FIRST RESULTS ON THE HIGH ENERGY COSMIC RAY ELECTRON SPECTRUM FROM FERMI LAT

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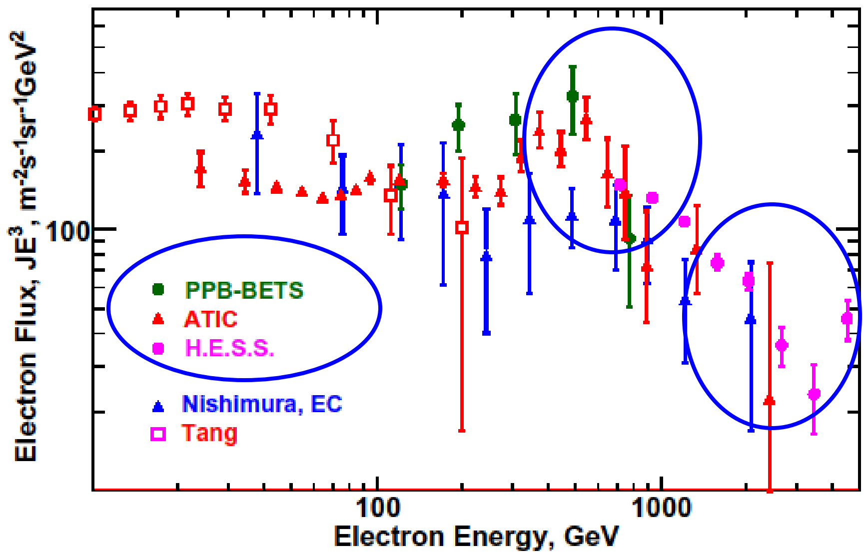
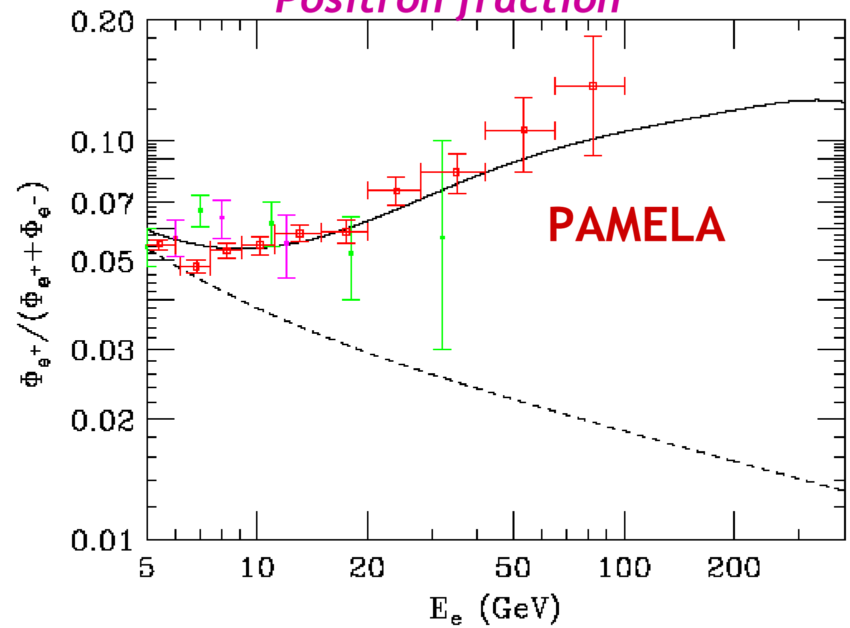
for the Fermi LAT Collaboration

2008: New results on high energy cosmic ray electrons and positrons

Electron + positron results above 100 GeV



Positron fraction



Astrophysicists are excited:

- *Spectral feature at ~ 620 GeV reported by ATIC and PPB-BETS suggests a nearby source (astrophysical or exotic)*
- *Pamela increase of positrons above 10 GeV also suggests new source or production process at high energy*
- *H.E.S.S. detects electrons above 1 TeV: local source? Weaker re-acceleration?*
- *More than 50 papers mentioning these results within a few months*

FERMI FLIGHT DATA ANALYSIS FOR ELECTRONS

Fermi Gamma-ray Space Telescope

Main issues we addressed:

Energy reconstruction:
- optimized for energy < 300 GeV; we extended it up to 1 TeV

Electron-hadron separation
- achieved needed 10^3 - 10^4 rejection power against hadrons, with hadron residual contamination < 20%

Validation of Monte Carlo with the flight data:
- carefully compared MC and flight data

Assessment of systematic errors:
- uncertainty in the resulting spectrum is systematic dominated due to very large statistics

Our strong points:

Extensive MC simulations:
- different particles, all energies and angles
- comparison with beam test
- accurate model of CR background

High precision 1.5 X_0 thick tracker:
- powerful in event topology recognition
- serves as a pre-shower detector

Segmented calorimeter with imaging capability:
- fraction of mm to a few mm accuracy position reconstruction depending on energy

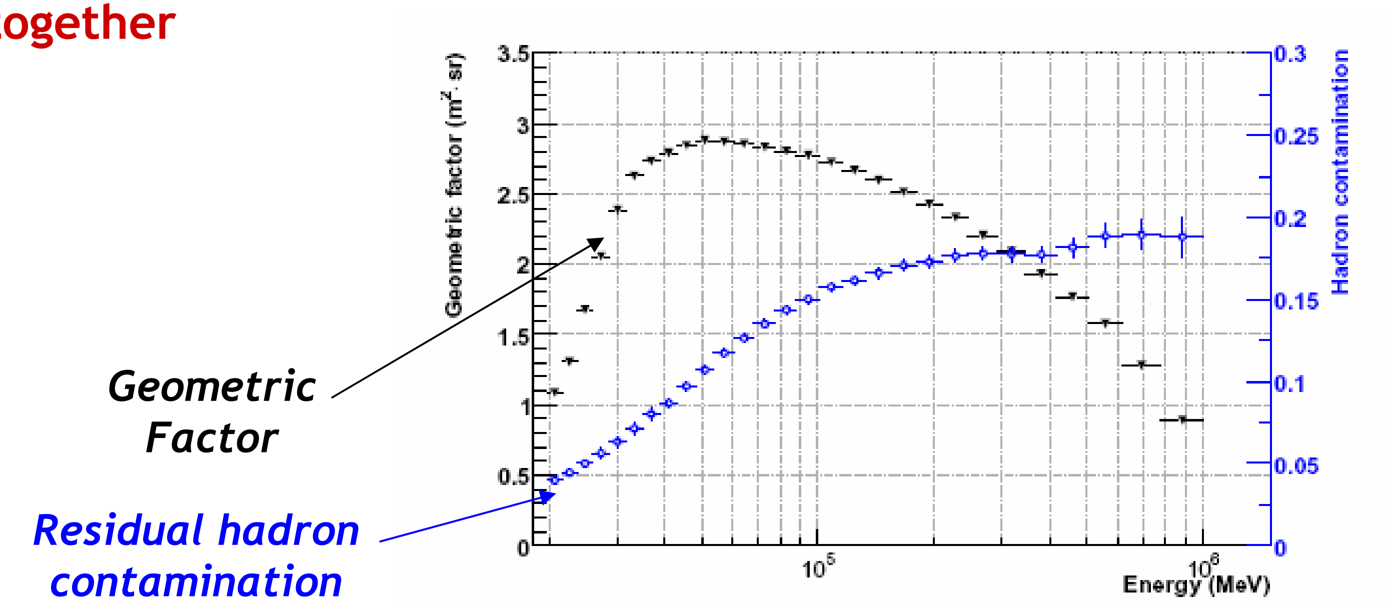
Segmented ACD:
- removes gammas and contributes to event pattern recognition

Extensive beam tests:
- SLAC, DESY, GSI, CERN, GANIL

High flight statistics:
- ~10 M electrons above 20 GeV a year

Achieved electron-hadron separation and effective geometric factor

- Candidate electrons pass on average 12.5 X_0 (Tracker and Calorimeter added together)
- Simulated residual hadron contamination (5-17% increasing with the energy) will be deducted from resulting flux of electron candidates
- Effective geometric factor exceeds 2.5 m^{2}sr for 30 GeV to 200 GeV, and decreases to ~1 m^{2}sr at 1 TeV
- Full power of all LAT subsystems is in use: tracker, calorimeter and ACD act together



Assessment of systematic errors

Contributors:

1. Uncertainty in geometric factor - comes from the residual discrepancy between Monte Carlo and the data. Carefully estimated for each variable used in the analysis

2. Uncertainty in determination of residual hadron contamination

   - comes mostly from the uncertainty of the primary proton model

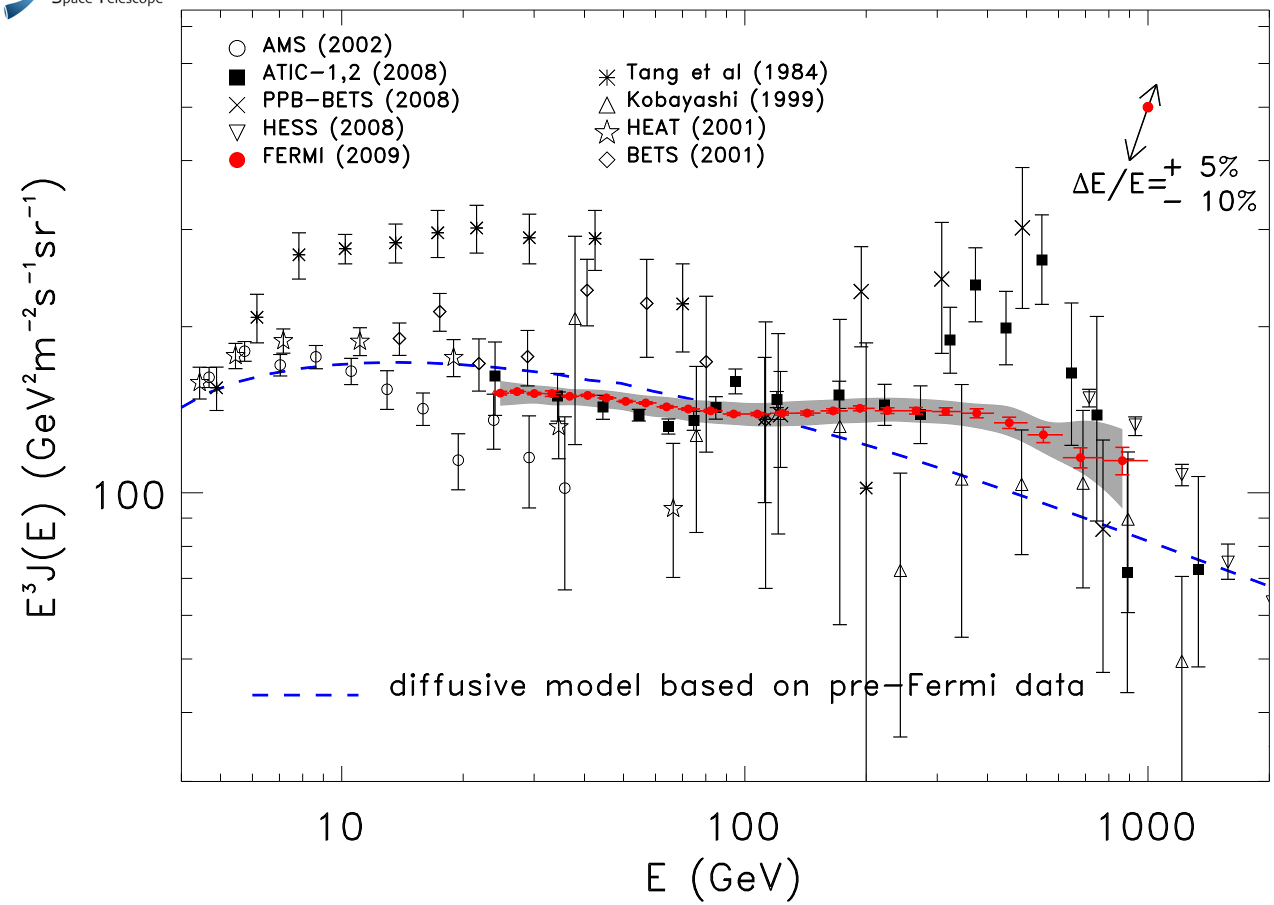
   - we validated the hadronic interaction model with beam test data

Contributors 1 and 2 result in total systematic error ranging from 10% at low energy end to 25-30% at high energy end (full width)

3. Possible bias in absolute energy determination

   - Included separately in the resulting spectrum as (+5, -10)% - estimated from MC simulations, calorimeter calibration and CERN beam test

Fermi-LAT electron spectrum from 20 GeV to 1 TeV



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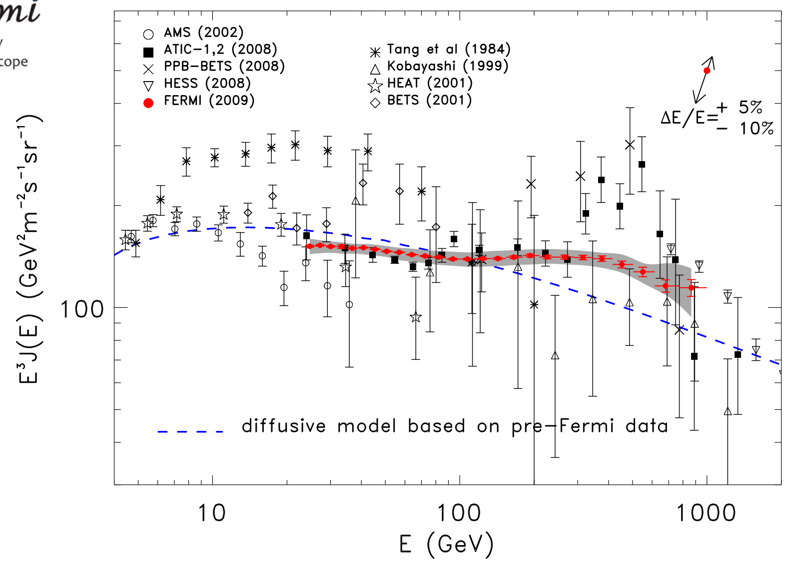
Accepted April 21

<u>Total statistics</u> collected for 6 months of Fermi LAT observations

- ***~4.5 million candidate electrons above 20 GeV***
- ***544 candidate electrons in last energy bin (770-1000 GeV)***

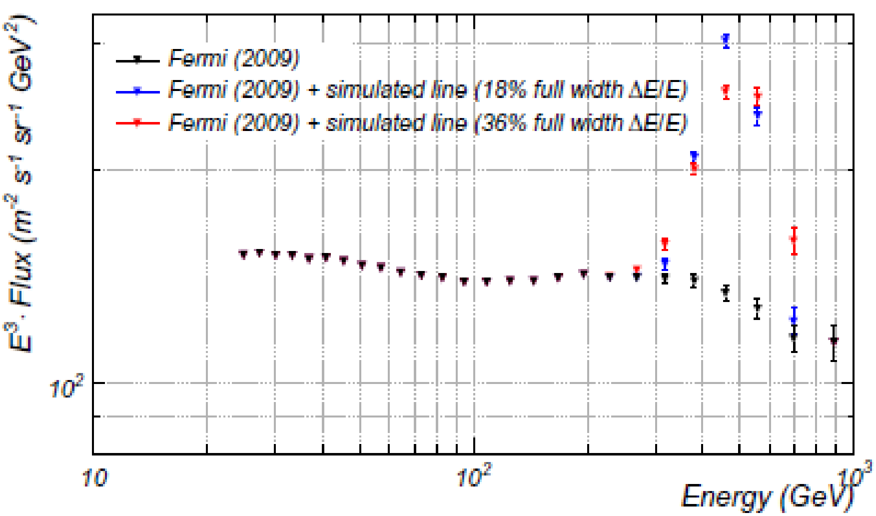


Energy (GeV)	GF (m^2sr)	Residual contamination	Counts	$E^3 \cdot J_E$ ($GeV^2s^{-1}m^{-2}sr^{-1}$)
23.6–26.0	1.65	0.04	478929	$151.6 \pm 1.2^{+7.3}_{-8.3}$
26.0–28.7	2.03	0.05	502083	$152.6 \pm 0.9^{+6.2}_{-7.3}$
28.7–31.7	2.35	0.05	487890	$151.4 \pm 0.8^{+5.1}_{-6.5}$
31.7–35.0	2.59	0.09	459954	$151.3 \pm 1.8^{+5.2}_{-6.5}$
35.0–38.8	2.67	0.07	385480	$149.6 \pm 0.7^{+4.4}_{-5.8}$
38.8–43.1	2.72	0.08	330061	$150.2 \pm 0.7^{+4.5}_{-6.0}$
43.1–48.0	2.76	0.10	276105	$148.6 \pm 0.7^{+4.9}_{-6.2}$
48.0–53.7	2.79	0.11	233877	$146.5 \pm 0.7^{+4.9}_{-6.1}$
53.7–60.4	2.77	0.12	194062	$145.5 \pm 0.7^{+5.0}_{-7.1}$
60.4–68.2	2.76	0.13	155585	$143.2 \pm 0.7^{+5.6}_{-6.8}$
68.2–77.4	2.73	0.14	126485	$141.9 \pm 0.8^{+5.6}_{-7.0}$
77.4–88.1	2.71	0.14	100663	$140.8 \pm 0.8^{+6.2}_{-7.0}$
88.1–101	2.68	0.15	77713	$139.0 \pm 0.9^{+6.4}_{-6.8}$
101–116	2.64	0.16	61976	$139.0 \pm 0.9^{+6.4}_{-7.2}$
116–133	2.58	0.17	46865	$139.4 \pm 1.0^{+6.9}_{-7.2}$
133–154	2.52	0.17	35105	$139.5 \pm 1.2^{+7.2}_{-7.4}$
154–180	2.44	0.17	27293	$140.8 \pm 1.3^{+6.9}_{-7.4}$
180–210	2.36	0.18	19722	$142.3 \pm 1.5^{+7.1}_{-7.4}$
210–246	2.27	0.18	13919	$140.9 \pm 1.7^{+7.4}_{-6.8}$
246–291	2.14	0.18	10019	$140.9 \pm 1.9^{+7.5}_{-6.7}$
291–346	2.04	0.18	7207	$140.4 \pm 2.2^{+6.7}_{-7.0}$
346–415	1.88	0.18	4843	$139.4 \pm 2.6^{+7.0}_{-7.2}$
415–503	1.73	0.19	3036	$134.0 \pm 3.1^{+9.3}_{-7.5}$
503–615	1.54	0.20	1839	$127.4 \pm 4.1^{+8.7}_{-8.6}$
615–772	1.26	0.21	1039	$115.8 \pm 4.8^{+15.2}_{-10.9}$
772–1000	0.88	0.21	544	$114.4 \pm 6.5^{+19.1}_{-17.8}$

- ***The measured spectrum is compatible with a power law within our current systematic errors. The spectral index (-3.04) is harder than expected from previous experiments and simple theoretical considerations***
- ***"Pre-Fermi" diffusive model requires a harder electron injection spectrum (by 0.12) to fit the Fermi data, but inconsistent with positron excess reported by Pamela if it extends to higher energy***
- ***Additional component of electron flux from local source(s) may solve the problem; its origin, astrophysical or exotic, is still unclear***
- ***Valuable contribution to the calculation of IC component of diffuse gamma radiation***

And finally we want to check - could we miss "ATIC-like" spectral feature?

We validated the spectrum reconstruction by different ways including the simulation the LAT response to a spectrum with an "ATIC-like" feature:



6-month Fermi LAT spectrum with the added spectral feature reported by ATIC, scaled for the statistics to be obtained by LAT for the same observation time:

Black points - LAT electron spectrum

Blue points: LAT spectrum + "ATIC-like" bump. LAT ΔE/E (68%, FW) = 18%. The excess would be ~ 7,000 events on the top of "background" of ~ 14,000 events between 300 and 800 GeV

Red points - the same but if LAT had twice worse energy resolution

This demonstrates that the Fermi LAT would have been able to reveal "ATIC-like" spectral feature with high confidence if it were there

Future plans:

- ✓ *Search for anisotropy in the electron flux*

- ✓ *Study systematic errors in energy and instrument response to determine whether or not the observed spectral structure is significant*

- ✓ *Expand energy range down to ~ 5 GeV (lowest possible for Fermi orbit) and up to ~ 2 TeV, in order to reveal the spectral shape above 1 TeV and provide more overlap with the H.E.S.S. data*

- ✓ *Increase the statistics at high energy end. Each year Fermi-LAT will collect ~ 400 electrons above 1 TeV with the current selections if the spectral index stays unchanged*