Recent Results from AMS-02

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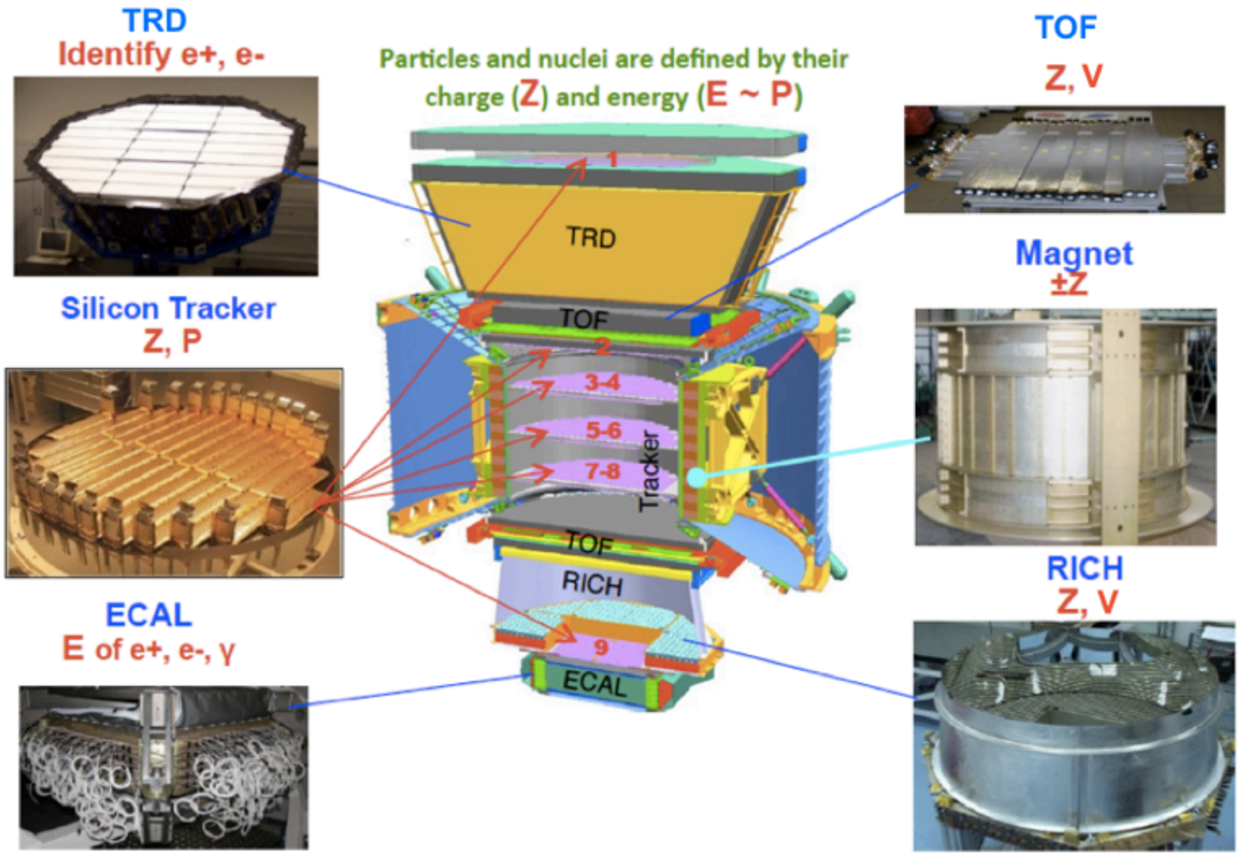
AMS is a US DOE lead International Collaboration

Spokesperson: Nobel laureate Prof. Dr. S. Ting from MIT

AMS-02 experiment has been installed
on the International Space Station on May 19th 2011

Scientific goals of AMS

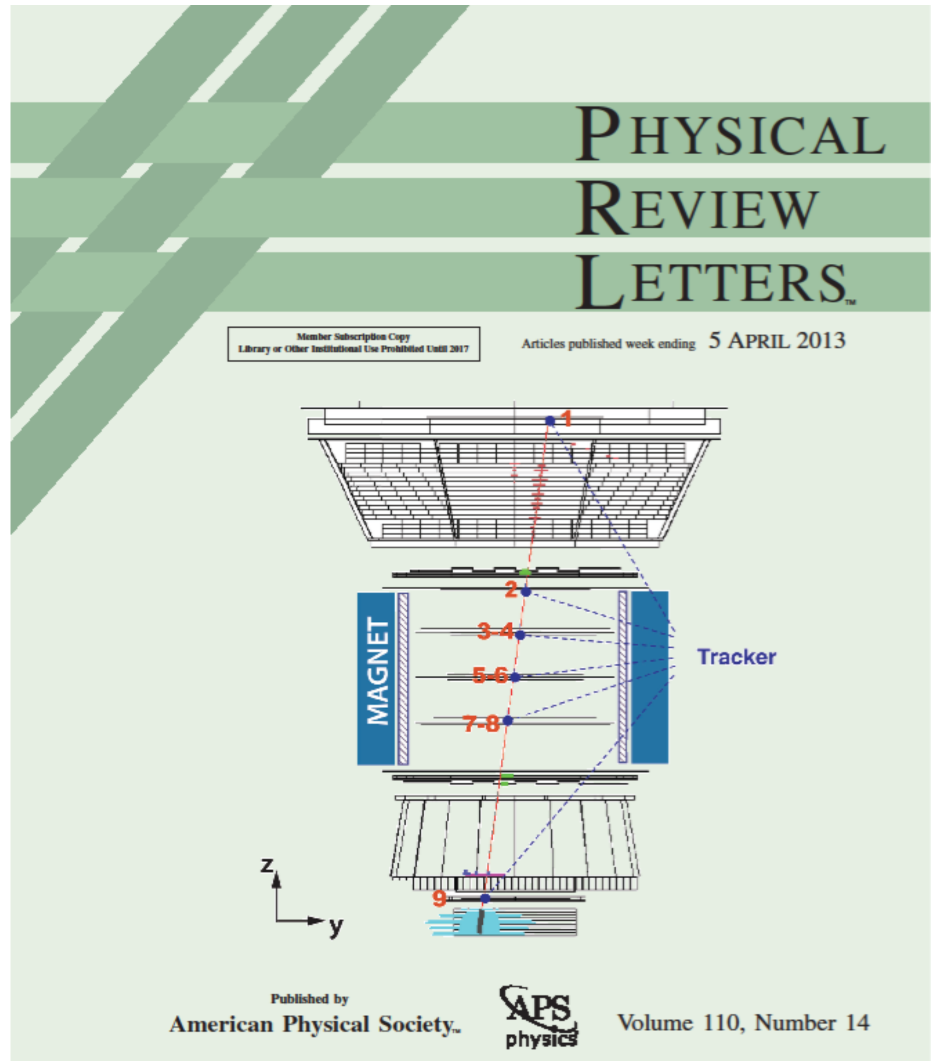


- **Indirect search of Dark Matter**: e^+, antiprotons, antideuteron, γ
- **Measuring CR spectra up to the iron**: refining propagation models;
- **Direct search of primordial antimatter**: Anti He, Anti C ...
- **New forms of matter**: strangelets
- **Identification of local sources of high energy photons**: SNR, Pulsars, ...
- **Solar activity and modulation**: CR spectra over 11 year solar cycle and SEPs

Precision Measurement of the Positron Fraction in Primary Cosmic Rays of 0.5-350 GeV

Aguilar,M. et al (AMS Collaboration) Phys. Rev. Lett. 110, 1411xx (2013)]

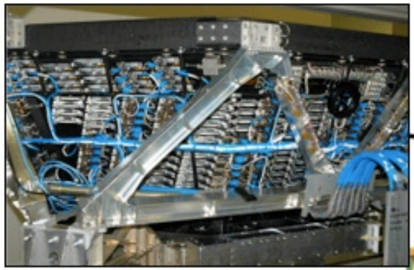
In the first 18 months in space, AMS has collected over 25 billion events. 6.8 million are electrons or positrons.



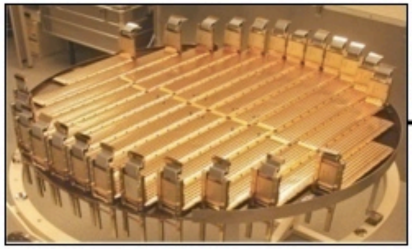
Positron identification and Proton rejection

e^+ low signal and high P background: P ~ ($10^3 \div 10^4$) e^+
P rejection factor: $10^5 \div 10^6$ to identify e^+ with an error at % level

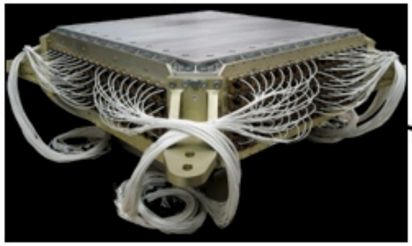
TRD
Distinguishes between e+ and P
TRD estimator:
likelihood based on signal amplitude

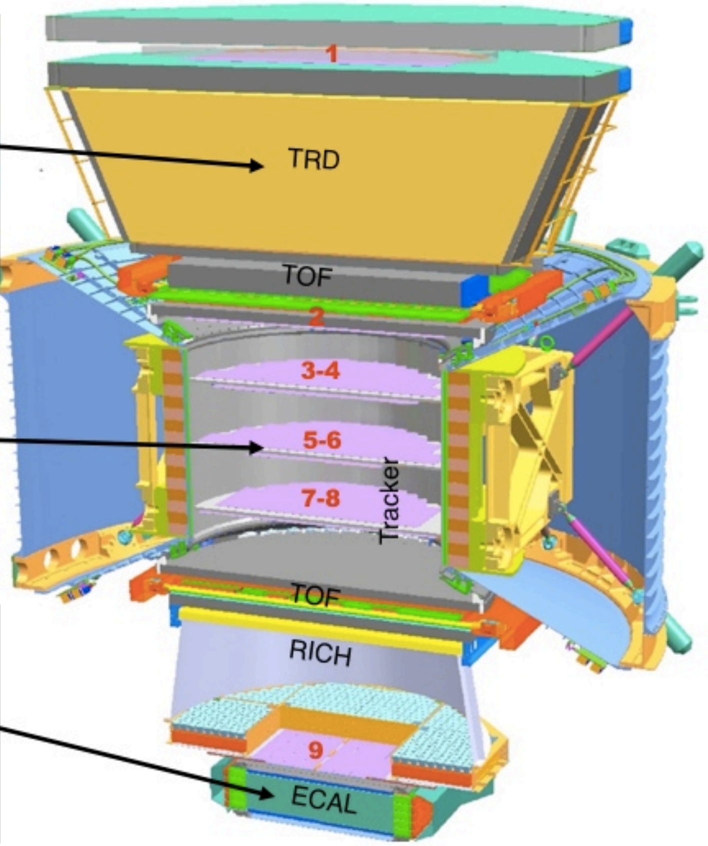


SILICON TRACKER + MAGNET
measure sign and momentum
Energy/Momentum match (EoP)



Electromagnetic CALorimeter
measures energy,
Identifies 3D positron shower and rejects hadronic showers
ECAL estimator: shower shape BDT

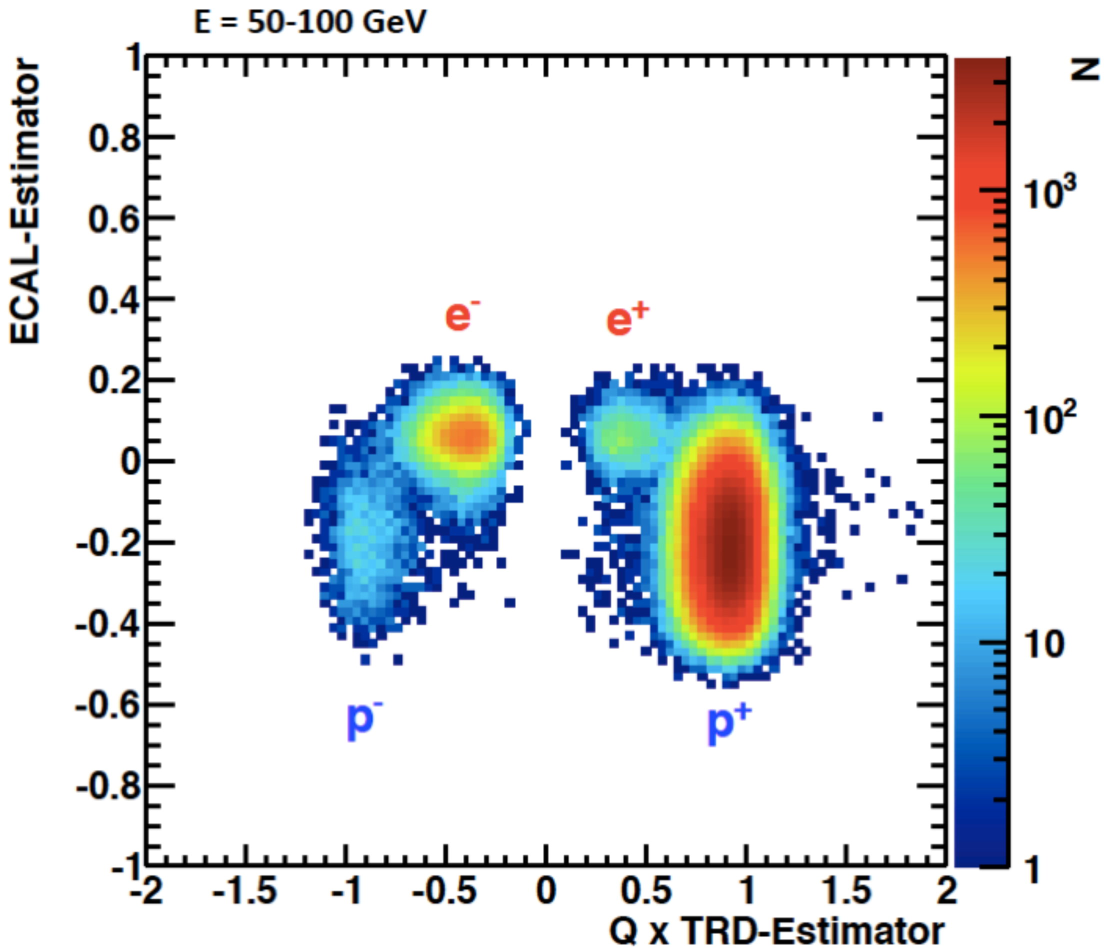




Total rejection of proton 10^6
Verified in test beam at CERN

Data selection

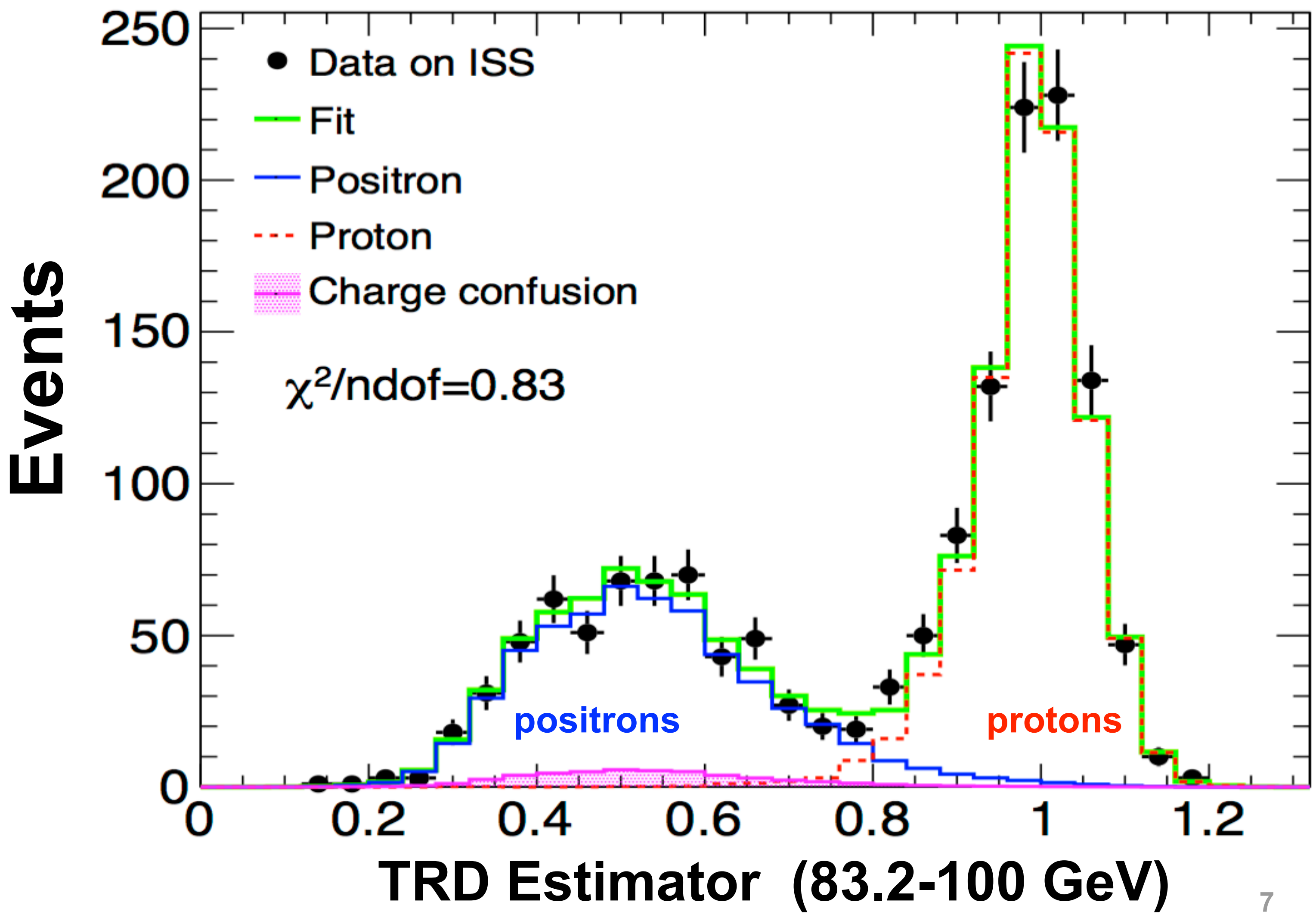
Dataset: 19 May 2011-10 December 2012, 18 months



In this sample we identify four components using an ECAL estimator (shower shape BDT) and a TRD Estimator (likelihood based on signal amplitude)

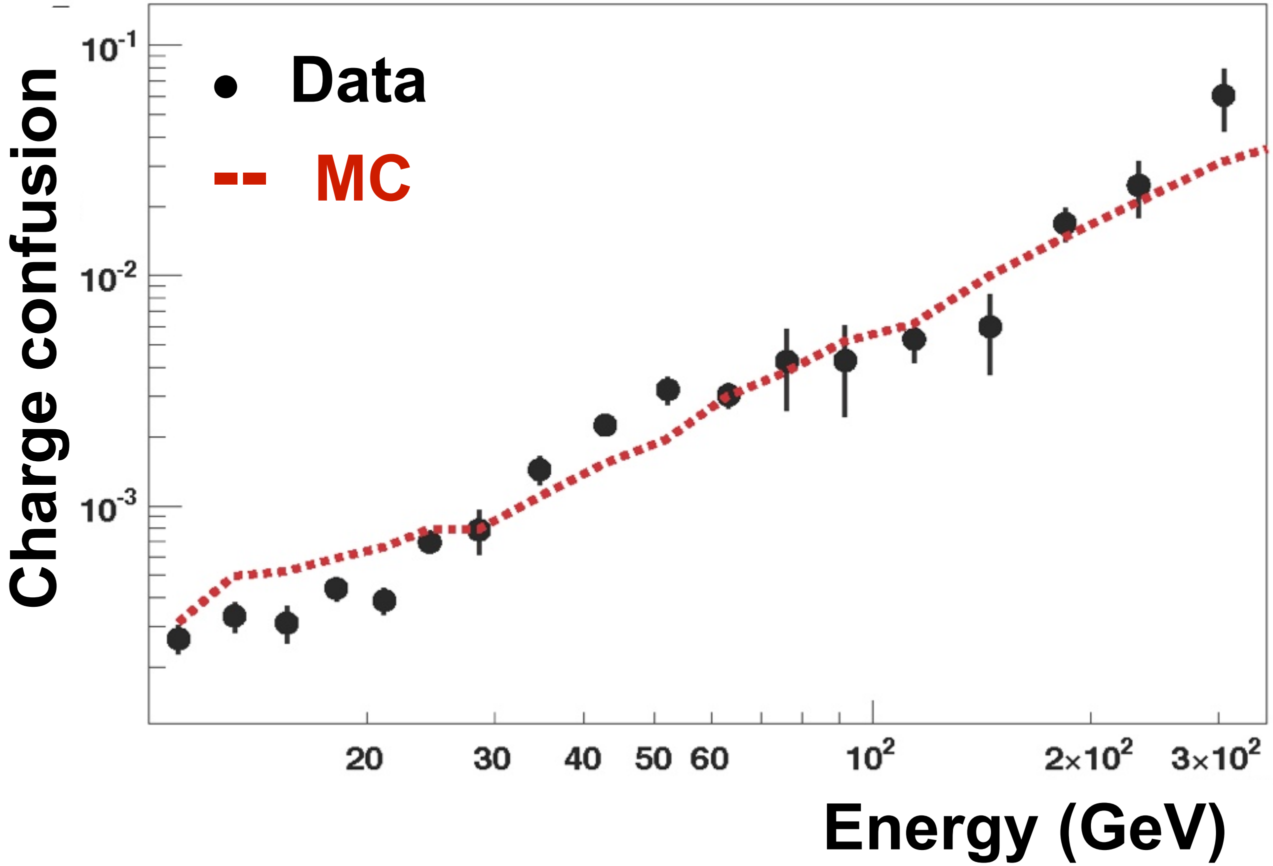
2D FIT results projected on the TRD estimator

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



Charge confusion

TB and MC have been used to define the shapes of the different charge confusion contributions

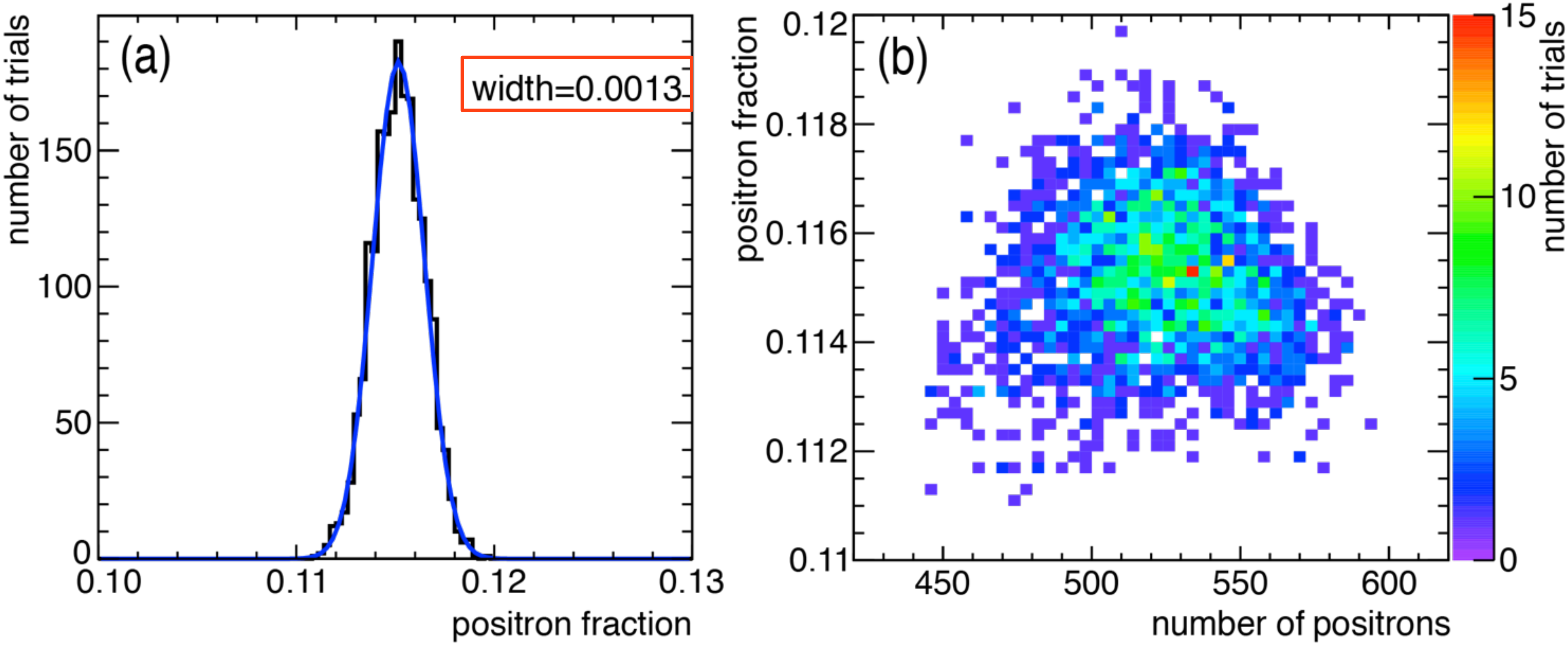


Two sources of charge confusion for electrons/positrons on TB:

- Spill over (due to resolution effect)
- Wrong hits (due to scattering, interactions, backscattering)

Difference between Data and MC added to systematic error

Systematic error example: selection dependence



For each energy bin, over 1,000 sets of cut were analyzed.
No correlation between number of positron and positron fraction.
The measurement is stable over wide variations of the cuts
in the TRD identification, ECAL Shower Shape,
E (from ECAL) matched to lPl (from Tracker).

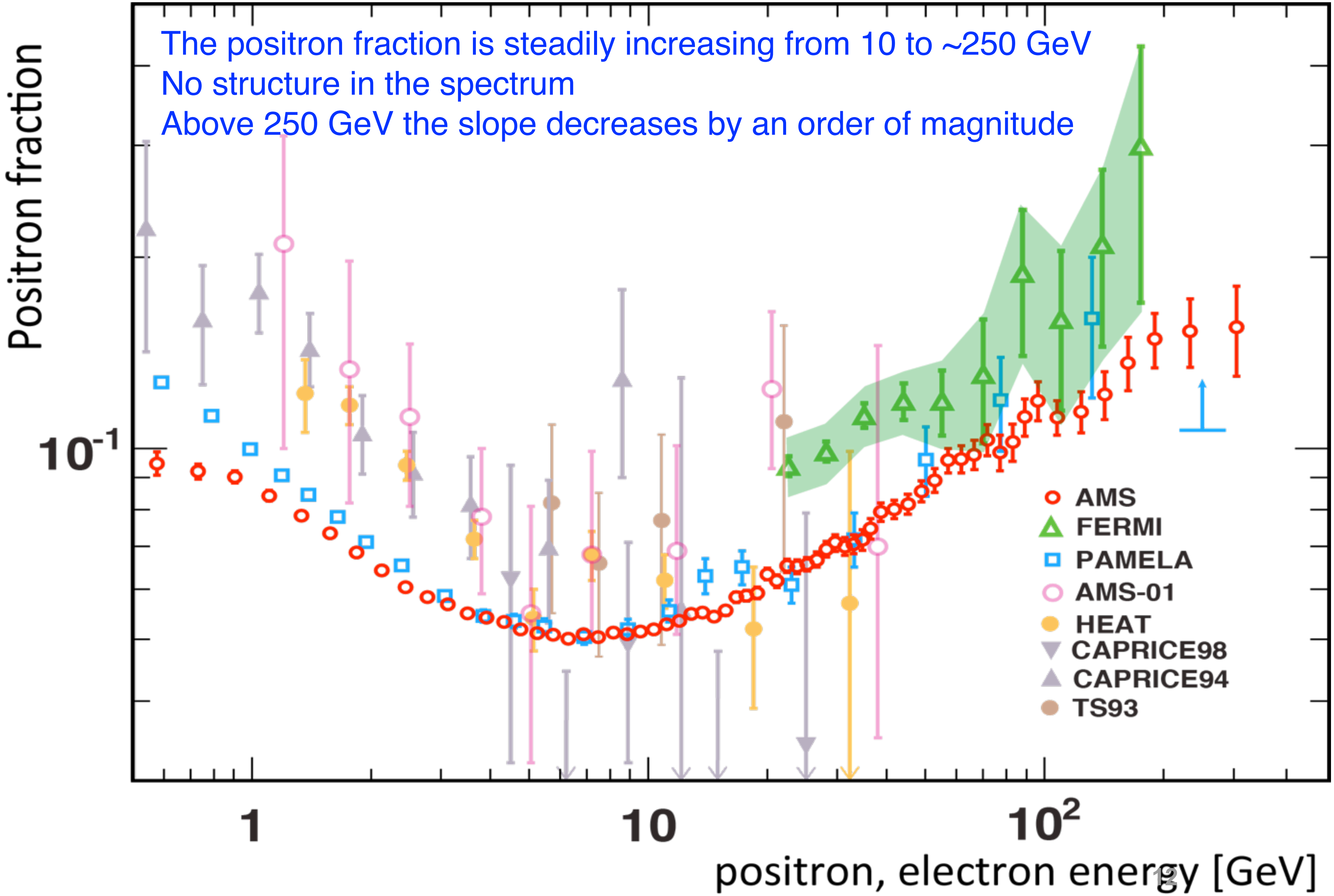
Systematic errors to positron fraction

1. Acceptance asymmetry
   - Difference between positron and electron acceptance due to known minute tracker asymmetry
2. Selection dependence
   - Dependence of the result on the cut values
3. Migration bin-to bin
   - Migration of electron and positron events from the neighboring bins affects the measured fraction
4. Reference spectrum
   - Definition of the reference spectra is based on pure samples of electrons and protons of finite statistics
5. Charge confusion
   - Two sources: large angle scattering and 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.

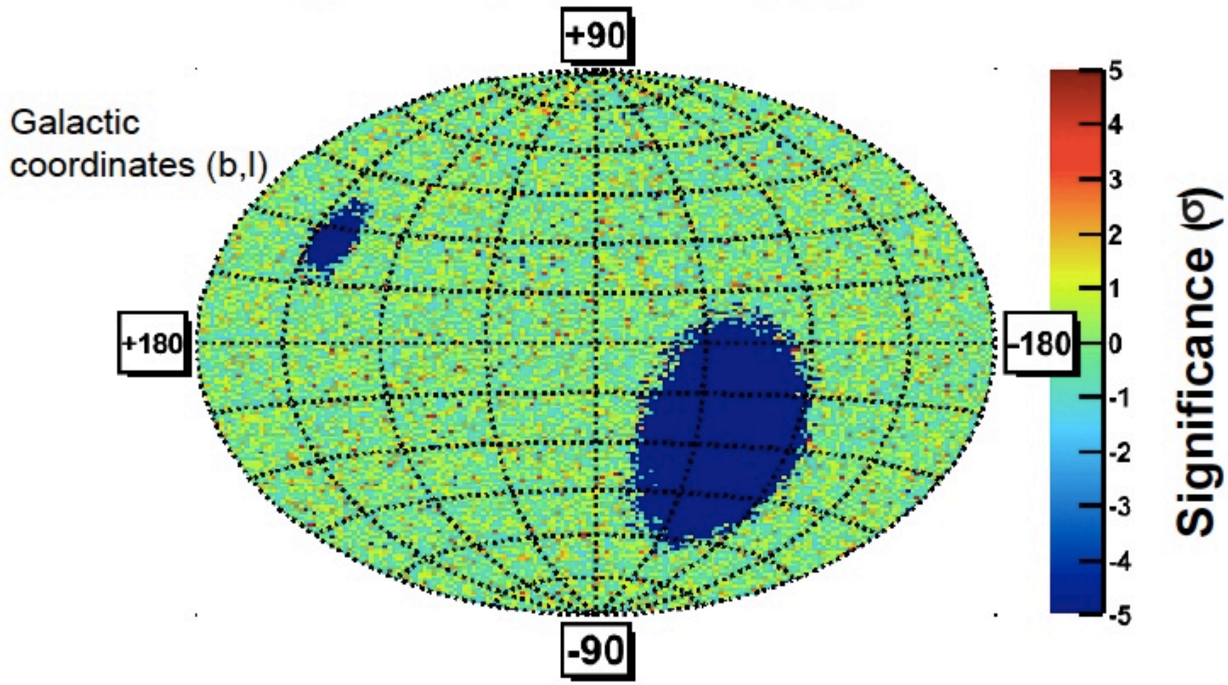
Representative bins of the positron fraction

positron fraction				Systematic Errors					
Energy [GeV]	N_{e+}	Fraction	statistical error	acceptance asymmetry	event selection	bin-to-bin migration	reference spectra	charge confusion	total systematic uncertainty
Energy[GeV]	N_{e+}	Fraction	$\sigma_{stat.}$	$\sigma_{acc.}$	$\sigma_{sel.}$	$\sigma_{mig.}$	$\sigma_{ref.}$	$\sigma_{c.c.}$	$\sigma_{syst.}$
1.00 -1.21	9 335	0.0842	0.0008	0.0005	0.0009	0.0008	0.0001	0.0005	0.0014
1.97 -2.28	23 893	0.0642	0.0004	0.0002	0.0005	0.0002	0.0001	0.0002	0.0006
3.30 -3.70	20 707	0.0550	0.0004	0.0001	0.0003	0.0000	0.0001	0.0002	0.0004
6.56 -7.16	13 153	0.0510	0.0004	0.0001	0.0000	0.0000	0.0001	0.0002	0.0002
09.95 -10.73	7 161	0.0519	0.0006	0.0001	0.0000	0.0000	0.0001	0.0002	0.0002
19.37 -20.54	2 322	0.0634	0.0013	0.0001	0.0001	0.0000	0.0001	0.0002	0.0003
30.45 -32.10	1094	0.0701	0.0022	0.0001	0.0002	0.0000	0.0001	0.0003	0.0004
40.00 -43.39	976	0.0802	0.0026	0.0002	0.0005	0.0000	0.0001	0.0004	0.0007
50.87 -54.98	605	0.0891	0.0038	0.0002	0.0006	0.0000	0.0001	0.0004	0.0008
64.03 -69.00	392	0.0978	0.0050	0.0002	0.0010	0.0000	0.0002	0.0007	0.0013
74.30 -80.00	276	0.0985	0.0062	0.0002	0.0010	0.0000	0.0002	0.0010	0.0014
86.00 -92.50	240	0.1120	0.0075	0.0002	0.0010	0.0000	0.0003	0.0011	0.0015
100.0 -115.1	304	0.1118	0.0066	0.0002	0.0015	0.0000	0.0003	0.0015	0.0022
115.1 -132.1	223	0.1142	0.0080	0.0002	0.0019	0.0000	0.0004	0.0019	0.0027
132.1 -151.5	156	0.1215	0.0100	0.0002	0.0021	0.0000	0.0005	0.0024	0.0032
151.5 -173.5	144	0.1364	0.0121	0.0002	0.0026	0.0000	0.0006	0.0045	0.0052
173.5 -206.0	134	0.1485	0.0133	0.0002	0.0031	0.0000	0.0009	0.0050	0.0060
206.0 -260.0	101	0.1530	0.0160	0.0003	0.0031	0.0000	0.0013	0.0095	0.0101
260.0 -350.0	72	0.1550	0.0200	0.0003	0.0056	0.0000	0.0018	0.0140	0.0152

Positron Fraction



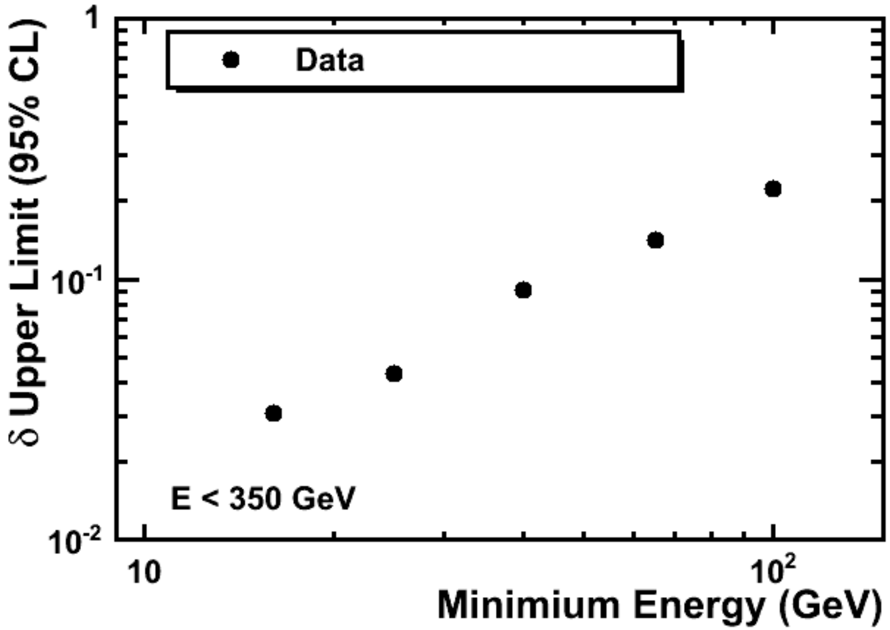
New results from the first 2 years of AMS: On the origin of excess of positrons



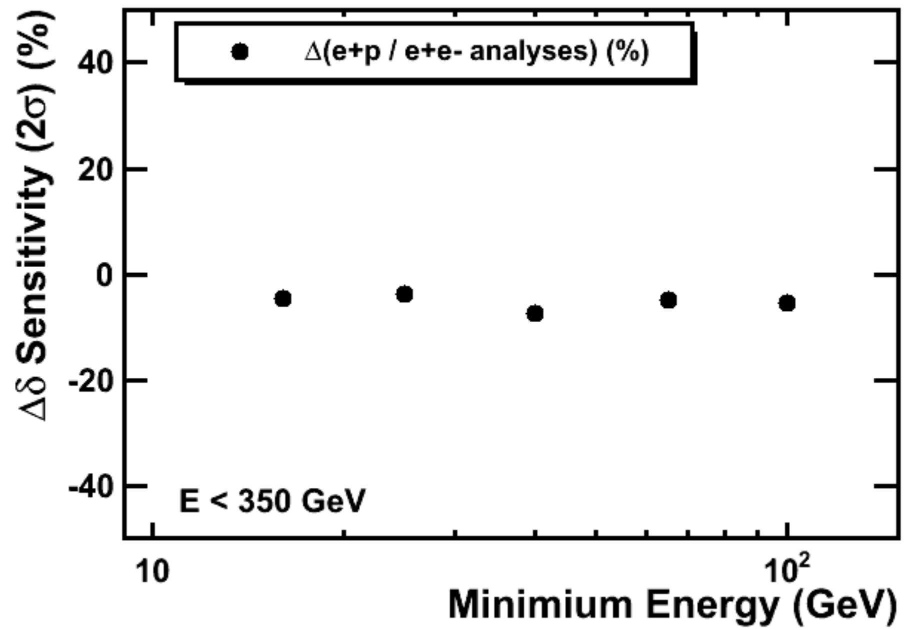
The fluctuations of the positron ratio e^+/e^- are isotropic

The relative fluctuations of the positron ratio across the observed sky map show no evident pattern.

New results from the first 2 years of AMS: AMS upper limits on dipole anisotropy at the 95% CL



Limits on the amplitude of a dipole anisotropy in any axis in galactic coordinates on the positron to electron ratio in the energy range from 16 GeV to 350 GeV



The sensitivity to a dipole anisotropy using the positron to proton ratio is consistent with the one obtained on the positron to electron analysis

δ <0.030 for 16<E<350GeV

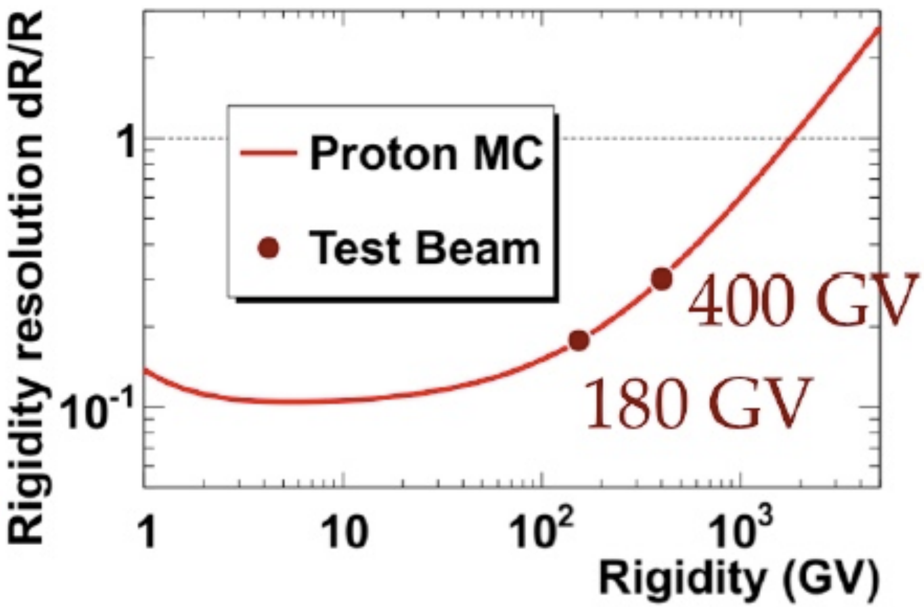
New results from the first 2 years of AMS: Proton flux

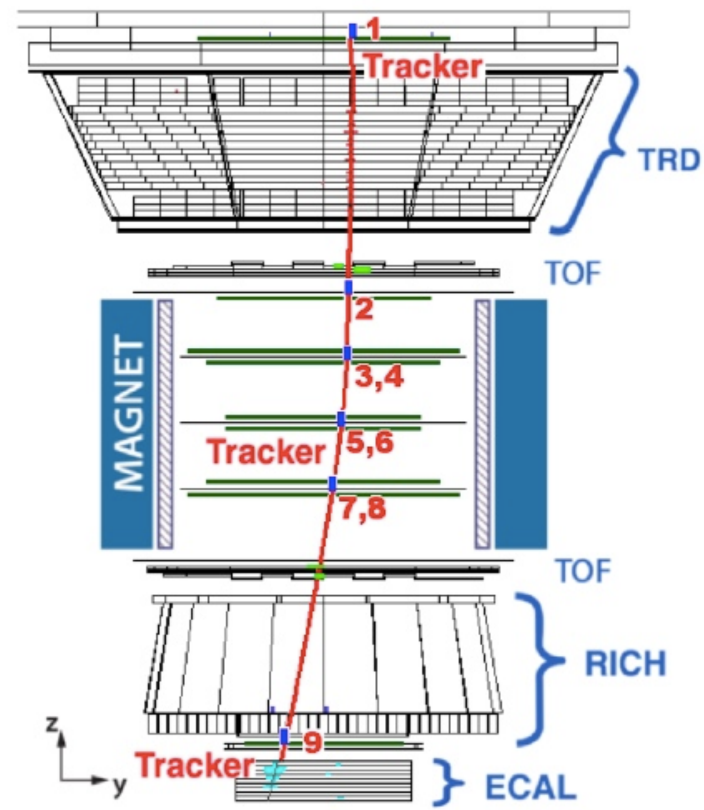
Selected events (N_{obs})

- Events with at least one track and signal from Layer 1 and 9
- Normalized χ^2 of the track fitting: $\chi^2 < 10$

Final selected events: N_{obs} (R>1GV) = 3.3×10^8

$B_x = \sim 0.14$ T
$L = \sim 3$ m
$\sigma_y = \sim 10$ μm
MDR : ~ 2 TV





New results from the first 2 years of AMS: Proton flux measurement

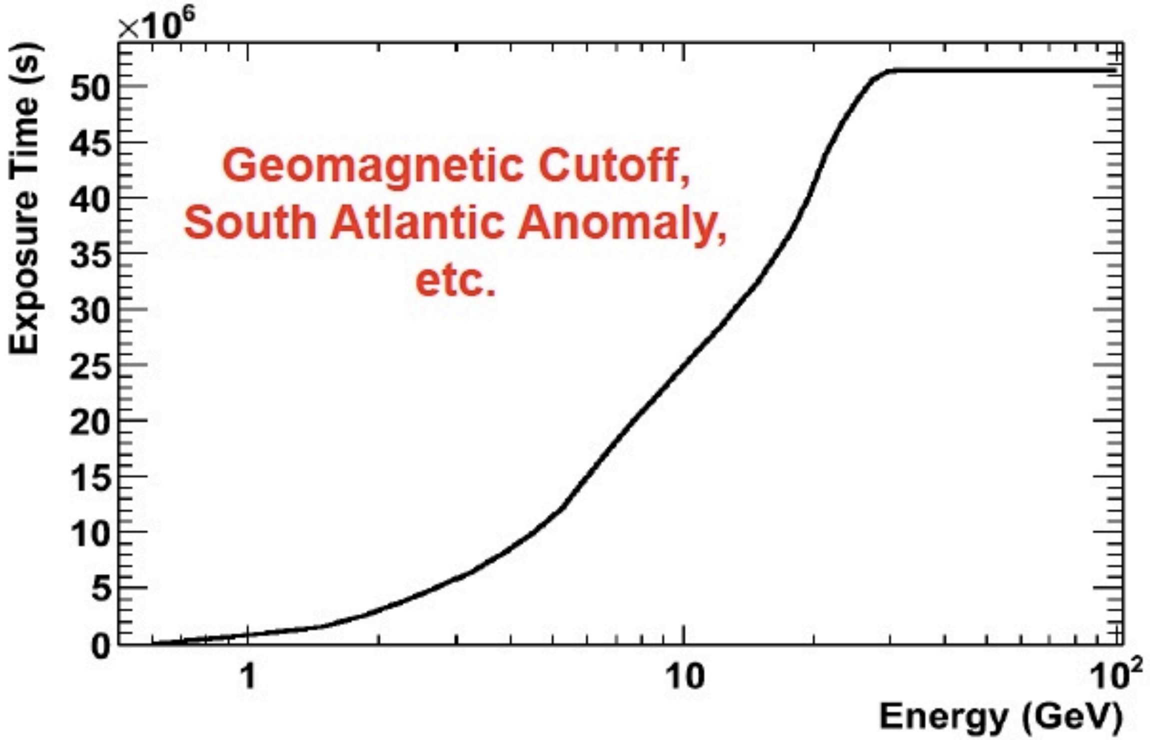
$$F(R) = \frac{N_{obs.}(R)}{T_{exp.}(R)\, A_{eff.}(R)\, \varepsilon_{trig.}(R)\, dR}$$

(For isotropic flux with $\theta_{zen} < 20°$)

- F : Absolute differential flux ($m^{-2}sr^{-1}s^{-1}GV^{-1}$)
- R : Measured rigidity (GV)
- $N_{obs.}$: Number of events after proton selection
- $T_{exp.}$: Exposure life time (s)
- $A_{eff.}$: Effective acceptance (m^2 sr)
- $\varepsilon_{trg.}$: Trigger efficiency
- dR : Rigidity bin (GV)

New results from the first 2 years of AMS: Exposure Time

Data taken:
from May 19, 2011 to May 19, 2013
Total exposure time (R>25 GV): 51.2 x 10^6 sec
Average Live time: T_{exp}/2 years = 81.6%



New results from the first 2 years of AMS: Effective Acceptance

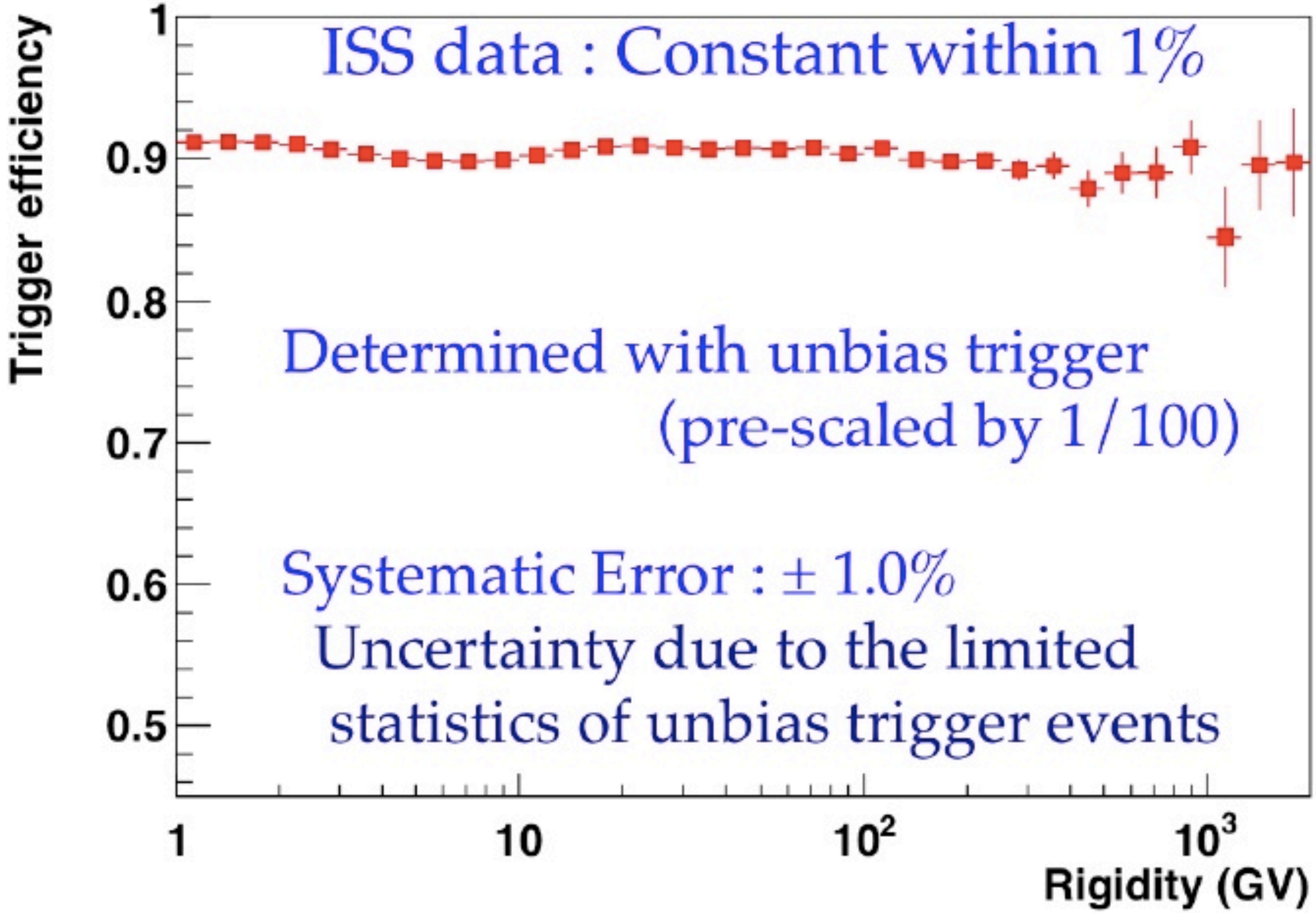
- Estimated with MC (Geant 4)

$$A_{\mathrm{eff.}}(R) = A_{\mathrm{generated}} \times \frac{N_{\mathrm{passed}}(R)}{N_{\mathrm{generaged}}(R)}$$

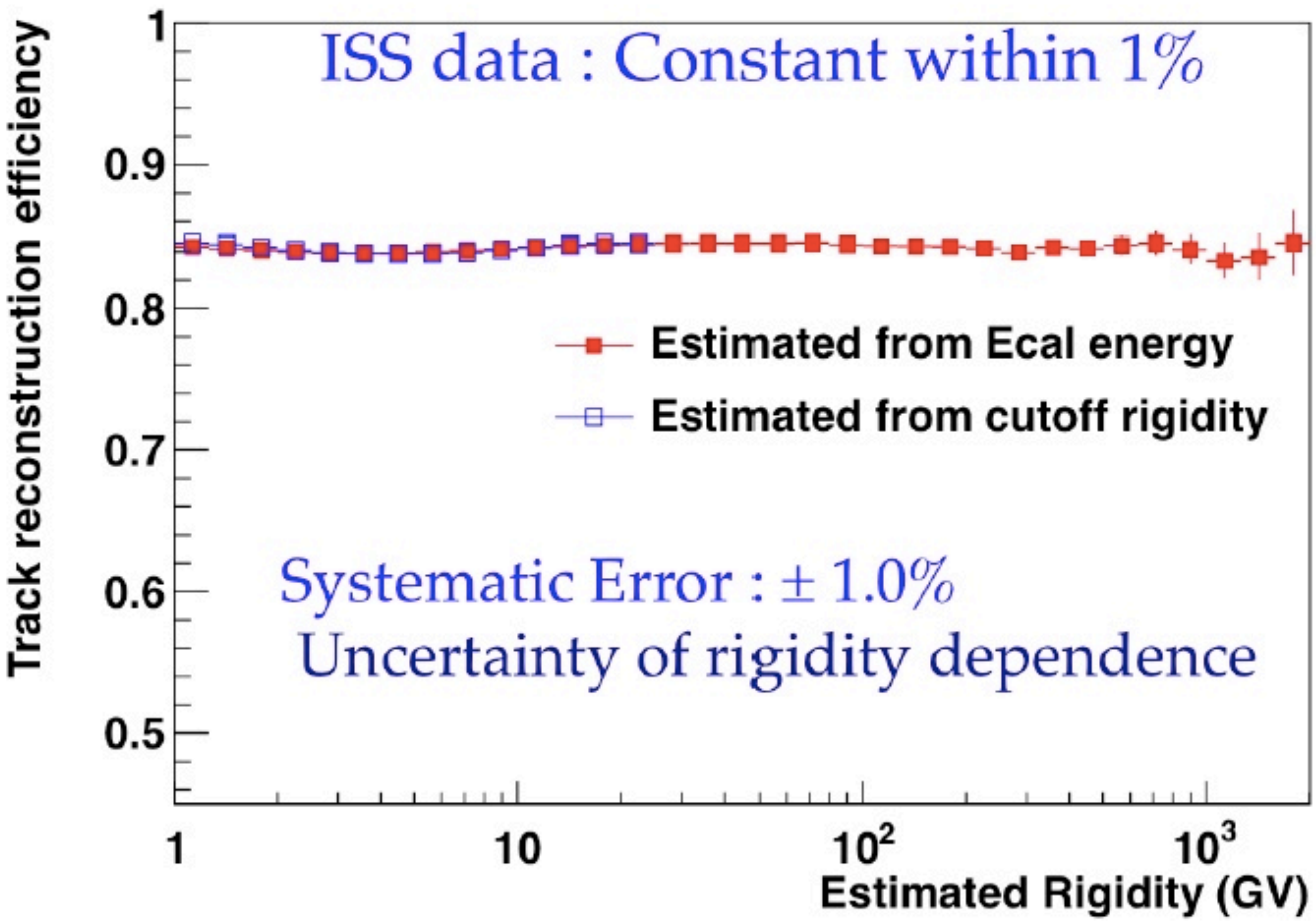
where $A_{\mathrm{generated}} = \pi \times 3.9 \times 3.9\ \mathrm{m^2 sr}$

- Constant for $R > 10$ GV
- Systematic error : ± 2.8 %
  due to the uncertainty of energy dependence of the hadronic interaction probability

New results from the first 2 years of AMS: Trigger Efficiency



New results from the first 2 years of AMS: Track Reconstruction Efficiency



Includes events passing out of tracker sensitive area (~91%)

New results from the first 2 years of AMS: Systematic errors

- Acceptance $\varepsilon_{acc} = 2.8\,\%$
- Trigger efficiency $\varepsilon_{trg.} = 1.0\,\%$
- Track reconstruction efficiency $\varepsilon_{trk.} = 1.0\,\%$
- Total systematic errors of normalization :

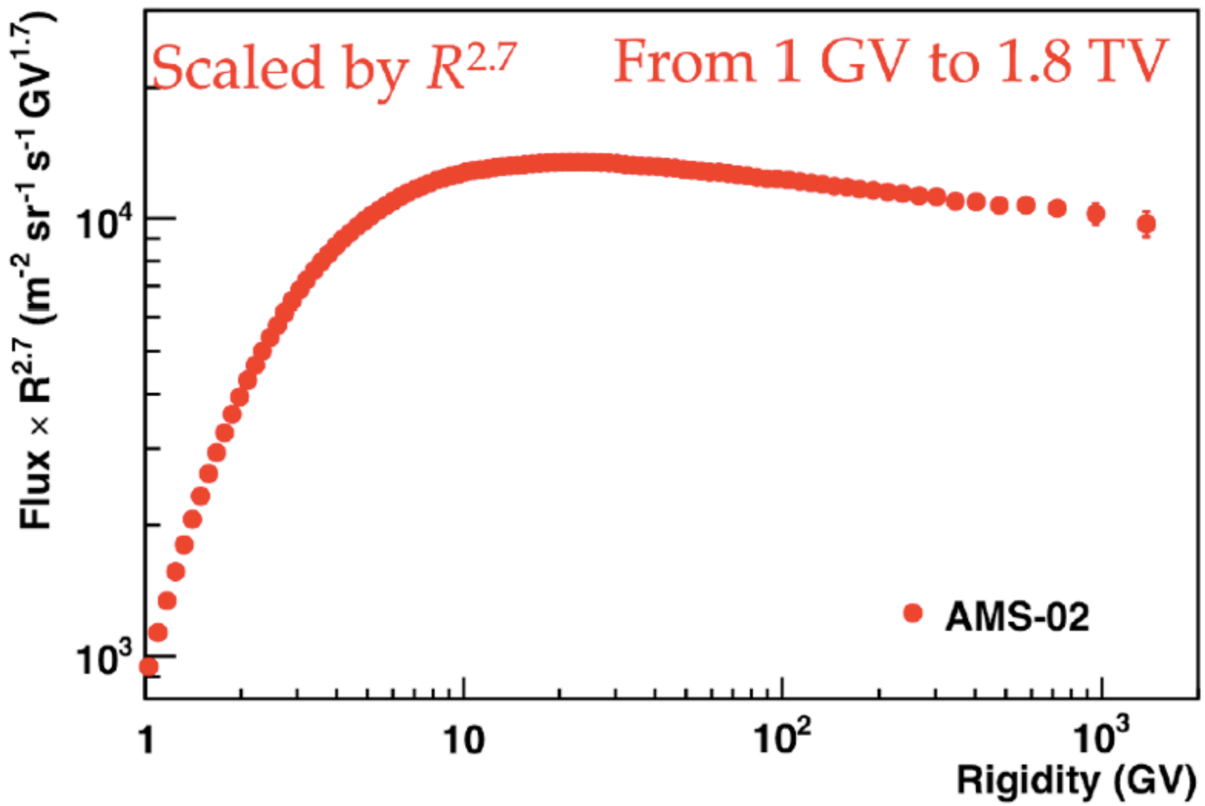
$$\varepsilon_{norm.} = (\varepsilon_{acc}{}^2 + \varepsilon_{trg}{}^2 + \varepsilon_{trk}{}^2)^{1/2} = 3.1\,\%$$

- Systematic error of unfolding

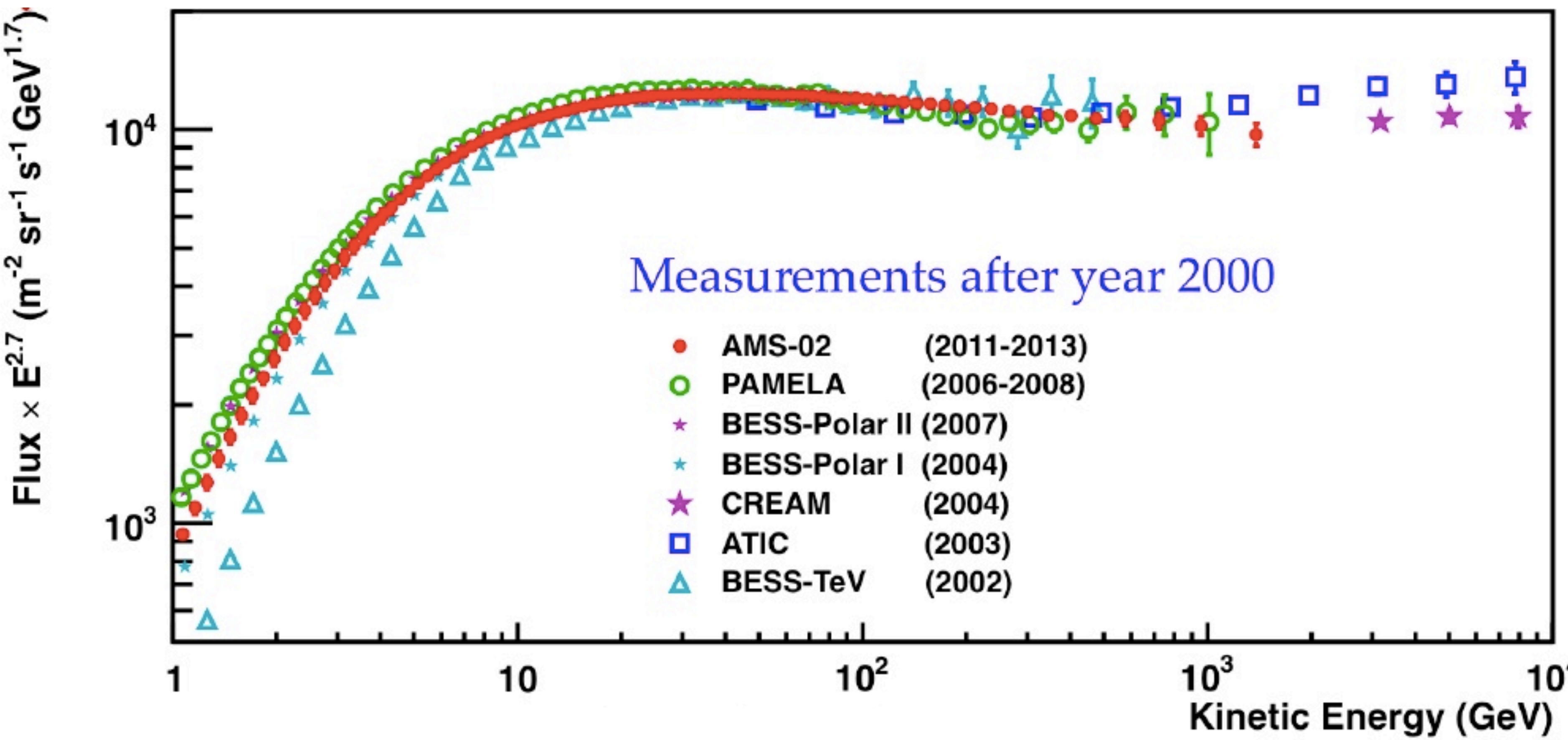
$$\varepsilon_{unfold} < 1\,\% \text{ at } R < 200 \text{ GV}$$
$$\varepsilon_{unfold} = 5.4\,\% \text{ at } R = 1 \text{ TV}$$

New results from the first 2 years of AMS: Proton flux (May 2011 / May 2013)

- The proton flux (multiplied by $R^{2.7}$) measured from 1 GV to 1.8 TV
- In the low rigidity region (R < 20 GV) the flux is determined every day with < ~ 1% stat. errors
- In the high rigidity region (R >100 GV) the spectrum is consistent with a single power law, no fine structures nor break were found on the spectrum

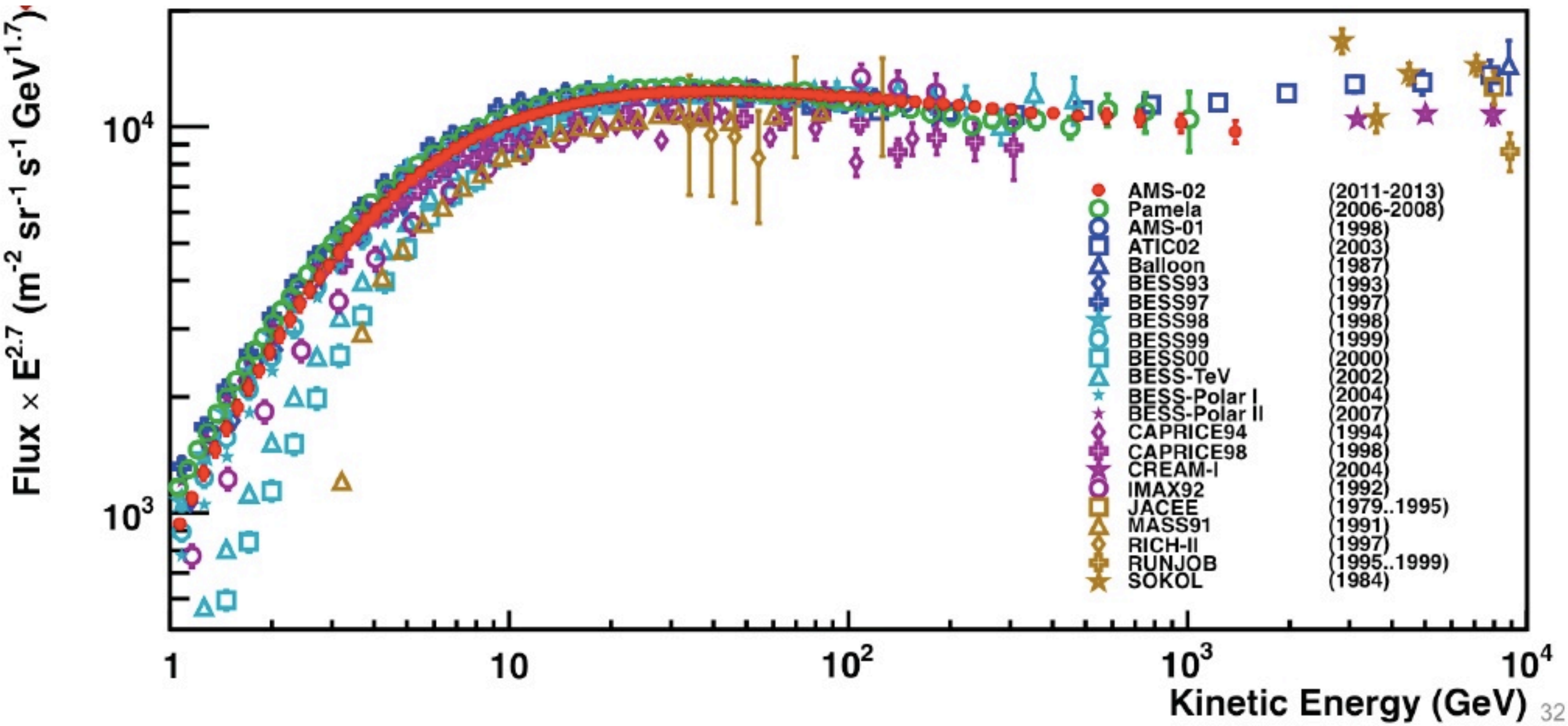


Proton flux:
Comparison with past measurements



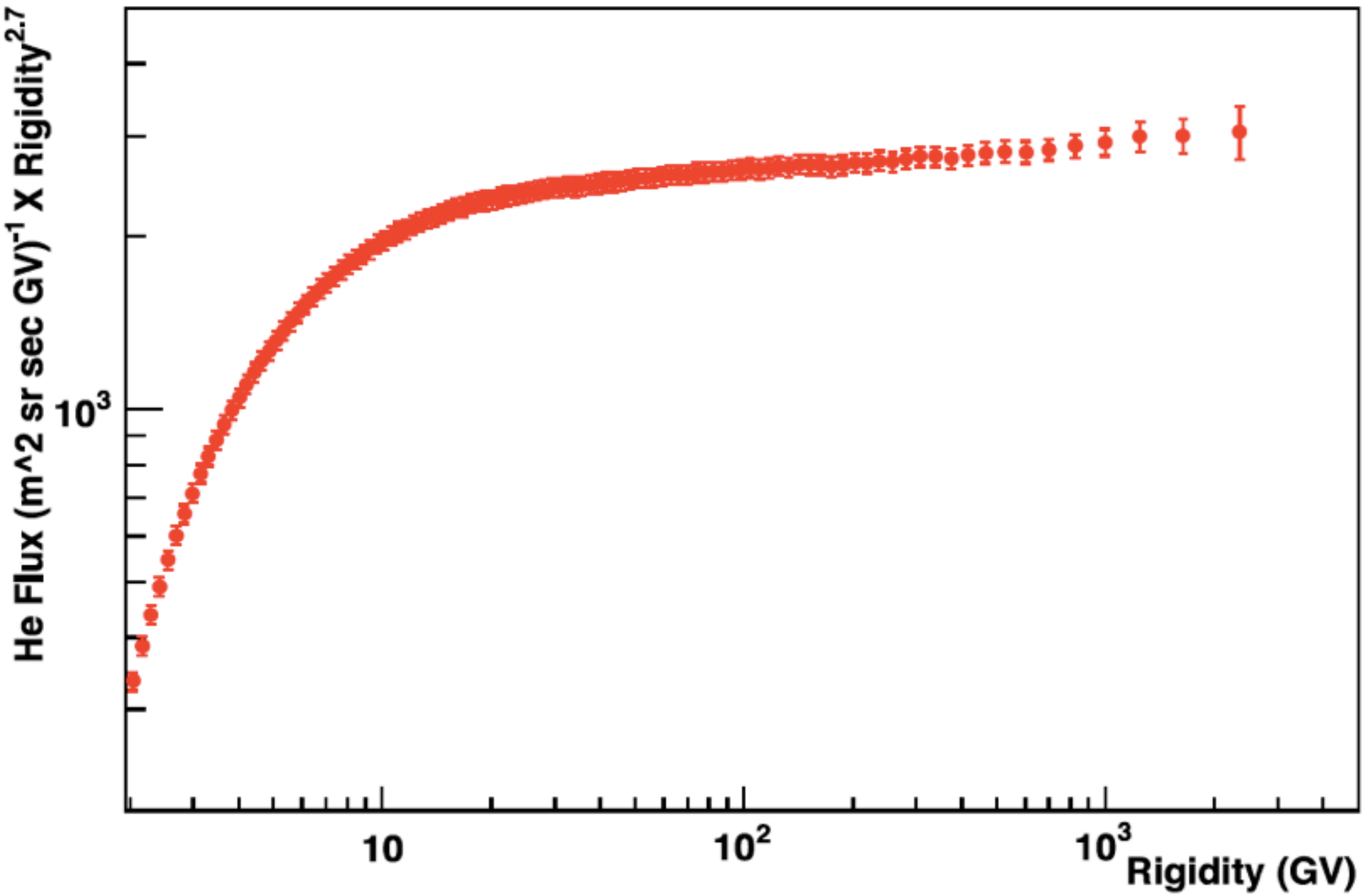
Comparison with latest measurements

Proton flux:
Comparison with past measurements

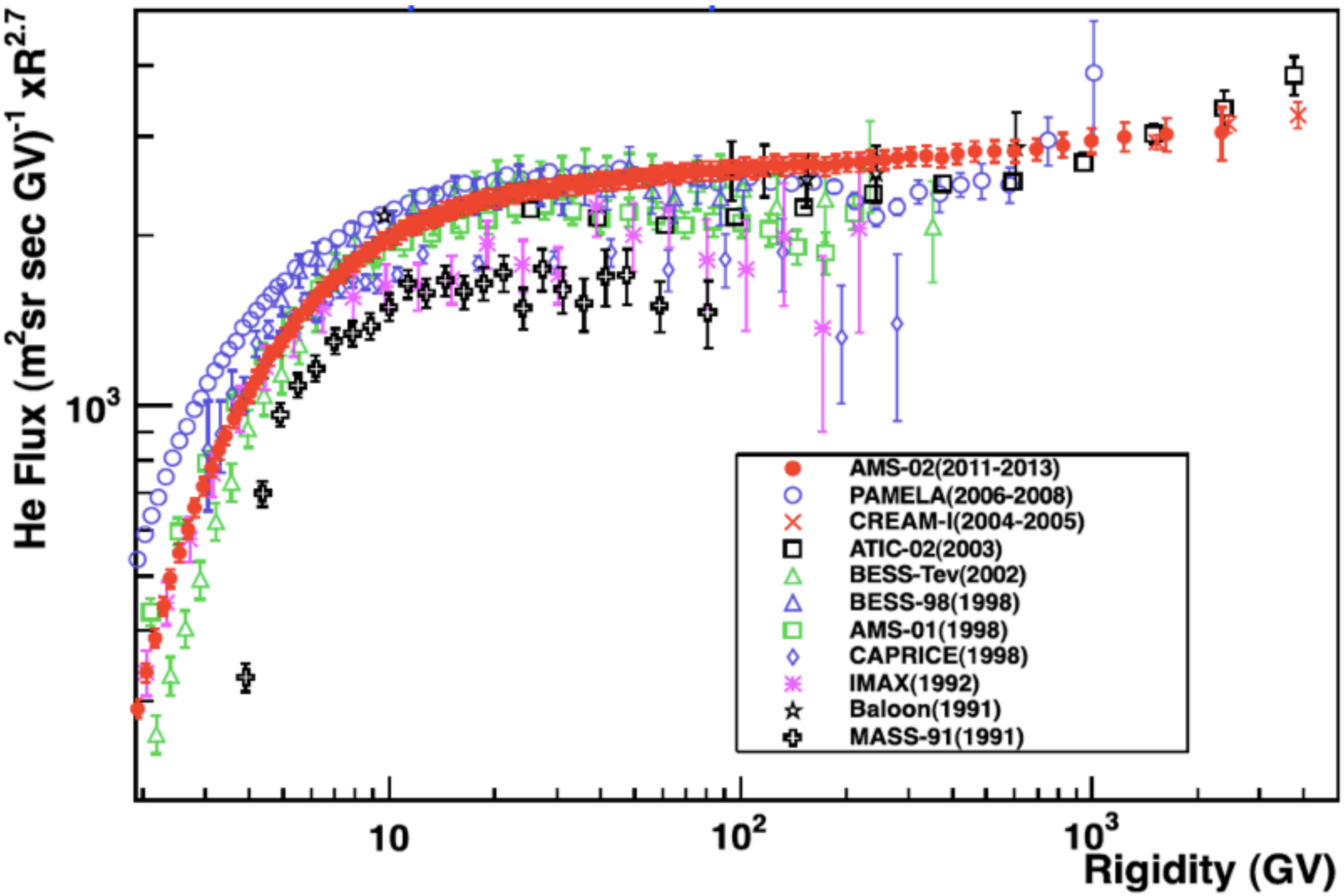


New results from the first 2 years of AMS: Helium flux (May 2011 / May 2013)

- The helium flux (multiplied by $R^{2.7}$) measured from 2 GV to 3.2 TV
- Above 10 GV the spectrum can be parametrized by a single power law
- No fine structures were found on the spectrum



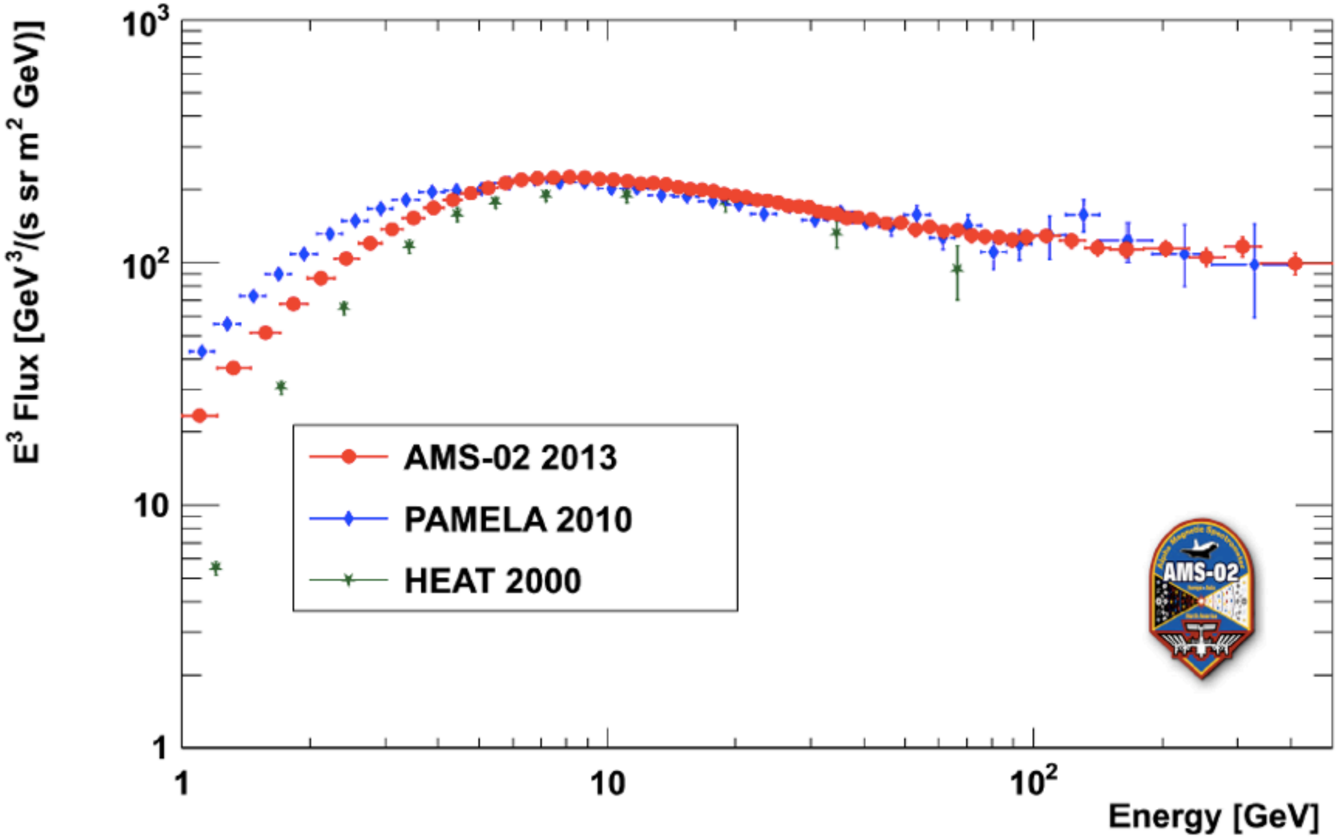
New results from the first 2 years of AMS: Helium flux (May 2011 / May 2013)



Comparison with past measurements

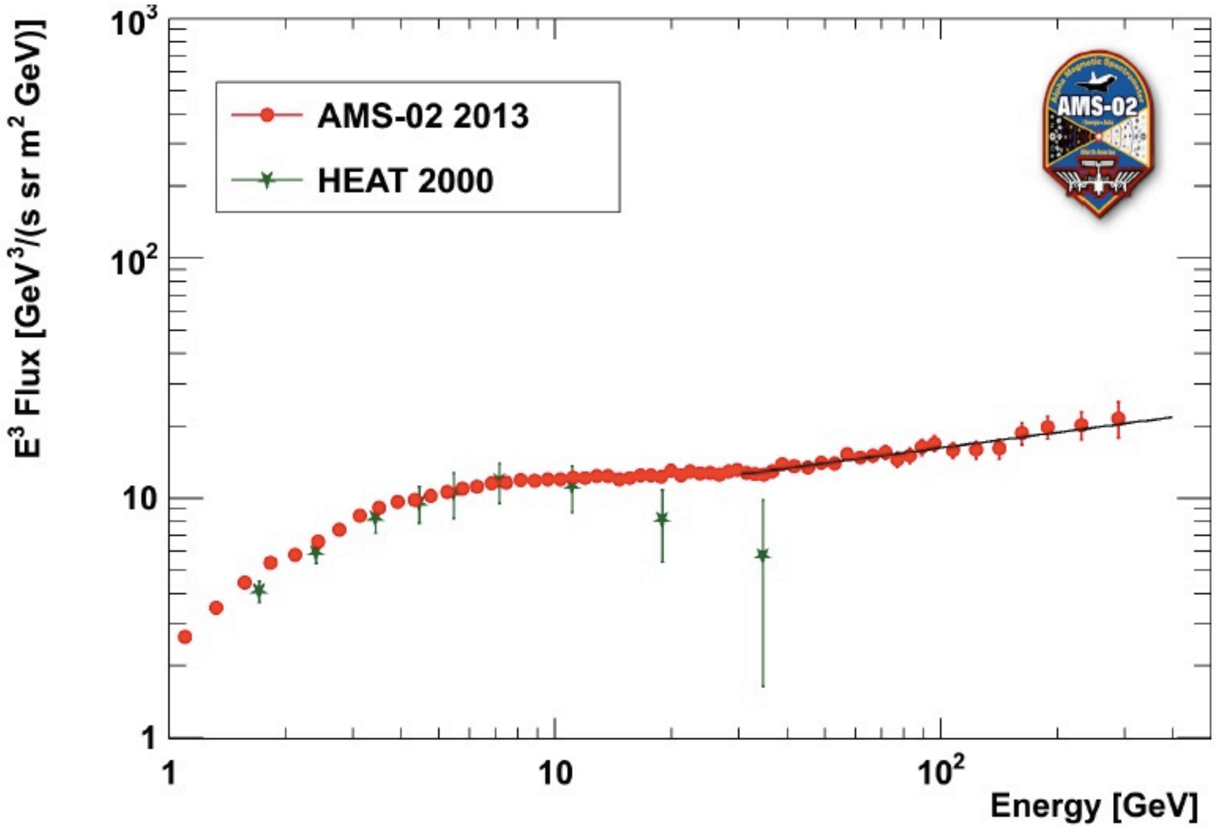
New results from the first 2 years of AMS: Electron flux (May 2011 / May 2013)

- The electron flux (multiplied by E^3) up to 500 GeV
- It is rising up to 10 GeV and appears to be on a smooth, slowly falling curve above.
- The measurement is in good agreement with the previous data.
- The differences at low energies can be attributed to the effect of the solar modulation.



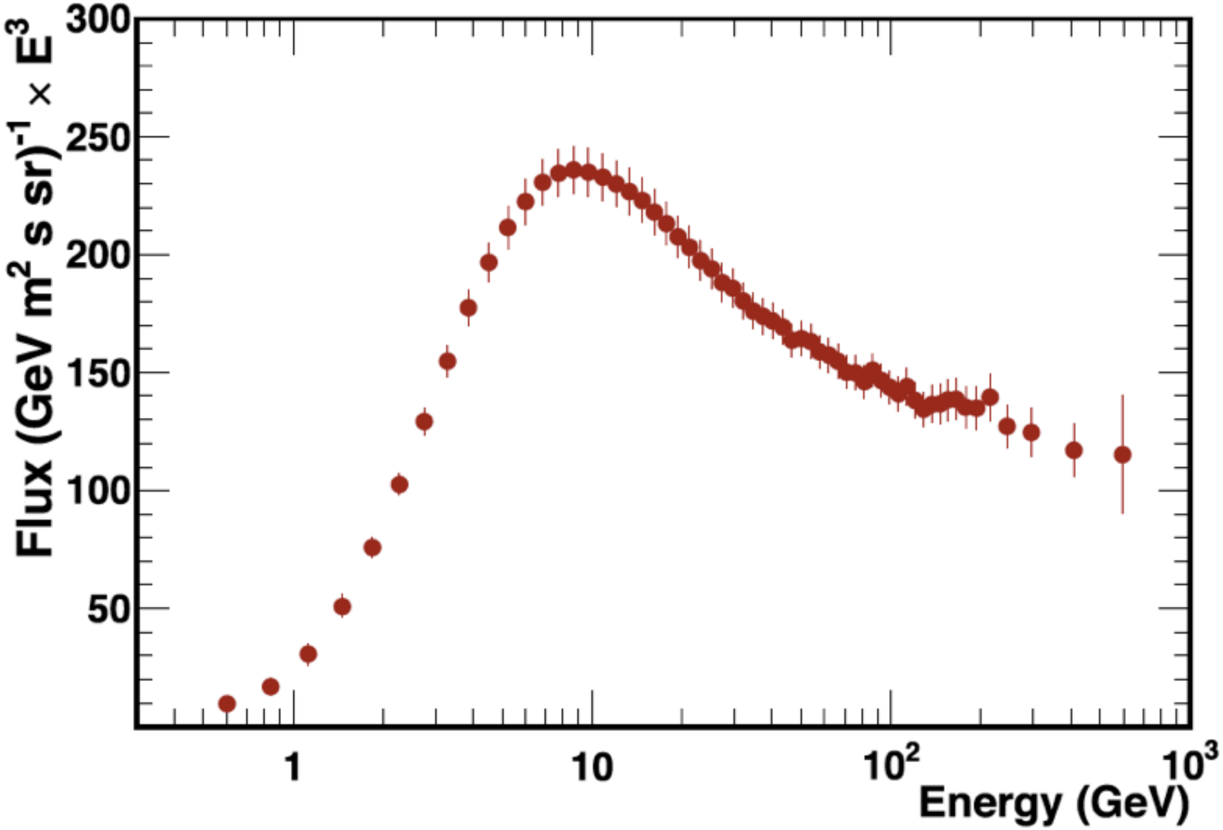
New results from the first 2 years of AMS: Positron flux (May 2011 / May 2013)

- The positron flux (multiplied by E^3) measured up to 350 GeV.
- It is rising up to 10 GeV, from 10 to 30 GeV the spectrum is flat and above 30 GeV again rising as indicated by the black line in the figure.
- The spectral index and its dependence on energy is clearly different from the electron spectrum.
- In the low energy range the agreement with HEAT results is good.

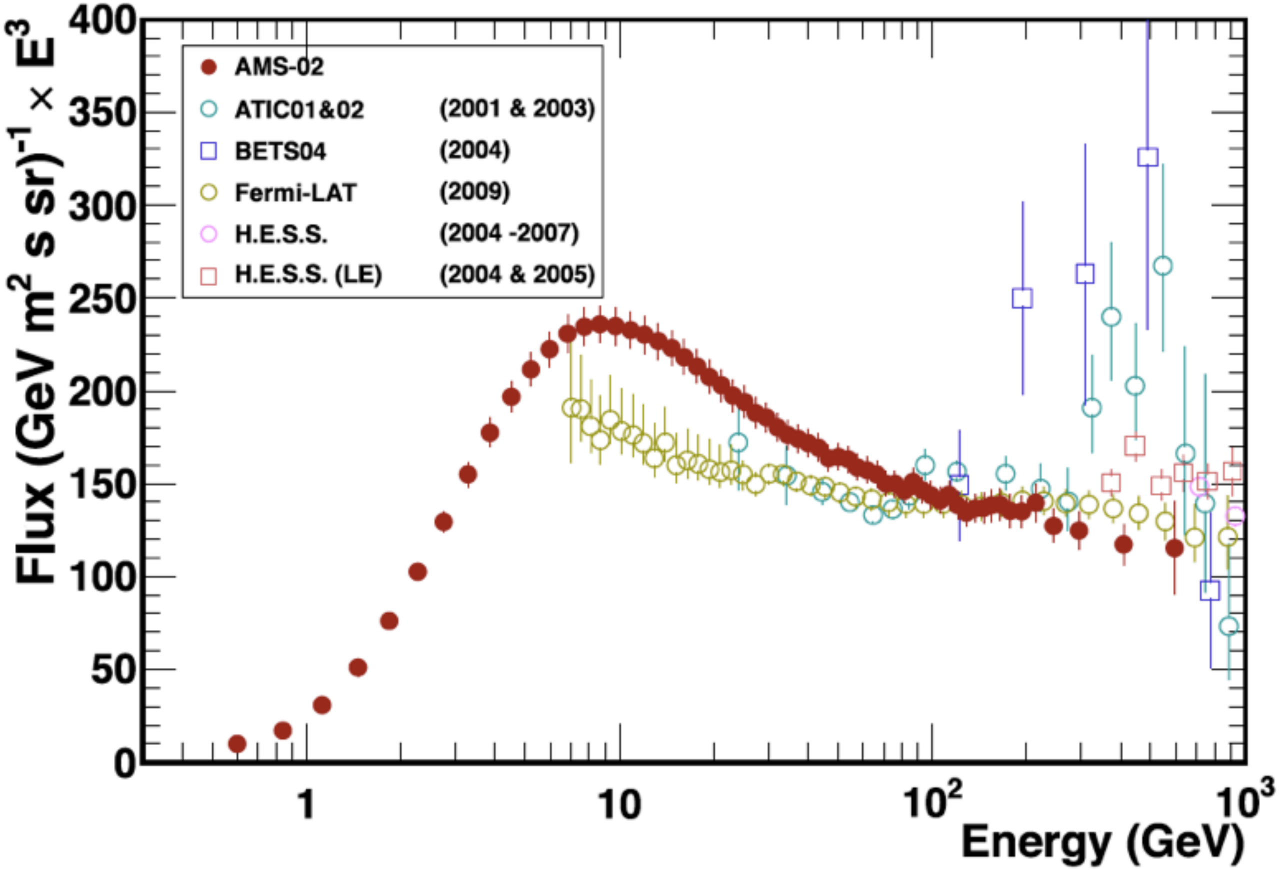


New results from the first 2 years of AMS: Electron plus Positron flux (May 2011 / May 2013)

- Electron plus positron spectrum measured up to 700 GeV and multiplied by E^3
- shows no evidence of structures.
- a change in the spectral distribution with increasing energy is seen compatible with the fraction.

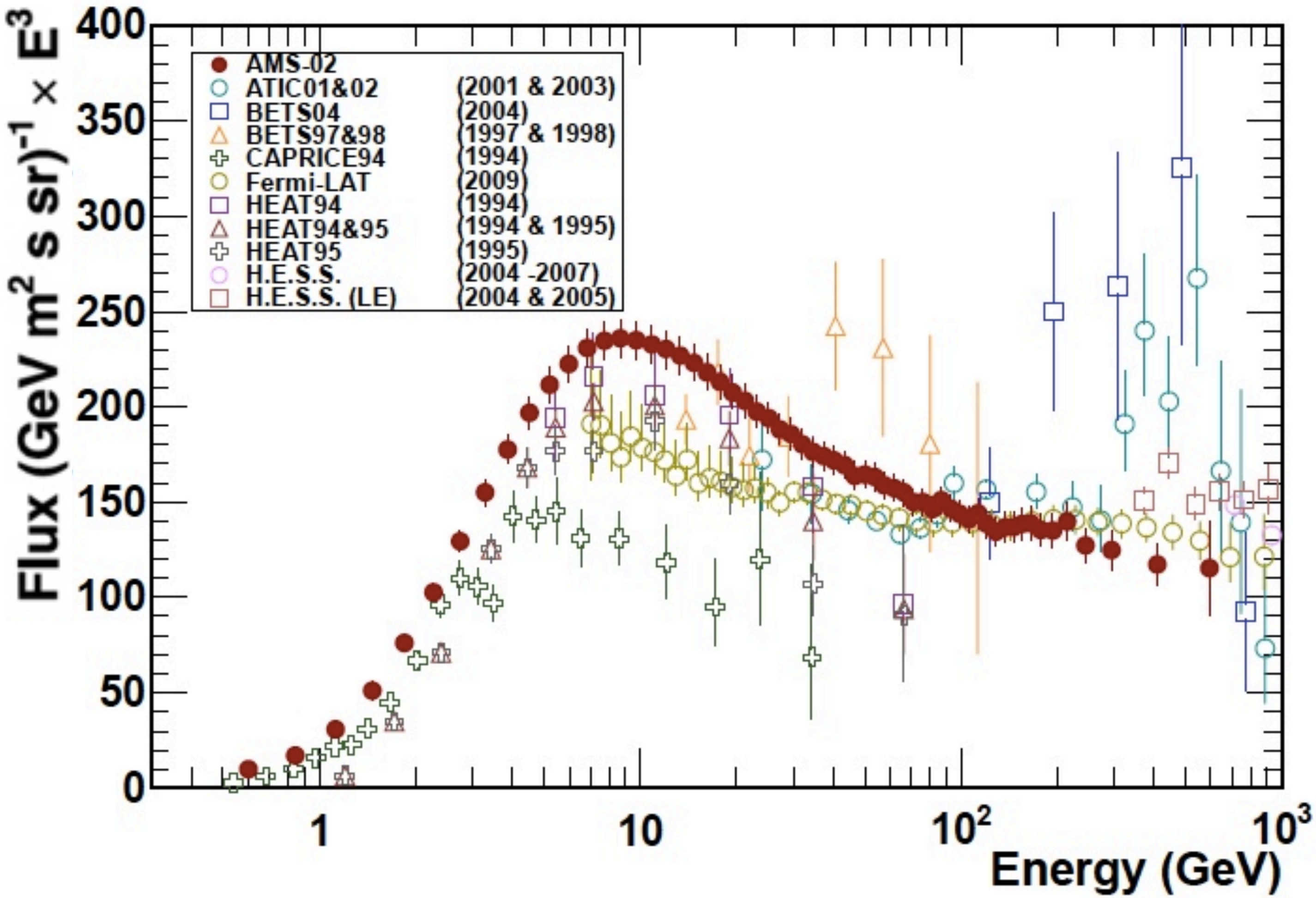


New results from the first 2 years of AMS: Electron plus Positron flux (May 2011 / May 2013)



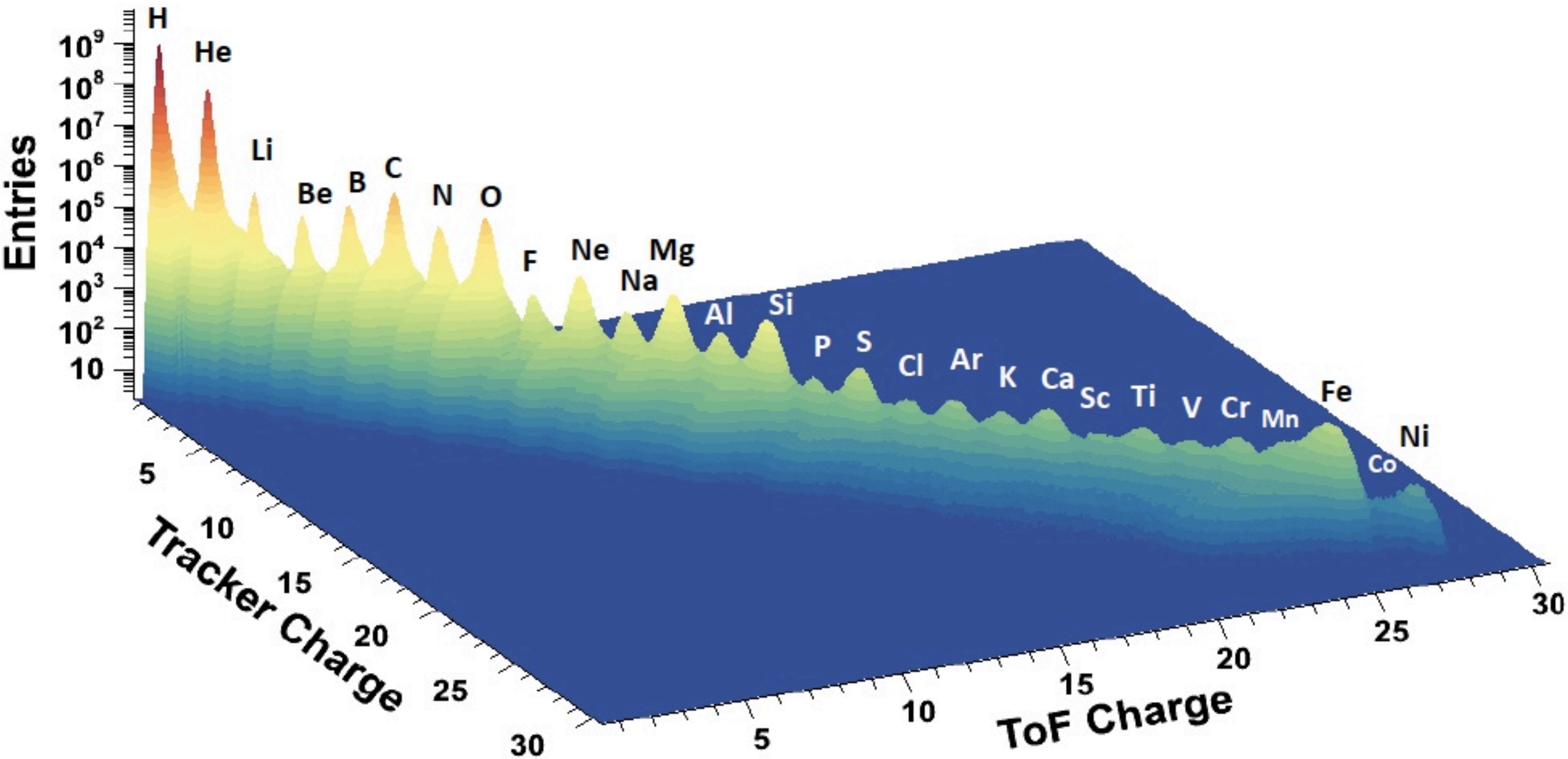
Comparison with latest measurements

New results from the first 2 years of AMS: Electron plus Positron flux (May 2011 / May 2013)



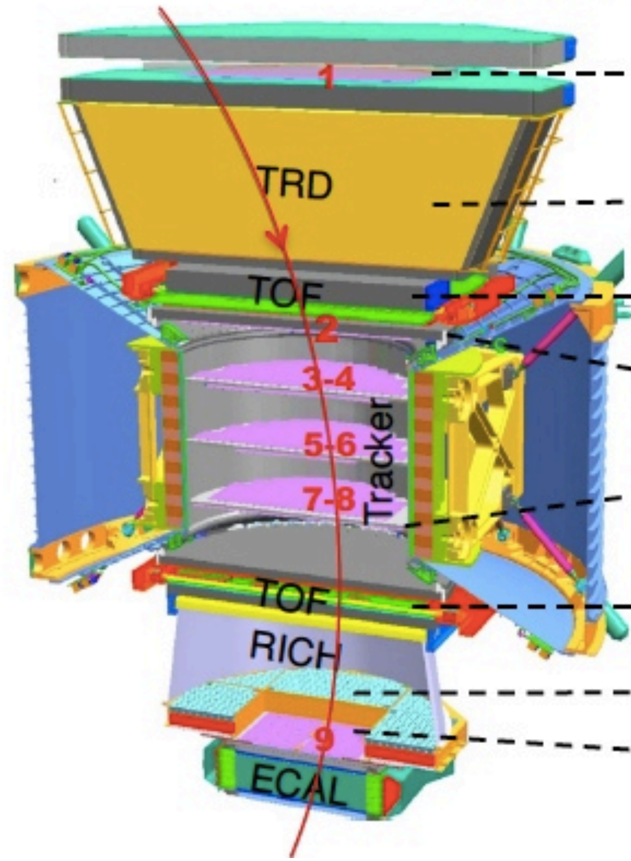
Comparison with past measurements

Nuclei identification in AMS



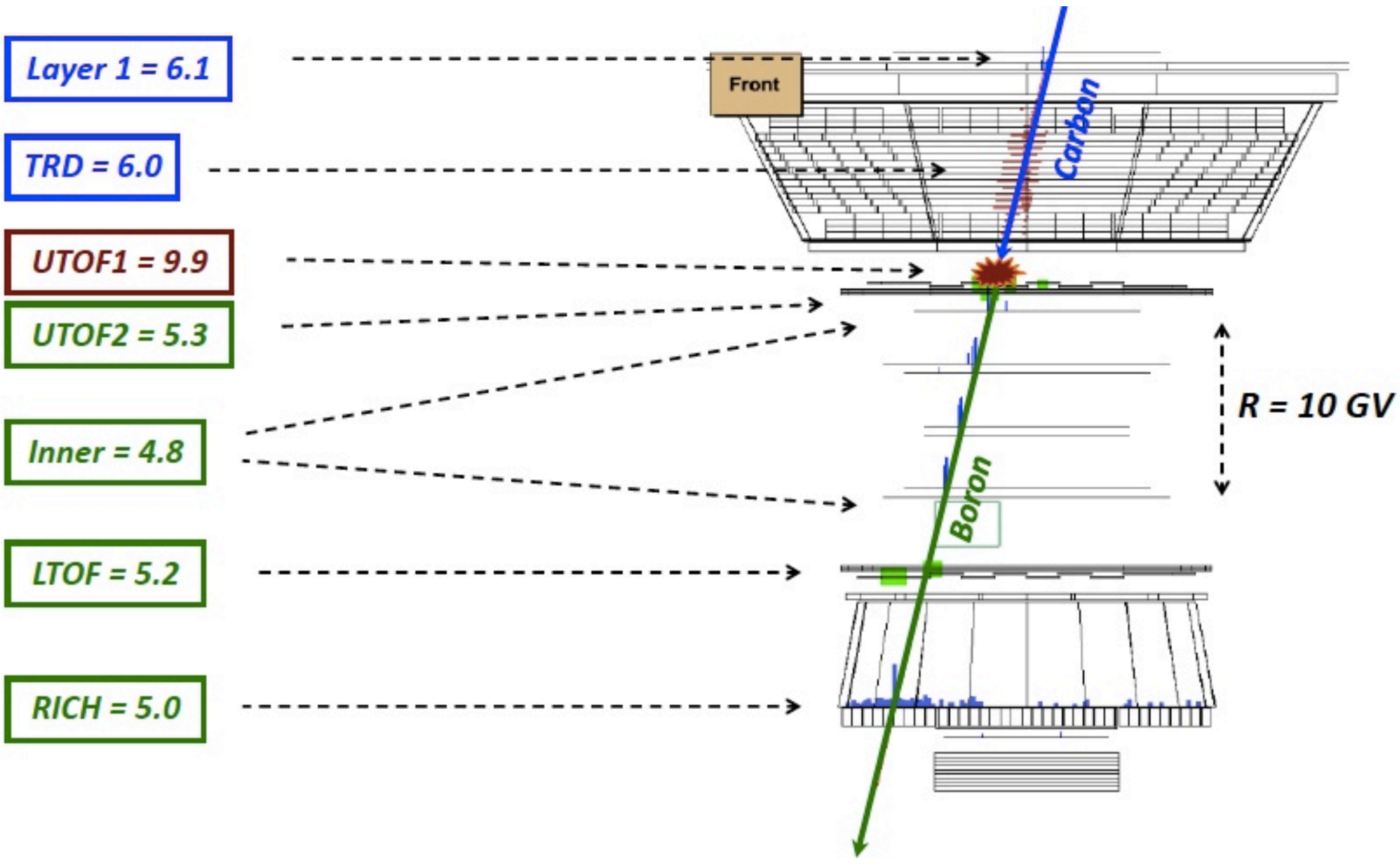
New results from the first 2 years of AMS: Boron to Carbon ratio

AMS: Multiple Independent Measurements of the Charge (|Z|)



	Carbon (Z=6) ΔZ (cu)
1. Tracker Plane 1	0.30
2. TRD	0.33
3. Upper TOF (1 counter)	0.16
4. Tracker Planes 2-8	0.12
5. Lower TOF (1 counter)	0.16
6. RICH	0.32
7. Tracker Plane 9	0.30

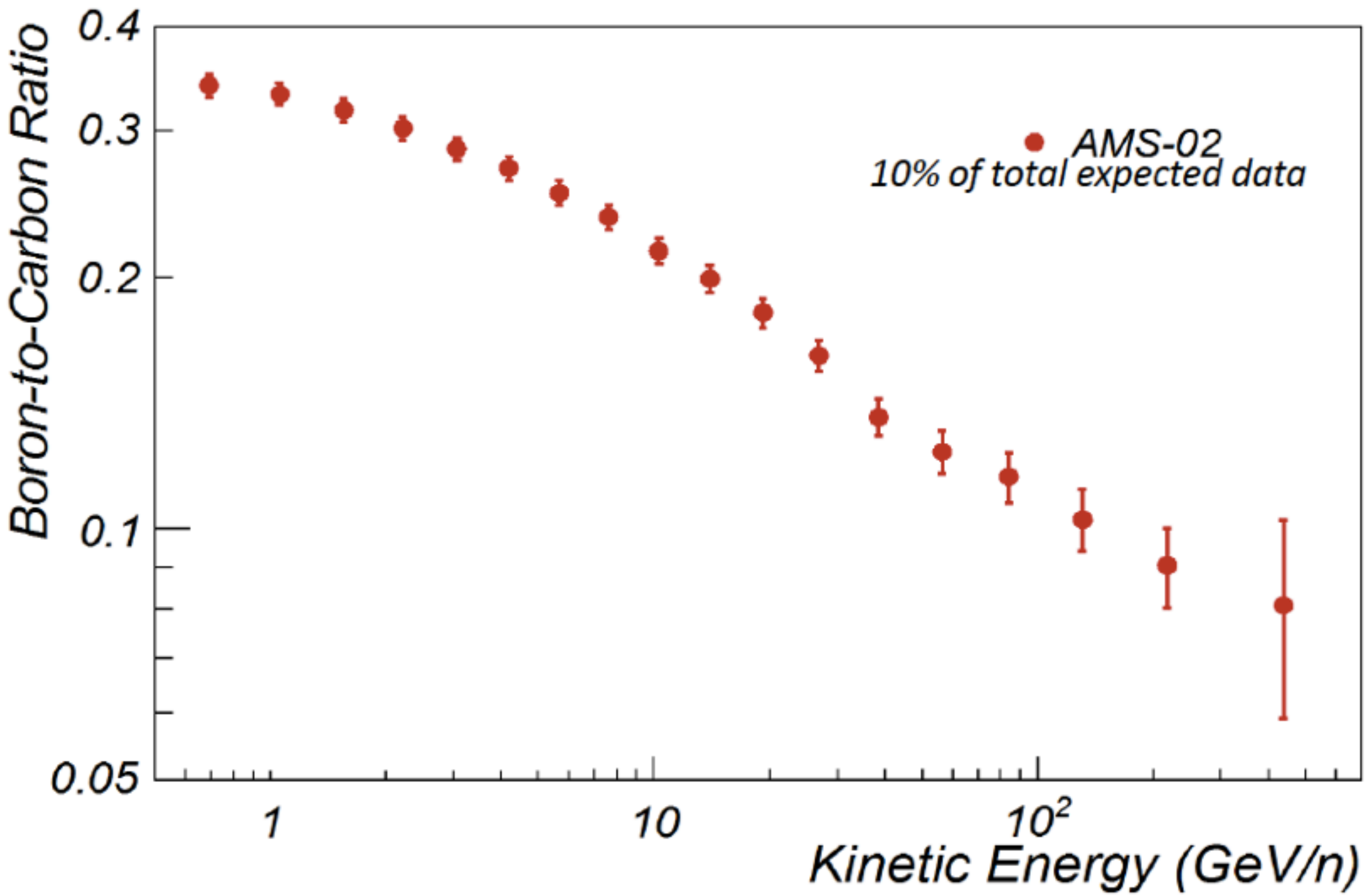
New results from the first 2 years of AMS: Boron to Carbon ratio



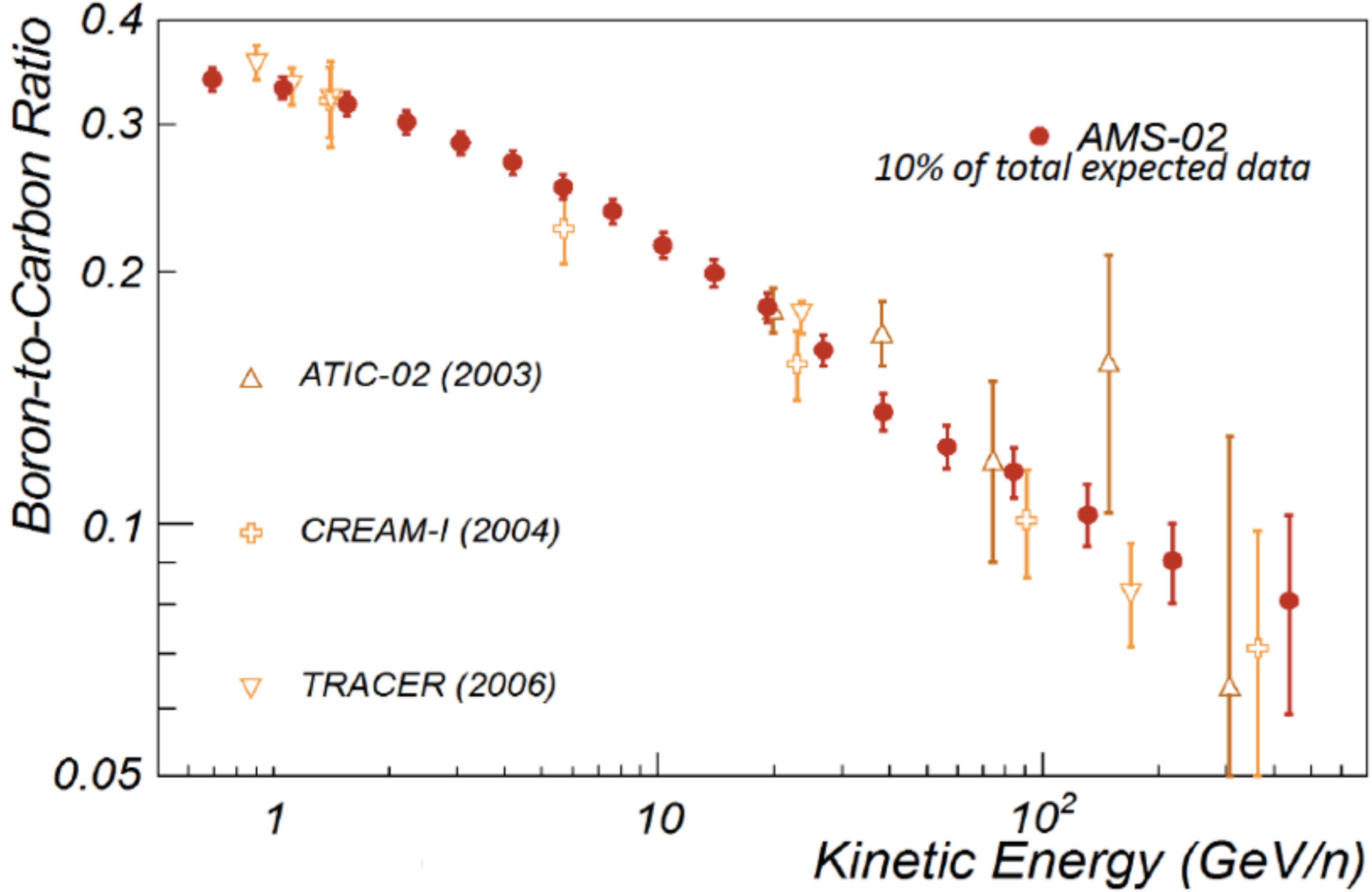
Identification of fragmentation events

New results from the first 2 years of AMS: Boron to Carbon ratio (May 2011 / May 2013)

- Measurement of the B/C between 0.5 to 670 GeV/n measured by AMS
- Statistics is the main limitation for the ratio measurement and systematics error evaluation.
- The B/C behavior at high energy will become more clear with more data

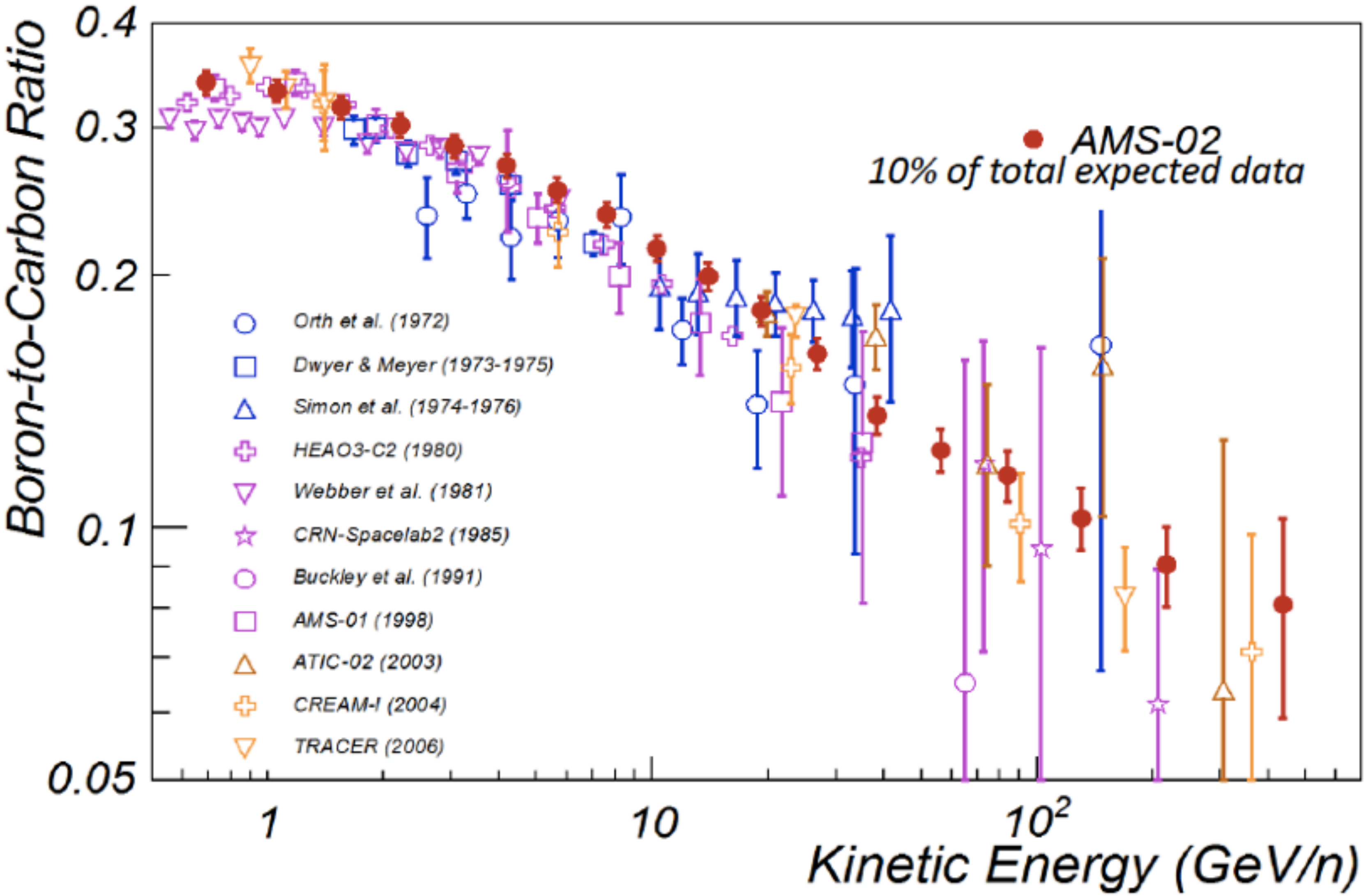


New results from the first 2 years of AMS: Boron to Carbon ratio (May 2011 / May 2013)



Comparison with latest measurements

New results from the first 2 years of AMS: Boron to Carbon ratio (May 2011 / May 2013)



Comparison with past measurements

Conclusions

•The AMS positron fraction (0.5 to 350 GeV) shows a clear steady increase above 10 GeV. More statistics is necessary to extend the measurement at higher energies to clarify the behavior above 250 GeV.

•Anisotropy studies indicate that the positron to electron ratio and the positron to proton ratio are consistent with isotropy (dipole parameter δ <0.030 16<E<350GeV).

•The AMS Proton flux (1.8TV), Helium flux (3.2TV) and electron flux (500 GeV) at high energy are consistent with a single power law with no fine structures nor break. Systematics still under study.

•The preliminary positron flux (350 GeV) shows a break at 30 GeV confirming the positron fraction measurements. Preliminary Electron + Positron spectrum (700 GeV) shows no evidence of structures. A change in the spectral distribution with increasing energy is seen compatible with the fraction. Details of the systematic errors are under investigations.

•Measurements of the B/C between 0.5 to 670 GeV/n has been presented, the behavior at high energy will become more clear with more data.

More science coming soon! Stay tuned!!!