


WFCTA和KM2A联合测量 Sub-EeV能区宇宙线

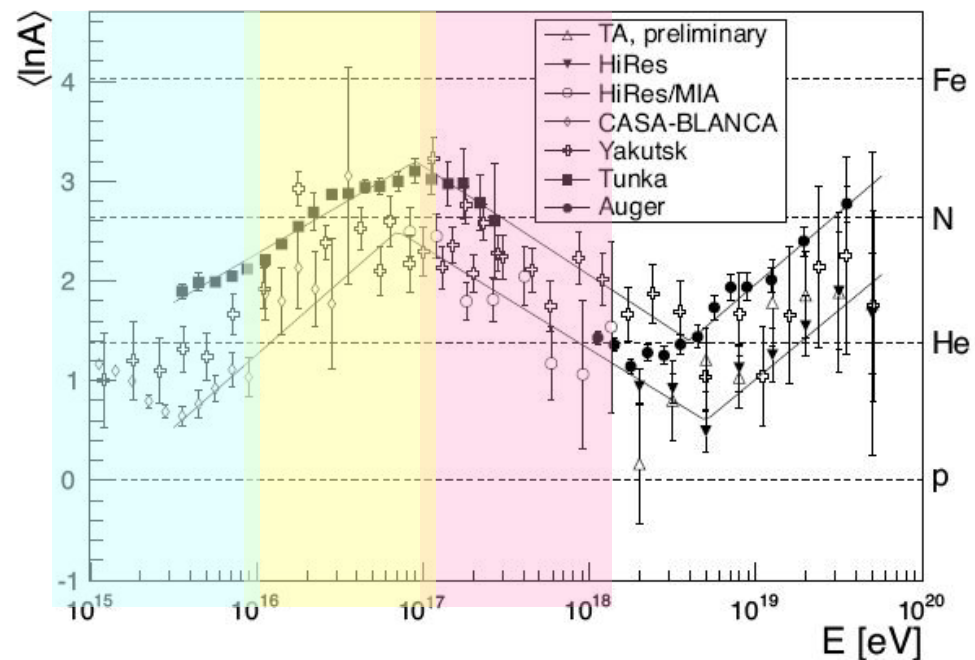
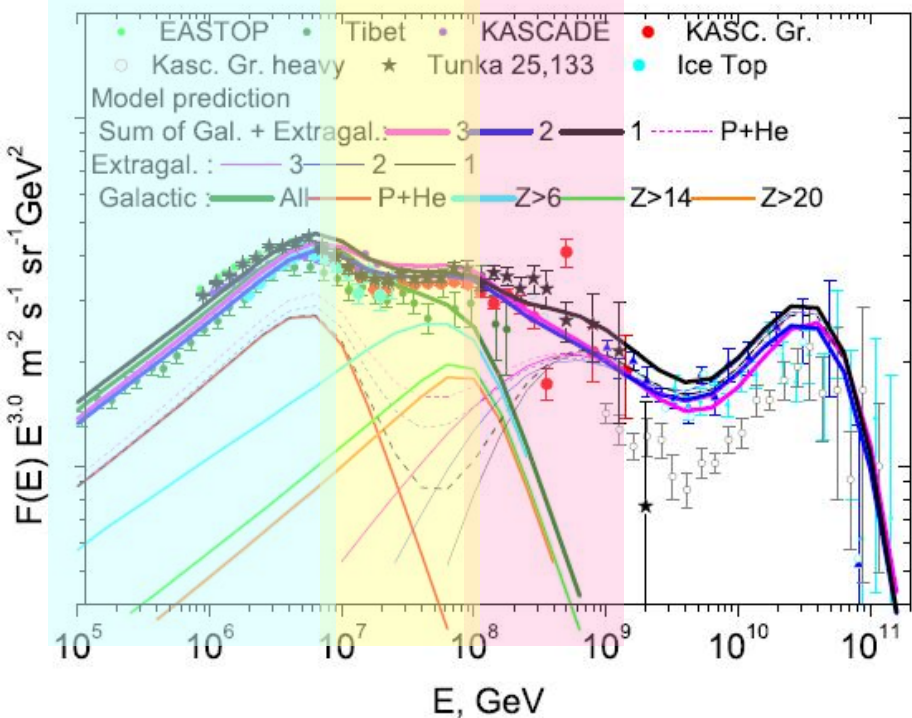
刘加丽
昆明学院

2016, 08, 17

主要内容

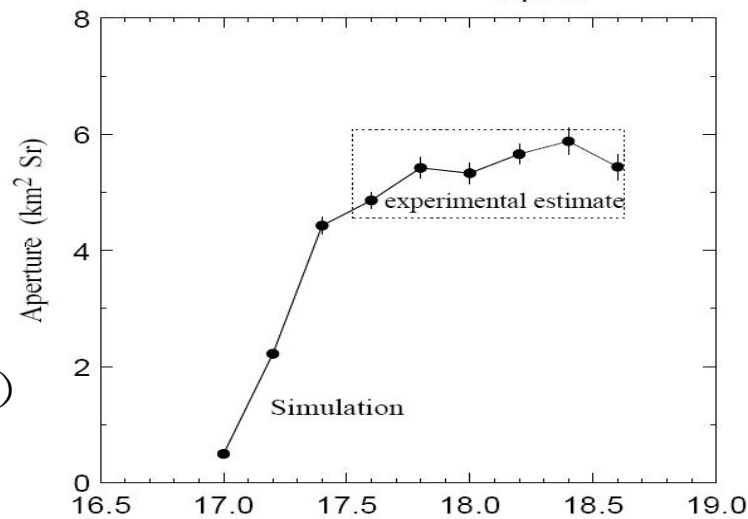
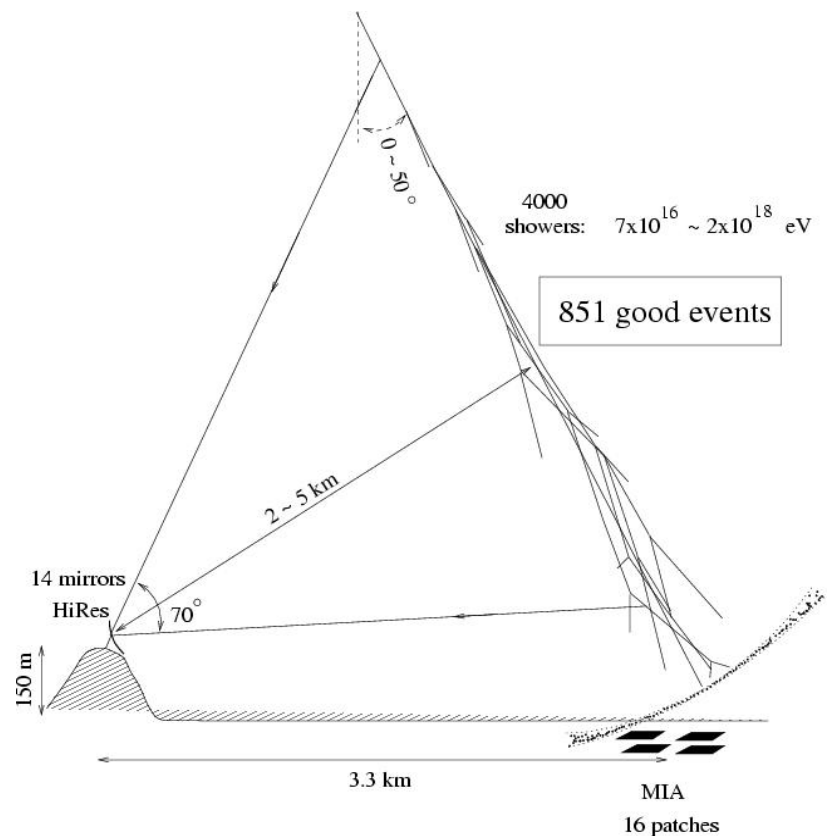
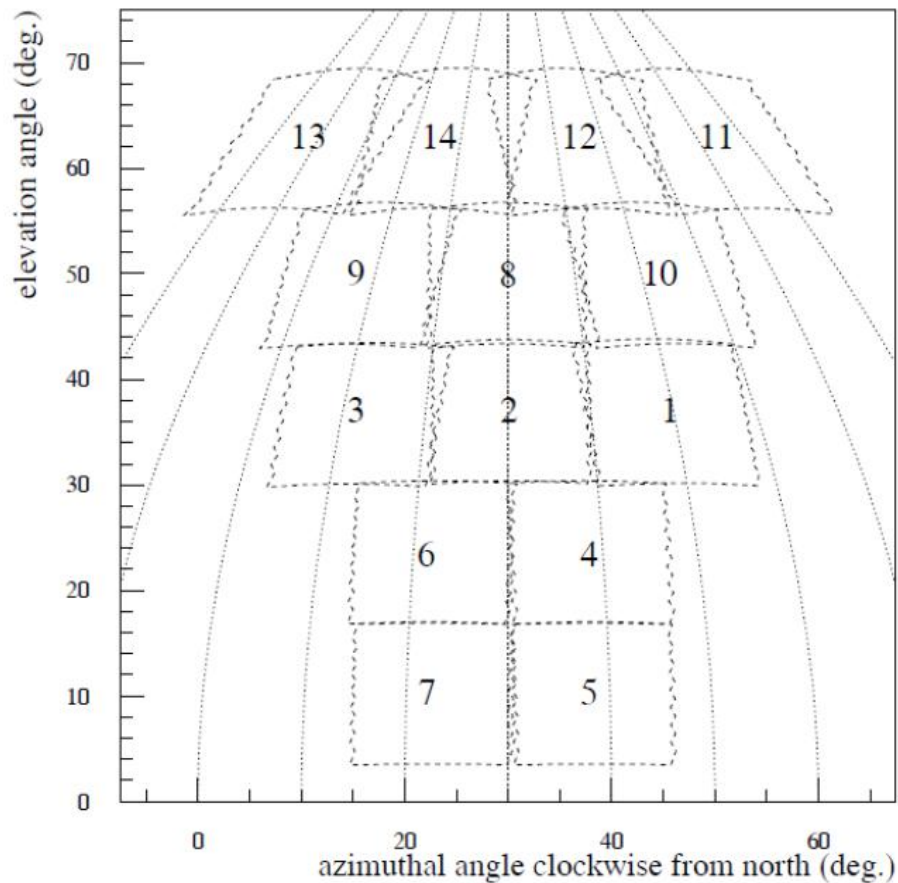
- * 研究背景
 - * 探测器设置
 - * 实验模拟
 - * 几何重建
 - * 总结
- 

研究背景 (1)



- ✓ LHAASO-WFCTA 实验的物理目标 (50TeV-10PeV;10PeV-100PeV;100PeV-1EeV.)
 - 宽范围的测量宇宙线能谱和成份 (50 TeV 至几个EeV) ;
 - 同一批望远镜, 采用不同的光学技术, 精确测量第一“膝”, 第二“膝”;
 - 低能端与空间直接测量相重叠, 将能标传递到高能端, 提高能谱测量的准确性。
- ✓ 该工作集中于采用荧光技术测量100PeV-1EeV的高能端宇宙线。

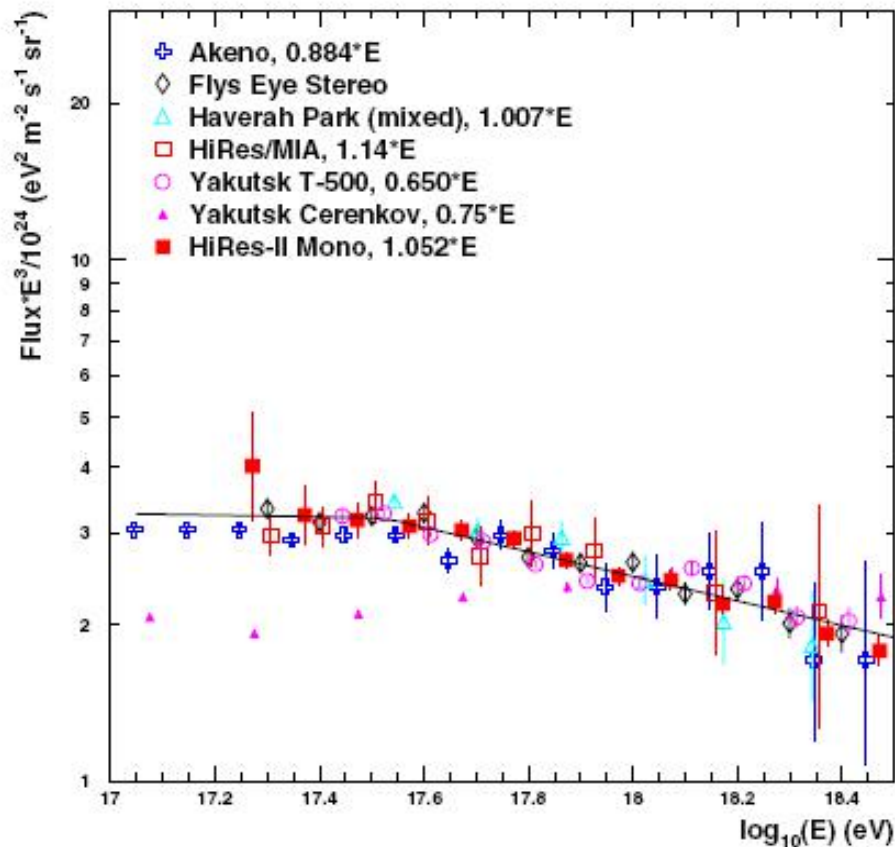
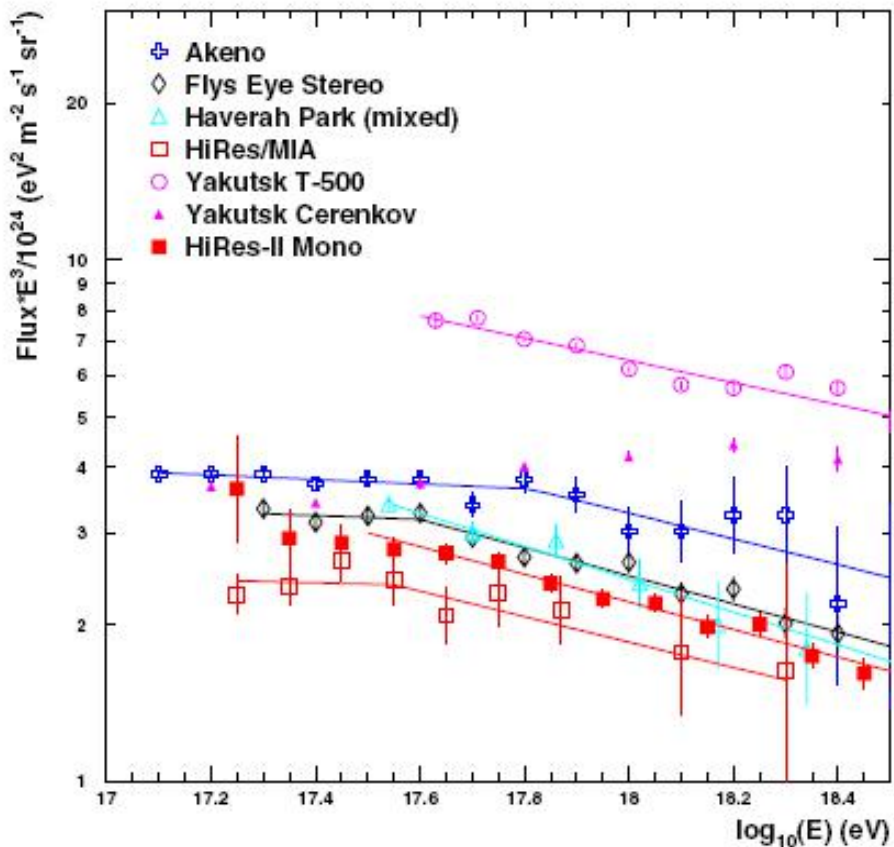
研究背景 (2)



HiRes/MIA

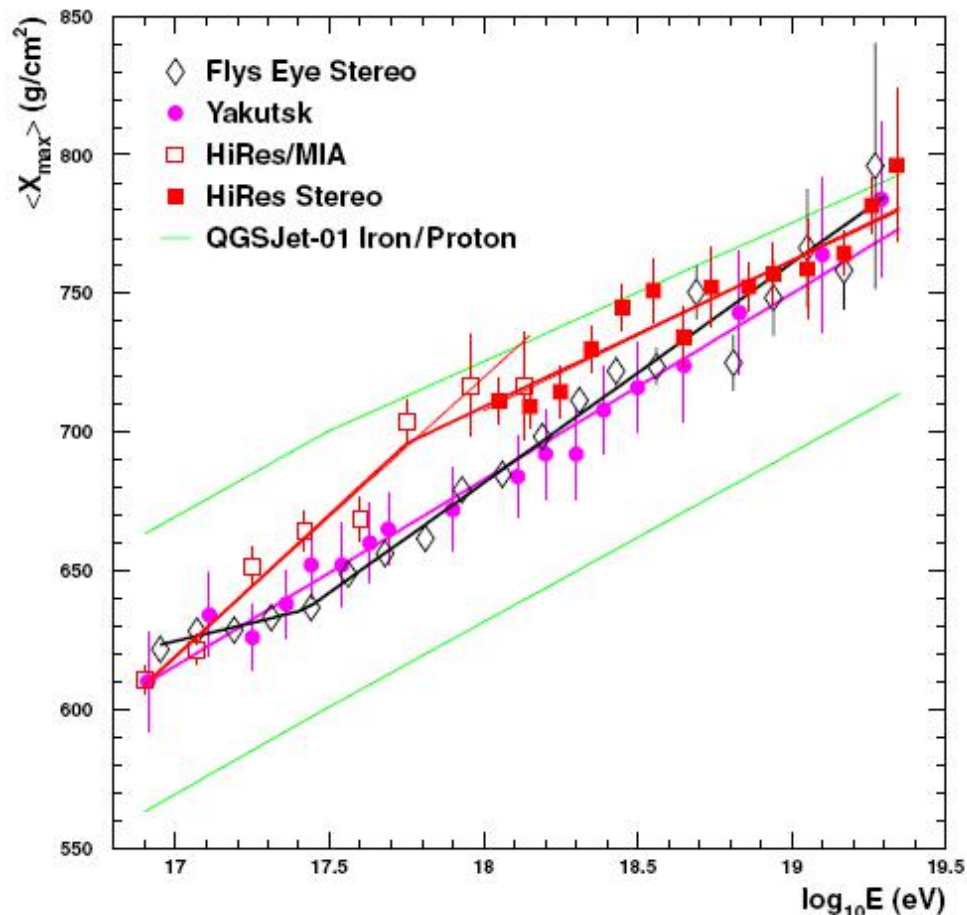
- ✓ hybrid measurement with HiRes and CASA-MIA)
- ✓ 观测时间: 1993,08,23—1996,05,24 (33个月);
- ✓ 几何重建需借助MIA的muon到达时间信息;
- ✓ 4034个符合测量事例, 经过重建和各种事例挑选, 保留有851个好事例。

测量结果—能谱



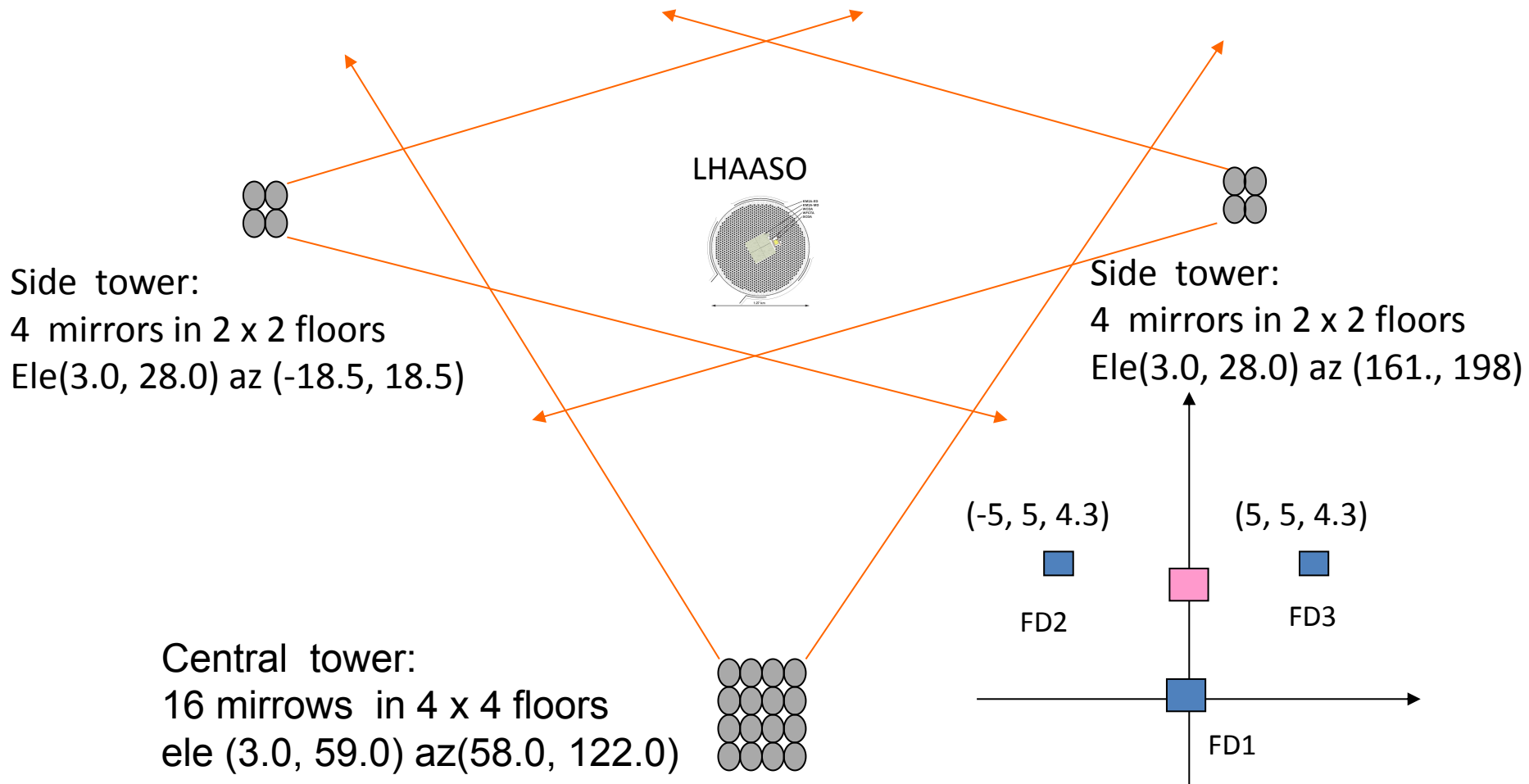
- 都测到了拐折。
- 但缺乏绝对的能量标度。

测量结果—原初成分



- 成分发生了变化，从混合成分向轻成分转变。
- 变化的趋势不同。

WFCTA 荧光实验 探测器设置



望远镜结构

望远镜主体

-- 1/4标准海运集装箱

光收集系统

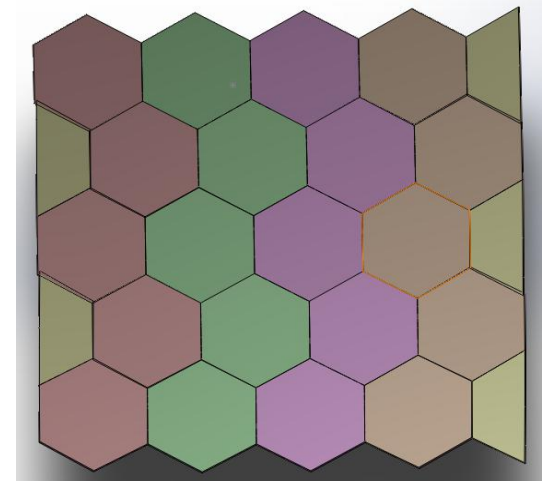
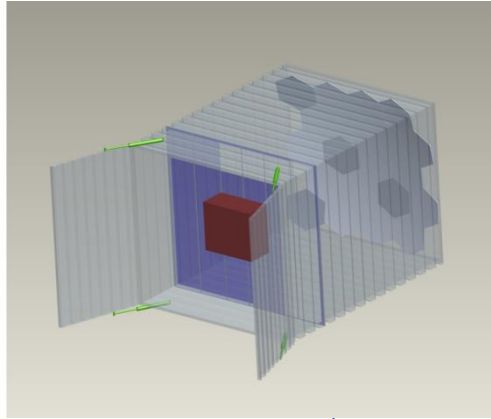
-- 20块整镜 + 5块半镜

-- 子镜

边长: 297.1mm

形状: 正六边形 球面镜

曲率半径: 5800mm



(Jiali Liu et al., Astroparticle Physics 67 : 8–17, 2015.)

成像系统

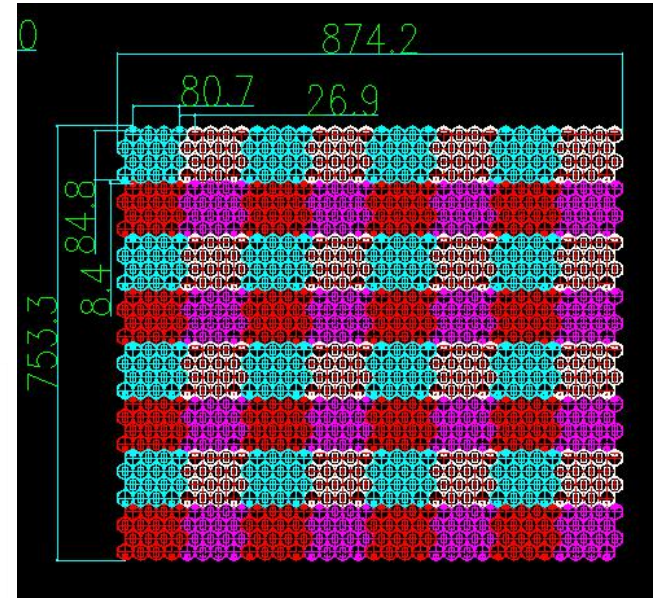
-- 32 x 32的PMT阵列

-- FOV: $16^\circ \times 14^\circ$

-- PMT

直径: 26.9mm 圆形

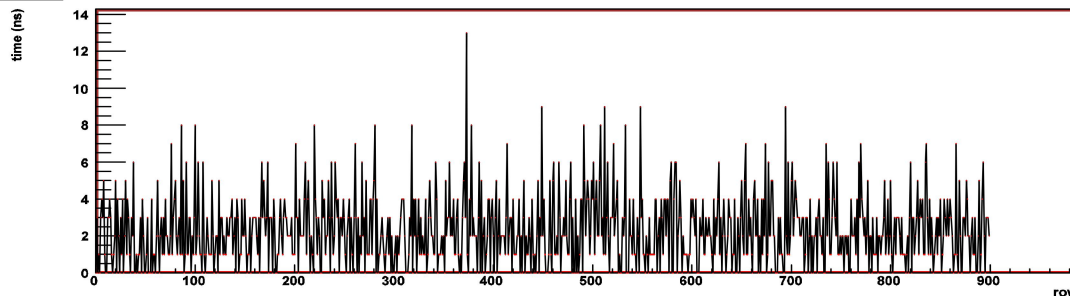
FOV: 0.5度



电子学系统

FADC, 每20ns采集一次波形。

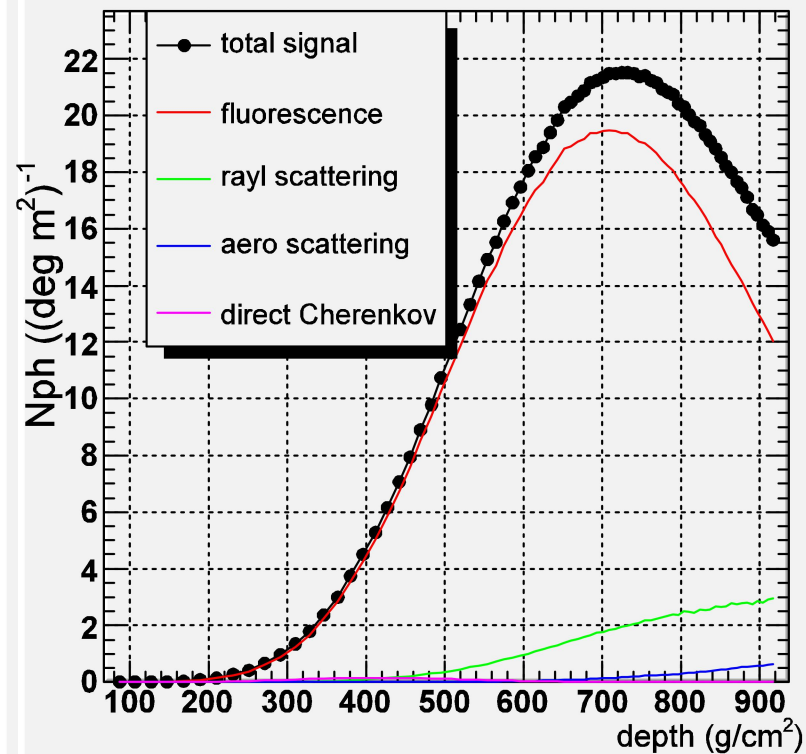
Graph



Simulation details

- **Shower production**
 - Corsika QGSJET-II /EPOS + FLUKA models
 - proton / Iron for both two models
 - E: 50 PeV ~ 5 EeV
 - inclined events:
 - zenith : 30~60 deg
 - 700 ~ 1200 g/cm²
 - azimuth: 0~360 deg
- **Detector simulation**
 - ✓ **WFCTA simulation package** (the longitudinal development curve of Nch)
 - photon generation and propagation
 - ray trace
 - electronics
 - event trigger
 - CT: S/N >3.5 sigma + line / circle pattern
 - ST: S/N > 2.5 sigma + line / circle pattern
 - Event trigger: CT + one ST
 - ✓ **KM2A simulation package** (muon information at o.b.s level)
 - Parameterization on full G4 detector simulation
 - ✓ **Offline combined events**

Event display



event: 1128

energy: 2.78e+17 eV

zenith: 53.19 deg

azimuth: 145.98 deg

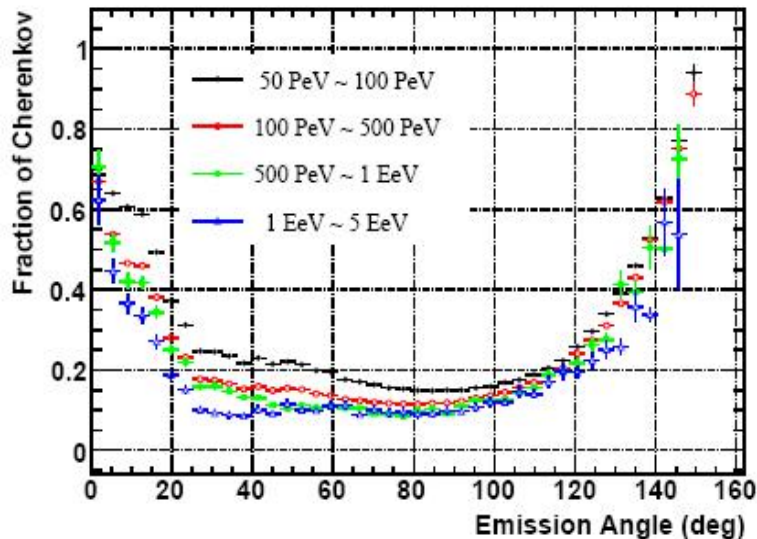
Rp: 5.439 km

core: (4.245 km 3.607 km)

Xmax: 710.92 g/cm²

事例选择

- Edge event
corner event or $d_{\text{the}} < 3^\circ$
- Cherenkov dominant event
viewing angle $< 25^\circ$ or $> 120^\circ$ and track length $< 10^\circ$
- Location of X_{max} out of the FOV of tower array.
- Diverging SDP event (side arrays)
the weighted center of event falls outer 0.5° of the SDP.



model	primary	trigger	cut	final
QGS+P	242540	33839	8059 (23.8%)	25780
QGS+Fe	121835	16037	3900 (24.3%)	12137
EPOS+P	237390	32581	7826 (24.0%)	24755
EPOS+Fe	124110	17144	4227 (24.7%)	12197

Fraction of Cherenkov lights
.vs. Emission angle

Table1: Data statistics

探测器设置优化

- FOV range (555 setup)

1. tower

$11^\circ \sim 67^\circ$ $31^\circ \sim 87^\circ$

2. side (tower FOV is set as $31^\circ \sim 87^\circ$)

$31^\circ \sim 59^\circ$ $45^\circ \sim 73^\circ$ $59^\circ \sim 87^\circ$

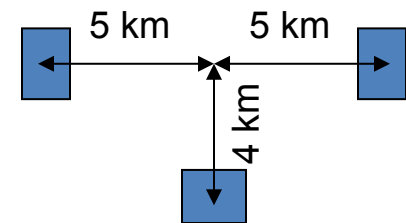
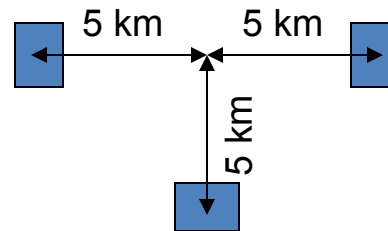
--Tower $31^\circ \sim 87^\circ$ and Side $59^\circ \sim 87^\circ$

- Relative location of arrays

1. 555

2. 554

3. 444



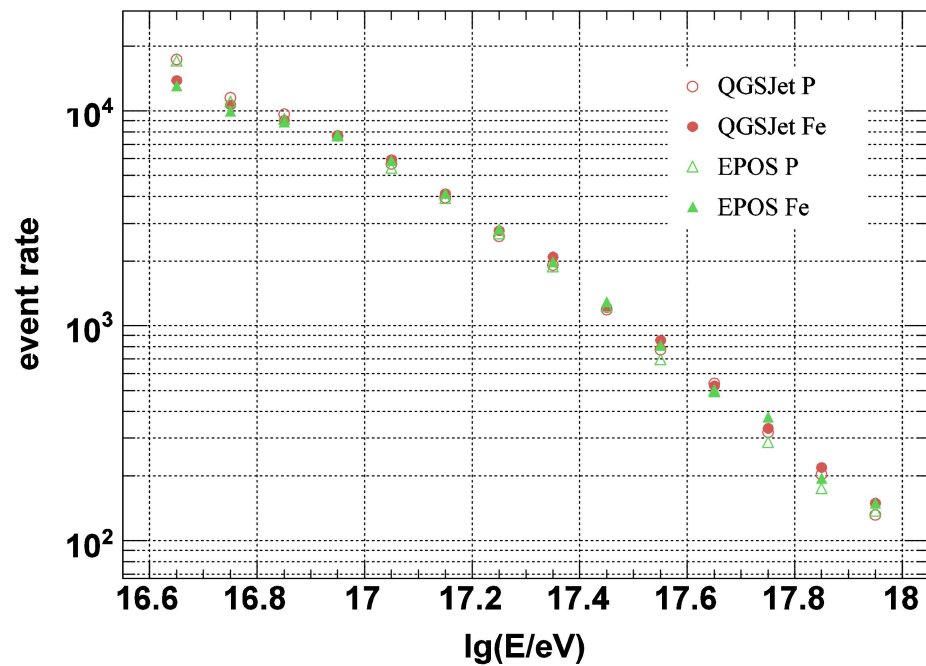
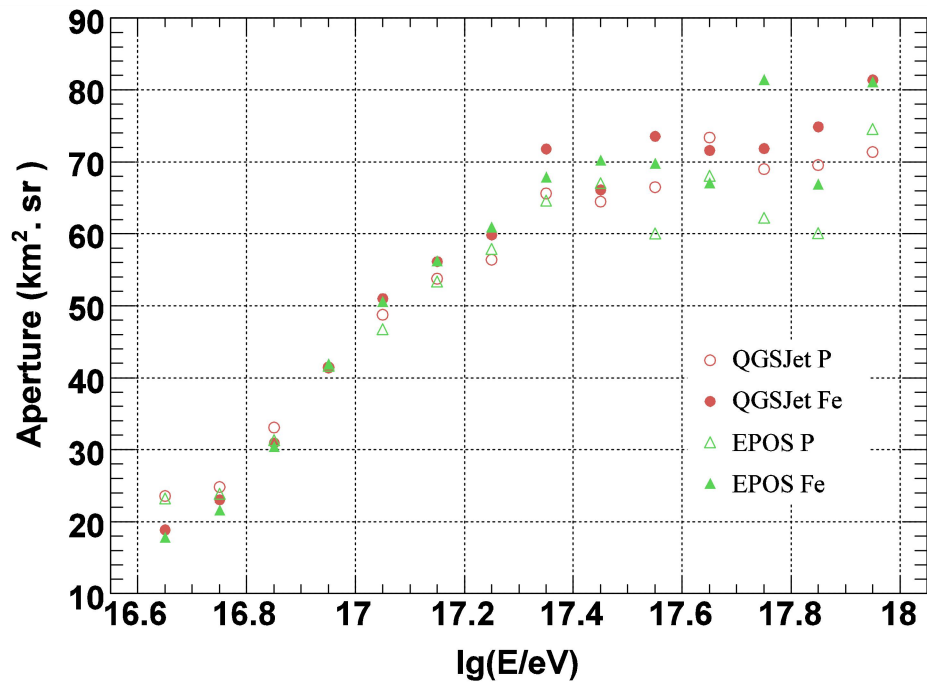
-- 555 and 554 setups are the candidate configurations.

探测器设置优化

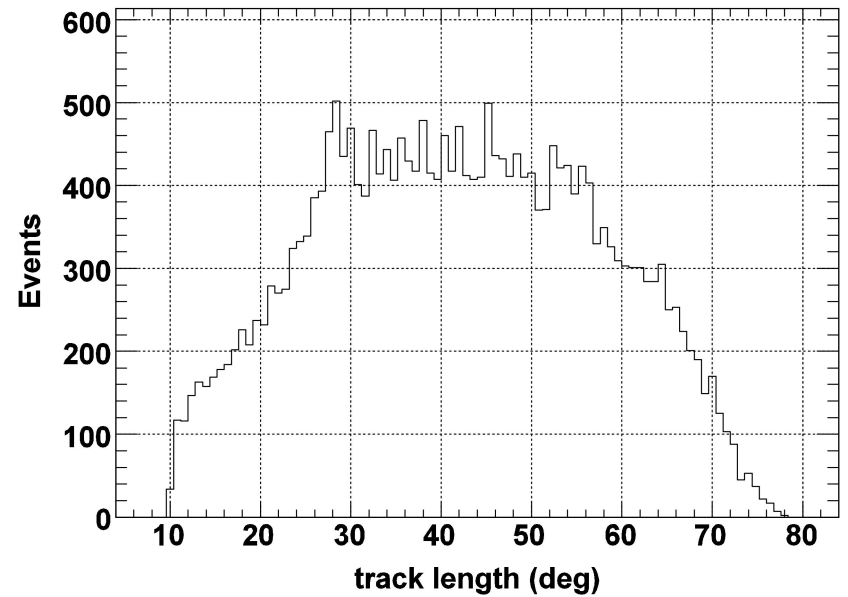
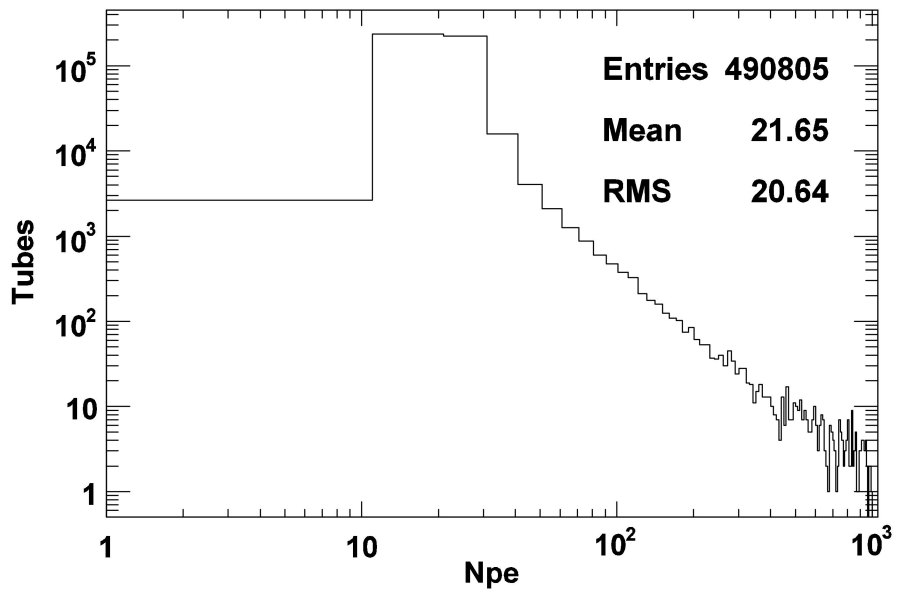
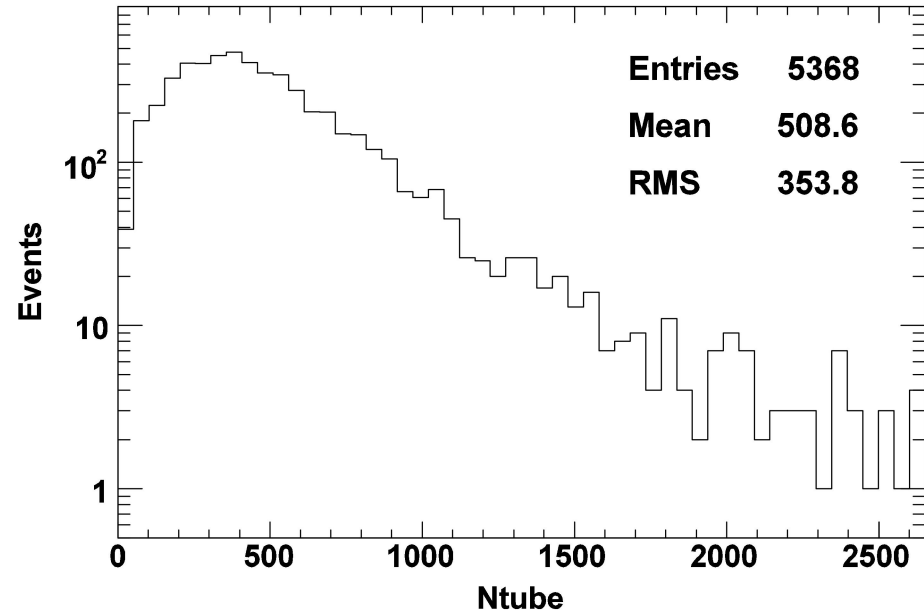
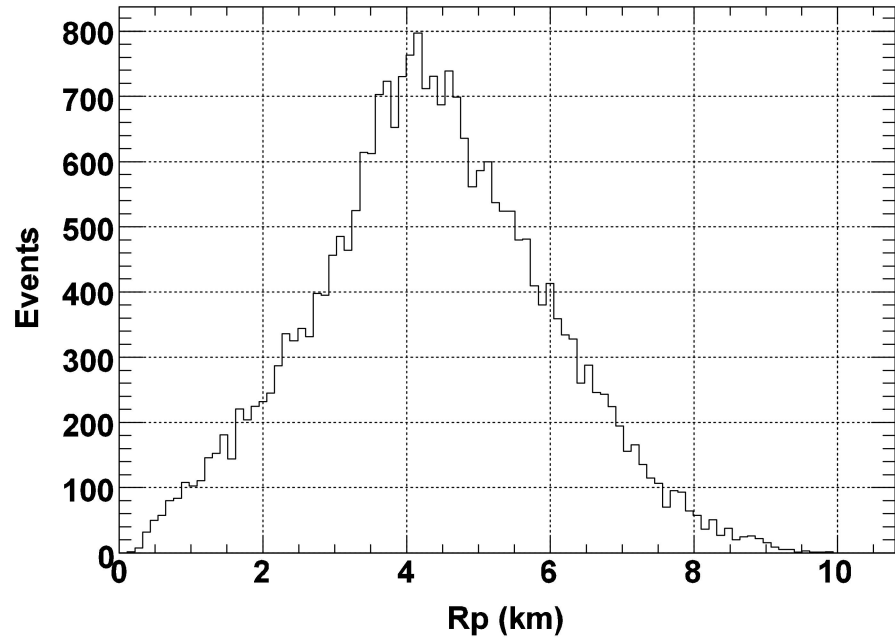
Setup	555								444		554	
Tower	11° ~ 67°		31° ~ 87°						31° ~ 87°		31° ~ 87°	
Side	39° ~ 67°		31° ~ 59°		45° ~ 73°		59° ~ 87°		59° ~ 87°		59° ~ 87°	
16.75	34.4	19.7	34.1	27.1	45.0	35.6	45.2	35.9	48.7	36.5	53.6	40.0
16.85	42.8	23.5	42.3	32.1	57.8	44.0	59.7	46.9	61.0	45.1	67.1	48.4
16.95	57.6	29.6	55.2	40.2	75.2	57.2	81.9	62.9	78.1	56.0	83.2	60.3
17.05	65.4	31.6	67.0	47.4	86.0	63.1	93.6	70.8	88.4	61.3	96.4	67.1
17.15	75.1	33.7	72.9	51.1	100.4	72.1	111.3	80.8	101.2	66.9	108.9	72.5
17.25	81.3	34.2	79.1	53.9	107.2	77.7	121.1	87.2	108.3	68.5	117.4	75.9
17.35	91.4	34.6	83.6	55.6	121.2	83.2	137.3	98.1	115.4	70.8	126.5	80.6
17.45	98.3	34.9	95.1	62.7	127.1	85.3	150.9	103.1	124.2	72.1	132.3	82.7
17.55	103.4	35.3	99.7	63.6	130.8	87.1	156.6	103.5	126.5	73.2	136.2	84.0
17.65	107.5	35.7	102.3	64.7	136.2	88.9	162.7	103.8	127.3	75.1	143.5	85.0
17.75	108.2	35.9	104.1	66.0	140.5	90.2	164.2	104.1	128.5	76.9	147.8	86.1
17.85	108.9	36.2	106.3	67.3	143.8	91.3	166.3	104.3	129.6	77.4	150.1	87.3
17.95	109.3	36.5	107.5	69.5	145.7	92.4	167.5	104.9	130.7	78.3	153.3	88.1
18.05	109.8	36.7	108.2	71.3	147.0	93.2	167.9	105.3	131.2	79.2	155.2	88.6
18.15	110.7	36.9	108.9	71.8	148.1	94.1	168.5	105.8	132.4	80.7	157.7	89.3
18.25	111.3	41.2	109.4	72.2	149.3	94.9	169.1	106.2	133.5	81.3	159.1	90.2
18.35	111.8	41.4	109.9	72.7	149.8	95.3	169.7	106.5	140.2	81.9	160.4	91.1

Table 2: Detector apertures under different configurations. (*unit* : $km^2 \cdot sr$)

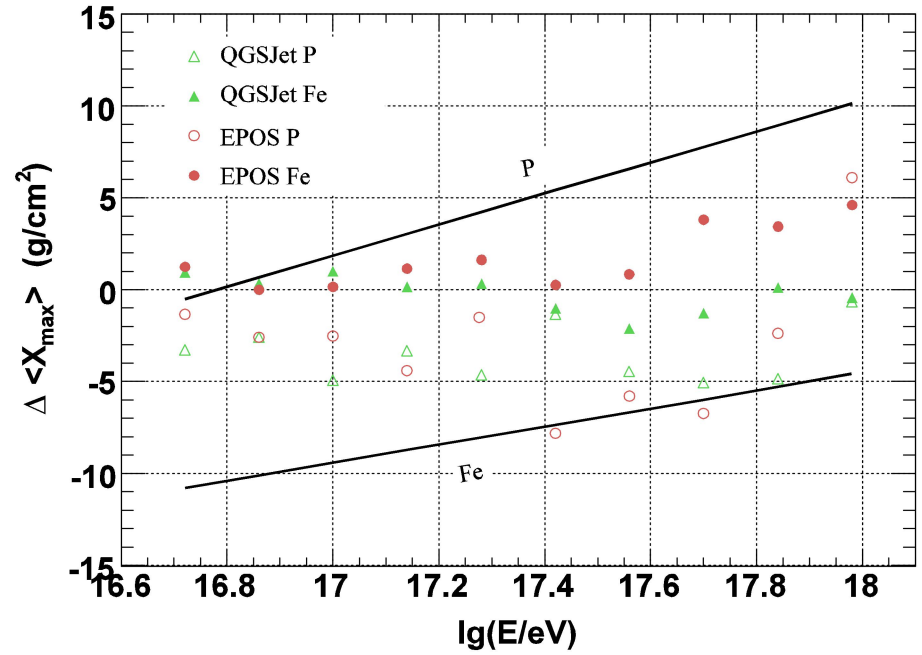
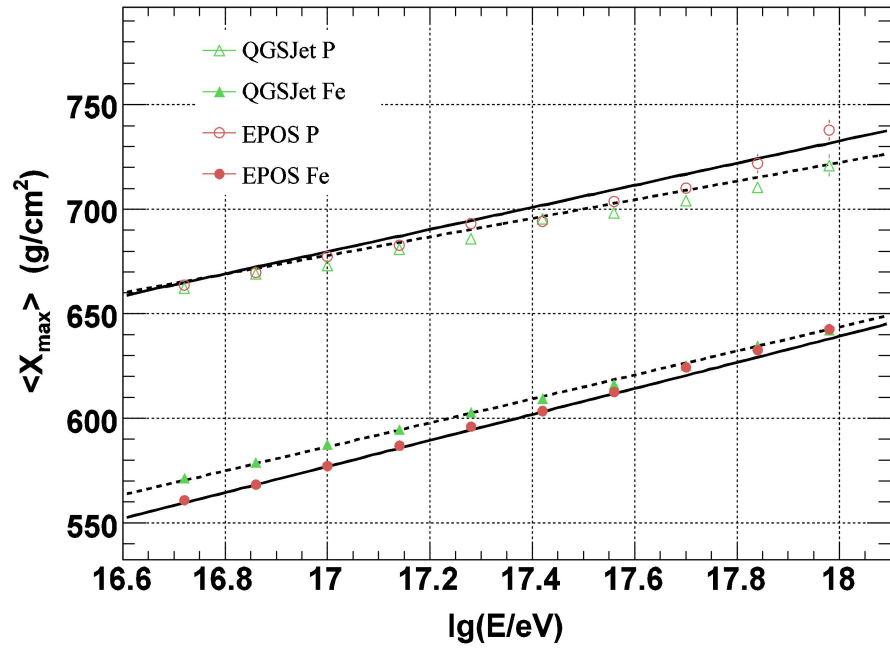
有效面积和事例率



参数分布



成份鉴别--Xmax

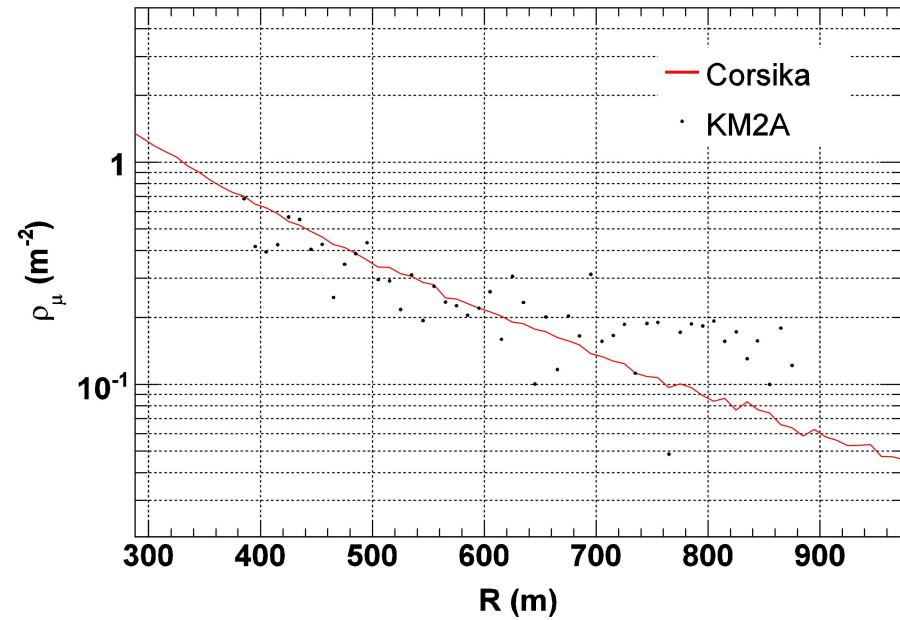
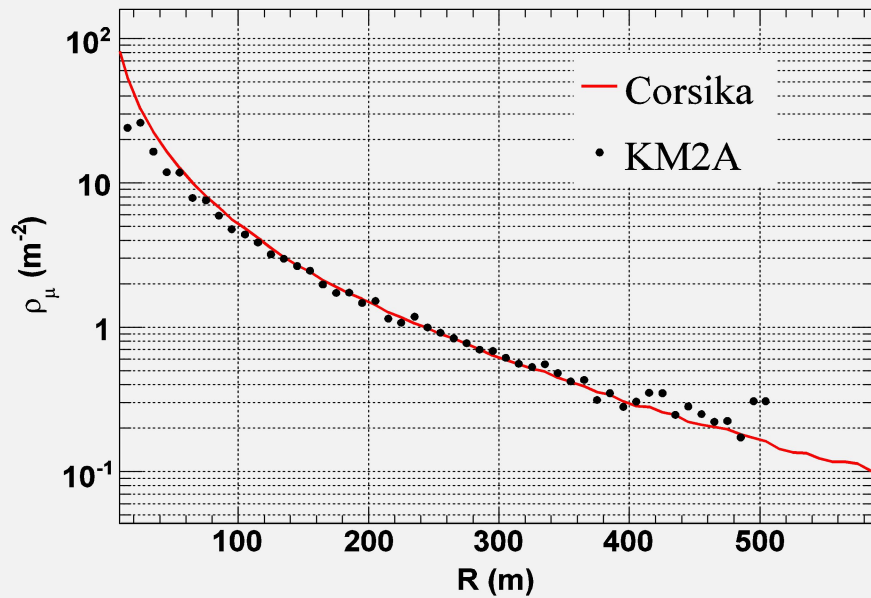


- Elongation rate

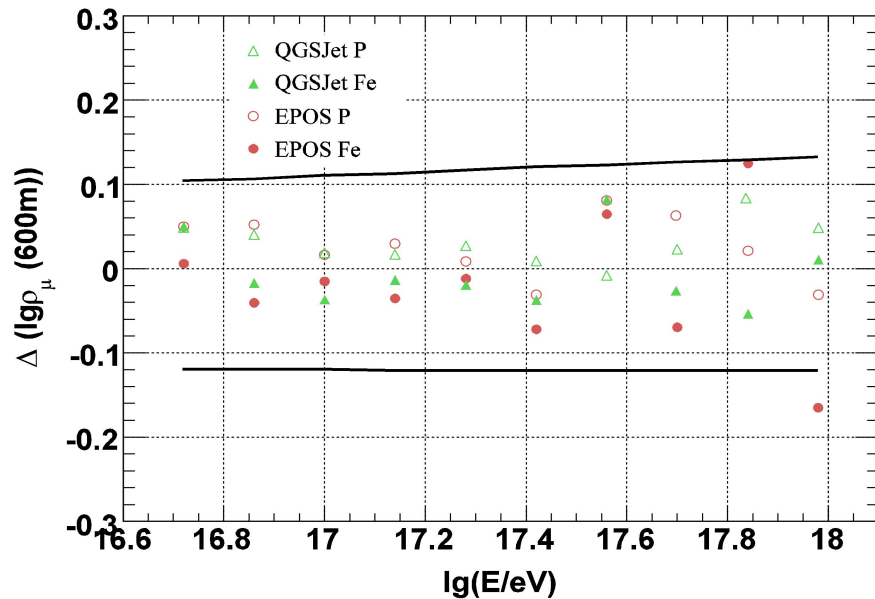
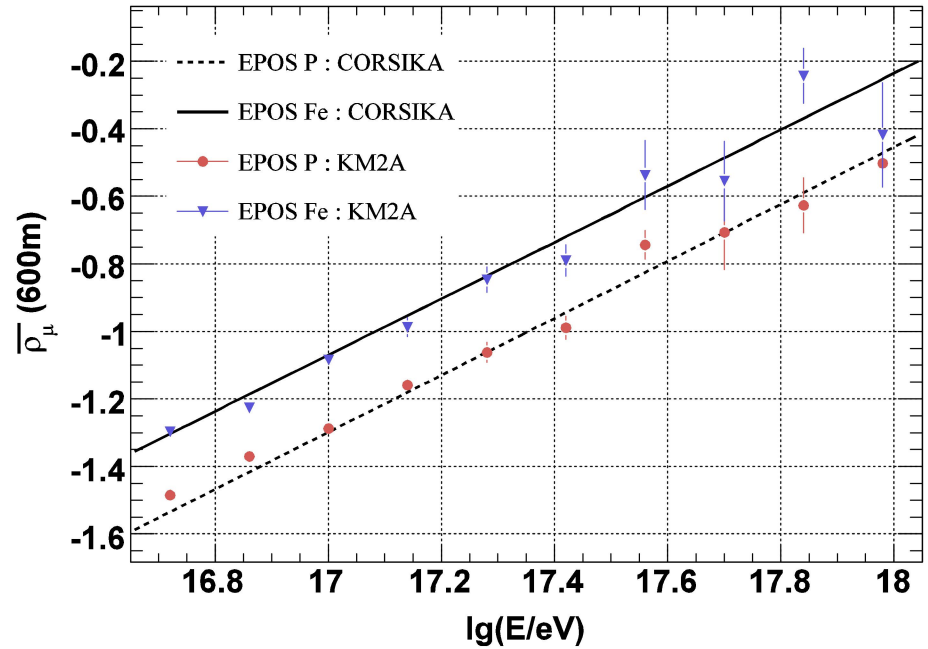
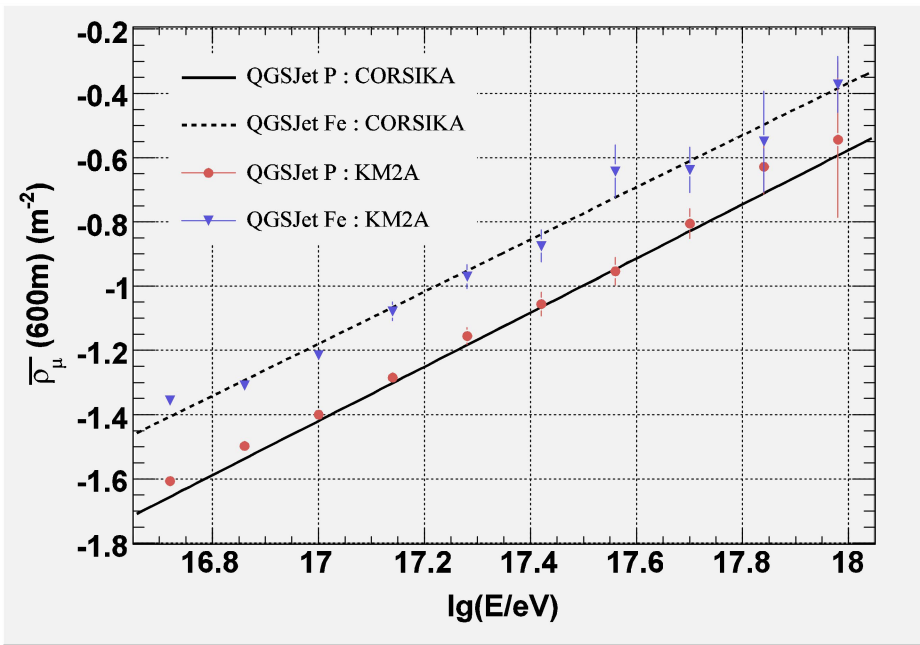
$$\alpha = \frac{d \langle X_{\max} \rangle}{d \lg E}$$

	EPOS + P	EPOS + Fe	QGS + P	QGS + Fe
ER^1	52.9 ± 1.4	62.2 ± 1.0	44.5 ± 1.7	57.3 ± 1.0
ER^2	50.7 ± 1.4	61.9 ± 1.1	44.2 ± 1.6	57.1 ± 1.2

Event display-- $\rho_\mu(600)$



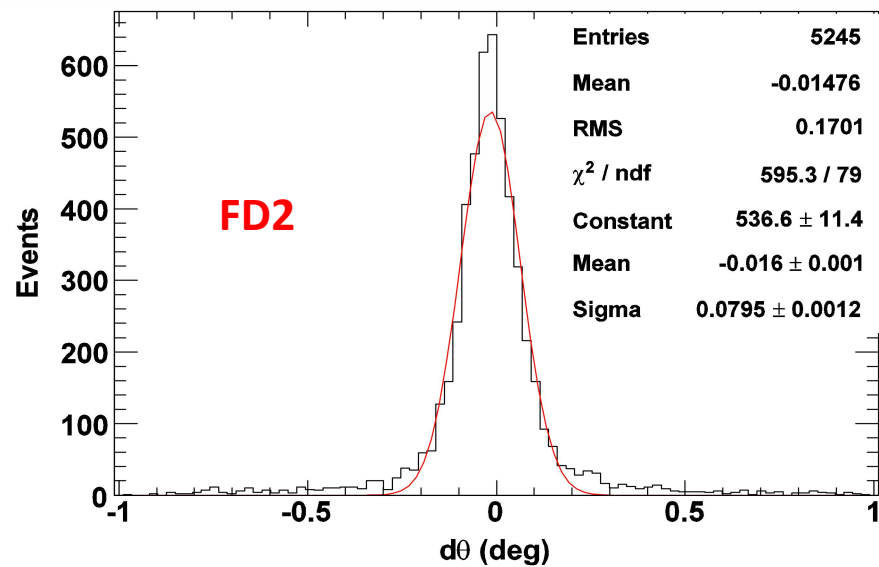
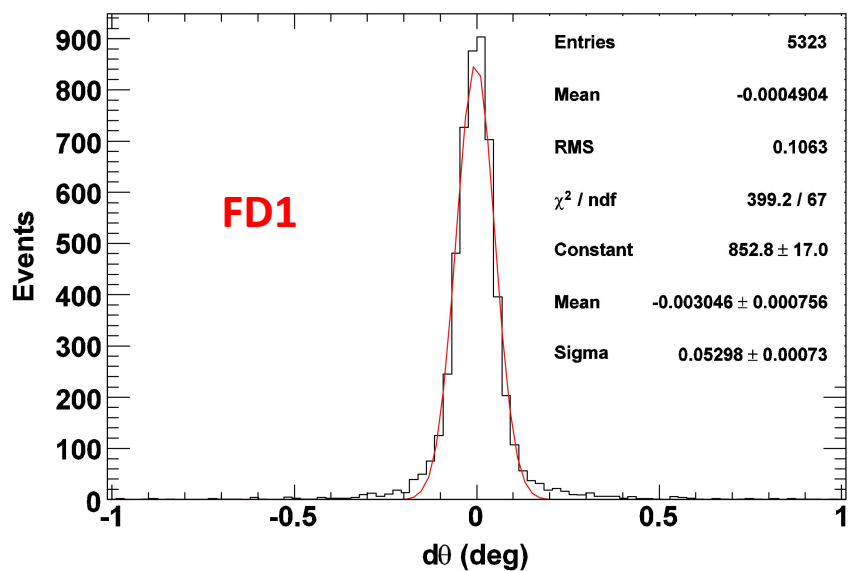
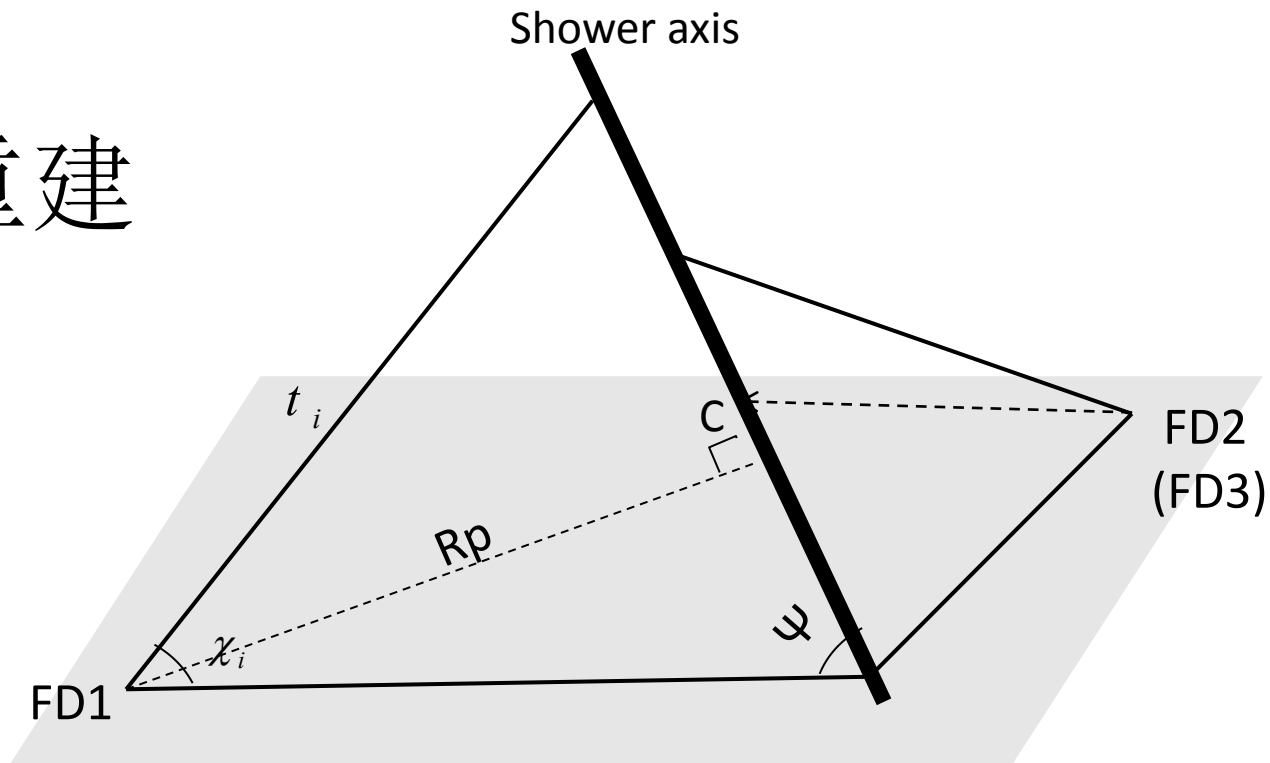
成份鉴别-- $\rho_\mu(600)$



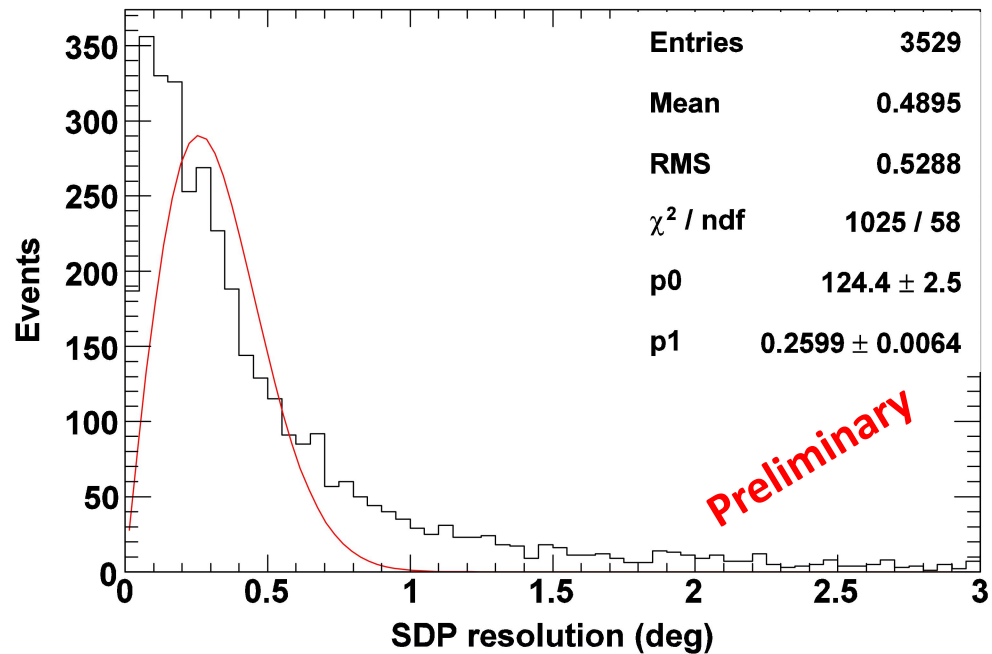
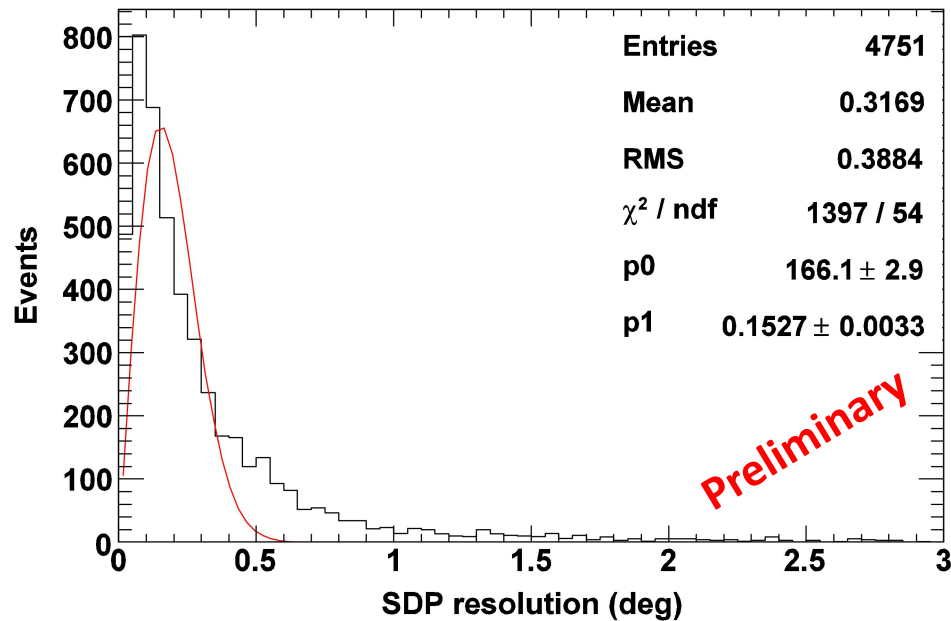
$$\beta = \frac{d \lg \rho_\mu(600)}{d \lg E}$$

	EP	EFe	QP	QFe
β_0	0.844	0.834	0.843	0.811
β	0.783	0.829	0.800	0.756

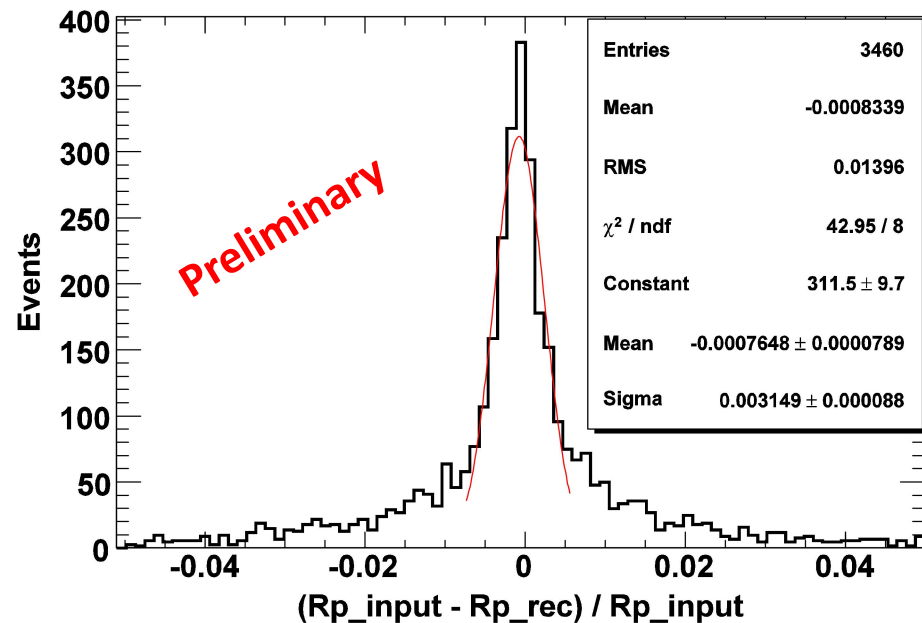
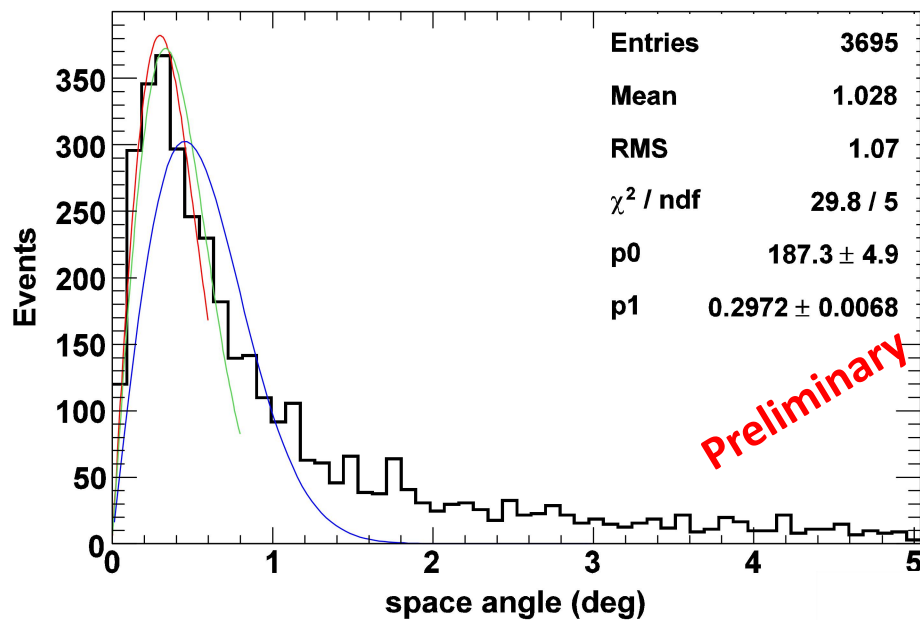
事例几何重建



事例几何重建--SDP



事例几何重建一方向、Rp



总结

- 利用WFCTA探测器重组，在荧光模式下具有对Sub-EeV能区的能谱精确的观测能力。
- WFCTA荧光观测模式具有较平的有效面积（ $70\text{km}^2\cdot\text{sr}@0.2\text{EeV}$ ）。
- 具有较高的事例率（ $14\text{k事例}@>0.1\text{EeV}$ ， $160\text{事例}@>1\text{EeV}$ ）。
- 与KM2A联合观测，具有较强的成份区分能力。
- 近期将要进行的工作
 - 事例纵向发展曲线、能量的重建。
 - 新模拟软件的编写 (C++， 合作者：洪孙焱)。



谢谢!

New Simulation Program

(合作者： 洪孙焱)

- Old Simulation Program
 - Used Fortran language, procedure oriented
 - Data and Logics are mixed
- New Simulation Program
 - Use C++ language, oop (面向对象)
 - MVC pattern
 - Cloud Computing

Hardware

1 computing server

CPU:Xeon E5 2620,2.4GHz,6
Cores

Memory:16G

Disks:12TB,RAID 5



Computing, Output Data

1 storage server

CPU:Xeon E5 2620,2.4GHz,6 Cores

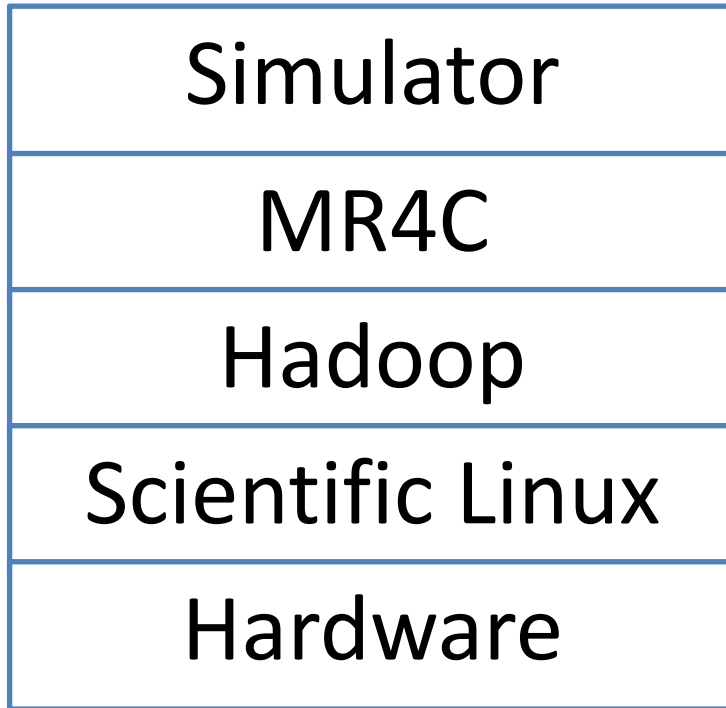
Memory:32G

Disks:24TB,RAID 5



Source Data

Software System

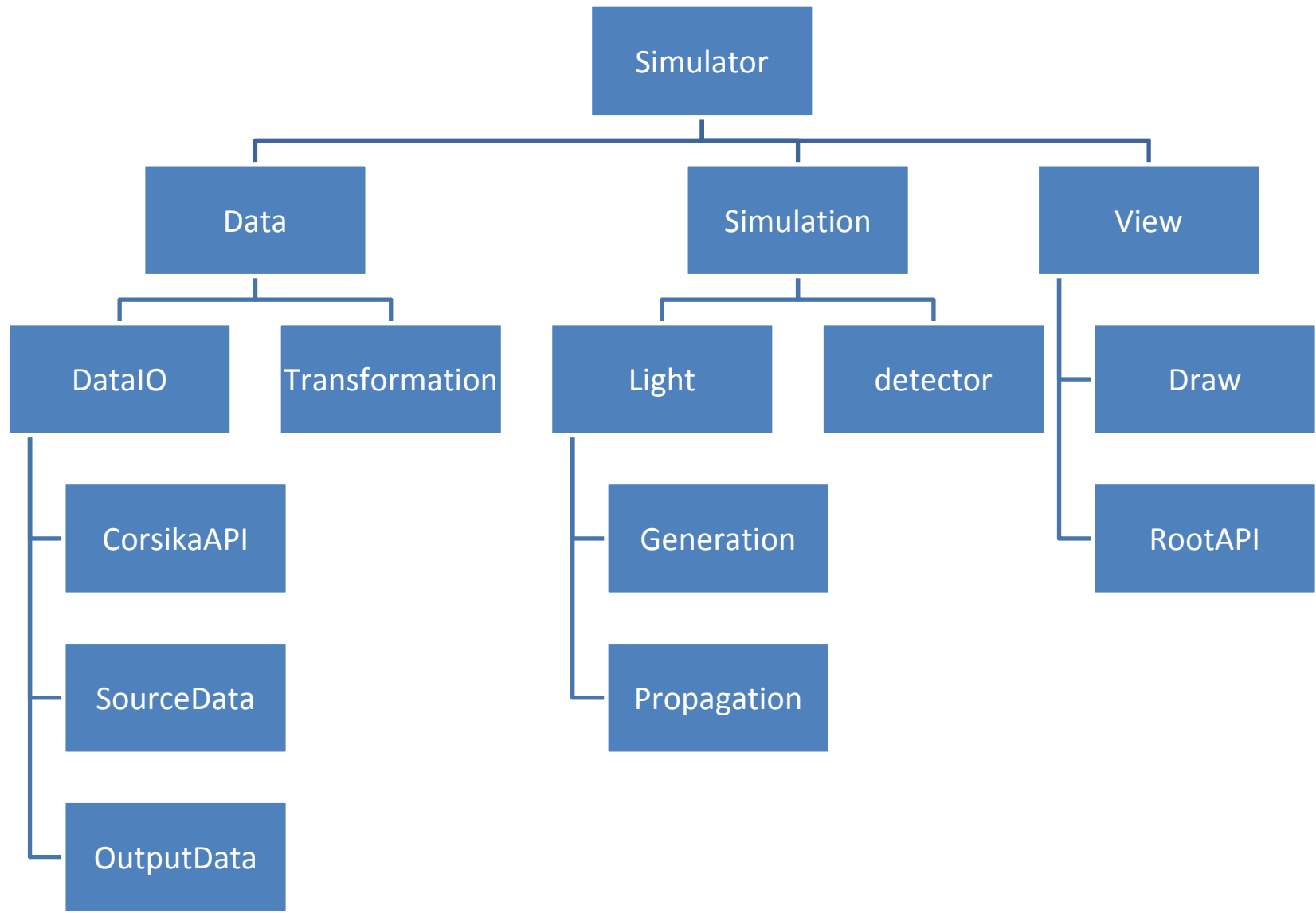


(云计算)

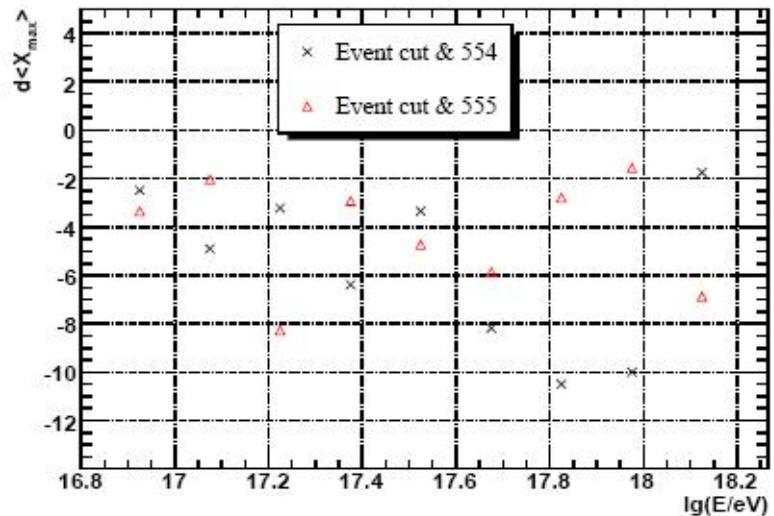
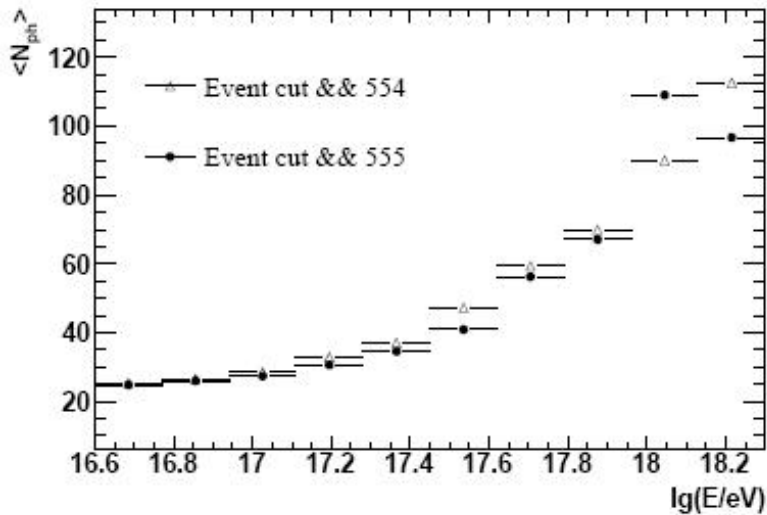
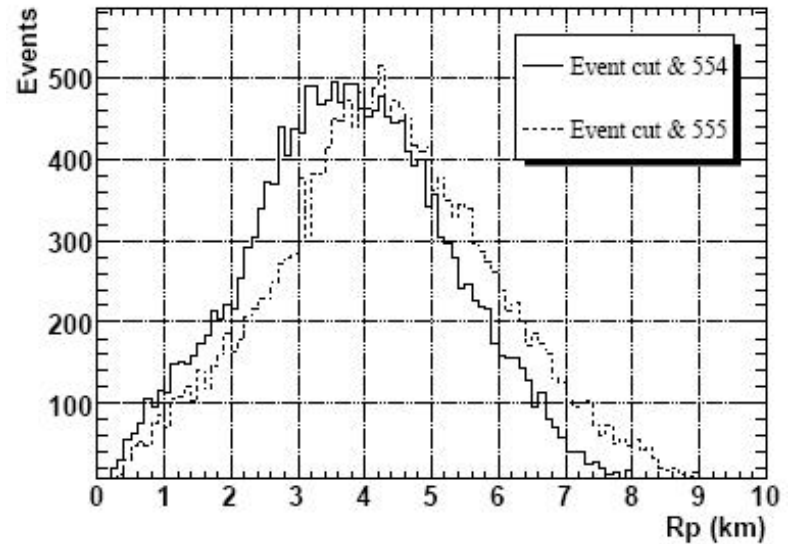
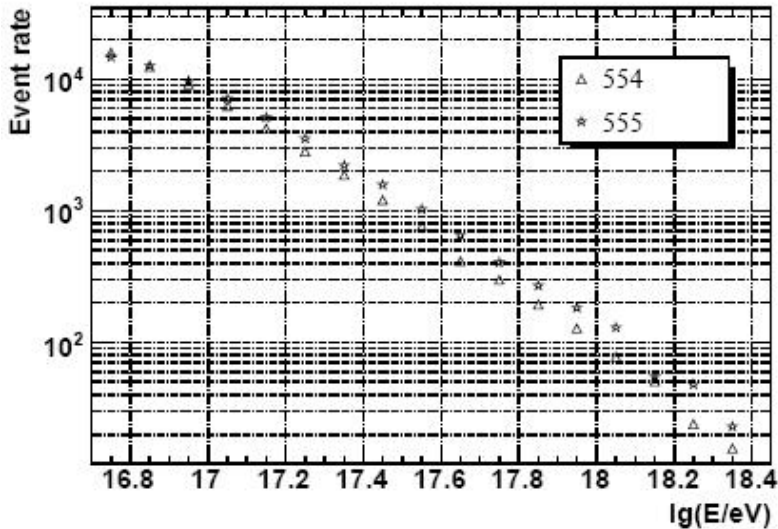
C++ MapReduce
(云计算)

GFS, BigTable

Simulator Classes Framework



optimization of detector configuration (3)



***** Comparison result: 555 setup is a final decision.**

