环形正负电子对撞机
Circular Electron Positron Collider

Status of CEPC Calorimeters

Haijun Yang (SJTU)

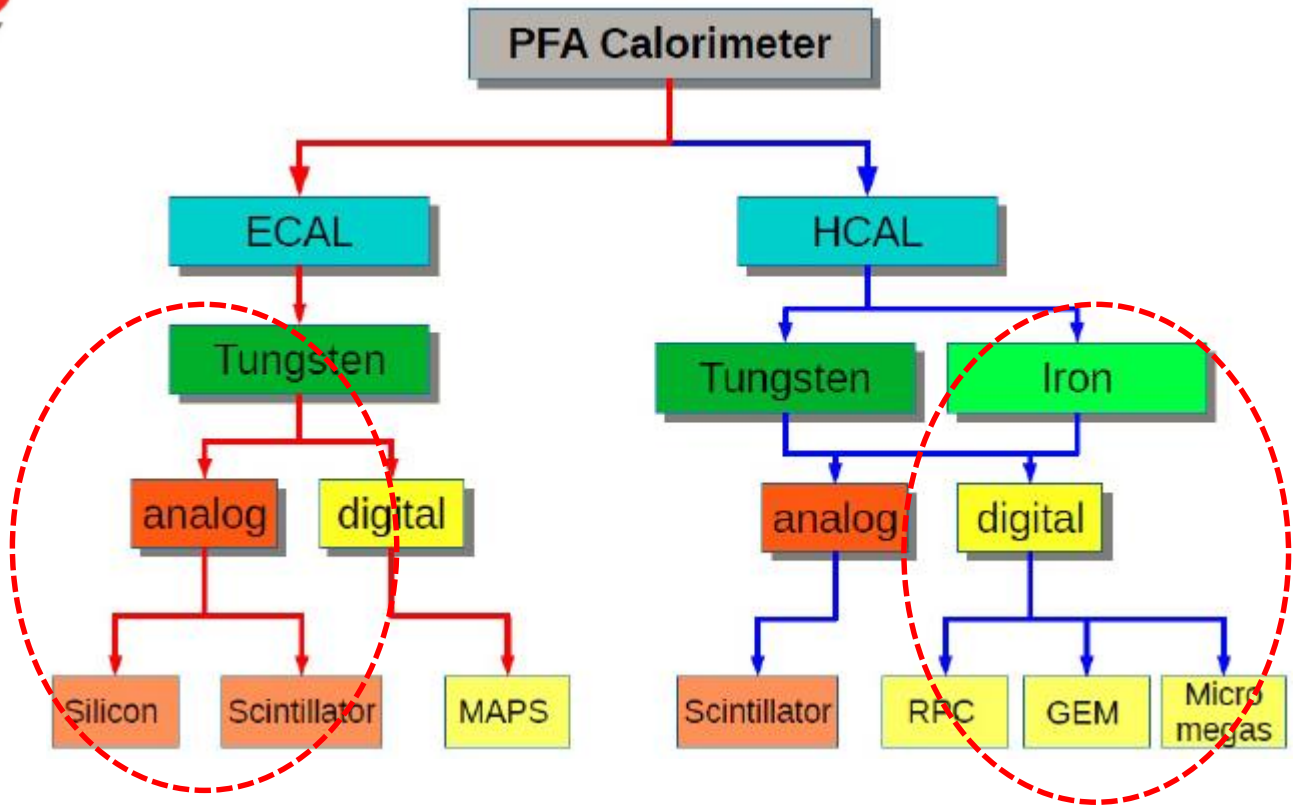
For the CEPC-Calo Group

CEPC Physics and Detector Group Meeting

November 4, 2016

CALICE: Imaging Calorimeter

https://twiki.cern.ch/twiki/bin/view/CALICE/CalicePapers



Readout cell size: 144 - 9 cm^2 → 4.5 cm^2 → 1 cm^2 → 0.25 cm^2 → 0.13 cm^2 → 2.5×10^{-5} cm^2

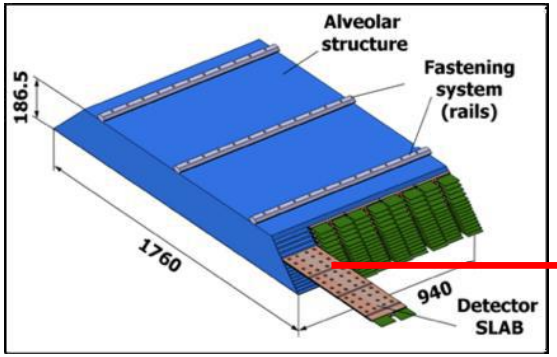
Technology:	Scintillator + SiPM/MPPC	Scintillator + SiPM/MPPC	Gas detectors Silicon	Silicon	Silicon	Silicon (MAPS)

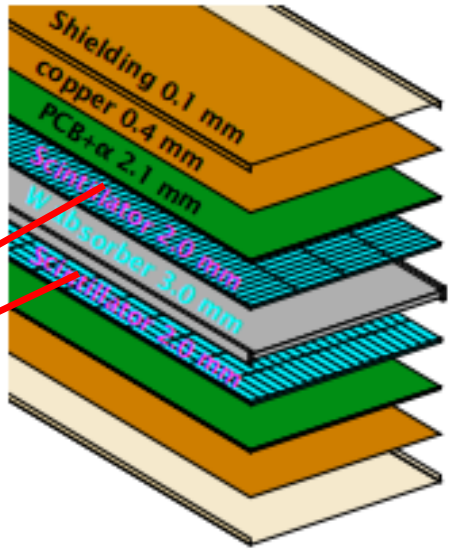
ECAL: Scintillator-W

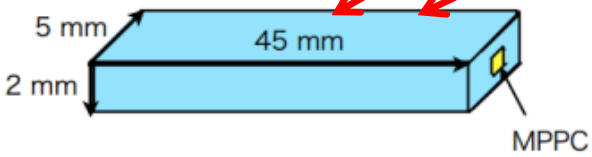
Zhigang Wang et.al.

A super-layer (7mm) is made of:

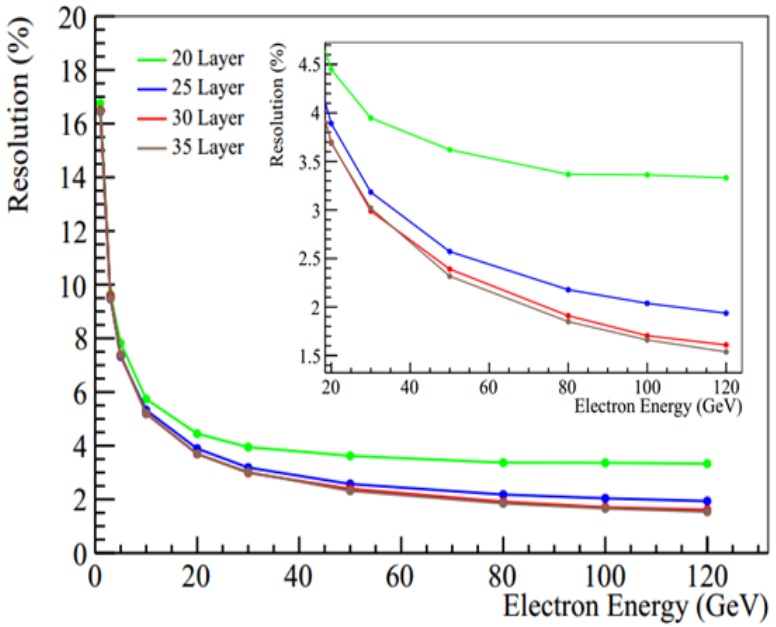
- Plastic scintillator (2mm) + Tungsten plate as absorber (3mm thick)
- A readout/service layer (2mm thick)







Scintillator + W + Scintillator

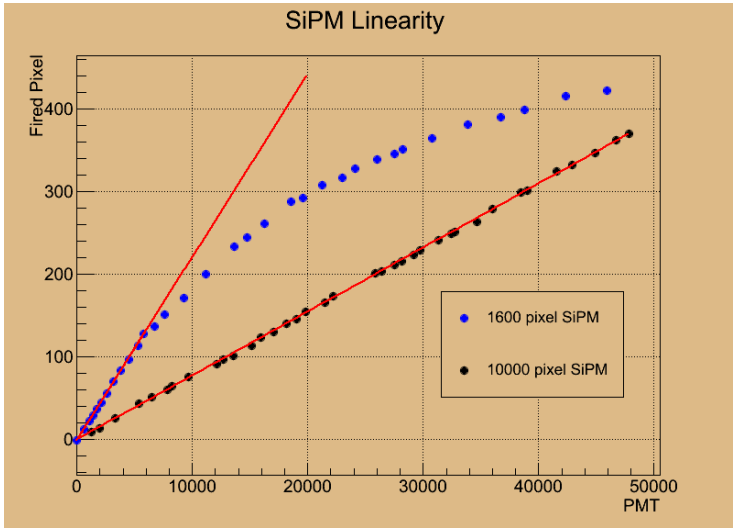


- **The energy resolution of 25GeV electron is about 3.3% (cf. CALICE TB results)**
- **To achieve required energy resolution, the number of layers should be ~ 25.**

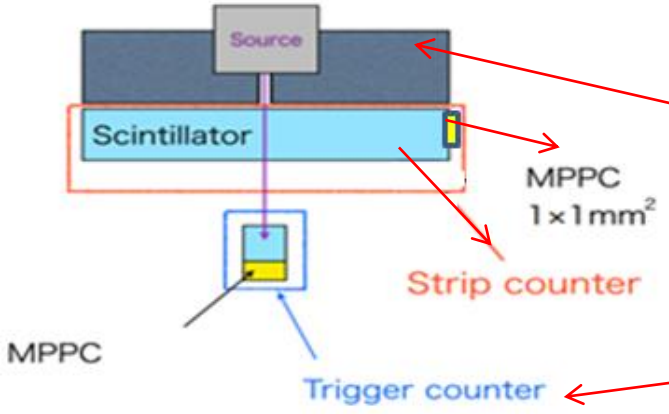
Test of SiPM (IHEP, USTC)

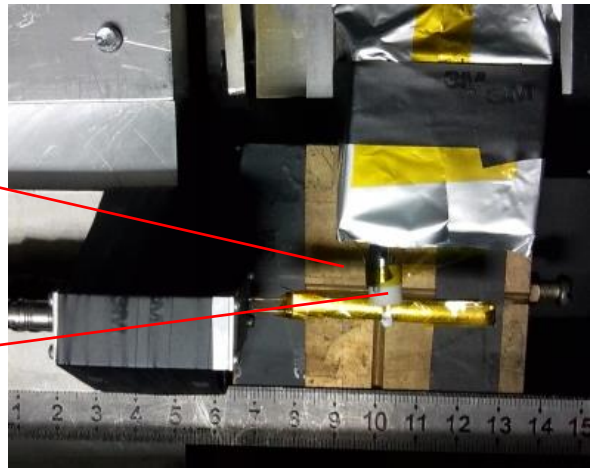
➔ **SiPM linearity range depends on number of pixels.**

➔**Photon detection efficiency for SiPM (10um) is about 1/3 of that for SiPM (25um).**



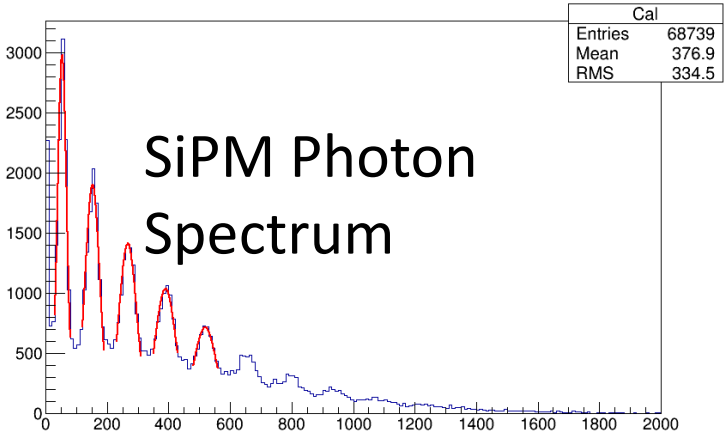
Scintillator strip irradiated with β collimated (1mm) from 锶Sr-90





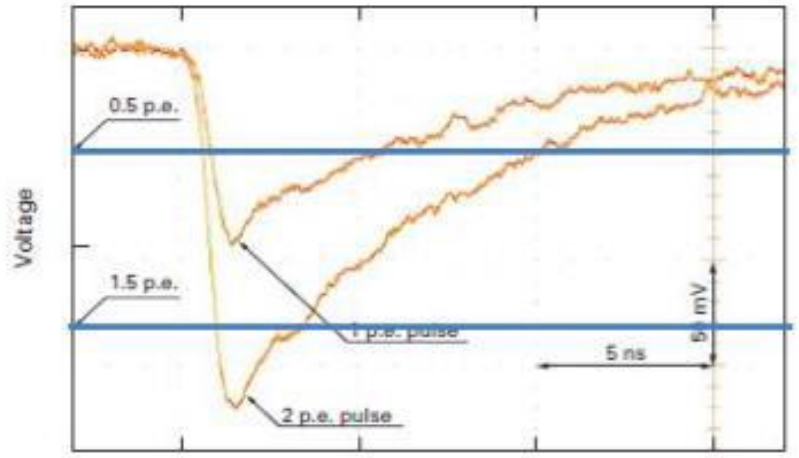
Test of SiPM (IHEP, USTC)

Z.G. Wang, Y.L. Zhang et.al.

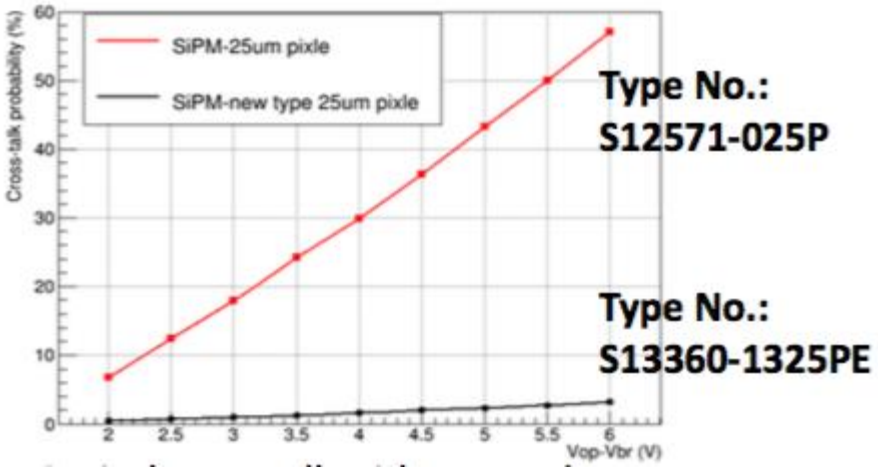


Power Spectrum

Excellent photon counting

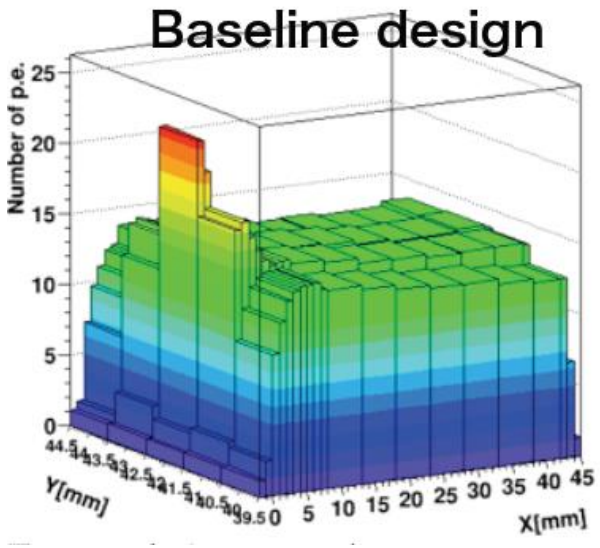


Cross talk rate = Events (> 1.5p.e)/Events (>0.5p.e)

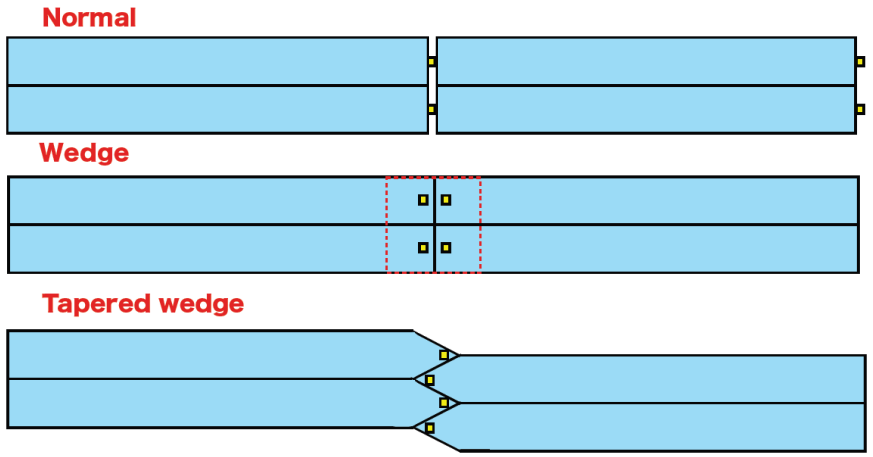


Optimization of Sct. Strip

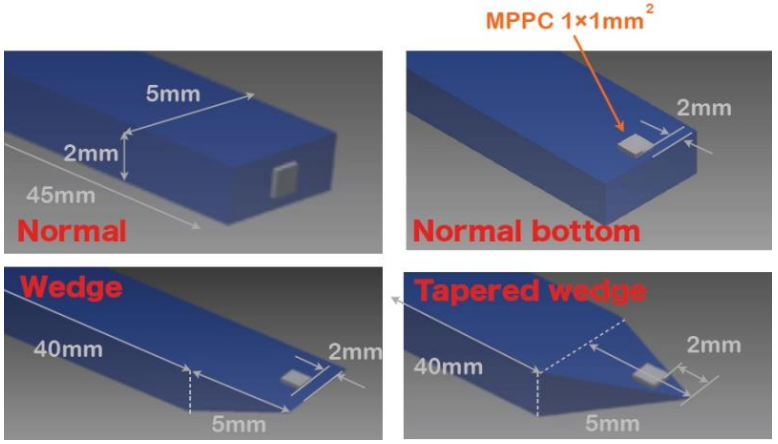
Z.G. Wang et.al.

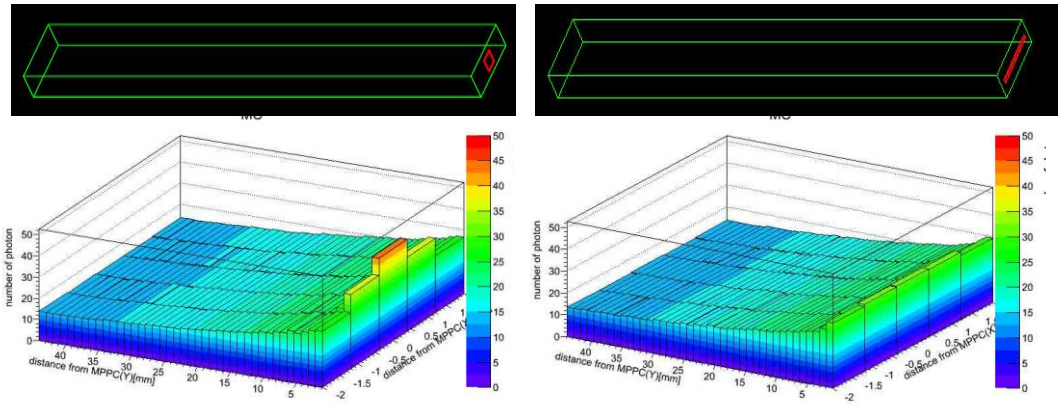


Optimizing the geometry and connection of scintillators.

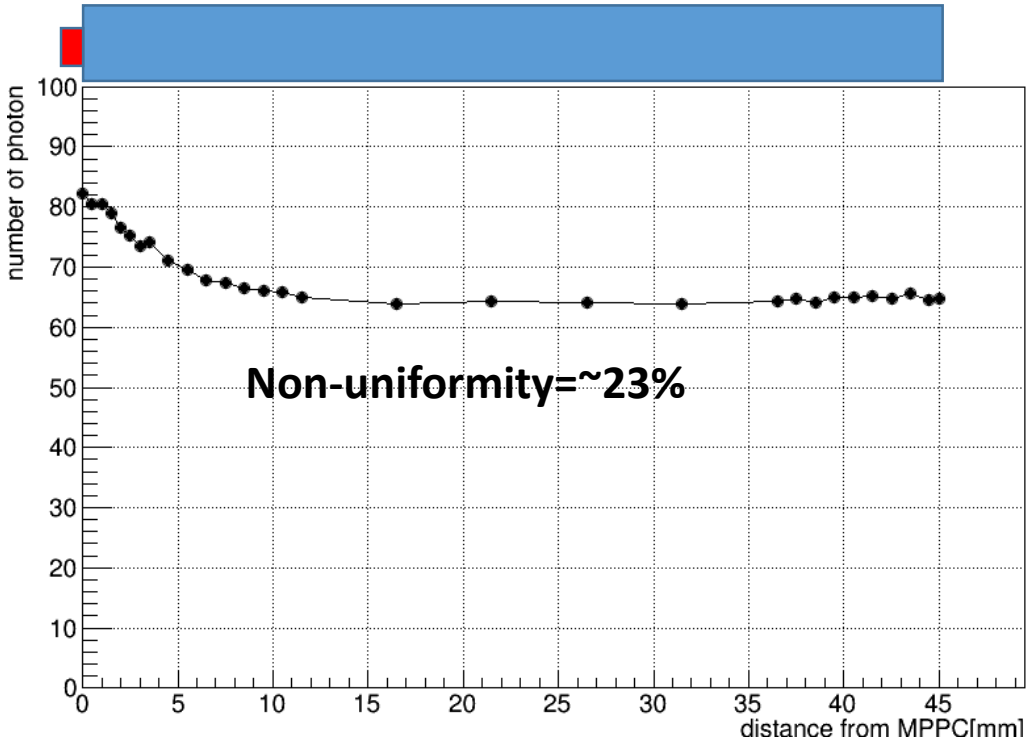


SiPM area: 1×1 mm^2 ➔ 0.25×4 mm^2:





Strip Structure Optimization



Scintillator strip： 5mm*45mm*2mm

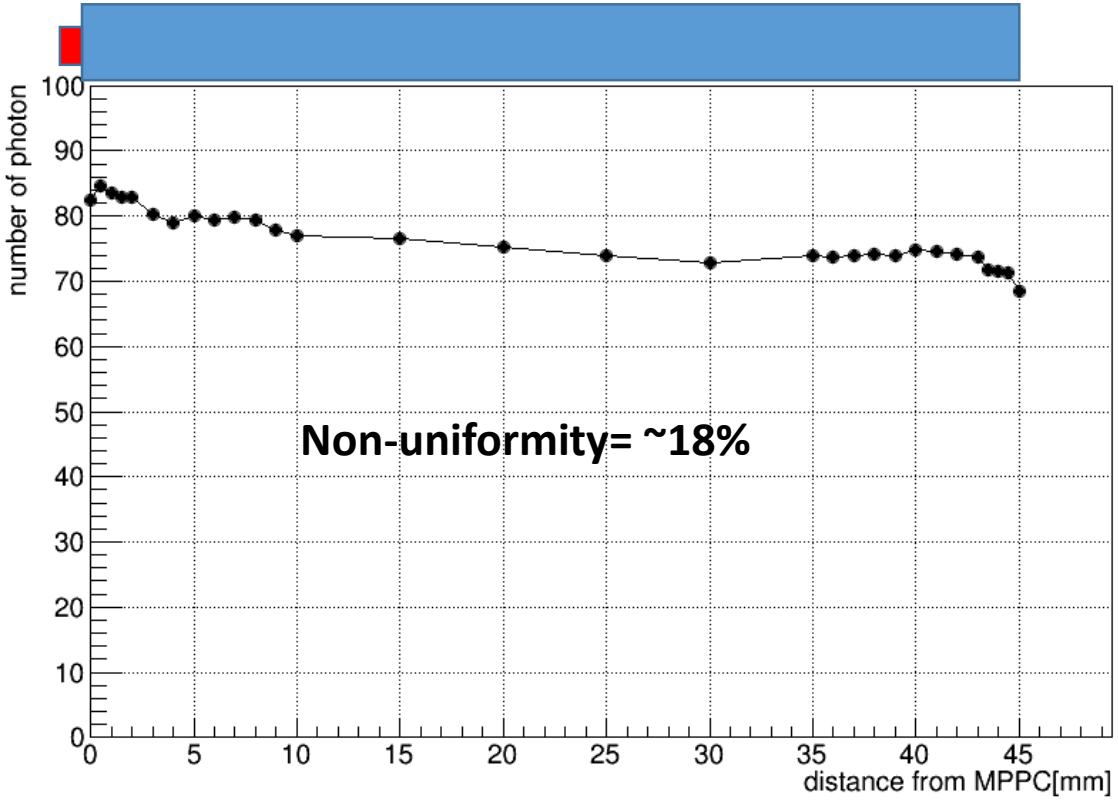
Z.G. Wang
Hang Zhao
Tao Hu (IHEP)

Baseline design of the CEPC ScW ECAL readout structure:

1 Peaky structure close to SiPM

2 Dead gap caused by SiPM

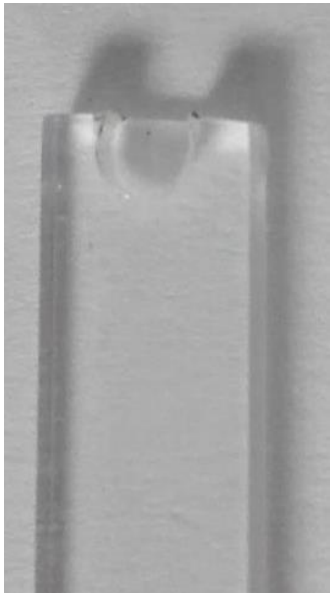
Optimization: Rough Surface

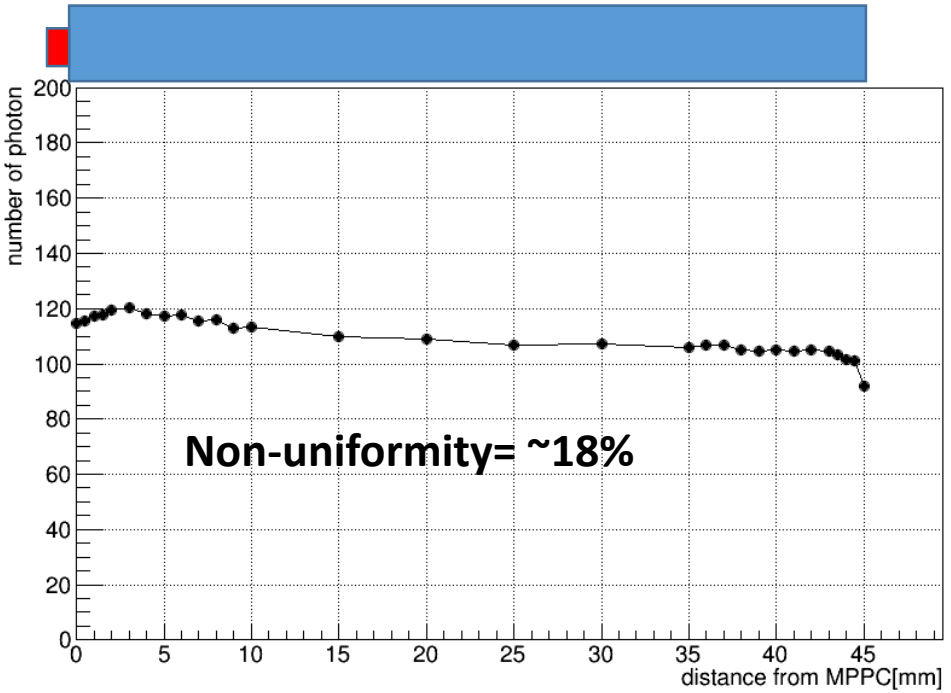


Scintillator strip： 5mm*45mm*2mm

The uniformity of rough surface strip is better than polished

Optimization: Drill hole





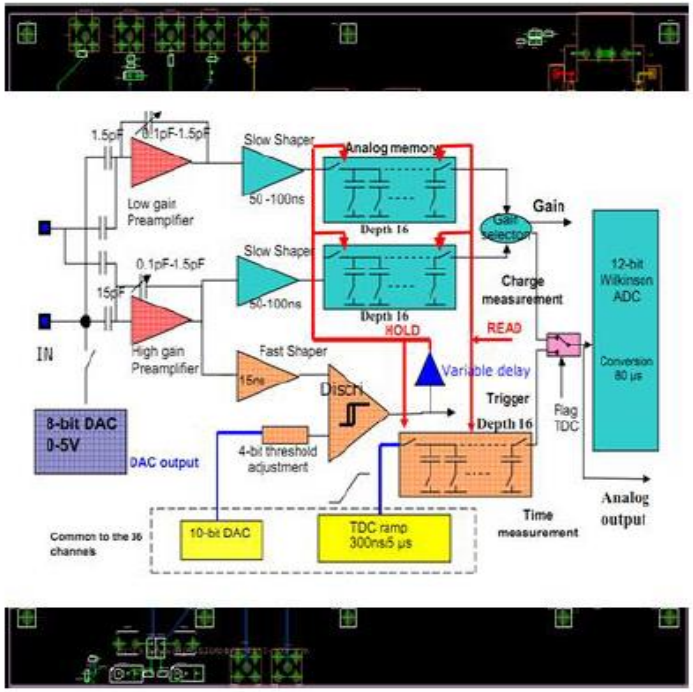
Scintillator strip： 5mm*45mm*2mm

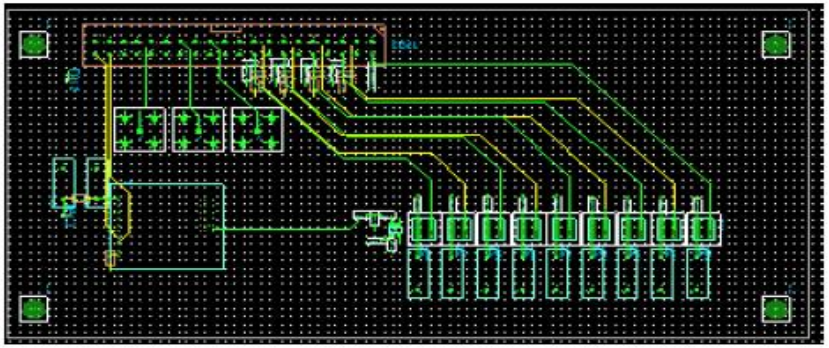
The dead gap is eliminated.

The photon number increases, need further tests !

Electronics Board of ECAL

- The PCB Board of ECAL ,which based on the SPIROC2b chips, has been designed and produced
- The FPGA firmware is being designed

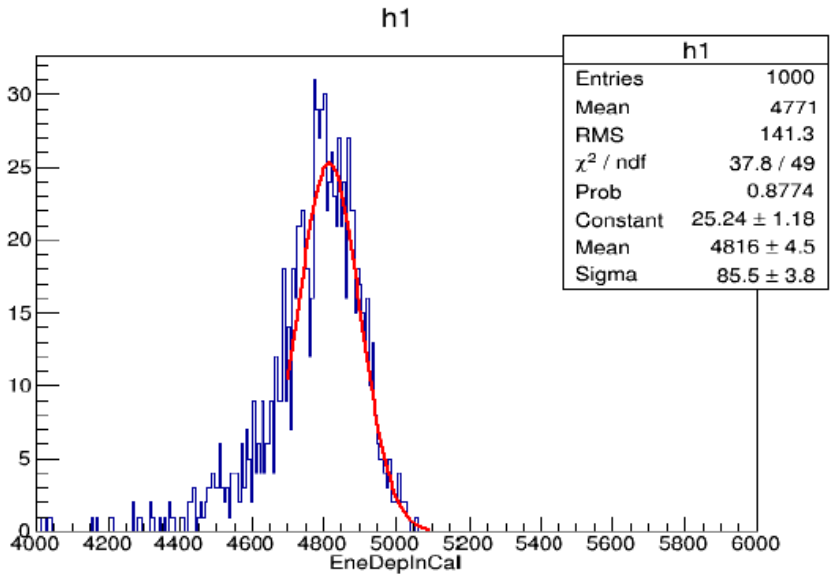


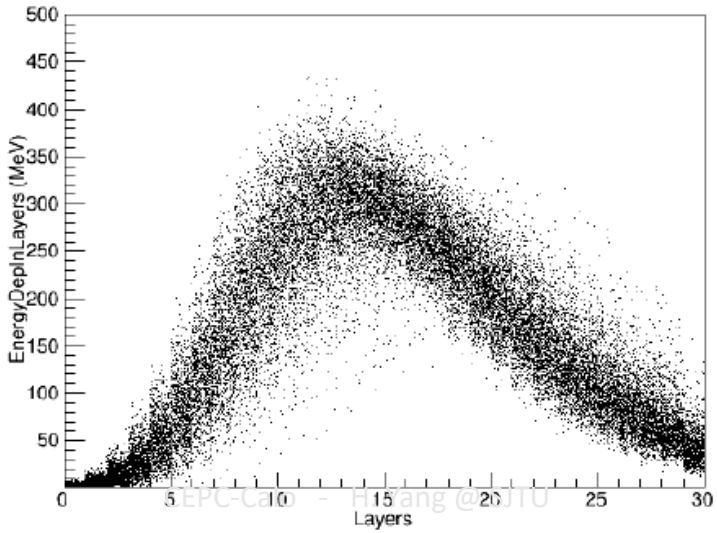


- Yunlong Zhang, Shensen Zhao, Jianbei Liu (USTC)

Standalone MC Package

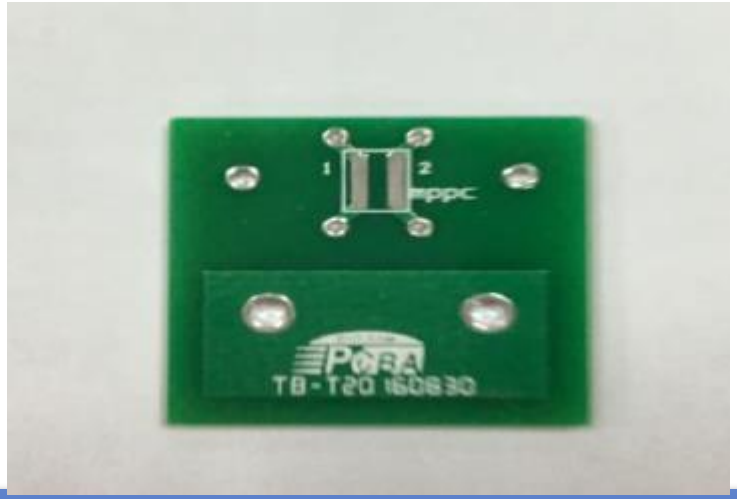
- A standalone simulation program based on GEANT4 code has been developed to study the capability of ECAL
- example: 100GeV e-
  - The energy deposition in Plastic scintillator is 4.8 GeV
  - Resolution:1.8%





The Purchase Order

- The VA Chips and FPGAs order has arrived
- The Si-PMT samples and HV power also has arrived



CEPC HCAL

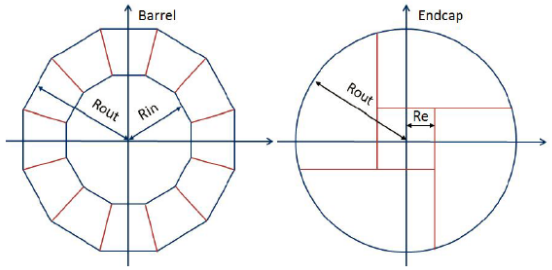
- The HCAL consists of
  - a cylindrical barrel system: 12 modules
  - two endcaps: 4 quarters
- Absorber: Stainless steel

- **Active sensor**
  - Glass RPC
  - Thick GEM or GEM
- **Readout (1×1 cm²)**
  - Digital (1 threshold)
  - Semi-digital (3 thresholds)

CEPC DHCAL OPTIMIZATION

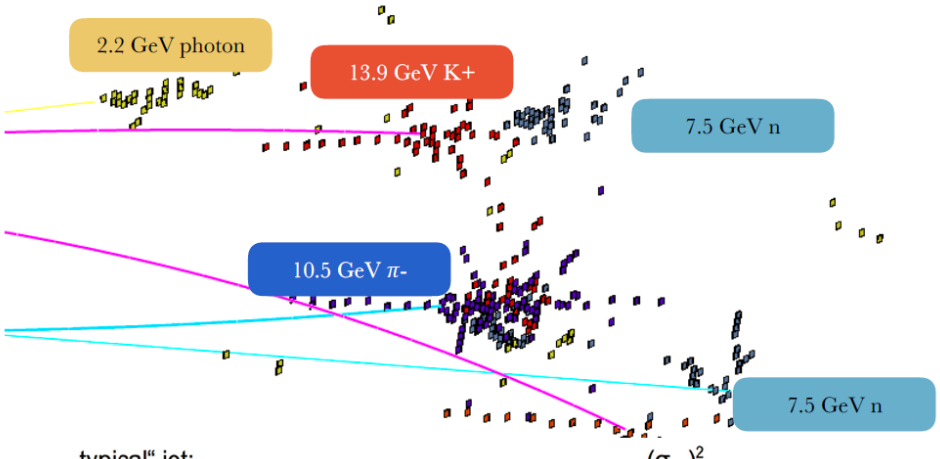
- To full fill the requirements of CEPC PFA, the DHCal is optimized by the following:
  - layers of DHCal, scanned from 20 layers to 48 layers.
  - size of each cell, scanned from 10 mm to 80 mm.
  - digitization (Q spectrum, spatial resolution, semi-Digi, etc..)

- The HCAL consists of
  - a cylindrical barrel system: 12 modules
  - two endcaps: 4 quarters
- Absorber: Stainless steel



SIMULATION - PRELIMINARY

By Shi CHEN (UCAS)

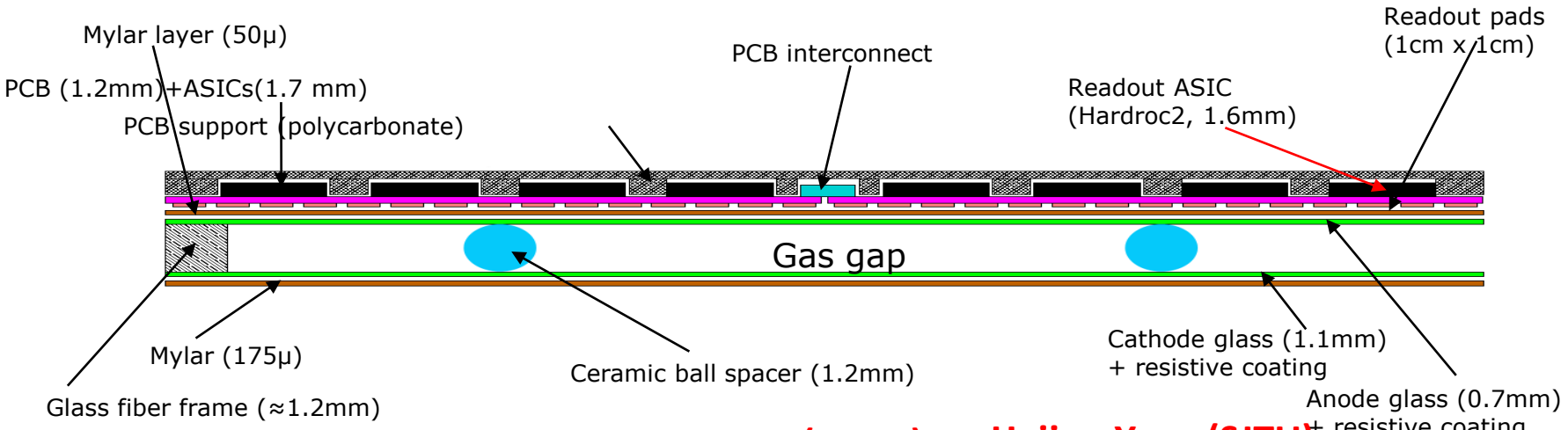


„typical" jet:
~ 60% charged particles
~ 30% photons
~ 10% neutral hadrons
~ 1% neutrinos

tracking
EM calorimeter
HAD calorimeter

$(\sigma_{jet})^2 = (\sigma_{tracks})^2 + (\sigma_{EMCalo})^2 + (\sigma_{HADCalo})^2 + (\sigma_{loss})^2 + (\sigma_{confusion})^2$

Schematic of RPC



Ran Han (BISEE)

Haijun Yang (SJTU)

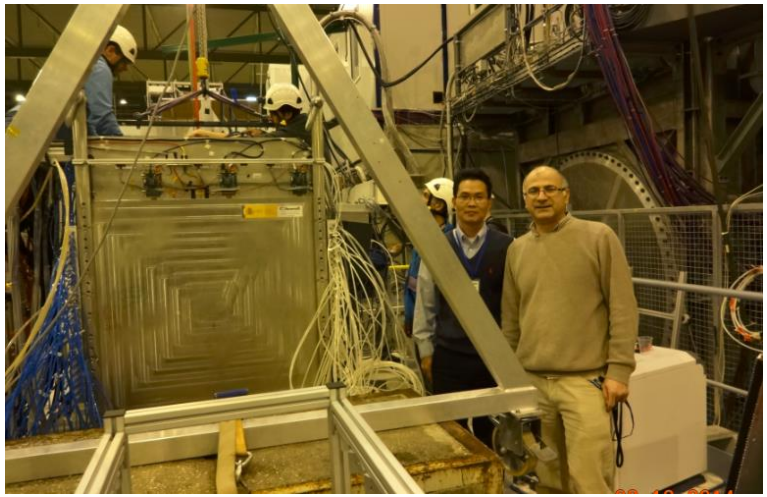
Large area gRPC:

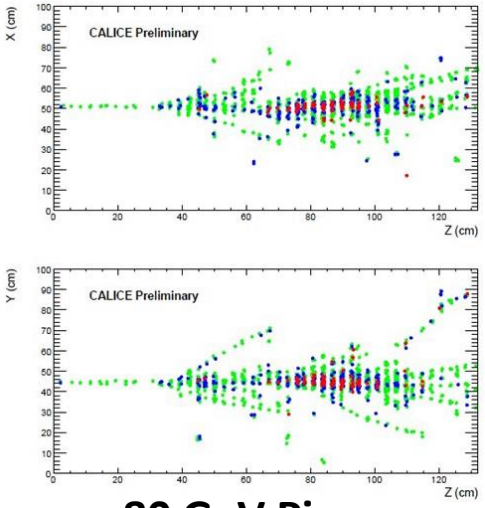
- ✓ Negligible dead zone (tiny ceramic spacers)
- ✓ Large size: 1 × 1 m^2
- ✓ Cost effective
- ✓ Efficient gas distribution system
- ✓ Homogenous resistive coating

DHCAL with RPC

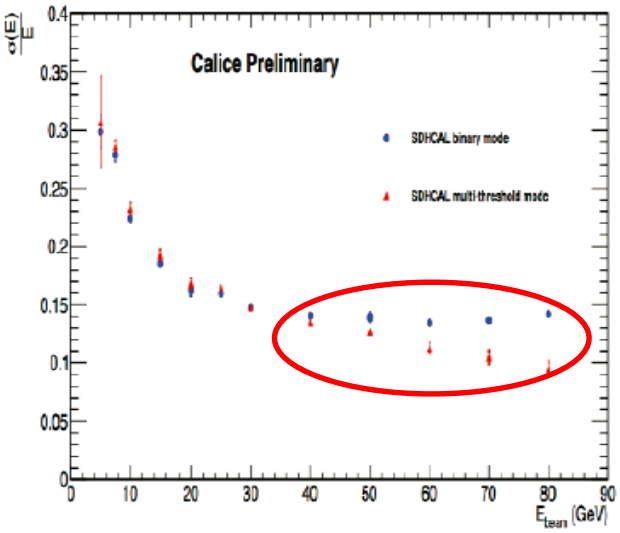
Prototypes of DHCAL based on RPC

- **ANL (J. Repond, L. Xia et.al.)**
  1m^3, 1 threshold, TB at CERN/Fermilab
- **IPNL (I. Laktineh, R. Han, B. Liu et.al.)**
  1m^3, 3 thresholds, TB at CERN since 2012



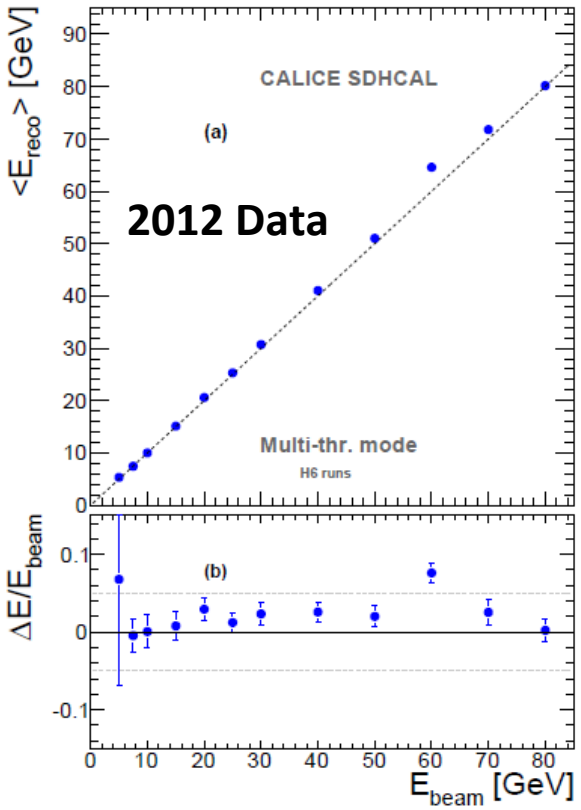


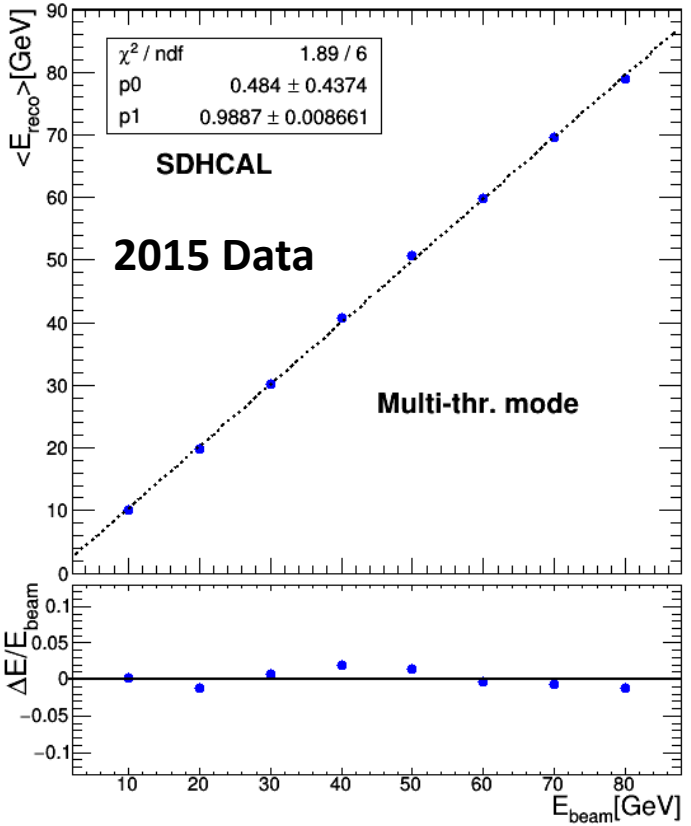
80 GeV Pion



DHCAL with RPC

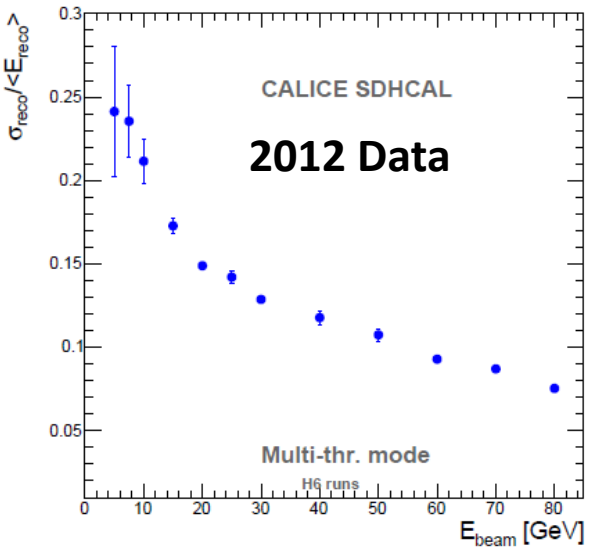
Collaborating with Imad Laktineh at IPNL since Sept. 2016, Bing Liu was attending TB at CERN in Oct. 2016 and analyzing 2015 data now. He will apply for joint Ph.D program (CSC) between SJTU and IPNL.

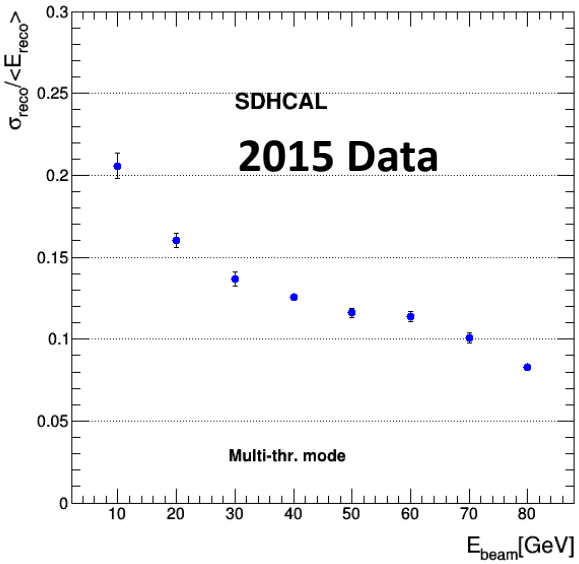




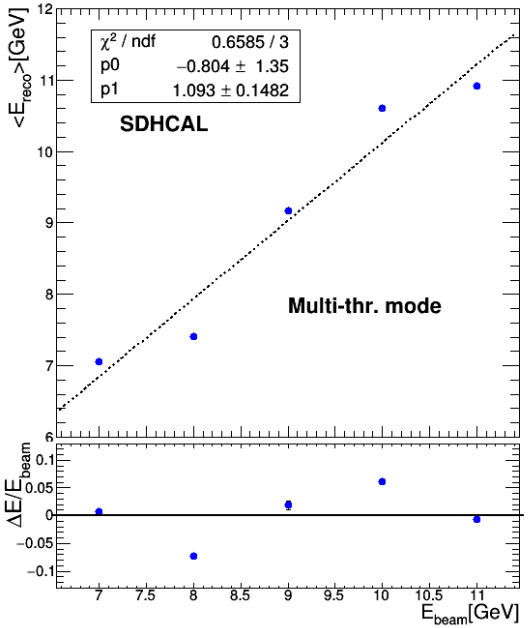
DHCAL with RPC

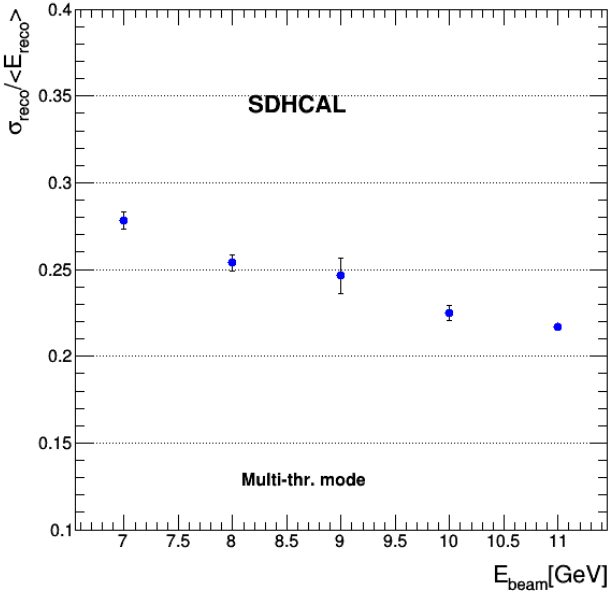
Bing Liu (SJTU)



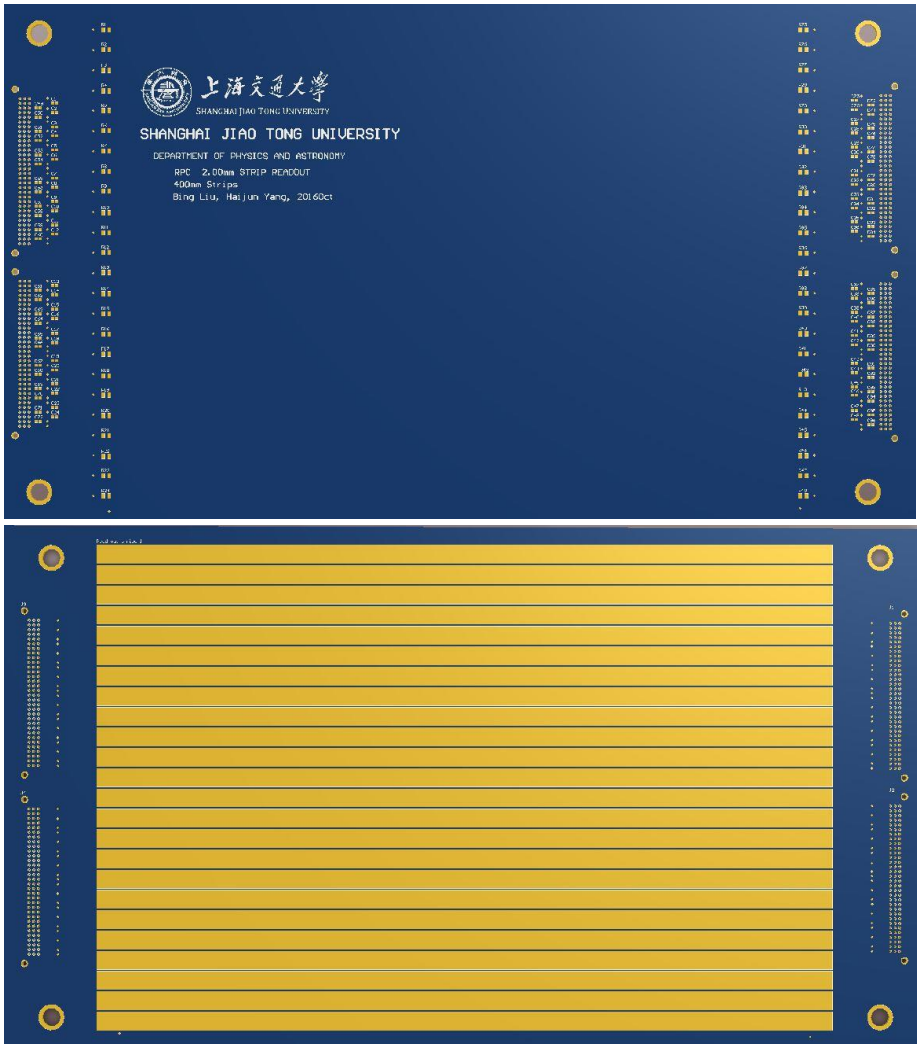


Low Energy Region (7 – 11 GeV)





Design of PCB for RPC



Bing Liu, Haijun Yang (SJTU)

24 strips with 1cm/strip, gap = 1mm, length = 40cm

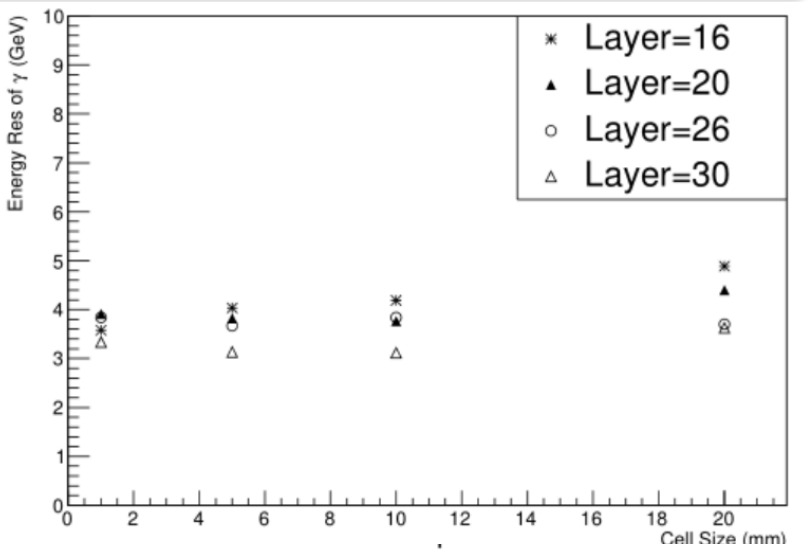
- PCB Output: 3 bins x 32 column = 96 pins
  - Molex DIN 41612 connectors (receptacles)

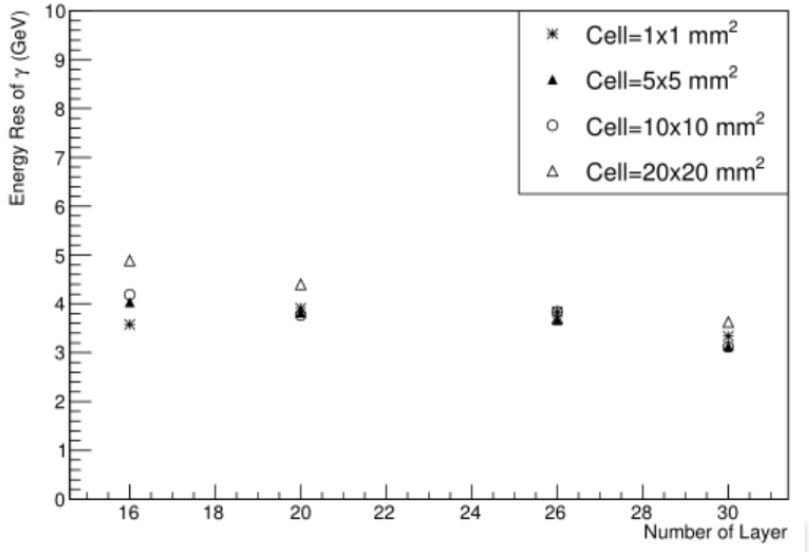
- NINO Input:
  - Molex DIN 41612 connectors (headers)

Calorimeter Optimization

Jifeng Hu, Jing Li, Liang Li, Haijun Yang (SJTU)

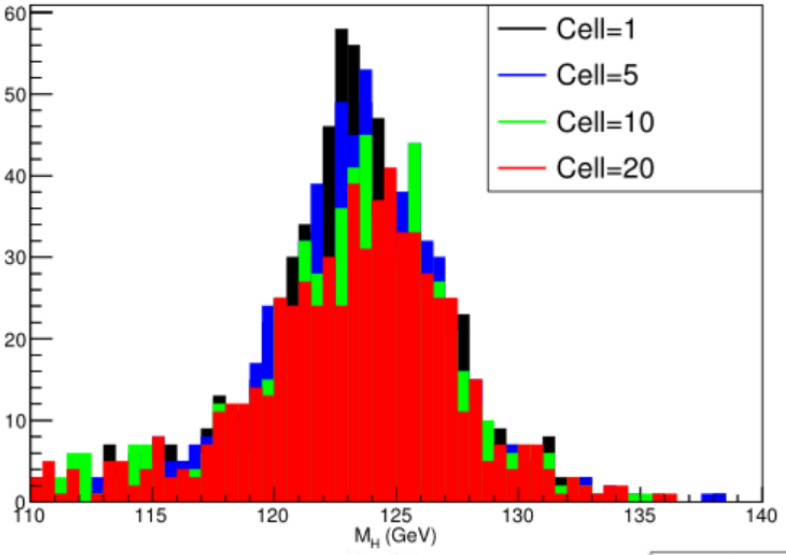
- Software versions,
  - Simulation: Mokka-08-03
  - Reconstruction: Arbor_KD_3.3 plus track-related processors
  - Digitization : G2CDArbor
- Samples,
  - e^-/γ single particle, energy@5,10,20,50,100 GeV
  - $ee \rightarrow ll\gamma\gamma@\sqrt{s} = 250\ GeV$, 1000 Events.
- Geometry: cepc_v1 using SiW in ECAL,
  - Cell size @ 1X1, 5X5, 10X10, 20X20 mm
  - Number of layers @ 15, 19, 25, 29
  - fixed total material.
  - other parameters will be investigated.

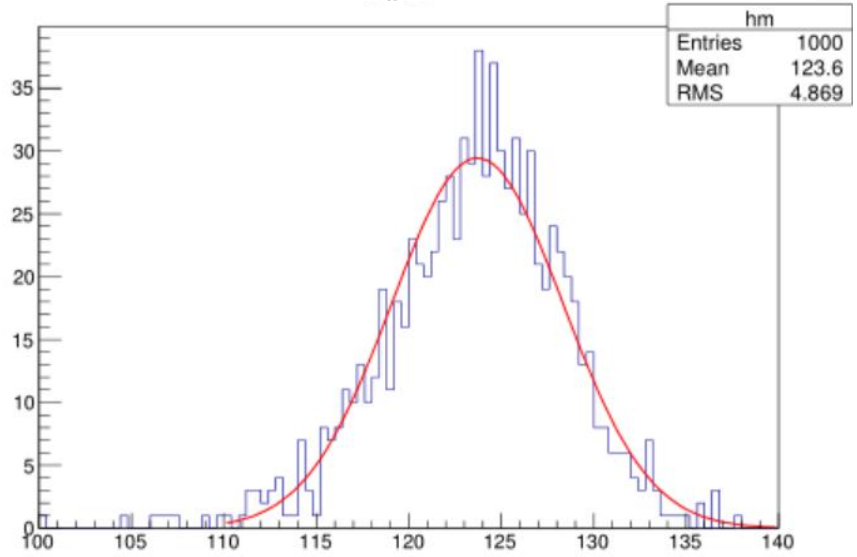


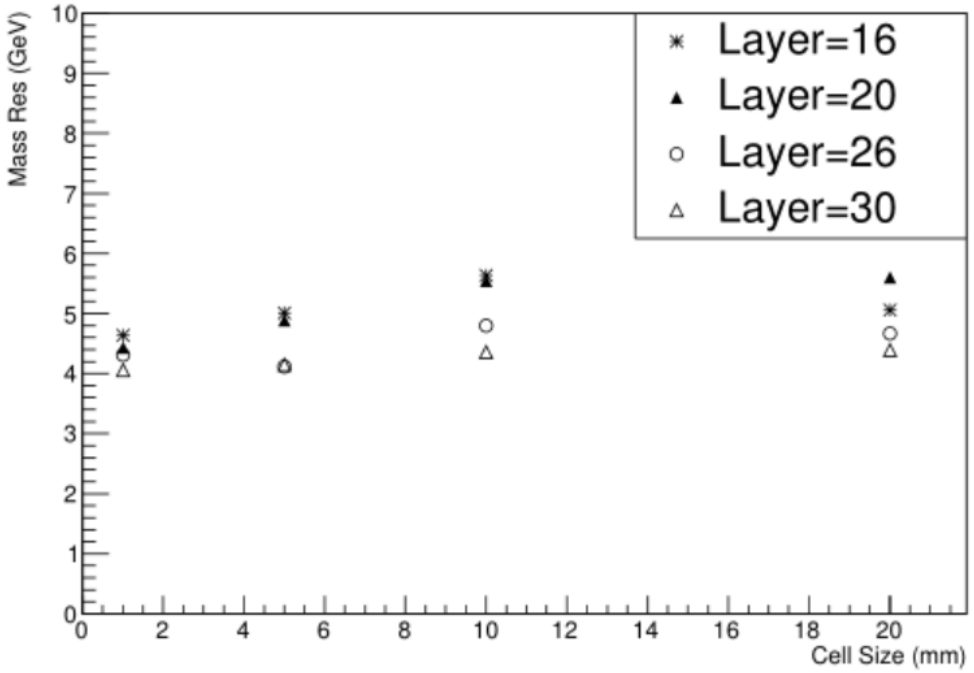


Calorimeter Optimization (ECAL)

Jifeng Hu, Jing Li, Liang Li, Haijun Yang (SJTU)



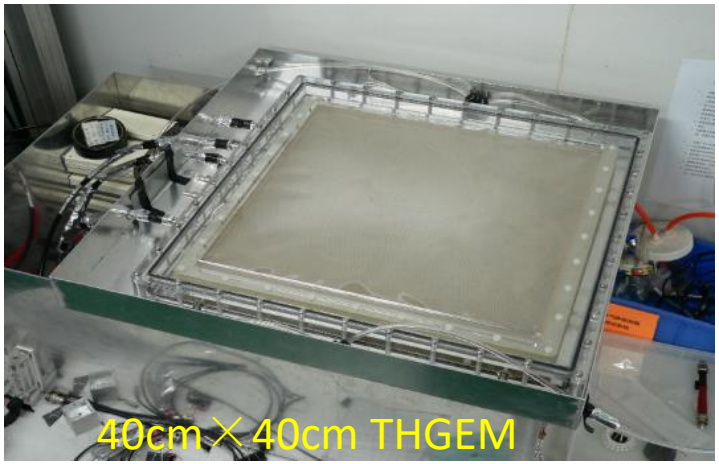


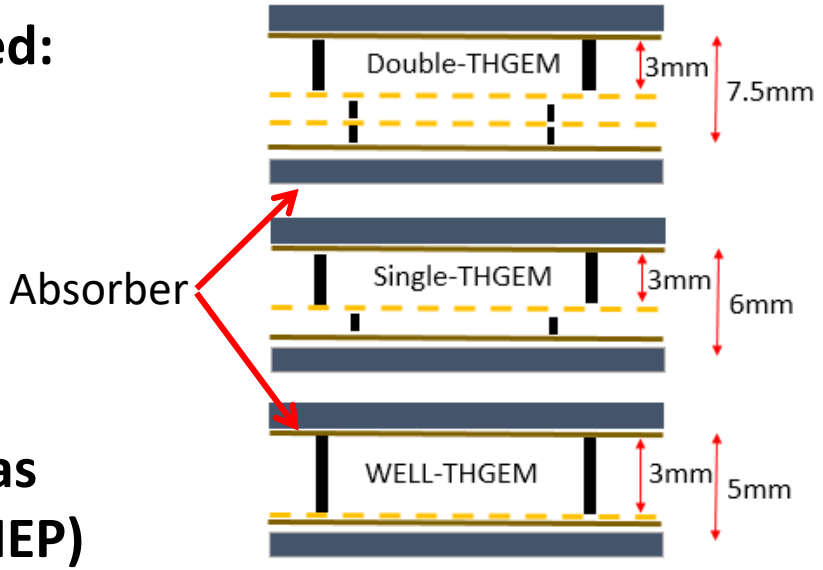


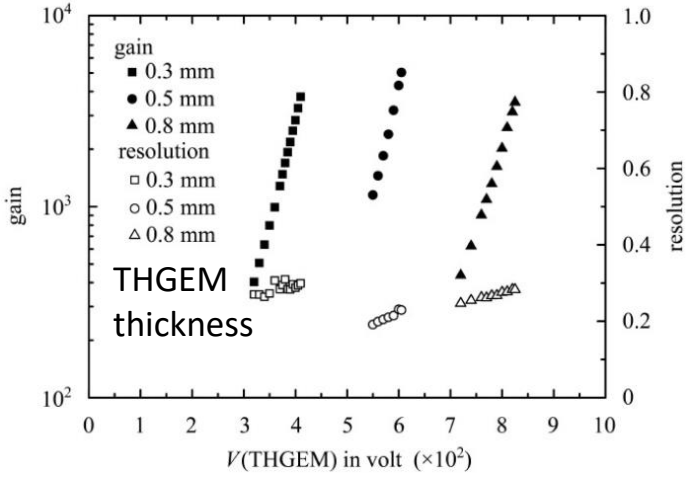
DHCAL based on THGEM

Boxiang Yu (IHEP)

- Three THGEM options are explored:
  - Double - THGEM
  - Single - THGEM
  - WELL - THGEM
- WELL-THGEM is optimal choice
  Thinner, lower discharge
- 40 × 40 cm² of THGEM (below) was produced in China (UCAS, GXU, IHEP)





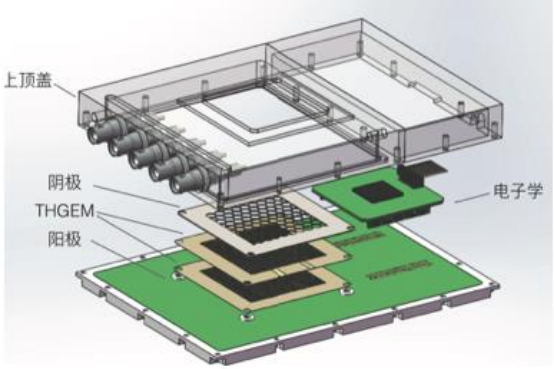


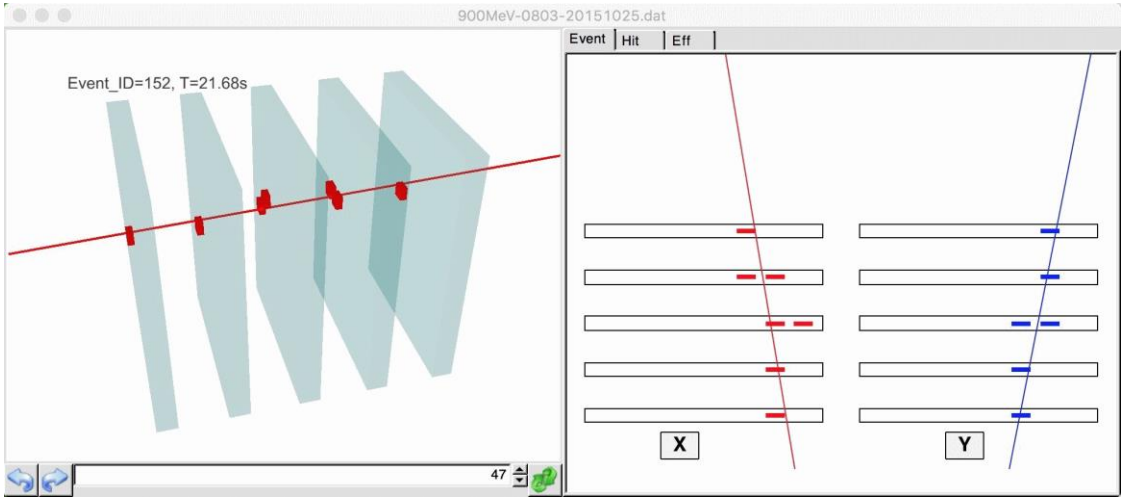
WELL-THGEM Beam Test @ IHEP

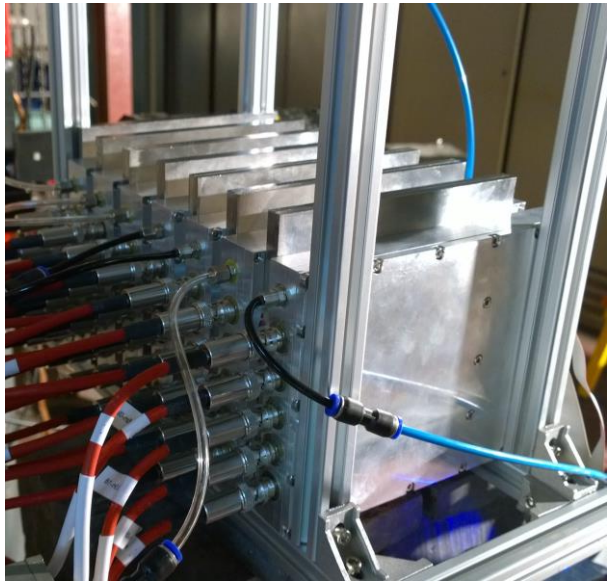
Hongbang Liu, Qian Liu (UCAS)

- 7 THGEMs ware installed, and 5 of them were used, and flushed with Ar/iso-butane = 97:3.
- 1 threshold, binary readout
- 900 MeV proton beam was used
- 5x5cm2 sensitive region

  → 20 x 20 cm2







Calorimeters R&D Plan (near term)

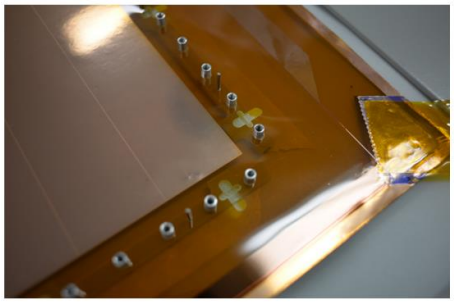
- IHEP: Zhigang Wang, Hang Zhao, Tao Hu
  - SiPM Test
  - Scintillator strip optimization
- USTC: Yunlong Zhang, Shensen Zhao, Jianbei Liu
  - Si-PMT linearity test
  - Electronics board design and test
- SJTU: Haijun Yang, Liang Li, Jifeng Hu, Bing Liu, Jing Li
  - SDHCAL performance study, PCB design
  - Calorimeter design based on benchmark H→$\gamma\gamma$ and WW
- IHEP+UCAS: Boxiang Yu, Qian Liu, Hongbang Liu
  - Thick GEM study with large active area (20x20cm^2)

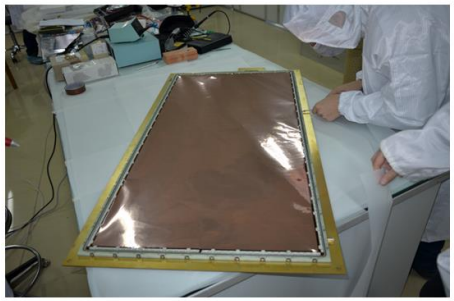
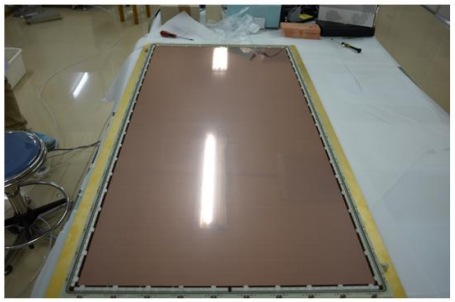
Backup Slides

Large-area GEM @ USTC

Jianbei Liu (USTC)

GEM assembly using a novel self-stretching technique

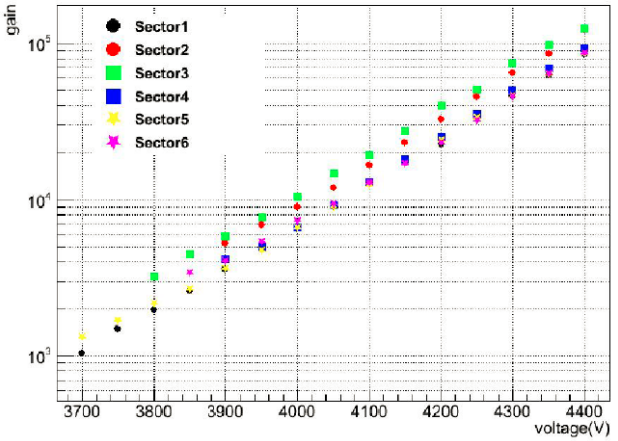


APV25 GEM readout

INFN APV25 chip

Sector1~6



- Large-area GEM (0.5x1m^2) is one of main detector R&D focuses at USTC recently.
- Technology has been developed and matured to produce high-quality GEM detectors as large as ~1m^2 that are also applicable to CEPC DHCAL.

➔ **Resolution uniformity ~11%**
➔ **Gain uniformity ~16%**
➔ **Can reach gain of 10^4 at 4000V**

科技部国家重点研发计划

“高能环形正负电子对撞机相关的物理和关键技术预研究”

课题四：探测器关键技术预研

课题编号：2016YFA0400404

本课题分为四个探测技术研究方向：

(1) 硅探测器ASIC芯片设计

(2) 时间投影室关键问题研究

(3) 电磁和强子量能器关键技术研究

(4) 大动量范围粒子鉴别技术研究

项目负责人：高原宁（清华大学）

课题负责人：杨海军（上海交通大学）

参加单位：高能所、科大、清华、华师、交大

参加骨干13人：4正高、8副高、1中级

团队成员：4 职工、5 博士后、15 研究生

CEPC Calorimeters for MOST project

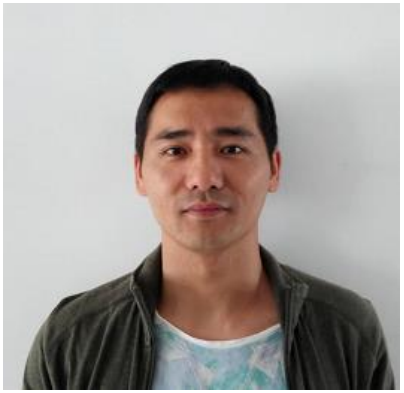
ECAL：2 Faculty，1 Postdoc(牛顺利)，2 Ph.D students, 2 Master students

王志刚（副研，高能所）

张云龙（副研，科大）

HCAL：3 Faculty, 1 Staff，1 Postdoc(胡继峰)，3 Ph.D，2 Master students

杨海军（教授,交大）



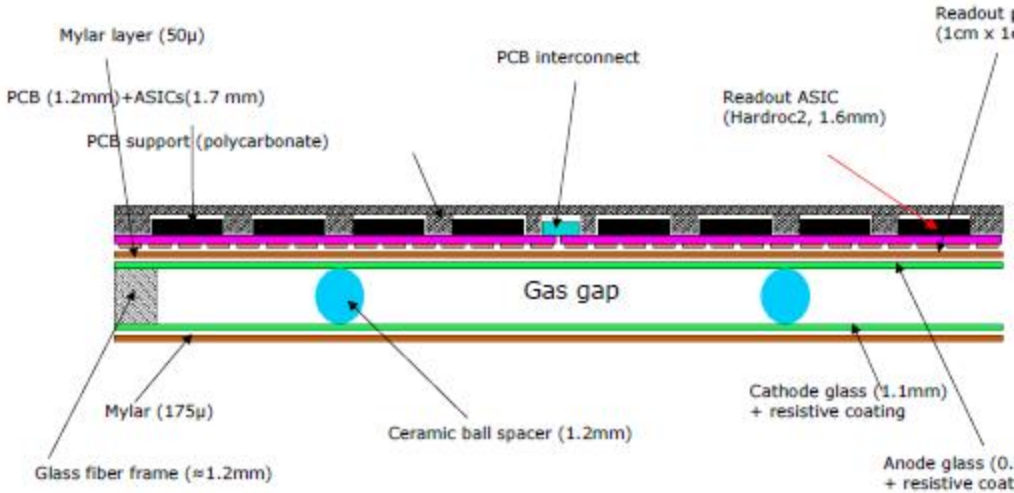
俞伯祥（副研，高能所）

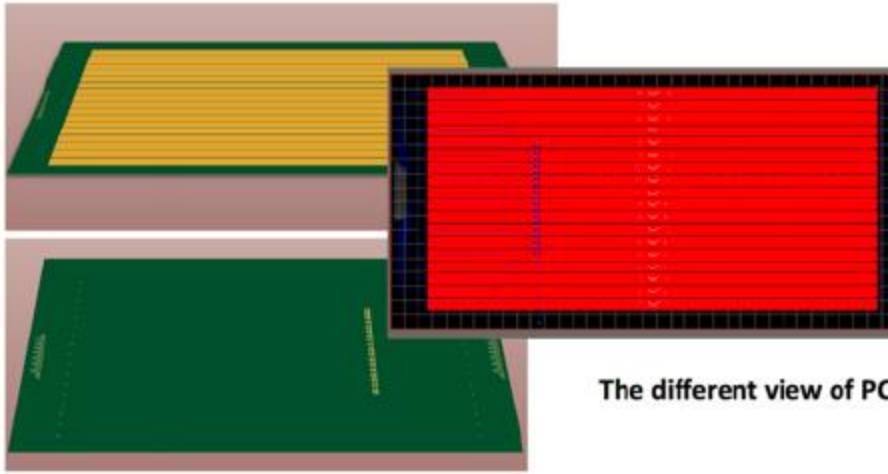
李昕（副研，科大）

RPC R&D

From Haijun Yang (SJTU)

- Large Glass RPC R&D
  - Negligible dead zone
  - Large size: 1x1 m^2
  - Cost effective
  - Efficient gas distribution system
  - Homogenous resistive coating





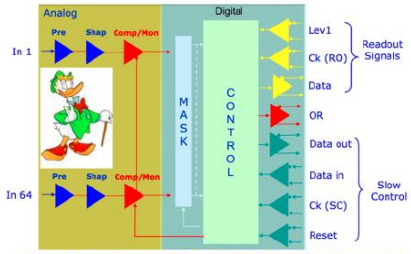
The different view of PC

CONCLUSION

- Detector simulation:
  - Granularity of calorimeters optimization
  - Number of layers of calorimeters optimization
  - Digitization (RPC/GEM/THGEM)
- Detector R&D
  - RPC (Glass RPC, Polyamide RPC)
  - GEM (double GEM structure, self-stretching)
  - THGEM (Well-THGEM, double THGEM structure)

DAQ SYSTEM: GASTONE

From Qian LIU/Hongbang LIU (UCAS / GXU)

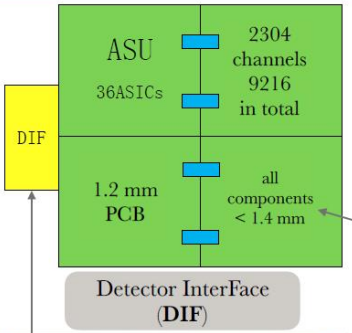


GASTONE (Gem Amplifier Shaper Tracking ON Events)

N channels	64
Chip dimensions	4.5 × 4.5 mm^2
Input impedance	120 Ω
Charge sensitivity	16 mV/fC (C_{det}=100 pC)
Peaking time	90 ns (C_{det}=100 pC)
Crosstalk	<3%
ENC	800 e$^-$+40 e$^-$/pF
Power consumption	~6 mW/ch
Readout	Serial LVDS (100 Mbps)

HARDROC/MICROROC

From Jianbei LIU (USTC)

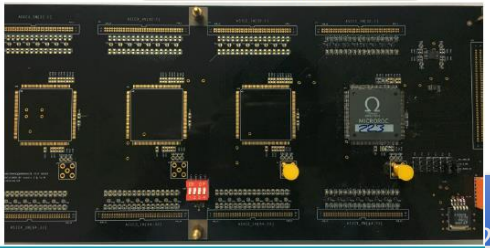


Detector InterFace (**DIF**)

Multi-thresholds	channels	Dynamic range
Hardroc2	64	10fC~10pC
Hardroc3	64	10fC~50pC
Microroc	64	1fC~500fC

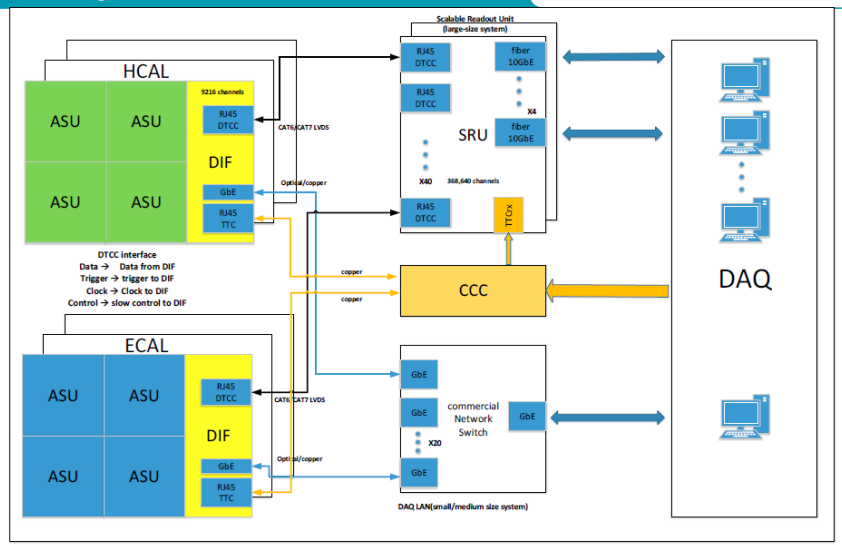
MICROROC is dedicated chip for GEM/MICROMEGAS. MICROROC (pin pin compatible with HR2b) is based on HR2b same back-end, same readout format, same pinout, only the preamplifier is changing.

Active Sensor Unit (**ASU**) Test boards



DAQ SYSTEM DESIGN

From Jianbei LIU (USTC)



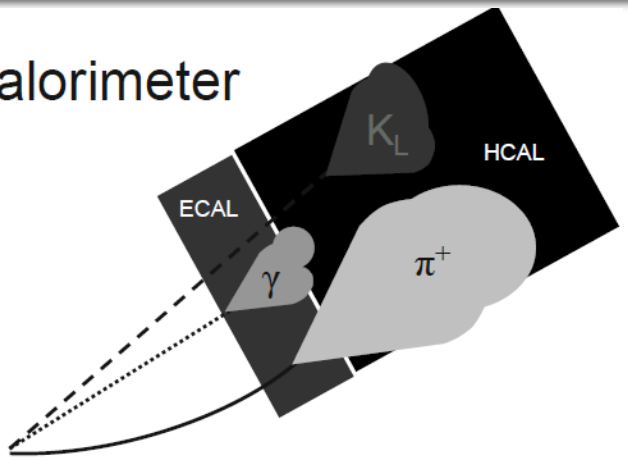
Imaging Calorimeter based on PFA

Particle Flow Algorithms and Imaging Calorimeter

The idea…

Charged particles } measured with the { **Tracker**

Neutral particles } { **Calorimeter**

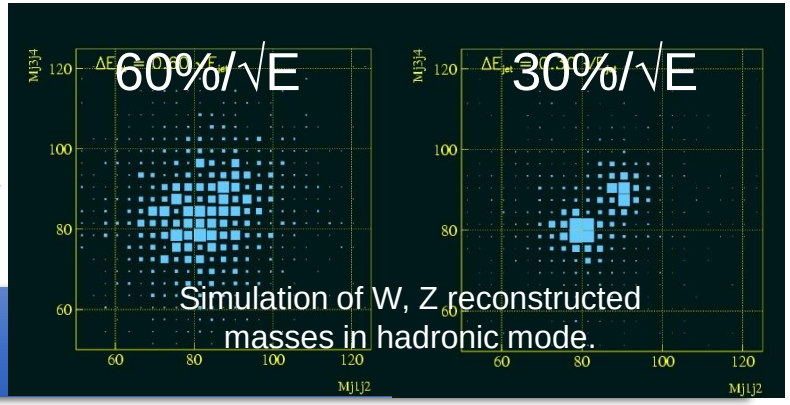


Particles in jets	Fraction of energy	Measured with	Resolution [σ^2]
Charged	65 %	Tracker	Negligible
Photons	25 %	ECAL with 15%/√E	$0.07^2\ E_{jet}$
Neutral Hadrons	10 %	ECAL + HCAL with 50%/√E	$0.16^2\ E_{jet}$
Confusion		Required for 30%/√E	$\leq 0.24^2\ E_{jet}$

} 18%/√E

Requirements for detector system

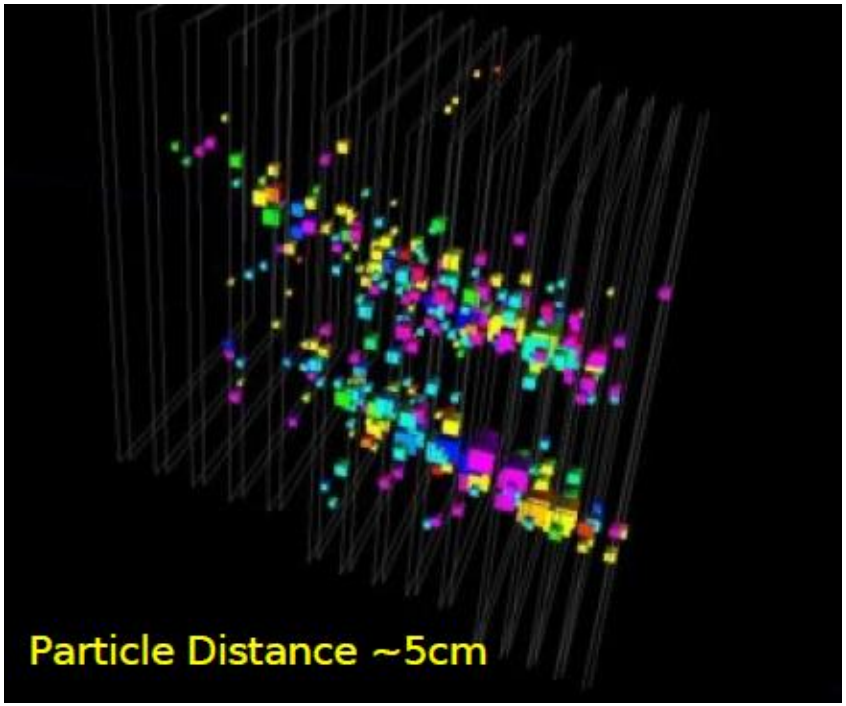
→ Need excellent tracker and high B – field
→ Large R_I of calorimeter
→ Calorimeter inside coil
→ Calorimeter as dense as possible (short X_0, λ_I)
→ Calorimeter with **extremely fine segmentation**



Simulation of W, Z reconstructed masses in hadronic mode.

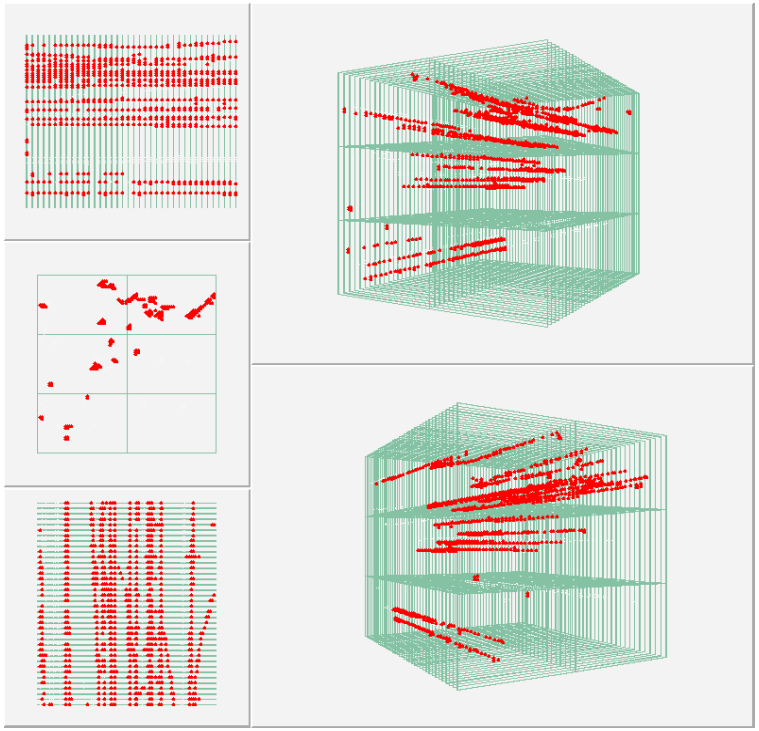
Imaging Calorimeters

L. Xia @ ANL



Two electrons ~5cm apart

SiW ECAL



~20 muons in 1m^2 area

RPC DHCAL

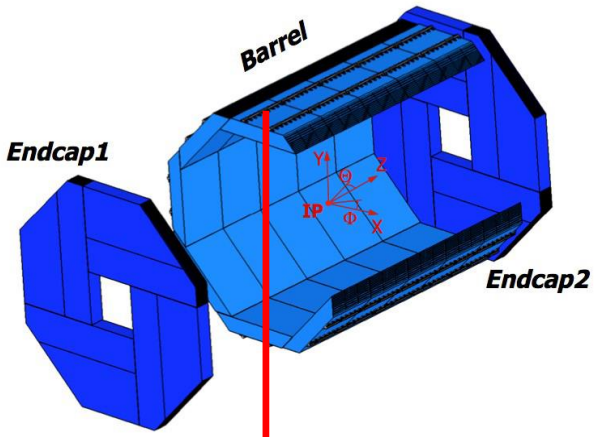
➔ **PFA requires calorimeters to separate the showers of jets.**

探测器课题任务分解

各子课题有多个单位参与研制，分工合作，密切配合。

	高能所	科大	清华	华师	交大
硅探测器	芯片设计			流片测试	
时间投影室	样机研制、测试		读出芯片设计测试		
电磁量能器	样机研制、散热研究、测试	读出电子学设计			
强子量能器	ThGEM单元研制测试	GEM单元研制测试			RPC单元研制测试
环像契伦科夫探测器		样机研制、测试			

电磁量能器研究目标



研究目标和考核指标：

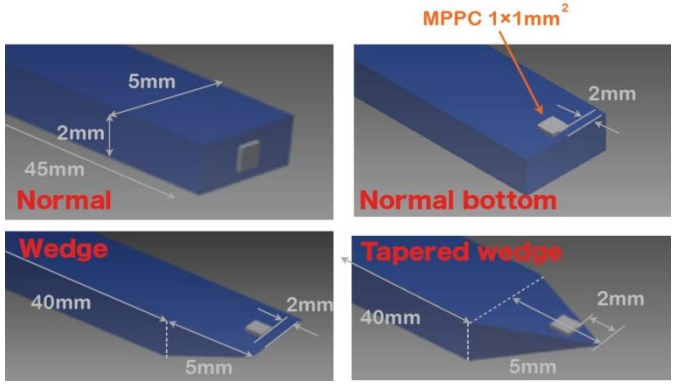
(1)解决基于SiPM读出电磁量能器的技术选型问题；

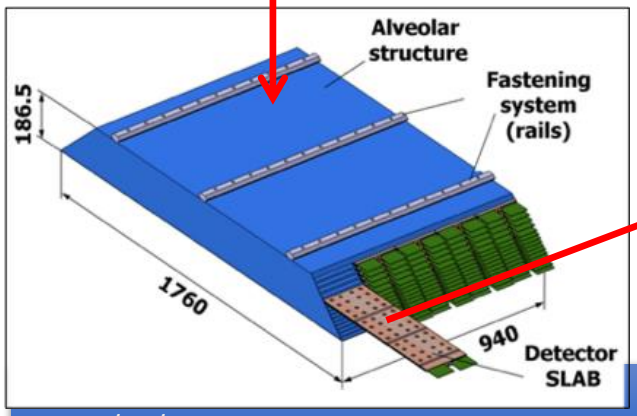
(2)实现电磁量能器读出单元颗粒度达到 5×5 mm^2；

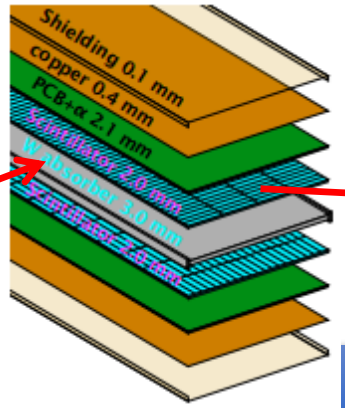
(3)研制小型电磁量能器原理样机；

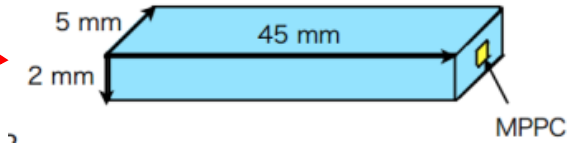
(4)针对CEPC的特点，研制一套基于两相二氧化碳制冷的主动散热系统，在-20^{0}C下，导热量大于30mW/cm^2；

(5)发表2-3篇论文。









基于塑料闪烁体和硅光电探测器

强子量能器研究目标

研究目标和考核指标：

1. 得到数字强子量能器的技术选型；

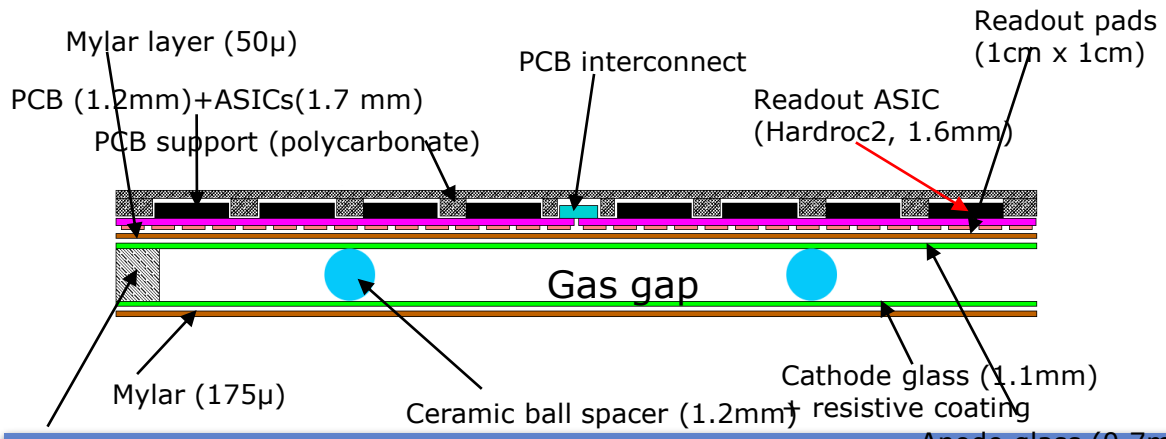
2. 在颗粒度达到1x1cm^{2}条件下，掌握厚度小于6mm的气体探测器制作工艺；

3. 制作面积达到1m×0.5m的微孔型探测器单元模型，探测器的整体增益均匀性好于20%，计数率达到1MHz/s，MIP粒子探测效率好于95%；

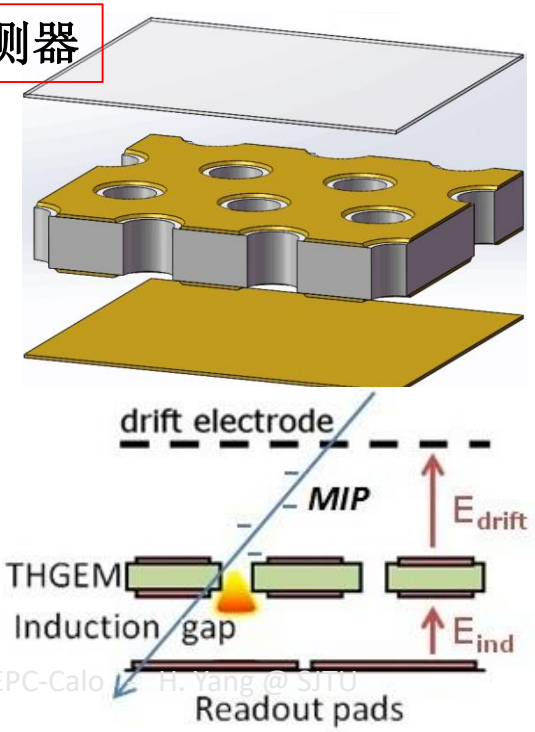
4. 制作面积达1m×1m的平板型探测器单元模型，MIP粒子探测效率好于95%；

5. 发表2-3篇论文。

RPC平板型探测器



微孔型探测器



科技部项目探测器课题参与人员

- 课题负责人：杨海军

  参加单位5家：高能所、科大、清华、华师、上海交大

  参加骨干13人：4正高、8副高、1中级

  团队成员：4职工、5博士后、15研究生

- 高能所：欧阳群，魏微，卢云鹏，祁辉荣，王志刚，俞伯祥

  职工：董明义、董静、张杰、赵梅；

  博士后：周扬，鞠旭东，牛顺利，

  学生：吴志岗、宋龙龙，张余炼，王海云，赵航，夏莉

- 科大：刘建北，张云龙，李昕，

  博士后：张志永，学生：牛亚洲

- 清华：邓智，学生：刘丰，赵馨远

- 华师：孙向明，杨苹，职工：肖乐、高超嵩

  学生：周威、黄兴、任伟平、刘建超、李雅淑

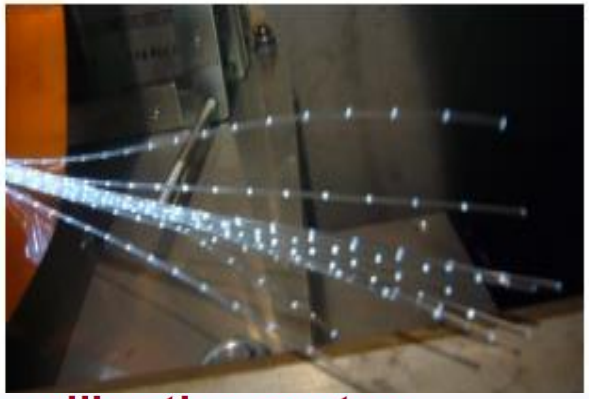
- 上海交大：杨海军，博士后：胡继峰，学生：刘冰

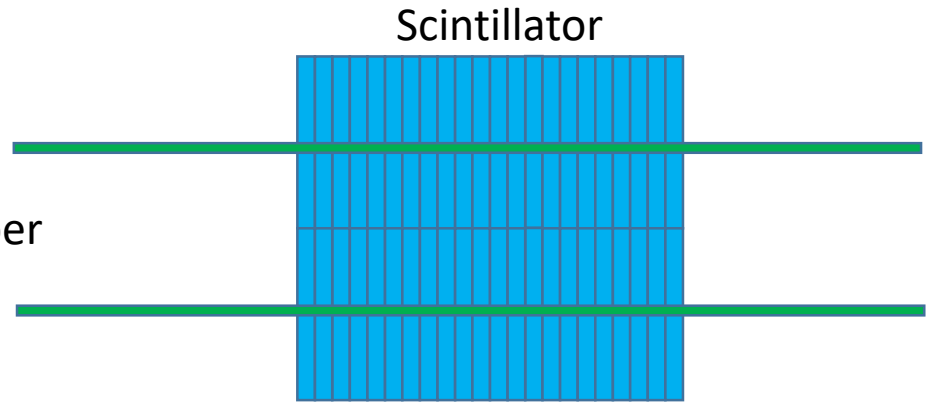
- 拟招聘：1-2名职工，2-3名博士后，8-10名研究生

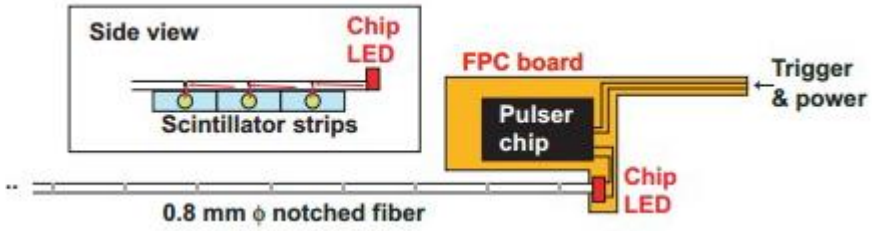
科技部CEPC预研究项目启动会

塑料闪烁体刻度系统

ECAL塑料闪烁体大约由800万闪烁条组成，需要对其光输出进行监测。
正在研究光路分配系统，通过监测光电子谱的峰研究SiPM增益的变化！







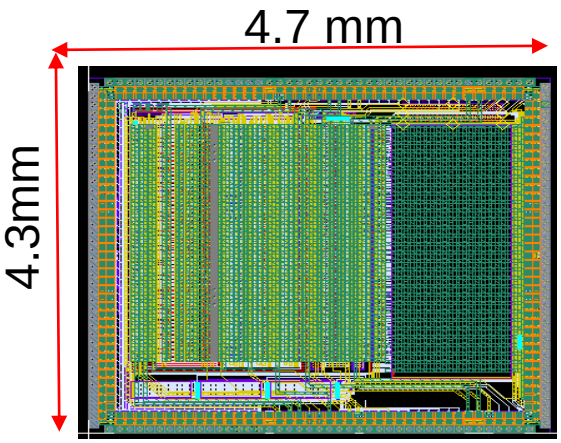
LED – 光纤刻度系统:

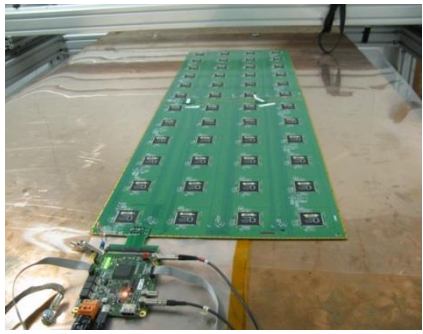
- 脉冲产生器，芯片LED 光导入带孔的光纤
- 带孔光纤把光传递到一组塑料闪烁条

RPC电子学读出系统

Imad Laktineh (IPNL)

ASICs : HARDROC2
64 channels
Trigger less mode
Memory depth : 127 events
3 thresholds
Range: 10 fC-15 pC
Gain correction → uniformity

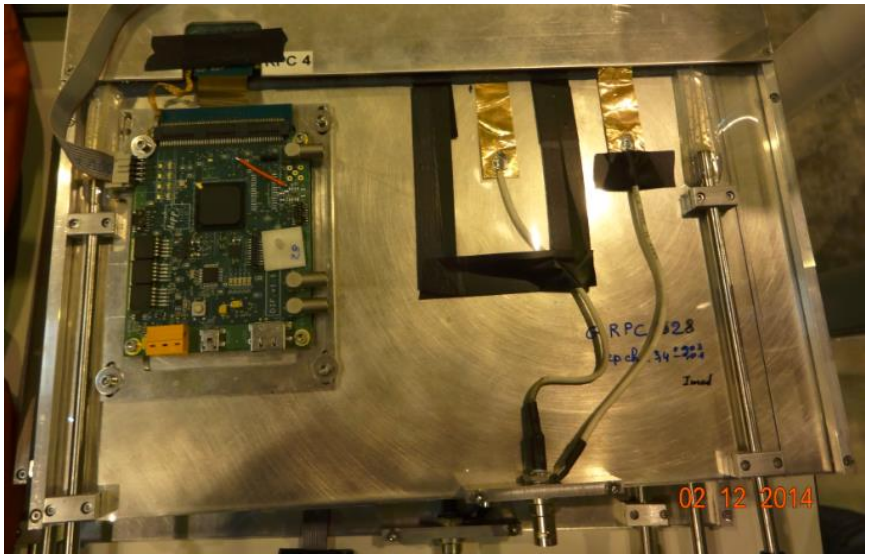




Printed Circuit Boards (PCB) were designed to reduce the cross-talk with 8-layer structure and buried vias.

Tiny connectors were used to connect the PCB two by two so the 24X2 ASICs are daisy-chained. $1\times1m^2$ has 6 PCBs and 9216 pads.

DAQ board (DIF) was developed to transmit fast commands and data to/from ASICs.



DHCAL Simulation

Boxiang Yu (IHEP)

- Absorber: 2cm stainless steel
- Drift gap: 3mm
- No. of layers: 40, 50
- Ecell = 1, 5 and 10MIP if the charge is above the thresholds typically placed at 0.1, 1.5 and 2.5 MIPs