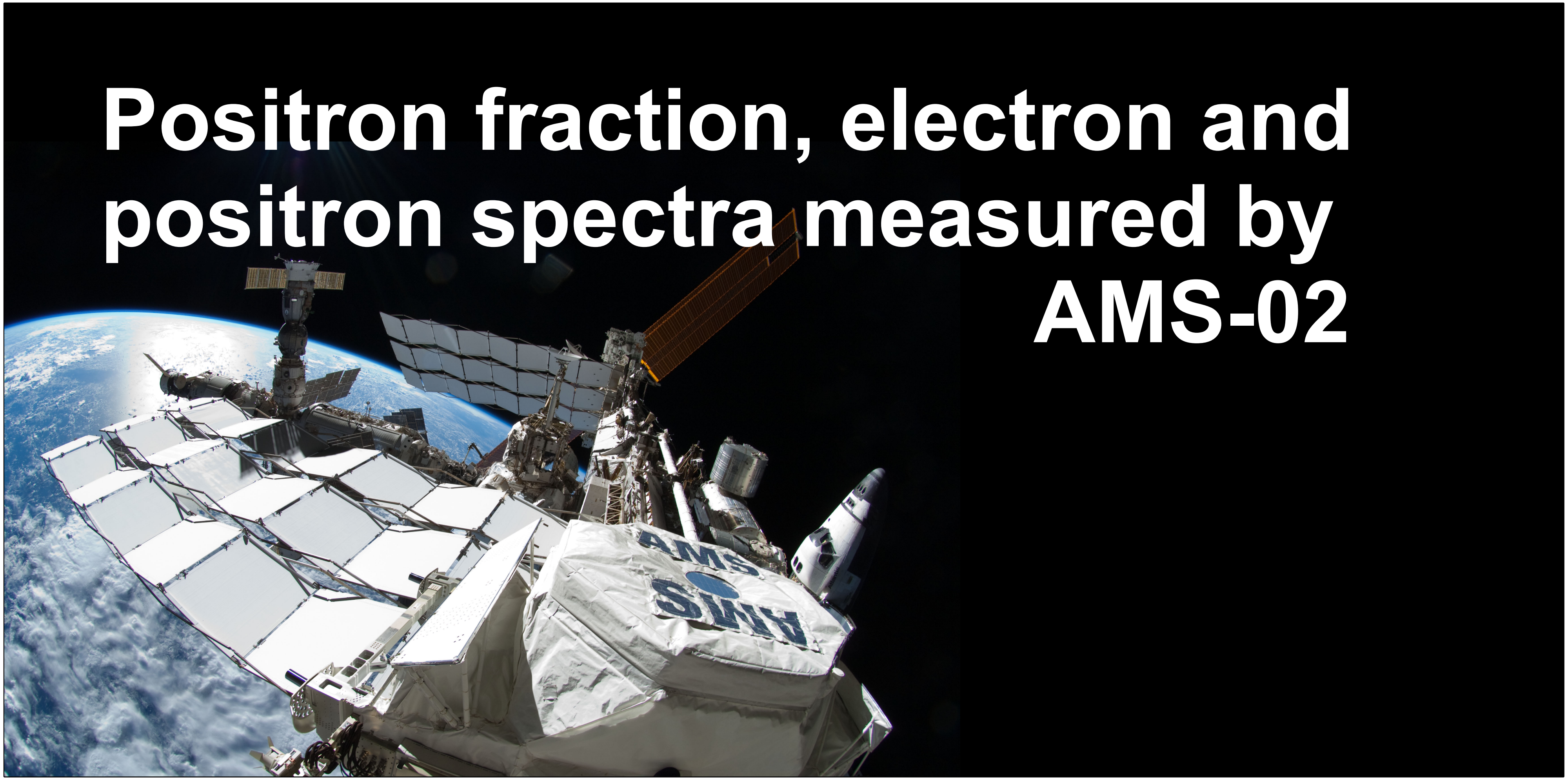
Positron fraction, electron and positron spectra measured by AMS-02



Cecilia Pizzolotto

INFN and ASI Science Data Center

INFN Istituto Nazionale di Fisica Nucleare

asdc ASI Science Data Center

RICAP 14

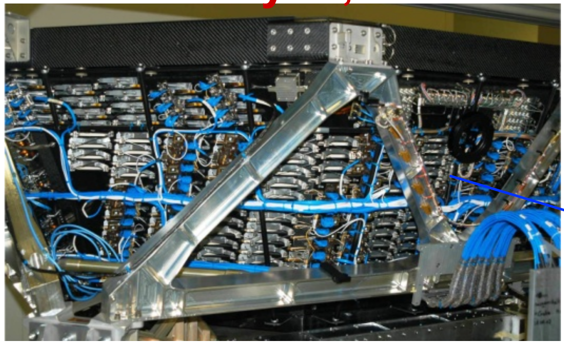
October 2nd 2014

Outline:

- AMS detector
- Positron fraction analysis & results
- Electron and positron fluxes
- Minimal model interpretation

AMS02: a TeV precision multipurpose spectrometer

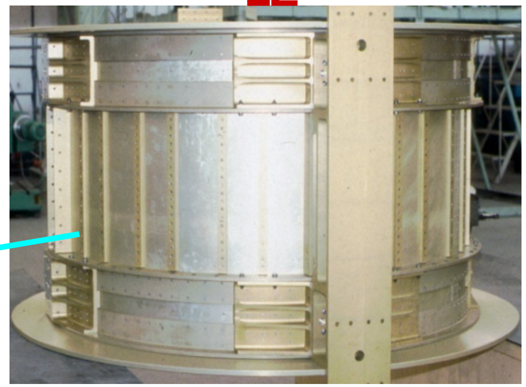
TRD
Identify e^+, e^-



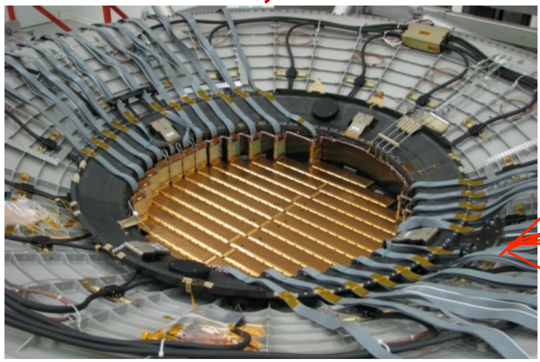
TOF
Z, E

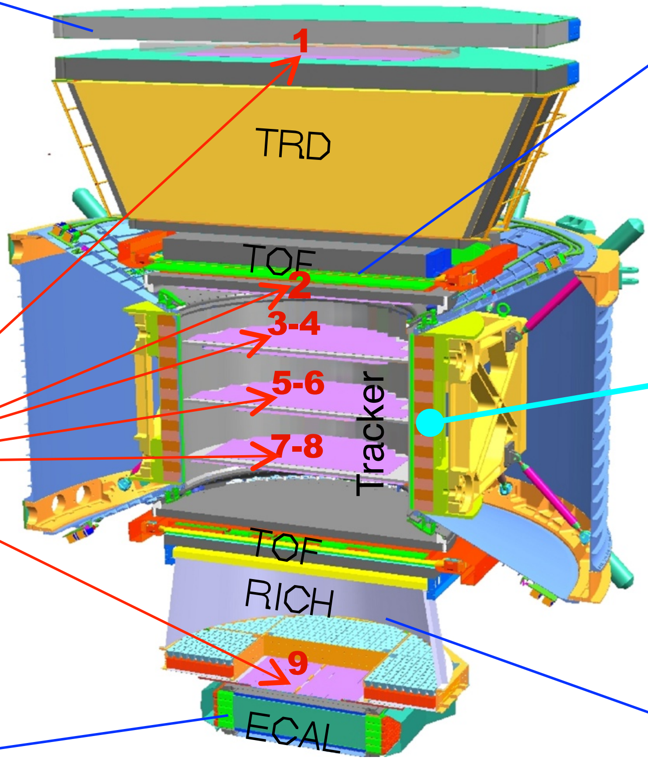
Particles and nuclei are defined by their charge (Z) and energy **(E ~ P)**

Magnet
±Z

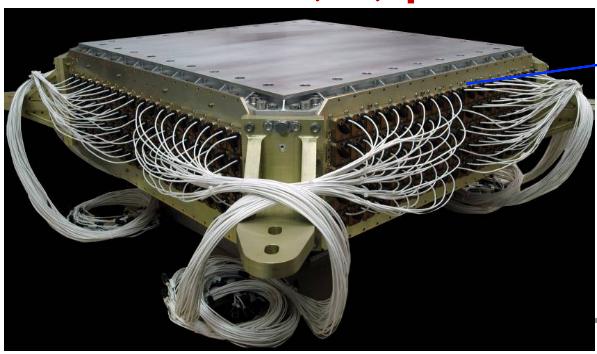


Silicon Tracker
Z, P

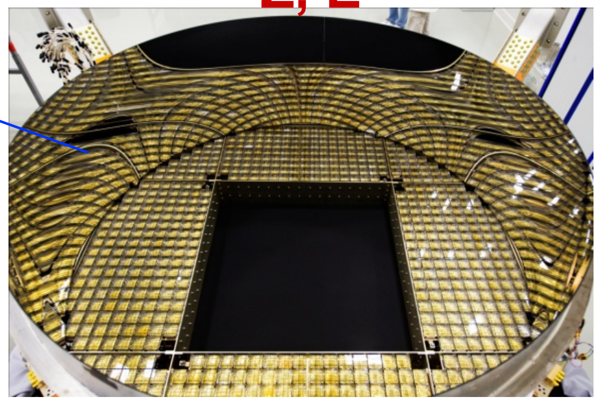




ECAL
E of e^+, e^-, γ



RICH
Z, E



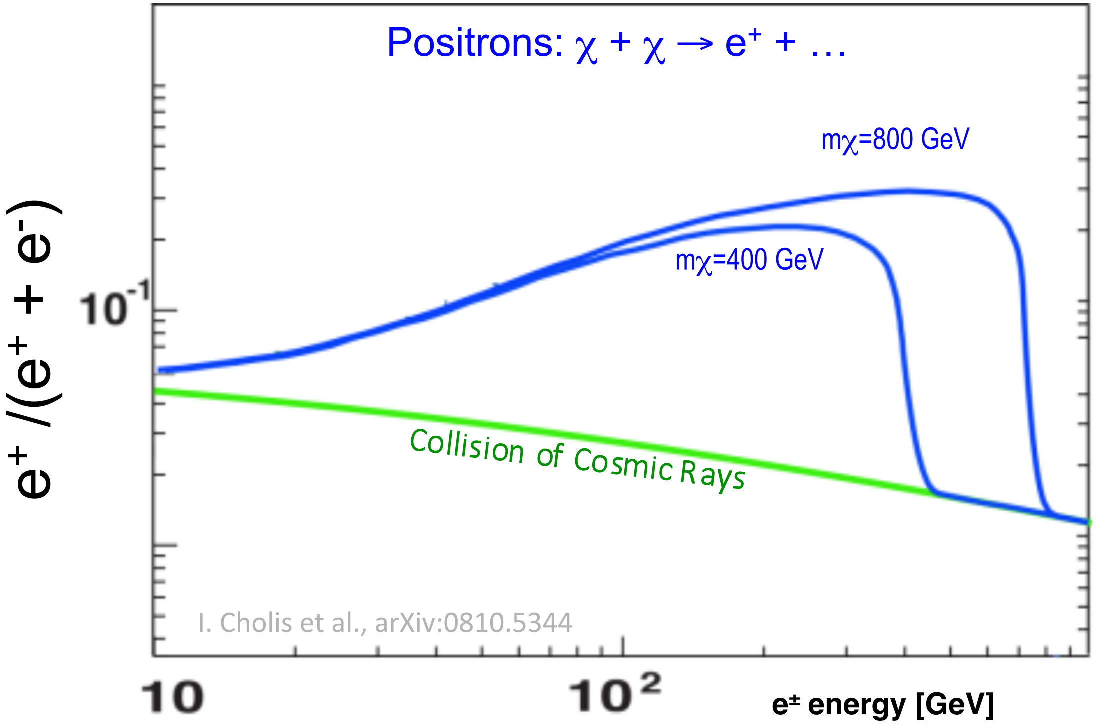
Z, P are measured independently by the Tracker, RICH, TOF and ECAL

MDR = 2 TeV

The study of Dark Matter
is one of the physics objectives of AMS

A known source of positrons is the collision of “ordinary” Cosmic Rays

Annihilation of Dark Matter (neutralinos, χ) will produce additional e+, $\bar{p}$, …



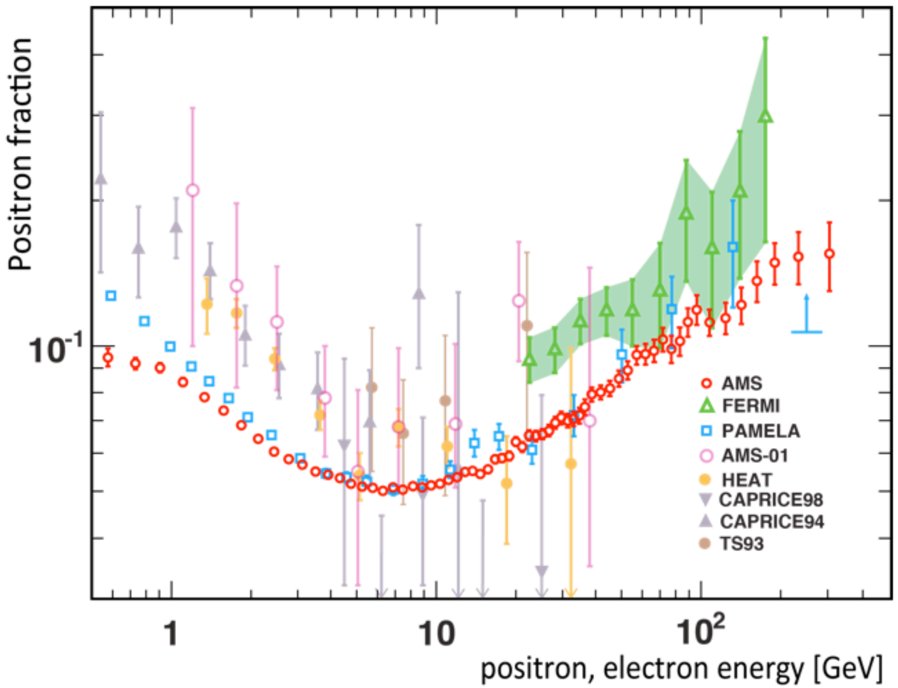
M. Turner and F. Wilczek, Phys. Rev. D42 (1990) 1001

Positron fraction

- energy range from **0.5 to 500 GeV**
- based on **10.9 million positron and electron events**

Respect to our previous observation this measurement

- extends the energy range
- increases its precision



PRL 110 (2013)141102

Positron fraction event selection:

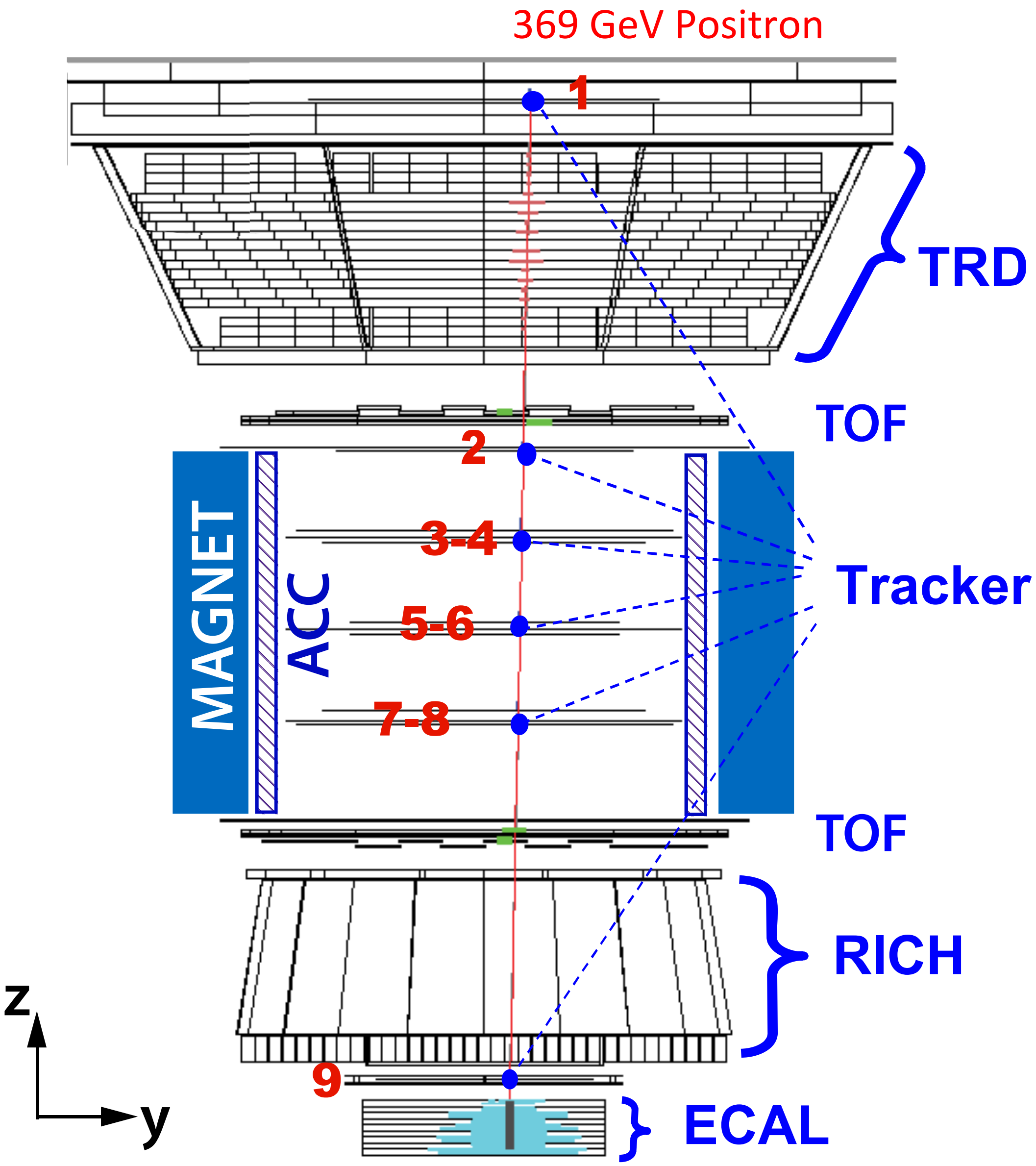
-TRD: at least 12 hits

-TOF: relativistic downgoing particle

-TRACKER:
- Good Track quality
- Geometrical match with TRD Track and ECAL shower
- Z<1.5

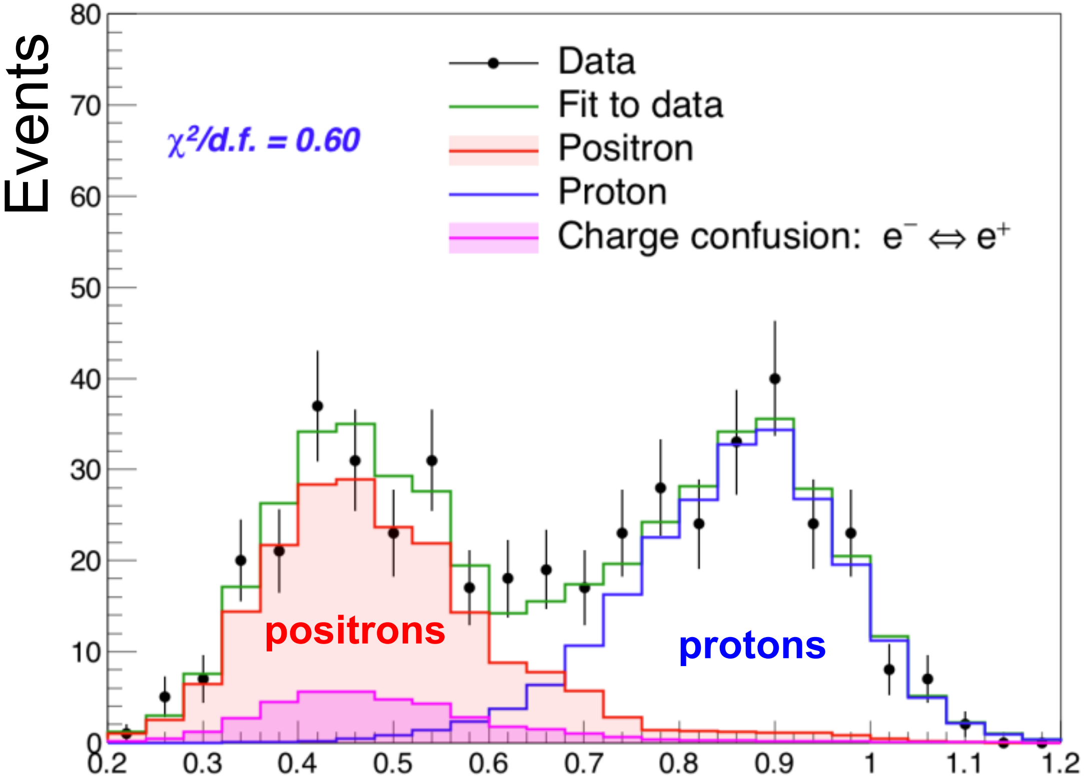
-ECAL:
- Shower axis within the ECAL fiducial volume
- Shower with electromagnetic shape

-Geomagnetic cutoff
- 1.2 times absolute Størmer value



The **numer of positrons**, the **number of electrons**, the number of residual protons and the amount of charge confusion is determined in each energy bin with **a fit of two-dimensional** reference spectra in the **TRD-Estimator – log(E/p) plane**

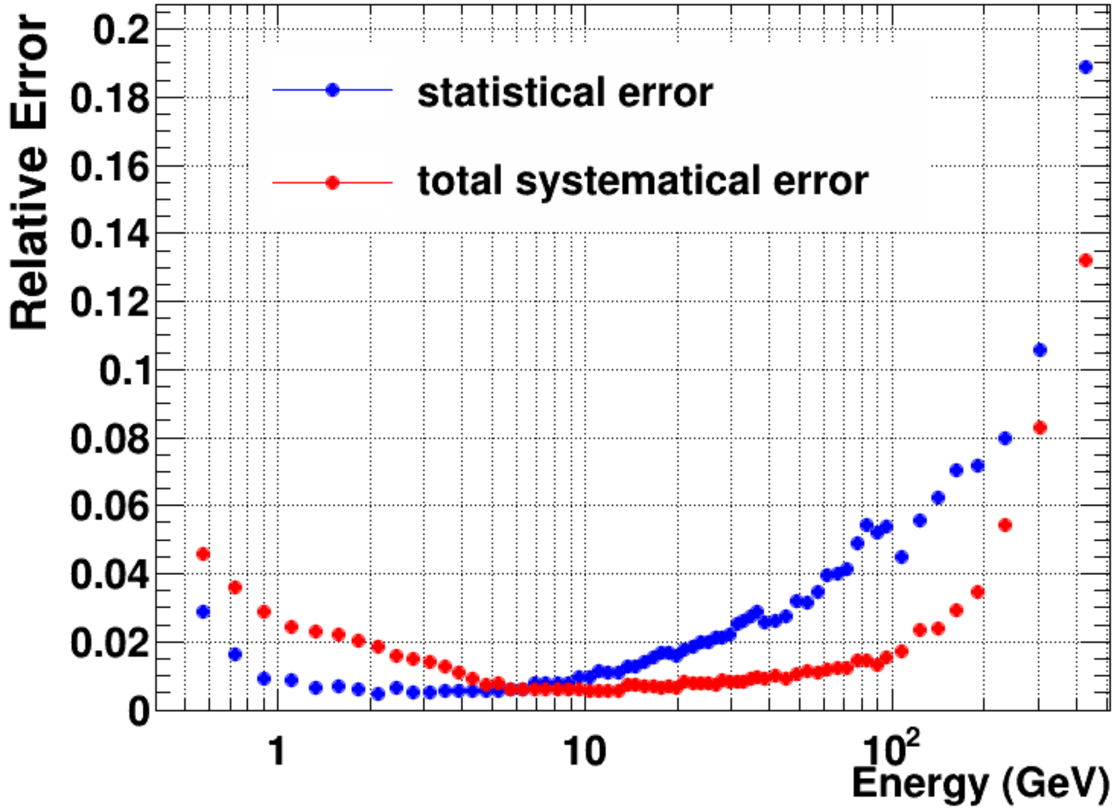
The TRD Estimator shows clear separation between **protons** and **positrons** with a small **charge confusion** background



TRD Estimator (173 – 206 GeV)

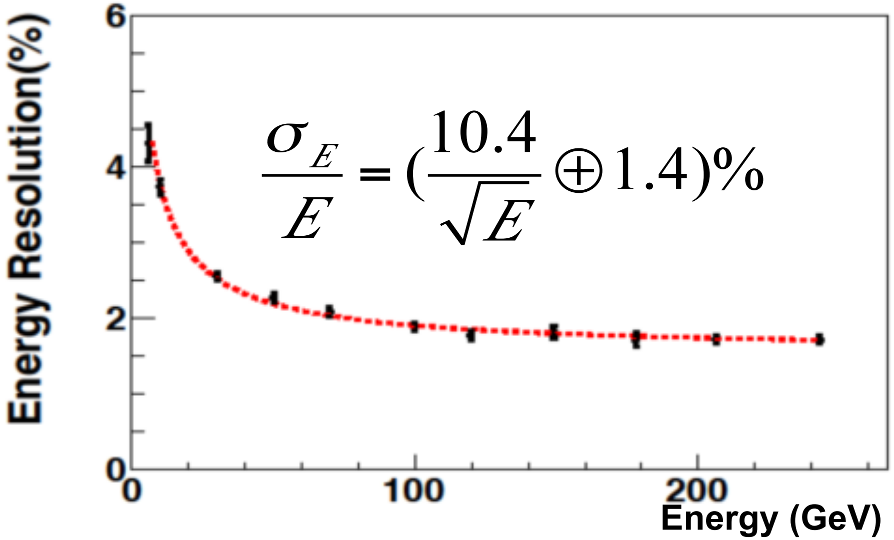
Systematic uncertainties on positron fraction

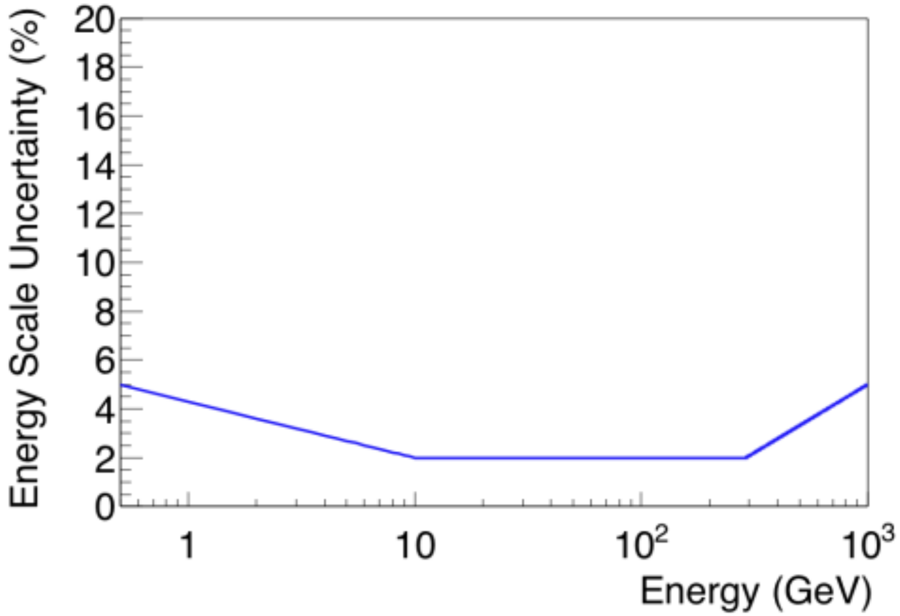
1. **Acceptance asymmetry** — Negligible above 3 GeV
2. **Bin to bin migration and energy scale** — Negligible above 5 GeV
3. **Reference spectra definition**
4. **Selection dependence**
5. **Charge confusion** — Dominant systematic above 100 GeV



Systematic uncertainties:

Bin to bin migration and energy scale





The bin widths chosen at least 2 times the energy resolution
- minimizes the migration of events to neighbouring bins
- has a negligible contribution to the systematic error

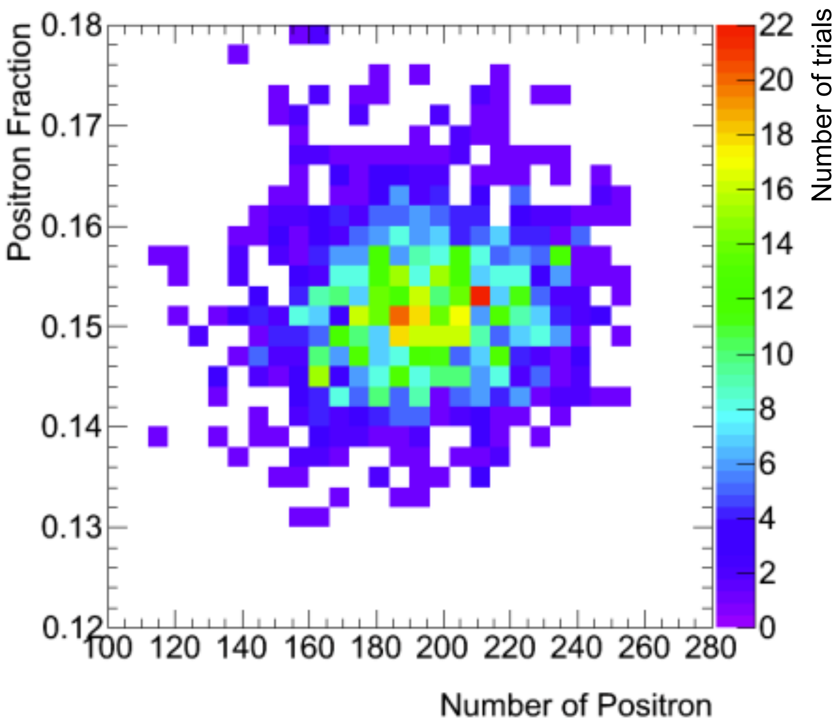
Energy scale verified with test beam up to 290 GeV

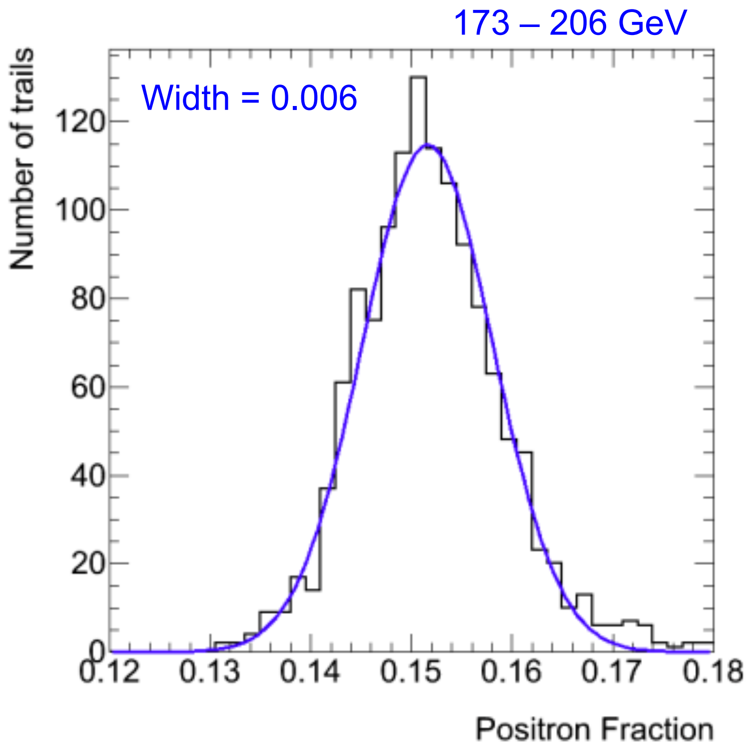
Negligible contribution to the systematical error above 5 GeV

Bin width: 2σ at 5 GeV; 4σ at 50 GeV; 8σ at 100 GeV; 19σ at 300 GeV.

Systematic uncertainties:

Selection dependence



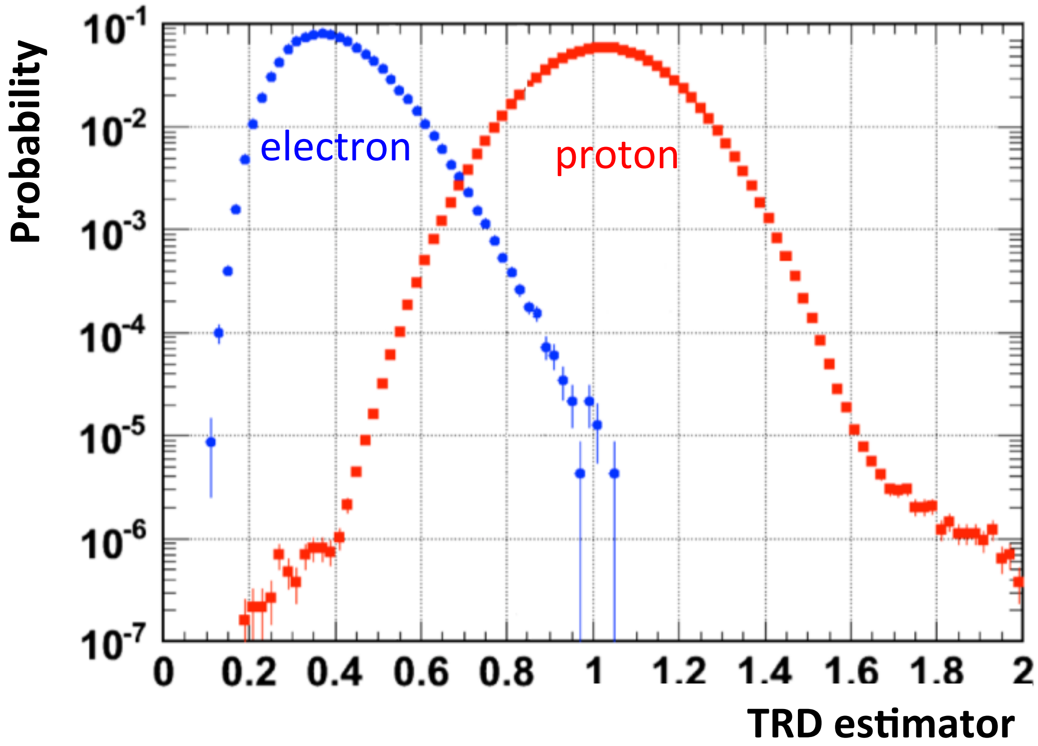


The measurement is stable **over wide variations of the cuts**
in the ECAL Shower Shape (BDT), E/p matching, etc.

For each energy bin, over 1,000 sets of cuts (trials) were analyzed.

Systematic uncertainties:

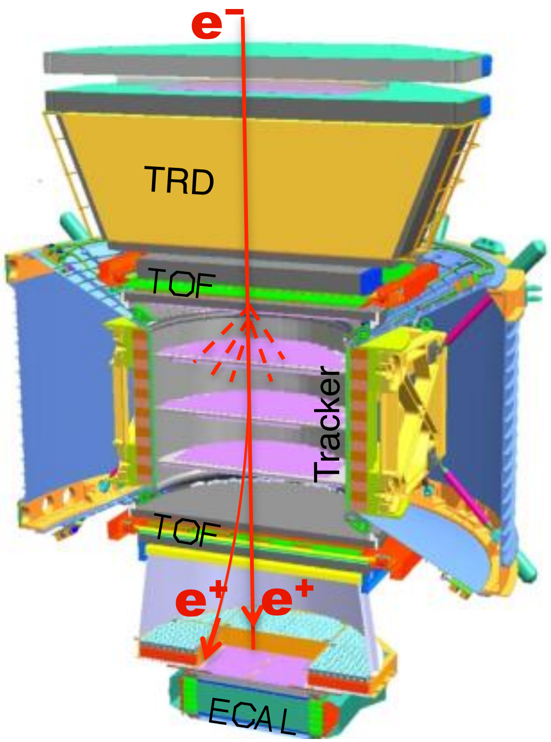
Reference spectra

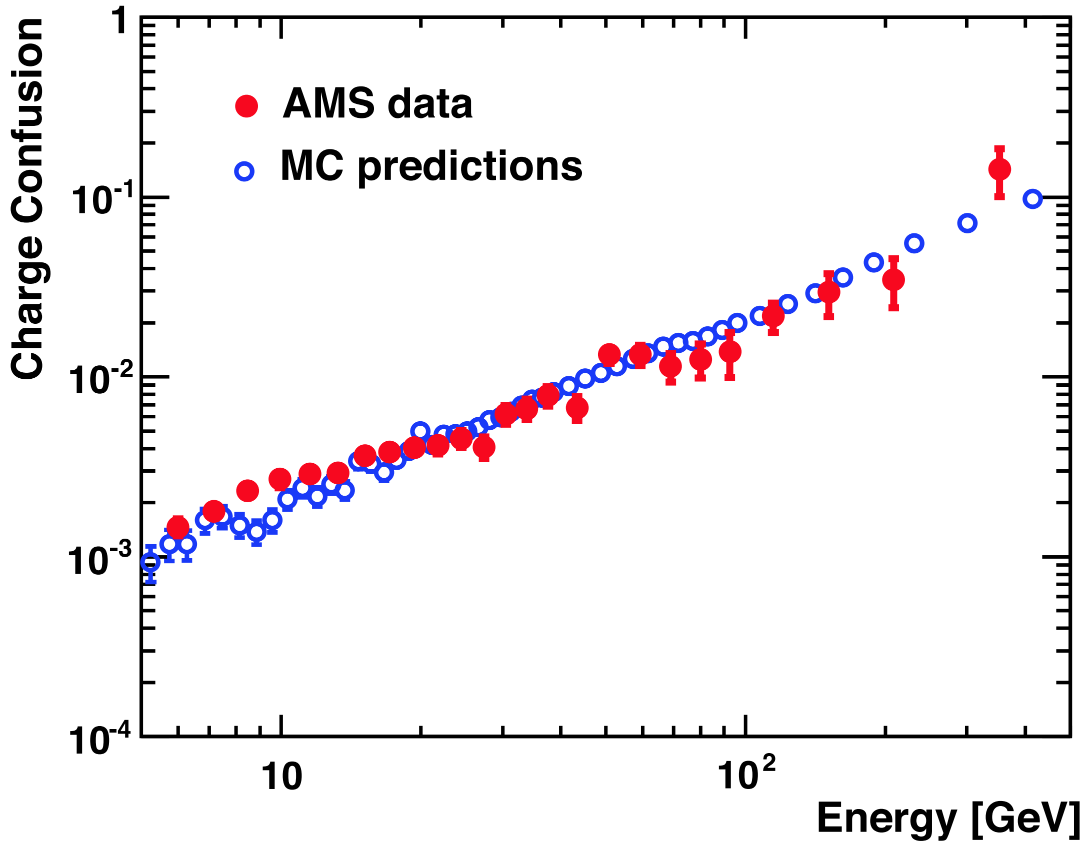


Definition of the reference spectra is based on pure samples of electrons and protons of **finite statistics**.
The systematic error associated is measured by **varying the shape** of the reference spectra **within the statistical uncertainties.**

Systematic uncertainties:

Charge confusion





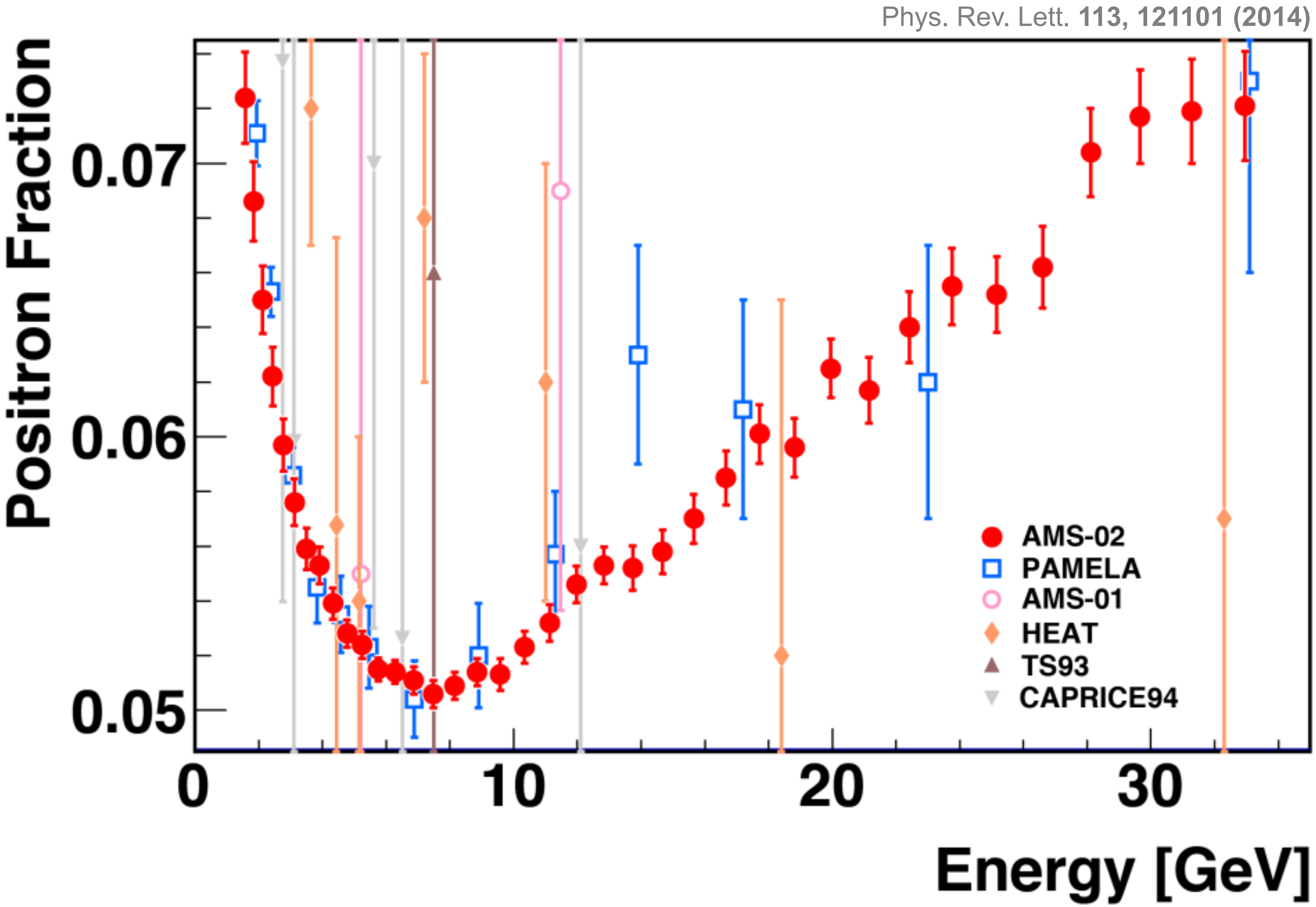
CC sources: 1) large angle scattering

2) production of secondary tracks along the path of the primary track

Both are **well reproduced** by MC.

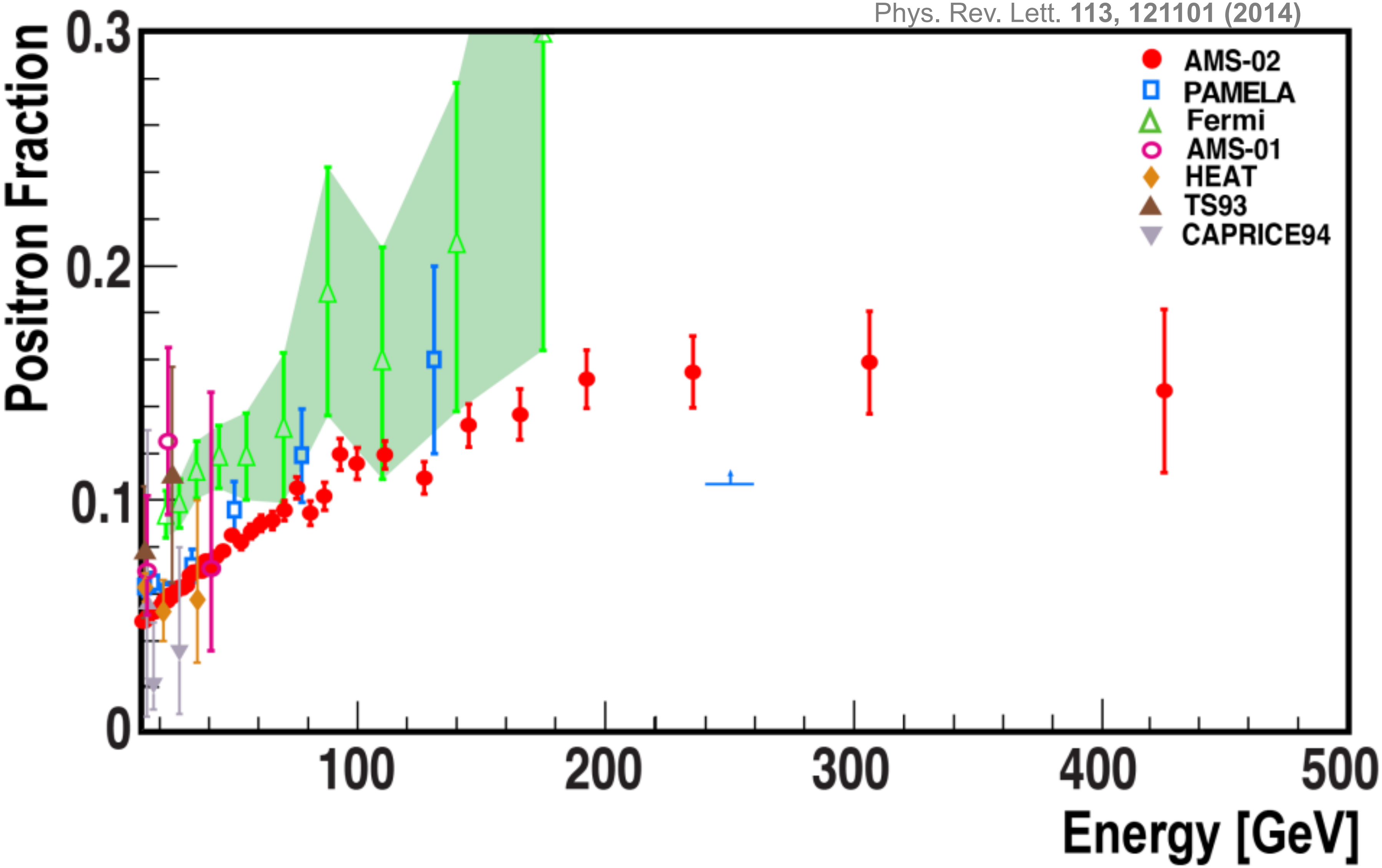
Systematic errors correspond to variations of these effects within their statistical limits and comparing the results with the MC

Positron fraction E<35GeV

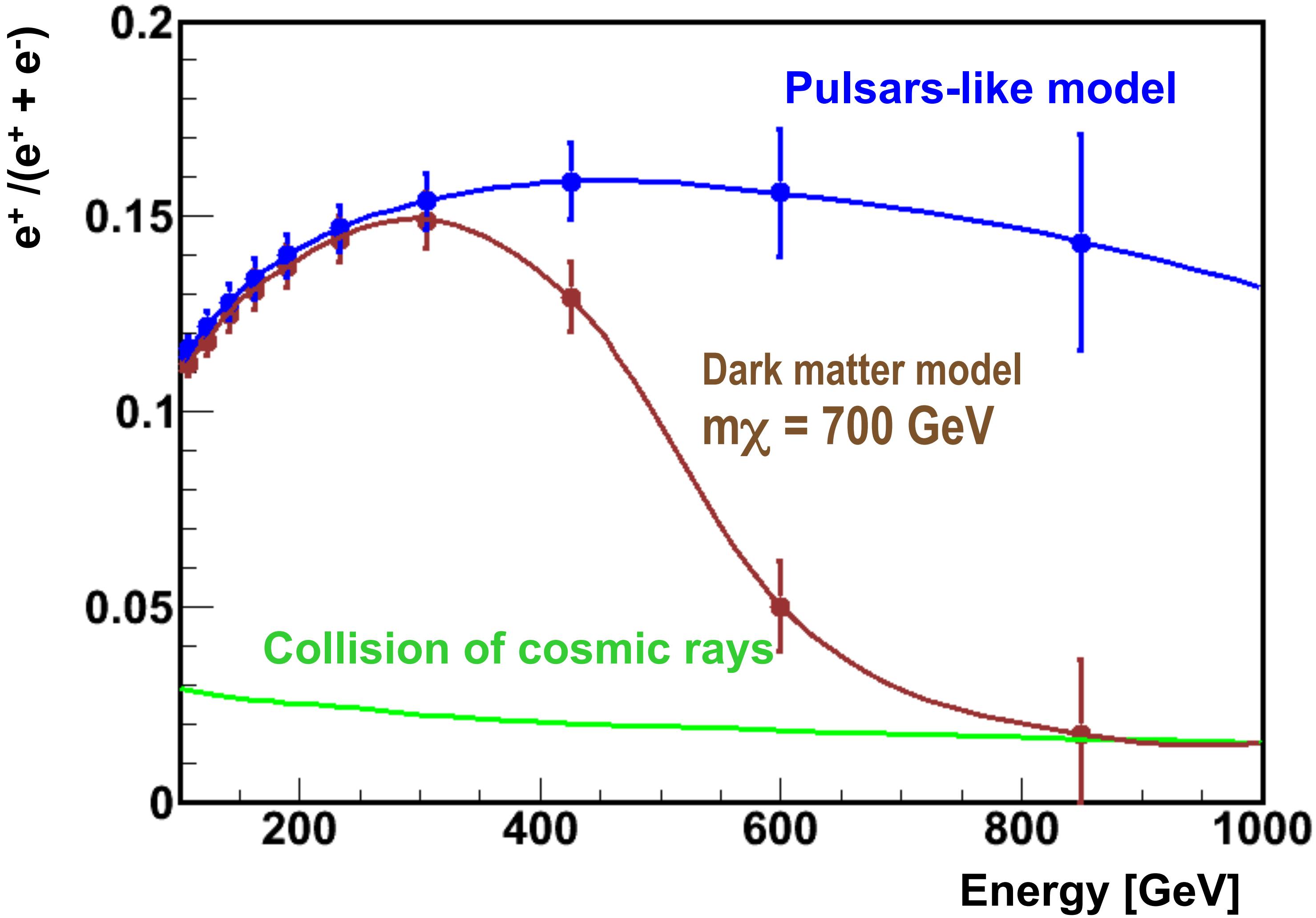


Positron fraction 0.5 – 500 GeV

Phys. Rev. Lett. **113, 121101 (2014)**



AMS sensitivity in 10 years from now

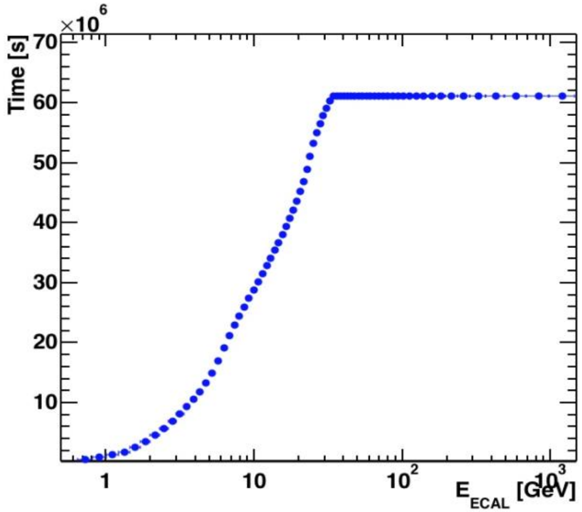


Electron and positron fluxes

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

ε_{trig} is the **trigger efficiency**
100% above 3 GeV
75% at 1 GeV

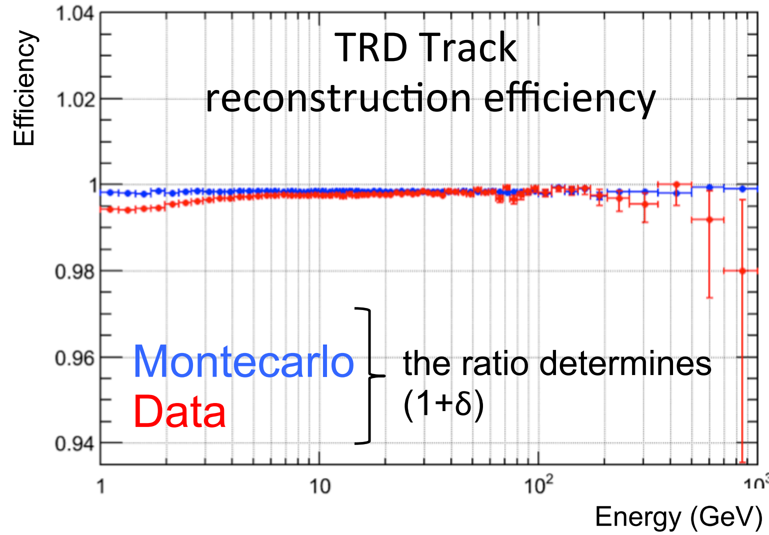
T is the **exposure time**



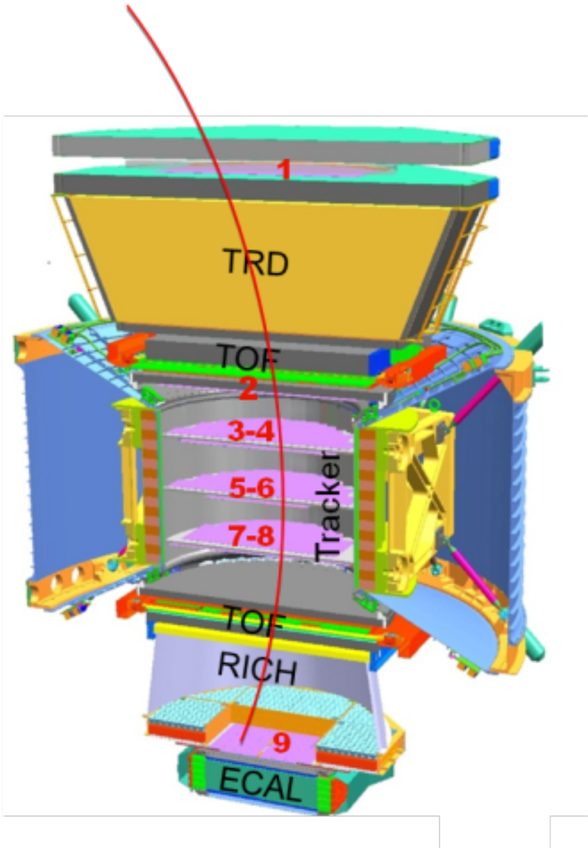
A_{eff} is the **effective acceptance**

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

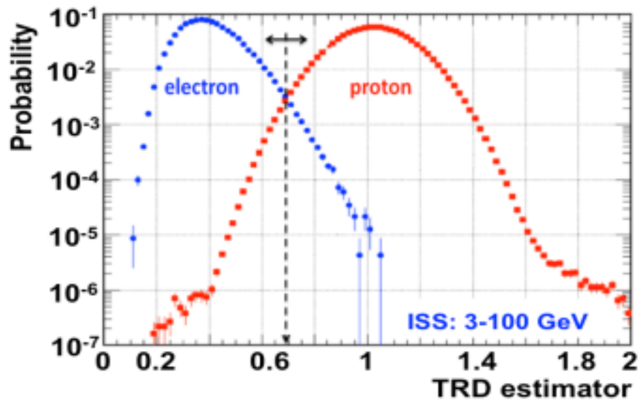
A_{geom} geometrical acceptance ≃ 550 cm^2sr
ε_{sel} is the event selection efficiency
ε_{id} is the $e^\pm$ identification efficiency
δ is a minor correction from the comparison between data and Monte Carlo (-2% at 10 Gev to -6% at 700 GeV).
The error on $(1+\delta)$ is ~2.5%.



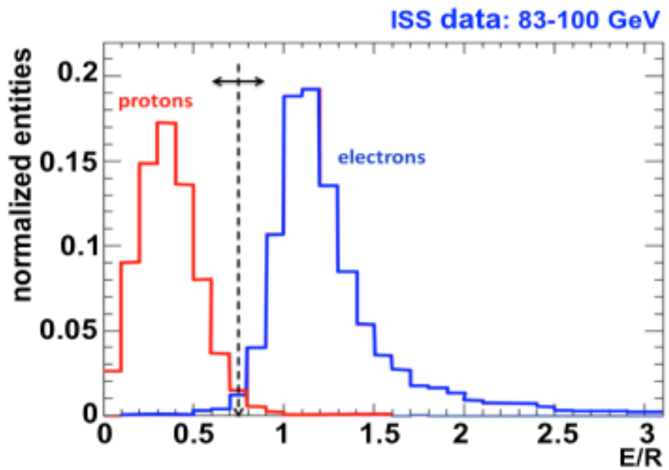
Event selection:



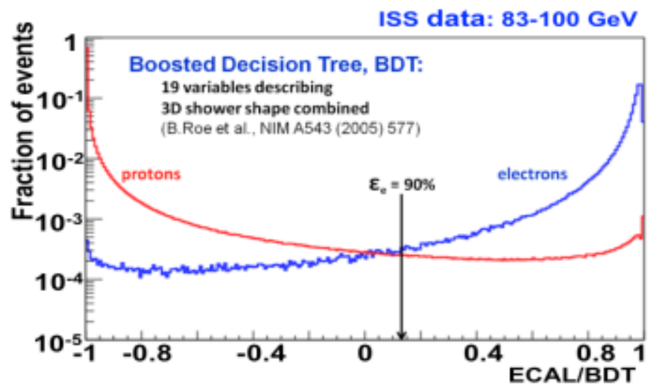
TRD
(transition radiation)



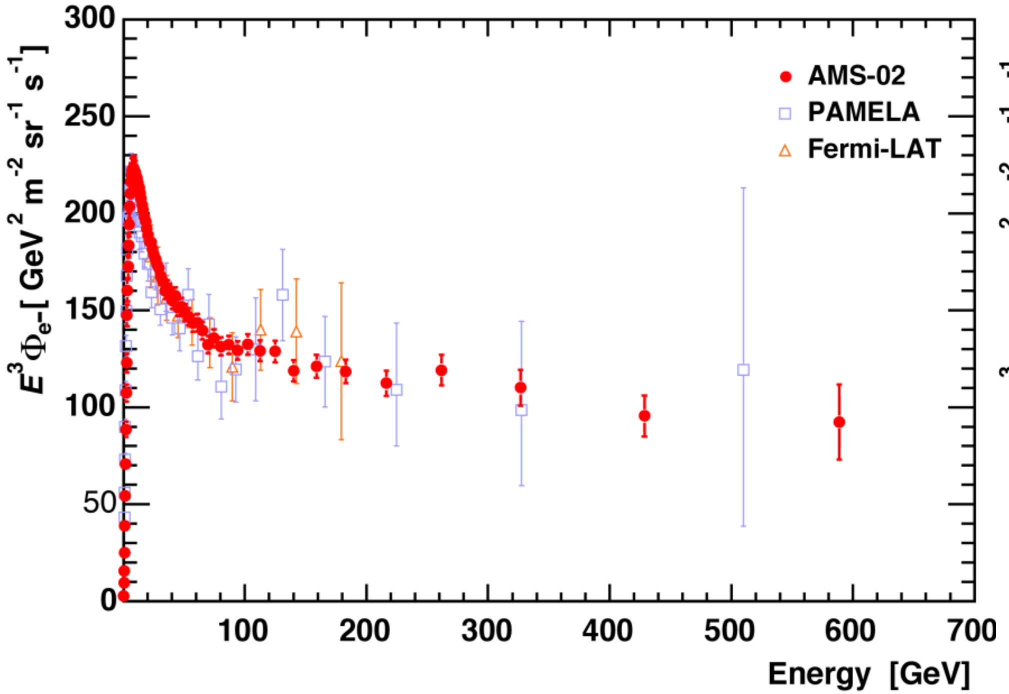
ECAL/Tracker
(E/p matching)

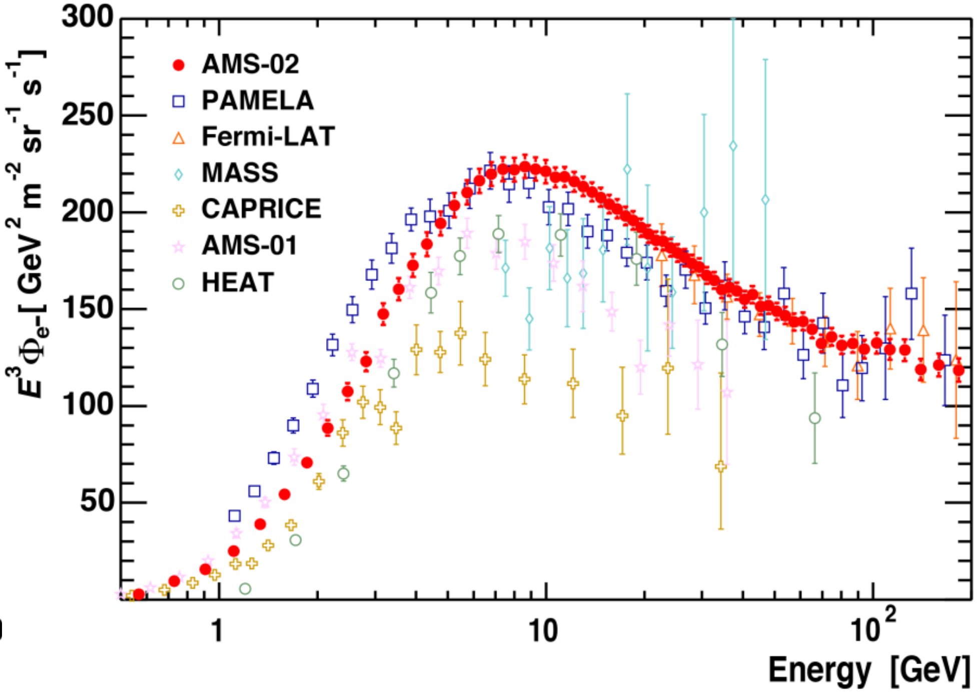


ECAL
(shower shape)



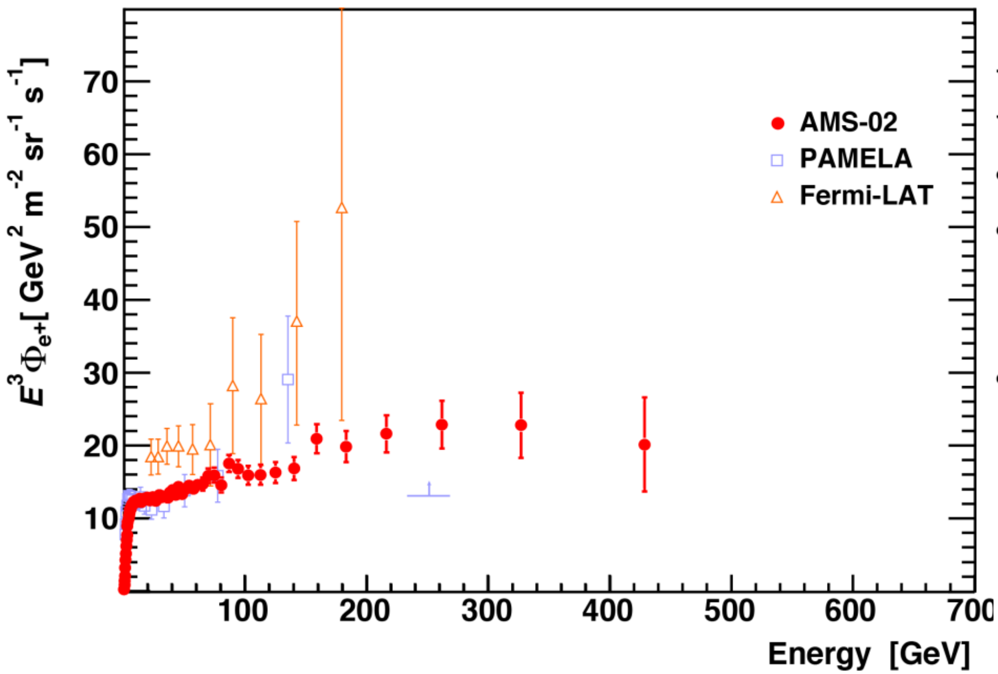
Electron flux

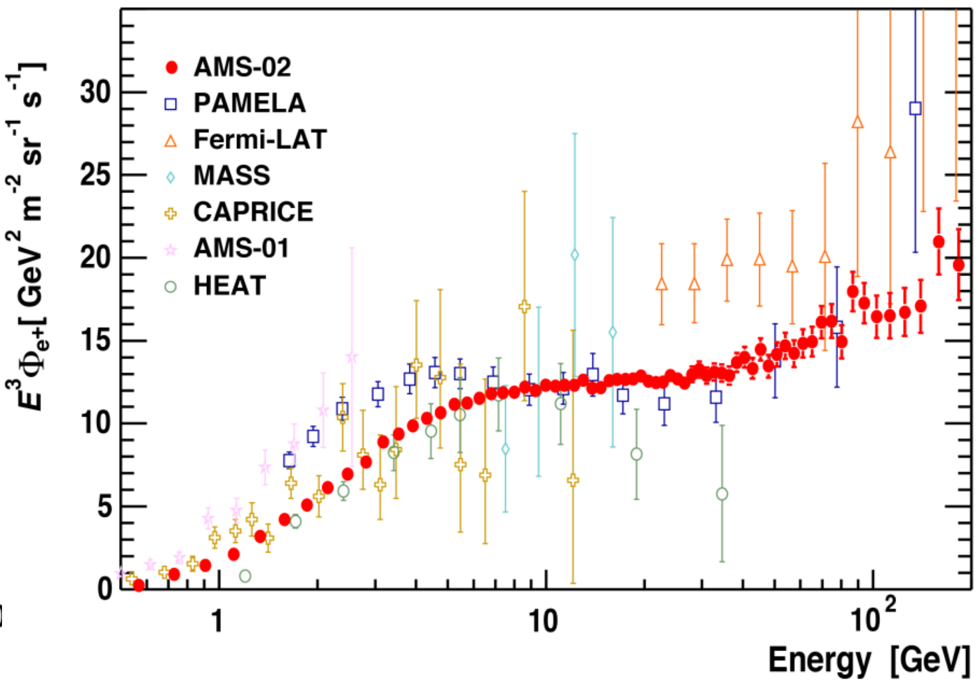




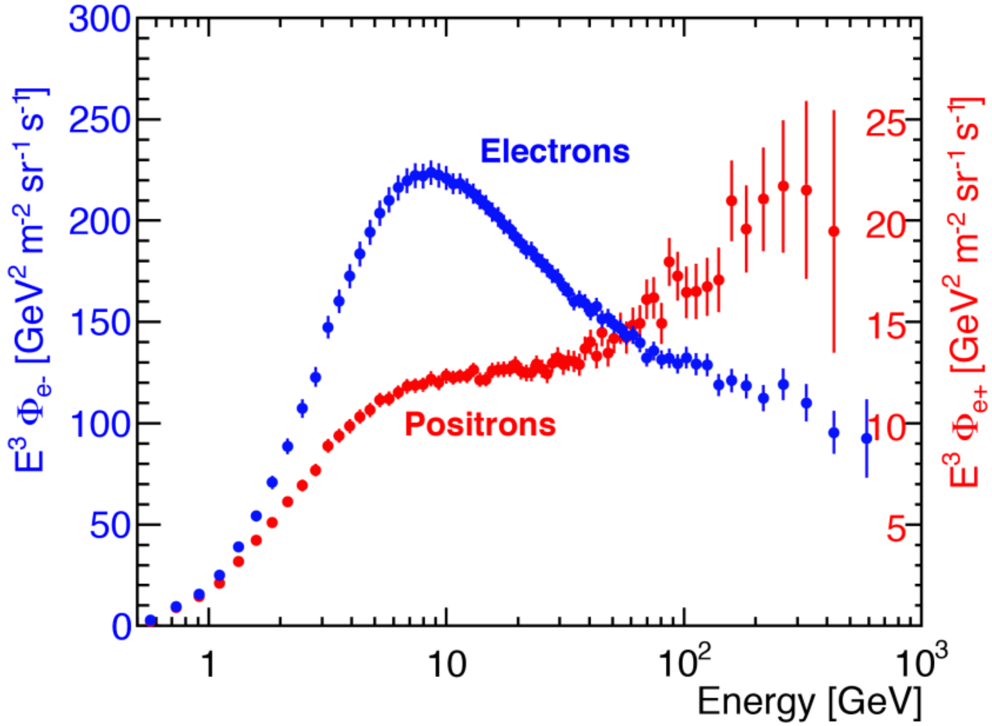
PRL **113, 121102(2014)**

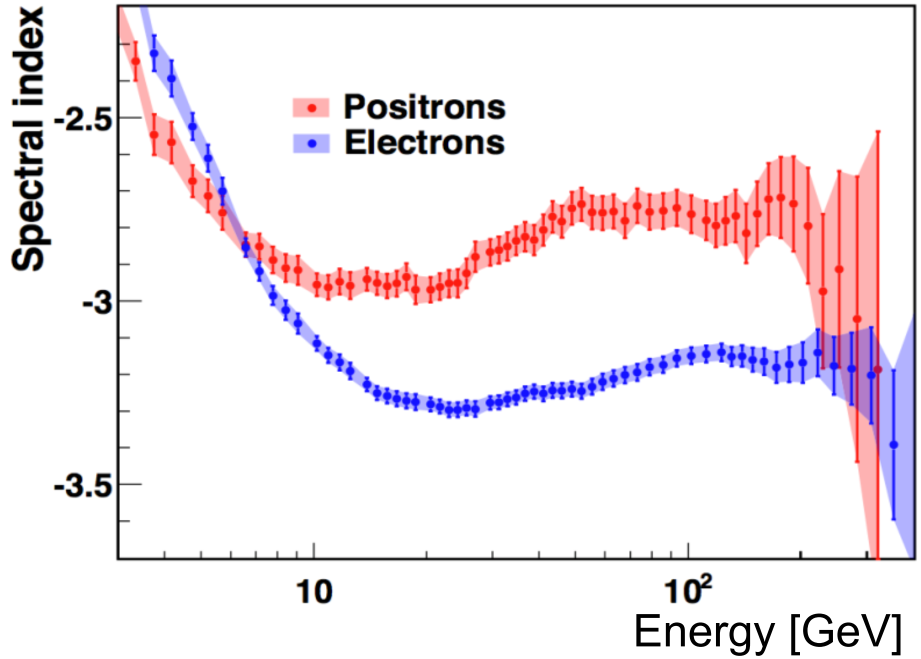
Positron flux





PRL **113, 121102(2014)**





- The electron flux and the positron flux are different in their magnitude and energy dependence.
- Both spectra **cannot** be described by a **single power law**
- The **spectral indices** of electrons and positrons are **different**
- Both change their behavior at ~30 GeV
- 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)

These new observations provide important information on the origin of cosmic ray electrons and positrons.

Minimal Model Fit to the data

Diffuse Flux / **Source Flux**

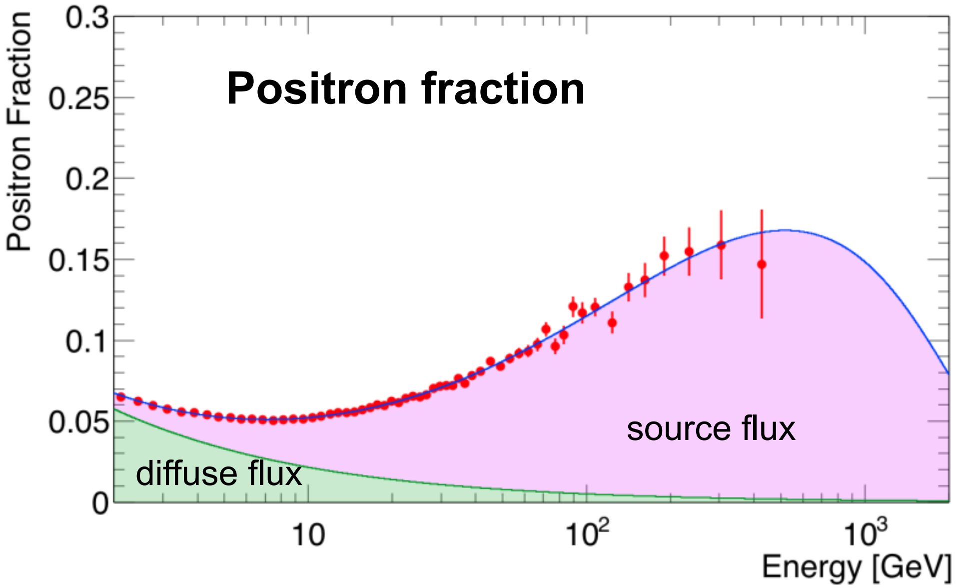
$$\Phi_{e^+} = C_{e^+}E^{-\gamma_{e^+}} + C_s E^{-\gamma_s} e^{-E/E_s}$$

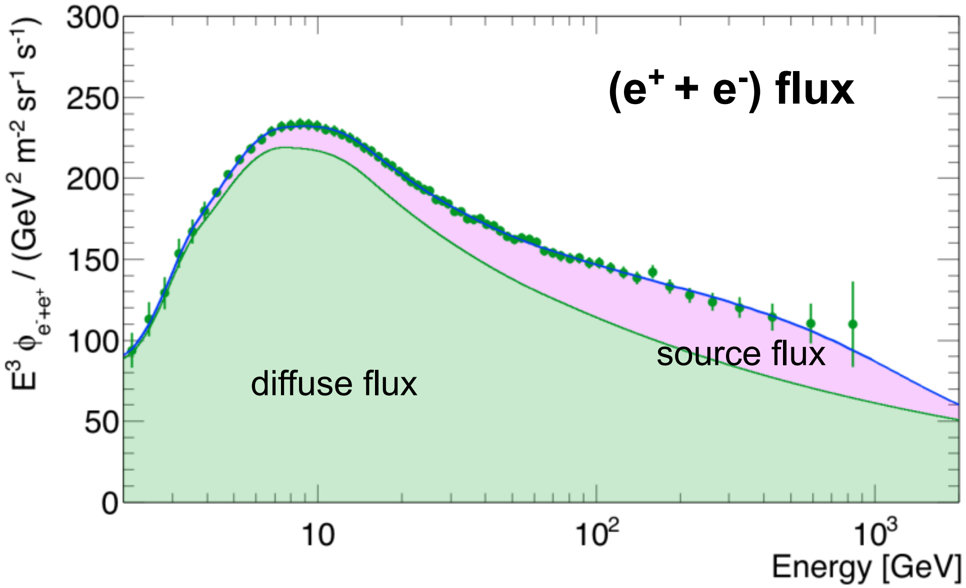
$$\Phi_{e^-} = C_{e^-}E^{-\gamma_{e^-}} + C_s E^{-\gamma_s} e^{-E/E_s}$$

The source term is identical in electron and positron

Simultaneous fit from 2 GeV to the positron fraction and to the ($e^+ + e^-$) flux to determine all the parameters

Talk by J.Bazo





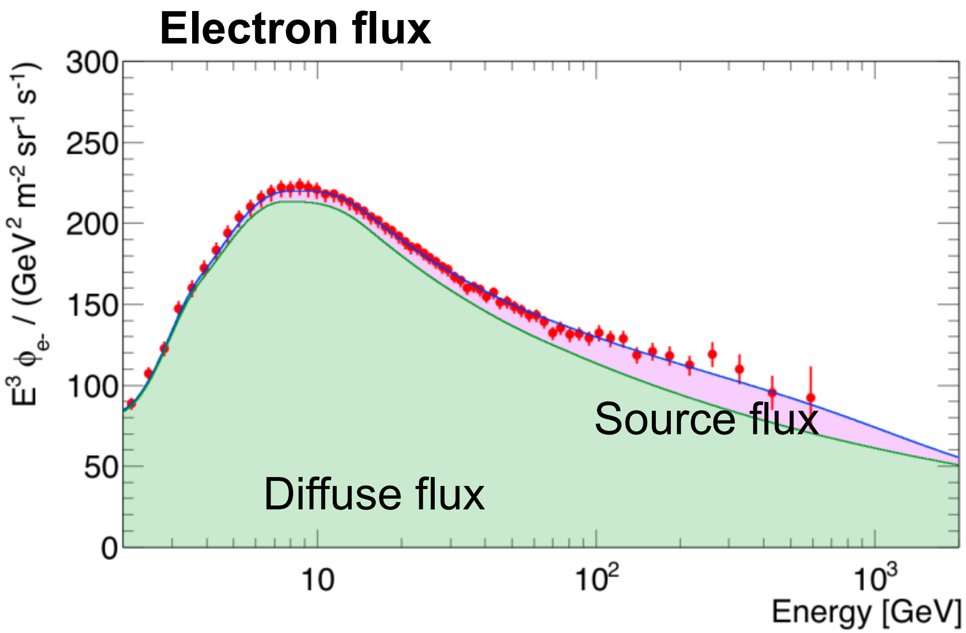
Minimal model prediction:

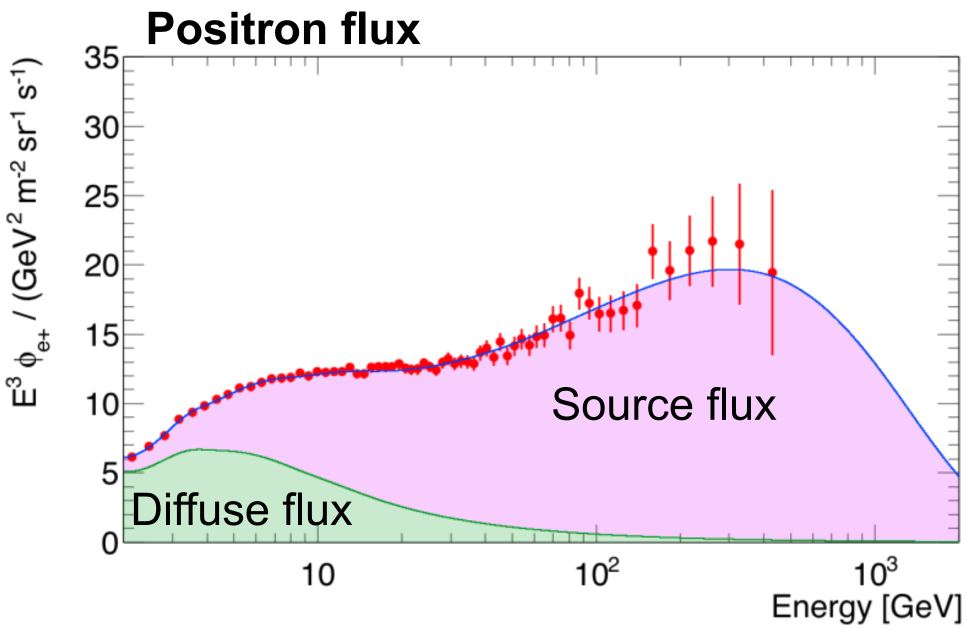
Diffuse Flux Source Flux

$$\Phi_{e^+} = \boxed{C_{e^+} E^{-\gamma_{e^+}}} + \boxed{C_s E^{-\gamma_s} e^{-E/E_s}}$$

$$\Phi_{e^-} = \boxed{C_{e^-} E^{-\gamma_{e^-}}} + \boxed{C_s E^{-\gamma_s} e^{-E/E_s}}$$

Curves drawn using the parameters predicted from fit to
a)Positron Fraction and
b)Electron + Positron Flux





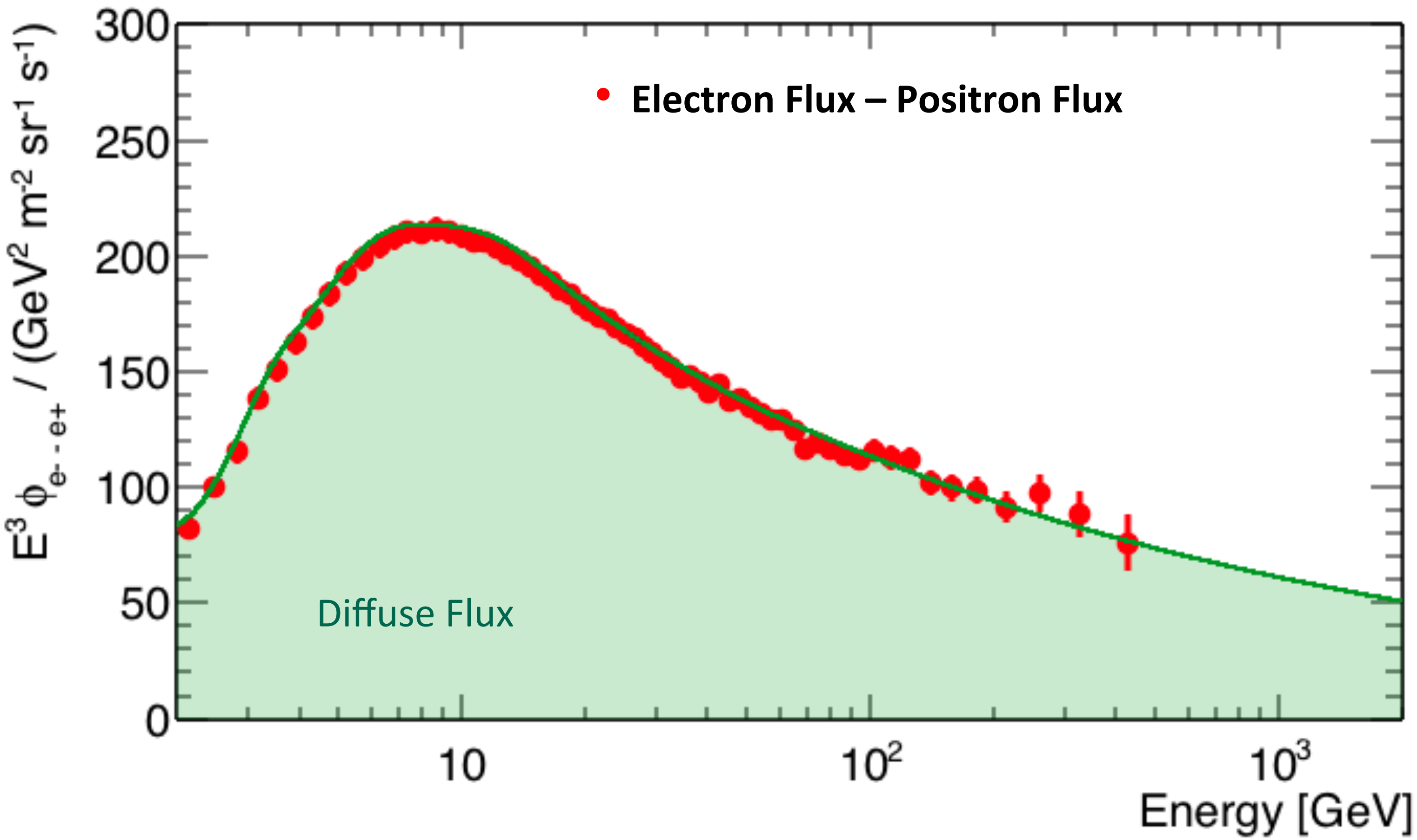
Minimal Model:

Diffuse Flux   Source Flux

$$\Phi_{e^+} = \boxed{C_{e^+}E^{-\gamma_{e^+}}} + \boxed{C_s E^{-\gamma_s} e^{-E/E_s}}$$

$$\Phi_{e^-} = \boxed{C_{e^-}E^{-\gamma_{e^-}}} + \boxed{C_s E^{-\gamma_s} e^{-E/E_s}}$$

Curve drawn using the parameters predicted from fit to
a)Positron Fraction and
b)Electron + Positron Flux



Conclusions

- AMS has been running smoothly for more than 3 years, 30 months of data have been analyzed
- New AMS results are presented:
  - **Positron fraction up to 500 GeV** PRL **113, 121101(2014)**
  - **Positron flux up to 500 GeV**
  - **Electron flux up to 700 GeV** PRL **113, 121102(2014)**
  - **Positron and electron combined flux up to 1 TeV** Subm. PRL
- CR positrons and electrons are not consistent with only diffuse power law component, **an additional source is needed** to explain the measured positron fraction and the positron and electron fluxes.

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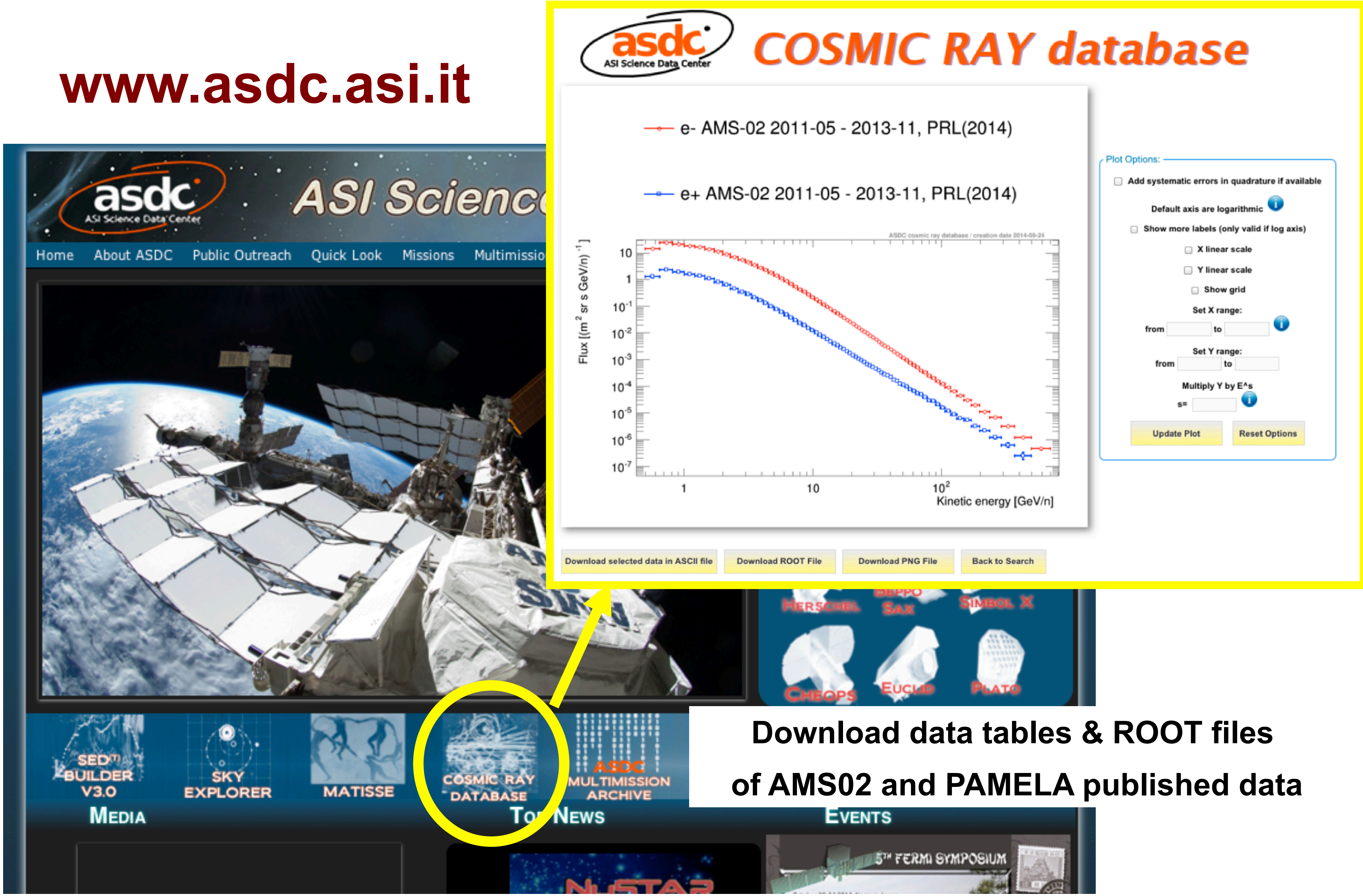


Download data tables & ROOT files of AMS02 and PAMELA published data

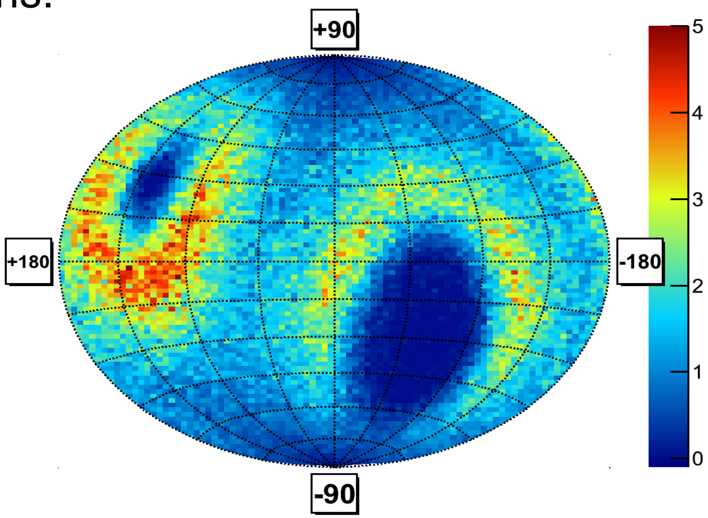
Backup slides

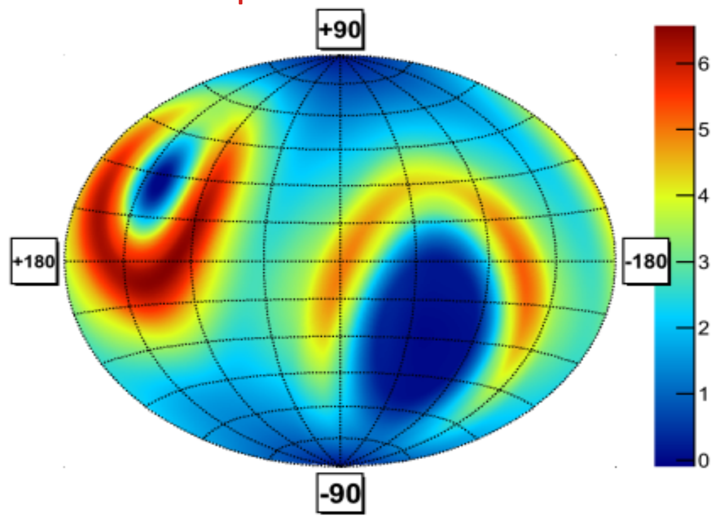
Flux anisotropy

Measured Distribution

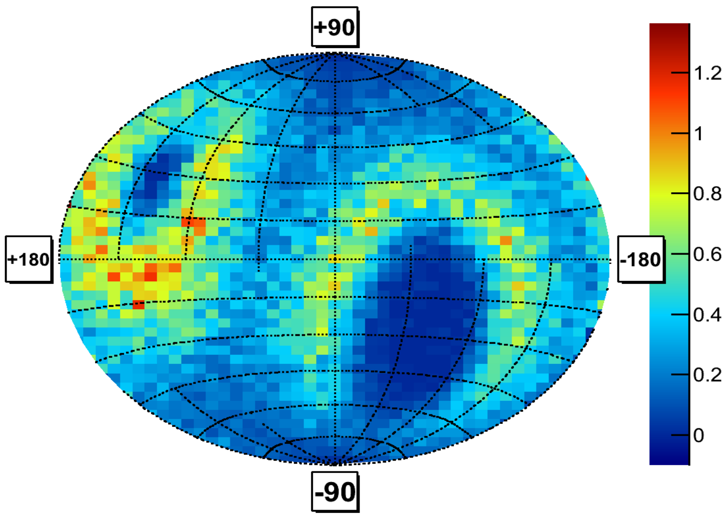
Expected Isotropic Distribution

Electrons:





Positrons:



The incoming direction of **electrons** above 16 GeV in galactic coordinates yields **δ ≤ 0.01 at the 95% confidence level**

The incoming direction of **positrons** above 16 GeV in galactic coordinates yields **δ ≤ 0.03 at the 95% confidence level**

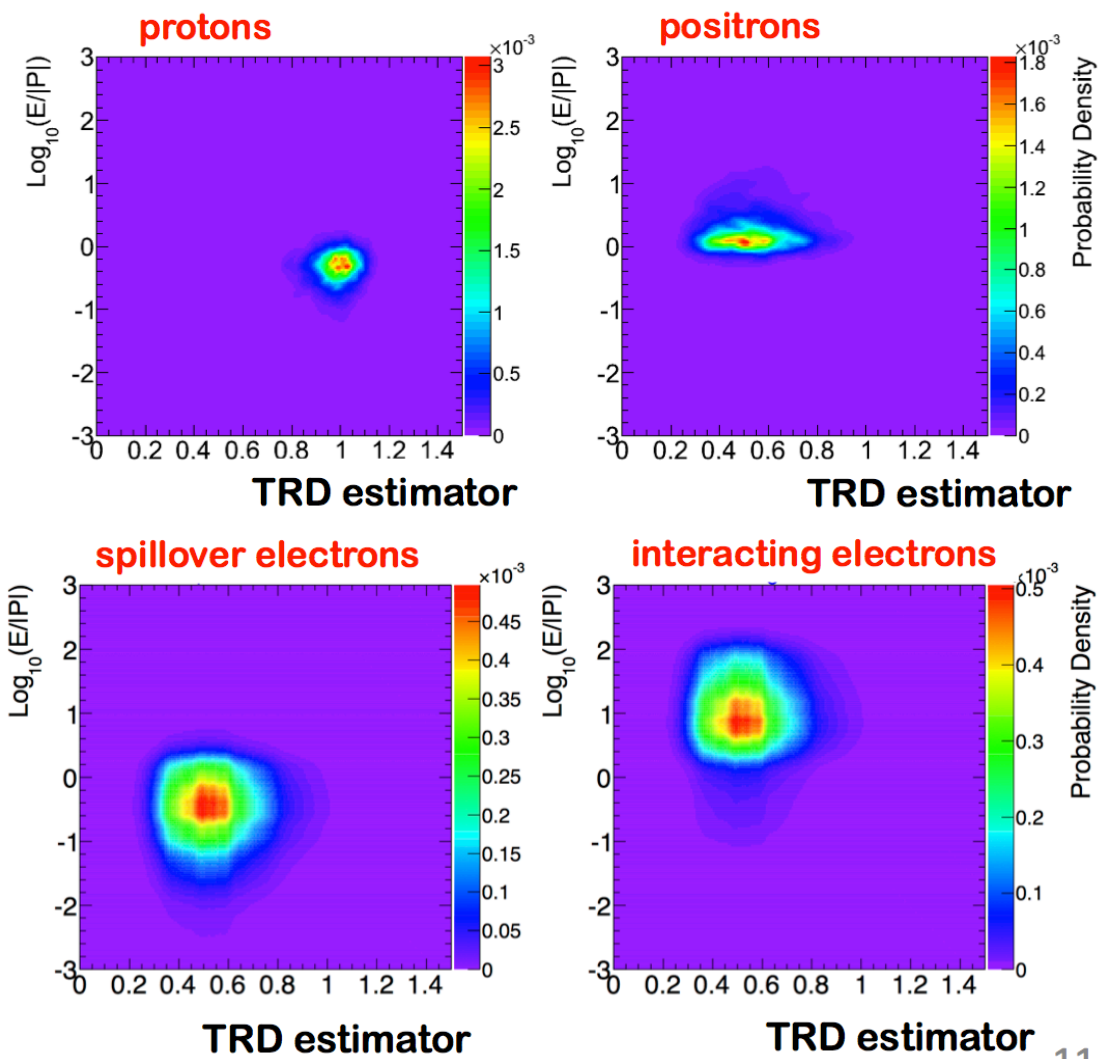
2D fit measuring Ne+ Ne+ Np

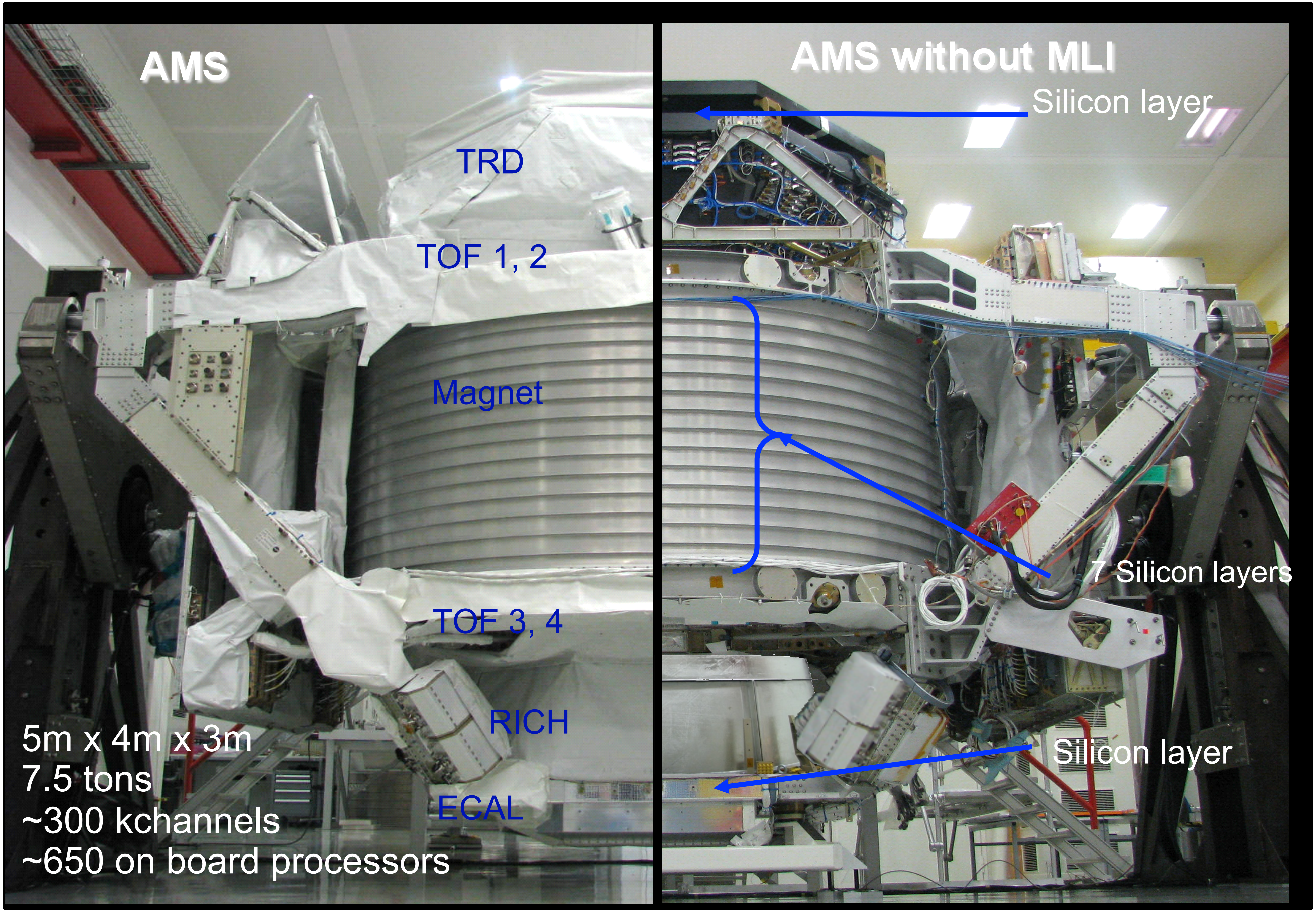
Fit in TRD Estimator - log(e/p) plane

Combines information from TRD; ECAL and Tracker

Proton event well separated

Charged confused events measured directly from data




AMS
TRD
TOF 1, 2
Magnet
TOF 3, 4
RICH
ECAL
5m x 4m x 3m
7.5 tons
~300 kchannels
~650 on board processors
AMS without MLI
Silicon layer
7 Silicon layers
Silicon layer

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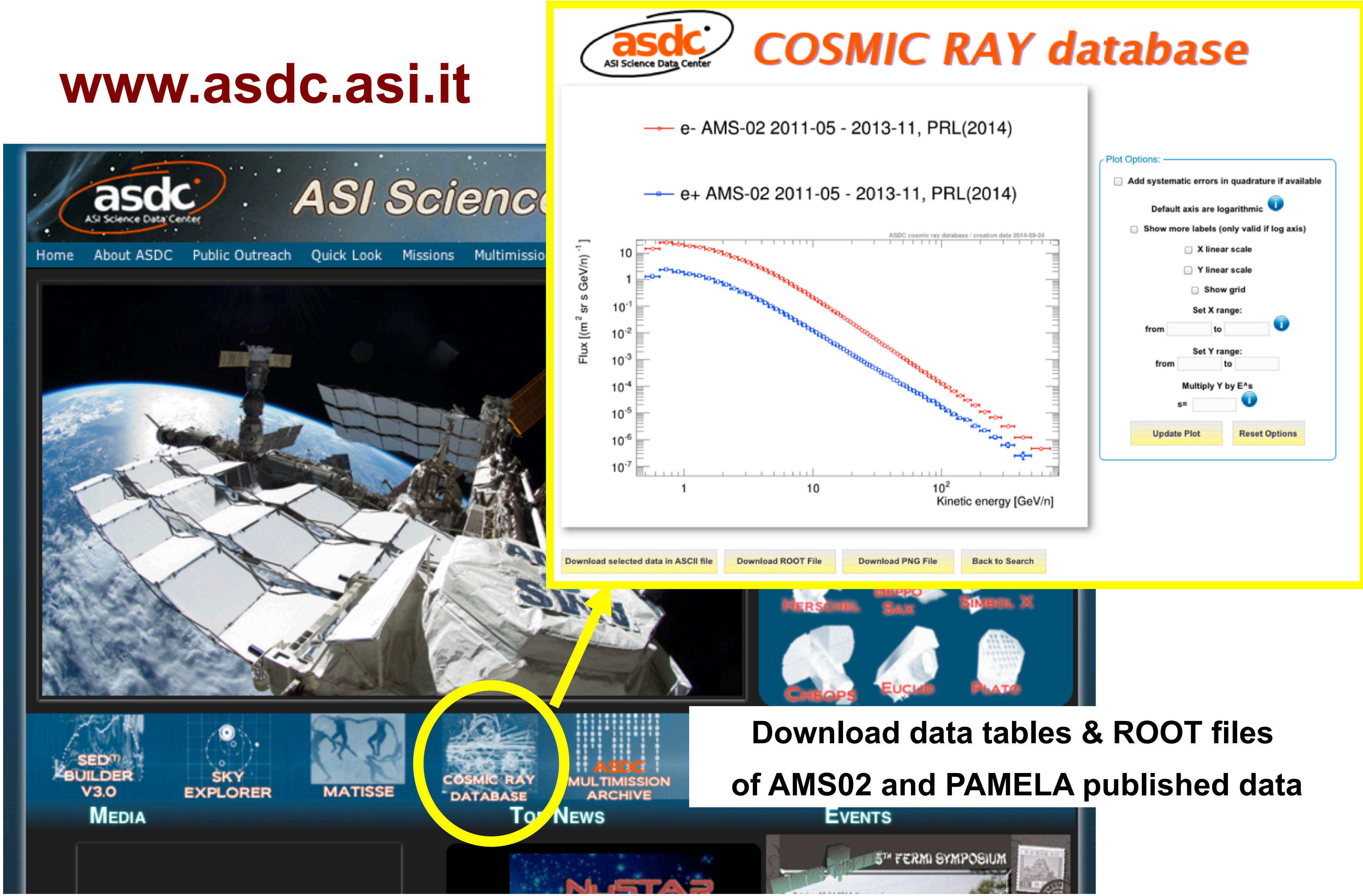

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