Recent results from the AMS-02 experiment

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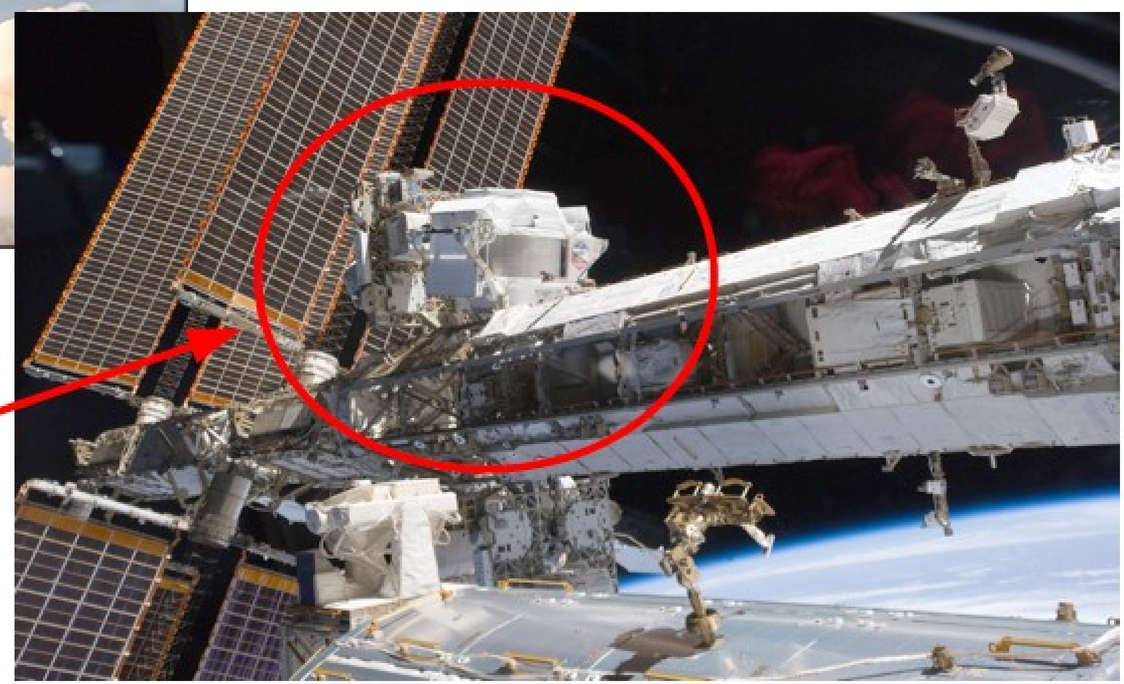
AMS-02 on board of the ISS

High acceptance magnetic spectrometer (~ 500 $cm^2 sr$) on board of the International Space Station (ISS)

May 16th 2011: Launch of Endeavour shuttle (mission STS 134). AMS-02 is brought to space!

Data taking up to ~ 2020



AMS-02

Cosmic rays detection with AMS

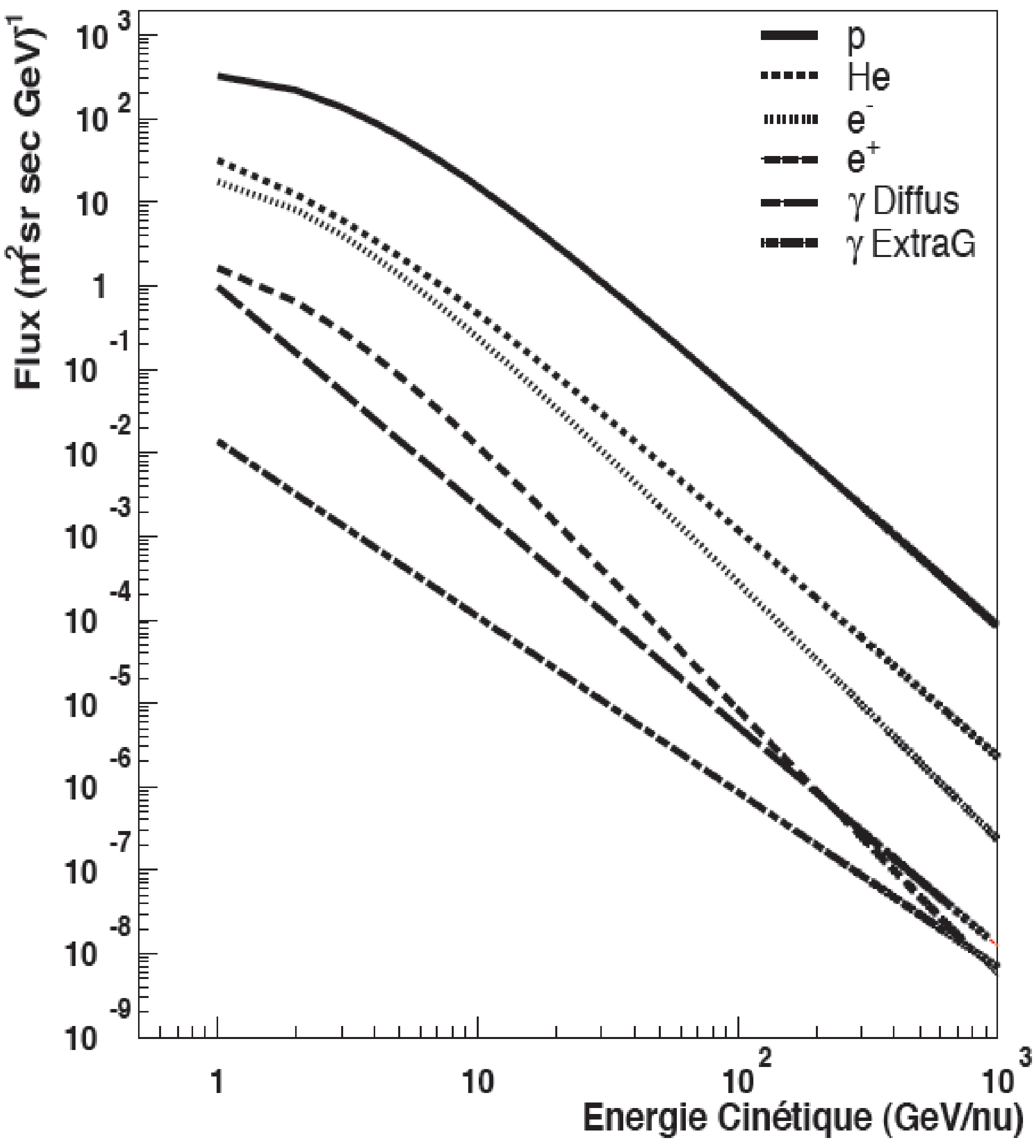
Scientific goals

- Cosmic Rays Fluxes in the GeV to TeV region
- Antimatter/dark matter search
- Cosmic rays propagation

Presented Today :

- Positron fraction
- Electrons and positron fluxes
- Proton and He flux

Cosmic Rays Composition



Cosmic Rays are made of:

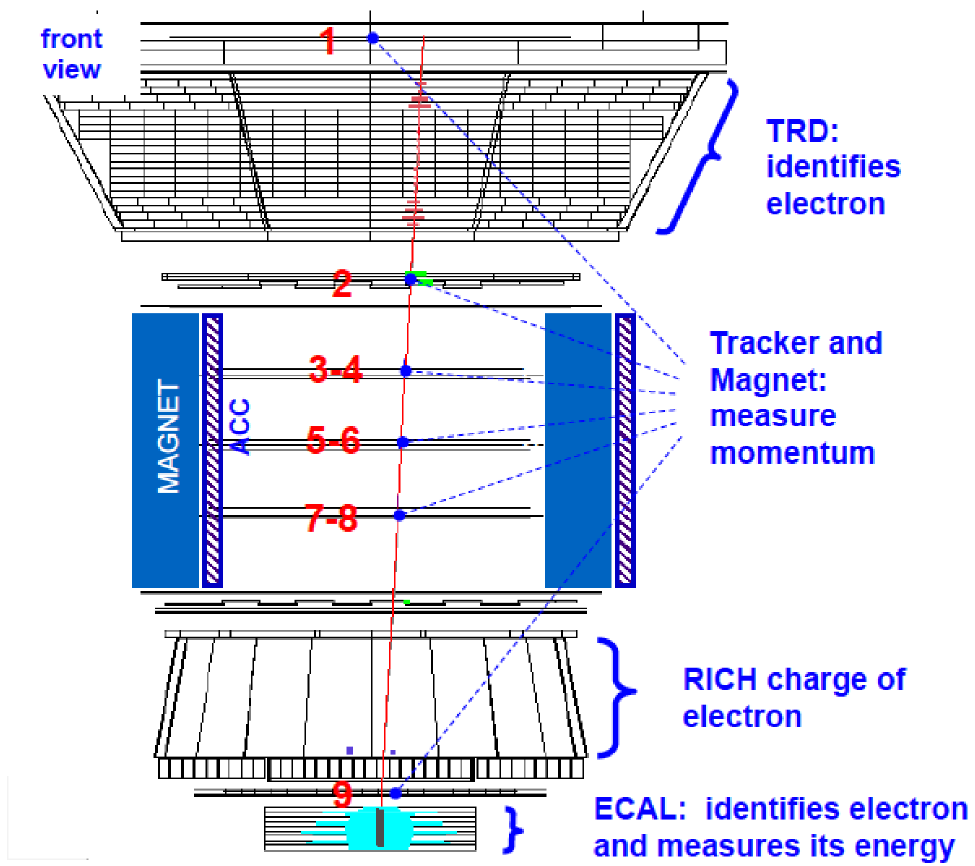
- Protons (~90%)
- He nuclei (~8%)
- Other nuclei (~1%)
- Electrons (~1%)
- Positrons (e+/p ~10^{-2}-10^{-4})
- Antiprotons (p-bar/p~ 10^{-4})
- ...

Detection redundancy
is necessary to get precise
measurements of cosmic rays

The AMS detector

AMS is a particle physics detector in space.

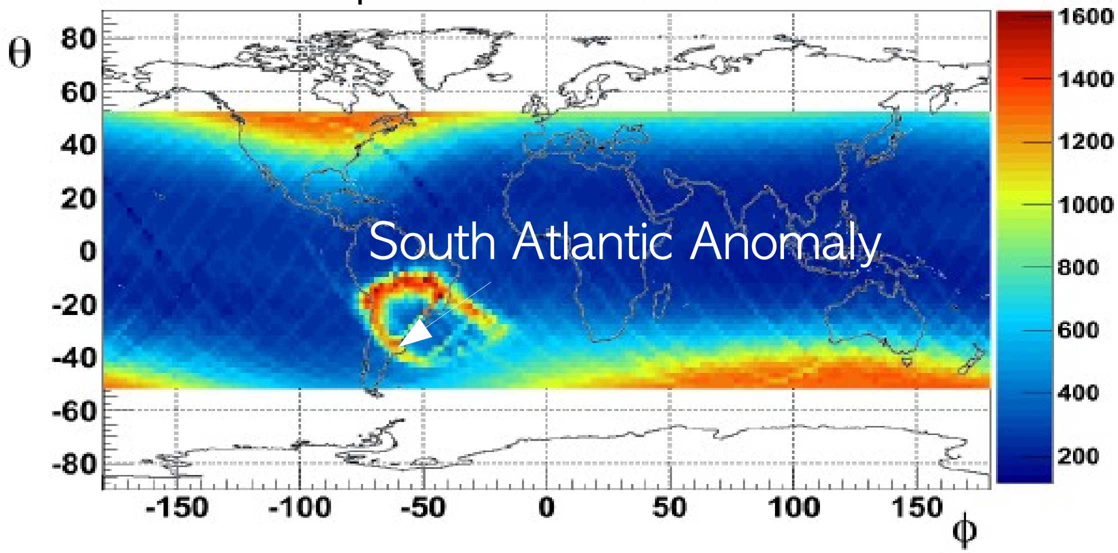
The redundancy of measurements, together with the large acceptance and long duration of the mission, allows for very precise measurements of cosmic rays in the GeV to TeV range.



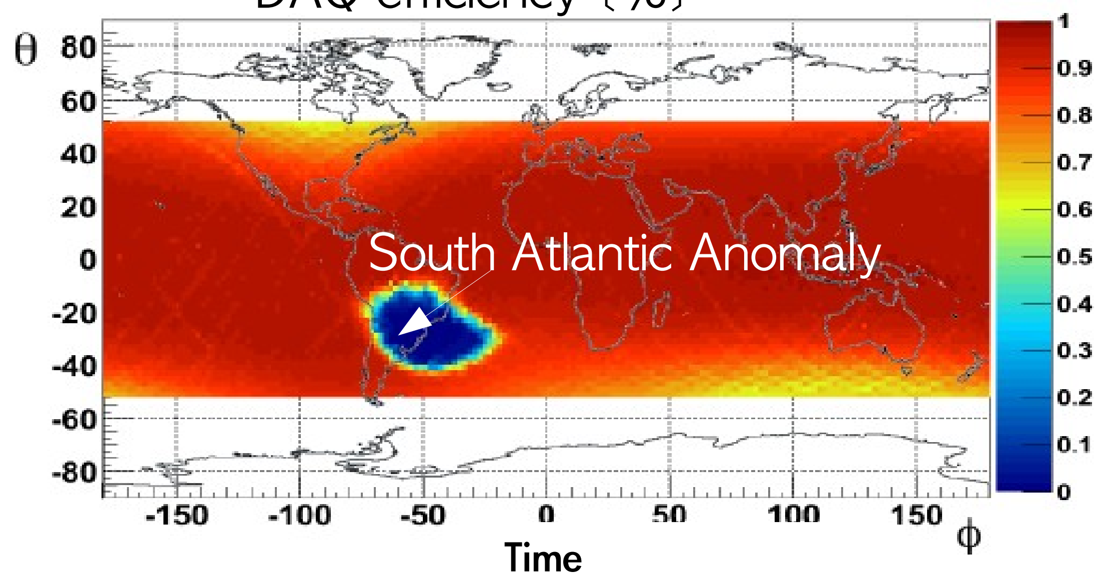
AMS data on ISS: 424 GeV positron

Orbital Parameters

Acquisition rate (Hz)



DAQ efficiency (%)

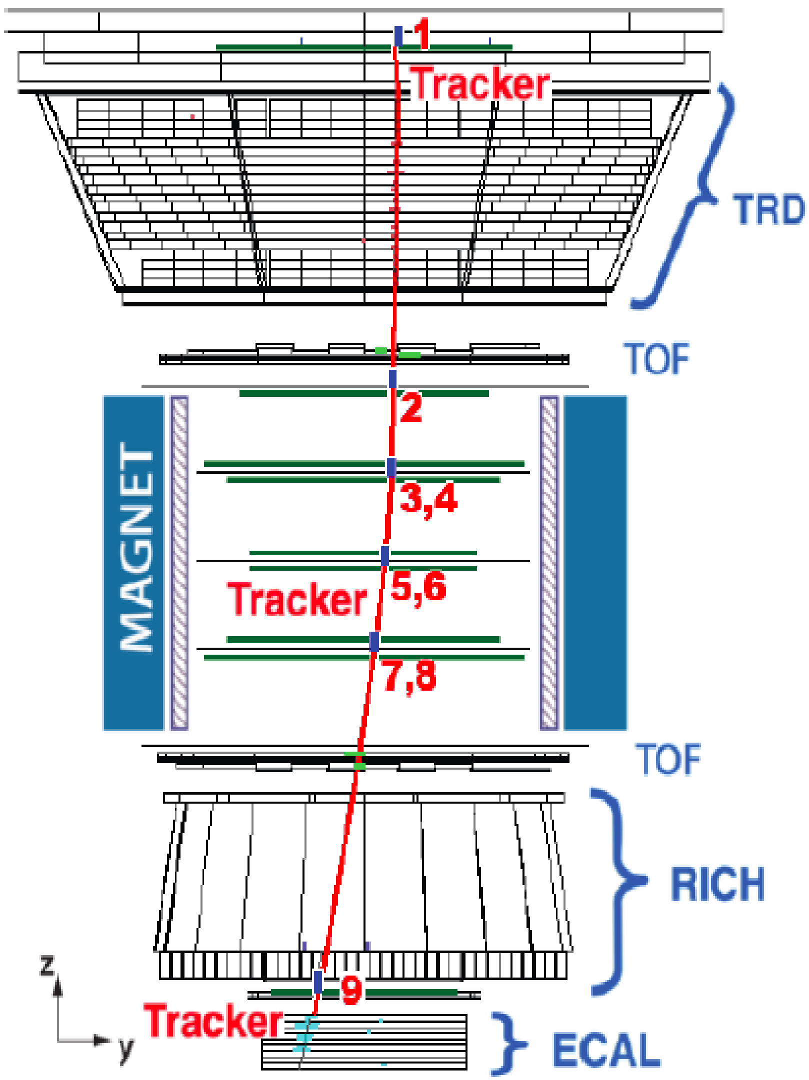


Particle rates: 200 to 2000 Hz per orbit

Orbit average:
DAQ efficiency ~ 80%
DAQ rate ~700Hz

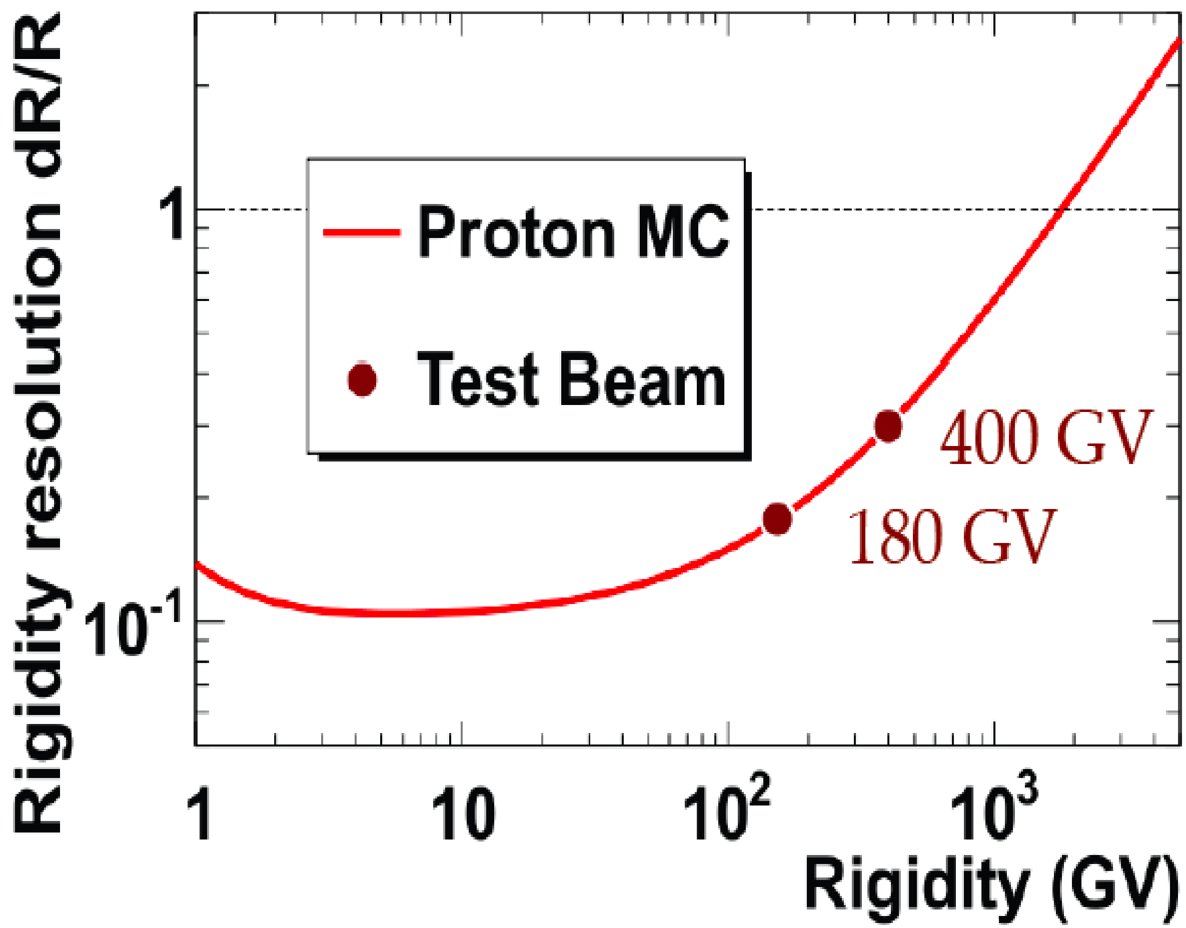
so far : ~40 10^9 events (33 TB/yr)

Rigidity Measurement



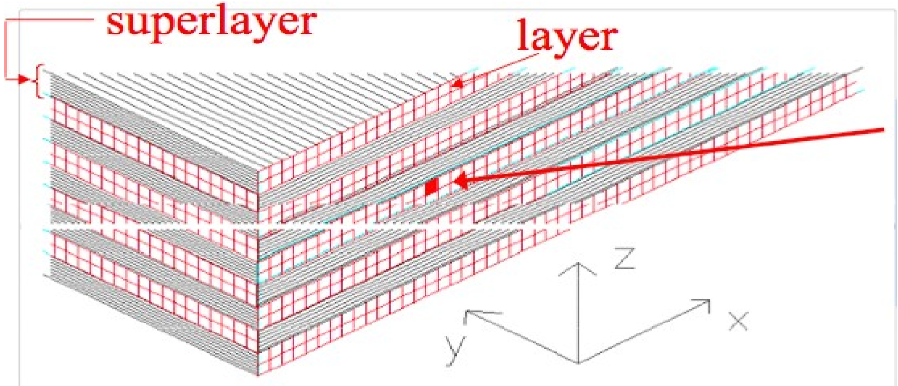
$B_x = \sim 0.14\ \mathrm{T}$ $L = \sim 3\mathrm{m}$

$\sigma_y = \sim 10\mu\mathrm{m}$ $\mathrm{MDR} : \sim 2\mathrm{TV}$



Energy Measurement

The AMS-02 electromagnetic calorimeter: a 3-D sampling calorimeter made out of lead and scintillating fibers

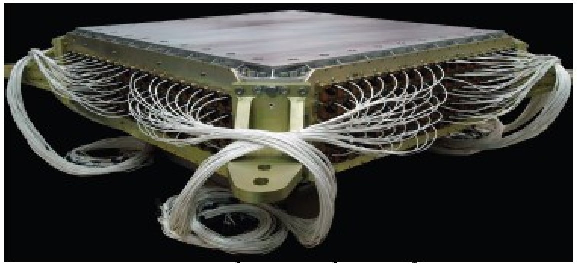


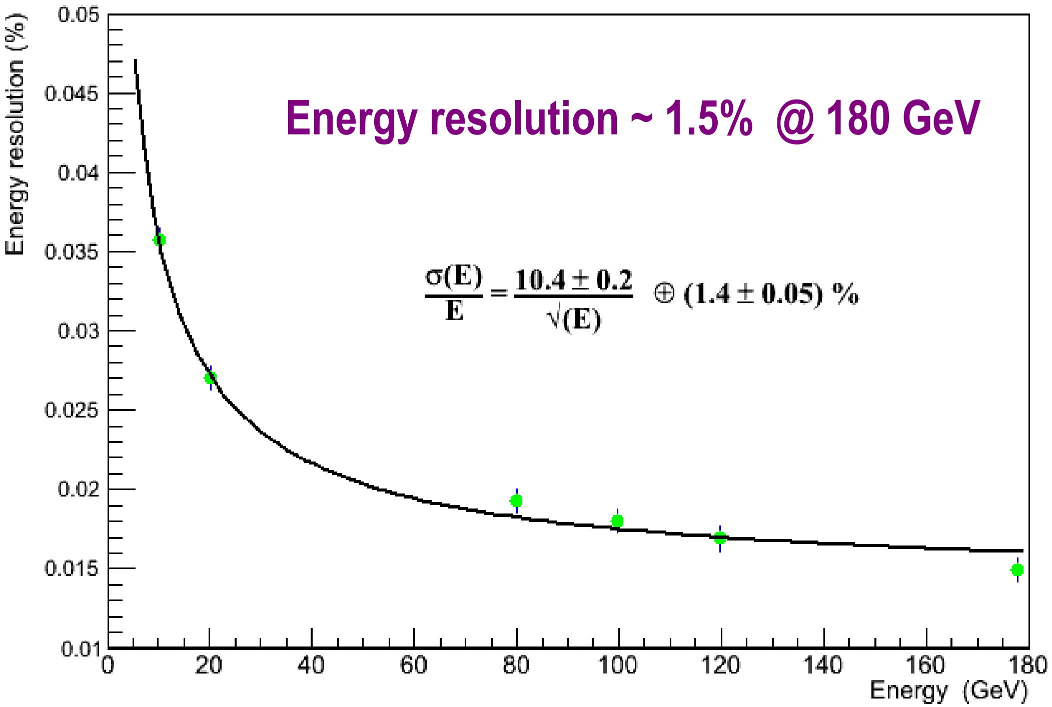
High granularity: ~ 0.9 x 0.9 cm

18 Longitudinal samplings

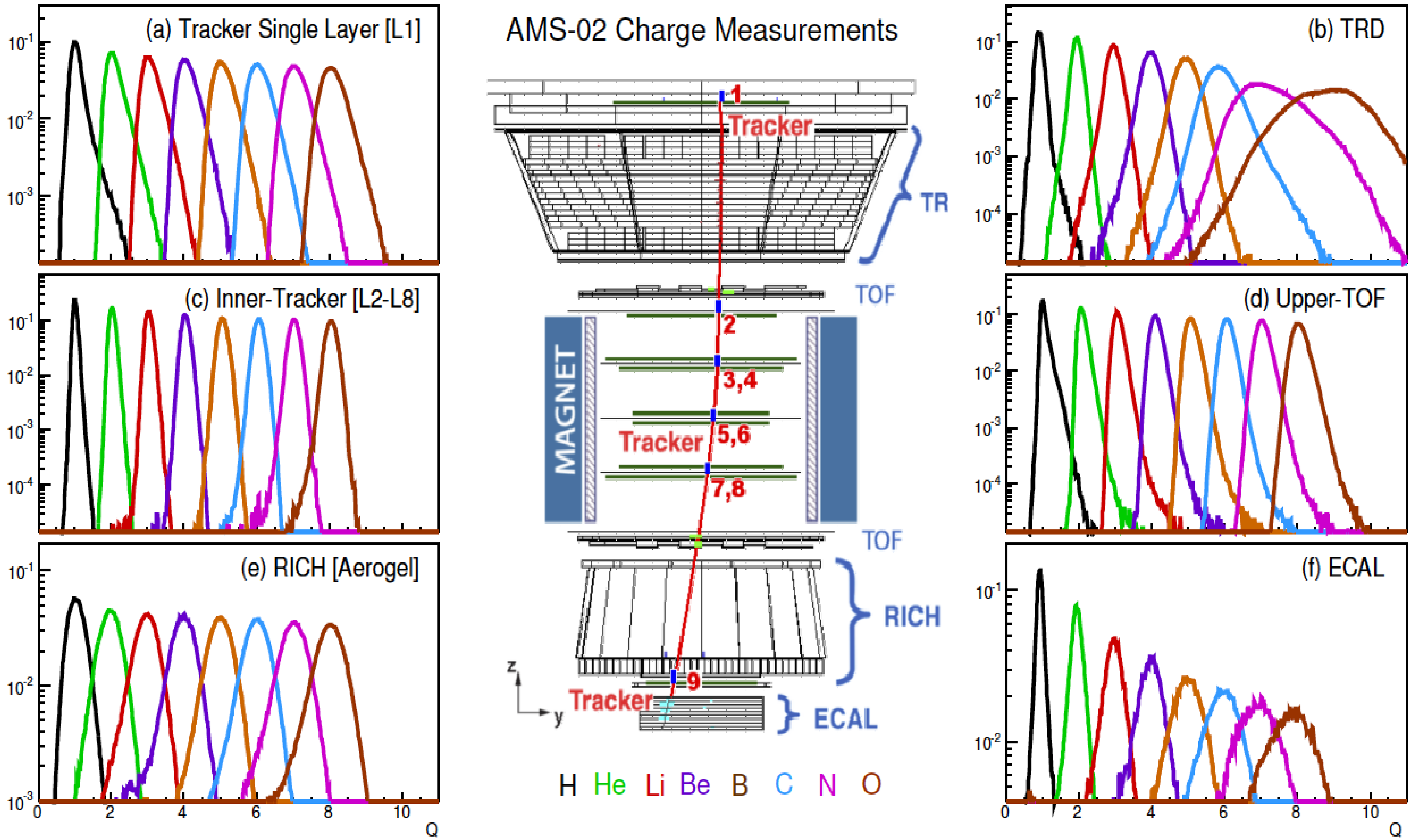
72 Lateral samplings

17 X_0, $\lambda_I / X_0 \sim 22$





Charge Measurement



Detection of electrons and positrons

Keys of success :

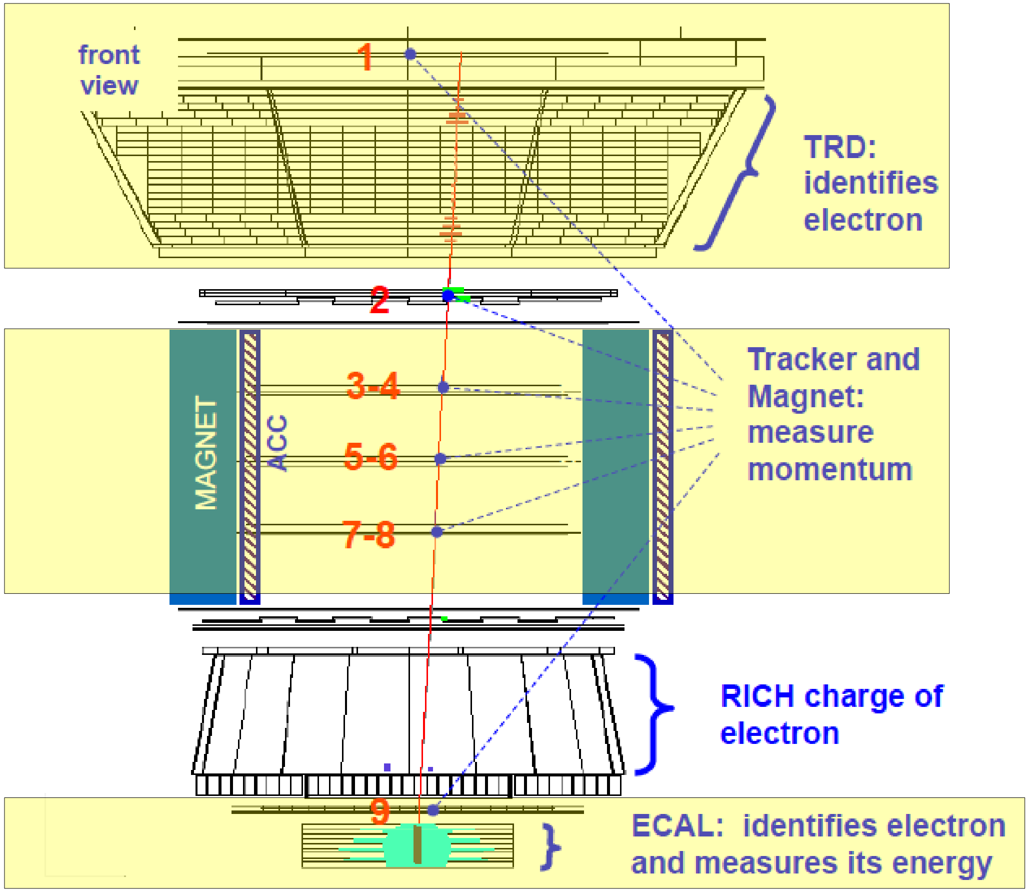
- redundancy of sub-detectors
- ECAL energy resolution
- Large data sample

Main sources of background :

- Lepton/hadron mis-identification

  (*p identified as e+*)
- Charge confusion

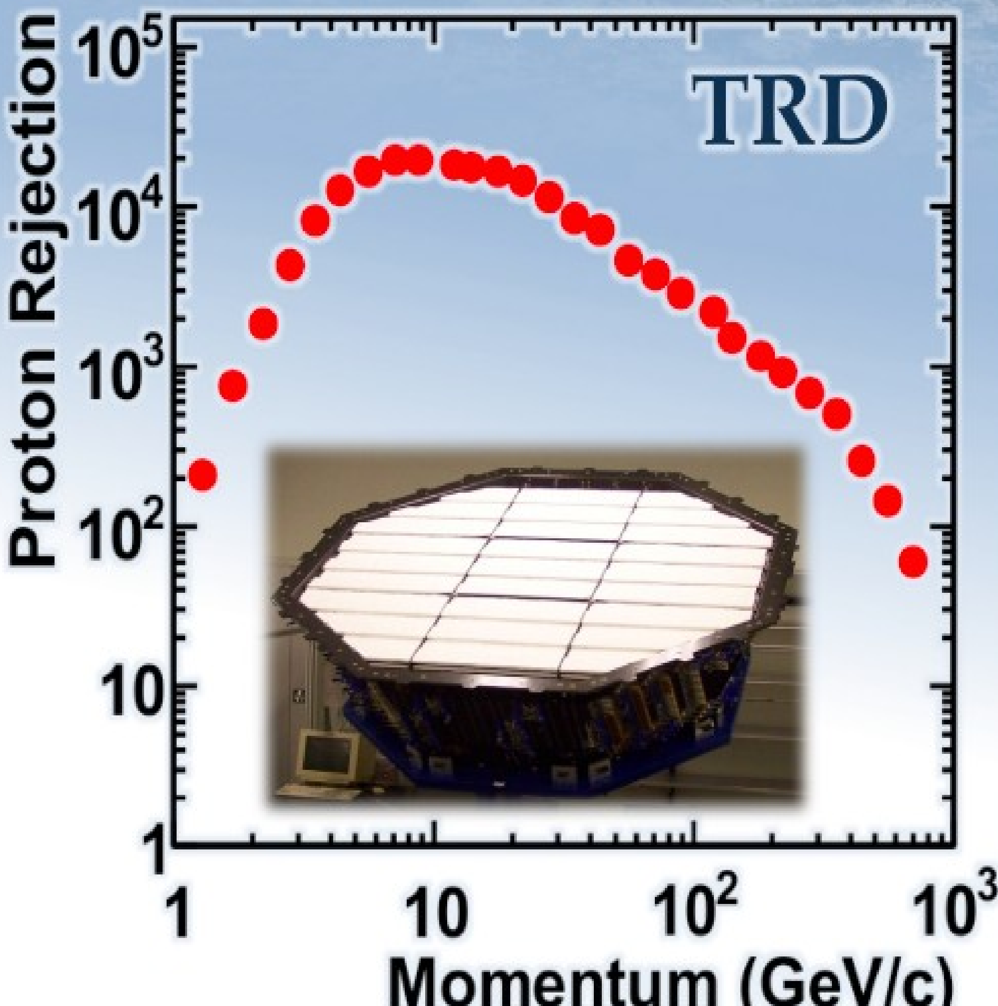
  (*e- identified as e+*)

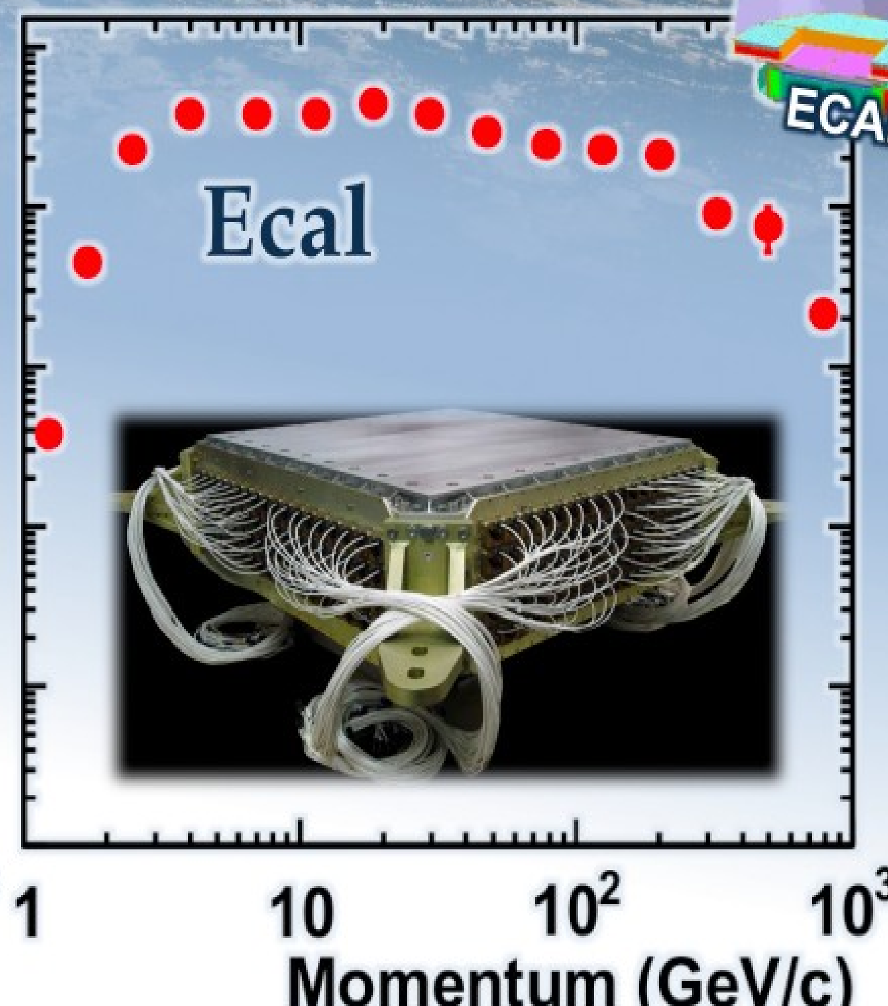


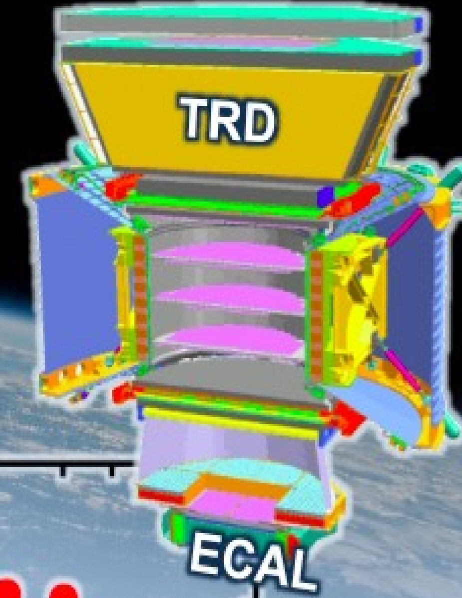
AMS data on ISS: 424 GeV positron

Proton rejection

With 90 % e^+ efficiency



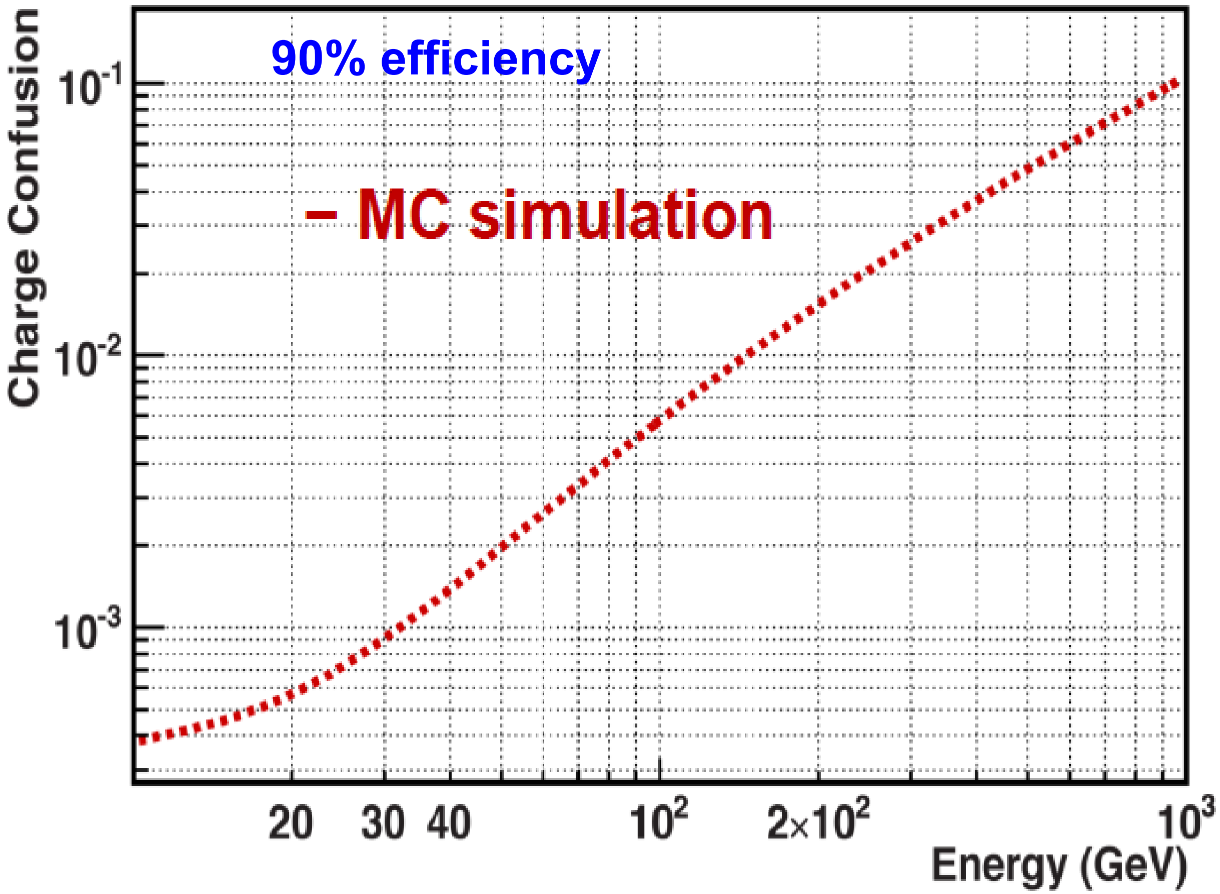




Charge confusion

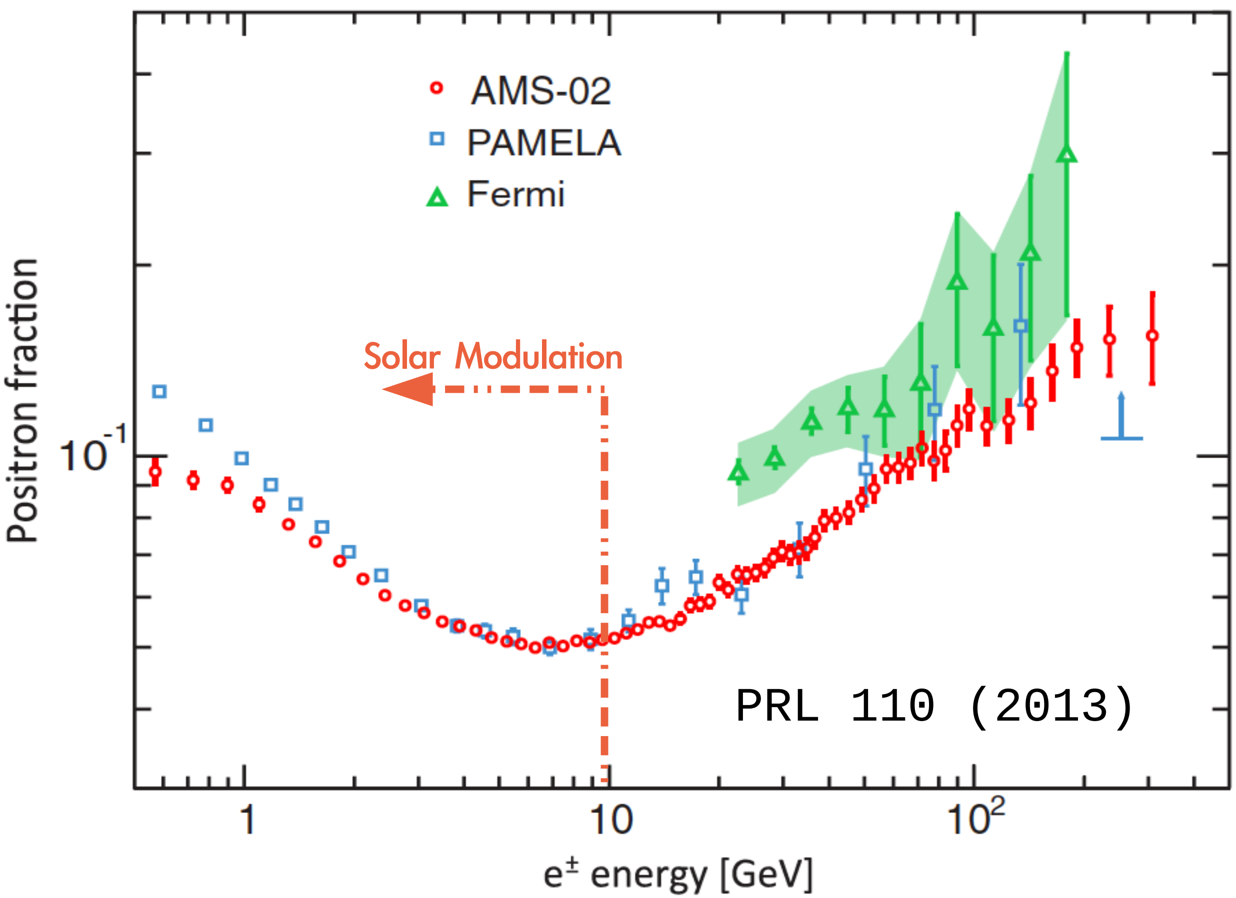
Main sources :

- Interactions along the track (radiating e- resulting in high E/P)
- Spillover due to finite tracker momentum resolution (small E/P)
- Well reproduced in simulation. The difference between data and MC is taken into account as systematic error



Positron fraction

Positrons are secondaries, produced in protons interactions with the Interstellar medium.
If positrons are ONLY secondaries, the positron fraction is expected to decrease with energy.

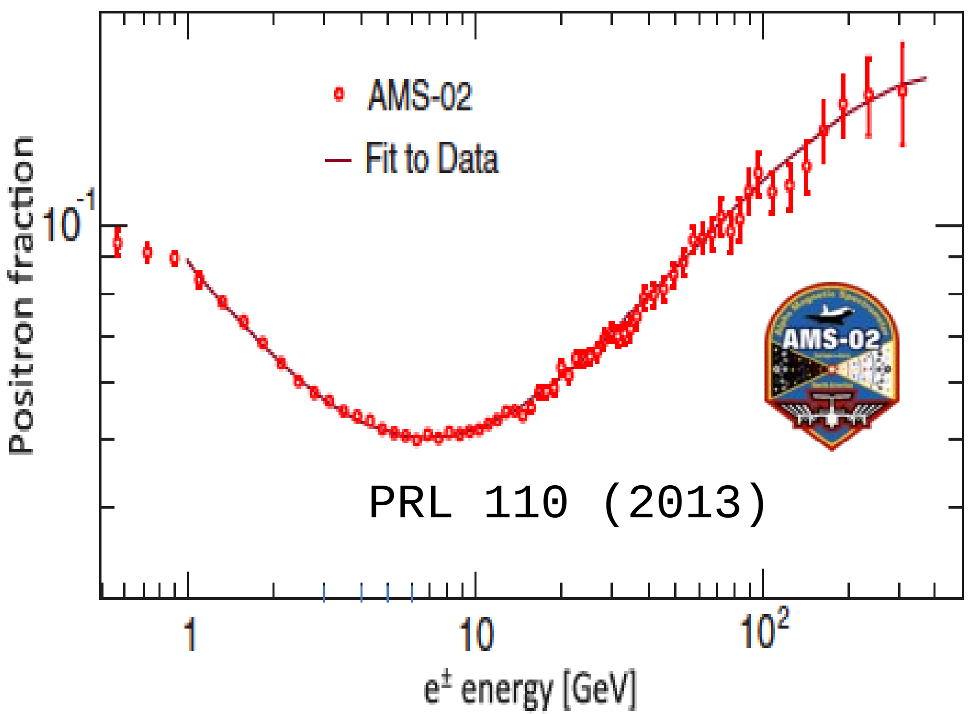


- Above 10 GeV the positron fraction is steadily increasing up to 350 GeV.
- A nearby source of positrons is needed to reproduce the measured positron fraction.
- More statistics is required to explore the region above 350 GeV.

Minimal Model for positron fraction

Electrons and positrons fluxes parametrized as: $\Phi = C E^{-\gamma_e} + K E^{-\gamma_S} e^{-E/E_S}$

Diffuse source — Single source



Fit to the positron flux → Source of primary positrons is needed !

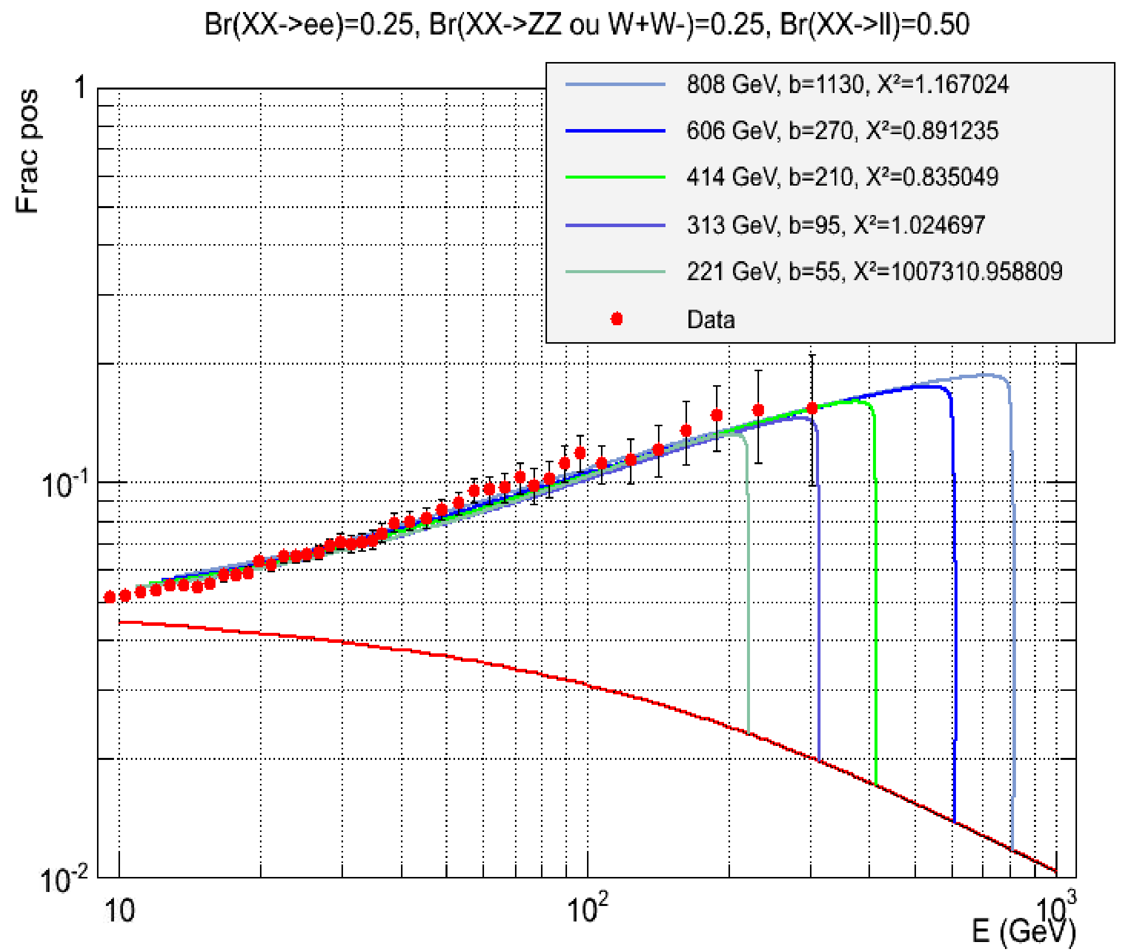
- Diffuse positron spectrum is softer than diffuse electron spectrum.
- Weight of diffuse positron flux is ~ 10% diffuse electron flux
- The weight of the common source is ~1% of diffuse electrons
- Source cutoff value is ~760 GeV (with large uncertainties)

Interpretations of the positron fraction

An example : **MicrOmegas*** is used to evaluate the flux of e^+ and e^- from Dark Matter annihilation

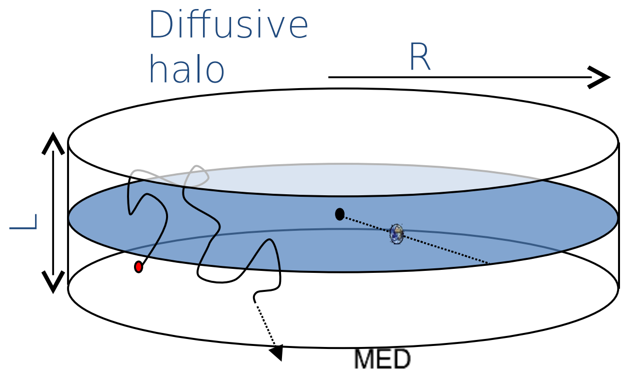
- Different annihilation modes with different production rates of e+ et e-
- Dark matter density (boost factor) used as a free parameter

- Low masses are disfavoured
- High masses are disfavoured



*G. Belanger et al, Comput. Phys. Commun. 182- 842 (2011)

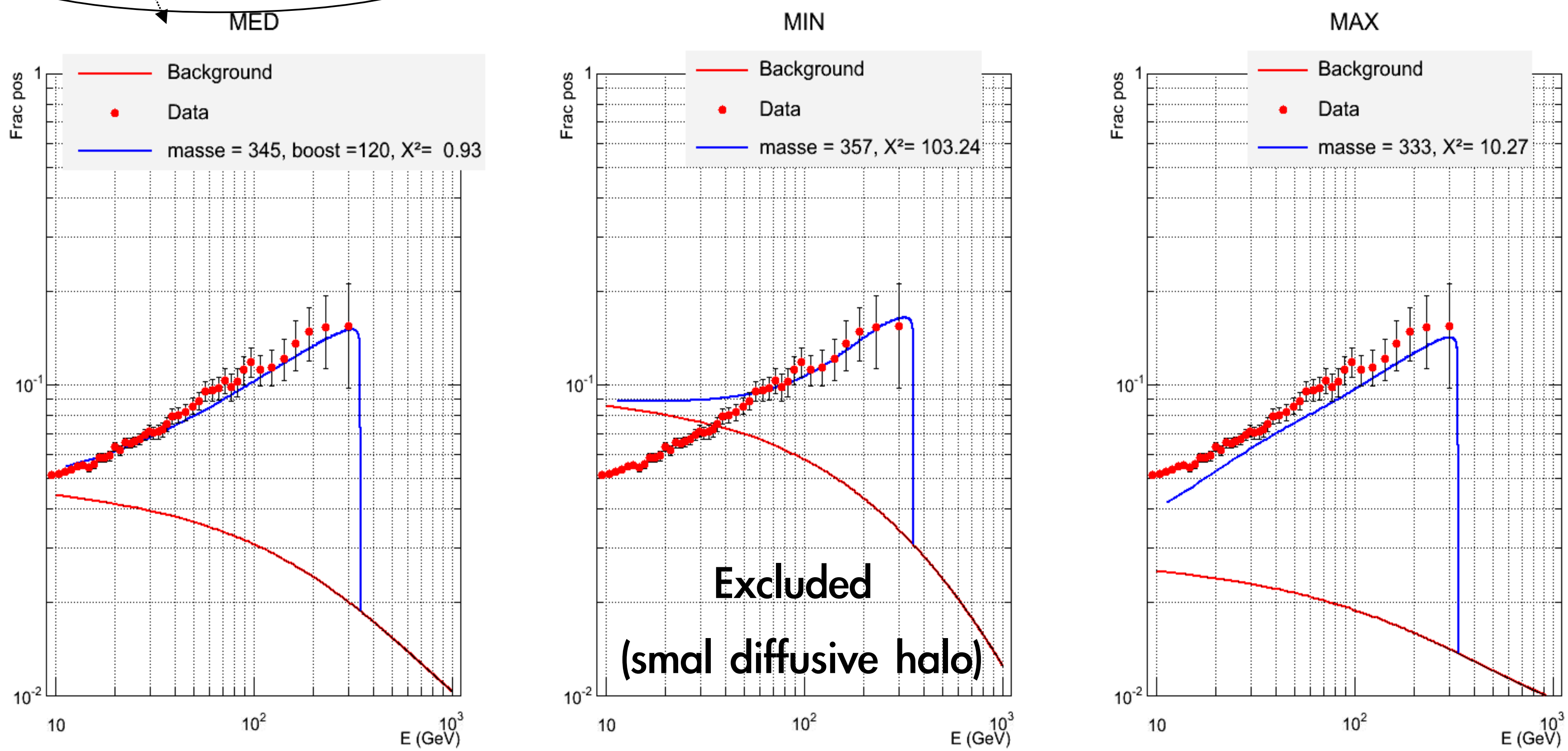
Test of propagation models



...besides the nature of the source ...

Modèle	δ	K_0 [kpc^2/Myr]	L [kpc]
min	0.85	0.0016	1
med	0.70	0.0112	4
max	0.46	0.0765	15

K: diffusion term
δ:diffusion index
α: index emission for the source j



- Important to constraint the propagation model parameters to draw any interpretations
- Important also to look at the positron and electron fluxes separately

Flux determination

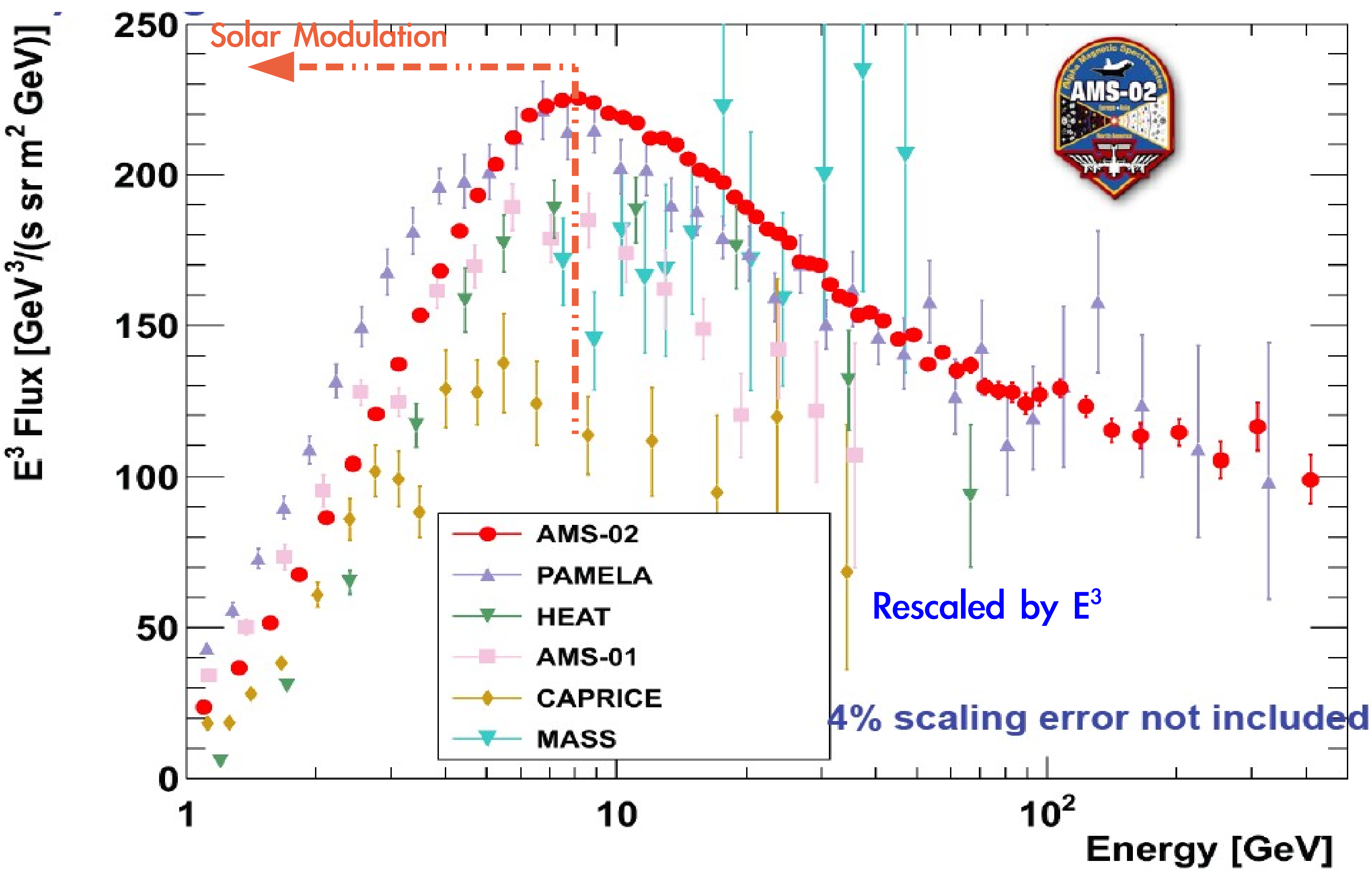
$$\Phi(E) = \frac{N(E, E + \Delta E)}{\Delta E \Delta T_{\exp} A_{\text{eff}} \varepsilon_{\text{trig}}}$$

- Φ: Absolute differential flux [$m^{-2}sr^{-1}s^{-1}GeV^{-1}$]
- E: measured energy [GeV]
- N: Number of events after selection
- T_{exp}: Exposure time [s]
- A_{eff} : Acceptance [m^2sr]
- ε : Efficiency
- Δ E: Energy bin [GeV]

AMS electron flux

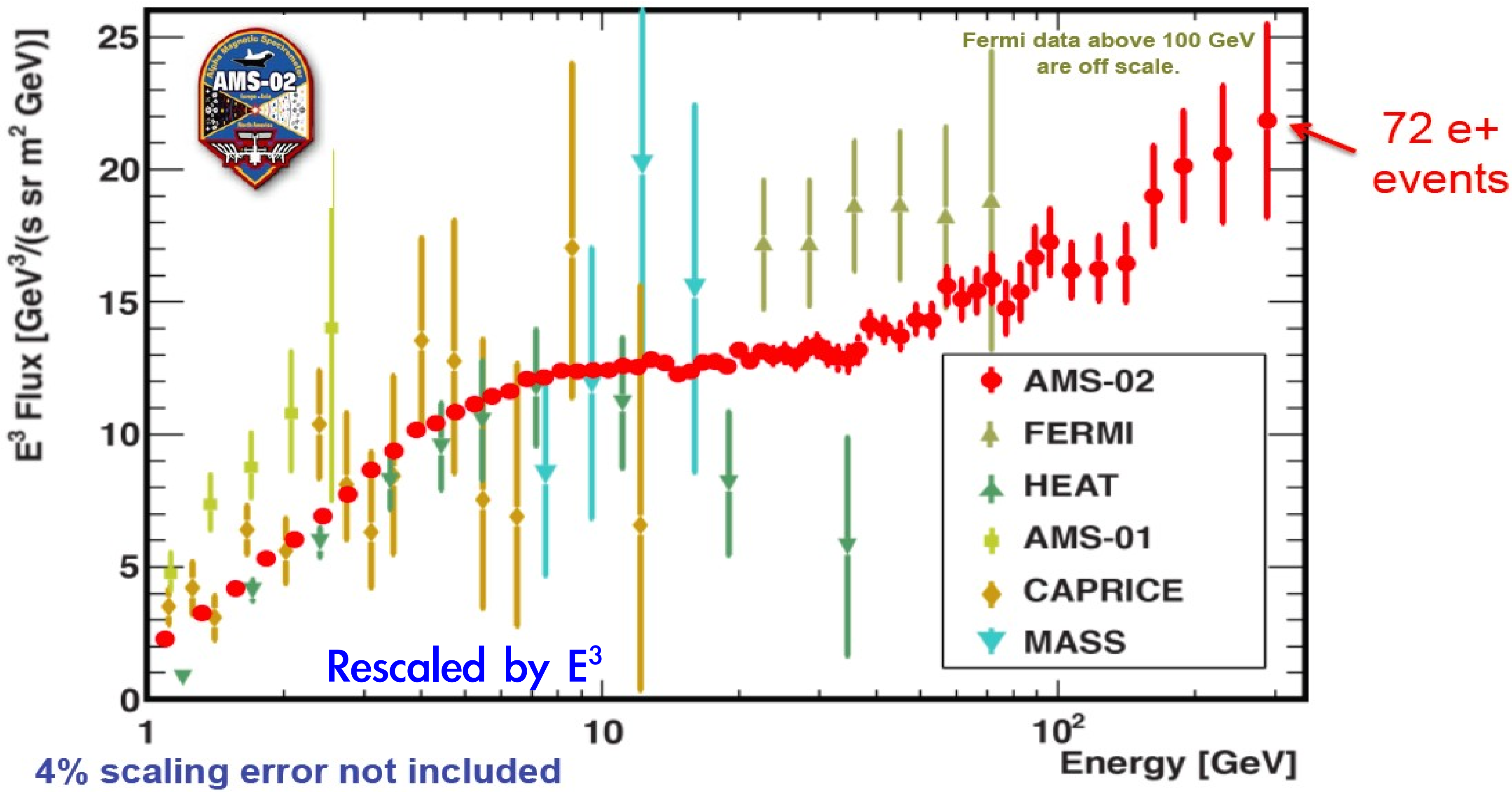
Data : May 2011 - May 2013 (~10% of expected AMS data sample)

~10^6 events out of 30 10^9 triggers



- Electron flux above 10 GeV follows a power law with index > 3.
- The analysis is being finalized for publication (systematic errors under study)

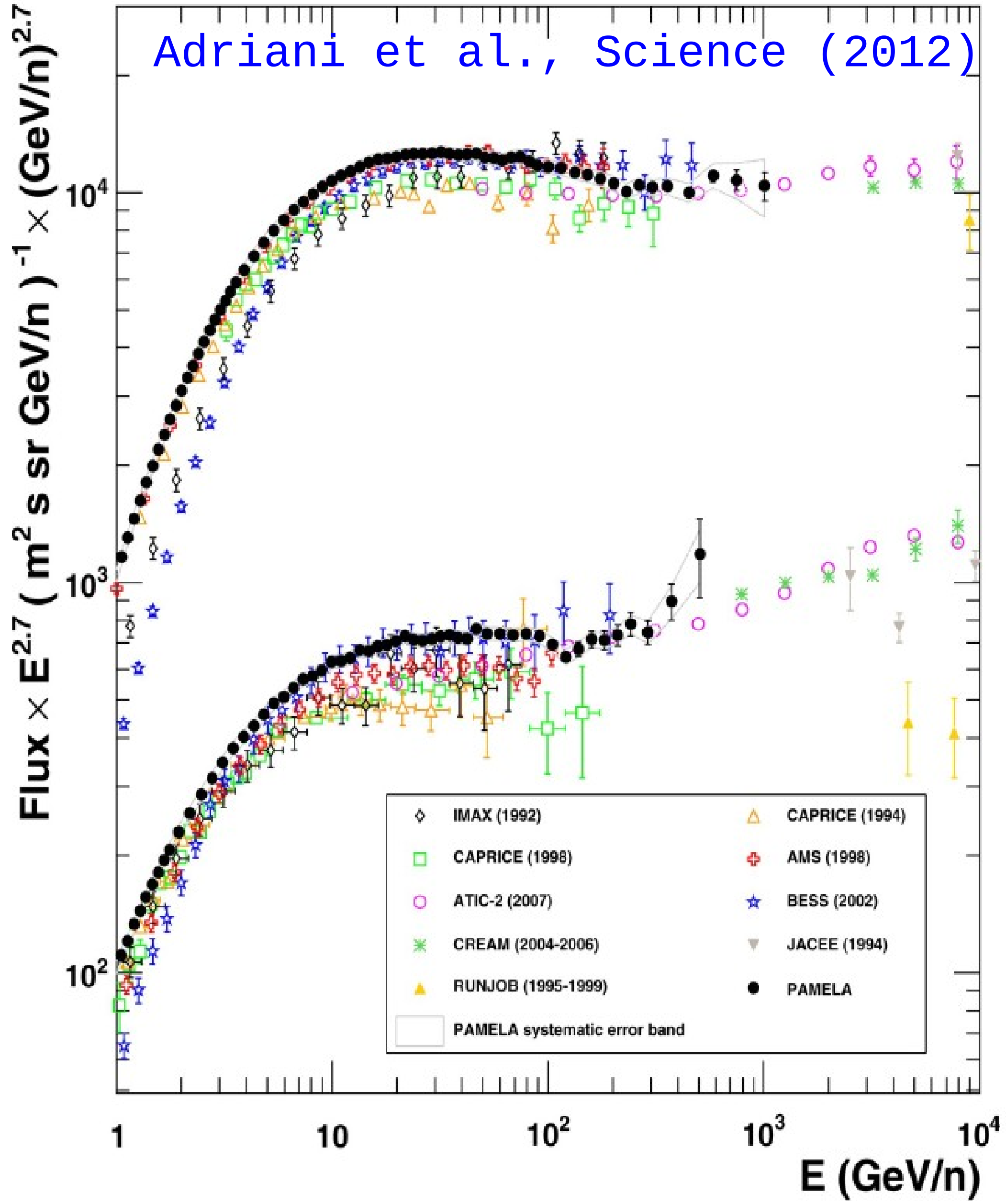
AMS-02 positron flux



- Multiplied to E^3 it is raising up to 10 GeV, flat up to 35 GeV and then raising again
- The analysis is being finalized for publication (systematic errors under study)

Protons and He fluxes

- Fundamental data to understand the origin and propagation of cosmic rays in our Galaxy (and outside!)
- Pioneered by ballons (ATIC, BESS,..)
- Recently PAMELA published a break in the published spectrum of p and He



Protons detection

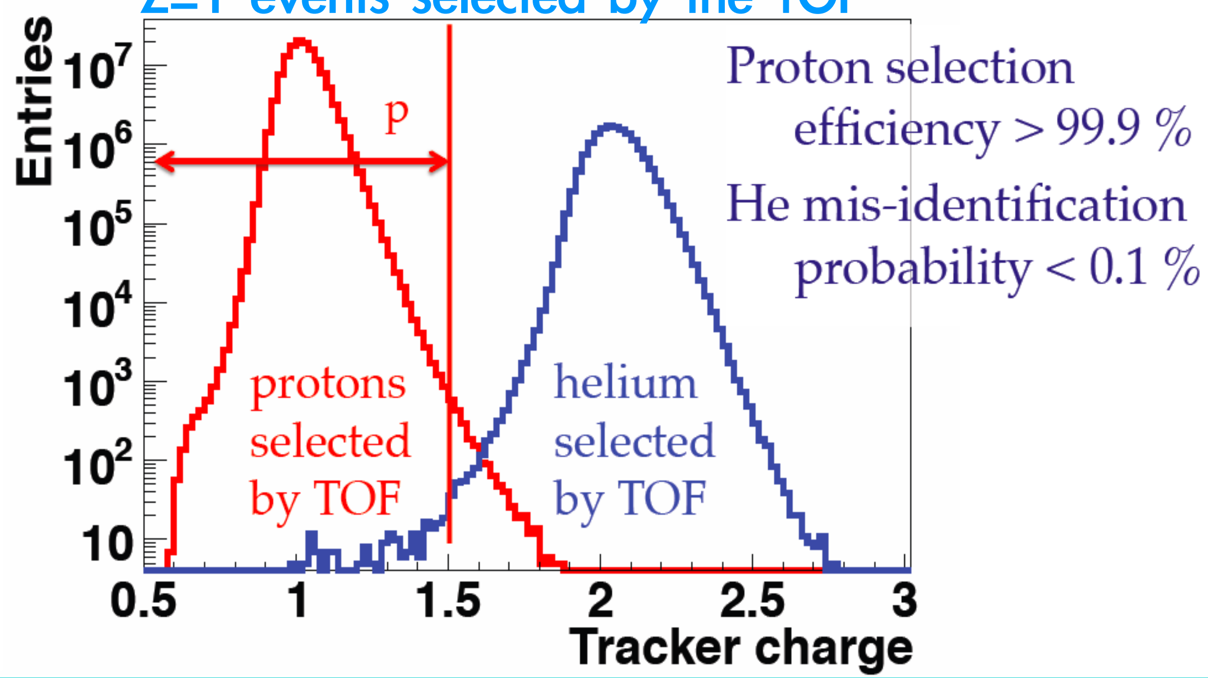
Keys of success :

- Protons are the most abundant particles in cosmic rays
- Redundancy of charge measurements
- Rigidity measurement : unfolding
- Maximum Detectable Rigidity ~ 2 TV

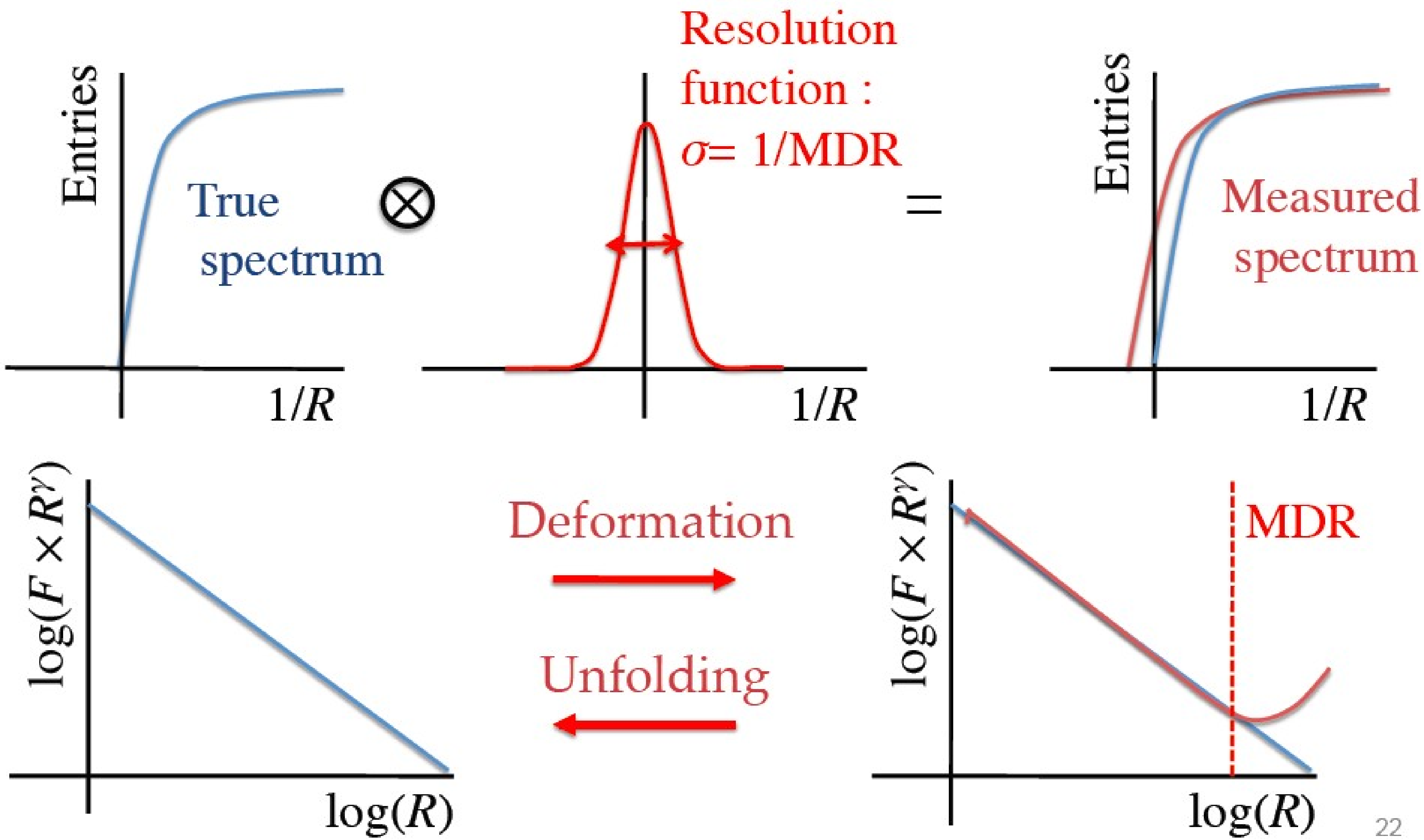
Main sources of background :

- He (<0.1%)
- Pions (<1% @1-2 GeV, then negligible)
- Electrons and positrons (negligible)

Z=1 events selected by the TOF



Spectrum Unfolding



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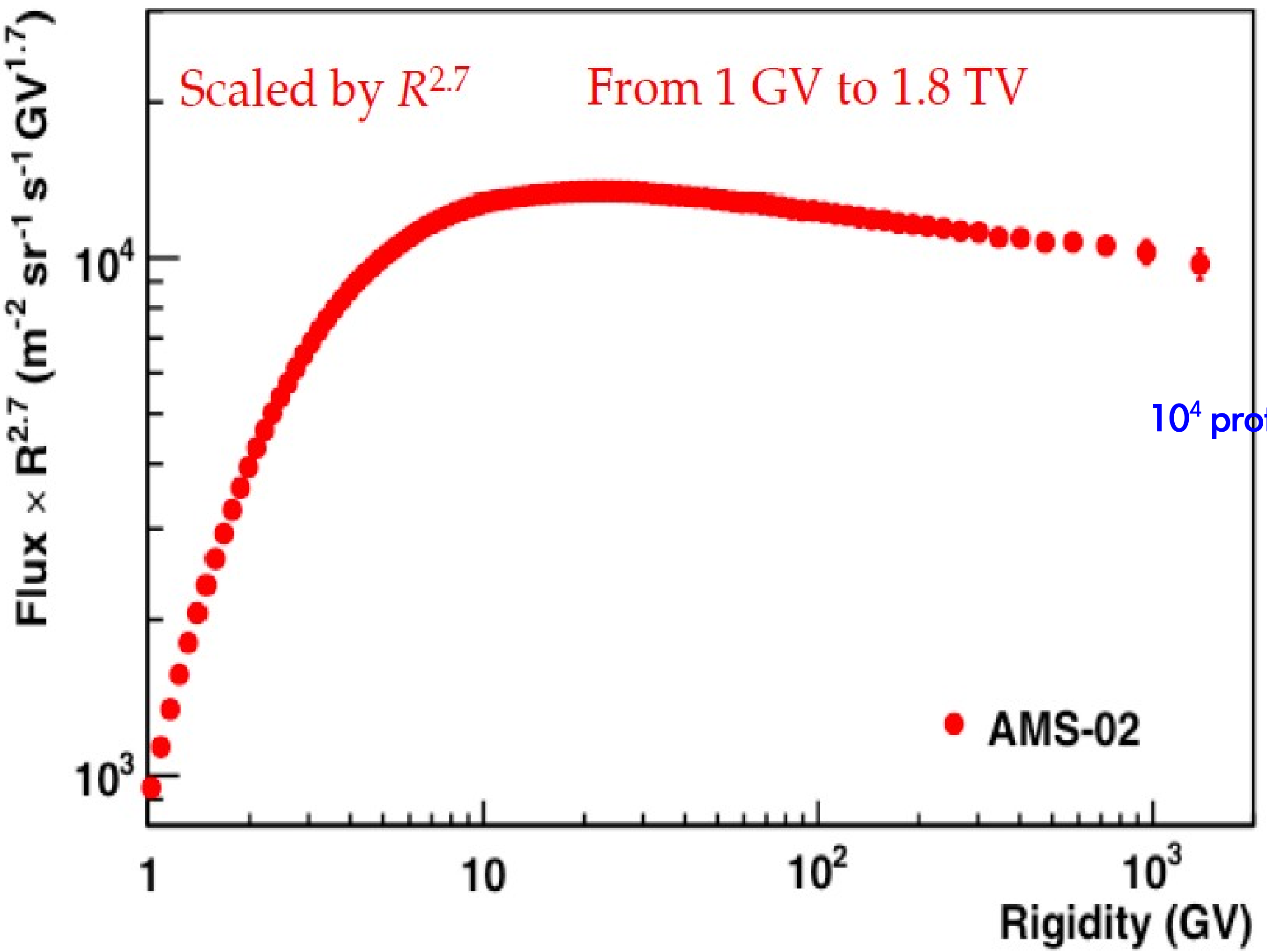
AMS-02 Proton Flux

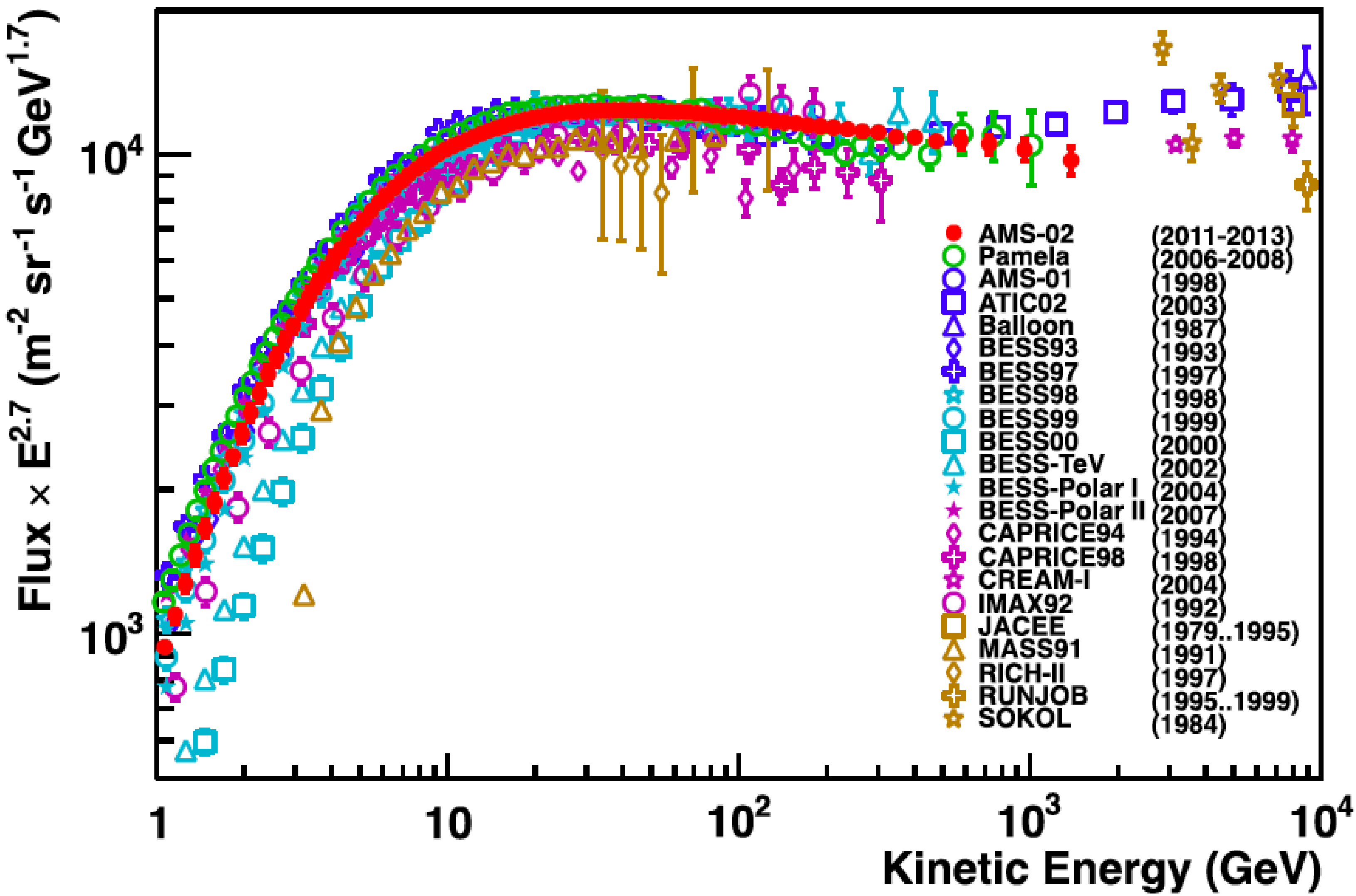
3.03 10^8 protons selected (May 2011 - May 2013)



10^4 protons @ R >1 TV

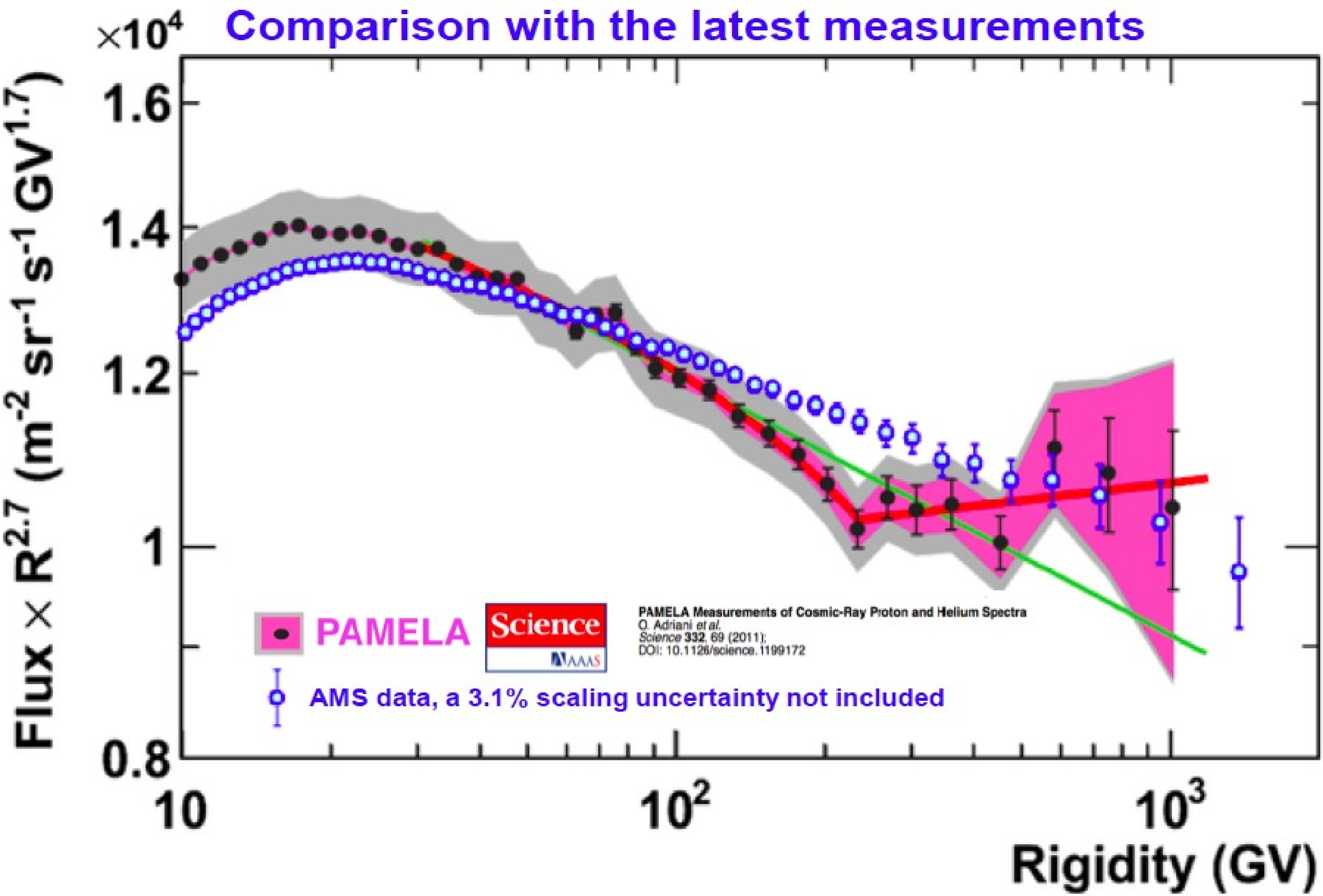
- Protons in AMS-02 : 5 10^6 millions events per day.
- Above 10 GV, spectral index higher than 2.7
- Analysis is being finalized for publication.

AMS-02 proton flux



- AMS-02 does not confirm break in spectral index as observed by PAMELA

AMS-02 and PAMELA p flux



AMS-02 He measurement

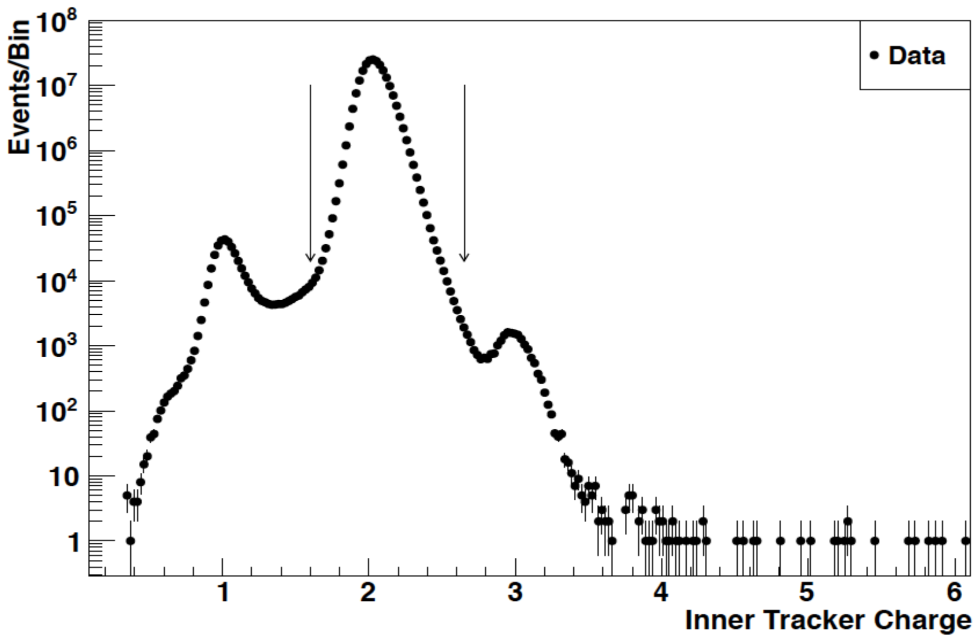
Keys of success :

- Redundancy of charge measurements
- Spectrum unfolding
- MDR ~ 3.2 TV

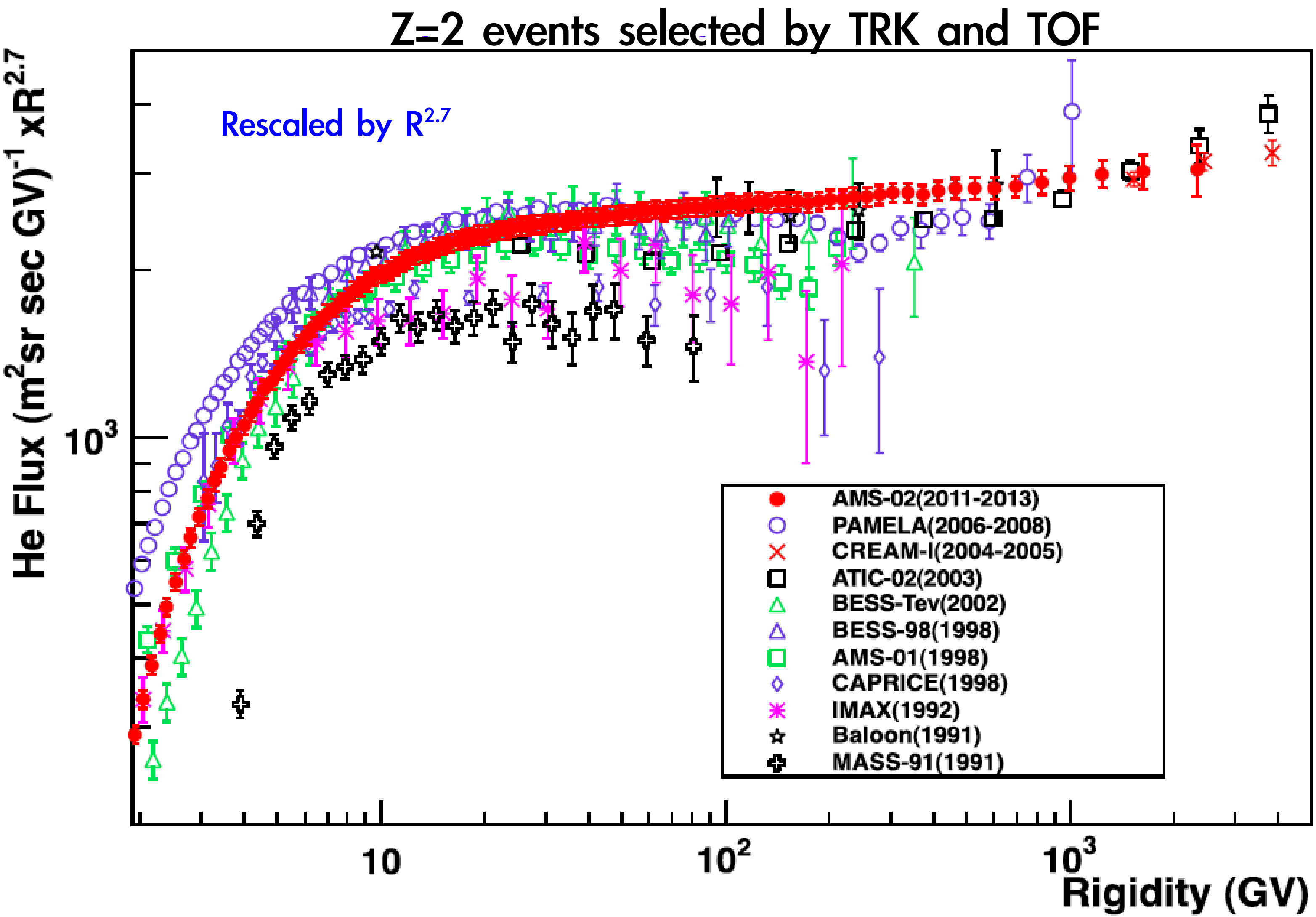
Main sources of background :

- Proton background < 10^{-5}
- Ions background < 10^{-3}

He candidates selected by Tracker L1 & TOF

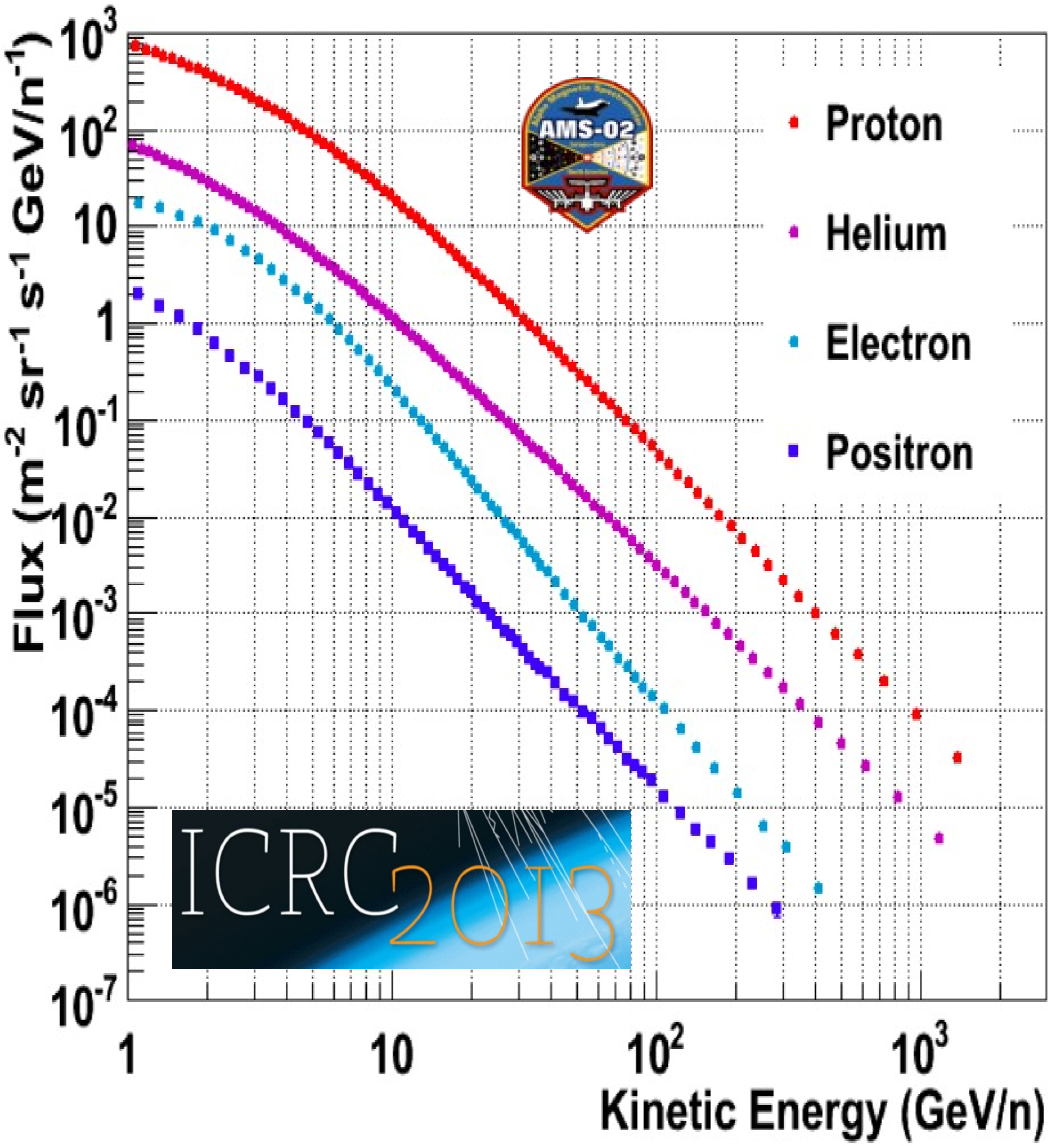


AMS-02 He flux



- Above 10 GV, spectral index lower than 2.7
- H and He do not show the same spectral index : disagreement with *standard* propagation models
- Analysis is being finalized for publication.

Summary



Stay tuned … more results to appear soon !