

Solar Energetic Particle Studies with PAMELA

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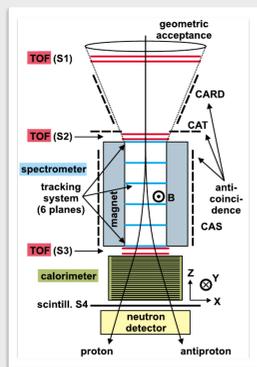
Introduction

Abstract

PAMELA presents a unique opportunity to study the highest energy SEP events. It spans the energy or rigidity range between the highest data channel of ACE or GOES and neutron monitors. Furthermore, it measures electrons, positrons, ³He and ions, up to and including carbon. The 2012 March 7 event was a strong gamma emitter and produced energetic ions just short of the neutron monitor threshold, i.e., it was not a GLE. However, PAMELA has the opportunity to see where the SEP spectrum rolls off, important for exploring the limits of the acceleration processes at play in the Sun. We also present preliminary results on the event-average composition. The 2012 May 17 GLE represents a fundamentally different opportunity, because neither the flare nor the CME is of a nature that would suggest an associated GLE. Because the particle event was impulsive, the PAMELA data allow us to closely examine the velocity dispersion characteristics of the event as well as allowing us to place the heliographic origin of the particles in altitude. We present the rigidity resolved intensity histories as well as the net composition of the particles at the highest energies.

PAMELA—Mission and Instrument A PAYLOAD FOR ANTIMATTER EXPLORATION AND LIGHT NUCLEI ASTROPHYSICS

- 71° inclination
- 350-610 km altitude
- Objective: to study galactic cosmic rays $-1 < Z < 6$ ions, positrons, electrons and light isotopes (D, ³He)
- Launch 2006 June 15
- Proton Energy Range 200 MeV (0.64 MV) to >100 GeV
- Zenith pointed with directional capability for particles



Schematic of PAMELA illustrating a proton/antiproton track.

Important PAMELA specifics

- Bridges energy gap between GOES/ ACE and neutron monitors
- Measures composition at neutron monitor energies
- Can search for presence of solar positrons
- Measures electron spectrum

PAMELA Solar/SEP science

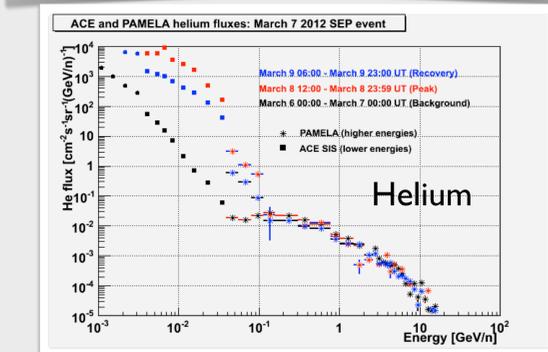
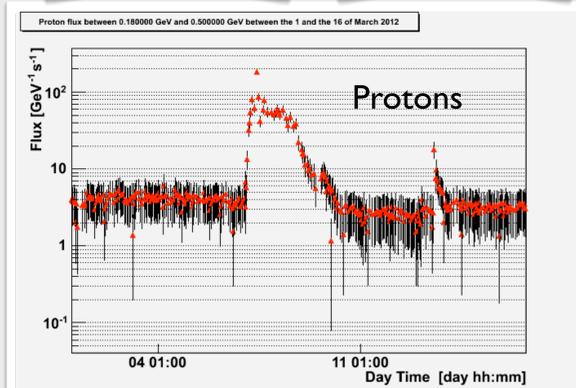
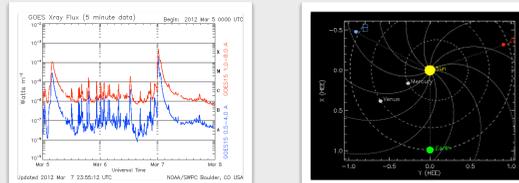
In the remainder of the poster we present examples of the types of science that can be performed with PAMELA. The data from 2012 is rich in the breadth of particle measurements that can be conducted with PAMELA with or without supporting data from other spacecraft or neutron monitors. See the poster by de Nolfo et al. for a more in-depth look at a single event. Two such important events include the 2012 May 17 GLE and the 2012 March 7. They are important for different reasons and illustrate different science.

With the recent flurry of solar activity, analysis on several events has just begun. Shown are snapshots of new observations and measurements

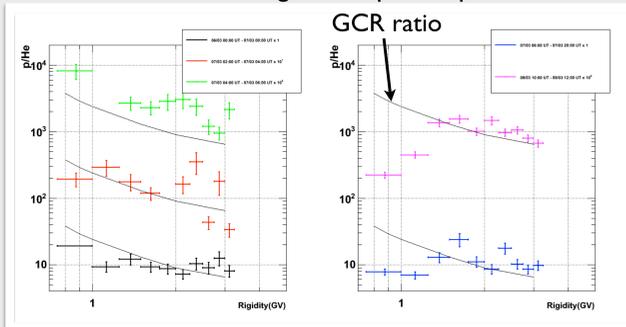
2012 March 7

Diffusive Energetic Events: East hemisphere events

For a diffusive event, we have as an example that of 2012 March 7. The active region was located at N18E31. The accompanying flare was an X5.4 and was observed by FERMI (see poster by de Nolfo et al., this meeting). Being on the east it was a slowly rising (6 hr), long duration event.



Bridges energy range between s/c and neutron monitors while measuring minor species spectra



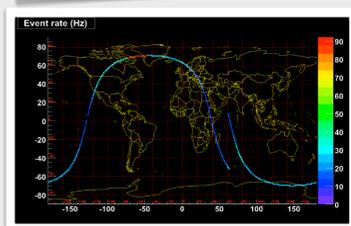
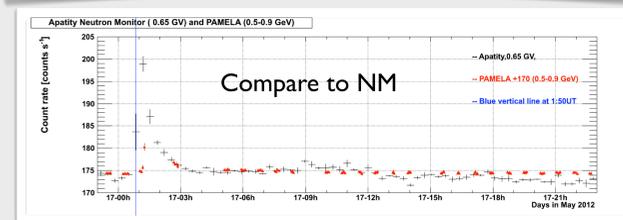
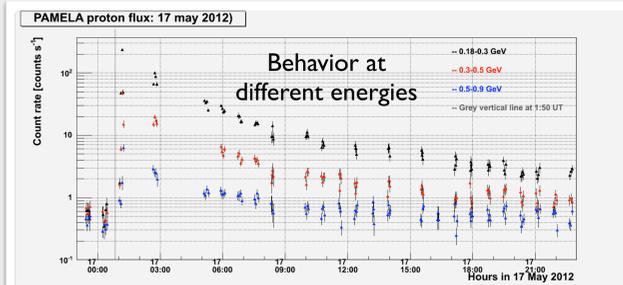
p/He ratio No major deviation from CR p/He ratio

2012 May 17

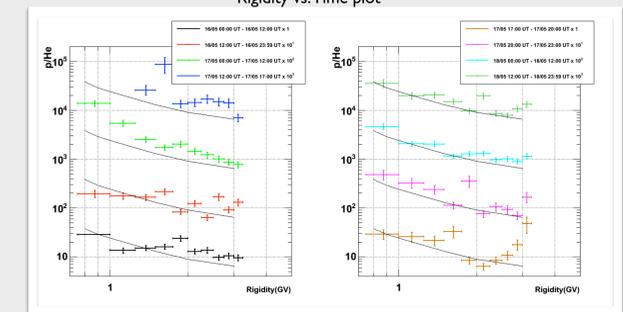
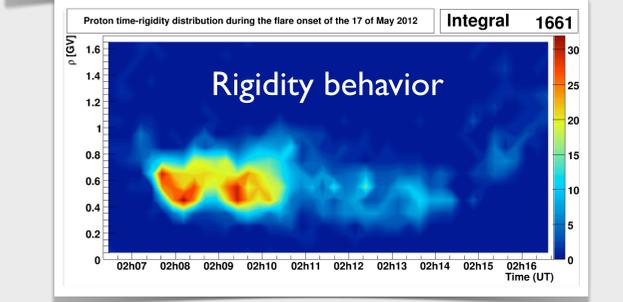
Well connected impulsive particle event

First GLE in six years and **first with high-energy γ observations to test the flare origin of GLEs.**

M5.1 event, N07W88, ~1200 km-s⁻¹ CME



Well positioned to catch onset and peak. Onset appears to be slightly later than Apatity, but can time the onset to ~1 min.



p/He ratio Deserves greater study, but no major deviation of p/He from that of GCR at high energies

Potential Future Studies

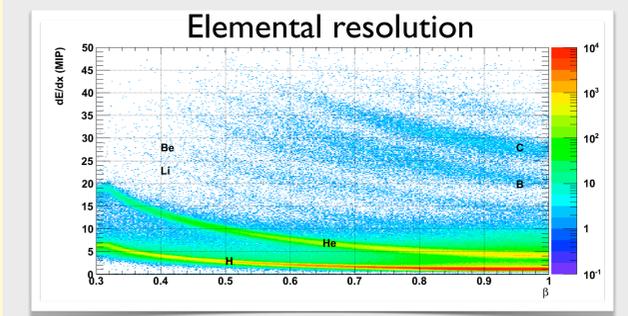
Electrons/Positrons

Electrons: Primary electron measurements at the high energies of PAMELA simultaneous with ion measurements would be a unique opportunity. Only cursory inspections on SEP data have been performed. Any electron measurement could be compared to γ -ray continuum measurements above 10 MeV and with μ -wave or sub-mm observations.

Positrons: Positrons are a significant by-product of nuclear processes in the low corona. Their presence is unambiguously revealed in the annihilation-line radiation. The detection of energetic positrons would be a clear signature of the flare origin of GLE particles. Their numbers would be of the same magnitude as solar neutrons. They are not present in the ISM nor are they easily produced in significant numbers by high-energy solar particles.

Composition

Composition has been a telling and critical component in studies of SEPs and the associated acceleration processes and scenarios. PAMELA is capable of taking composition studies into the GeV range. One would search for anomalies in the abundance of He and C. Below is the discrimination capabilities as demonstrated on Galactic Cosmic Rays, where the abundances are similarly useful in studies of their origin.



Light Isotope measurements

Shown below is a helium mass histogram from an inspection of the 2012 March 7 event. The detection of an elevated ³He abundance at high energies would suggest a low corona origin of GLE particles. No such search has yet been conducted comprehensively or conclusively on the PAMELA data. The ³He signal shown below is not inconsistent with corresponding measurement with ULEIS. This is work in progress.

