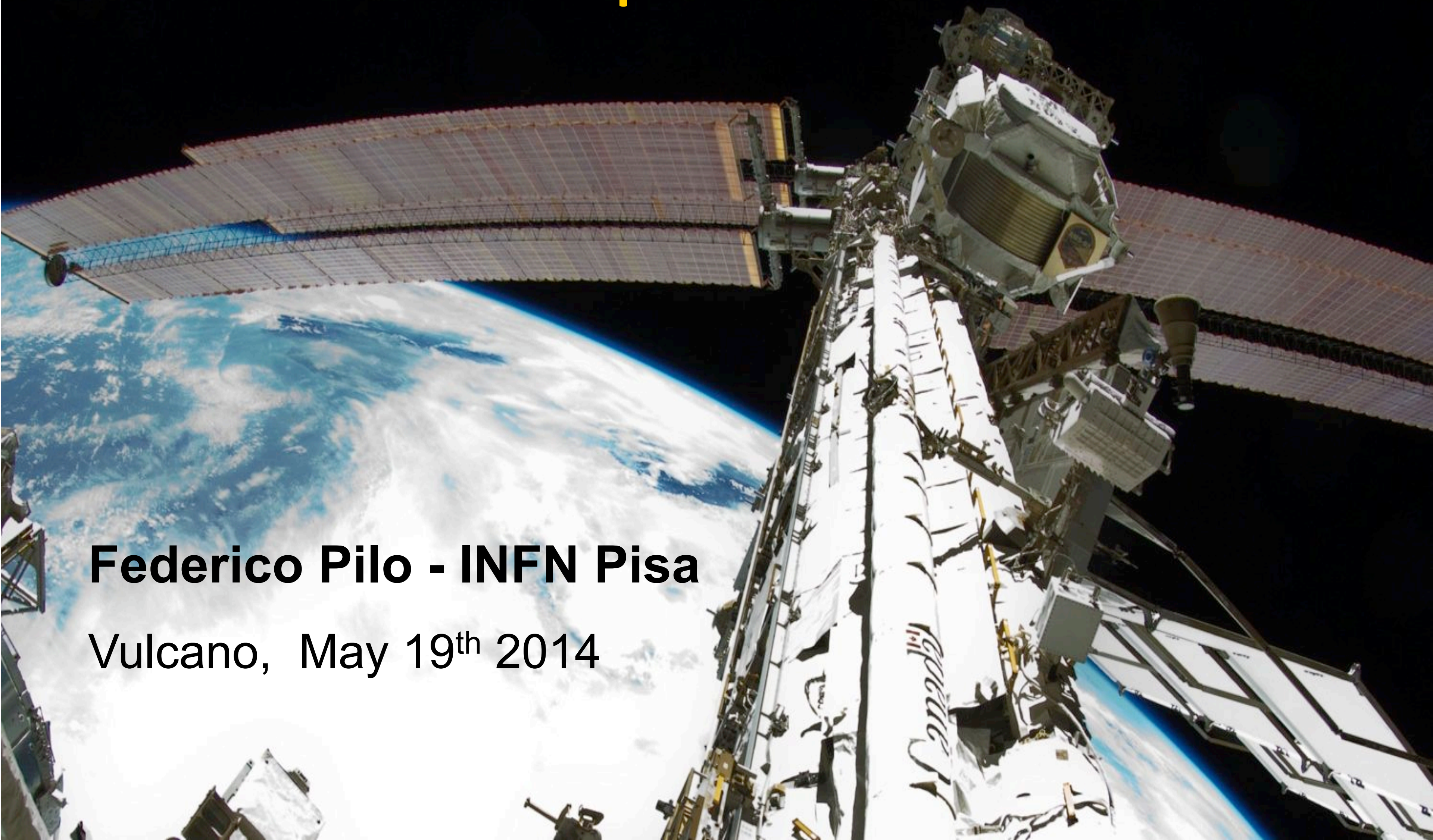
Recent results from the Alpha Magnetic Spectrometer (AMS) Experiment on the International Space Station



Federico Pilo - INFN Pisa

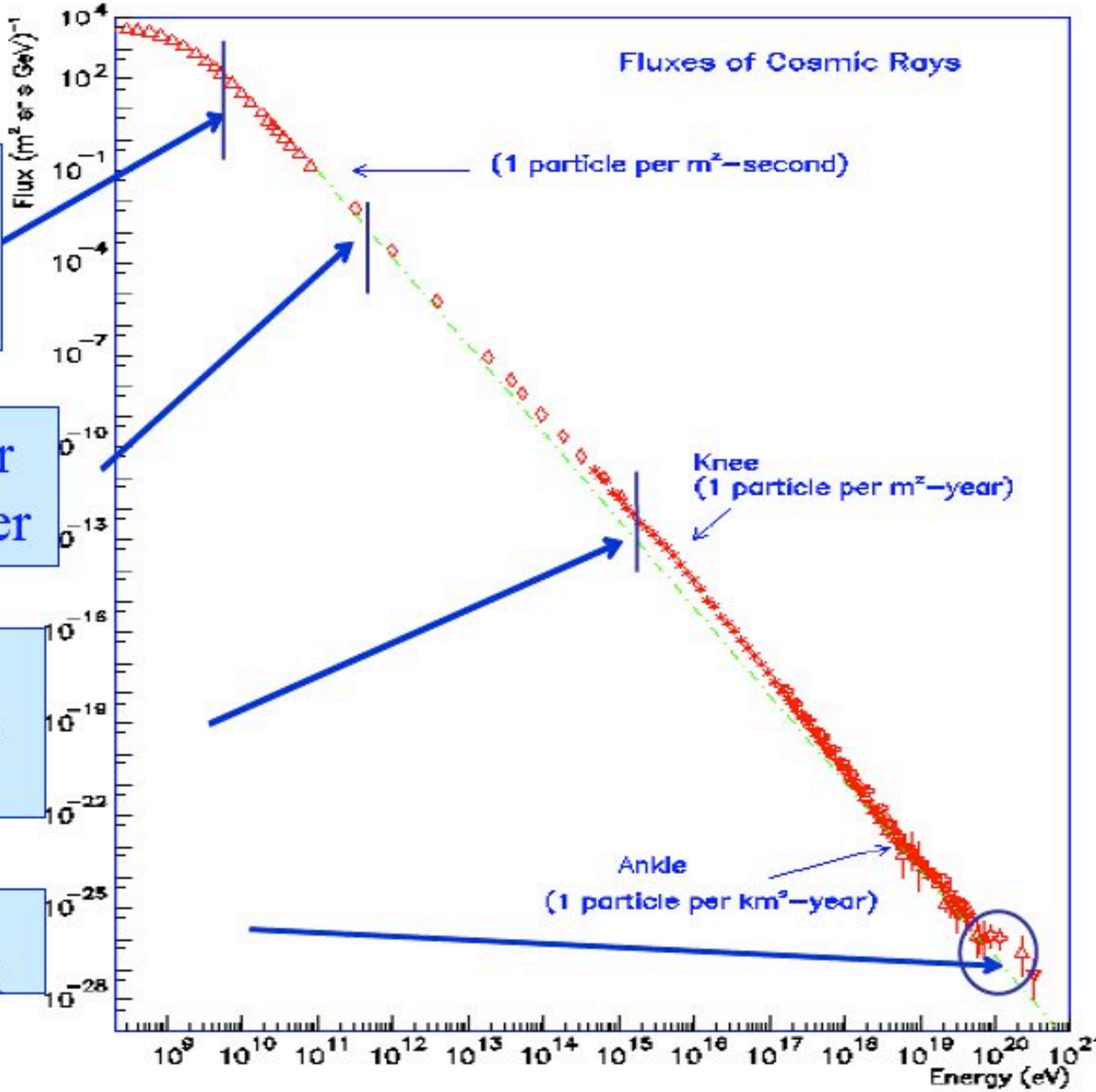
Vulcano, May 19th 2014

Isotopic composition Solar Modulation

Antimatter Dark Matter

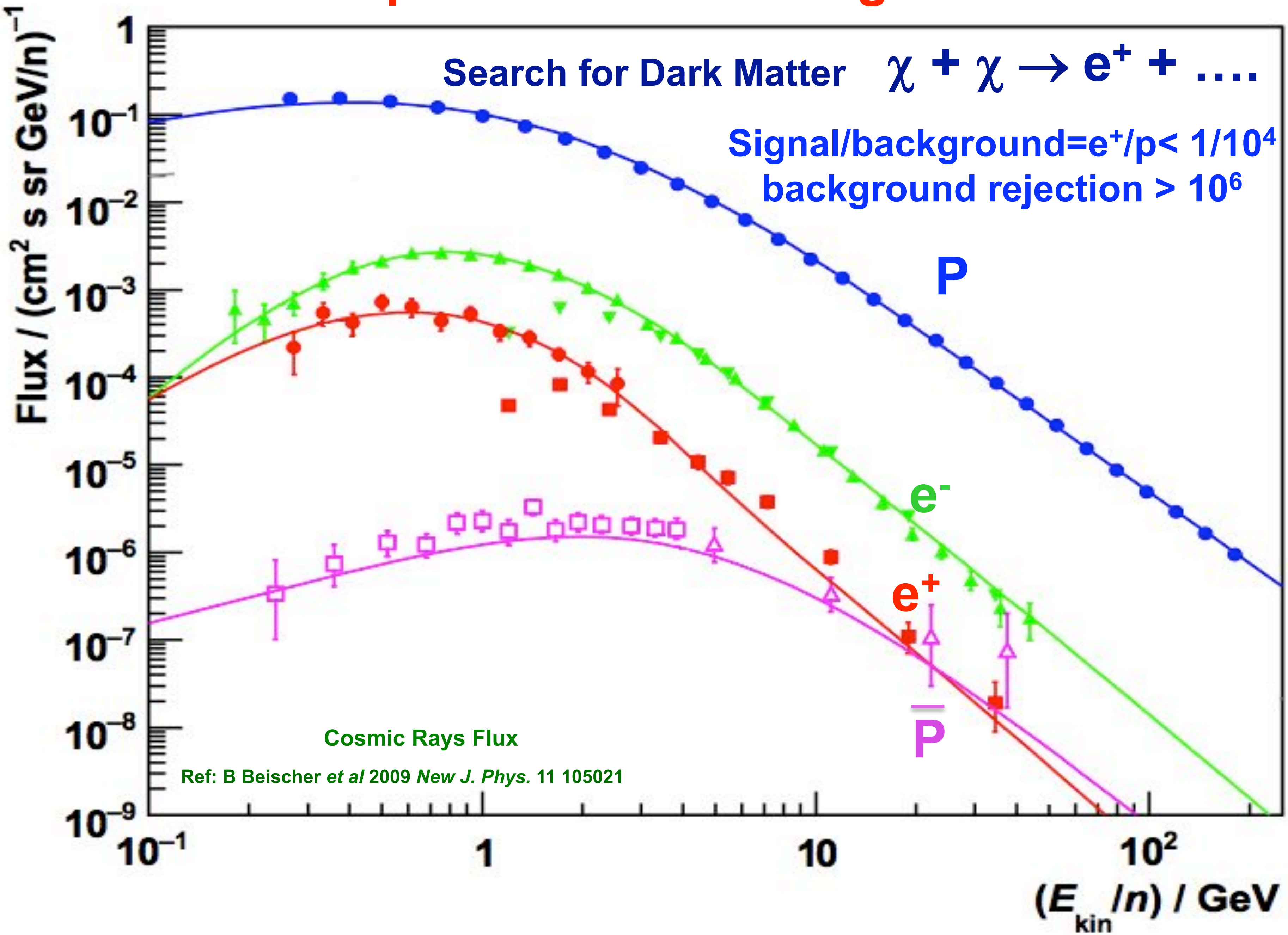
Elemental Composition

Extreme Energy CR



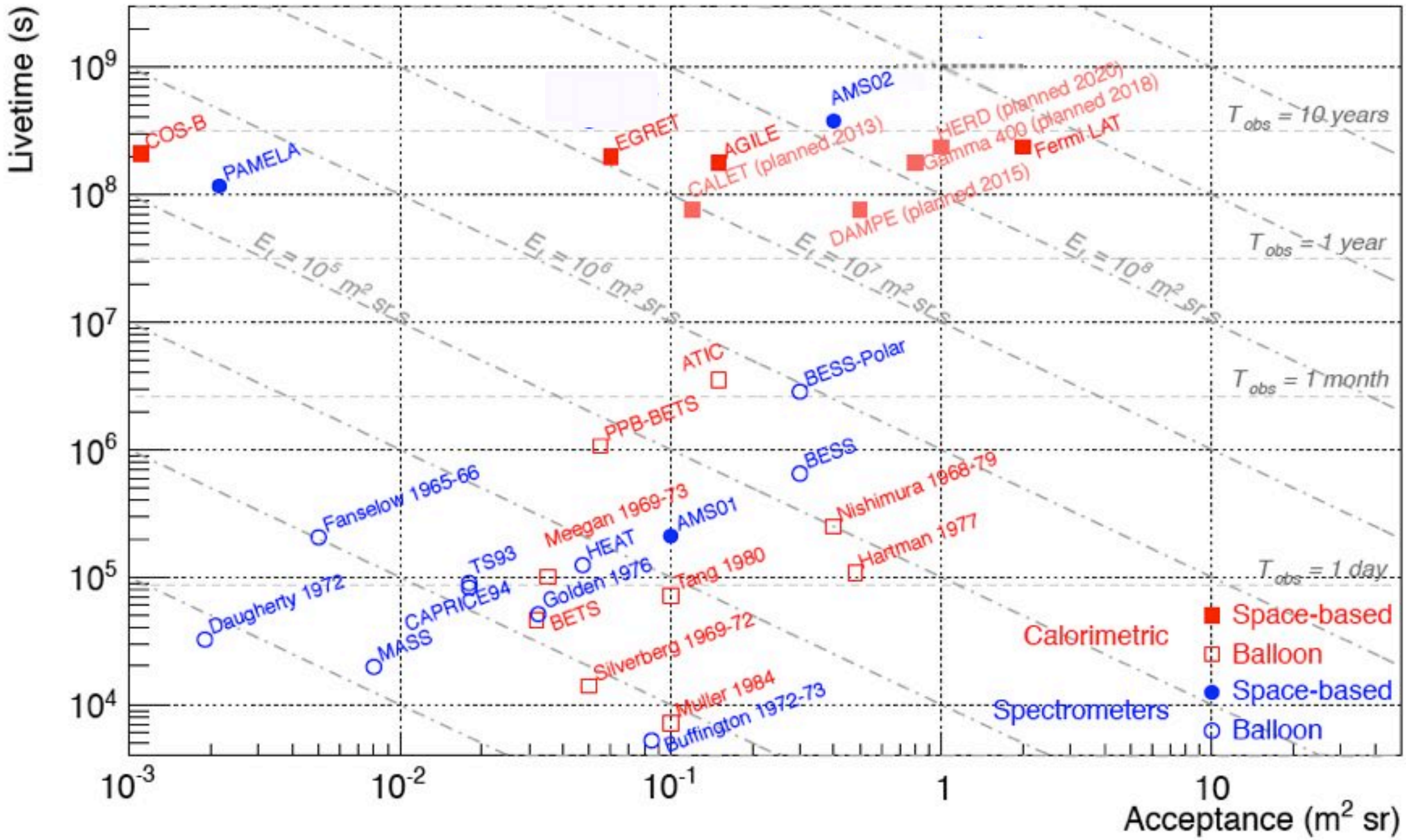
J. Cronin ,T.K. Gaisser & S.P. Swordy, Sci. Amer. 276 (1997) 44

Experimental Challenges



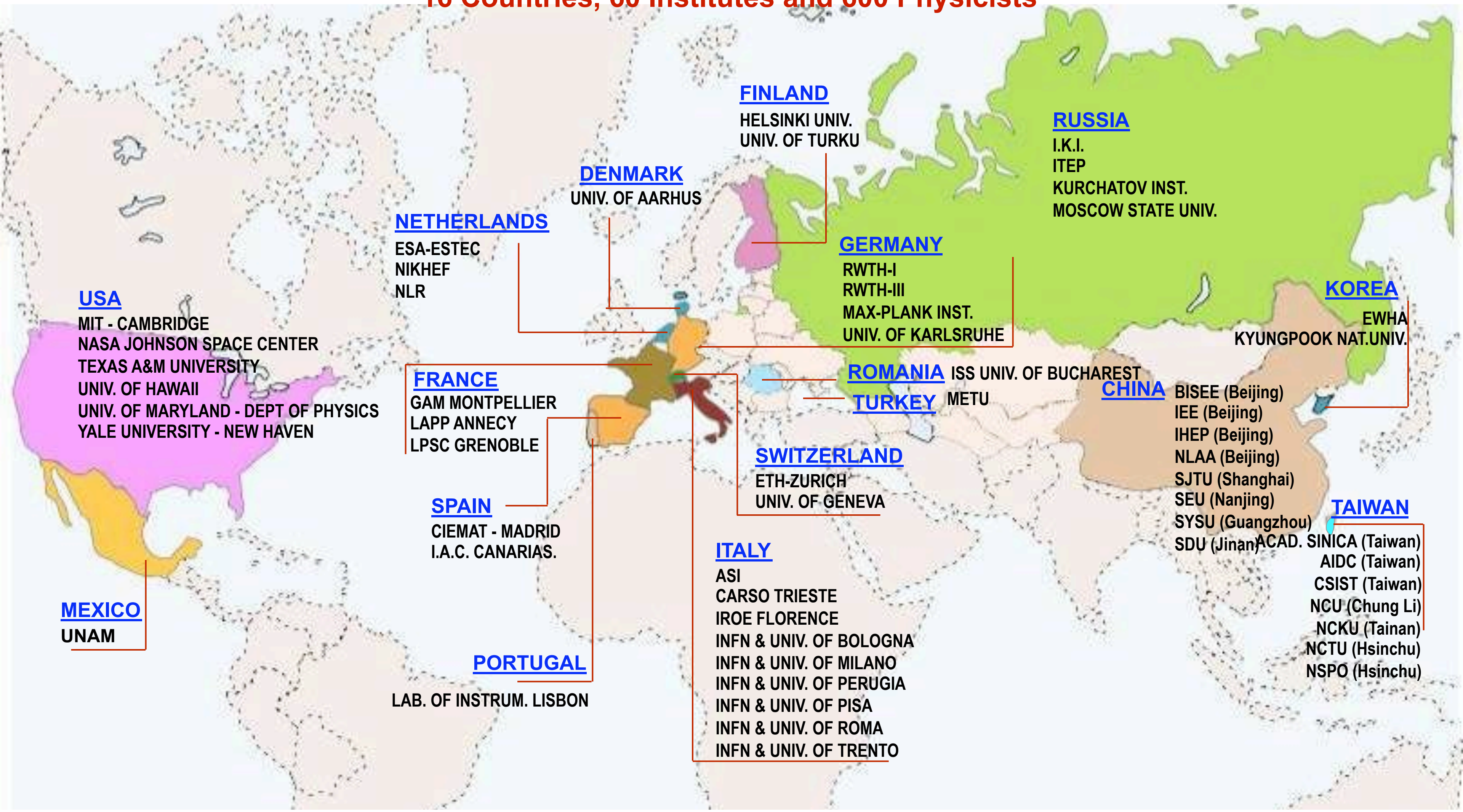
A Large Magnetic Spectrometer in Space : a game changing for the study of Cosmic Ray

L. Baldini 2012



AMS International Collaboration

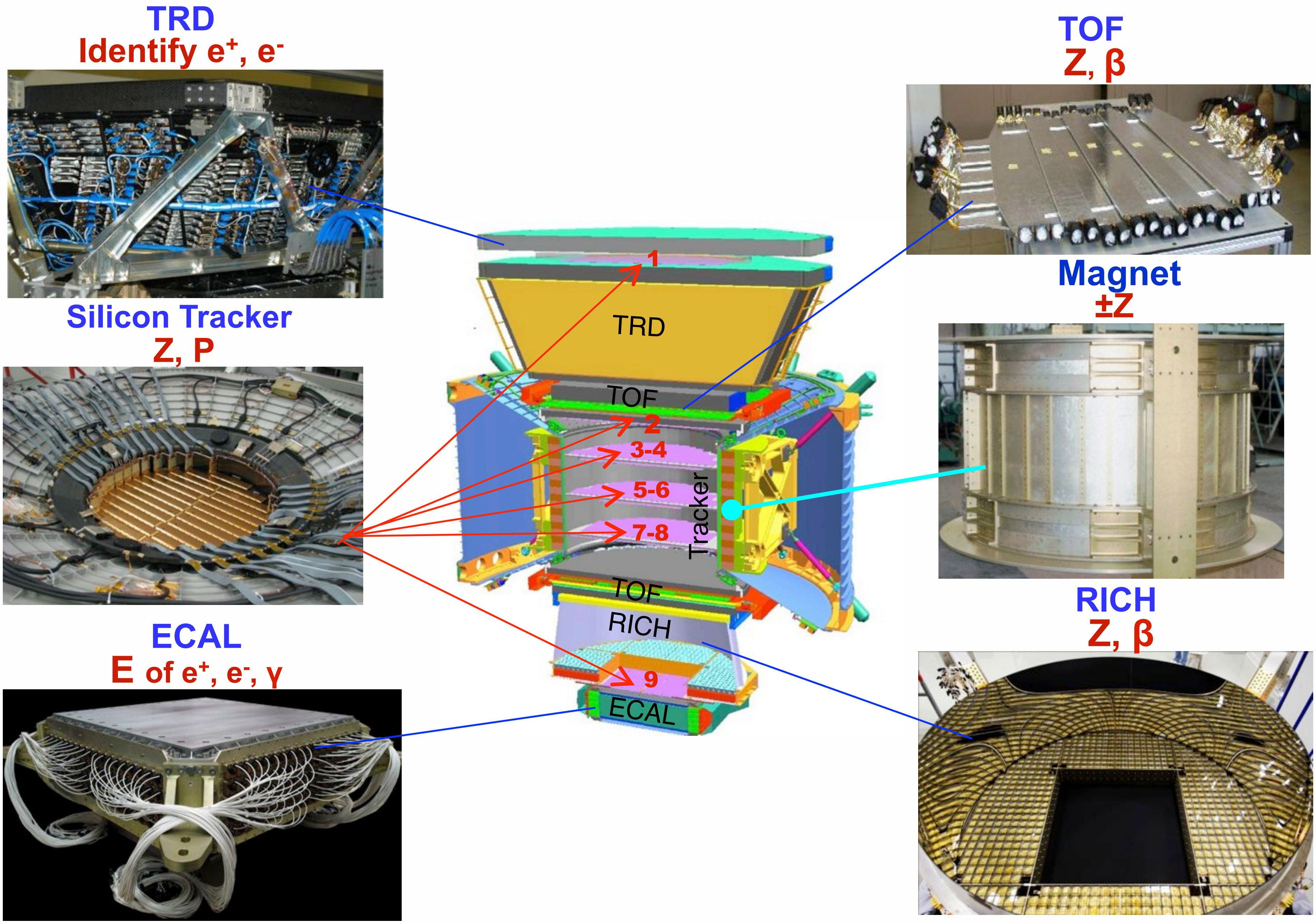
16 Countries, 60 Institutes and 600 Physicists



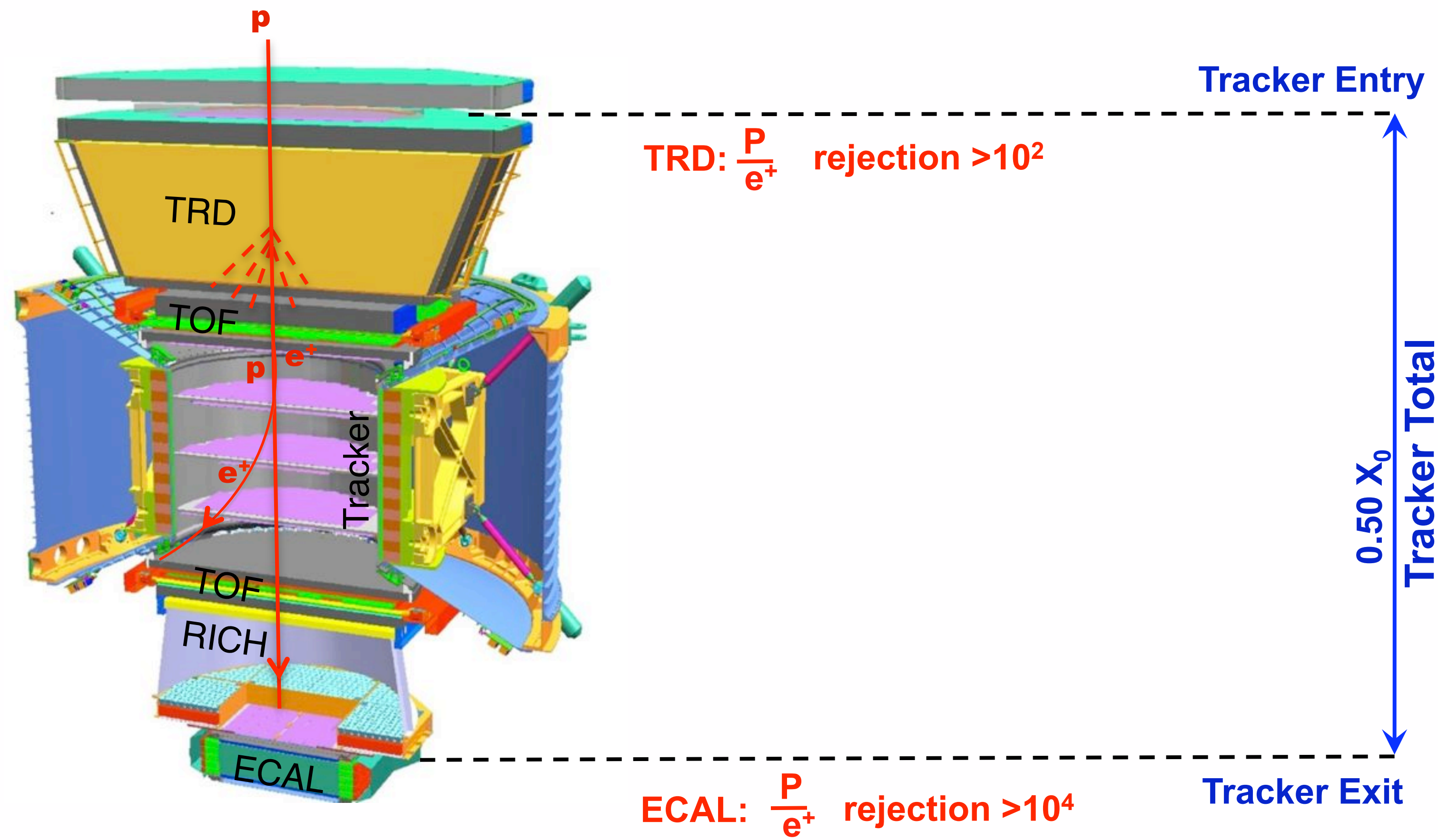
DOE sponsored experiment, NASA space operation

95% construction from Europe and Asia

AMS: A TeV precision, multipurpose spectrometer



Sensitive Search for the origin of Dark Matter with $p/e^+ > 10^6$



a) Minimal material in the TRD and TOF
So that the detector does not become a source of e^+.

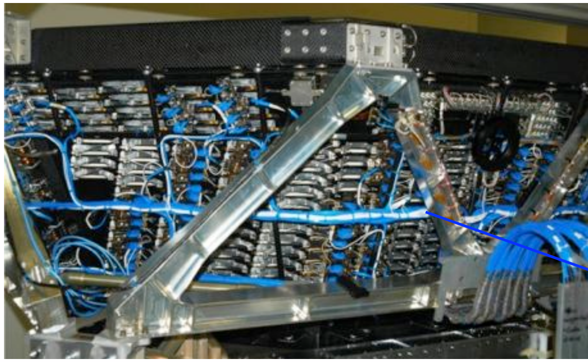
b) A magnet separates TRD and ECAL so that e^+ produced in TRD will be swept away and not enter ECAL
In this way the rejection power of TRD and ECAL are independent

c) Matching momentum of 9 tracker planes with ECAL energy measurements

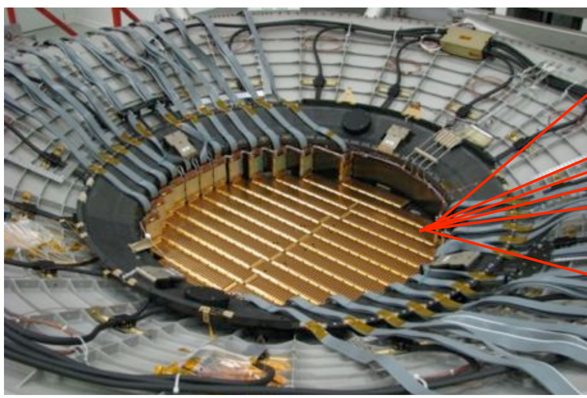
AMS Flight Electronics for Data Acquisition (DAQ)

300,000 channels at 2 KHz,
650 computers
designed and built by AMS

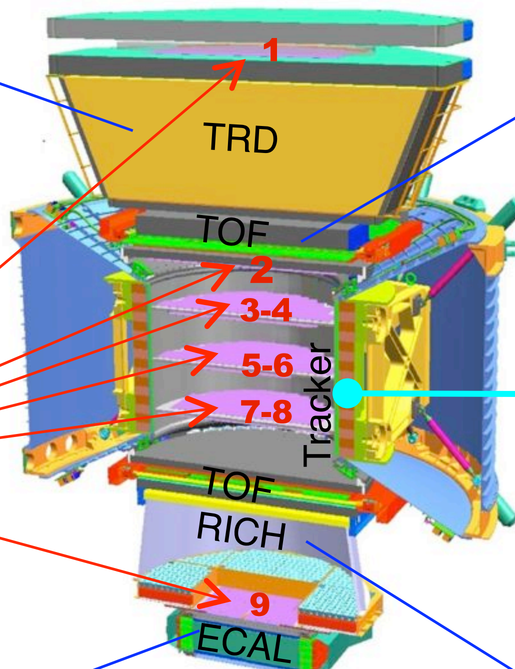
TRD: 5248 Signals



Silicon Tracker:
196,608 Signals

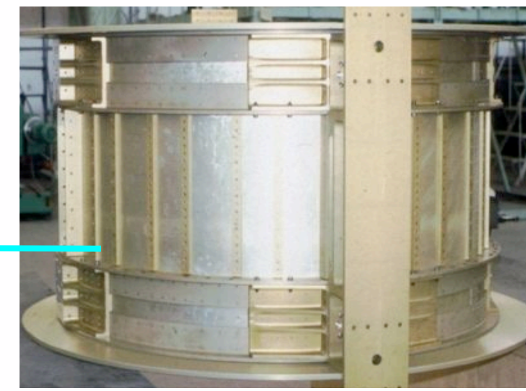


ECAL: 2,916 Signals

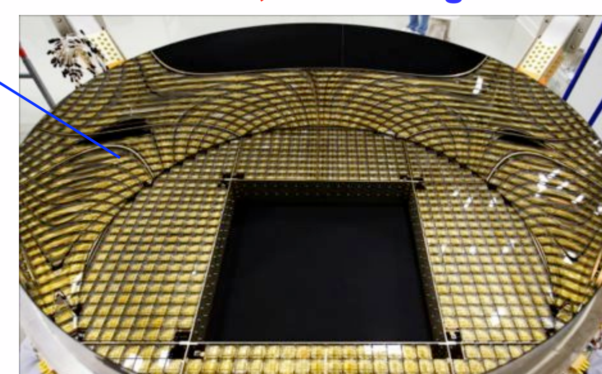


TOF & ACC: 88 Signals

Magnet



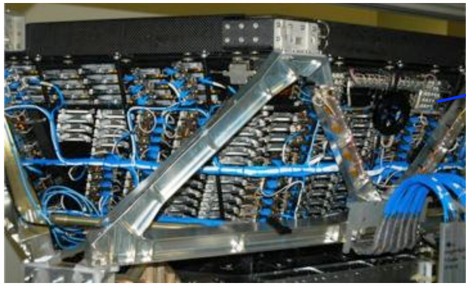
RICH: 10,800 * 2 Signals

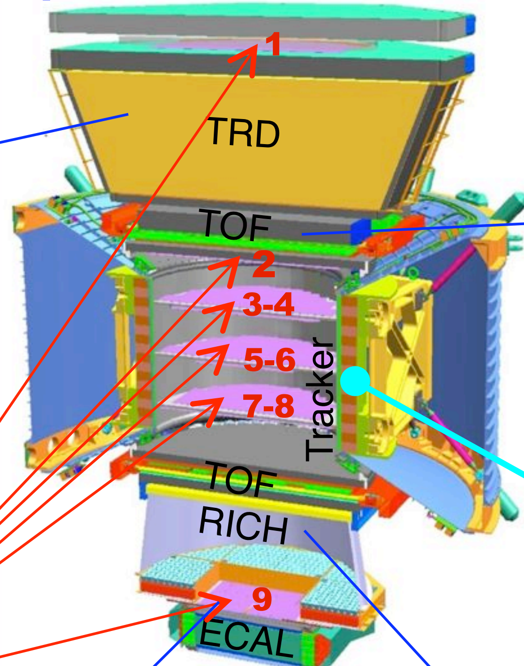


AMS Flight Electronics for Thermal Control

1118 temperature sensors, 298 heaters

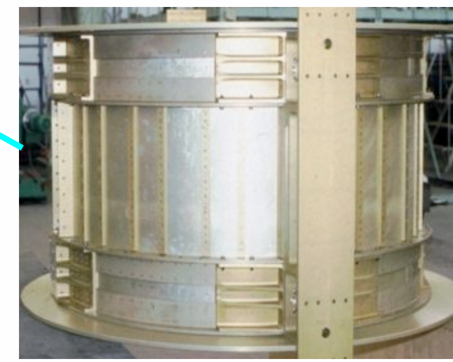
TRD
24 Heaters
8 Pressure Sensors
482 Temperature Sensors



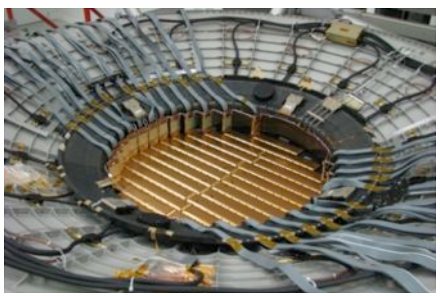


TOF & ACC
64 Temperature Sensors

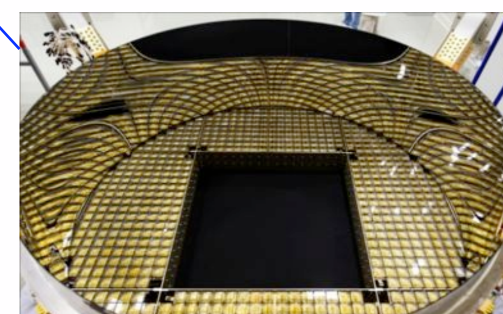
Magnet
68 Temperature Sensors



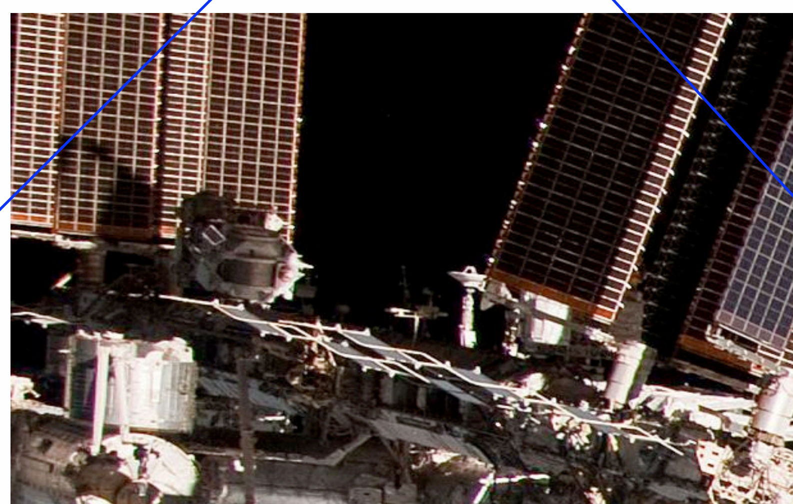
Silicon Tracker
4 -Pressure Sensors
32 Heaters
142 Temperature Sensors



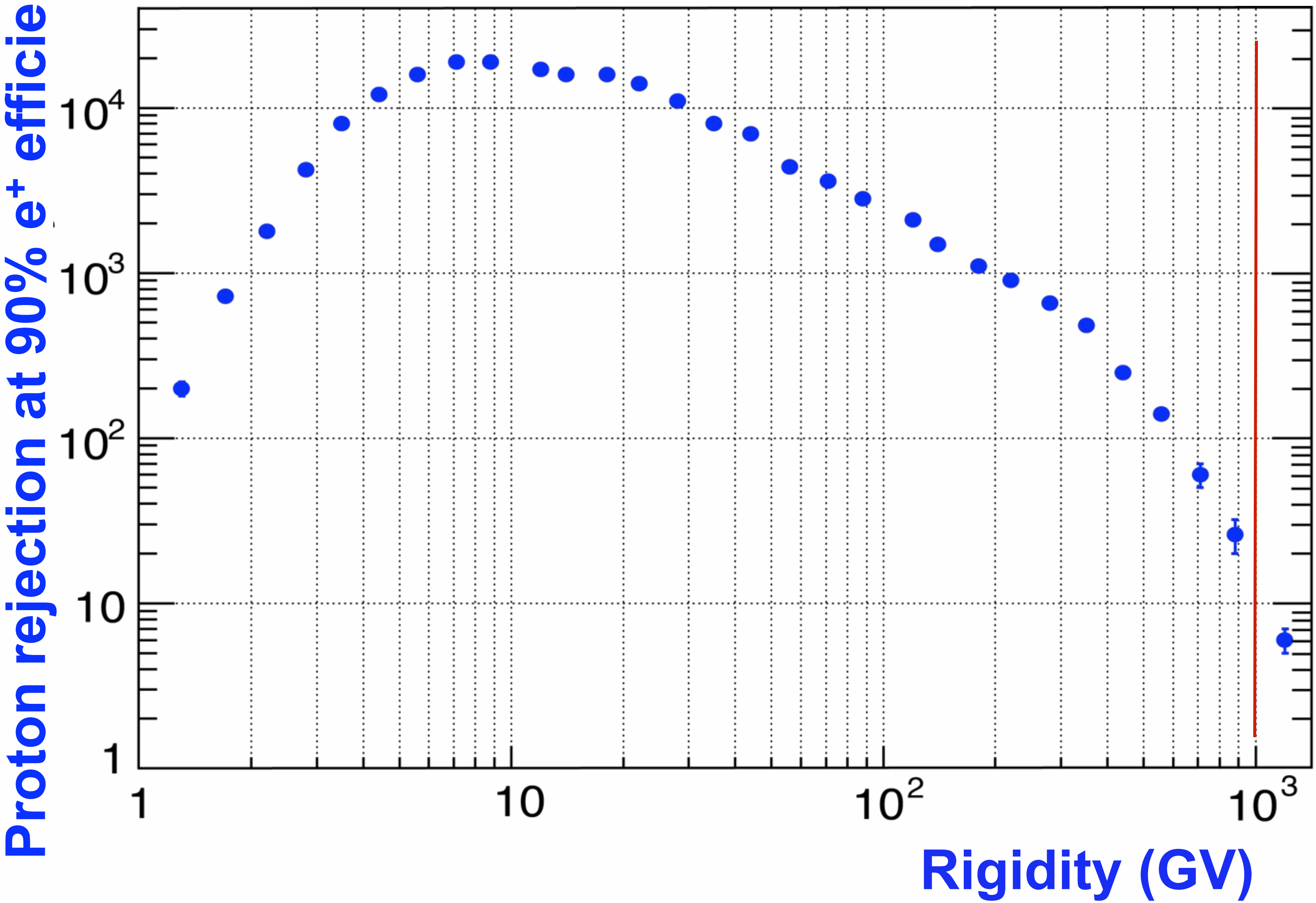
RICH
96 Temperature Sensors



ECAL
80 Temperature Sensors



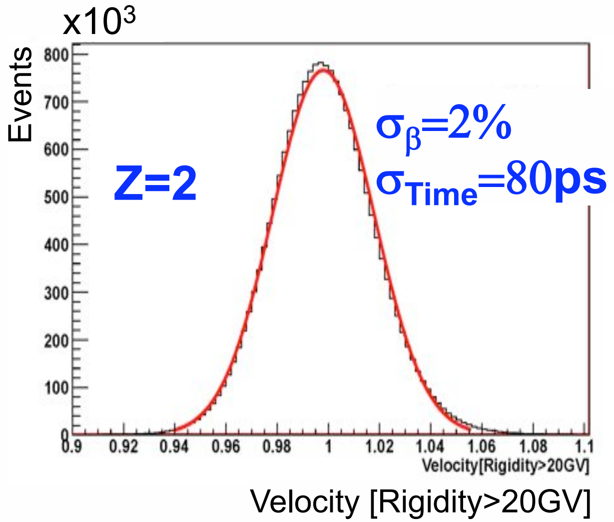
TRD performance on ISS

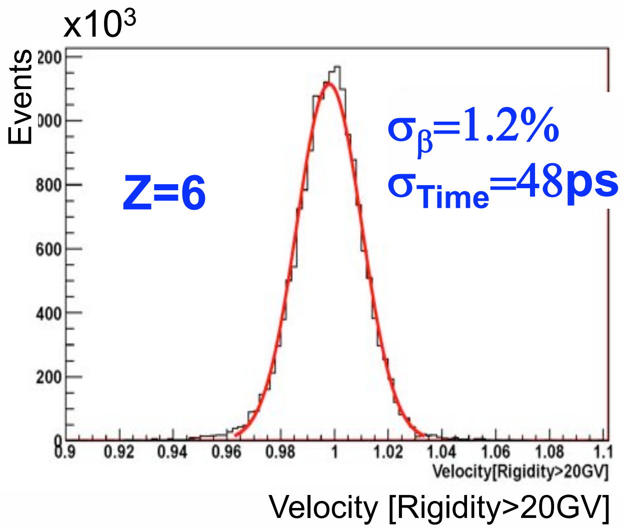


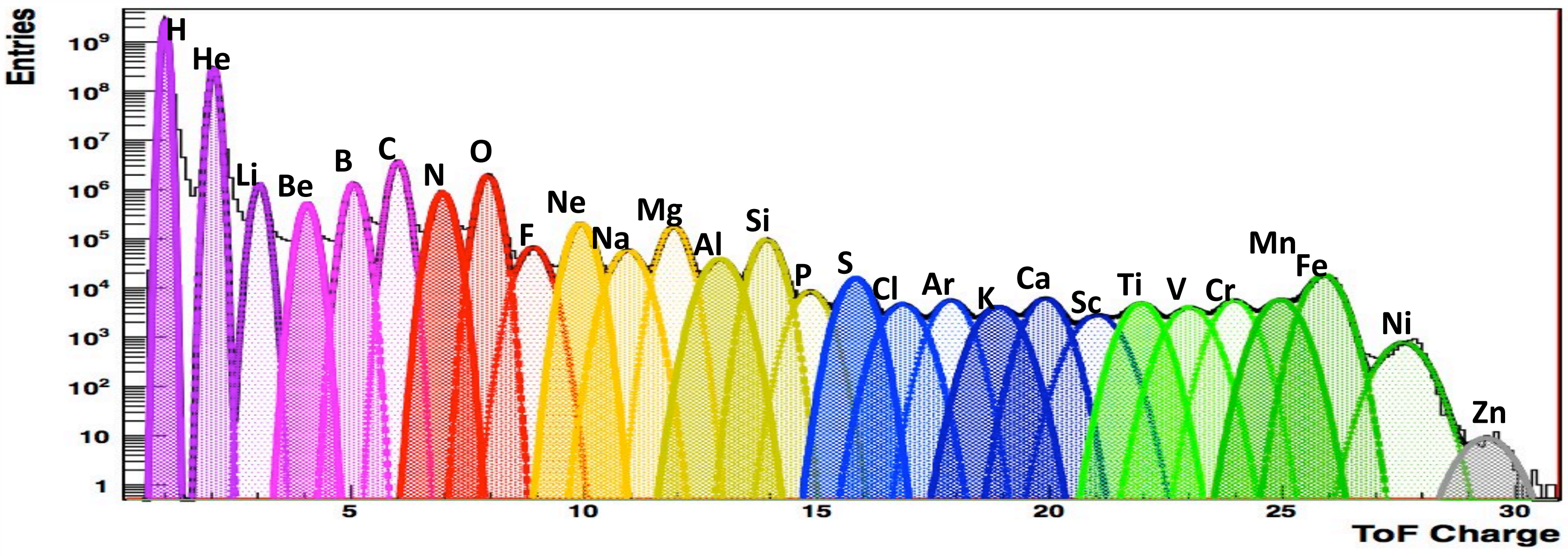
Time of Flight System

Measures Velocity and Charge of particles

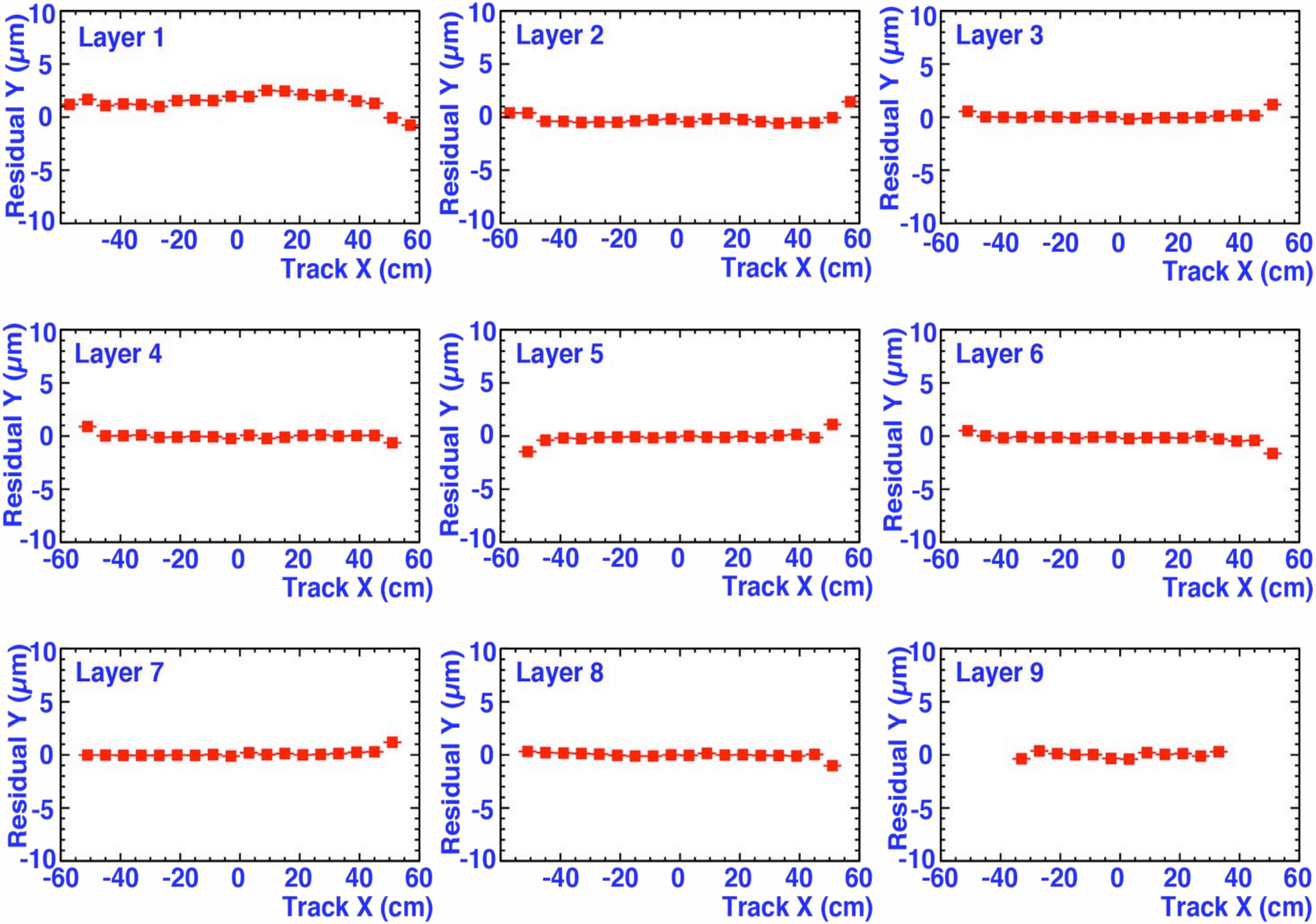
Data from ISS



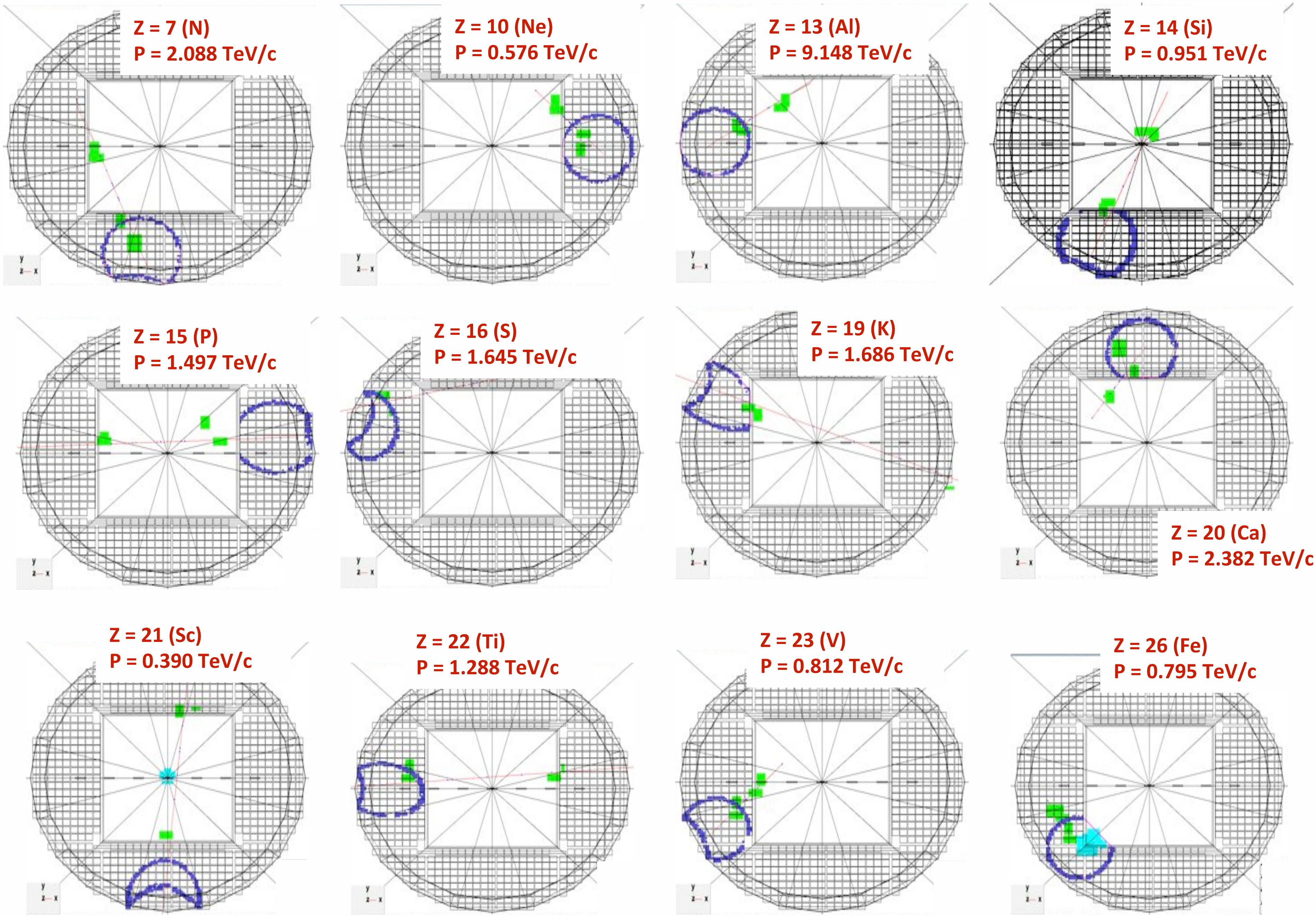




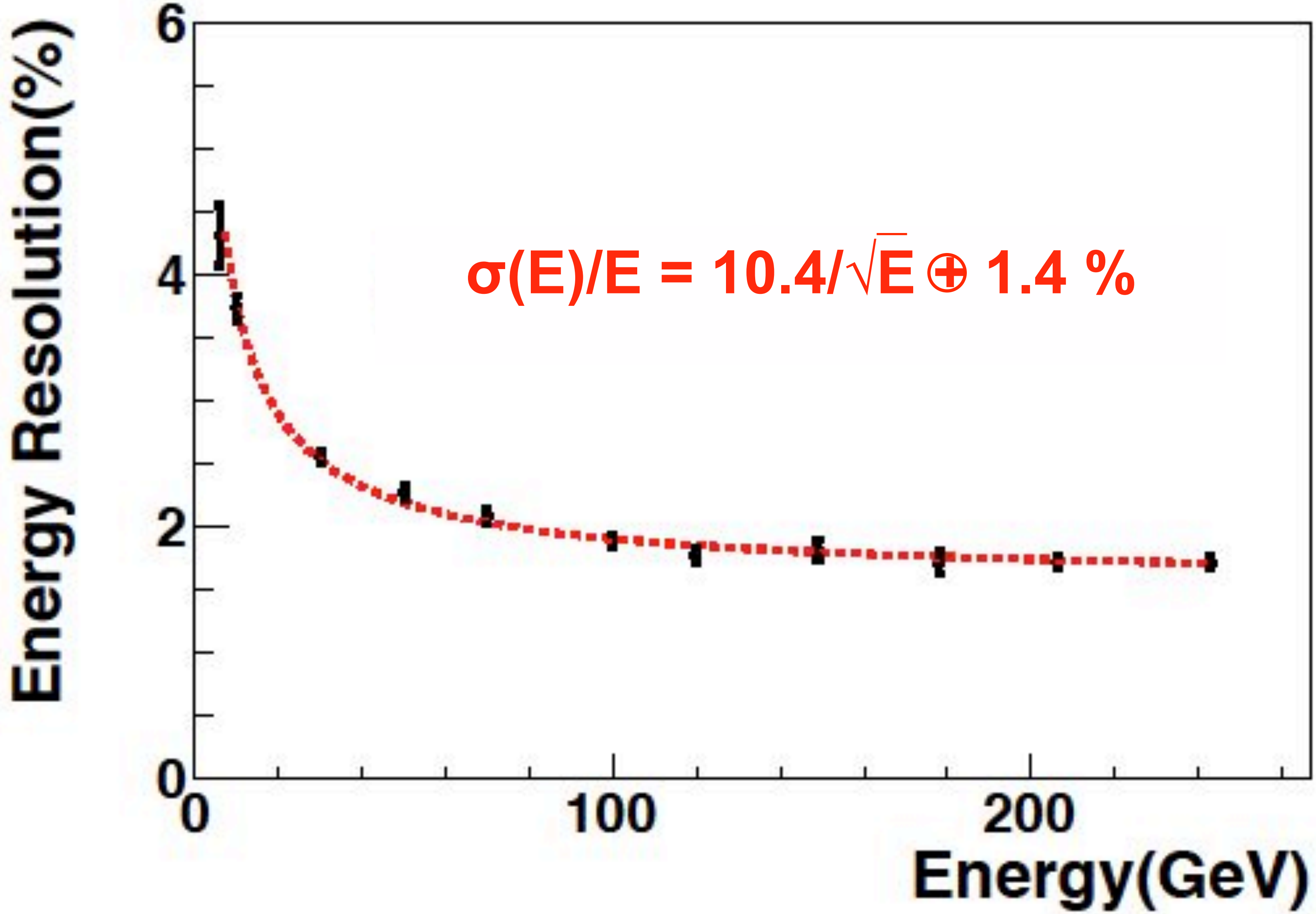
Alignment accuracy of the 9 Tracker layers over 18 months



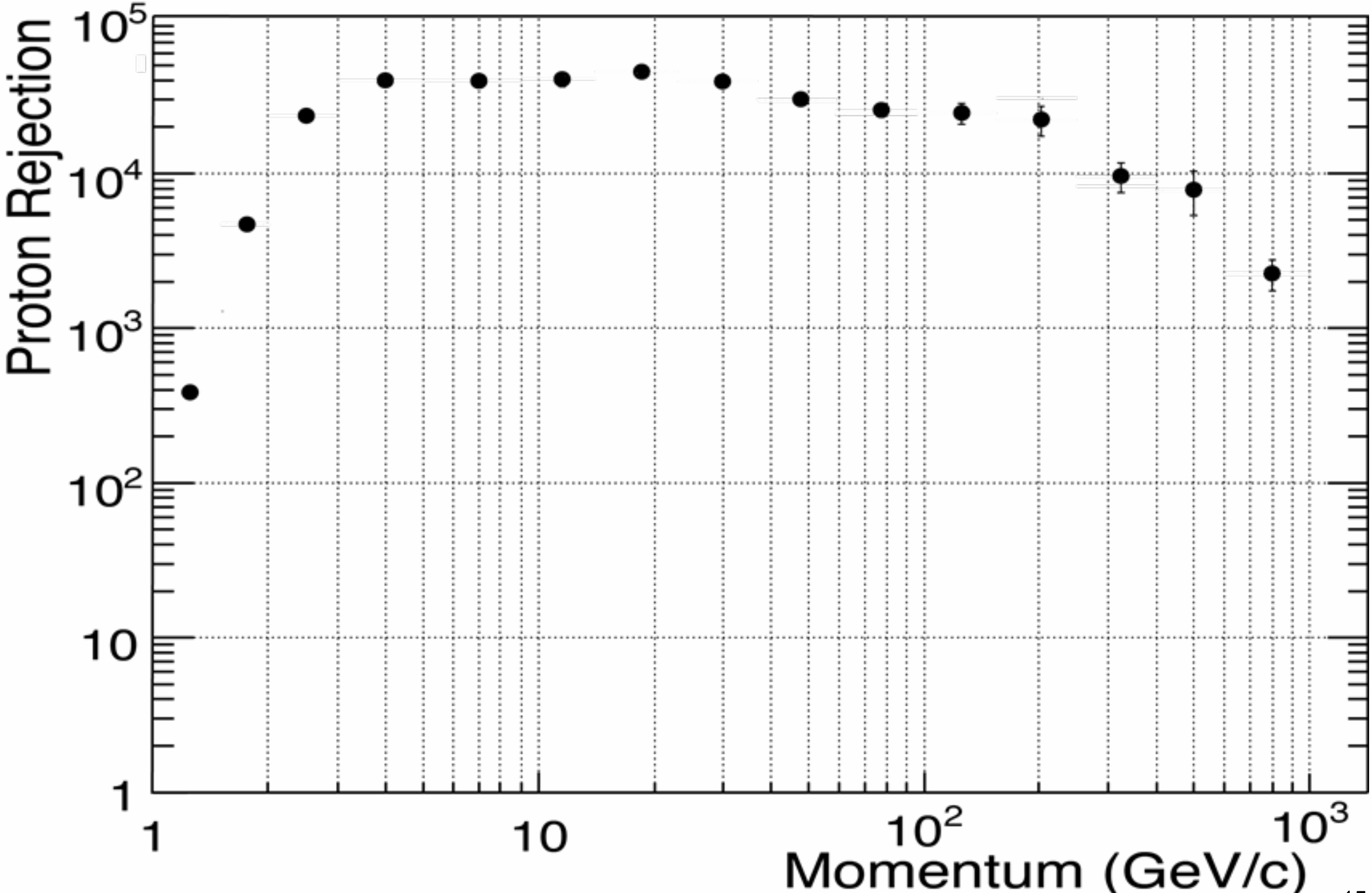
RICH - Detector performance on ISS



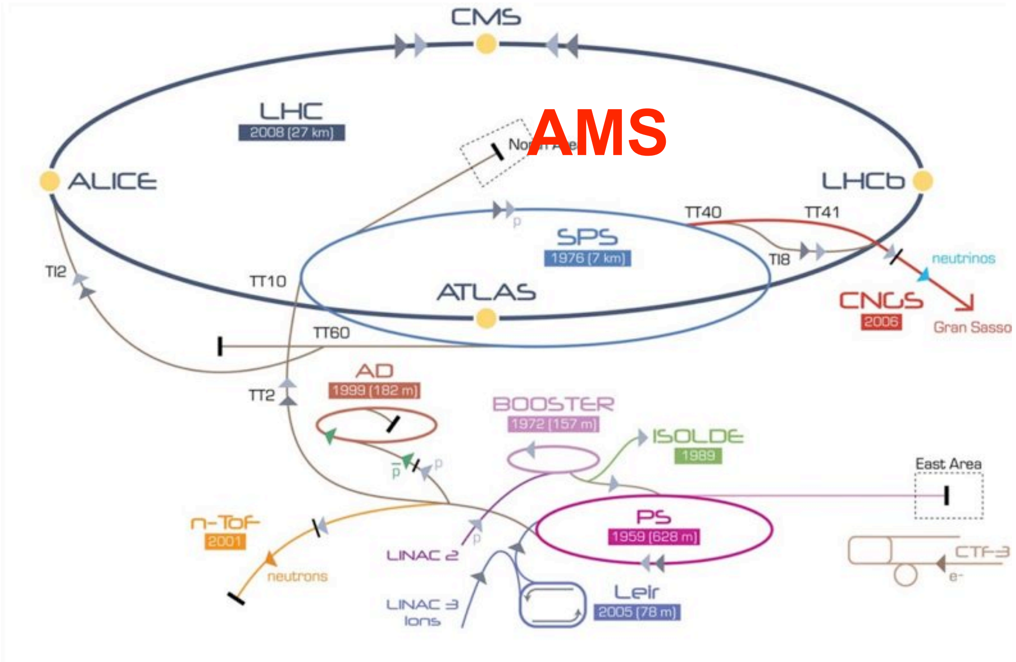
ECAL Performance

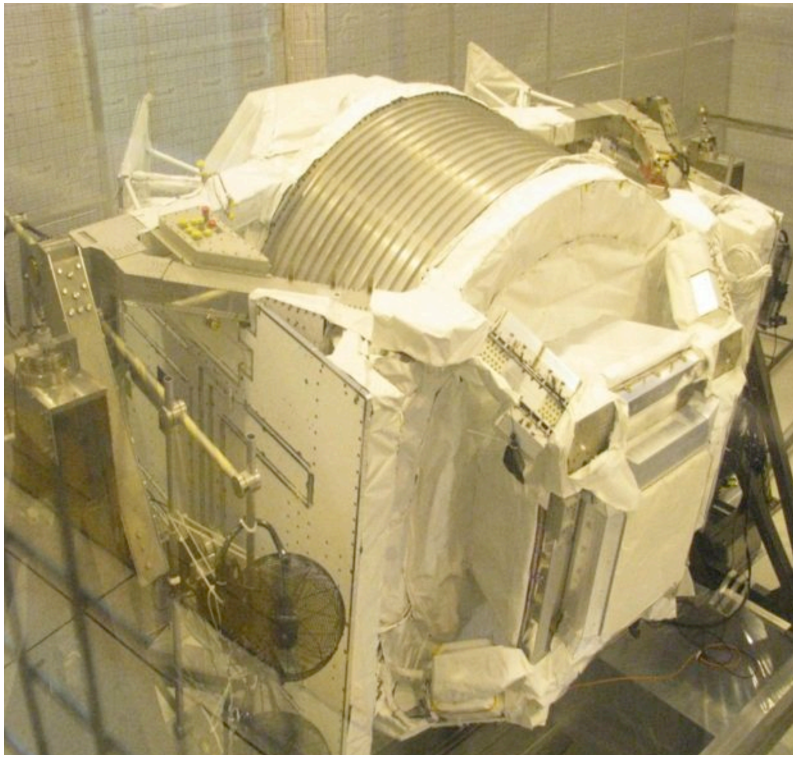


Data from ISS: Proton rejection using the ECAL



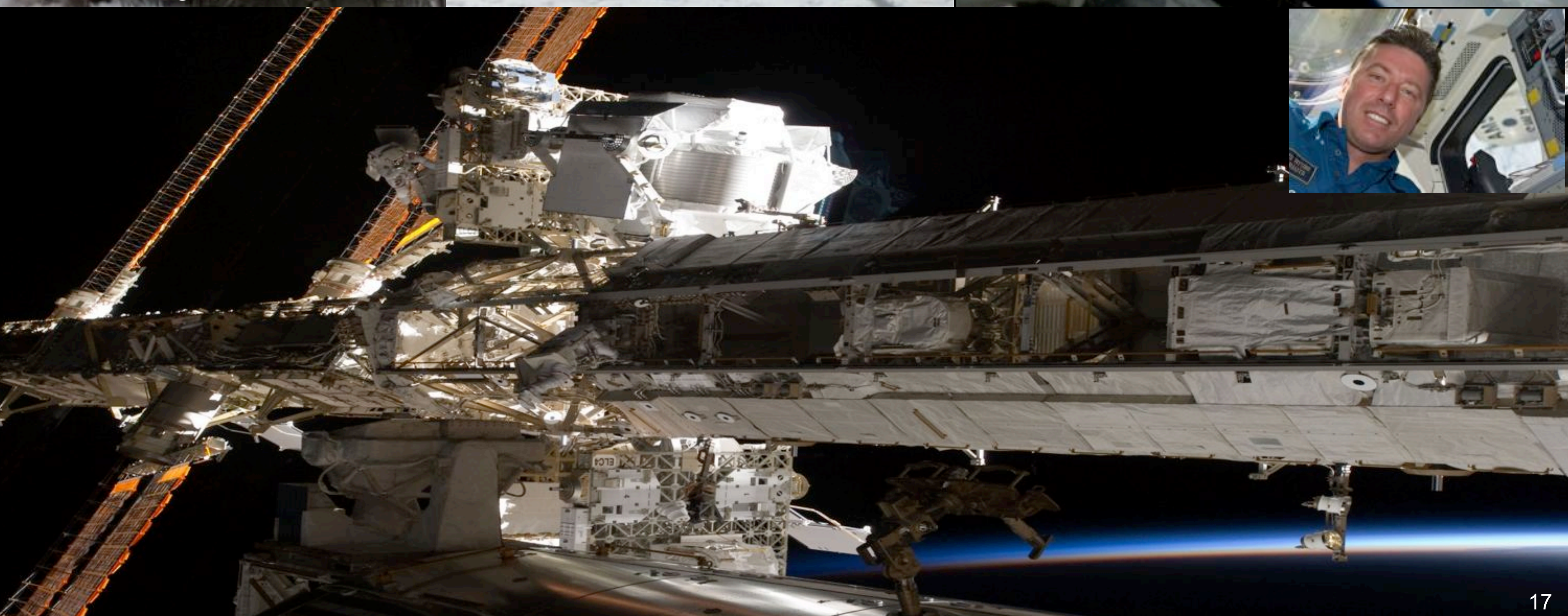
Intensive Beam Tests at CERN





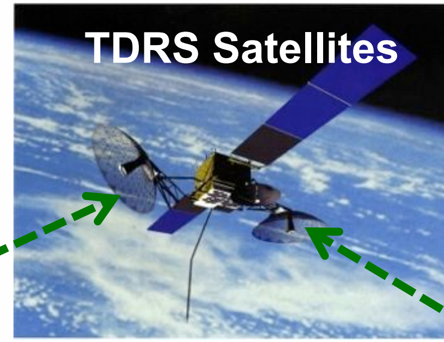
Particle	Momentum (GeV/c)	Positions	Purpose
Protons	400 + 180	1,650	Full Tracker alignment, TOF calibration, ECAL uniformity
Electrons	100, 120, 180, 290	7 each	TRD, ECAL performance study
Positrons	10, 20, 60, 80, 120, 180	7 each	TRD, ECAL performance study
Pions	20, 60, 80, 100, 120, 180	7 each	TRD performance to 1.2 TeV


May 16th, 2011

AMS today

AMS Operations



White Sands, NM

24 hours
x 365 days
x 10-20 years

AMS

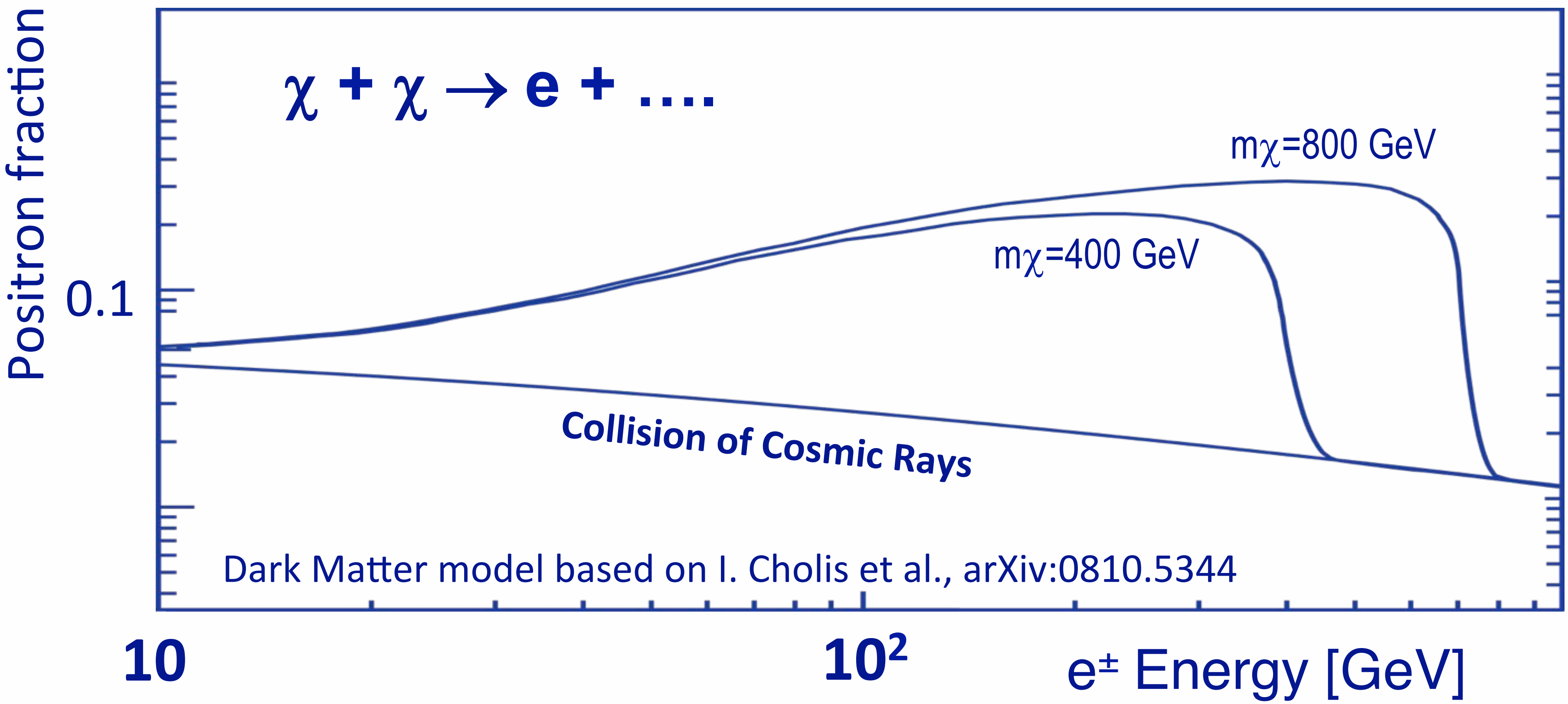
Physics results

Physics results (ICRC 2013)

1. $e^+/(e^+ + e^-)$ ratio and anisotropy
2. Proton spectrum
3. Helium spectrum
4. Electron Spectrum
5. Positron Spectrum
6. All electron spectrum
7. Boron-to-Carbon ratio

Physics of Positron Fraction: $e^+/(e^+ + e^-)$

M. Turner and F. Wilczek, Phys. Rev. D42 (1990) 1001;
J. Ellis, 26th ICRC Salt Lake City (1999) astro-ph/9911440;
H. Cheng, J. Feng and K. Matchev, Phys. Rev. Lett. 89 (2002) 211301;
S. Profumo and P. Ullio, J. Cosmology Astroparticle Phys. JCAP07 (2004) 006;
D. Hooper and J. Silk, Phys. Rev. D 71 (2005) 083503;
E. Ponton and L. Randall, JHEP 0904 (2009) 080;
G. Kane, R. Lu and S. Watson, Phys. Lett. B681 (2009) 151;
D. Hooper, P. Blasi and P. D. Serpico, JCAP 0901 025 (2009) 0810.1527; B2
Y–Z. Fan et al., Int. J. Mod. Phys. D19 (2010) 2011;
M. Pato, M. Lattanzi and G. Bertone, JCAP 1012 (2010) 020.

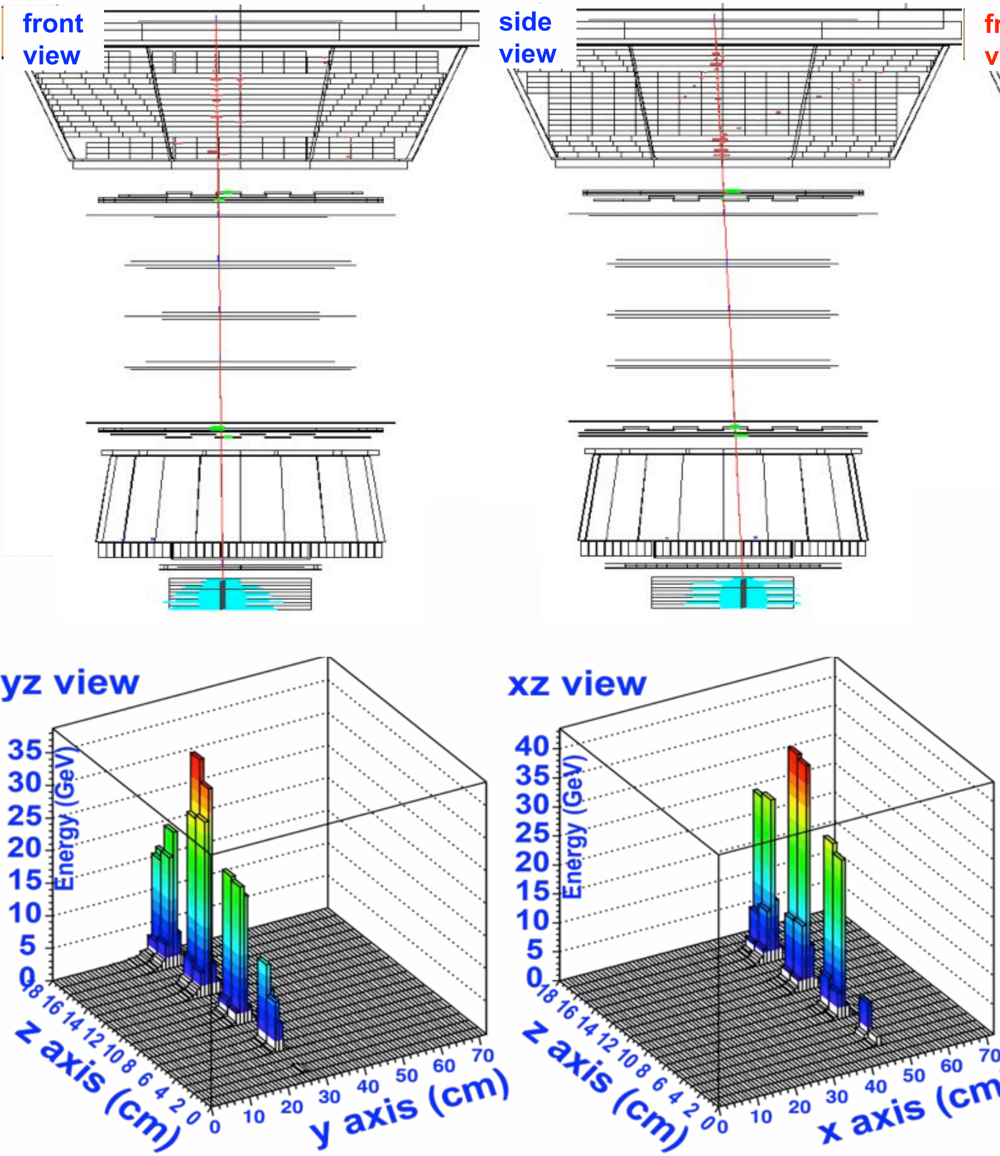


In the first 1.5 years in space, AMS has collected over 25 billion events.

6.8 million are electrons or positrons.

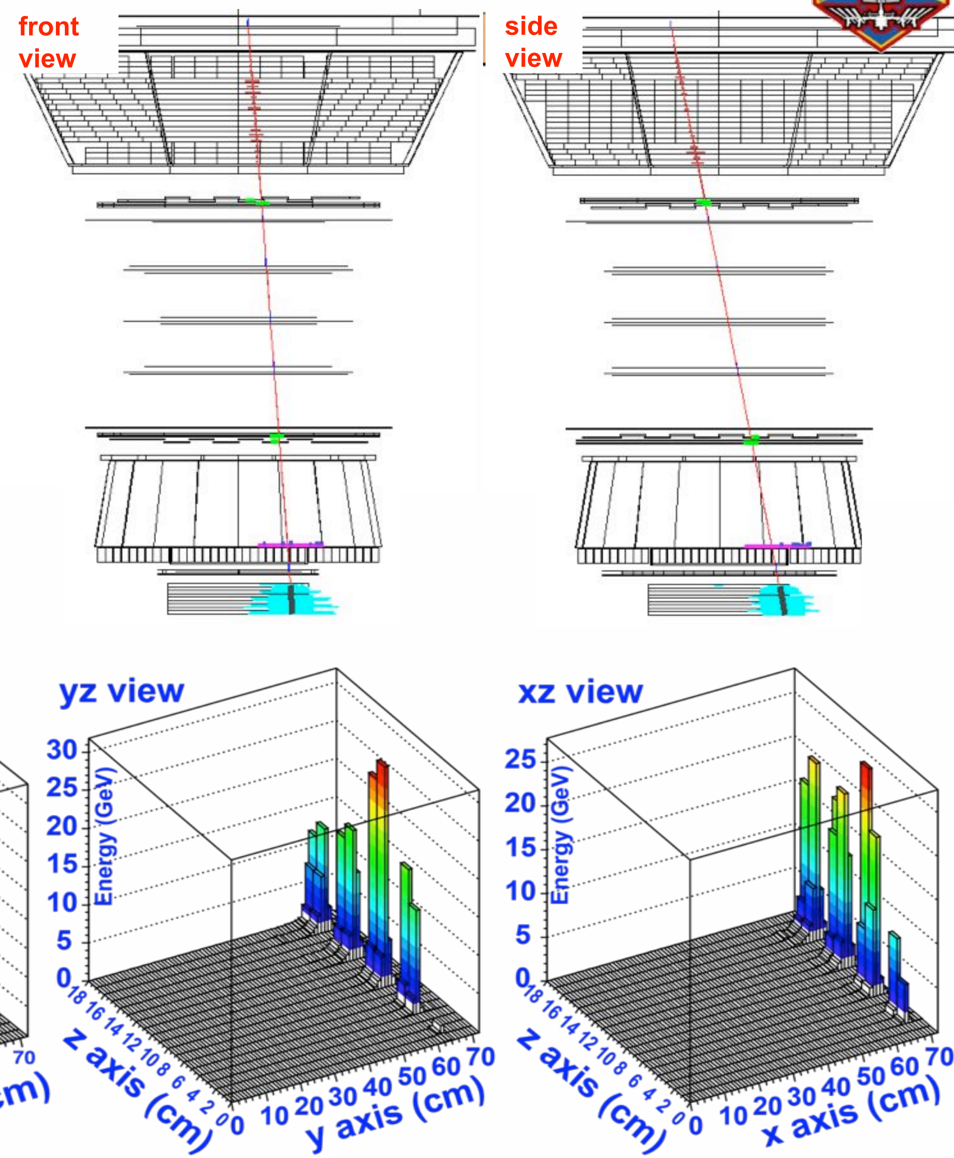
Electron E=982 GeV

Run/Event 1329775818/ 60709



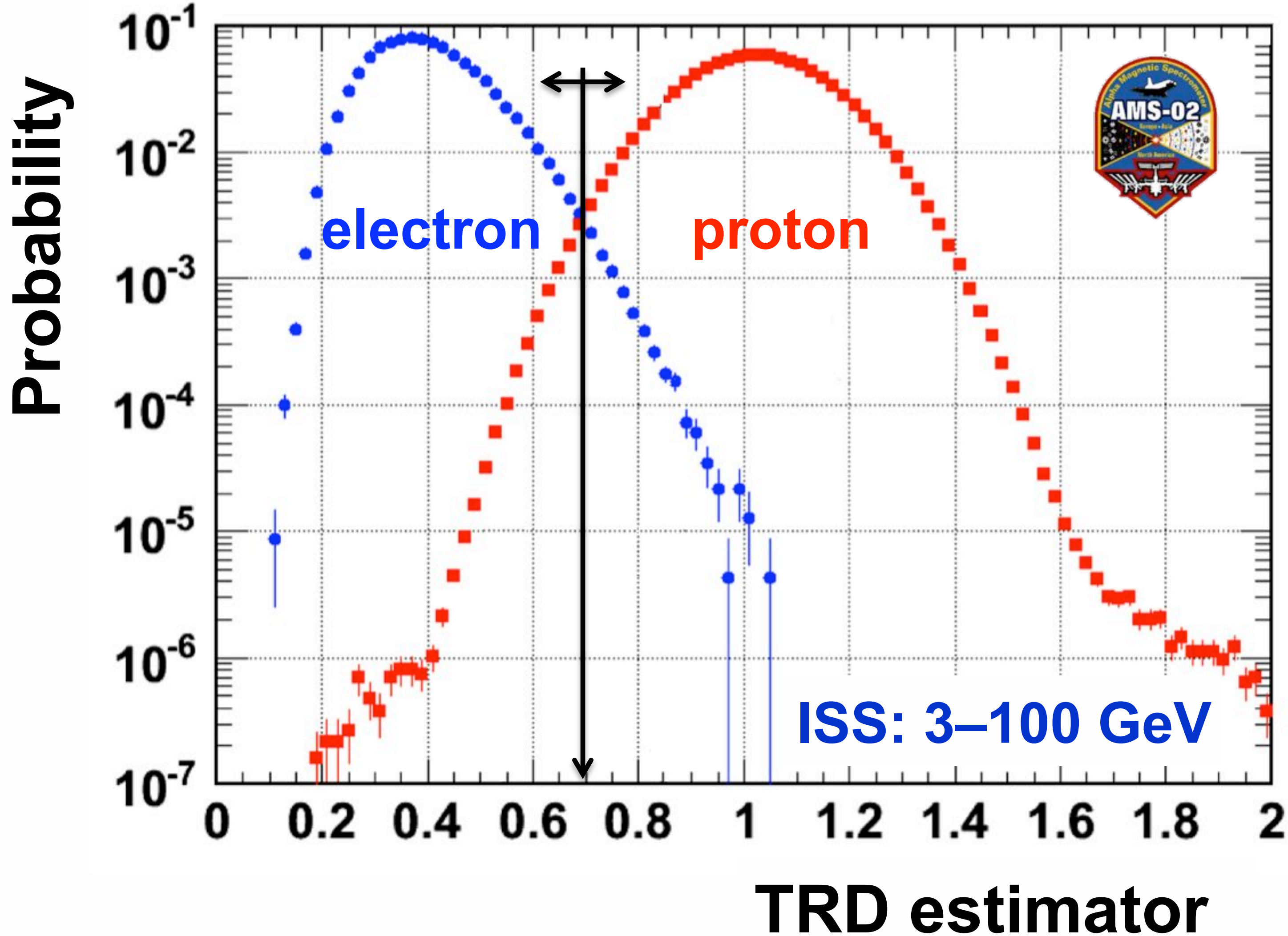
Positron E=636 GeV

Run/Event 133119-743/ 56950



TRD performance on ISS

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

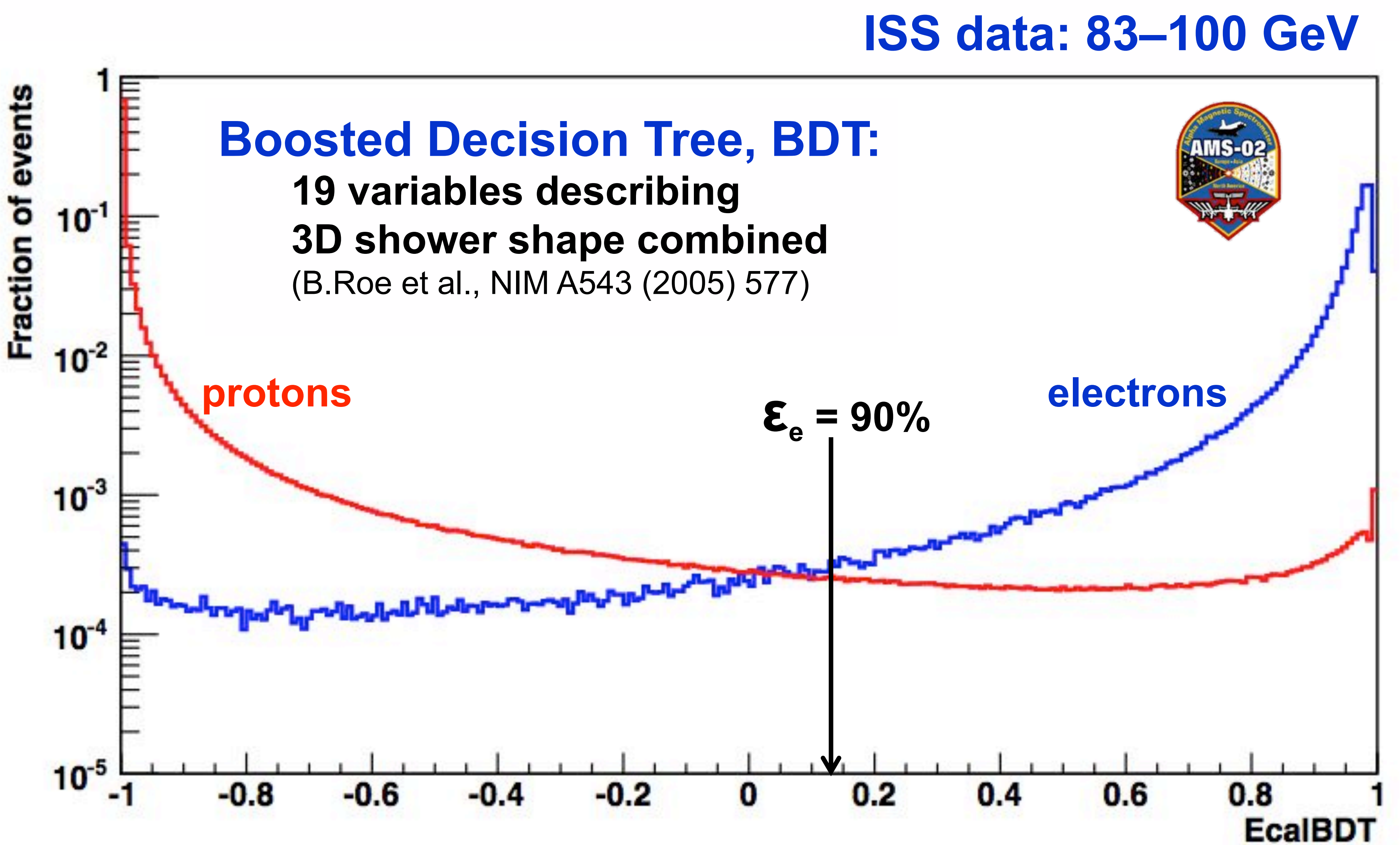


Normalized probabilities P_e and P_p

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

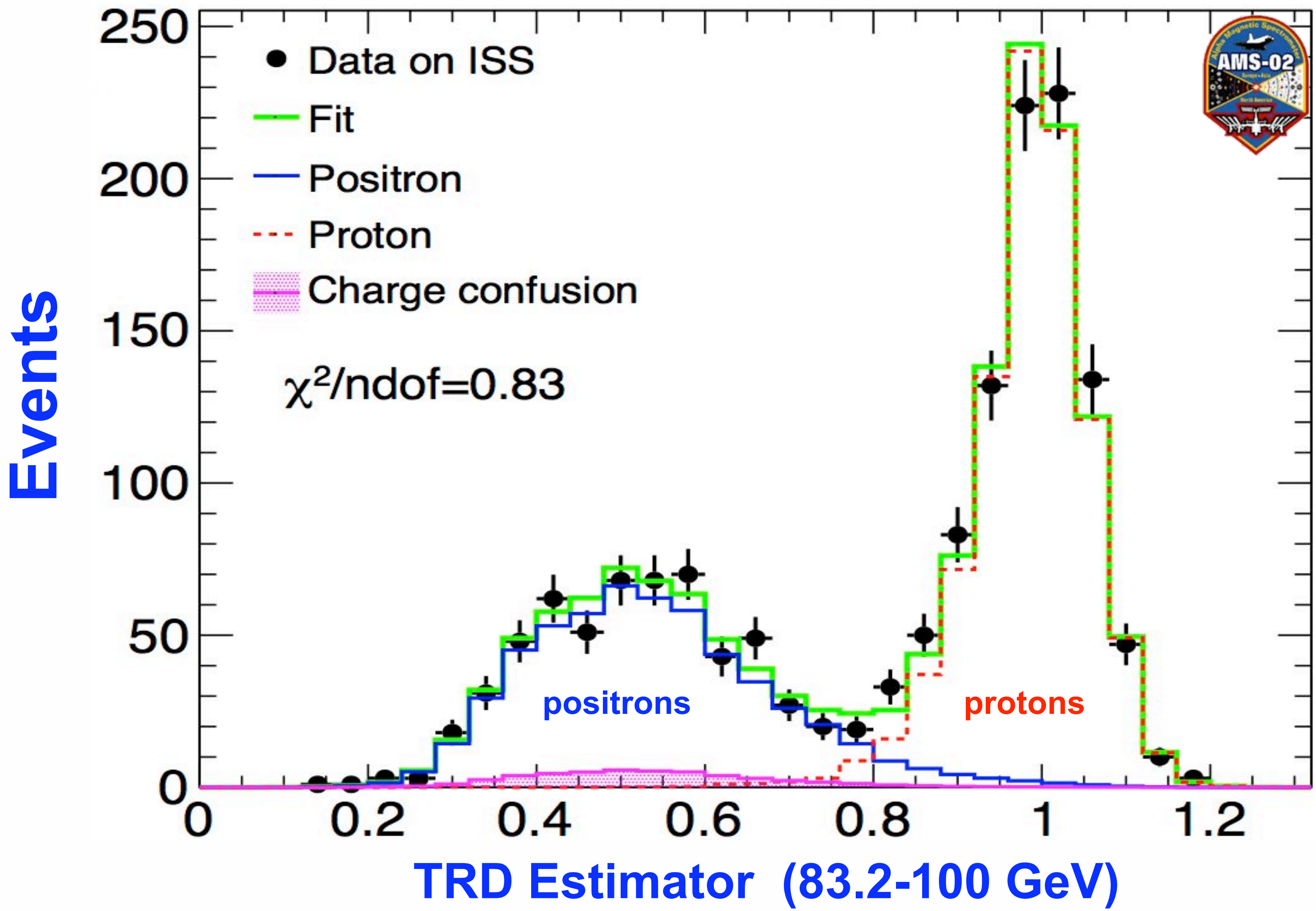
$$P_p = \sqrt[n]{\prod_i^n P_p^{(i)}(A)}$$

Separation of protons and electrons with ECAL



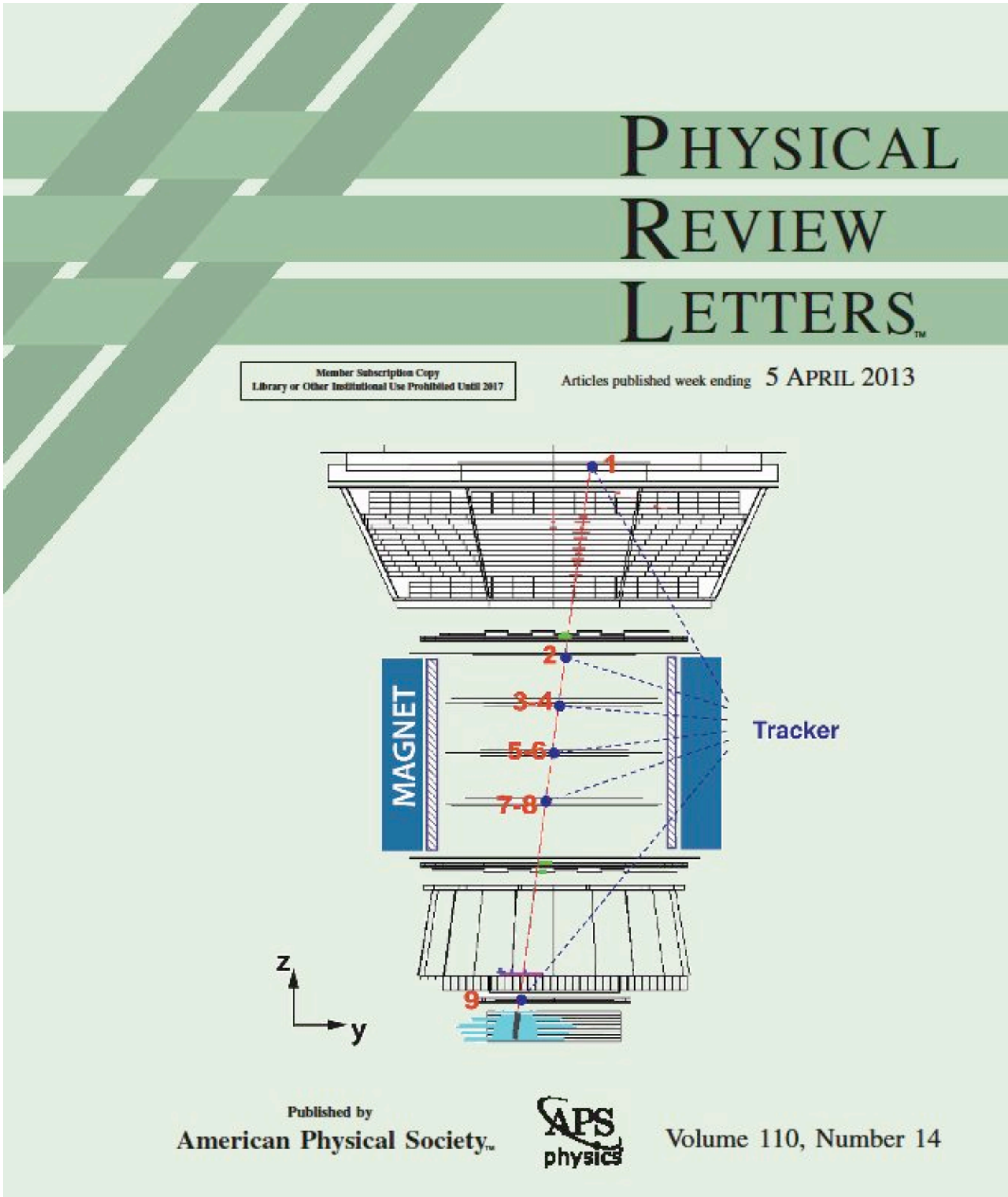
Results of the fit:

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

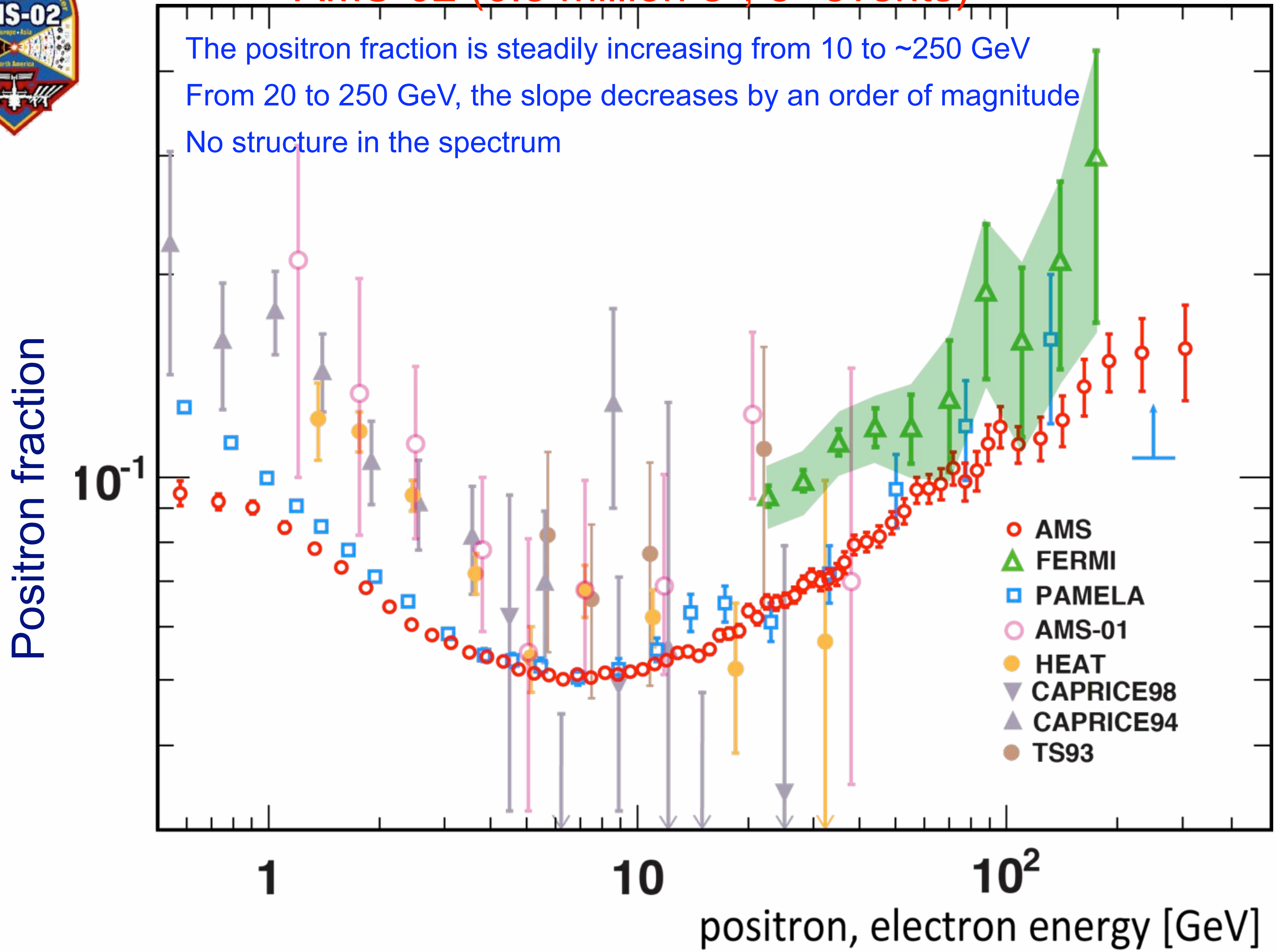


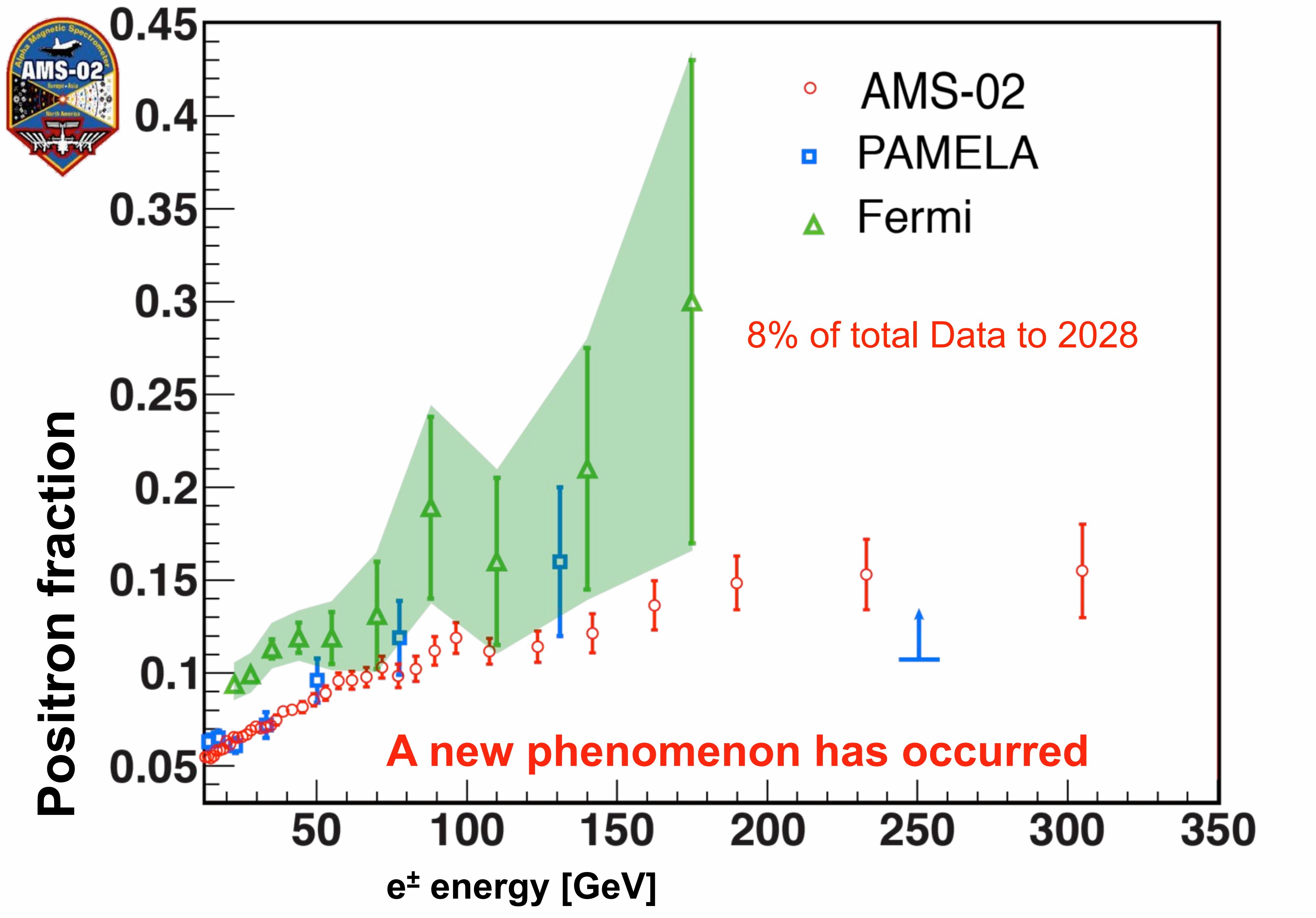
“First Result from the AMS on the ISS: Precision Measurement of the Positron Fraction in Primary Cosmic Rays of 0.5-350 GeV”

Selected for a Viewpoint in Physics and an Editors’ Suggestion [Aguilar,M. et al (AMS Collaboration) Phys. Rev. Lett. 110, 1411xx (2013)]

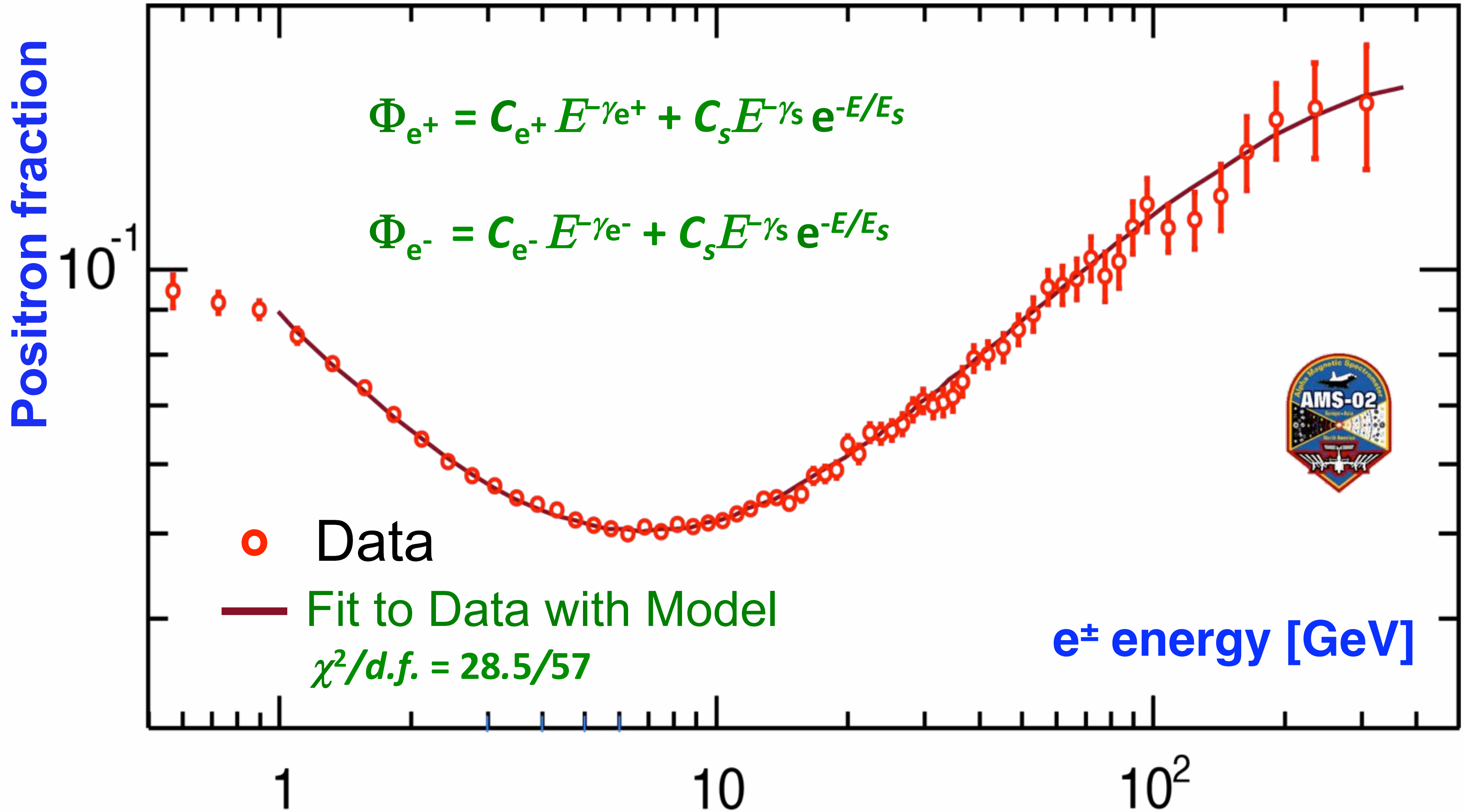


AMS-02 (6.8 million e^+, e^- events)




AMS-02
PAMELA
Fermi
8% of total Data to 2028
A new phenomenon has occurred
Positron fraction
e± energy [GeV]
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

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

$1/E_s = 0.0013 \pm 0.0007\ \mathrm{GeV}^{-1}$,

corresponding to a cutoff energy of 760^{+1000}_{-280} **GeV**.

Bergstrom,Bringmann,Cholis,Hooper,Weniger 2013

PRL **111,** 171101 (2013) PHYSICAL REVIEW LETTERS week ending 25 OCTOBER 2013

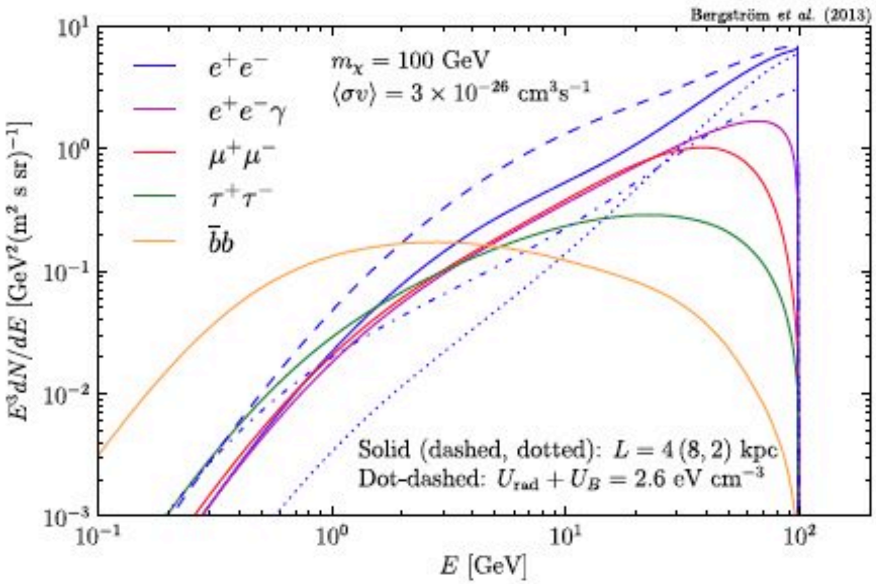


FIG. 1 (color online). The $e^\pm$ spectrum from annihilating DM, after propagation, for different annihilation final states, assuming $\langle\sigma v\rangle = 3 \times 10^{-26}$ cm^3 s^{-1}. Solid lines refer to reference diffusion zone ($L = 4$ kpc) and energy loss assumptions ($U_{\rm rad} + U_B = 1.7$ eV cm^{-3}). Dashed (dotted) lines show the effect of a different scale height $L = 8(2)$ kpc. The dotted-dashed line shows the impact of increasing the local radiation plus magnetic field density to $U_{\rm rad} + U_B = 2.6$ eV cm^{-3}.

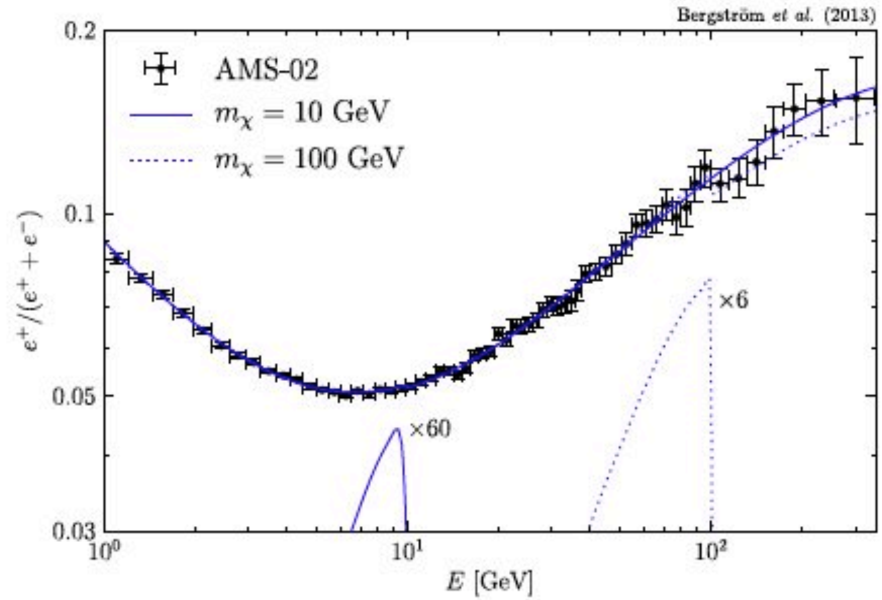
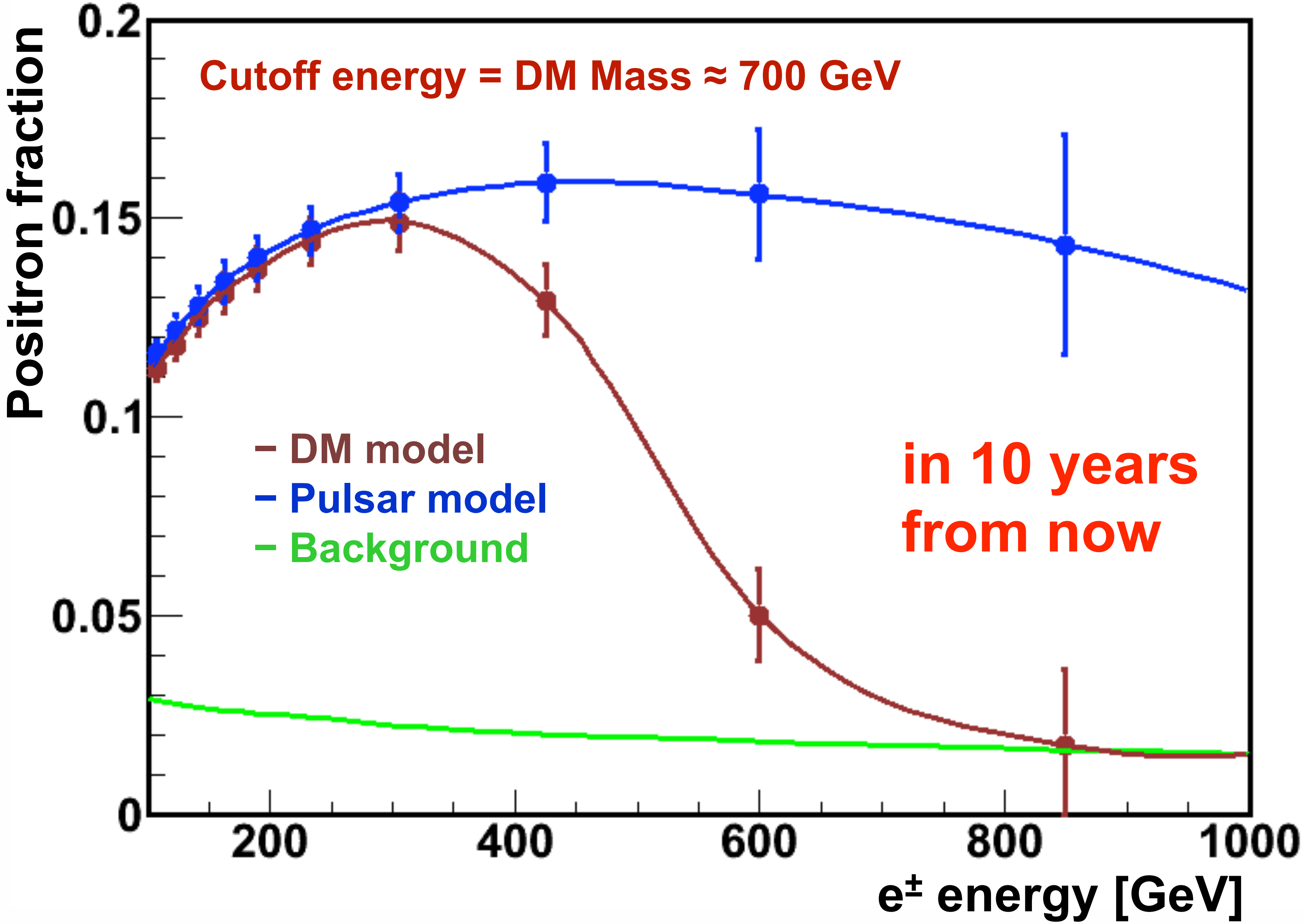


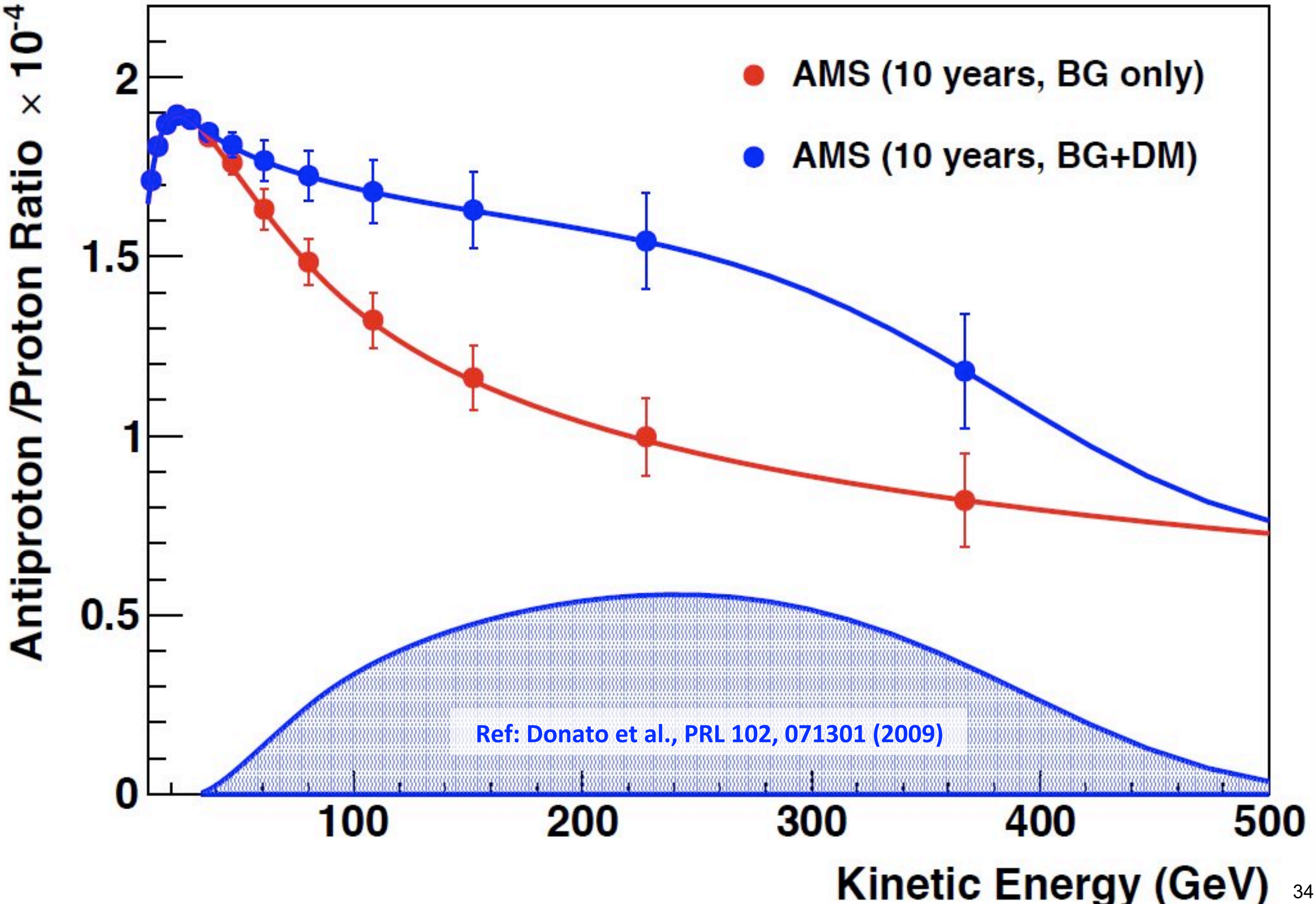
FIG. 2 (color online). The AMS positron fraction measurement [2] and background + signal fit for DM annihilating directly to e^+e^-, for $m_\chi = 10$ GeV and 100 GeV. The normalization of the DM signal in each case was chosen such that it is barely excluded at the 95% C.L. For better visibility, the contribution from DM (lower lines) has been rescaled as indicated.

Also : Ibarra,Lamperstorfer,Silk 2013



What will the Positron Fraction look like at high energy?

Comparison of $\overline{p}/p$ with Models in 10 more years



We now understand
the systematic errors to ~1%.

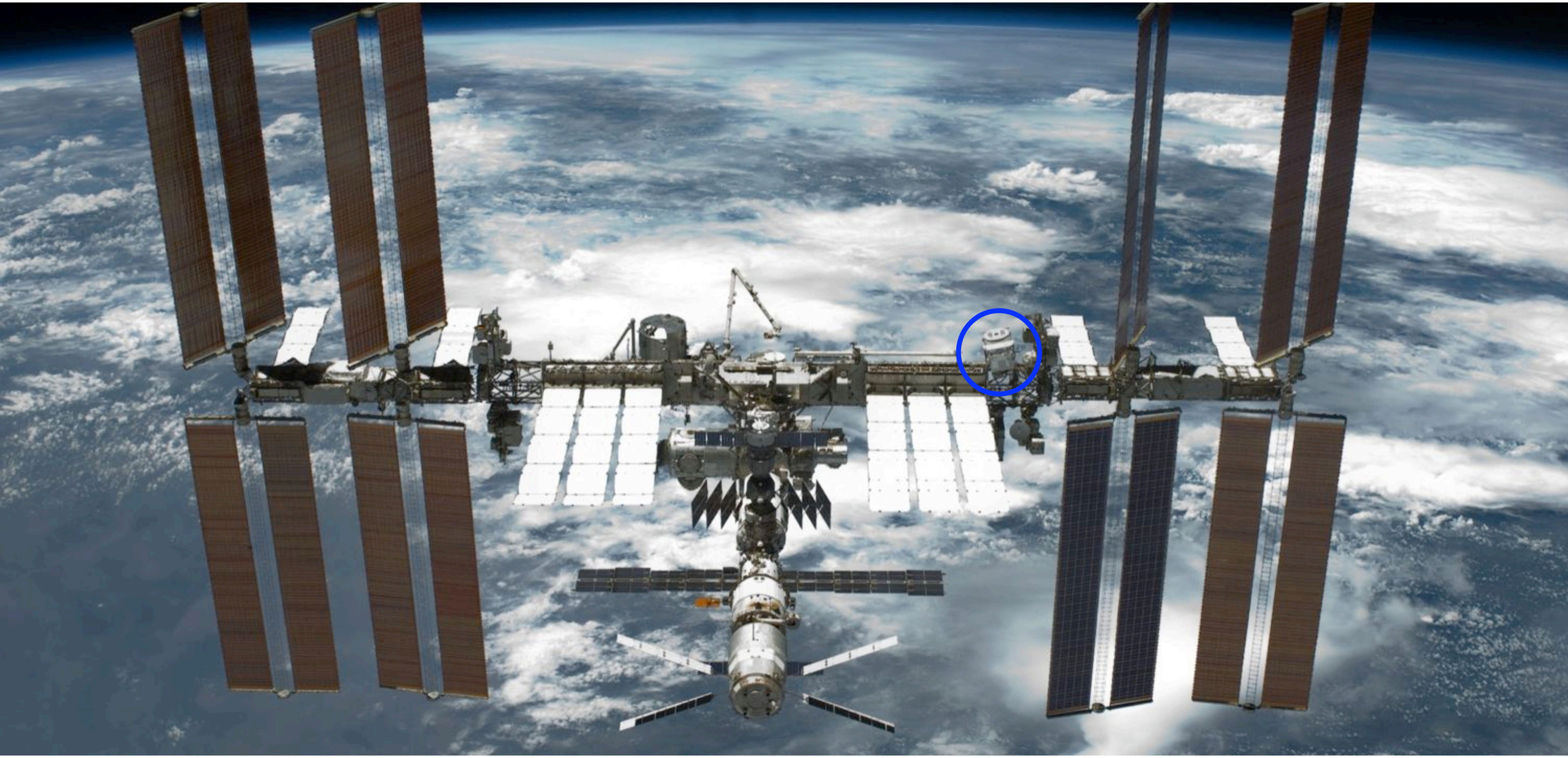
Studies with 1% statistical error
will take time to collect the data.

Physics analysis nearing completion

1. Antiprotons (0.5-300 GeV)
2. Anti-He (@ few 10^8 He events)
3. Ion fluxes
4. Solar physics
5. ….

The Cosmos is the Ultimate Laboratory

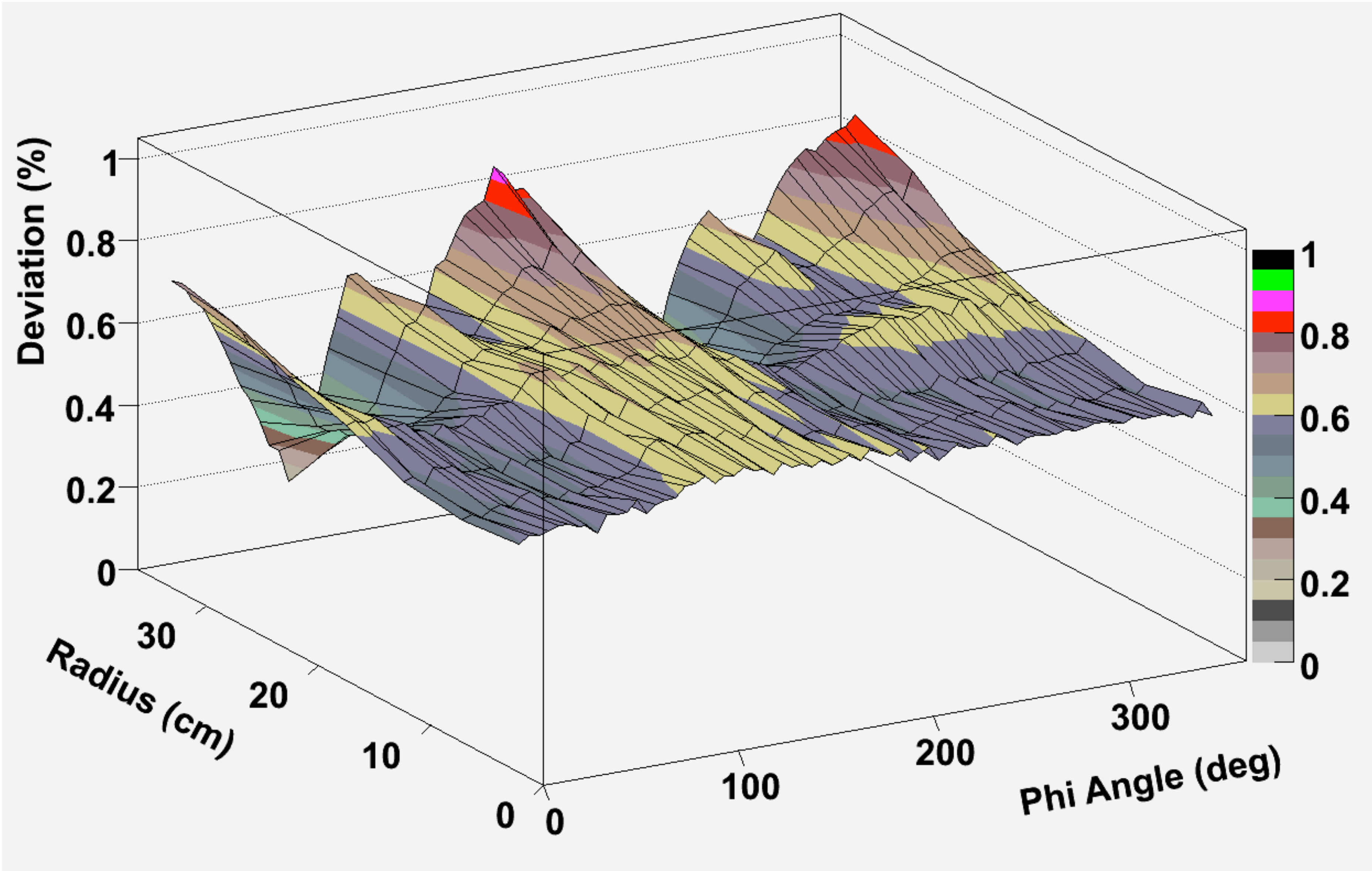
Cosmic rays can be observed at energies higher than any accelerator



With AMS-02 on the ISS we have entered the era of precision Cosmic Ray physics to search for phenomena which exist in nature but we have not yet imagined nor had the tools to discover

SPARE SLIDES

Deviation from 1997 measurements in R-Phi coordinates, Z=0



AMS in SPS Test Beam, 2010

Particle	Momentum (GeV/c)	Positions	Purpose
Protons	400 + 180	1,650	Full Tracker alignment, TOF calibration, ECAL uniformity
Electrons	100, 120, 180, 290	7 each	TRD, ECAL performance study
Positrons	10, 20, 60, 80, 120, 180	7 each	TRD, ECAL performance study
Pions	20, 60, 80, 100, 120, 180	7 each	TRD performance to 1.2 TeV


May 16, 2011


Data analysis in AMS (2 years of data)

AMS is a very precise particle physics detector.

Precision physics results require attention to detail and a large analysis effort.

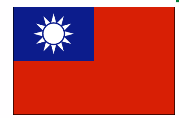
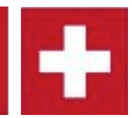
The data are analysed by two independent AMS international teams.

Example: the positron fraction paper

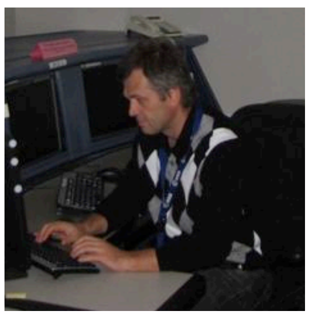
Group A

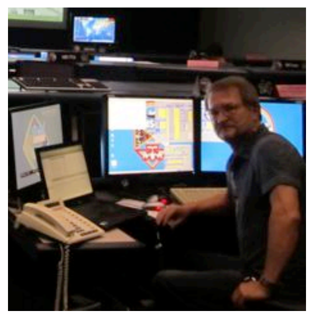
   

Group α


B. Bertucci


V. Choutko


A. Kounine


J. Berdugo


S. Schael


M. Incagli

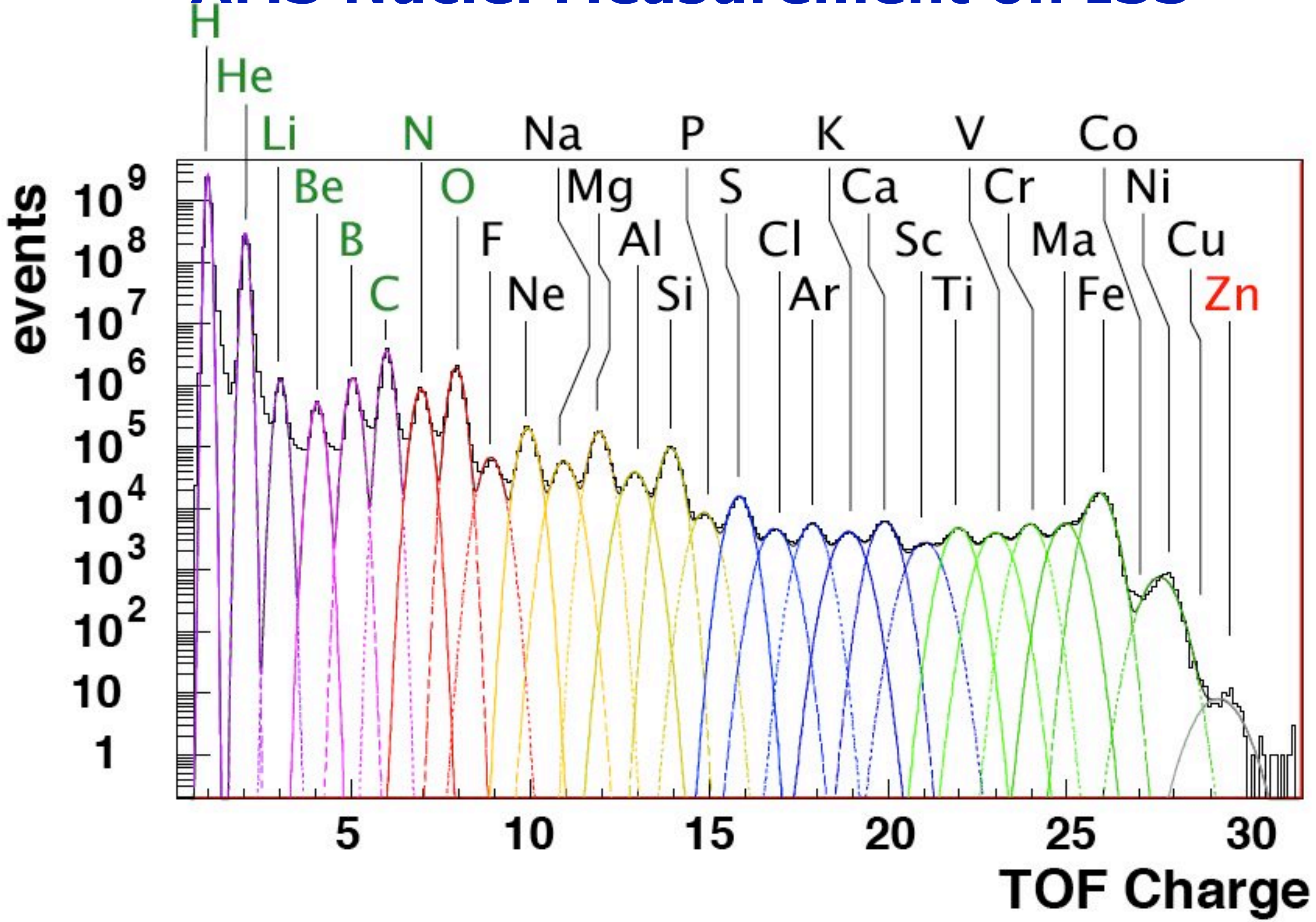

S. Rosier-Lees


S. Haino, A. Oliva


J. Casaus, P. Zuccon


A. Contin

AMS Nuclei Measurement on ISS



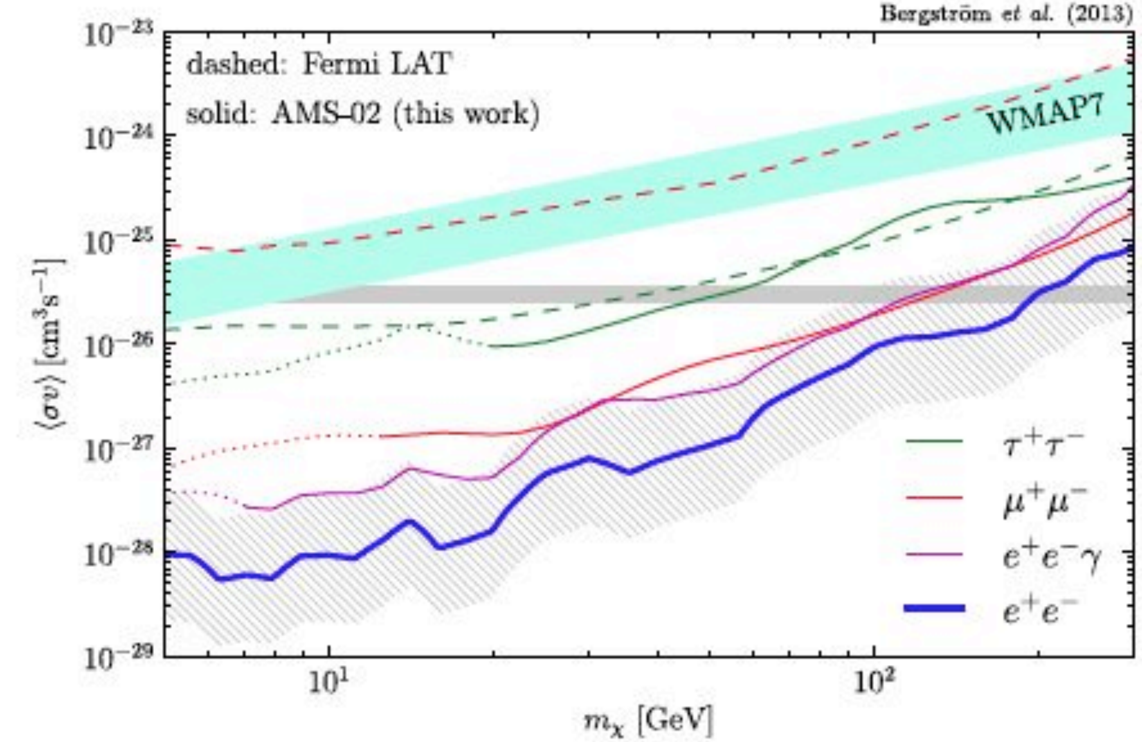
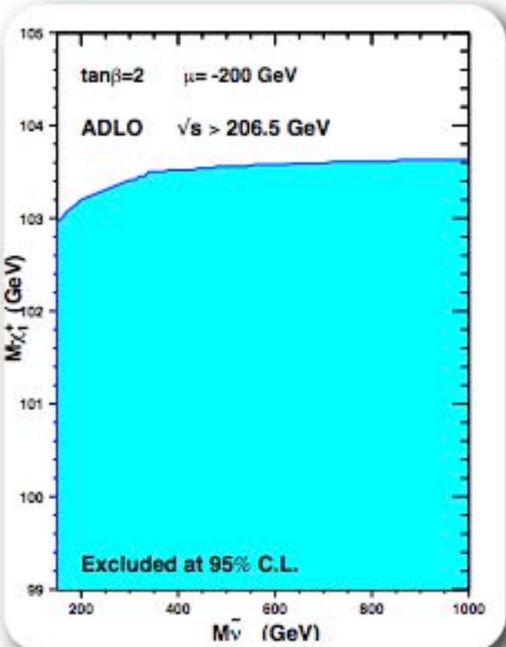


FIG. 3 (color online). Upper limits (95% C.L.) on the DM annihilation cross section, as derived from the AMS positron fraction, for various final states (this work), WMAP7 (for $\ell^+\ell^-$) [44], and Fermi LAT dwarf spheroidals (for $\mu^+\mu^-$ and $\tau^+\tau^-$) [43]. The dotted portions of the curves are potentially affected by solar modulation. We also indicate $\langle \sigma v \rangle_{\rm therm} \equiv 3 \times 10^{-26}$ cm^3 s^{-1}. The AMS limits are shown for reasonable reference values of the local DM density and energy loss rate (see text), and can vary by a factor of a few, as indicated by the hatched band (for clarity, this band is only shown around the e^+e^- constraint).

Current limits: neutralino/chargino

7

canonical case



$m_{\chi_1^\pm}$ > 103.5 GeV
for m_{snue} > 300 GeV

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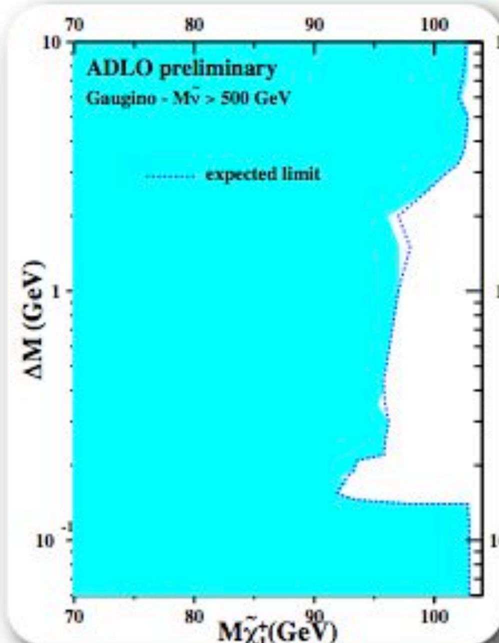
degenerate case



$m_{\chi_1^\pm}$ > 91.9 /92.4 GeV

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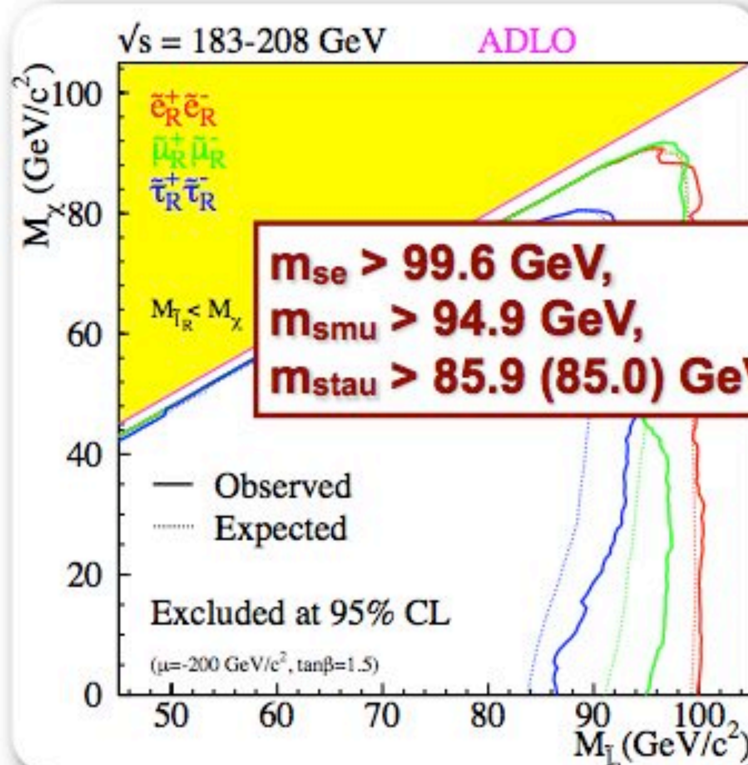
$m_{\chi_1^0}$ > 47/50 GeV
(CMSSM, mSUGRA)
No mass limit in general



m_{se} > 99.6 GeV,
m_{smu} > 94.9 GeV,
m_{stau} > 85.9 (85.0) GeV

LEPSUSYWG/04-01.1