High Energy Electrons/Positrons and Gamma Rays Detector (TANSUO) of China

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Abstract: A detector that used to measure the high energy electrons/positrons and gamma rays in space will be presented. The readout system that could cover $10^5$ and a cosmic ray test results of a BGO matrix will be introduced.

Keywords: cosmic ray, high energy electron, TANSUO, readout system, BGO calorimeter

1 Introduction

TANSUO, the model we designed as shown in Fig. 1, is a high energy electrons/positrons and gamma rays detector. Some papers about this detector was introduced in reference [1-2]. TANSUO will be composed of 4 parts: a telescope (red part) and a BGO calorimeter (blue part) are shown in fig. 1, a silicon matrix above telescope and a neutron detector under calorimeter will be added in future. The BGO calorimeter will be composed of 576 BGO crystal bars. The size of each BGO bar is 2.5 cm * 2.5 cm * 30 cm. The BGO crystal bars form 12 layers with an area of about 60 cm * 60 cm each. In this paper, the electron and proton separation ability, the readout system and cosmic ray test results will be presented.

2 Detector

2.1 response to high energy electrons

The mean of energy deposition distributions and the energy resolution are shown in Figs. 2(a) and 2(b), respectively. The energy deposition is almost linear with the incident energy. The energy resolution varies from 0.2% to 1% below 10 TeV. The resolution degrades worse when the energy above TeV because of the energy leakage from back of the calorimeter.

2.2 separation ability

Because of the flux of protons is much more than electrons in space, so the main work is to separate electrons from protons. We use GEANT4 [3] software to simulate the response of detector to high energy electrons and protons, and then to separate them. The method to separate electrons and protons was introduced in reference [4]. The result was shown in Fig. 3. The black dot is proton and red one is electron. It is clear that as the layers increase, the separation ability increases too. From simulation result, the separation ability is up to $10^4$ while the electron detection efficiency is 98%.

2.3 readout system design

The energy upper limit is 10 TeV for electron. From simulation with GEANT4 codes, the maximum value of deposit energy in one crystal is about 1.7 TeV (see Figs. 4). Fig. 4(a) shows the 10 TeV electron energy distribution in each layer of calorimeter, Fig. 4(b) shows the mean maximum value of energy deposition in one BGO crystal bar is about 17% of incident kinetic energy (about 1.7 TeV). For identification of EM shower from hadron shower...
based on shower profile, the minimum measurable energy deposit per BGO bar down to 0.5 MIPs (about 11.5 MeV) is required. So the dynamic readout range from 0.5 MIPs to 1.7 TeV (about $7.4 \times 10^4$ MIPs) should be available. Hamamastu PMT R5611 coupled with a BGO bar is supposed to collect fluorescence. The signals output from three different dynodes 7, 4 and 1 (marked as D7, D4 and D1). The sketch was shown in Fig. 5. The FEE chip is VA32 which consists of 32 channels [5]. Linearity up to 12 pC could be reached. The relationships between D7/D4 and D4/D1 output channels are shown in Figs. 6(a) and 6(b), respectively. In order to cover $10^5$ dynamic range, the fluorescence of BGO crystal should be attenuated. We put a filter between BGO crystal and PMT entrance window to attenuate. The response of high gain channel to muons was shown in Fig. 7. It is clear that the signal could be separated from pedestal when it is about 20 fC. So we can set signal of 1 MIPs in 70 fC for high gain channel. That this readout system could cover dynamic range was shown in Table 1.

2.4 cosmic test system

We also set up a BGO matrix cosmic ray test system. The instrument was shown in Fig. 8. It composed of 24 BGO bars. There are 2 layers with area 30 * 30 cm$^2$ each. The response of each crystal to muons were shown in Fig. 10.

Figure 2: Energy dependent of (a) energy deposition and (b) energy resolution for electrons.

Figure 5: Sketch of readout system.

Figure 7: The response of high gain channel to cosmic rays after attenuate fluorescence.

Figure 8: BGO matrix cosmic ray test system.

3 Summary

We introduced the structure of detector that will be used to measured high energy electrons/positrons and gamma rays. The readout system was also presented here. Finally, a BGO matrix cosmic test system and test results were shown.

References

Figure 3: Separation ability of electron and protons in each layer of calorimeter.


Figure 4: Energy deposition in each layer (a) and maximum value in one BGO bar (b).

Figure 6: The relationship between different readout channels.

Table 1: dynamic range of readout system.

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<th></th>
<th>High gain channel</th>
<th>Medium gain channel</th>
<th>Low gain channel</th>
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<tbody>
<tr>
<td>Min (MIPs)</td>
<td>0.5</td>
<td>11</td>
<td>374</td>
</tr>
<tr>
<td>Max (MIPs)</td>
<td>171</td>
<td>3762</td>
<td>$1.3 \times 10^5$</td>
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Figure 9: Cosmic ray test results.