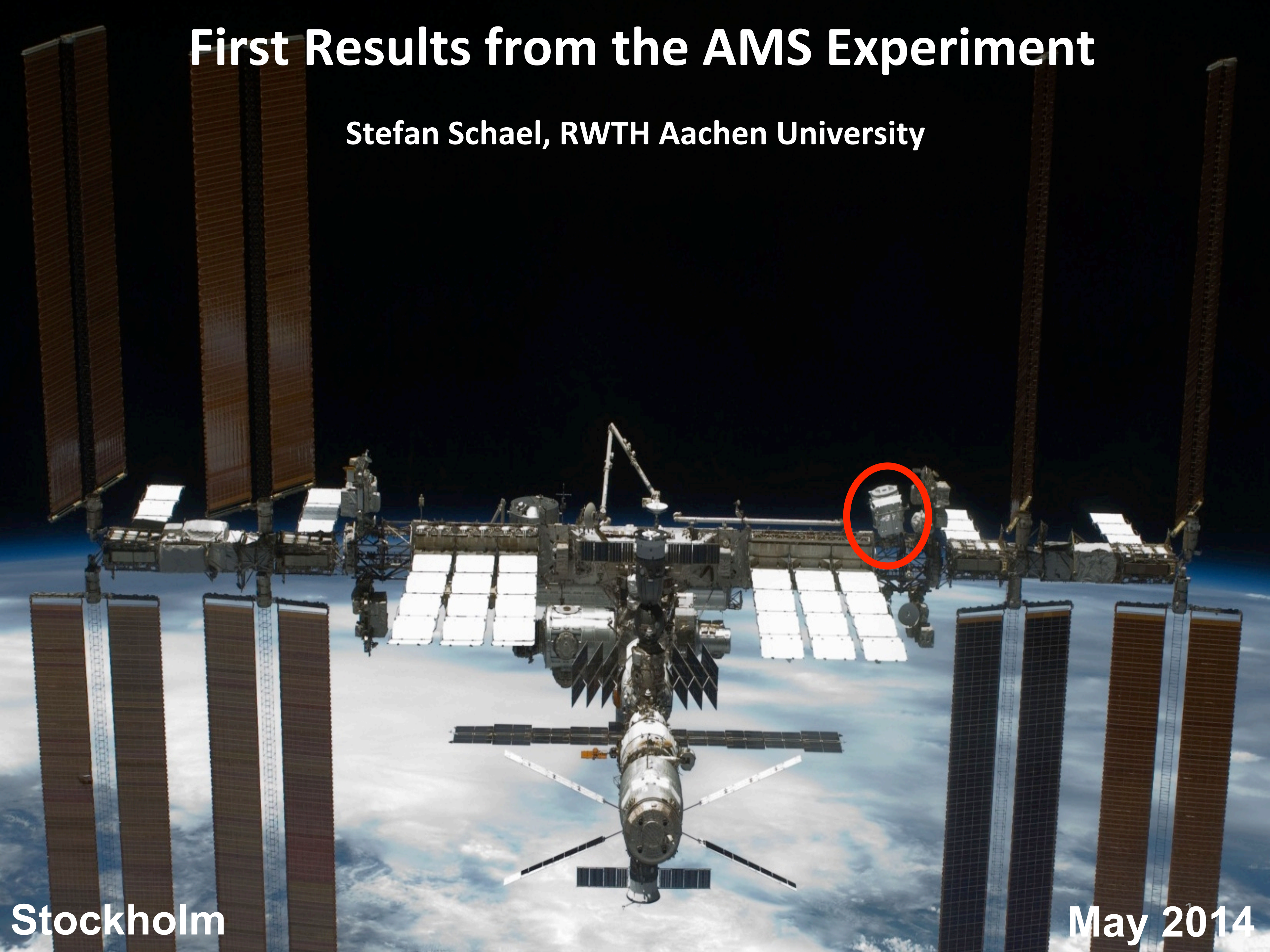
First Results from the AMS Experiment

Stefan Schael, RWTH Aachen University



Stockholm

May 2014

Search for Dark Matter

FERMI, AMS, ICECUBE, HESS, ...

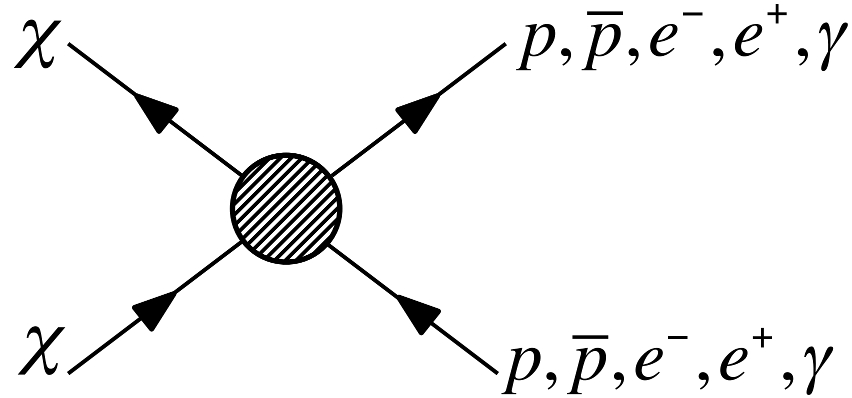
Annihilation

$\chi + \chi \to e^{+}, \bar{p}, \gamma, \ldots$

LUX
DARKSIDE
XENON 100
CDMS II
...

Scattering

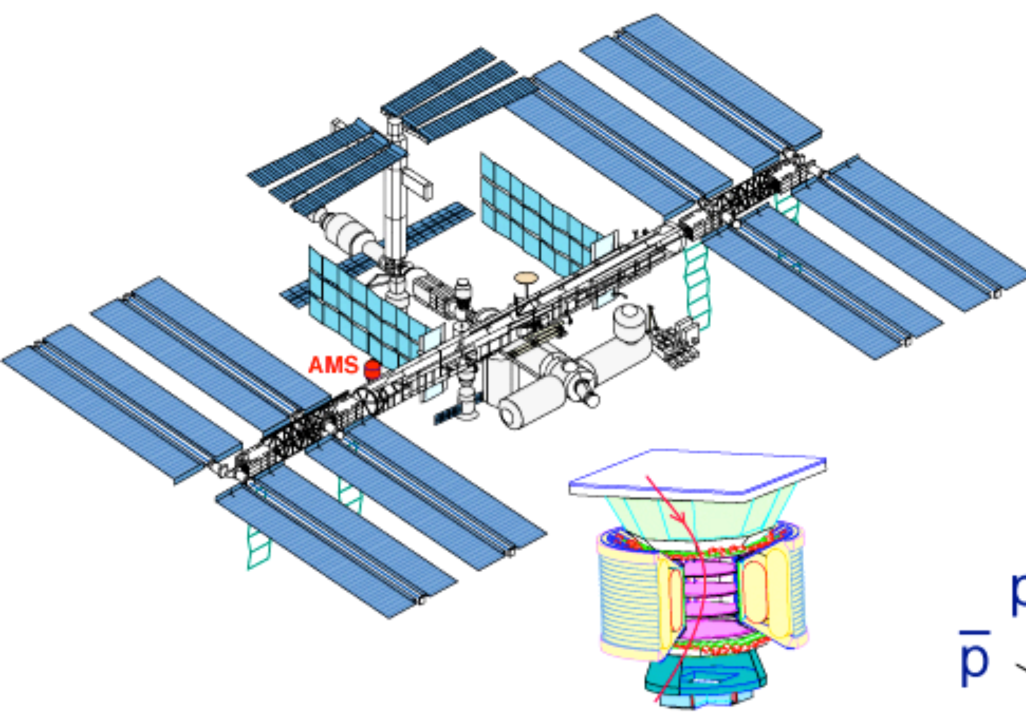
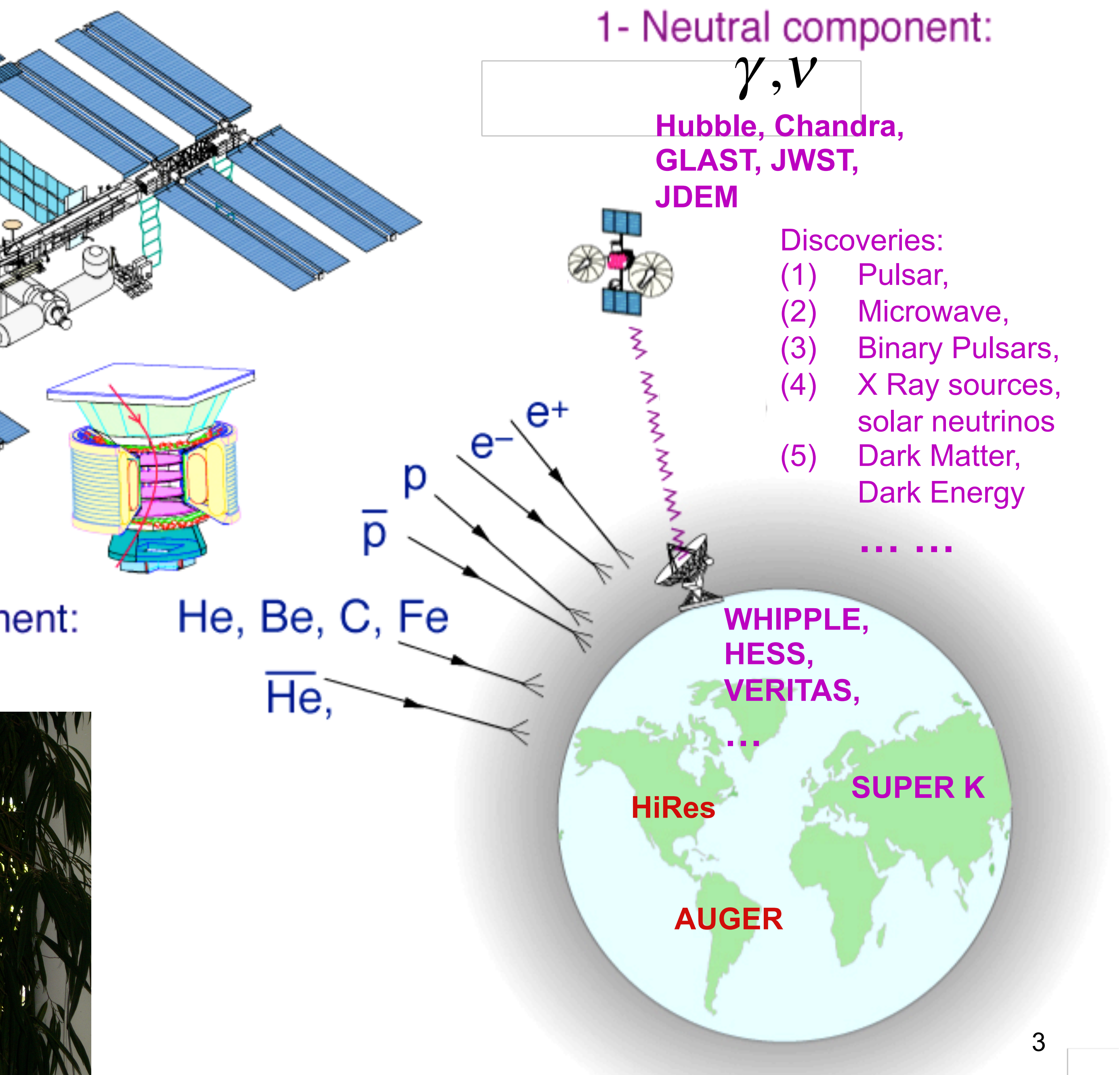
$\chi + p \to \chi + p$



$\chi + \chi \leftarrow p + p$

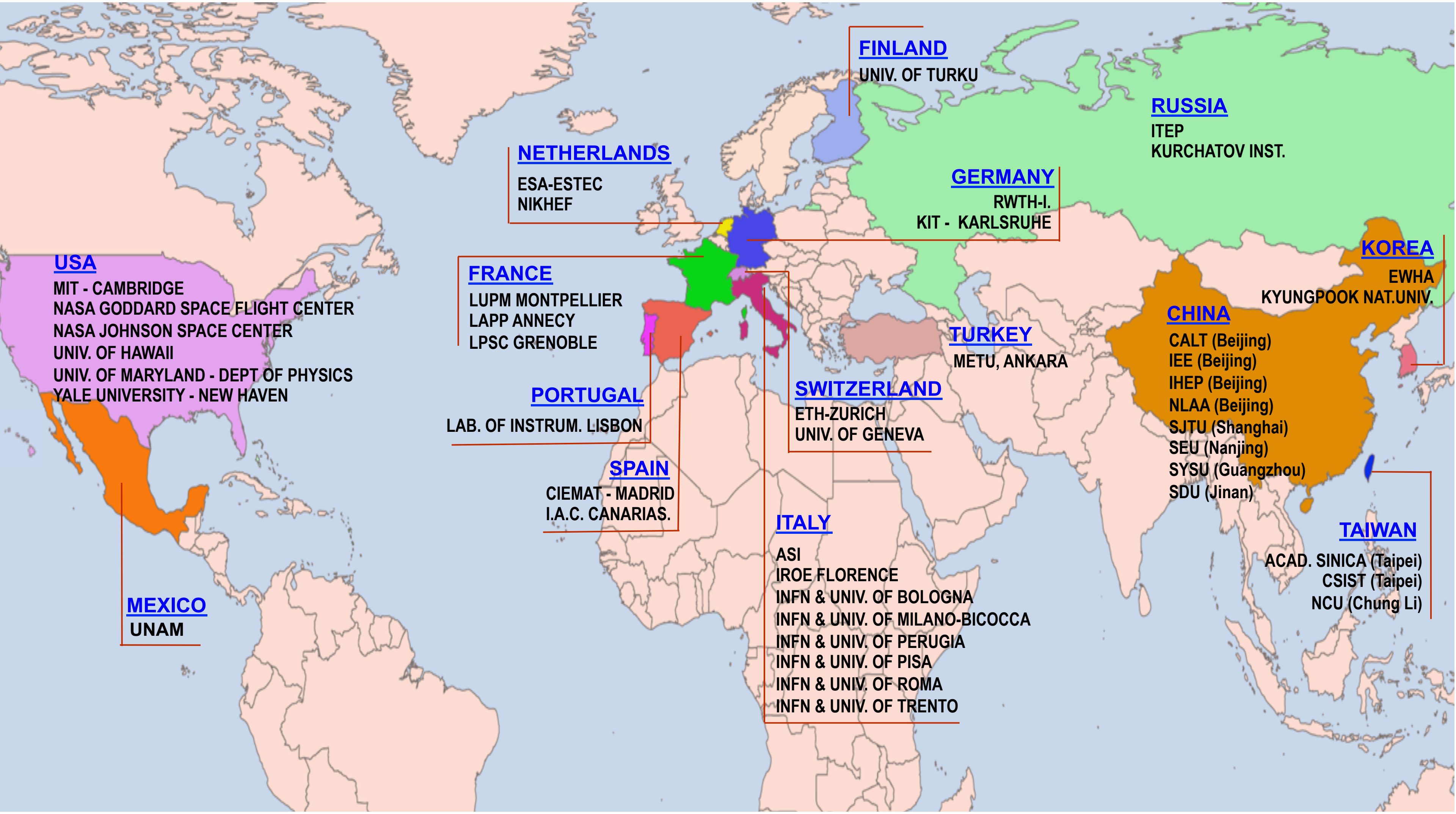
Production

LHC



1- Neutral component:
γ, ν
Hubble, Chandra, GLAST, JWST, JDEM
Discoveries:
(1) Pulsar,
(2) Microwave,
(3) Binary Pulsars,
(4) X Ray sources, solar neutrinos
(5) Dark Matter, Dark Energy
… …
AMS
e^+
e^-
p
$\bar{p}$
2- Charged component:
He, Be, C, Fe
$\overline{\text{He}}$,
WHIPPLE, HESS, VERITAS, …
HiRes
SUPER K
AUGER
S. Ting, MIT


Partons, 4-th Quark
Gluons

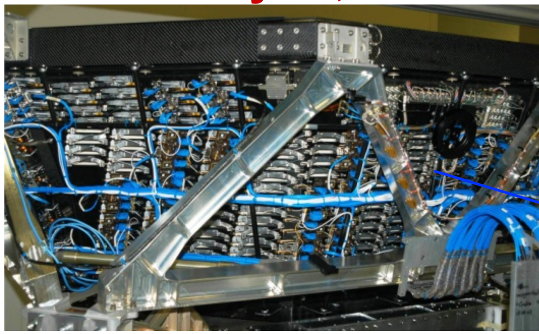
AMS : an International Collaboration
15 Countries, 44 Institutes and 600 Physicists



The detectors were built all over the world and assembled at CERN, Geneva, Switzerland

AMS: A TeV precision, multipurpose spectrometer

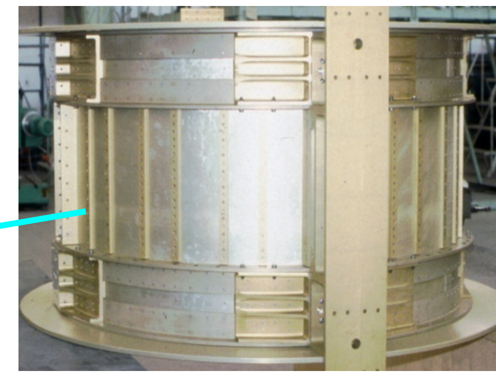
TRD
Identify e^+, e^-



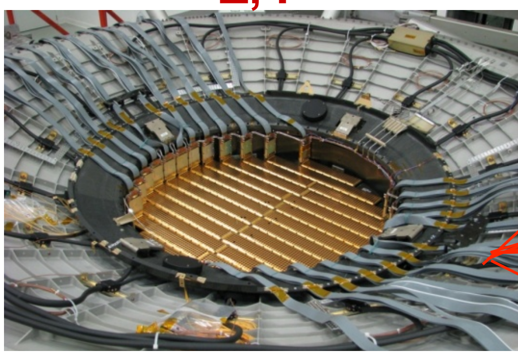
Particles and nuclei are defined by their charge (**Z**) and energy (**E ~ P**)

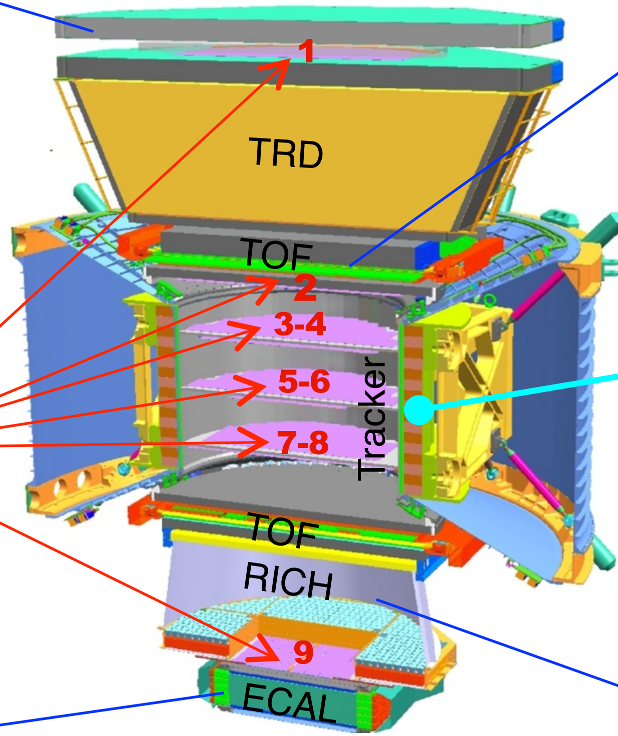
TOF
Z, E

Magnet
±Z

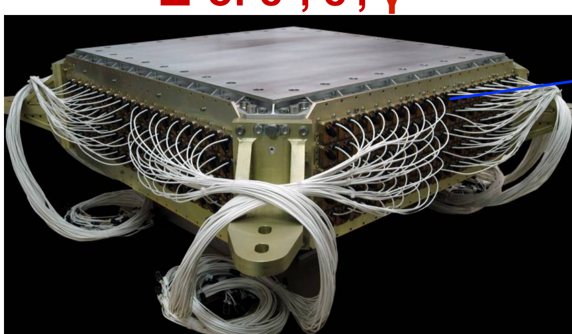


Silicon Tracker
Z, P

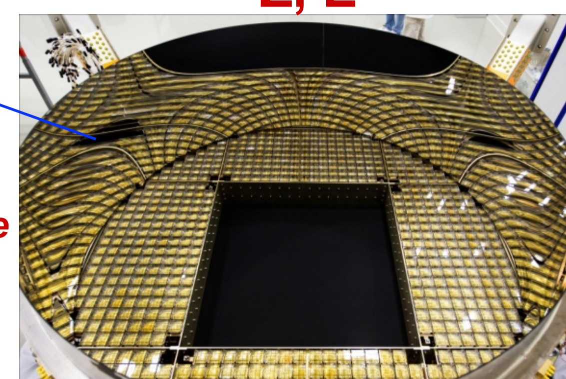




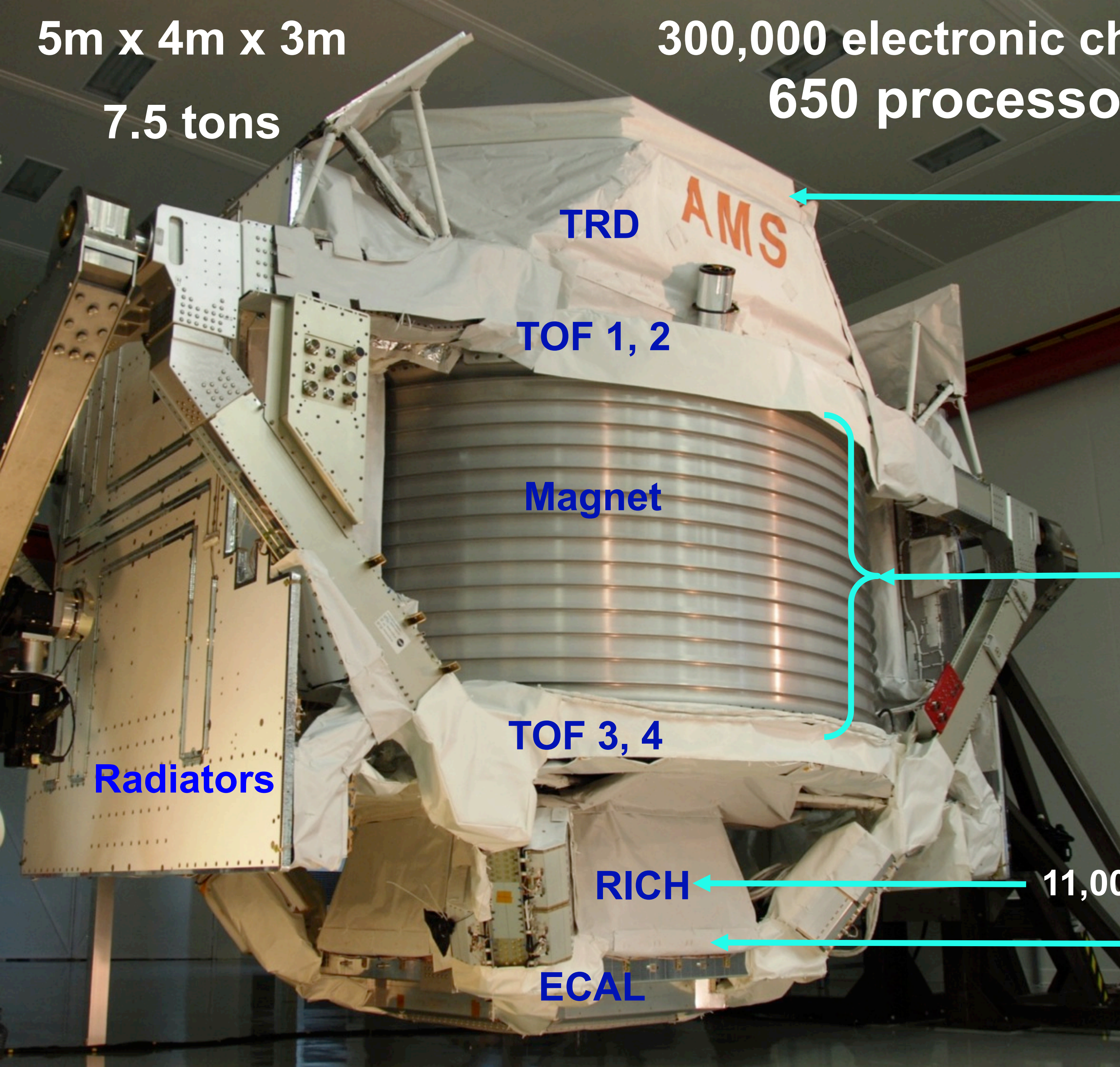
ECAL
E of e^+, e^-, γ



RICH
Z, E

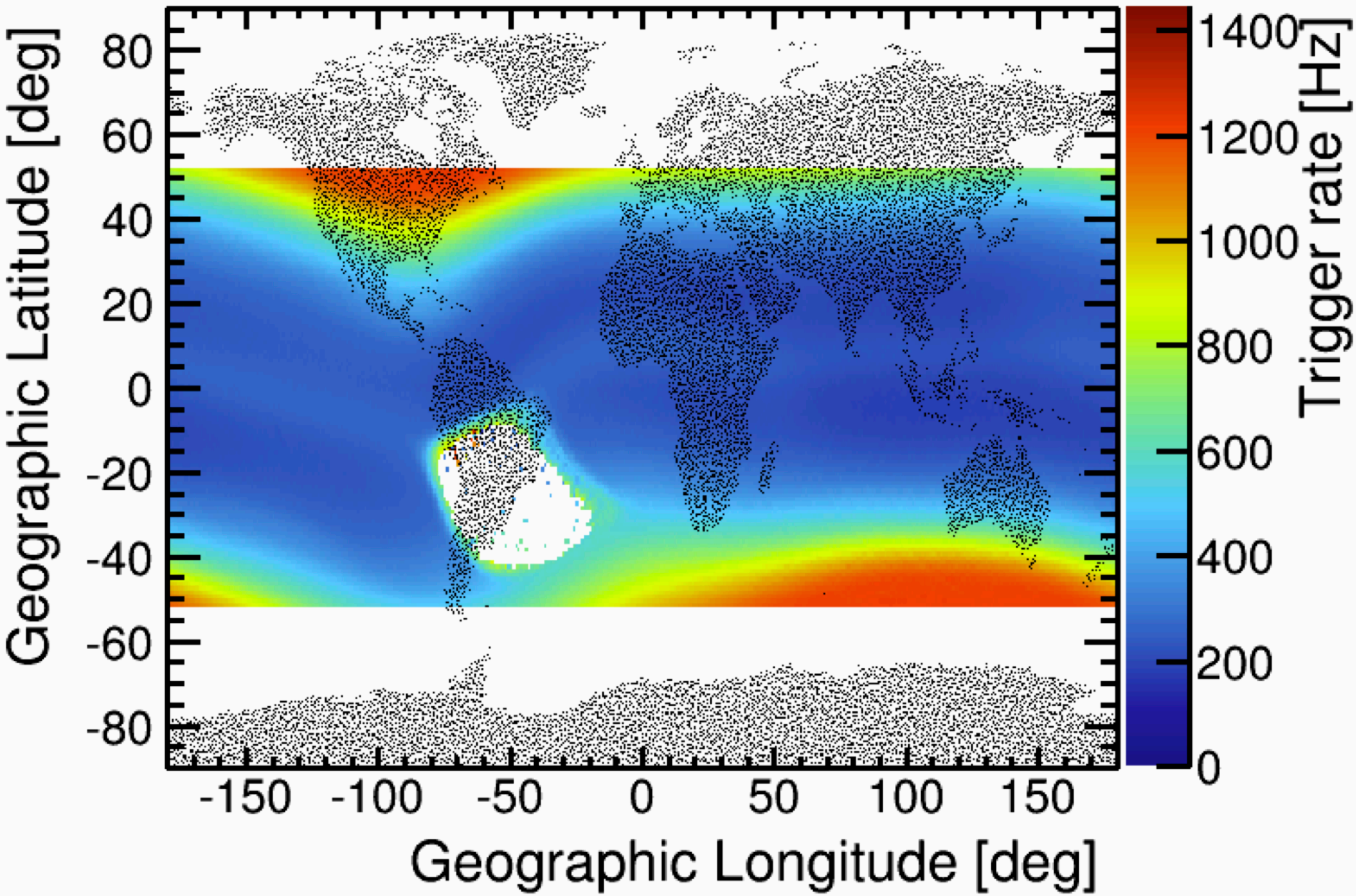


***Z, P* are measured independently by the Tracker, RICH, TOF and ECAL**


5m x 4m x 3m
7.5 tons
300,000 electronic channels
650 processors
AMS
TRD
TOF 1, 2
Magnet
TOF 3, 4
Radiators
RICH
ECAL
Silicon layer
7 Silicon layers
11,000 Photo Sensors
Silicon layer

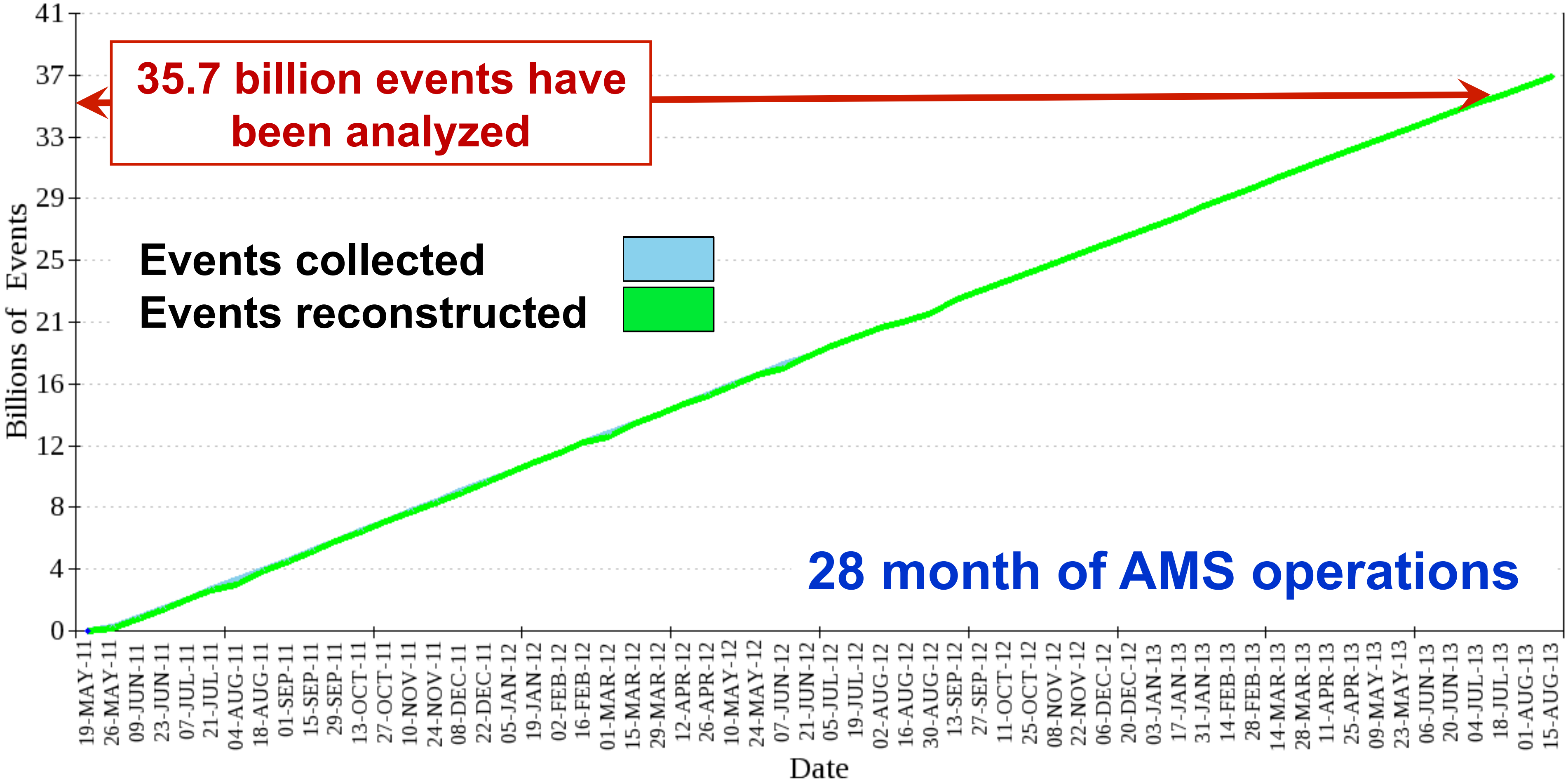

STS-134 launch   May 16, 2011 @ 08:56 AM

AMS installed on the ISS
Truss and taking data
May 19, 2011

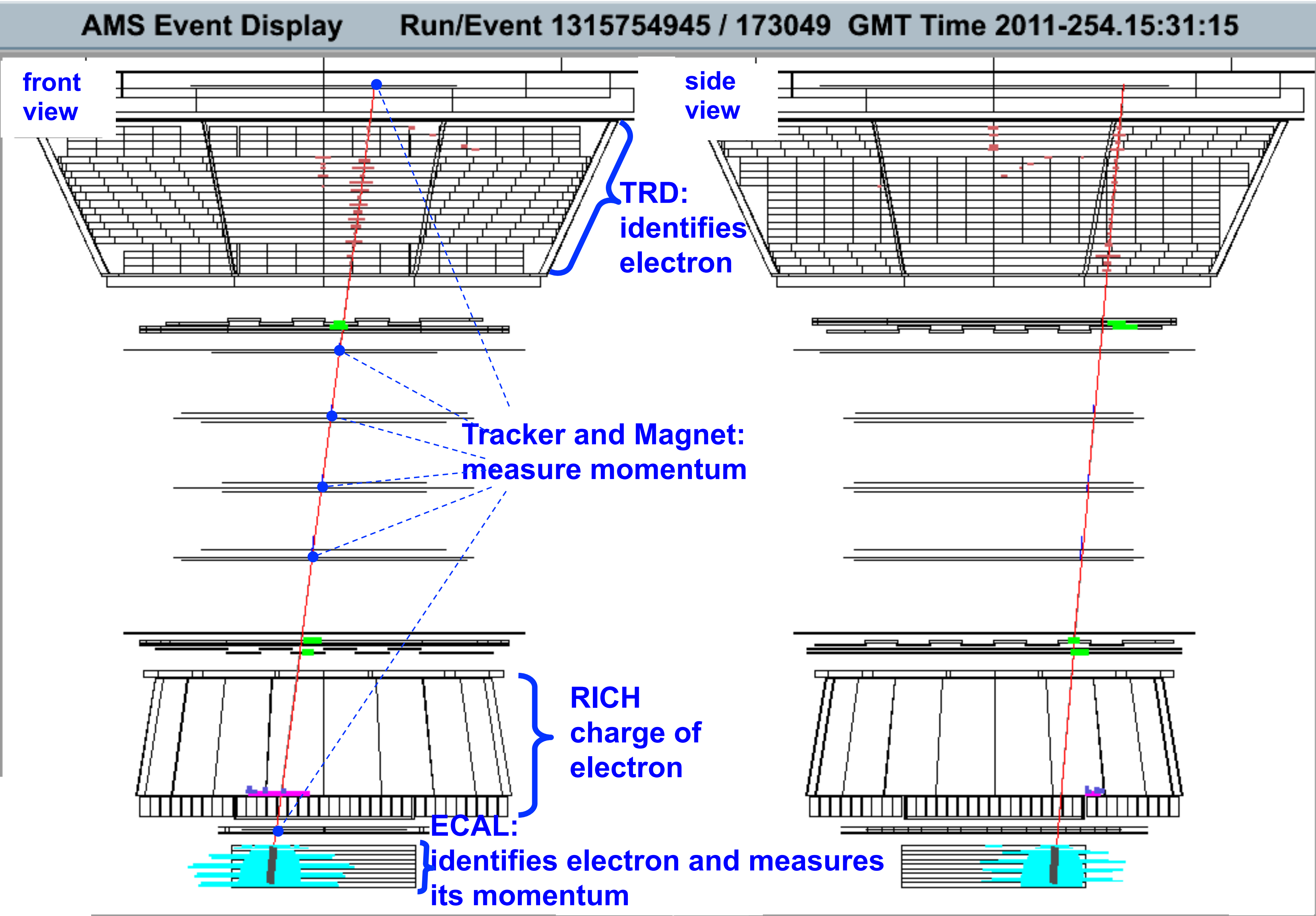


Geographic Latitude [deg]
80
60
40
20
0
-20
-40
-60
-80
-150
-100
-50
0
50
100
150
Geographic Longitude [deg]
Trigger rate [Hz]
1400
1200
1000
800
600
400
200
0

Up to August 26, 2013, 38 billion events have been processed by the Data Production Operations in the POCC

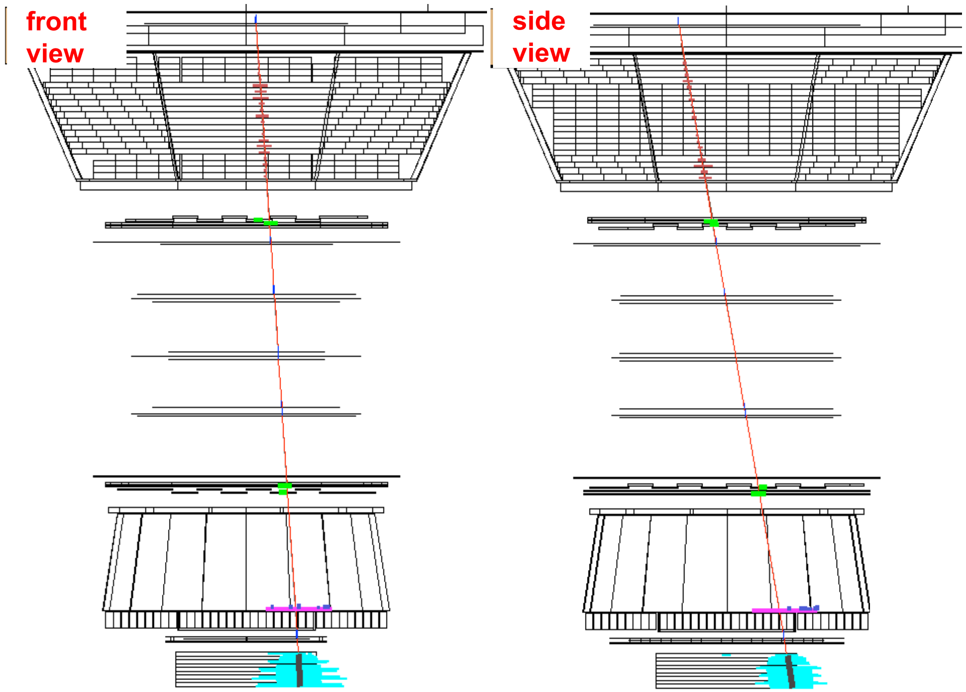


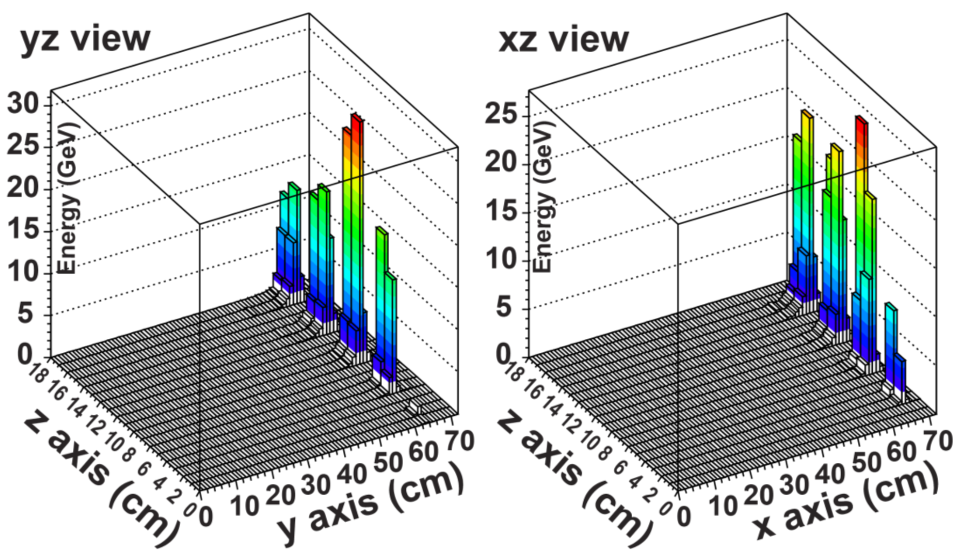
1.03 TeV electron

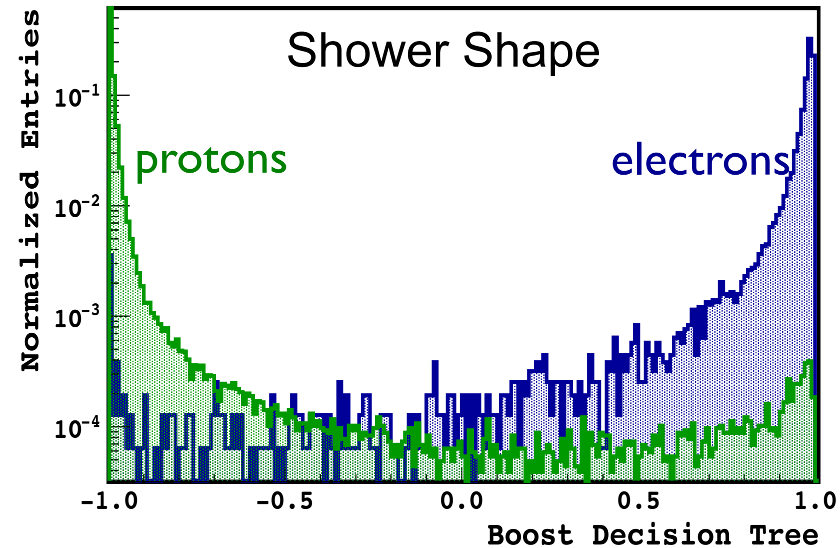


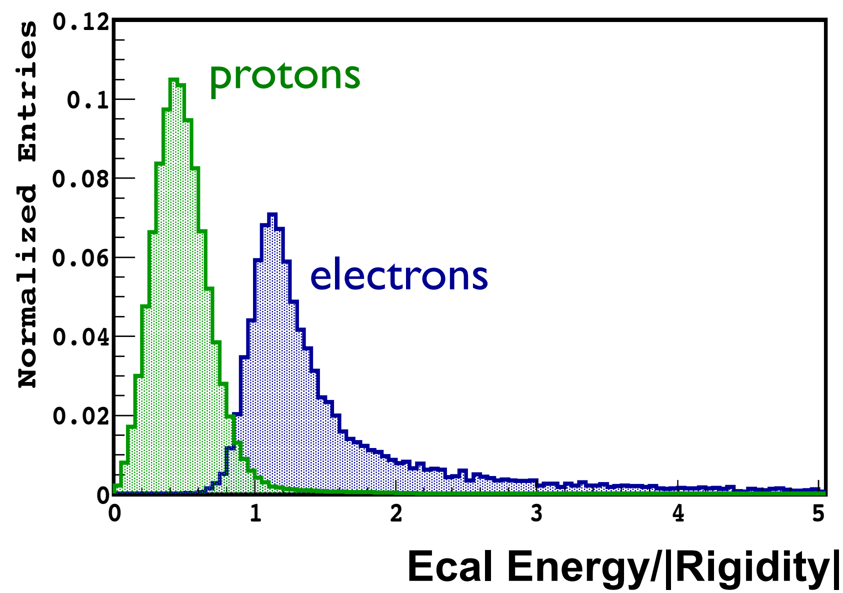
Positron E=636 GeV

Run/Event 133119-743/ 56950

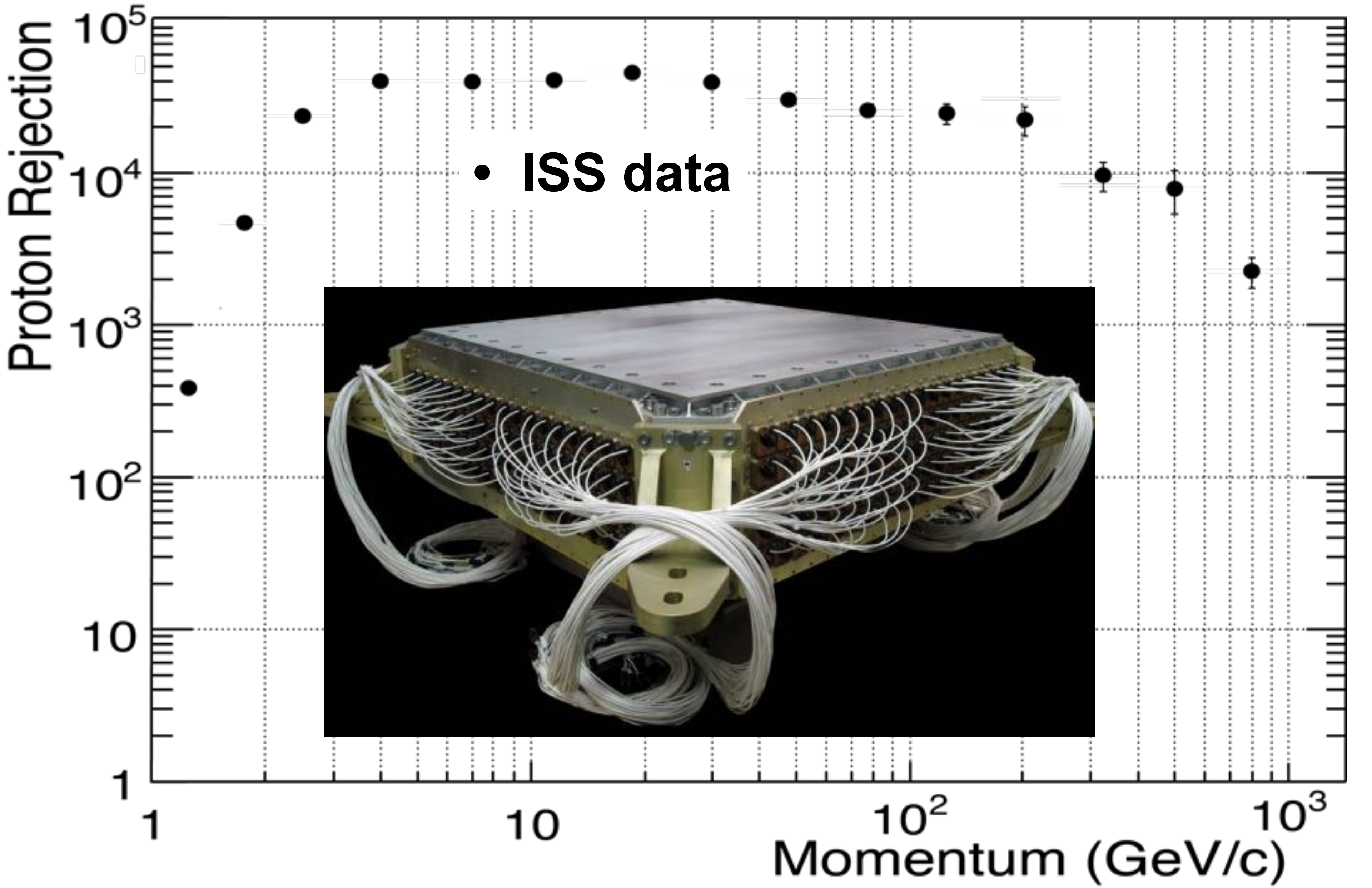








Proton Rejection by ECAL and Tracker

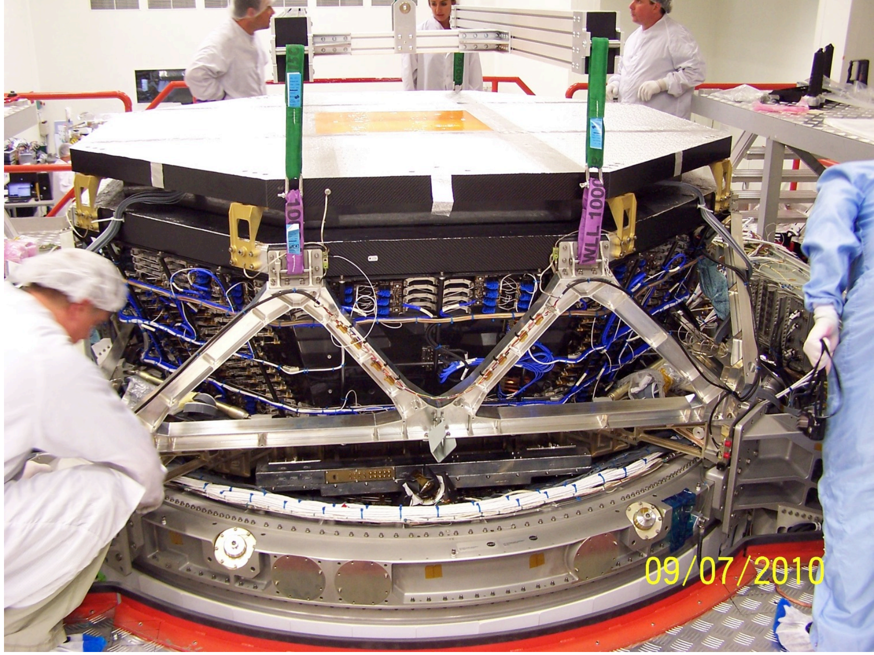


Transition Radiation Detector

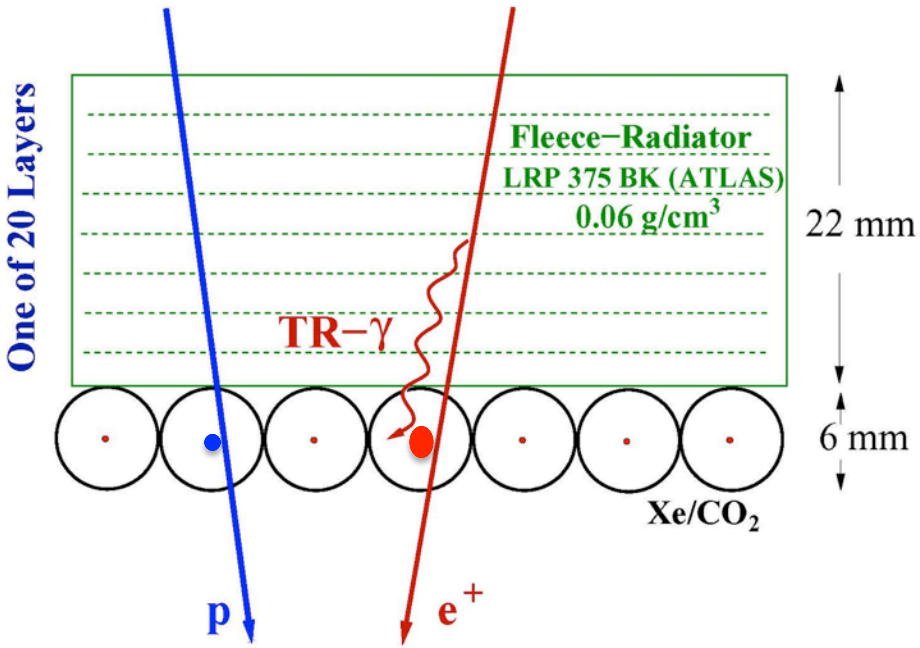
p^+ rejection $>10^2$ 1-400 GeV
acceptance: $0.4 m^2 sr$

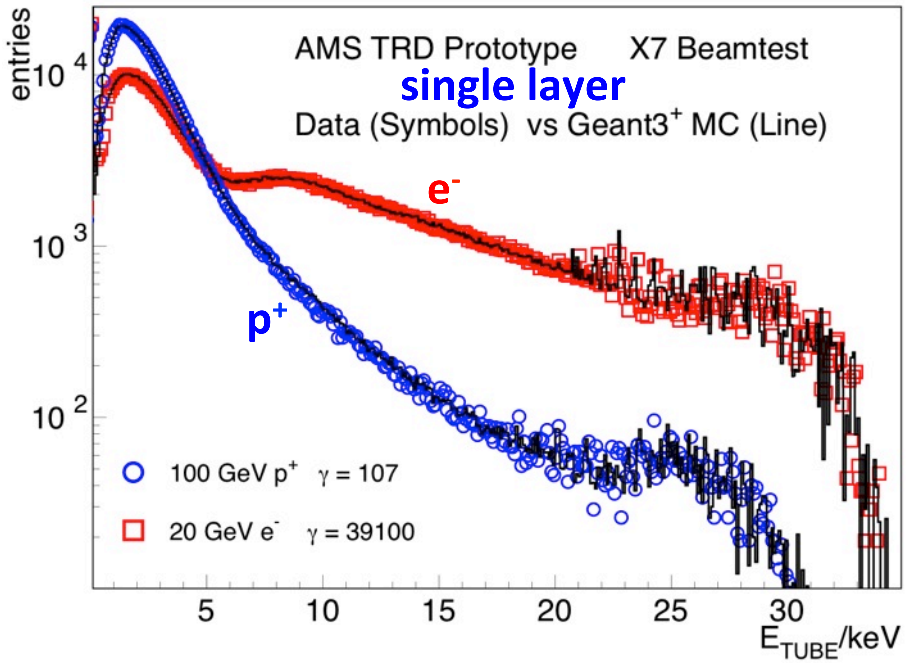
20 Layers each consisting of:

- **22 mm fibre fleece**
- **Ø 6 mm straw tubes filled with Xe/CO_2 80%/20%**

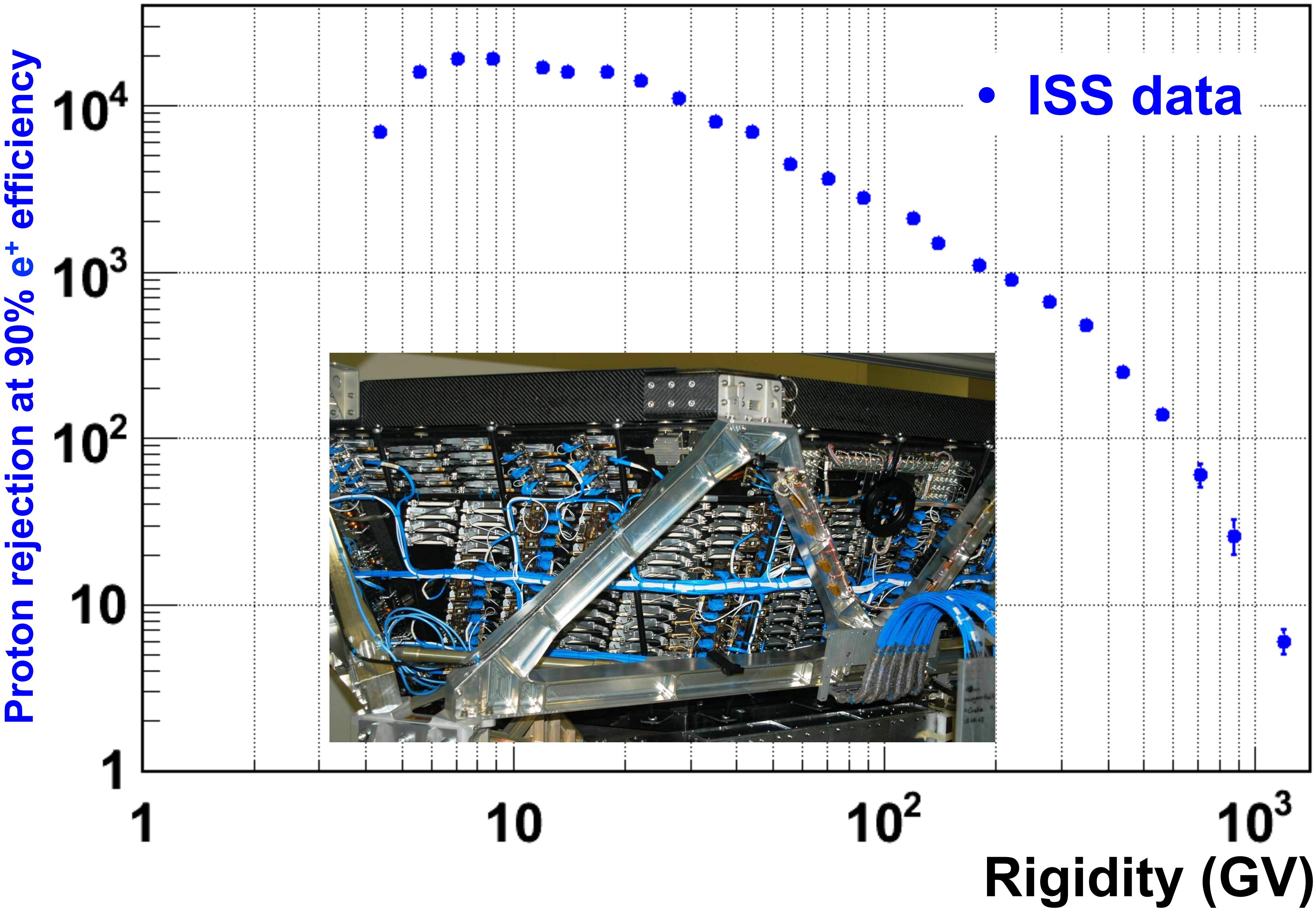


P. Doetinchem et al., Nucl.Instrum.Methods A, 558:608641, 2006.

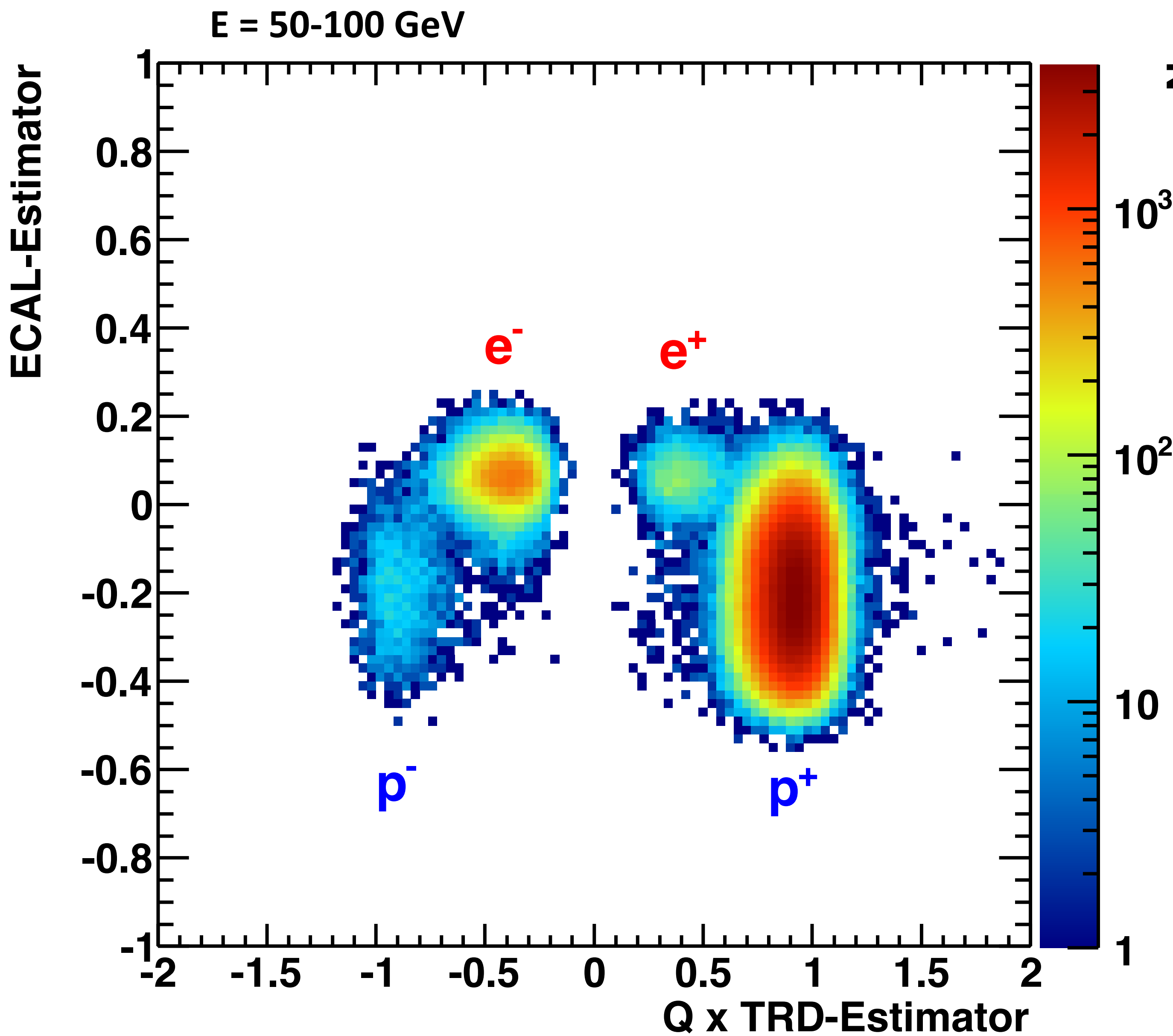




Proton Rejection by TRD



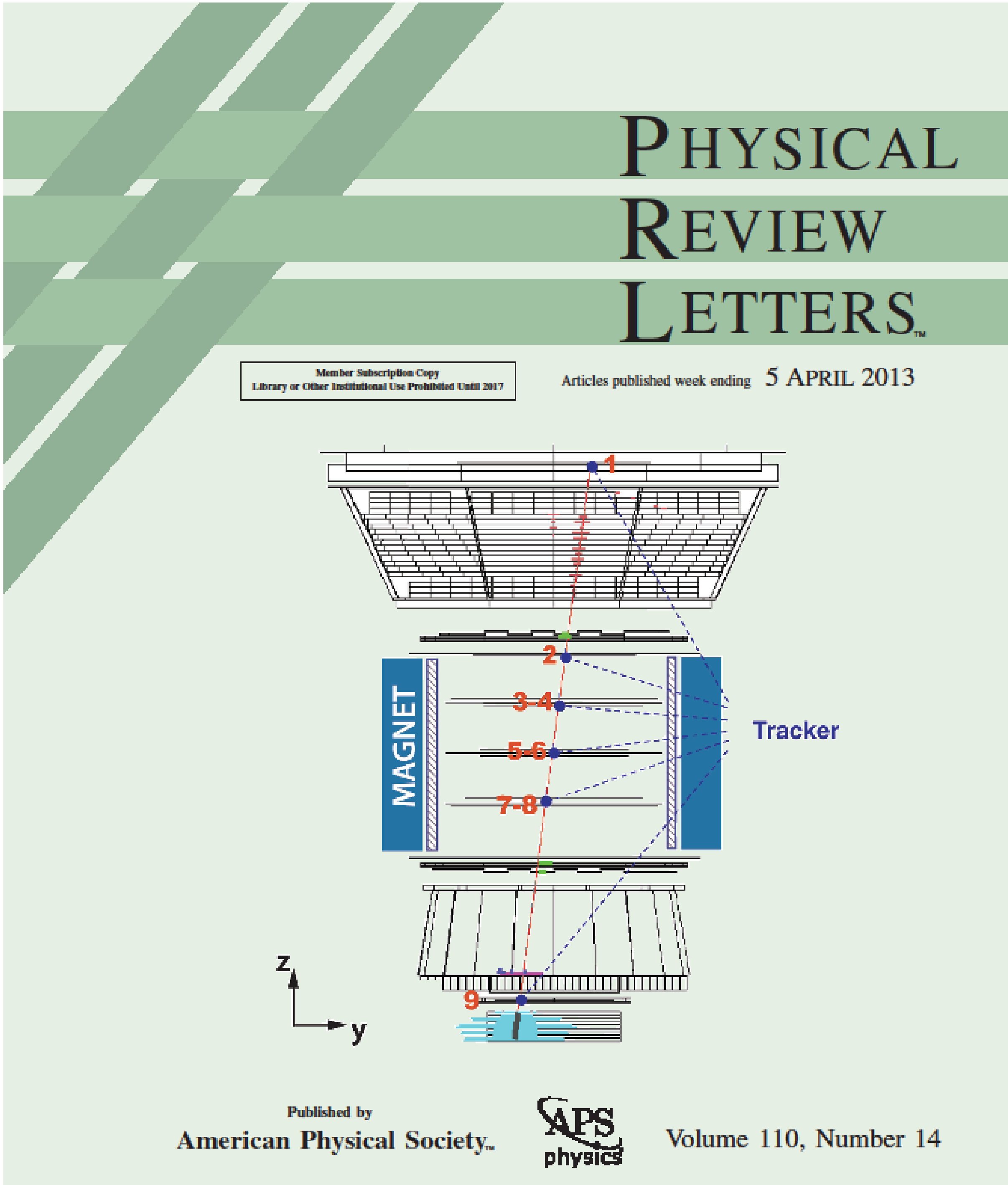
In our data sample we identify four components using an ECAL Estimator and a TRD Estimator.

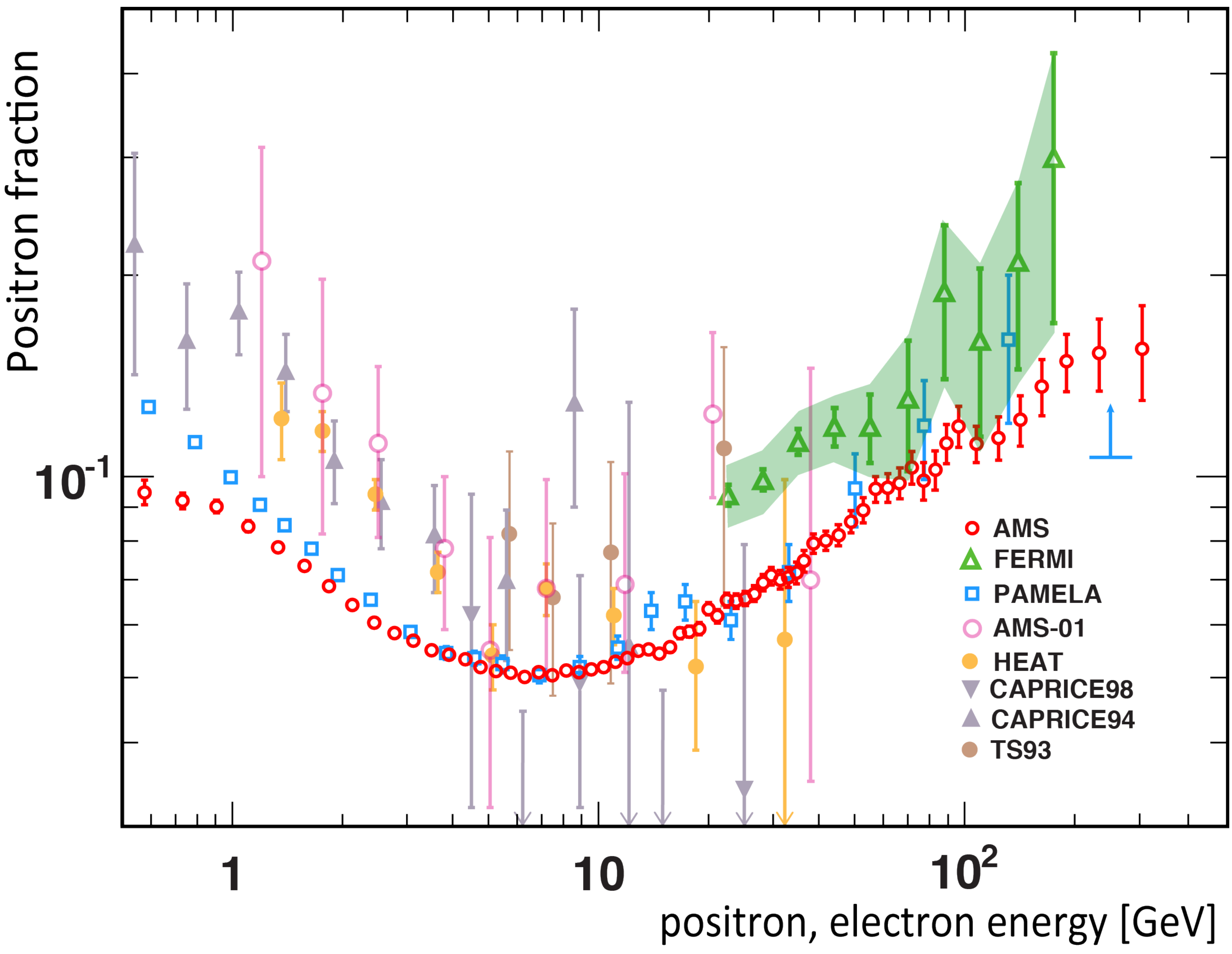


“First Result from the AMS on the ISS: Precision Measurement of the Positron Fraction in Primary Cosmic Rays of 0.5-350 GeV”

Selected for a Viewpoint in Physics and an Editors’ Suggestion [Aguilar,M. et al (AMS Collaboration) Phys. Rev. Lett. 110, 1411xx (2013)]

Oct. 2013: 79 citations





Positron fraction
10^-1
1
10
10^2
positron, electron energy [GeV]
AMS
FERMI
PAMELA
AMS-01
HEAT
CAPRICE98
CAPRICE94
TS93

An Example:
Comparing AMS data with a minimal model.

In this model the e^+ and e^- fluxes, **F_{e+}** and **F_{e-}**, are parameterized as the sum of individual diffuse power law spectra and the contribution of a single common source of **$e^{\pm}$:**

$$F_{e^-} = C_{pri.} E^{-\gamma_{pri.}} + C_{\sec.} E^{-\gamma_{\sec.}} + C_S E^{-\gamma_S} \exp(-E/E_S)$$

$$F_{e^+} = C_{\sec.} E^{-\gamma_{\sec.}} + C_S E^{-\gamma_S} \exp(-E/E_S)$$

Coefficients $C_{pri.}$ and $C_{sec.}$ correspond to relative weights of the primary spectrum for electrons and the secondary component produced in the interstellar medium.

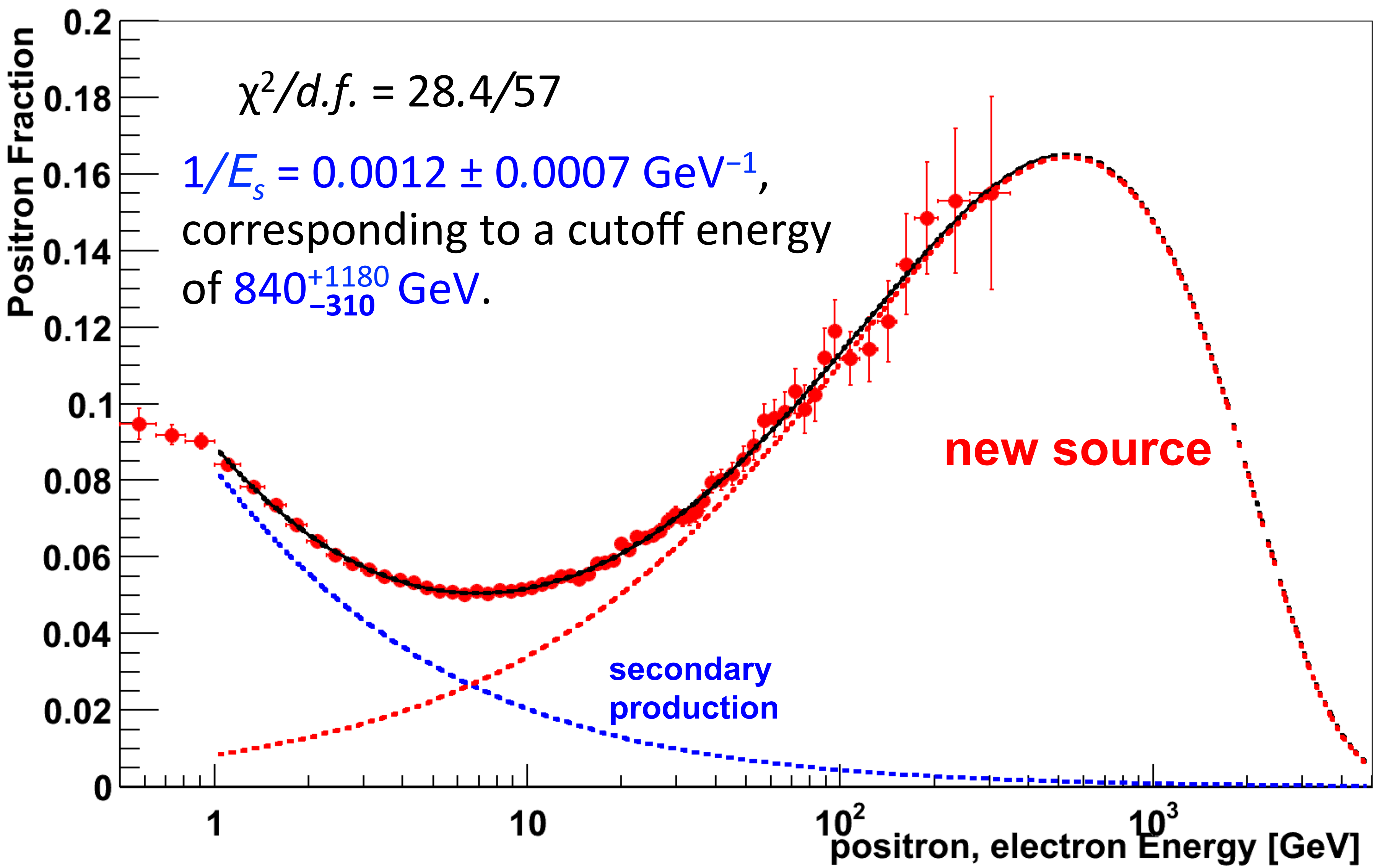
C_s is the weight of the source spectrum.

$\gamma_{pri.}$, $\gamma_{sec.}$ and γ_s are the corresponding spectral indexes.

E_s is a characteristic cutoff energy for the source spectrum.

With this parametrization the positron fraction depends on 5 parameters.

The agreement between the data and the model shows that the positron fraction spectrum is consistent with $e^{\pm}$ fluxes each of which is the sum of its diffuse spectrum and a single common power law source.



A fit to the data in the energy range 1 to 350 GeV yields a **$\chi^2/d.f. = 28.4/57$** and:

$\gamma_{pri.} - \gamma_{sec.} = -0.67 \pm 0.03$, *i.e.*, the diffuse secondary spectrum is less energetic than the primary electron spectrum;

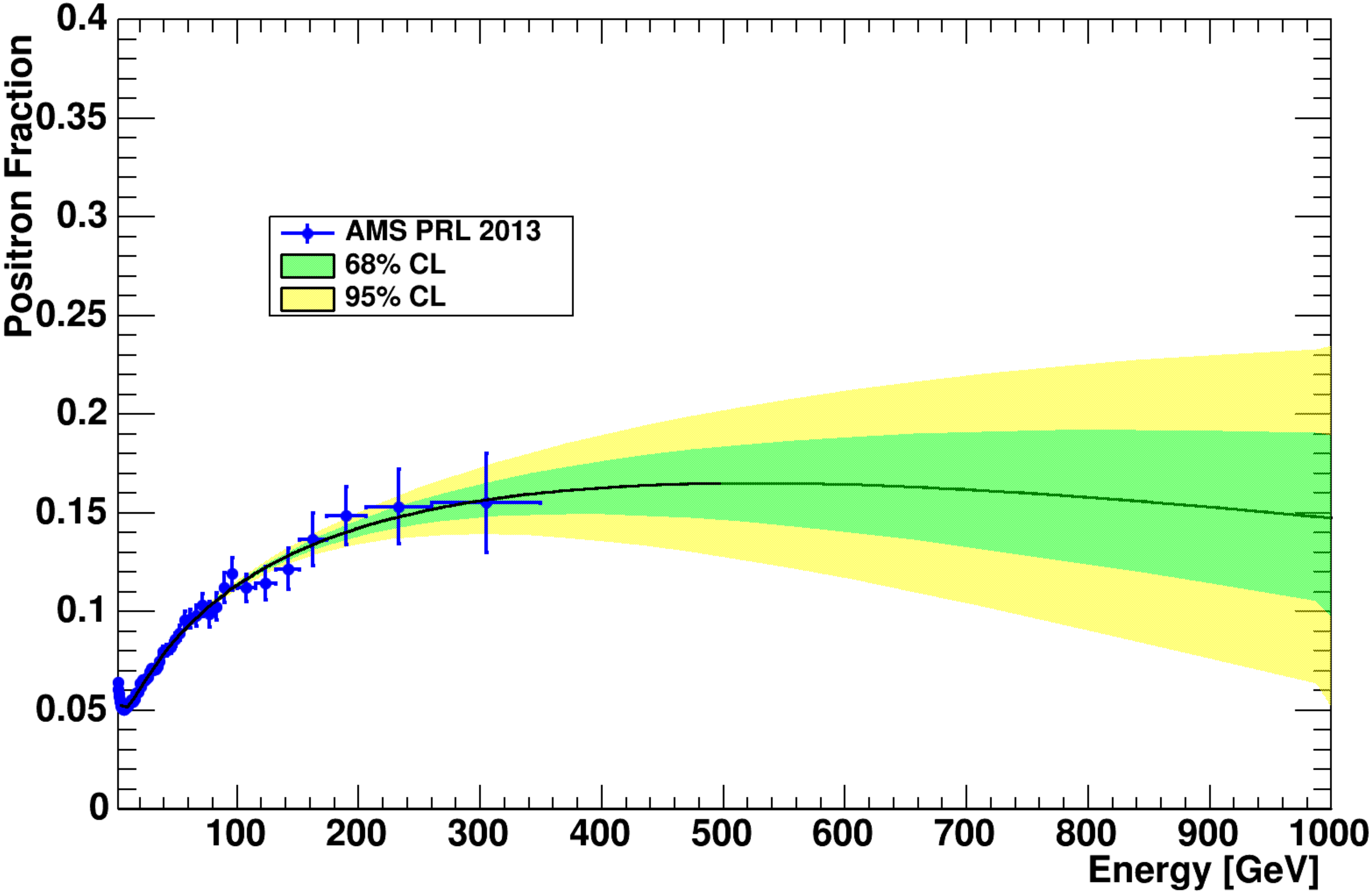
$\gamma_{pri.} - \gamma_{S} = 0.64 \pm 0.04$, *i.e.*, the source spectrum is more energetic than the primary electron spectrum;

$C_{sec.}/C_{pri.} = 0.0997 \pm 0.0012$, *i.e.*, the weight of the secondary electron and positron flux amounts to 10% of that of the primary electron flux;

$C_{S}/C_{pri.} = 0.0086 \pm 0.0012$, *i.e.*, the weight of the common source constitutes only ~1% of that of the diffuse electron flux;

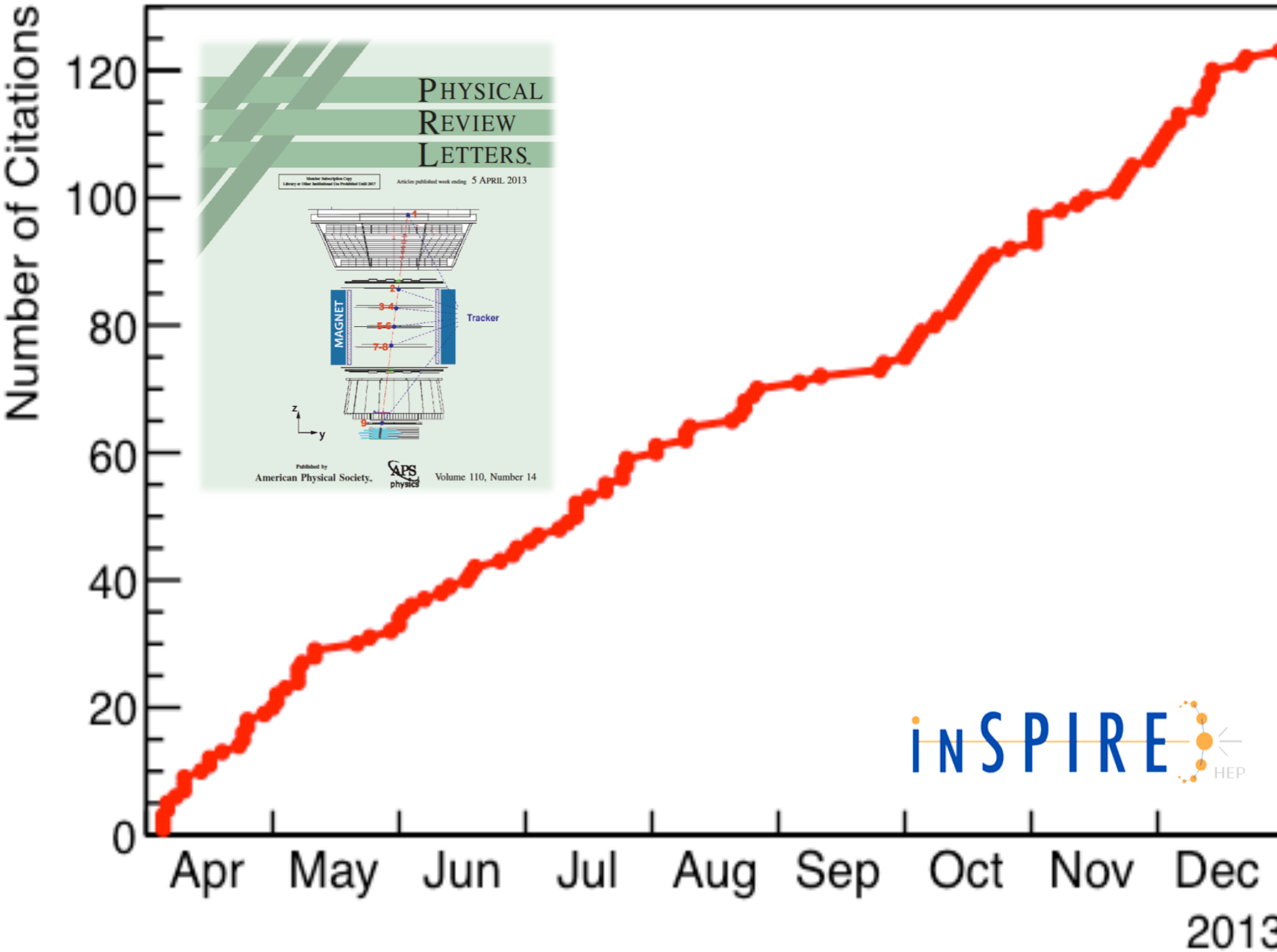
$1/E_s = 0.0012 \pm 0.0007\ \text{GeV}^{-1}$,

corresponding to a cutoff energy of **840^{+1180}_{-310} GeV**.

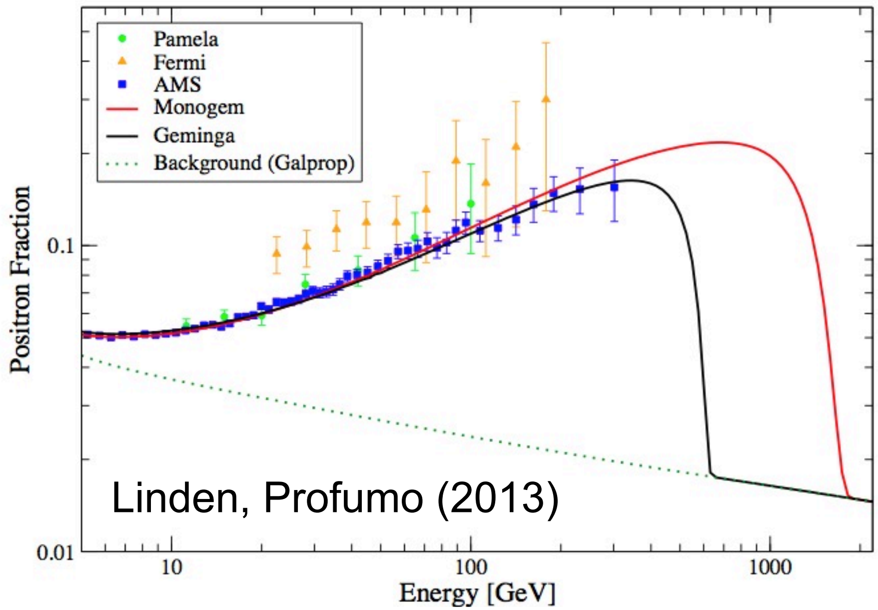


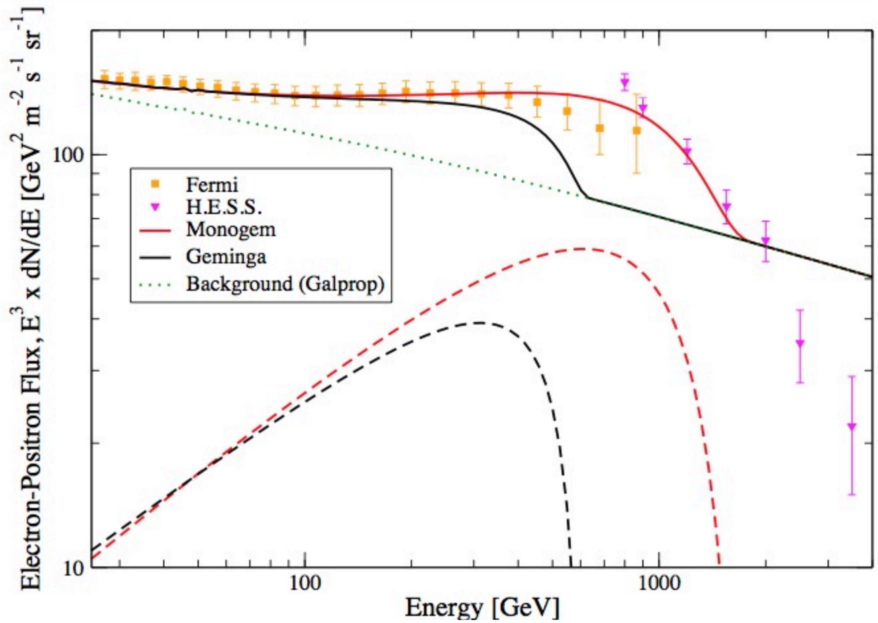
Positron Fraction
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
100
200
300
400
500
600
700
800
900
1000
Energy [GeV]
AMS PRL 2013
68% CL
95% CL

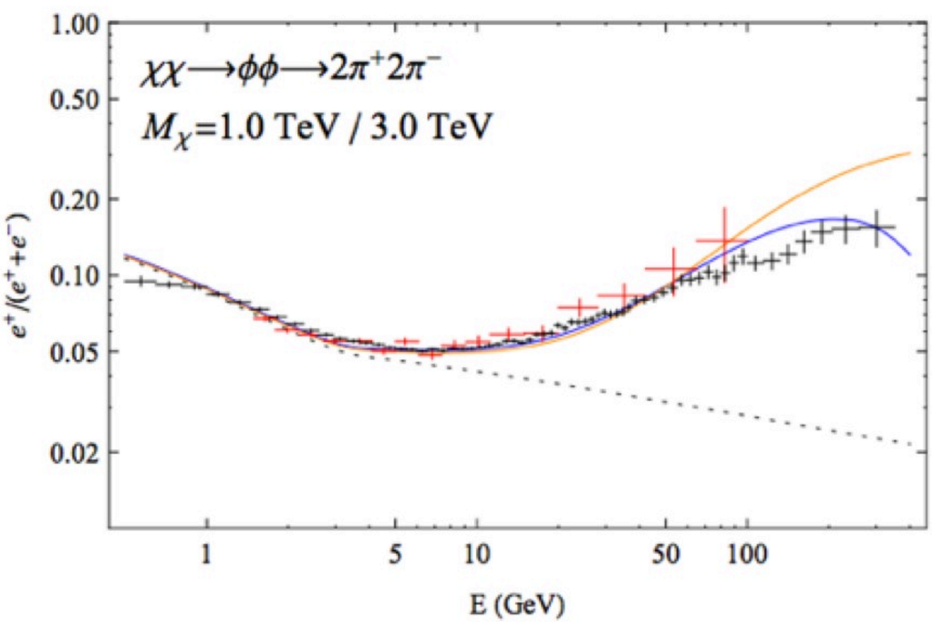
"First Result from the AMS on the ISS: Precision Measurement of the Positron Fraction in Primary Cosmic Rays of 0.5-350 GeV"

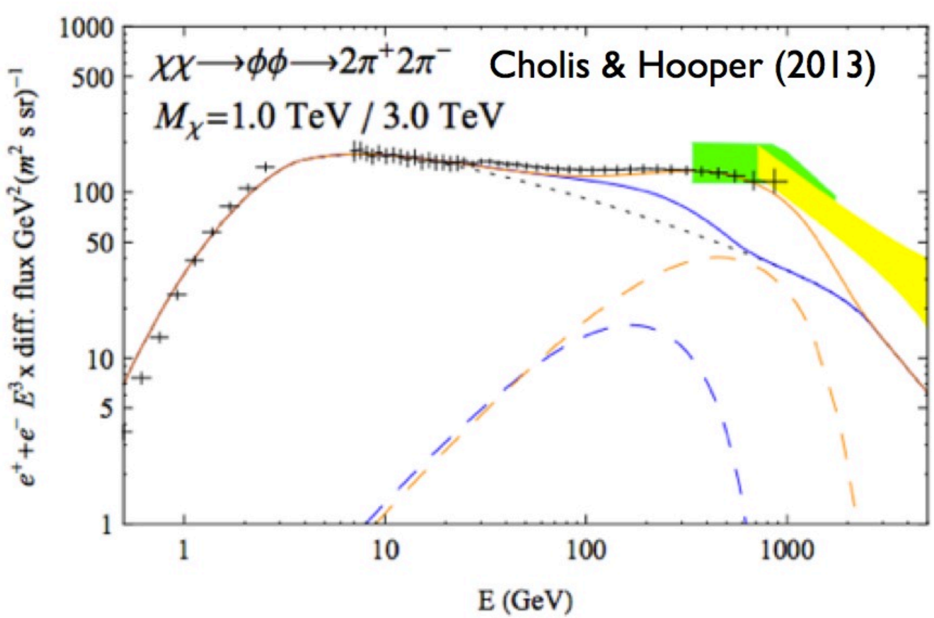


Pulsar or Dark Matter ?

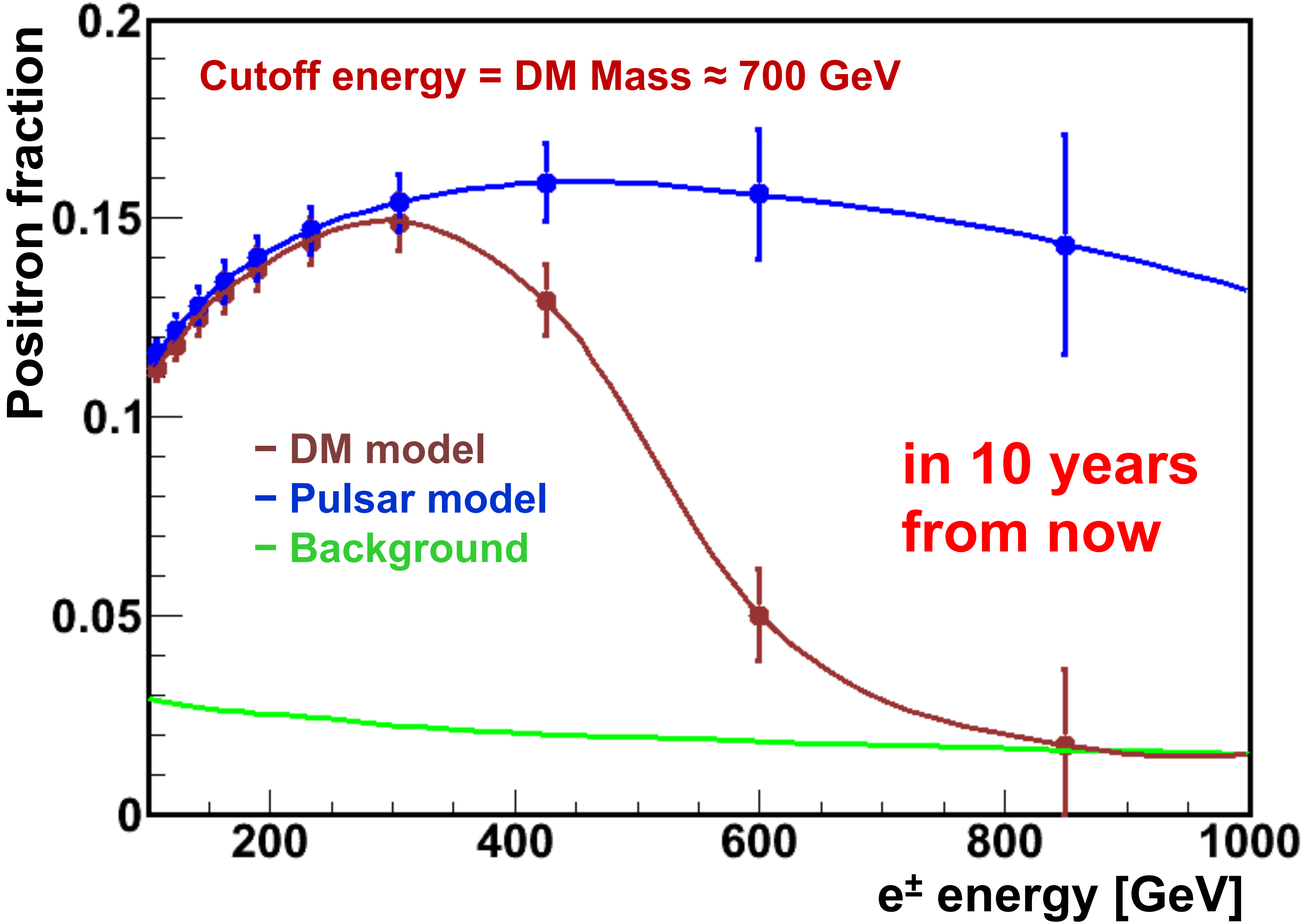






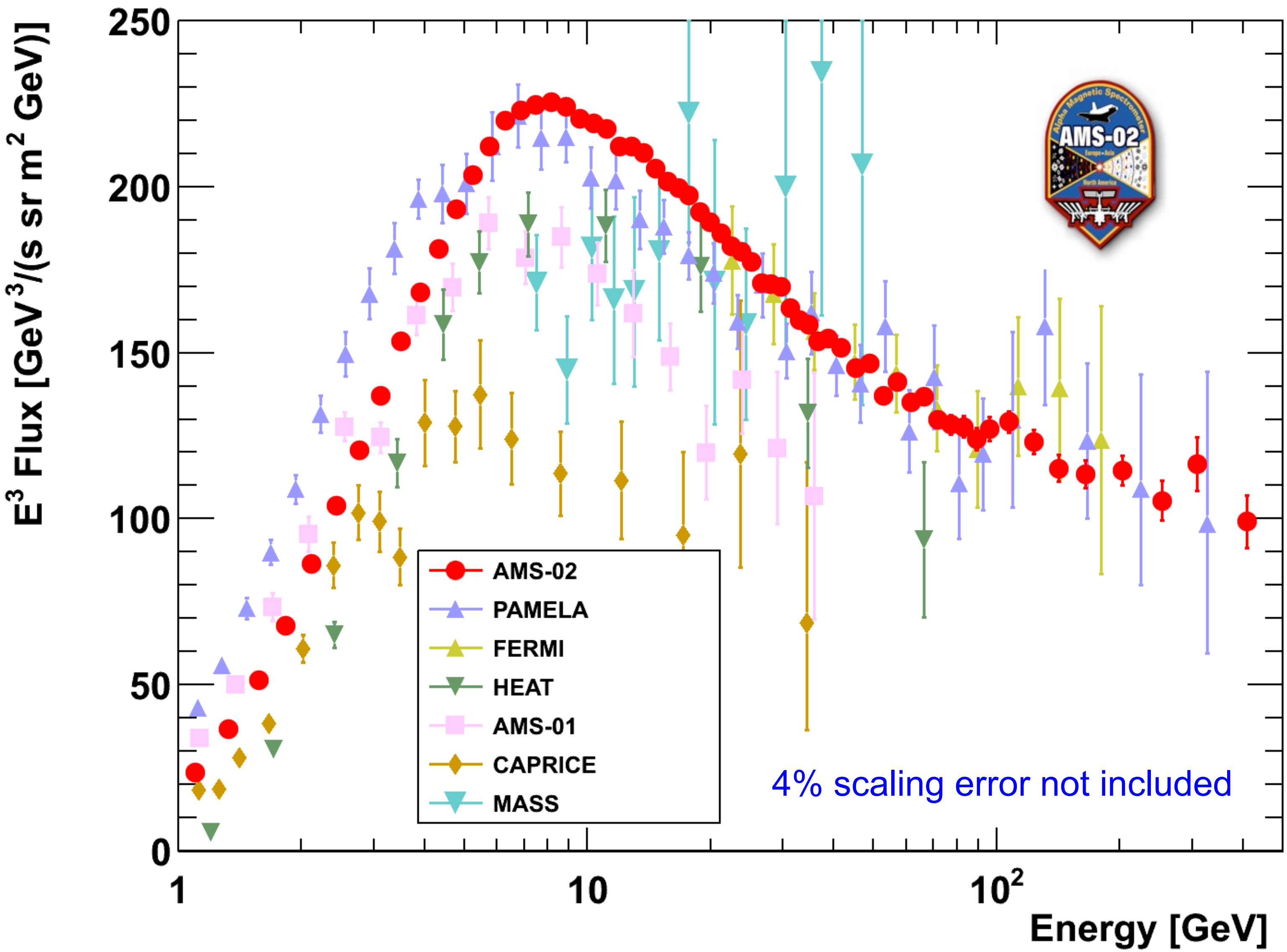


Expected AMS-02 reach in 10 more years



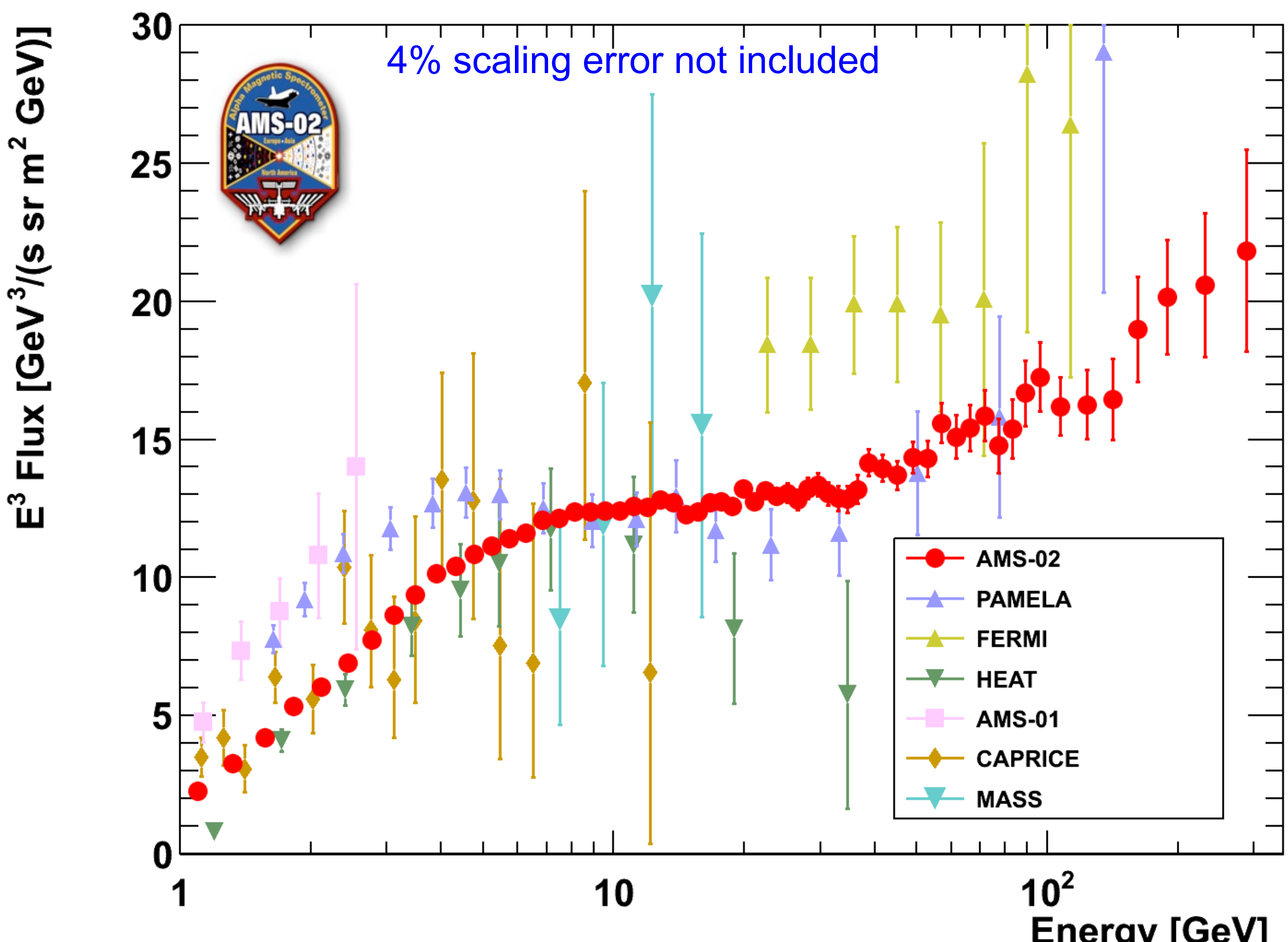
ICRC 2013 Results from AMS: Electron Flux $J_{e-}(E)$

- The electron flux measurement extends up to 500 GeV.
- Multiplied by E^3 it is rising up to 10 GeV and appears to be on a smooth, slowly falling curve above.



ICRC 2013 Results from AMS: Positron Flux $J_{e+}(E)$

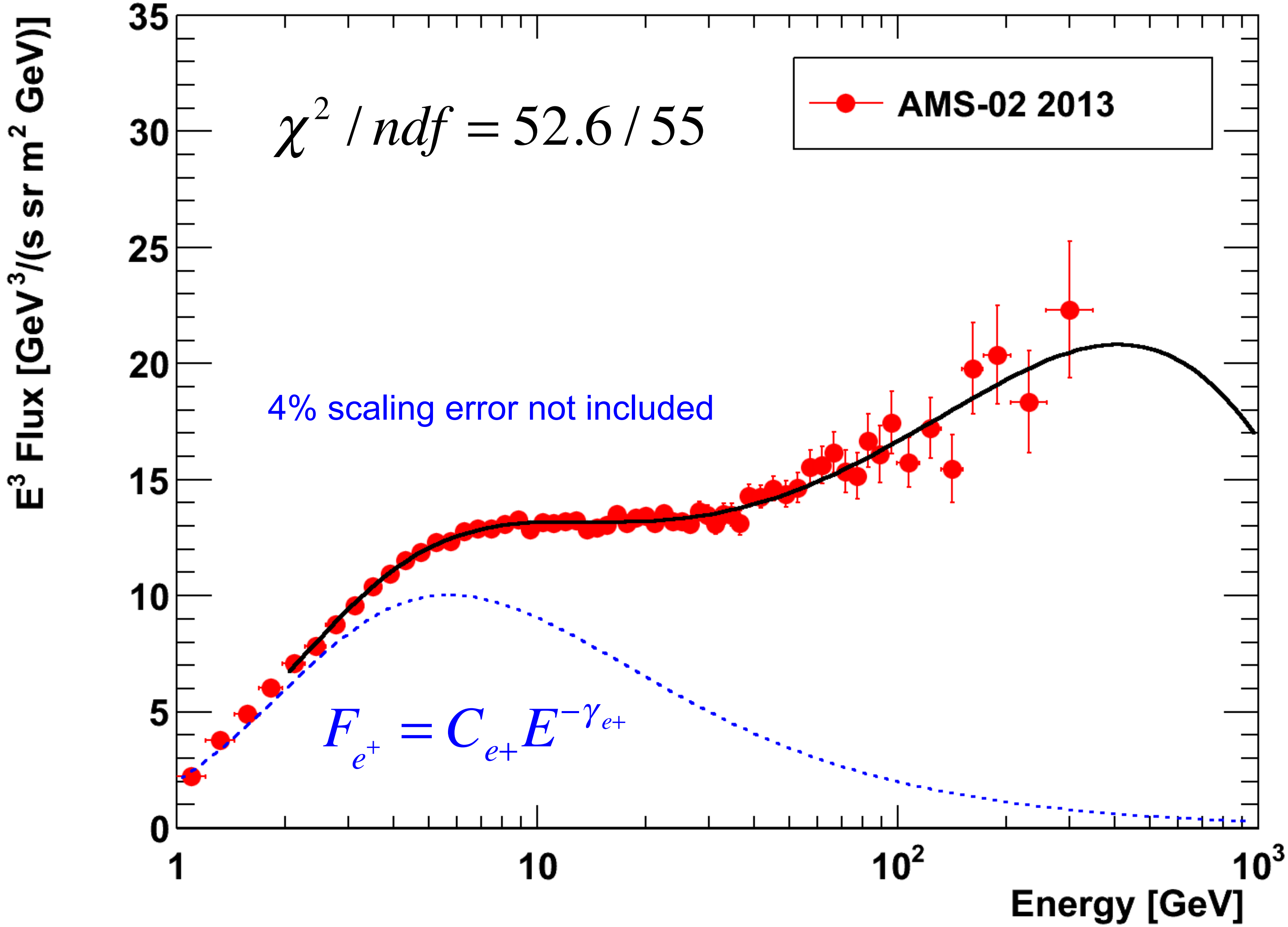
- The positron flux measurement extends up to 350 GeV.
- Multiplied by E^3 it is rising up to 10 GeV, from 10 to 35 GeV the spectrum is flat and above 35 GeV again rising.
- The spectral index and its dependence on energy is clearly different from the electron spectrum.



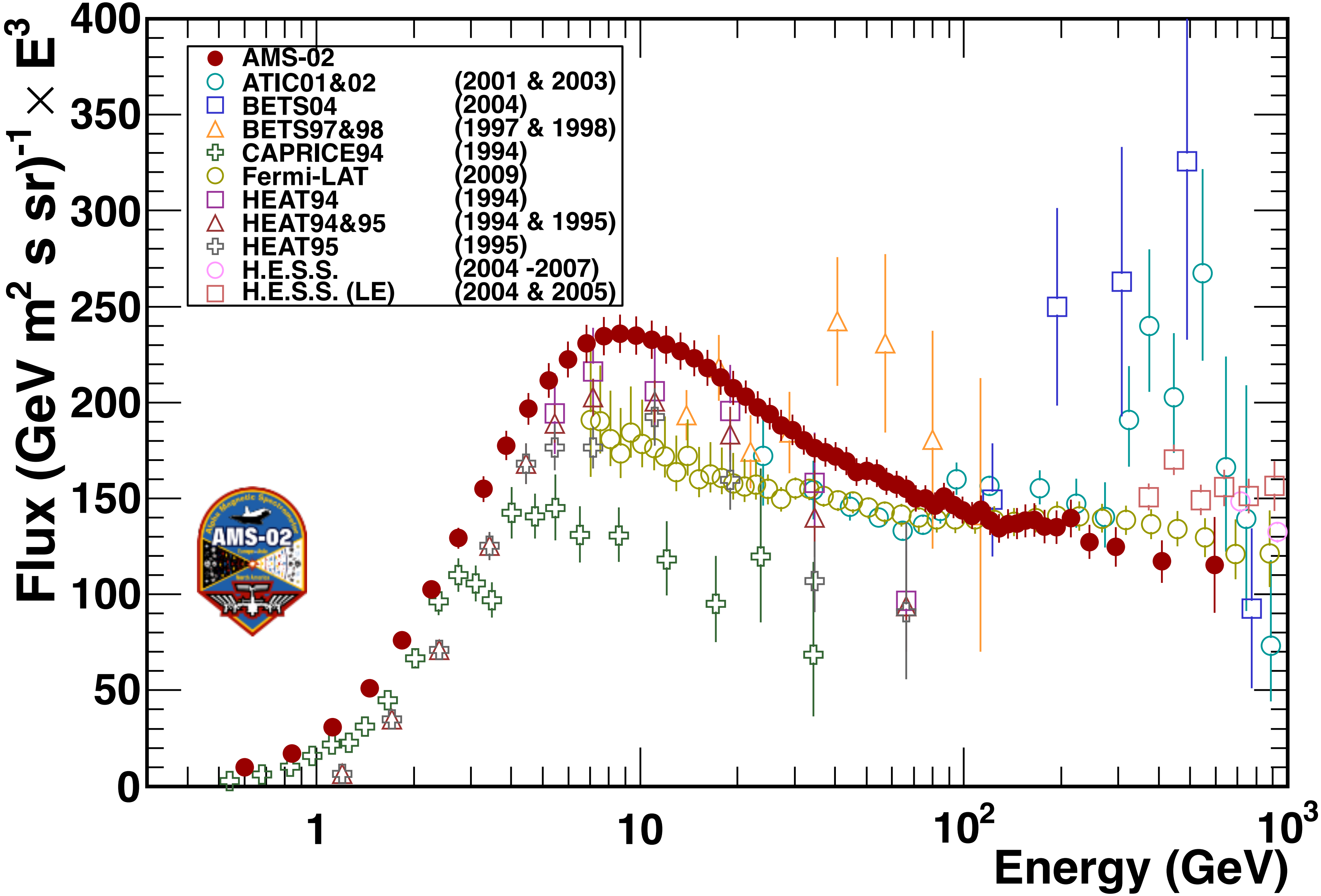
AMS-02 Positron Flux Update

$$F_{e^+} = C_{e+} E^{-\gamma_{e+}} + C_S E^{-\gamma_S} \exp(-E / E_S)$$

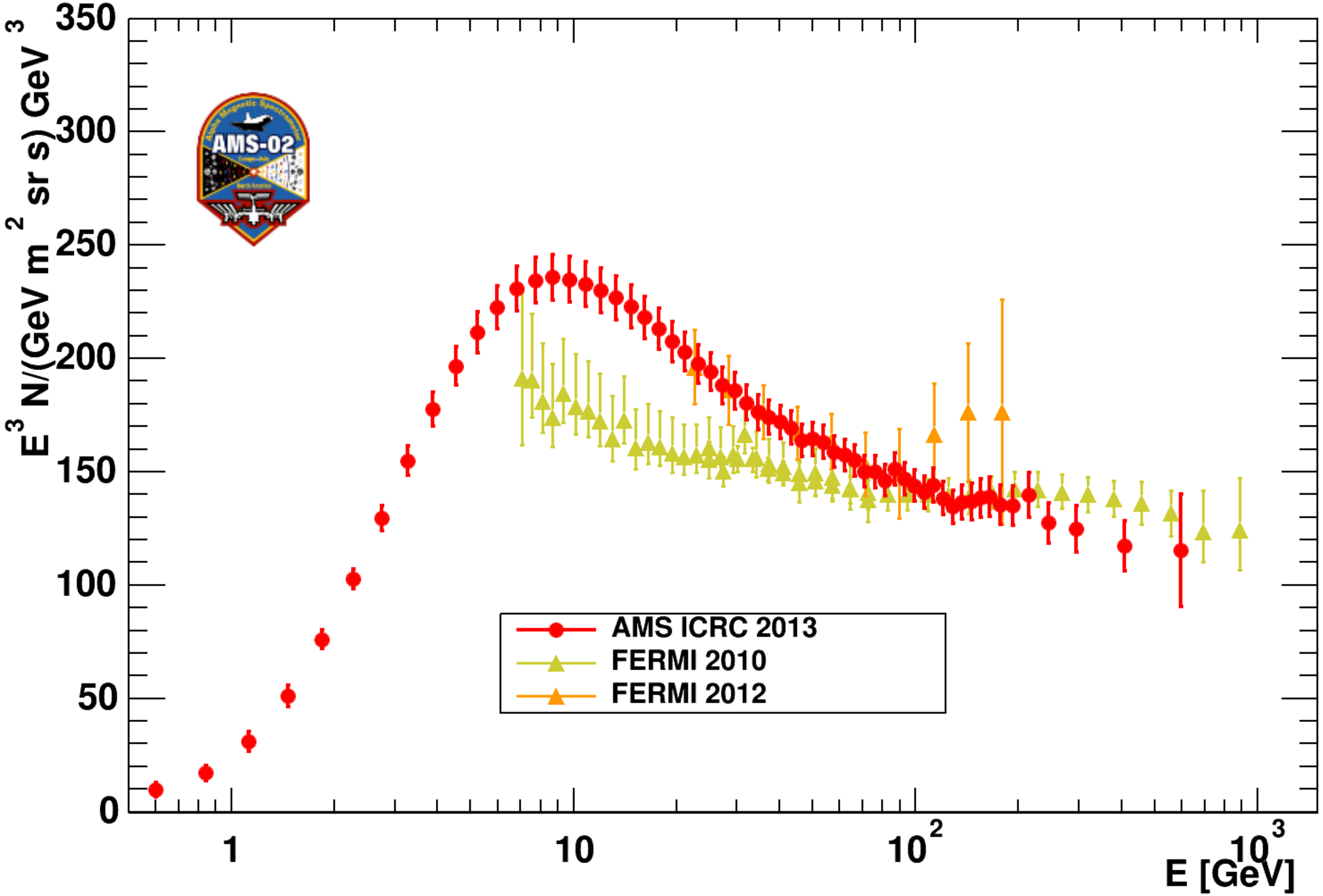
E_S=1000 GeV fixed



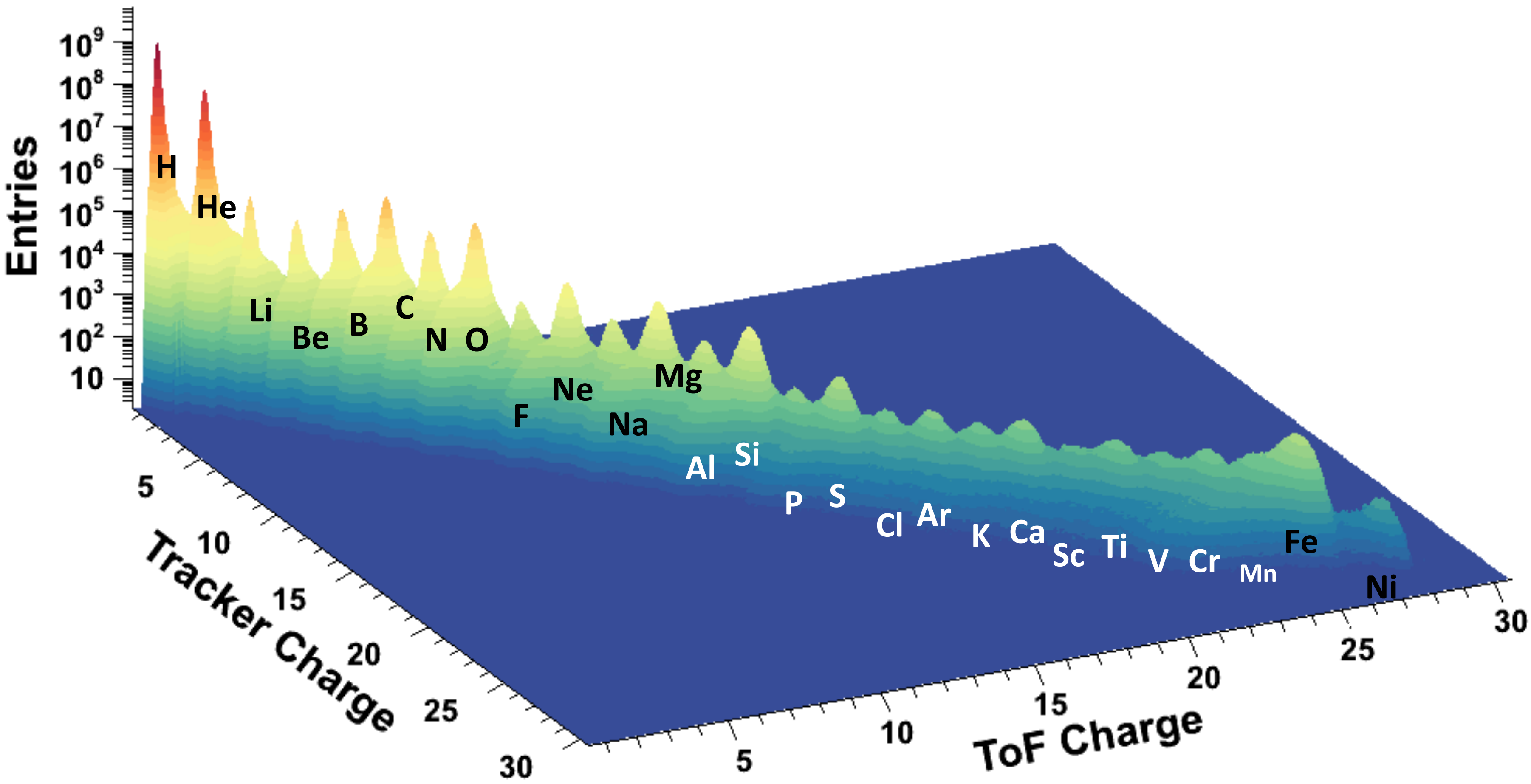
ICRC 2013 Results from AMS: (Electron plus Positron) Spectrum



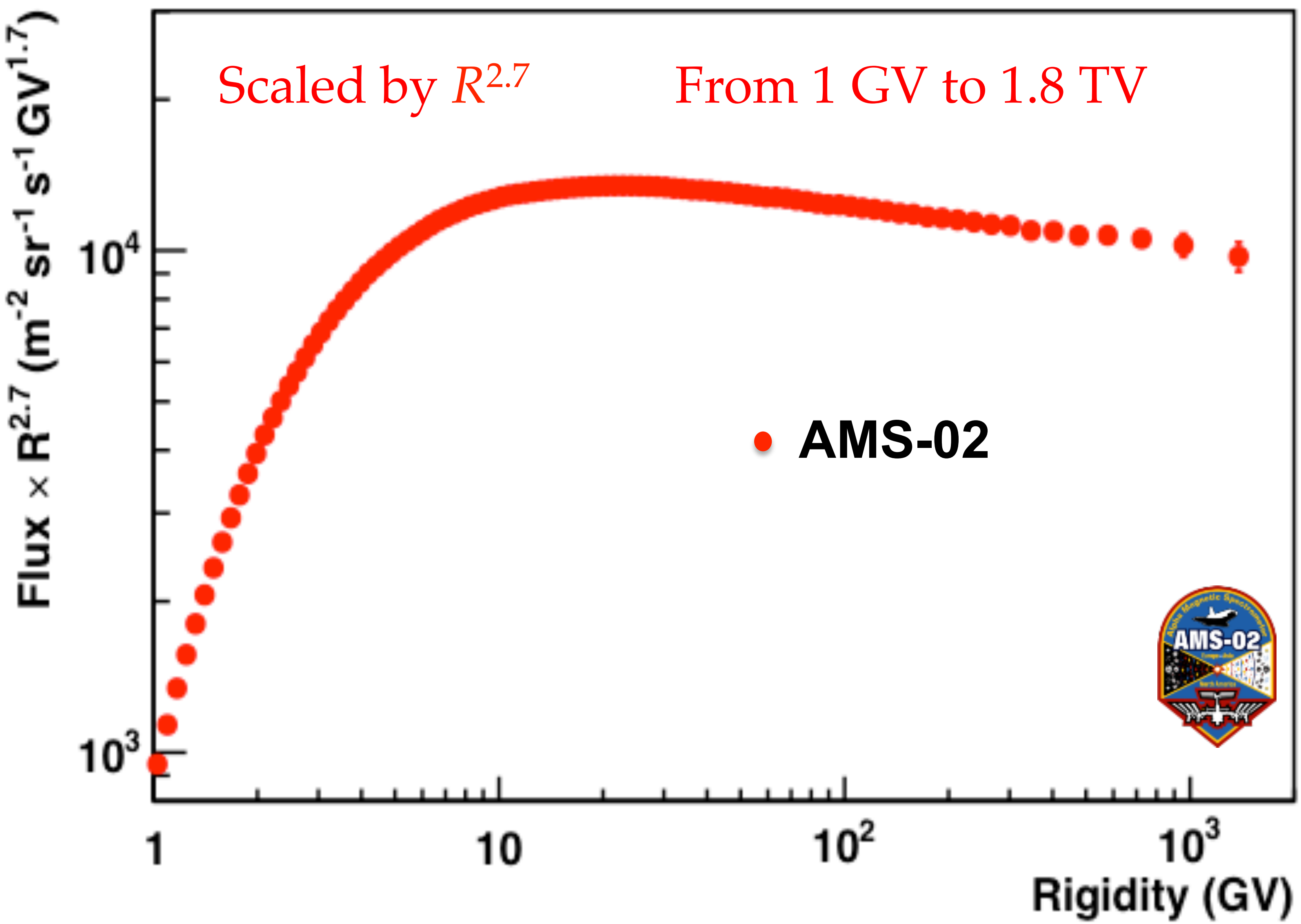
ICRC 2013 Results from AMS:
(Electron plus Positron) Spectrum



AMS Nuclei Measurement on ISS

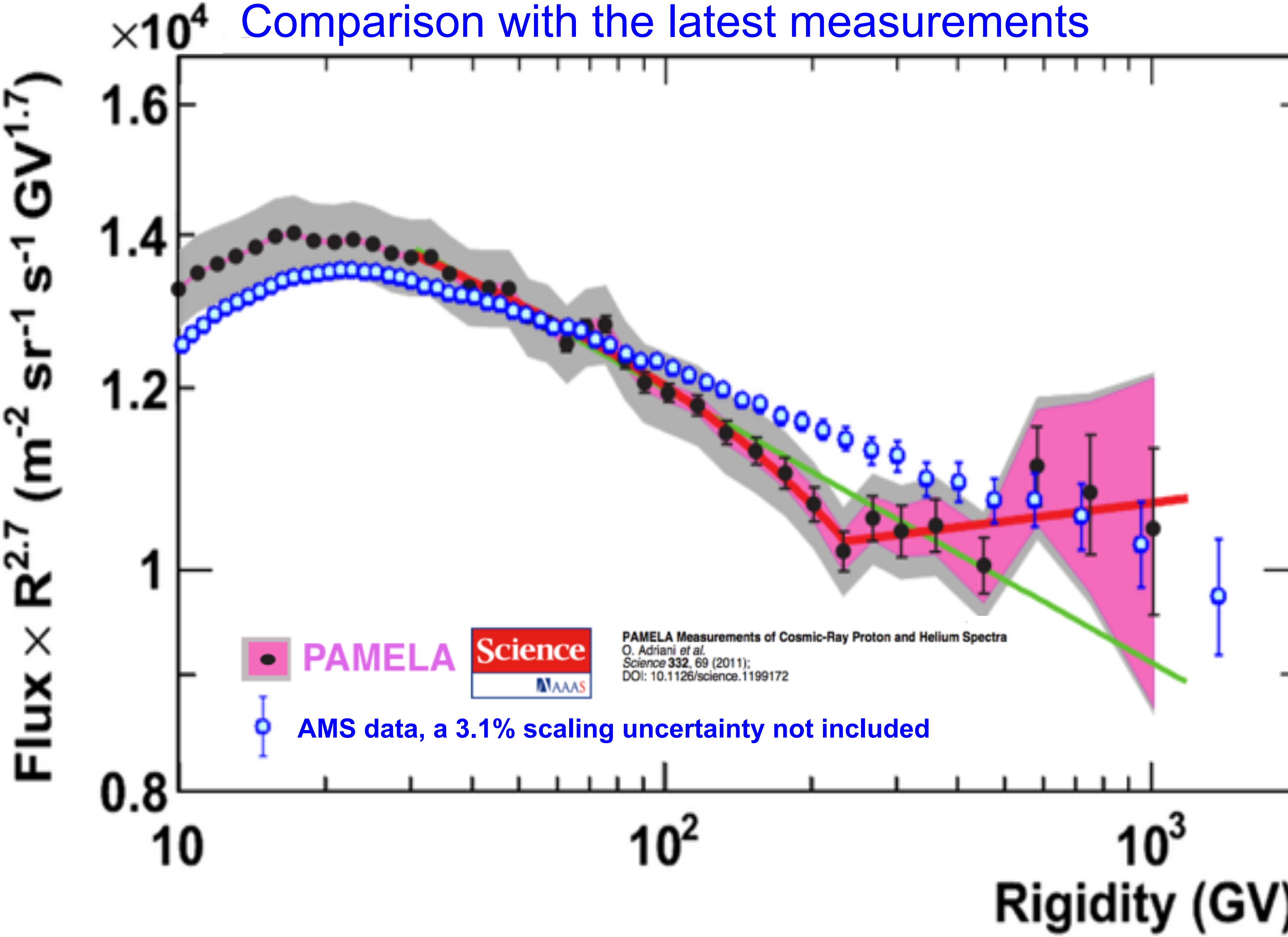


ICRC 2013 Results from AMS: Proton flux

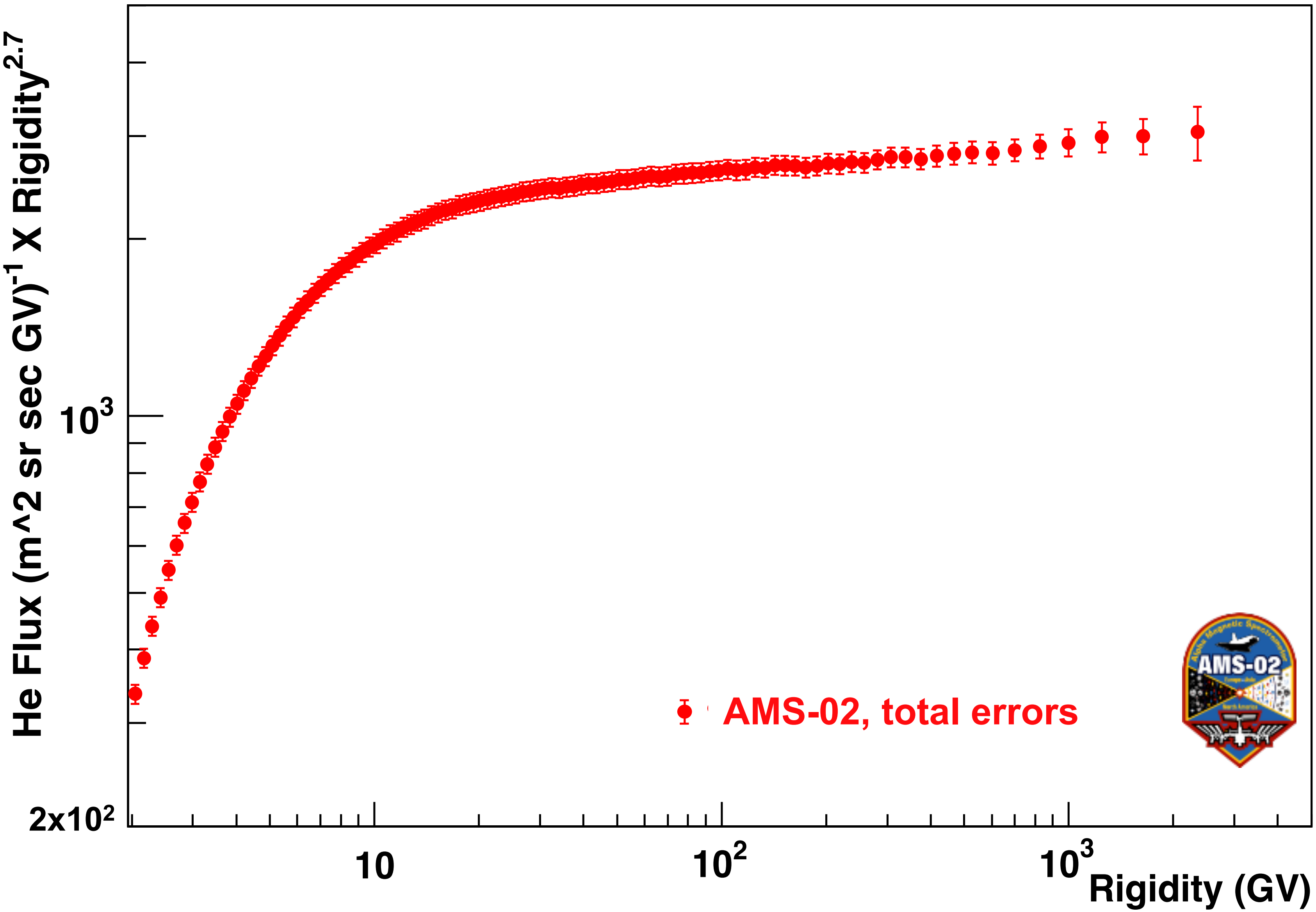


Proton flux

Comparison with the latest measurements

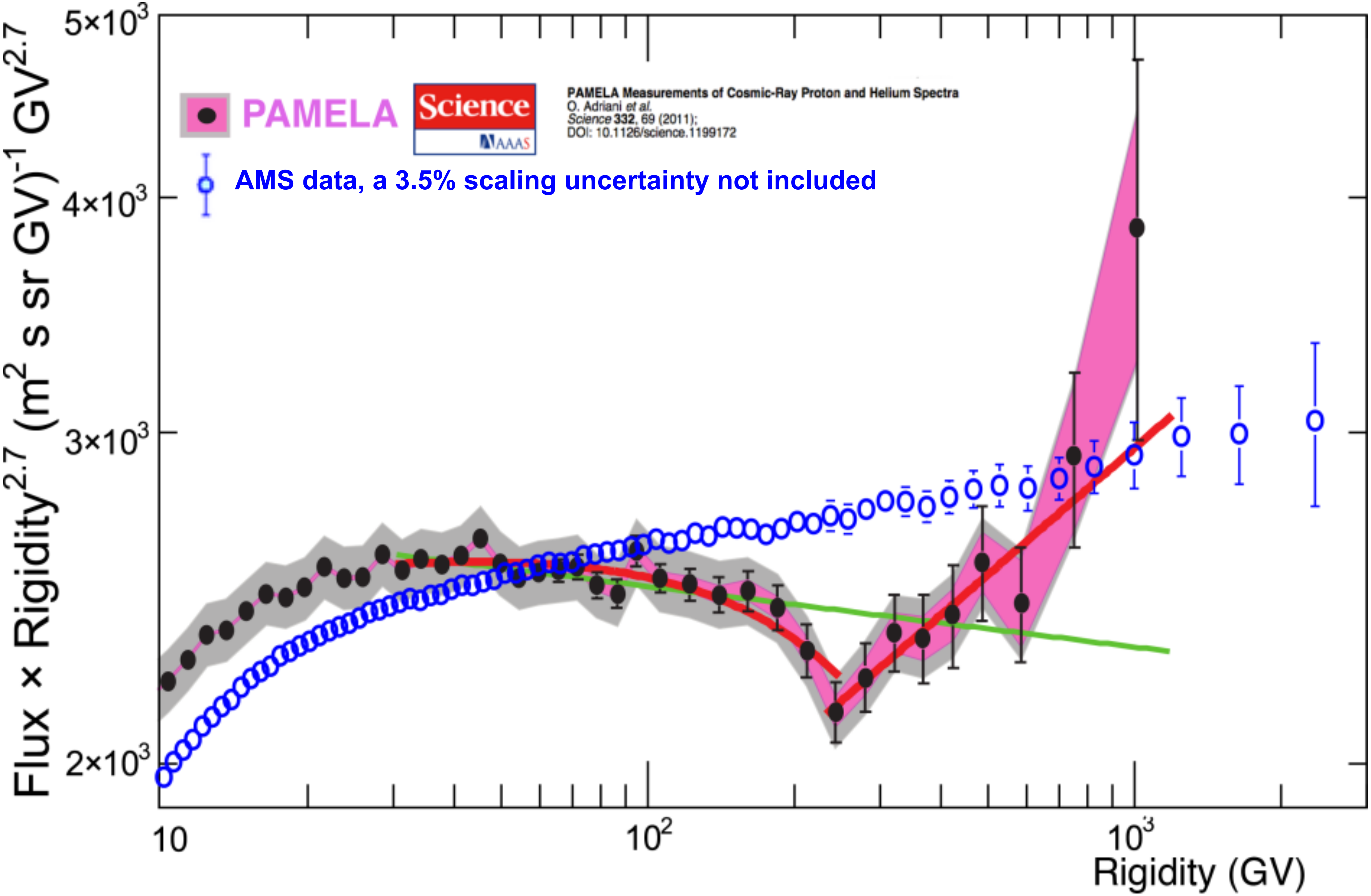


ICRC 2013 Results from AMS:Helium flux



Helium flux

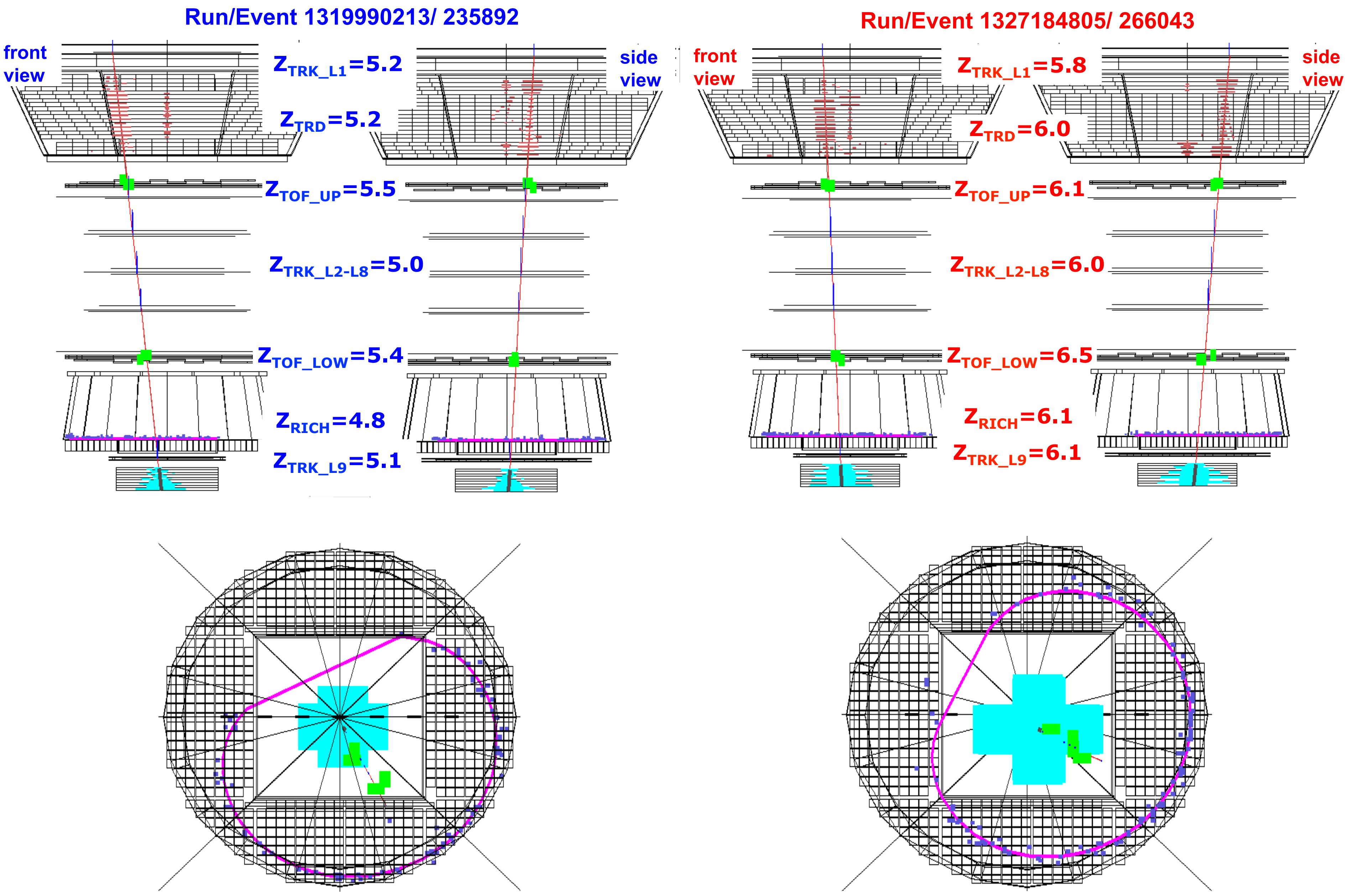
Comparison with the latest measurements



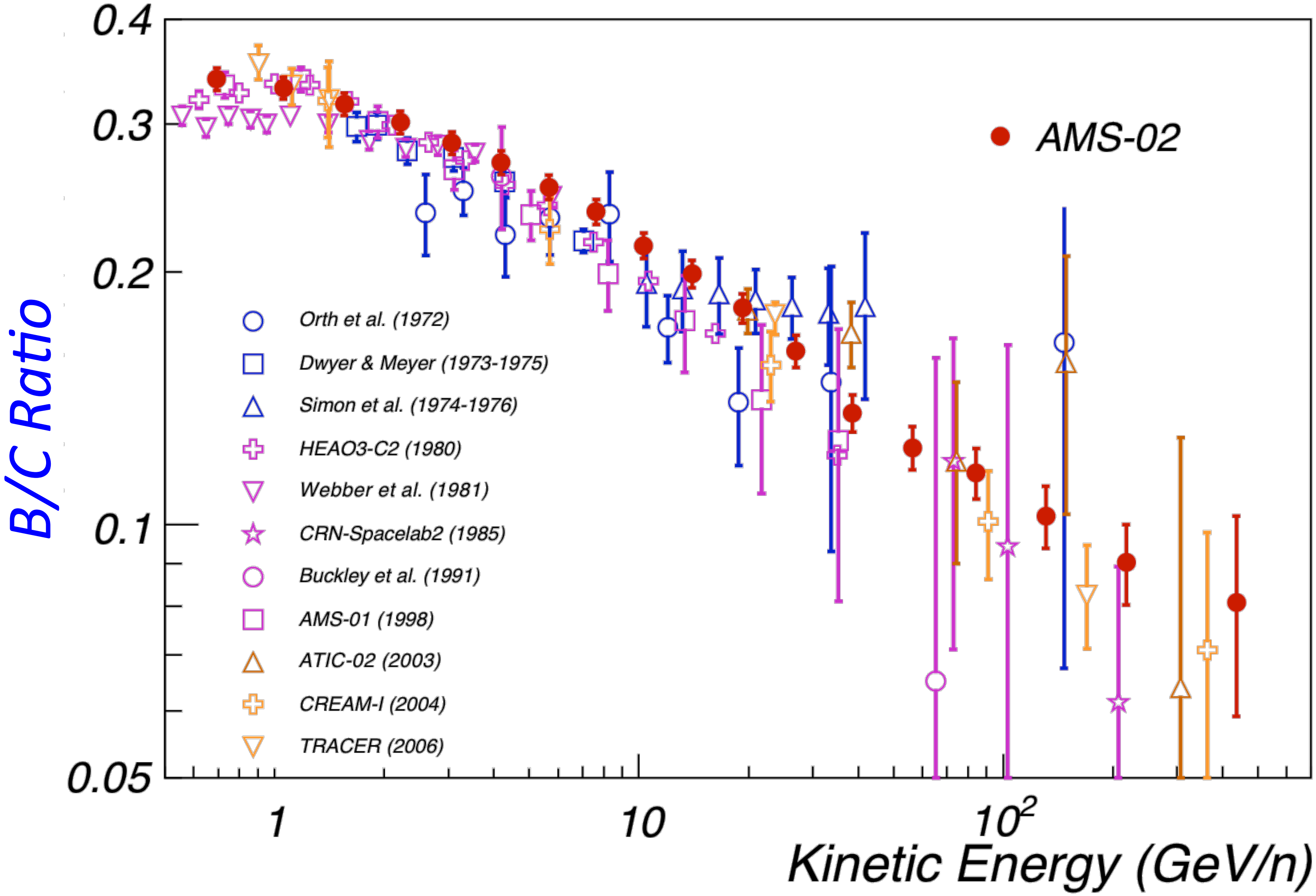
Rigidity ≈ 700 GV

Boron
Rigidity=680 GV

Carbon
Rigidity=666 GV



Boron-to-Carbon ratio

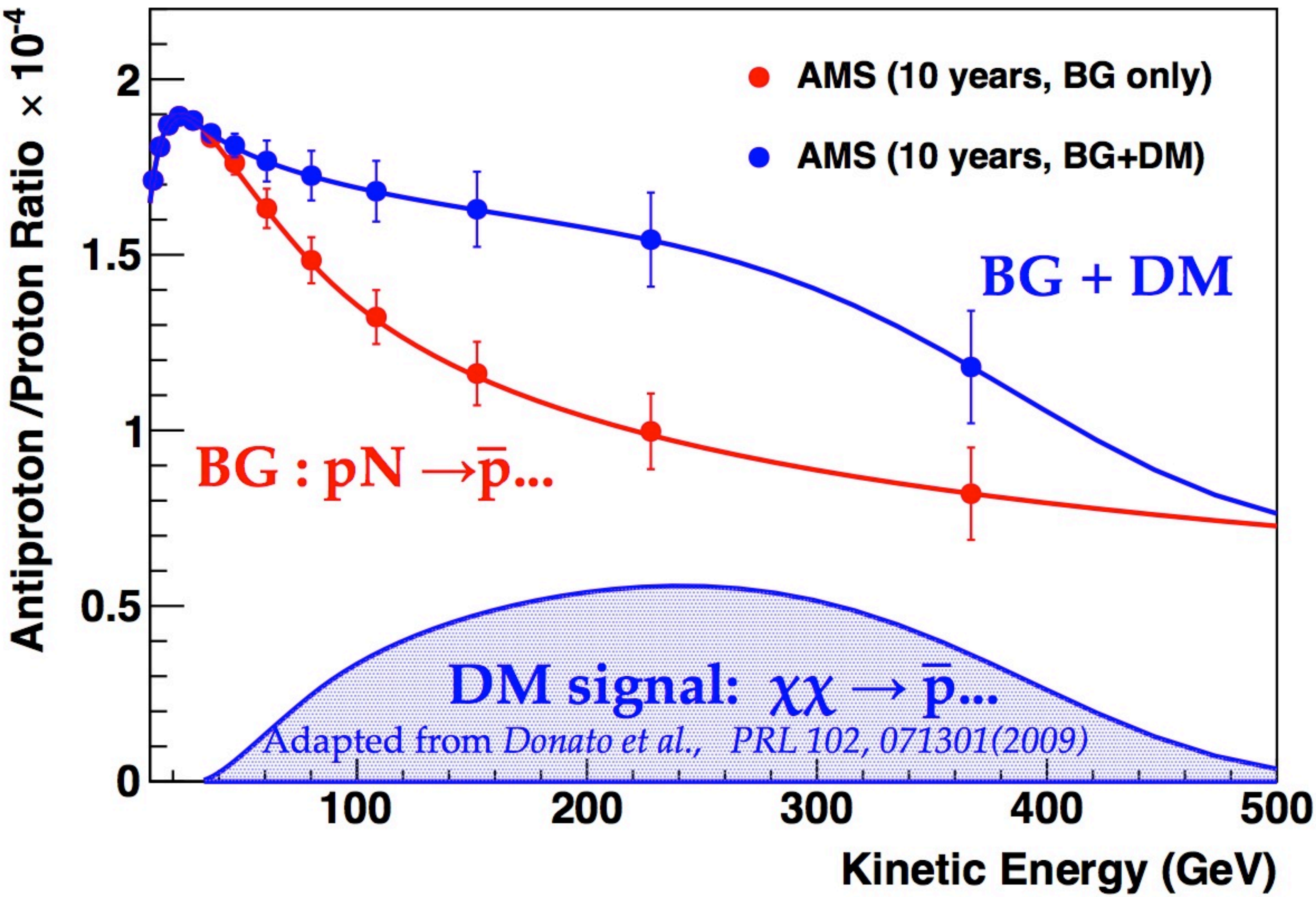


Measurement of Antiproton flux

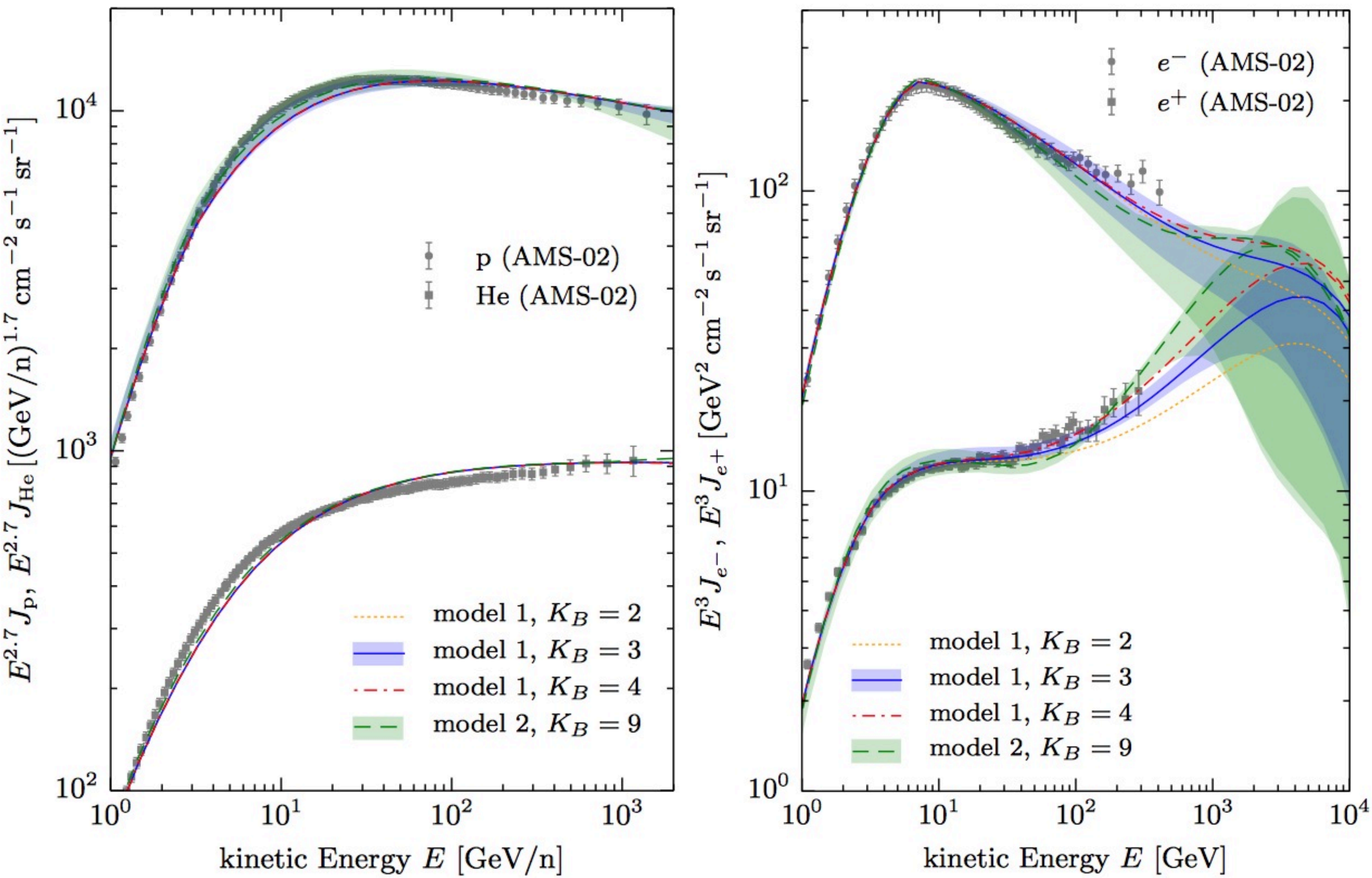
Physics importance

- Antiprotons : Only ~10^{-4} of cosmic ray particles
- Produced by cosmic ray collisions
  e.g. $pN \rightarrow \bar{p}...$
- Probe of indirect Dark Matter detection
  e.g. $\chi\chi \rightarrow \bar{p}...$
  Complementary to $\chi\chi \rightarrow e^{+}...$

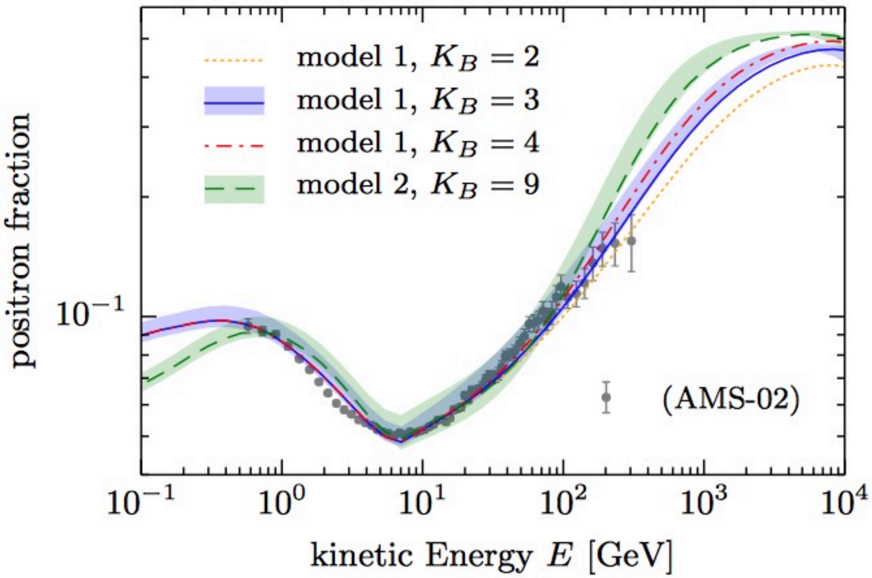
AMS in ten years from now

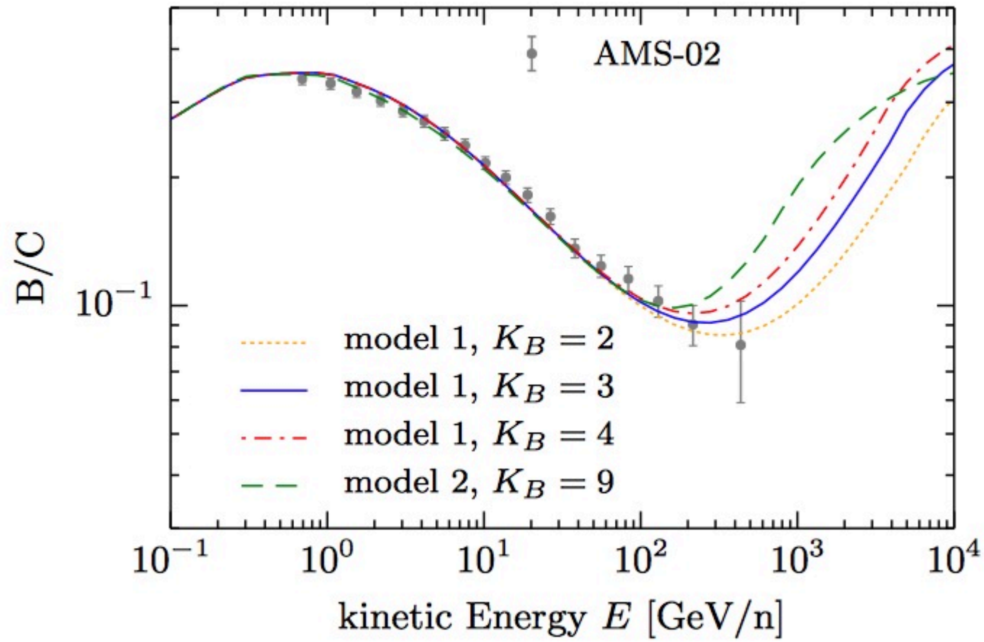


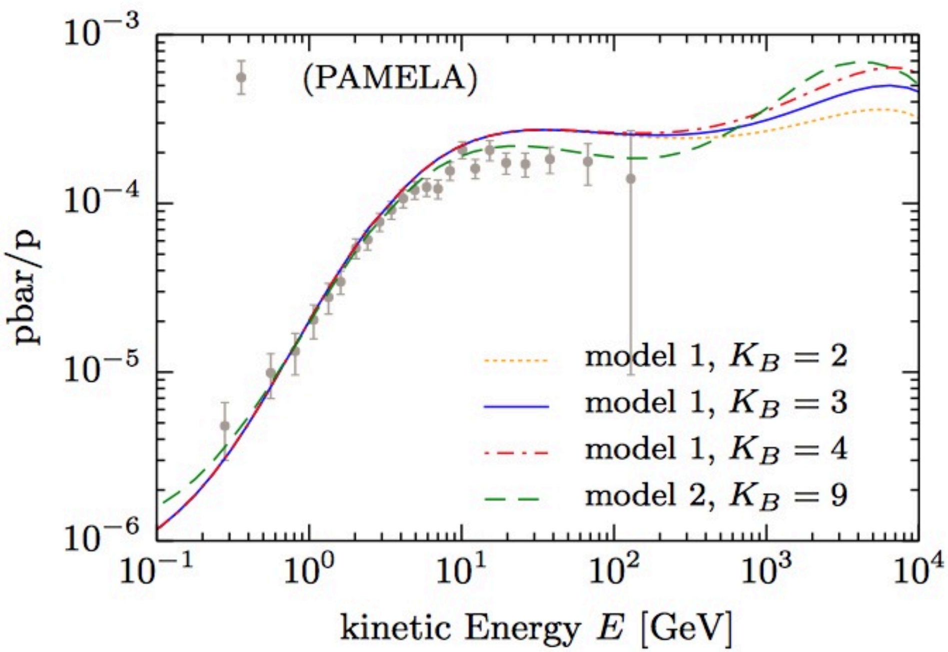
Combined Fit of AMS Data



P. Mertsch and S. Sarkar, arXiv:1402.0855



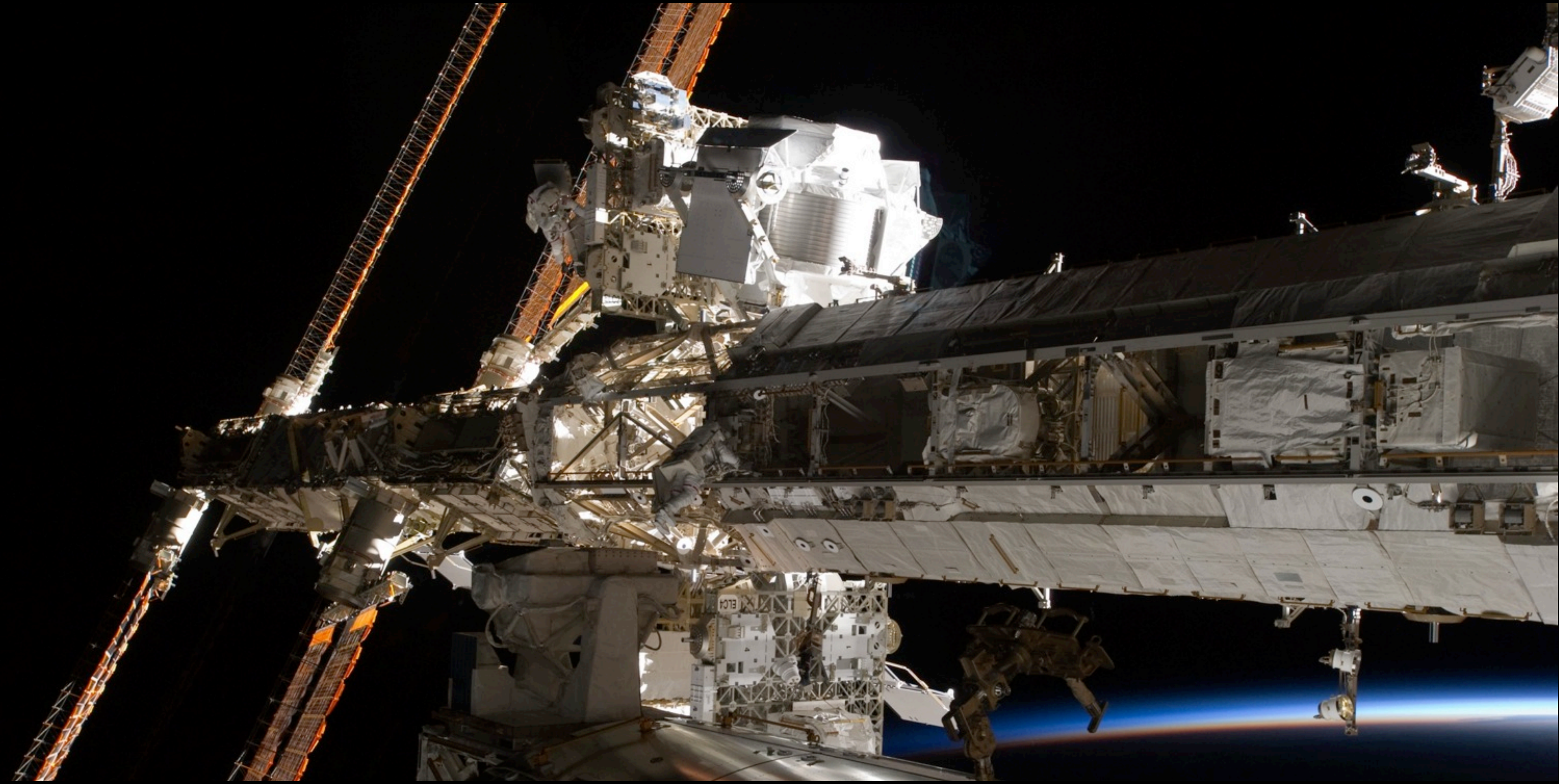




P. Mertsch and S. Sarkar, arXiv:1402.0855

The Cosmos is the Ultimate Laboratory.

Cosmic rays can be observed at energies higher than any accelerator.



"The most exciting objective of AMS is to probe the unknown; to search for phenomena which exist in nature that we have not yet imagined nor had the tools to discover."

S. Ting