Velocity measurement of cosmic muons using INO prototype detector

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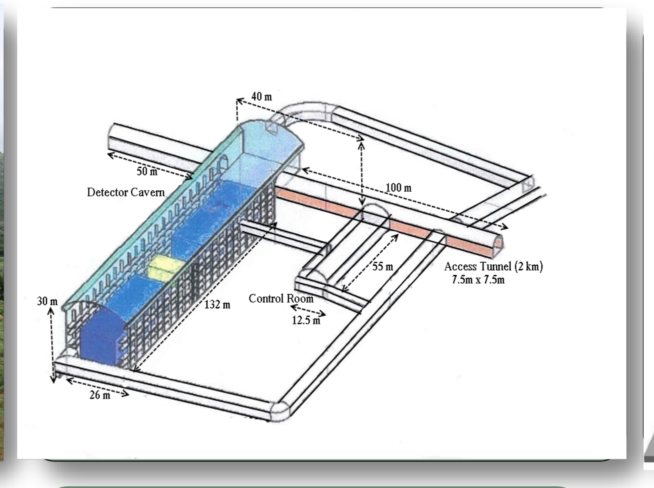
About INO Project

The India-based Neutrino Observatory (INO) collaboration is planning to set up a magnetised 50kton Iron-Calorimeter (ICAL) with Resistive Plate Chambers as active detectors to study neutrino oscillation. Considering the physics possibilities and the past experience of Indian scientists at the Kolar Gold Mines, it was decided to start with a modern detector. This massive detector will be housed inside a mountain with rock burden of over 1km on all the directions to block cosmic rays. Two caverns, one for the detector & other for the control systems, will be built inside the mountain. A 2km long tunnel will connect these caverns to the portal outside the mountain.

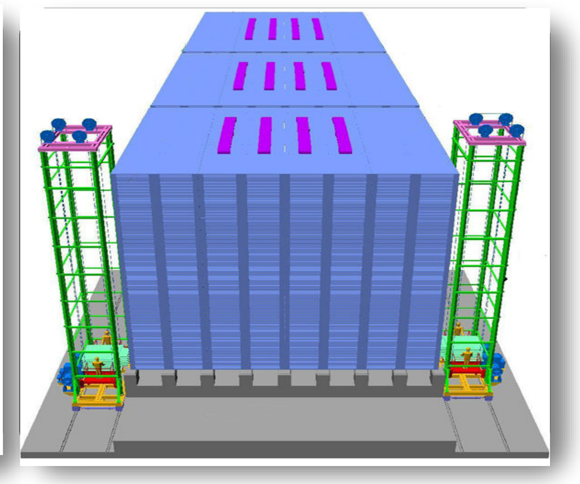
Genereal Information on site and ICAL

1. Location of the site: West Bodi Hills, near Theni district in Tamil -nadu, South India (~10^0N, 77^0E).
2. Advantage: Near to the equator. Detector distance from existing acclerators is close to the Magic base line.
3. Detector dimension: 16m x 16m x 14.5m.
4. 150 layers of RPCs interleaved by Iron pates of thickness 56mm.
5. 28,000 RPCs of size 1.84m x 1.84m x 24mm.
6. Magnetic field ~1.3 Tesla.
7. 3.6 million electronic channels.

INO Site



Schematic of INO Cavern



Schematic of ICAL

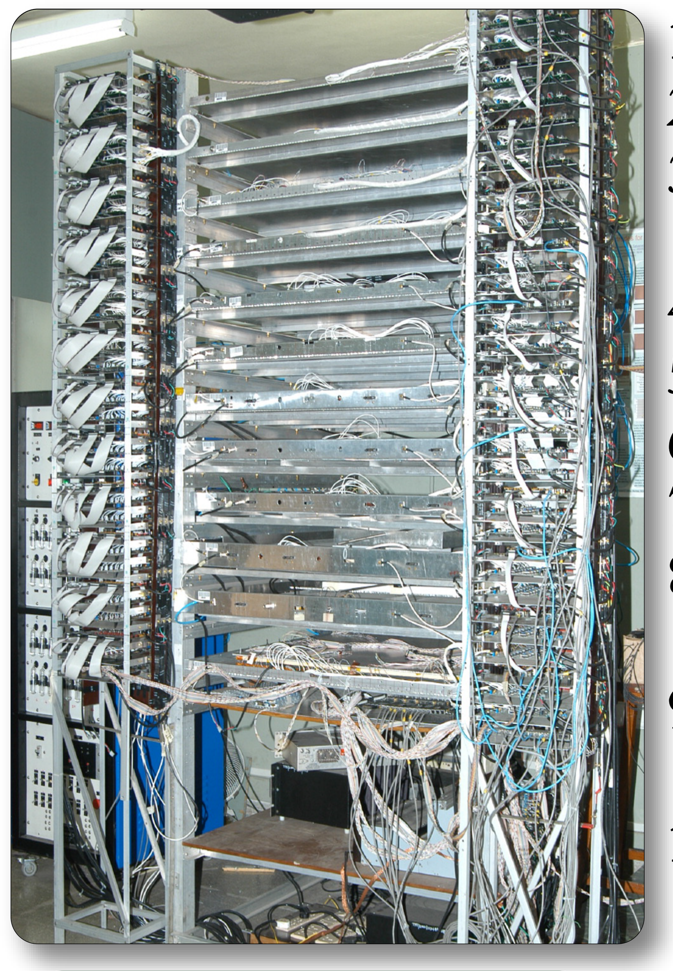
The INO facility will also host Neutrino-less double beta decay (NDBD) experiments in parallel with ICAL. Low temperature bolometric detectors are ideally suited for this experiment. R&D on the feasibility of a Sn cryogenic bolometric detector is also under progress.

Physics Goal in 1st Phase of operation

1. Unambigous and more precise determination of oscillation parameters using atmospheric neutrinos.
2. Study of matter effect through electric charge identification, leading to determination of δm^2_{23}.
3. Study of CP violation in the leptonic sector and possible CPT violation studies.
4. Study of very-high energy neutrinos and multi-muon events.

Experiments with neutrino beam using neutrino factories is in the planning of 2^{nd} phase of operation.

Prototype Stack in TIFR



12 layers RPC Cosmic Stand

1. 12 layers of RPCs without magnet.
2. Detector dimension: 1m x 1m x 1.76m.
3. 32 strips on either side of the electrode in each plane.
4. Operating in avalanche mode.
5. Detector bias voltage 9.9kV.
6. Chamber current ~50-100nA.
7. Detector tracking efficiency ~95%.
8. Noise rate and current is stable through out 3 years of continuous operation.
9. Gas mixture: Freon(~95%), Isobutane (~4%), SF_6(<1%).
10. VME based DAQ.

2m x 2m RPC

2m x 2m RPC development is also successfull and the industrial R&D is progressing to manufacture such a large number of RPCs for ICAL. Other area like physics simulation, front end electronic chip(ASIC based) designing, testing of those chips, gas recovery and recirculation system is also under progress.

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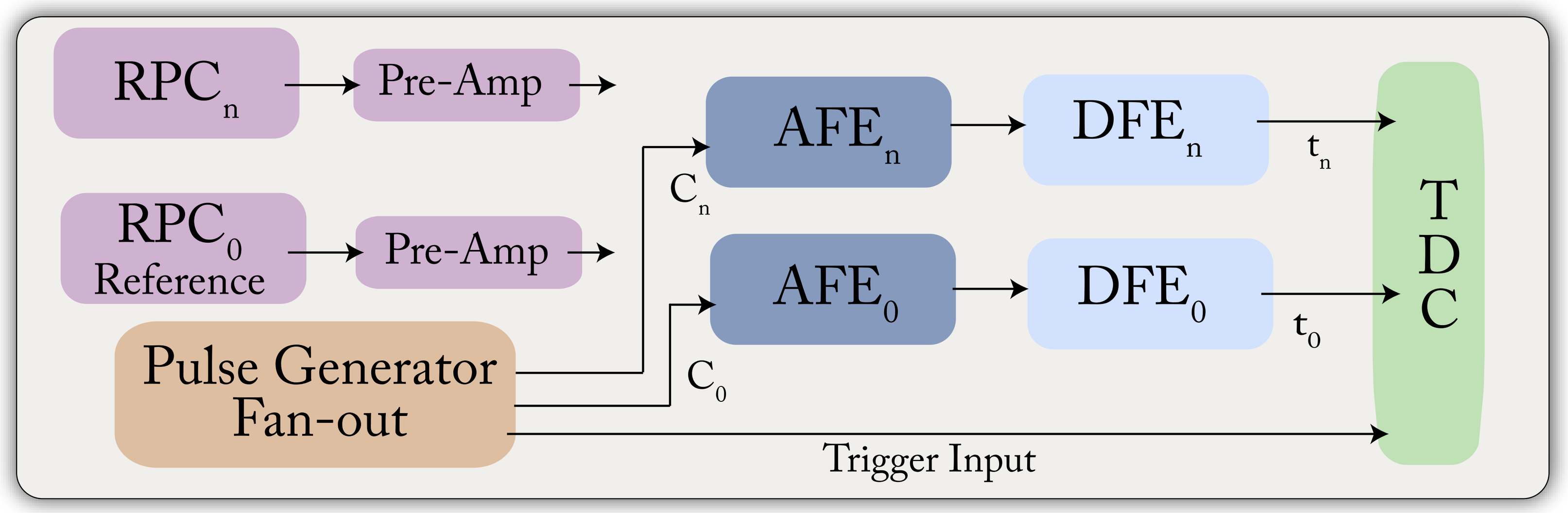
Time Calibration

The measurement of the velocity of the particles involves the estimation of the path length traversed in the detector and the time taken for the same. A time calibration for all strips is done to take into account the differences in propagation delay from strip to strip as they take its own path to TDC. It is assumed that the effective contribution in time delay comes from the electronics succeeding the pre-amplifier stage. To reduce the systematics, the fan-out channels are swapped at the AFE (Analog Front End) input and time measurement is repeated. The measured time in two cases are given by $t = (C_0+t_0)-(C_n+t_n)$ and $t_{swap} = (C_n+t_0)-(C_0+t_n)$. The corrected time offset is thus given by : $t_{offset} = (t+t_{swap})/2$



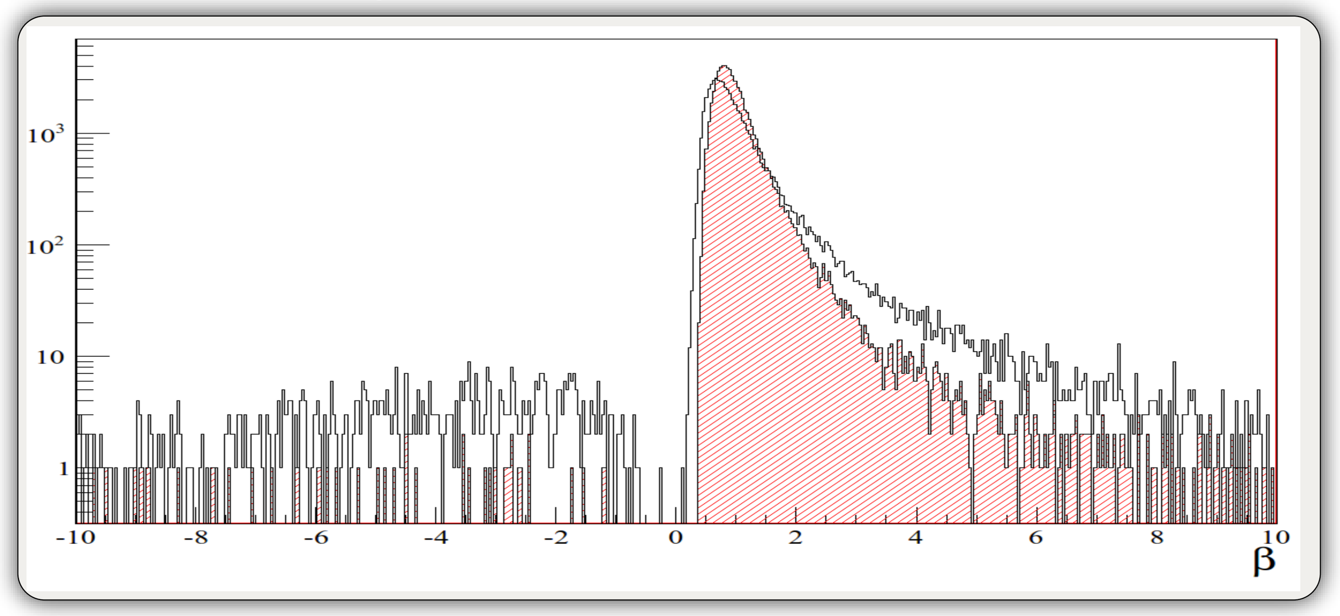
Schematic of time calibration circuit

CONCLUSION

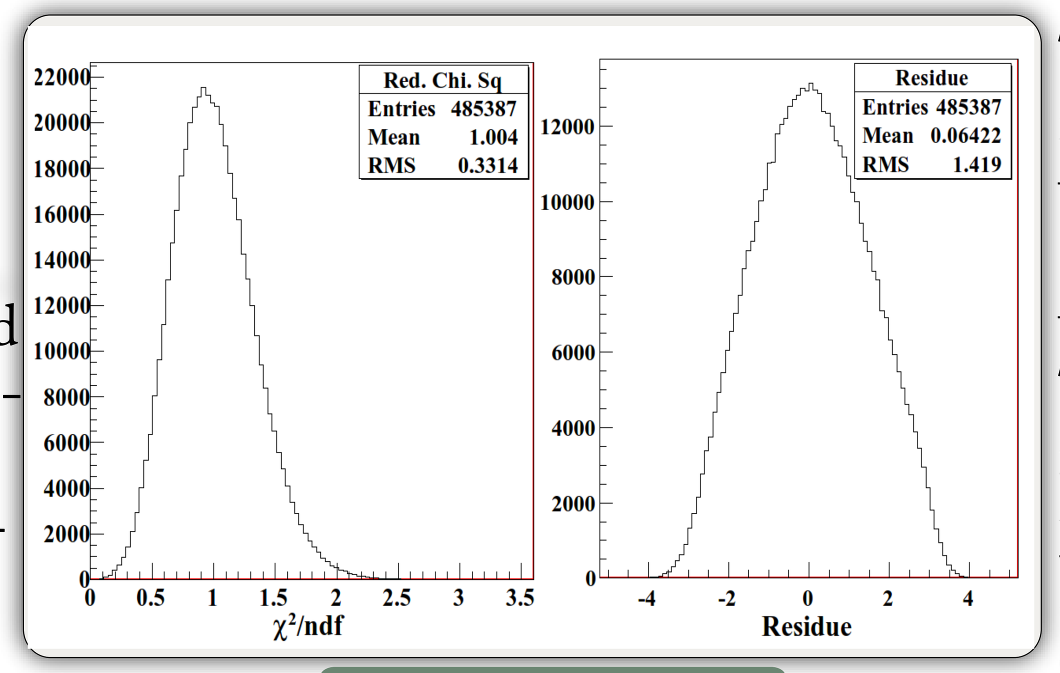
So far the prototype detector stack has been used to study the detector related parameters. This work is the first step towards a particle physics oriented analysis. The aim of this work is to study the feasibility of using this detector to distinguish between up-going and down-going particles. Since up-going cosmic muons are stopped by the earth, the only possibility of up-going muon is the neutrino induced interactions. But the flux is so small for those events, it is not possible to record such event in a short period of time in this small detector. This study has opend up other issues related time calibration and analysis that need to be addressed and helpful for the final set up.

Velocity distribution of Cosmic Muons

After correcting the timing offsets, the data (l_i, t_i) is fit to a straight line of the form: $t_i - t_0 = l_i/v$ where l_i is the track length from 0^{th} layer to ith layer. t_0 & t_i are TDC times for 0^{th} layer & i^{th} layer respectively, after applying the corrections. v is the velocity of the particle. Both X and Y timing data are used in the fit.



Velocity Distribution of Cosmic Muons



χ^2/ndf and Residue Plot

The velocity distribution in logarithmic scale shows a small no of events (0.3% of the total entries) with negative velocity. These negative values are from some uncorrelated points and they could not be rejected on a generic criterion like χ^2 cut and there is no clue so far to the origin of such points. The detector time resolution (~1.5ns)is reflected in the time residue plot.