Shower Difference between Electron and Proton in Simulation and Flight Data

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Abstract

Up to now, many projects need to observe high energy electrons above 100 GeV by using the difference of shower development between electron and proton. Monte Carlo simulation is very important in the instrument design and data analysis. The background suppression is strongly dependent on electron and proton shower development. This paper presents the difference of shower simulation between different code and the comparison of simulations with beam test and flight data.

1. Introduction

Because the shower development of electron and proton in calorimeter are quite different, many recent projects (BETS, PPB, ATIC, AMS, CALET) are designed to observe the 3-dimensional (3D) shower development in the detector of cosmic rays up to TeV. If the detector is deep enough, above 35 radiation length like CALET, the proton rejection power is about 10^6, and we can observe electron up to 10 TeV. For electron observation, Monte Carlo simulation is very important in the instrument design and data analysis. The background suppression is strongly dependent on the difference of electron and proton shower development. In this paper we use the Balloon-borne Electron Telescope with Scintillating Fibers (BETS) detector as an example to show the difference of shower simulation in different codes and the comparison to the flight data [1]. From comparison most reliable code is selected.

2. BETS detector

The BETS detector can record the image of 3D shower development in real time. It has enough imaging resolution to observe the details of shower starting points and lateral distribution. As a result, it is capable of selecting electron events from the background protons.

Figure 1 shows the schematic side view of the BETS. It is consisted of eight

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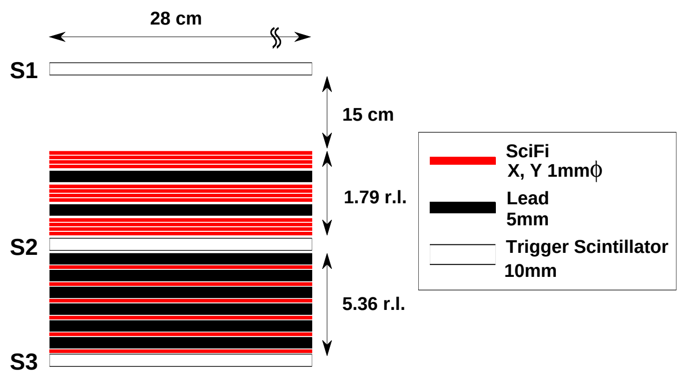

Fig. 1. Schematic configuration of the BET detector

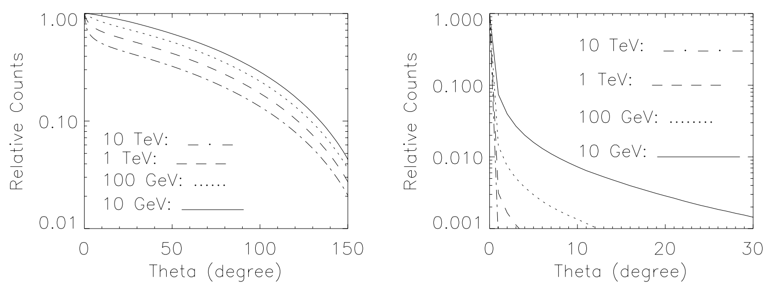

Fig. 2. The angular distribution of secondaries from P+Lead and electron+Lead interaction

lead plates, 5 mm (0.9 radiation length) thick each, nine belts of scintillating fibers and three plastic scintillators, 10 mm thick each. The plastic scintillators are used for event trigger and electron energy measurement, and the scintillating fibers are adopted for recording the 3D shower development in lead.

Figure 2 presents the angular distribution of secondary particles at the P-Pb interaction simulated by FLUKA2002. Table 1 shows the multiplicities and the median angles of the secondary particles. It can be seen that average lateral spread of electron-induced shower is much narrower than proton-induced one because of the wider spread of secondary particles in the P-Pb interaction. According to simulation and beam test, if the first interaction point of proton is within 1 radiation length from the top, the proton deposits about 1/3 of its total energy in BETS. The typical 50 GeV electron and 150 GeV proton shower image are shown in Fig.3. From the above results it can be seen that electron can be selected by the imaging analysis. According to the BETS analysis, we define a parameter RE to describe the shower, RE is the ratio of energy deposit within 5mm from the shower axis to the total [1].

Fig. 3. 50 GeV electron shower in X direction

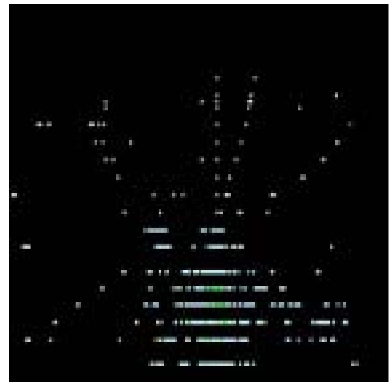

Fig. 4. 150 GeV proton shower in X direction

Table 1. Multiplicities, Angular Dependencies of p-Lead Nuclear Interaction

Energy(GeV)	10	100	10^3	10^4
multiplicity	43.8	67.0	101.	142.7
median angle [$deg.$]	69.6	56.4	36.5	13.5

3. BETS Flight Result and Comparision with Simulation

We set a trigger condition using the energy deposit information in the 3 plastic scinitillators which are arranged at the different depths in BETS calorimeter (see Fig. 1). According to CERN beam test and simulation result, the proton-rejection power is about 100 (heavier primary can not be triggered by the higher energy threshold in S1) at the trigger efficiency of electrons above 85% over 10 GeV. Only those protons which have the first interaction point is at the top of calorimeter can pass the trigger condition.

In 1997 and 1998, the BETS were launched twice at Sanriku Balloon Center in Japan. Since most of the backgrounds triggered during the flights were particles incident from the side of the detector. By image reconstruction of all events, only those events pass the following cuts can be selected.1). The shower axis passes through the top to the bottom in the region inside 20mm from the edge. 2). The zenith angle of the shower axis is less than 30 degree. 3). Particle charge is single. After these cuts, only a few percent events are survived. Figure 4 shows the RE distribution of the observed events which pass through all slection criteria. It is found that electron 'signal' can be easily selected.

Monte Carlo simulations were performed by using three different codes: GEANT321-FLUKA and GEANT-GHEISHA, and FLUKA2002 [2, 3]. An isotropic event geanerator was developed for the BETS geometry with particles incident from the upper hemisphere. According to beam test and simulation result [1],

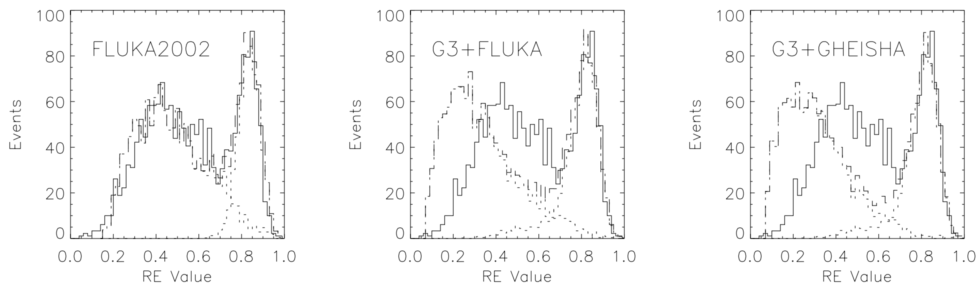

Fig. 5. The Observed RE distribution from the flight events at an altitude over 35km (solid line) and comparision with simulation, dotted line are protons ($\geq$ 10GeV) and electrons ($\geq$ 5 GeV), dashed line are expected results from simulation. Left: FLUKA2002, Middle: GEANT3 with FLUKA, Right: GEANT3 with GHEISHA

electron below 5 GeV and proton below 10 GeV can not satisfy the above trigger condition. After considering the corrections in the image reconstruction, the M.C.simulations compared with the flight data are shown in Fig.5. The proton ($\geq$ 10 GeV) and electron ($\geq$ 5 GeV) spectra are derived from published observation data [1]. It can seen that the result by FLUKA2002 agrees with the flight results very well, but GEANT3 can not explain the flight data. This conclusion is consistent with the ATIC simulation result by J. Chang in this volume.

4. Summary

By comparision between flight data and simulated results are presented in this paper, FLUKA2002 can explain BETS flight result very well both of electrons and protons.

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