TerrestrialSources/Earth/v0r1

A quick update on the status of the simulation of the Earth as a background source for the LAT

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A detailed model of the Earth's gamma-ray emission is now available in the SLAC CVS repository. Check out the package

`terrestrialSources/Earth v0r1`

Quick facts:

1) Based on results from EGRET data (my talk at the last collaboration meeting)
2) The model is a 20 parameter representation of the Earth gamma emission with all spacial and spectral features.
3) Model good in energy range 10 MeV – 10 GeV
4) Difference in altitude between EGRET and GLAST is accounted for (altitude is an input parameter which can be set by the user)
5) Package structured like Jim Chiang's celestialSources package (thanks to Jim for his help with plugging the Earth model into the package)
6) First tests of `Earth v0r1` with `observationSim` look good!
7) People who do background studies are encouraged to start using this source model.

Brief summary of the EGRET results that went into the model:

- Bright rim with gaussian profile and exponential tail towards Nadir
- Spectrum hardest (1.7) at rim peak, softer both towards Nadir and Zenith, softest at Nadir (2.4)
- Exponential cutoff at ca. 3 GeV
- Rim peak position is energy dependent (ZA=116 deg at 60 MeV, converging towards 110.4 deg, the geometrical horizon with increasing E)
- Rim width decreasing with increasing energy, but significantly larger than EGRET PSF (10 σ)
- Azimuthal variation to a very good approximation symmetric around West (no North-South effect)
- East-West ratio first increasing with energy, peaking at around 600 MeV, then decreasing again
- Azimuthal width of Western peak decreasing with increasing energy
- Altitude-dependence consistent with expectations from simple geometry

The model:

Part I

$$\begin{aligned} \theta_{peak}(E) &= a_1 + a_2 E^{a_3} \\ \sigma(E) &= a_4 E^{a_5} \end{aligned}$$

If $E > 60$ MeV:

$$\theta_0(E) = \theta_{peak}(E) + (a_6 + \sqrt{\log_{10}(E - a_7)}) \cdot \sigma(E)$$

else

$$\theta_0(E) = \theta_{peak}(E)$$

$$\begin{aligned} g_0(E) &= a_8 E^{a_9} \cdot \exp(-E/a_{10}) \\ g_1(E) &= a_{11} E^{a_{12}} \cdot \exp(-E/a_{13}) \\ \sigma_{AZ}(\theta) &= a_{14} \exp(-\frac{1}{2} \cdot ((\theta - a_{15})/a_{16})^2) \\ f_0(\theta, \phi, E) &= g_0(E) + g_1(E) \cdot \exp(-\frac{1}{2} \cdot ((\phi - a_{17})/\sigma_{AZ}(\theta))^2) \\ b &= a_{18} \cdot E^{a_{19}} \cdot \exp(-E/a_{20}) \end{aligned}$$

The model:

Part II

The Earth's differential gamma-ray flux $F(\theta, \phi, E)$

If $\theta_0(E) - 5\sigma(E) < \theta \leq \theta_0(E)$:

$$F(\theta, \phi, E) = \exp(-\frac{1}{2} * ((\theta - \theta_{peak}(E))/\sigma(E))^2) \cdot f_0(\theta, \phi, E)$$

else if $\theta_0(E) < \theta$:

$$F(\theta, \phi, E) = \exp(c_0(E, \phi) + c(E, \phi) \cdot \theta)$$

where

$$\begin{aligned} c(E, \phi) &= (\log(F(\theta_0(E), \phi, E)) - \log(b(E)))/(\theta_0(E) - 180.^\circ) \\ c_0(E, \phi) &= \log(F(\theta_0(E), \phi, E)) - c(E, \phi) * \theta_0(E) \end{aligned}$$

$F = 0$ for $\theta < \theta_0(E) - 5\sigma(E)$

The model parameters:

Parameter Values

$a_1 = 110.4^\circ$ (Geometrical Horizon ZA)

$a_2 = \exp(3.6835)$ (normalization of $\theta_{peak}(E)$)

$a_3 = -0.4830$ (index of $\theta_{peak}(E)$)

$a_4 = \exp(3.011)$ (normalization of $\sigma(E)$)

$a_5 = -0.350$ (index of $\sigma(E)$)

$a_6 = -0.569$ (energy dependence of θ_0)

$a_7 = 57.45$ (energy dependence of θ_0)

$a_8 = \exp(-0.8219)\ \mathrm{cm}^{-2}\mathrm{s}^{-1}\mathrm{sr}^{-1}\mathrm{MeV}^{-1}$ (normalization of $g_0(E)$)

$a_9 = -2.000$ (index of $g_0(E)$)

$a_{10} = 2514$ MeV (cutoff of $g_0(E)$)

$a_{11} = \exp(-1.036)\ \mathrm{cm}^{-2}\mathrm{s}^{-1}\mathrm{sr}^{-1}\mathrm{MeV}^{-1}$ (normalization of $g_1(E)$)

$a_{12} = -1.811$ (index of $g_1(E)$)

$a_{13} = 2914$ MeV (cutoff of $g_1(E)$)

$a_{14} = 76.9^\circ$ (normalization of $\sigma_{AZ}(\theta)$)

$a_{15} = 98.6^\circ$ (mean of $\sigma_{AZ}(\theta)$)

$a_{16} = 13.8^\circ$ (std. dev. of $\sigma_{AZ}(\theta)$)

$a_{17} = 180^\circ$ (peak position of azimuthal profile, 180° = West)

$a_{18} = \exp(-0.06731)\ \mathrm{cm}^{-2}\mathrm{s}^{-1}\mathrm{sr}^{-1}\mathrm{MeV}^{-1}$ (normalization of central flux)

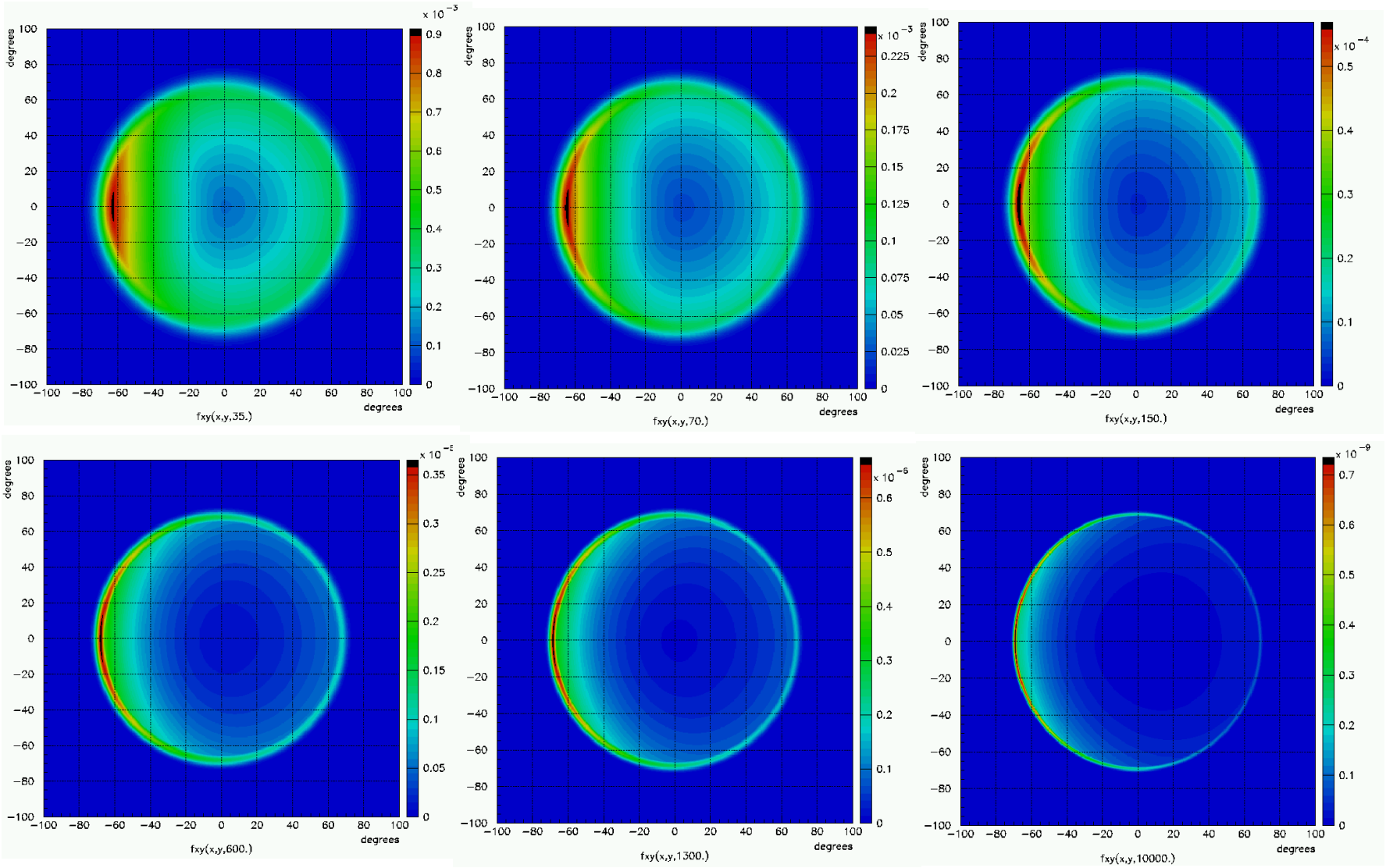
$a_{19} = -2.512$ (index of central flux)

$a_{20} = 3$ GeV (cutoff of central flux)

Additional parameters are the three input parameters E_{min}, E_{max}, altitude

Energy range : (10 MeV) 35 MeV – 10 GeV

Images obtained from the model for an ideal detector with PSF = 0.

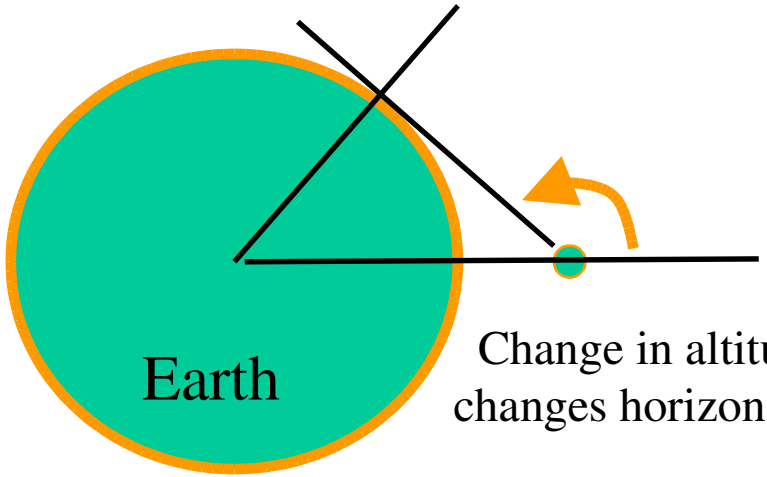


Altitude dependence:

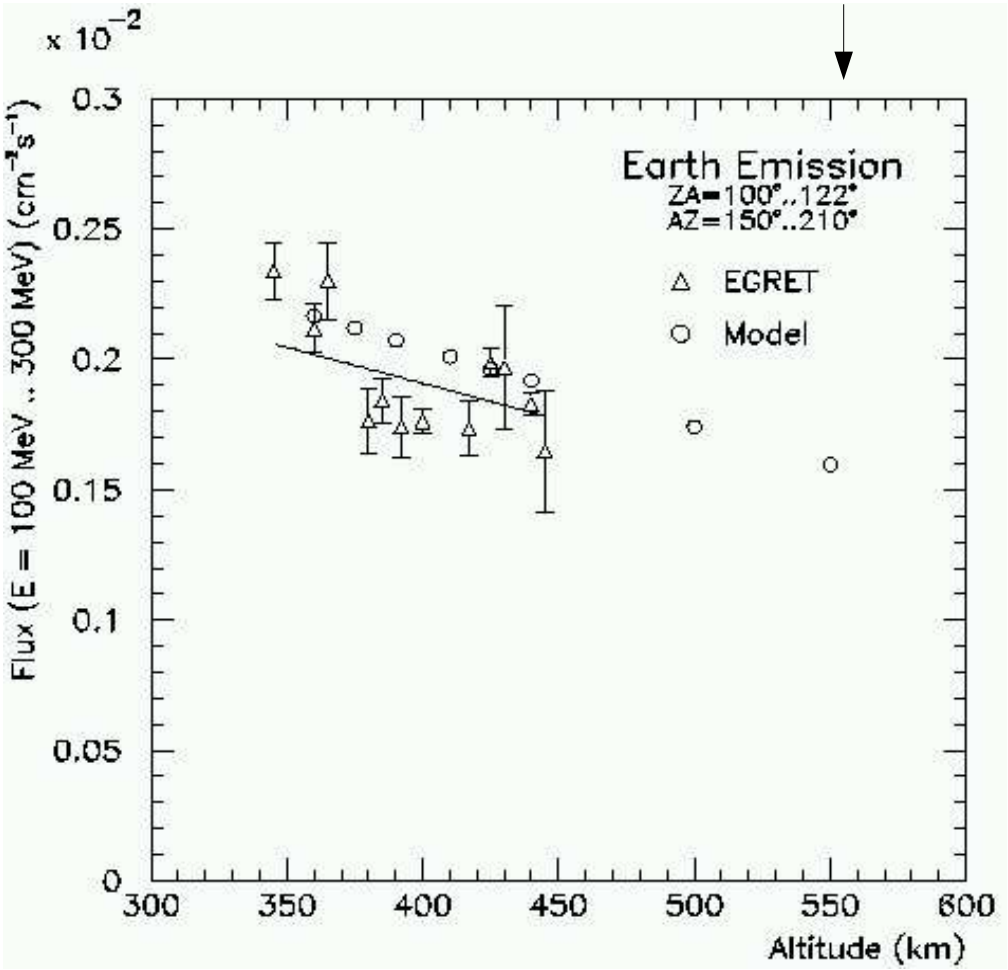
Dedicated study of EGRET data confirms:
Altitude dependence as one would expect from purely geometrical considerations, i.e. surface brightness constant, intensity decrases as the solid angle.

In addition all zenith angle-related parameters scale with the

$$\text{Horizon ZA} = 90^{\circ} + \arccos(R_E/R_O)$$



GLAST



Package structure:

Exactly as in Jim Chiang's celestialSources:
Container package terrestrialSources v0v0 contains Earth v0r1.

SpectrumFactory for Earth is called in observationSim.
HEAD version of observationSim has the call already implemented.

Example of the necessary "source library" xml file comes with Earth v0r1.

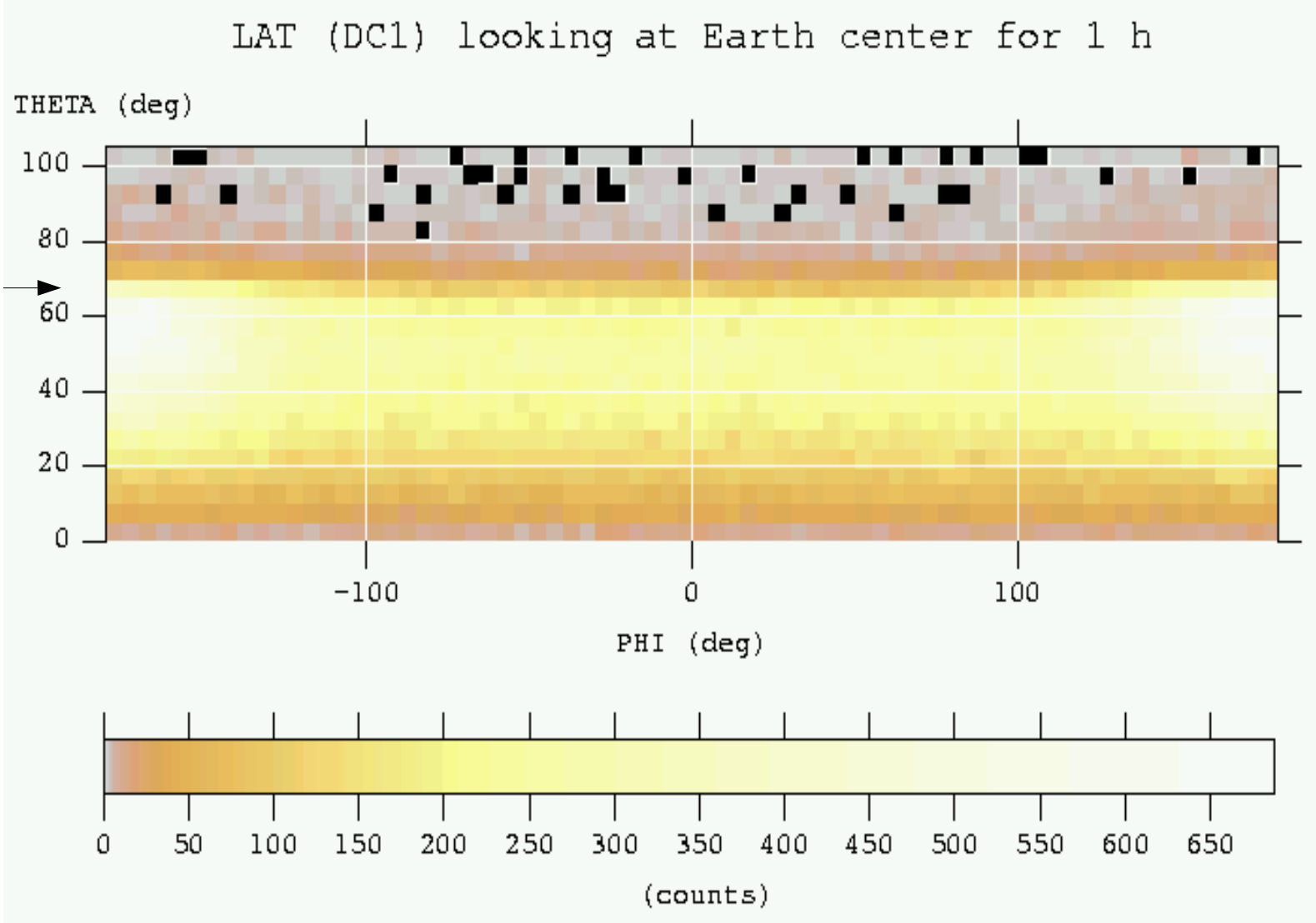
```
<source_library>
 <source name="Earth">
  <spectrum escale="MeV">
   <SpectrumClass name="Earth" params="565.,10.,10000."/>
   <!-- params: altitude (km), min. energy (MeV), max. energy (MeV)  -->
   <use_spectrum frame="zenith"/>
  </spectrum>
 </source>
</source_library>
```

(no defaults, warnings when ranges exceeded)

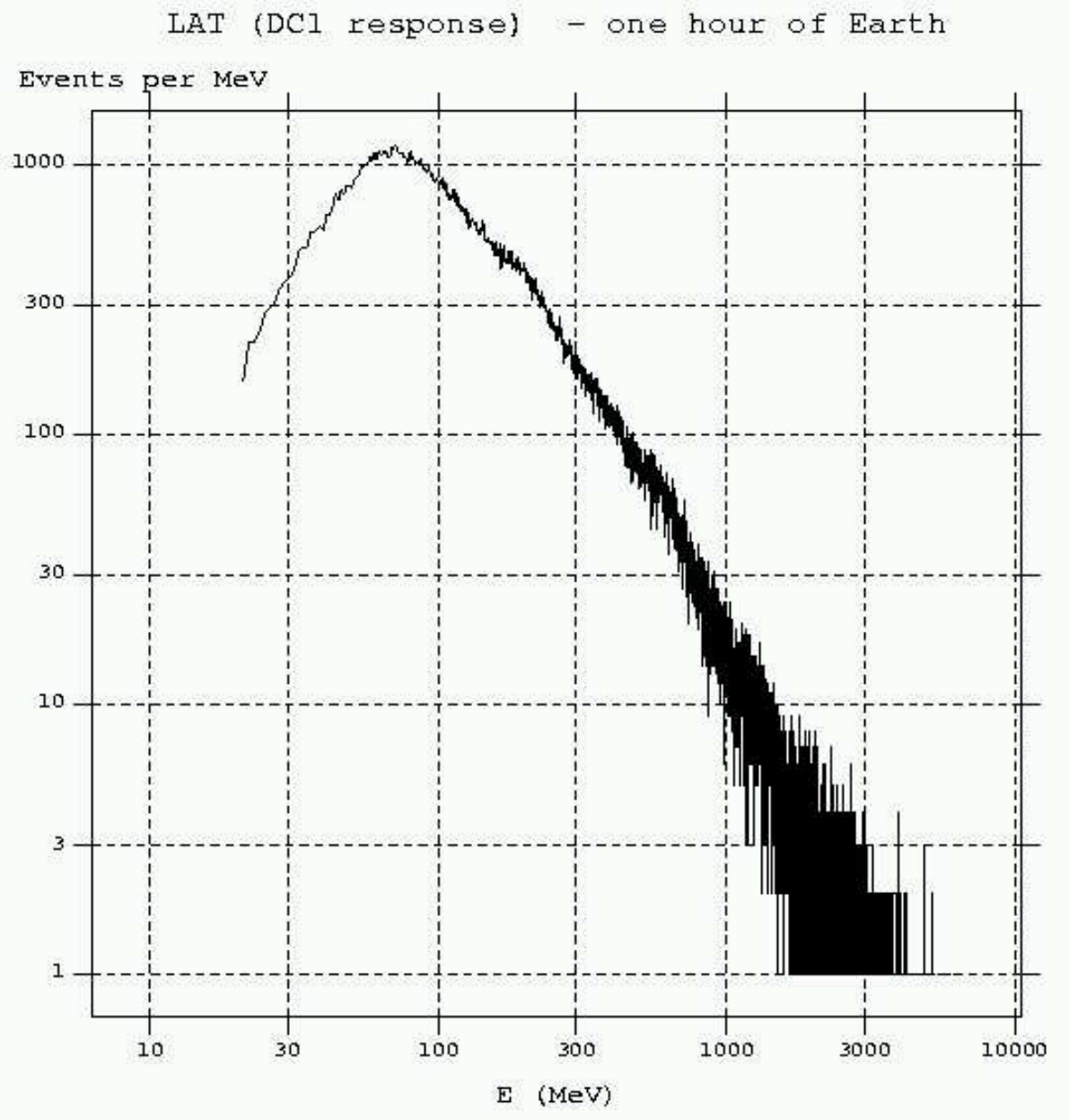
First results from observationSim: a LAT image of the Earth 20 MeV-10 GeV

(total: 205000 counts, observationSim computing time = 30 minutes)

66.7 deg = geom. horizon for alt. 565 km



First results from observationSim: Counts Spectrum



Features to be added in future versions:

1) Longitudinal variations
2) Latitudinal variations
3) more detailed spectrum (especially below 100 MeV)
4) solar cycle