利用宇宙线中的缪子信号测量LHAASO-WCDA水质

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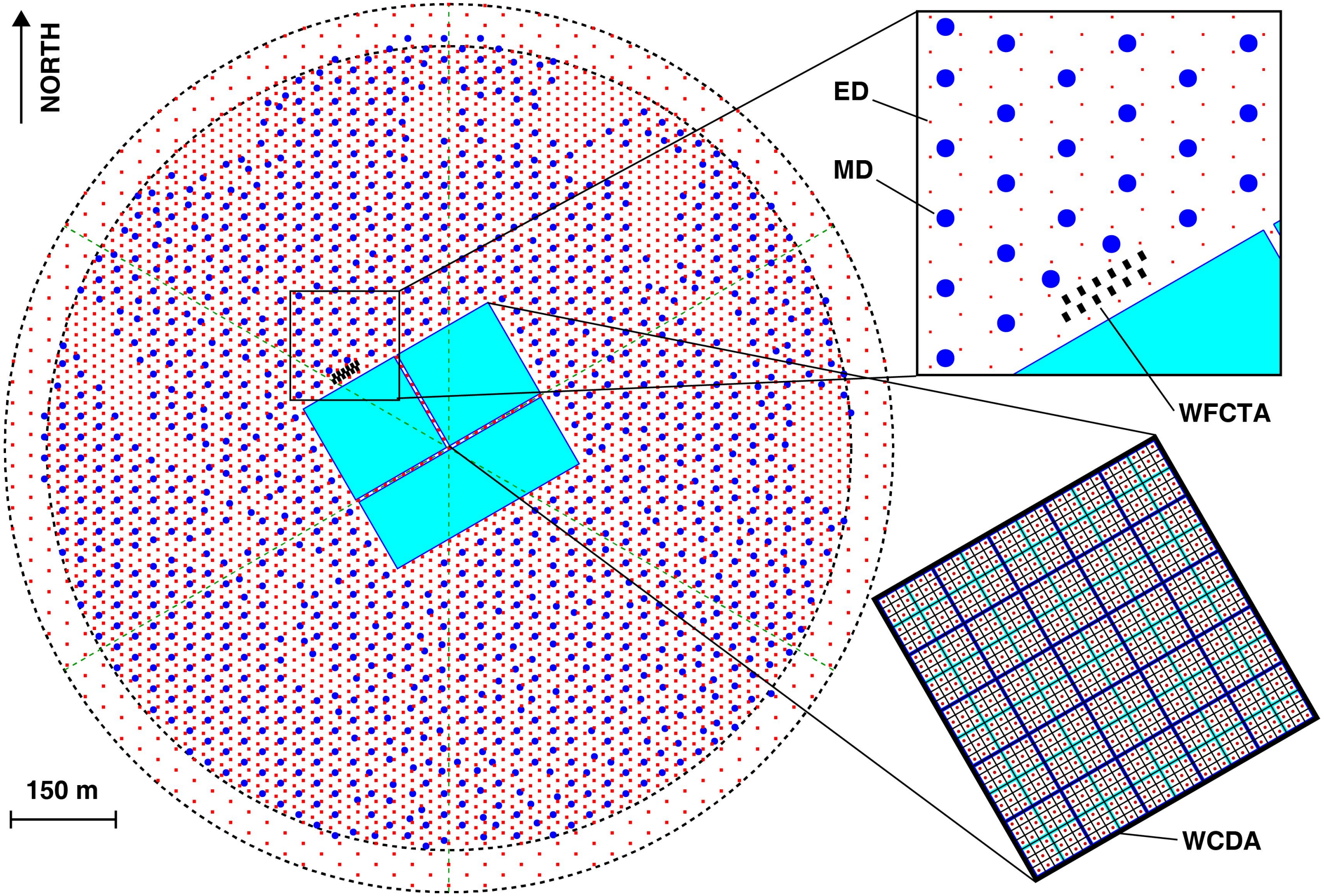
Outline

- LHAASO-WCDA
- Prototype array
- The feature of the single-channel signals
- The second peak VS the attenuation length
- Summary

LHAASO



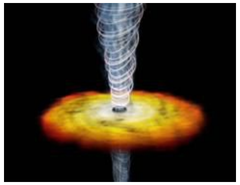
KM2A:
5195 EDs
1171MDs
1.2 Km^2

WFCTA:
12 telescopes

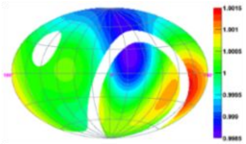
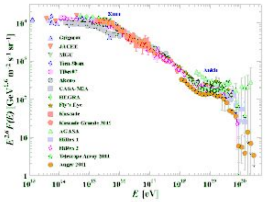
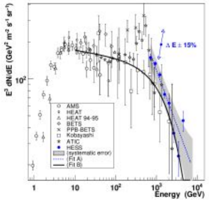
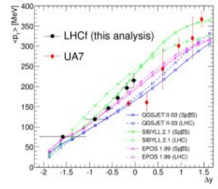
WCDA:
3000 cells
78,000 m^2

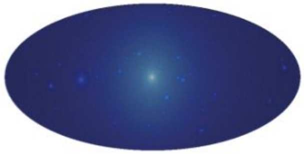
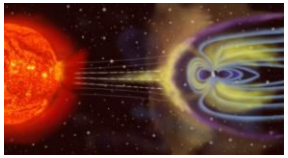
Physics Goals

- 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.



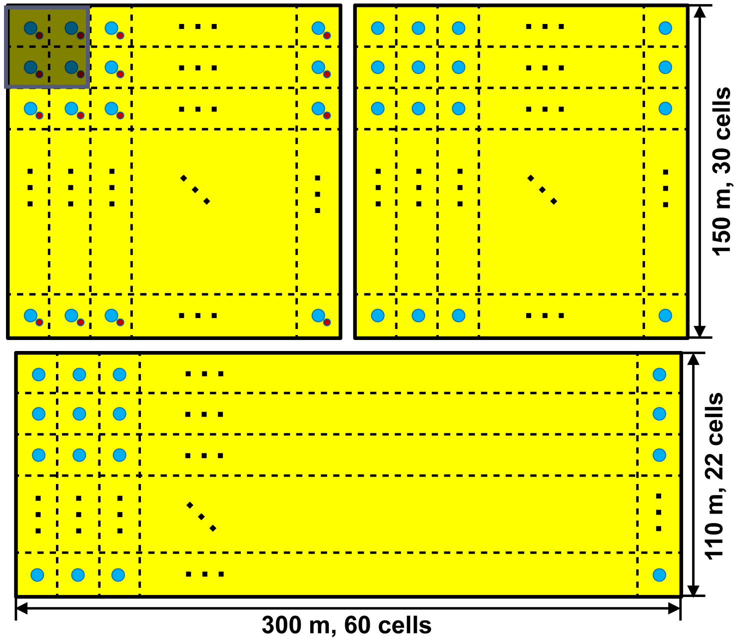


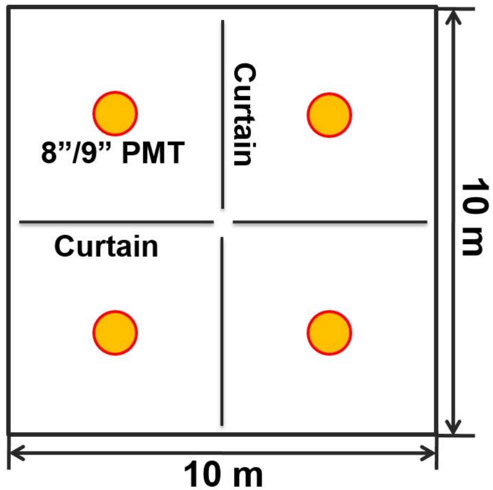





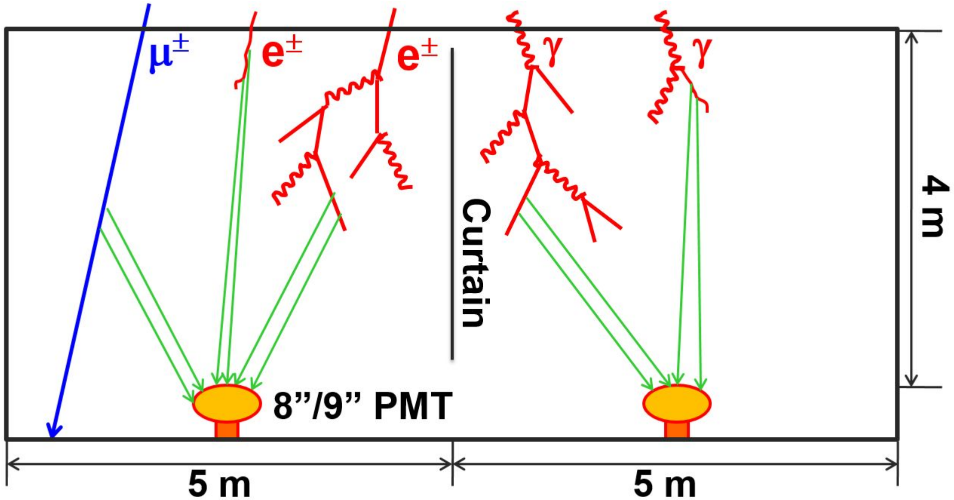



Water Cherenkov Detector Array

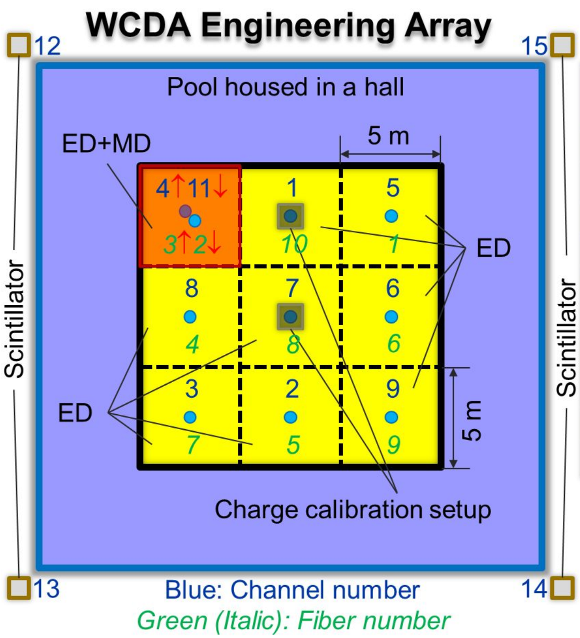
- 3 water ponds:
  - 3000 cells;
  - Cells are partitioned with black curtains;
  - 4 m effective depth;
  - **78,000 m² in total;**
  - **350,000 tons of purified water.**







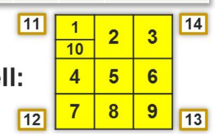
Prototype array

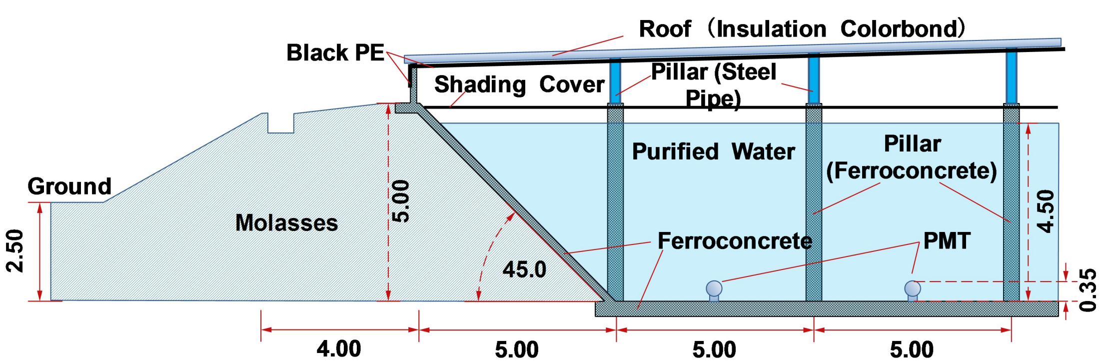


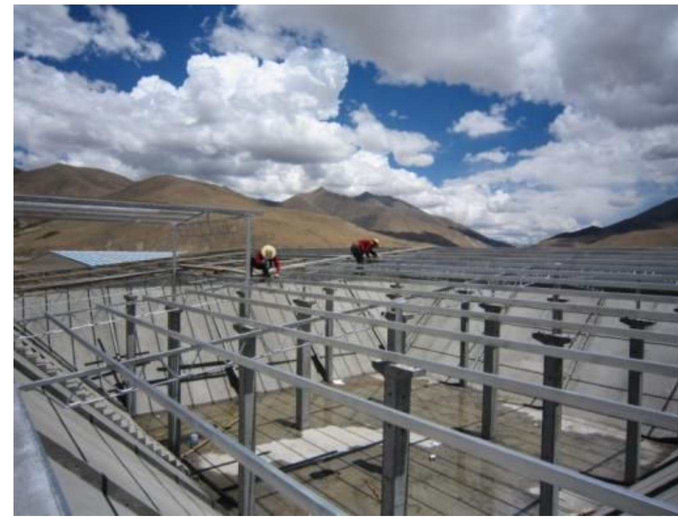
↑North

Cell	CH	Fiber	PMT
1	4	*3*	SD2538
2	1	*10*	SD2585
3	5	*1*	SD1766
4	8	*4*	SD2580
5	7	*8*	SD1769
6	6	*6*	ET3996
7	3	*7*	SD2559
8	2	*5*	SD2602
9	9	*9*	SD2576
10	11	*2*	SD2586

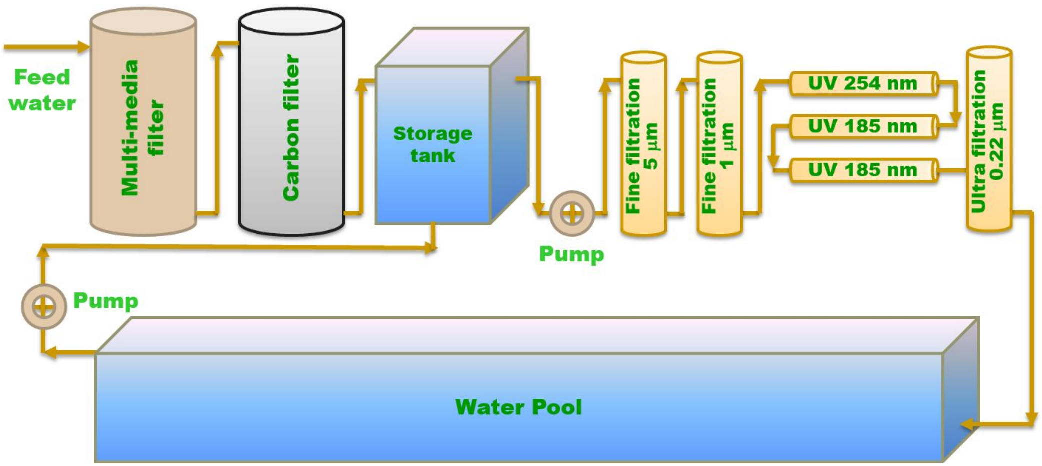
Cell:



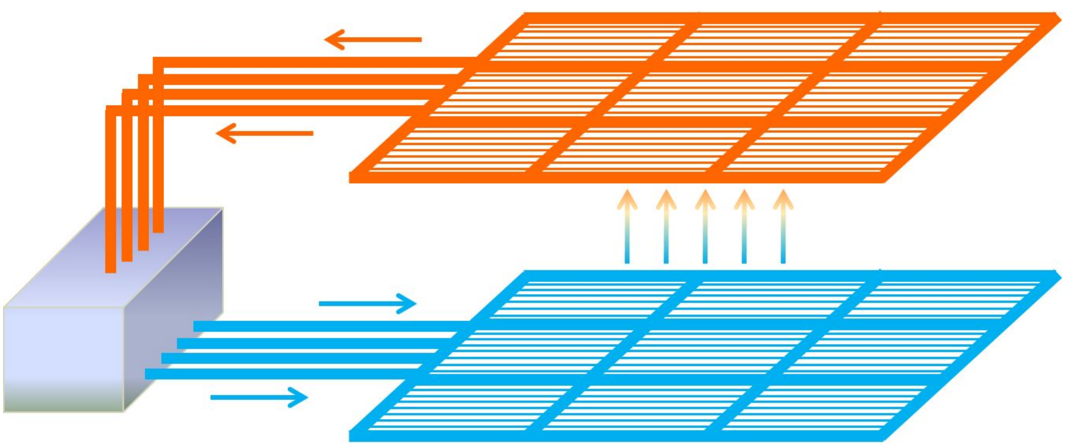




Water purifying and recirculating system

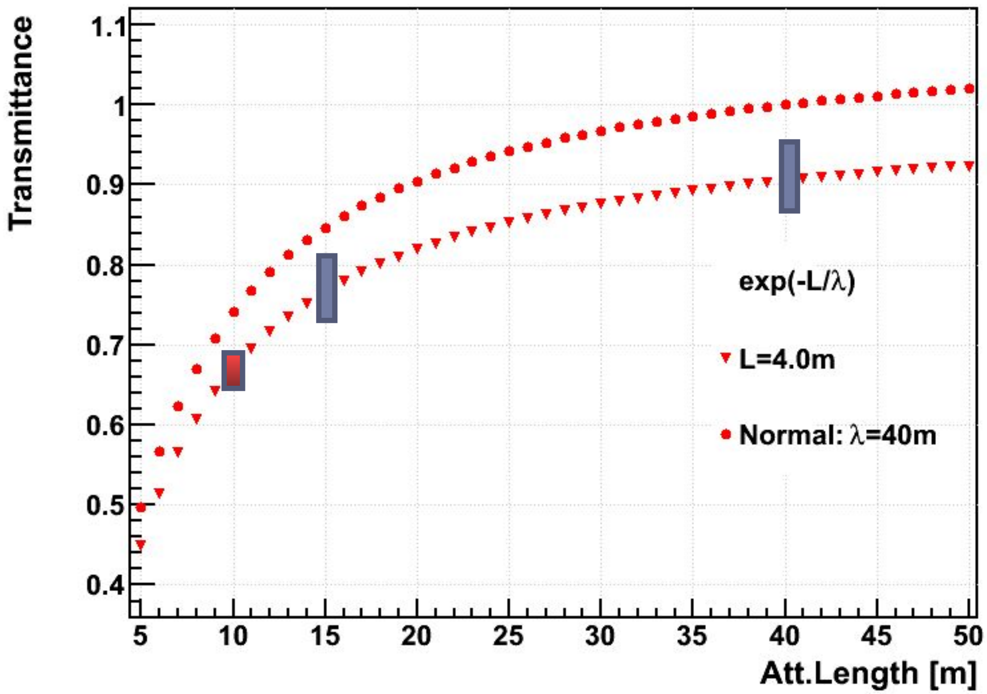


- Given the effects of bacteria, dust, and ions, the Att. Length of natural water <8 m;
- Major pollution is TOC/DOC:
  -> UV185 + UV254 + 0.22um;
- Other pollutions:
  -> Industrial solutions.



- Pollution tends to appear in the top of the water;
- Water is exchanged uniformly;
- Low water flow: 1 volume/month
  -> low maintenance cost.

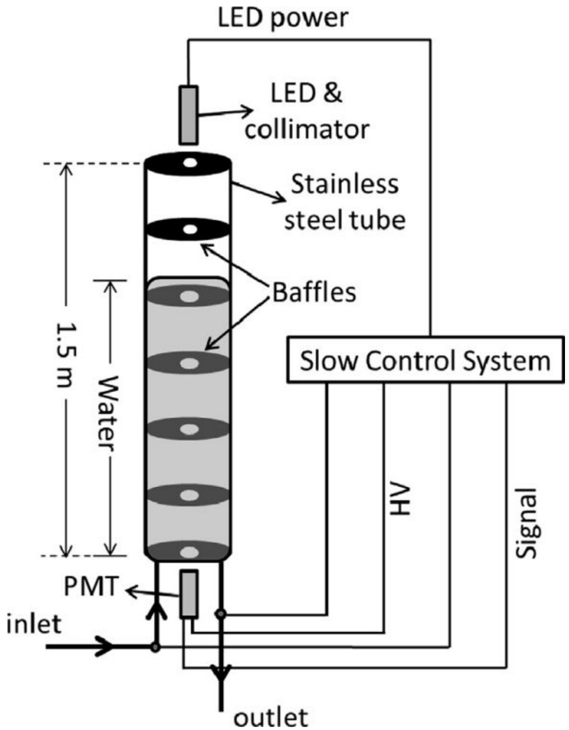
Water transparency

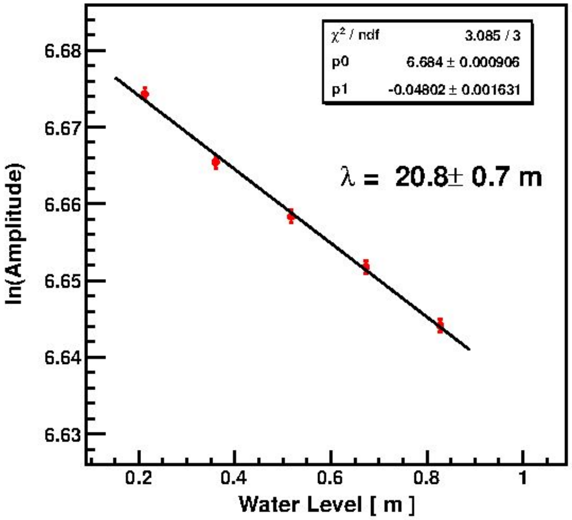


- λ_{att} : >15 m (400 nm);
- λ_{att} : 40 m is limit;
- Efficiency difference <20%.

- The detector efficiency is a crucial factor for obtaining a high sensitivity;
- Time by time monitoring and accurate calibration of the detector is of importance for achieving good spectrum measurement.

Measurement with the tube device





$$A = A_0 e^{-h/\lambda}$$

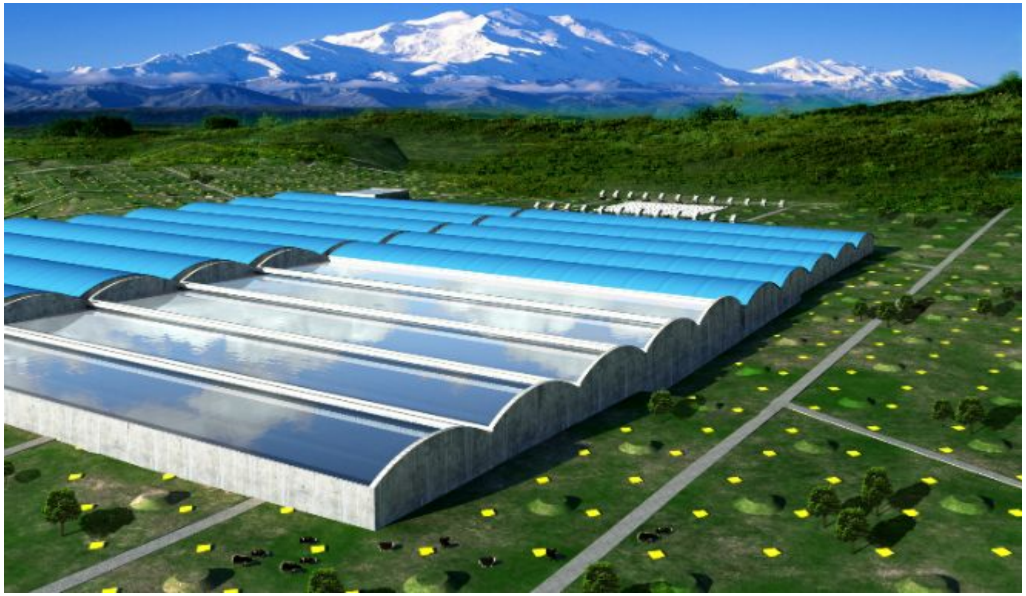
$$\ln A = \ln A_0 - \frac{h}{\lambda}$$

$$\ln(A / A_0) = -\frac{1}{\lambda} h$$

- Controled by slow control system;
- Realized automatic monitoring (1.5 hours);
- 20m: less than 7%.

- Affected by the temperature effect of Led;
- Monitoring area is very limited;
- The cost may be huge.

Difficulties and challenges



WCDA:

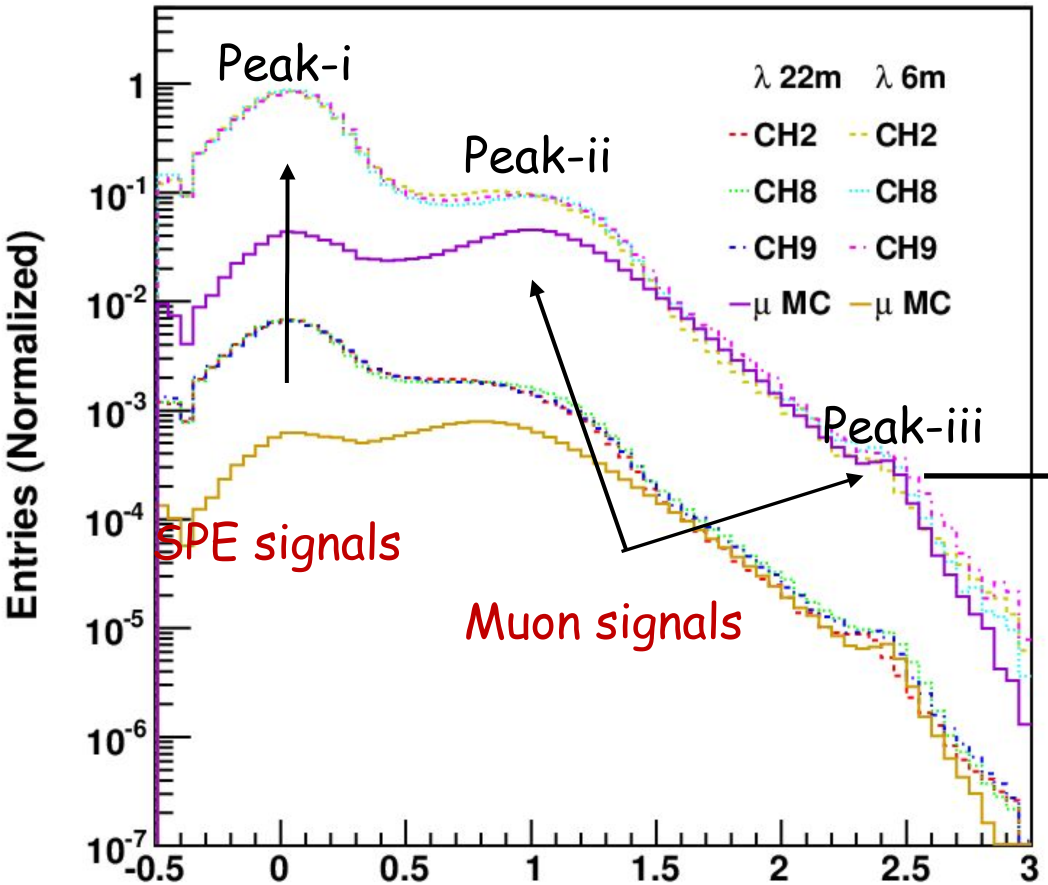
- 78,000 m^2 in total;
- 350,000 tons of purified water;
- 50m x 25 m x 1.8 m;
- Area: 62.

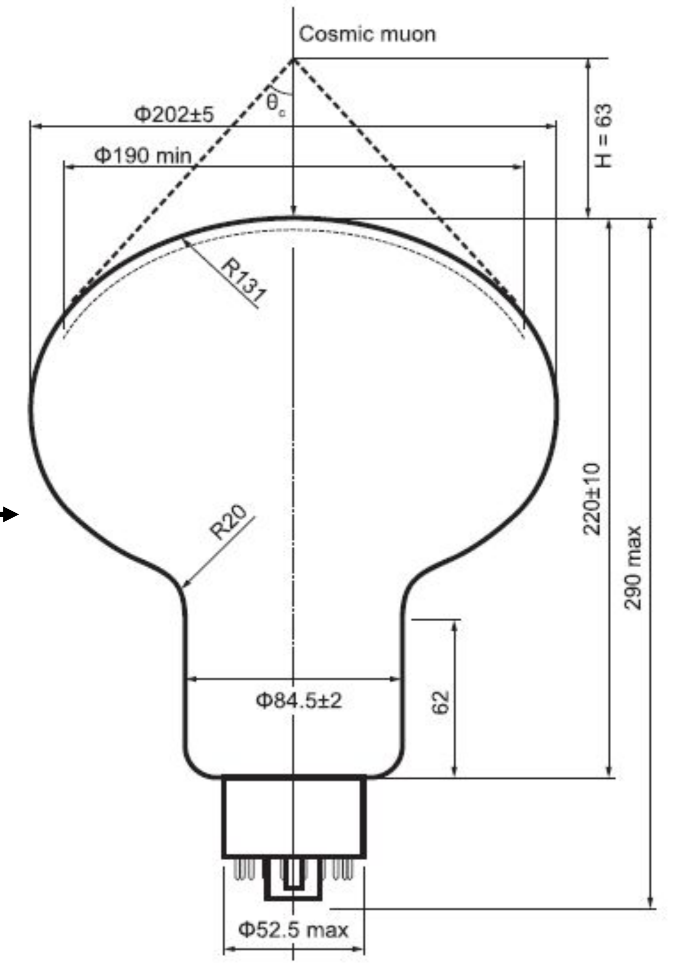
Water Cube:

- 31,000m^2(177m x 177m).

- New method has to be figured out.

Feature of the charge distribution

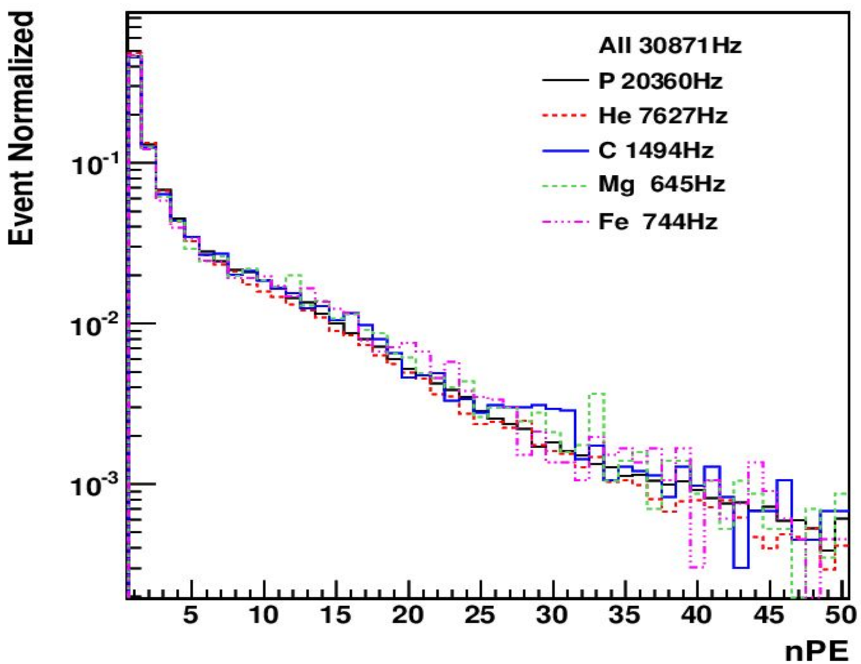


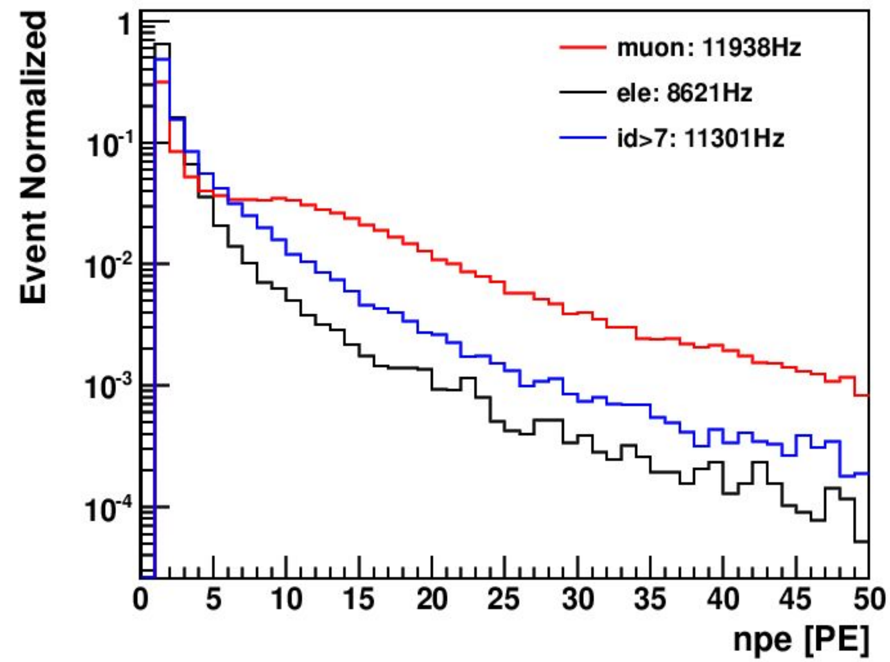


Experimental data and the simulated muon data

NIM A, 644 (2011): 11–17

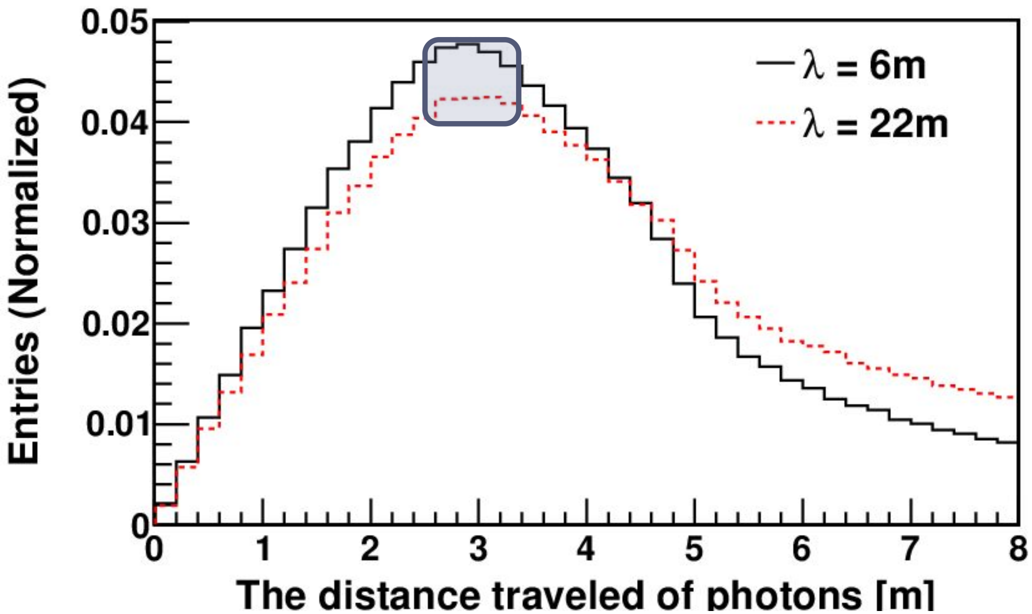
Peak-ii：muon

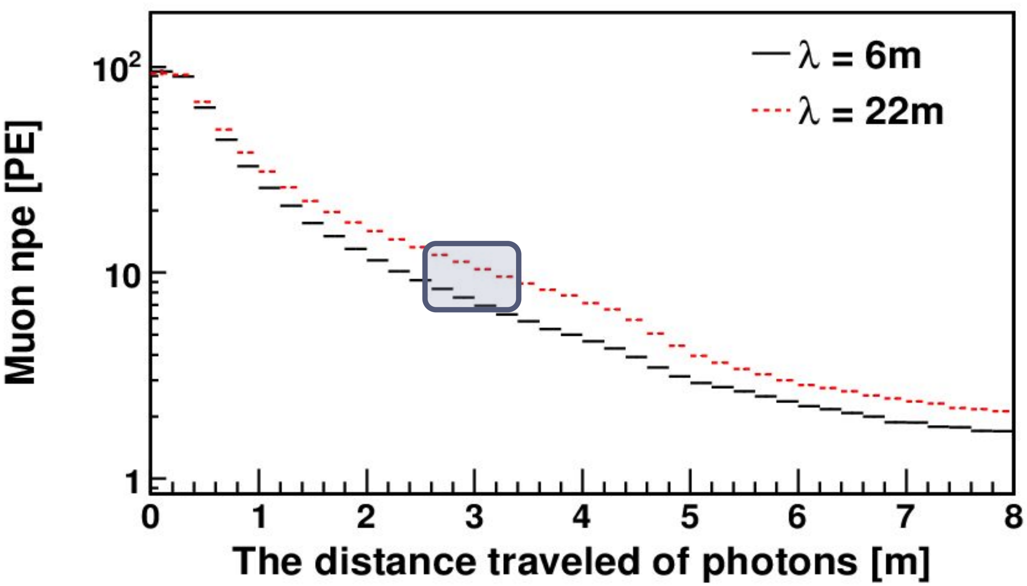




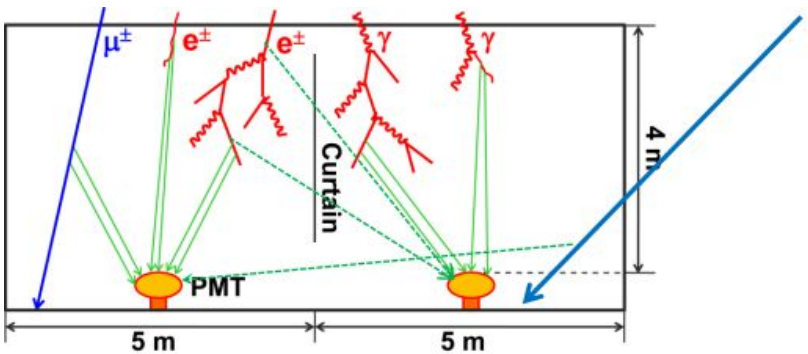
- Corsika74005: QGSII04 --- FLUKA;
- P、He、CNO、MgAlSi、Fe;
- Querry water absorption, normalized to 20 m;
- Rate: 30 kHz;   CE=70%; Curtain PR=5%;

Peak-ii: geometry of muon-track





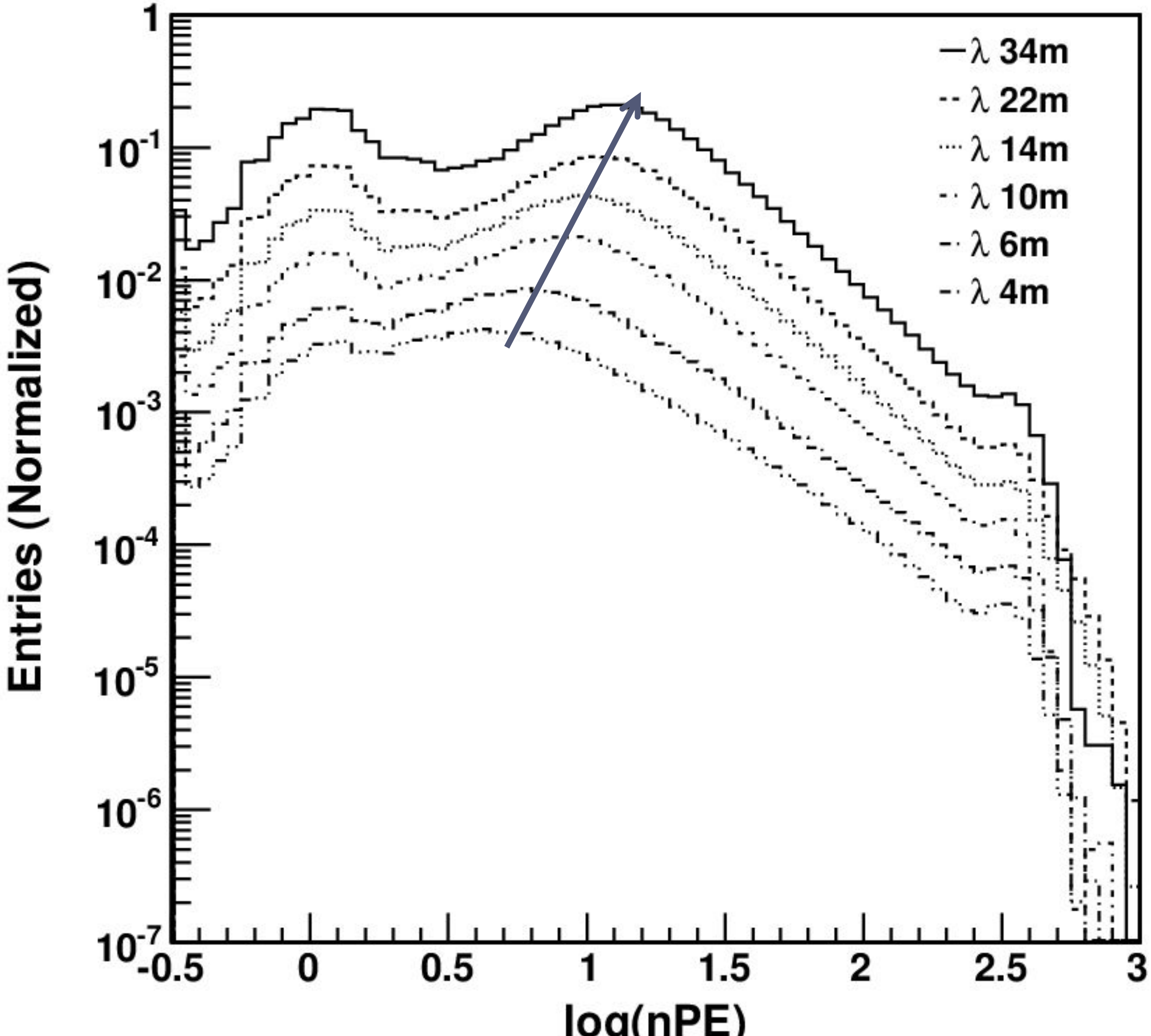
◆ Distribution of the traveling distance of the Cherenkov photons;



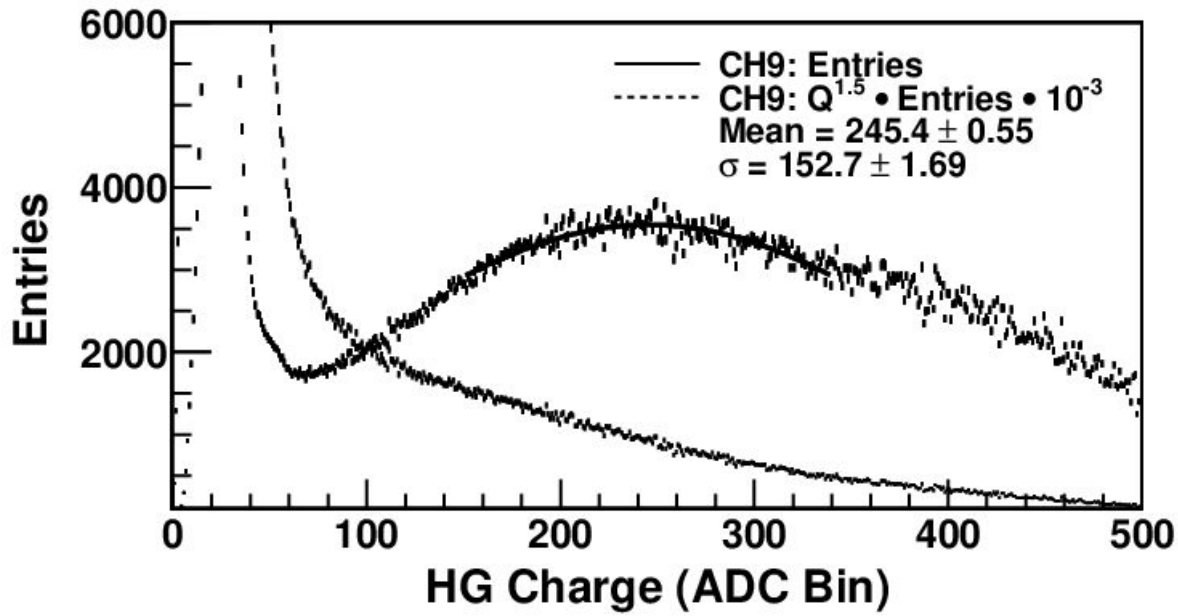
◆ Correlation between the signal charge and the traveling distance of the Cherenkov photons;

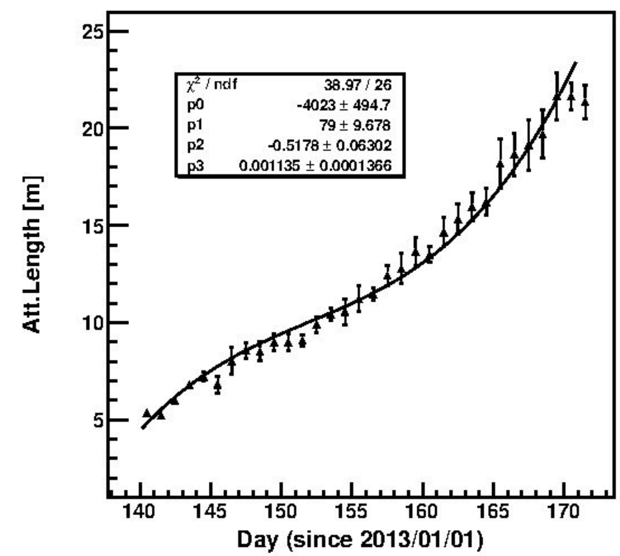
$$N_{\mathrm{pe}} = N_0 \cdot \mathrm{e}^{-d/\lambda}$$

Simulation: pure muon



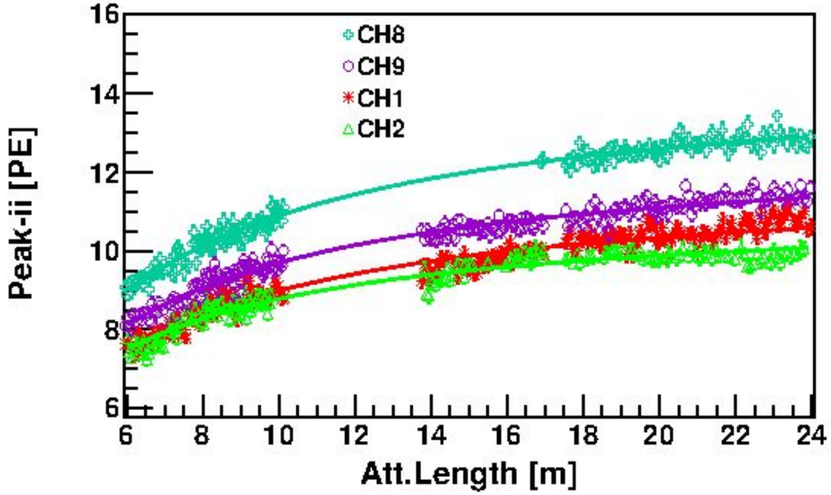
Analysis of the peak position





- ◆ The 2nd peak: Gaussian fitting after a power law of charge is multiplied;
- ◆ Variation of the attenuation length during a month.

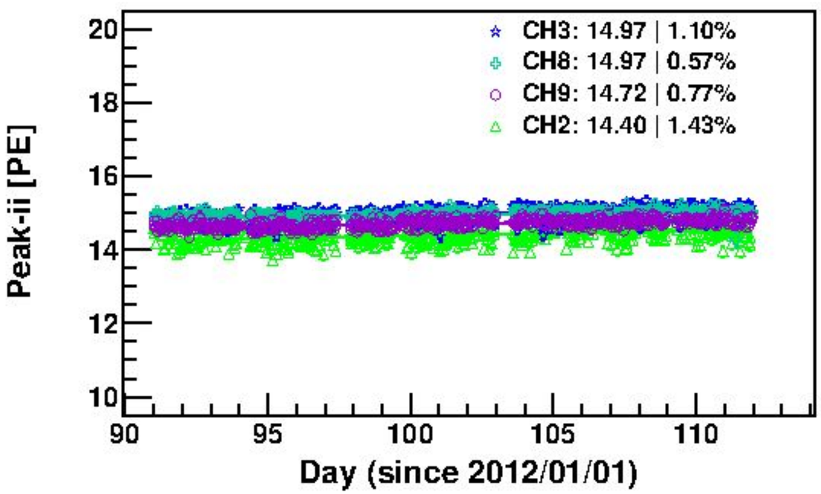
Peak position versus the attenuation length



- Using a simple function to fit:

$$N_{pe} = N_0 \cdot e^{-d/\lambda}$$

- Big difference among PMTs:
  - Mainly comes from the efficiency difference:
  - dirt on the PMT surface, as the water was ever very dirty in 2013.



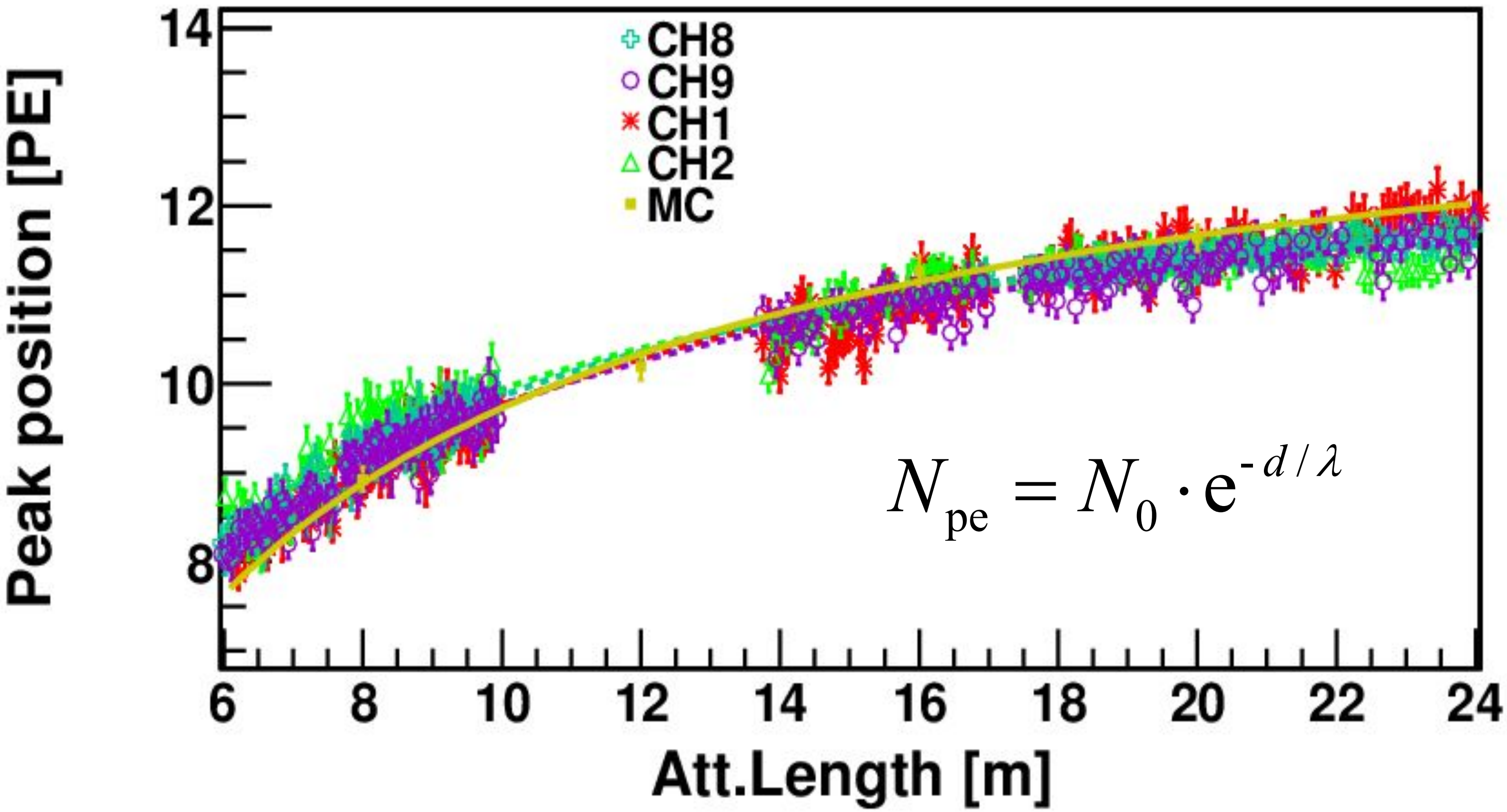
- Much identical if the water keeps always clean:
  - Water quality is very clean (34m);
  - Nonuniformity: RMS of all tubes < 4%;
  - Temperature effect;
  - PMT; Cable; Electronics.

Treatment of the efficiency difference

PMT channel	CH1	CH2	CH8	CH9
Threshold before (PE)	6.0	6.0	6.0	6.0
Rate before (kHz)	5.43	5.27	6.36	5.86
Threshold after (PE)	5.5	5.4	6.9	6.2
Rate after (kHz)	5.74	5.71	5.77	5.73
Scaling factor	0.93	0.90	1.15	1.03
Threshold before (PE)	12.0	12.0	12.0	12.0
Rate before (kHz)	2.59	2.39	3.38	2.86
Threshold after (PE)	11.2	10.7	13.4	12.1
Rate after (kHz)	2.81	2.80	2.80	2.82
Scaling factor	0.93	0.89	1.12	1.01

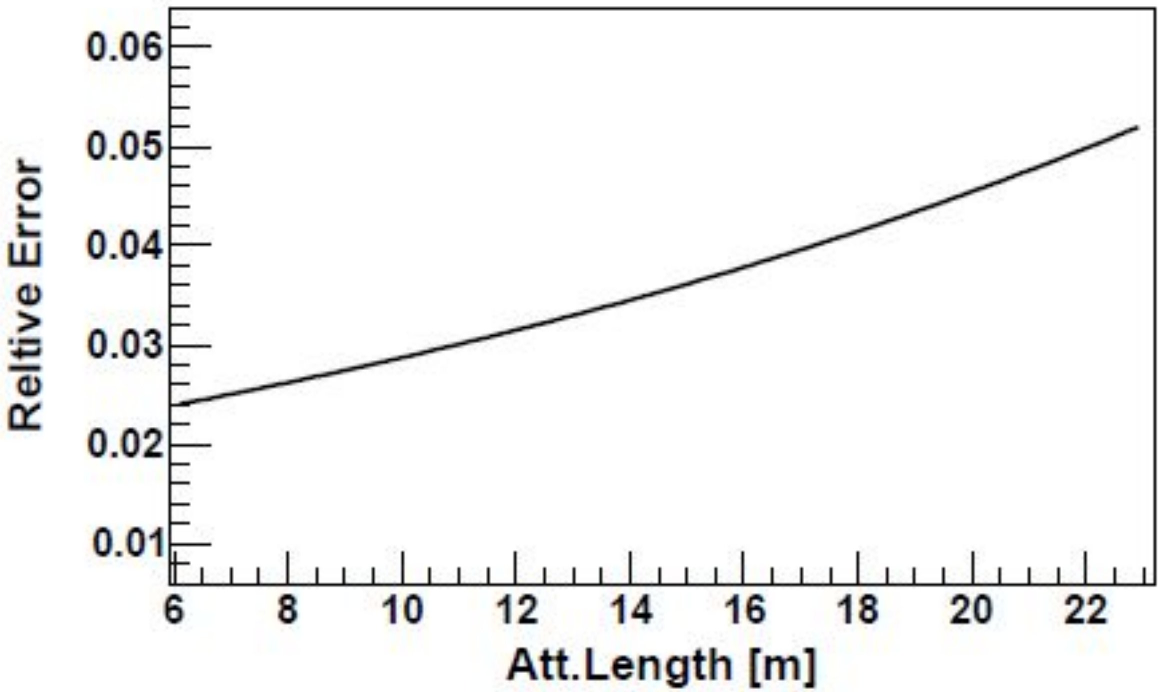
- Rate of single-channel signals should be same for different cells in a fixed physical threshold;
- Constant rate scaling (CRS) method is invented and applied.

Peak position versus the attenuation length



- Correlation between the 2nd peak position and the attenuation lengths after CRS is applied;
- Deviation (RMS) for different cells < 4%.

Error analysis



$$N_{pe} = N_0 \cdot e^{-d/\lambda}$$

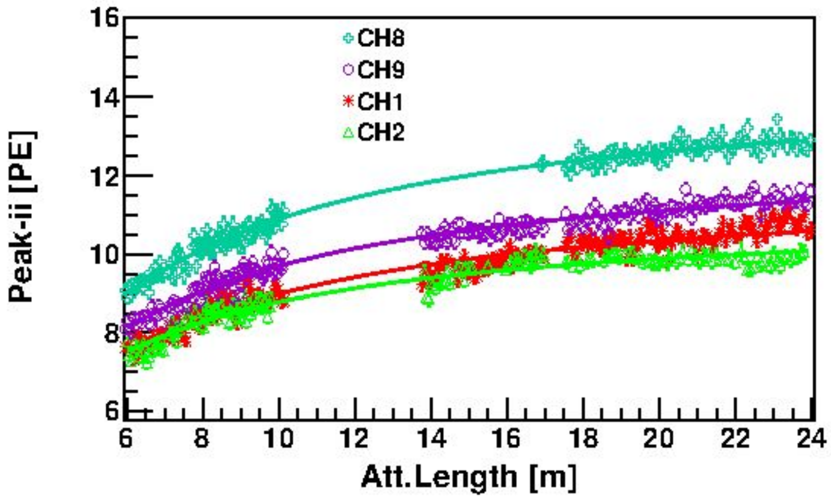
$$\frac{\Delta\lambda}{\lambda} = \frac{\Delta N_{pe}}{N_{pe}} \cdot \frac{\lambda}{d}$$

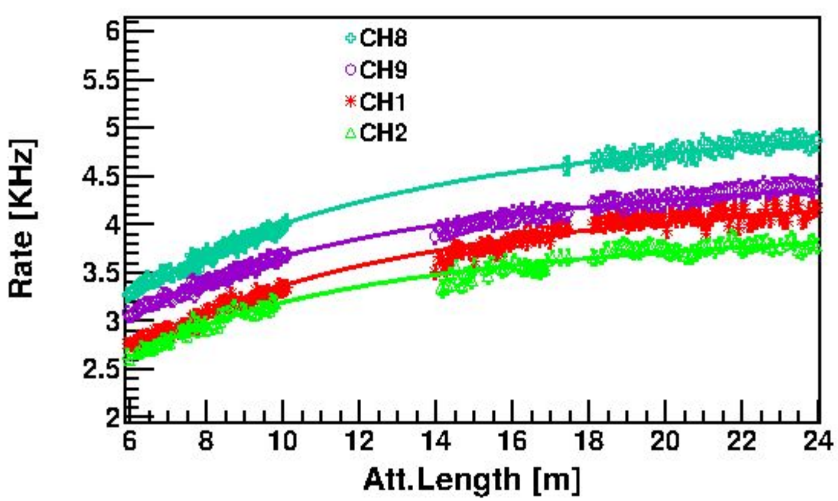
- The relative error < 5%;
- A measurement takes only 20 seconds!

Summary

- The charge distribution of the single-channel signals in the prototype array exhibits a 3-peak feature;
- The 2nd peak, mainly produced by cosmic muons, shows a pretty correlation with the water transparency;
- Fitting the 2nd peak, the water transparency can be frequently monitored and measured with a precision better than 5%:
  - Taking only 20 seconds;
  - Fine-grained up to every detector cell.
- The method will be adopted for the LHAASO-WCDA experiment:
  - Thanks to the triggerless data-taking algorithm of the LHAASO;
  - The time window for each measurement will be increased to around 30 minutes -> even smaller statistical error.

Thank you



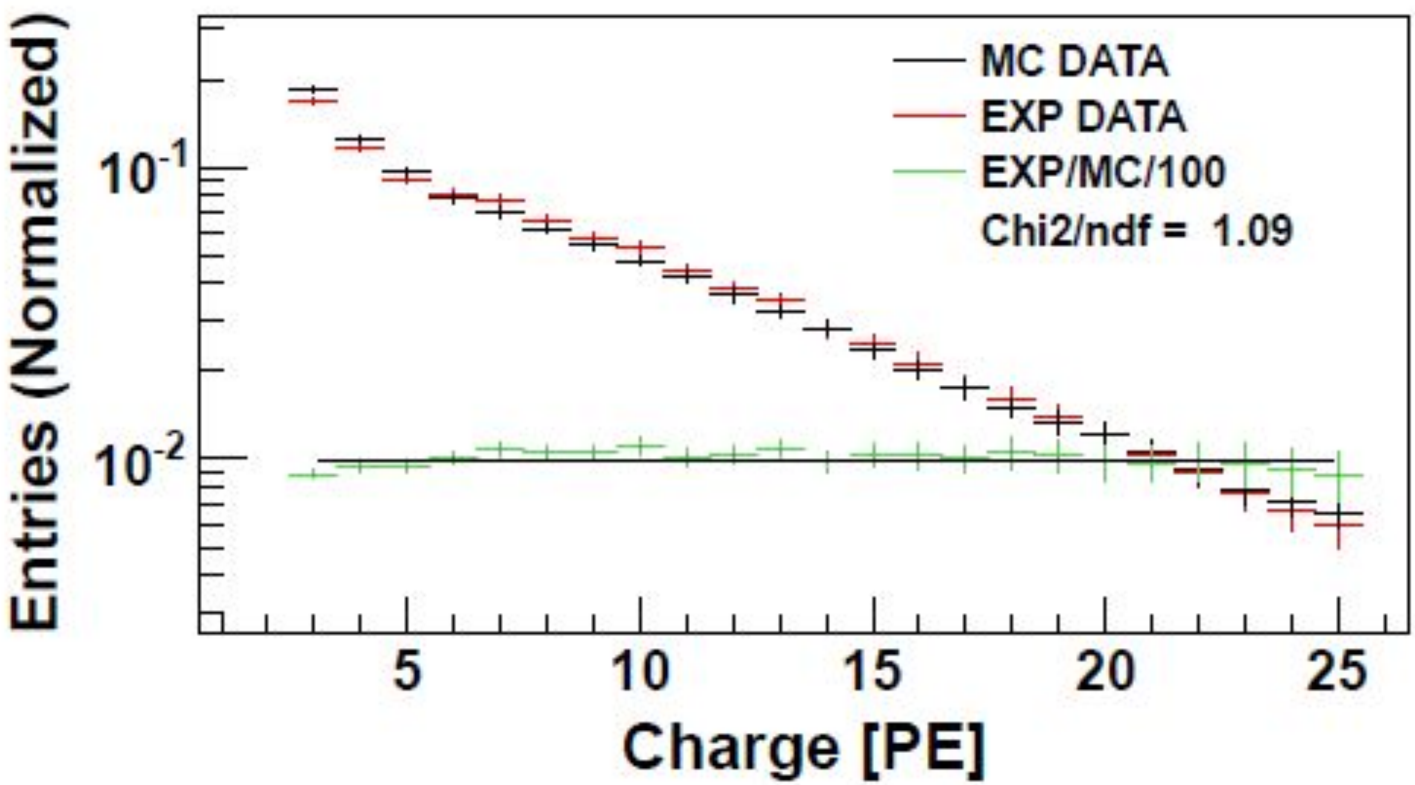


- Using a simple function to fit

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

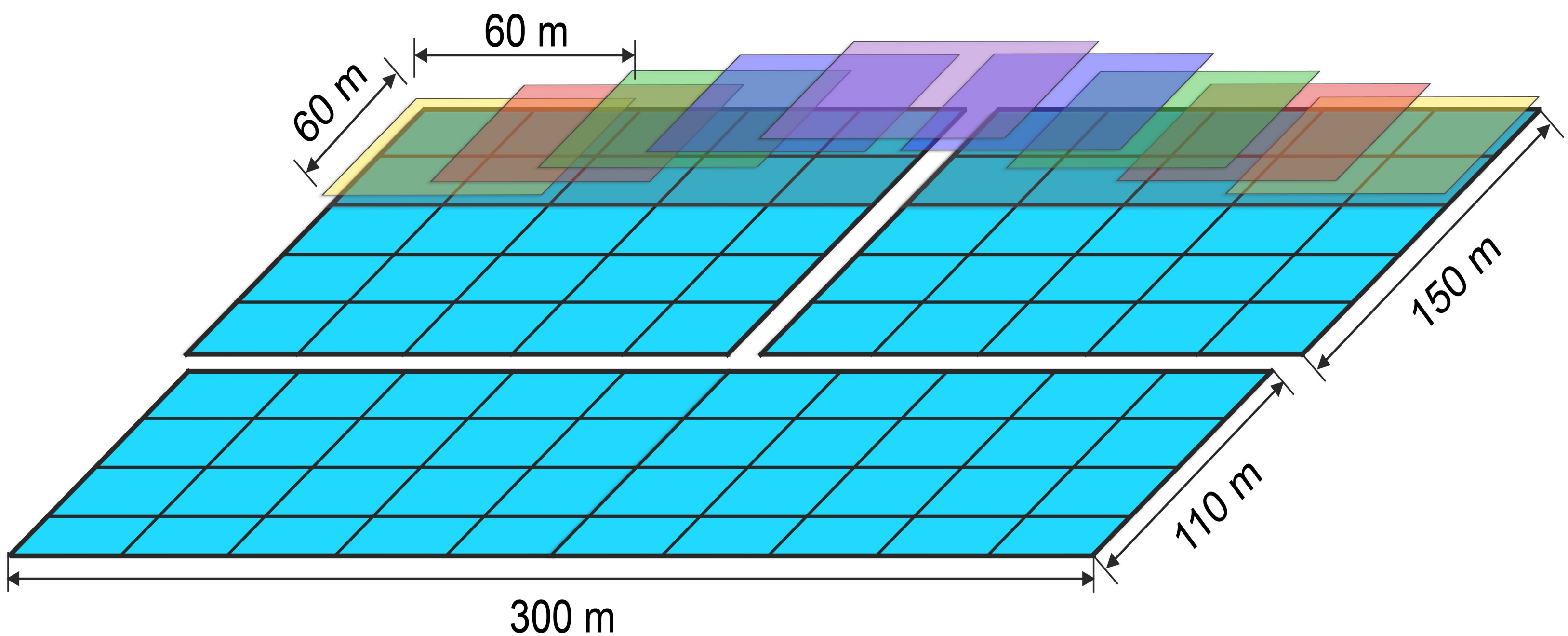
- About big difference among PMTs:
- Mainly comes from the efficiency difference (dirt on the PMT surface, as the water was ever very dirty in 2013);
- Much identical if the water keeps always clean (as verified by 2012 data).
- Water quality up to a cell can be obtained – uniformity study;

To compare MC and DATA



◆ To compare simulation results with experimental data;

区域水质监测预警机制--初步考虑



- 基于单独或相互重叠的“cluster”；
- 每个cluster的大小为6×6=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。