Fermi Gamma-ray Space Telescope

Cosmic-Ray Positron Measurement with the Fermi-LAT

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on behalf of the Fermi-LAT Collaboration

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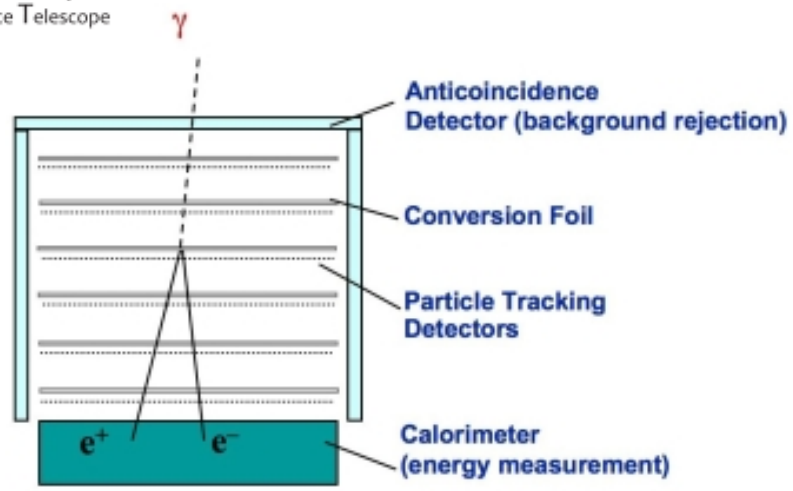
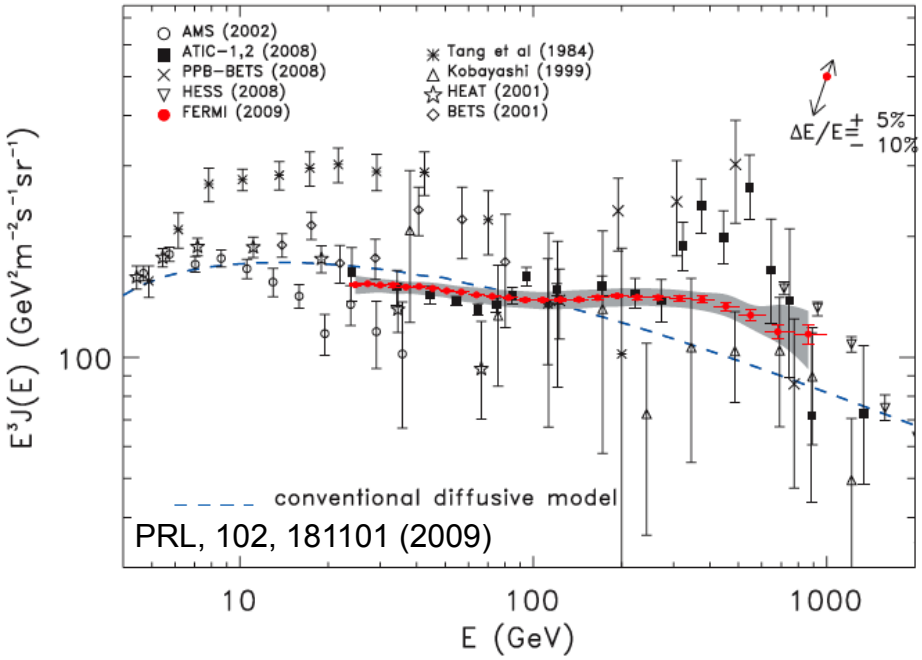
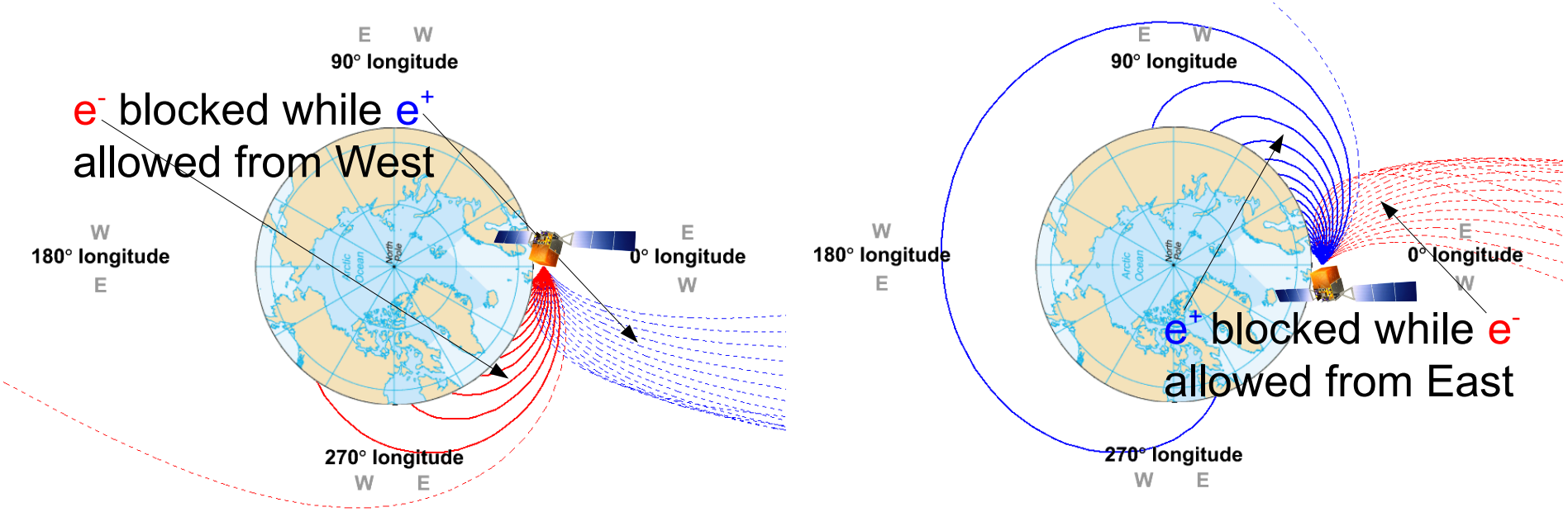
Fermi-LAT and Cosmic Rays





- **Designed to detect high-energy photons**
- **But also detects cosmic-ray (CR) e^+ and e^-**
- **Results on the combined spectrum of $e^+ + e^-$ are published and well-known**
- **Some unexpected results (PAMELA e^+ excess, Fermi hard spectrum) question our understanding of CR e^+**
- **Even without a magnet on board, Fermi has a way to distinguish e^+ and e^-**

Principle: Use the Earth's Magnetic Field to Distinguish e^+ and e^-

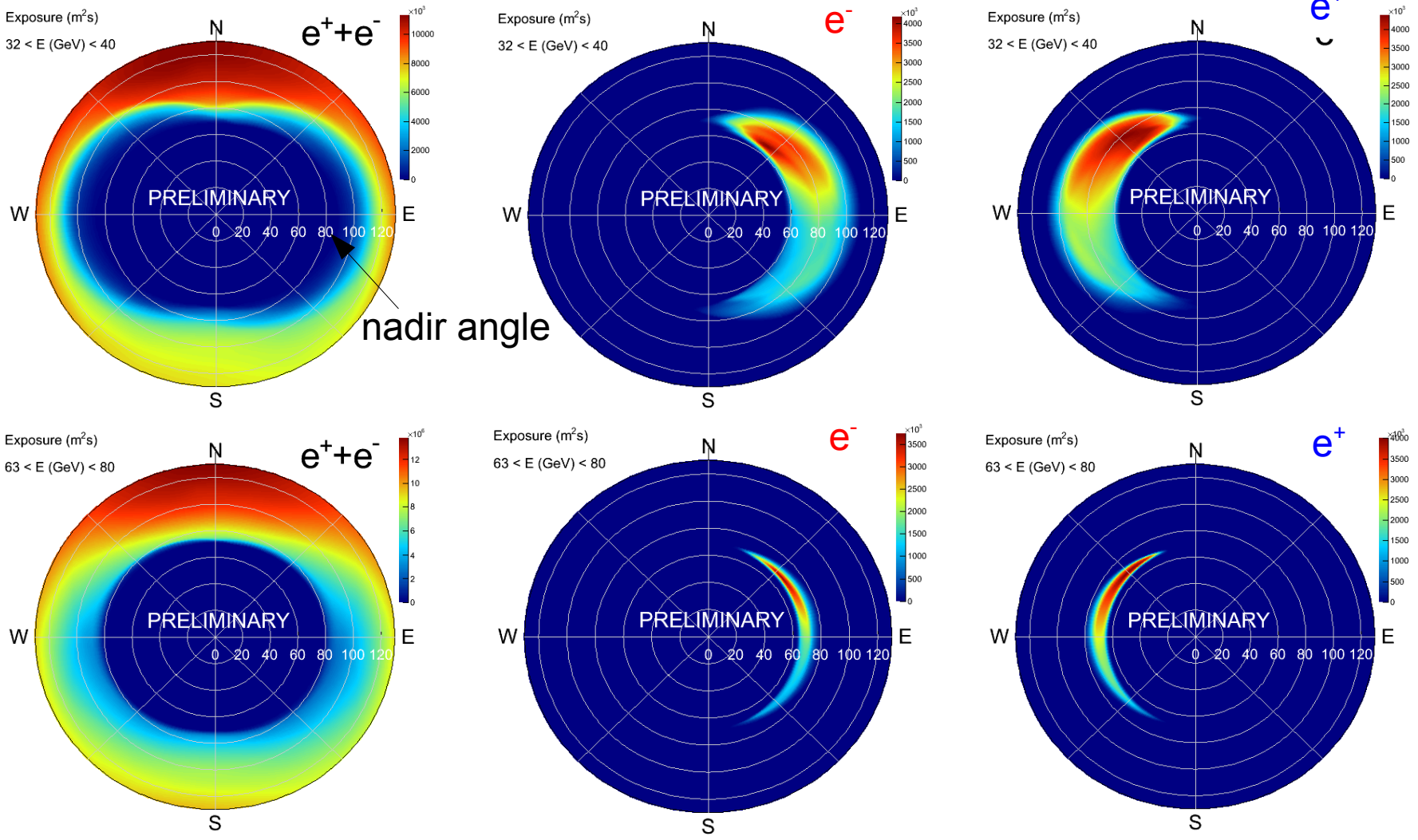


- **Pure e^+ region in the west, and pure e^- region in the east**
- **The regions vary with particle energy and the Fermi-LAT position**
- **To locate these regions, we use a code written by Smart, D. F. and Shea, M. A.* which numerically calculates a particle's trajectory in the most up-to-date geomagnetic field model (IGRF2010)**

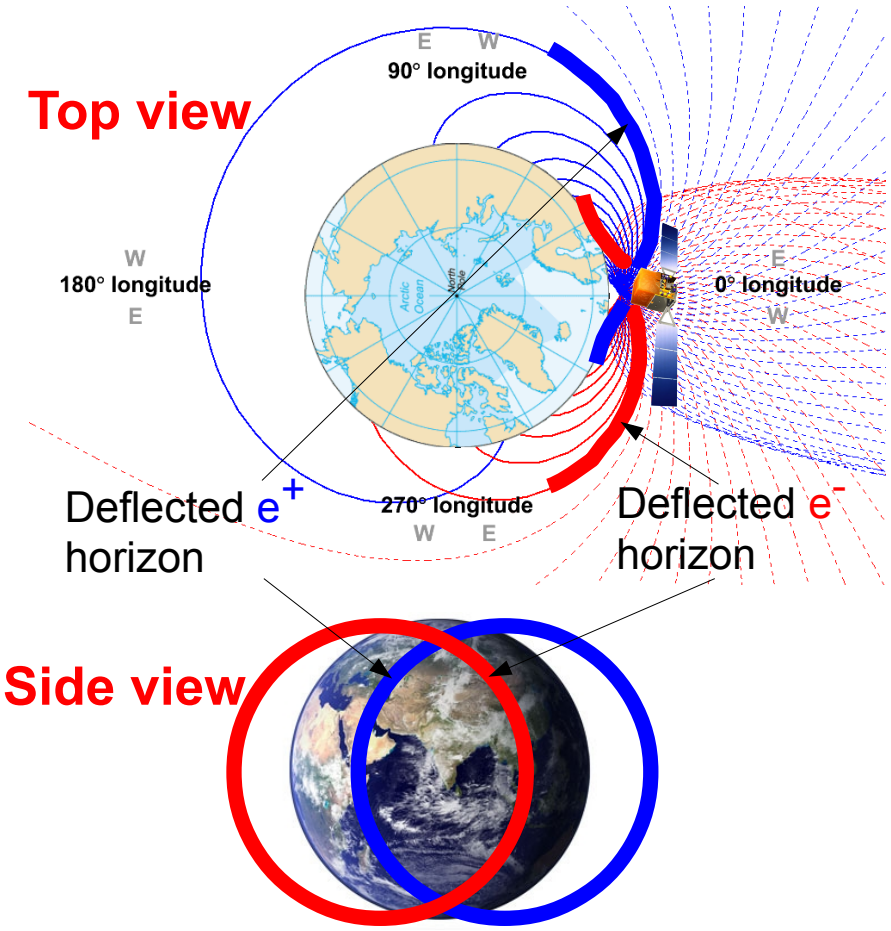
Center for Space Plasmas and Aeronomic Research, The University of Alabama in Huntsville

e^+ and e^- Exposure

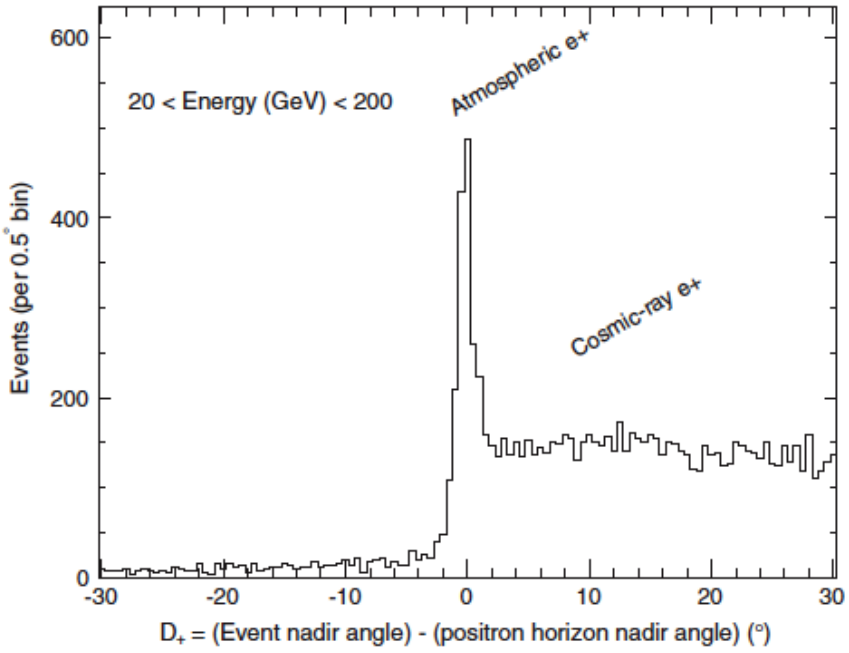
All data when the East or West Earth's limb lies well inside the Fermi-LAT's field of view up to April 2011 (~39 days of livetime)



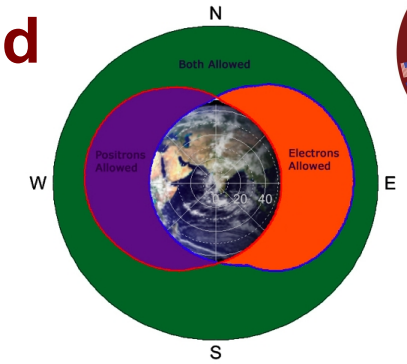
Atmospheric e^+ and e^- Background



- Produced by CR-atmosphere interactions
- At high energy, secondaries are tightly collimated with the grazing incidence primaries
- Trim 4 deg around the deflected horizon below 100 GeV and 2 deg above 100 GeV



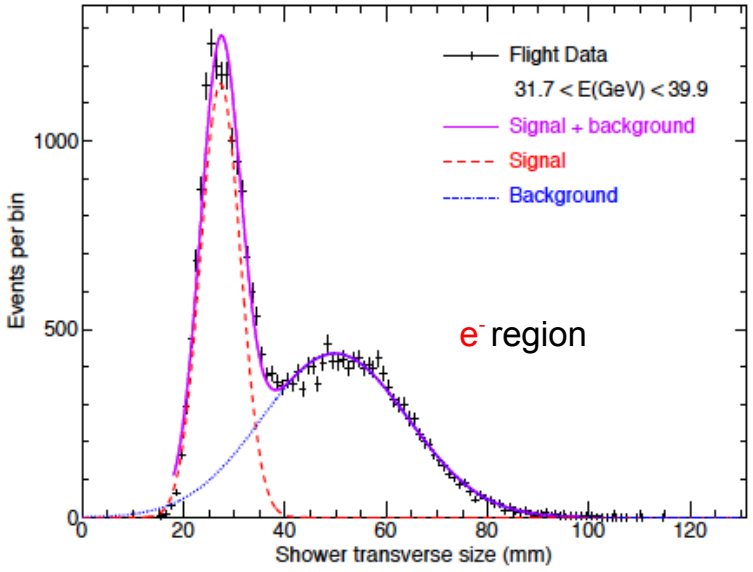
Cosmic-Ray Background



- **The main background is CR protons**
- **Contamination level:** $e^+ + e^-$ **~5-20%**
  e^+ **~20-50%**
  e- **~1-5%**

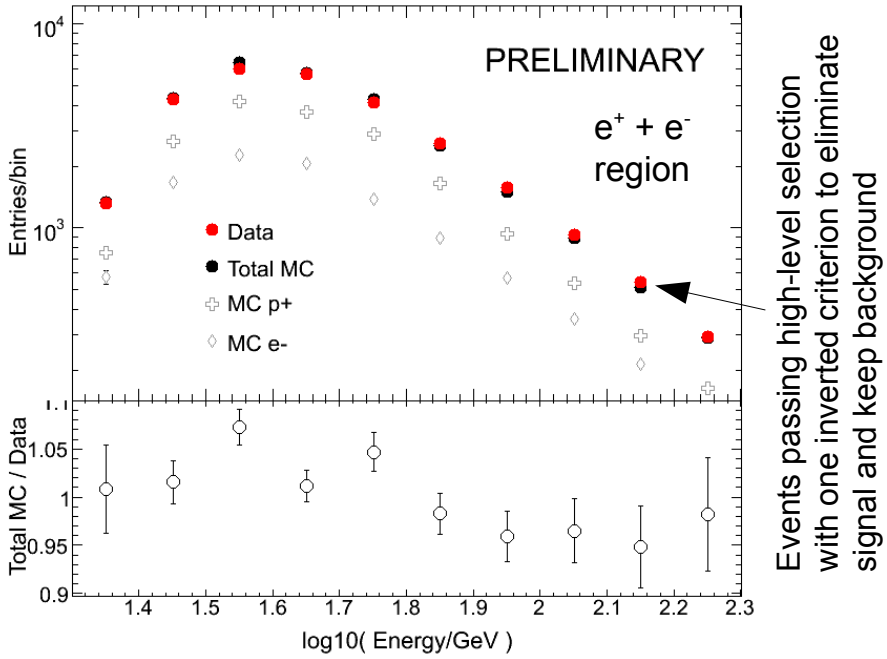
Fit-Based Method

Fit two gaussians to the distribution of the transverse shower size in the calorimeter for events passing relaxed selection to determine signal and background



MC-Based Method

Apply event selection to a large set of CR proton Monte-Carlo simulations to estimate surviving background

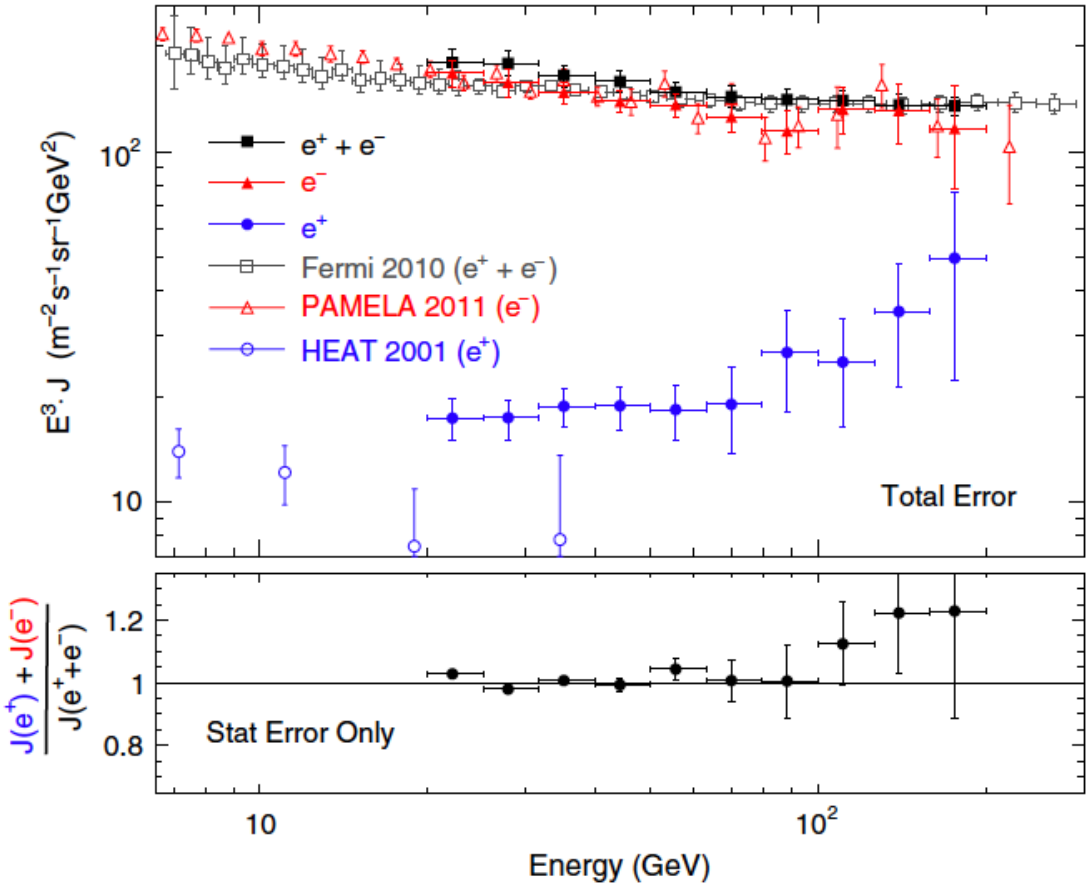


Fit-Based vs MC-Based Systematic Errors for e^+

Error Component	Fit-based	MC-based
Effective Area	5%	5%
Onboard filter efficiency	5%	5%
Atmospheric e+ below 100 GeV	+0%, -3%	+0%, -3%
Atmospheric e+ above 100 GeV	+0%, -10%	+0%, -10%
Data-MC p+ agreement	N/A	8%
CR p+ spectral index uncertainty	N/A	2-10%
Fit parameterization	5-10%	N/A
Reference theta distribution	2-4%	N/A
Total (sum in quadrature)	**10-16%**	**8-19%**

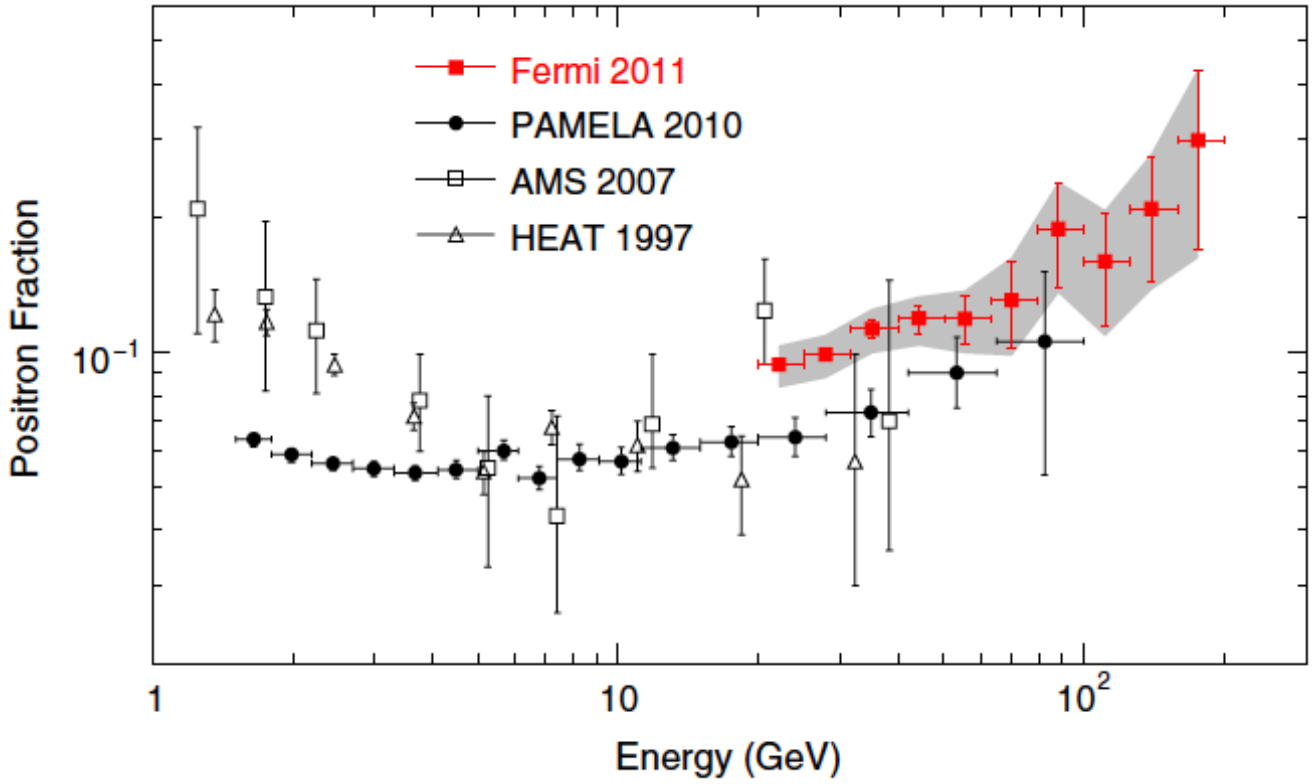
- **Fit-based method has lower systematic errors**
- **Results from two methods are consistent within errors**
- **Use Fit-based results up to 160 GeV, where statistics are not enough for the fitting procedure anymore, and use MC-based results above 160 GeV**

Spectra



- **The ratio of $J(e^+) + J(e^-)$ and $J(e^+ + e^-)$, being consistent with 1, shows that the results are self-consistent**
- **Fitted spectral indices are 2.77 ± 0.14 for e^+ and 3.19 ± 0.07 for e^-**

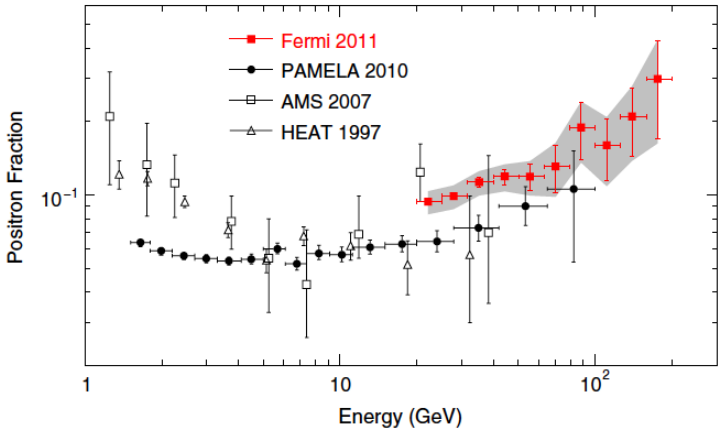
Positron Fraction

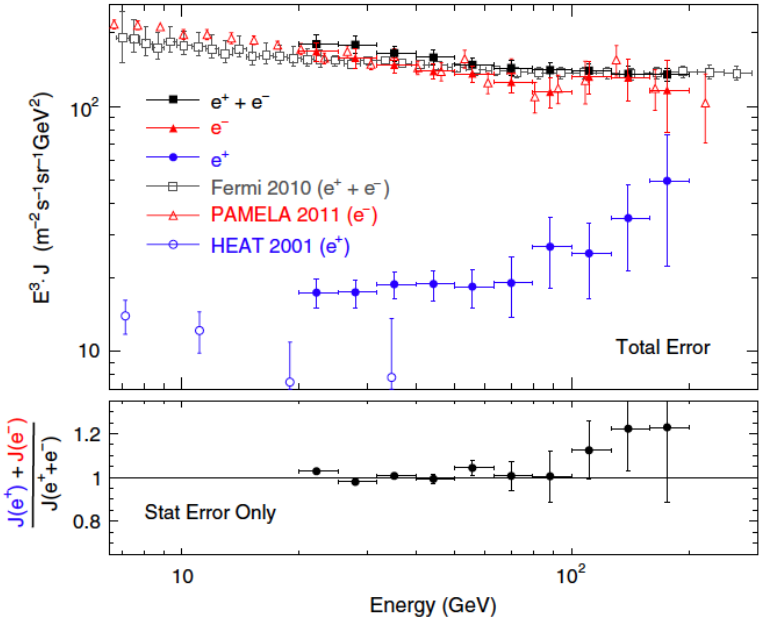


- **Some systematic uncertainties cancel in ratio calculation**
- **Error bars = statistical errors, and the grey band = total errors**
- **The e^+ fraction is increasing with energy, consistent with PAMELA results**

Conclusion

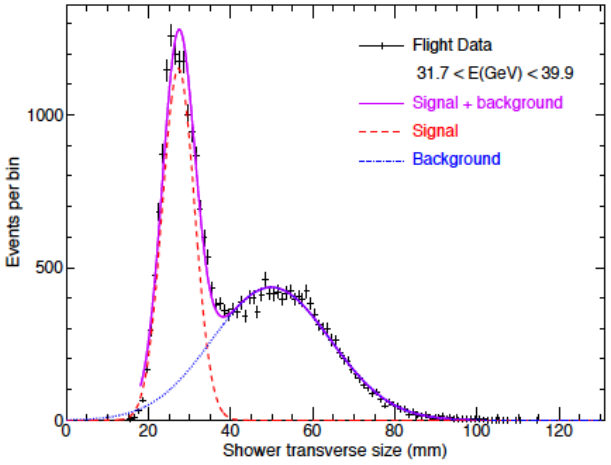
- **The Fermi-LAT has measured the cosmic-ray e^+ and e^- spectra separately, between 20 – 200 GeV, using the Earth's magnetic field as a charge discriminator**
  - **First measurement of absolute e^+ spectrum above 50 GeV**
  - **First published e^+ fraction above 100 GeV**
- **Two independent methods of background subtraction, Fit-Based and MC-Based, produce consistent results**
- **The observed e^+ fraction rises with energy, showing no sign of decreasing between 100-200 GeV**

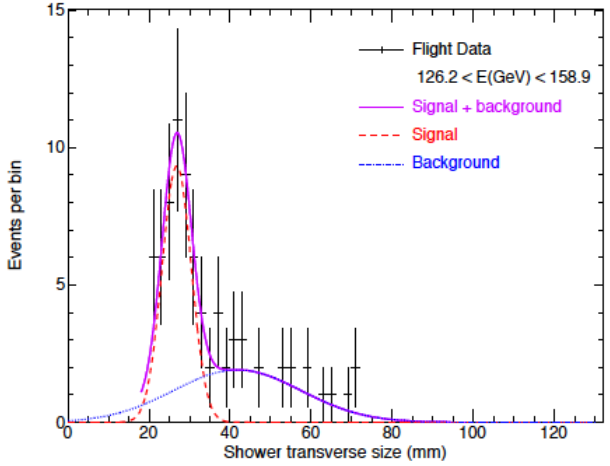




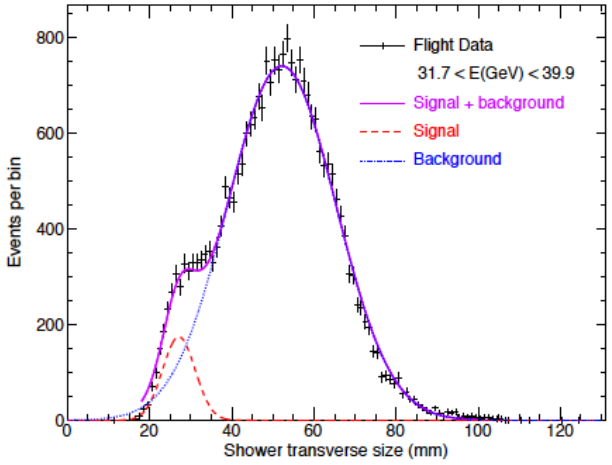
Back Up I: Fit Result Examples

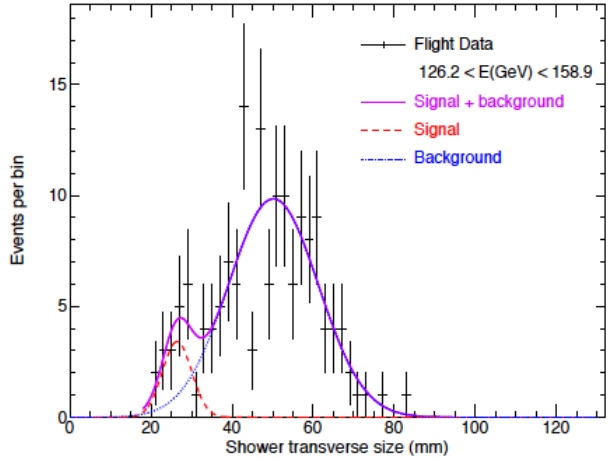
e^- region



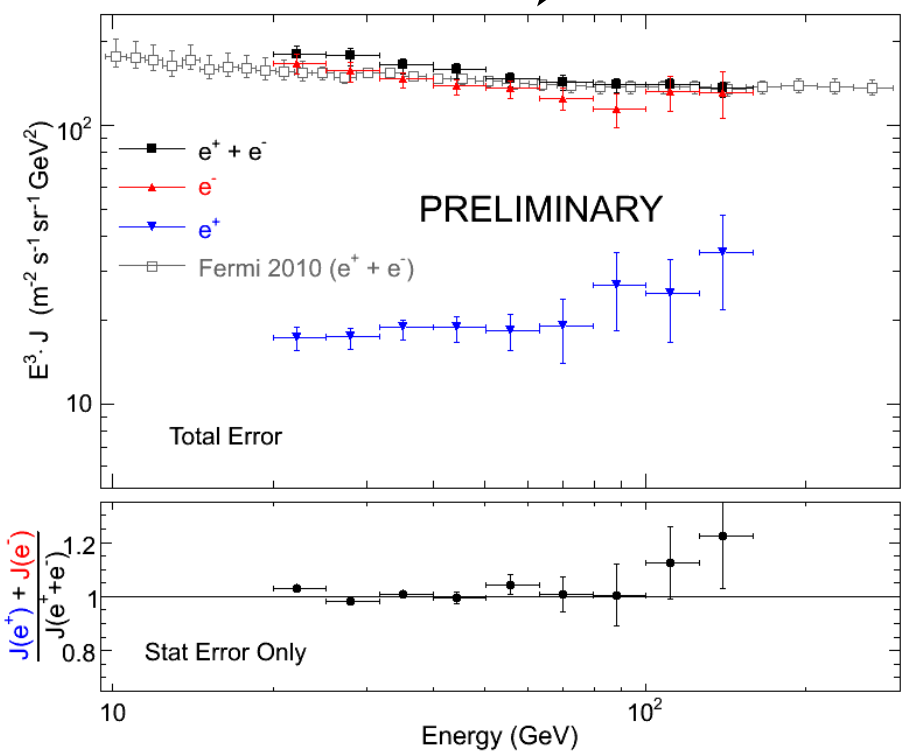


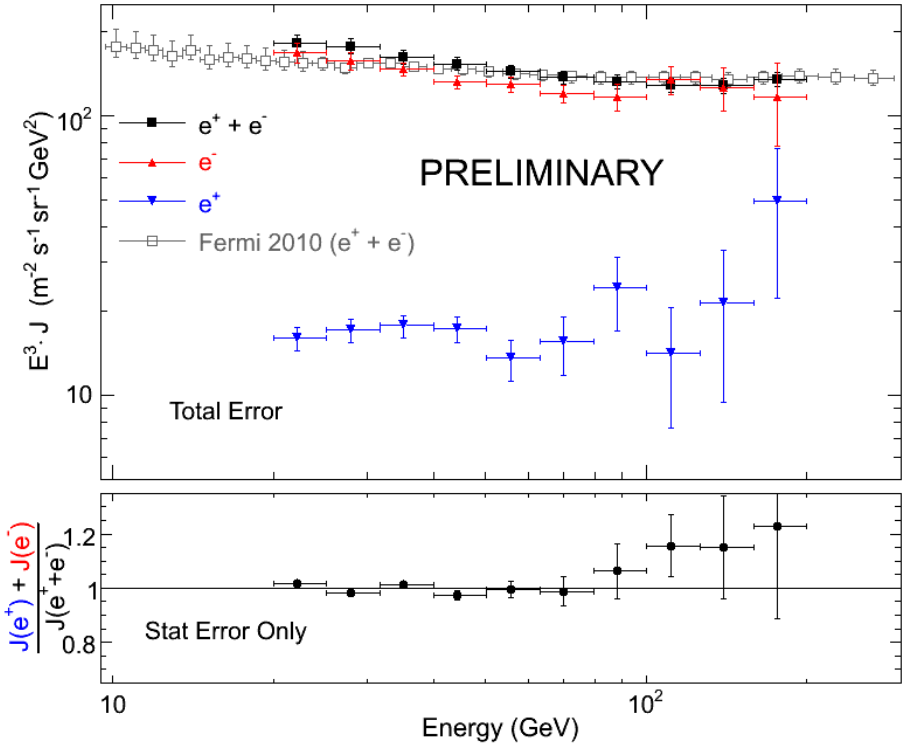
e^+ region





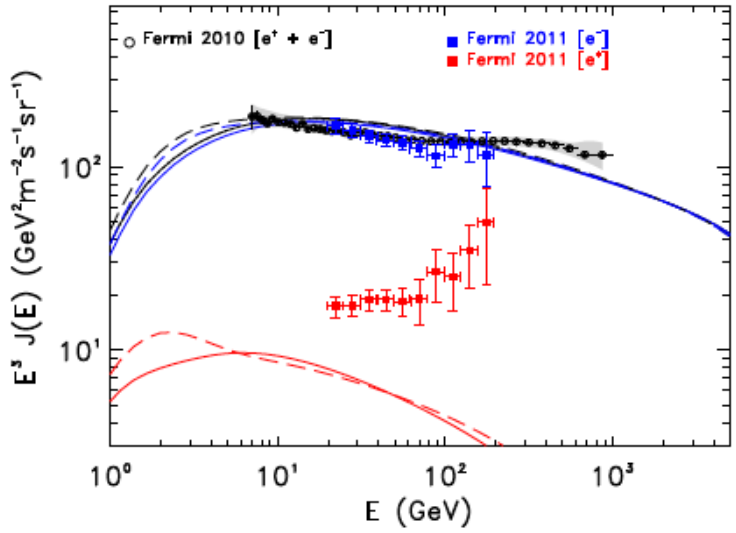
Back Up II: Fit-Based and MC-Based Spectra





Back Up III: Model Comparison

Single-component model



- From arXiv:1110.2591 by D. Grasso and D. Gaggero et al.
- The model with an extra component of e+ and e- is in better agreement with measurements

Extra-component model