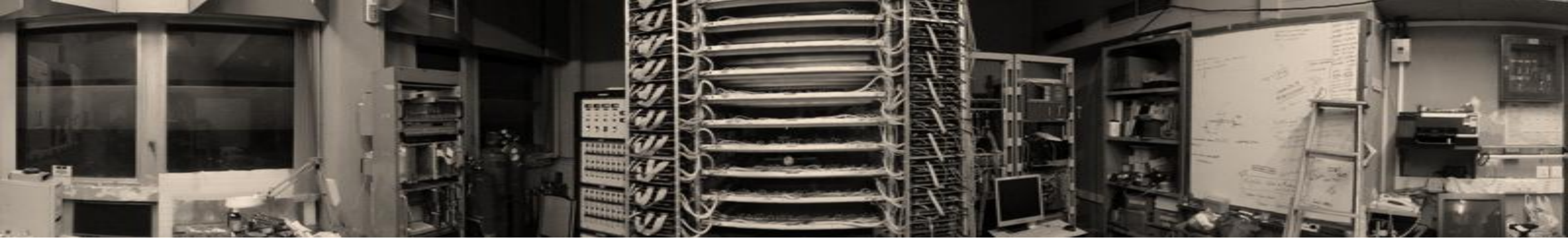

Directionality measurement of cosmic muon using INO prototype detector

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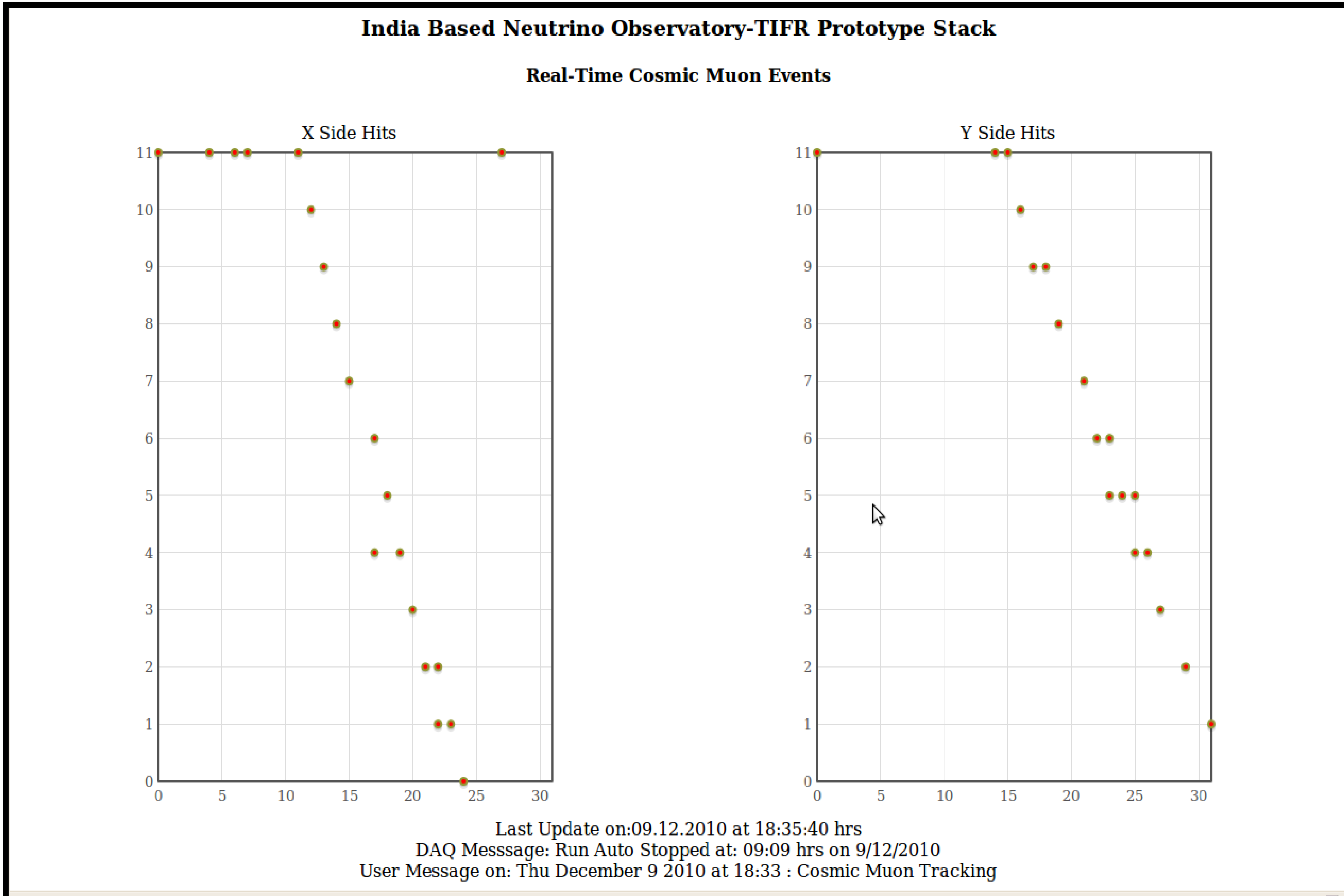
TIFR-INO, Mumbai

Welcome and Introduction

- Welcome all participants in this session. My overall talk is based on the INO R&D status at TIFR.
- 12 layers glass RPCs(Resistive Plate Chamber) of 1m x 1m in area, without magnet, is tracking cosmic muon 24x7 hours for last 3 years.
  - Detector related parameters are stable and under well controlled.
  - ~5 lacks of cosmic muon events are getting recorded per day.
- We are now looking for some physics study using this setup.
  - As an example, can we distinguish between up-going and down-going particles by measuring the velocity of cosmic muon recorded in this stack?
- Overall goals in this talk – explaining the detector's capability and feasibility to answer this physics question.

Cosmic Muon Tracking Display (in web)

(http://www.ino.tifr.res.in/ino/ ->Online Event Display)



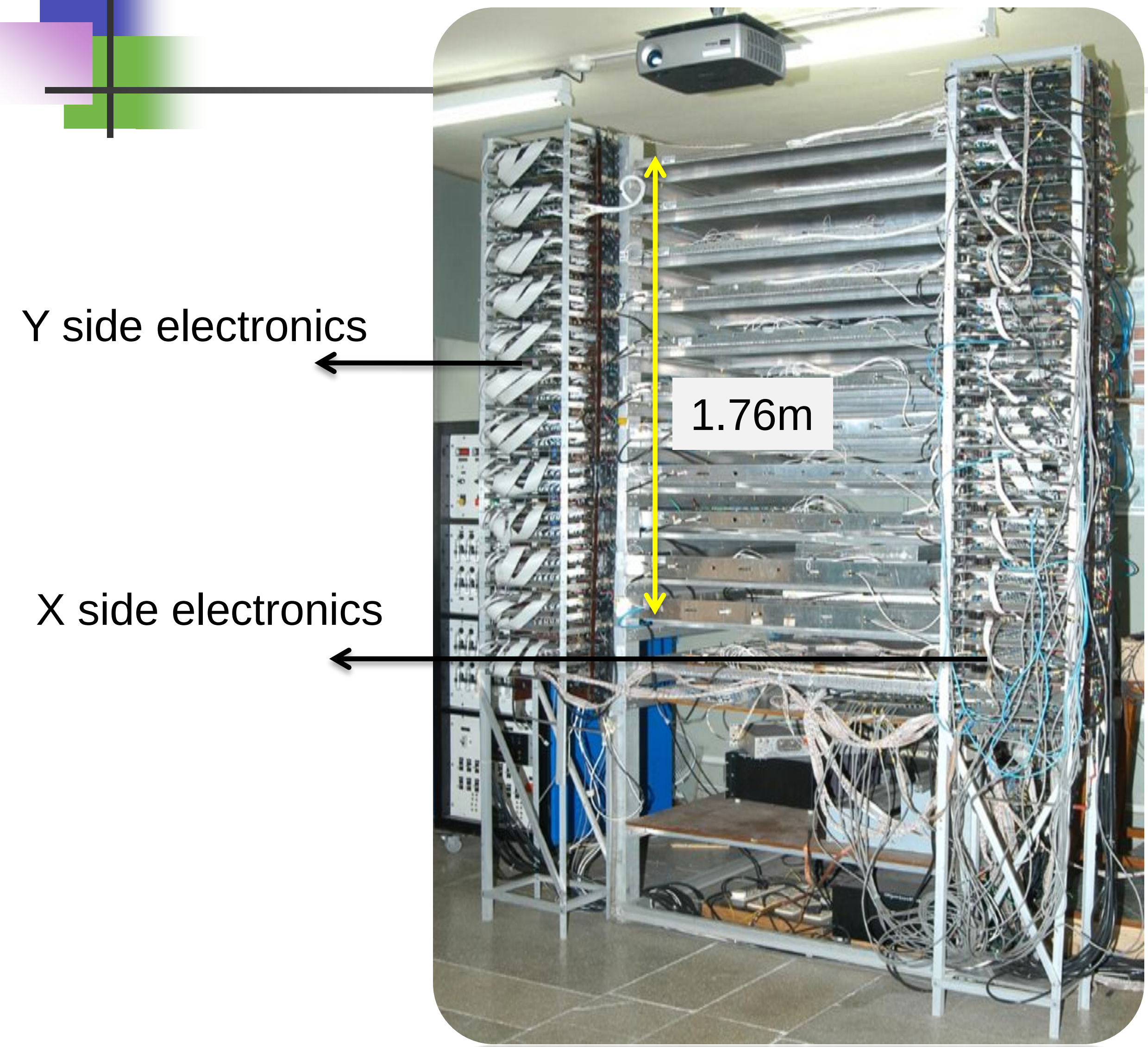
How can we get the directionality of a particle?

- A straight line fit, separately for X & Y side, can give the idea of the zenith angle of an cosmic muon event.
- This gives the idea of the path length traversed by a particle through the detector.
- From each plane, from each side (X & Y independently) timing information is available.
- A linear fit of timing & path length can provide the velocity distribution of cosmic muon recorded in the stack.
- The sign(+/-) of velocity can give the directionality of an incoming particle. (+) for a down-going, (-) for up-going event.

Overview

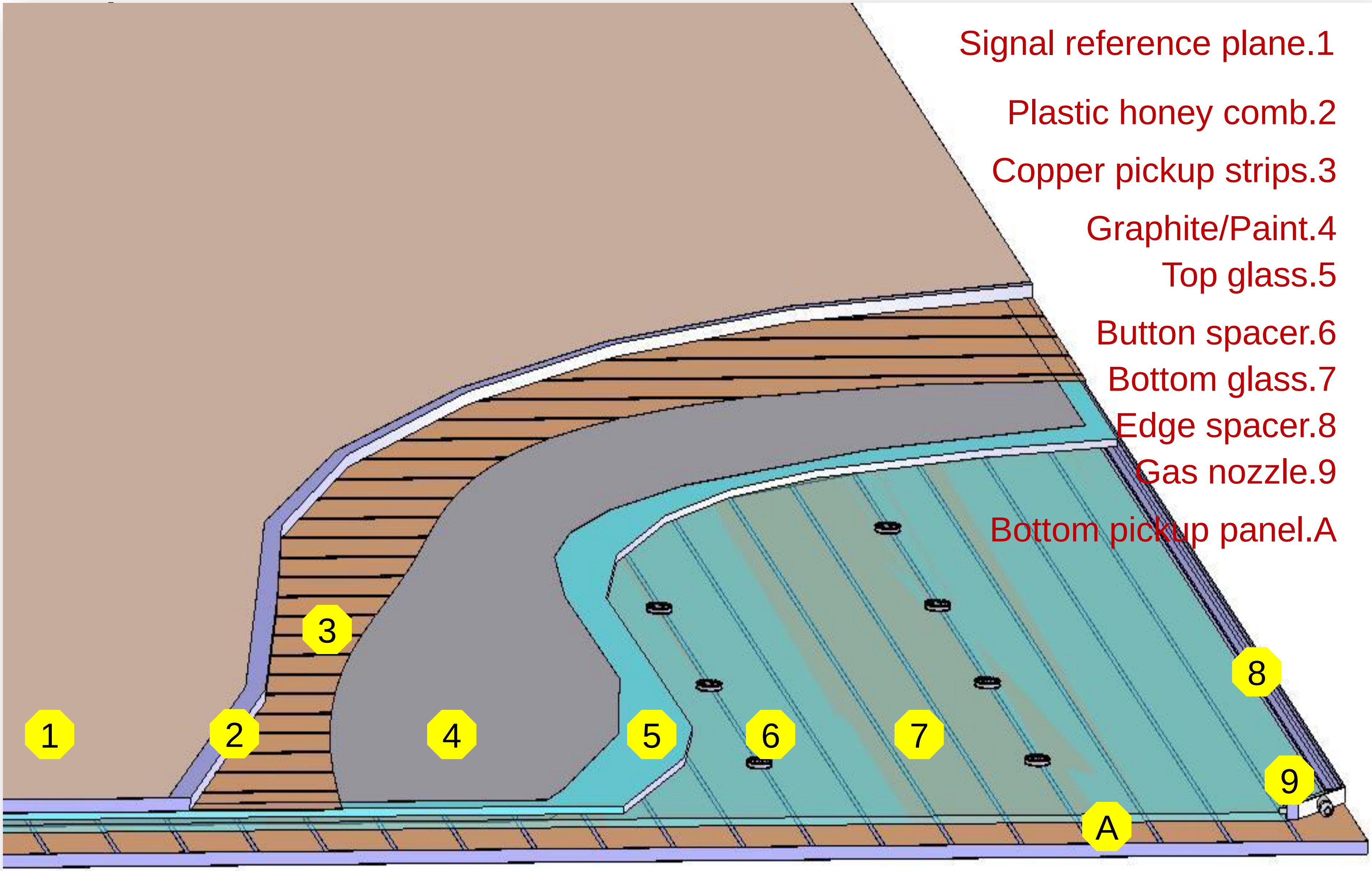
- Detector Setup.
- Measurement Procedure.
- Calibration.
- Results.

12 layers 1m x 1m RPC Detector Stack

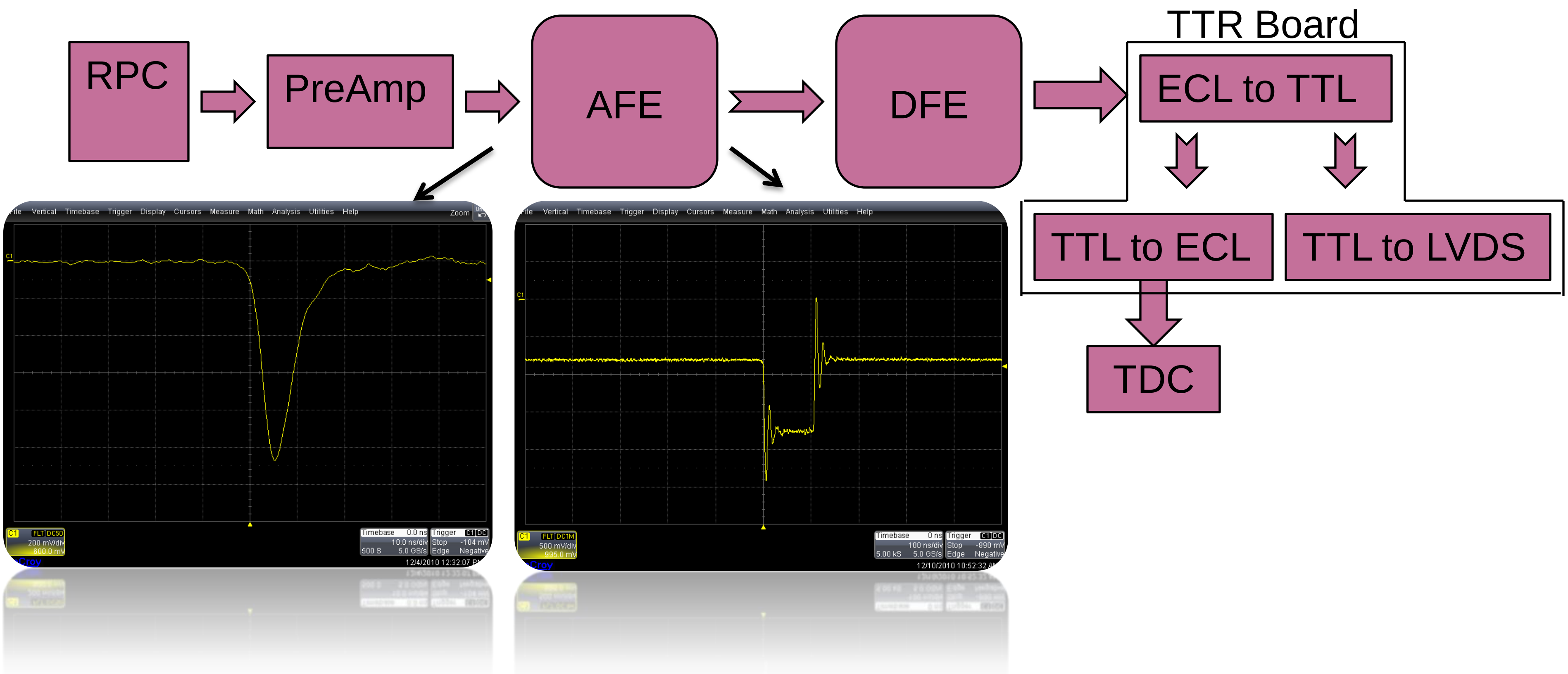


- Operating in avalanche mode
- HV applied : 9.9kV
- Current : 20-80 nA, depends on relative humidity & ambient temperature
- Chamber time resolution : ~ 1.5nS
- Chamber Tracking efficiency : ~95%

Basic construction of an RPC



Signal path from RPC to DAQ

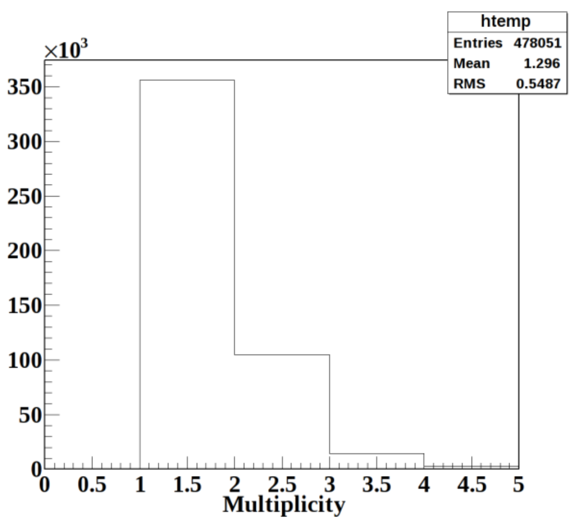


Analog Front End
Digital Front End
Trigger & TDC Router

Measurement Procedure

- Velocity measurement involves:
  - the estimation of the path length traversed by a muon in the detector
  - Time taken to traverse that path
  - Trigger Condition: selected 8/12 layer coincidence

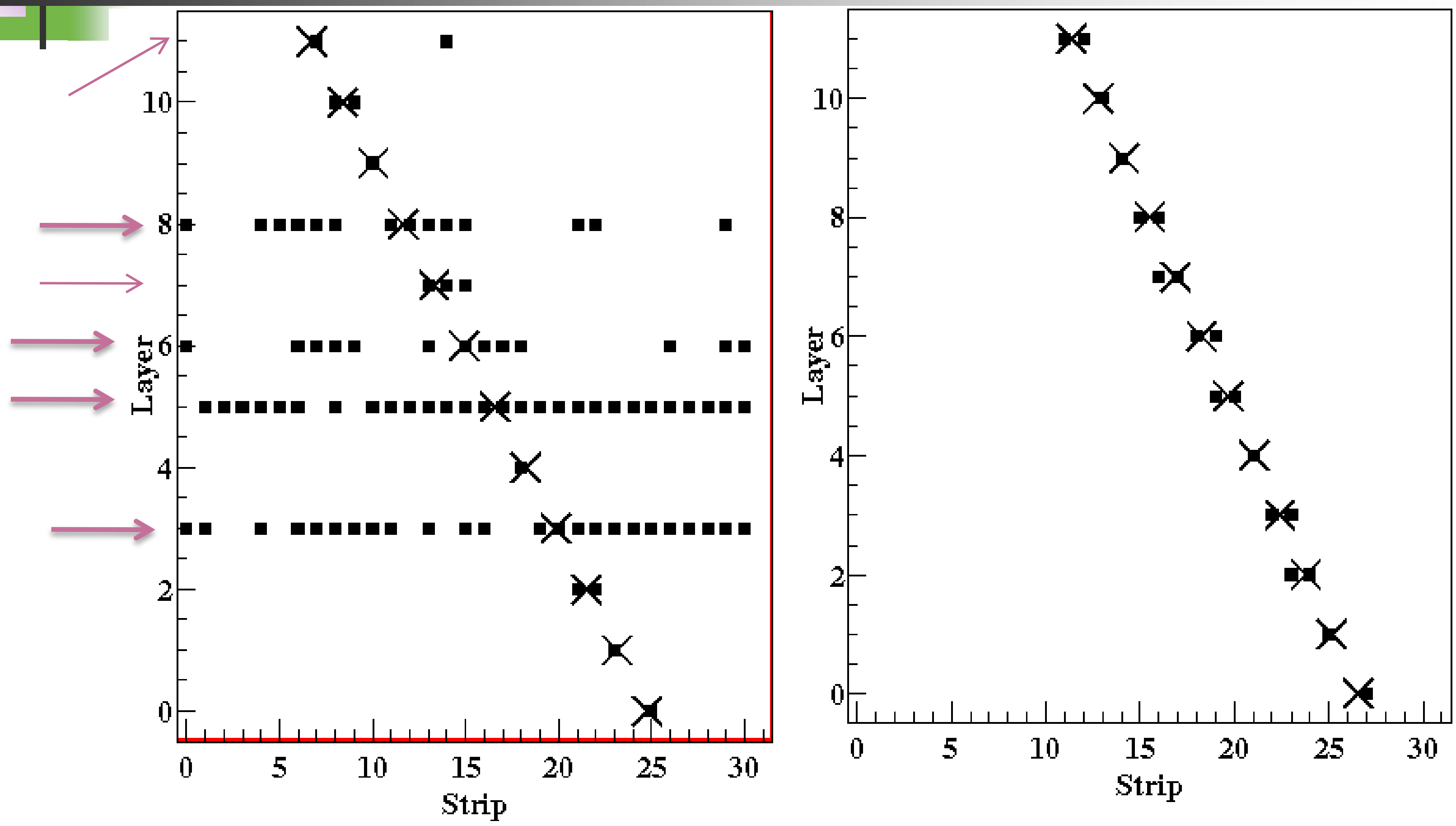
Estimation of the path length



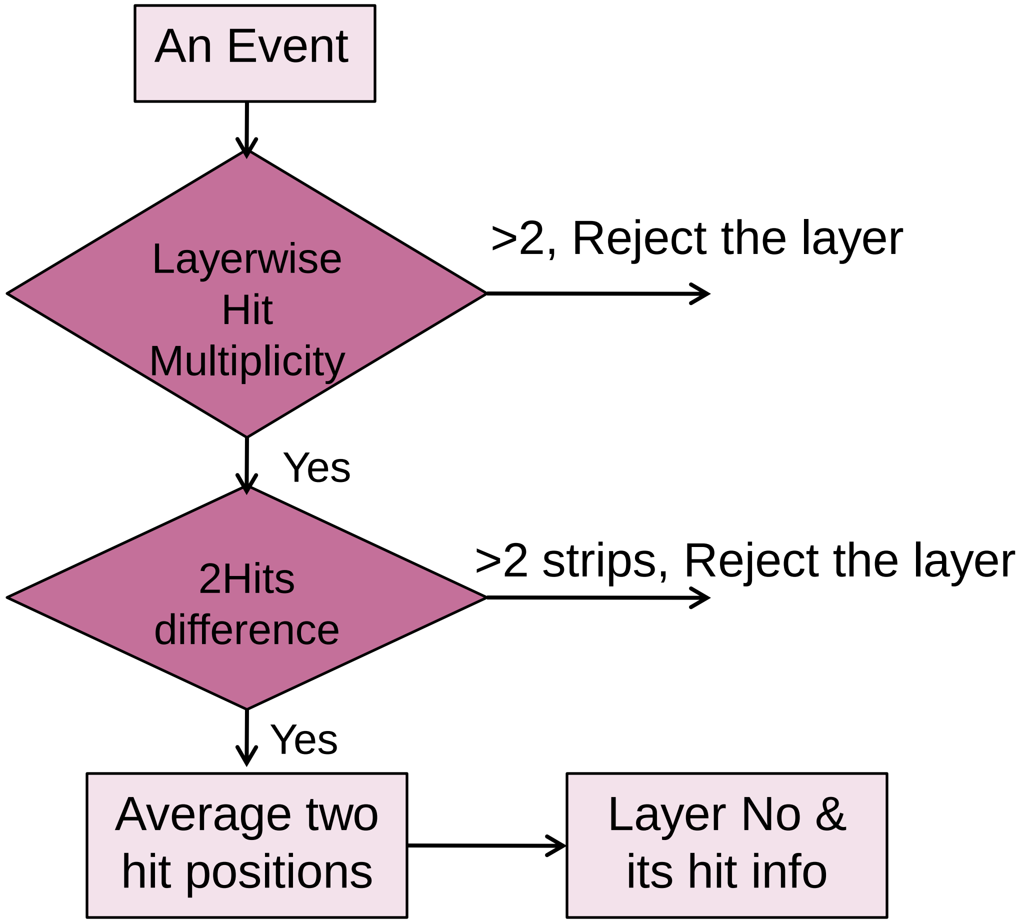
- Strip Hit Information from DAQ:
  - Strip-wise hit patterns in the X & Y planes in the layers through which the particle has gone through satisfying trigger condition.
  - Using these hit information a straight line fit can be done separately for X & Y sides.
- Average Cluster Size/Strip Multiplicity : ~1.5 strips
  - But sometimes outliers present in the hit pattern due to correlated electronic noise.
- Data reduction is necessary before fitting.

A typical noisy event and a good event

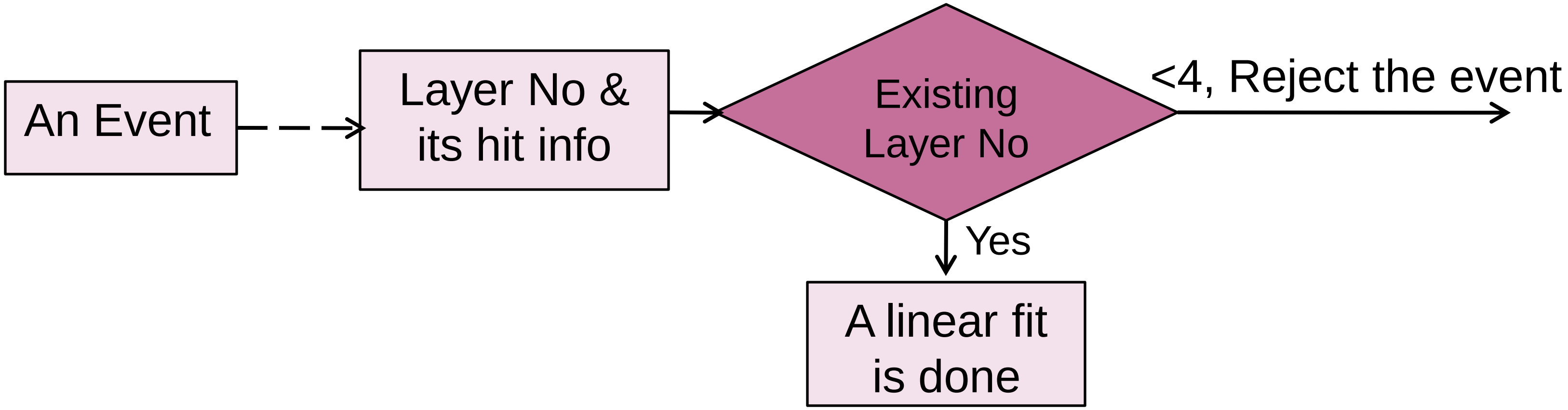
▪ is hit data, X is fit data



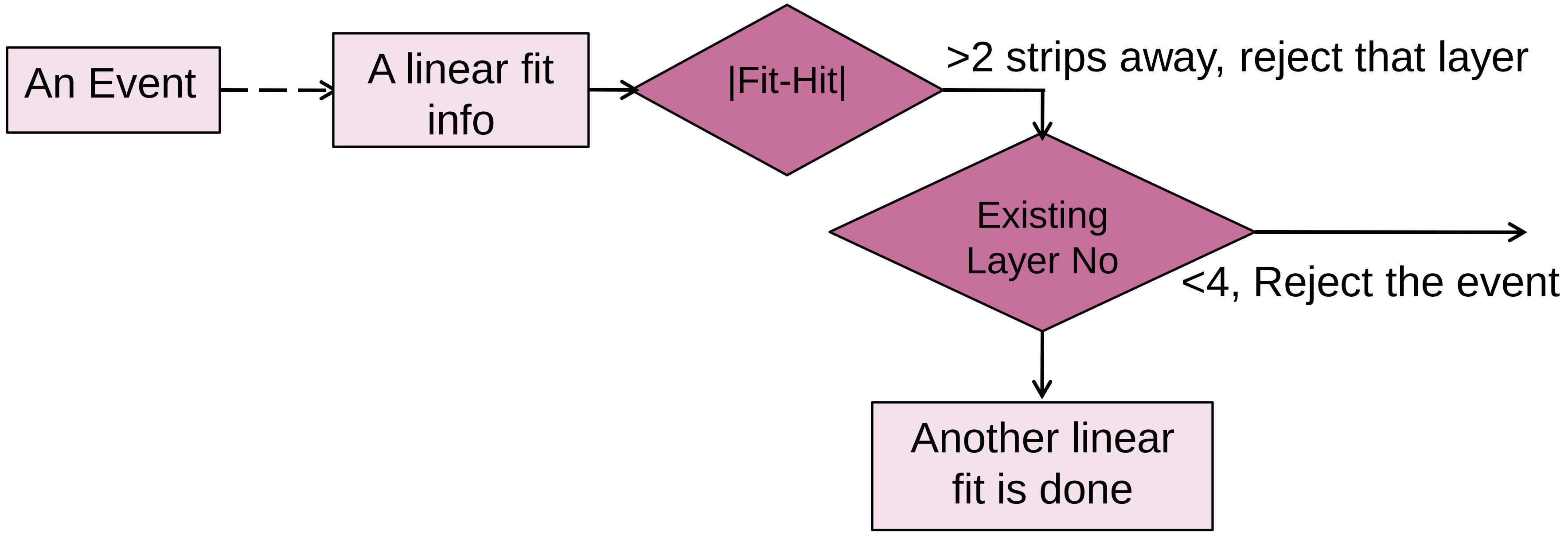
Data Reduction Conditions



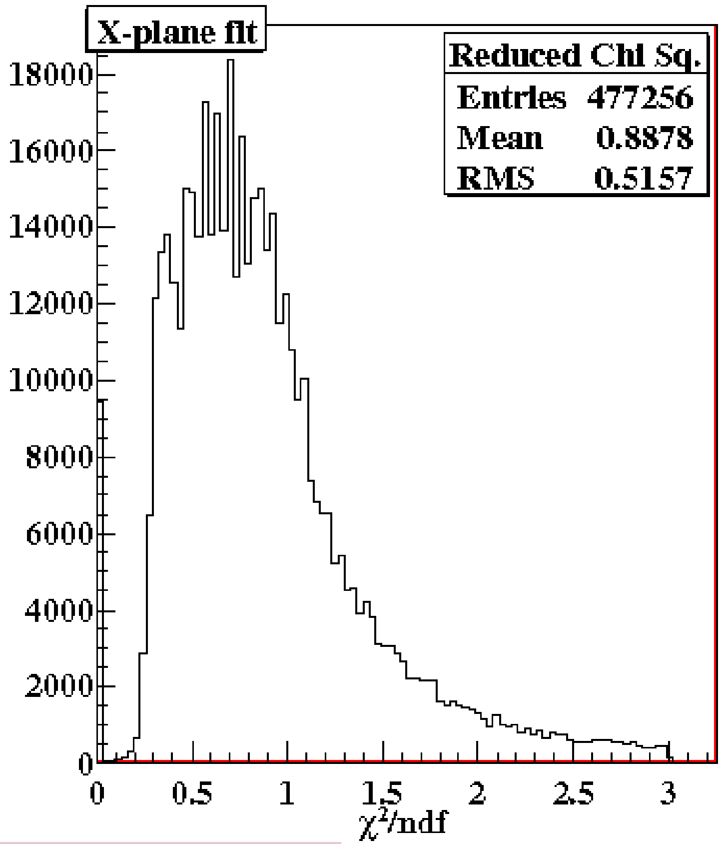
Data Reduction Conditions……contd.

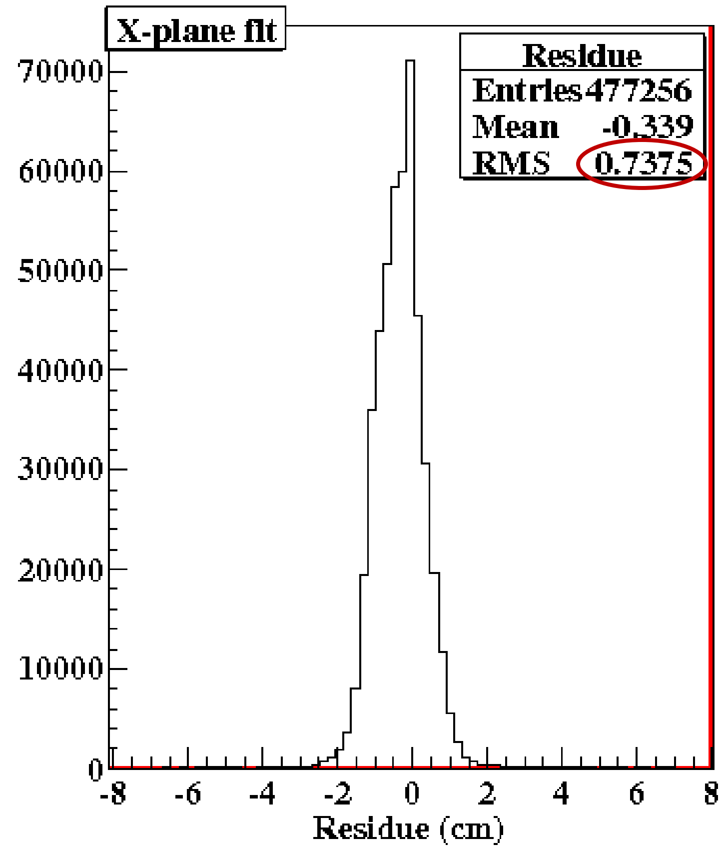


Data Reduction Conditions……contd.



Reduced χ^2 distribution & the residual (|Fit-Hit|) distribution for the linear fit to the X plane hits





Strip width=2.8cm,
Position resolution = ~0.8cm

Path length & zenith angle

- The total path length of the top layer & bottom layer:

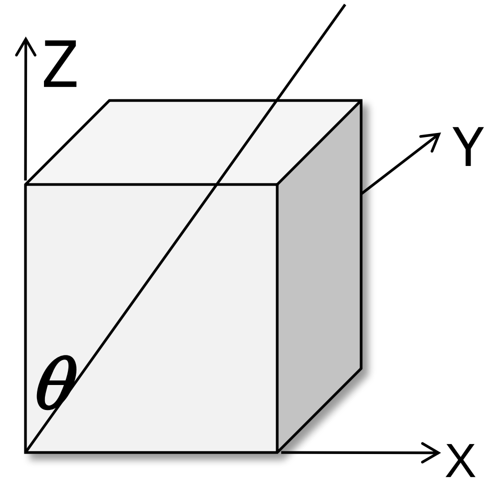
$$l = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2 + (z_2 - z_1)^2}$$

  - (x_2, y_2, z_2) are the coordinates in the plane of the top layer and (x_1, y_1, z_1) are the same for the bottom layer, estimated from the linear fit.

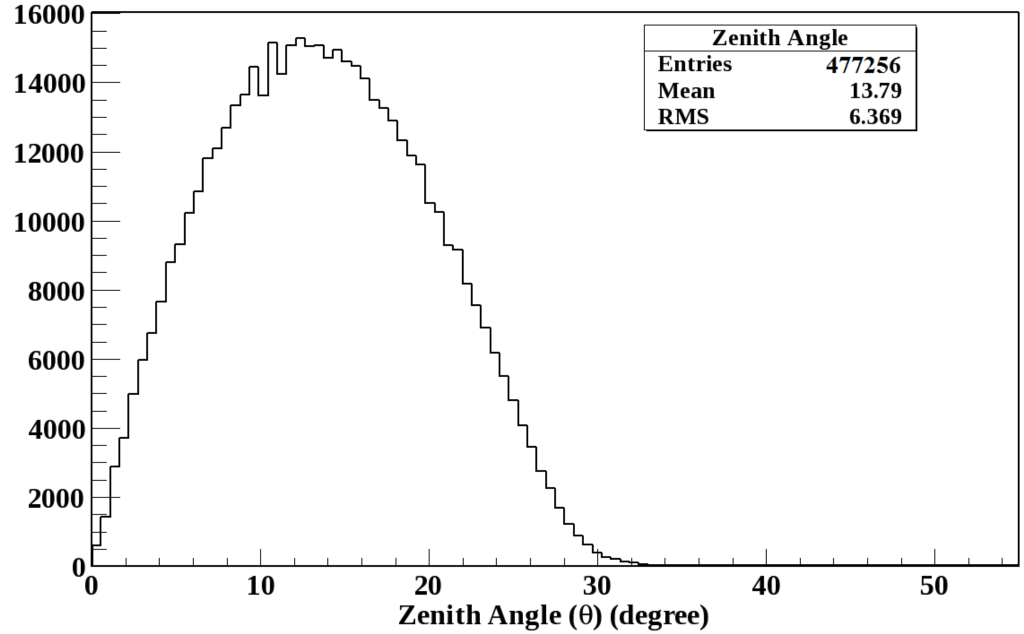
- Zenith Angle (θ) of a track :

$$\theta = \cos^{-1}\left(\frac{h}{l}\right)$$

  - h is the stack height.



Zenith angle distribution



- Events having reduced χ^2 in the range of 0-3 for both X and Y track fits are selected.
- Up to track fitting using this reduced χ^2 range, overall data rejection is ~8-12 %.

Timing Measurement

- Time is recorded in a Multi-Hit TDC (V1190B, CAEN).
  - LSB = 100ps
- Time offset calibration
  - To correct the differences in propagation delay from strip to strip
  - Each strip signal takes its own path to the TDC
  - Strip -> Pre-Amplifier -> AFE -> DFE -> TDC

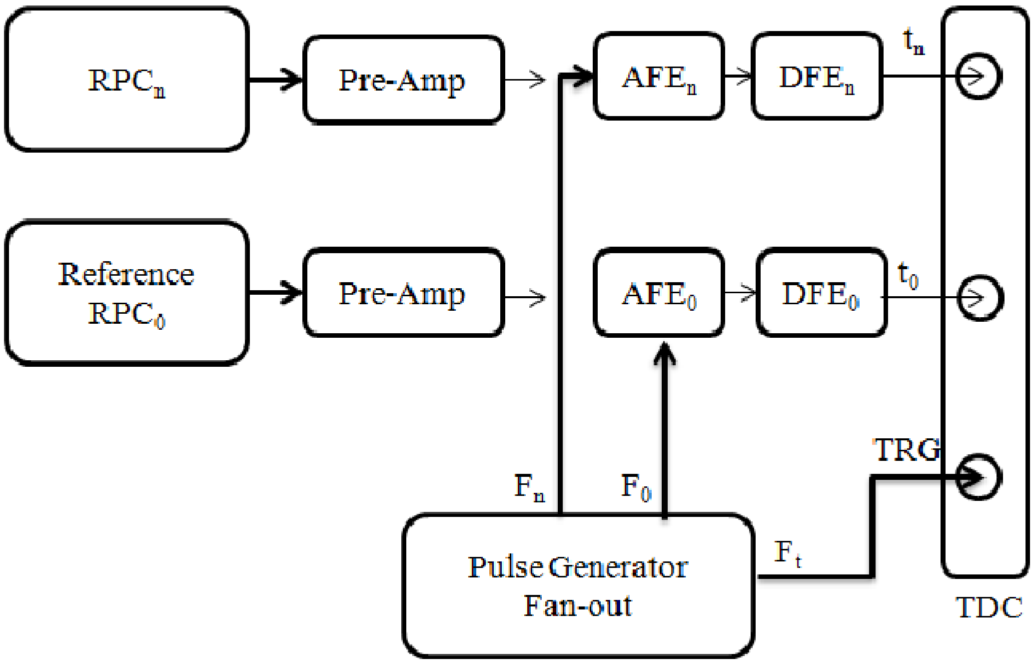
AFE(analog front end), DFE (digital front end)

Calibration procedure

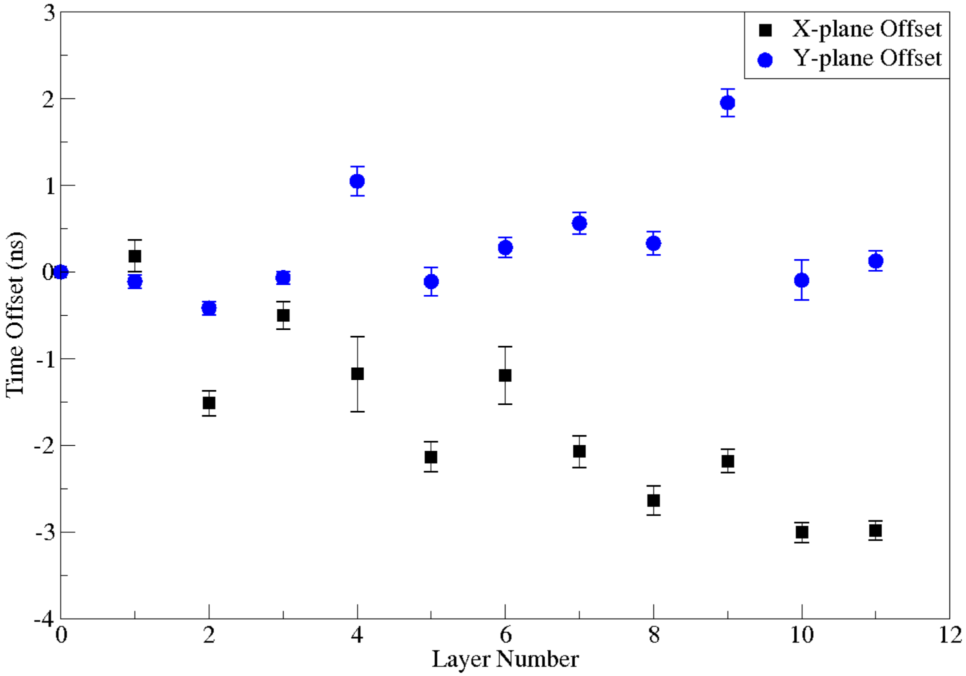
$$\Delta t = (\Delta C_n - \Delta C_0) + (\Delta t_n - \Delta t_0)$$

$$\Delta t_{swap} = (\Delta C_0 - \Delta C_n) + (\Delta t_n - \Delta t_0)$$

$$\Delta t_{offset} = \frac{\Delta t + \Delta t_{swap}}{2}$$



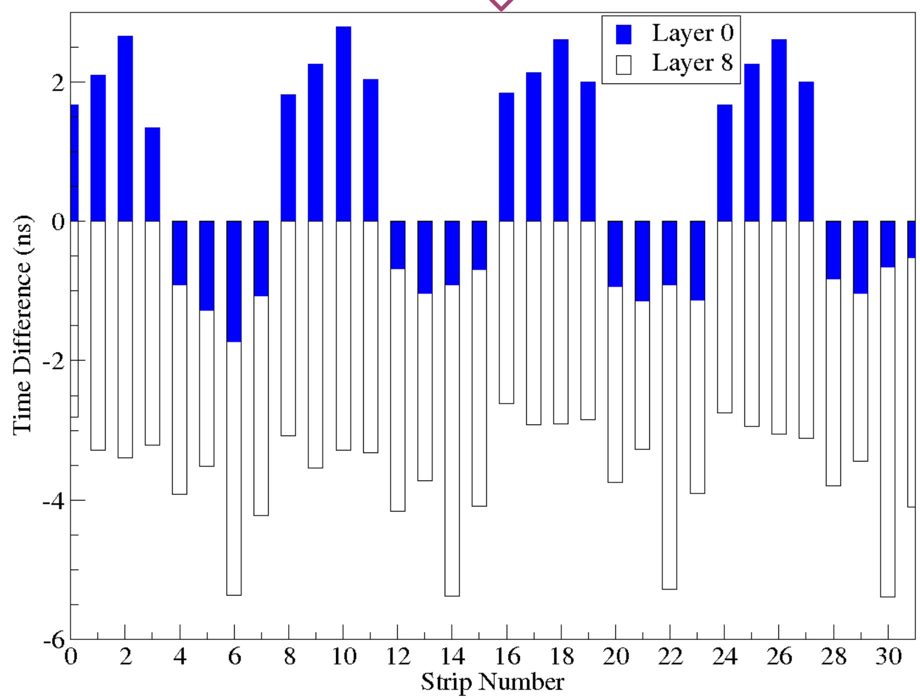
Typical nature of time offsets



Layer wise offset

(Taking 31st channel of each layer)

Channel wise offset



Results

- After correcting time offsets, the time data (l_i , t_i) is fit to a straight line :

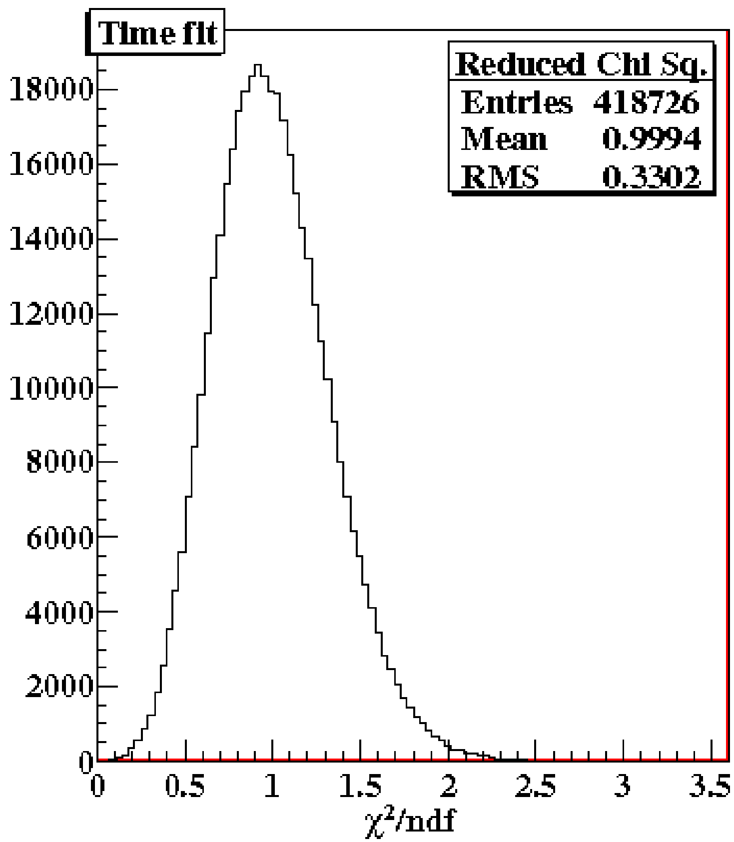
$$t_i - t_0 = \frac{l_i}{v}$$

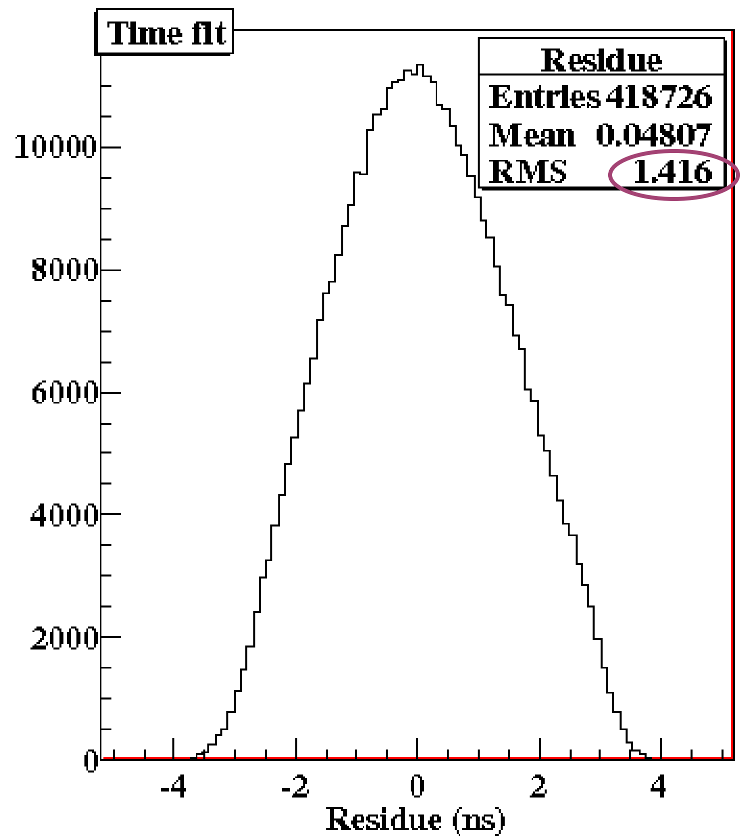
  - l_i is the track length from 0^{th} layer (bottom layer) to i^{th} layer, t_0 & t_i are the corresponding times.
  - v is the velocity of the particle.

Cuts in time fit

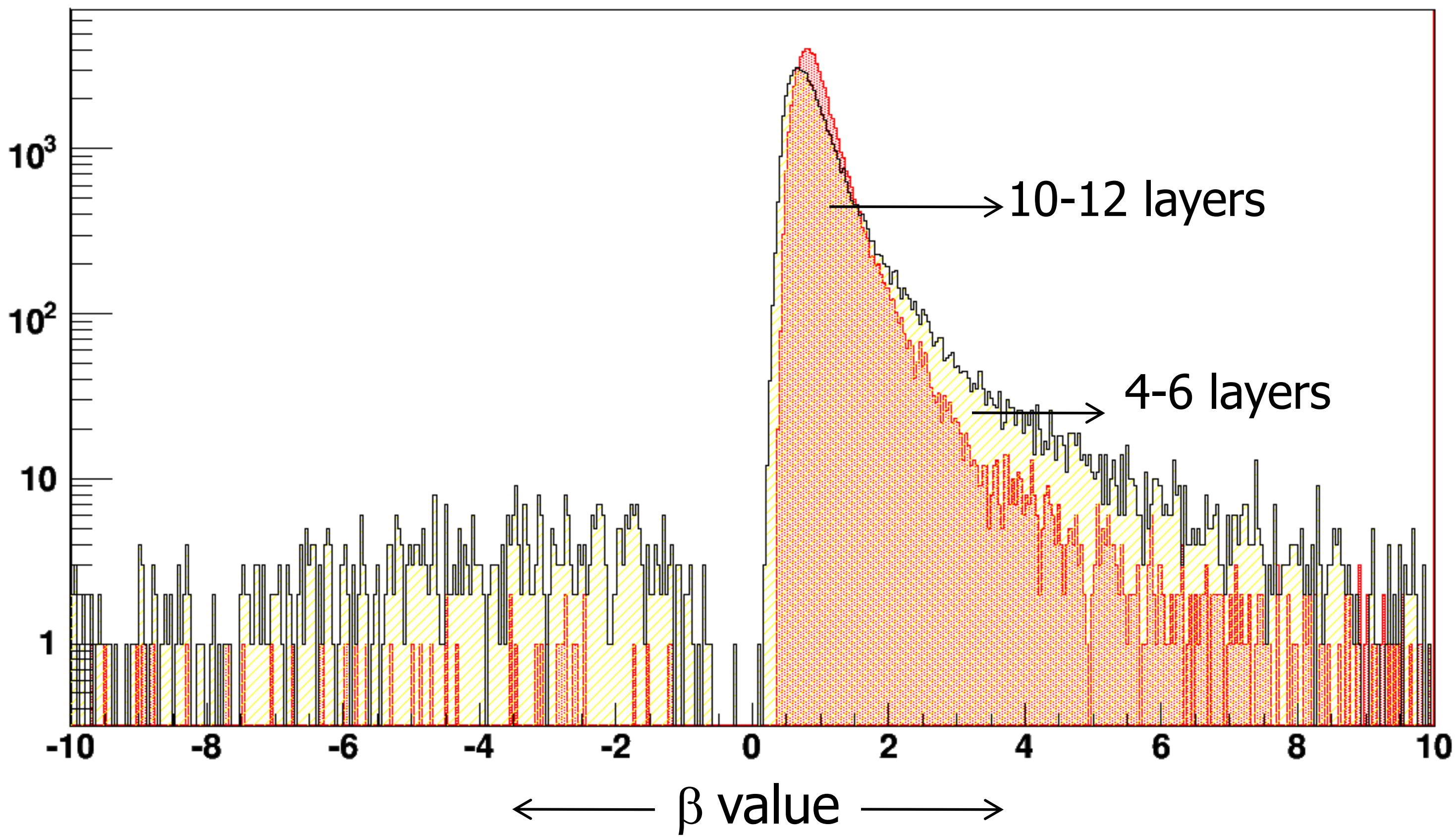
- Tracks traversed through the entire stack are considered for this time-length fit.
  - This is imposed by a cut on the zenith angle ($0\text{-}38^0$).
- An event is rejected if the reference layer (0^{th} layer) timing is missing.
- A first linear fit is done if number of layers is >3.
- After first fit, if |time hit - fit|>2ns remove that point.
- Again a linear fit is done if number of existing layers is at least 4.
- Here rejection is ~3-5% of the existing events.

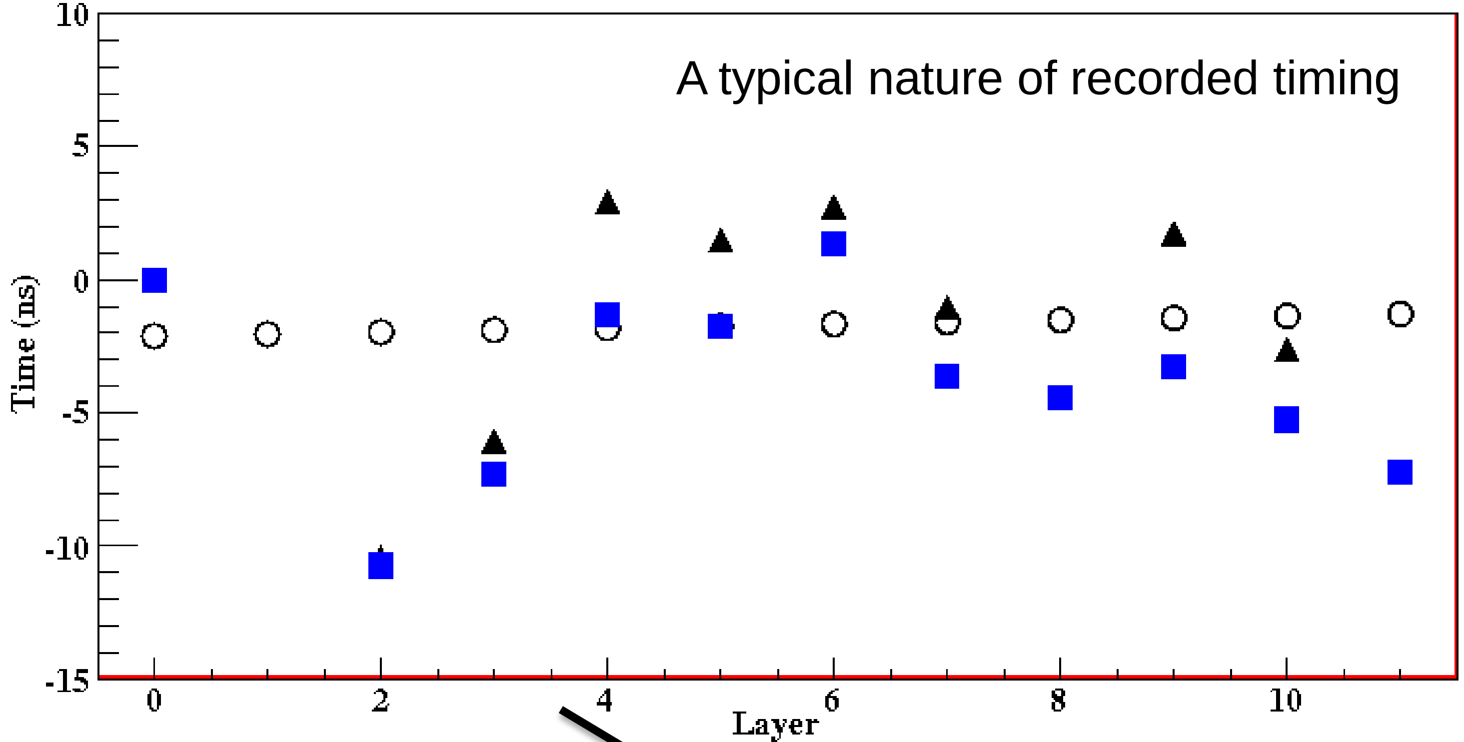
Reduced χ^2 distribution & time residual distribution for the linear fit to the timing data



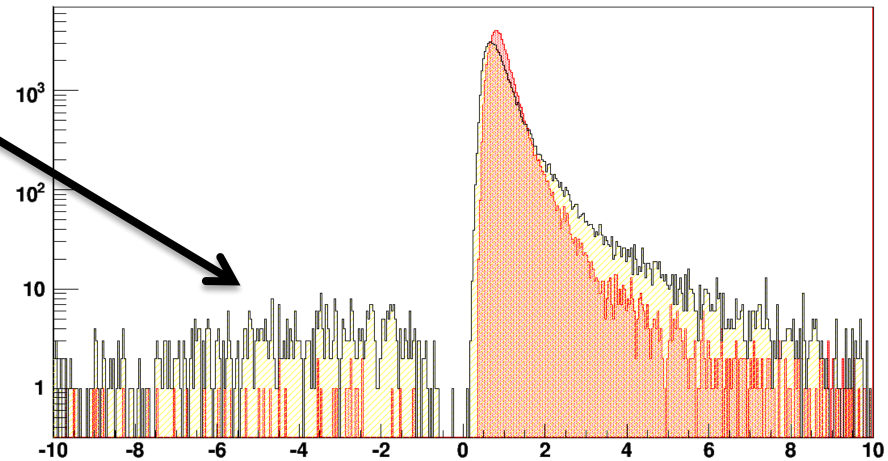


Velocity Distribution





X –side time
Y –side time



Summary

- As we have only 12 layers, selecting data with a cut is very much stringent.
- It is also important to remind that this detector is made for mainly to do detector characterization and its parameter optimization.
- Present electronics are also not very much sensitive to do this type of precision study.
- Timing recorded by DAQ, responsible for negative velocity, can only be judged in offline analysis. There is no way to trace their recording history.

Summary ………….contd.

- Just putting TDC values in the graph, without using layer 0 as reference, also have same type of problem
- Knowing time residue for every layer and implementing that as time offset has also been checked.
- We are also looking for alternate algorithm for analysis.

References

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- N.K.Mondal, et al., Nucl. Instr. And Meth.A(2010), doi:10.1016/j.nima.2010.08.034.
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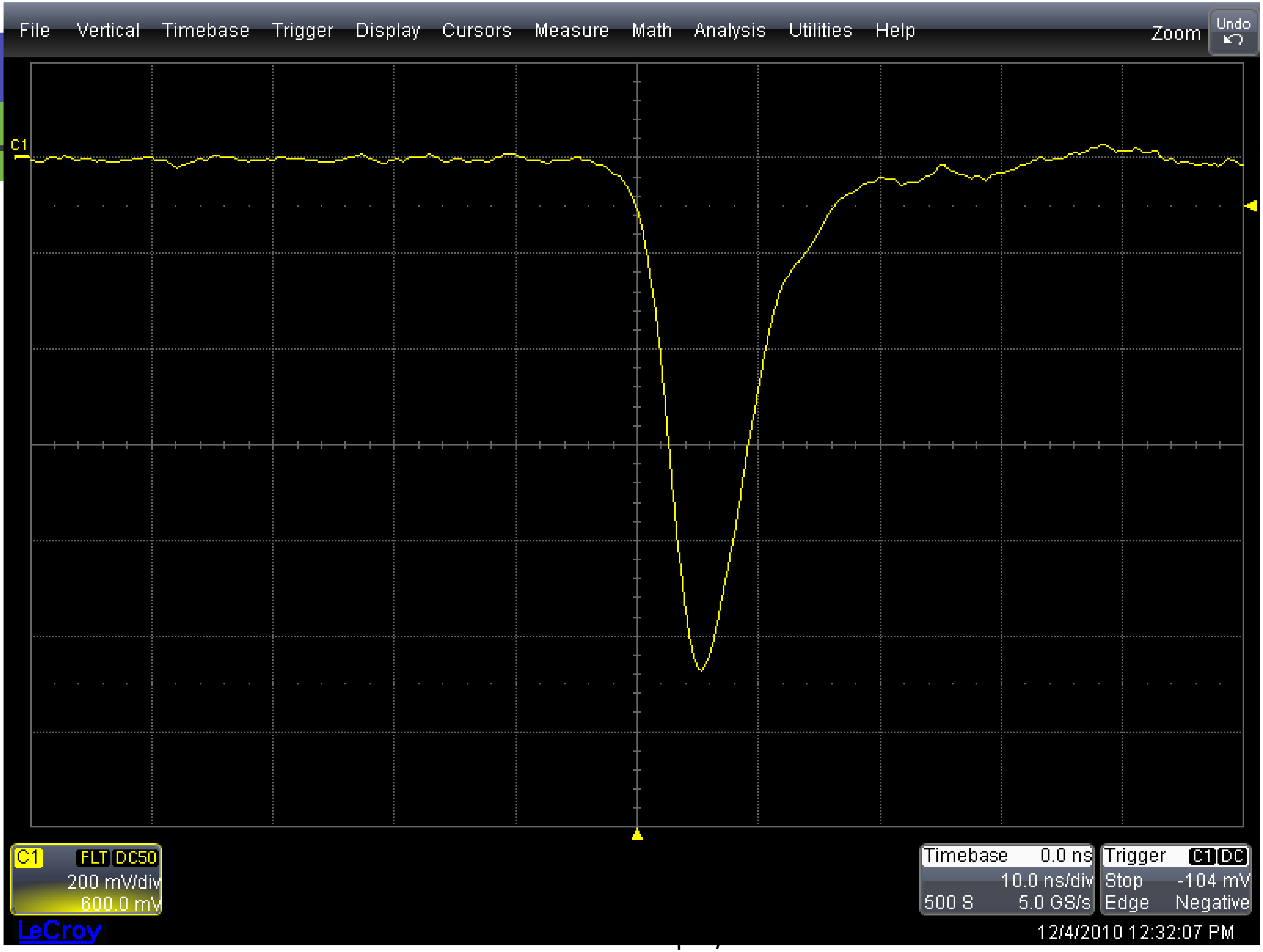
- B.Satyanarayana, et al., Nucl. Instr. And Meth.A 602 (2009) 784.
- D.Samuel, et al., Nucl. Instr. And Meth.A (2010) 784, doi:10.1016/j.nima.2010.08.075.
- S.Pal, et al., Nucl. Instr. And Meth.A (2010) 784, doi:10.1016/j.nima.2010.09.178.

Thank you

More information

- In AFE, Ultrafast dual comparator, i/p-> Analog, o/p-> ECL[AD96687], ECL Monostable or monoshot [MC10198]
- In DFE, MC10115 take AFE Level O signal, finally give after ANDing Level 1 ECL signal.
- This ECL level 1 signal in TTR board goes double conversion and finally send ECL output to the TDC.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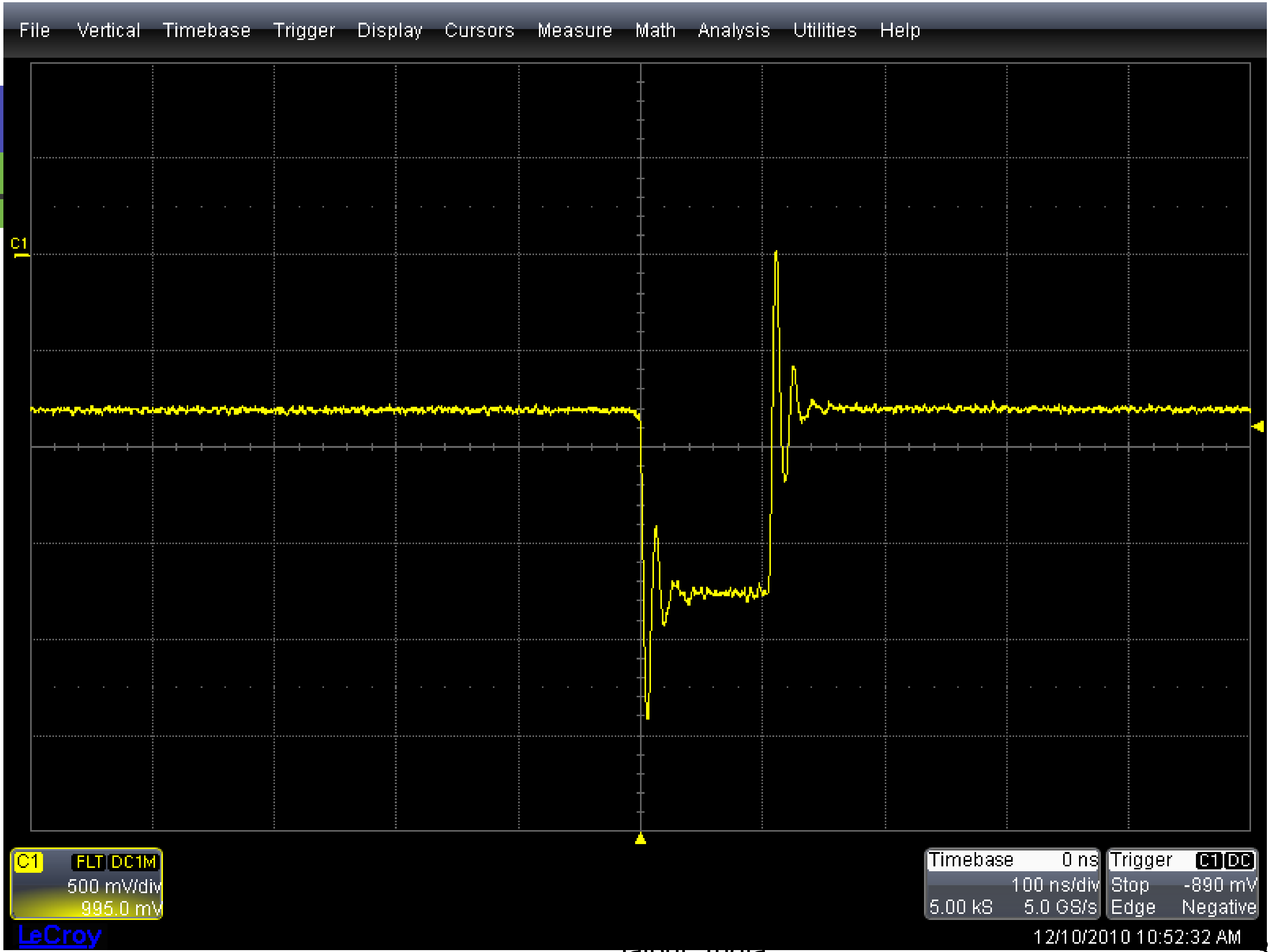
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Edge Negative
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