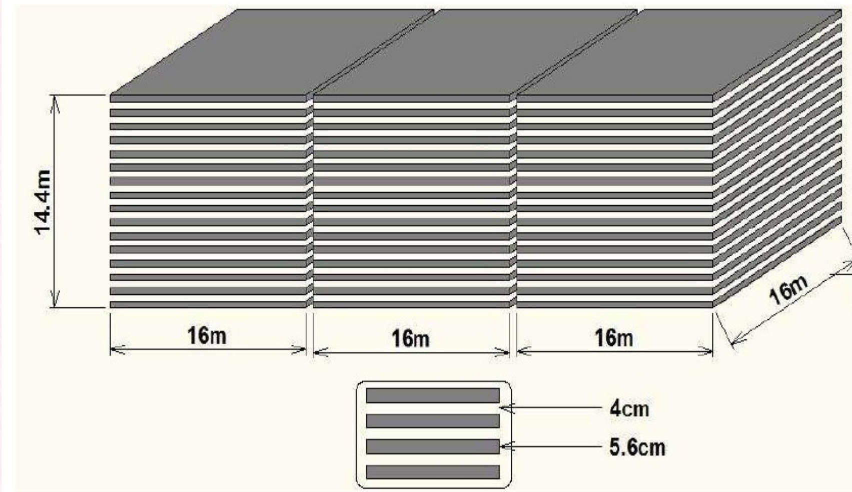
India-based Neutrino Observatory (INO)



Amol Dighe
TIFR, Mumbai
(On behalf of the INO Collaboration)
http://www.ino.tifr.res.in/ino/

NuFact 2012
July 27, 2012

INO Collaboration

Ahmadabad: *Physical Research Lab.*

Aligarh: *Aligarh Muslim University*

Allahabad: *HRI*

Calicut : *University of Calicut*

Chandigarh: *Panjab University*

Chennai : *IIT, Madras IMSc*

Delhi : *University of Delhi*

Guwahati : *IIT, Guwahati*

Hawaii (USA) : *University of Hawaii*

Indore: *IIT, Indore*

Jammu : *University of Jammu*

Kalpakkam : *IGCAR*

Kolkata : *Ramakrishna Mission Vivekananda University, SINP, VECC , University of Calcutta*

Lucknow : *Lucknow University*

Madurai : *American College*

Mumbai : *BARC*

Mumbai : *IIT, Bombay TIFR*

Mysore : *University of Mysore*

Sambalpur : *Sambalpur University;*

Srinagar : *University of Kashmir*

Varanasi : *Banaras Hindu University*

INO: the physics

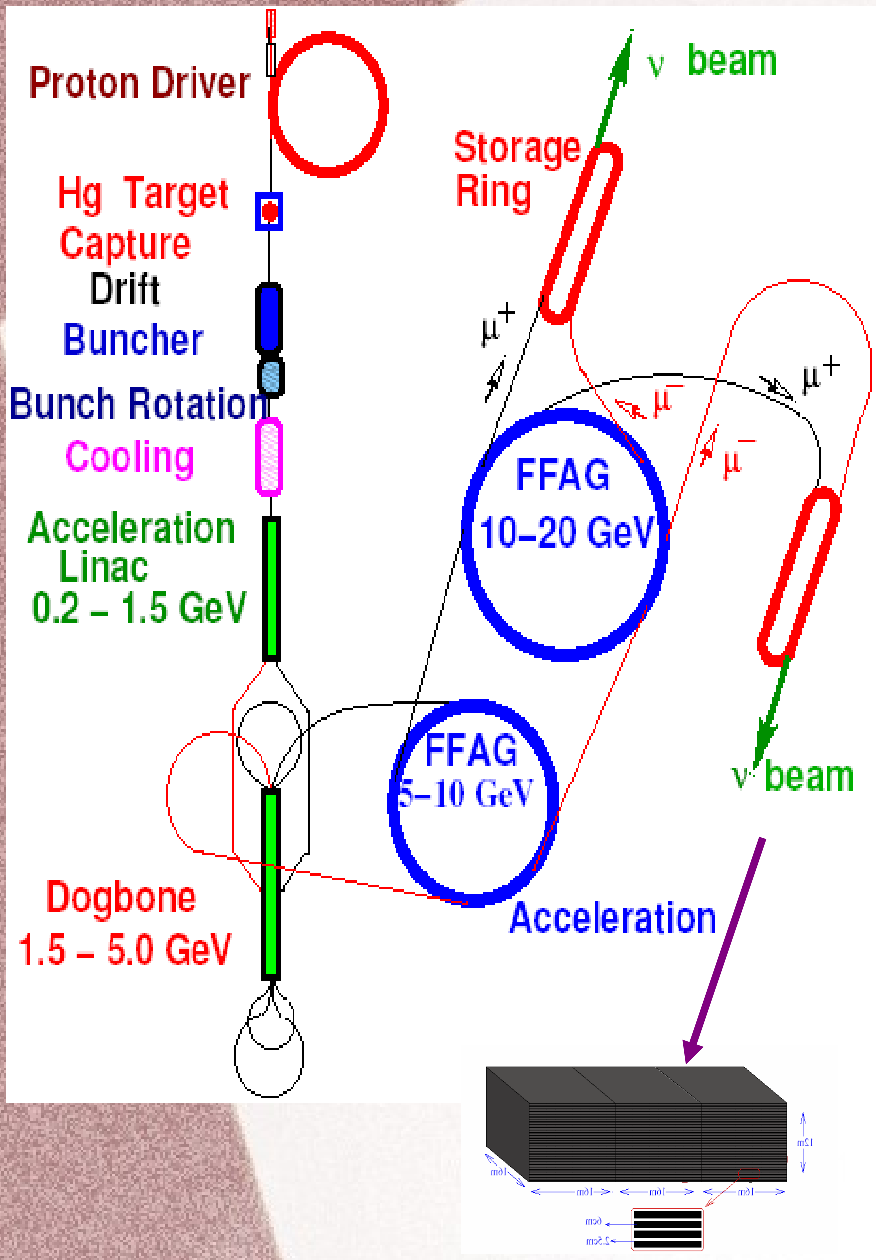
INO: The physics motivation

- *Atmospheric neutrinos provide a wider range for E and L than any artificial neutrino source*
- *An ability to discriminate between neutrinos and antineutrinos enables efficient determination of neutrino mass ordering*
- *Magnetized iron calorimeter (ICAL): excellent muon energy measurement, muon direction reconstruction and charge identification*
- *Hadron shower reconstruction allows access to neutrino energy and high-energy cosmic rays*

INO: the physics goals

- Accurate determination of the atmospheric parameters (theta23 octant, deviation of theta23 from maximality)
- Determination of neutrino mass hierarchy (large theta13 is good news !)
- Determination of CP violation in the lepton sector (with a future long baseline experiment with a neutrino factory)
- Non-standard interactions, CPT violation, long range forces, ultrahigh-energy muon fluxes, ...

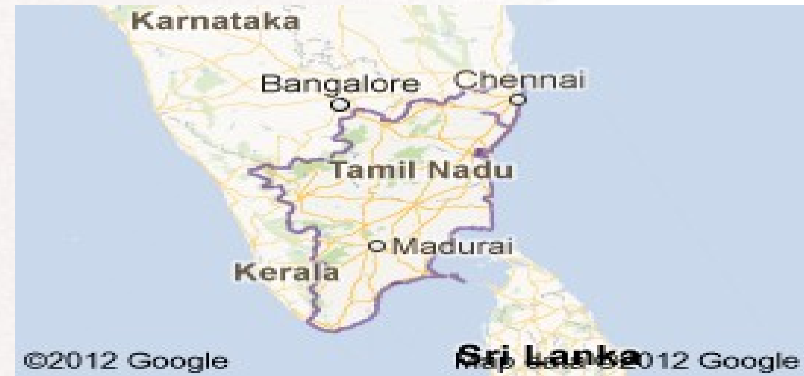
INO phase II: with a neutrino factory?



- *Charge-ID crucial for identification of wrong-sign muons*

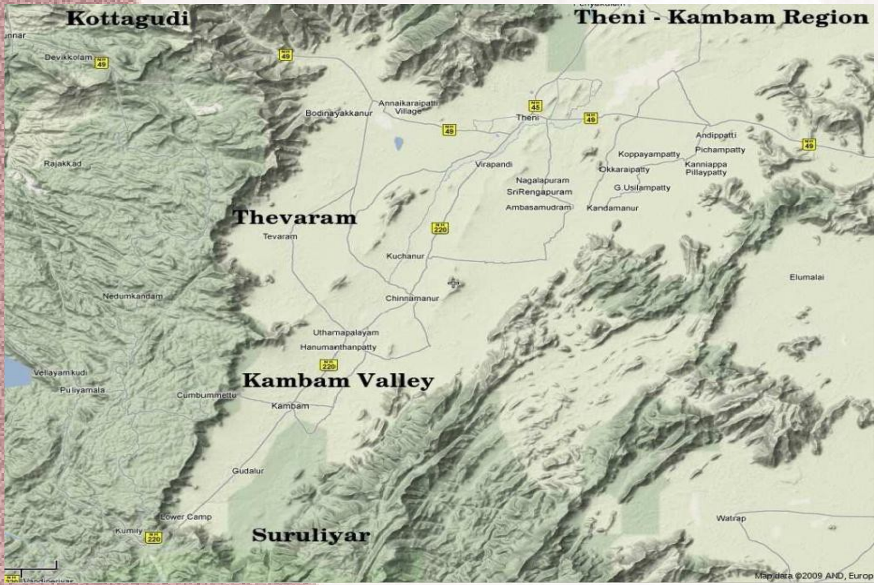
INO: the location

The nearest major city: Madurai



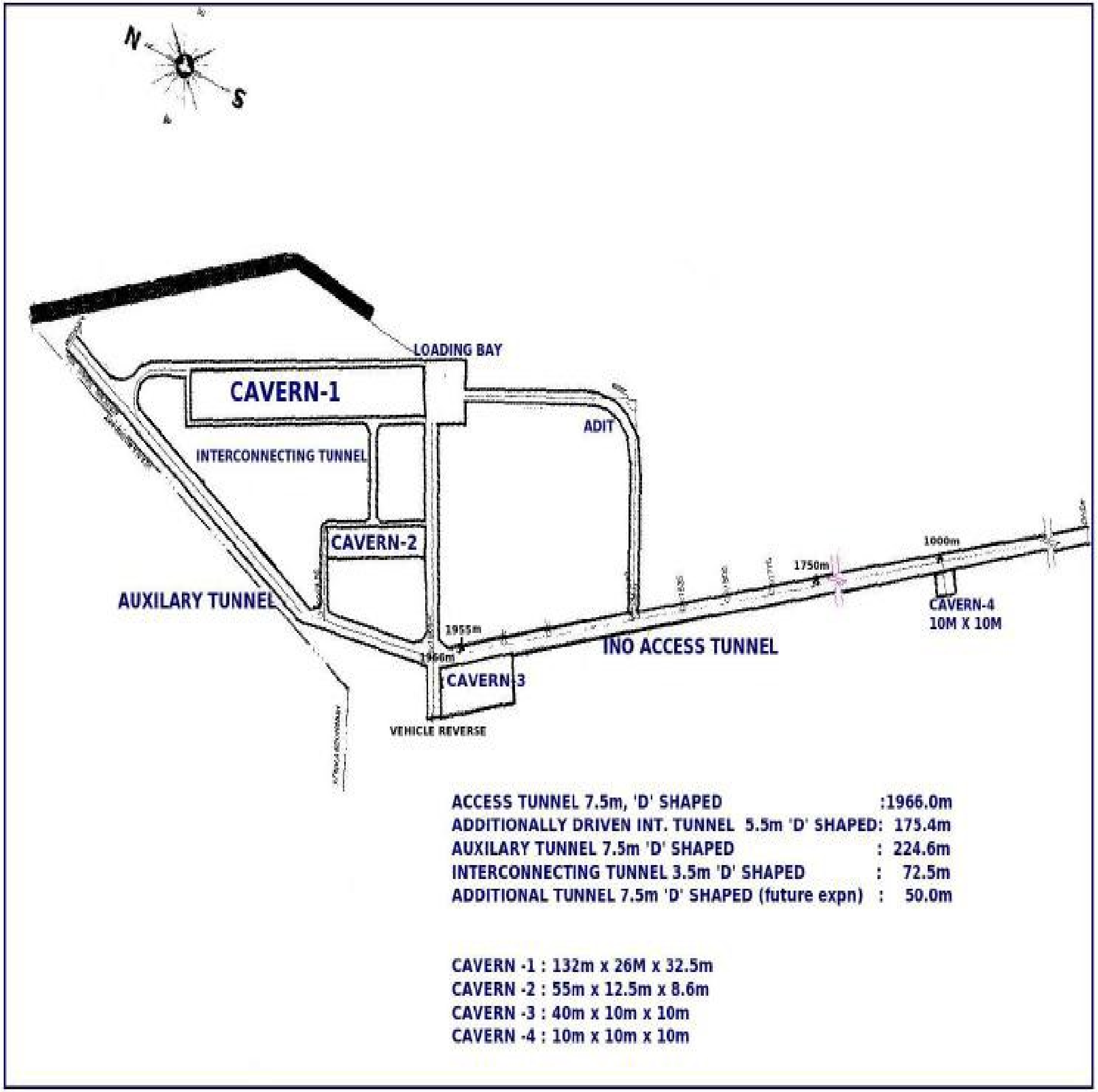
- *South India, 120 km from the temple city of Madurai (has airport)*

The site: Bodi West Hills



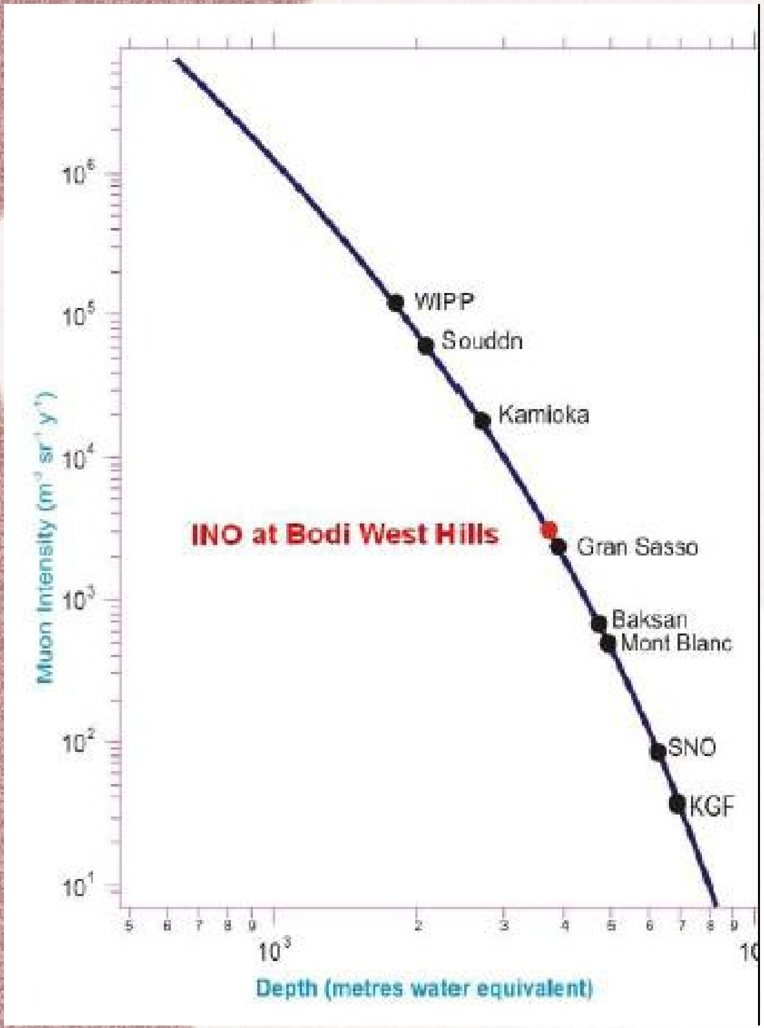
- *(9 58' N, 77 16'E)*
- *Pottipuram village*
- *Theni district*
- *Tamil Nadu state*

The caverns



- *Accessible through a 2km tunnel*
- *Cavern 1 will host 50kt ICAL (space for 100 kt)*
- *Other caverns available for multiple experiments (NDBD, dark matter, ...)*

Geography of the site



- *Cavern set in Charnockite rock under the 1589 m peak*
- *Vertical cover: 1289 m, all-round cover ~1000m*
- *Warm, low-rainfall area, low humidity throughout the year, unusual wind speed in some seasons*

Organization at the site

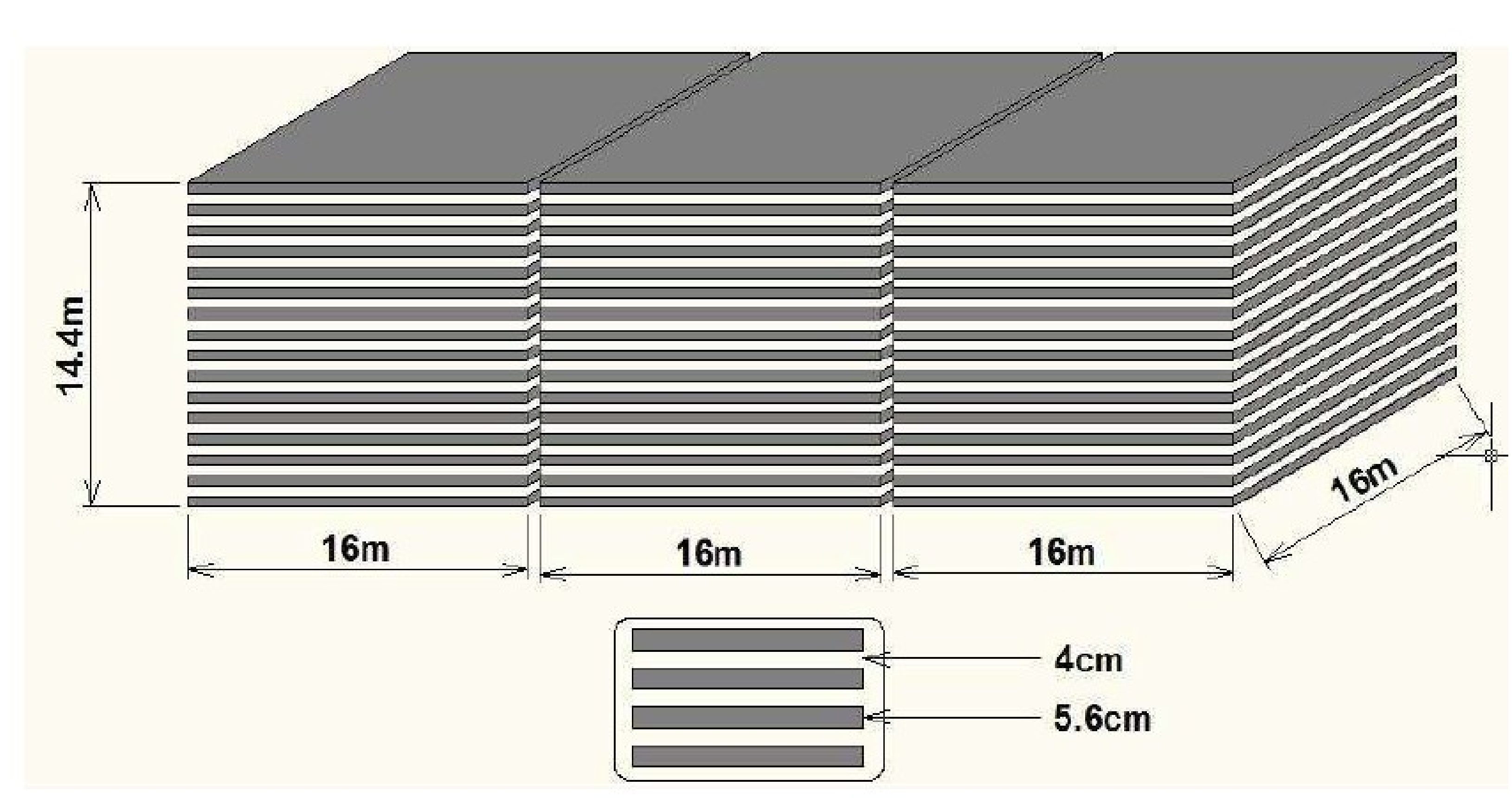
- Flat terrain with good access to major roads
- All major components to be located underground , Small surface lab on the outside (Pottipuram)
- Tunnel and cavern under forest on the surface, but the portal outside the reserve forest boundary
- Surface facilities not on the forest land, so no forest clearing required.

Updates on the site front

- INO project approved by the Indian funding agencies
- Environmental and Forest Clearance for the site obtained. 26 hectars of land provided free by Tamil Nadu state government
- Site preparation works are being tendered
- Plans are being prepared for construction of approach roads, water and electricity connections to the INO site
- Construction of an INO Centre: National Centre for High Energy Physics (NCHEP) planned at Madurai, land available against payment

INO-ICAL: The detector

Magnetized Iron calorimeter (ICAL)



- *Iron plates separated by resitive plate chambers (RPCs): 150 layers*

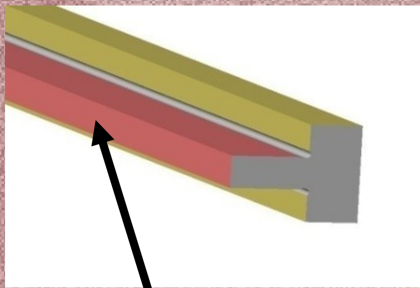
Salient features of the detector

- Magnetized iron as target mass and glass RPCs as the active detector
- Modularity and ease of construction
- Good energy measurement through tracking of muons bending in the magnetic field
- Directionality through tracking and timing (~1ns resolution)
- Charge identification through bending of muons
- Complementarity to existing and future detectors

Detector factsheet

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	1.3Tesla
RPC dimensions	1,950mm × 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 (97,505m^2)
No. of readout strips	3,686,400

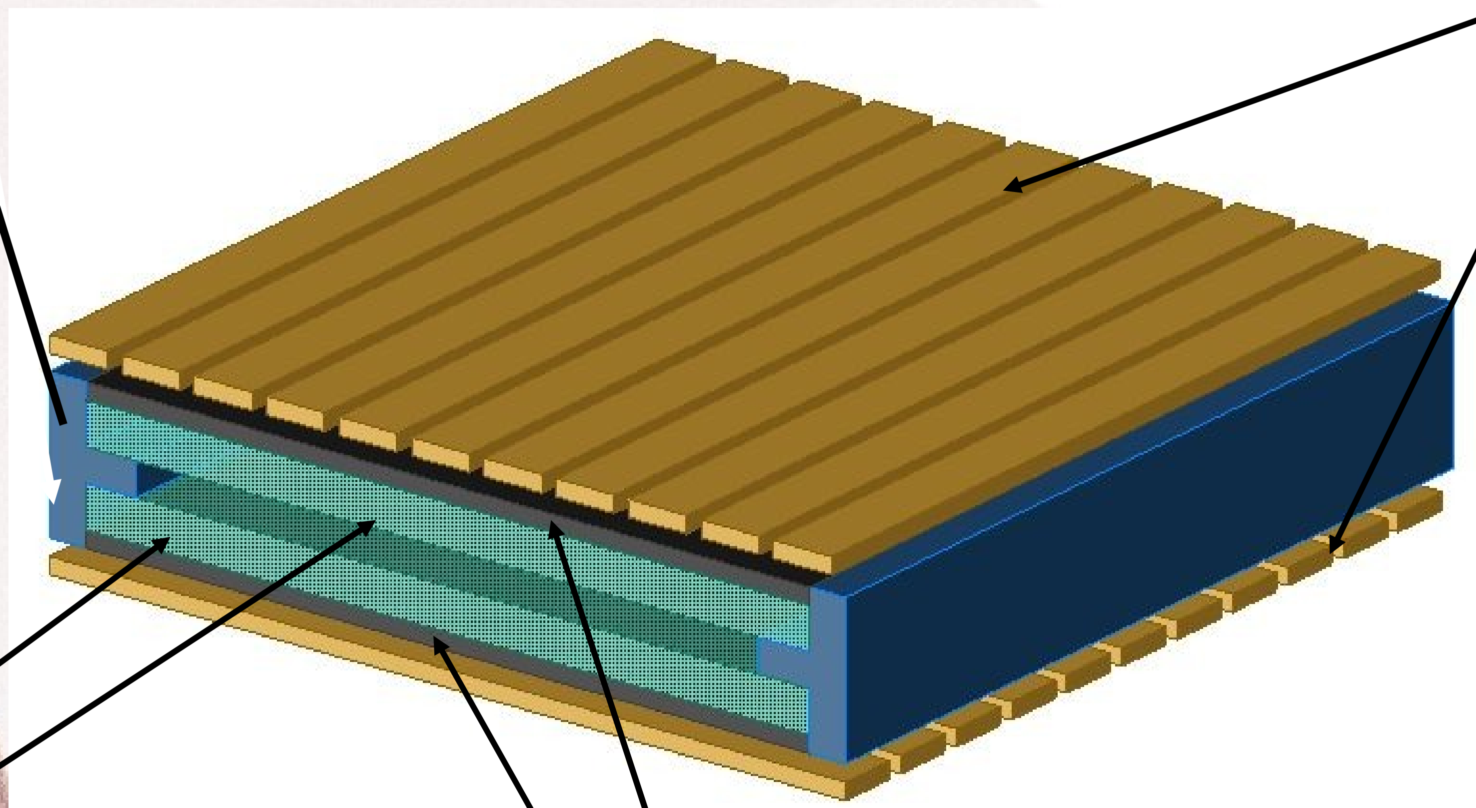
Construction of RPC



Two 2 mm thick float Glass
Separated by 2 mm spacer

2 mm thick spacer

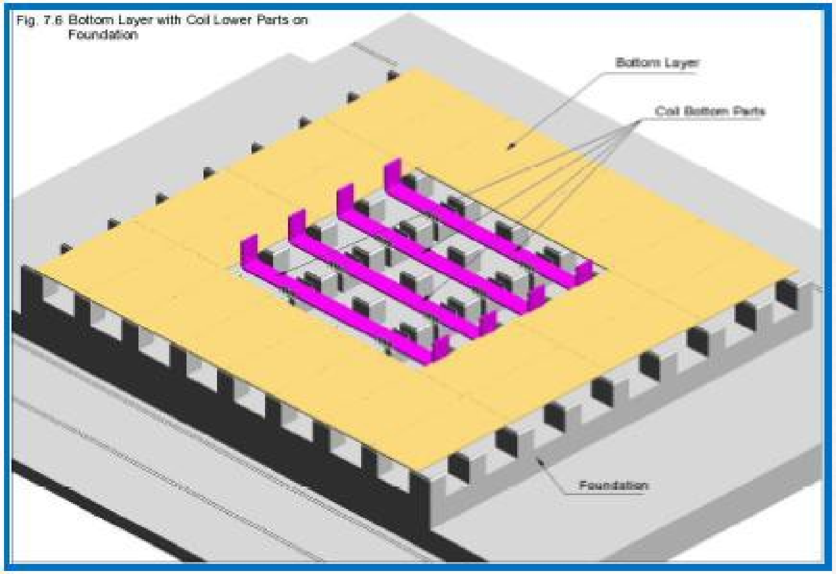
Pickup strips

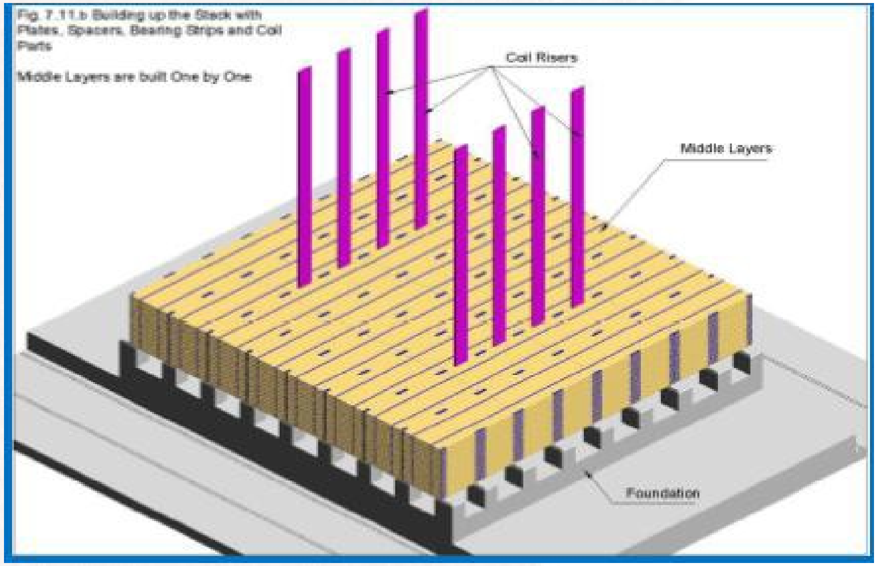


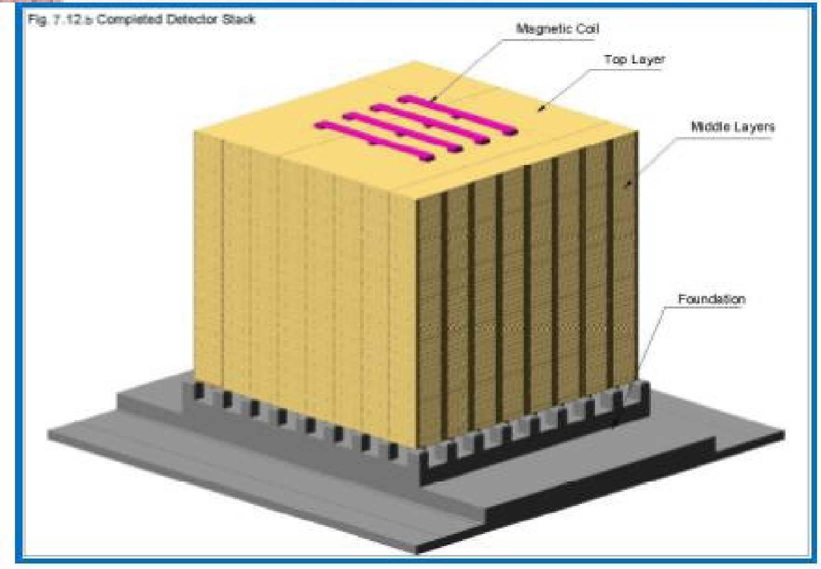
Glass plates

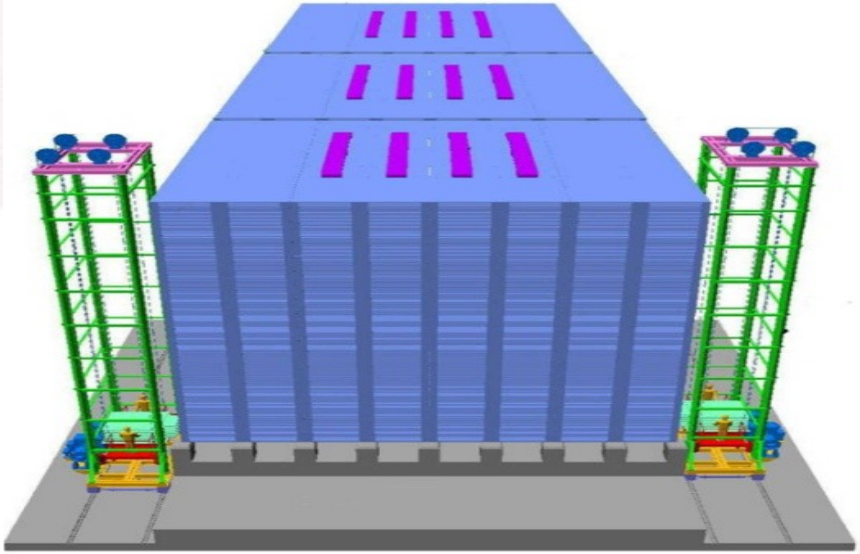
Resistive coating on the outer surfaces of glass

Construction of the ICAL

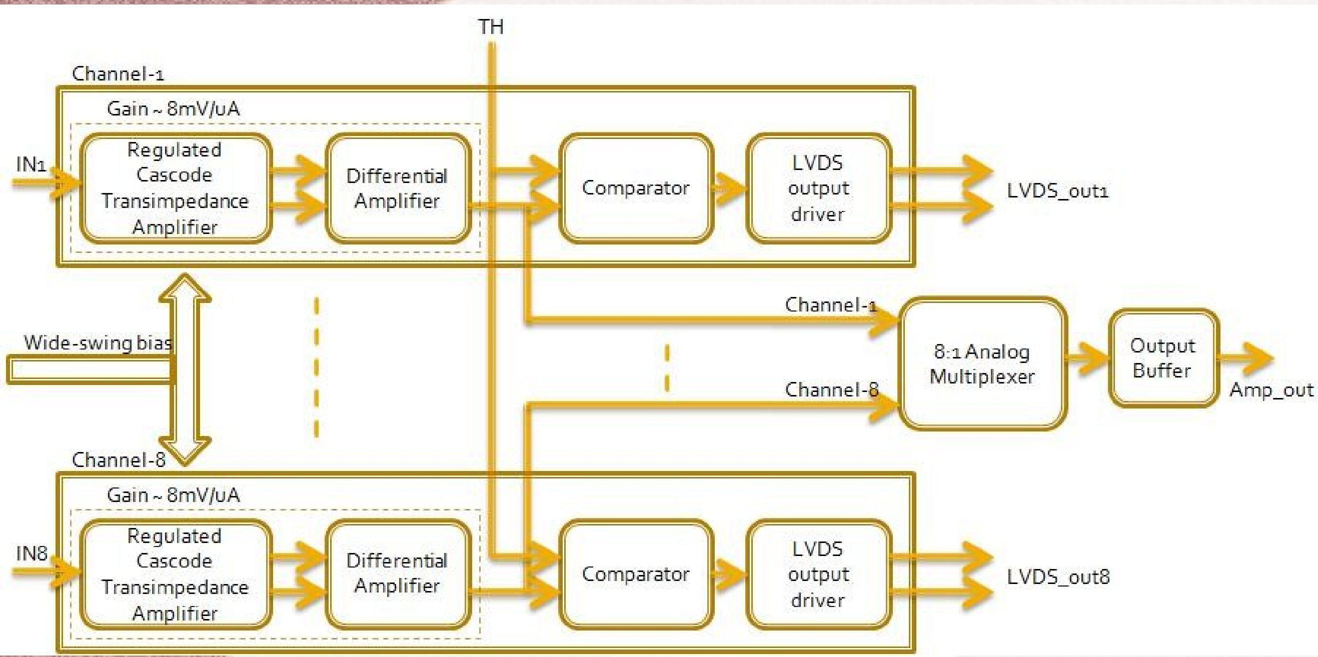


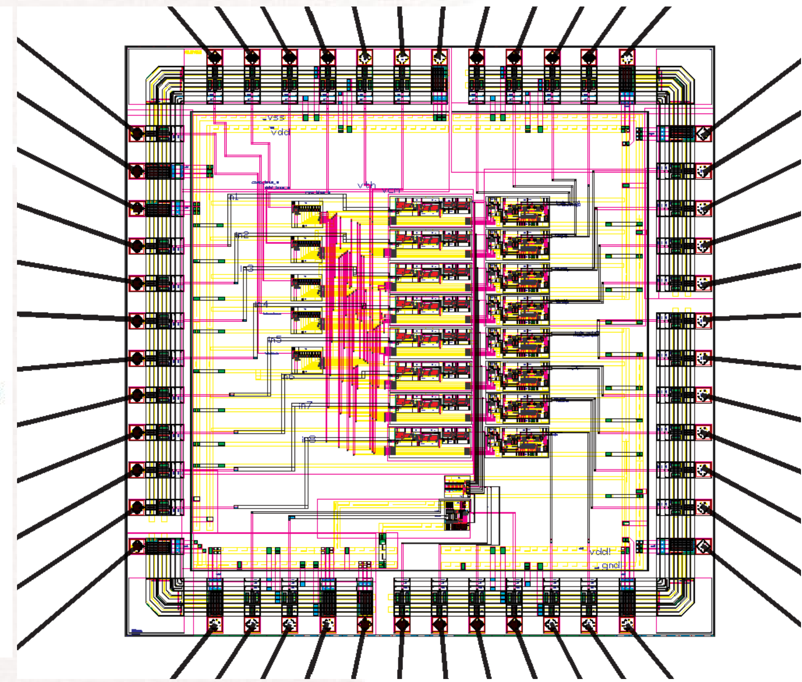


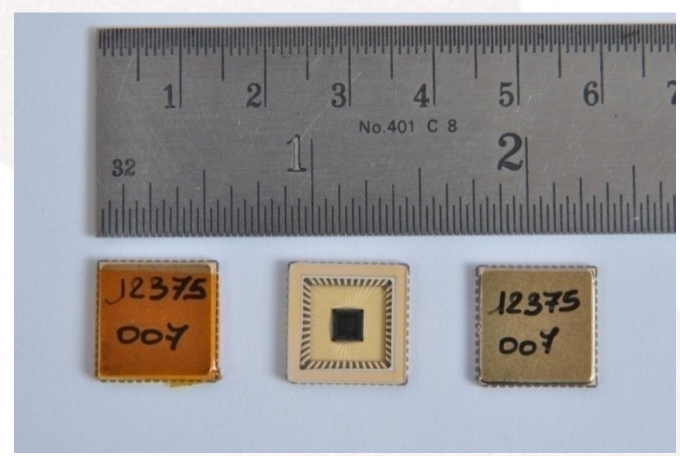




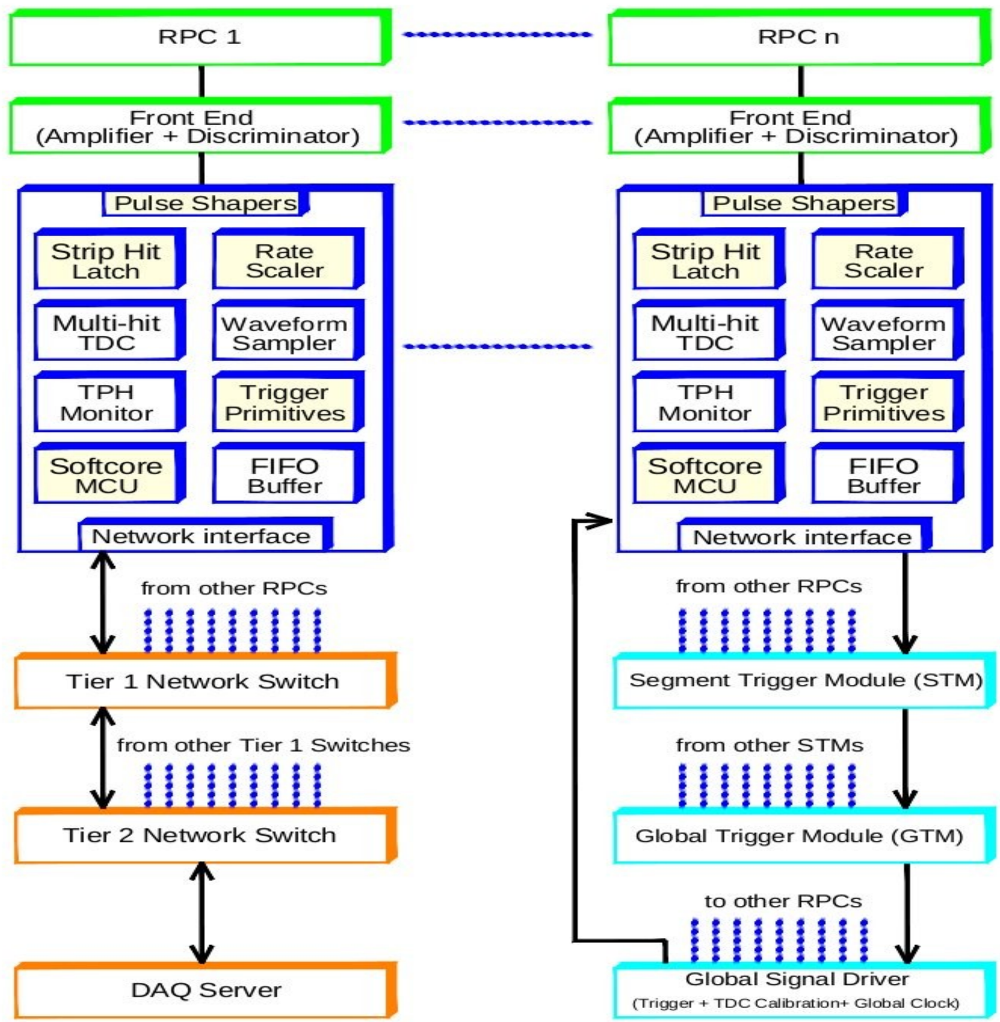
ICAL Front End Electronics chip developed at BARC Electronics Division





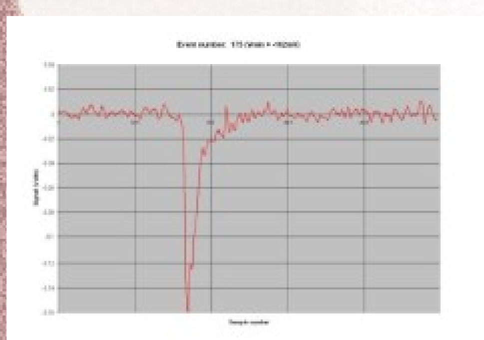


ICAL Electronics: schematic

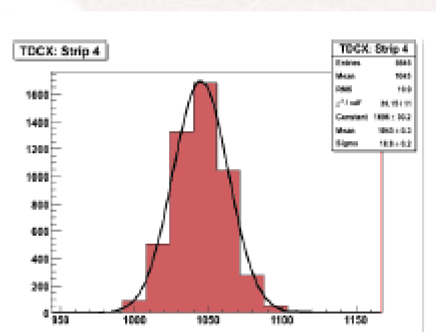


Testing the RPCs

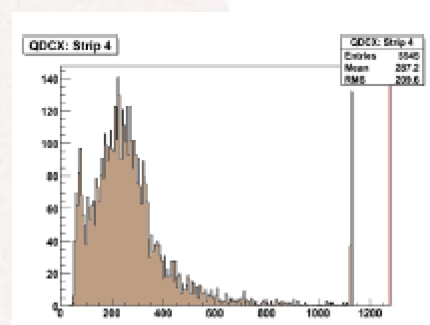
RPC stack being used for cosmic ray measurements



Muon Pulse in RPC



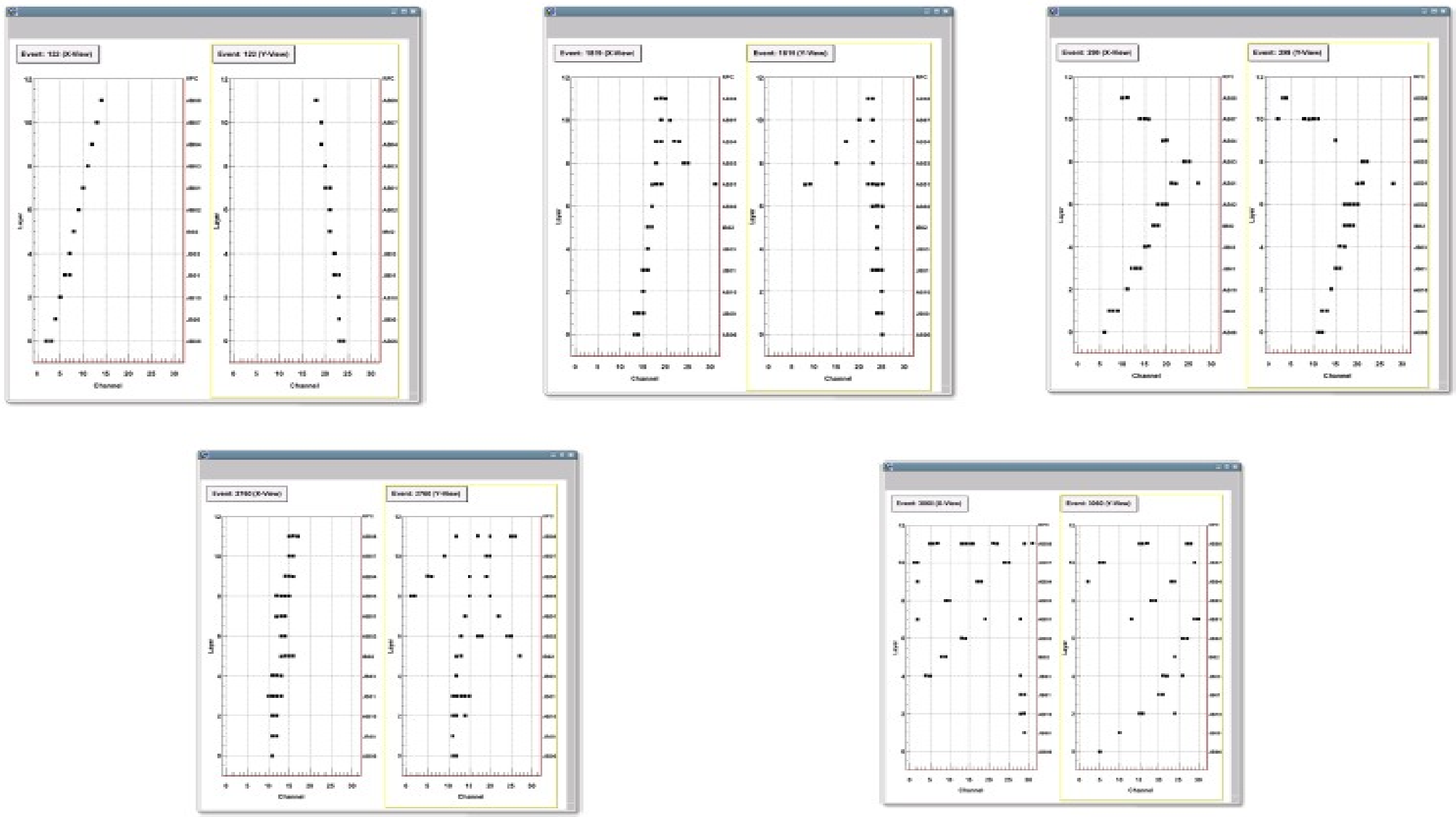
RPC timing resolution



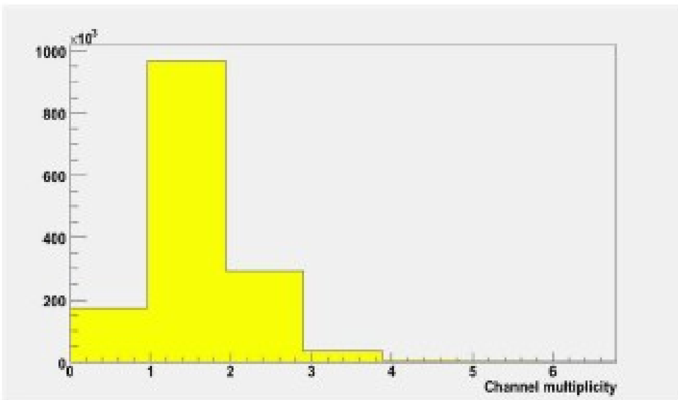
RPC Pulse ht. resolution

Cosmic ray tracks in the RPC stand

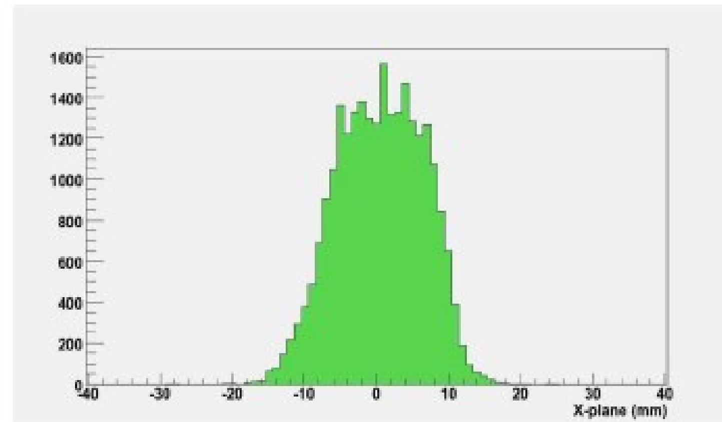
- *Demonstrates tracking capability of the INO RPC system*



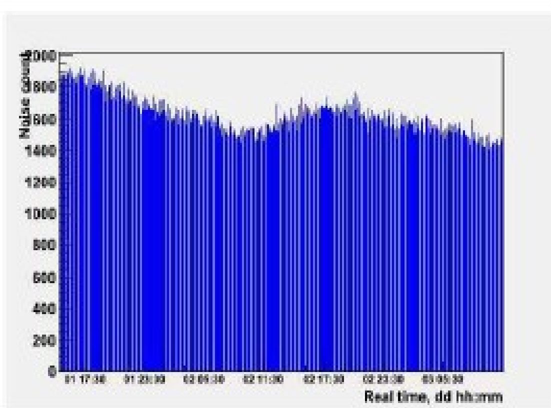
RPC performance with cosmic rays



Strip Multiplicity due to crossing muons



Track residue in mm



Strip noise rate vs time

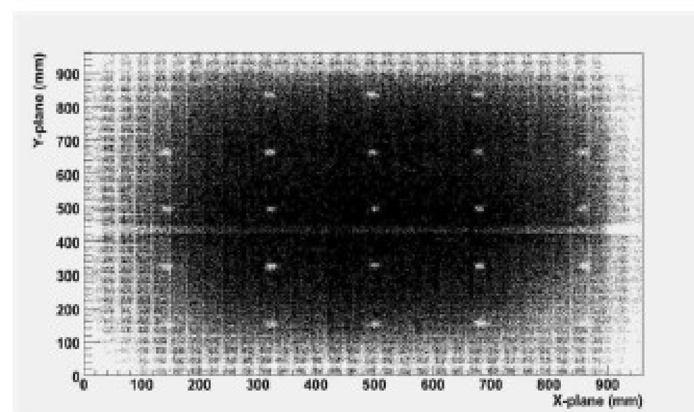
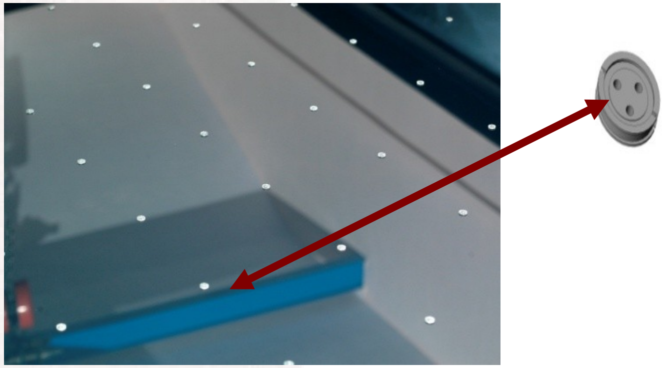
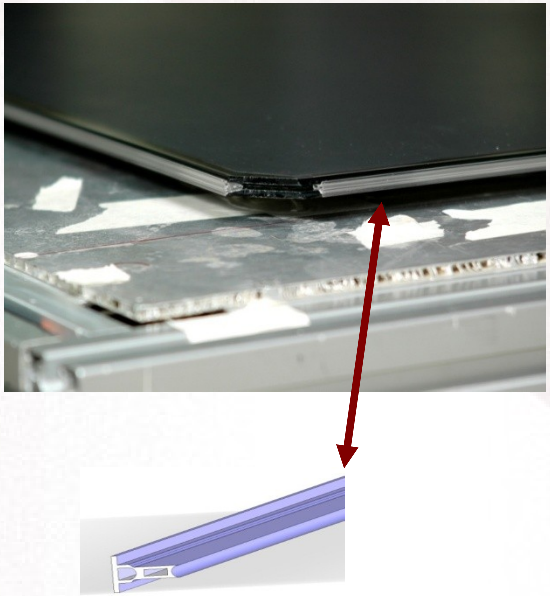


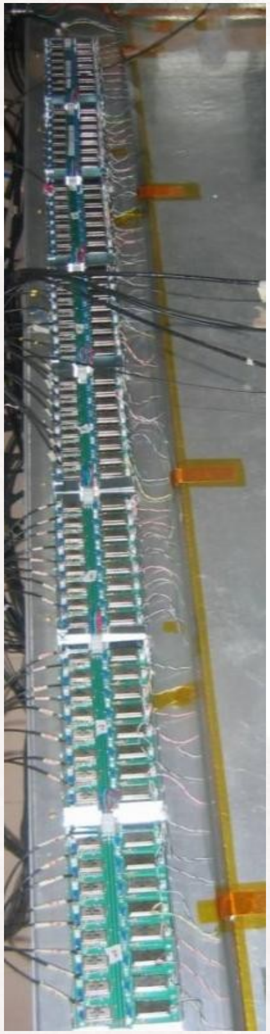
Image of a RPC using muons

Fabricating 2mx2m glass RPC in the lab



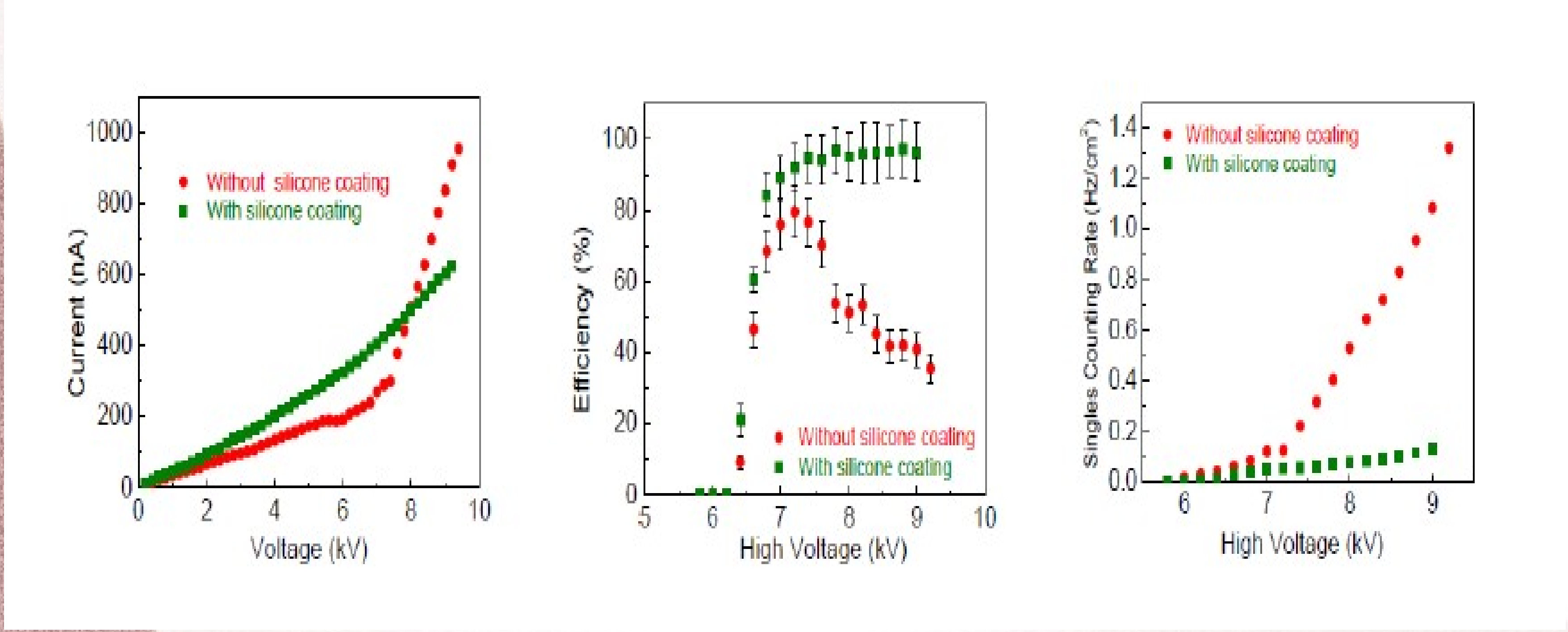


2m x 2m glass RPC test stand

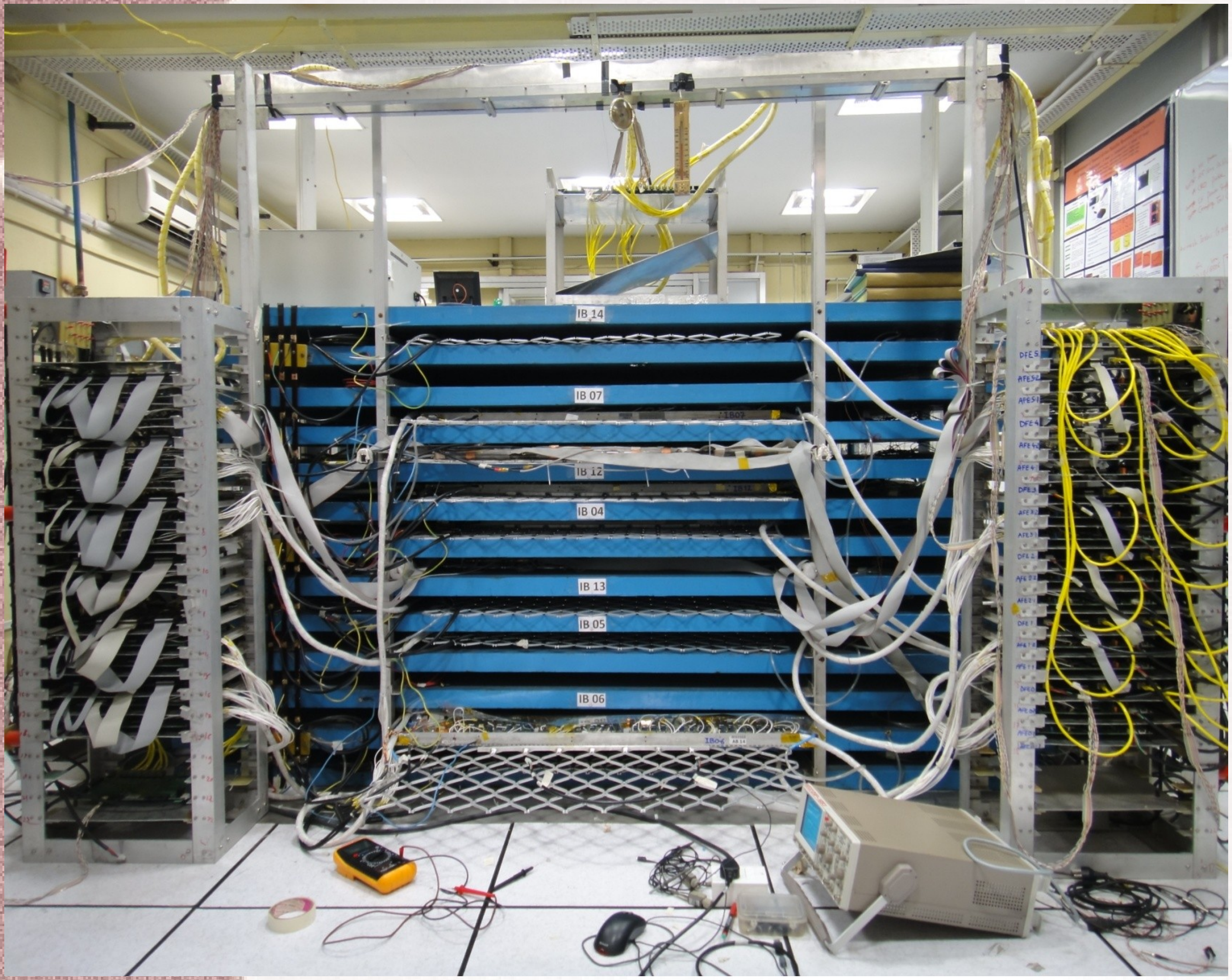


Bakelite RPC R&D

- *SINP and VECC groups in Kolkata developing bakelite RPCs in streamer mode*
- *Inner surface of bakelite coated with PDMS (silicone) to make the surface smooth*
- *Efficiency plateau over 96% obtained with reduced noise rate and long term stability*
- *INO-ICAL being modular, can use both, glass and/or bakelite RPCs*



Detector prototype (40 ton) in Kolkata



- *Both, glass and bakelite RPCs tested in this magnetized ICAL prototype*

Status of detector development

- **RPC development for ICAL**:
  - → R&D almost complete
  - → Full size RPCs (2m X 2m) are being fabricated not just in the INO labs but also by the industry
  - → Methods, machinery and production optzmisation for large scale production of RPCs are being developed with the help of an industry

- **Electronics for ICAL**
  - → Design and prototyping of electronics, trigger and data acquisition systems progressing well.
  - → First batch of ASIC front end designed by the INO electronics team & fabricated by Euro Practice IC Services being tested in the RPC lab
  - → TDC ASIC developed at IIT Madras

- **Magnet for ICAL**
  - → Prototype magnet running at VECC, Kolkata

8m x 8m x 20 layer engineering module (800 ton) being planned

INO: Simulations

Overview of simulation framework

Simulation Framework

NUANCE

Neutrino Event Generation

$\nu_a + X \rightarrow A + B + \ldots$

Generates particles that result from a random interaction of a neutrino with matter using theoretical models .

Output:
i) Reaction Channel
ii) Vertex Information
Iii) Energy & Momentum of all Particles

GEANT4

Event Simulation

A + B + … through RPCs + Mag.Field

Simulate propagation of particles through the detector (RPCs + Magnetic Field)

Output:
i) x,y,z,t of the particles at their interaction point in detector
ii) Energy deposited
iii) Momentum information

Event Digitisation

(x,y,z,t) of A + B + … + noise + detector efficiency

Add detector efficiency and noise to the hits

Output:
i) Digitised output of the previous stage (simulation)

Event Reconstruction

(E,p) of ν + X = (E,p) of A + B + …

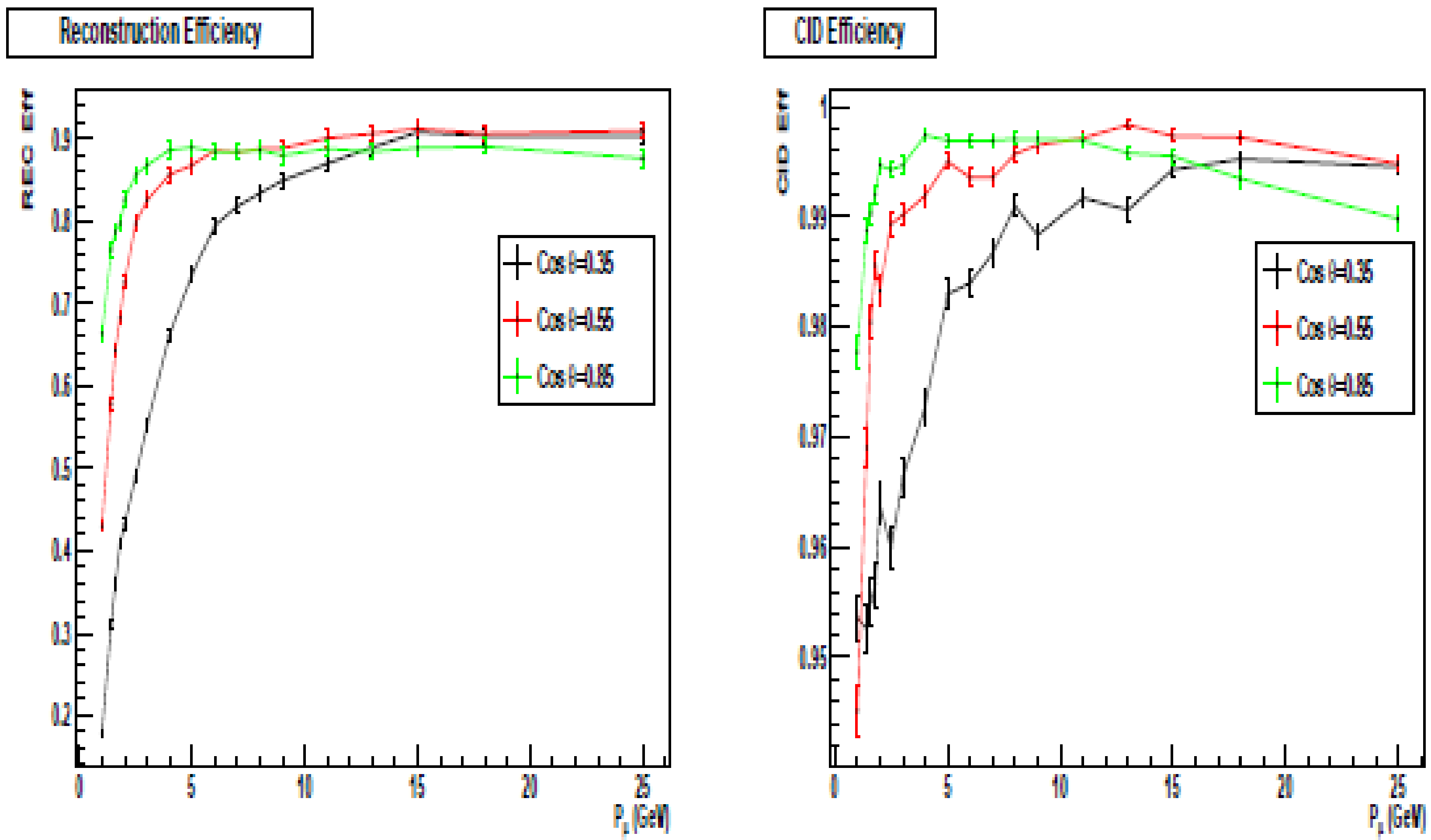
Fit the tracks of A + B + … to get their energy and momentum.

Output:
i) Energy & Momentum of the initial neutrino

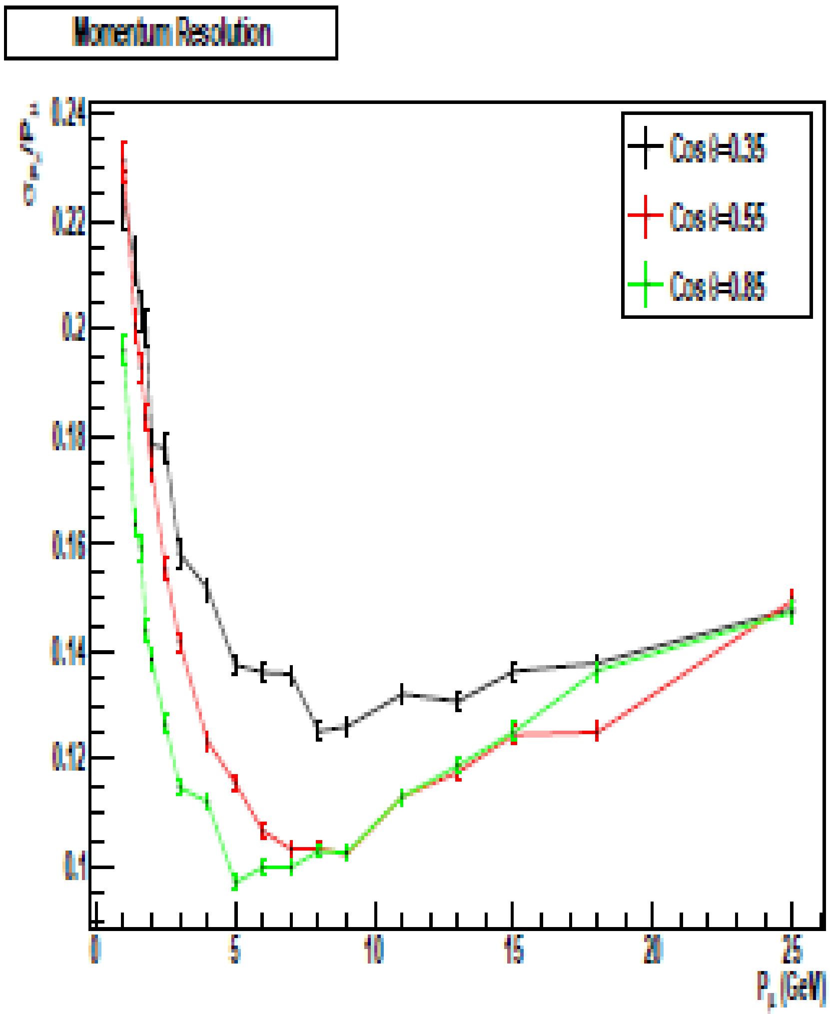
The status of INO simulations

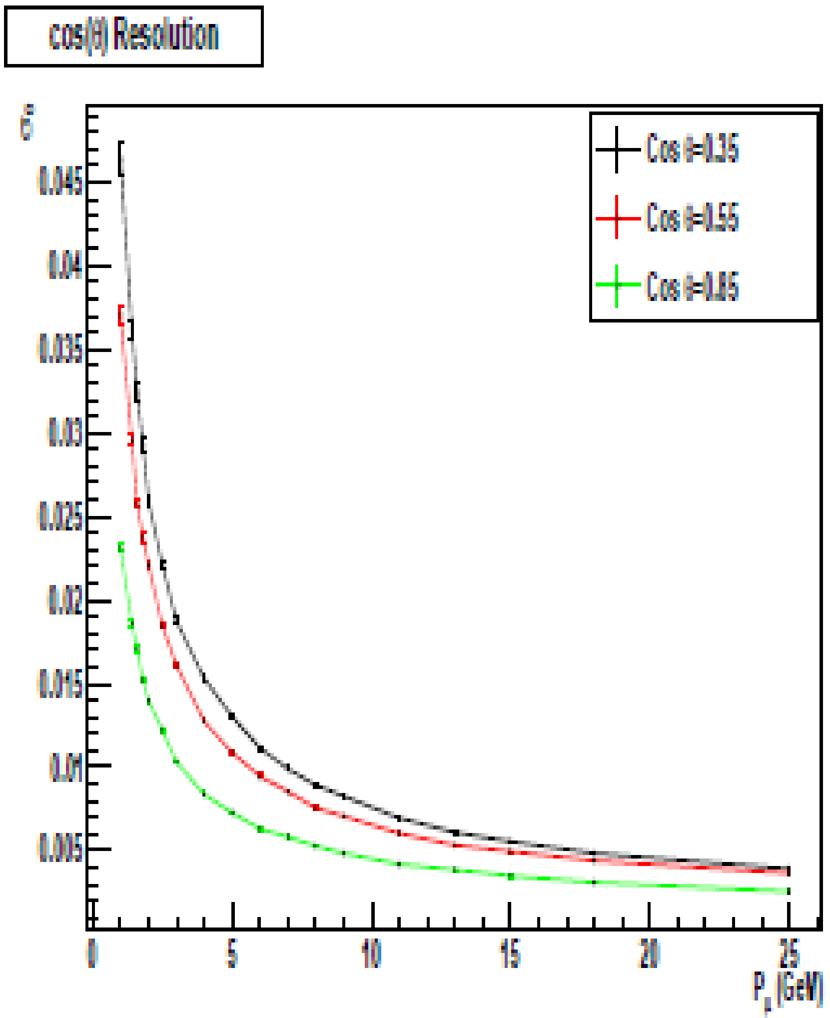
- Inhomogeneous magnetic field implemented
- Muon track reconstruction: good understanding of energy and direction resolution, but improvements still possible
- Hadron energy resolutions available (but not used in the results shown in this talk)
- Neutrino energy reconstruction using muon and hadron momenta possible
- Optimization of iron plate thickness in progress

Detector performance: efficiencies

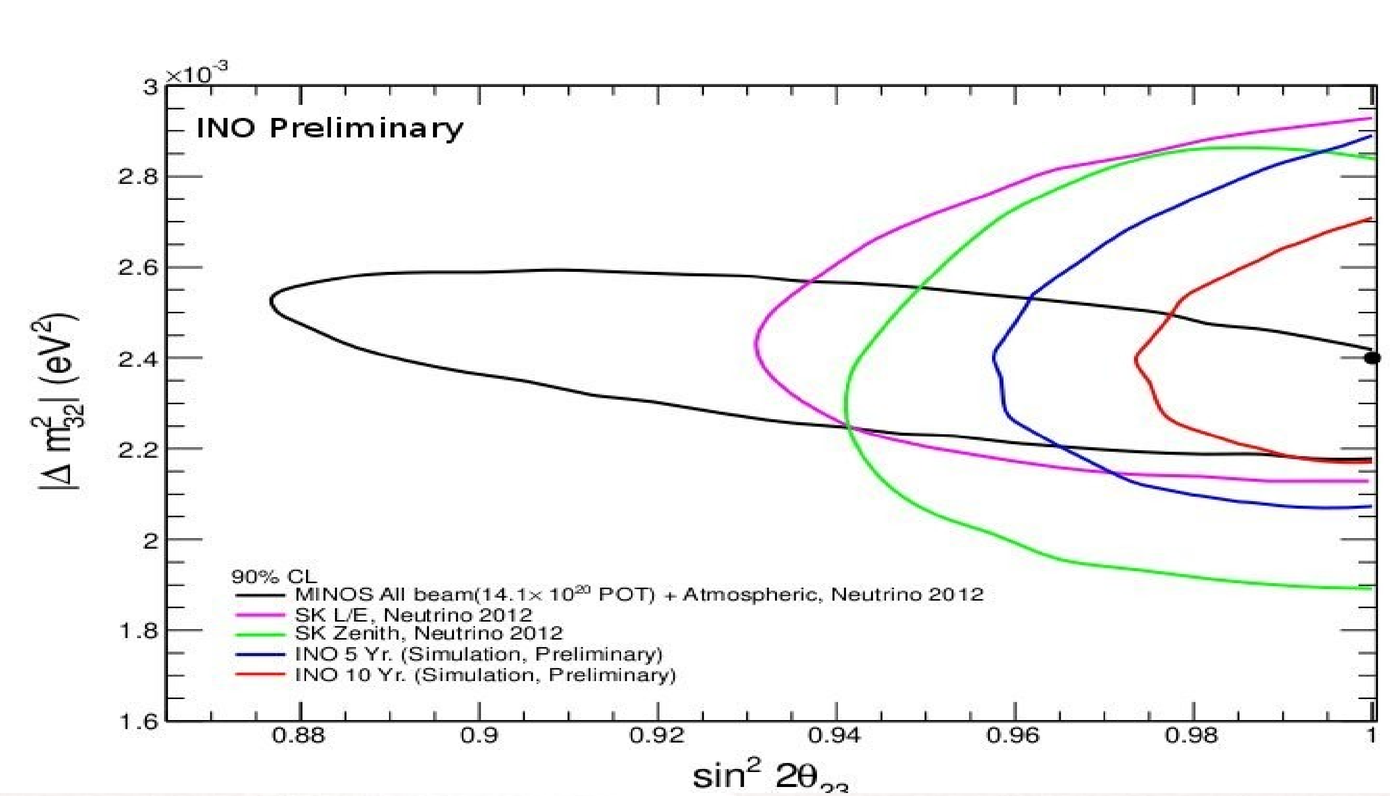


Detector performance: resolutions



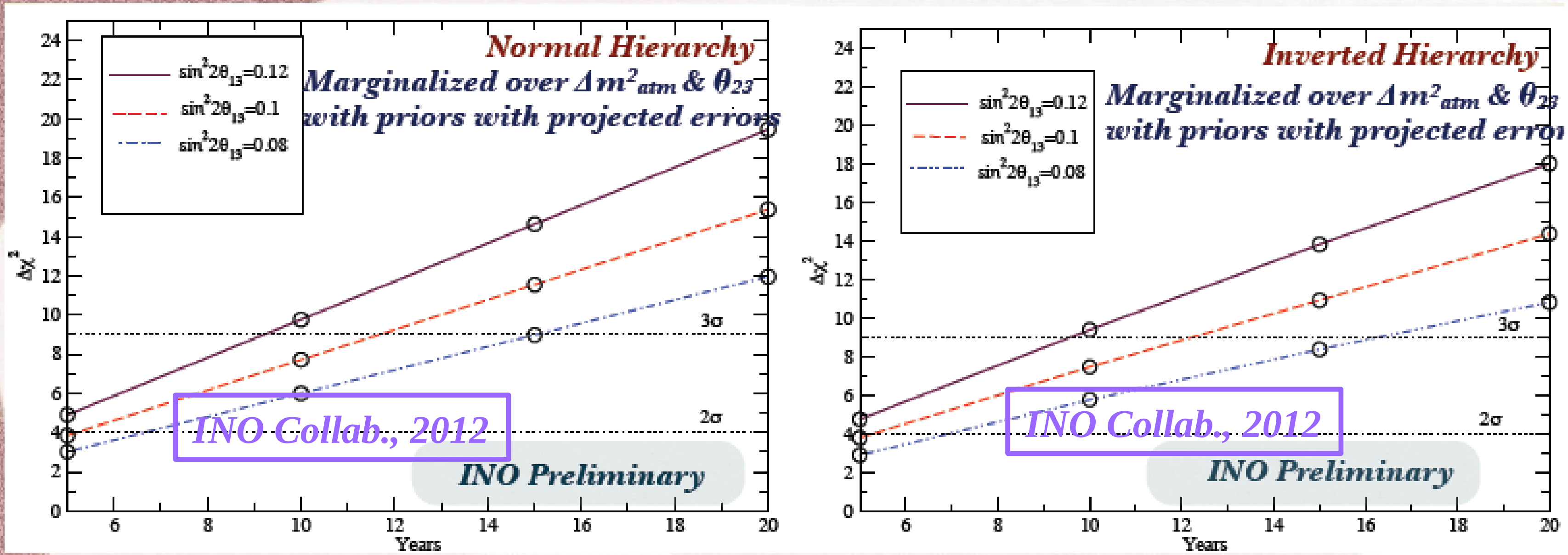


Atmospheric parameters with INO-ICAL



- *Priors used on |Delta32|, theta23, theta13 projected reach*
- *Precision complementary to LBL experiments: better for theta23, but worse for |Delta32|.*

Mass hierarchy with INO-ICAL

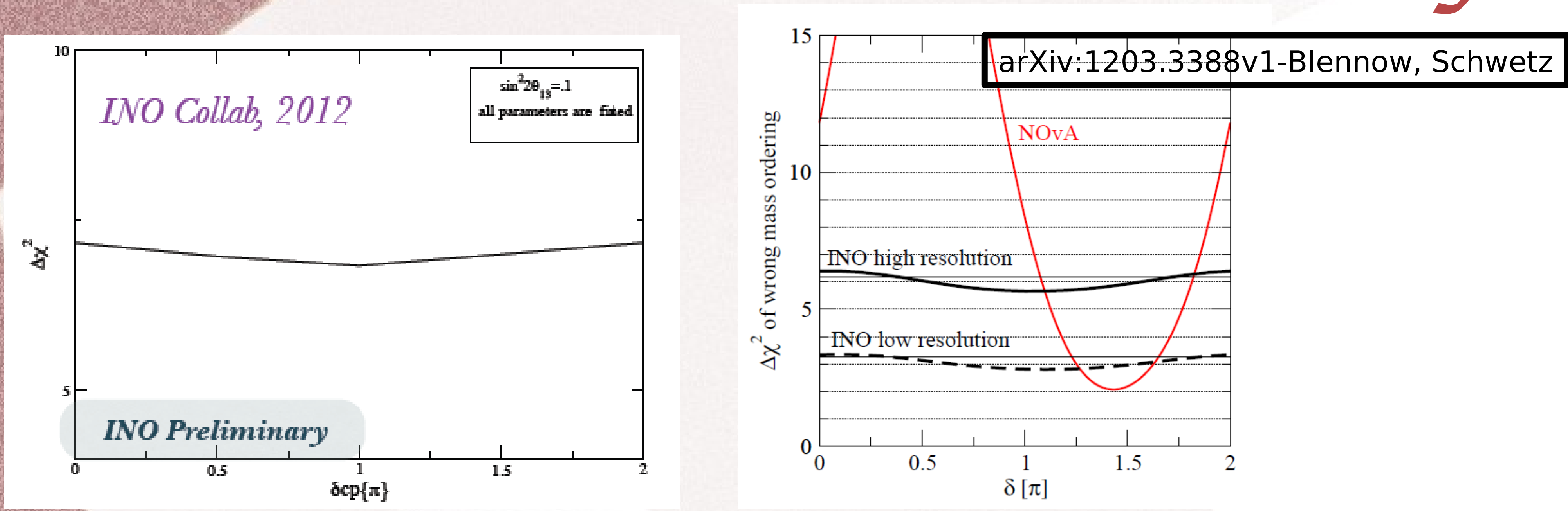


- *Events generated using NUANCE and ICAL resolutions in*
  E and cos(theta_zenith)
- *For sin^2(theta23)=0.5, sin^2(2 theta13)=0.1:*

  In 5 years (2022), 2 sigma sensitivity to MH

  In 10 years (2027), 2.7 sigma sensitivity to MH

Impact of CP phase on MH sensitivity



- *Data generated at deltaCP=0 and fitted to nonzero deltaCP*
- *MH sensitivity almost independent of the CP phase*

INO: Timeline

INO-ICAL timeline

SN	Description of work	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17
	Civil work at Pottipuram						
1	Land acquisition and pre-project work						
2	Architectural and Engineering consultancy						
3	Tendering and award of contracts						
4	Mining of access portal						
5	Excavation of tunnel						
6	Excavation of caverns						
7	Installation of services, cranes, lifts etc.						
8	Civil work for magnet support bed						
9	Surface facilities						
	Magnet						
10	Procurement of steel plates						
11	Machining job for steel plates						
12	Transportation of machined plates at site						
13	Procurement of copper coils						
14	Assembly/erection of magnet (3 modules)						
	RPC						
15	Finalization of all design details, tendering						
16	Procurement of components						
17	Fabrication and assembly of 30000 pcs						
18	Transportation to site and tests						
19	Procurement of electronics, gas handling						
20	Installation and commissioning						

Thank You

Collaborators are welcome !

http://www.ino.tifr.res.in/ino/

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