Background Cosmic Ray Flux Measured by Balloon Flight Engineering Model

GLAST-LAT Collaboration Meeting
October 22, 2002
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(Real work done mostly by T.Mizuno)
Balloon Engineering Flight Model

- **Monte-Carlo detector simulator** using Geant4 toolkit.
- **Cosmic-ray spectral models** referring to previous measurements.
  - proton: primary/secondary
  - alpha: primary
  - electron/positron: primary/secondary
  - gamma: primary, secondary
    (downward/upward)
  - muon: secondary
    (All but secondary downward gamma will be present in the low earth orbit.)
- BFEM data and G4 simulation are compared.
Cosmic-Ray Model: Proton(1)

Energy spectrum from zenith downward: well measured

- our model
- AMS
- BESS (at magnetic north pole)

*The flux in high geomagnetic latitude (~0.73 radian) shown here corresponds to the maximum flux expected in the GLAST orbit.*
Cosmic-Ray Model: Proton(2)

Proton zenith angle distribution: only poorly known

AMS and BESS measurements were restricted to <30 degree.

AMS and BESS agree with each other within ~15%.

Only poorly measured by old rocket experiments.

AMS exp. BESS exp.
Cosmic-Ray Model: Gamma

Energy spectrum

- Atmospheric gamma (upward)

- Geant4 simulation
- Imhof et al. 1986, R-3GV
- Bignami et al. 1979
- Thompson 1974
- Kuroyan et al. 1979

Upward gamma-ray flux will be similar to that in GLAST orbit.

Zenith angle dependence

- Schonfelder et al. 1977
- Our model function

Angular dependence of the flux is poorly known.

We also implemented alpha, e-, e+, and muon spectra.
Count Rate per Layer for “Charged Events”: Real Data

“Charged Events” = Events with one or more hits in ACD

![Graph showing count rate per layer for charged events with annotations for complete and incomplete layers, and labels for CAL, TKR, and ACD.](image-url)
Count Rate per Layer for “Charged Events”: Data vs. Simulation

• Trigger rate (Data) ~445Hz
• Simulation total (our prediction before the flight) ~350Hz
  - proton : 145Hz
  - alpha : 18Hz
  - e- : 45Hz
  - e+ : 30Hz
  - gamma : 50Hz
  - muon : 62Hz

• Our model reproduced the shape of the distribution very well.
• Our prediction of the trigger rate is ~20% smaller than observed data.
"Chi-square" Distribution of Straight Tracks

Root mean square of reconstructed track (simulation)

\[ \text{rms (arbitrary unit)} \]

We can separate proton/alpha/muon from e-/e+/gamma, select straight track events and study the angular distribution of them.
Count Rate per Layer for “Neutral Events”: Real Data

“Neutral Events” = Events without hit in ACD

[Graph showing count rates for different conditions and materials like thick Pb, thin Pb converters, No Pb, and low energy gamma/e-/e+.]

T. Kamae, GLAST-LAT Collaboration Meeting at Goddard, Oct.22, 2002
Count Rate per Layer for Neutral Events: Data vs. Simulation

- Trigger rate (Data) ~55Hz
- Simulation total (our prediction before the flight) ~52Hz
  - proton : 3.1Hz
  - alpha : ~0Hz
  - e- : 6.9Hz
  - e+ : 3.9Hz
  - gamma : 35.5Hz
  - muon : 2.4Hz

Overall agreement is good between data and prediction.
Count rate in upper layers are smaller than data.
Need a reconstruction program for low-energy (<=100MeV) gammas to study angular dependence.
East-West Effect Seen in Data

Time history of azimuth direction of the BFEM

Azimuth dependence of “charged” straight tracks (0.5<cos(theta)<0.7)

Direction was stable in the level flight.

We see the east-west effect.

Particle comes from east in 2\textsuperscript{nd} region
Study of Particle Composition by Straightness of Tracks

Study shown in a previous slide opened a possibility to study composition of tracks.

A few disagreements were there between Data and Simulation:
1) Obvious effect of misalignment in “chi-square” <10**(-2)
2) “Anomalous” bump in “chi-square” at around 1.0

Resolution:
Res. 1) Hiro Tajima ran his SSD alignment program (under development for LAT) and fixed it.
Res. 2) With Leon’s help, we found that inaccurate CAL calibration in BFEM lead to a strange “local minimum ch-square”. We ignored CAL data.
New “Chi-square” Distribution of Tracks: data and simulation

CAL data ignored in recon.

Agreement is better but we find more “stiff tracks” in the BFEM data.
Revisit the angular dependence of single/straight tracks

Zenith angle distribution of single and straight (chi²<=0.1) tracks.

Now the agreement near cos(θ)=1 with BESS and AMS is gone! WHY?
Other Disagreement?: Topmost Layer Distribution

The Shape of two distribution appears to be in agreement.
Other Disagreement?: Total Number of Layers with Hits

Data show typically 10-20% more layers spill over to odd numbers for total numbers less than 17.
Other Disagreement?: Total number of layers for straight tracks

Single and straight (chi^2<=0.1) tracks selected

Odd numbers are filled more in data by ~20% for total number 6-18
Revisit Angular Dependence of Single/Straight Tracks

Total number of layers with hit = 8-12  Total number of layers with hit = 23-26

Normalization is off by 30%.

Good agreement btwn Data and Simulation.
Number of reconstructed tracks

Number of layers with hit = (8-12) selected. Note that the number of tracks is 2 for single track events (x and y tracks).
Hit Strip Distribution

Total number of layers with hit is large (23-26).

Total number of layers with hit is small (8-12).

Data and simulation agree in the shape of distribution.
Summary and Future Plan

• We see ~20% more charged tracks in BFEM data than our Cosmic Ray model predicts.
• We found straightness (least square) of tracks can be used in filtering e-/e+ from protons.
• When incorporating the CAL energy in the straightness of tracks analysis, inaccurate CAL measurements can mislabel protons as e-/e+.
• Simulation reproduces data well when the number of layers with hit is large, but it underestimates data when the number of layers is small and the ratio between layer even and odd is off.
  – ~20-30% additional stray hits may explain this: stray X-rays and noise?
  – Simplification of honeycomb structure problematic: delta-rays?
  – ACD leakage on the 4 side corners: measured to be small.
  – Inclusion of protons with E>100GeV?
  – And ~ 20% higher proton flux?
• Eye scanning of short tracks and stray hits.
• Improved use of CAL data
• Reconstruction of gamma rays