Solar Particle Events Observation Capabilities Of PAMELA Experiment

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Abstract

PAMELA is a satellite borne experiment to be launched in low Earth orbit on board of the ResursDK1 Russian satellite in the early of the year 2003. It consists of a permanent magnet core, a Transition Radiation Detector, a Time of flight system and a Silicon Tungsten tracking calorimeter. Its main aim is the investigation of the cosmic radiation: origin and evolution of matter in the galaxy, search for antimatter and dark matter of cosmological significance, understanding of origin and acceleration of relativistic particles in the galaxy. The detector can however be used also to address issues relative to the solar - terrestrial environment (above 50 MeV) such as Solar particle events (isotopic composition of H and He, e- and e+ spectrum) and composition and temporal dependence of the trapped and albedo particle component. In this work we will describe the observational capabilities of PAMELA in presence of solar particle events.

1. Introduction

The Pamela spectrometer[1] will be launched in a semi-polar (70.4^o inclination) orbit (altitude between 300 and 600 km) in the first half of year 2004. Its expected lifetime will be 3 years. The primary scientific objectives of Pamela are:

- Measure of the energy spectrum of antiprotons (80 MeV - 190 GeV) and positrons (50 MeV - 270 GeV).
- Measure of the proton (80 MeV - 700 GeV), electron (50 GeV - 2 TeV) and ligtt nuclei(up to several hundred of GeV/n).
- Measure of the antihelium/helium ratio with sensitivity of at least 10^{-7}.

To achieve these goals, the instrument uses a permanent (0.4 T) magnet with six layers of double-sided silicon microstrip detectors to measure particle rigidity and sign. Lepton/Hadron identification is ensure by a Transition Radiation Detector (TRD) located on top of the magnet and a Silicon-Tungsten Calorimeter (44 planes; 16.3 Rad. Len.). Trigger and albedo particle rejection is

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given by a series of scintillator counters placed on top of the detector, above the magnet and below it. Detailed description of the device are given elsewhere at this conference; in this work we focus mainly on the observational capabilities of Pamela in respect to solar particle events.

2. Solar Particle Events

The launch of Pamela is expected in the first half of 2004, that is about 4 years from the last solar maximum (Sept. 2000). The number of solar proton events can be estimated from [8]: taking into account our minimum energy acceptance of 80 MeV we expect about 10 significant events during Pamela lifetime. The background rate of particles on the topmost scintillator could be very high for intense events; therefore a dedicated trigger for Solar active days is currently under study.

- Measurement of the positron component. Positrons have up to now only been measured indirectly by remote sensing of the 511 eV gamma ray annihilation line. Using the magnetic spectrometer it will be possible to separately analyze the high energy tail of electron and positron spectra.

- Proton component. Pamela can measure the energy spectrum of solar protons in a very wide energy range (from 80 MeV to some GeV). These measurements will be correlated with other instruments placed in different points of the magnetosphere to give information on the acceleration and propagation mechanisms of SEP events. Up to now there has been no direct measurement[2] of the high energy ($> 1GeV$) proton component of SEPs. The importance of a direct measurement of this spectrum is related to the fact [3] that there are many events where the energy of protons is above the highest ($\simeq 100MeV$) detectable energy range of current spacecrafts but is below the detection threshold of ground Neutron Monitors. However [3], at these energies is possible to examine the turnover of the spectrum, where we find the limit acceleration processes at the Sun. Pamela has a maximum trigger rate of 100 Hz and a geometrical factor of 20.5 $cm^2\ sr$. This implies that we will be able to read all events with a integral flux ($E > 80MeV$) up to $4p/cm^2\ s\ sr$). For such events we expect about 2×10^6 events/day (assuming a spectral index of $\gamma = 3$ we have 2×10^3 events/day above 1 GeV). Larger events saturate the trigger, so the number of protons will be of the order mentioned or lower due to dead time. In Fig. 1 are shown Pamela energy range of acceptance compared with the spectra of several events [6].

- Nuclear component. The same arguments of the proton component can be applied to the study of the heavy nuclei component of SEP events. We expect $\simeq 10^4$ ^4He events and $\simeq 10^2$ ^3He nuclei for gradual events and more for impulsive ones. This statistics will allow to examine in detail the amount of the ^3He and understand selective nuclear enhancement processes in the high energy range of impulsive [7] events to gather information on the selective acceleration processes.

- Lowering of the geomagnetic cutoff. The high inclination orbit of the satellite Resource will allow to study [9,10] the variations of cosmic ray geomagnetic cutoff due to the interaction of the solar particle event with the geomagnetic field.

3. Jovian protons

It has been supposed [4,5] that Jupiter could be a source of high energy protons (in addition to the well known electron flux) of energies up to 30 GeV. The protons could be accelerated through non stationary processes in the magnetosphere; a part of these protons are supposed to propagate through the interplanetary magnetic field and reach the Earth if both planets are on the same field line. This alignment will occur once per year (one Earth revolution) but in different locations due to Jupiter's own revolution around the Sun. During this period, it is expected to see an increase of the Galactic proton component. Within the expected lifetime of Pamela it will be therefore possible to measure the presence and magnitude of this effect at least three times.

4. Conclusions

We have shown some observational capabilities of Pamela in respect of Solar particle events and other heliospheric processes. In addition also Solar modulation at 1 AU and secondary particle production in the atmosphere will be studied in parallel to the main physics objectives of this experiment.

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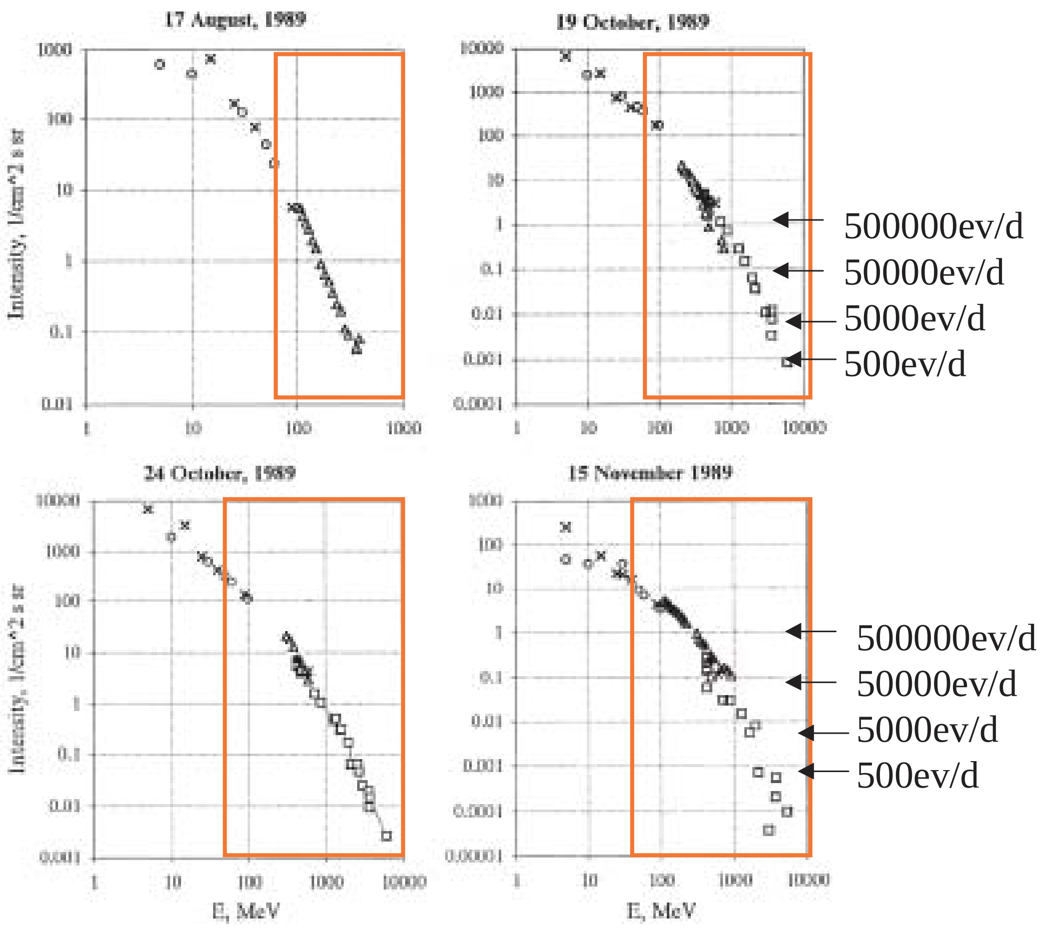

Fig. 1. Integral spectra of protons for some SPE (from [6]). Data are from Meteor (crosses), GOES (open circles), IMP (Shadowed circles), Balloon (triangles), Neutron Monitor (squares). The framed area is Pamela energy range of detection. Some estimates on the expected number of events is also shown. Note that some events are very large and thus the probability of occurrence is small.