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PFA ScECAL prototype update

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On behalf of the CEPC Calorimeter working group

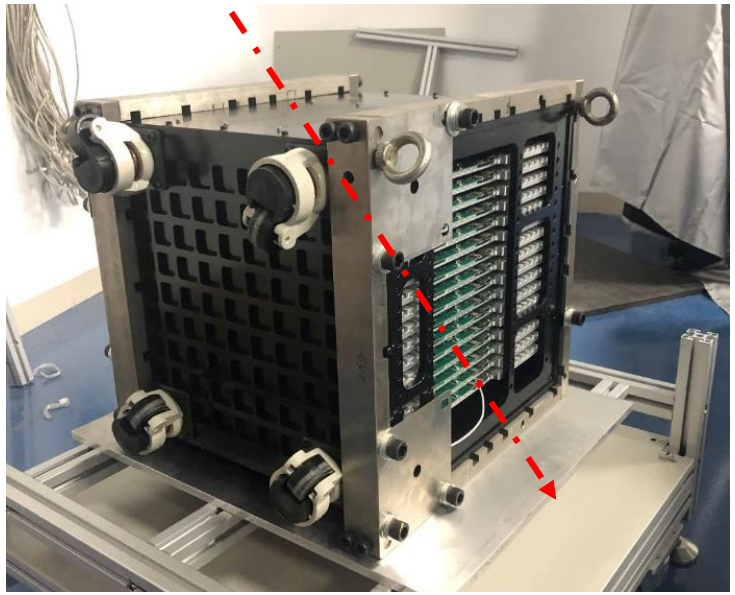
CEPC Physics and Detector Plenary meeting
14 Jul. 2021

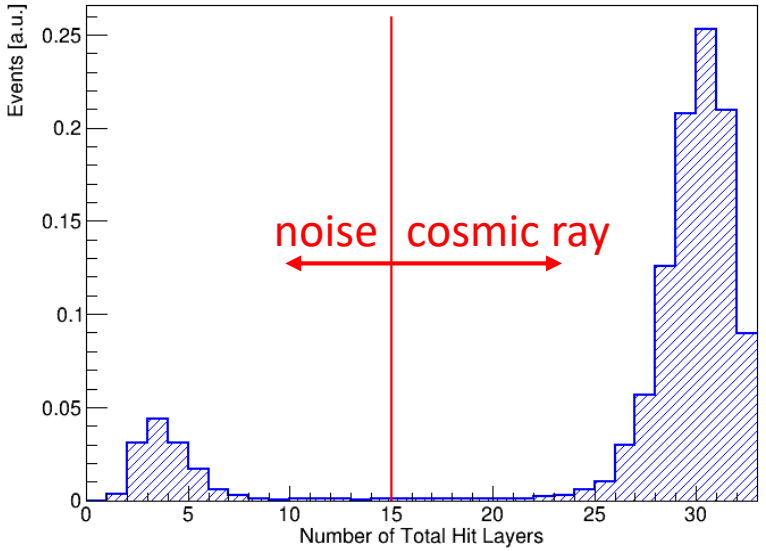
Outline

- ScECAL prototype long-term cosmic ray test
  - Technological : demonstrate reliable operation of ScECAL prototype
  - Scientific : quantitatively evaluate the key performance
- Essential calibration
  - SiPM gain calibration
  - ASIC internal factor calibration
- Future beam test plan

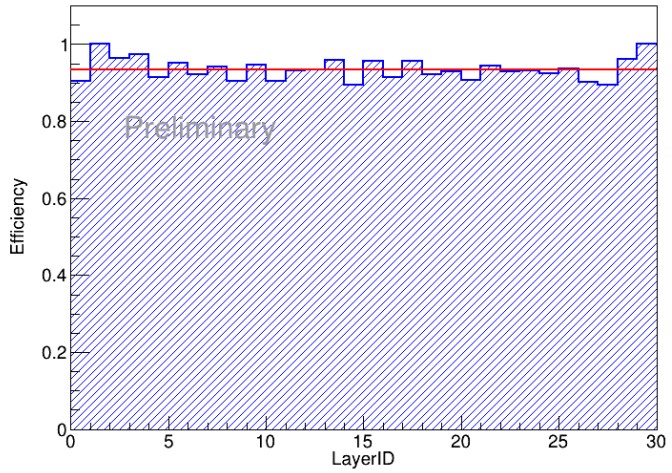
Long-term cosmic ray test

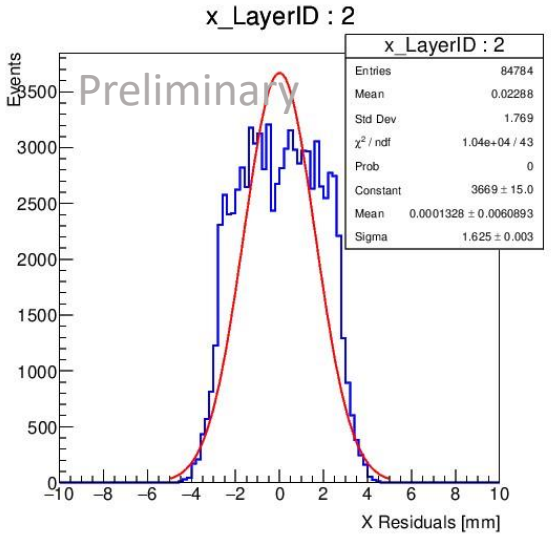
- Long-term cosmic ray test ~ 3 months
  - Coincidence trigger of Layer1 & Layer29
  - Event rate : ~ 16 per minute
  - 1.4 million effective events collected
- Main scientific purposes
  - Detection efficiency for all EBU layers
  - Track finding and Position resolution
  - Cell-to-cell MIP response calibration

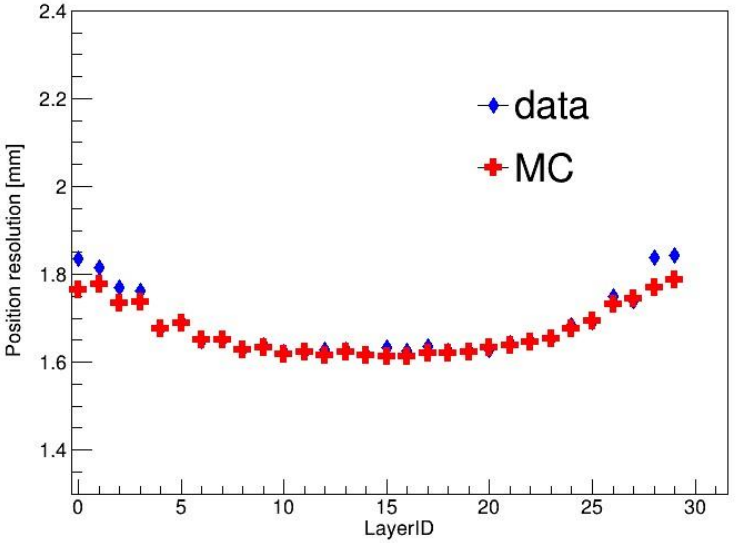




Cosmic ray test results I



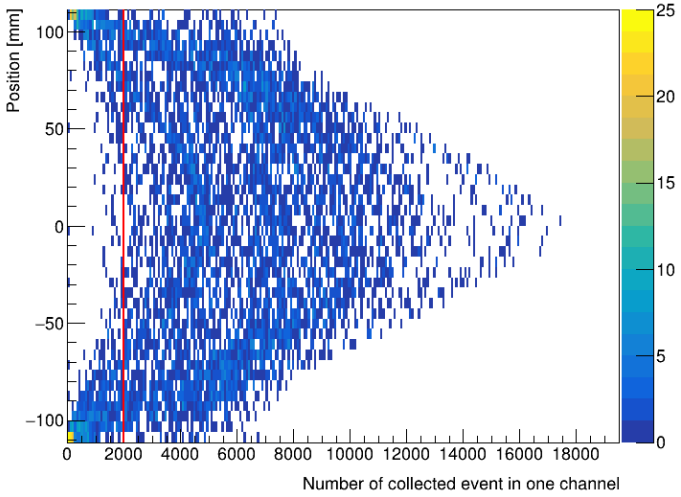


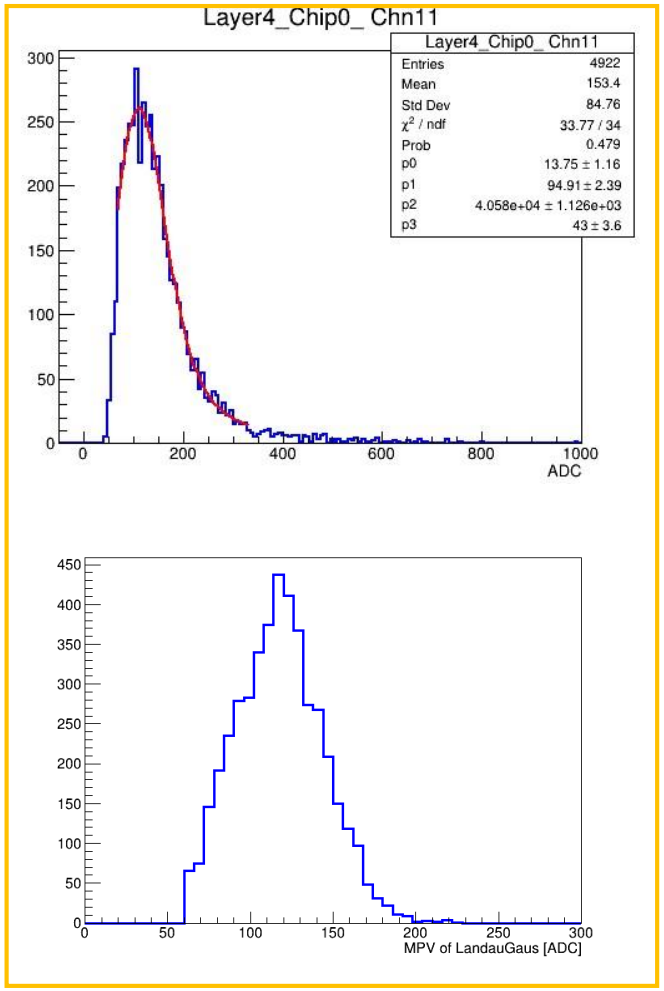


- Efficiency above than 90% for all layers
  - Layer 1 & 29 are trigger layers
  - Sensitive area is about 93.5%
- Position resolution better than 2 mm - Achieve the requirement for ScECAL
  - Strongly affected by large angle scattering (22 X_0)

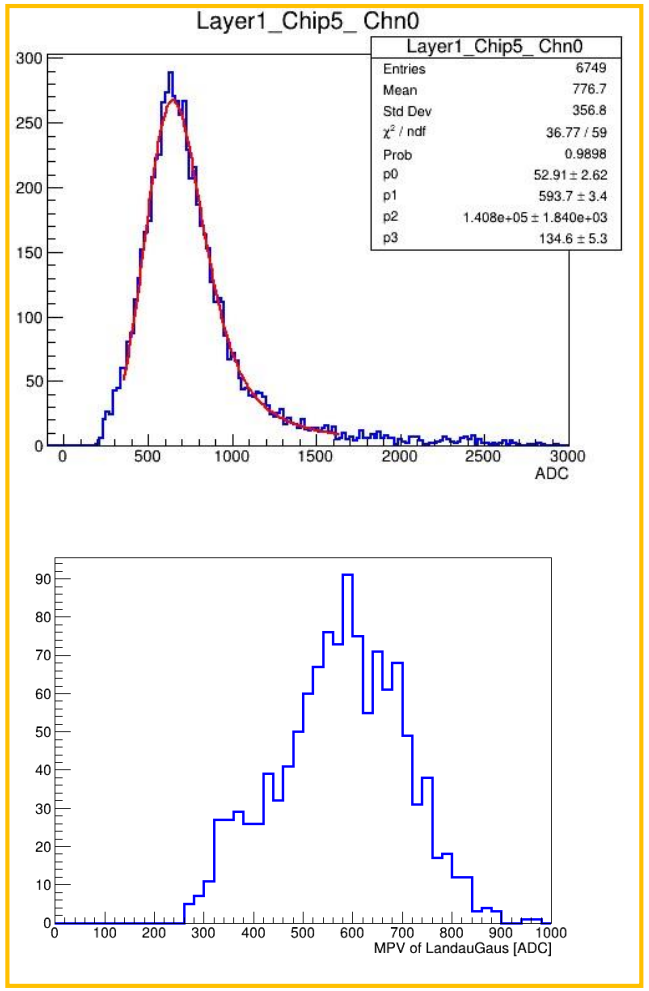
Cosmic ray test results II

- MIP response calibration
  - 92% channels collected more than 1000 cosmic-ray events
  - The MIP response with 15 um SiPM is ~ 5 times of 10 um SiPM
  - The non-uniformity of MIP response are about 20%





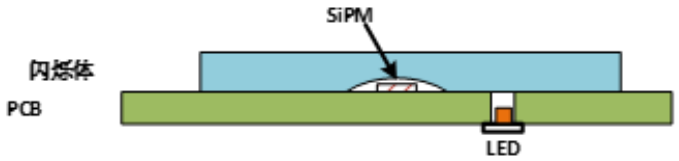
10 um SiPM

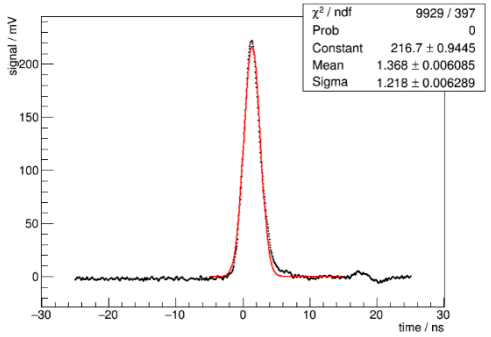


15 um SiPM

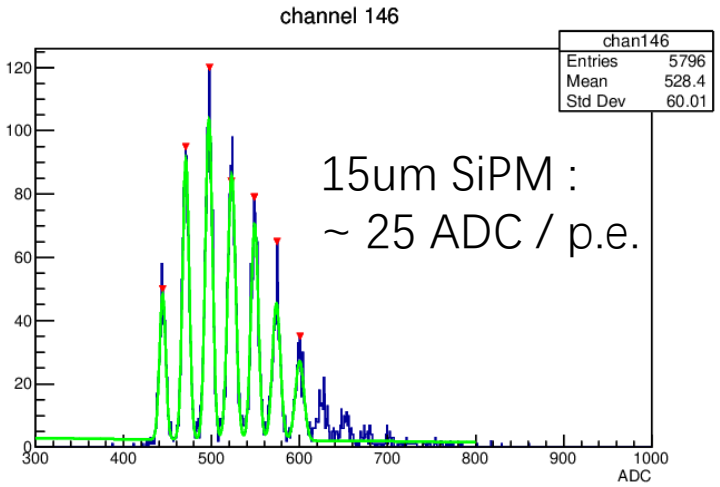
SiPM gain calibration

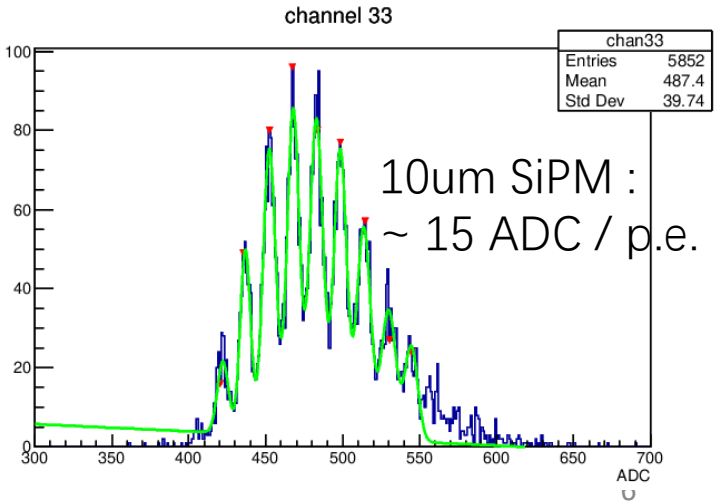
- LED-based calibration system for each channel
  - Very narrow blue light pulse : < 3 ns



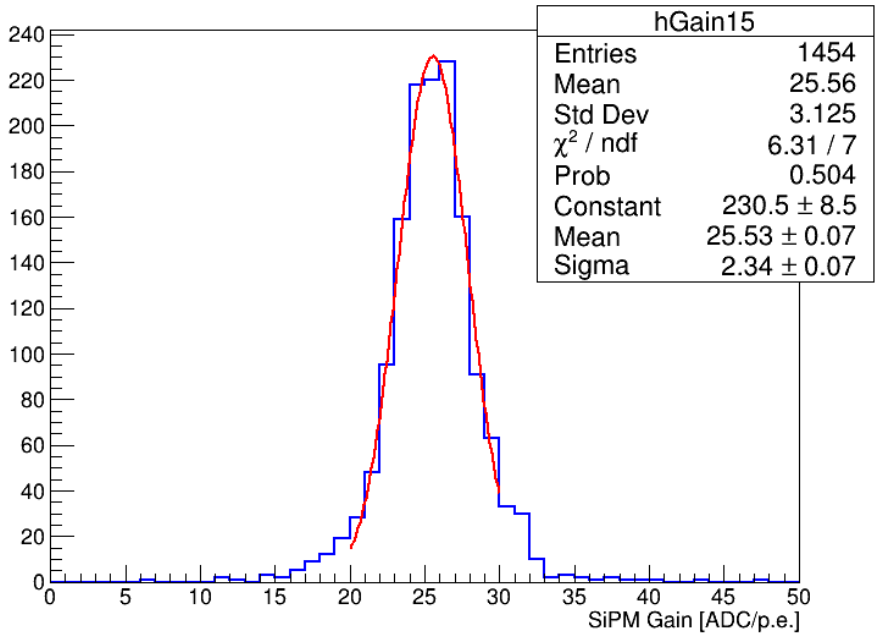


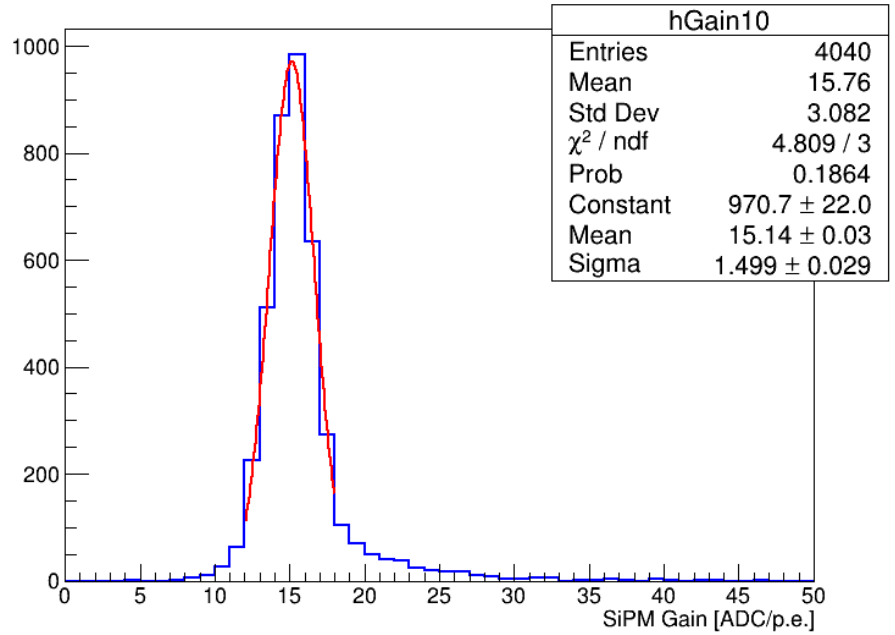
- Single-photon spectrum
- ROOT TSpectrum class find multi-peaks
- Multi Gaussian function fit the single photon spectrum
- The distance among two peaks is the gain of SiPM





SiPM gain calibration

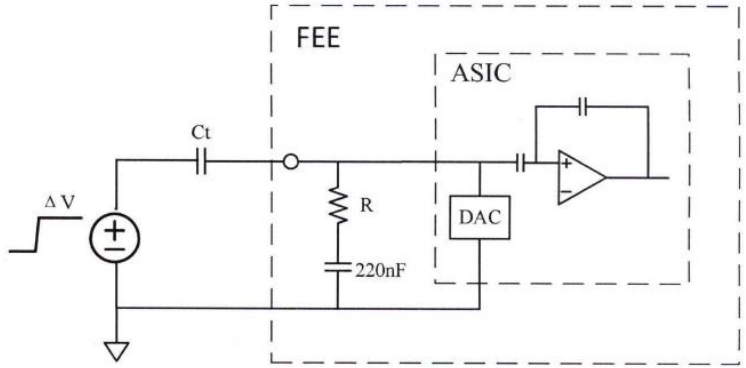




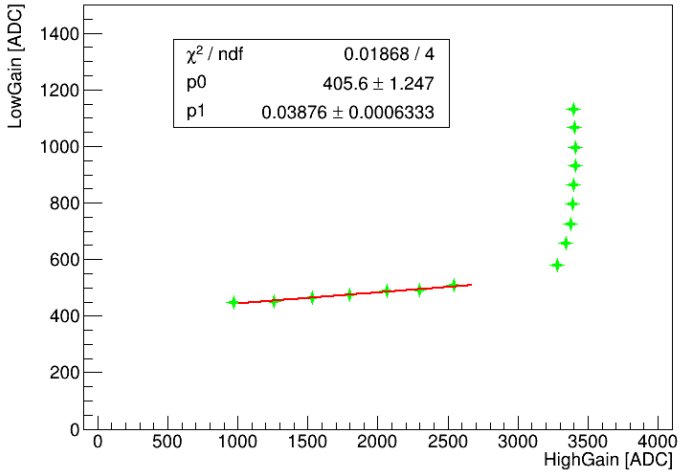
- More than 95% channels distinct photon spectrum successfully
- SiPM gain variation are ~10% for both 15 um & 10 um pixel size
- The gain of 15 um SiPM is ~1.7 the gain of 10 um SiPM

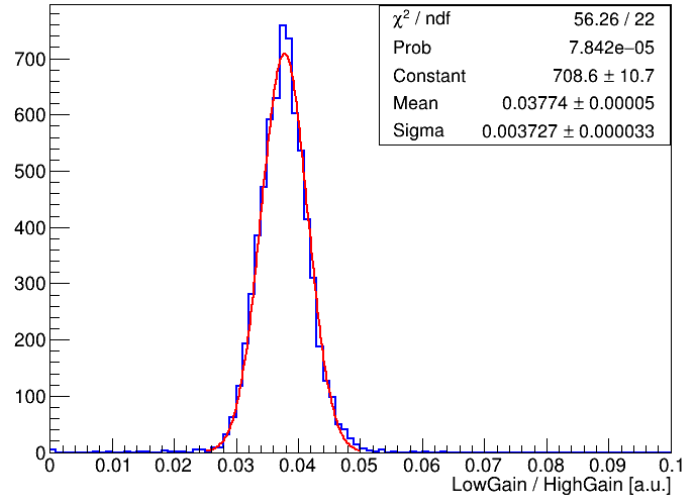
ASIC Inter-calibration

- Charge injection calibration system
  - DAC Range : 0 – 5 V
  - Signal waveform : $\tau \sim 3.5\ ns$



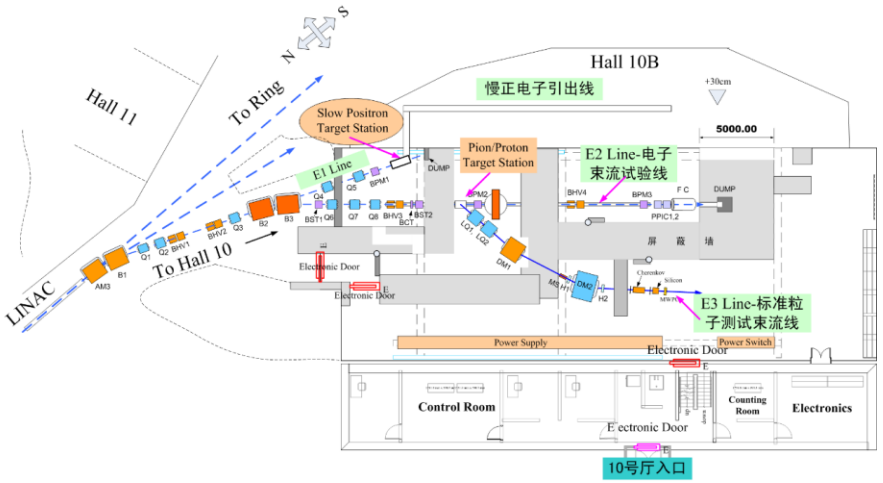
- Linear fitting the overlap range between high gain and low gain
- Low / High gain ~ 0.038 with 10% variation





New beam test at IHEP option I

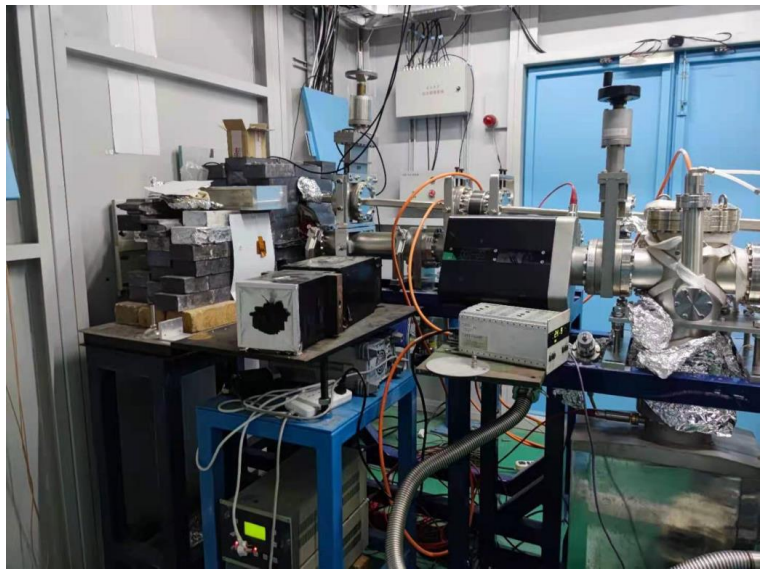
- Tested the ScECAL prototype at E3 line during Oct. – Nov. 2020
  - Suffered from low event rates and poor-quality beam (possible reasons figured out)
- E3-line of the TBF at Hall-10
  - Maintenance work expected during the summer shutdown, Jul.–Aug. 2021
    - Upstream line : dipole magnet, power supply, vacuum box
  - Expected event rates : a few Hz level, much higher than what we had in 2020
  - Secondary particles
    - Protons (dominate), pion, the same as in 2020
    - Target for electrons: still to be confirmed

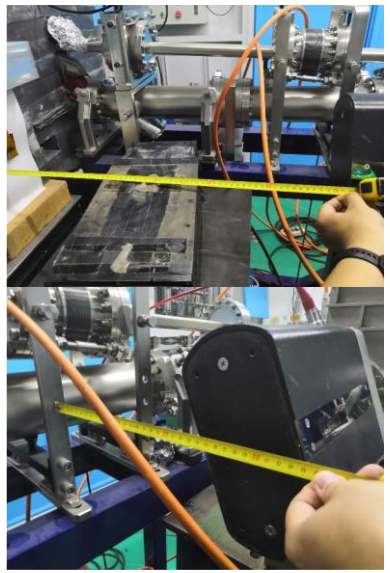


The Configuration of Beijing-BTF Upgrade at Hall 10

New beam test at IHEP option II

- Beijing Synchrotron Radiation Facility (BSRF) stations
  - 1 – 2.5 GeV & ~50 Hz/cm^2 electrons (1B3 station) much better for ECAL calibration
  - Verified the particle energy and even rate with BGO calorimeter
  - Mechanical stage, power cabling, space for the ScECAL prototype
  - Preparations ongoing by Yong
    - http://cicpi.ustc.edu.cn/indico/getFile.py/access?contribId=1&resId=0&materialId=slides&confId=3911





1B3A station

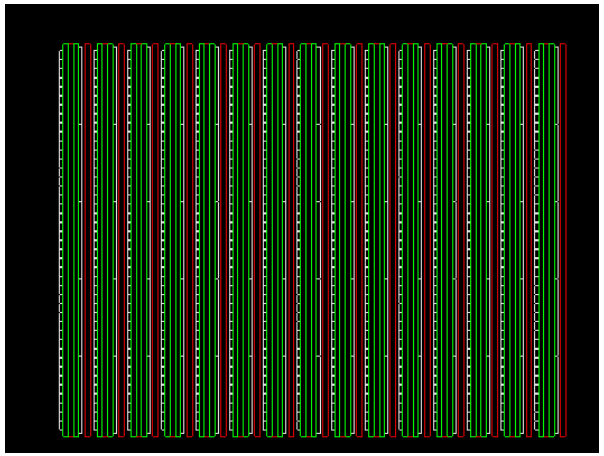
Summary and plan

- Some key performances have been evaluated
  - All EBU layers detection efficiency : > 90%
  - Position resolution achieve the requirement : < 2mm
  - Cell-to-cell MIP response calibration : ~ 20% non-uniformity
- Essential calibration
  - SiPM gain calibration : ~ 10% variation
  - ASIC internal factor calibration : ~ 10% variation
  - Time resolution calibration is ongoing
- Preparation the beam test at IHEP is ongoing

Thank you!

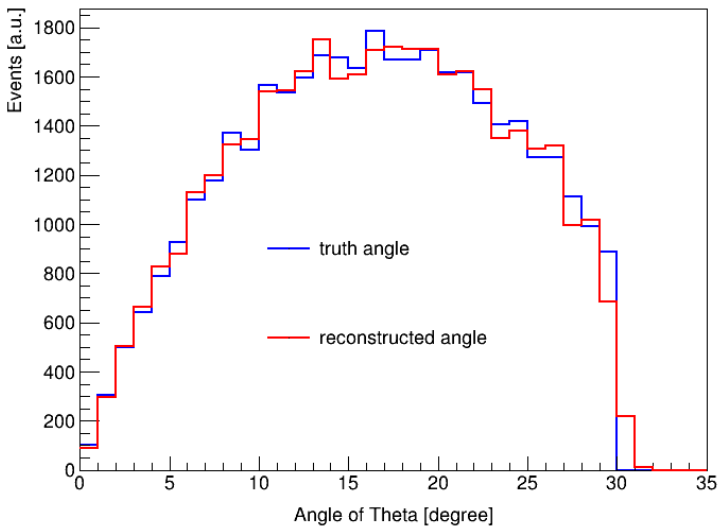
Additional

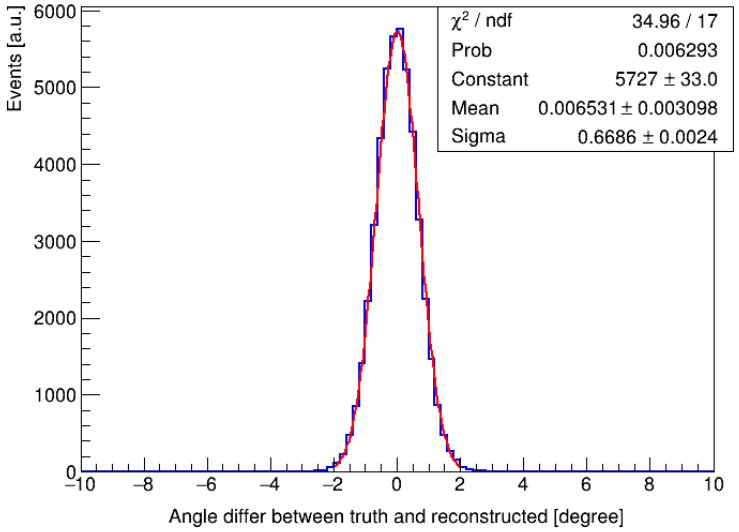
Geant4 simulation



- A standalone package based on GEANT4 developed
- The track finding and fitting algorithm works fine
- The intrinsic angle resolution is about 0.7 degree
- Cosmic ray generator would be performed

- CEPC Sc-ECAL prototype
  - 30 layers
  - Absorber: WCu (85:15) 3.2 mm
- Version: Geant4-10.2.1
- Physics List: QGSP_BERT
- Cut: > 0.5 MIP





mu-@ 4GeV, plane, iso 0-30 degree

First beam test at IHEP E3

- IHEP E3 beam line: secondary particle beam
  - Mixed with proton/pion: proton dominate
  - Momentum : 300MeV-1.2GeV
  - Event rate: less than 100 per minute
- Task : learn to do beam test
  - Combined test with other detector
  - Event build through triggerID
  - “rehearsal” for future more beam test
- Data collection
  - 500 MeV, 800 MeV, 1 GeV momentum measured
  - Total 12 thousands events collected
  - Limited by the poor beam quality and low event rates

proton@1GeV candidate