Cosmic-ray test of the Sci-W ECAL Technological Prototype

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On behalf of CEPC Calorimeter working group

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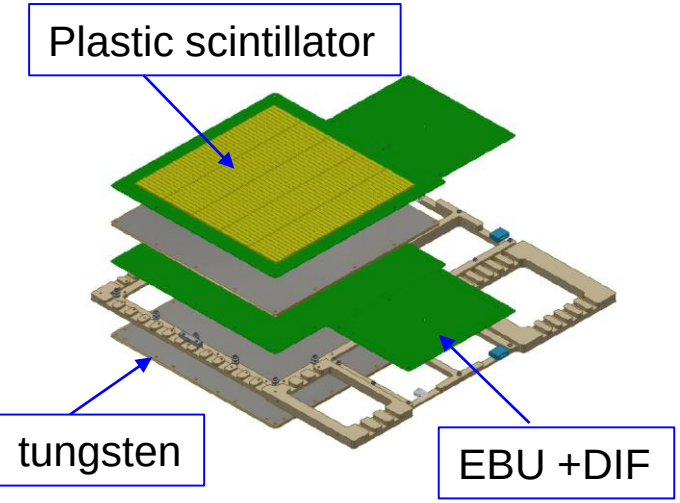
Outline

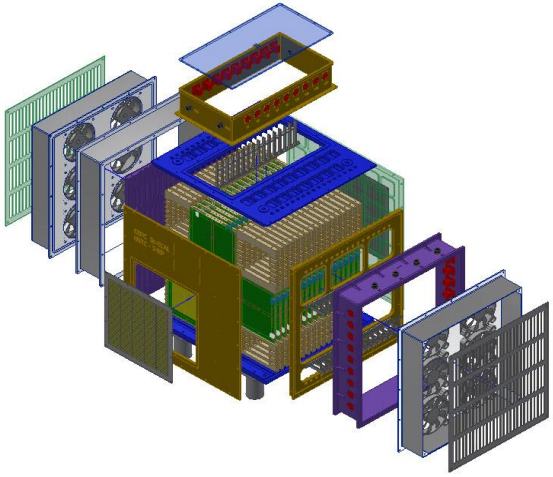
- Brief review of Sci-W ECAL
- CEPC Sci-W ECAL Cosmic Ray Test
  - Some key parameters calibration
    - Pedestal, low/high gain ratio, MIPs..
  - Position resolution study
  - Time measurement
- Summary

Sci-W ECAL of CEPC

- The calorimeter prototype has 16 super-layers
  - Plastic scintillator strip, 10 um and 15 um pixel SiPM, tungsten plate
- The adjacent layers are arranged in orthogonal to ensure the 5 mm granularity
- The total radiation length is about 23.4 X_0



superlayer



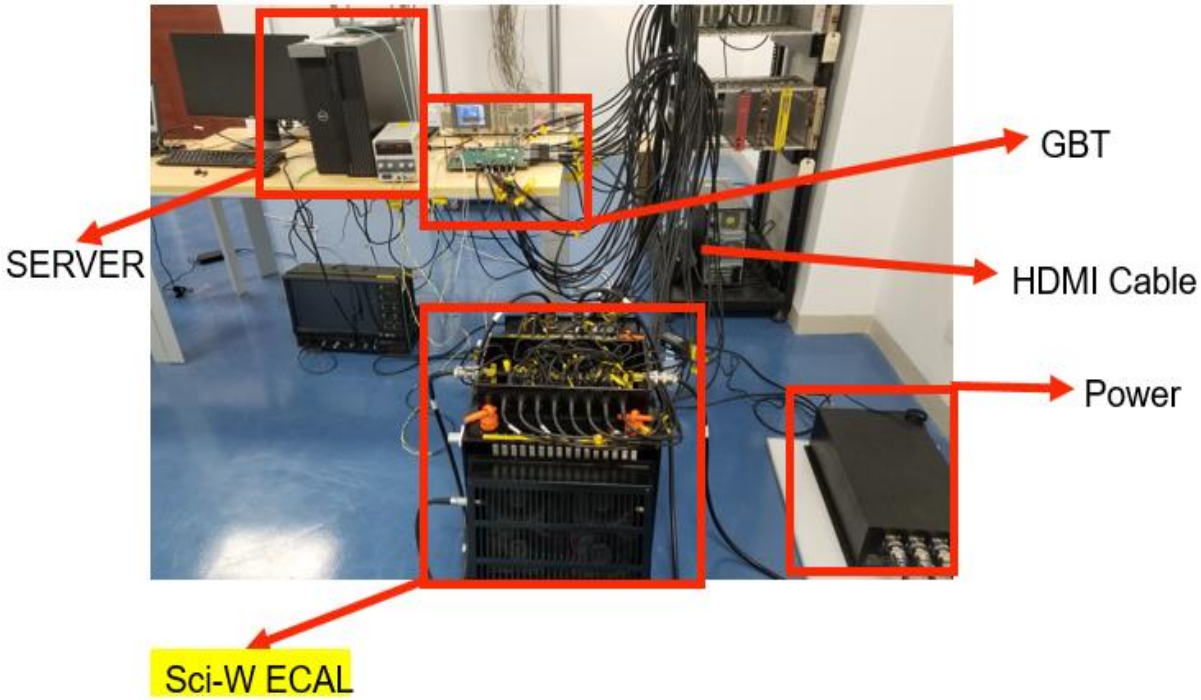
Calorimeter structure

Calorimeter

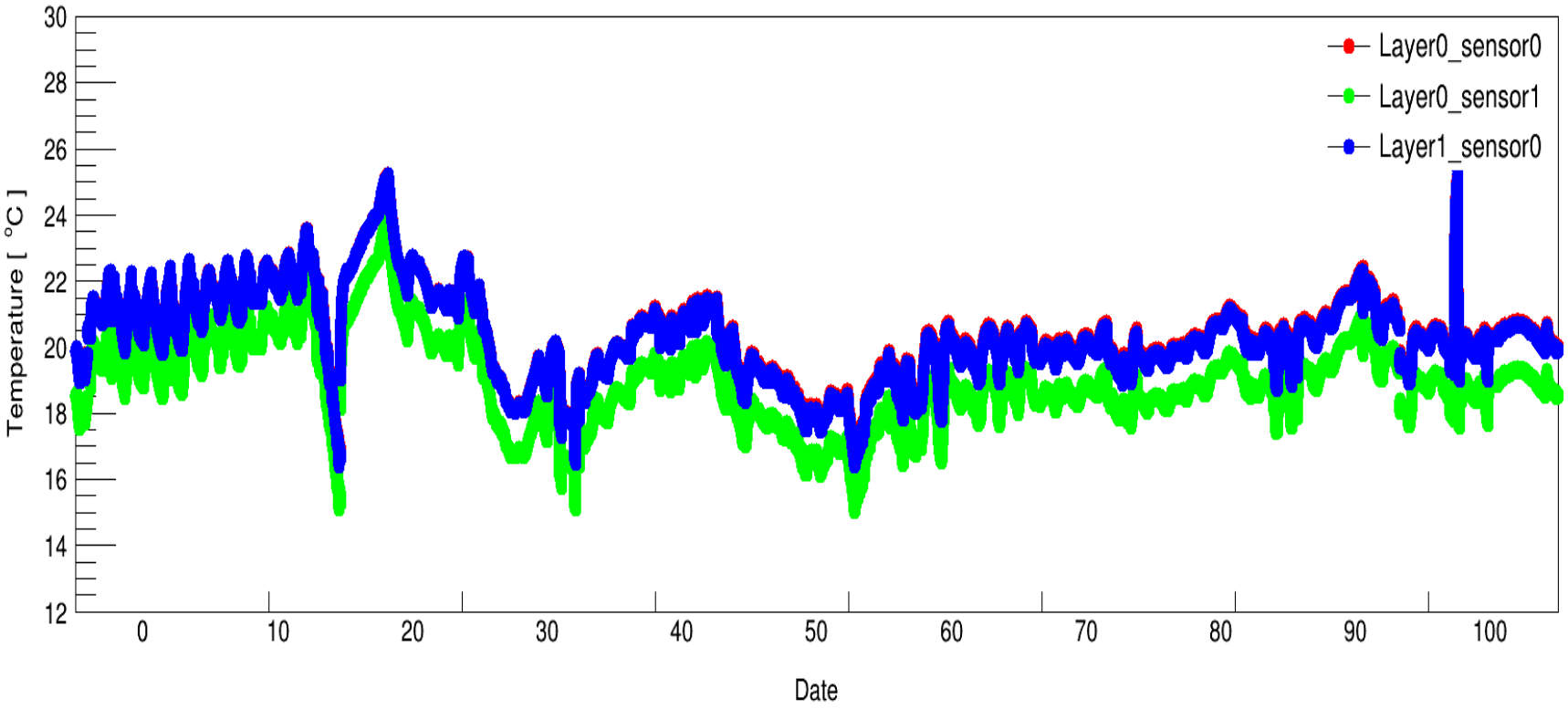
What could we get from Cosmic Test

- Study the performance of calorimeter in long term, and some analysis methods can also be tested with these data
- Calibrate some important parameters of calorimeter, like the pedestal, low gain/high gain ratio, electronics linearity, energy scale and so on
- Also include the engineering parameters, like temperature, voltage, current..

- Long term cosmic ray test: ~100 DAYs
  - Coincidence trigger of Layer1 & Layer29
  - Event rate : ~ 16 per minute
  - ~1.5 million cosmic ray events collected



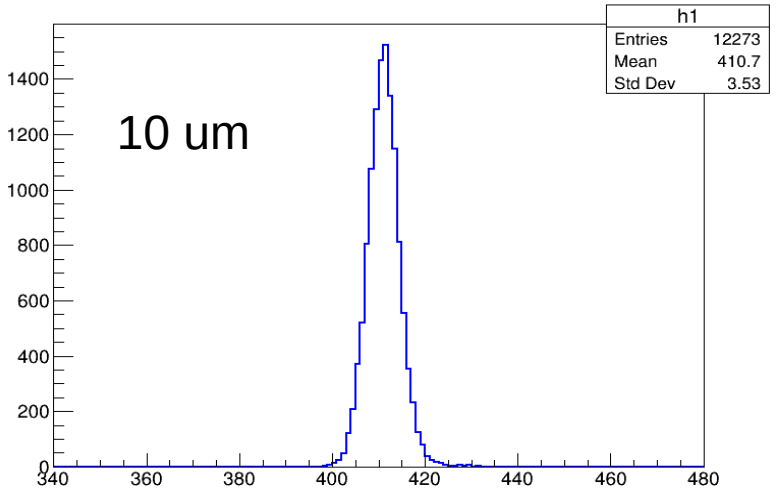
Temperature

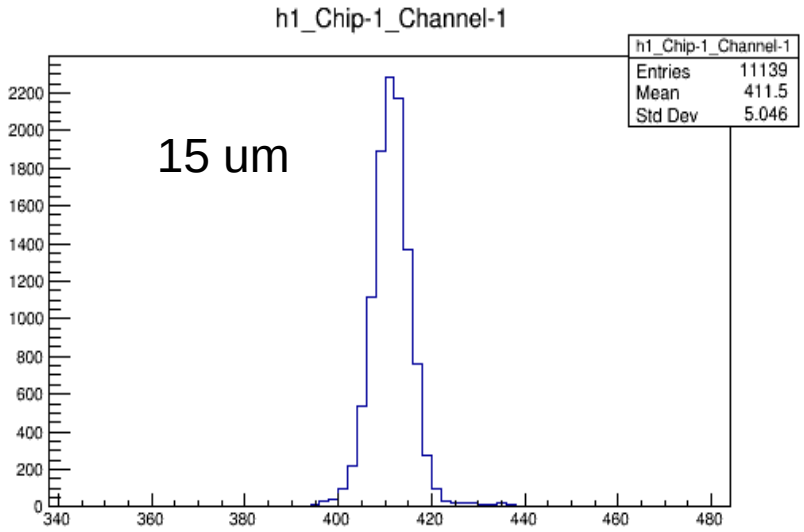


- The temperature is between 14 and 26 degrees, with an average of 20 degree
- There are slight differences in different locations in the same layer
- The temperature difference between different layers is also very small

pedestal

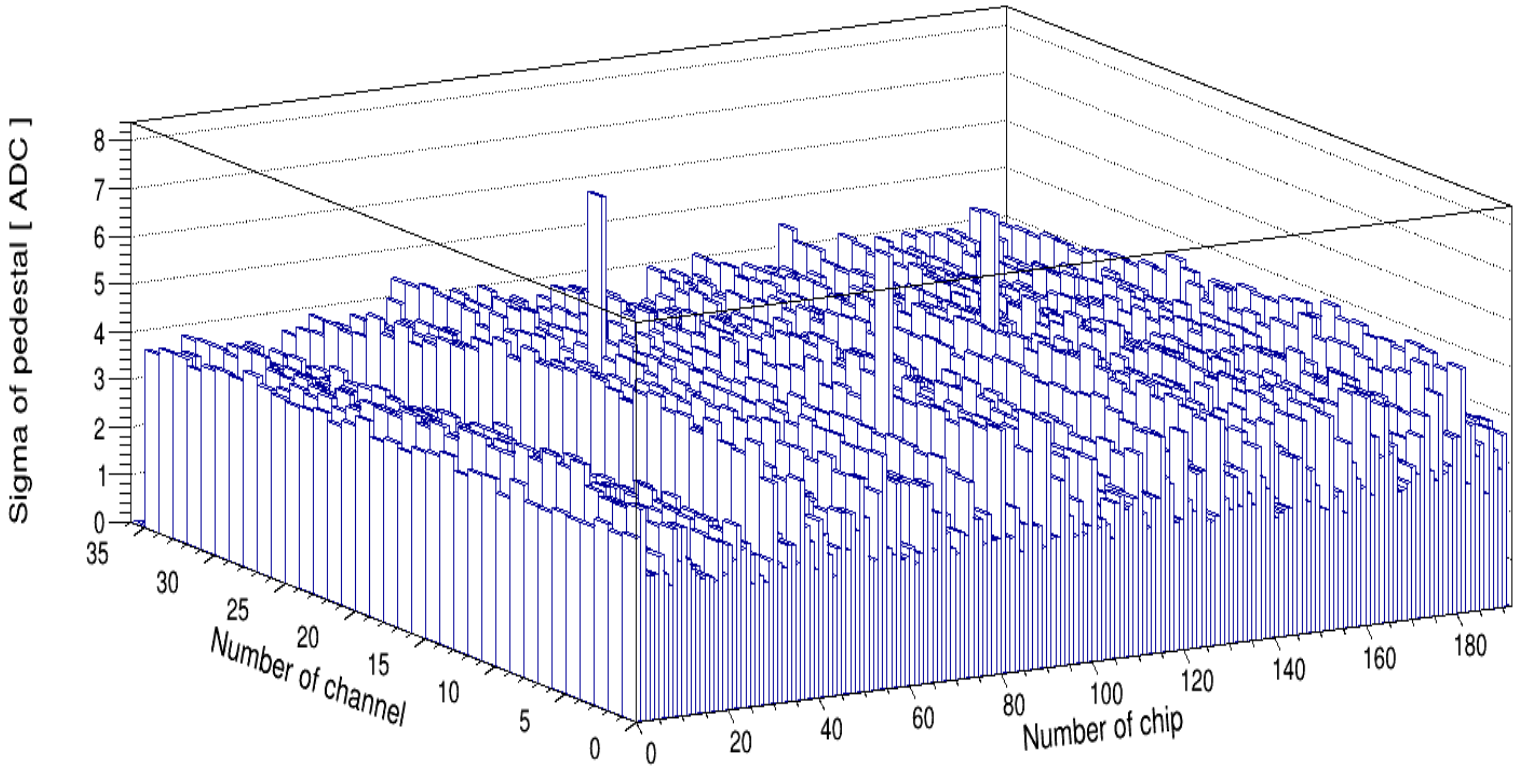
- The pedestal distribution could be get from “hittag=0” channel
- The pedestal width of 10 um and 15 um pixel SiPM are about 3-5 ADC counts





pedestal

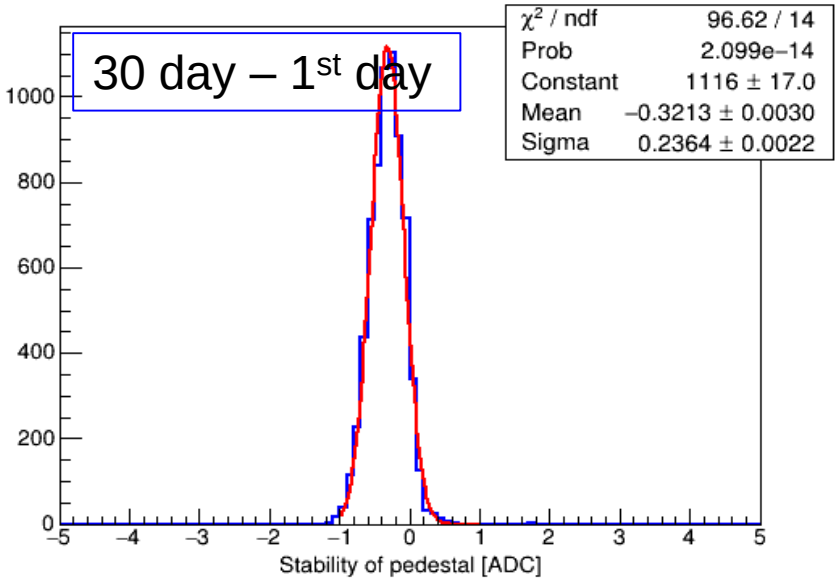
- The pedestal width of different chips is a little different
- The pedestal width of the same chip is more uniform



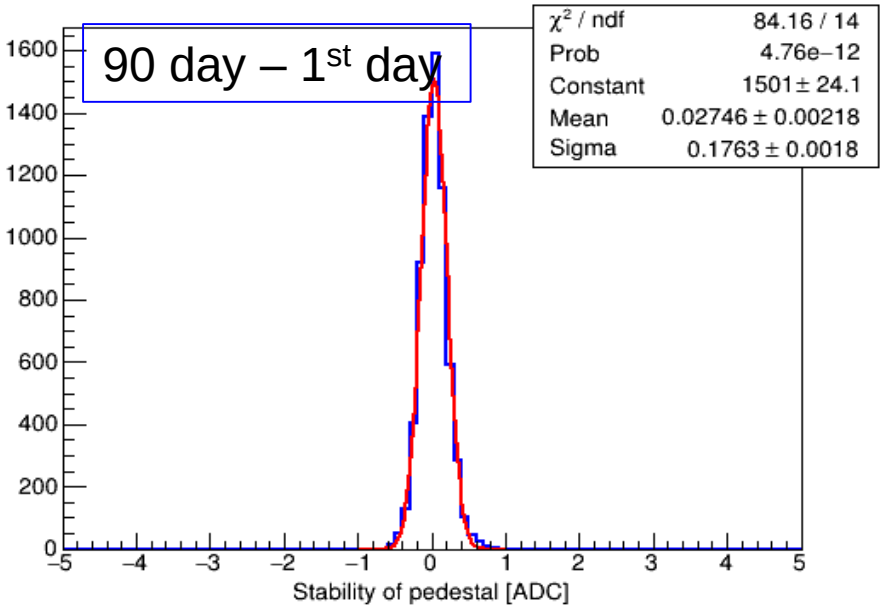
Pedestal width of each channel

Pedestal stability

- Compared with the first day, the change of pedestal position in one month and three months is very small, 0.3 and 0.2 ADC counts respectively



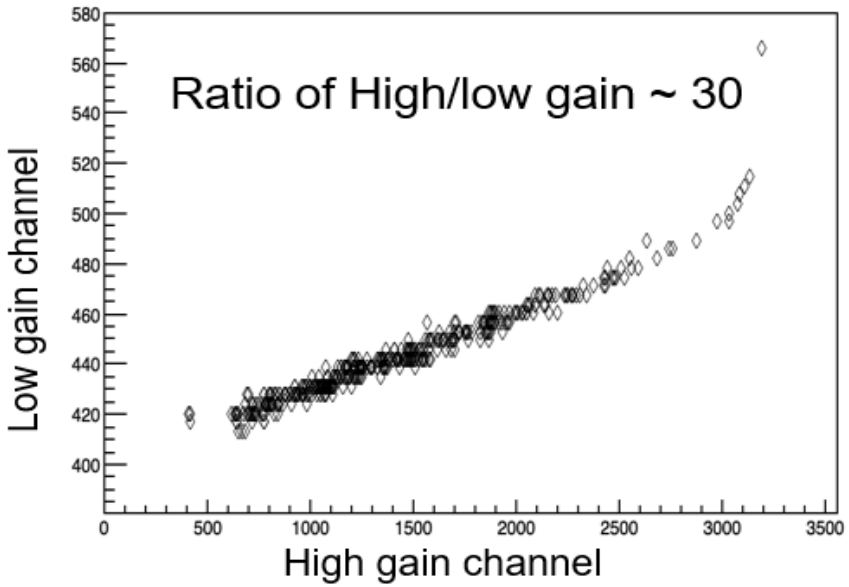
30-day shift, rms 0.3 ADC



90-day shift, rms 0.2 ADC

High gain and low gain ratio

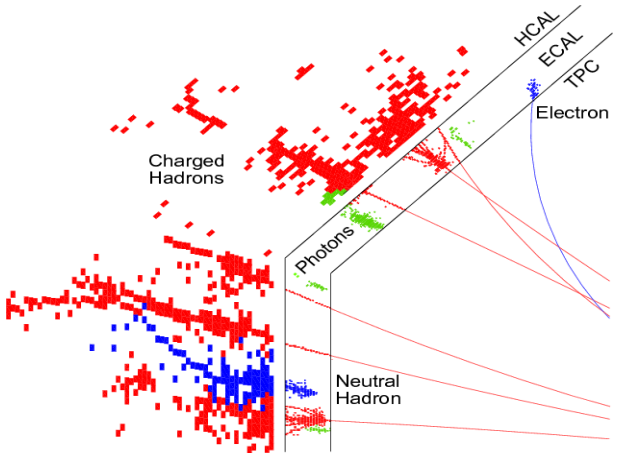
- SPIROC2E chip has two different gain channels
- The coefficient of high and low gain is very important to realize the conversion of high and low gain channels
- Cosmic ray test could be used to calibrate the ratio

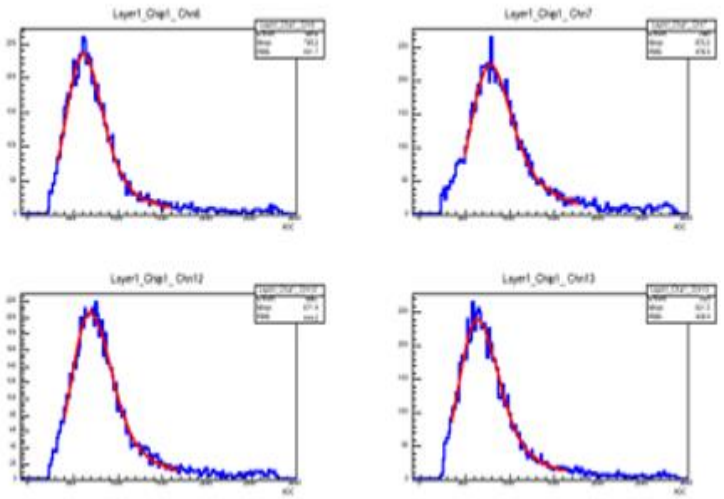


The ratio could also be calibrated by LED test, and the details could be seen in Naoki's talk

MIPs spectra

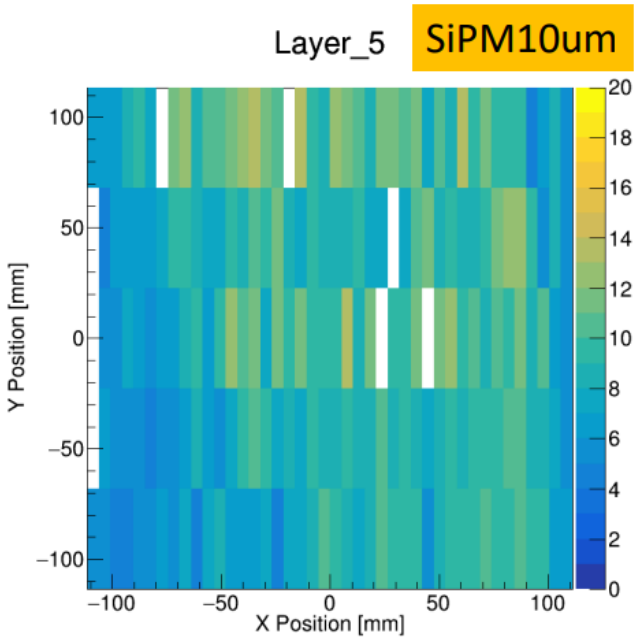
- In order to reconstruct the total energy deposition in calorimeter of incident event, we should know the deposition in each SD element
- MPV value of MIPs is the reference for SD energy reconstruction
- Landau convolution Gaussian function is used to fit
  - Landau describes the energy fluctuation
  - Gauss describes the fluorescence process, electronic gain and so on

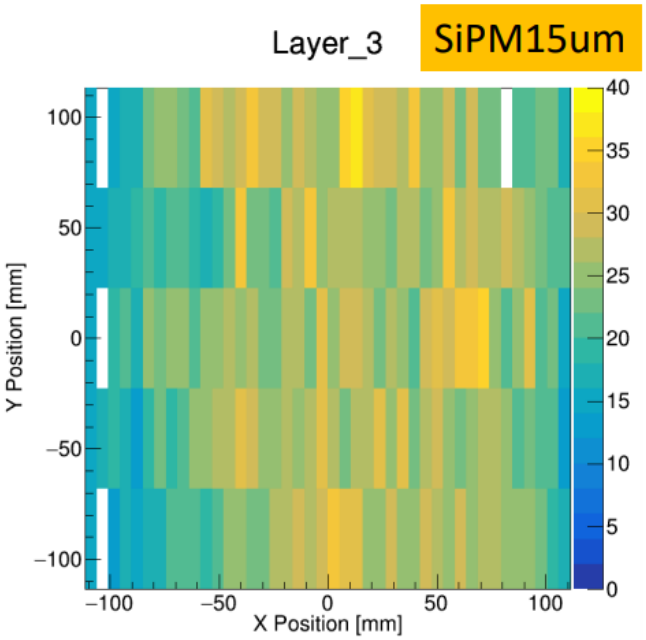




Light yield of each channel

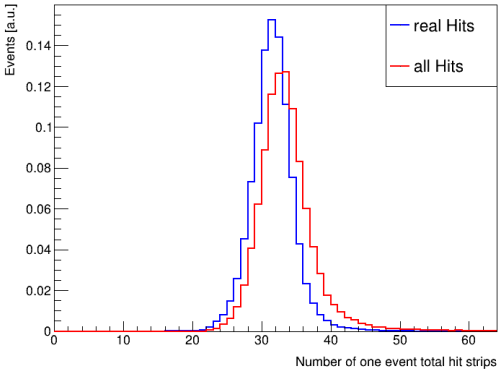
- Combined with the SiPM single photon electronic peak obtained from LED test, the light yield of each unit can be obtained
- The light yields using 10um and 15um SiPM readout units are about 10 pe/MIP and 20 pe/MIP, respectively



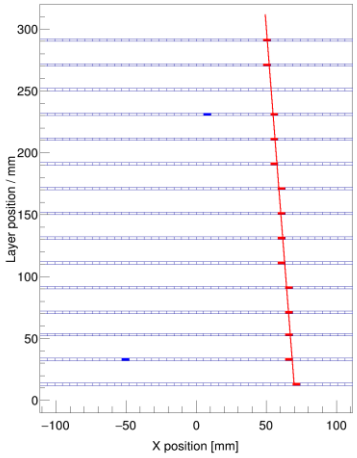


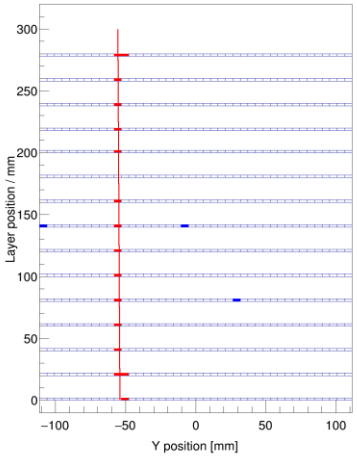
Track finding and fitting

- A preliminary algorithm performed
  - Find and fit the precise cosmic-ray track
  - Distinguish real hit cells and noise cells



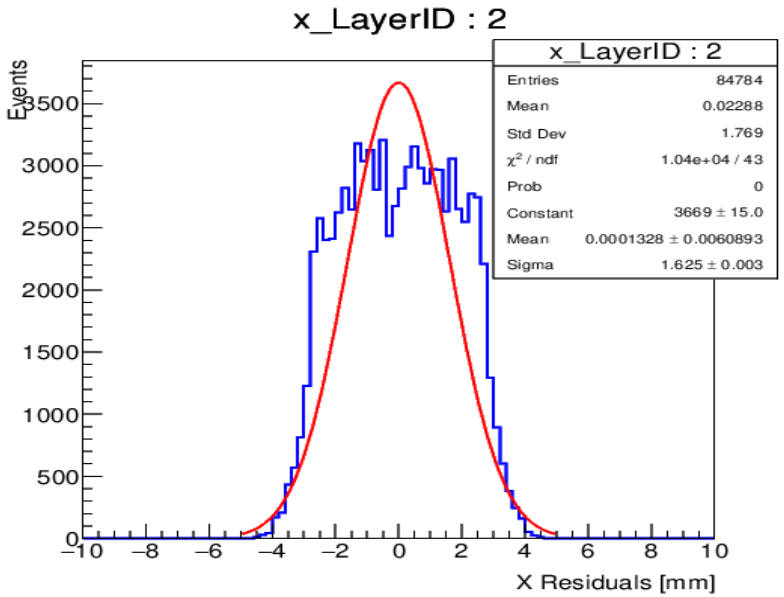
Process	Selection	Efficiency
preSelection	$TotalHitLayer \geqslant 22$	92%
	$TotalHitStrips \leqslant 64$	99.6%
	$ADC \geqslant 5\sigma$	99%
Iteration Fitting	All Hits	
	$Pos - tracking \leqslant (47.5,\ 5,\ 7.5)$	
	Nearest point in one layer	
Track Selection	$\lvert Intercept\rvert \leqslant 114, \lvert\varphi\rvert \leqslant 0.7$	98.2%
	$\sigma^2 \leqslant 9.6$	98.3%
	$TotalHitLayer \geqslant 6$	99.8%
Alignment	$Position - trackfittingresidual$	



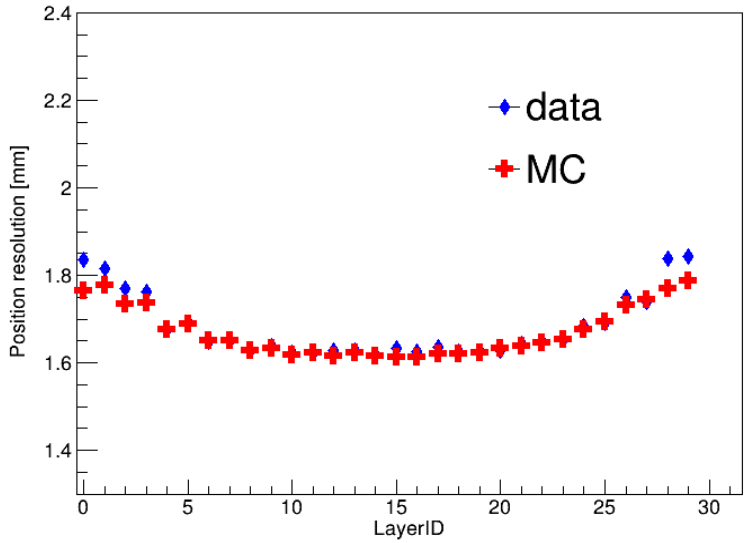


Position resolution

- Position resolution better than 2 mm
  - Strongly affected by large angle scattering
  - The RMS of residual distribution is referred as the position resolution
  - The settings of simulation should fine tuning



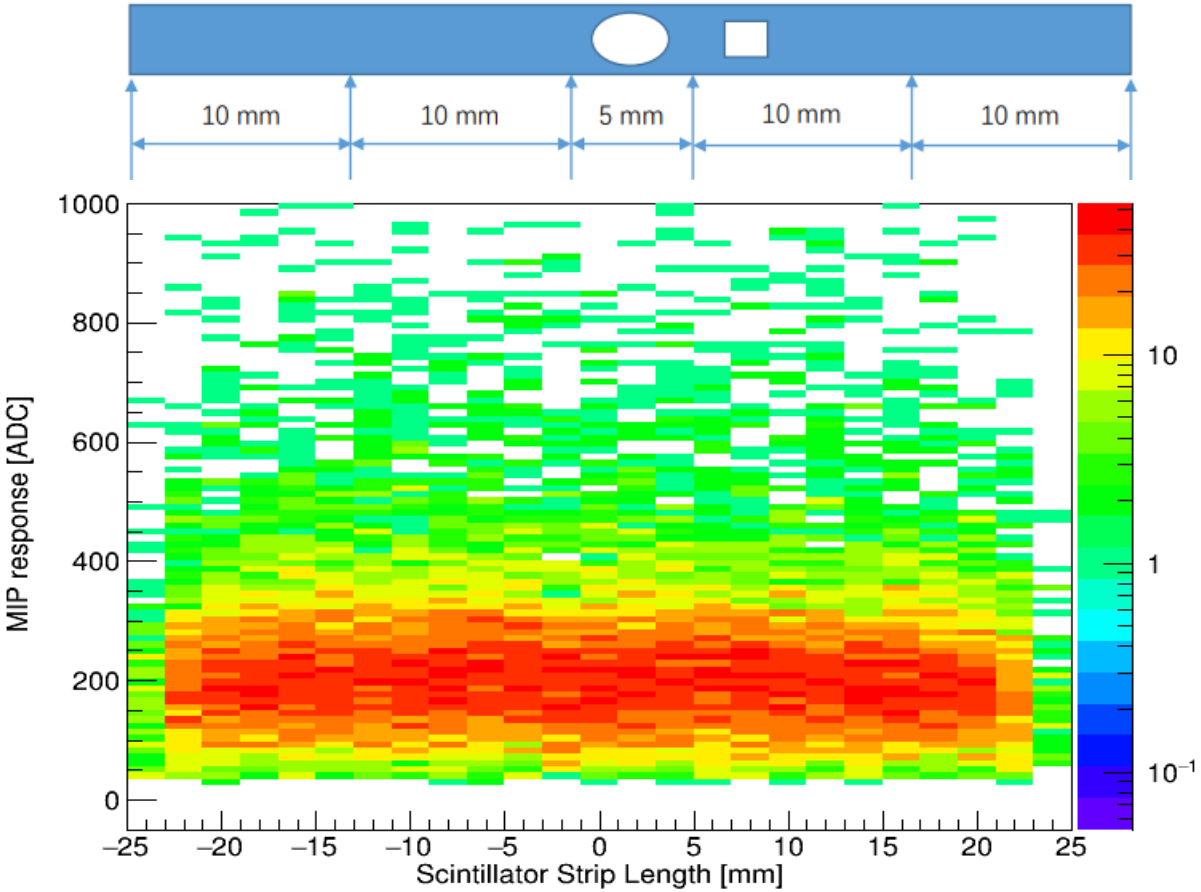
Position resolution



Resolution of each layer

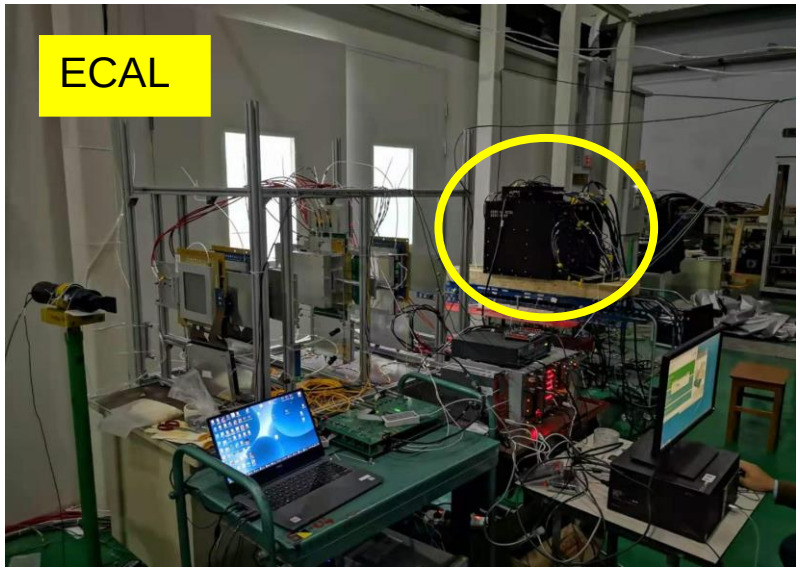
Position resolution

Based on this position resolution, we can study the fluorescence collection uniformity of scintillation unit

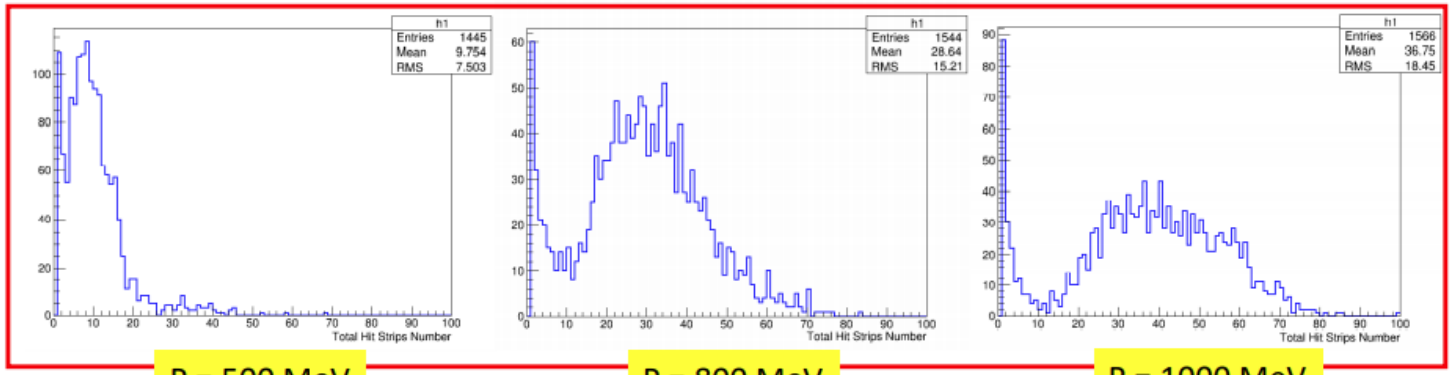


Beam Test data reconstruction

- Through the cosmic test, we can get the pedestal, energy scale and high-low gain conversion coefficient of each channel
- In the next step, we will carry out energy reconstruction on the beam test data of last year in IHEP



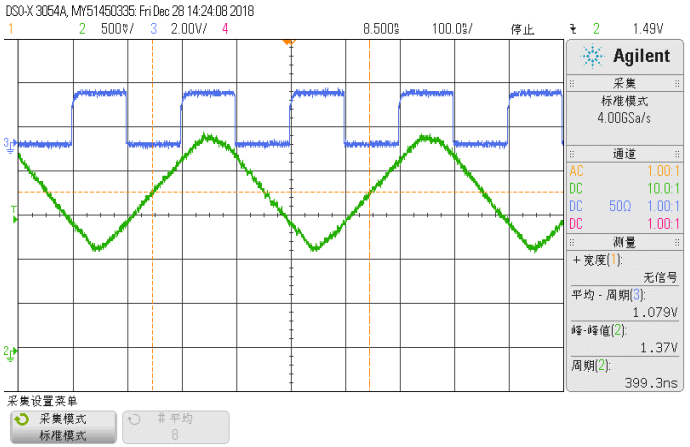
E3 beam line in IHEP



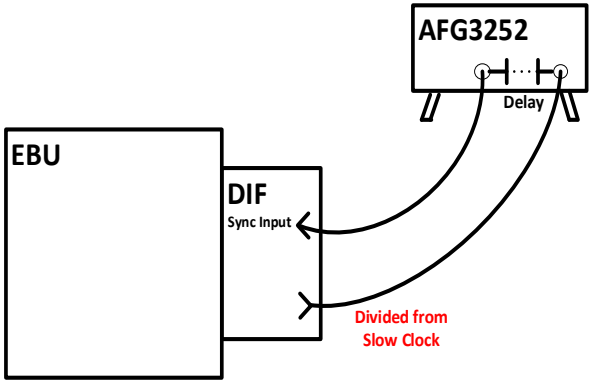
P = 500 MeV P = 800 MeV P = 1000 MeV

Time Measurement

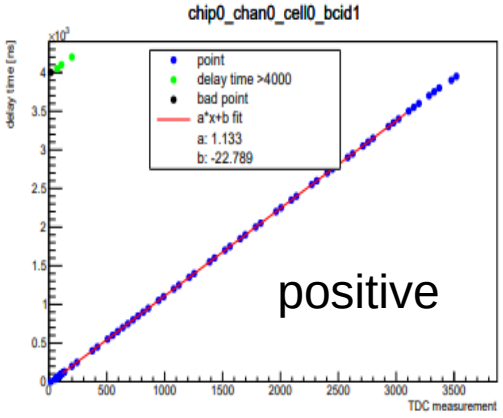
- Time response of SPIROC2E
  - SPIROC2E could give time information using an Integral TDC
  - two ramps: positive and negative
  - The linearity of TDC could be calibrated

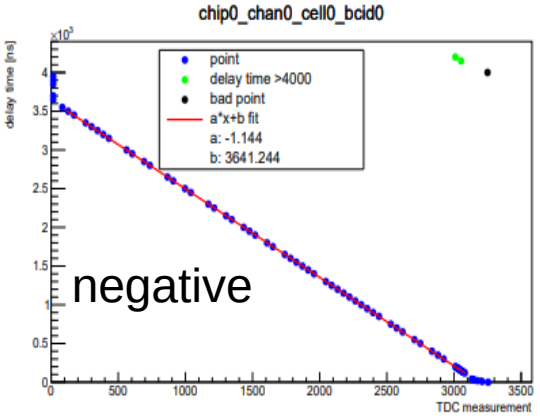


SPIROC2E chip



A pulse generator was used to calibrate the TDC

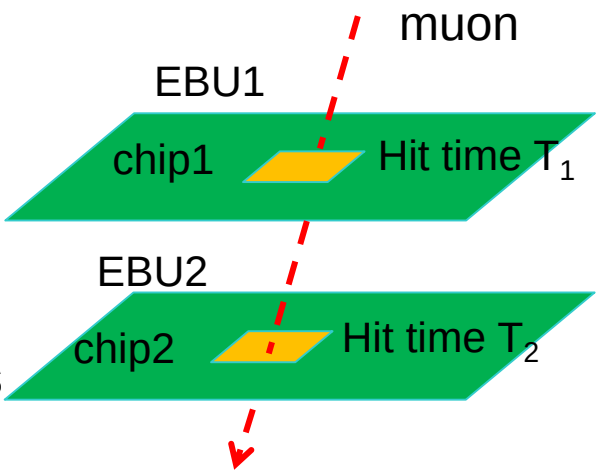


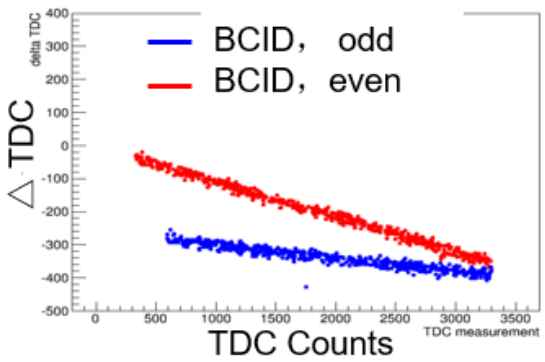


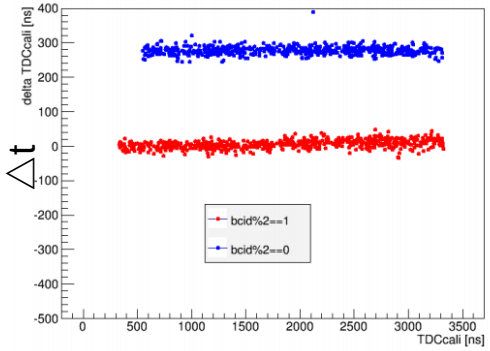
The linearity of TDC output

Time Measurement

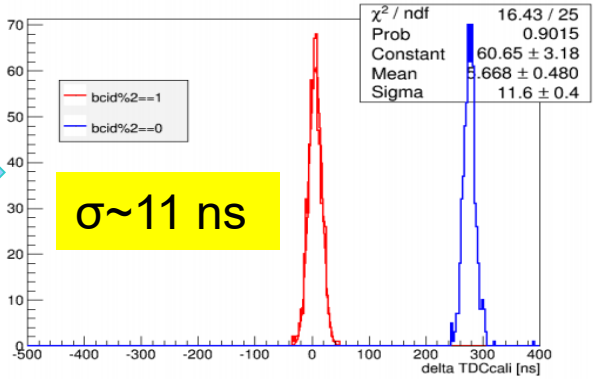
- Cosmic Ray could be used to calibrate the “TDC offset” of each chip or channel
  - Select one chip on each of the two EBUs
  - Calculate the difference of TDC channels measured by the two chips
  - The TDC counts to seconds convert coefficients are from pulse generator calibration







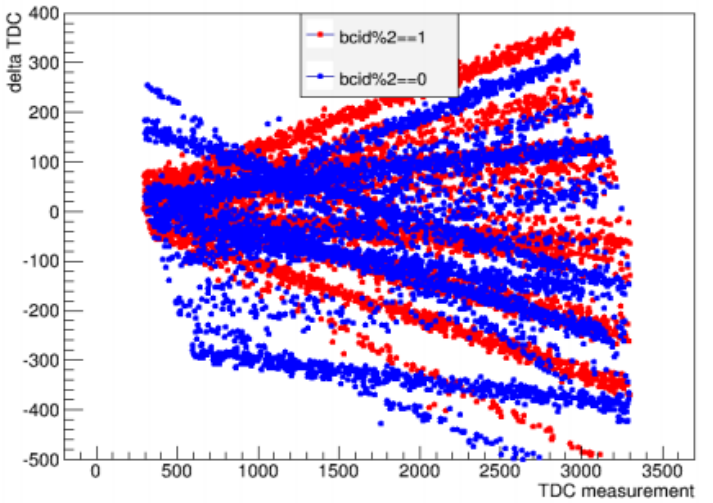
Time (ns)



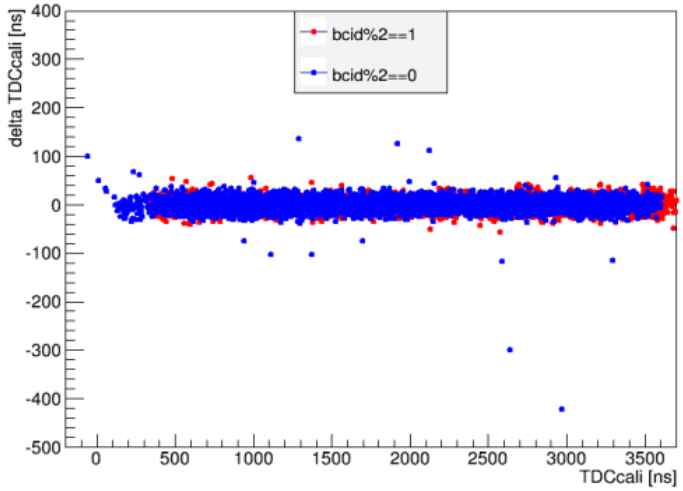
Time resolution (ns)

Time Measurement

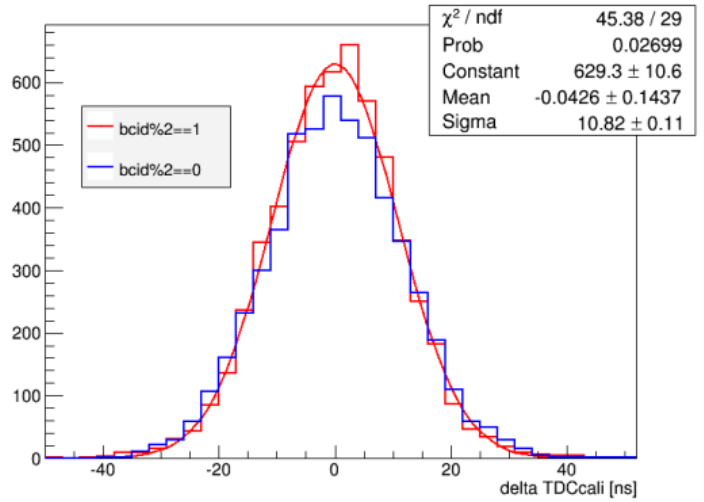
- Here is the time measurement relationship of all chips on the two EBUs
- The time resolution after offset correction is shown
- Both the positive and negative ramp, the time resolutions are about 11 ns after correction



Before offset correction



after offset correction



Time resolution

Summary and outlook

- The calorimeter prototype based on Sci-W (and SPIROC2E chip) has been developed
  - 32 sampling layers, great than 6720×2 channels
  - The granularity is 5 mm×5 mm
- A long-term cosmic ray test have been carried out
  - The results show that the performance of the prototype is good
  - the design functions can be realized
    - The noise, MIPs amplitude, temperature…
- Next step, we hope to reconstruct the beam test data of last year in IHEP, and prepare for a new beam test in near future
  - Desy, CERN, IHEP

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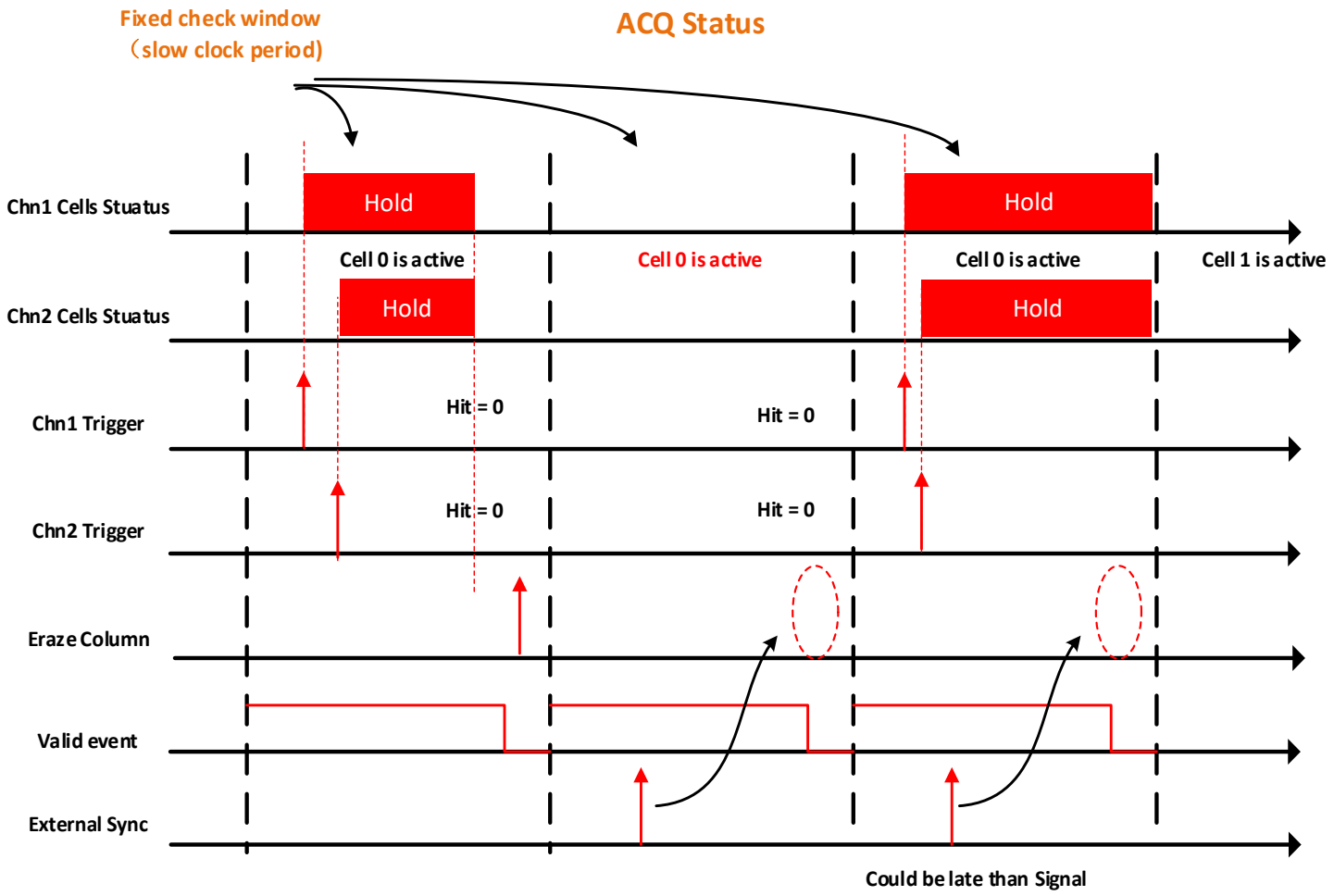
THANKS

backup

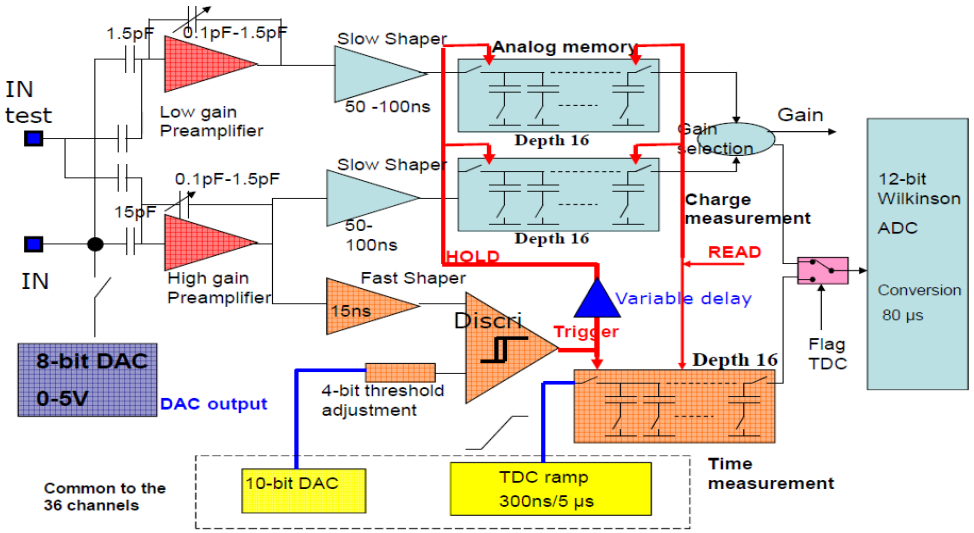
ECAL trigger

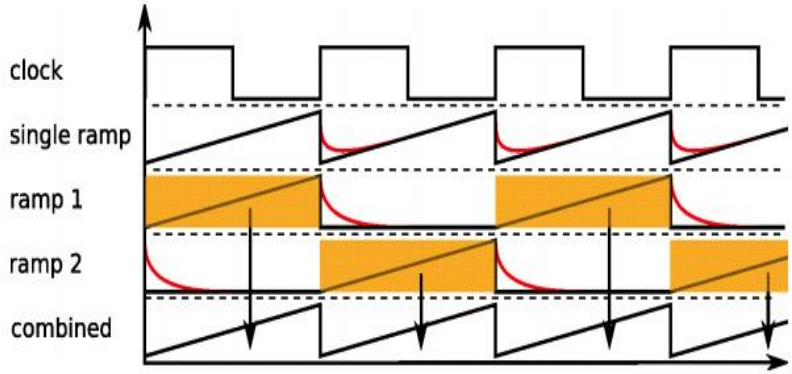


Validation Mode

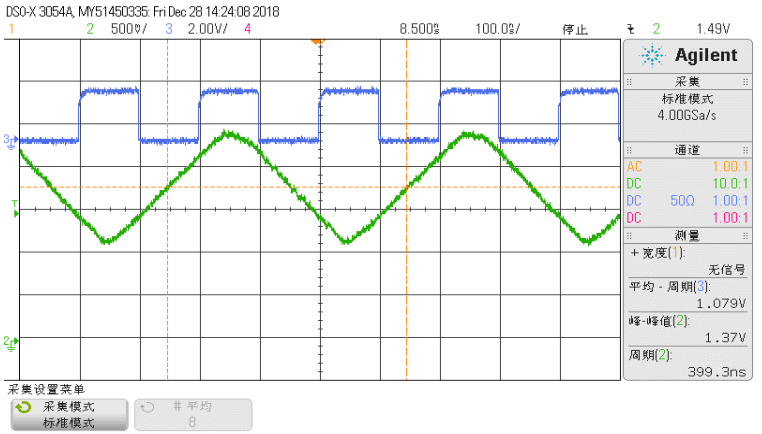
Time measurement

- Channel schematic of SPIROC2E chip
  - High gain
  - Low gain
  - Time measurement





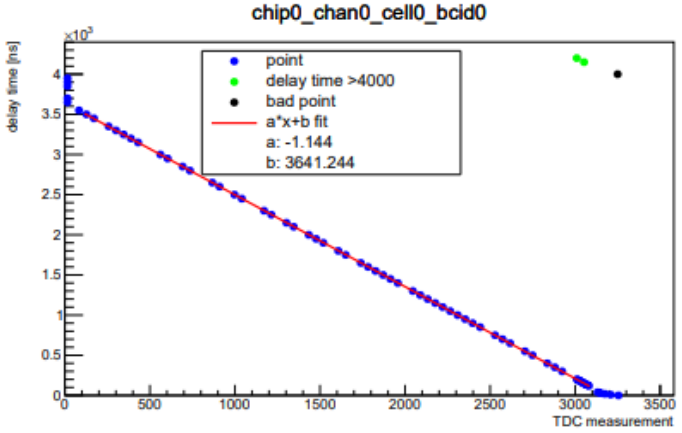
SPIROC2B chip

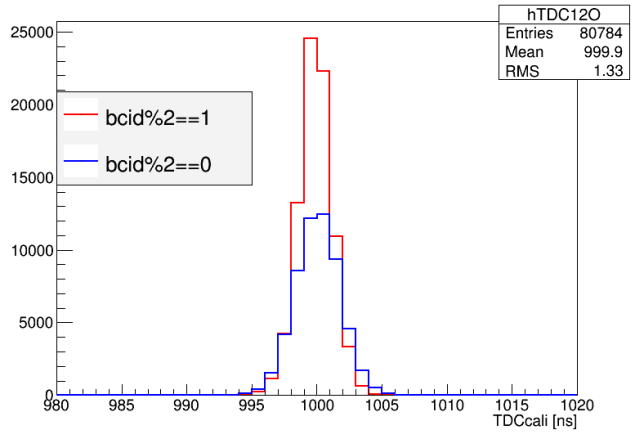


SPIROC2E chip

Time calibration

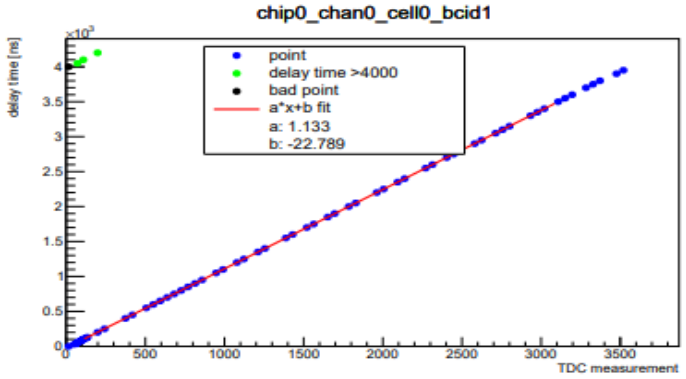
Negative slope ramp



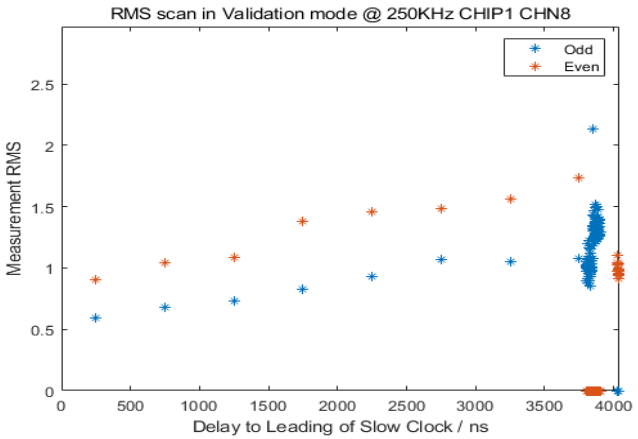


Time resolution at 1000 ns

Positive slope ramp



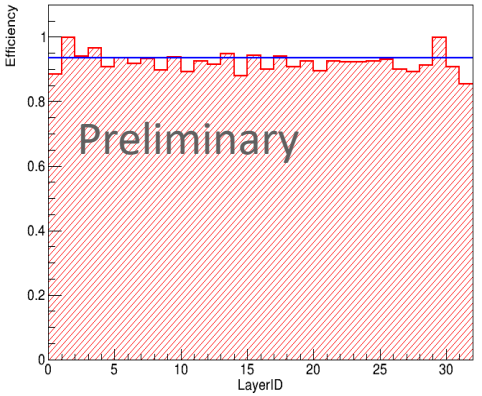
TDC Channel vs. delay time

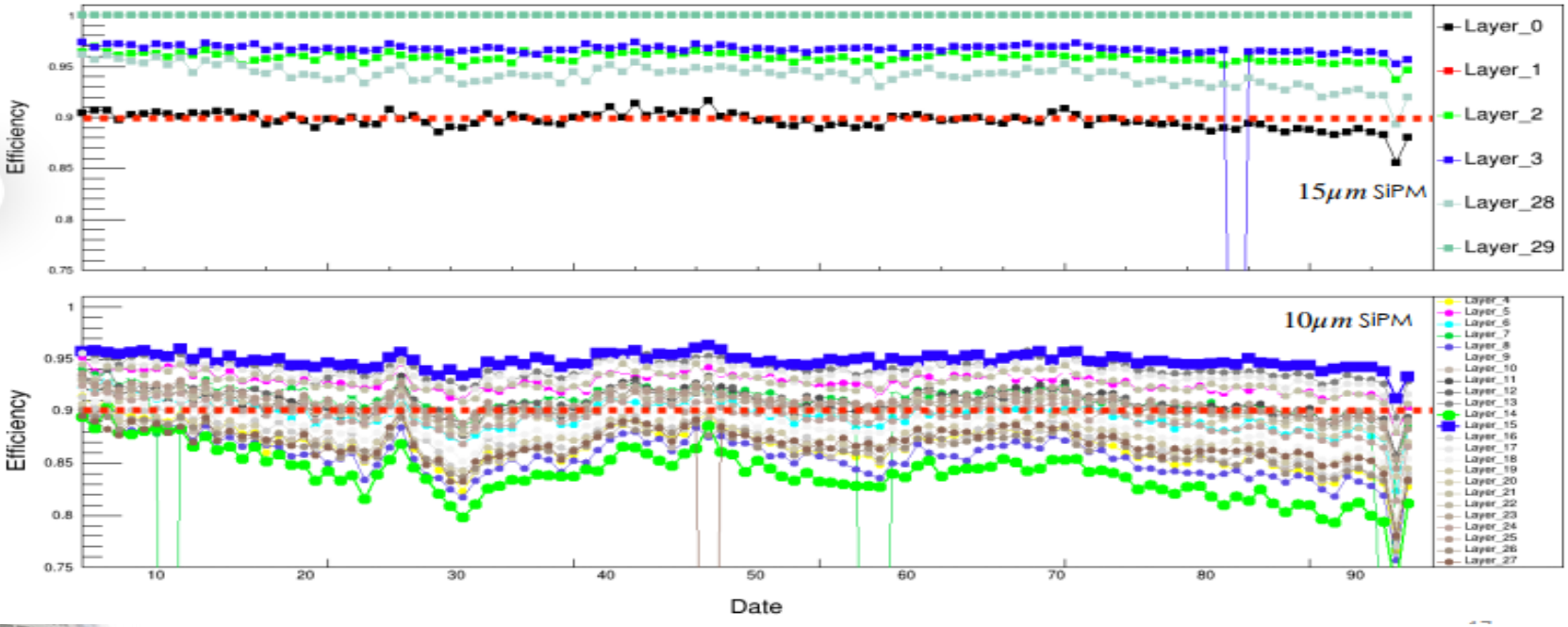


Time resolution of TDC

Detection efficiency

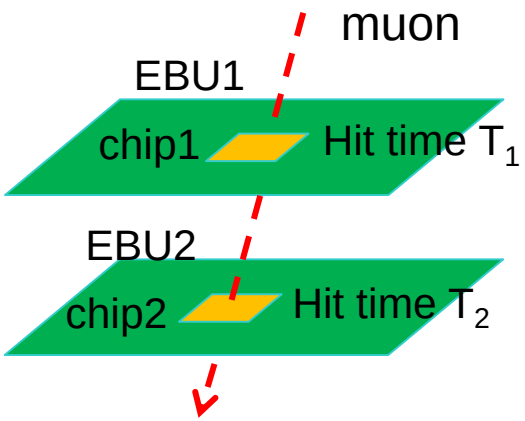
- Efficiency achieve about 90% for all layers
  - Layer 1 & 29 are trigger layers
  - Sensitive area is about 93.5%
  - Affected by the MIP threshold
  - Stable continuous for long period operation

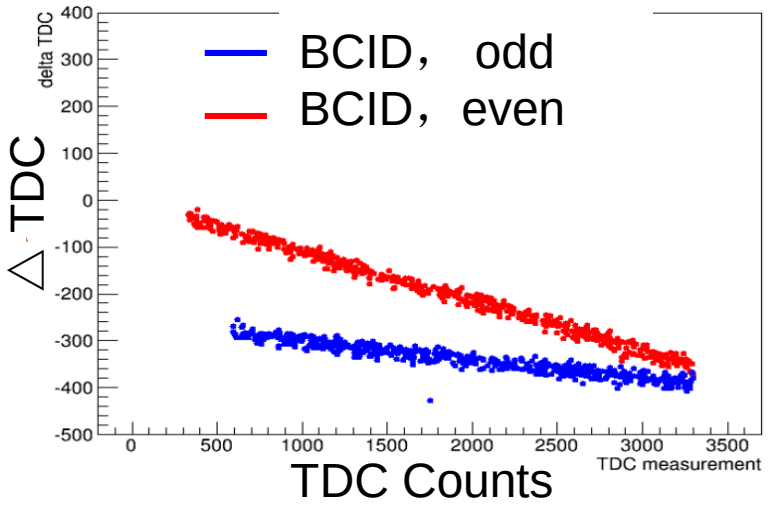


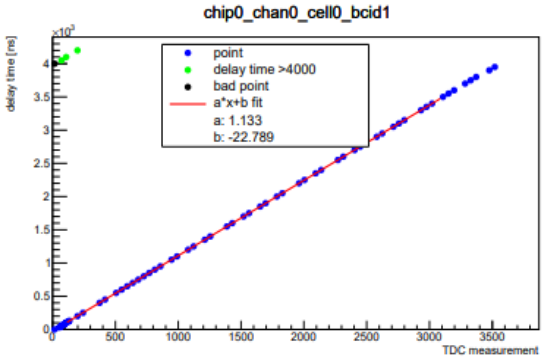


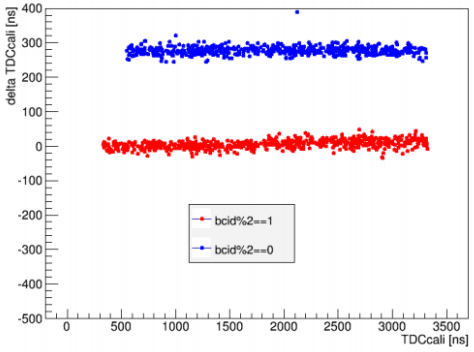
Time Measurement

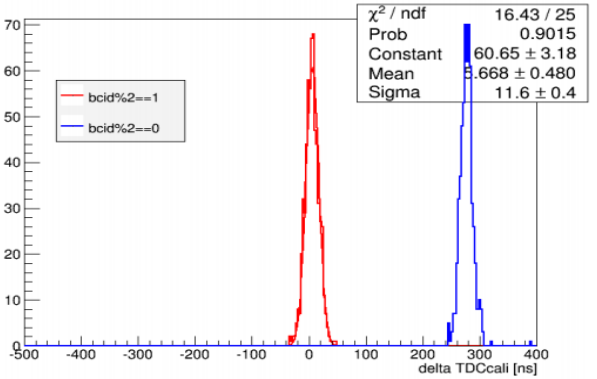
- Cosmic Ray could be uesd to calibrate the “offset”





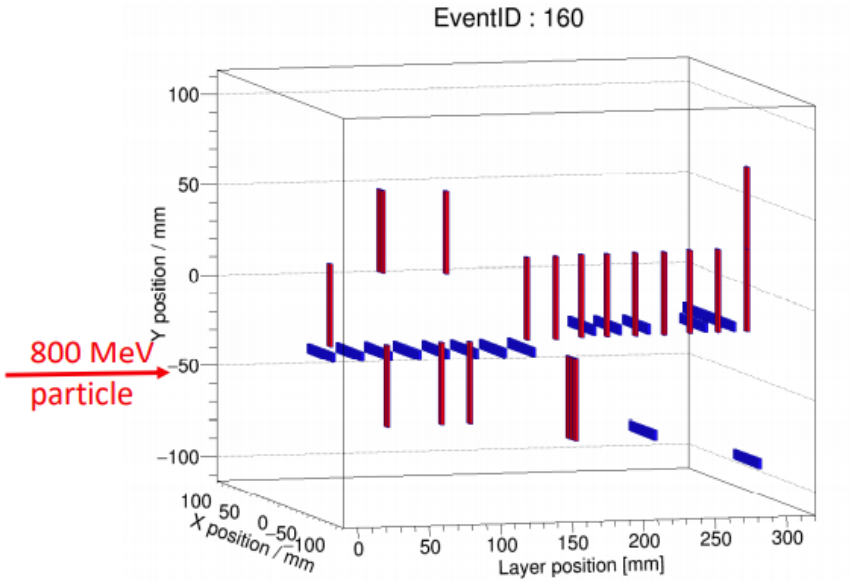


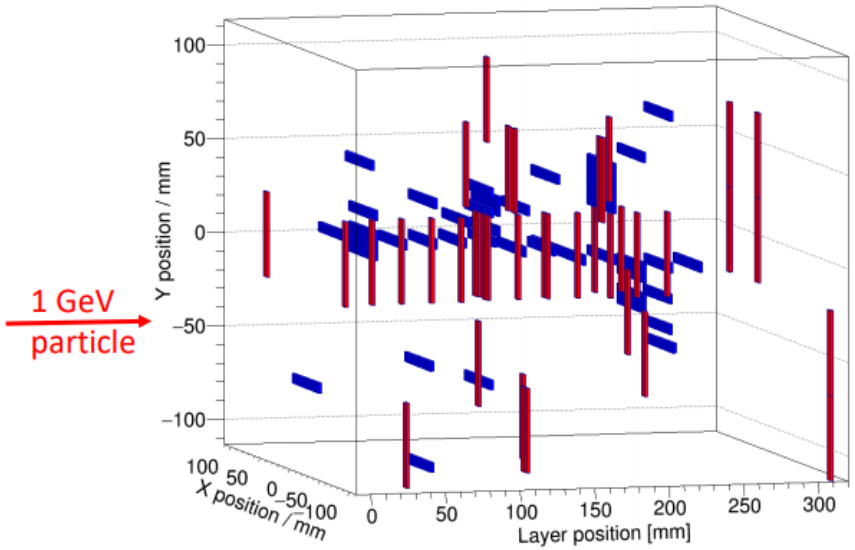


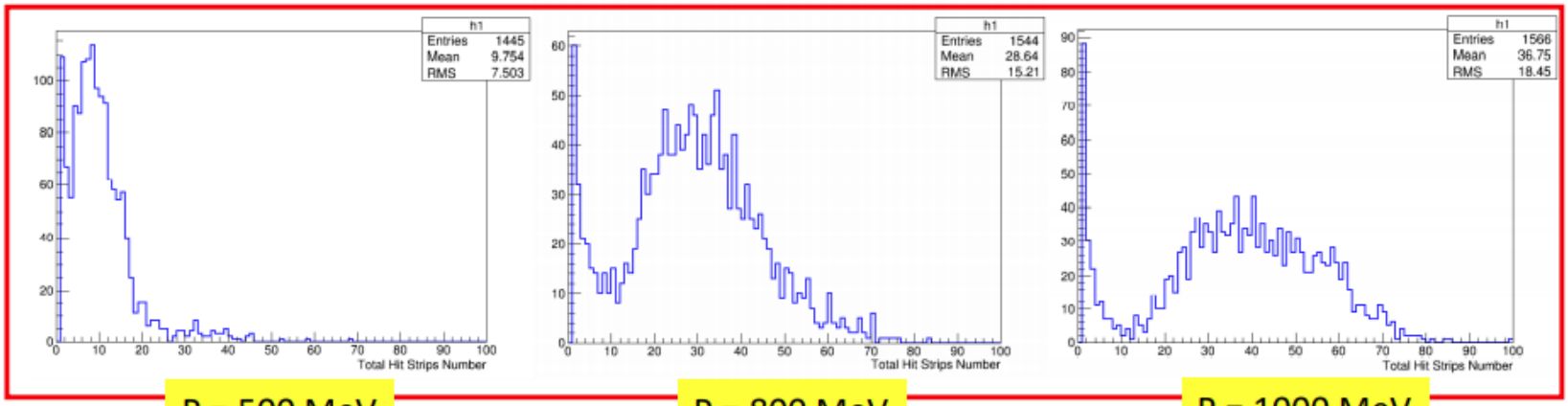


TDC Channel vs. delay time

Beam Test in IHEP







Total hits Number in ECAL