CEPC PFA-Calorimetry Workshop at USTC

A Brief Summary

Yong Liu (IHEP)

Aug. 14, 2019

CEPC Physics and Detector Plenary Meeting

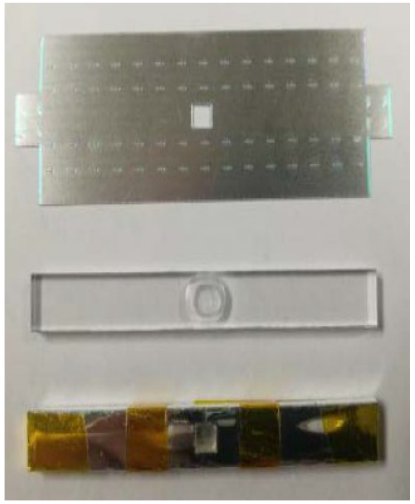
General introduction

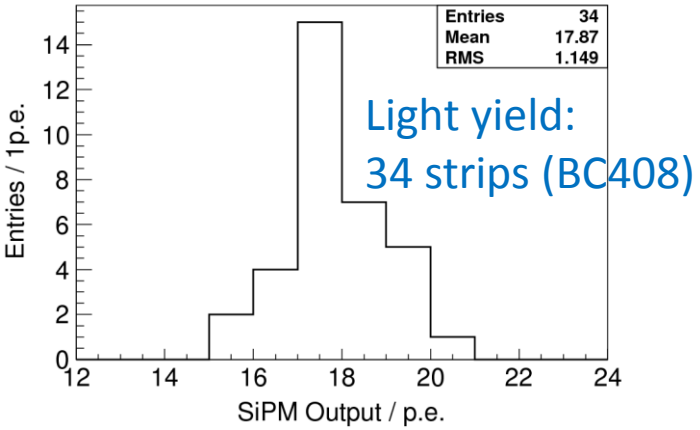
- CEPC PFA-Calorimetry Workshop at USTC
  - Two full days: Aug. 8-9, 2019
  - http://cicpi.ustc.edu.cn/indico/conferenceOtherViews.py?confId=2131&view=standard
- Covered a broad range of topics: R&D and new ideas
  - Scintillator-Tungsten ECAL
    - R&D focus: towards a 30-layer prototype
    - Mechanics and cooling
  - Scintillator-Steel HCAL
    - Design optimization in PFA: cell size, #layers
    - Mass production and assembly, QA chain, cooling
  - Common efforts
    - Scintillator: optimisation, performance and QA
    - SiPM characterization
    - Electronics: readout board with SPIROC2E chips
  - New ideas: 3D integration of sensors and ASICs

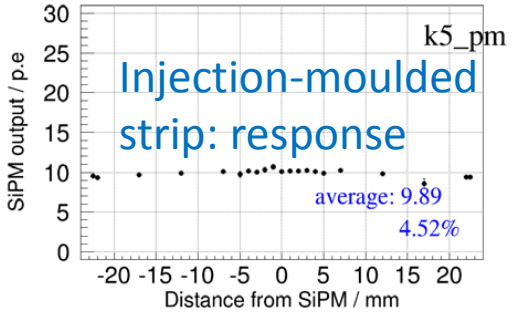
ECAL: scintillator optimisation

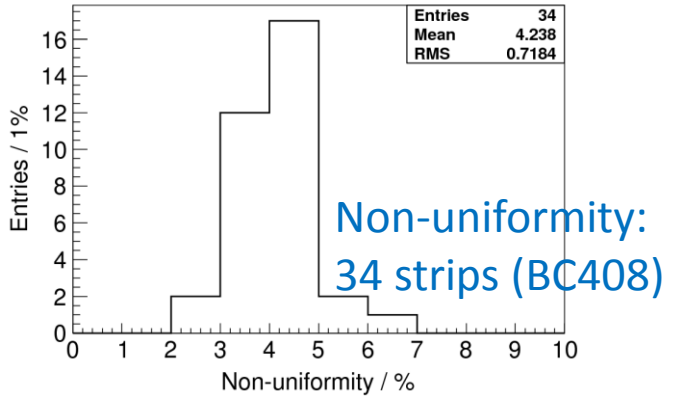
Mingyi Dong (IHEP)

- Scintillator-SiPM coupling
  - Chosen an optimal design from various shapes tried out
  - Strips from Saint-Gobain BC408 sheets
    - Cutting, milling and polishing
  - Light yield: 17~19 p.e./MIP
  - Non-uniformity: 4~5%
- New: injection moulding
  - Pros
    - Better surface properties and cost effective
    - Better quality uniformity in different batches
  - Cons
    - PS-based: 50% less light yield than BC408





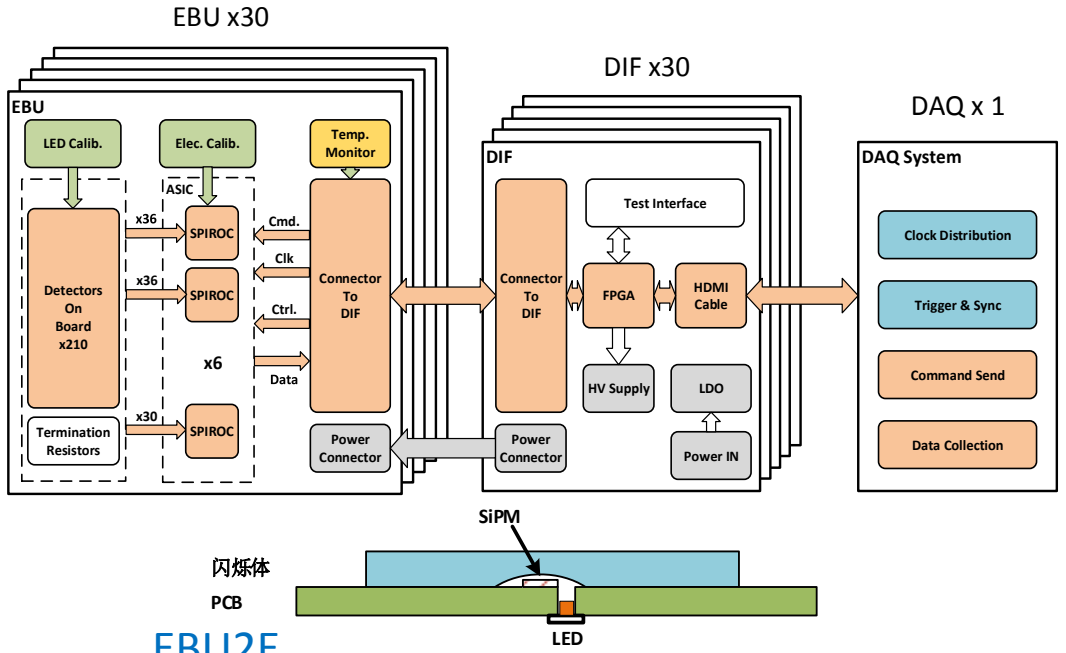




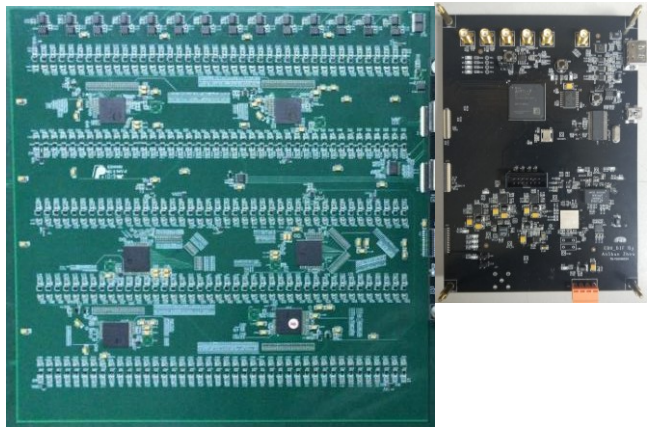
ECAL: electronics and readout boards

Shensen Zhao (USTC)

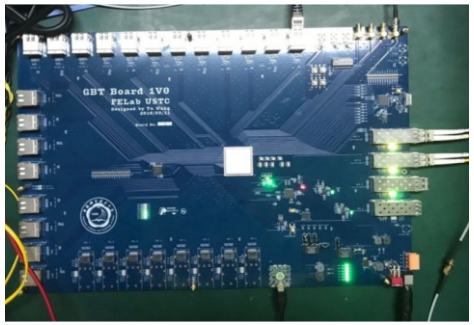
- FE ASIC chosen: Omega SPIROC2E
- LED calibration system: integrated
  - 210 channels per board to monitor SiPMs
- Temperature monitor/compensation system
  - 16 sensors per board: fully tested
  - Feedback to SiPM bias voltage: not tested
- ECAL readout board (EBU)
  - 14-layer PCB: 1.2mm thick, height<1.8mm
  - Final design finished: EBU2E (210 chs)
    - Tested board performance: pedestal, uniformity
- DAQ: under development
  - Based on the GBT FELIX board (ATLAS)



EBU2E



GBT FELIX board

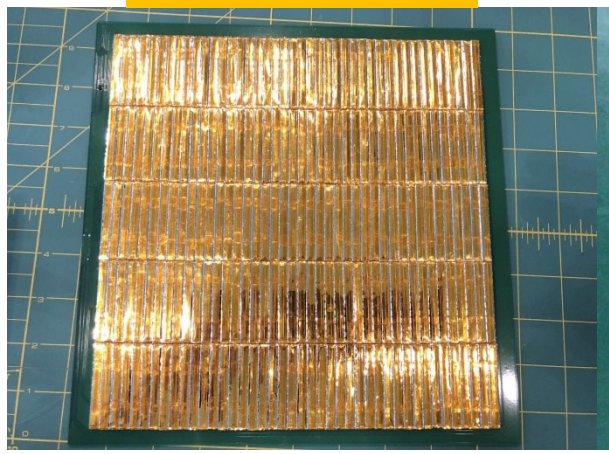


ECAL: characterization of readout board

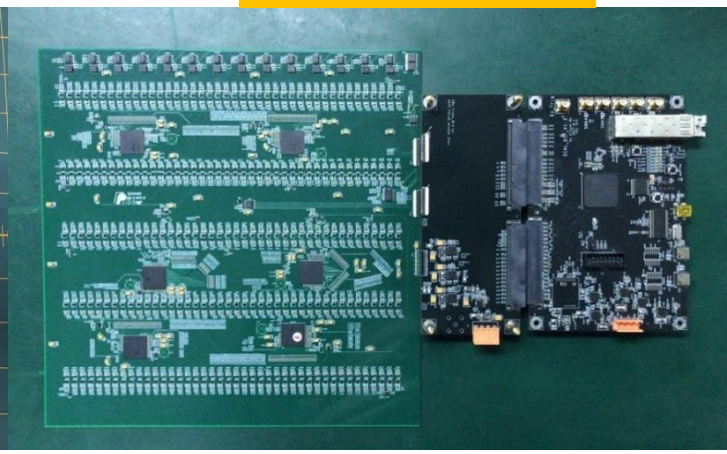
Yazhou Niu (USTC)

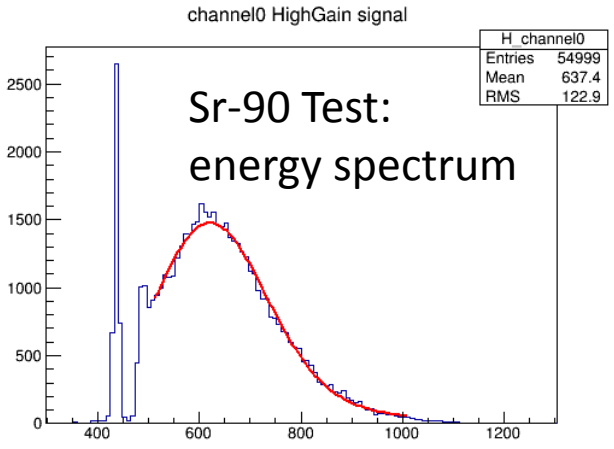
- ECAL readout module (EBU2E)
- Response per channel
  - Cosmic muons
  - Beta electrons from Sr-90 source
- LED calibration system
  - SiPM gain, ASIC gain (inter-calibration)
- Temperature monitor system

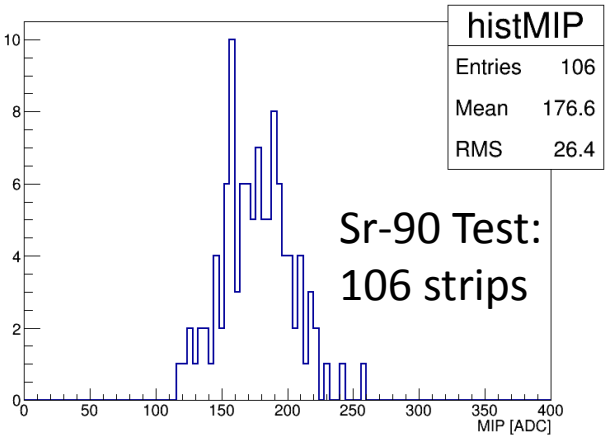
Scintillator side

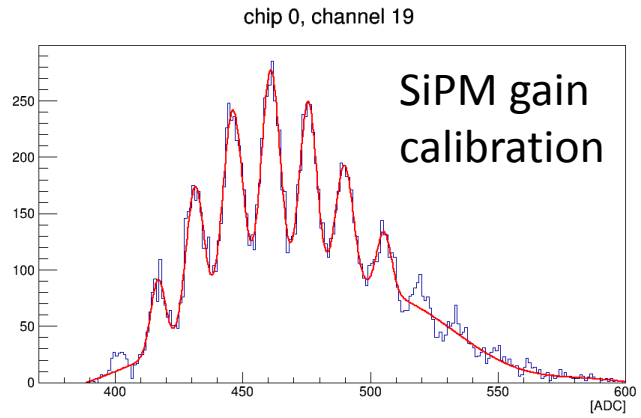


Electronics side

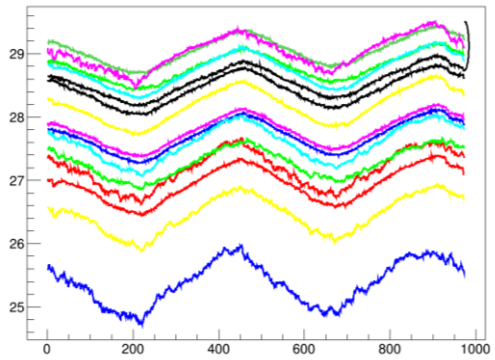








Temperature monitor

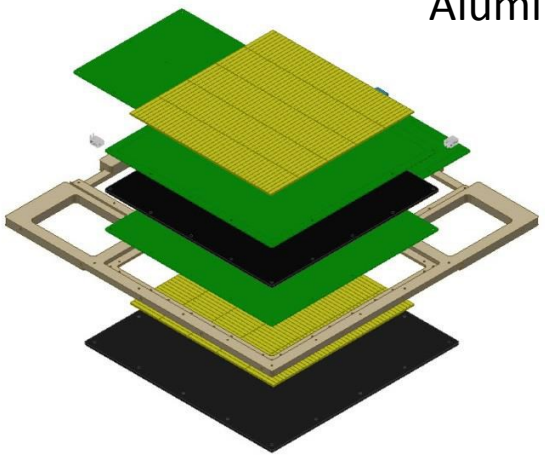


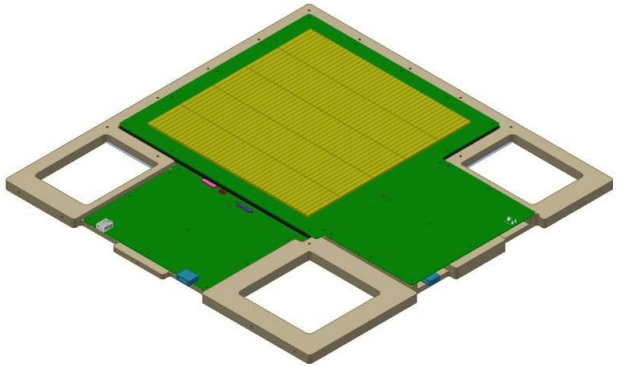
ECAL: 30-layer prototype

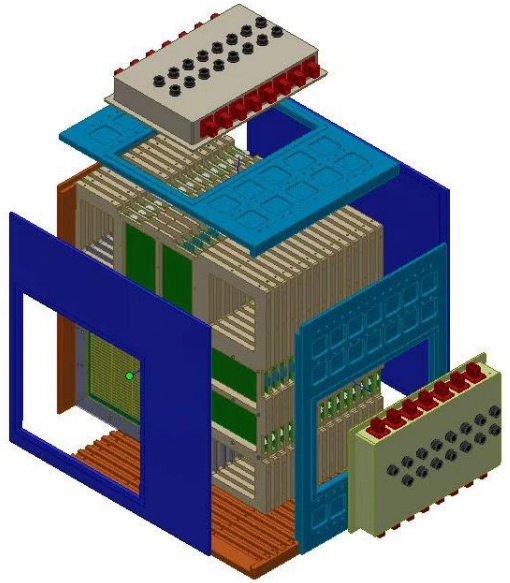
Zhigang Wang (IHEP)

- Status
  - Procurement finished
    - SG scintillator sheets, HPK SiPMs
  - Alternative option “injection moulding”
    - LY not sufficient
  - Mechanics under development
- Mechanics design
  - Aluminum frame
    - 2 readout modules + DIF boards
    - 1 tungsten plate
  - 1st version frame produced
    - Dummy boards installed
  - Design for the 30-layer prototype

Aluminum frame



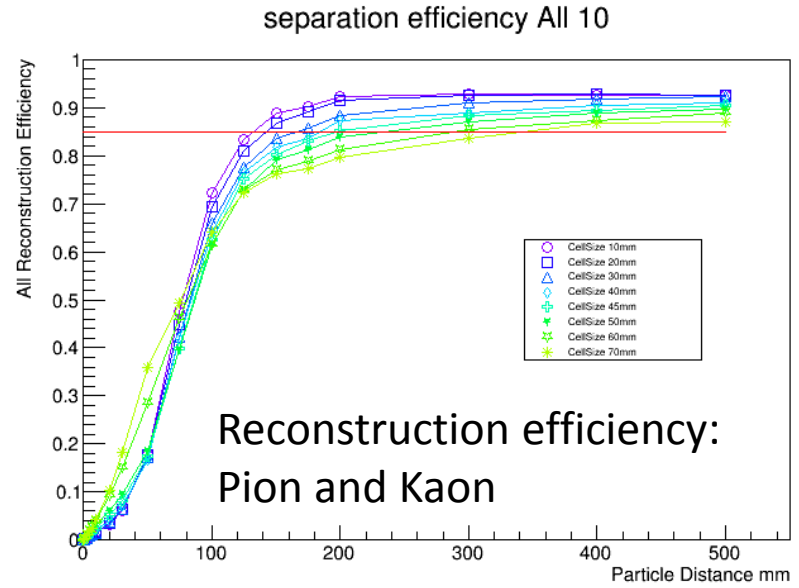


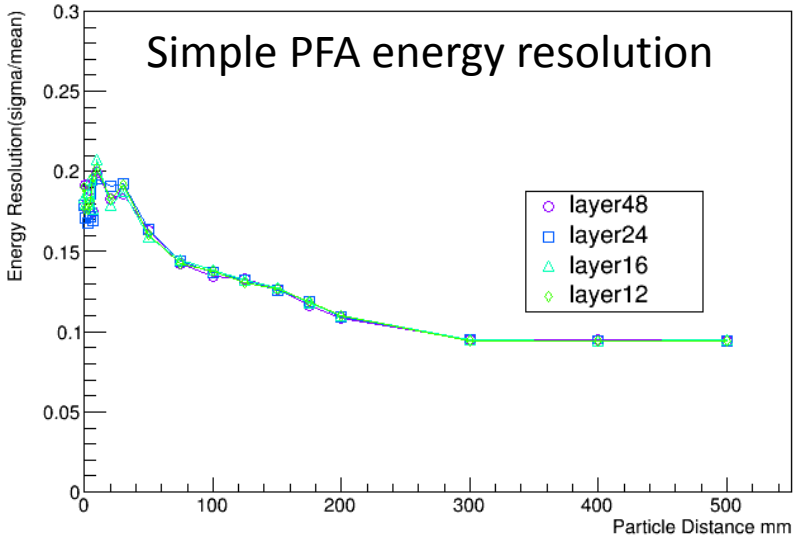


HCAL: design optimisation in PFA

Yukun Shi (USTC)

- Optimisation in PFA
  - How fine is the granularity to be good enough?
  - Detailed studies on hadronic showers in HCAL
    - Initiated by pions, kaons and neutrons
  - Key parameters
    - Transverse granularity: cell size
    - Longitudinal sampling frequency: #layers
- Conclusions
  - Cell size: 30 mm is a safe option
  - #layers
    - Performance stays unchanged till 12 layers
    - Combined readout of every 2 layers: will not affect PFA performance

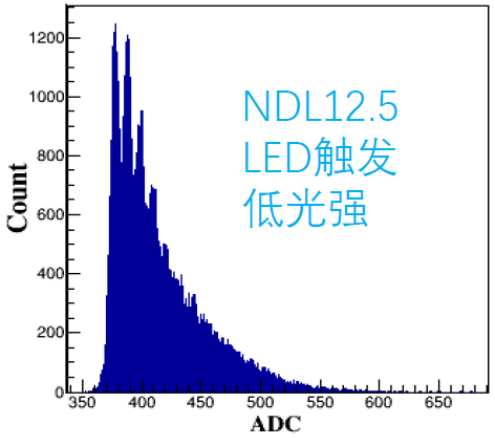


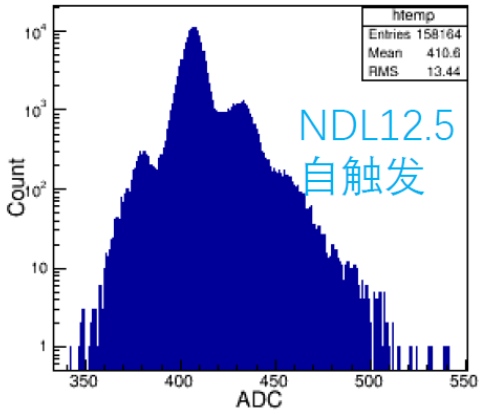


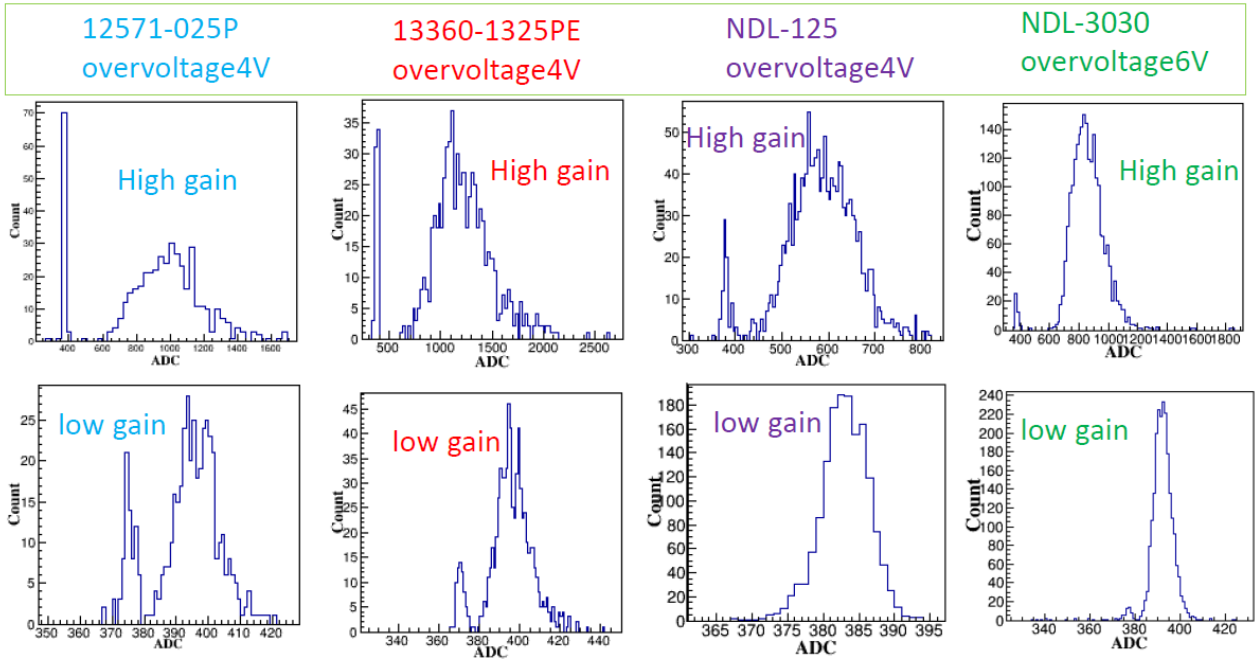
HCAL: detector unit

Jiechen Jiang (IHEP)

- SiPM characterisation
  - Hamamatsu: 25um pixel
    - Low DCR and crosstalk
  - BNU-NDL: pixel <15um
    - Larger dynamic range
    - Cost effective
- Testing with SPIROC2E and LED



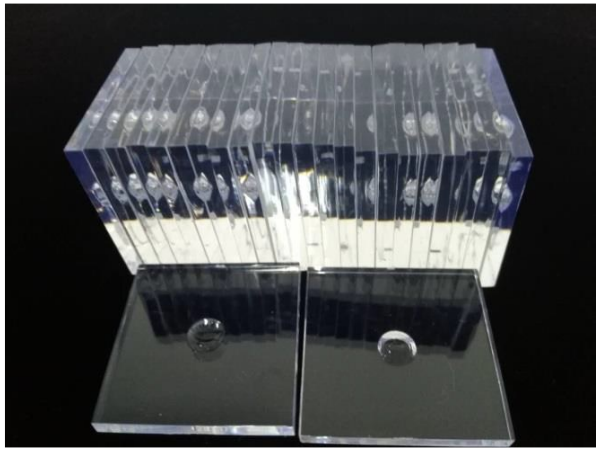


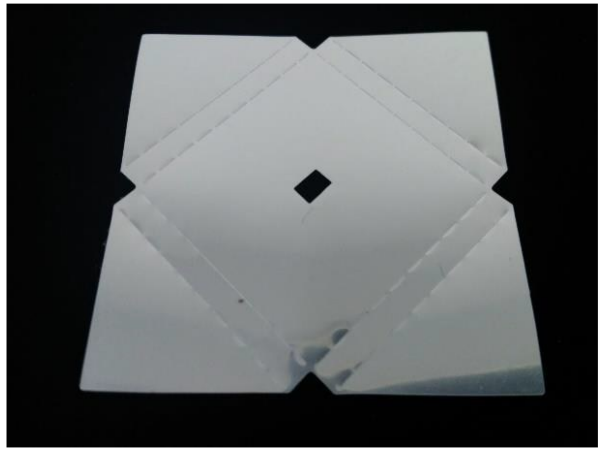


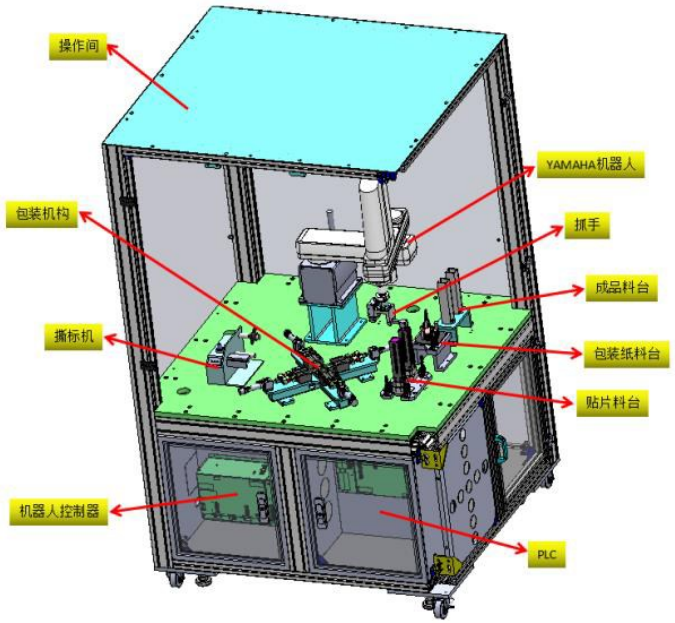
HCAL: mass production and assembly

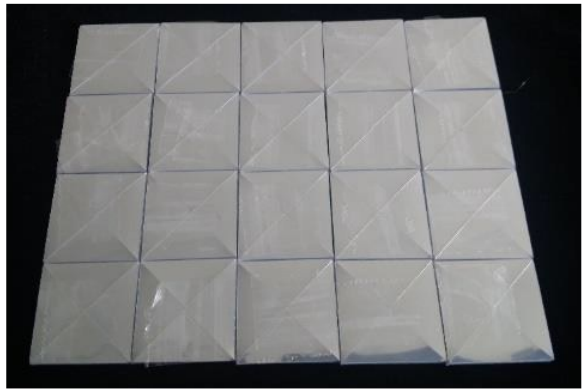
Jiechen Jiang (IHEP)

- Scintillator via injection moulding
  - 8 iterations of prototyping
  - Success
    - Dimensions, surface properties
    - Performance: light yield and uniformity
    - Cost effective
- Wrapping machine
  - Automated procedure to wrap ESR foil around tiles, via a robot arm
  - Mostly ready
- Glue dispensing on PCB
  - Fix tiles on the readout modules
  - Successful tests on small PCBs





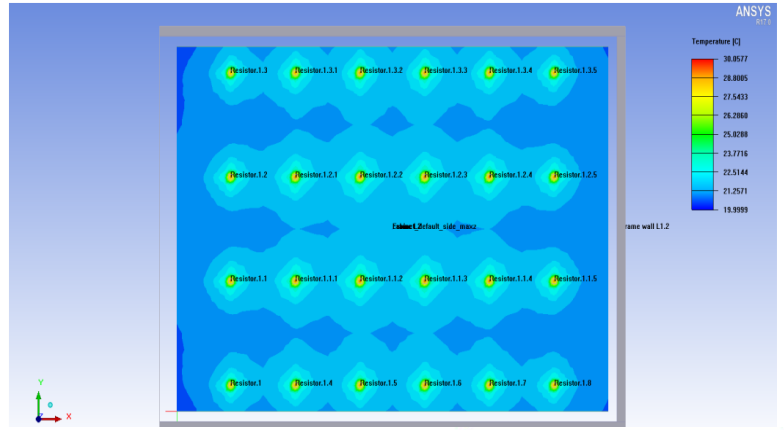


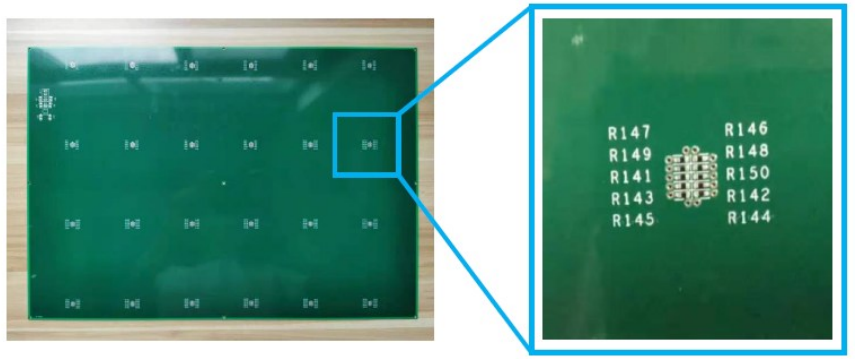


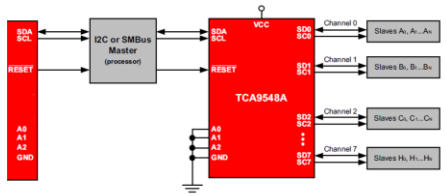
HCAL: cooling system

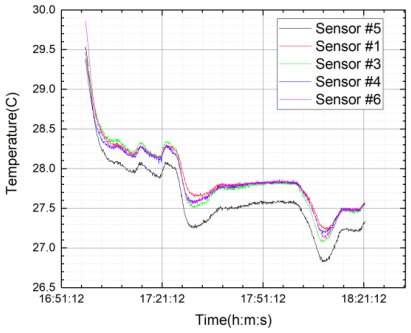
Yifan Zhu (SJTU)

- Material to be determined for cooling plates
  - Stainless steel
    - High strength, poor heat transmission, difficult to produce, few companies, high cost of prototyping
  - Aluminum or copper
    - Soft, good heat transmission, easy to produce
- Excluded 2 options
  - Air cooling: no space
  - Heat pipes: long-term maintenance
- Cooling R&D
  - Simulation established
  - Mockup PCB: with resistors to mimic heating
  - 64 temperature sensors testing simultaneously



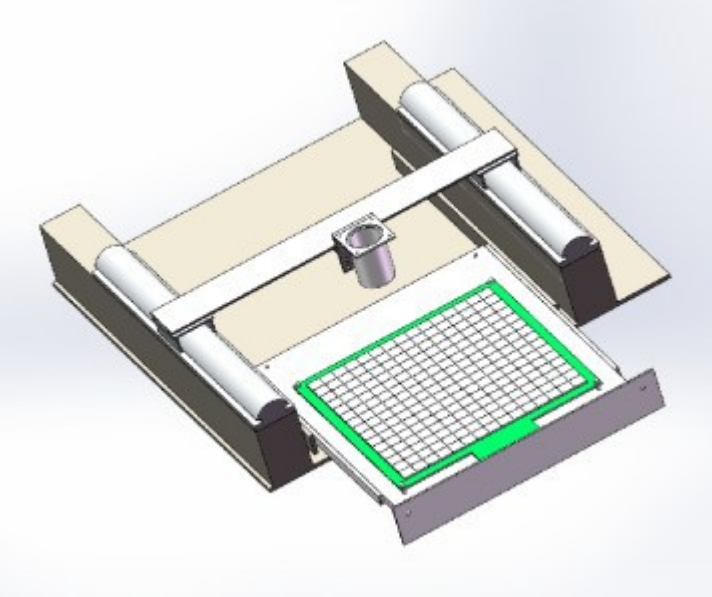






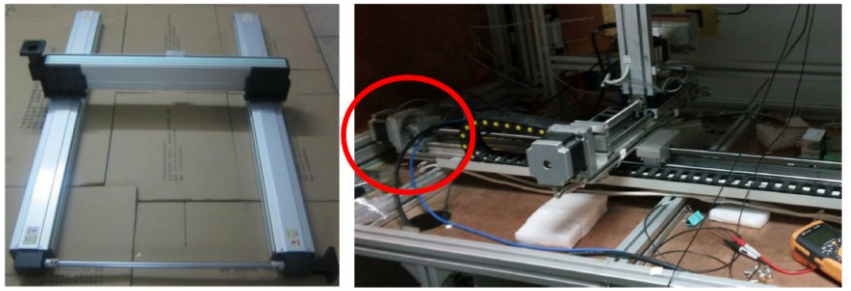
HCAL: QA system

- Scintillator Batch Testing System
  - Test many scintillator tiles in a fast and automatic way
  - Sr-90 as the source
- Design: drawer-like plate
  - 360 scintillators per batch: 1 minute per scintillator, 6 hours per batch



Dark Box: 1200 x 1185 mm x 620 mm³

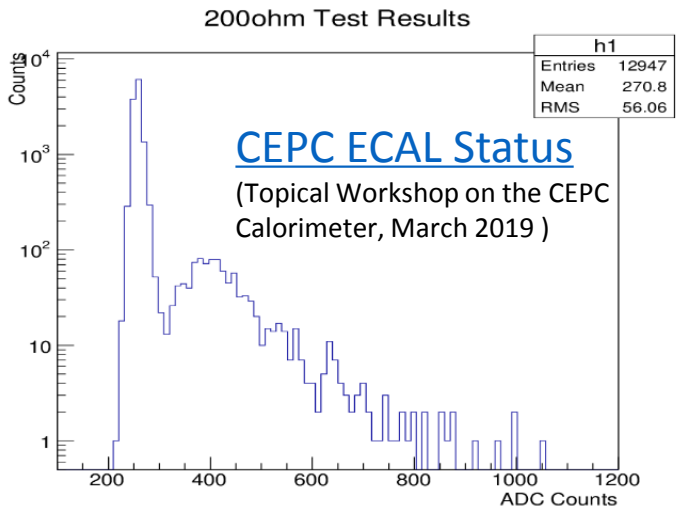
Progress of construction

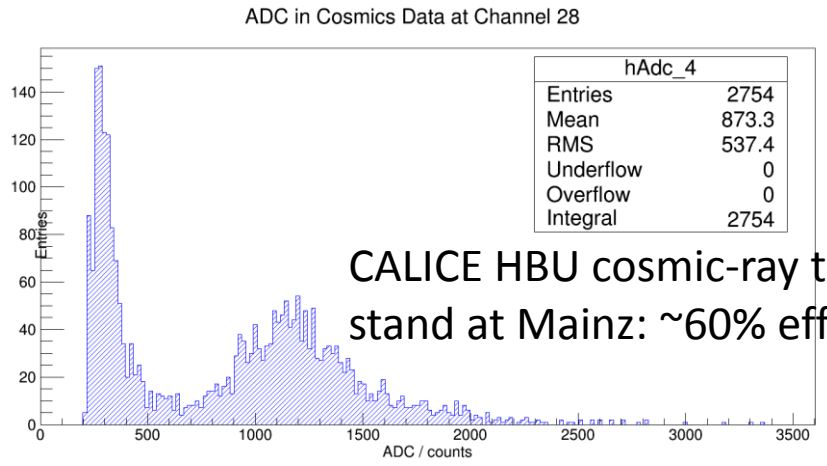


Slide rail

DAQ functionalities

- CEPC DAQ for ECAL/HCAL modules
  - Finely segmented scintillator read out by SiPMs
  - Integrated with SPIROC chips (version 2E) from Omega, originally designed for ILC
- Issues and solutions are identified
  - Low efficiency for cosmic muon collection: < ~1% → "validation" signals (HW+FW)
  - Limited #cells (in a channel) are used → flexible FW in DIF





CALICE HBU cosmic-ray test stand at Mainz: ~60% efficiency

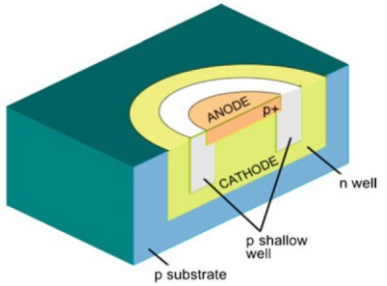
DIF board for CALICE HBUs

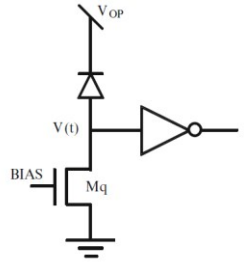
LEMO connector to receive validation signals

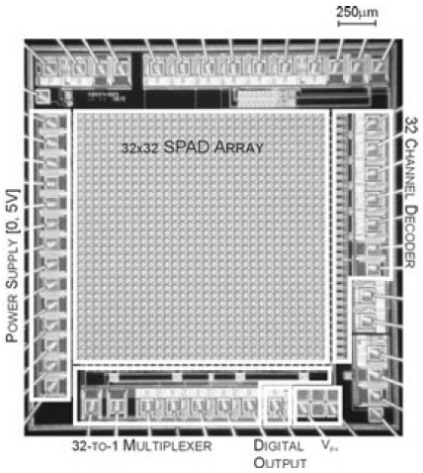
New ideas on the sensors

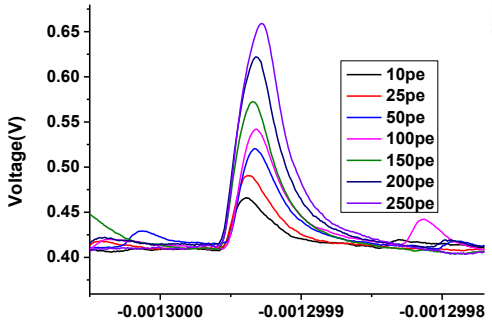
Xiaoshan Jiang, Junguang Lü (IHEP)

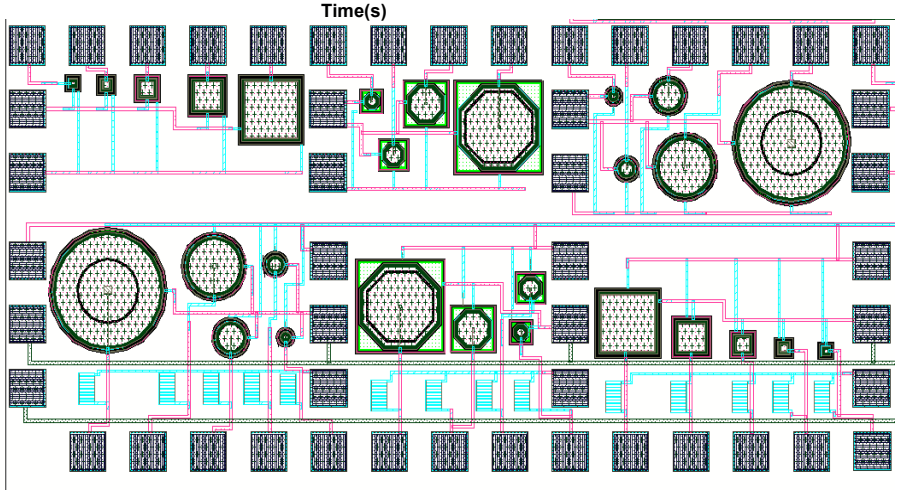
- Smart sensors for optical photons
- Past experiences with SPADs
  - Tape-out of prototypes: different shapes and sizes of SPADs
- Plans
  - Will continue SPAD R&D on high/low-R silicon wafers
  - Timing measurements
  - Back-illumination structure: higher light collection efficiency







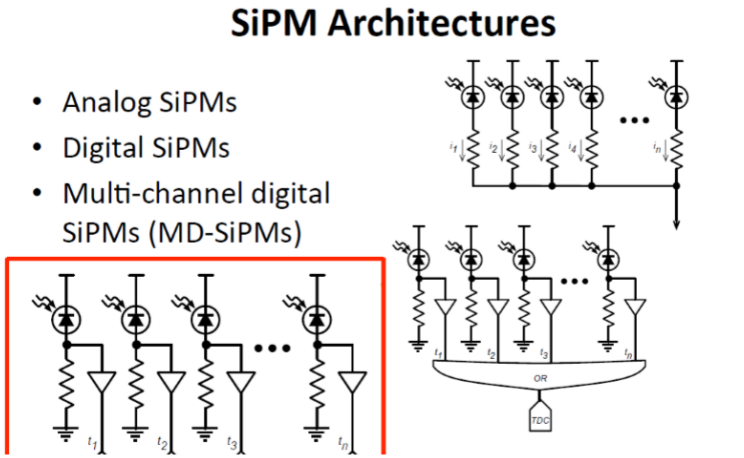




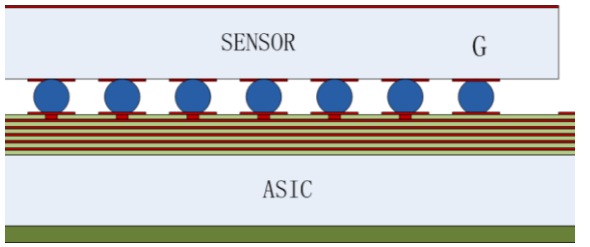
New ideas on the sensors

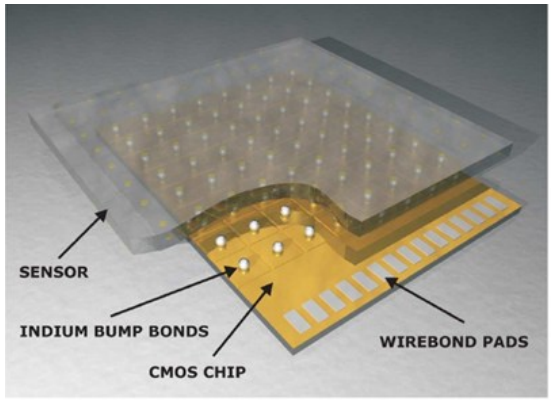
Xiaoshan Jiang, Junguang Lü (IHEP)

- Smart sensors for charged particles
  - Precision timing measurements
  - 3D integration: sensor and ASIC
- Ideas for the design and plan
  - Sensor: 10x10 SPADs (10μm pitch) as a “pixel”
  - bump bonding between each sensor pixel and each FE-electronics pixel
  - FE-electronics pixel: performance
    - <=30 ps timing resolution for MIP signals
    - <=100 μW per pixel
  - First prototype
    - CMOS 130nm or 65nm
    - Area < 5x5 mm²



针对穿透粒子进行高精度时间测量的阵列





Summary

- Ongoing R&D activities
  - Towards ECAL and HCAL prototypes
- Scintillator-tungsten ECAL
  - Component procurement finished: SiPMs, scintillator
  - Readout modules: design finalized
  - Mechanics under development for the 30-layer prototype
  - Will apply to schedule beam tests at IHEP and DESY in 2020
- Scintillator-steel HCAL
  - PFA optimisation studies
  - Steady progress on SiPM testing with FE electronics, mass production, QA, cooling
- New ideas emerging
  - Smart sensors vertically integrated with readout electronics