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Effect of albedo particles on charge measurement

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Abstract: The balloon-borne Cosmic Ray Energetics And Mass (CREAM) experiment is designed to make direct measurements of high energy cosmic-ray particles at the top of the atmosphere. The Silicon Charge Detector (SCD) provides charge measurements of all primary particles from protons to iron nuclei. As the SCD is mounted above the calorimeter, albedo particles backscattered from the calorimeter are major background sources for charge measurements. The SCD with double layers of the silicon sensors in the calorimeter module was tested with high-energy electron and hadron beams at CERN in October 2006. The efficiency of the charge reconstruction is studied using the beam test data and GEANT based Monte Carlo simulation data. Effect of albedo particles on charge measurements is discussed in this paper.

Introduction

The CREAM [1, 2] is balloon-borne experiment designed for the direct measurement of high energy cosmic ray spectra from proton to iron nuclei. Detailed study on the elemental spectra with energy of $10^{11} \sim 10^{15}$eV is important to understand the flux change in the all particle spectrum where the rigidity-dependent supernova acceleration limit is predicted to be existed. The CREAM collected ~70 days of data with two successful flights [3].
The SCD was constructed for the charge measurements of primary particles with $1 \leq Z \leq 26$ [4]. Since the SCD is located on top of the calorimeter, albedo particles produced during the shower development in the calorimeter are the major background sources.
A dual layer SCD used in the second flight of CREAM was recovered successfully. After the refurbishment, the SCD assembled with the calorimeter module was tested with high-energy electron and hadron beams at CERN in October 2006. The efficiency of the charge reconstruction has been studied using the beam test data and GEANT based simulation data.
A preliminary study on the effects of albedo particles on charge measurements will be discussed.

Silicon Charge Detector

In order to minimize miss-identification of charge by the secondary particles, SCD was comprised of fine silicon pad sensors. Total active area of SCD layer was covered with 2912 silicon sensors segmented in 2.1cm^2. Dual layer of the SCD containing 4992 pixels was constructed for the second flight of CREAM [5]. The typical leakage current was measured to be 3.5 nA at operating bias voltage of 100 V.

Beam Test

For the beam test, refurbished SCD was assembled on the surface of graphite target located above calorimeter [6]. Two different triggers were prepared from the non-flight DAQ system - one for the pedestal measurement and another for the beam trigger [7]. By using the rotation fixture and movable table, the active area of SCD was scanned over the channels for the calibration. The average signal to noise (S/N) ratio in the SCD was measured to be 7.0 [8]. Also data to study the effect of backscattered particle were collected with long exposure time. In this paper, analysis with charged pion particles will be discussed.

Simulation setup

The Monte Carlo simulation is carried out to study the efficiency of charge selection algorithm and influence from the other processes than the energy deposition of incident primary particles. A simple model of CREAM-III beam test was constructed with GEANT4 simulation package [9]. The main purpose of the simulation study is to estimate the influence of secondary particles to the charge identification in the SCD.

In the current simulation model, simple geometry of beam test set up is included. From the upstream, plastic scintillation counters as the beam trigger, silicon beam trackers [10], and CREAM-III beam test apparatus are included. CREAM-III beam test apparatus is comprised of dual layers of silicon sensor with aluminum plates, two graphite targets and 20 layers of tungsten plate in calorimeter. The details of detector such as electronics, mechanical supporters, and tilting angle (less than 4 degree) of silicon sensor were ignored.

Total energy deposition in each pixel sensor from different processes is saved per event. To identify the energy deposition by primary (beam) particles from the secondary particles, the information of particles is recorded per each step. Flags are categorized in 3 different classes – primary particle, secondary particle with positive momentum (same direction with primary particle), and secondary particle with negative momentum (opposite direction with primary particle). Secondary particles with negative momentum passing through the silicon sensor are defined as backscattered particles.

Incident beam in the simulation is set to be as point source. The position of beam is determined from the real beam data.

The most probable value of distribution in the simulation data is compared with real data to convert deposited energy to ADC count. Based on this conversion factor, electronics noise of each channel is added by using the standard deviation value of pedestal events collected from real instrument during the beam test. Electronics noise is generated as Gaussian distribution with a random number generator.

Following the same charge selection algorithm with real data, maximum signal in the SCD plane is selected per event for the test of simulation model. In Fig.1, the result of the selection is compared with the energy deposition of primary particle. It is shown that the simulation produces the secondary particles which give higher signal than primary particle.

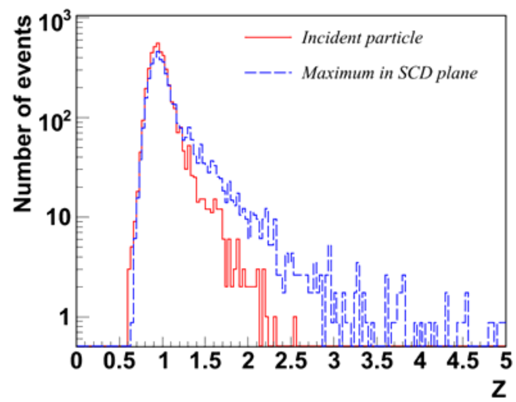

Figure 1: Simulated charge distribution in the SCD with 150 GeV pion injections. Data from incident particles (line) and maximum signals in SCD plane (broken line) were plotted.

Data analysis

If the energy deposition by the primary particle is the only physical process, selecting the maximum signal in the SCD plane would give the information of incident particle. In the real condition, however, secondary particles with low momentum or with large angle such as particles produced in front of the SCD or back-scattered particles could make bigger signal in the SCD.

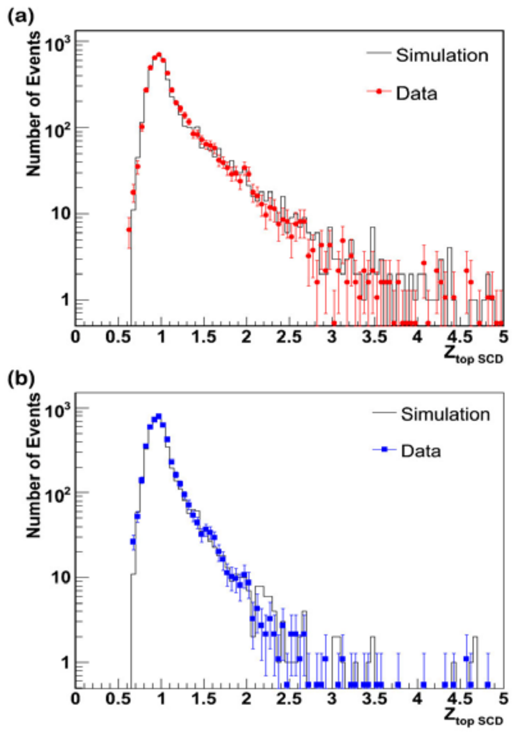

Figure 2: Comparison between simulation and real data. (a) maximum in SCD plane (b) maximum in a 5 × 5 pixel area around the hit position.

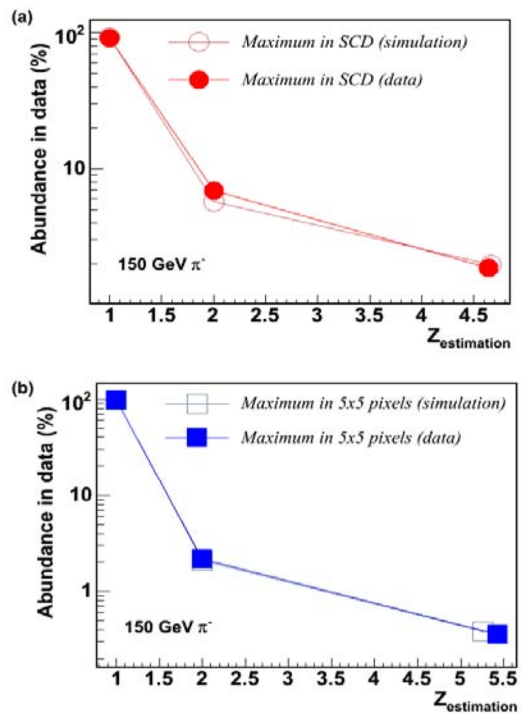

Figure 3: Percentage of charge identification in a 150 GeV pion run with (a) maximum signals in the SCD plane (b) maximum signals in a 5 × 5 pixel array around hit position.

To check the influence of these secondary particles, the maximum signal in the selected area of the SCD is estimated in the simulation and real data. For the study, 150 GeV pion data were used. During the analysis, noisy sensors defined by the large standard deviation in the pedestal runs are eliminated because their broad Gaussian tail can be faked as maximum.
If the hit position is known, the probability to collect primary particles by the maximum selection algorithm would be increased around the hit position. Maximum signal selection in a 5 × 5 pixel area covering 25 pixel sensors around the hit position is compared with the selection in the whole SCD plane. Hit position in the real data is defined as a channel which has largest number of hits above pedestal value in the all beam triggered events. The comparison between simulation data and real data in each case is shown in Fig. 2. Maximum signals in the SCD plane shows a bigger tail in the region of Z>1 by the influence of secondary particles.

Charge identification with SCD

To estimate the influence of secondary particles in the charge identification of the SCD, it is necessary to define the charge selection method. In this study, particles with Z <1.7 is defined as Z=1 particle.
Because the energy deposition of low charged particles in a thin material follows the Landau distribution, the tail of primary particles' distribution can be larger than Z=1.7 which will be identified as Z=2 in the current charge definition. According to the simulation data shown in Fig. 1, ~ 2% of primary particles can be identified as Z=2 with one layer of SCD measurement.
In Fig. 3, the percentage of miss-identification with maximum selection algorithm in different region is shown. 1.7≤ Z <2.7 is defined as Z=2 particle. For the events with Z≥2.7, the average charge is calculated.
The production of backscattering particle will increase as the energy of incident particle in-

creases. The probability of miss-identification in charge information is shown in Fig. 4 with different incident energy.

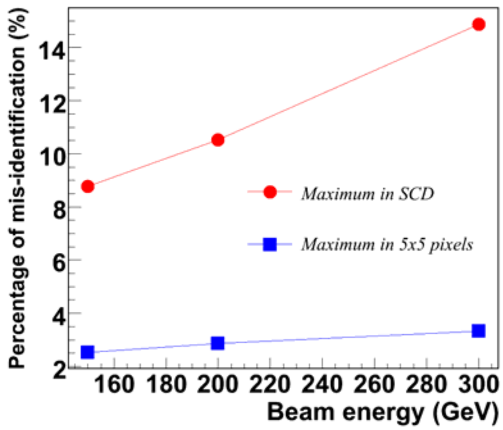

Figure 4: Energy dependence of charge mis-identification probability is plotted for maximum signals of the SCD plane and for maximum signals in a 5×5 pixel array around the hit position

Conclusion

Influence of secondary particles in charge measurement was studied with beam test and simulated data.

When the hit position in the SCD was known within 5 pixel area, ~ 3% of charge mis-identification was occurred with the injection of 150 GeV pion beam. ~ 2% of mis-identification was originated from the characteristics of Landau distribution of energy loss in a thin material. The probability of mis-identification showed energy dependence up to 300 GeV.

Further study as well as the improvement on the simulation model is going to be done. Expansion of this study would help to understand the flight data with high energy cosmic ray particles.

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References

[1] E.S. Seo et al., Adv. in Space Res., vol. 33, no. 10, 1777-1785, 2004
[2] H.S. Ahn et al.: The Cosmic Ray Energetics And Mass (CREAM) Instrument, Nucl. Instr. Meth. A, in press, 2007
[3] E.S. Seo et al., Adv. in Space Res., in press. 2007
[4] I.H. Park et al. : Silicon charge detector for the CREAM experiment, Nucl. Instrum. Methods A, 570, 286-291, 2007
[5] S. Nam et al.: Performance of a Dual Layer Silicon Charge Detector during CREAM Balloon Flights, Proc. of IEEE, submitted, 2006
[6] M.H. Lee et al : the CREAM-III calorimeter. Porc. of the 20th Int. Cosmic. Ray. Conf. Merida, 2007
[7] J.H. Yoo et al: Improved Data Acquisition System for CREAM-III, Proc. of the 20th Int. Cosmic. Ray. Conf., Merida, 2007
[8] N.H. Park et al., Proc. of the 11th VCI conference, Vienna, submitted, 2007
[9] S. Agostinelli et al., Nucl. Inst. & Meth. A, 506, 250-303, 2003
[10] J.H. Han et al.: Construction and Performance of a Silicon Beam Tracker, Proc. of the 20th Int. Cosmic. Ray. Conf., Merida, 2007