Design and Performances of Electromagnetic Particle Detectors of LHAASO-KM2A

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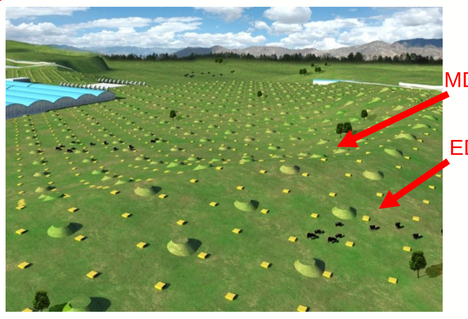
Introduction

The Large High Altitude Air Shower Observatory (LHAASO) is a proposed cosmic ray experiment which will be built at Mount Haizi (4400m in altitude) in Daocheng, Sichuan Province of China.

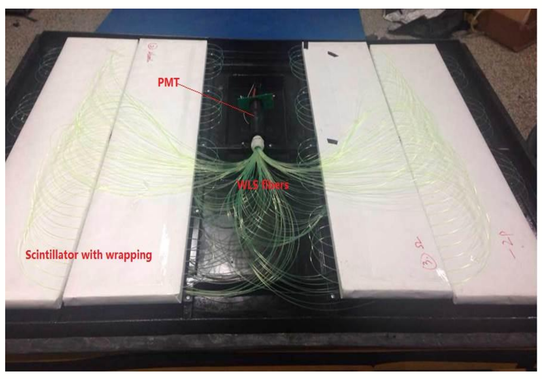
As one part array of LHAASO, one square kilometer extensive air shower array (KM2A) consists of 5242 electromagnetic particle detectors(EDs) and 1146 muon detectors(MDs), which are distributed in the area with a radius of 635m.



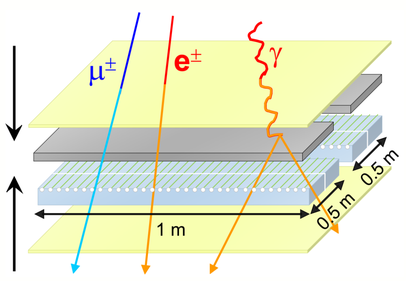
Sketch Picture for KM2A

KM2A aims for the discovery of the Galactic CR sources, the survey of the northern sky exploring the radiation mechanism of Gammas with energy range of 10TeV~ PeV and the study of Cosmic ray physics (20TeV—100PeV).

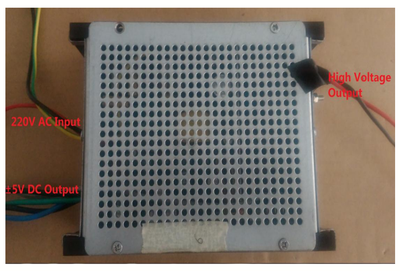
Design



A ED prototype is shown in Fig.2, where 128 WLS fibers (BCF92,1.5mm) were coupled with 4 scintillator Tiles (100cm*25cm*2.5cm) with tyvek layer wrapping. All fibers ends were connected to one PMT (1.5 inches), while the readouts of anode and DY6 were transported to one electronics module to record the charge and timing message. All the above components were fixed in a metal box.



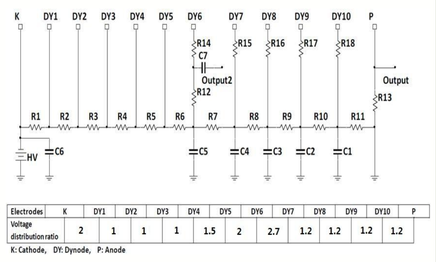
A 5mm-thick lead layer covered the tiles' surface



The power supply provides the HV and LVs to the PMT and electronics. Its HV values can be remote controlled.

One kind of PMT, with good time characters and low temperature coefficient(<0.1%/℃), is used in ED prototype with magnetic shield to reduce the affect of geomagnetic.

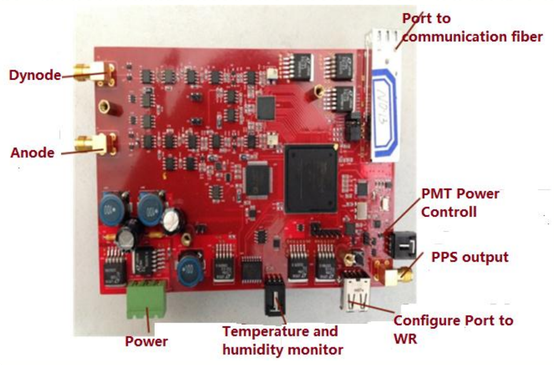
A divider design with dual-readout of both anode and 6th dynode has been finished to realize a wide linearity, which meets the ED requirement and the equivalent current of the PMT could reach 1163mA.



Electrodes	K	DY1	DY2	DY3	DY4	DY5	DY6	DY7	DY8	DY9	DY10	P
Voltage distribution ratio	2	1	1	1	1.5	2	2.7	1.2	1.2	1.2	1.2	

K: Cathode, DY: Dynode, P: Anode

Circuit Design with Dynode readout



Front-end electronics

Front-end electronics can deal with the charge and triggering times from anode and DY6 signals.

A set of White Rabbit timing system is used to obtain good timing measurement with an accuracy of ±150ps.

Requirements

As one type of plastic scintillator detector, EDs will detect the secondary particle densities and arrival times in EAS fronts of Primary particles. The main requirements of each ED are as below,

1. Effective area: $1m^2$, 5mm Lead covered
2. Detection efficiency (>5MeV):>95%
3. Number of photoelectron for minimum iron particles: >20
4. Time resolution: <2ns
5. Count rate: <2kHz
6. Dynamic range: 1~ 10 000particles/ m^2
7. Stable operation (0.6atm., ±25℃): more than 15yrs

Performance studies

A telescope system has been installed in Shandong University (see Fig.5) to study the performances of ED prototype in detail. The vertical MIPs events were chosen, while TGC detector in the system were to fix on the incoming particles' tracks with the high precision.

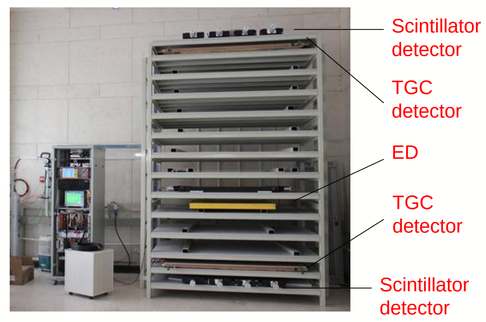
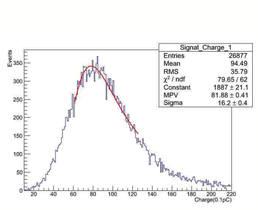
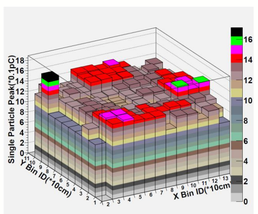


Fig.5 Test system for ED.

1. Number of Photoelectrons





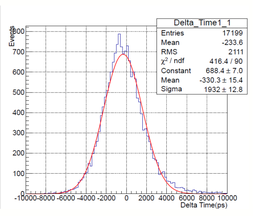
The experimental and simulated results show that the light collection efficiency in ED were affected by the scintillator, WLS fibers, PMT and the couplings among them, as well as the tyvek layer. Here, the number of photoelectrons(Npe) collected by DY1 could present the capability of ED.

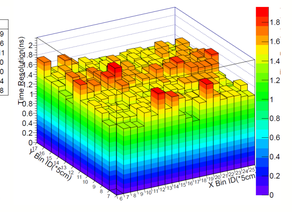
It shows that the mean Npe value is 20.2 for ED prototype in case of single particle events. There is a fine position uniformity of 9.9% in ED and WLS fibers of less than 7%. The differences among ED prototypes will be reduced by setting the suitable PMTs' gains.

2. Count Rate

The tested results present that the count rates of 640Hz for ED prototypes came from the distribution of the MIP signals (about 160Hz), environmental radiation (about 480Hz) and dark noise of PMT(<20Hz).

3. Time Resolution





Time resolution of prototype ED is 1.78ns with a good uniformity of ±0.2ns for different position. Time resolution is affect by three factors:

$$\sigma_{ED} = \sqrt{\sigma_{tile}^2 + \sigma_{PMT}^2 + \sigma_{TDC}^2}$$

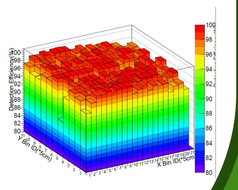
σ_{tile}: time fluctuation of photon collection process in scintillator tiles and WLS fibers

σ_{PMT}:TTS(300ps for 20pe) and CTTD(400ps)

σ_{TDC}:time resolution of TDC(480ps),time walking effect(700ps)

4. Detection Efficiency

The detection efficiency of ED prototype is better than 96% with PMT gain of 4*10^5 and the threshold of 1mV.



Acknowledgement

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Conclusion

The design of ED and its components have been presented. Detailed studies of the ED prototypes have been done, which shows that EDs' performances can reach the experimental requirements. The factors affected the performances also were studied in good precision with the appropriate telescopes system.