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A method of electromagnetic shower identification by using isolated bars with DAMPE BGO calorimeter

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Abstract: A method is proposed for electromagnetic-hadronic shower discrimination for DAMPE (DArk Matter Particle Explorer) 3D-imaging BGO electromagnetic calorimeter. The technique uses the isolated bars which are extracted by comparing to the adjacent bars in the same layer of the BGO calorimeter of DAMPE. It's found that, the energy distribution and location of isolated bars are sensitive to the nature of the incident particles. For electromagnetic showers, more than 96.6% isolated bars' energy less than 20MeV, as for protons, there is a peak between 20 and 40 MeV. While the deposited energy increasing for certain energy incidence, the location of isolated bars in hadronic showers become more and more similar to that of electromagnetic showers. Based on those properties, we illustrate a possible method to separate electromagnetic showers and hadronic showers.

Keywords: icrc2015, DAMPE, calorimeter, isolated bars, e/p discrimination

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1. Introduction

DAMPE (DArk Matter Particle Explorer) is one of the five scientific science missions approved by Chinese Academy my of Science in 2011[1], which aims at study of the spectra of gamma, electrons and positrons from cosmic radiation with high precision in the energy range between 5 GeV and 10 TeV. The detector of DAMPE[2] is detailed in Fig. 1. It consists of 4 sub-detectors, from top to bottom is plastic scintillator strips detector (PSD), silicon-tungsten tracker-converter (STK), BGO Electromagnetic CALorimeter (BGO ECAL) and neutron detector (NUD). The BGO ECAL is formed by 14 layers of BGO bars in a hodoscopic arrangement, each layer is composed of 22 BGO crystals. The lateral dimensions of single BGO crystal are 2.5 *2.5 cm^2 and the length is 60 cm. Thus the total depth of DAMPE BGO ECAL could reach as high as 31.25 X0 (radiation lengths), corresponding to 1.6 nuclear interaction lengths.

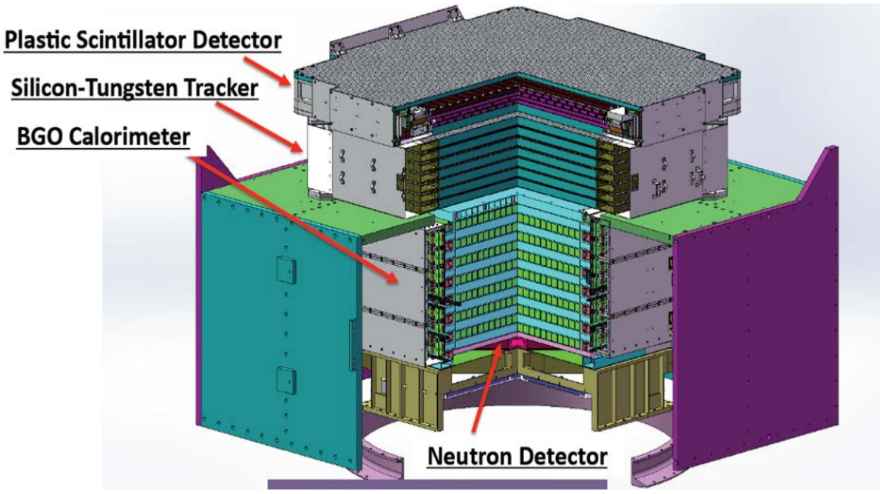

Fig. 1 DAMPE layout with the different sub-detectors

An accurate determination of the electrons plus positrons energy spectra allows to study the annihilation of Kaluza-Klein[3-5] dark matter particles. In order to achieve this goal, the capability of e/p separation of BGO ECAL is important. Based on Monte Carlo study, it's observed that the energy spectra and location of isolated bars are sensitive to the type of the incident particles. A possible particle identification method is illustrated using the properties of the isolated bars.

2. Method

The hadronic shower is much more complicated than electromagnetic shower, due to Pi^0 production and Pi^0 to gamma + gamma[6], the hadronic shower contains electromagnetic components. On the other hand, since the strong interaction between nuclei and hadron, the secondary hadrons will increase the transverse distance. The Fig. 2 shows the component of secondary particles in proton showers.

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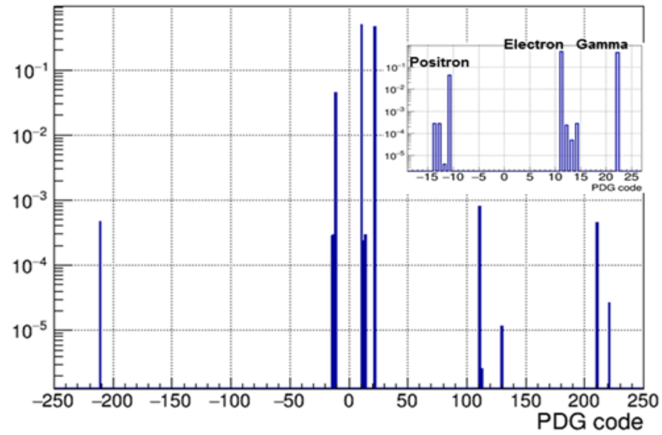

Fig.2. Components of secondary particles (400GeV proton, MC)

For one event, if one BGO bar is fired and the nearest two bars in the same layer have no signals, we call this bar is an isolated bar. The isolated bar number of single incident particle as shown in Fig. 3.

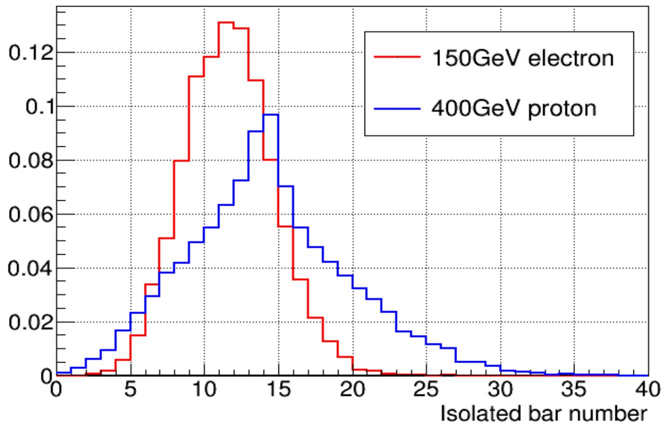

Fig.3 Isolated bar number of single event (10k MC events).
Noise cut 2.5 MeV. Energy cut of isolated bars 2.5 MeV to 200 MeV

The Fig.4 shows the energy spectra of isolated bars in different layers. Comparing to electron, there is a clearly peak around 25MeV of proton case, and more high energy (>30 MeV) isolated bars of proton shower.

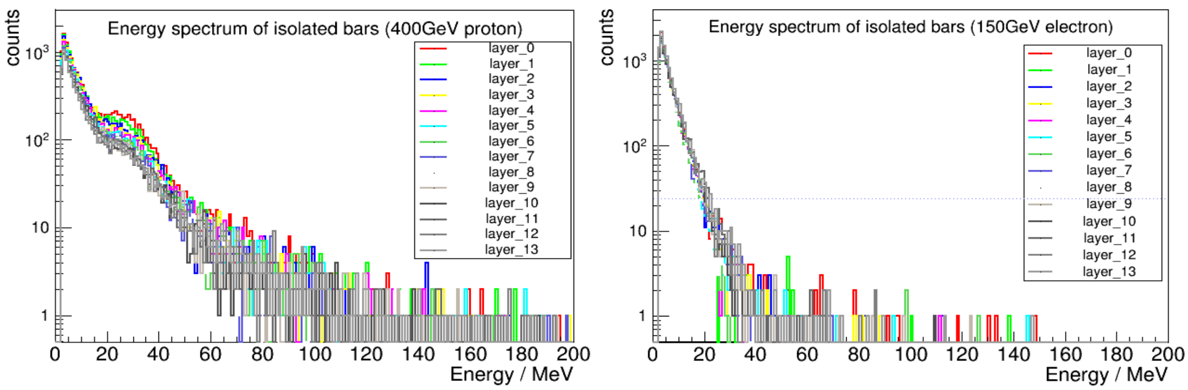

Fig.4 Energy spectrum of isolated bars of 400GeV proton and 150GeV electron

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3. Application

Based on the energy spectrum of isolated bars, we define:

R = (number of isolated bars which energy > 20 MeV) / (total isolated bar number) (1)

The Fig. 5 shows the separation ability of R value.

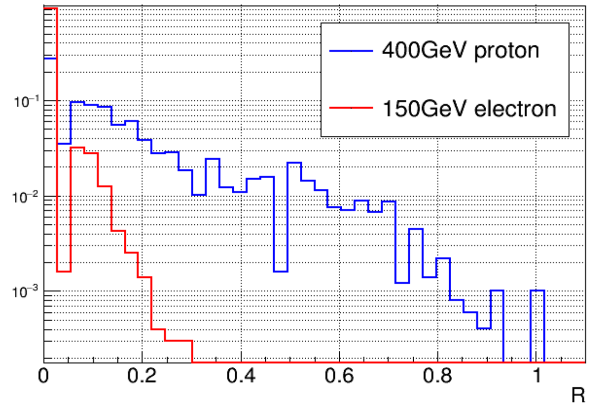

Fig.5 R value of 150GeV electron and 400GeV proton

The center of geometry (CoG) for each layer is calculated as:

$$X_{l_c} = \frac{\sum_{i=1}^{n} E_{l_i} X_{l_i}}{\sum_{i=1}^{n} E_{l_i}} \tag{2}$$

The distance to CoG of isolated bar is:

$$D_{l_i} = X_{l_i} - X_{l_c} \tag{3}$$

In Fig.6, we illustrate the D_{li} value versus layer ID of 150 GeV electron for both Monte Carlo and test beam data. The shape is almost the same and the gap of two color zones gives us the shower size clearly.

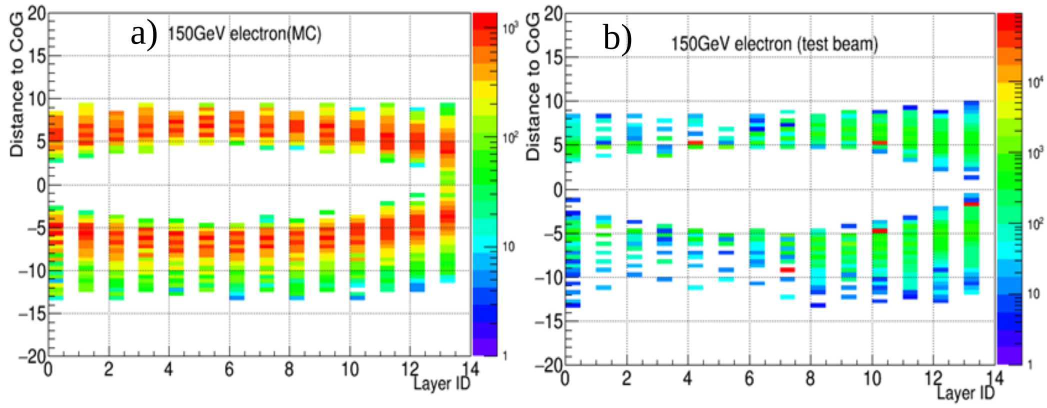

Fig.6 D value versus layer ID of 150 GeV electron

Since the deposited energy of incident hadron is a wide range spectrum. The development of D_{li} value along z axis depends on the deposited energy in BGO ECAL, as shown in Fig.7.

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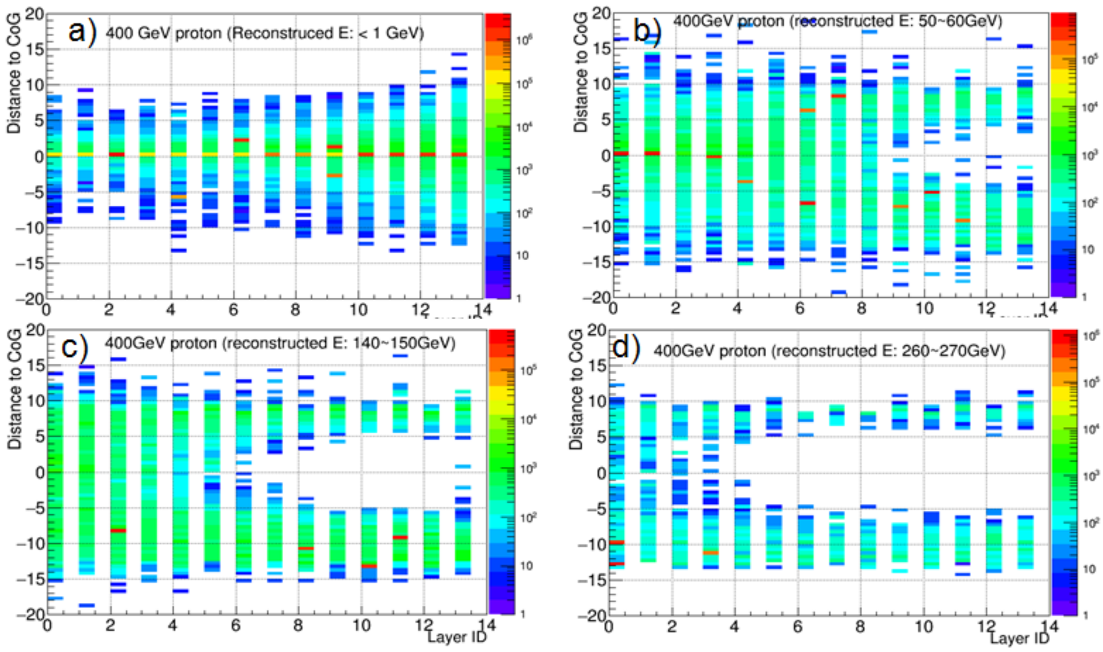

Fig. 7 D value versus layer ID of 400GeV proton. a) Reconstructed energy (0, 1)GeV. b) Reconstructed energy (50, 60) GeV. c) Reconstructed energy (140, 501) GeV. d) Reconstructed energy (260, 270) GeV

From Fig.6 and Fig.7, it's observed that the location of isolated bar is highly sensitive to the shower type. We construct two values based on absolute value of D_{li} to describe the difference of electromagnetic shower and hadronic shower:

$$\mathrm{RMS_D} = \frac{\sum_{l=0}^{13}\sum_{i=0}^{n_l}\left(|D_{l_i}|-\overline{|D|}\right)^2 * E_{l_i}}{\sum_{l=0}^{13}\sum_{i=0}^{n_l}E_{l_i}} \tag{4}$$

$$\mathrm{Sum_D} = \frac{\sum_{l=0}^{13}\sum_{i=0}^{n_l}|D_{l_i}| * E_{l_i}}{\sum_{l=0}^{13}\sum_{i=0}^{n_l}E_{l_i}} \tag{5}$$

Where:

$$\overline{|D|} = \frac{\sum_{l=0}^{13}\sum_{i=0}^{n_l}|D_{l_i}|}{\sum_{l=0}^{13}n_l} \tag{6}$$

The separation results as shown in Fig.8.

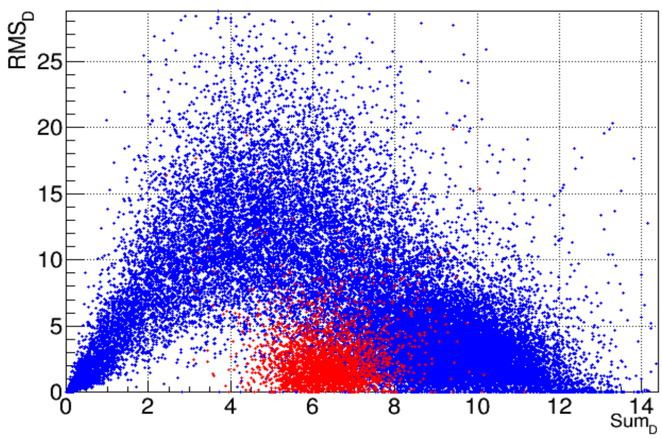

Fig. 8 $\mathrm{RMS_D}$ versus $\mathrm{Sum_D}$ (Red dots: 150GeV electron, blue dots: 400GeV proton)

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4. Summary

We investigated the characters of the isolated bars in DAMPE BGO ECAL by Monte Carlo data. It's observed that the location of the isolated bars is almost symmetry around the particle incidence direction, but the shape is difference for electromagnetic shower and hadronic shower. There are more high energy isolated bars in hadronic showers than electromagnetic showers. Based on the isolated bar properties, we constructed RMS_D and Sum_D and presented a possible e/p separation method.

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