Measuring the e^+ / e^- fluxes with AMS-02 on the ISS

Nikolas Zimmermann | 1. Physikalisches Institut B

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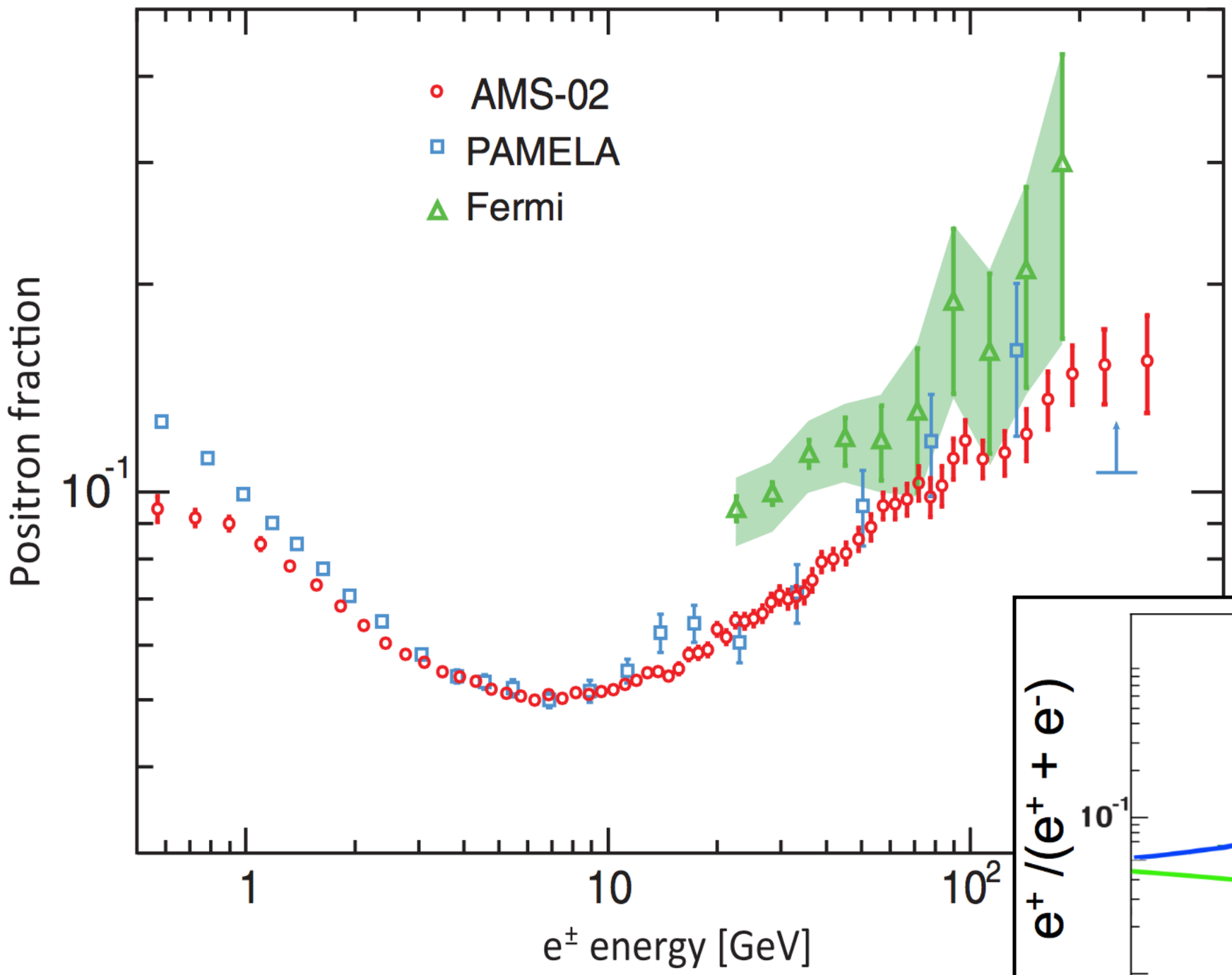
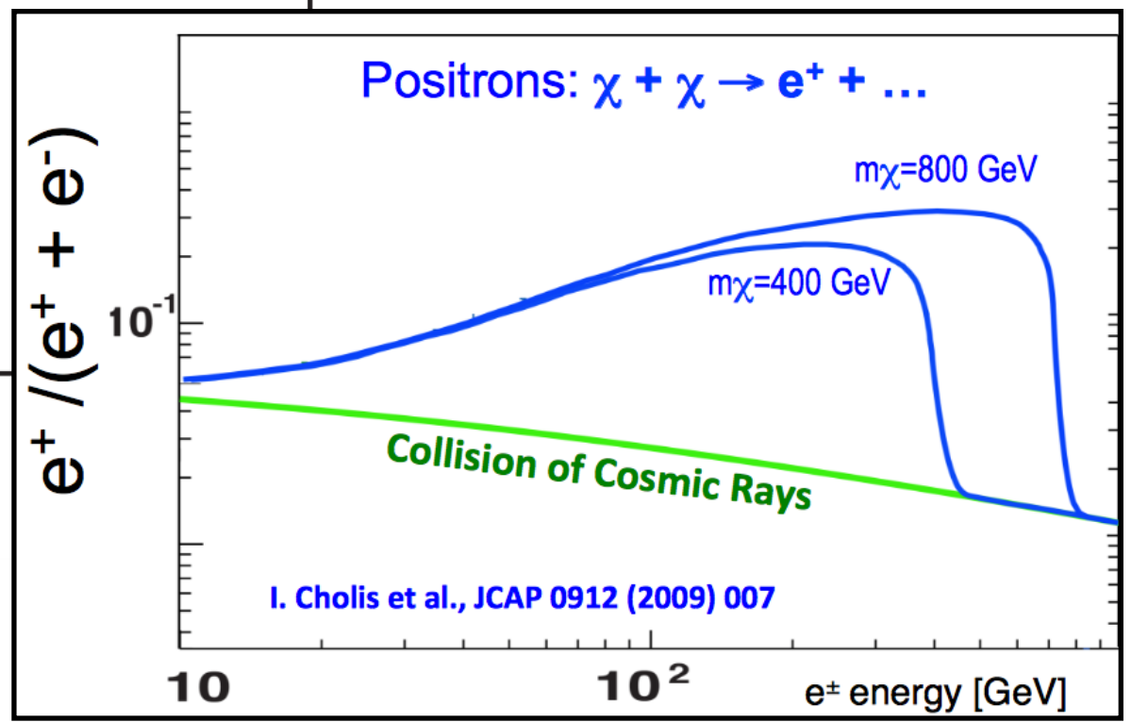
Motivation

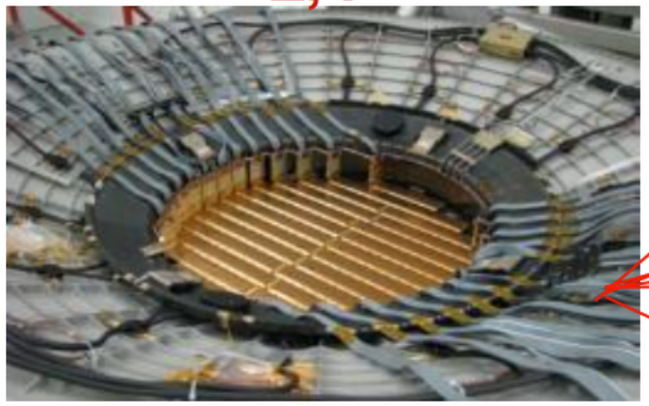

AMS-02
PAMELA
Fermi
Positron fraction
10^{-1}
1
10
10^2
$e^{\pm}$ energy [GeV]


Positrons: $\chi + \chi \rightarrow e^+ + \ldots$
m_χ=800 GeV
m_χ=400 GeV
Collision of Cosmic Rays
I. Cholis et al., JCAP 0912 (2009) 007
$e^+/(e^+ + e^-)$
10^{-1}
10
10^2
$e^{\pm}$ energy [GeV]

AMS-02: A TeV precision multipurpose spectrometer

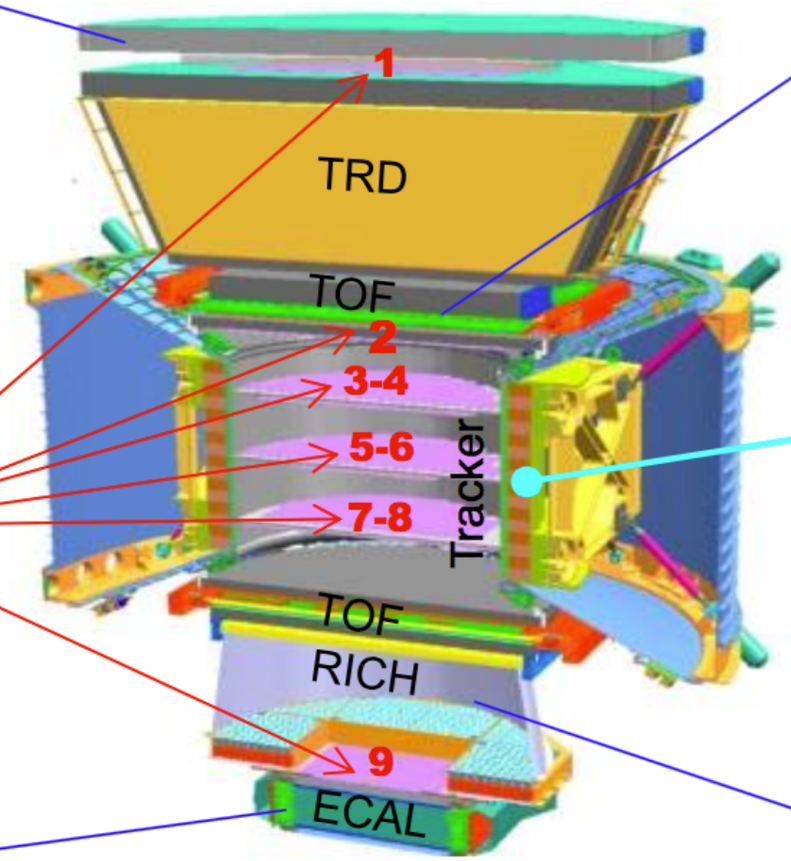
TRD
Identify e^+, e^-

Silicon Tracker
Z, P



ECAL
E of e^+, e^-

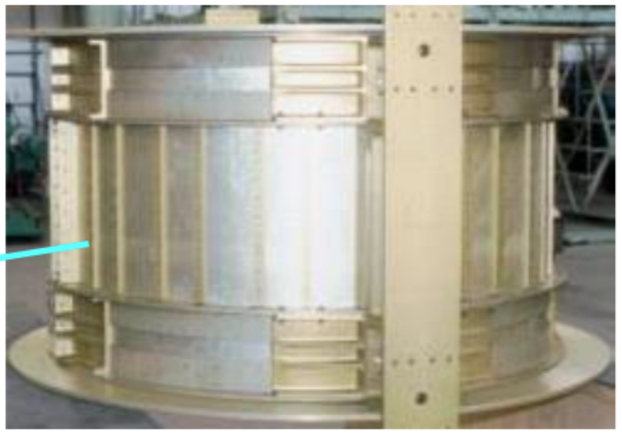
Particles and nuclei are defined by their charge (Z) and energy (E ~ P)



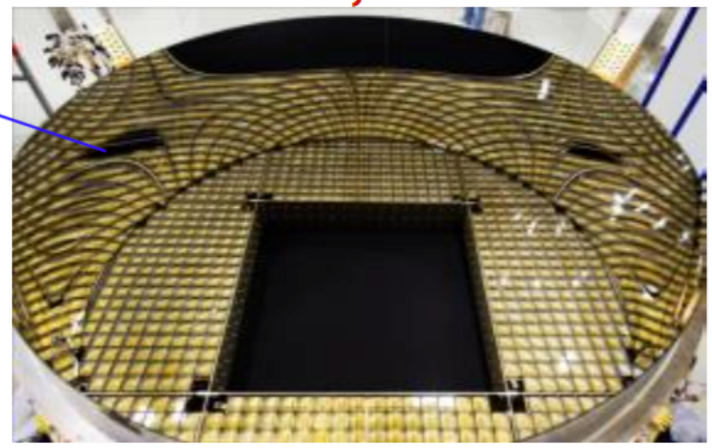
Z and P
are measured independently by the Tracker, RICH, TOF and ECAL

TOF
Z, E

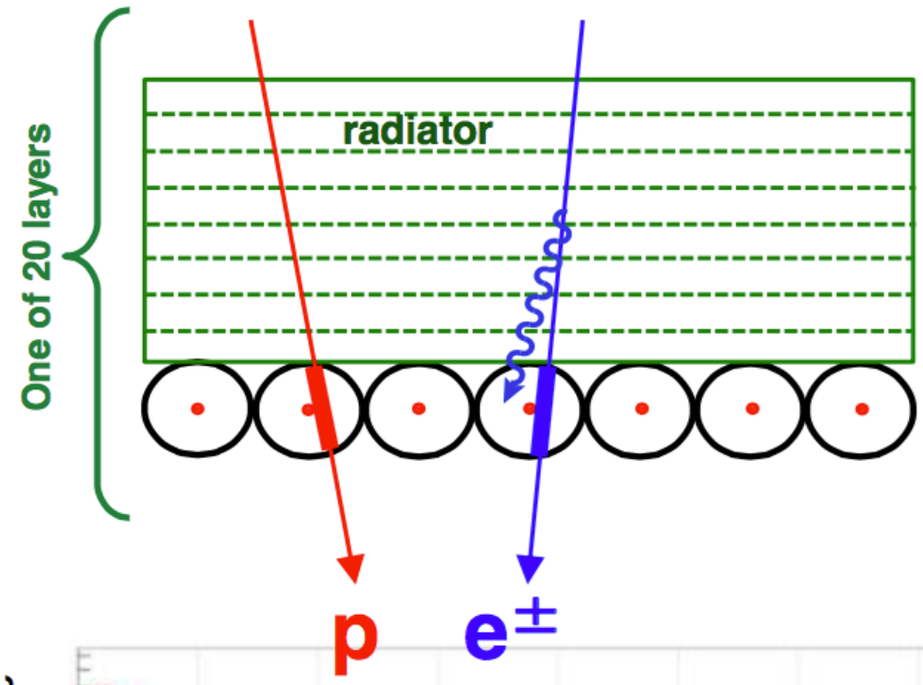
Magnet
±Z



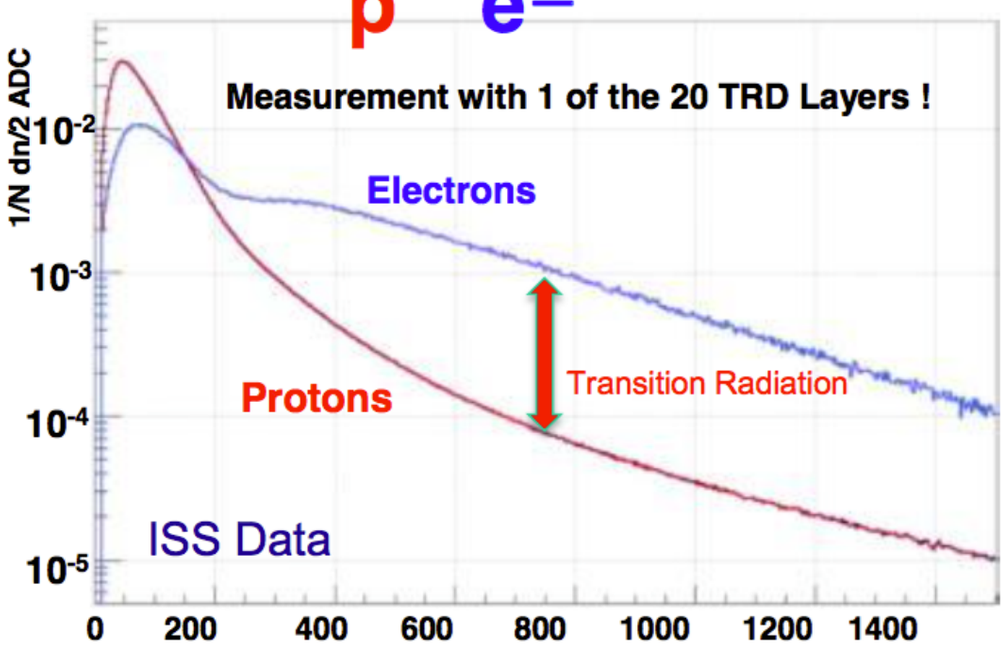
RICH
Z, E



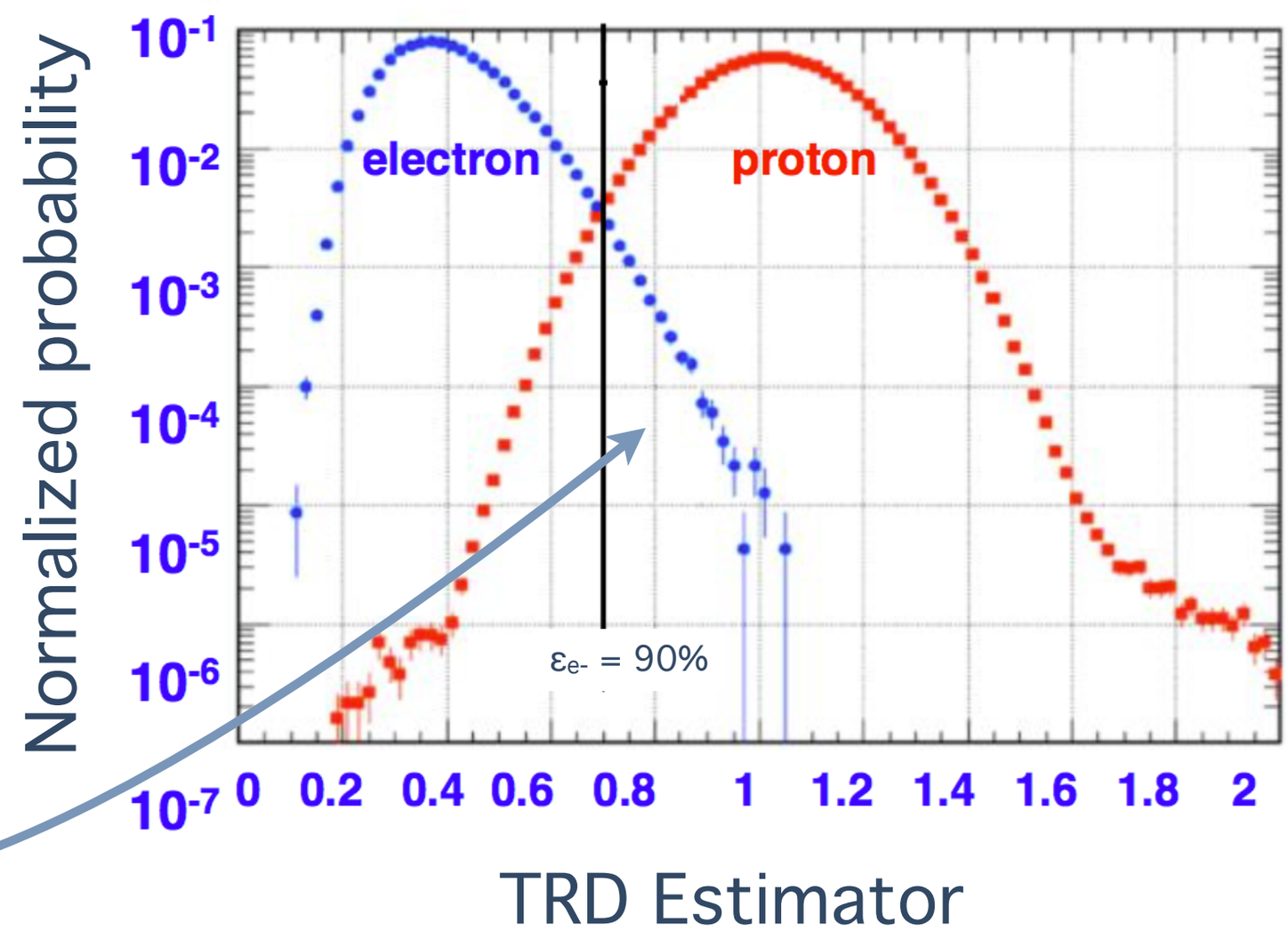
AMS-02 Transition Radiation Detector



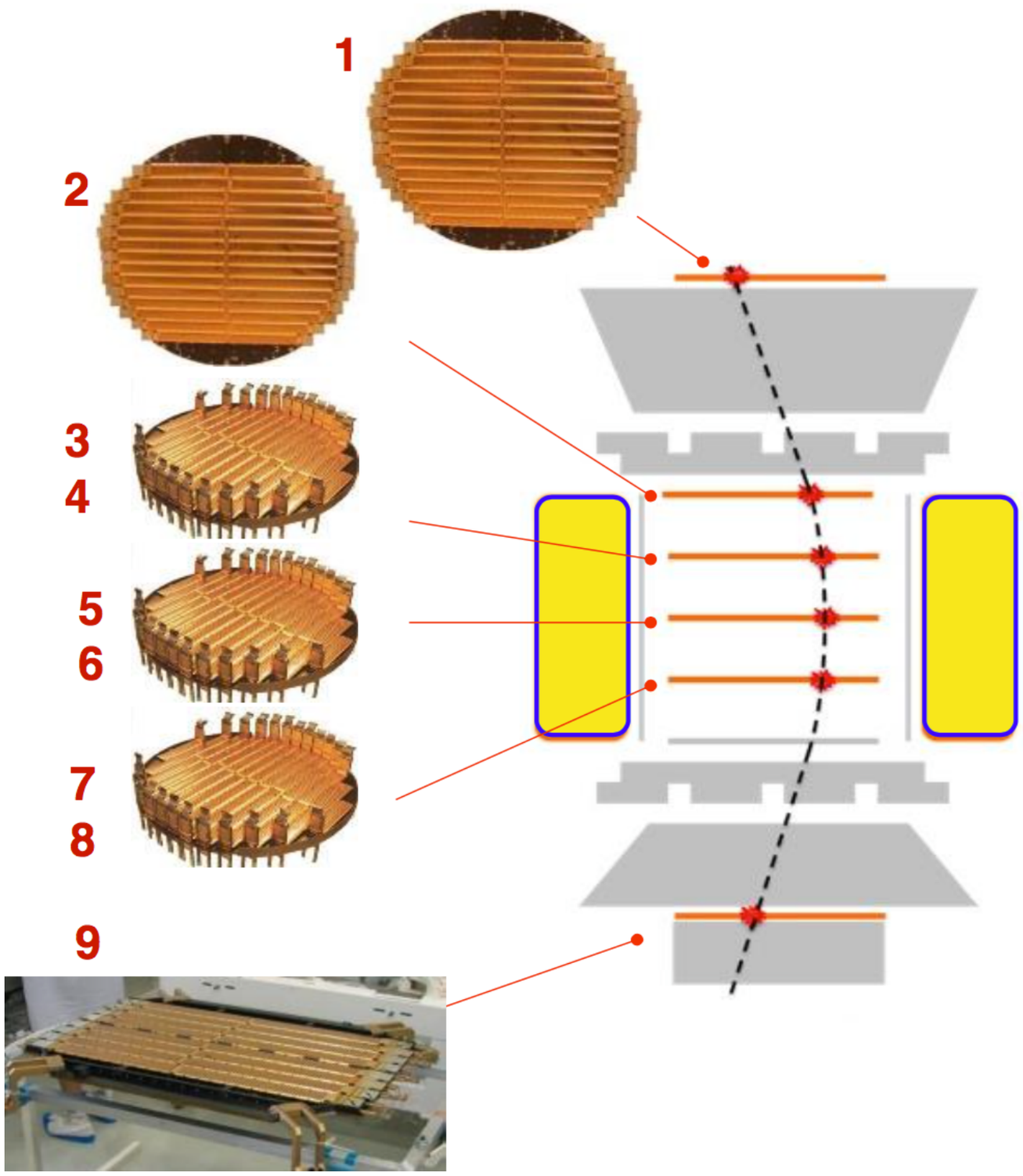
- 20 layers (5248 tubes)
- Xe/CO_2 gas mixture



ISS data 83 - 100 GeV

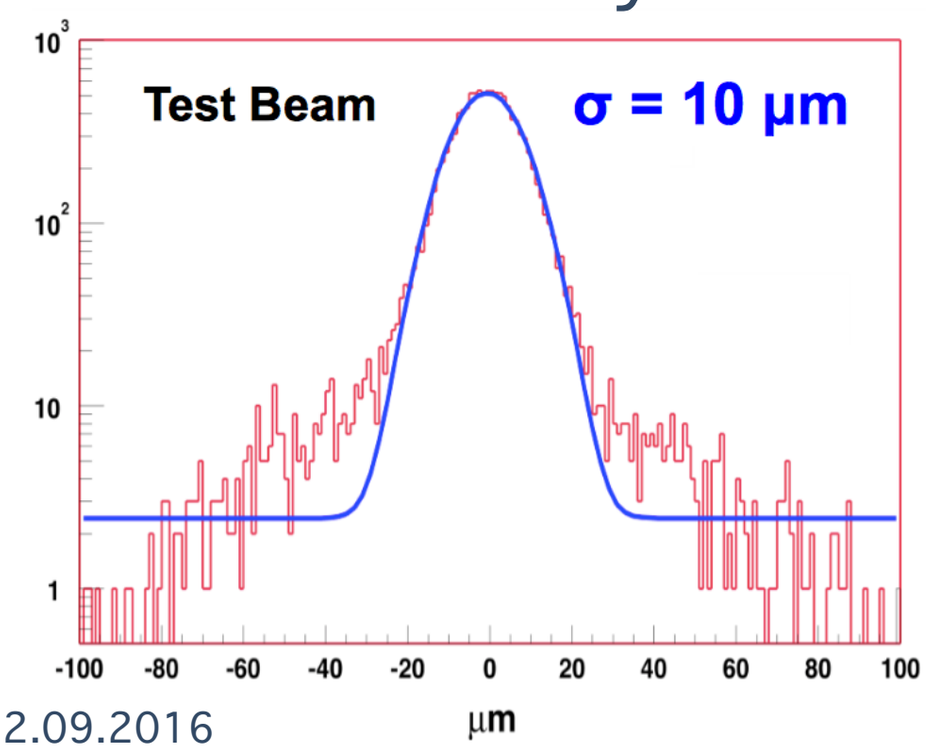


AMS-02 Sillicon Tracker



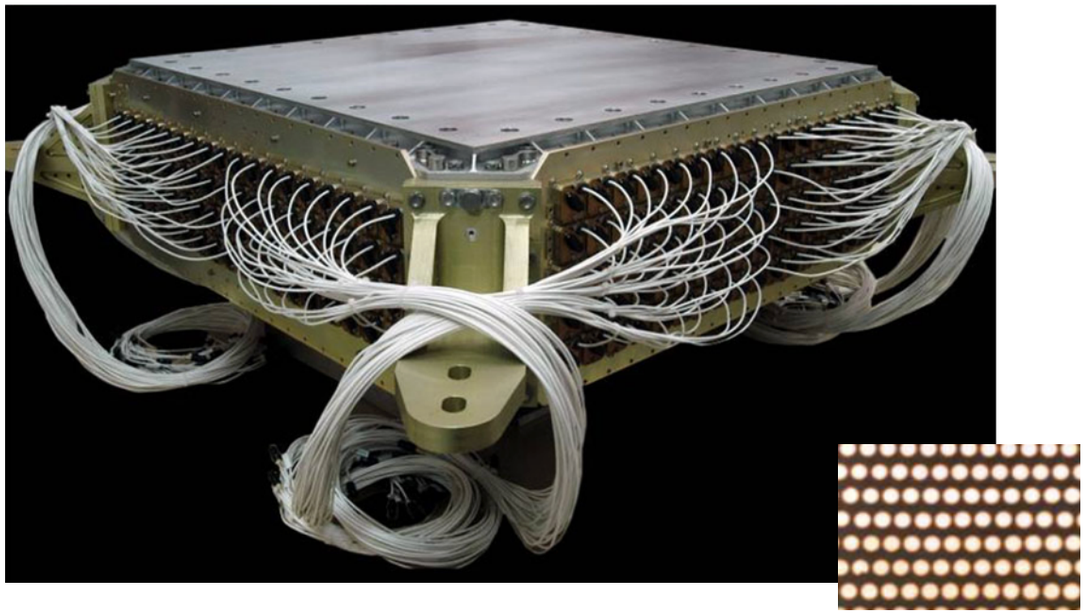
- 9 tracker planes
- Coordinate resolution 10 µm
- Inner tracker alignment stability monitored using IR laser beam
- Outer tracker planes (1 / 9) aligned using cosmic-rays in 2 minute window
- MDR ~ 2 TV for electrons

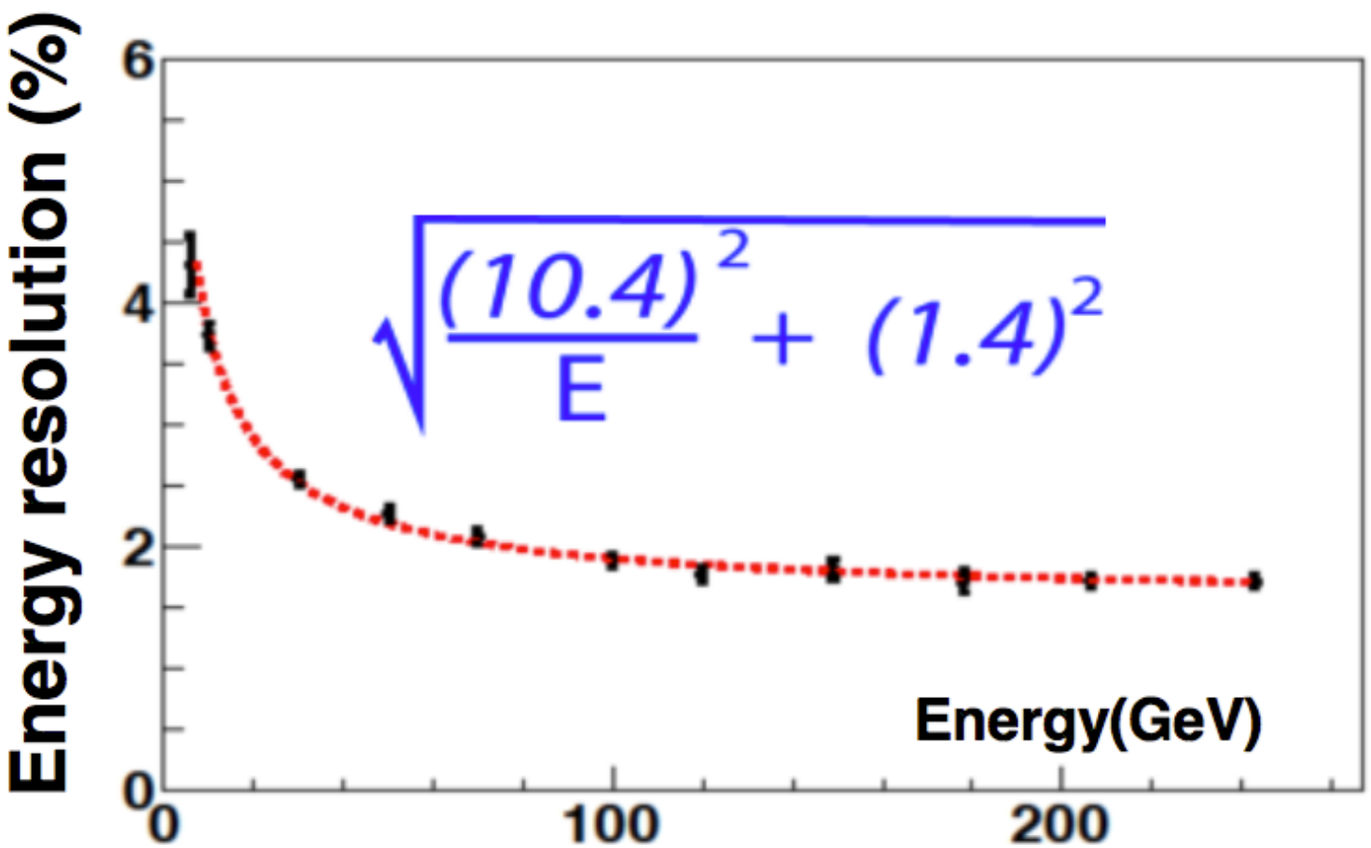
Residual in layer 1

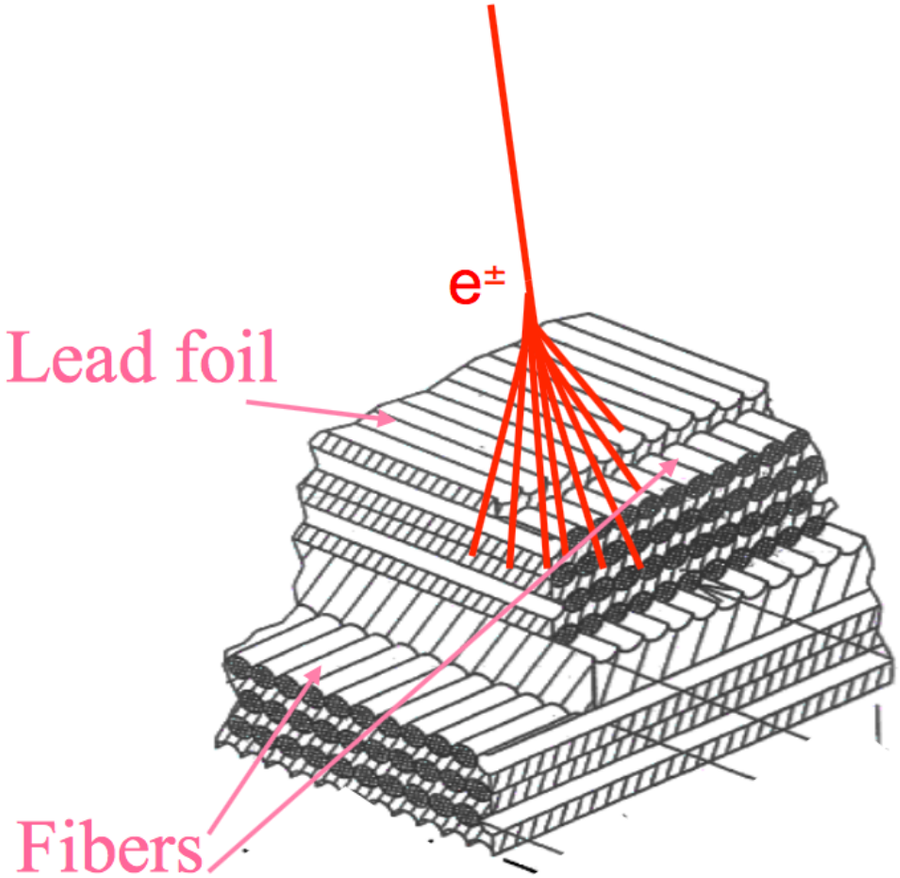


AMS-02 Electromagnetic Calorimeter

- 50.000 fibers, diameter of 1mm distributed uniformly inside 600 kg of lead
- 17 X_0 measurement of $e^{+/-}$ energies up to TeV
- Calibration in CERN testbeam

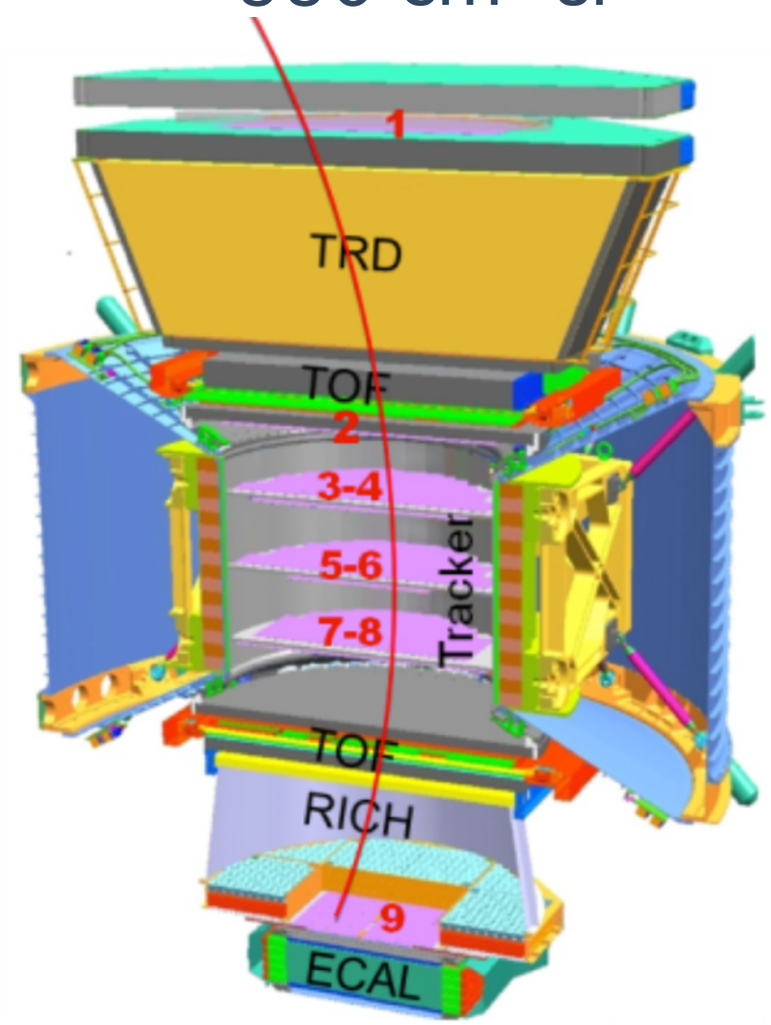






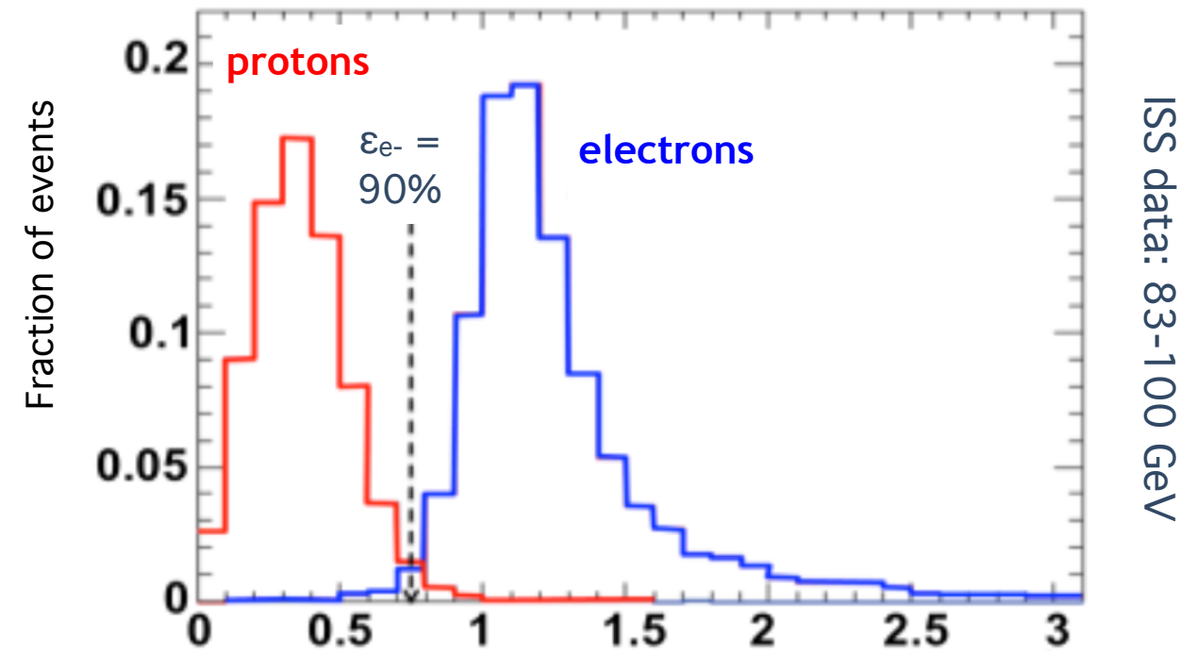
Analysis flow: Prepare e^+ / e^- sample

Geometric acceptance
~ 550 cm^2 sr

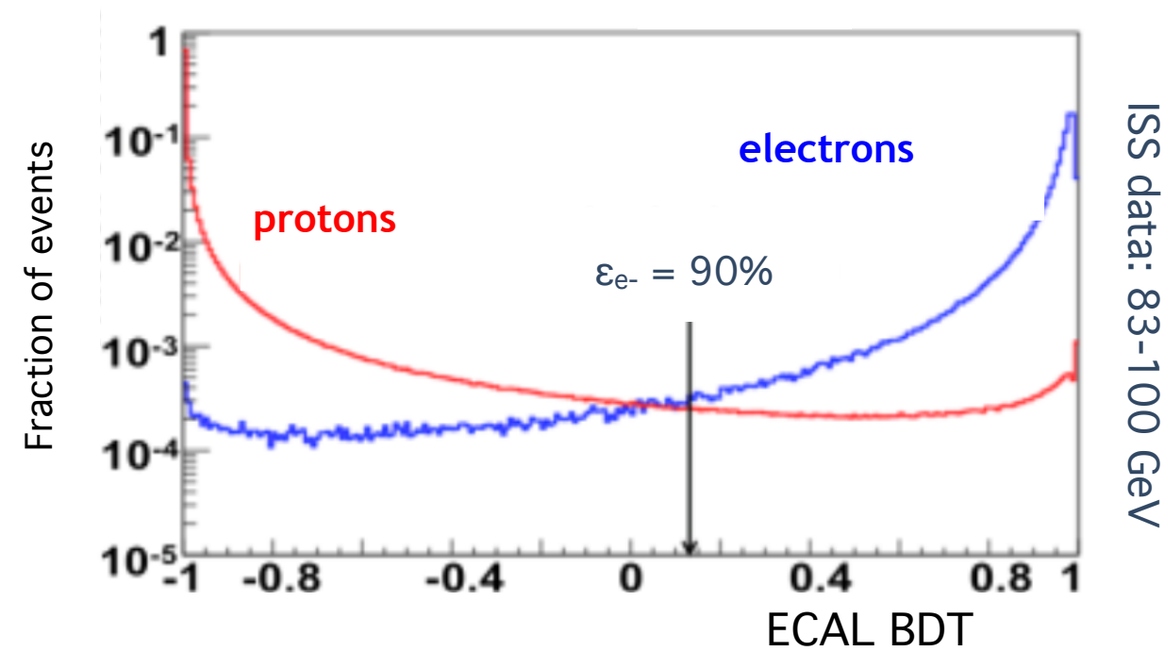


ECAL + Tracker provide
p^+ rejection ~ 10^4

- ECAL / Tracker (E / P matching)

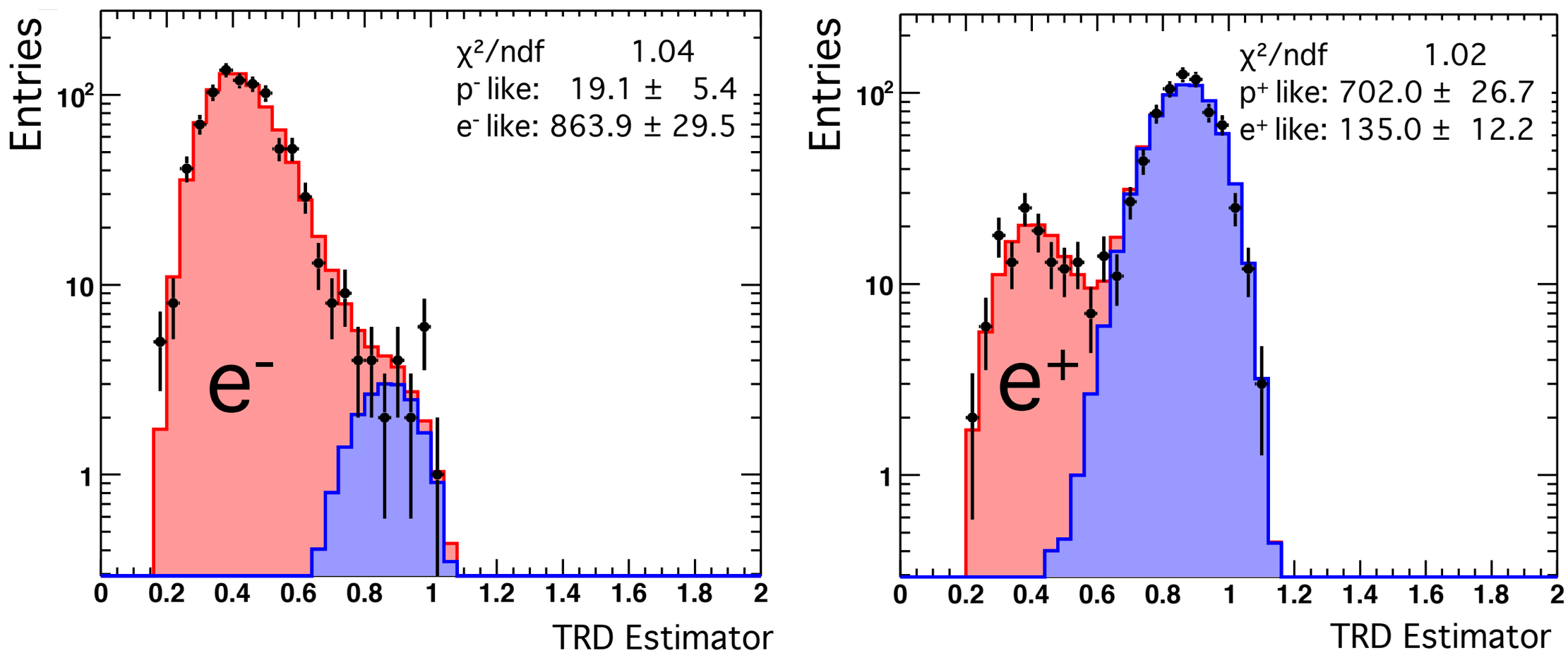


- ECAL shower shape



Flux calculation

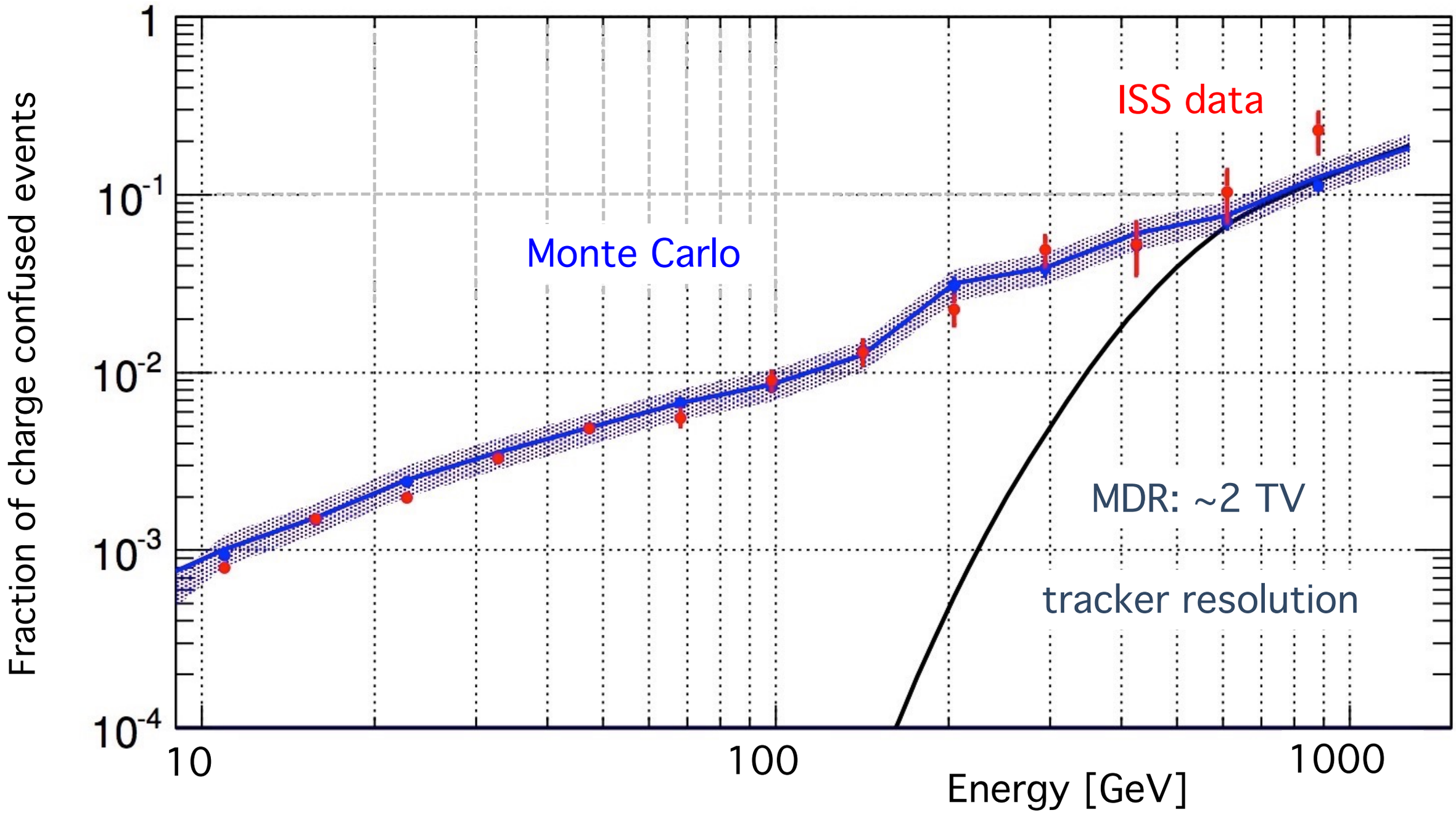
169.86 - 197.69 GeV



- Determine acceptance, efficiencies, measuring time —> calculate flux

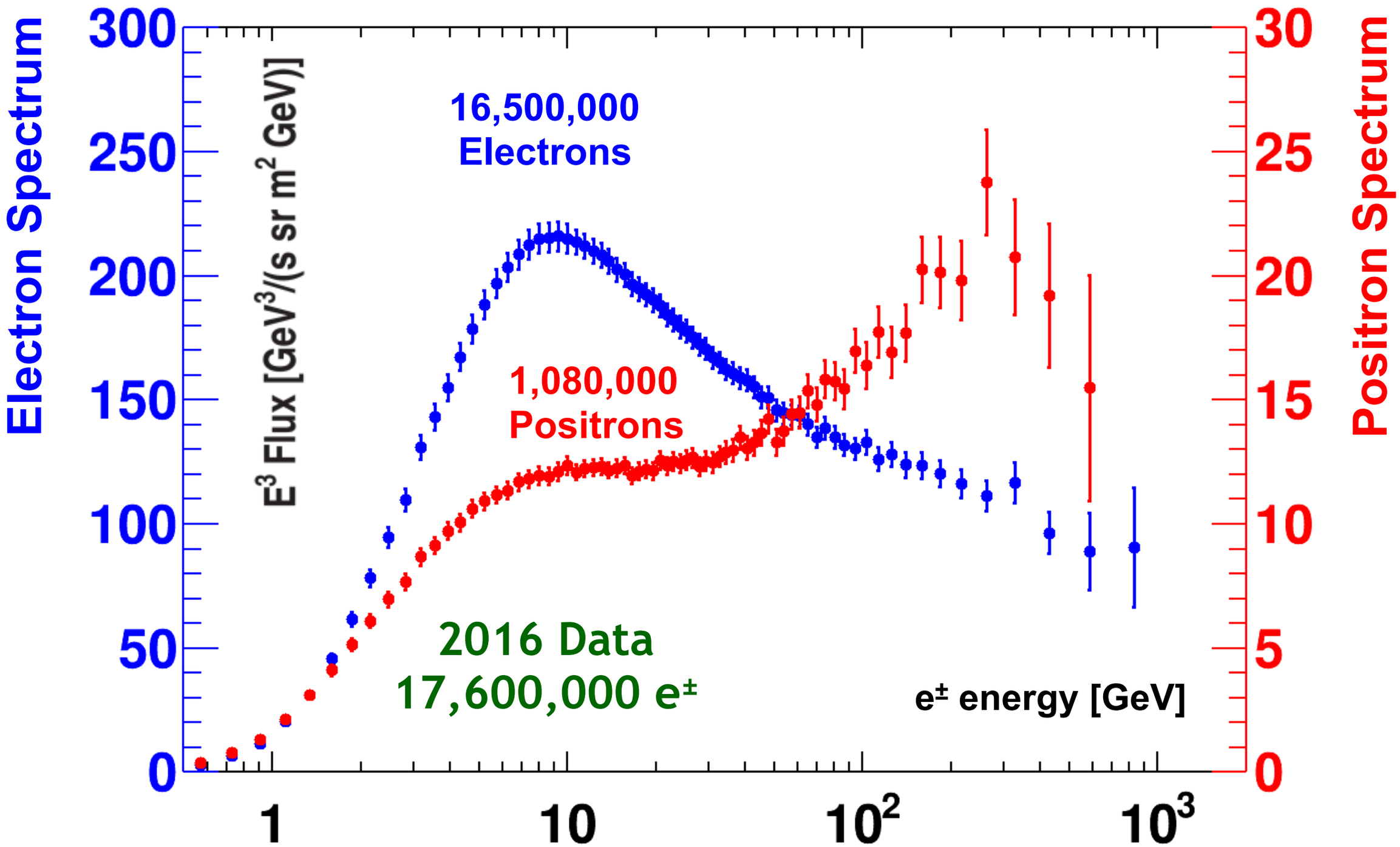
$$\Phi(E) = \frac{N_{\text{particle}}(E)}{\mathrm{d}E \times A(E) \times \epsilon(E) \times T(E)}$$

Correcting wrong measurements of the charge sign



- Full Geant4 detector simulation agrees with „charge-confusion“ obtained directly from ISS data using template fit in BDT using c.c-sensitive variables

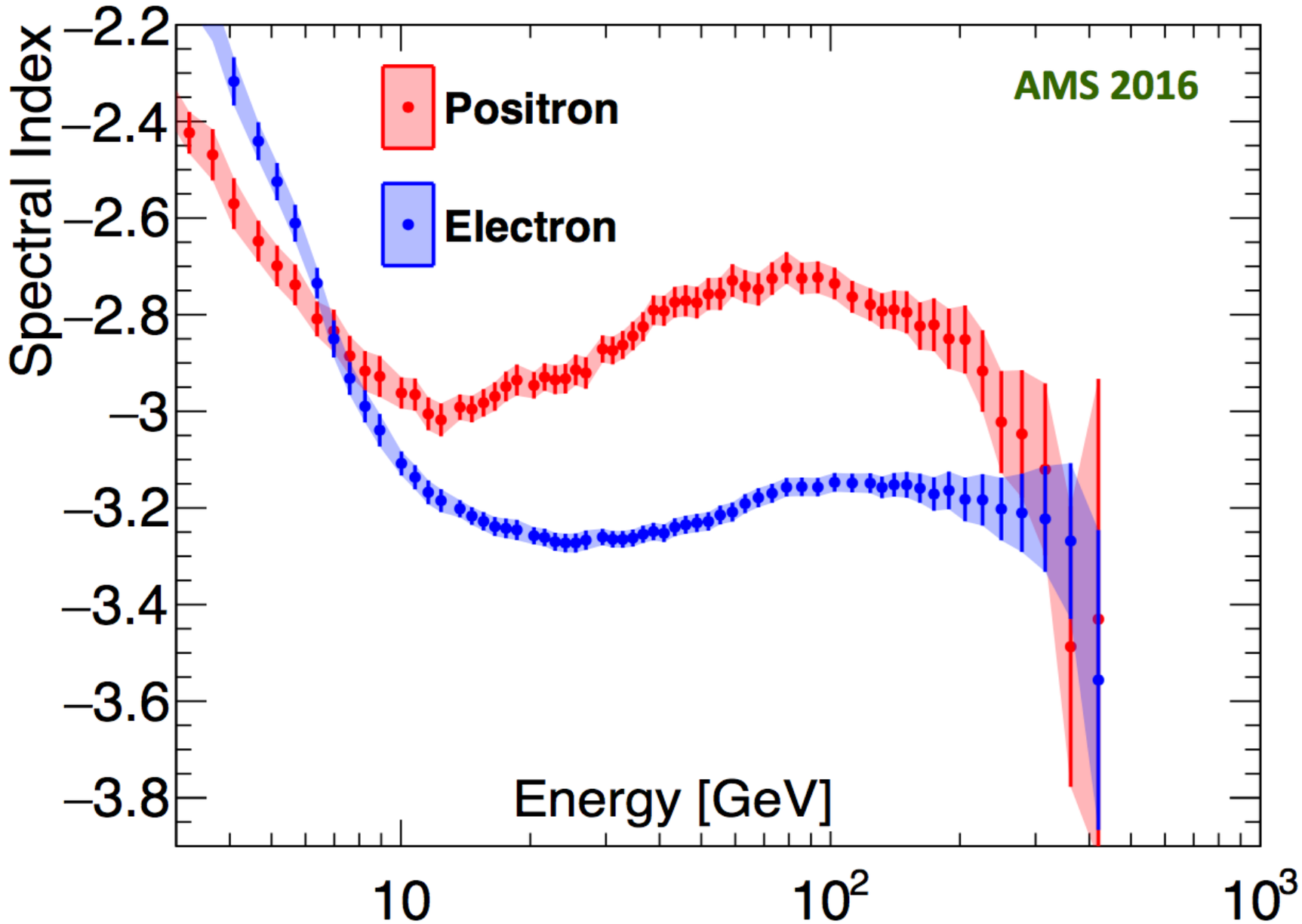
Electron / Positron flux with 5 years data



- e^- extended up to 1 TeV / e^+ extended up to 700 GeV compared to PRL publication in 2014

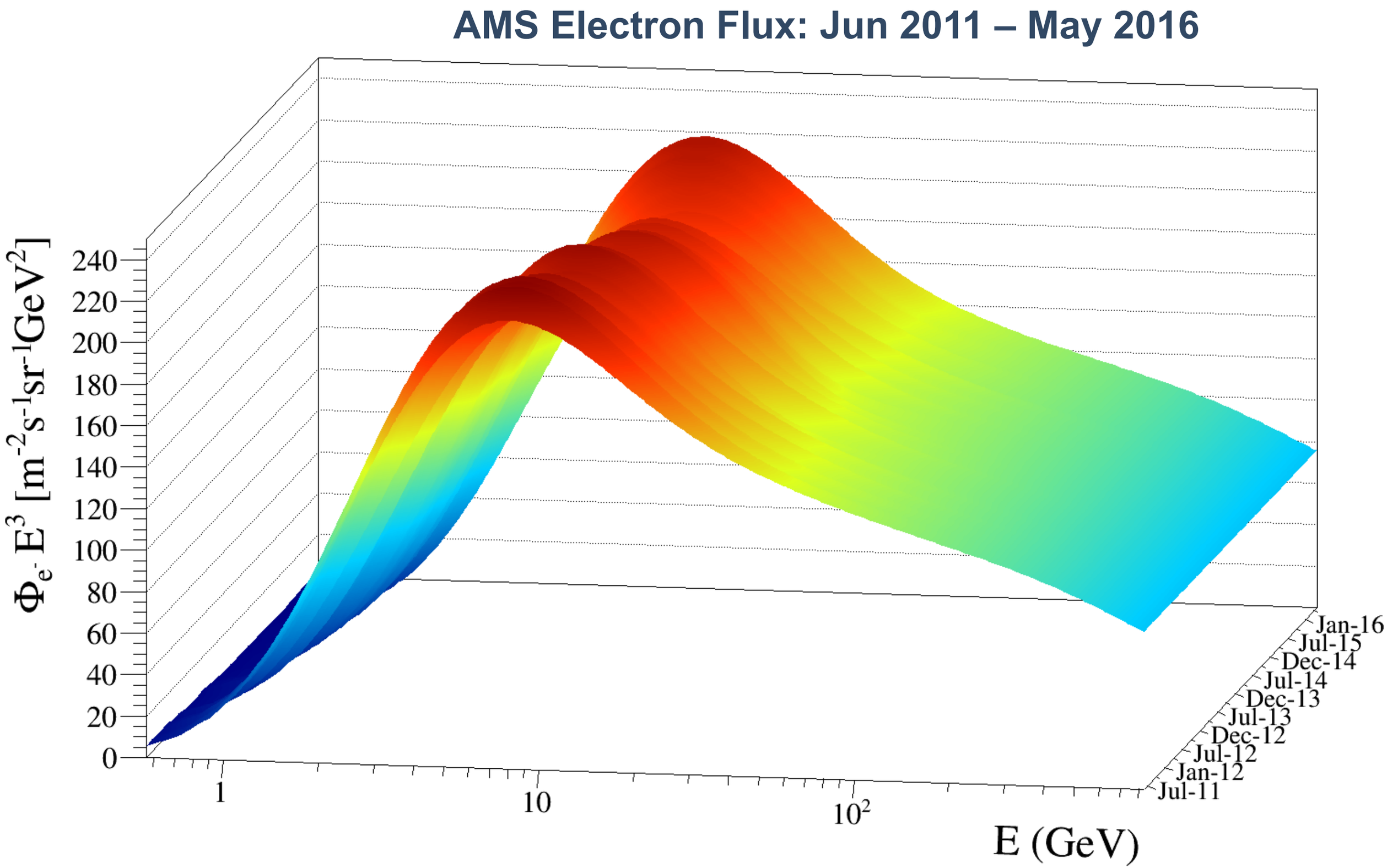
Electron / Positron flux - spectral indices

$$\Phi_{e^\pm}(E) = C_{e^\pm} E^{\gamma_{e^\pm}} \quad \text{or} \quad \gamma_{e^\pm} = d[\log(\Phi_{e^\pm})]/d[\log(E)]$$

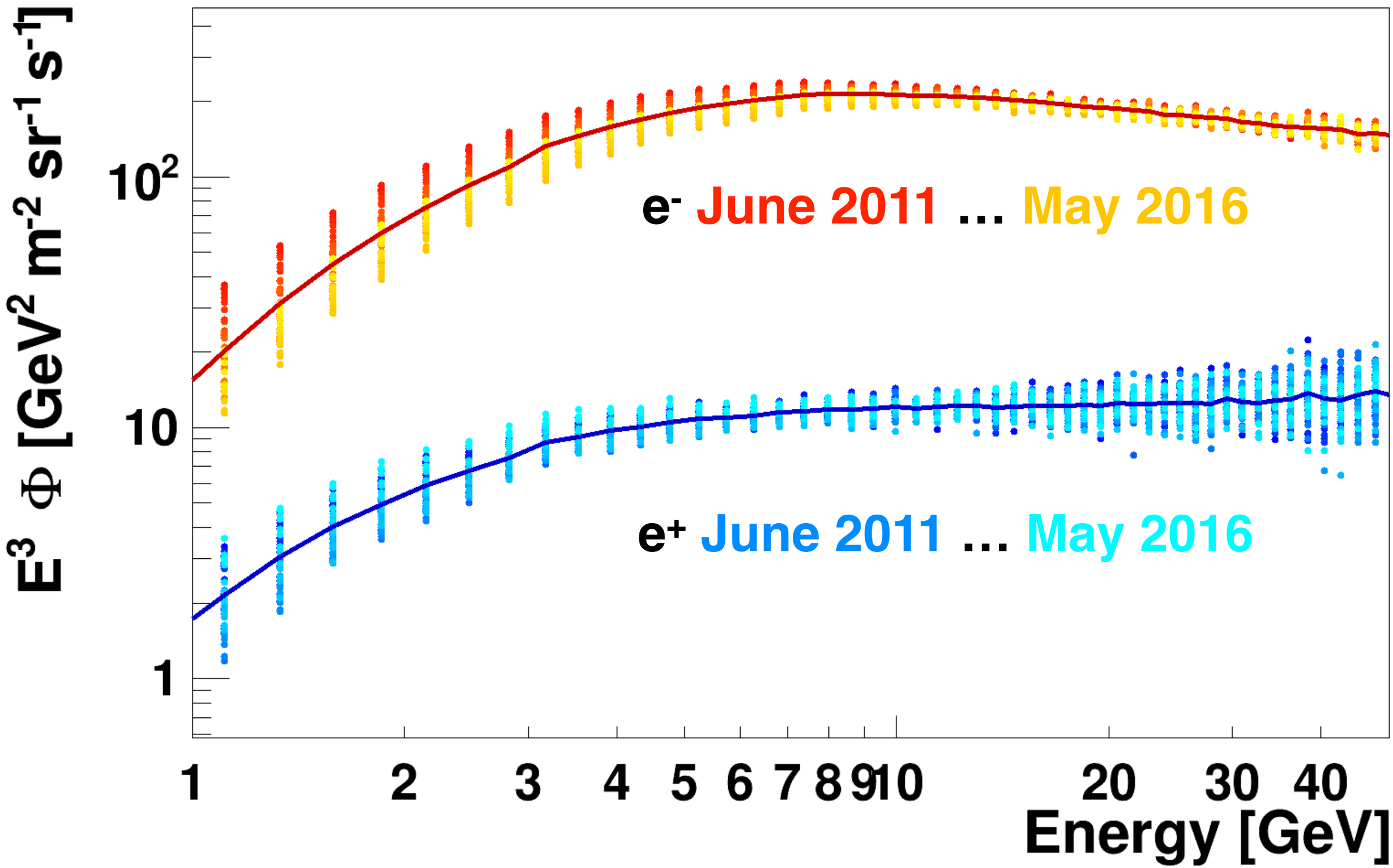


- Between 20 and 200 GeV the positron spectral index is significantly harder than the electron spectral index and this causes the rise in the positron fraction

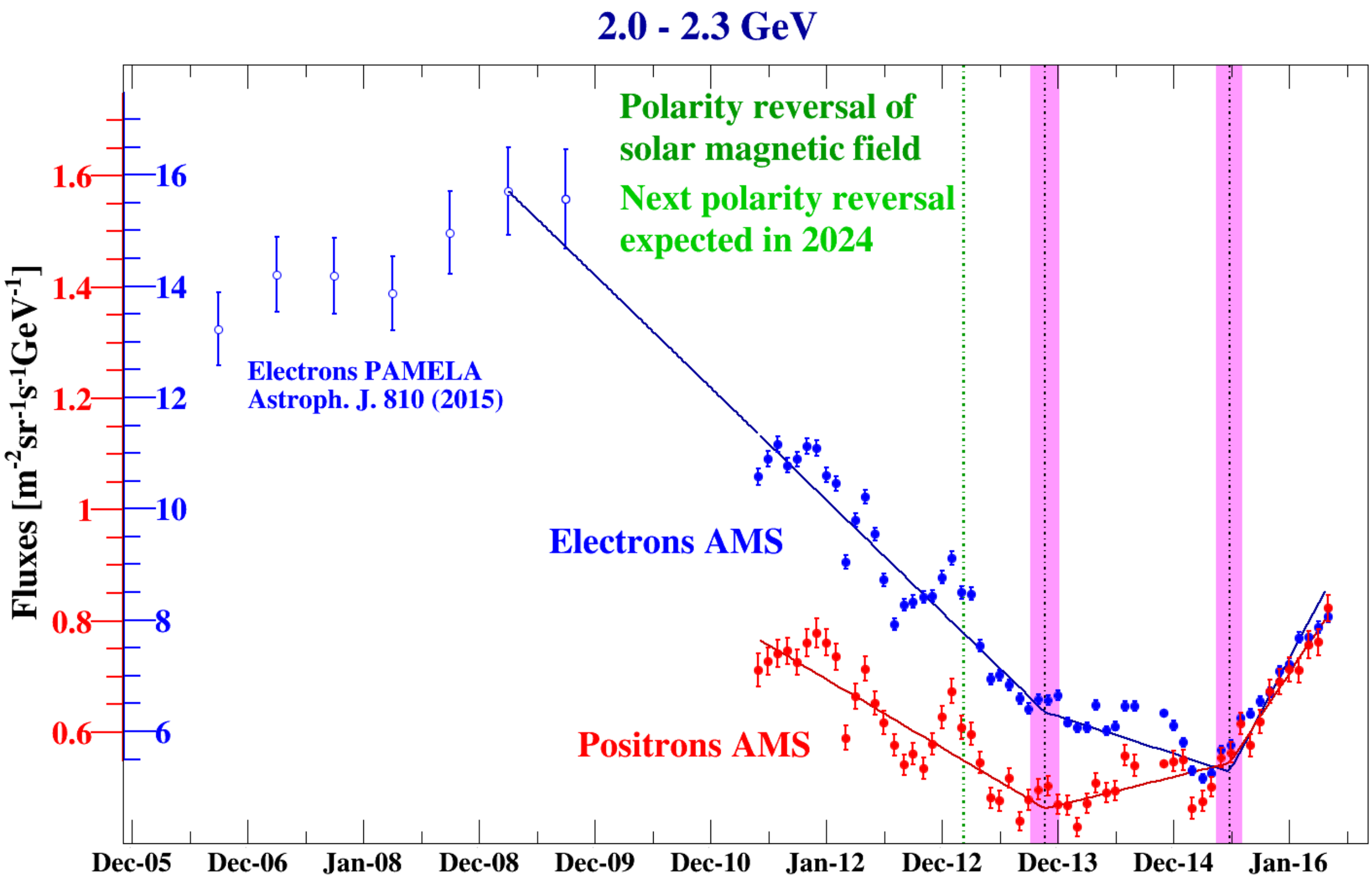
Time-dependent electron flux



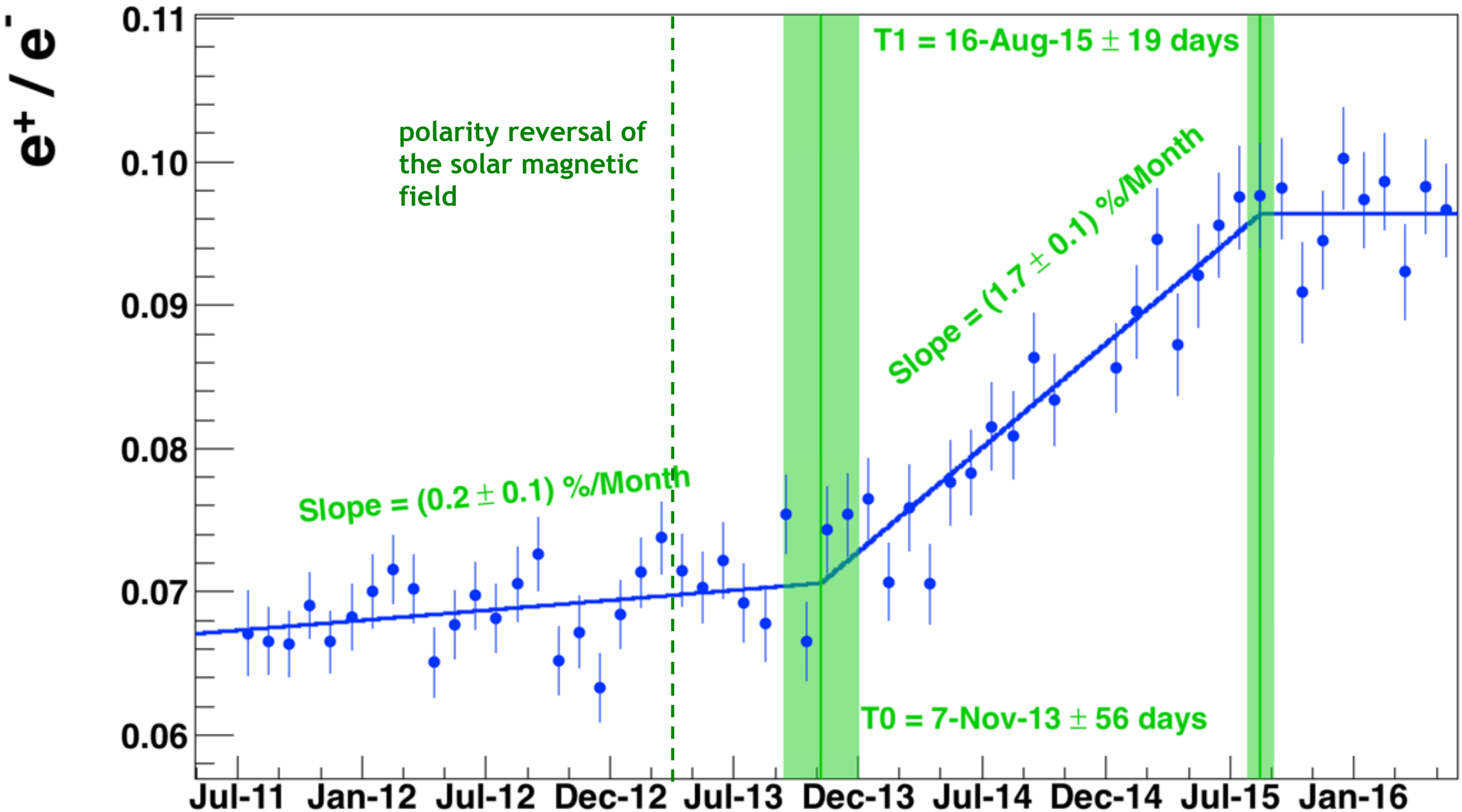
Time-dependent electron / positron fluxes



Time-dependent electron / positron fluxes



Time-dependent positron / electron ratio



- After the reversal of the solar magnetic field in 03/2013 it takes (8 ± 1.5) month till this has a visible effect on the e^+/e^- ratio.
- It takes (21 ± 1) month to stabilize the e^+/e^- ratio again.

Summary

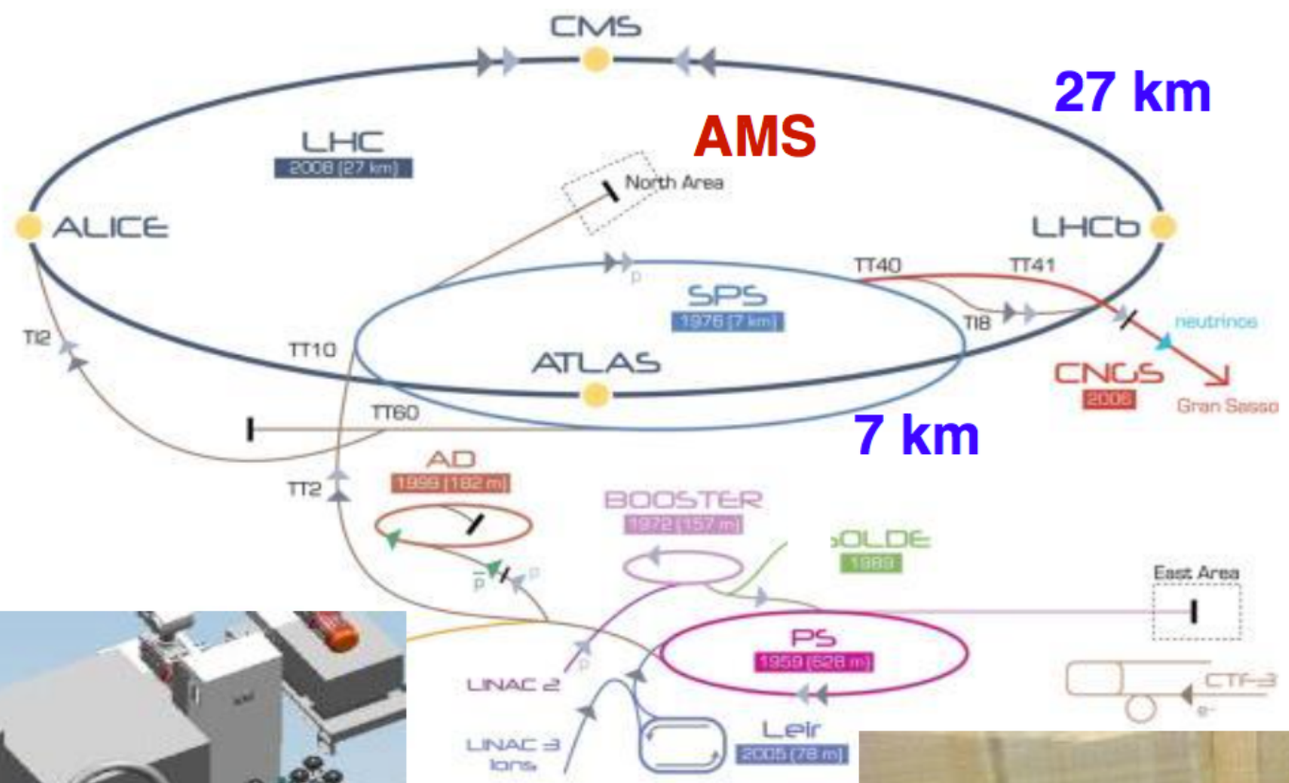
- e^- / e^+ flux energy ranges were extended with the 5y dataset
- e^- / e^+ flux are significantly different in magnitude and energy dependance
- The differing behavior of the spectral indices versus energy is a new observation and provides important information on the origins of cosmic-ray electrons and positrons
- The reversal of the solar magnetic field polarity shows a drastic charge-sign dependency of the solar modulation

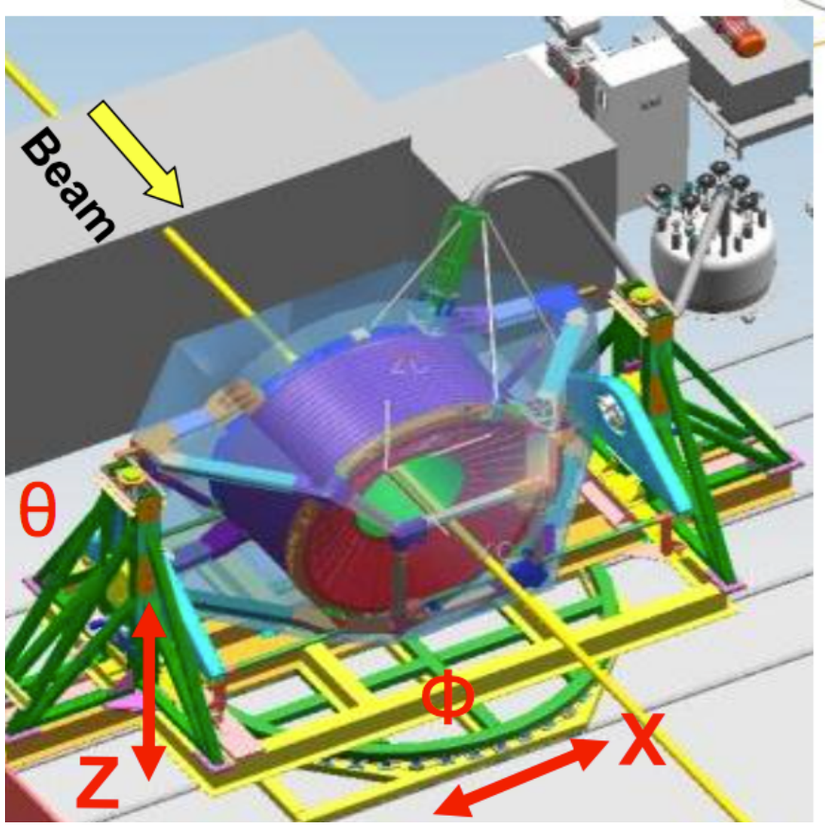
Stay tuned for upcoming results from AMS-02!

Backup Calibration

Test beam calibration @ CERN

Extensive tests and calibration at CERN





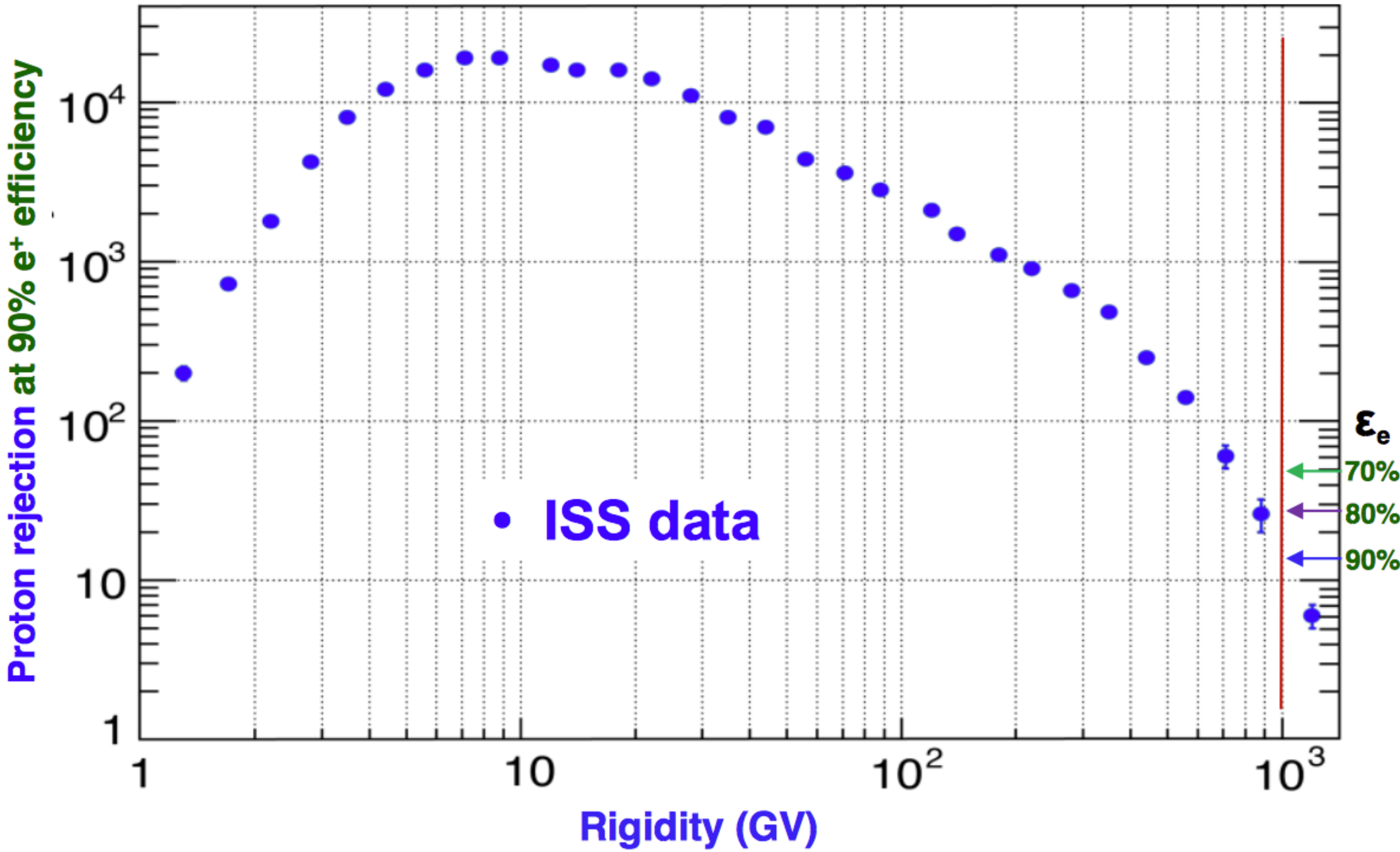
Test beam calibration @ CERN

AMS in SPS Test Beam, 2010

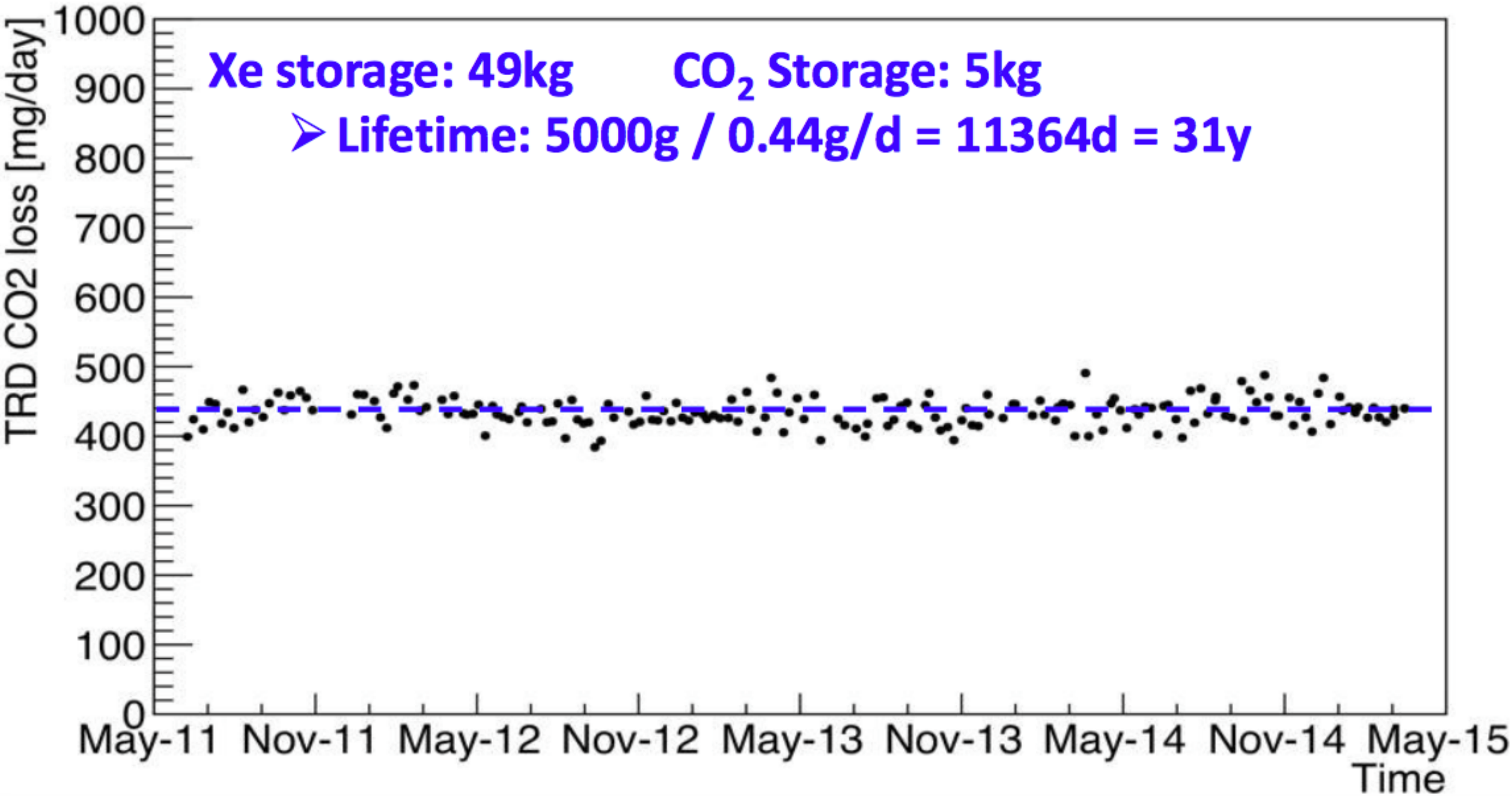
Particle	Momentum (GeV/c)	Positions	Purpose
Protons	400 + 180	1,650	Full Tracker alignment, TOF calibration, ECAL uniformity
Electrons	100, 120, 180, 290	7 each	TRD, ECAL performance study
Positrons	10, 20, 60, 80, 120, 180	7 each	TRD, ECAL performance study
Pions	20, 60, 80, 100, 120, 180	7 each	TRD performance to 1.2 TeV

Backup TRD

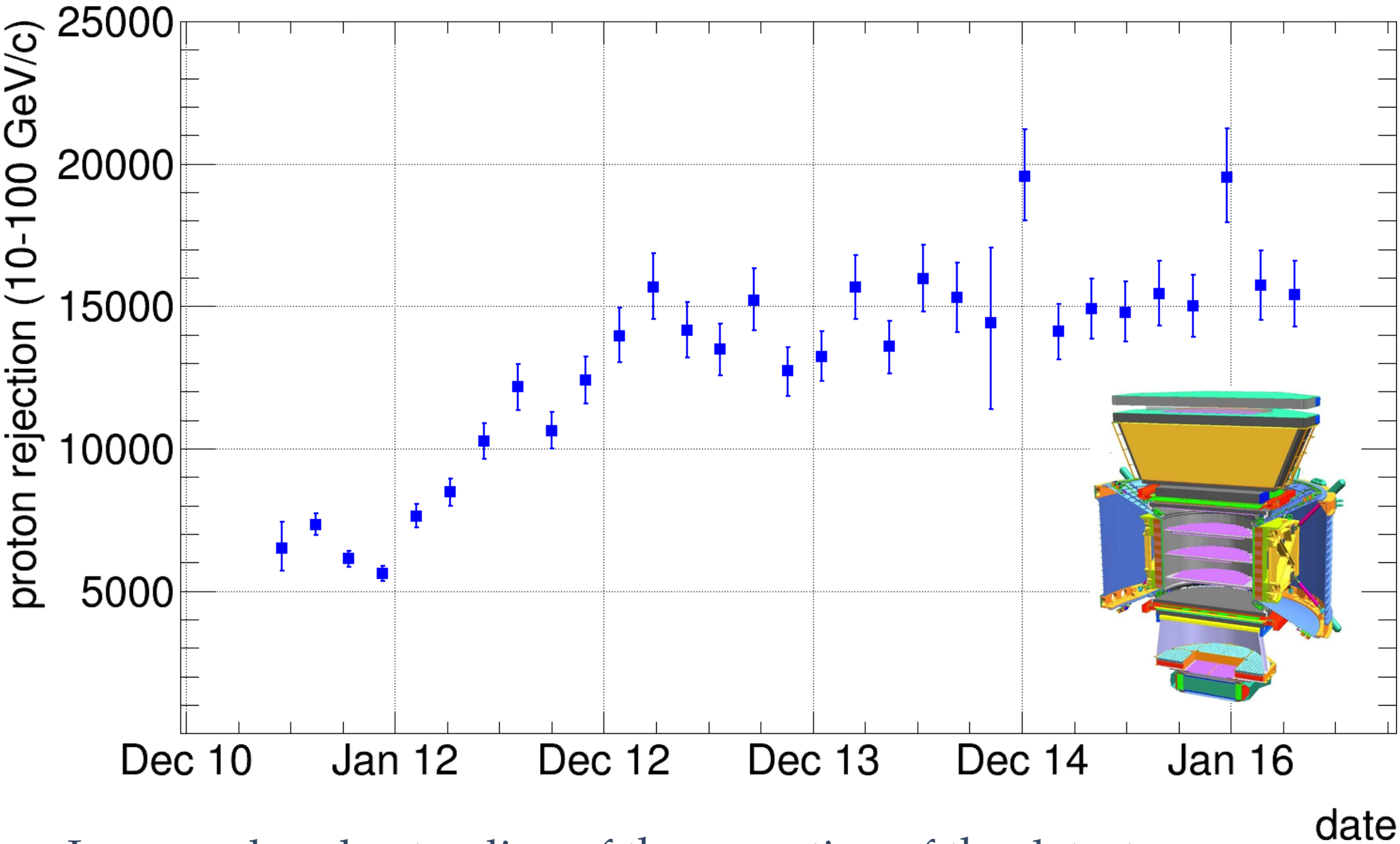
TRD performance on ISS



TRD lifetime on ISS



TRD proton rejection on ISS

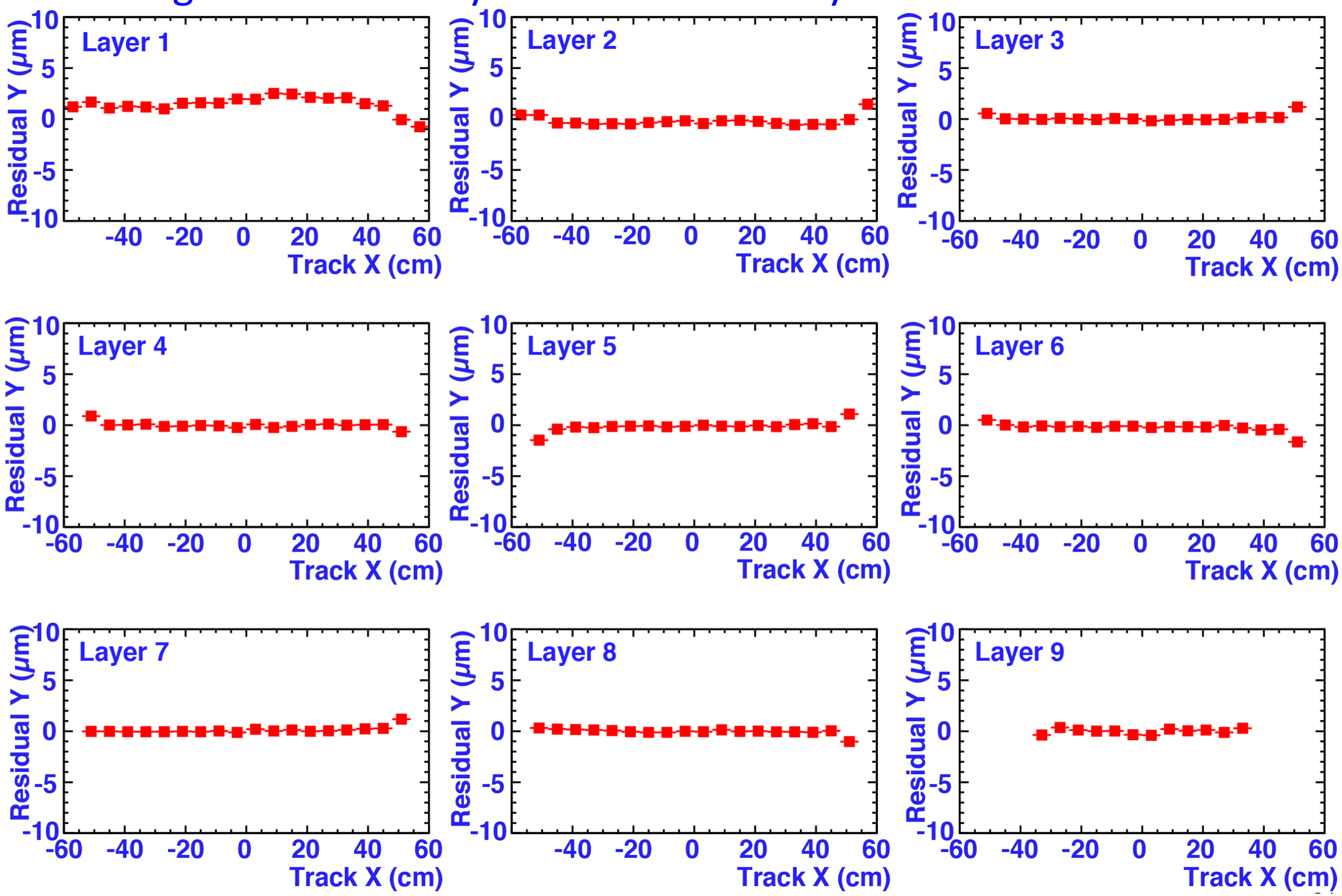


Improved understanding of the operation of the detector, led to a factor ~ 2 improvement of the proton rejection

Backup Tracker

Tracker alignment accuracy

Alignment accuracy of the 9 Tracker layers over 40 months



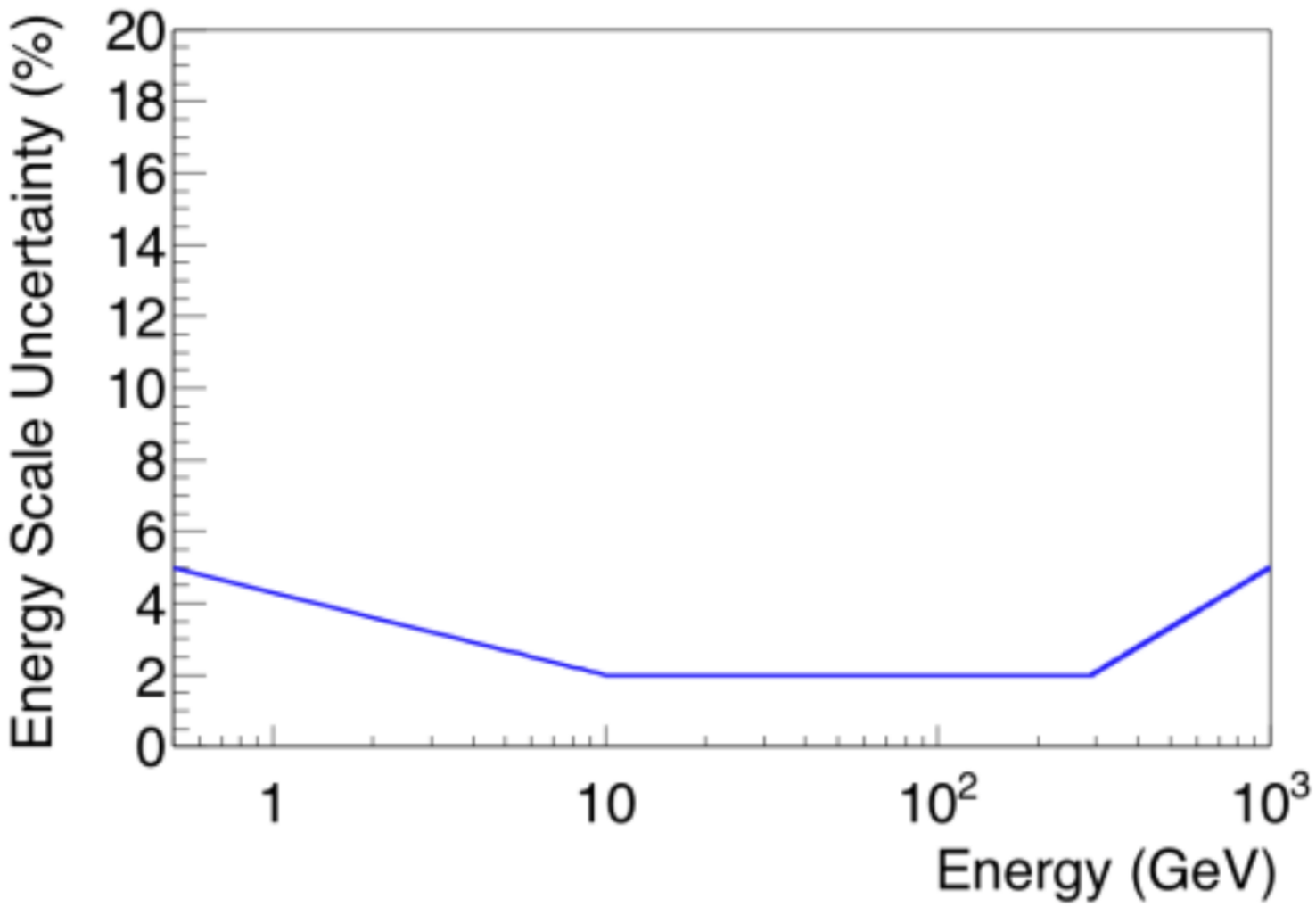
Backup

ECAL

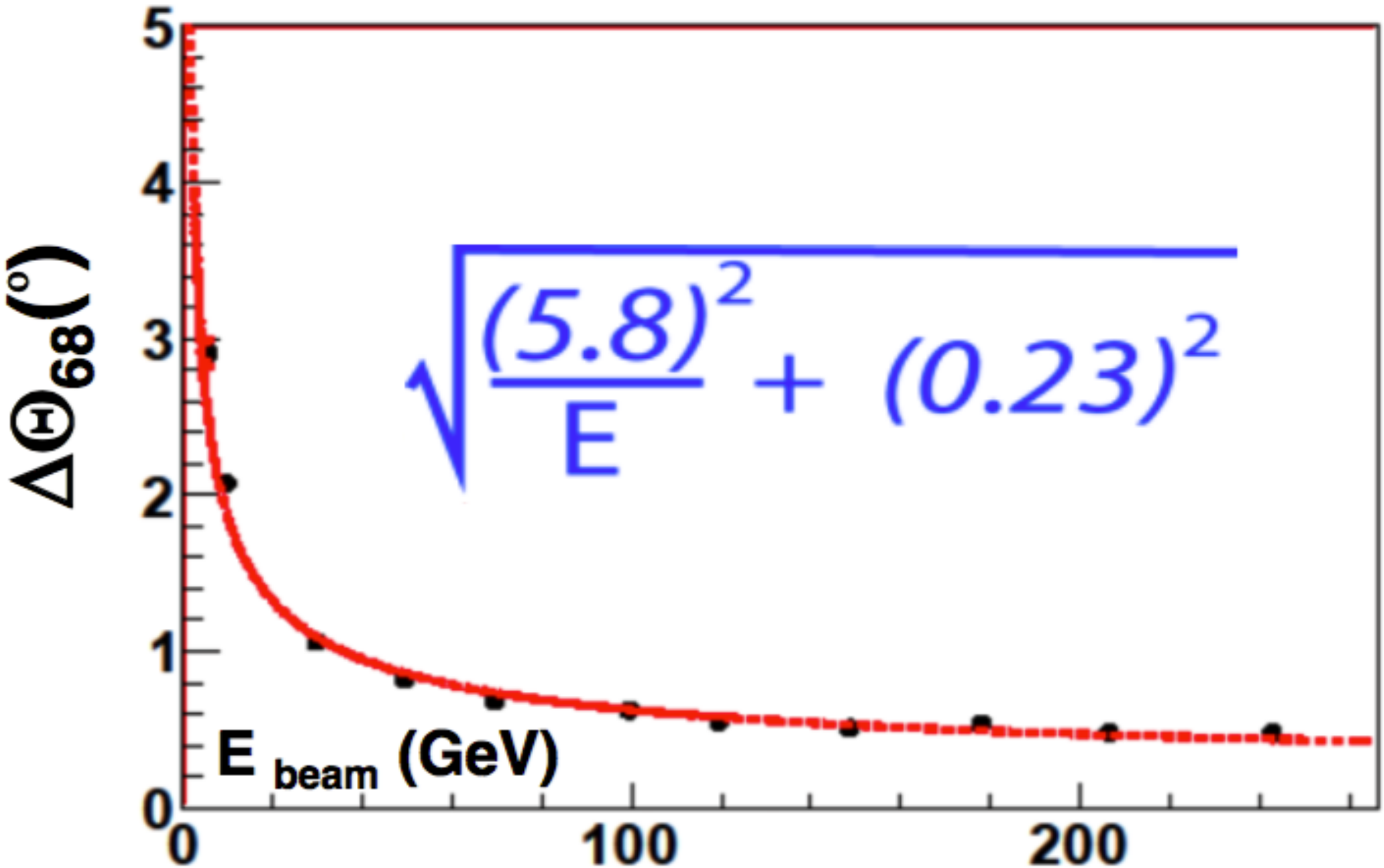
ECAL energy resolution

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.

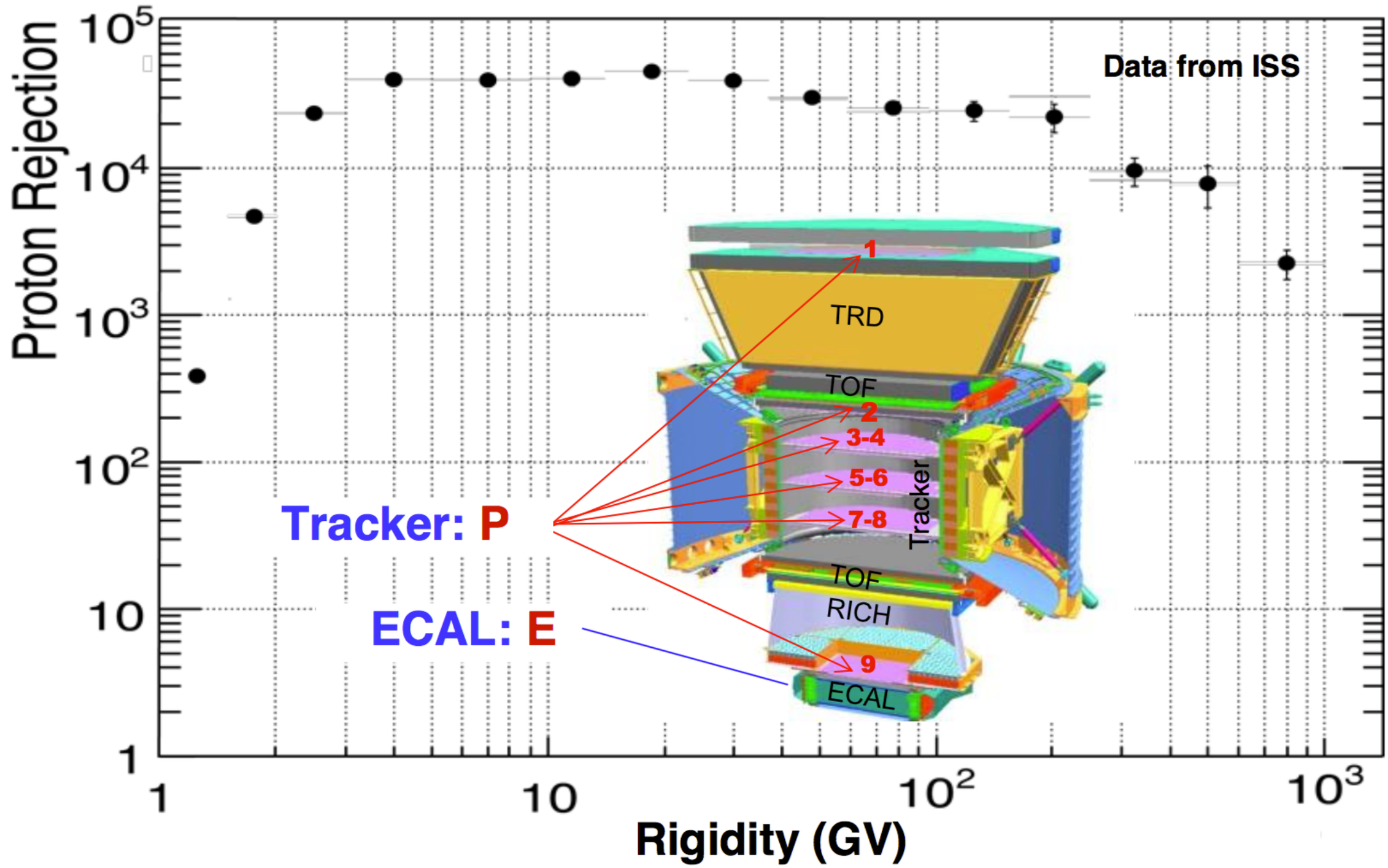


ECAL angular resolution



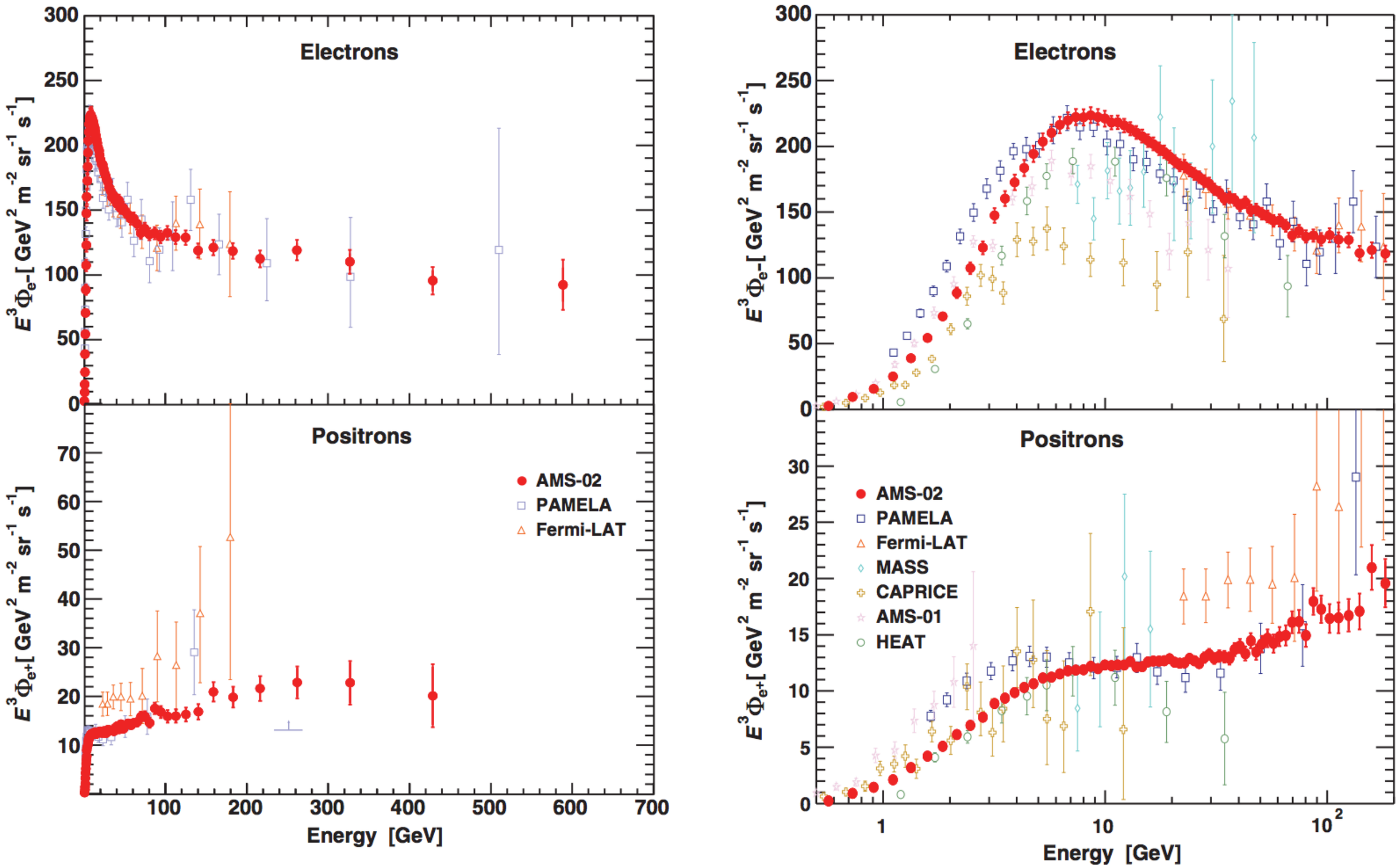
ECAL proton rejection

Proton rejection: 1. ECAL 3-D Shower Shape of $e^{\pm}$
2. P from the Tracker = E from ECAL

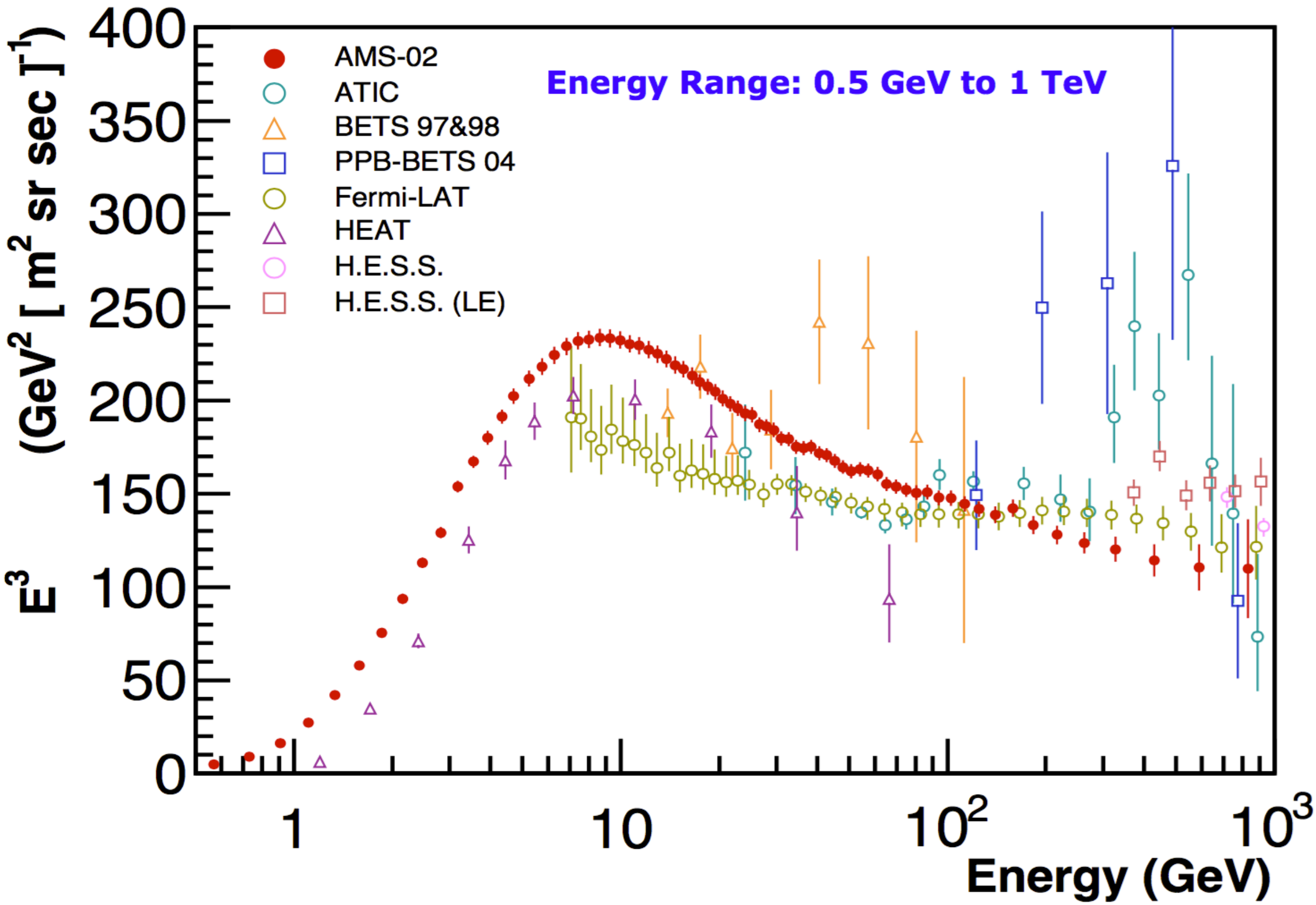


Backup Physics Results

Electron / Positron flux



All-electron flux



Electron / positron flux table

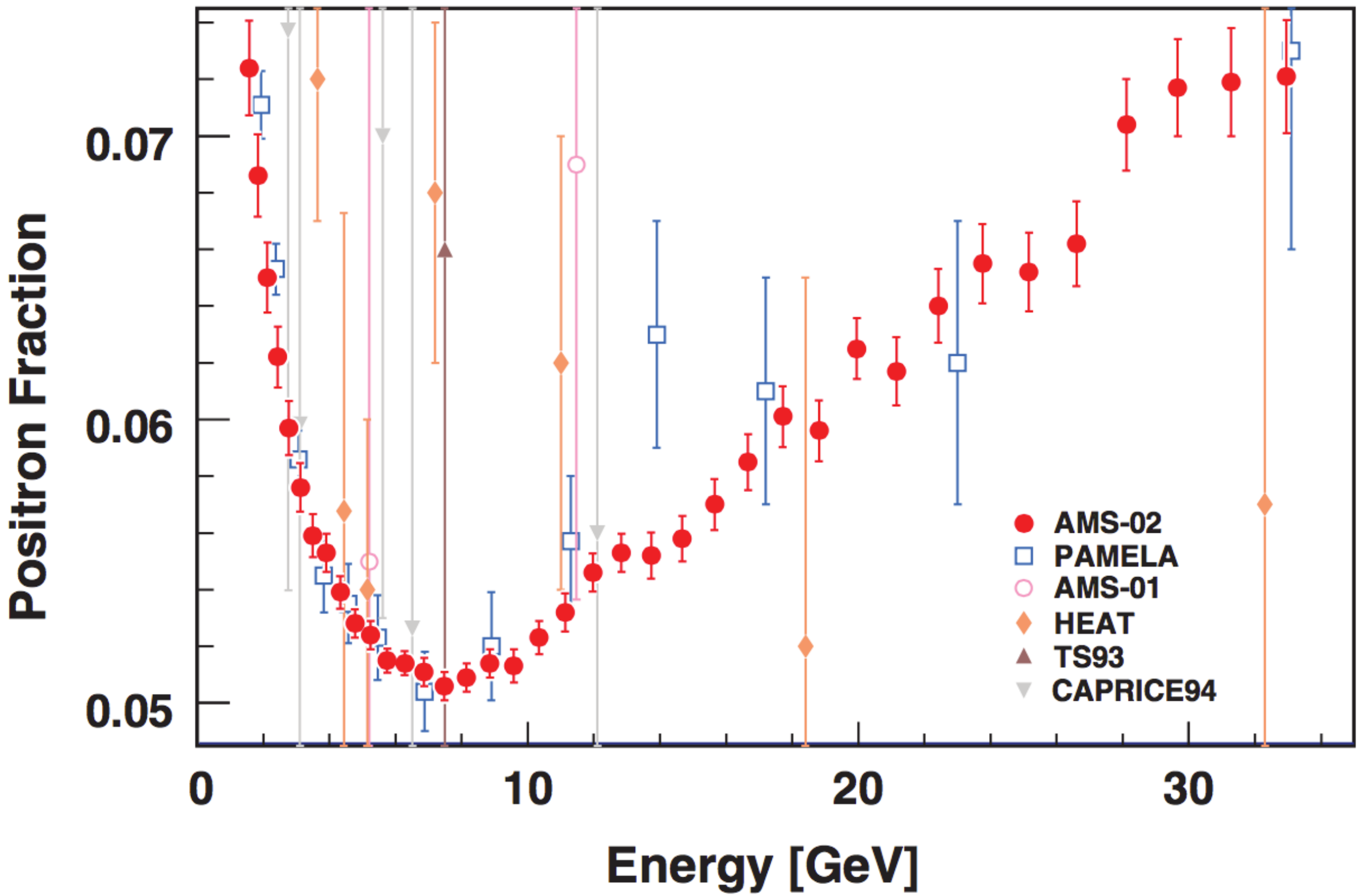
PRL 113, 121102 (2014) PHYSICAL REVIEW LETTERS week ending 19 SEPTEMBER 2014

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

Energy (GeV)	$\tilde{E}$ (GeV)	$\Phi_{e^-} \pm \sigma_{stat} \pm \sigma_{syst}$ [m^2 sr s GeV]$^{-1}$		$\Phi_{e^+} \pm \sigma_{stat} \pm \sigma_{syst}$ [m^2 sr s GeV]$^{-1}$	
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.

Positron fraction - low energies



Positron fraction - high energies