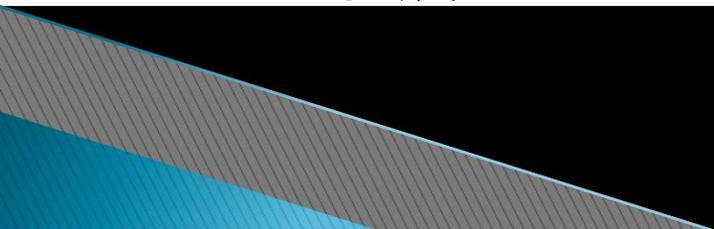


首届LHAASO合作组会议

LHAASO-WFCTA模拟和重建

马玲玲
高能所

主要内容

- ▶ LHAASO对宇宙线能谱的测量
 - ▶ LHAASO-WFCTA介绍
 - ▶ LHAASO-WFCTA模拟
 - ▶ LHAASO-WFCTA成分鉴别
 - ▶ LHAASO-WFCTA能量重建
 - ▶ 总结和展望
- 

LHAASO对宇宙线能谱的测量

- ▶ 在10TeV至EeV能量段对宇宙线的成分能谱进行一致性测量，以期解答宇宙线起源问题

- 多参数：WCDA, KM2A, WFCTA
- 分阶段：WFCTA阶段性布局调整

- ▶ 10TeV~100TeV

- 进行能量的绝对标定

- ▶ 100TeV~10PeV

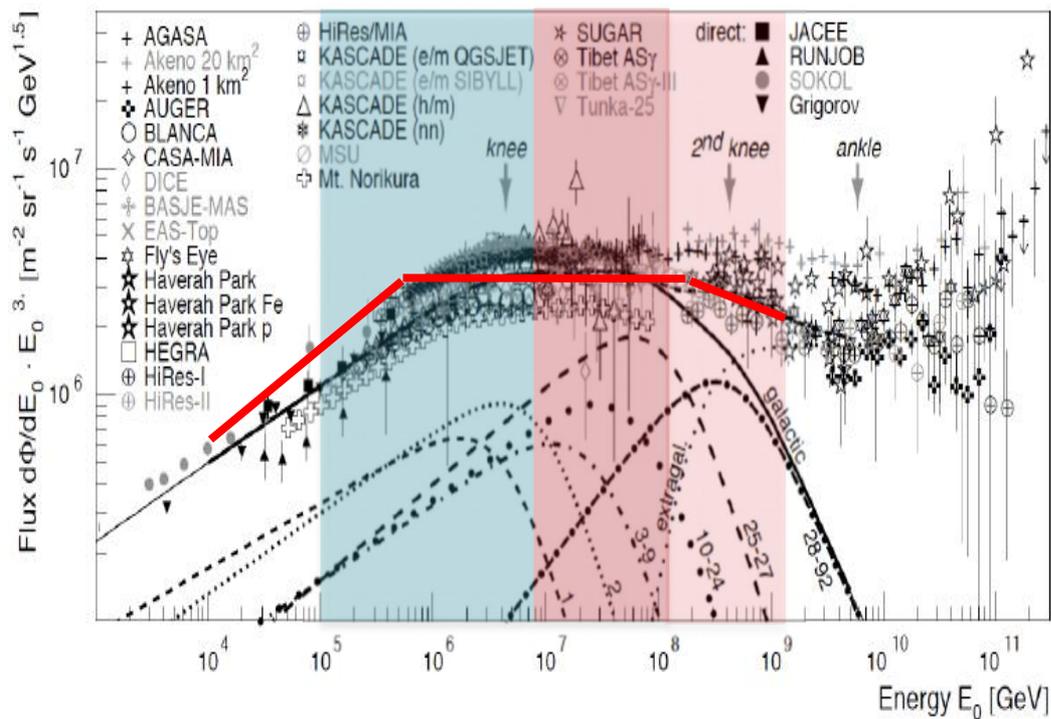
- 质子、氦核的膝
- 各向异性研究

- ▶ 10PeV~100PeV

- 铁核的膝

- ▶ 100PeV~2EeV

- 第二膝，成分变化
- 从河内到河外的变化



LHAASO-WFCTA介绍

Wide Field of Cherenkov Telescope Array

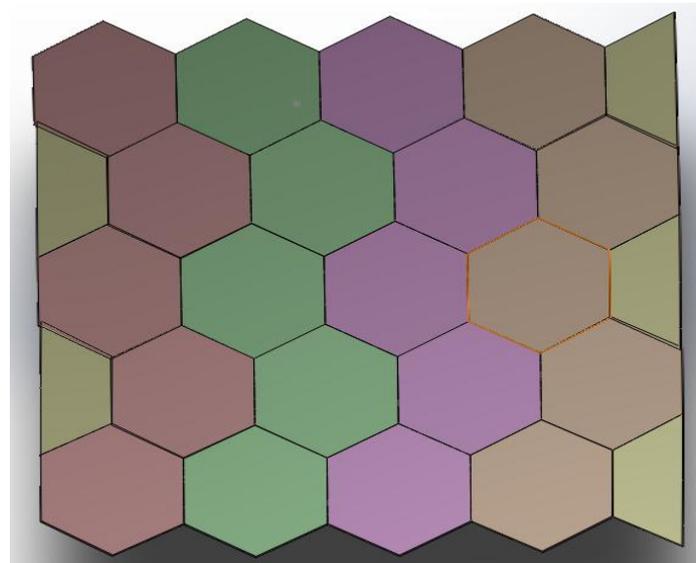
- ▶ 通过契伦科夫（荧）光成像进行宇宙线能量和成分的测量
 - 量能器性质，能量估计成分和模型依赖较少
 - 成分区分：Hillas参数， X_{\max} 位置

▶ 反射镜

- 25面球面镜拼接而成
- 边长：300mm
- 曲率半径：5800mm

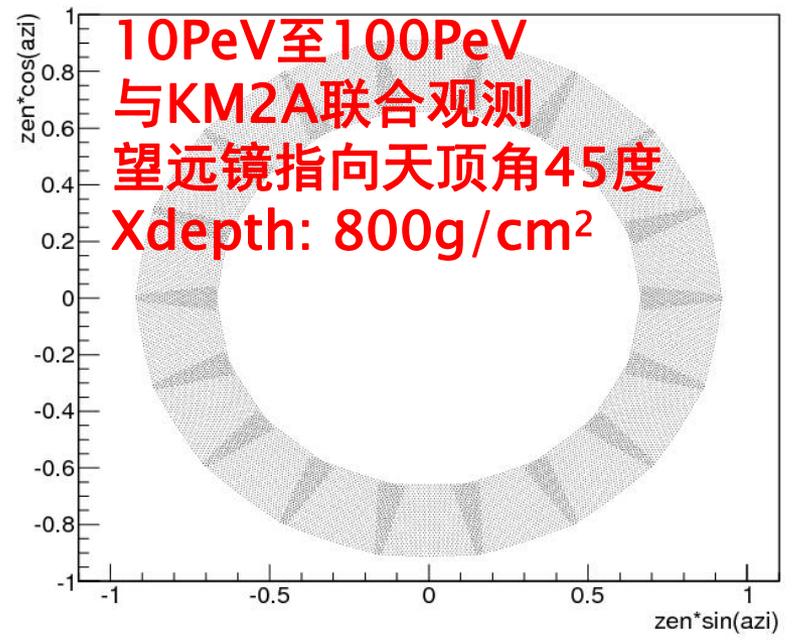
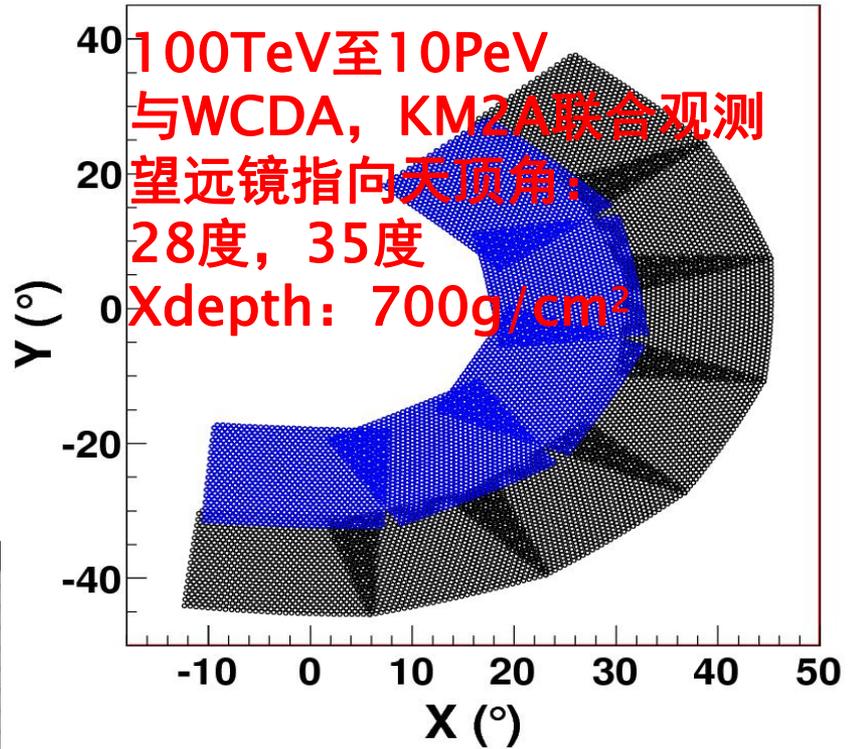
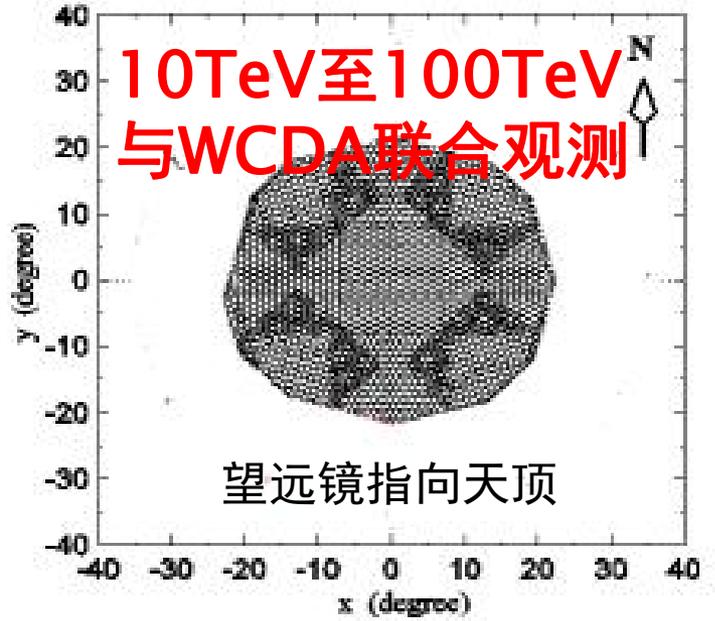
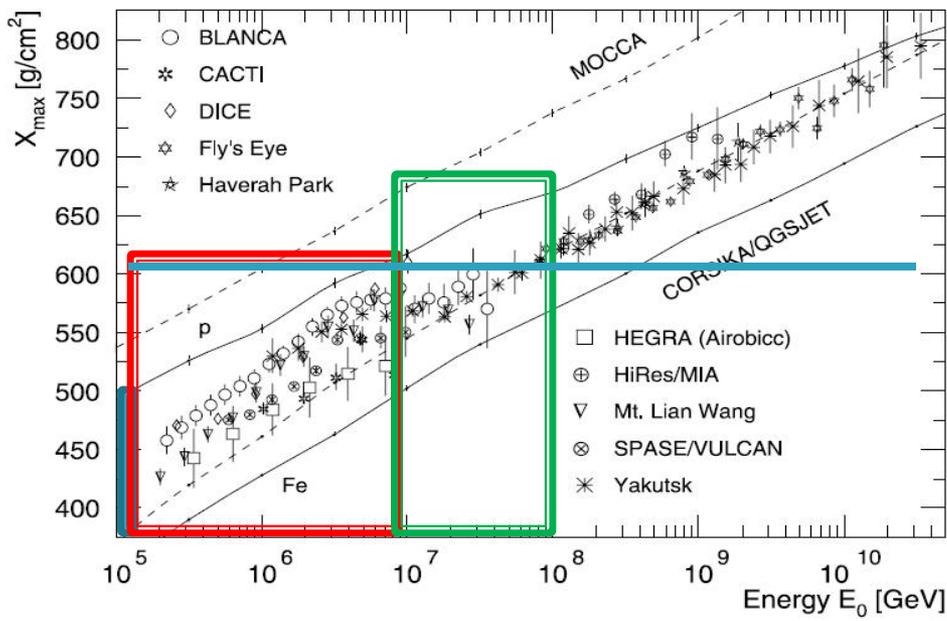
▶ PMT阵列

- 32 x 32 PMTs/SiPMs
- PMT直径: 26.9mm
- 光阴极距离反射镜中心的距离: 2870mm



▶ 可移动性设计：

- 根据不同的观测阶段进行不同的排布

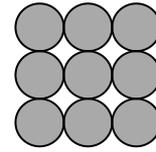


$E < 2 \text{ EeV}$ 第二膝 传递能标

Tower CT: 9

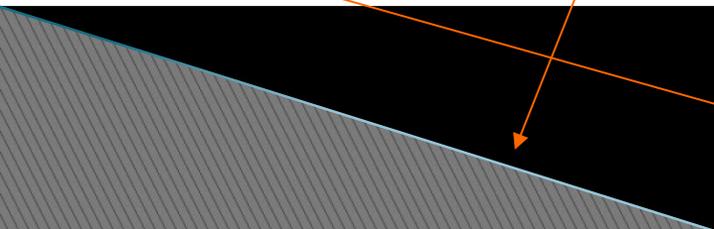
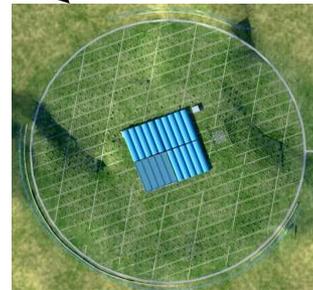
μ : $1200 \times 36 \text{ m}^2$

Side Trigger CT: 2×2



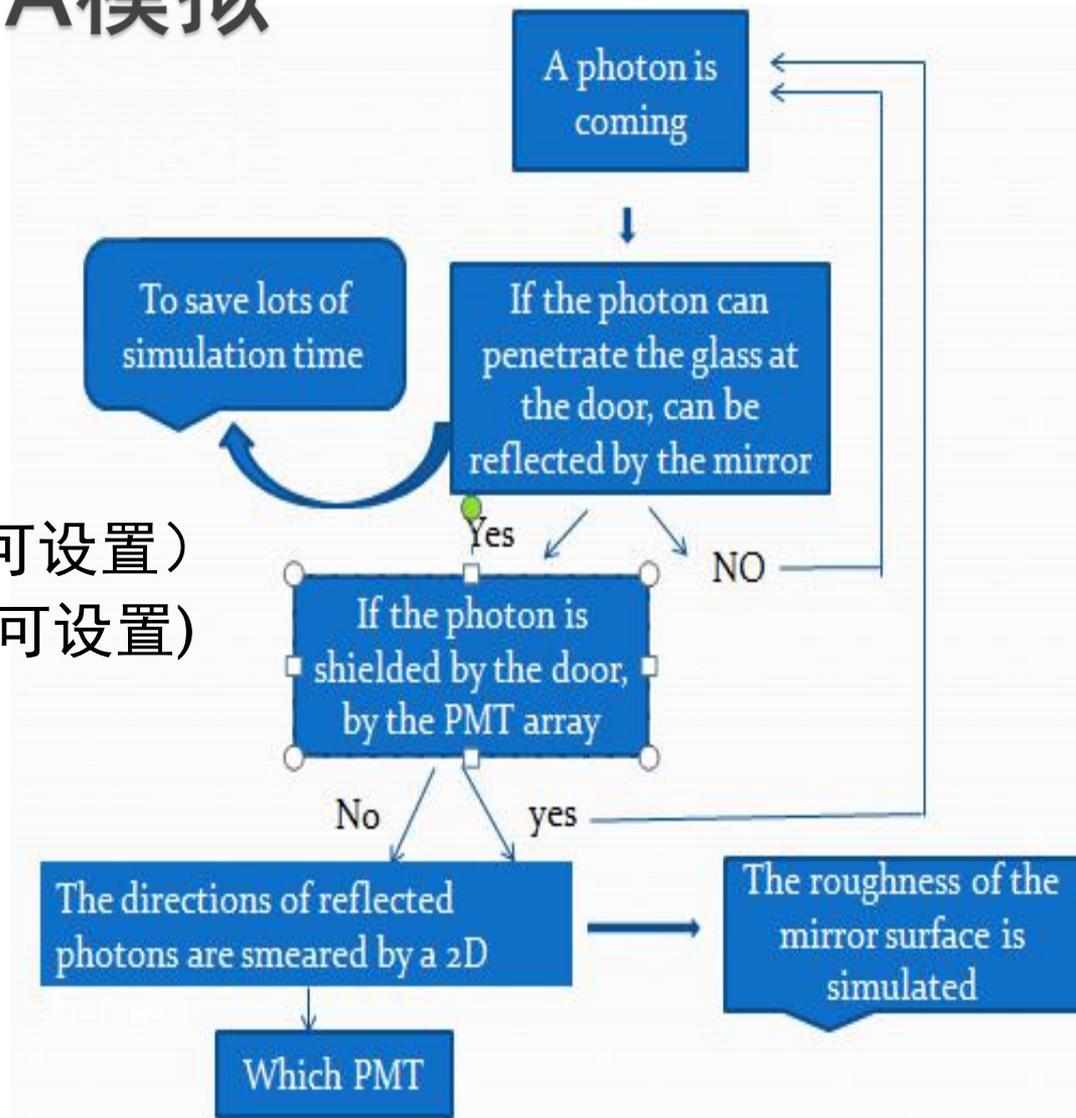
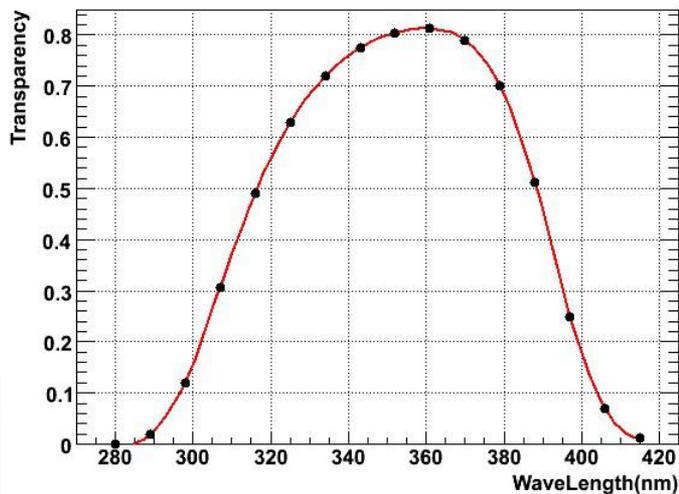
Fluorescent Telescopes + μ -content in KM2A

Parameters for
CR composition:
 X_{max} , μ -
content



LHAASO-WFCTA模拟 光线追踪

- 挡风玻璃的透过率：0.87
- 滤光片的滤光效率（可选）
- 反射镜的反射率：0.83
- 反射镜光斑：0.75mm（可设置）
- 反射镜的安装精度(可选，可设置)



LHAASO-WFCTA模拟 PMT阵列

▶ 夜空背景模拟

- 背景光子在达到时间上服从指数分布
- $mean = \sigma^2 = 2.35 * \frac{2.35}{4} = 1.38$ within 20ns

▶ FAST

- 统计每个PMT内的光子数

▶ Normal:

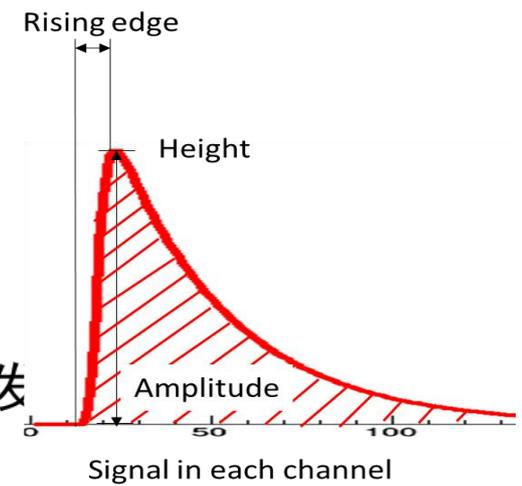
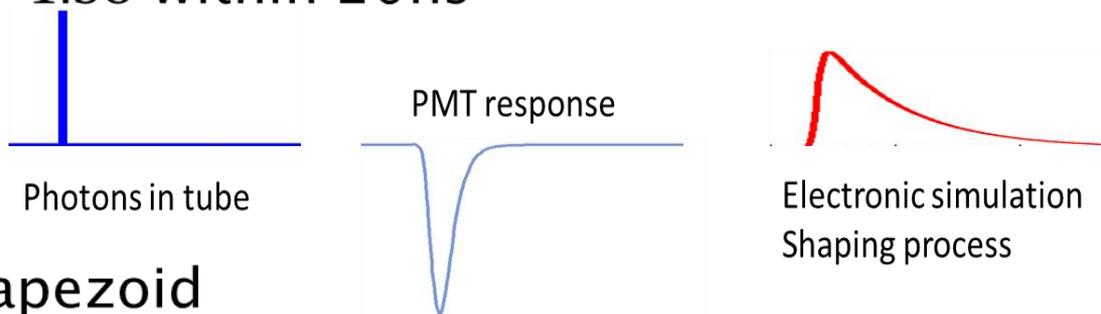
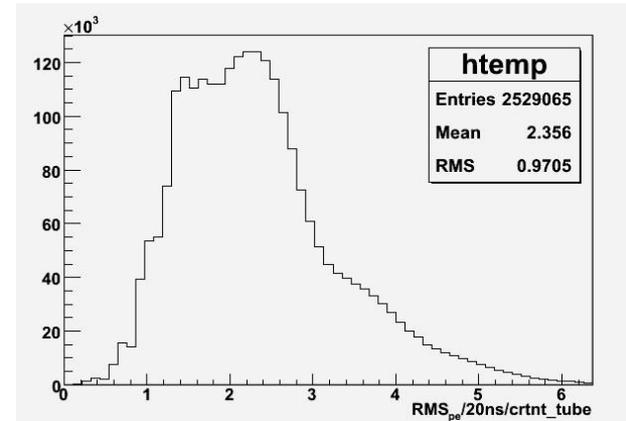
- PMT响应: R1924A | Trapezoid
- 电子学整形: ASIC | TraditionalElec
- PMT触发: Amplitude | Height | Winsum

▶ Advanced:

- Npe, Time RMS, 平均到达时间

▶ 望远镜触发:

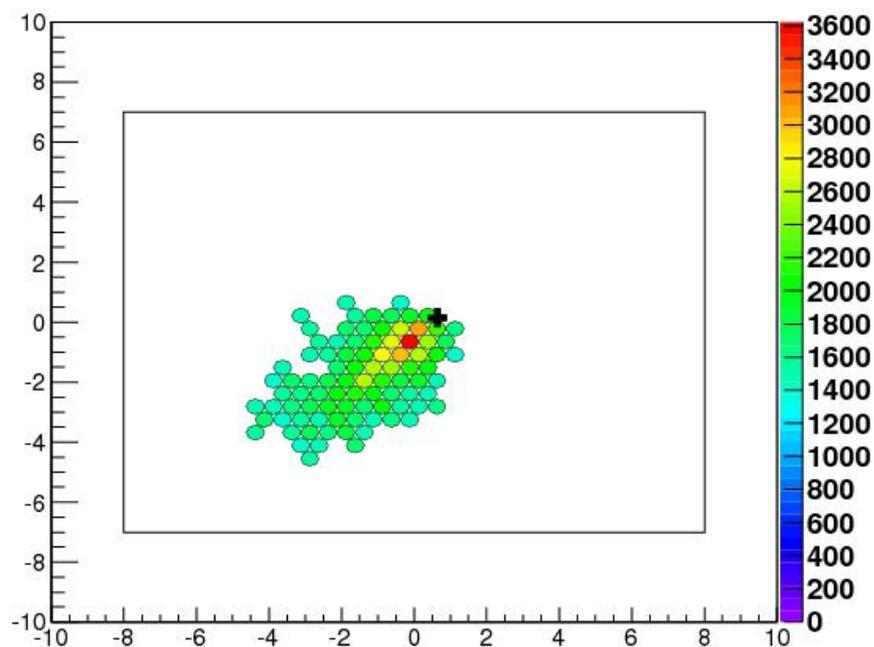
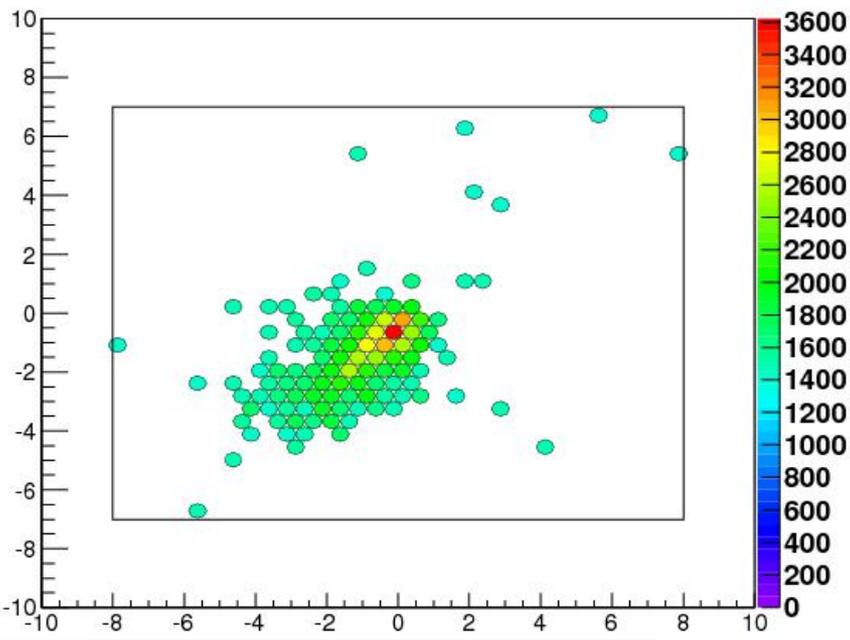
- 地... 的PMT触发, 则望远镜触发



LHAASO-WFCTA的重建

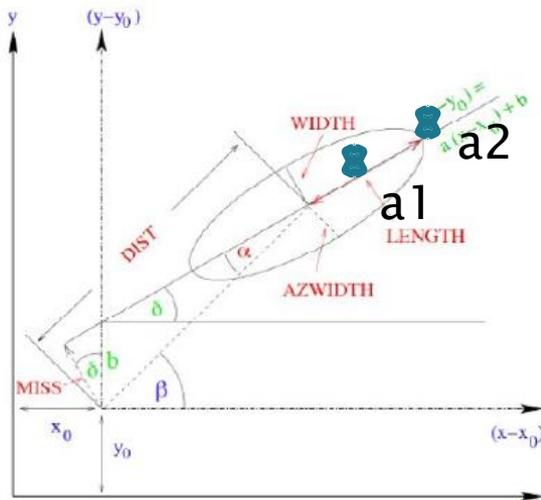
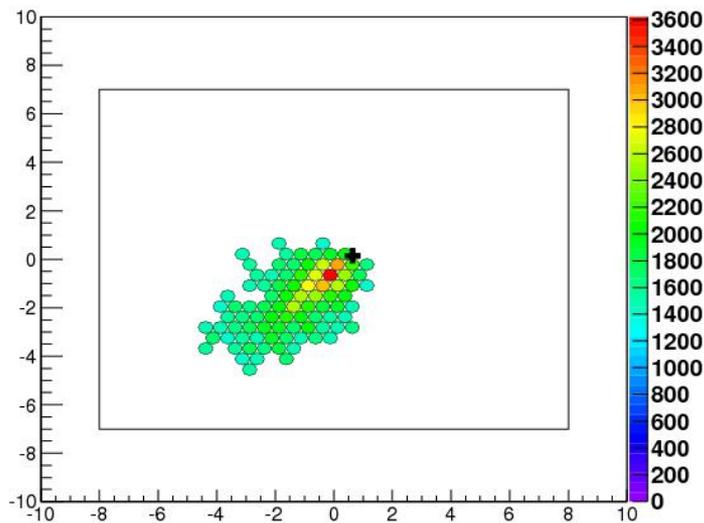
图像清理

- ▶ PMT上的光电子数： $>30\text{pe}$
 - 夜空背景噪音约为： 16pe
- ▶ 每个PMT至少有两个相邻的PMT



LHAASO-WFCTA的重建

契伦科夫像的参数化



$$w_i = \frac{N_i}{\sum_k N_k}$$

$$\bar{x} = \sum_i w_i \cdot x_i$$

$$\bar{y} = \sum_i w_i \cdot y_i$$

$$\overline{x^2} = \sum_i w_i \cdot x_i^2$$

$$\overline{y^2} = \sum_i w_i \cdot y_i^2$$

$$\overline{xy} = \sum_i w_i \cdot x_i \cdot y_i$$

$$SIZE = \sum N_k$$

$$c_{xx} = \overline{(x - \bar{x})^2} = \overline{x^2} - \bar{x}^2$$

$$c_{yy} = \overline{(y - \bar{y})^2} = \overline{y^2} - \bar{y}^2$$

$$c_{xy} = \overline{(x - \bar{x}) \cdot (y - \bar{y})} = \overline{xy} - \bar{x} \cdot \bar{y}$$

$$a = \tan \delta = \frac{c_{yy} - c_{xx} + \sqrt{(c_{yy} - c_{xx})^2 + 4c_{xy}^2}}{2c_{xy}}$$

$$b = \bar{y} - y_0 - a \cdot (\bar{x} - x_0)$$

$$LENGTH = \sqrt{\frac{c_{xx} + 2a \cdot c_{xy} + a^2 \cdot c_{yy}}{1 + a^2}}$$

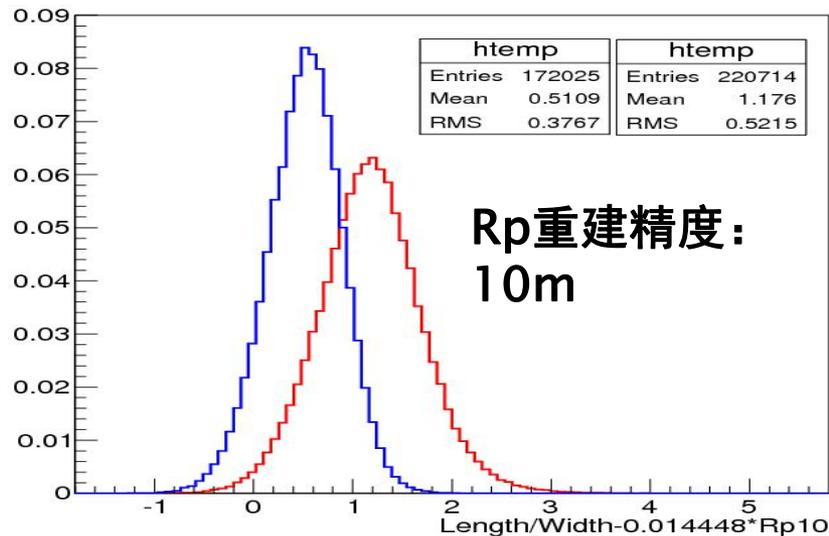
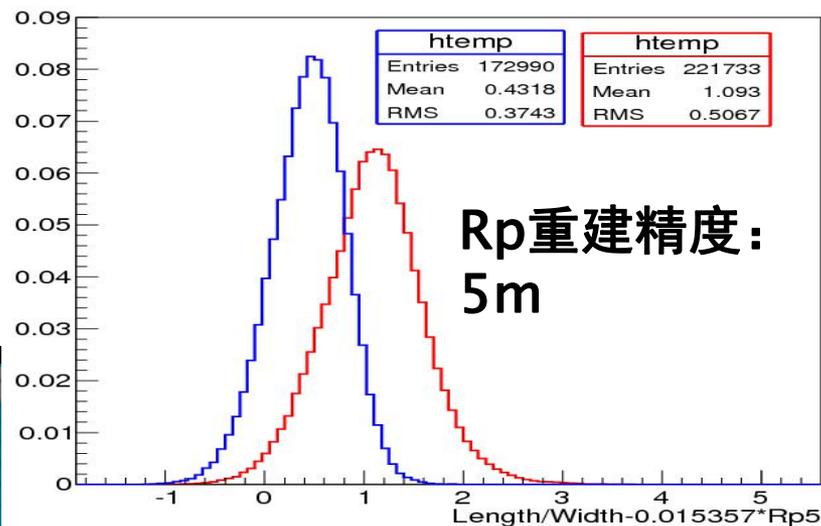
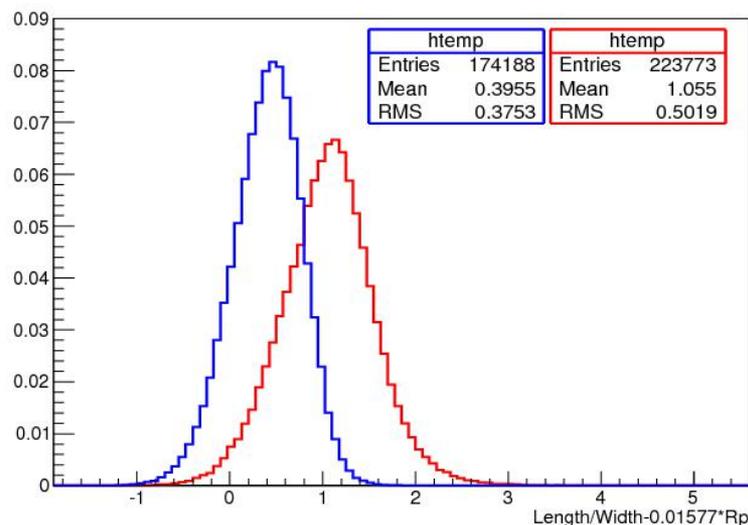
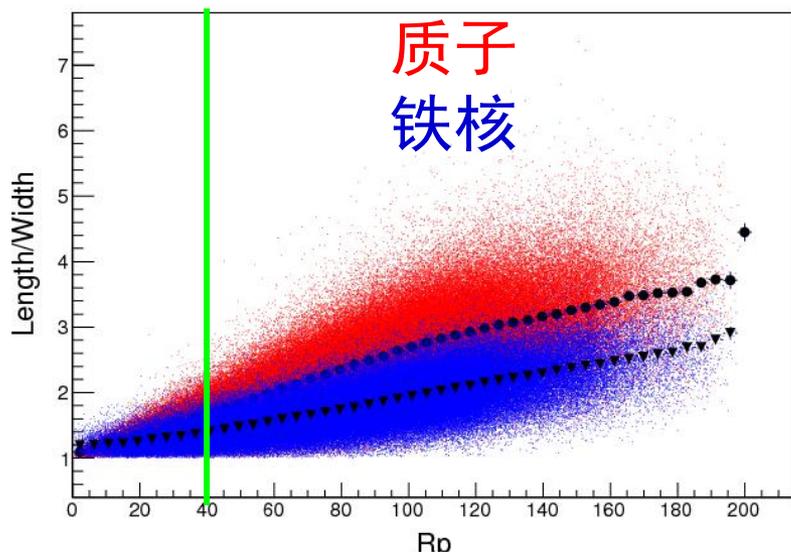
$$WIDTH = \sqrt{\frac{a^2 \cdot c_{xx} - 2a \cdot c_{xy} + c_{yy}}{1 + a^2}}$$

$$DIST = \sqrt{(\bar{x} - x_0)^2 + (\bar{y} - y_0)^2}$$

$$ALPHA = \arcsin\left(\frac{|b|}{DIST \cdot \sqrt{1 + a^2}}\right)$$

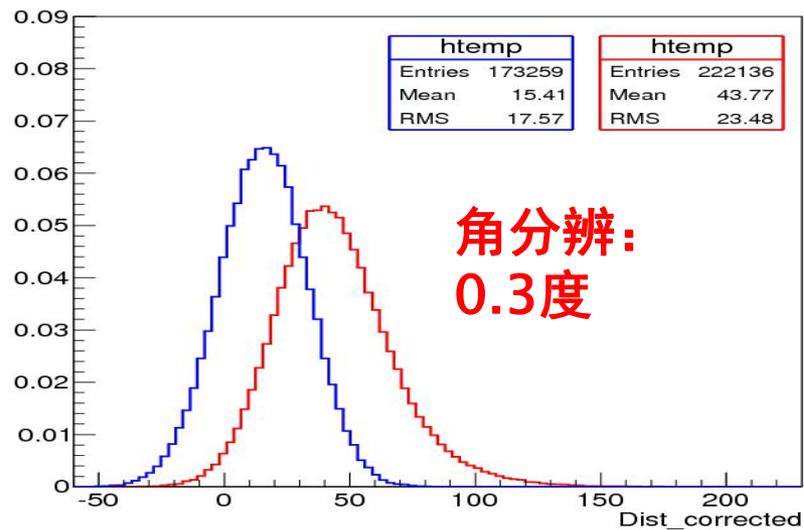
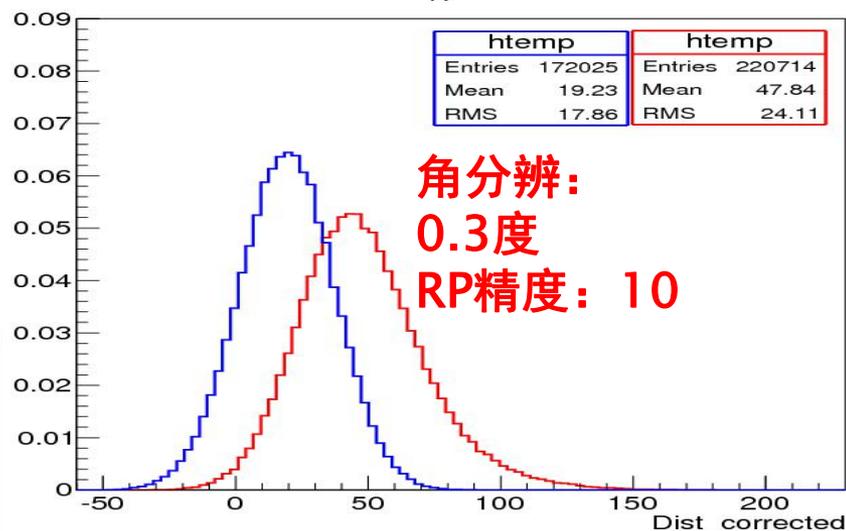
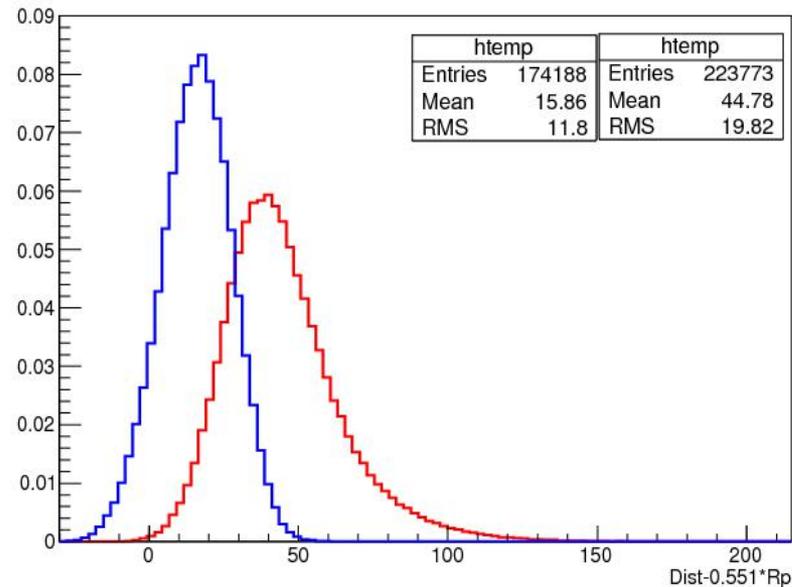
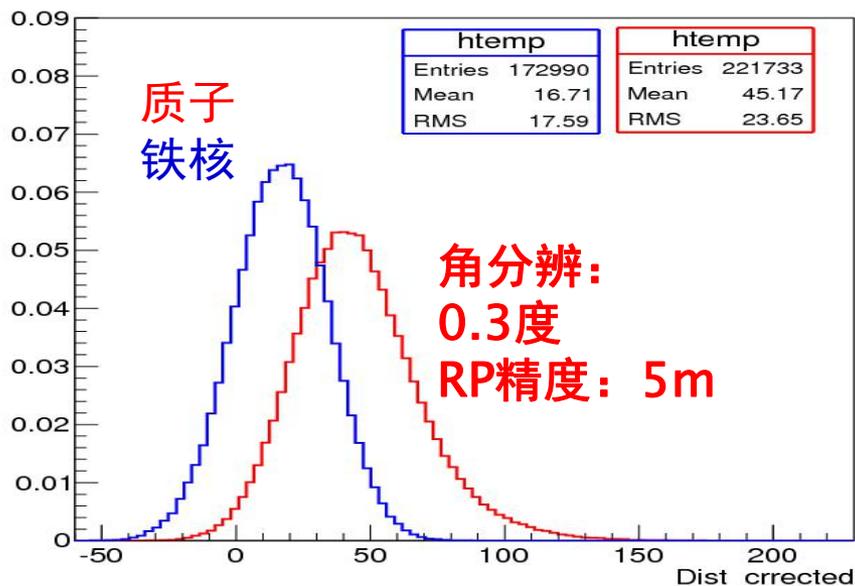
LHAASO-WFCTA成分区分

Length、Width, 100TeV至1PeV



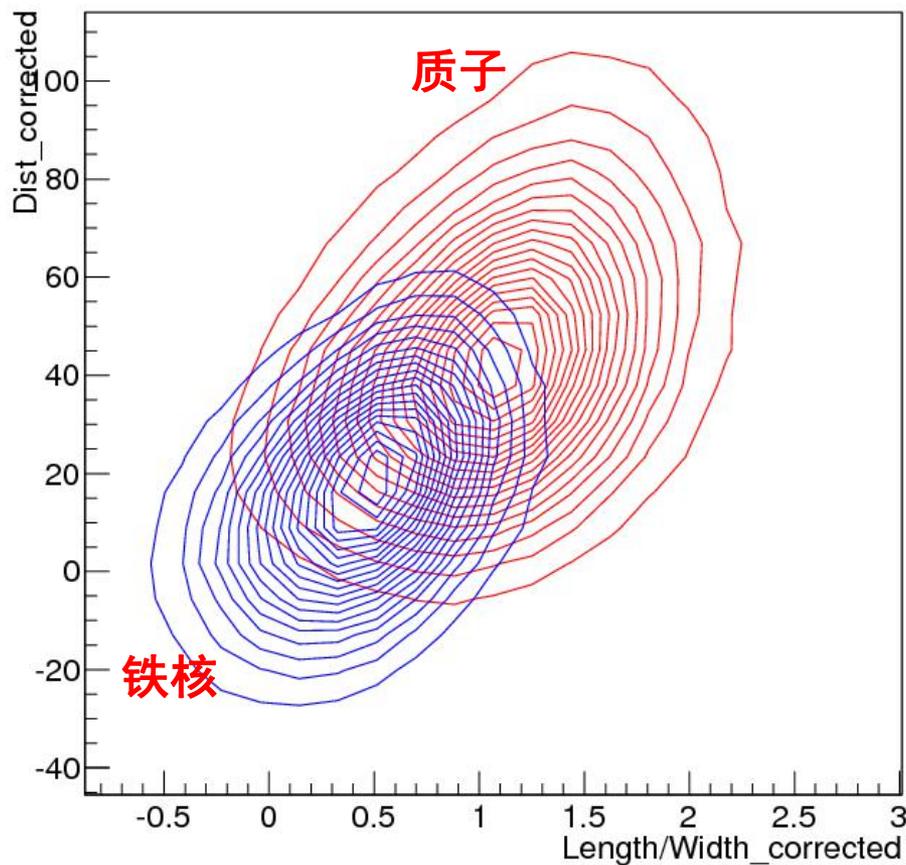
LHAASO-WFCTA成分区分

Distance: 像的质心至到达方向的距离

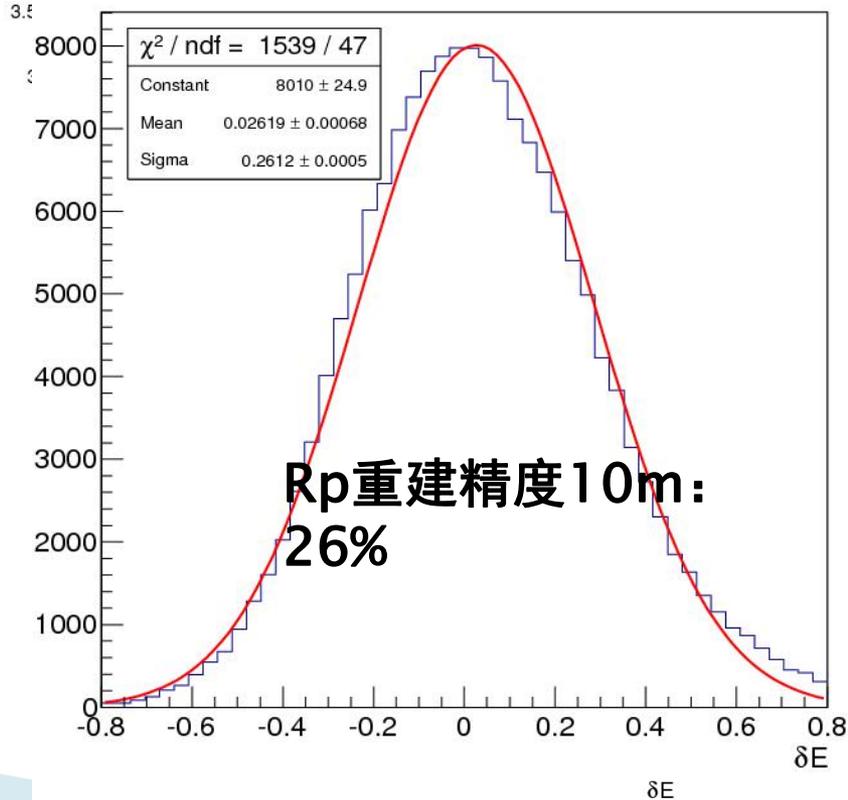
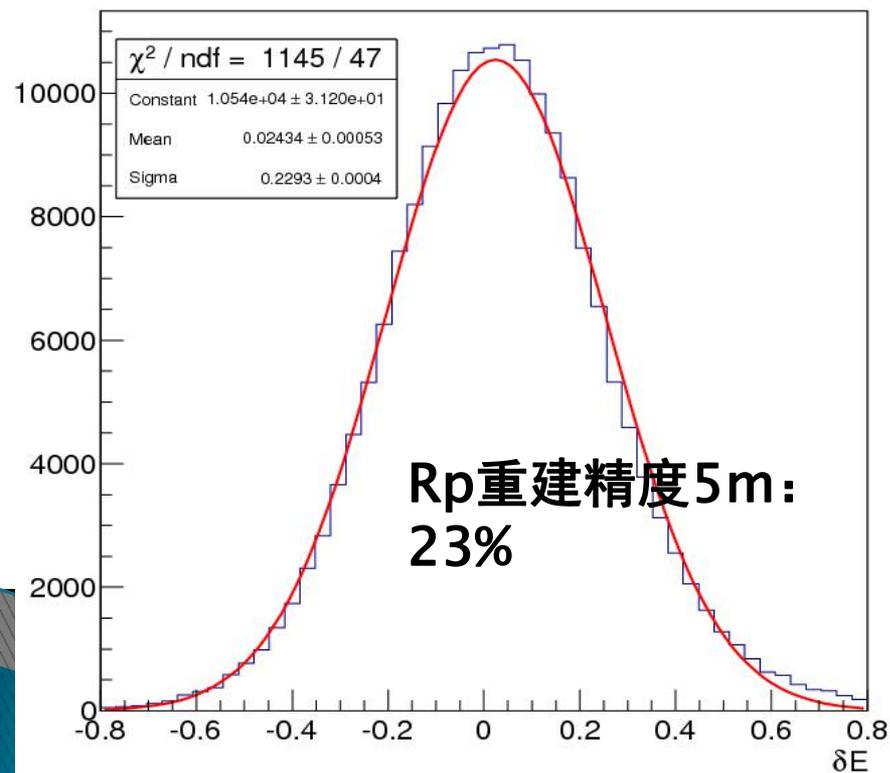
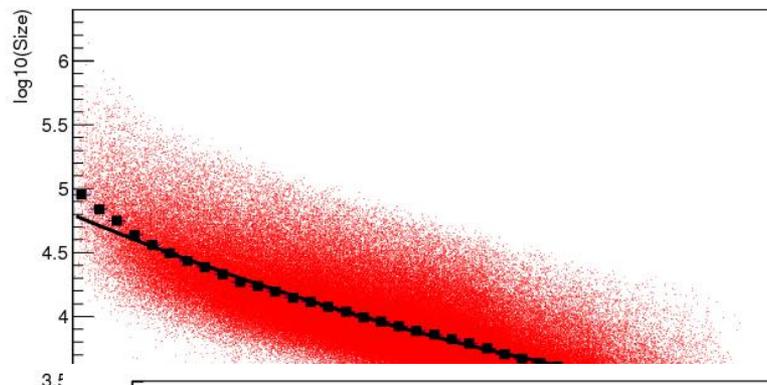
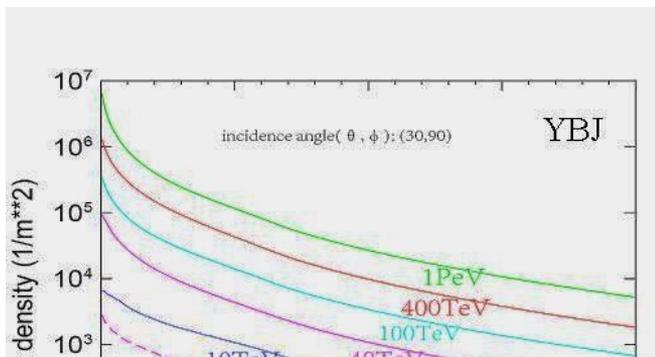


LHAASO-WFCTA成分区分

Length、Width、Distance

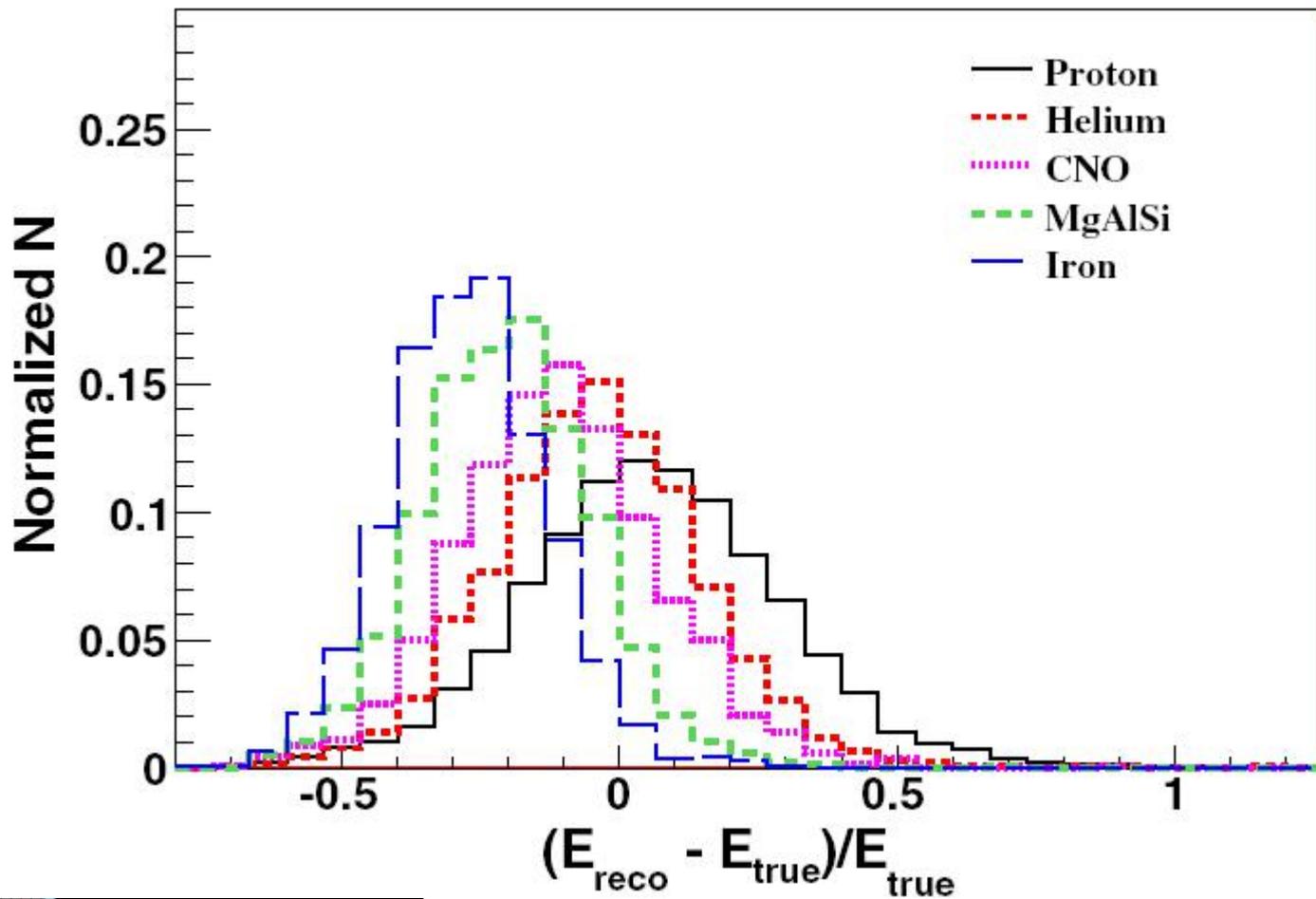


LHAASO-WFCTA能量重建



位
的影响

能量重建系统误差



总结和展望

- ▶ 契伦科夫像中包含了簇射发展和横向扩展的信息，包含了簇射极大位置的信息，敏感与成分
 - Length/Width, Distance
- ▶ 契伦科夫望远镜具有量能器性质
 - 能量重建精度：25%
 - 成分模型造成的系统误差 < 30%
- ▶ 在模拟程序方面：
 - 加入对光收集器的模拟
 - 加入对SiPM的模拟
- ▶ 联合观测方面：
 - 和WCDA, KM2A联合模拟，实现多参数分析
 - 使用Framework

谢谢