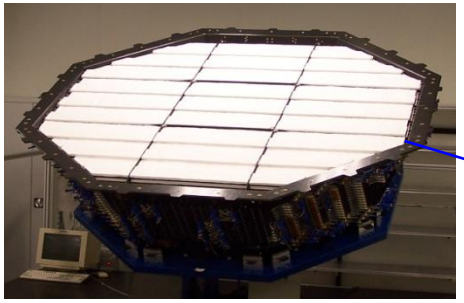
Precision measurement of the positron fraction with the Alpha Magnetic Spectrometer

A.Kounine / MIT
on behalf of the
AMS Collaboration

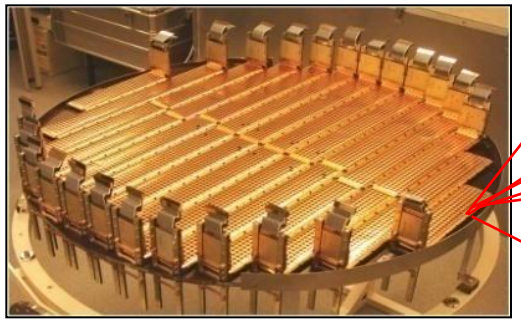
ICRC-2013, 8 July 2013, Rio de Janeiro

AMS: A TeV precision, multipurpose spectrometer in space.

TRD
Identify e+, e-



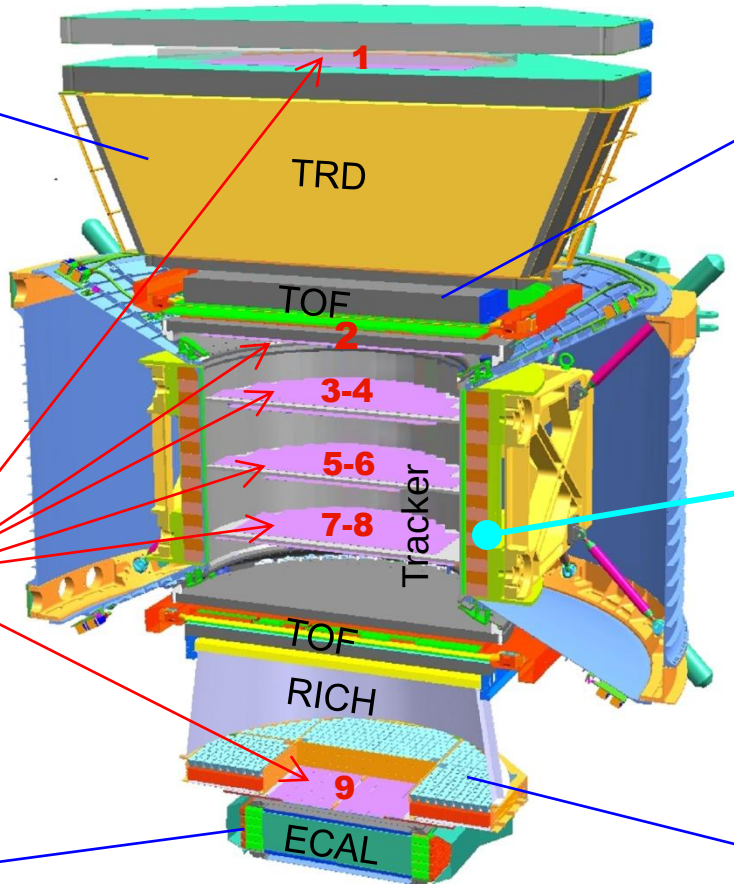
Silicon Tracker
Z, P



ECAL
E of e+, e-, γ

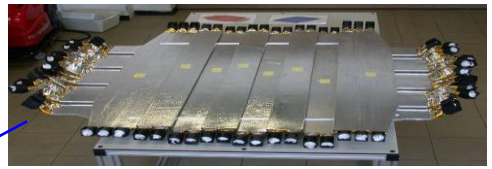
Positron fraction:

$Ne^+/(Ne^+ + Ne^-)$

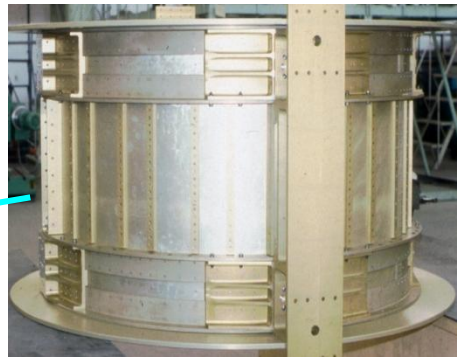


***Z, P** are measured independently from Tracker, RICH, TOF and ECAL*

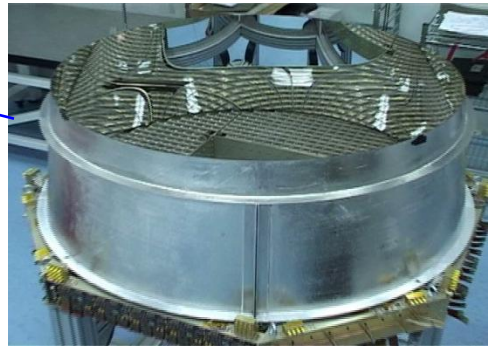
TOF
Z, E



Magnet
±Z

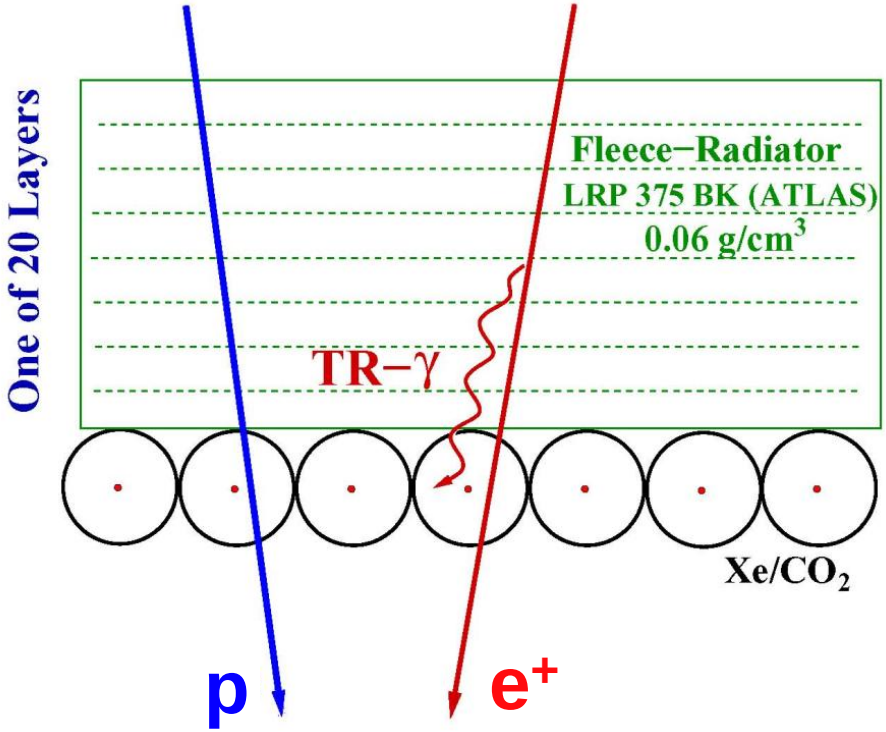


RICH
Z, E



Transition Radiation Detector.

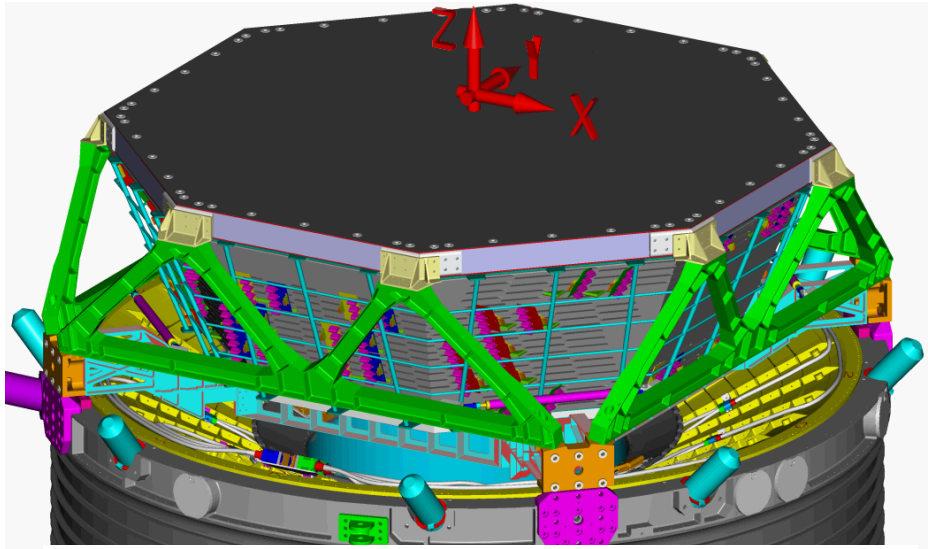
Identify e^+, reject P

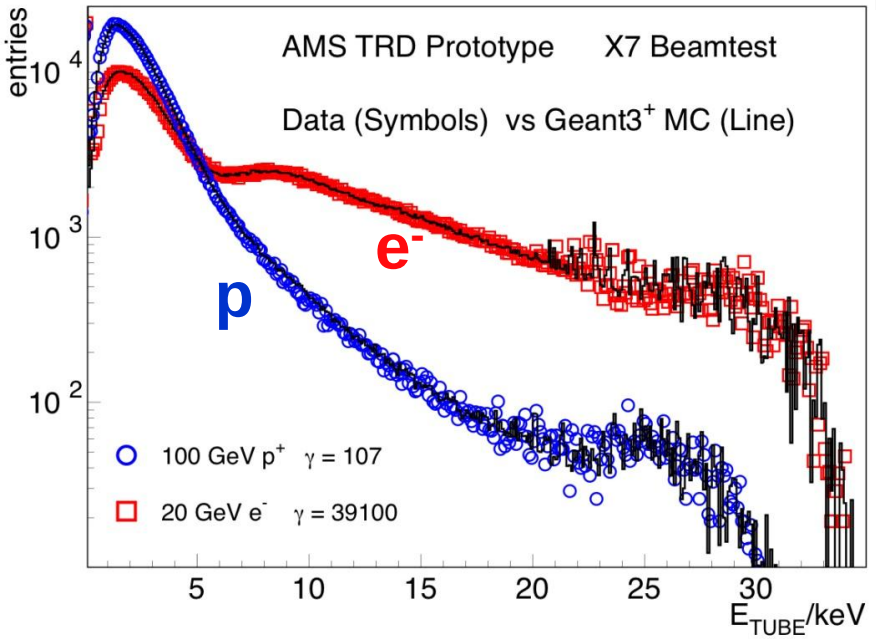


Leak rate: CO2 ≈ 5 μg/s

Storage: 5 kg, >20 years lifetime

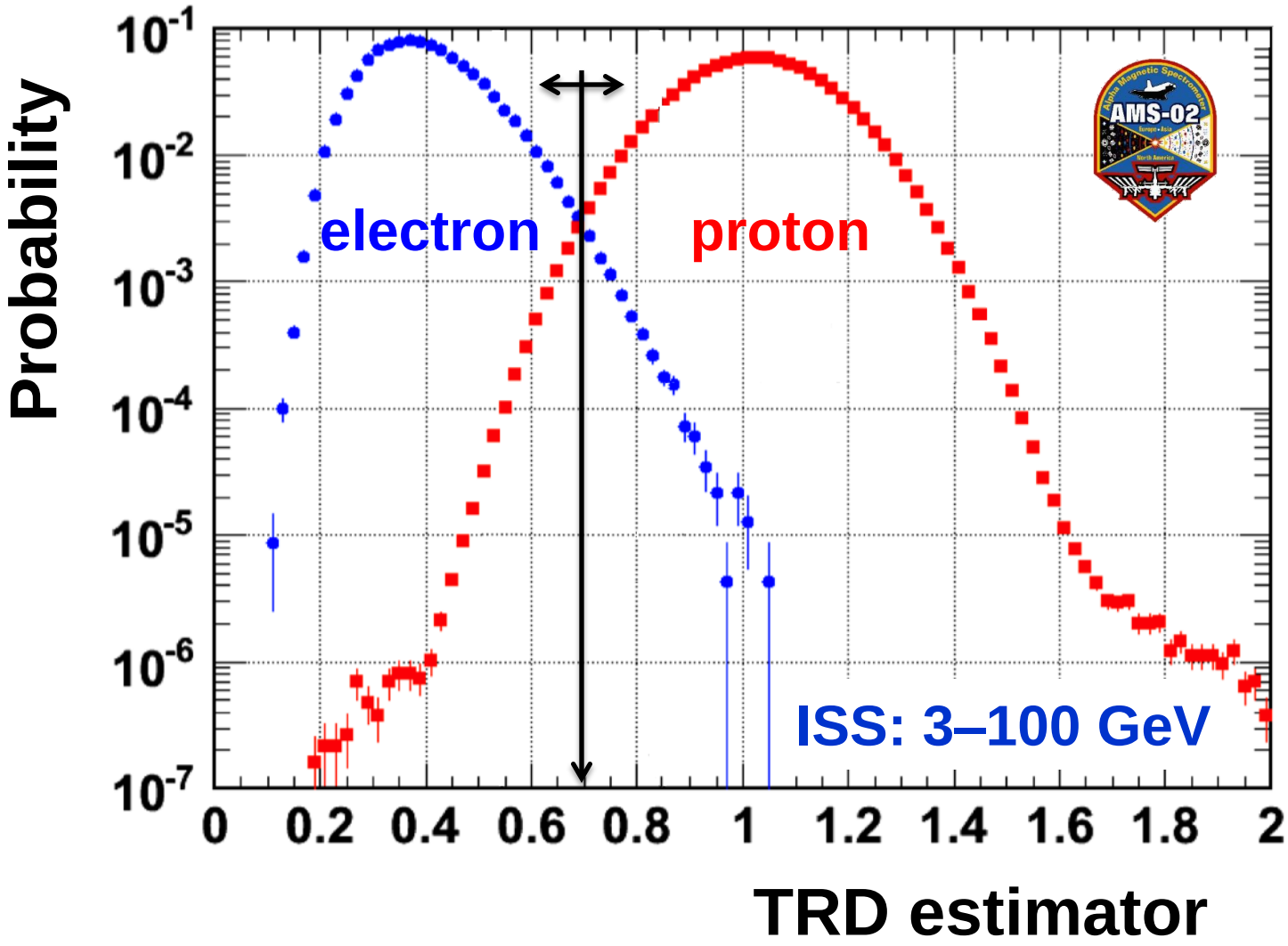
Reported by H.Gast, ICRC





TRD performance on ISS

TRD estimator = $-\ln(P_e/(P_e+P_p))$

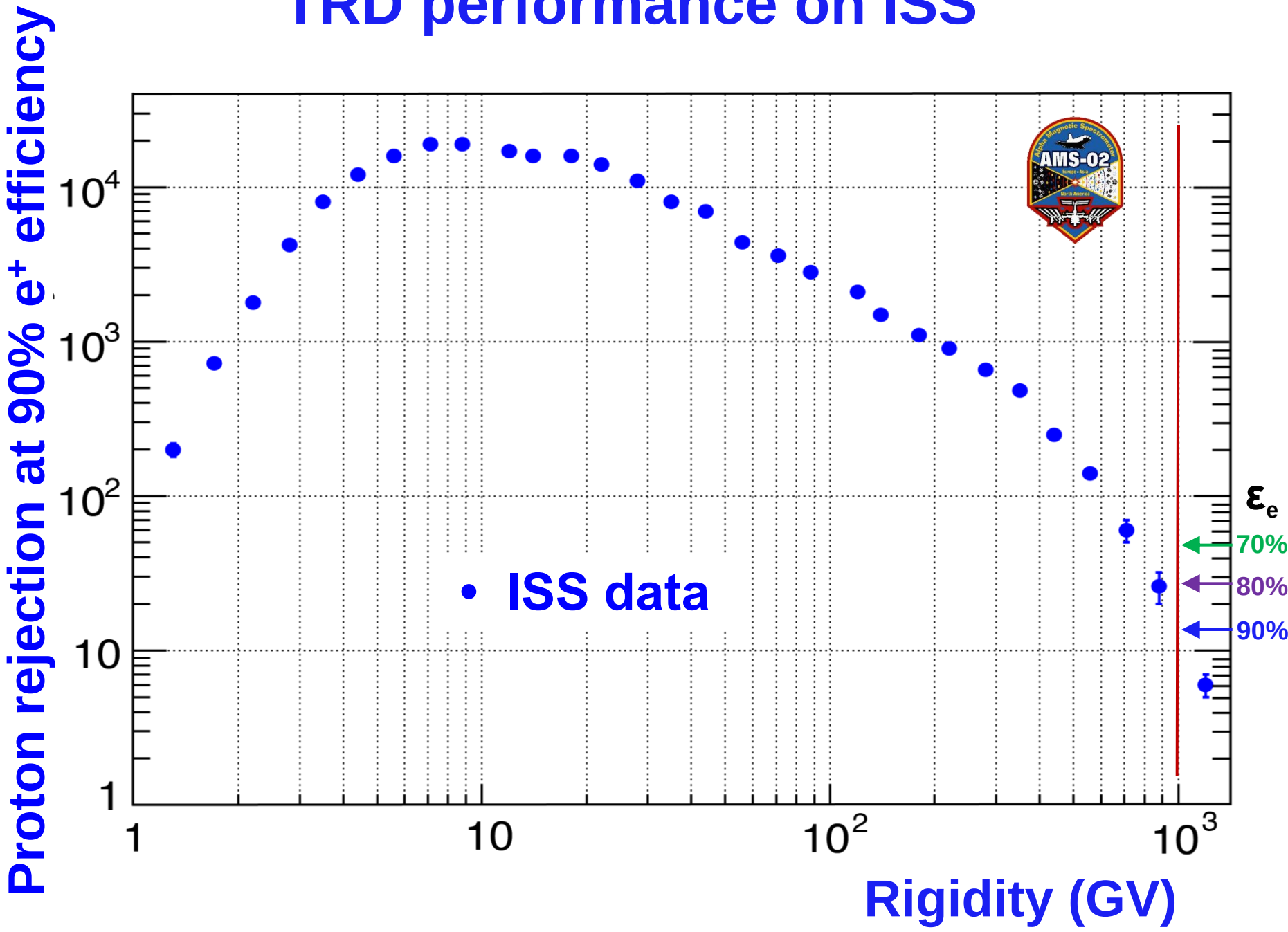


Normalized probabilities P_e and P_p

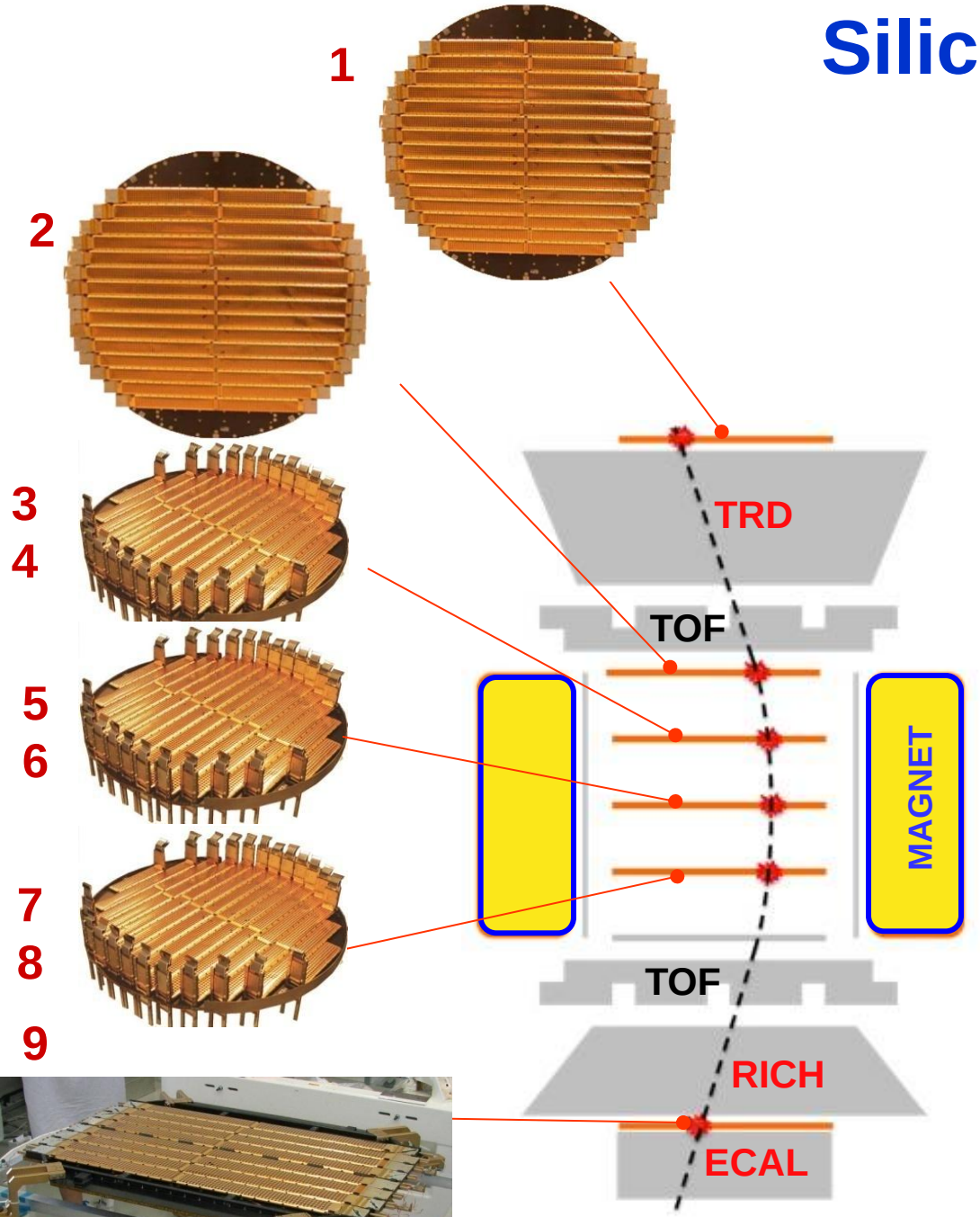
$$P_e = \sqrt[n]{\prod_i^n P_e^{(i)}(A)}$$

$$P_p = \sqrt[n]{\prod_i^n P_p^{(i)}(A)}$$

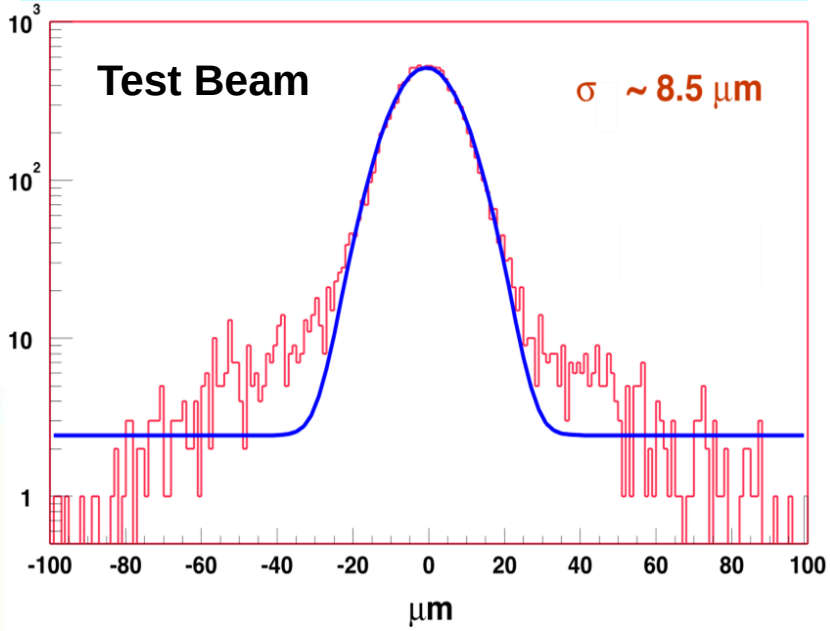
TRD performance on ISS



Silicon Tracker



Reported by P. Zuccon and by C. Delgado, ICRC

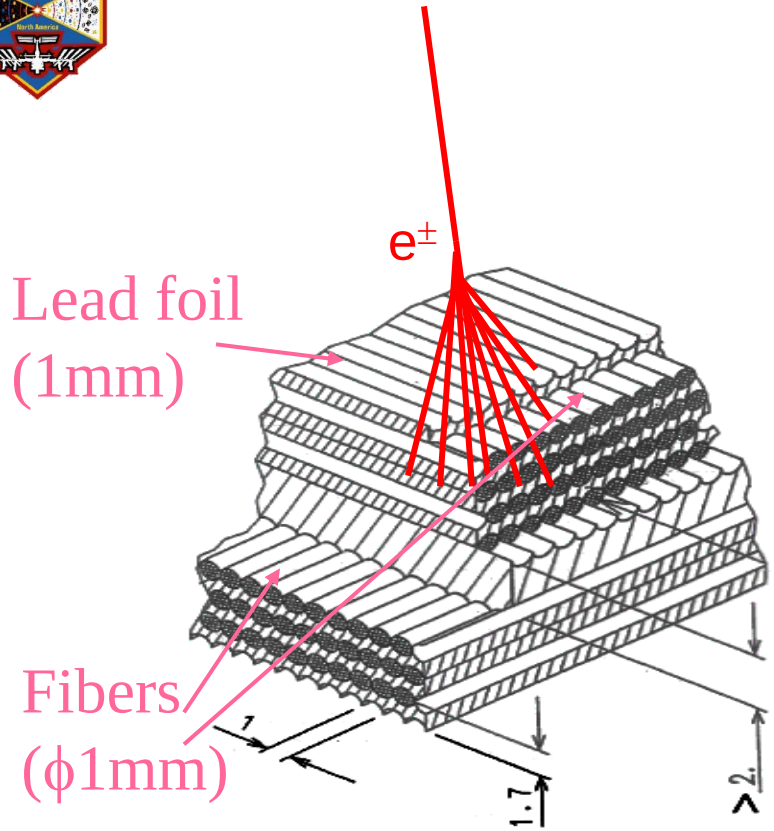


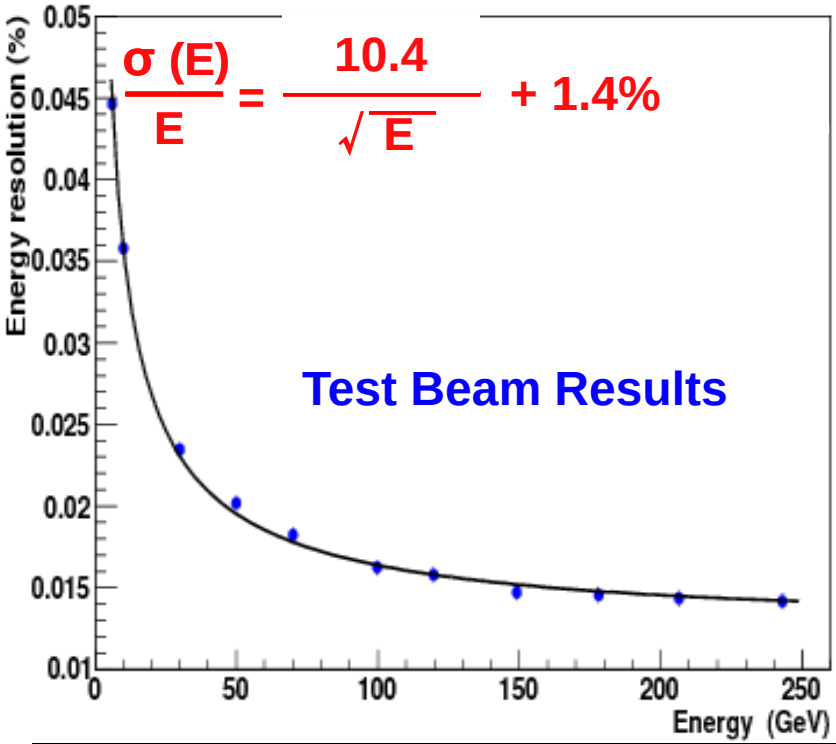
MDR ~2.0 TV

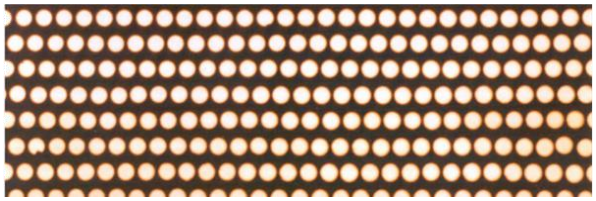
E / |p| matching

Electromagnetic Calorimeter

A precision, 17 X_0, TeV, 3D measurement of the directions and energies of light rays and electrons





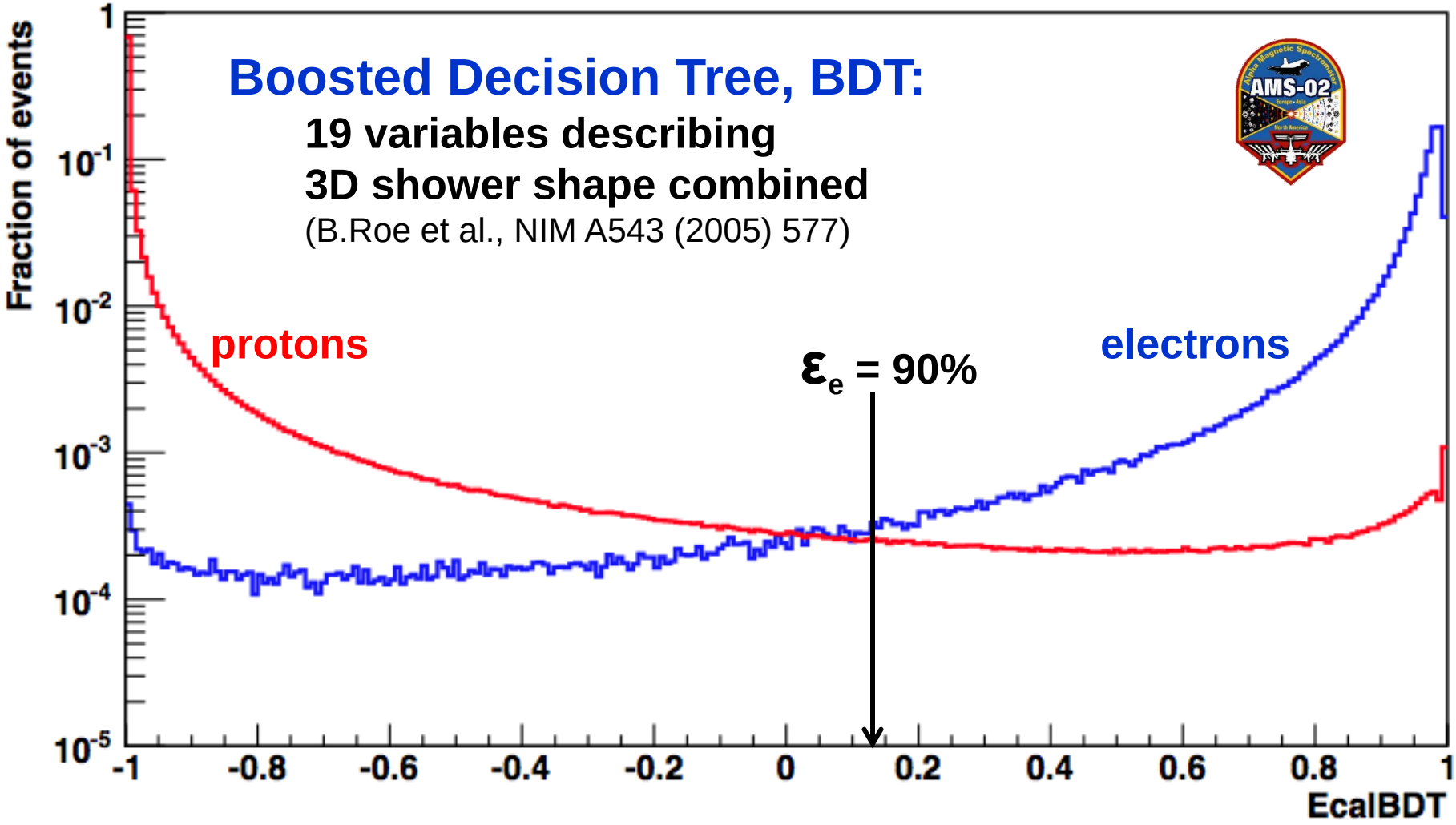


50 000 fibers, ϕ = 1 mm
distributed uniformly
Inside 1,200 lb of lead

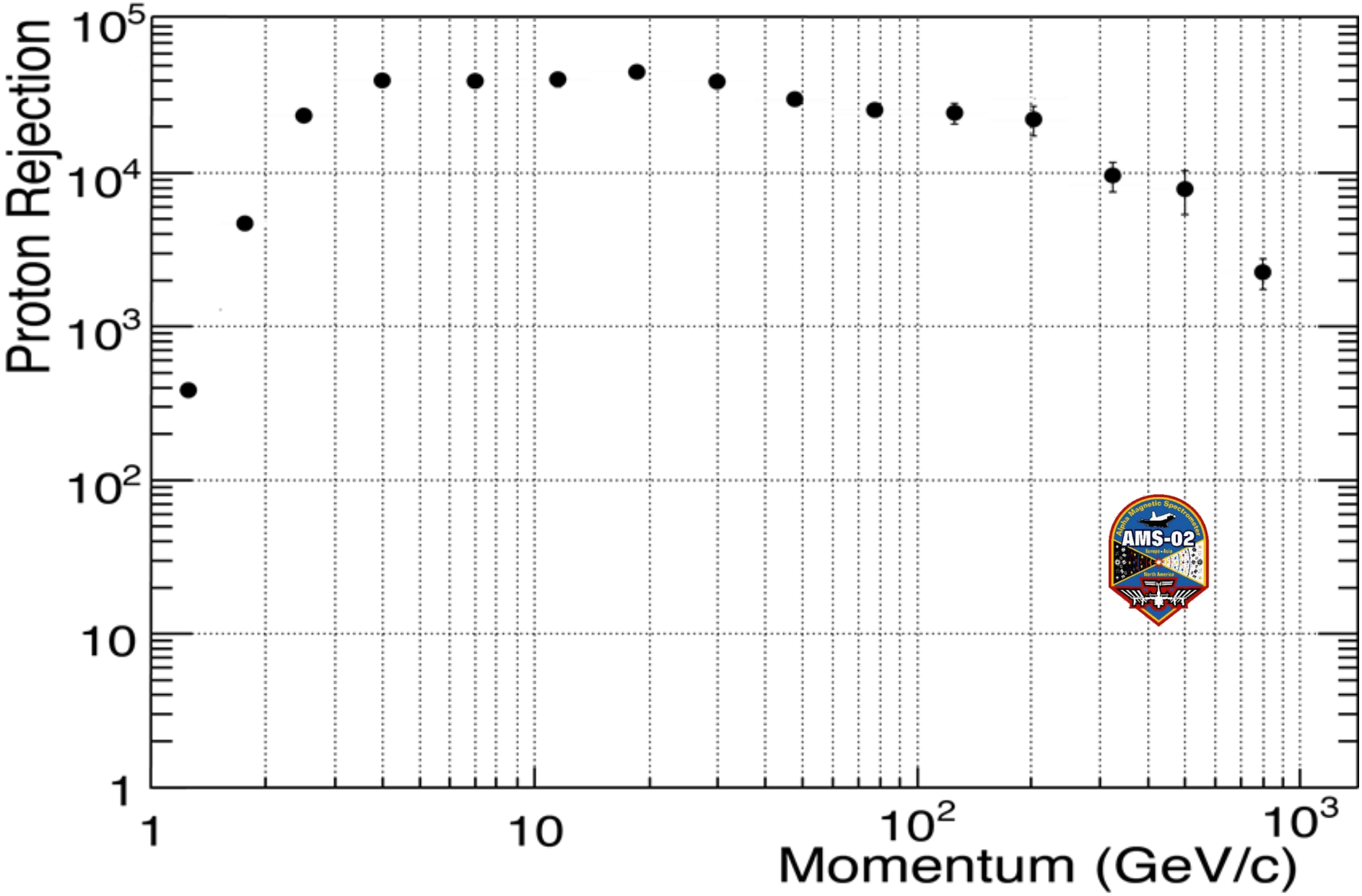
Reported by S. Di Falco, ICRC

Separation of protons and electrons with ECAL

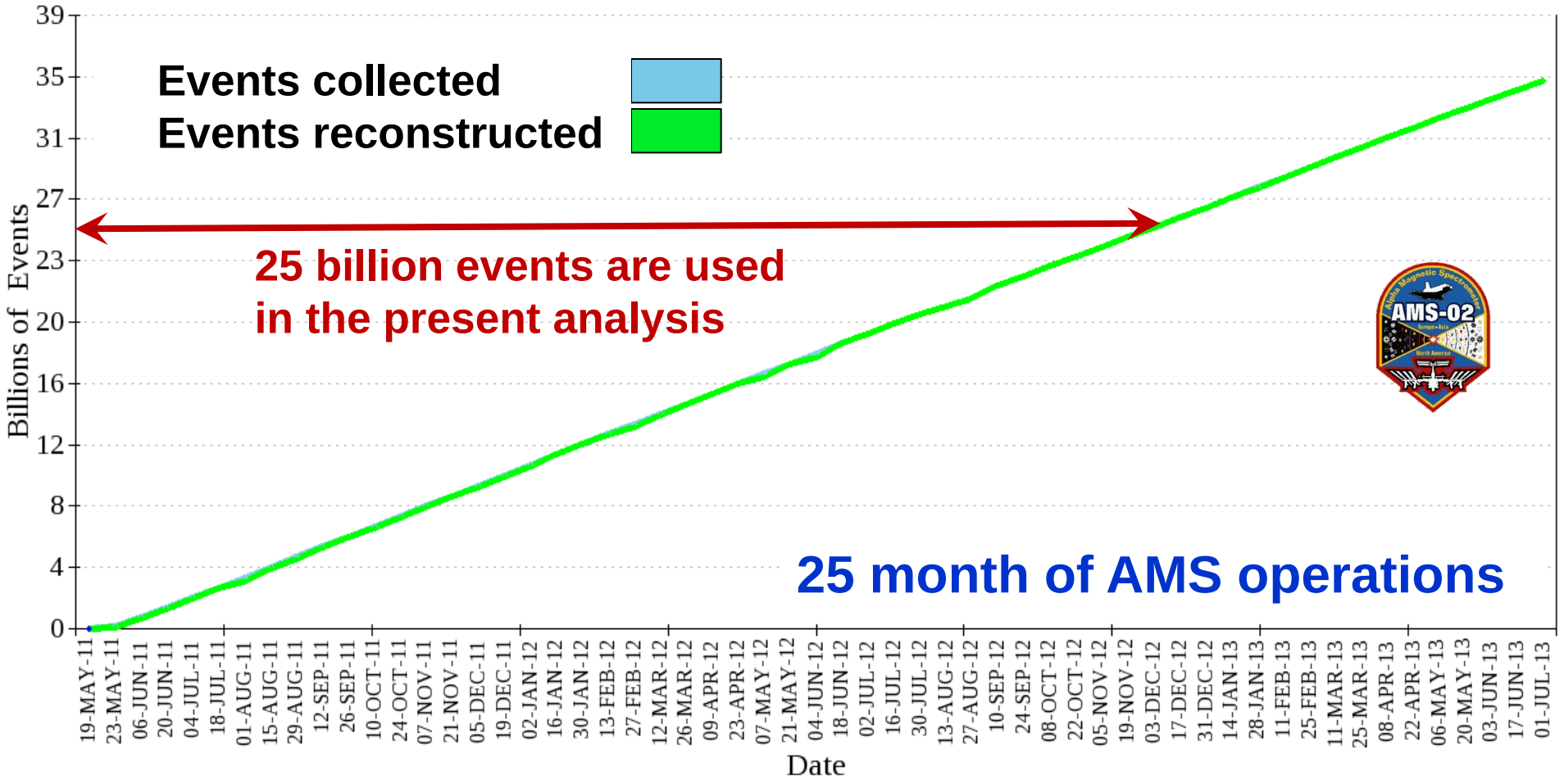
ISS data: 83–100 GeV



Data from ISS: Proton rejection using the ECAL

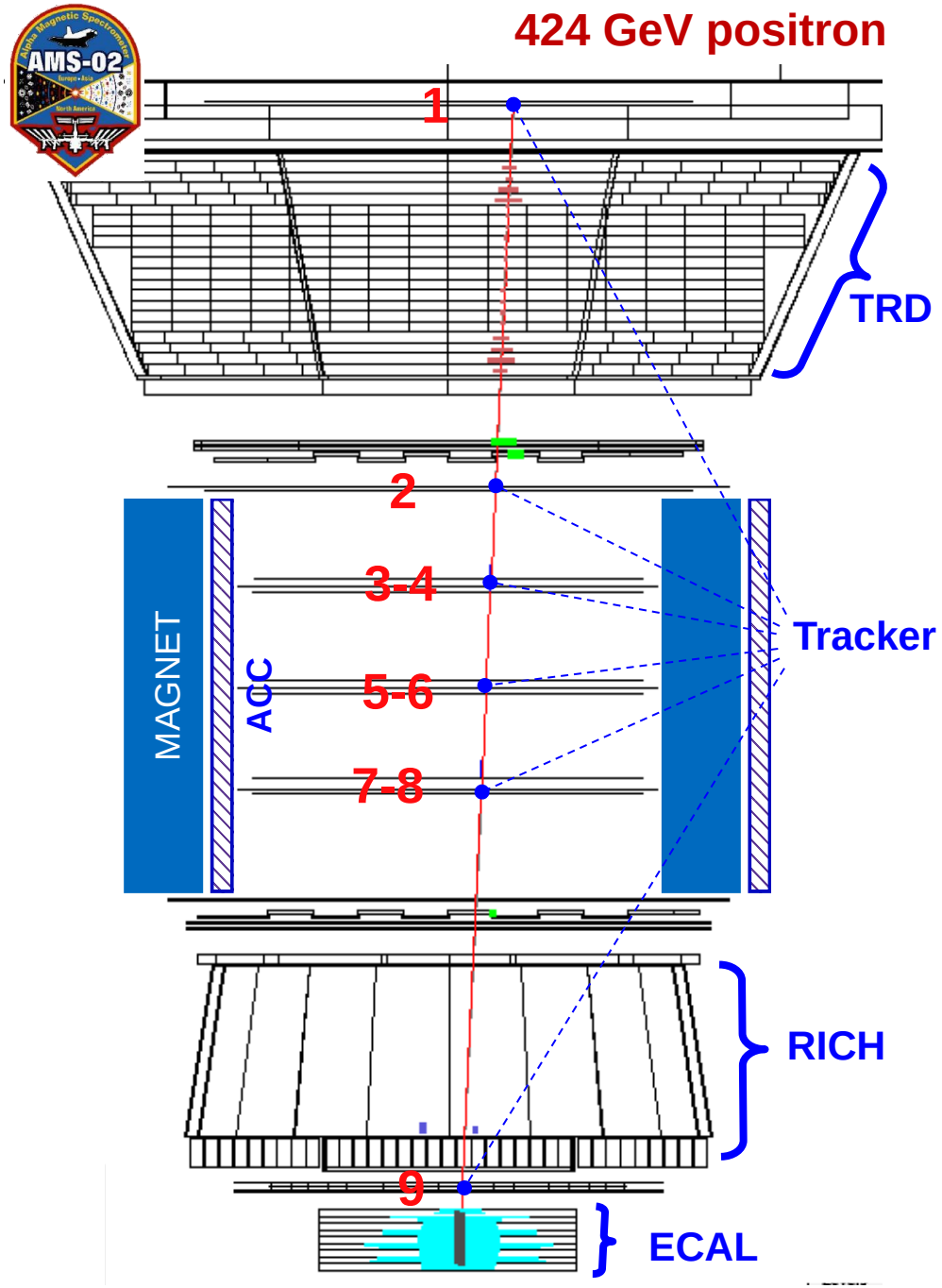


To date AMS collected over 35 billion events



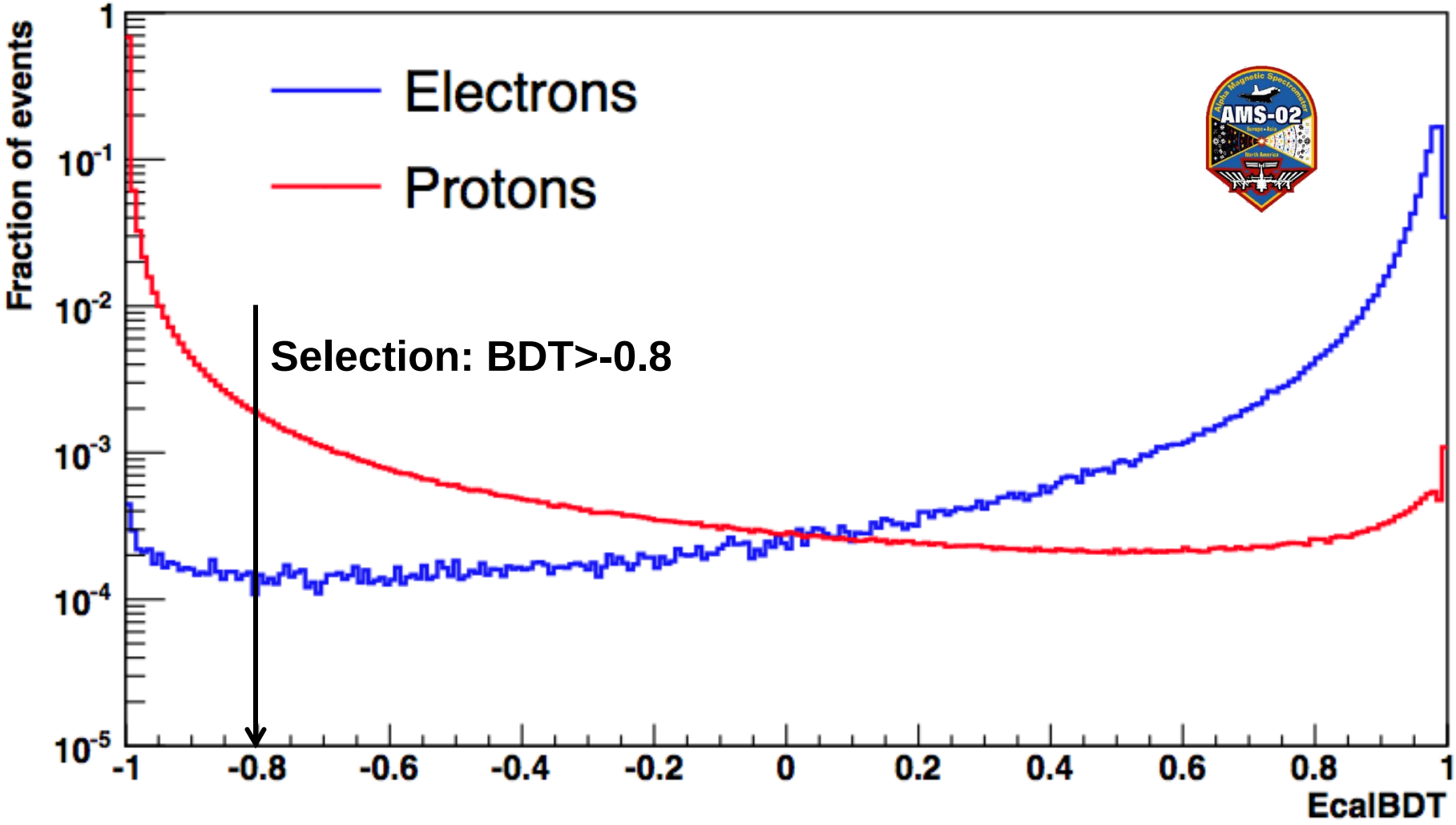
Event selection.

- **DAQ:** efficiency > 50% (no SAA)
- **Geomagnetic cutoff:**
  E>1.2·max cutoff
- **TRACKER:**
  - Track quality
  - geometrical match with ECAL shower
- **TRD:** at least 15 hits
- **TOF:** downgoing particle,
  β>0.8, 0.8<Z<1.4
- **ECAL:**
  - shower axis within the fiducial ECAL volume
  - electromagnetic shape of the shower

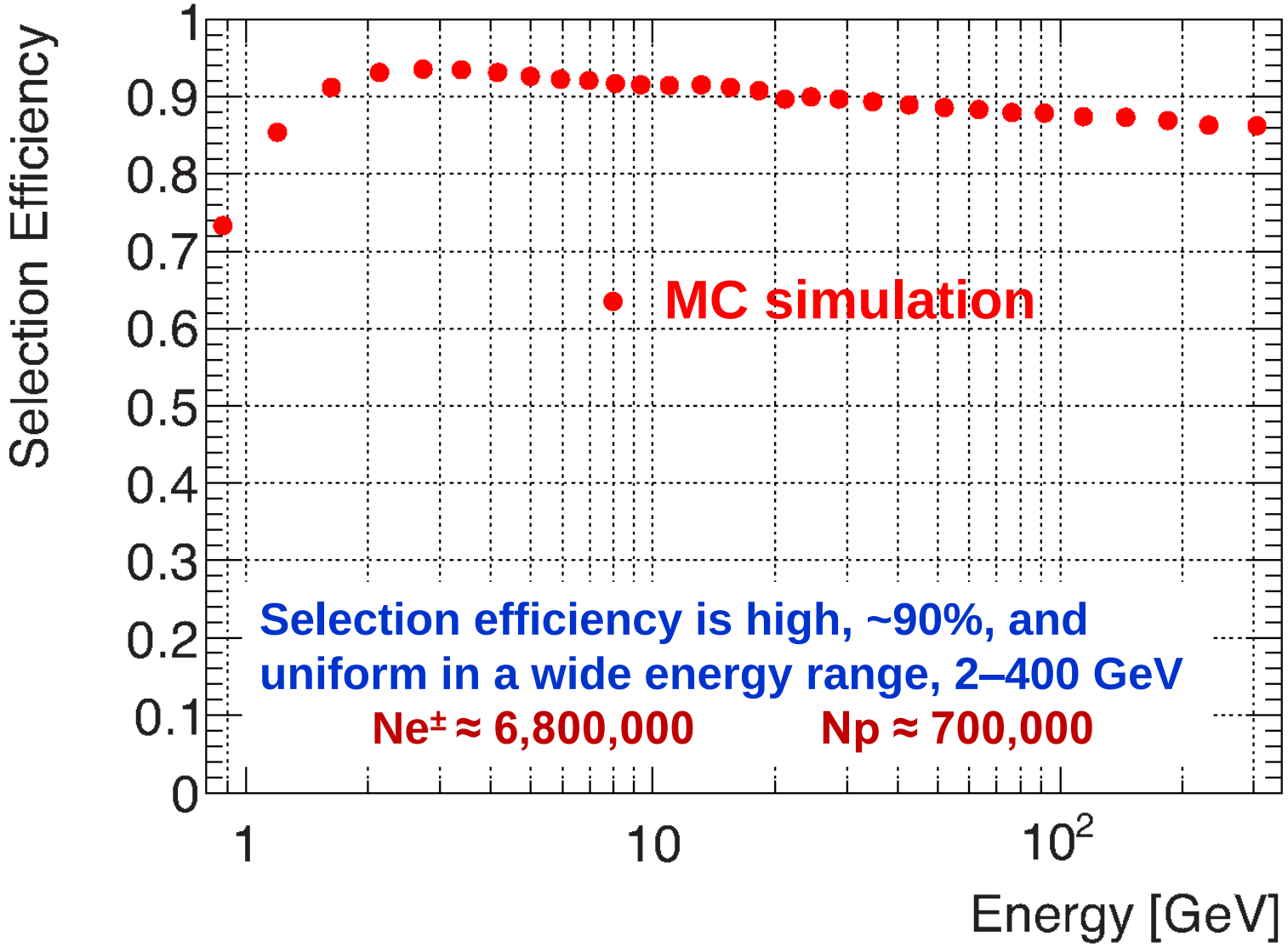


Event selection: ECAL BDT

ISS data: 83–100 GeV



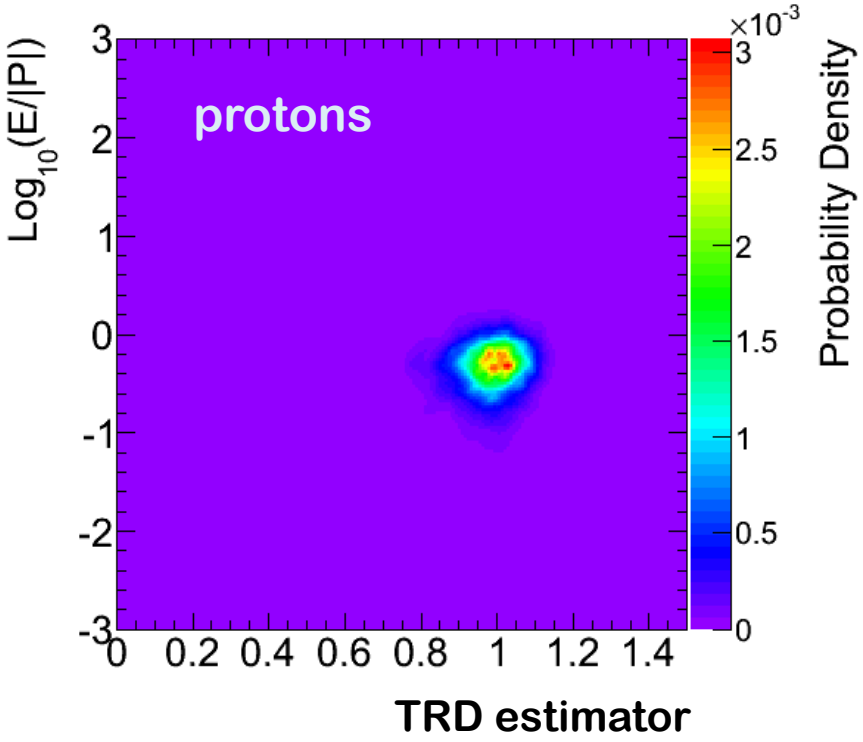
Selection efficiency

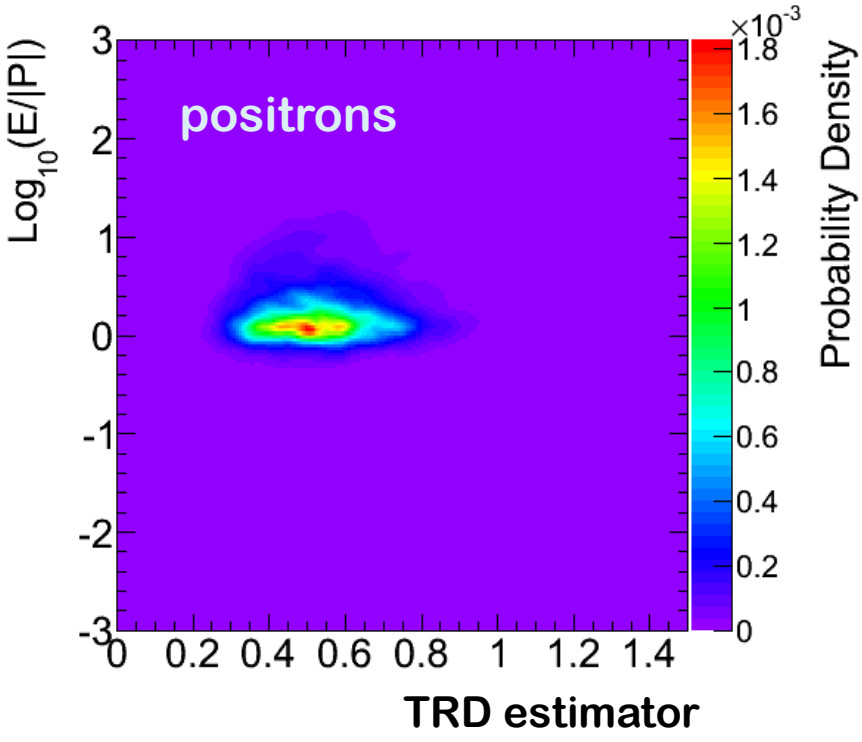


Analysis: 2D fit to measure $Ne^{\pm}$ and Np

2D reference spectra for the signal and the background are fitted to data in the [TRD estimator- log(E/|P|] plane.

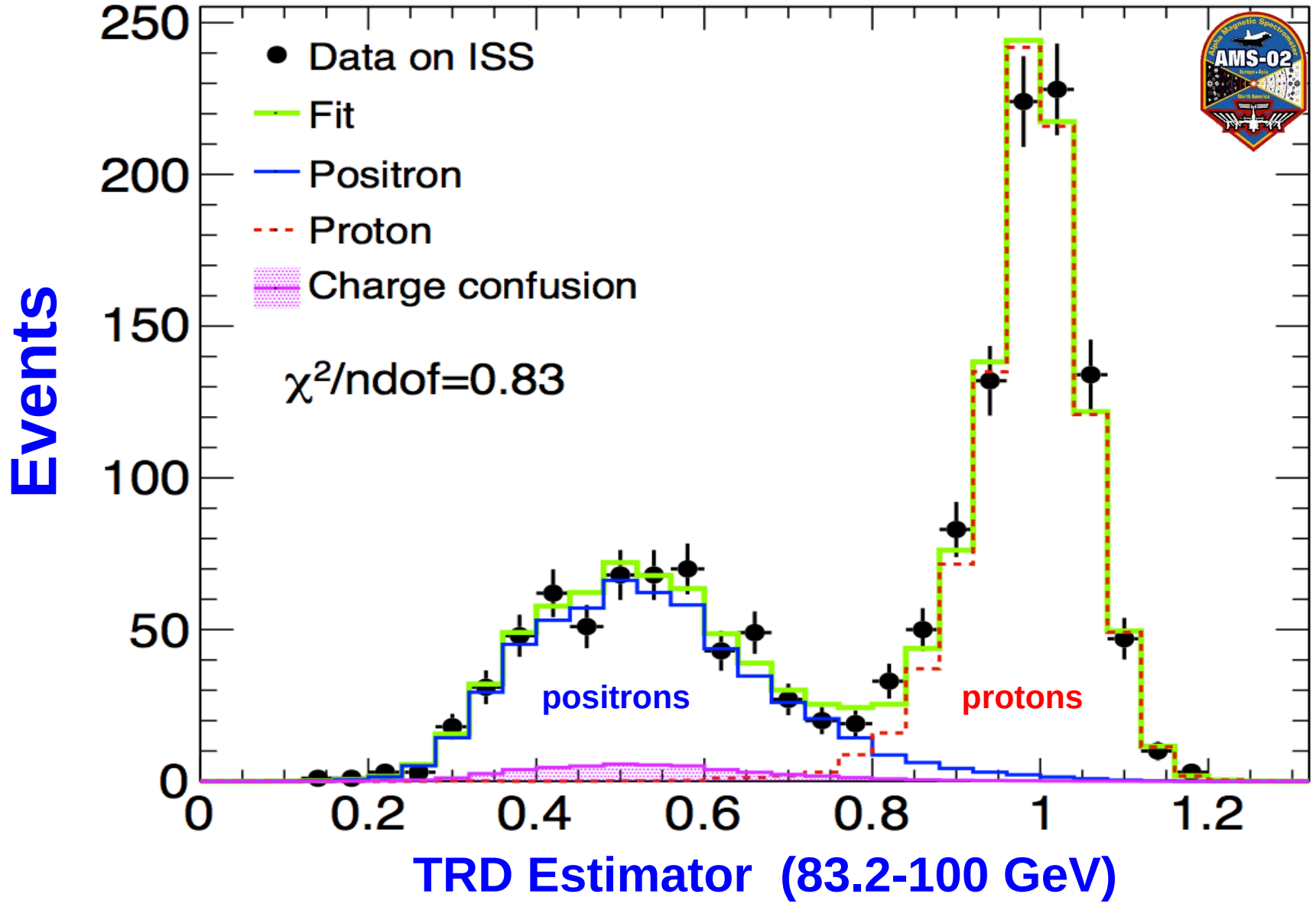
The method combines redundant information from TRD, ECAL, and Tracker; and provides much better statistical accuracy compared to cut-based analysis.



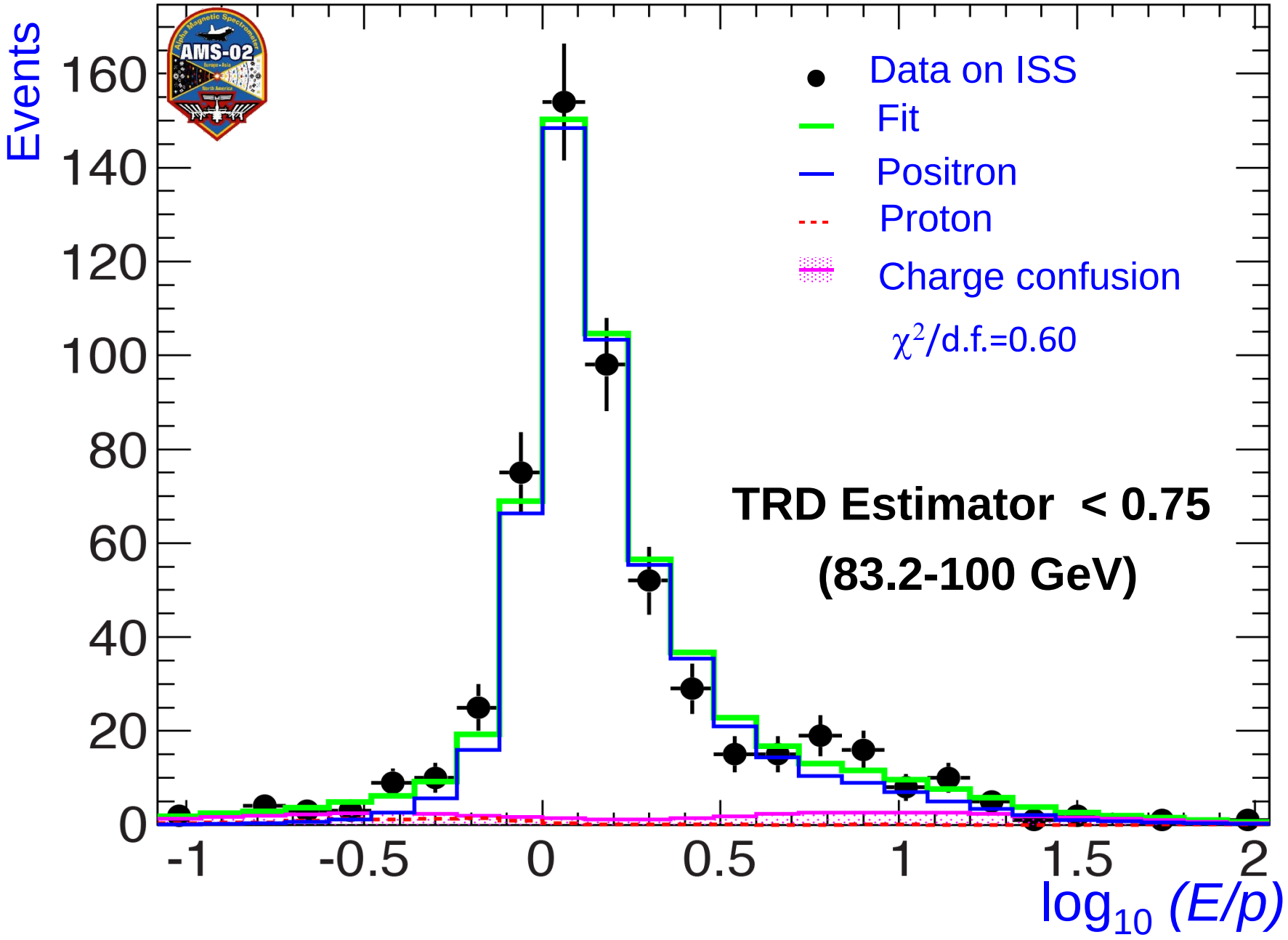


Results of the fit:

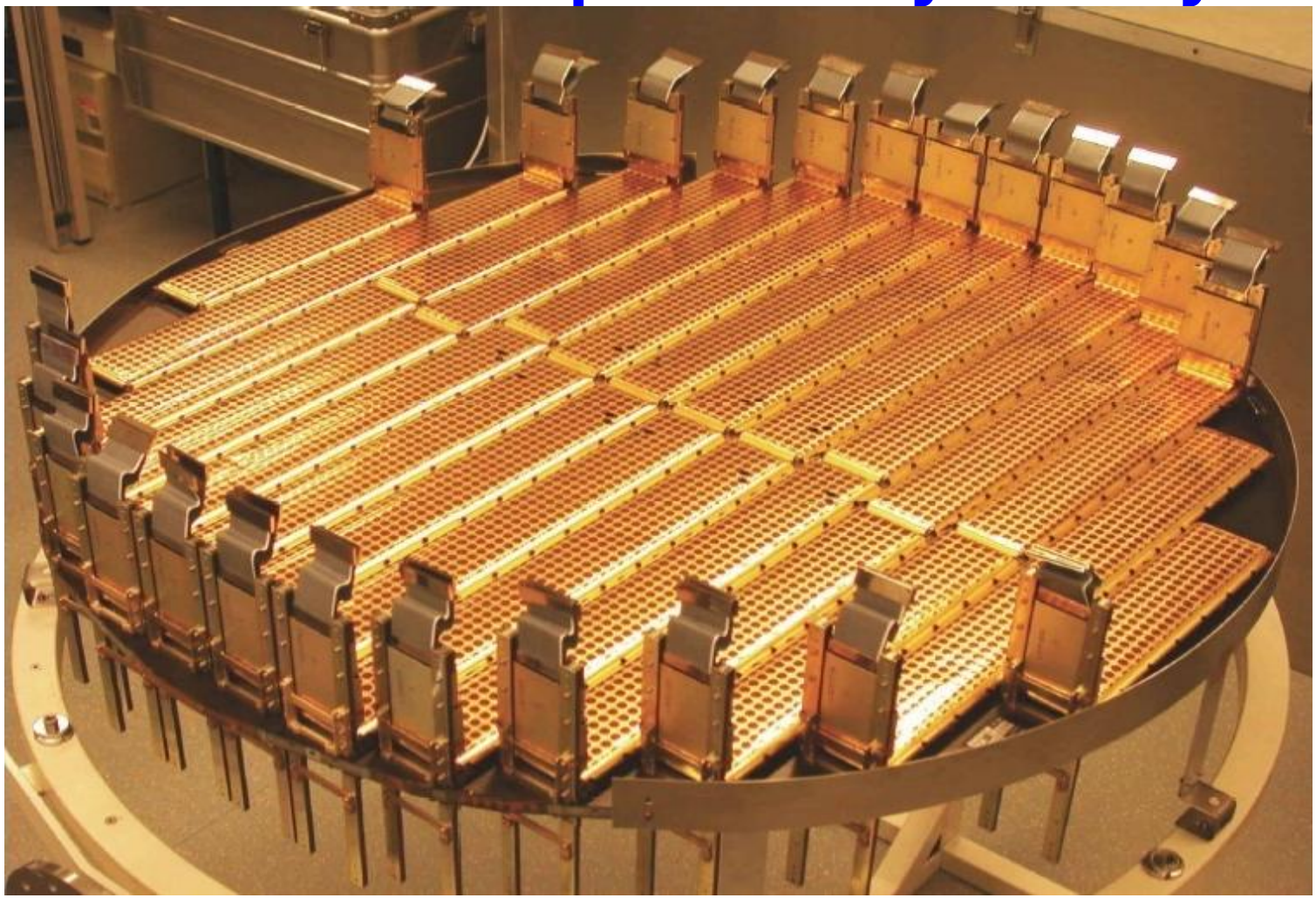
The TRD Estimator shows clear separation between protons and positrons with a small charge confusion background



Results of the fit: in the signal region only 1 % of protons

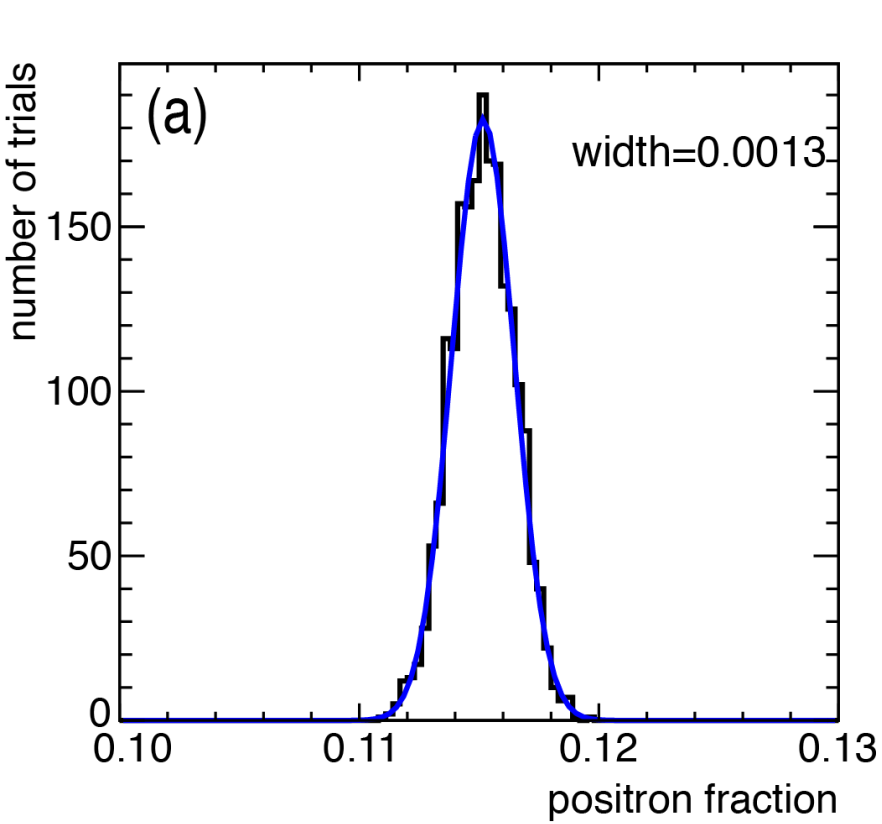


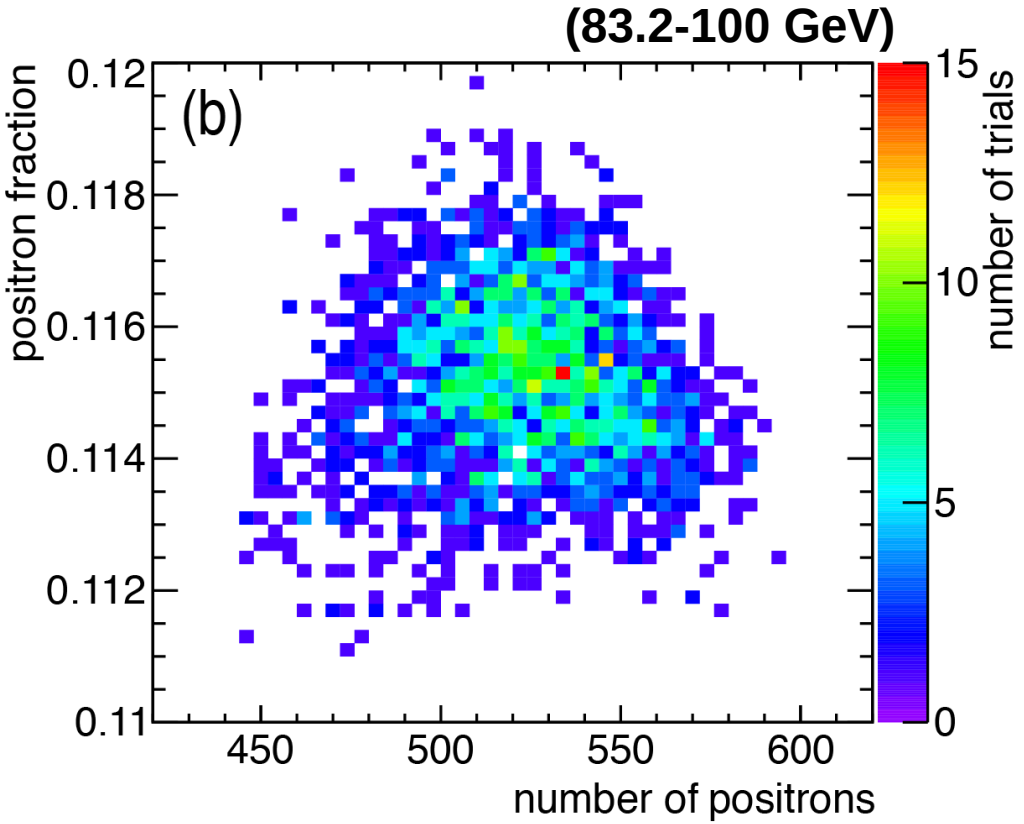
Systematic error on the positron fraction: 1. acceptance asymmetry



Difference between positron and electron acceptance due to known minute tracker asymmetry

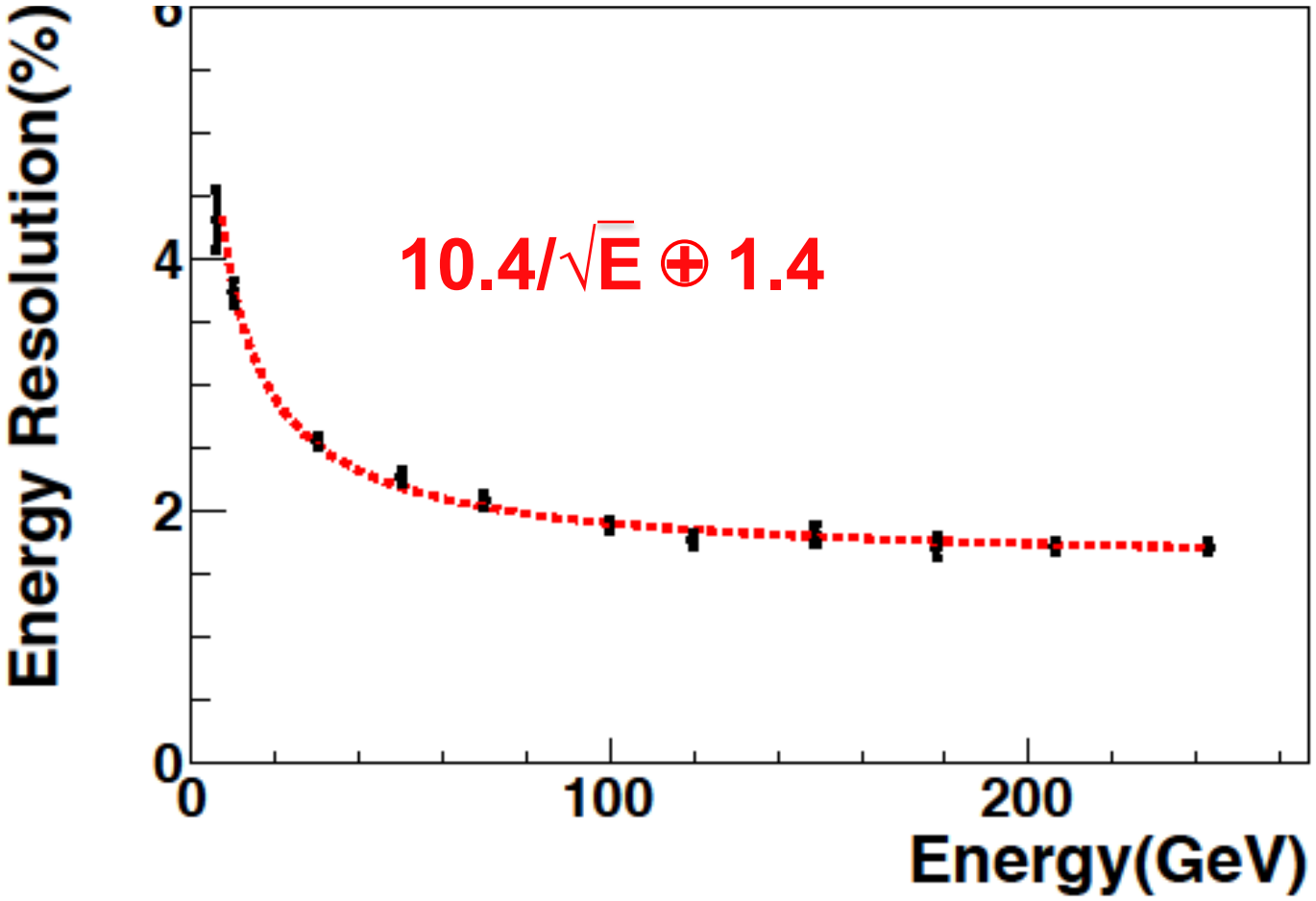
Systematic error on the positron fraction: 2. Selection dependence





The measurement is stable over wide variations of the cuts in the TRD identification, ECAL Shower Shape, E (from ECAL) matched to |P| (from the Tracker), … For each energy bin, over 1,000 sets of cuts were analyzed.

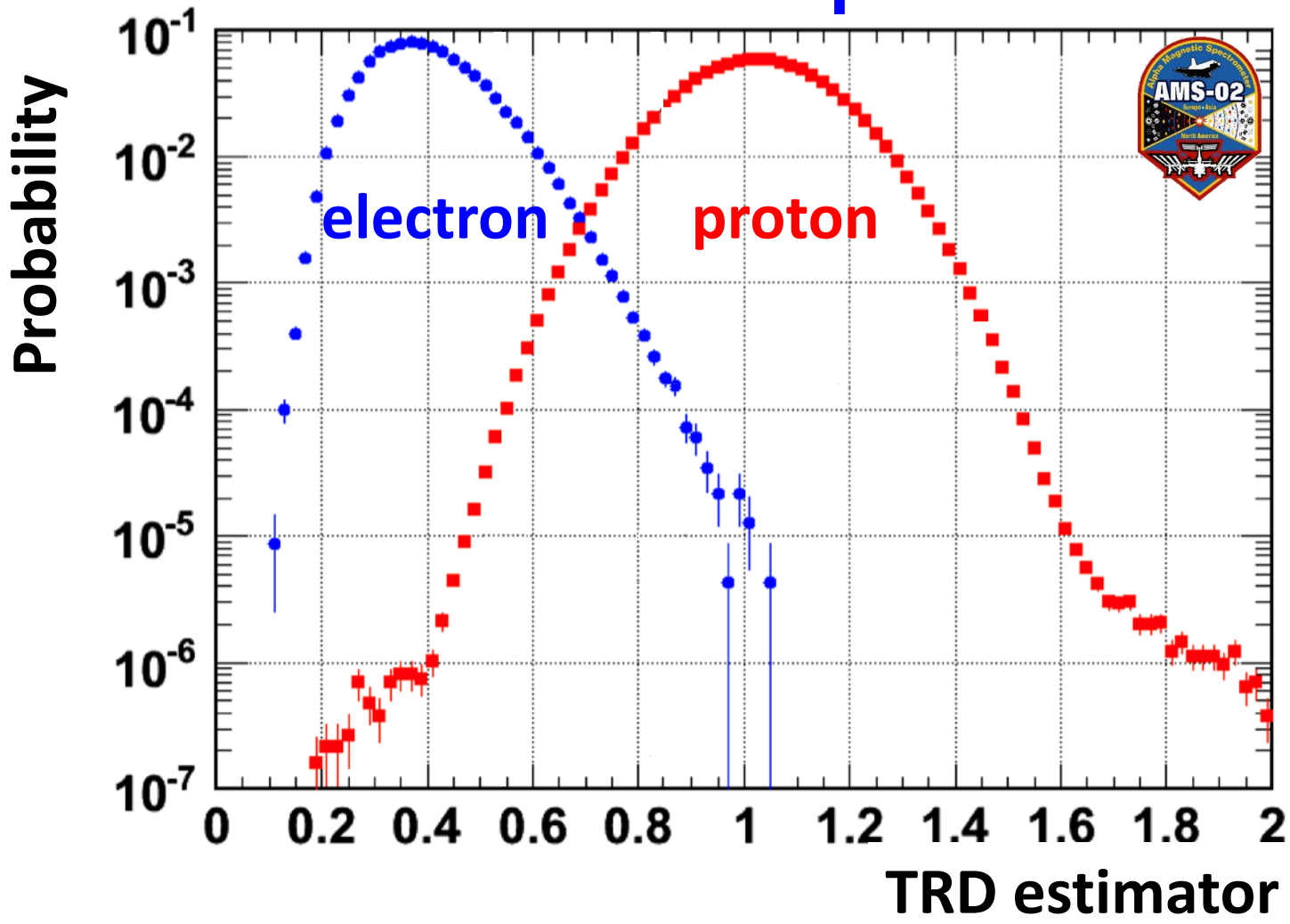
Systematic error on the positron fraction: 3. Bin-to-bin migration



Event migration effects are obtained by folding the measured spectra of positrons and electrons with the ECAL energy resolution.

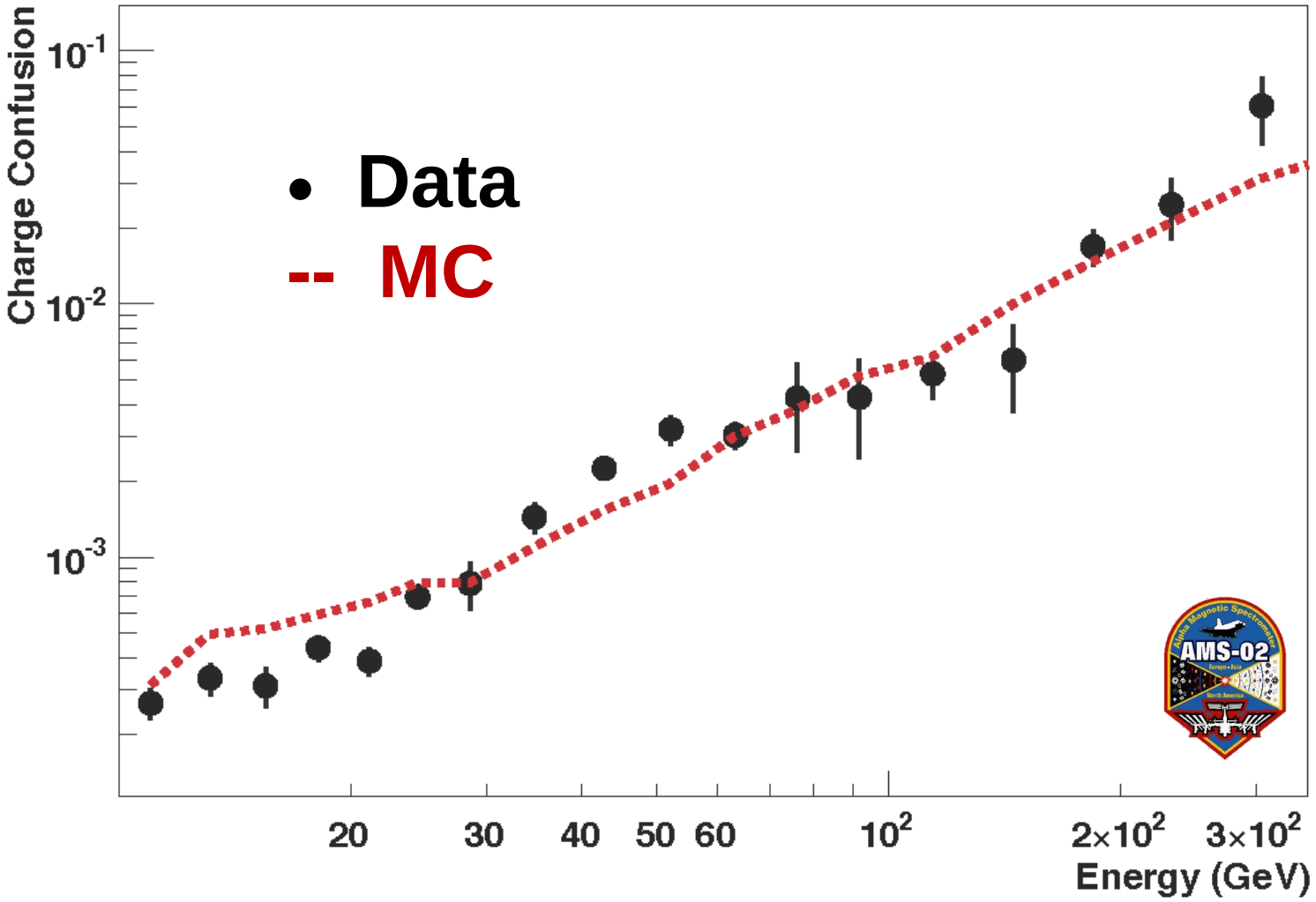
Bin width: 2σ at 5 GeV; 4σ at 50 GeV; 8σ at 100 GeV; 19σ at 300 GeV.

Systematic error on the positron fraction: 4. Reference spectra



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

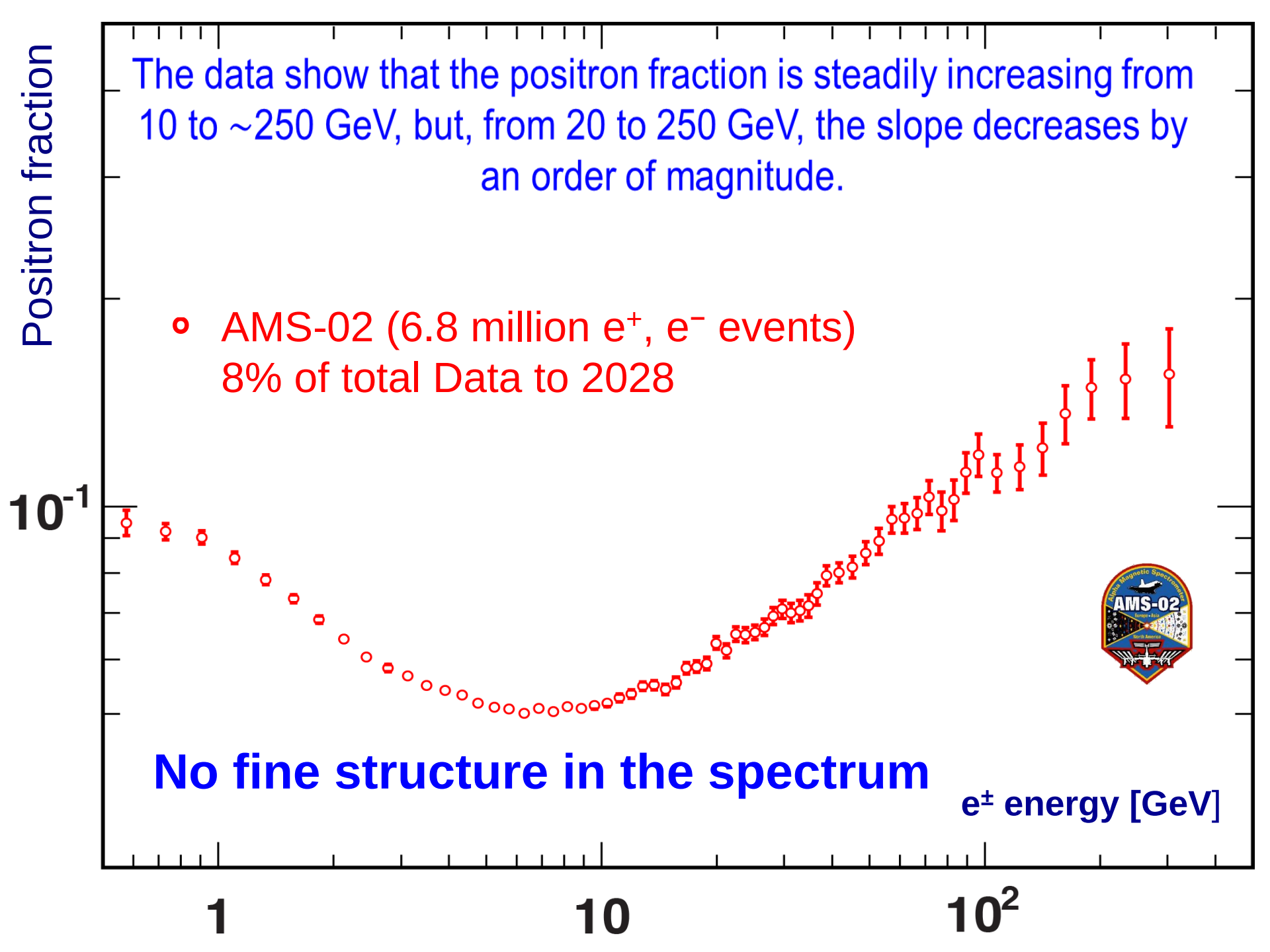
Systematic error on the positron fraction: 5. e+/- Charge confusion



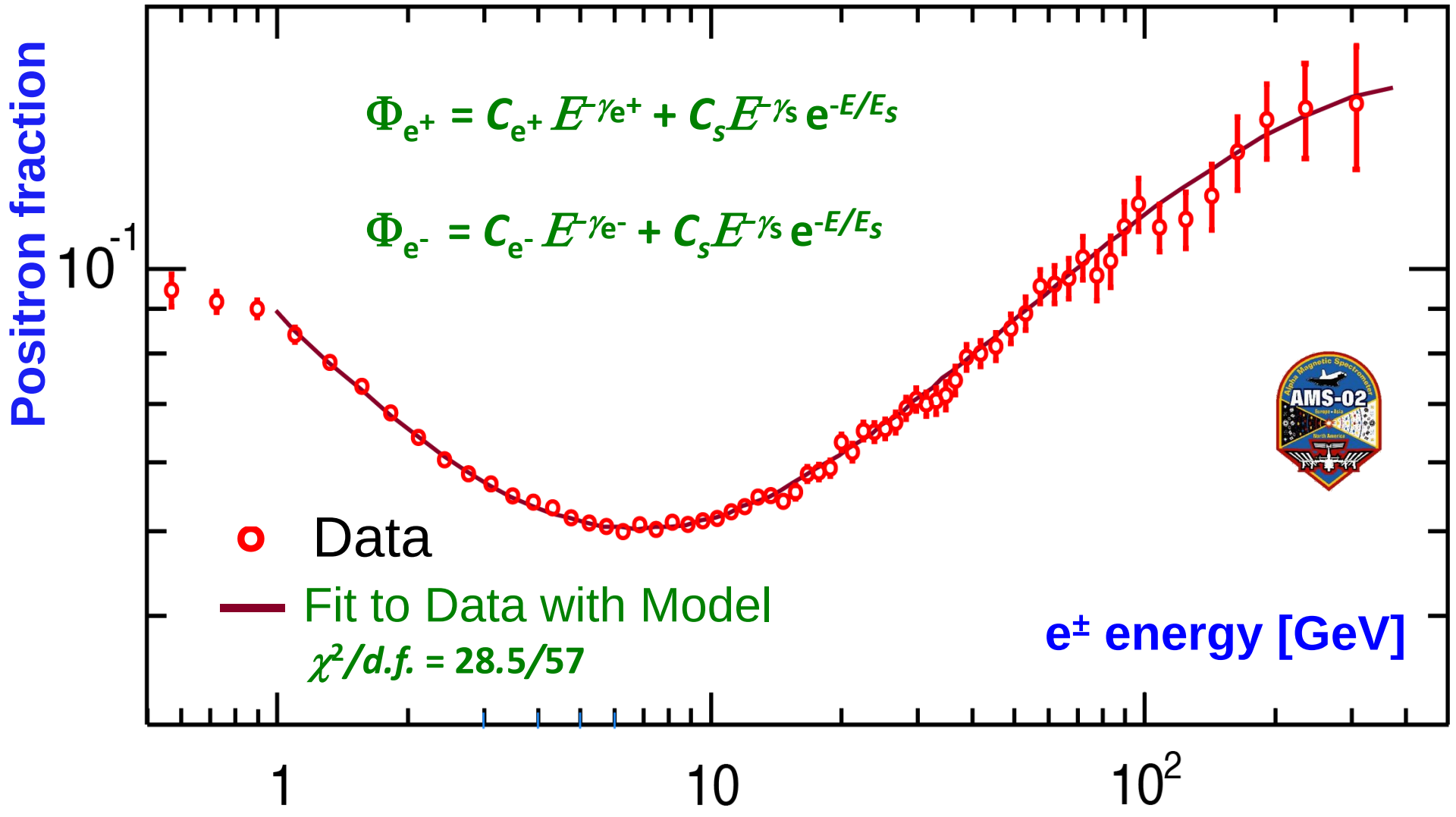
Two sources: large angle scattering and production of secondary tracks along the path of the primary track. Both are well reproduced by MC. Systematic errors correspond to variations of these effects within their statistical limits.

AMS Result: Measurement of the positron fraction

Positron events, positron fraction in each energy bin				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	9335	0.0842	0.0008	0.0005	0.0009	0.0008	0.0001	0.0005	0.0014
1.97-2.28	23893	0.0642	0.0004	0.0002	0.0005	0.0002	0.0001	0.0002	0.0006
3.30-3.70	20707	0.0550	0.0004	0.0001	0.0003	0.0000	0.0001	0.0002	0.0004
6.56-7.16	13153	0.0510	0.0004	0.0001	0.0000	0.0000	0.0001	0.0002	0.0002
09.95-10.73	7161	0.0519	0.0006	0.0001	0.0000	0.0000	0.0001	0.0002	0.0002
19.37-20.54	2322	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


The data show that the positron fraction is steadily increasing from 10 to ~250 GeV, but, from 20 to 250 GeV, the slope decreases by an order of magnitude.
AMS-02 (6.8 million e+, e− events)
8% of total Data to 2028
Positron fraction
10-1
No fine structure in the spectrum
e± energy [GeV]
1
10
10²

Physics Example: Comparing data with a minimal model.



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:

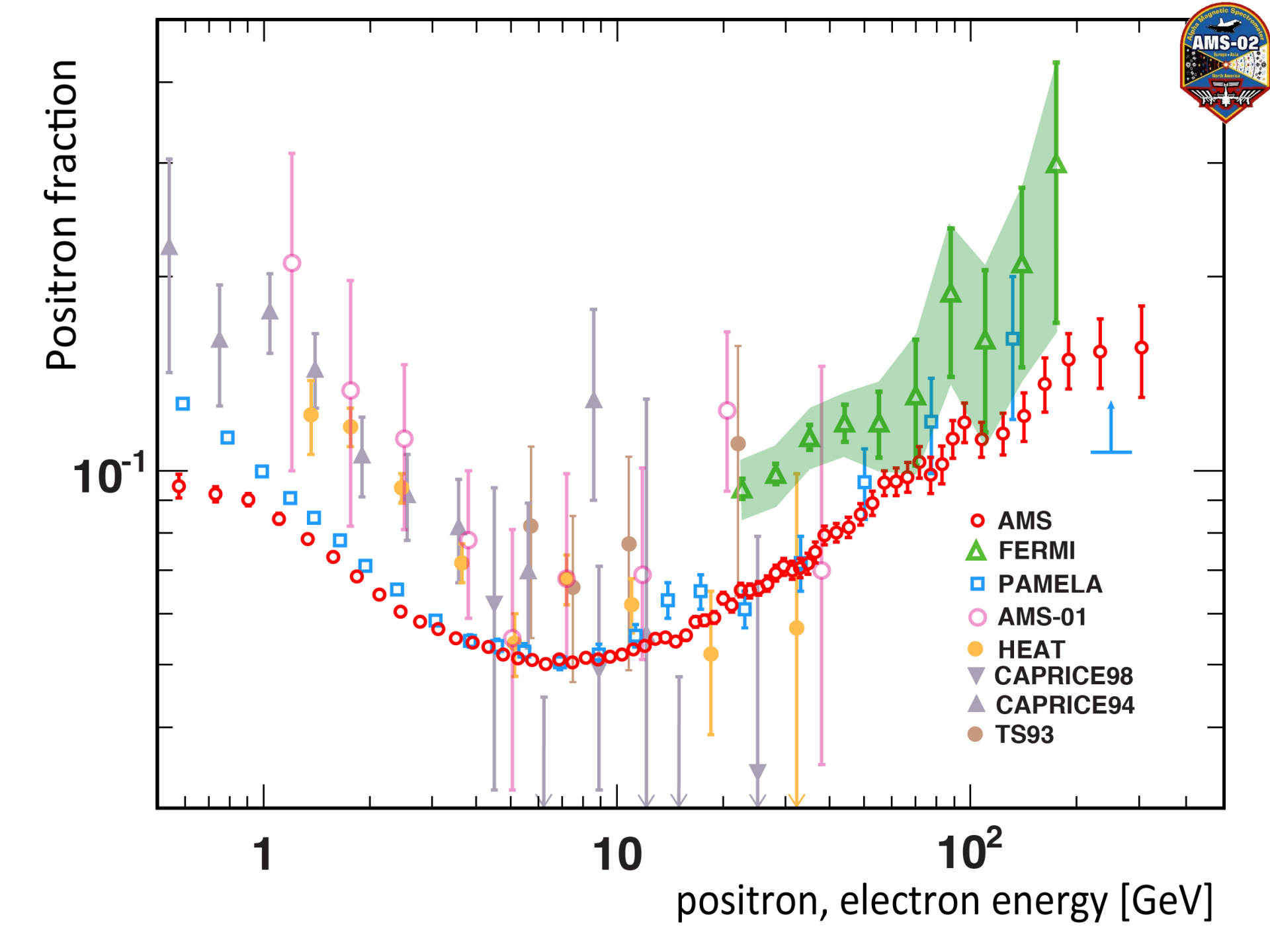
$\gamma_{e-} - \gamma_{e+} = -0.63 \pm 0.03$, *i.e.*, the diffuse positron spectrum is less energetic than the diffuse electron spectrum;

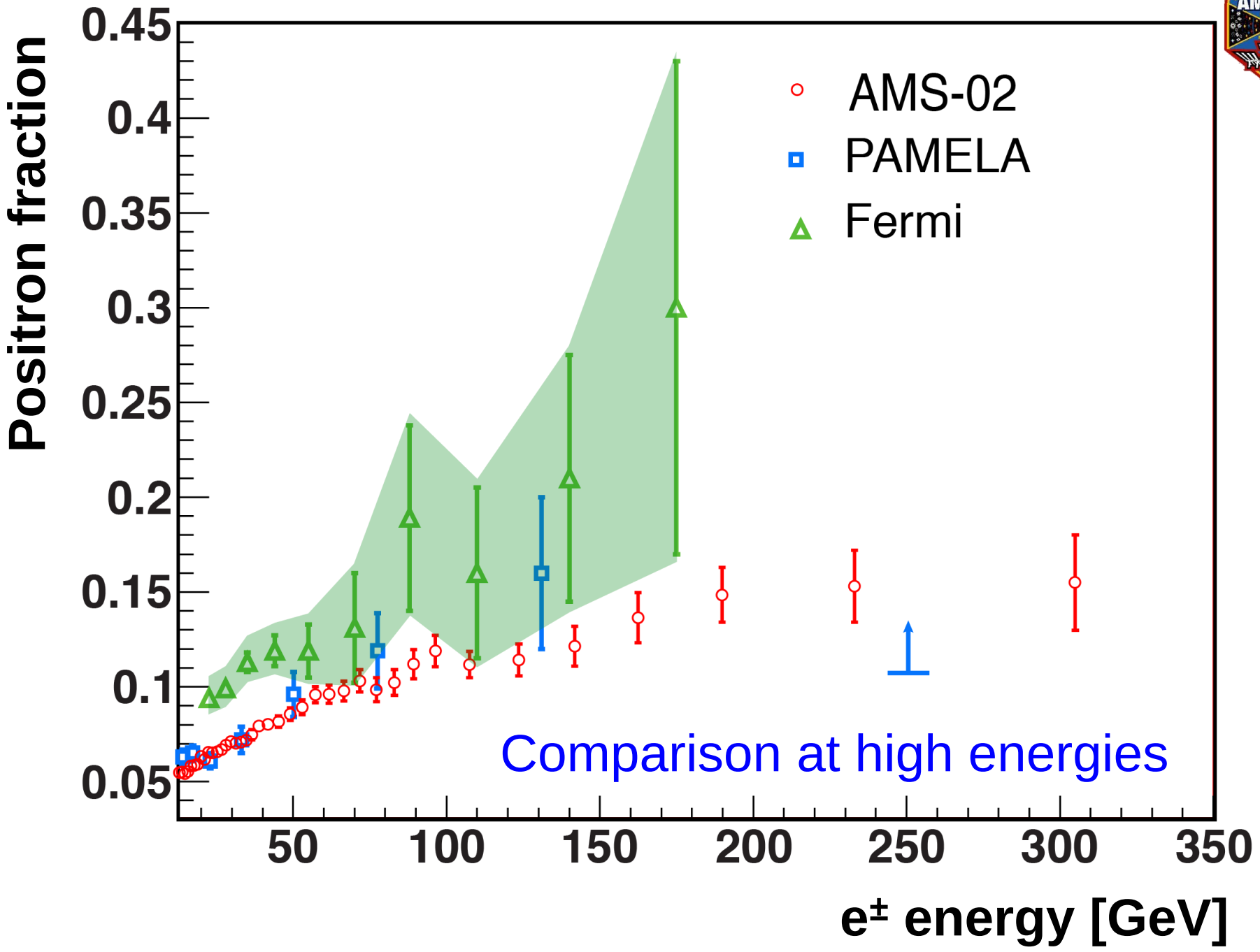
$\gamma_{e-} - \gamma_{S} = 0.66 \pm 0.05$, *i.e.*, the source spectrum is more energetic than the diffuse electron spectrum;

$C_{e+}/C_{e-} = 0.091 \pm 0.001$, *i.e.*, the weight of the diffuse positron flux amounts to ~10% of that of the diffuse electron flux;

$C_{S}/C_{e-} = 0.0078 \pm 0.0012$, *i.e.*, the weight of the common source constitutes only ~1% of that of the diffuse electron flux;

$1/E_s = 0.0013 \pm 0.0007$ GeV^{-1},
corresponding to a cutoff energy of 760^{+1000}_{-280} GeV.


Positron fraction
10^{-1}
1
10
10^2
positron, electron energy [GeV]
AMS
FERMI
PAMELA
AMS-01
HEAT
CAPRICE98
CAPRICE94
TS93
AMS-02


Positron fraction
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
50
100
150
200
250
300
350
e± energy [GeV]
AMS-02
PAMELA
Fermi
Comparison at high energies

In conclusion,
the first 6.8 million primary positron and electron events collected with AMS on the ISS show:

I. At energies < 10 GeV, a decrease in the positron fraction with increasing energy.

II. A steady increase in the positron fraction from 10 to ~250 GeV.

III. The determination of the behavior of the positron fraction from 250 to 350 GeV and beyond requires more statistics.

IV. The slope of the positron fraction versus energy decreases by an order of magnitude from 20 to 250GeV and no fine structure is observed. 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.

These observations show the existence of new physical phenomena, whether from a particle physics or an astrophysical origin.

Electron E=982 GeV

Run/Event 1329775818/ 60709

Positron E=636 GeV

Run/Event 133119-743/ 56950