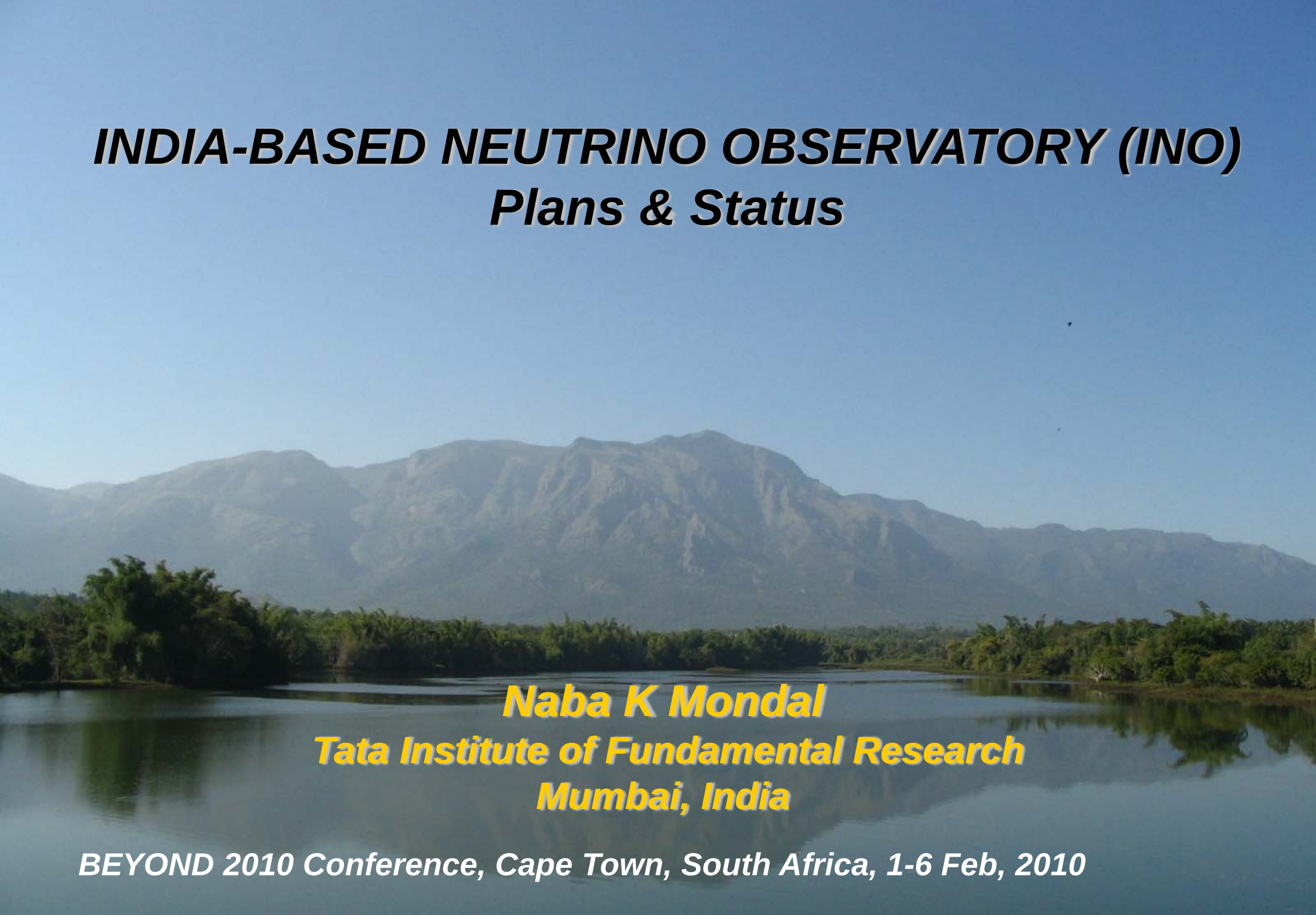


INDIA-BASED NEUTRINO OBSERVATORY (INO)
Plans & Status

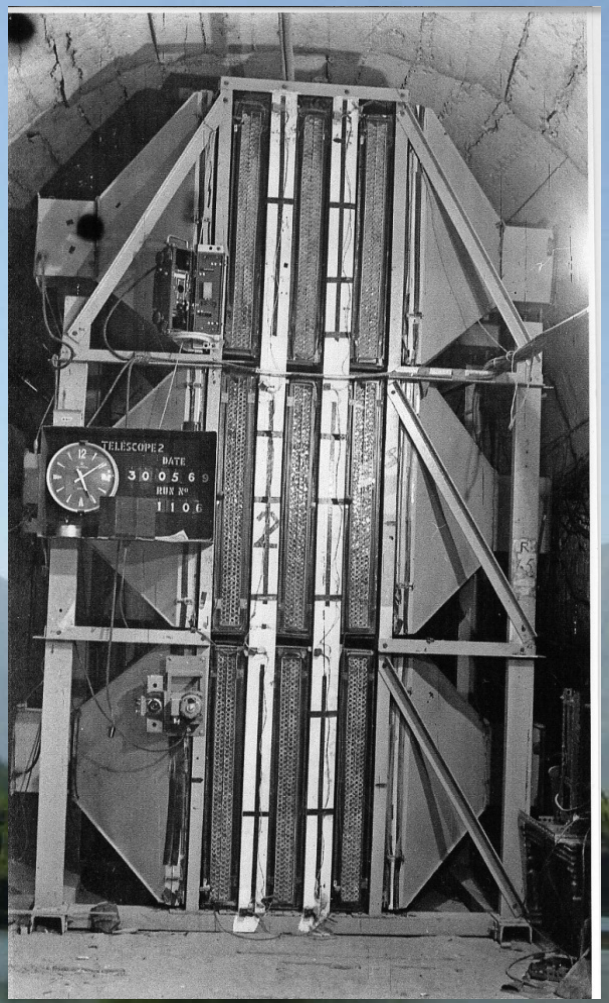
Naba K Mondal

Tata Institute of Fundamental Research

Mumbai, India

BEYOND 2010 Conference, Cape Town, South Africa, 1-6 Feb, 2010

Atmospheric neutrino detection in 1965 in India & South Africa



Atmospheric neutrino detector at Kolar Gold Field –1965

DETECTION OF MUONS PRODUCED BY COSMIC RAY NEUTRINO DEEP UNDERGROUND

C. V. ACHAR, M. G. K. MENON, V. S. NARASIMHAM, P. V. RAMANA MURTHY and B. V. SREEKANTAN,
Tata Institute of Fundamental Research, Colaba, Bombay

K. HINOTANI and S. MIYAKE,
Osaka City University, Osaka, Japan

D. R. CREED, J. L. OSBORNE, J. B. M. PATTISON and A. W. WOLFENDALE
University of Durham, Durham, U.K.

Received 12 July 1965

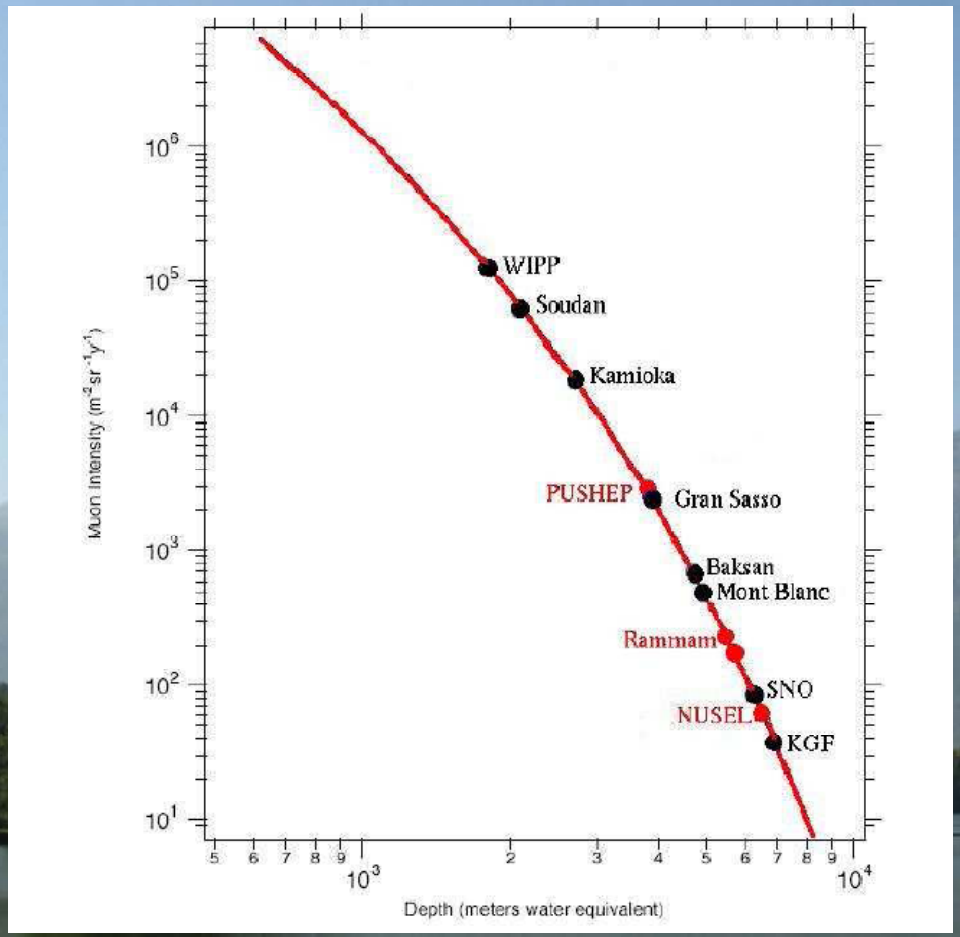
Physics Letters 18, (1965) 196, dated 15th Aug 1965

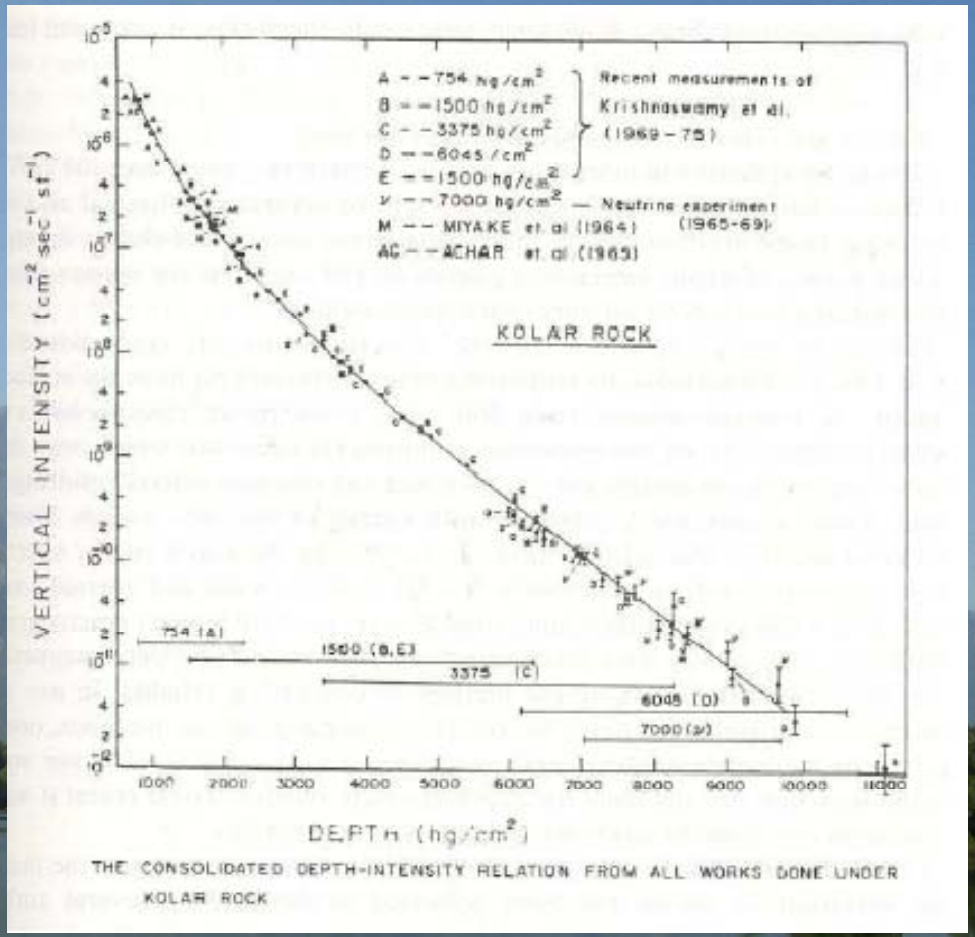
EVIDENCE FOR HIGH-ENERGY COSMIC-RAY NEUTRINO INTERACTIONS*

F. Reines, M. F. Crouch, T. L. Jenkins, W. R. Kropp, H. S. Gurr, and G. R. Smith
Case Institute of Technology, Cleveland, Ohio
and
J. P. F. Sellschop and B. Meyer
University of the Witwatersrand, Johannesburg, Republic of South Africa
(Received 26 July 1965)

PRL 15, (1965), 429, dated 30th Aug. 1965

Kolar Gold Fields





THE CONSOLIDATED DEPTH-INTENSITY RELATION FROM ALL WORKS DONE UNDER KOLAR ROCK

India-based Neutrino Observatory Project

- *India-based Neutrino observatory is a Mega Science Project funded by Dept. of Science & Technology and Dept. of Atomic Energy, Govt. of India . The project will lead to:*
- *Creation of an underground laboratory in the country for carrying out research in the emerging field of neutrino physics. Will develop into a full fledged underground laboratory over the years for other studies.*
- *Involvement of Universities in a big way for carrying out large basic science projects- healthy development of University-Research lab partnership.*
- *A Centre for particle physics and detector technology and its varied applications in areas like medical imaging.*
- ***INO graduate training program will lead to Ph.D. in particle physics and more importantly creating highly skilled scientific manpower for experimental high energy and nuclear physics. Hands on training on all aspect of experiments with strong emphasis on detector development.***

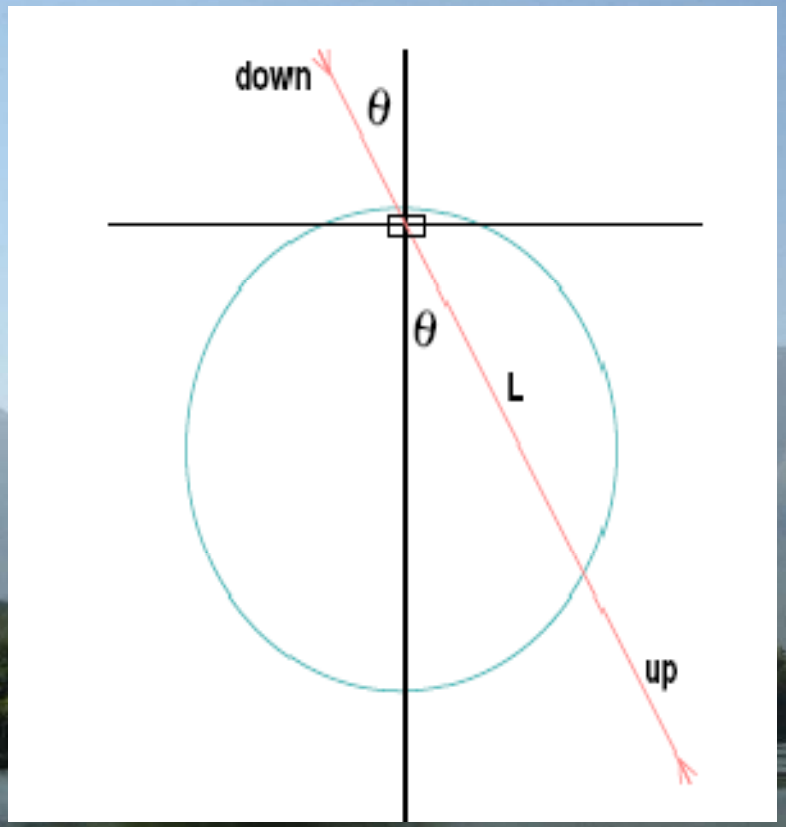
India-based Neutrino Observatory Proposal

A large mass detector with charge identification capability

Physics goal:

- ***Reconfirm atmospheric neutrino oscillation***
- ***Improved measurement of oscillation parameters***
- ***Search for potential matter effect in neutrino oscillation***
- ***Determining the sign of Δm^2_{23} using matter effect***
- ***Measuring deviation from maximal mixing for θ_{23}***
- ***Probing CP and CPT violation***
- ***Constraining long range leptonic forces***
- ***Ultra high energy neutrinos and muons***

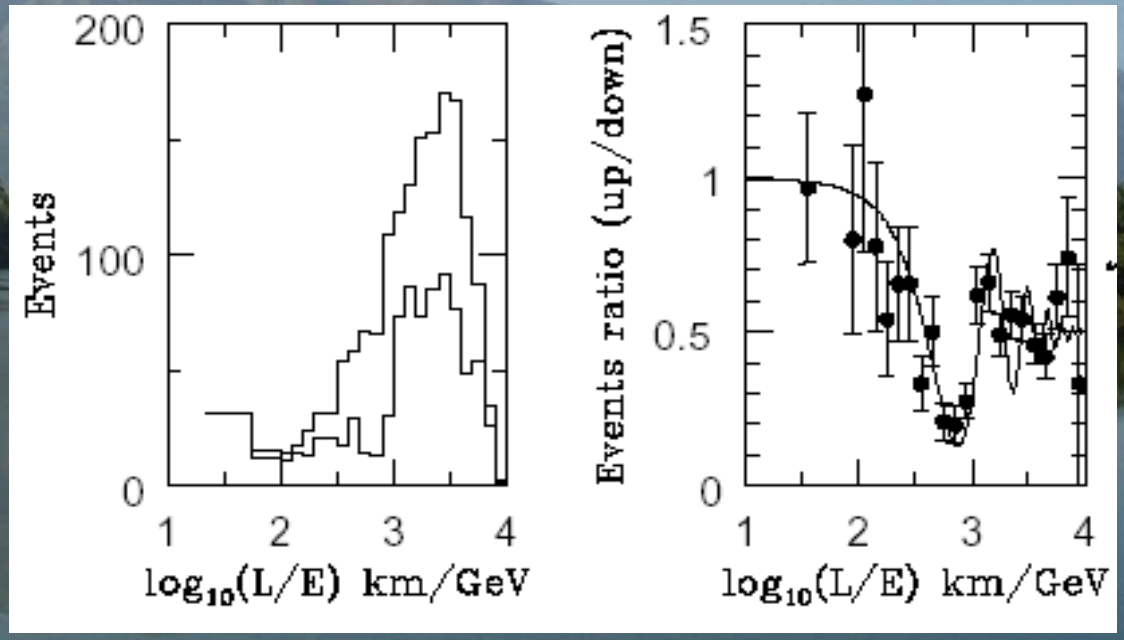
Disappearance of ν_μ Vs. L/E



The disappearance probability can be measured with a single detector and two equal sources:

$$\frac{N_{up}(L/E)}{N_{down}(L/E)} = P(\nu_\mu \rightarrow \nu_\mu; L/E)$$

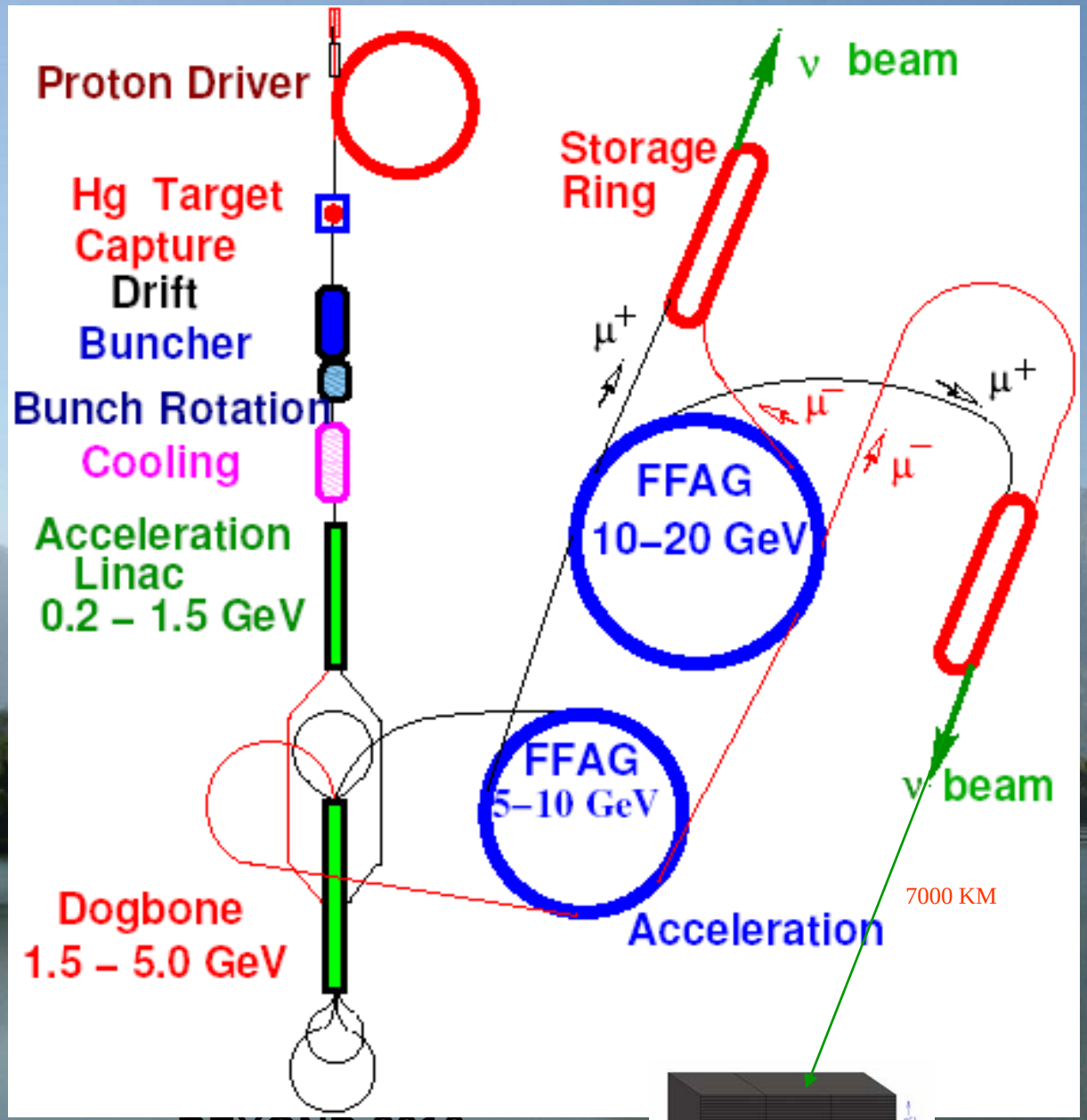
$$= 1 - \sin^2(2\Theta)\sin^2(1.27\,\Delta m^2\,L/E)$$

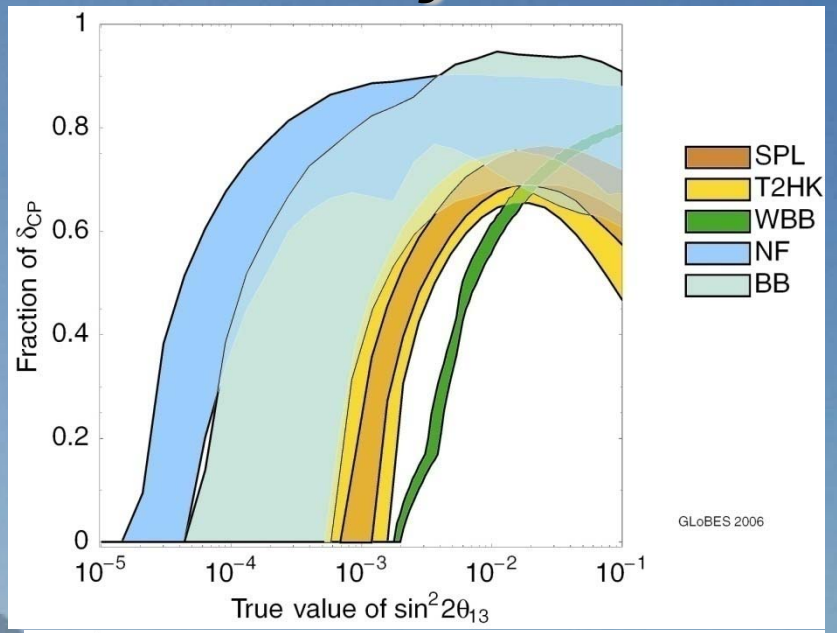


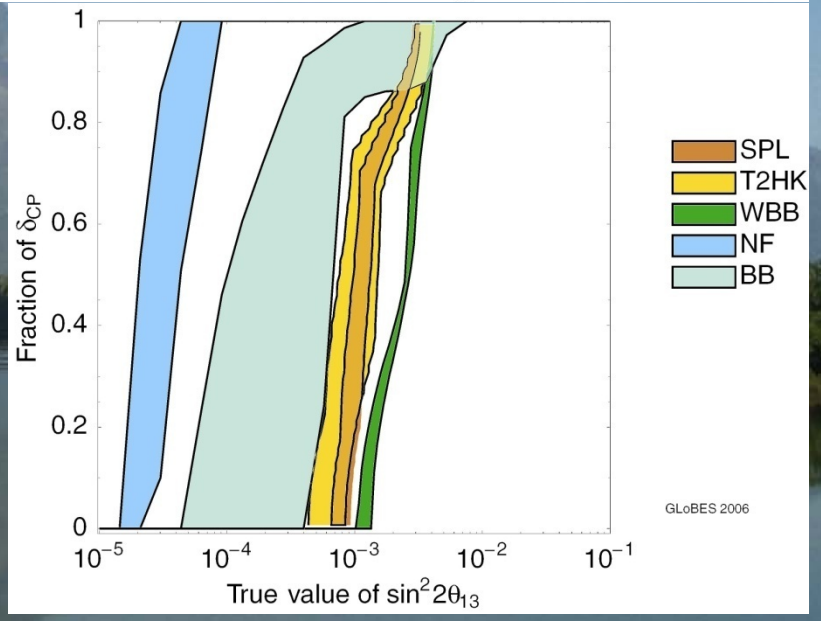
Precision measurement of Δm^2_{31} and θ_{23}

Experiment	$\lvert\Delta m^2_{31}\rvert$	$\sin^2\theta_{23}$
Current	30%	34%
MINOS + CNGS	13%	38%
T2K (5 yrs)	6%	22%
NOvA (5 yrs)	13%	42%
SK20 (1.84 MTy)	17%	24%
INO (250 KTy)	10%	30%

Beyond Superbeam - Neutrino Factory



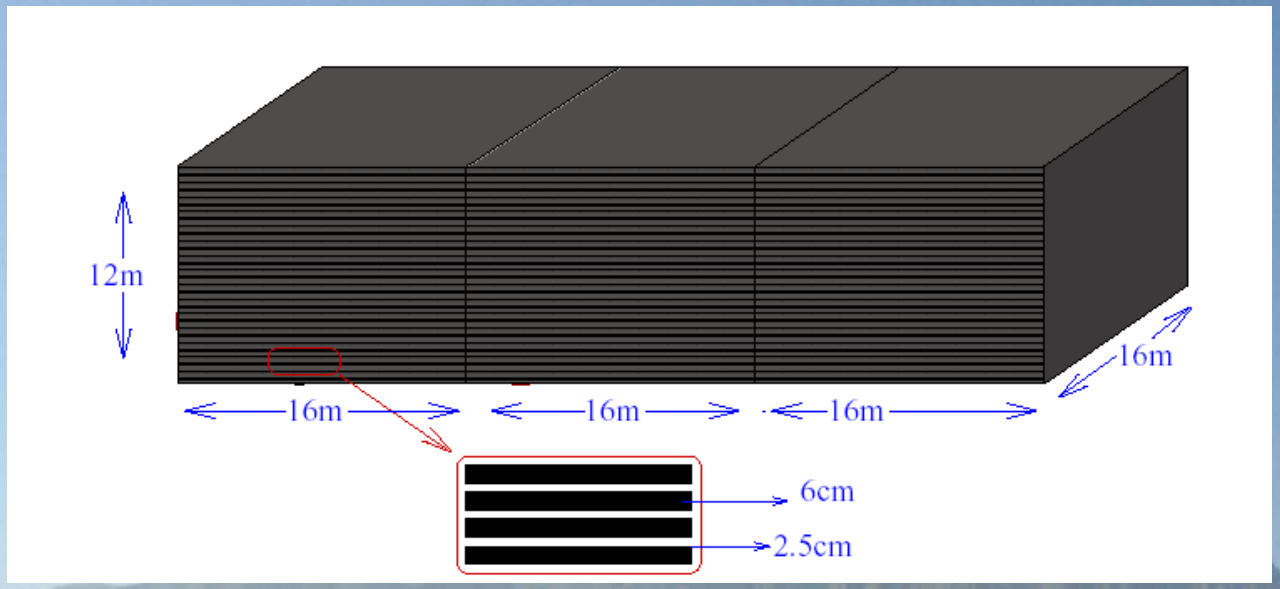


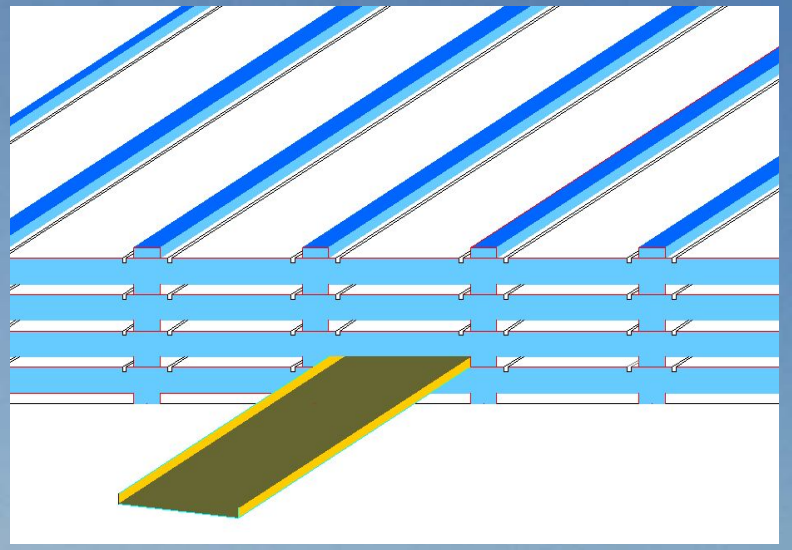


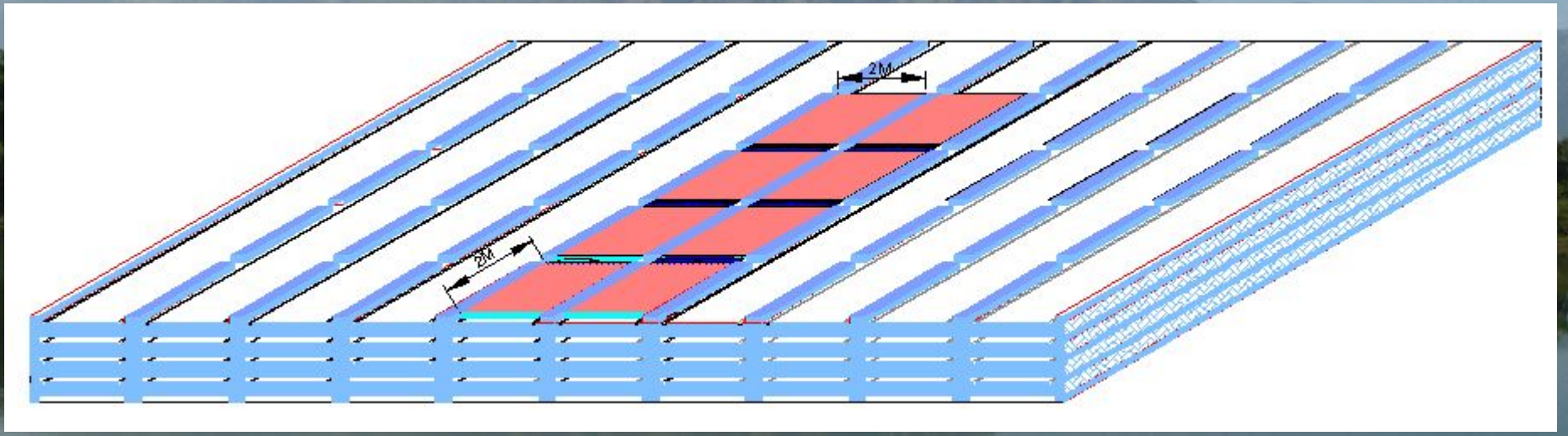
INO Phase 1

- *Neutrino Source*
  - *Need to cover a large L/E range*
    - *Large L range*
    - *Large E_ν Range*
  - *Use Atmospheric neutrinos as source*
- *Detector Choice*
    - *Should have large target mass (50-100 kT)*
    - *Good tracking and Energy resolution (tracking calorimeter)*
    - *Good directionality (<= 1 nsec time resolution)*
    - *Charge identification*
    - *Ease of construction*
    - *Modularity*
    - *Complimentarity with other existing and proposed detectors*
  - *Use magnetised iron as target mass and RPC as active detector medium*

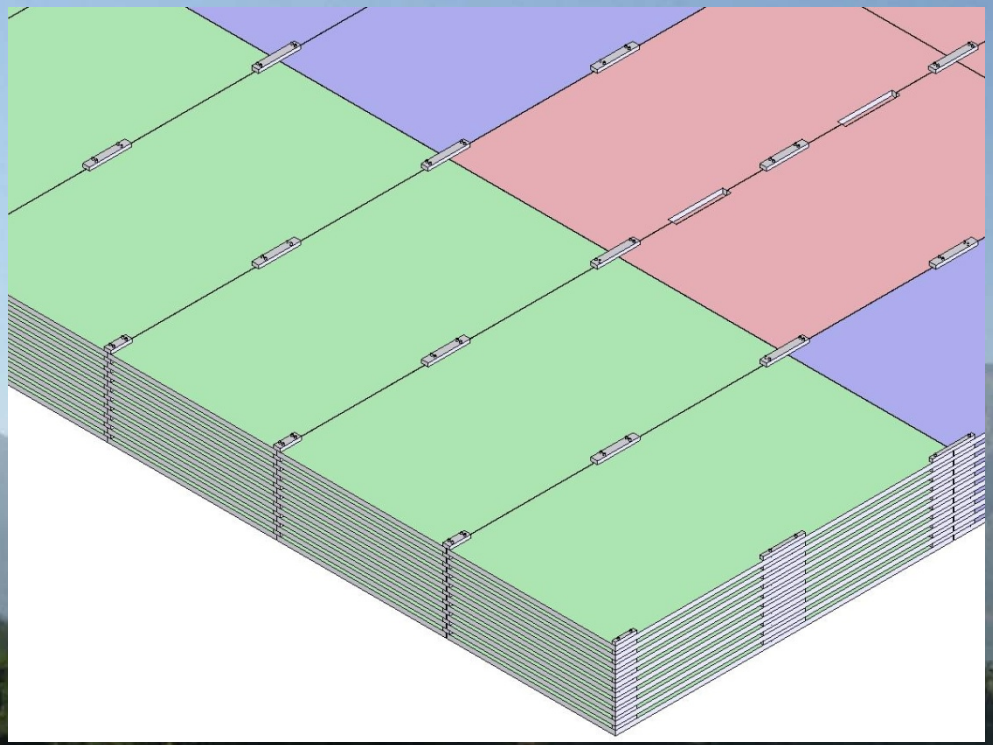
INO Detector Concept

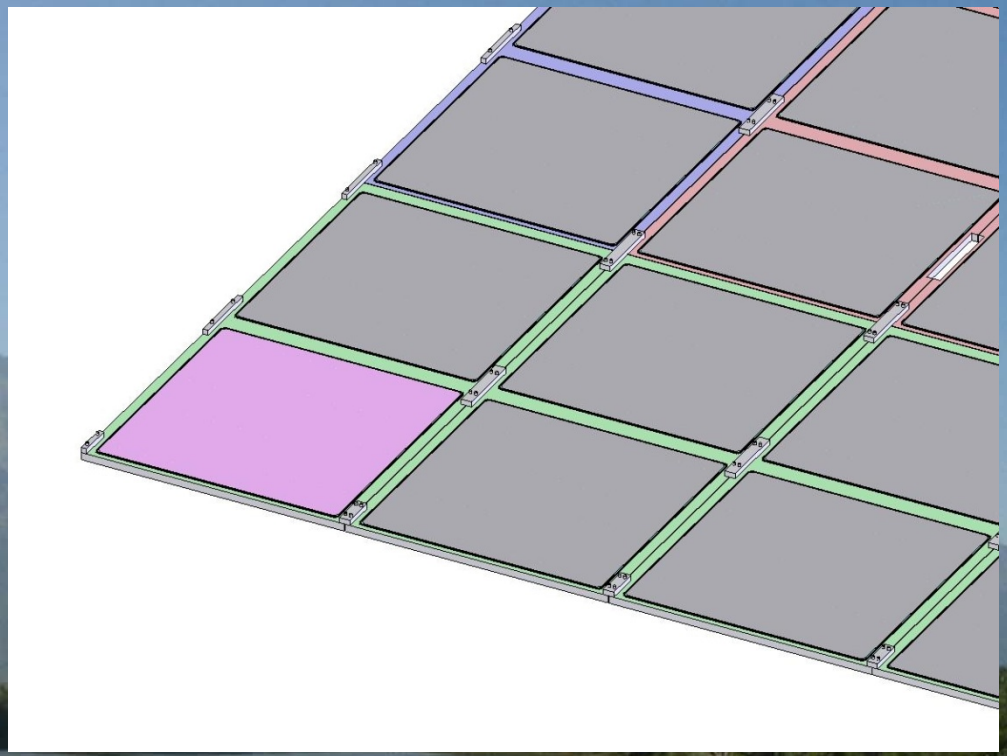




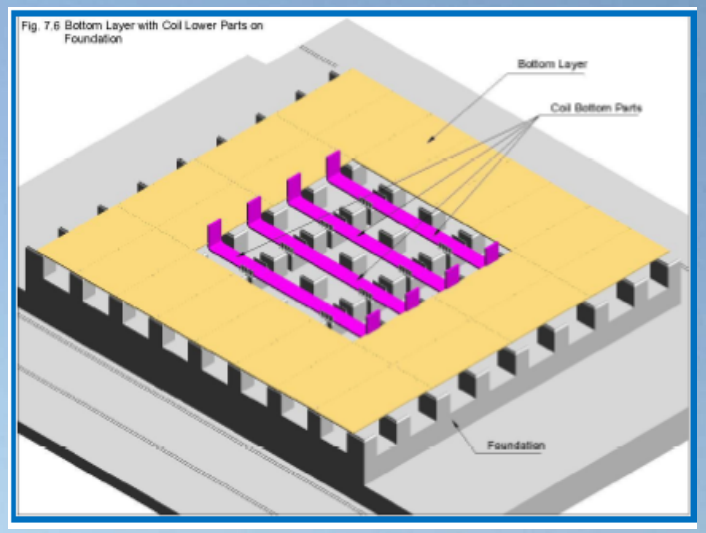


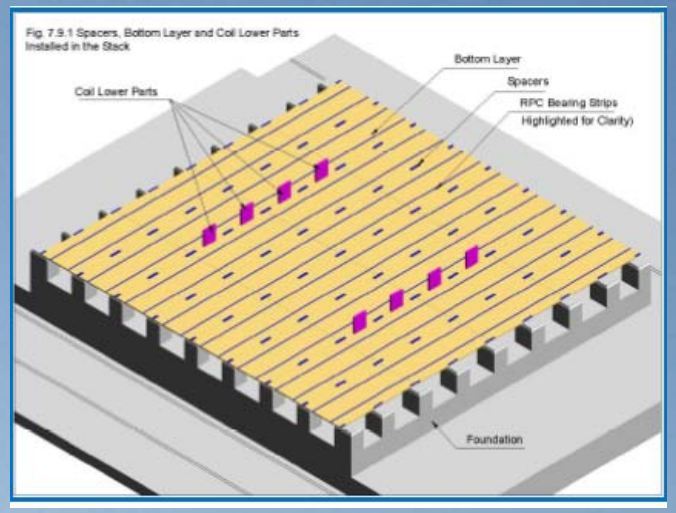
Assembly of INO-ICAL detector

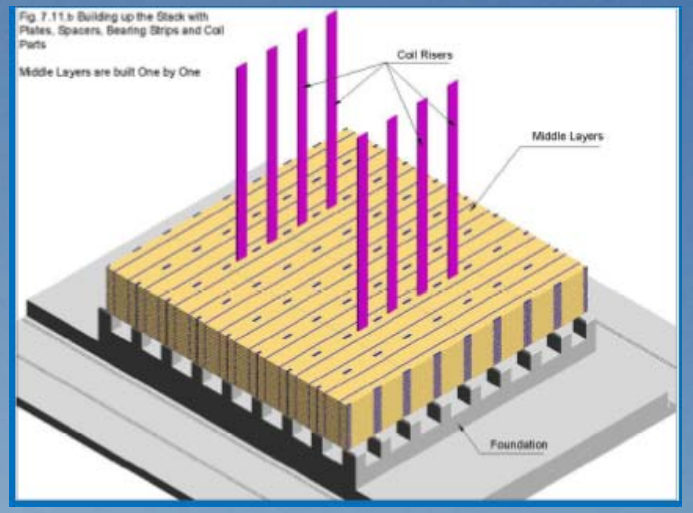


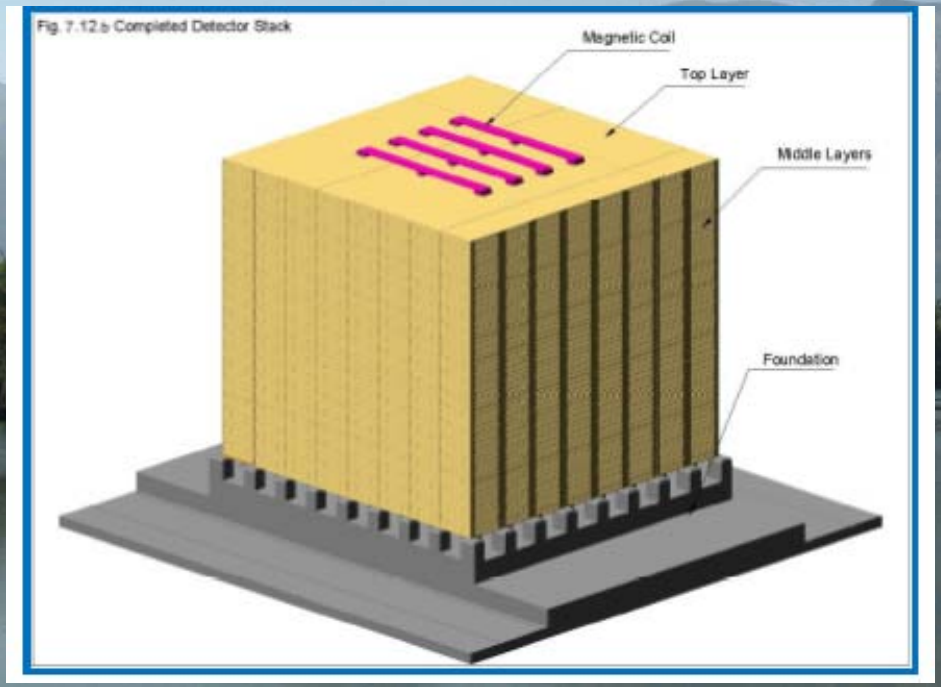


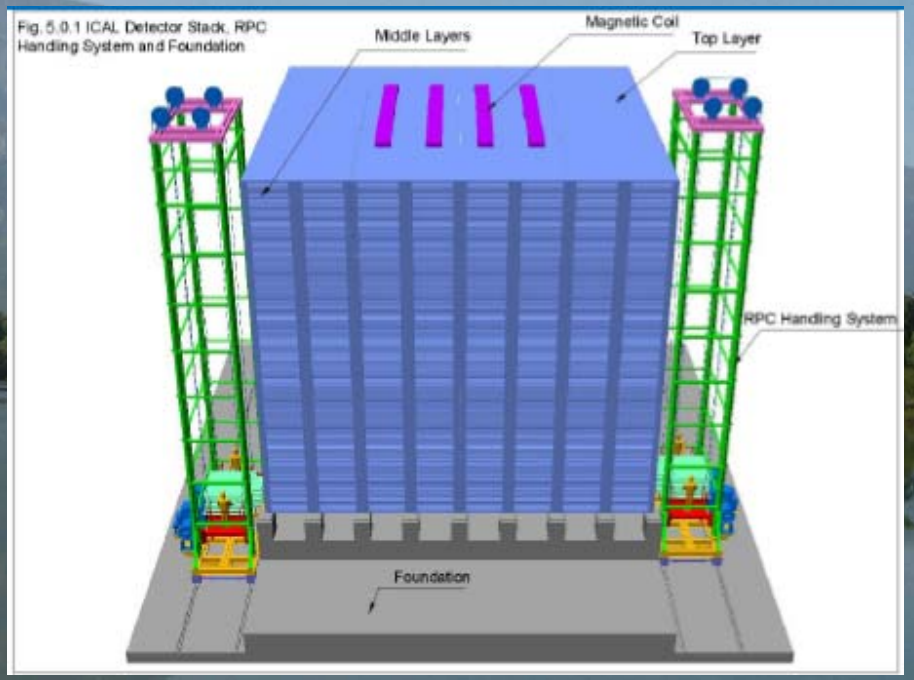
Construction of the ICAL detector







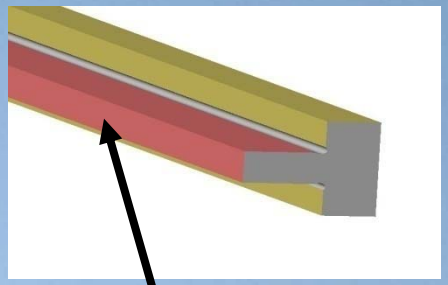




Largest Basic Science Project in India

No of modules	3
Module dimension	16 m X 16 m X 12 m
Detector dimension	48 m X 16 m X 12 m
No of layers	140
Iron plate thickness	6 cm
Gap for RPC trays	2.5 cm
Magnetic field	1.5 Tesla
RPC unit dimension	2 m X 2 m
Readout strip width	2 cm
No. of RPCs/Road/Layer	8
No. of Roads/Layer/Module	8
No. of RPC units/Layer	192
Total no of RPC units	27000
No of Electronic channels	3.6×10^6

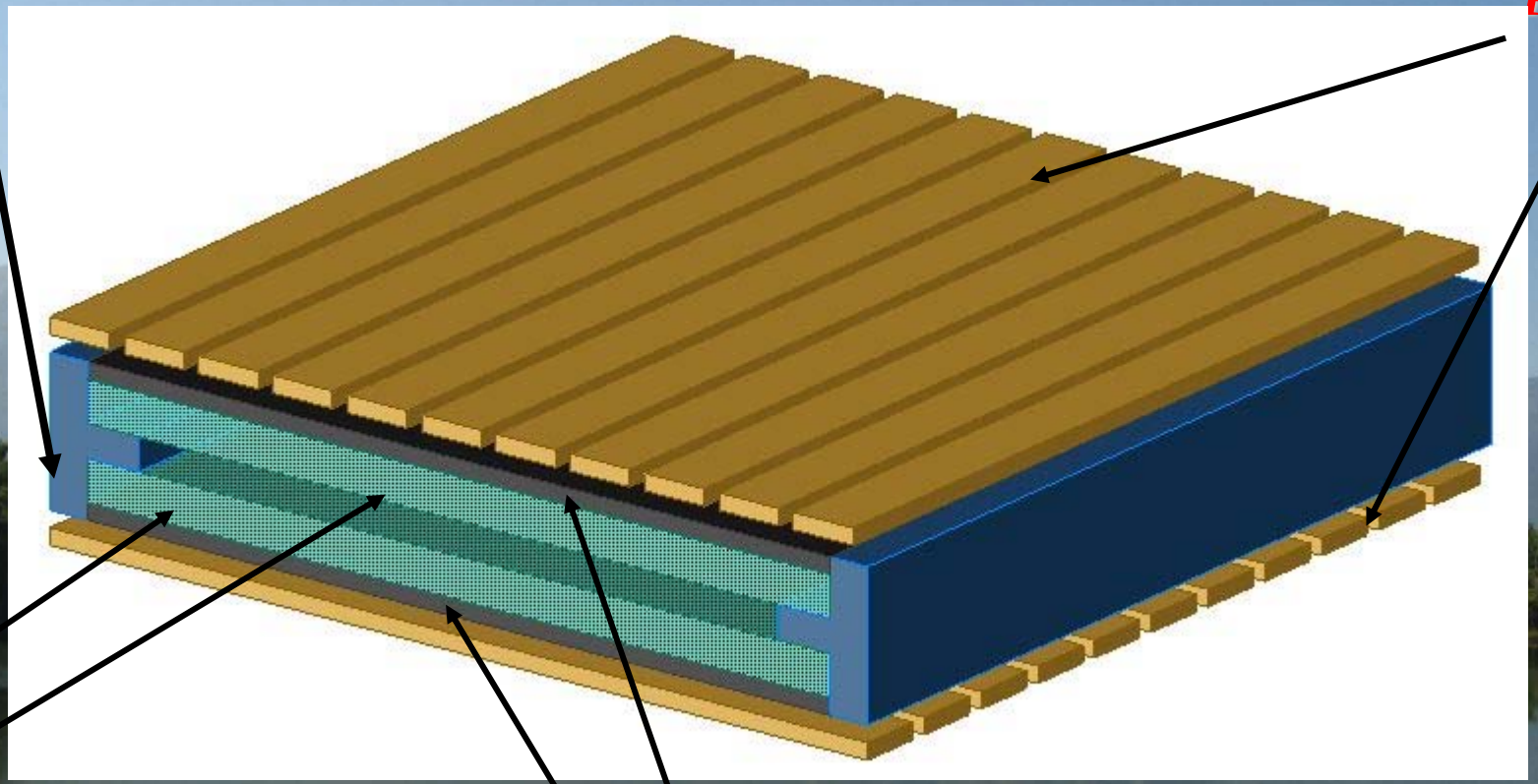
Construction of RPC



2 mm thick spacer

Two 2 mm thick float Glass
Separated by 2 mm spacer

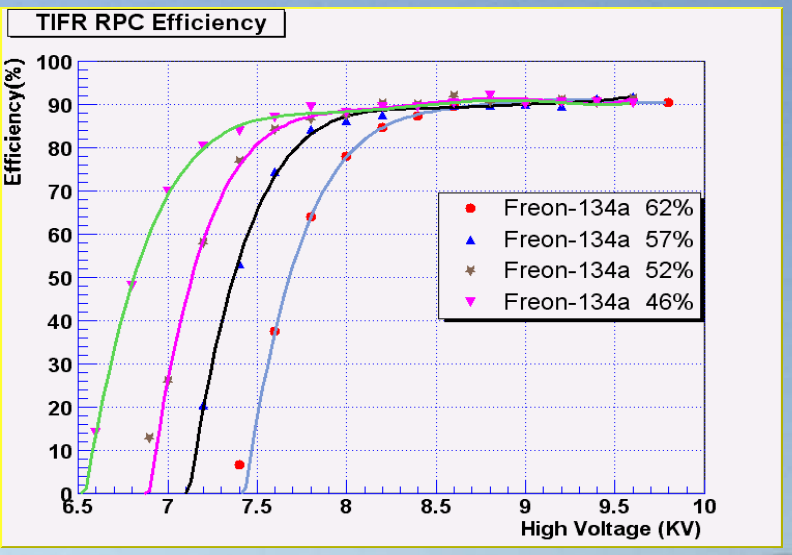
Pickup strips

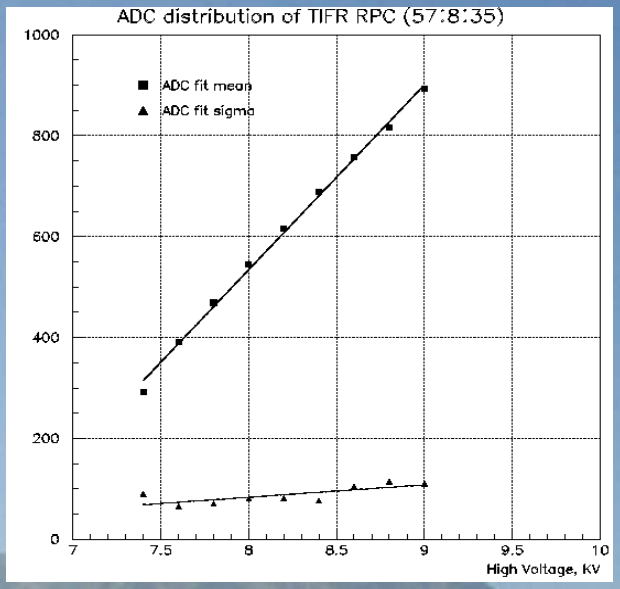


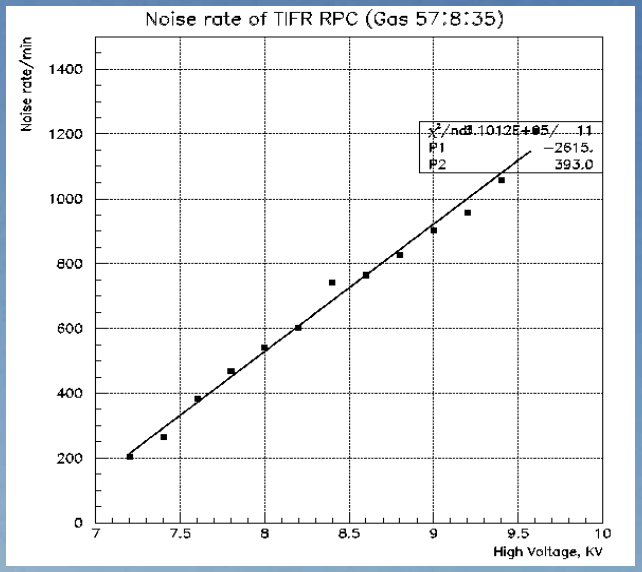
Glass plates

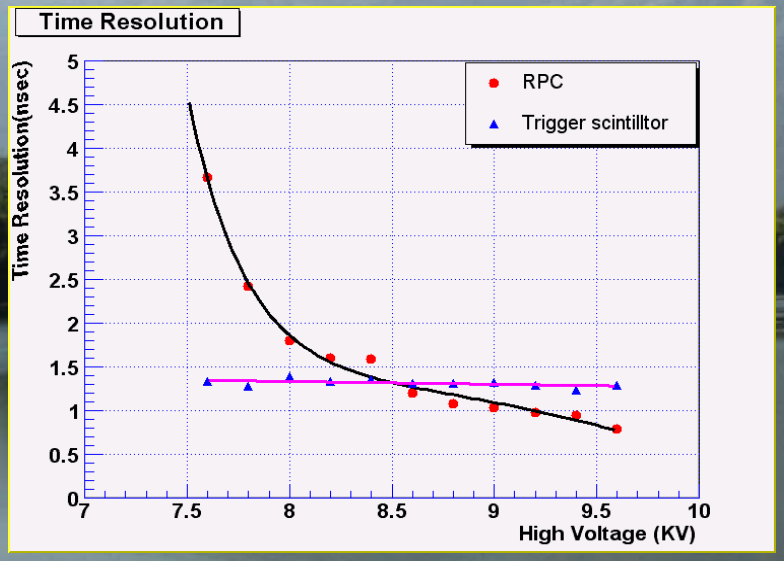
Resistive coating on the outer surfaces of glass

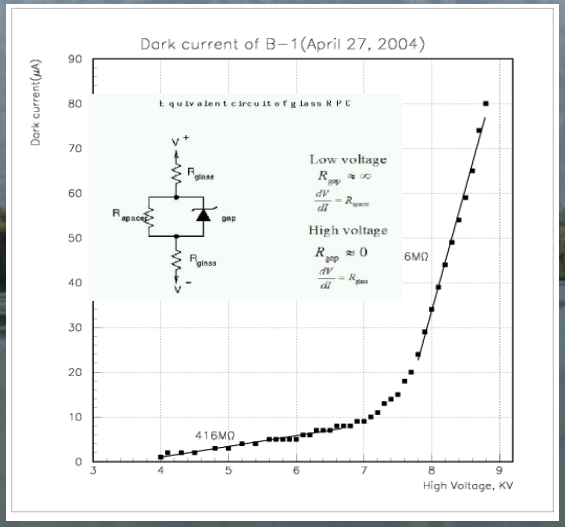
RPC Characteristics





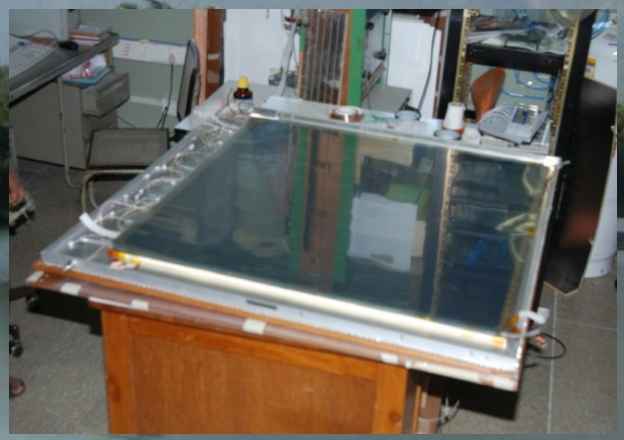


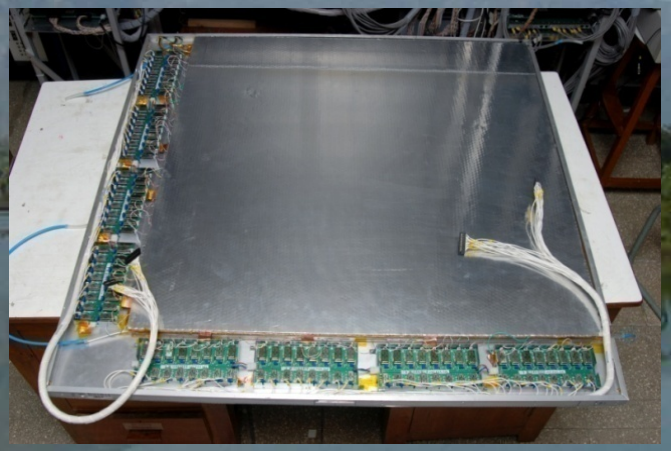




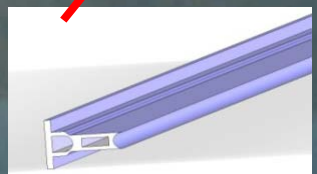
Gas Mixture	Tele window (mm)	Cross talk (%)
62:8:30	10	6.8
62:8:30	15	6.7
62:8:30	20	6.2
57:8:35	20	6.5
52:8:40	20	5.9
46:8:46	20	6.3

Fabrication of 1m x 1m RPCs

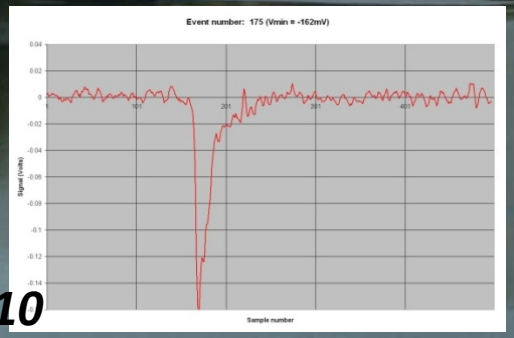


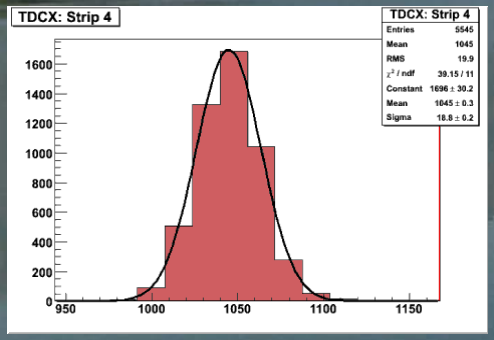


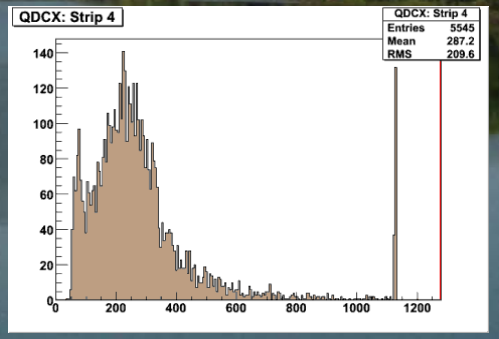
Making of 2m x 2m RPCs



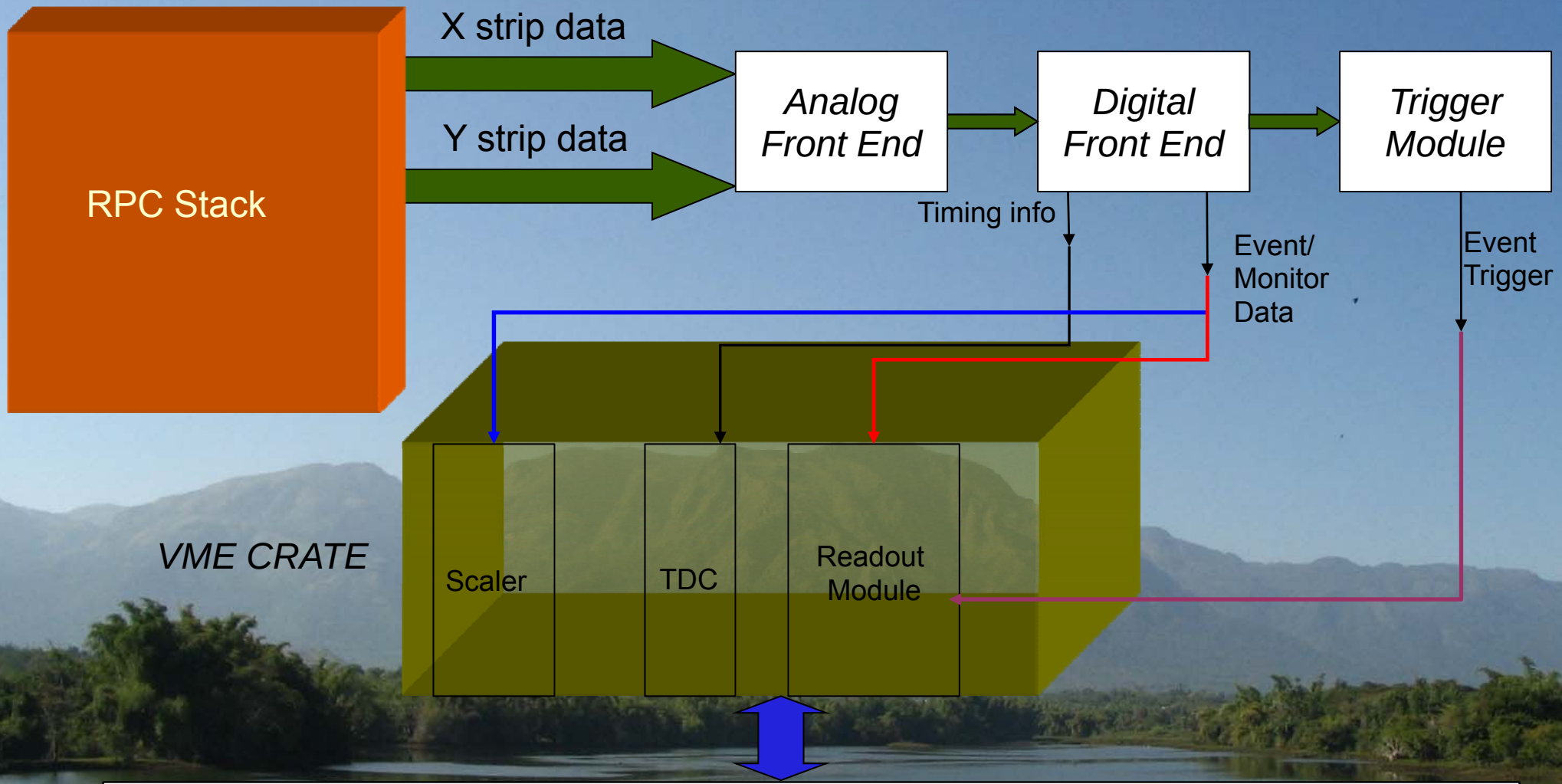
Prototype RPC Stack at TIFR tracking Muons







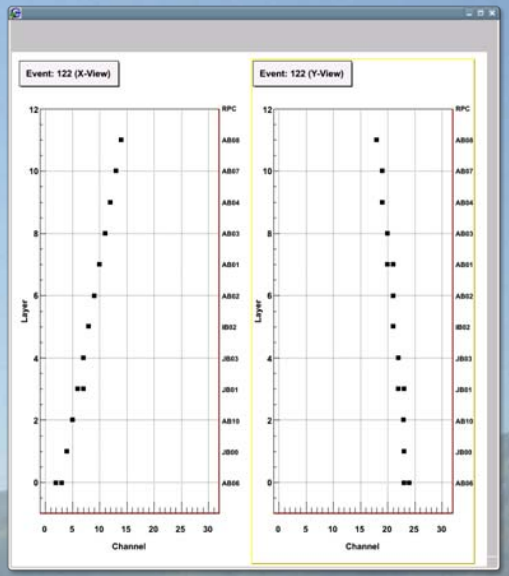
VME BASED DAQ SETUP

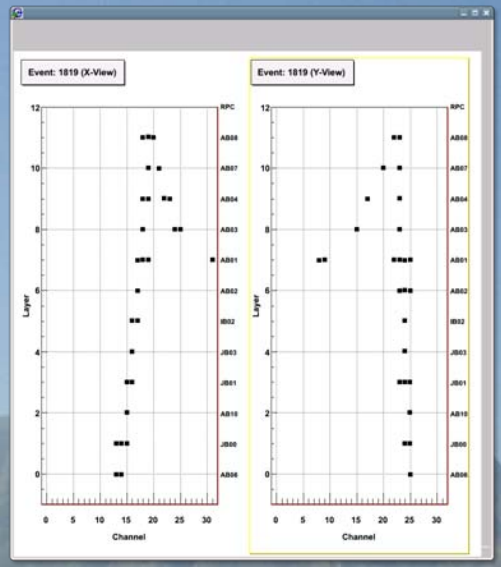


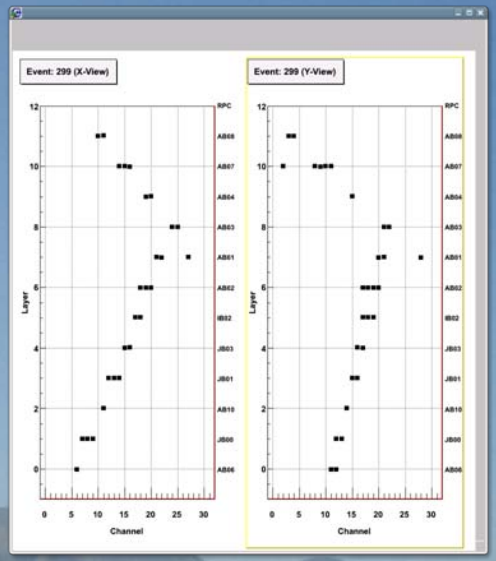
Linux based DAQ software (C++, Qt, ROOT)

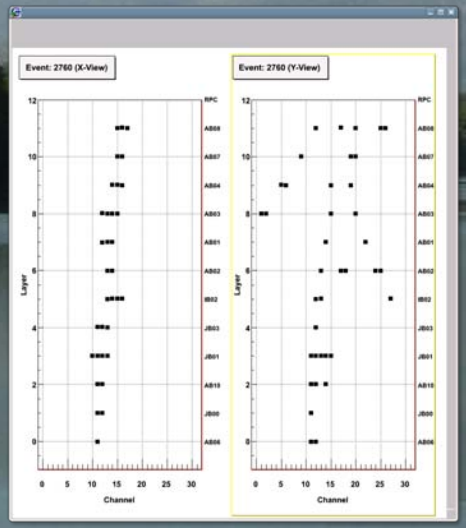
- ✓*Interrupt Based*
- ✓*Multi-Threaded*
- ✓*Graphical User Interface*
- ✓*Online 2D/3D Event Display*
- ✓*RPC Strip Monitoring*
- ✓*Online Error Reporting*

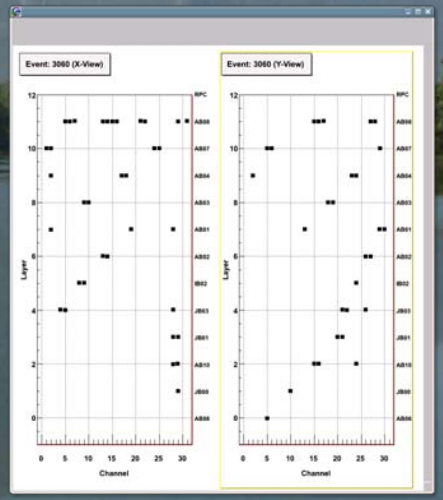
Some interesting cosmic ray tracks



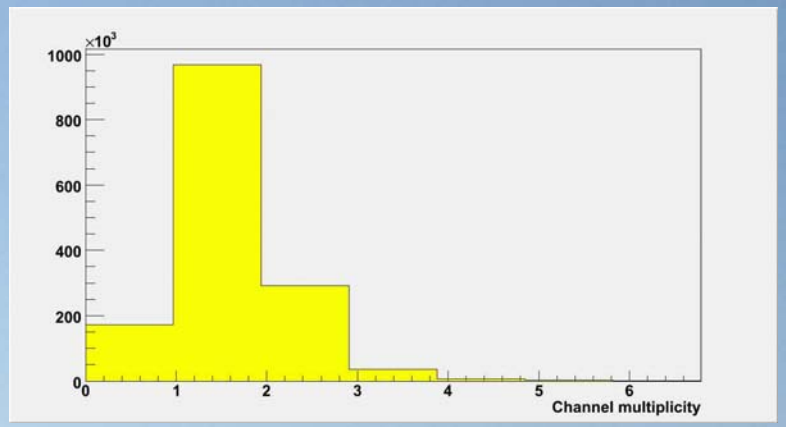




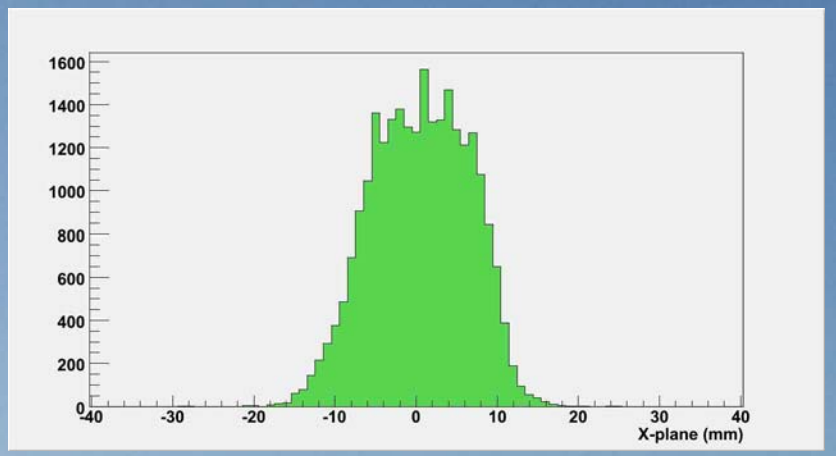




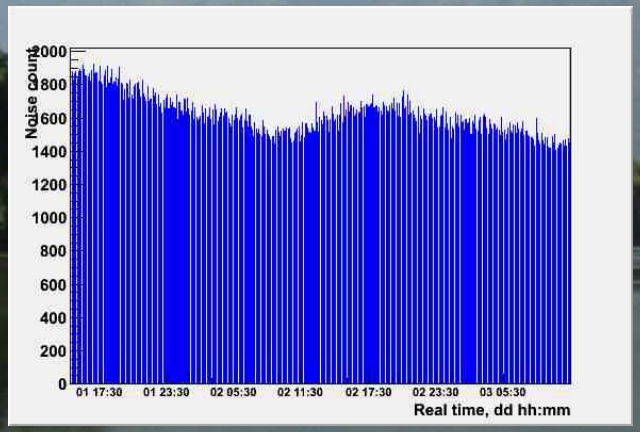
Study of RPC performance using cosmic muons



Strip Multiplicity due to crossing muons



Track residue in mm



Strip noise rate vs time

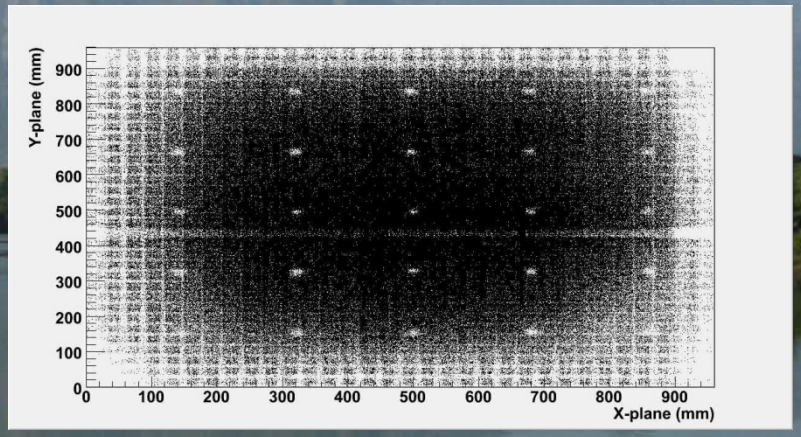
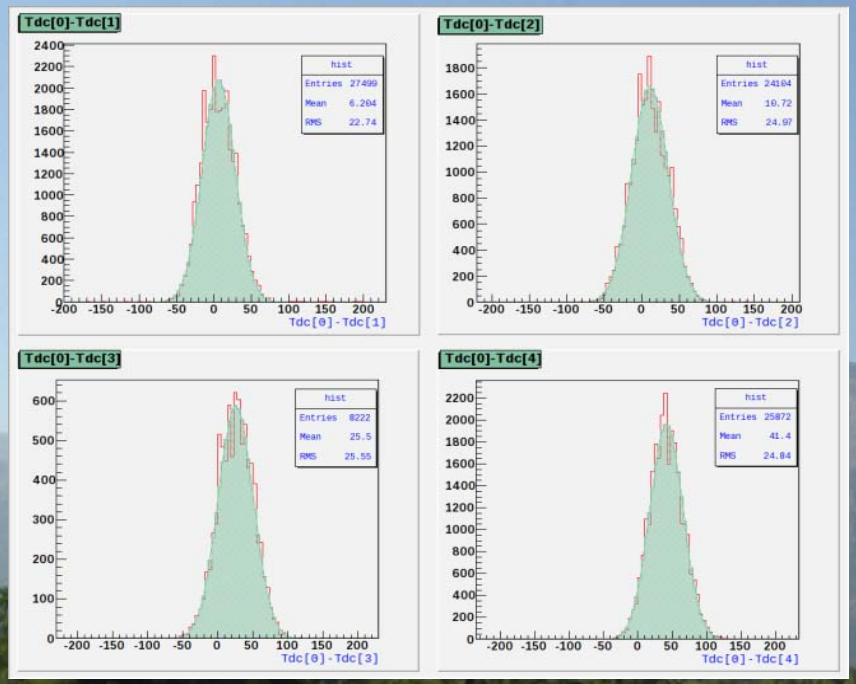
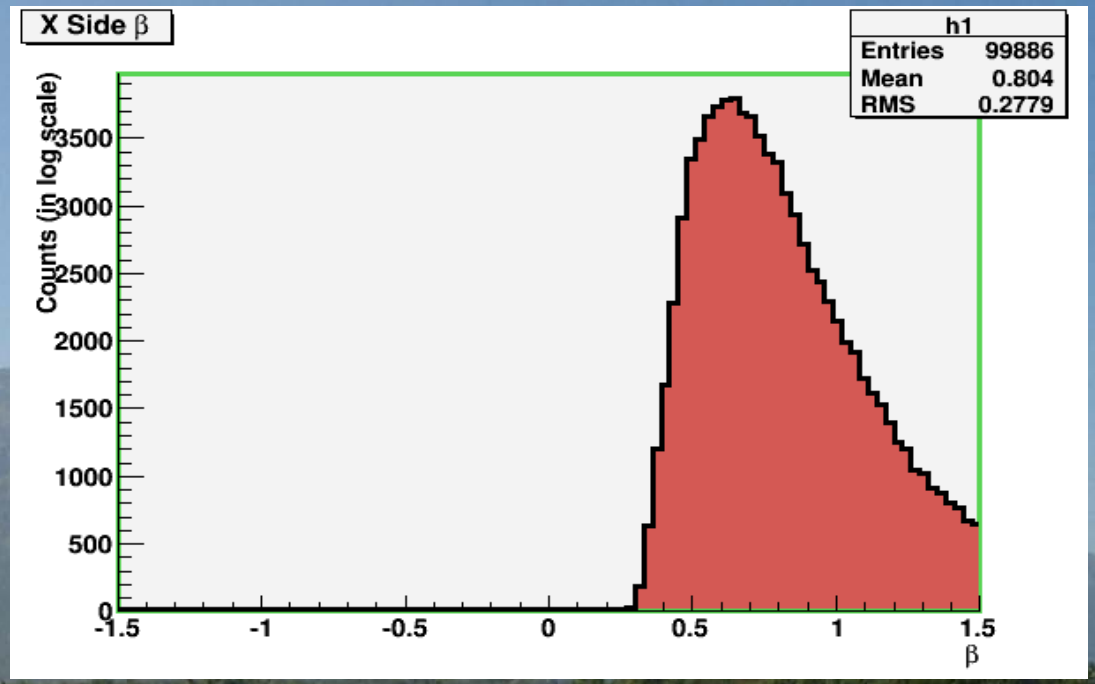


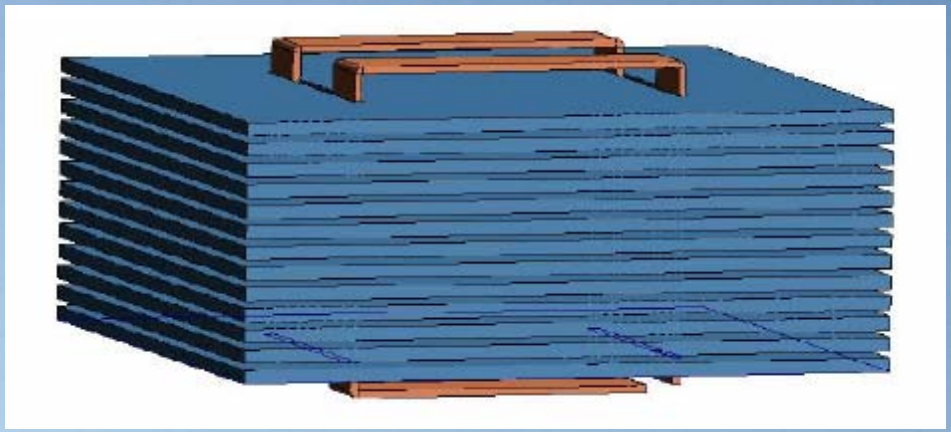
Image of a RPC using muons

Particle Direction using time information

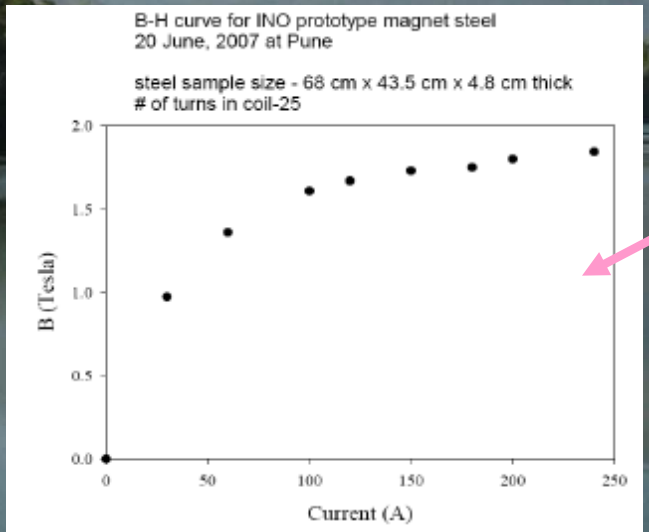




INO Prototype



- *12, 1m² RPC layers*
- *13 layers of 5 cm thick magnetised iron plates*
- *About 1000 readout channels*
- *RPC and scintillation paddle triggers*
- *Hit and timing information*



Simulation Framework

NUANCE

Neutrino Event Generation

ν_a + X -> A + B + ...

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

GEANT

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

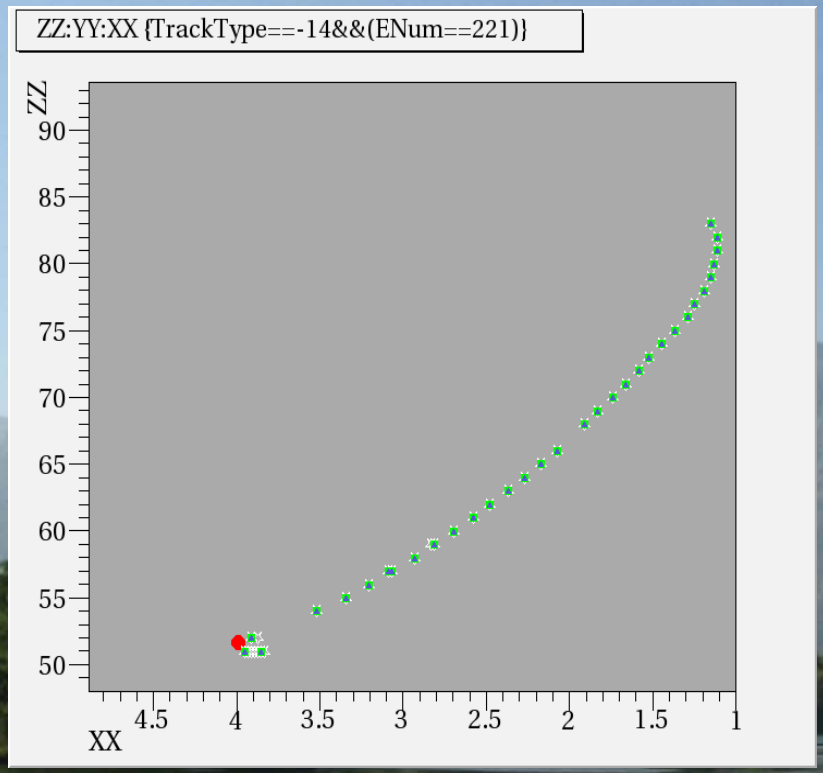
(E,p) of v + X = (E,p) of A + B + ...

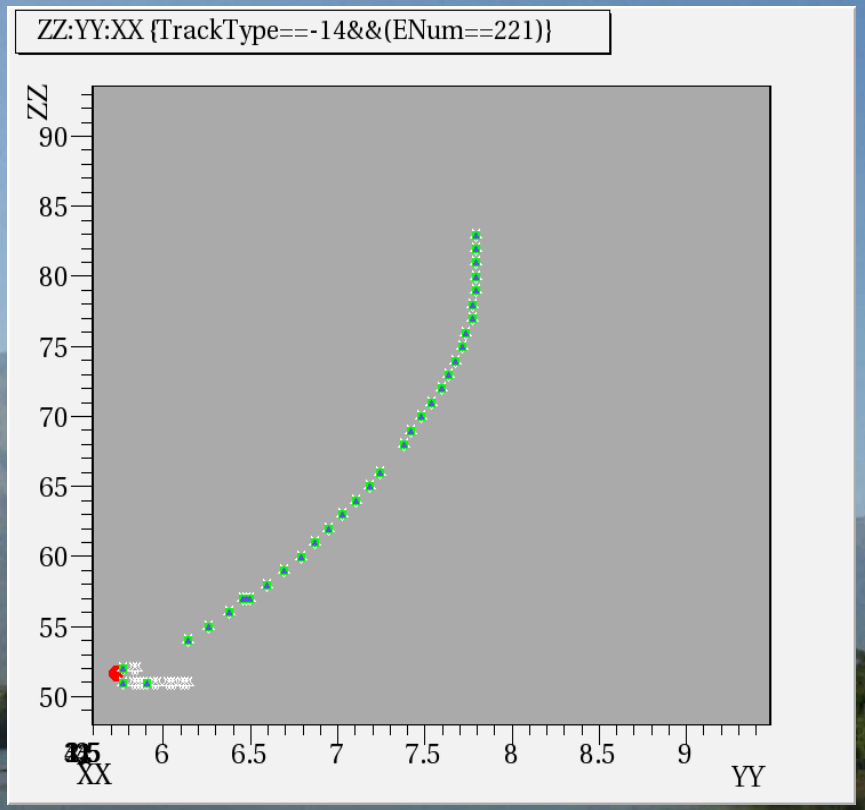
Fit the tracks of A + B + ... to get their energy and momentum.

Output:

i) Energy & Momentum of the initial neutrino

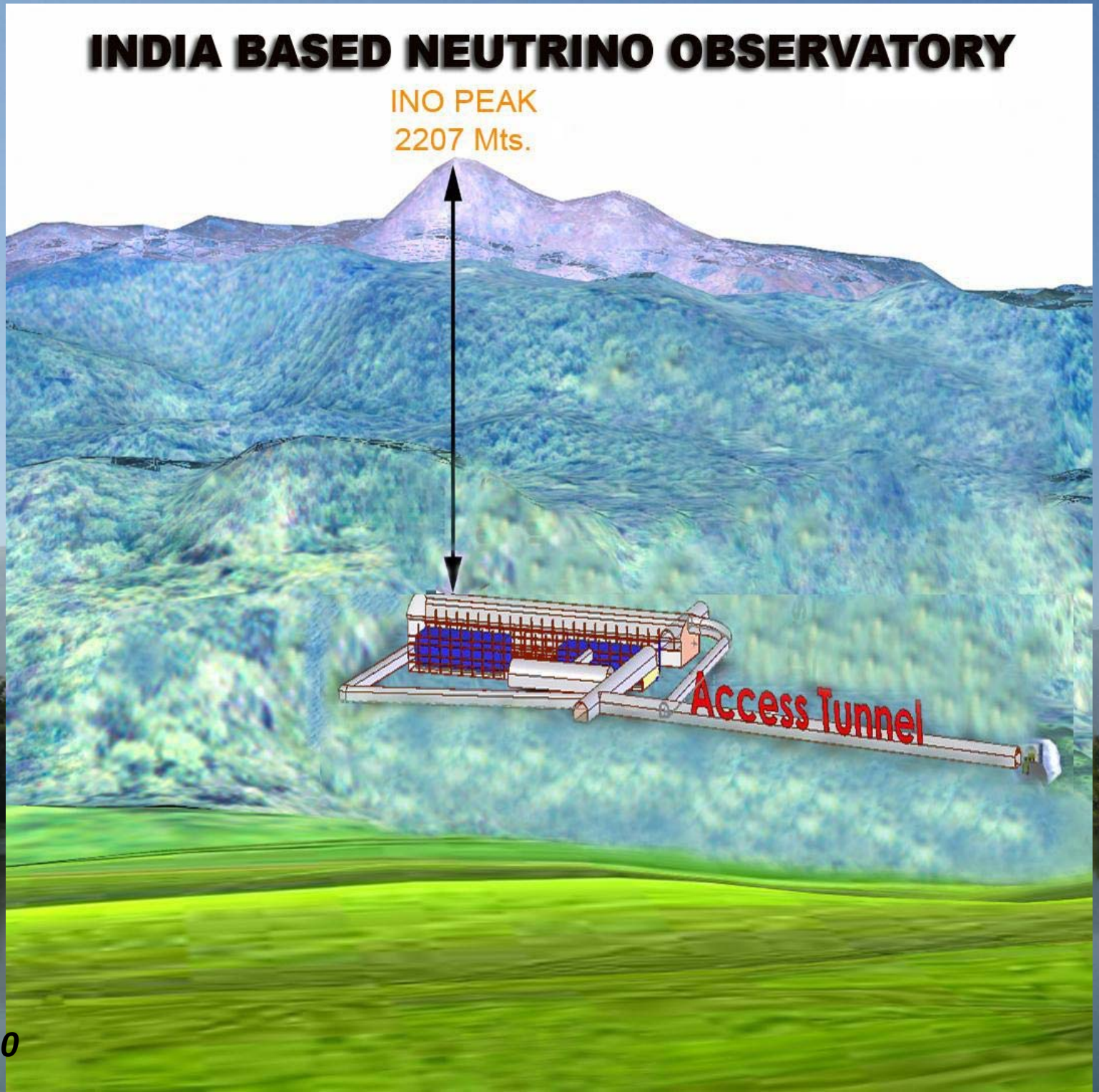
Simulated neutrino event in INO-ICAL





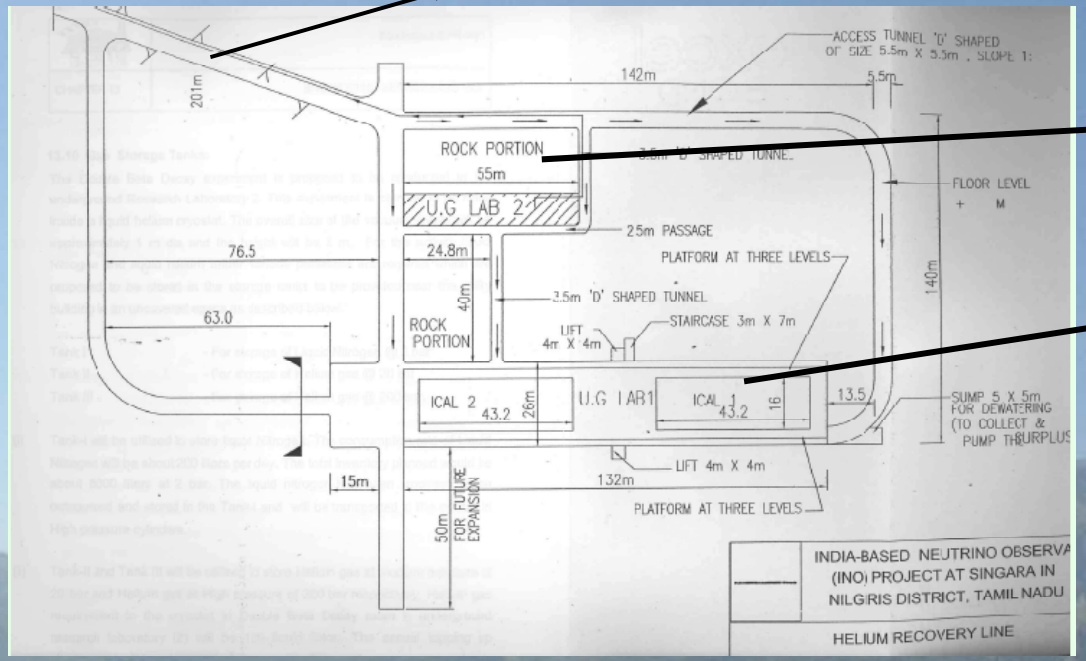

INO Site

INDIA BASED NEUTRINO OBSERVATORY



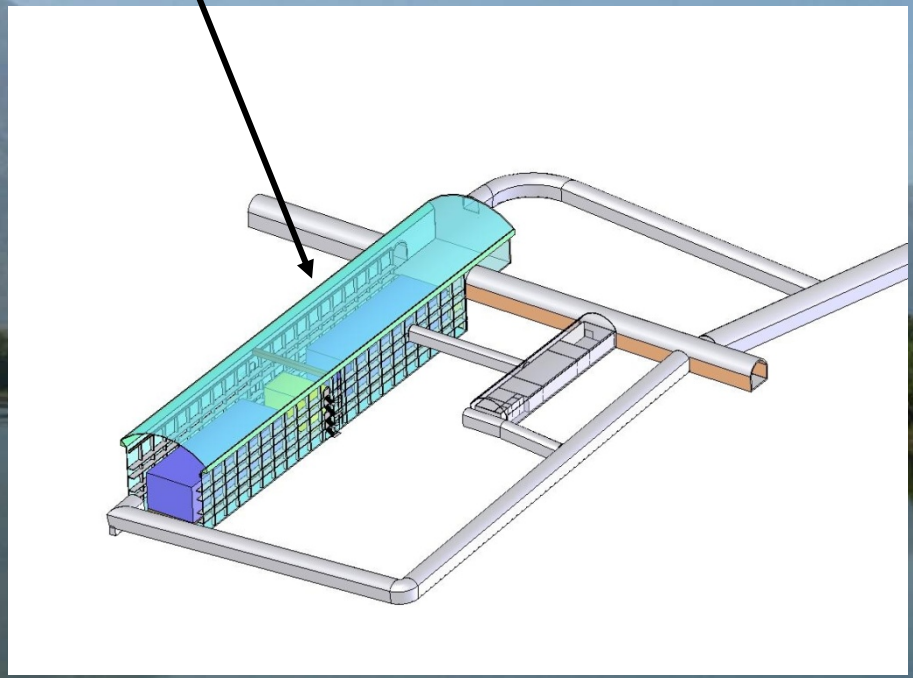
INO Underground Laboratory

2.2km long access tunnel



Cavern 2: 55m x 12.5m x 8.6m

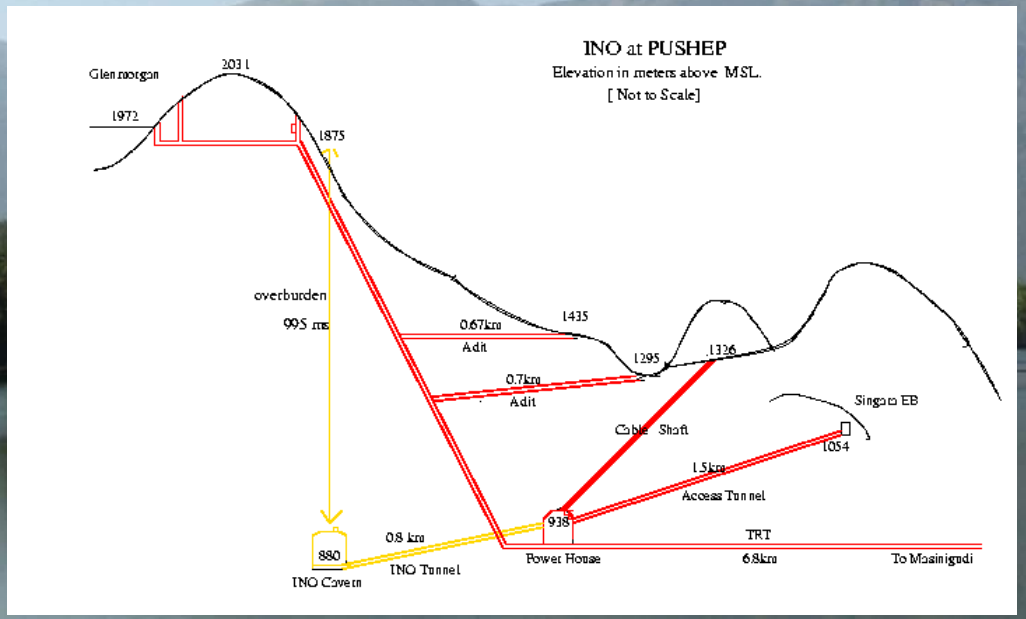
Cavern 1: 132m x 26m x 20m



Vertical rock coverage : 1300 m

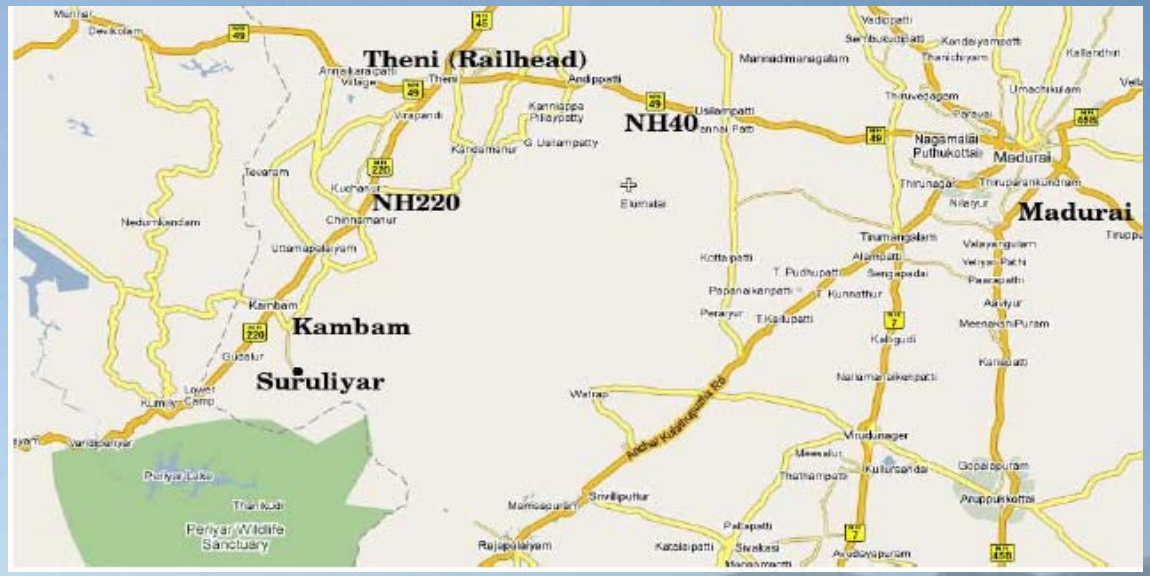
Location of the Underground Laboratory

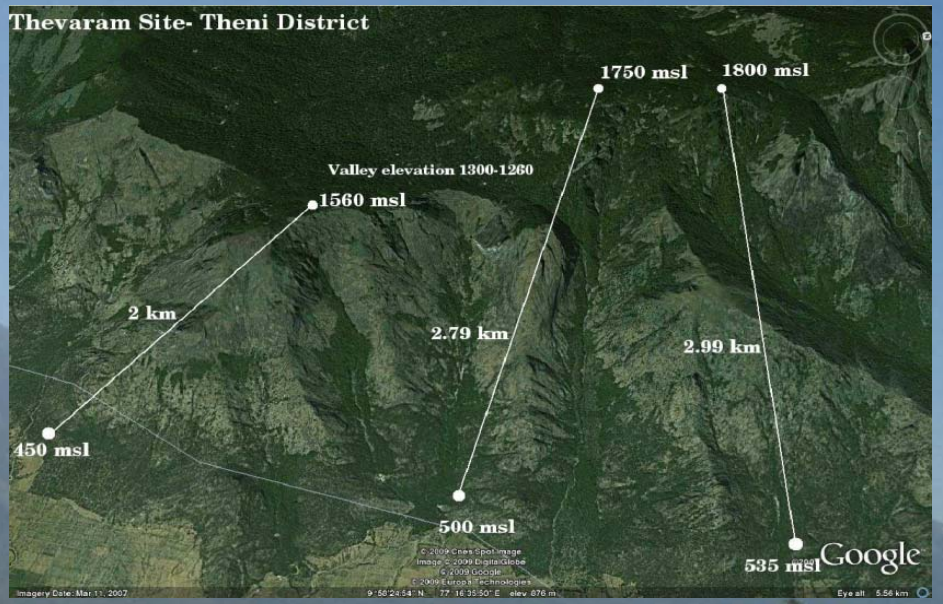
- *Studies were performed on two potential sites.*
  - *Pykara Ultimate Stage Hydro Electric Project (PUSHEP) at Masinagudi, Tamilnadu*
  - *Rammam Hydro Electric Project Site at Darjeeling District in West Bengal*
- *INO Site Selection Committee after thorough evaluation recommended PUSHEP at Tamilnadu as the preferred site for the underground lab.*



However Environmental activists have opposed locating INO at this site

New site at Kambam Valley





Project Status

- *A prototype RPC stack is now operational at TIFR. A second prototype with the magnet is getting ready at VECC.*
- *Full size RPCs are now made in the lab.*
- *Electronics DAQ for the prototype is operational. Final electronics for the 50 Kton detector is under design.*
- *A gas purification & recirculation system is under test.*
- *Long term stability test of RPCs continuing.*
- *INO-Engineering task force has prepared a Detailed Project Report (DPR) on the INO cavern and surface lab .*
- *Detailed Project Report for the detector structure with all engineering details is ready.*
- *Discussion with SAIL for producing low carbon steel needed for INO magnet.*
- *Interaction with Industry for mass production of RPCs by the industry.*
- *First pass design for the INO front end electronics is ready.*
- *We are approaching Tamil Nadu Forest Dept and MOEF for necessary clearances for the new INO site at Kambam vally*
- *Environmental Impact Assesment for the INO lab at Kambam Vally is under preparation.*

Summary

- *A large magnetised detector of 50-100 Kton is needed to achieve some of the very exciting physics goals using atmospheric neutrinos.*
- *Physics case for such a detector is strong.*
- *It will complement the existing and planned water cherenkov detectors.*
- *Can be used as a far detector during neutrino factory era.*
- *We will soon complete the R & D phase and begin construction of the INO facility and the ICAL detector.*
- *Looking forward for international participation.*

For more information on INO please visit the website www.ino.tifr.res.in

Thank You