Simulation of atmospheric Background for PEBS

Graduiertenkolleg, August 2006
Bad Honnef

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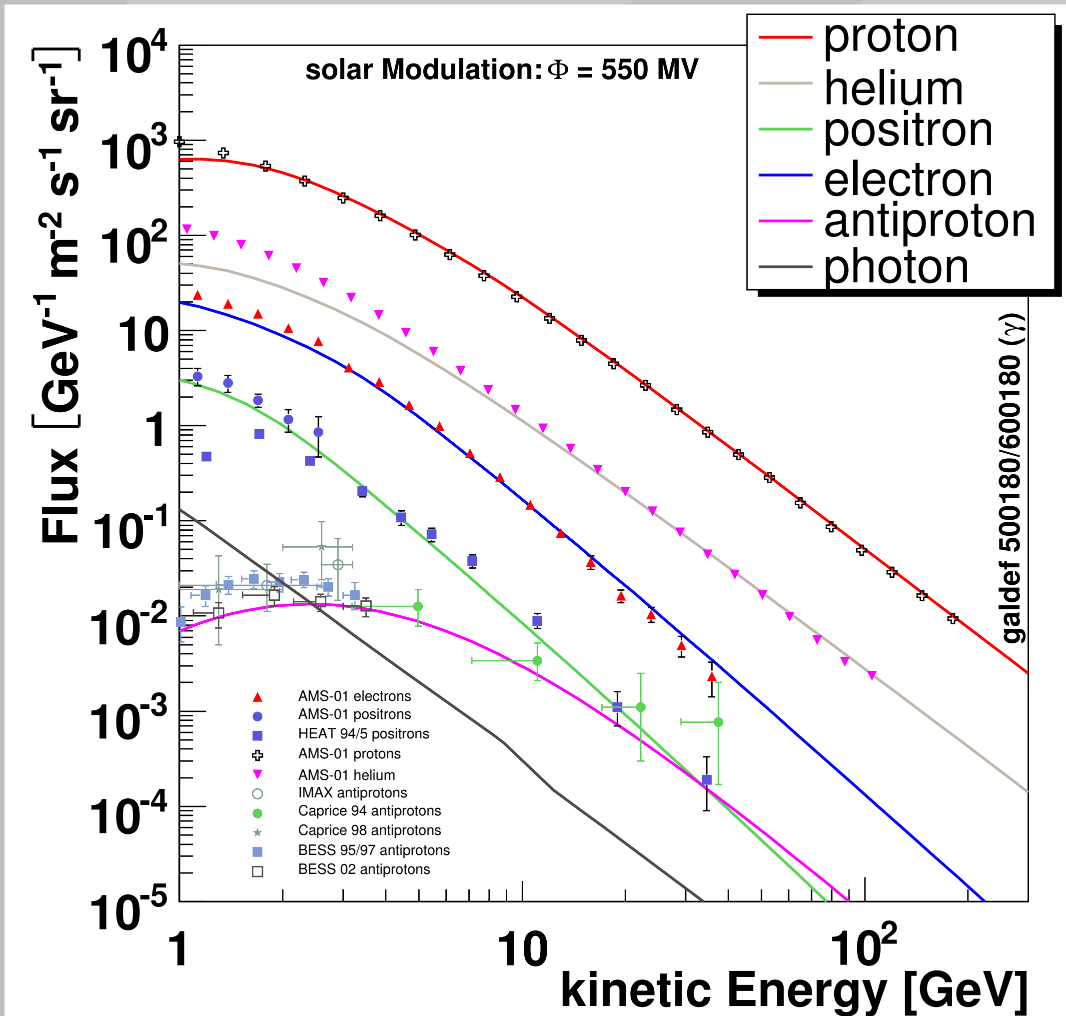
Fluxes of Galactic Cosmic Rays

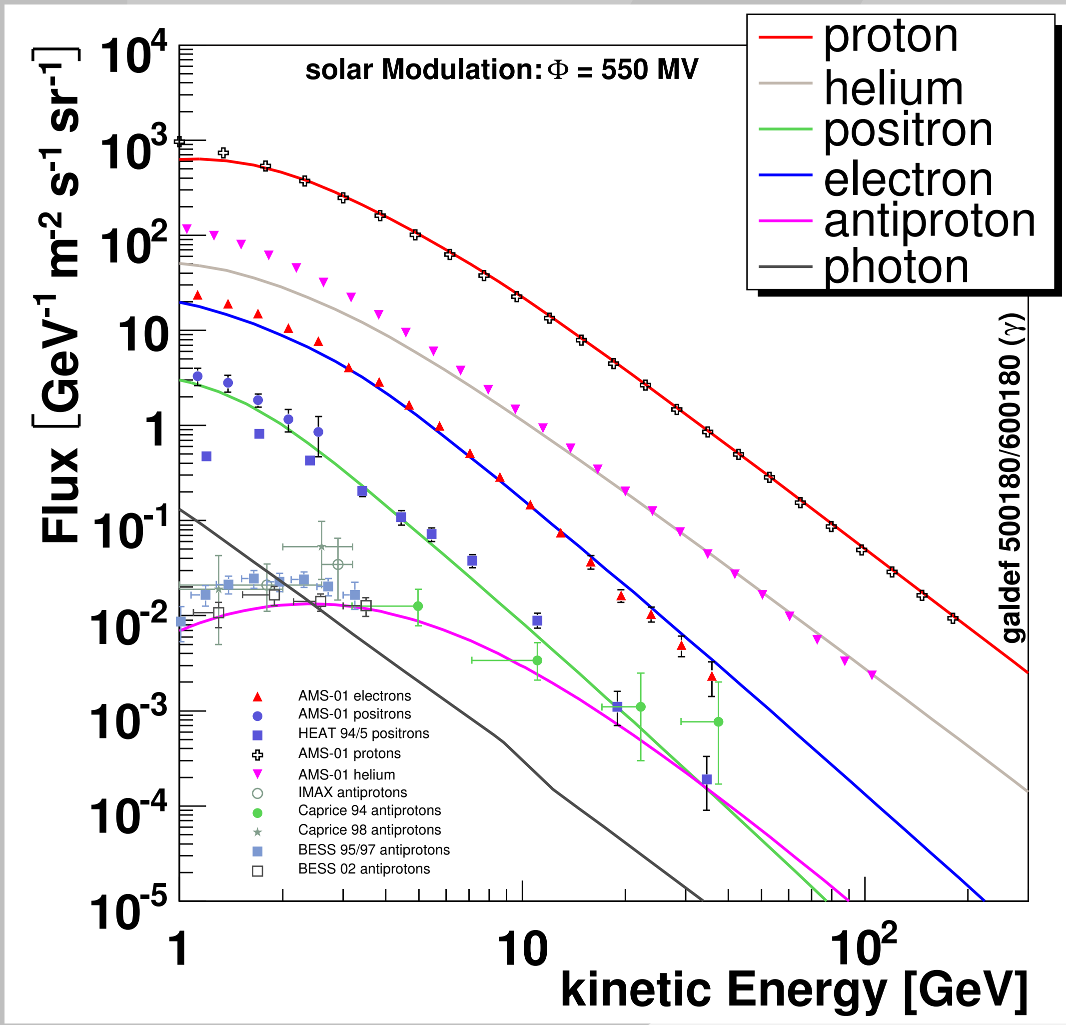


Status of Cosmic Ray Measurements:

★ good agreement between cosmic ray propagation/production model and data in background fluxes (p, e^-, α, other heavy nuclei)

$\rightarrow$ **general model works!**

Fluxes of Galactic Cosmic Rays



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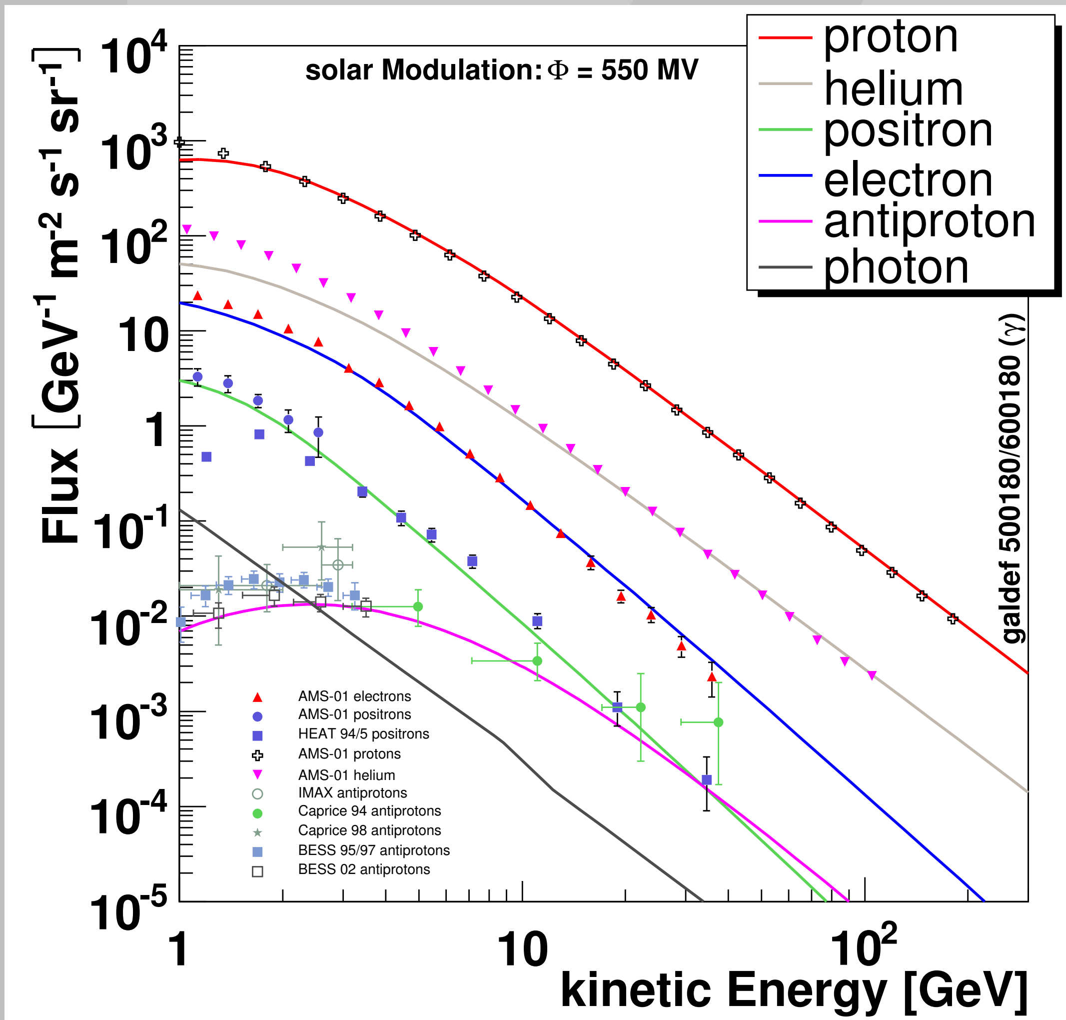
  $\rightarrow$ **need precise measurement of fluxes up to high energies!**

Fluxes of Galactic Cosmic Rays



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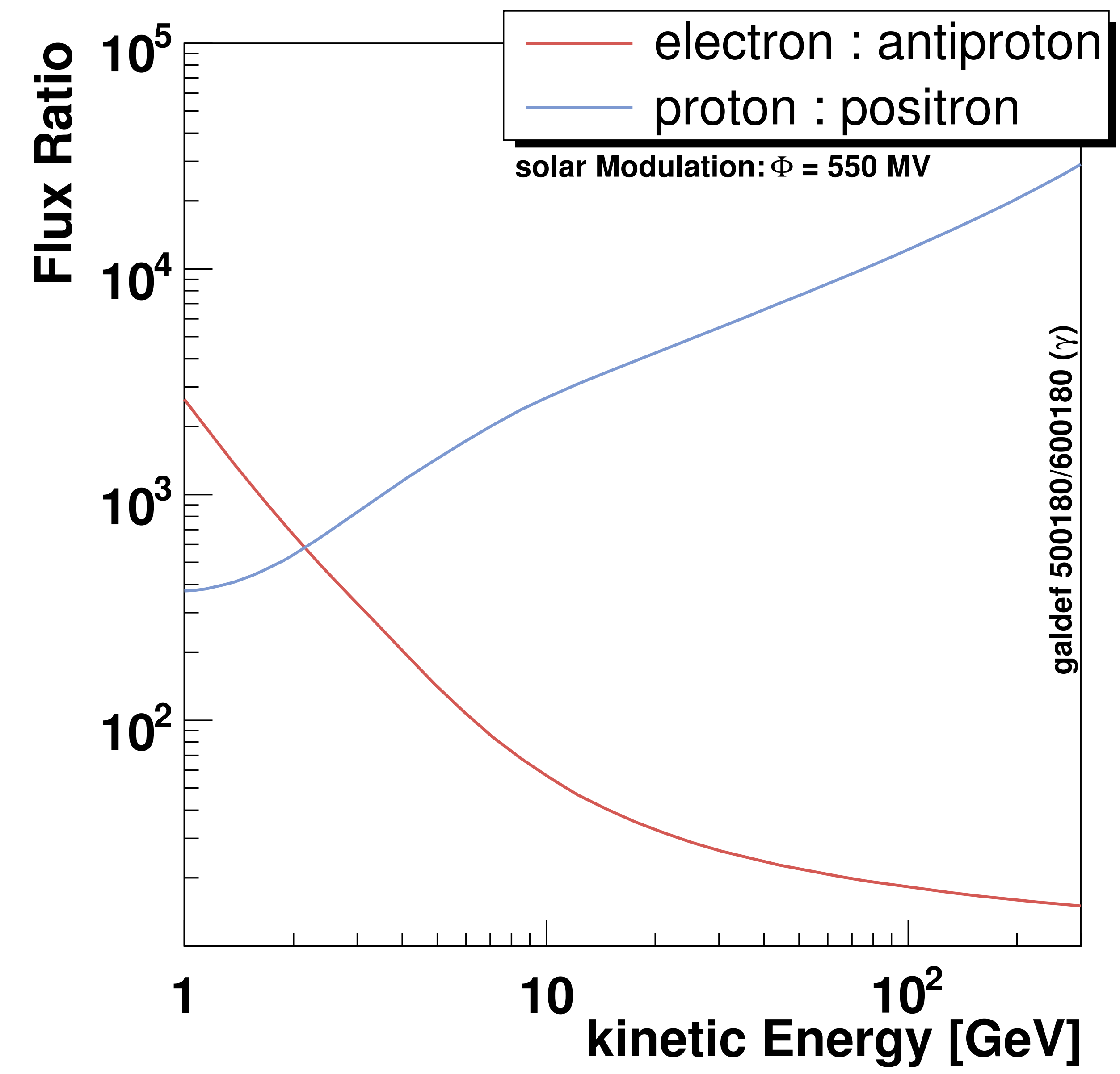
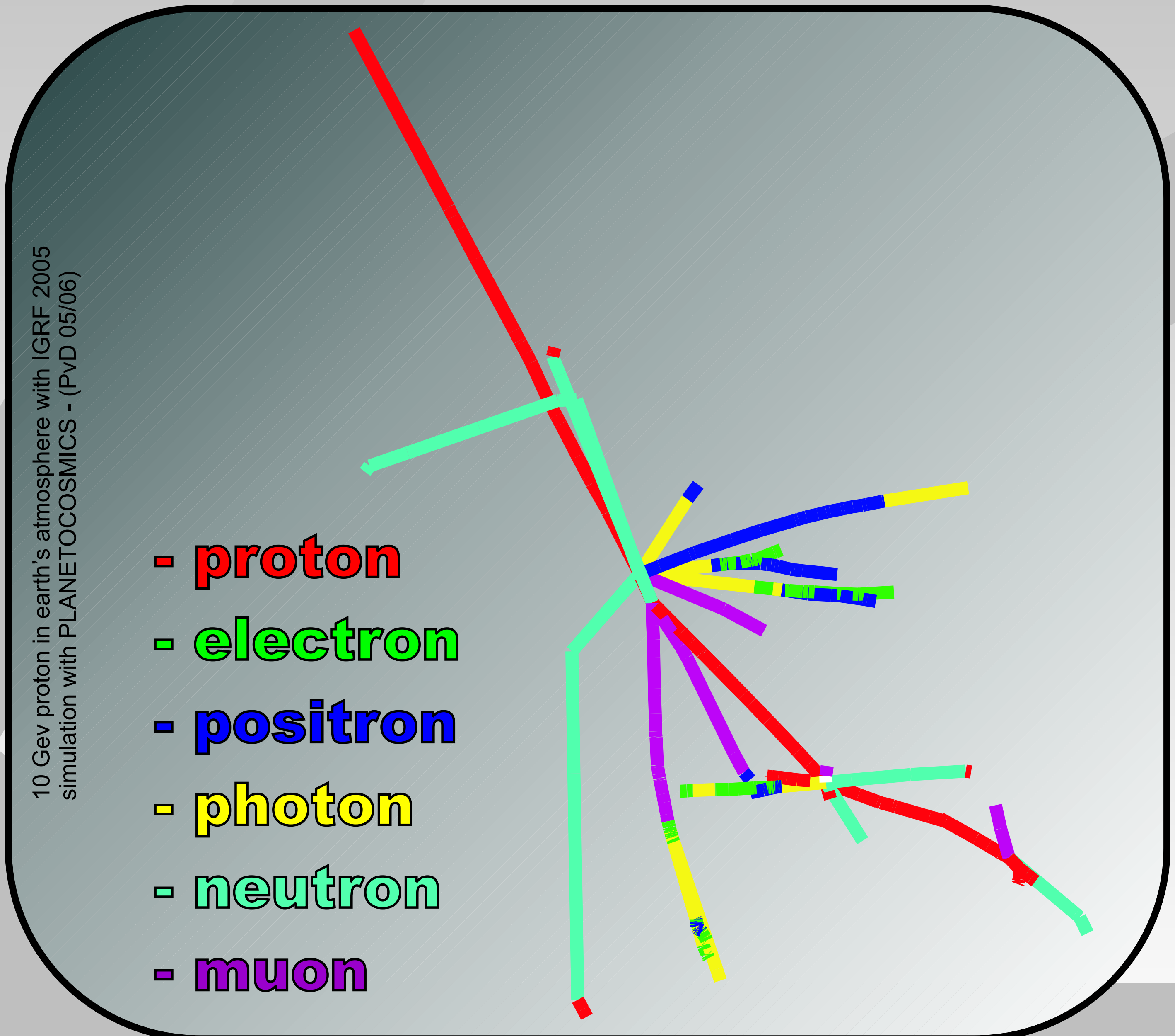
$\Longrightarrow$ **Balloon Experiment: Investigate influence of atmosphere on flux measurements!**

Requirements for positron flux measurements



★ total rejection is made up of the single rejections of the different subdetectors

Air shower in Earth's atmosphere



PLANETOCOSMICS

Simulation of the Earth's atmosphere and magnetic field with PLANETOCOSMICS

(developed by L. Desorgher, Uni. Bern http://cosray.unibe.ch/ laurent/planetocosmics)

★ **general properties:**

- based on GEANT4
- atmospheric model: NRLMSISE00
- magnetic field: IGRF 2005
- solar modulation: mean field approximation

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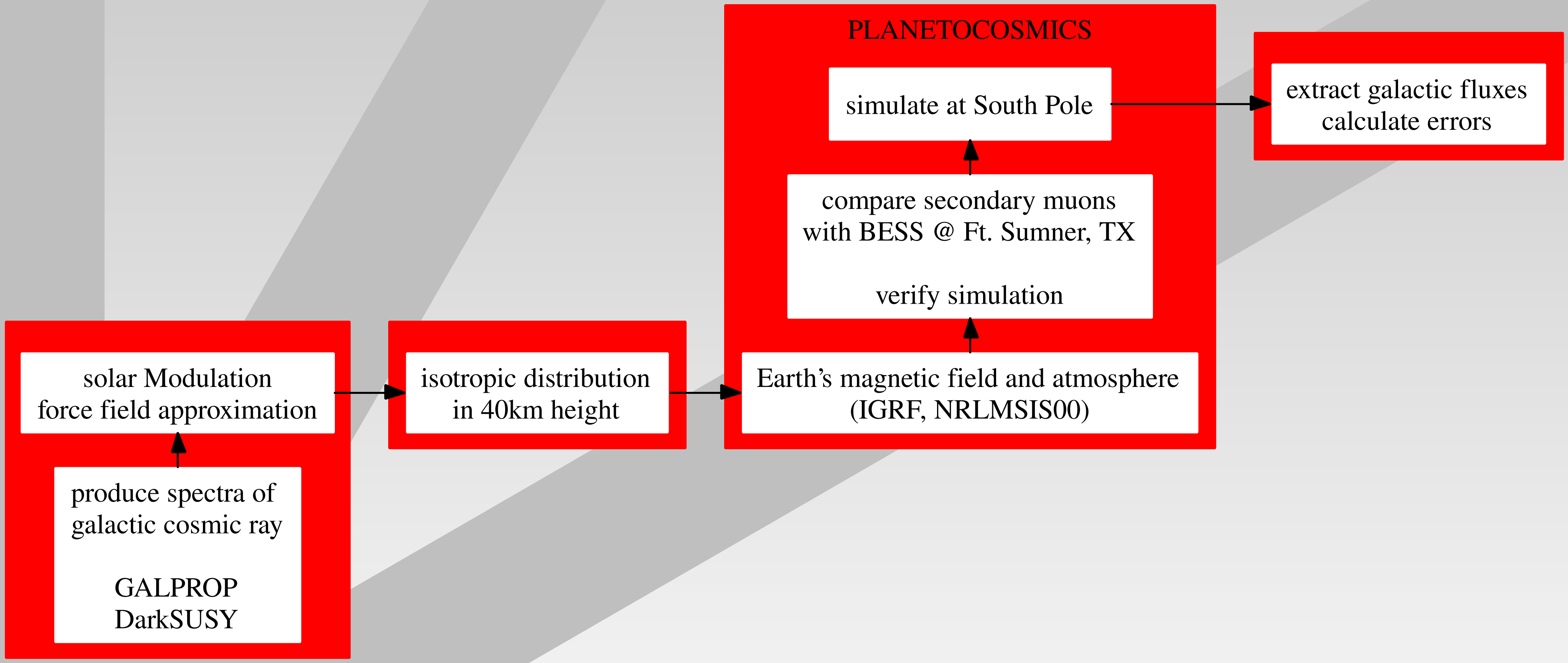
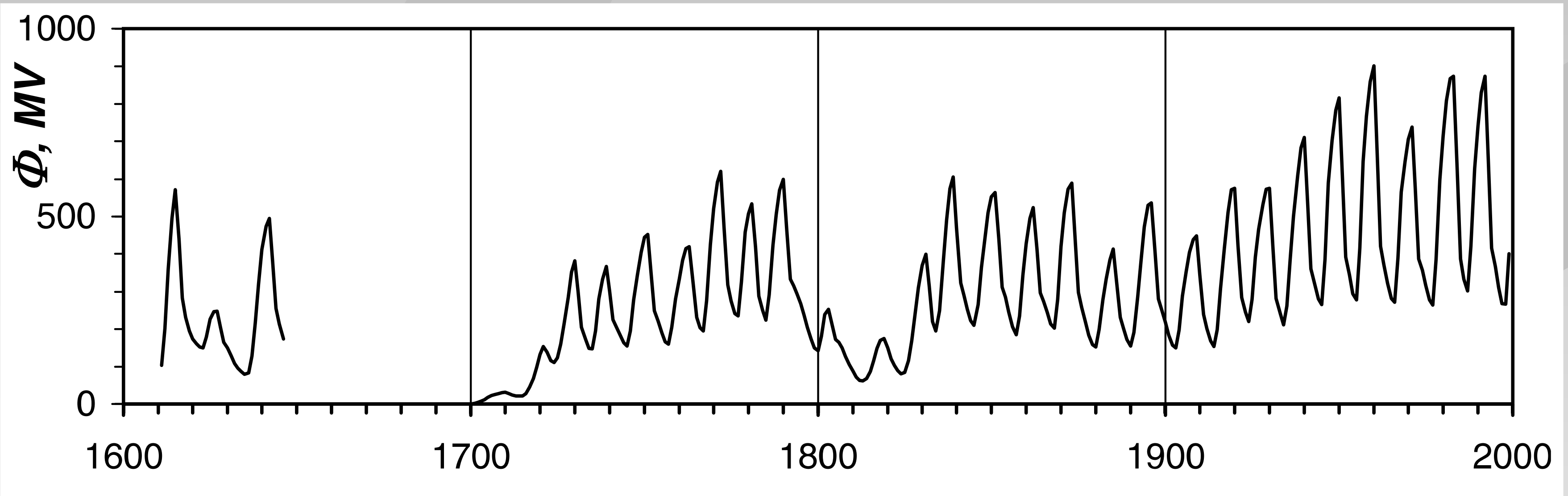
★ **properties of this simulation:**

- input spectra are the fluxes of the conventional Galprop model tuned in the lower energy region to match the data (galdef 500180 $\rightarrow$ astro-ph/0406254)
- detection planes in several altitudes around the earth
- particle gun in 500 km height
- starting positions are choosen to produce a isotropic distribution of cosmic rays
- only primaries that can hit the detection planes are started

Scheme of simulations and analysis



Solar Modulation



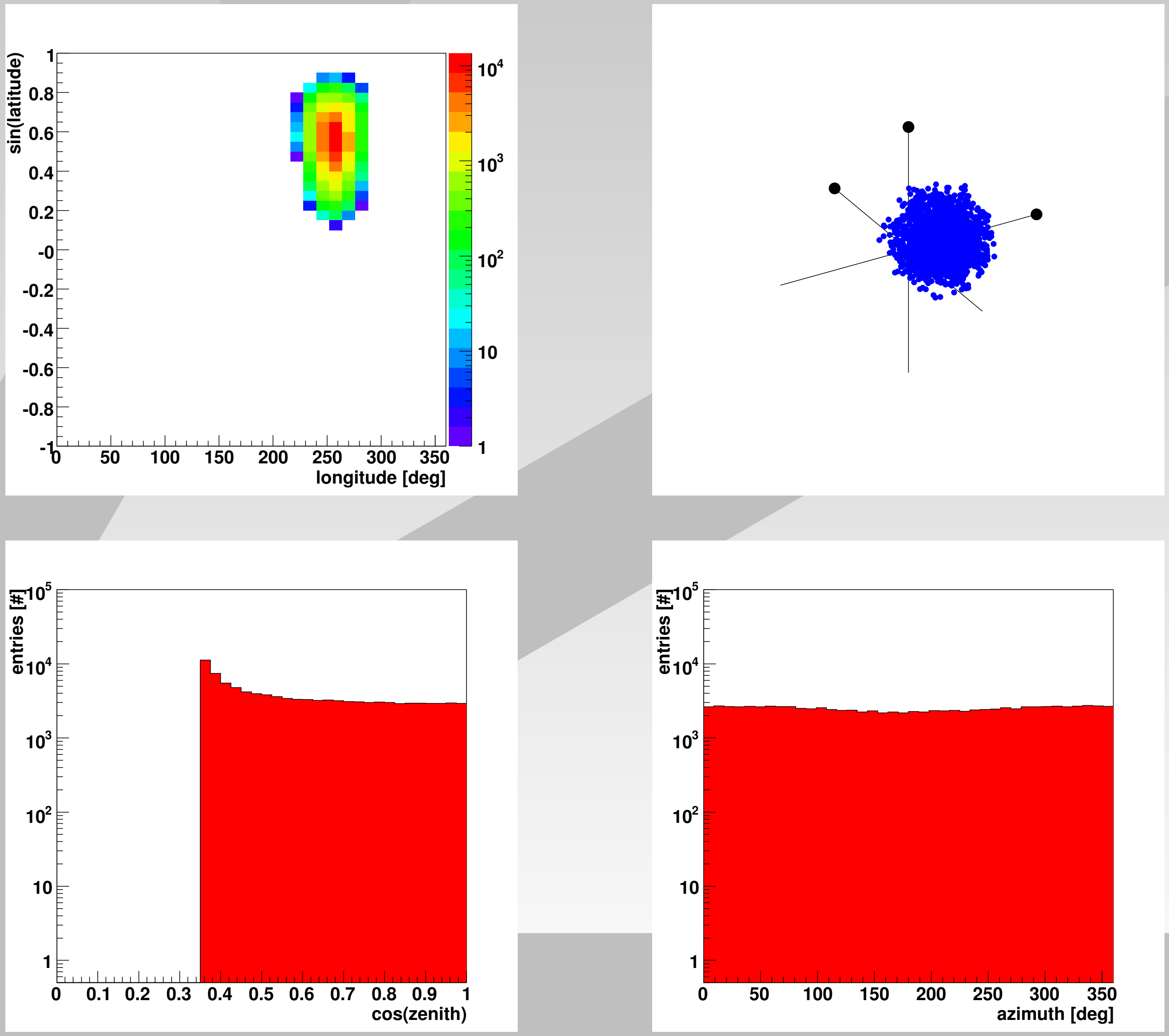
- taken from: Journal of geophysical Research, Vol. 107: *Usoskin et. al., A physical reconstruction of cosmic ray intensity since 1610*
- solar modulated flux, mean field approximation:

$$F(r, E_{\mathrm{LIS}} - |Z|e\Phi) = F(\infty, E_{\mathrm{LIS}}) \cdot \frac{(E_{\mathrm{LIS}} - |Z|e\Phi)^2 - m_0^2}{E_{\mathrm{LIS}}^2 - m_0^2}$$

- Ft. Sumner 09/2001: $\Phi \approx 430\,\mathrm{MV}$
- South Pole 12/2005: $\Phi \approx 750\,\mathrm{MV}$

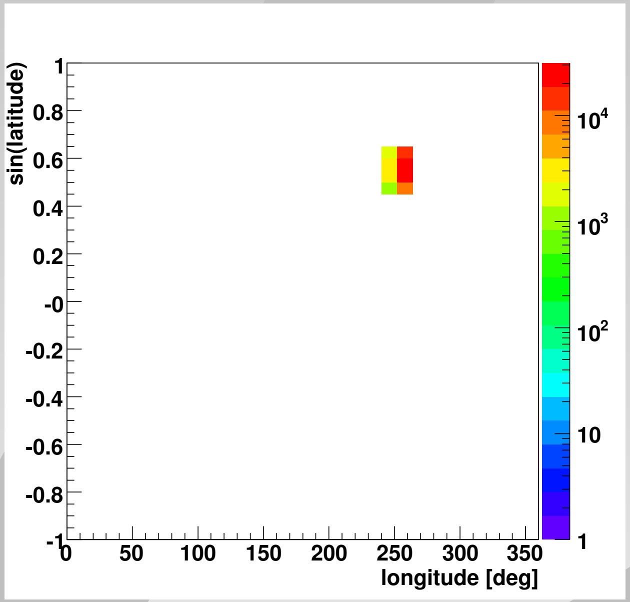
Isotropic distribution of cosmic rays

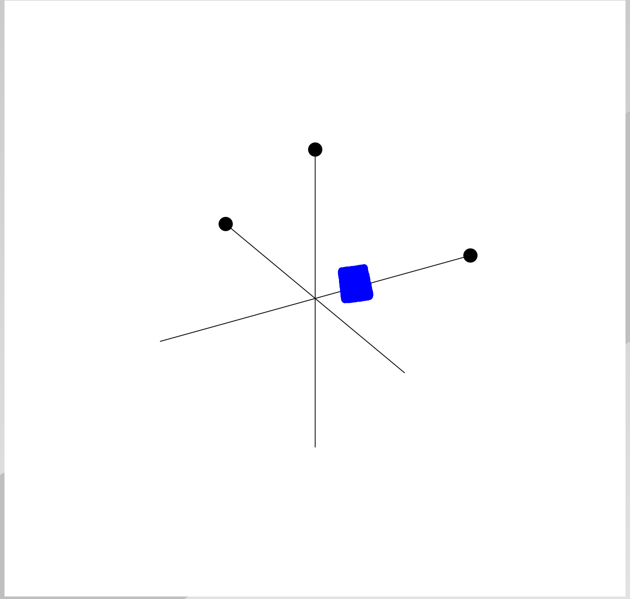
starting plane 500 km

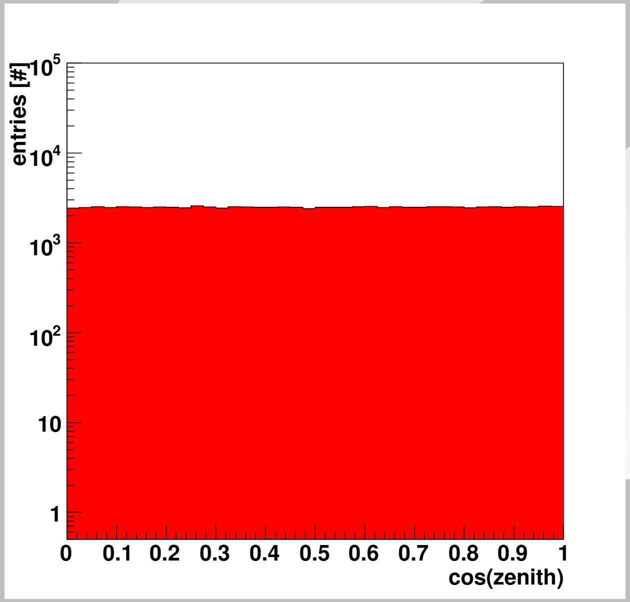


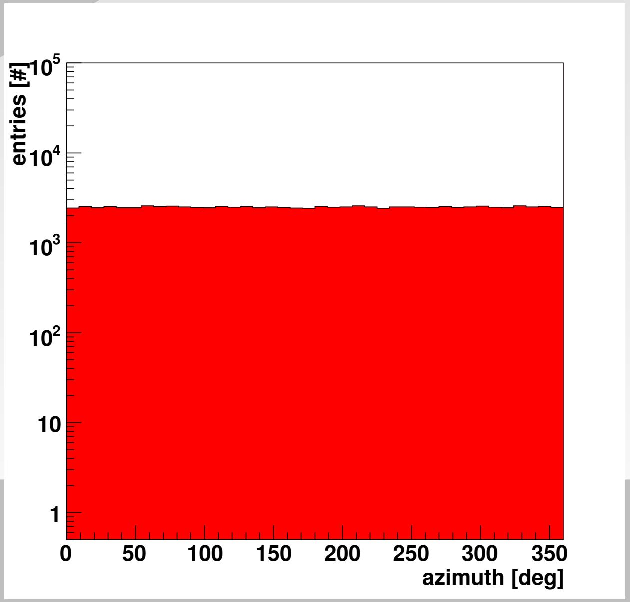
Isotropic distribution of cosmic rays

detection plane 40 km









NRLMSISE00 atmospheric model & depth

★ NRLMSISE00 properties:

- atmospheric model fitted to
  1. data of satellite accelerometers and orbit determination (mass density)
  2. data of incoherent scatter radar (temperature)
  3. data of solar ultraviolet occulatation (O_2 mass density)
- dependency on date/solar and magnetic parameters

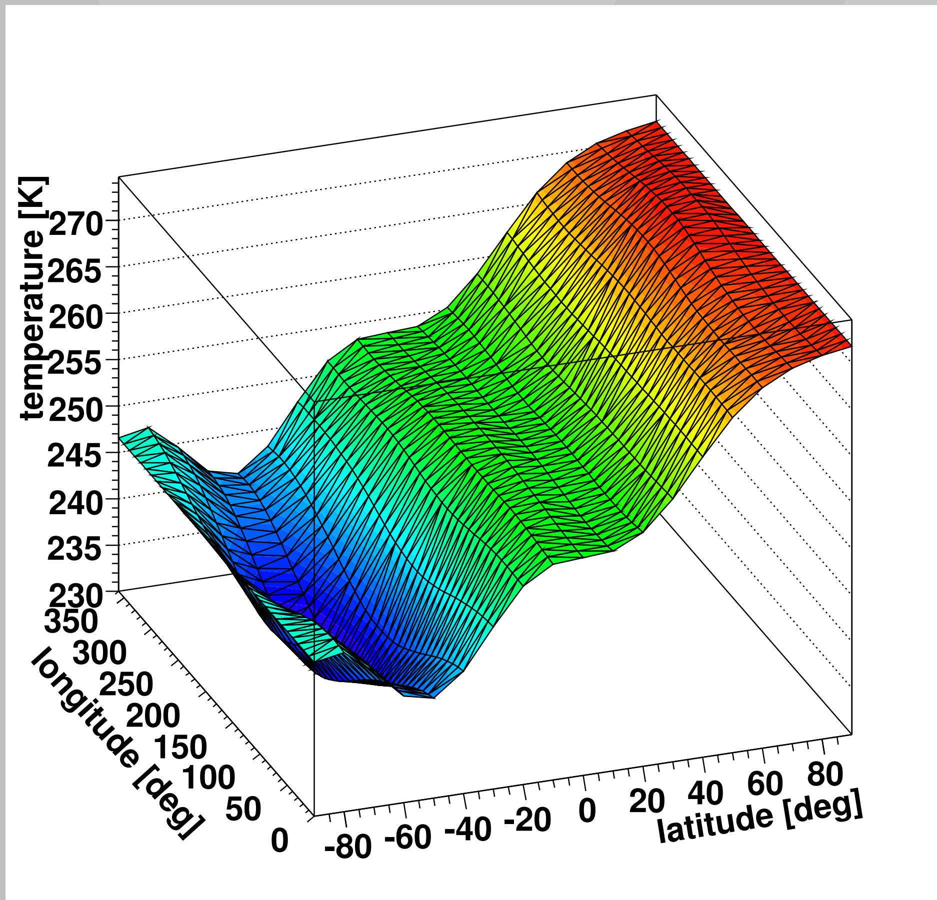
★ defintion of atmospheric depth:

$$d(H) = \int_H^\infty \rho(h)\mathrm{d}h$$

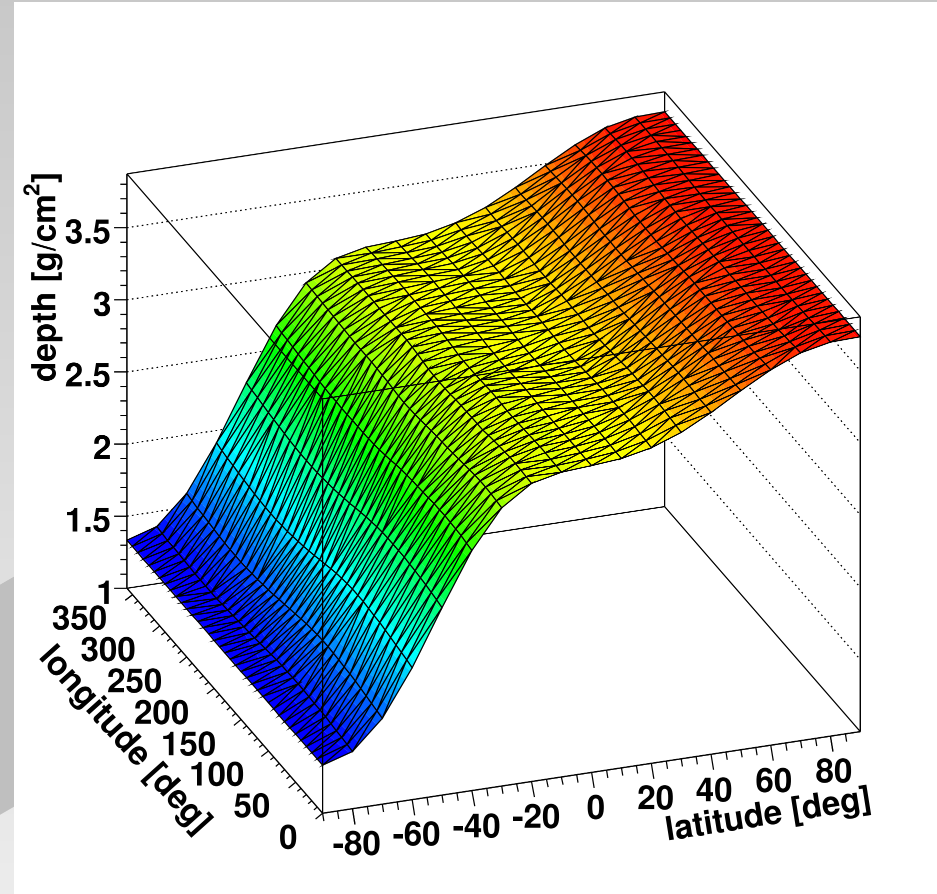
$\rho(h)$ altitude dependent atmospheric density, H detection altitude

★ provided by the NASA via:
http://uap-www.nrl.navy.mil/models_web/msis/msis_home.htm

Temperature & depth profile



Temperature

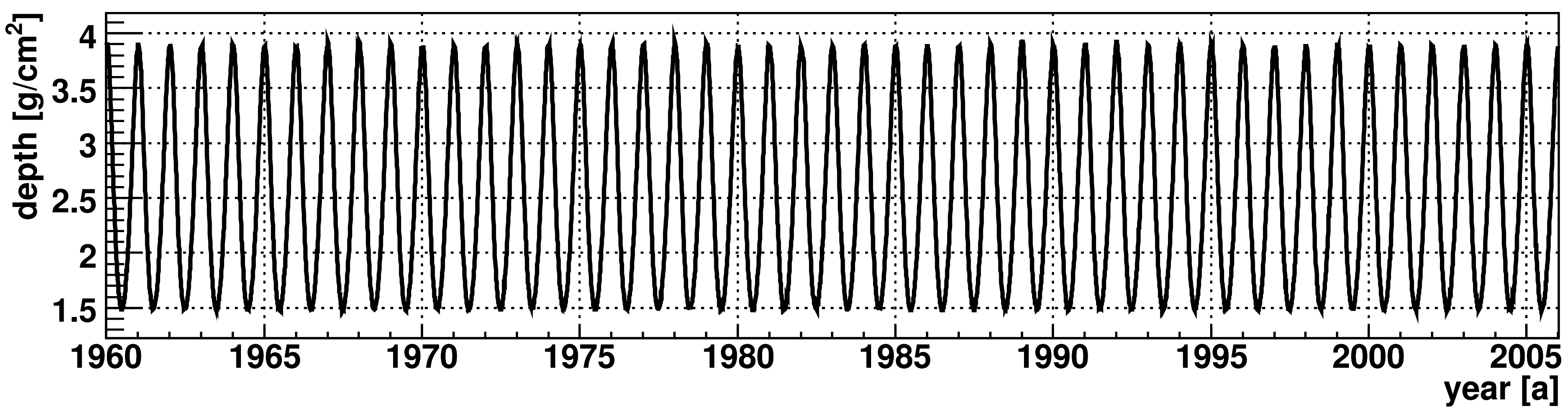


Depth

Calculations done with the following parameters:

- 40 km altitude
- date: 20.6.00 17:00 for the solar and magnetic parameters

Depth over time on South Pole



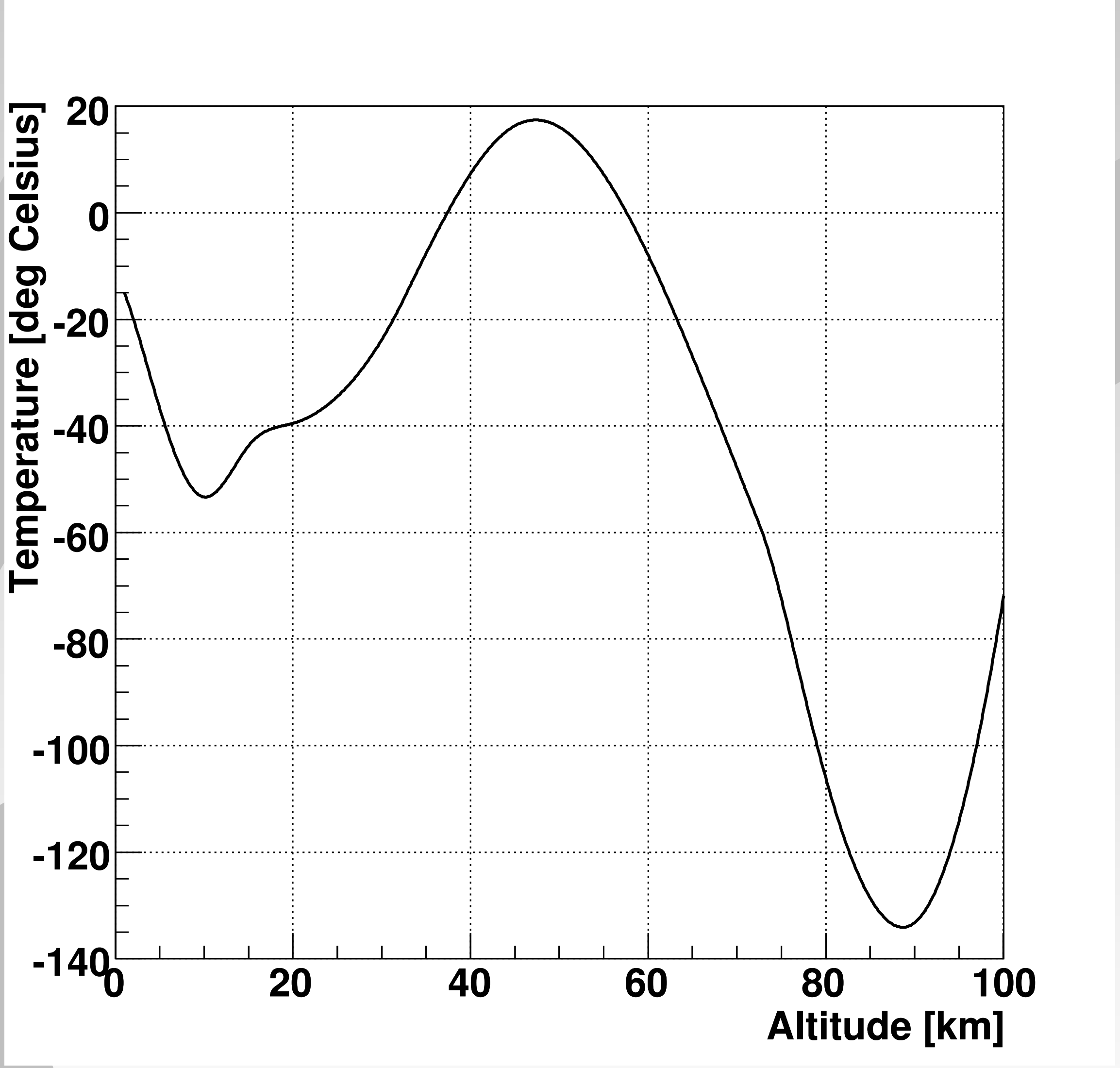
- 40 km altitude
- latitude$= -75$ deg, longitude$= 0$ deg: mean trajectory on South Pole
- solar and magnetic parameters for each day

$\Longrightarrow$ **time has the largest influence on the atmospheric depth**

(only small dependency on solar and magnetic parameters)

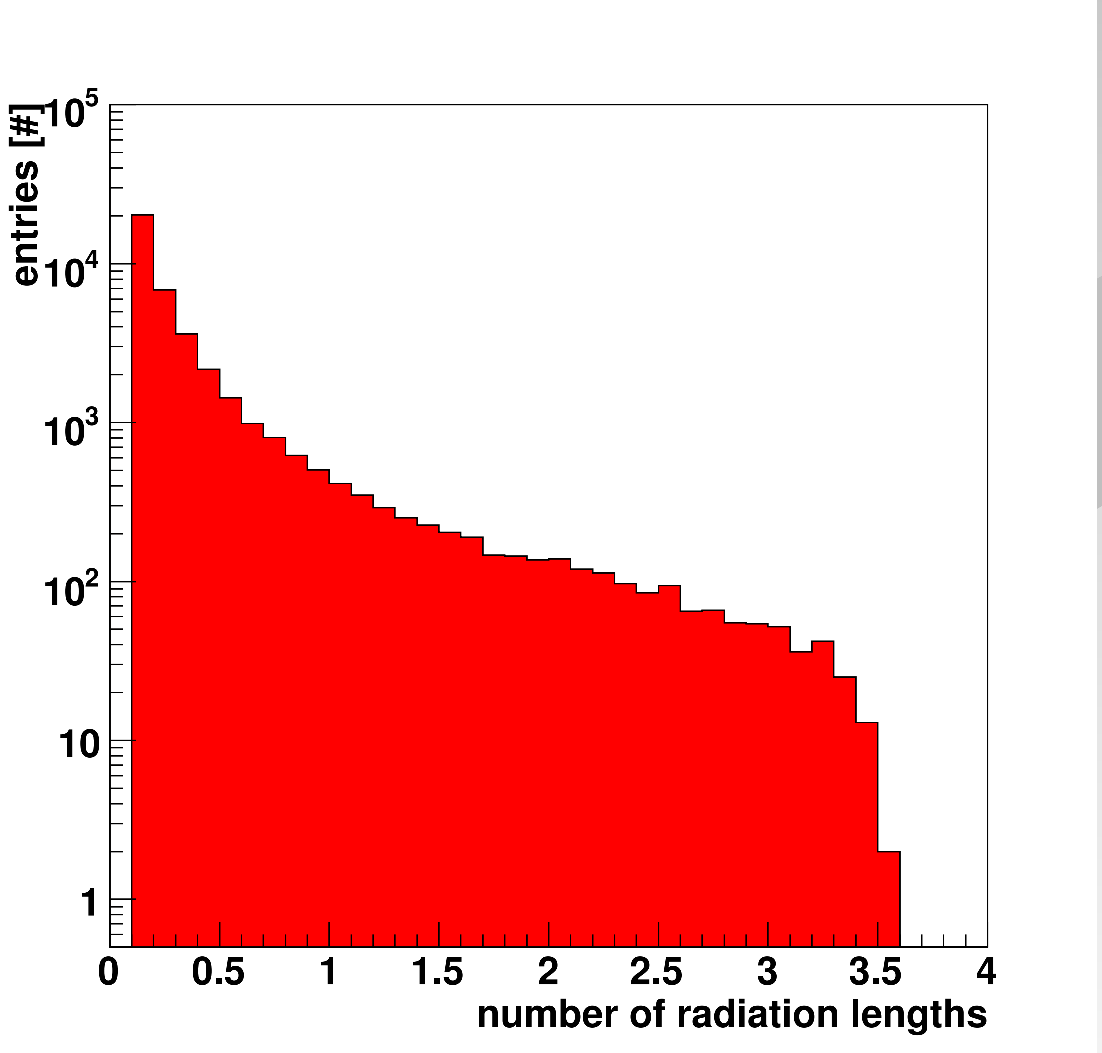
Properties of Earth's Atmosphere (NRLMSISE00)

Calculation at mean balloon trajectory at south pole (lat.: −75 deg, long.: 0 deg), Dec. 2005



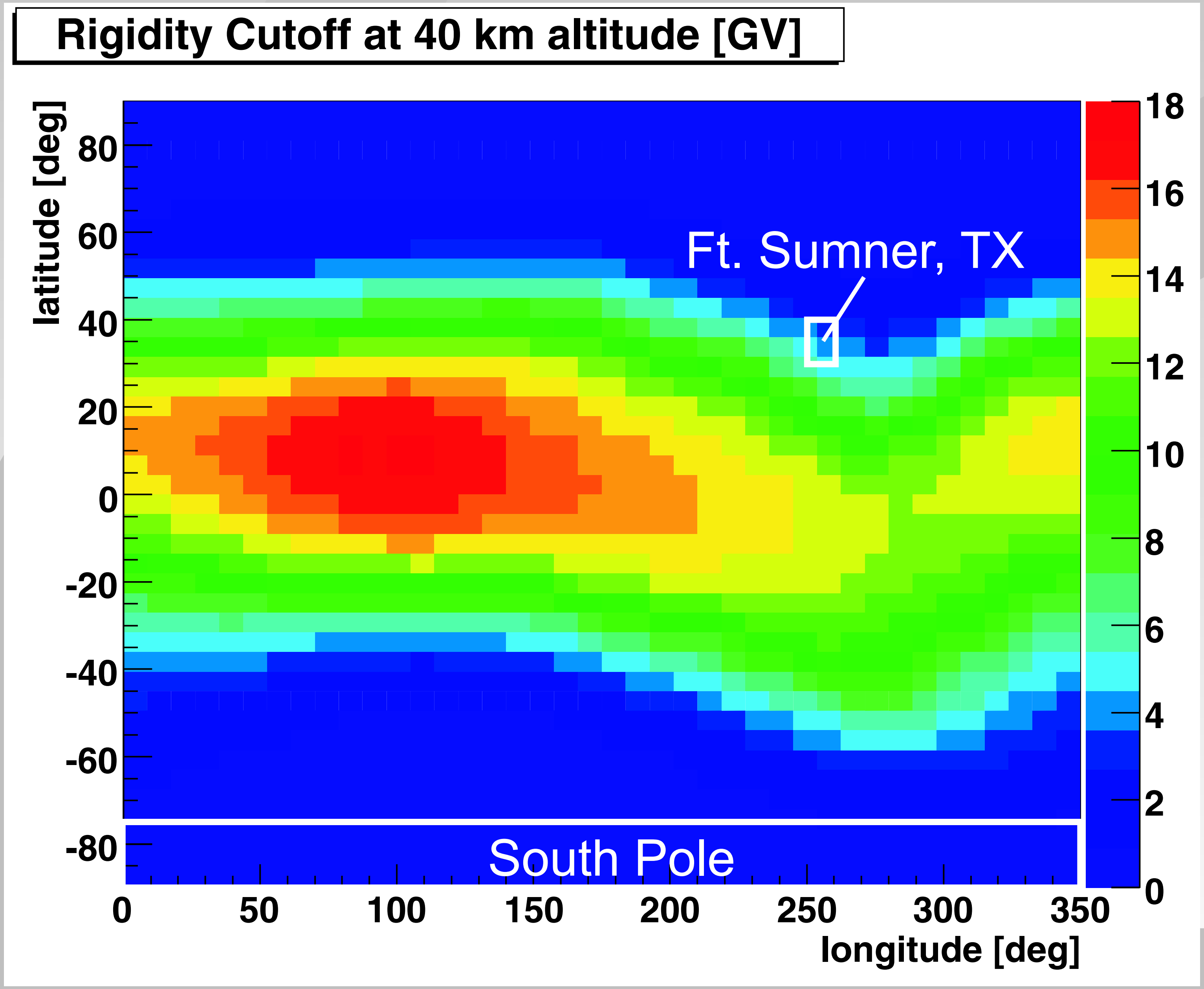
kinetic energy/temperature of atmosphere (ideal gas)

Mean radiation length in Dec. 2005 at the South Pole



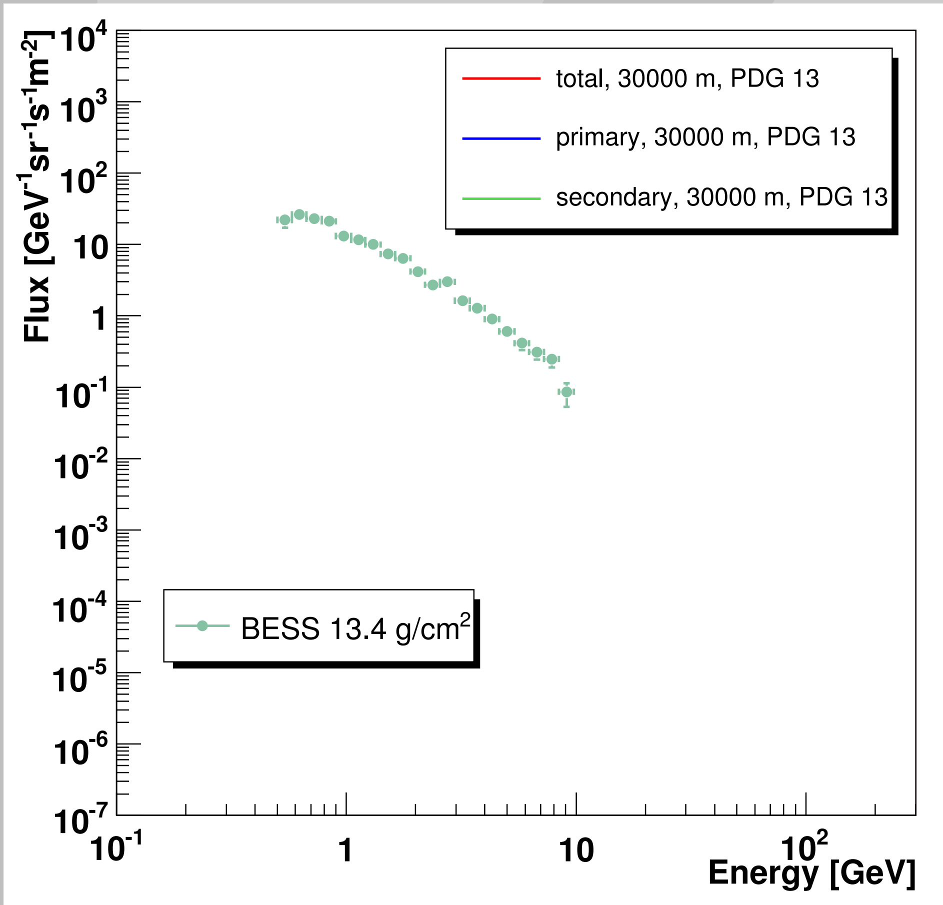
- ★ calculated with the atmospheric model and the trajectory of the cosmic rays
- ★ mean number of crossed radiation lengths of all cosmic rays before 40 km is 39 % because of the angular distribution of cosmic rays

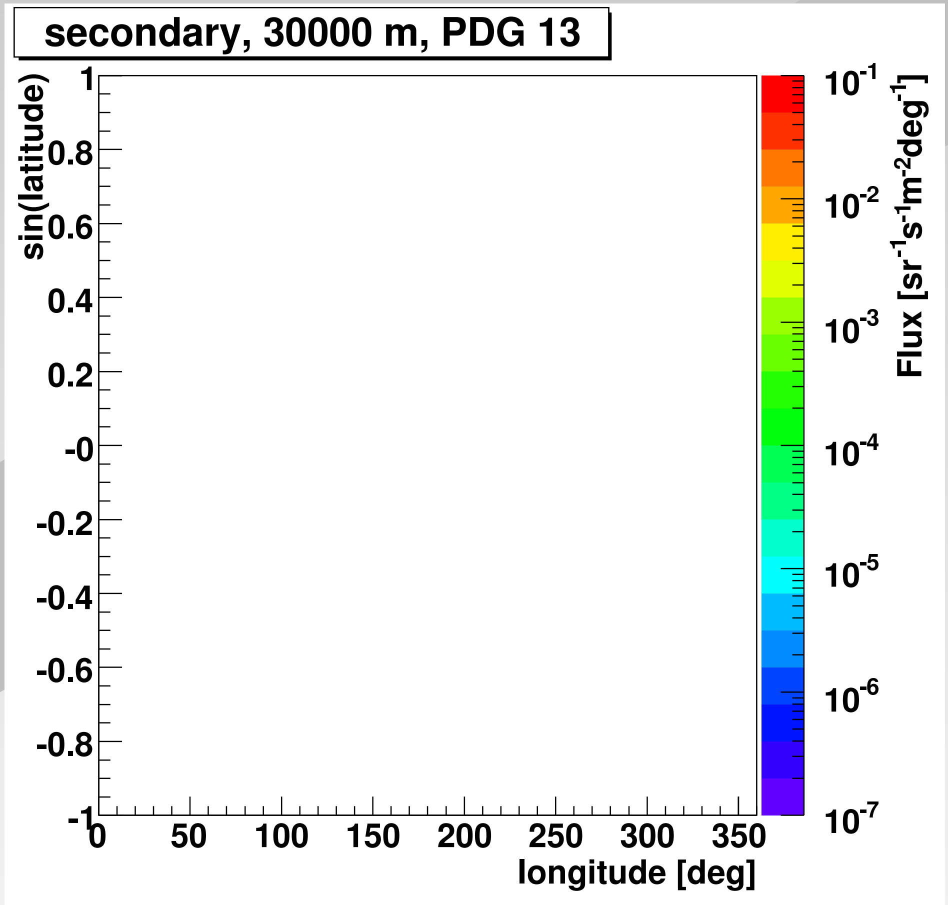
Rigidity Cutoff with IGRF 2005



Influence of magnetic field to secondary muon fluxes

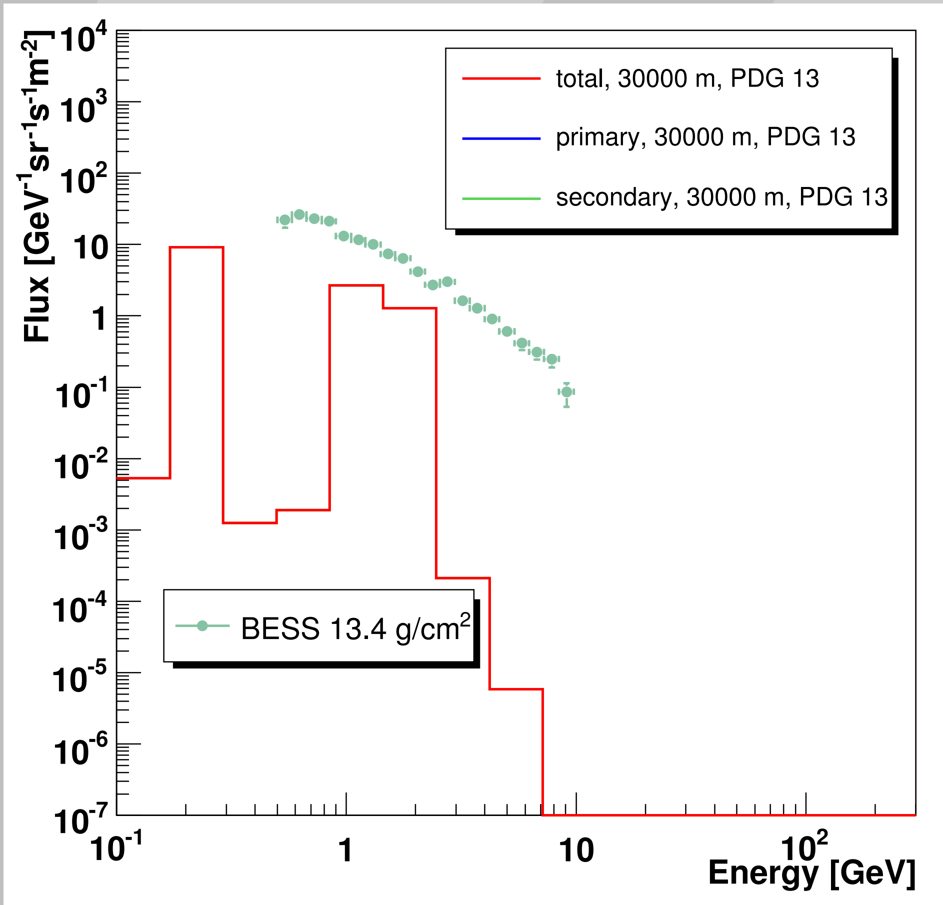
energy range of primaries: 0.1 - 1 GeV

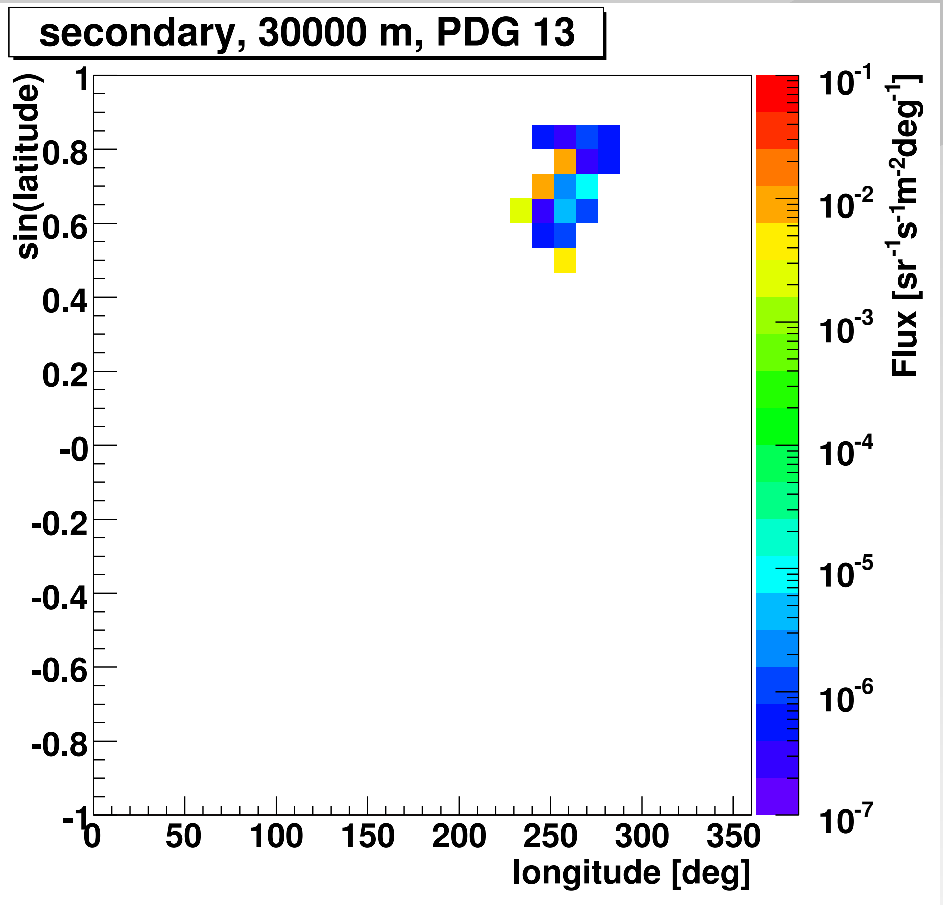




Influence of magnetic field to secondary muon fluxes

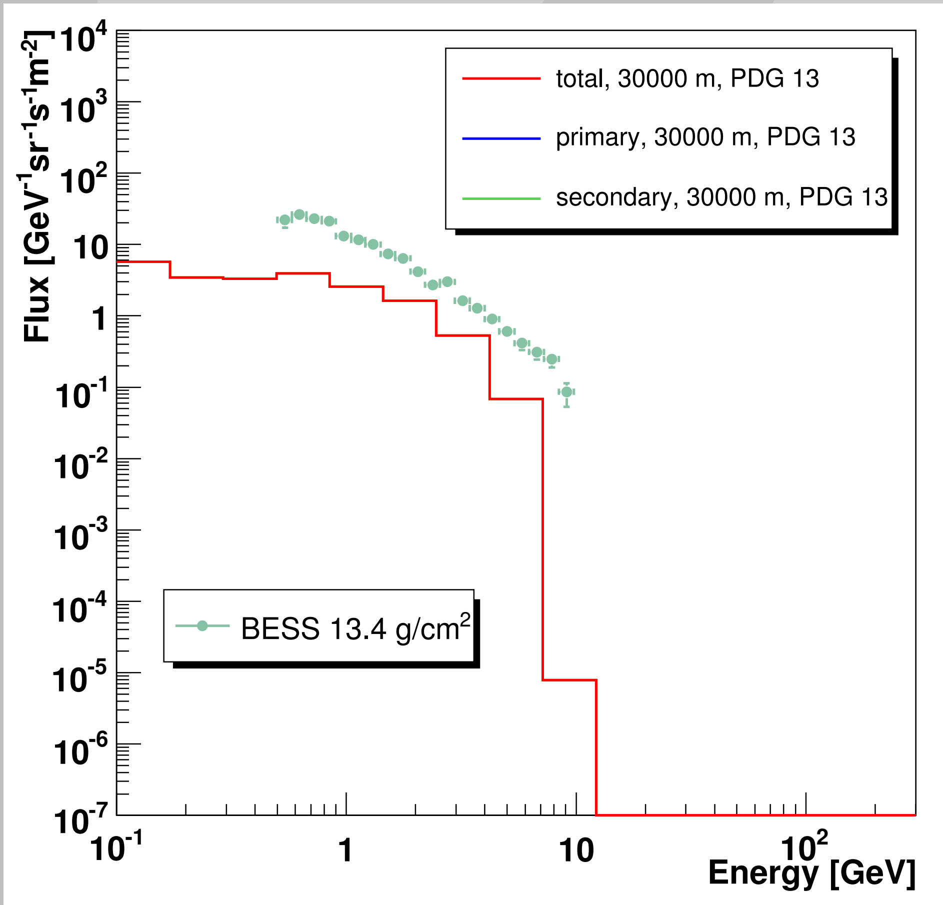
energy range of primaries: 1 - 5 GeV

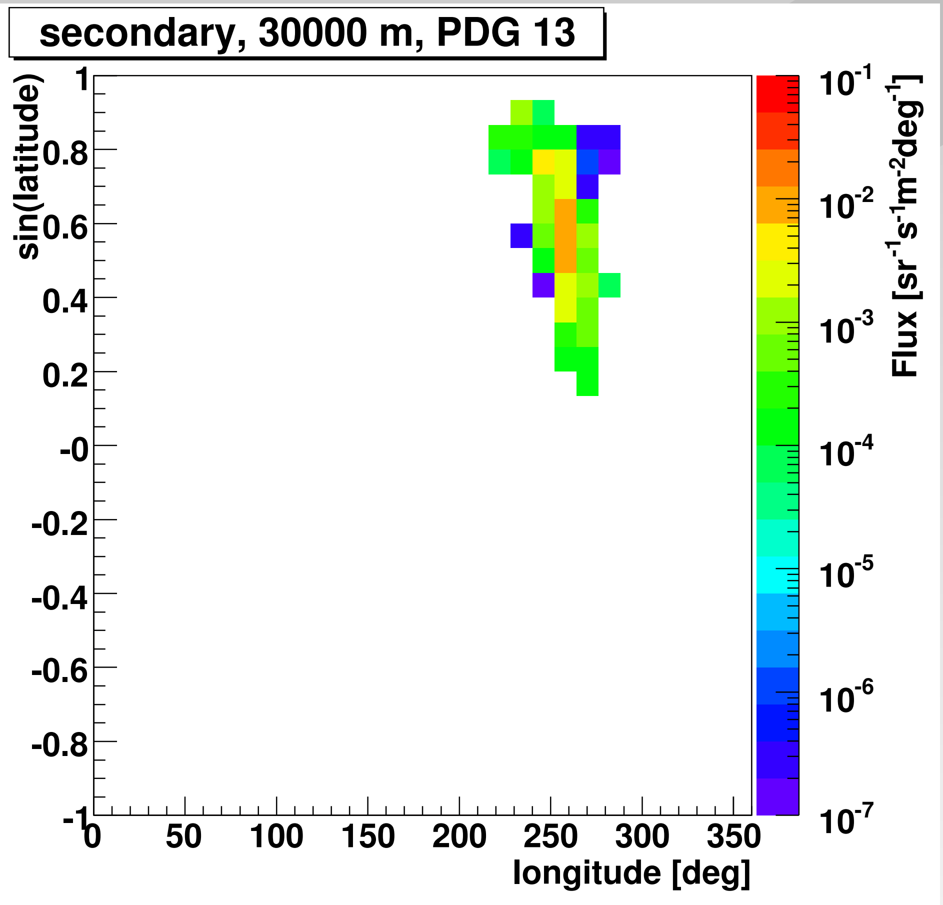




Influence of magnetic field to secondary muon fluxes

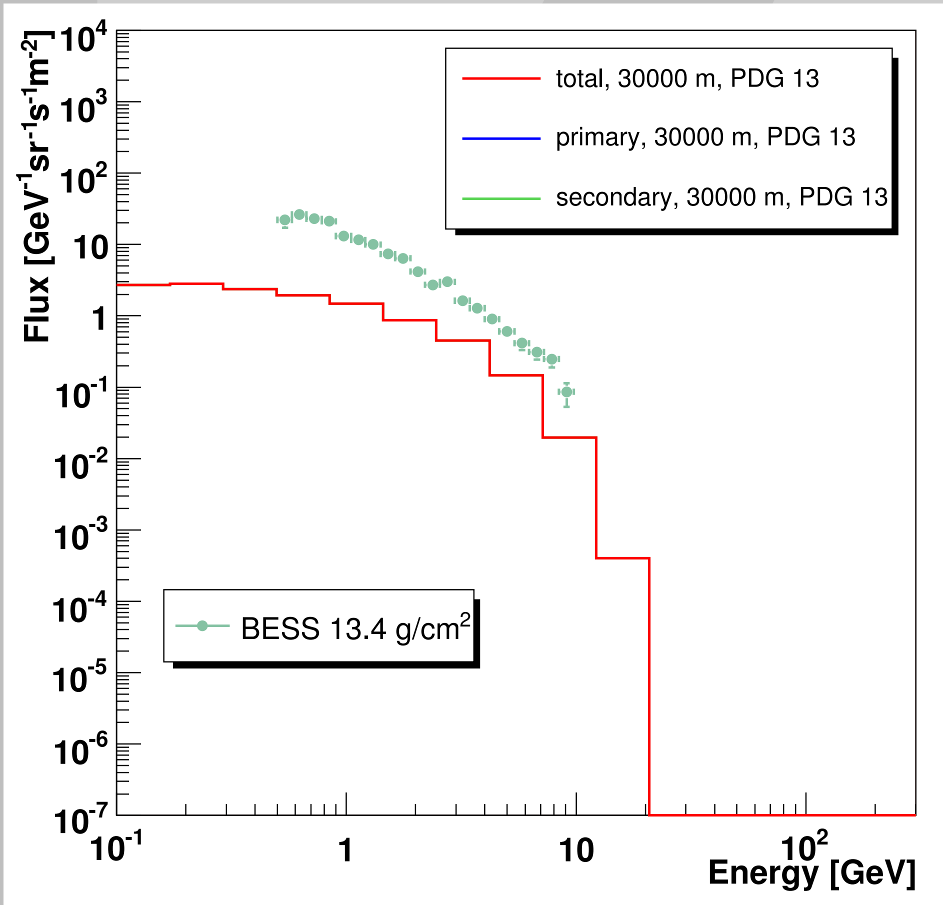
energy range of primaries: 5 - 15 GeV

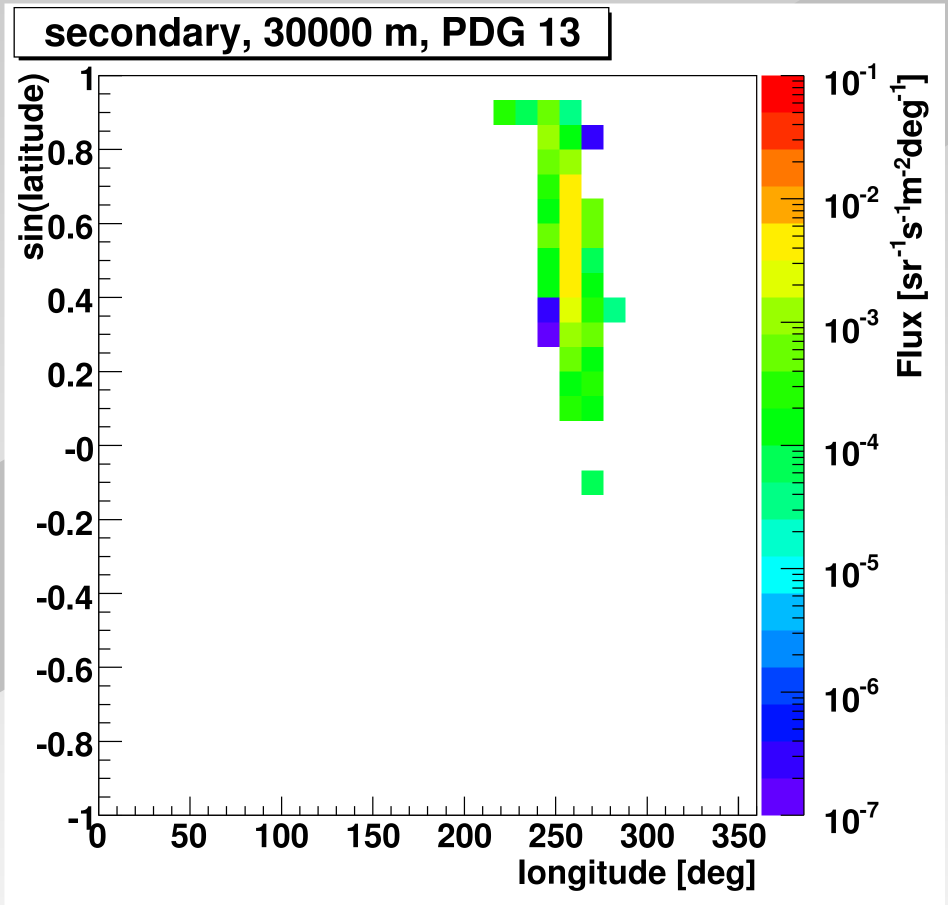




Influence of magnetic field to secondary muon fluxes

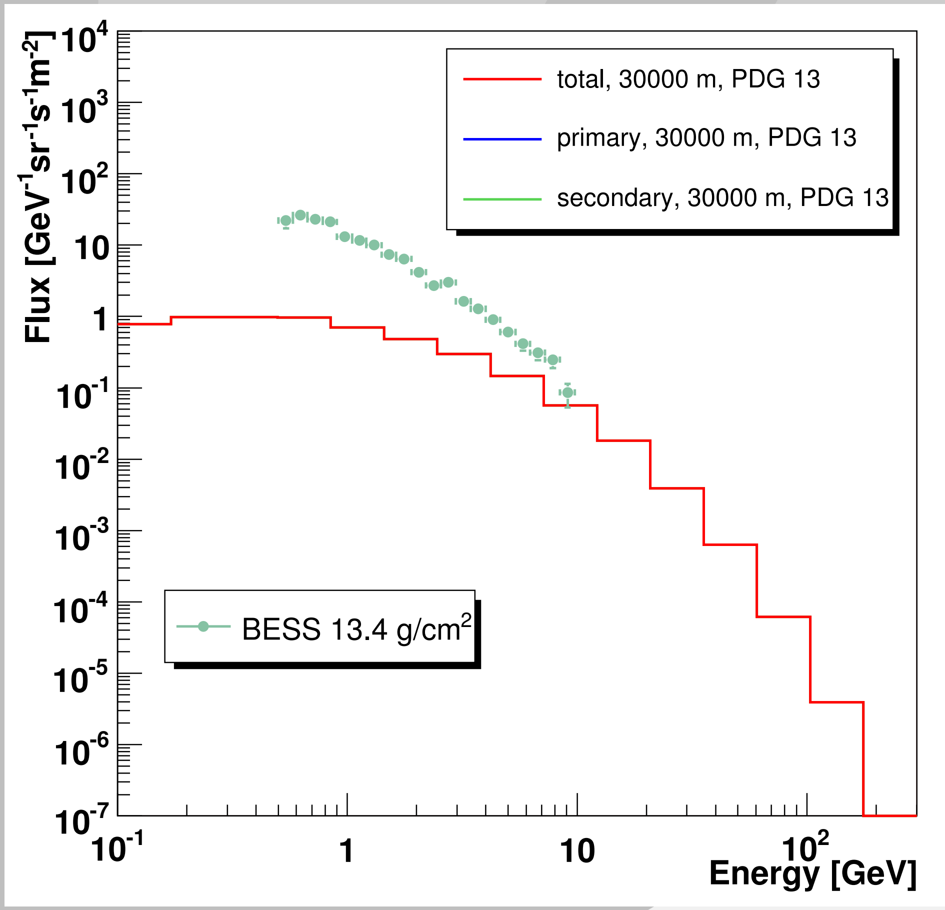
energy range of primaries: 15 - 30 GeV

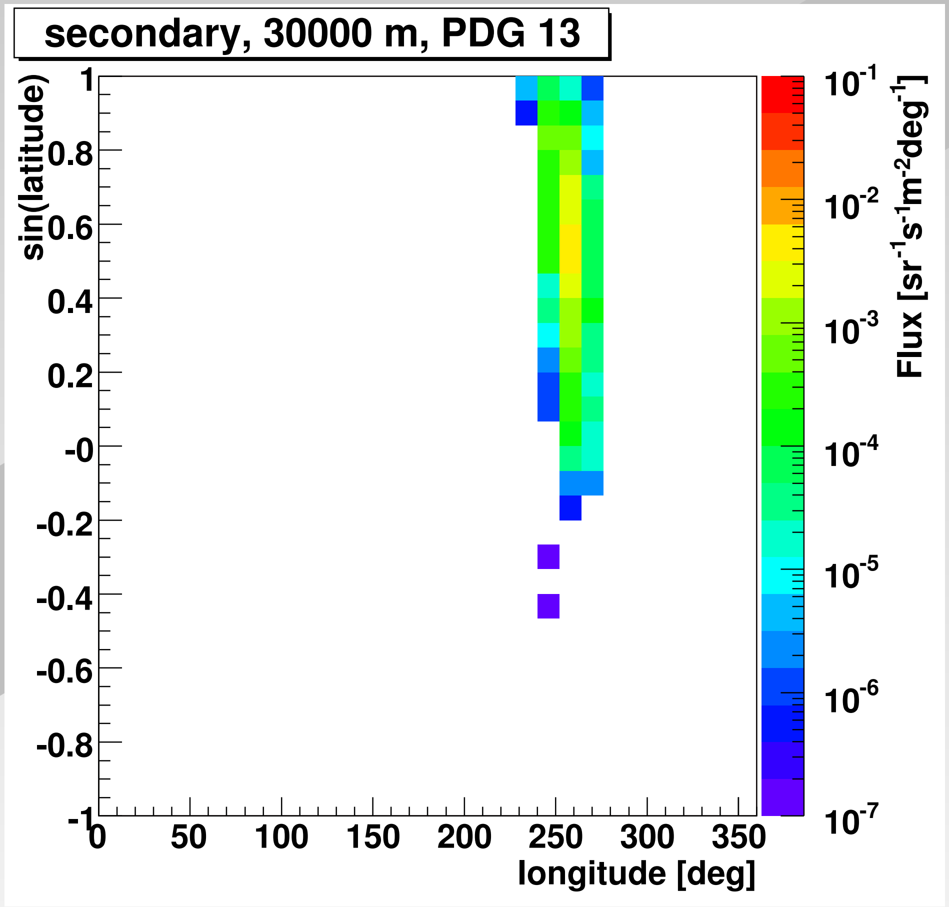




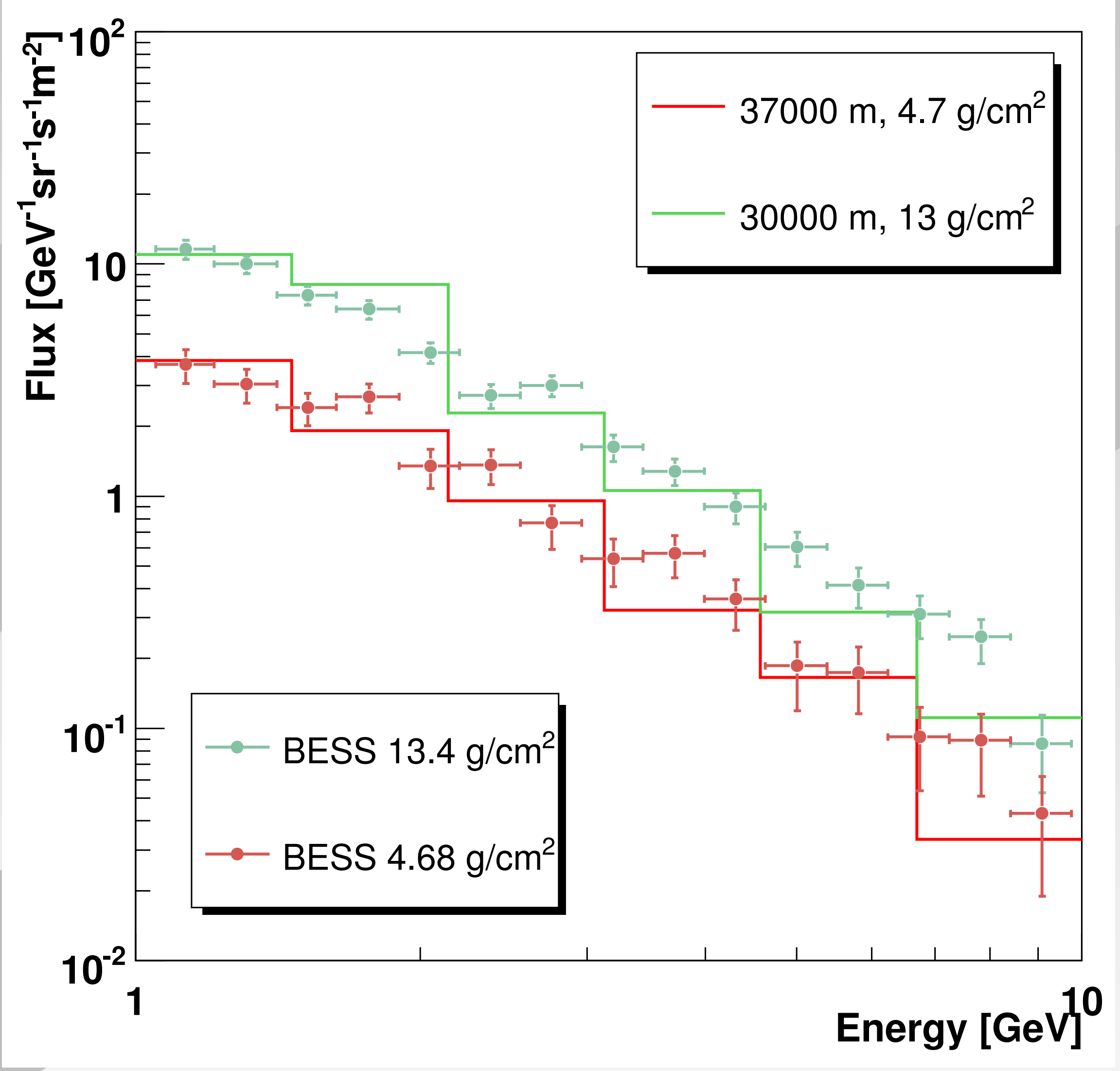
Influence of magnetic field to secondary muon fluxes

energy range of primaries: 30 - 300 GeV





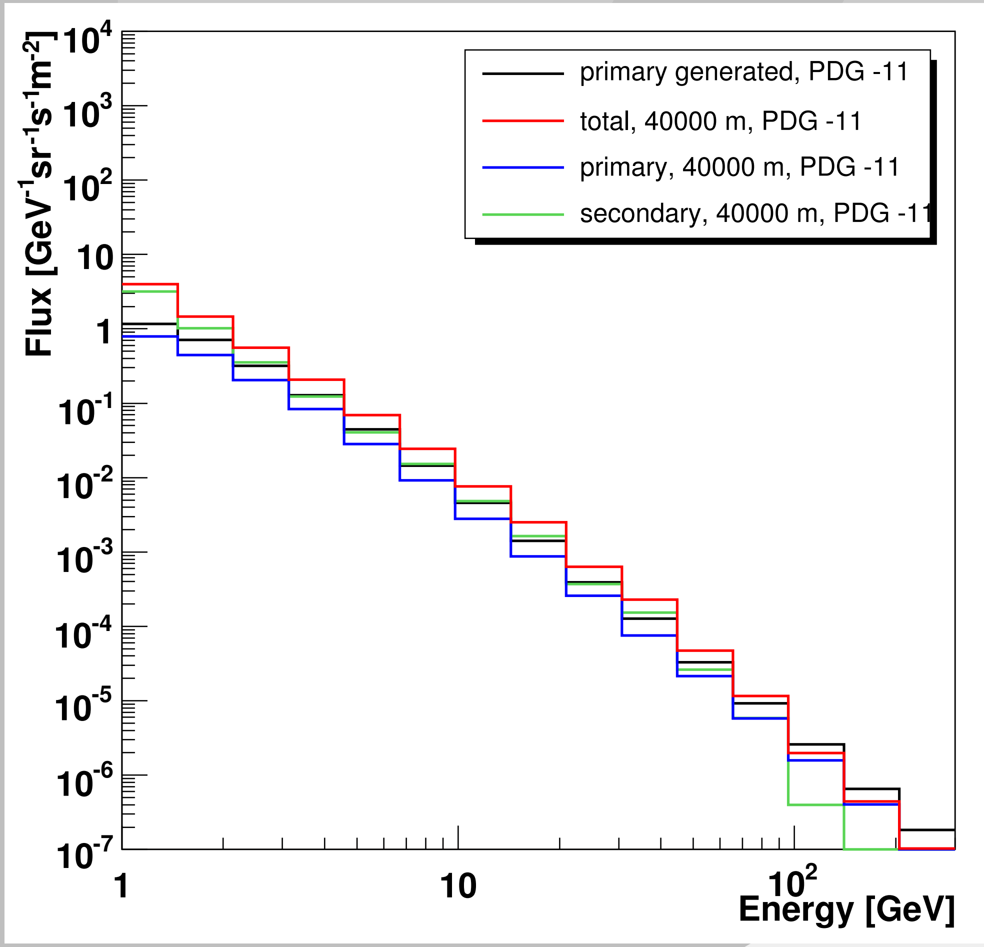
Verification of atmospheric physics model

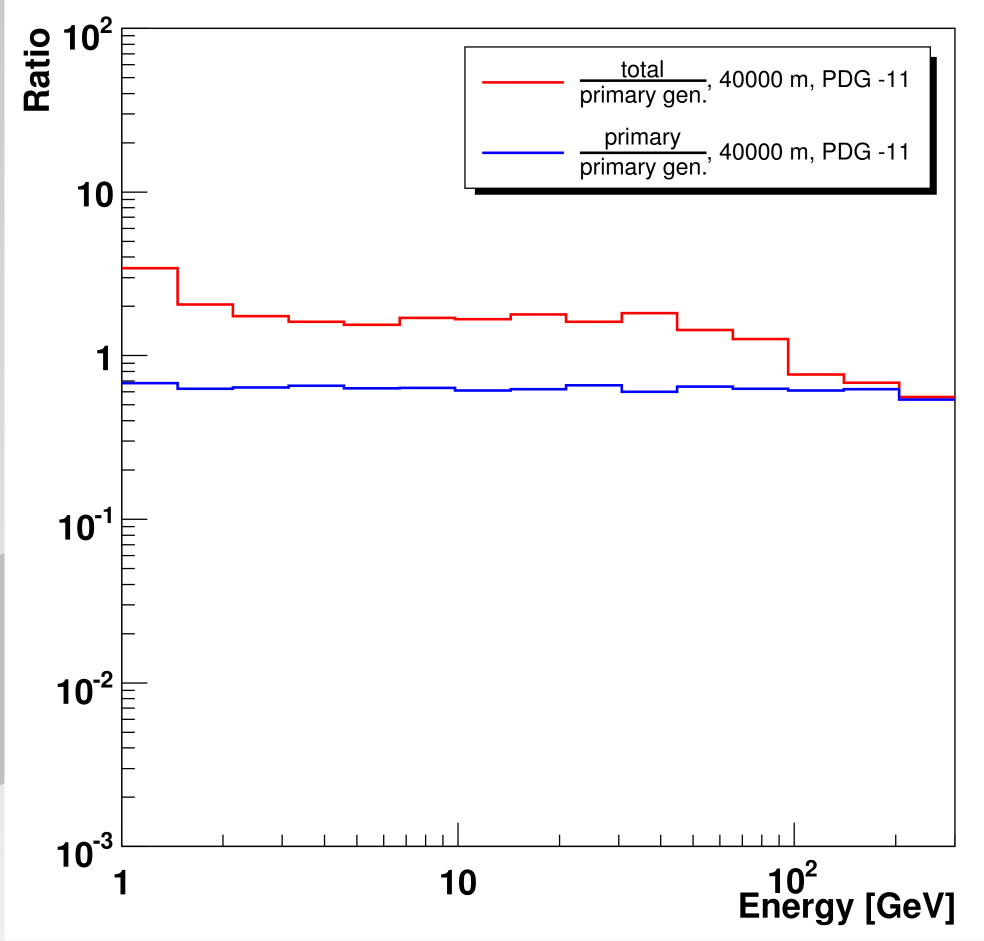


Comparison of simulations with BESS data in Ft. Sumner, TX (09/2001).

Simulation seems to work within the errors!

Positron fluxes in 40 km – South Pole Dec. 2005





- ★ simulations done in the same way as for Ft. Sumner, except of date and location

Positron fluxes in 40 km – corrections

$$N_{e^+}^{\mathrm{PEBS}} = N_{e^+}^{\mathrm{prim}} \cdot \epsilon_{e^+}^{\mathrm{PEBS}} \cdot \epsilon_{e^+}^{\mathrm{atmo}} + N_{e^+}^{\mathrm{sec}} \cdot \epsilon_{e^+}^{\mathrm{PEBS}} + \frac{N_p^{\mathrm{tot}}}{R_p} + N_{e^-}^{\mathrm{tot}} \cdot \epsilon_{e^- \to e^+}^{\mathrm{PEBS}}$$

(all quantities are energy dependent)

★ **meaning of quantities:**

- **number of particles** (GalProp, PLANETOCOSMICS):

  $N_{e^+}^{\mathrm{PEBS}}, N_{e^+}^{\mathrm{prim}}, N_{e^+}^{\mathrm{sec}}, N_p^{\mathrm{tot}}, N_{e^-}^{\mathrm{tot}}$

- **detection efficiency** (detector simulation):

  to take lower acceptance of TRD into account:

  $$\epsilon_{e^+}^{\mathrm{PEBS}} = 0.35 \cdot \left(\frac{1}{1+\exp\left(0.3\,\mathrm{GeV}^{-1} \cdot (-E+10\,\mathrm{GeV})\right)} + 1 \right)$$

- **proton Rejection** (detector simulation):

  $R_p = 10^4$ for all energies

- **loss of particles in atmosphere** (PLANETOCOSMICS):

  $\epsilon_{e^+}^{\mathrm{atmo}}$ energy dependent

- **tracker misidentification** (detector simulation):

  $\epsilon_{e^- \to e^+}^{\mathrm{PEBS}}$ energy dependent

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★ **error estimates:**

- statistical errors: $\sqrt{N_{\dots}^{\dots}}$
- systematic errors for atmospheric physics: 5 %
- systematic errors for detector properties: 3 %

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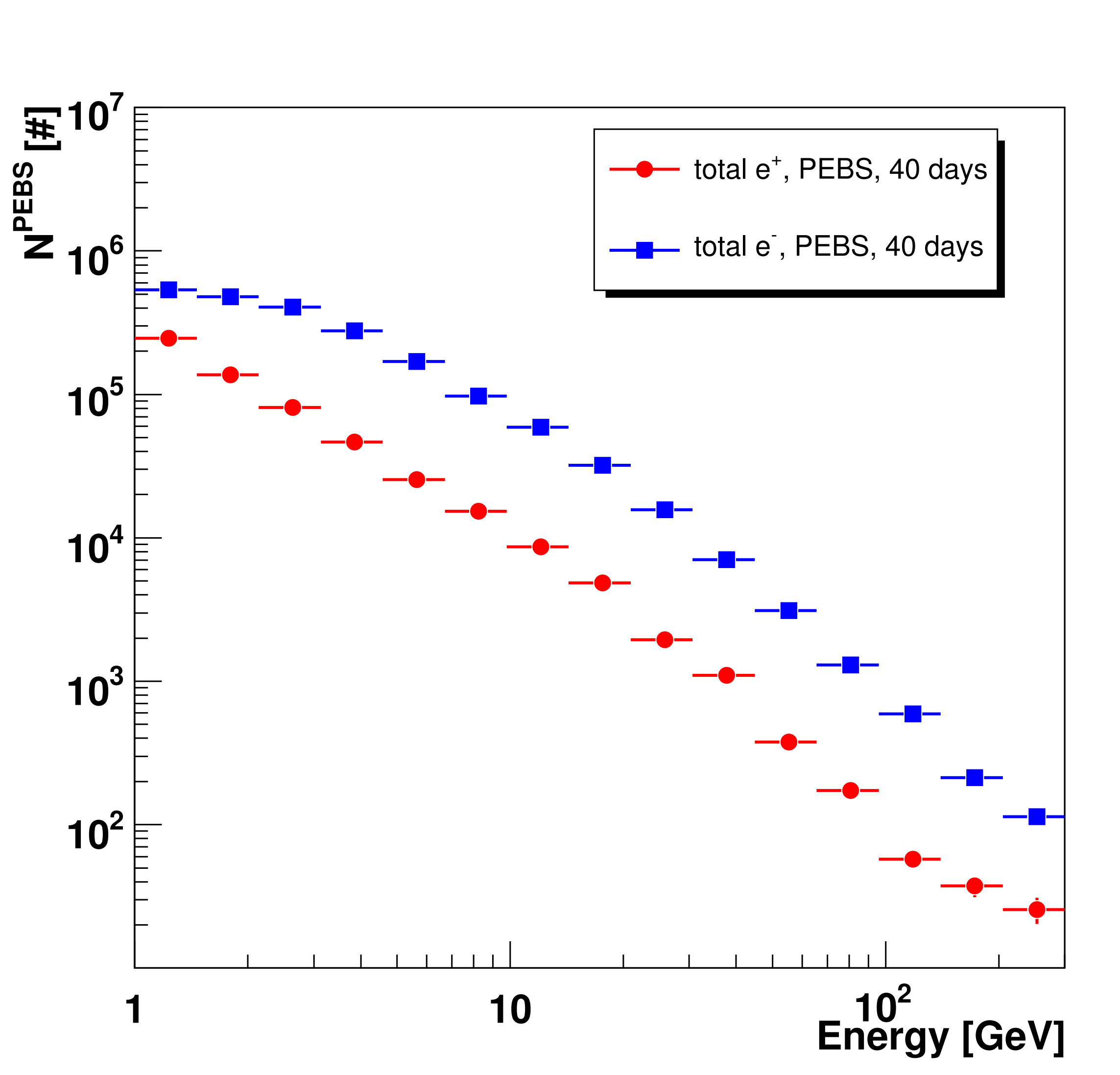
(all quantities are energy dependent)

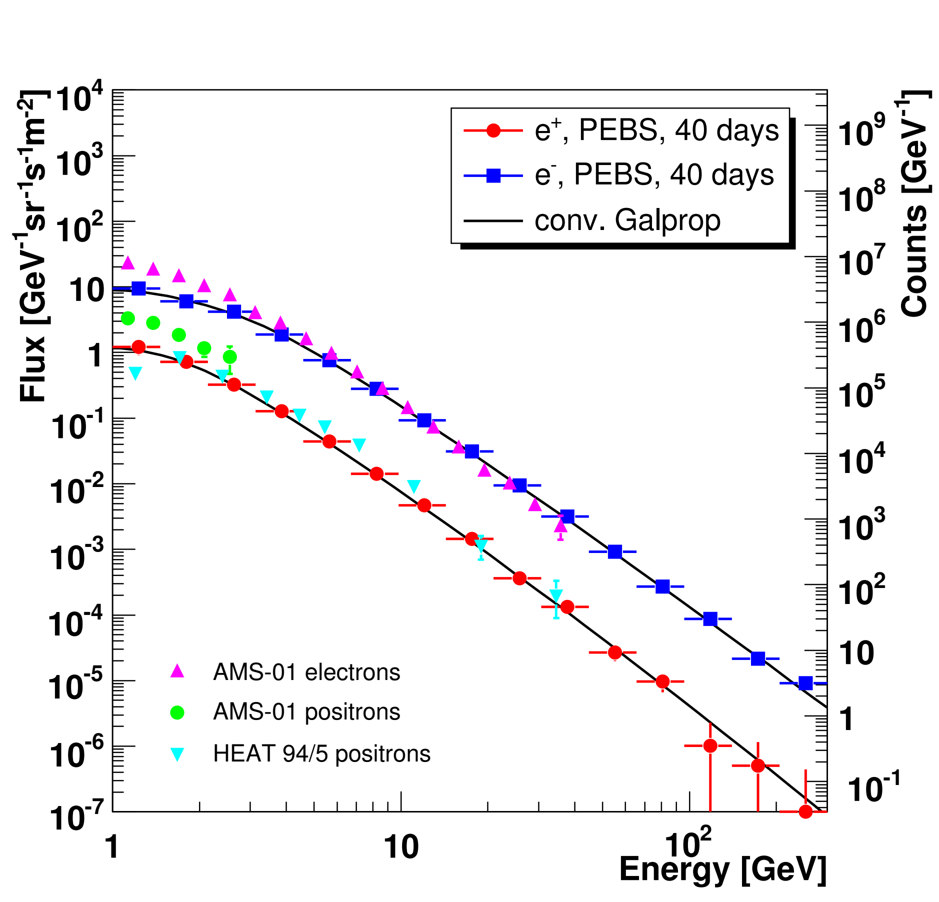
- ★ **Rejections**:
  - Proton rejections of **ECal** and **Tracker** → presentation H. Gast
  - not yet: consider μ-/π-efficiencies of detector
- ★ **general:** use energy dependent rejections (to be done . . .)

Total counts of e^-- and e^+-fluxes ($N^{PEBS}_{e^+/e^-}$)



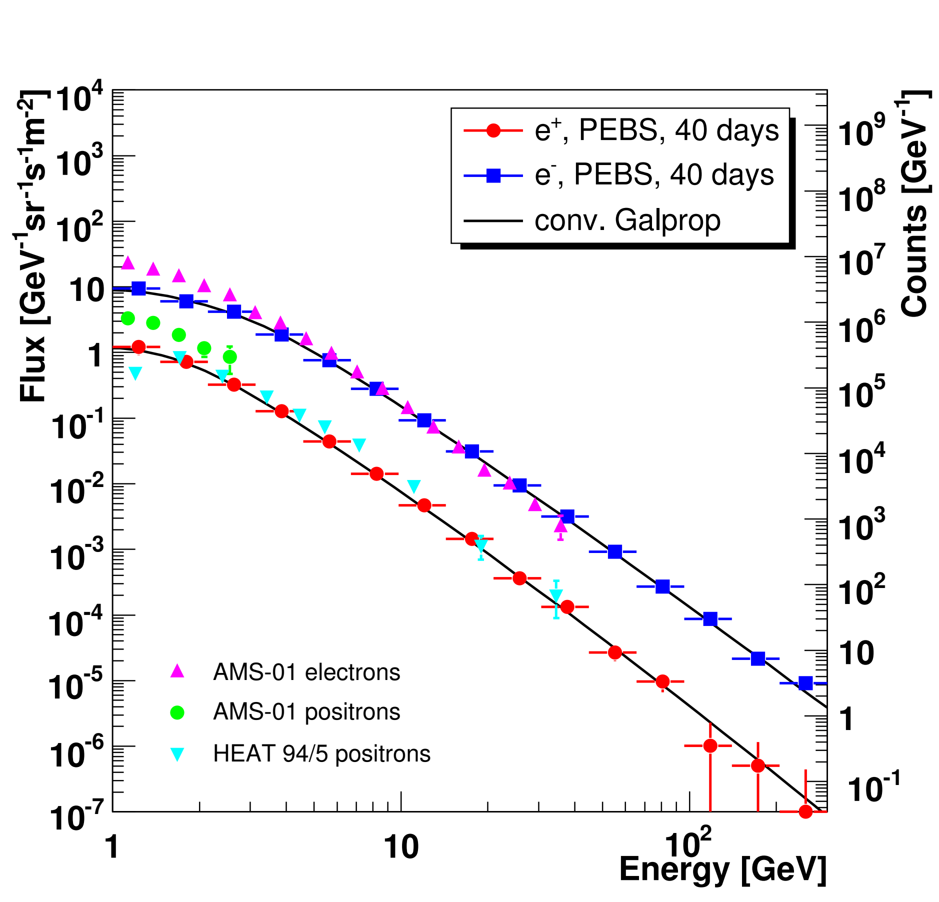
- ★ counts with detector efficiencies and atmospheric loss!
- ★ 40 days PEBS with acceptance $0.1\,\mathrm{m}^2\mathrm{sr}$

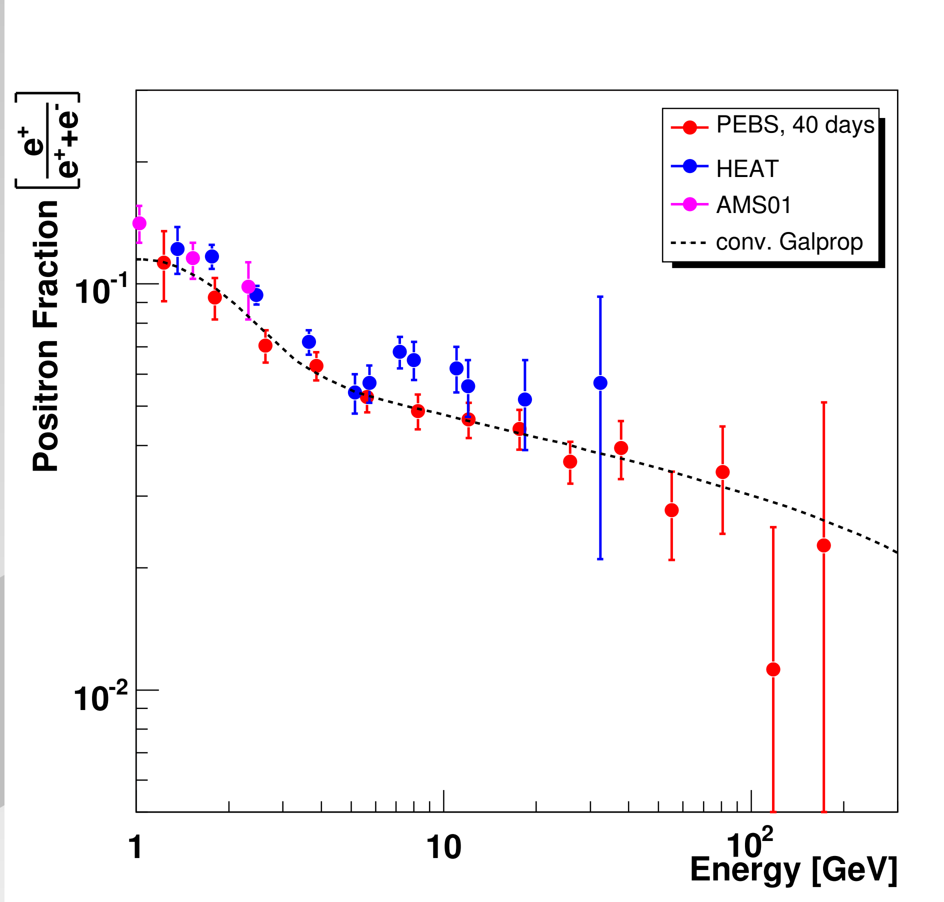
Electron and Positron fluxes with 40 days PEBS



- ★ all corrections applied

Electron and Positron fluxes with 40 days PEBS





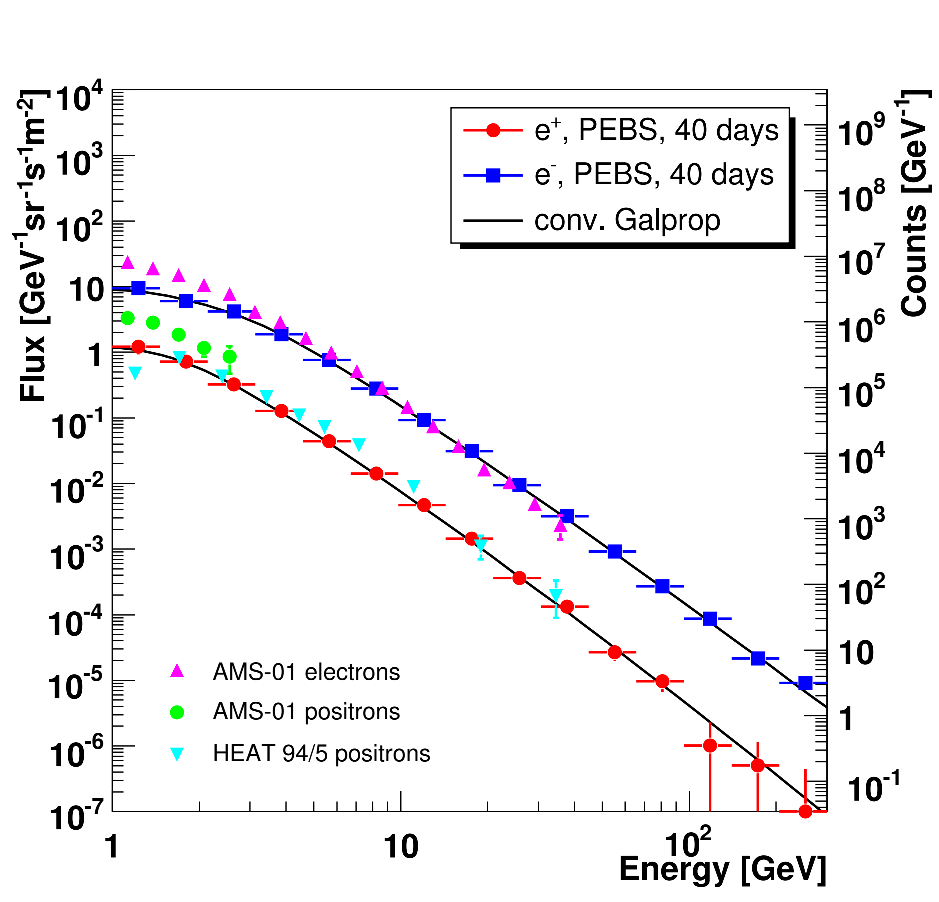
★ all corrections applied

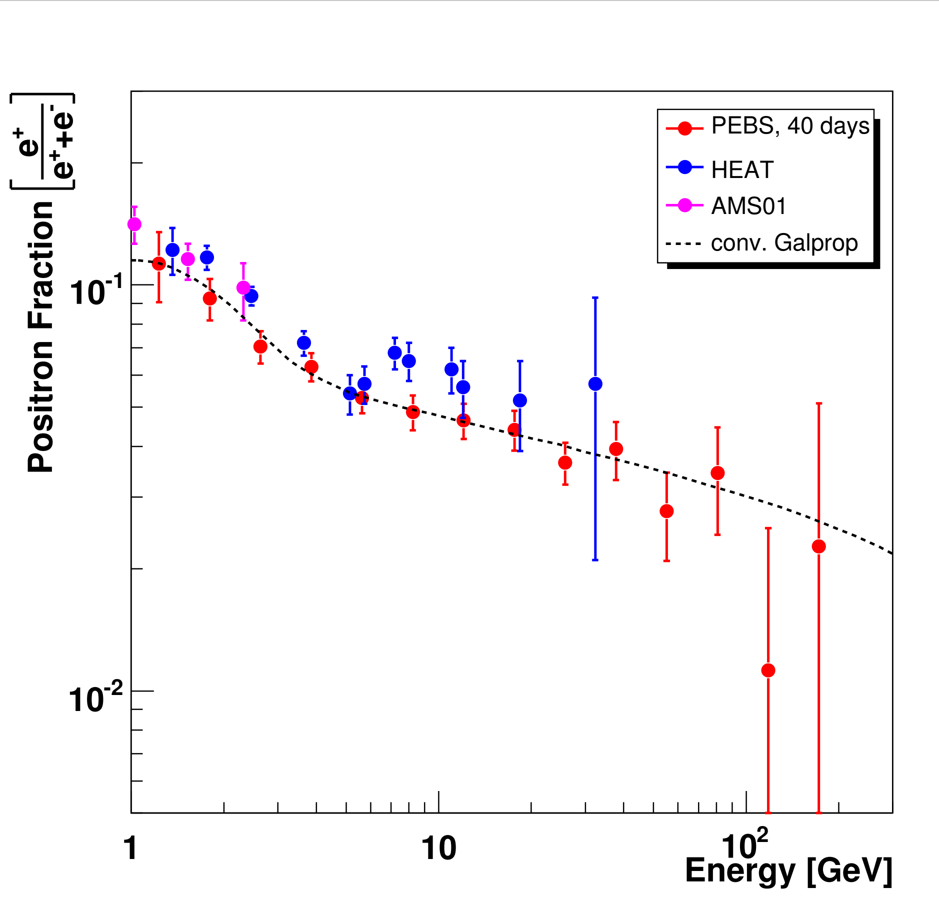
★ **assumptions for e^- and e^+:**

- same behaviour in atmosphere
- same rejection
- same tracker resolution

$\Longrightarrow$ smaller errors ($\epsilon^{atmo}_{e^+}$ cancels in fraction)

Electron and Positron fluxes with 40 days PEBS

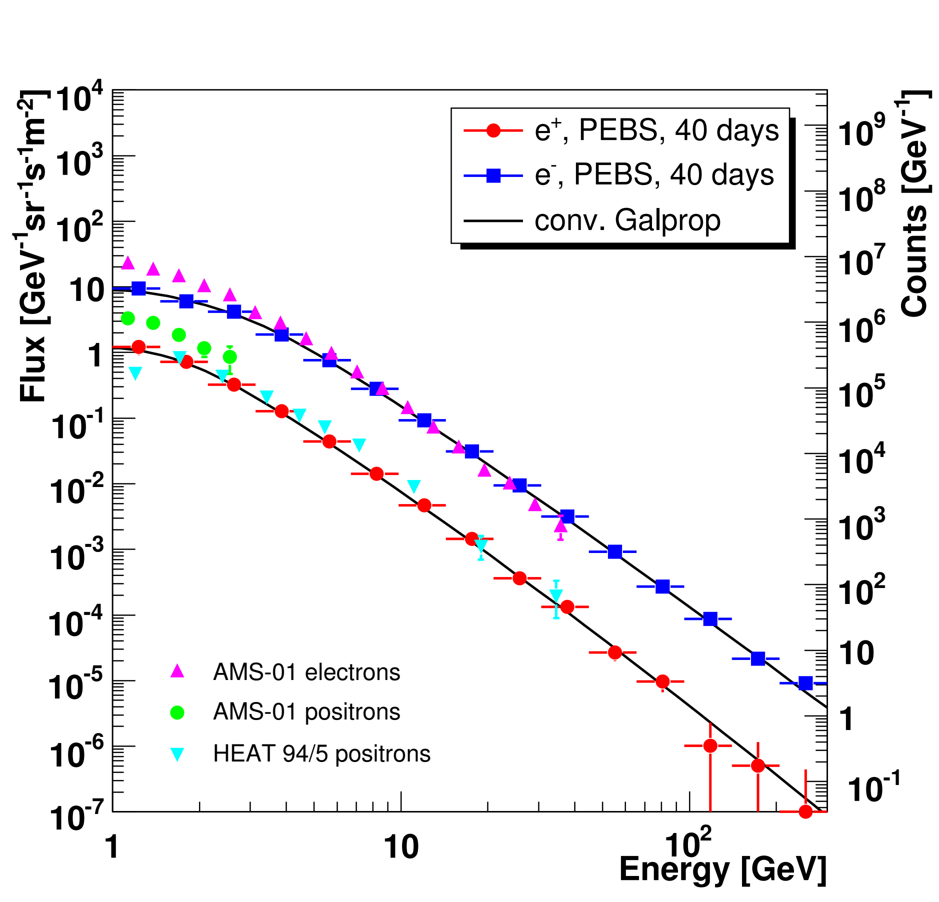


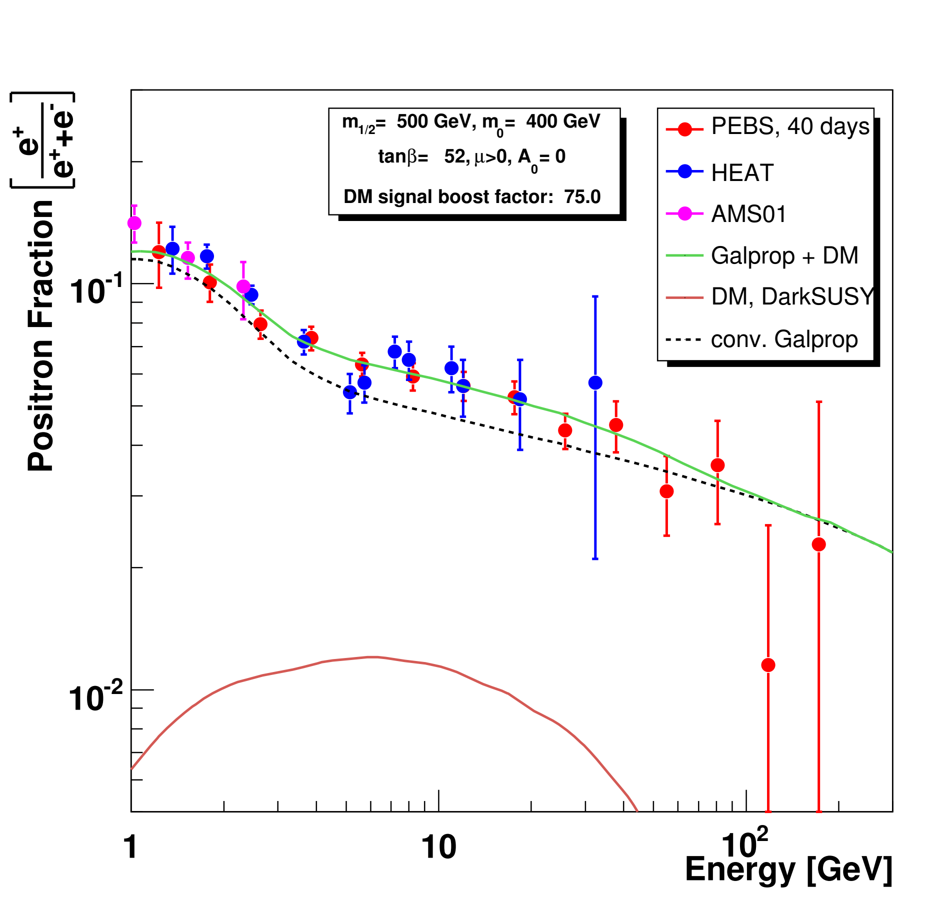


- ★ all corrections applied

- ★ PEBS errors are dominated by statistics at higher energies
- ★ **this PEBS has ca. $10^2\times$ statistics of HEAT**

Electron and Positron fluxes with 40 days PEBS



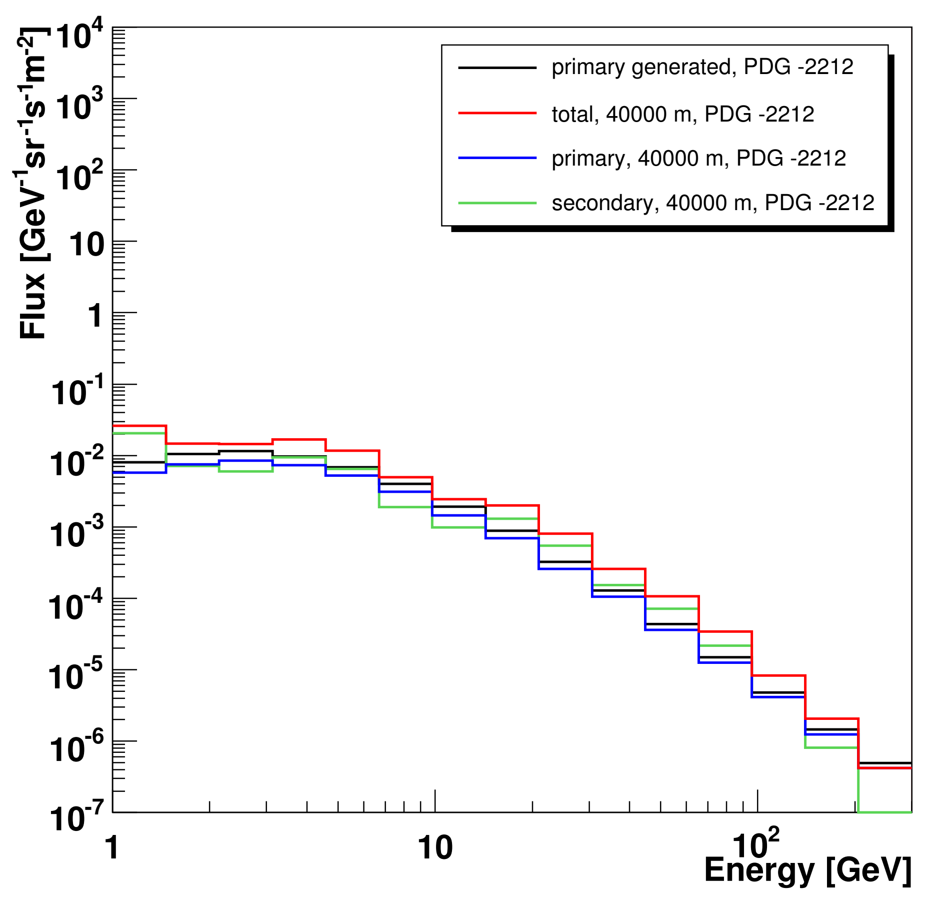


★ all corrections applied

★ **this dark matter signal is probably distinguishable with a** 40 **days PEBS flight in** 40 **km altitude**

Antiproton fluxes in 40 km

(counts for 40 days with acceptance $0.1\,m^2$sr and without detector effiencies)



- ★ influence of atmosphere seems to be in the same order as for positrons!

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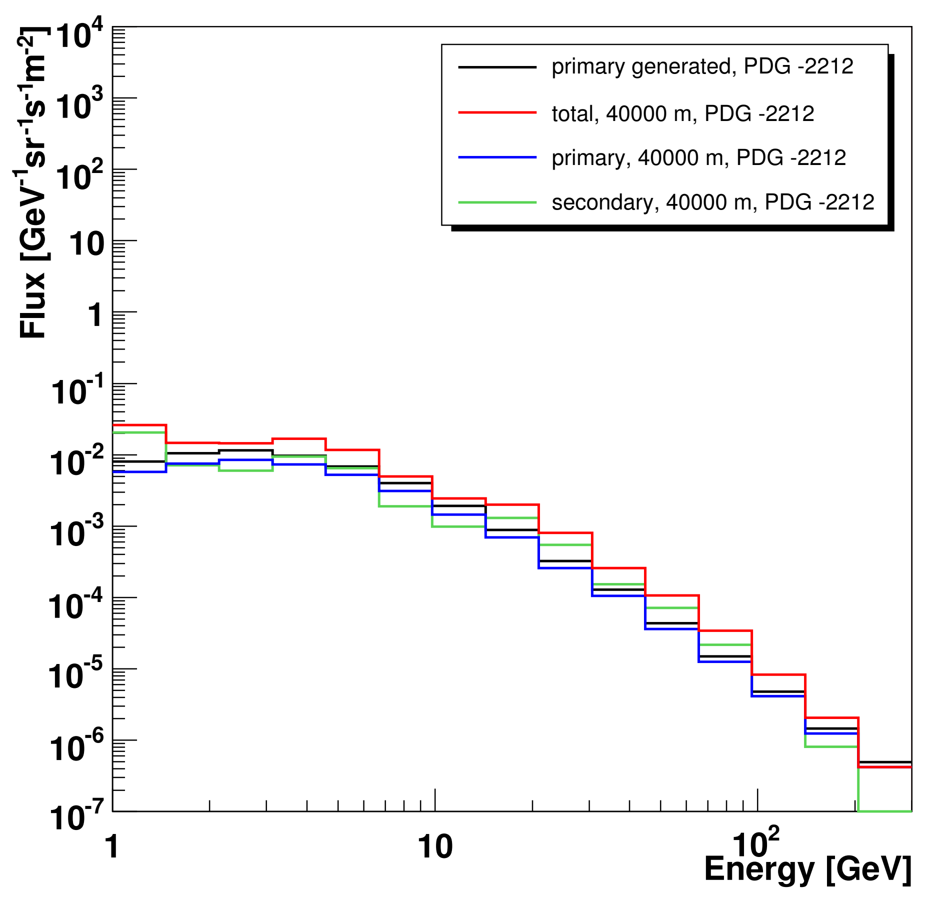
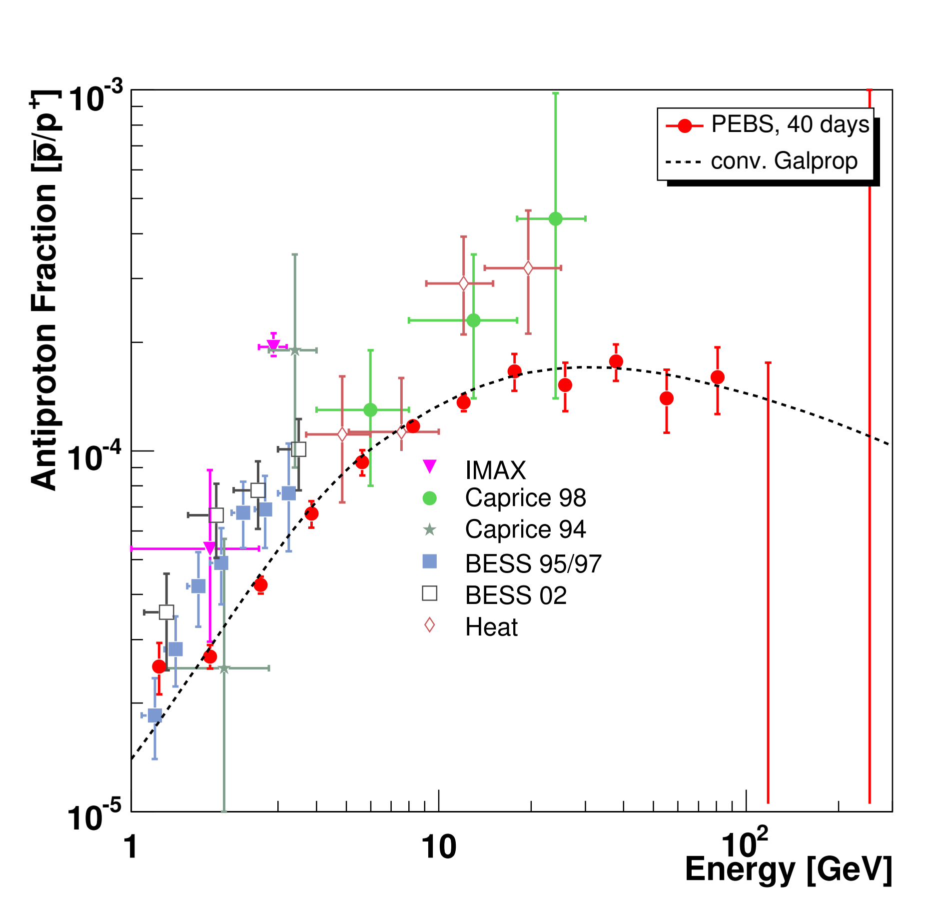
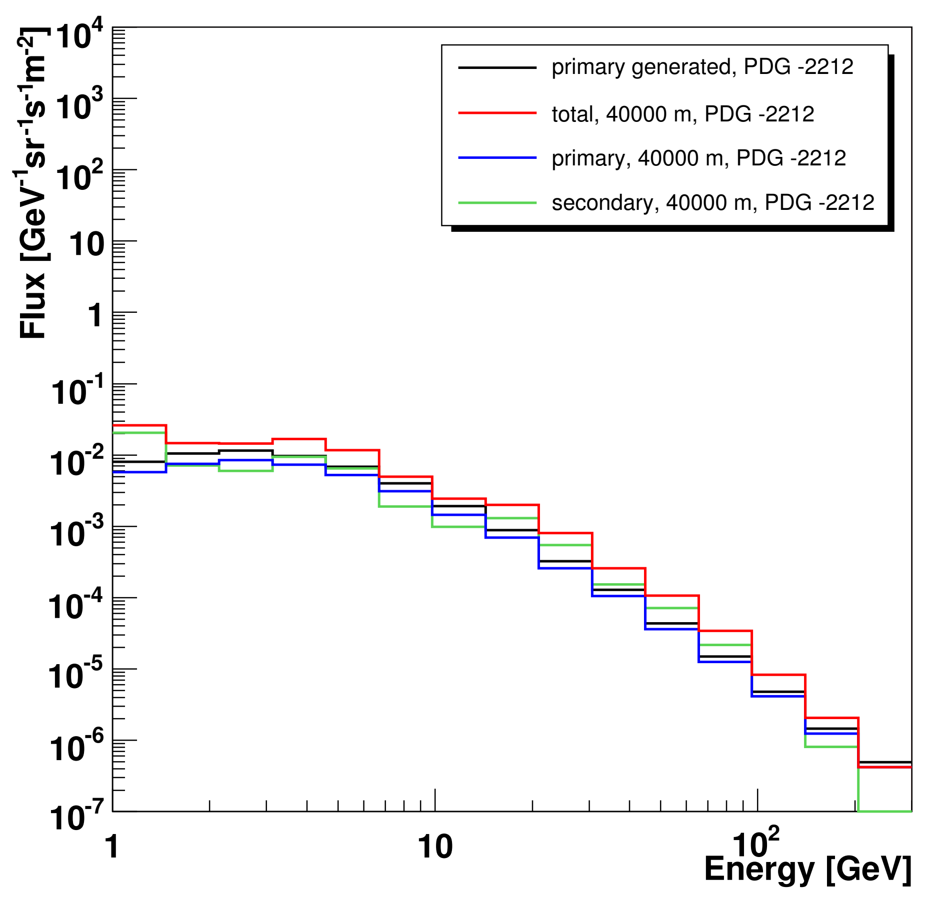


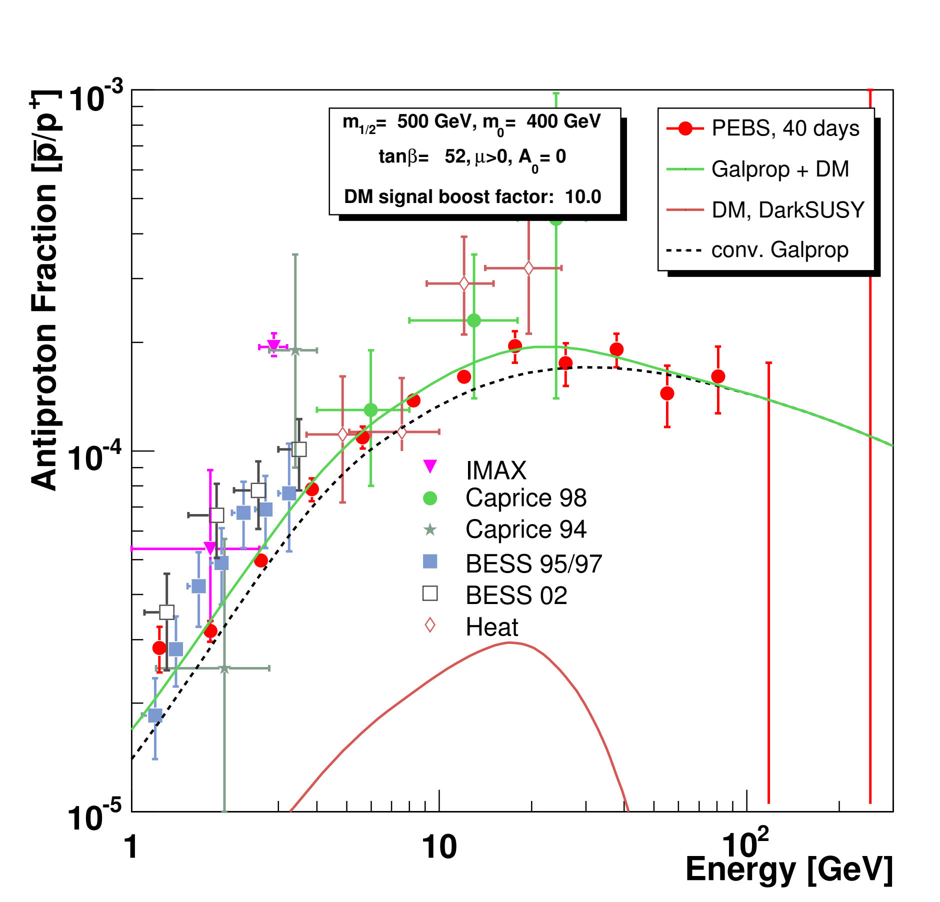


- ★ influence of atmosphere seems to be in the same order as for positrons!
- ★ same assumptions for detector efficiencies as for $e^{\pm}$ $\Longrightarrow$ room for improvement!

Antiproton fluxes in 40 km

(counts for 40 days with acceptance 0.1 m^2sr and without detector effiencies)

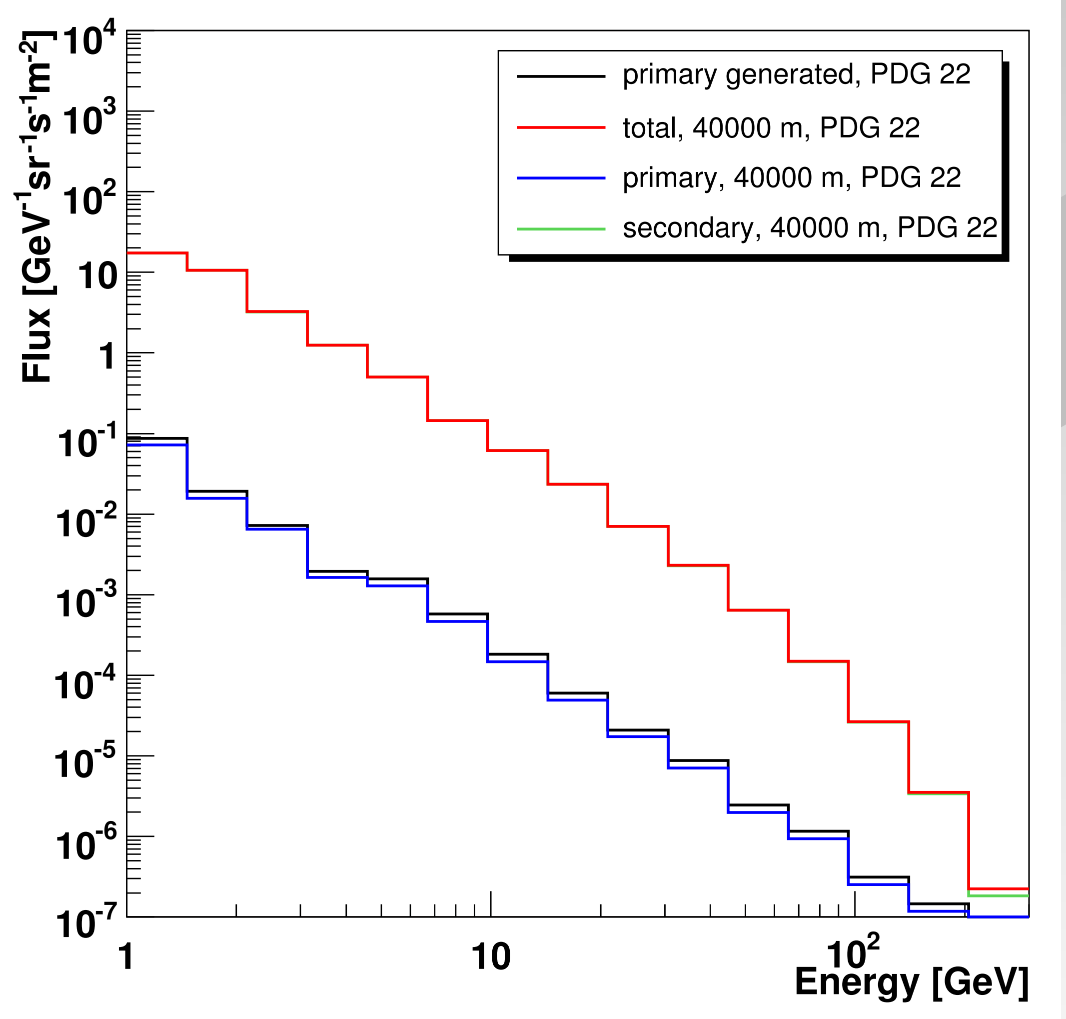




- ★ influence of atmosphere seems to be in the same order as for positrons!
- ★ dark matter contribution

Photon fluxes in 40 km

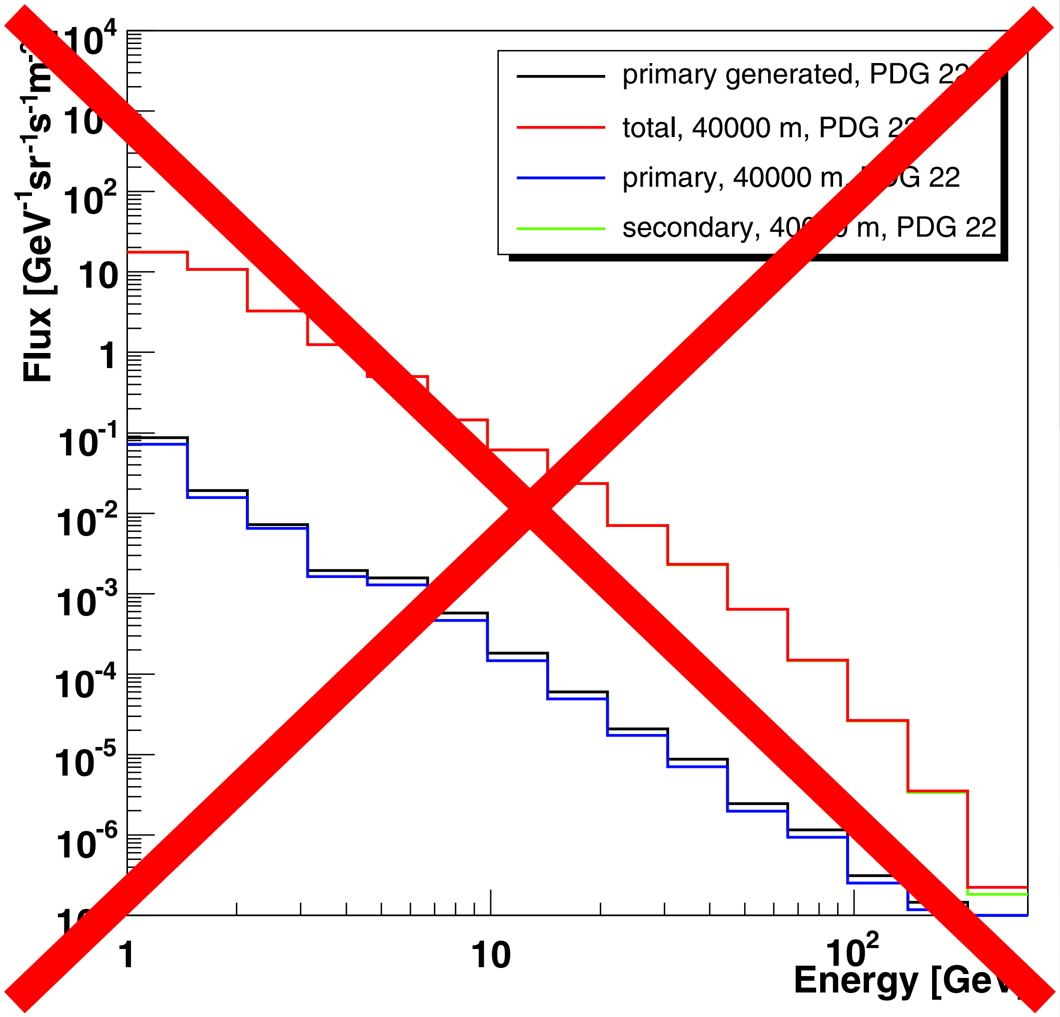
(counts for 40 days with acceptance $0.1\,m^2$sr and without detector effiencies)



★ diffuse γ's, averaged over all directions in the galaxy

Photon fluxes in 40 km

(counts for 40 days with acceptance $0.1\,m^2 sr$ and without detector effiencies)



- ★ diffuse γ's, averaged over all directions in the galaxy
- ★ **too many secondaries, flux measurement not possible!**

Summary & Outlook

What have been done:

- simulation of the positron fraction measurement on the South Pole in $40\,\text{km}$ altitude with PEBS
- error estimation including the correction of the main uncertainties
- good measurement of positron fraction possible (ca. $10^2\times$ statistics of HEAT)
- good measurement of antiproton ratio possible

Summary & Outlook

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- simulation of the positron fraction measurement on the South Pole in $40\,\text{km}$ altitude with PEBS
- error estimation including the correction of the main uncertainties
- good measurement of positron fraction possible (ca. $10^2\times$ statistics of HEAT)
- good measurement of antiproton ratio possible

What should be done:

- use more precise properties of PEBS detector
- find a better implementation of high energetic alphas
- find out about the detecabilty of heavy ions to measure e.g. B/C ratio
- check for detectibility of other dark matter signals