Simulationen der Wechselwirkungen von kosmischer Strahlung mit der Erdatmosphäre

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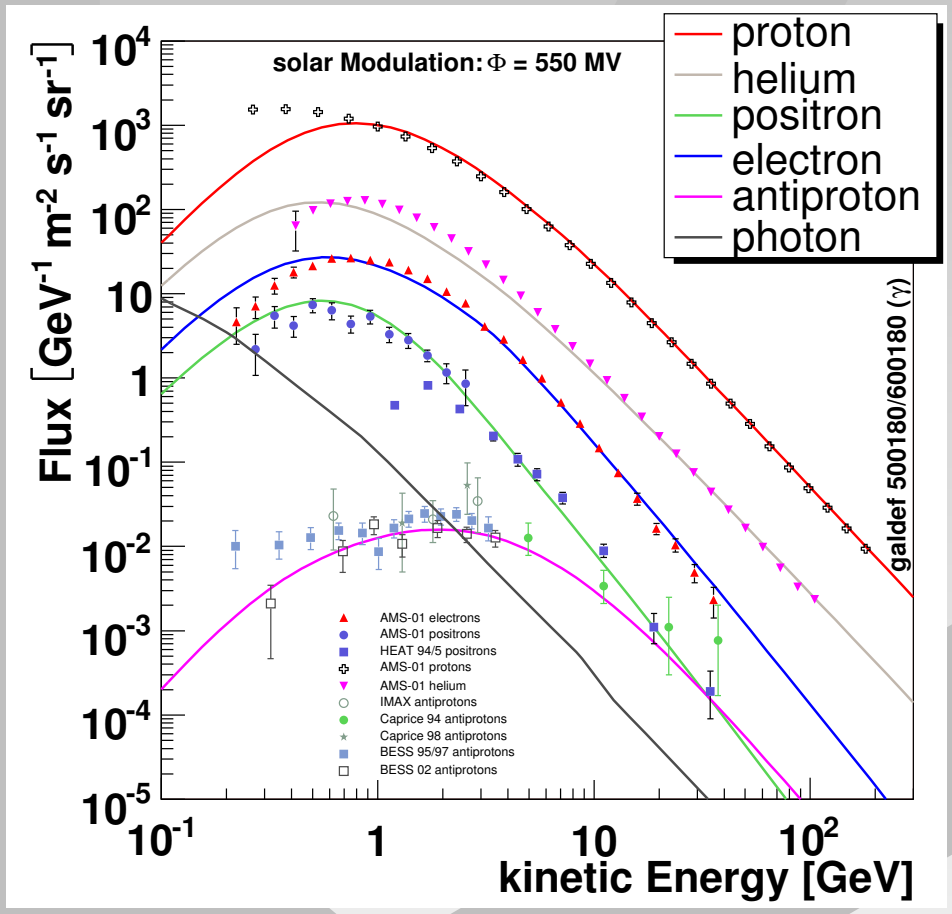
Status of galactic cosmic ray measurements



★ good agreement between cosmic ray propagation/production model and data in background fluxes (p, e^-, α, other heavy nuclei) $\rightarrow$ **general model works!**

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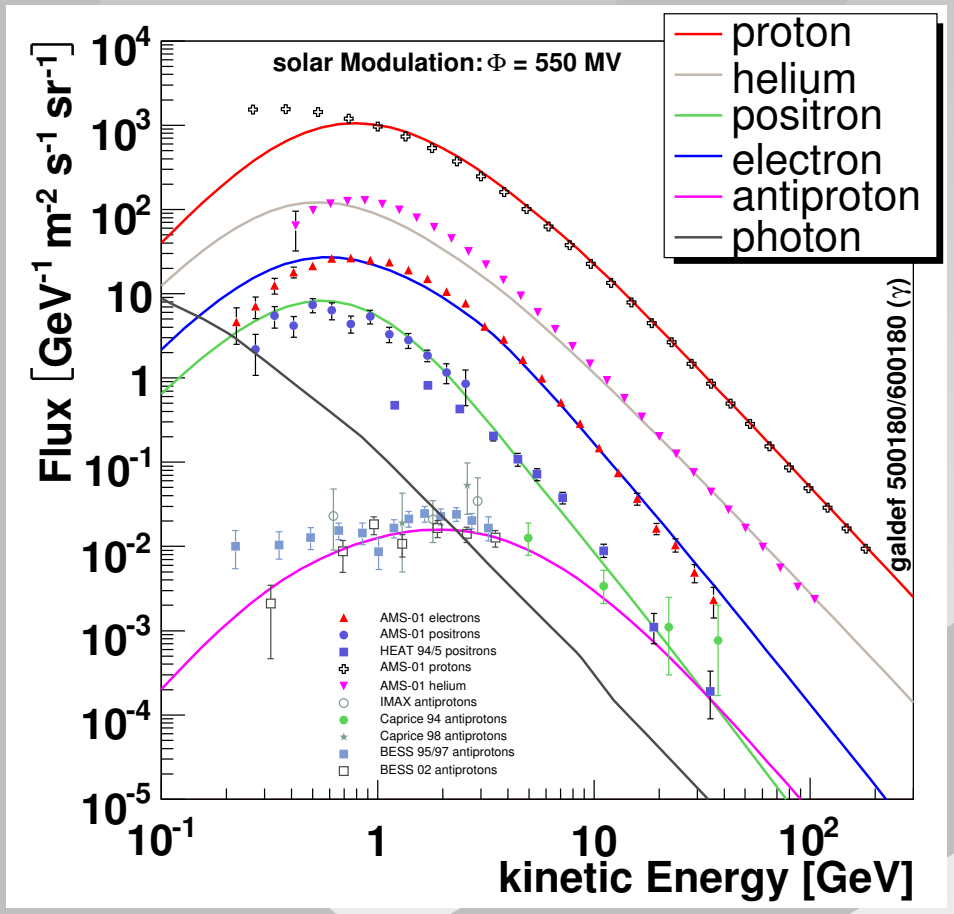
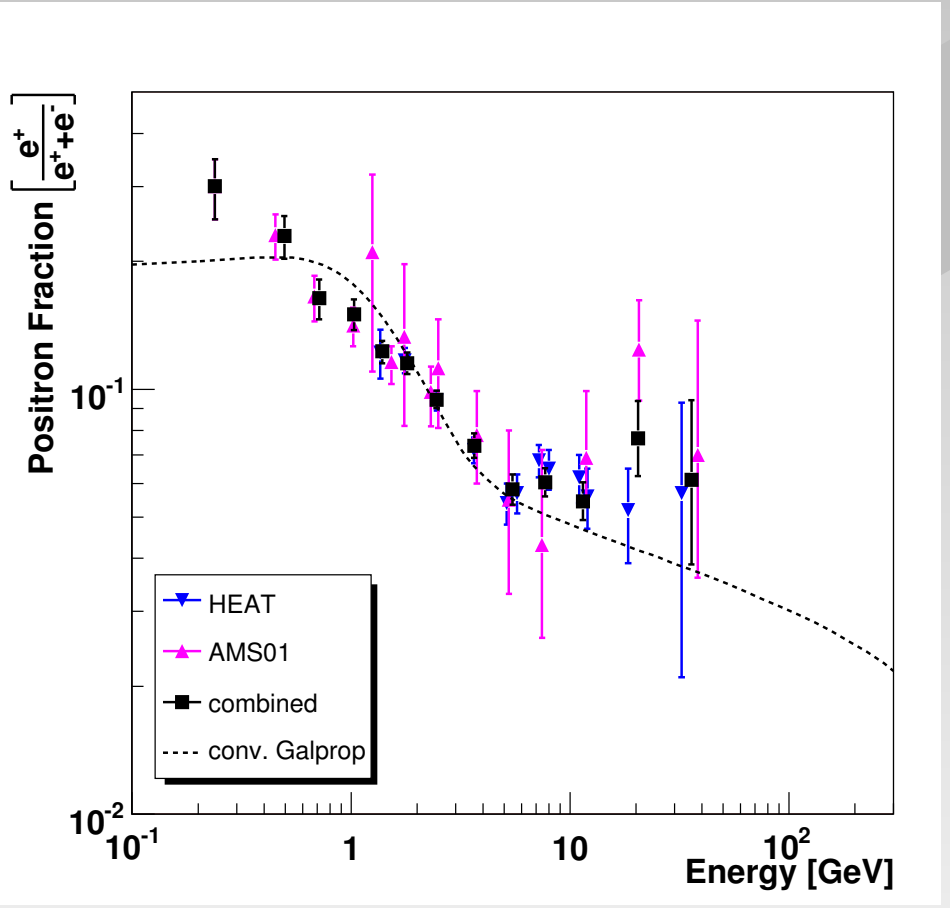
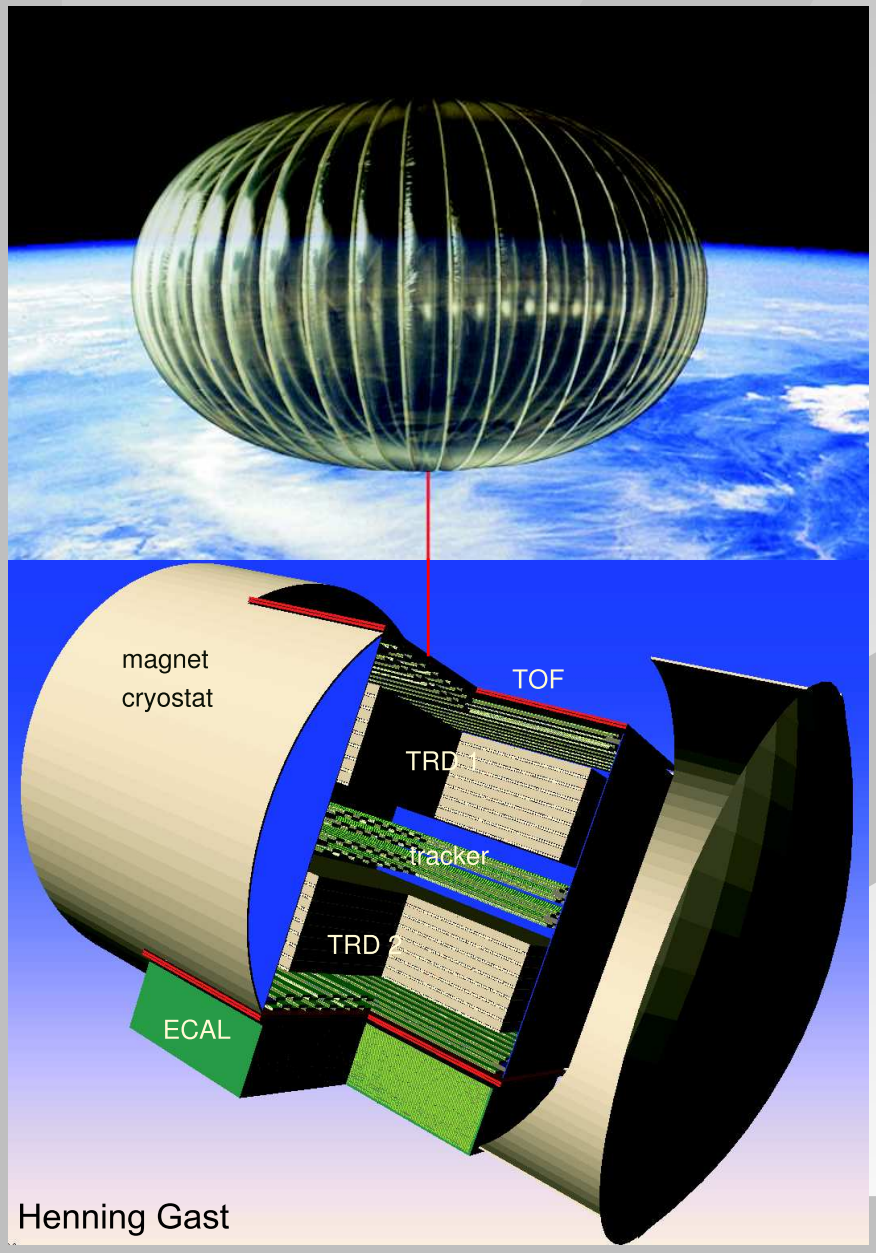




- ★ good agreement between cosmic ray propagation/production model and data in background fluxes (p, e^-, α, other heavy nuclei) → **general model works!**
- ★ e^+, $\bar{p}$, γ are sensitive to possible dark matter signals (annihilation) and fluxes/fractions show some unexplained features
  → **need precise measurement of fluxes up to high energies!**
- ★ measurements are **old**: HEAT (balloon: 94/95), AMS (space: 98)

PEBS detector



PEBS Detector

PEBS detector proposal:

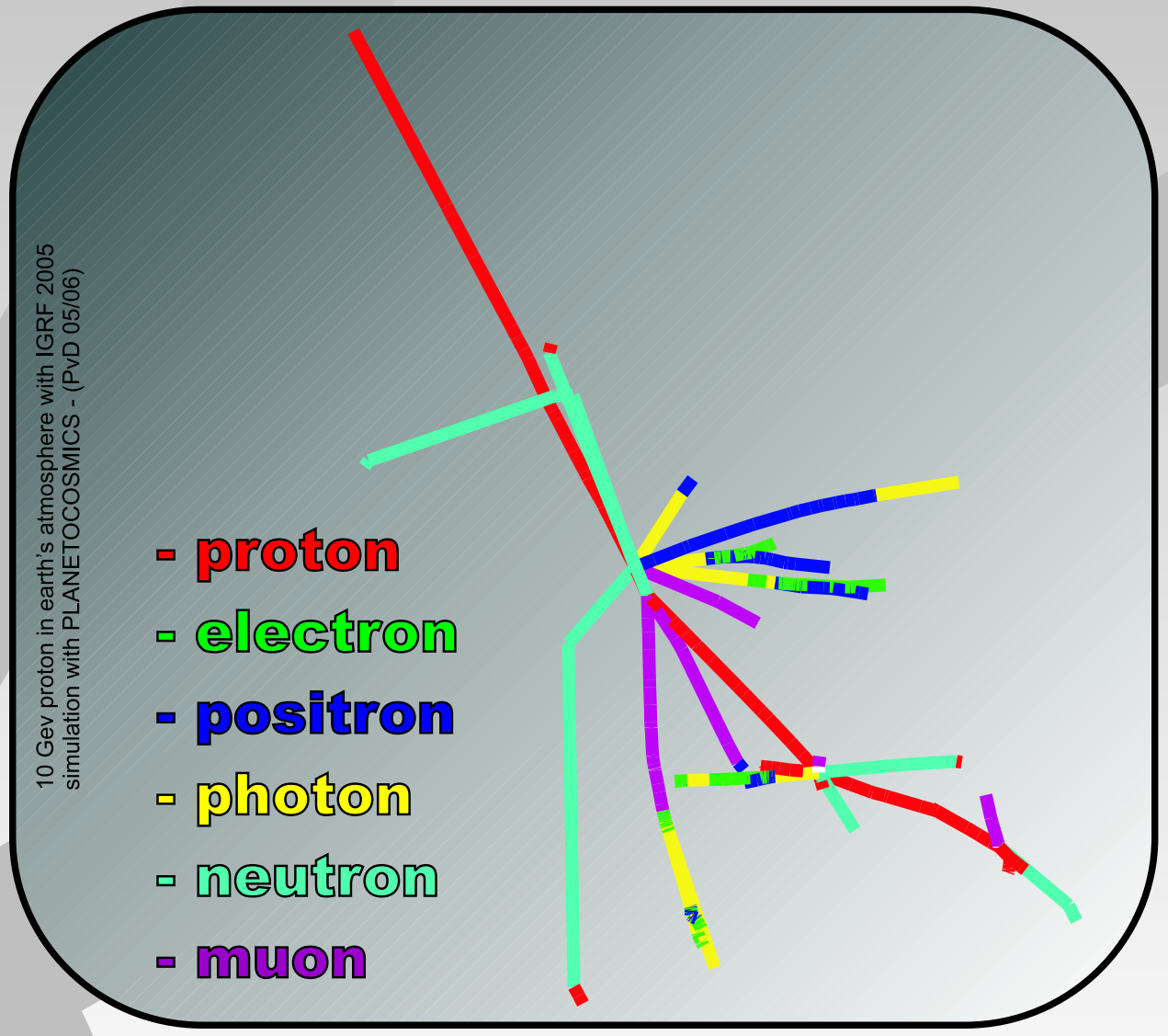
- ★ cosmic ray mearsurements @ North- or Southpole
- ★ use of a balloon to measure in Earth's atmosphere @ 40 km altitude

Detector properties:

flight time:	20 days
acceptance:	2500 $\mathrm{cm}^2\mathrm{sr}$
weight:	$< 2\,\mathrm{t}$
magnetic field:	1 T
momentum resolution:	$\sigma_p = \frac{0.14\,\%}{\mathrm{GeV}} p \oplus 2\,\%$
proton-positron rejection:	$\mathcal{O}(10^6)$
electron-antiproton rejection:	$\mathcal{O}(10^5)$

→ Details: presentation H. Gast

Air shower in Earth's atmosphere



$\Longrightarrow$ **careful study of secondary fluxes caused by atmosphere needed!**

PLANETOCOSMICS

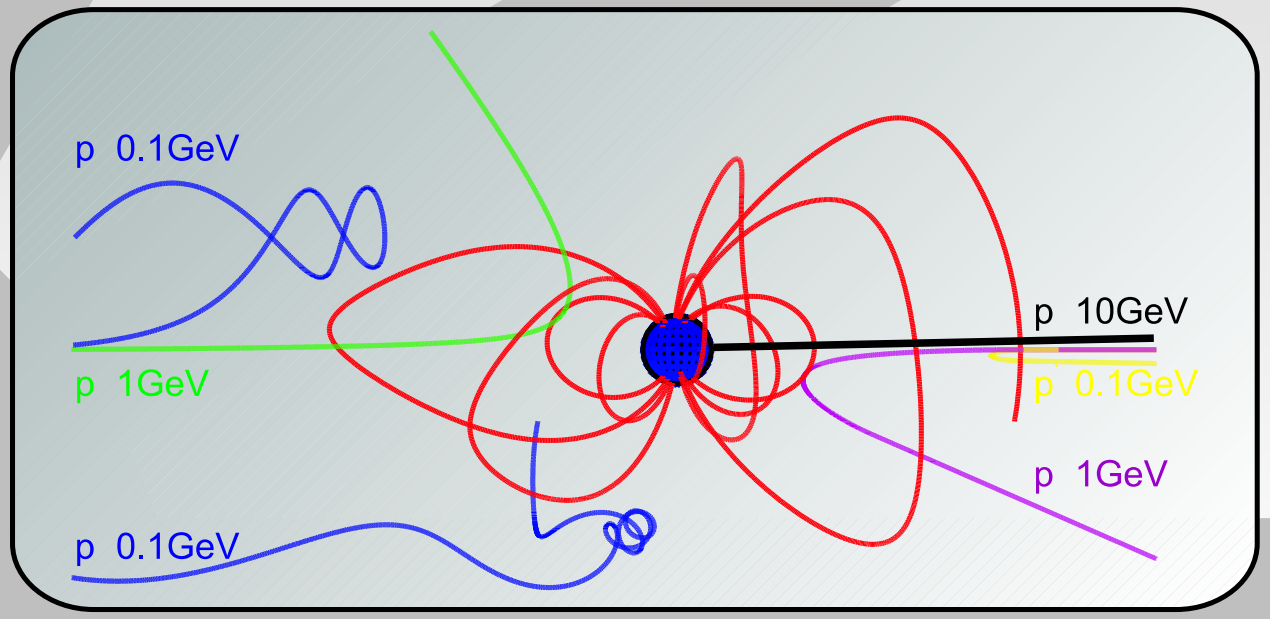
Simulation of the Earth's atmosphere and magnetic field with PLANETOCOSMICS (GEANT4)
(developed by L. Desorgher, Uni. Bern http://cosray.unibe.ch/ laurent/planetocosmics)

★ **general properties:**

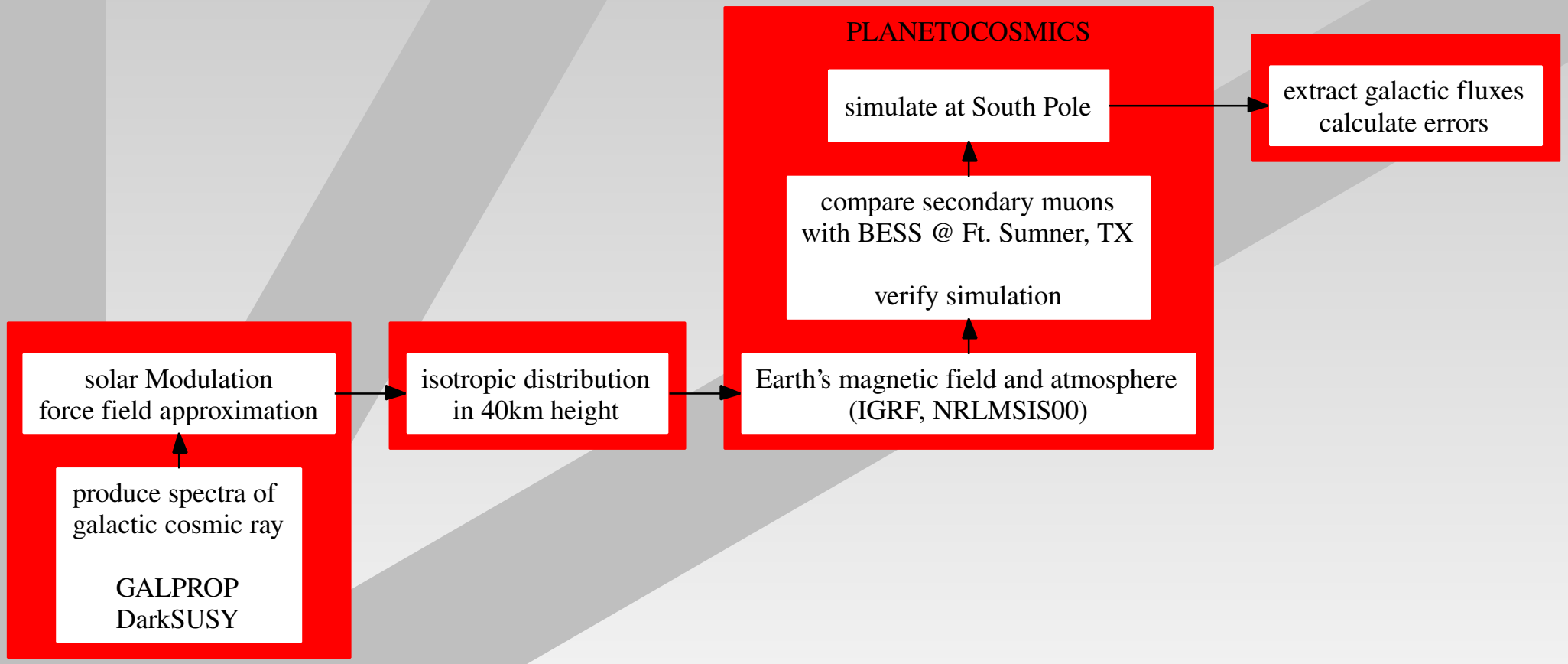
- atmospheric model: NRLMSISE00
- magnetic field: IGRF 2005
- solar modulation: mean field approximation

★ **properties of this simulation:**

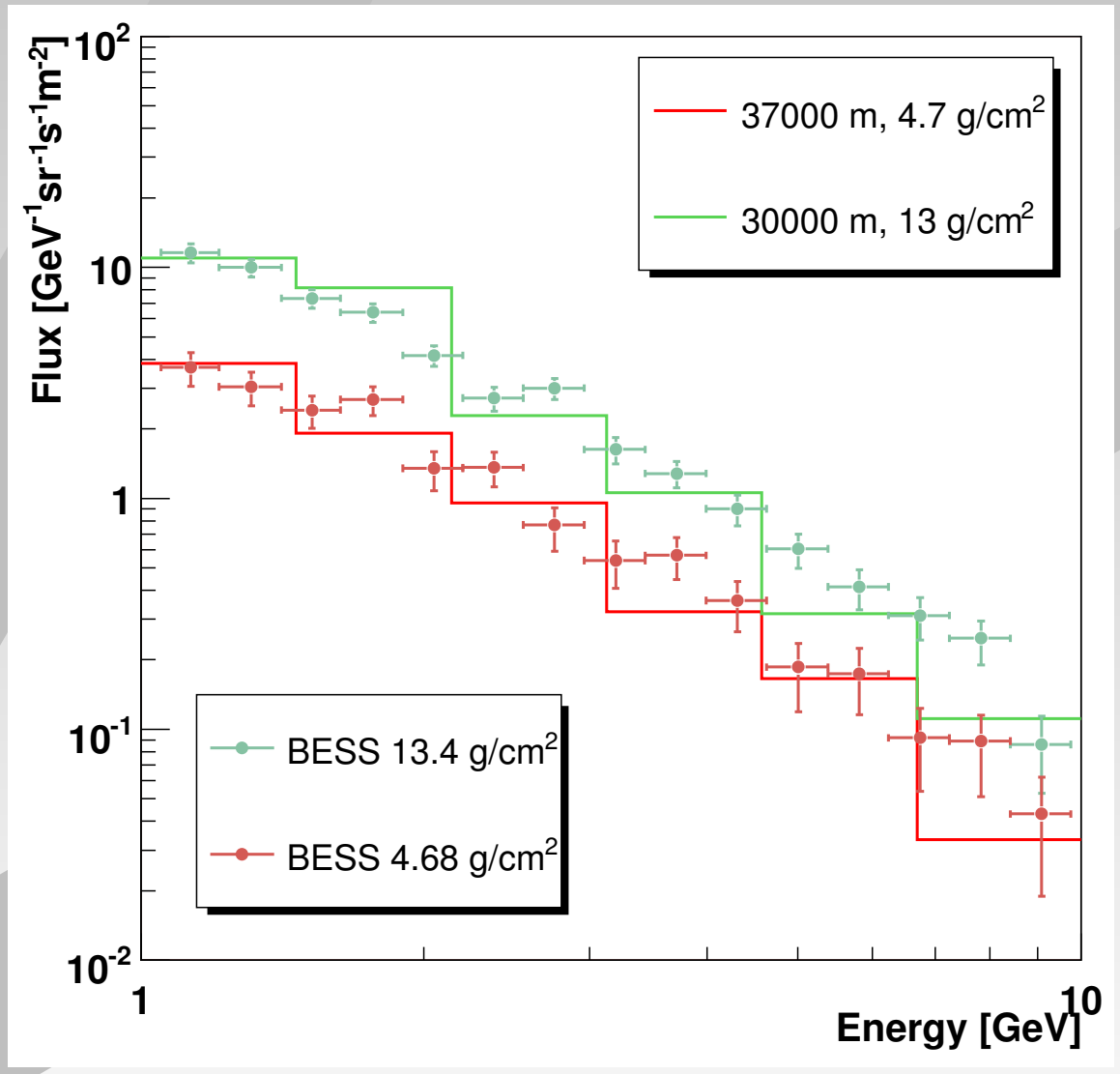
- input spectra fluxes: conventional Galprop model (tuned in the lower energy region) (galdef 500180 → astro-ph/0406254)
- particle gun in 500 km altitude produces isotropic distribution in altitudes



Scheme of simulations and analysis



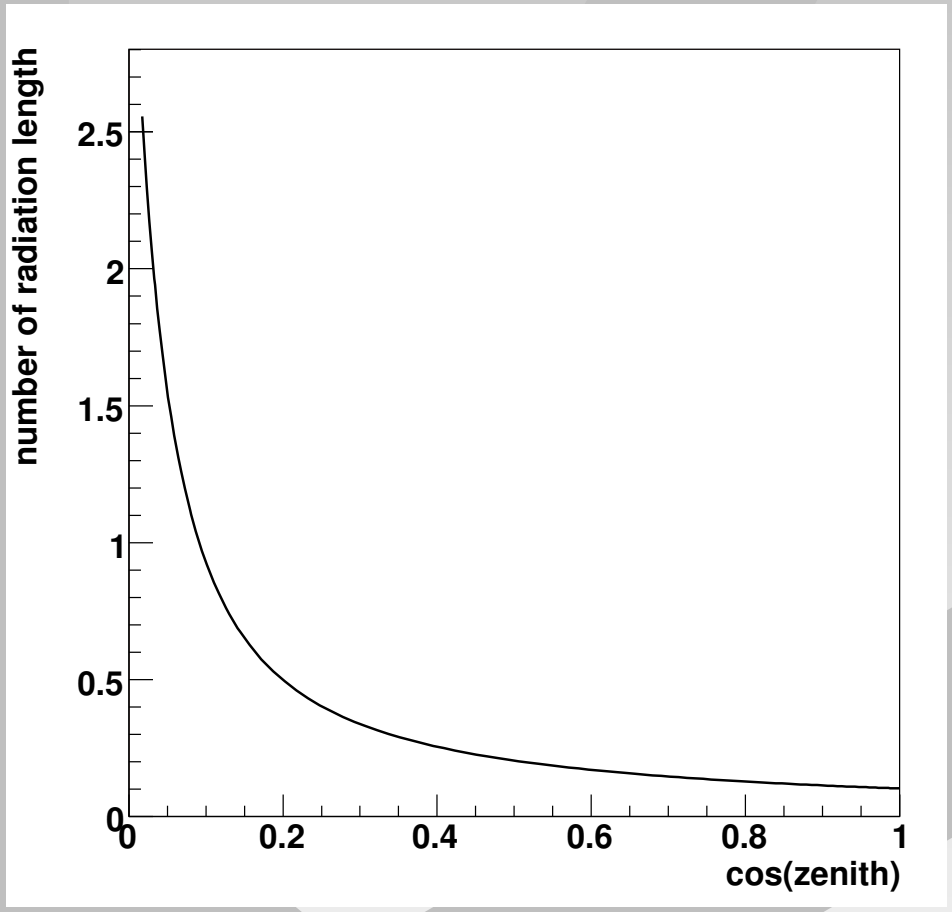
Verification of atmospheric physics model



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

Simulation seems to work within the errors!

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 radiation lengths before 40 km is 39 % for isotropic distribution

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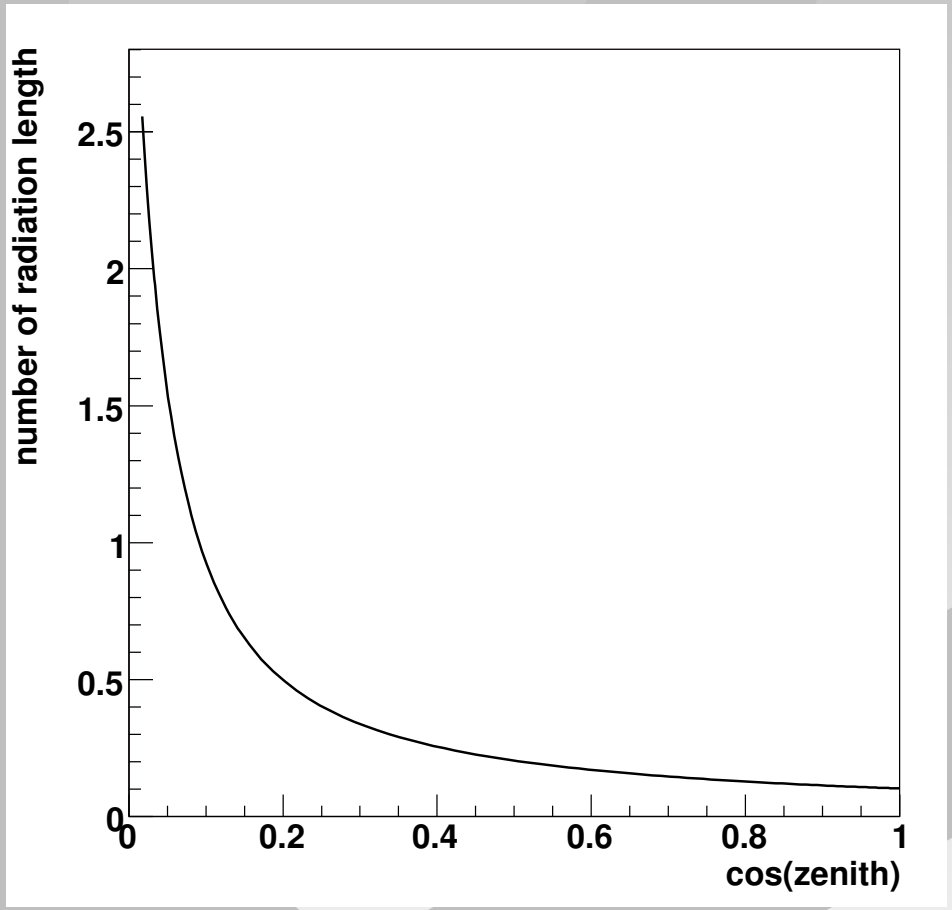

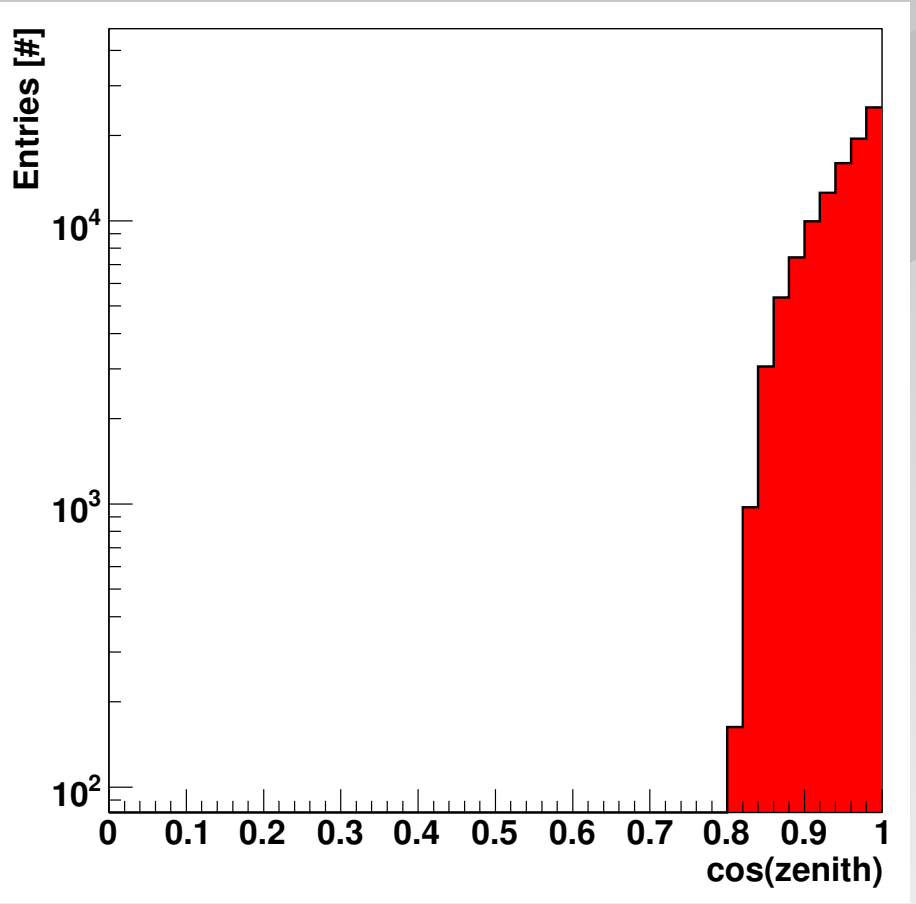

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- ★ mean number of radiation lengths before 40 km is 39 % for isotropic distribution

- ★ **BUT:** upright detector in atmosphere is only sensitive to small zenith angles
  $\Longrightarrow$ mean number of radiation lengths goes down (less secondaries)

Corrections & detector properties

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

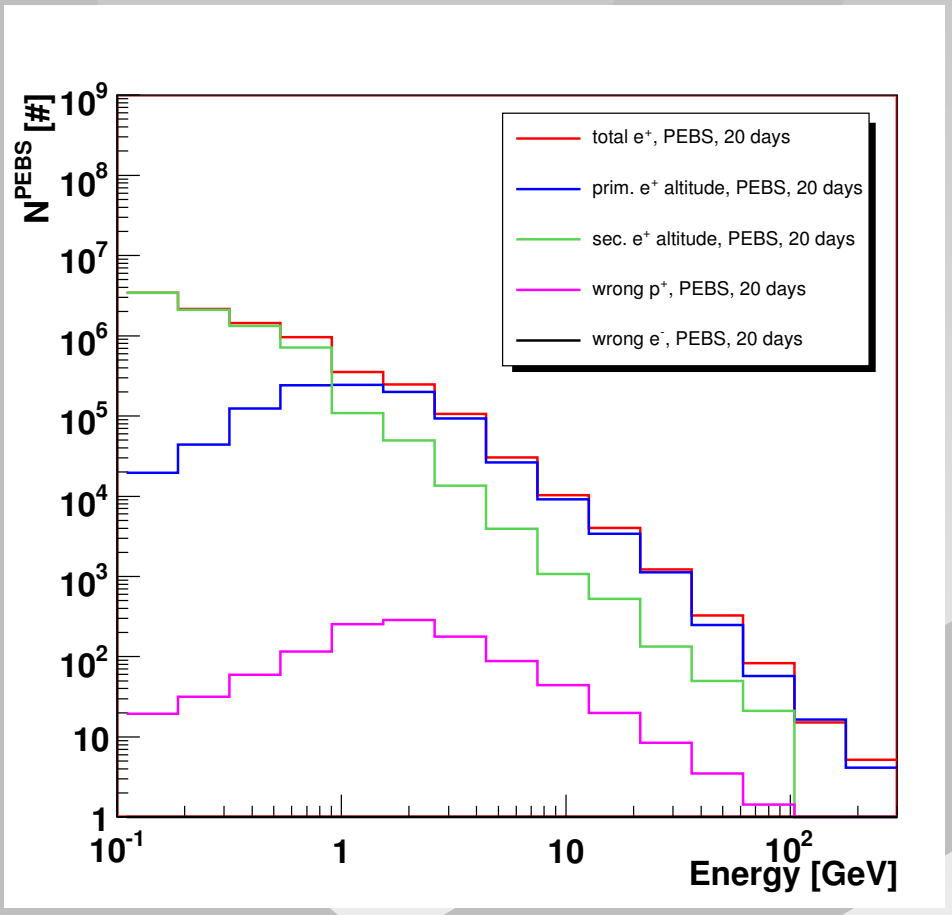
★ **meaning of quantities:**

- **number of particles** (GalProp, PLANETOCOSMICS):
  $N_{e^+}^{\text{PEBS}}$, $N_{e^+}^{\text{prim}}$, $N_{e^+}^{\text{sec}}$, N_p^{tot}, $N_{e^-}^{\text{tot}}$
- **detection efficiency** (detector simulation):
  $\epsilon_{e^+}^{\text{PEBS}} = 50\,\%$
- **proton-positron Rejection** (detector simulation):
  $R_p = 10^6$ for all energies
- **electron-antiproton Rejection** (detector simulation):
  $R_{e^-} = 10^5$ for all energies
  with very high rejection for $E_{\text{kin}} < 1\,\text{GeV}$ (TOF $\rightarrow$ time resolution)
- **loss of particles in atmosphere** (PLANETOCOSMICS):
  $\epsilon_{e^+}^{\text{atmo}}$ energy dependent
- **tracker misidentification** (detector simulation):
  $\epsilon_{e^- \to e^+}^{\text{PEBS}}$ from $\sigma_p = \frac{0.14\,\%}{\text{GeV}} p \oplus 2\,\%$

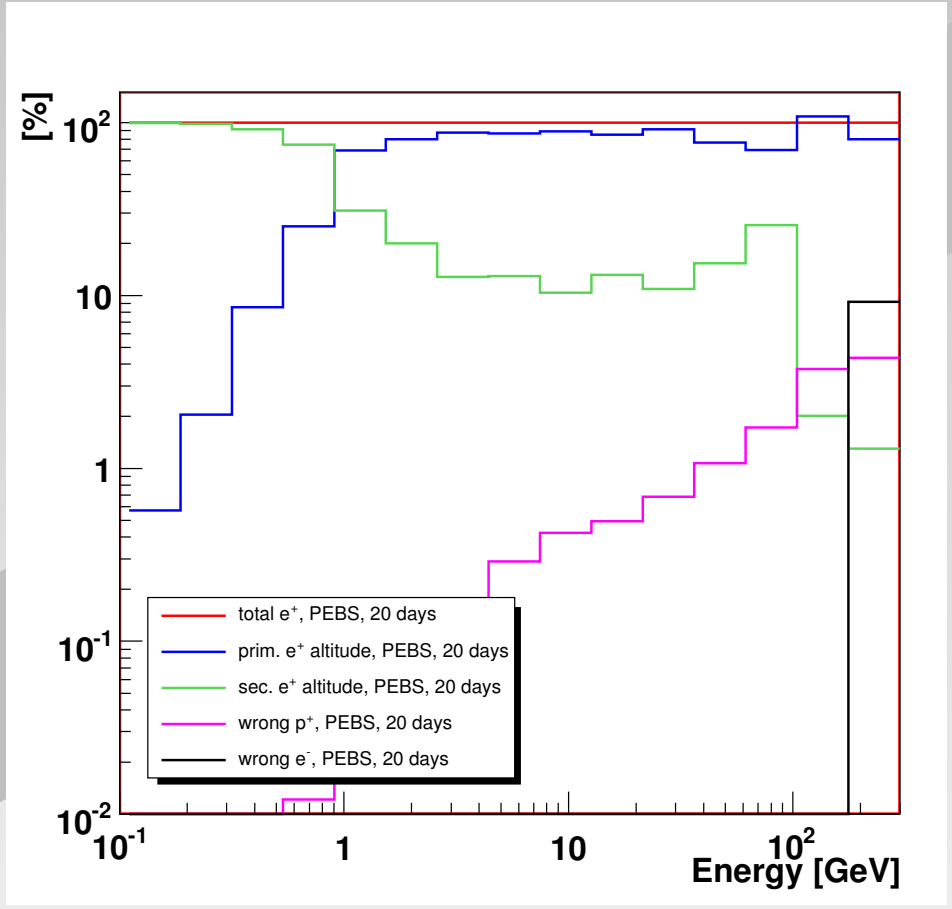
★ **error estimates:**

- statistical errors: $\sqrt{N_{\cdots}}$
- systematic errors for atmospheric physics: 10 %
- systematic errors for detector properties: 3 %

Positrons



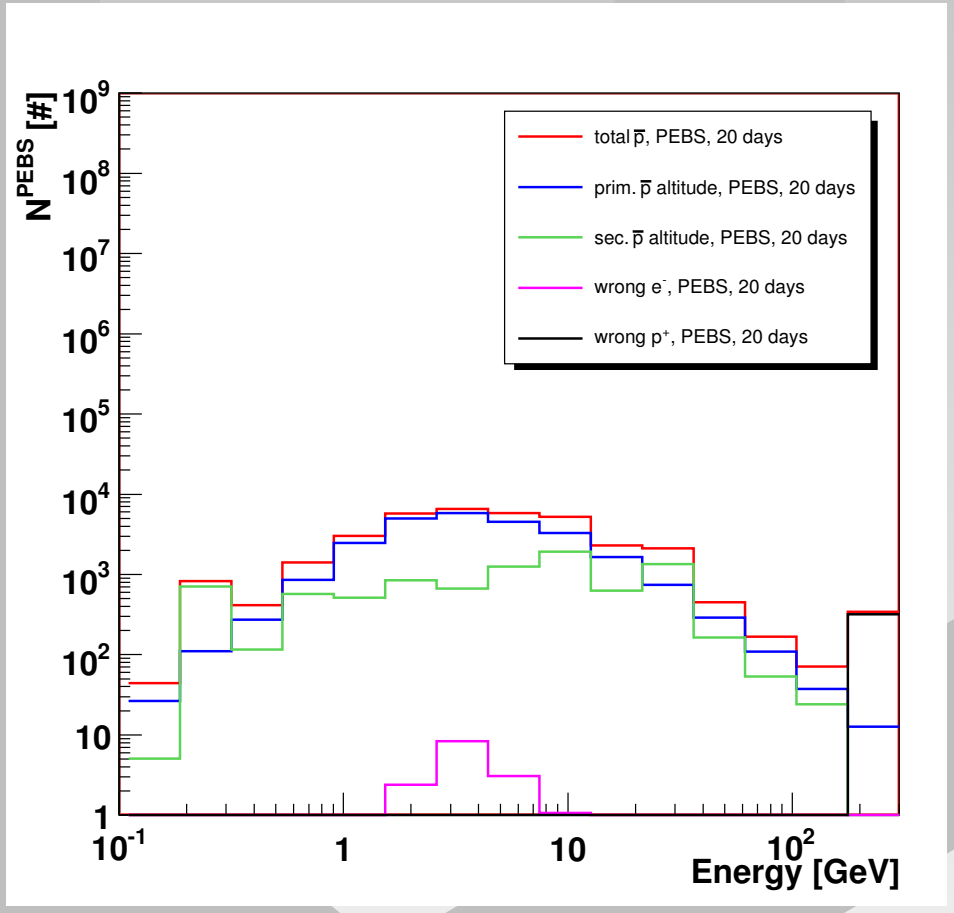
flux composition of simulated positron flux in 40 km



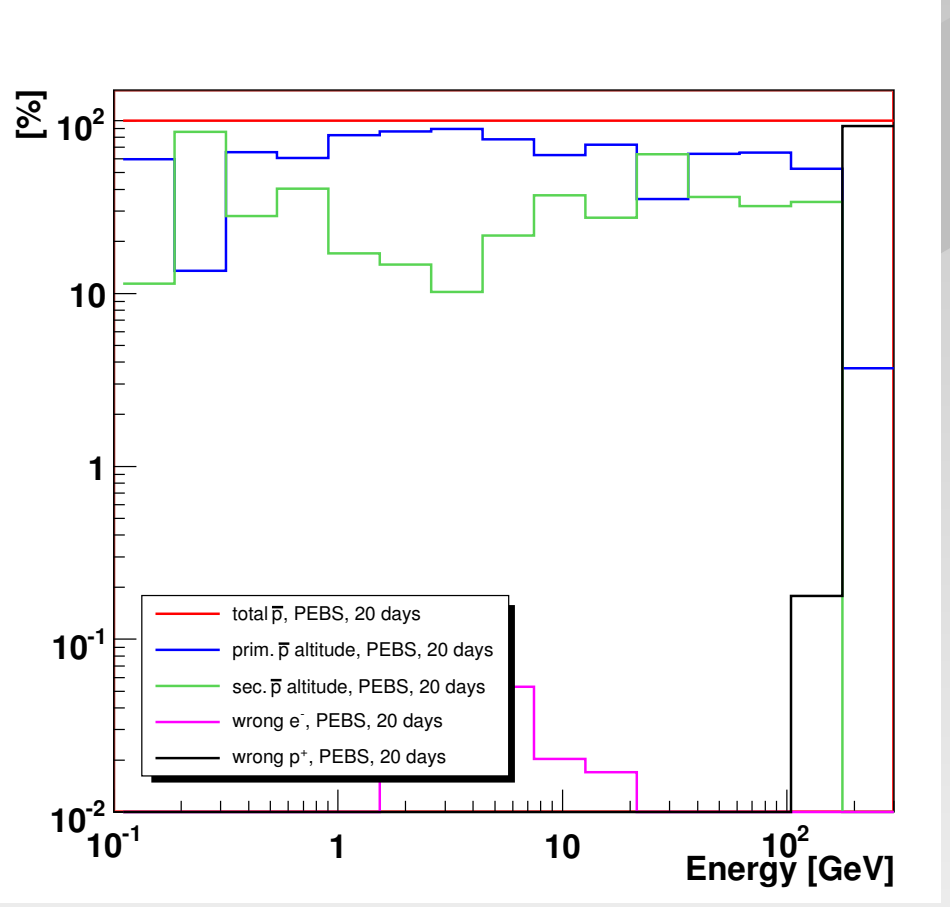
composition of simulated positron flux in 40 km

altitude	=	40 km
acceptance	=	0.25 m^2sr
time	=	20 days
solar Modulation Φ	=	750 MV

Antiprotons



flux composition of simulated antiproton flux in 40 km



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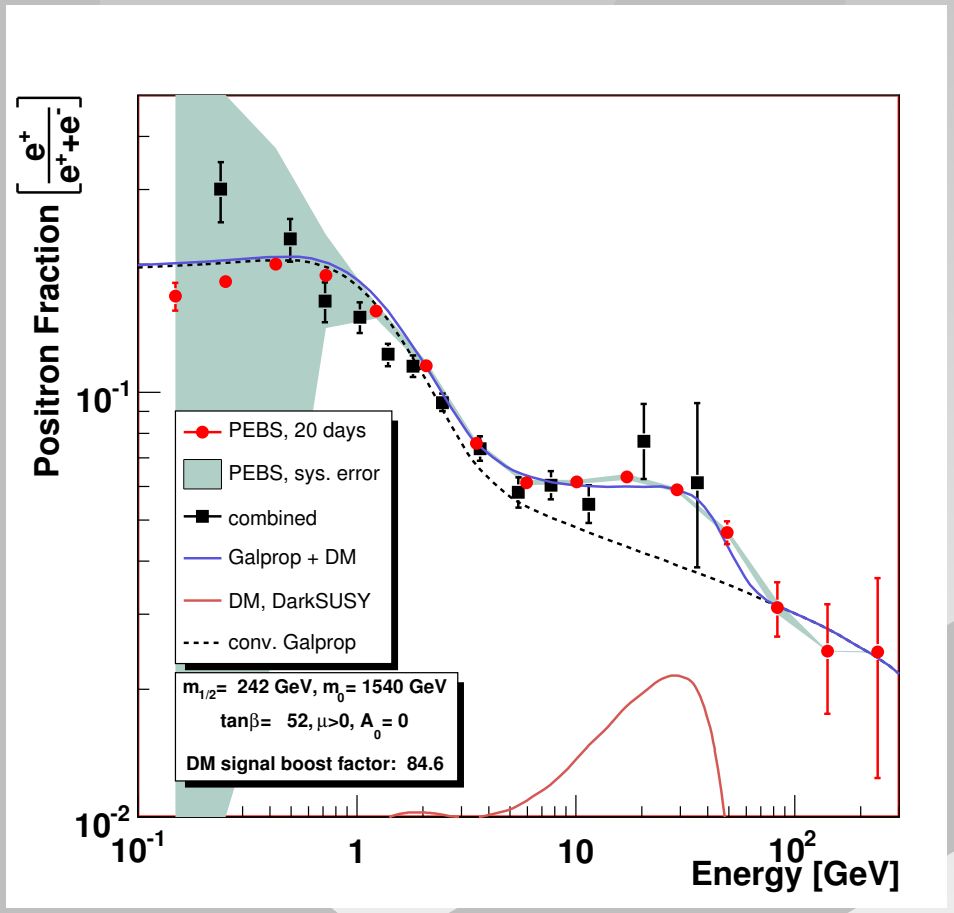
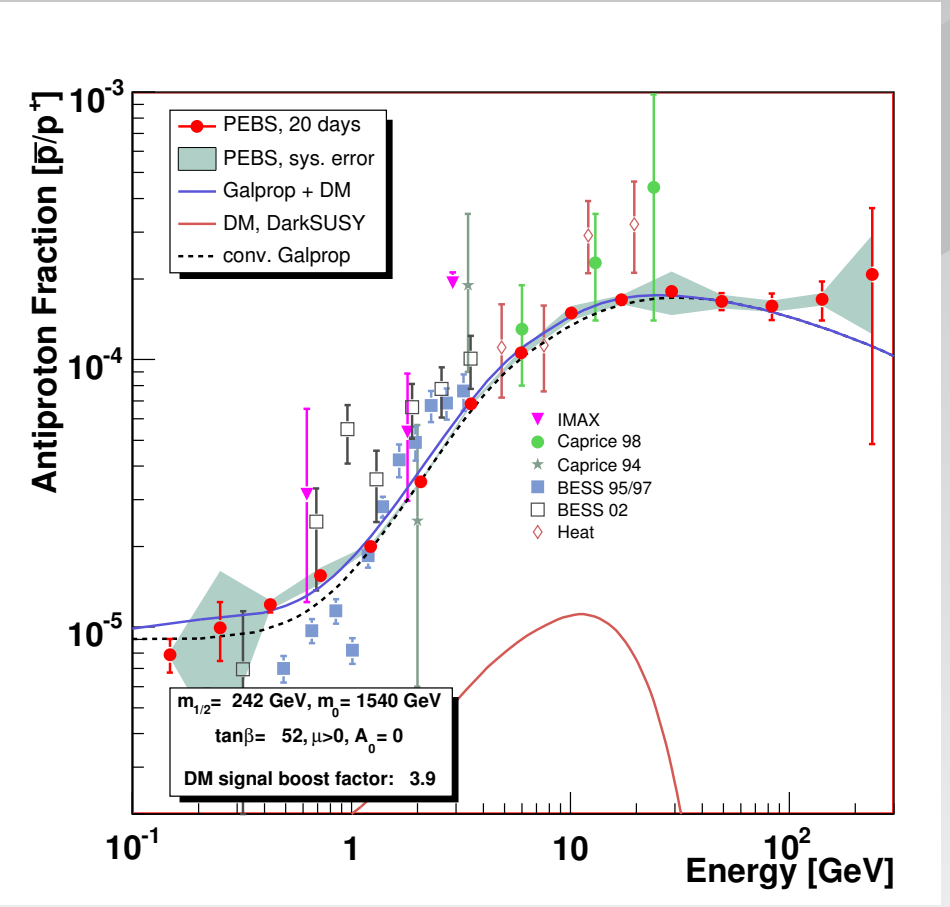
Fractions (lower sys. errors!) : $e^+/(e^+ + e^-)$ & $\bar{p}/p$



Positron fraction (50 % detector eff.)



Antiproton fraction (50 % detector eff.)

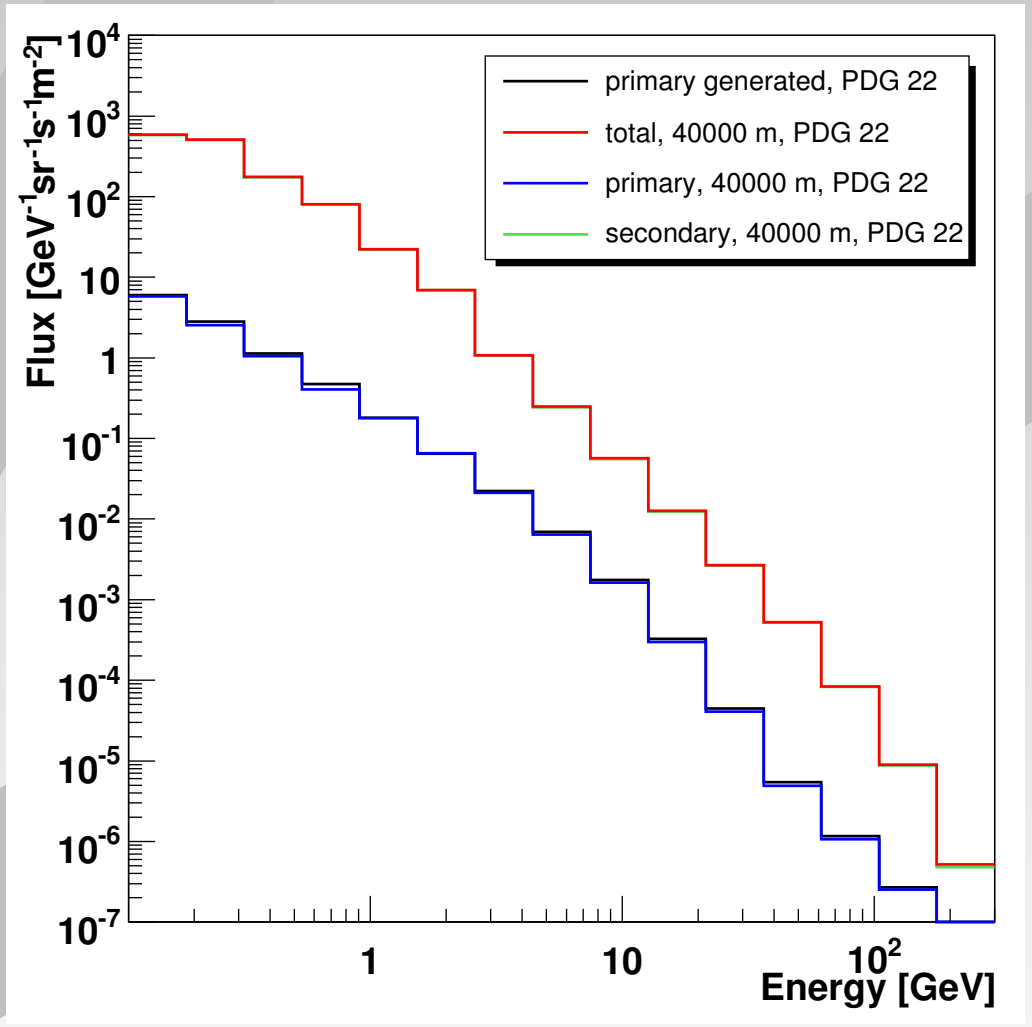
altitude = 40 km

acceptance = 0.25 m^2sr

time = 20 days

solar Modulation Φ = 750 MV

Photon fluxes in 40 km



★ 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 cosmic ray measurement on the South Pole in 40 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

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What should be done:

- ★ study the detecabilty of heavy ions to measure e.g. B/C ratio
- ★ develope a simulation for a better estimation of solar modulation
- ★ study a better implementation of high energetic alphas in GEANT4?