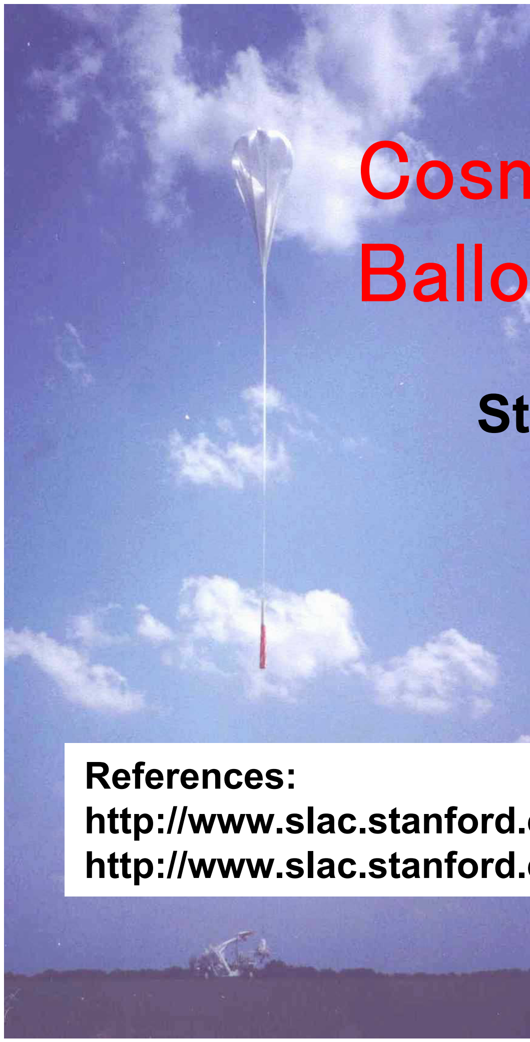

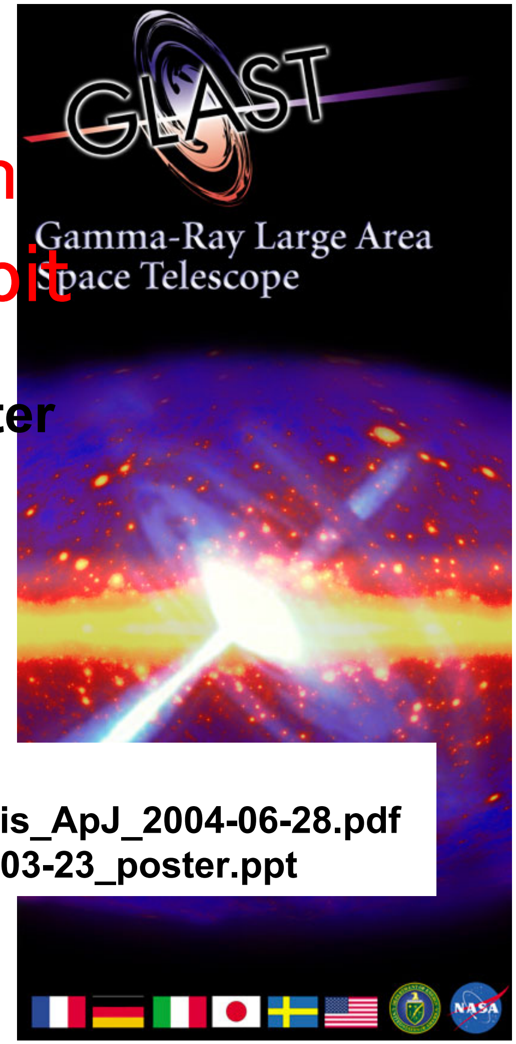

Cosmic-Ray Background in Balloon and Low-Earth Orbit

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History of Changes:
June 24, 2004 written by T. Mizuno
June 30, 2004 modified by T. Mizuno

References:
http://www.slac.stanford.edu/~mizuno/GLAST/Balloon/BalloonAnalysis_ApJ_2004-06-28.pdf
http://www.slac.stanford.edu/~mizuno/GLAST/Presentation/CR_2004-03-23_poster.ppt

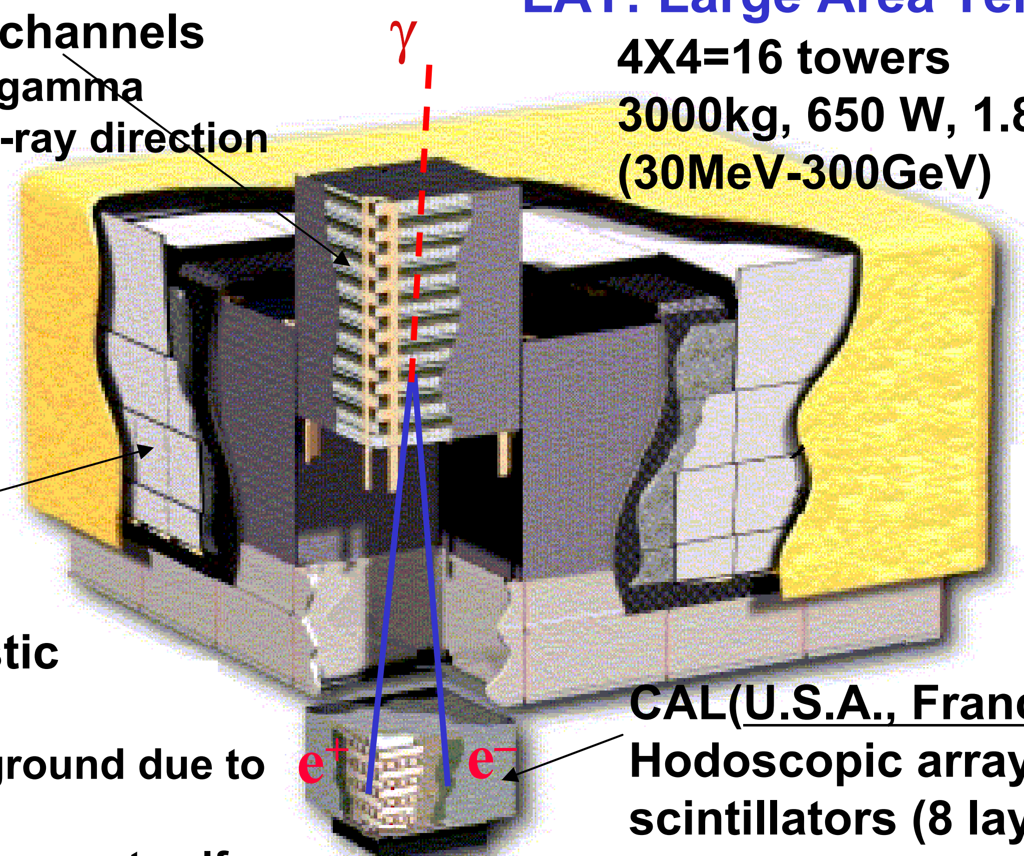
Outline of This Talk

GLAST Large Area Telescope

TKR(U.S.A., Japan, Italy):
Si-Strip Tracker with Lead converter
18 X-Y tracking planes,
228um pitch, 8×10^5 channels
- Identification of gamma
- Measure gamma-ray direction

GLAST (Gamma-ray Large Area Space Telescope)=LAT+GBM

LAT: Large Area Telescope
4X4=16 towers
3000kg, 650 W, $1.8\times1.8\times1m^3$
(30MeV-300GeV)



ACD(U.S.A.):
Segmented 89 plastic scintillator tiles
- Eliminate background due to charged particle
- Segmentation: prevent self-veto in high energy

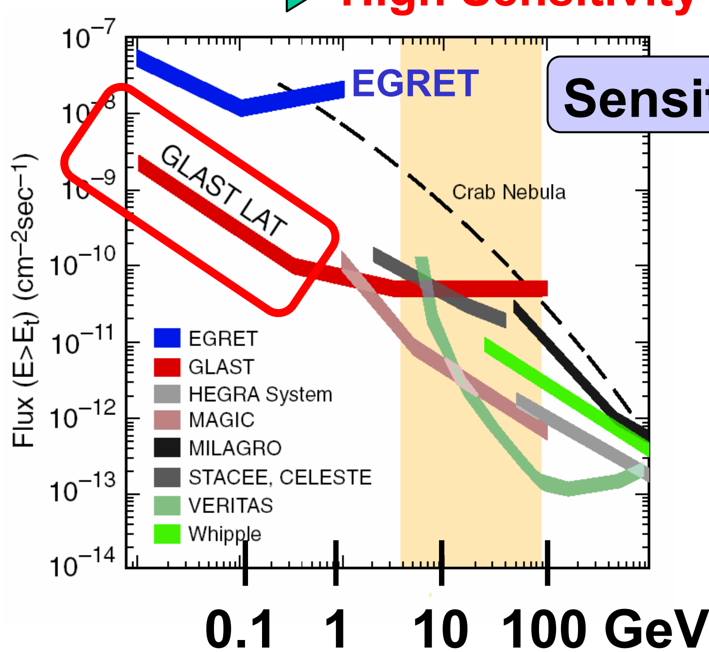
CAL(U.S.A., France, Sweden):
Hodoscopic array of 1536 CsI(Tl) scintillators (8 layers in each tower)
- Energy measurement

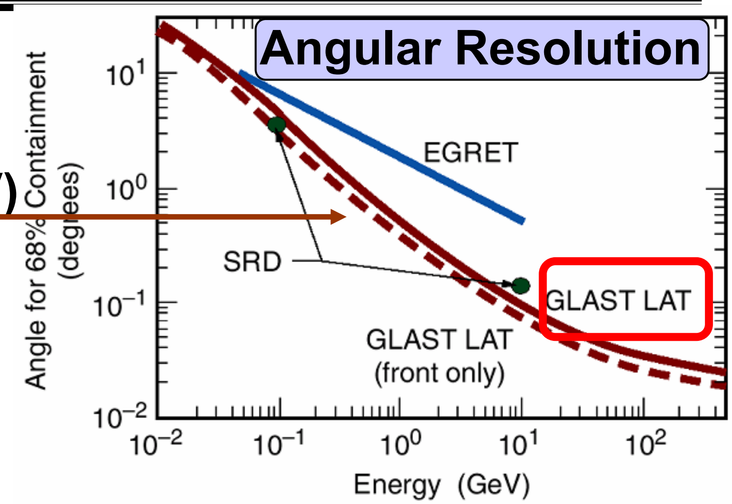
GLAST Performance

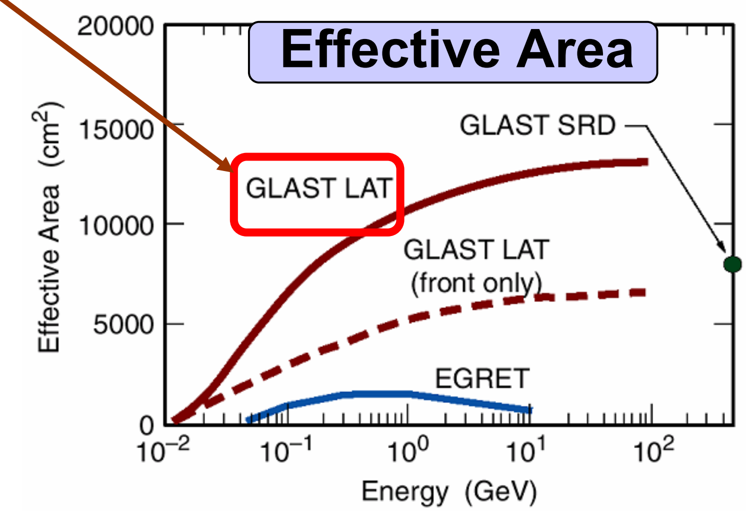
GLAST Large Area Telescope

- **wide FOV (~2sr, 20% of all-sky)**
- **high angular resolution(10' in E>10 GeV)**
- **large effective area (~10000 cm^{-2})**

High Sensitivity

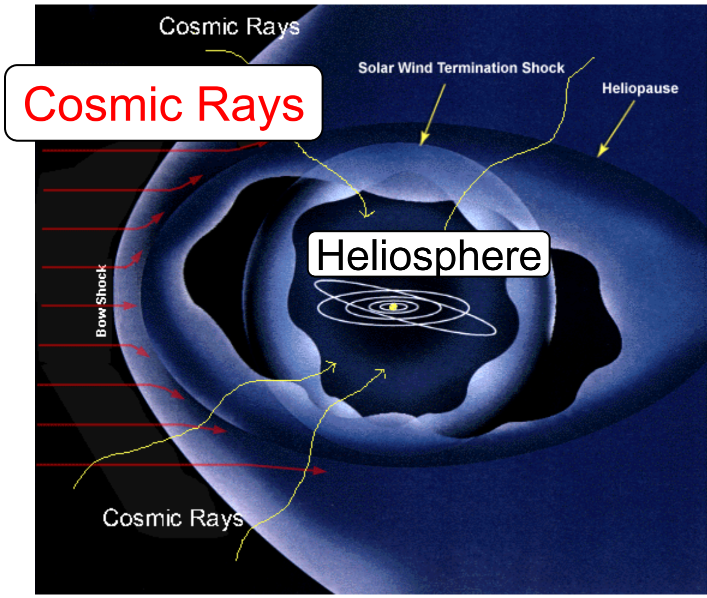






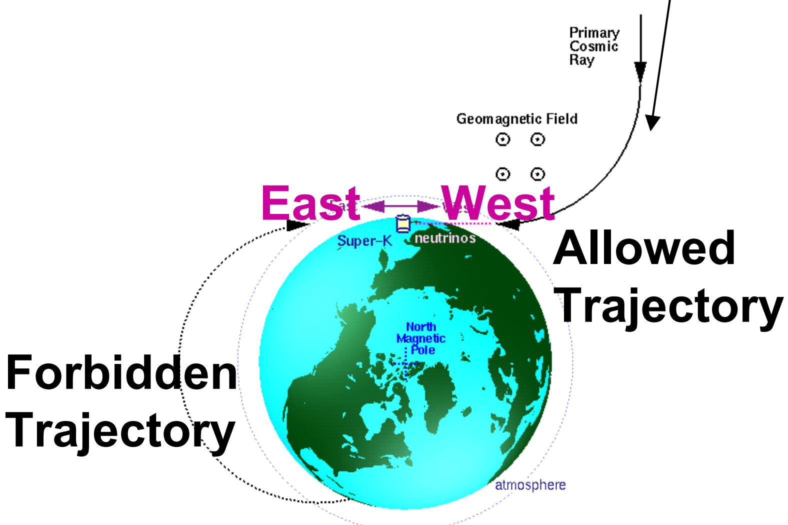
•To estimate the trigger rate and to eliminate the background in orbit, we need to know the cosmic-ray background environment.

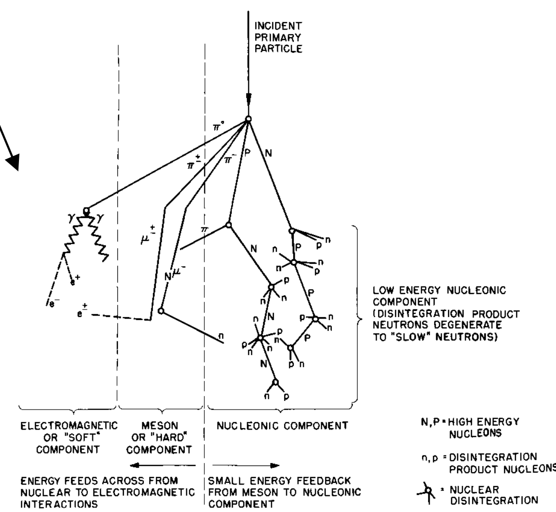
Overview of CR Environment (1)



- Charged primary cosmic-rays, generated in extraterrestrial space, are decelerated by solar wind (solar modulation)
- Primary charged CRs are affected by earth magnetic field (geomagnetic cutoff, east-west effect)
- Secondary CRs are generated in earth atmosphere

  - Primary: high energy (above geomag. cutoff)
  - Secondary: low energy (below cutoff)
  - Both primary and secondary depend on geomag. cutoff





Schematic Diagram of Cosmic Ray Shower

Overview of CR Environment (2)

- Protons
  - Primary: fluxes are similar in balloon altitude and low-earth orbit (small difference due to attenuation by air: ~5% at 3.8g/cm2)
  - Secondary: fairly different (Larmor radius is much smaller than satellite altitude)
- Alpha primary: fluxes are similar
- Electron/positrons
  - Primary: fluxes are similar (small difference due to energy loss in air, ~10% at 3.8g/cm2)
  - Secondary: fairly different
- Gamma
  - Primary: fluxes are similar (except for energy depedent attenuation by air)
  - Secondary downward: only in balloon altitude
  - Secondary upward: fluxes are similar (small difference due to the different solid angle of earth atmosphere)
- Muons: only in balloon altitude

Fluxes in balloon altitude and low-earth are similar to each other:

⇒ GLAST Balloon Experiment

Primary Charged Particle Spectra

•Primary spectra before being affected by modulation

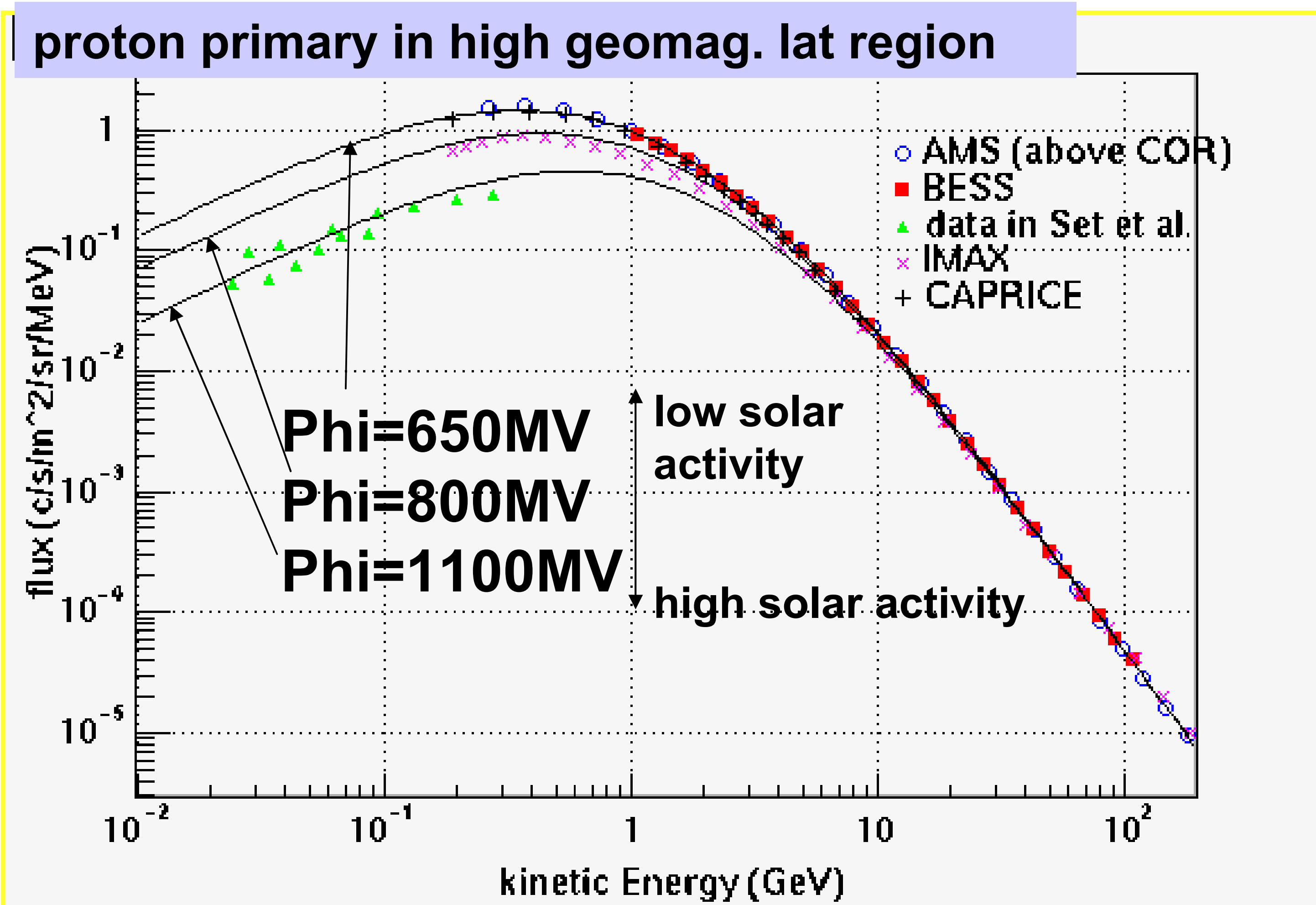
$$\mathrm{Unmod}(E) = \mathrm{A} \times \left(\frac{R(E)}{\mathrm{GV}} \right)^{-a}$$

$$\mathrm{Primary}(E) = \mathrm{Unmod}(E + e\Phi) \times \frac{(E)^2 - (Mc^2)^2}{(E + e\Phi)^2 - (Mc^2)^2} \times \frac{1}{1 + \left(\frac{R}{R_{\mathrm{cutoff}}} \right)^{-r}}$$

•Solar modulation formula given by Gleeson and Axford (1968)

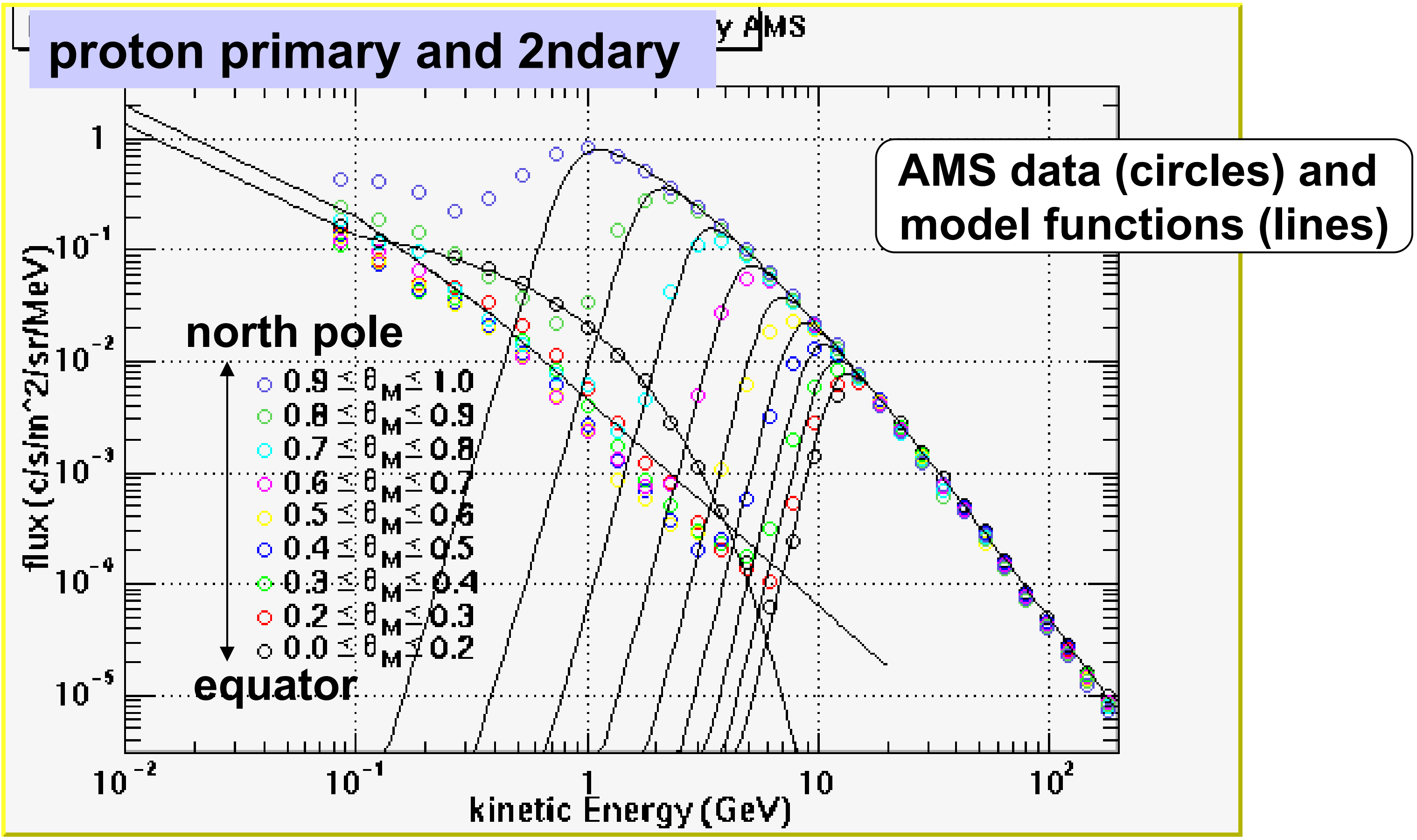
•Our reduction factor to reproduce the geomagnetic cutoff in AMS data.
•A parameter r=12.0 for proton/alpha and 6.0 for electron/positron.

Proton Primary Spectra



Flux anticorrelates the solar activity, which was minimum in year 1996 (and so it will be in 2007)

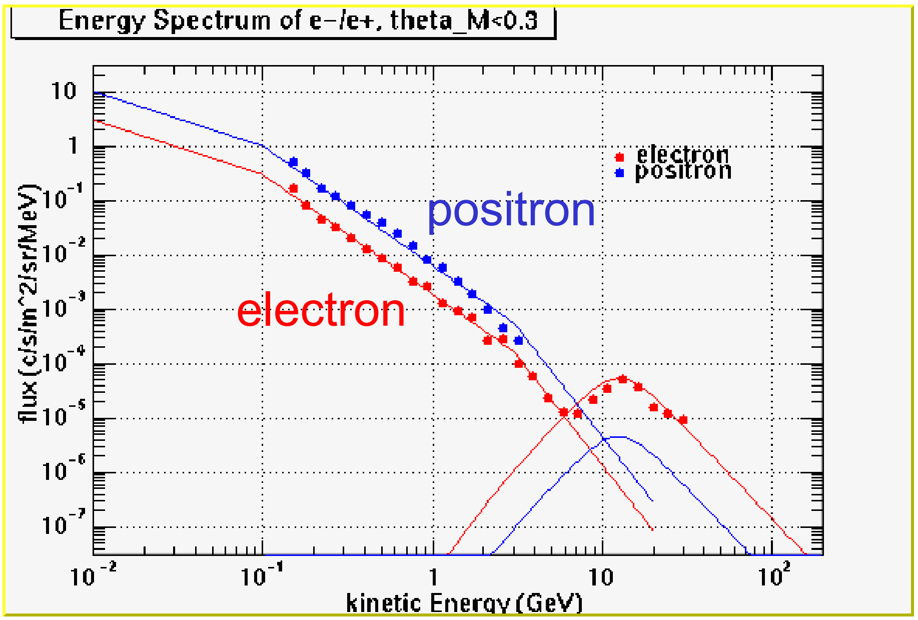
Proton Spectra in Low-Earth Orbit



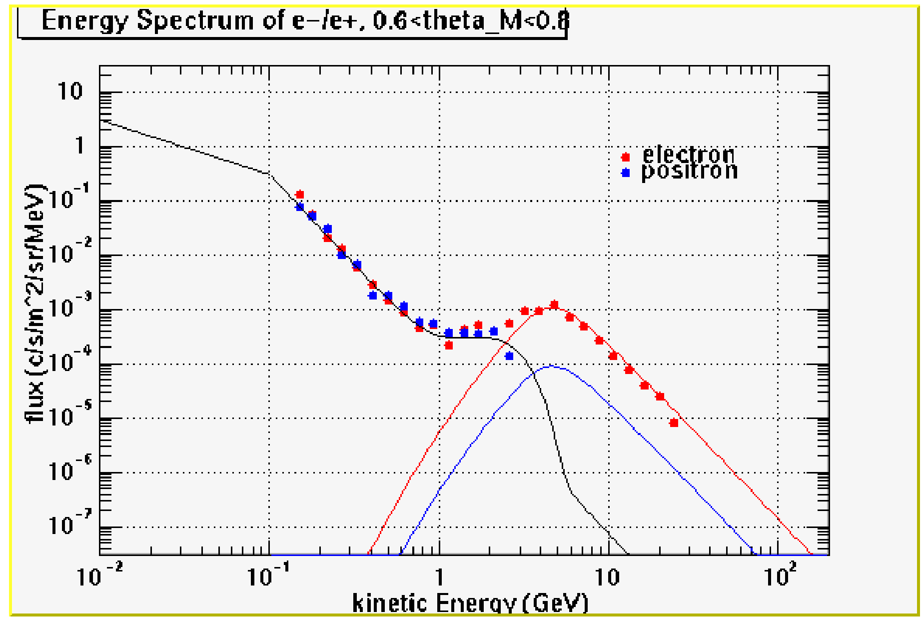
- Our model reproduces primary spectra except for high geomag. lat region.
- Secondary fluxes in AMS(@380km) could be somewhat higher than those in low-earth orbit (550km). Our model is a conservative estimate.
- Zenith angle distribution of 2ndary could be uniform (particles are confined by geomag. field).

Electron/Positron Spectra in Low-Earth Orbit

e^-/e^+ spectra in geomagnetic equator

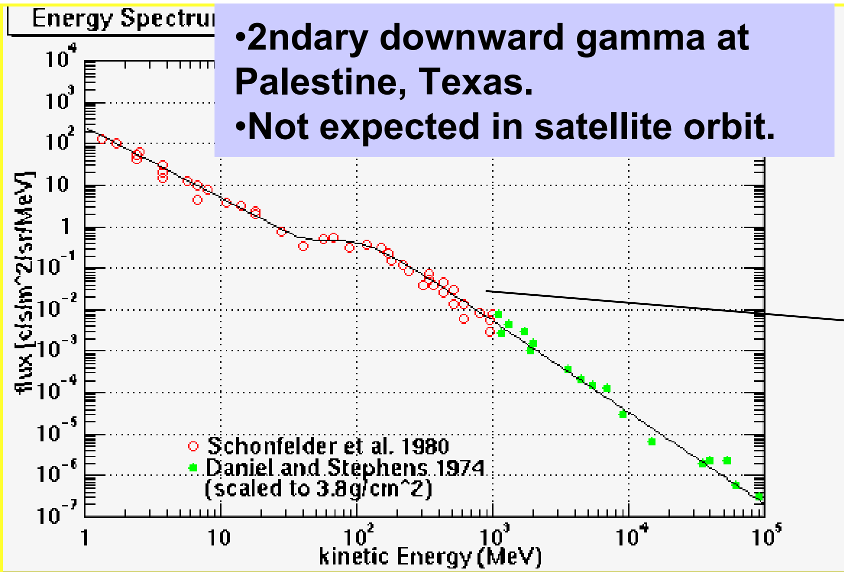


e^-/e^+ spectra in high goemag. lat. region

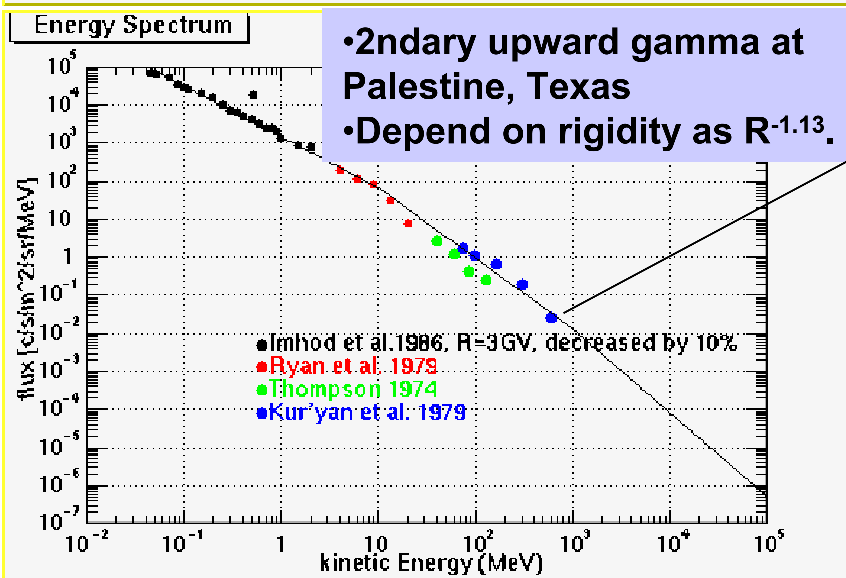


- Low primary flux (large geomag. cutoff) ↔ high primary flux (small geomag. cutoff)
- High secondary flux, differenct in electron/positron. ↔ low secondary flux, similar in electron/positron.

Gamma Spectra

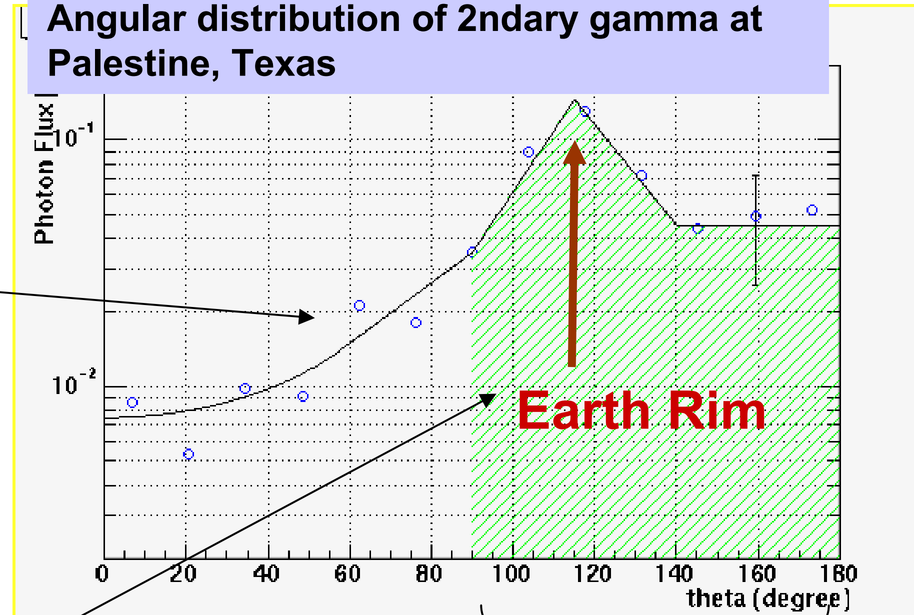


•2ndary downward gamma at Palestine, Texas.
•Not expected in satellite orbit.



•2ndary upward gamma at Palestine, Texas
•Depend on rigidity as $R^{-1.13}$.

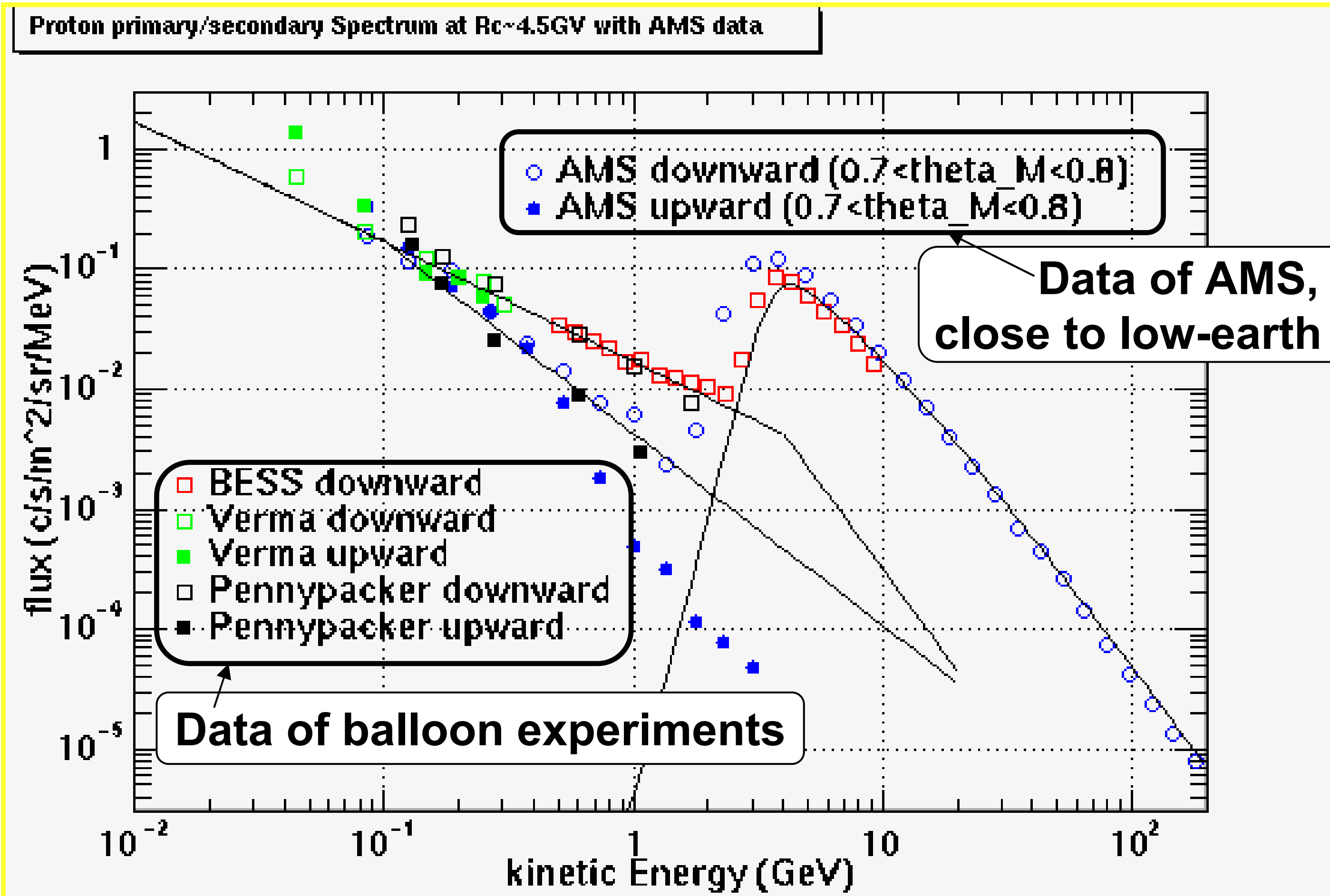
Angular distribution of 2ndary gamma at Palestine, Texas



Upwawrd flux in balloon altitude could be somewhat higher than that in satellite altitude. Our model gives a conservative estimate.

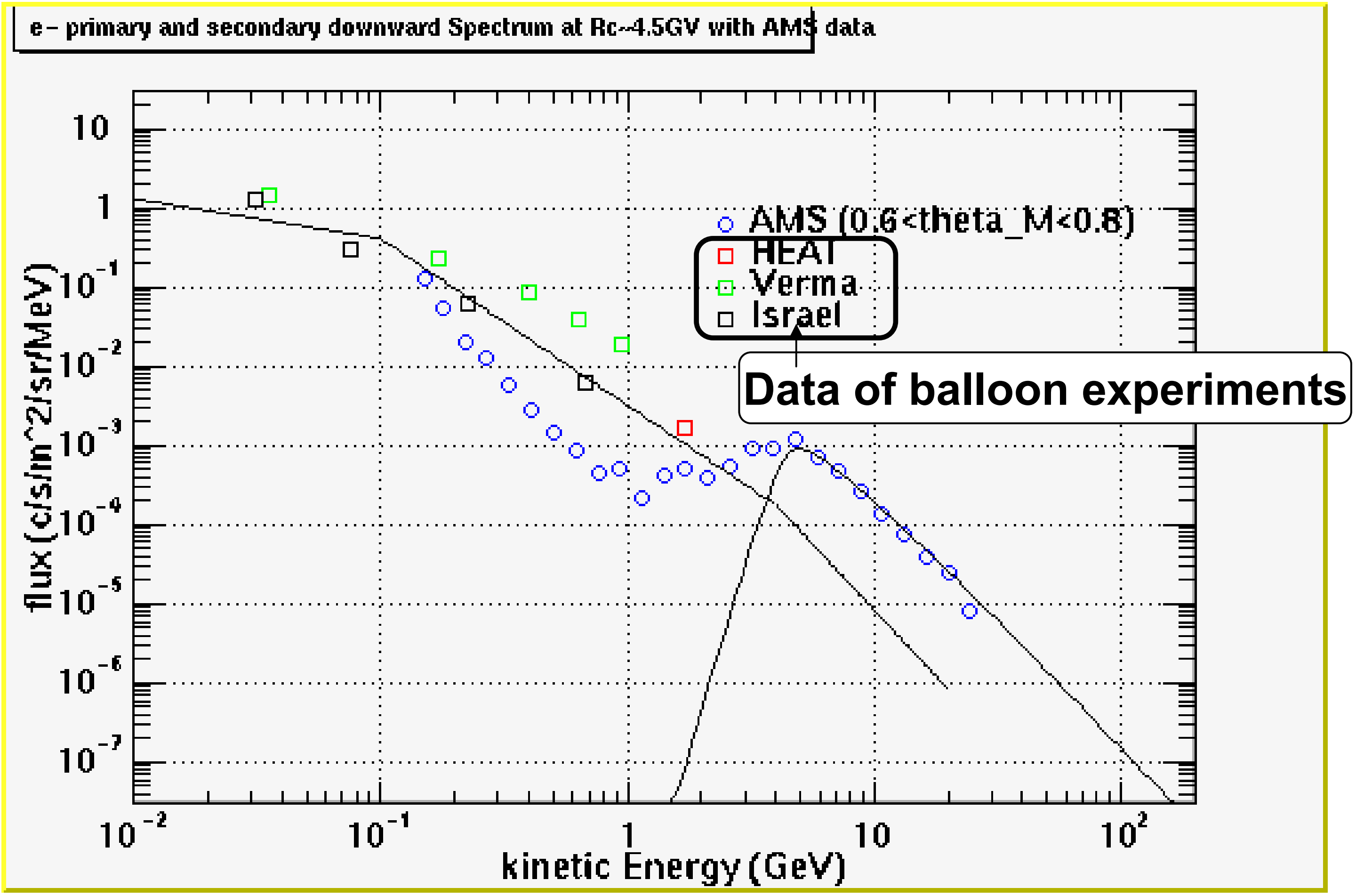
Large uncertainty, need to be verified by GLAST Balloon Experiment

Reference: Proton Spectra at Balloon Altitude



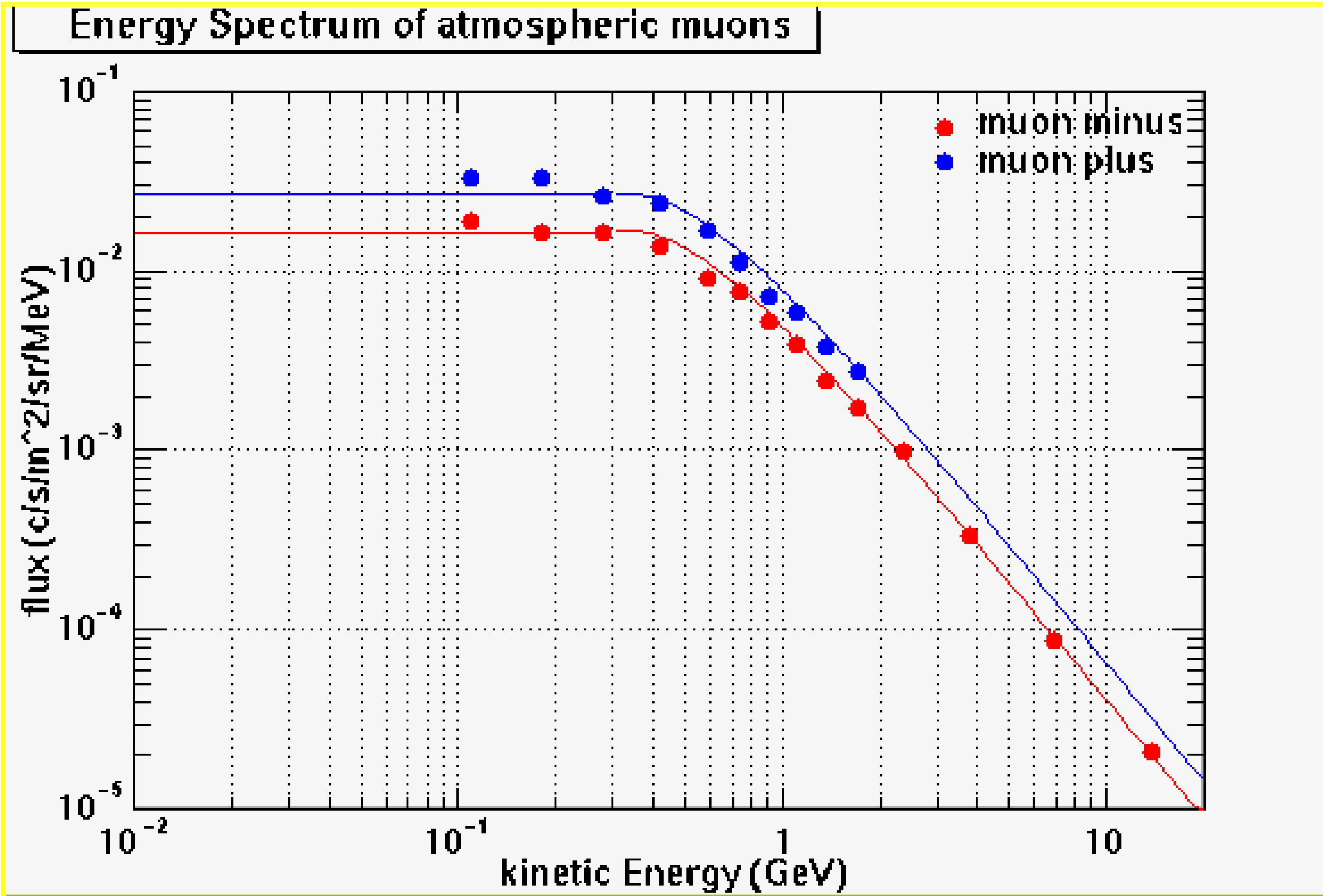
•Secondary flux in balloon altitude is much higher than that of low-earth orbit

Reference: e^-/e^+ Spectra at Balloon Altitude



•Secondary flux in balloon altitude is much higher than that of low-earth orbit

Reference: Muon Spectra at Balloon Altitude



Documents and sour codes

- Model description (paper accepted for publication by ApJ):
  http://www.slac.stanford.edu/~mizuno/GLAST/Balloon/BalloonAnalysis_ApJ_2004-06-28.pdf
- Summary of models (poster presented in meeting in Japan):
  http://www.slac.stanford.edu/~mizuno/GLAST/Presentation/CR_2004-03-23_poster.ppt
- Source Codes (CRflux package):

  glastpack.pl rco GlastRelease HEAD

  glastpack.pl rco CRflux HEAD

  glastpack.pl build CRflux

  glastpack.pl run CRflux test_CRflux.exe

  (edit CRTestAlg.cxx to choose particle type)

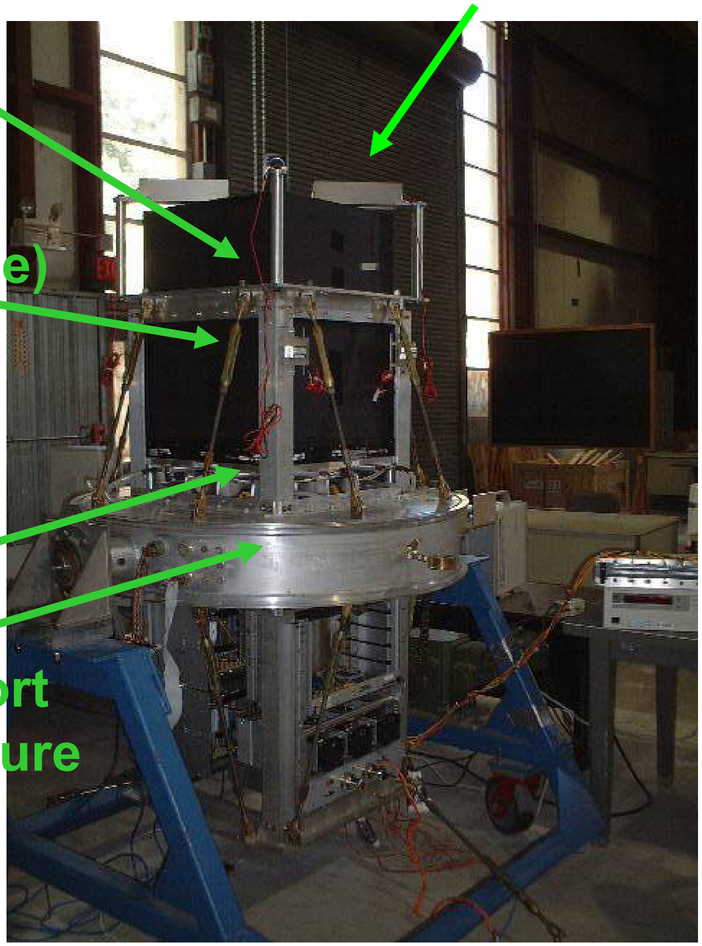
The GLAST Balloon Experiment

Balloon Flight Engineering Model (BFEM)

eXternal Gamma-ray Target(XGT)

ACD

TKR (inside)



CAL

Support Structure

D. Thompson et al., 2002

Objectives:

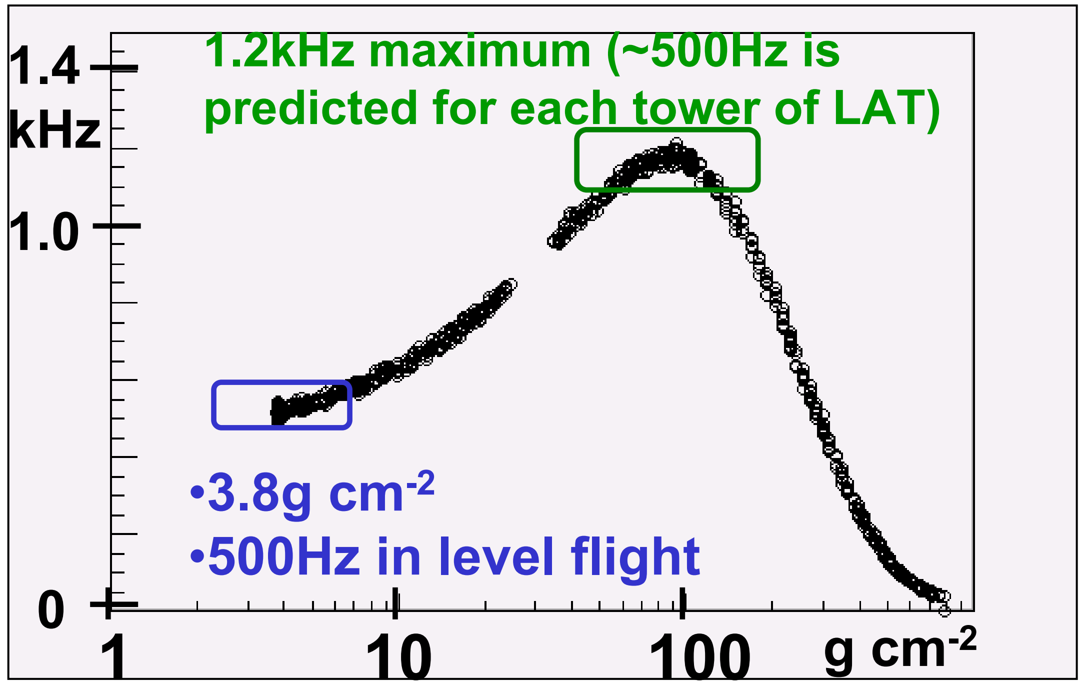
a. Validate the LAT design at the single tower level
b. Show the ability to take data in a space-like high-counting environment.
c. Collect cosmic-ray events to be used for a background database for LAT.

•We have developed cosmic-ray spectral models and an instrument simulator.

Balloon Flight Operation

- August 4th , 2001 @Palestine, Texas
- 38km altitude
- 3 hours level flight

Trigger rate vs. atmospheric depth



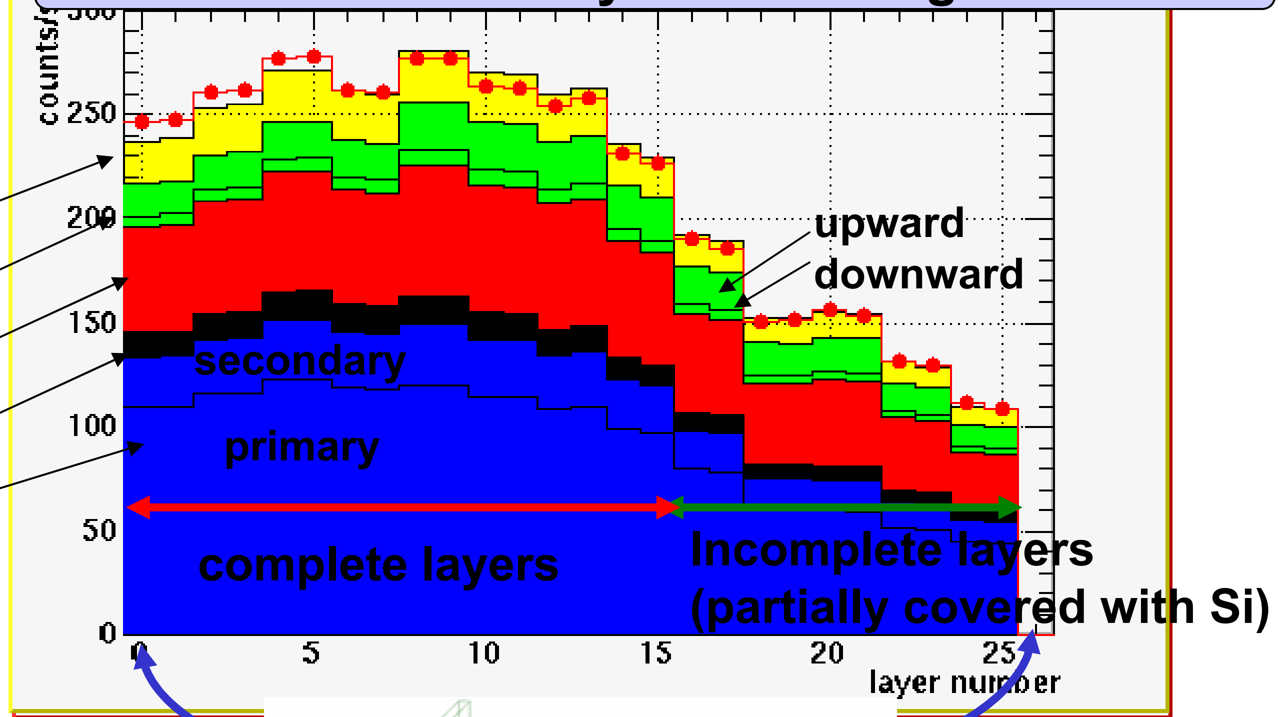
- All detector components worked well in high-counting environment.

- We collected over 100k events during level flight via telemetry. (~2.5% out of all triggered events)
- We compensated small bias in event sampling.

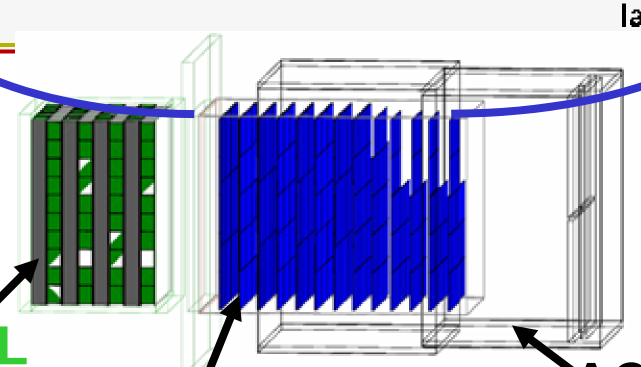
Count Rate of Each Layer for "Charged Events" (Hit in ACD)

- trigger rate (data): ~440Hz
- simulation total: ~440Hz
  - muon : 39 Hz
  - gamma : 54 Hz
  - e-/e+ :110 Hz
  - alpha : 19 Hz
  - proton : 216 Hz

Count rate of each layer for "Charged Events"

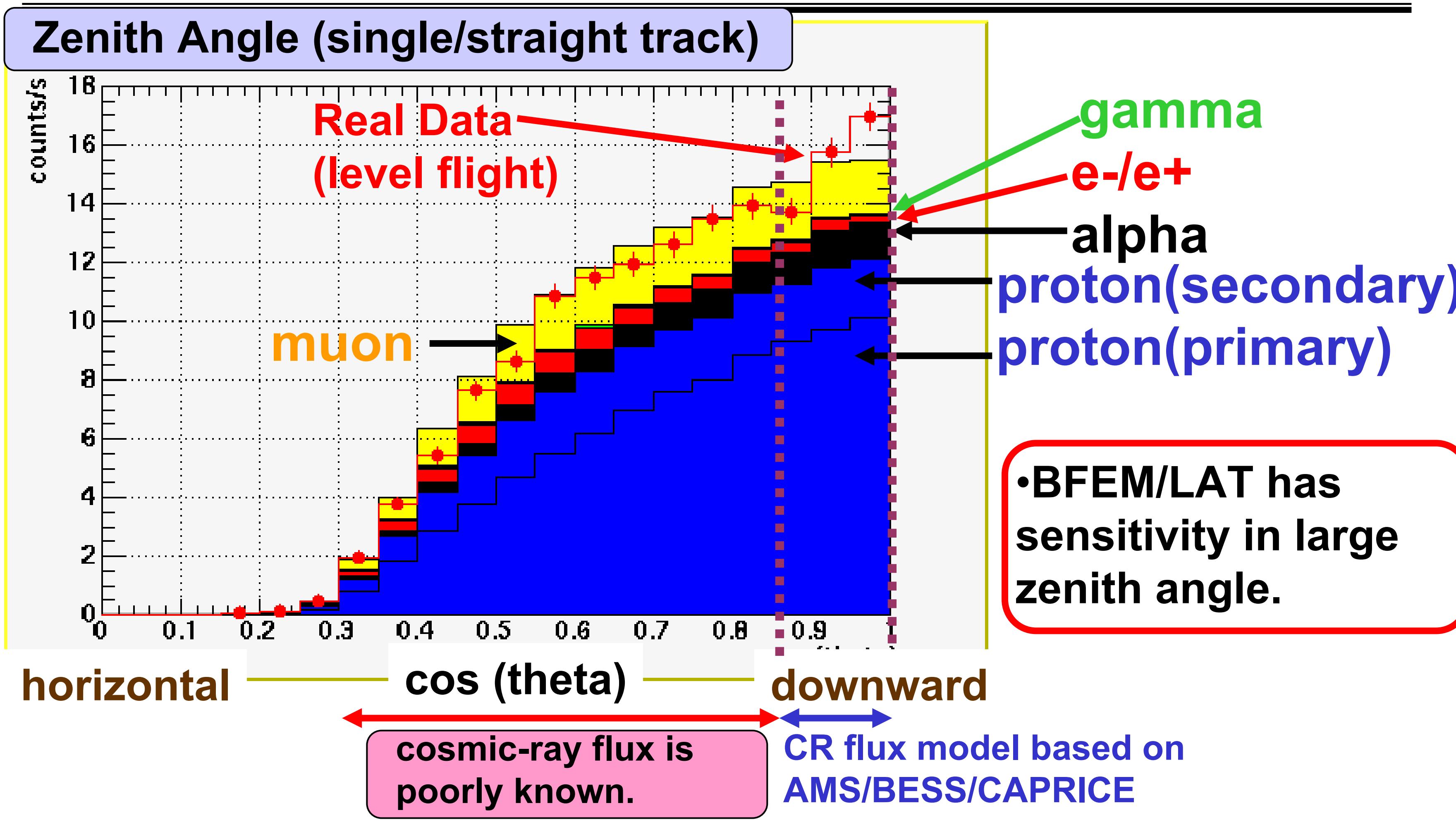


- Succeeded in reproducing data in all 26 Si layers



26 Si layers (13 planes: x-y pair)

Angular Distribution of "Charged Events"



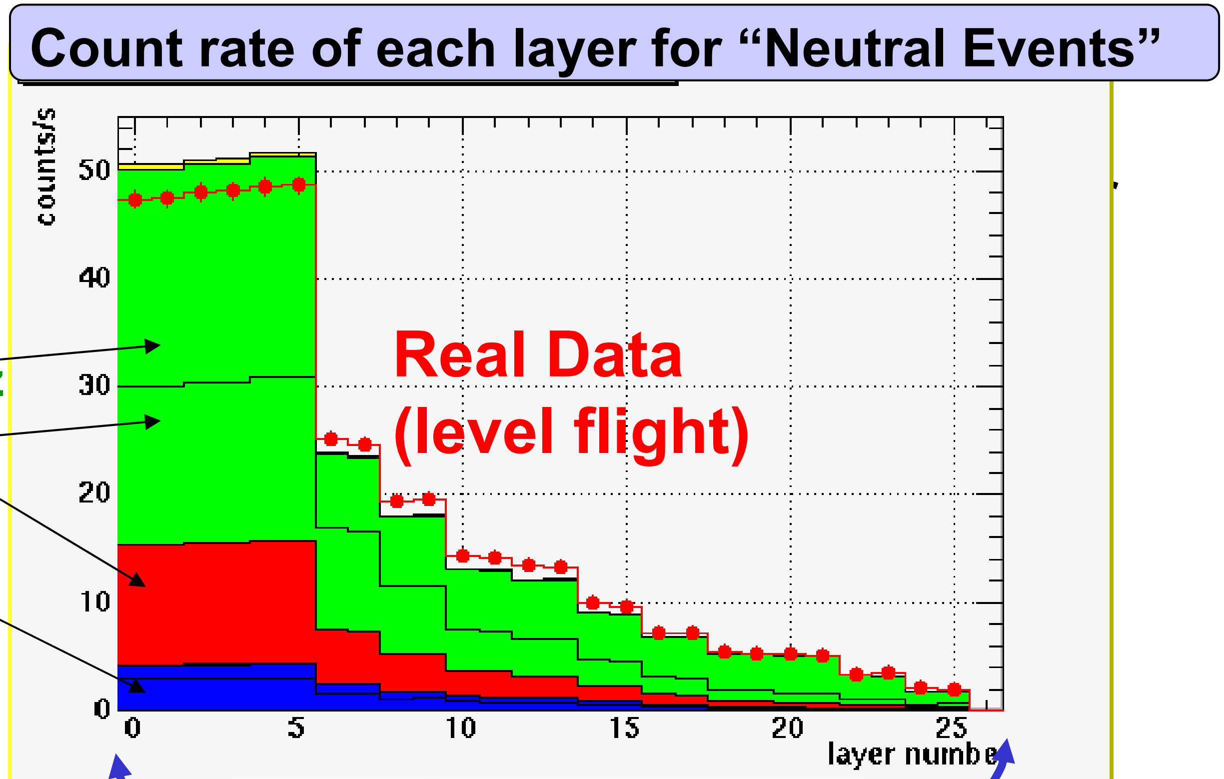
•BFEM/LAT has sensitivity in large zenith angle.

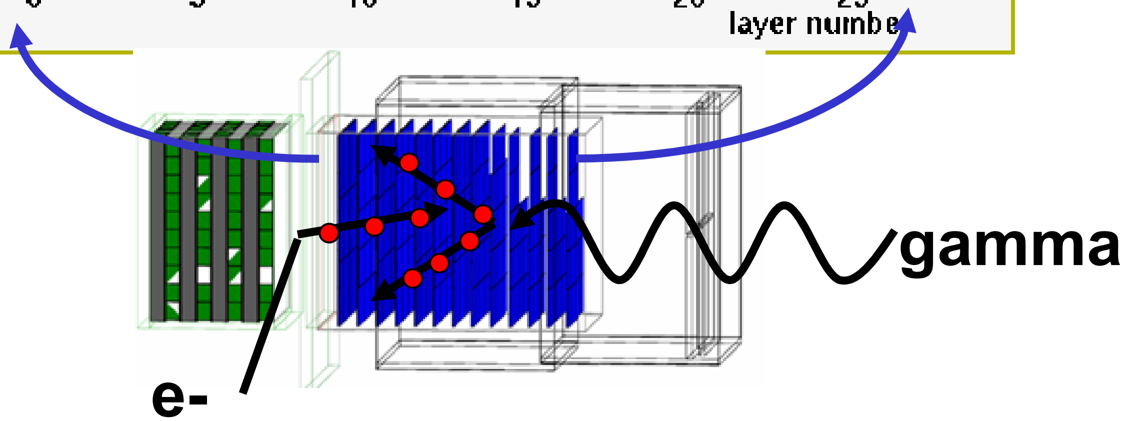
•Reproduce zenith angle distribution in region of cos(theta)=1.0-0.3 (0-70degree)

Count Rate of Each Layer for "Neutral Events" (no Hit in ACD)

- trigger rate (data): ~58Hz
- simulation total: ~61Hz

muon	: 0.5Hz
gamma upward	: 26.8 Hz
gamma downward	: 16.8Hz
e-/e+	: 12.3Hz
alpha	: 0.1Hz
proton	: 4.8Hz



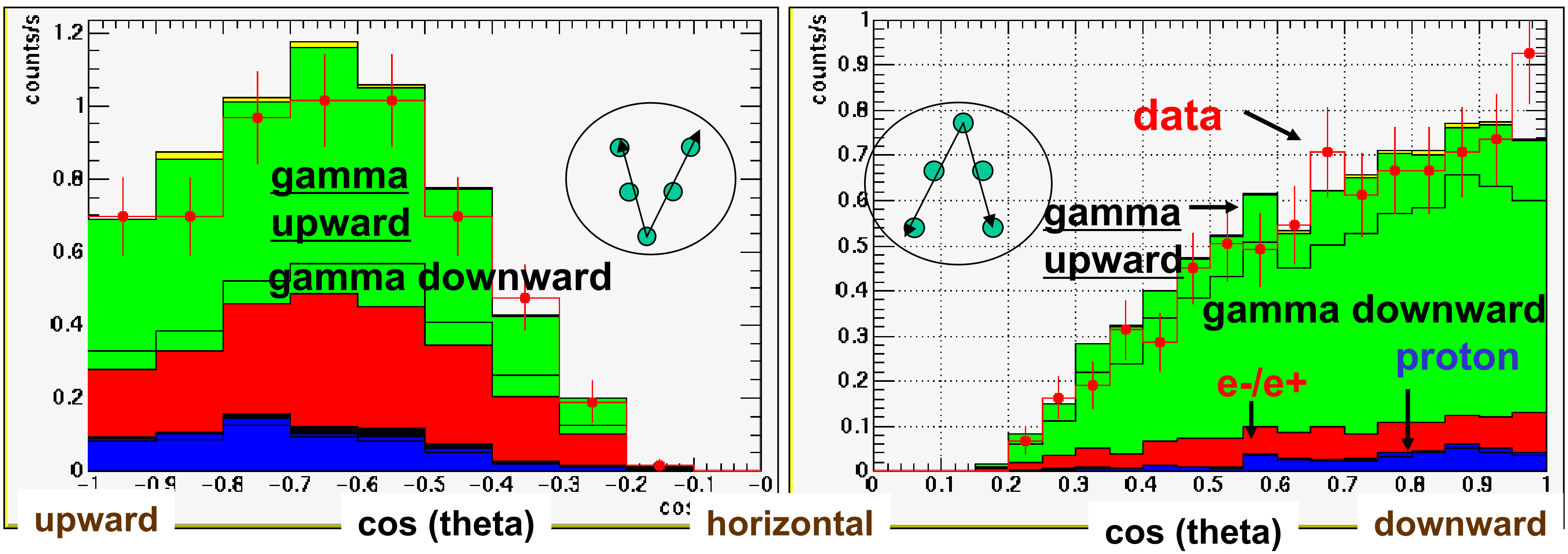


- Succeeded in reproducing data in all 26 Si layers

Angular Distribution of atmospheric gamma

Zenith angle distribution

gamma upward candidate | gamma downward candidate



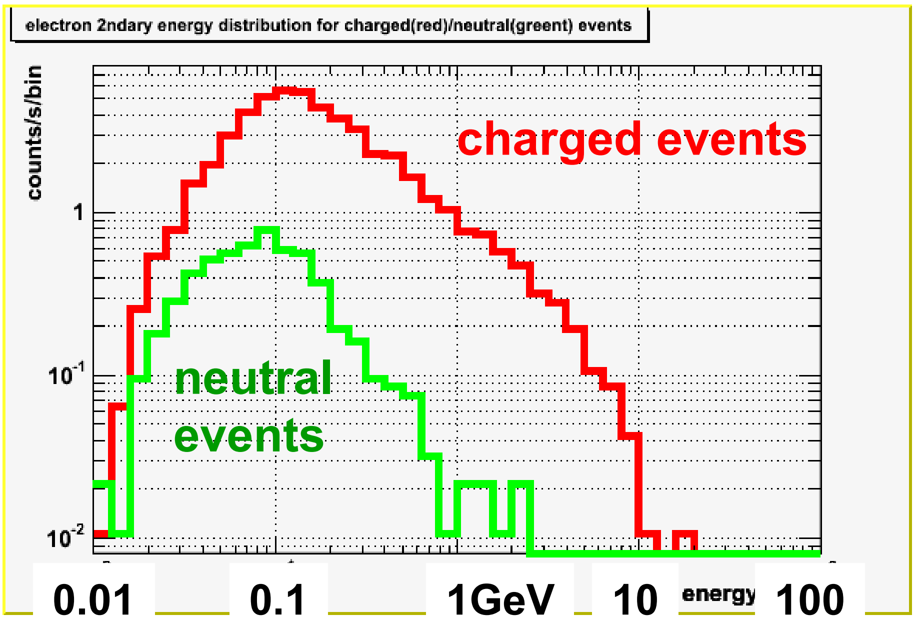
•Succeeded in reproducing downward gamma in cos(theta)=1~0.3 (0-70degree) and upward gamma in cos(theta)=-1~-0.3(180-110degree)

➡ We verified atmospheric gamma-ray fluxes

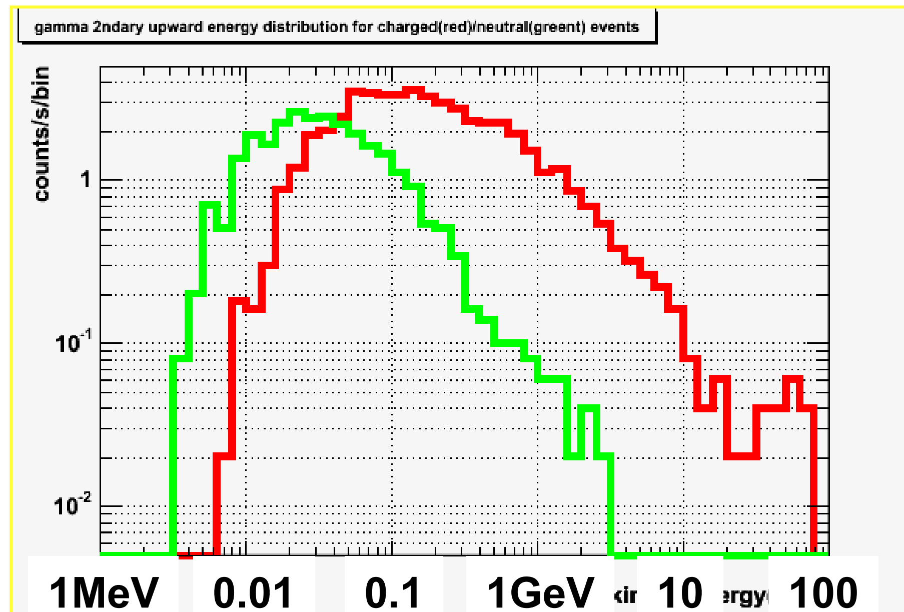
Importance of low-energy particles

Energy distribution of particles which trigger BFEM

2ndary electron



gamma upward



• e^-/e^+ of ~100MeV and upward gammas below 100MeV contribute to neutral events. We must eliminate those low energy particles by an on-line/off-line filtering in GLAST observation.

Summary

- Cosmic-Rays consists of the primary and secondary components
  - Primary: high energy, depend on solar modulation and geomag. cutoff
  - Secondary: low energy, depend on (solar modulation and) geomag. Cutoff
- We modeled proton, alpha, electron, positron, gamma in low-earth orbit by referring to existing measurements and theoretical predictions.
- Model descriptions and source codes are available.
  - http://www.slac.stanford.edu/~mizuno/GLAST/Balloon/BalloonAnalysis_ApJ_2004-06-28.pdf
  - Glastpack.pl rco CRflux HEAD
- We “validated” our model through analysis of BFEM data.
- Low energy (<=100MeV) electron/positron/gamma significantly contribute to neutral events and we must eliminate them in GLAST observation.