

# LHAASO-WCDA单路计数谱形研究

李会财

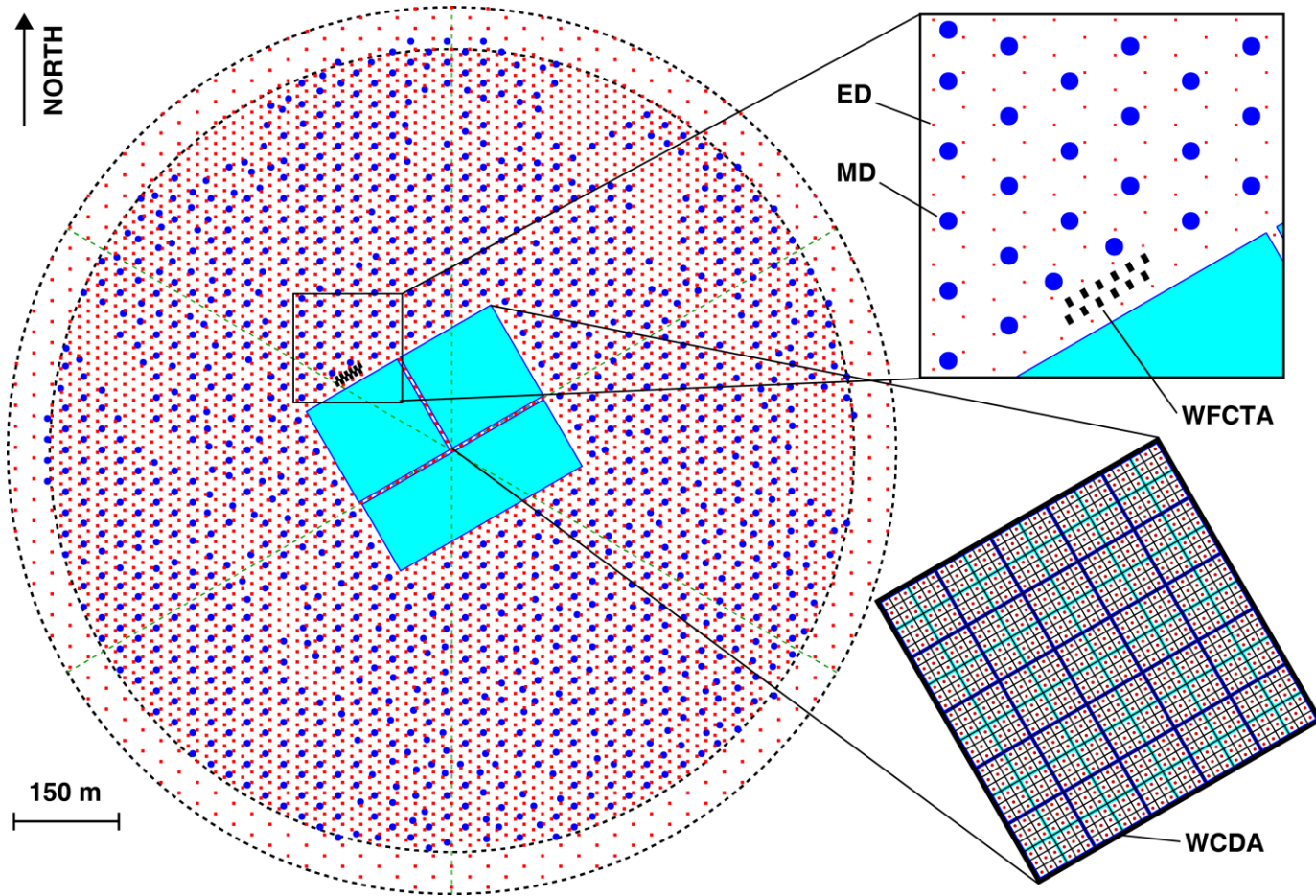
南开大学/高能所

2017. 1. 18

# 主要内容

- ◆ LHAASO-WCDA
- ◆ 工程阵列单路计数谱形研究
  - 单路计数率的研究
  - 单路计数谱形研究
- ◆ 总结

# LHAASO



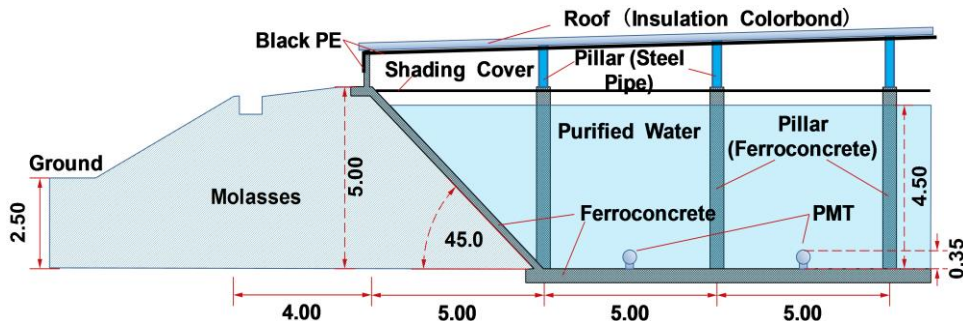
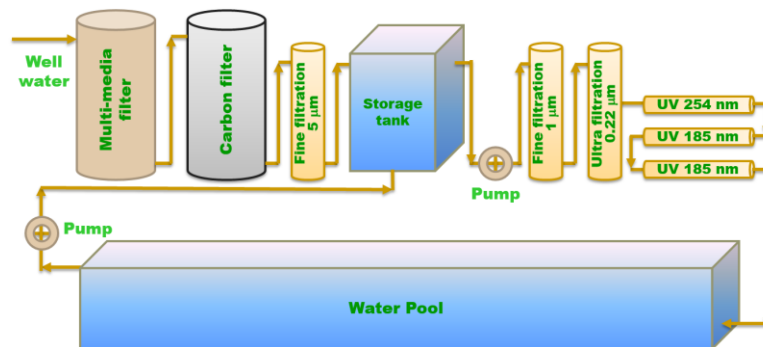
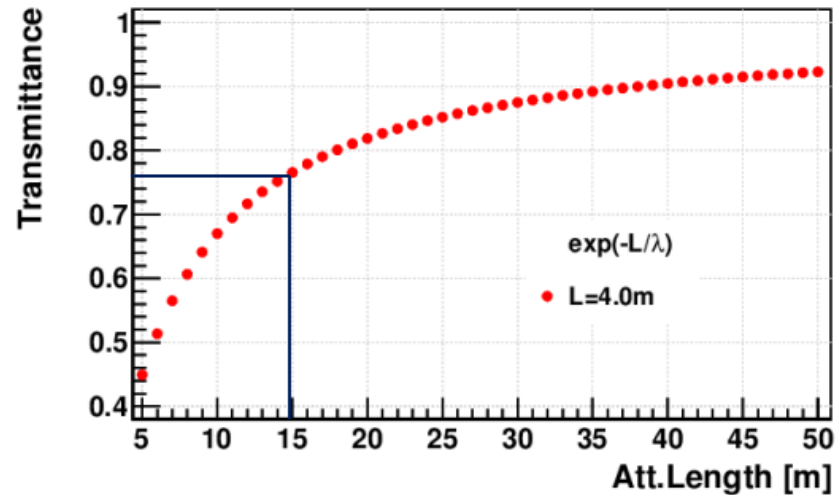
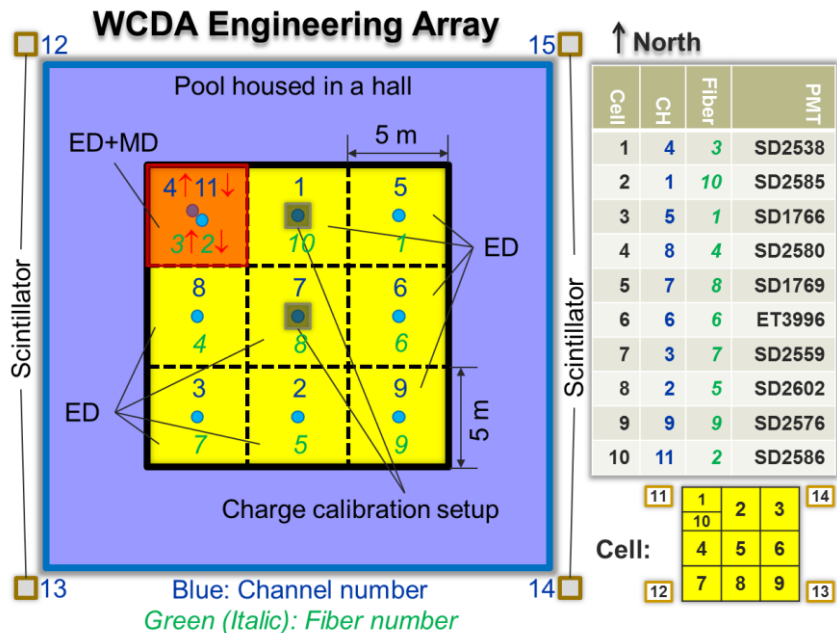
**KM2A:**  
5195 EDs  
1171 MDs  
1.2 Km<sup>2</sup>

**WFCTA:**  
12 telescopes

**WCDA:**  
3 pond  
3000 cells  
78,000 m<sup>2</sup>  
4.4 m depth  
350,000 tons



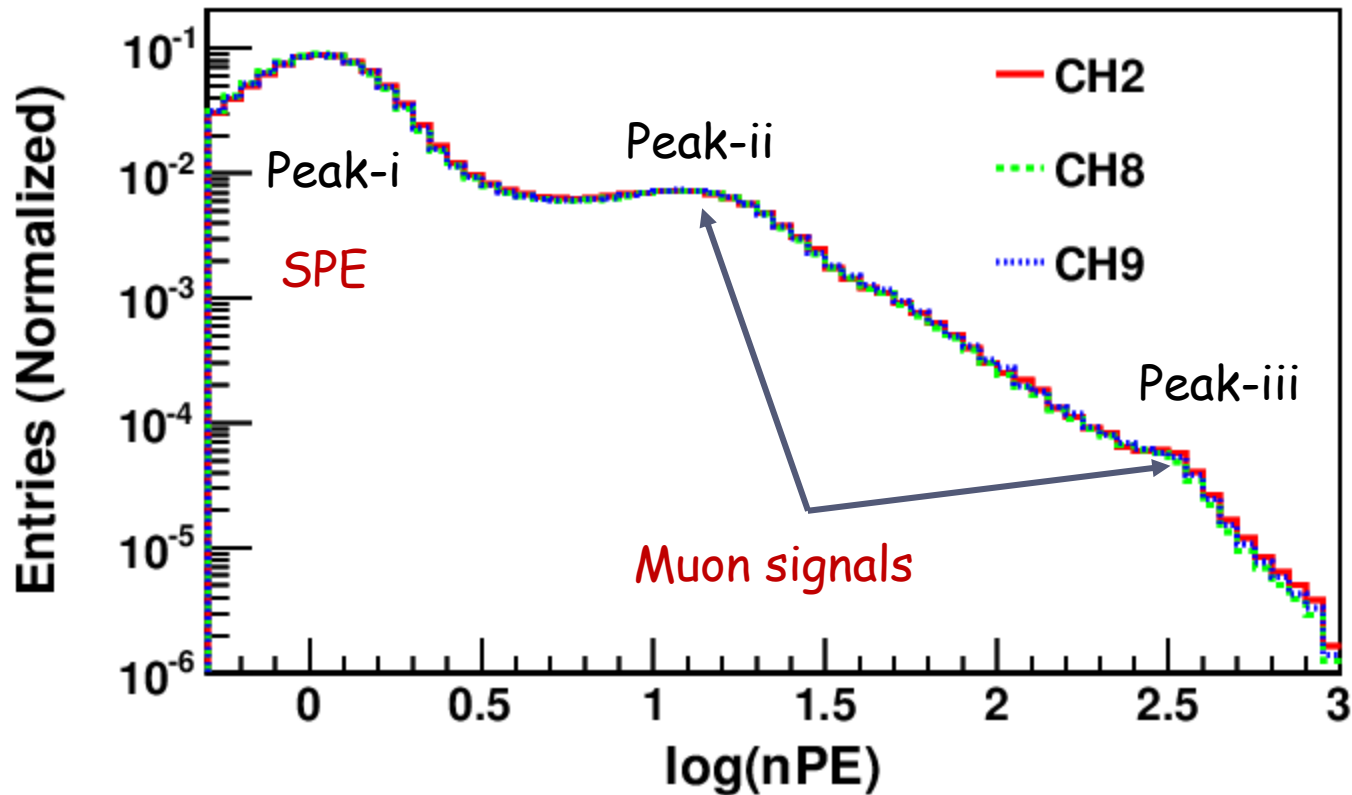
# Prototype array



## ◆ 水透明度的提高

- 探测效率的提高
- 电荷的精确测量
- cell的不均匀度研究
- $\lambda_{att} > 15 \text{ m}$  (400 nm)

# 工程阵列单路计数谱形 [DATA]



- ◆ Rate 55kHz

- ◆ 影响计数率的因素

- ◆ 分布谱中的三峰结构

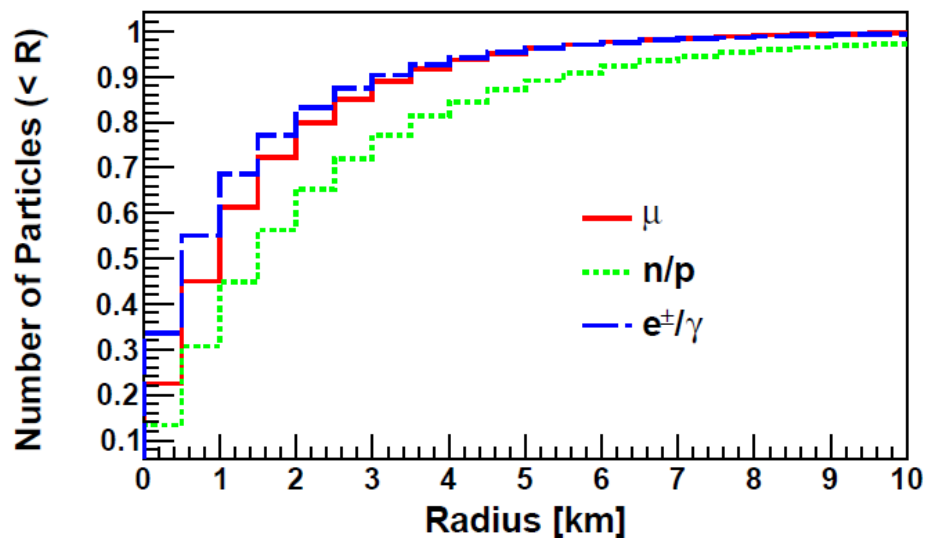
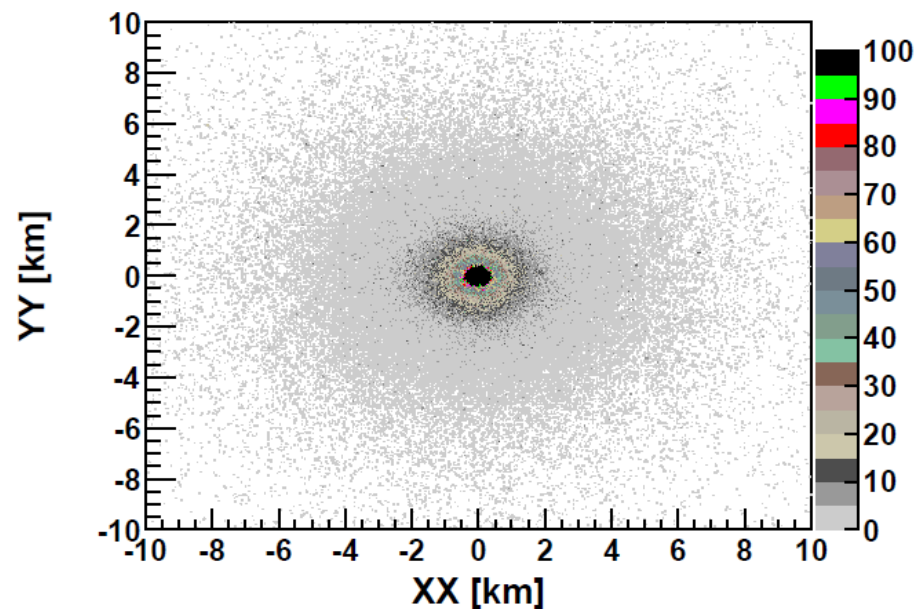
- ◆ 谱形的成因及应用

➡ 单路计数率的研究

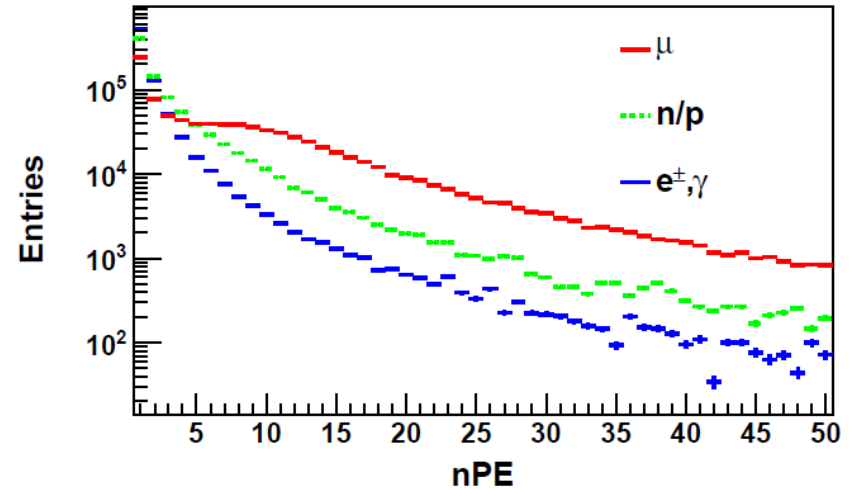
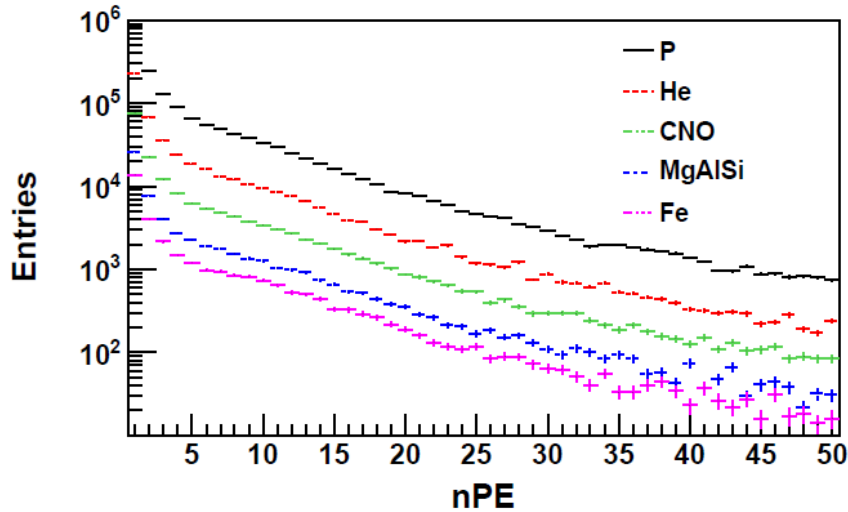
➡ 单路计数谱形的研究

# 单路计数率模拟方法

- ◆ CORSIKA75000
- ◆ QGSJETII-04、FLUKA
- ◆ P、He、CNO、MgAlSi、Fe
- ◆ 10GeV--1TeV proton
- ◆  $10^4$ 个shower示意图
- ◆ u, EM 收集率 $\approx 99.5\%$
- ◆ n/p收集率 $\approx 97.0\%$
- ◆ 25m \* 25m一个grid
- ◆ 收集每个grid里的所有粒子，把这些粒子做为generator MC



# 单路计数率模拟结果



- ◆ P、He: 占总Rate的90%
- ◆ 其余三种成分占10%
- ◆ u: n-p: EM = 10.3:9.9:8.8
- ◆ MC Rate = 31.4kHz
- ◆ Data: 30.5--32.2kHz

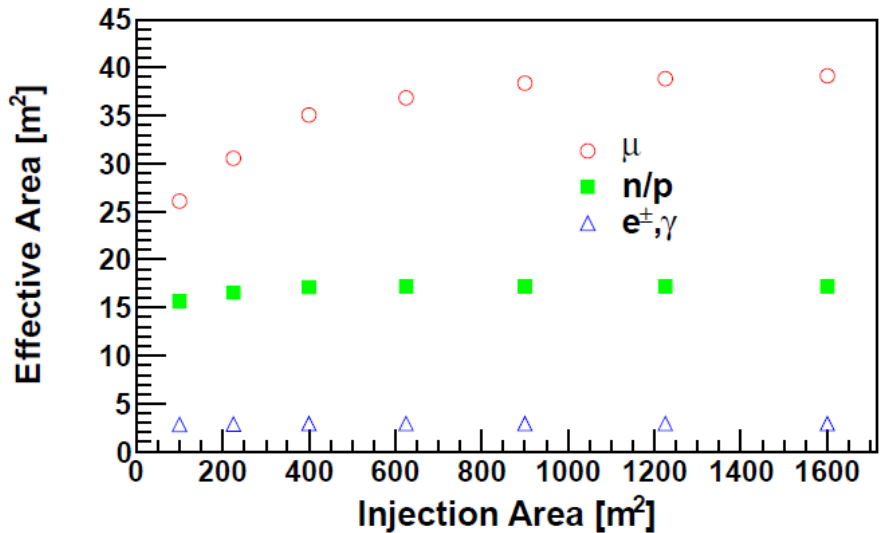
Table 2. The single rate comparison.

Primary CR	rate/kHz	Secondary particles	Rate/kHz
P	20.37	$\mu$	10.27
He	5.69	n-p	9.91
CNO	1.94	$e^\pm, \gamma$	8.82
MgAlSi	0.68		
Fe	0.36		
Total	29.04	Total	29.00
Corrected	APR: 3.0%	Dark noise: 1.5 kHz	
MC		31.4 kHz	
DATA		30.5~32.2 kHz	

# 对计数率有影响的因素

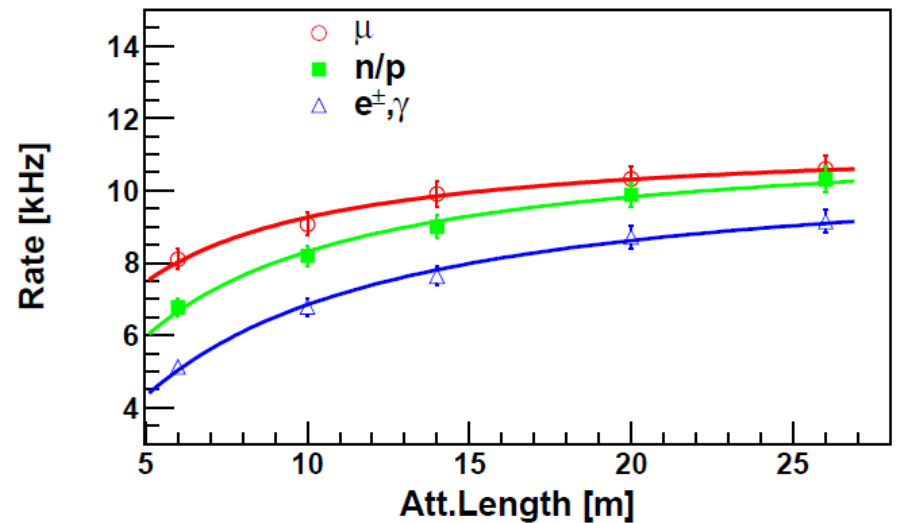
## ◆ muon punch-through

- muon: 39m<sup>2</sup>
- n-p: 17m<sup>2</sup>
- EM: 2.9m<sup>2</sup>



## ◆ 水透明度对计数率的影响

$$R_1 = R_0 \cdot e^{(-d/\lambda)}$$





# 太阳调制作用

- ◆ 太阳调制作用对计数率的影响：峰年和谷年的计数率差别12%；

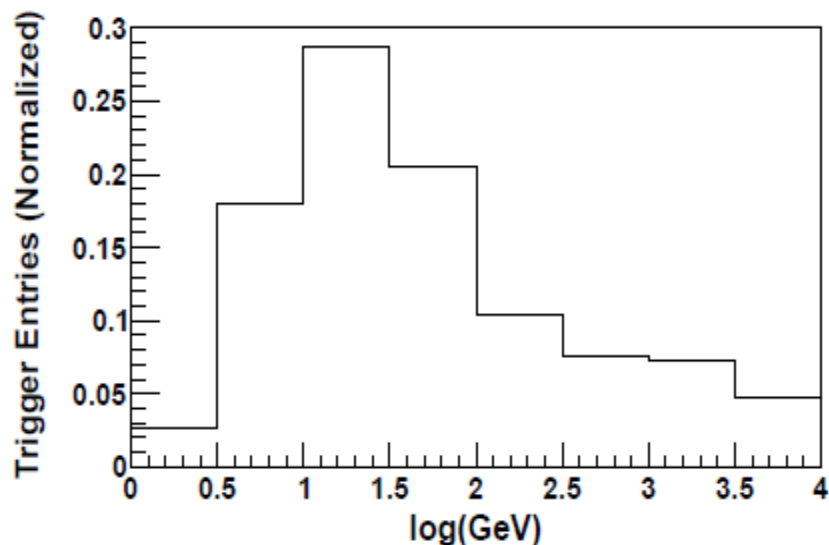
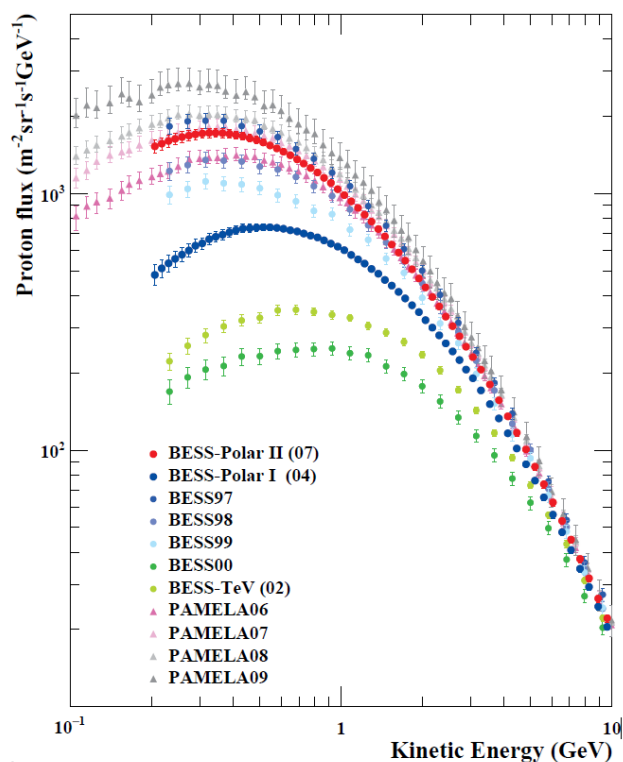
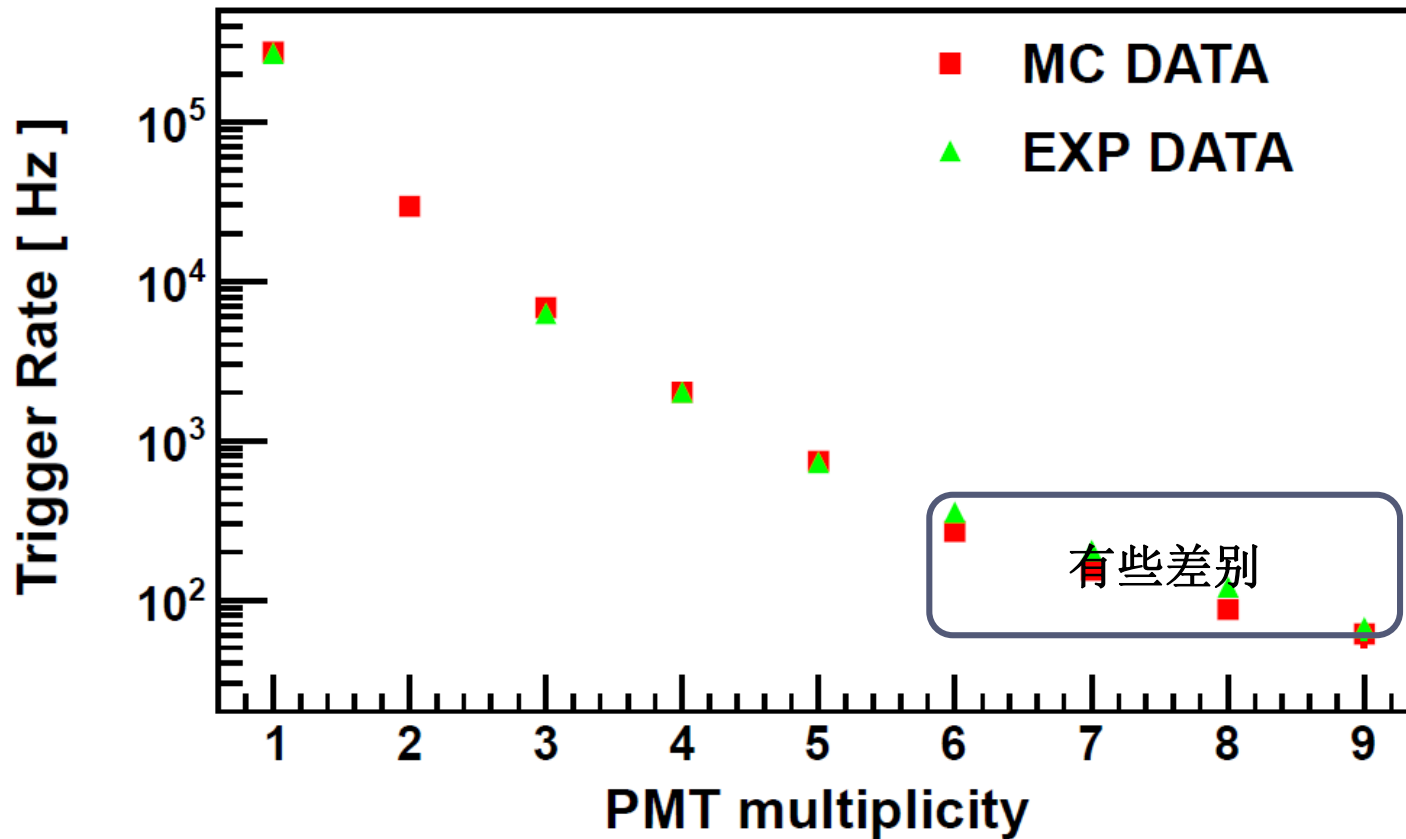


Fig. 11. The energy distribution for triggered primary cosmic ray.

Table 4. The solar cycle in a sunspot activity period of  $\sim 11$  years. Absolute differential energy spectra of primary protons.

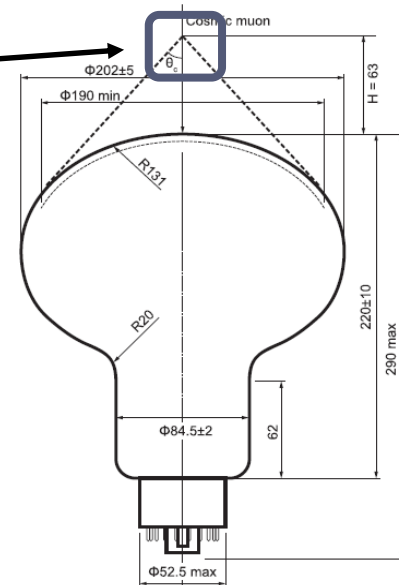
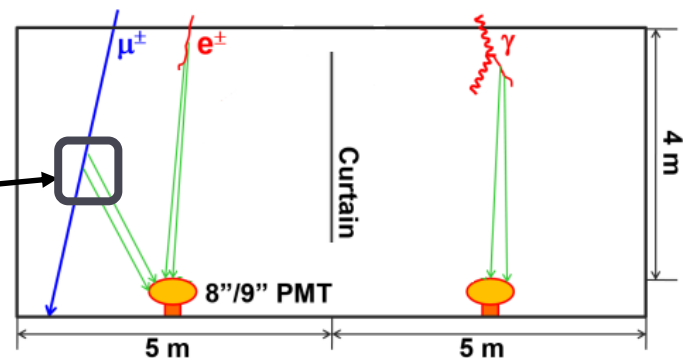
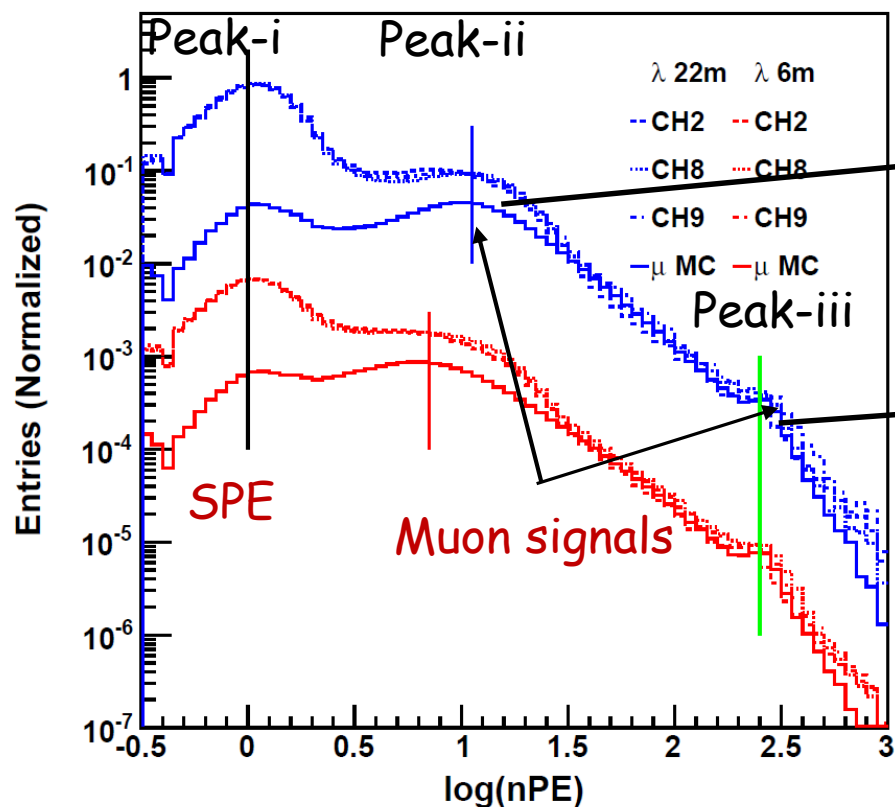
Energy range (GeV)	Difference	Rate change
2.0 – 3.16 (2.51)	118.1%	3.01%
3.16 – 10 (5.62)	32.1%	5.65%
10 – 31.6 (17.8)	8.1%	2.28%
31.6 – 100 (56.2)	2.3%	0.46%
total		$\approx 12\%$

# 触发率和PMT多重度的关系



- ◆ 计数率的研究对数据获取、探测器的触发方案设定、事例重建以及探测器的深入理解等具有重要意义

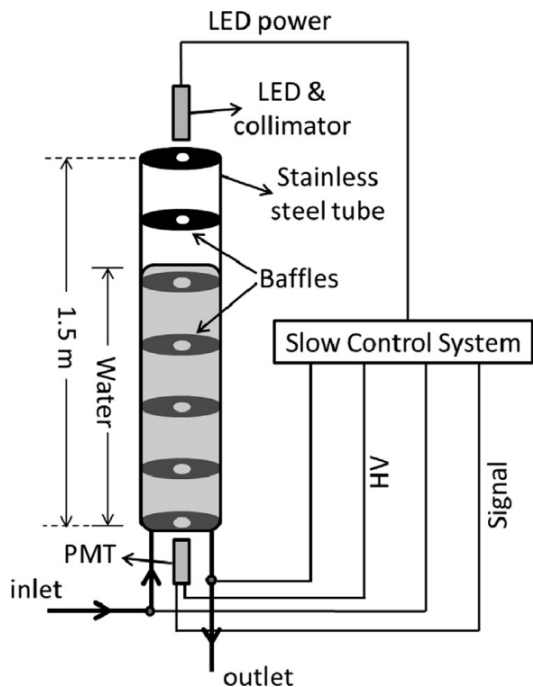
# 电荷分布谱的三峰结构特点



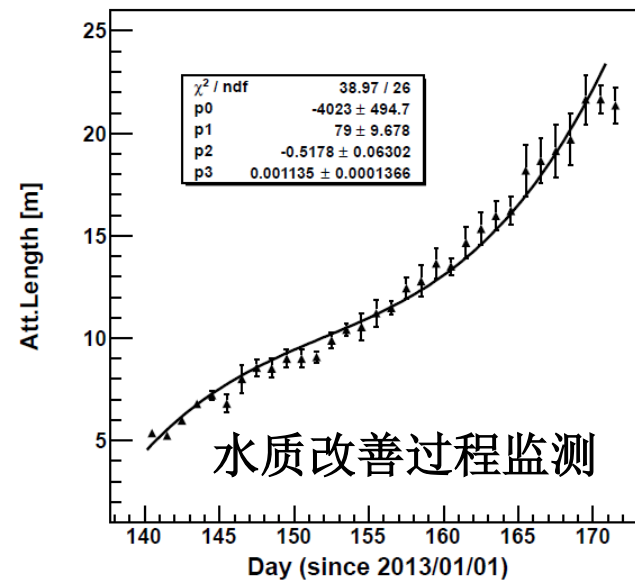
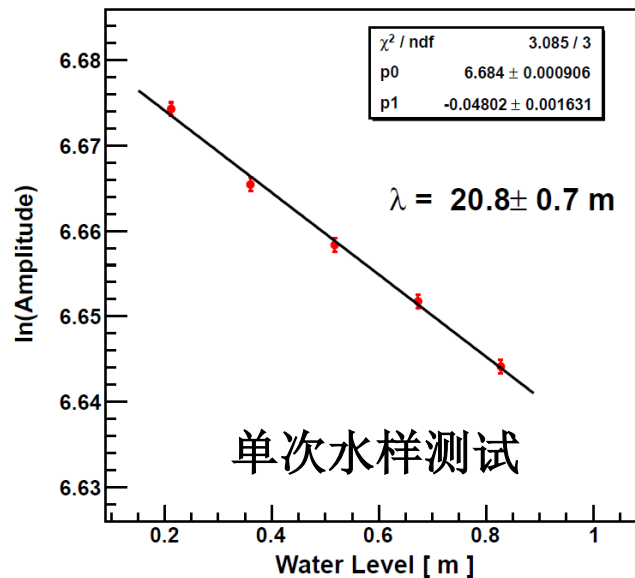
- ◆ 电荷分布谱中的第二个峰由muon贡献
- ◆ Peak-ii随水质的改善，锋位右移

NIM A, 644 (2011): 11-17

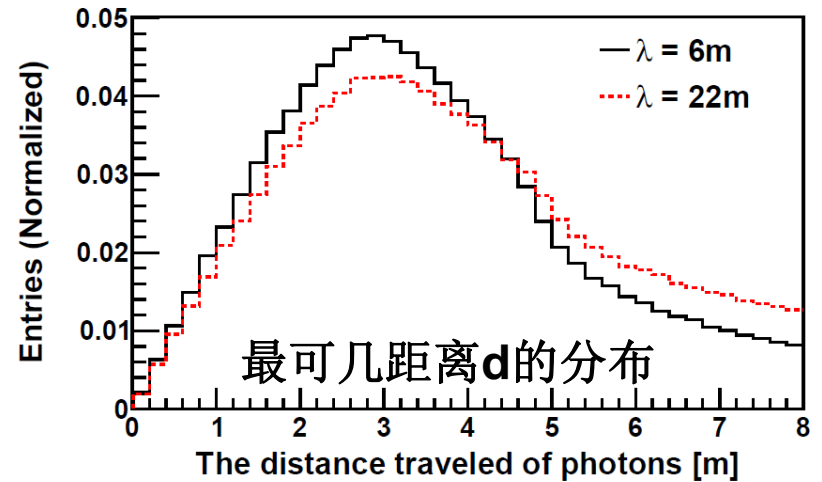
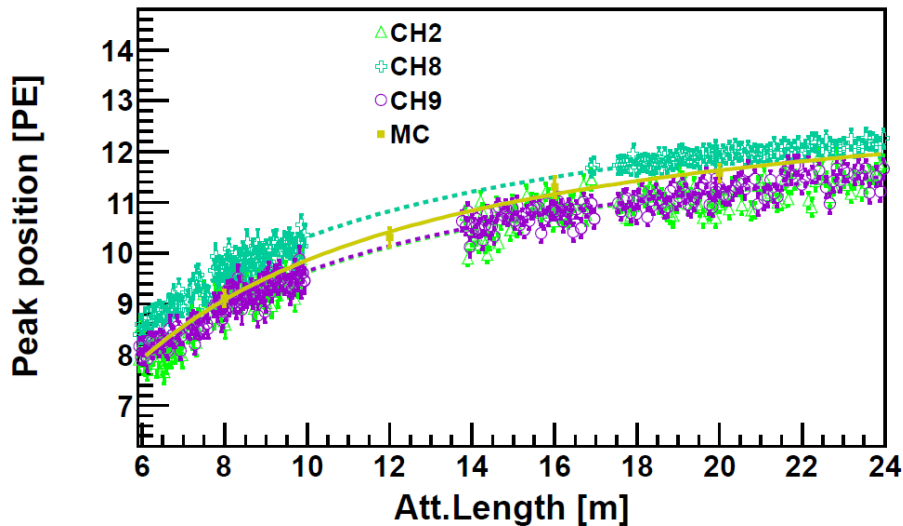
# 直接测量装置



- ◆ 由慢控制系统实现远程控制
- ◆ 自动不间断测量(单次1.5h); 20m: 误差7%
- ◆ LED温度效应对测量有影响
- ◆ 监测的水域十分有限

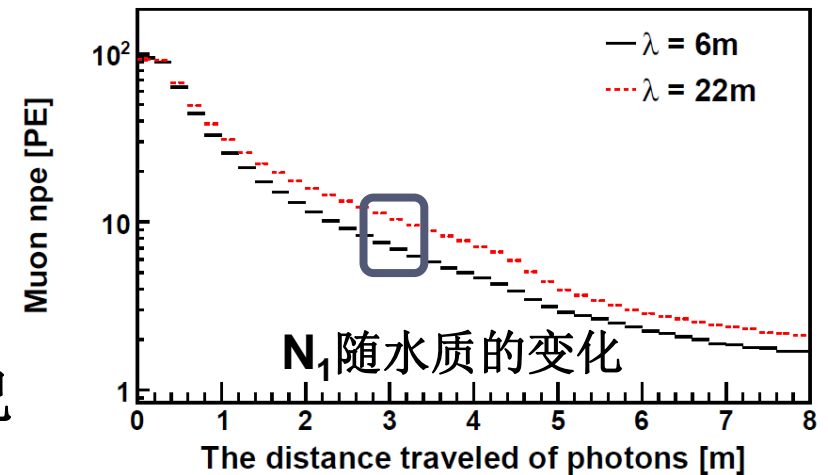


# Peak-ii和水质关联



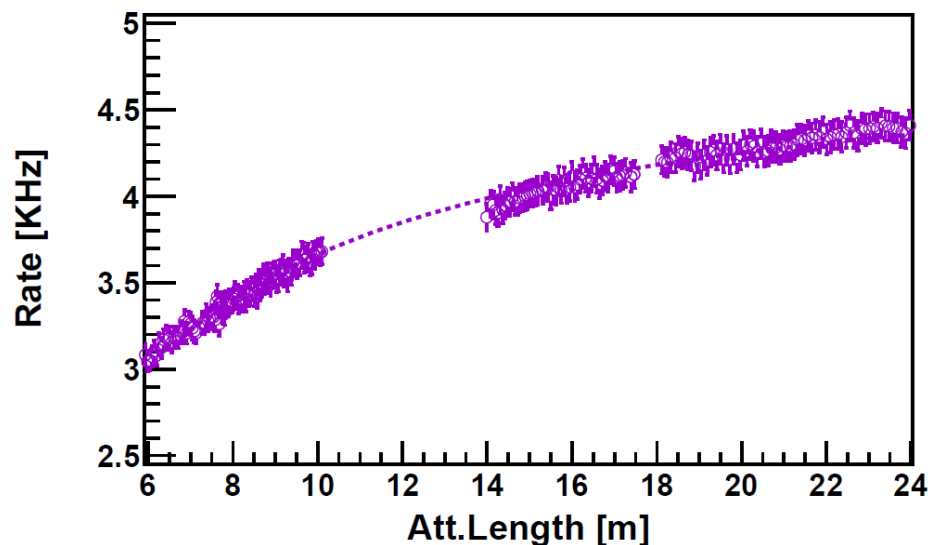
$$N_1 = N_0 \cdot e^{(-d/\lambda)}$$

- ◆ 弥补了直接测量装置的局限性
- ◆ 可以对**cell**的不一致性进行研究
- ◆ 用物理数据分析，更符合实际情况

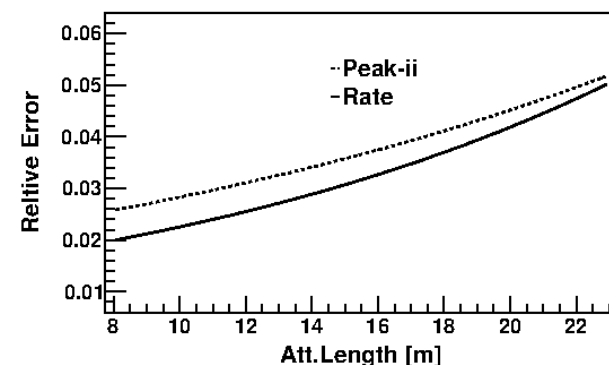
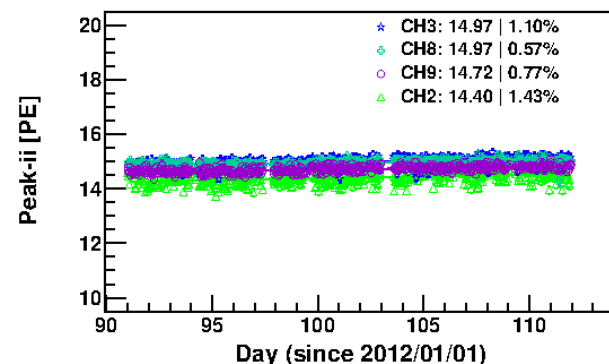
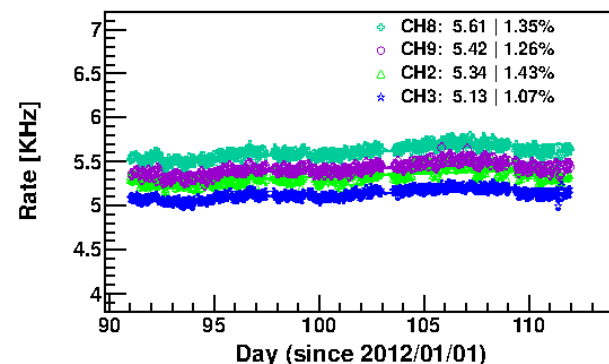




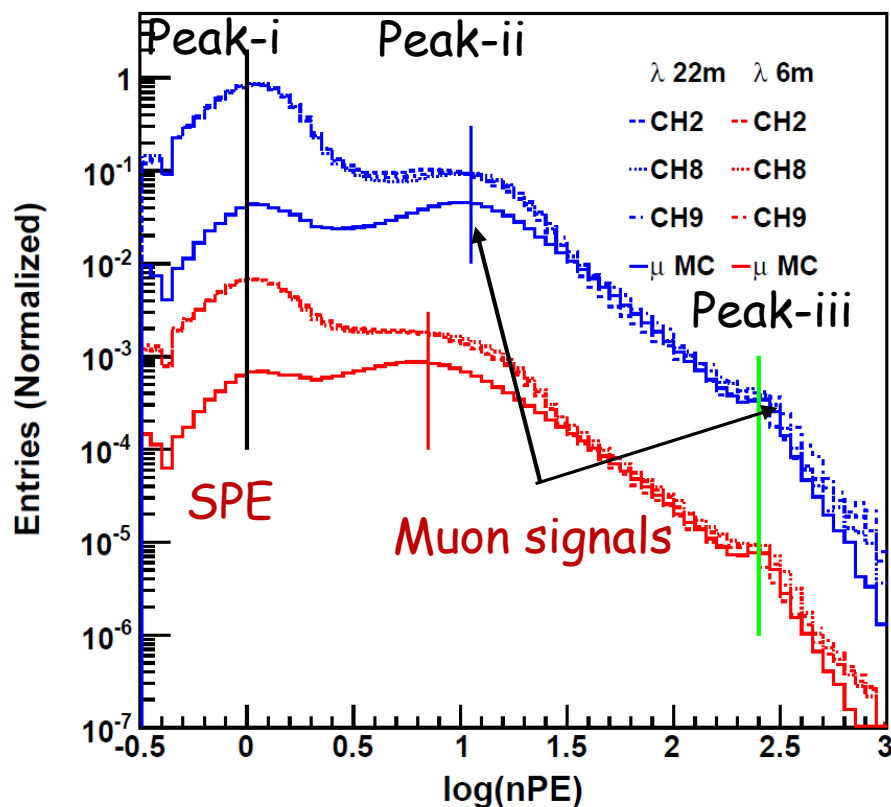
# 一定阈值下的计数率监测水质



- ◆ 通过电荷分布谱的锋位变化监测水质
- ◆ 一定阈值上的计数率变化实现水质监测
- ◆ 实时性：实时分析各个cell内水质变化，结合硬件测量，对池内整体水质变化进行实时监测
- ◆ 高效性：单次测量时间只有几十秒，并且不引入死时间，不影响正常的物理取数
- ◆ 高精度：测量精度达到测量装置同等水平



# Charge and PMT performance Calibration



- ◆ Low range: single rate (**peak-i**)
  - SPE signal dominated;
  - Including PMT low range Gain + cable + pre-amp + electronics.
- ◆ Low range: muon peak (**peak-ii**)
  - PMT low range Gain + QE + CE cable + pre-amp + electronics.
- ◆ High range: muon peak (**peak-iii**)
  - Vertical muons hitting PMT;
  - PMT high range gain + QE + CE + cable + pre-amp + electronics;

- ◆ Charge Calibration : peak-i and peak-iii
- ◆ PMT performance (QE+CE) Calibration:  
 peak-i and peak-ii / peak-i and peak-iii

$$G\beta\mu m = q_{spe}$$

$$N_{C,\mu} Q\eta G\beta\mu m = q_{\mu}$$

$$Q\eta = \frac{1}{N_{C,\mu}} \frac{q_{\mu}}{q_{spe}}$$

# 总结

## ◆ 单路计数率的研究

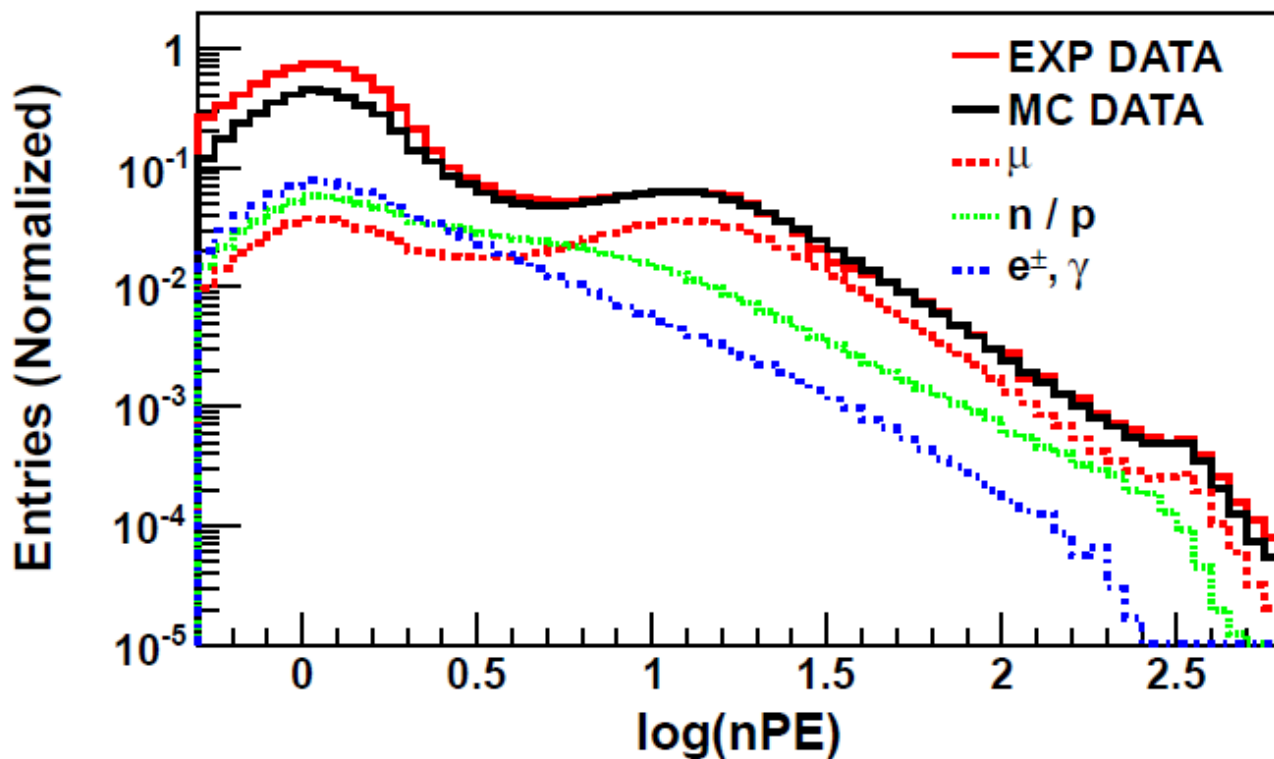
- MC和数据符合比较:
- 计数率、电荷分布谱、触发率和PMT多重度的关系
- 影响计数率的三个主要因素:
- 水透明度、**muon**的**punch-through**效应、太阳调制作用

## ◆ 单路计数谱形的研究

- 电荷分布谱上具有三峰结构特点
- 利用谱形中的**Peak-ii**峰位变化和一定阈值下的计数率变化实现对水质的实时、高效、高精度的监测
- 此监测方法将应用于**LHAASO-WCDA**实验
- 三峰的峰位变化可用于**charge**的标定, **PMT**性能(**QE+CE**)的监测

Thank you

# 附录：工程阵列单路计数谱形



## ◆ 单路计数率的研究

- MC和数据的对比
- 影响计数率的因素

## ◆ 单路计数谱形的研究

- 三峰的结构特点
- peak-ii标定水质

# 模拟中的一些参量

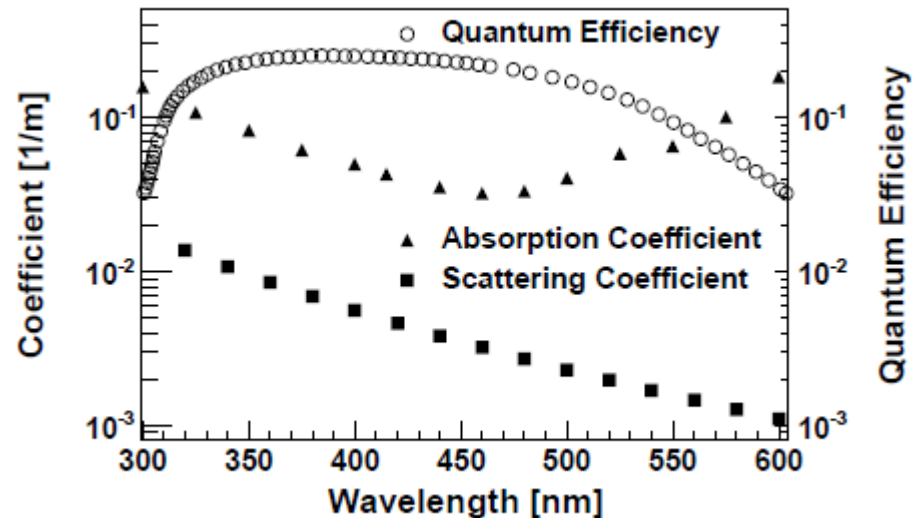
Table 1. Summary of the input parameters of the five primary particles.

CR	energy range (GeV)	spectral index
P	1.4 – 4.1 – 10.1 – $10^3$ – $10^4$	-1.6, -2.4, -2.7, -2.71
He	5.4 – 10.5 – 22.3 – $2 \times 10^3$ – $10^4$	-1.8, -2.3, -2.6, -2.64
CNO	17.6 – 52.6 – $10^4$	-1.9, -2.60
MgAlSi	41.7 – 200 – $10^4$	-2.0, -2.66
Fe	97.4 – 300 – $10^4$	-2.2, -2.63

## ◆ AMS-02和CREAM-II测量结果

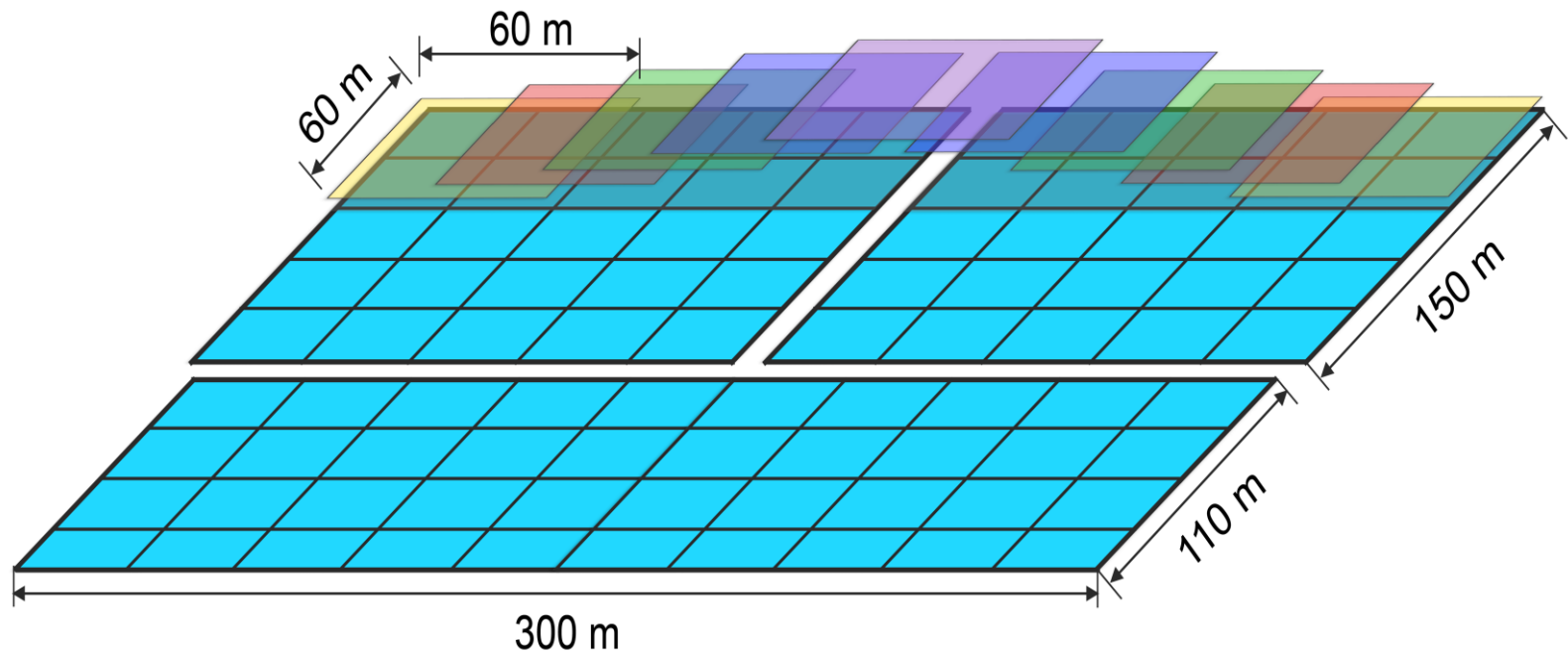
### ◆ QE

### ◆ Abs 和 Scat 系数





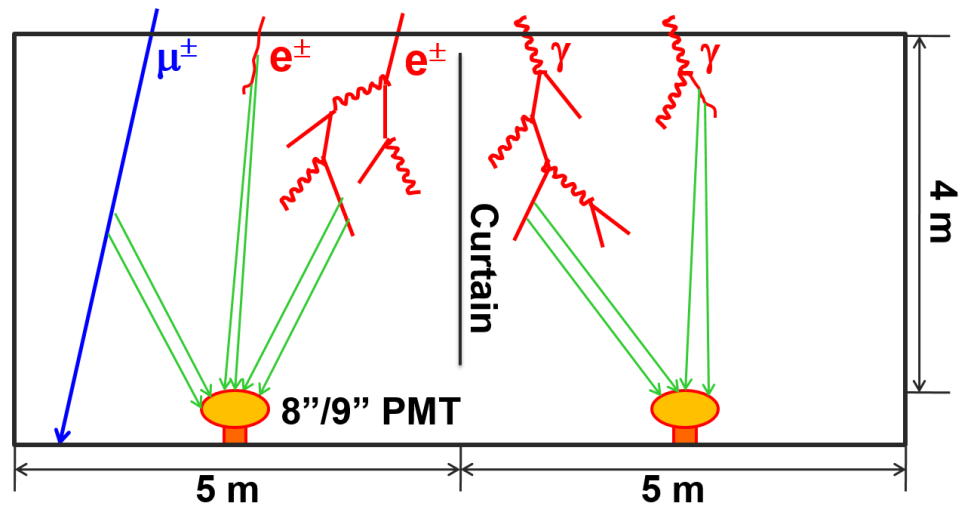
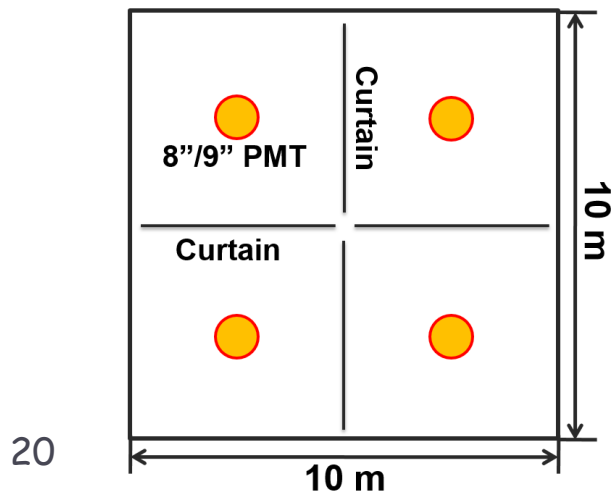
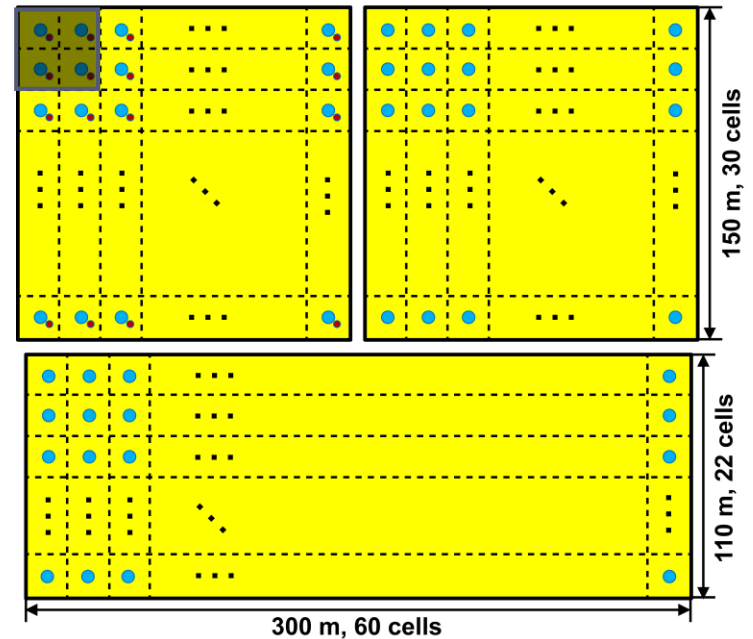
# 区域水质监测预警机制



- ◆ 基于单独或相互重叠的“cluster”；单个大小为 $6 \times 6 = 36$ 个单元
- ◆ 一段时间内：cluster内的有一定量的 (e. g. 20%) 的PMT监测的cell内平均水质降低20%，发送预警信息
- ◆ 迅速反馈一定区域内水质的实际情况，便于发现运行中出现的问题；
- ◆ 做到见微知著，防患于未然

# Water Cherenkov Detector Array

- ◆ 3 water ponds
  - 3000 cells
  - partitioned by black curtains
  - 4 m effective depth
  - 78,000 m<sup>2</sup> in total
  - 350,000 tons of purified water



# Physics Goals

## ◆ VHE gamma sky survey (100 GeV-30 TeV):

- Extragalactic sources & flares;
- VHE emission from Gamma Ray Bursts;
- Galactic sources;
- Diffused Gamma rays.

## ◆ Cosmic Ray physics (1 TeV-10 PeV):

- Anisotropy of VHE cosmic rays;
- Cosmic ray spectrum;
- Cosmic electrons;
- Hadronic interaction models.

## ◆ Miscellaneous:

- Gamma rays from dark matter;
- Sun storm & IMF.

