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

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
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/year
Achieved electron-hadron separation and effective geometric factor

- Candidate electrons pass on average $12.5 \times X_0$ (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 $2.5 \text{ m}^2\text{sr}$ 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

Submitted to PRL on March 19, 2009
Accepted April 21

Total statistics 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)
• 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 $\Delta E/E$ (68%, FW) = 18%. The excess would be $\sim 7,000$ events on the top of “background” of $\sim 14,000$ 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

Alexander Moiseev     May 4, 2009     APS meeting
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