

Dayabay RPC Detector

Zhang Jiawen

2010-7-19

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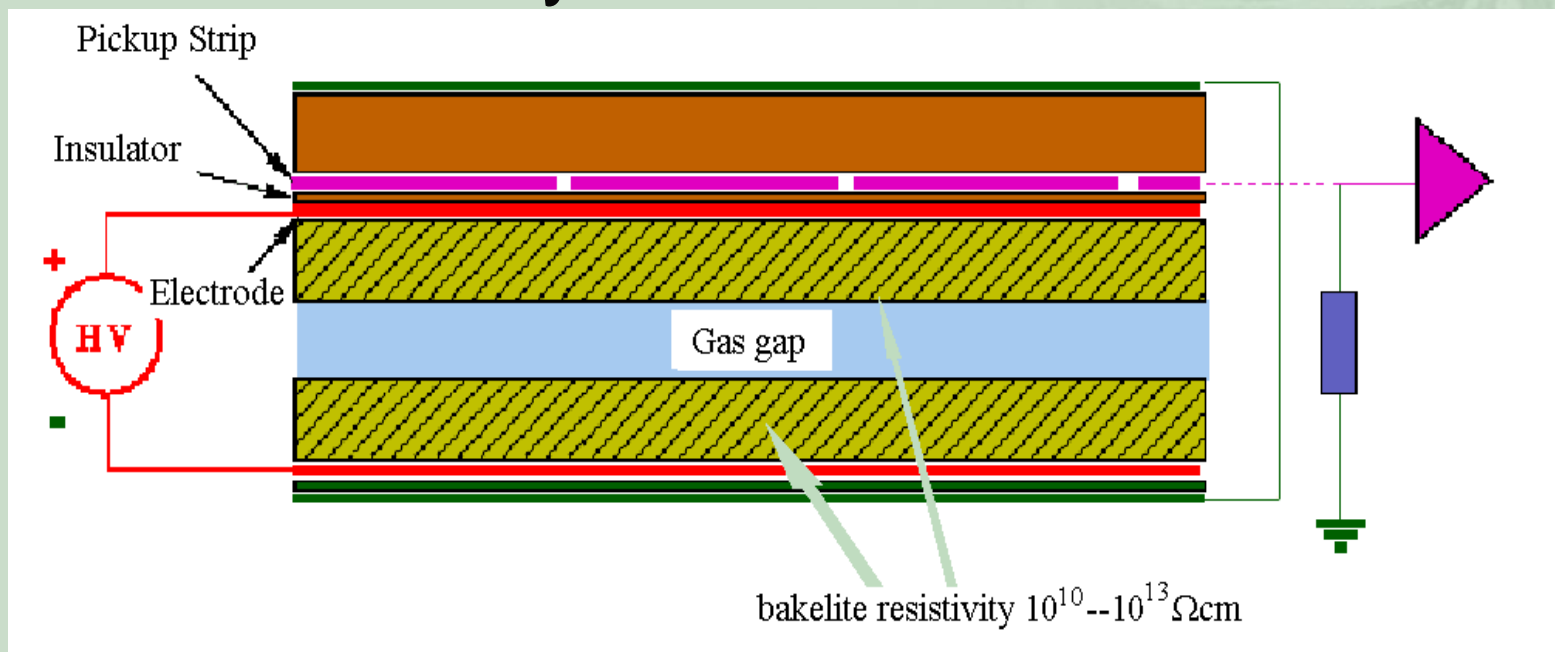
Motivation

- At dayabay neutrino experiment, the goal of the muon detector is to reject the cosmic background, and to increase the experiment precision.
- The AD target Module radius is about 1.5m, after calculated we know, at far site, there will be $4 \times 0.36\text{Hz} \times 3600\text{s} \times 24\text{h} = 125000/\text{day}$ cosmic ray pass through the 4 AD modules target, it much more then the neutrino events, so the muon detector must has high efficiency to reject almost the cosmic ray. The muon detector must is lower noise to ensure the measurement precision.
- As we know, there is a water chelenkov as a muon detector, but its efficiency can not reach the requirement of the experiment, so we must design another detector to supplement it.

| | Near Site | Far Site |
|-------------------------------|-----------|----------|
| Neutrino rate (/day) | 560 | 80 |
| Muon Flux(Hz/m ²) | ~1 | 0.045 |

RPC introduce

- An RPC is composed of two resistive plates with gas flowing between them. High voltage is applied on the plates to produce a strong electric field in the gas. When a cosmic-ray passes through the gas between two plates, a signal is produced, which is then picked up on the pickup strip and sent to the DAQ system.



RPC for Daya Bay

- Adopt 2 dimension readout
- RPC operation as streamer mode
- The gas mixture used as
 $A_r:C_2H_2F_4:C_4H_{10}:SF_6=65.5:30:4:0.5$
- HV+4000V, -4000V



Efficiency and noise(2/3)

- Efficiency of each layer is $\varepsilon \sim 95\%$, and adopt choose 2 out of 3 as a hit, their coincidence efficiency is

$$\varepsilon^3 + C_3^2 \varepsilon^2 (1 - \varepsilon)$$

$$= 0.95^3 + 3 \times 0.95^2 \times (1 - 0.95) = 99.3\%$$

- The RPC bare chamber noise rate $r \sim 800\text{Hz}/\text{m}^2$, the shaped signal width is $\tau = 100\text{ns} = 10^{-7}\text{s}$, so the module noise rate is

$$3C_3^2 r^2 \times 3\tau$$

$$= 3 \times (800)^2 \times 3 \times 10^{-7} = 0.192\text{Hz}$$



Efficiency and noise(2/4)

- Efficiency of each layer is $\varepsilon \sim 95\%$, and adopt choose 2 out of 4 as a hit, their coincidence efficiency is

$$\begin{aligned} & \varepsilon^4 + C_4^3 \varepsilon^3 (1 - \varepsilon) + C_4^2 \varepsilon^2 (1 - \varepsilon)^2 \\ &= 0.95^4 + 4 \times 0.95^3 \times (1 - 0.95) + 6 \times 0.95^2 \times (1 - 0.95)^2 \\ &= 99.96\% \end{aligned}$$

- The RPC bare chamber noise rate $r \sim 800\text{Hz}/\text{m}^2$, the shaped signal width is $\tau = 100\text{ns} = 10^{-7}\text{s}$, so the module noise rate is

$$\begin{aligned} & C_4^2 r^2 \times 3 \tau \\ &= 6 \times (800)^2 \times 3 \times 10^{-7} = 0.384\text{Hz} \end{aligned}$$



Efficiency and noise(3/4)

- Efficiency of each layer is $\varepsilon \sim 95\%$, and adopt choose 3 out of 4 as a hit, their coincidence efficiency is

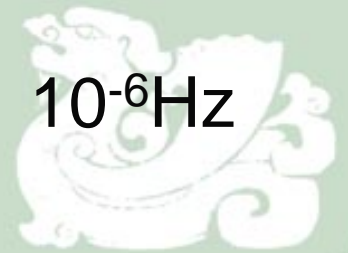
$$\begin{aligned} & \varepsilon^4 + C_4^3 \varepsilon^3 (1 - \varepsilon) \\ &= 0.95^4 + 4 \times 0.95^3 \times (1 - 0.95) \\ &= 98.6\% \end{aligned}$$

if the Efficiency of each layer is $\varepsilon \sim 96\%$, their coincidence efficiency is $\sim 99.1\%$

if the Efficiency of each layer is $\varepsilon \sim 97\%$, their coincidence efficiency is $\sim 99.5\%$

- The RPC bare chamber noise rate $r \sim 800\text{Hz}/\text{m}^2$, the shaped signal width is $\tau = 100\text{ns} = 10^{-7}\text{s}$, so the module noise rate is

$$C_4^3 r^3 \times (3\tau)^2 = 4 \times (800)^3 \times (3 \times 10^{-7})^2 = 2.88 \times 10^{-6}\text{Hz}$$



compare

If single gap RPC efficiency is 95%

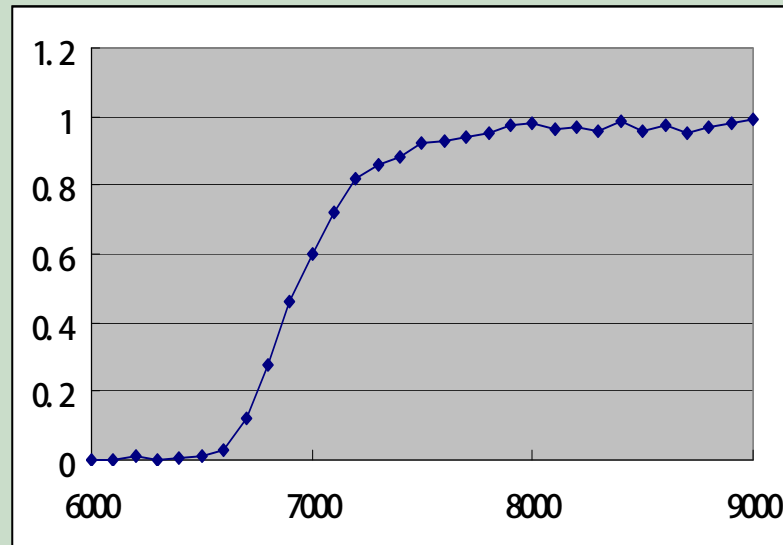
| | 2/3 | 2/4 | 3/4 |
|------------------------|------------------------|------------------------|----------------------------------|
| Coincidence efficiency | 99.3% | 99.96% | 98.6% |
| Random coincidence | 0.192Hz/m ² | 0.384Hz/m ² | $\sim 10^{-5}$ Hz/m ² |

If use $\frac{3}{4}$ with different RPC efficiency

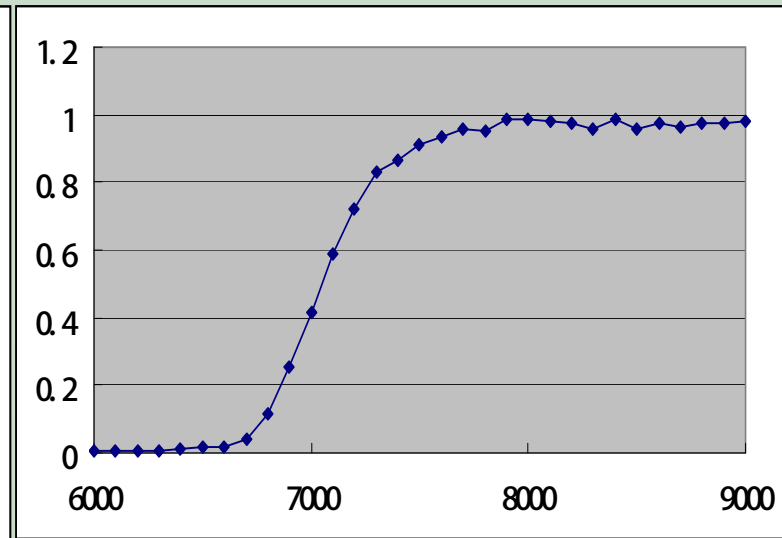
| | | | |
|------------------------|-------|-------|-------|
| RPC efficiency | 95% | 96% | 97% |
| Coincidence efficiency | 98.6% | 99.1% | 99.5% |

Prototype test

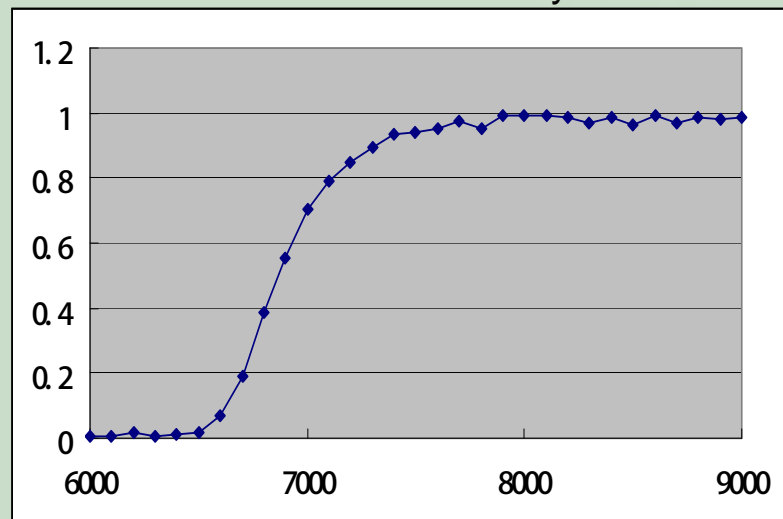
■ We use 3 RPCs test for this idea, the result shows, adopt choose 2 out of 3 as a hit, their coincidence efficiency is $99.5 \pm 0.25\%$, very closed to our calculated.



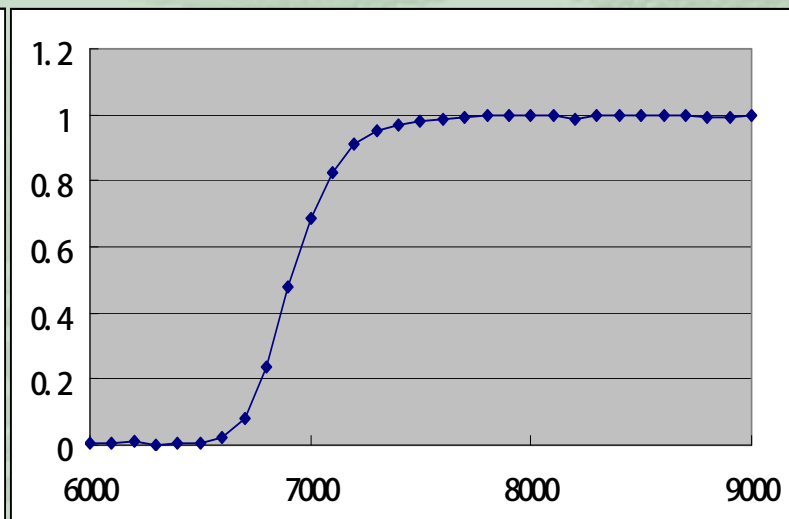
First RPC Efficiency



Second RPC Efficiency



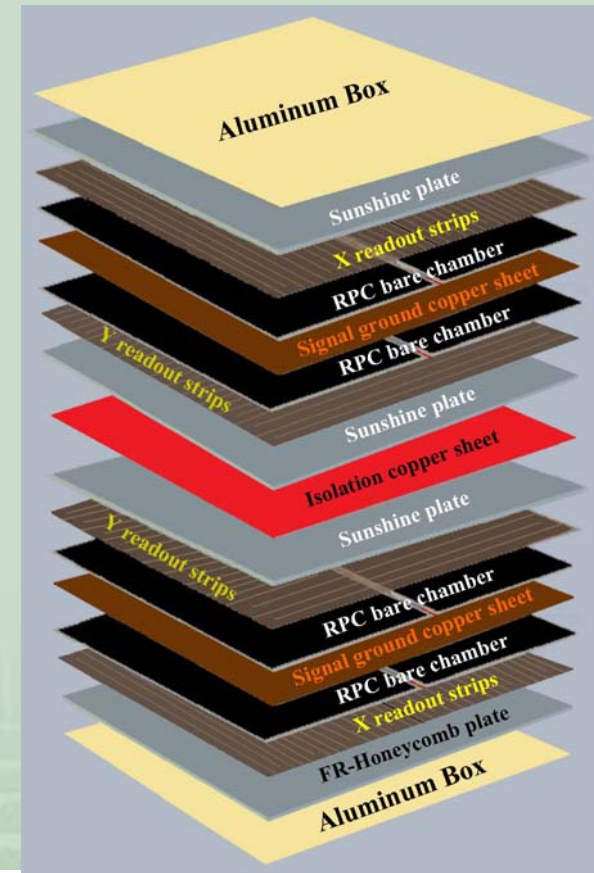
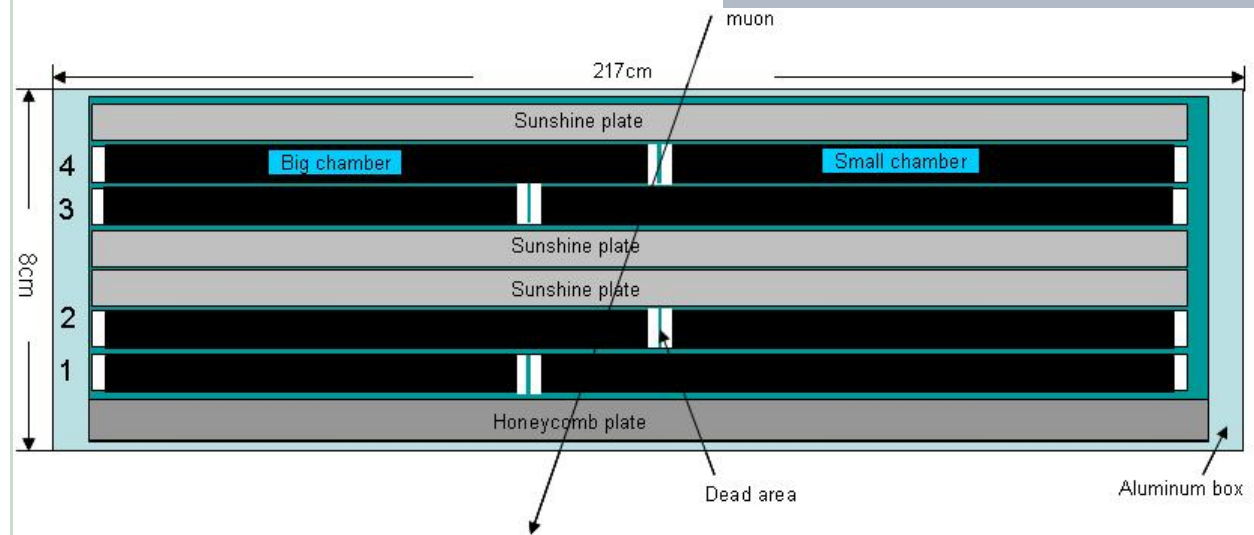
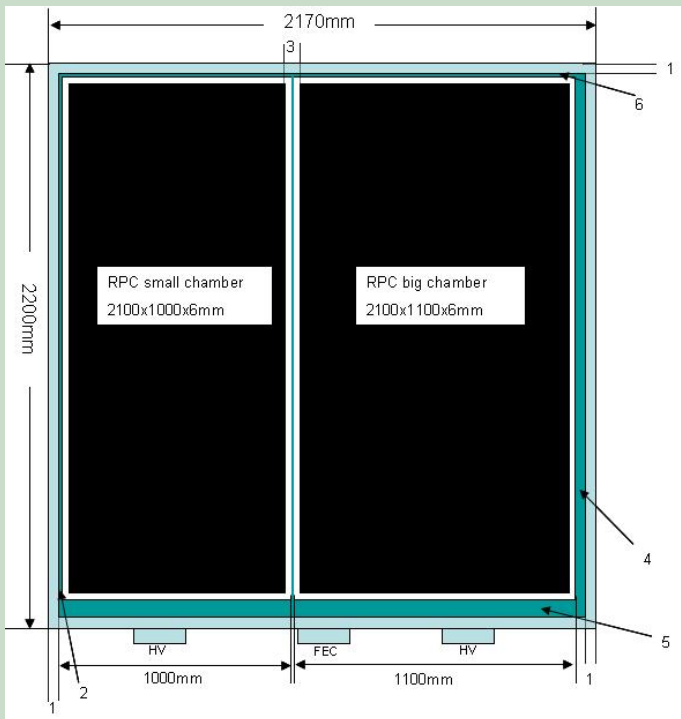
Third RPC Efficiency



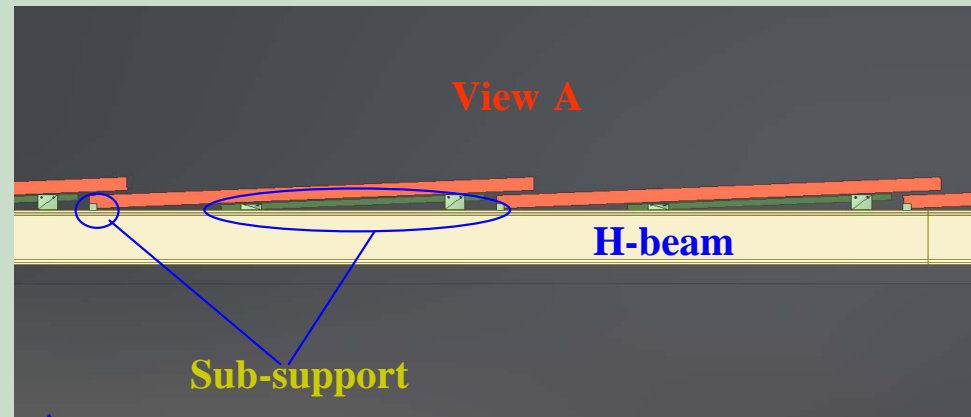
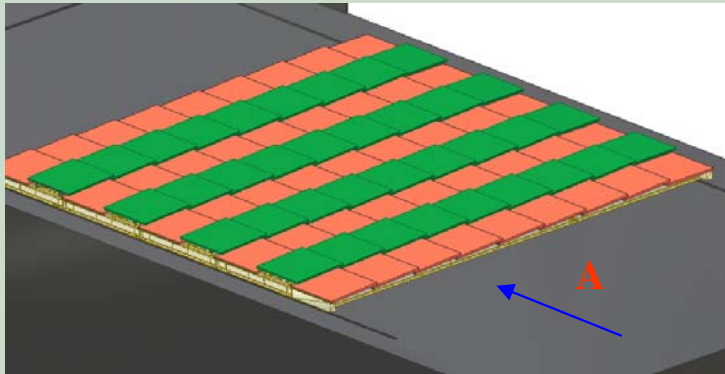
2/3 Efficiency

Module structure

- Compare the options, we selected 4 gaps RPC assemble in one module. Each layer overlapping assembly, no dead space. Trigger adopt choose 2 out of 4 layers, this can refuse almost the cosmic background.

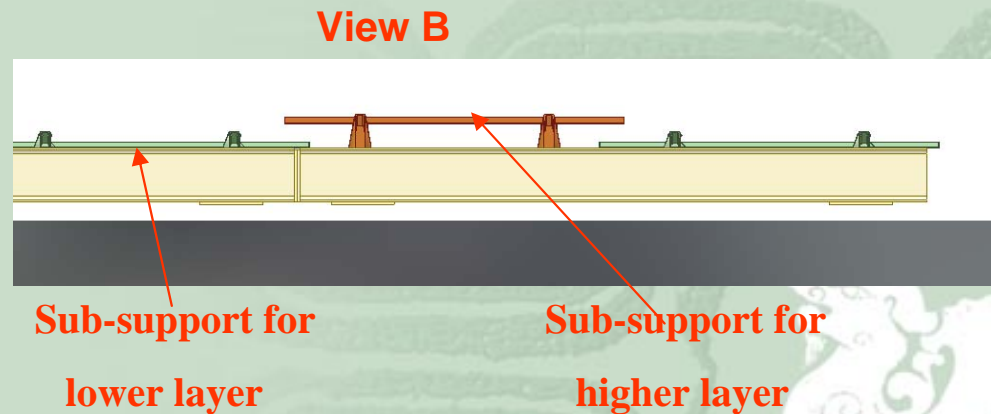
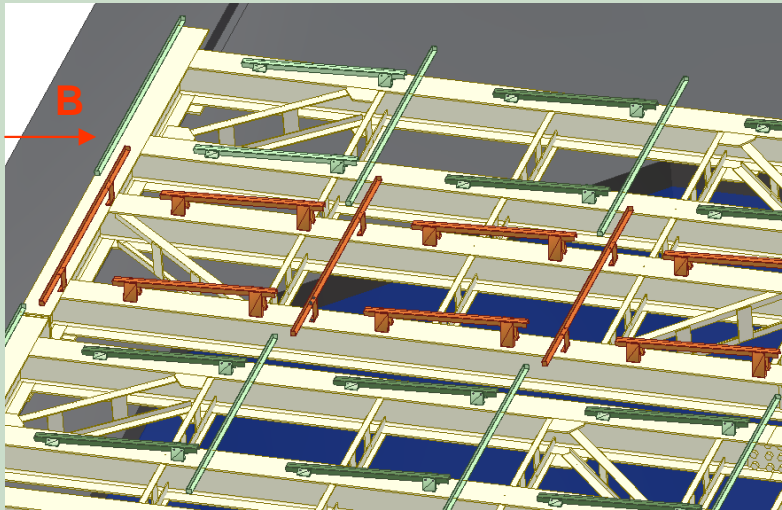


Module layout on support frame



modules (81 pieces in far hall and 54 pieces in near hall) are assembled on the support frame by their sub-support

Module just put on the sub-support and needn't be fastened on it.

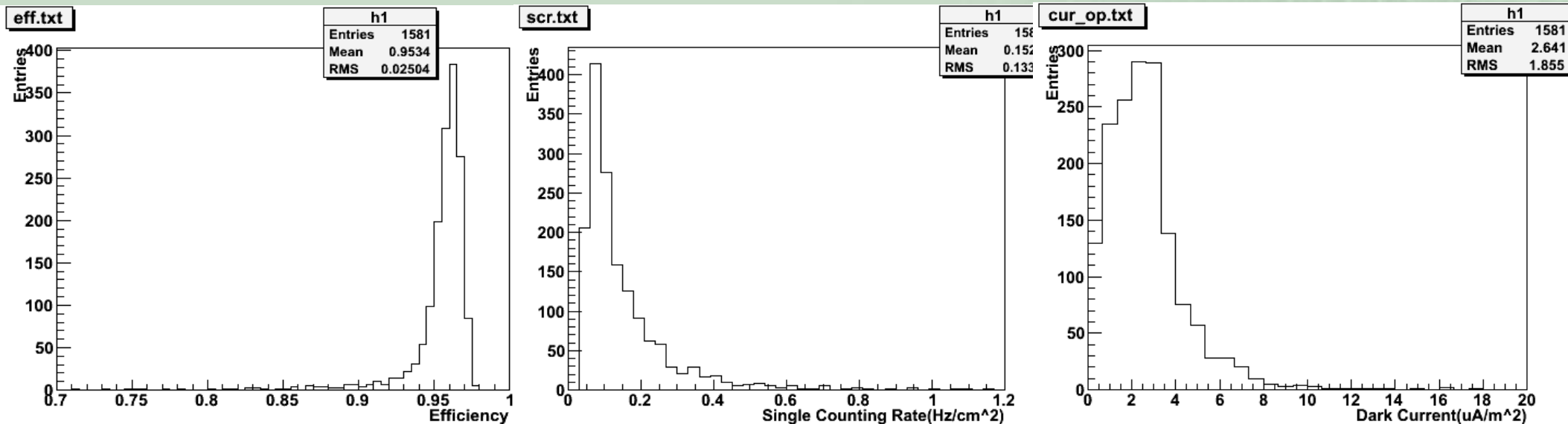


Being the overlap modules, the sub-support have two types for two height layers of module.

Progress

RPC bare chambers

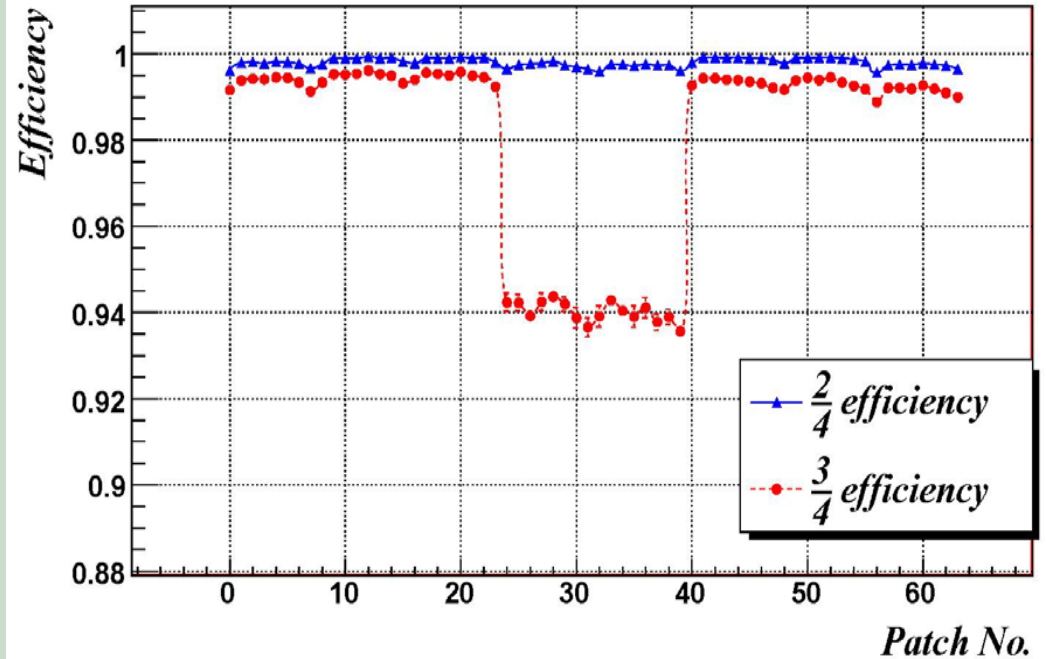
- Almost all of the bare chambers have been produced and tested
- Some of the bare chambers are rejected, and we begin reproduce new bare chambers to replace the rejected chambers.



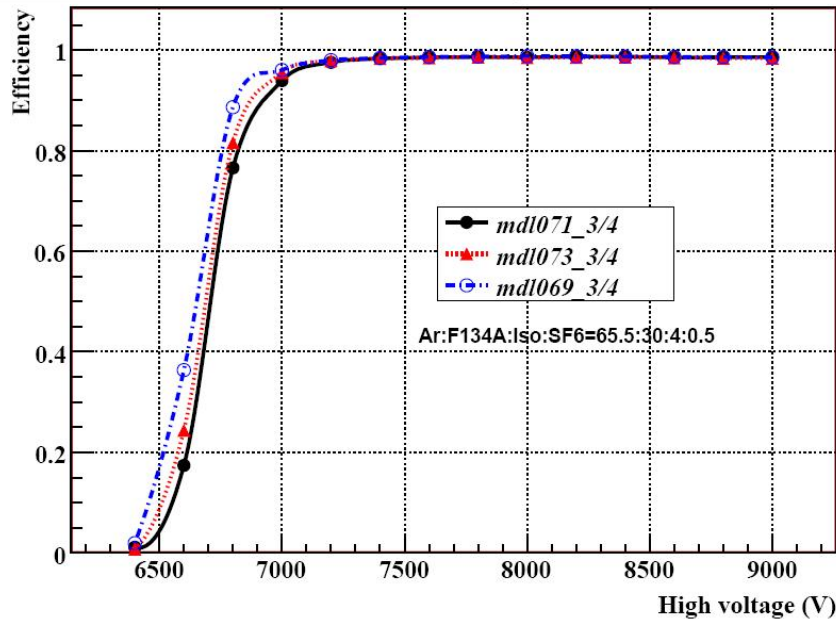
Modules

- 170 modules have been assembled
- 143 modules have been tested, the $\frac{3}{4}$ average efficiency is about 97.9%, and $\frac{2}{4}$ average efficiency is about 99.8%.

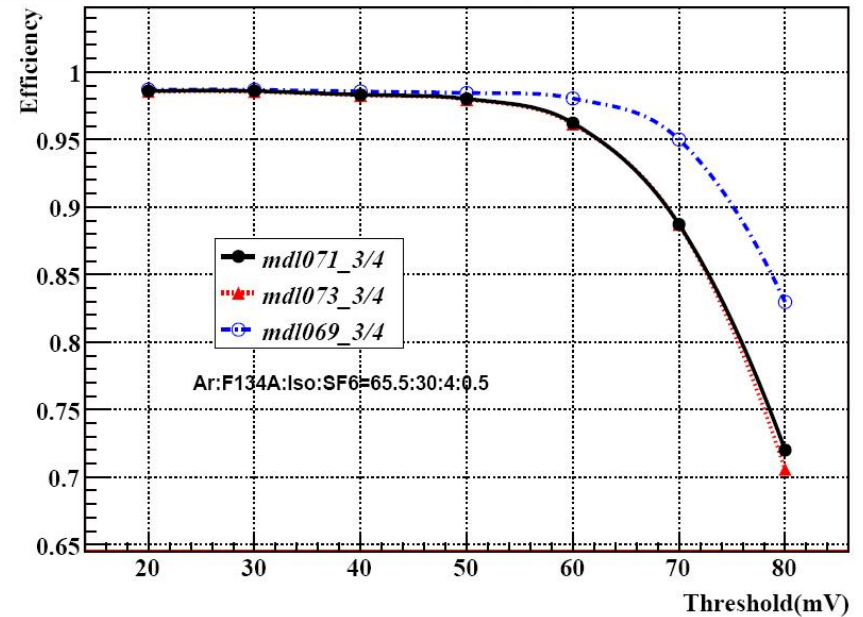
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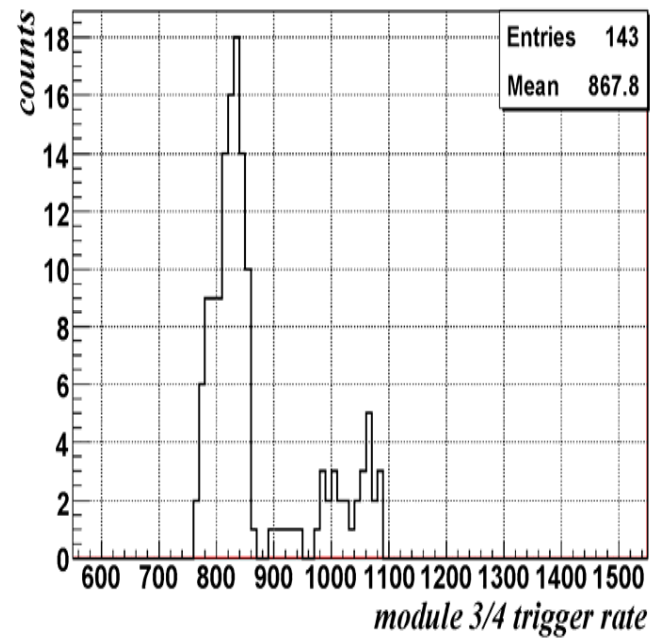
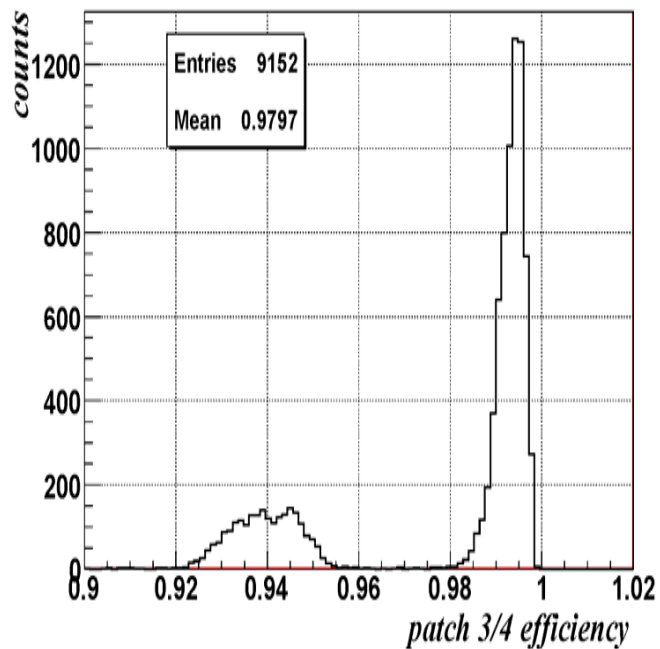
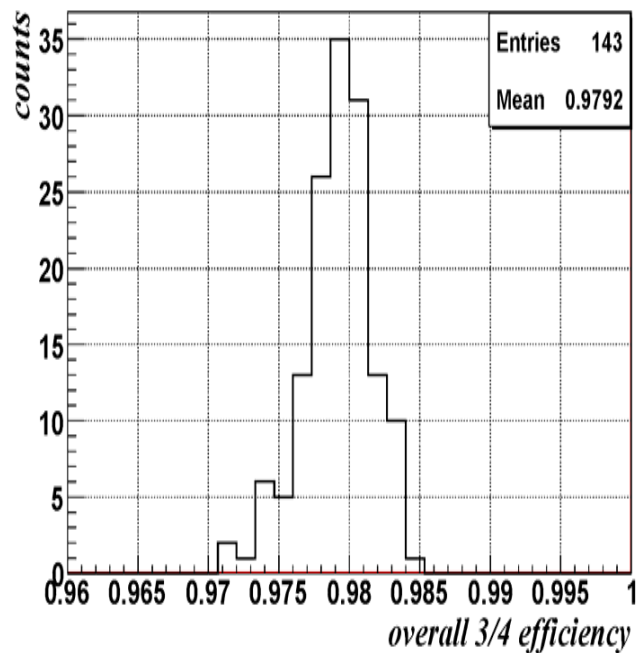
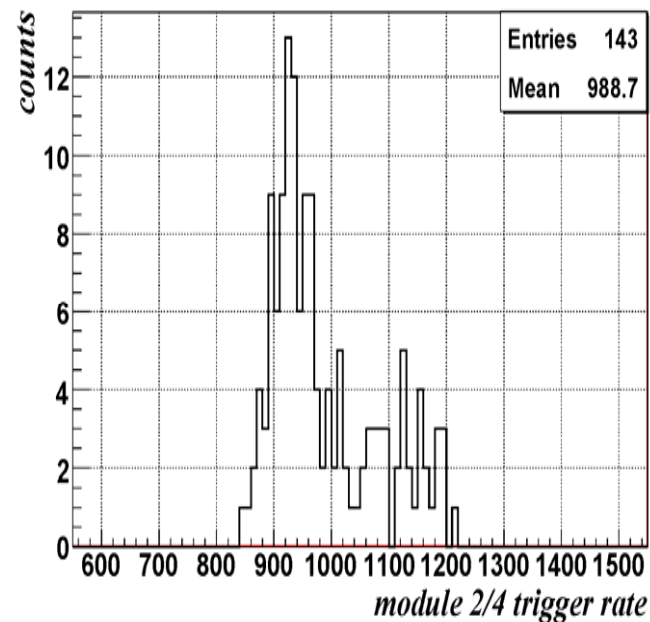
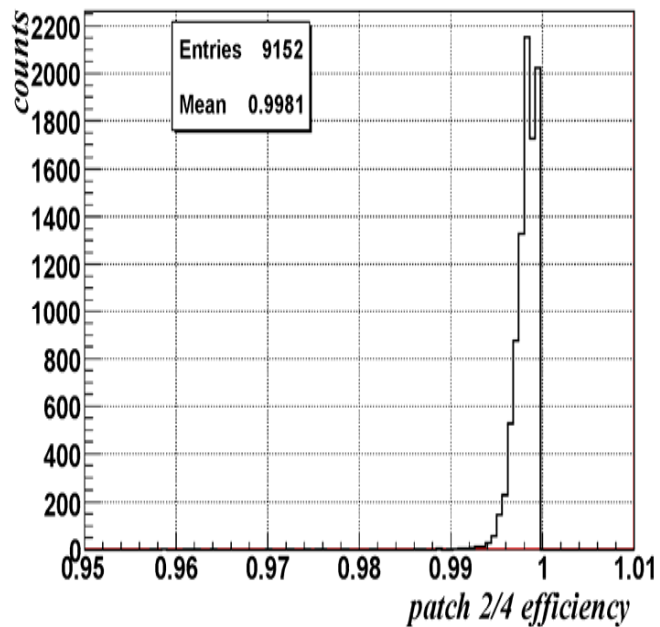
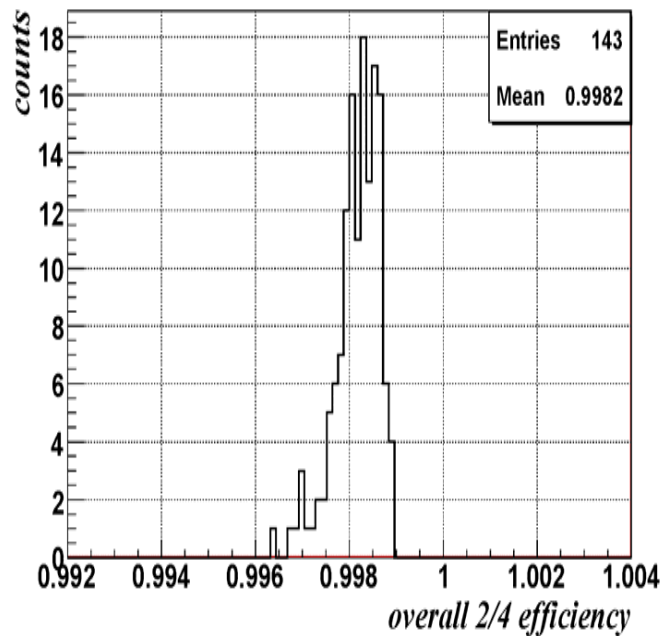


Module efficiency plateau @ 30mV



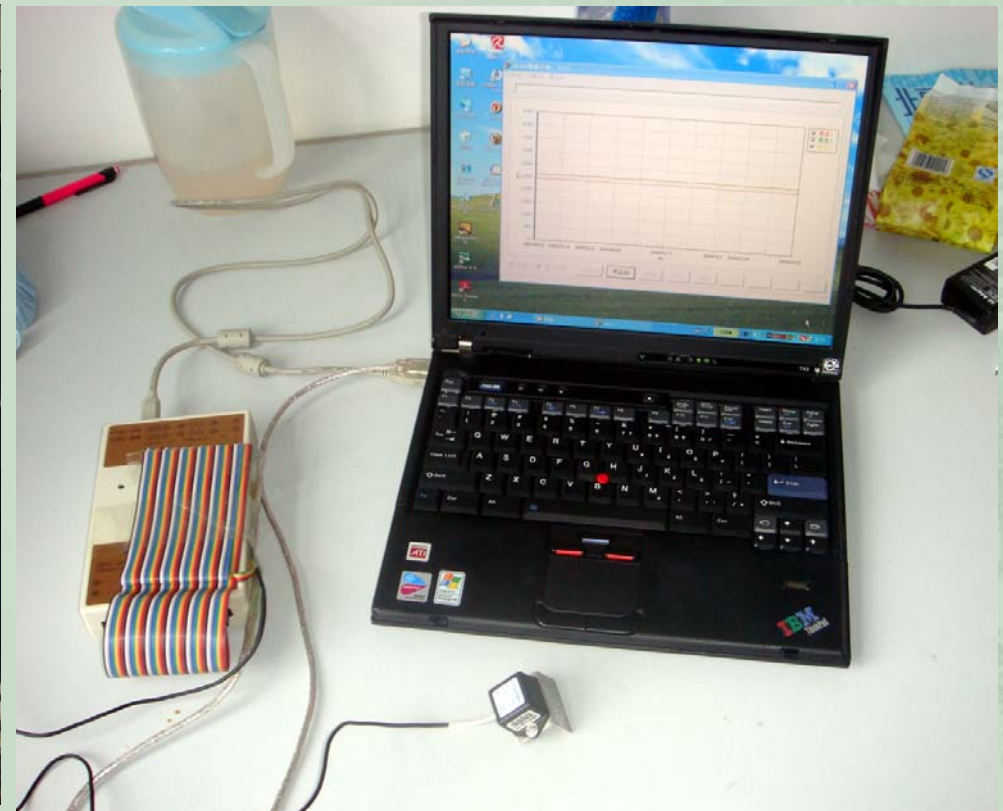
Module efficiency plateau @ 7600V





Transportation test

- Transportation test have do two times, vibration sensor is used to monitor the shochproofness, totale about more then 200km country road, not found any problem.



Road photo



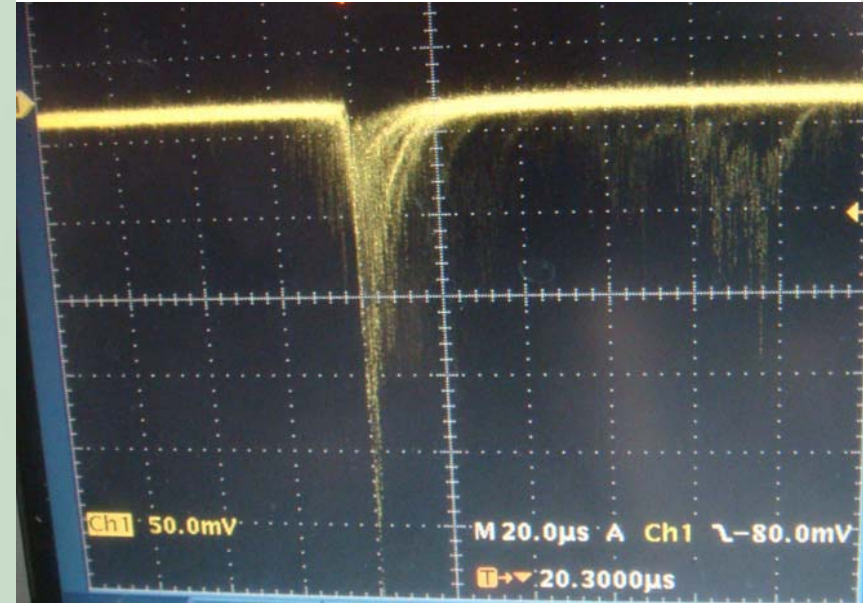
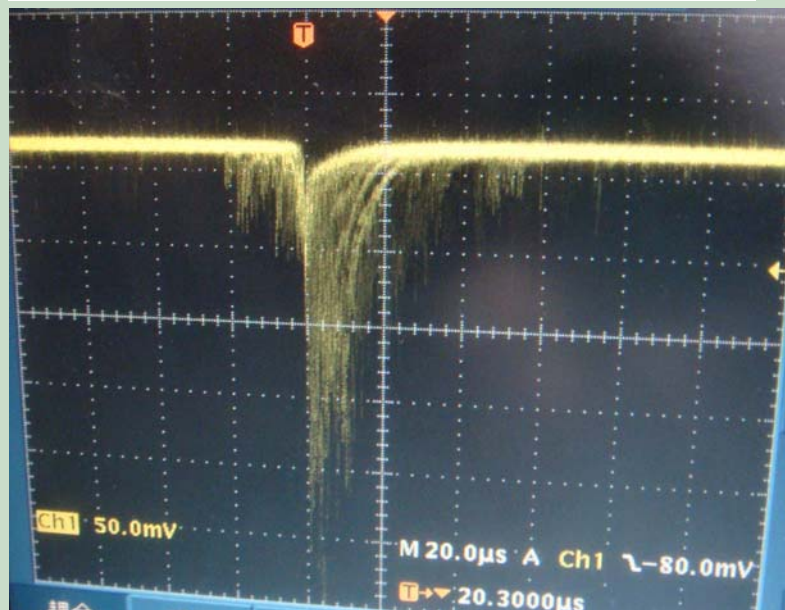
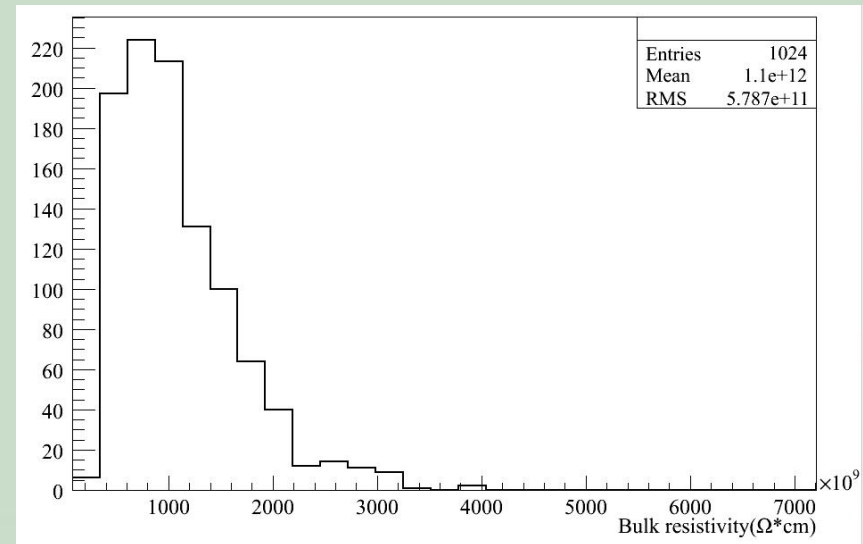
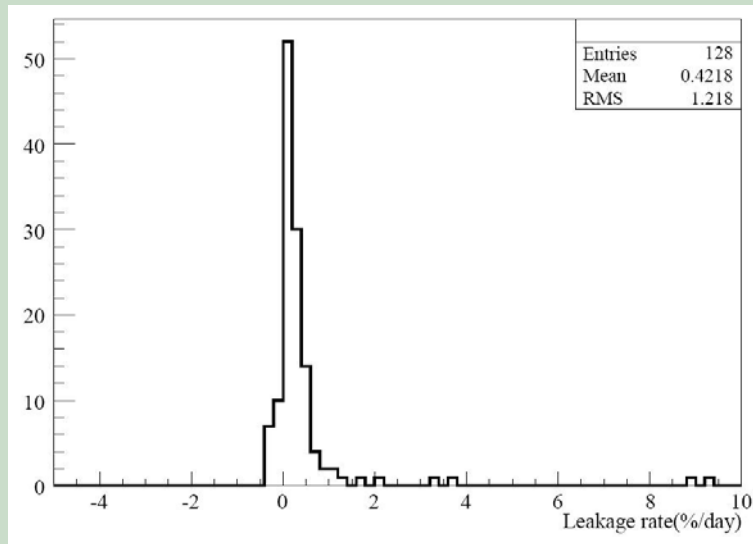
Transportation

- 128 modules have been transported to SAB



Test at SAB

- At SAB, the gas leakage, signals, HV and bulk resistivity are tested.



Summary

- RPC is economical for a large area detector
- Dayabay RPC modules are selected 4 layers to increase the efficiency and decrease the noise.
- Most of the work in Beijing have finished, the test shows the detector performances are very good.
- 128 modules have been transported to SAB, and the tests at SAB have completed, the detector not damaged in transport.



The detectors have been ready,
can be installed at any time!

