Electronic Progress of CEPC AHCAL Prototype

Zhongtao Shen

University of Science and Technology of China

On behalf of the CEPC calorimeter working group

CEPC MOST Project Midterm Review Meeting

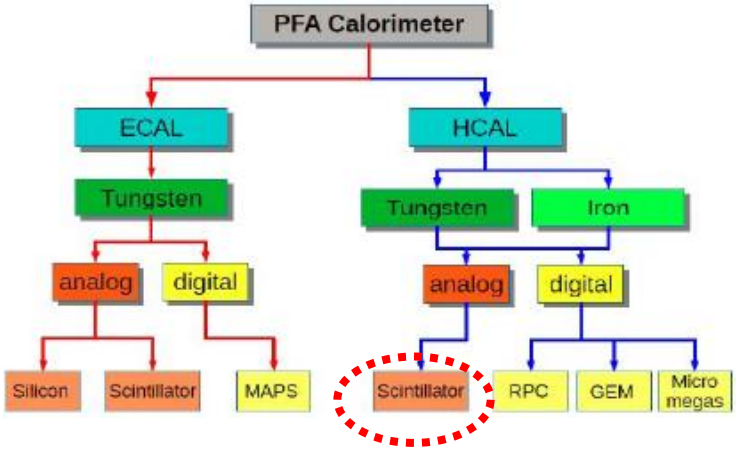
Beijing, August 2020

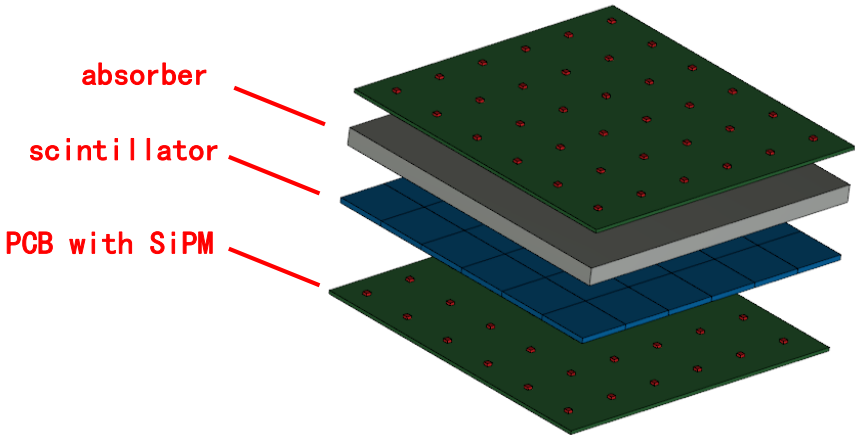
Outline

- CEPC AHCAL prototype
- ASIC selection & test
- HBU design
- DAQ system development

AHCAL prototype

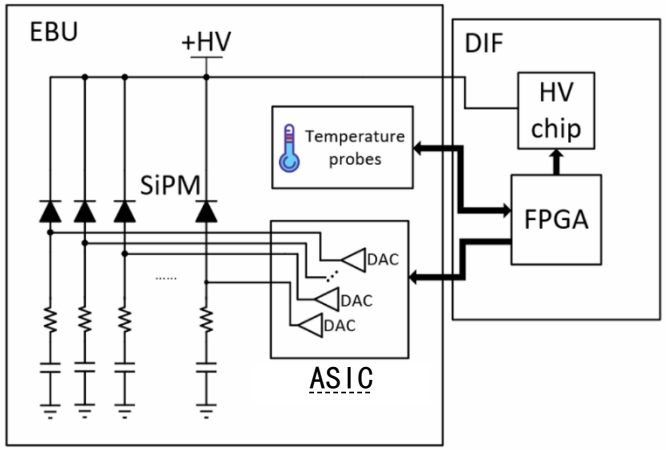
- The AHCAL prototype is task3 of MOST2, for exploring the techniques of CEPC PFA HCAL.
- The prototype is optimized to a 40-layer sampling calorimeter. And each layer consists of one-layer 2 mm Fe as absorber, one-layer scintillators as sampler and one-layer PCB with SiPMs for signal readout.
- Cross section of prototype: 72 cm x 72 cm
  Scintillator cell size: 4 cm x 4 cm
  There are 18 x 18 readout channels per layer and 12,960 channels for the prototype.





ASIC selection

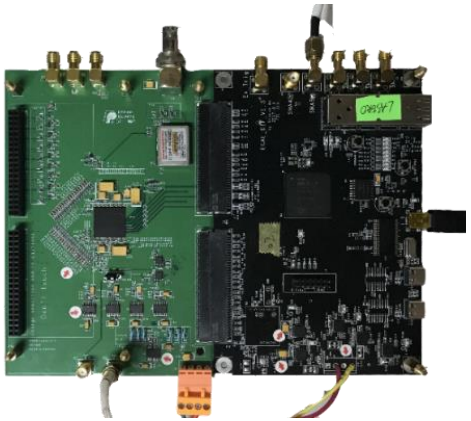
- Demands:
  - Low power and high integration
  - Dynamic range:
    30 fC ~ 150 pC (1 p.e. ~ 250 MIP)
    SiPM gain: 2 x 10^5, L.Y. = 20 p.e./MIP
  - Input voltage adjustment (Input DAC)
  - Time measurement
  - Digital output



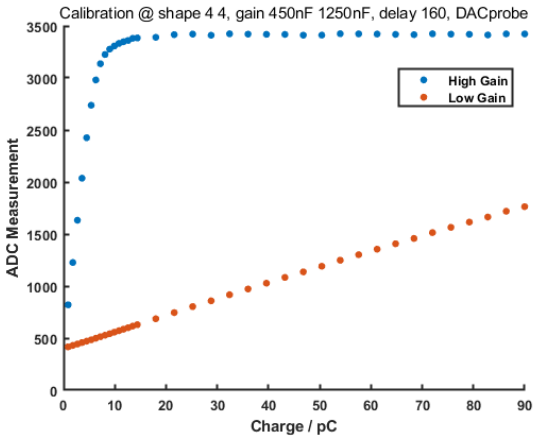
ASIC	Channel	Input DAC	Dynamic Range	Time Measure (bin/ps)	Output	Power（mW/ch）
SPIROC √	36	Y	30 fC~300 pC	100	Digital	6.5
PETIROC	32	Y	160 fC~400 pC	37	Digital	6
CITIROC	32	Y	Up to 400 pC	--	Analog	--
VATA64-HDR16	64	Y	5 fC~12 pC	--	Analog	--
KlauS √	36	Y	13 fC~450 pC	200	Digital	3.6

Spiroc-2E test board

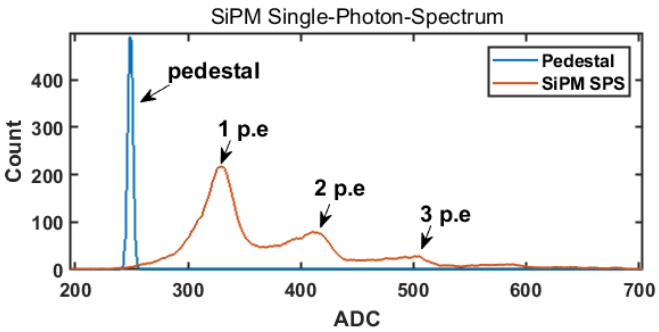
- A chip developed by Omega group for SiPM signal readout, especially for PFA calorimeter.
- Developed a one-chip test board based on Spiroc-2E.
- The function of the chip was learned and the performance was tested.
- Tested with different SiPMs.



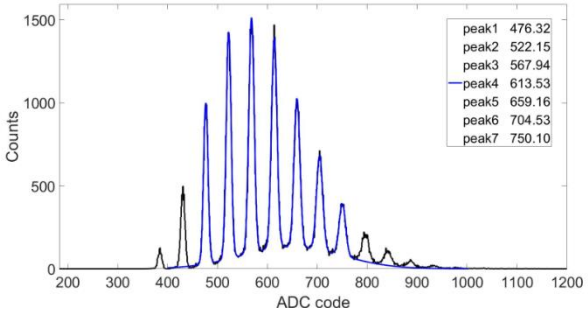
Board with one chip



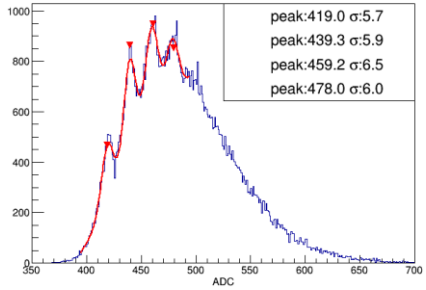
High gain & Low gain response



S.P. spectrum of S12572-025P



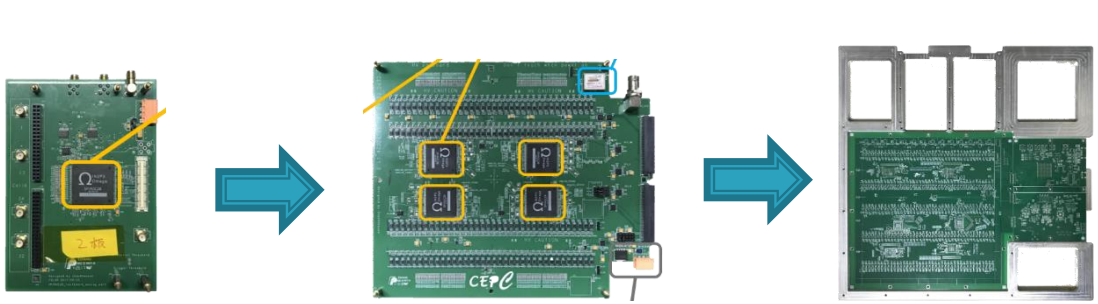
S.P. spectrum of S13360-1325PE



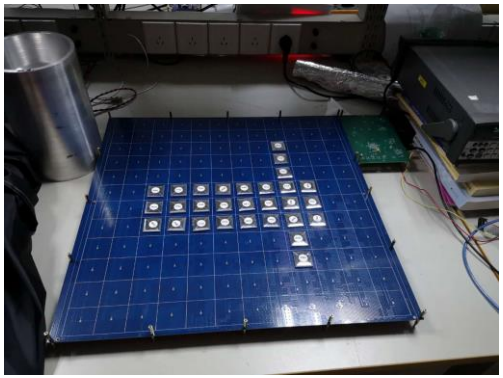
S.P. spectrum of NDL 22-1313-15S

Spiroc-2E-based design

- Based on Spiroc-2E, several readout systems have been successfully developed, including the ECAL prototype readout system and the batch test platform (details in Yanyun's report "Batch Test Platform of CEPC AHCAL").
- Spiroc-2E proves to be a good solution for AHCAL prototype and we have many experiences in using it. So it's the baseline for AHCAL prototype readout system.
- The old packaging company cooperating with Omega group went bankrupt, and now we have problems buying the packaged chips. Maybe we must buy the bare chips and package them by ourselves in China.



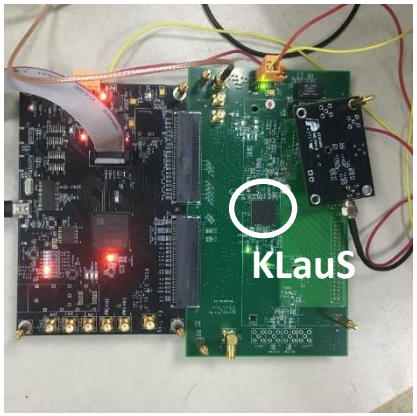
ECAL prototype readout system development



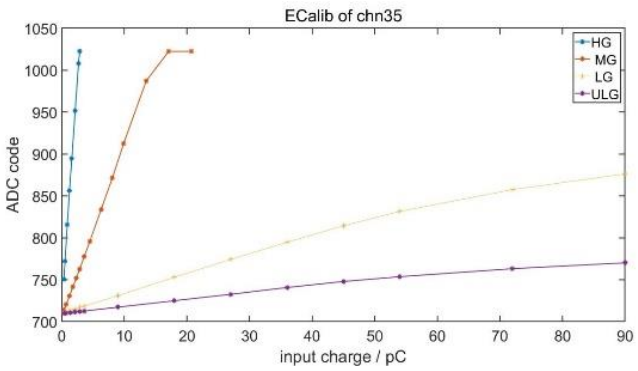
Batch test platform

KLauS-5 test board

- KLauS is an option for AHCAL thanks to its better noise performance and shorter dead time.
- Developed a one-chip test board based on Spiroc-2E. The function of the chip was learned and the performance was tested.
- Because the chip correction is complicated, we can't use it to read SiPM signals now. (The chip developer is plan to come to China to help us solve the problem recently.)
- Despite its advantages, the KLauS chip is not the mature one, so its only an option for AHCAL. Also expensive than Spiroc-2E.
- A new version, KLauS-6 is plan to be published in the beginning of 2021, and maybe we can attempt to use it to read a small part of the prototype channels.



Board with one chip



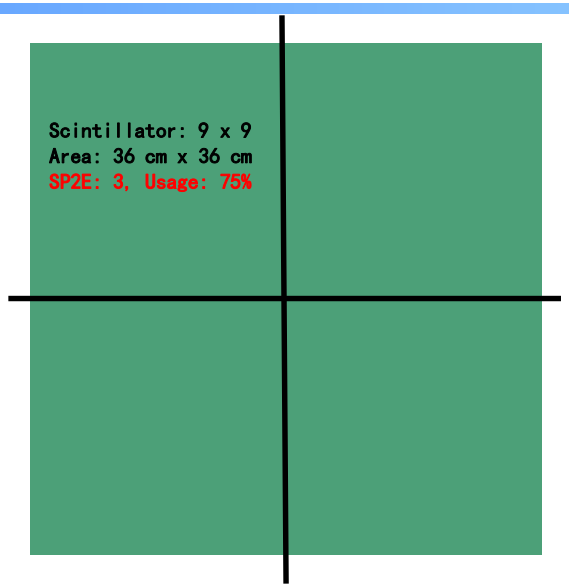
High gain & Low gain response

HBU design

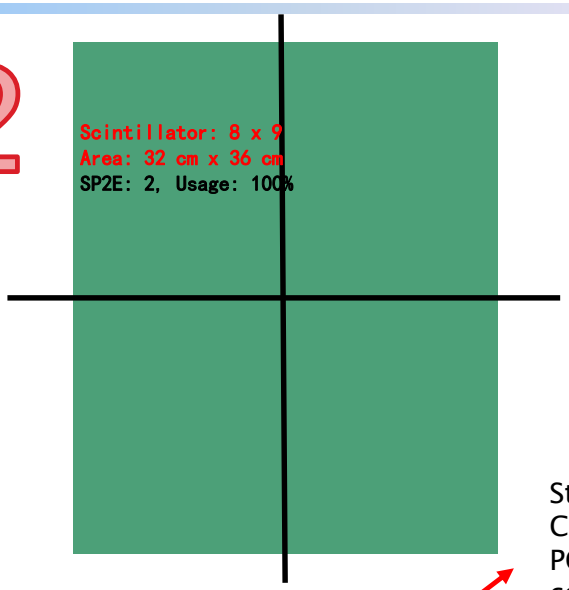
- HBU
  - Active area: 72 cm x 72 cm
  - Scintillator size: 4 cm x 4 cm
  - 18 x 18 readout channel per layer
- The active area is too large, must be divided into several PCBs
- Consideration
  - Cover the active area.
  - The PCB must be small enough, for production and soldering.
  - The usage percentage of SP2E channel (36 channel/chip) should as high as possible.
  - The type of PCB board should be as small as possible.

HBU design

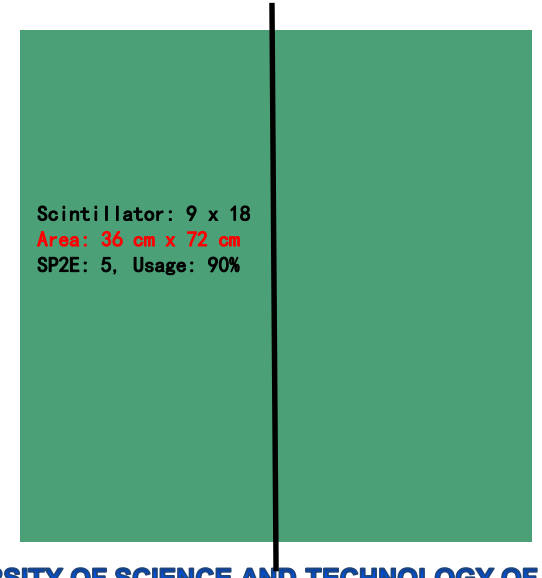
1



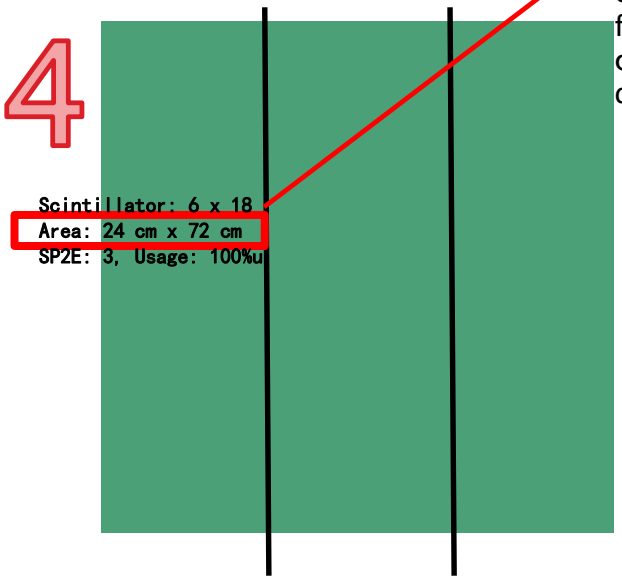
2



3



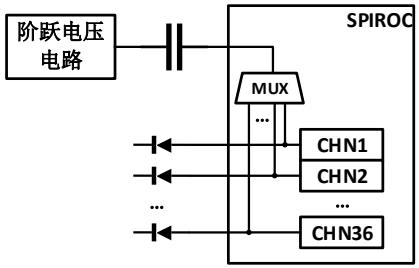
4



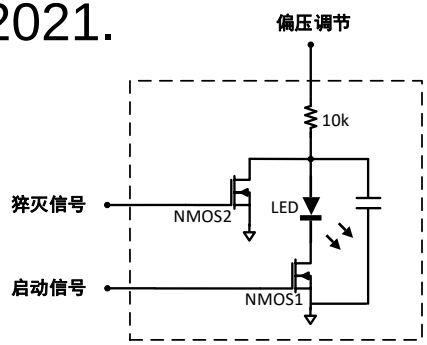
Still very large. Consulted many PCB production company and finally found one company called Xinnuojin can deal with this size.

HBU design

- Design one type of PCB, with connect both on the left side and right side for cascading.
- 3 SP2E is mounted on one PCB and each chip is responsible for the area of 6 x 6 scintillators.
- Besides the function of signal readout, electronics calibration, light calibration and temperature monitor is also implemented on HBU.
- HBU board schematic is finished and the PCB layout is in progress.
- We have the experience of ECAL prototype, and the HBU development is plan to be finished at the end of this year. Considering SP2E purchase, mass production will begins in 2021.



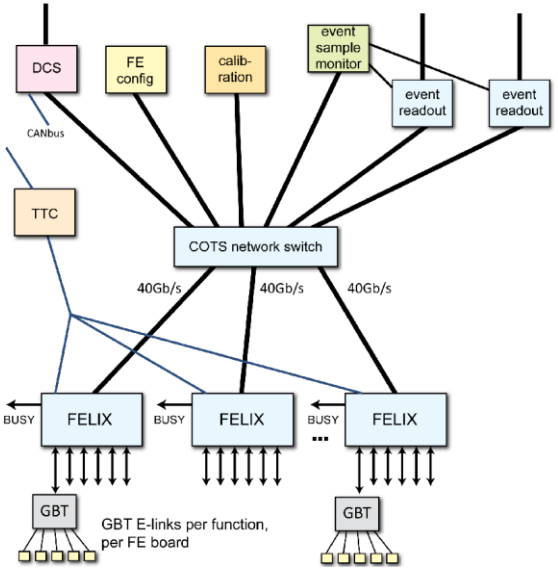
Electronic calibration circuit



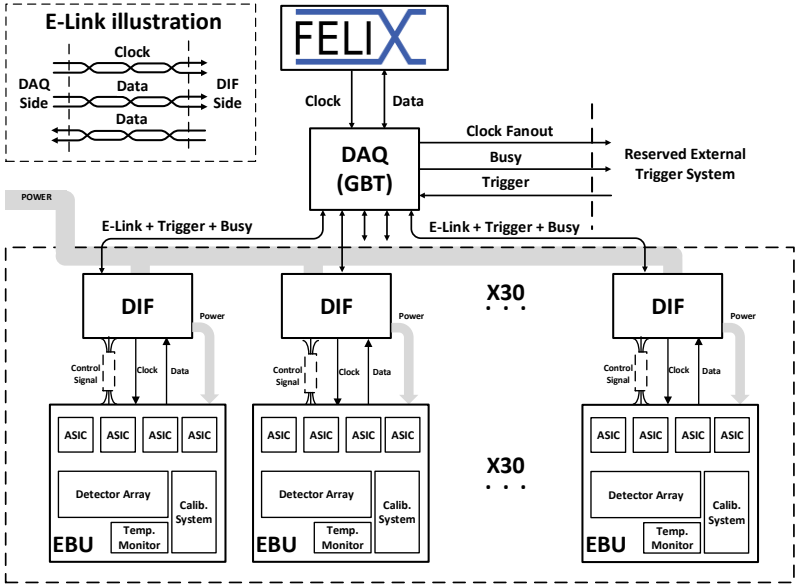
Light calibration circuit

DAQ system development

- FELIX（FrontEnd LInk eXchange）is the DAQ system used in the ATLAS upgrade. And EUDAQ is a DAQ system developed by CALICE group for PFA calorimeter.
- Reference these two system, we developed a DAQ system friendly to the PFA calorimeters and successfully used in the ECAL prototype.



Structure of the FELIX system

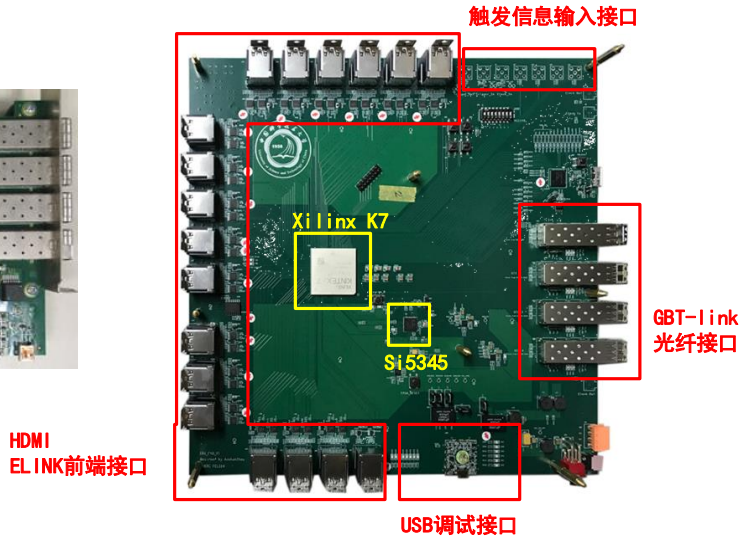


ECAL DAQ system

DAQ system development

- The system consists of a FELIX card, the DAQ board, the DIF (Data Interface) boards and the end units (EBU or HBU).
- The DAQ board, the DIF board, firmware and software are developed and successfully used in ECAL prototype.

FELIX Card (VC709)



DAQ board

DIF board

Summary

- ASIC selection
  - Finished.
  - Spiroc-2E as baseline and KLauS-6 as option.
- Readout electronics design
  - Not completely finished.
  - Spiroc-2E-based HBU is in design. HBU board schematic is finished and the PCB layout is in progress. After optimizing the design, HBU mass production is plan to begin in 2021.
  - KLauS-6-based HBU design maybe start at the end of 2020.
- DAQ system design
  - Finished.
  - DAQ board, DIF board, Hardware and software are all finished and the system is verified in ECAL prototype.