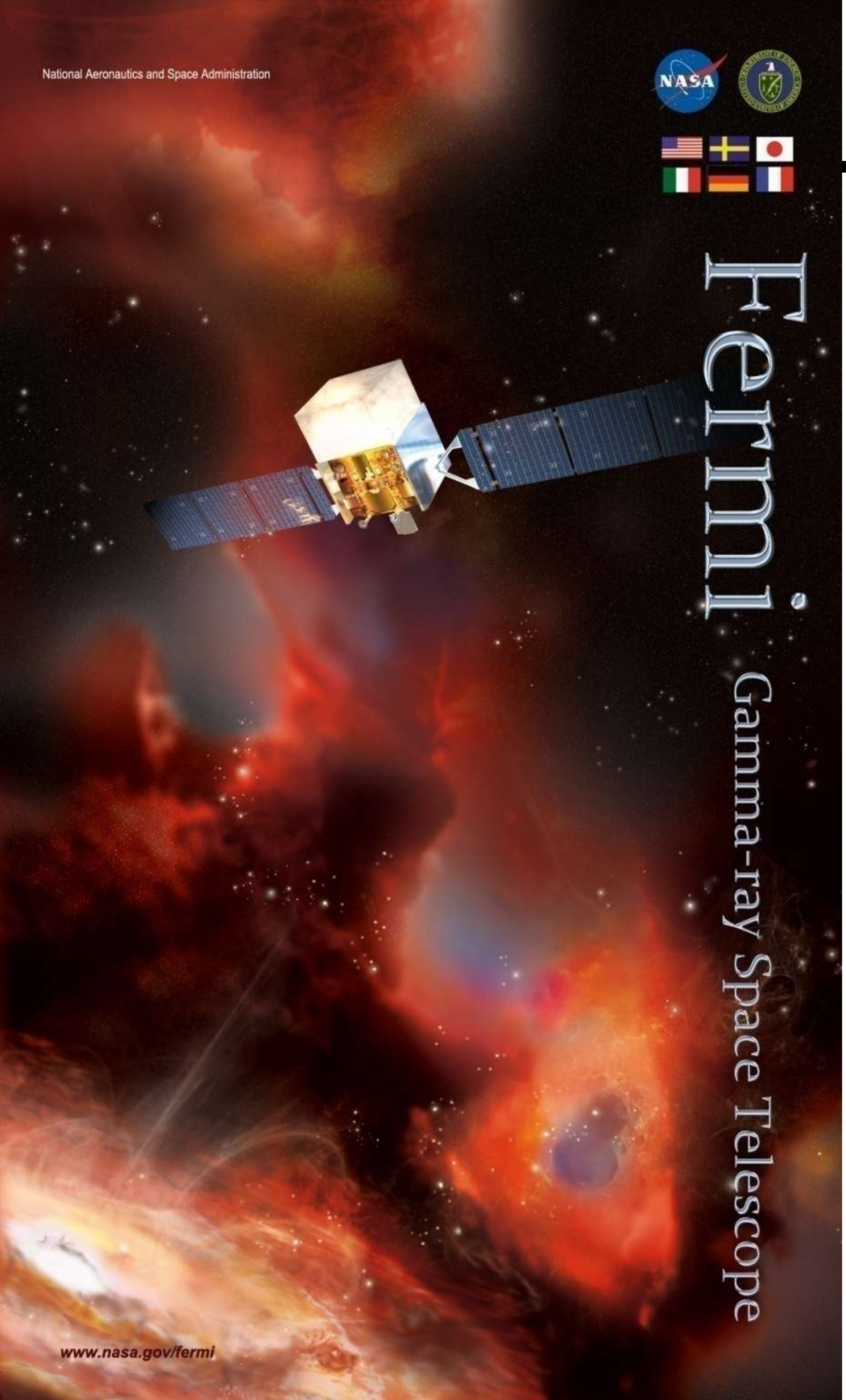

Cosmic-Ray Positron Measurement with the Fermi-LAT Using the Earth's Magnetic Field

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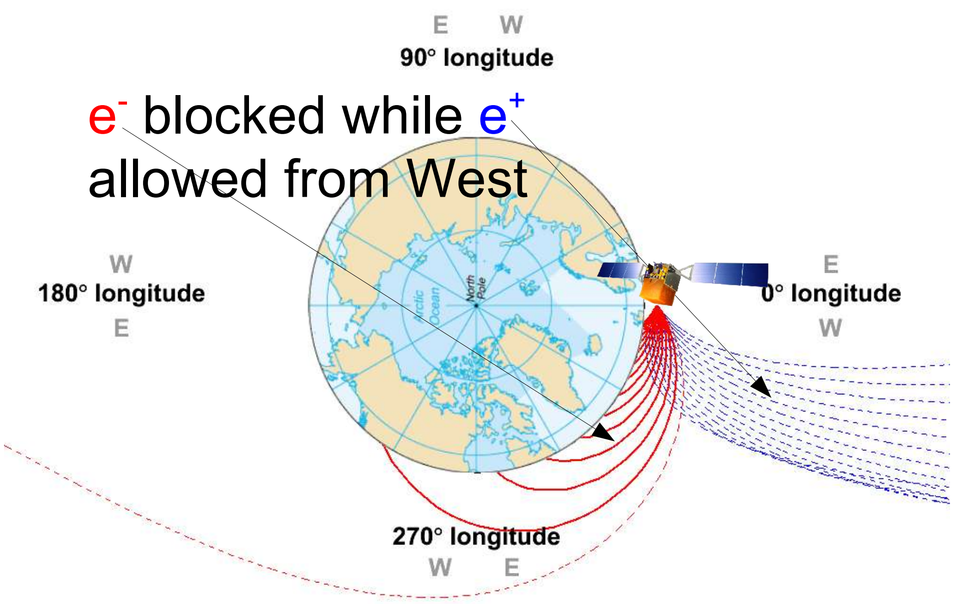
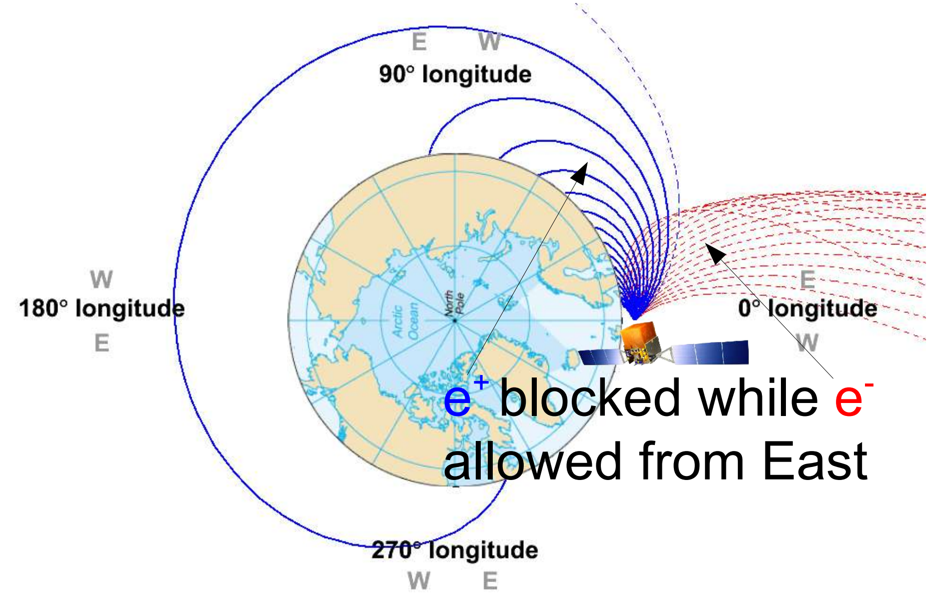
Stefan Funk

on behalf of the Fermi-LAT collaboration

Fermi Symposium 2011
Rome, Italy
May 9, 2011

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


e^- blocked while e^+ allowed from West

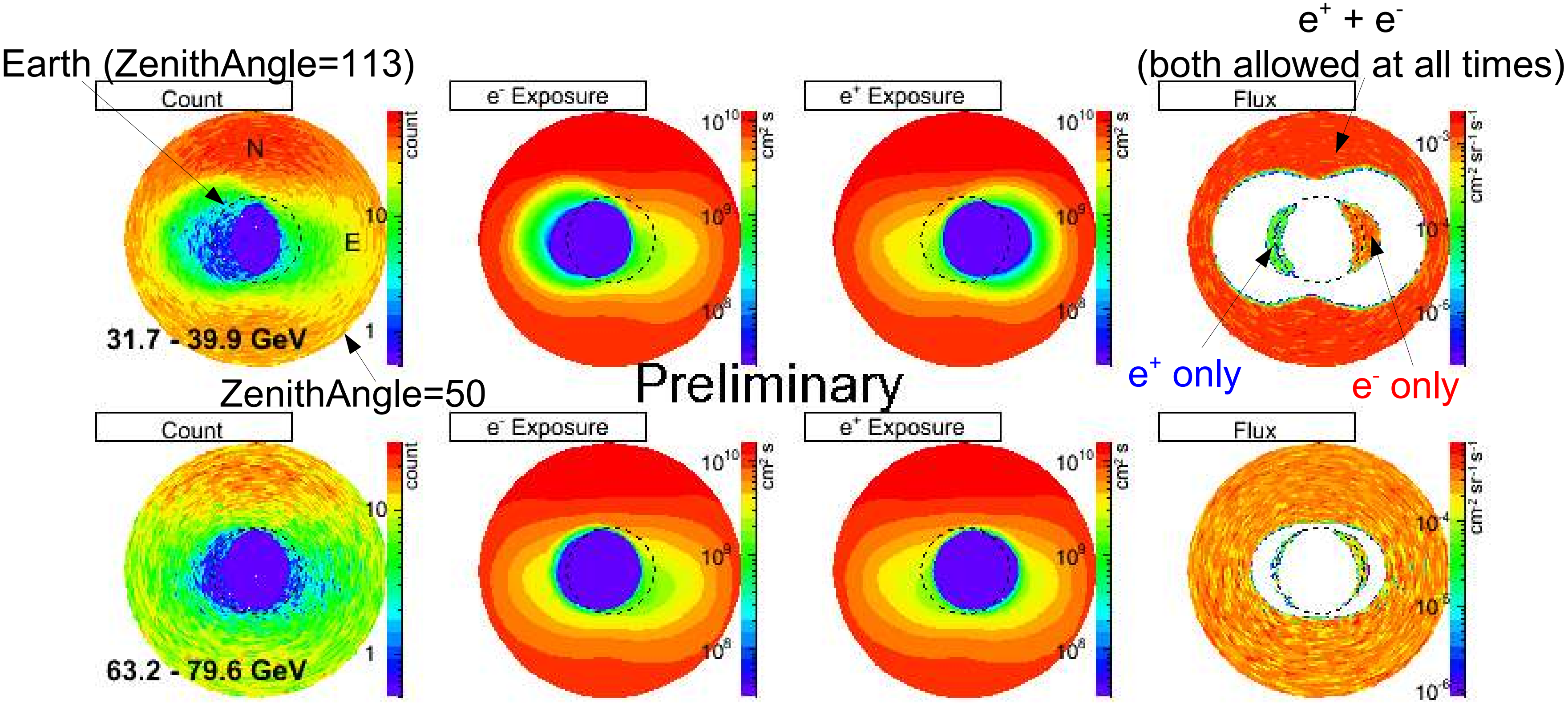

e^+ blocked while e^- allowed from East

- **Pure e^+ region is in the west and same for e^- in the east**
- **The regions vary with particle energy and the 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 geomagnetic field**

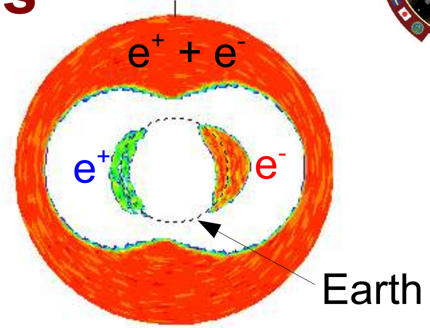
****Center for Space Plasmas and Aeronomic Research, The University of Alabama in Huntsville***

Data

- **All data when the Earth limb is within 60 deg from the center of the LAT's field of view, up to April 15, 2011 (~41 days of livetime)**
- **Logarithmic energy binning, 10 bins per decade, starting from 20 GeV**



Background Subtraction: Two Independent Methods



- **The main background is CR proton**
- **Contamination level:**

$e^+ + e^-$	**5-20%**
e^+	**20-50%**
e-	**1-5%**

Fit-Based Method

- **For the events passing a relaxed selection, the distribution of the transverse shower size in the calorimeter shows separate signal and background peaks**
- **Fit the distribution with two Gaussians to determine signal and background**
- **Systematic errors**
  - **Effective area:** **5%**
  - **Fitting:**

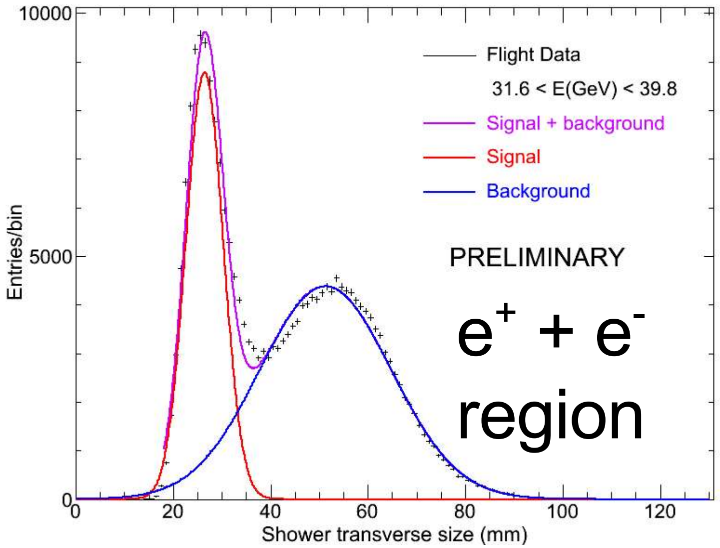
$e^+ + e^-$	**1-3%**
e^+	**1-13%**
e^-	**1-3%**

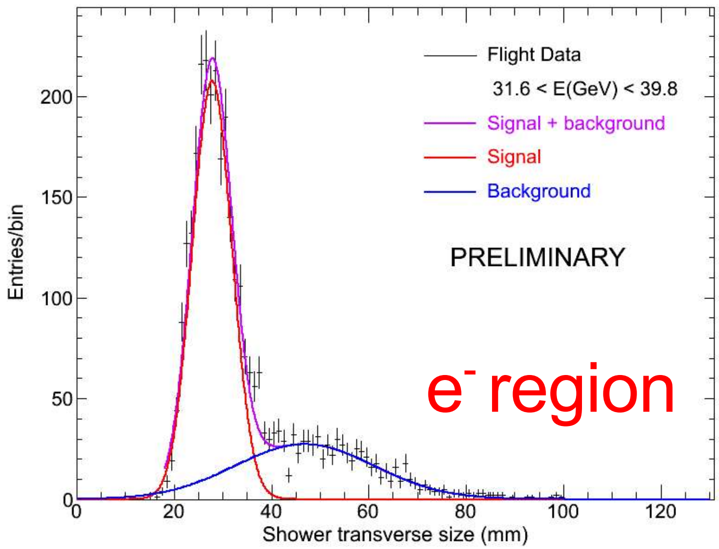
MC-Based Method

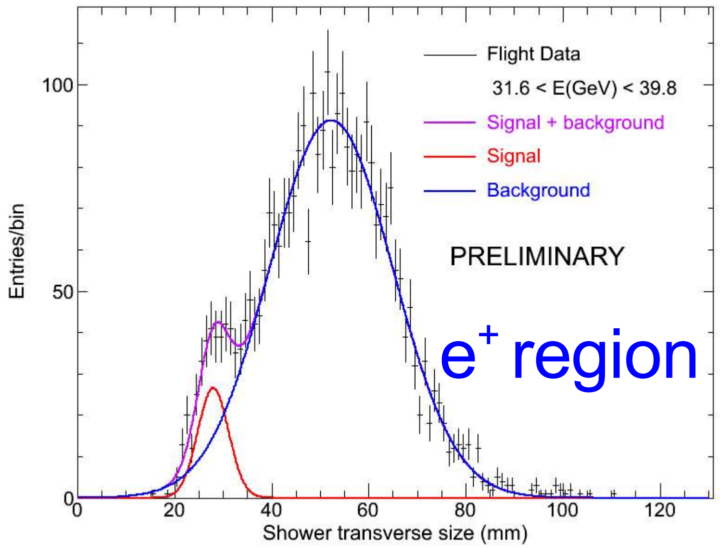
- **Produce a large set of CR proton Monte-Carlo simulation**
- **Apply event selection to the simulation to estimate the surviving background**
- **Systematic errors**
  - **Effective area:** **5%**
  - **MC systematics:** **5-10%**
  - **CR proton spectral Index:**

$e^+ + e^-$	**0.5-2%**
e^+	**2-7%**
e^-	**0.5-1%**

Background Subtraction: Fit-Based

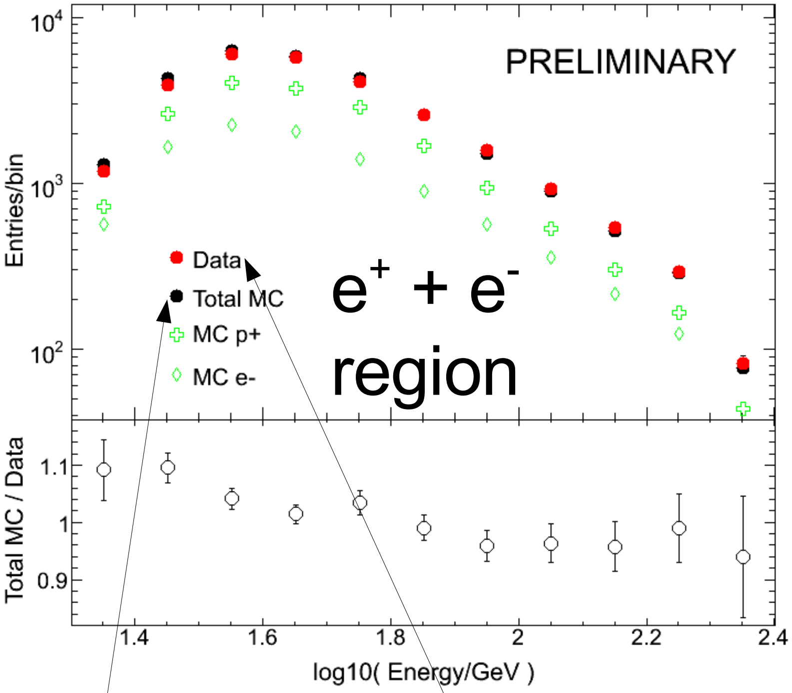


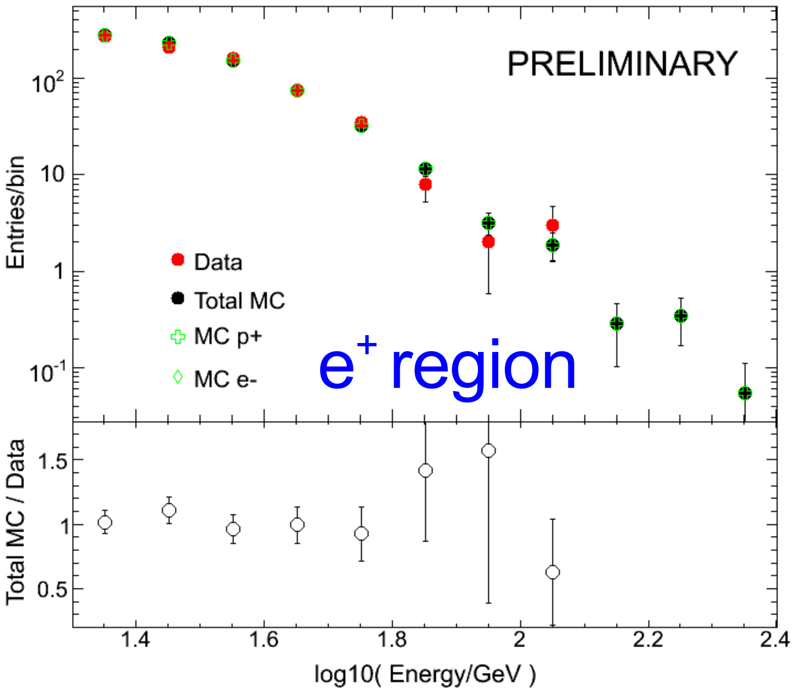




- **Two Gaussians fit well**
- **Fitting is stable for** e$^+$ + e$^-$ **and** e$^-$, **but is more challenging for** e$^+$ **because the statistics is lower**

Background Subtraction: MC-Based

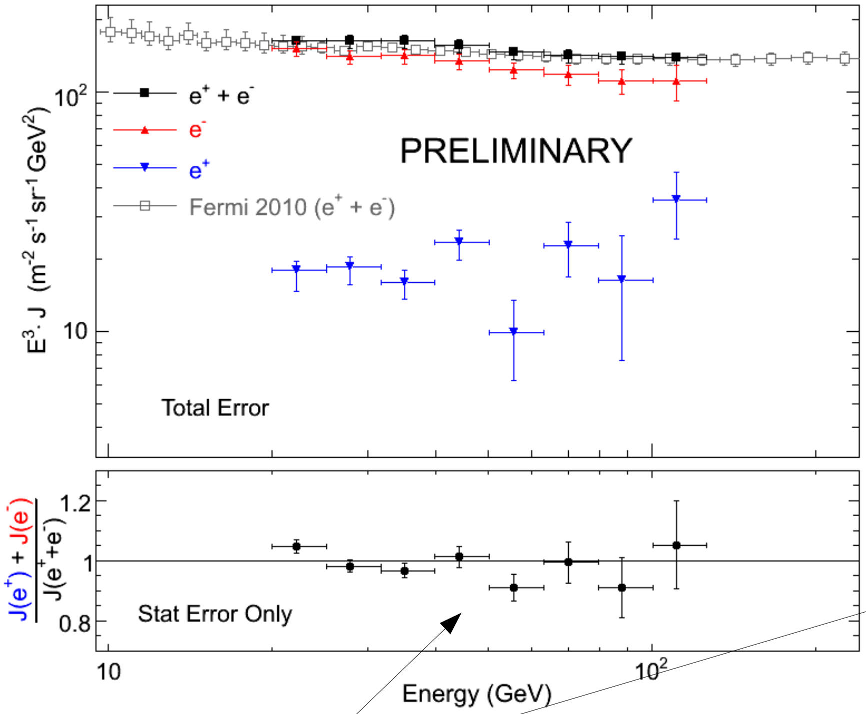




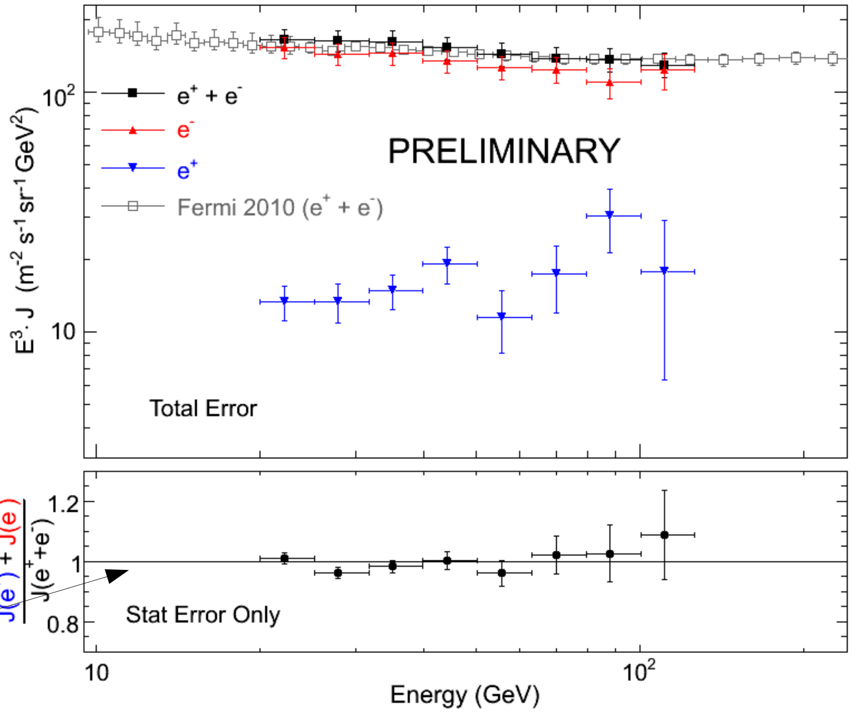
- **Simulations and data are shown at high-level event selection with an inverted criterion because we want to eliminate the signal and keep the background for comparison**
- **Simulations and data in** $e^+ + e^-$ region **and** e^+ region **agree within ~15%, sufficient for this analysis, which is dominated by statistical uncertainties**

e^+ and e^- Spectra

Fit-Based Result

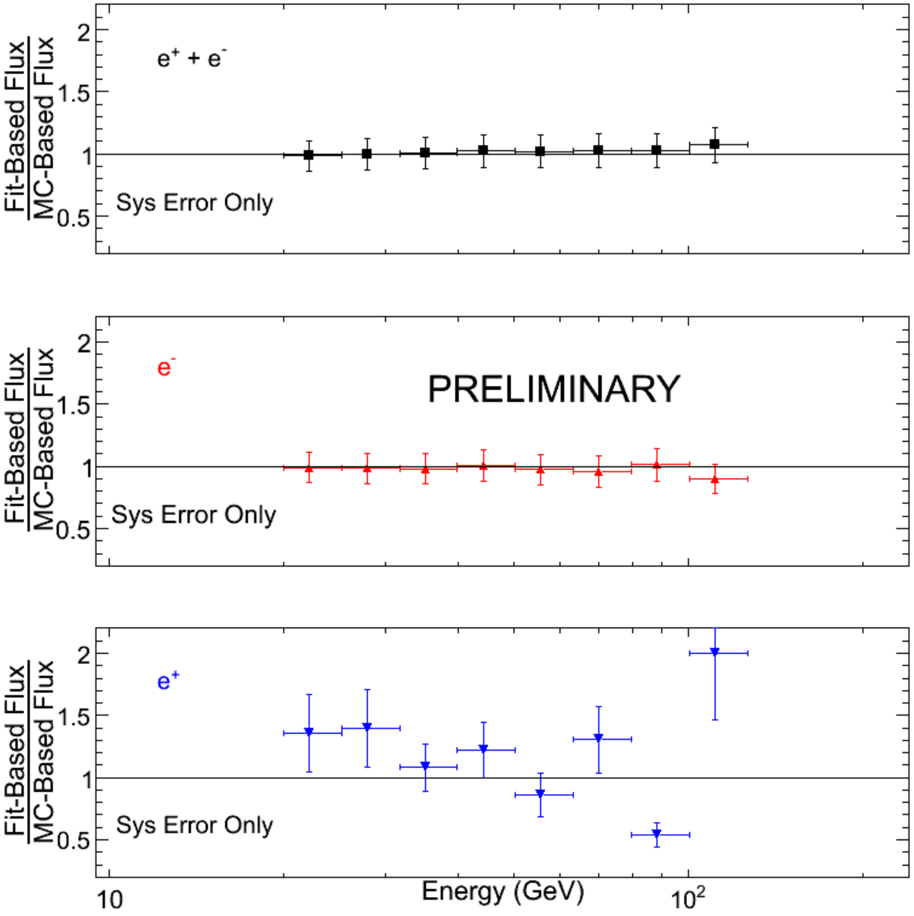


MC-Based Result



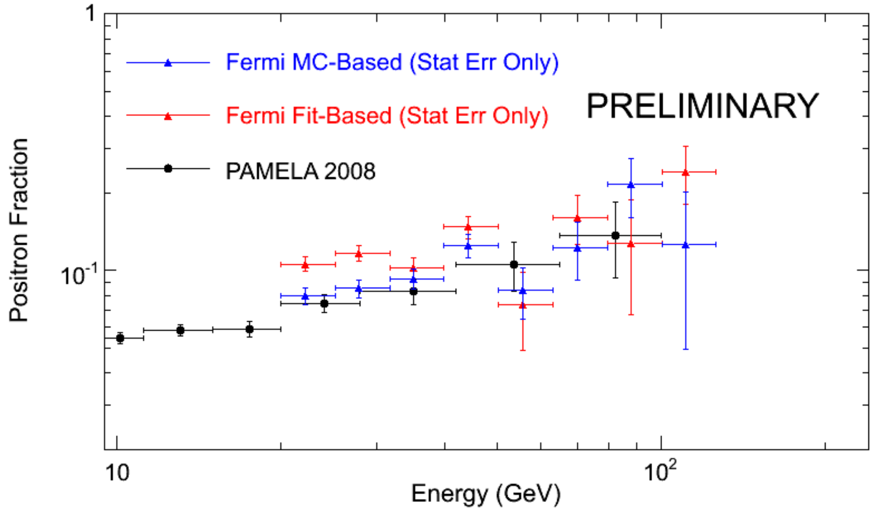
The ratio of the sum $J(e^+)+J(e^-)$ and the total flux $J(e^+ + e^-)$ being compatible with 1 shows that each method is self-consistent

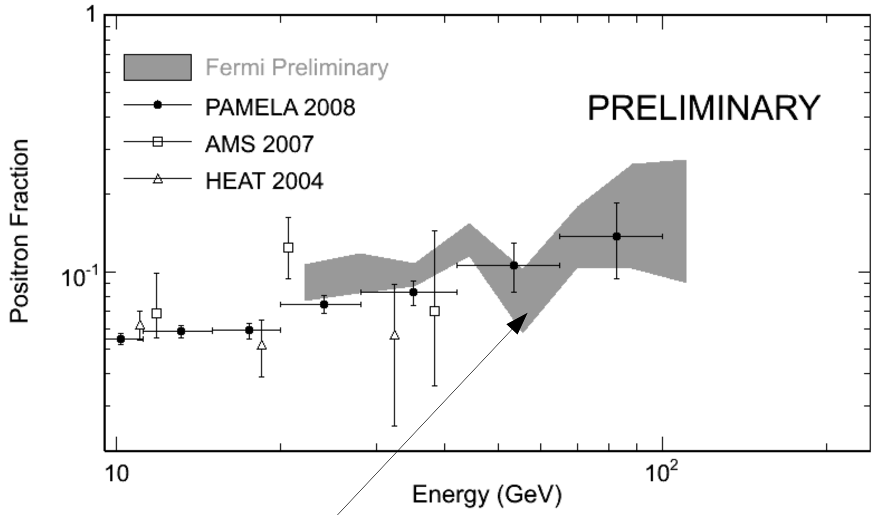
Flux Comparisons between Two Background Subtraction Methods



- **Only systematic errors are shown because the two methods use the same data, so they are statistically correlated**
- $e^+ + e^-$ **and** e^- **spectra agree well within 10%**
- e^+ **spectrum ratio fluctuates more but is still consistent with 1**
- **The agreement between the results from the two methods is an excellent cross check**

Positron Fraction

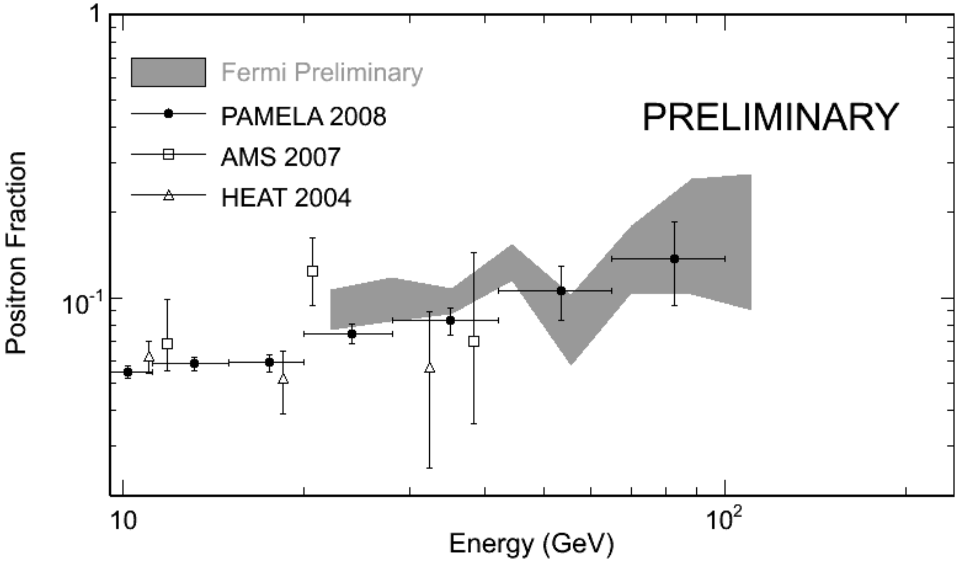




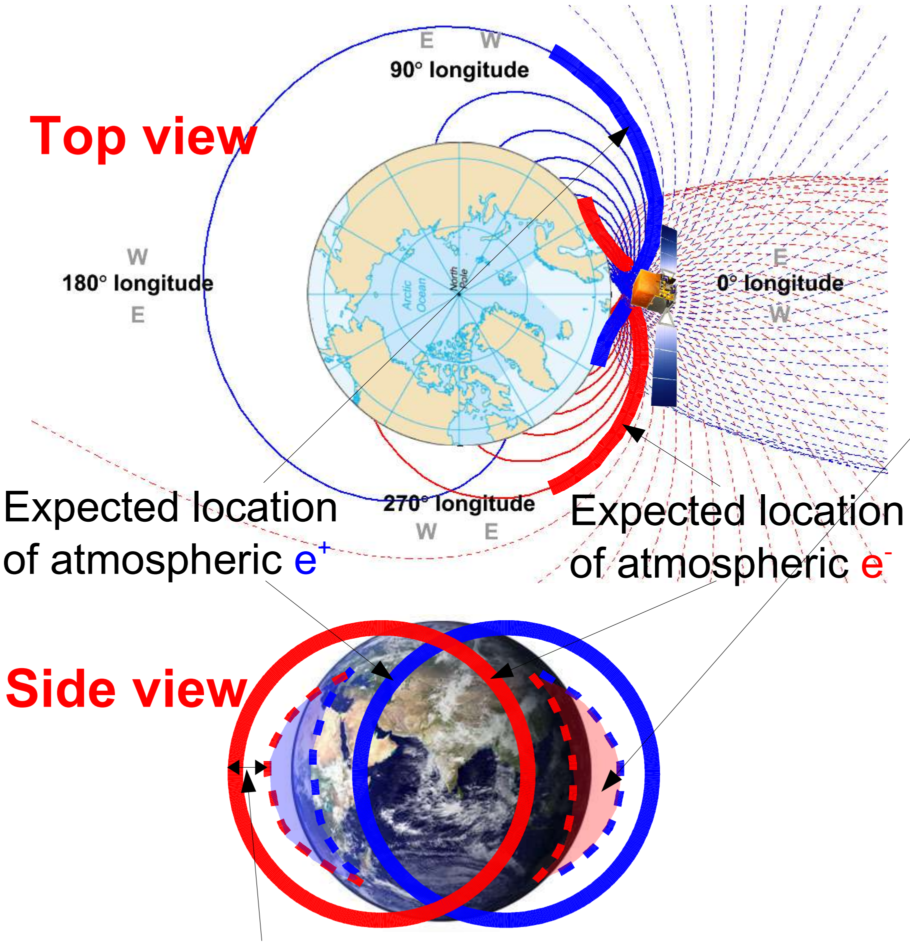
- **The final positron fraction is shown as a band centered at the average value between the Fit-Based and MC-Based results**
- **The width of the band for each bin is a quadrature sum of the final statistical and systematic error**
  - **The final statistical error is the average of the statistical errors from the two methods**
  - **The final systematic error is determined by the difference between the results from the two methods**

Conclusion

- **The Fermi-LAT has measured the cosmic-ray positron and electron spectra separately, between 20 – 130 GeV, using the Earth's magnetic field as a charge discriminator**
- **The two independent methods of background subtraction, Fit-Based and MC-Based, produce consistent results**
- **The observed positron fraction is consistent with the one measured by PAMELA**



Back up 1: Reliability of the Geomagnetic Field Model



Top view

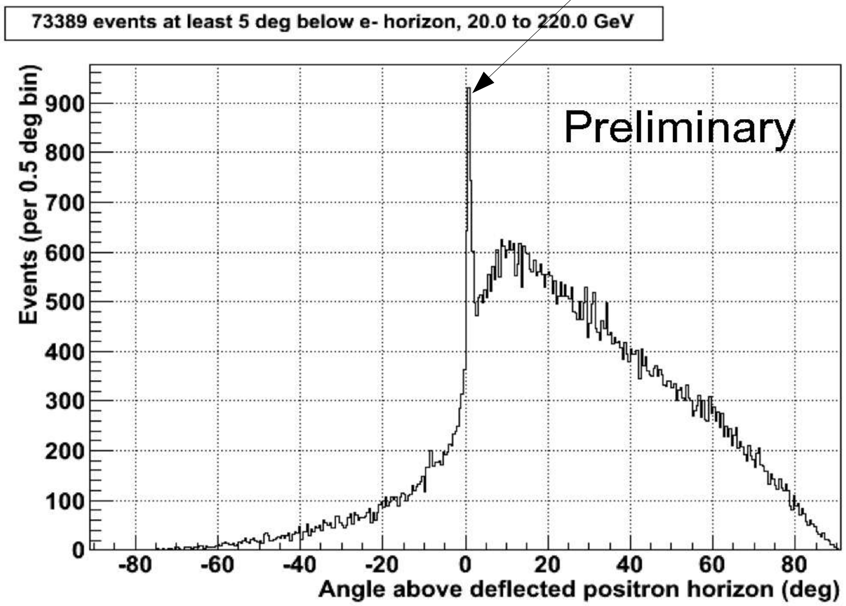
Expected location of atmospheric e$^+$

Expected location of atmospheric e$^-$

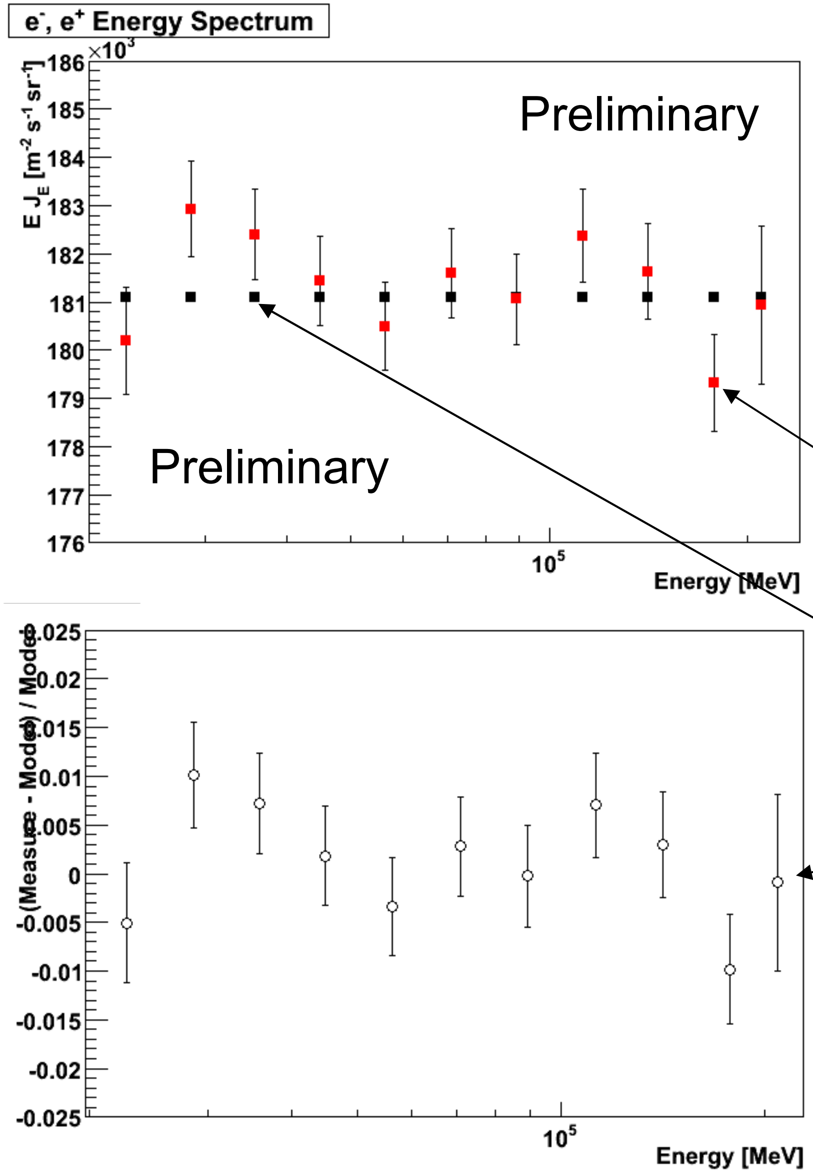
Side view

e$^+$ and e$^-$ horizons wobble as the LAT changes position

- **Atmospheric e$^+$ and e$^-$ are observed at precisely where the particle trajectory tracing code predicts**
- **Here is an example for atmospheric e$^+$**
- **We choose conservative regions, located inside the innermost boundaries**

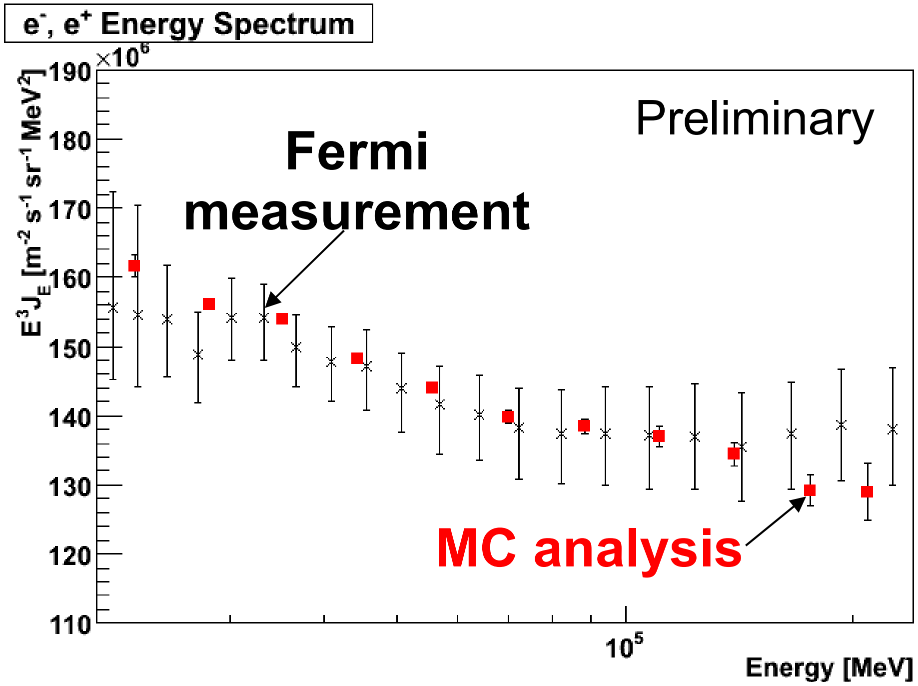


Back up 2: MC Full Circle Validation I



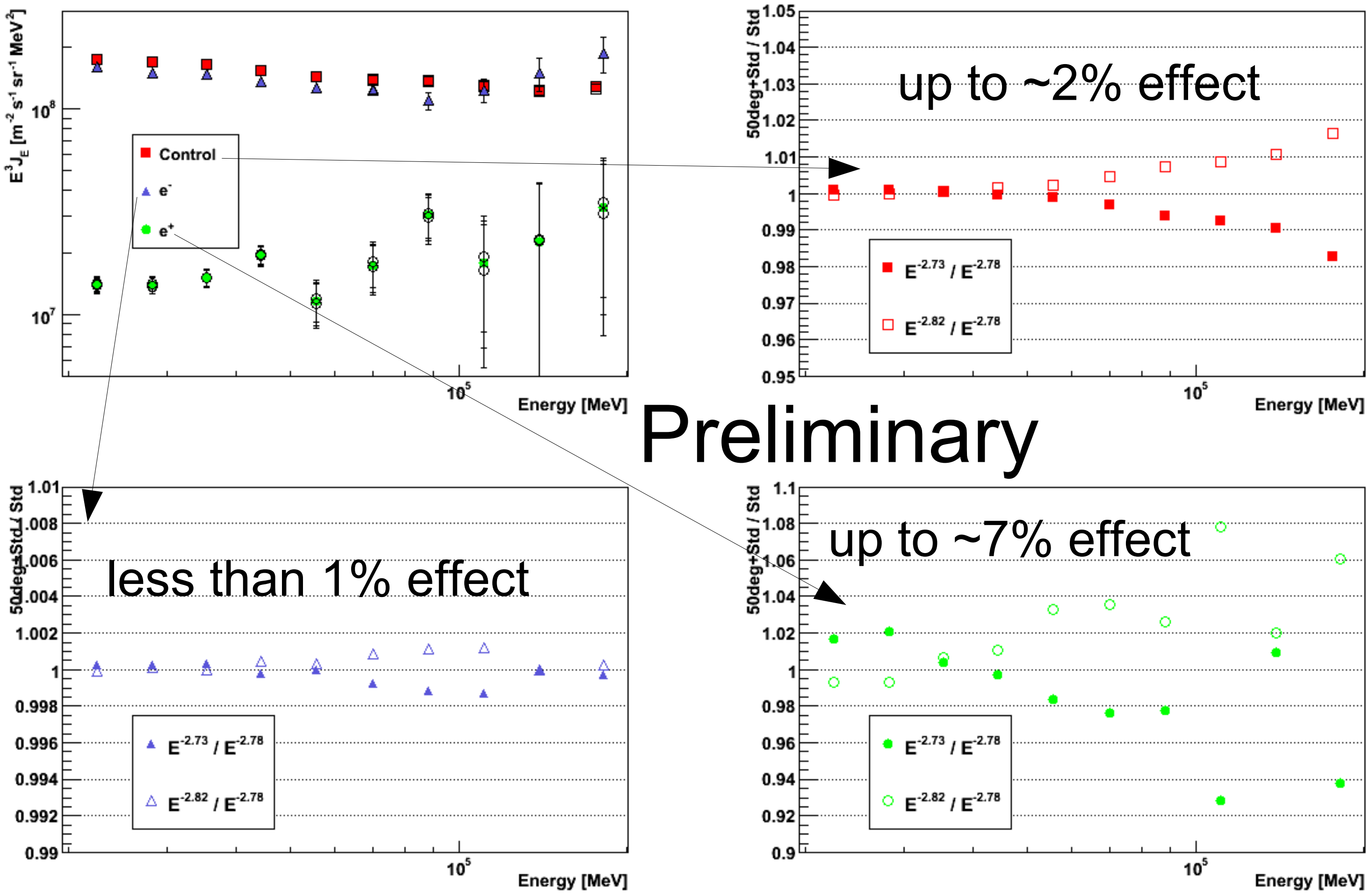
- **Produce E^{-1} isotropic e^- MC**
- **Calculate the IRFs from this MC**
- **Perform our analysis on this MC using the above IRFs**
- **The analysis result reproduces input model within ~1%**

Back up 3: MC Full Circle Validation II



- Use E^{-1} e^- MC and IRFs from the previous slide
- Transform to the same orbit as the data set used
- Do geomagnetic tracing
- Reweigh the above MC to the fitted power-law $E^{-3.08}$ in the publication by Fermi
- Perform our analysis on this transformed MC
- The MC analysis result agrees very well with the Fermi measurement

Back up 4: Effects of Proton Spectral Index



up to ~2% effect

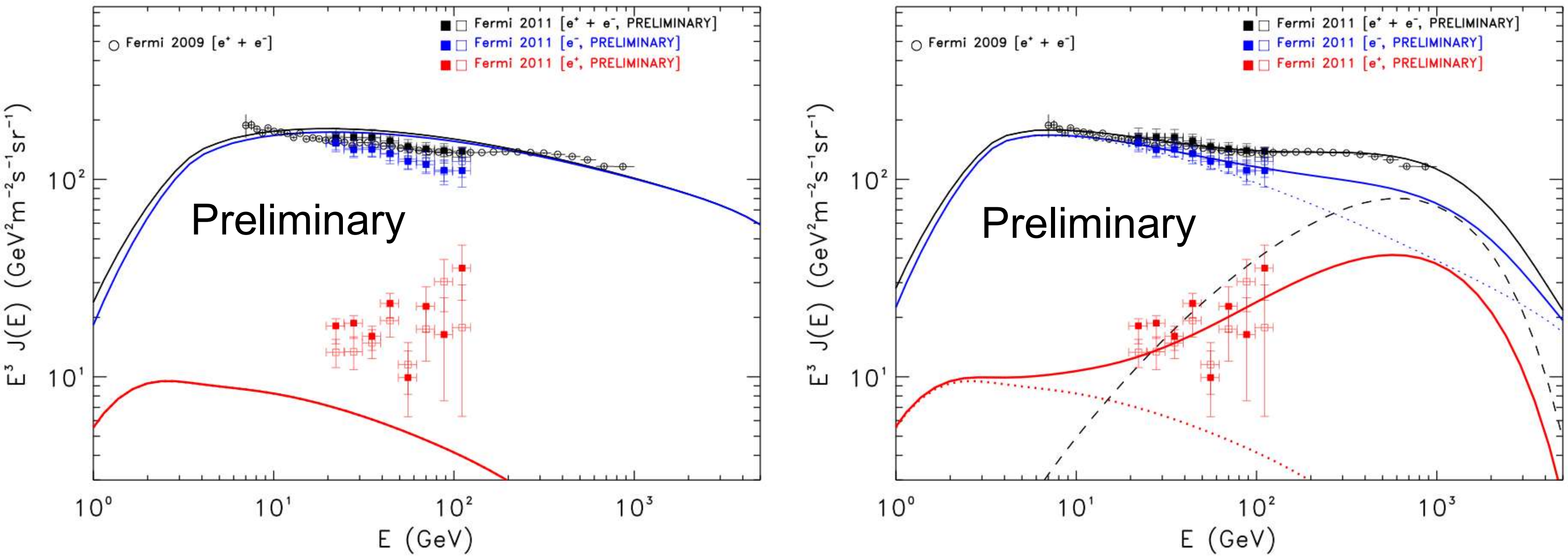
Preliminary

less than 1% effect

up to ~7% effect

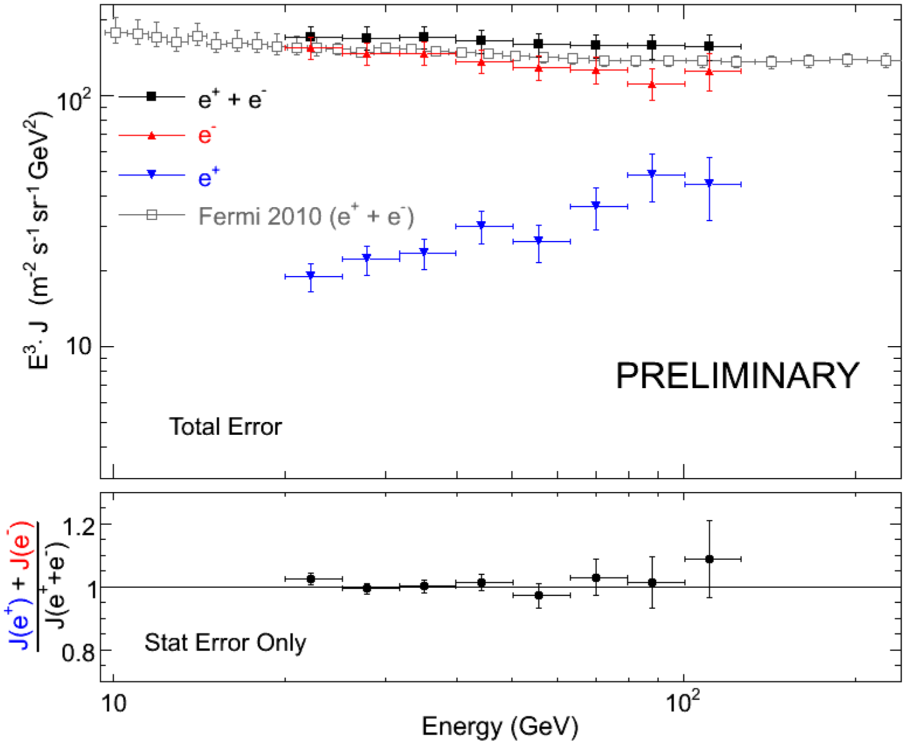
Upper Limit	Use	Lower Limit
BESS (2004)	AMS01 (2002)	PAMELA (2011)
13700$E^{-2.73}$	17100$E^{-2.78}$	20087$E^{-2.82}$

Back up 5: Model Comparison

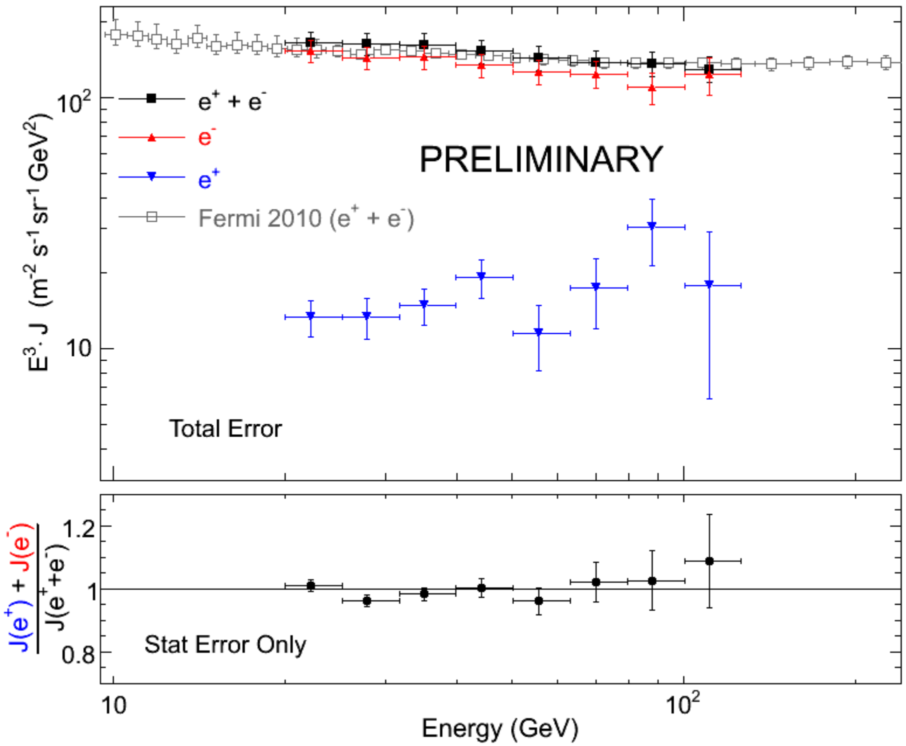


Single and extra component model comparison
from Dario Grasso and Daniele Gaggero

Back up 6: Spectra with and without Background (MC-Based)



With background



Background Subtracted