CEPC的强子量能器的初步研究

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On behalf of CEPC-Calo Group
SJTU,IHEP,USTC,UCAS

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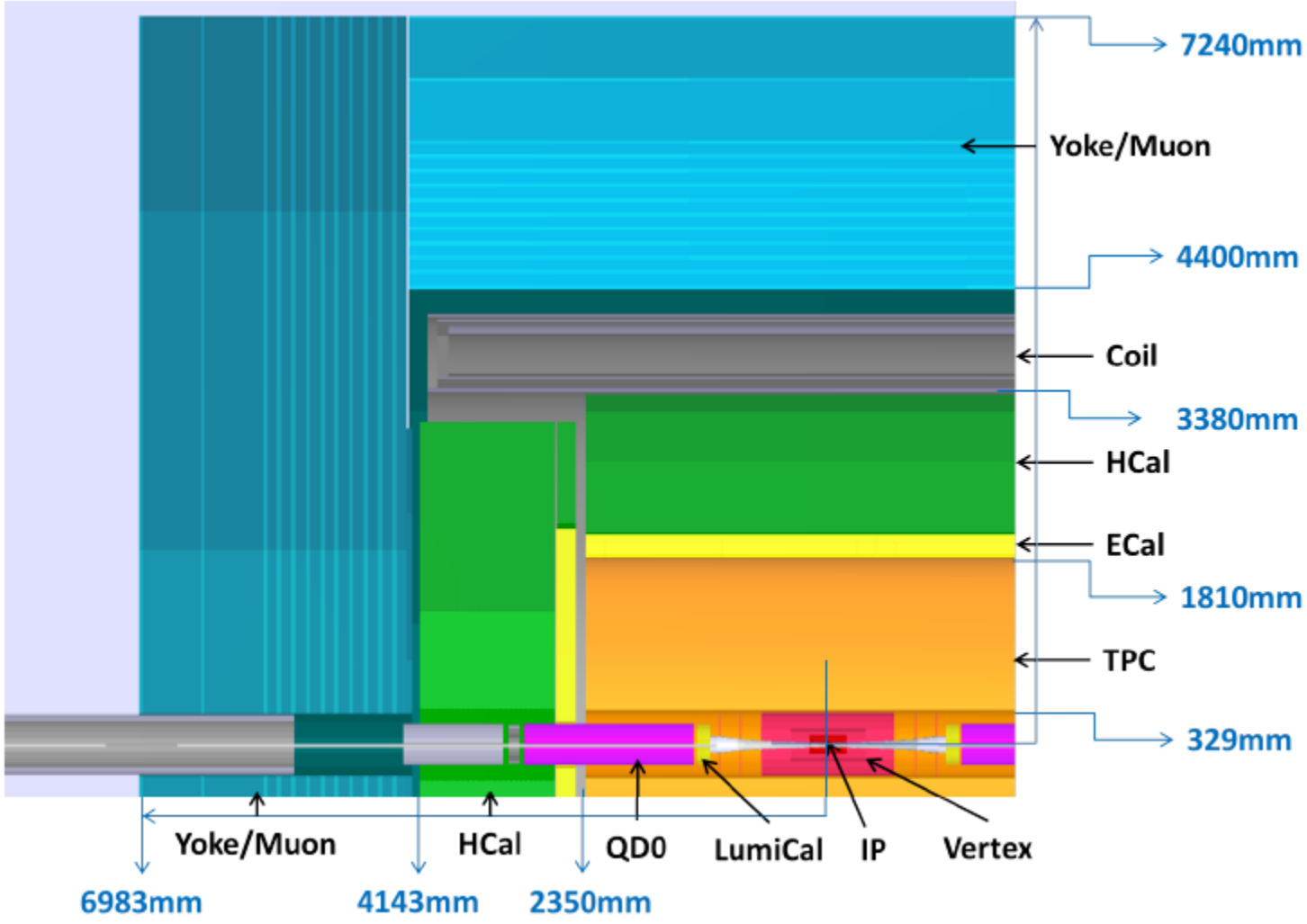
目录

CEPC概述

- 正负电子对撞机有本底低且初态精确可调的特点，而CEPC的质心能量可以达到Higgs粒子的产生阈值（~240 GeV）进而产生大量的干净Higgs粒子（Higgs工厂），利用CEPC，人们可以对Higgs粒子以及其他的标准模型粒子（比如Z粒子）进行精确测量，从而搜索出新物理乃至预言新物理能标。
- 初步拟选址区位于深汕特别合作区中部和汕尾市、惠东县东部；

CEPC探测器的初步设计
(From CEPC-PreCDR)



PFA-HCAL的国际研究现状

PFA: current status

- Relevant jet energy scale

$\sqrt{s}$	#fermions	Jet energy
250 GeV	4	~60 GeV
500 GeV	4 – 6	80 – 125 GeV
1 TeV	4 – 6	170 – 250 GeV
3 TeV	6 – 8	375 – 500 GeV

ILC - like

CLIC - like

- PFA performance: PandoraPFA + ILD + uds jets

	E_{JET}	$\sigma_E/E = \alpha/\sqrt{E_{jj}}$ $\lvert\cos\theta\rvert<0.7$	σ_E/E_j
	45 GeV	25.2 %	3.7 %
rms_{90}	100 GeV	29.2 %	2.9 %
	180 GeV	40.3 %	3.0 %
	250 GeV	49.3 %	3.1 %

★ Equivalent stochastic term shown for comparison, PFA resolution is not stochastic, CONFUSION

ILC Goals: ~3.5 % jet energy resolution for 50 – 250 GeV jets

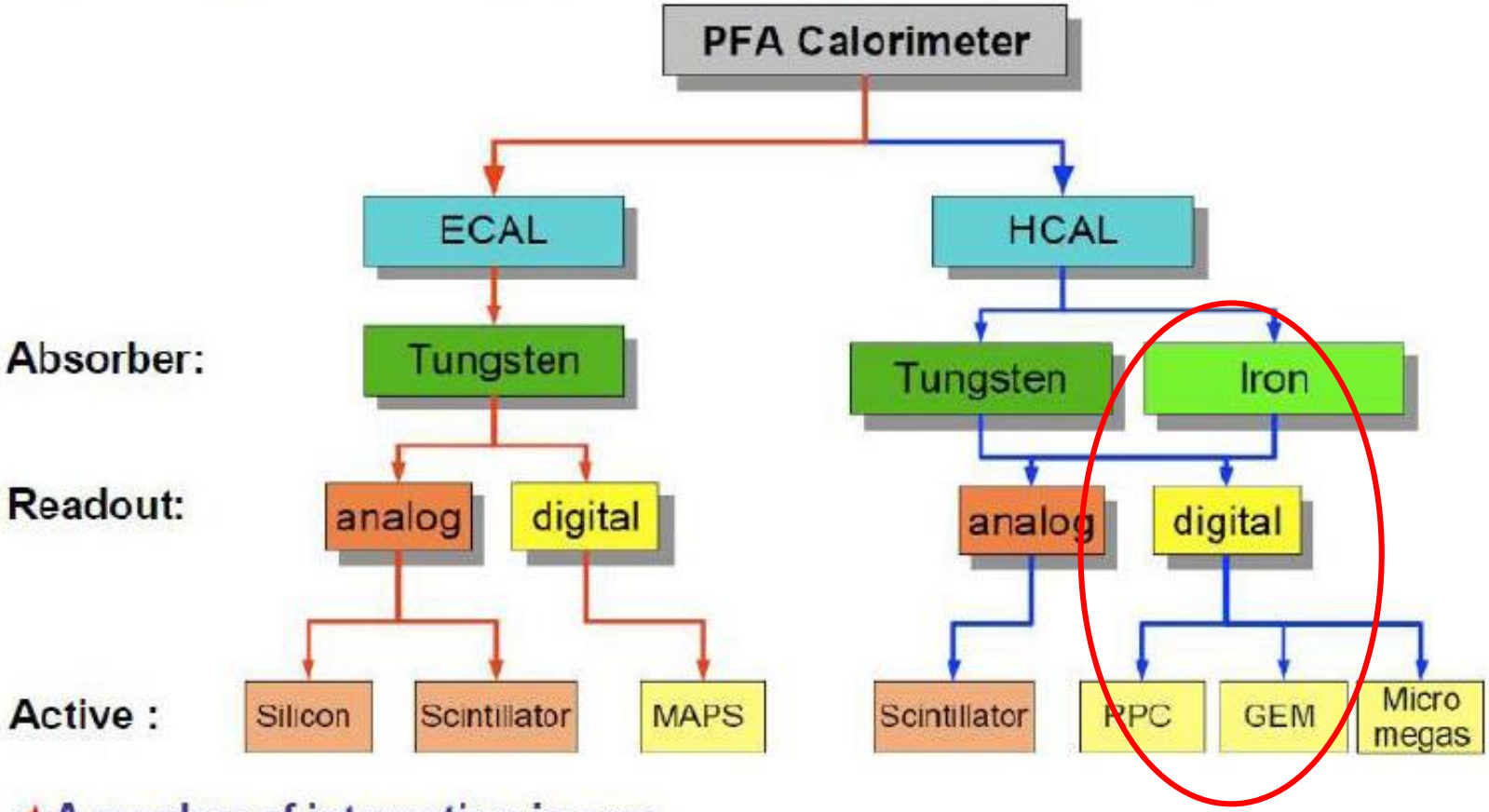
CLIC Goals: ~3.5 % jet energy resolution for 100 – 500 GeV jets

Credit: Mark Thomson, CALOR'2010 talk

PFA is up to the task ← if we DO have an imaging calorimeter system

LC PFlow Calorimetry options

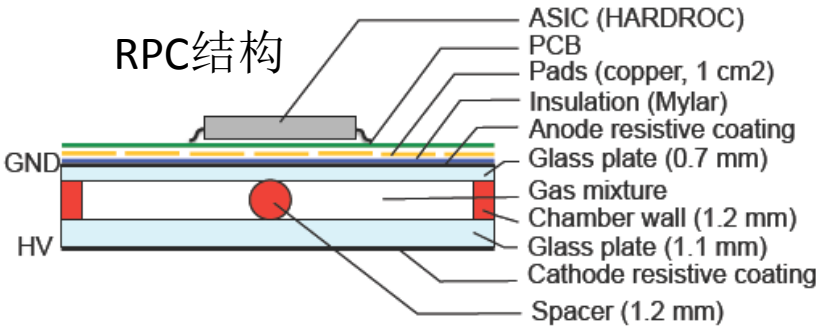
★ Various options for high granularity sampling calorimeters…

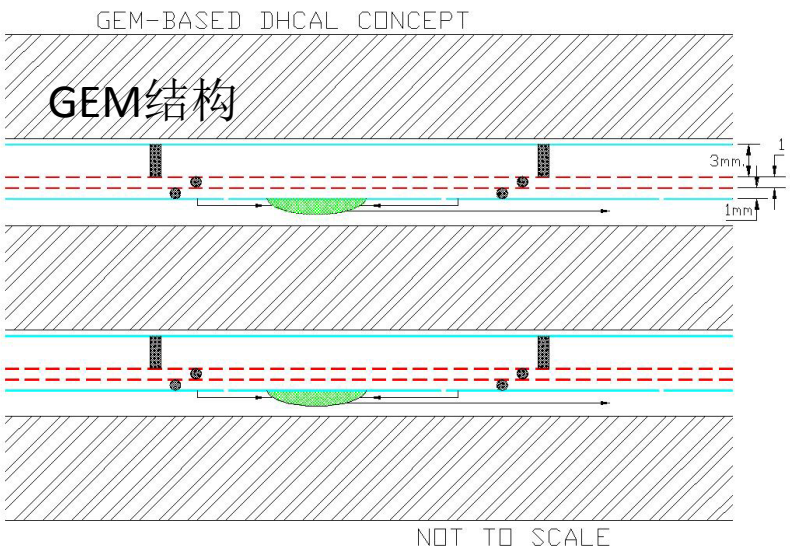


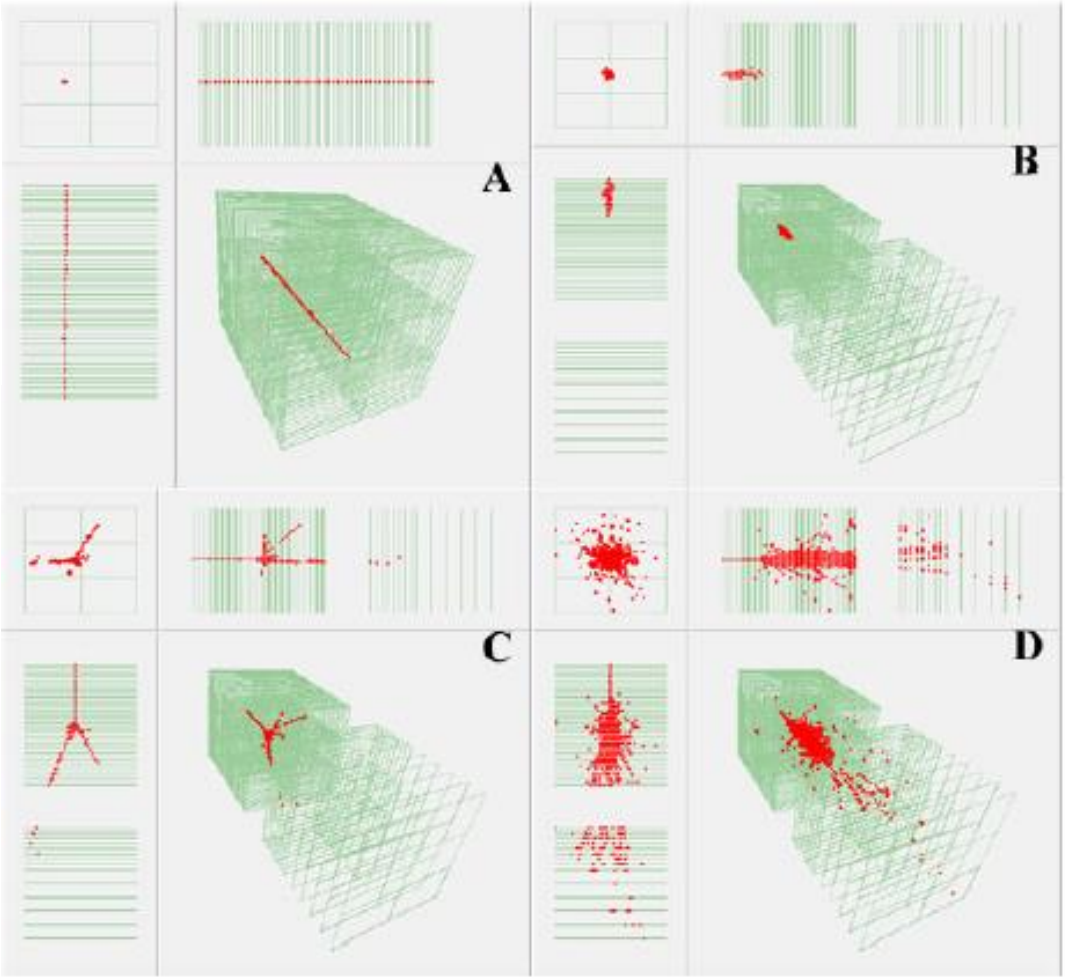
★ A number of interesting issues…

ILD基于气体探测器的DHCAL或者SDHCAL

- 主要是基于RPC或者GEM的方案，已经有prototype及束流实验结果；

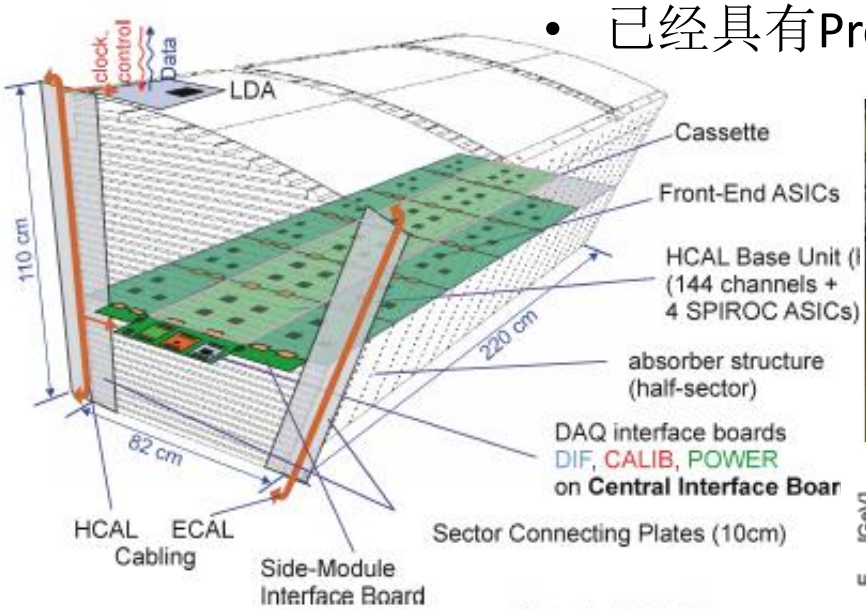


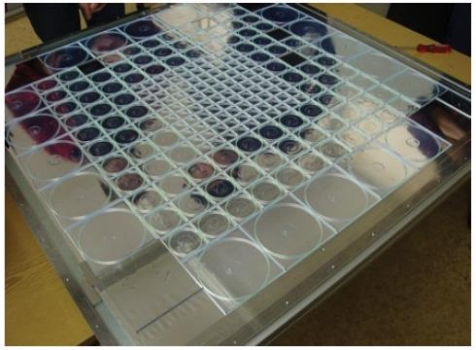


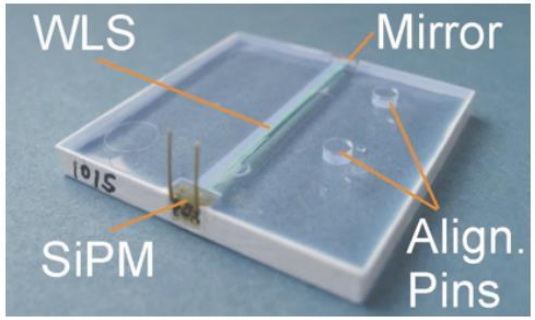


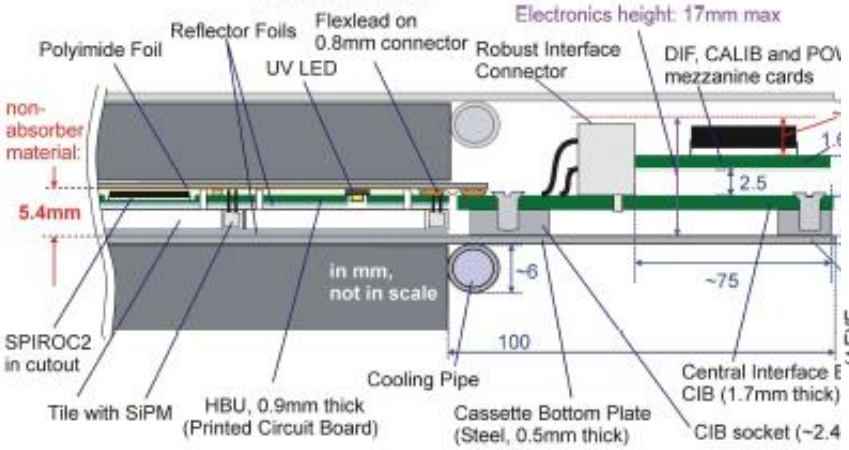
ILD基于塑料闪烁体的AHCAL

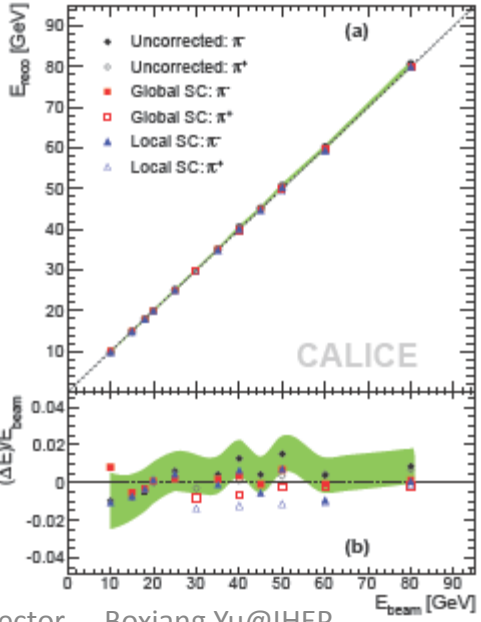
- 塑料闪烁体+WS fiber+SiPM的方案；
- 已经具有Prototype和Beamtest的结果；

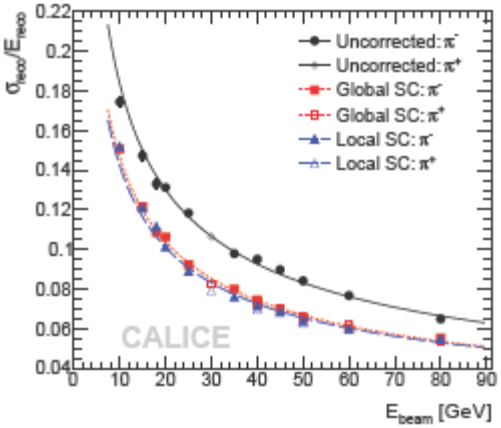












fit results		
	stochastic	constant
initial	57.6%	1.6%
global SC	45.8%	1.6%
local SC	44.3%	1.8%

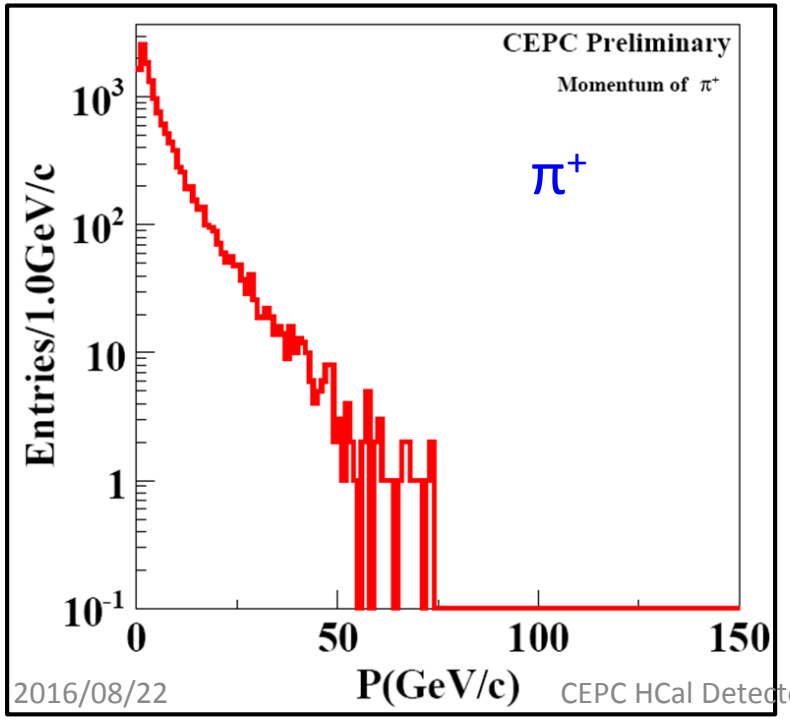
CEPC-HCAL的研究现状

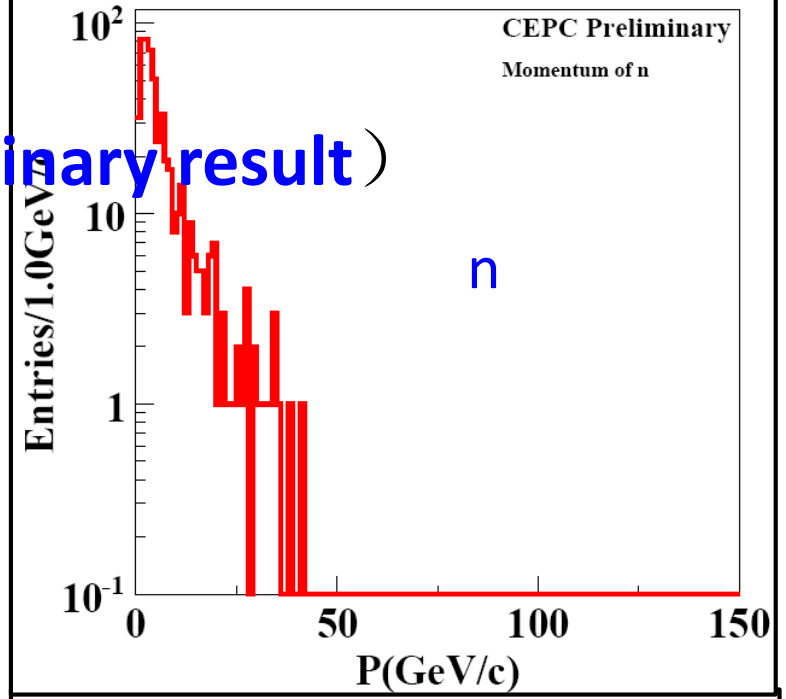
- Full-simulation 对探测器优化正在展开，优化探测器设计，包括能量分辨、层数、读出Pad大小；
- 几种灵敏探测器的候选方案正在开展研究，目前主要集中在基于气体探测器DHCAL的研究；
  - RPC探测器方案 (SJTU)；
  - THGEM探测器方案 (IHEP,UCAS)；
  - GEM探测器方案 (USTC)；
- MOST项目已经获得批准，探测器研究已经展开；

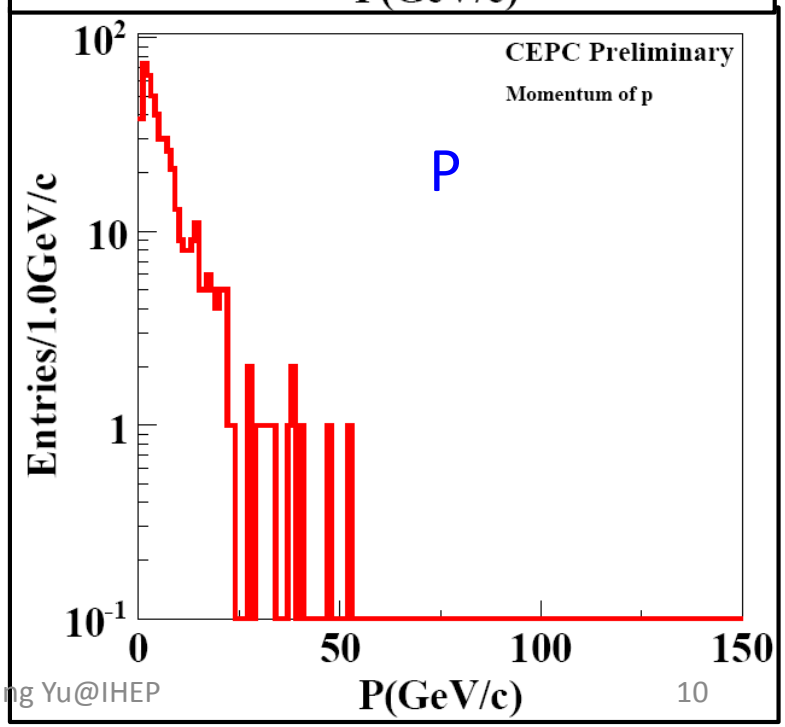
CEPC中的强子能量分布（preliminary result）

- 125GeV的e^+e^-的对撞（质心能量250GeV）得到的强子能谱；
- 绝大多数的强子能量要小于50GeV。
- 大量的强子是低能强子，需要保证它们能高效、准确地重建

Simulation Result from LiGang





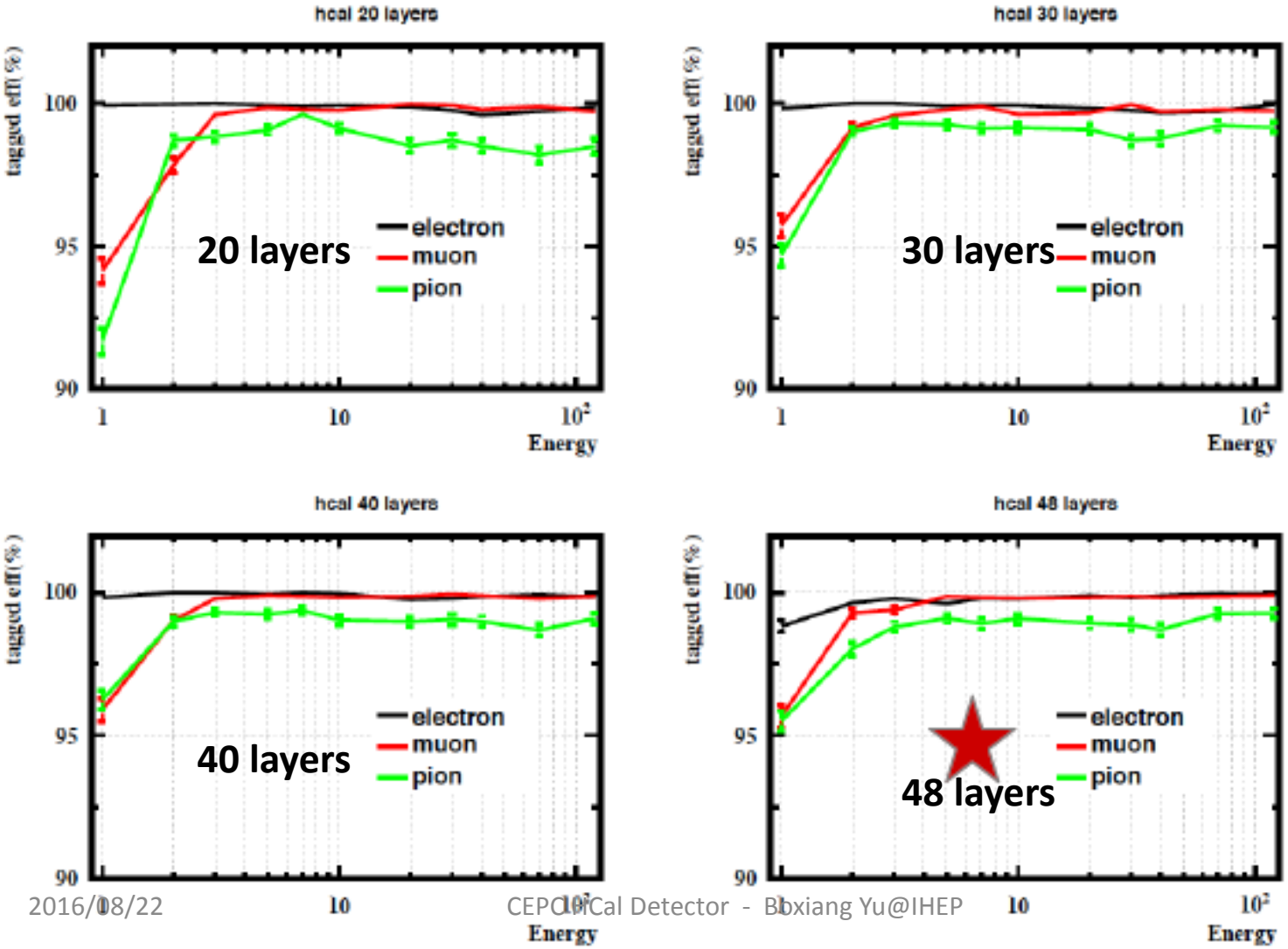


PID @ Different Granularity

Preliminary Simulation result from **Manqi and Dan Yu's talk（IHEP）**

HCAL层数对粒子鉴别的影响

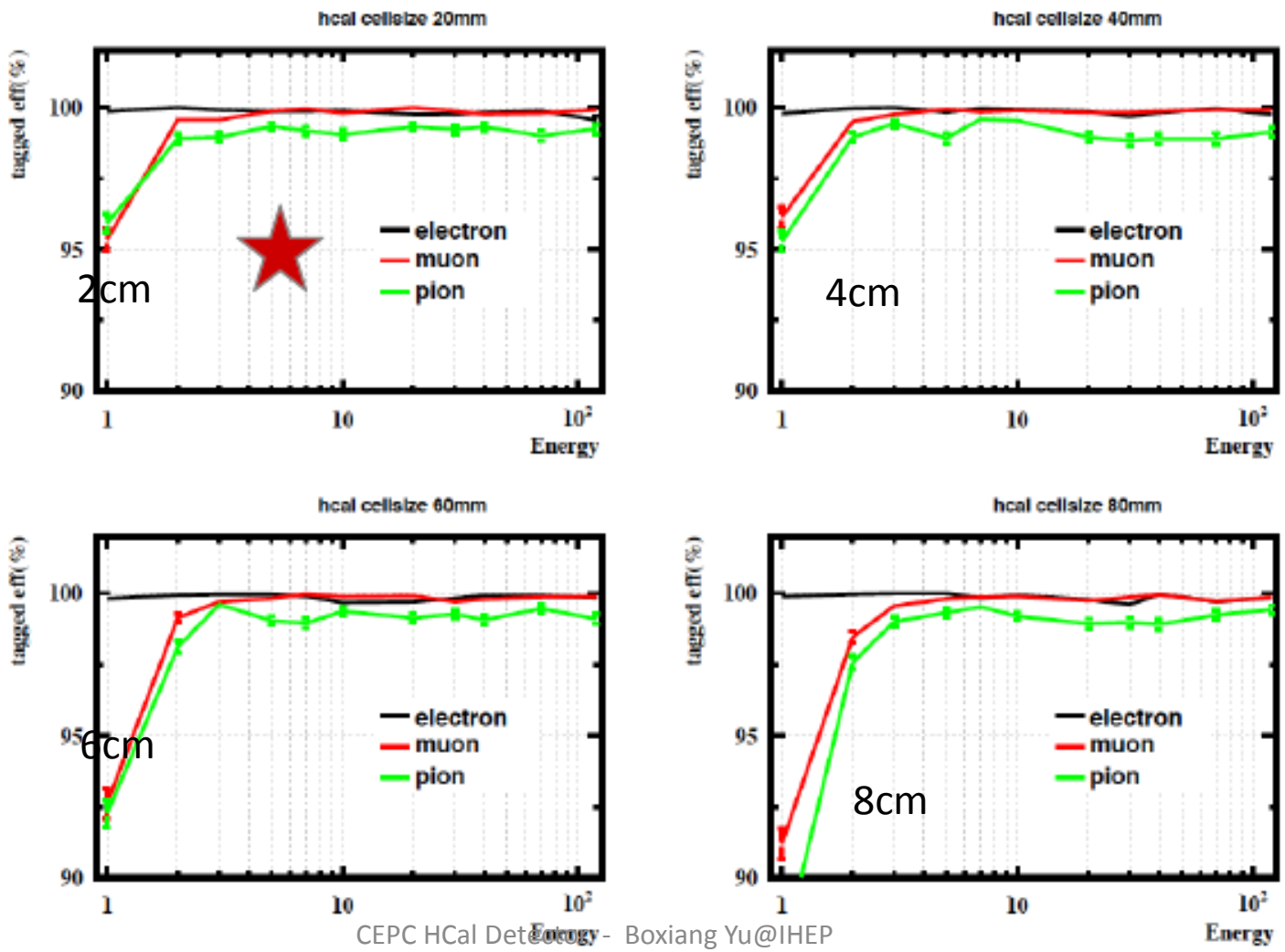
已系统解决了在不同颗粒度的量能器下的轻子鉴别问题



PID @ Different Granularity

Preliminary Simulation result from **Manqi and Dan Yu's talk（IHEP）**

读出Pad大小对粒子鉴别的影响
已系统解决了在不同颗粒度的量能器下的轻子鉴别问题



different ECAL & HCAL Layers

Preliminary Simulation result from **Manqi and Dan Yu's talk（IHEP）**

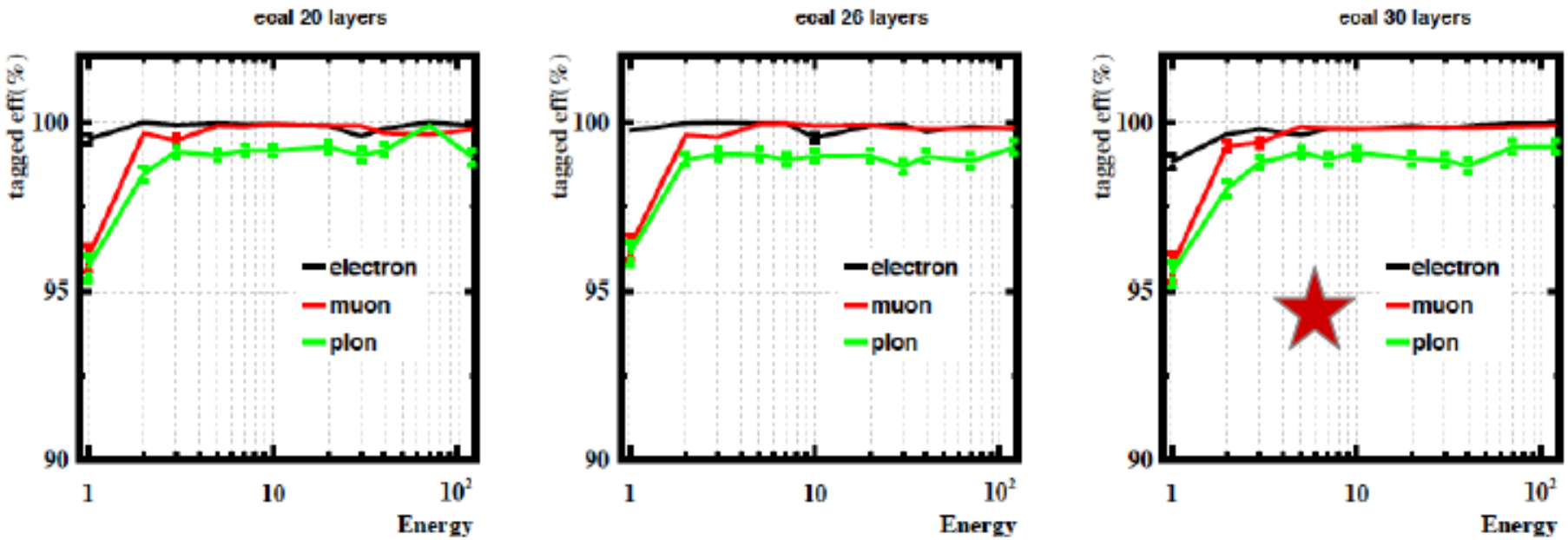
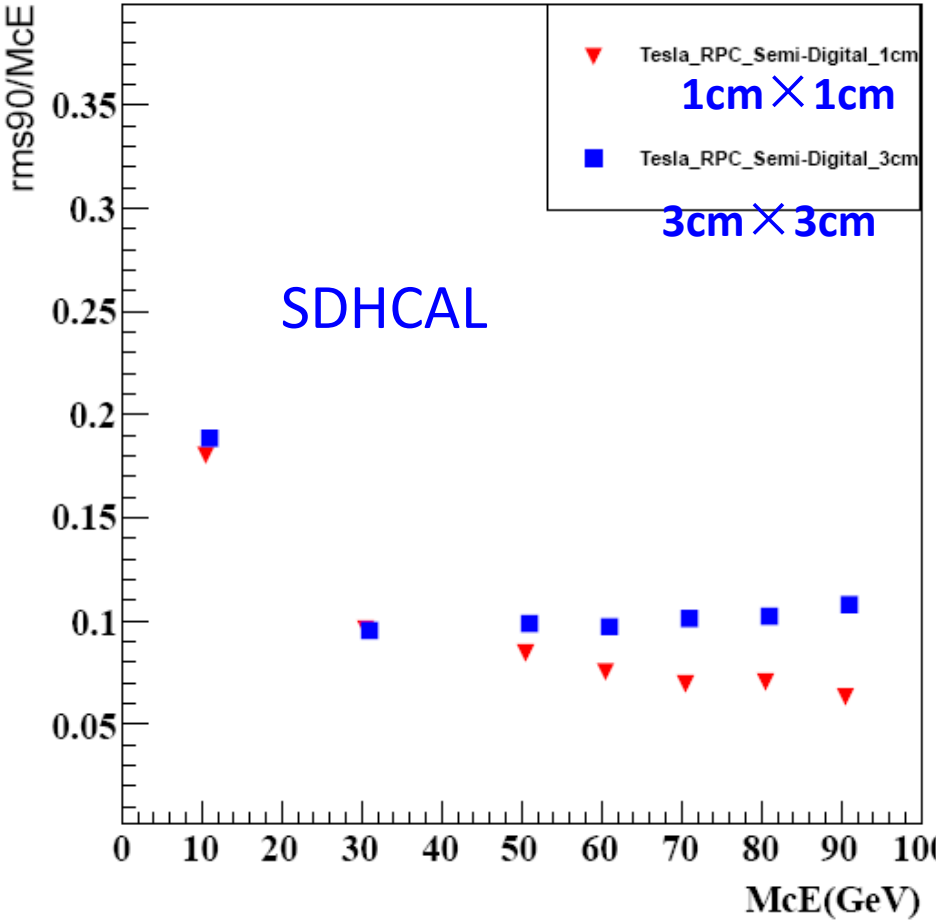


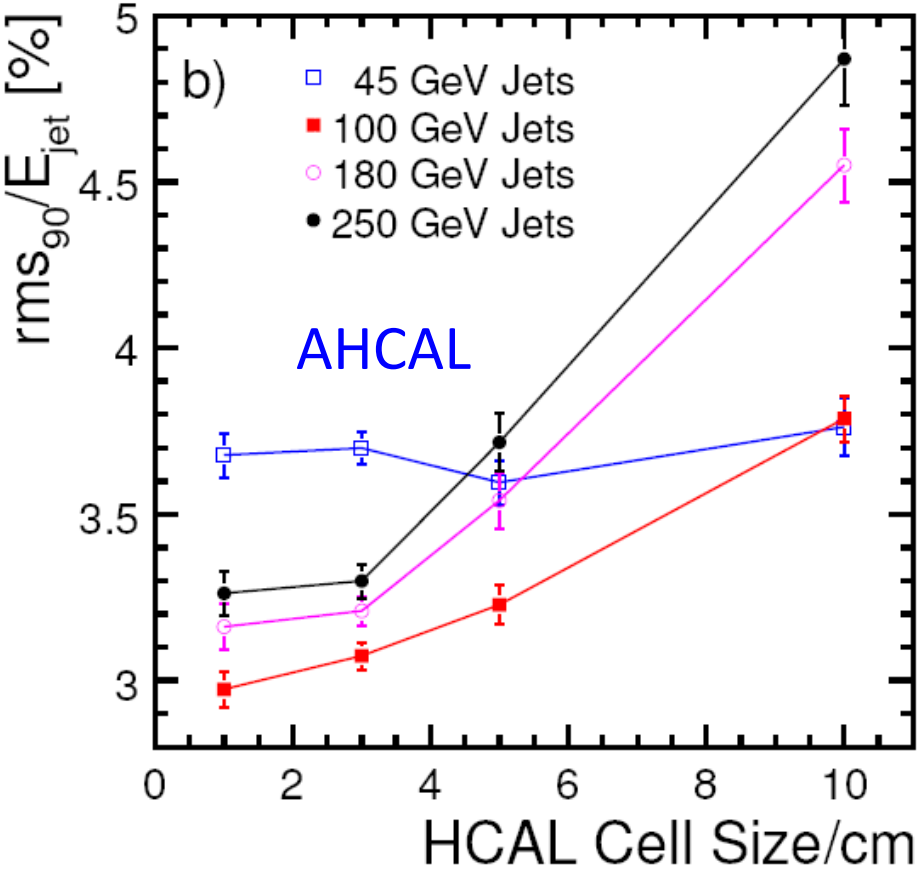
Table 3 $\mu\mu H$ events muon pid efficiency

	Geom 1	Geom 2	Geom 3
ECAL N layers	30	30	20
ECAL cell size	10	20	20
HCAL N layers	48	48	20
HCAL cell size	10	20	20
$\mu\mu H$ efficiency (%)	97.99 ± 0.44	96.48 ± 0.58	95.17 ± 0.73

channels compare to ILD:

ECAL	1/4	1/16	1/24
HCAL	1	1/4	1/10

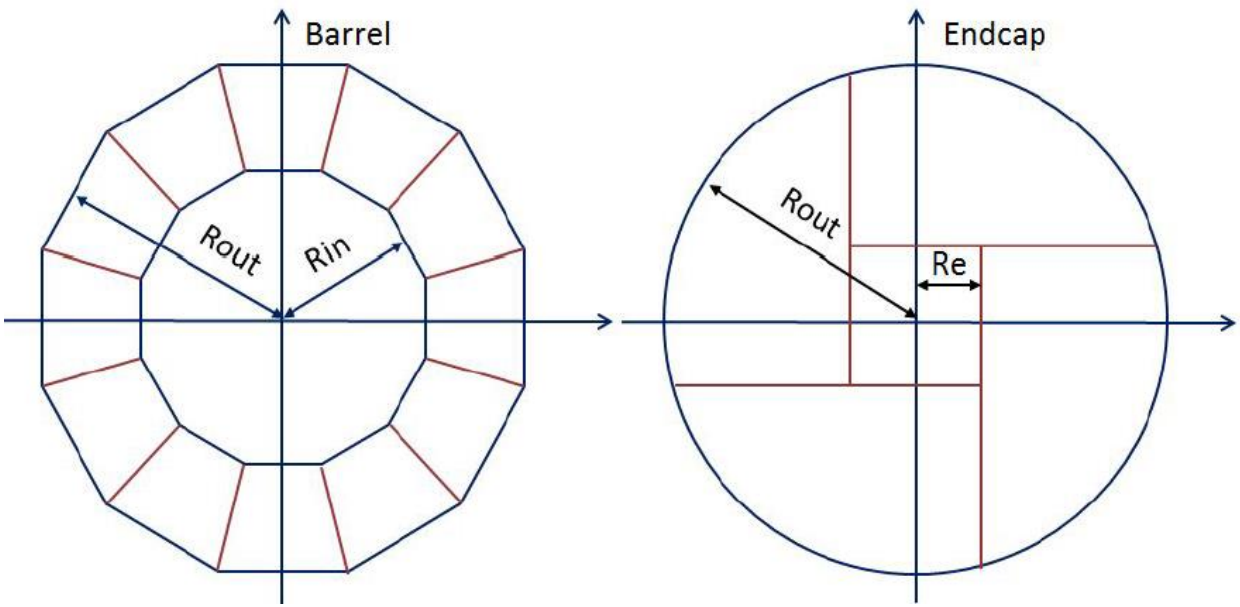




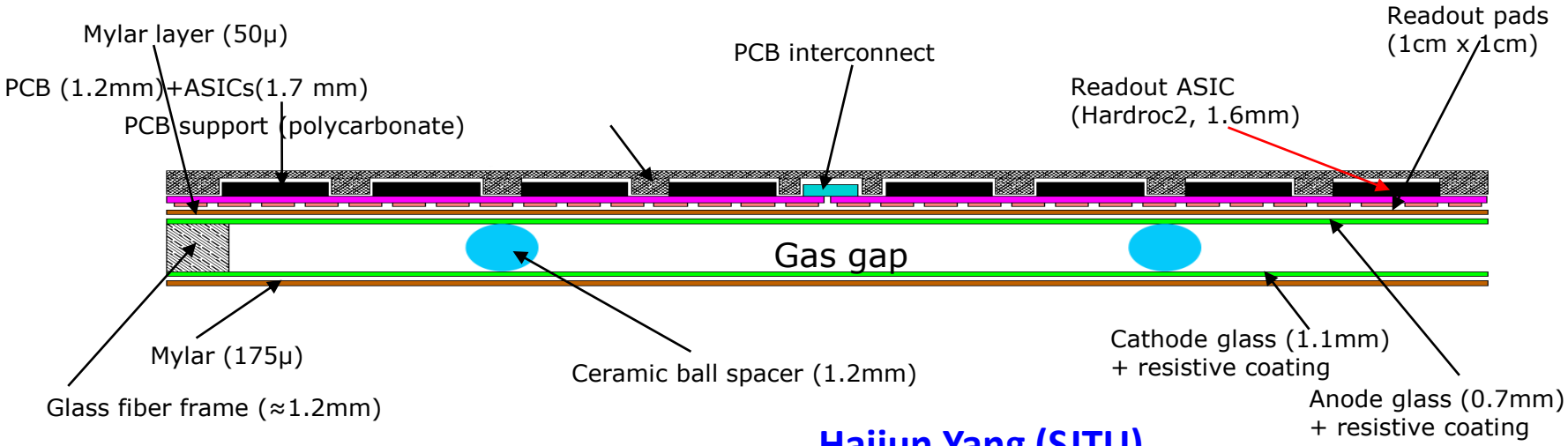
- ILD的模拟优化结果，读出Pad大小对能量分辨的影响；
- 从他们的优化结果来看，在50GeV以下，3cm×3cm和1cm×1cm的读出Pad对能量分辨影响不大；

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

- 灵敏探测器
  - Glass RPC
  - Thick GEM or GEM
- 读出单元
- **(1×1 cm² or 3×3 cm² ？)**
  - Digital (1 threshold)
  - Semi-digital (3 thresholds)



• RPC探测器的相关研究



Haijun Yang (SJTU)

Large GRPC R&D

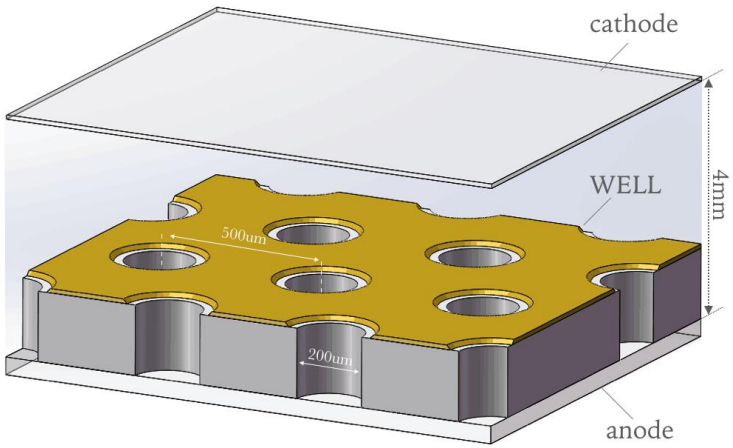
- ✓ Negligible dead zone (tiny ceramic spacers)
- ✓ Large size: 1 × 1 m^2
- ✓ Cost effective
- ✓ Efficient gas distribution system
- ✓ Homogenous resistive coating

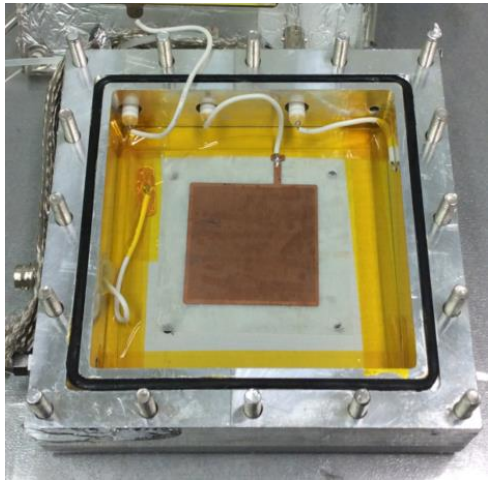
• THGEM探测器的相关研究

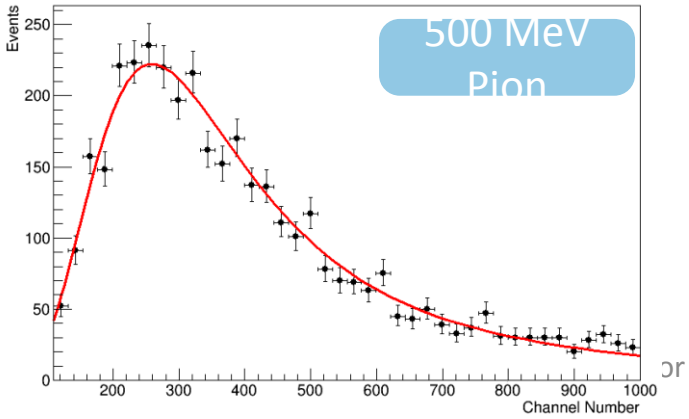
- **Detection efficiency of well-THGEM was measured with BEPC pion / proton beams.**
- **Efficiency:**

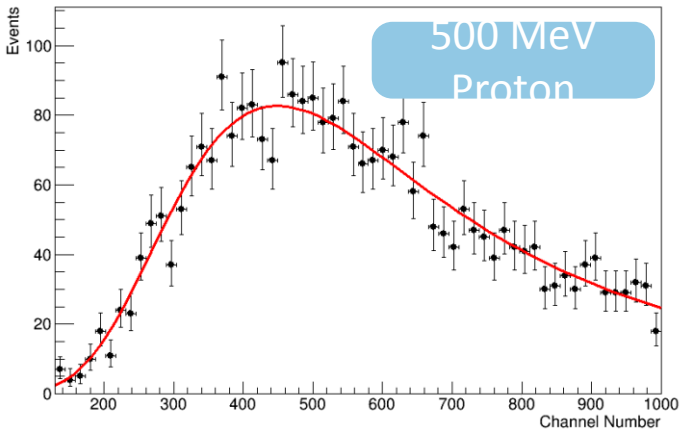
Qian Liu, Hongbang Liu (UCAS)

  - Ne/CH4 (95/5) ,Gain ~ 9000; Eff (proton) > 99%; Eff(Pion) > 94%





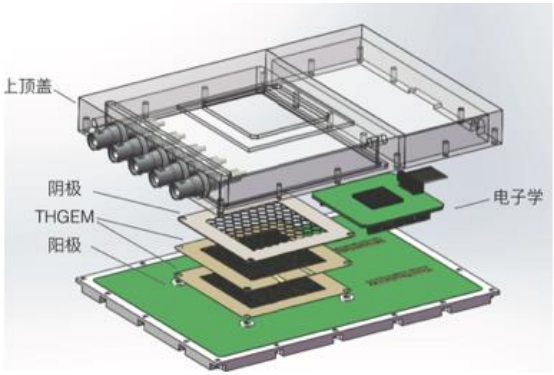


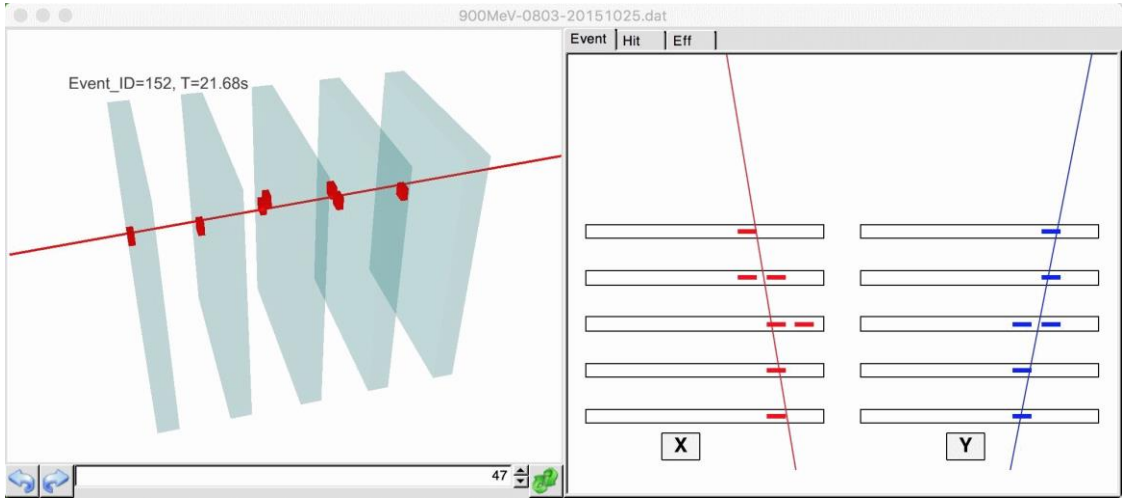


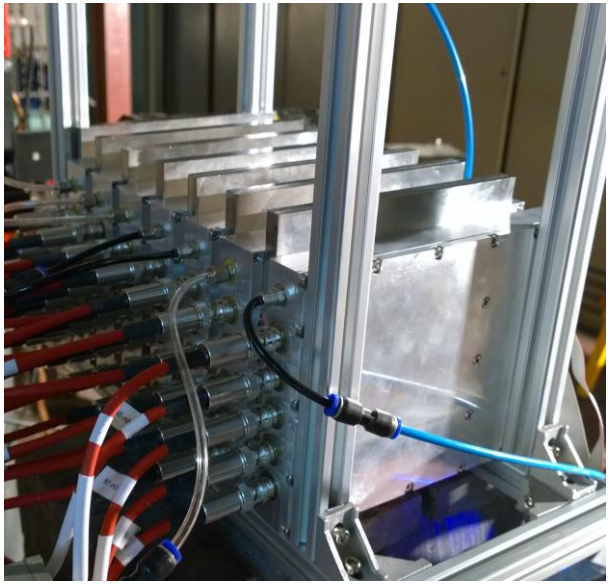
WELL-THGEM Beam Test in Oct., 2015

- 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
- 5cm x 5cm sensitive region
- ASIC: Gastone (From INFN)

Qian Liu, Hongbang Liu (UCAS)

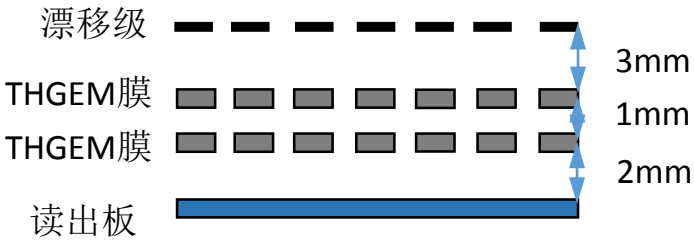






HCAL-THGEM (current work)

Boxiang Yu (IHEP)

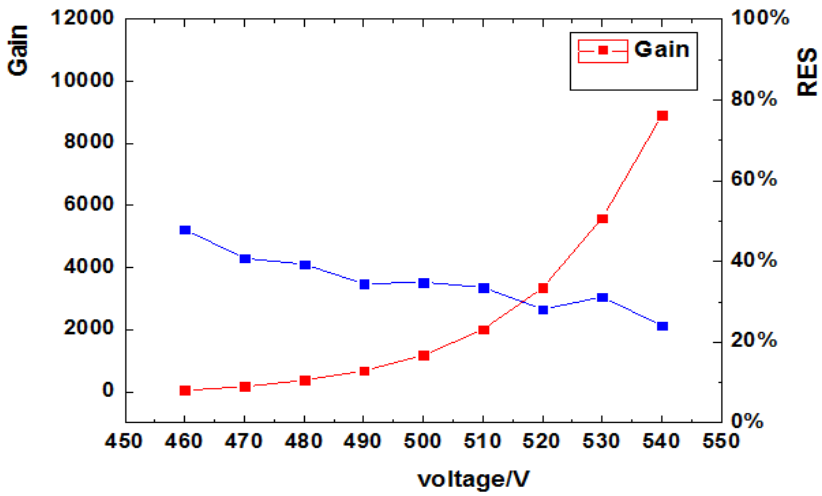


探测器结构（6mm厚）

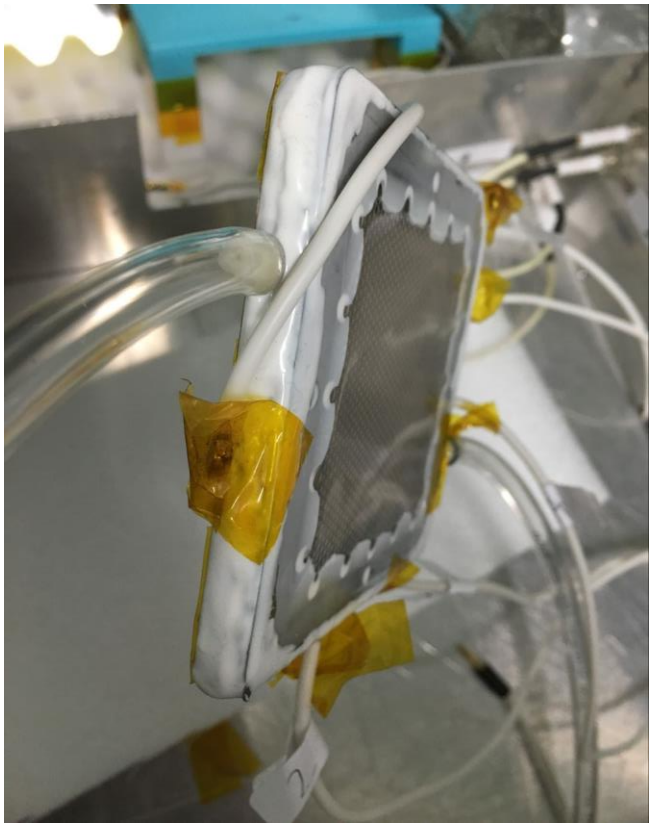
小面积（6cm×6cm）THGEM探测器的结构改造

工作气体：氩气异丁烷（3.00%）

THGEM膜尺寸： 60mm × 60mm × 0.2mm



THGEM气体探测器的增益曲线以及能量分辨

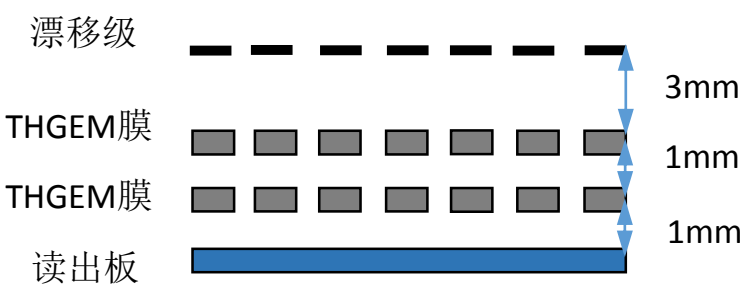


THGEM气体探测器腔室

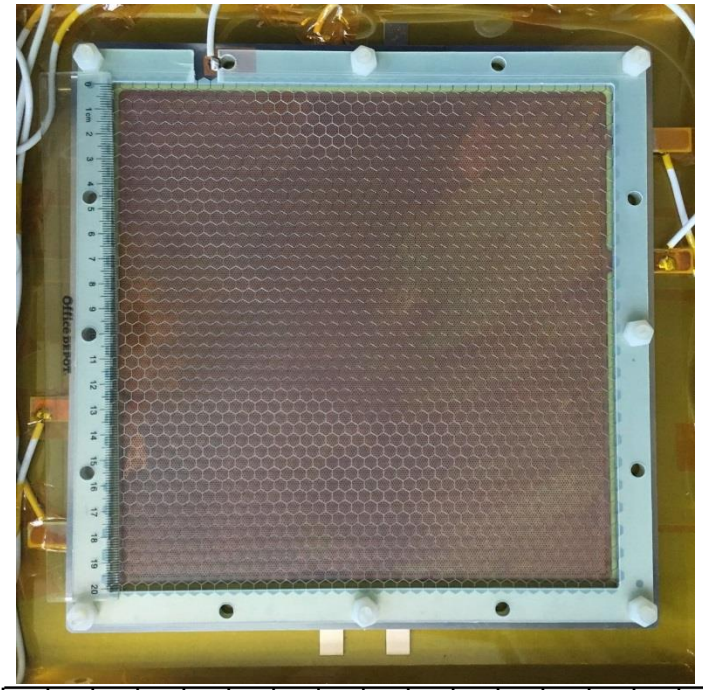
Boxiang Yu (IHEP) Qian Liu (UCAS)

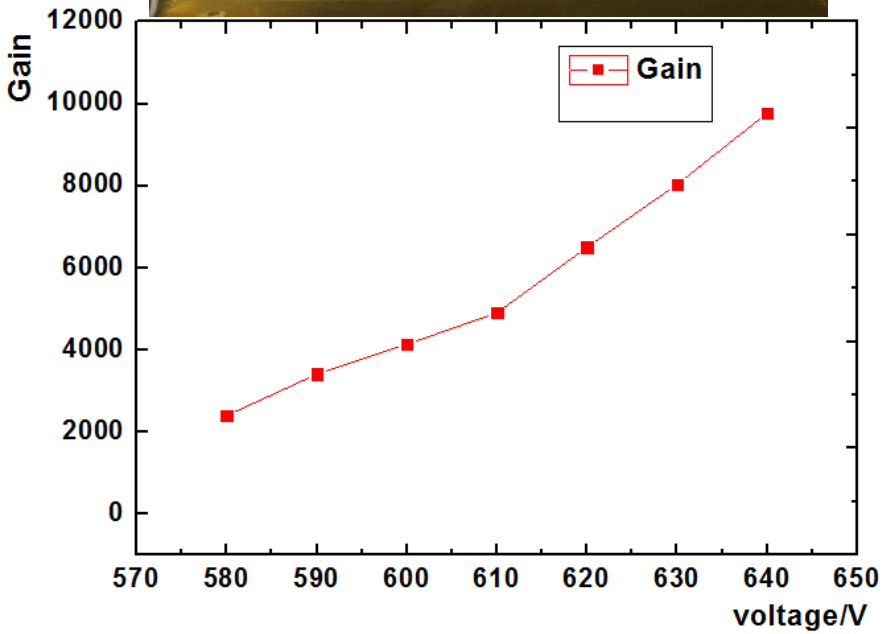
20厘米THGEM探测器的结构优化

工作气体：Ar+ISO（3%）
THGEM膜尺寸：面积20cm*20cm
厚6mm
正在看着探测器的均匀性和稳定性的测量



探测器结构



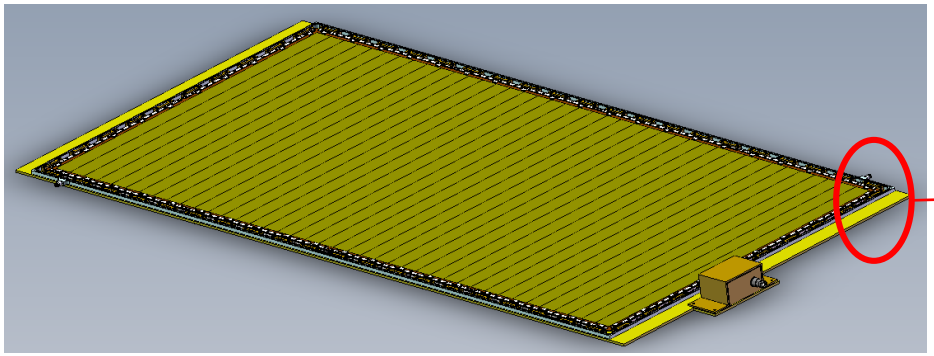


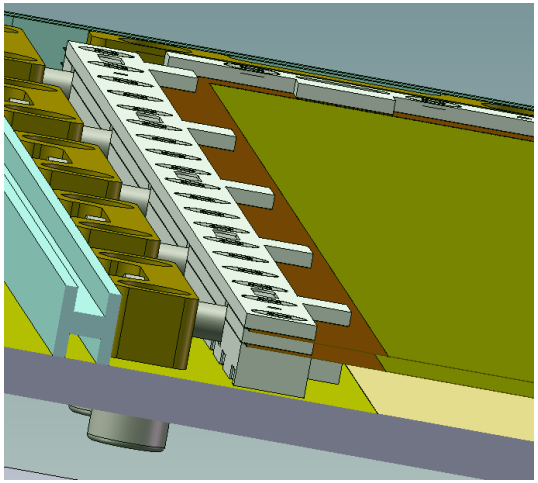
双层THGEM气体探测器的增益曲线

➢ GEM探测器的相关研究

Jianbei Liu (USTC)

- Detector size: 1m*0.5m, limited by GEM foil size
- Double-GEM structure (3mm-1mm-1mm) adopted to minimize the thickness of detectors to accommodate the compactness requirement of DHCAL.
- Double-GEM can still produce reasonable gain under safe operation condition according to our measurements and experience.

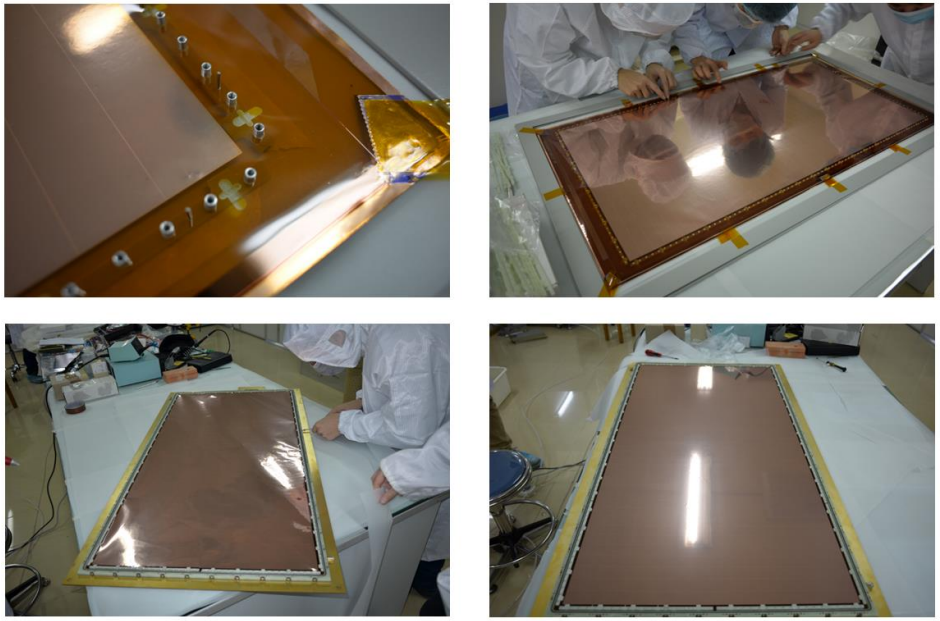




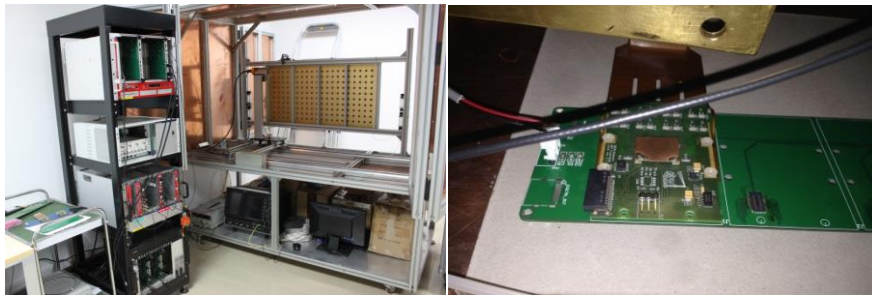
Mechanical design already finished !

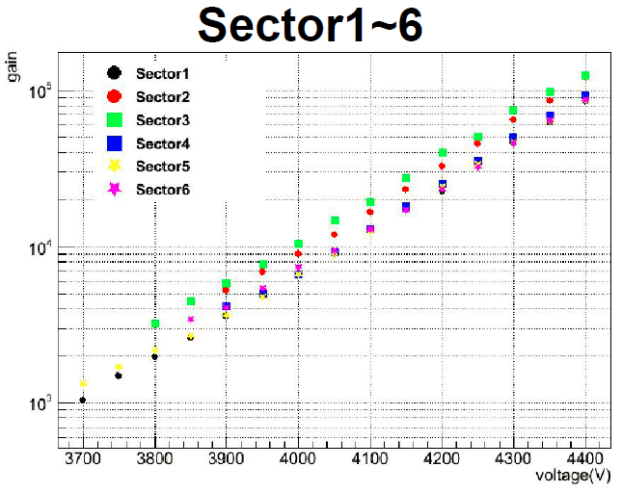
Jianbei Liu (USTC)

GEM assembly using a novel self-stretching technique



APV25 GEM readout **INFN APV25 chip**





- Large-area GEM (0.5x1m^2) is one of main detector R&D focuses at USTC recently.

- **研究内容：掌握50cm x 100cm 大面积GEM的制作工艺，开展性能研究**

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

总结

- CEPC的HCAL模拟优化工作已经有了初步的结果；
- CEPC-HCAL的探测器有三种可选项：RPC、THGEM和GEM都开展一些初步的研究，并得到一些初步的结果；

Thanks！