

基于塑闪-钨的电磁量能器 (ScW ECAL) 模拟优化

报告人：赵航

CEPC上的电磁量能器

基于粒子流算法（PFA）进行设计

核心思想是重建每一个末态粒子，区分开不同入射粒子在量能器中的能量沉积

- 高颗粒度
- 取样型

主要目的为精确测量光子和强子喷注的能量，并为粒子鉴别提供信息

- 光子的能量分辨要求达到 $16\%/\sqrt{E(\text{GeV})}$
- JET能量分辨要求达到 $\sigma_E/E \approx 3\sim 4\%$ 或者当能量低于100GeV时好于 $30\%/\sqrt{E(\text{GeV})}$

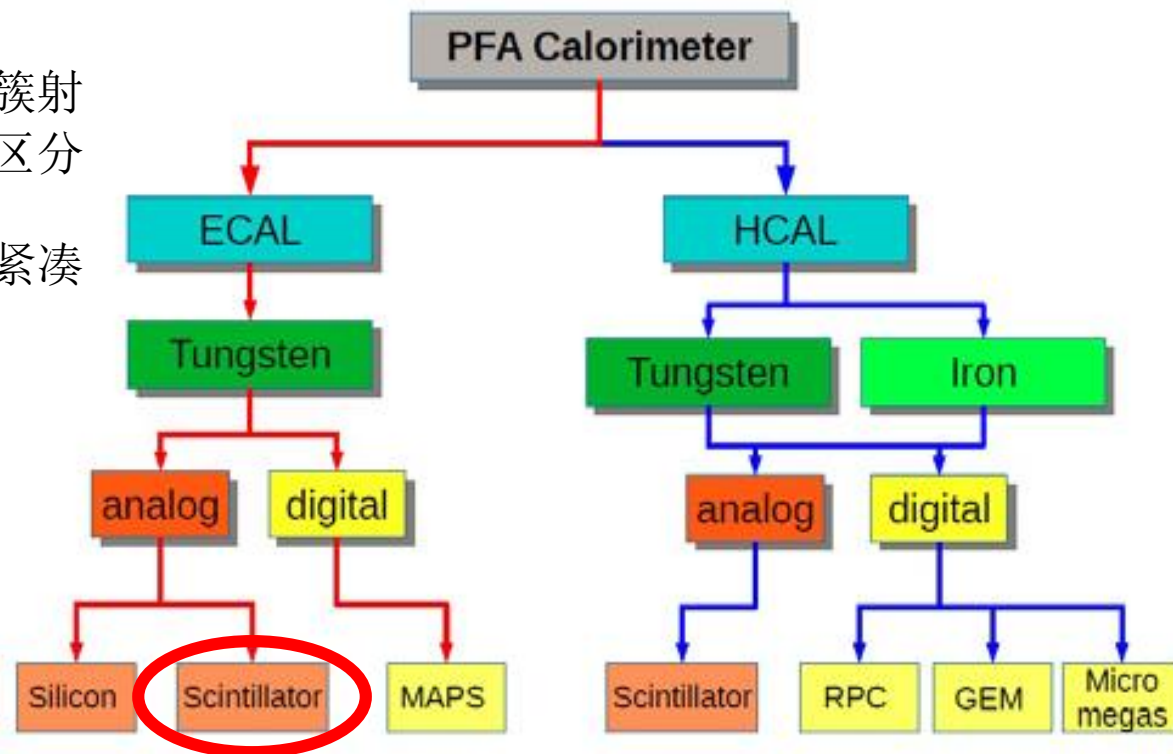
ScW ECAL

采用Tungsten (W) 作为吸收层

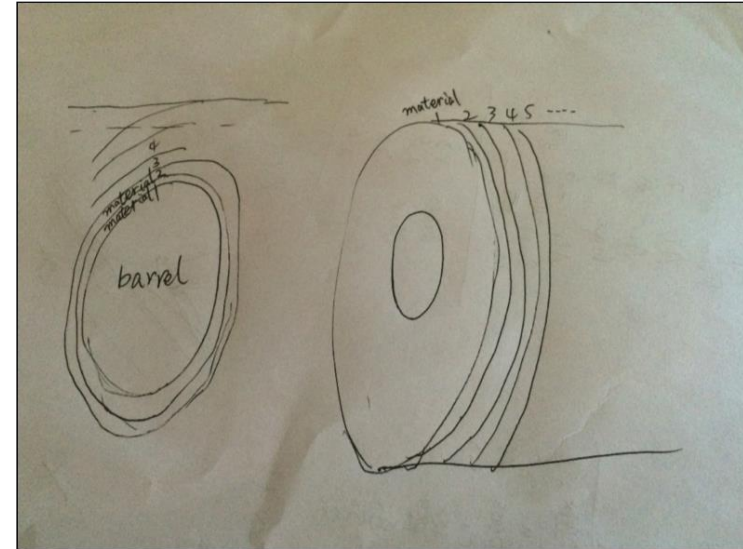
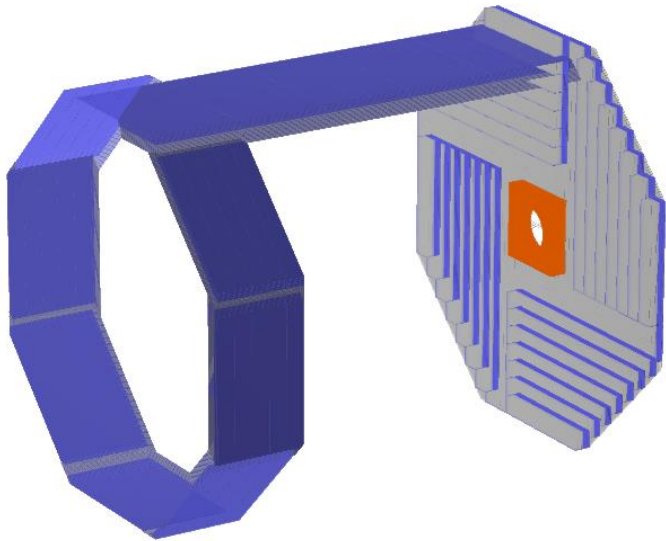
- 小的莫尔半径区分靠的很近的簇射
- 大的核作用长度和辐射长度比区分电磁簇射和强子簇射
- 尽量大的辐射长度以使ECAL更紧凑

采用塑料闪烁体作为灵敏层

- 价格便宜，易于加工
- 长塑闪条正交排列的方式减少读出通道数目



Simplified CEPC-SPPC Geometry



```
/Mokka/init/globalModelParameter world_box_hx 100000
/Mokka/init/globalModelParameter world_box_hy 100000
/Mokka/init/globalModelParameter world_box_hz 250000
/Mokka/init/globalModelParameter SiCalLayerStructure Si:0.5;(Cu:0.5,W:0,Cu:0.5,Si:0.5,PCB:1.2,Air:0.5)*20;(Iron:0,RPC1:1.2,PCB:1.2,Air:0.5)*40
/Mokka/init/globalModelParameter SiCalZeroThickReset 2.8*20,25*40
/Mokka/init/globalModelParameter SiCalInnerRadius 1845
/Mokka/init/globalModelParameter SiCalBarrelHalfZ 2450
/Mokka/init/globalModelParameter SiCalEndcapEta1 4
/Mokka/init/globalModelParameter SiCalEndcapEta2 4
/Mokka/init/globalModelParameter SiCalBuildBarrel 1
/Mokka/init/globalModelParameter SiCalXCellSize 5,10
/Mokka/init/globalModelParameter SiCalYCellSize 5,10
/Mokka/init/globalModelParameter SiCalEndcapOuterR 3113.5
```

只包含量能器部分，几何结构简单，易于修改和优化

ScW ECAL 几何尺寸模拟

Baseline Design in preCDR

- 纵向：25个厚度7mm的超层，每个超层由3mm厚的钨板、2mm厚的塑闪条以及2mm的读出/服务层组成，总厚度是175mm，对应 ≈ 21.4 个辐射长度。
- 横向： $5 \times 45\text{mm}^2$ 的塑料闪烁体条，相邻两层的塑闪条正交排列以此获得 $5 \times 5\text{mm}^2$ 的有效横截面

模拟参数

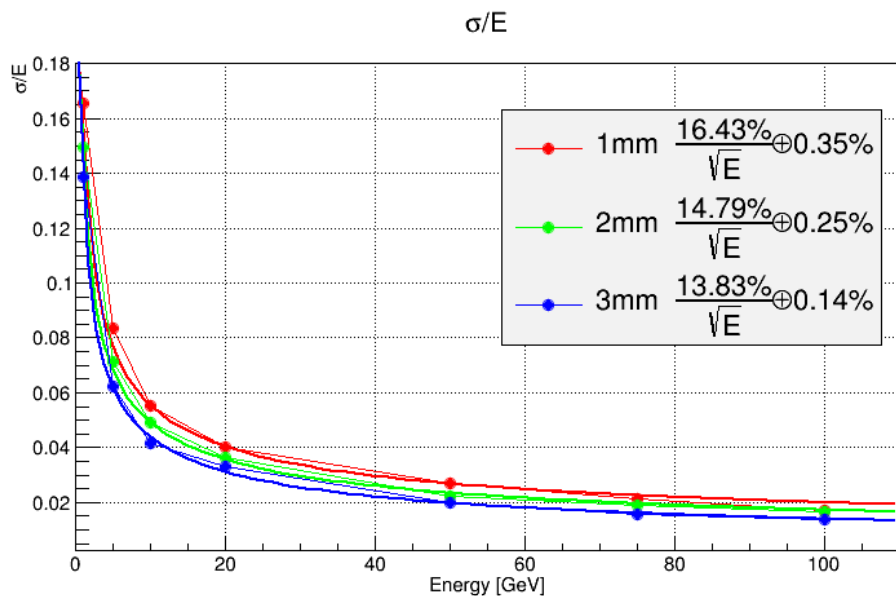
- 灵敏层厚度
- 总层数
- 吸收层单层厚度及总厚度
- 灵敏层横向截面大小

参考指标

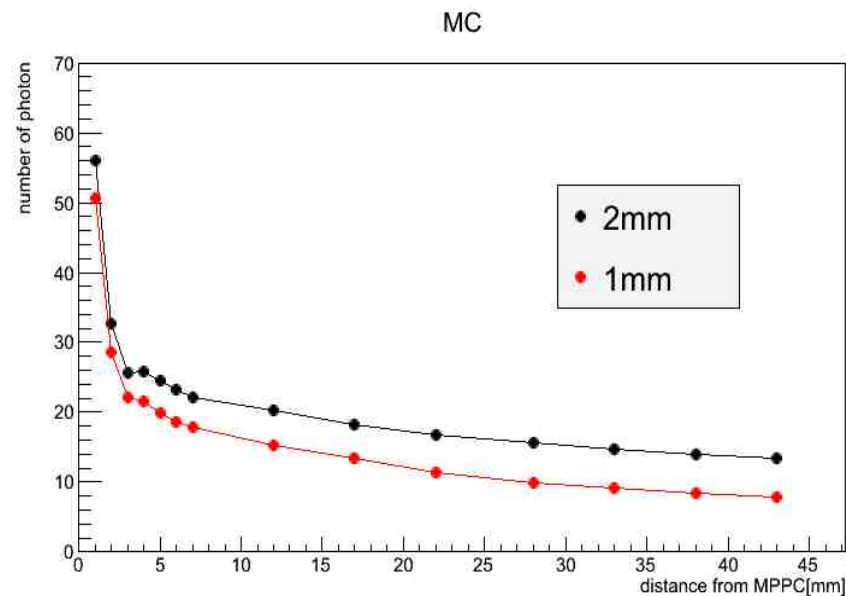
光子能量分辨率

位置分辨率

灵敏层厚度模拟结果



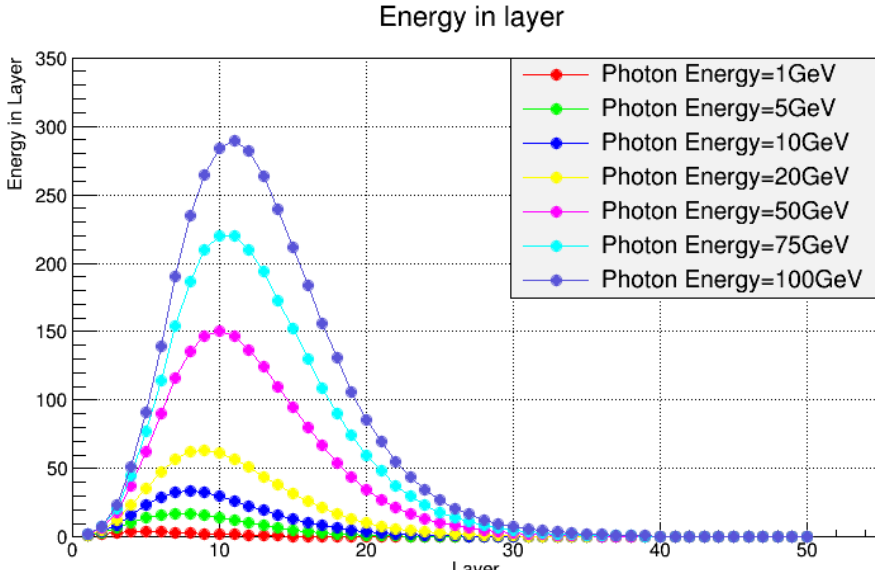
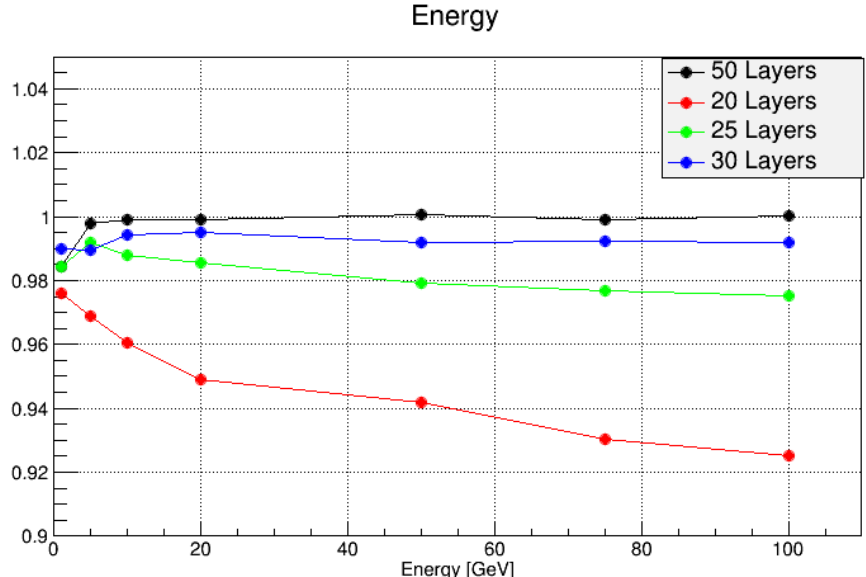
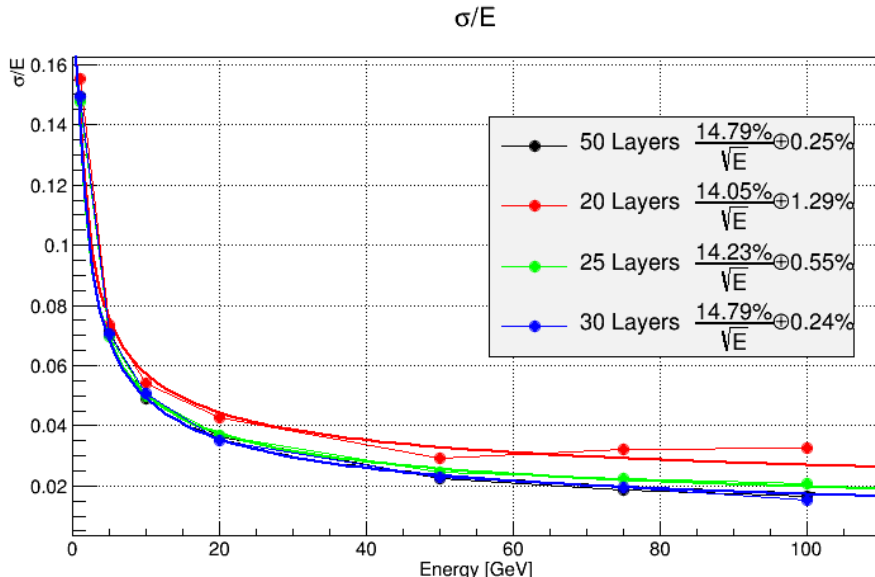
塑闪条厚度对光子能量分辨率的影响



塑闪条厚度对光子探测数目影响

塑闪越厚，光子能量分辨率越好，2mm厚度已可以满足要求
塑闪太薄会影响光子探测数目，1mm大约是2mm的2/3

总层数



簇射能量在每一层的分布

层数	沉积能量占比 (175GeV光子)
20	88.4%
25	96.4%
30	98.9%

吸收层厚度变化

吸收层厚度相同

共30层，每层3mm

共90mm，25.7个辐射长度

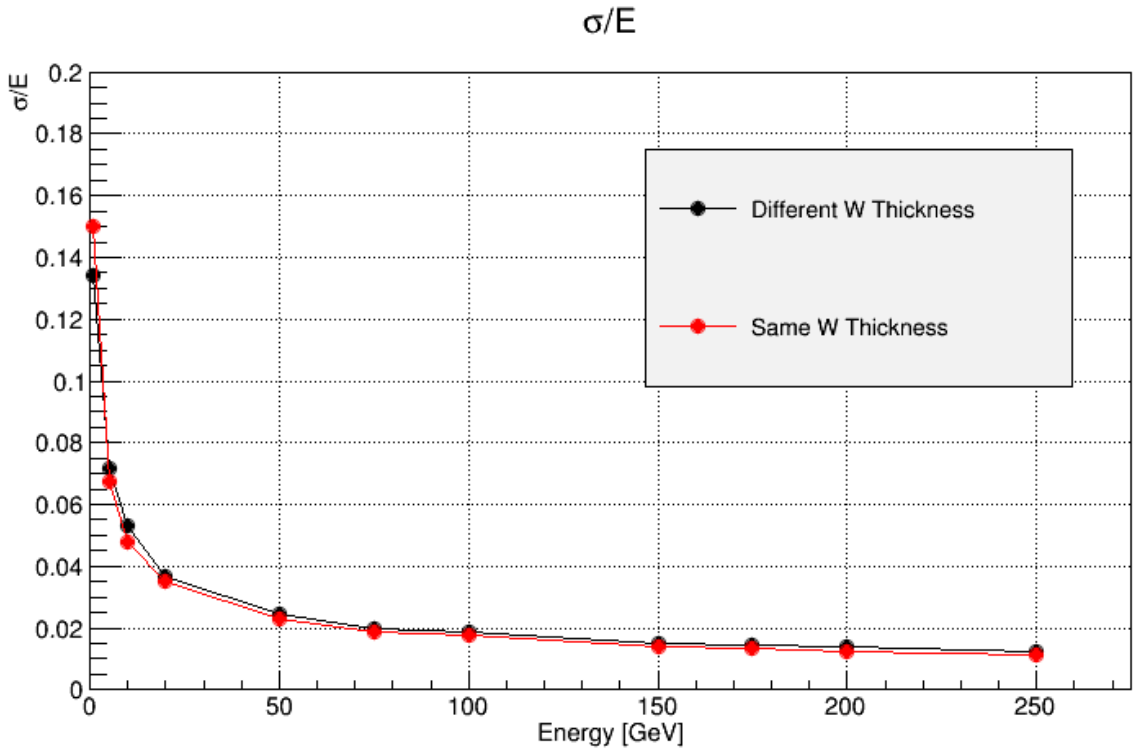
每层权重系数相同

吸收层厚度不同

前10层 1.2mm ,11~20, 2.4mm ,21~30层 4.8mm

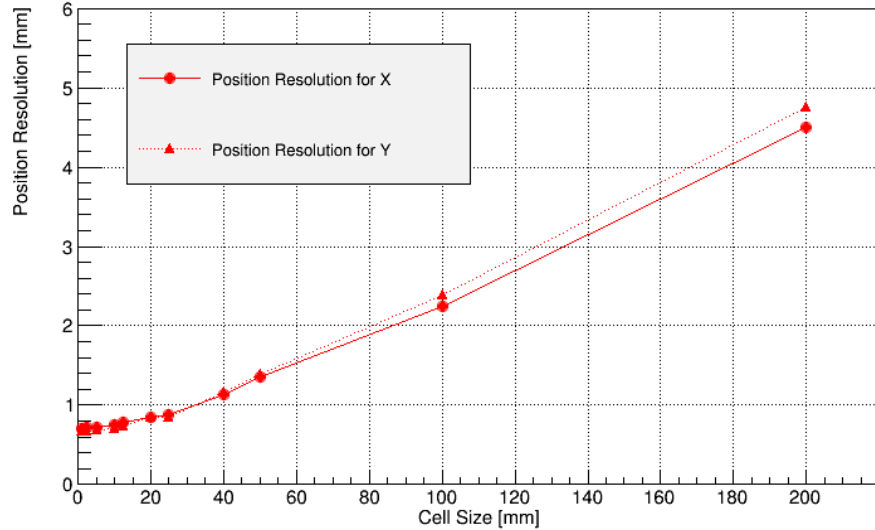
共84mm，24个辐射长度

由吸收层厚度决定系数，前10层为a，中间10层为2a，后10层为4a



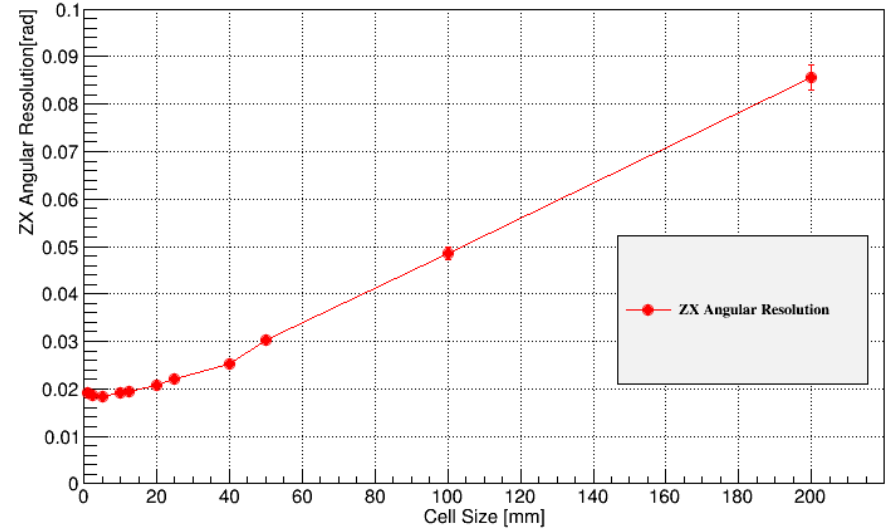
灵敏层横向截面大小

PositionResolution/CellSize



Position Resolution 随Cell Size 变化

Track Fit : ZX Angular Resolution



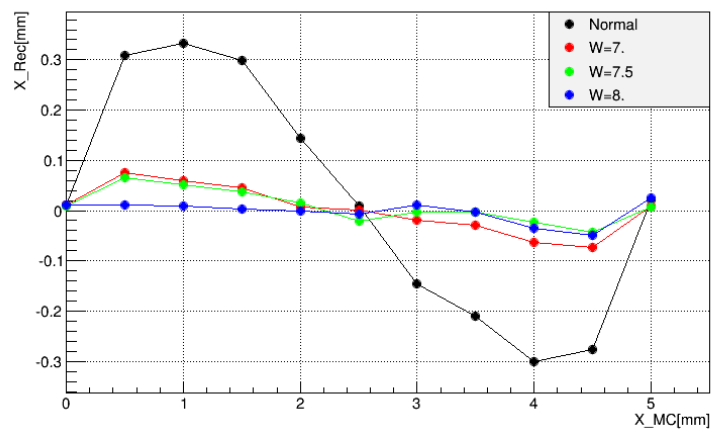
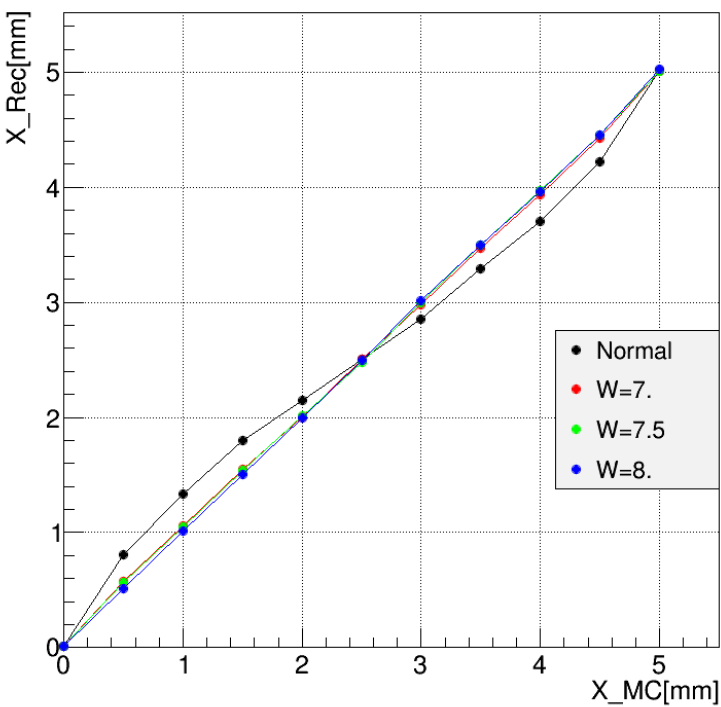
Angular Resolution 随Cell Size 变化

选用50GeV 光子

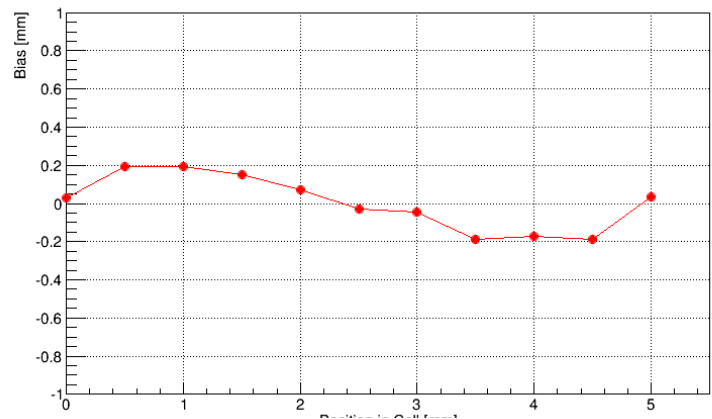
Cell Size < 20mm 时变化很小

位置重建算法研究

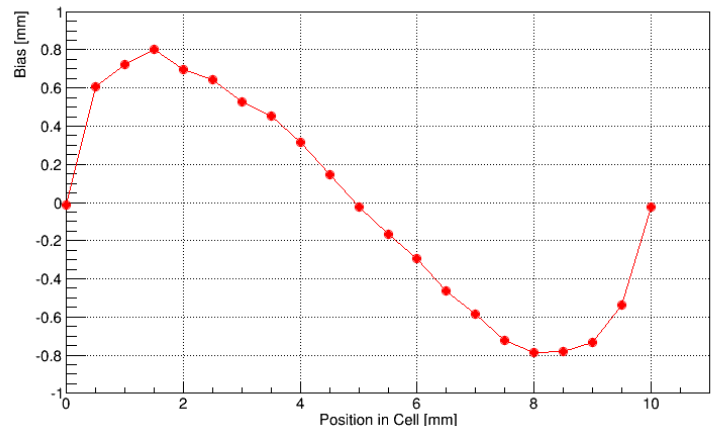
$$X_{\text{Calc}} = \frac{\sum_i w_i x_i}{\sum_i w_i}, \quad w_i = \max\left\{0, \left[W_0 + \ln\left(\frac{E_i}{E_T}\right)\right]\right\},$$



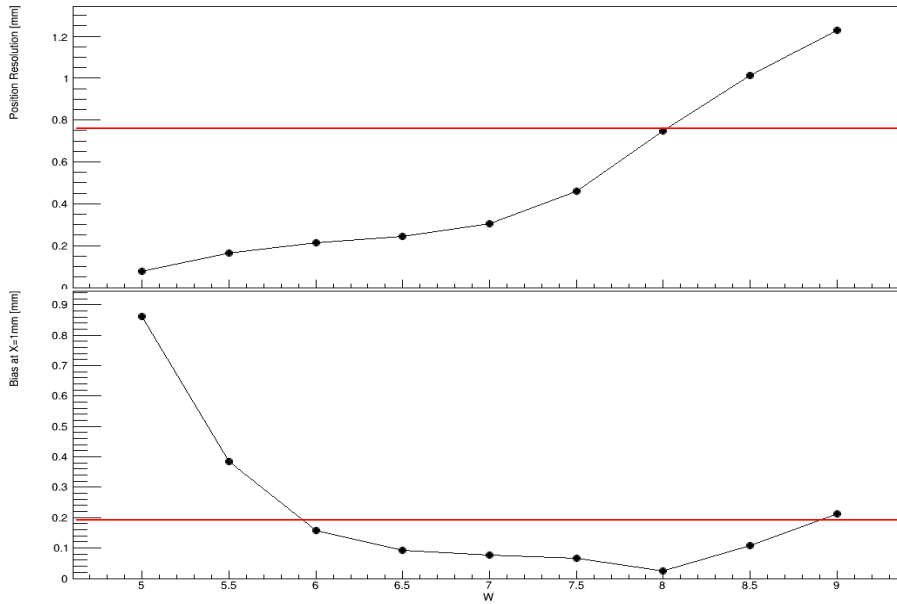
Inside Cell Bias : Cell Size =5mm



Inside Cell Bias : Cell Size =10mm

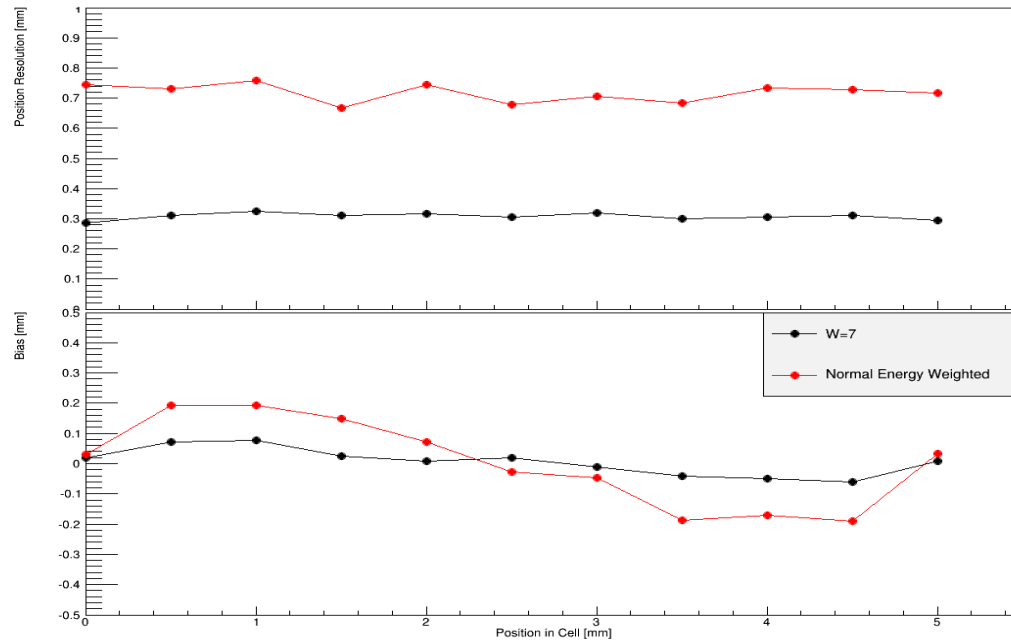


在Cell上不同击中点与重建的击中点关系



红线为普通重心法结果

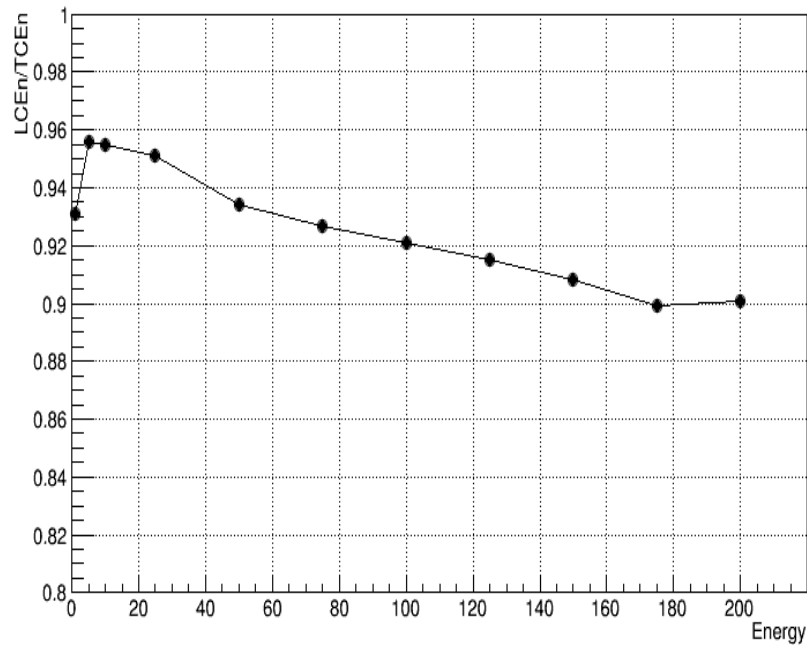
理论上bias 最大位置为X=1.125mm, 这里选取X=1mm处结果



W=7时优化结果

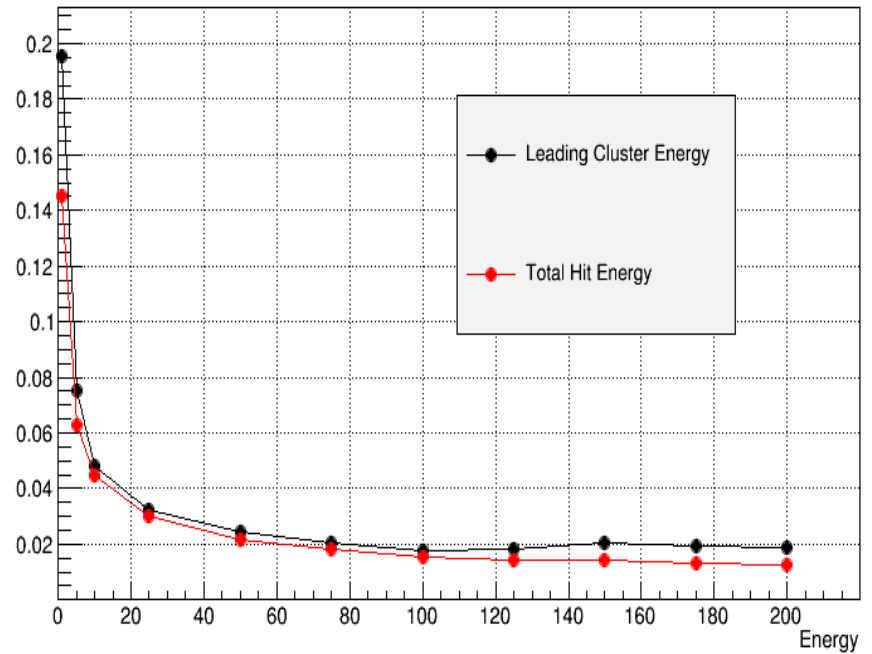
Arbor Test by Energy

LCEn/TCEn



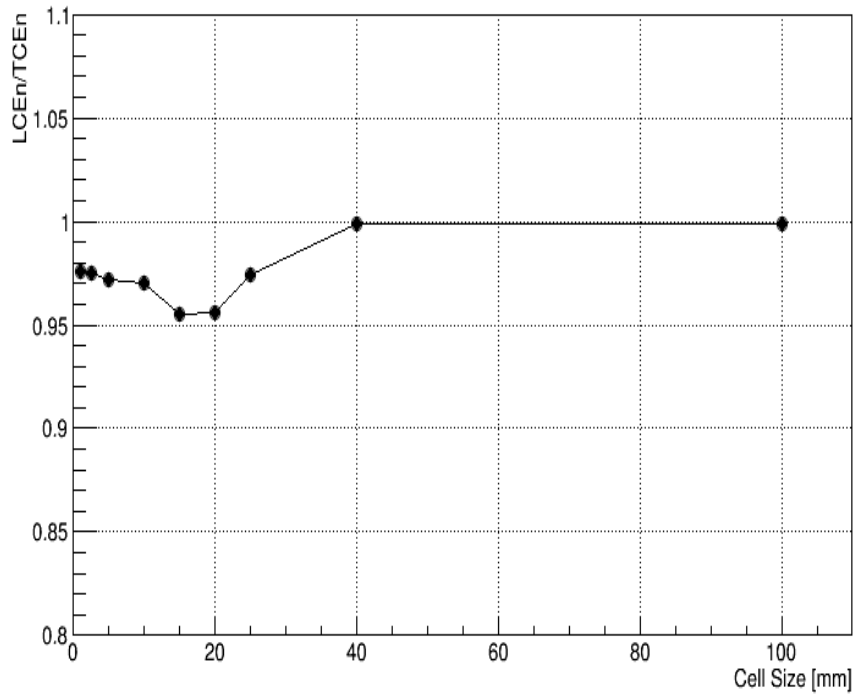
Leading Cluster Energy /
Total Cluster Energy

SigmaE/E

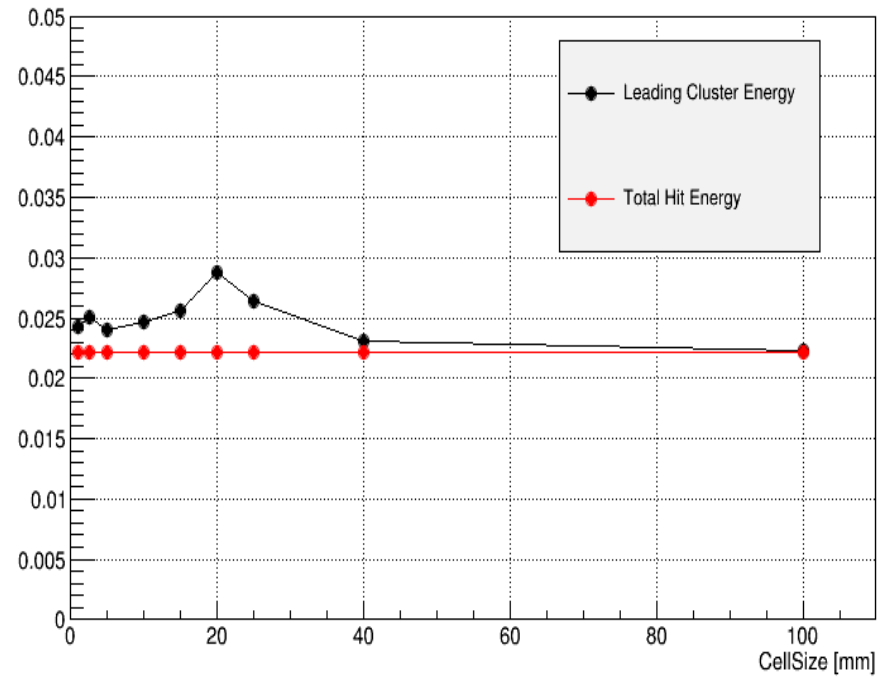


Arbor Test by Cell Size

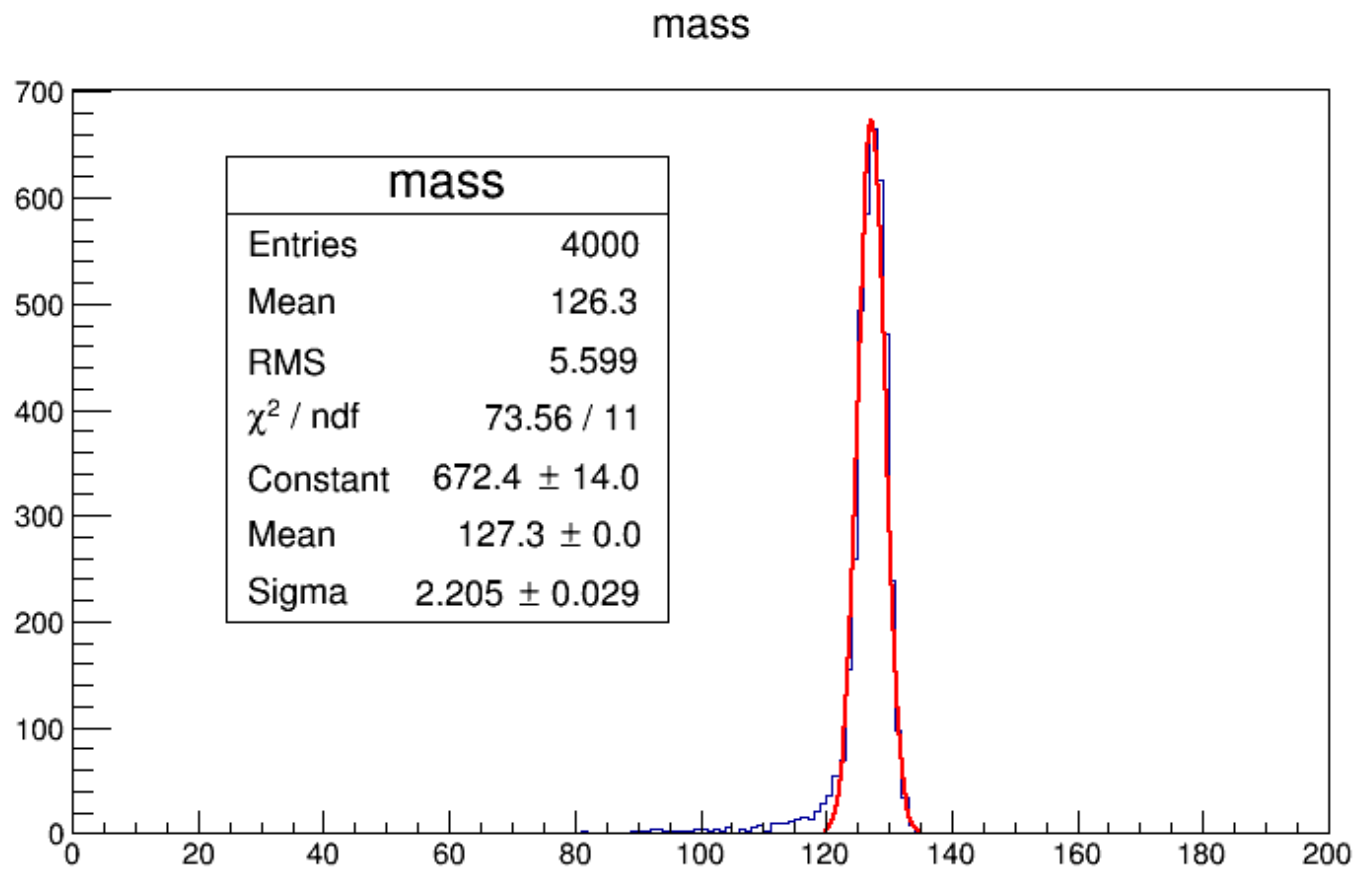
LCEn/TCEn



SigmaE/E



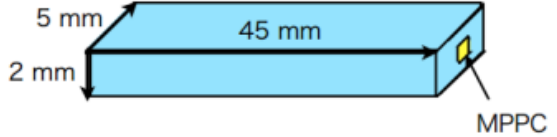
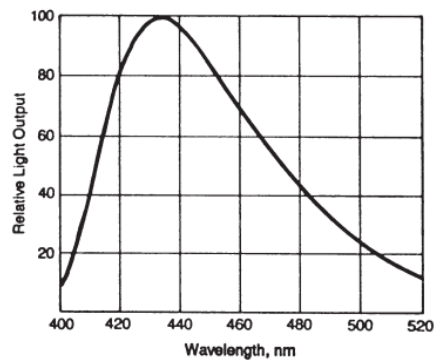
H- \rightarrow $\gamma\gamma$



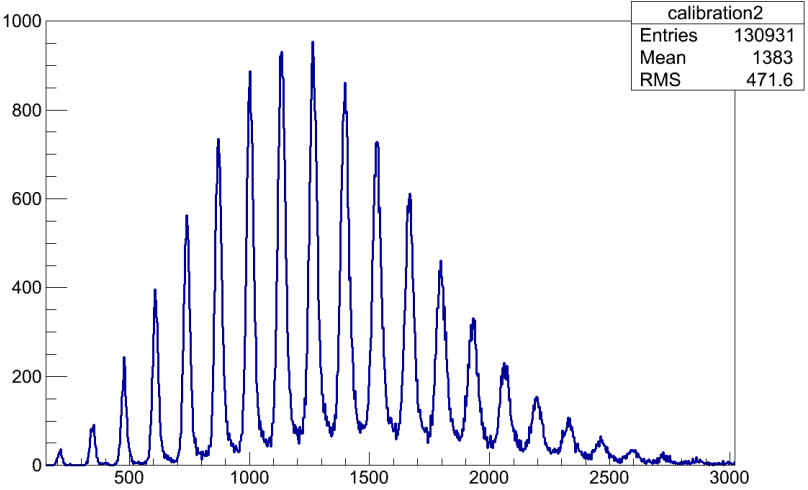
Simple Digitizer

- Saturation
- Homogeneity
-

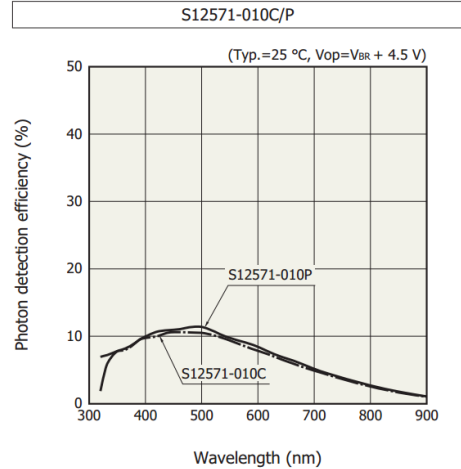
BC-412 & BC-416



Baseline design of scintillator and SiPM



Photon detection efficiency vs. wavelength

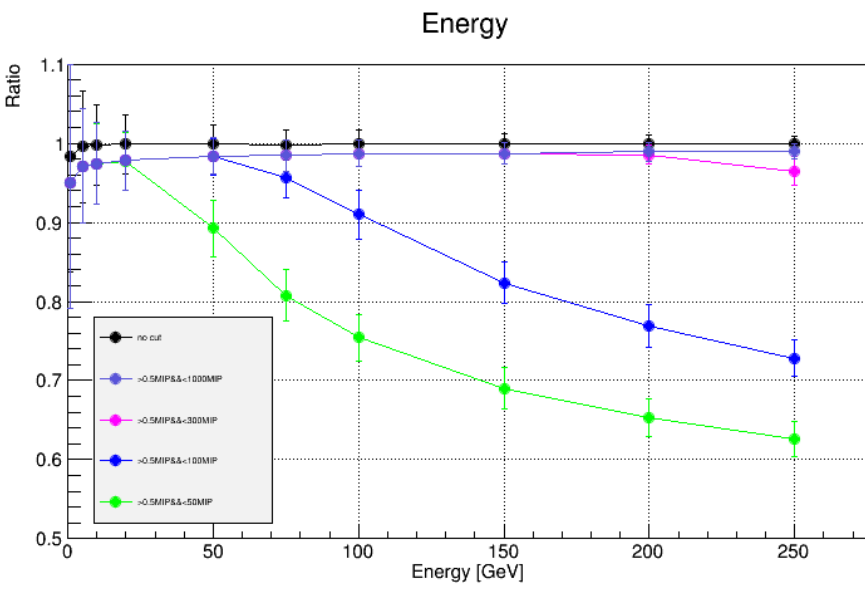
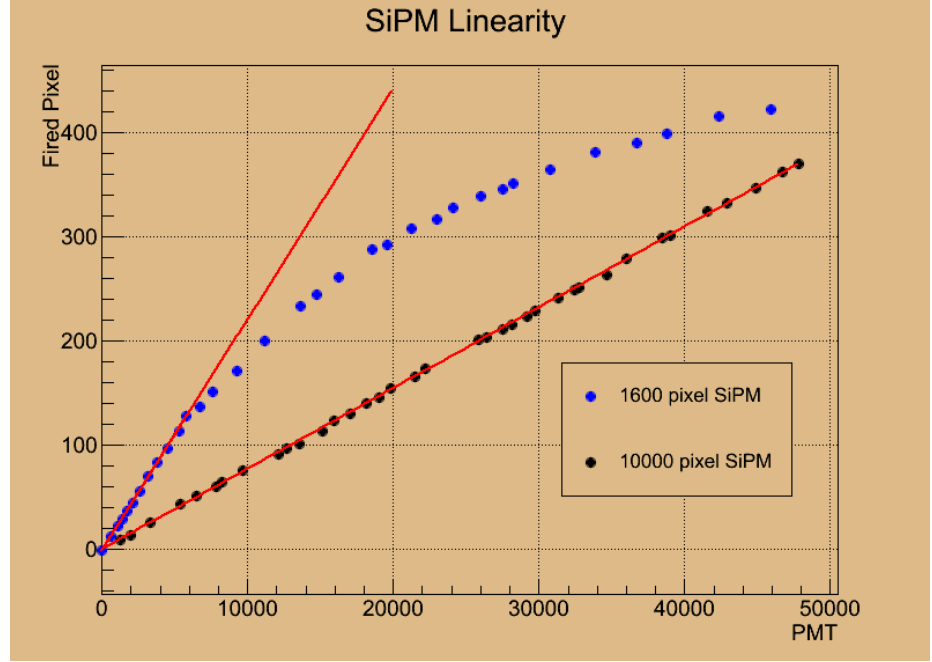


Excellent photon counting ability

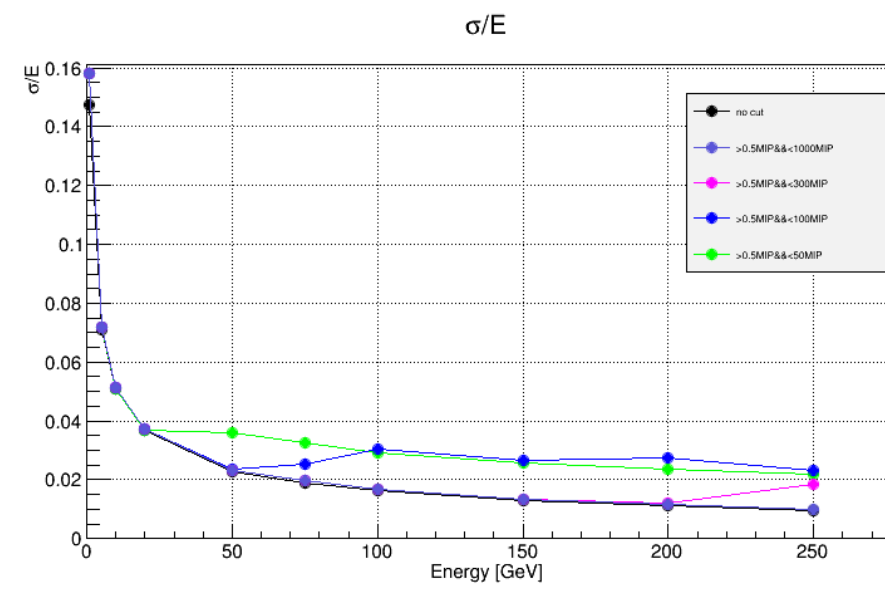
Saturation

- The SiPM dynamic range is determined by the number of pixels.

The manufactures have developed the SiPM with the pixel pitch of 10um, which increase the number of pixel per unit area, drastically extends the SiPM dynamic range

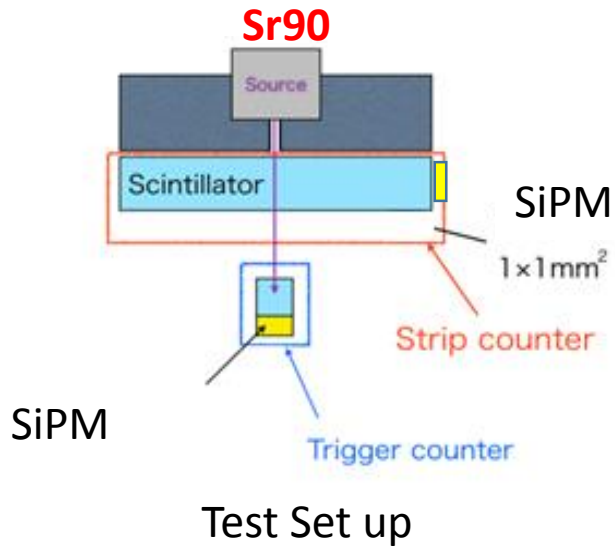


Energy Linearity

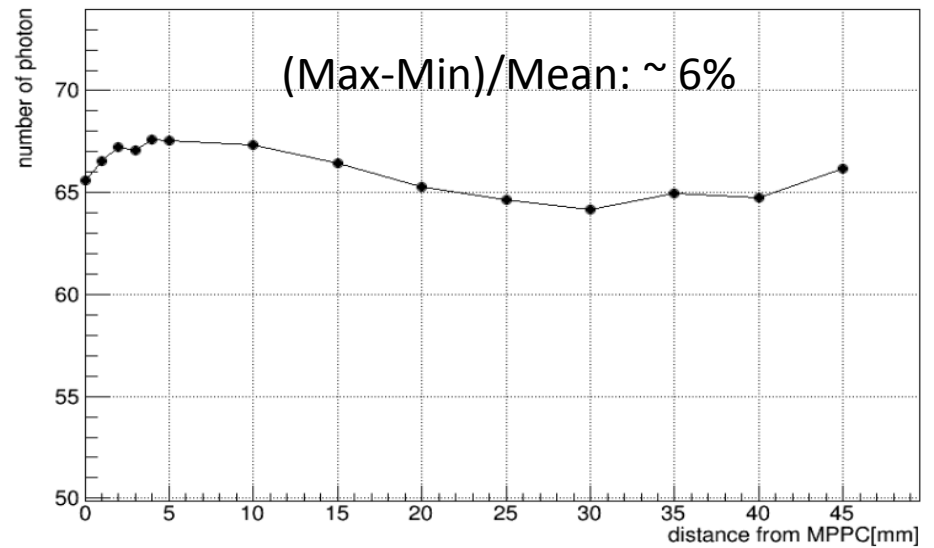


Energy Resolution

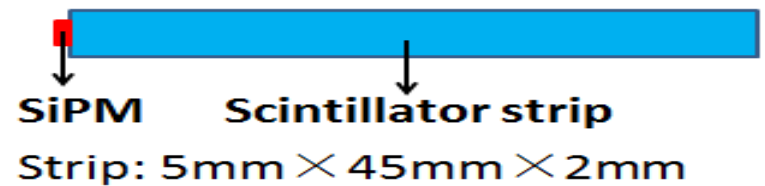
Scintillator strip test



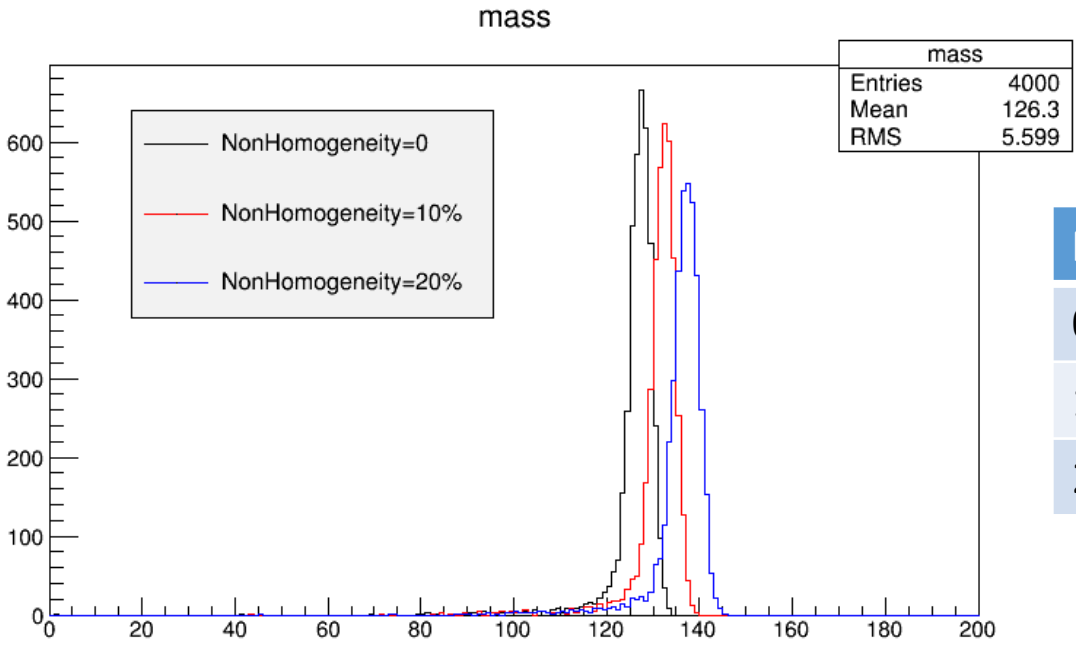
5mm × 45mm scintillator strip



Scintillator strip and SiPM



Non-Homogeneity



Non-Homogeneity	Sigma/Mean
0	1.73%
10%	1.78%
20%	1.92%