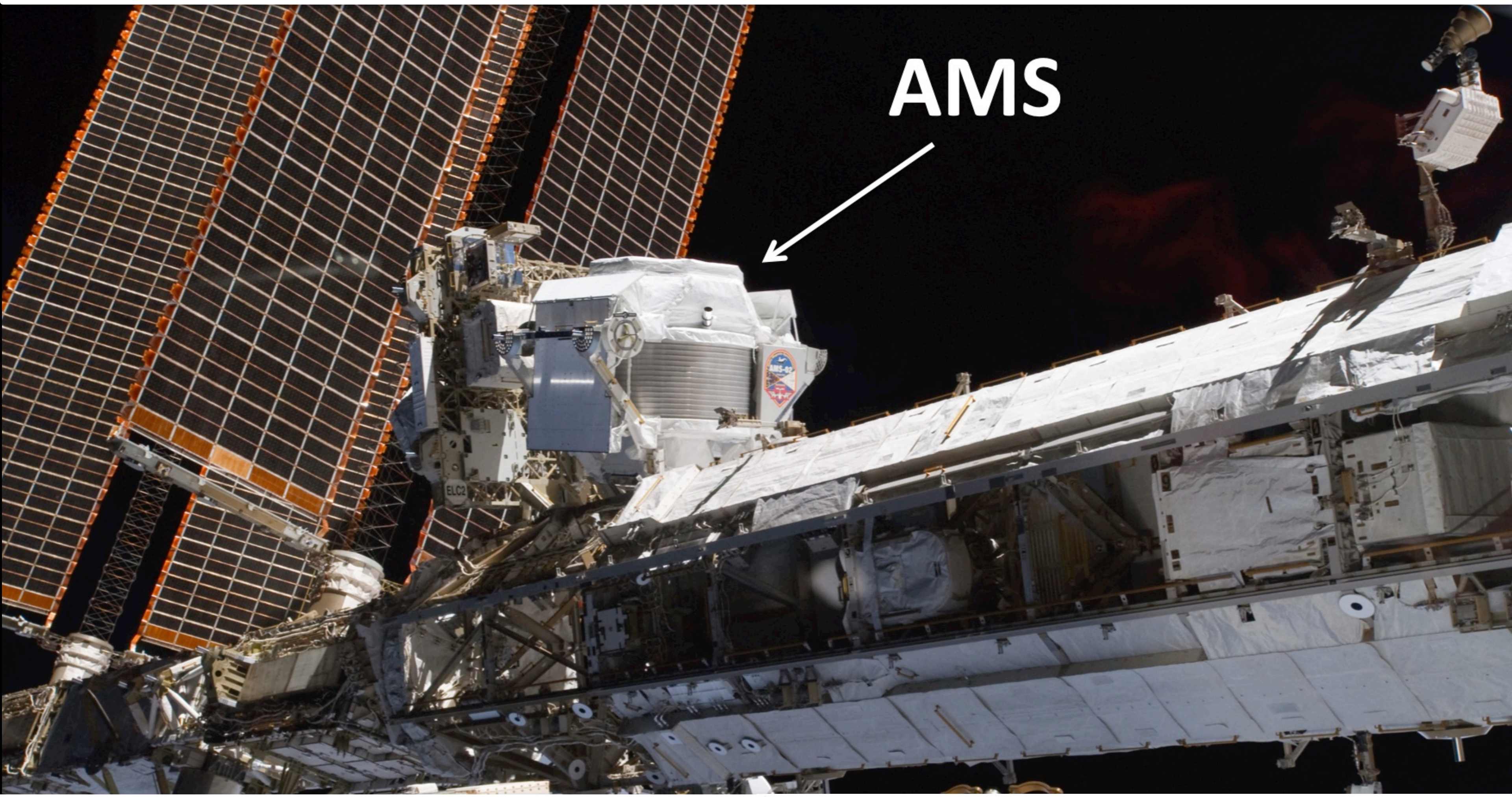
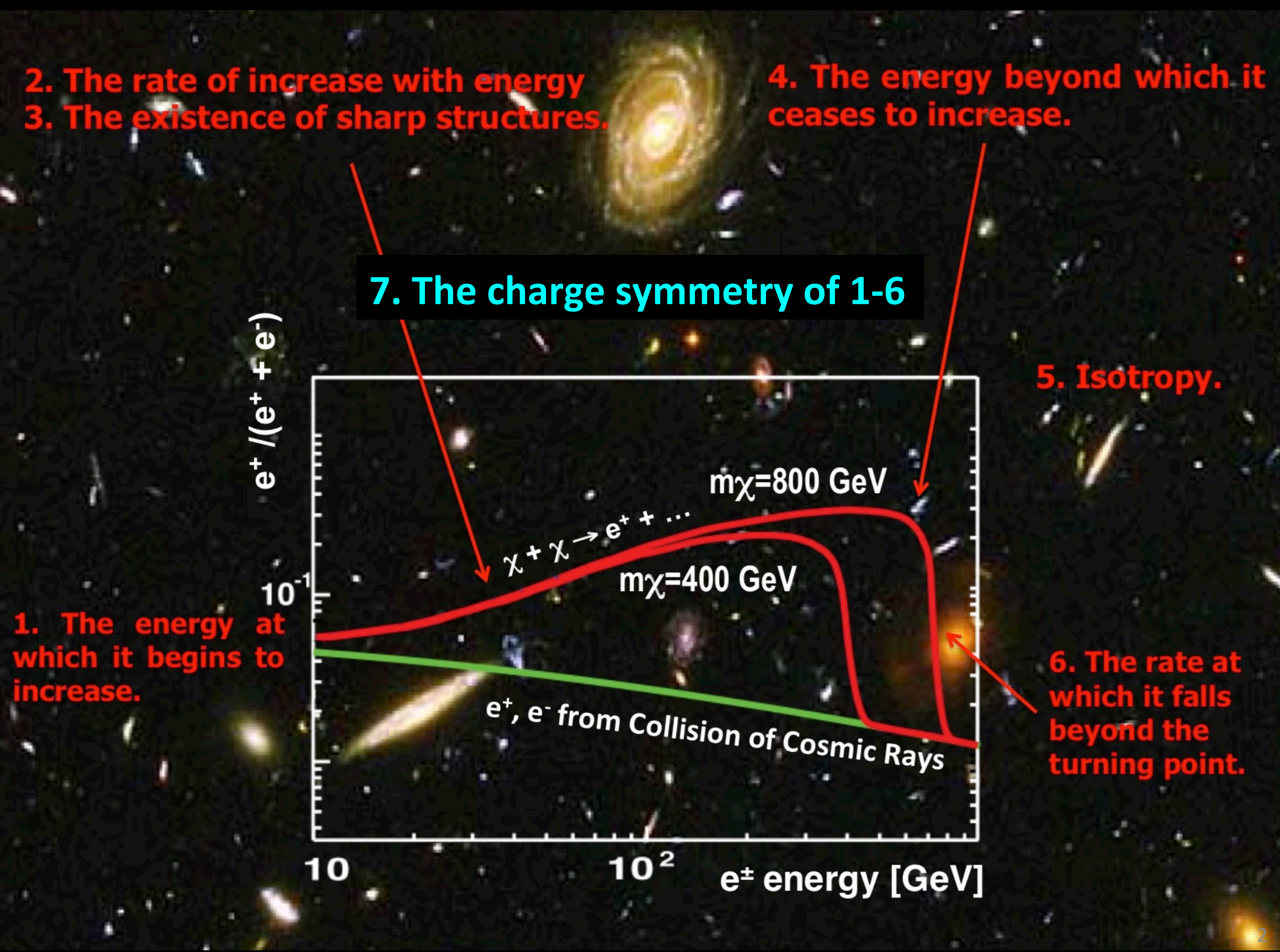
The Electron Spectrum and Positron Spectrum from AMS



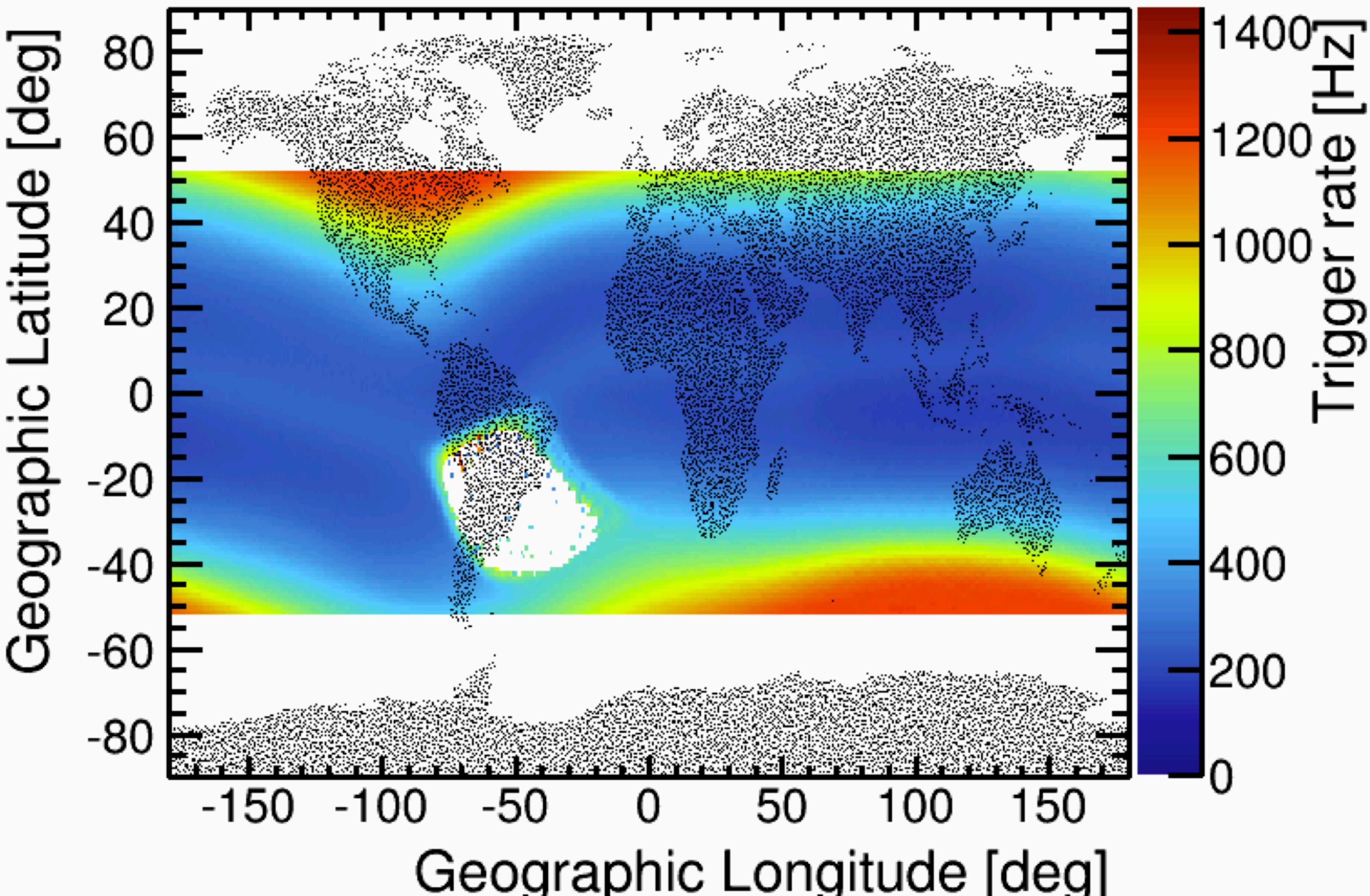
AMS Days at CERN
The Future of Cosmic Ray Physics and Latest Results
CERN, Main Auditorium,
April 15-17, 2015

S. Schael, RWTH Aachen University
on behalf of the AMS Collaboration

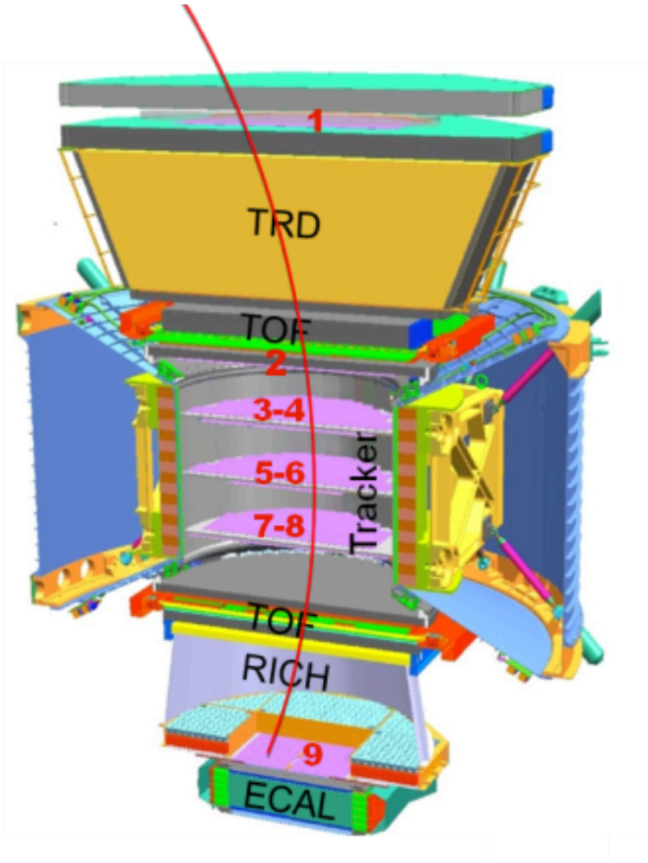


2. The rate of increase with energy
3. The existence of sharp structures.
4. The energy beyond which it ceases to increase.
7. The charge symmetry of 1-6
5. Isotropy.
e+ /(e+ + e-)
mχ=800 GeV
χ + χ → e+ + ...
mχ=400 GeV
10-1
1. The energy at which it begins to increase.
6. The rate at which it falls beyond the turning point.
e+, e- from Collision of Cosmic Rays
10
10 2
e± energy [GeV]

The measurements are based on 41 × 10^9 events collected between May 19, 2011, and November 26, 2013



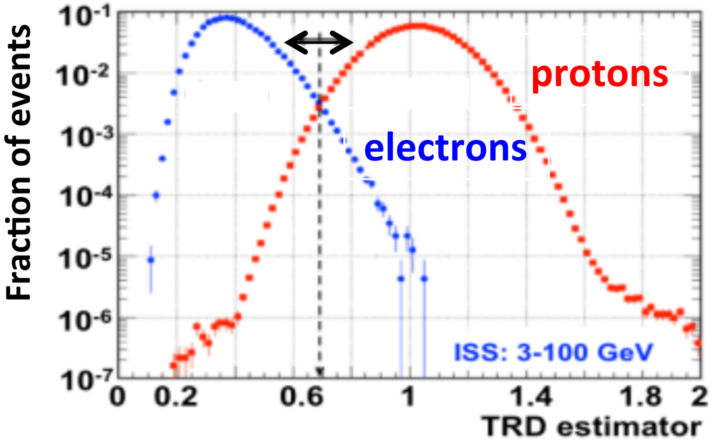
Analysis Flow

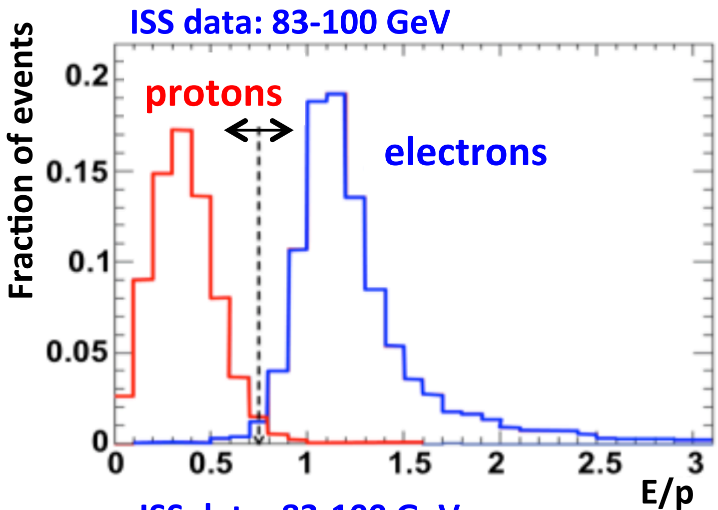


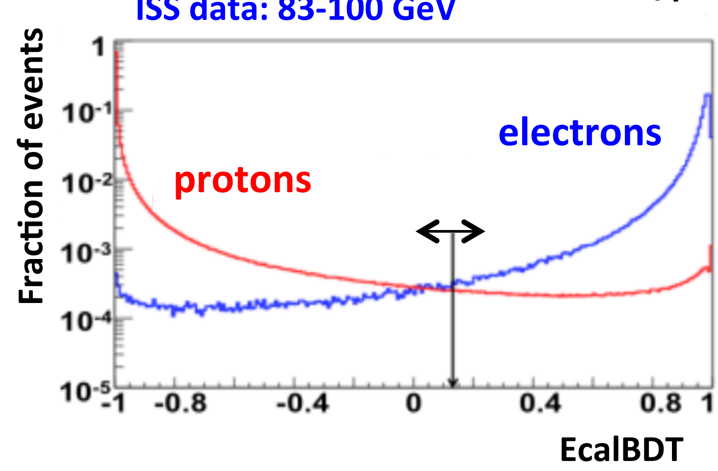
TRD
(transition radiation)

ECAL/Tracker
(E/p matching)

ECAL
(shower shape)







TRD, TOF, tracker, and ECAL define:

1)Geometric acceptance, A_{GEOM}, ~ 550 $cm^2 sr$

2)Selection efficiency, ε_{SEL} for downward |Z|=1 track

3)Identification efficiency, ε_{ID}, for $e^{\pm}$

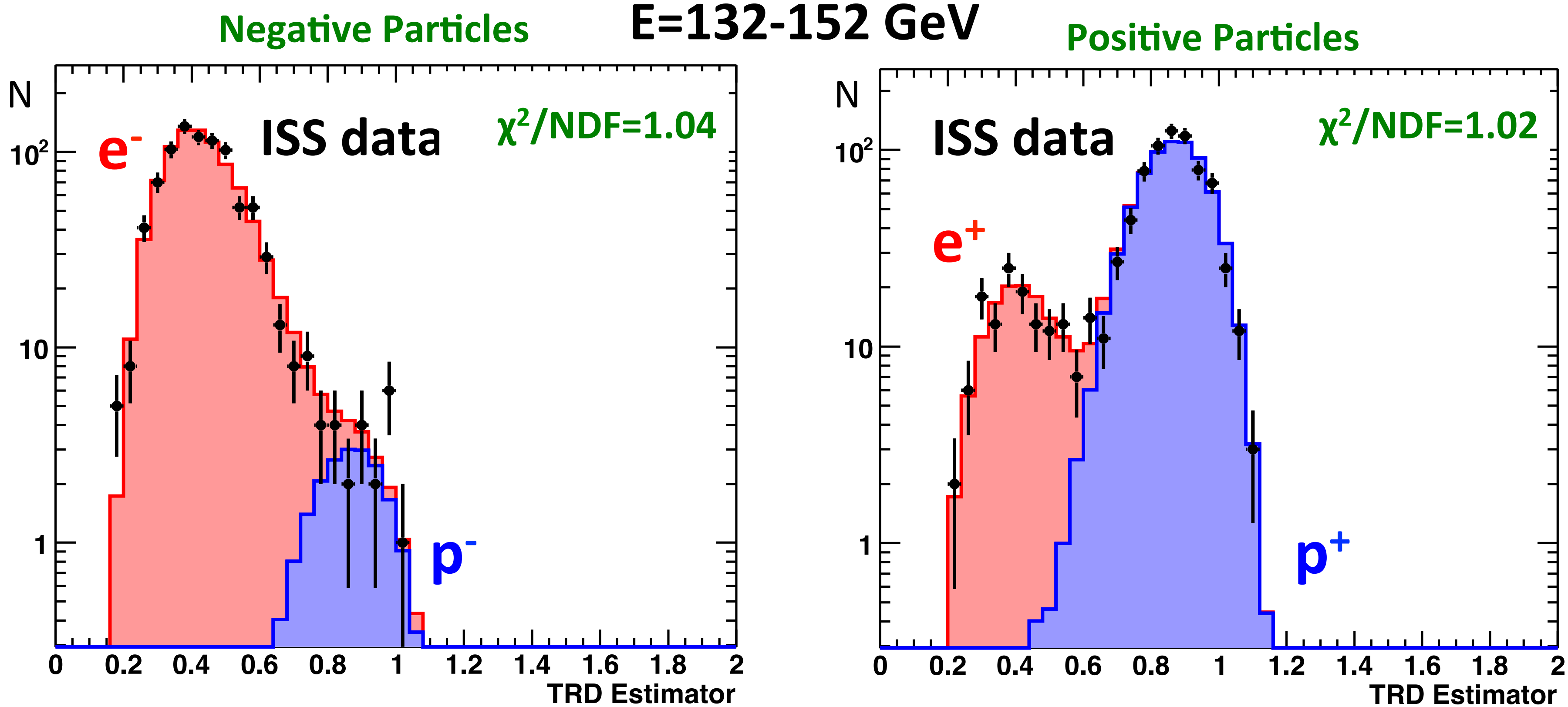
Particle Identification

We produce an $e^{\pm}$ enhanced sample by soft cuts on:

- the ratio Energy/|Rigidity|, were the Energy is measured by ECAL and the rigidity by the Tracker.
- the ECAL Estimator, to separate hadronic showers from electromagnetic showers by their 3D-shape

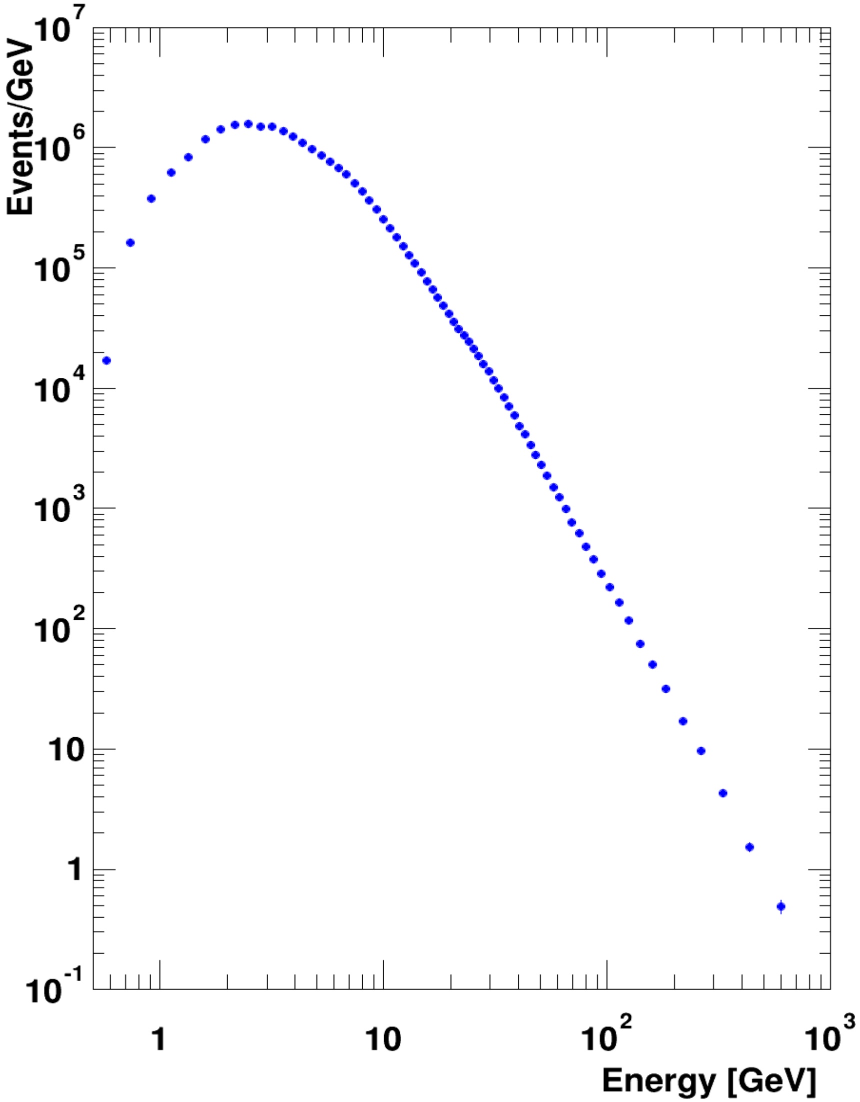
The proton templates are taken from ISS Data, the electron templates from Monte Carlo.

E=132-152 GeV

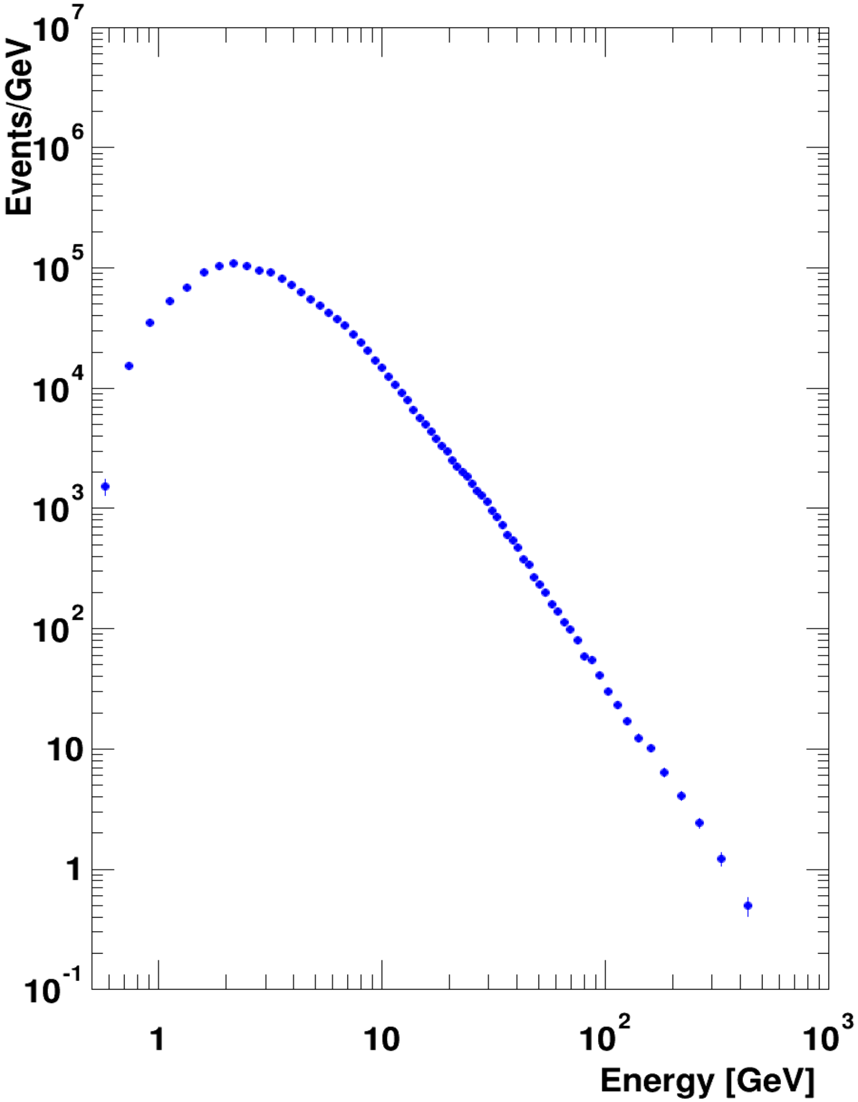


Raw Event Rates, statistical errors only

Electrons: 0.5 - 700 GeV

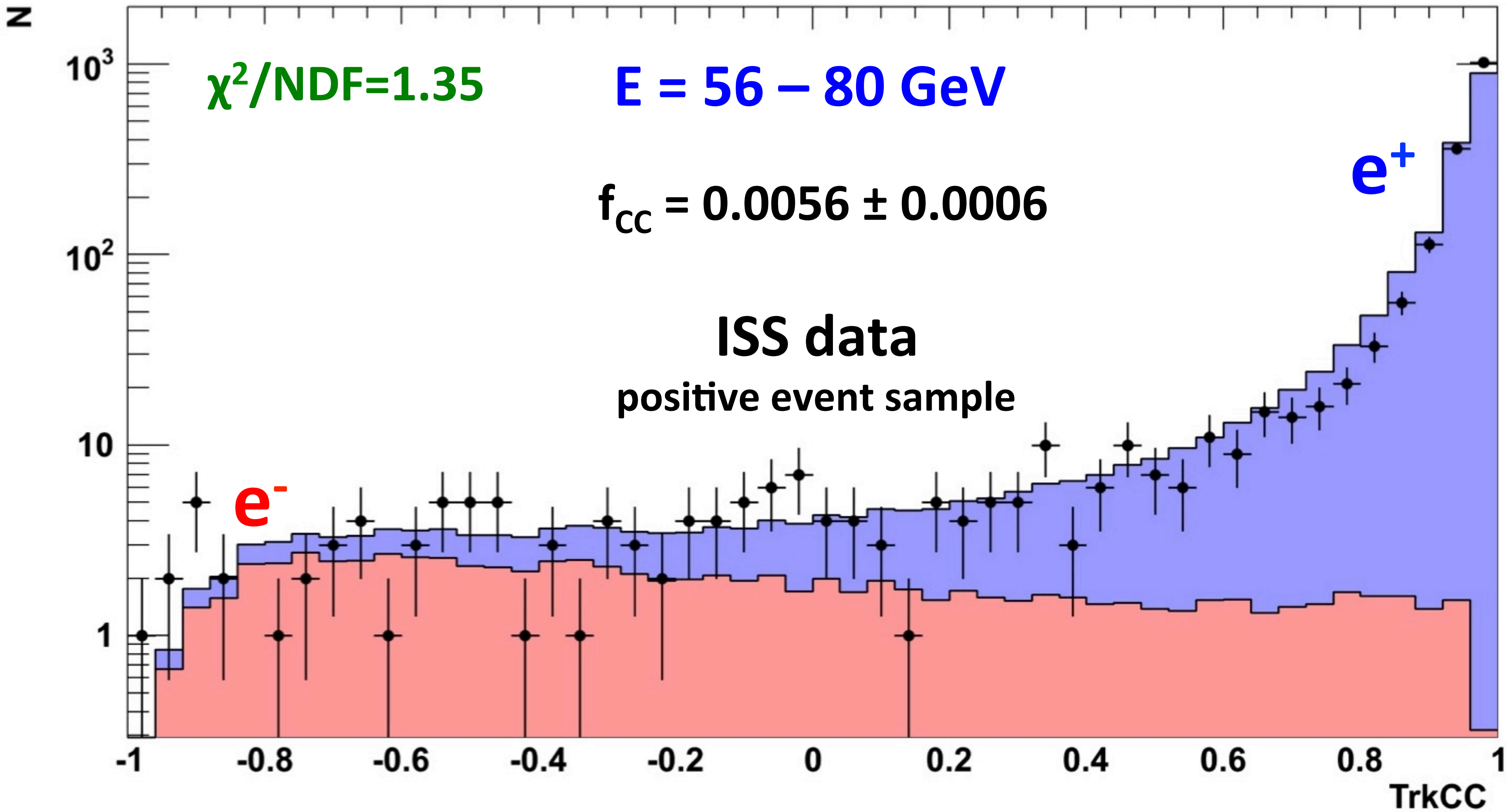


Positrons: 0.5 - 500 GeV

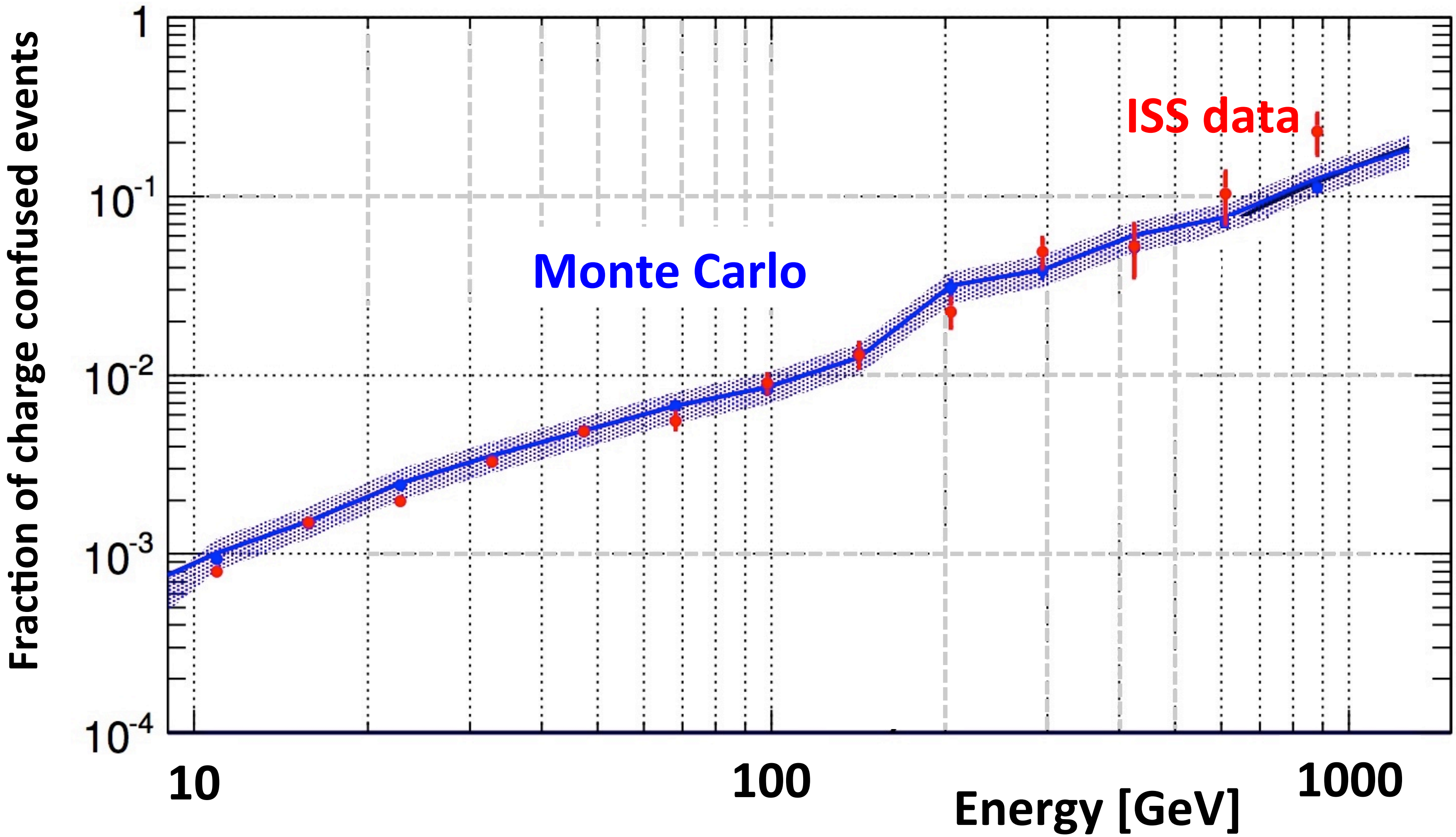


Fraction of charge confused events: f_{CC}

- **We use another BDT to derive for each event a classifier (TrkCC) to determine the charge confusion directly from ISS data with a template fit.**



Fraction of charge confused events vs Energy



The determination of the Flux

In total, 9.23×10^6 events are identified as electrons and 0.58×10^6 as positrons.

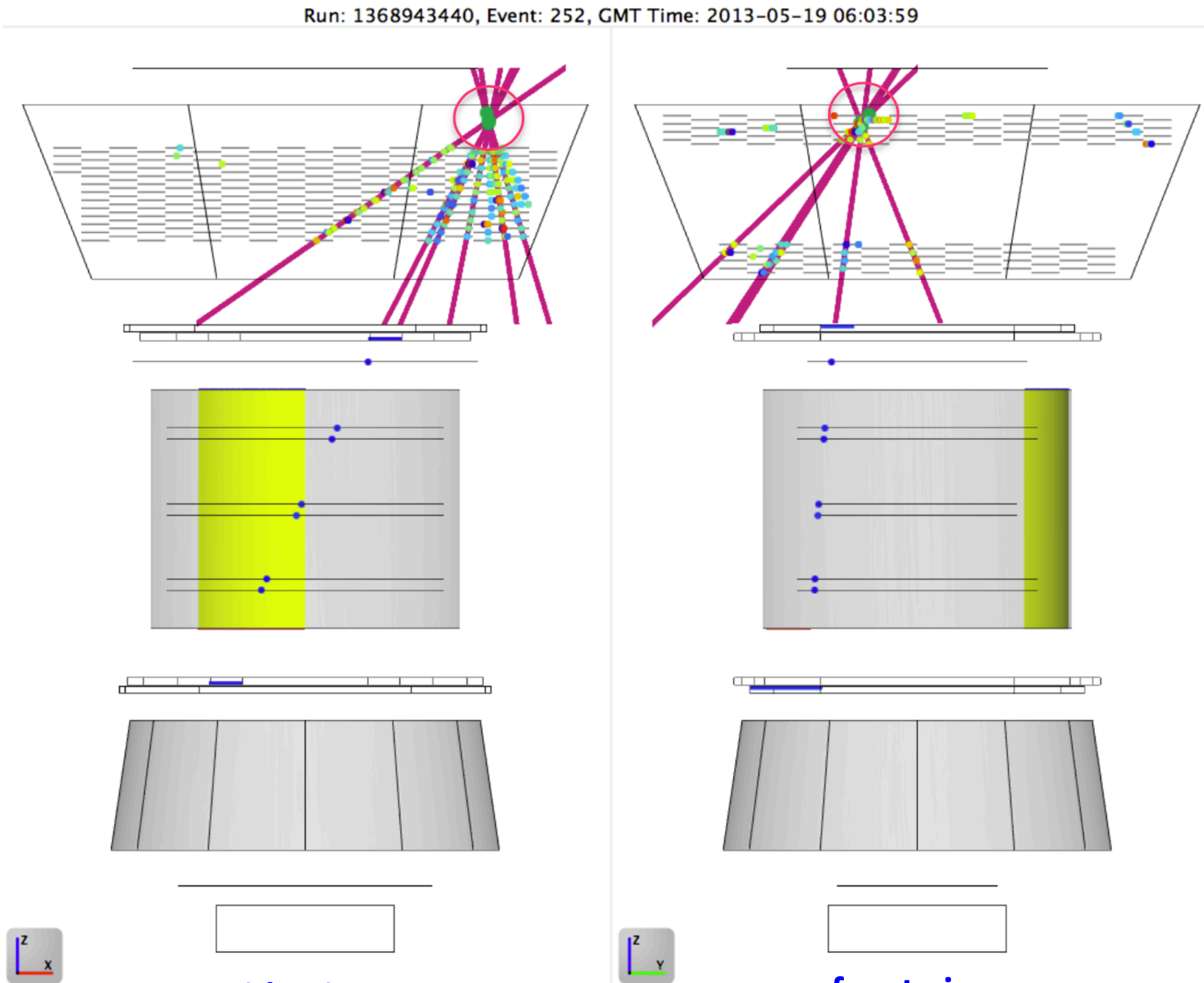
$$\Phi_{e^\pm}(E) = \frac{N_{e^\pm}(E)}{A_{eff}(E) \cdot \varepsilon_{trig}(E) \cdot T(E) \cdot \Delta E}$$

$N_{e\pm}$ is the number of electron or positron events
ε_{trig} is the trigger efficiency
T is the exposure time

A_{eff} is the effective acceptance $A_{eff} = A_{geom} \cdot \varepsilon_{sel} \cdot \varepsilon_{id} \cdot (1+\delta)$

A_{geom} is the geometrical acceptance, ≃ 550 cm^2sr
ε_{sel} is the event selection efficiency
ε_{id} is the $e^\pm$ identification efficiency
δ is a minor correction from the comparison between data and Monte Carlo (-2% at 10Gev to -6% at 700 GeV). The error on $(1+\delta)$ is ~2.5%.

Use rare nuclear interaction events to optimize the material description in the Monte Carlo

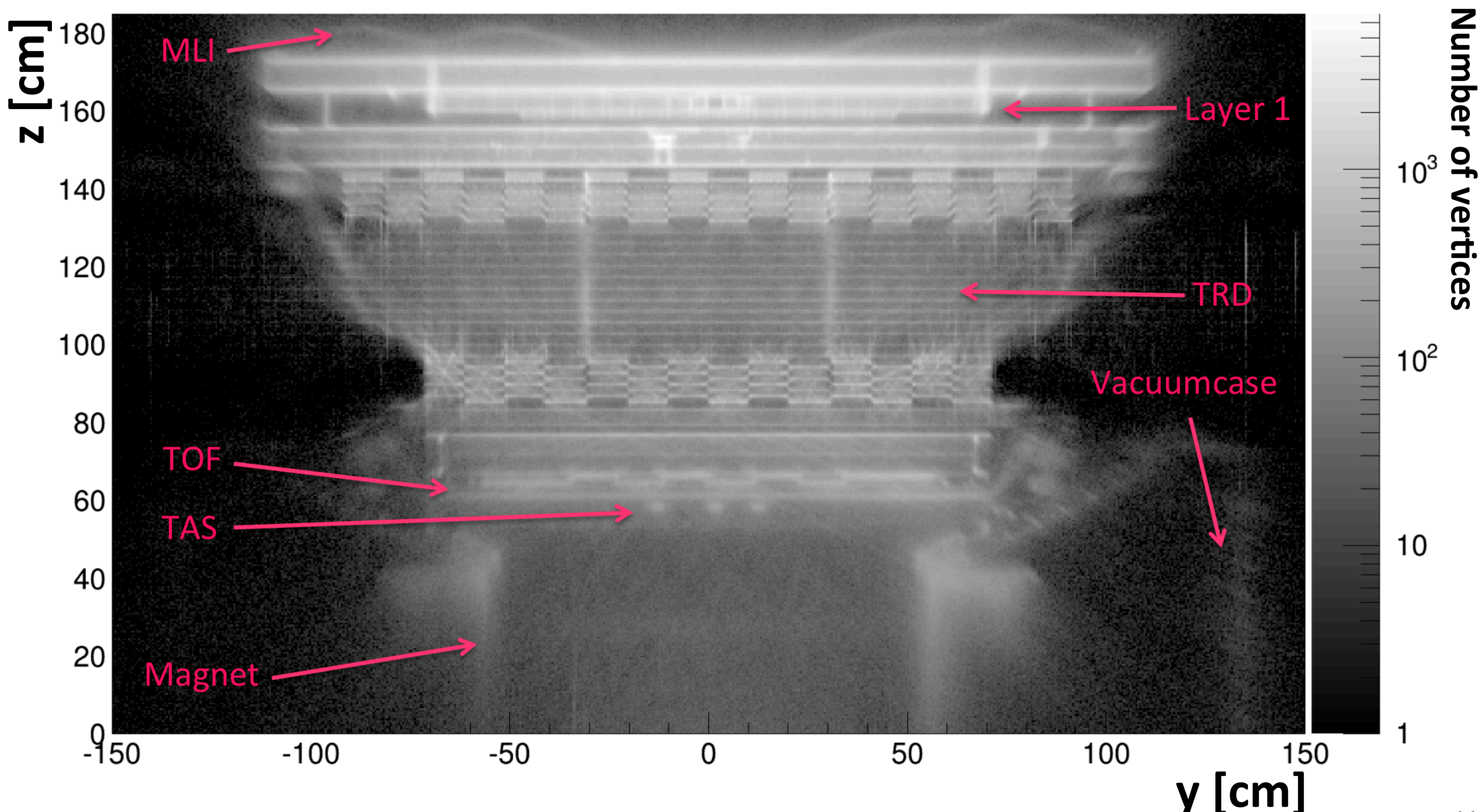


side view

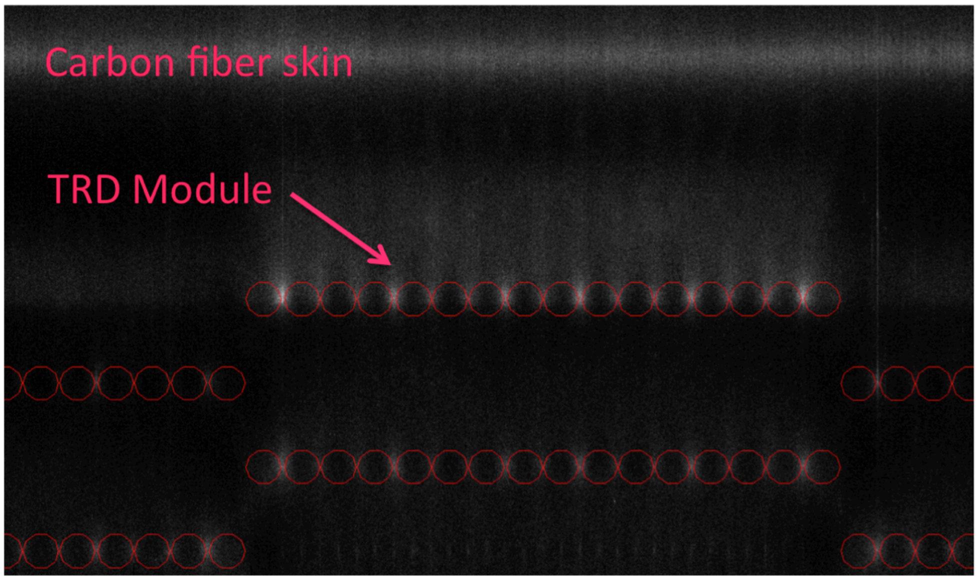
front view

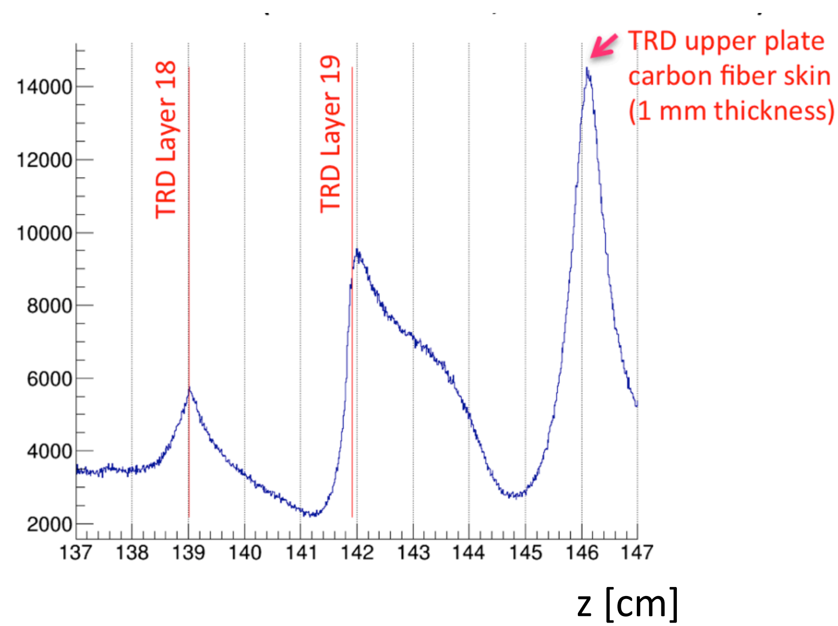
X-Ray of AMS on the ISS from rare nuclear interaction events

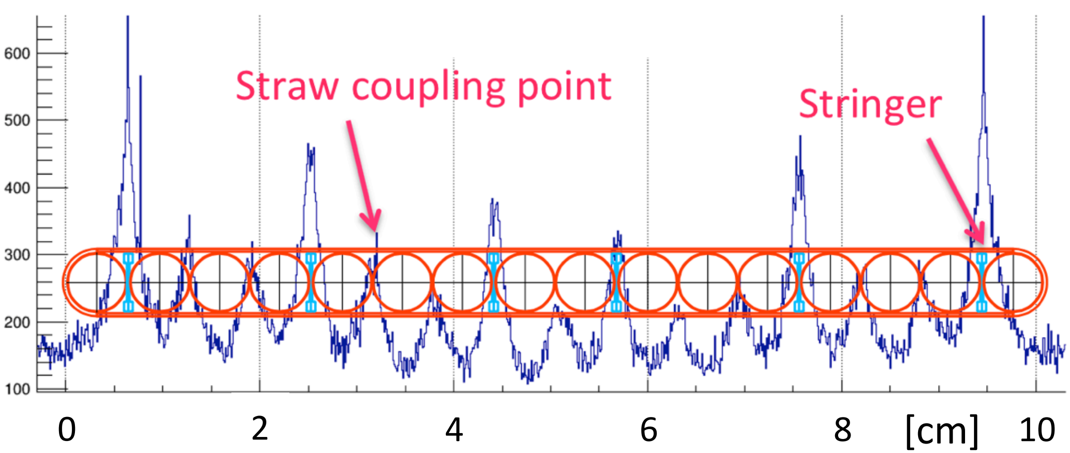
The gray scale is proportional to the number of vertices found.



Control the TRD Geometry at g=0 with an accuracy of 0.1 mm







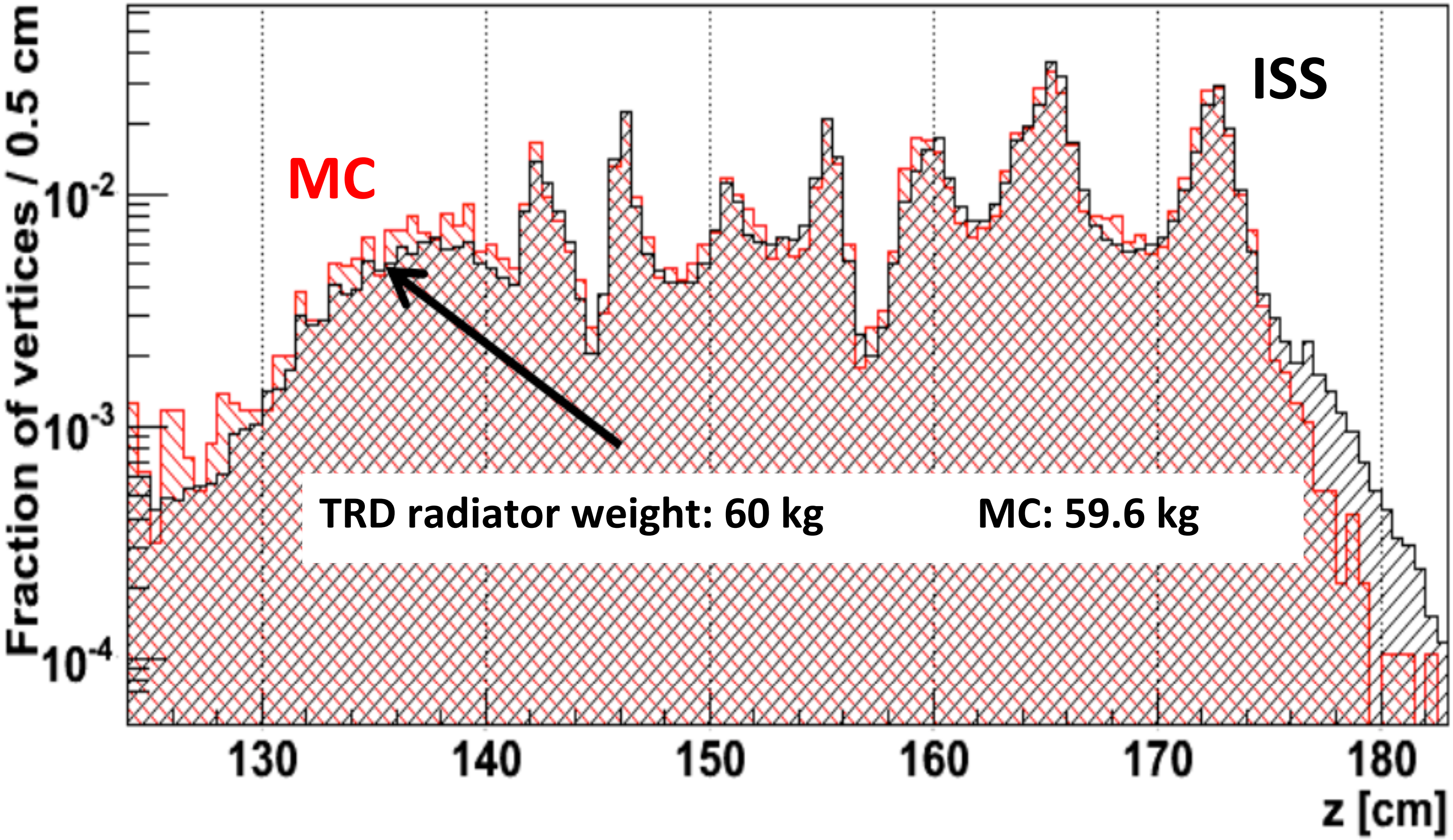
Upper plate carbon fiber skin

$z_{Measured}$ = 1461.21 mm

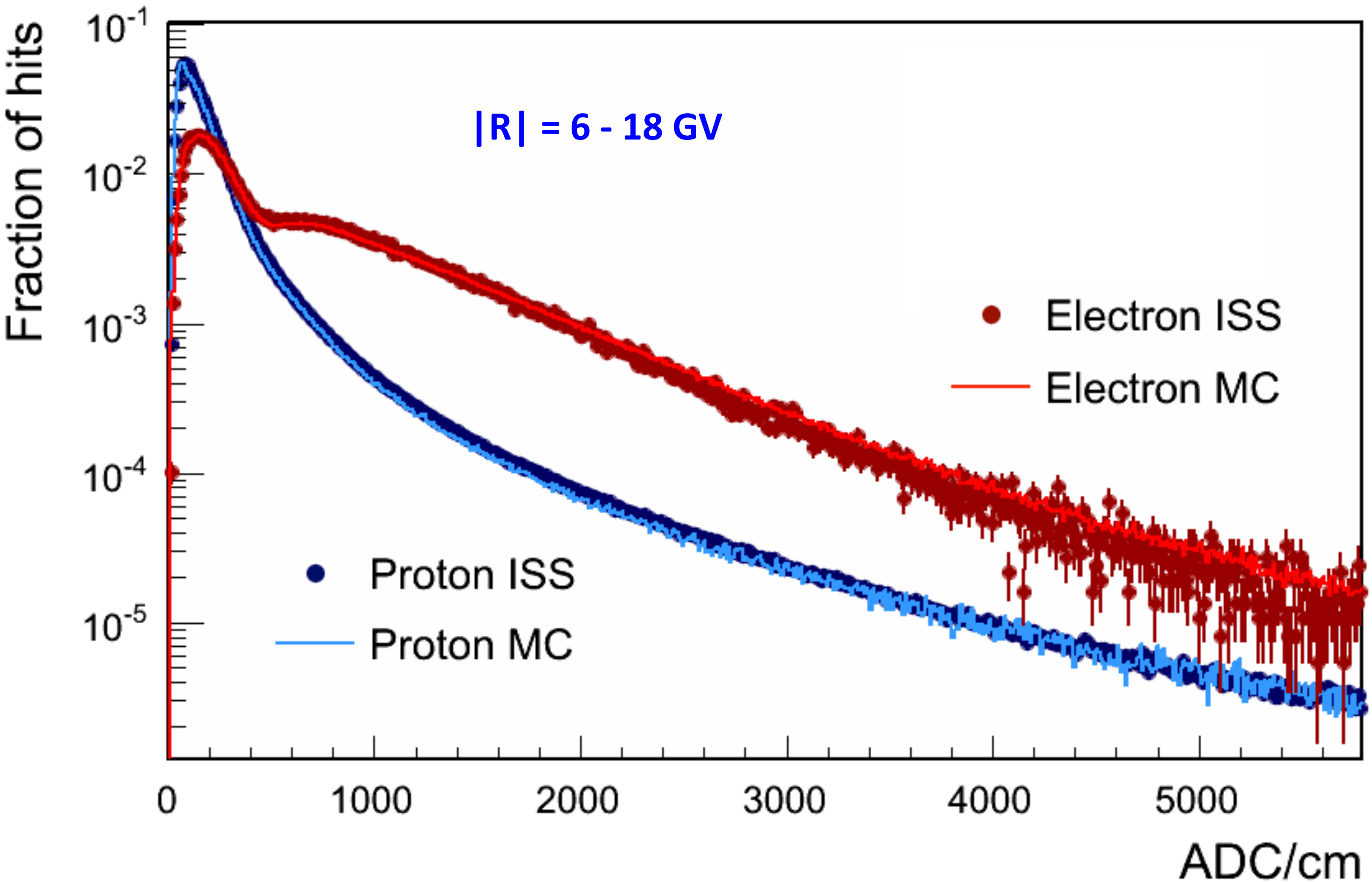
$z_{Nominal}$ = 1460.90 mm

0.31 mm deviation

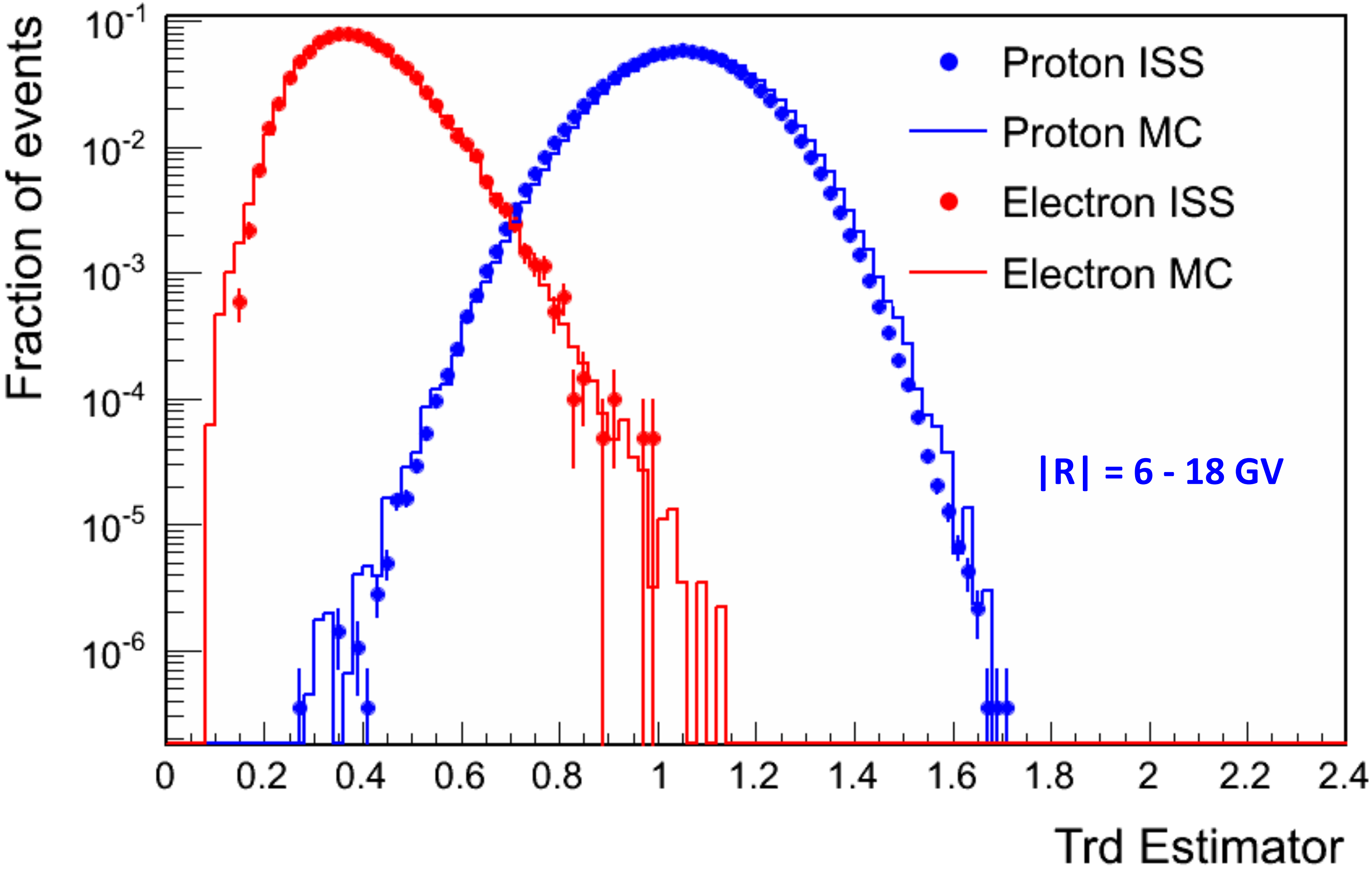
ISS Data ⇔ MC Data



ISS Data ⇔ MC Data



ISS Data ⇔ MC Data

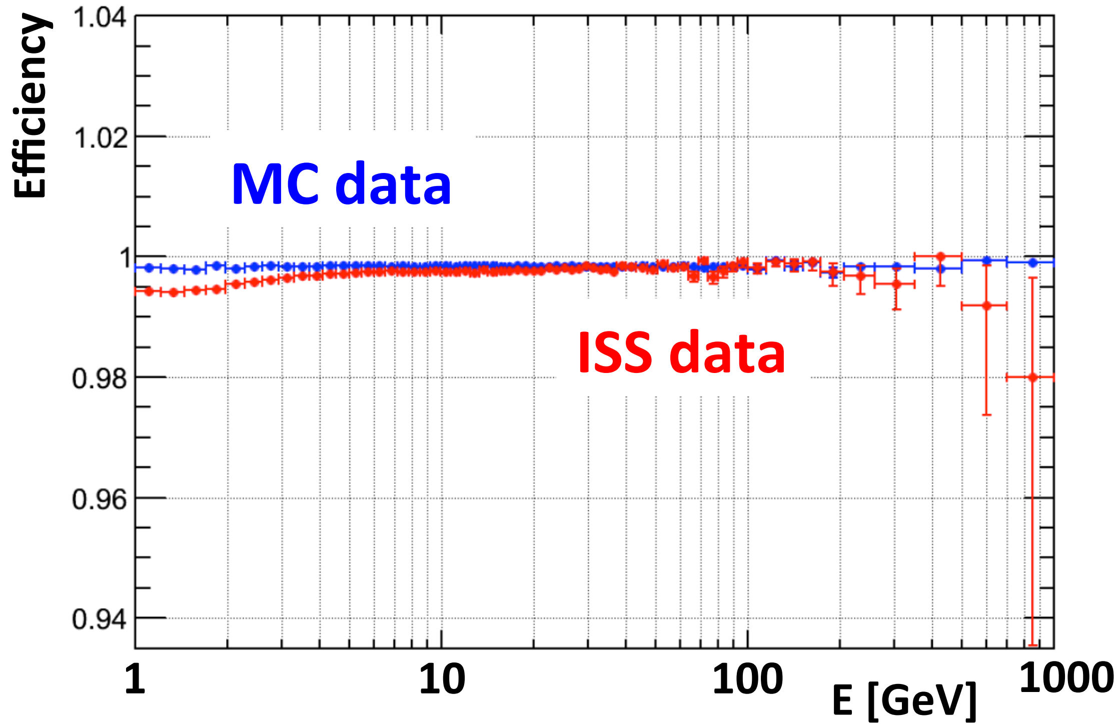


In order to determine the correction, δ, a negative rigidity sample is selected for every cut (i) using information from the detectors unrelated to that cut.

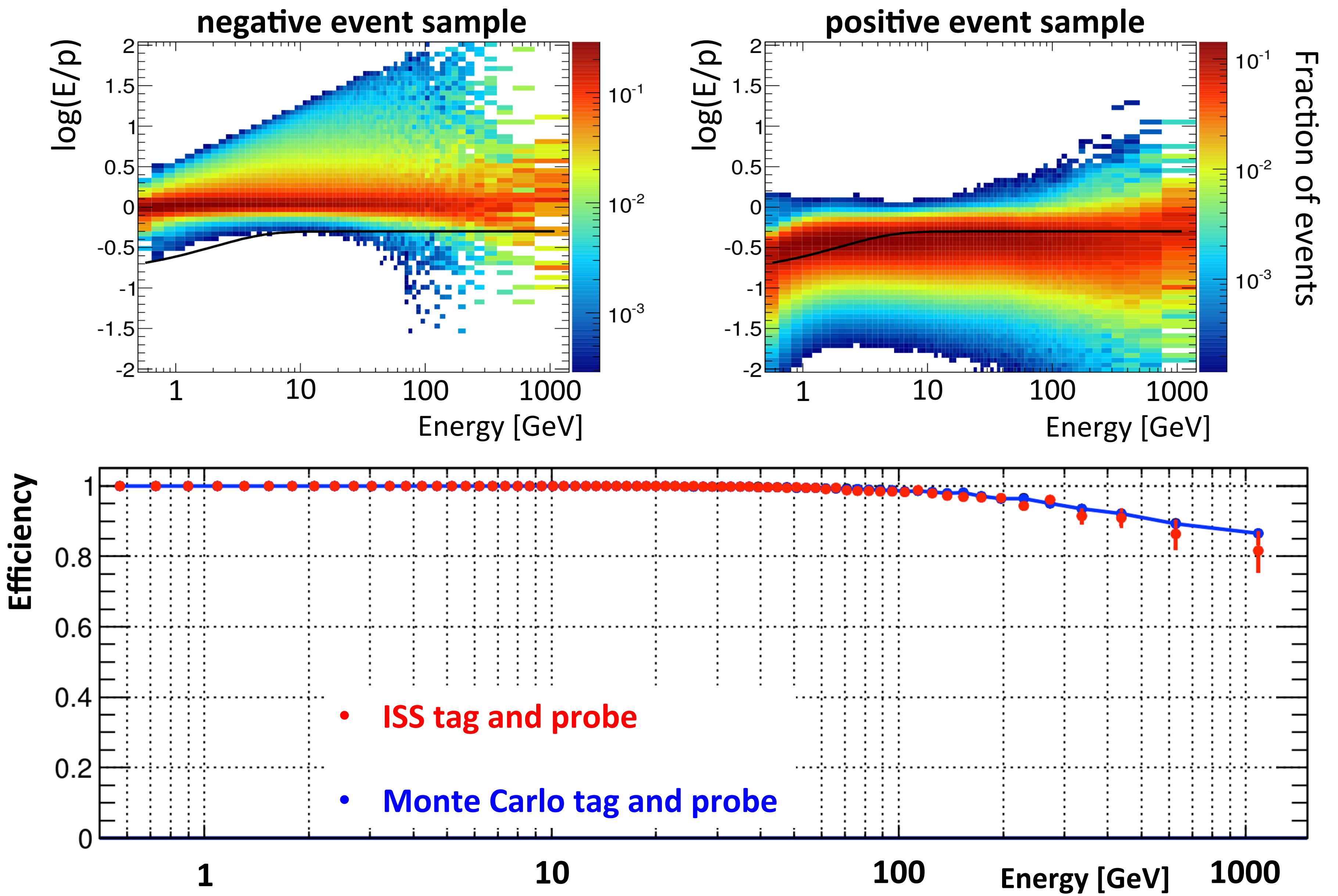
$$(1+\delta) = \prod_{\text{Cuts}} (1+\delta_i)$$

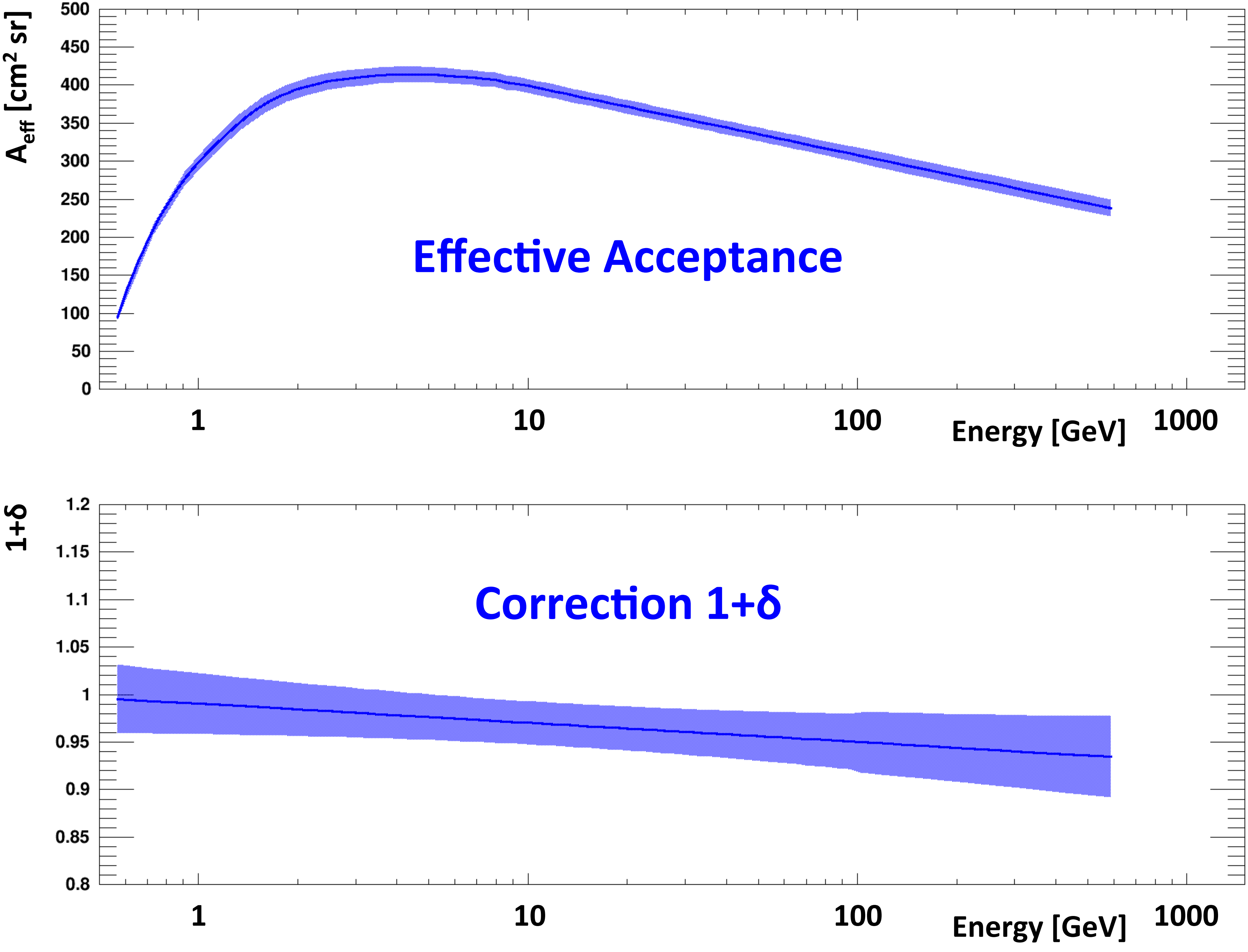
Example: TRD Track reconstruction

- Select electron candidate events using information from Tracker, TOF and ECAL.
- Calculate the efficiency of a **matching** TRD Track being reconstructed.
- The difference between **Monte Carlo** and **Data** determines the correction $\boldsymbol{\delta_i}$.



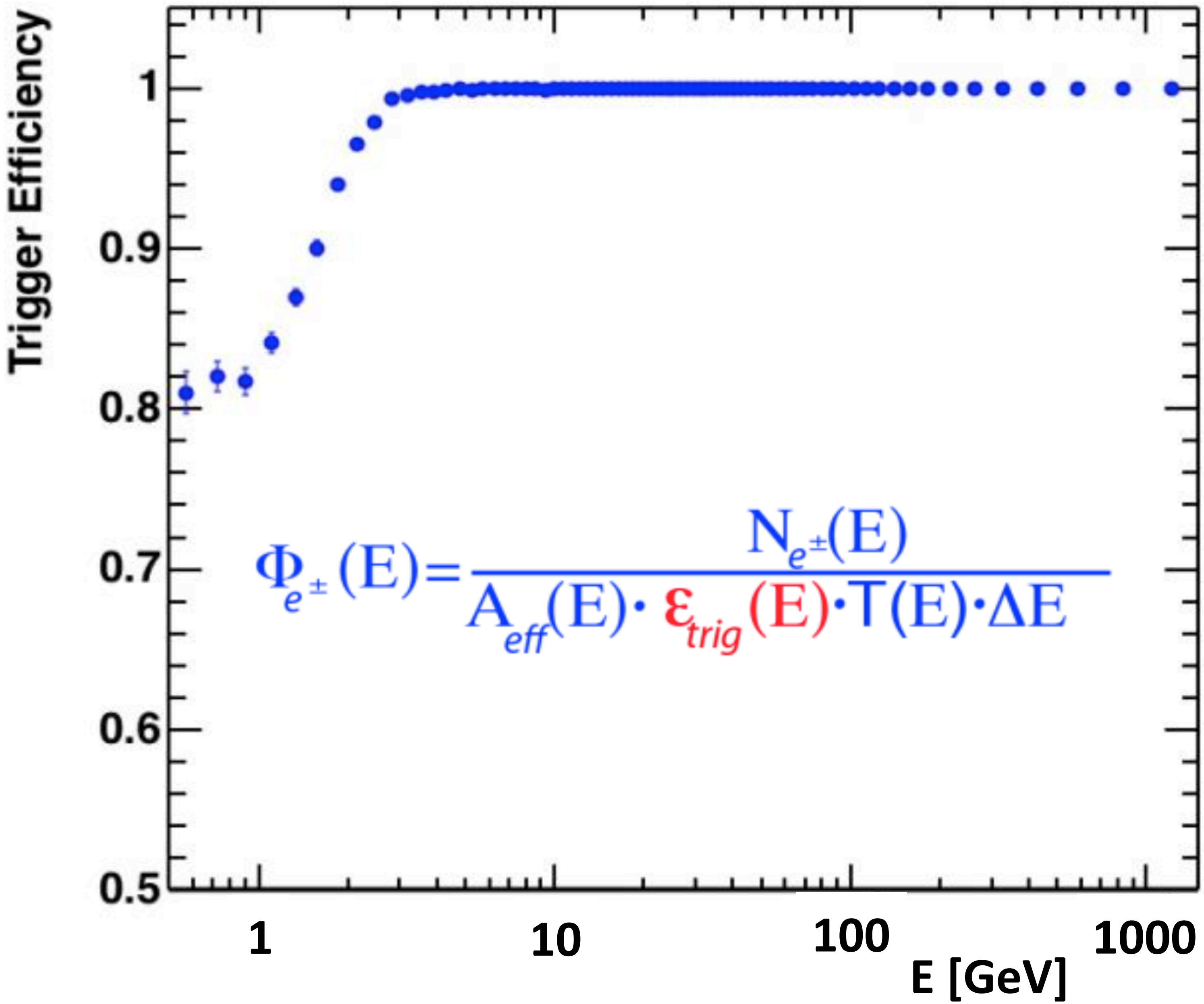
$e^{\pm}$ Identification: E/p





Effective Acceptance
A_eff [cm² sr]
Energy [GeV]
Correction 1+δ
1+δ
Energy [GeV]

Determined from ISS data using the unbiased trigger sample.

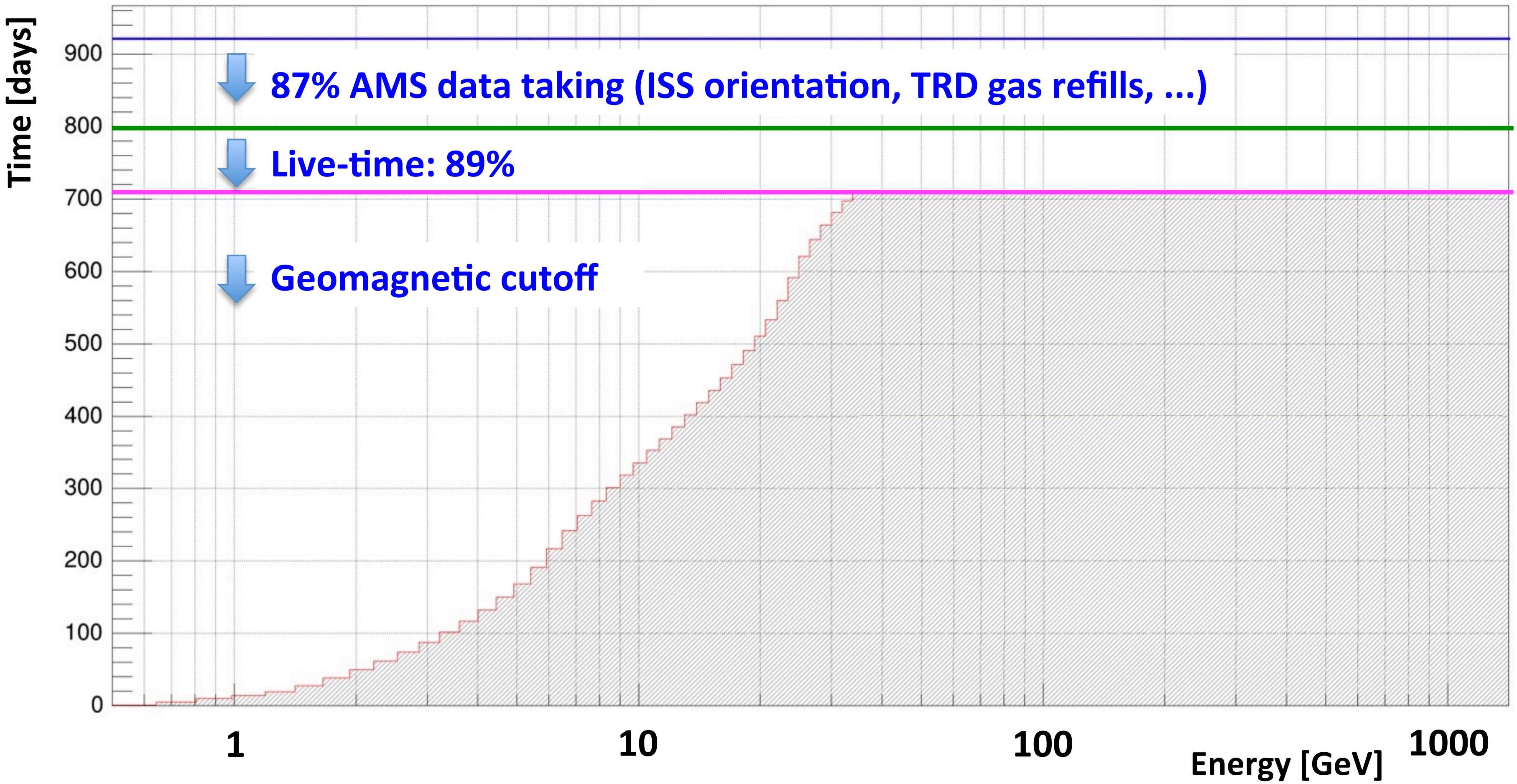


$$\Phi_{e^\pm}(E) = \frac{N_{e^\pm}(E)}{A_{eff}(E) \cdot \varepsilon_{trig}(E) \cdot T(E) \cdot \Delta E}$$

Data taking time

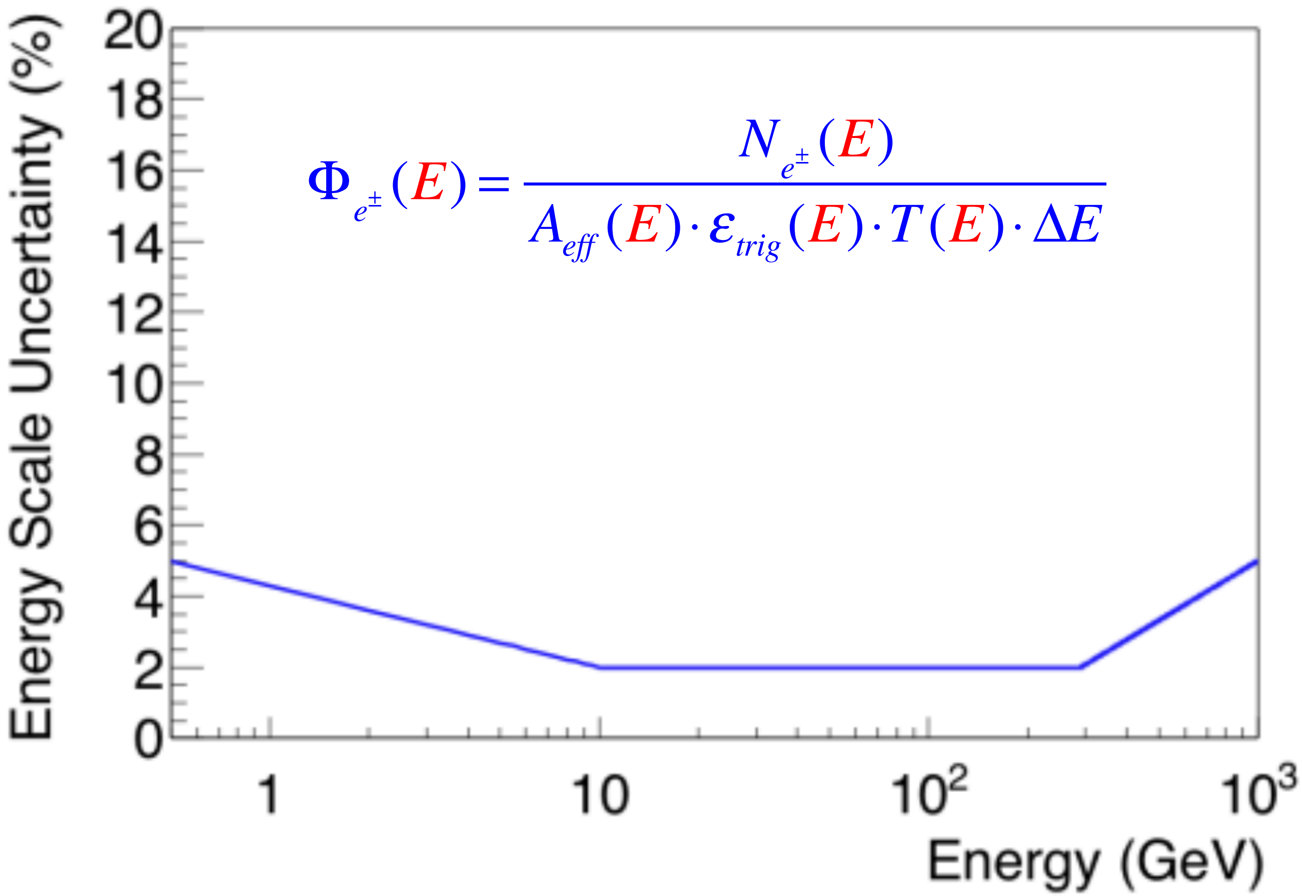
$$\Phi_{e^\pm}(E) = \frac{N_{e^\pm}(E)}{A_{eff}(E)\cdot\varepsilon_{trig}(E)\cdot T(E)\cdot\Delta E}$$

- We have analyzed data taken from 19 May 2011 to 26 November 2013 ⇔ 921 days.
- Due to the geomagnetic cutoff the exposure time is energy dependent.
- The exposure time is for energies above 30 GeV constant 708 days ⇔ $61 \cdot 10^6$ seconds



Absolute Energy Scale for $e^{\pm}$ (at the top of AMS)

Verified using MIPs and E/p; compared to the test beam.
In the test beam range (10-290 GeV) the uncertainity is 2%.
It increases to 5% at 0.5 GeV and 1 TeV.



$$\Phi_{e^{\pm}}(E) = \frac{N_{e^{\pm}}(E)}{A_{eff}(E) \cdot \varepsilon_{trig}(E) \cdot T(E) \cdot \Delta E}$$

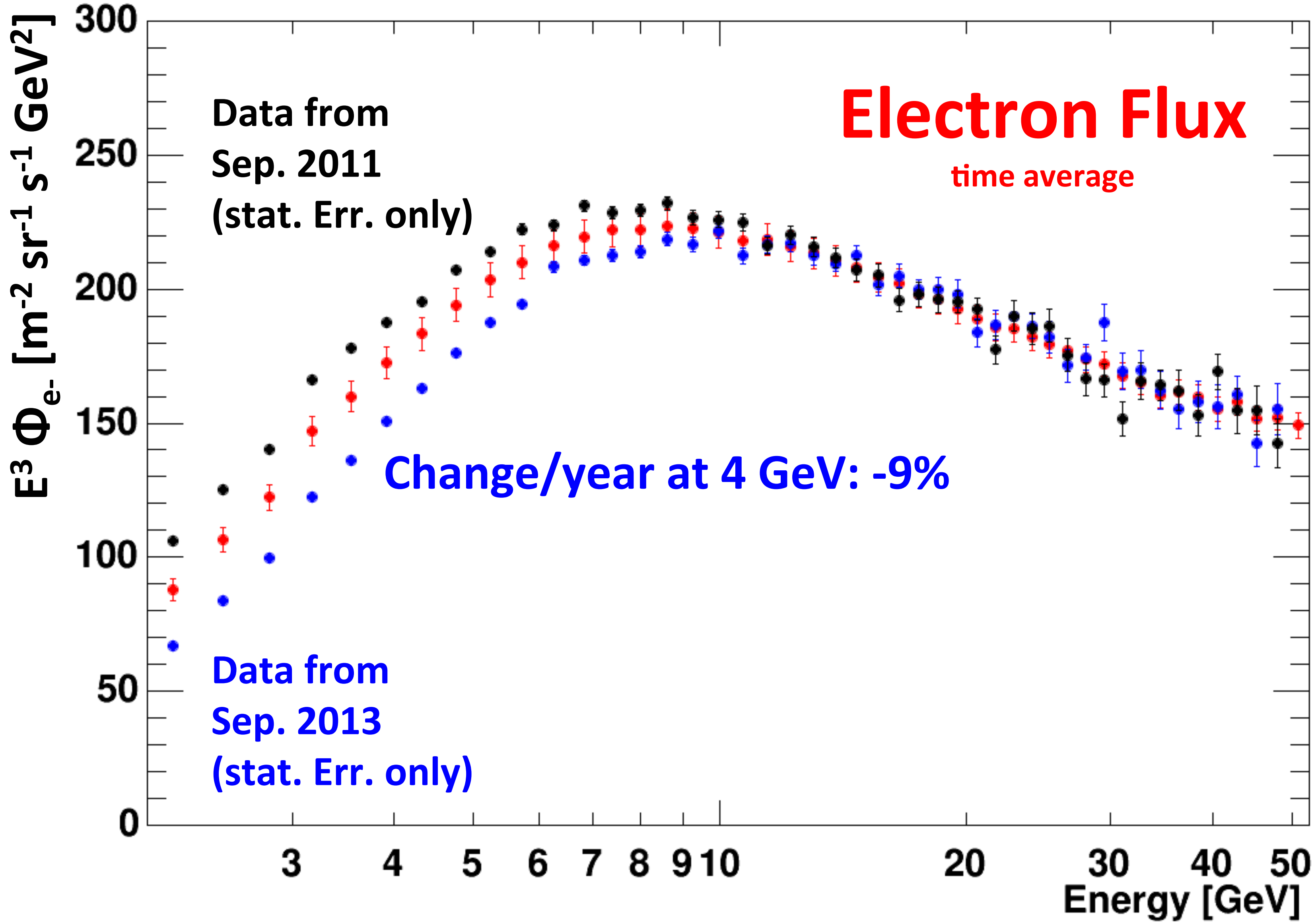
PRL **113,** 121102 (2014) PHYSICAL REVIEW LETTERS week ending 19 SEPTEMBER 2014

Electron and Positron Fluxes in Primary Cosmic Rays Measured with the Alpha Magnetic Spectrometer on the International Space Station

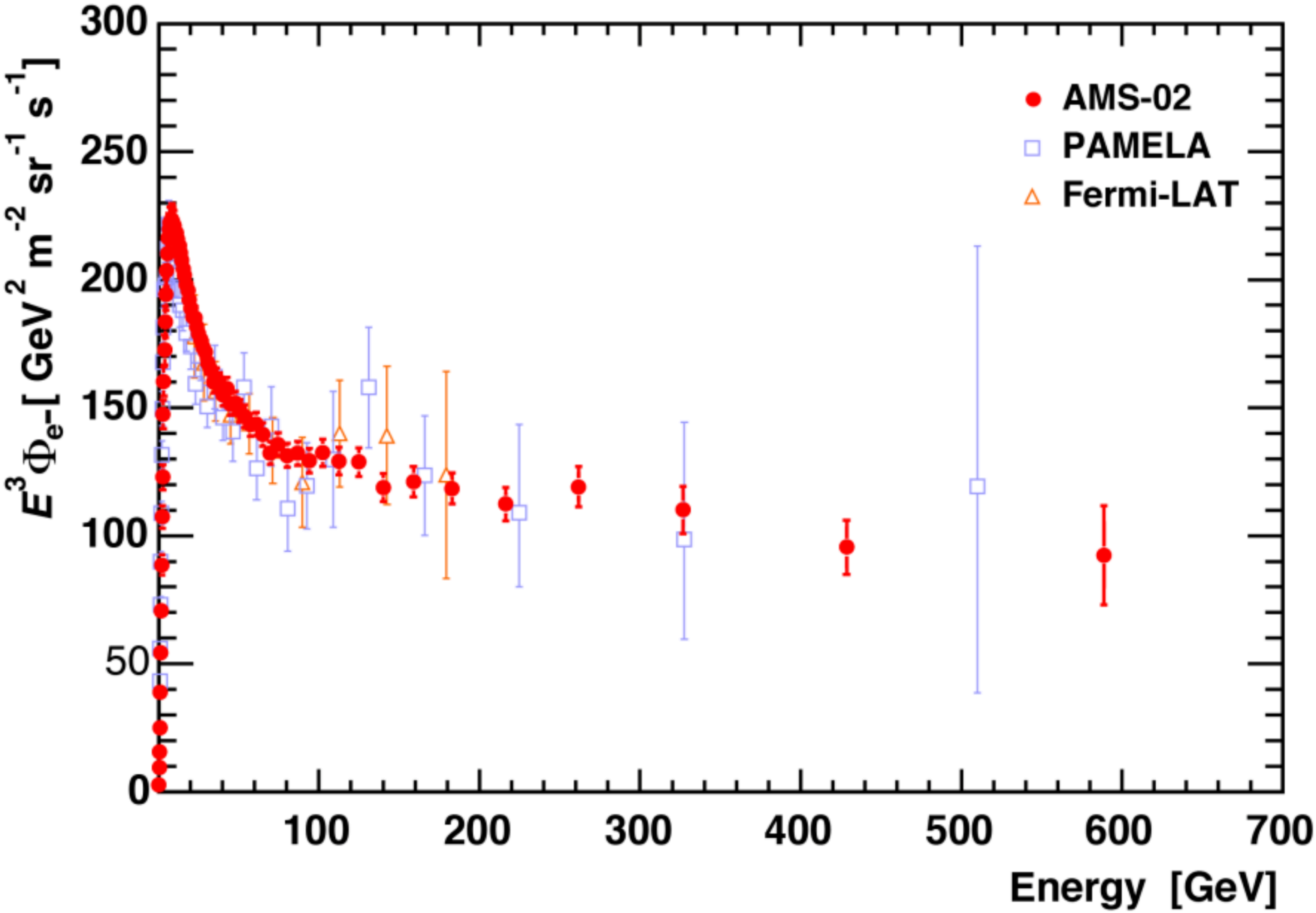
Energy (GeV)	$\tilde{E}$ (GeV)	$[m^2\ sr\ s\ GeV]^{-1}$ $\Phi_{e^-} \pm \sigma_{stat} \pm \sigma_{syst}$		$[m^2\ sr\ s\ GeV]^{-1}$ $\Phi_{e^+} \pm \sigma_{stat} \pm \sigma_{syst}$	
52.3–55.6	53.9 ± 1.1	$(9.35 \pm 0.12 \pm 0.26) \times 10^{-4}$	**±~3%**	$(9.37 \pm 0.42 \pm 0.27) \times 10^{-5}$	**±~5%**
55.6–59.1	57.3 ± 1.1	$(7.61 \pm 0.10 \pm 0.21) \times 10^{-4}$		$(7.55 \pm 0.36 \pm 0.22) \times 10^{-5}$	
59.1–63.0	61.0 ± 1.2	$(6.32 \pm 0.09 \pm 0.18) \times 10^{-4}$		$(6.53 \pm 0.32 \pm 0.19) \times 10^{-5}$	
63.0–67.3	65.1 ± 1.3	$(5.05 \pm 0.08 \pm 0.14) \times 10^{-4}$		$(5.41 \pm 0.28 \pm 0.16) \times 10^{-5}$	
67.3–72.0	69.6 ± 1.4	$(3.92 \pm 0.07 \pm 0.11) \times 10^{-4}$		$(4.78 \pm 0.25 \pm 0.14) \times 10^{-5}$	
72.0–77.4	74.6 ± 1.5	$(3.26 \pm 0.06 \pm 0.10) \times 10^{-4}$		$(3.89 \pm 0.21 \pm 0.12) \times 10^{-5}$	
77.4–83.4	80.3 ± 1.6	$(2.54 \pm 0.05 \pm 0.08) \times 10^{-4}$		$(2.88 \pm 0.17 \pm 0.09) \times 10^{-5}$	
83.4–90.2	86.7 ± 1.7	$(2.03 \pm 0.04 \pm 0.06) \times 10^{-4}$		$(2.76 \pm 0.16 \pm 0.09) \times 10^{-5}$	
90.2–98.1	94.0 ± 1.9	$(1.56 \pm 0.03 \pm 0.05) \times 10^{-4}$		$(2.08 \pm 0.13 \pm 0.07) \times 10^{-5}$	
98.1–107	103 ± 2	$(1.23 \pm 0.03 \pm 0.04) \times 10^{-4}$	**±~4%**	$(1.53 \pm 0.10 \pm 0.06) \times 10^{-5}$	**±~7%**
107–118	113 ± 2	$(9.02 \pm 0.21 \pm 0.31) \times 10^{-5}$		$(1.15 \pm 0.08 \pm 0.04) \times 10^{-5}$	
118–132	125 ± 3	$(6.59 \pm 0.16 \pm 0.23) \times 10^{-5}$		$(8.56 \pm 0.66 \pm 0.33) \times 10^{-6}$	
132–149	140 ± 3	$(4.32 \pm 0.12 \pm 0.16) \times 10^{-5}$		$(6.21 \pm 0.53 \pm 0.25) \times 10^{-6}$	
149–170	159 ± 3	$(3.02 \pm 0.09 \pm 0.11) \times 10^{-5}$		$(5.23 \pm 0.45 \pm 0.22) \times 10^{-6}$	
170–198	183 ± 4	$(1.93 \pm 0.07 \pm 0.07) \times 10^{-5}$		$(3.19 \pm 0.32 \pm 0.14) \times 10^{-6}$	
198–237	216 ± 4	$(1.11 \pm 0.04 \pm 0.05) \times 10^{-5}$		$(2.08 \pm 0.23 \pm 0.10) \times 10^{-6}$	
237–290	262 ± 5	$(6.64 \pm 0.31 \pm 0.31) \times 10^{-6}$		$(1.21 \pm 0.17 \pm 0.07) \times 10^{-6}$	
290–370	327 ± 7	$(3.15 \pm 0.19 \pm 0.19) \times 10^{-6}$		$(6.17 \pm 1.20 \pm 0.38) \times 10^{-7}$	
370–500	429 ± 13	$(1.21 \pm 0.10 \pm 0.09) \times 10^{-6}$	**±~11%**	$(2.47 \pm 0.73 \pm 0.22) \times 10^{-7}$	**±~30%**
500–700	589 ± 22	$(4.53 \pm 0.64 \pm 0.70) \times 10^{-7}$			

- **For the positron flux, the statistical error dominates above ~50 GeV.**
- **For the electron flux above ~200 GeV, the systematic error and the statistical error are compatible.**

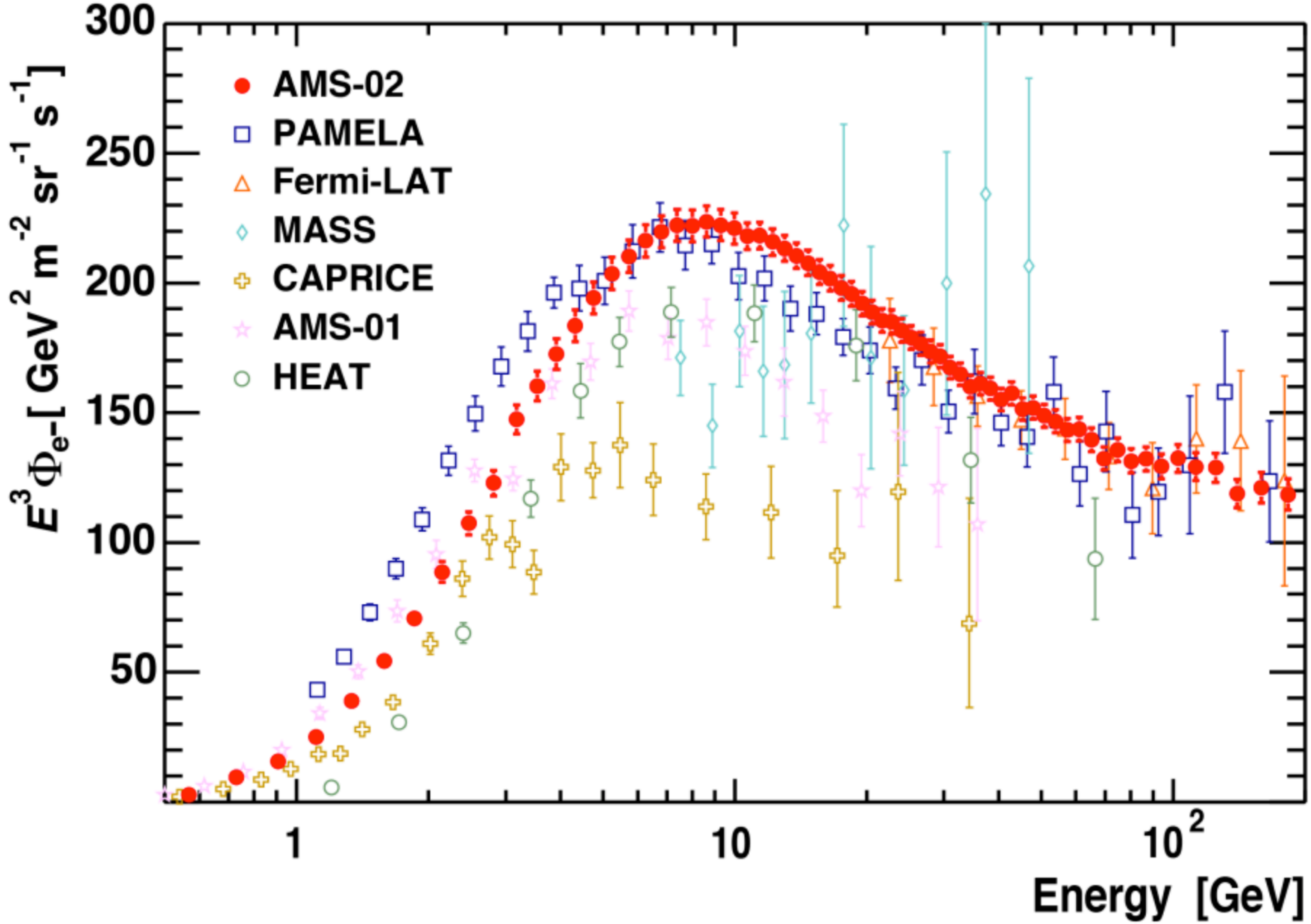
Time Dependence (to be published)



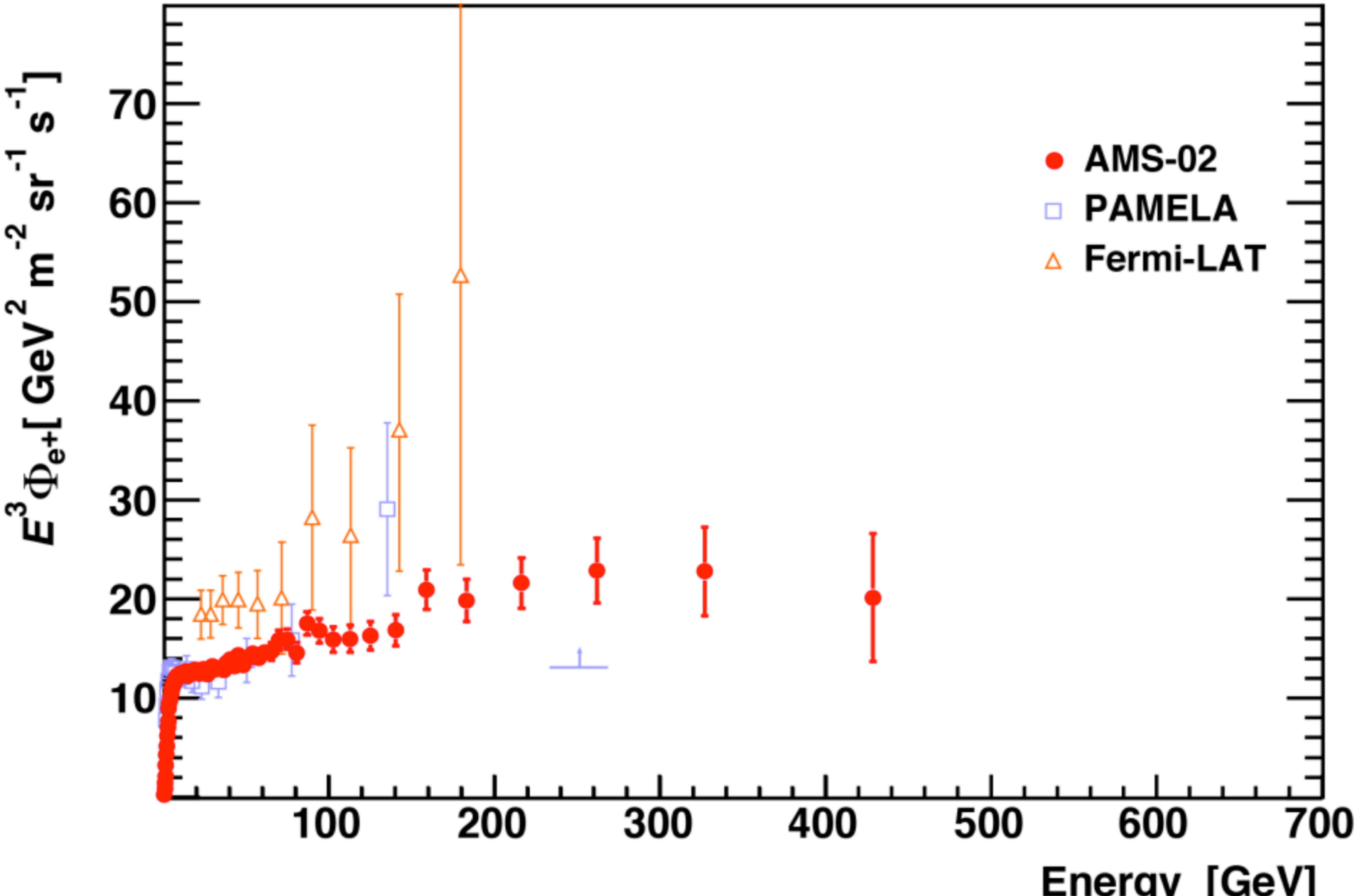
Electron Flux



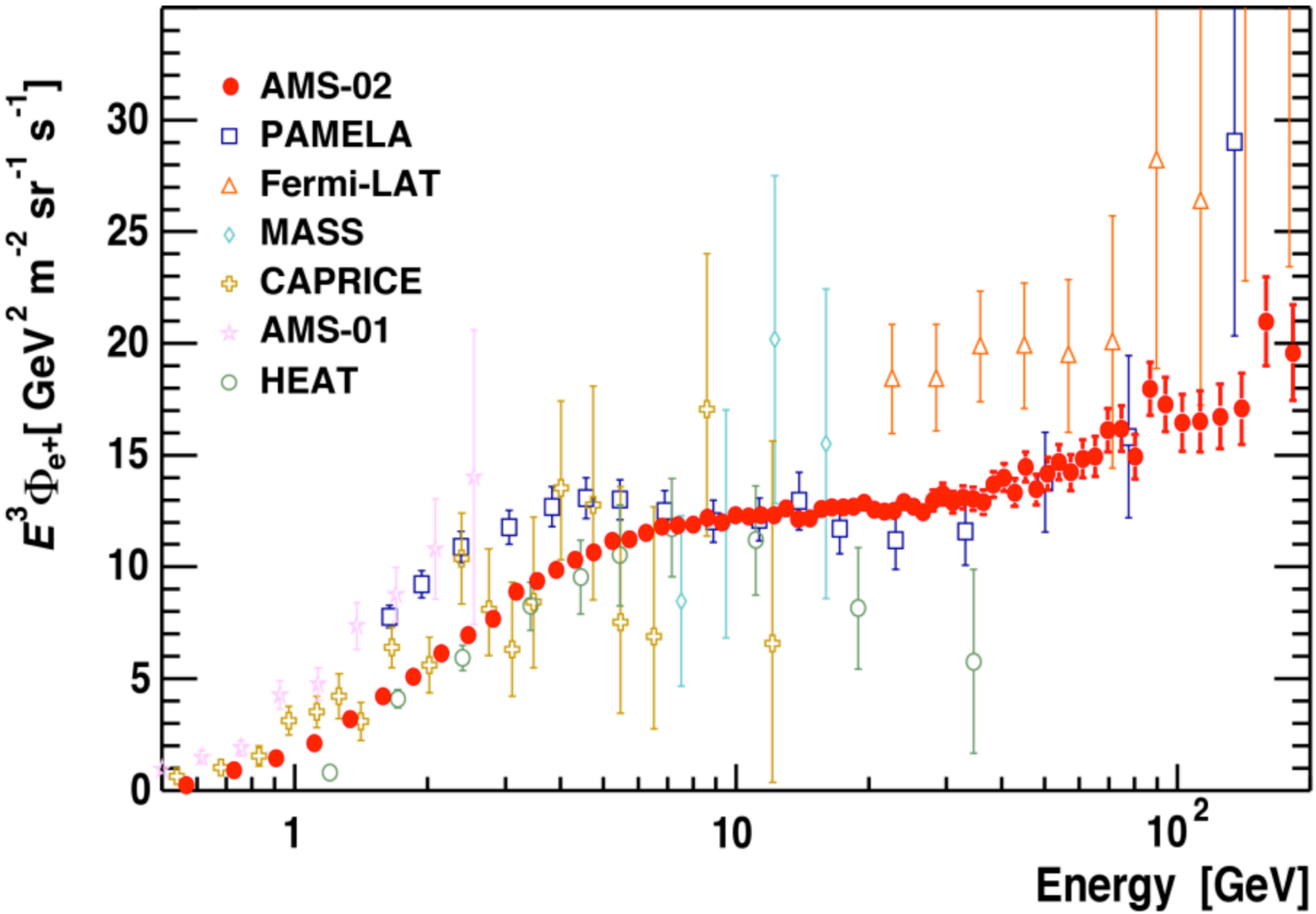
Electron Flux

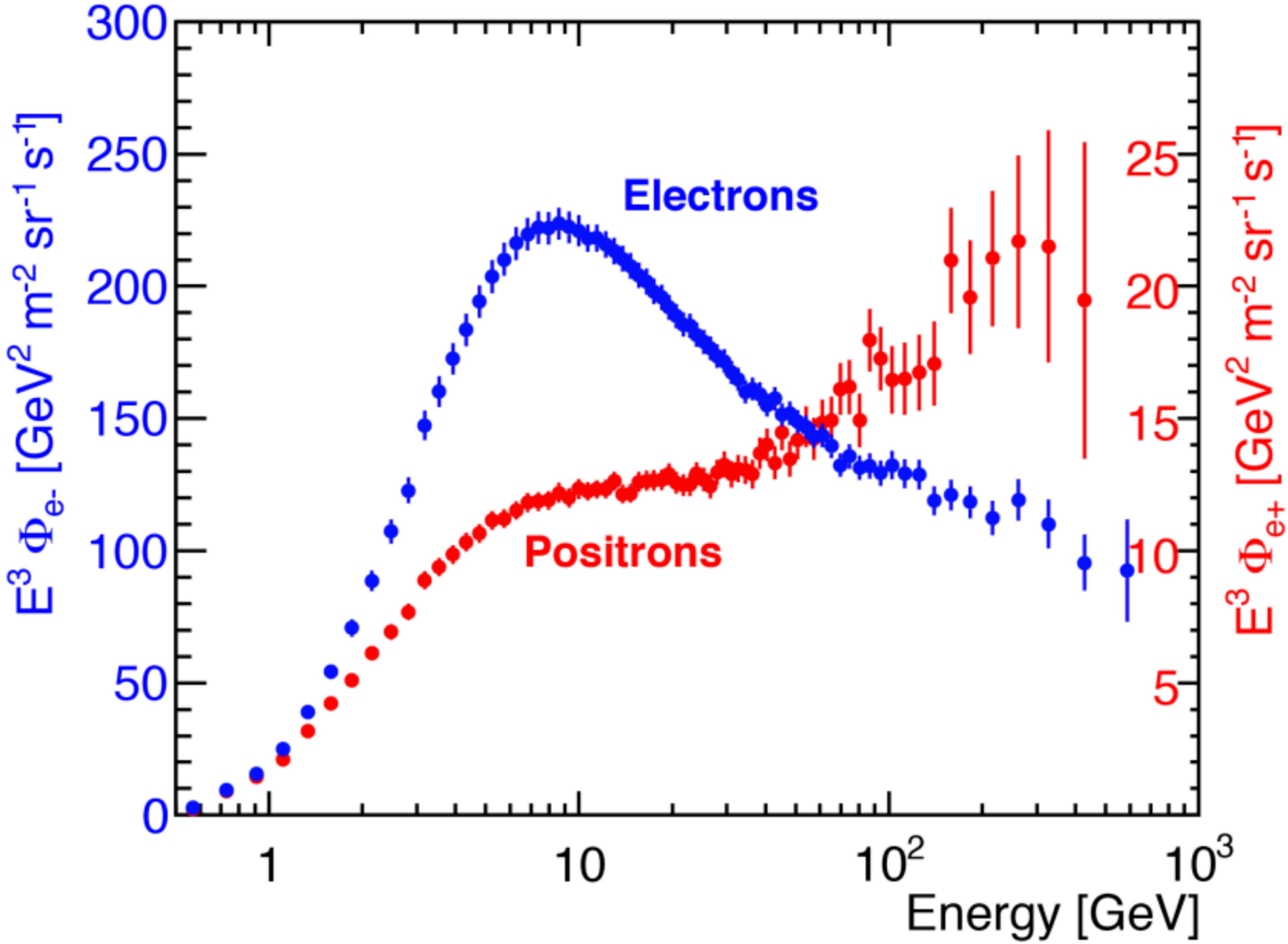


Positron Flux



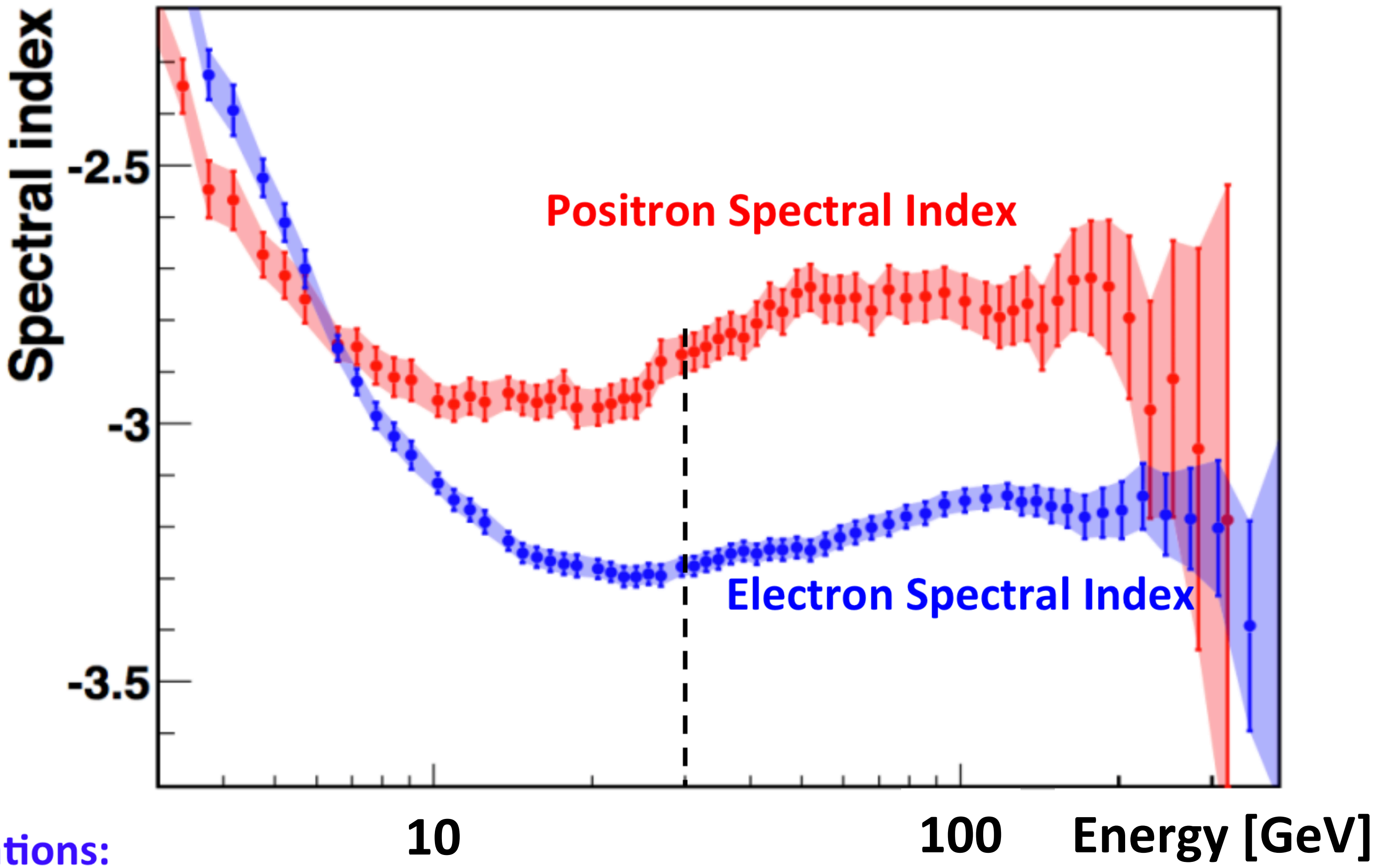
Positron Flux





Conclusion: The electron flux and the positron flux are different in their magnitude and energy dependence.

Spectral indices (E^{γ}) of electron and positron fluxes



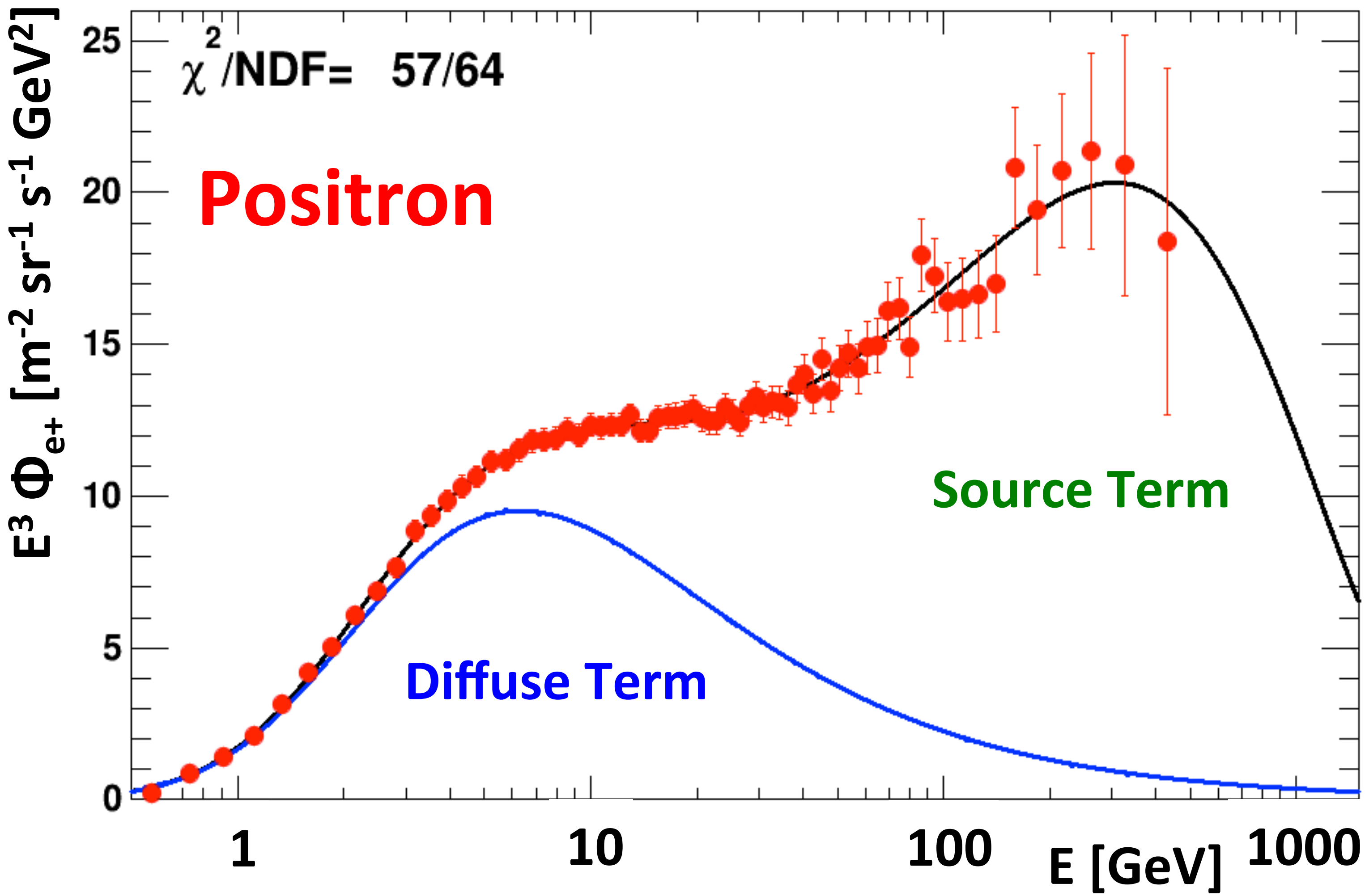
Observations:

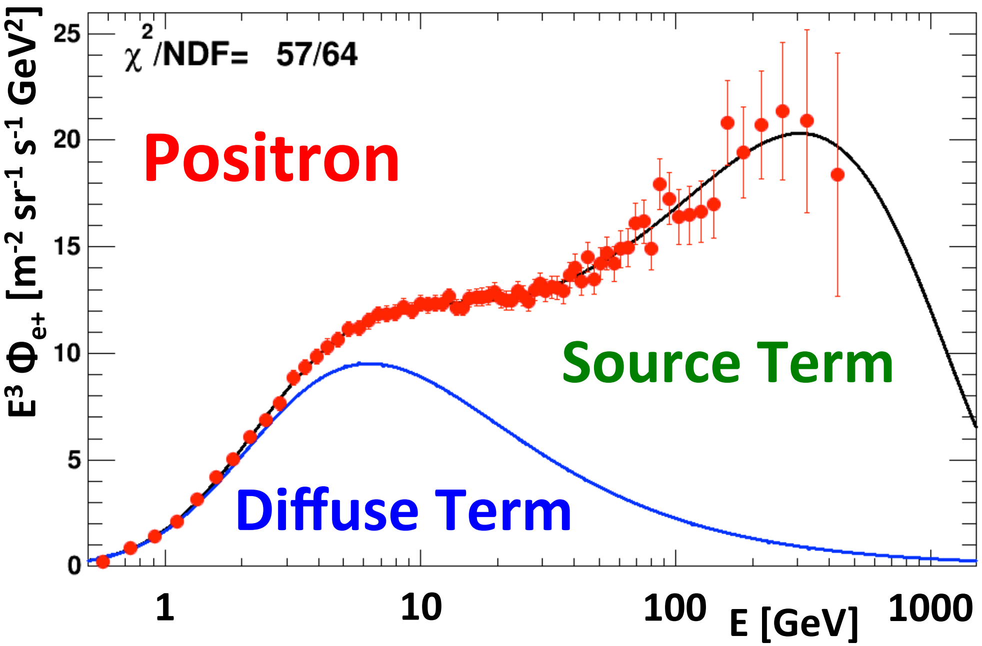
1. Both spectra cannot be described by single power laws.
2. The spectral indices of electrons and positrons are different.
3. Both change their behavior at ~30GeV.
4. The rise in the positron fraction from 20 GeV is due to an excess of positrons, not the loss of electrons (the positron flux is harder).

$$\Phi_{e+}(E) = \frac{E^2}{\hat{E}^2}\left[C_{e+}\hat{E}^{\gamma_{e+}} + C_S\hat{E}^{\gamma_S}\exp(-\hat{E}/E_S)\right]$$

with $E_S = 540$ GeV from the $e^+/(e^+ + e^-)$ fit and $\hat{E}$ as the energy scale of the LIS

The Positron Flux has no sharp structures and is dominated at high energies by the source term.



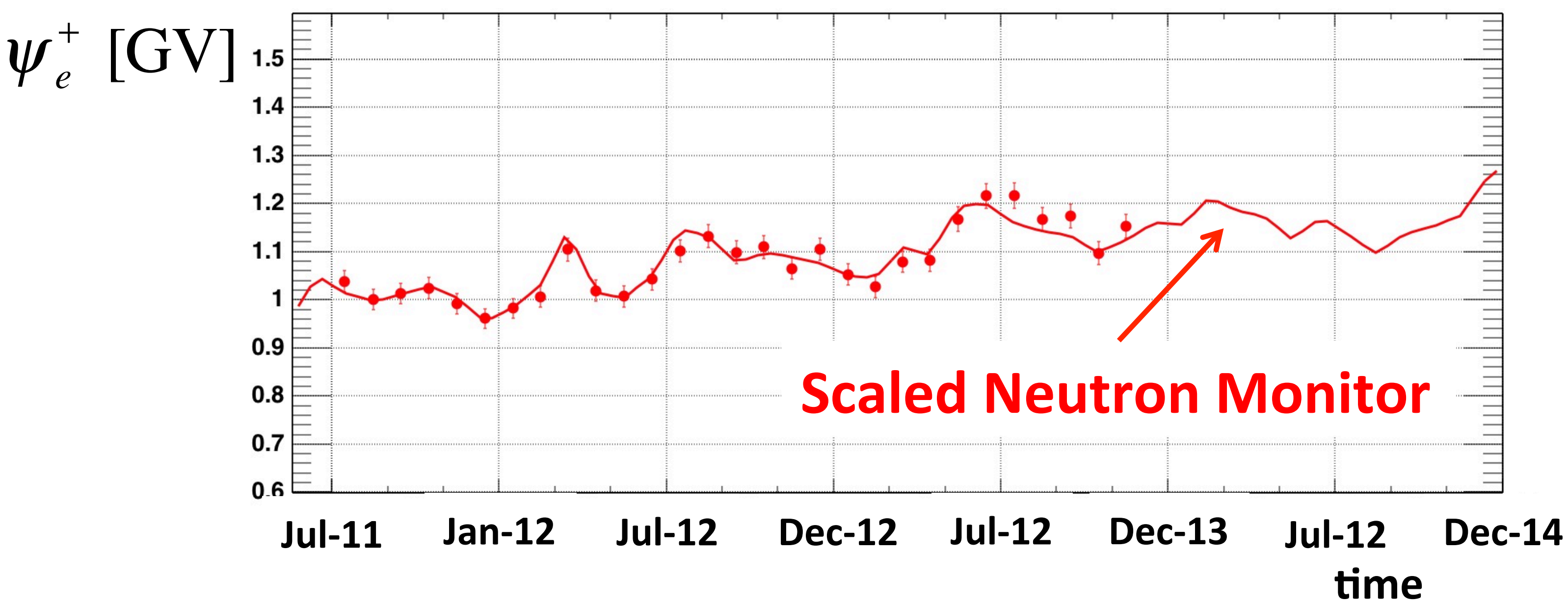


$$\Phi_{e+}(E) = \frac{E^2}{\hat{E}^2}\left[C_{e+}\hat{E}^{\gamma_{e+}} + C_S \hat{E}^{\gamma_S} \exp(-\hat{E}/E_S)\right]$$

$$\hat{E} = E + \psi_e^+(t)$$

- **Within this ansatz only one parameter has to be time dependent:**

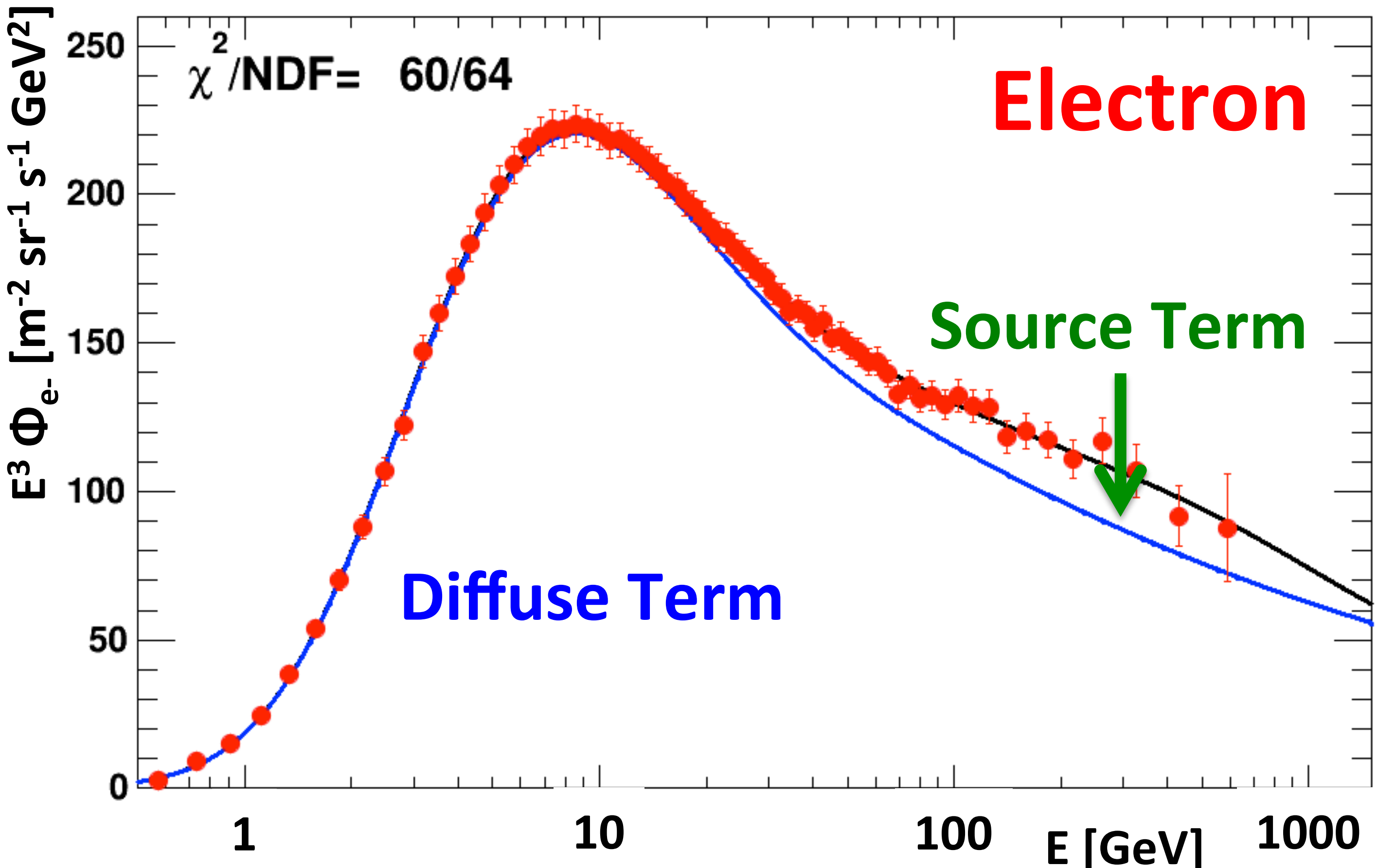
  $\psi_e^+(t)$, which describes the solar modulation.



The spectral index of the diffuse term has to become energy dependent:

$$\Phi_{e-}(E) = \frac{E^2}{\hat{E}^2}\left[C_{e-}\hat{E}^{\gamma_{e-}(\hat{E})} + C_S\hat{E}^{\gamma_S}\exp(-\hat{E}/E_S)\right]$$

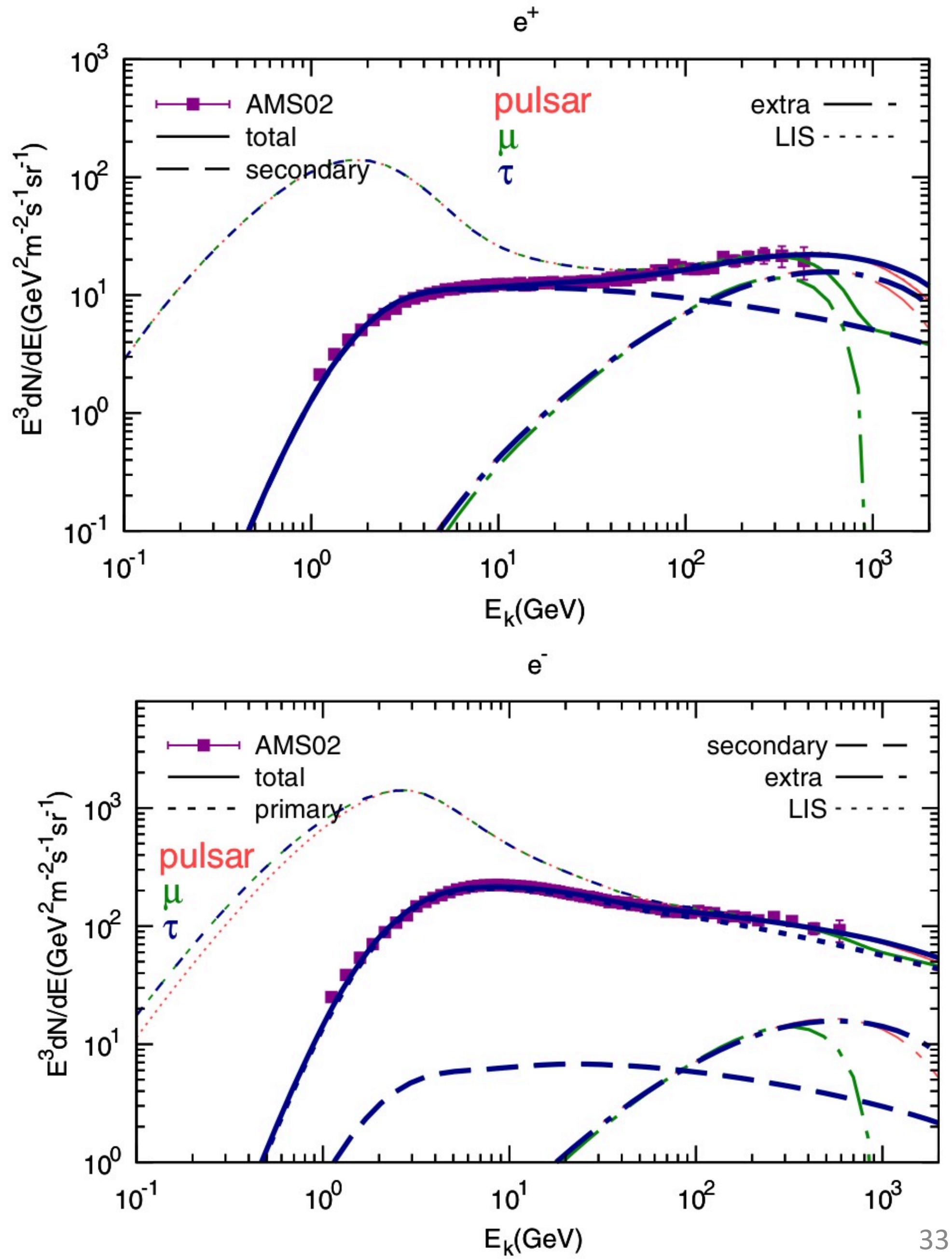
The source term parameters are constrained from the positron flux fit.



The Electron Flux

- has no sharp structures and is dominated by the diffuse term.
- is consistent with a charge symmetric source term.

S. Lin, Q. Yuan, and X.-J. Bi
PHYSICAL REVIEW D 91, 063508 (2015)



- **Since September 2014 our publication [PRL 113, 121102 (2014)] has been cited many times.**
- **The models to explain the observed spectral features can be divided into two catergories:**
  1. **New astrophysical processes in cosmic ray acceleration and/or propagation.**
  2. **Dark Matter annihilation or decay.**
- **A typical example is shown on the right.**
- **We are pleased to have the world leading experts with us during these days to discuss these aspects in detail.**

Summary

1. Both the Electron Flux and the Positron Flux are significantly different in their magnitude and energy dependence.

2. Neither the Electron Flux nor the Positron Flux has any sharp structure.

3. Both Fluxes can not be described by a single power law.

4. Both spectra are consistent with a charge symmetric and time independent source term with a cutoff at E_s=540 GeV.

5. AMS will be able to extend these measurements to the TeV scale.