

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



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INFN and ASI Science Data Center



October 2nd 2014

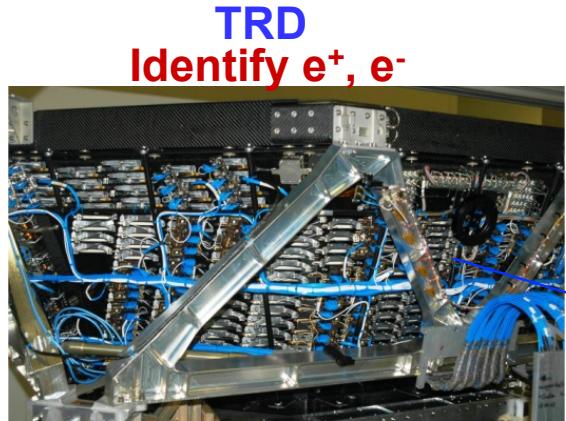


Outline:

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



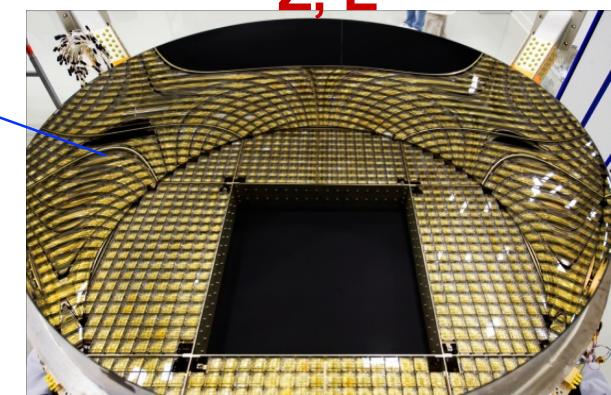
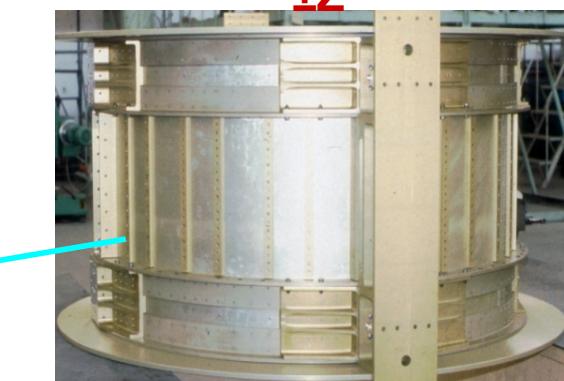
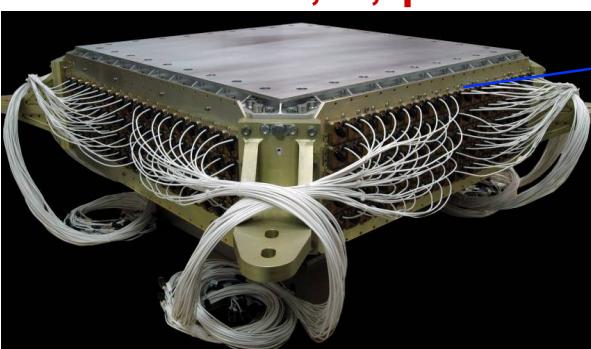
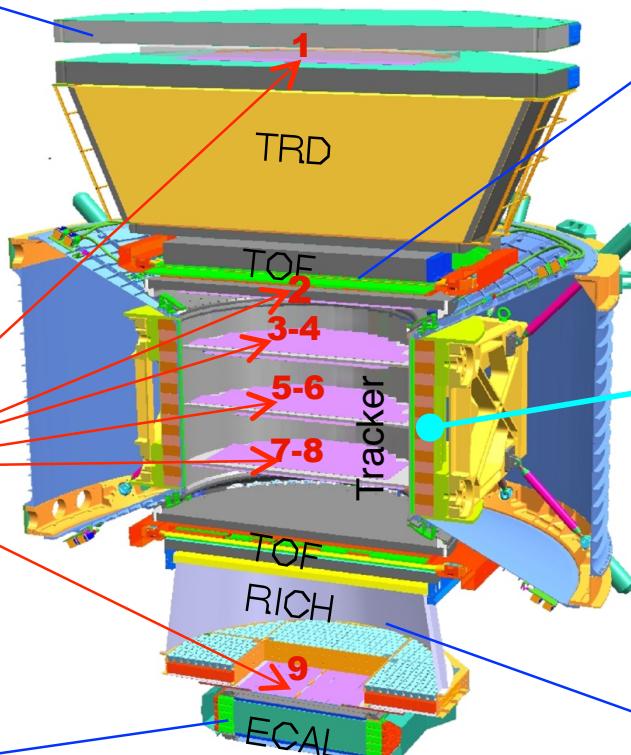
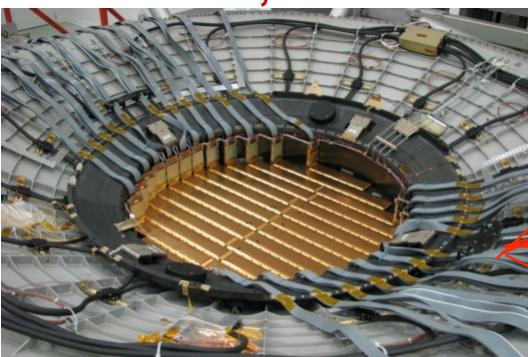
AMS02: a TeV precision multipurpose spectrometer



Particles and nuclei are defined by their charge (Z) and energy ($E \sim P$)

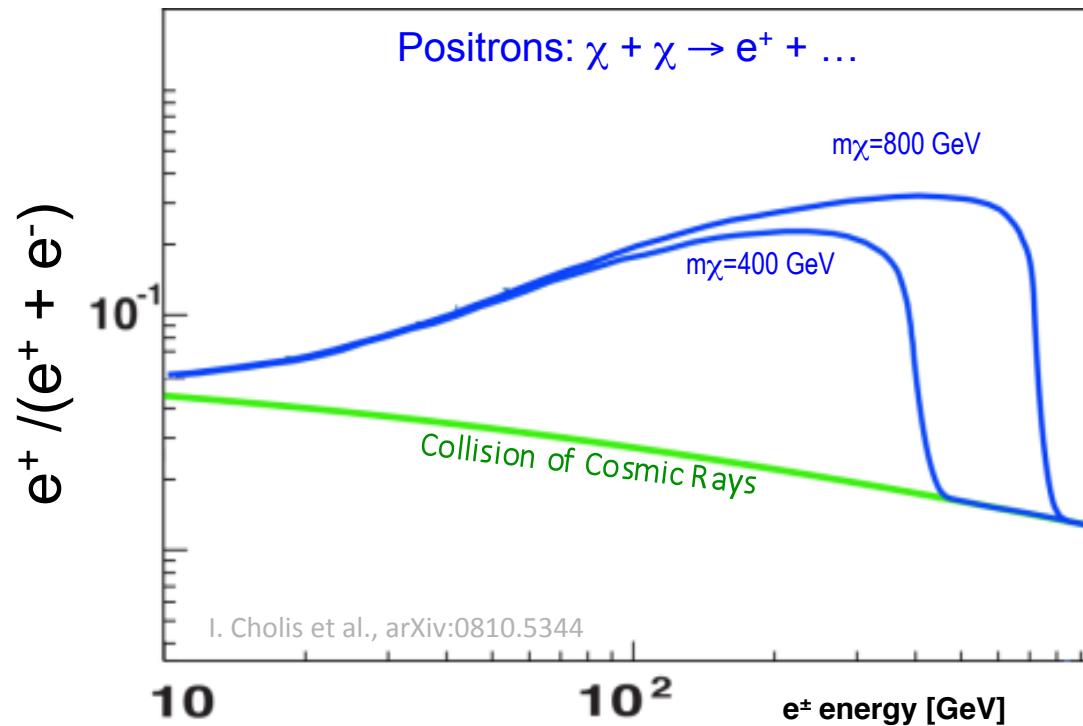


Silicon Tracker
 Z, P



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} , ...



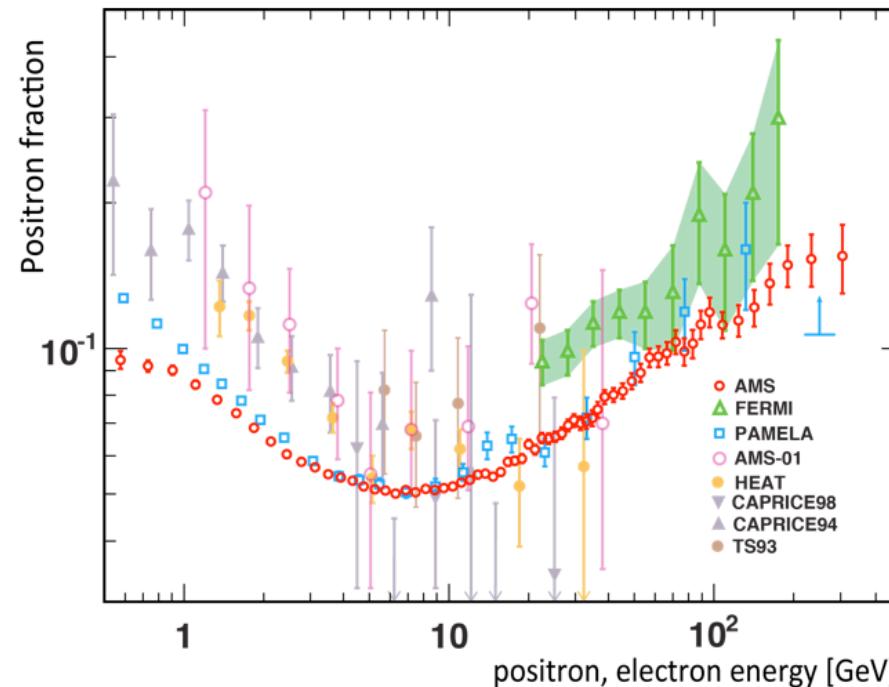
M. Turner and F. Wilczek, Phys. Rev. D42 (1990) 1001

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

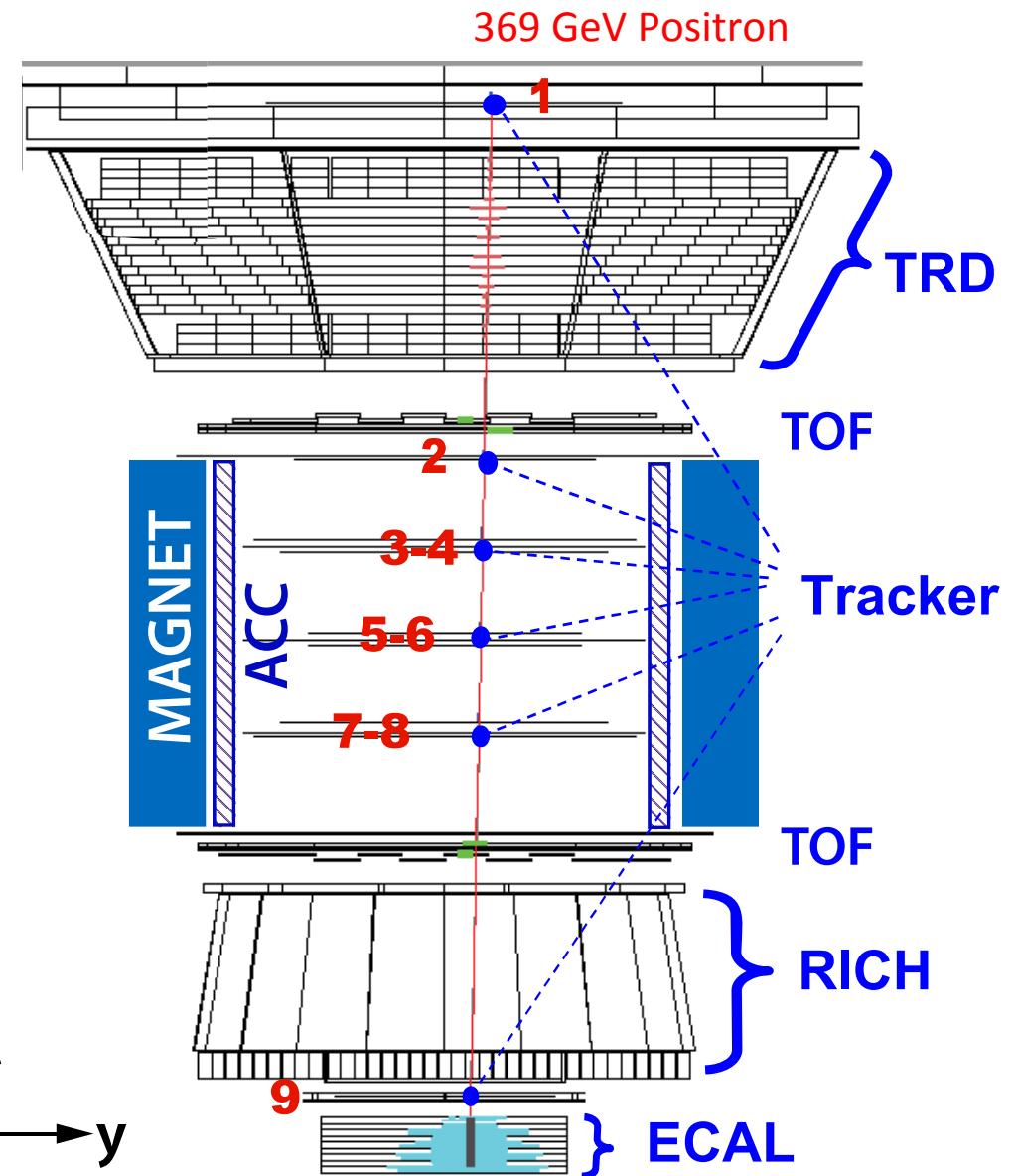
- extends the energy range
- increases its precision



PRL 110 (2013)141102

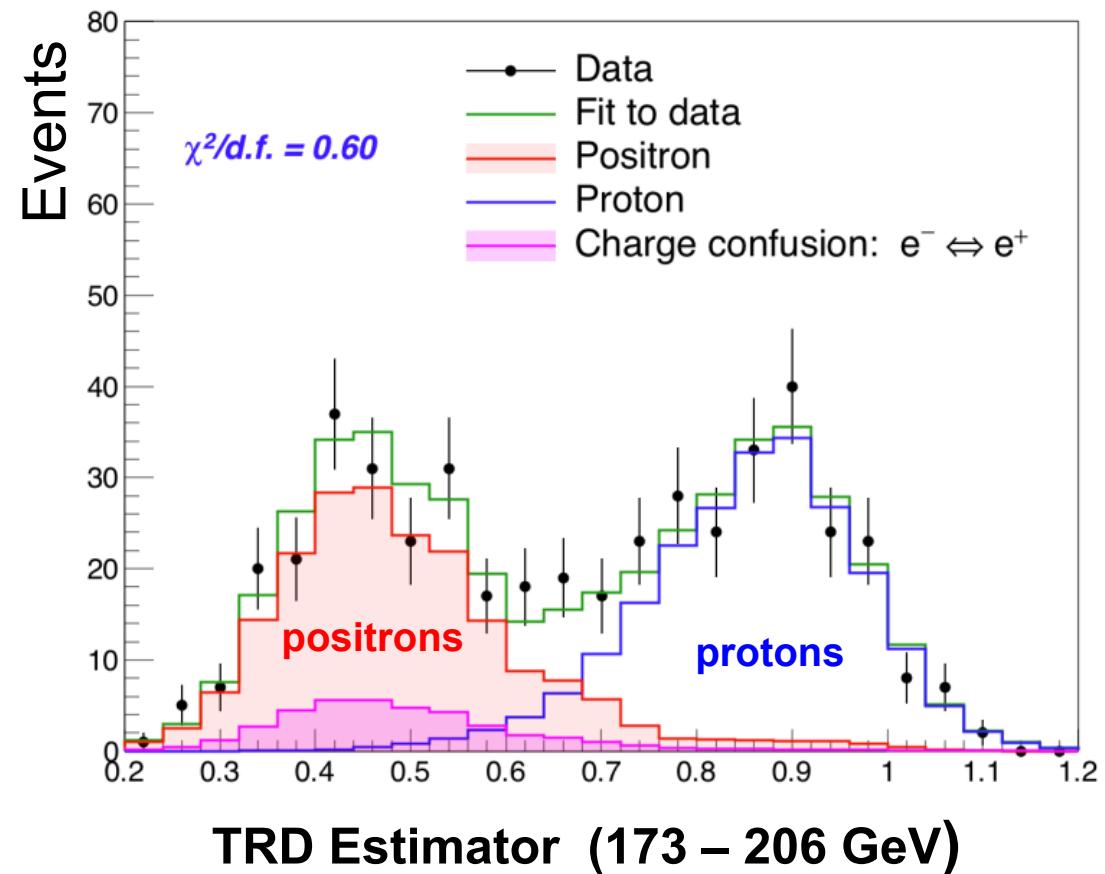
Positron fraction event selection:

- 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



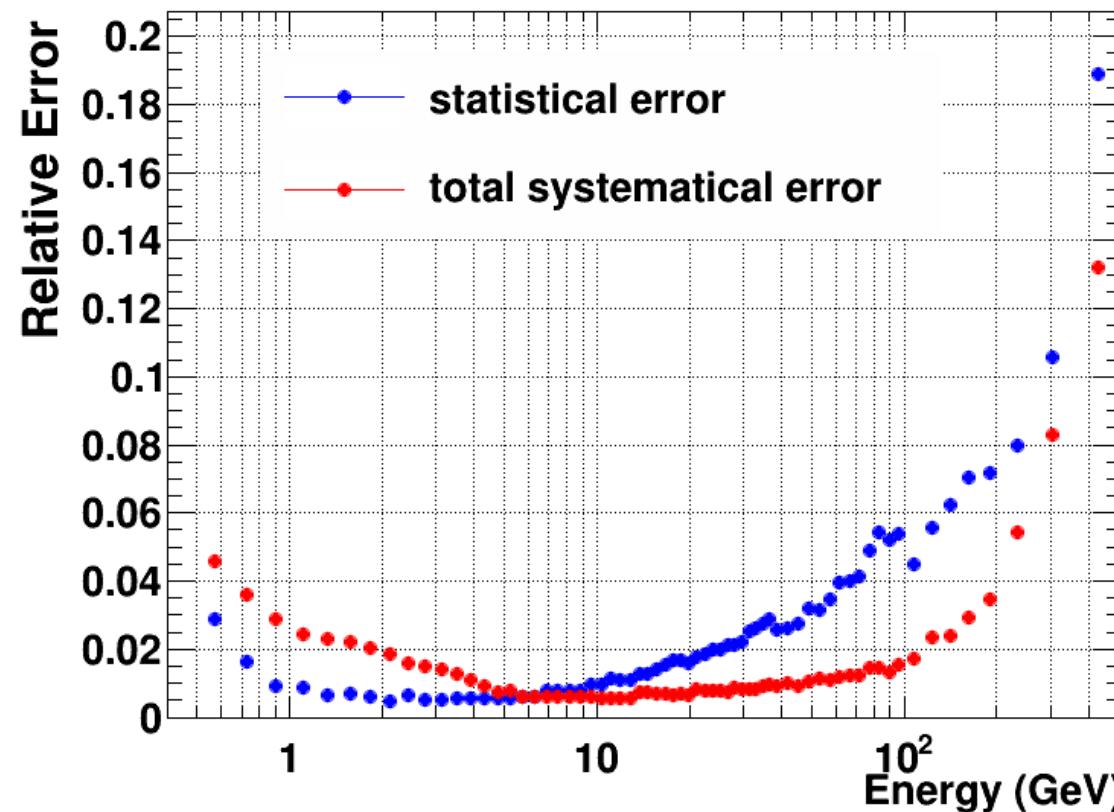
The number of positrons, the number of electrons, the number of residual protons and the amount of charge confusion is determined in each energy bin with a fit of two-dimensional reference spectra in the TRD-Estimator – log(E/p) plane

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



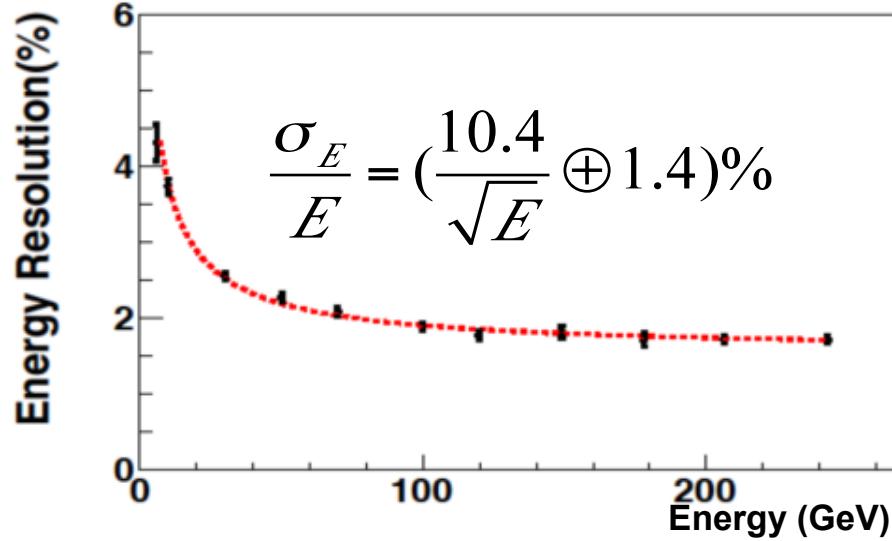
Systematic uncertainties on positron fraction

- | | |
|--|-----------------------------------|
| 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 |



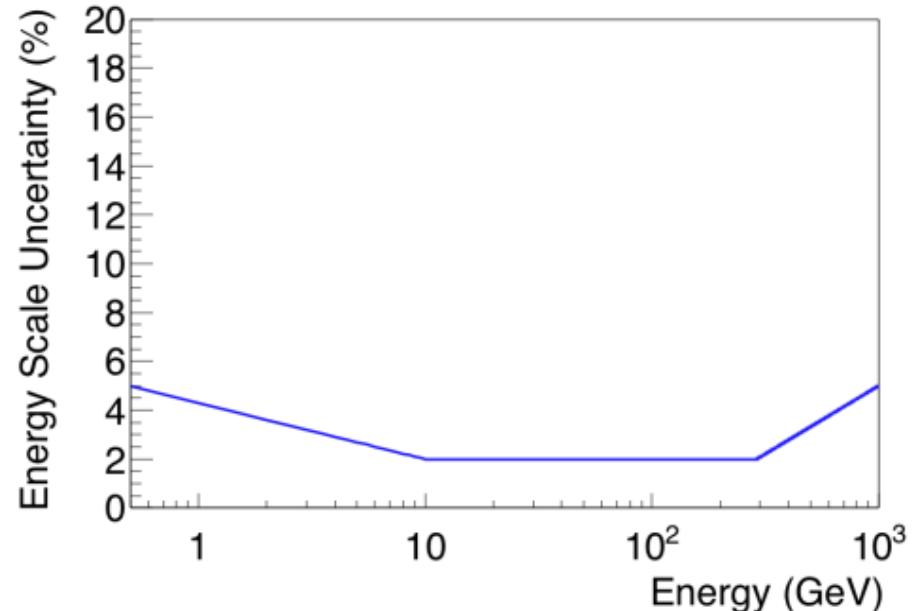
Systematic uncertainties:

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



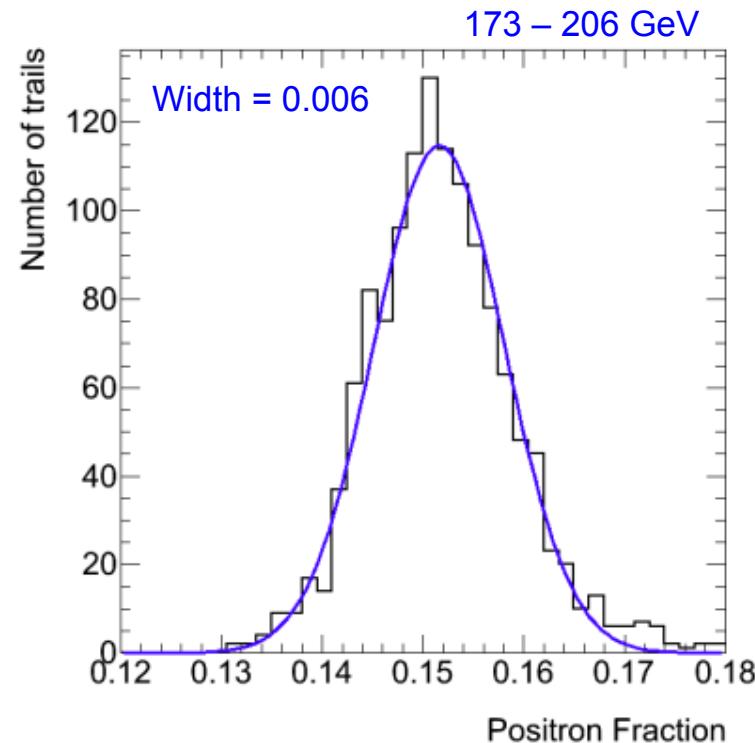
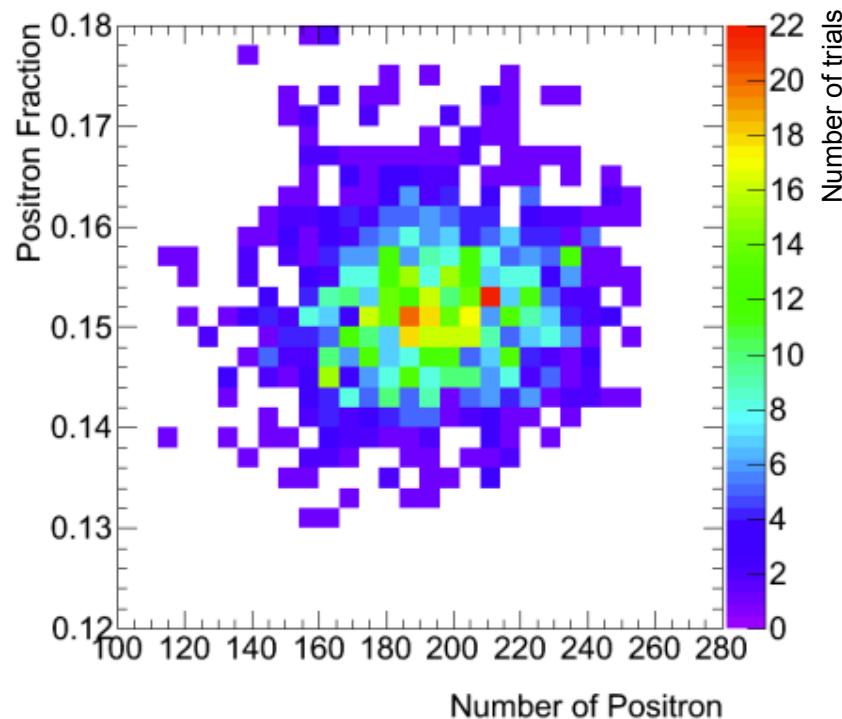
Energy scale verified with test beam up to 290 GeV

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

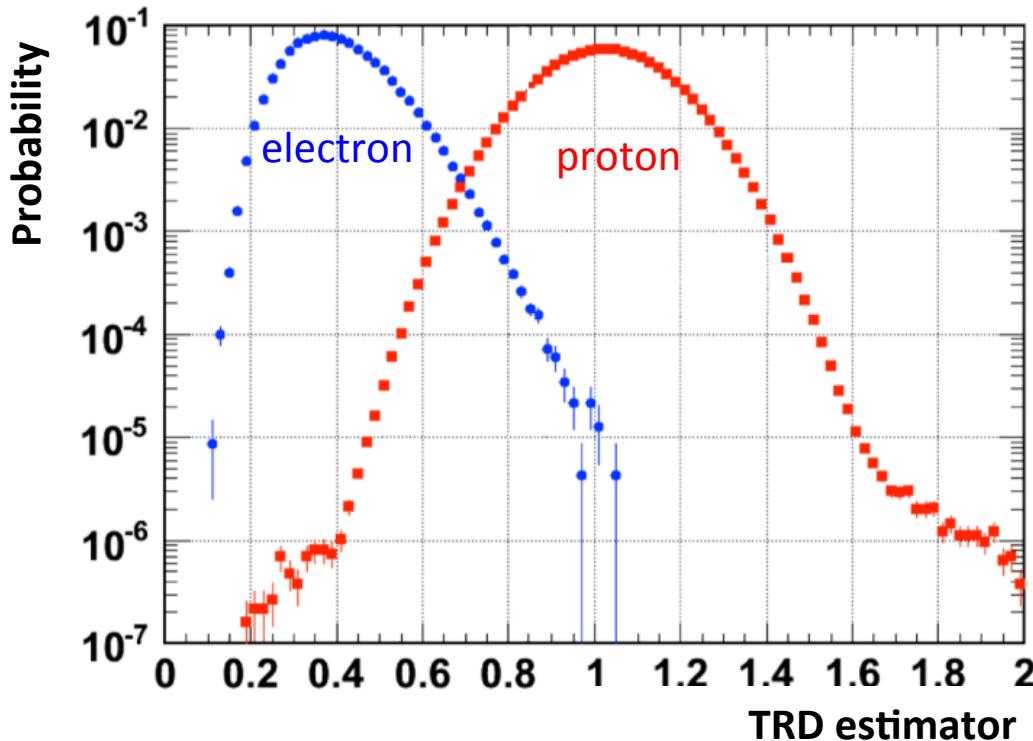


The measurement is stable **over wide variations of the cuts**
in the ECAL Shower Shape (BDT), E/p matching, etc.

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

Systematic uncertainties:

Reference spectra

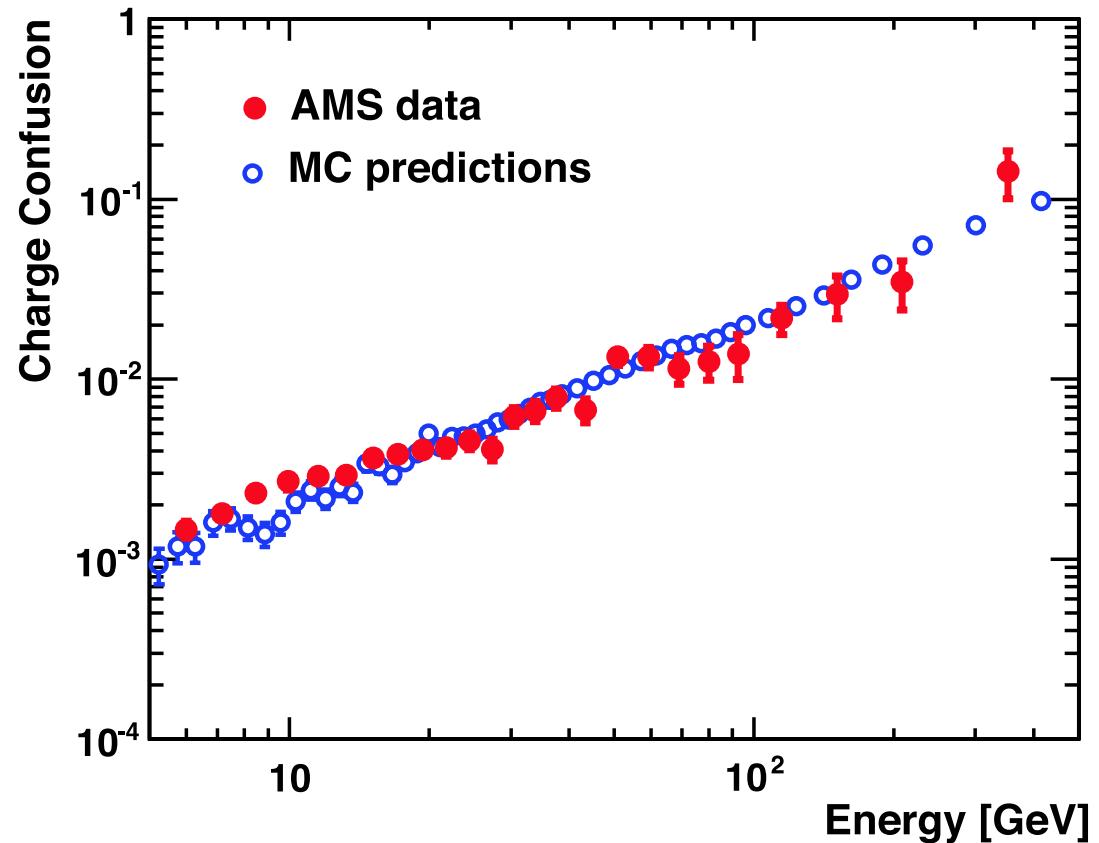
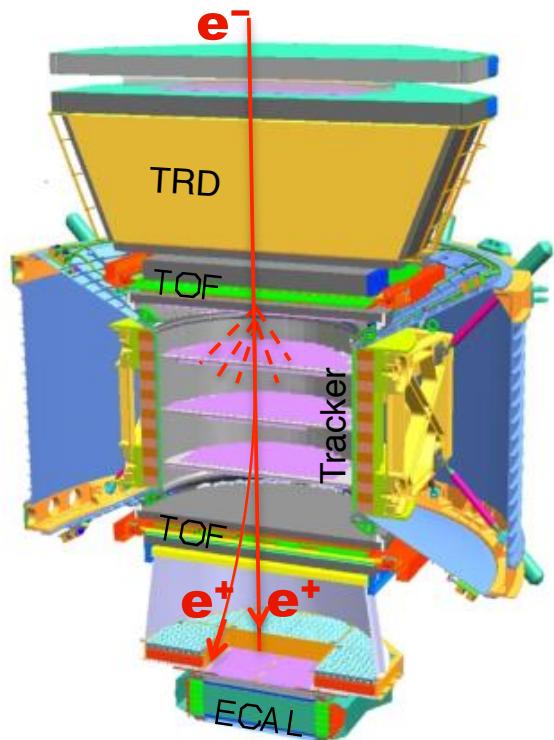


Definition of the reference spectra is based on pure samples of electrons and protons of **finite statistics**.

The systematic error associated is measured by **varying the shape** of the reference spectra **within the statistical uncertainties**.

Systematic uncertainties:

Charge confusion



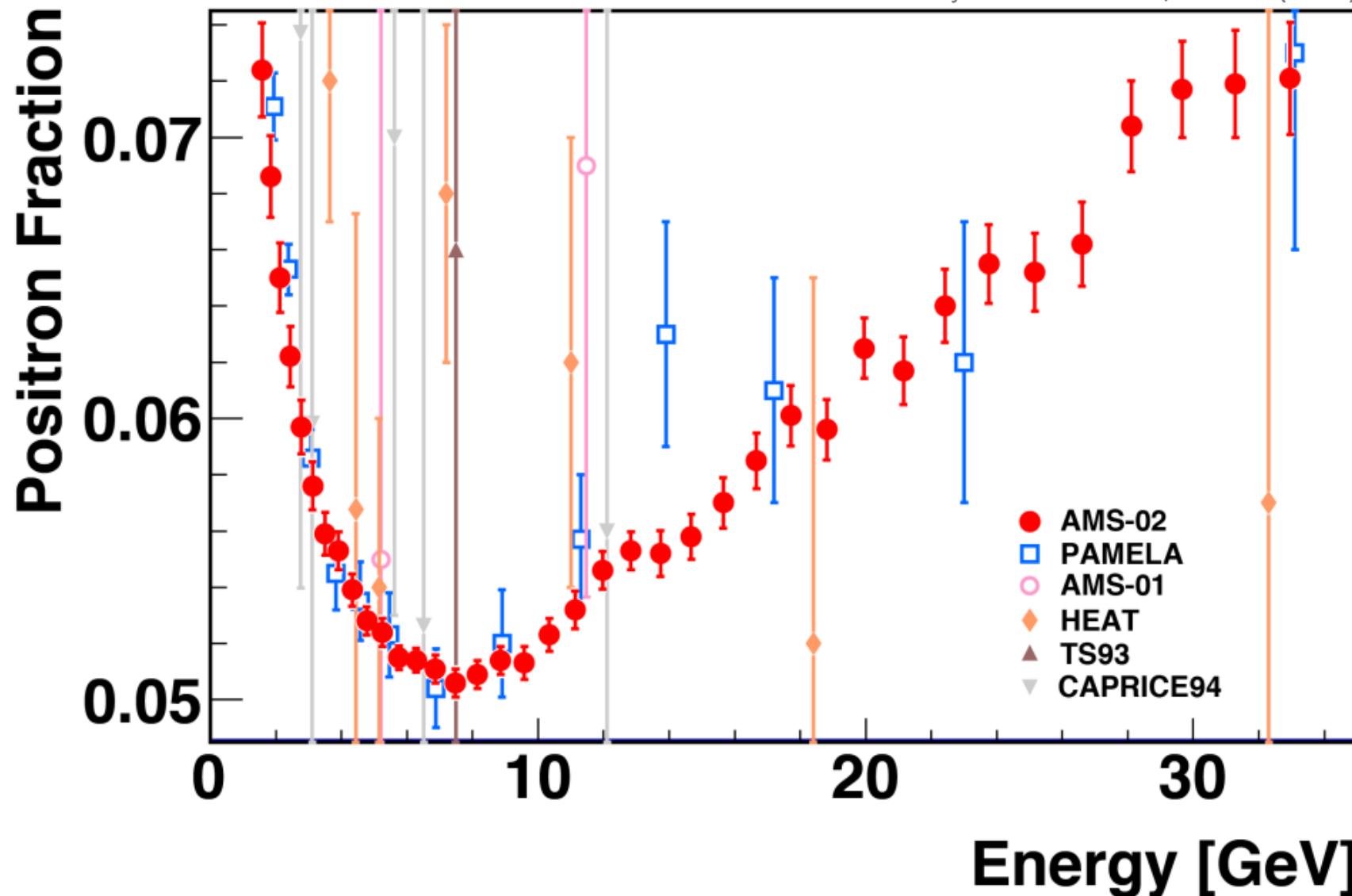
- CC sources:**
- 1) large angle scattering
 - 2) production of secondary tracks along the path of the primary track

Both are **well reproduced** by MC.

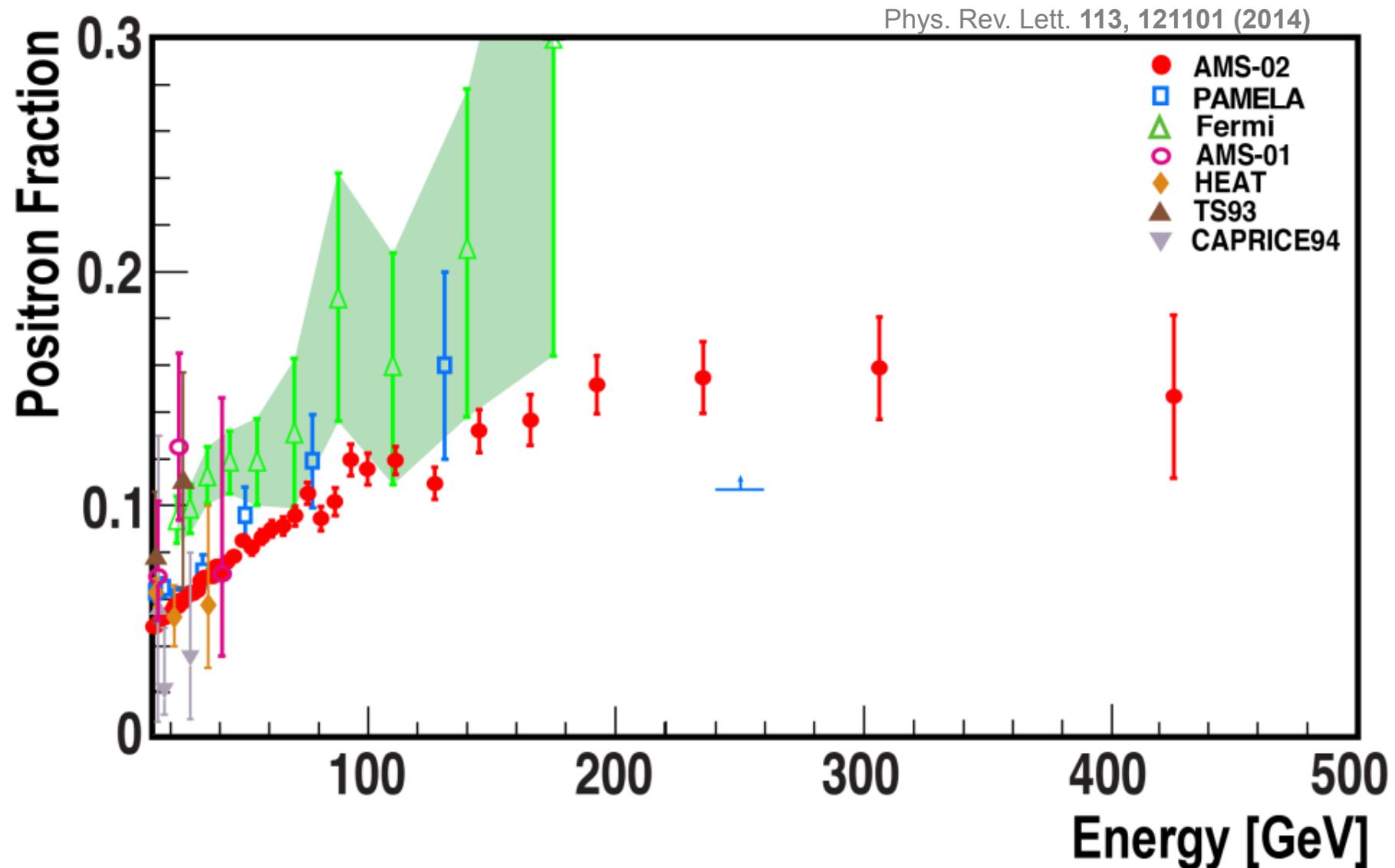
Systematic errors correspond to variations of these effects within their statistical limits and comparing the results with the MC

Positron fraction E<35GeV

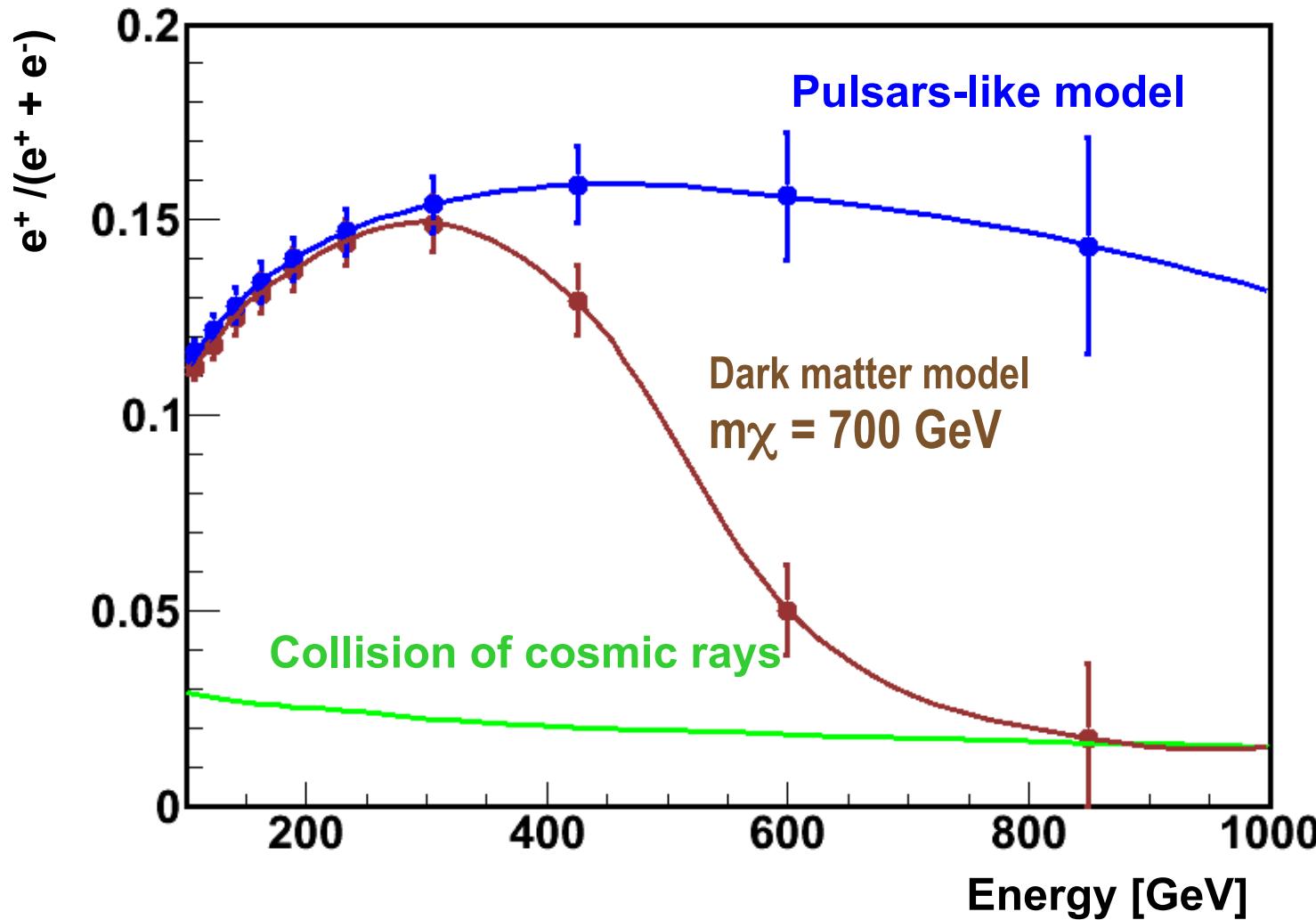
Phys. Rev. Lett. 113, 121101 (2014)



Positron fraction 0.5 – 500 GeV



AMS sensitivity in 10 years from now

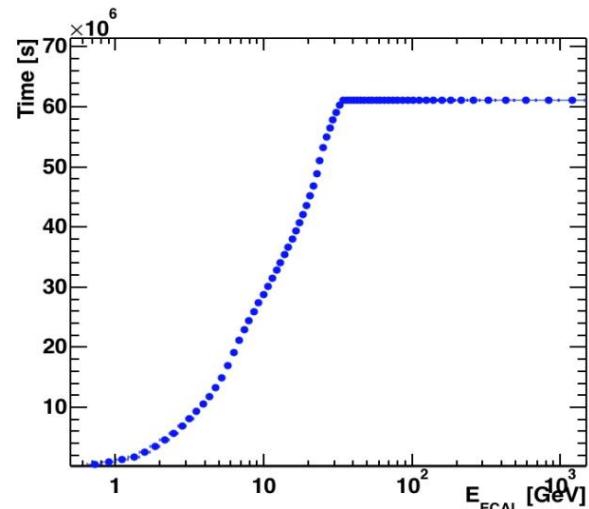


Electron and positron fluxes

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

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**

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

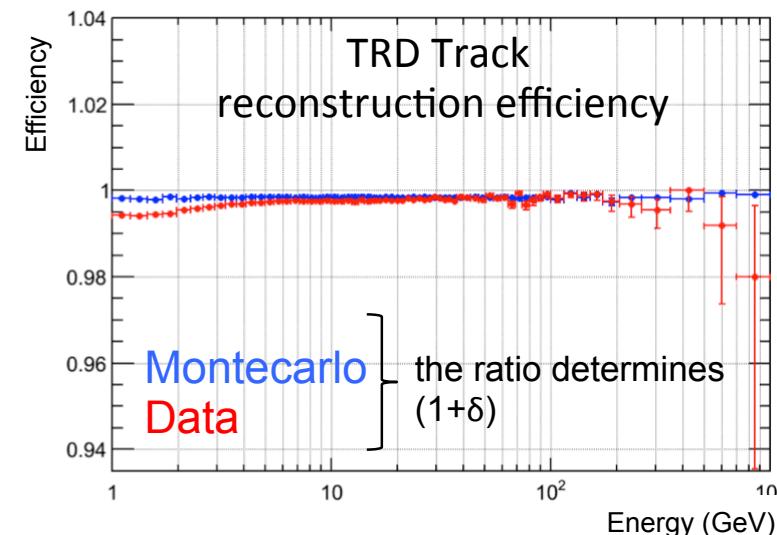
A_{geom} geometrical acceptance $\approx 550 \text{ cm}^2\text{sr}$

ϵ_{sel} is the event selection efficiency

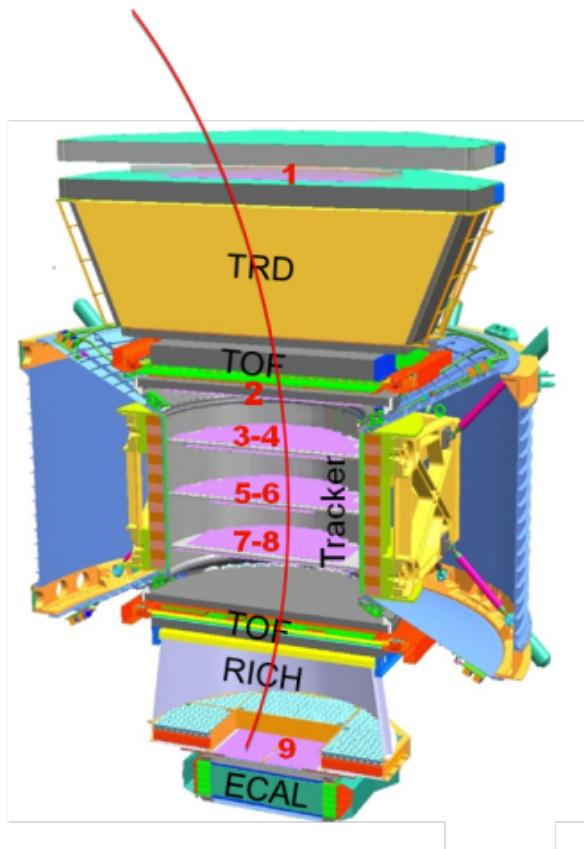
ϵ_{id} is the e^\pm identification efficiency

δ is a minor correction from the comparison between data and Monte Carlo (-2% at 10 GeV to -6% at 700 GeV).

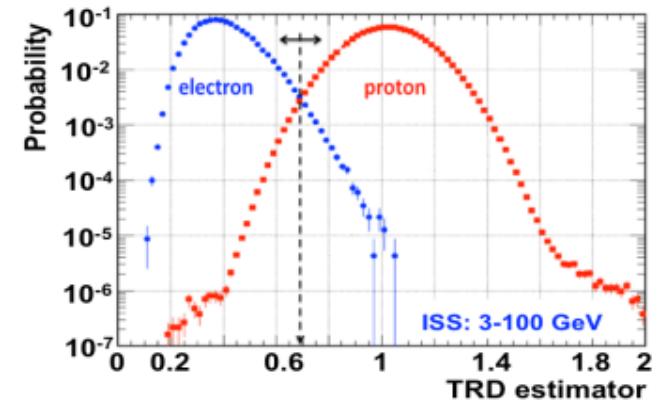
The error on $(1+\delta)$ is $\sim 2.5\%$.



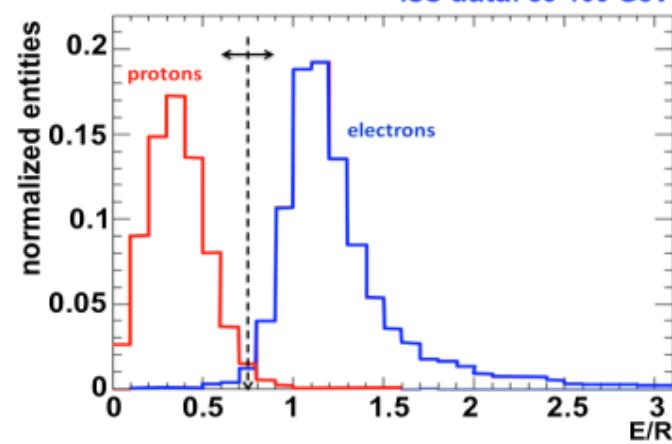
Event selection:



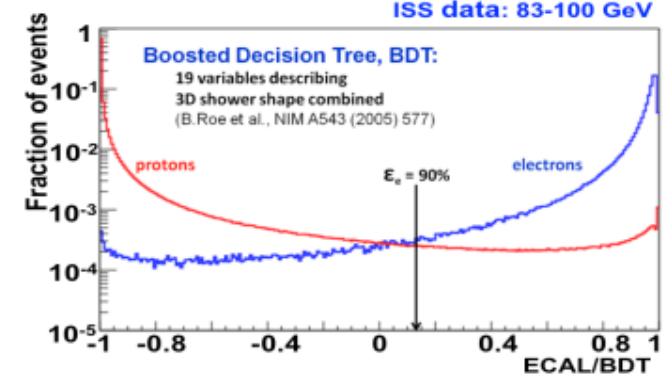
TRD
(transition radiation)



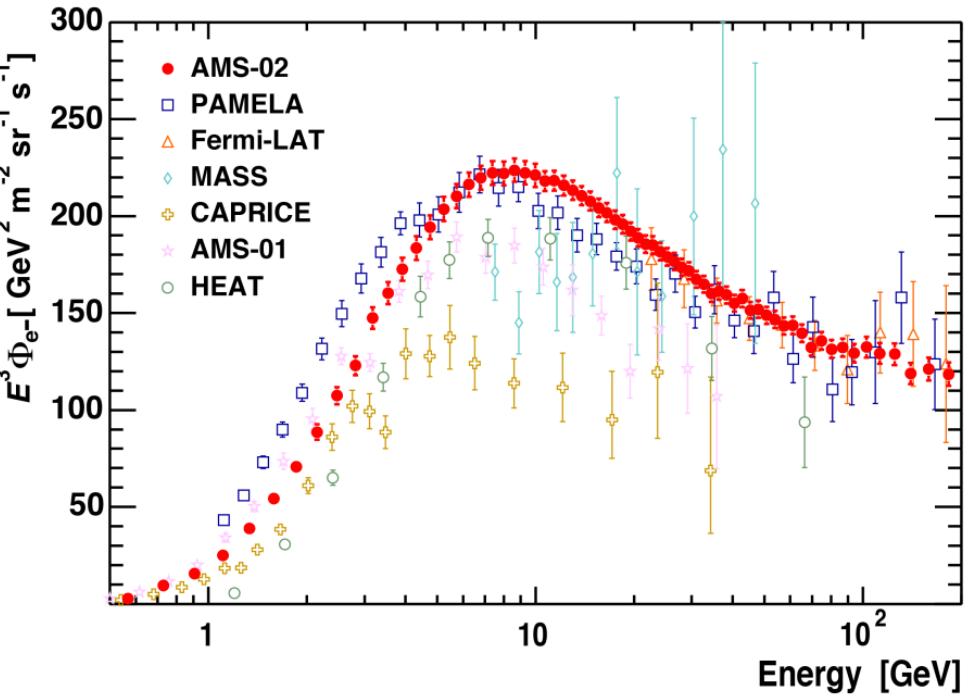
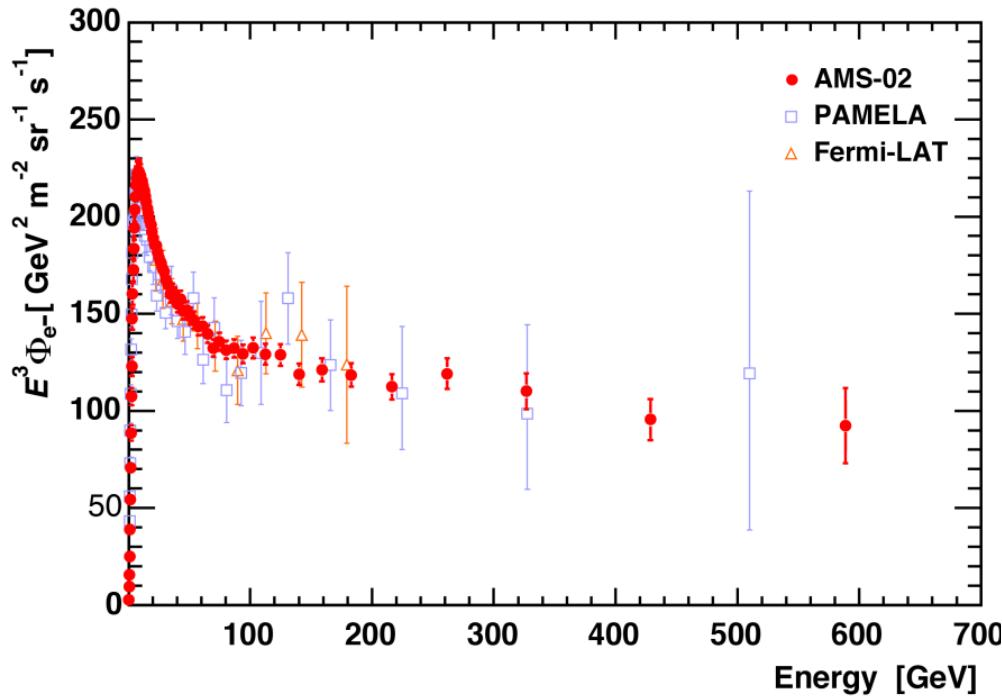
ECAL/Tracker
(E/p matching)



ECAL
(shower shape)

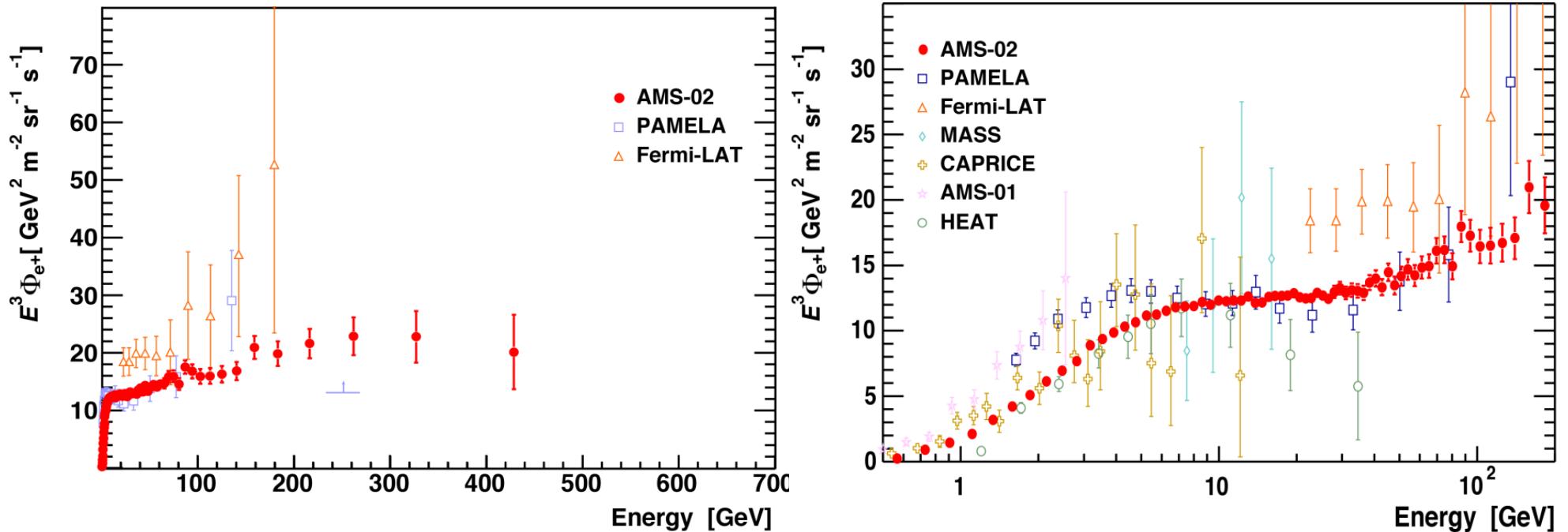


Electron flux

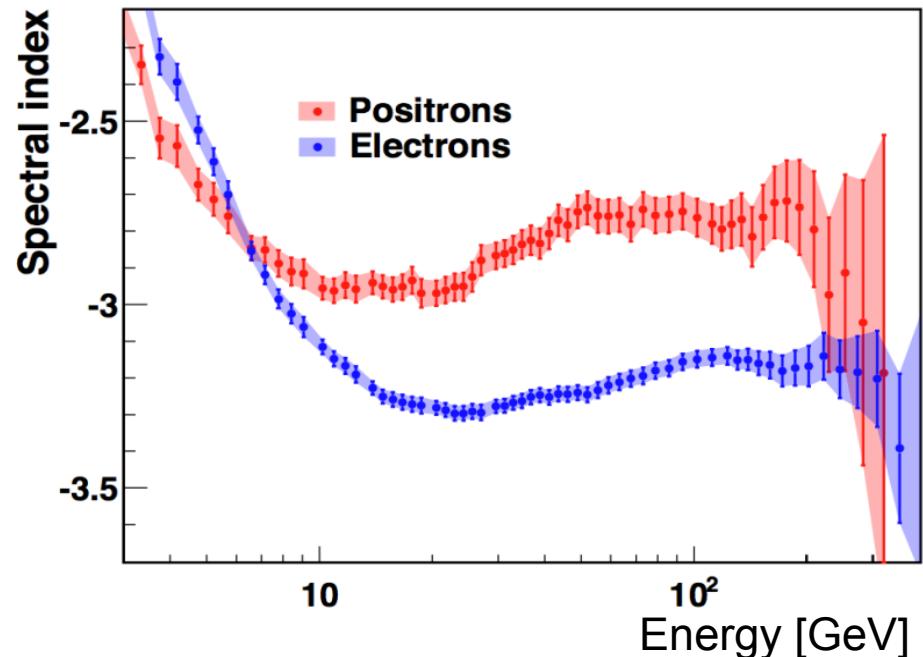
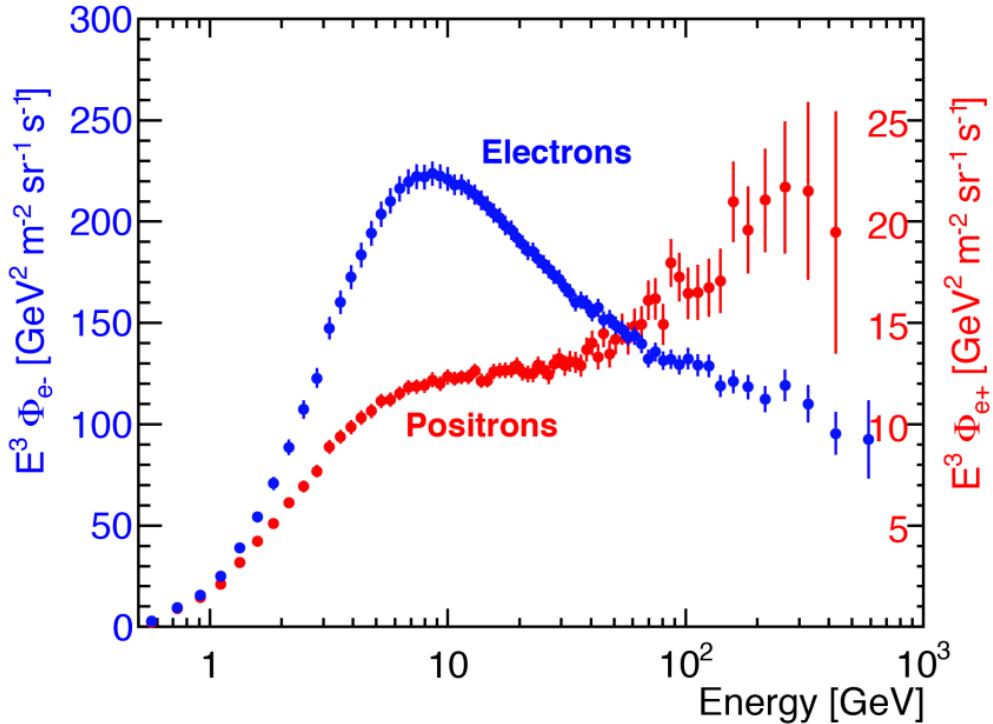


PRL 113, 121102(2014)

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)

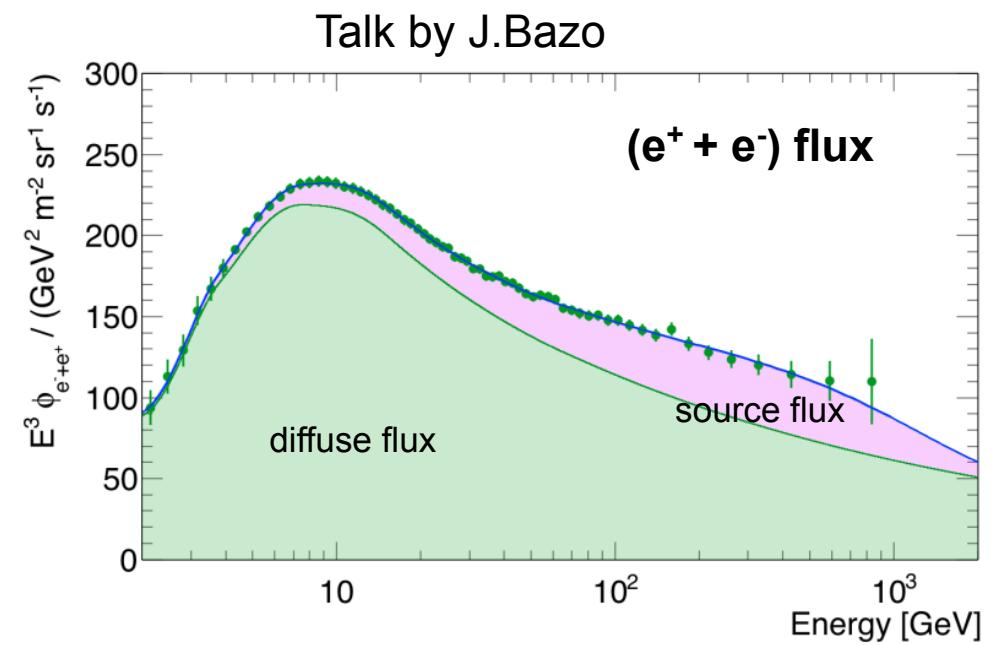
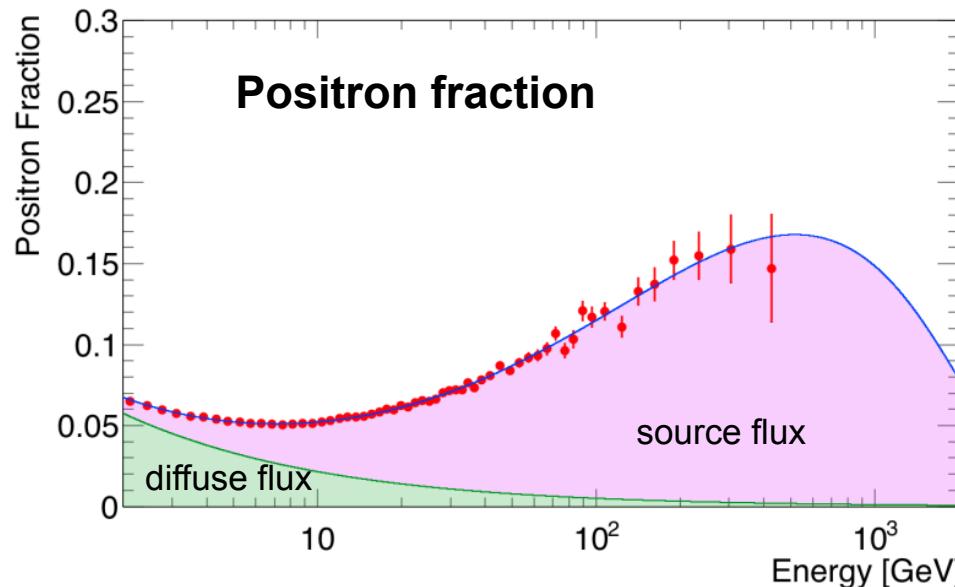
These new observations provide important information on the origin of cosmic ray electrons and positrons.

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

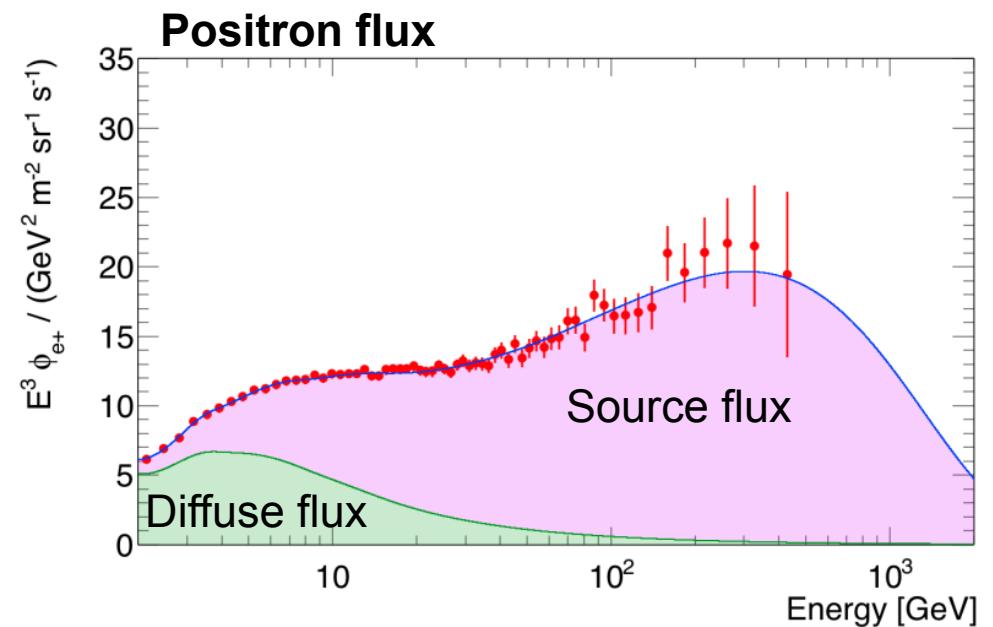
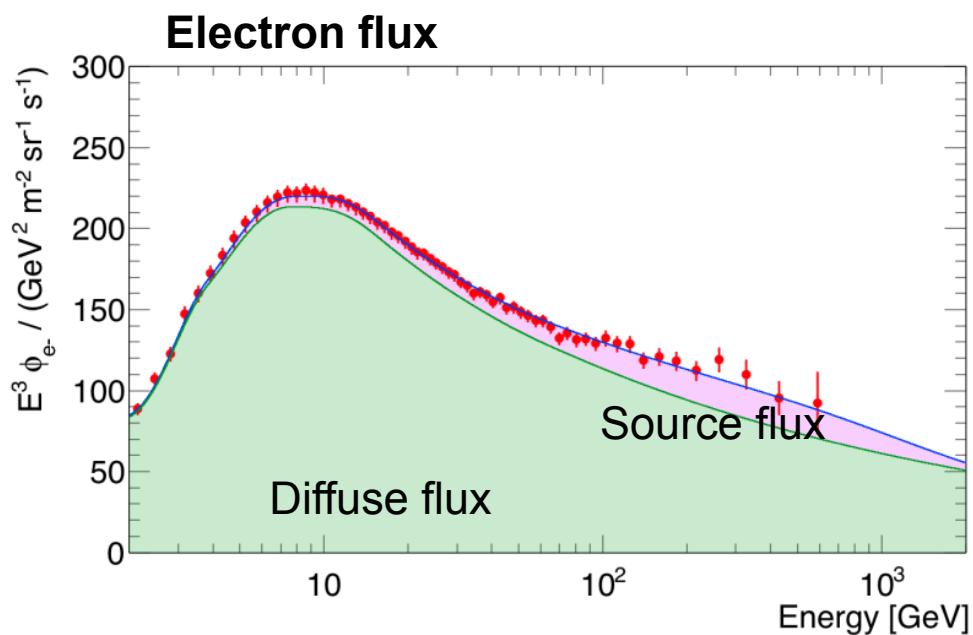


Minimal model prediction:

Diffuse Flux **Source Flux**

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

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

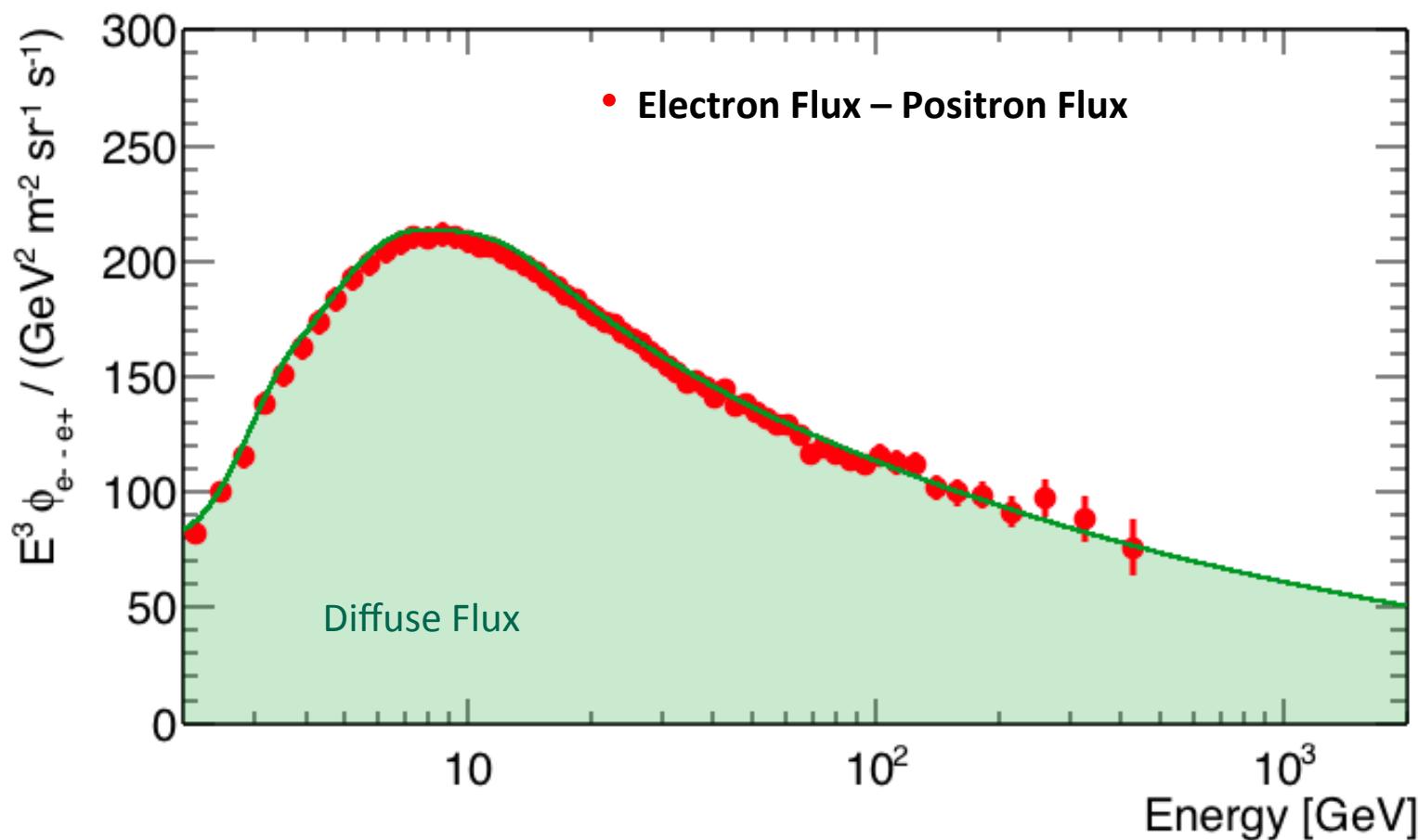


Minimal Model:

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

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

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**
 - **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.

www.asdc.asi.it

The screenshot shows the homepage of the ASI Science Data Center (ASDC) website. At the top, there are two logos: 'asdc' (ASI Science Data Center) on the left and 'ASI' (agenzia spaziale italiana) on the right. Below the logos, the main title 'ASI Science Data Center' is displayed in a large, stylized font. A horizontal menu bar follows, containing links for Home, About ASDC, Public Outreach, Quick Look, Missions, Multimission Archive, Catalogs, Tools, Links, Bibliographic services, and Helpdesk.

The central feature of the page is a large image of the International Space Station (ISS) in orbit around Earth. To the right of this image is a grid of icons representing various space missions:

- Row 1: AGILE, SWIFT, FERMI
- Row 2: NUSTAR, AMS-02, PLANCK
- Row 3: SOLAR SYSTEM, PAMELA, GAIA
- Row 4: HERSCHEL, BEPPO SAX, SIMBOL X
- Row 5: CHEOPS, EUCLID, PLATO

Below the main image and mission grid, there are several sections and links:

- MEDIA**: Includes links to SEDm BUILDER V3.0, SKY EXPLORER, MATISSE, COSMIC RAY DATABASE, ASDC MULTIMISSION ARCHIVE, ASDC CATALOGS, ASDC BIBLIOGRAPHY TOOL, and NEWSLETTER.
- TOP NEWS**: A section featuring the 'NUSTAR' mission.
- EVENTS**: A section featuring the '5th FERMI SYMPOSIUM'.

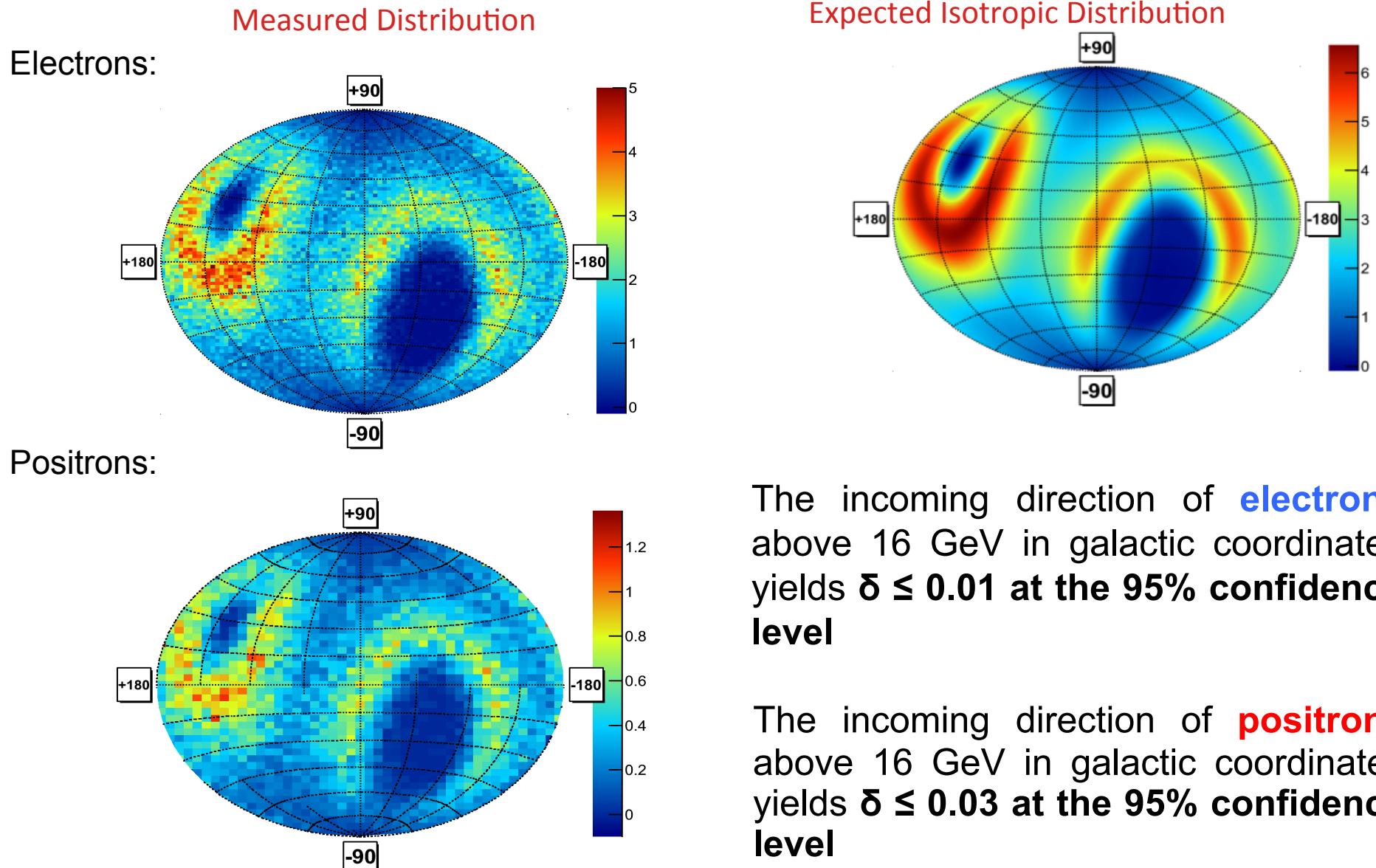
www.asdc.asi.it

The screenshot shows the ASDC website interface. At the top, there's a banner featuring the International Space Station (ISS) in orbit. Below the banner, the main navigation menu includes Home, About ASDC, Public Outreach, Quick Look, Missions, and Multimission. A yellow circle highlights the "COSMIC RAY DATABASE" link in the "Multimission" section. To the right of the main content area, there's a detailed plot titled "COSMIC RAY database". The plot shows two data series: "e- AMS-02 2011-05 - 2013-11, PRL(2014)" represented by red open circles and "e+ AMS-02 2011-05 - 2013-11, PRL(2014)" represented by blue crosses. Both series show a decreasing flux as kinetic energy increases, plotted on a logarithmic scale from 1 to 10² GeV/n. The y-axis is labeled "Flux [cm⁻² sr s GeV/n]⁻¹". The plot also includes a legend, download options (ASCII file, ROOT File, PNG File), and a "Back to Search" button. On the far right, there are "Plot Options" for adjusting the plot's appearance. Below the main content, there's a section titled "MISSIONS" featuring logos for HERSCHEL, BEPPO SAX, SIMBOL X, CHEOPS, EUCLID, and PLATO.

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

Backup slides

Flux anisotropy



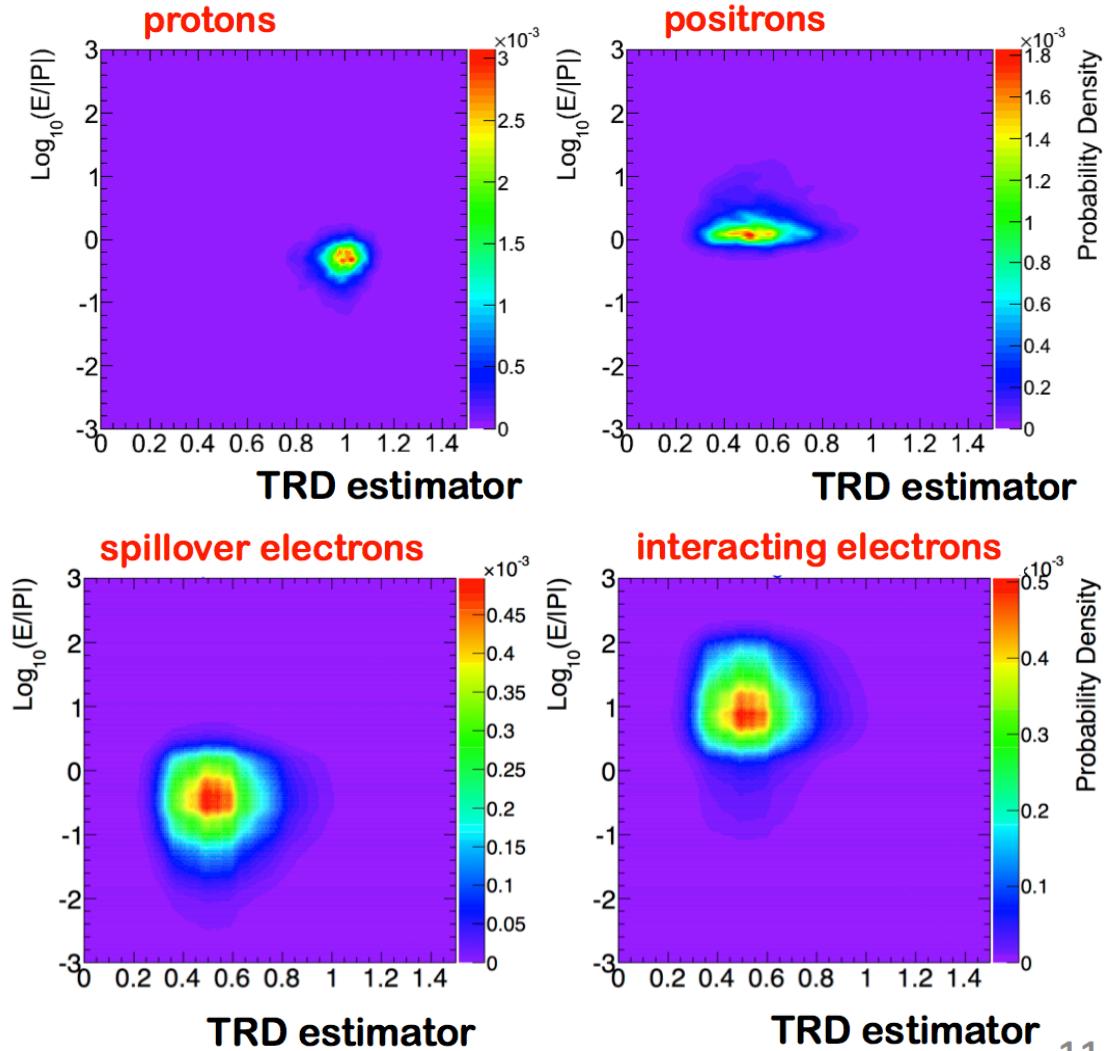
2D fit measuring Ne+ Ne+ Np

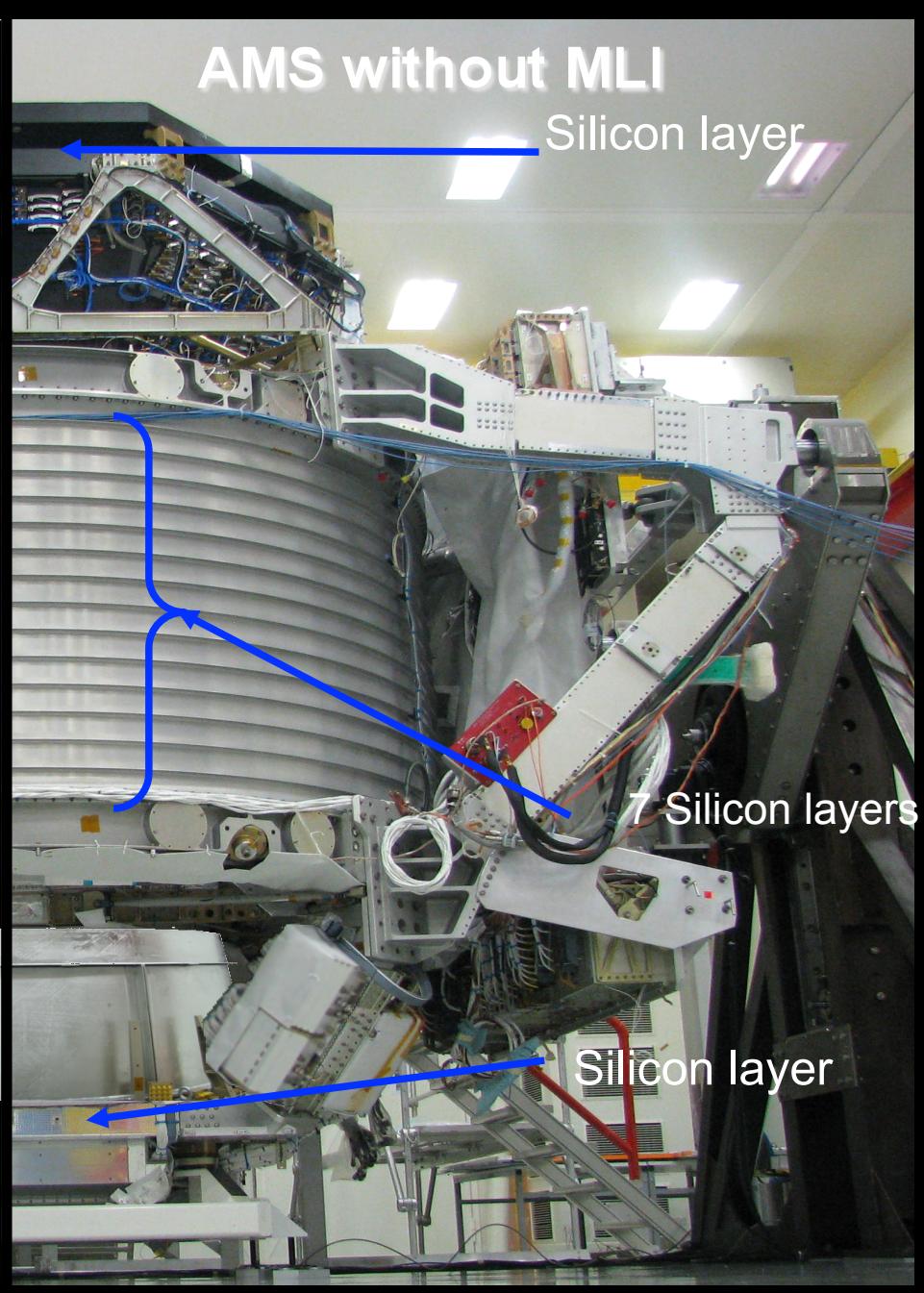
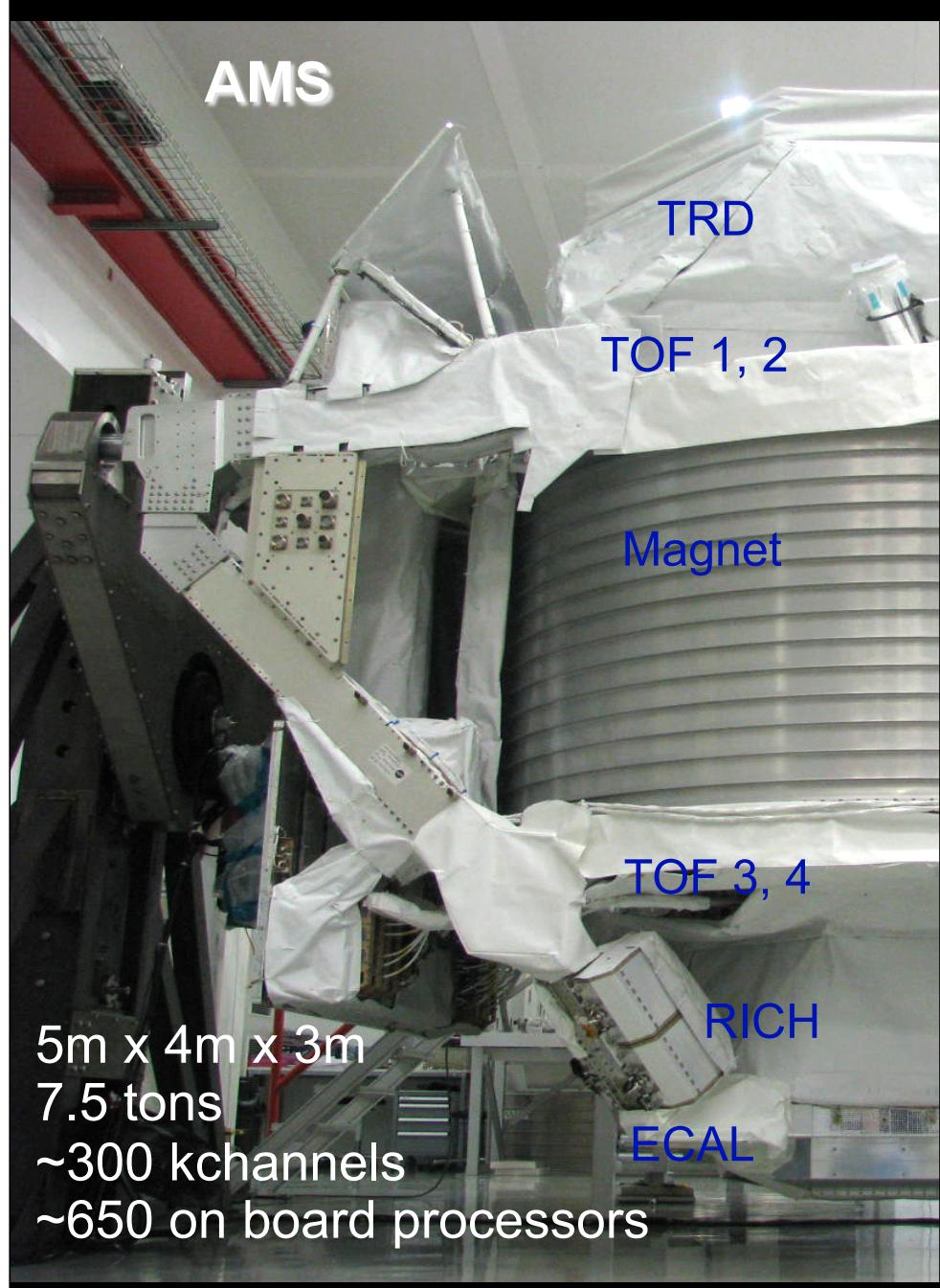
Fit in TRD Estimator - log(e/p) plane

Combines information from TRD; ECAL and Tracker

Proton event well separated

Charged confused events measured directly from data





www.asdc.asi.it

The image shows two parts of the ASDC website. The top part is a detailed plot of cosmic ray flux versus kinetic energy for the e- AMS-02 and e+ AMS-02 experiments. The bottom part is the main homepage, featuring a large image of a satellite in space, navigation links like Home, About ASDC, Public Outreach, Quick Look, Missions, Multimission, and a search bar. A yellow circle highlights the 'COSMIC RAY DATABASE' link in the news section of the homepage.

COSMIC RAY database

e- AMS-02 2011-05 - 2013-11, PRL(2014)

e+ AMS-02 2011-05 - 2013-11, PRL(2014)

ASDC cosmic ray database / creation date 2014-09-24

Flux [$\text{cm}^{-2} \text{sr s GeV/n}^{-1}$]

Kinetic energy [GeV/n]

Plot Options:

- Add systematic errors in quadrature if available
- Default axis are logarithmic
- Show more labels (only valid if log axis)
- X linear scale
- Y linear scale
- Show grid

Set X range:
from _____ to _____

Set Y range:
from _____ to _____

Multiply Y by E^s
s= _____

Update Plot Reset Options

Download selected data in ASCII file Download ROOT File Download PNG File Back to Search

HERSCHEL BEPPO SAX SIMBOL X

CHEOPS EUCLID PLATO

SED^m BUILDER V3.0 SKY EXPLORER MATISSE COSMIC RAY DATABASE ASDC MULTIMISSION ARCHIVE Top NEWS EVENTS 5th FERM SYMPOSIUM NUSTAR

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