Lab report
E217 STYX

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This is abstract.

1. Introduction

2. Cosmic rays

Cosmic rays are a population of elementary particles and nuclei coming from outer space with several MeV to macroscopic energies ($\sim$ J). Energy spectra of cosmic rays follow a falling power-law (albeit with several small features) [1] [2]

$$N(E) \propto E^{-\gamma}$$

Cosmic rays of primary origin (i.e. directly from astrophysical sources without interactions) enter the earth atmosphere and they will produce the so-called secondary cosmic rays. Comparing the interaction lengths for hadronic and leptonic particles and atmosphere column density reveals that practically all cosmic rays at sea level are secondary [3]. All primary particles either interaction with air or decay depending on their energies. Essentially the atmosphere acts like a giant calorimeter and particle cascades are generated [3].

Most of primary cosmic rays consist of hydrogen atoms [2]. In fact, 85% are protons [3]. These protons produce mainly secondary pions and then kaons. In the end, at sea level most abundant particles with energy $> 1\,\text{GeV}$ are muons (and corresponding neutrinos) [1]. There is a rather important angle dependence of muon spectra because of competition between decay and interaction. At large zenith angle, muons can travel long distance in rare parts of the atmosphere and it leads to increased decay probability [3]. This can be parametrized as [3]

$$I_\mu(\theta) = I_\mu(\theta = 0) \cos^n \theta \tag{1}$$

with $n \approx 2$. Energetic particle will produce extensive shower in the atmosphere. This makes electrons and positrons quite abundant at sea level. They usually have pretty low energy, because of production mechanisms and energy losses [3].

3. setup

3.1. Individual components

Drift chamber is a type of gaseous ionization detector. As its name suggest, it detects ionizing particles by a electric field inside. When the gas atoms get ionized, the electron will transport to the anode and generate a signal. Especially near the anode wire, the electric field is so huge that the electron becomes ionizing itself and cause further discharge. This effect is called avalanche [4]. Obviously, number of ions collected at anode depends strongly on the voltage put between anode and cathode.

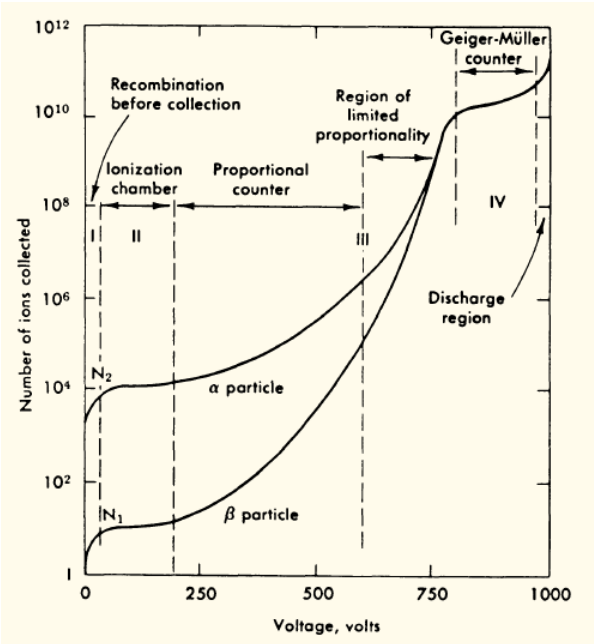

Figure 1: Example diagram of number of ions versus applied voltage in a single wire gas chamber [4]. Note that vertical axis is in logarithmic scale.

An exemplar development of number of ions with increasing voltage is shown in figure 1. In this setup, we essentially want to saturate the gas chamber (thus to region IV in figure 1) so that it can reliably count the ionizing particles regardless of their energy.

In this experiment, there are three drift chamber modules. In each of these, there are three layers of 88 straws [5].

Scintillator and PMT work as external trigger here. They together are able to convert ionizing particle into relatively low energy photons (scintillator), convert photon into electrons using photoelectric effect, and finally with electric field to multiply the number of electrons to generate visible signals [6]. Here two such detectors are used, one on top of the drift chamber and on below [5].

Shaper A shaper is a module which turns inputs pulse into logic signals of standard levels and fixed width [4].

TDC stands for Time-to-Digital Converter measures the time between two signals and gives the time difference of these two [4].

Coincidence unit determines if two or more logic signals overlap with each other within a preset time intervals and output signal if true and no signal if false. The present time is called resolving time. It can be implemented with a transmission gate or simply summing and passing through a discriminator [4].

3.2. Whole setup

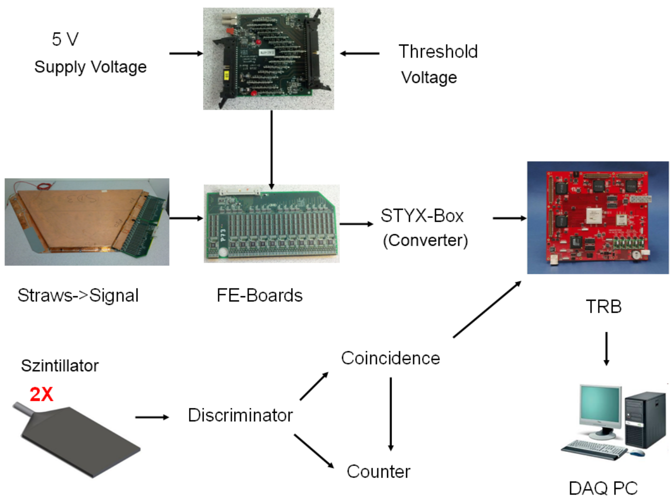

Figure 2: Schematics of the experiment setup [5].

Schematically the setup is like in figure 2. The front end boards (FE-boards) are attached to the straws. The boards contain amplifiers, shapers and discriminators, so that as long as input signal pass a set threshold, a logic signal is generated. The threshold voltage can be set on an external power supply. As for the trigger part, the signal will need to pass discriminators (to filter out noises) and goes to a coincidence unit. The coincidence unit makes sure that an event is only recorded when it flies through both scintillators. In the end, signals from straw modules and scintillator units go into TRB board and to the PC [5].

4. Voltage determination

- checked gas system is working
- PMT voltage diagram. Don't forget to compare the plot to the one in the setup.
- Include overlay and rate plots. In rate plots, it should go down. In overlay, with the right voltage, all pulses should has similar height. Just need to argue somehow why 2.0 is the right voltage.

5. Calibration

6. Analysis

7. Conclusion

A. Appendix

References

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