

# 粒子密度对比 & 径迹匹配算法

张洋

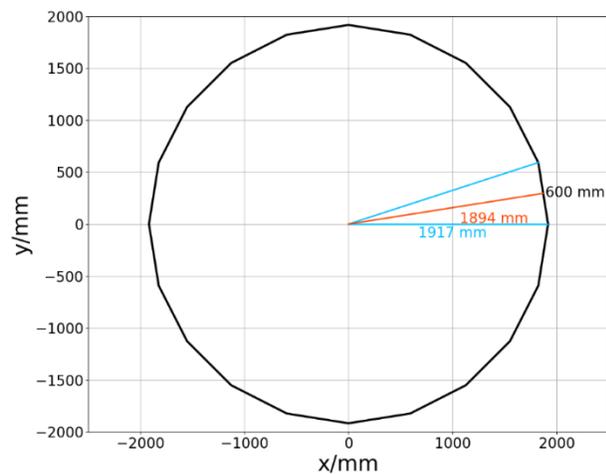
2023年3月22日

$400 \times 400 \text{ mm}^2$  与  $600 \times 600 \text{ mm}^2$   
两种不同尺寸 tower 的粒子数密度对比

# 虚拟的几何

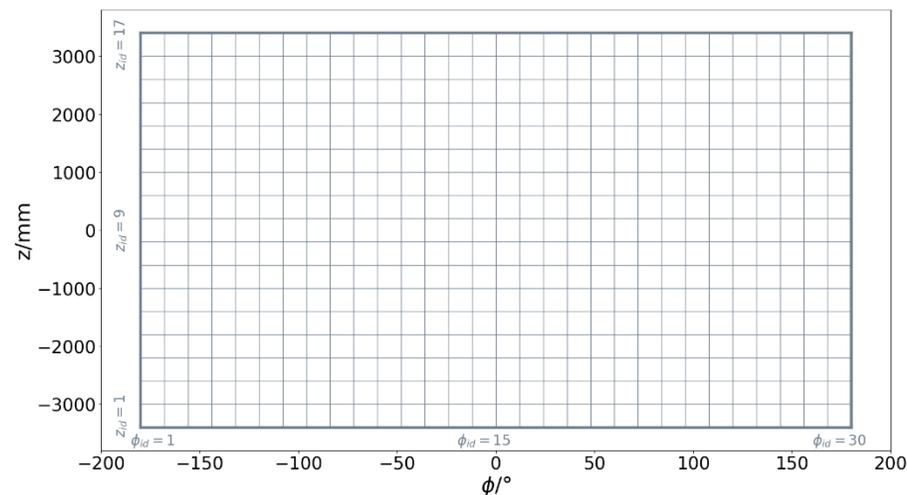
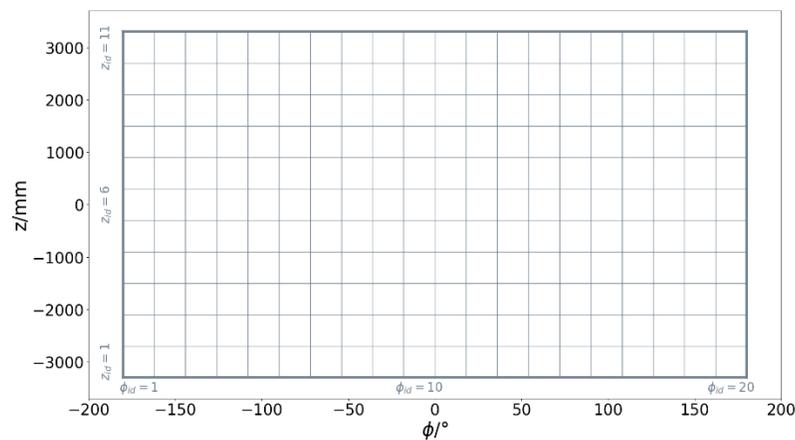
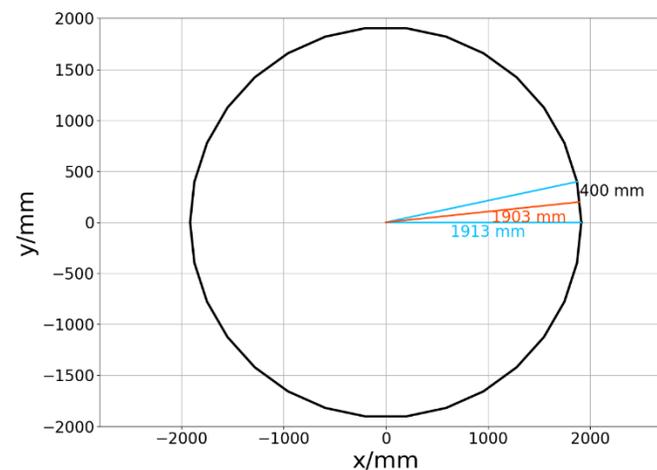
## ➤ 600mm × 600mm tower

- xy 平面为正 20 边形,
- z向长6600mm, 11个tower( $\cos \theta = 0.864$ )



## ➤ 400mm × 400mm tower

- xy 平面为正 30 边形,
- z向长6800mm, 17个tower( $\cos \theta = 0.872$ )

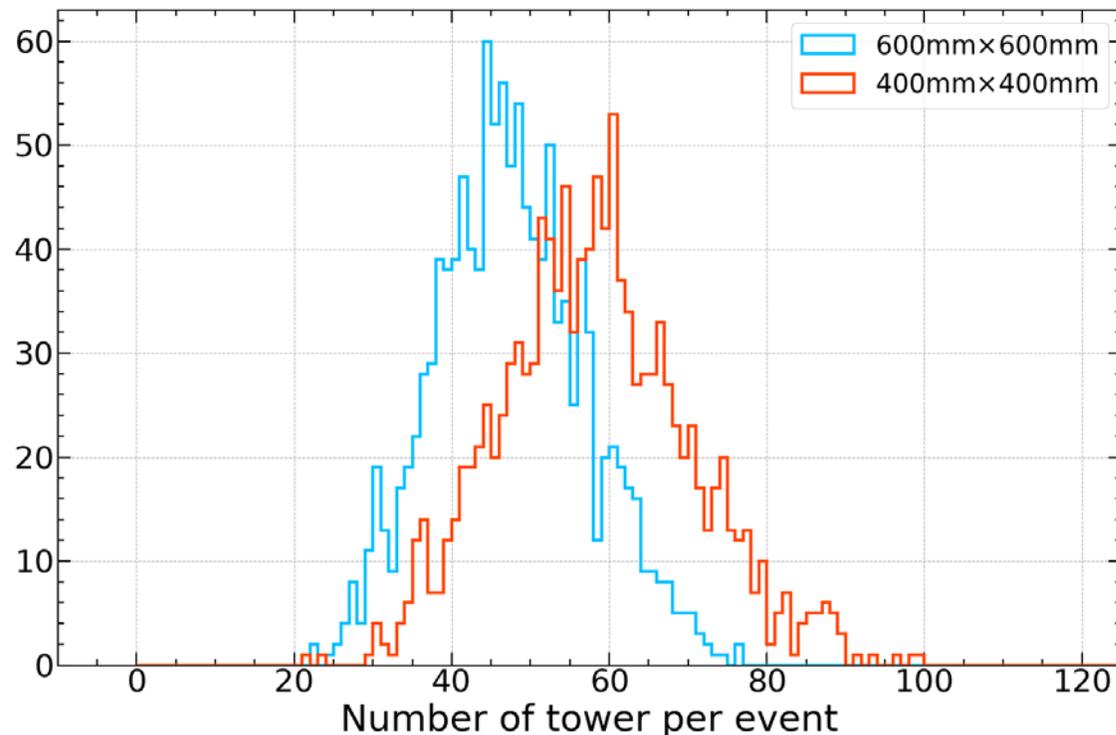
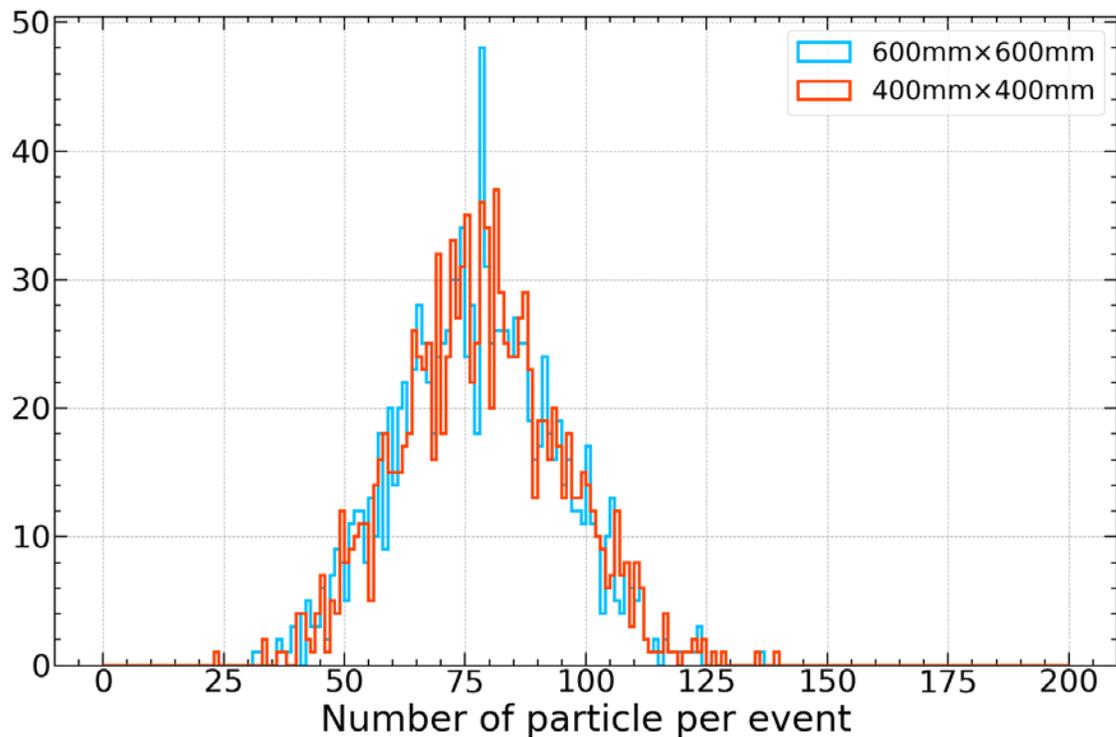


# 每个事例中的粒子数与 tower 数

➤ 每个事例中，击中量能器桶部的粒子数

■  $e^+e^- \rightarrow ZH, Z \rightarrow q\bar{q}, H \rightarrow gg$

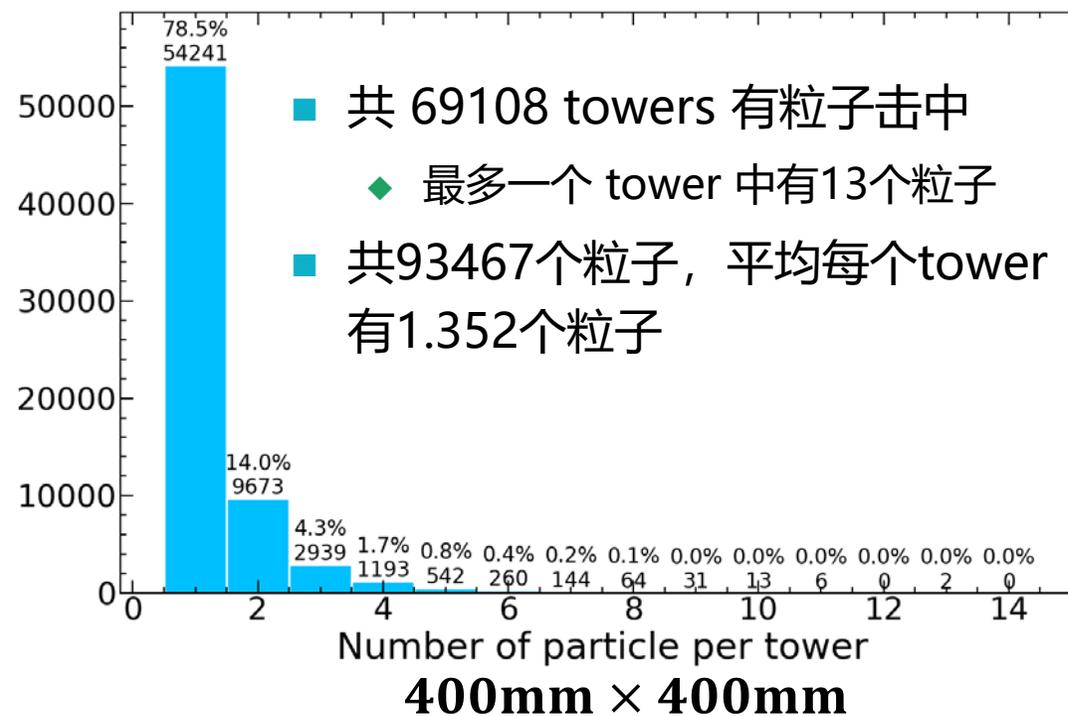
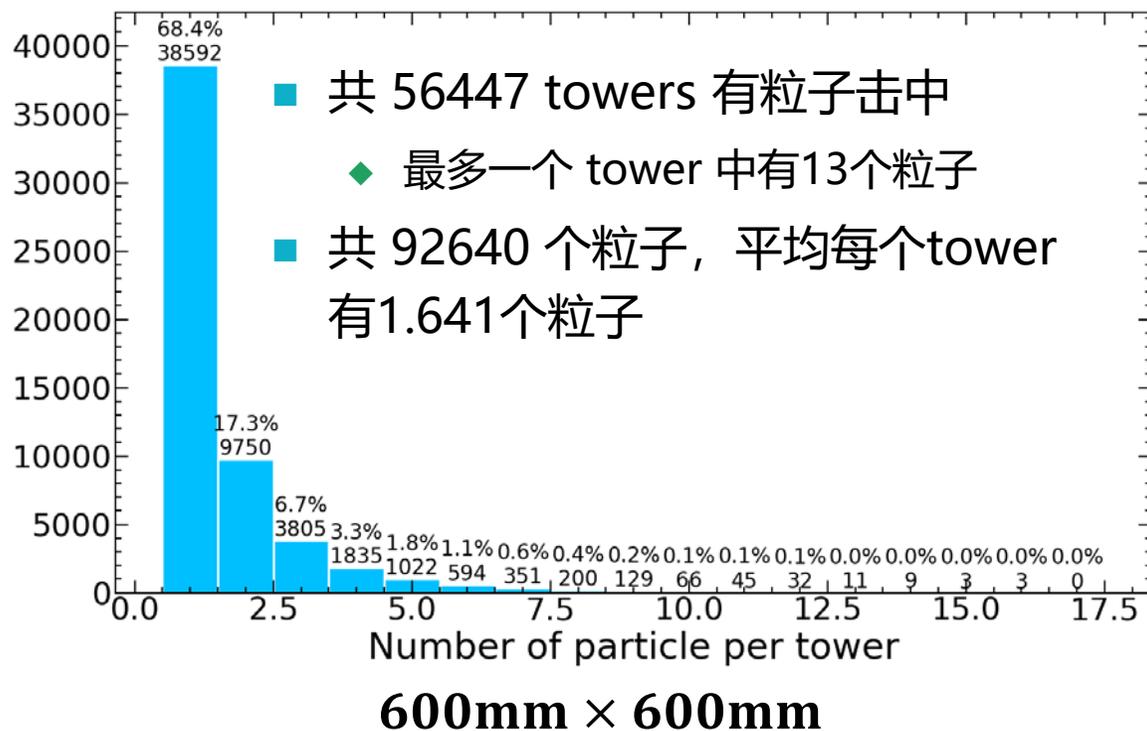
➤ 每个事例中被击中的tower数



# tower 中粒子数分布

➤  $e^+e^- \rightarrow ZH, Z \rightarrow q\bar{q}, H \rightarrow gg$ , 1200 events

➤ 600mm→400mm, 每个 tower 中粒子数大于 1 的占比 31.6%→21.5%

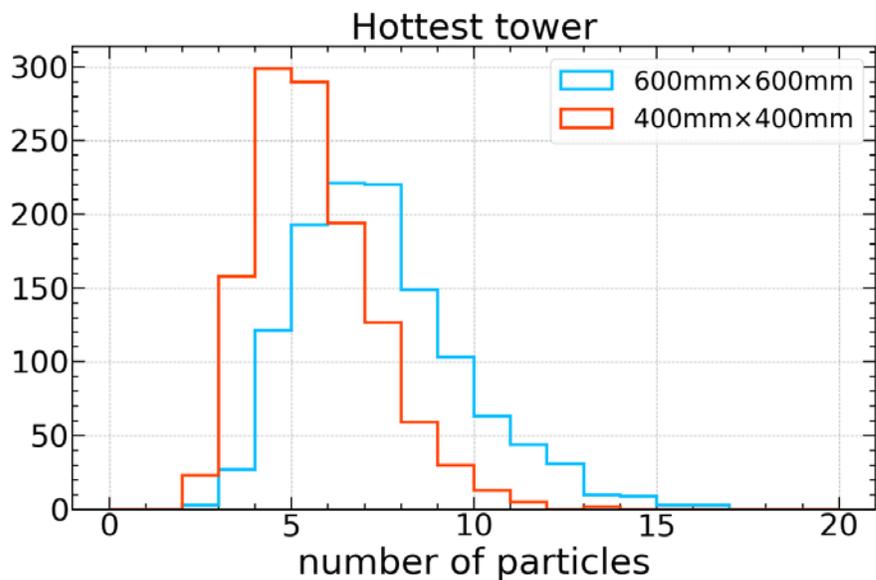


# Hottest Tower 对比

➤ Hottest tower: 一个事例中，击中粒子数最多的 tower

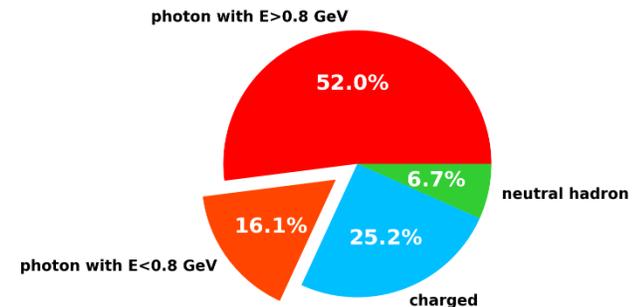
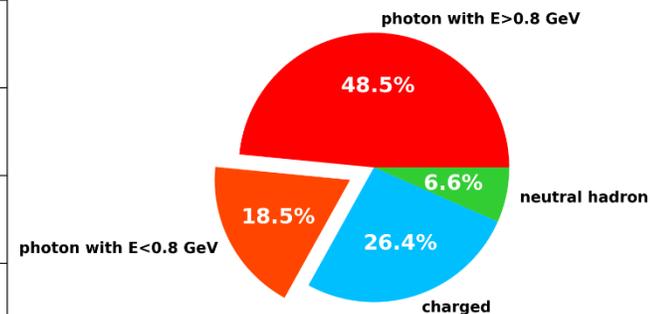
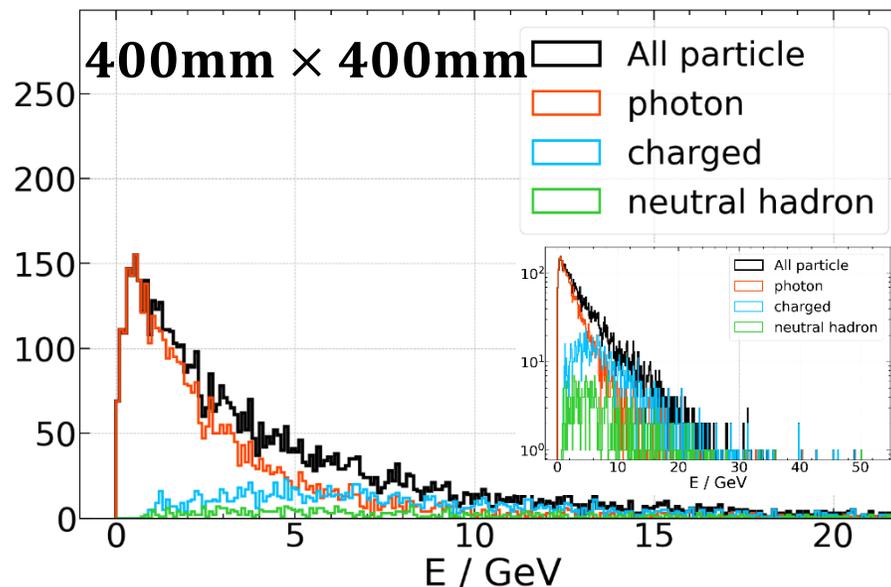
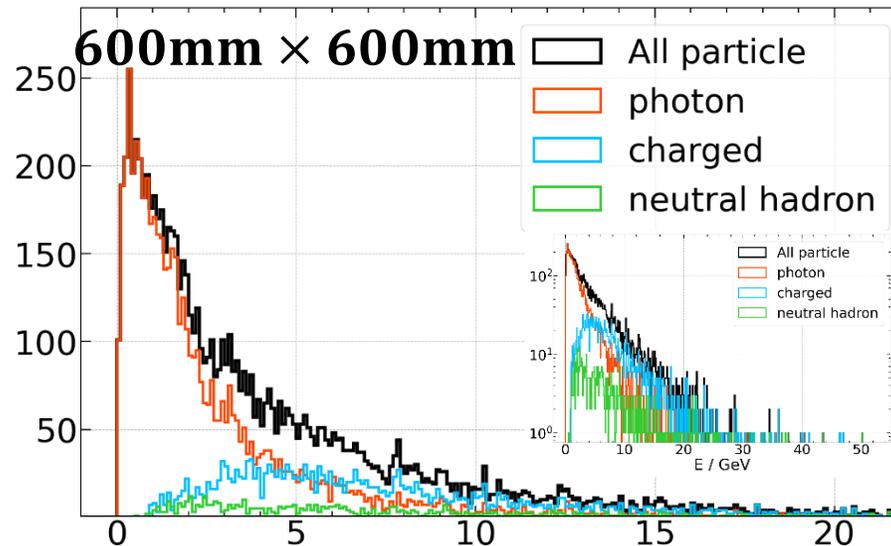
■  $e^+e^- \rightarrow ZH, Z \rightarrow q\bar{q}, H \rightarrow gg,$

■ 1200 events



jet 核心的粒子数密集，  
每个事例都有粒子数多的 tower

Hottest towers 中，光子数占比约  $\frac{2}{3}$   
低能光子占比~17%

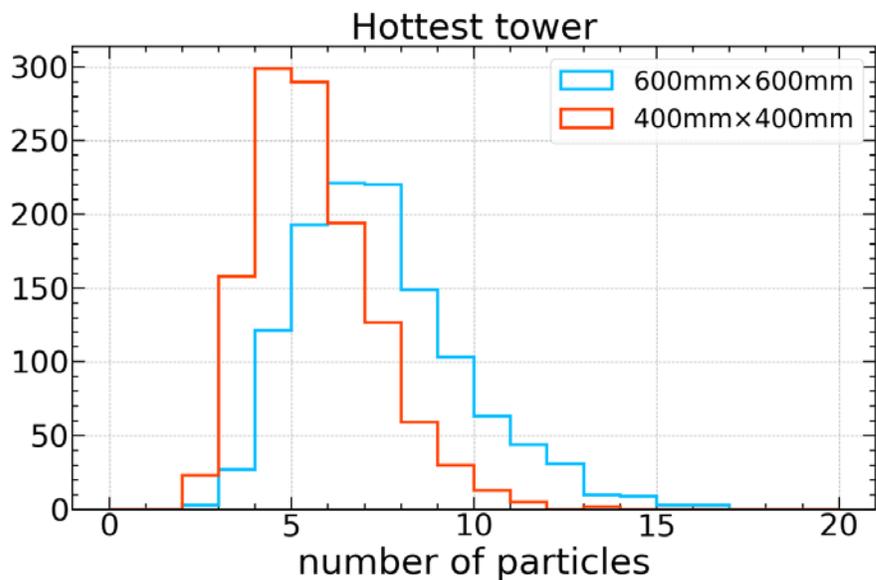


# Most Crowded Tower 对比

➤ Most crowded tower: 一个事例中, 击中粒子数最多的 tower

■  $e^+e^- \rightarrow ZH, Z \rightarrow q\bar{q}, H \rightarrow gg,$

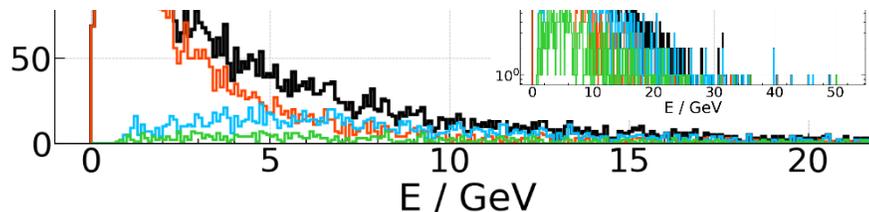
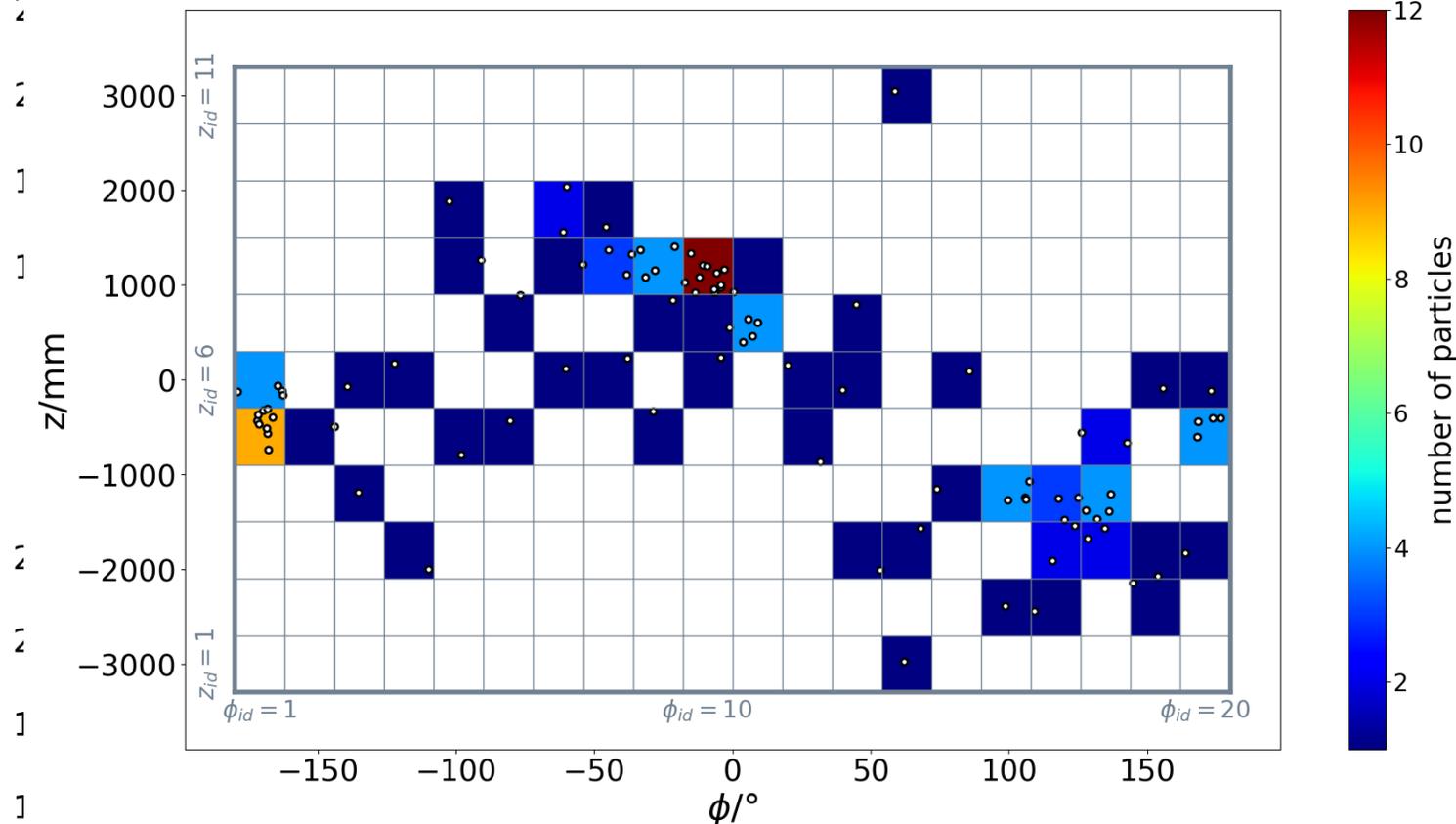
■ 1200 events



jet 核心的粒子数密集,  
每个事例都有粒子数多的tower

Hottest towers 中, 光子数占比约  $\frac{2}{3}$   
低能光子占比~17%

600mm x 600mm All particle

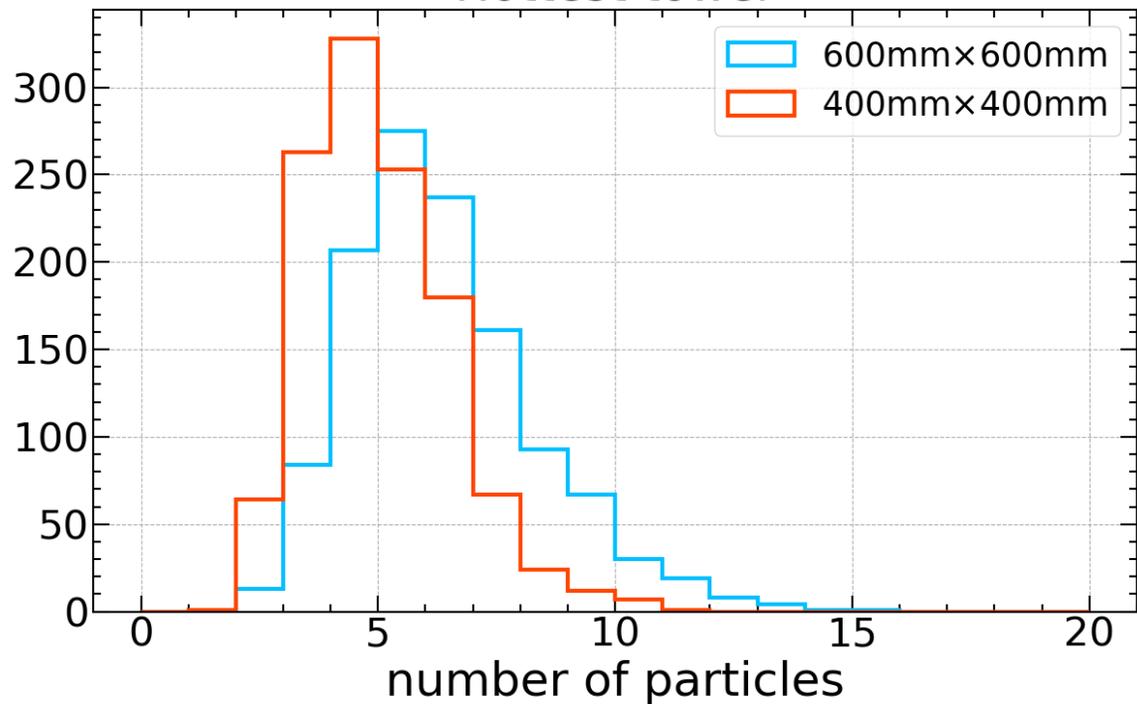


# Most Crowded Tower 对比

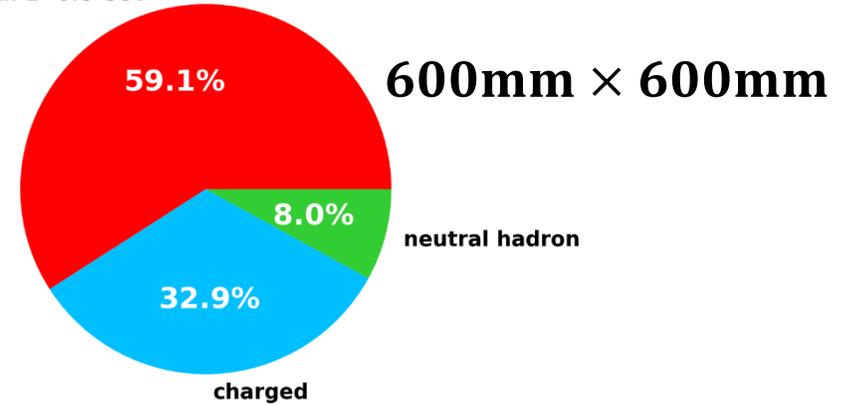
➤ 忽略  $E < 0.8$  GeV 的光子，重新统计 Hottest tower

- Hough 算法对 jet 中 0.8 GeV 以上的光子识别效率在 90% 以上
- 低能光子簇射的位置重建对最终 jet 能量分辨影响较小

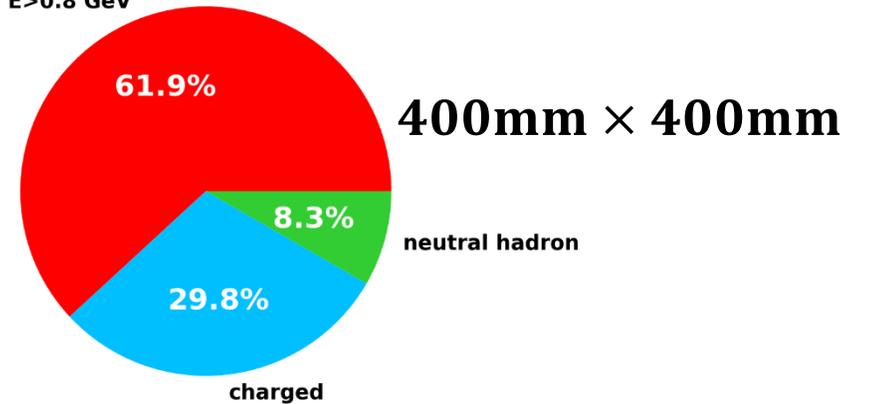
Hottest tower



photon with  $E > 0.8$  GeV



photon with  $E > 0.8$  GeV



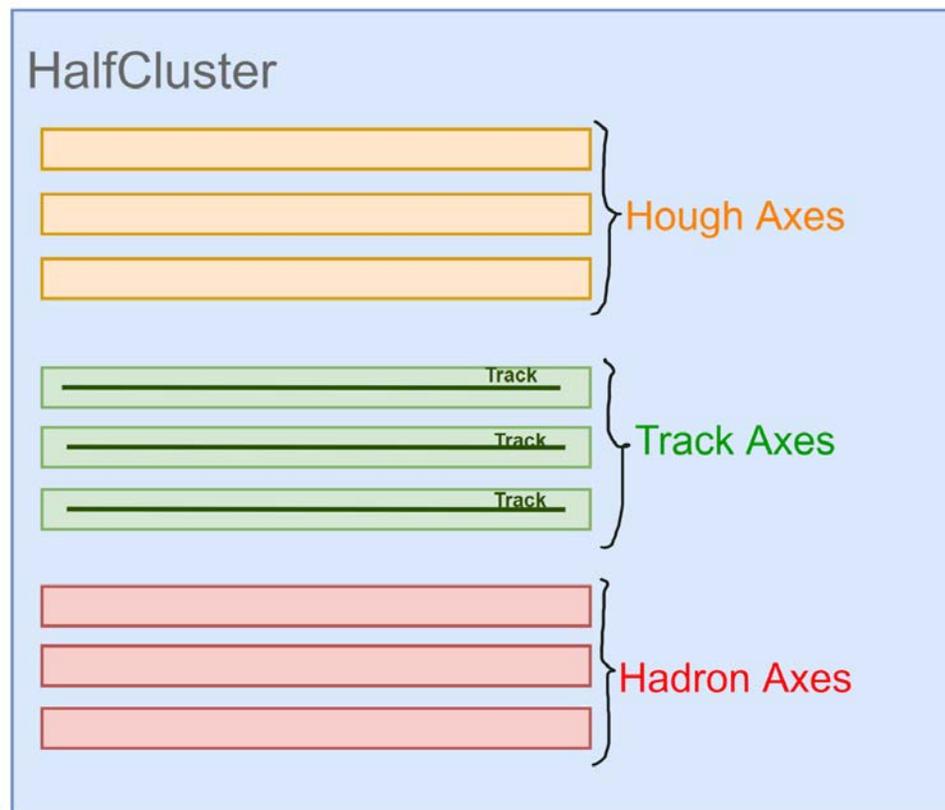
# 径迹匹配算法

# 重建流程

- 聚类
- 簇射识别
  - 霍夫变换 → 光子
  - **径迹匹配 → 带电粒子**
  - Cone Clustering → 强子簇射
- 能量劈裂
- 能量、时间匹配

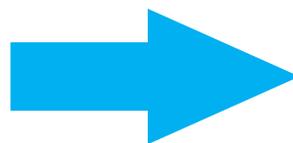
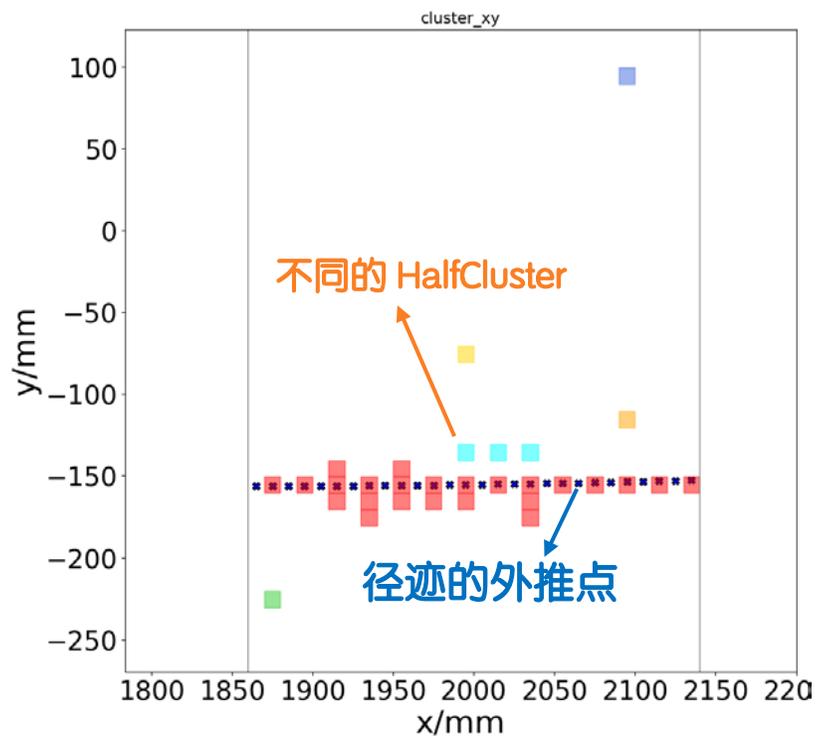
# 径迹匹配

- 根据外推径迹给出 HalfCluster 的轴，作为能量劈裂算法的依据
  - 径迹匹配算法给出带电粒子径迹的轴: *TrackAxis*
  - Hough 算法识别光子的轴: *HoughAxis*

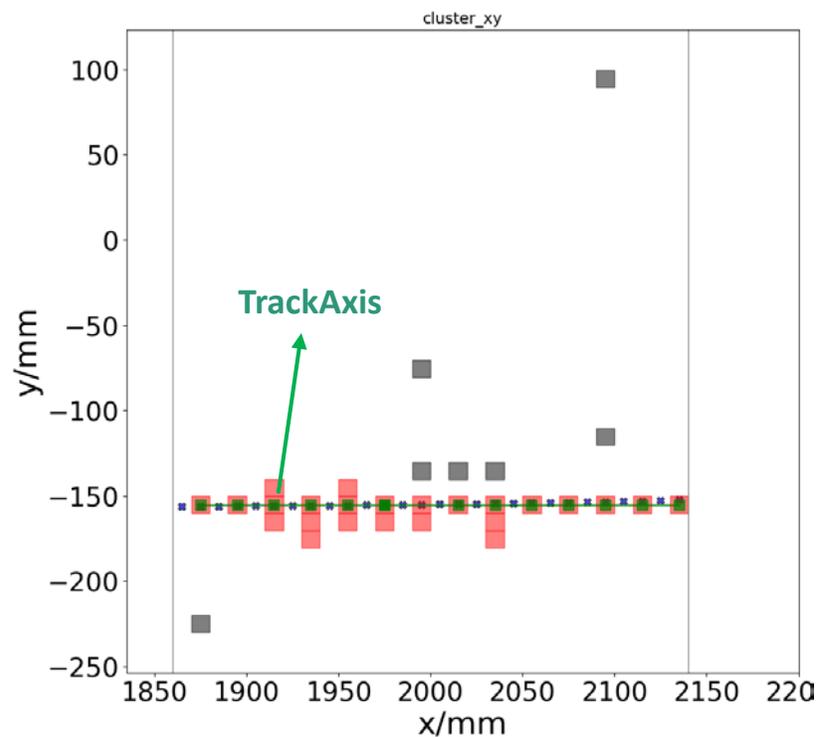


# 径迹匹配

track 与 HalfClusters  
尝试两两匹配

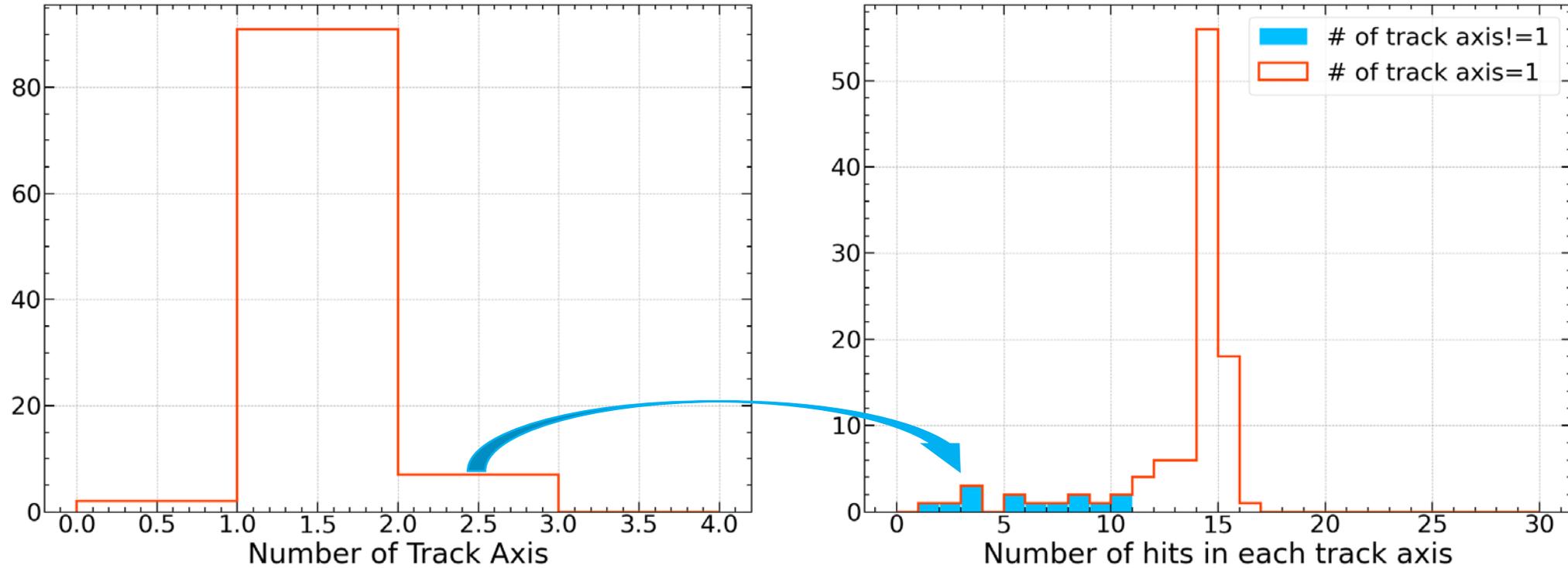


以有外推点的 local max 创建  
带电粒子的轴: *TrackAxis*



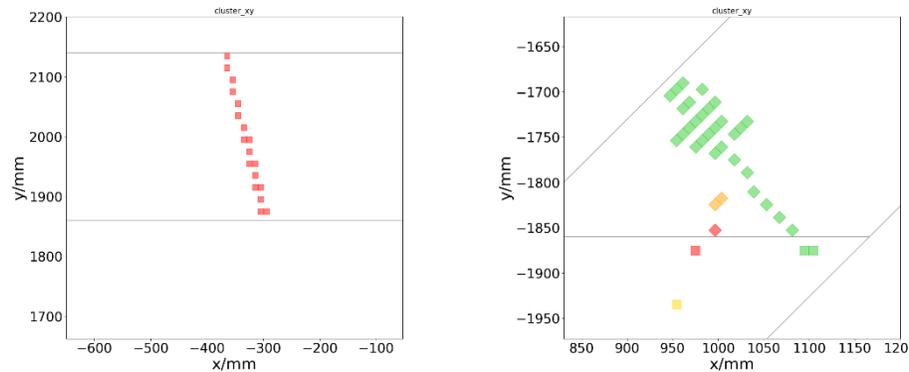
# 性能检查

➤  $\mu^-$ ,  $E = 10\text{GeV}$ ,  $\phi = 0^\circ \sim 360^\circ$ ,  $\theta = 50^\circ \sim 140^\circ$

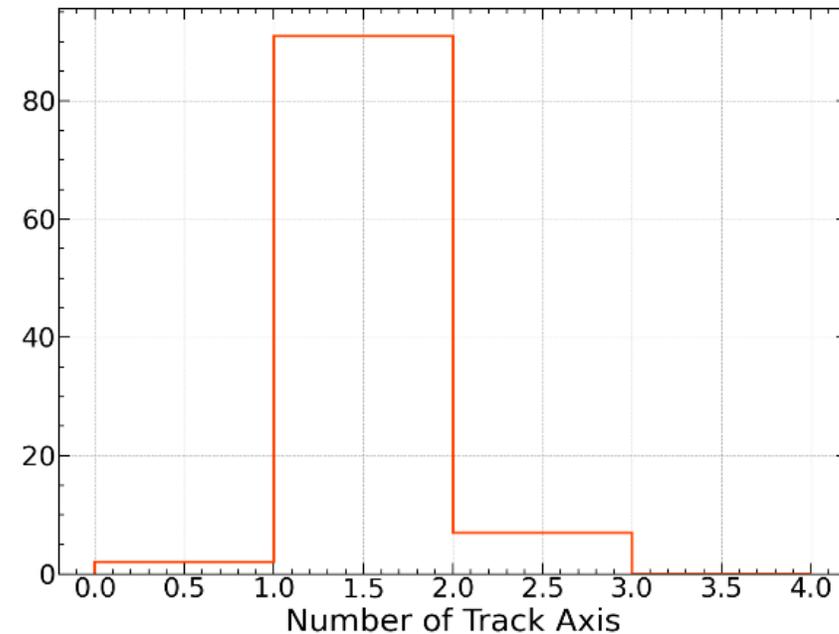
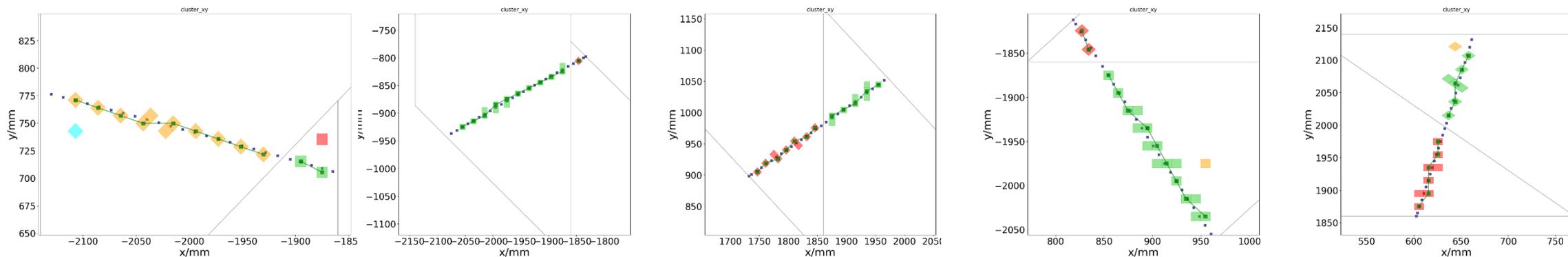


# 性能检查

➤ 0 个 track axis 是因为没有 track 输入



➤ 2 个 track axis 是因为 HalfCluster 在 module 交界处没有连起来



# 总结

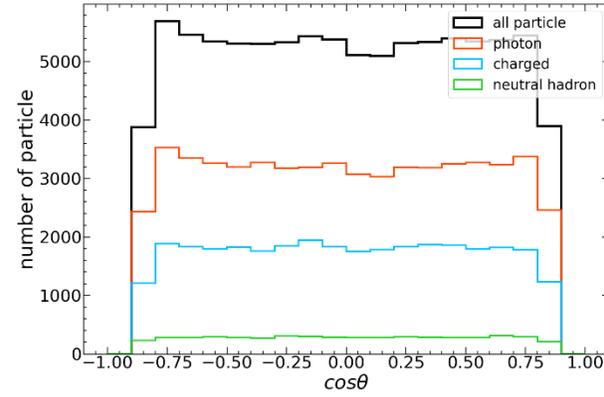
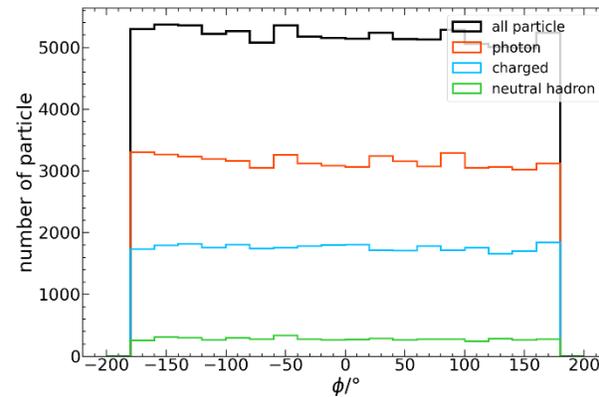
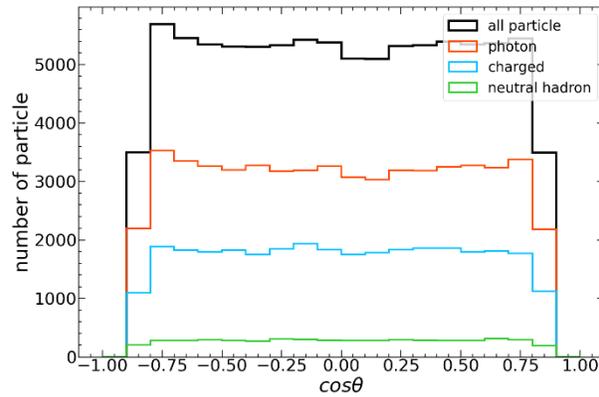
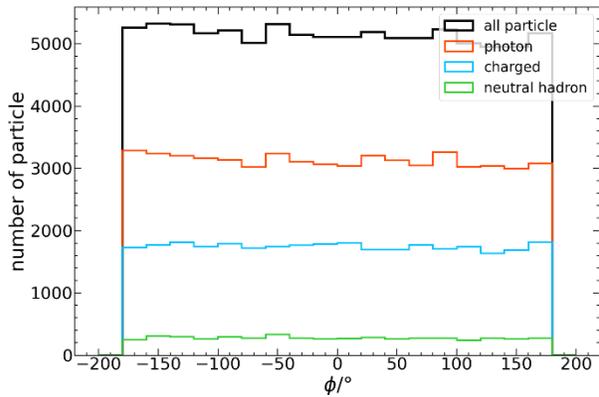
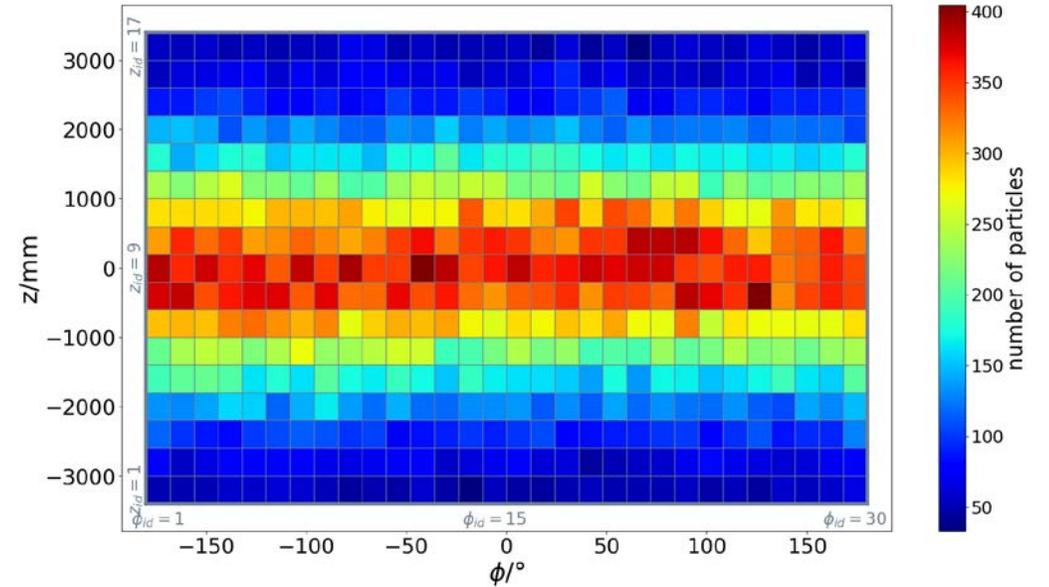
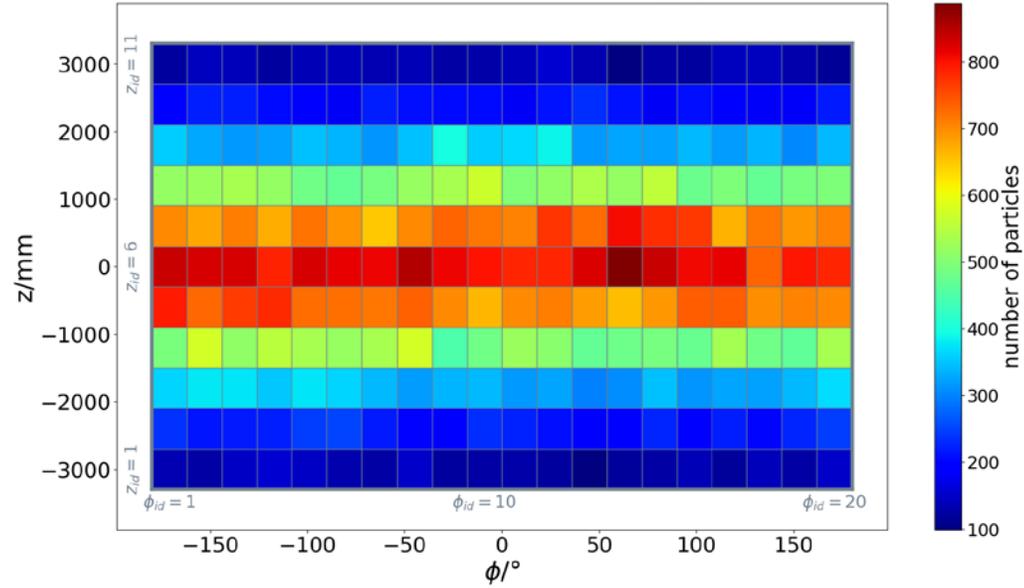
- 600mm→400mm, 每个 tower 中粒子数大于 1 的占比 31.6%→21.5%
- 大部分击中 tower 只有一个粒子。但由于jet存在一个核心, 几乎每个事例都有击中粒子数较大的 tower (>3个粒子)
- Hottest tower 中, 光子占粒子总数约  $\frac{2}{3}$ , 其中低能光子( $E < 0.7\text{GeV}$ )占约占17%
  - 低能光子簇射的识别效率较低, 但它们的位置重建对 jet 的能量分辨可能影响较小
- 完成了径迹匹配算法的开发
- 对径迹匹配算法做了初步的性能检查
  - 在正确给出径迹和 HalfCluster 时, 10GeV 的 MIP 可以匹配成功

Backup

# 粒子分布

➤ 所有事例中，粒子在量能器的位置分布

■  $e^+e^- \rightarrow ZH, Z \rightarrow q\bar{q}, H \rightarrow gg$ , 1200 events

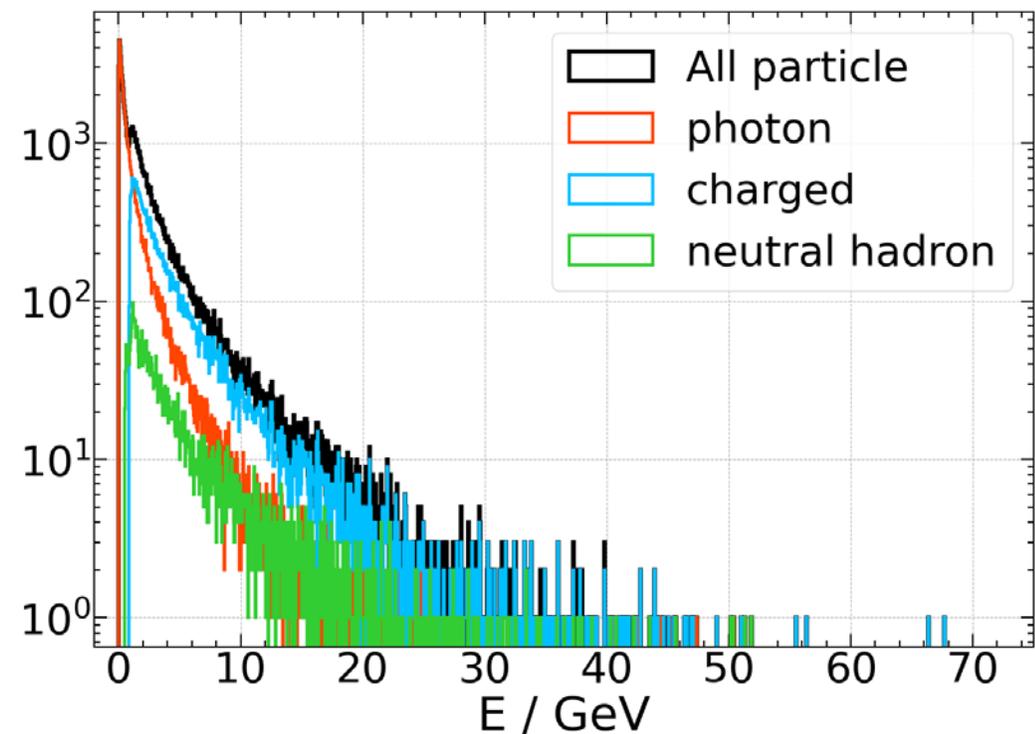
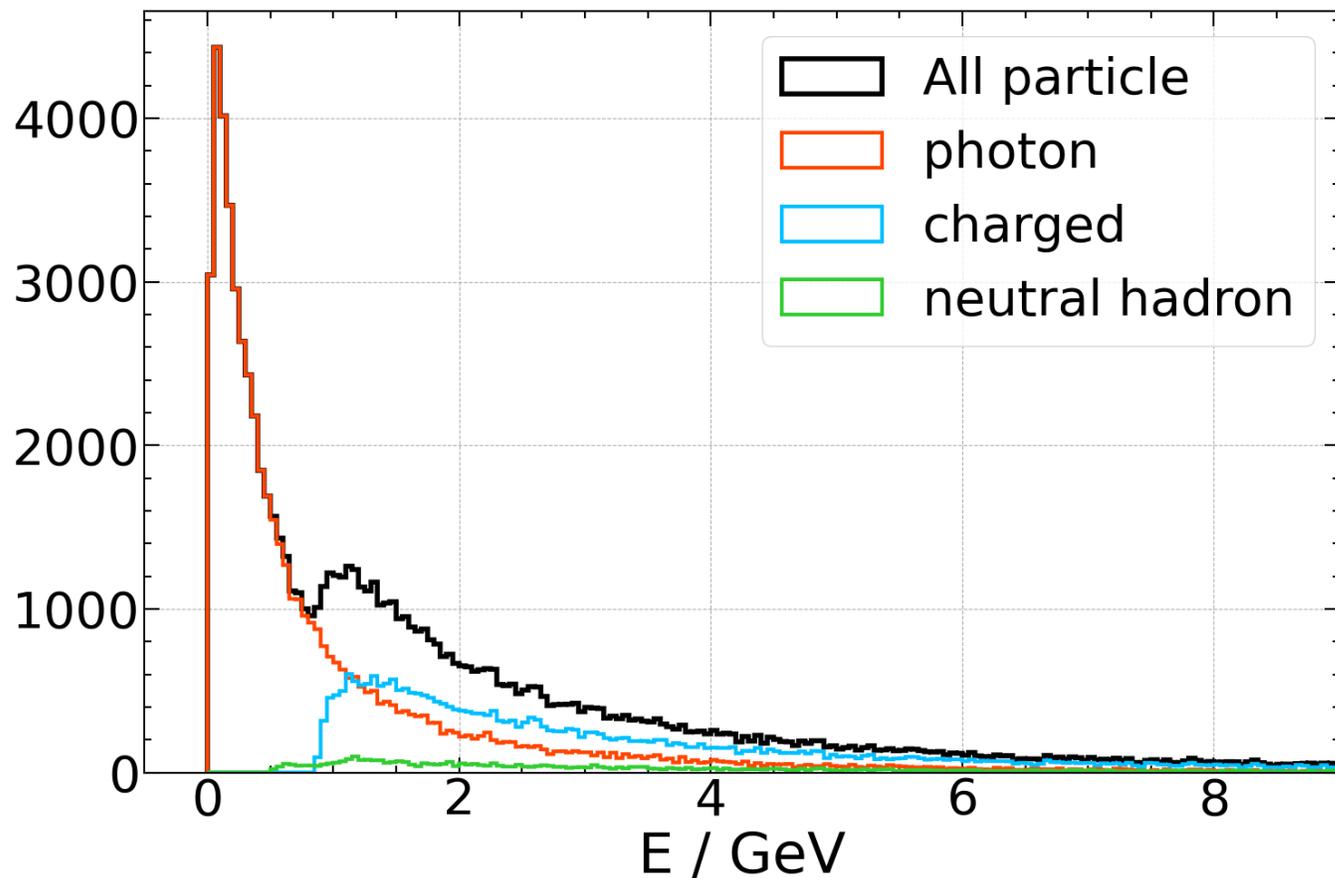


600mm × 600mm

400mm × 400mm

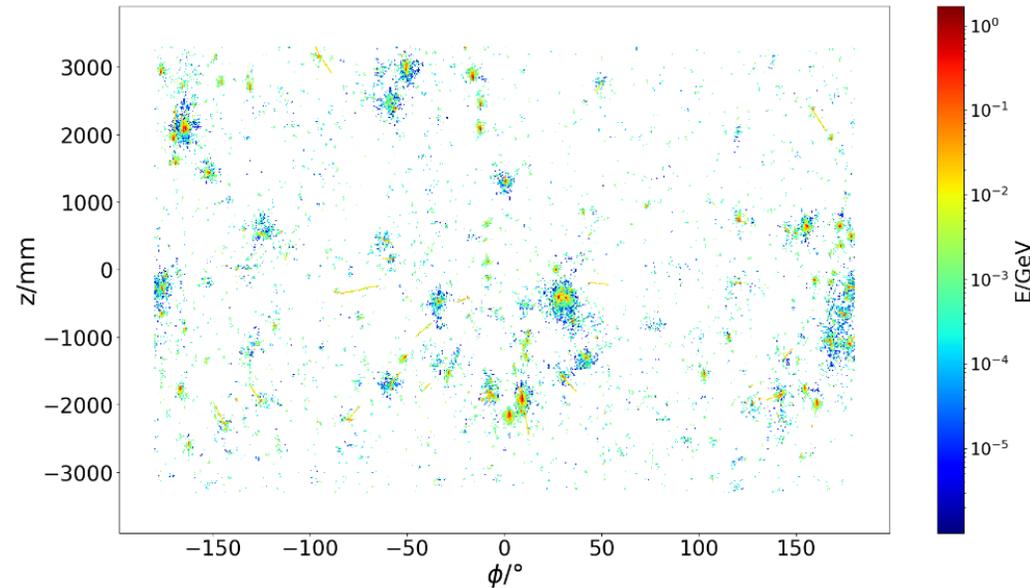
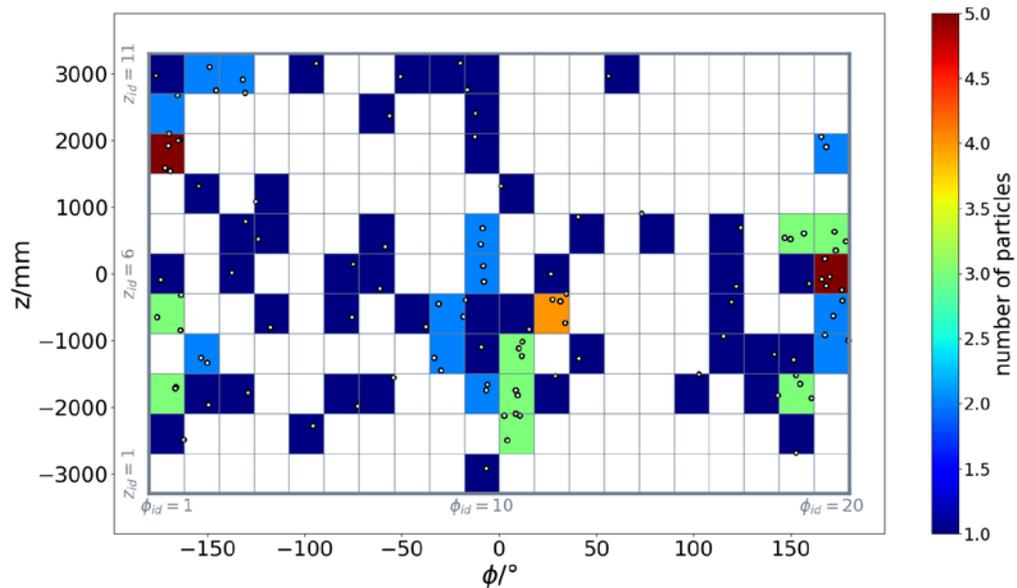
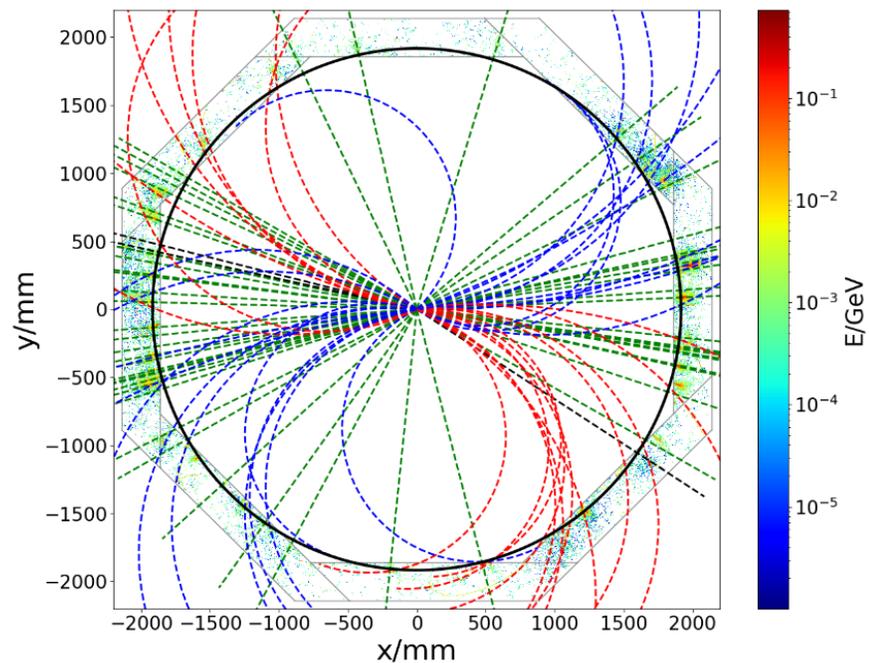
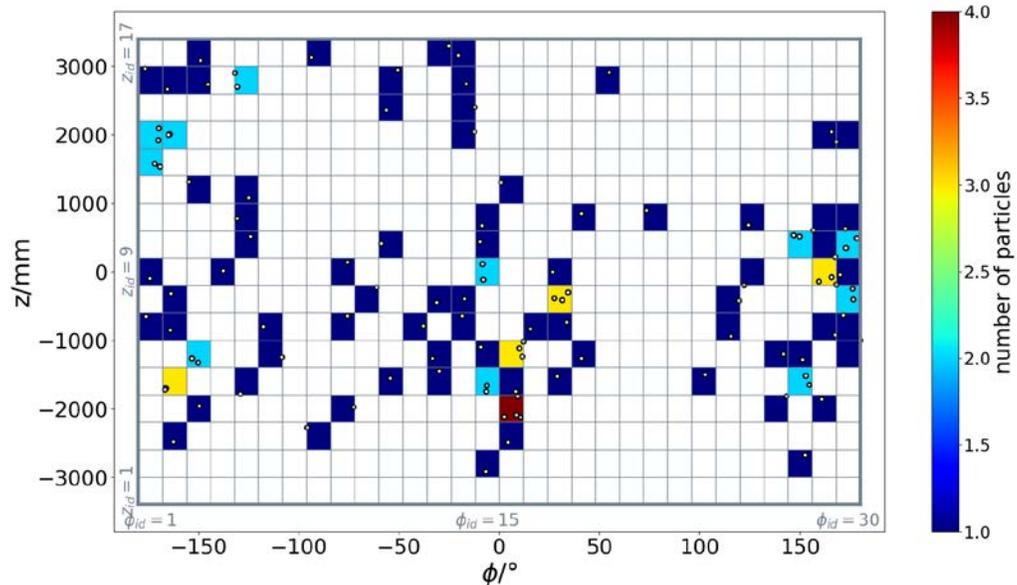
# 粒子能量分布

➤ 所有击中在量能器桶部的粒子能量分布(600mm×600mm)

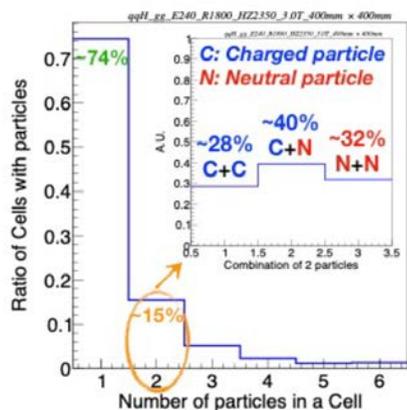


# 事例显示

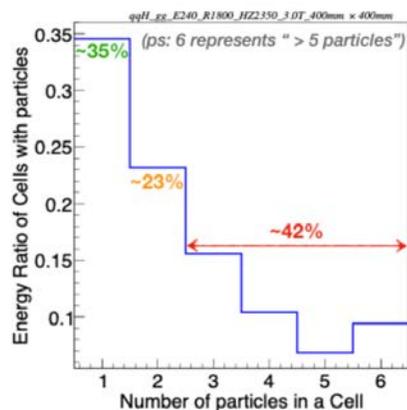
➤  $e^+e^- \rightarrow ZH, Z \rightarrow q\bar{q}, H \rightarrow gg$ , event2



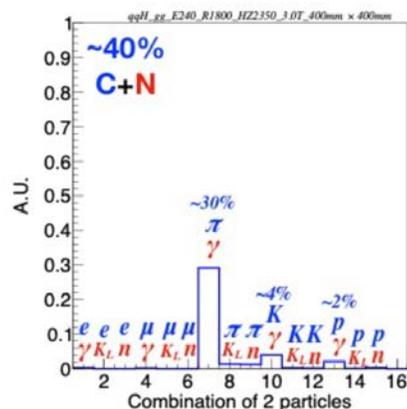
# Result from Yuexin



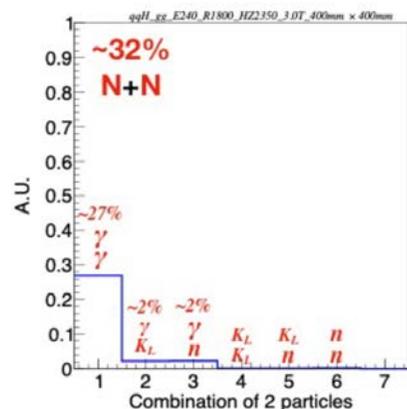
(a)



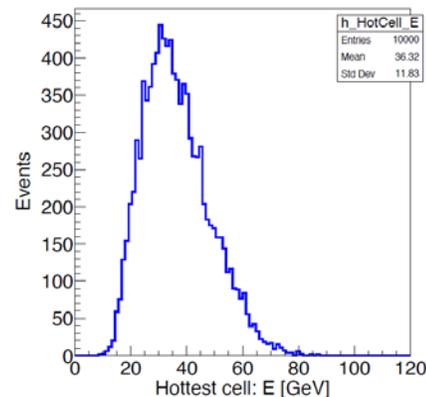
(b)



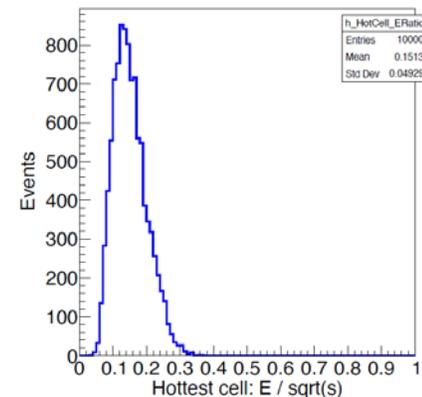
(c)



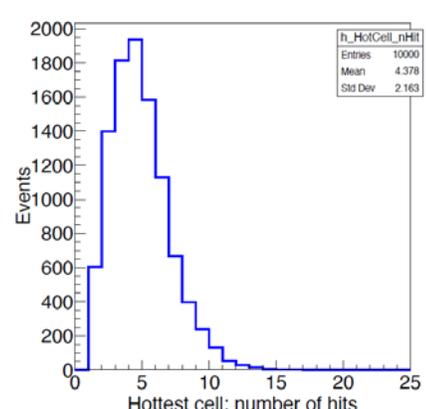
(d)



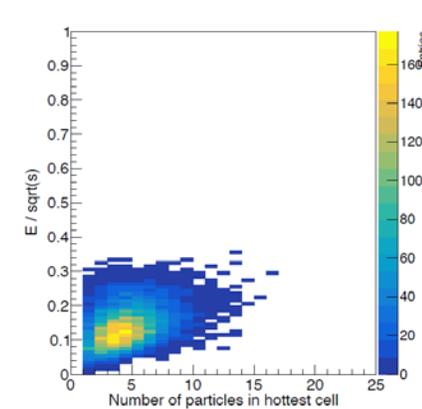
(a)



(b)



(c)



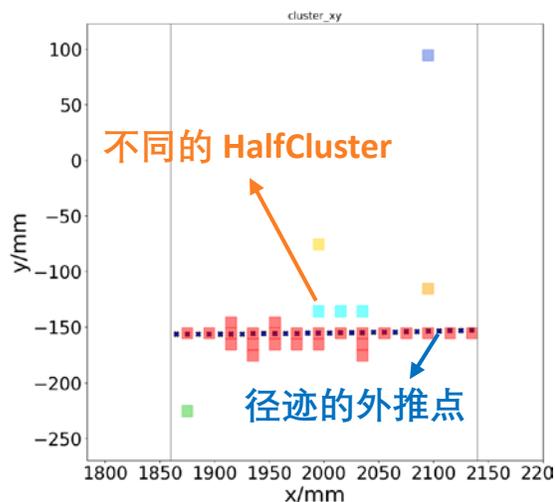
(d)

图 5-7 240 GeV 质心能量下  $e^+e^- \rightarrow Z(\rightarrow q\bar{q})H(\rightarrow gg)$  事例中  $40 \times 40 \text{ cm}^2$  超级单元内击中不同粒子数目的 (a) 比例和 (b) 能量占比, 以及只有两个粒子击中的超级单元内 (c) 带电 + 中性和 (d) 中性 + 中性粒子组合的粒子种类。

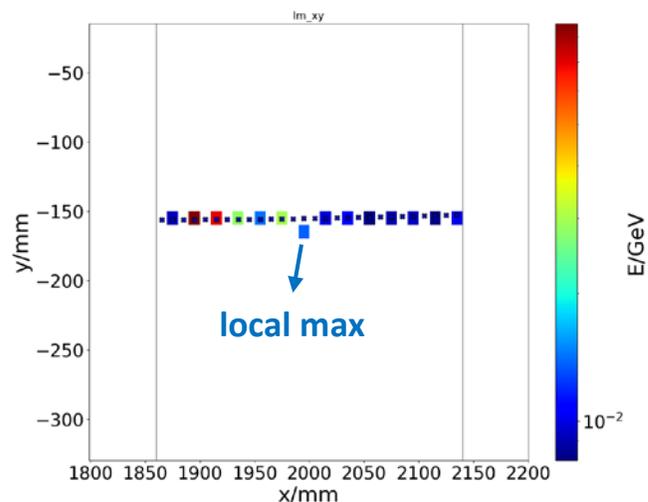
图 5-6 240 GeV 质心能量下  $e^+e^- \rightarrow Z(\rightarrow q\bar{q})H(\rightarrow gg)$  事例中击中粒子总能量最大的  $40 \times 40 \text{ cm}^2$  超级单元内的 (a) 总能量 (b) 总能量与质心能量之比 (c) 击中粒子数 (d) 能量占比与粒子数关系。

# 径迹匹配

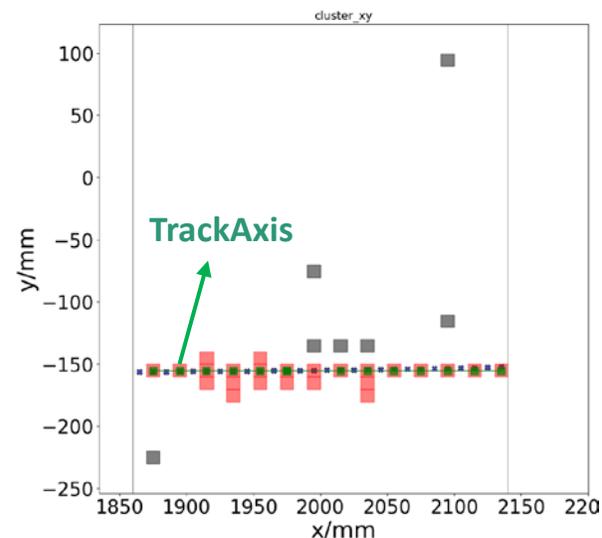
径迹与 HalfClusters  
尝试两两匹配



判断是否有外推点落在  
HalfCluster 的 local max 中

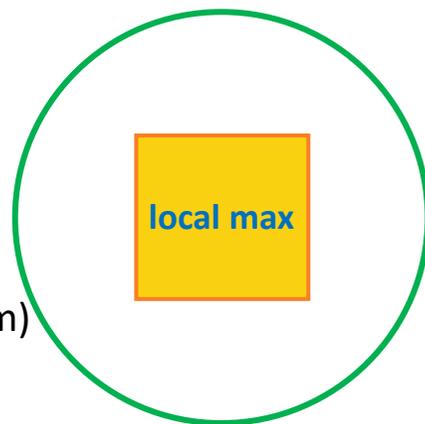


以有外推点的 local max 创建  
带电粒子的轴: **TrackAxis**



外推点只需要落在半径为  $r$ ,  
长为  $z$  的圆柱中;

$r$  为可调参数, (当前  $r=10\text{mm}$ )  
 $z$  为晶体条长度



track 是 TrackAxis 的成员,  
而不是 HalfCluster 的成员