基于THGEM的数字强子量能器的可行性研究

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- CEPC及其DHCAL概述
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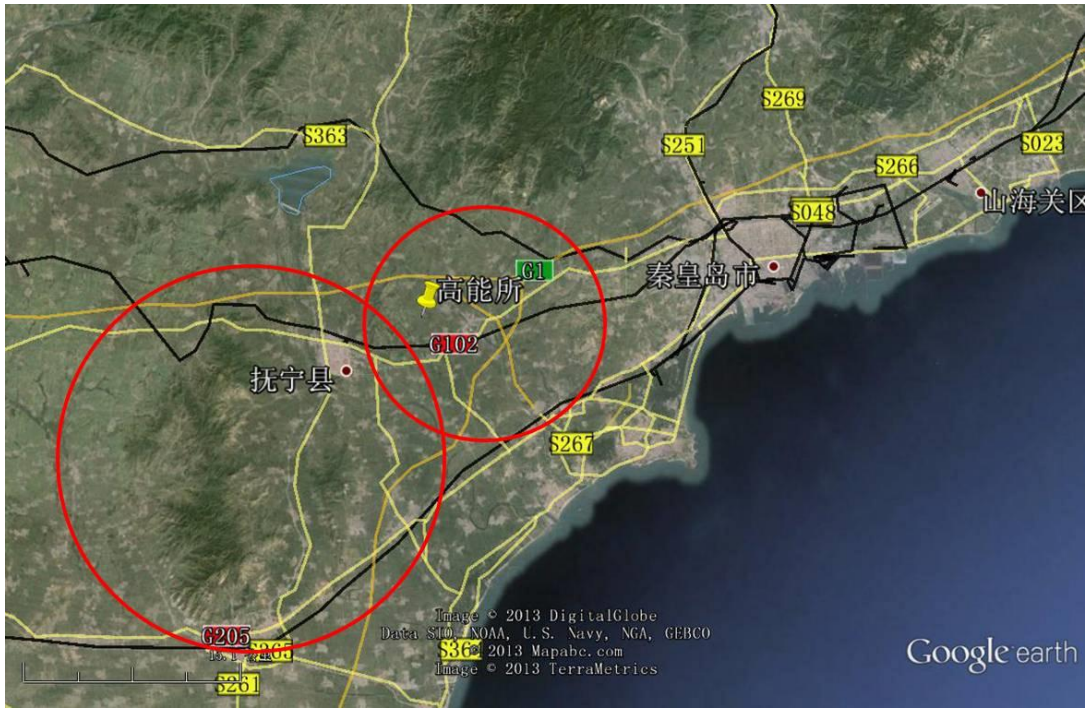
- 基于THGEM的DHCAL的Geant4模拟
- 宇宙线测试及束流实验
- 总结

■ CEPC及其DHCAL的概述



主要作用：

Higgs工厂

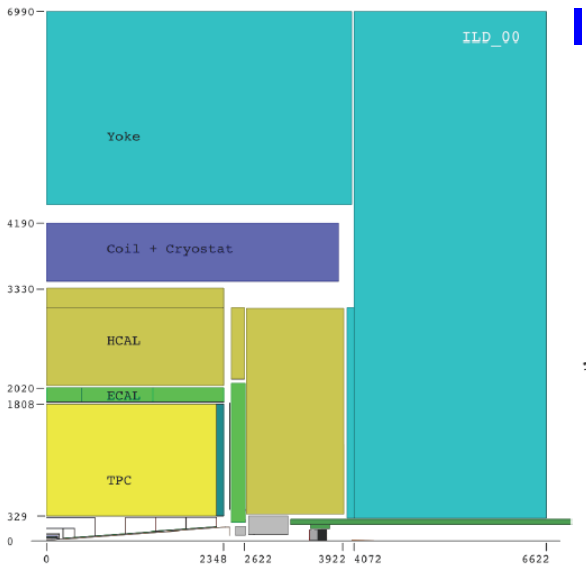
精确研究Higgs性质

主要参数：

- 束流能量：120GeV；
- 束流周长：50-70km
- 亮度：1.8×10^{34} $cm^{-2}s^{-1}$

- 2014提交Conceptual Design Report（CDR）；
- 2020完成Technical Design Report (TDR)；
- 2021年开始建设，2027年完成；
- 2028年取数，取数到2035年；
- 2035年后开始PP对撞机建设。

ILC的ILD方案



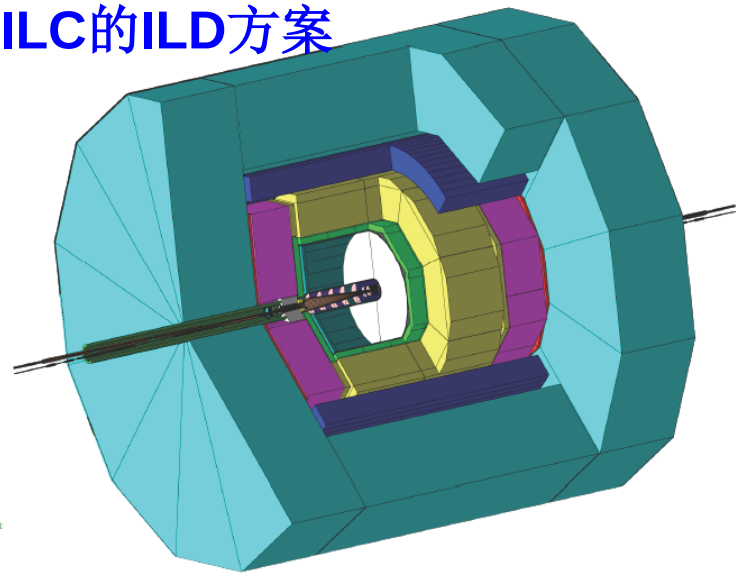
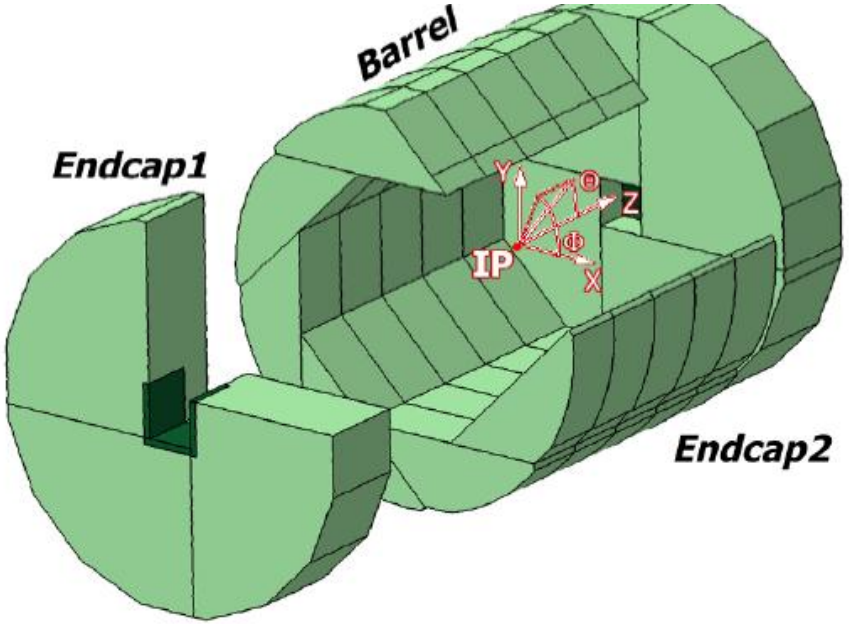


FIGURE 3.1-1. The ILD_00 detector model as implemented in Mokka. From the inside to the outside, the detector components are the: VTX, SIT, TPC, SET, ECAL, HCAL and Yoke. In the forward region the FTD, ETD, LCAL, LHCAL and BCAL are shown.



HCAL的总体设计方案

- 这种探测器方案是ILD提出的；
- 这种方案可以减小能量泄露，我们目前正在调研这种方案；
- 这种方案如果采用1cm×1cm的出的话需要50M道（40层）；

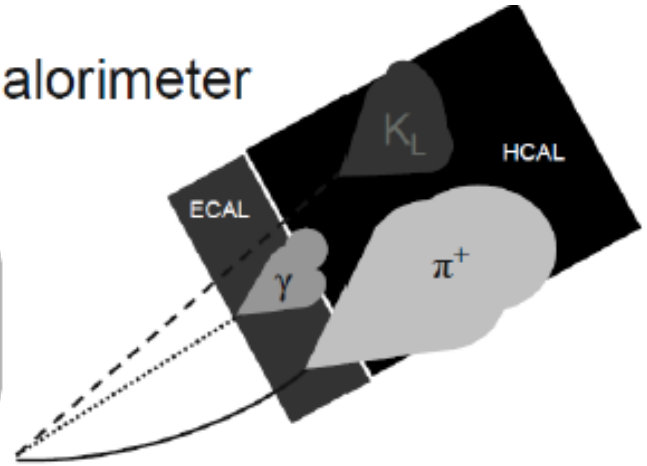
PFA and Imaging Calorimeter

Particle Flow Algorithms and Imaging Calorimeter

The idea…

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

Neutral particles } measured with the { **Calorimeter**



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

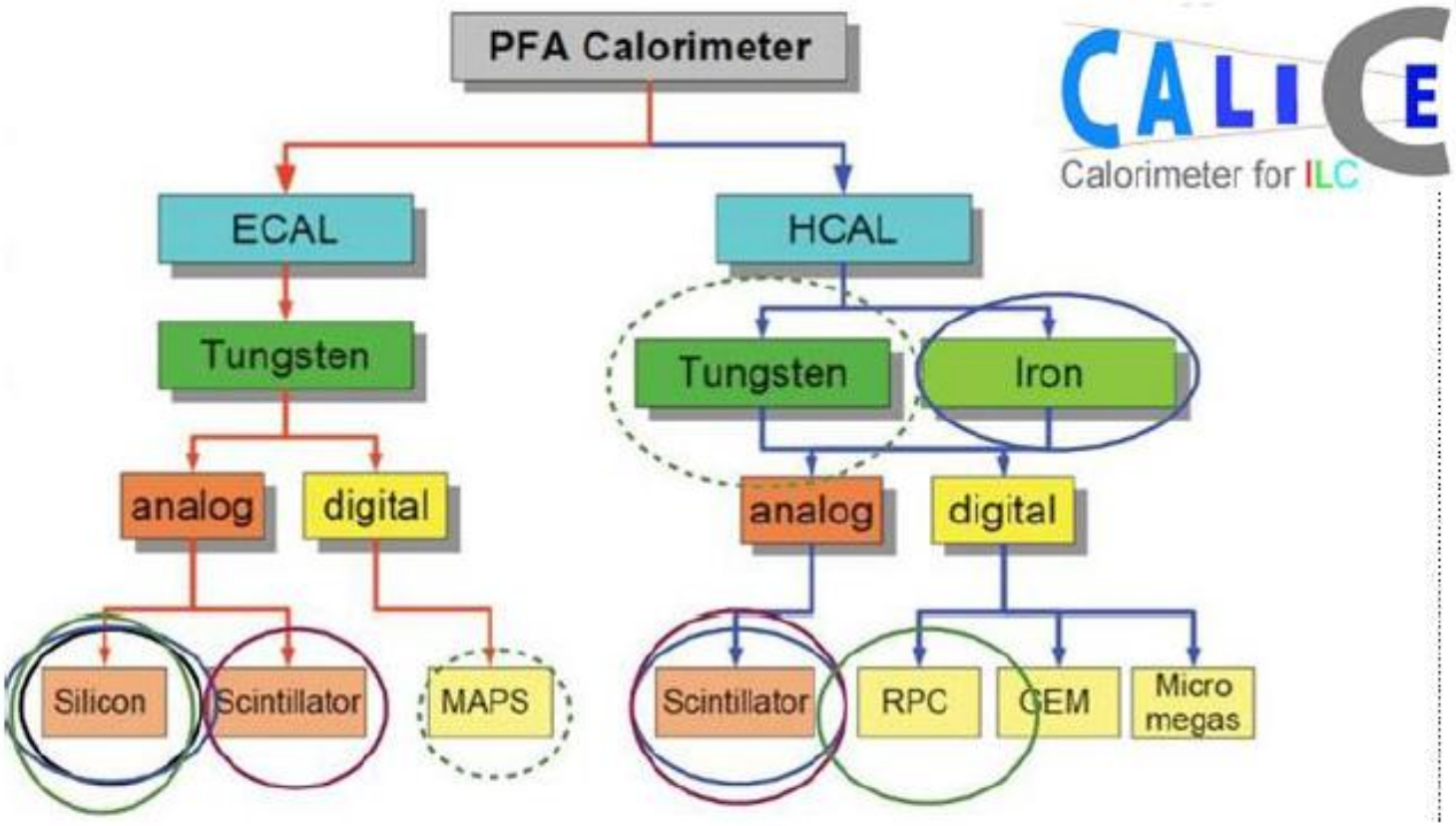
} 18%/$\sqrt{E}$

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) } **thin active medium**
→ Calorimeter with **extremely fine segmentation**

ILD探测器中的量能器方案中的方案

- AHCAL(Analog),DHCAL(Digital),SDHCAL(Semi-digital)
- SiWECAL(Silicon-W),ScWECAL(Scintillator-W)



■基于THGEM的DHCAL简介

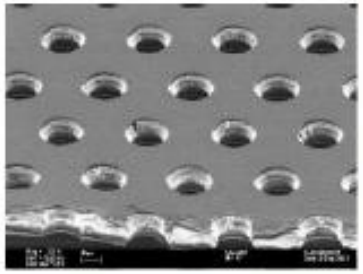
Thick-GEM-DHCAL （DHCAL）

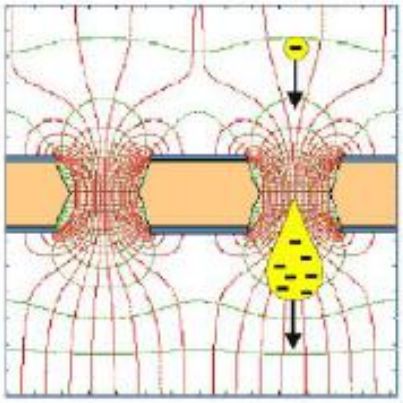
- Collab. Institutions: IHEP, UCAS, GXU, XJTU

Standard GEM

Developed from 1997 by F. Sauli (CERN)

Typical parameters:
- 50μm Kapton
- Ø60μm holes
- 100-200μm pitch





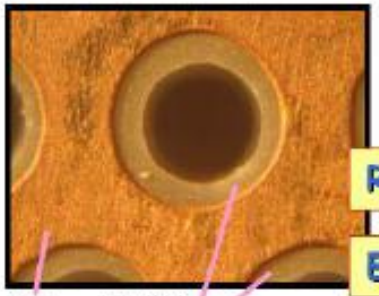
F. Sauli NIM A 433 (1997) 531

THGEM

Developed from 2004 by A. Breskin (Israel, CERN) :

Typical parameters:

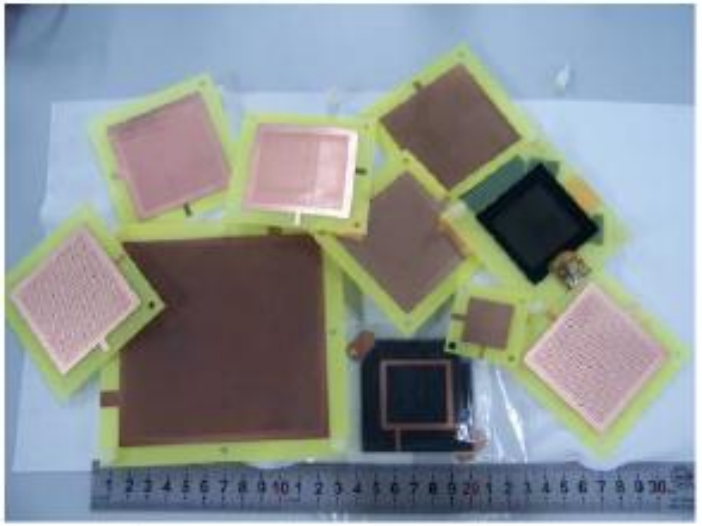
Thickness	t = 0.4 - 3 mm
Hole diameter	d = 0.3 - 1 mm
Pitch	a = 0.7- 7 mm

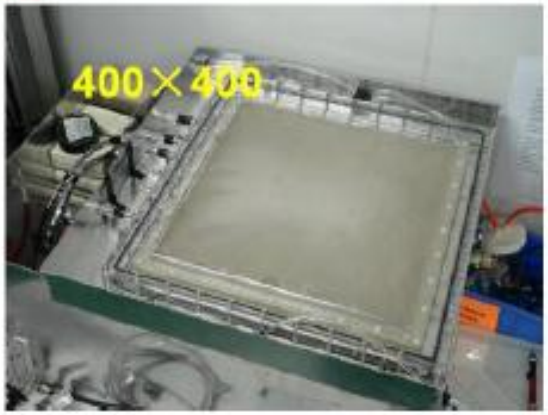


Chechik et al. NIM A535 (2004) 303

高能所及国科大的THGEM制作达到的水平

- Production of THGEM
  - Thickness=0.3~2.0mm,
  - Size=3cm×3cm~40cm×40cm,
  - Two factory can produce THGEM in China,
  - 40×40cm THGEM have pass 120 hours stability test,
  - The maximum size is 60cm ×60cm.

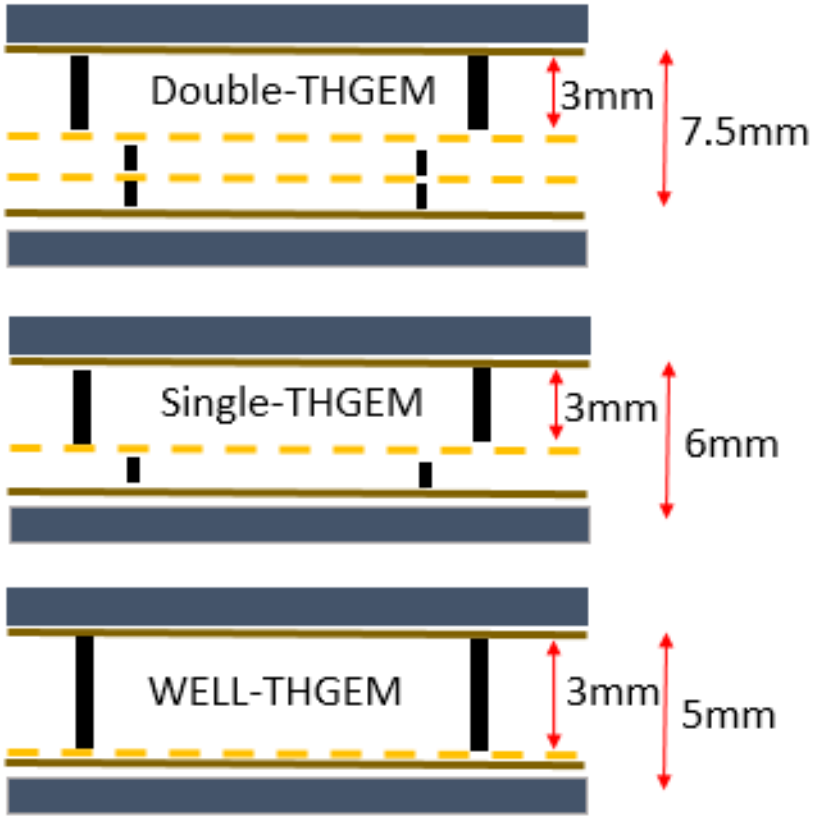




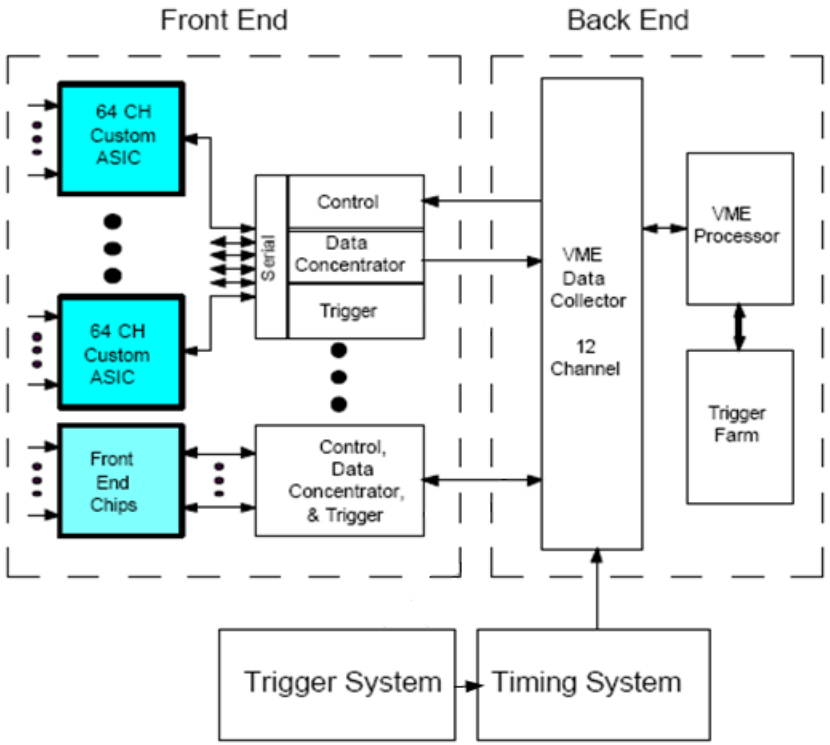
Designed by Xie Yuguang

Designed and produced by UCAS

THGEM探测器结构设计及电子学方案



THGEM灵敏体积的几种构想



Argon给的电子学的一个方案

我们有目前有1k路，张清民负责

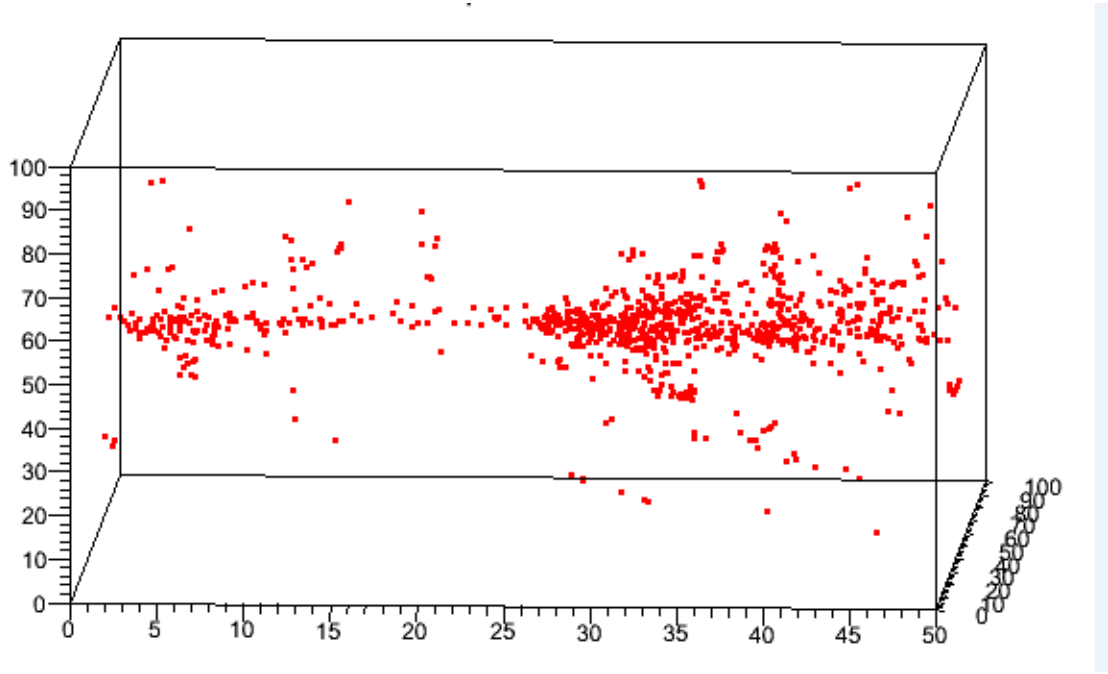
初步经费估算

Content	Unit cost	Total require	Total cost
THGEM	0.4 yuan/cm^2	50 M cm^2	￥ 20 M
Electronics	**8 yuan/channel**	**50 M channel**	**￥ 400 M**
Absorber	30 k yuan/ton	1200 ton	￥ 36 M
total			￥ 456 M

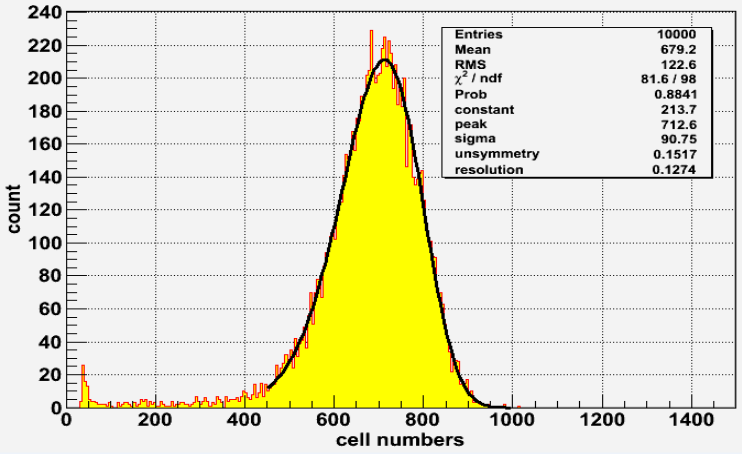
- 主要经费在ASIC电子学，江晓山老师 上午 说 6元/channel电子学，可以便宜一个亿；
- 探测器占比最小，所以THGEM、RPC等探测器只要性能合适就可用；

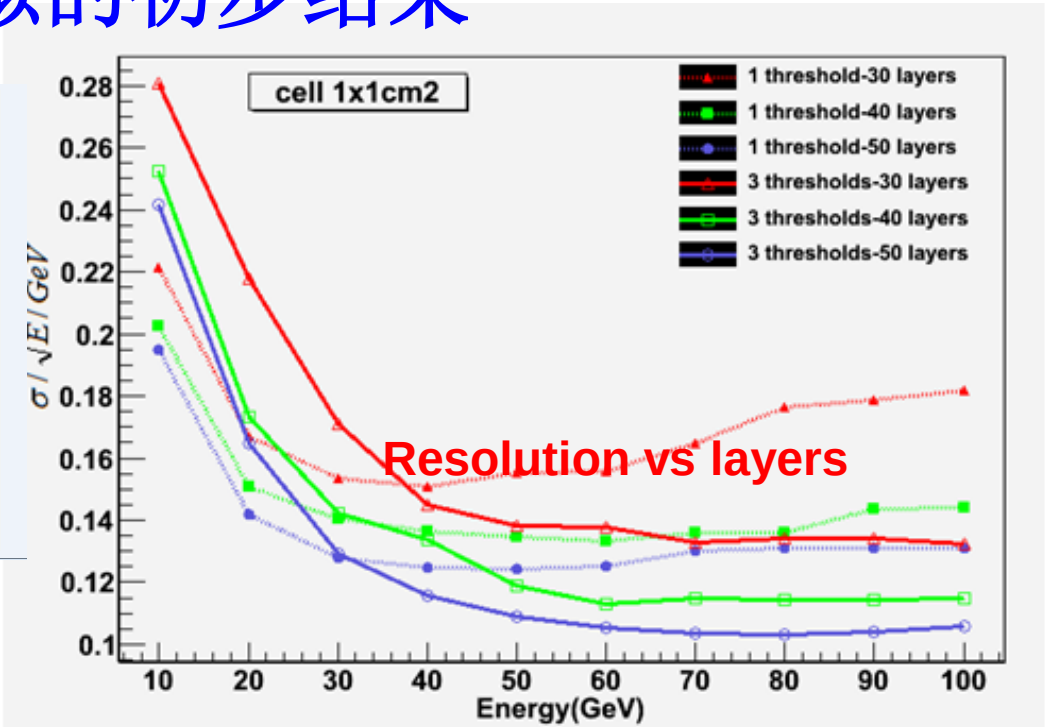
■ THGEM的DHCAL的G4模拟

- 采用2cm不锈钢作为吸收体；
- 单层THGEM探测器作为灵敏层，漂移区设为3mm；
- 模拟时用高能（10-100GeV）强子如 π^+入射
- 研究其能量分辨等信息。

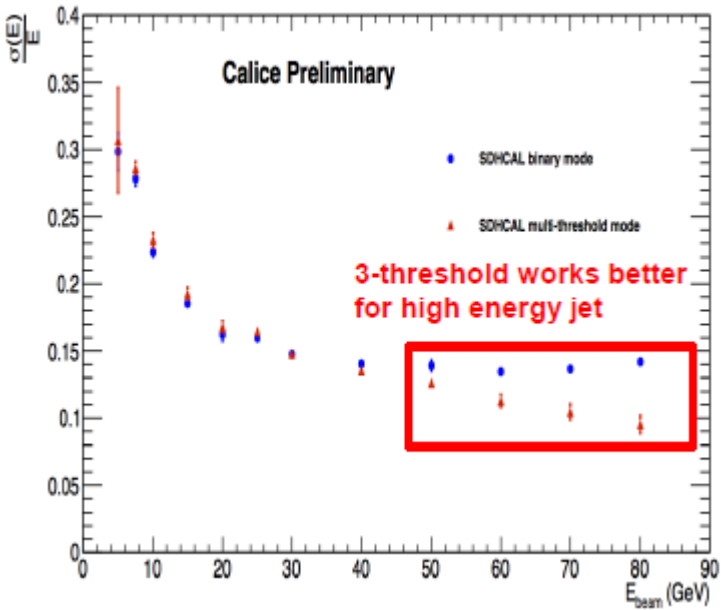


G4模拟的初步结果





- 没有加入PFA算法，就是击中个数的统计；
- 单阈值阈值设在0.5MIPS；
- 三阈值分辨设在：0.1、2、8对应的设在的MIP个数为1,5,10
- π作为入射粒子，比较在不同层数且不同阈值时探测器的能量分辨



■宇宙线实验结果

宇宙线实验

探测器大小：16cm×16cm

探测器结构：4mm/2mm/2mm

工作气体：氩气/异丁烷：97/3

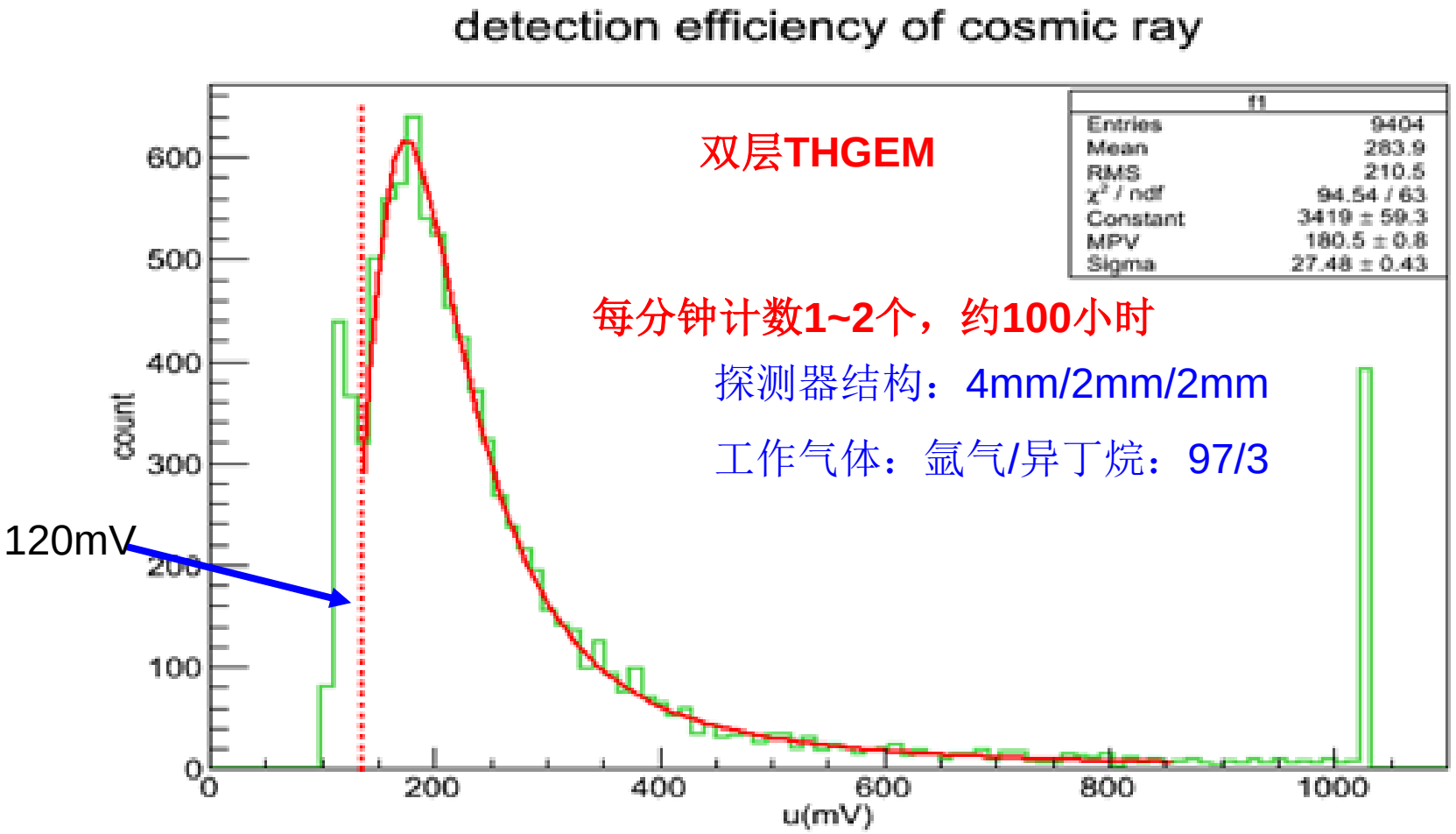
测试装置简易图

上下符合闪烁体尺寸：6.0cm×6.0cm

DT5751

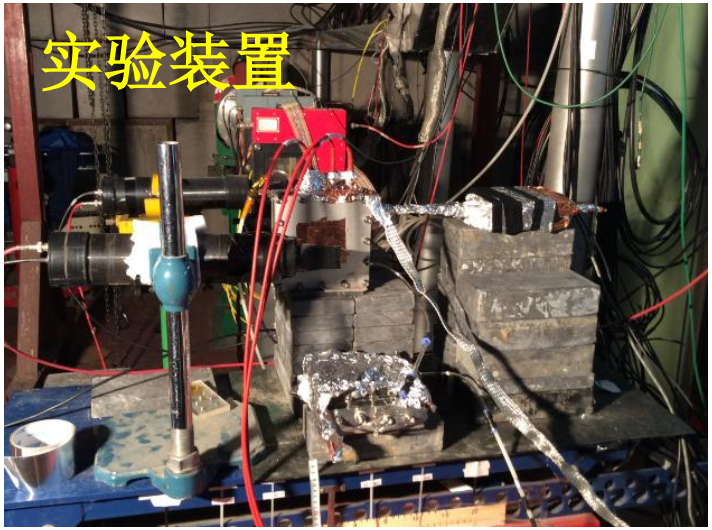
μ效率测试装置

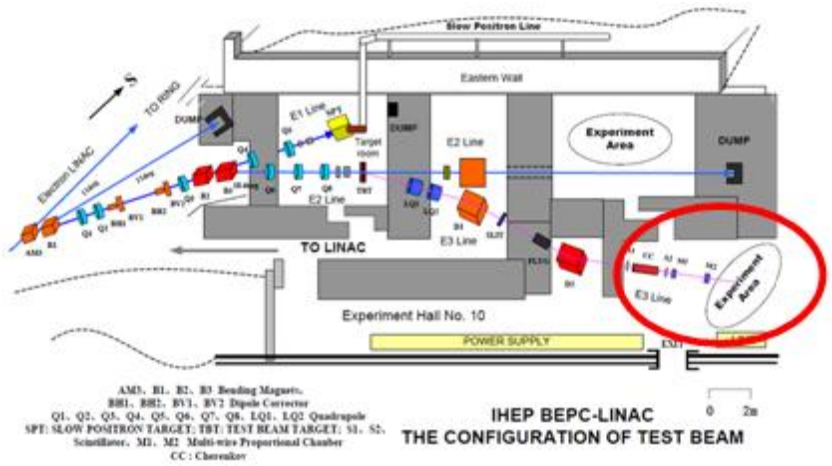
宇宙线实验结果

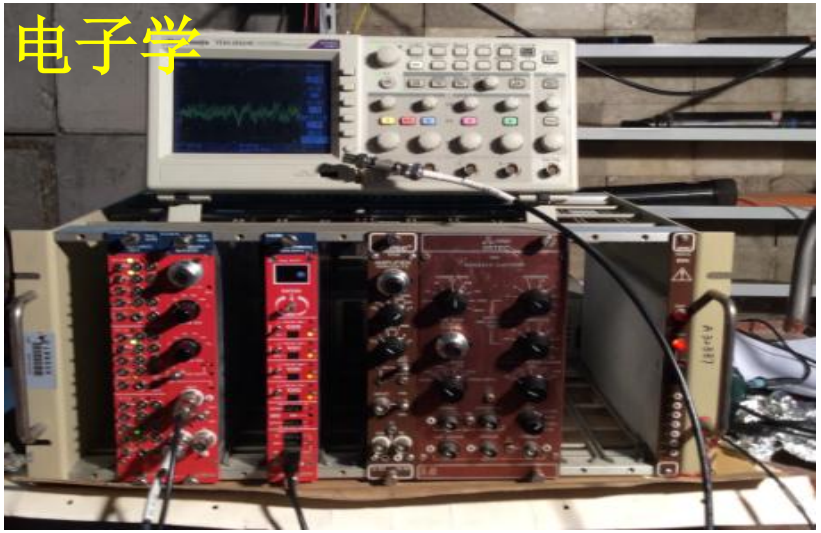


设置阈值为120mV，探测效率为94.2%。

束流实验装置

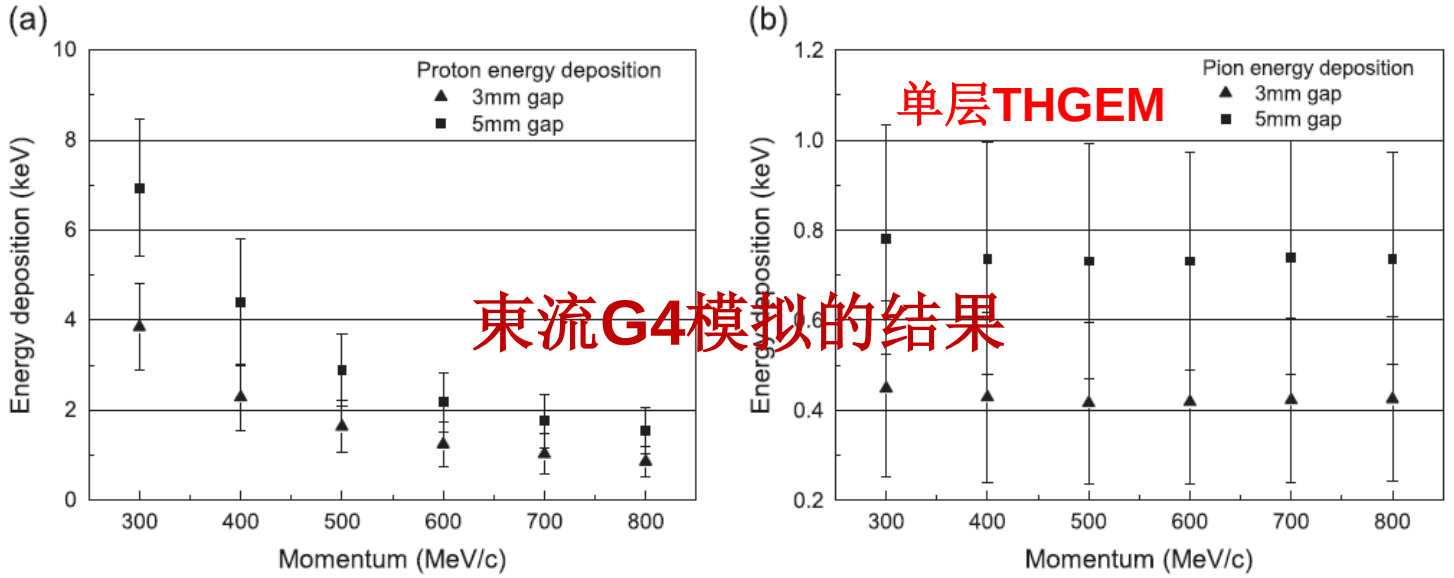






- 采用三层TOF符合；
- 用CAEN DT5751波形进行取数；
- 经常用Fe55-刻度探测器。

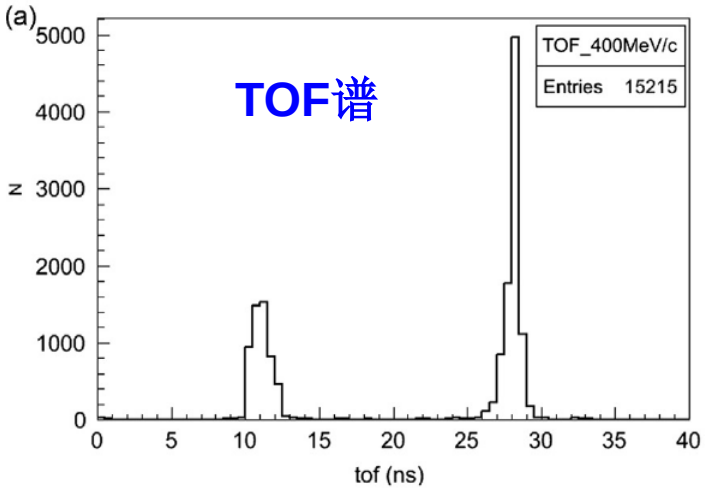
第一次束流实验结果（2012.7）

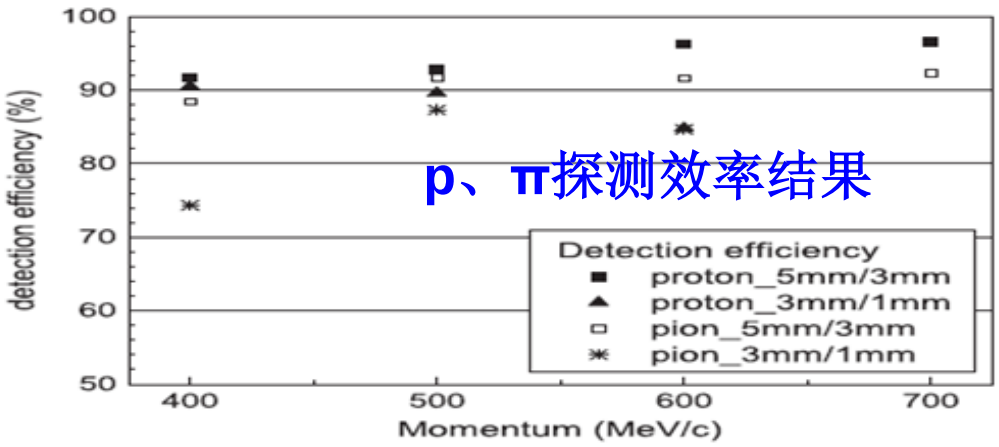


束流G4模拟的结果

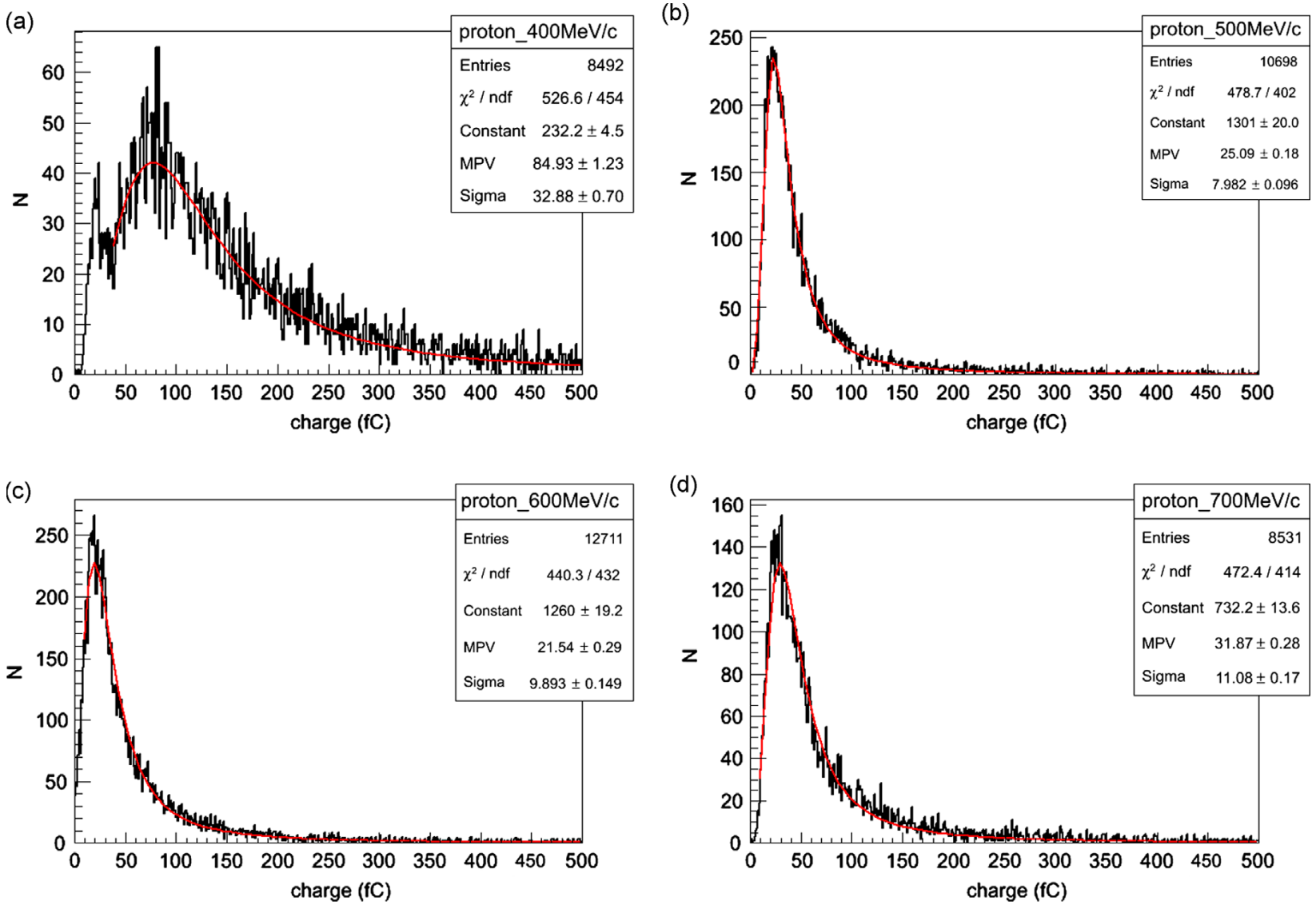
Geant4 simulation of p/π⁺ energy deposition **in Ne/CH4 (95/5),**

(a) p energy deposition and (b) π⁺ energy deposition.





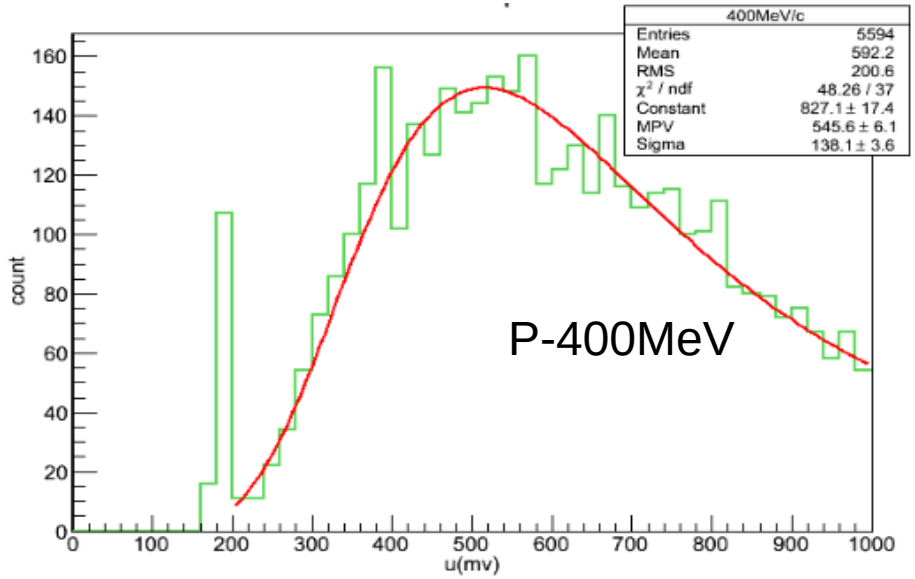
第一次束流实验结果

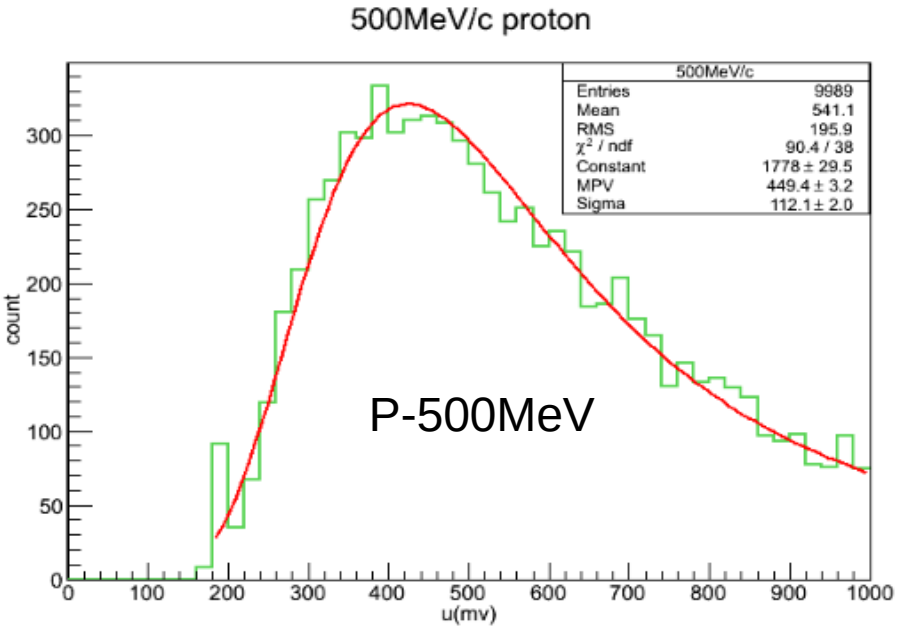


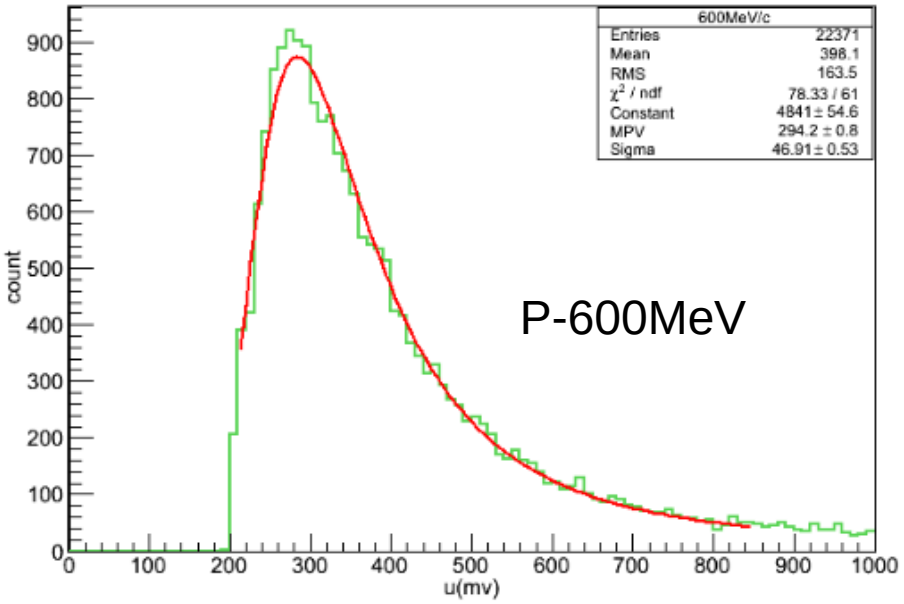
入射质子动量为400~700MeV/c的朗道分布

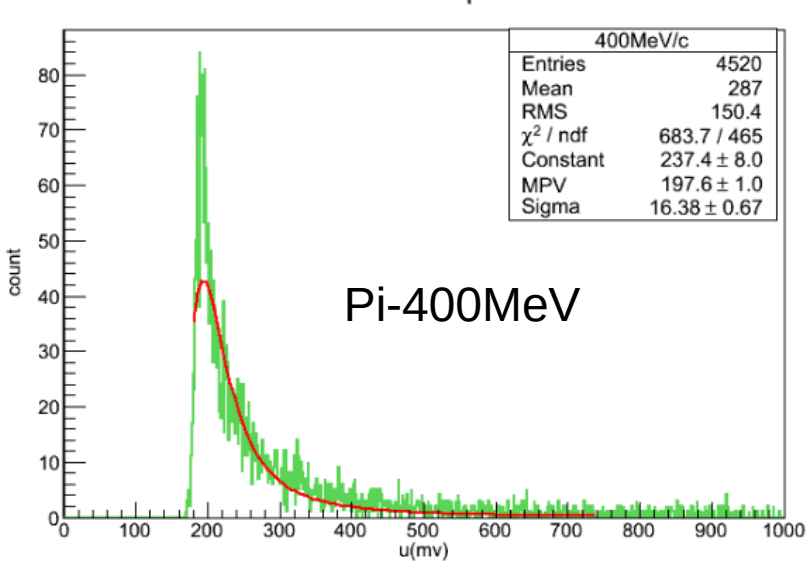
第二次束流实验结果（2014.7）

单层THGEM—4mm漂移区



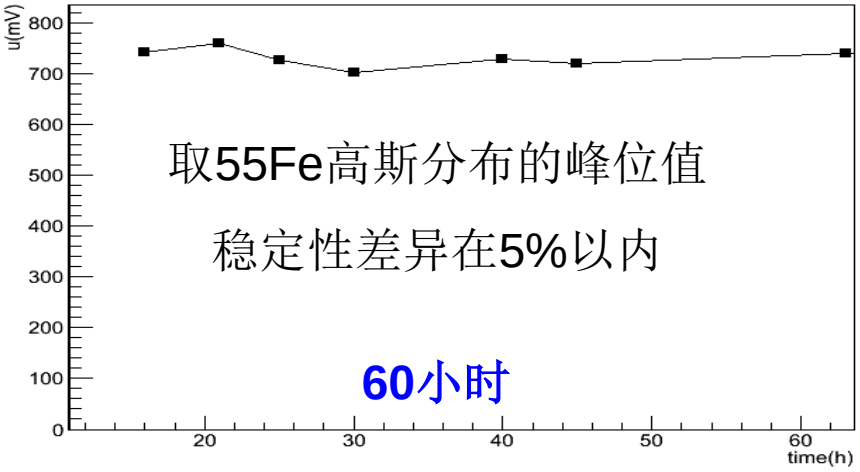


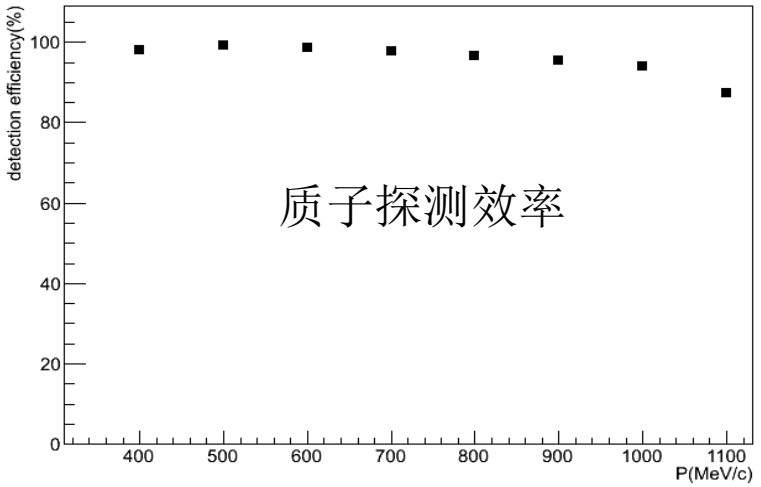


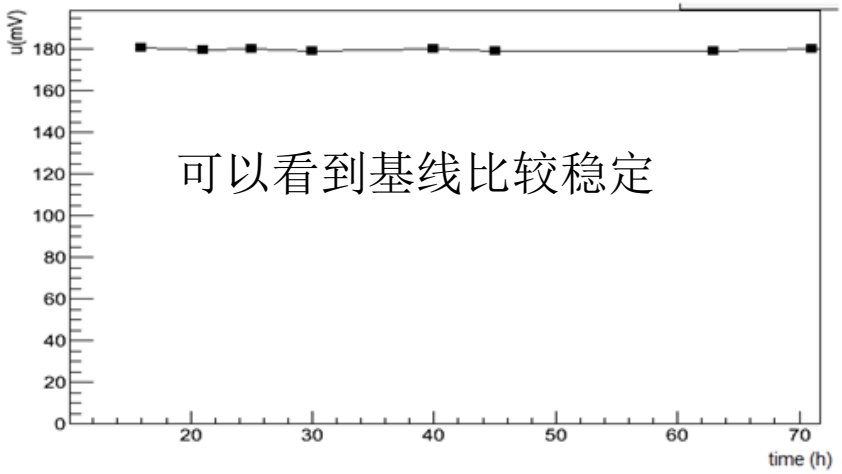


第二次束流实验结果

探测器稳定性（ ^{55}Fe）及基线稳定性测试

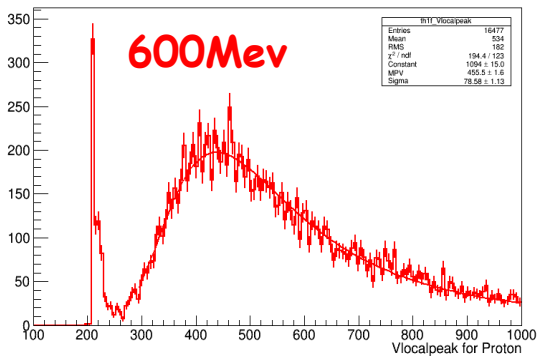


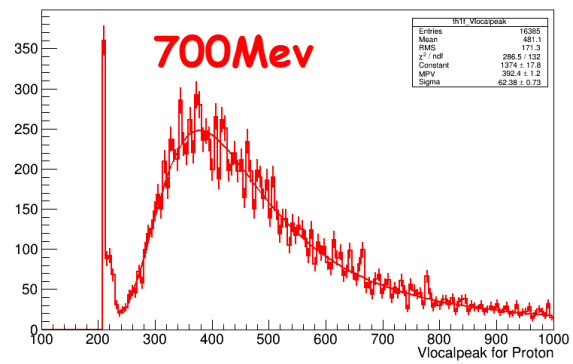


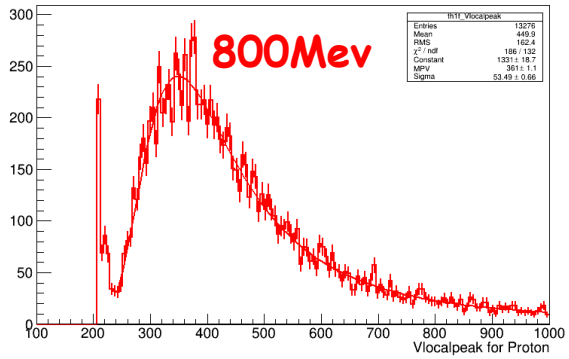


- 探测器增益稳定性很好；
- 对质子的探测效率还是能到95%左右；
- 对Pion的探测效率无法给出，主要还是单层THGEM的增益还不够。

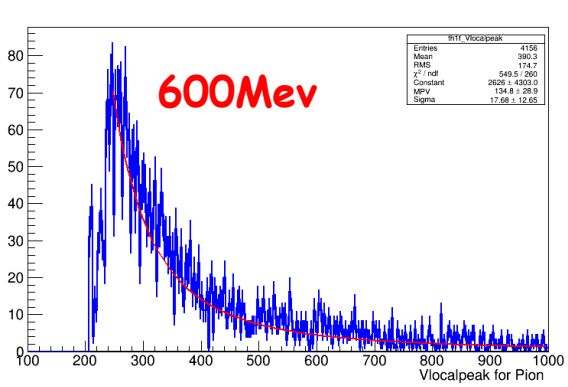
WELL-THGEM束流实验结果

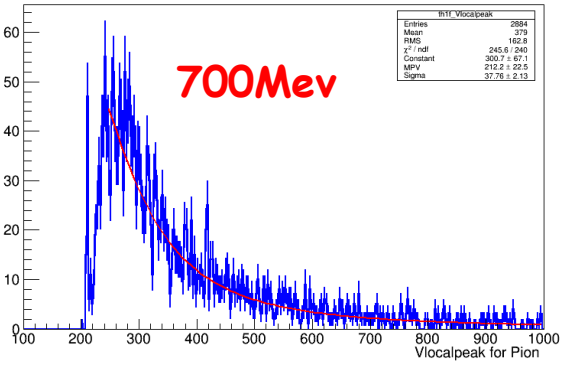


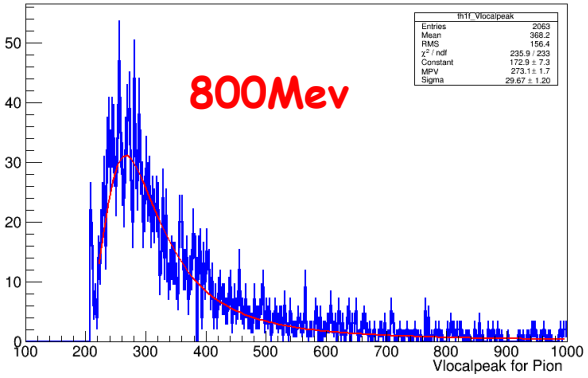




增益高30%







实验过程中利用^{55}Fe对探测器增益稳定性刻度，误差小于3%，探测效率还在分析中。

小结

- 模拟结果用THGEM做DHCAL的灵敏探测器是可行的；
- 束流实验及宇宙线实验结果表明单层THGEM作为DHCAL的灵敏体积增益有待进一步提高，但是采用双层的THGEM是能达到95%左右的效率，**Well-THGEM在增益上有优势**；
- 下一步工作，希望能把Argon给我们的电子学调通（调了半年没调通），希望在会上的同事给我们提供电子学的支持，开展WELL-THGEM的研究，还有大面积THGEM探测器的研究。