Recent Results from Alpha Magnetic Spectrometer

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AMS collaboration

Pheno13, Pittsburgh
May 6-8, 2013

國立中央大學
National Central University

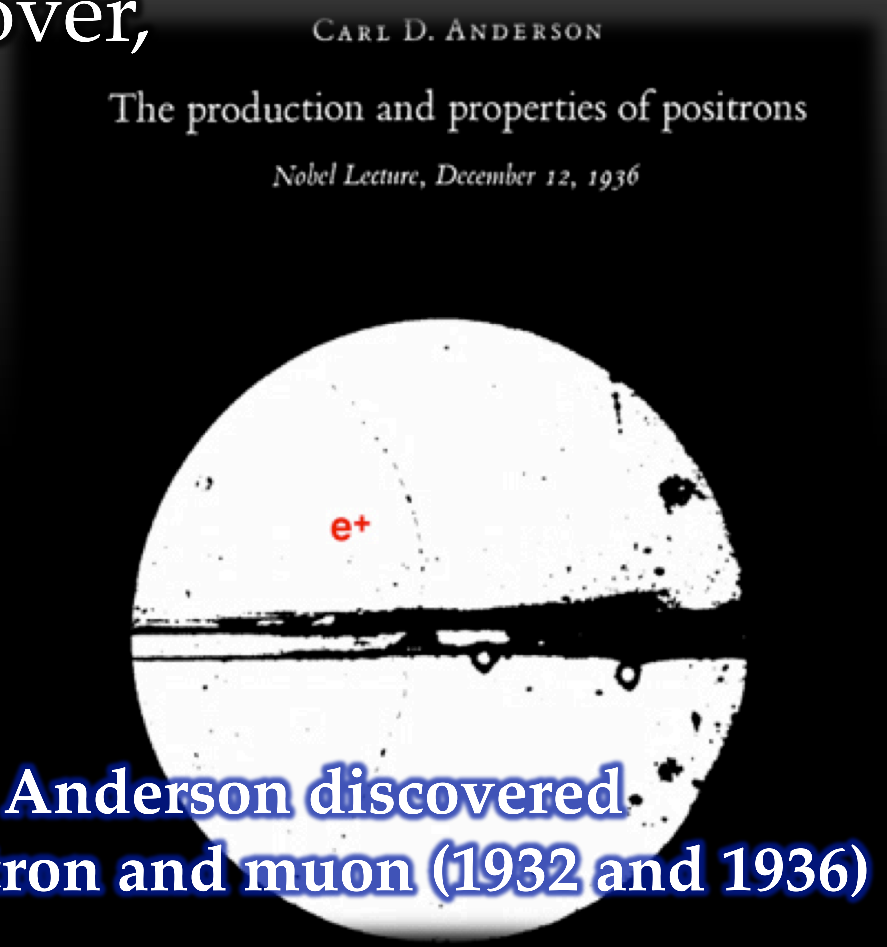
AMS a U.S. DOE sponsored international collaboration

16 Countries, 60 Institutes and 600 Physicists

from Asia, Europa, and USA

1912 – 2012 : A century of Cosmic Rays

- Until 1950's, new particles had been discovered in Cosmic Rays
- Even after accelerators took over, Cosmic Rays play important role in Particle Physics

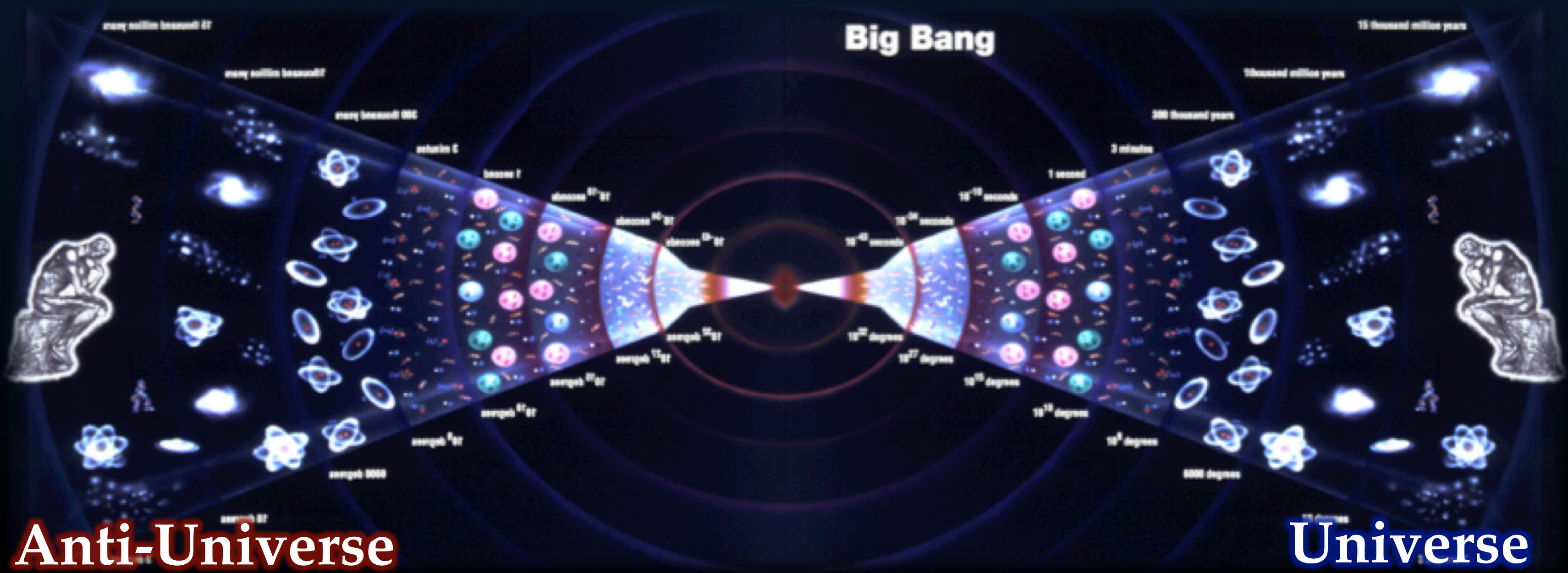


V. Hess discovered Cosmic Rays (1912)

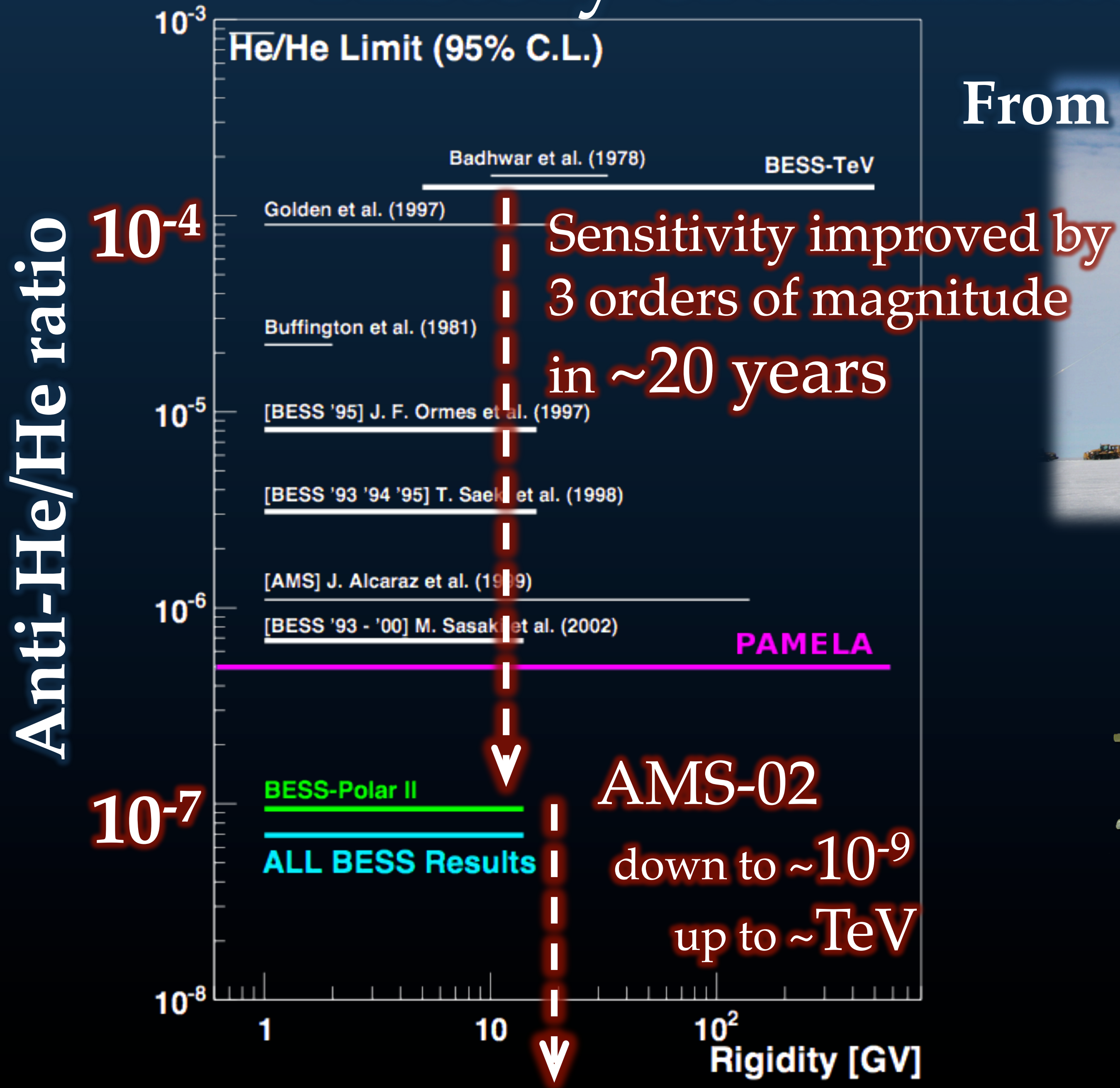
C.D. Anderson discovered positron and muon (1932 and 1936)

Example 1 : Search for antimatter

- Apparent asymmetry of matter and antimatter is one of the fundamental problems in cosmology
- Detection of anti-nuclei in Cosmic Rays will be a strong evidence of primordial Anti Matter



History of antimatter search

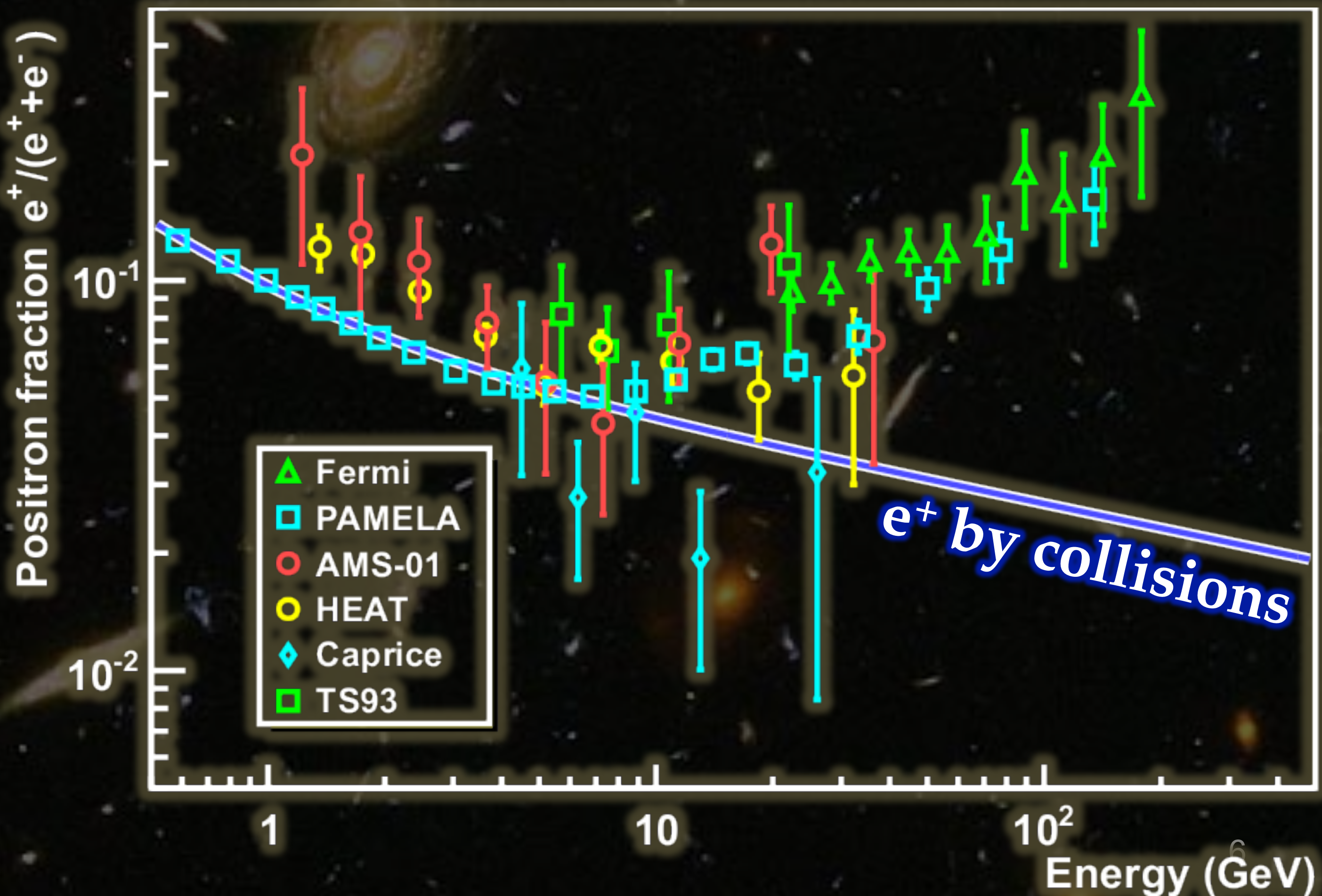


... and ISS

Example 2 : Cosmic-Ray Positrons

- Mostly produced by collisions of Cosmic Rays
- Annihilation/Decay of Dark Matter

will produce additional positrons

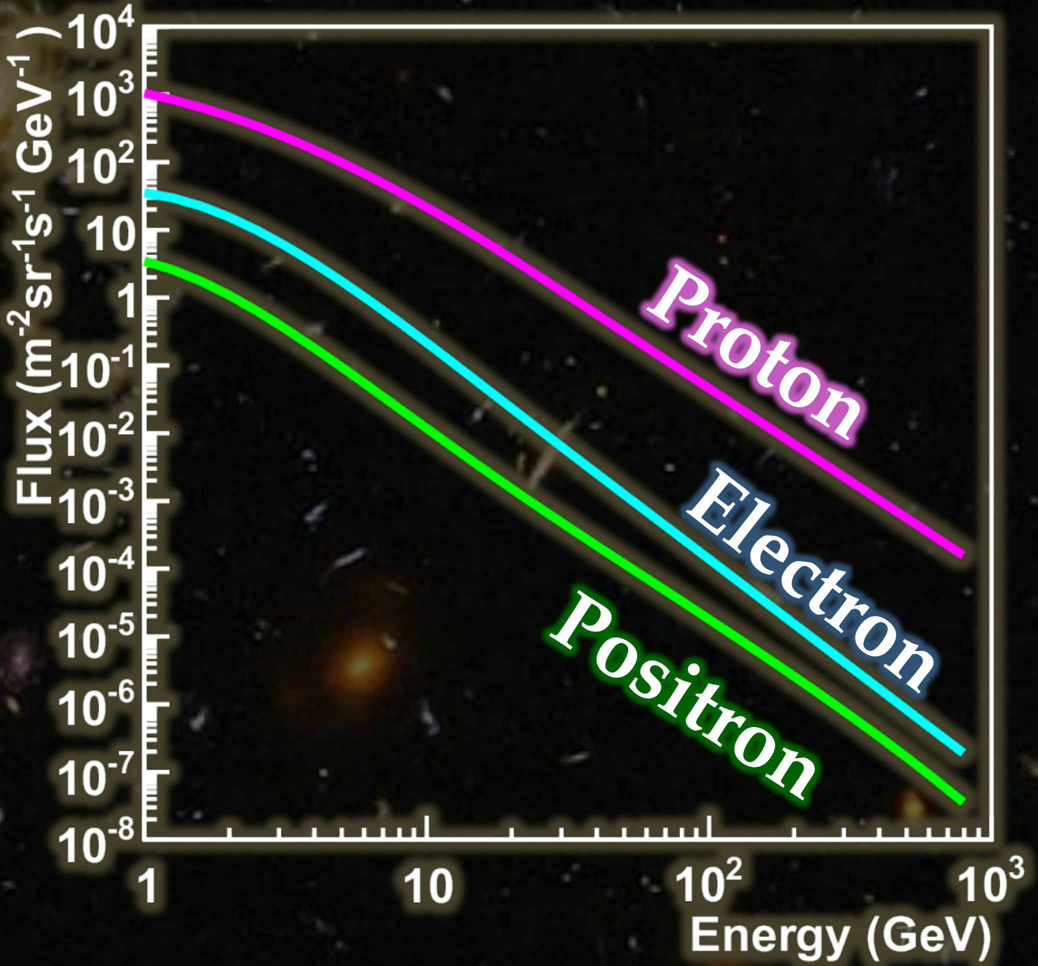


Difficulties – positron measurement

- **Low abundance** : 0.01~0.1 % of Cosmic Rays
  ➔ Large acceptance and long duration needed
- Large backgrounds

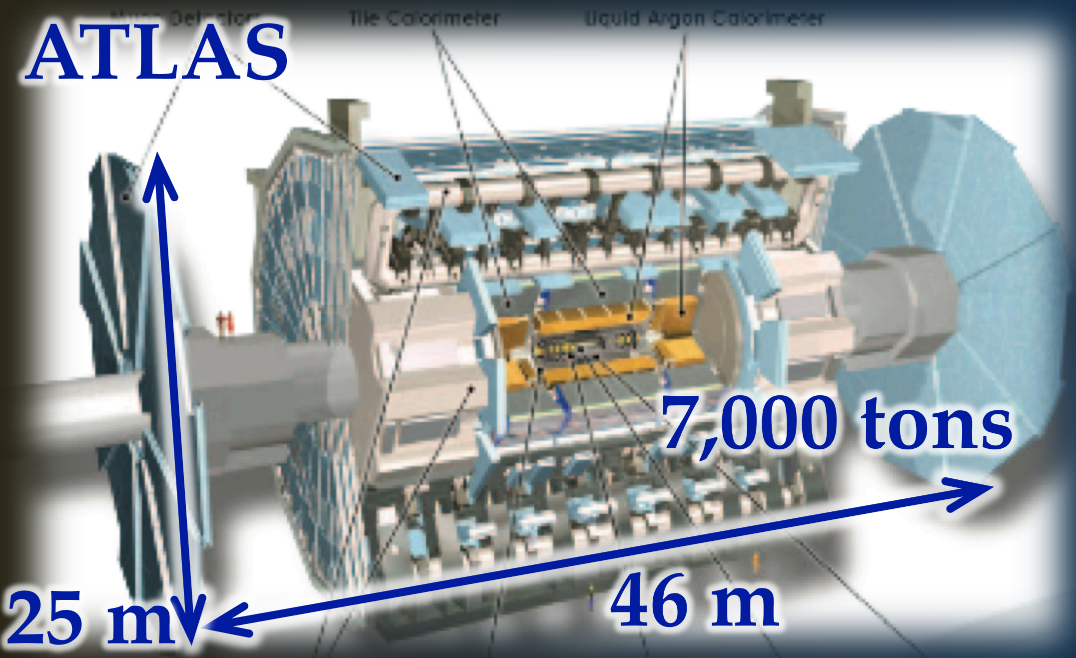
(1) **Protons × 10^3~10^4**
➔ Redundant e^+/p separation capability

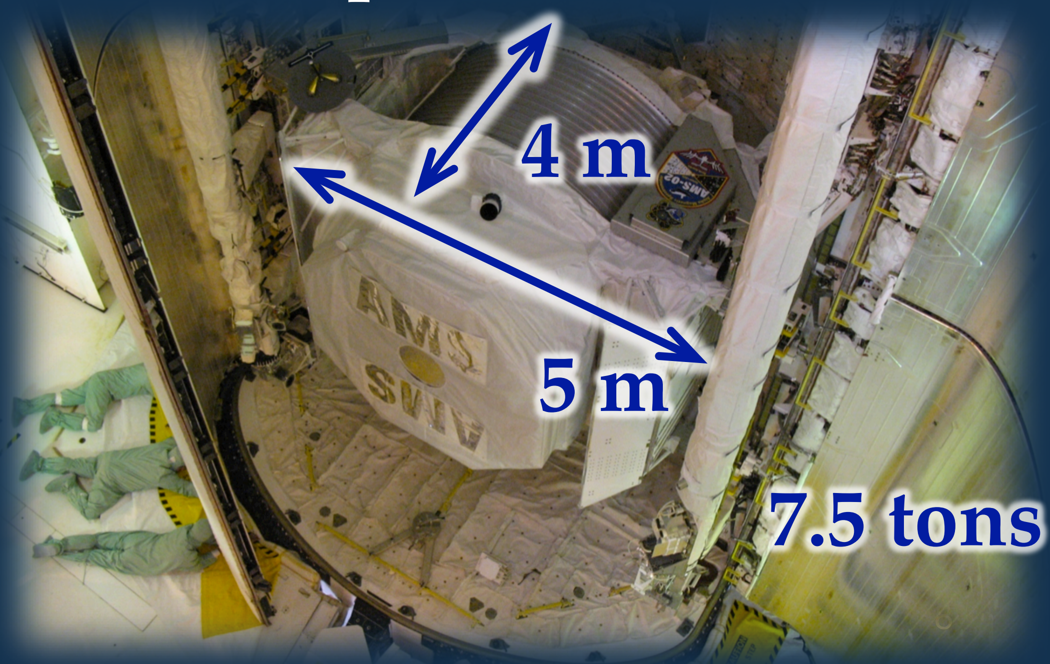
(2) **Electrons × 10~100**
➔ Deflection measurement in a magnetic field to determine charge sign



Technical challenges

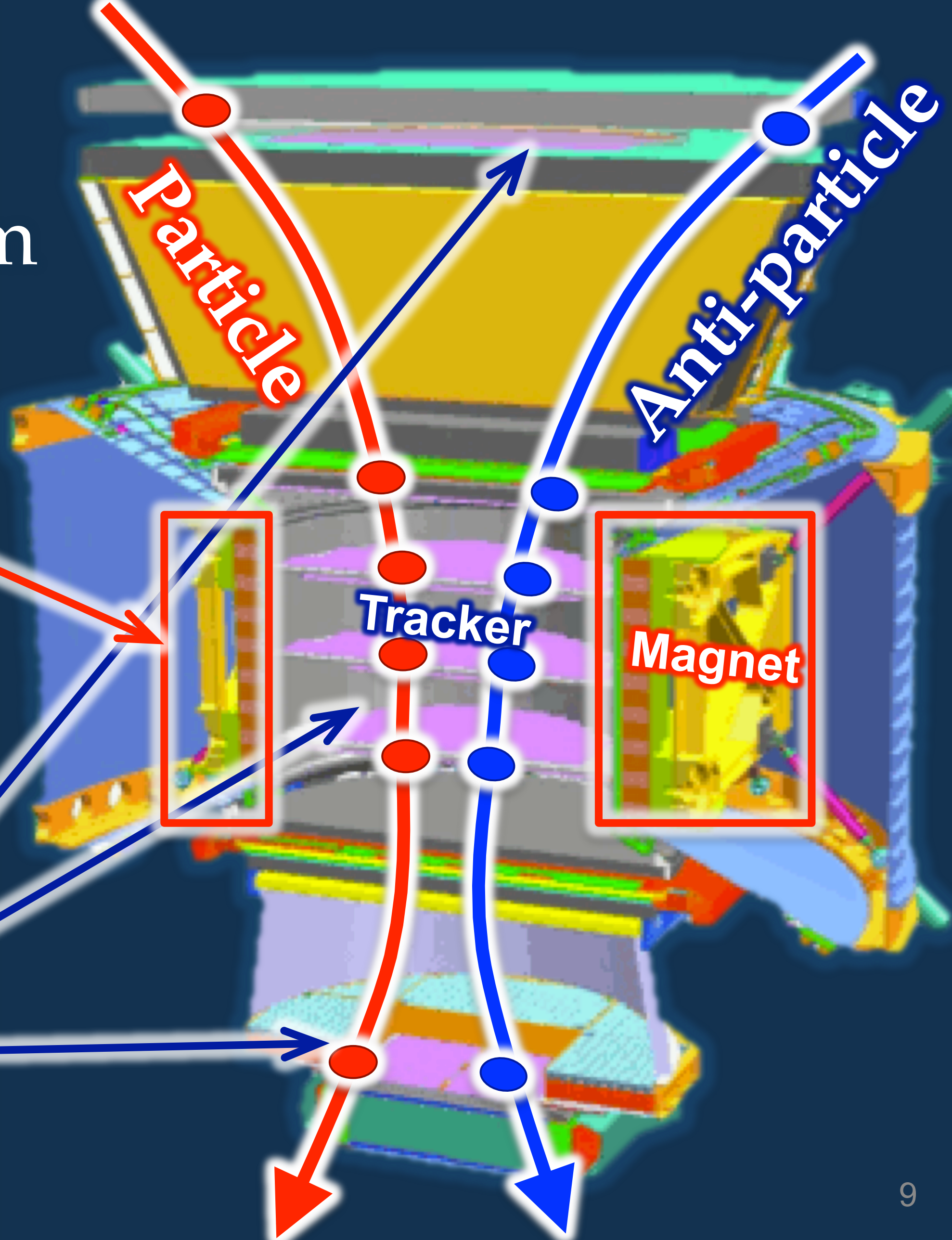
- AMS is designed with the same capability as state-of-art CERN-LHC detectors
  but small enough to fit in space shuttle
- AMS needs to work for 20 years in extreme space enviroment without access nor repair





Magnet and Tracker

- Determine charge sign and measure momentum

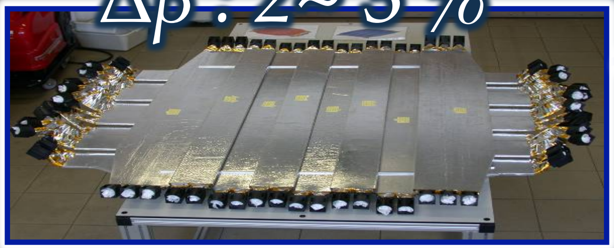


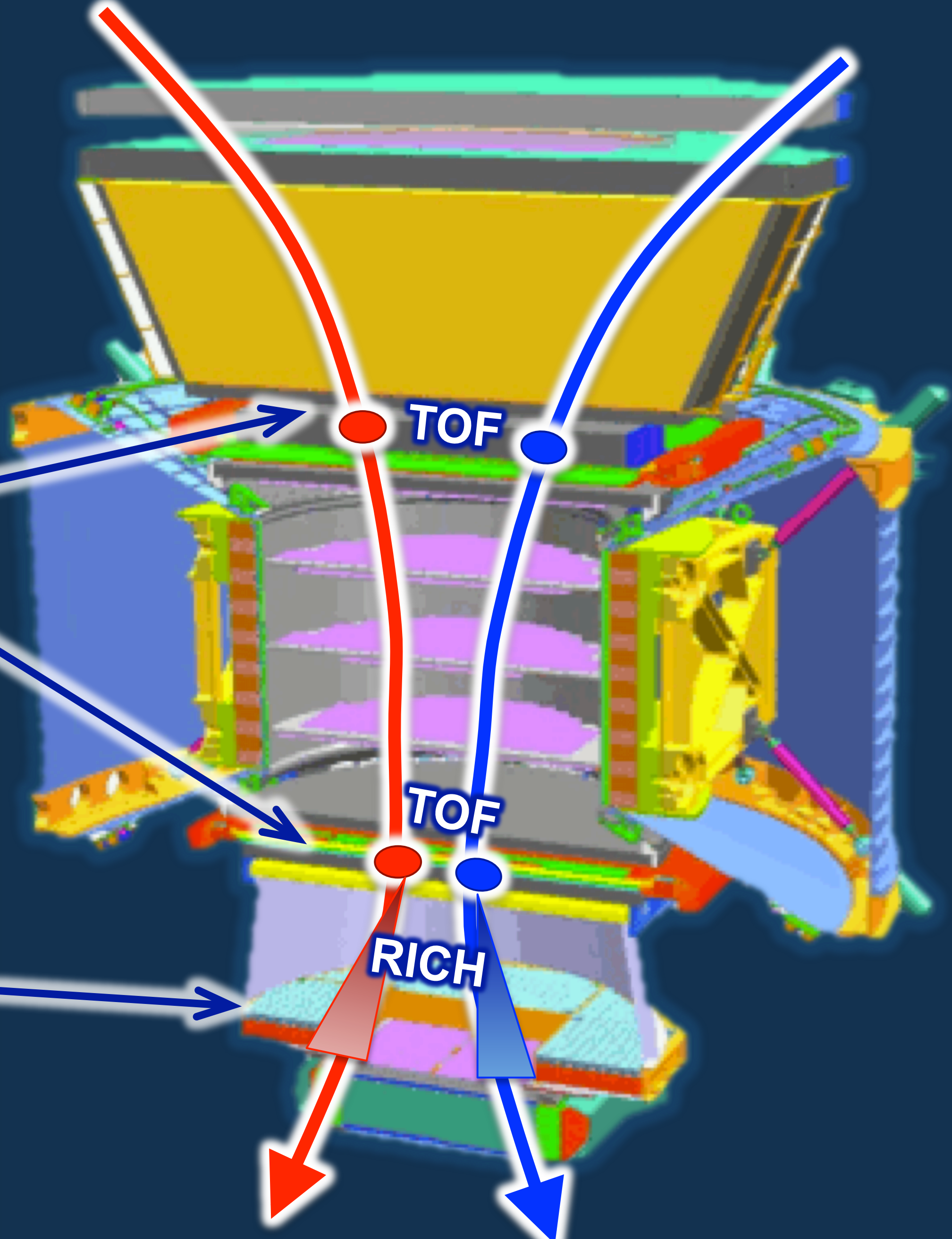
TOF and RICH

- Determine direction and mesure velocity

Time Of Flight

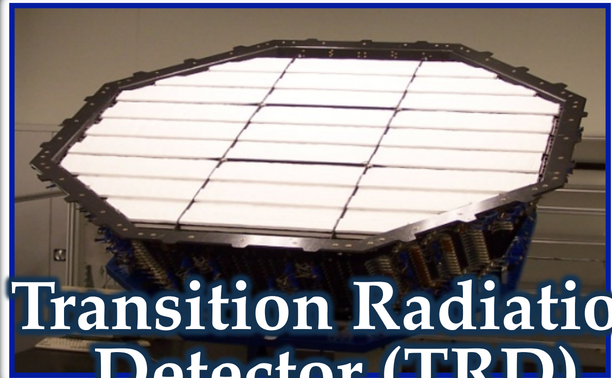
$\Delta\beta : 2\sim 3\ \%$





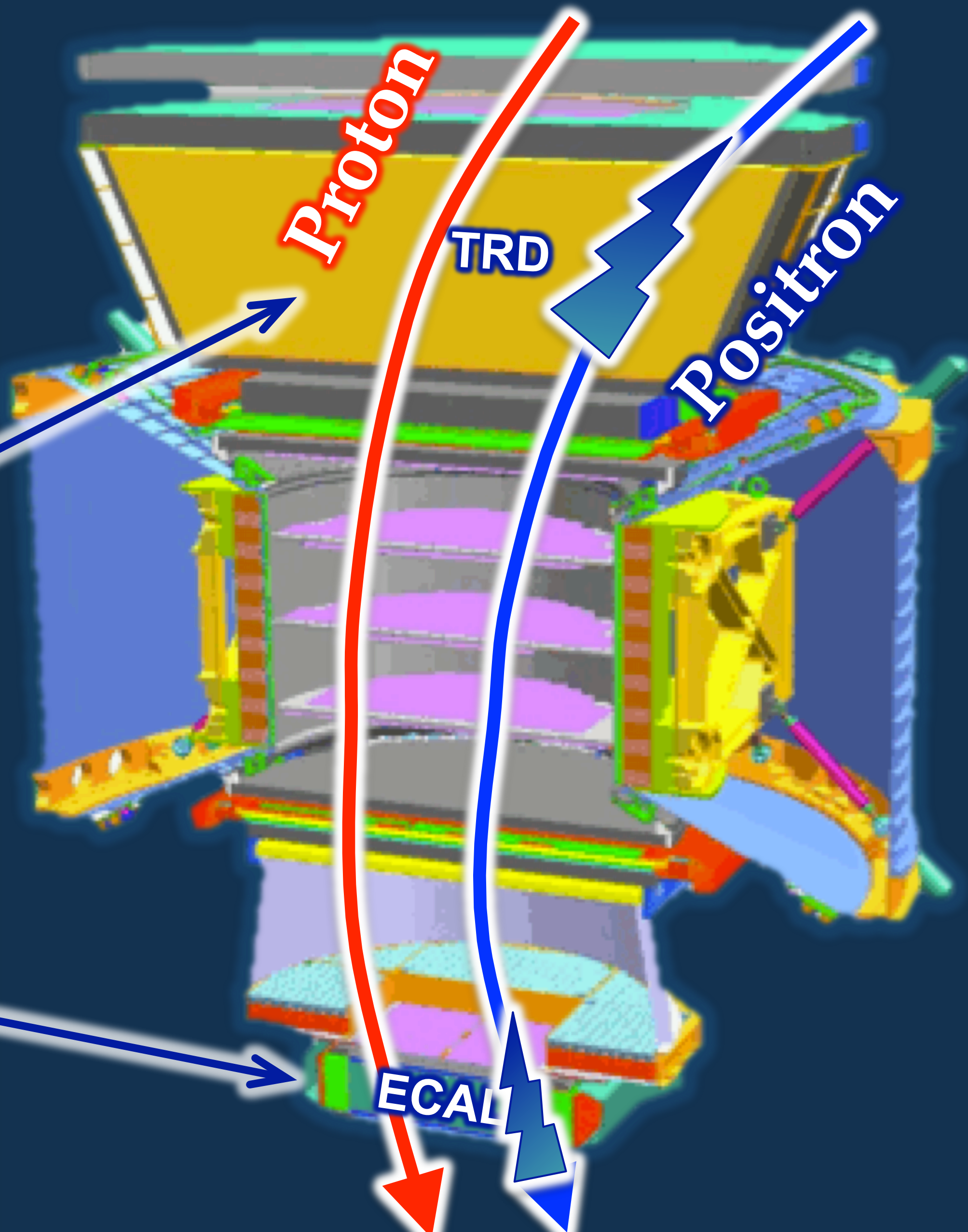
TRD and Ecal

- Distinguish e+/e- from proton backgrounds



Transition Radiation Detector (TRD)

EM Calorimeter ($17\ X_0$)



AMS proposed in 1994

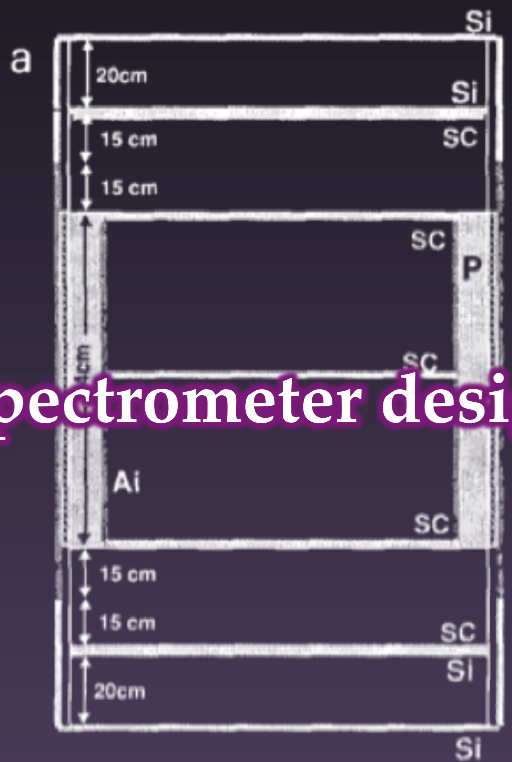
Nuclear Instruments and Methods in Physics Research A 350 (1994) 351–367
North-Holland

NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH
Section A

An antimatter spectrometer in space

Antimatter Study Group

Spectrometer design



P permanent magnet with supporting structure
SC Double sided silicon detector resolution (7μ) and $\frac{dE}{dX}$ (charge) measurements
Si scintillators for time a flight and $\frac{dE}{dX}$ (charge)
veto scintillators

Magnet design

Fig. 6. Magnetic field distribution at a cross-section of the center of the magnet.

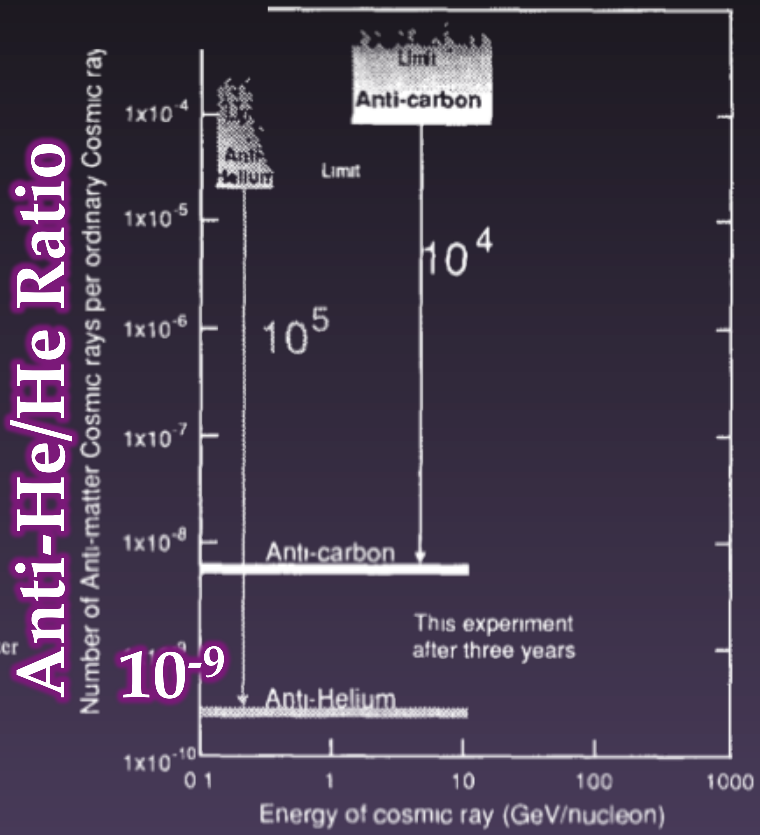
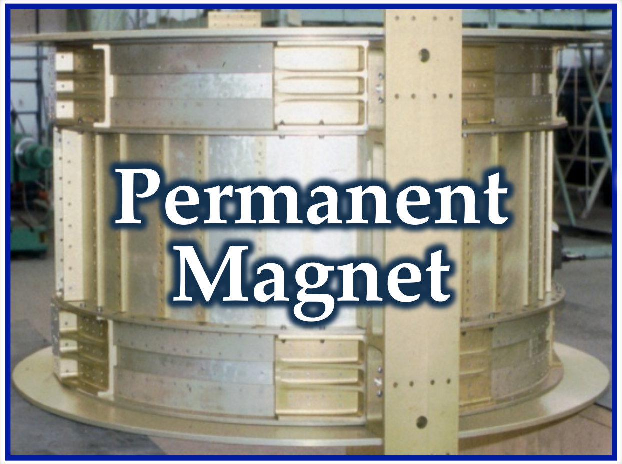


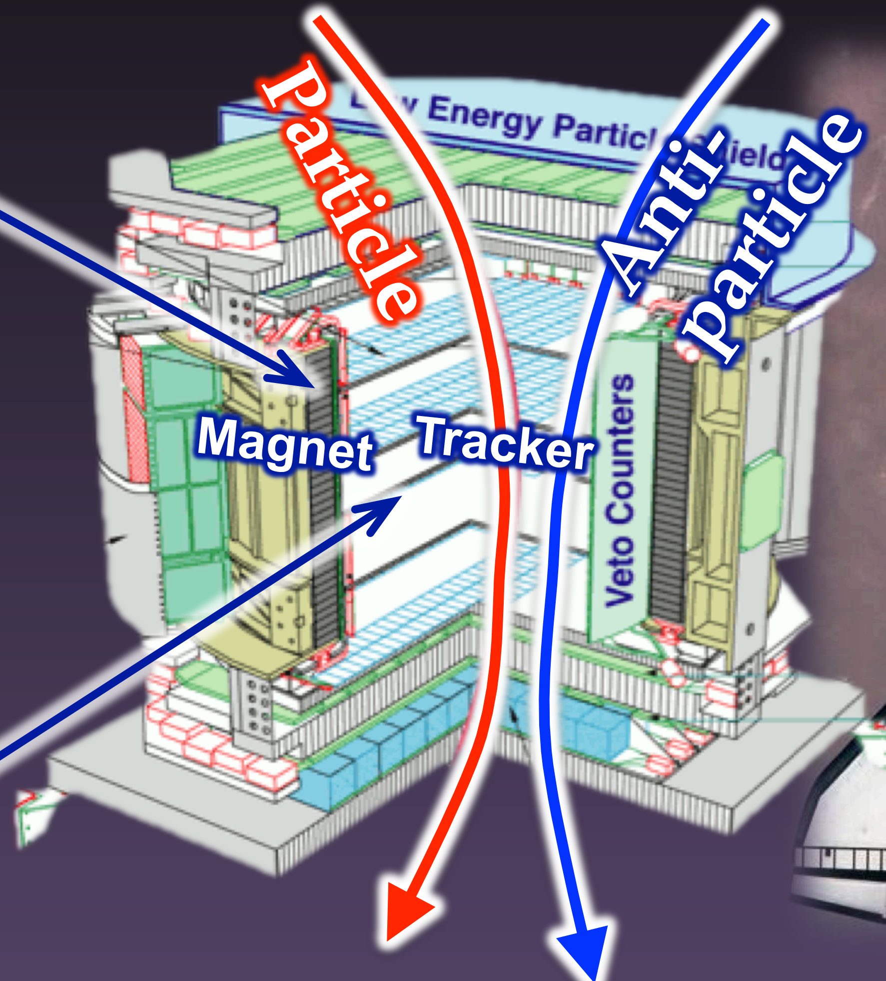
Fig. 30. Current limits and sensitivity of this experiment for antimatter. In addition to the search for antimatter, our detector could be easily modified (particularly for options 2 and 4) to explore the search of $\bar{p}$ and e^+.

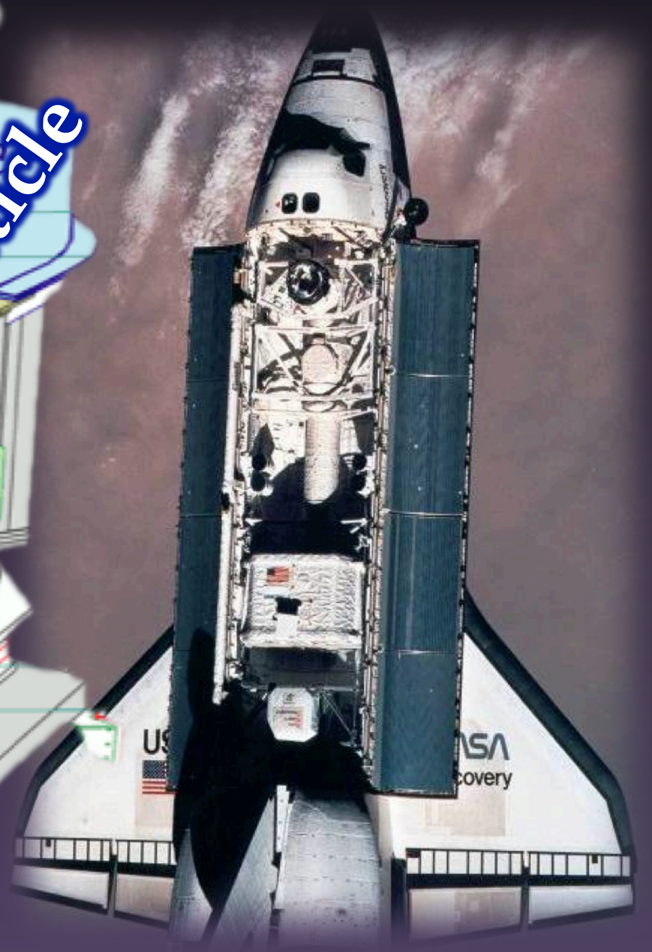
Test flight : AMS-01 in 1998

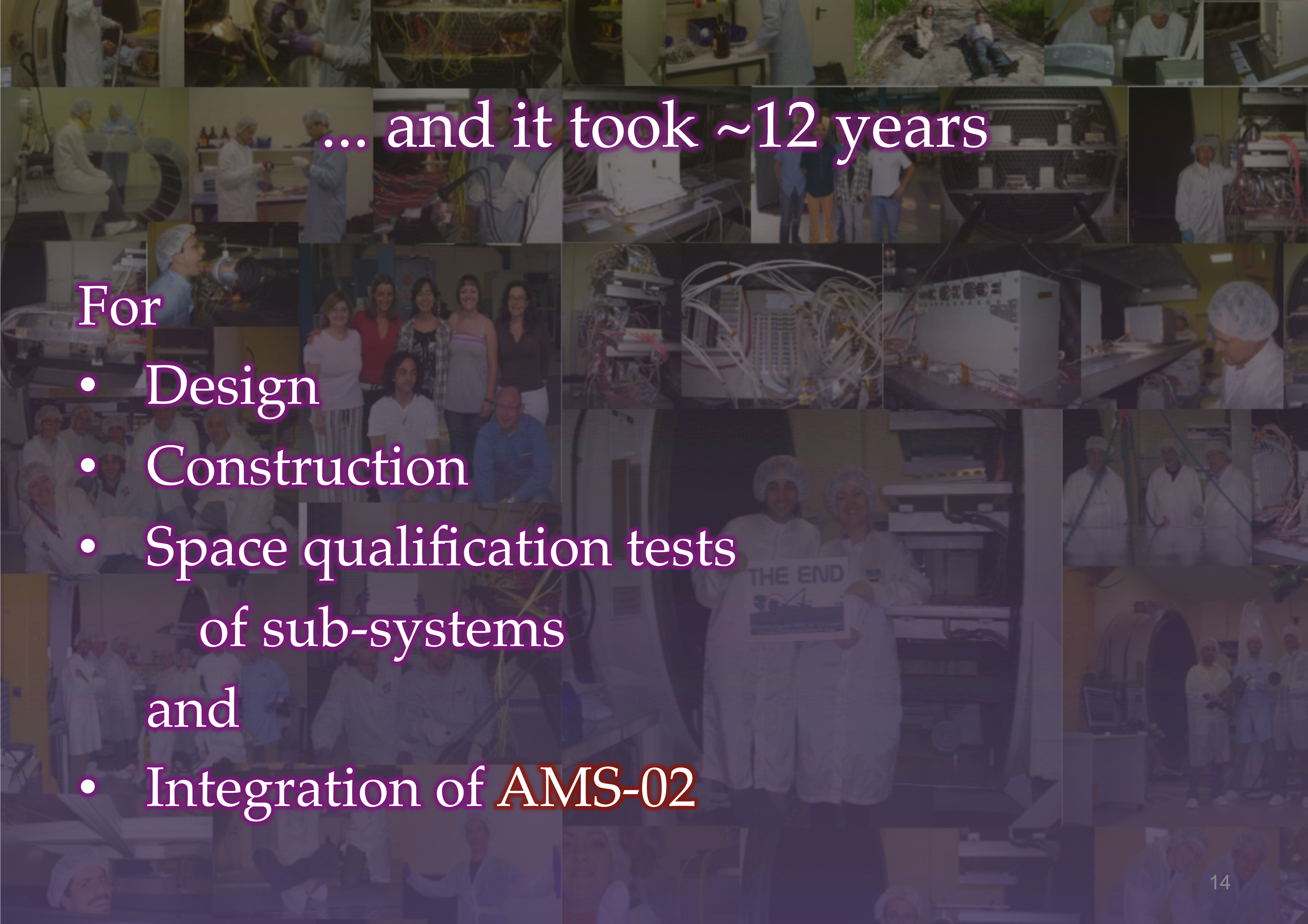
- One week flight on space shuttle *Discovery* with the same magnet as AMS-02



Silicon Tracker







... and it took ~12 years

For

- Design
- Construction
- Space qualification tests of sub-systems

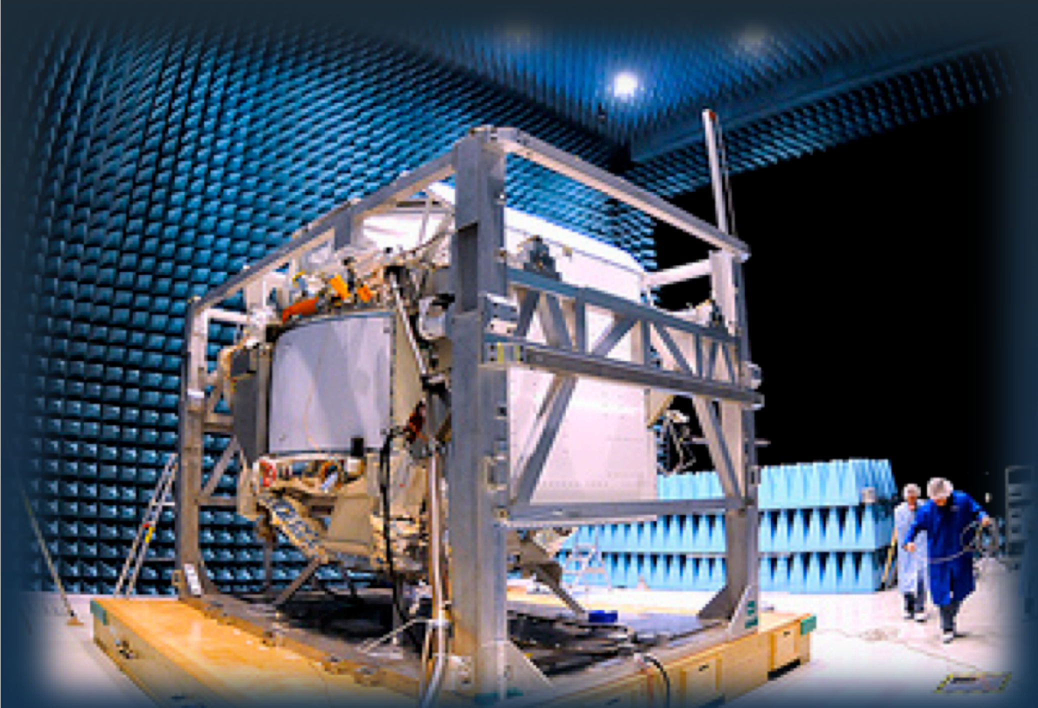
and

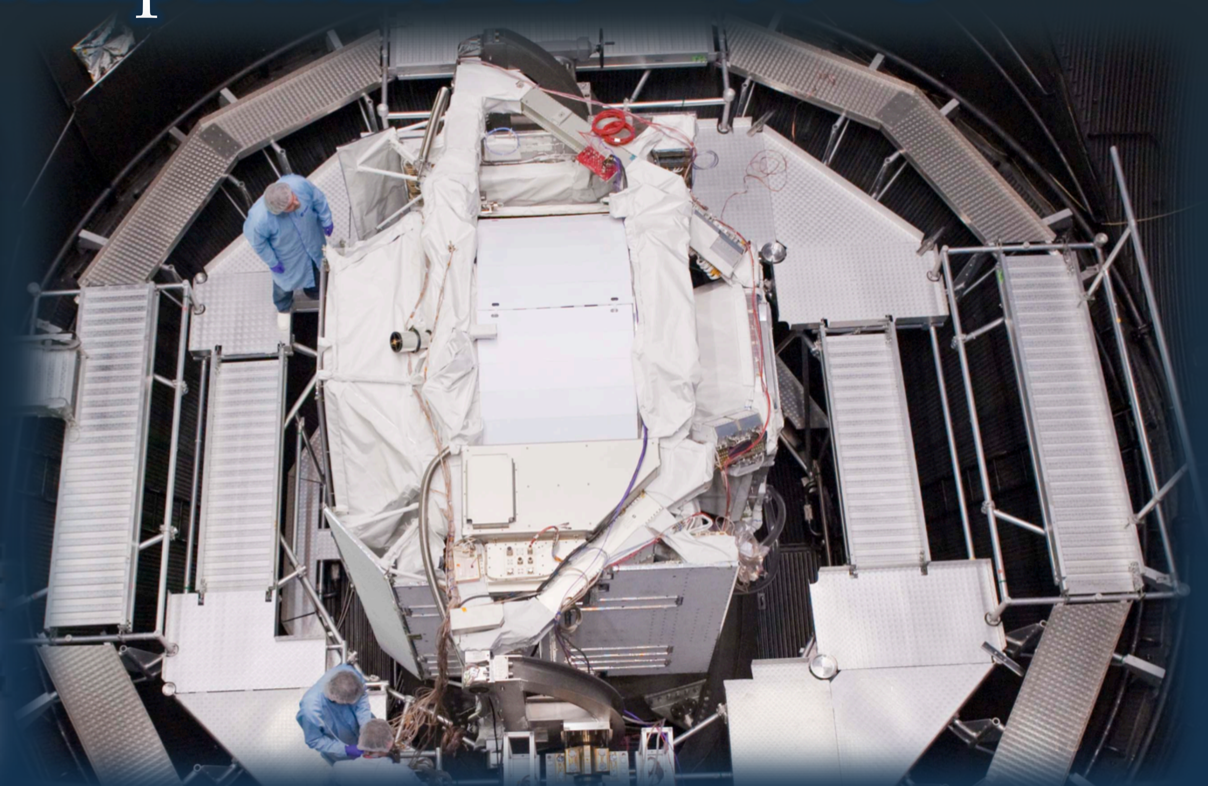
- Integration of AMS-02

Space qualification test

At European Space Agency
Mar~Apr/2010

- EMI (Electro Magnetic Interference) test
- Thermal Vacuum test
  Pressure < 10^{-9} bar, Temperature -40 ~ +90 °C

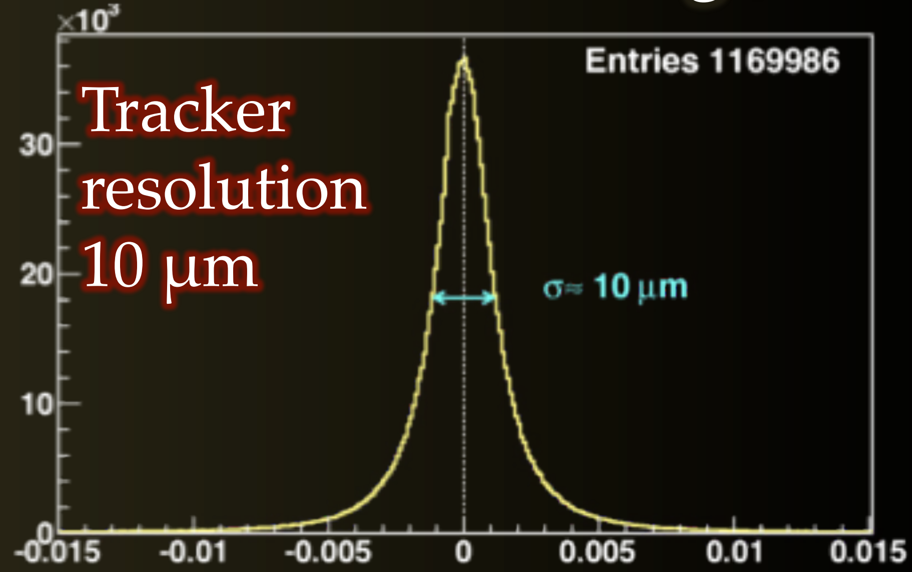


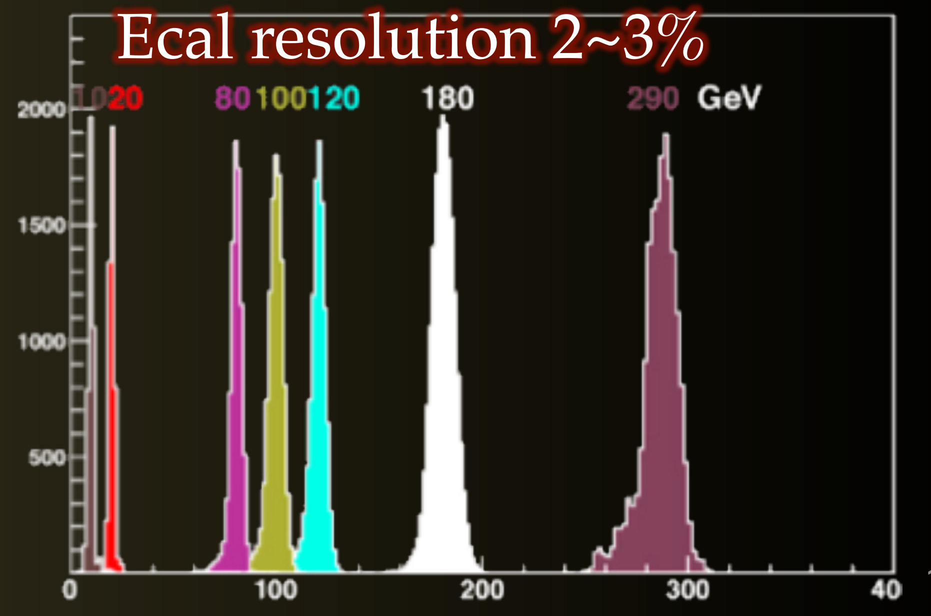


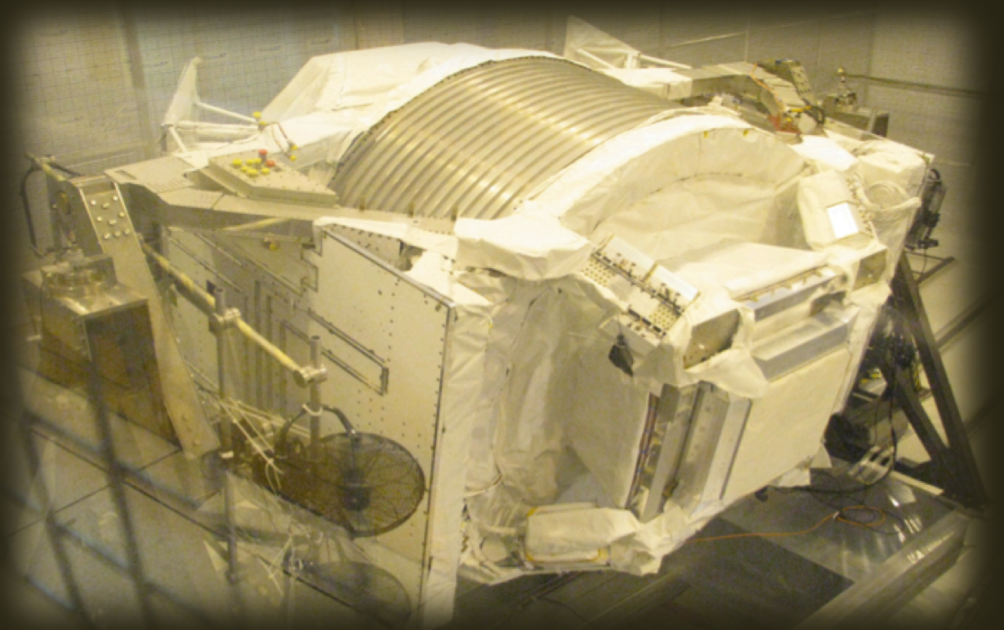
Particle beam Tests at CERN

Aug./2010

- Proton 400 GeV/c
- e+, e- 80 ~ 290 GeV



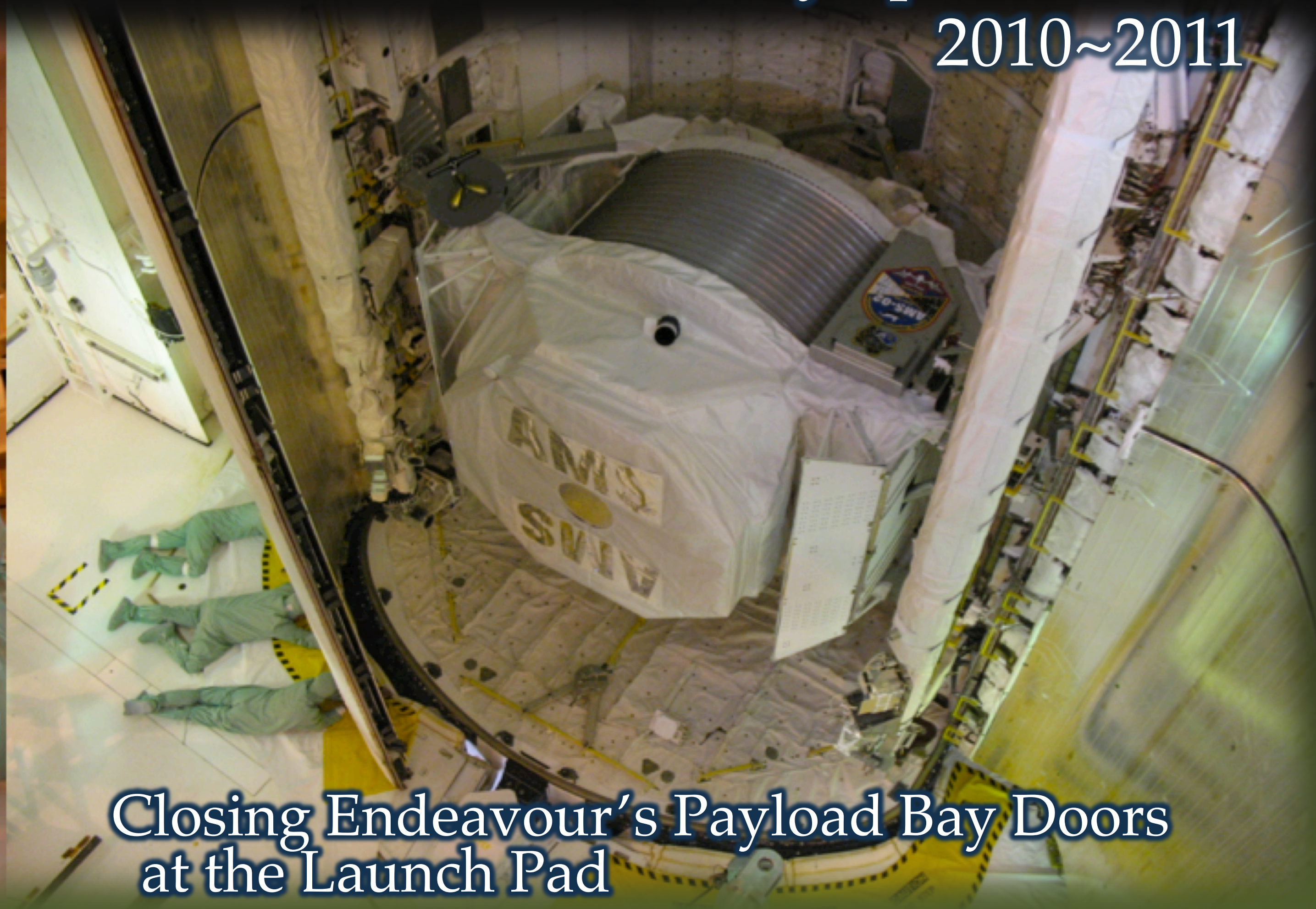




AMS installed in Space Shuttle

At Kennedy Space Center
2010~2011

Final inspection
by S. Ting

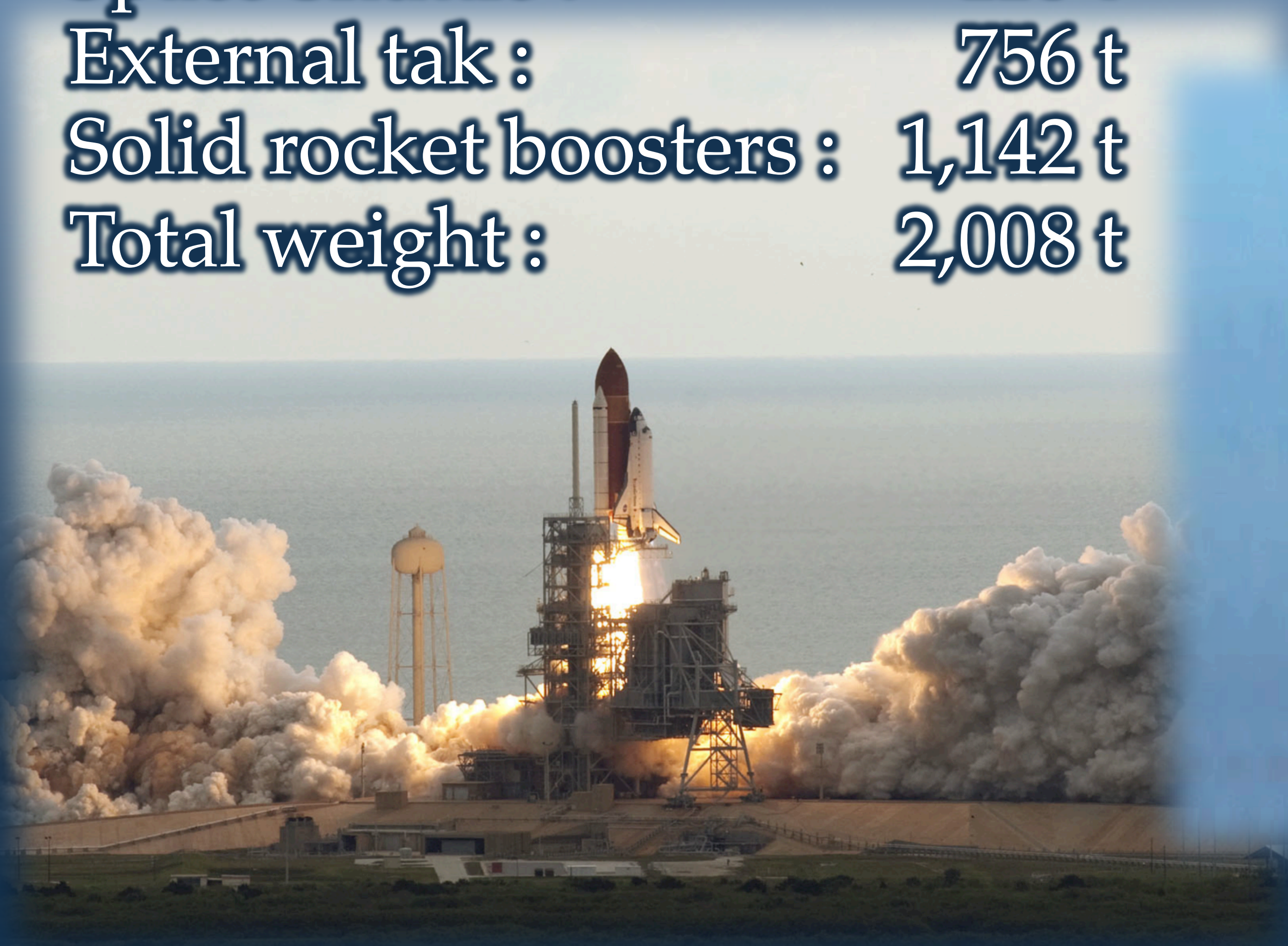


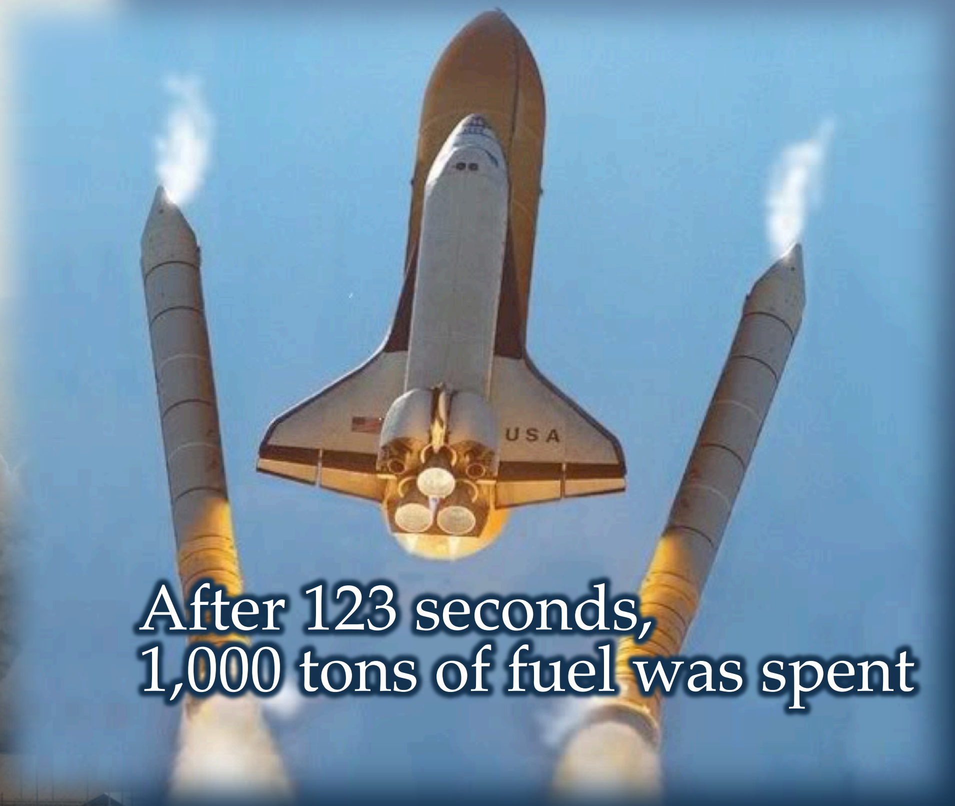
Closing Endeavour's Payload Bay Doors
at the Launch Pad

STS-134 Launch (Last *Endeavor* flight)

May 16, 2011 8:56 EDT

AMS :	7.5 t
Space Shuttle :	110 t
External tak :	756 t
Solid rocket boosters :	1,142 t
Total weight :	2,008 t





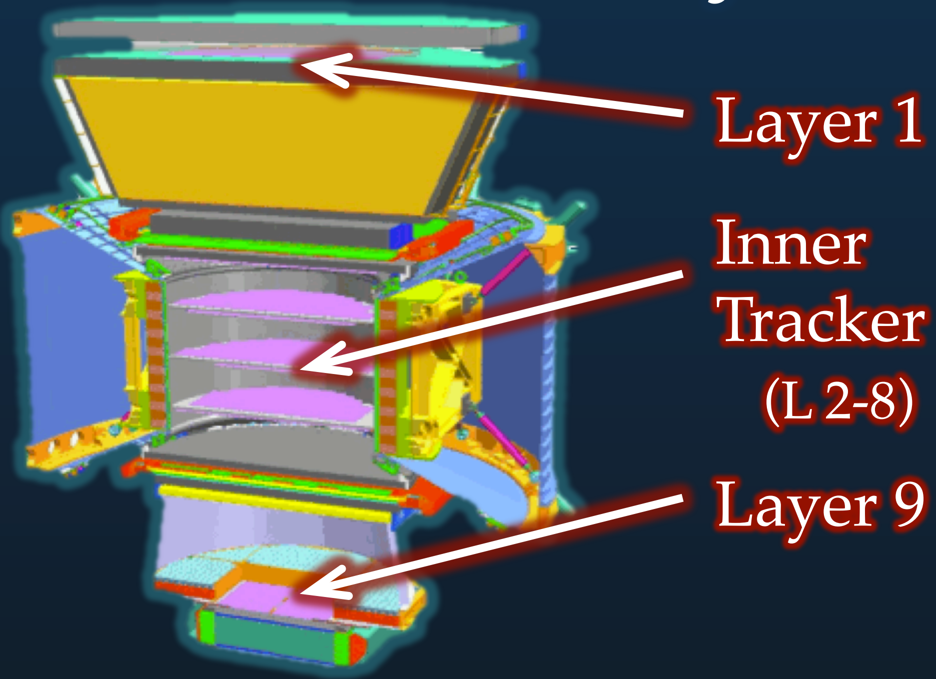
After 123 seconds,
1,000 tons of fuel was spent

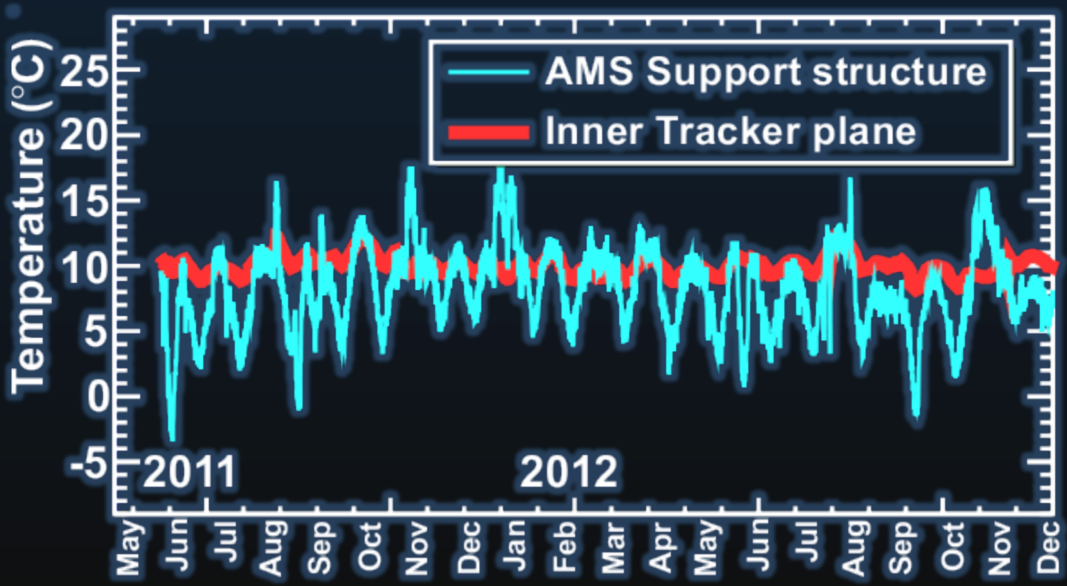
AMS installed on the ISS

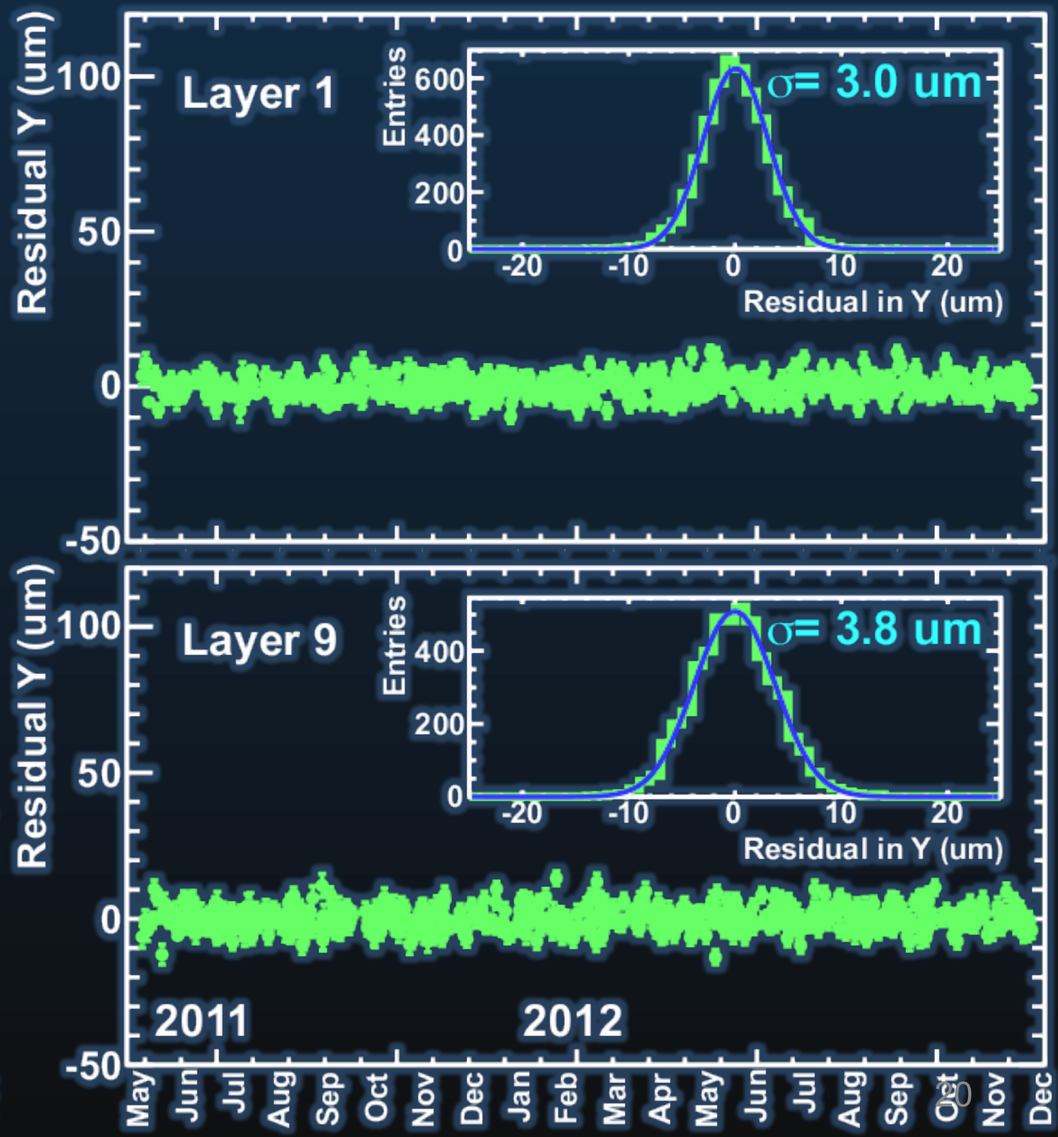
- May 19, 2011 5:15 CDT
- Start taking data 9:35 CDT

Since then, AMS is continuously recording 16 billion Cosmic-Ray events every year...

Stability of Tracker layers

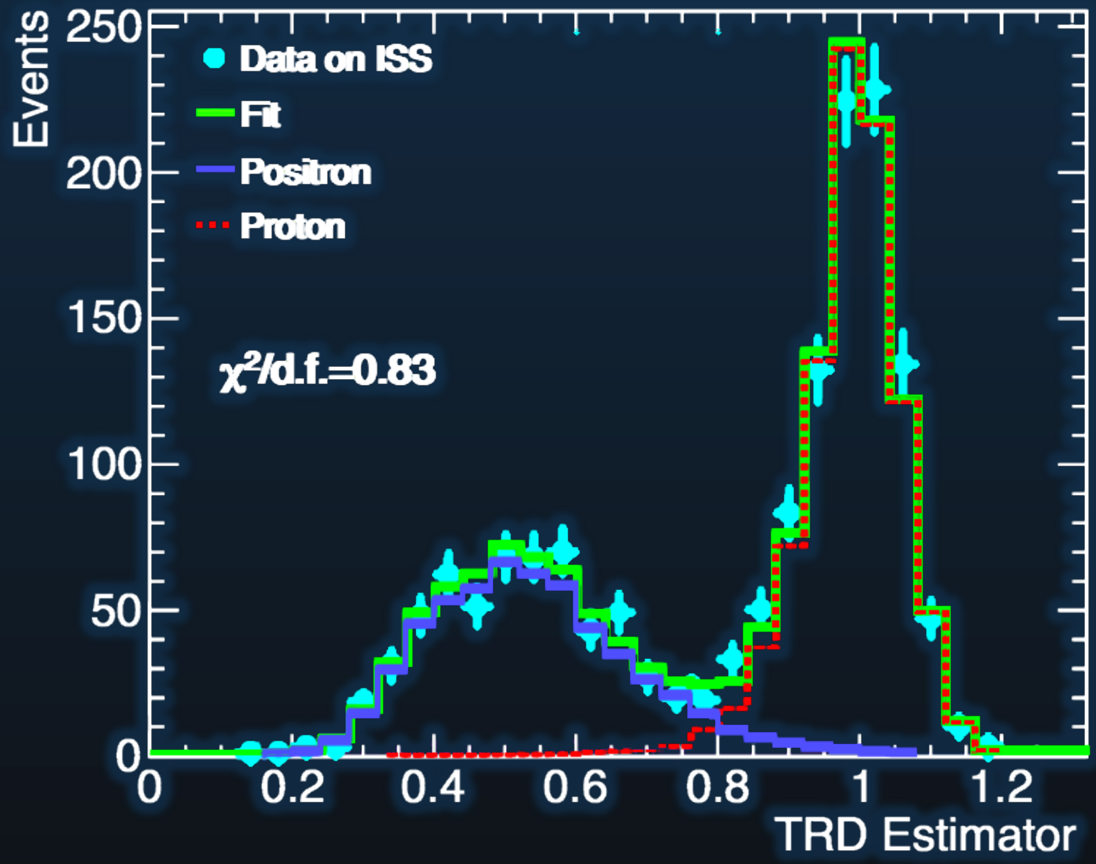


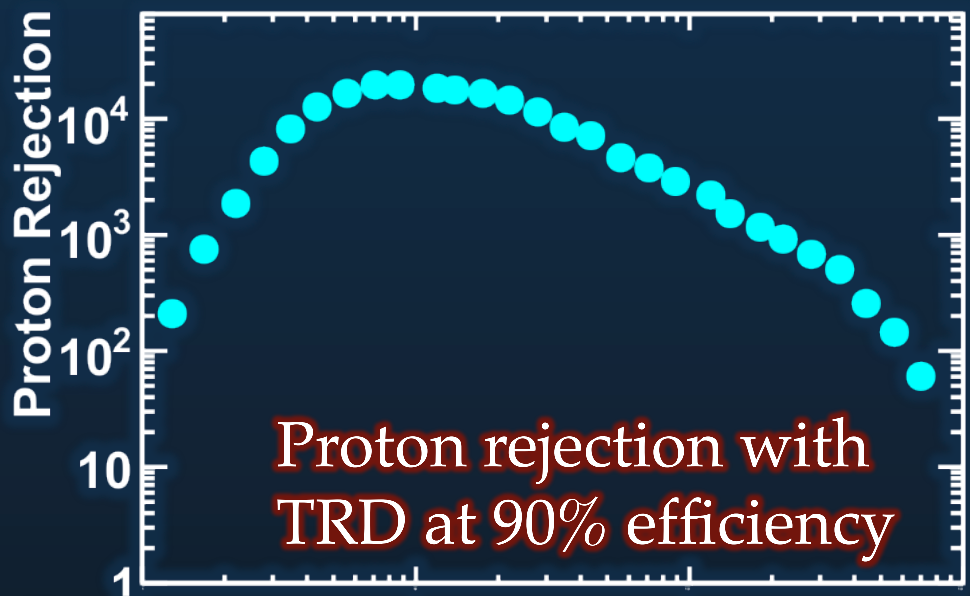


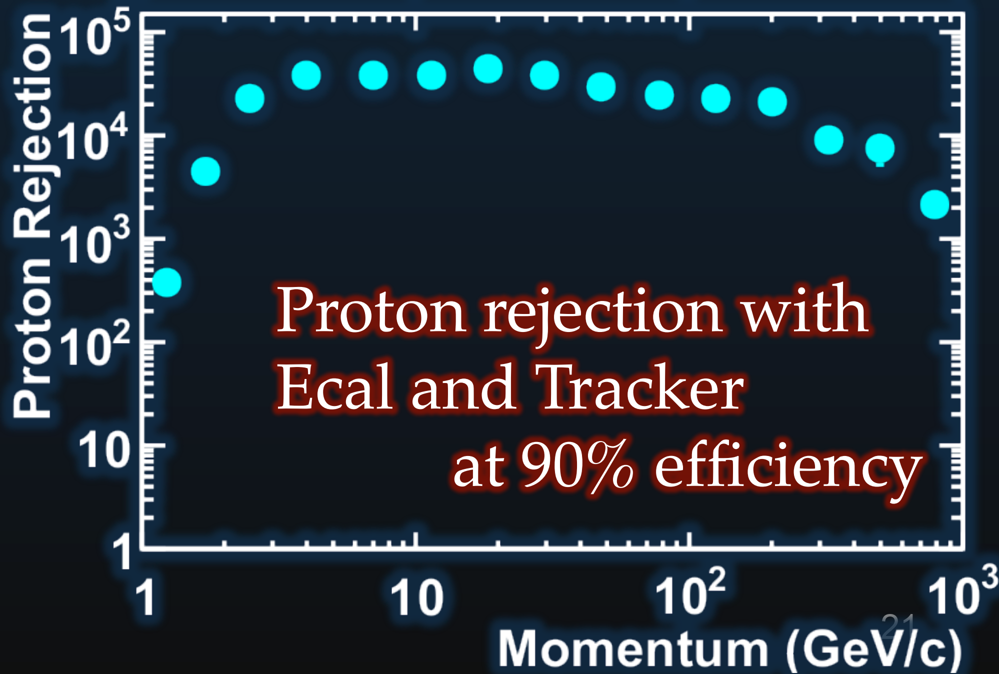


Positron identification

Positive charge data in 83-100 GeV



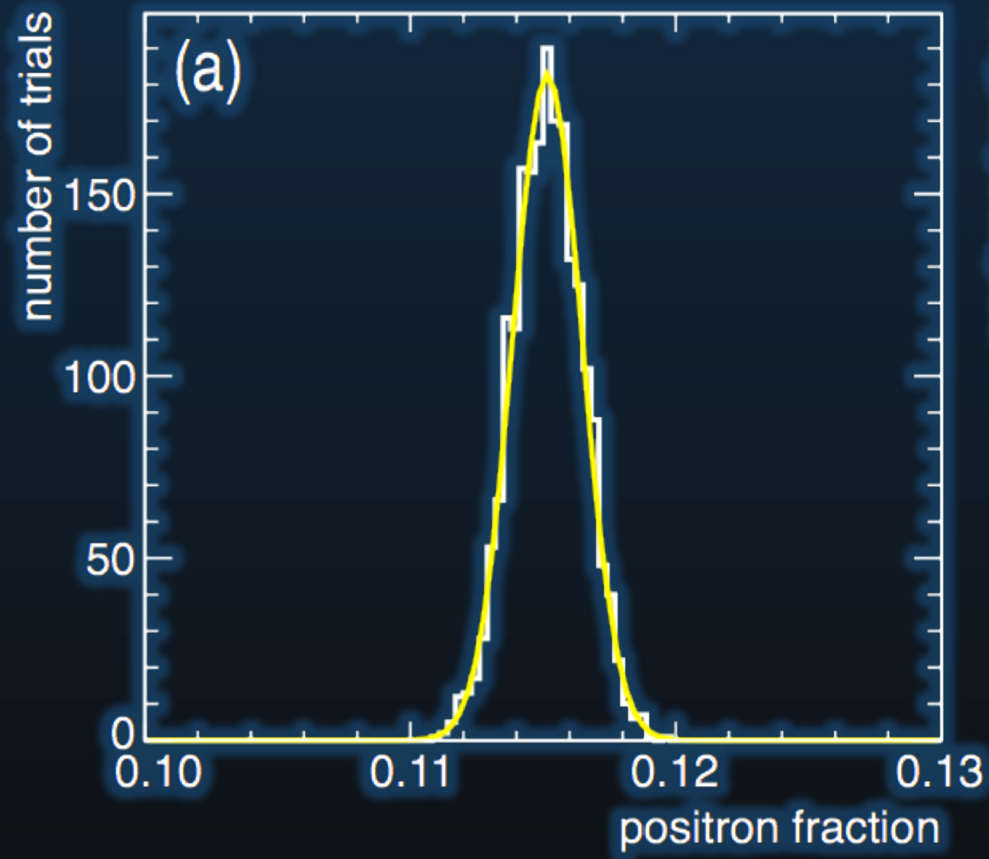


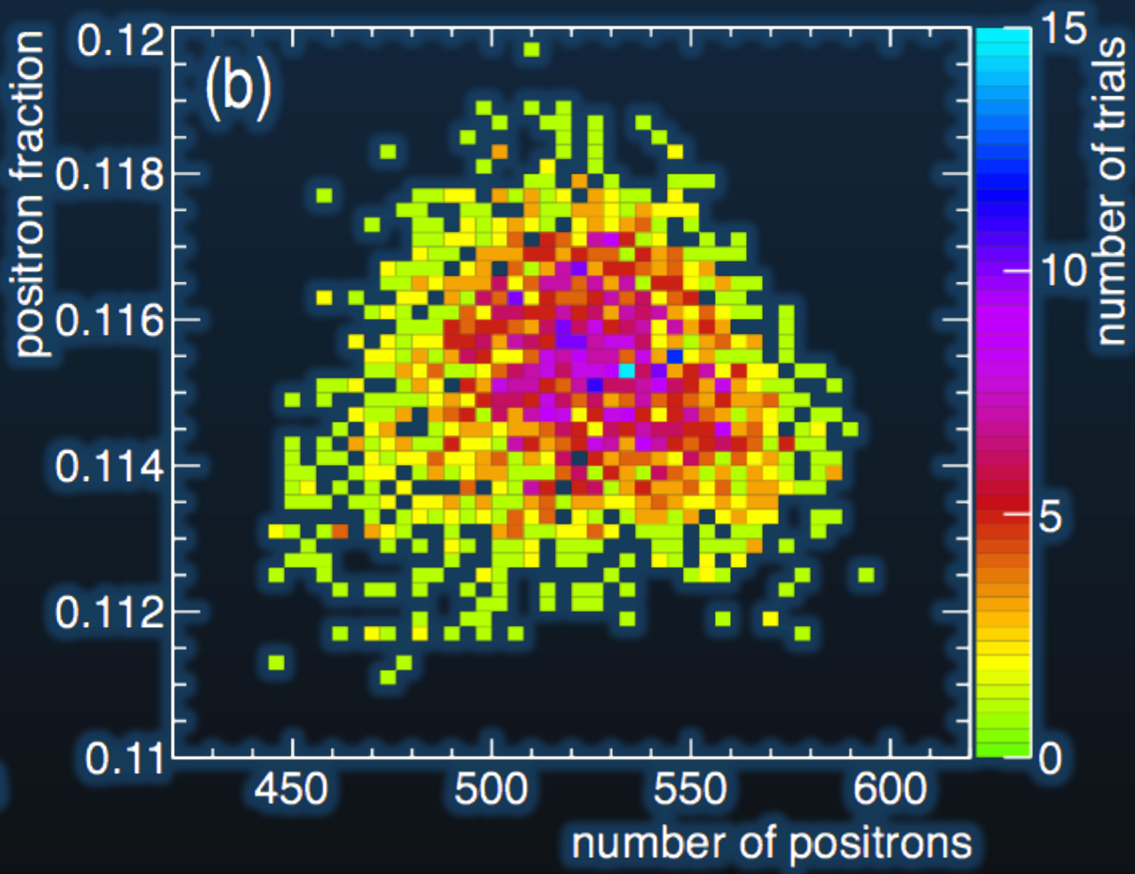


Systematics : Selection dependence

~1000 different cuts tested
and all gave the same result

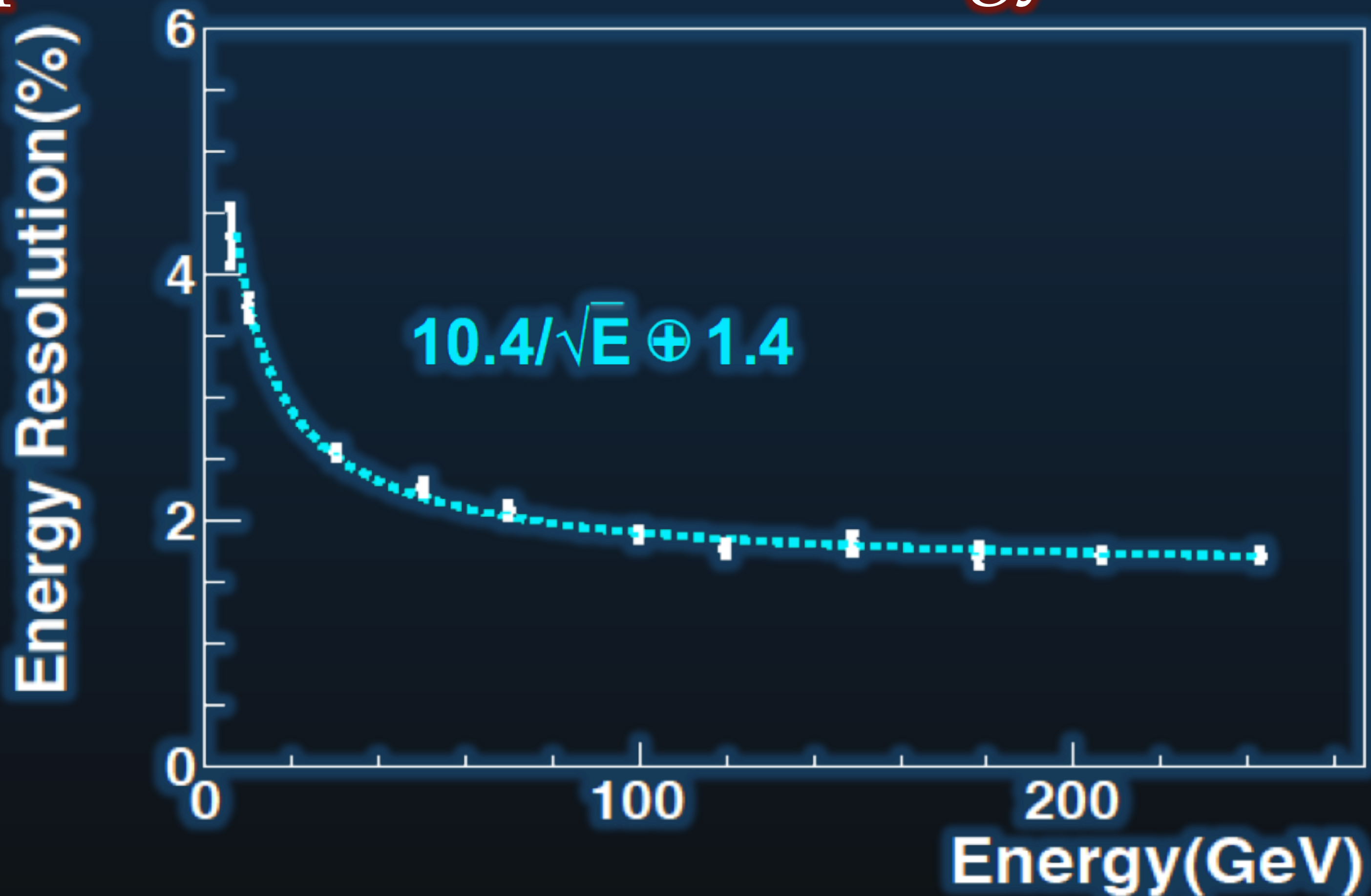
ISS data in 83-100 GeV





Systematics : Bin-to-bin migration

Effect obtained by folding the measured spectra with the ECAL energy resolution



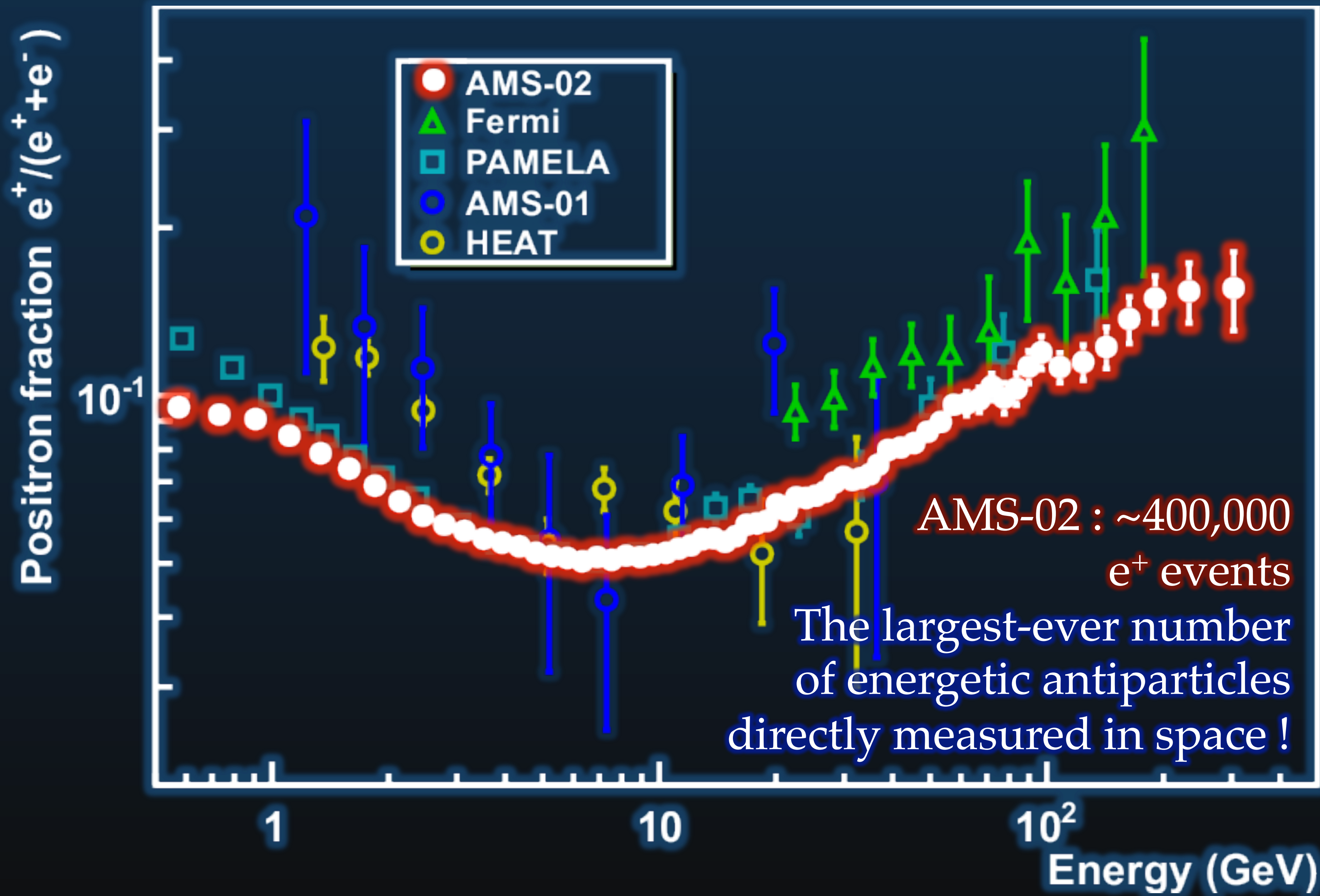
Bin width: 2σ at 5 GeV; 4σ at 50 GeV; 8σ at 100 GeV; 19σ at 300 GeV

Data table (highest points)

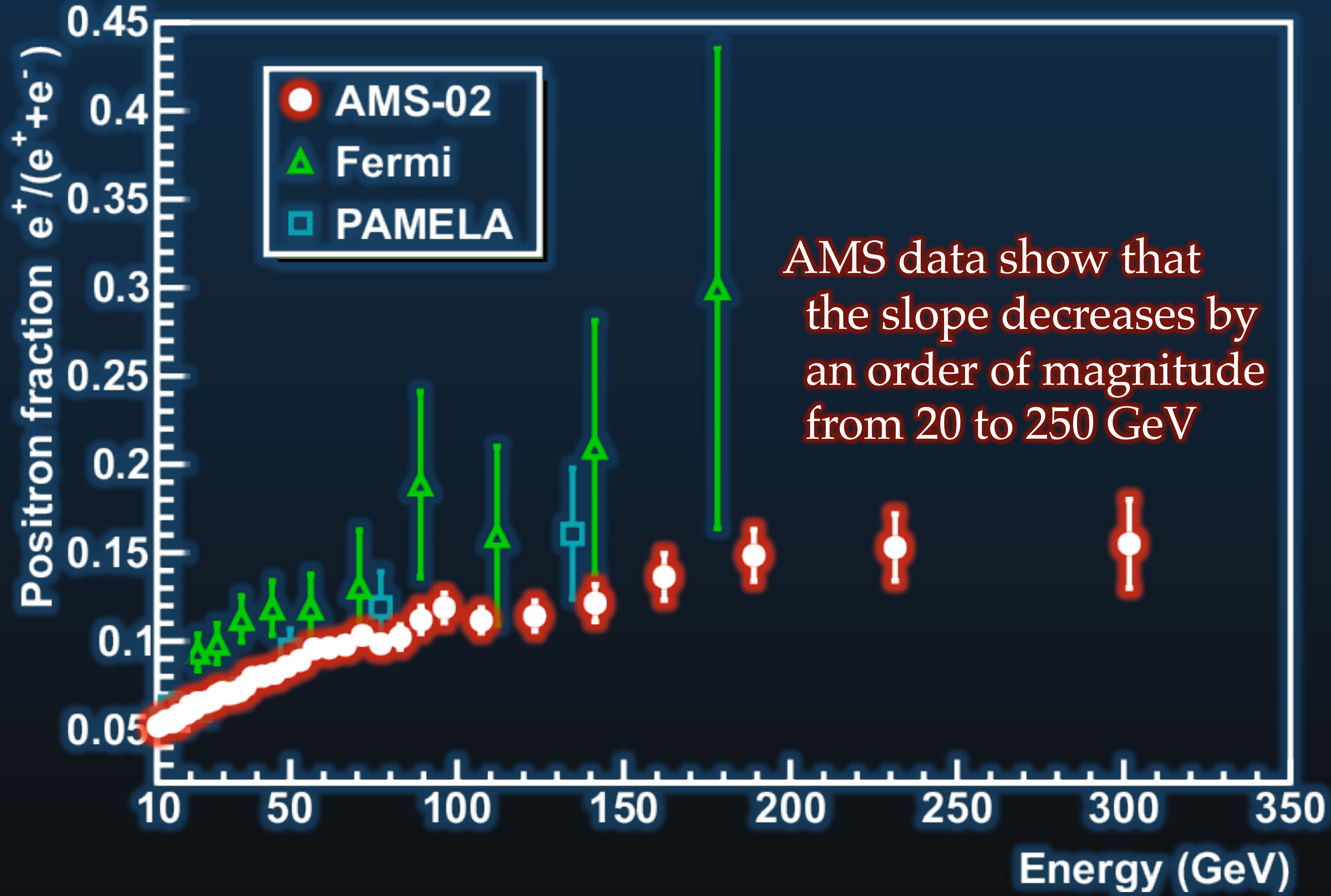
- **~1,100 e+ identified** above 100 GeV
- Syst. errors are always smaller than stat. errors, both of which are kept **within ~10 % level**

Energy [GeV]	N_{e^+}	Fraction	σ_{stat}	$\sigma_{acc.}$	$\sigma_{sel.}$	$\sigma_{mig.}$	$\sigma_{ref.}$	$\sigma_{c.c.}$	$\sigma_{syst.}$
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



Positron fraction



AMS data show that the slope decreases by an order of magnitude from 20 to 250 GeV

An example: Minimal model

- Positron fraction = $\dfrac{\Phi_{e+}}{\Phi_{e+} + \Phi_{e-}}$

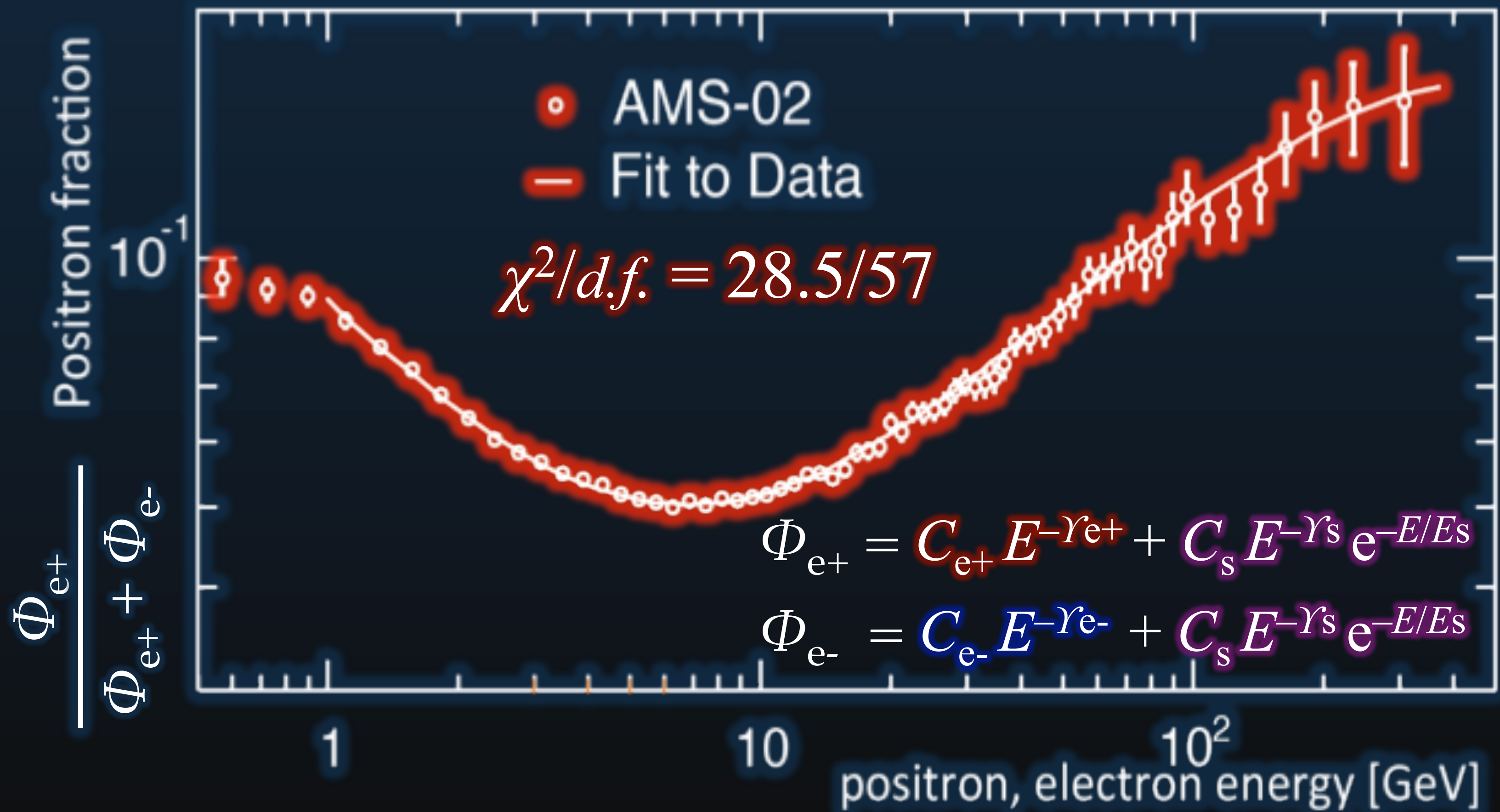
where $\Phi_{e+} = \underbrace{C_{e+} E^{-\gamma_{e+}}}_{\text{e+ diffuse}} + \underbrace{C_s E^{-\gamma_s} e^{-E/E_s}}_{\text{common source}}$

$\Phi_{e-} = \underbrace{C_{e-} E^{-\gamma_{e-}}}_{\text{e- diffuse (and primary)}} + \underbrace{C_s E^{-\gamma_s} e^{-E/E_s}}_{\text{common source}}$

Fit with minimal model

$\Upsilon_{e-} - \Upsilon_{e+} = -0.63 \pm 0.03$ Diffuse e+ is less energetic than e-

$\Upsilon_{e-} - \Upsilon_{s} = 0.66 \pm 0.05$ Source is more energetic than diffuse e-

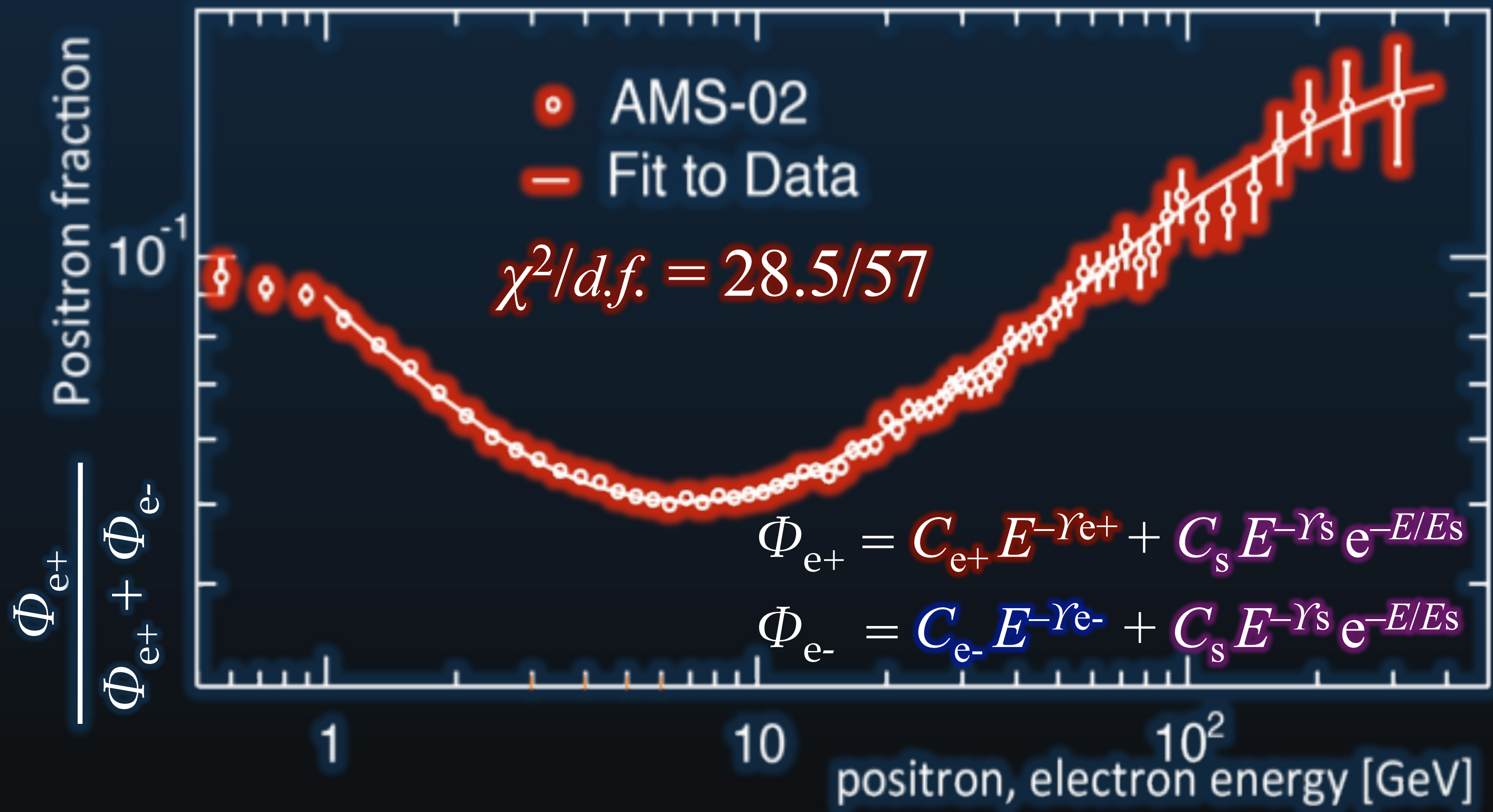


Fit with minimal model

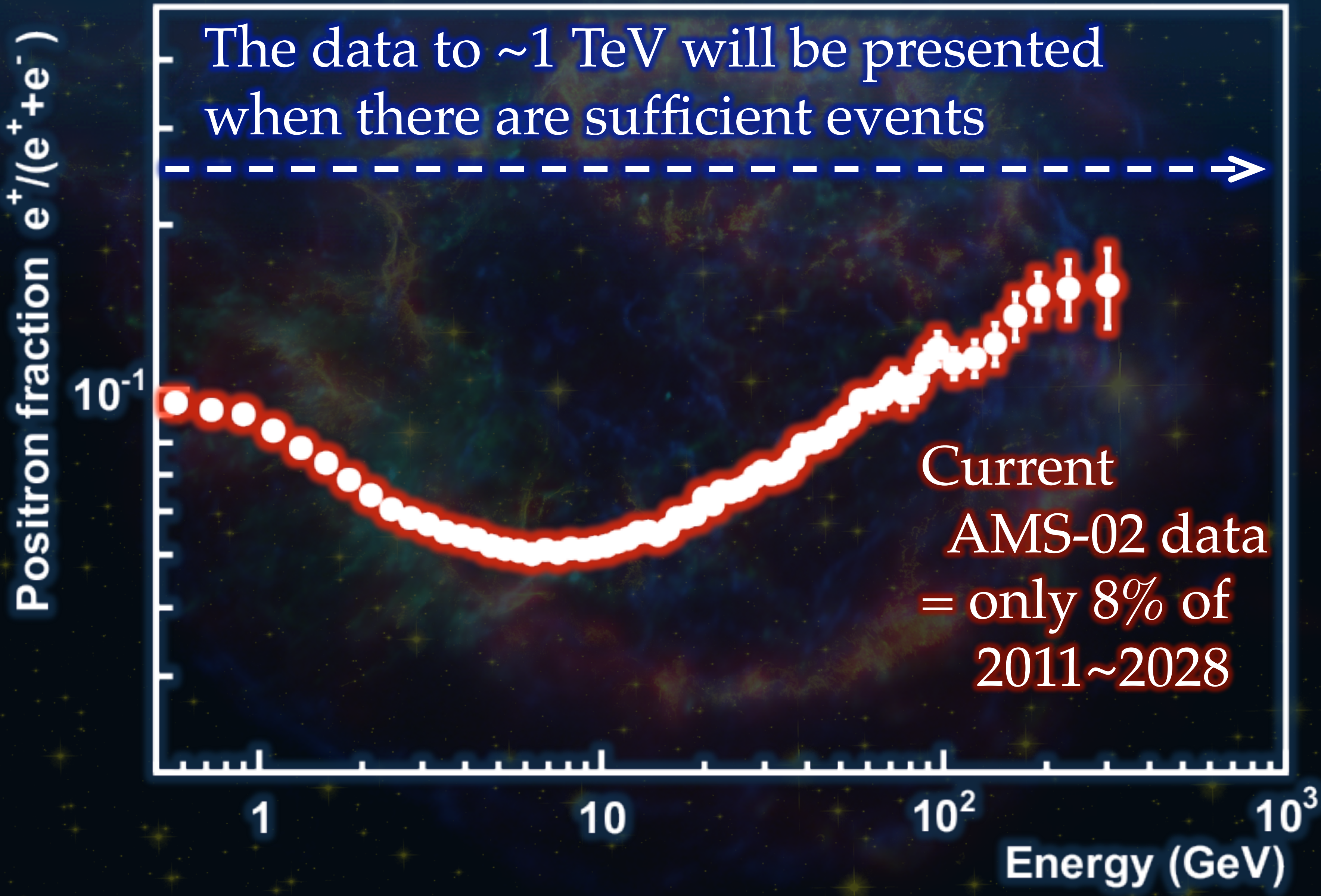
$C_{e+} / C_{e-} = 0.091 \pm 0.001$

$C_s / C_{e-} = 0.0078 \pm 0.0012$

$1/E_s = 0.0013 \pm 0.0007\ \mathrm{GeV}^{-1}$ (Cutoff energy 760^{+1000}_{-280} GeV)



On going work : Positron to ~TeV




To be continued ...
Thanks for
your attention !