AHCAL Project Status

Jianbei Liu

for the AHCAL group (USTC+IHEP+SJTU)

State Key Laboratory of Particle Detection and Electronics
University of Science and Technology of China

Feb. 20, 2020

Outline

中国科学技术大学
University of Science and Technology of China

- Mid-term tasks and targets
- What have been done
- What still needs to be done
- Issues and problems

Mid-term tasks and targets

年度	任务	考核指标	成果形式
2018年5月|2019年4月	开展量能器原型机的物理设计，优化量能器关键设计参数。采购制作灵敏探测器的原材料和器件，设计并优化灵敏单元结构，研究闪烁单元批量生产工艺并开始批量生产，研制闪烁单元自动包装设备，研制闪烁单元批量测试装置。设计灵敏层机械结构。采购电子学元器件，设计前端读出电子学。	完成灵敏单元批量制作和测试工艺研究；完成读出电子学的设计。	课题年度技术进展报告
2019年5月|2020年4月	模拟量能器原型机整机性能，开发建立相关软件框架。进行塑闪单元的生产、包装及测试，研究单层灵敏探测器的组装工艺。开发读出电子学，设计数据获取系统。设计探测器灵敏层结构，设计原型机吸收体和支撑结构。设计SiPM监测刻度系统。	完成量能器原型机物理设计，模拟得到原型机能量线性达到3%，能量分辨达到60%/(E/GeV)3%（10 GeV<E<80 GeV）；完成灵敏层结构设计和组装工艺研究；完成数据获取系统的设计。	课题中期技术进展报告

Mid-term tasks and targets

中国科学技术大学
University of Science and Technology of China

Tasks

- Development of software for AHCAL simulation
- AHCAL design optimization
- Sensitive cells production
  - Production of scintillator tiles
  - Wrapping of the tiles (auto wrapping machine)
  - Quality check (batch testing setup)
- Study of basic unit assembling (sensitive cells being glued onto PCB)
- Design of sensitive layers
- Design of readout electronics and DAQ
- Design of SiPM monitoring system
- Mechanical design of the AHCAL prototype

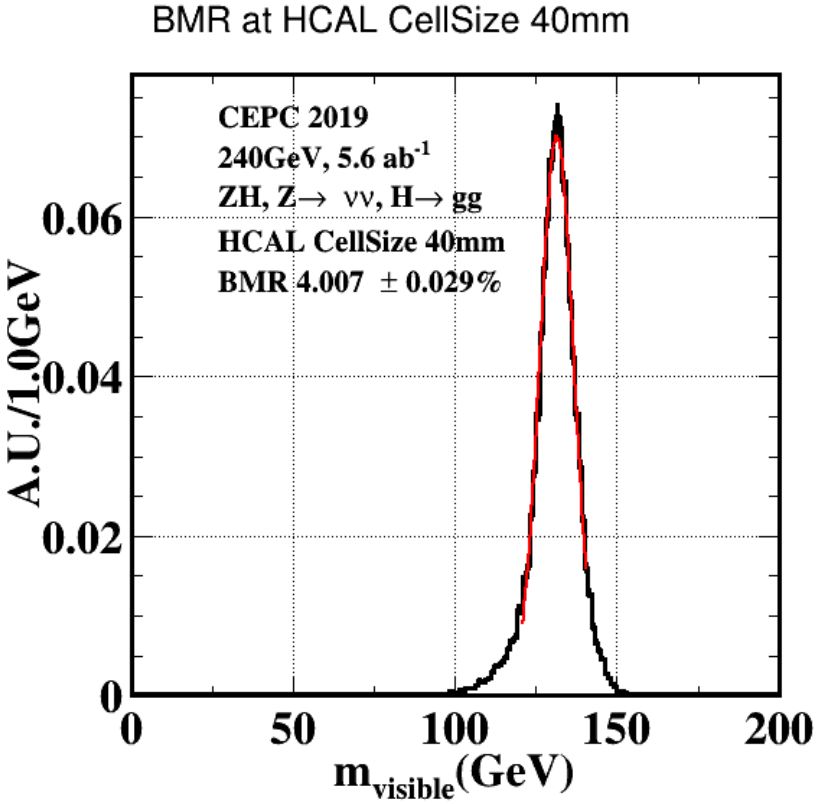
Targets

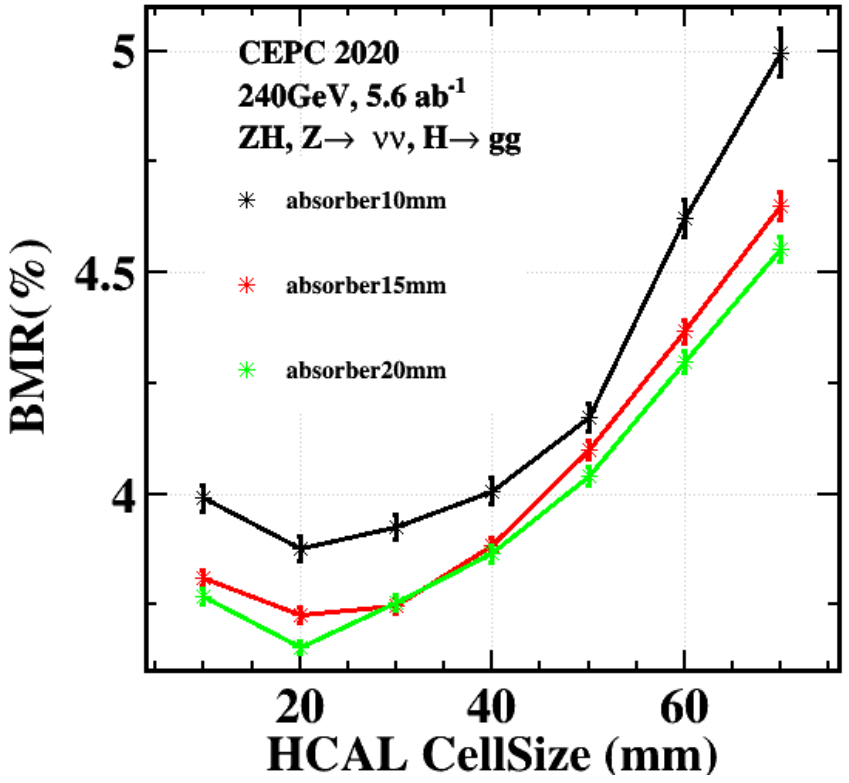
- Complete AHCAL design
  performance from simulation satisfies the requirements on energy resolution and linearity
- Complete production of sensitive cells
- Complete studies on design and assembling of active layers
- Complete design of readout electronics and DAQ

What have been done (progress)

Design optimization

- Using Boson Mass Resolution (BMR) from the H→gluon gluon process as the figure of merit

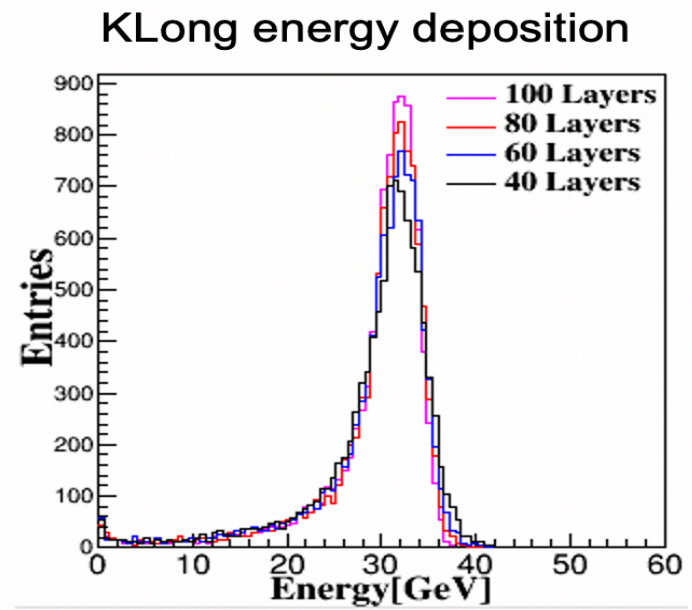


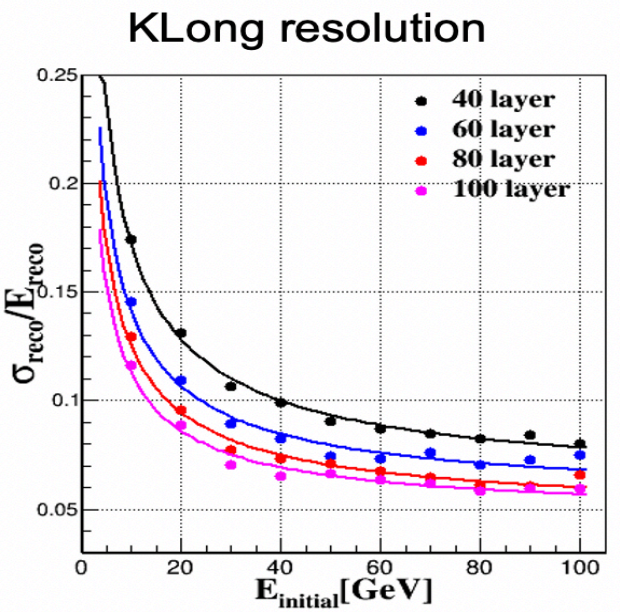


AHCAL prototype design and expected performance

中国科学技术大学
University of Science and Technology of China

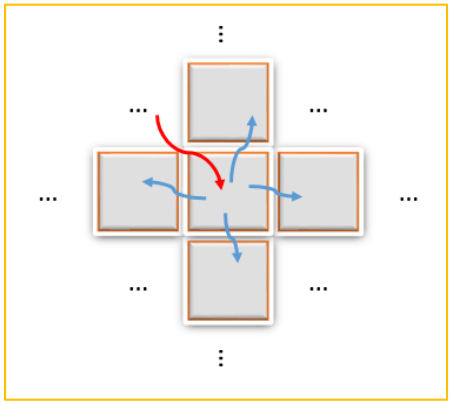
- Cell size: 4cm *4cm
- Scintillator tile thickness: 3 mm
- Absorber layer thickness: 2 cm
- Number of layers : 40
- Transverse active area: ~ 72 cm * 72 cm

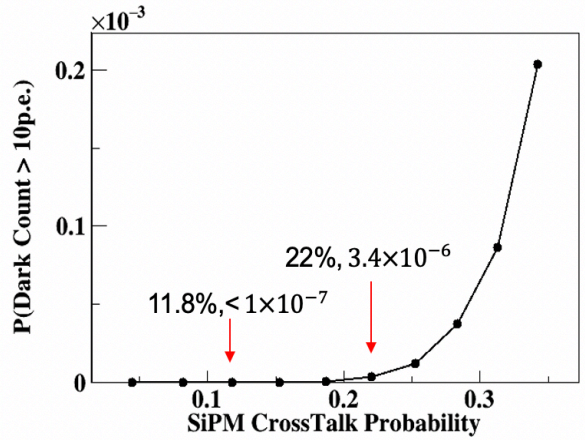


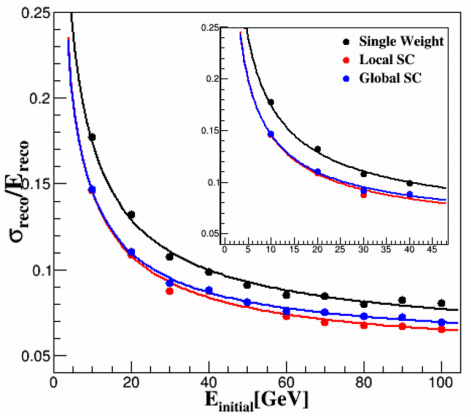


AHCAL “software”

- Saturation and cross-talk effects of SiPM have been added to simulation. This is the key to the digitization in the AHCAL simulation.
- Software compensation algorithms have been developed



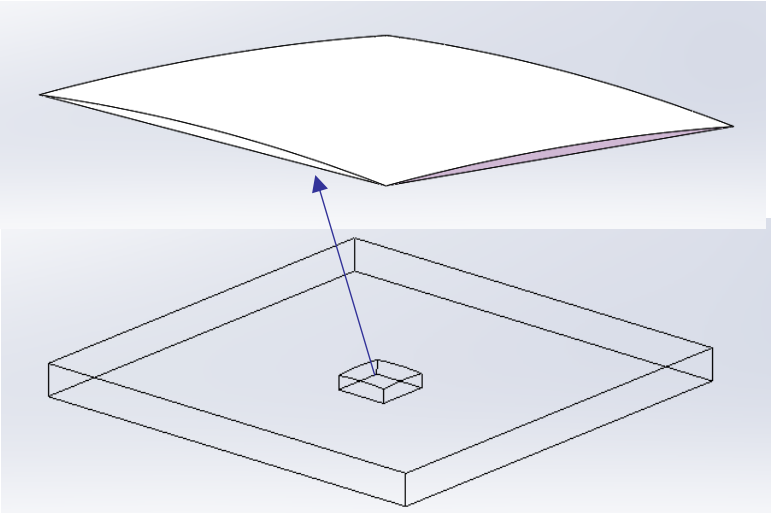


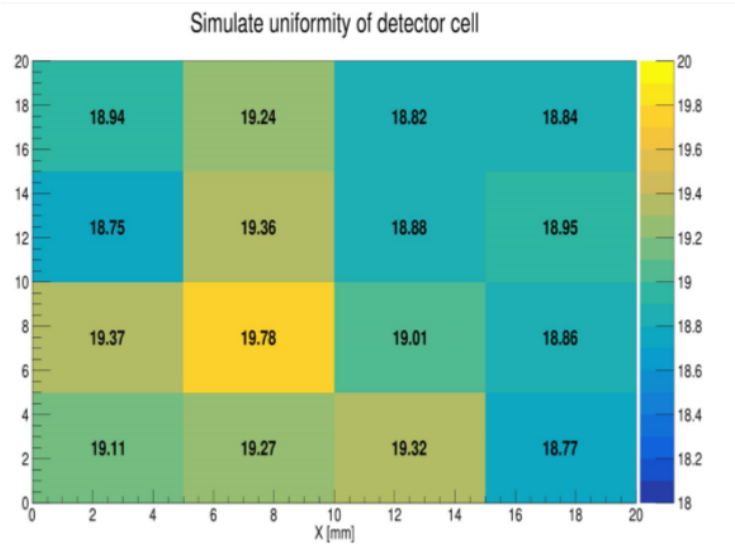


Design of sensitive cell

- Design of 4cm*4cm scintillator tile is completed
- Light yield uniformity is satisfactory, but absolute value a bit low
- Large size SiPM is needed

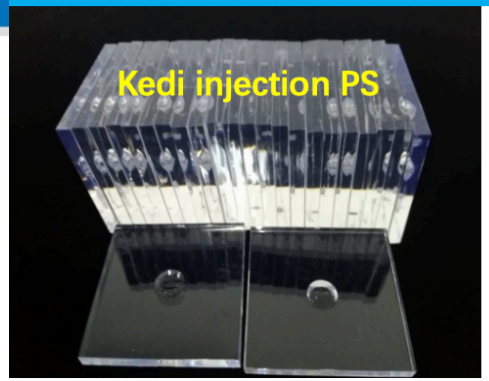
the central cavity in the new design :
5mmx5mmx1.5mm



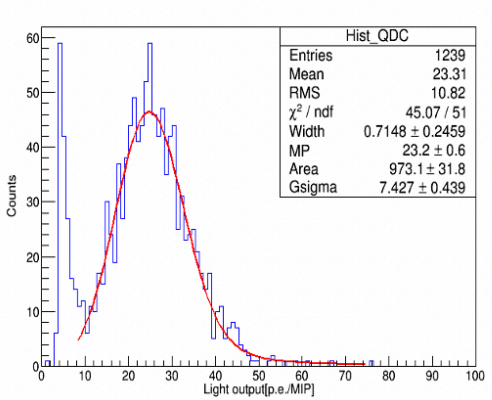


mean=19.0794
Max mean deviation value=3.7%
uniformity≤5.4%

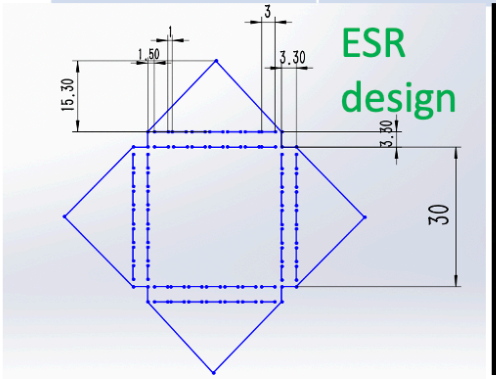
Chinese injection scintillator

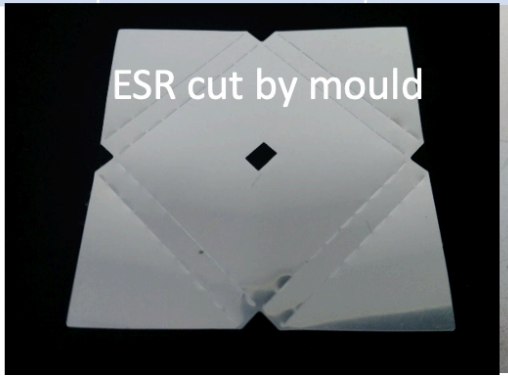


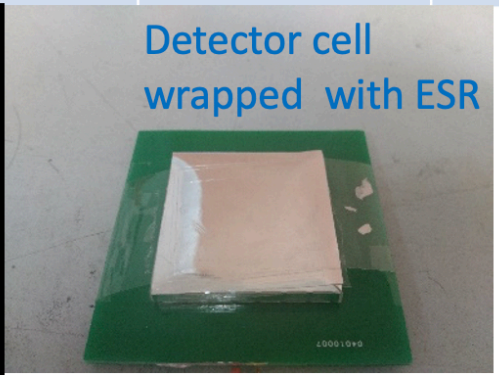
- Made by Injection molding (custom-made and 8 iterations of recipe testing)
- Without polished, smooth
- Dimension deviation below 50um from each other (30 tiles)
- Light yield winthin 10% deviation



Tiles size(mm)	30.08x30.01 x3.08	30.07x30.04 x3.09	30.04x30.02 x3.09	30.09x30.09 x3.09	30.05x30.03 x3.09
Light yield(p.e.)	23.5	22.78	22.86	25.02	23.54





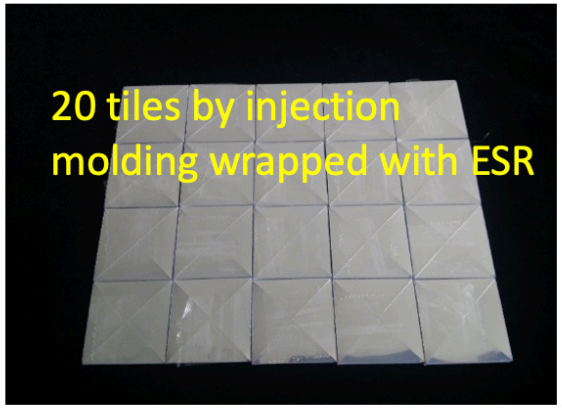


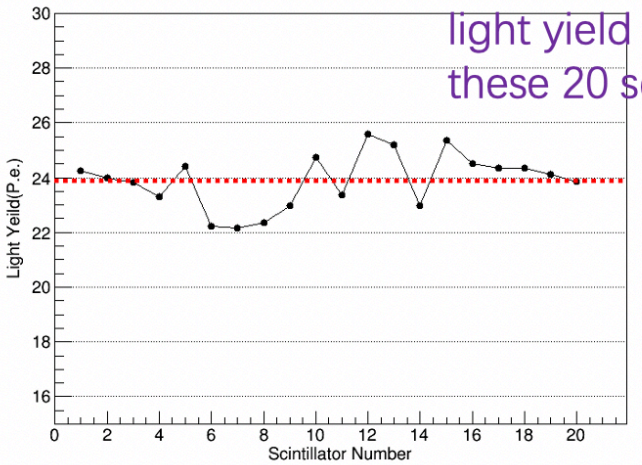
The effect of ESR cut by mould is good and it has few gap, ESR and detector cell can be wrapped compactly.

- This is for 3cm*3cm. New injection moulds need to be developed for 4cm*4cm .

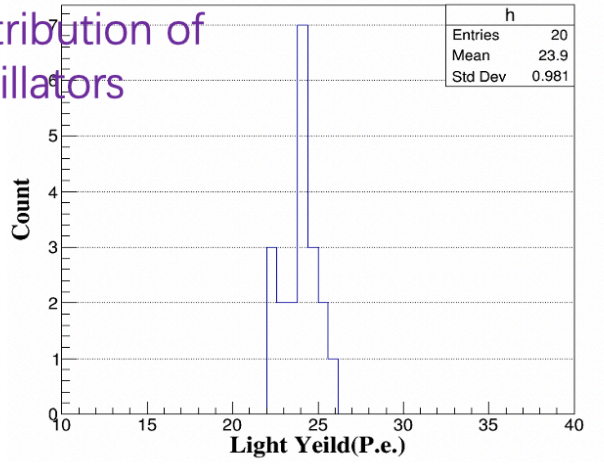
uniformity of Chinese scintillator

Light yield measurement with different scintillator and ESR films





light yield distribution of
these 20 scintillators

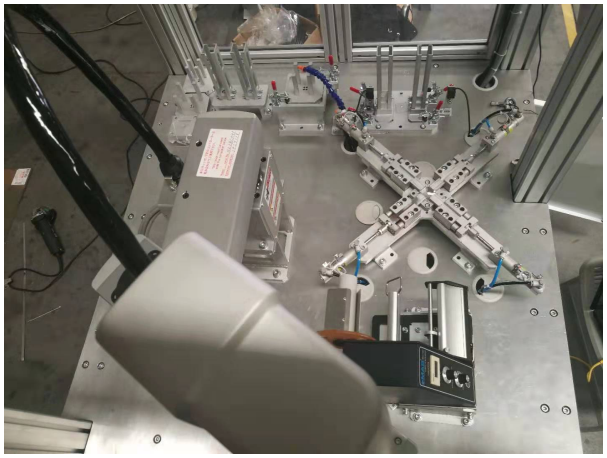


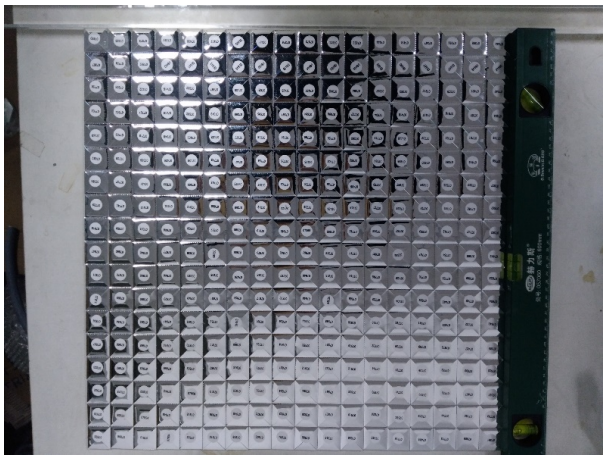
The deviation of response are winthin 10% from mean value.
For AHCAL detector cell could be massively produced now.

- This testing needs to be redone for 4cm*4cm

Scintillator tile wrapping machine

中国科学技术大学
University of Science and Technology of China





- An auto-wrapping machine has been built and tested.
- Average wrapping time for a single tile: 45 s

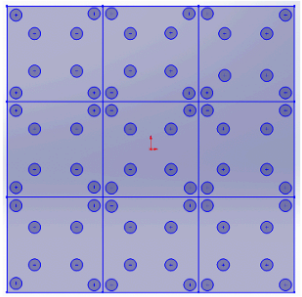
Detector cell gluing experiment

motivation：

In order to quickly and effectively realize the integration of large area AHCAL detection unit.

Materials：

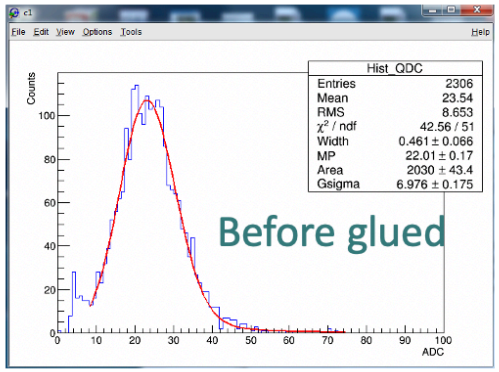
1. Araldite 2011 epoxy glue
2. 3×3 PCB board
3. Detector cell;
4. A film used to brush glue

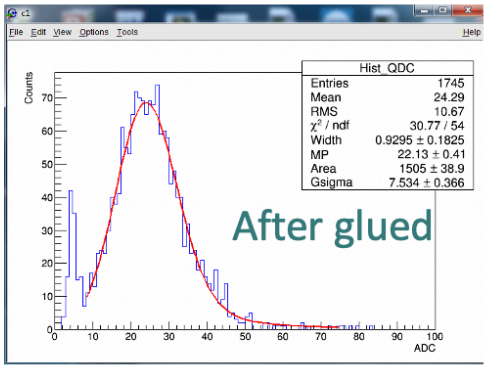


Result:

1. This way is working;
2. The detector cell was glued on PCB fasten;
3. Maybe reduce to 4 glue hole;
4. Plan to test crosstalk and prototype.

Light output

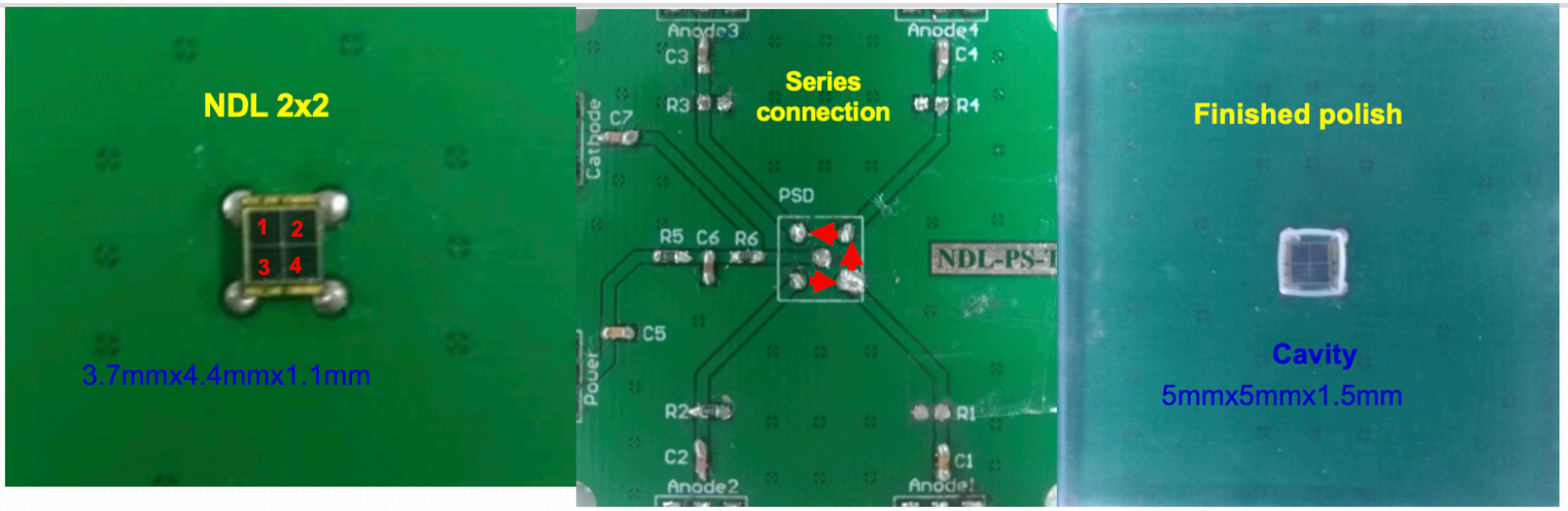




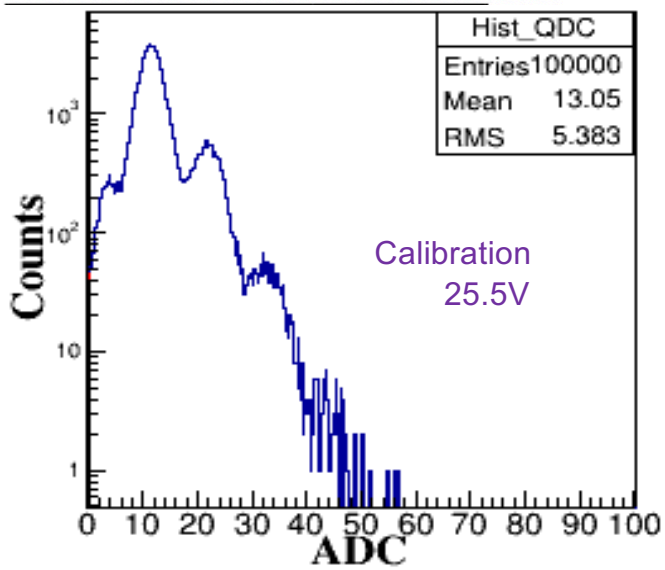
Large NDL-SiPM

中国科学技术大学
University of Science and Technology of China

NDL 22-1414B-S

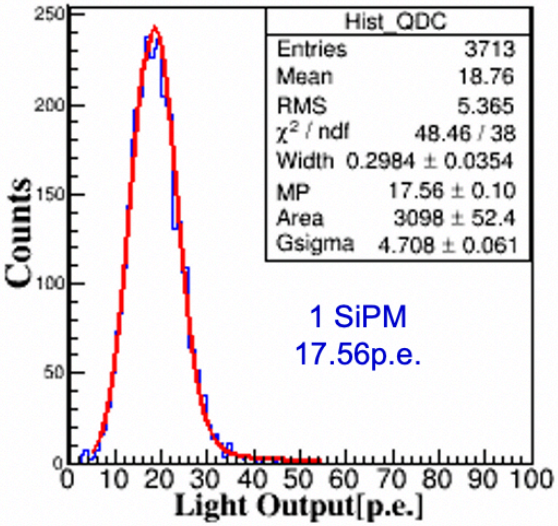


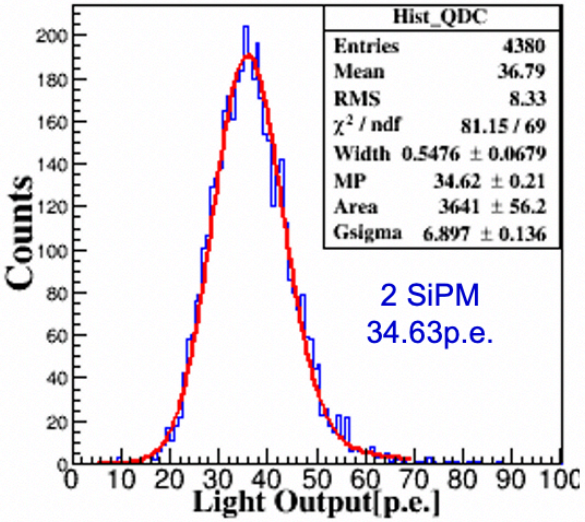
Active area	4x1.3mmx1.3mm
Pixel size	10um
Breakdown	23.7V
PDE@420nm	35%

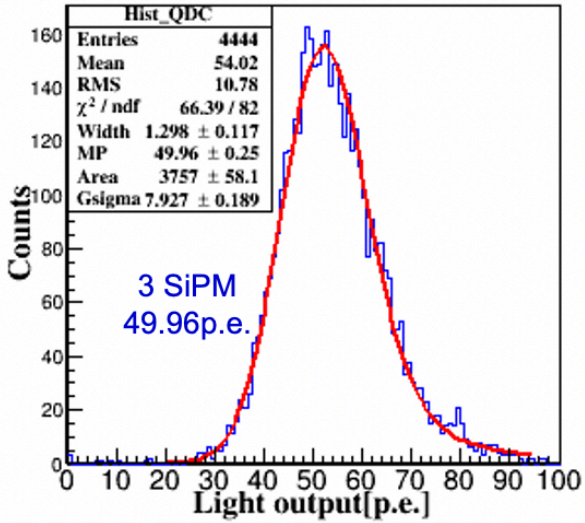


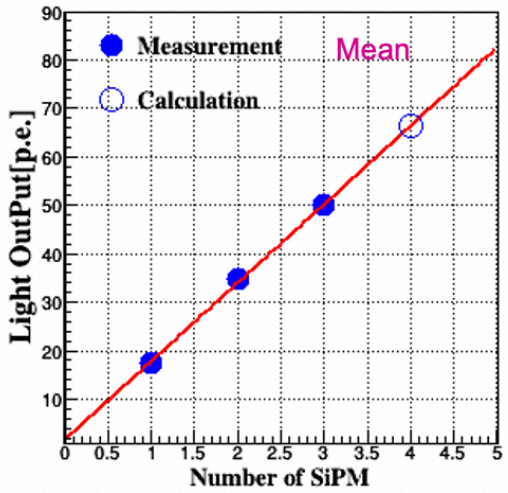
Light-yield test

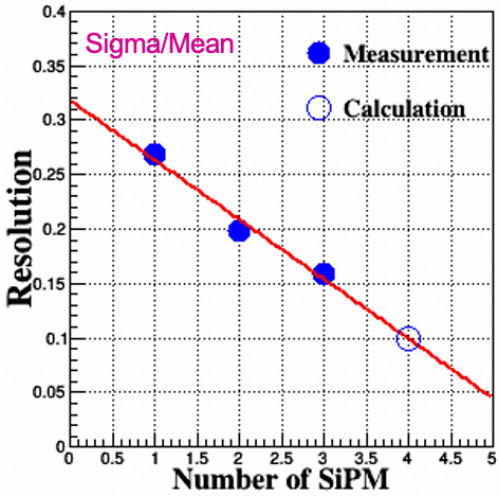
中国科学技术大学
University of Science and Technology of China











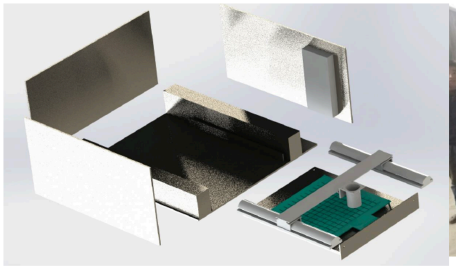
- The SiPM behaved as expected.
- The combination feature of the SiPM also offers us flexibility in adjusting light yield.

Quality check of wrapped scintillator tiles

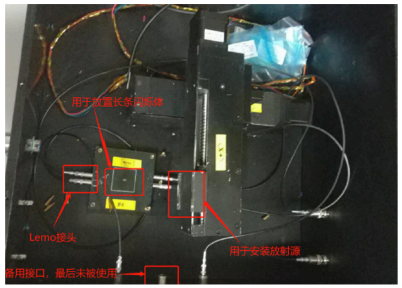
中国科学技术大学
University of Science and Technology of China

- Development of a batch test system

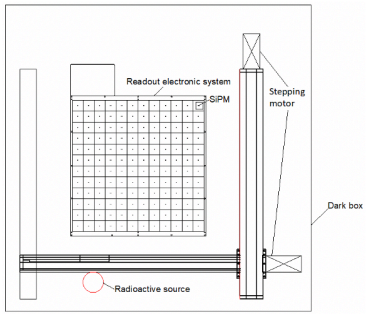
Batch test system outlook



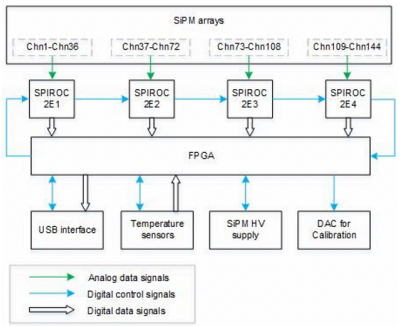
Single scintilator test unit



- The scintillator test platform is based on 4 SPIROC2E chips, which can test 144 scintillators at one time. There're about 10,000 scintillators used in the AHCAL prototype, and they can be tested by 70 runs.
- Design and one board production are finished now, and the system is planed to run before April.
- If needed, one or two more test platform can be made, and this will takes about 2 weeks.



Structure of the test platform



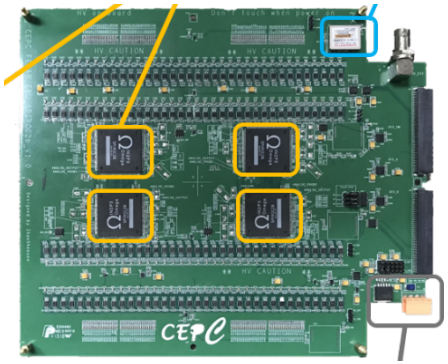
Readout system of the test platform

SPIROC-based readout electronics

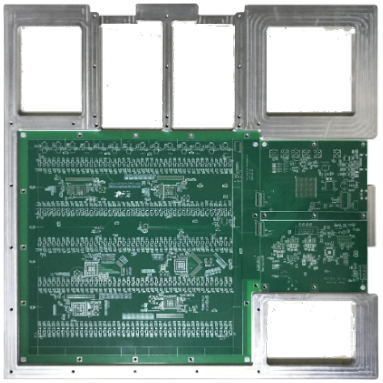
中国科学技术大学
University of Science and Technology of China

- SPIROC2E is the baseline in the AHCAL prototype production.
- SPIROC2E has been used in the ECAL prototype production, and many versions of readout board have been developed.
- The version used in the AHCAL prototype is planed to be finished at the end of 2020.

Board with one chip



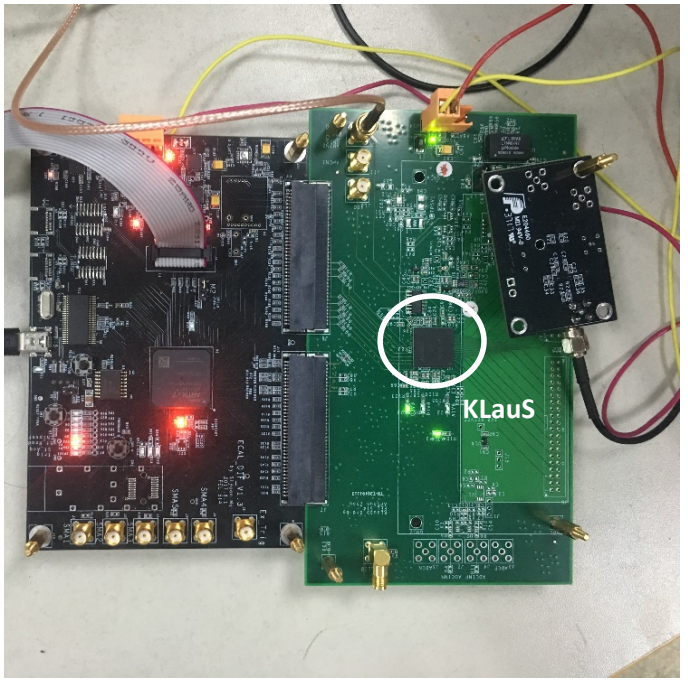
Board with 4 chips and scintillators on the back



Board used in the ECAL prototype (6 chips, 210 chns)

KLauS-based readout electronics

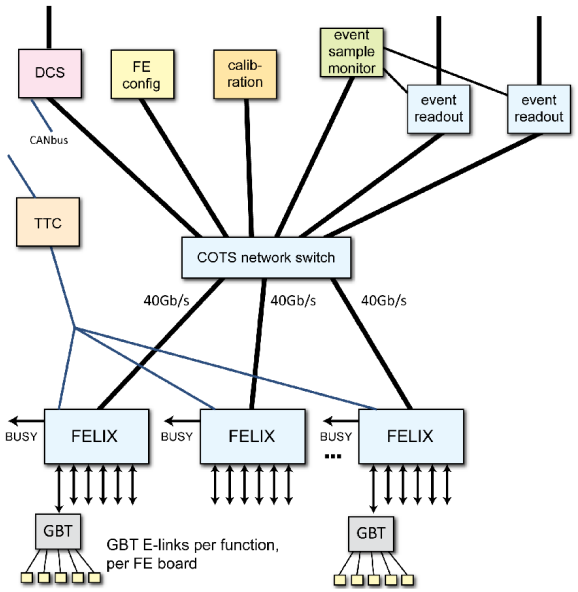
- KLauS is an option for AHCAL thanks to its better noise performance and shorter dead time. But the chip itself is now under development and it is hard to be used.
- A readout board with one KLauS chip has been developed, but it hasn't worked well up to now. We have communicated with the chip designer and the system hopes to work before April.
- If KLauS is used in the AHCAL prototype, an engineering version is planed to be finished at the end of 2020.



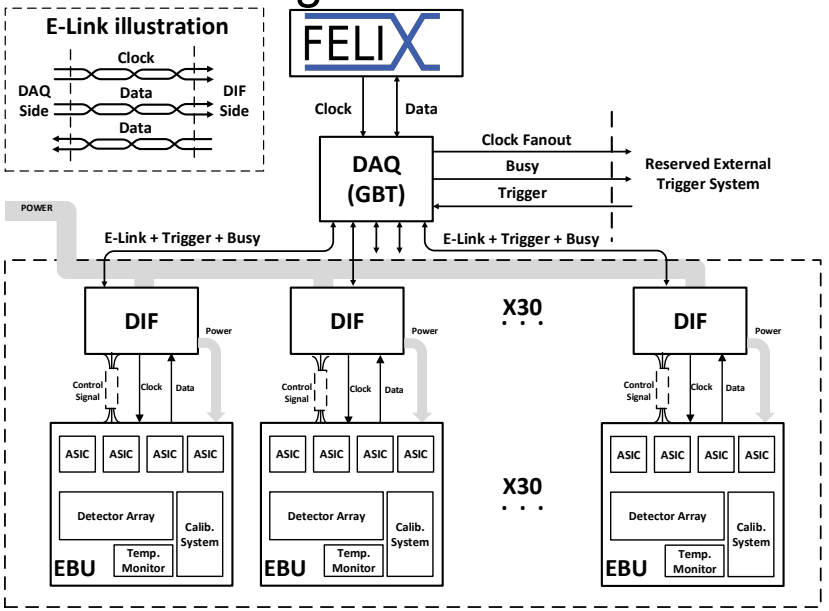
Board with one KLauS

DAQ system

- FELIX（FrontEnd LInk eXchange）is the DAQ system used in the ATLAS upgrade.
- A DAQ system based on FELIX is developed in the ECAL prototype production, which consists of the FELIX card, the GBT board, the DIFs and the EBUs.
- AHCAL prototype plans to adopt the same DAQ system, just by replacing the EBUs with HBUs and modifying some interface logics.



Structure of the FELIX system



ECAL DAQ system based on FELIX

What still needs to be done

AHCAL design and simulation

中国科学技术大学
University of Science and Technology of China

- Transversal size of the AHCAL prototype to be finalized
- The tentative design is 72cm *72cm. But it is subject to fine tuning depending on the readout splitting scheme.
- Add SiPM digitization and software compensation to full simulation and improve energy reconstruction and calibration, and simulation with PFA

Sensitive cell and layer

中国科学技术大学
University of Science and Technology of China

- Mass production of scintillator tiles to be started as soon as possible, which would take 2 months or so to complete.
- Wrapping machine needs to be adjusted for the size of 4cm*4cm. This may take one month.
- Finalize basic sensitive unit assembling procedure. This requires the final version of readout PCB and would take about 2 months.
- Start the design work of sensitive layers
- Make final choice of SiPM

Mechanical Design

中国科学技术大学
University of Science and Technology of China

- Nothing has happened yet. Needs to ramp up the effort in this aspect !

Electronics

中国科学技术大学
University of Science and Technology of China

- Need to make a final decision on what readout chip to use
  - Baseline: SPIROC
  - Alternative: Klaus
- Then complete the development of readout electronics
- The first scintillator tile batch test system to be ready by April

Issues and Problems

中国科学技术大学
University of Science and Technology of China

- Not until late last year did simulation with PFA really start to pick up the pace. This slowed down the whole optimization work quite a lot.
- So cell-size was determined rather late, which caused significant delay to work on sensitive cells
  - Scintillator tile production
  - Wrapping machine
- Large size NDL SiPM requires a new batch of production, which implies extra wait time and testing work.
- The company the Omega group had relied on for BGA packing is no longer available. Need to find an alternative company. They are looking for help from China.
- Not too much work has been done in the mechanical aspect of the project yet (mechanical design of sensitive layers, the absorber and the supporting structure …). We need to ramp up the effort in this direction.
- Last but not the least: the virus !

Very near-term plan

中国科学技术大学
University of Science and Technology of China

- If we can start lab work next month, then

Time	Items
2020-03-31	Scintillator injection mould development
2020-04-30	Production of scintillator tiles and testing
2020-05-31	Mass production of scintillator tiles and assembling experiment of basic active unit.
2020-06-30	Scintillator tile wrapping