



成像型电磁量能器的研究

张云龙

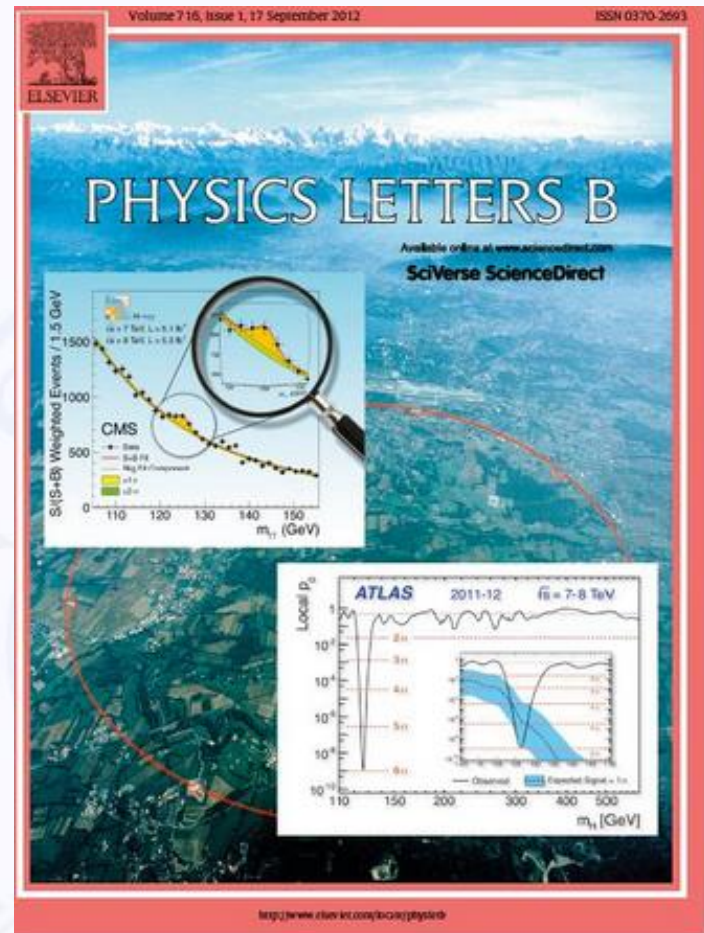
核探测与核电子学国家重点实验室

Outline

- 背景
- 成像型电磁量能器
- 进展
- 总结

背景—Higgs粒子的发现

- Higgs粒子的发现是标准模型的又一次伟大胜利
- 而其粒子属性还有待于进一步研究
 - 精确质量
 - 自旋
 - CP
 - 耦合...
- 正负电子对撞机是回答这些问题的钥匙
 - ILC, CEPC...

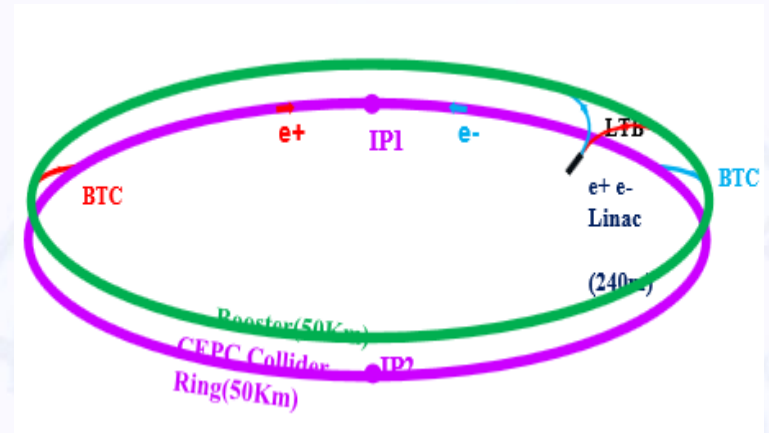




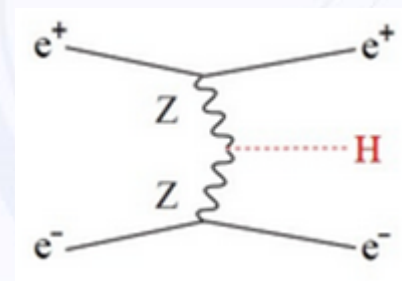
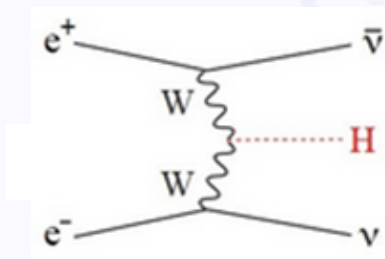
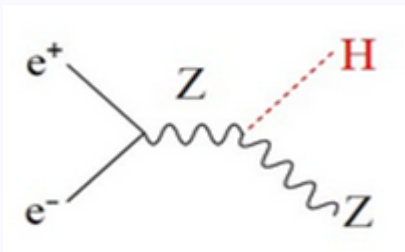
背景—CEPC

➤ Circular Electron Positron Collider

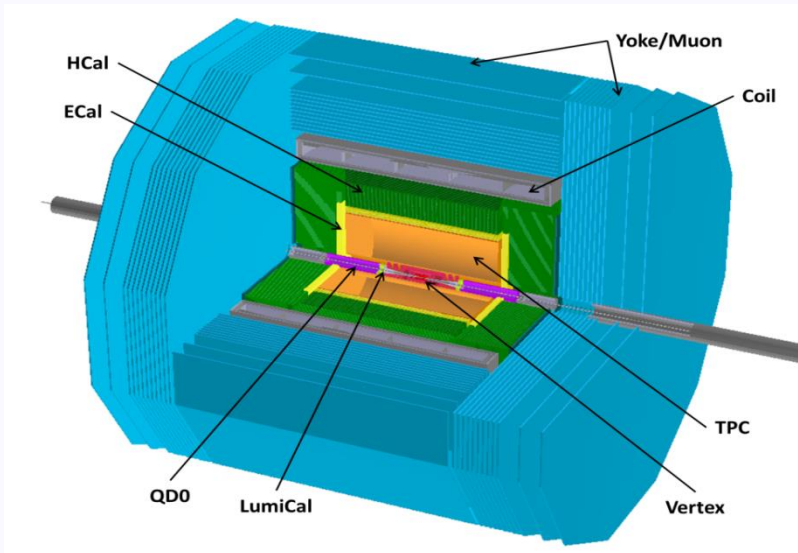
- 中国独立提出的新一代加速器
- 束流能量：120GeV
- 亮度： 2.04×10^{34}
- 对撞时间间隔： $\sim 3.5\mu\text{s}$



- 目标：
 - Higgs粒子的精确测量



CEPC Detector



- ILD-like detector with additional considerations.
- Similar performance requirements to ILC detectors

Challenges:

- Momentum:
- Impact parameter:
- **Jet energy:**

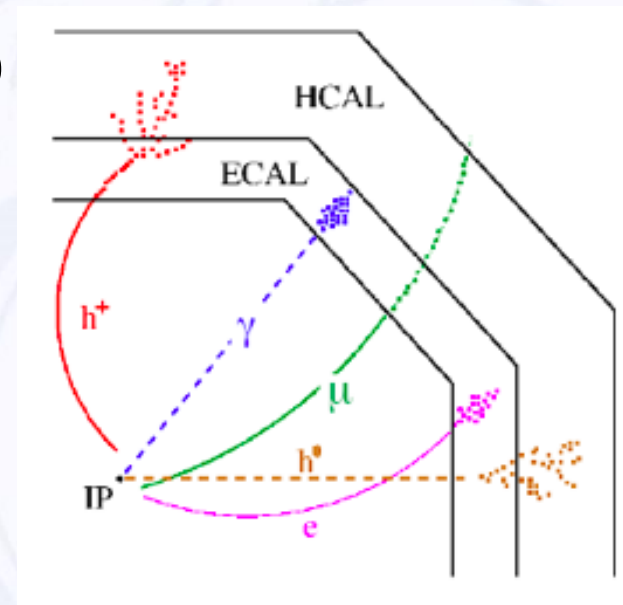
$$\sigma_{1/p} < 5 \times 10^{-5} \text{ GeV}^{-1}$$

$$\sigma_{r\phi} = 5 \oplus 10 / (p \cdot \sin^{\frac{3}{2}} \theta) \mu\text{m}$$

$$\frac{\sigma_E}{E} \approx 3 - 4\%$$

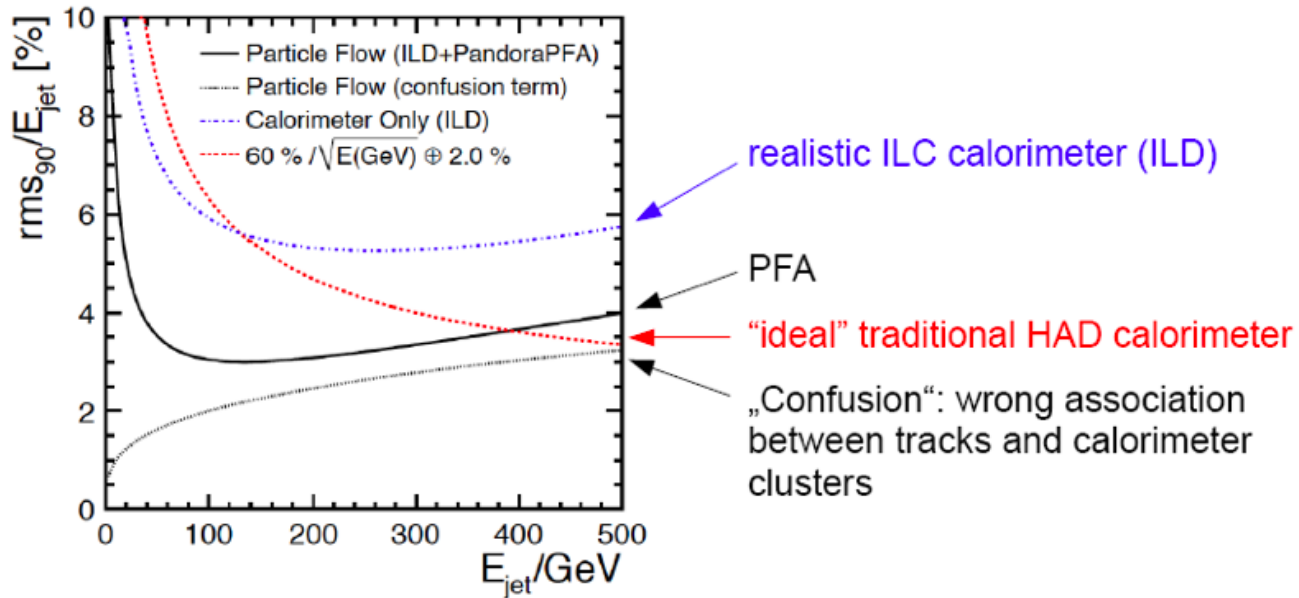
The requirement of EMCal

- Good separation of particles
 - Large detector size
 - Large magnet field
- Compact showers to minimize overlap
 - Small moliere radius
- Minimum amount dead material
 - Calorimeter inside the magnet coil
- Detailed information of showers
 - High granularity





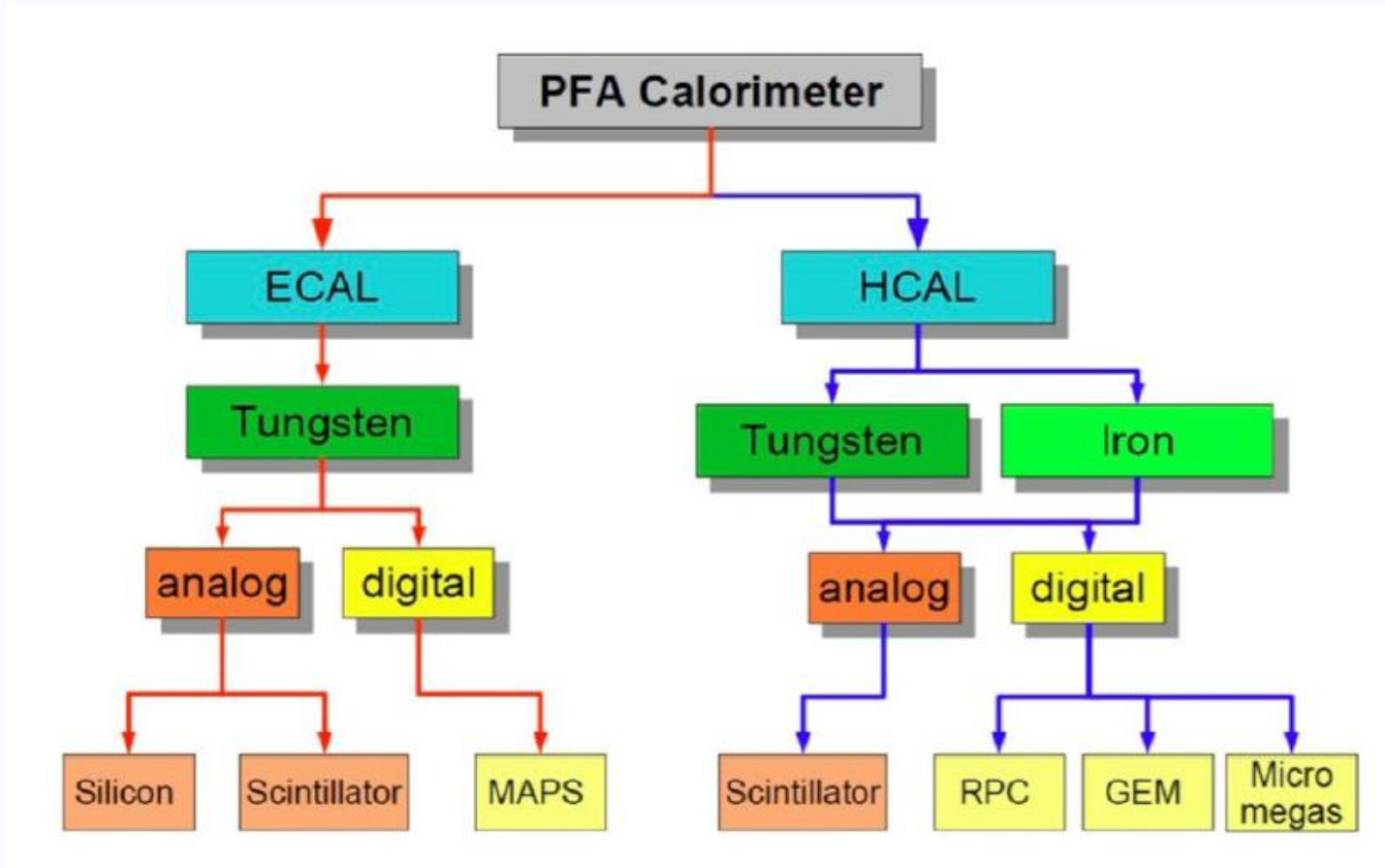
The PFA Calorimeter



- PFA+Calorimeter is clear better than calorimeter alone
 - At high energy, correct association between tracks and calorimeter clusters is very important



PFA Calorimeter



研究进展

模拟方案2：闪烁体+SiPM 灵敏层

➤ Sandwich structure

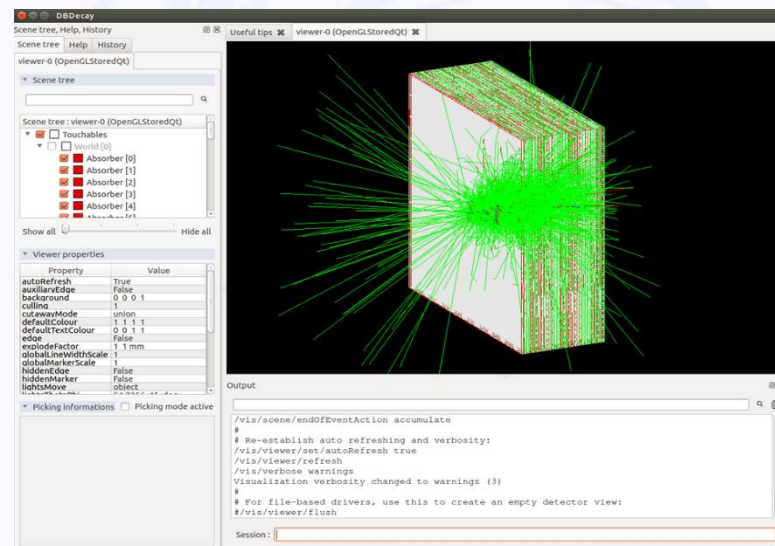
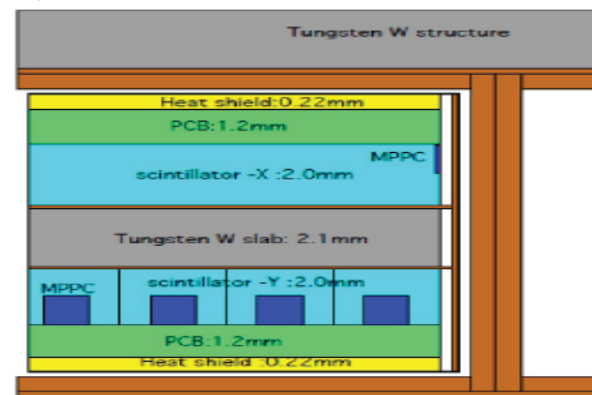
- W+SD+PCB

➤ SD

- Scintillator+SiPM
- 5mm*45mm*2mm

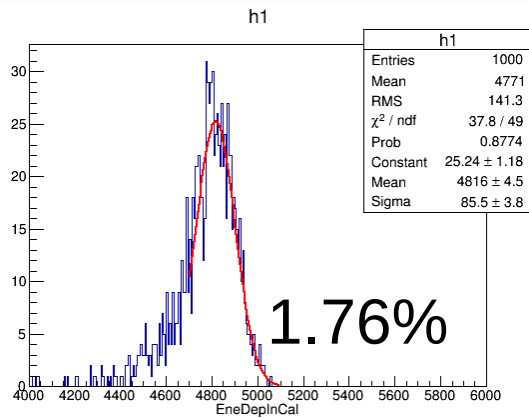
➤ Absorber

- Tungsten
- 2.8mm(0.8X0)

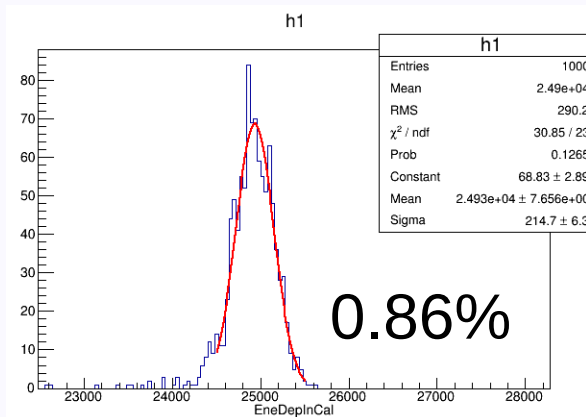


The performance of EMCal (MC)

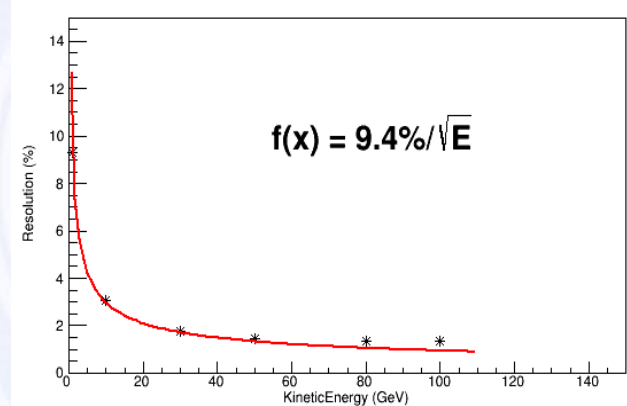
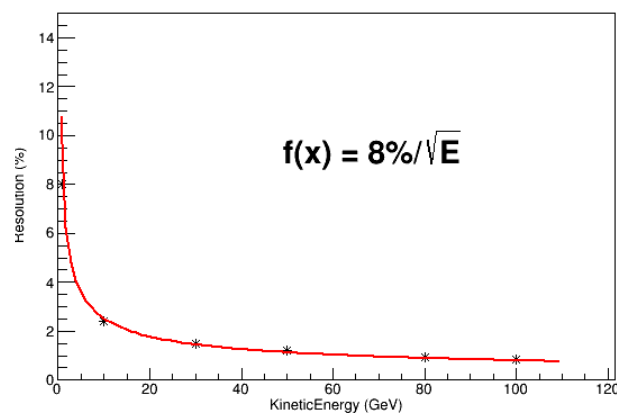
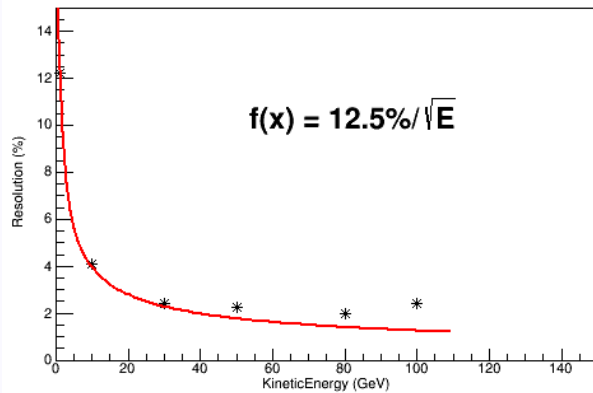
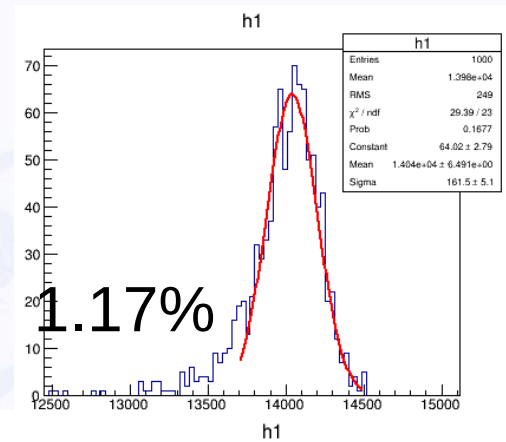
PSD:2mm



LSO:2mm



LSO:1mm



➤ PSD: 2mm thickness

– The light yield (do not consider the nonlinearity of SiPM):

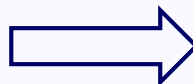
- 1 MIPs: $\sim 10\text{pe}$
- 600 MIPs: $\sim 6000\text{pe}$



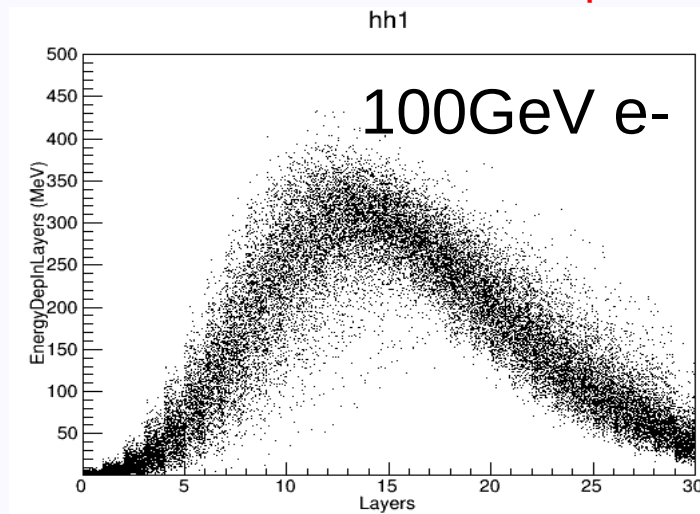
Determine the SiPM model:
 $\sim 10,000\text{ pixels}$

– Gain of the SiPM is $\sim 2 \times 10^5$

- 1MIPs: $\sim 320\text{fC}$
- 600MIPs: $\sim 200\text{pC}$

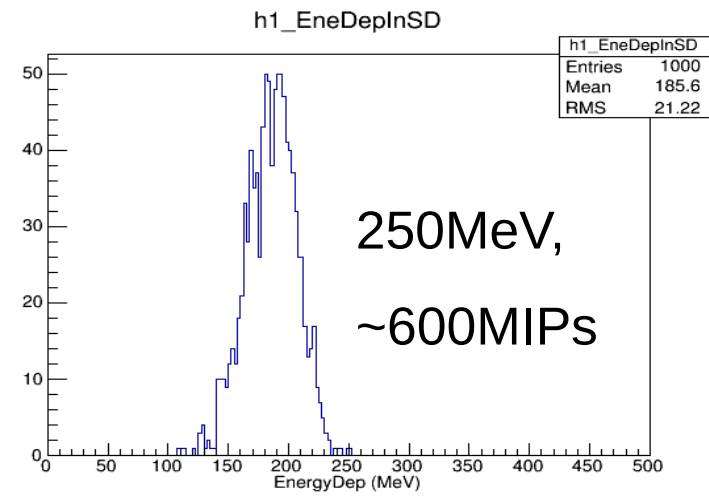


Determine the FEE Chip model:
dynamic range $\sim 100\text{fC} - \sim 200\text{pC}$



Edep in each SD layers

2017/4/11



The MAX edep in one SD

元器件的选择



Scintillator (5mm*45mm*2mm)



SiPM (1mm * 1mm 10000 pixels)

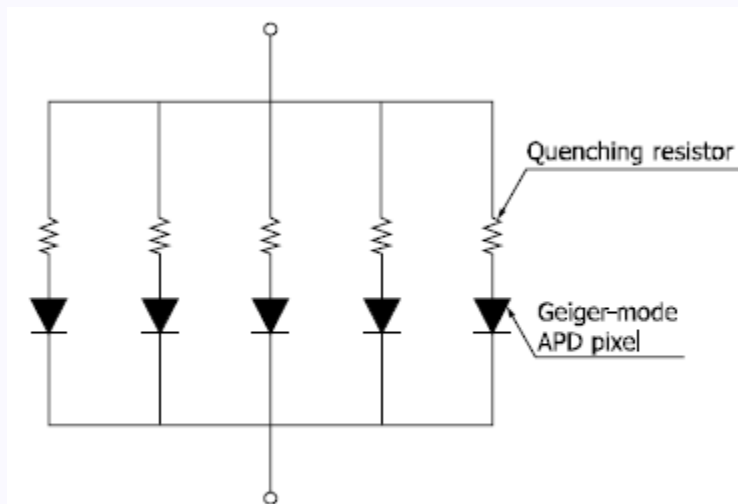
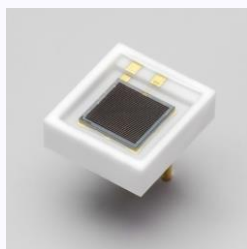


- Dynamic range: **~100fC~320pC**
- channels: 36
- Dead time: 2ms
- Polar: positive
- power: 8mW/channel

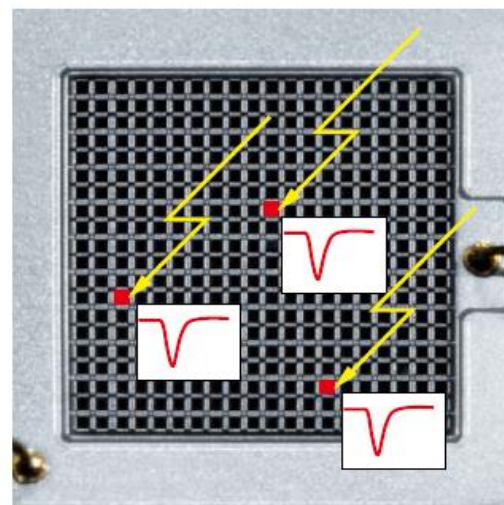
SiPM

➤ SiPM是一种被称为硅光电倍增器的光电器件。

- 由多个工作在盖格模式的APD组成的光子计数产品。
- 低功耗 ($<100V$, $<1\mu A$)
- 高增益 (10^5 - 10^6)、
- 高探测效率
- 好时间分辨率
- 宽的光谱响应范围等



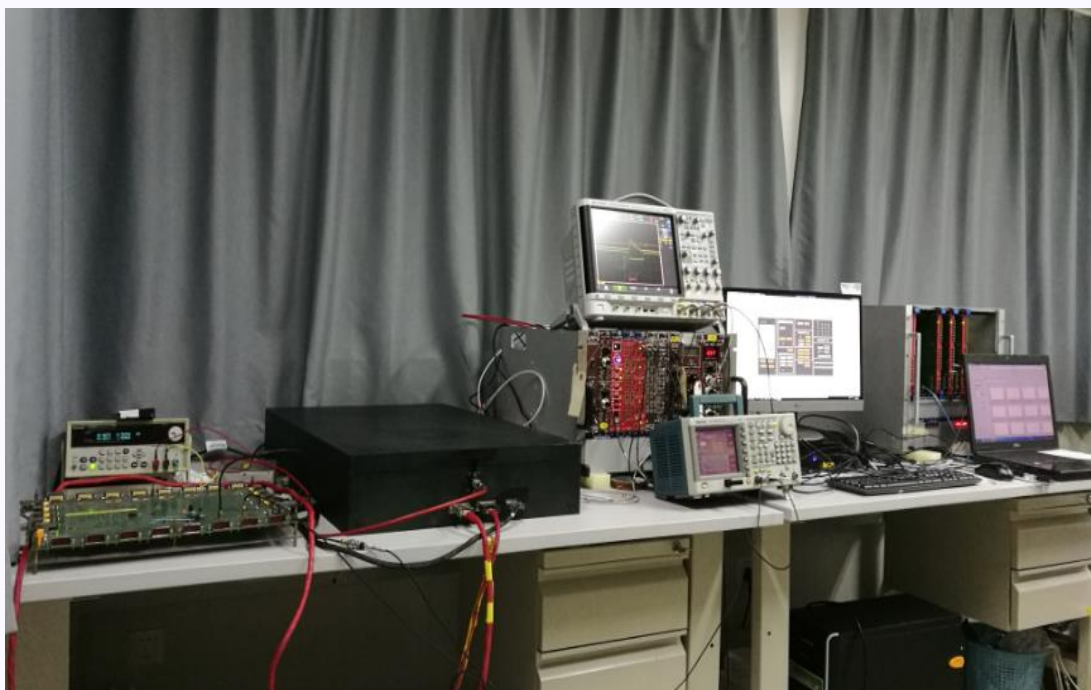
KAPDC0029EA



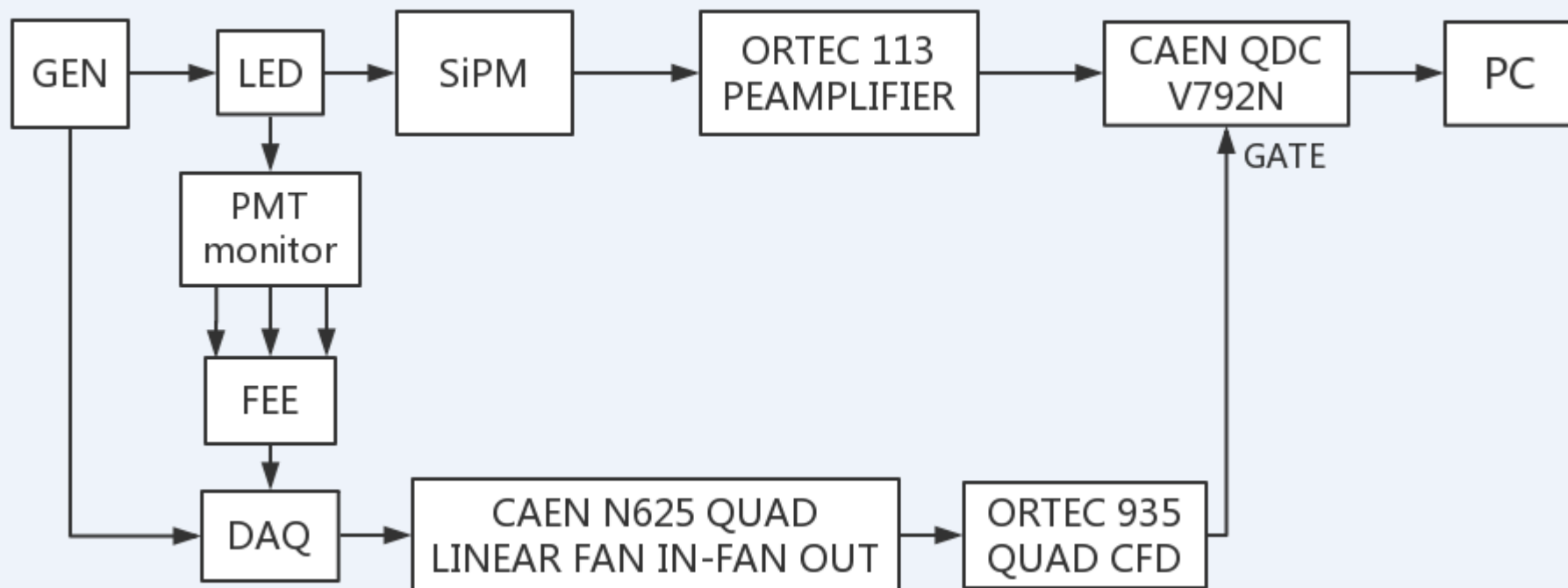
KAPDC0049EA

SiPM的性能

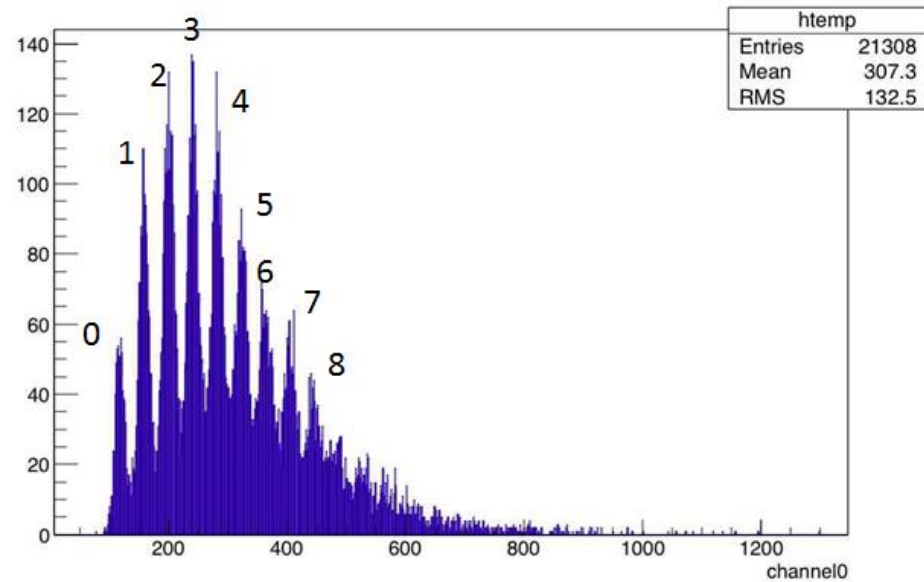
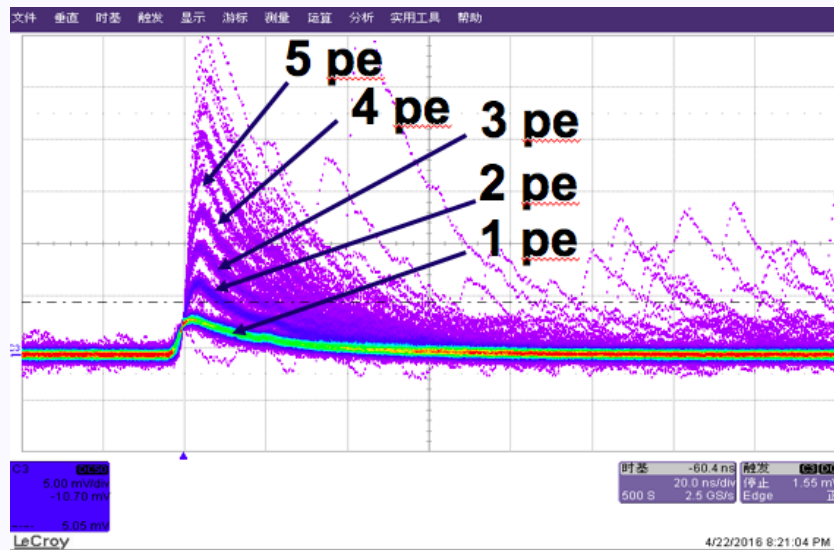
LED Test System



LED测试系统



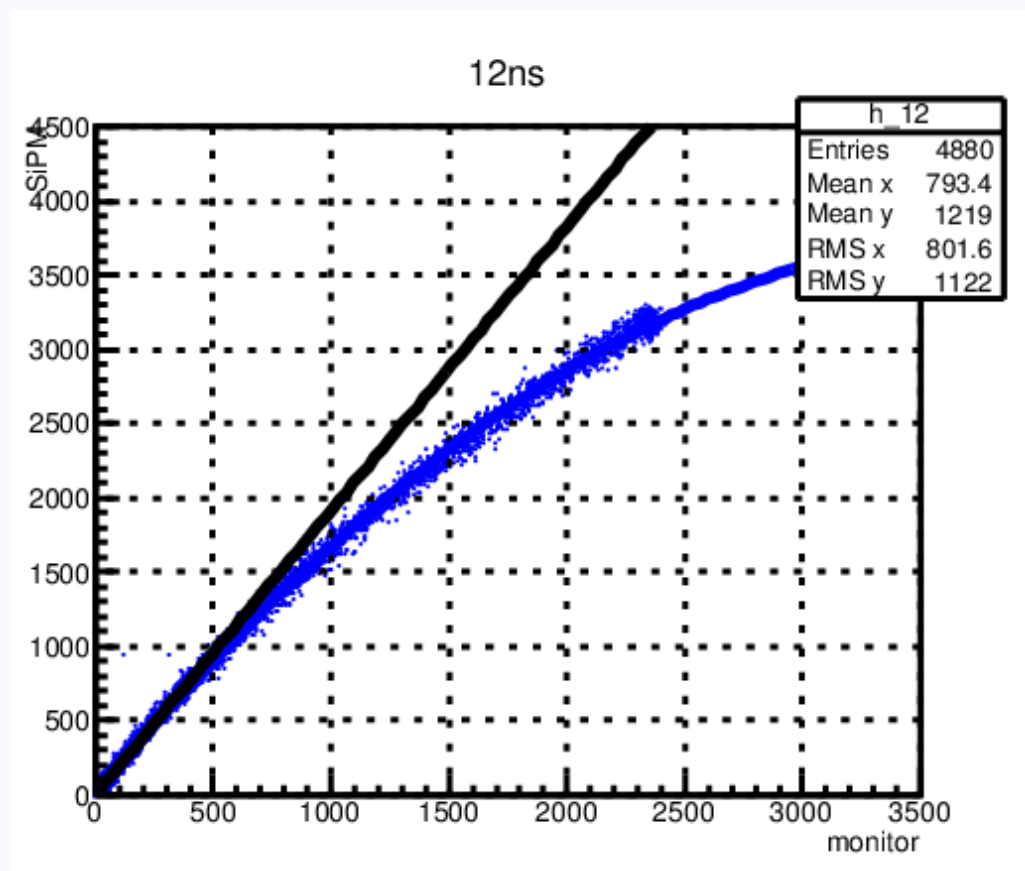
SiPM性能



SiPM线性测量

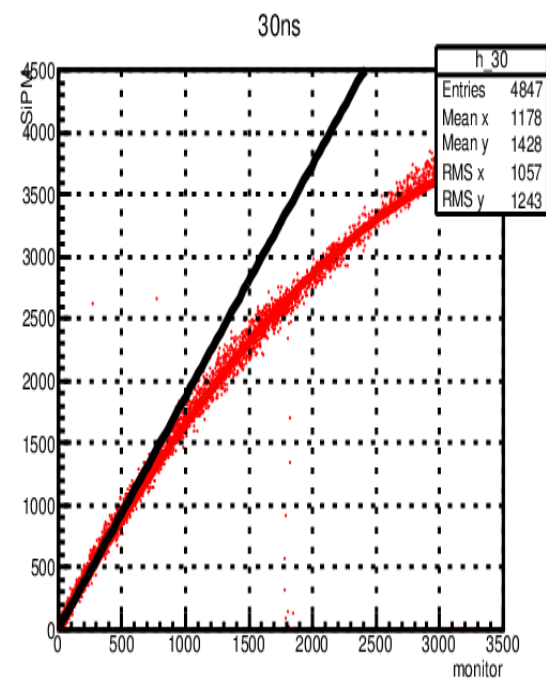
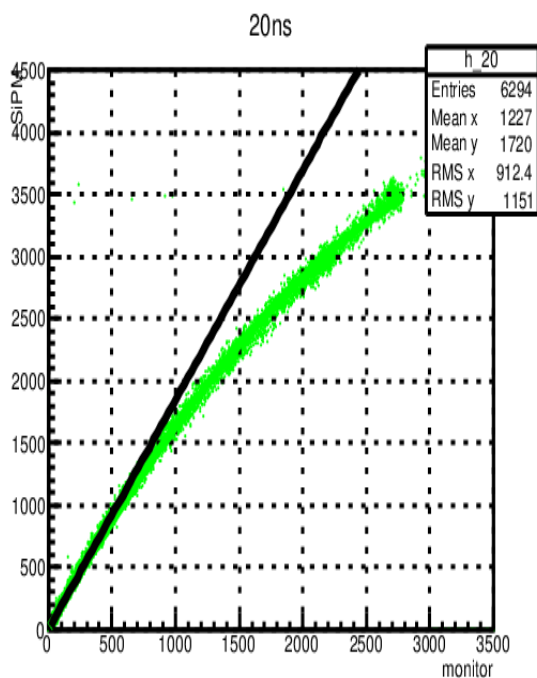
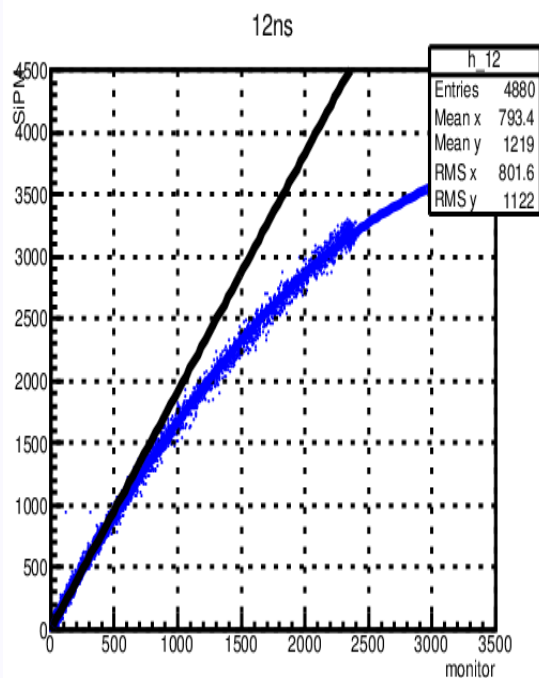
➤ Type No. : S12572-025P

Effective photosensitive area	3 × 3 mm
Pixel pitch	25 μm
Number of pixels	14400
Number of channels	1 ch
Package	Surface mount type
Cooling	Non-cooled
Spectral response range	320 to 900 nm
Peak sensitivity wavelength (typ.)	450 nm
Dark count (typ.)	1000 kcps
Terminal capacitance (typ.)	320 pF
Gain (typ.)	5.15×10^5
Recommended operating voltage (typ.)	$V_{BR} + 3.5 \text{ V}$
Measurement condition	$T_a = 25 \text{ }^\circ\text{C}$



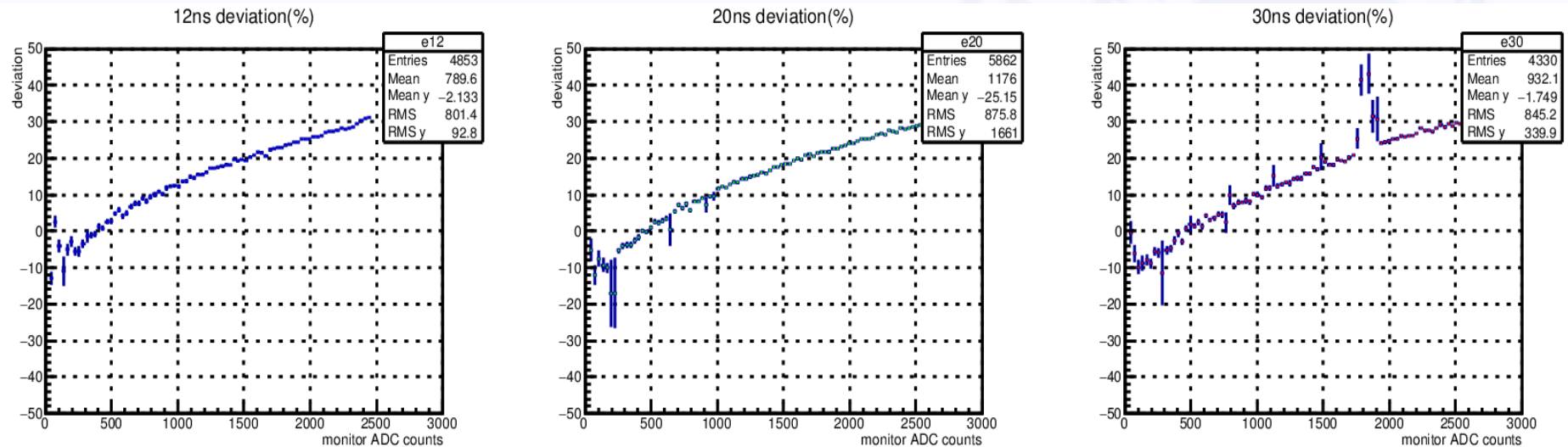
SiPM响应线性

➤ 信号源激发宽度为12ns、20ns和30ns

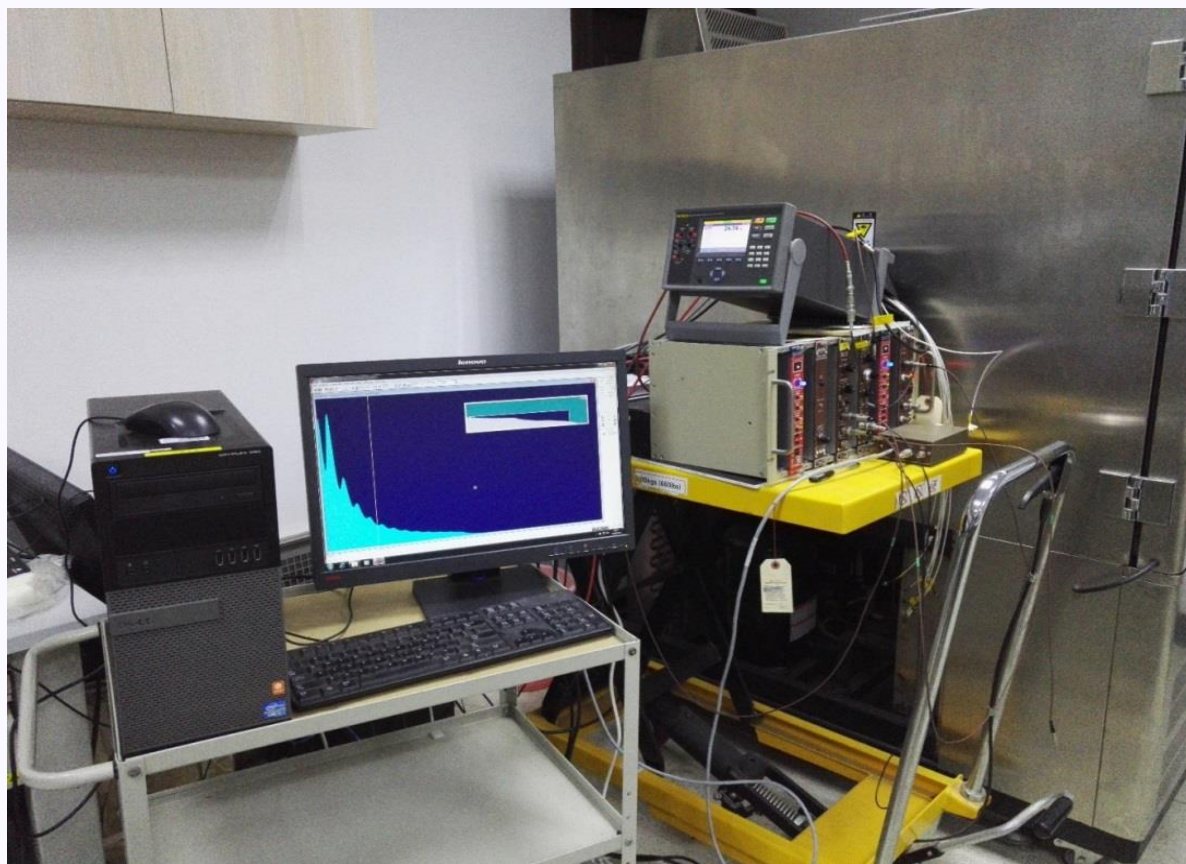


SiPM响应线性

- SiPM响应到4000-5000个光电子，其线性在 $\pm 10\%$ ，约为总的pixels的1/3

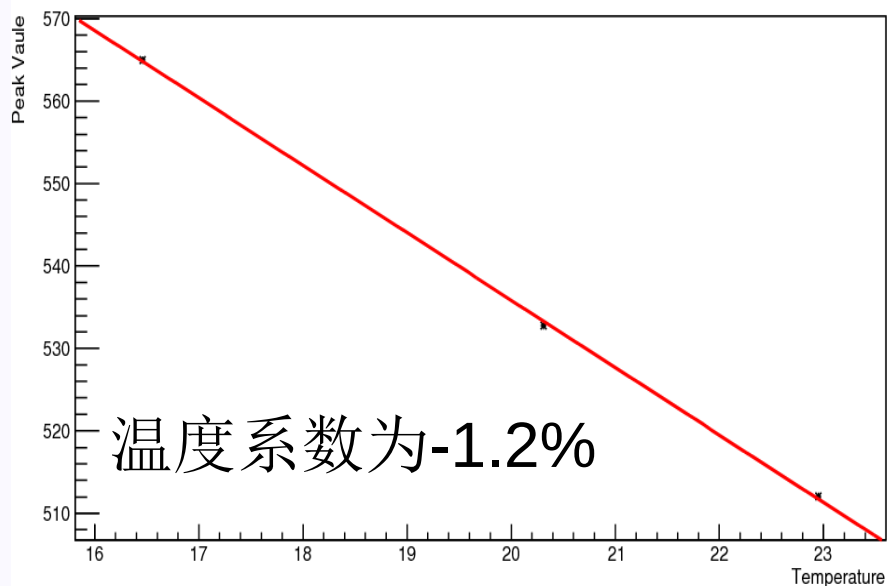


温度效应测试



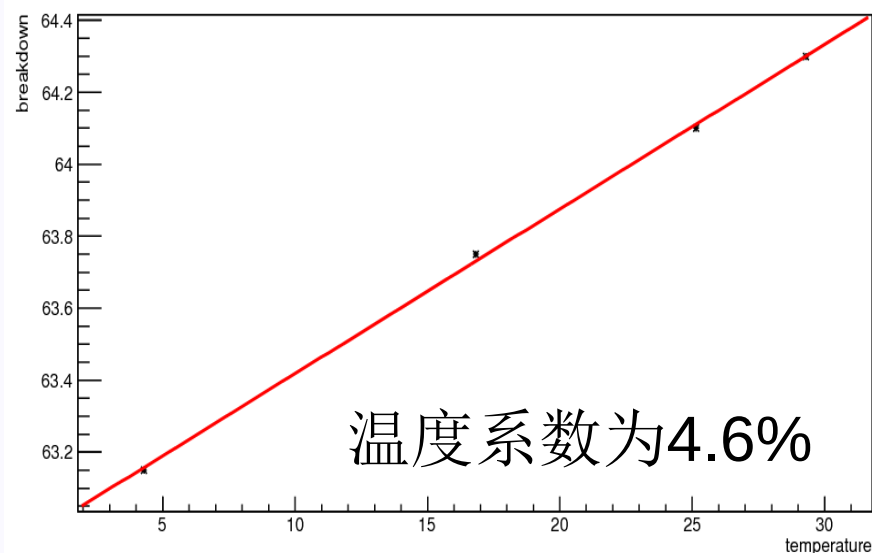
温度效应

Graph



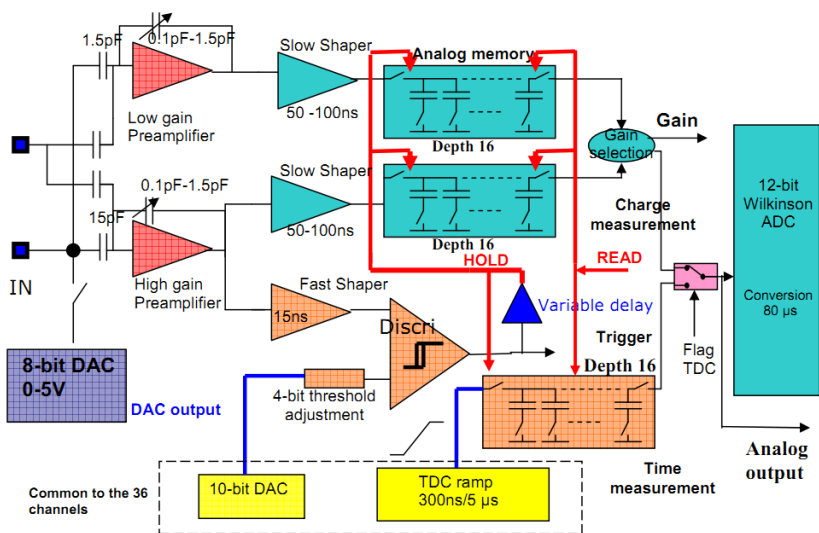
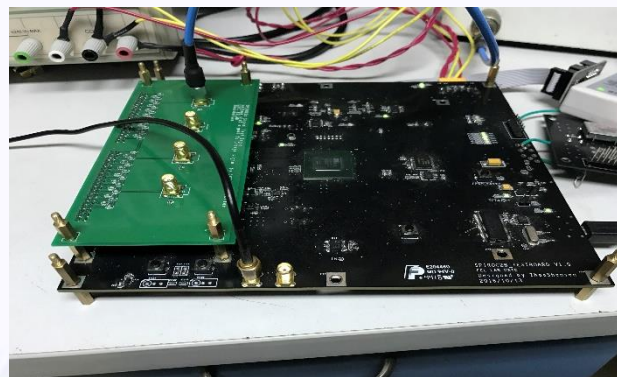
增益vs. 温度

Vbreakdown vs temperature



击穿电压vs. 温度

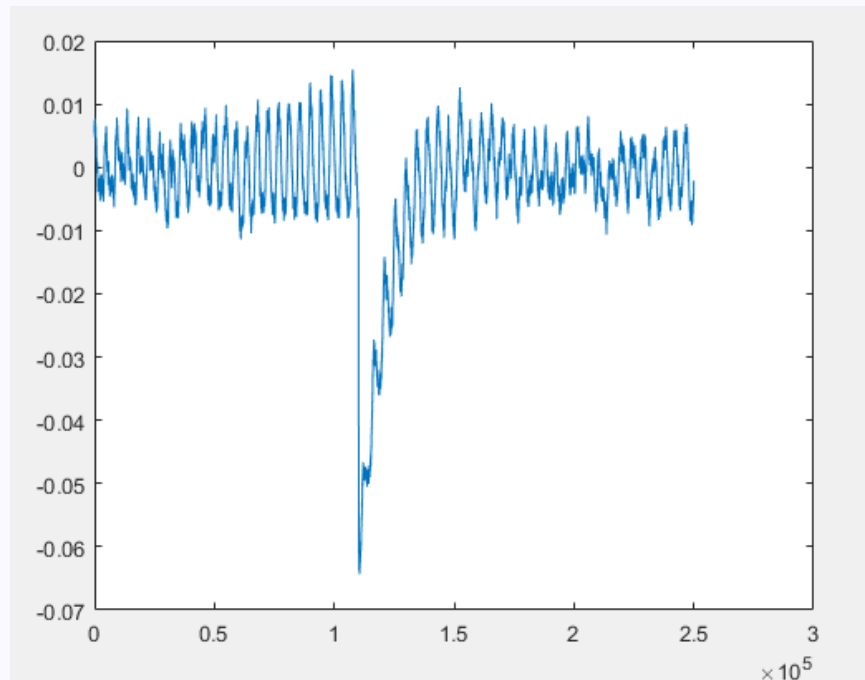
电子学板进展



电子学板进展

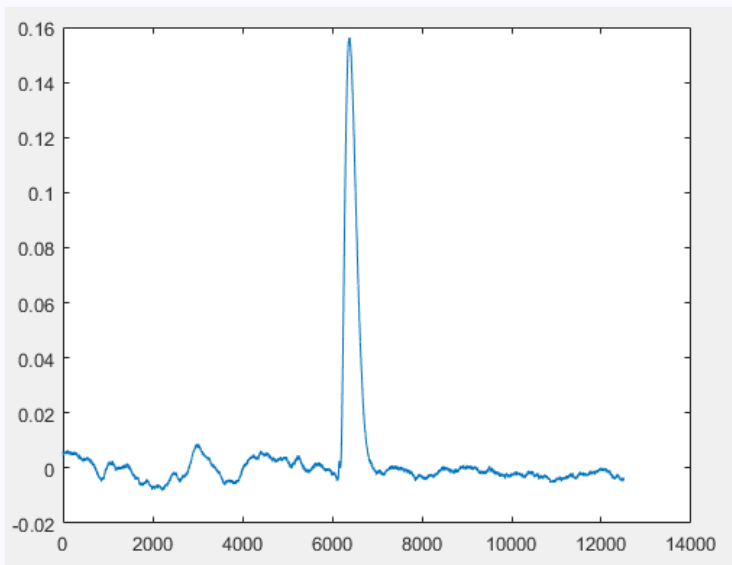
➤ 经过电荷灵敏前放放大过后的信号：

- 输入为50mv，经过15pf输入电容后经过高增益放大器放大后的信号。

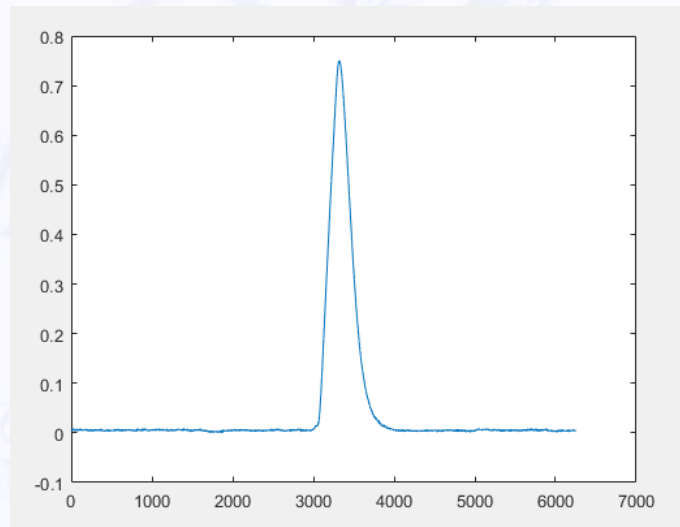


电子学板进展

- 经过电荷灵敏前放放大过后的信号：
- 输入为50mv，经过15pf输入电容两个增益放大成形后的信号。



高增益通道



低增益通道

Summary

- 成像型电磁量能器是未来加速器物理的一个重要方案
- 通过MC仿真，确定了成像型量能器的基本需求
- 建立LED测试平台，针对SiPM的线性响应等性能进行了测试
- 利用温箱系统，开展了SiPM的温度特性的研究
- 电路板的设计及测试在有条不紊地开展



THANKS