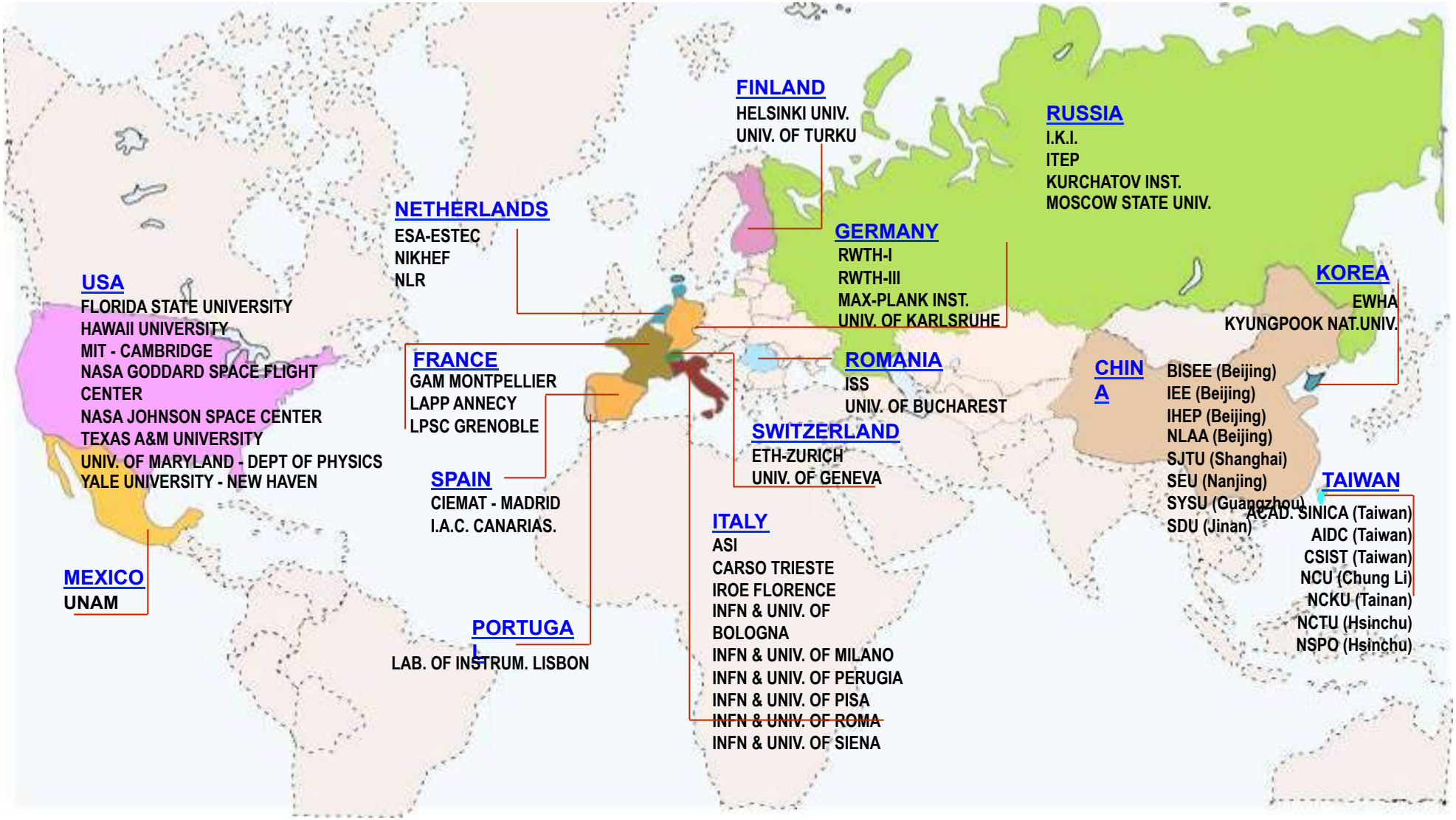
AMS-02
Stato e risultati

Matteo Duranti
INFN Sez. Perugia
per la collaborazione AMS

On behalf of the AMS Collaboration
16 Countries, 60 Institutes and 600 Physicists

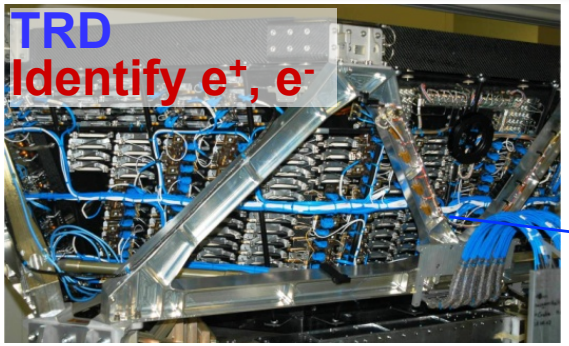


Italy in AMS

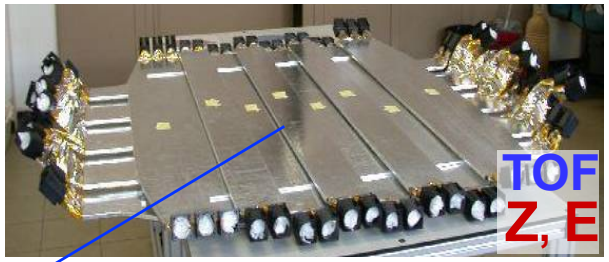

Perugia
INFN
Istituto Nazionale
di Fisica Nucleare
agenzia spaziale
italiana
Milano
LNL
Bologna, CNAF
Pisa
Perugia
Terni
Roma
LNS
60 Scientists and Engineers
6 Universities
5 INFN Sections
2 INFN National Laboratories + computing
16 years of collaboration among INFN and ASI

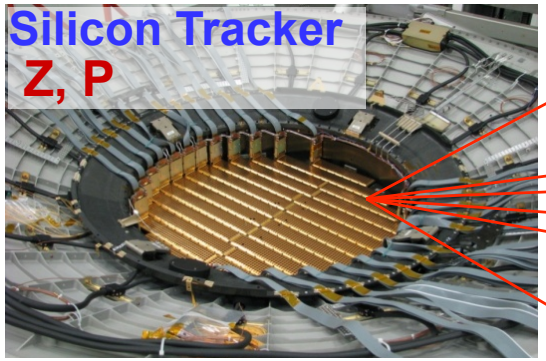
Perugia in AMS

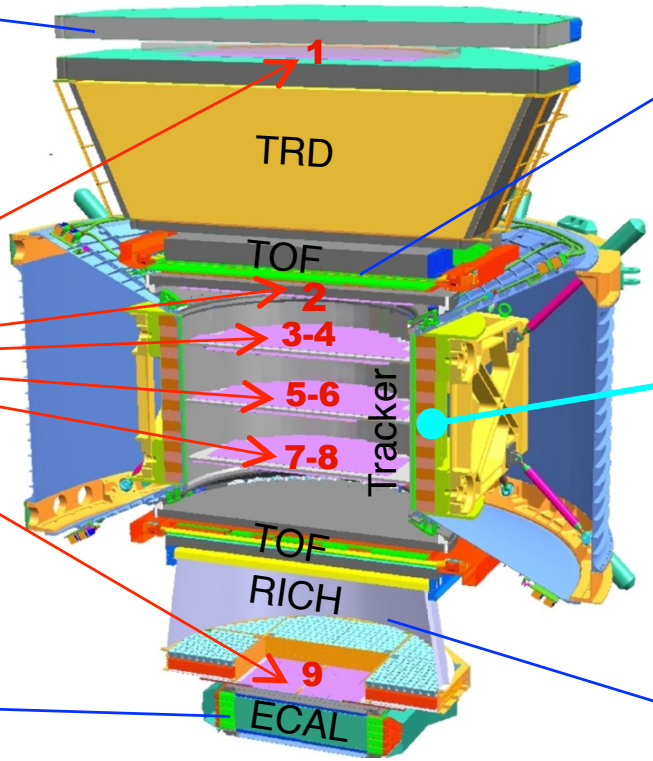
A precision, multipurpose spectrometer up to TeV

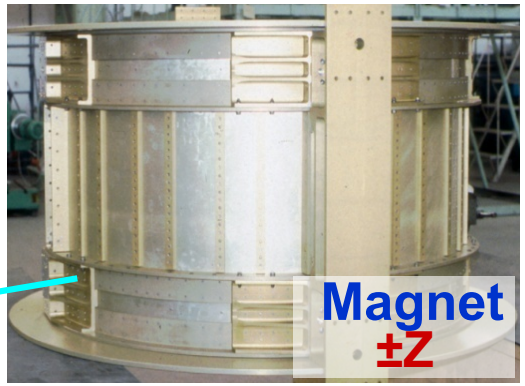


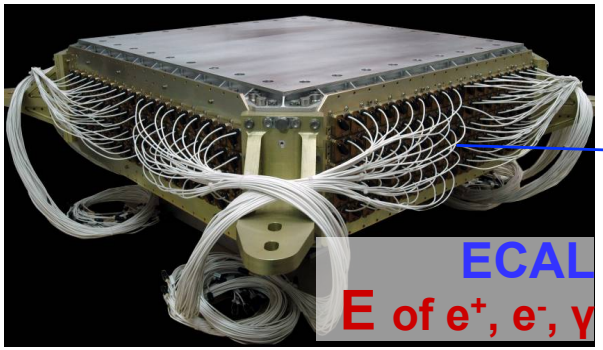
***Z, P** are measured independently by the Tracker, RICH, TOF and ECAL*

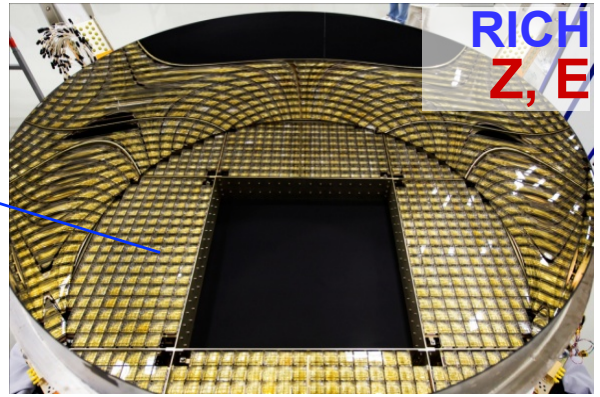




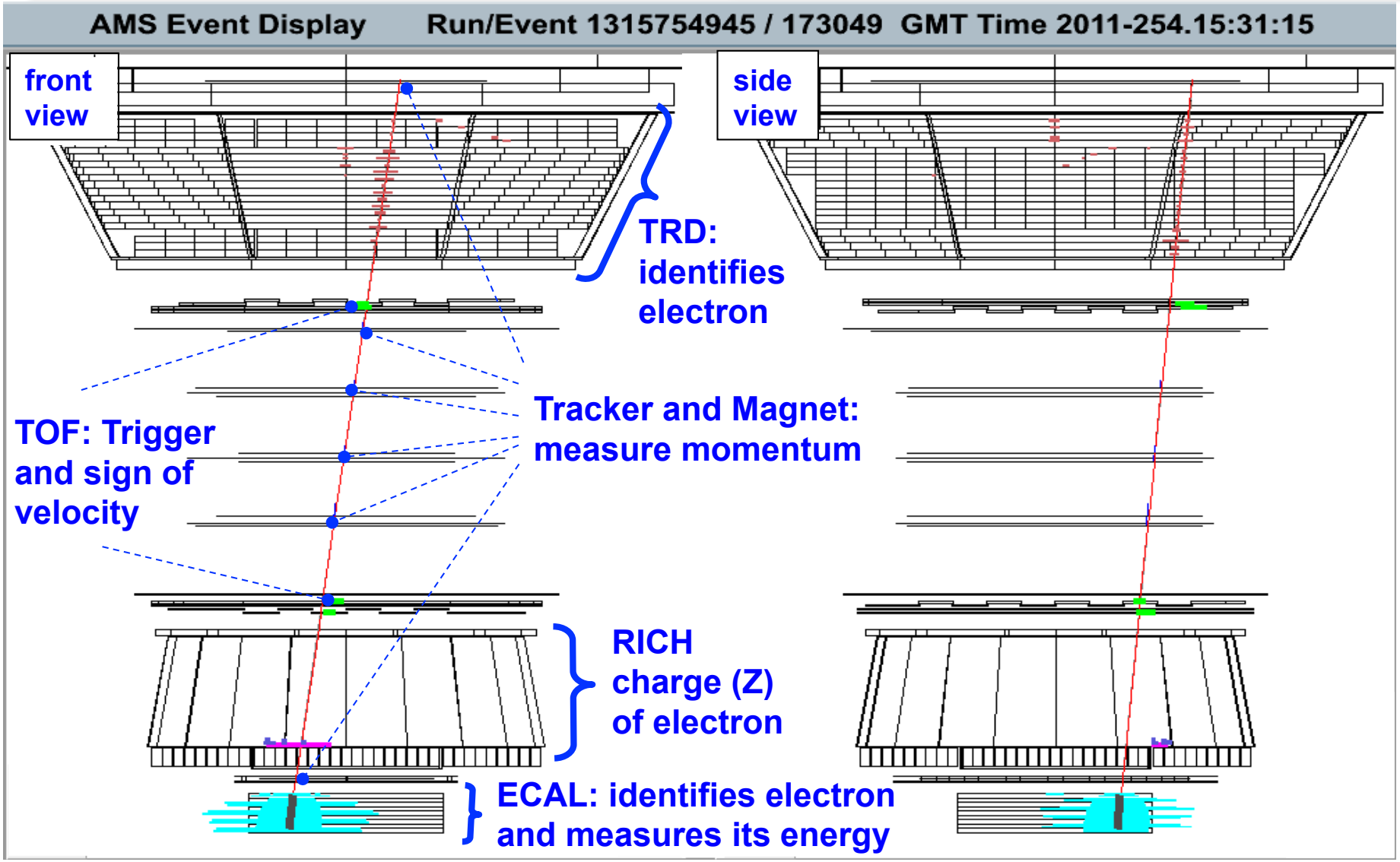






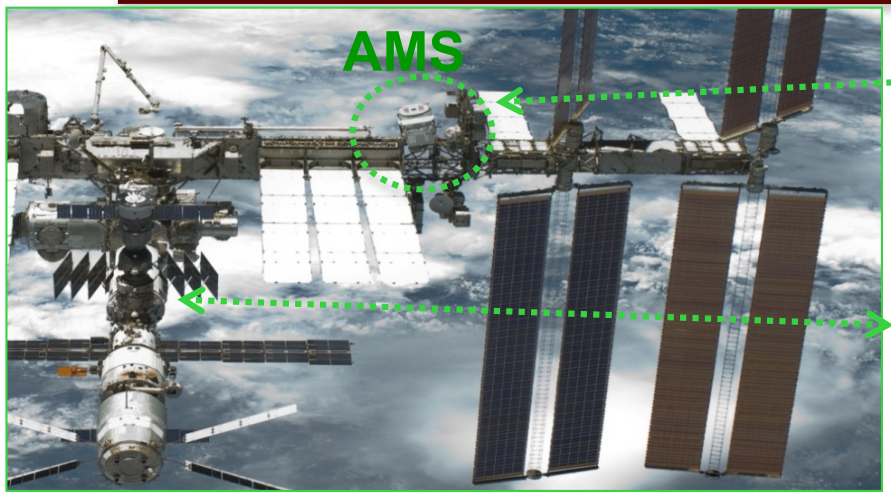


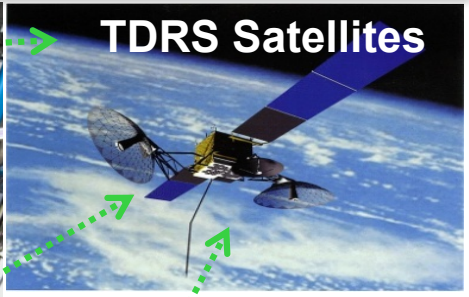
AMS data on ISS - 1.03 TeV electron



AMS on the International Space Station

AMS operation : 24/24 – 7/7 – 365/year





Ku-Band
High Rate (down):
Events <10Mbit/s>
≈30 billion triggers
70 TB of raw data

Flight Operations

Ground Operations

S-Band
Low Rate (up & down):
Commanding: 1 Kbit/s
Monitoring: 30 Kbit/s

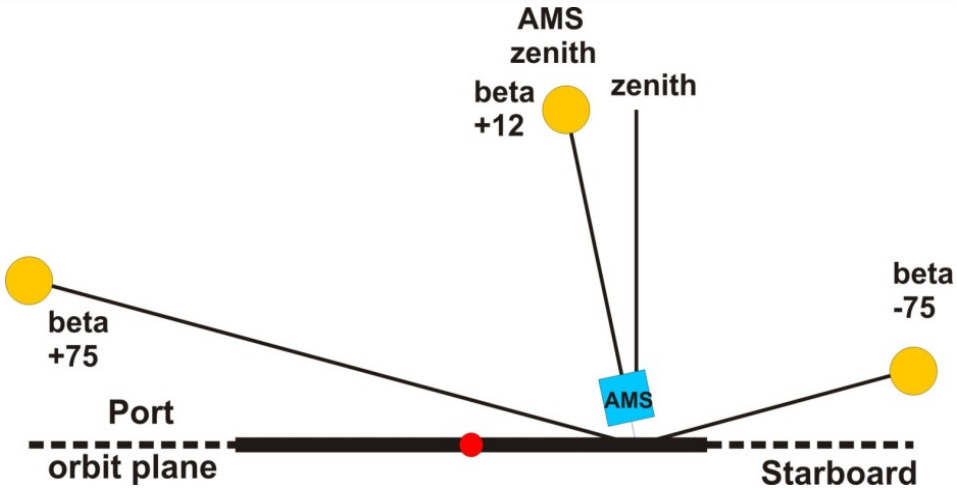
AMS Payload Operations Control and Science Operations Centers (POCC, SOC) at CERN

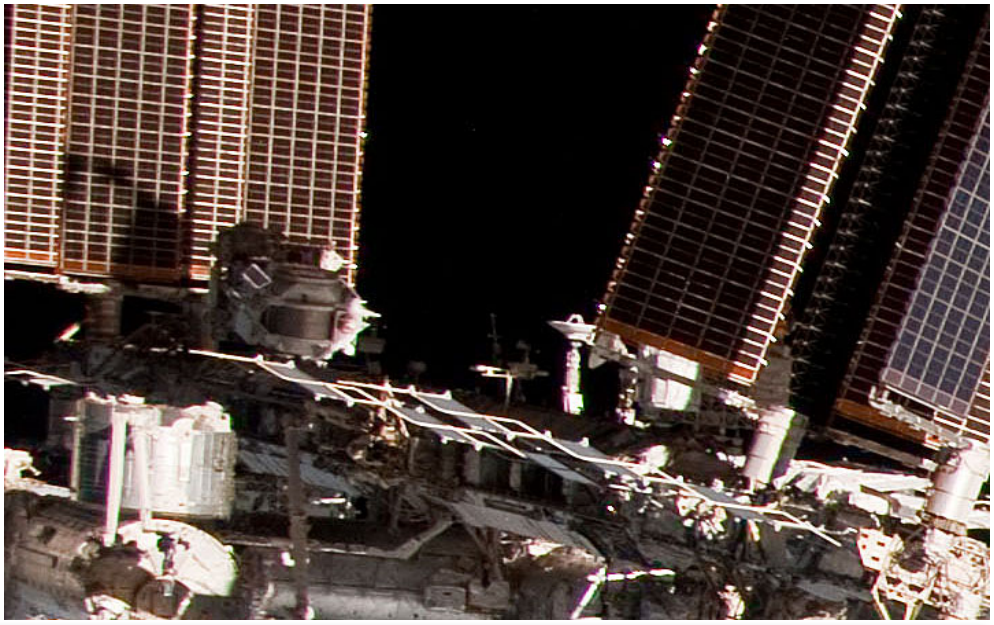
AMS Computers at MSFC, AL

White Sands Ground Terminal, NM

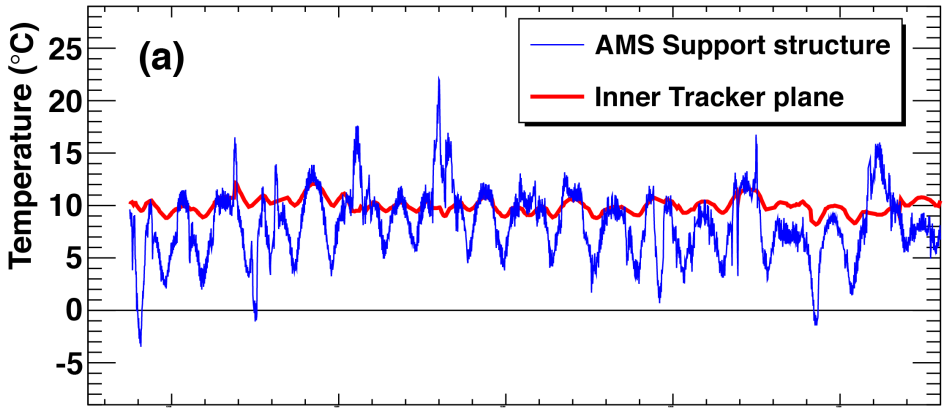
The thermal environment

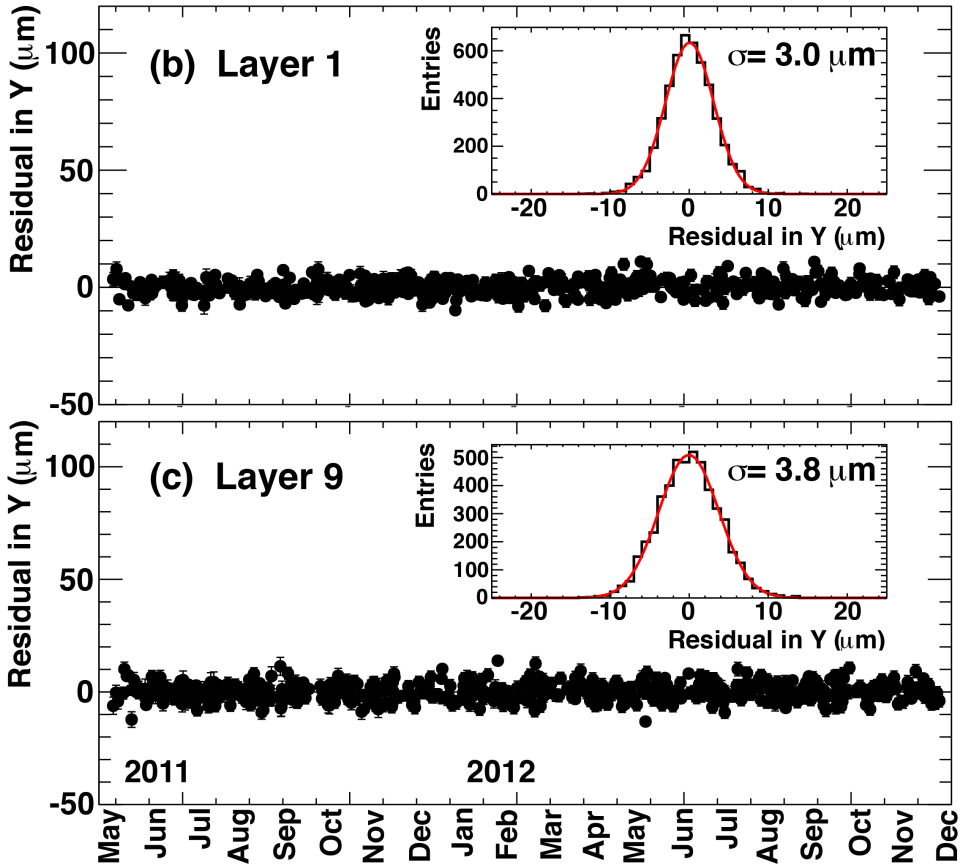
- Sun position: along the orbit + seasonal variation
- Solar array and ISS radiator position
- ISS attitude and visiting vehicles





Tracker alignment & Calibration





The tracker has been aligned and particular care has been used for the two external layers

Objectives

- Fundamental physics & Antimatter :
  - Primordial origin (signal : anti-nuclei)
  - Exotic sources (signal: positrons, anti-p, anti-D, γ)

- The CR composition and energy spectrum
  - Sources & acceleration : Proton and He
  - Propagation in the ISM: secondaries (B/C, ...)

Antimatter

Primordial origin (Signal: anti-nuclei)

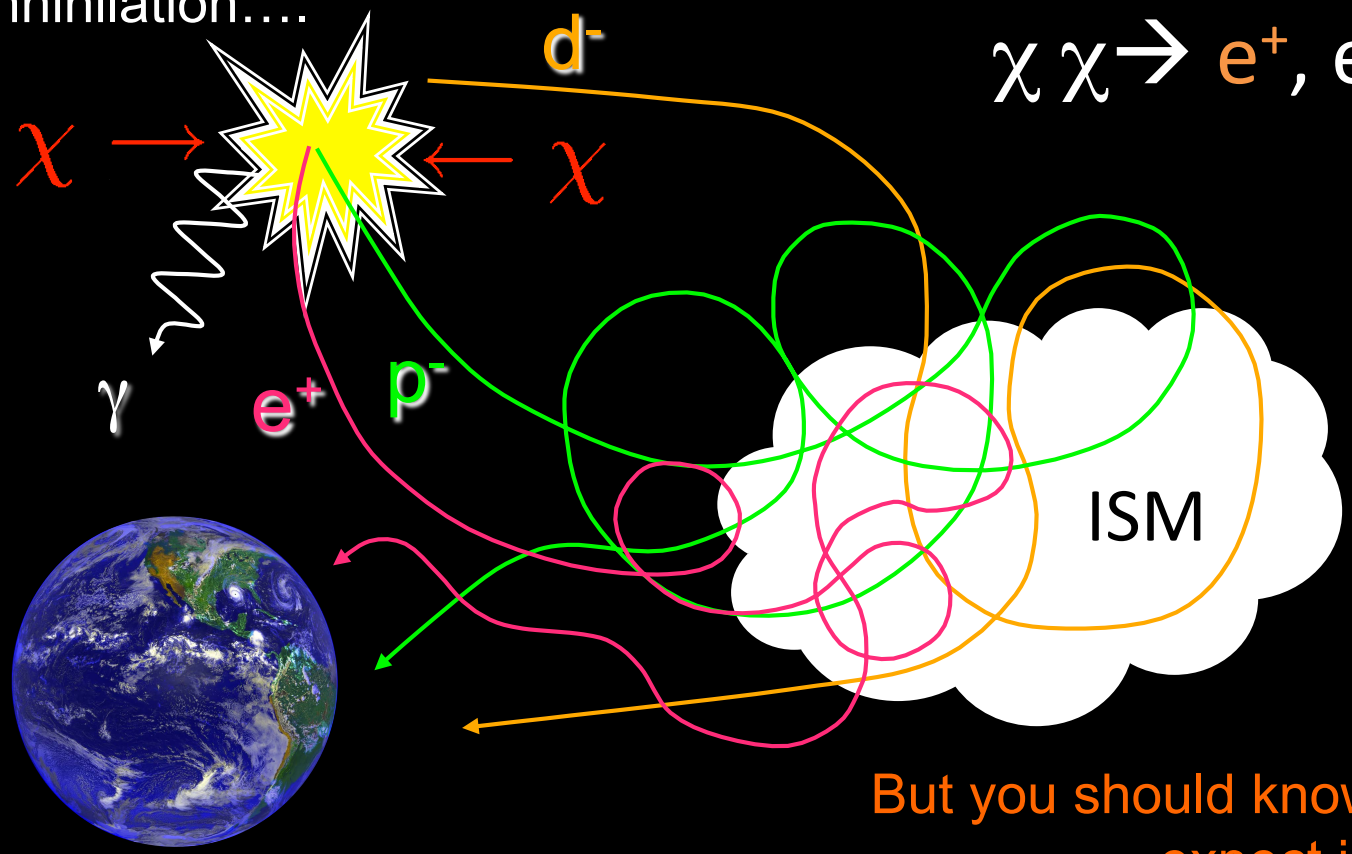
Dirac's Nobel speech

"We must regard it rather as an accident that the Earth [...] contains a preponderance of negative electrons and positive protons. It is quite possible that for some stars it is the other way about."

Dark Matter

WIMP as the responsible of Dark Matter (?)

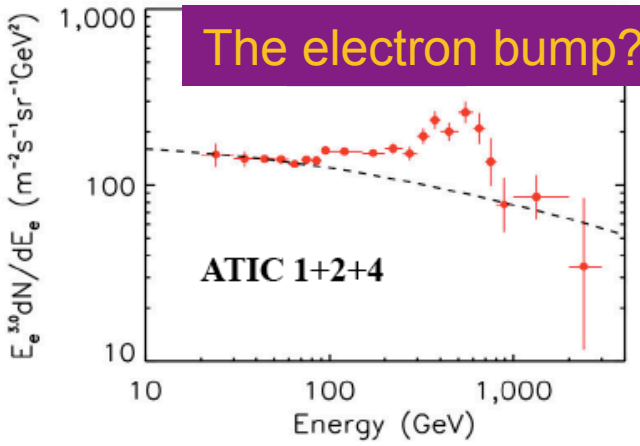
Indirect DM search → search for (rare in CR) products from their annihilation….



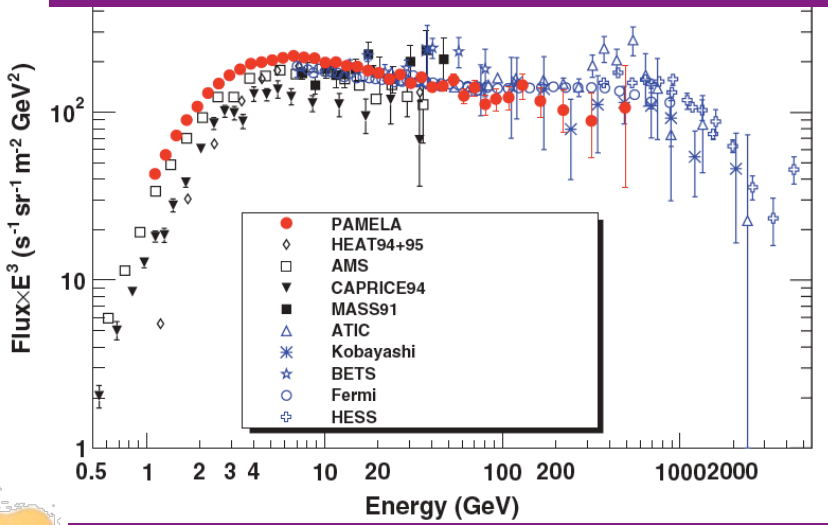
But you should know what you expect in the ISM !!

Exotic sources (DM ?)

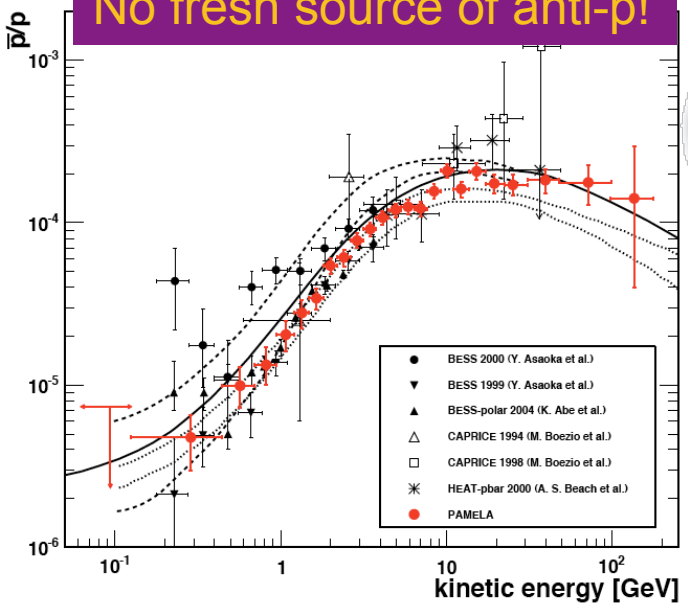
The electron bump?



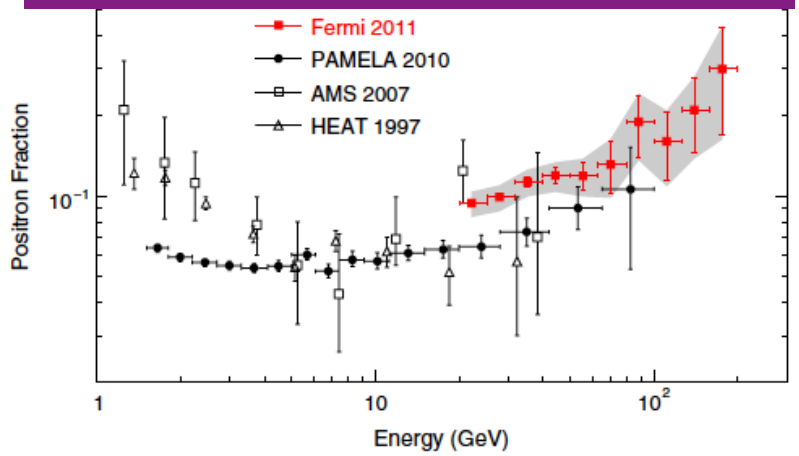
No bump in Fermi / PAMELA data



No fresh source of anti-p!

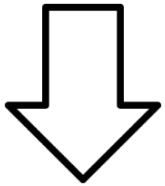


A confirmed positron "excess"



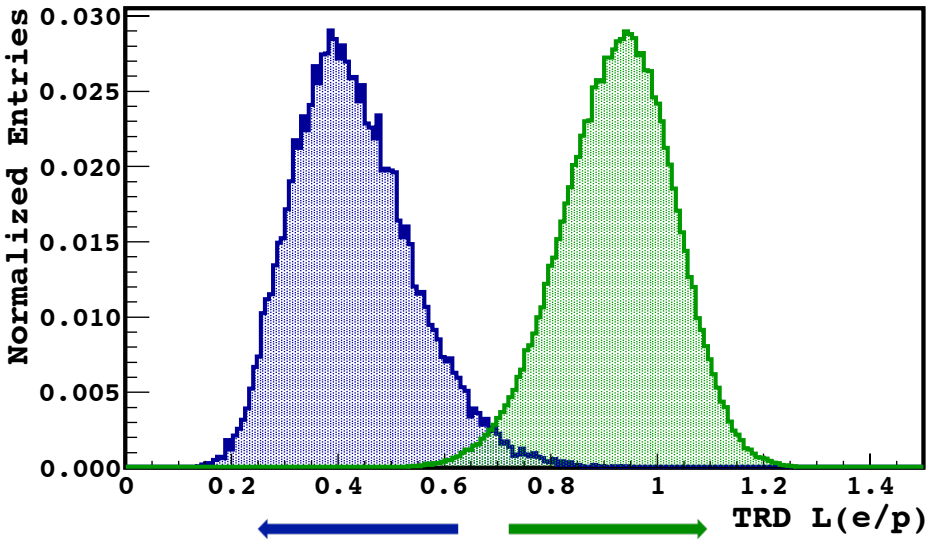
What is needed?

- Particle identification and energy measurement up to TeV:
  - e/p separation at the 10^4 level : TRD, e.m. calorimeter + energy momentum matching
  - Z : redundant measurements to evaluate fragmentation
  - Charge sign: matter to anti-matter separation
- Statistics
  - acceptance & efficiency
  - Exposure time

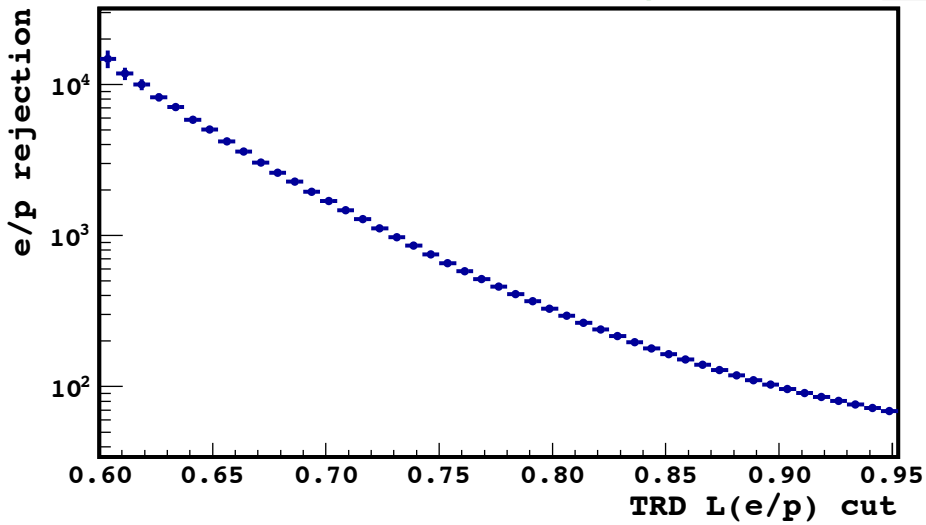


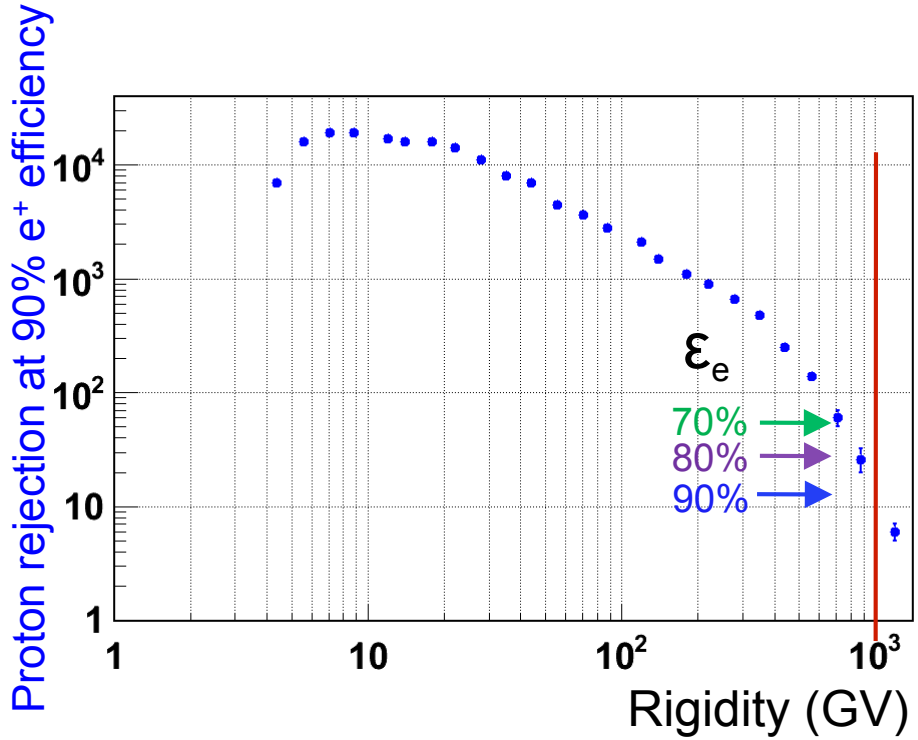
AMS

Particle identification in TRD

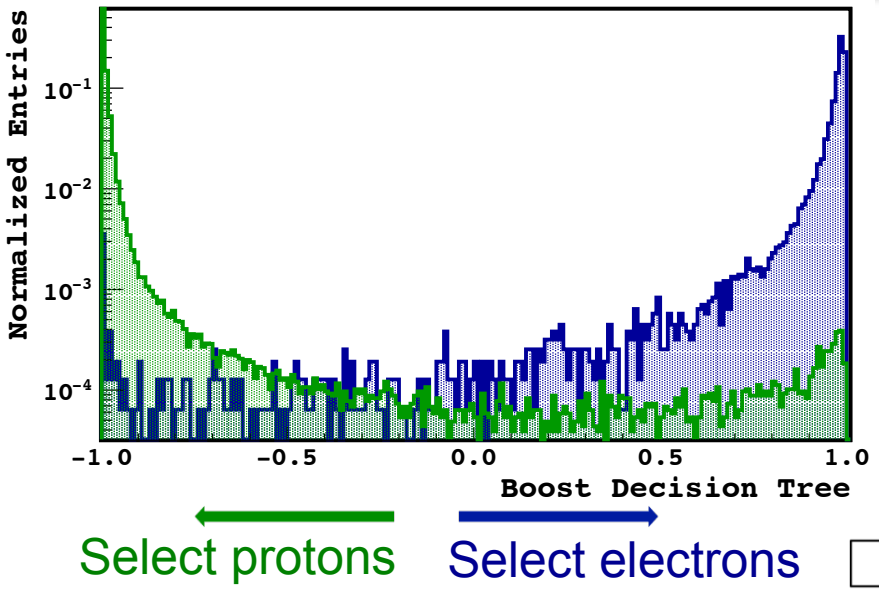


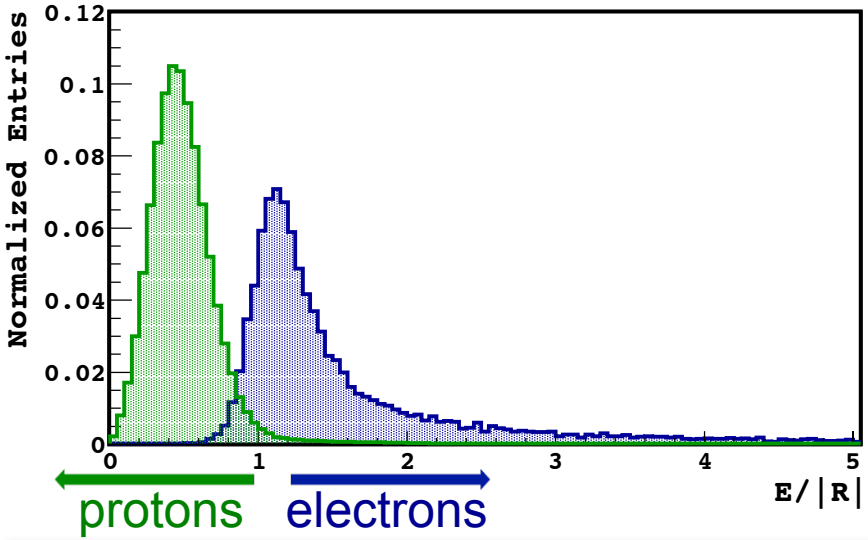
Select electrons Select protons

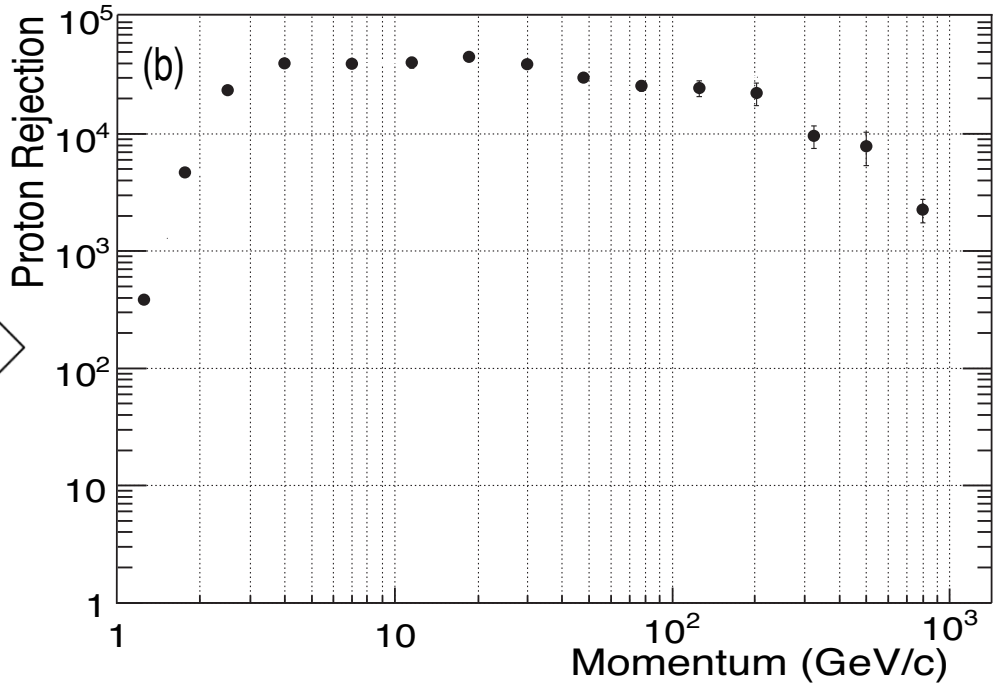




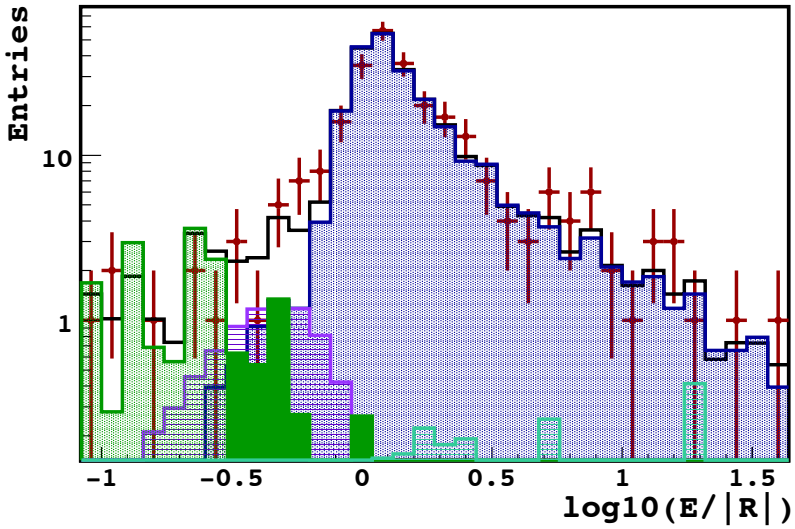
Particle identification in ECAL





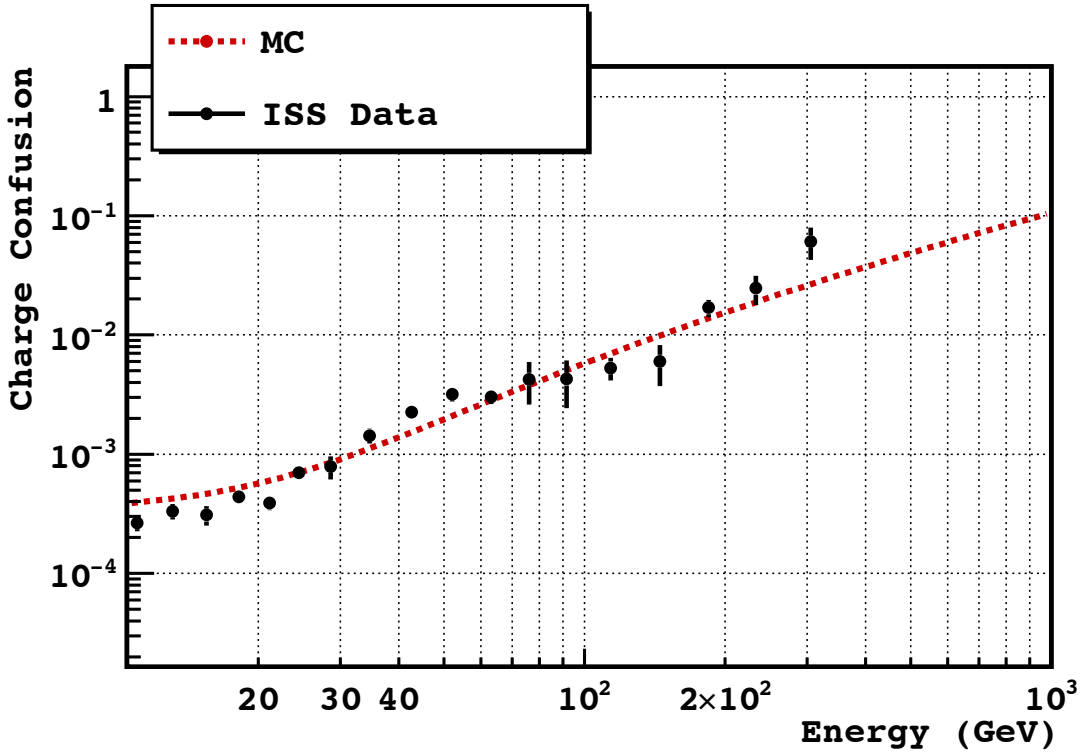


Electron charge identification in tracker



The Charge Confusion can be kept under 10% up to ~ TeV

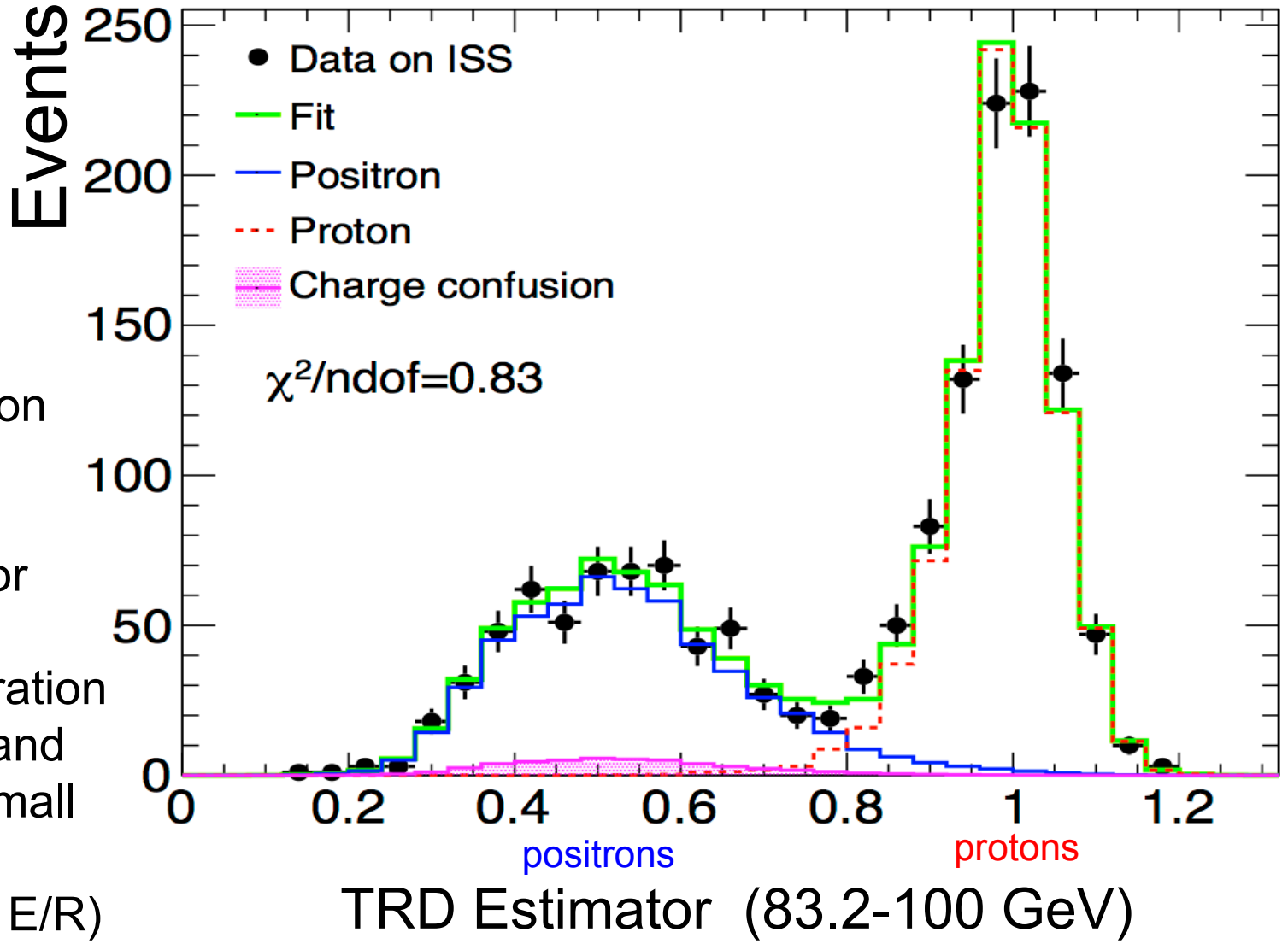
Using the ratio between Tracker rigidity and ECAL energy is possible to fit, directly from ISS data, the amount of Charge Confusion



Selection and background estimation

Example of Positron Selection:

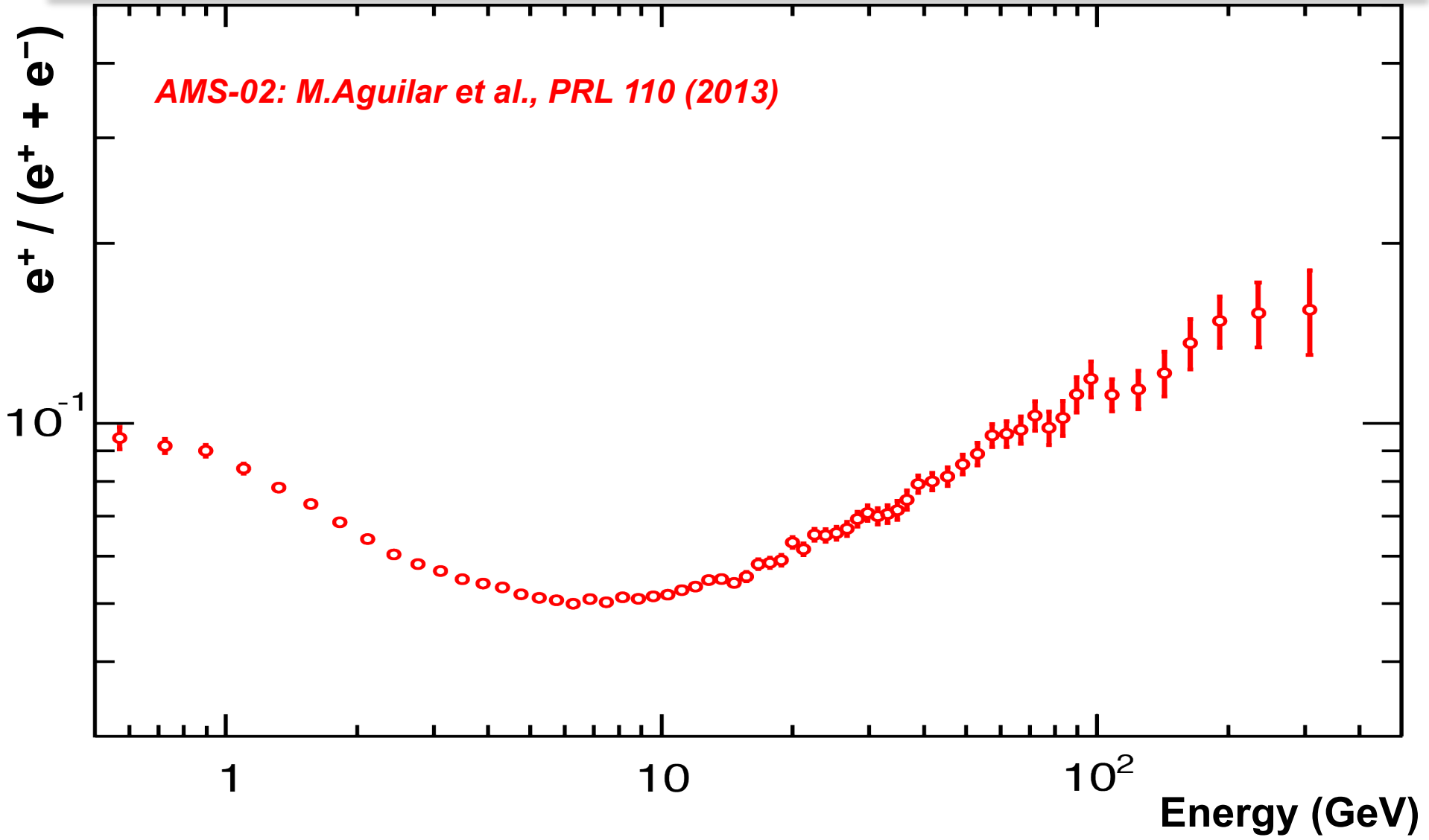
The TRD Estimator (Likelihood Ratio) shows clear separation between protons and positrons with a small charge confusion background (from E/R)



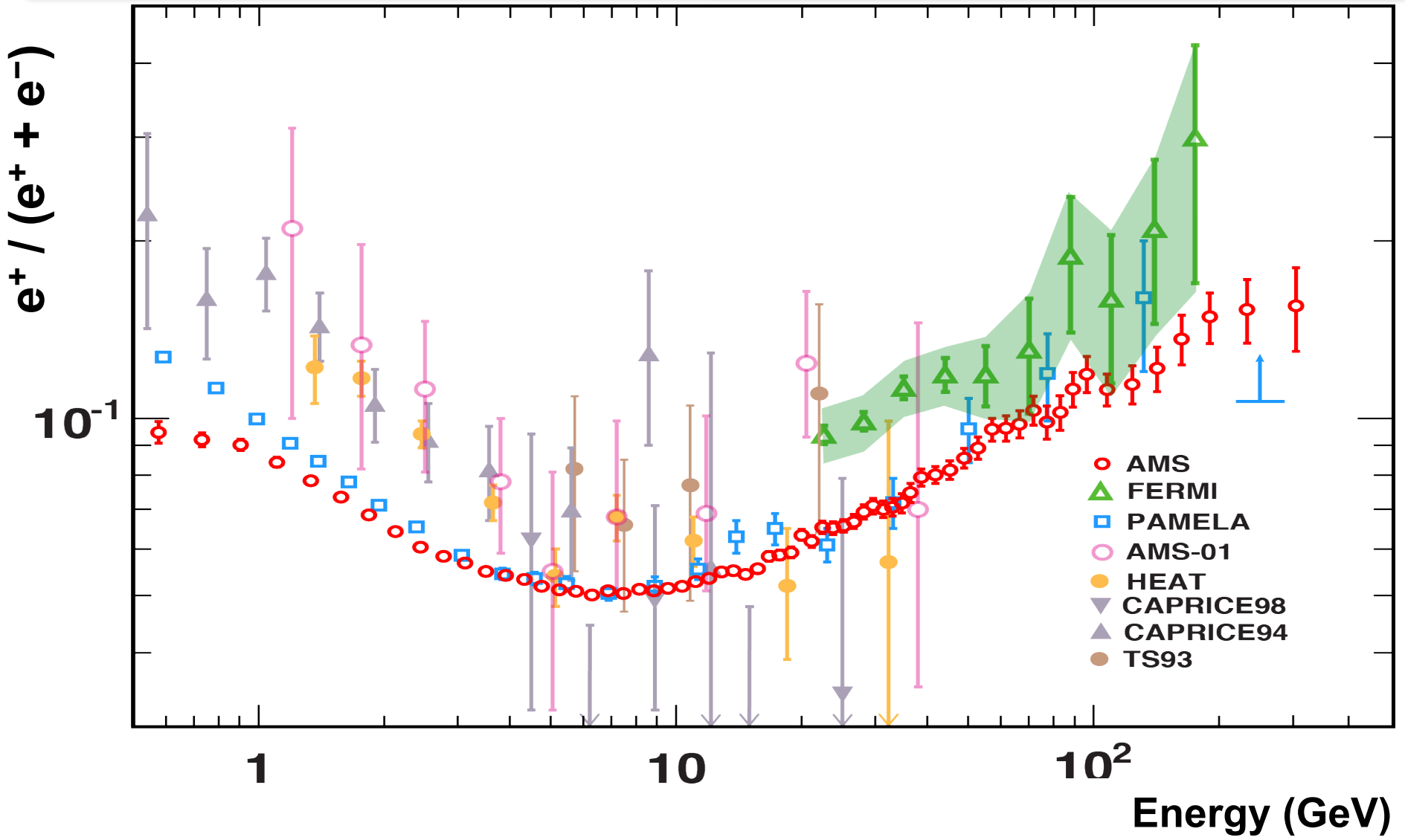
Systematic errors on positron fraction

1. Acceptance asymmetry
   - Difference between positron and electron acceptance due to known minute tracker asymmetry → err.rel = 1% - 0.2%
2. Selection dependence
   - Dependence of the result on the cut values → err.rel = 2% - 0.4%
3. Migration bin-to bin
   - Migration of electron and positron events from the neighboring bins affects the measured fraction → err.rel = 0.5% - 0.01%
4. Reference spectrum
   - Definition of the reference spectra is based on pure samples of electrons and protons of finite statistics → err.rel = 0.2% - 1%
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 → err.rel = 1% - 10%

Positron fraction (0.5 - 350 GeV)



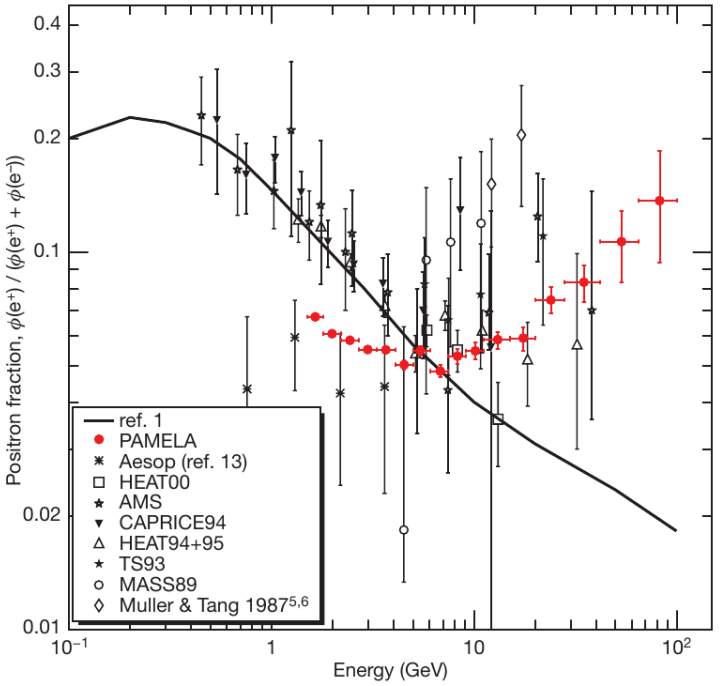
Positron fraction (0.5 - 350 GeV)



Minimal model

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

$$\Phi_{e^+} = C_{e^+} E^{-\gamma_{e^+}} + C_s E^{-\gamma_s} e^{-E/E_s}$$
$$\Phi_{e^-} = C_{e^-} E^{-\gamma_{e^-}} + C_s E^{-\gamma_s} e^{-E/E_s}$$



Coefficients C_{e+} and C_{e-} correspond to relative weights of diffuse spectra for positrons and electrons.

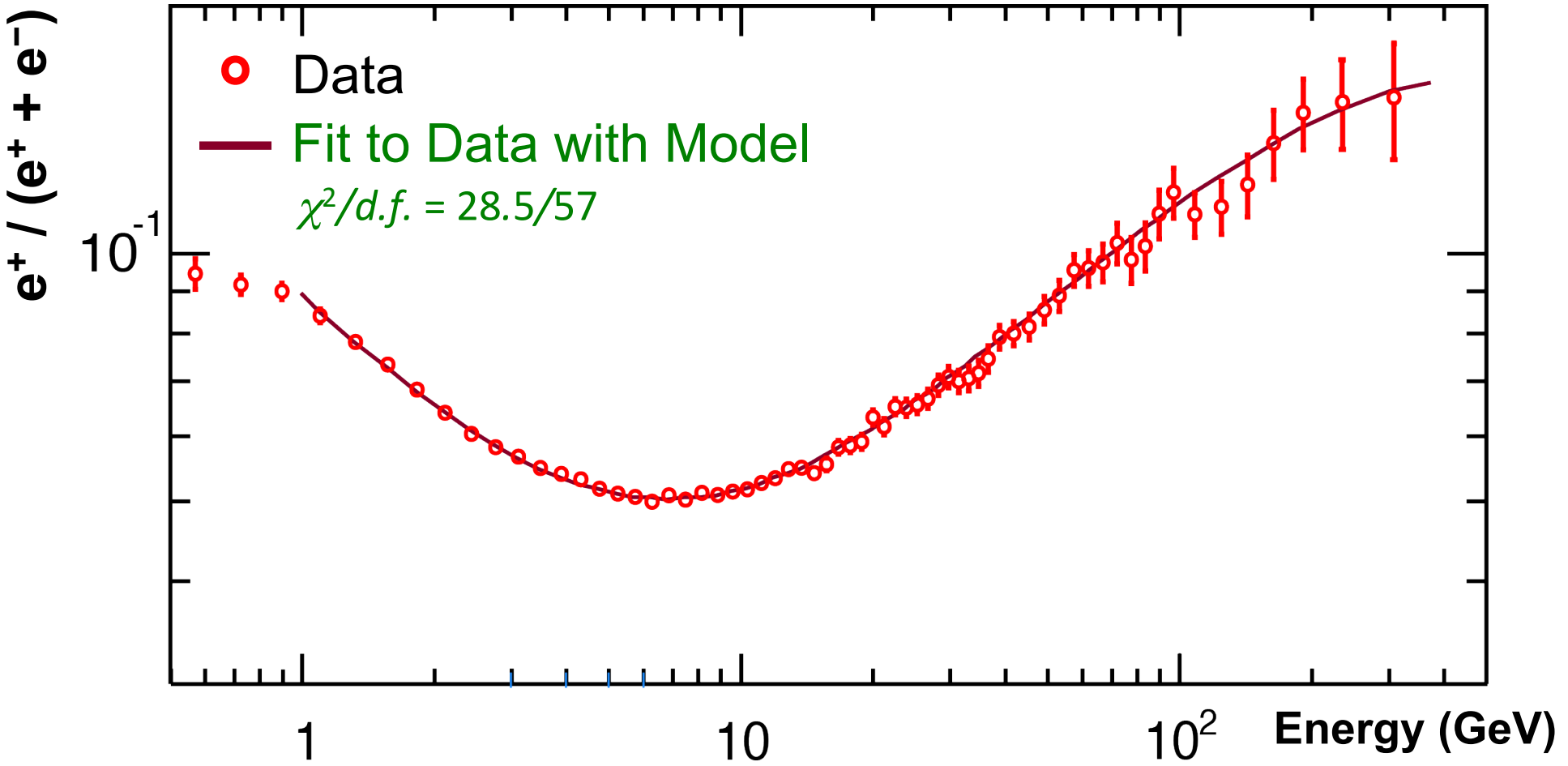
C_s is the weight of the source spectrum.

γ_{e+}, γ_{e-} 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.

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.

Minimal model

A fit to the data in the energy range 1 to 350 GeV yields a $\chi^2/d.f. = 28.5/57$ and:

$\gamma_{e-} - \gamma_{e+} = -0.63 \pm 0.03$, *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.

Summary & Conclusions

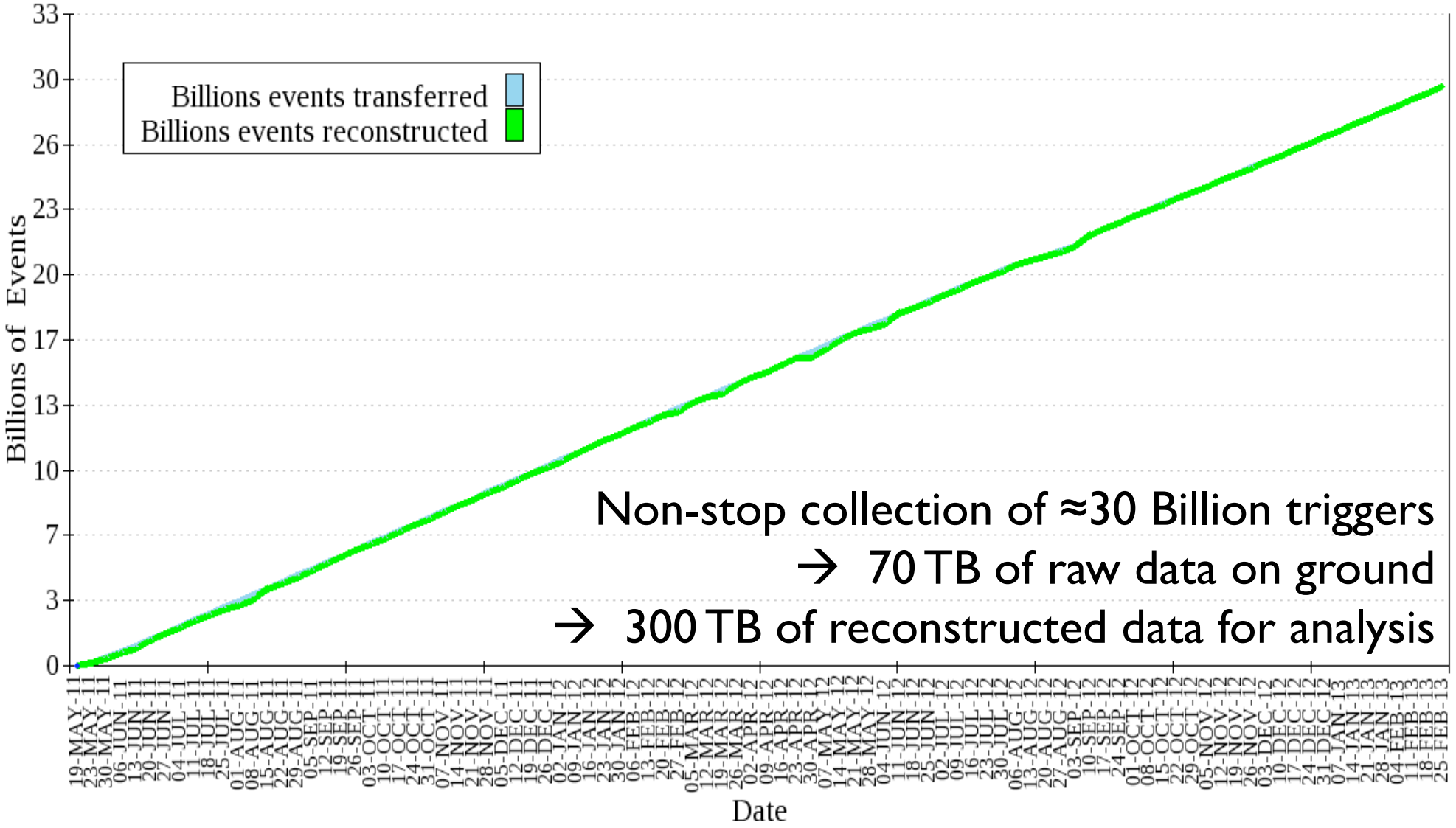
- More than 30 billion triggers have been collected by AMS-02 since May 19th 2011
- Accurate calibration of the apparatus is completed
- First publication on the precision measurement of the positron fraction at energies up to 350 GeV published!
- More to come soon...


AMS-02
AMS Tracker
AMS Lead
STS-134
Thank you for your attention!

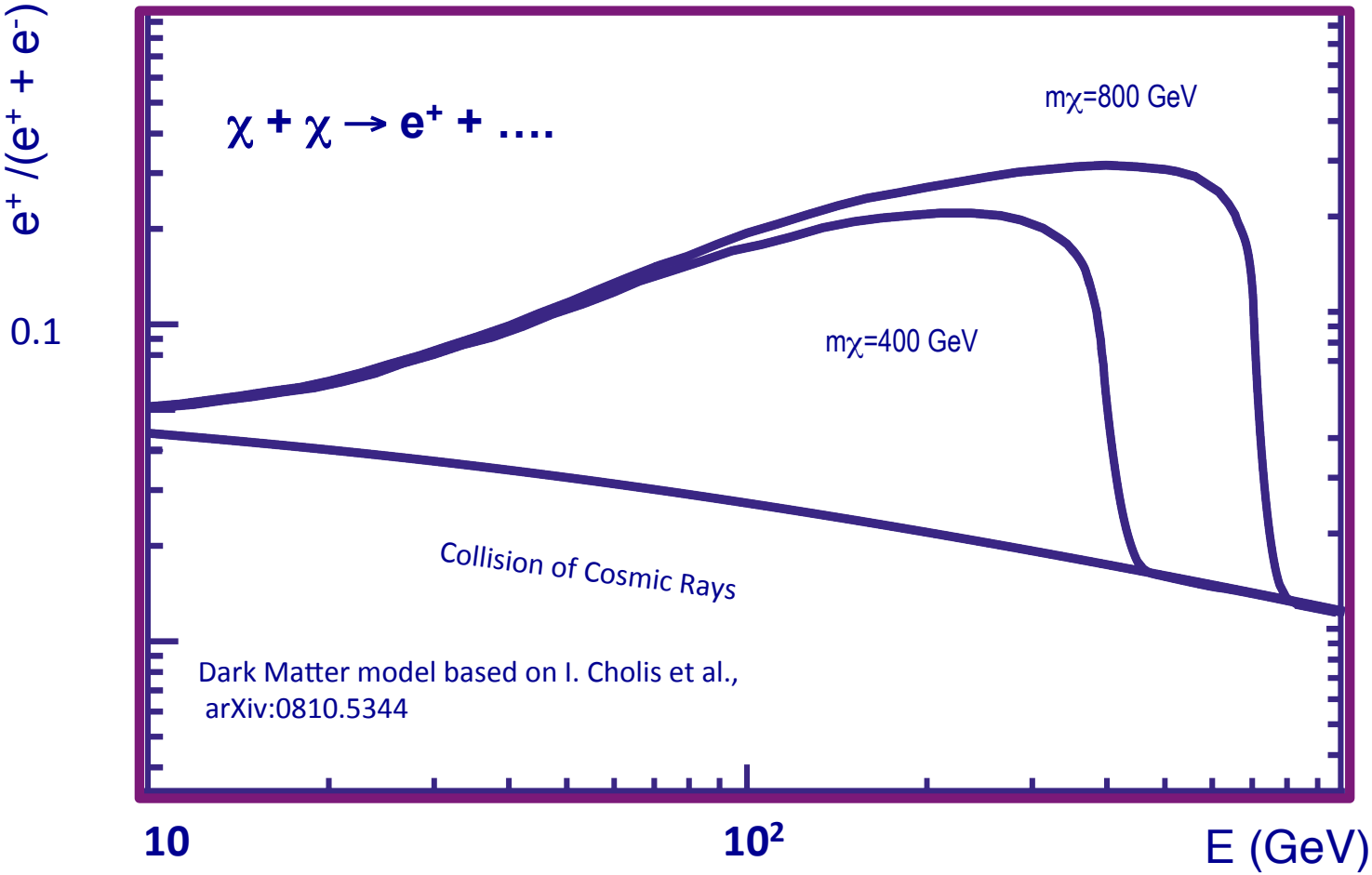

Alpha Magnetic Spectrometer
AMS-02
Europe • Asia
North America

Backup

Data collected

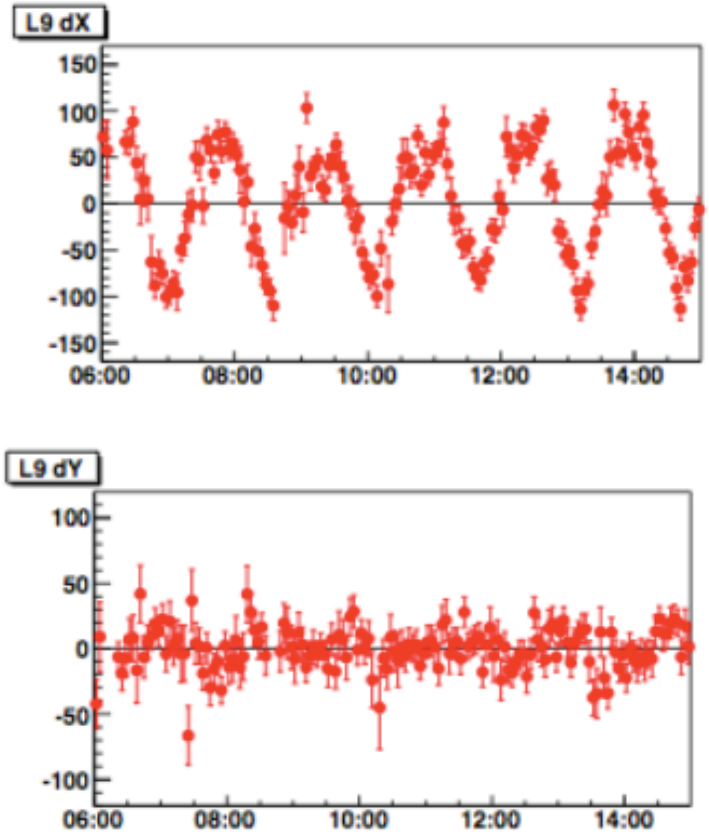


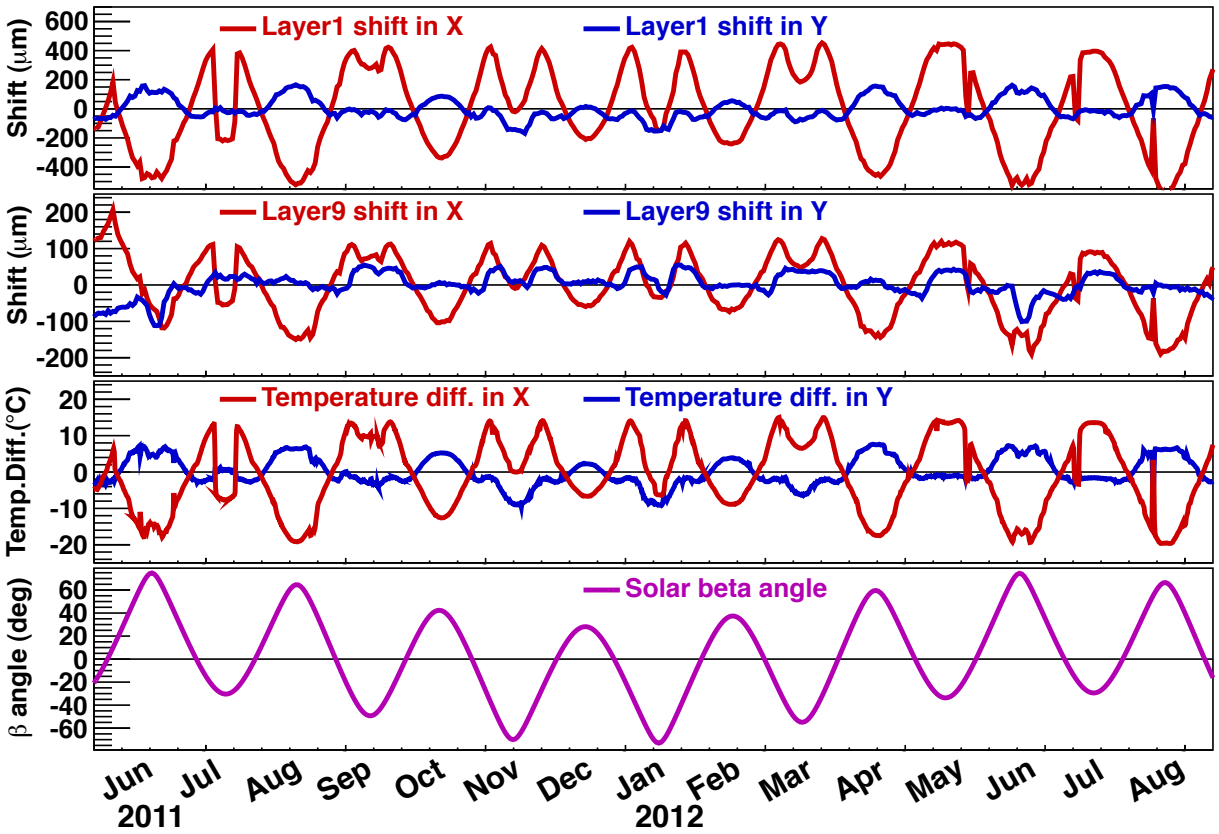
What is needed?



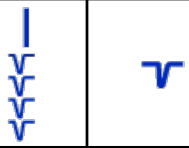
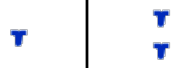
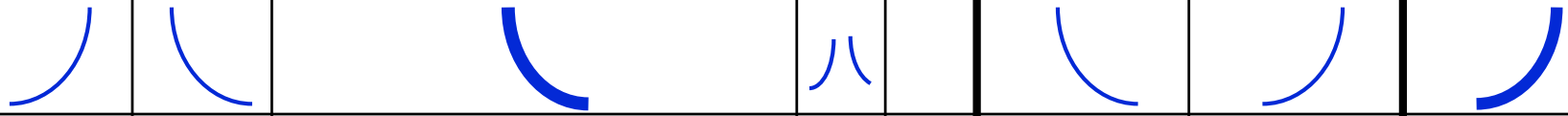
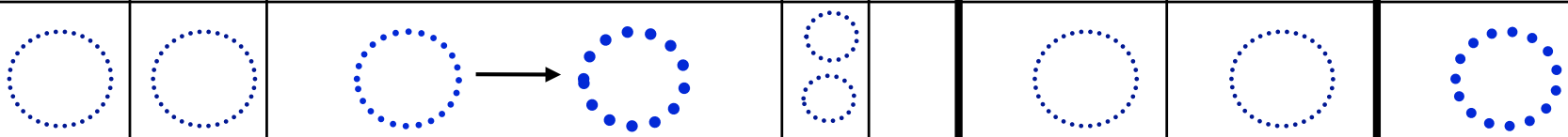
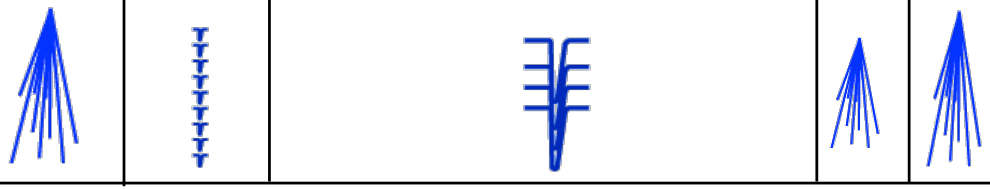
Leptophilic dark matter or astrophysical sources ??

Stability of external layers

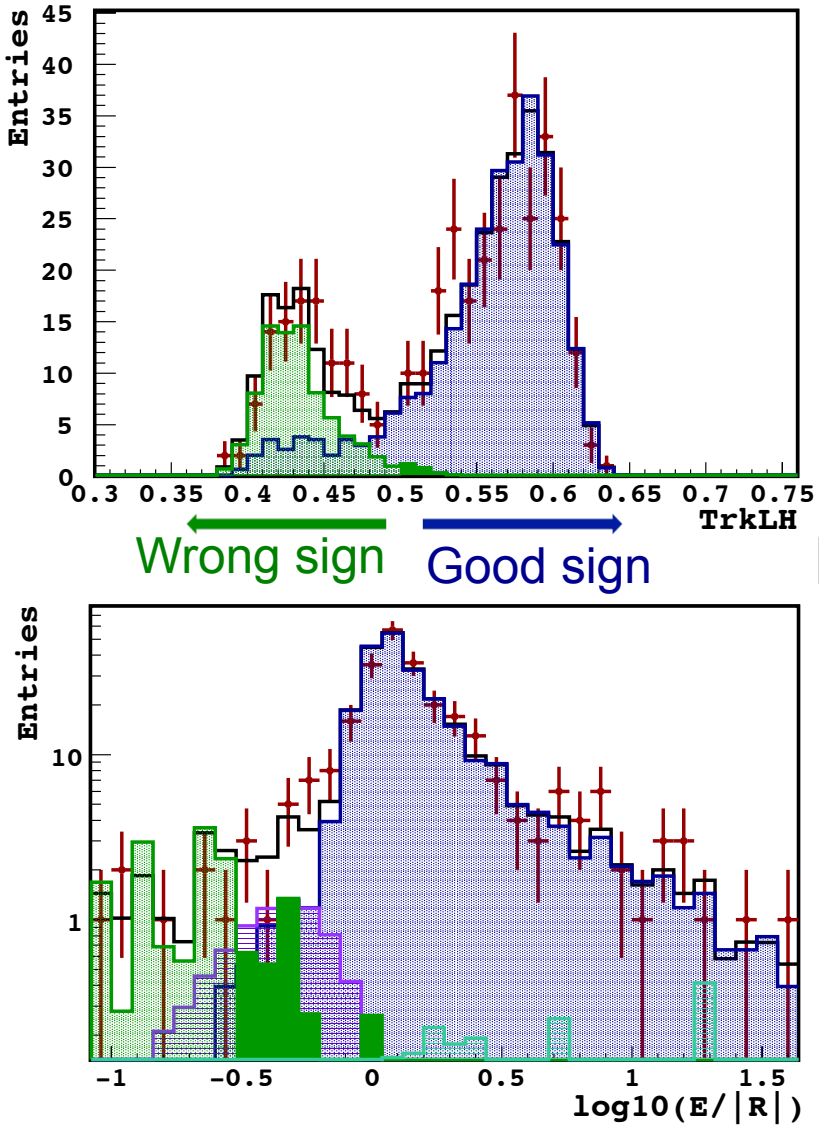


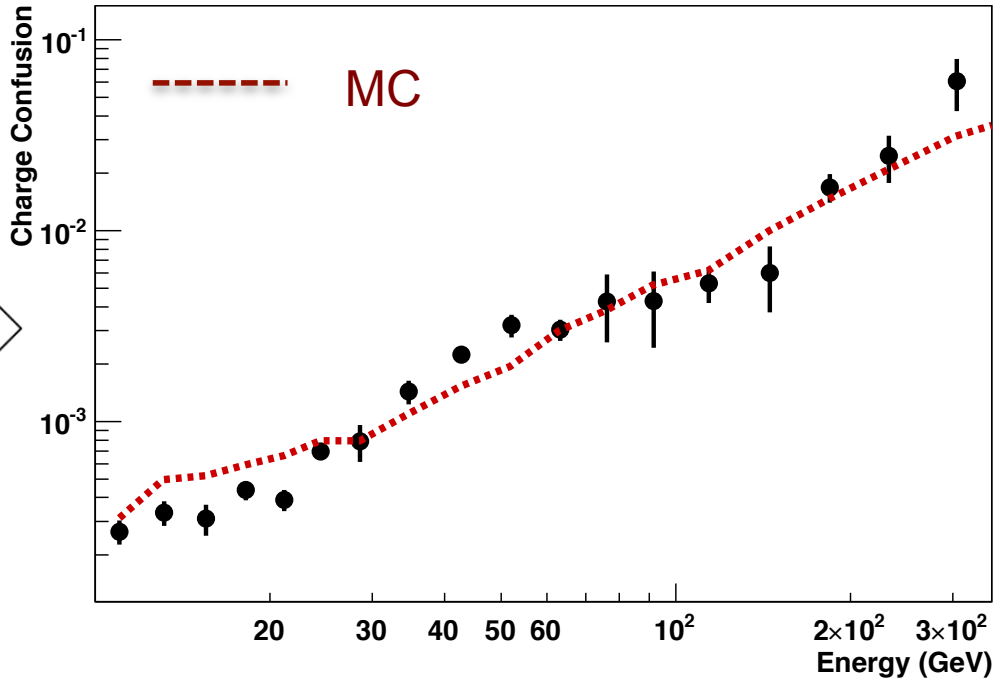


Full coverage of anti-matter & CR physics

	e^-	P	He,Li,Be,..Fe	γ	e^+	$\bar{P}$, $\bar{D}$	$\bar{He}$, $\bar{C}$
TRD							
TOF							
Tracker							
RICH							
ECAL							
Physics example	Cosmic Ray Physics				Dark matter		Antimatter

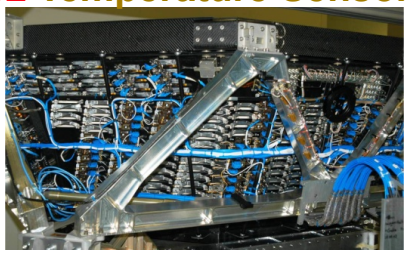
Electron charge identification in tracker



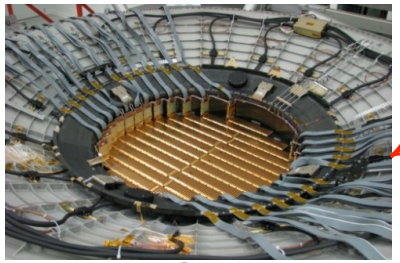


AMS sensors for Thermal Control

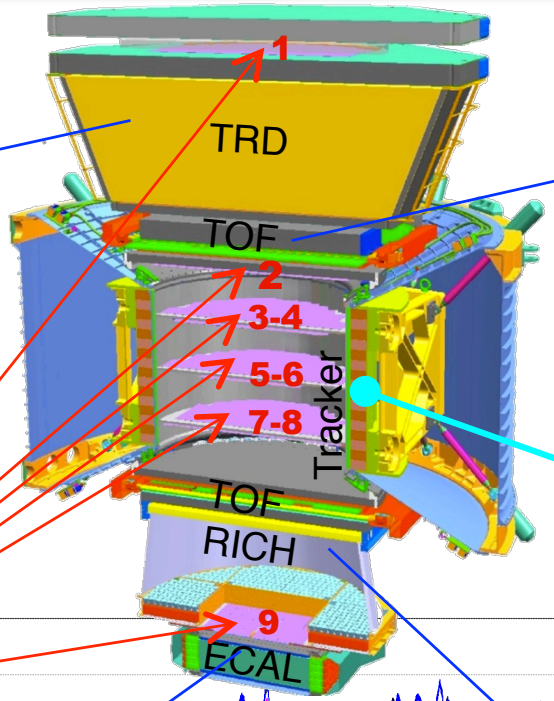
TRD
24 Heaters
8 Pressure Sensors
482 Temperature Sensors

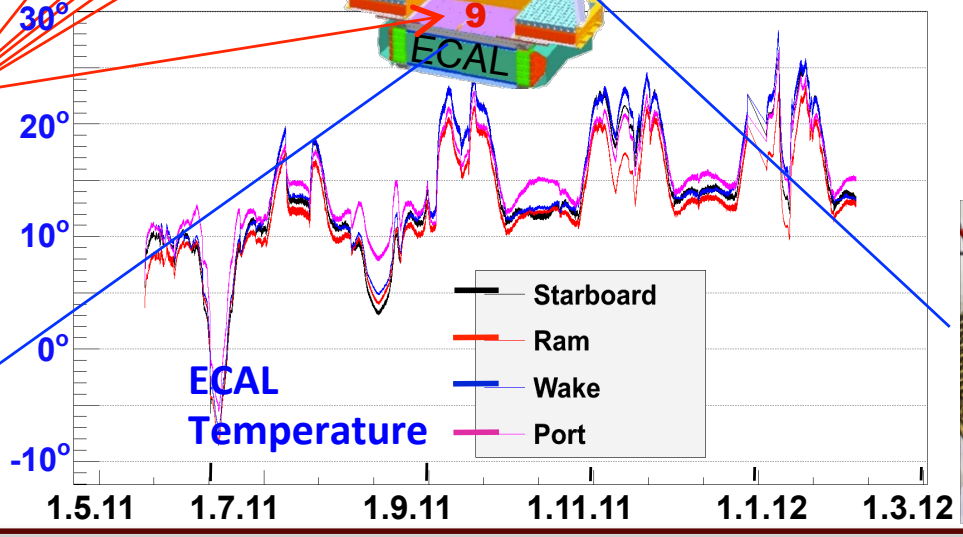


Silicon Tracker
4 Pressure Sensors
32 Heaters
142 Temperature Sensors



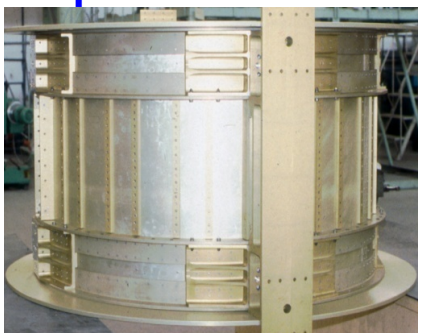
ECAL
80 Temperature Sensors



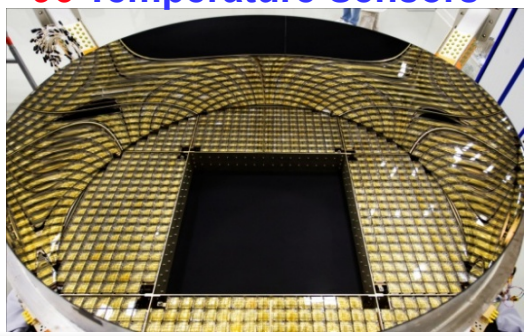


TOF & ACC
64 Temperature Sensors

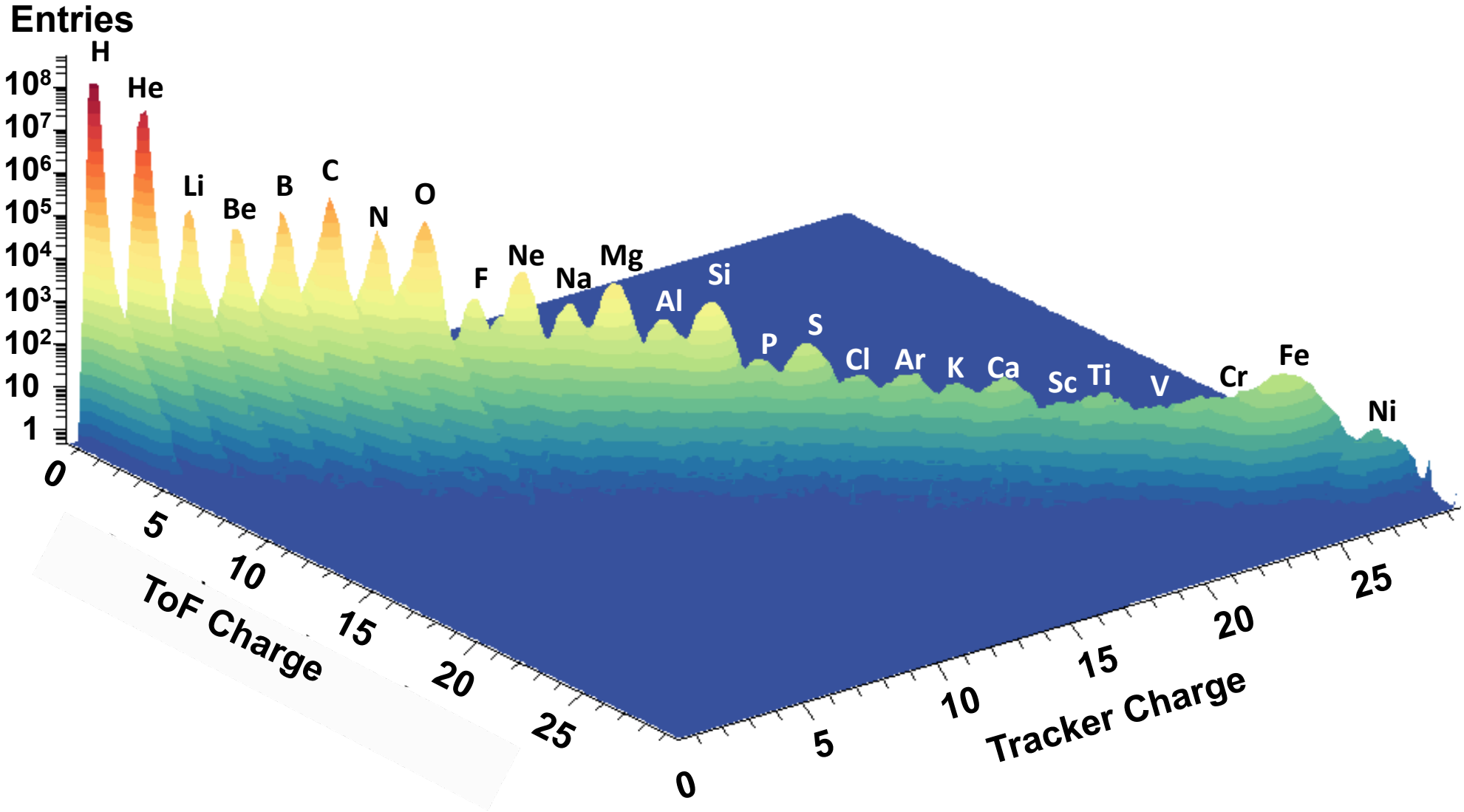
Magnet
68 Temperature Sensors



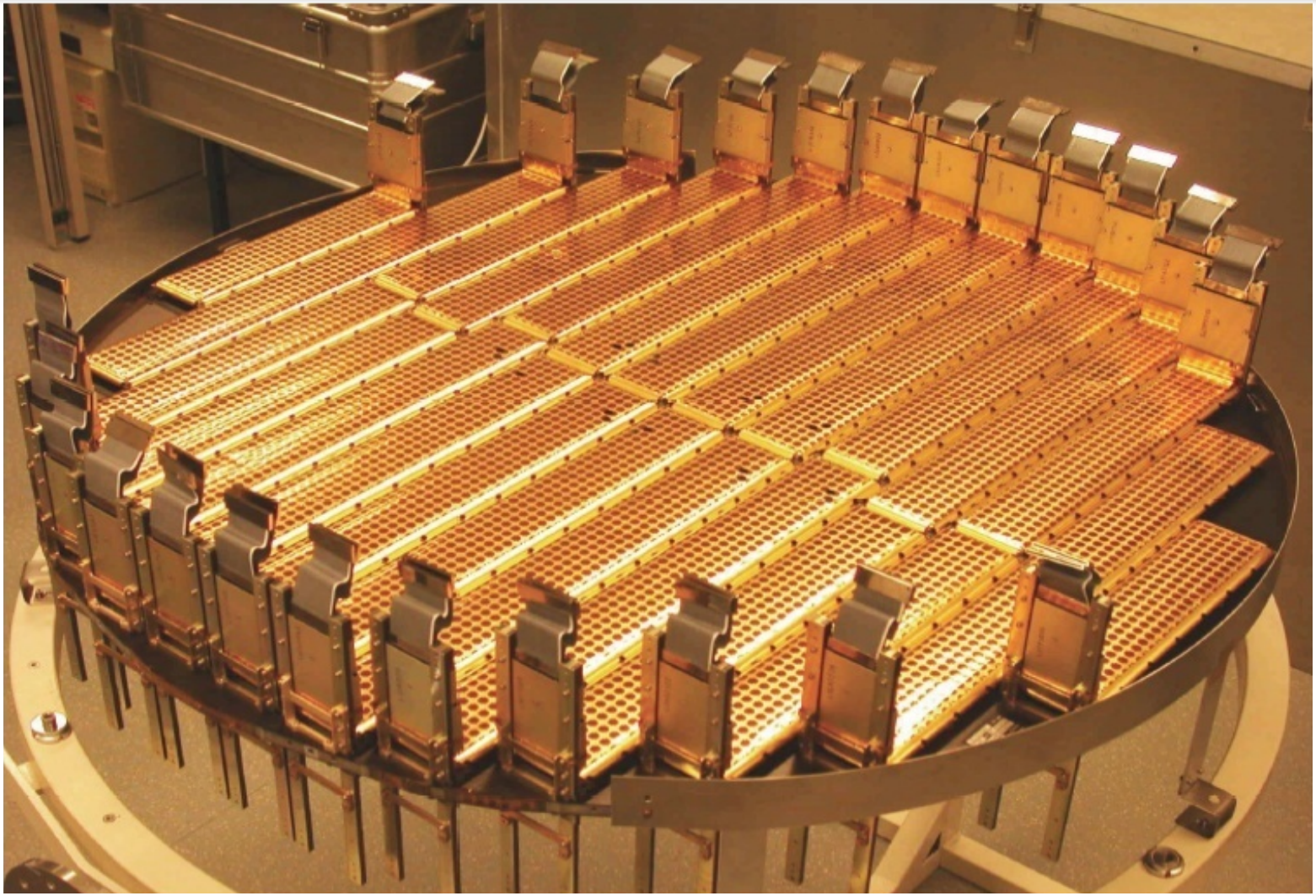
RICH
96 Temperature Sensors



AMS Nuclei Measurement on ISS

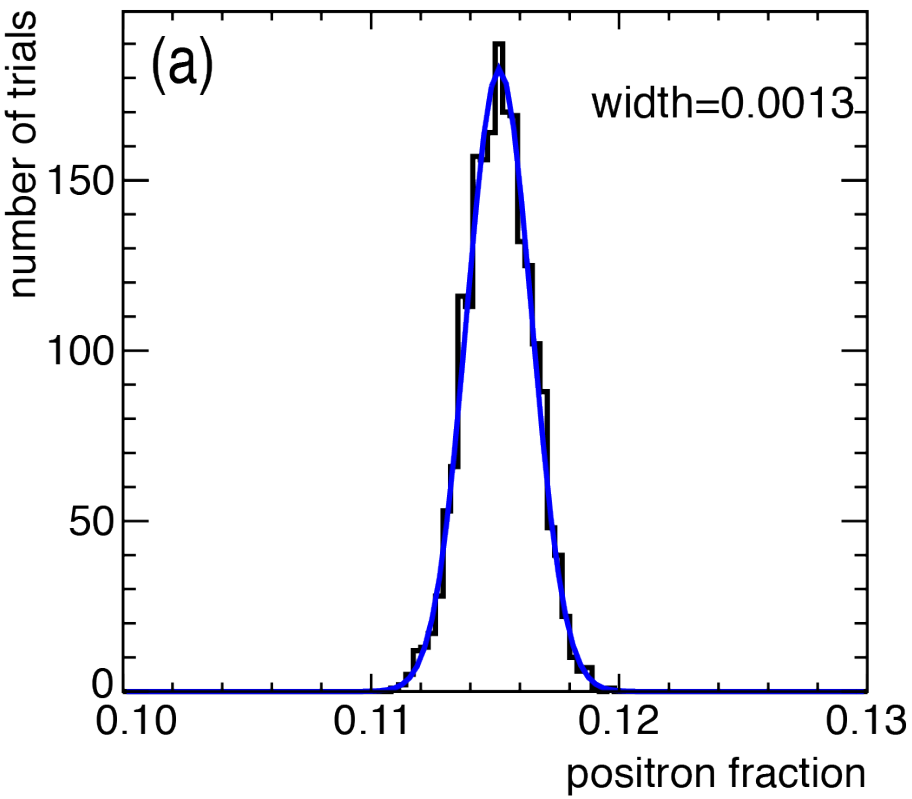


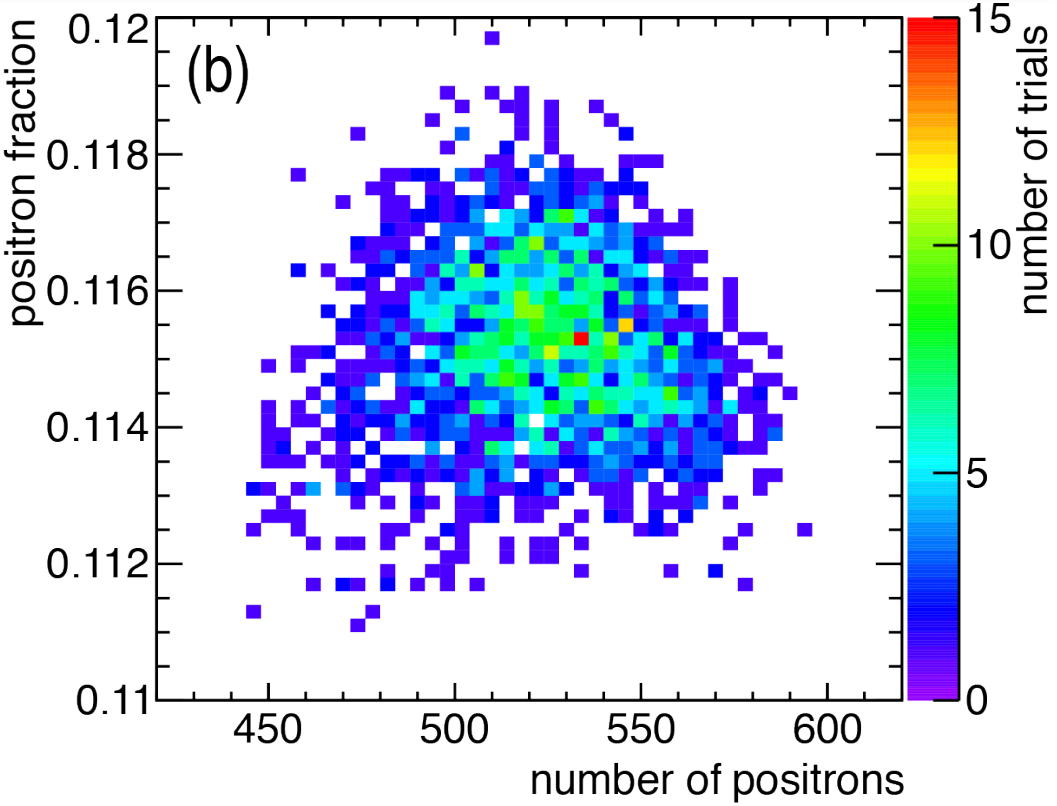
Acceptance asymmetry



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

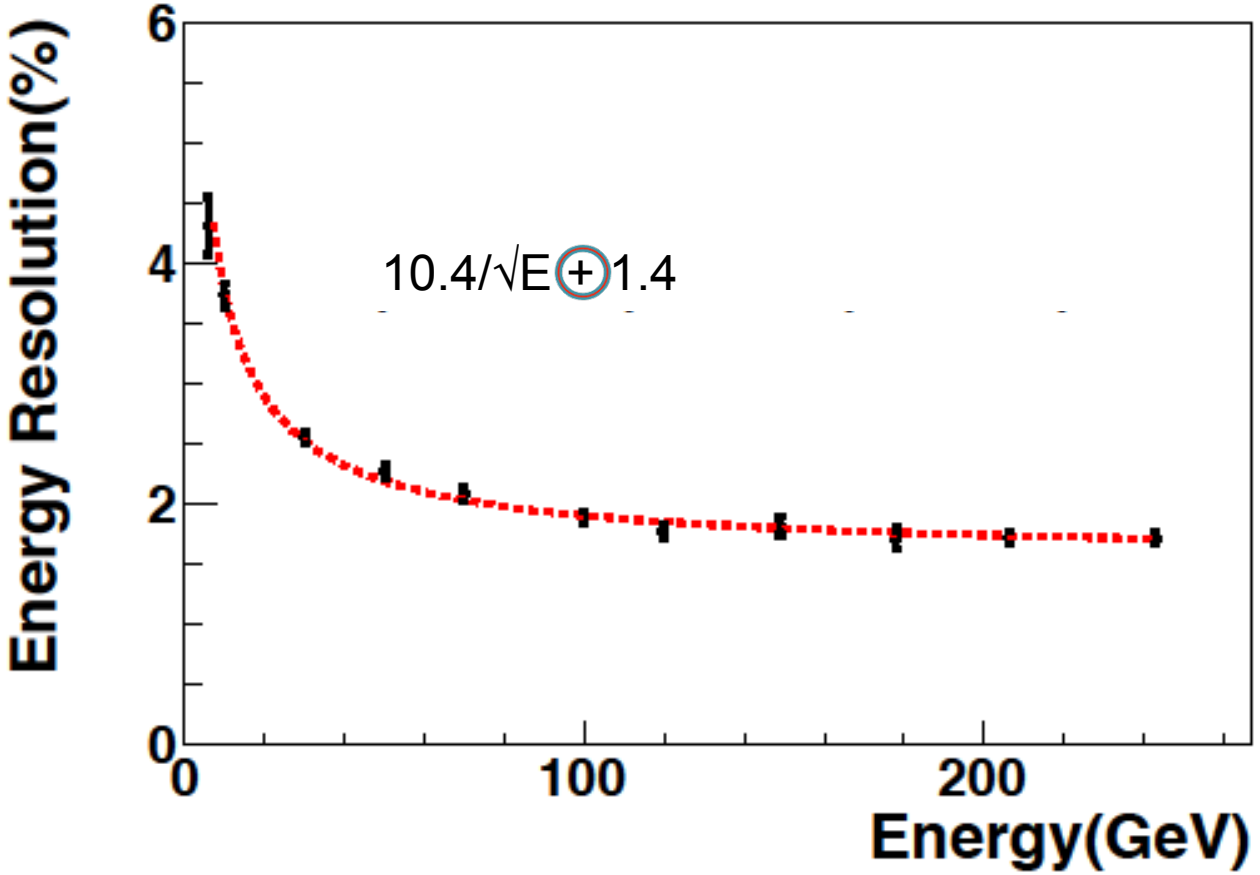
Selection dependence





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

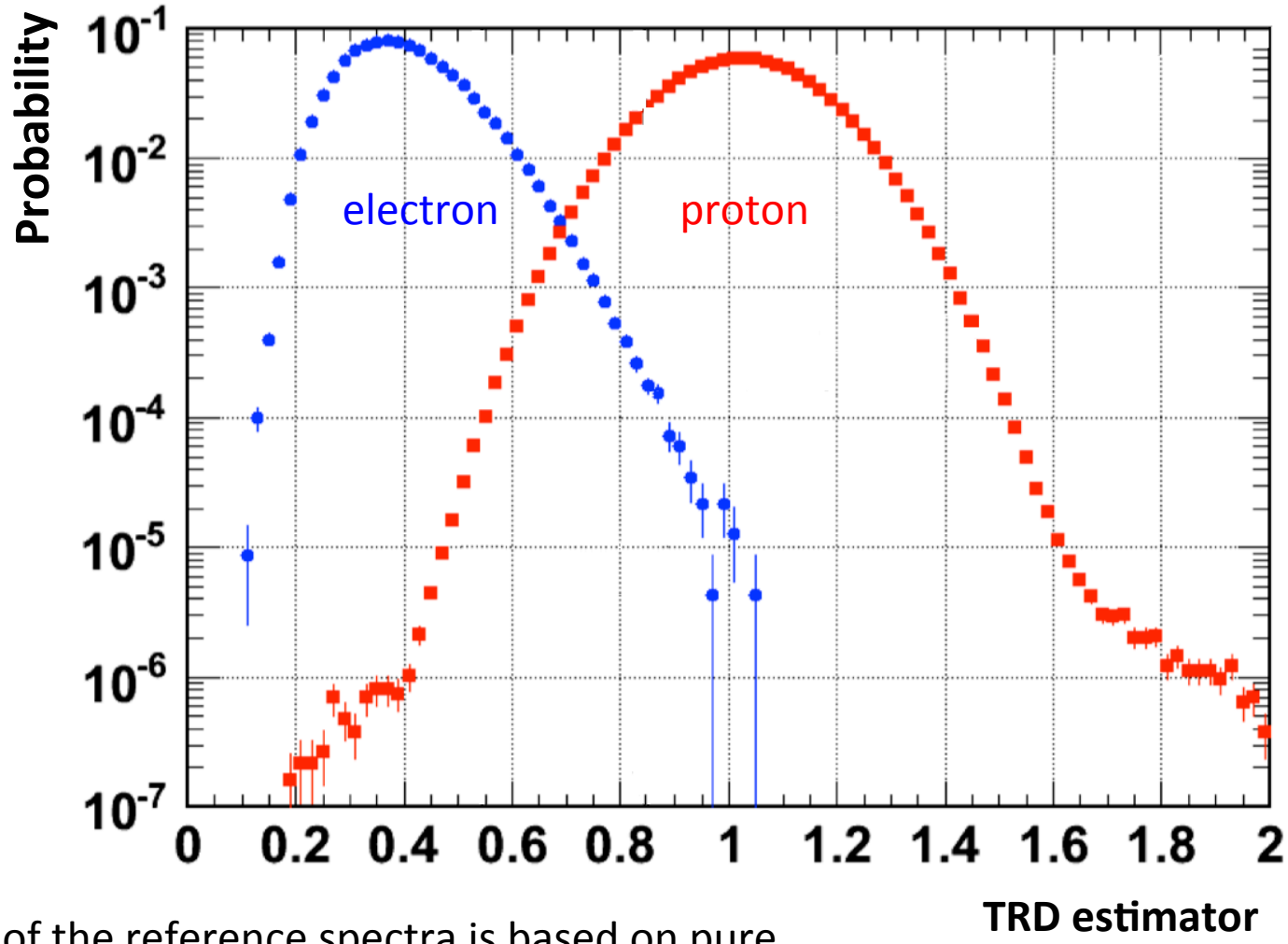
Migration bin-to-bin



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

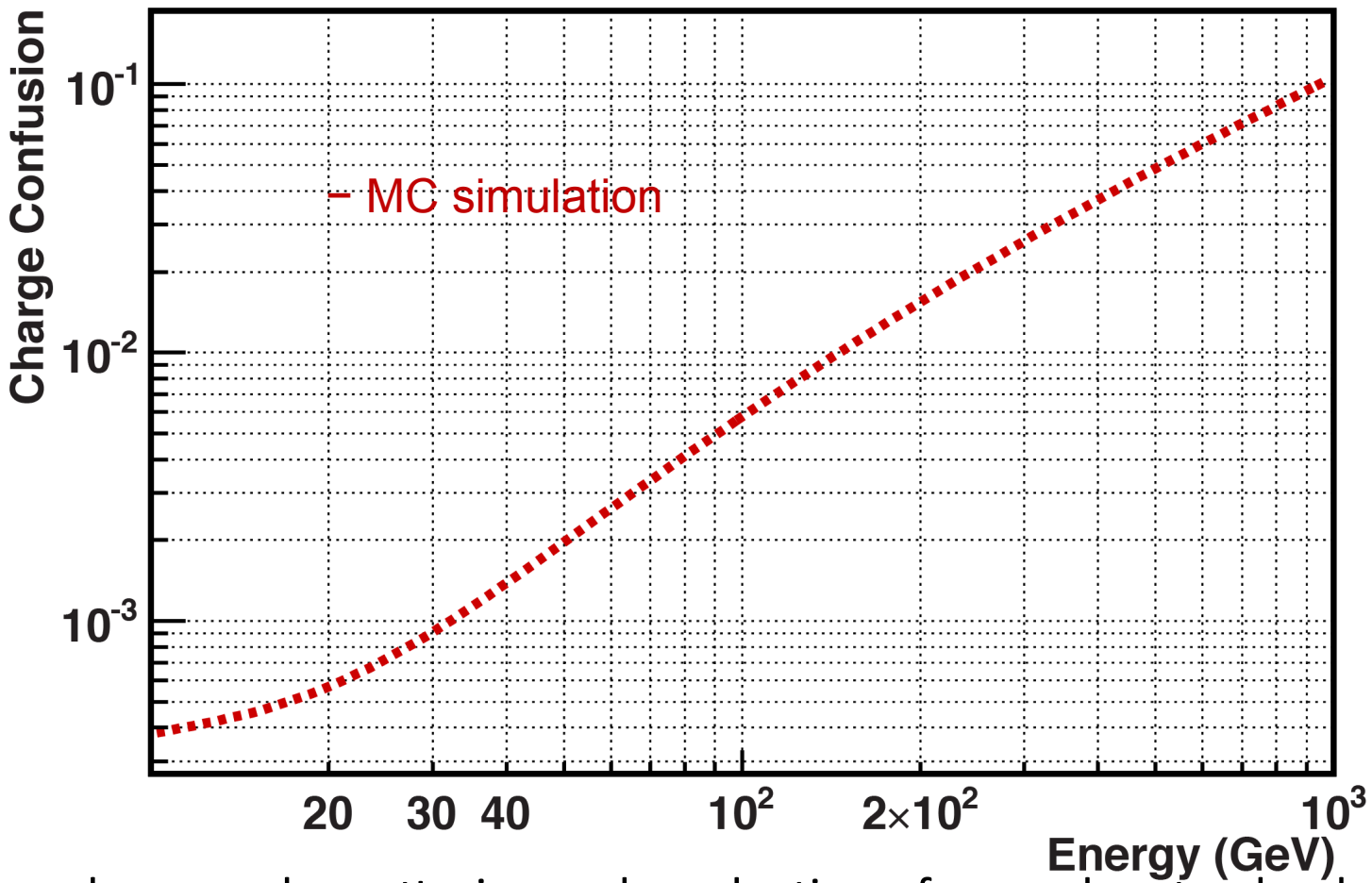
Bin width: 2σ at 5 GeV; 4σ at 50 GeV; 8σ at 100 GeV; 19σ at 300 GeV.

Reference spectra



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

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.

Positron fraction (0.5 - 350 GeV)

				Systematic errors					
			statistical error	acceptance asymmetry	event selection	bin-to-bin migration	reference spectra	charge confusion	total systematic uncertainty
Energy[GeV]	N_{e+}	Fraction	$\sigma_{stat.}$	$\sigma_{acc.}$	$\sigma_{sel.}$	$\sigma_{mig.}$	$\sigma_{ref.}$	$\sigma_{c.c.}$	$\sigma_{syst.}$
0.50 -0.65	822	0.0947	0.0034	0.001	0.0016	0.0005	0.0002	0.001	0.0022
0.65 -0.81	3,045	0.0919	0.0016	0.0007	0.0014	0.0007	0.0002	0.0008	0.0019
0.81 -1.00	6,504	0.0902	0.0011	0.0006	0.0012	0.0009	0.0002	0.0006	0.0017
1.00 -1.21	9,335	0.0842	0.0008	0.0005	0.0009	0.0008	0.0001	0.0005	0.0014
1.21 -1.45	12,621	0.0783	0.0007	0.0004	0.0007	0.0006	0.0001	0.0005	0.0011
1.45 -1.70	15,189	0.0735	0.0006	0.0003	0.0005	0.0004	0.0001	0.0003	0.0008
1.70 -1.97	18,400	0.0685	0.0005	0.0003	0.0005	0.0003	0.0001	0.0003	0.0007
1.97 -2.28	23,893	0.0642	0.0004	0.0002	0.0005	0.0002	0.0001	0.0002	0.0006
2.28 -2.60	22,455	0.0605	0.0004	0.0002	0.0005	0.0001	0.0001	0.0002	0.0006
2.60 -2.94	21,587	0.0583	0.0004	0.0001	0.0005	0.0001	0.0001	0.0002	0.0006
2.94 -3.30	21,158	0.0568	0.0004	0.0001	0.0004	0	0.0001	0.0002	0.0005
3.30 -3.70	20,707	0.055	0.0004	0.0001	0.0003	0	0.0001	0.0002	0.0004
3.70 -4.11	19,429	0.0541	0.0004	0.0001	0.0002	0	0.0001	0.0002	0.0003
4.11 -4.54	18,370	0.0533	0.0004	0.0001	0.0001	0	0.0001	0.0002	0.0003
4.54 -5.00	17,064	0.0519	0.0004	0.0001	0.0001	0	0.0001	0.0002	0.0003
5.00 -5.50	16,385	0.0512	0.0004	0.0001	0.0001	0	0.0001	0.0002	0.0003
5.50 -6.00	14,244	0.0508	0.0004	0.0001	0	0	0.0001	0.0002	0.0002
6.00 -6.56	13,880	0.0501	0.0004	0.0001	0	0	0.0001	0.0002	0.0002
6.56 -7.16	13,153	0.051	0.0004	0.0001	0	0	0.0001	0.0002	0.0002

Positron fraction (0.5 - 350 GeV)

			statistical error	acceptance asymmetry	event selection	bin-to-bin migration	reference spectra	charge confusion	total systematic uncertainty
Energy[GeV]	N_{e+}	Fraction	$\sigma_{stat.}$	$\sigma_{acc.}$	$\sigma_{sel.}$	$\sigma_{mig.}$	$\sigma_{ref.}$	$\sigma_{c.c.}$	$\sigma_{syst.}$
7.16 -7.80	11,747	0.0504	0.0005	0.0001	0	0	0.0001	0.0002	0.0002
7.80 -8.50	10,910	0.0513	0.0005	0.0001	0	0	0.0001	0.0002	0.0002
8.50 -9.21	9,110	0.051	0.0005	0.0001	0	0	0.0001	0.0002	0.0002
9.21 -9.95	7,501	0.0515	0.0006	0.0001	0	0	0.0001	0.0002	0.0002
9.95 -10.73	7,161	0.0519	0.0006	0.0001	0	0	0.0001	0.0002	0.0002
10.73 -11.54	6,047	0.0528	0.0007	0.0001	0	0	0.0001	0.0001	0.0002
11.54 -12.39	5,246	0.0535	0.0007	0.0001	0	0	0.0001	0.0001	0.0002
12.39 -13.27	4,787	0.0549	0.0008	0.0001	0	0	0.0001	0.0001	0.0002
13.27 -14.19	4,166	0.0551	0.0008	0.0001	0	0	0.0001	0.0001	0.0002
14.19 -15.15	3,698	0.0543	0.0009	0.0001	0.0001	0	0.0001	0.0001	0.0002
15.15 -16.15	3,326	0.0556	0.001	0.0001	0.0001	0	0.0001	0.0001	0.0002
16.15 -17.18	3,007	0.0583	0.0011	0.0001	0.0001	0	0.0001	0.0002	0.0003
17.18 -18.25	2,663	0.0586	0.0011	0.0001	0.0001	0	0.0001	0.0002	0.0003
18.25 -19.37	2,410	0.0592	0.0012	0.0001	0.0001	0	0.0001	0.0002	0.0003
19.37 -20.54	2,322	0.0634	0.0013	0.0001	0.0001	0	0.0001	0.0002	0.0003
20.54 -21.76	2,052	0.0618	0.0014	0.0001	0.0001	0	0.0001	0.0002	0.0003
21.76 -23.07	1,992	0.0653	0.0015	0.0001	0.0001	0	0.0001	0.0002	0.0003
23.07 -24.45	1,788	0.0651	0.0016	0.0001	0.0001	0	0.0001	0.0002	0.0003
24.45 -25.87	1,642	0.0657	0.0016	0.0001	0.0001	0	0.0001	0.0002	0.0003
25.87 -27.34	1,447	0.0668	0.0018	0.0001	0.0001	0	0.0001	0.0003	0.0003
27.34 -28.87	1,260	0.0694	0.002	0.0001	0.0001	0	0.0001	0.0003	0.0003
28.87 -30.45	1,137	0.071	0.0021	0.0001	0.0002	0	0.0001	0.0003	0.0004
30.45 -32.10	1,094	0.0701	0.0022	0.0001	0.0002	0	0.0001	0.0003	0.0004
32.10 -33.80	888	0.0707	0.0024	0.0001	0.0002	0	0.0001	0.0004	0.0005

Positron fraction (0.5 - 350 GeV)

			statistical error	acceptance asymmetry	event selection	bin-to-bin migration	reference spectra	charge confusion	total systematic uncertainty
Energy[GeV]	N_{e+}	Fraction	$\sigma_{stat.}$	$\sigma_{acc.}$	$\sigma_{sel.}$	$\sigma_{mig.}$	$\sigma_{ref.}$	$\sigma_{c.c.}$	$\sigma_{syst.}$
33.80 -35.57	807	0.0718	0.0026	0.0001	0.0003	0	0.0001	0.0004	0.0005
35.57 -37.40	787	0.0747	0.0027	0.0001	0.0003	0	0.0001	0.0004	0.0005
37.40 -40.00	982	0.0794	0.0026	0.0002	0.0004	0	0.0001	0.0004	0.0006
40.00 -43.39	976	0.0802	0.0026	0.0002	0.0005	0	0.0001	0.0004	0.0007
43.39 -47.01	856	0.0817	0.0029	0.0002	0.0005	0	0.0001	0.0004	0.0007
47.01 -50.87	739	0.0856	0.0032	0.0002	0.0006	0	0.0001	0.0004	0.0008
50.87 -54.98	605	0.0891	0.0038	0.0002	0.0006	0	0.0001	0.0004	0.0008
54.98 -59.36	558	0.0957	0.0041	0.0002	0.0008	0	0.0001	0.0005	0.001
59.36 -64.03	448	0.0962	0.0047	0.0002	0.0009	0	0.0002	0.0006	0.0011
64.03 -69.00	392	0.0978	0.005	0.0002	0.001	0	0.0002	0.0007	0.0013
69.00 -74.30	324	0.1032	0.0057	0.0002	0.001	0	0.0002	0.0009	0.0014
74.30 -80.00	276	0.0985	0.0062	0.0002	0.001	0	0.0002	0.001	0.0014
80.00 -86.00	232	0.1023	0.0067	0.0002	0.001	0	0.0002	0.001	0.0014
86.00 -92.50	240	0.112	0.0075	0.0002	0.001	0	0.0003	0.0011	0.0015
92.50 -100.0	226	0.1189	0.0081	0.0002	0.0011	0	0.0003	0.0012	0.0017
100.0 -115.1	304	0.1118	0.0066	0.0002	0.0015	0	0.0003	0.0015	0.0022
115.1 -132.1	223	0.1142	0.008	0.0002	0.0019	0	0.0004	0.0019	0.0027
132.1 -151.5	156	0.1215	0.01	0.0002	0.0021	0	0.0005	0.0024	0.0032
151.5 -173.5	144	0.1364	0.0121	0.0002	0.0026	0	0.0006	0.0045	0.0052
173.5 -206.0	134	0.1485	0.0133	0.0002	0.0031	0	0.0009	0.005	0.006
206.0 -260.0	101	0.153	0.016	0.0003	0.0031	0	0.0013	0.0095	0.0101
260.0 -350.0	72	0.155	0.02	0.0003	0.0056	0	0.0018	0.014	0.0152

Positron fraction (0.5 - 350 GeV)