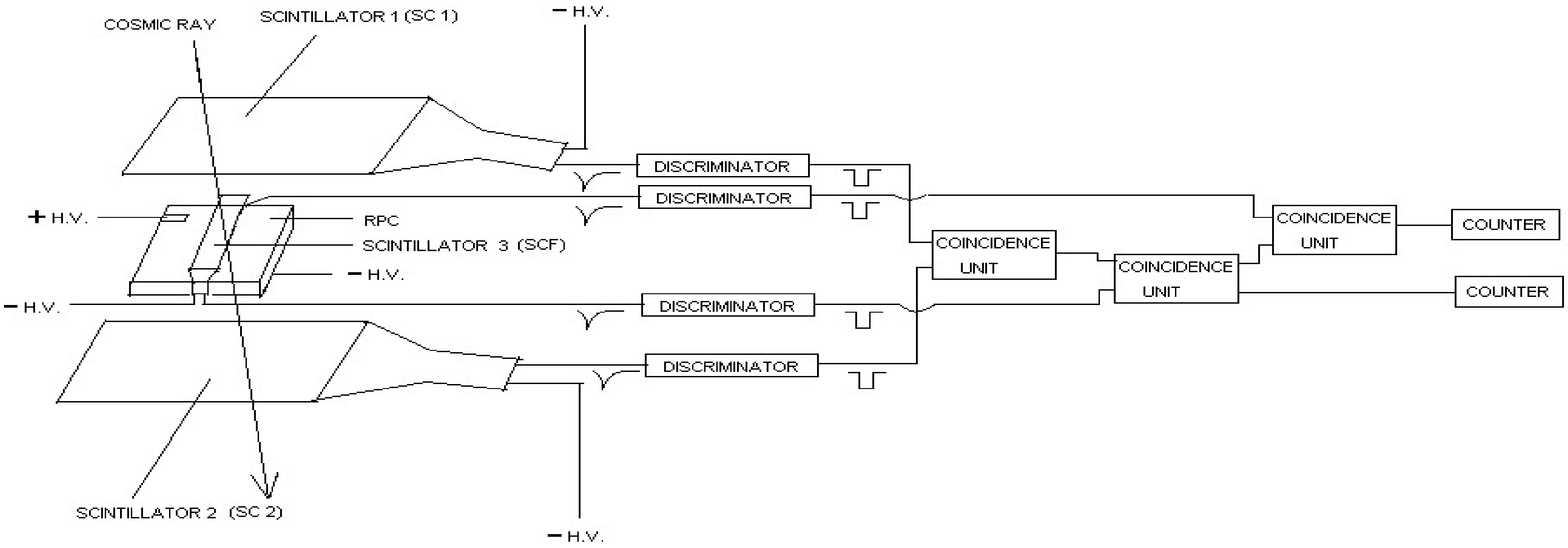
- Surface smoothness of glossy-finish melamine coated bakelite sheet is comparable to glass.
- Bakelite sheet is more flexible than glass and it is unbreakable.
- Bakelite sheet can be made 1.2 m in width and any size in length.
- Bulk resistivity of bakelite can be controlled adjusting the ratio of the phenol and melamine.

Bakelite RPC

- This RPC brought from China and tested in SINP.
- Dimension of the RPC : 30cm × 30cm.
- Thickness of each plate : 2mm
- Gas gap between two plates : 2mm
- Width of each pick up strip 3cm

High voltage testing of Bakelite RPC using Cosmic Ray at SINP/VECC

Arrangement of the scintillators and the RPC in SINP



Schematic representation of cosmic ray setup

Experimental setup

- Dimension of the RPC : 30cm × 30cm
- Width of the pick up strip : 3cm
- Dimension of the big scintillators (SC1 & SC2) : 25cm × 35cm
- Dimension of the finger scintillator (SCF) : 4cm × 20cm & 2cm × 20cm

- Trigger signal = SC1 .AND. SC2 .AND. SCF

- Efficiency = $\dfrac{\text{(RPC count with signal in coincidence with trigger)}}{\text{(Trigger count)}}$

Power supply and the read out system

- RPC s are operated in premixed mode.
- There is the provision to use it in flow mode using Mass Flow Controller (MFC).

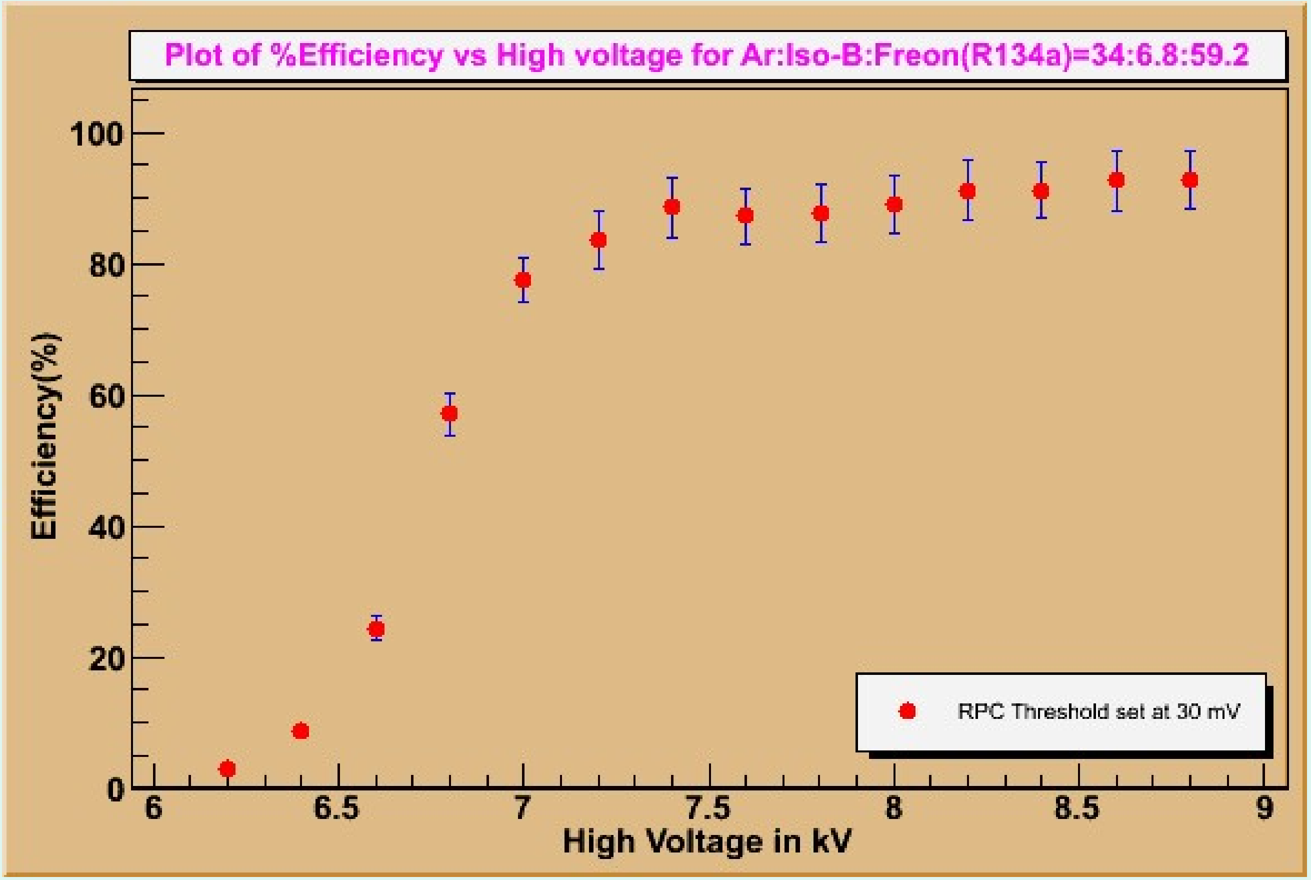
Gas mixing control panel in SINP

Gas Mixture

- Argon : To provide the efficient gas amplification.
- Isobutane : To absorb UV photon. It is the “photon quench gas”
- Freon (R134a) : To control charge and physical size of streamer. It is the “electron quench gas”.

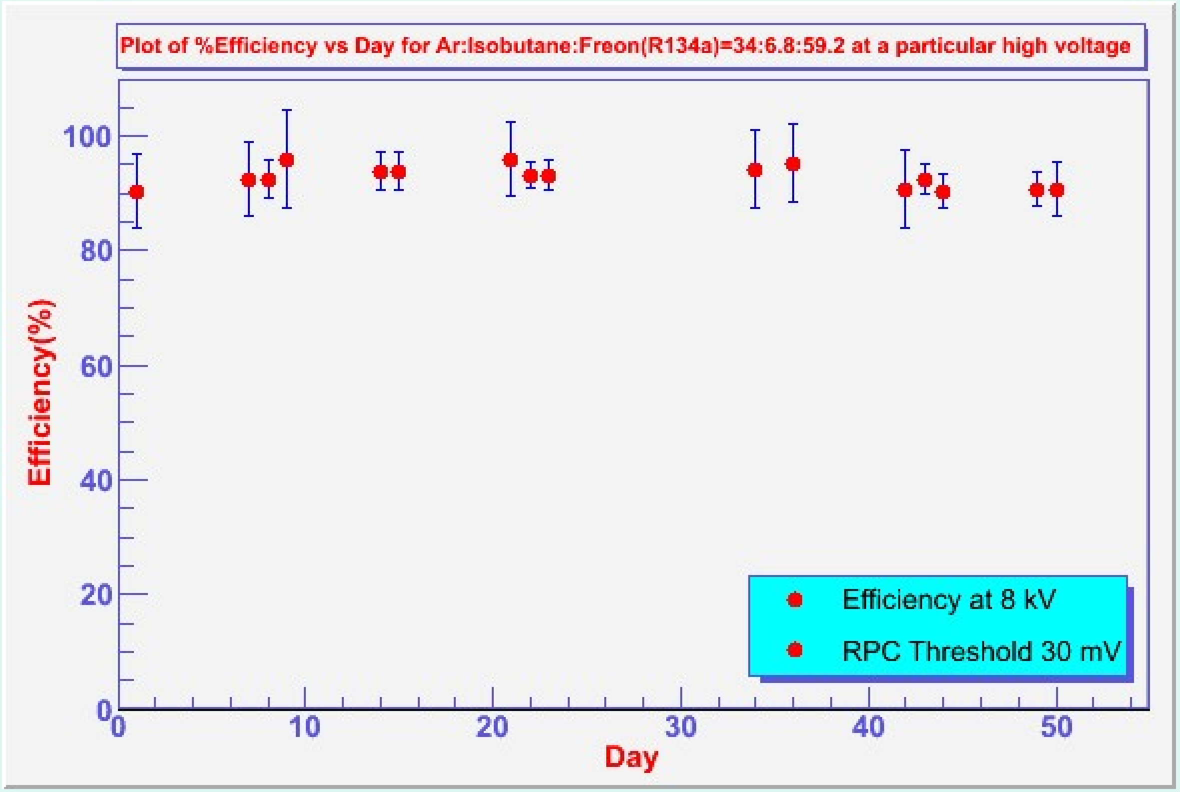
Test result of Chinese RPC

Efficiency curve for RPC



- The Trigger rate is around 0.31/cm^2/min.
- Plateau region has been found from voltage 7.5 KV onwards at efficiency 91% .

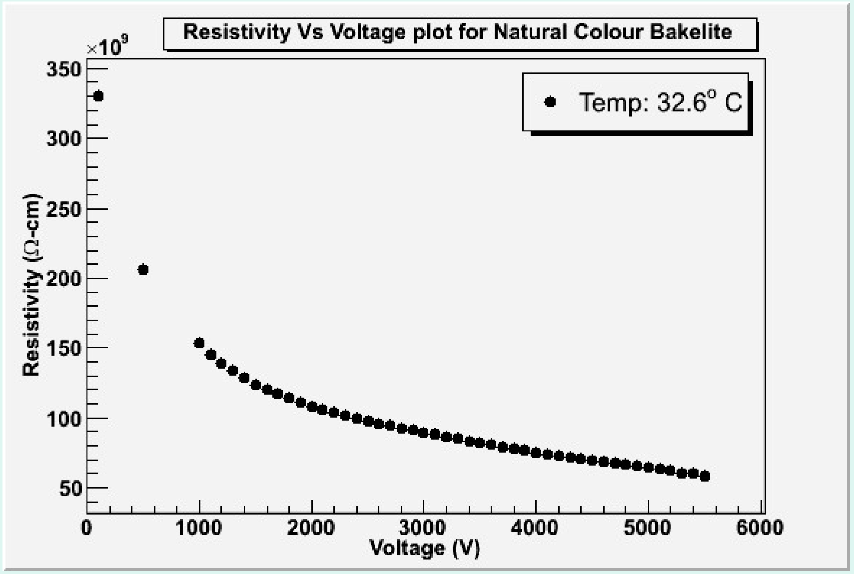
Test of stability for Chinese RPC



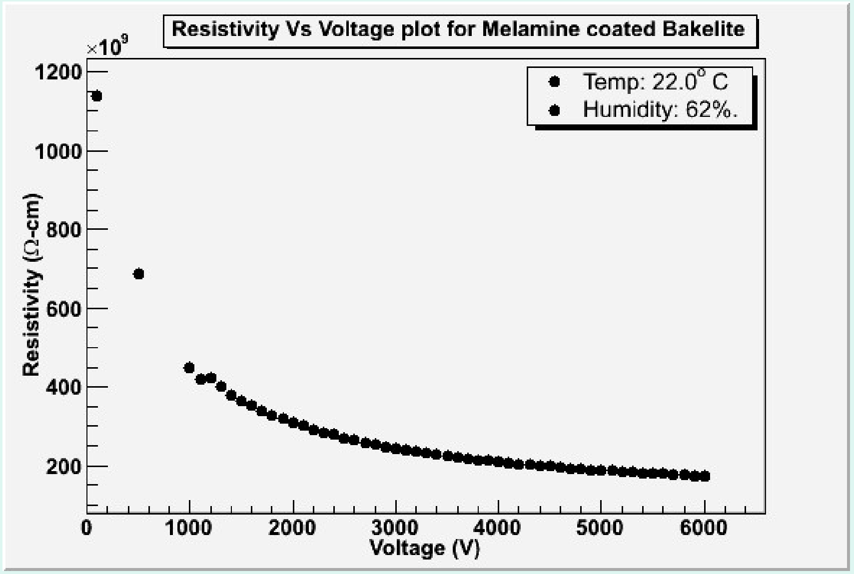
- Curve is showing the constancy of the efficiency at a particular high voltage.
- Average efficiency (92.7 ± 1.9)% have been observed.

Fabrication of RPC using local Bakelite sheet

Results of Resistivity Measurement of Bakelite Sheet (Grade P-1001 and Superhylam)



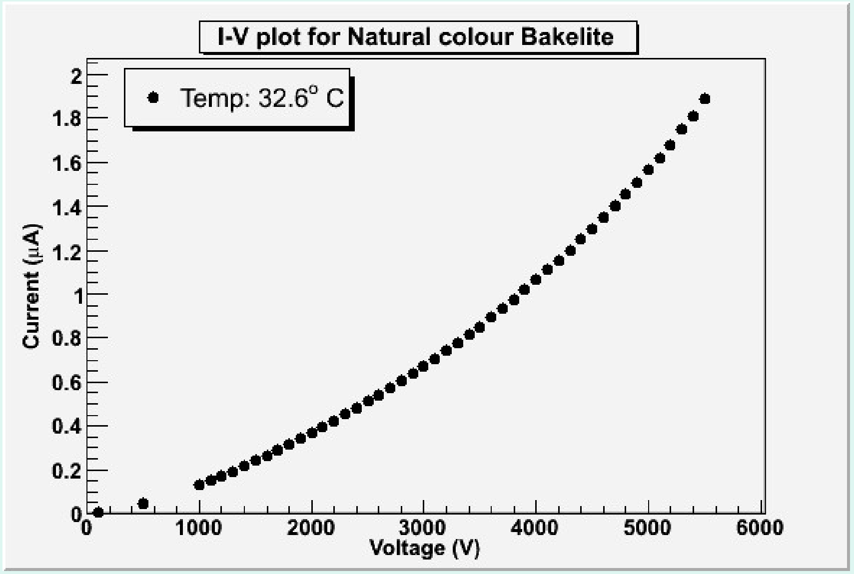
For grade Grade P-1001



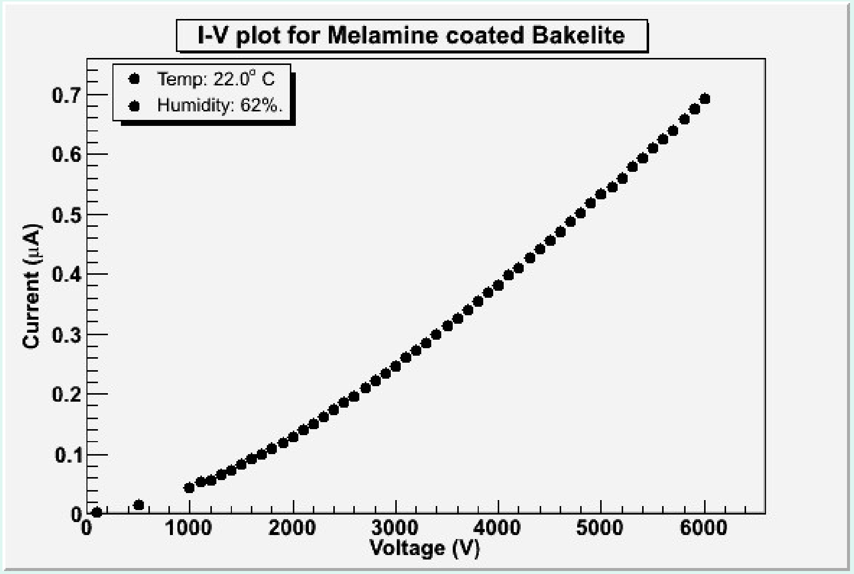
For Superhylam

- Resistivity varies from 1.5×10^{11} Ω-cm to 5.8×10^{10} Ω-cm with voltage for P-1001.
- Superhylam is a melamine coated Bakelite.
- For Superhylam $\rho \sim 2 \times 10^{11}$ Ω – cm at 6 KV.

I-V Characteristics of Bakelite (Grade P-1001 and Superhylam)



For grade Grade P-1001

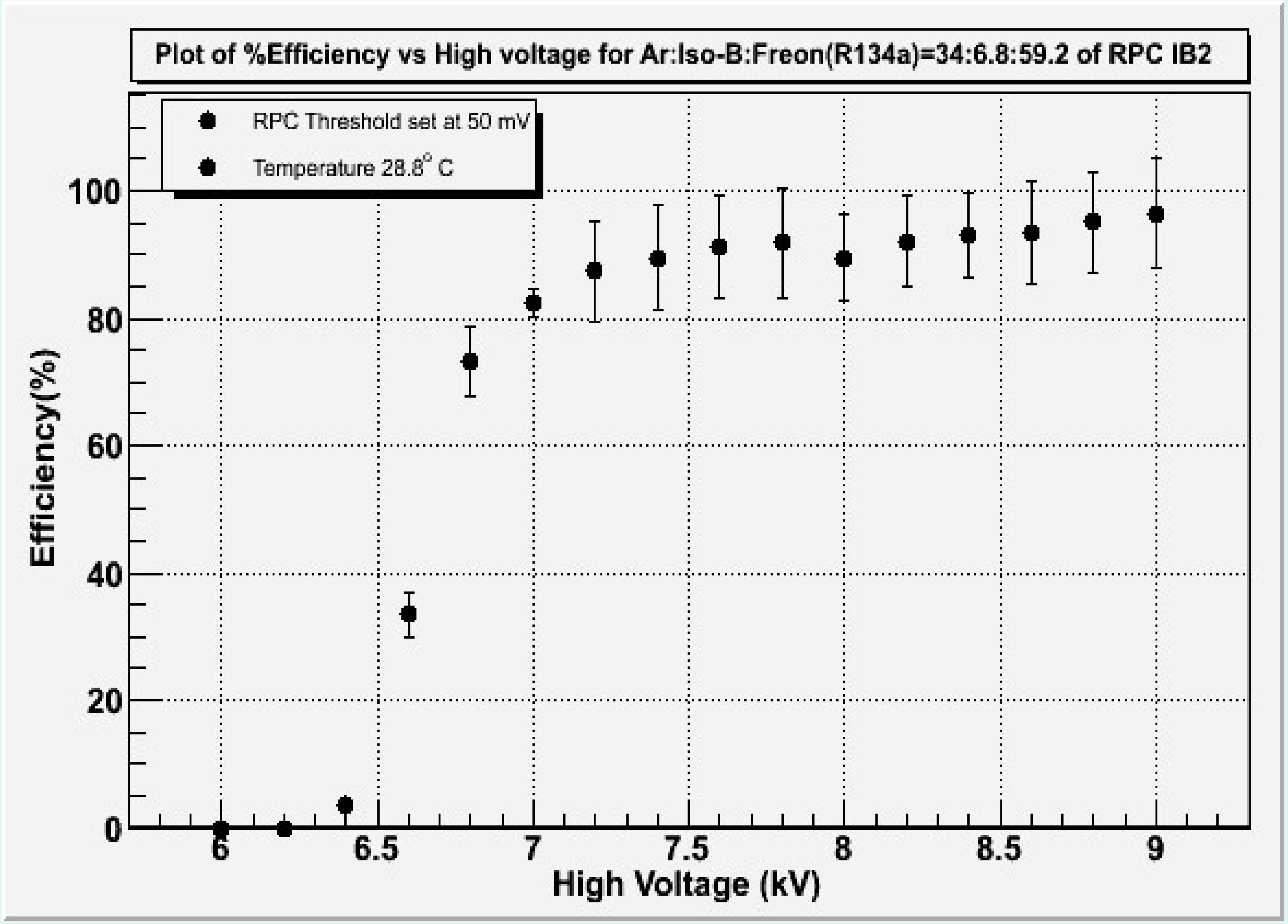


For Superhylam

Test of RPC made in VECC

- RPC is made by white melamine coated superhylam bakelite.
- Dimension of the RPC : 30 cm X 30 cm .
- It is tested using premixed gas of Argon, Iso-Butane and R-134a (34:6.8:59.2).
- RPC is operated in Streamer mode.

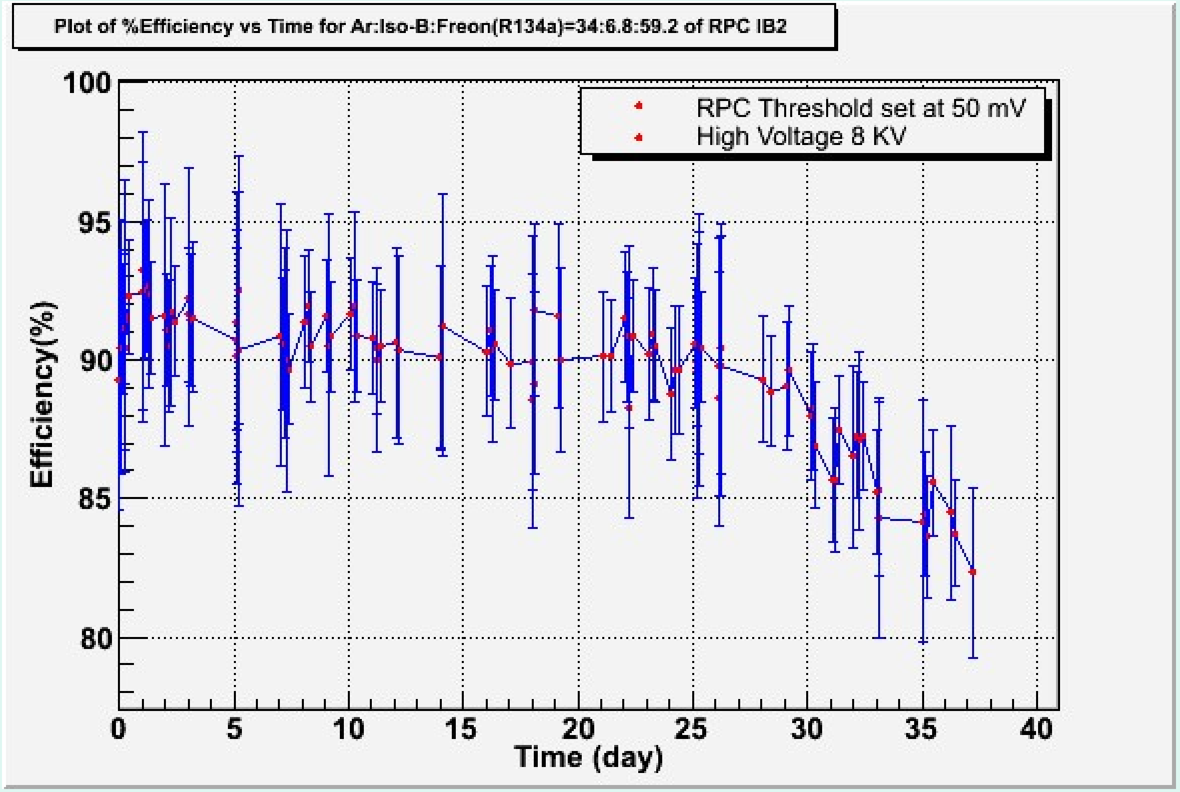
Efficiency curve



- The Trigger rate is ~0.3/cm^2/min.
- Plateau region has been found from voltage 7.5 KV onwards at efficiency >91%.
- At 9 KV current through the RPC ~5 μ A.

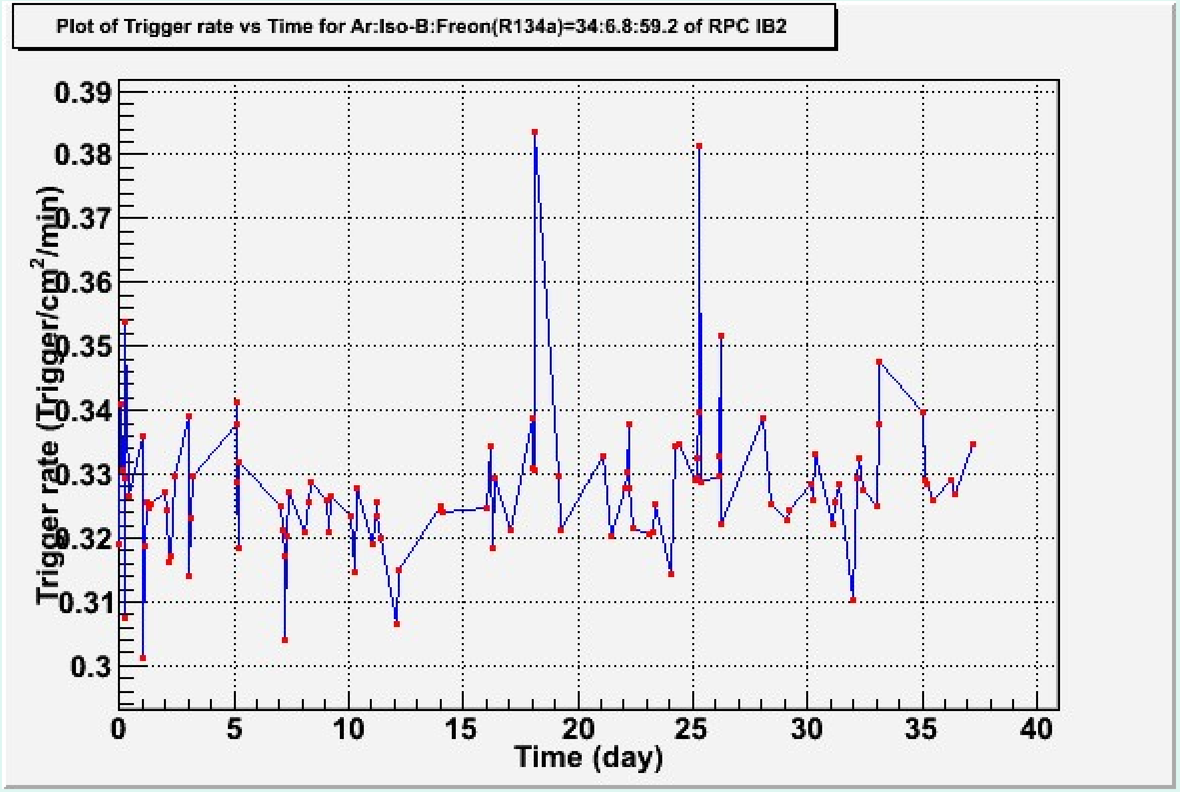
Long term stability test of RPC made by Superhylam Bakelite

Efficiency Vs Day

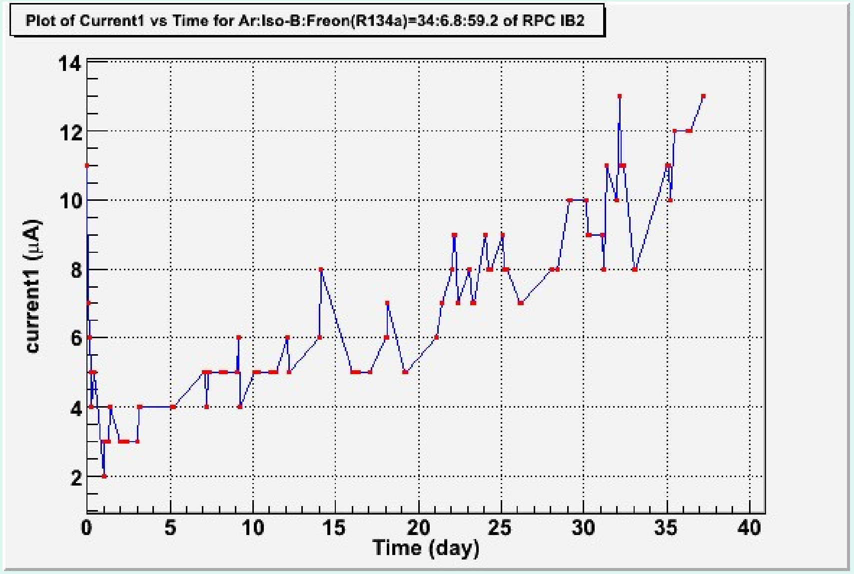


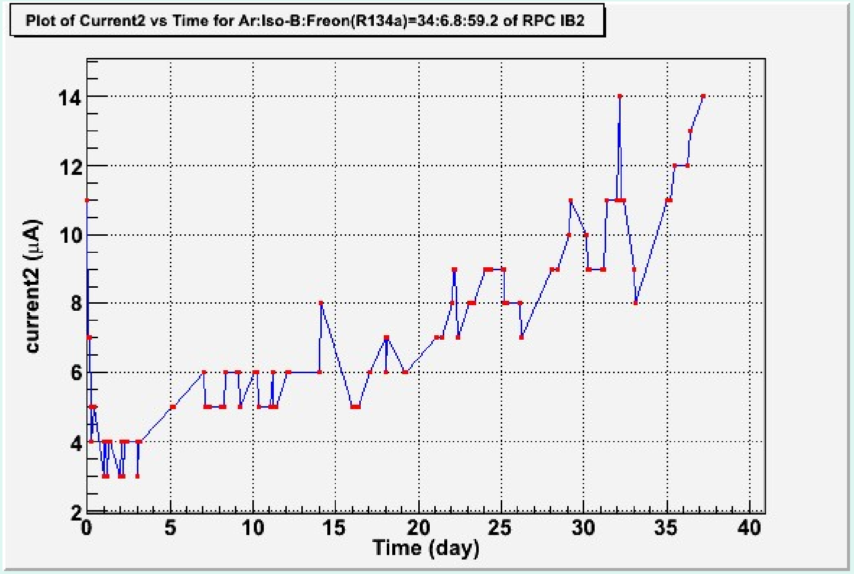
- RPC operated continuously for 38 days.
- RPC is tested at 8 KV.
- Efficiency decreases from a value ~92% to 82% within 38 days.

Trigger rate Vs Day



Current in two channels

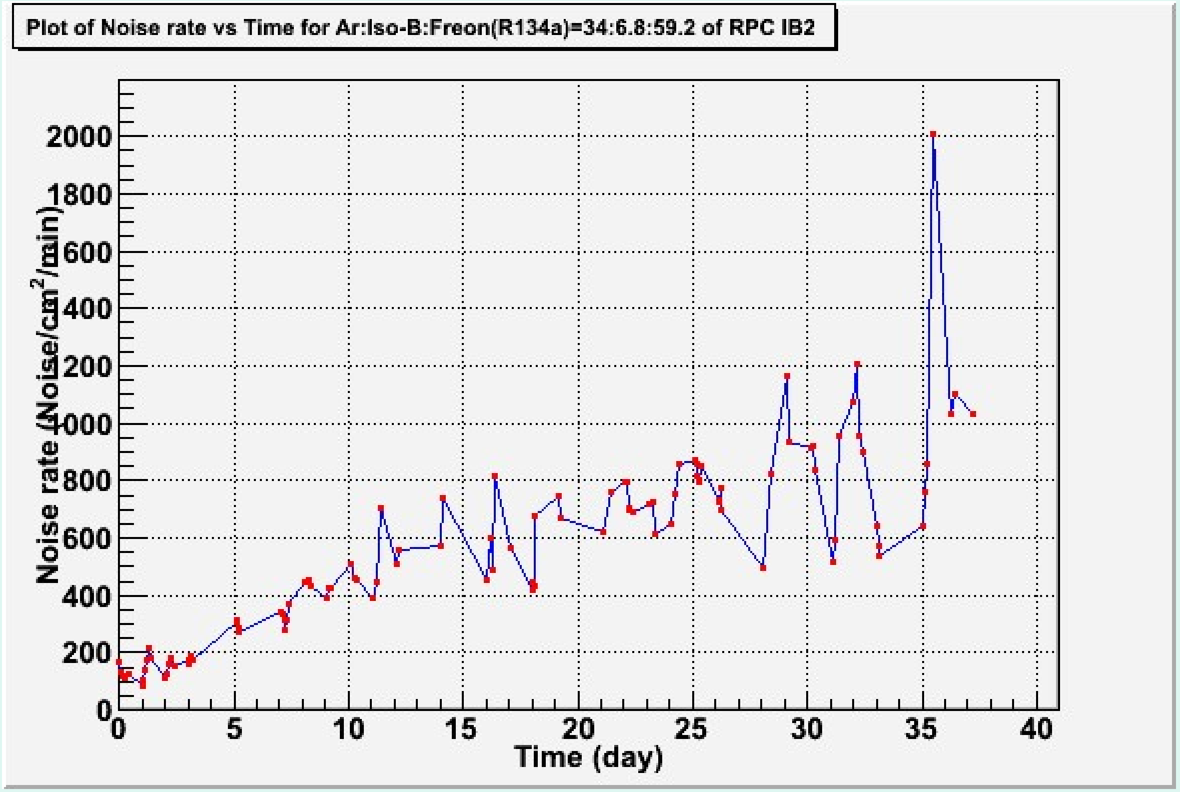




Current in Channel 1

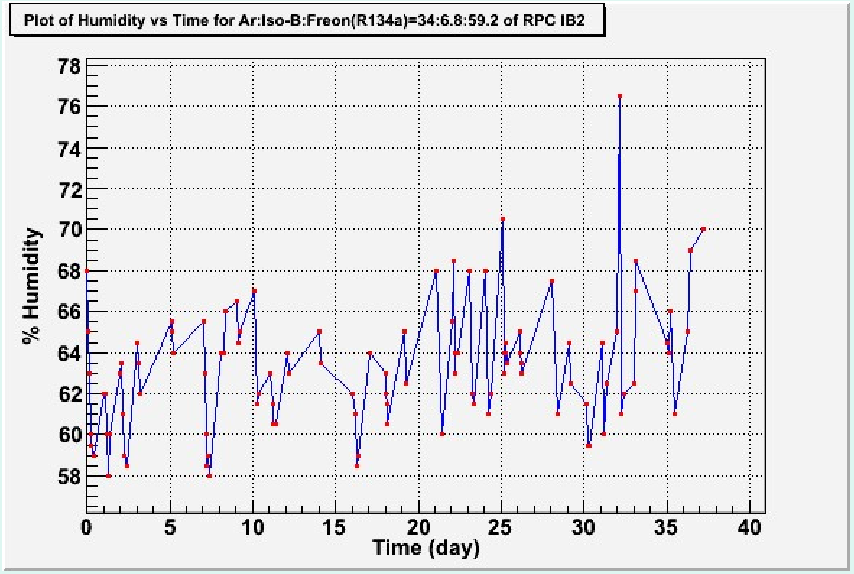
Current in Channel 2

Noise rate Vs Day

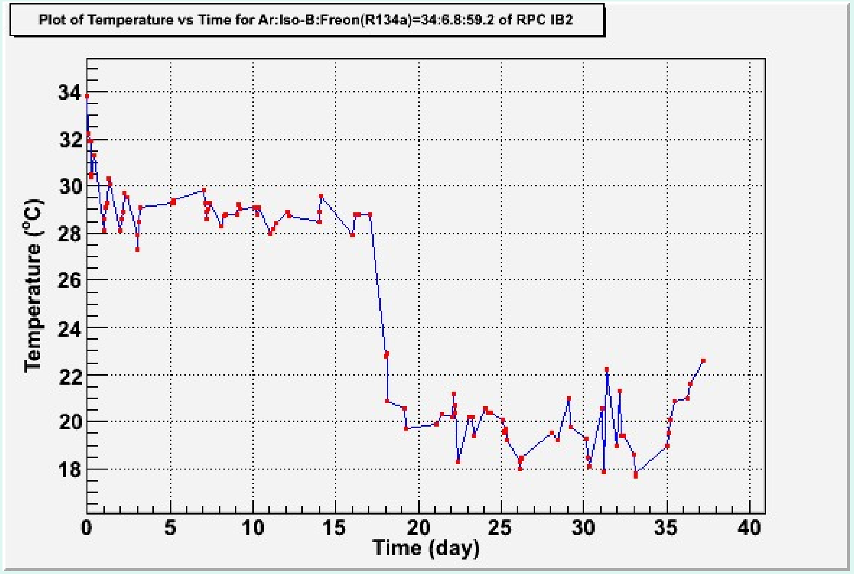


- Noise rate increases with time.

Humidity and Temperature



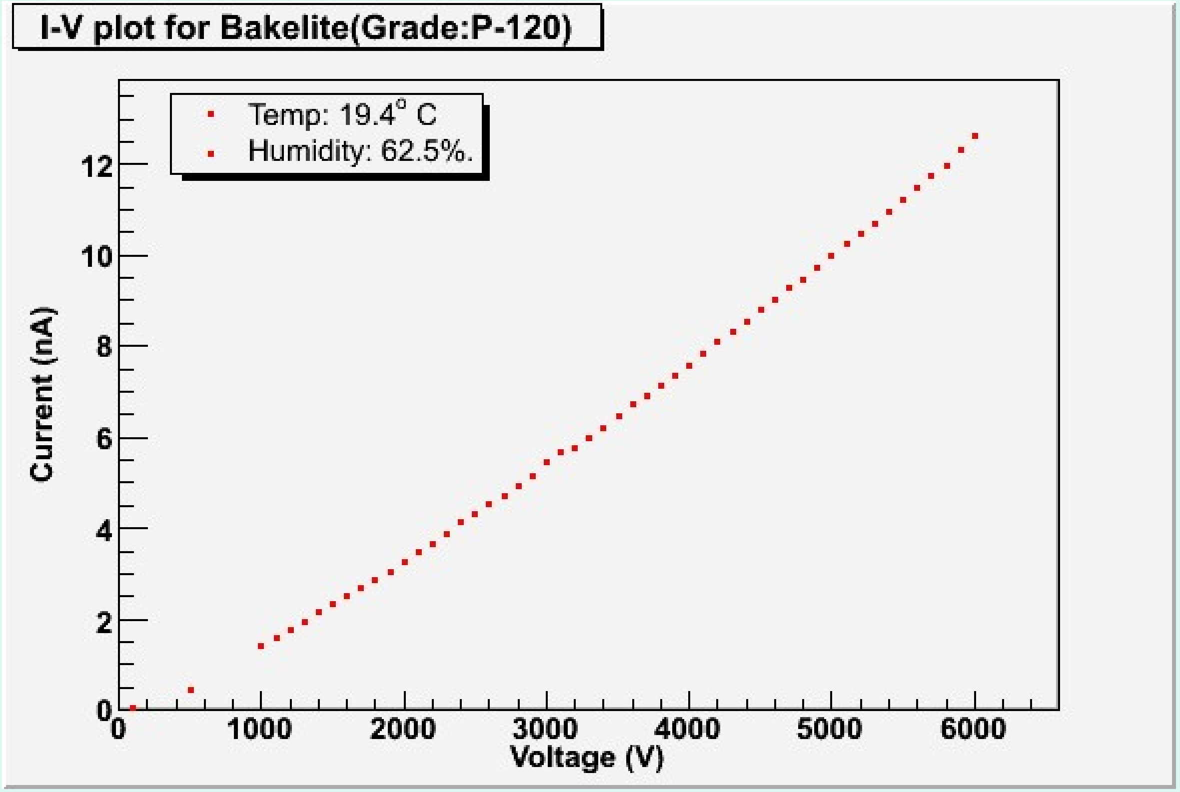
Humidity Vs Day



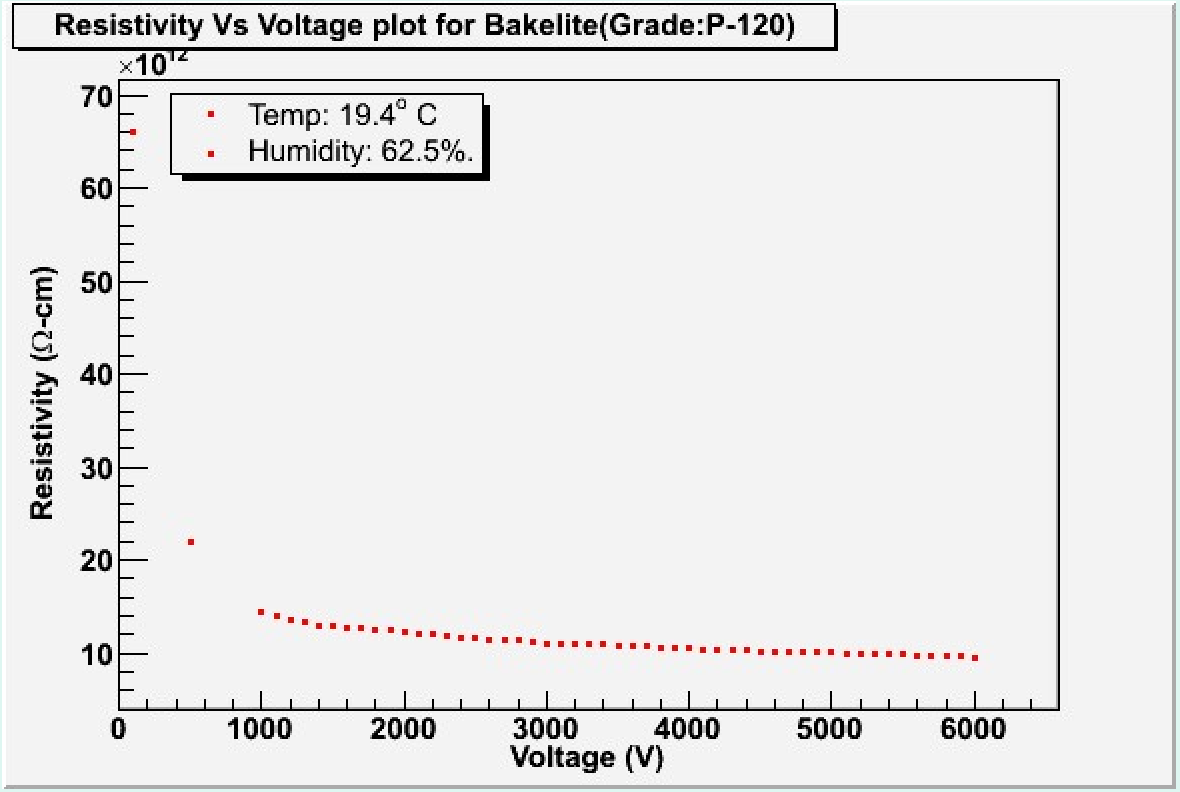
Temperature Vs Day

Study of some properties of Bakelite (P-120) and construction of new RPC

I-V Characteristics of Bakelite (P-120)

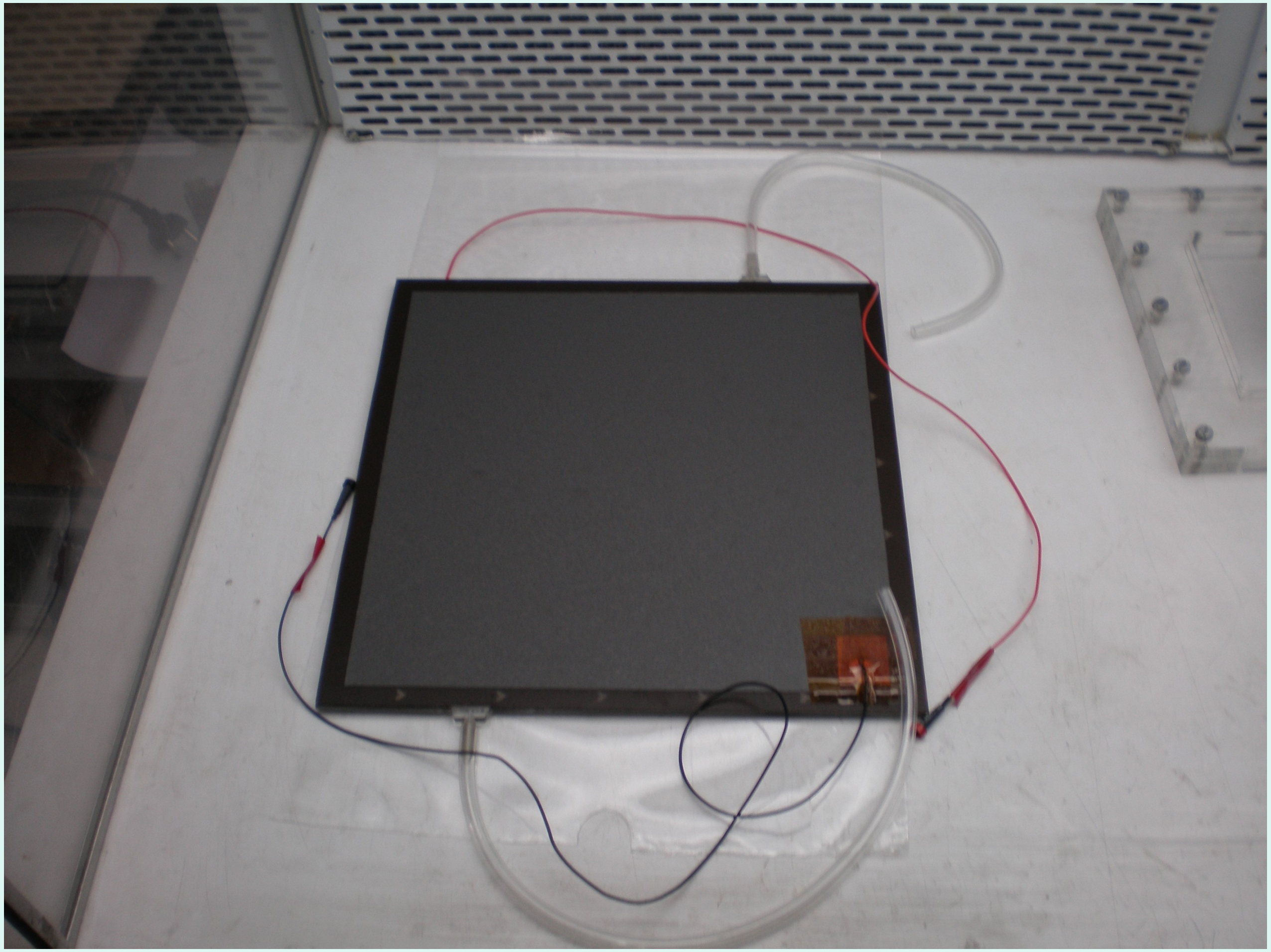


Results of Resistivity Measurement of Bakelite Sheet (P-120)

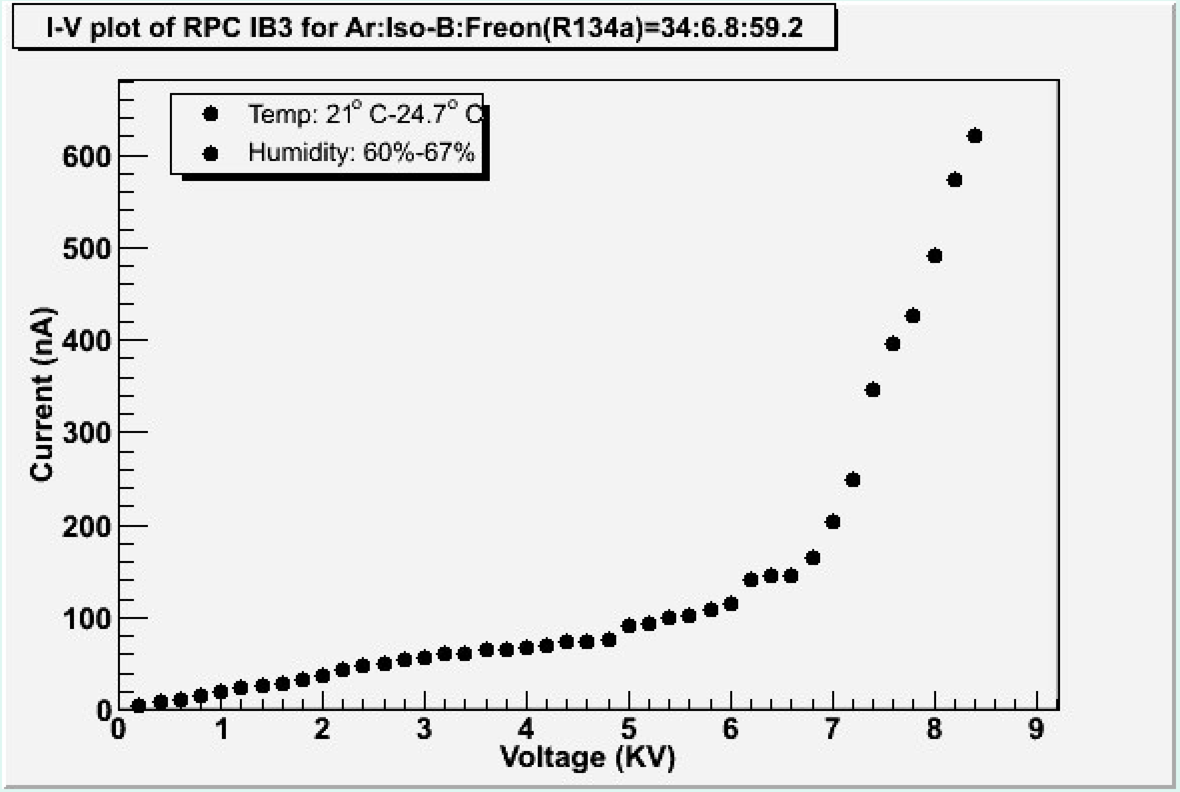


- ρ ~ 9 x 10^{12} Ω–cm at 6 KV.

Complete RPC made by P-120

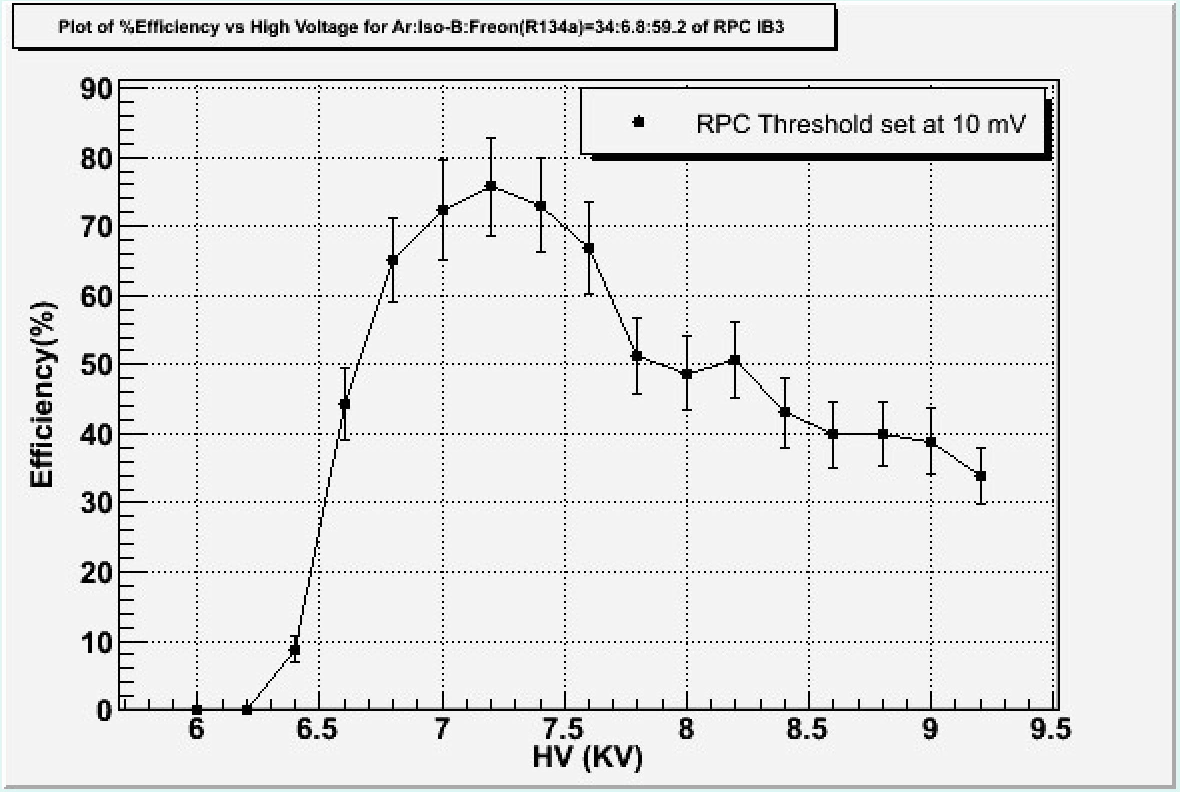


I-V plot for RPC IB3



- Current is ~600nA at 9 KV.

Efficiency plot for RPC IB3



- Efficiency starts to decrease after a certain HV.

Present status of INO

- Simulations on detector geometry and material is done.
- Site for the experiment has been fixed.
- R & D on Glass RPC is going on in TIFR and BARC.
- R & D on Bakelite RPC is going on in SINP and VECC.
- A prototype of ICAL will be tested at VECC.
- Magnet for prototype is Ready.

Future plans

- Testing of 1m x 1m Chinese RPC .
- RPC testing using the gas system of VECC.
- Measurement of time resolution of RPC.
- Installation of Lab View and starting on line monitoring.
- Construction of pick up panel using G-10.

We are beginning to learn to manage large collaboration

Welcome to all International collaborators.........

Acknowledgement

I am grateful to Prof. Jiawen Zhang for arranging this talk. I want to express my gratitude to Dr. Subhasis Chattopadhyay, Professor Satyajit Saha, Professor Sudeb Bhattacharya, Dr. Manoj Sharan, Dr. Abhijit Samanta and Dr. Y.P. Viyogi for all kind of supports, suggestions and discussions. Finally I want to acknowledge the supports from INO Collaboration, India as well as from IHEP, China.

Thank You