Extending the Galactic Cosmic-Ray electron + positron spectrum with the Fermi LAT

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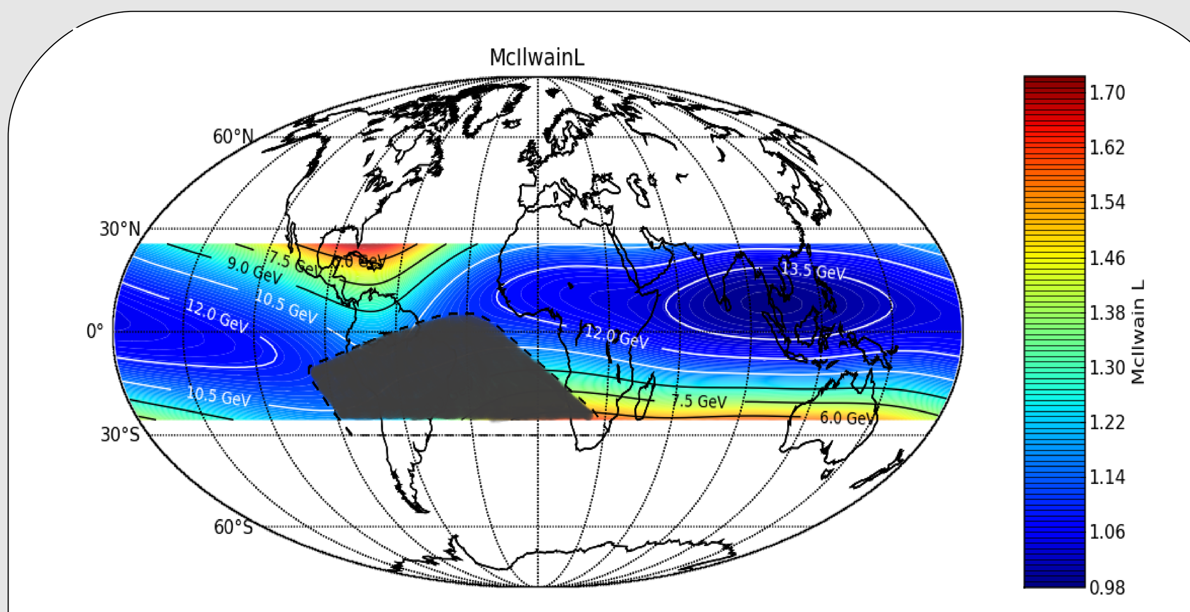
Abstract

Launched on the 11th of June 2008, the Fermi Large Area Telescope (LAT) has made several outstanding scientific contributions to the high energy astrophysics community. One of these contributions was the high statistics measurement of the Galactic Cosmic Ray (GCR) electron + positron spectrum from 20 GeV to 1 TeV.
The Fermi satellite is in a nearly circular orbit with an inclination of 25.6 degrees at an altitude of 565 km. Given this orbit it is possible to measure the GCR electrons + positrons down to ~5 GeV. However, this lower limit in energy is highly dependent on the orbital position of the LAT in geomagnetic coordinates due to the rigidity cutoff. In order to measure the spectrum down to these energies it is necessary to sample the population of electrons + positrons in several different geomagnetic positions. In this poster we present the analysis performed to extend the lower limit in energy of the GCR electron + positron spectrum measured by the Fermi LAT.

The Geomagnetic Environment

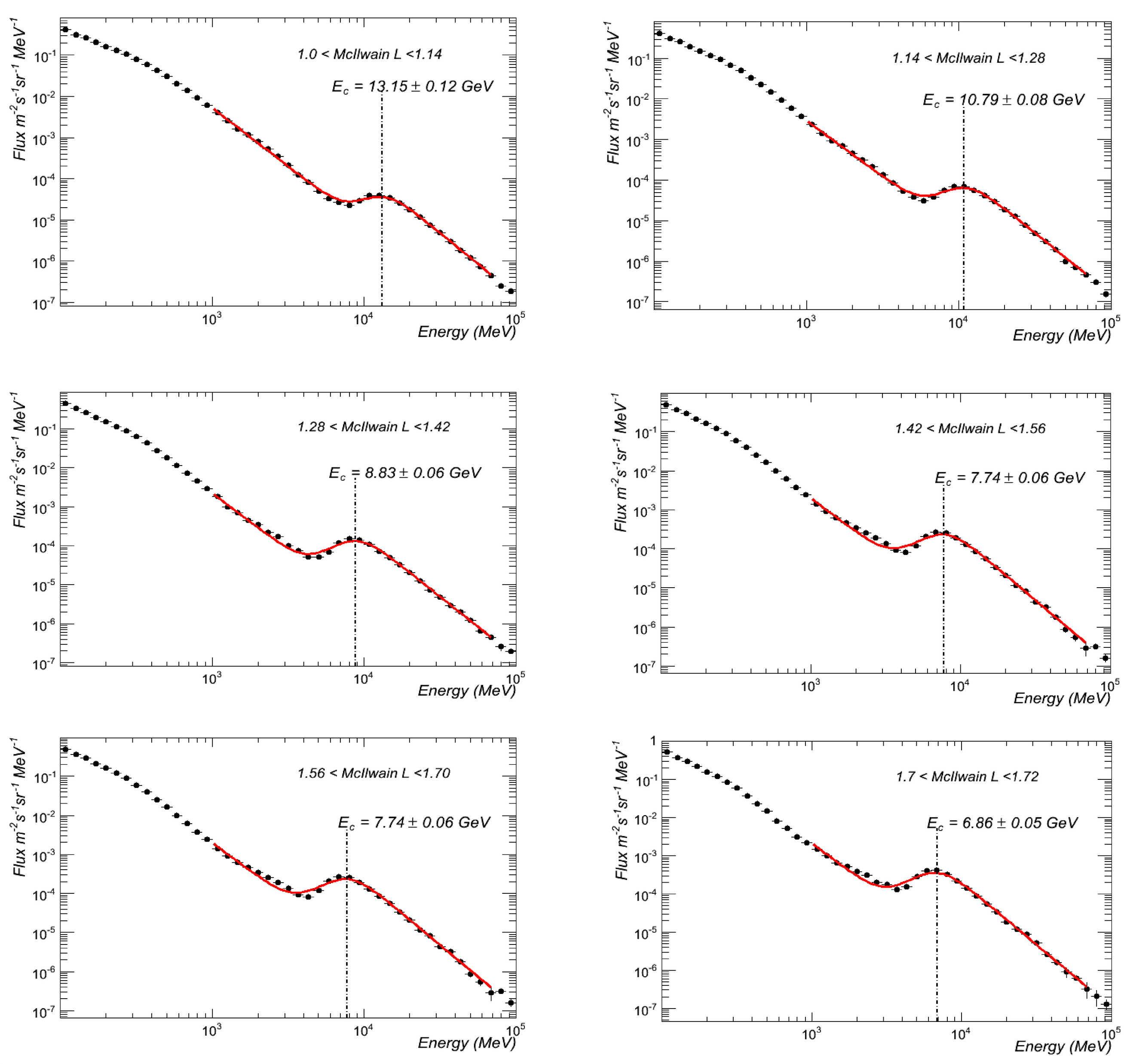


Map of the McIlwain L values for the Fermi orbit. The contours represent the corresponding geomagnetic cutoff rigidities (in GeV) for each McIlwain L region. The shaded area is the South Atlantic Anomaly, where we do not take data.

The Fermi orbital inclination (25.6 degrees) fixes the geomagnetic cutoff window over which we can sample the incoming Cosmic-Rays and thus also fixes the minimum energy that we can measure Galactic Cosmic-Ray electrons and positrons.

The McIlwain L parameter is a geomagnetic coordinate which denotes the distance in Earth radii from the center of the Earth's tilted, off-center, equivalent dipole to the equatorial crossing of a field line. Positions around the world with the same value of McIlwain L are magnetically equivalent. The shielding effect of the Earth's magnetic field is smaller (larger) for larger (smaller) values of McIlwain L. Therefore, to extend the electron + positron spectrum it is necessary to sample events in different McIlwain L bins.

How we extend the electron + positron spectrum

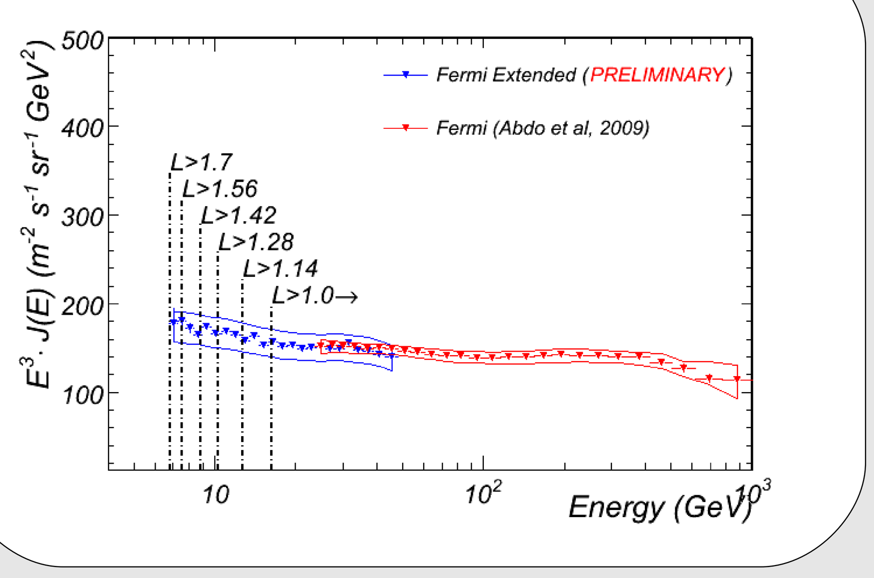


Measure the spectrum in bins of McIlwain L. The shape of the spectrum can be parametrized as:

$$dN/dE = c_s E^{-\Gamma_s} + (c_p E^{-\Gamma_p})/(1+ (E/E_c))^{-6}$$

Where the subscripts s and c stand for secondary and primary components and E_c is the cutoff energy in that McIlwain L bin.

Once the E_c has been estimated, it is possible to extend the spectrum by taking the appropriate slices from each McIlwain L bin (as is shown in the plot on the right).



Two different analysis approaches, two different on-board sources:

The Diagnostic (DGN) filter

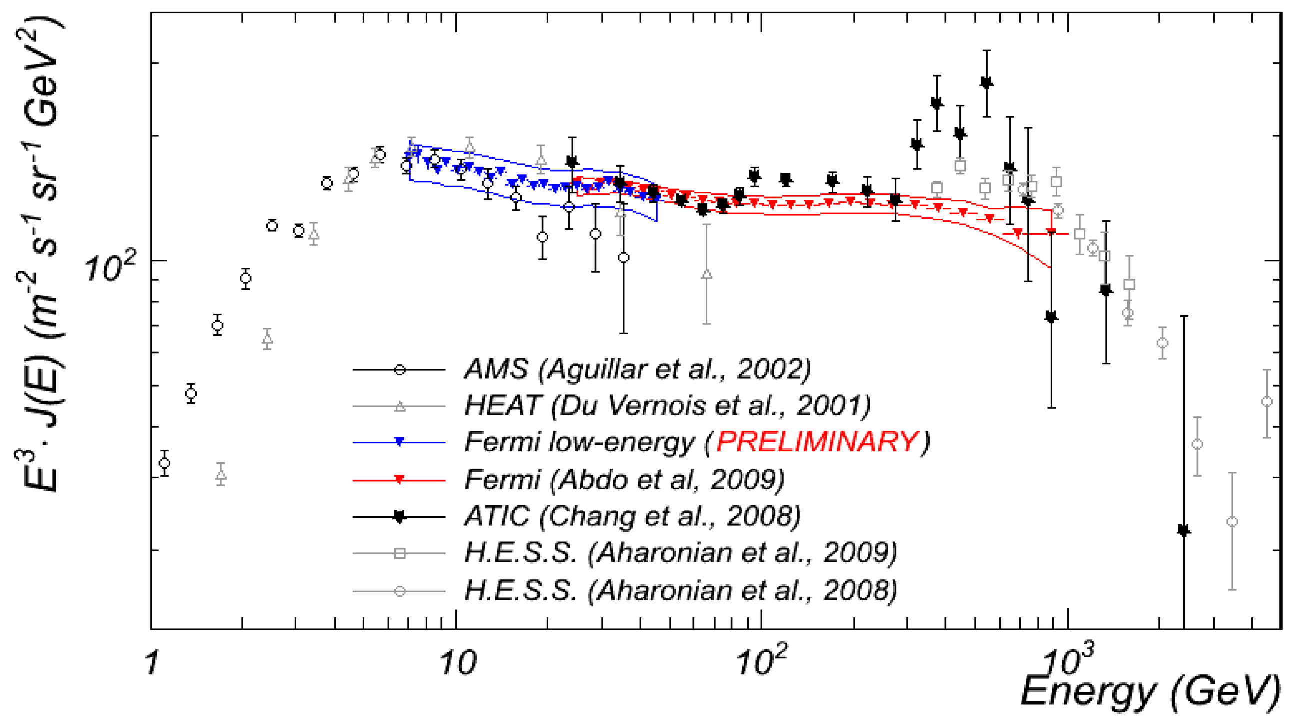
- Unbiased sample of all events that trigger the LAT.
- Prescaled 1:250 on-board.
- ~ 20 Hz orbital average rate.
- Excellent source of CR electrons + positrons with energies < ~50 GeV.

The Gamma filter

- Main on-board filter gammas
- High pass condition:
  - Downlinks all events with on-board energy > 20 GeV.
  - Excellent source of CR electrons + positrons above 20 GeV.

To extend the GCR electron + position spectrum we use the events passing the DGN filter.

The resulting spectrum

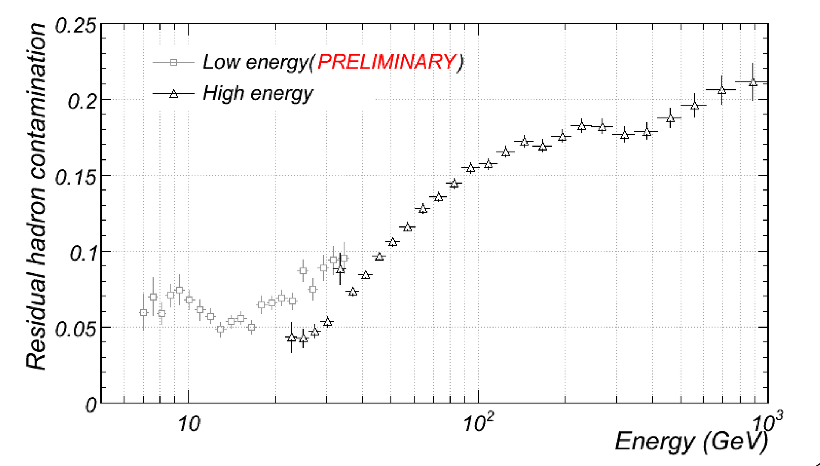


The low energy Fermi points are compatible with the AMS measurements below ~15 GeV. The data below ~10 GeV adds valuable information that allows to make constraints on propagation models. However, the systematic uncertainties for low energy data still need to be better understood and possibly reduced.
The agreement in the energy overlap region, 20 – 40 GeV, between the high energy and low energy Fermi points serve as an excellent cross check for the two independent analysis.

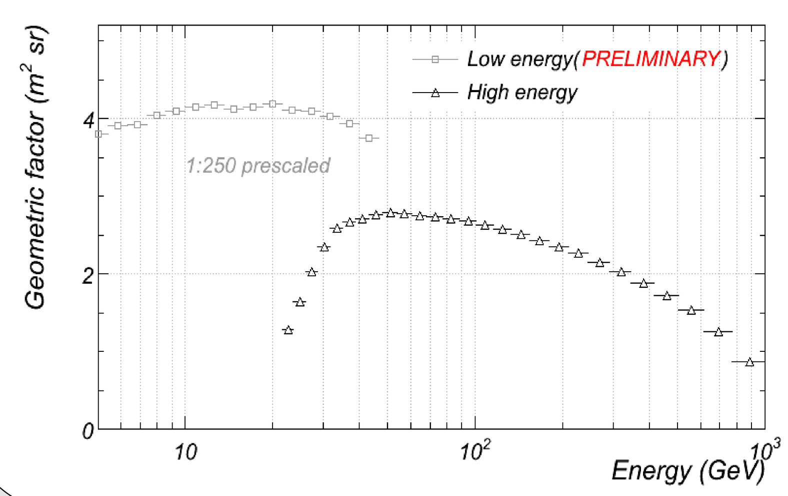
Figures of Merit

Hadron Contamination

Residual hadron contamination after all selection cuts have been applied. The black triangles are for the high energy analysis and the gray squares are for the low energy. Throughout the entire energy range the contamination remains below 20% and in the extended region (~7 - 40 Gev) resides below 10% .



Effective Geometric Factor



The effective geometric factor for high and low energy analysis. The low energy geometry factor has been multiplied by the DGN filter prescale of 250 for graphical clarity and in order to give an idea of the relative electron efficiencies of the two selections.