

Positron identification on proton background using combined detector data for PAMELA experiment

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Abstract. On the base of Monte-Carlo simulation of PAMELA experiment detection of charge particles the possibility to increase the positron to proton discrimination ratio using the correlation of responses of electromagnetic calorimeter and leakage scintillation detector is shown. This method allows to achieve proton discrimination factor of some hundred times.

Keywords: proton rejection, method, calorimeter

I. INTRODUCTION

The PAMELA space experiment [1] housed on board Russian Resurs DK satellite which was launched on June 2006. Its main task is a study of the antimatter component of the cosmic radiation. The quasipolar orbit (71 degrees) allows PAMELA to investigate a wide ranges of energies for antiprotons (80 MeV - 190 GeV) and positrons (50 MeV - 270 GeV) [2]. The central part of apparatus is a magnetic spectrometer consisting of permanent magnet and a silicon tracking system. The magnetic spectrometer is used to determine the sign of the electric charge and the rigidity of particles. The Time-of-Flight system comprises 6 layers of fast plastic scintillators arranged in three double planes. The sampling electromagnetic calorimeter [3] comprises 44 silicon planes interleaved with 22 plates of tungsten absorber. The total depth of the calorimeter is 16.3 radiation length. The one of main goals of the calorimeter is to select positrons and antiprotons from background of particles with the same charge which are significantly more abundant [4]. The leakage scintillation detector S4 placed below the calorimeter. The neutron detector ND is located below S4. The sensitive elements in the ND are the ³He neutron proportional counters. ND and S4 complement the electron-proton discrimination capabilities of the calorimeter [5].

Protons and electrons dominate the positively and negatively charged components of the cosmic radiation, respectively. Positrons must be identified at a background of protons that increases from about 10³ times the positron component at 1 GeV/c to about 5×10³ at 10 GeV/c and antiprotons at a background of electrons that decreases from about 5×10³ times the antiproton component at 1 GeV/c to less than 10² times above 10 GeV/c. This means that the PAMELA system has to separate electrons from hadrons at a level of 10⁵÷10⁶. Main part of this separation must be provided by the calorimeter, i.e. electrons have to be selected with an

acceptable efficiency and with as small hadron contamination as possible [6].

However, in certain cases it is necessary to improve separation level. The ability S4 to distinguish between electrons (positrons) and hadrons has been studied using particle beam tests and Monte-Carlo simulations. On the base of these investigations new method of positron identification on proton background for PAMELA experiment was developed.

II. ELECTRON-HADRON SEPARATION

As a rule in experiment Pamela one use of a simple variable, such as total energy deposited Q_{tot} in calorimeter to separate electrons and protons [7,8]. For incident hadrons of a given energy, the distribution of total energy deposited in the calorimeter is essentially flat with a sharp peak at low energies for non-interacting hadrons. For electrons, the total energy deposited in the calorimeter for a given incident energy is normally distributed, as long as most of the showers is contained inside calorimeter. Thus one can find total energy deposited threshold for each fixed incident energy to identify protons and electrons. For higher electron energies, a tail to low energies can, however, decrease the efficiency for electron identification. The use of this variable is illustrated in Fig. 1 where the total energy deposited by 67504 protons and 3342 electrons at 50 GeV/c of momentum are shown. After a threshold placed at 7300 mip (where 1 mip is the energy deposited by a minimum ionizing particle) 14 protons (99.98% reduction) and 3197 electrons (4.3% reduction) remain [9]. Though it turns out that using two-dimensional cut is more effective, when the value of calorimeter energy deposition linearly depends on the value of S4 energy deposition. The total deposited energy in calorimeter Q_{tot} dependence of S4 signal E_{S4} shown in Fig.2 for primary particles with energy 50 GeV and 100 GeV. It could be seen that proton and electron events are located in different strict zone. It gives possibility to select electron events from proton ones. Such dependence was plotted for varied value of primary particle energy E . For proton-electron rejection the definition of threshold curve was carried out to these dependencies and its behaviour is defined as:

$$Q_{tot} = A(E) \times E_{S4} + B(E) \quad (1)$$

TABLE I: The comparison results from two different methods.

Energy, GeV	Number of protons	Number of electrons	Efficiency (a)	Rejection (a)	Efficiency (b)	Rejection (b)
50	5000	651	99.85%	2×10^{-4}	98.92%	2×10^{-4}
100	6000	565	99.29%	5×10^{-4}	97.88%	7.7×10^{-4}
400	5000	635	98.89%	1×10^{-3}	95.9%	4.5×10^{-4}
1000	2566	387	99.48%	1.2×10^{-3}	96.64%	5.6×10^{-4}

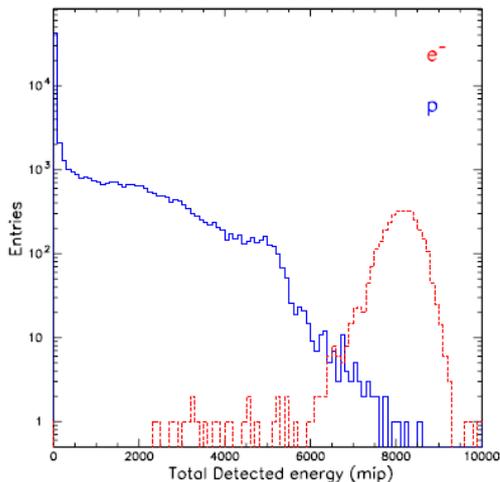


Fig. 1: Electron–proton separation using a simple total deposited energy variable. The test beam data were collected for particles of momentum 50 GeV/c.

where:

$$A(E) = -0.76 + 0.05 \times \ln(E - 15.5) \quad (2)$$

$$B(E) = 163 + 14 \times E^2 \quad (3)$$

and E in GeV.

In table 1 shown comparison results obtained from described method (a) and method which used Q_{tot} only (b). Efficiency is fraction of electrons after cut, rejection is ratio of number protons after cut to primary proton number. It appears from this table that use S4 give the best results.

This method based on using both Q_{tot} and E_{S4} was applied to beam test data. The results of such analyze were similar to ones from Monte-Carlo data. In addition one can use ND to separate electrons and protons and then number of remaining protons will become half as much.

III. CONCLUSION

The method of positron identification on proton background with electromagnetic calorimeter and bottom leakage scintillation detector of PAMELA instrument was developed using simulation data. This method based on value of total deposit energy in calorimeter and S4 signal. The electron efficiency (by several percents) and proton rejection (by an order of magnitude) in this case

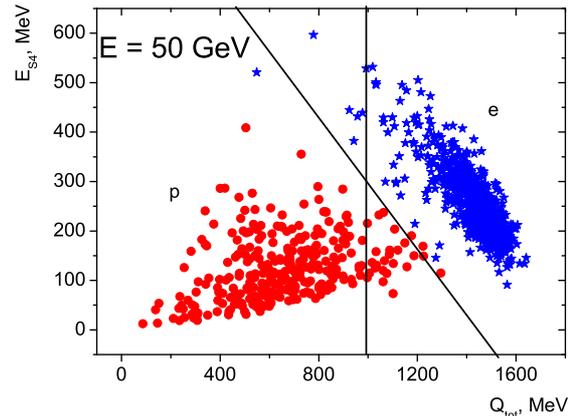


Fig. 2: Electron–proton separation using a total deposited energy variable and signal from S4. Slant line correspond to two–dimension threshold, straight line correspond to one–dimension threshold for Q_{tot} only.

is better than in case using only total energy deposited in calorimeter.

IV. ACKNOWLEDGMENTS

This work was partially supported by RFBR (grant #07-02-000922a). The authors thanks for help NtSOMZ and TsKB Progress.

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