Alpha Magnetic Spectrometer 02

status and perspectives

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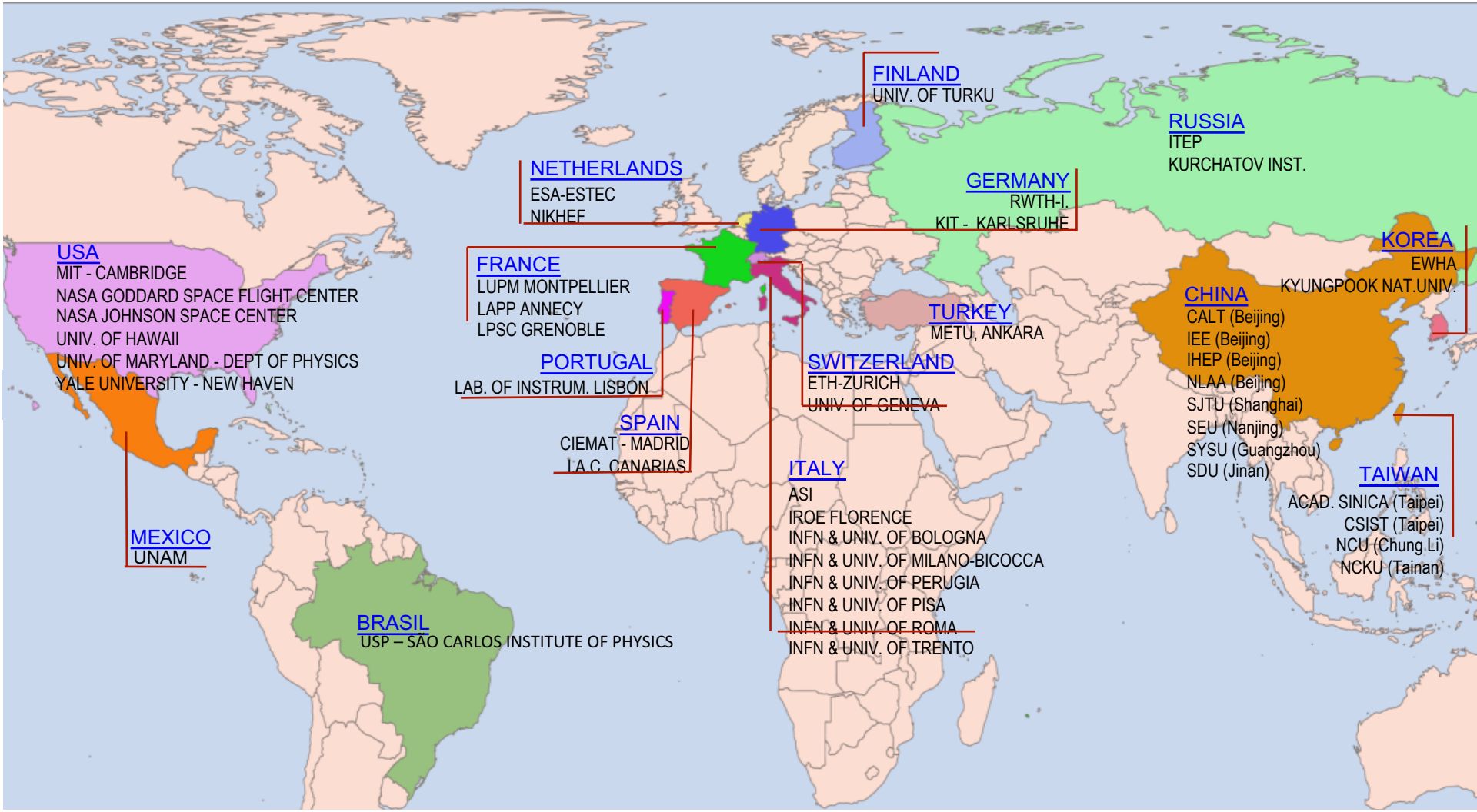
CRIS2018
11th Cosmic Ray International Seminar

Alpha Magnetic Spectrometer

- AMS-02 is a particle physics detector devoted to the measurement of cosmic rays fluxes in the near Earth orbit in the range 0.1 GV – 2 TV
- It will take data data for the rest of the life of the ISS (extends to 2024)

AMS is MIT led International Collaboration

16 Countries, 60 Institutes and 600 Physicists, 17 years



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

POCC at CERN in control of AMS since May 19th 2011

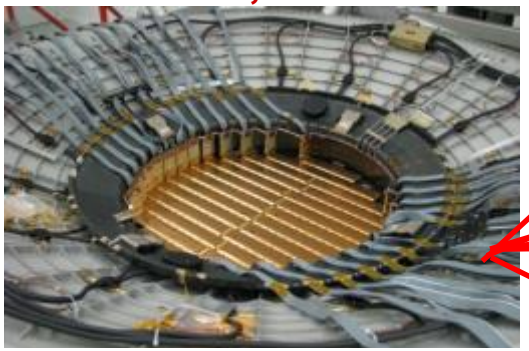
100 BILLIONS events collected

AMS: A TeV precision, multipurpose spectrometer

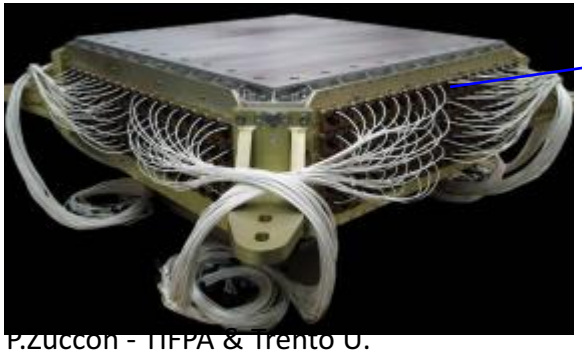
Particles and nuclei are defined by their charge (Z) and energy (E ~ P)

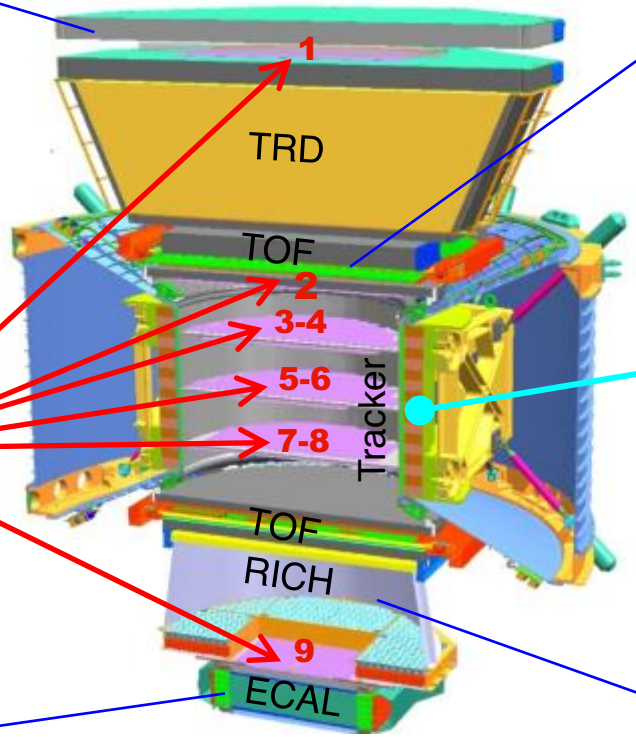
TRD
Identify e^+, e^-, Z

Silicon Tracker
Z, P



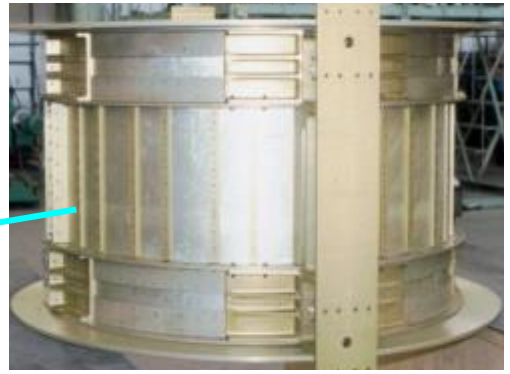
ECAL
E of e^+, e^-



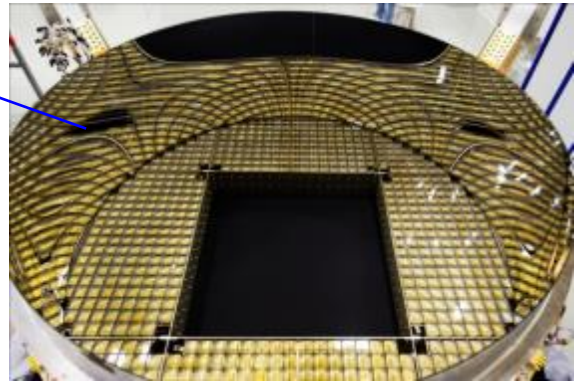


TOF
Z, E

Magnet
±Z



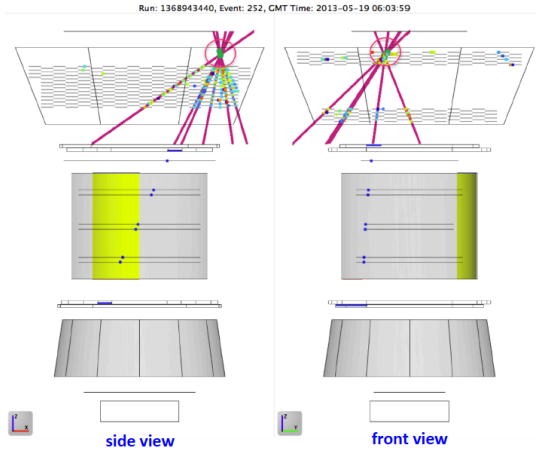
RICH
Z, E



Z and P

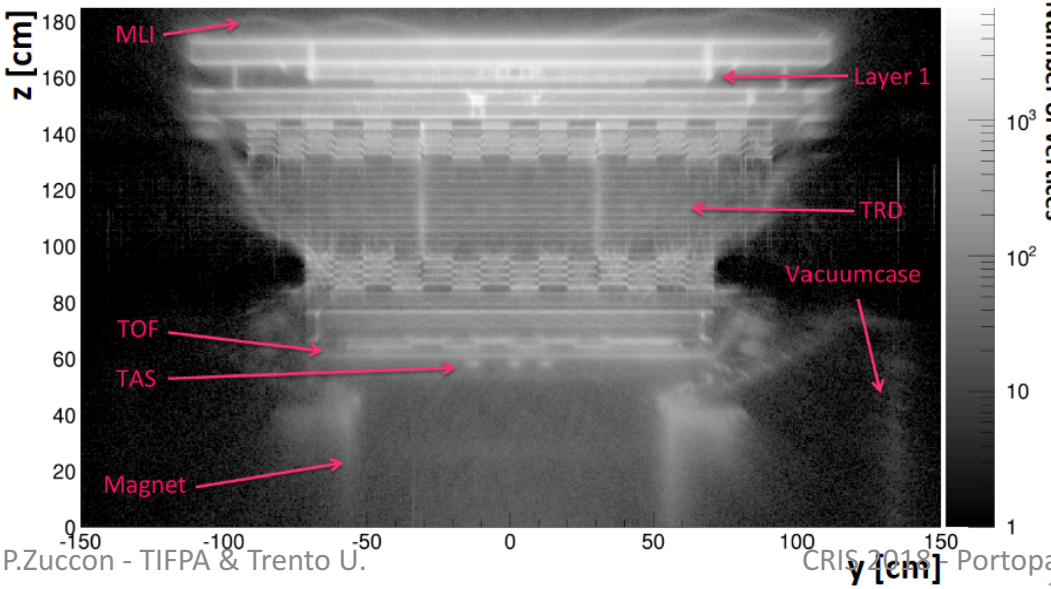
are measured independently by the Tracker, RICH, TOF and ECAL

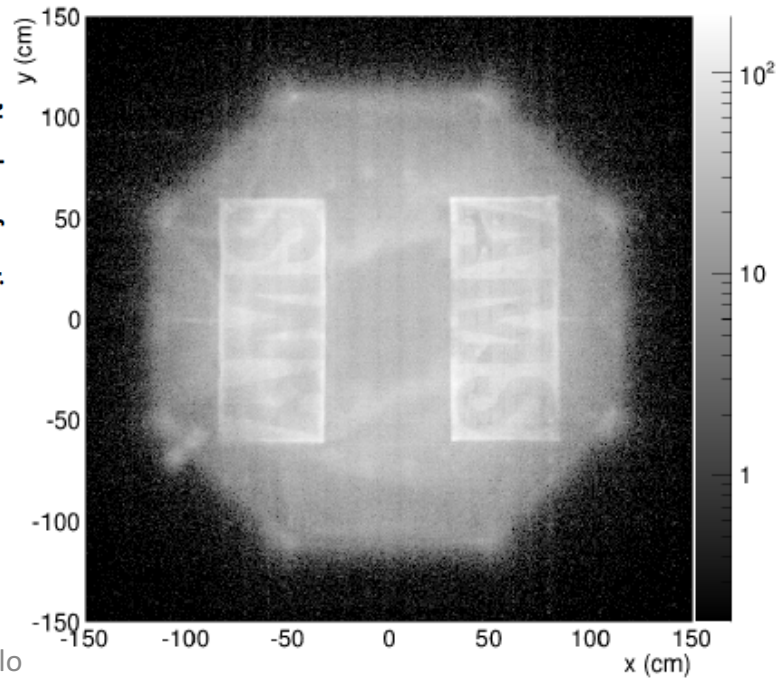
AMS “tomography” using rare nuclear interaction events



The gray scale is proportional the the number of found vertices

Z=178.5 cm





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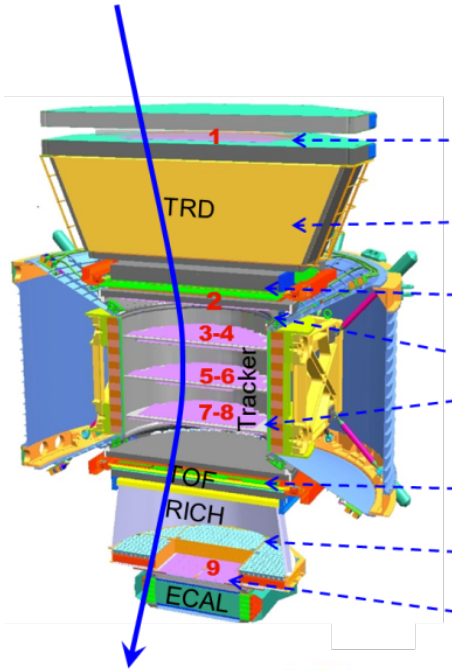
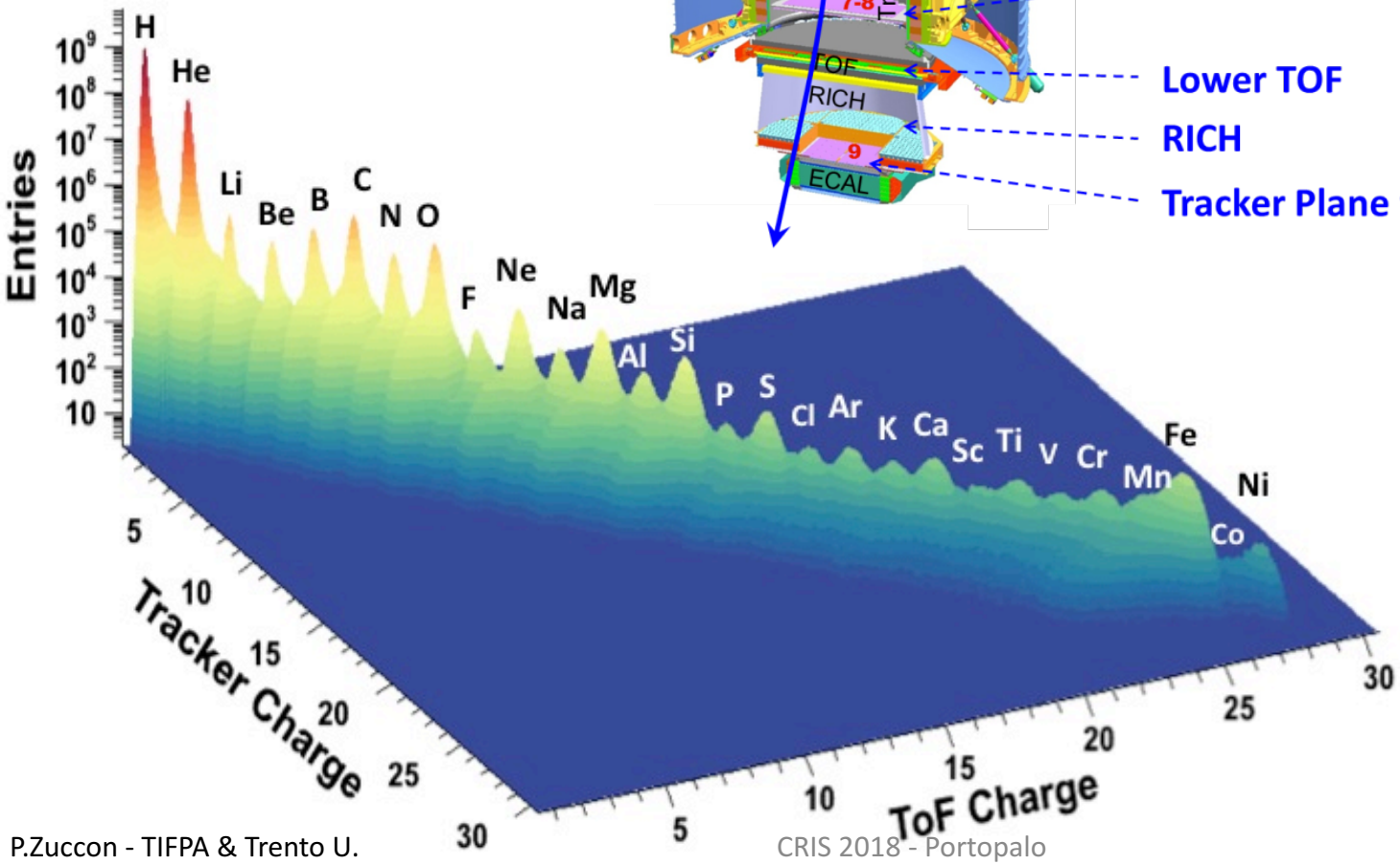
- **…**

Multiple Measurements of Charge

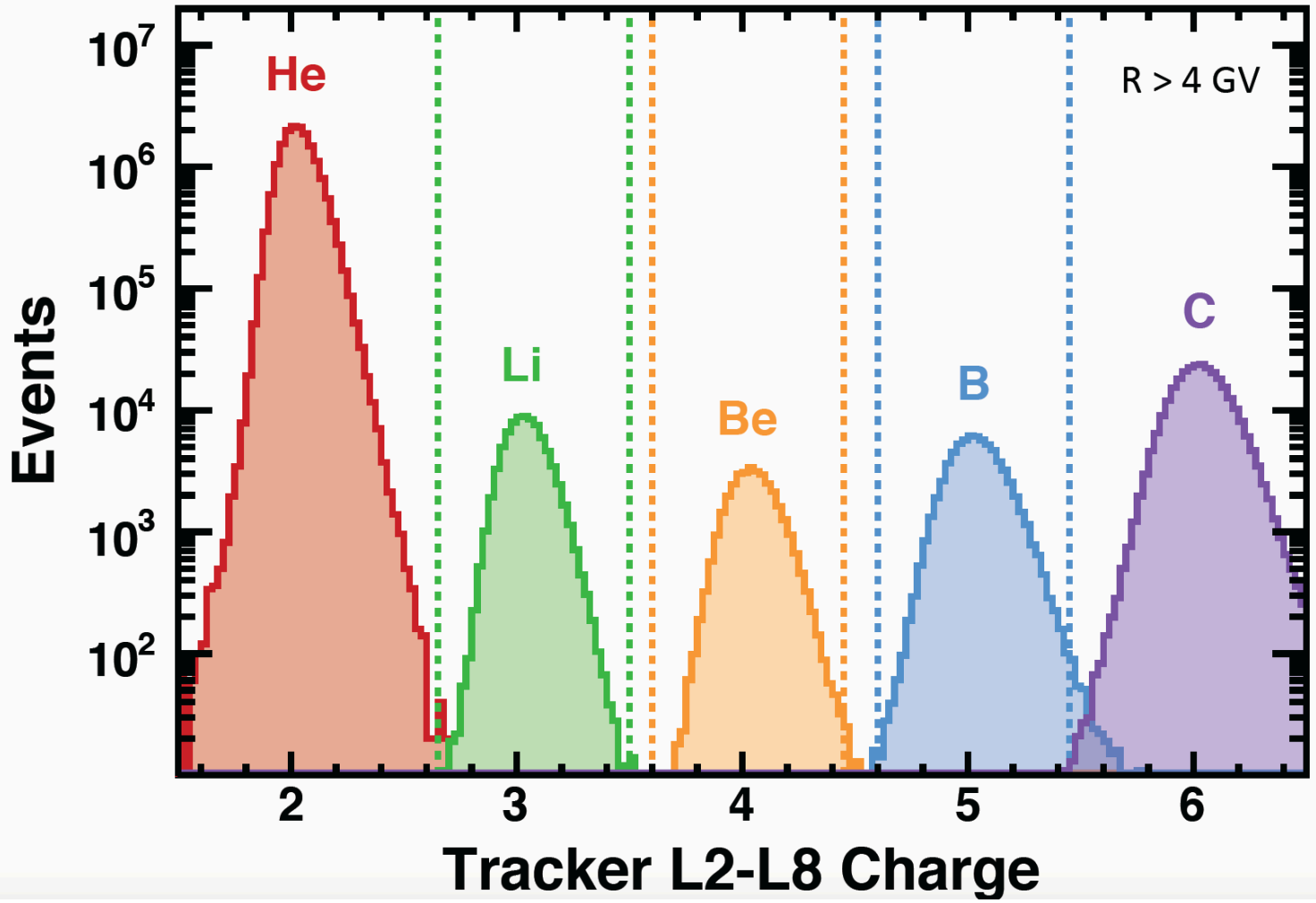


	Charge Resolution for Z=6 (c.u.)
Tracker Plane 1	0.30
TRD	0.33
Upper TOF	0.16
Tracker Planes 2-8	0.12
Lower TOF	0.16
RICH	0.32
Tracker Plane 9	0.30



Event Selection

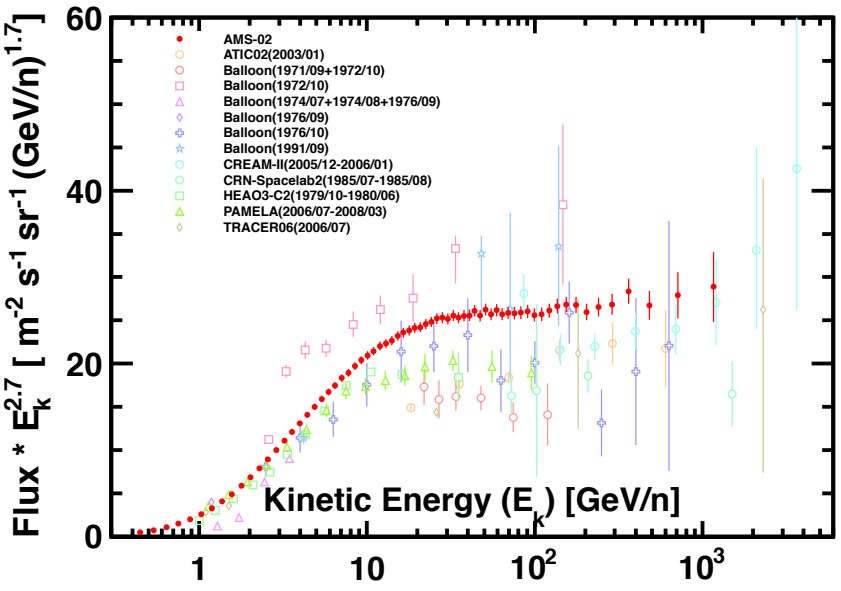
Tracker and TOF Charges compatible with Z=3,4,5 with negligible misidentification.
In 5 years we collected **1.9M Lithium**, **0.9M Beryllium** and **2.6M Boron nuclei.**



Carbon & Oxygen Flux

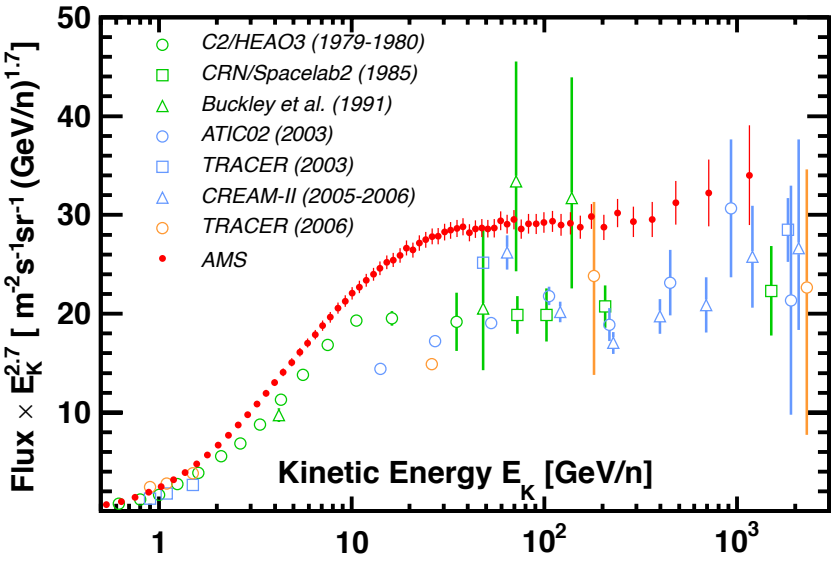
The current precision of the data at highest energies is limited by statistics.

8.3 Million Events



Carbon

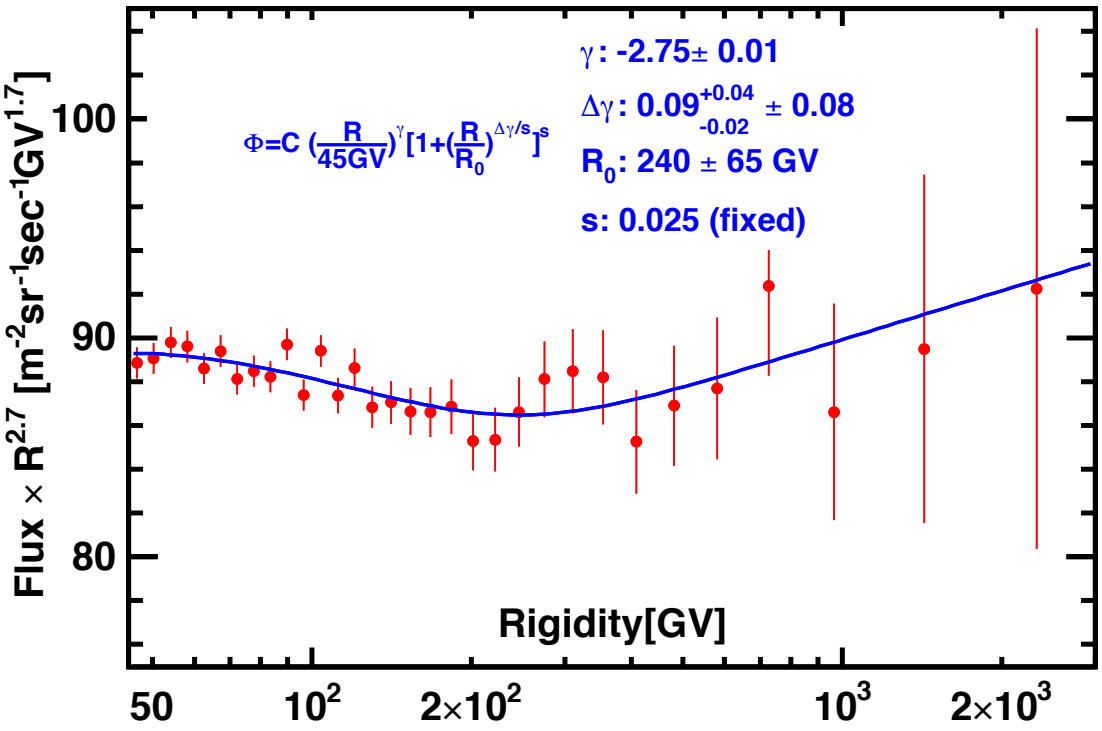
7.4 Million Events



Oxygen

The High Rigidity Behavior of Carbon Flux

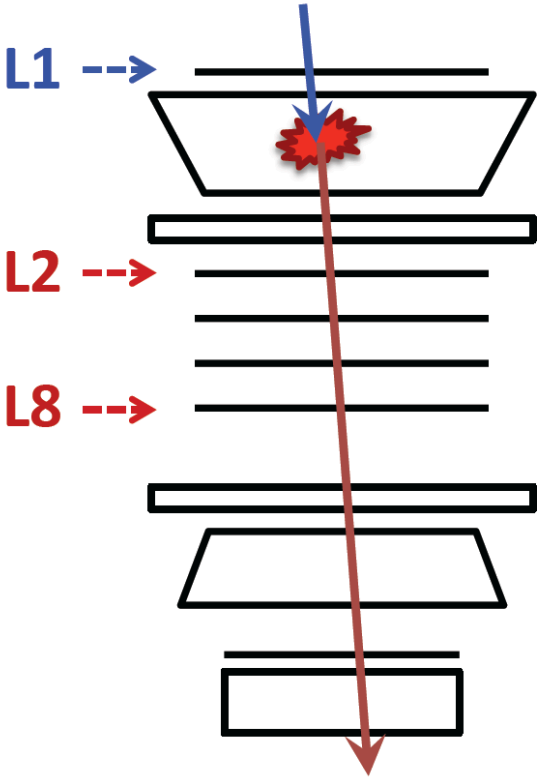
Current Data

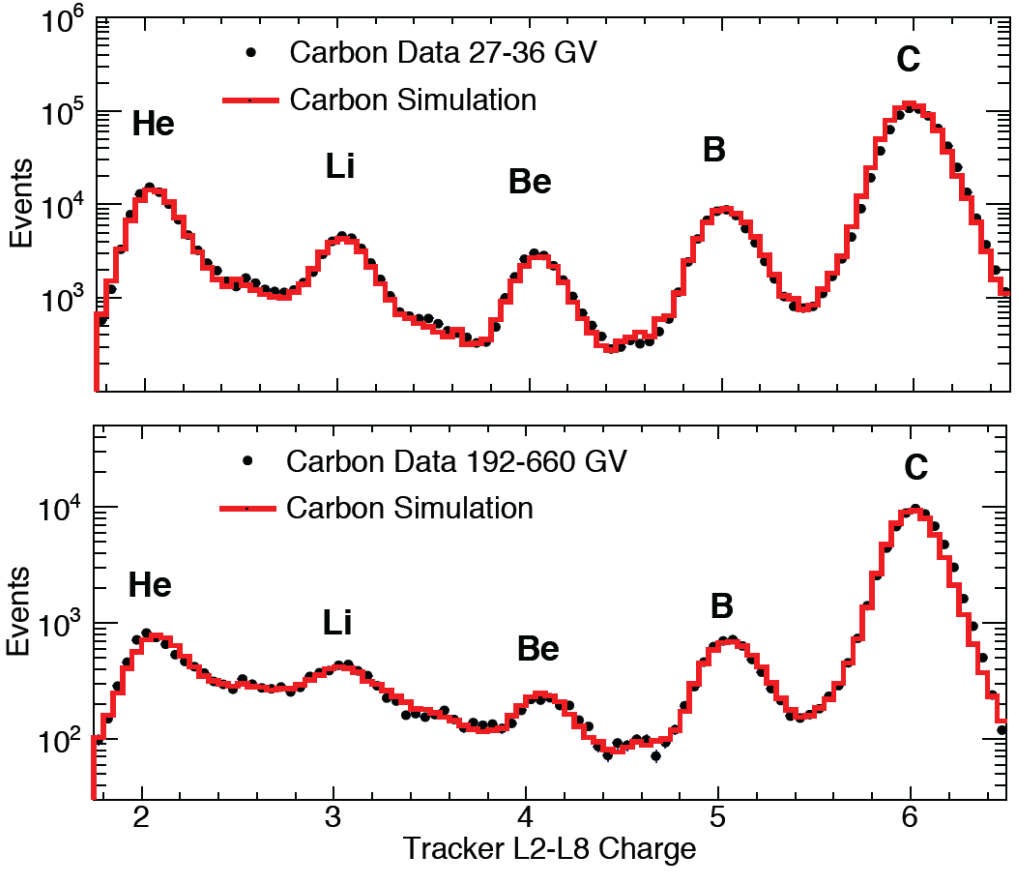


Background from Interactions Above L1

Bkg. generated above L1 is calculated using MC and nuclei fluxes measured by AMS.

MC interaction channels (ex. C + C, Al → Li, Be, B + X) have been verified with data.
Background for Li, Be and B are 2%, 13% and 8% at 3.3 TV respectively.

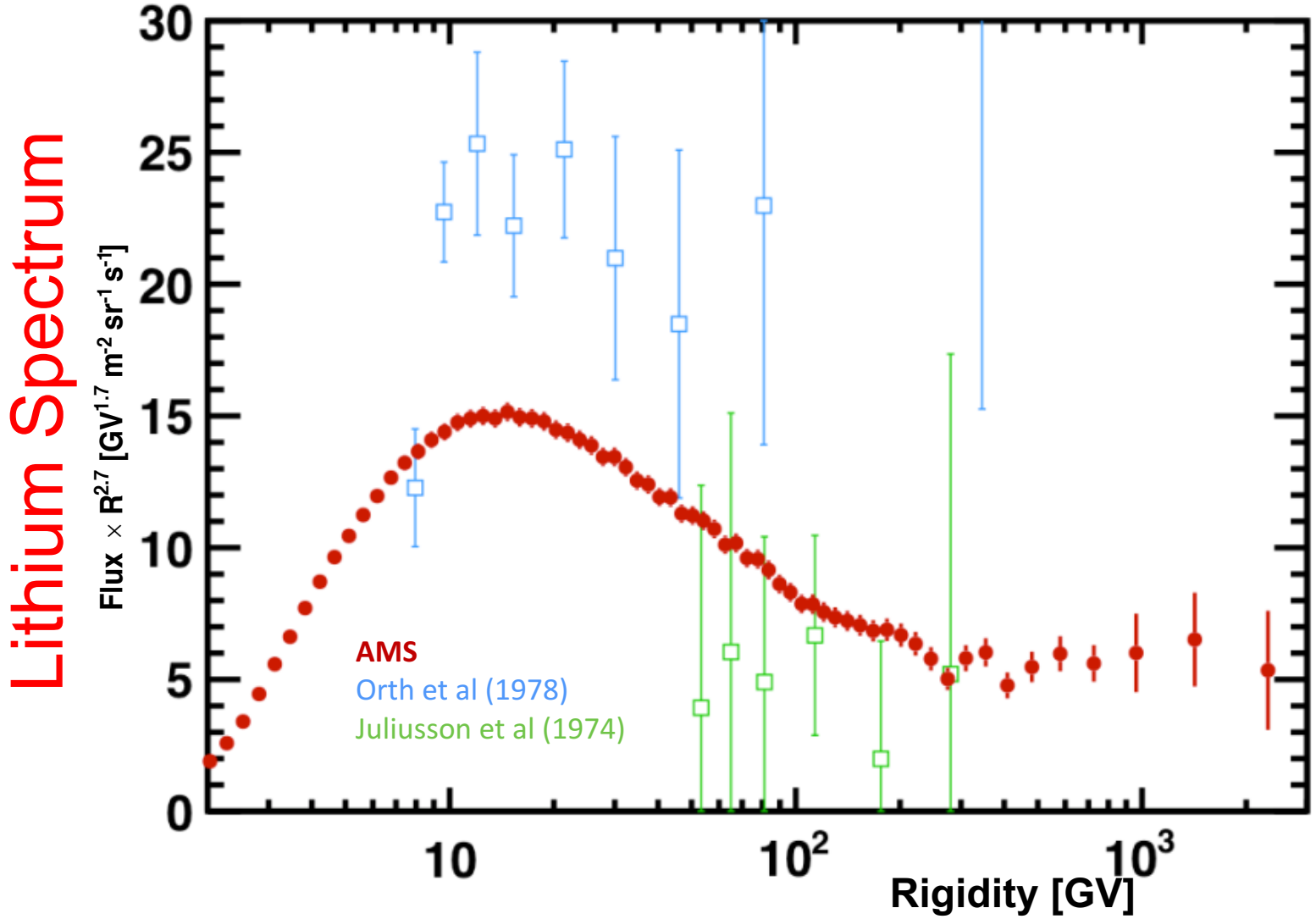




Uncertainties on interactions above L1 by cross-section validation give < 1.5% systematic error.

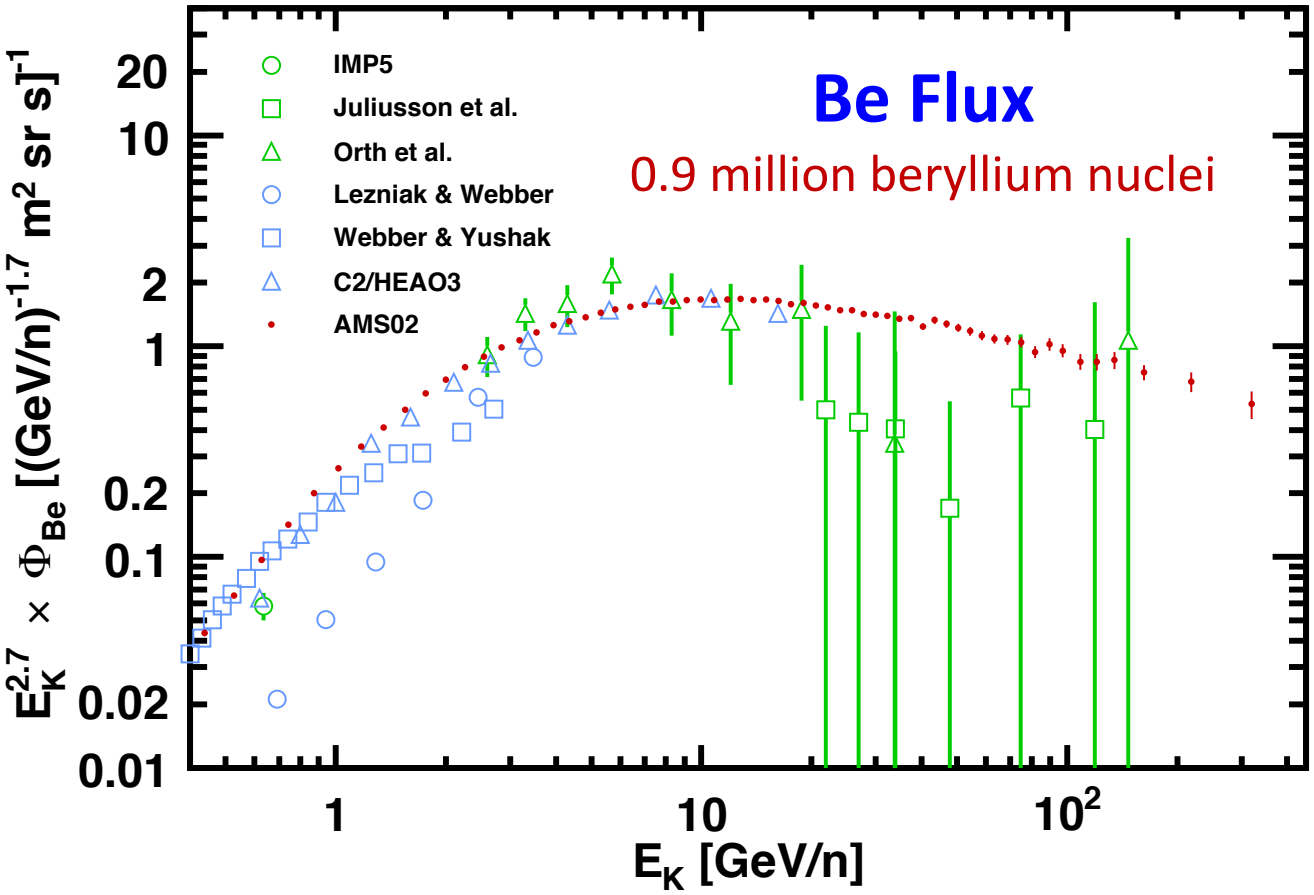
AMS Lithium flux

The results contradict the assumption that cosmic lithium is purely secondary in origin.
Purely secondary production of lithium would not produce a sharp transition.

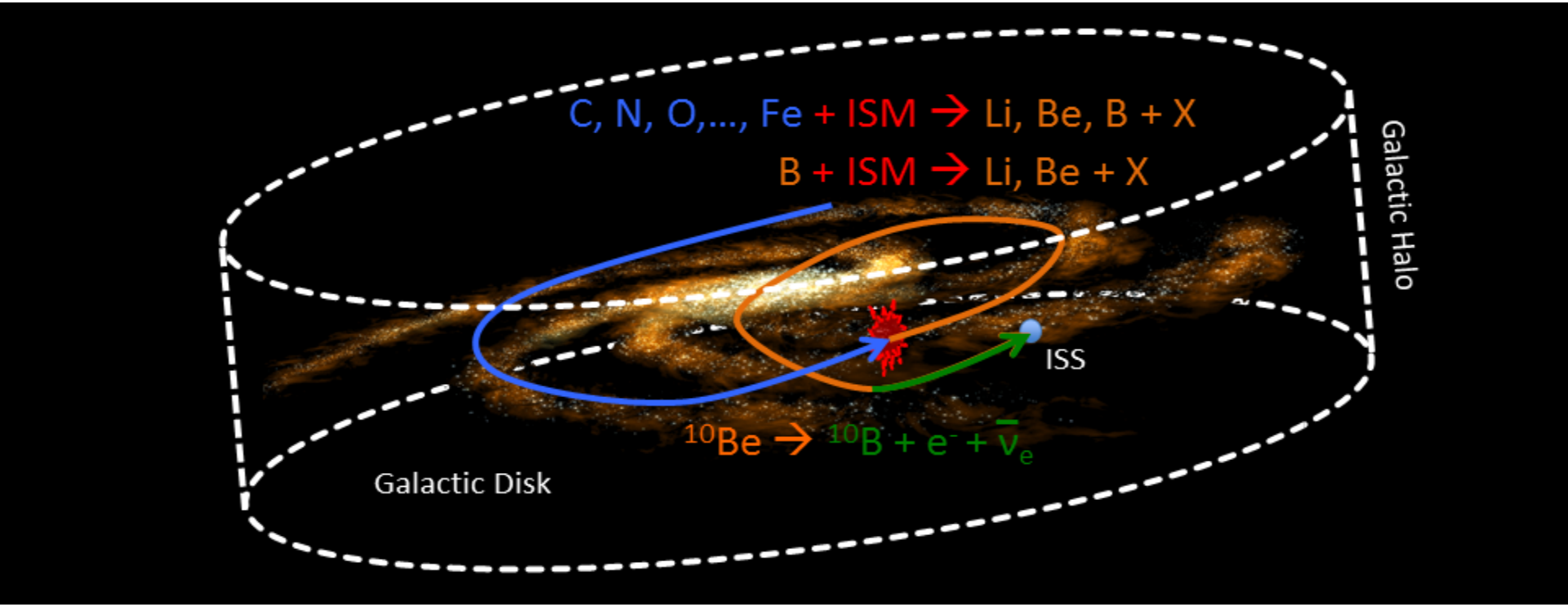


13

Be Flux

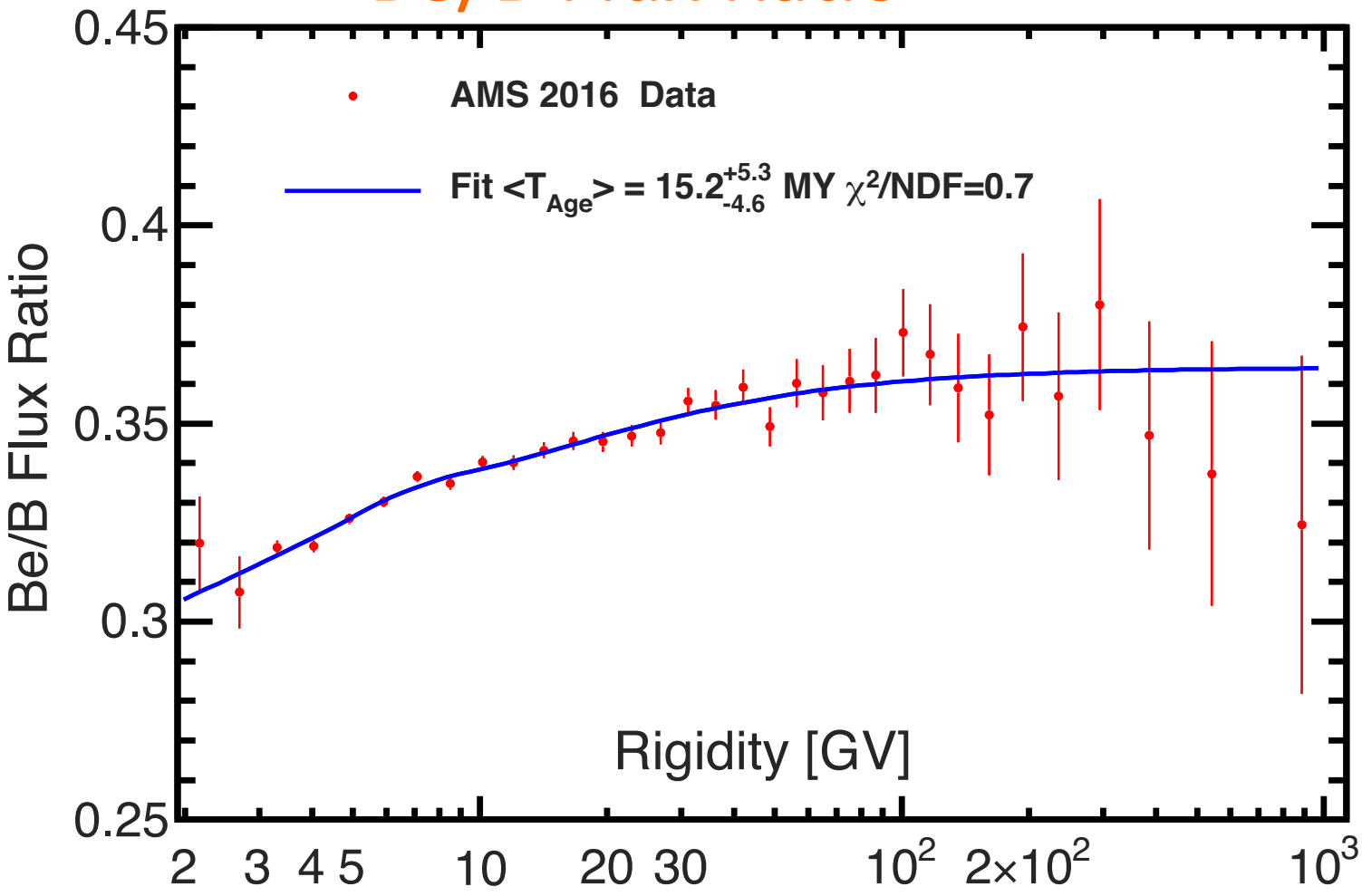

Be Flux
0.9 million beryllium nuclei
IMP5
Juliusson et al.
Orth et al.
Lezniak & Webber
Webber & Yushak
C2/HEAO3
AMS02
$E_K^{2.7} \times \Phi_{Be}$ [(GeV/n)$^{-1.7}$ m^2 sr s]$^{-1}$
20
10
2
1
0.2
0.1
0.02
0.01
1
10
10^2
E_K [GeV/n]

Be/B Flux Ratio Measurement



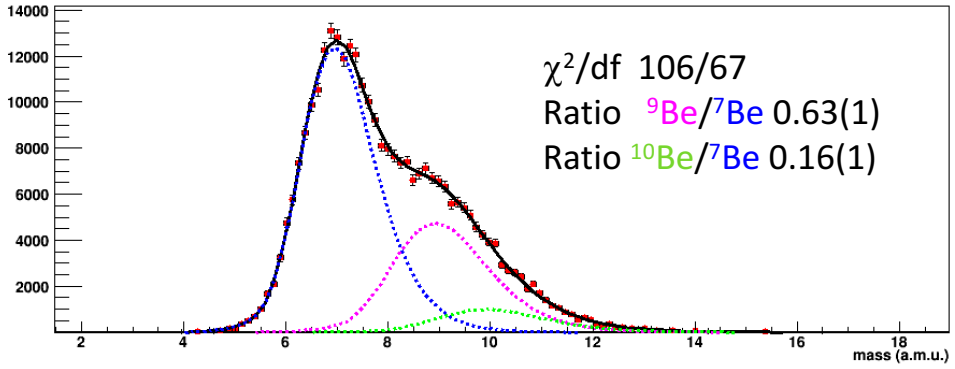
Be isotopes (^{7}Be, ^{9}Be, ^{10}Be) are generated by spallation of B, C,N,O …
^{10}Be is not stable, decays into ^{10}B with half-life of 1.5 My.
Due to relativistic time dilation the fraction of decaying ^{10}Be decrease with energy, so the raising energy dependence of Be/B reveals the characteristic lifetime of cosmic rays in the Galaxy.

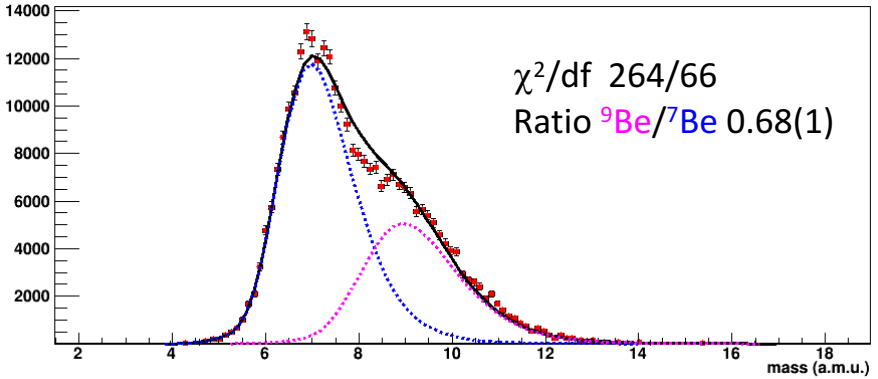
Be/B Flux Ratio

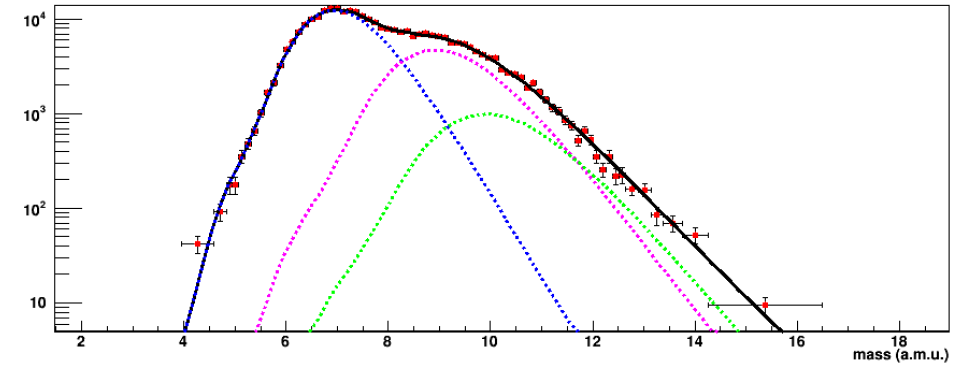


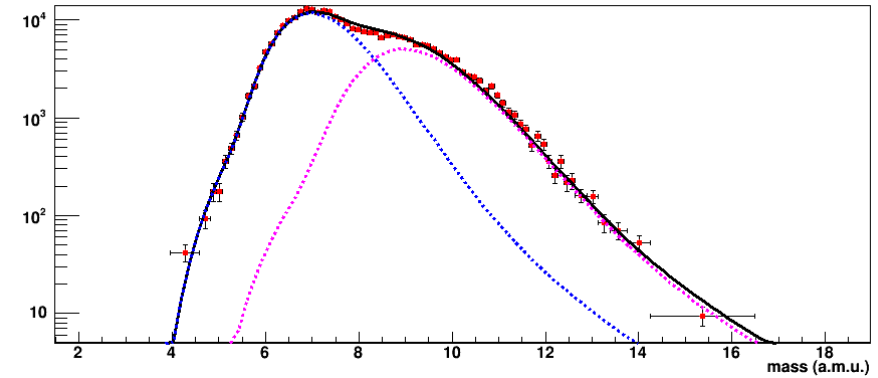
AMS Data (Ek= 3.9 GeV/n)

Three isotopes FIT ^{7}Be ^{9}Be ^{10}Be **Two isotopes FIT**









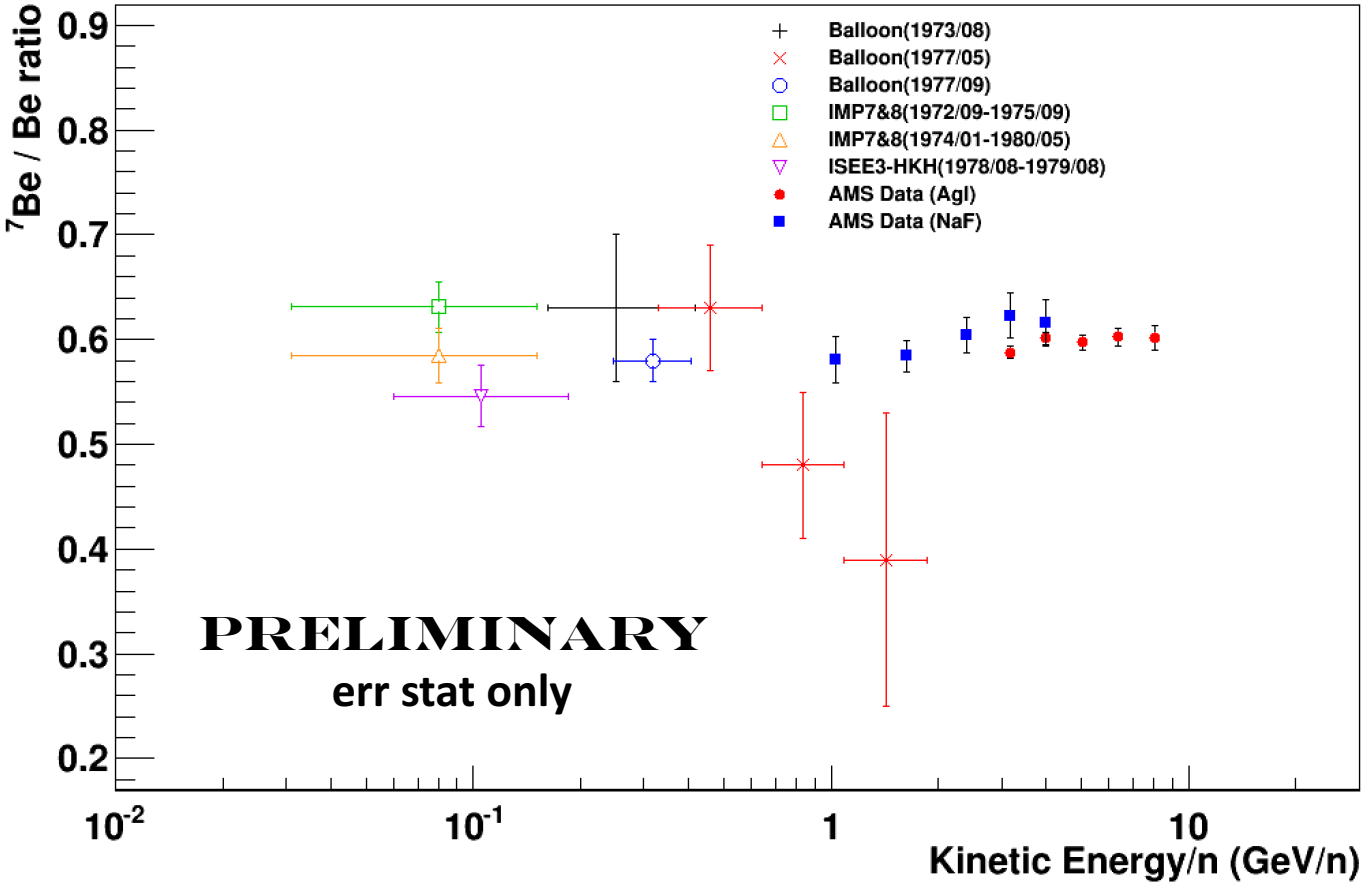
Mass (a.m.u.)

Mass (a.m.u.)

GOOD

BAD

^{7}Be fraction (preliminary)



Boron and Nitrogen Fluxes

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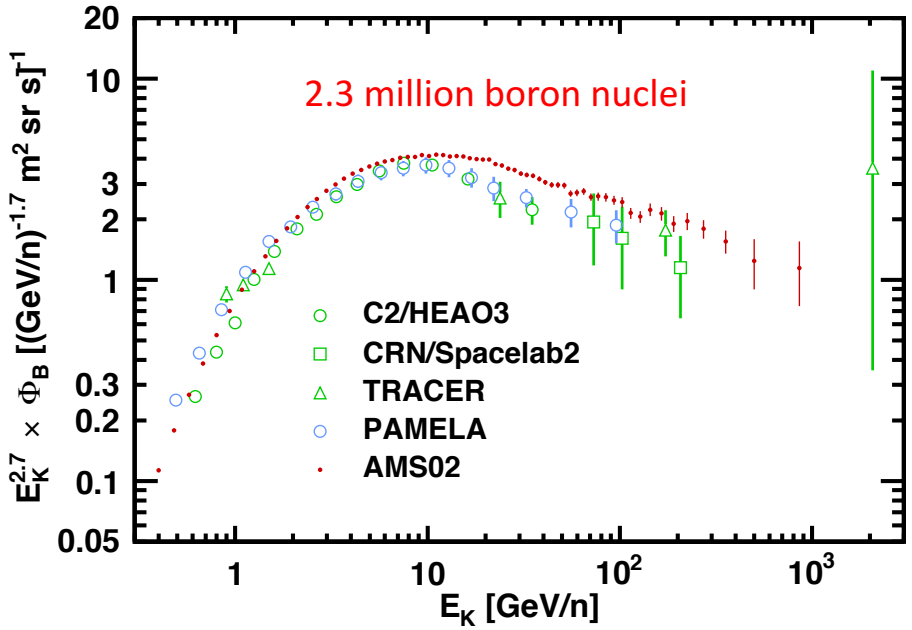
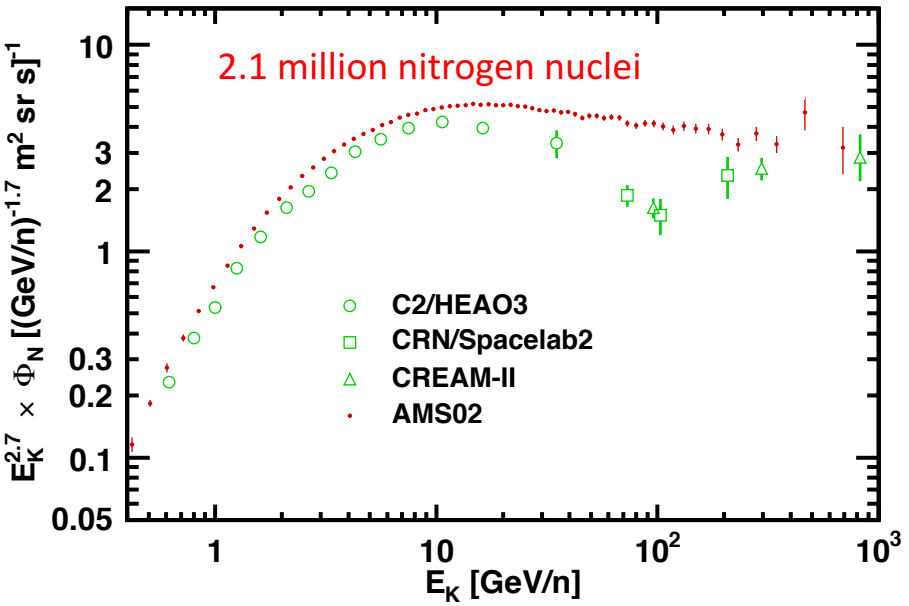
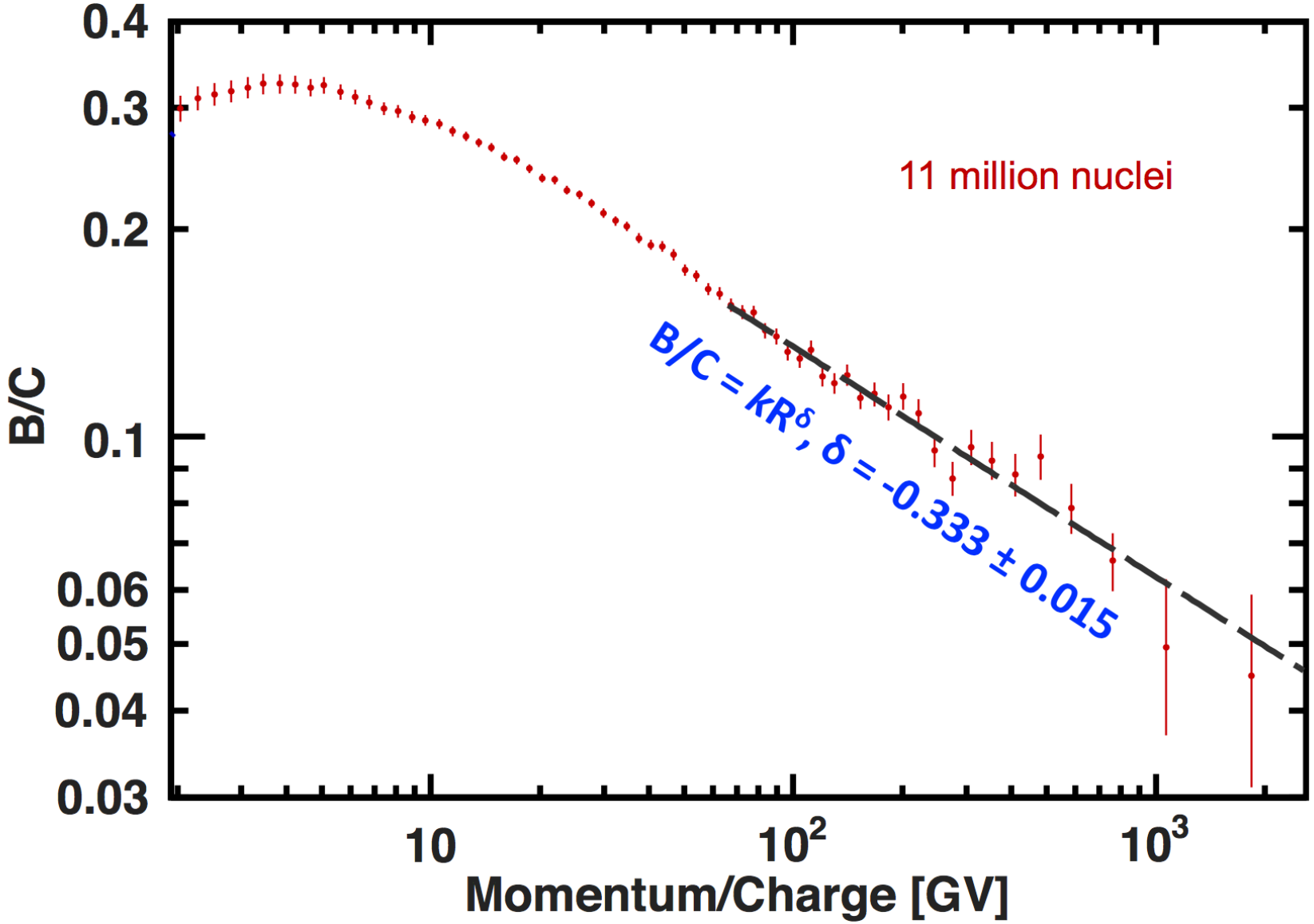


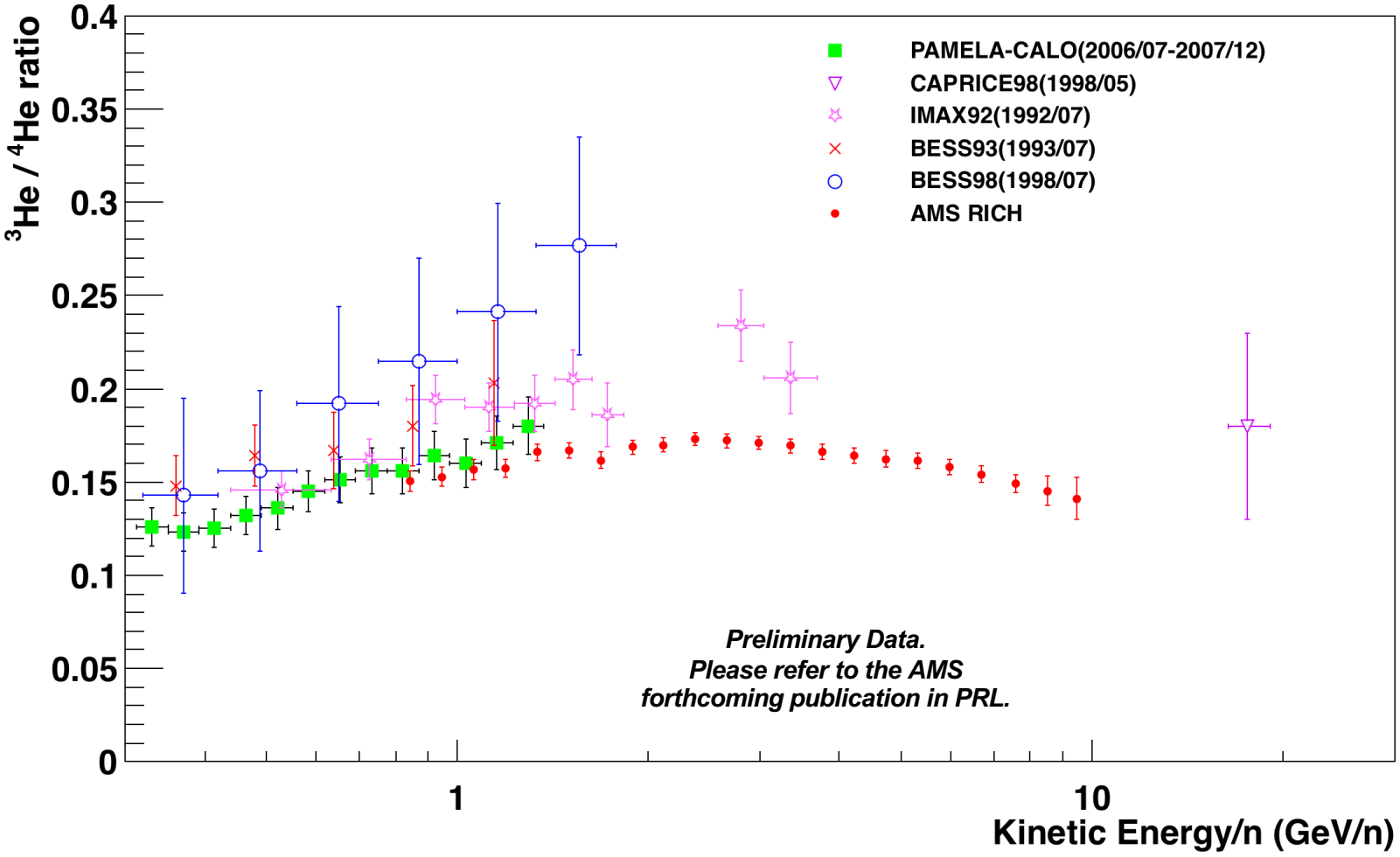


Boron-to-Carbon Ratio



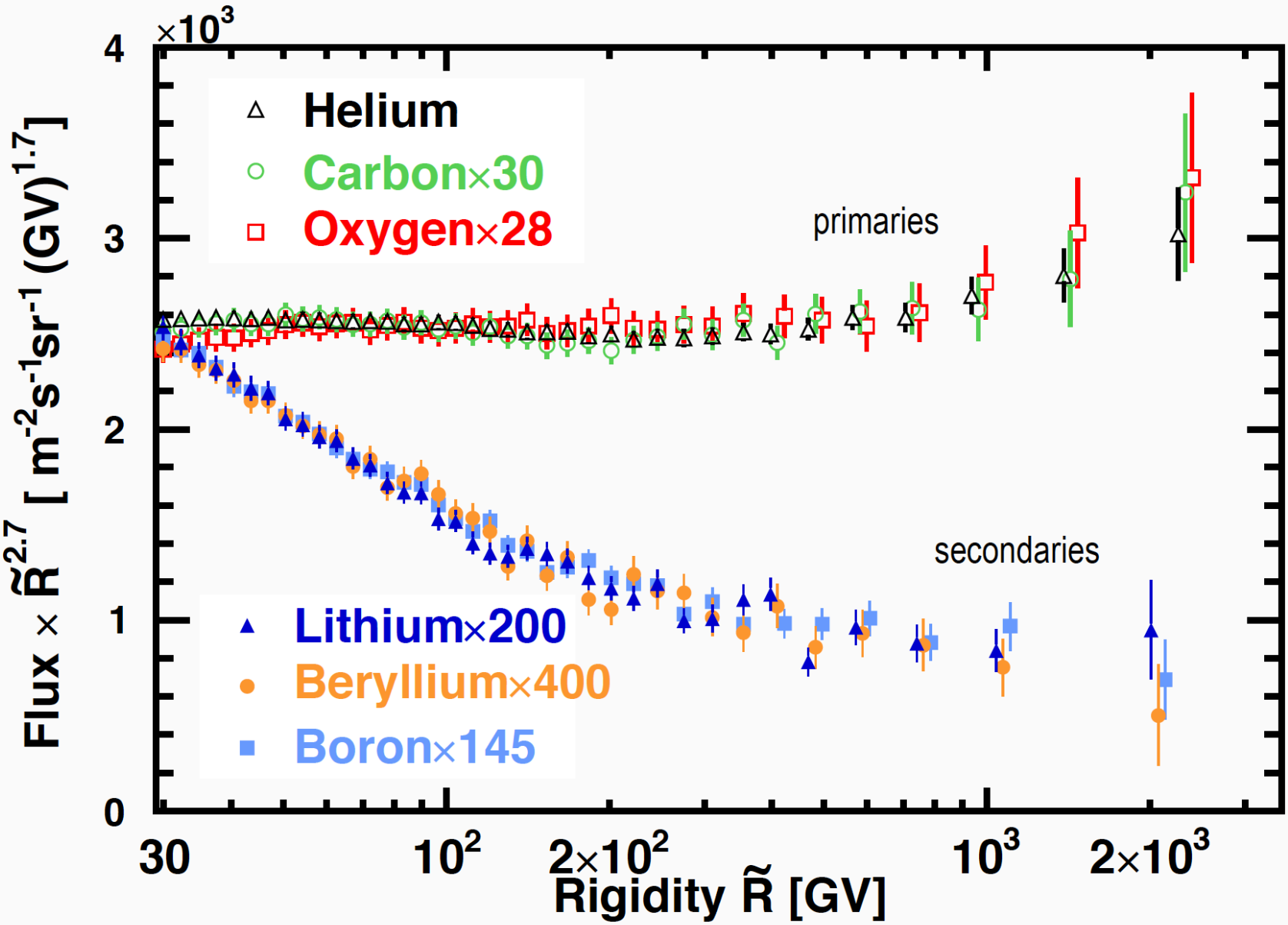
M. Aguilar *et al.*, Phys. Rev. Lett. **117,** 231101 (2016)

$^3He/^4He$ ratio

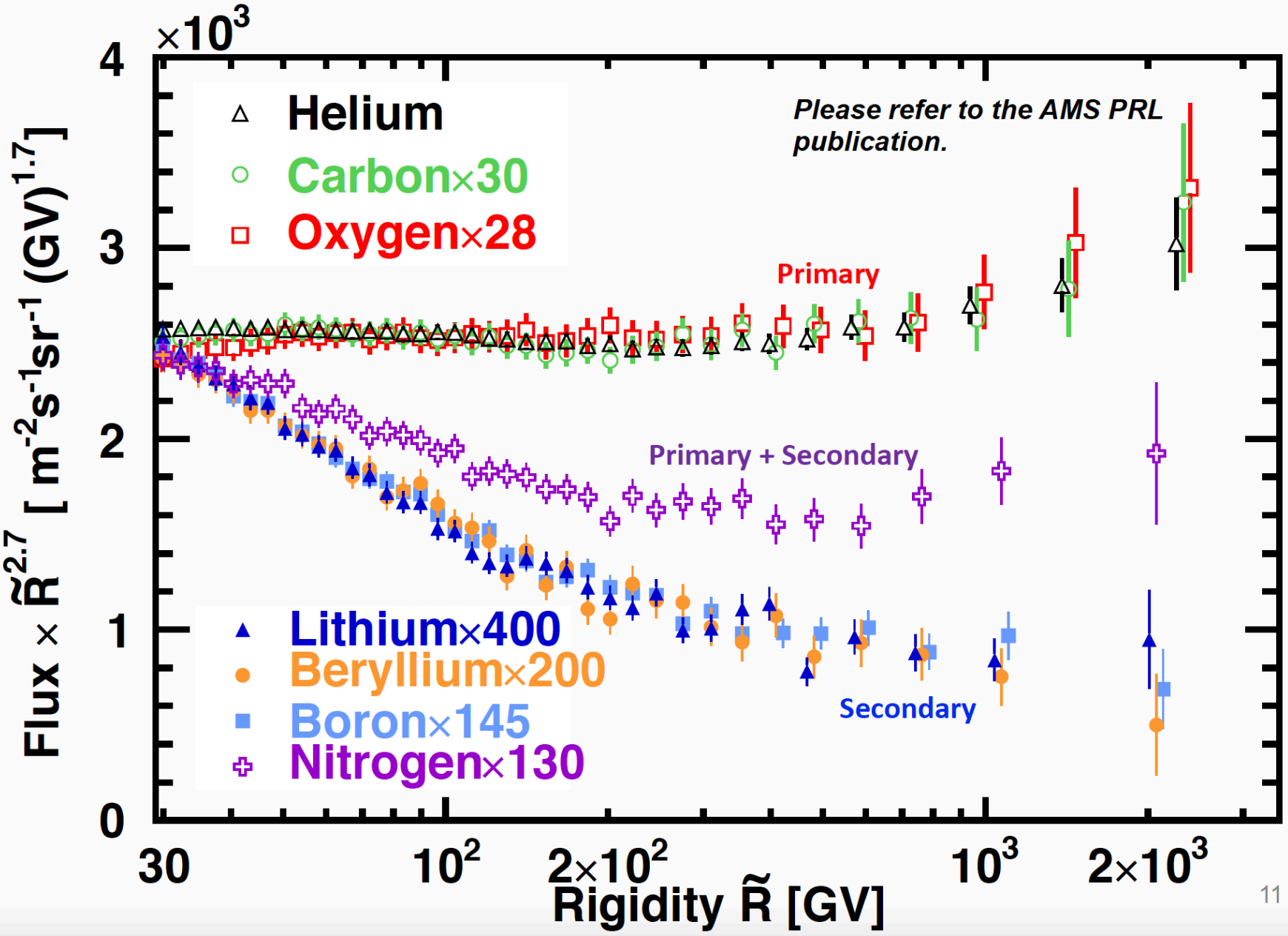


Error bars: stat + sys

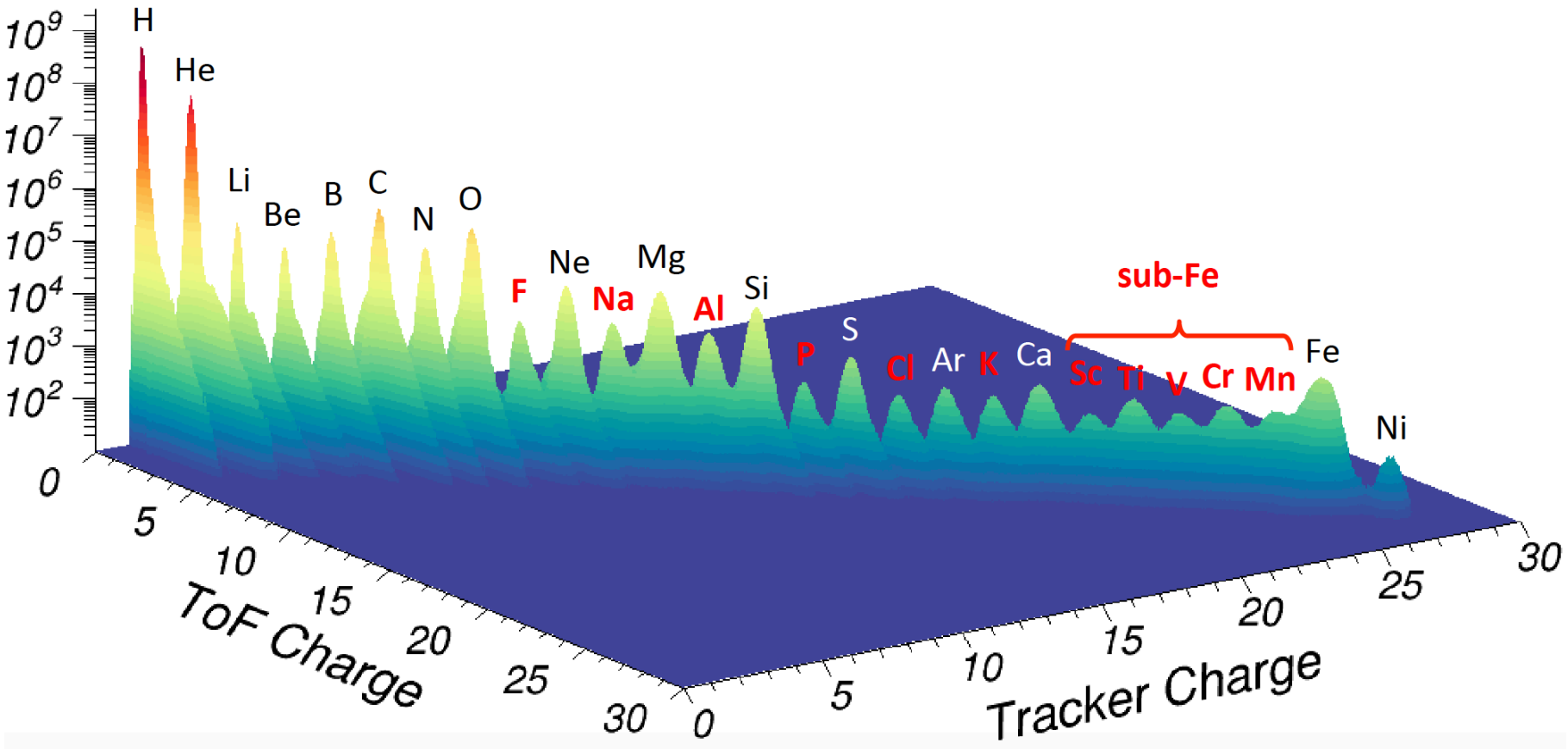
Primary and Secondary Cosmic Ray Fluxes



Nitrogen Flux has peculiar Rigidity Dependence



In the Future



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  - Anti-nuclei: **He, …**
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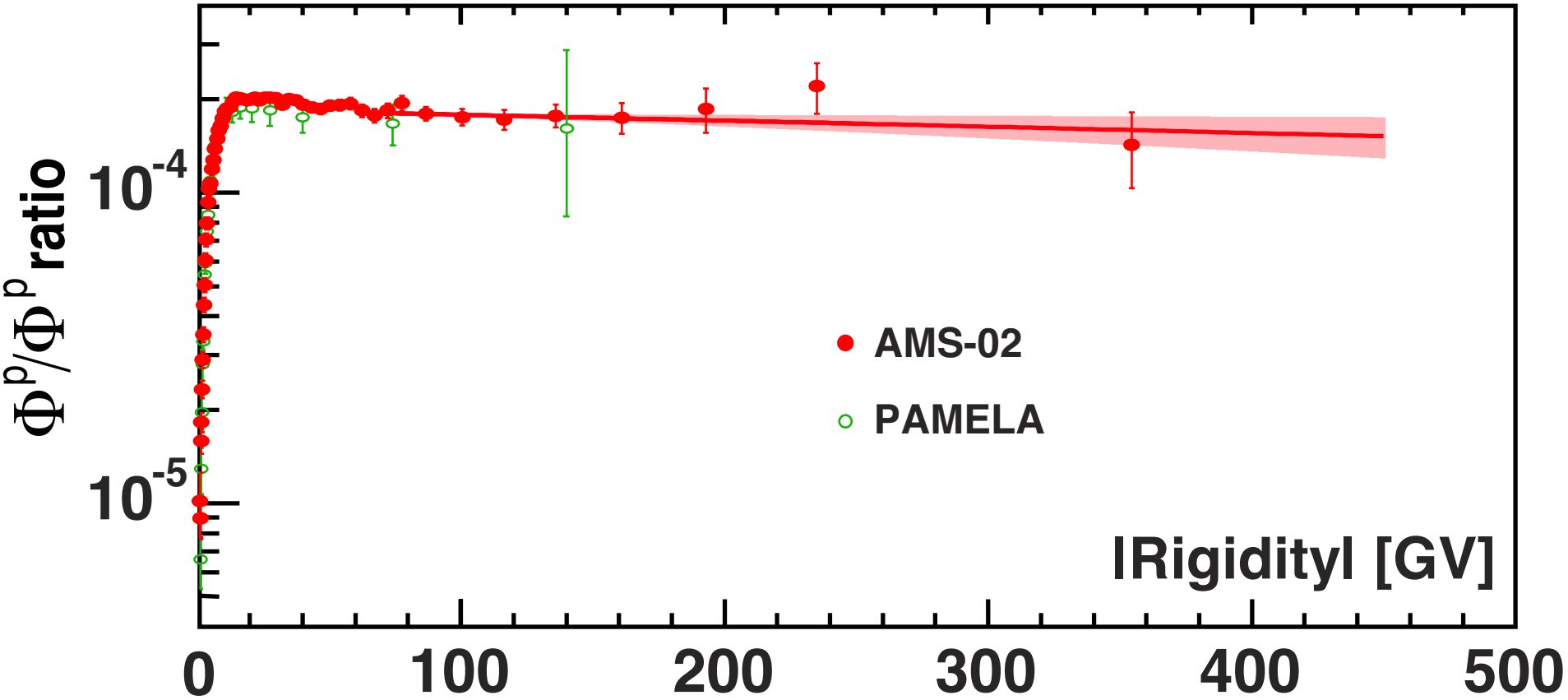
Unexpected Result

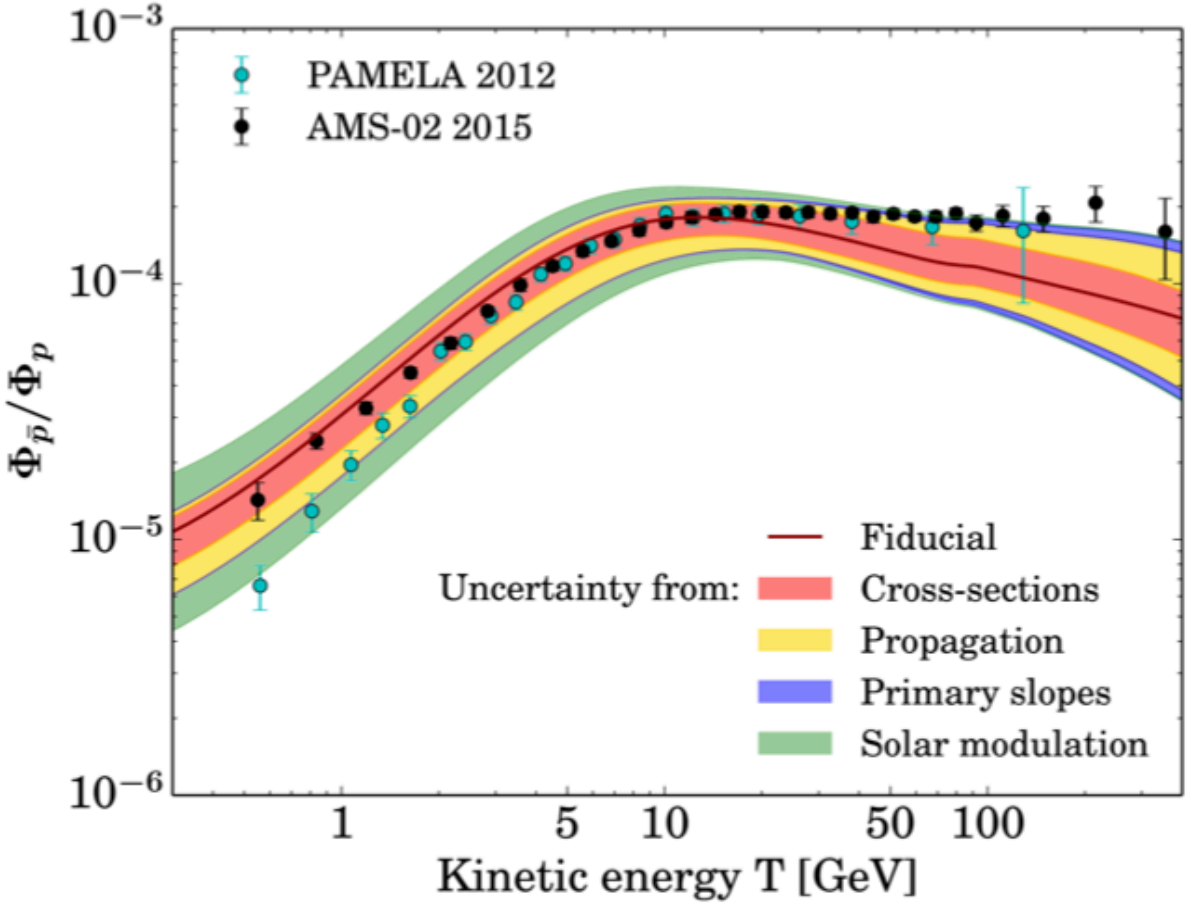
Flux Ratio of Elementary Particles $p/\overline{p}$

is energy independent above 60 GeV



PRL **117,** 091103 (2016)

Compare antiproton fraction data to diffuse production scenario:



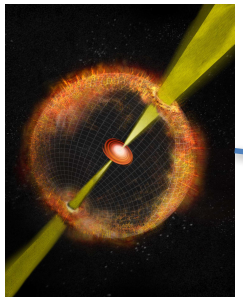
arXiv:1504.04276

AMS data lies at the edge of the allowed band.

Propagation and primary slopes systematics can be improved through AMS measurements.

Cross-sections systematics can only be improved by **new data**

Precise AMS measurements will help to constrain these error:
B/C, nuclei fluxes, isotope ratios



Primary CR (H, He, C, etc.)

ISM

$$p + p \rightarrow \bar{p} + X$$
$$p + He \rightarrow \bar{p} + X$$

Anti-proton Production Cross Section

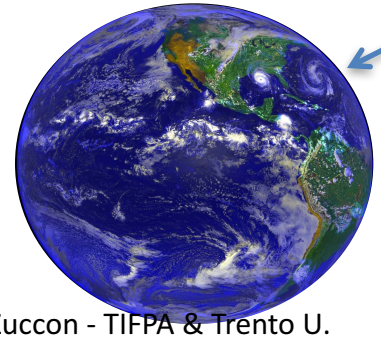
Secondary CR (Li, Be, B, N, etc.)

$$C + p \rightarrow B + X$$

ISM

$$B/C$$

Spallation Cross Section (N-N)



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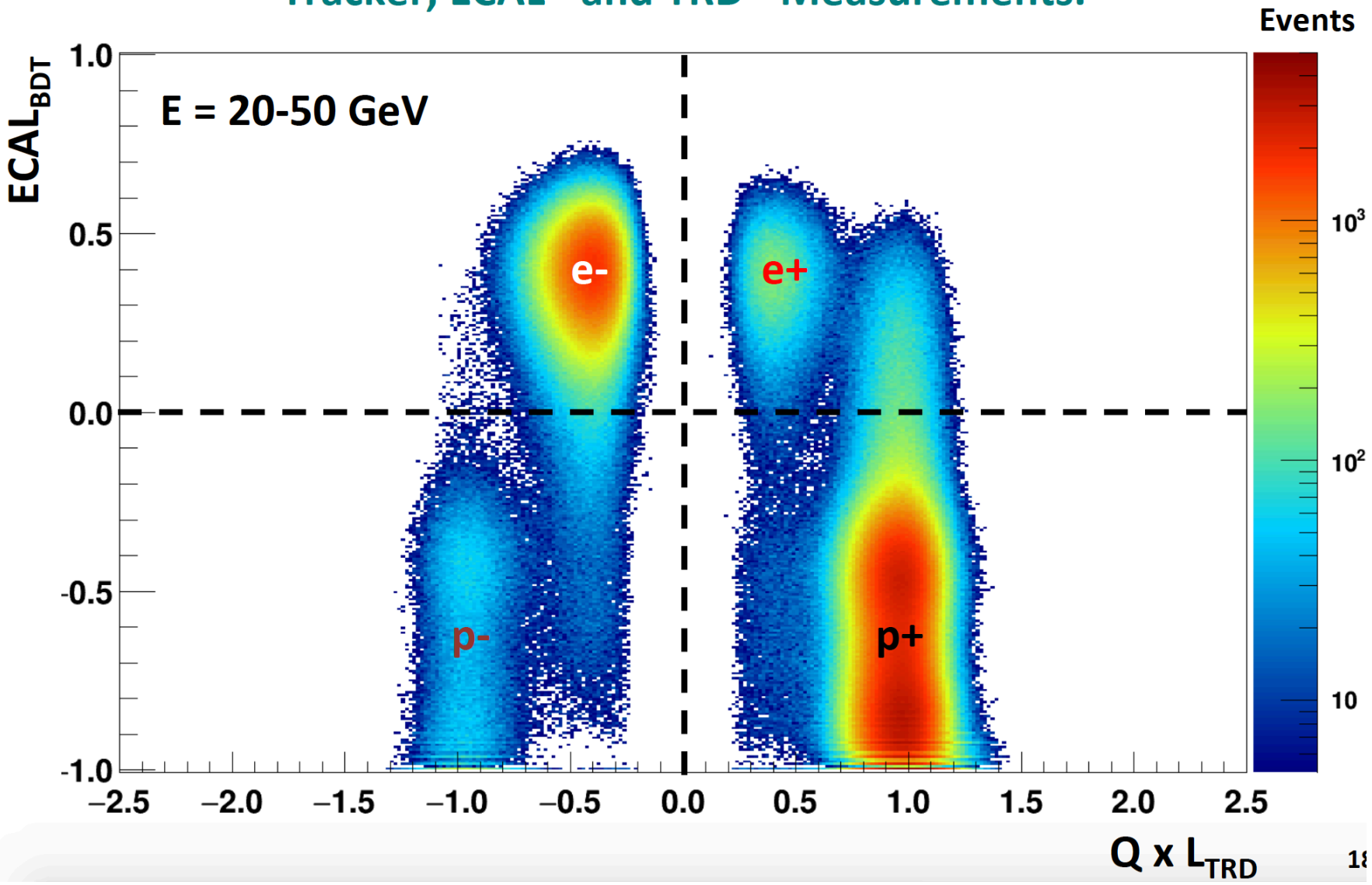
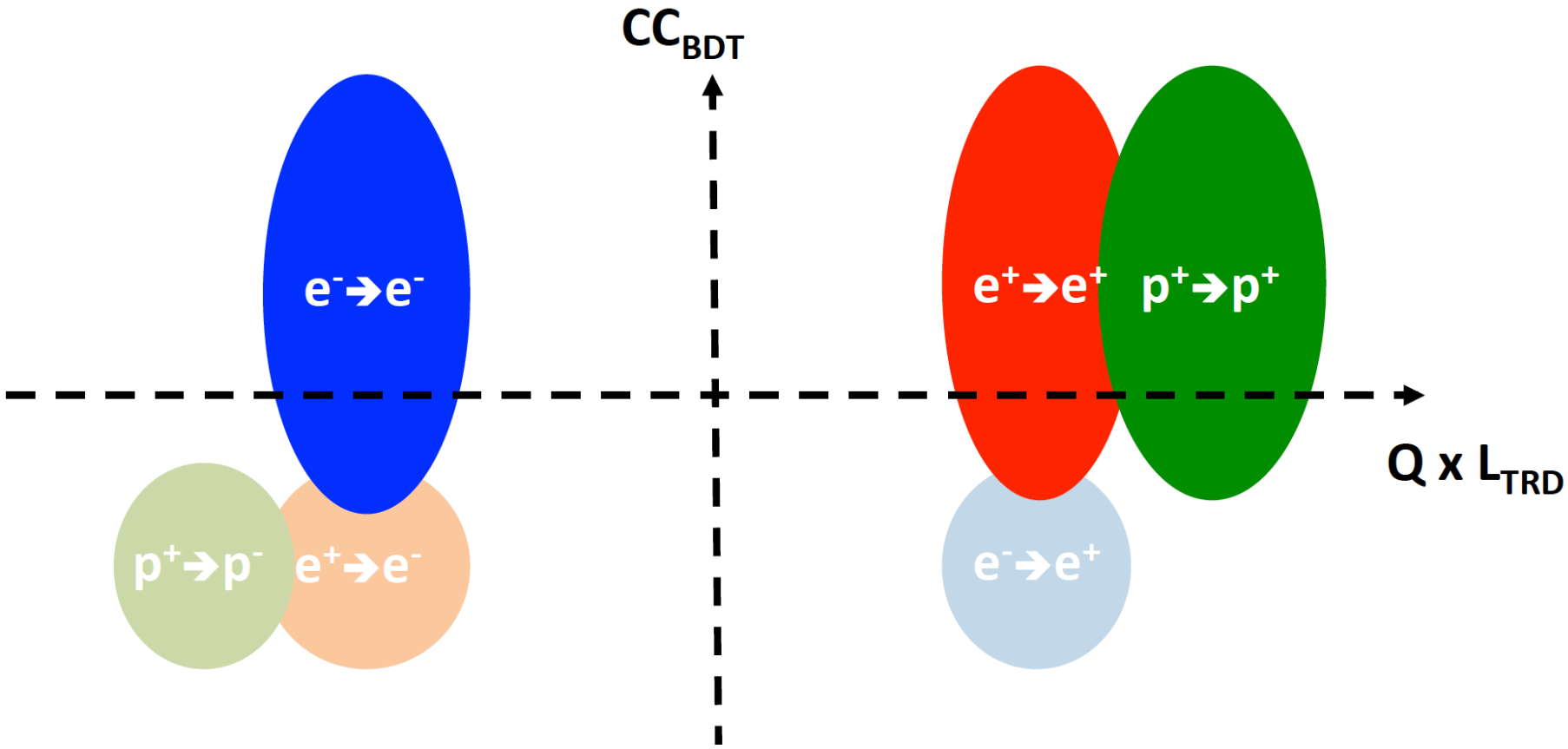
Due to its magnetic spectrometer AMS can accurately identify four components combining the Tracker, ECAL - and TRD - Measurements.



2D-Template Fit to count $e^{\pm}$ Events in AMS Data

1. From the AMS Data an $e^{\pm}$ enhanced event sample is selected by soft cuts on the ratio ECAL-Energy/|Rigidity| and on $ECAL_{BDT}$.
2. Then the number of **electrons** and **positrons** is determined in each energy bin from a 2D-Template Fit in the ($Q \times L_{TRD}$, CC_{BDT}) – Plane.



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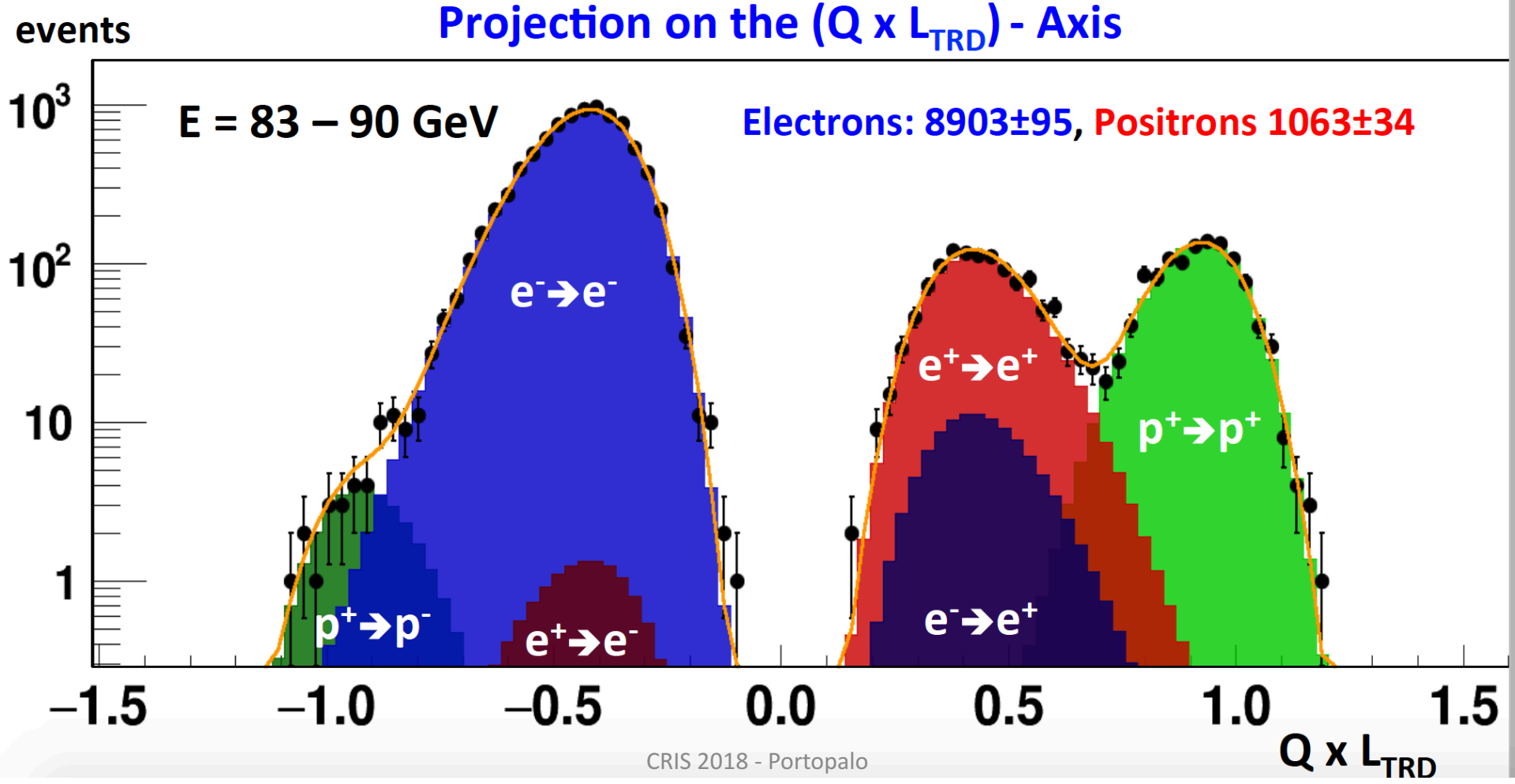
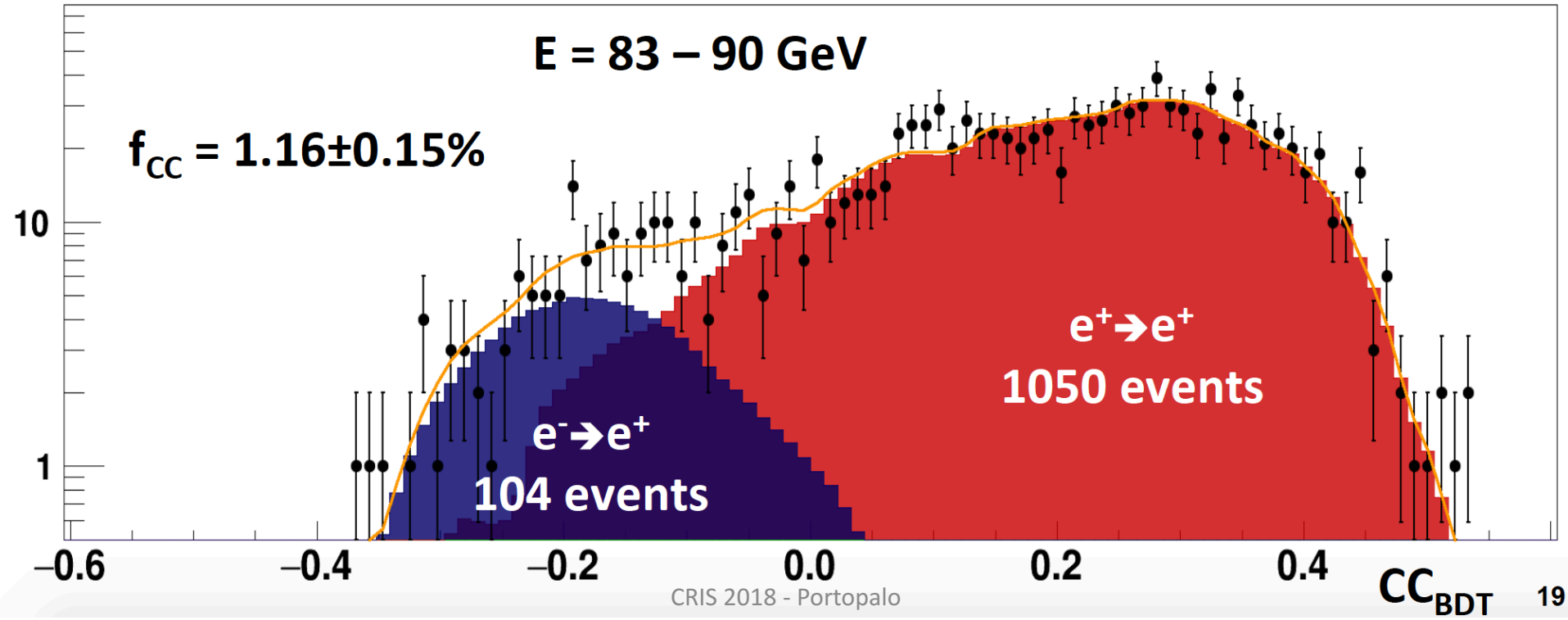


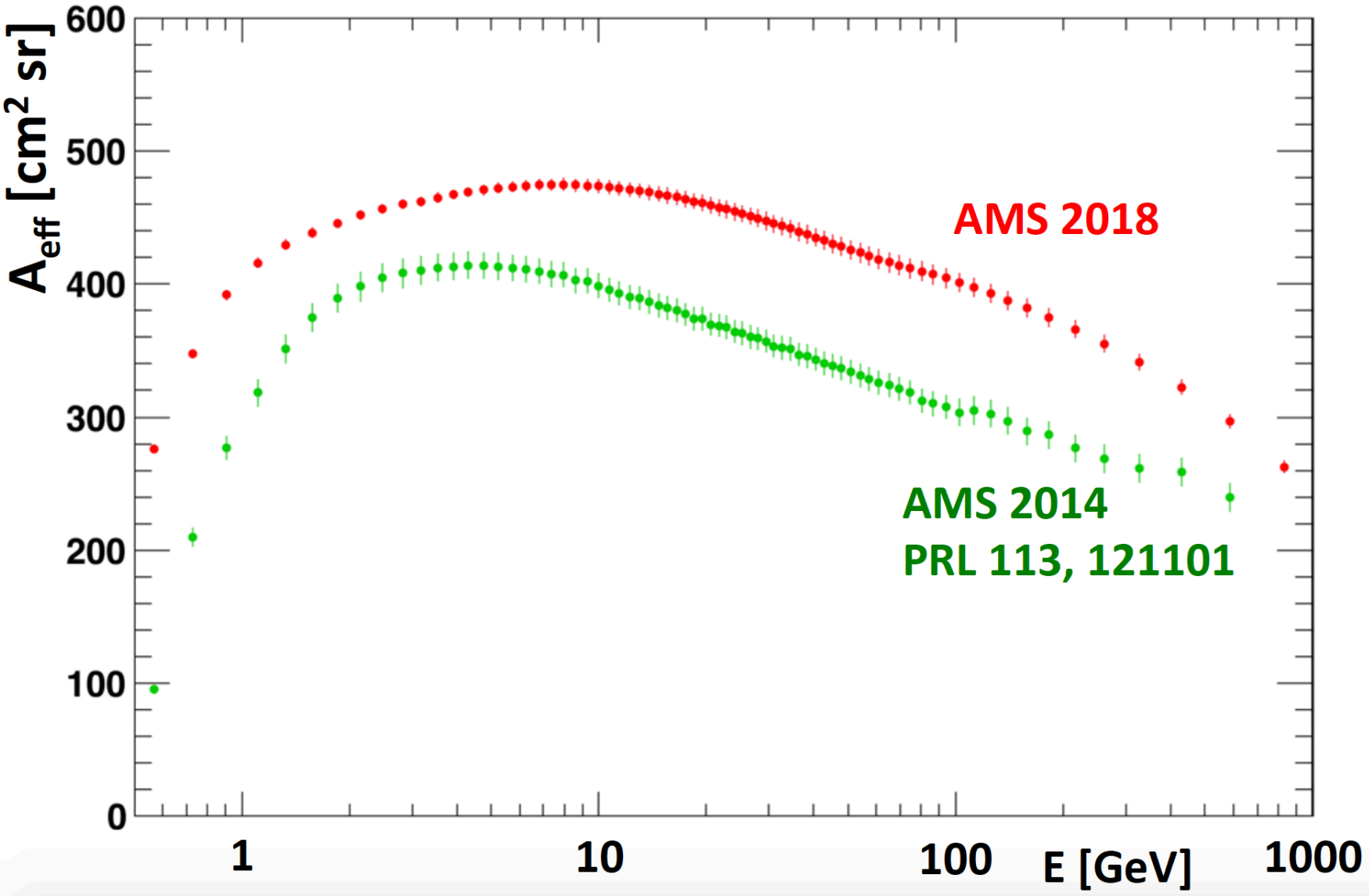
Fraction of charge confused events: f_{CC}

- Charge confusion occurs when an electron is reconstructed as a positron and vice versa. At low energies this happens due to interactions in the detector material. At high energies the finite detector resolution leads to charge confusion.
- We combine observables sensitive to this effect in another BDT to derive for each event a classifier (CC_{BDT}) to determine the charge confusion directly from ISS data with a template fit.

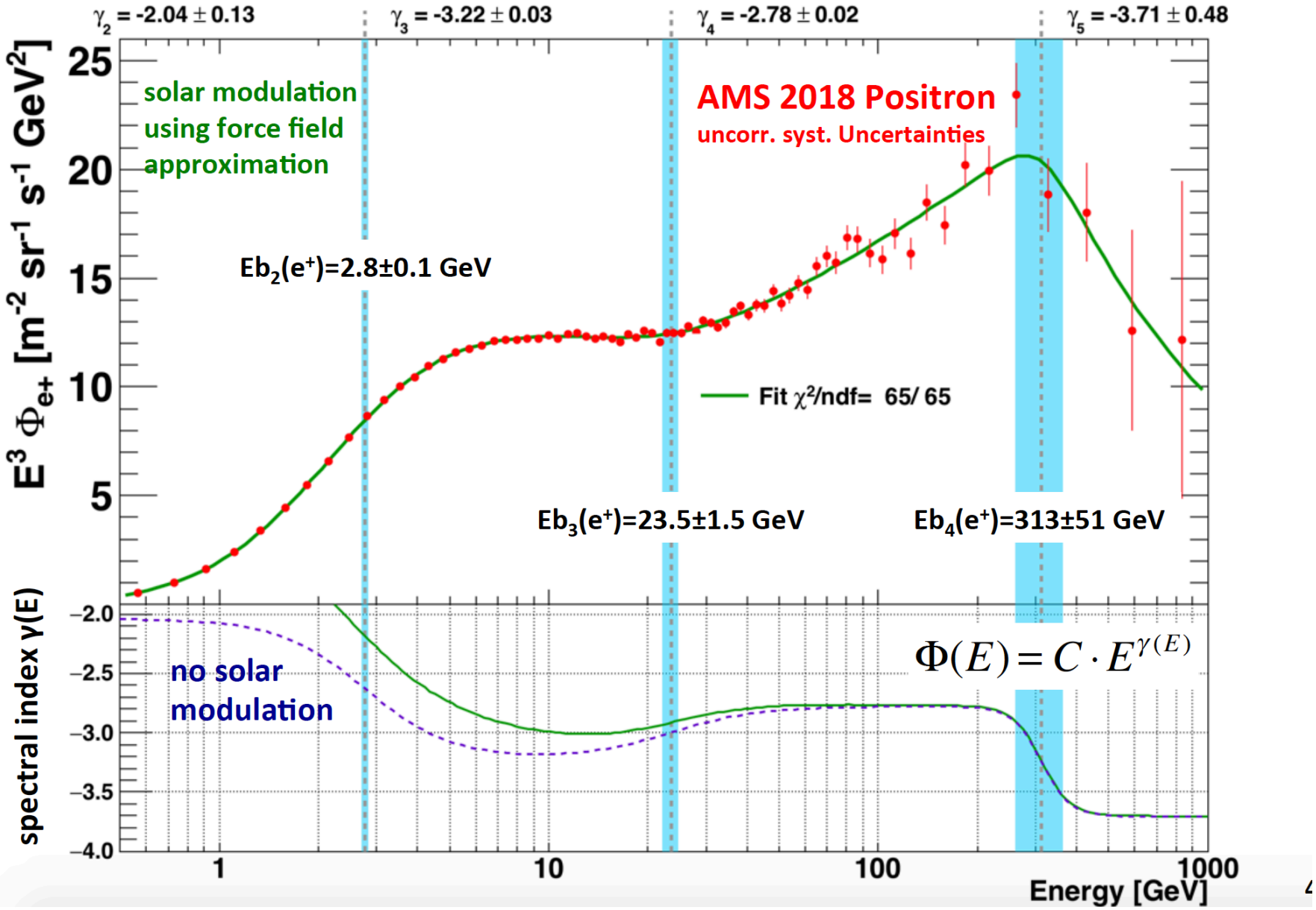
104 out of 8903 electron events are reconstructed with the wrong charge sign.



Effective Acceptance



Describe the positron flux by a combination of several power laws with smooth transitions, i.e the spectral index follows a logistic function in log(E) around the break energies.



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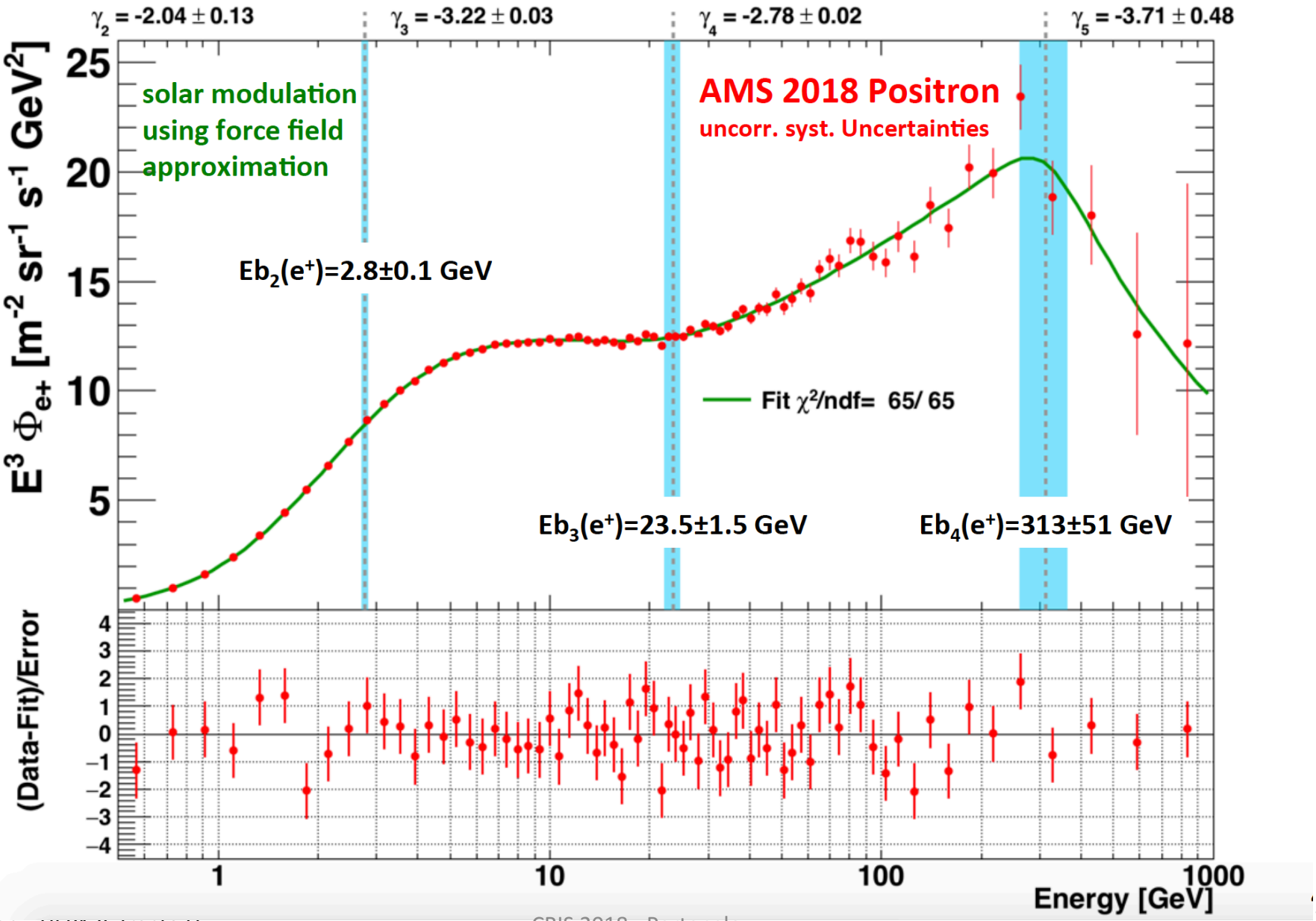
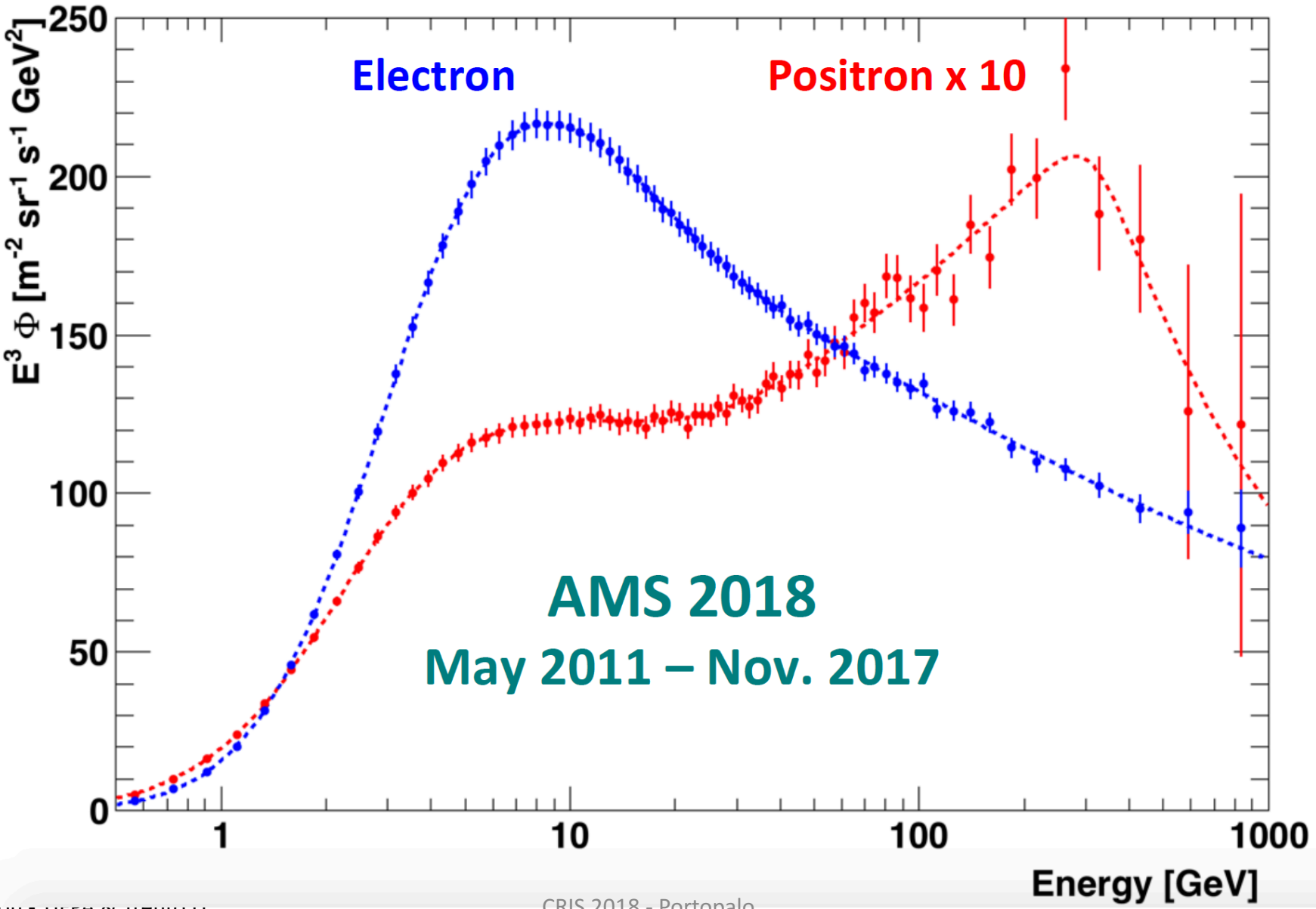
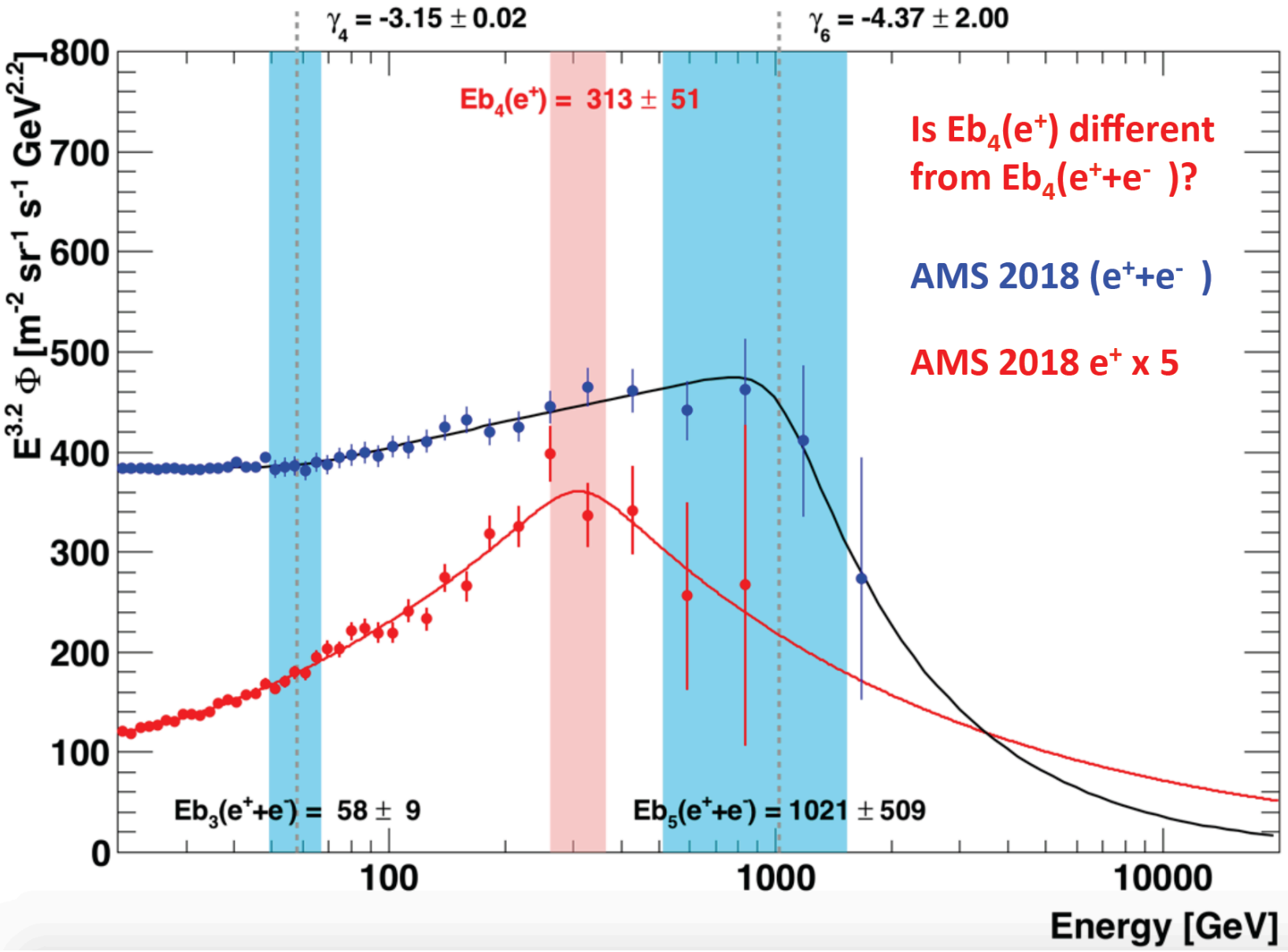


Measurements of the Electron and Positron spectra

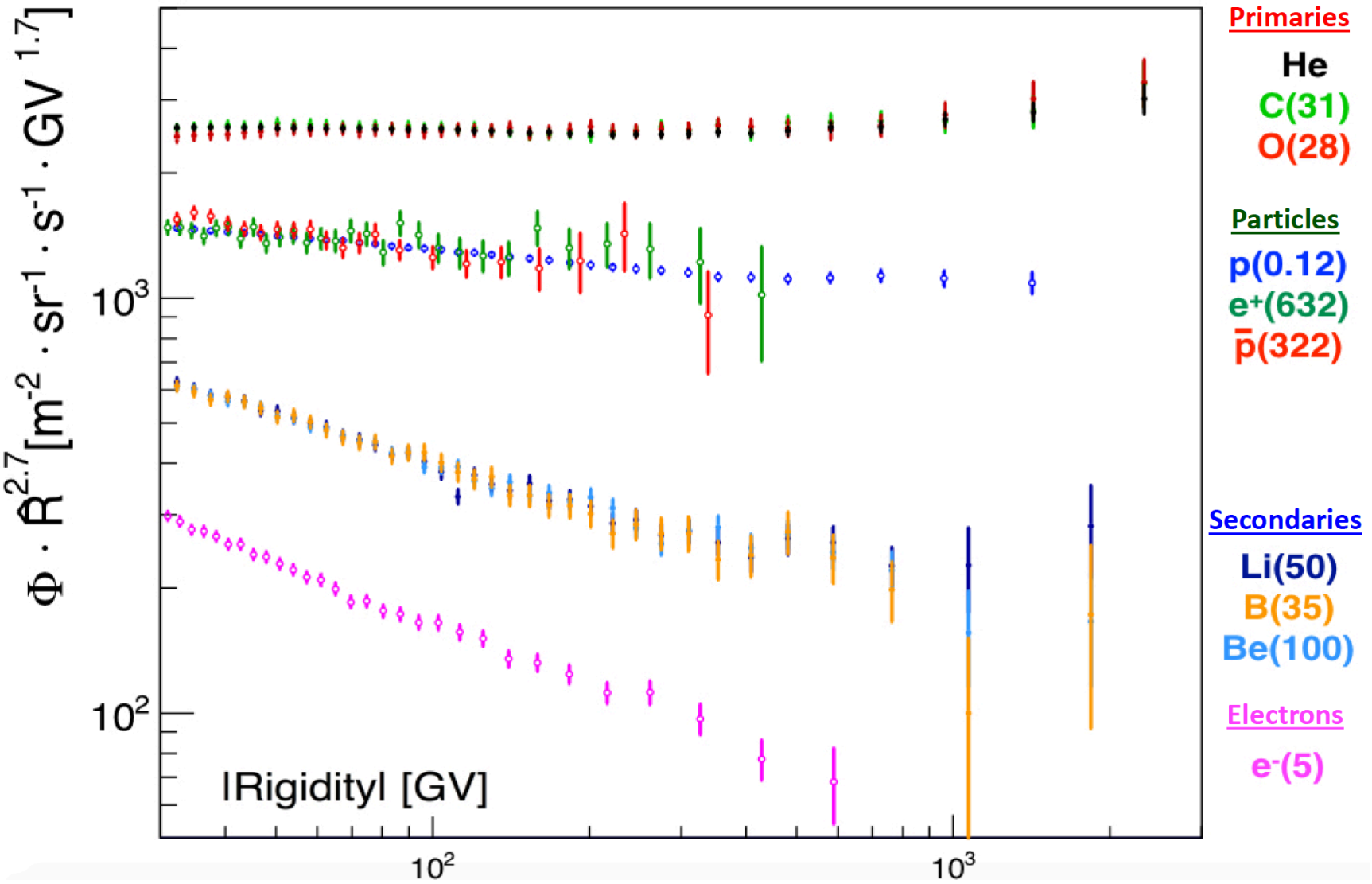


e^+ Data compared to (e^++e^-) Data



Summary of AMS results on Cosmic Ray Fluxes

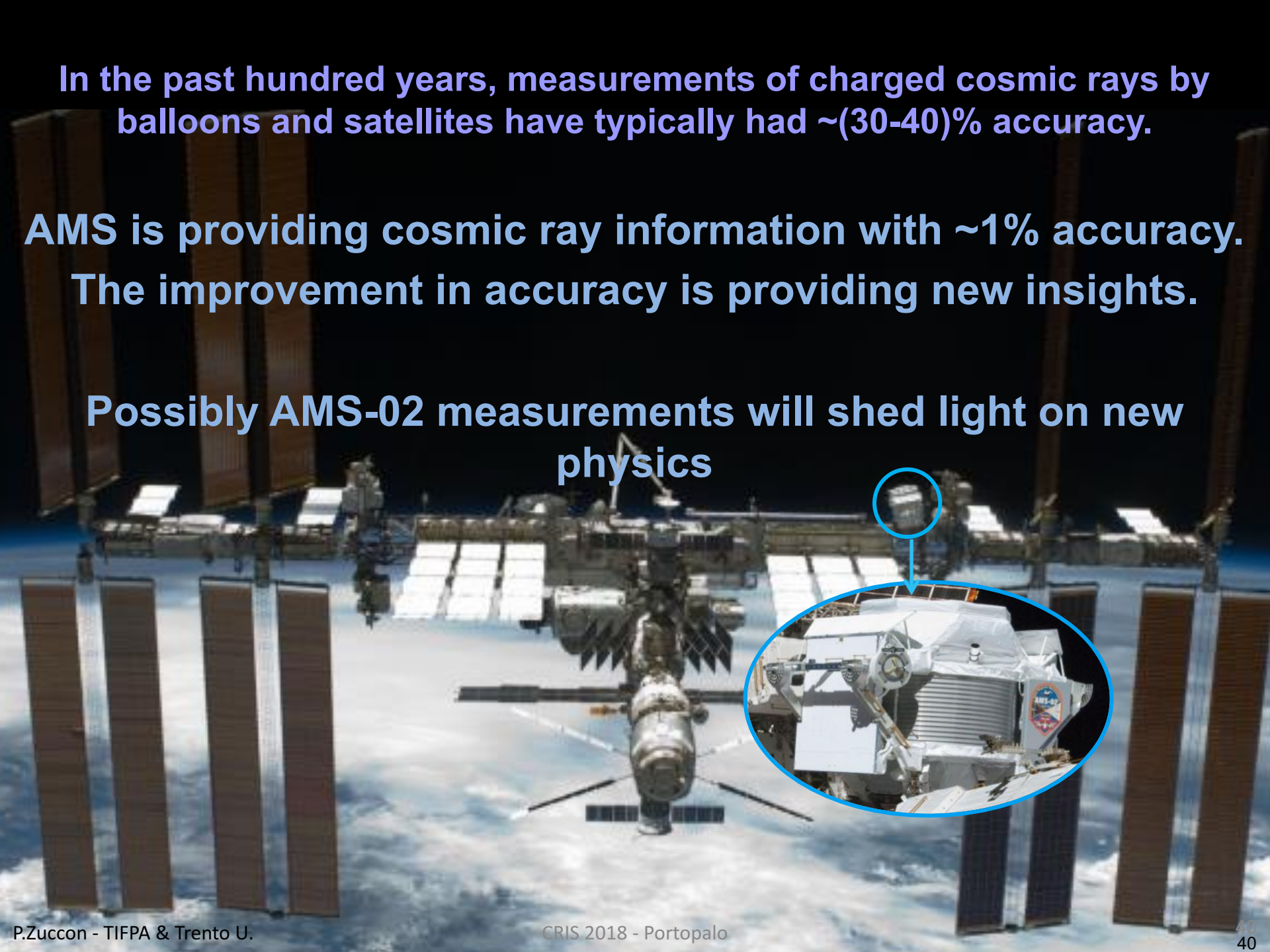
High energy cosmic ray fluxes have 4 classes of rigidity dependence.



In the past hundred years, measurements of charged cosmic rays by balloons and satellites have typically had ~(30-40)% accuracy.

AMS is providing cosmic ray information with ~1% accuracy.
The improvement in accuracy is providing new insights.

Possibly AMS-02 measurements will shed light on new physics

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