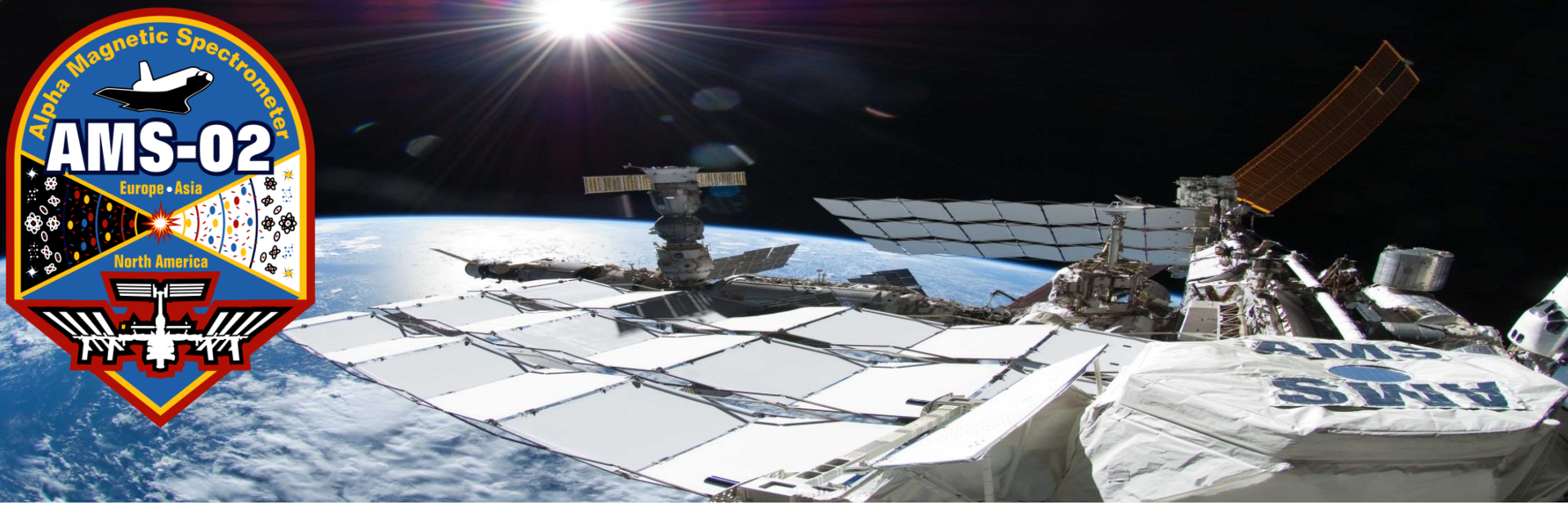


Cosmic Ray Positron Fraction and Lepton Fluxes With AMS-02

Li TAO

AMS - LAPP

Enigmass
The enigma of mass

Enigmass @ LAPP
November 2014

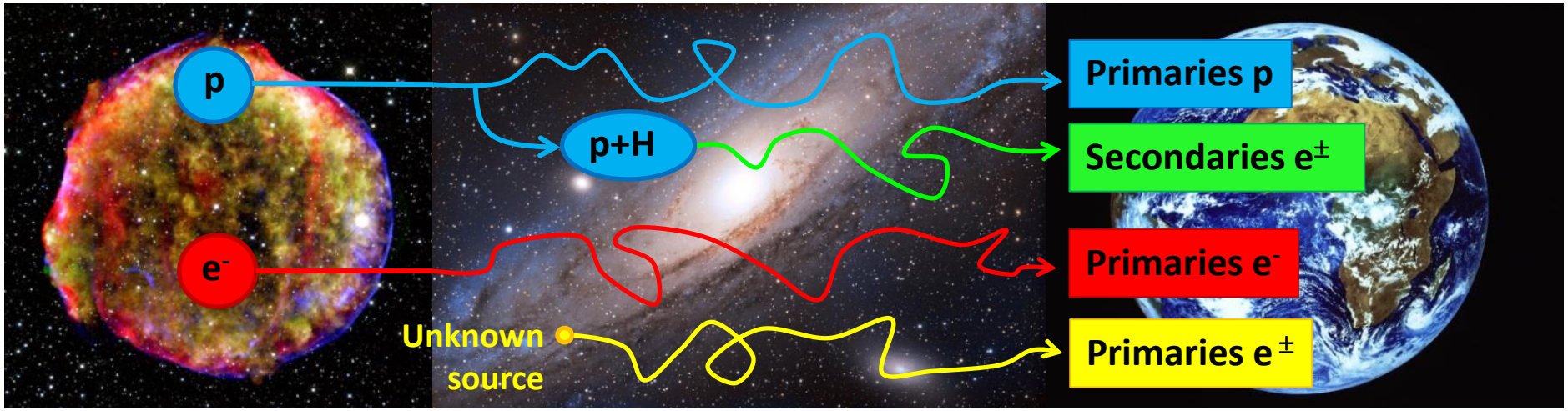
lapp

Life of cosmic ray particles

Production and acceleration:
e^-, p, He, C

Propagation and interaction :
e^+, $\bar{p}$, B…

Observation



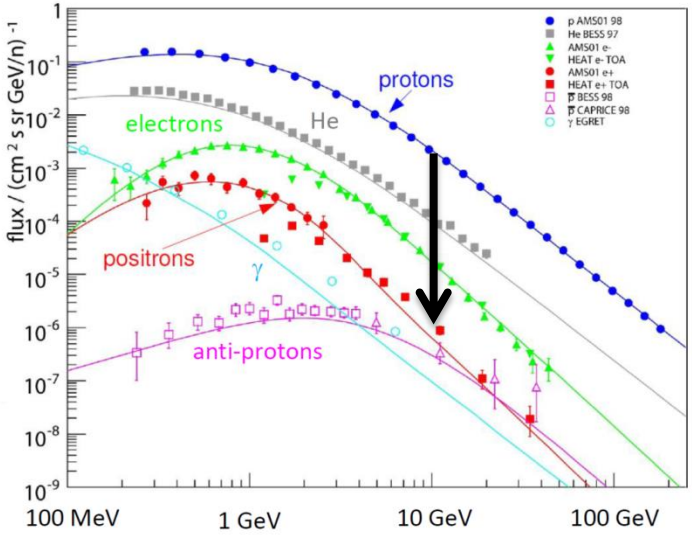
Injection power law
$\Phi \propto E^{-\gamma}, \gamma \sim 2$

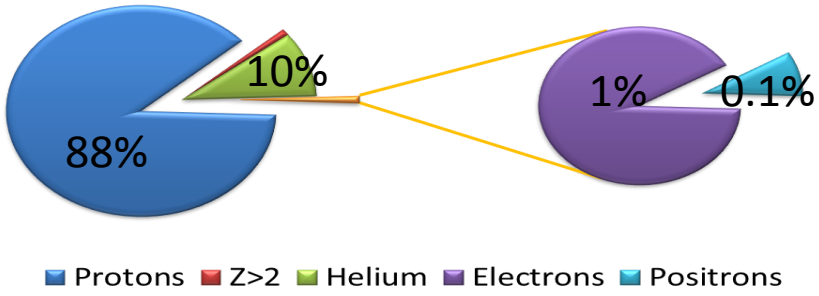
Secondaries

- **Solar modulation**
- **Geomagnetic field**
- **Atmosphere**

Goals of AMS

- **Measure cosmic rays in the space (ISS)**
  - Indirect search of evidence of **dark matter** and primordial **antimatter**
  - Refinement of the **propagation** models
  - Indentification of astrophysical **sources**



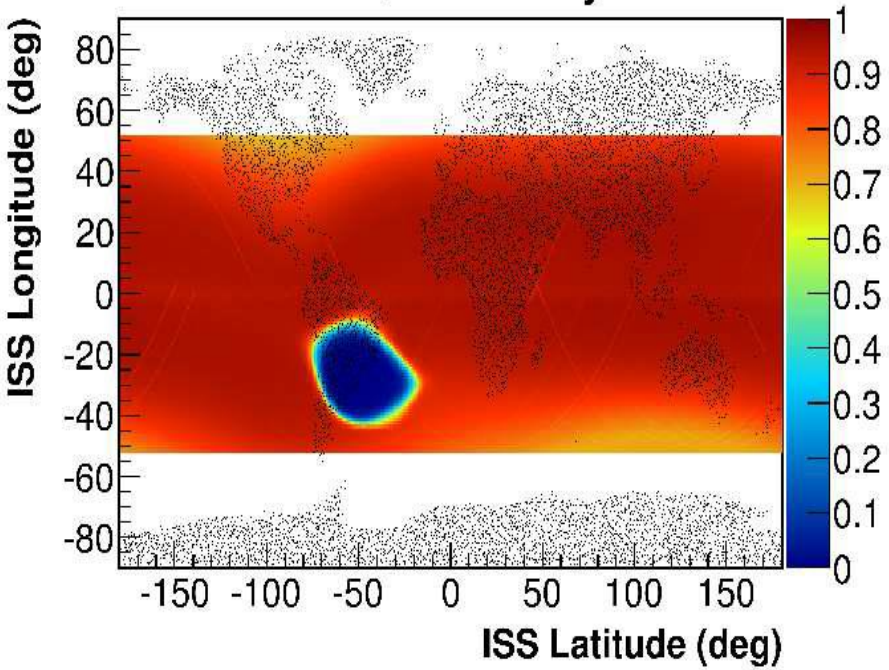


- Challenges for positron measurement:
  - Statistical precision at high energy
  - proton rejection power greater than 10^5
  - Good control of charge confusion

DAQ Since May 2011

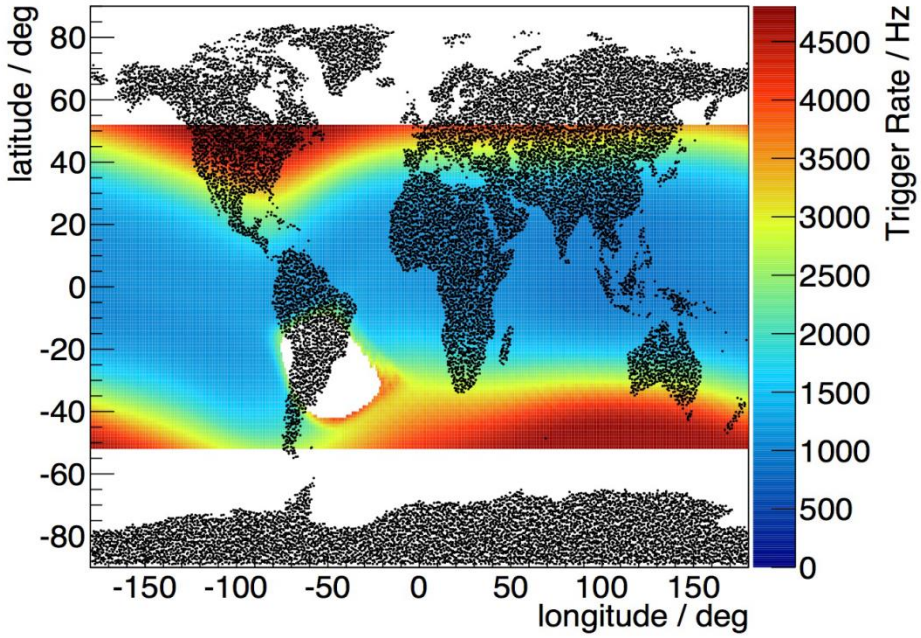
More than 50 billion events have been collected in the past 3 years.

DAQ efficiency



DAQ efficiency reaches 90% (South Atlantic Anomaly excluded)

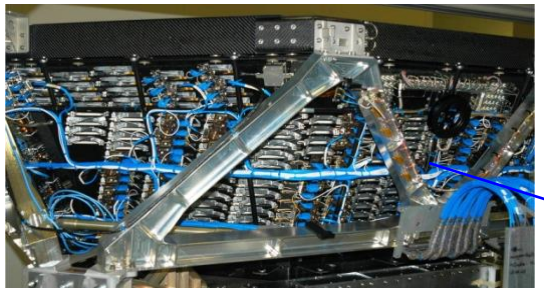
Trigger Rate (Hz)



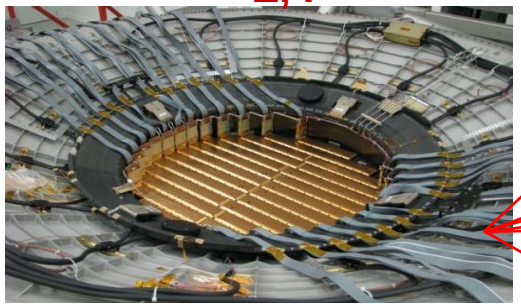
The trigger rates vary from 200 to 2000 Hz per orbit

Overview of the AMS detector

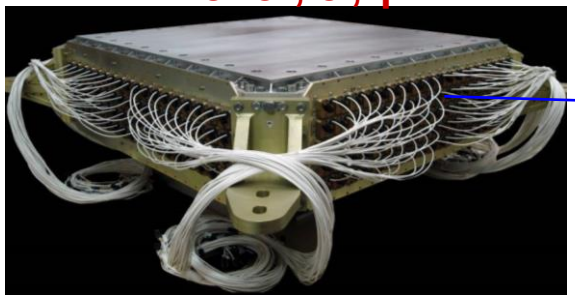
Transition radiation detector
Identify e^+, e^-

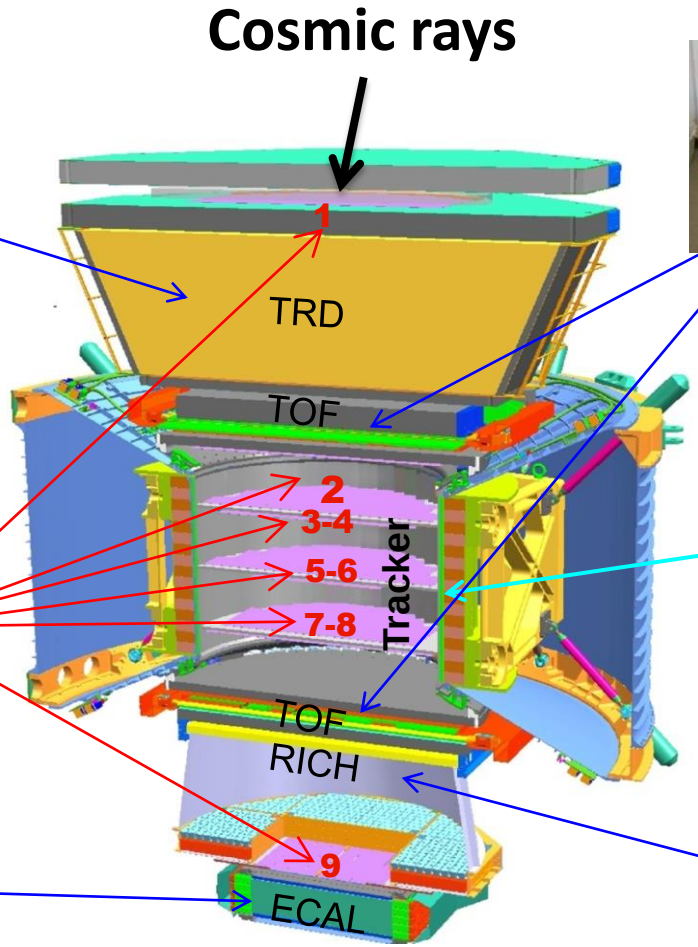


Silicon tracker
Z, P



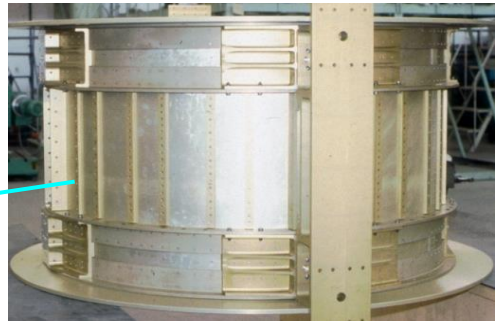
EM calorimeter
E of e^+, e^-, γ



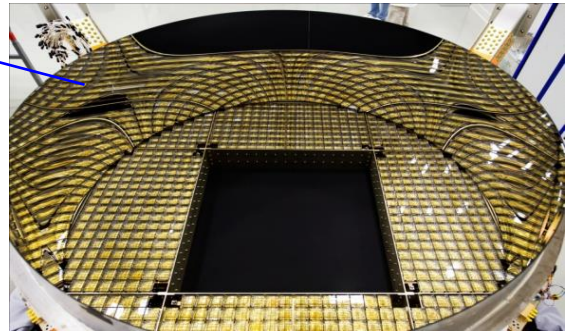


Time of flight
Z, E, trigger

Magnet 0.14 T
±Z



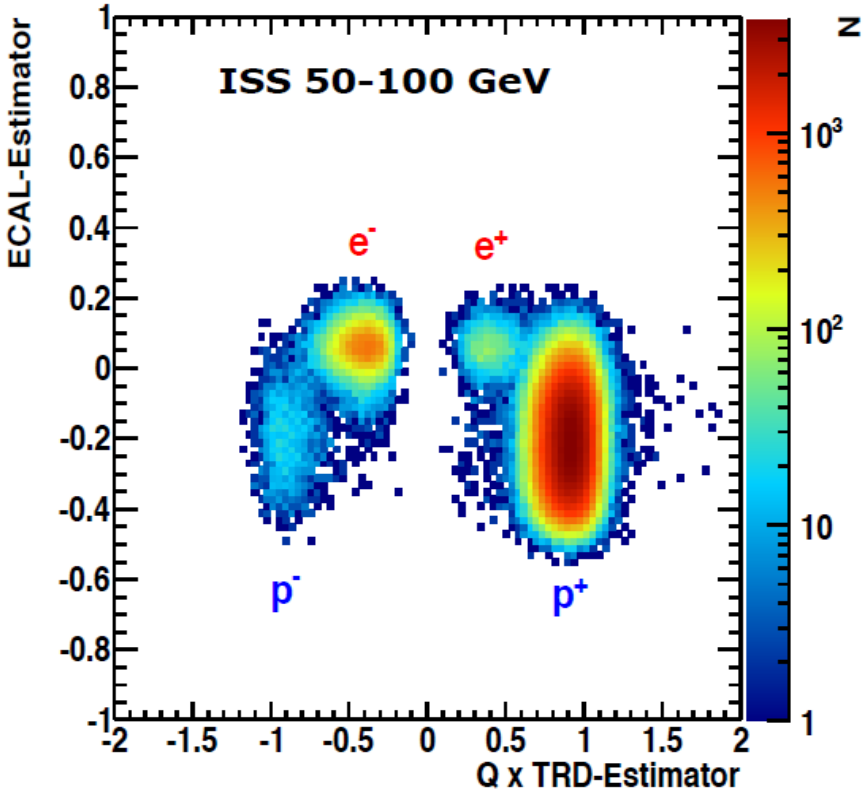
Ring Imaging Cherenkov
Z, E



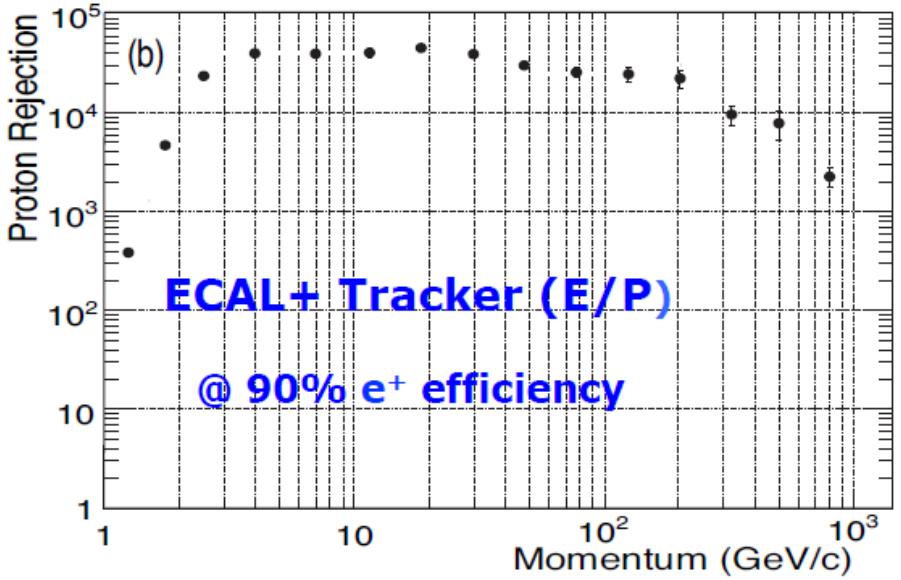
Proton Rejection

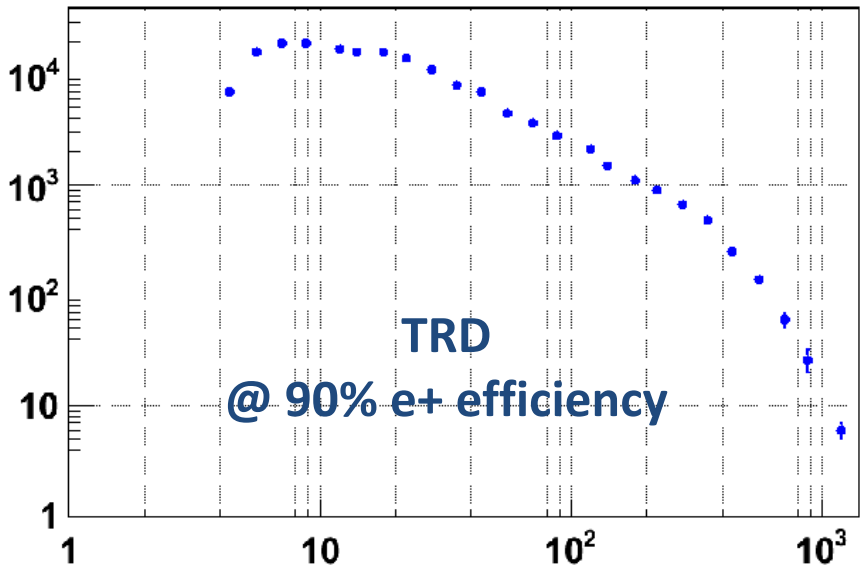
Ecal estimator: Boosted Decision Tree using 3D shower features

(Developped by L.Basara at LAPP)



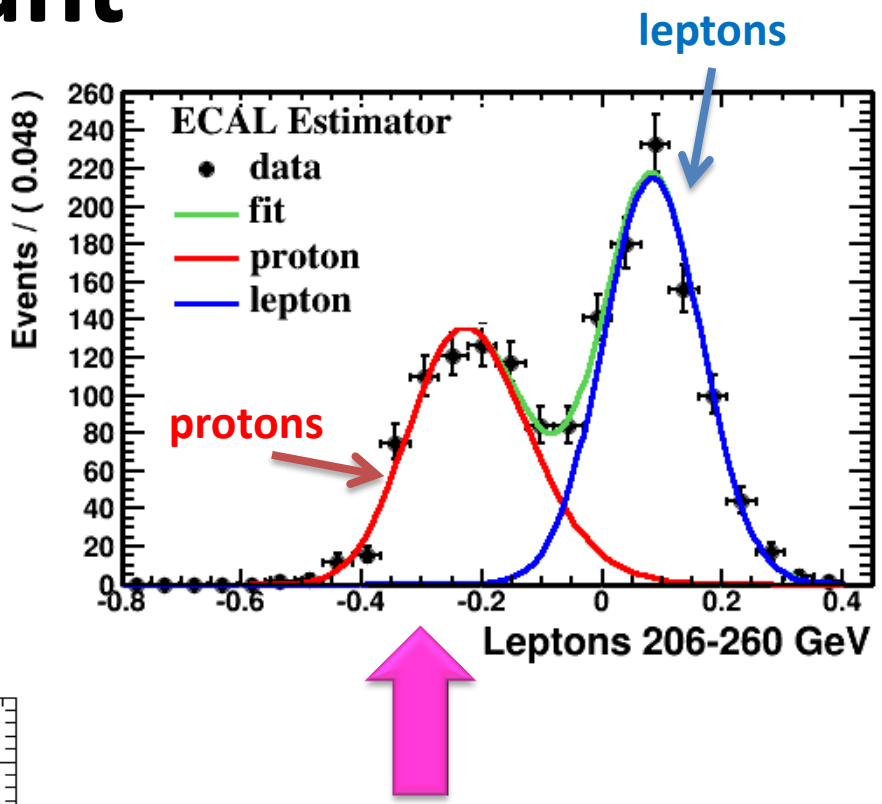
TRD estimator: likelihood based on the signal amplitude in each layer (20 in total)



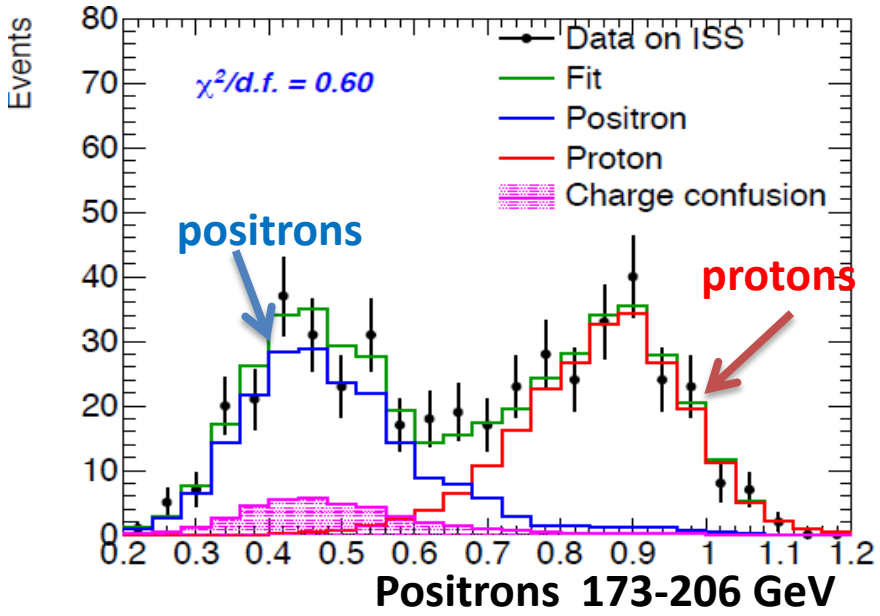


Positron number count

- Number of leptons and positrons extracted from fitting data with electron and proton templates
- Templates obtained from data
- Electron and proton templates well separated using ECAL and TRD estimators



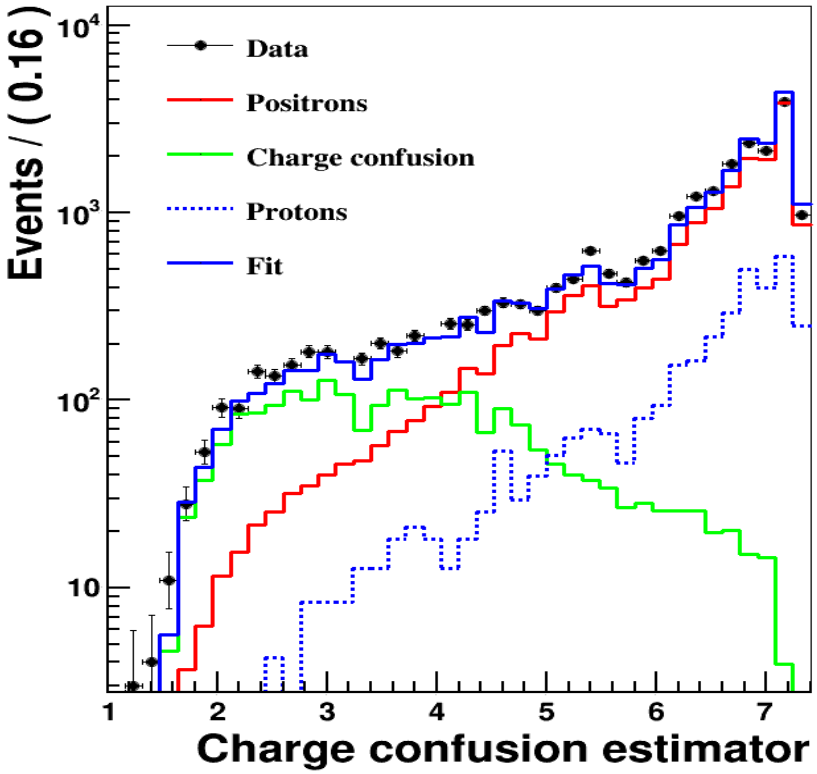
ECAL estimator fit
Lepton sample



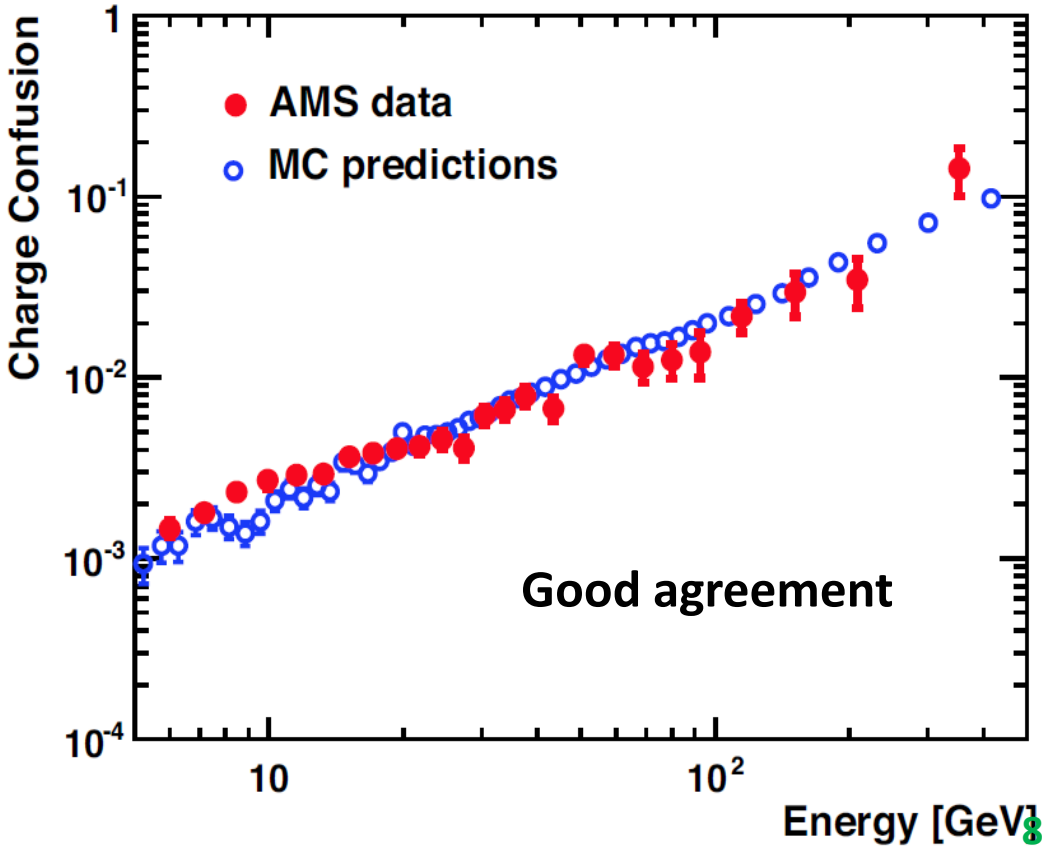
TRD estimator fit
Positron sample

Charge Confusion

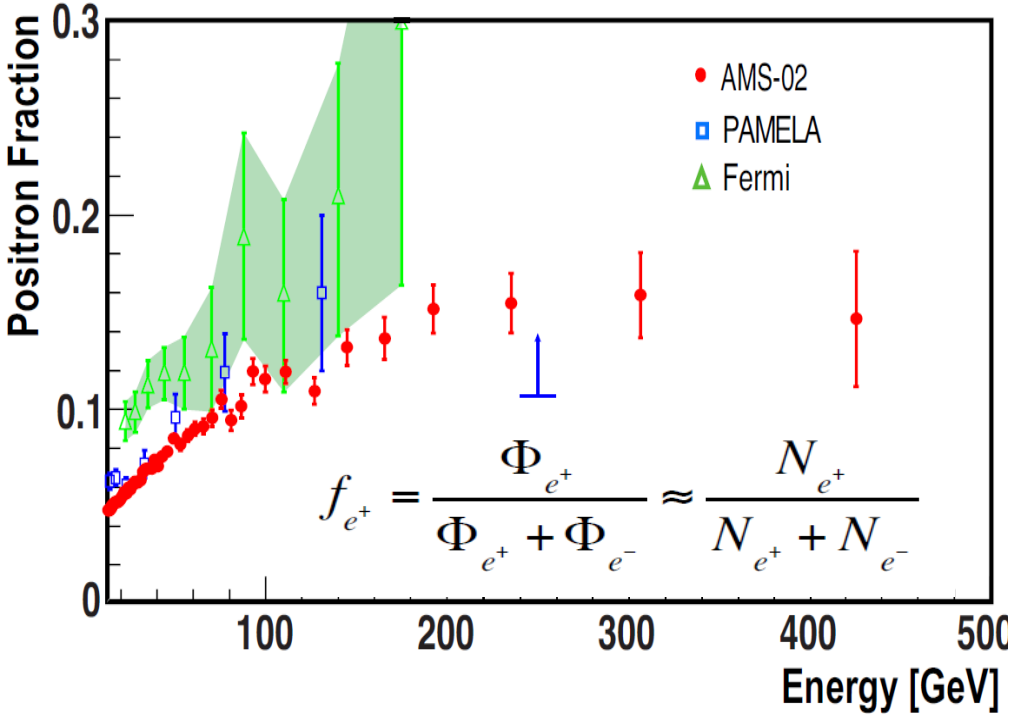
- Estimator (**BDT**) developped using tracker information
  - Other estimators such as $\text{Energy}_{\text{ECAL}}/\text{Momentum}_{\text{Tracker}}$
- Charge confusion obtained by simultaneously fitting with electron/proton estimator

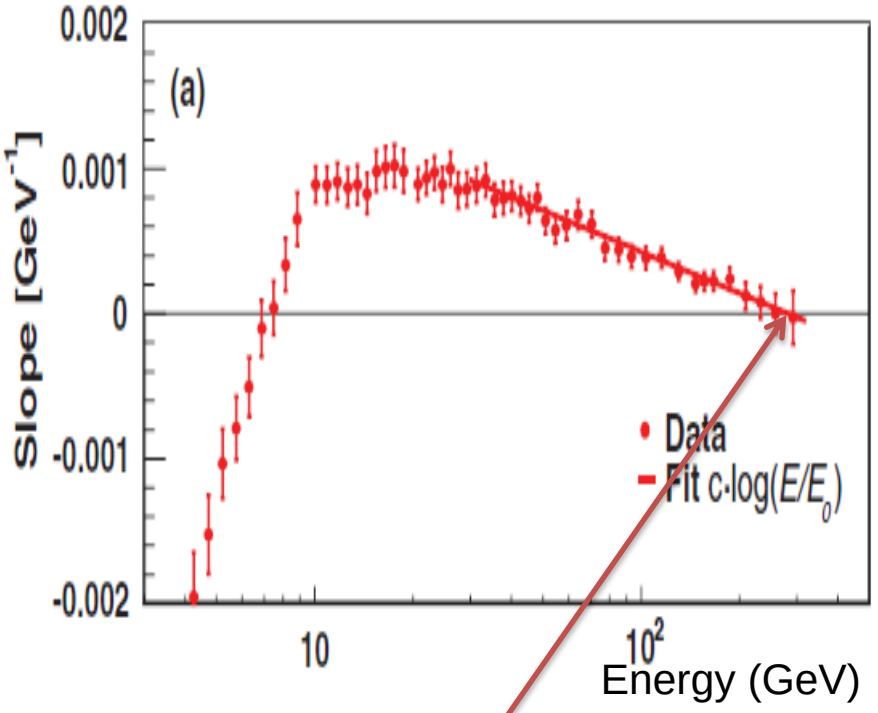


AMS note 2014-11-01



Positron Fraction (PRL 2014)

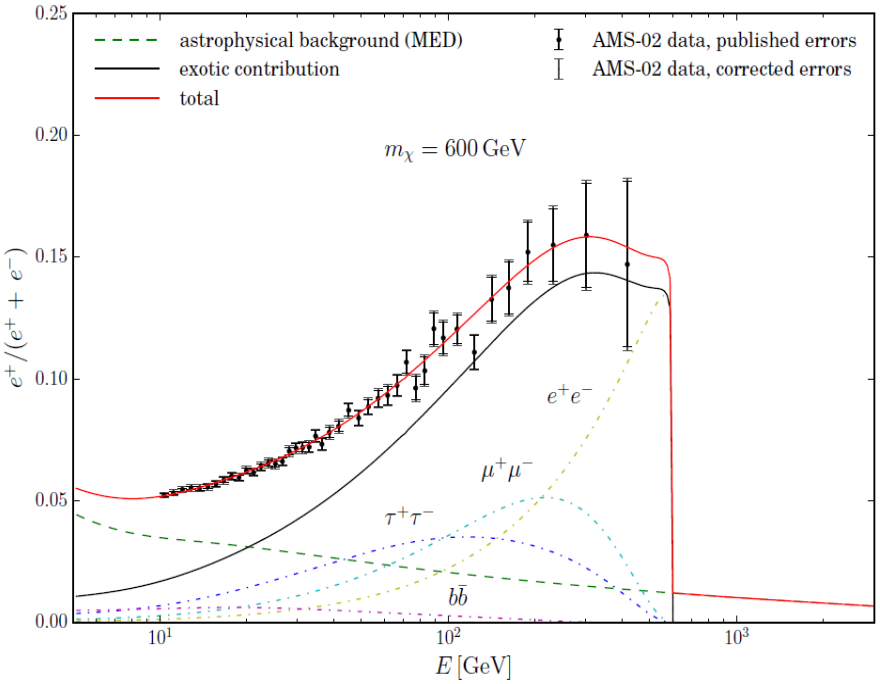




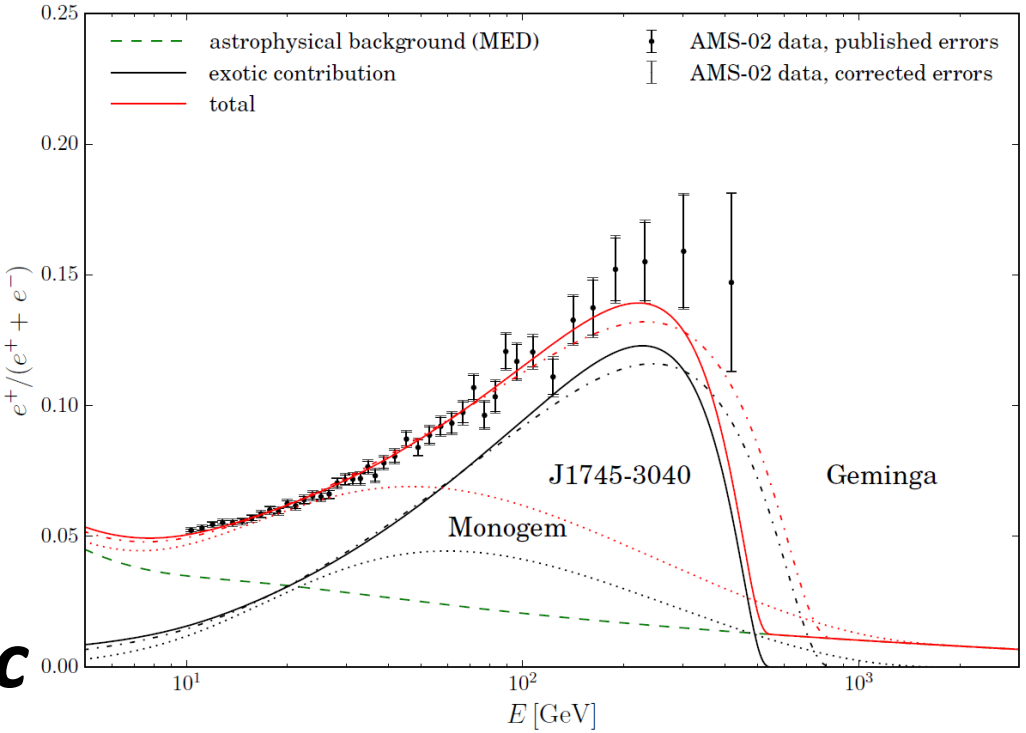
- Compared to PRL result 2013
  - Energy extended to 500 GeV
  - Improved accuracy
- 72 positrons for 350-500 GeV: $\sigma_{stat.}$ 0.028, $\sigma_{syst.}$ 0.019

275±32 GeV:
the positron fraction ceases to increase with energy

Cosmic Ray Alpine Collaboration



Dark matter



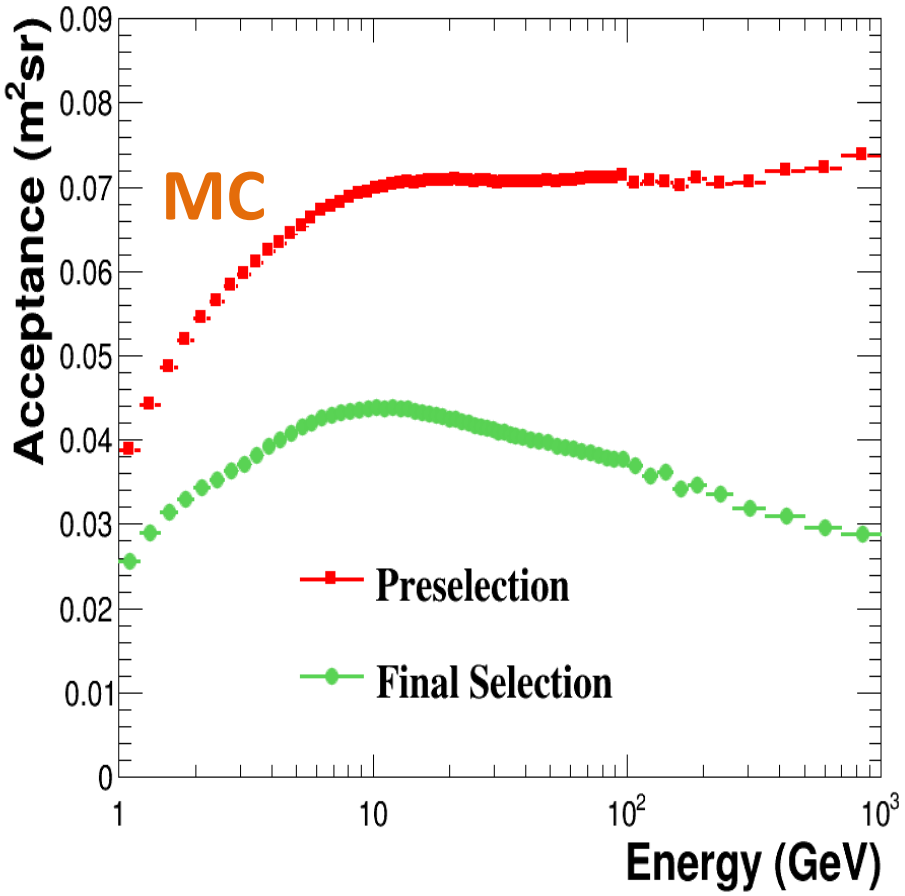
Single pulsar

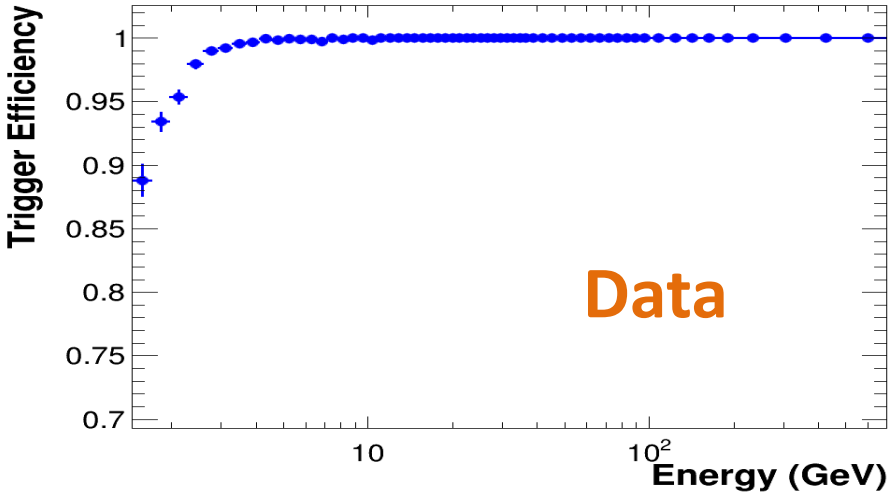
A new look at the cosmic ray positron fraction

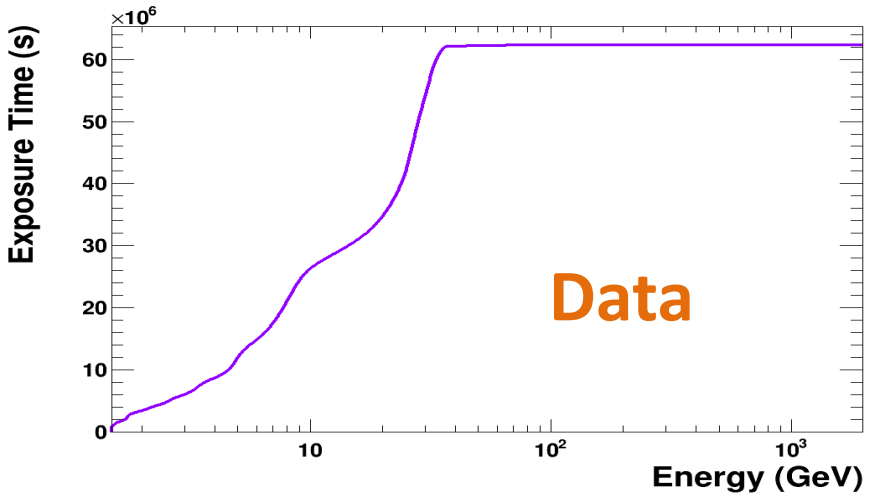
arXiv:1410.3799 [astro-ph.HE]

Flux Measurement Procedure

Isotropic flux: $\Phi(E, E+\Delta E) = \dfrac{N_{signal}}{A_{geo} * \varepsilon_{sel.} * \varepsilon_{trig.} * T_{expo}(E) * \Delta E}$

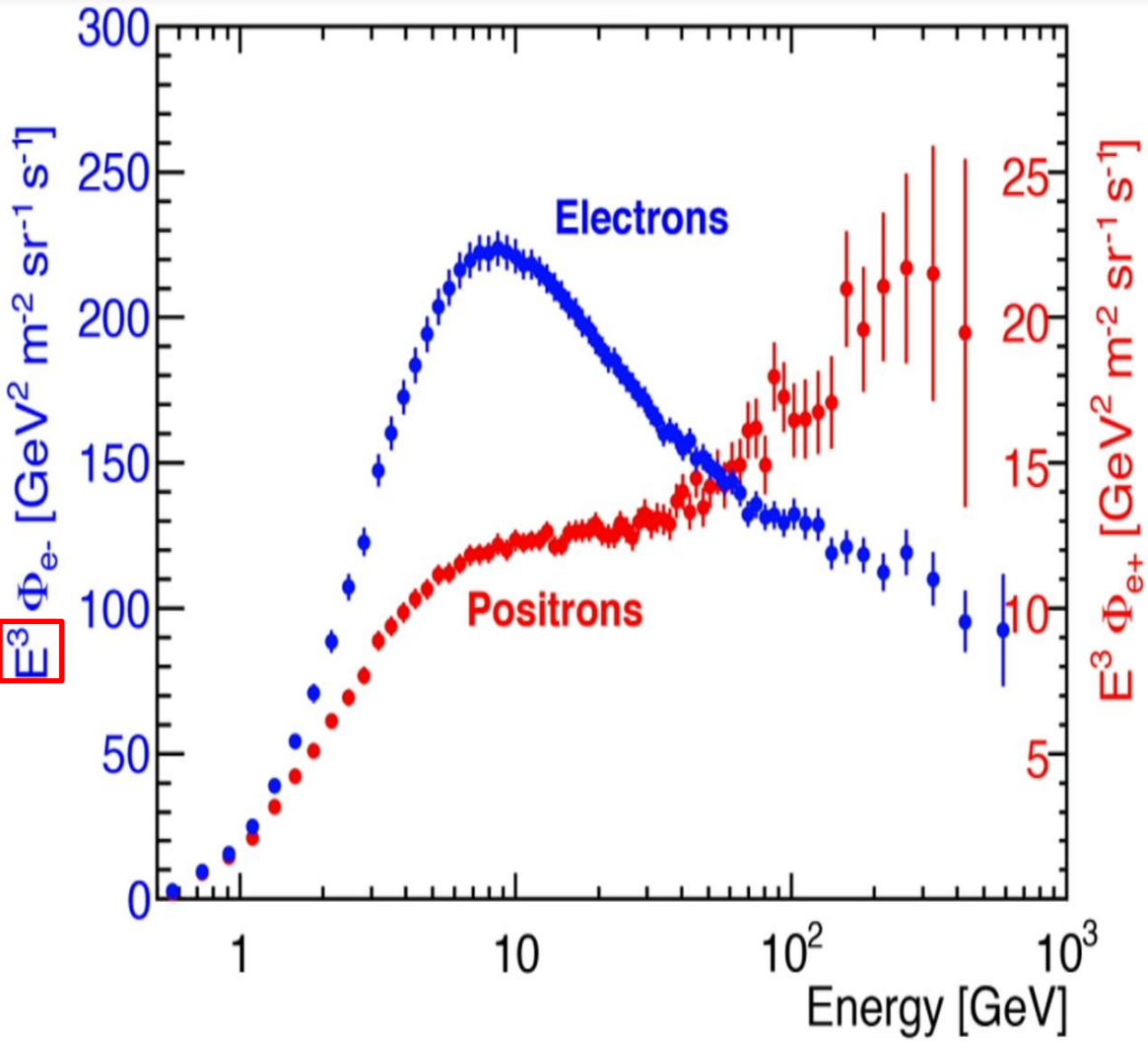


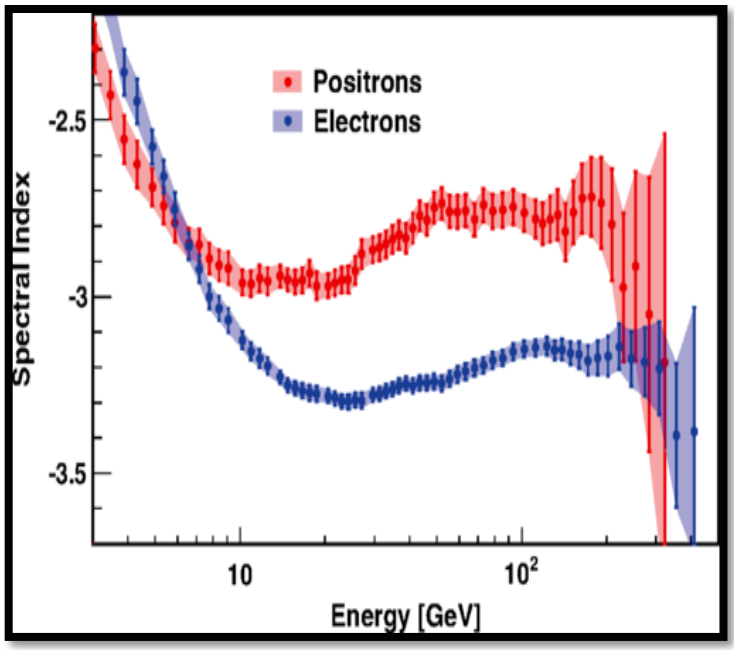




Electron and positron fluxes (PRL 2014)

Different scales for electrons and positrons

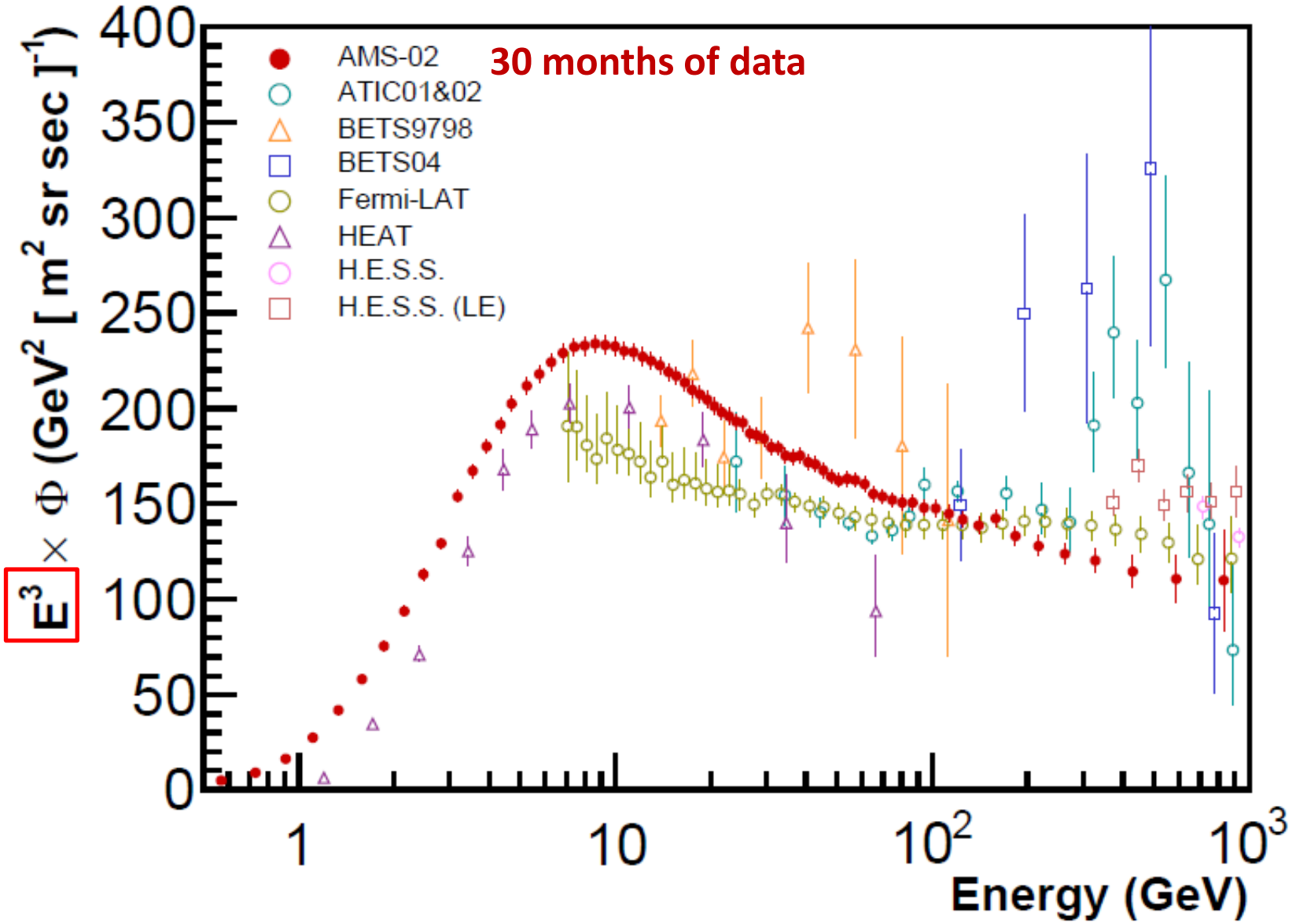




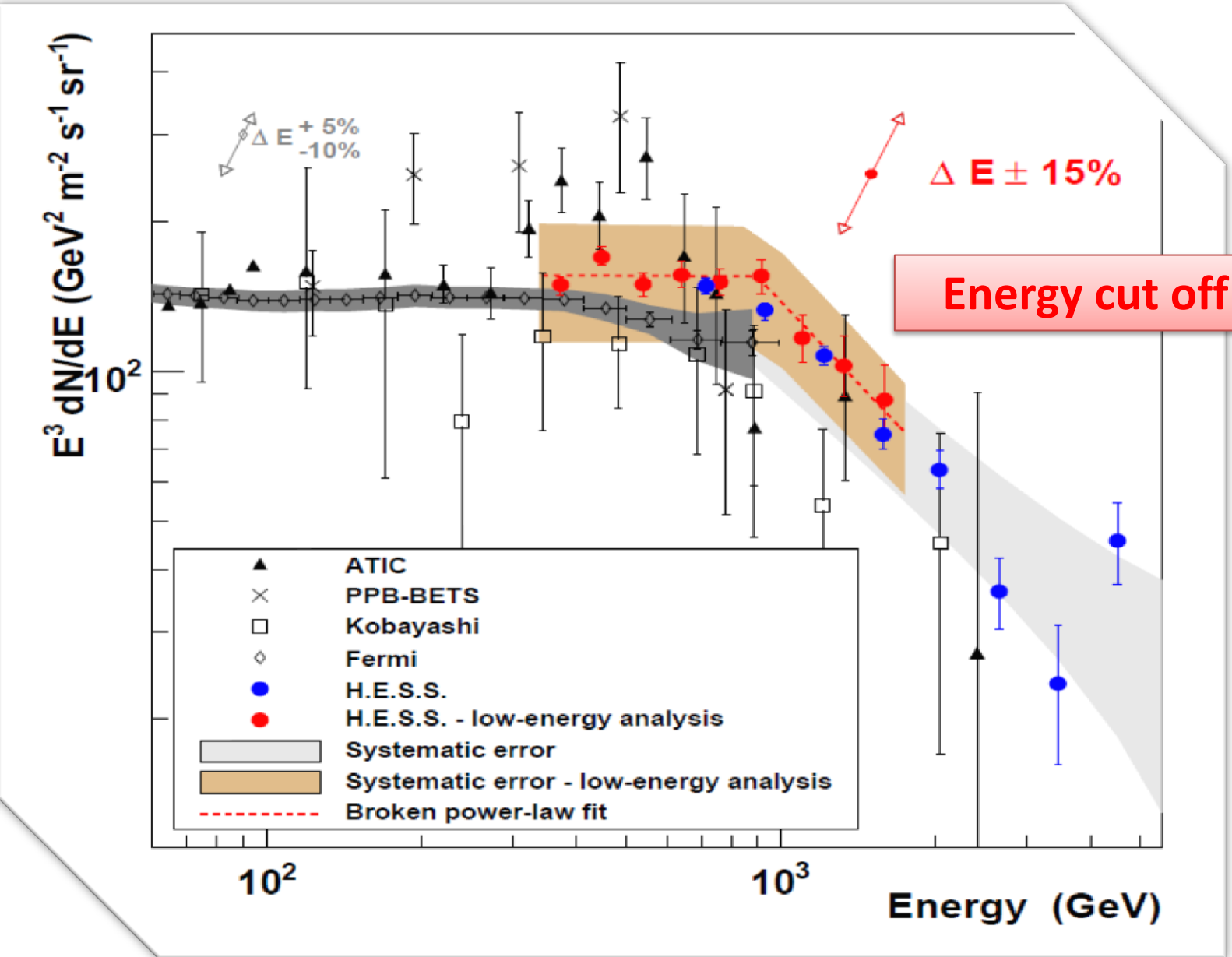
$$\Phi_{e^\pm}(E) = C_{e^\pm} E^{\gamma_{e^\pm}}$$

Different spectral indices for electrons and positrons

Combined $e^+ + e^-$ Flux (PRL 2014)



Combined flux after 1 TeV



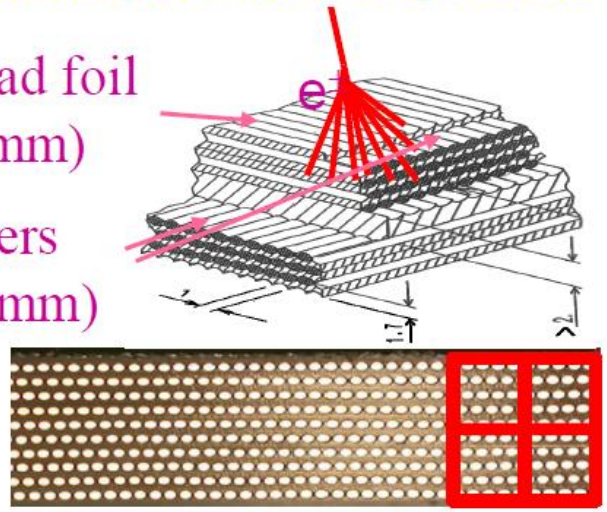
Energy cut off @ 1-2 TeV

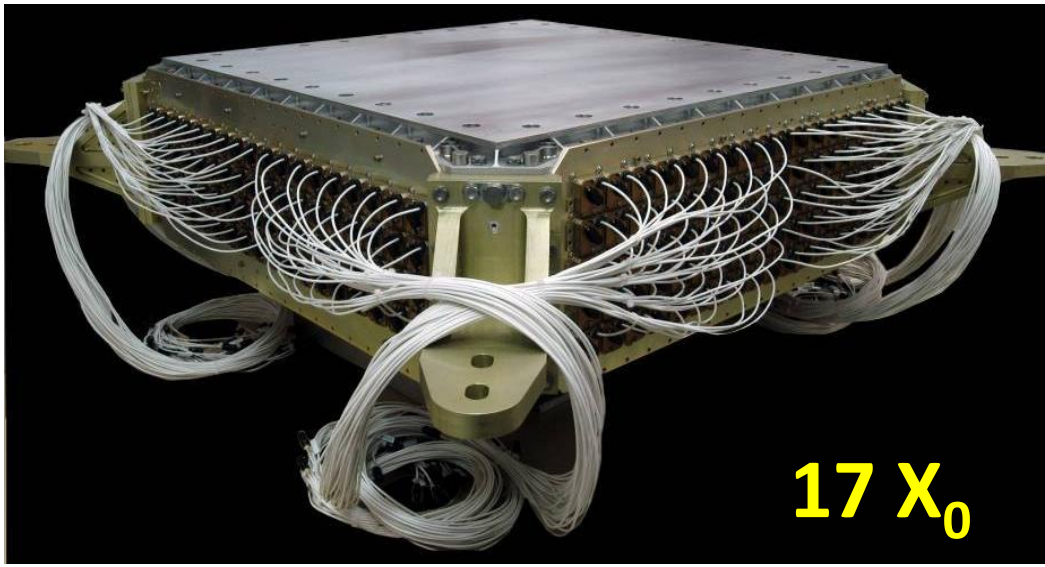
Conclusion

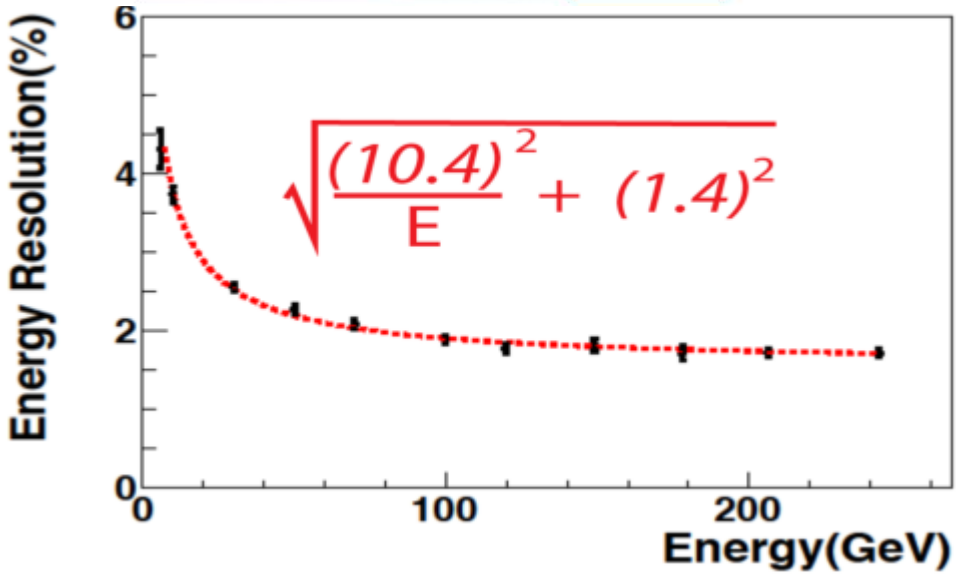
- AMS has been performing smoothly for more than 3 years. 30 months of data have been analyzed.
  - 11 million positrons and electrons collected
- The combination of TRD and ECAL achieves a proton rejection power greater than 10^5.
- Latest AMS results are presented:
  - Positron fraction up to 500 GeV
    - Phys. Rev. Lett. 113, 121101 (2014)
  - Positron flux up to 500 GeV
    - Phys. Rev. Lett. 113, 121102 (2014)
  - Electron flux up to 700 GeV
    - Phys. Rev. Lett. 113, 121102 (2014)
  - Combined positron and electron flux up to 1 TeV
    - Phys.Rev.Lett. 113, 221102 (2014)
- More results are yet to come
  - Protons, helium, antiprotons, Boron/Carbon, etc

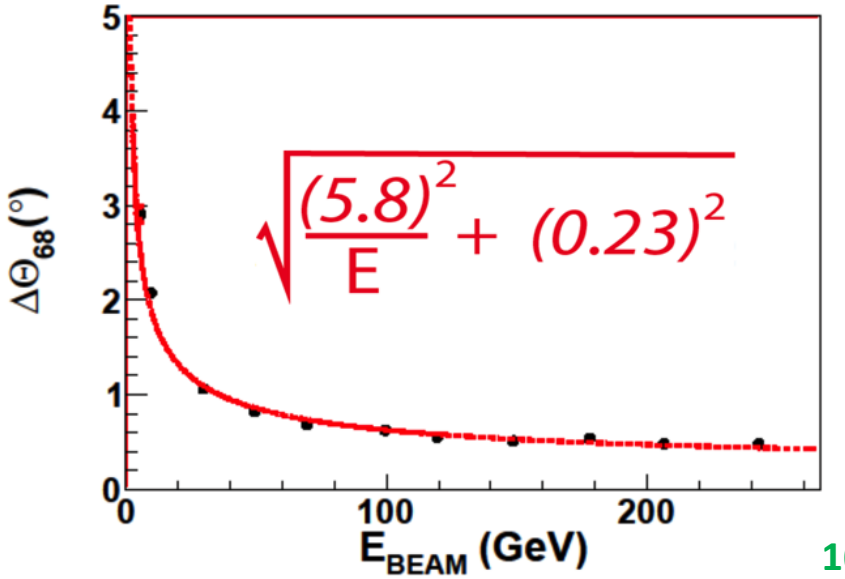
ECAL Resolution

50 000 fibers, $\phi = 1$ mm distributed uniformly Inside 600 kg of lead

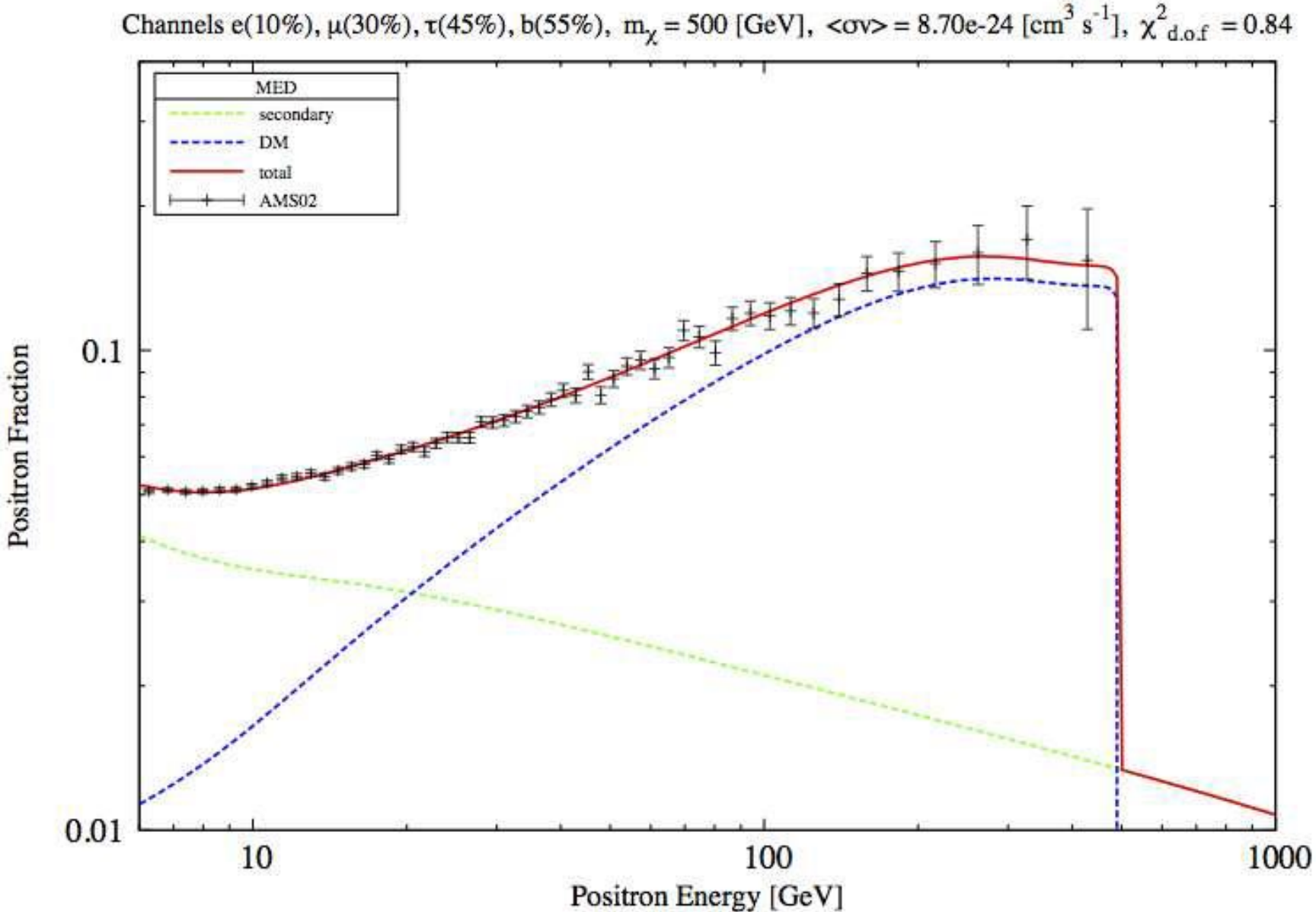




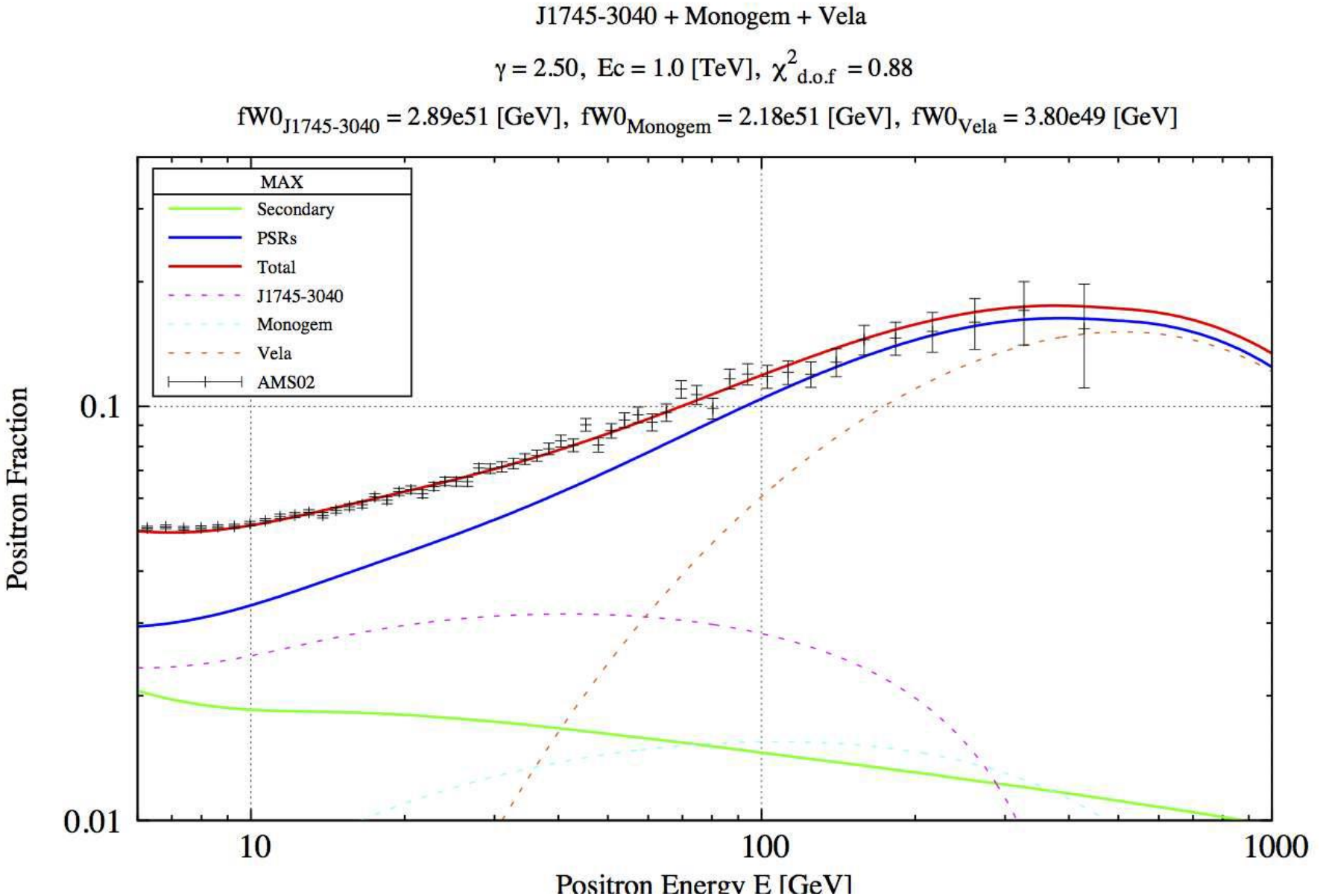




DM origin of positron fraction rise

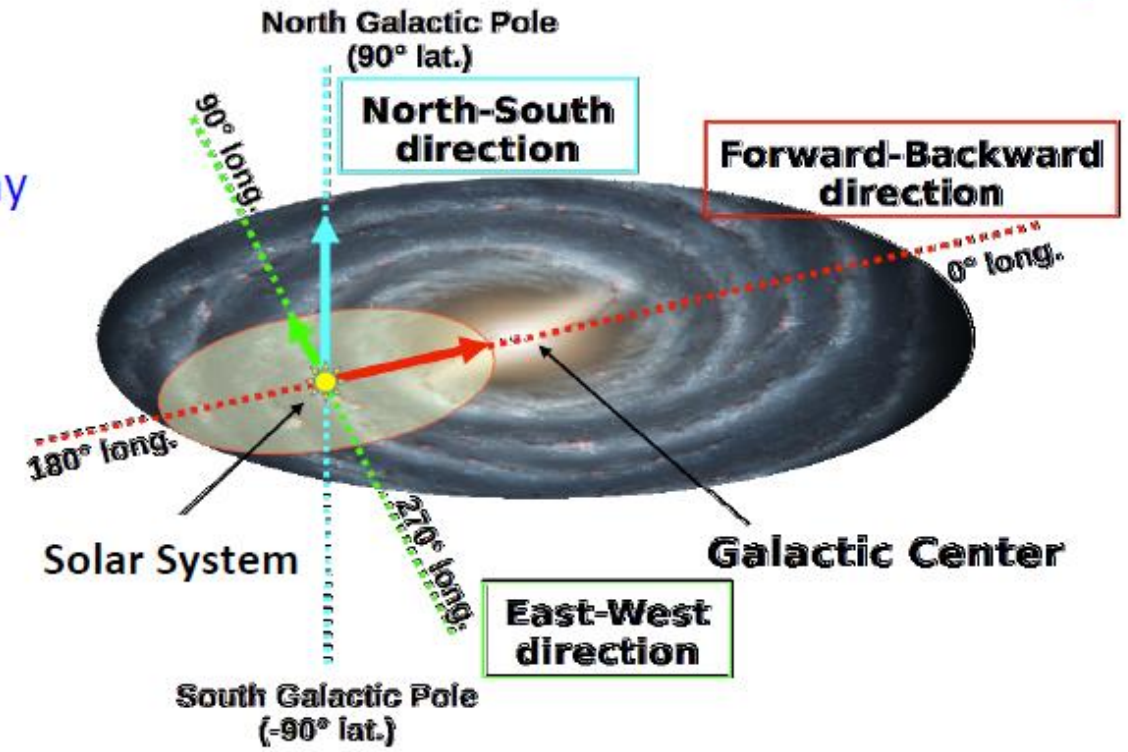


Pulsar origin of the positron fraction rise



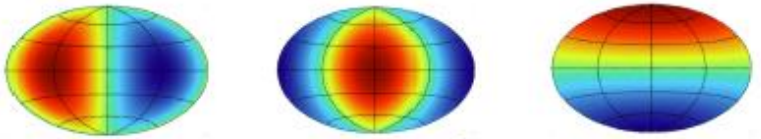
Positron and Electron Anisotropy

- Additional source of cosmic ray positrons and electrons may induce some degree of anisotropy on their arrival direction
- AMS measures the level of anisotropy for positrons and electrons independently



Source term:

Spherical harmonic expansion

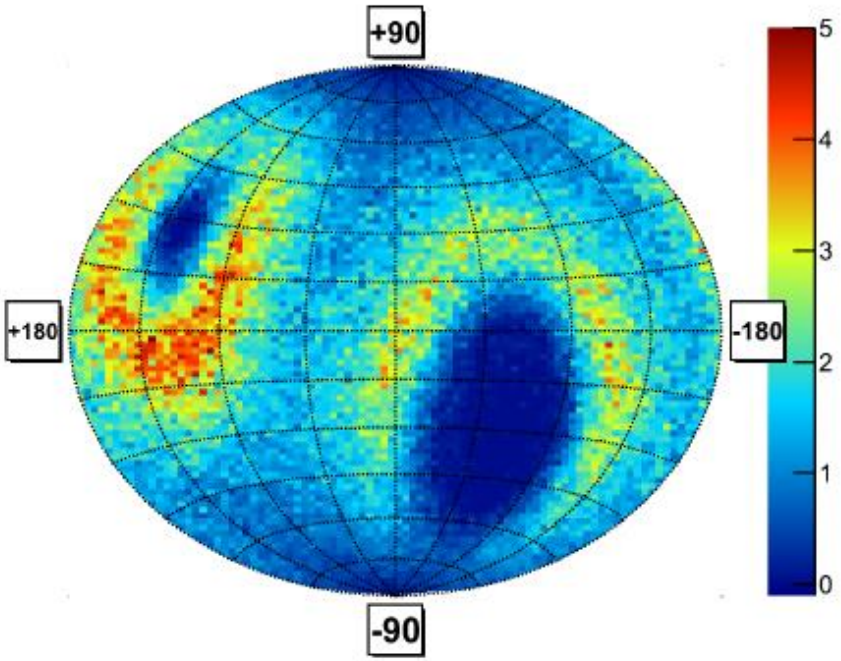


$$J(b,l) = J \times (1 + \sum_{\ell=1}^{\infty} \sum_{m=-\ell}^{\ell} a_{\ell m} Y_{\ell}^{m}(b,l))$$

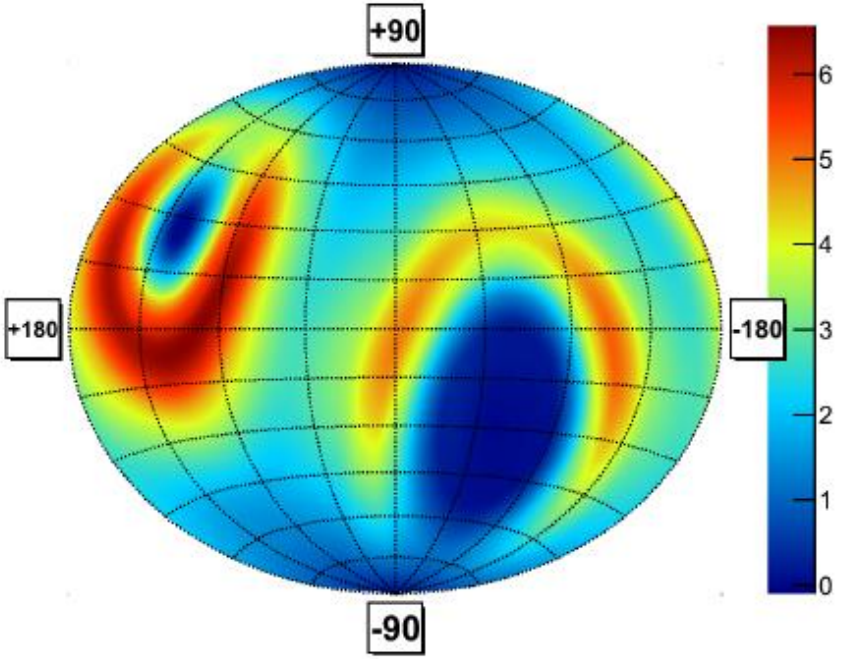
Positron and Electron Anisotropy

- Arrival direction of electrons, positrons are compared with Exposure map (A*T)

Data on ISS, Electrons, E>25GeV



Exposure map for E>25GeV



$$N = \int_b \int_l J(b,l) \times AT(b,l) \times \sin b \times db\, dl$$

- A fit is done obtaining coefficient of spherical harmonic expansion for the source term

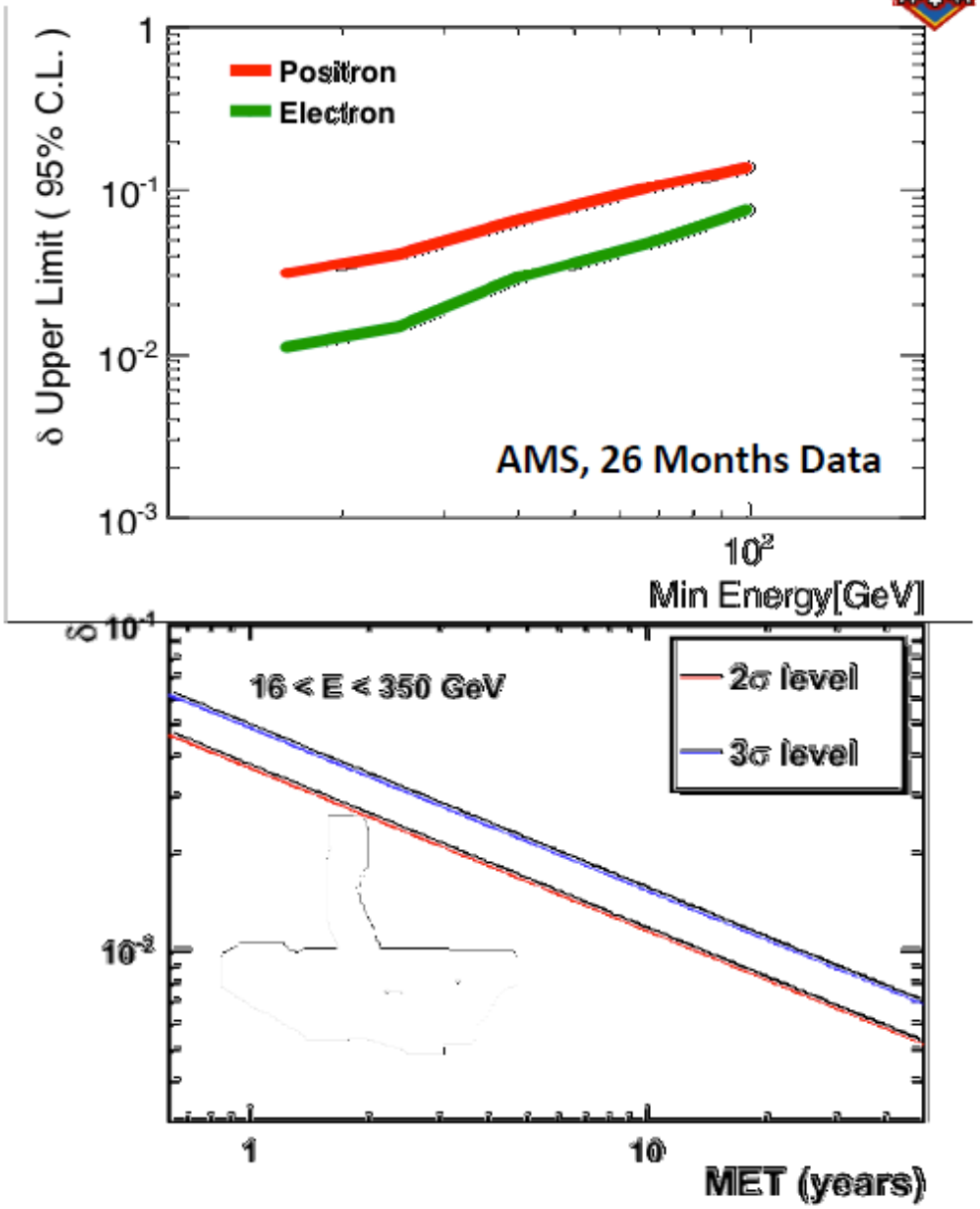
Upper Limit on Positron, Electron Flux Anisotropy

- **The fit amplitudes are found to be consistent with the hypothesis of isotropy at all energies and angular scales.**
- **Dipole anisotropy:**

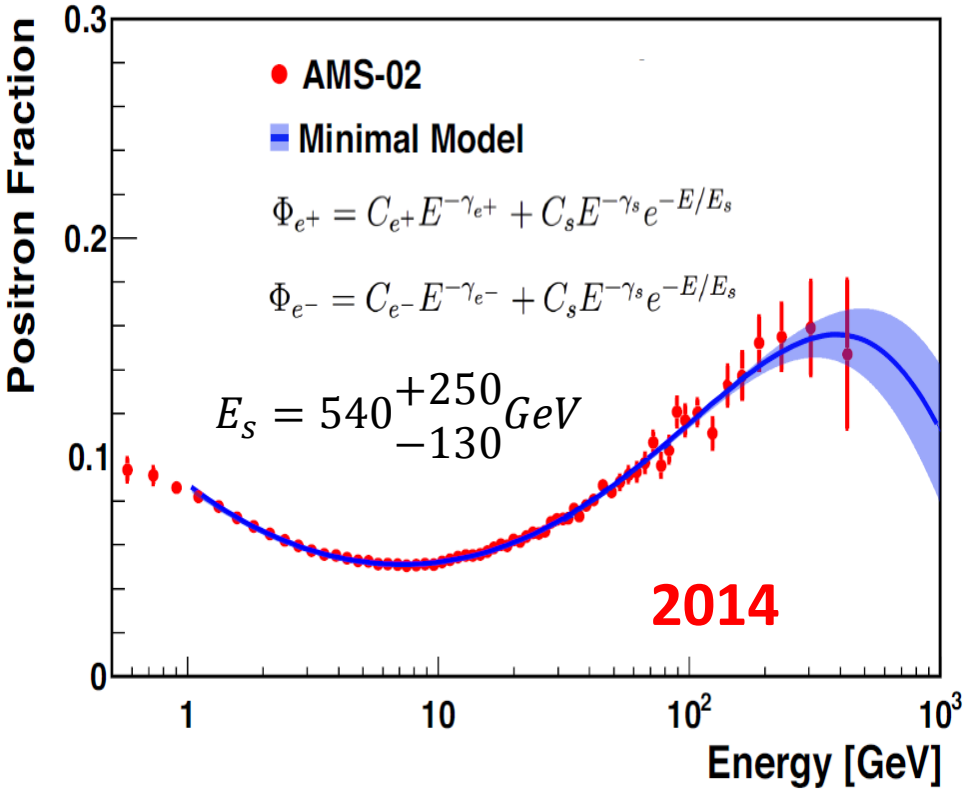
$$\delta = \sqrt{\frac{3}{4\pi}}\sqrt{(a_{1-1}^2 + a_{10}^2 + a_{11}^2)}$$

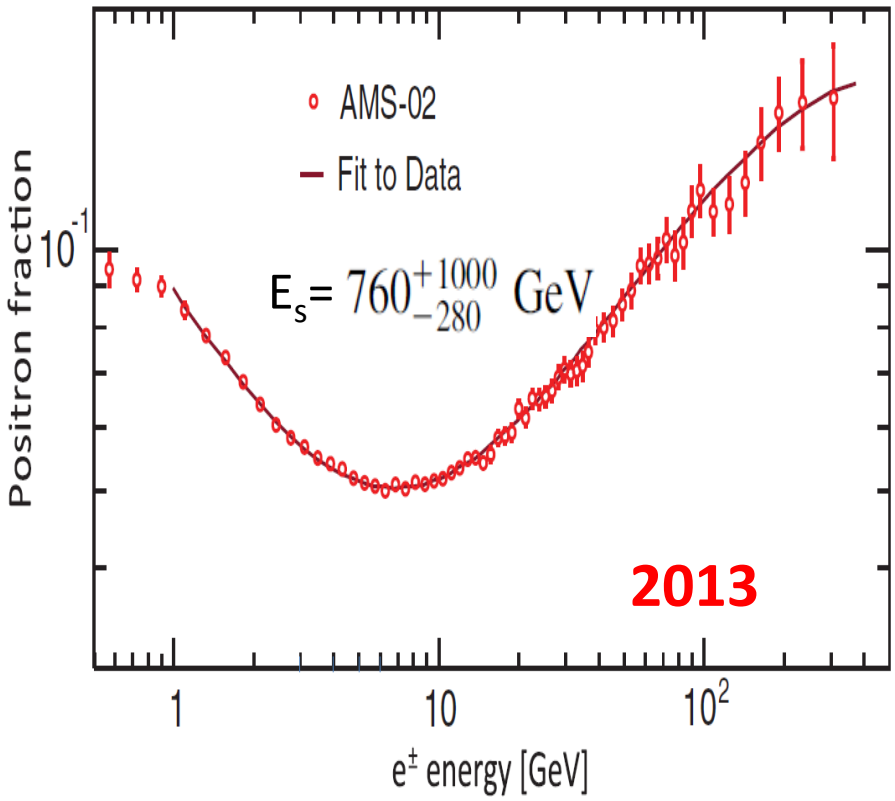
- **For positron above 16GeV**
  - **Delta upper limit: <0.03**

- In 10 years, the projected sensitivity of AMS to a positron dipole anisotropy is
- **2 sigma for delta = 0.010**
- **3 sigma for delta = 0.014**



Positron fraction

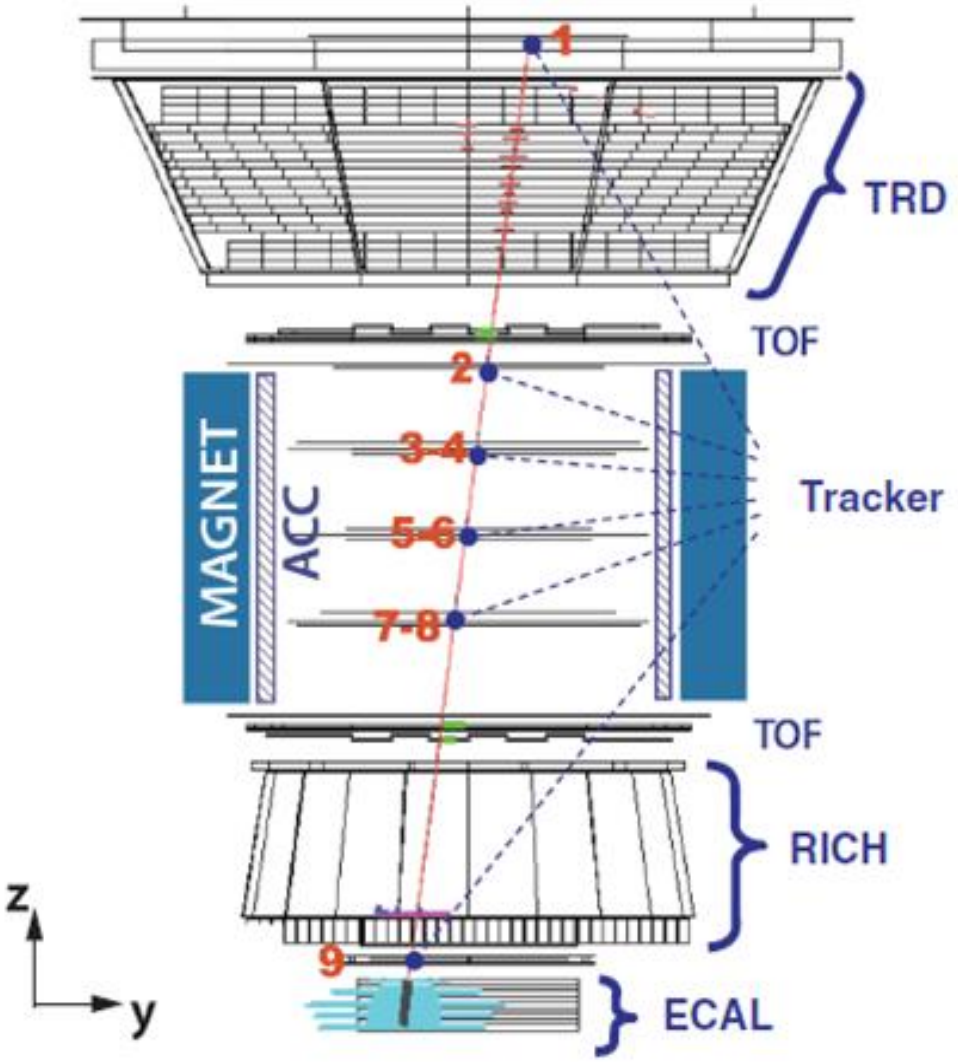




Diffuse power law and source terms are used to describe the behaviour of positron fraction

Electron Identification

Electron event @ 1.03TeV



Proton rejection

Charge Z
Velocity β

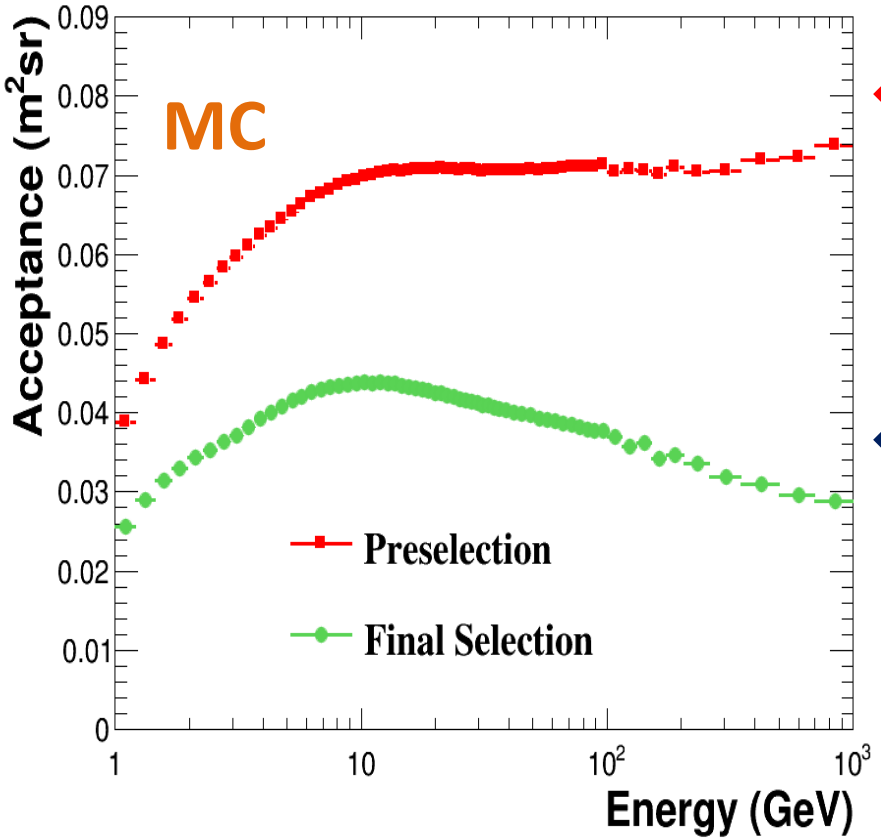
Charge Z
Sign of the charge
Momentum P

Electron Selection

Electron energy E
Proton rejection

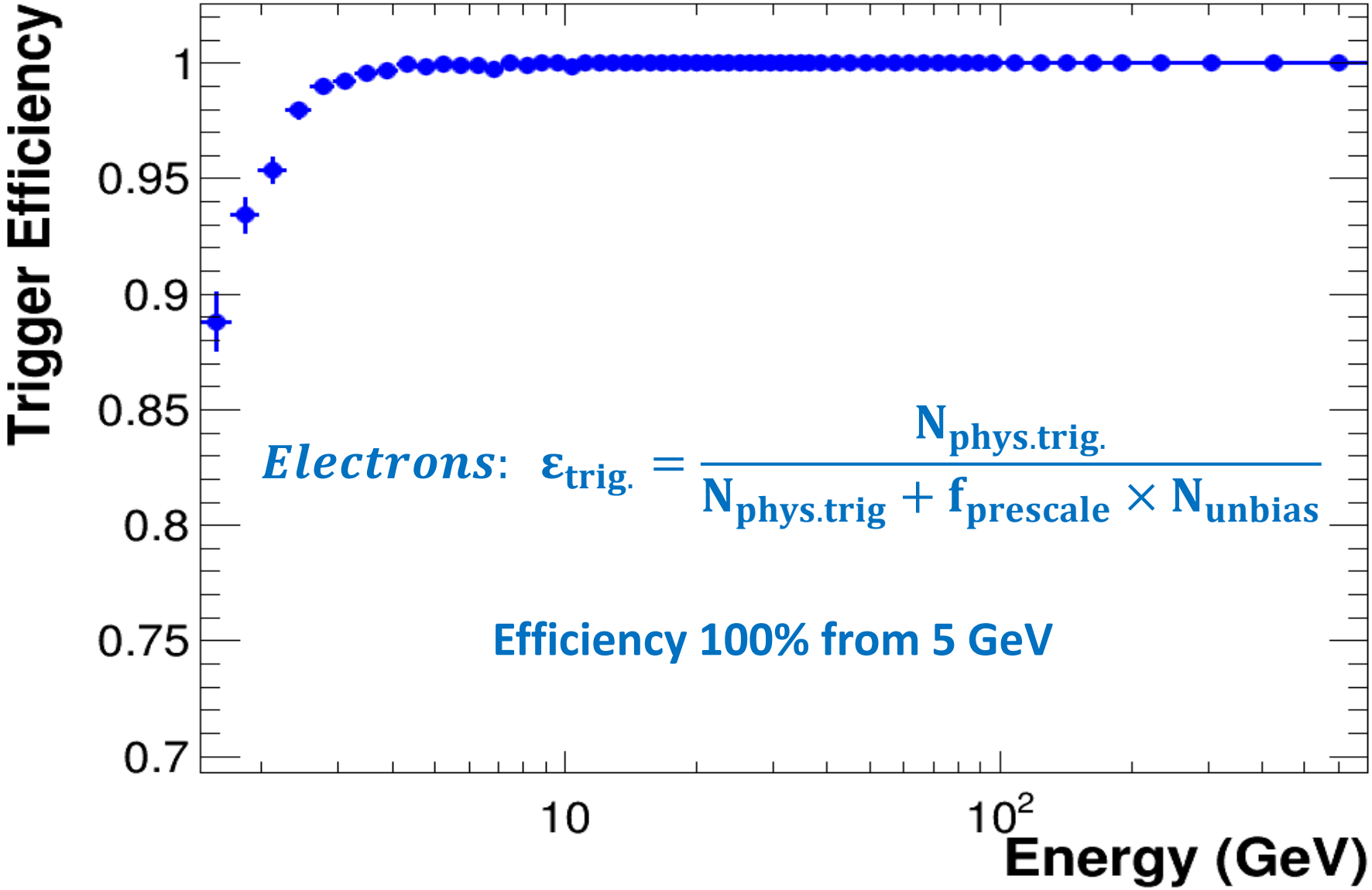
Flux Measurement Procedure

Isotropic flux: $\Phi(E, E+\Delta E) = \dfrac{N_{signal}}{\underbrace{A_{geo} * \varepsilon_{sel.}}_{\text{MC}} * \varepsilon_{trig.} * T_{expo}(E) * \Delta E}$

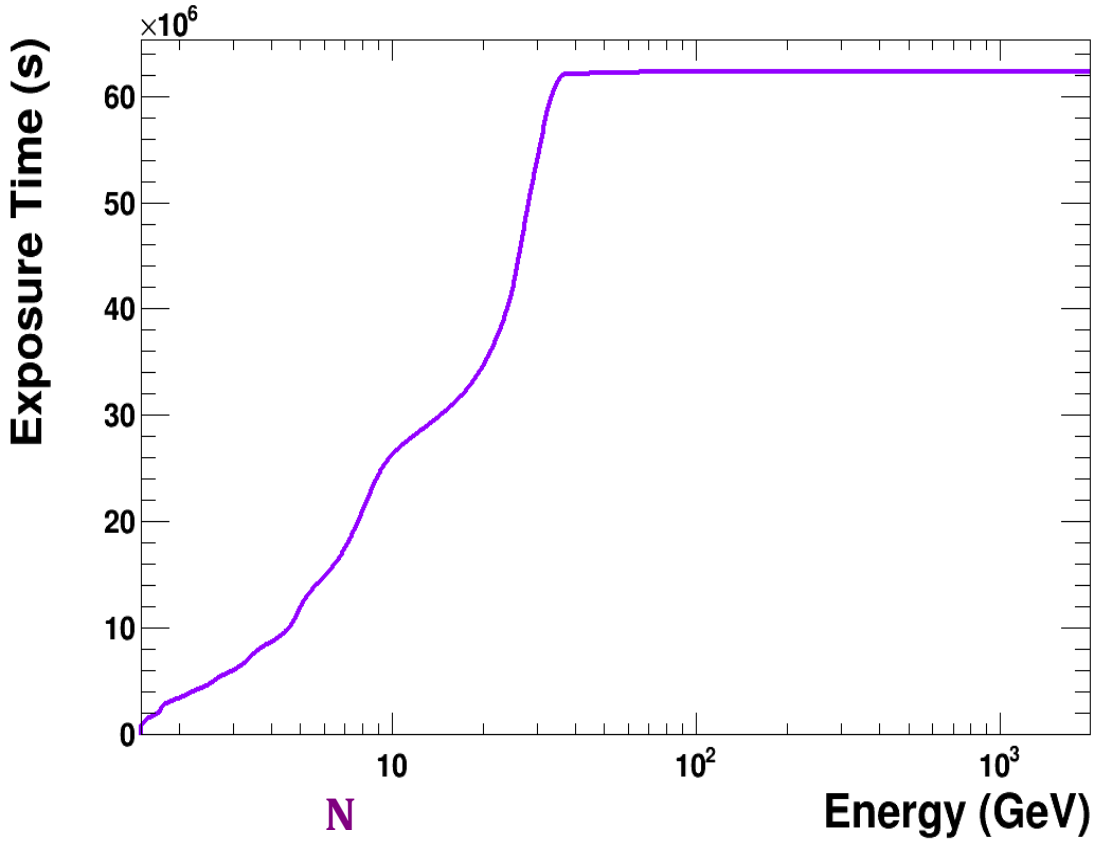


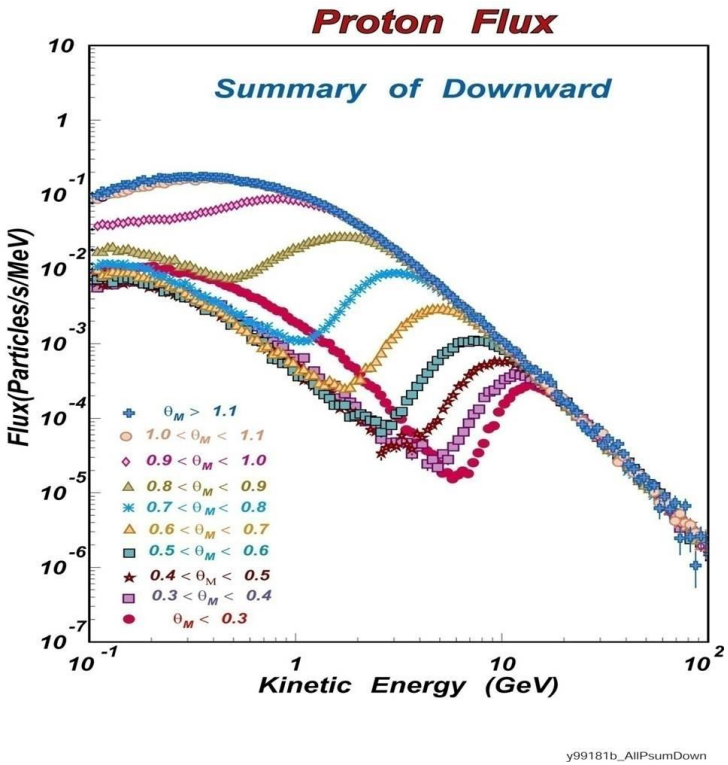
- ❖ **Acceptance & Selection efficiency**
  - calculated with MC
  - corrected with data
- ❖ **Systematic uncertainties:**
  - 2-3% from acceptance
  - 2% from energy measurement

Trigger Efficiency



Exposure Time





$$\mathbf{T_{expo}(E) = \sum_{0}^{N} LiveTime * H(E - f * R^{Max}{}_{cutoff})}$$

H(x) is the Heaviside step function

R_{cutoff} is the geomagnetic cutoff value, f the safety factor