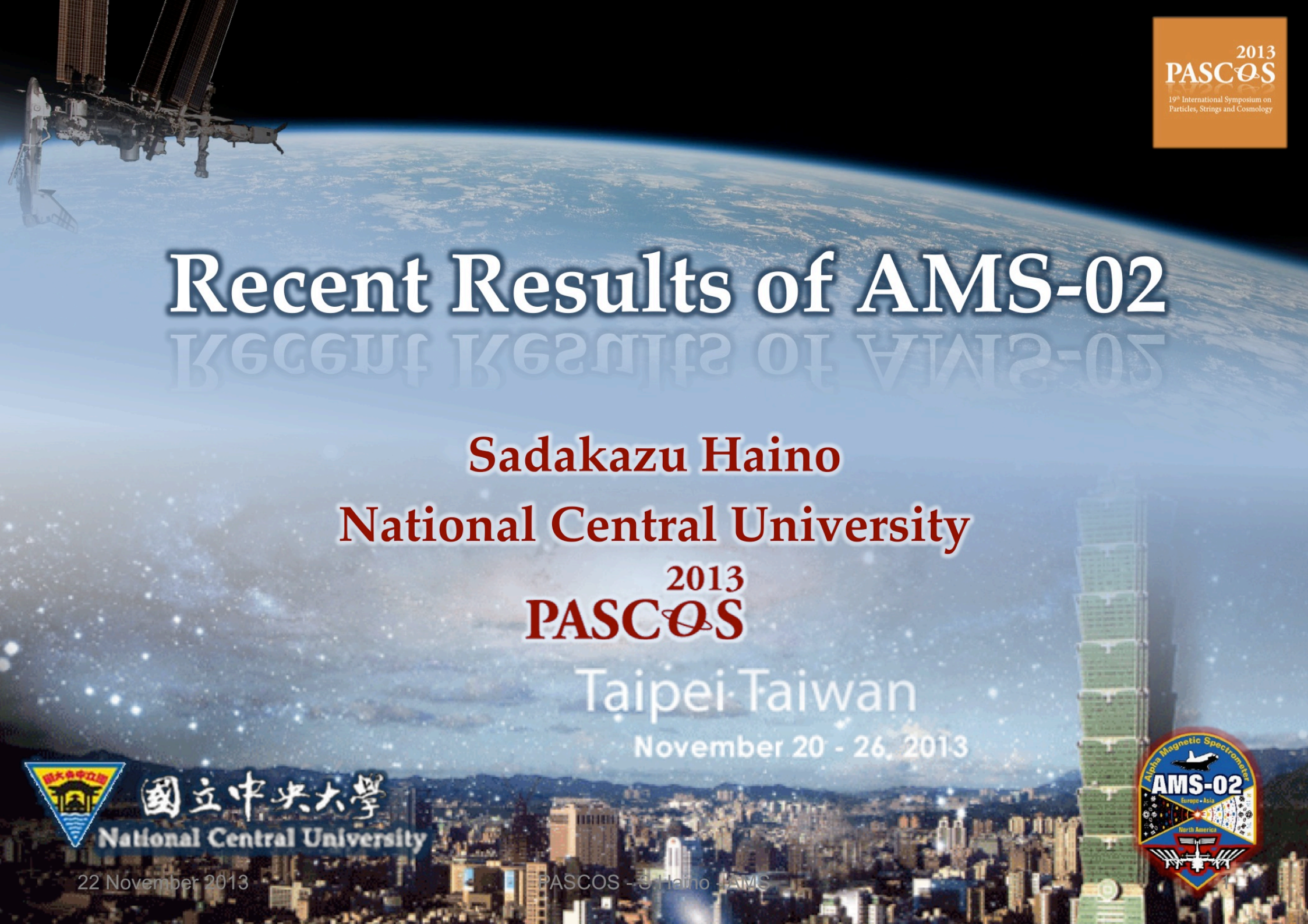



# Recent Results of AMS-02

Sadakazu Haino
National Central University

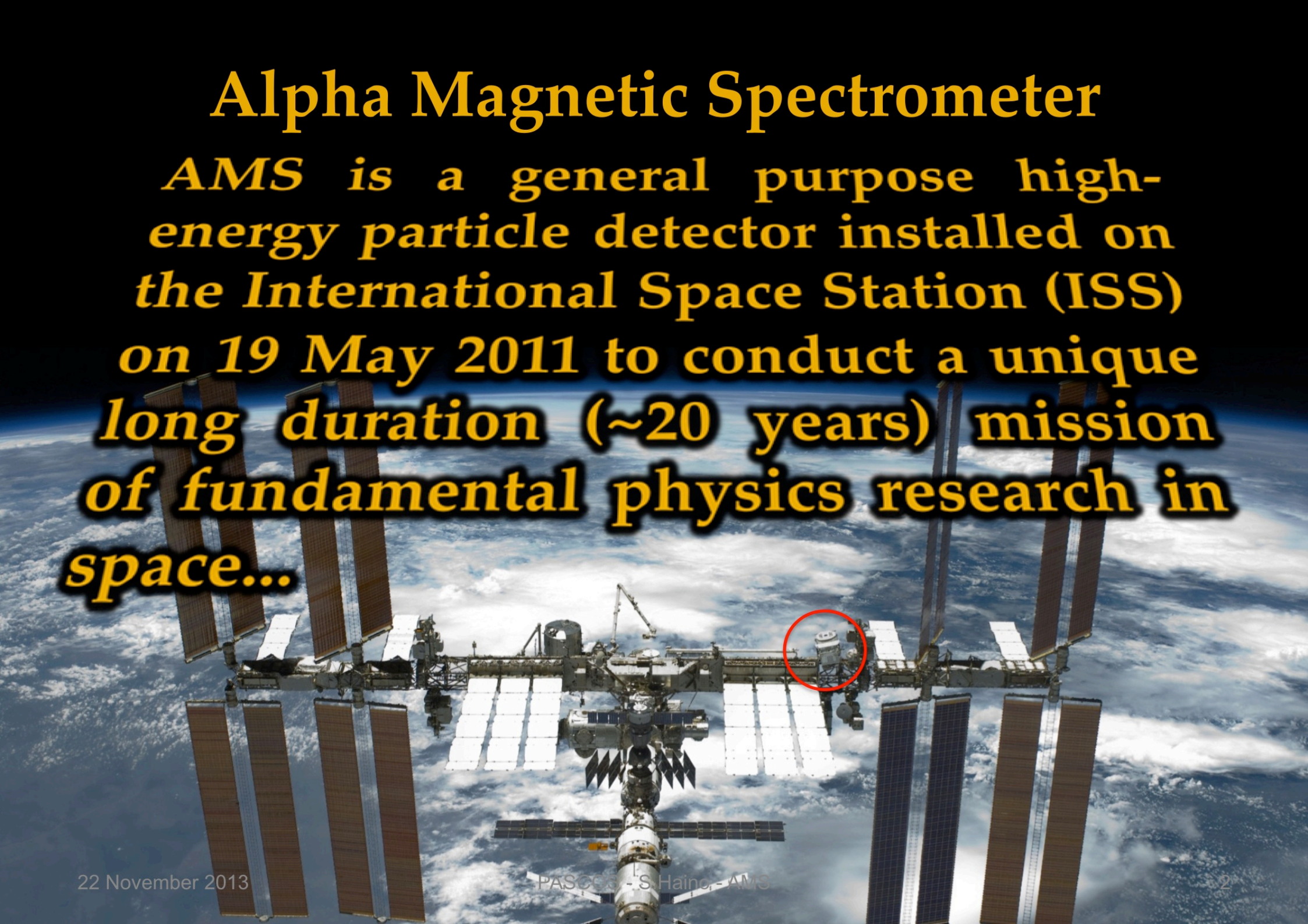
2013
PASCOS

Taipei Taiwan

November 20 - 26, 2013

國立中央大學
National Central University

# Alpha Magnetic Spectrometer



# AMS collaboration

## 16 Countries, 60 Institutes and 600 Physicists from Asia, Europa, and U.S.

# Taiwan in AMS

AMS is the only project supported by Academia Sinica, National Science Council as well as the defence and the space agencies, all with the highest priority

NCU

National ChiaoTung University

AIDC

National Cheng Kung University

Academia Sinica

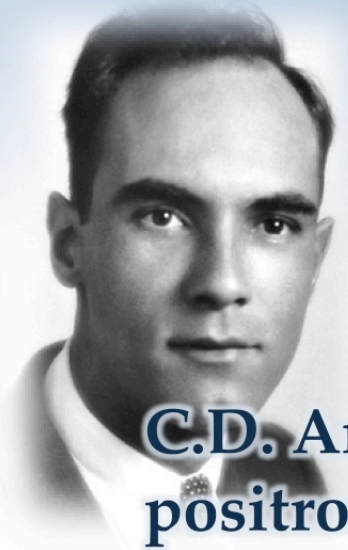
Chung-Shan Institute of Science and Technology

National Space Organization

# 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

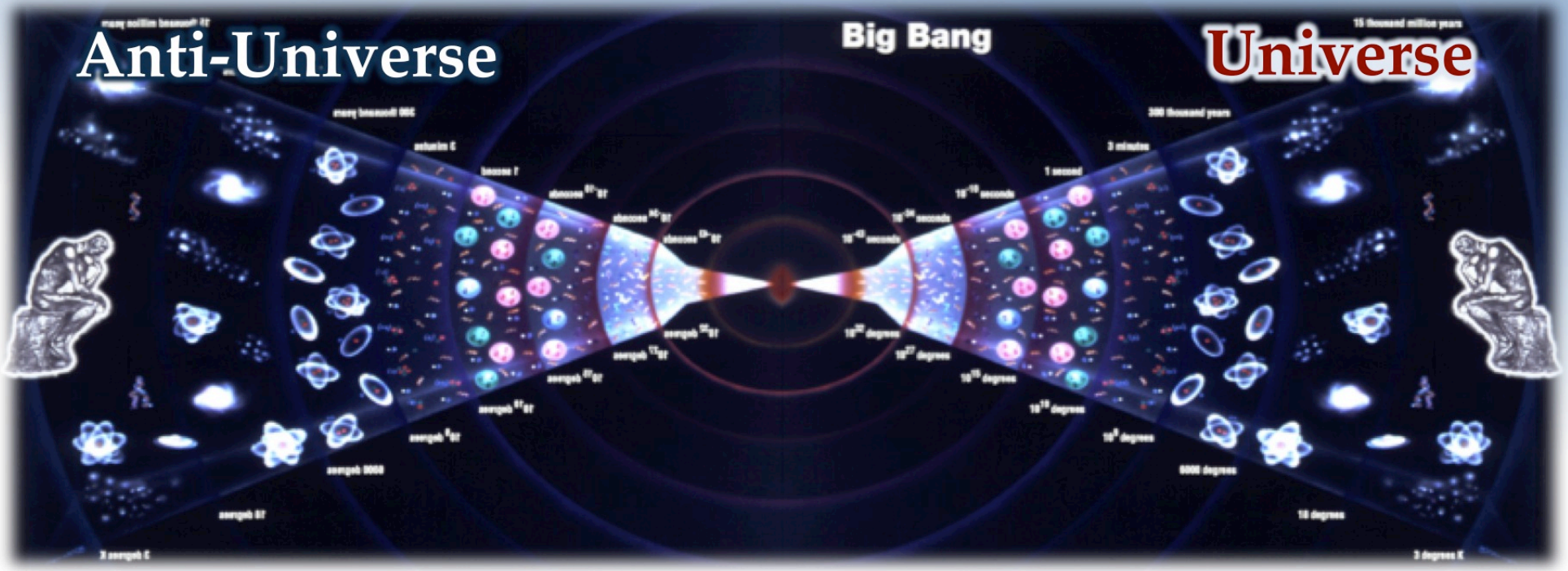
V. Hess discovered Cosmic Rays (1912)



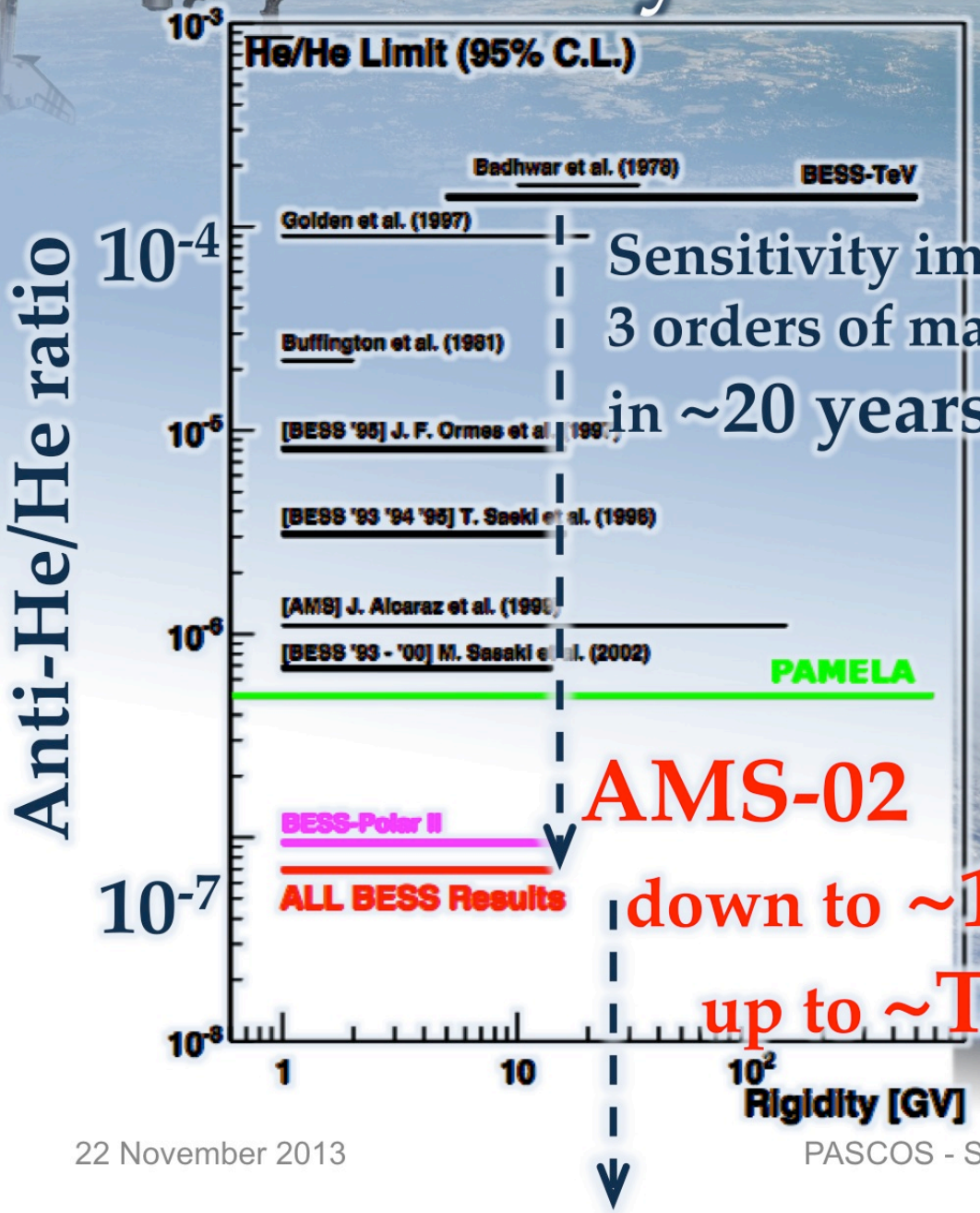

C.D. Anderson discovered positron and muon (1932 and 1936)

# 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




Sensitivity improved by
3 orders of magnitude
in ~20 years

AMS-02
down to ~$10^{-9}$
up to ~TeV

PAMELA

BESS-Polar

From balloons to satellite

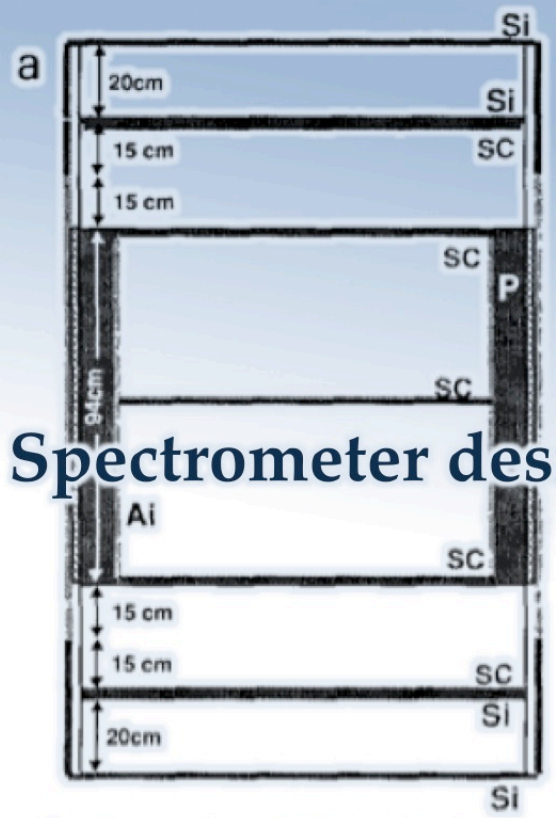
... and ISS

# Original idea of AMS (1994)

NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH
Section A

## An antimatter spectrometer in space

Antimatter Study Group




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)
Ai veto scintillators

**Spectrometer design**

**Magnet design**

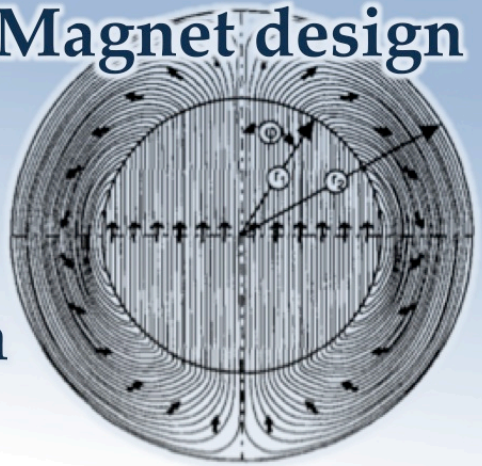


Fig. 6. Magnetic field distribution at a cross-section of the center of the magnet.

**Anti-He/He Ratio**

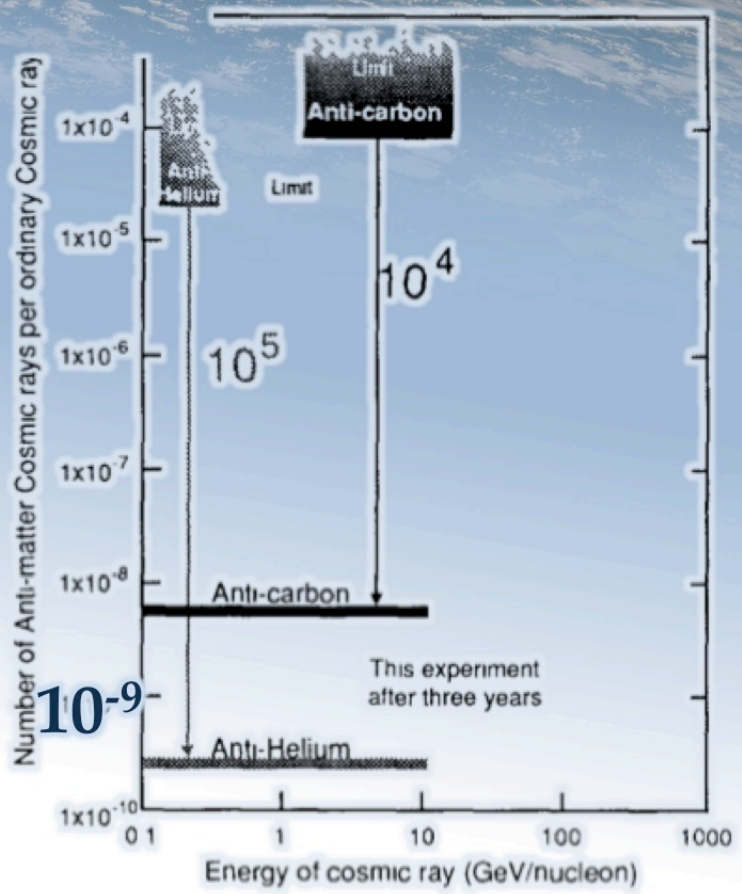
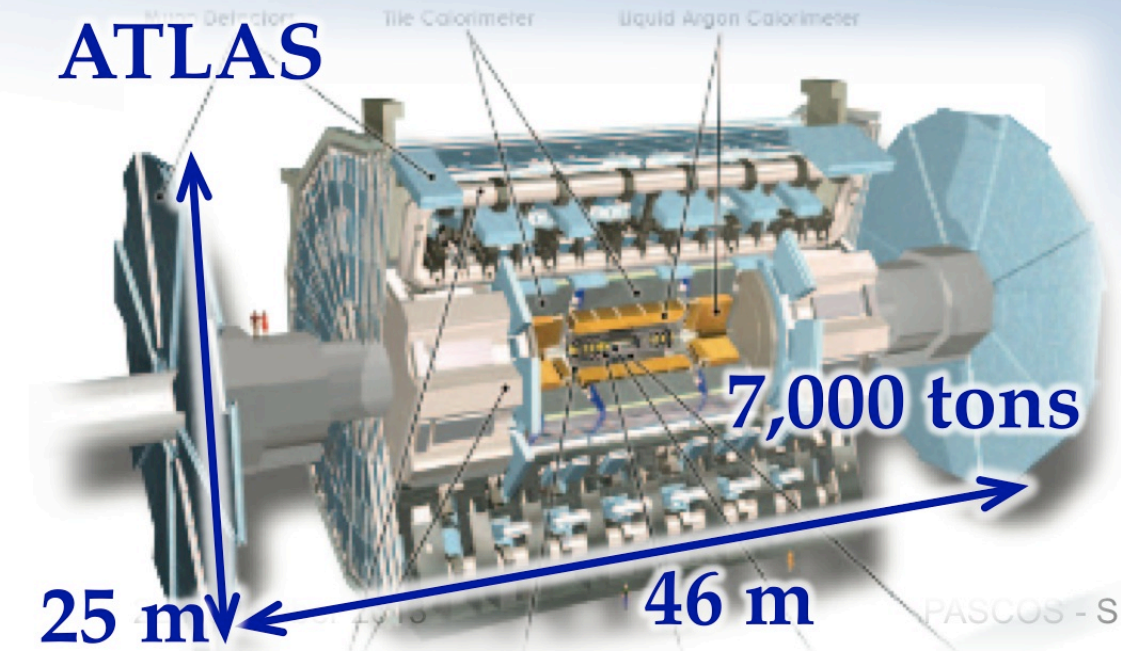
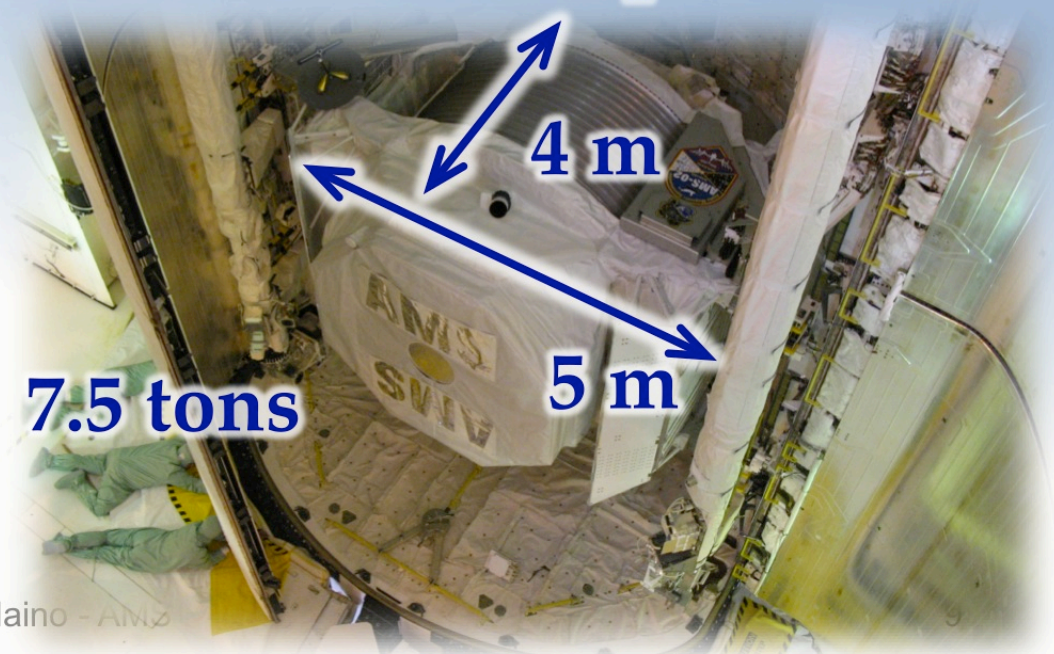



Fig. 30. Current limits and sensitivity of this experiment for antimatter. In addition to the search for antimatter, our detector could be easily modified (particularly for options 2 and 4) to explore the search of $\bar{p}$ and $e^+$.

# Technical challenges

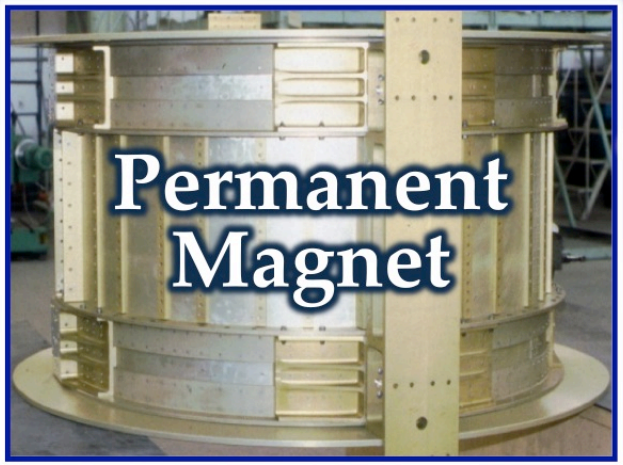
- AMS is designed with the same capability as state-of-art CERN-LHC detectors
  but small enough to fit in space shuttle
- AMS needs to work for 20 years in extreme space enviroment without access nor repair



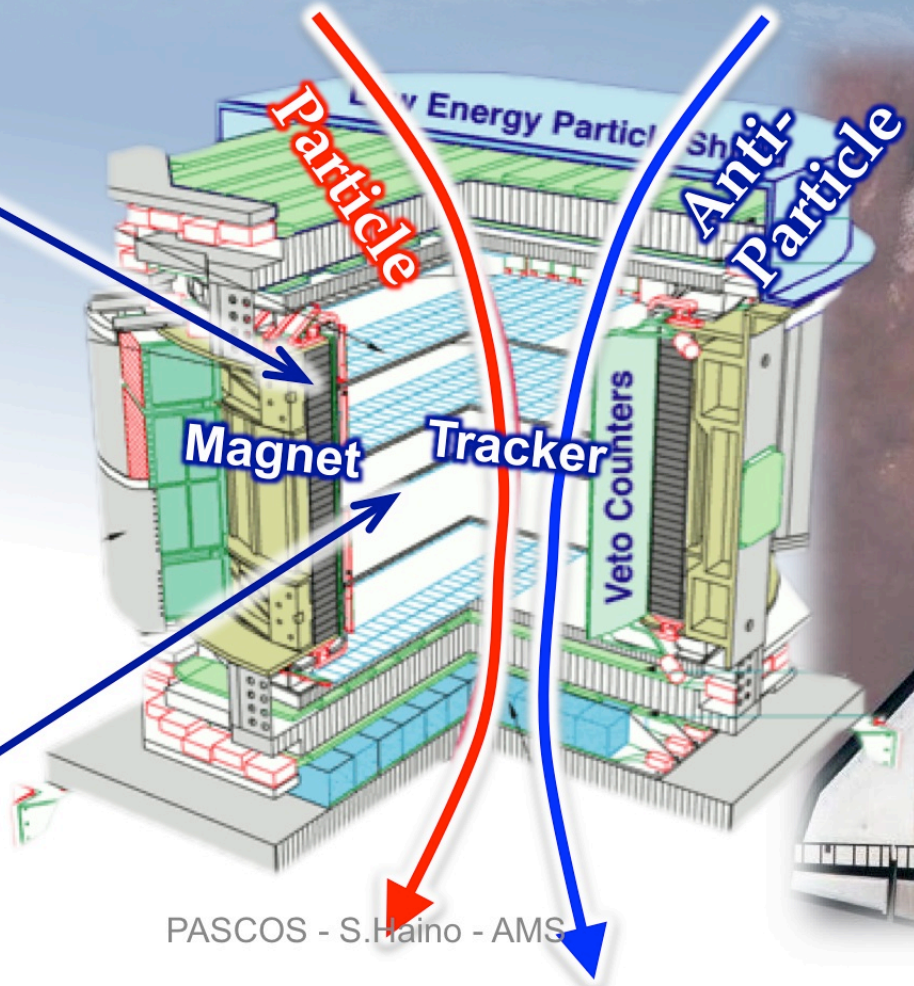



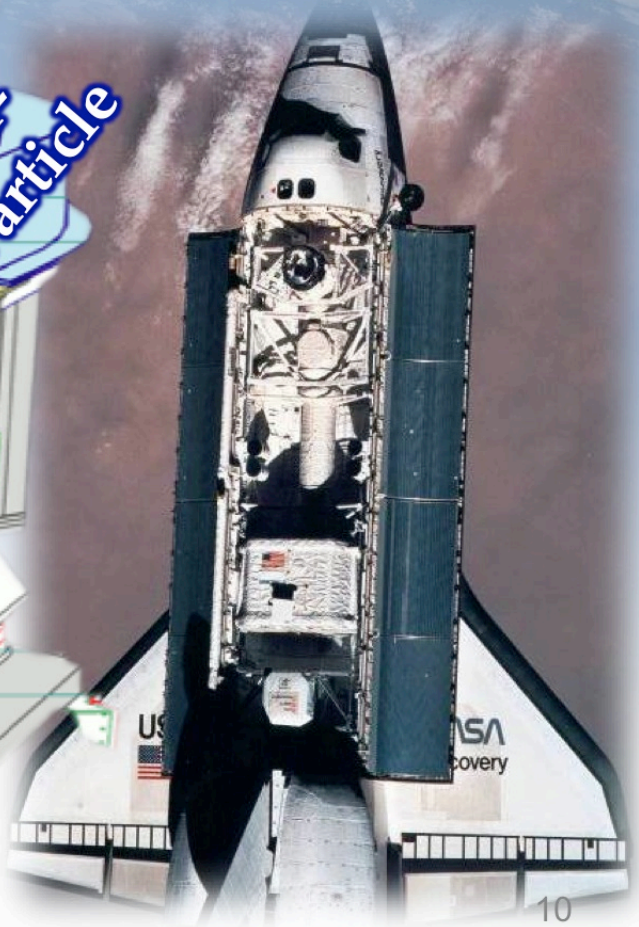
# Test flignt : AMS-01 (1998)

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








# ... and it took ~12 years

For

- Design
- Construction
- Space qualification tests
  of sub-systems
  and
- Integration of AMS-02

# Launch of AMS-02

- May/16/2011
- Last Endeavor flight
- Total weight 2008 t
- AMS 7.5 t


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

# AMS installed on the ISS

**19/May/2011**

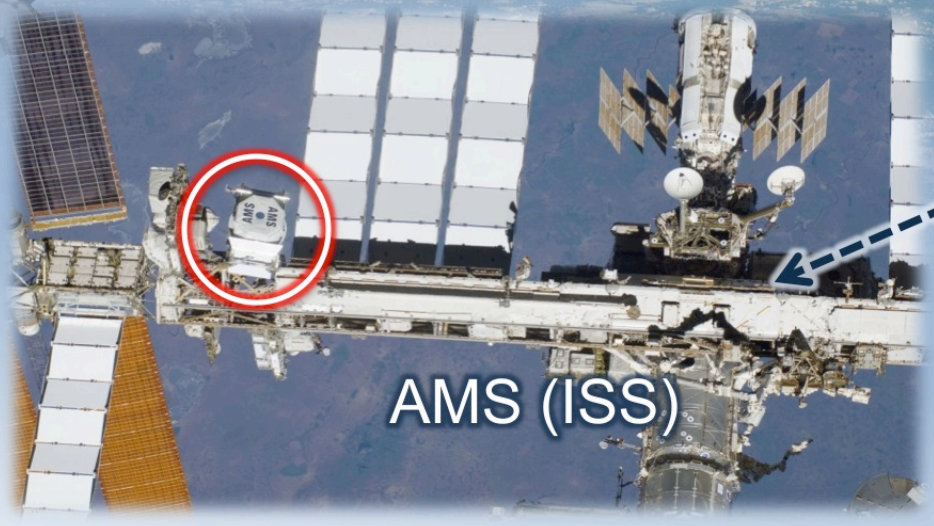
Start taking data only 4 hours later

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

# Operation and data link

**Ku-Band (down):**
Events <10Mbit/s>

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







# Operatio


## Taiwan POCC opening celemony (Jul./2012)

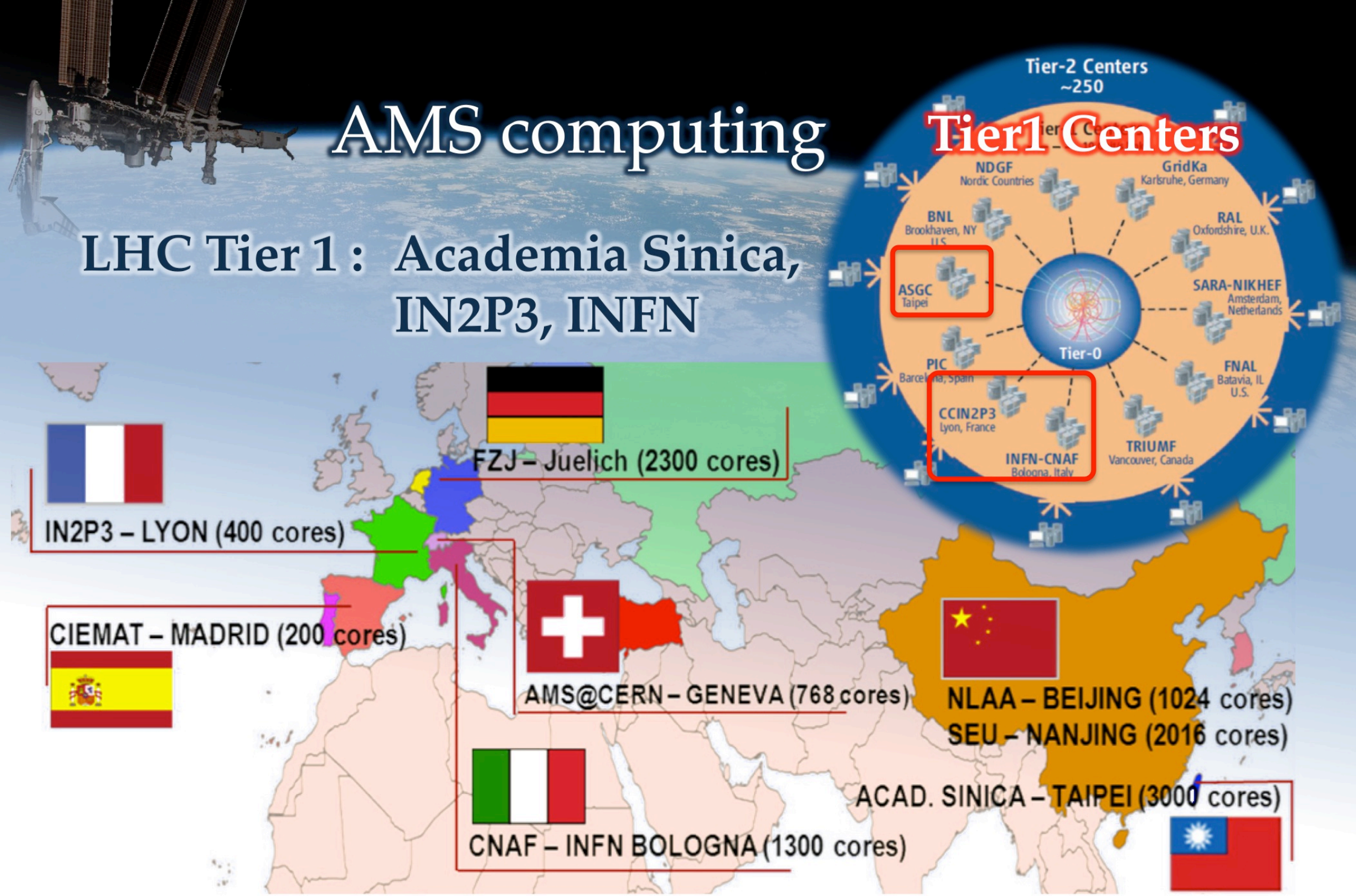

馬英九總統（圖中）與研發太空磁譜儀監控中心的日籍中大教授灰野楨一（右）握手致意，諾貝爾獎得主丁肇中（左）在旁陪同。（記者沈繼昌攝）


Payload Operations Control Center (POCC) in Taiwan


Payload Operations Control Center (POCC) at CERN

# AMS computing

## LHC Tier 1 : Academia Sinica, IN2P3, INFN

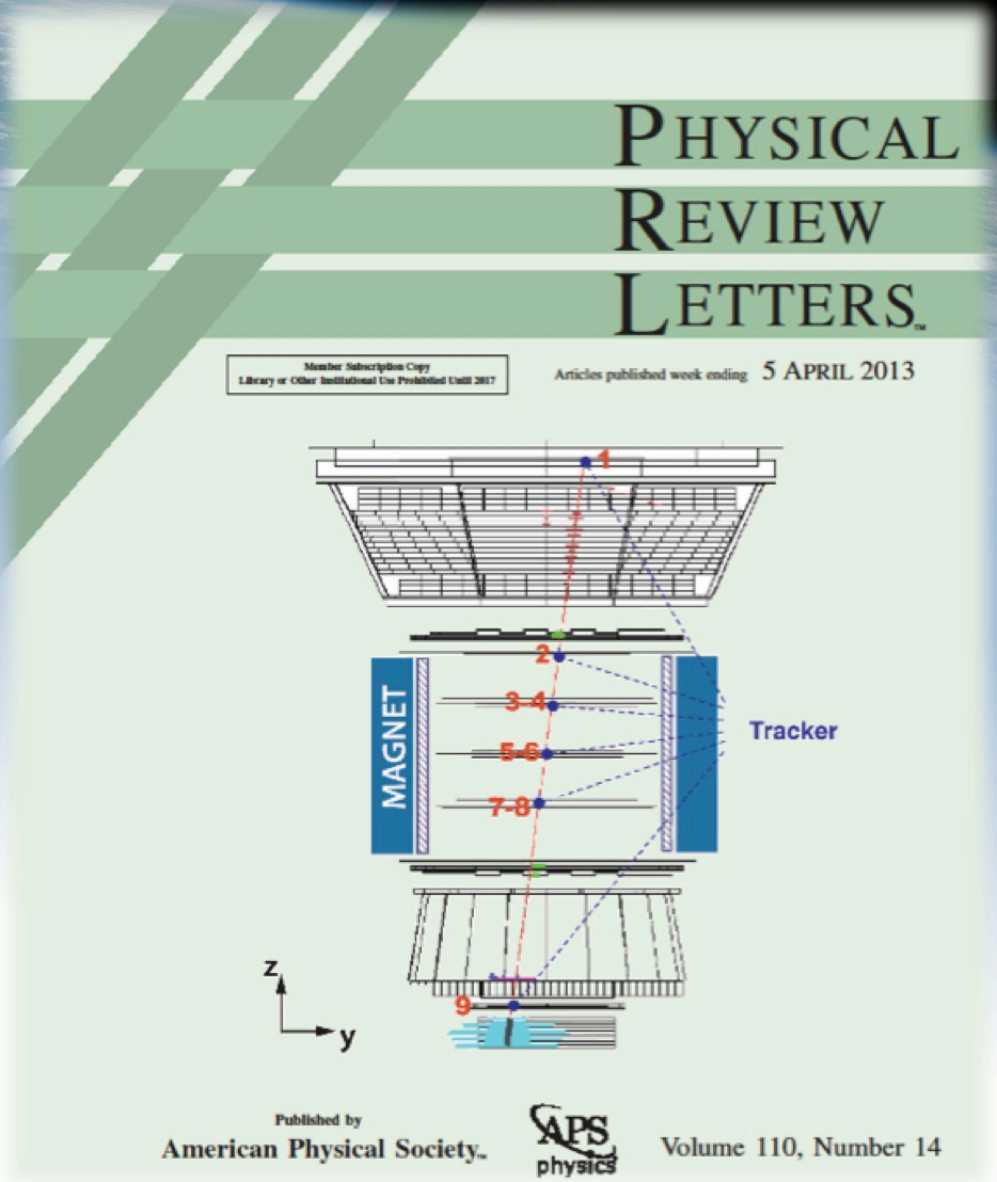


# First results of AMS

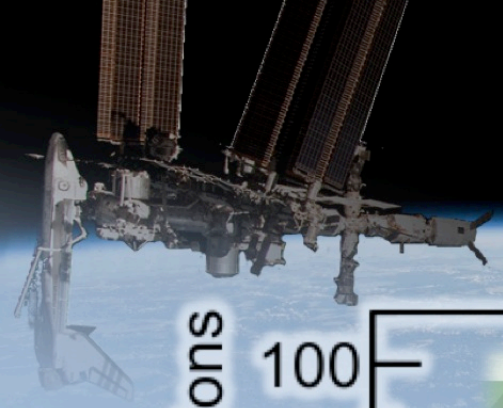
**M. Aguilar *et al.*,**
**PRL 110, 141102 (2013)**

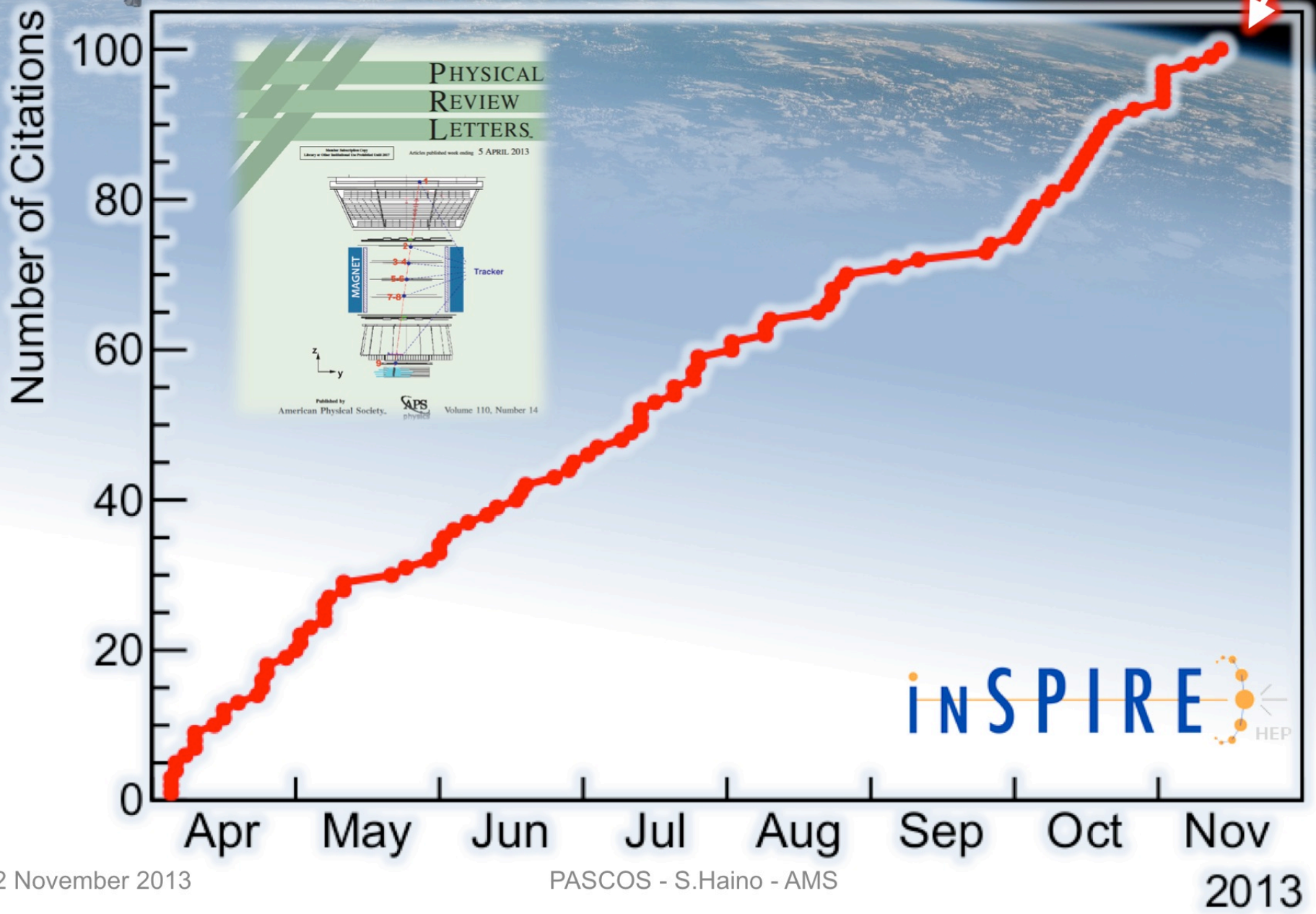
**"Precision Measurement of the Positron Fraction in Primary Cosmic Rays" of 0.5-350 GeV**

**(April/2013)**



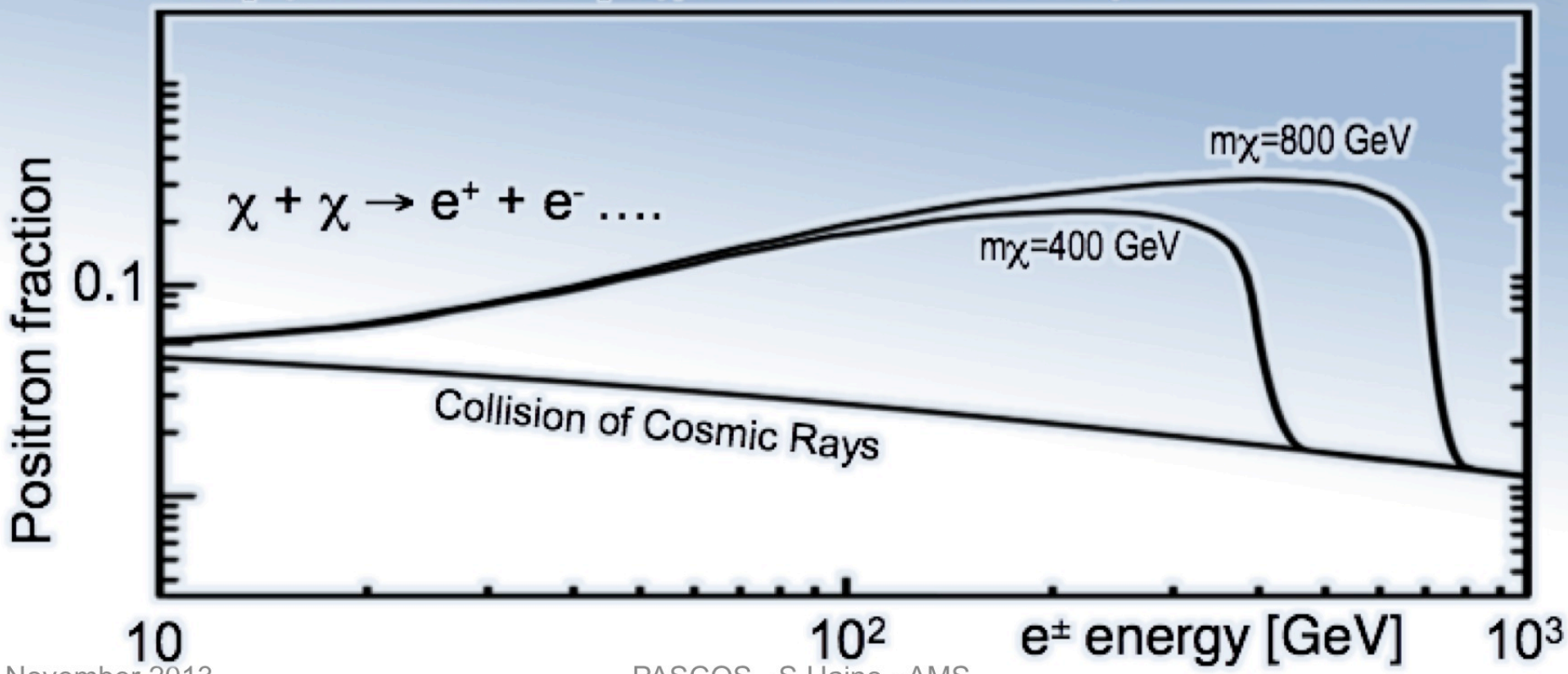
# Citation increasing ...





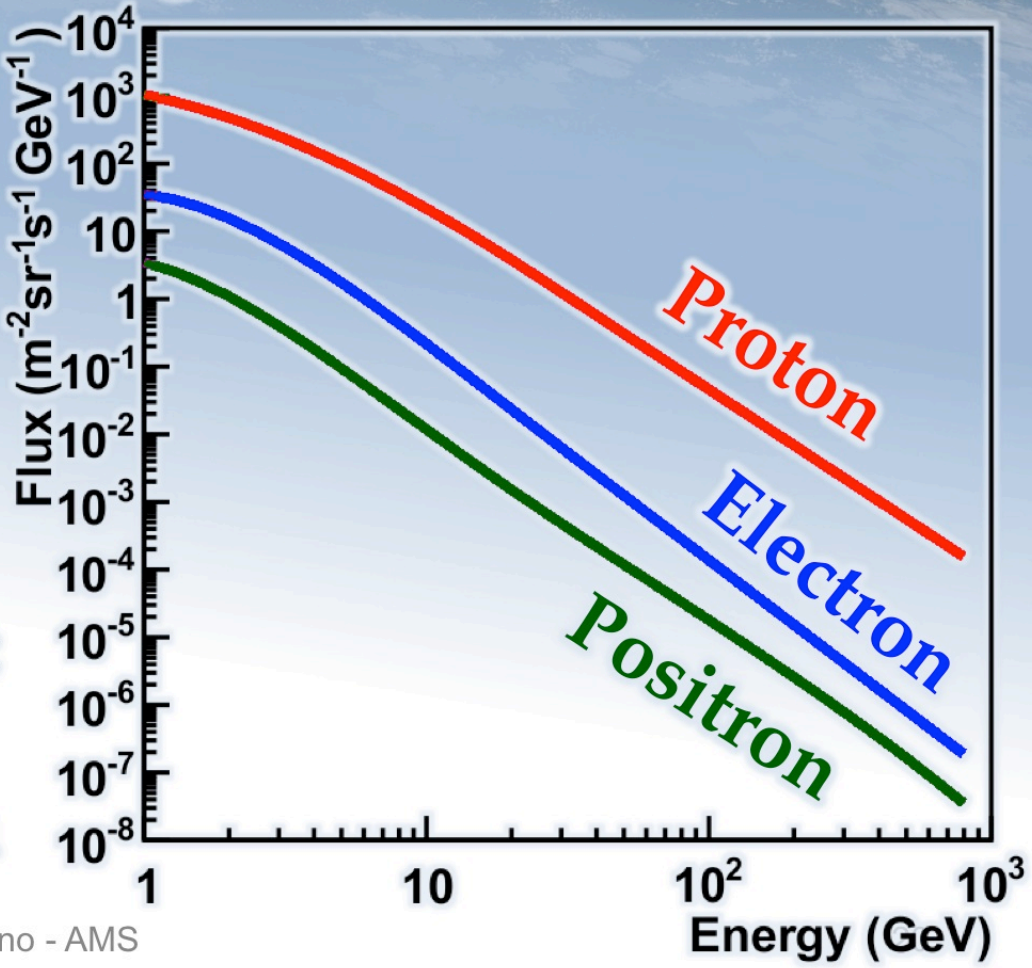
# Physics of CR Positron Fraction

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

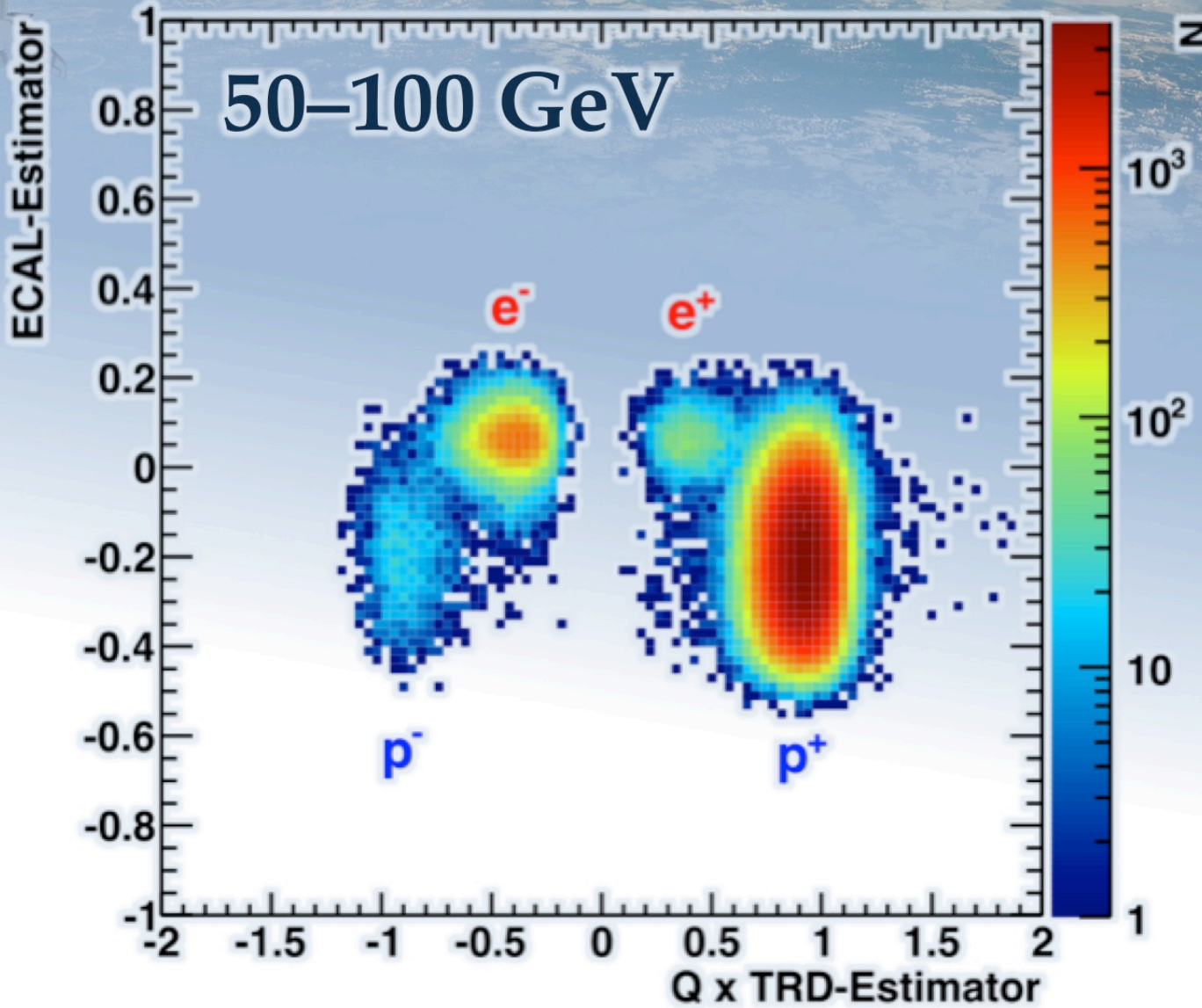


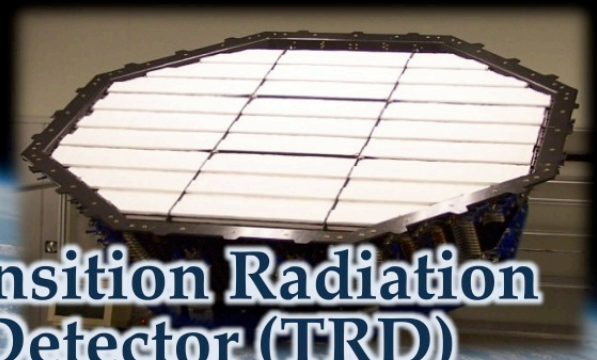
# Difficulties – CR positron measurement

- Low abundance : 0.01~0.1 % of Cosmic Rays
  ➔ Large acceptance and long duration needed
- Large backgrounds
  (1) Protons $\times 10^3$~$10^4$
  ➔ Redundant $e^+/p$ separation capability
  (2) Electrons $\times$ 10~100
  ➔ Deflection measurement in a magnetic field to determine charge sign



# Positron identification

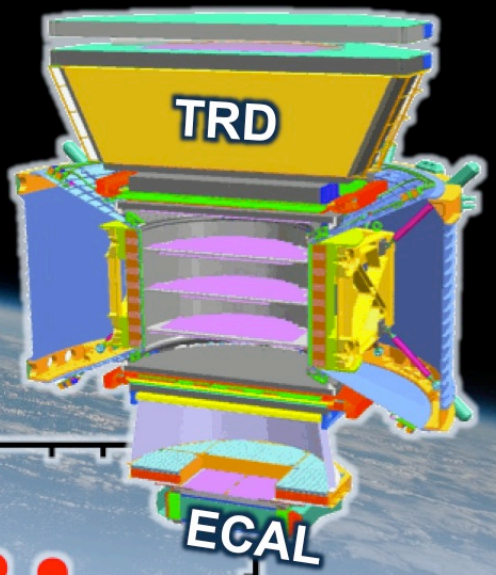


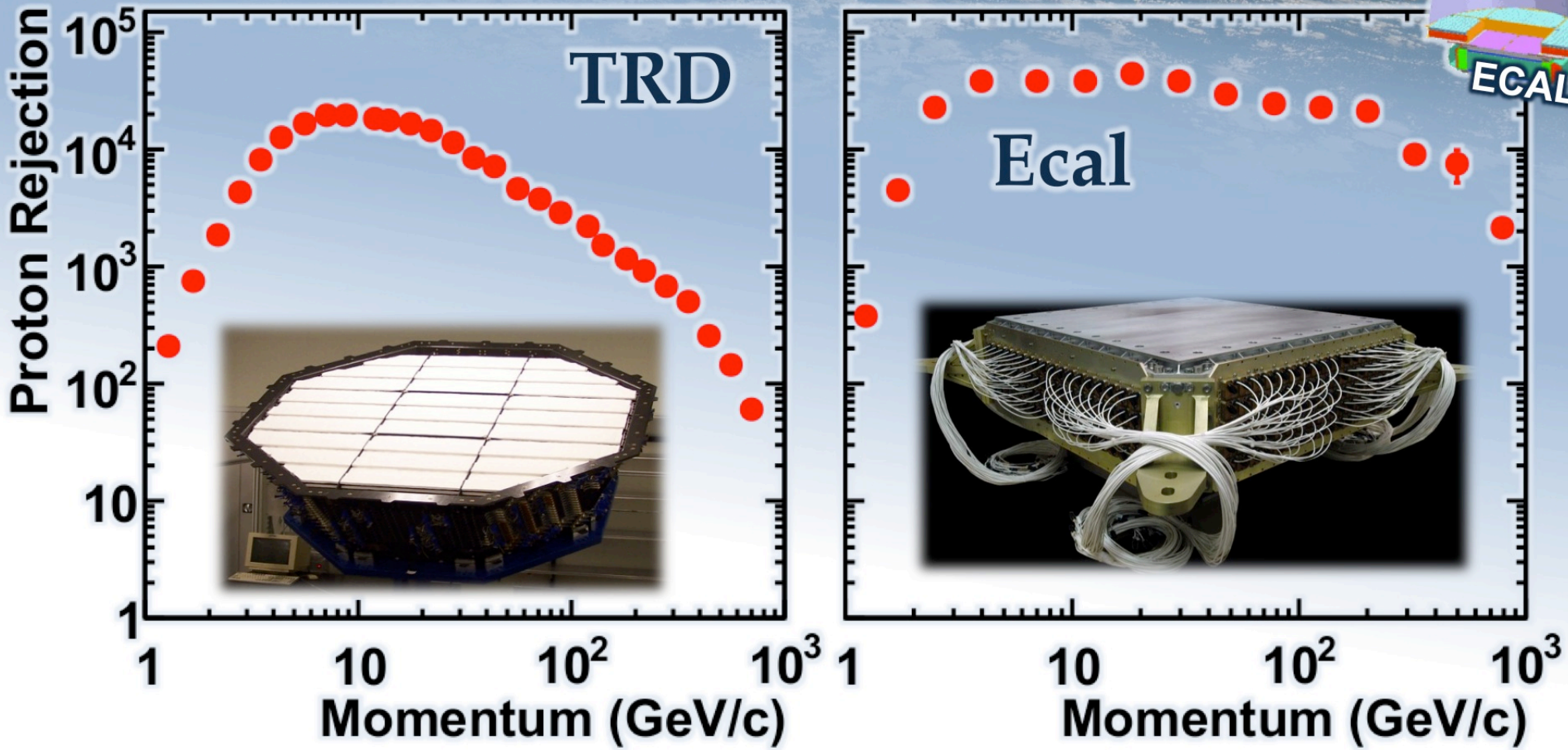





# Proton rejection

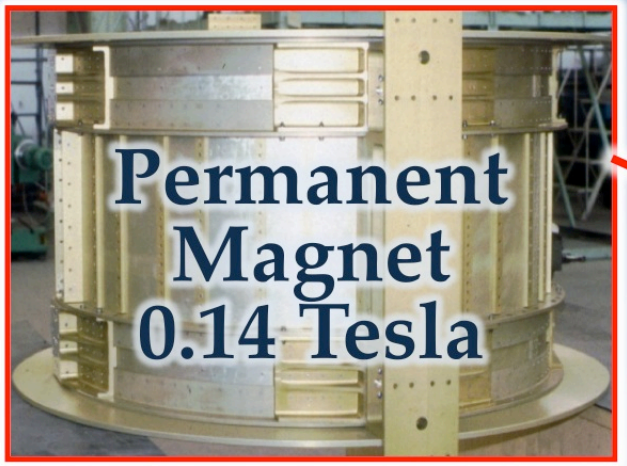
## With 90 % $e^+$ efficiency



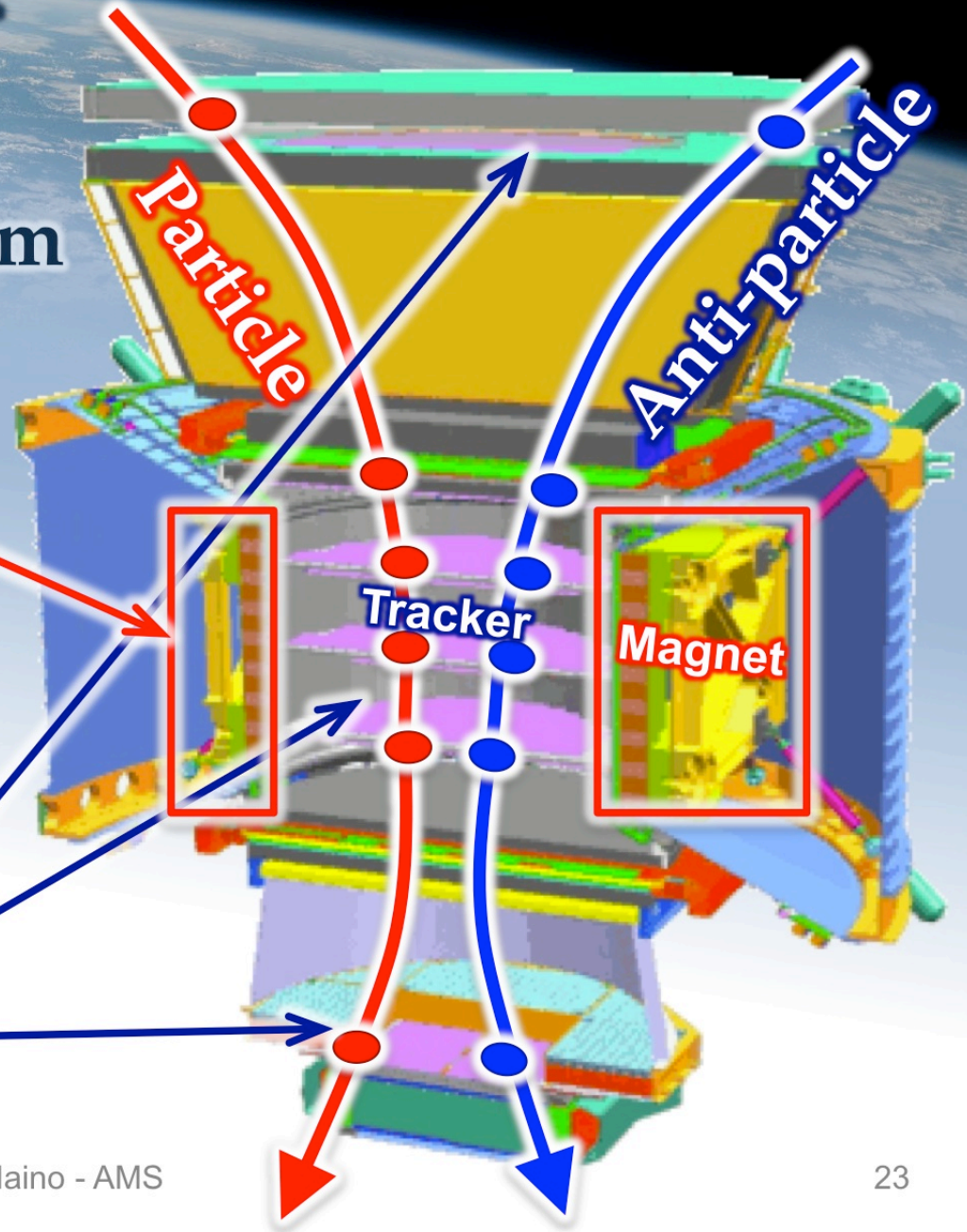



# e+/e- separation

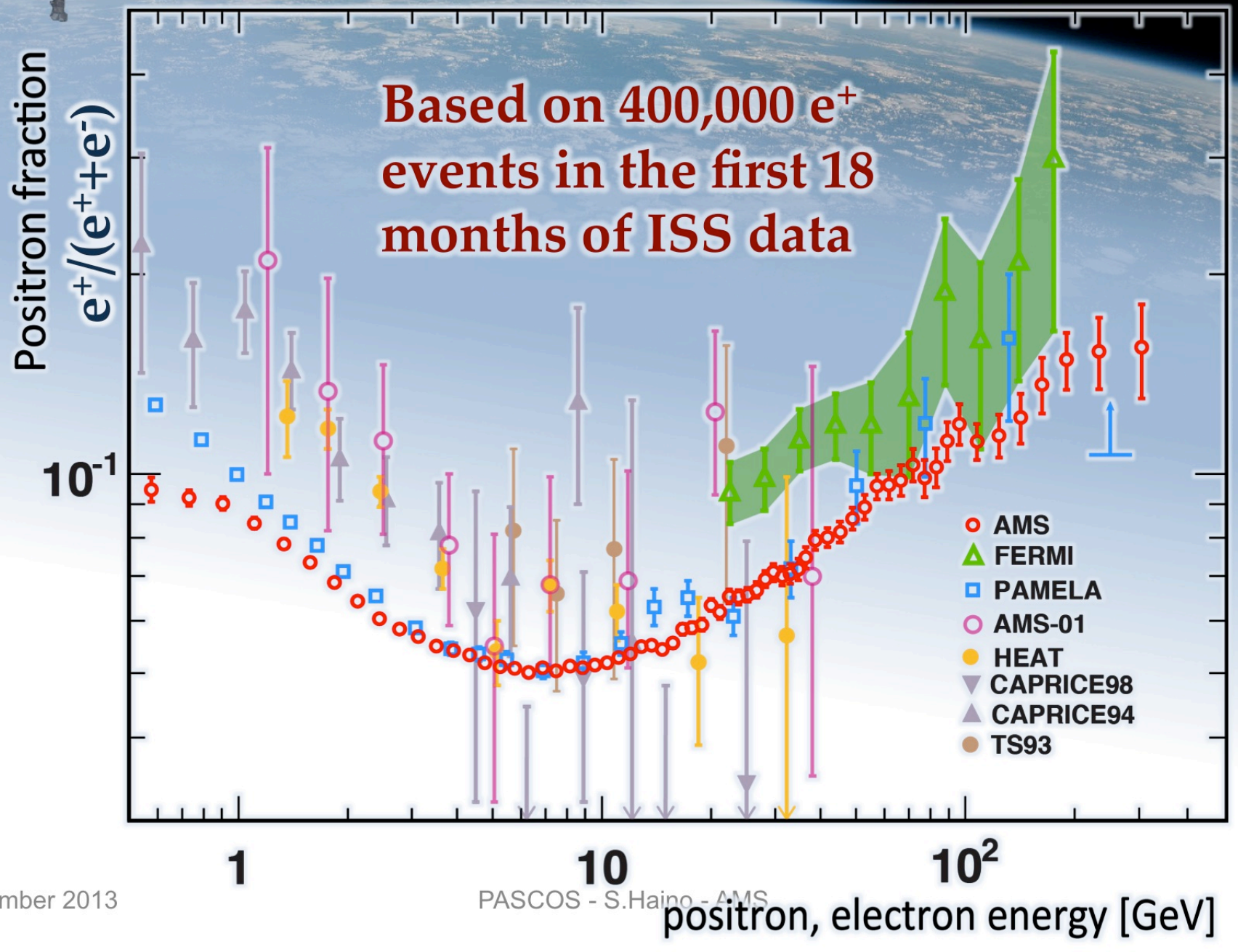
- Determine charge sign and measure momentum



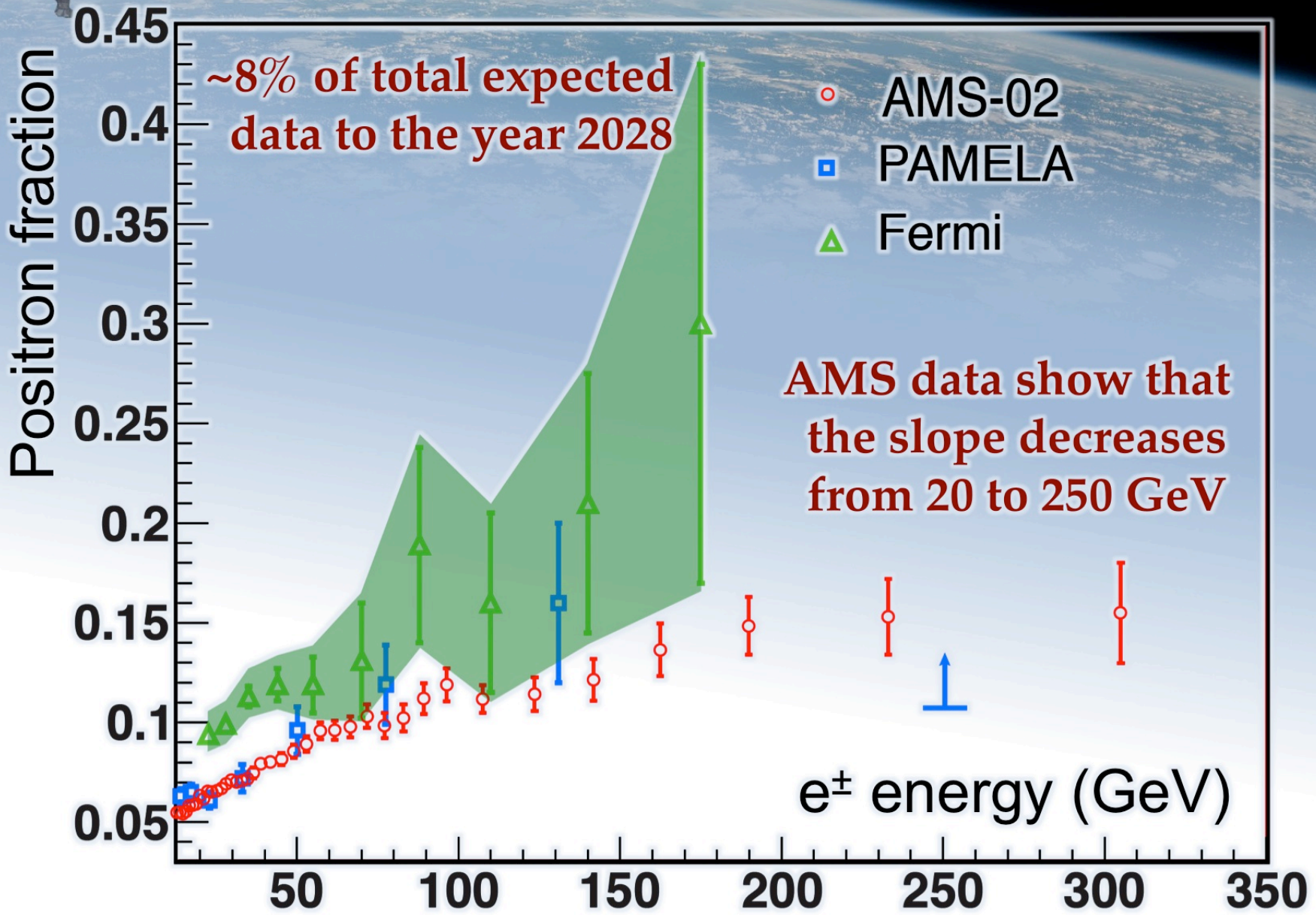




# First results of AMS – $e^+$ fraction



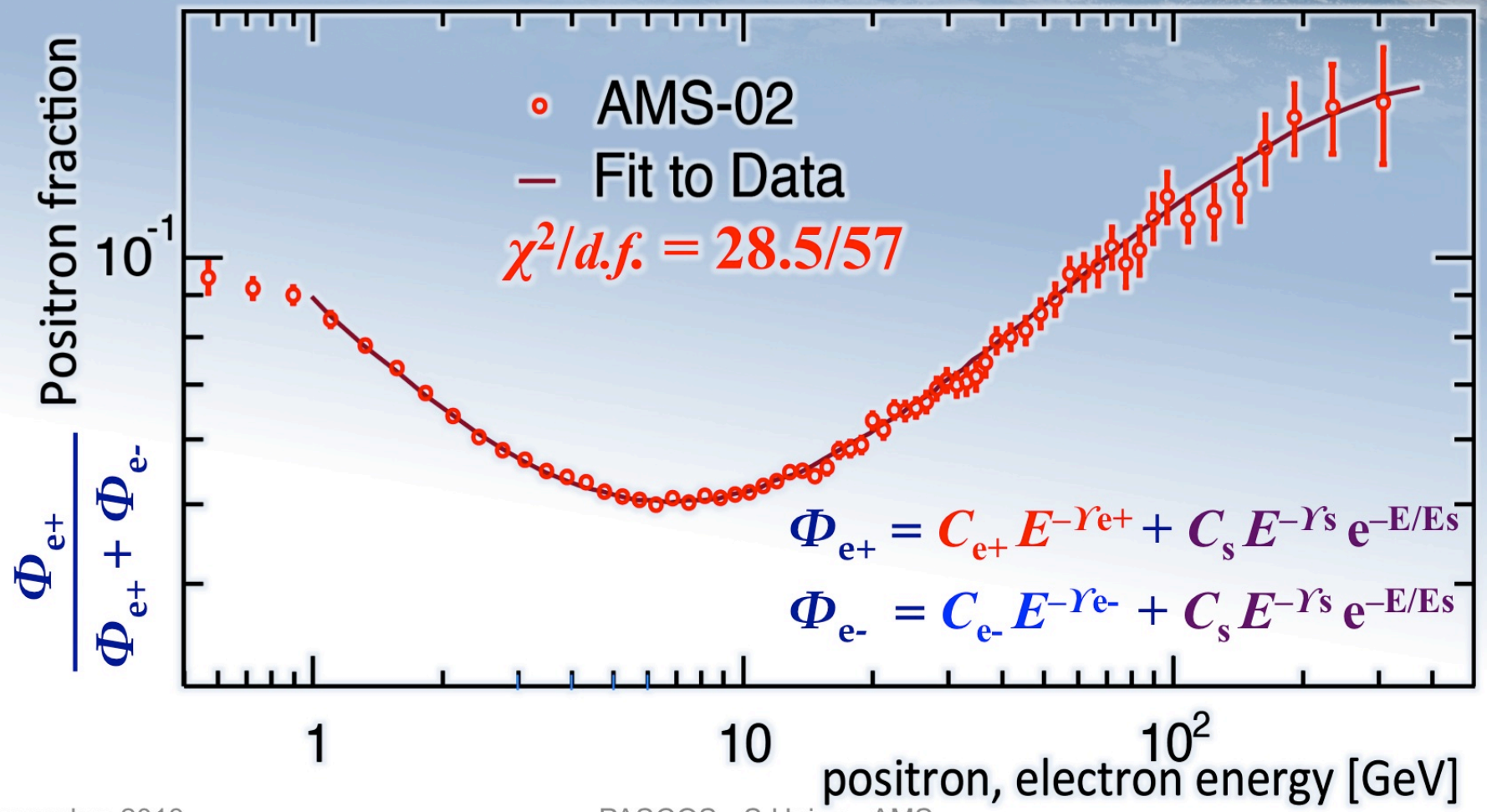
# First results of AMS – $e^+$ fraction



# Fit with minimal model

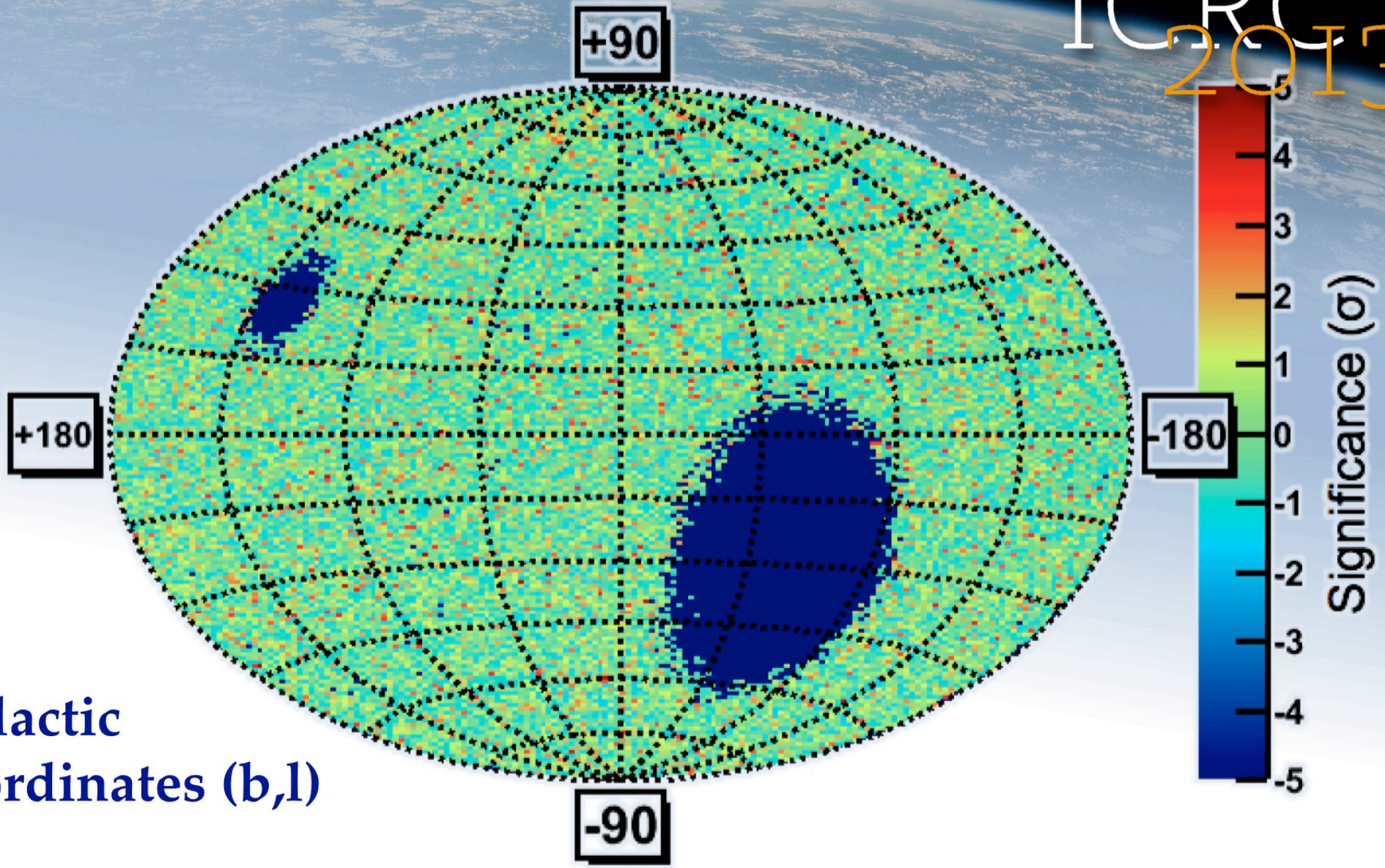
$1/E_s = 0.0013 \pm 0.0007\ \mathrm{GeV}^{-1}$

(Cutoff energy $760\ ^{+1000}_{-280}$ GeV)



# Positron anisotropy

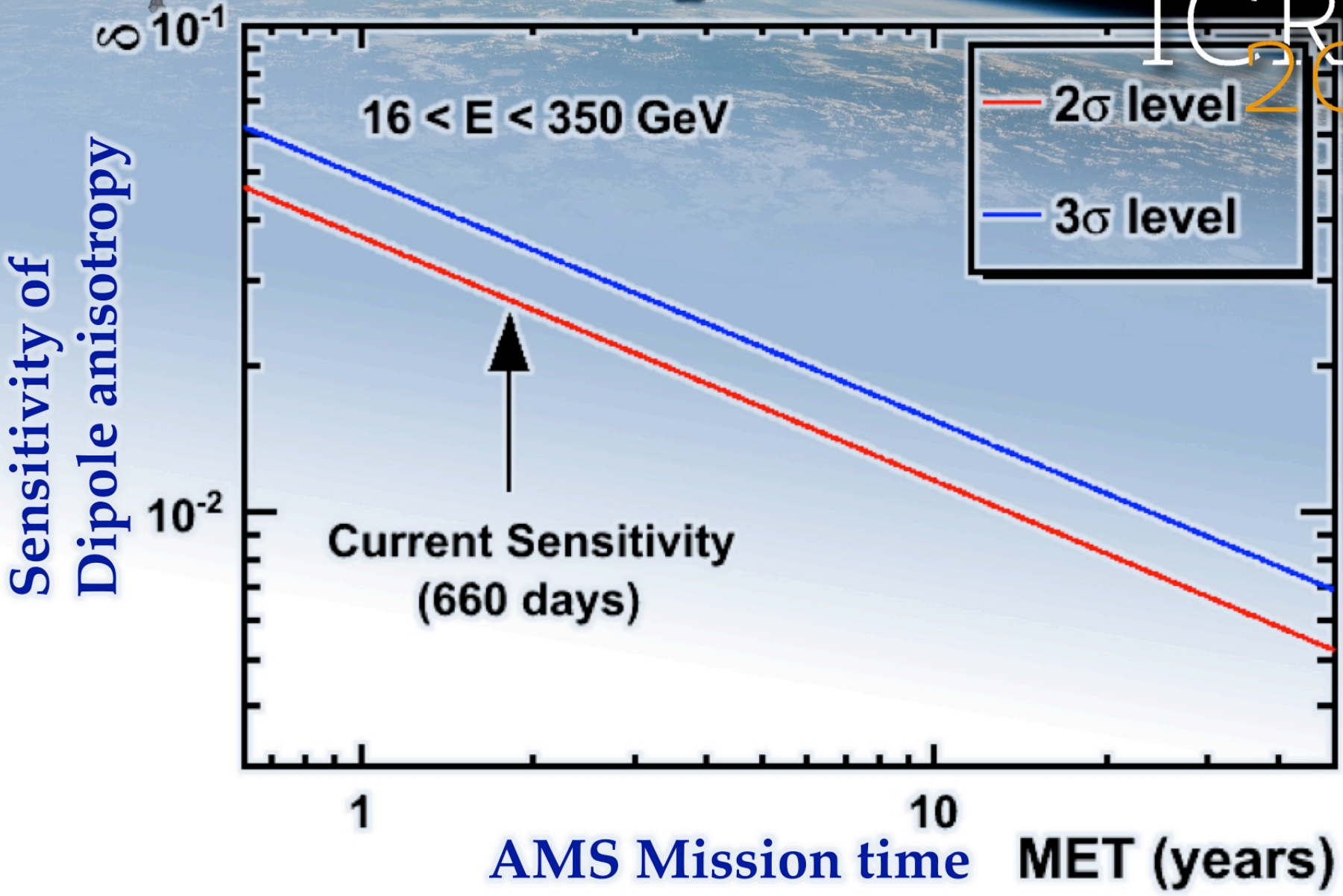
ICRC 2013




**Galactic coordinates (b,l)**

# AMS potential

ICRC 2013



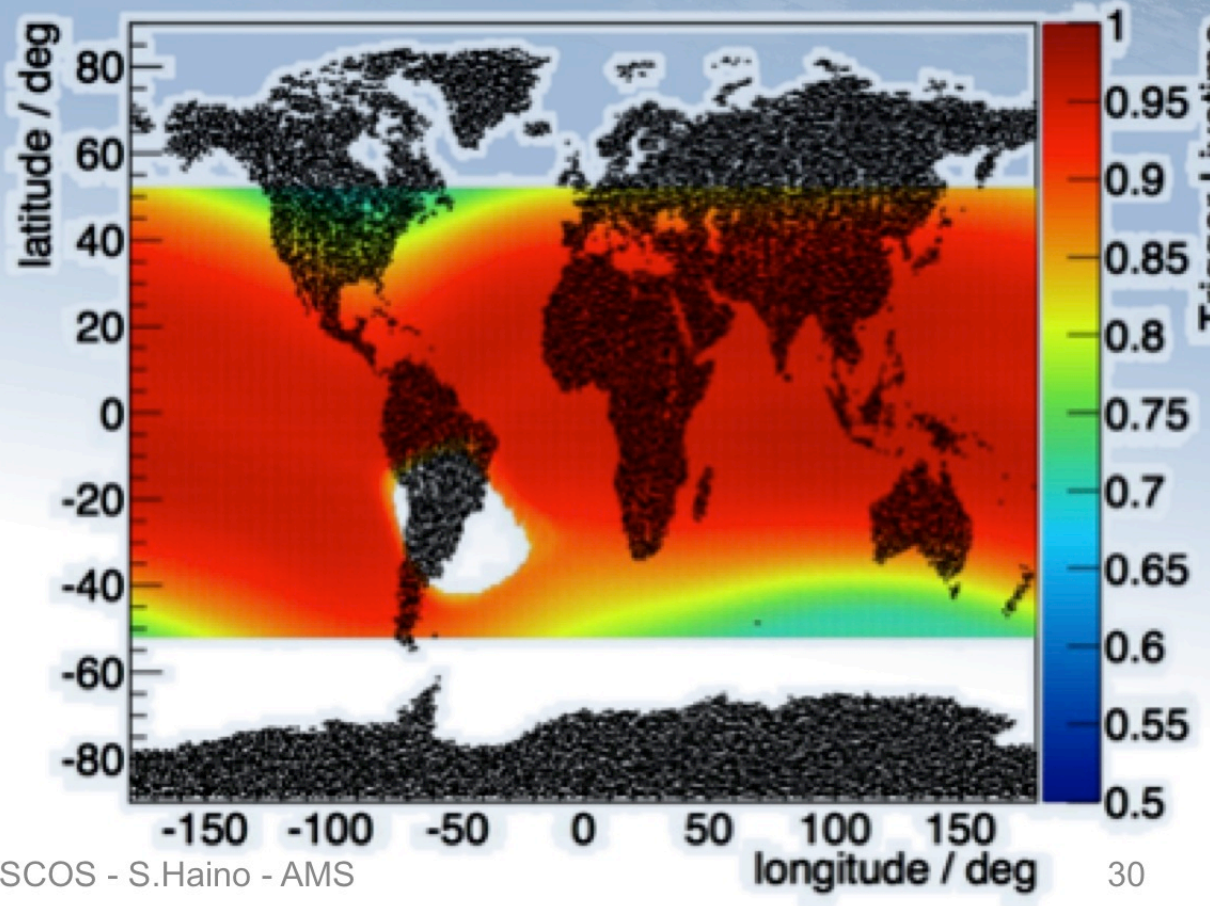
# Flux determination

$$F(E) = \frac{N}{T \cdot A \cdot \varepsilon_{trig.} \cdot dE}$$

| | | |
|---|---|---|
| $F$ | : Absolute differential flux | ($m^{-2}sr^{-1}s^{-1}GeV^{-1}$) |
| R | : Measured energy | (GeV) |
| N | : Number of events after proton selection | |
| T | : Exposure life time | (s) |
| A | : Effective acceptance | ($m^2$ sr) |
| $\varepsilon_{trg.}$ | : Trigger efficiency | |
| dR | : Energy bin | (GeV) |

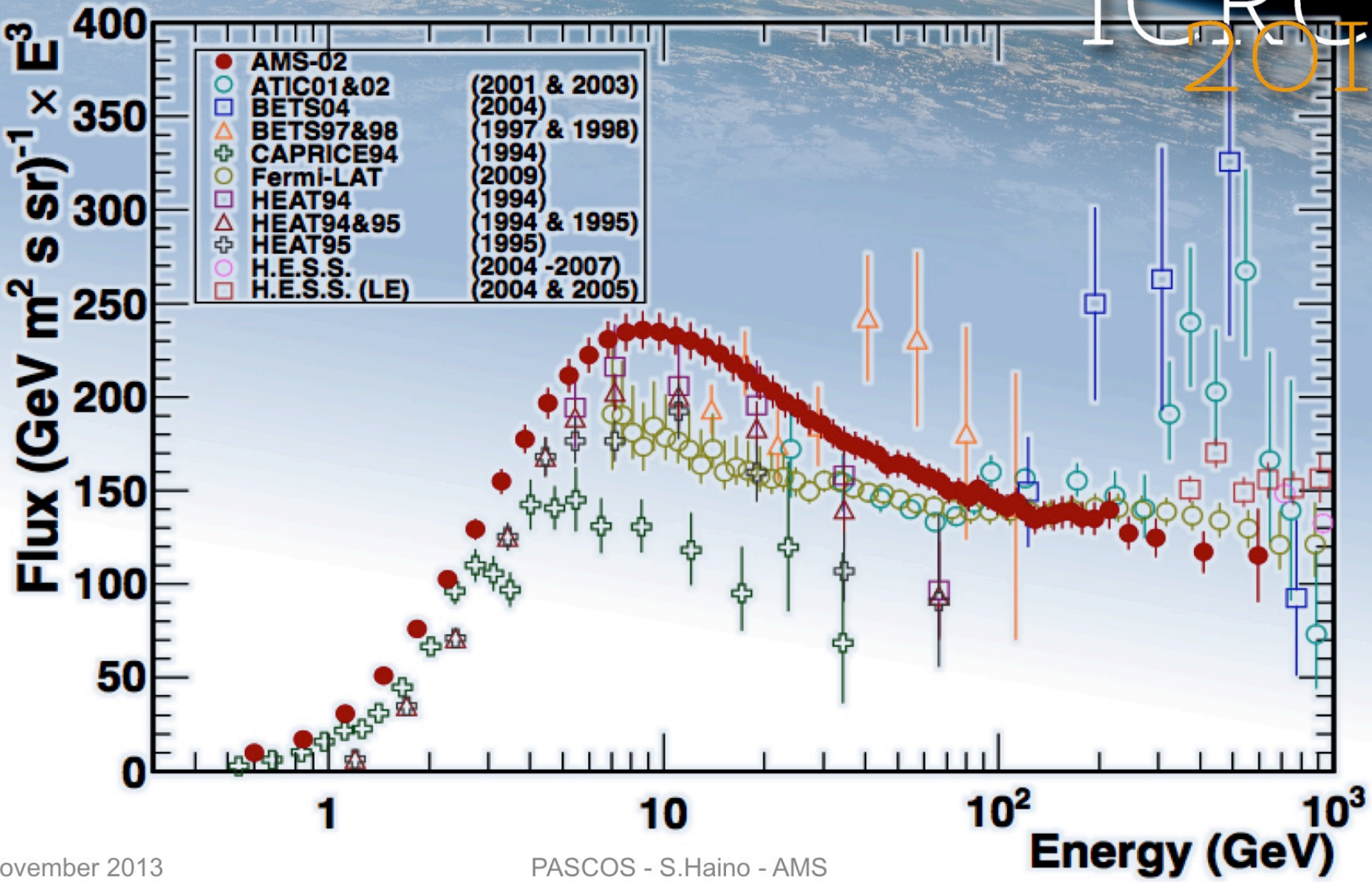
# Data period

- Data taken from : May 2011
  to : May 2013 (2 years)
- Total exposure time :
  $51.2 \times 10^6$ sec
  (R > 25 GV)
- Average live time fraction :
  81.6 %

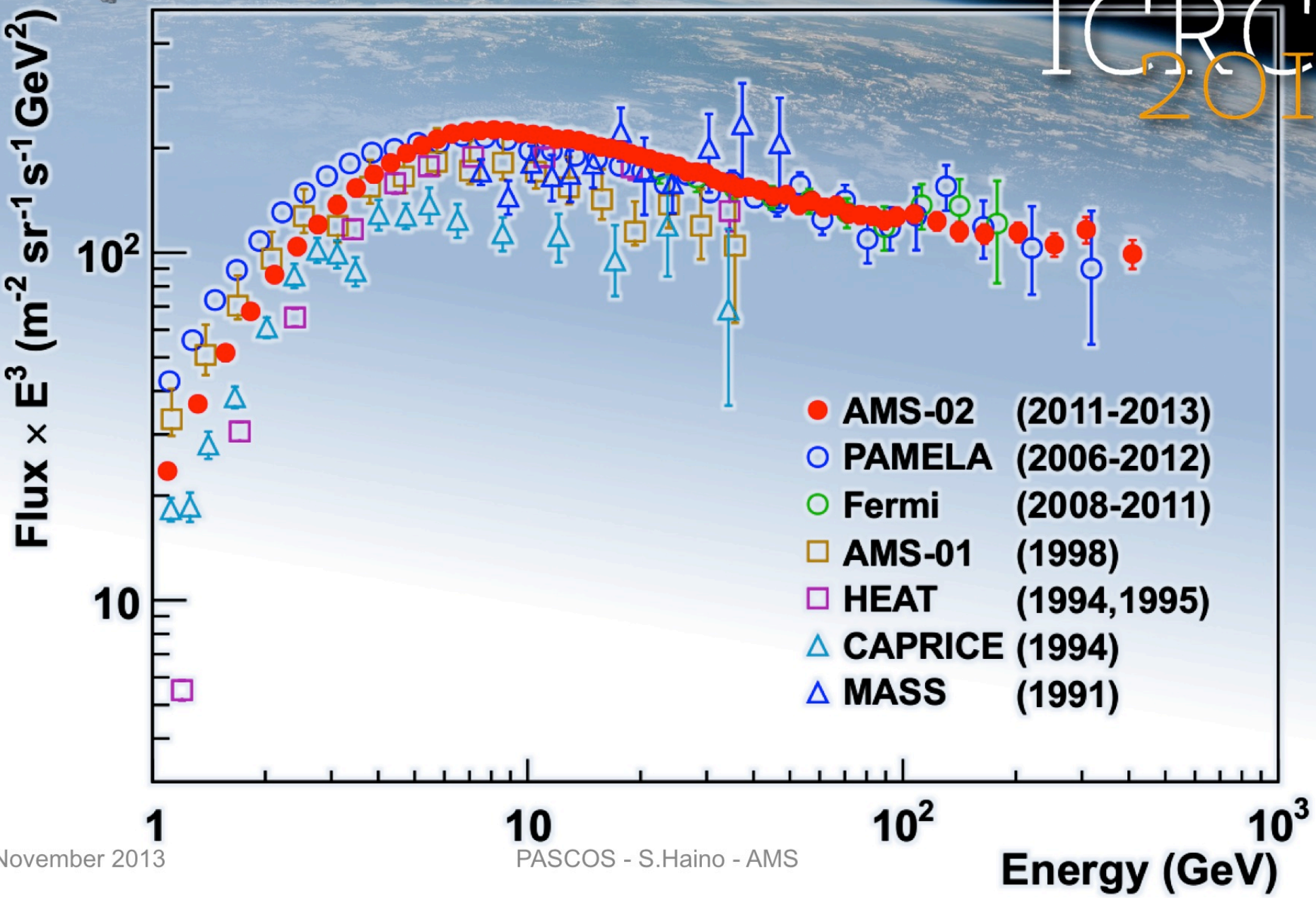


# $e^+ + e^-$ flux

ICRC 2013

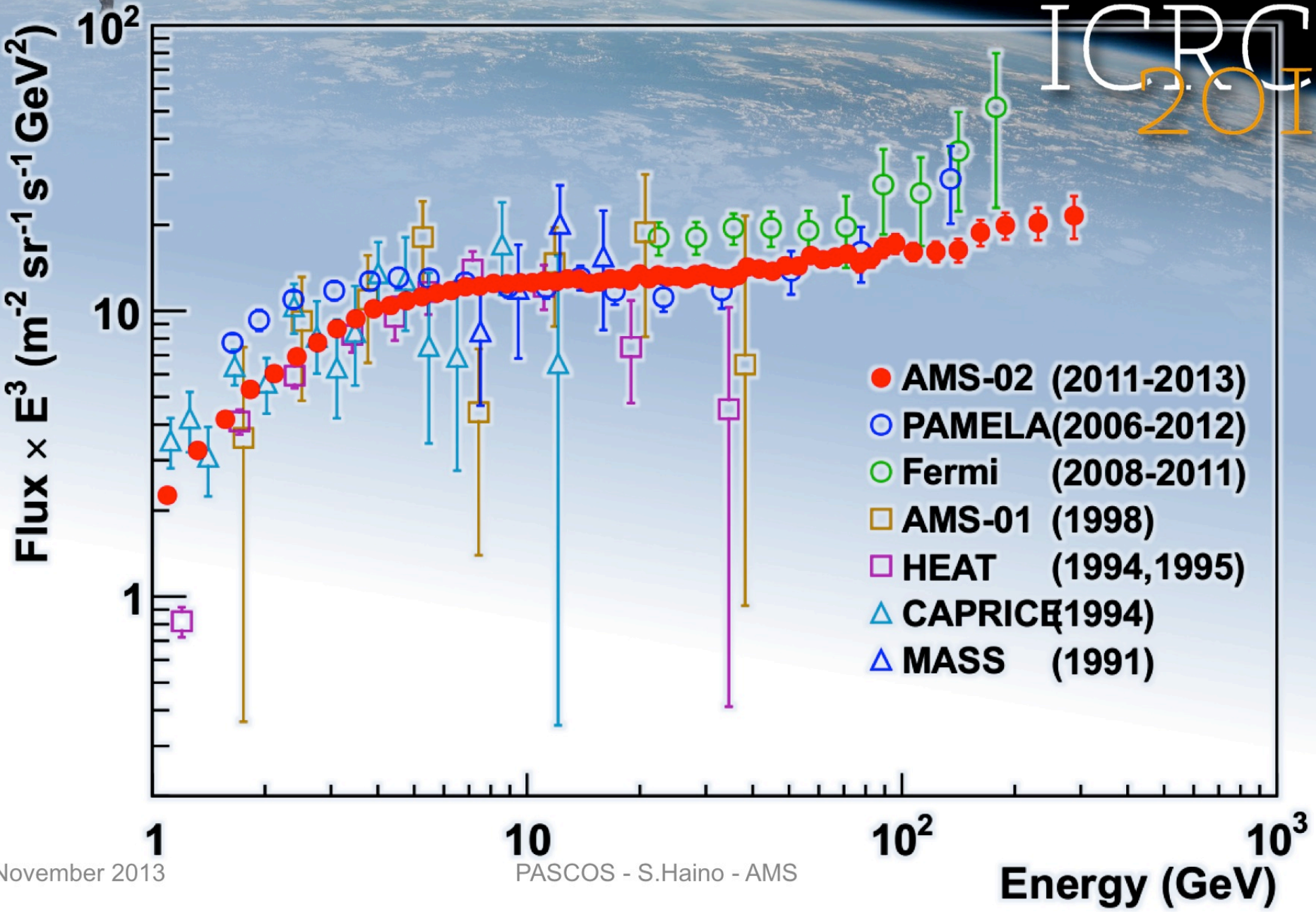


# $e^-$ flux

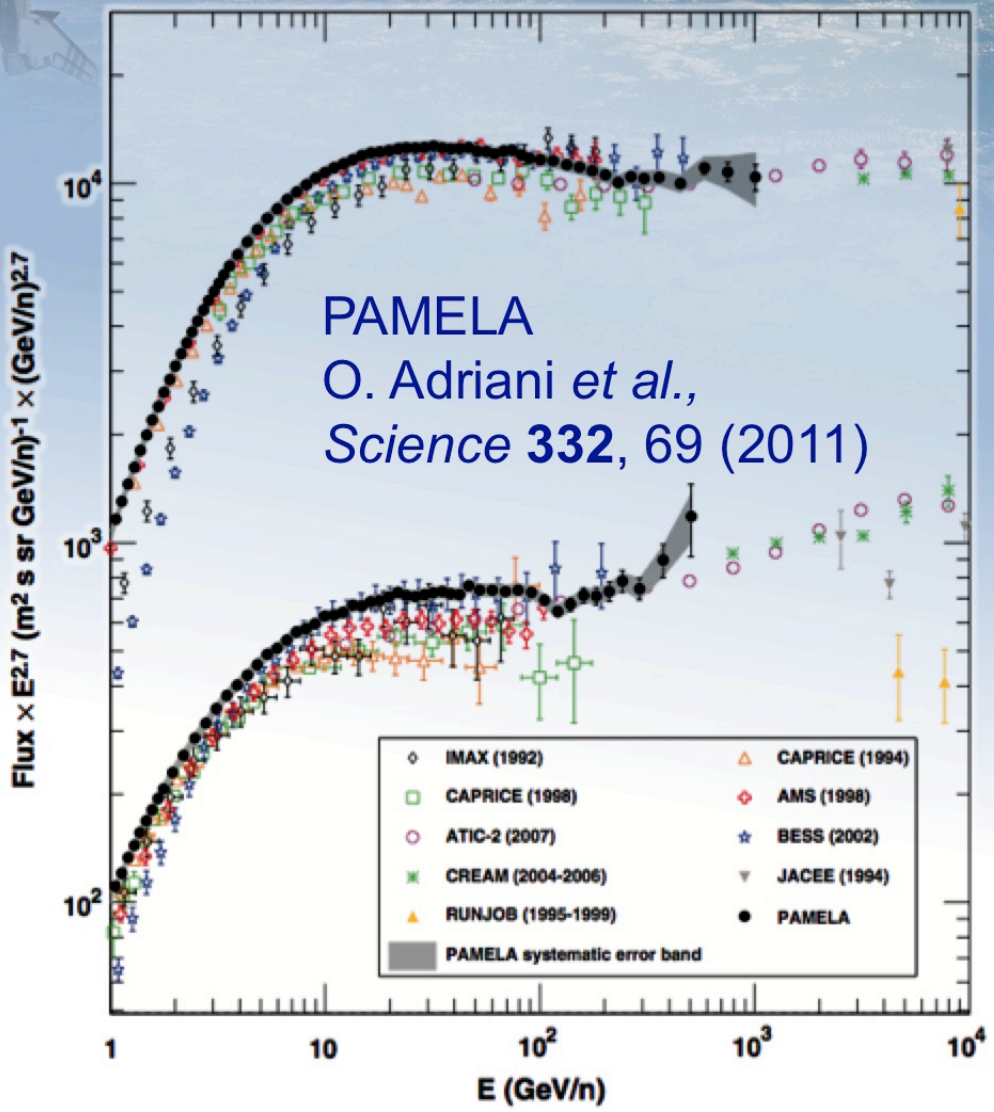



ICRC 2013

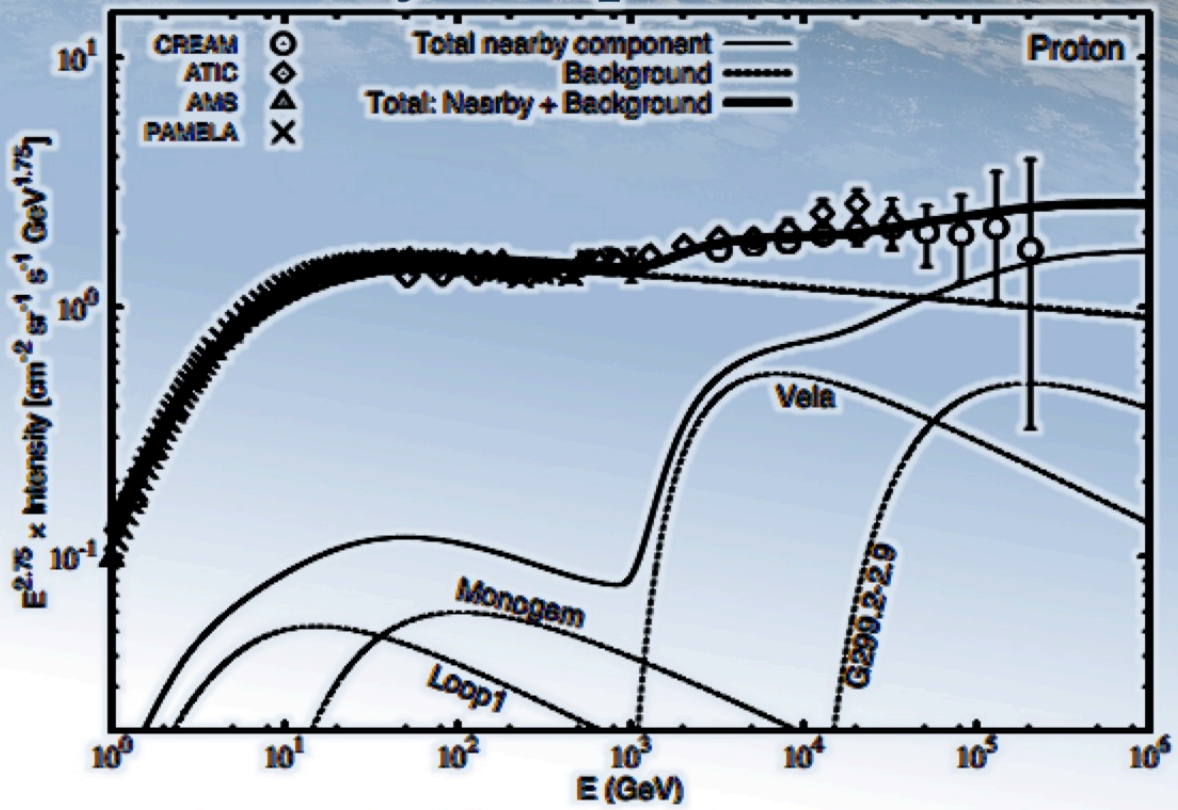
# $e^+$ flux


ICRC 2013
Flux × E³ (m⁻² sr⁻¹ s⁻¹ GeV²)
10²
10
1
1
10
10²
10³
Energy (GeV)
AMS-02 (2011-2013)
PAMELA (2006-2012)
Fermi (2008-2011)
AMS-01 (1998)
HEAT (1994,1995)
CAPRICE (1994)
MASS (1991)

# Proton and He fluxes




## Proton flux model with nearby components




Satyendra Thoudam, Jorg R. Horandel
arXiv:1304.1400

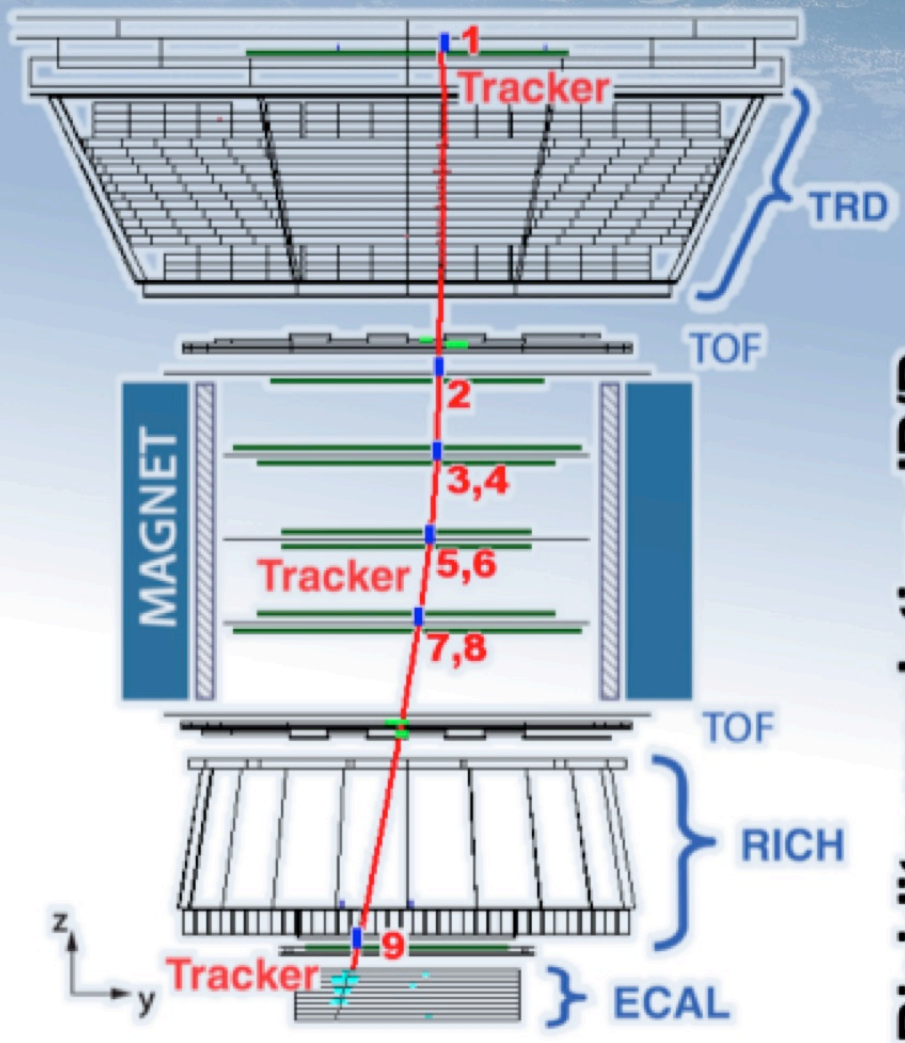
# Rigidity Measurement

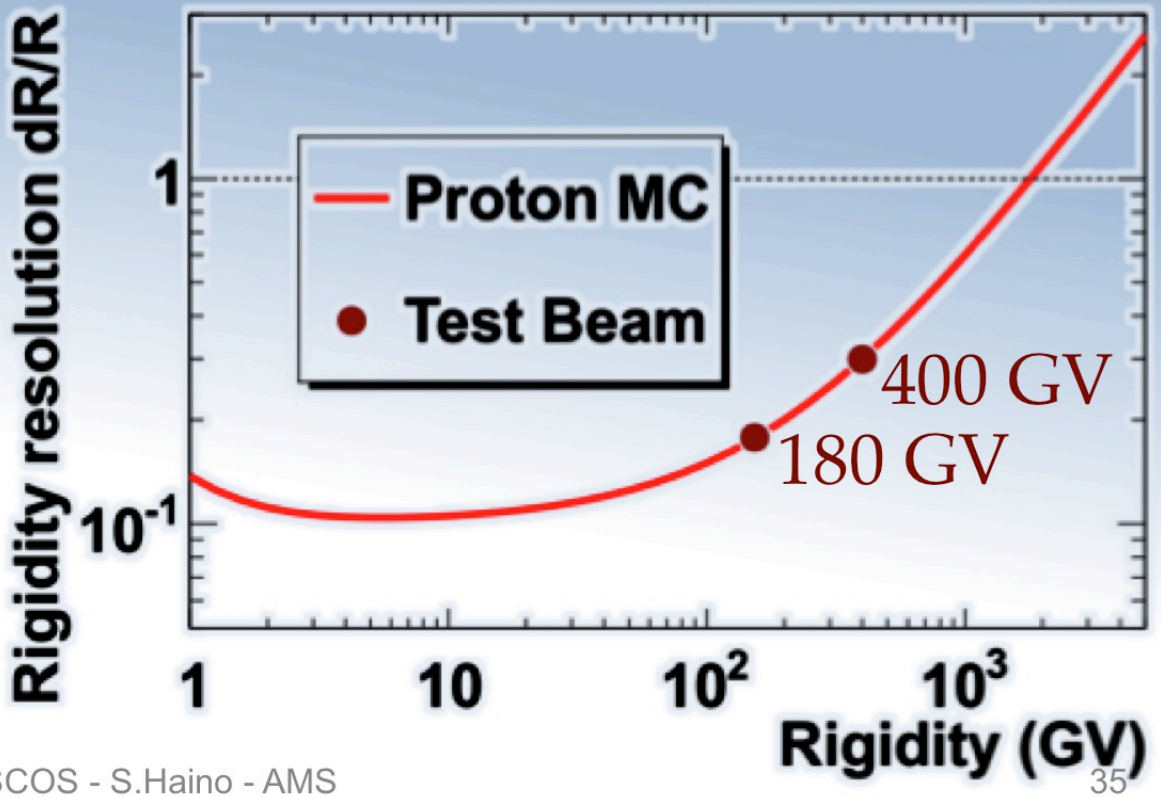
$B_x$ = ~0.14 T  $L$ = ~3m

$\sigma_y$ = ~10μm

**MDR : ~2 TV (p)**

**~3.2TV (He)**

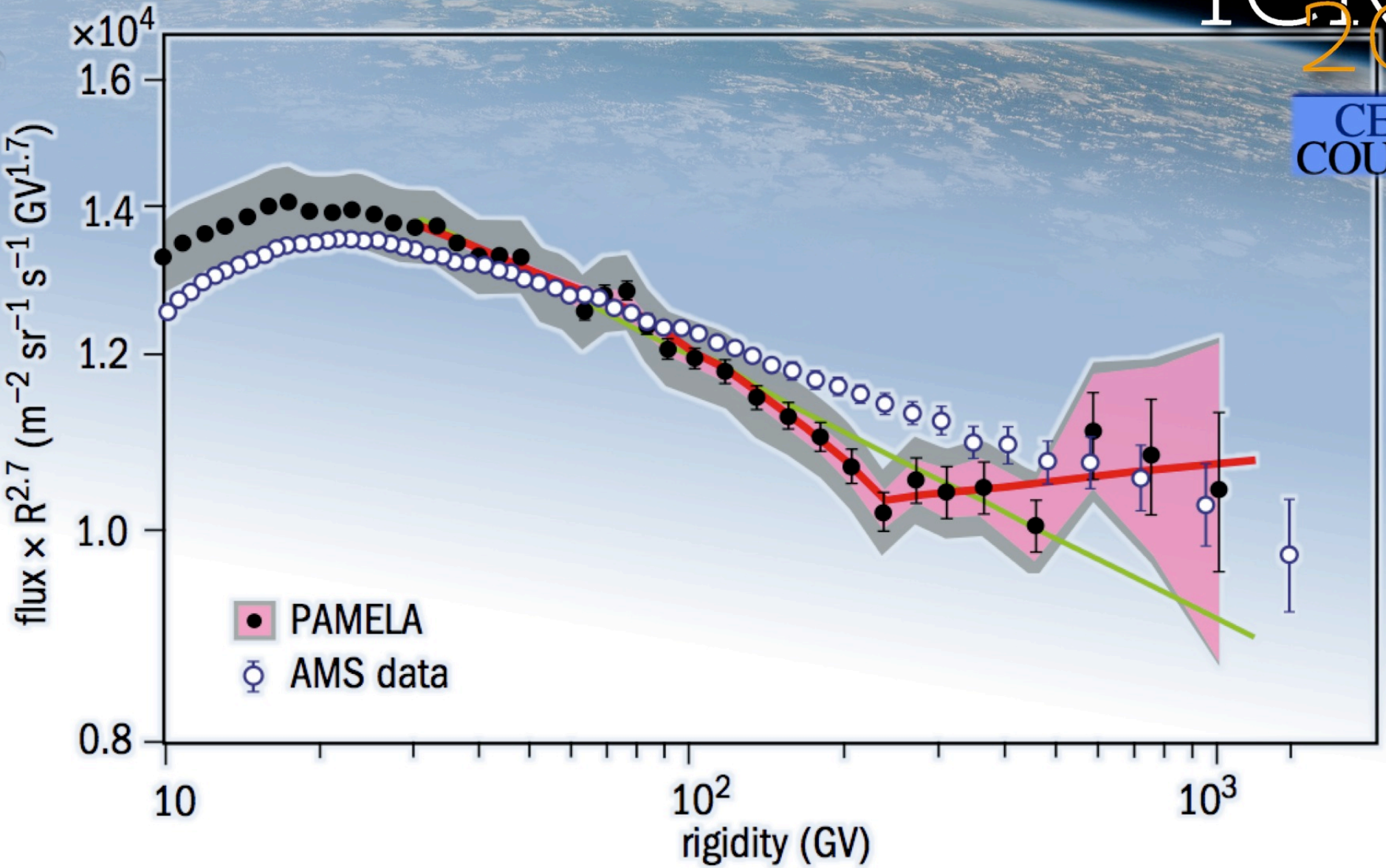


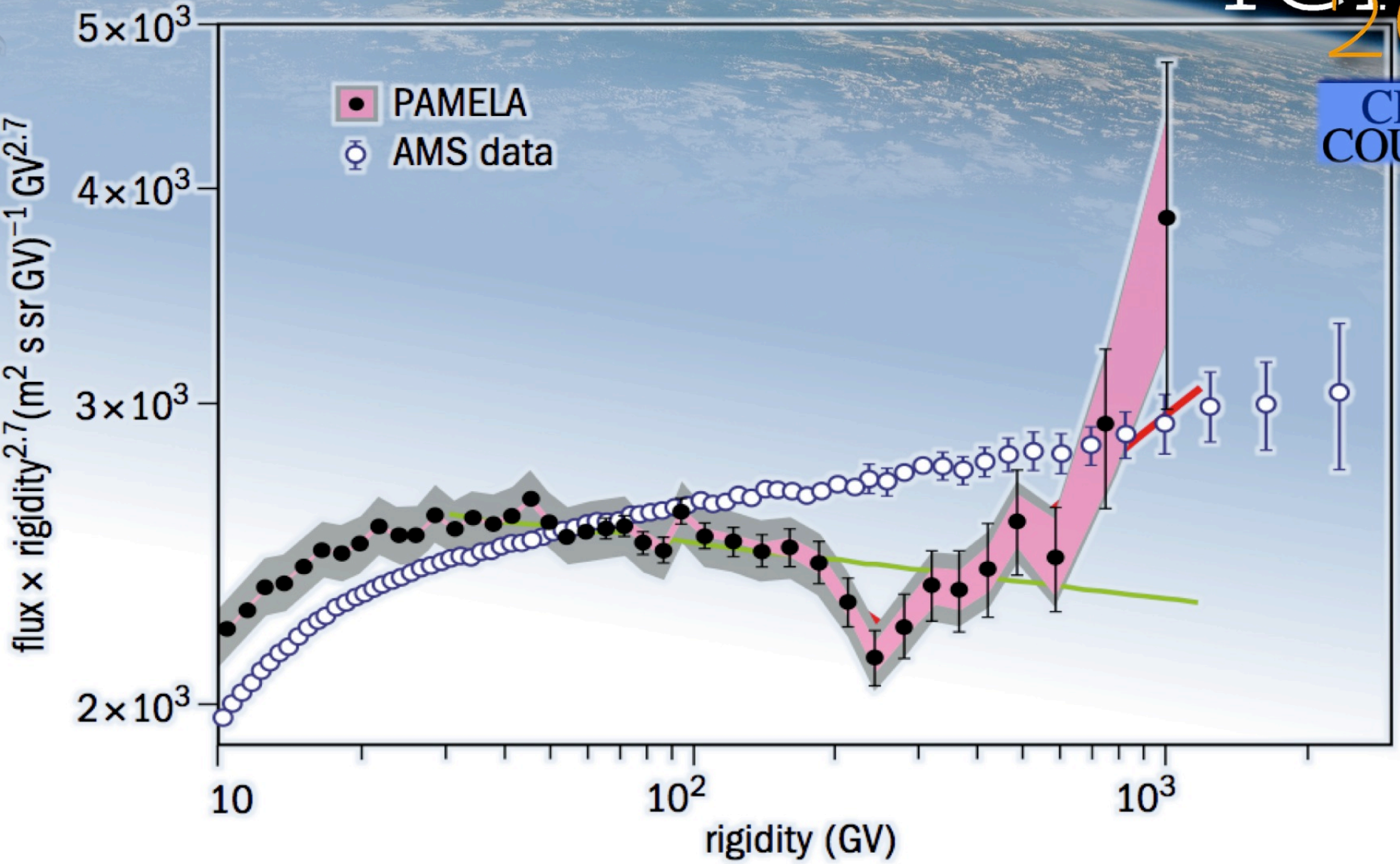
# Proton flux

ICRC 2013

CERN COURIER



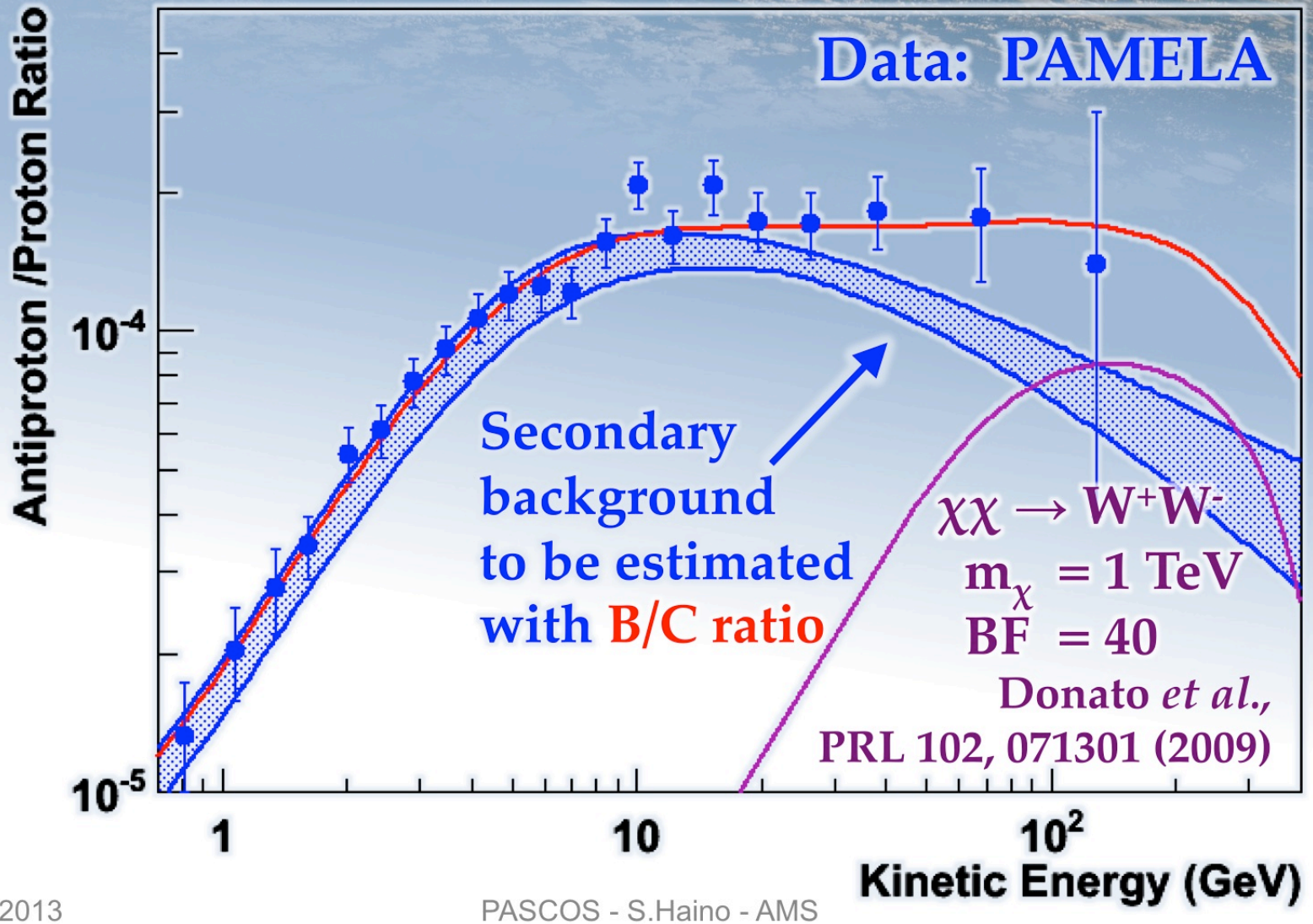
# He flux



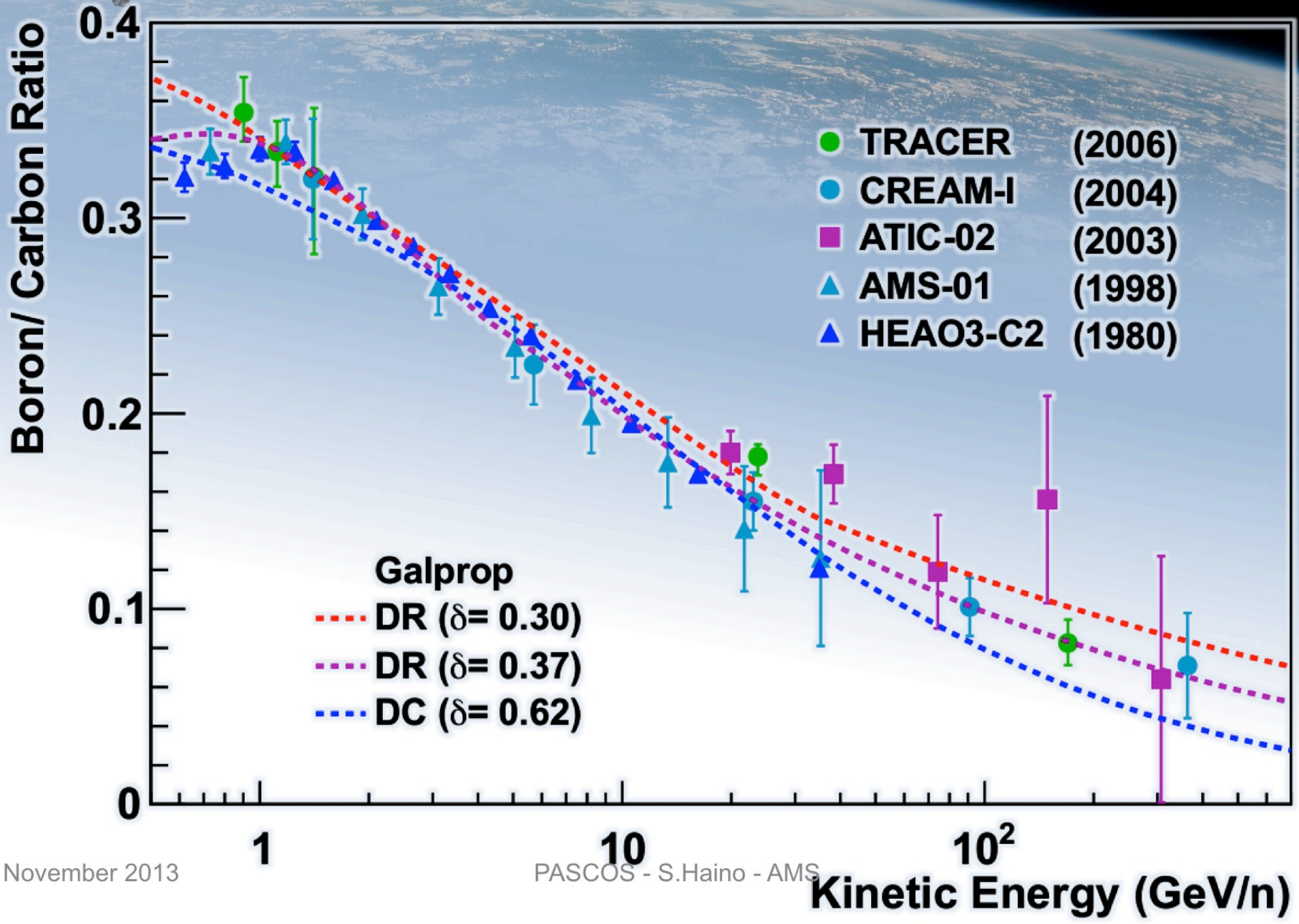

ICRC 2013

CERN COURIER

# DM search with antiprotons



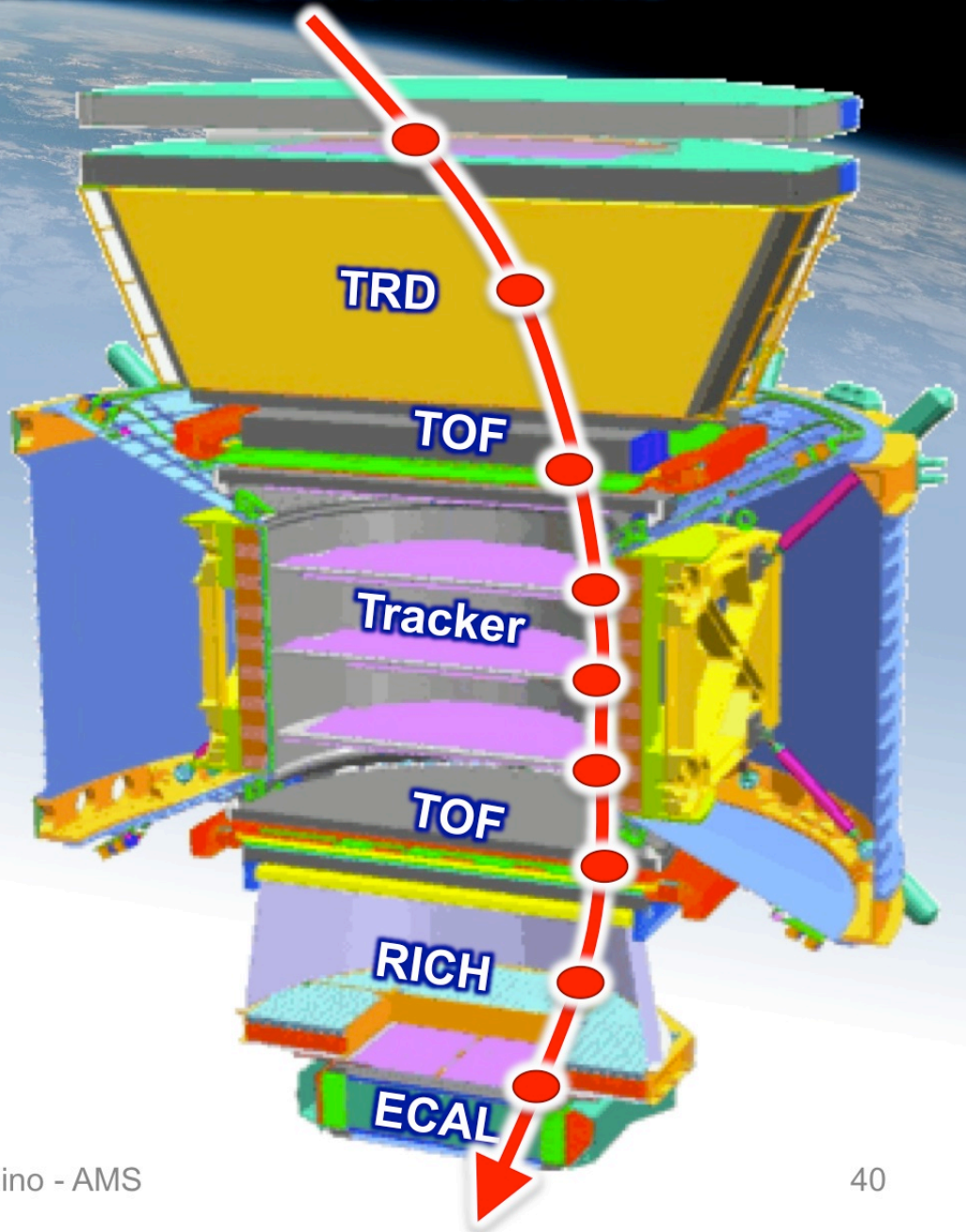
# B/C ratio – before AMS



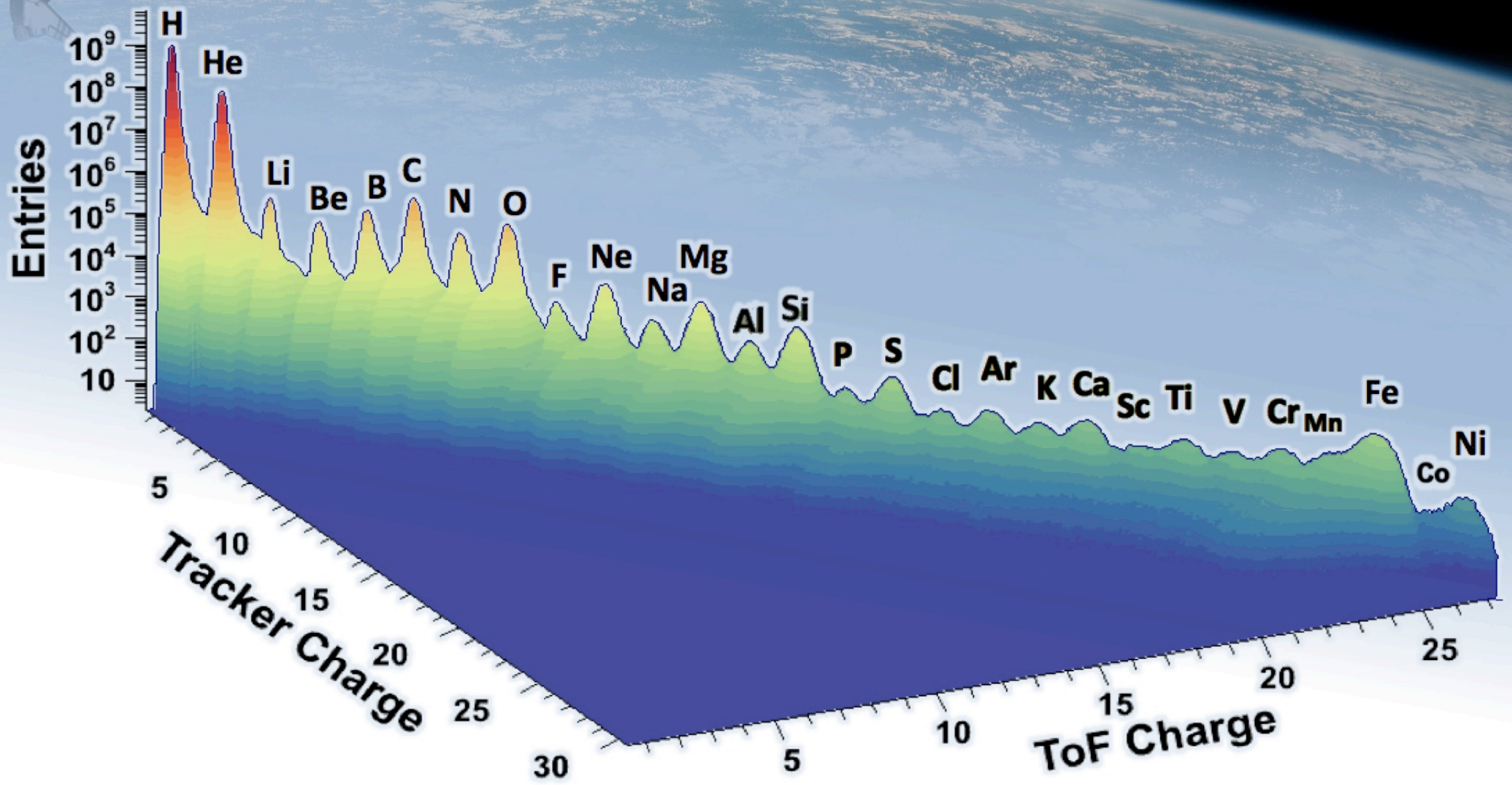
# Multiple charge measurements

**Charge resolution ΔZ (au) for Carbon (Z=6)**

- **Tracker plane 1 : 0.30**
- **TRD : 0.33**
- **Upper TOF : 0.17**
- **Inner plane 2-8 : 0.15**
- **Lower TOF : 0.20**
- **RICH : 0.32**
- **Tracker plane 9 : 0.30**

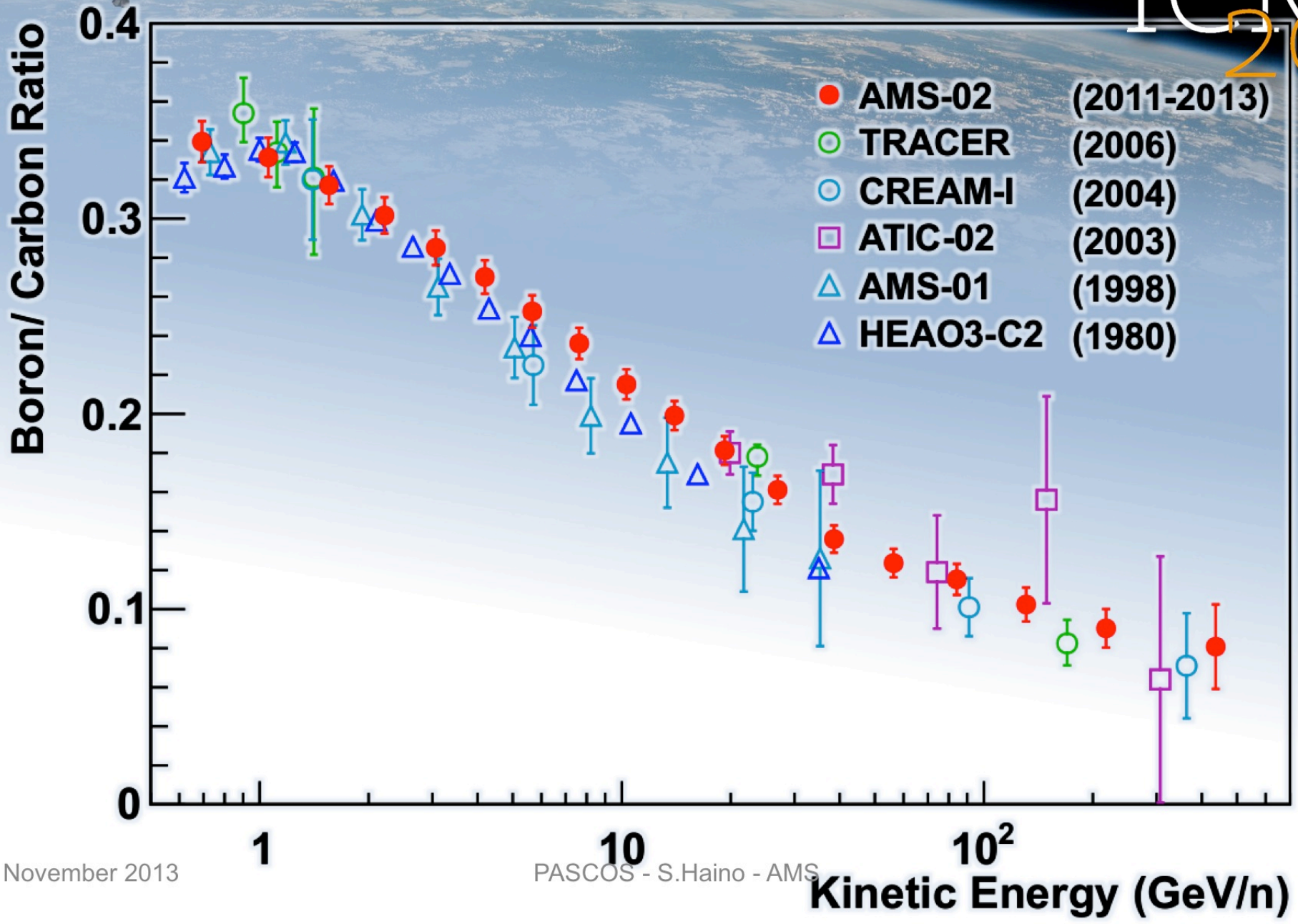


# Nuclei identification in AMS

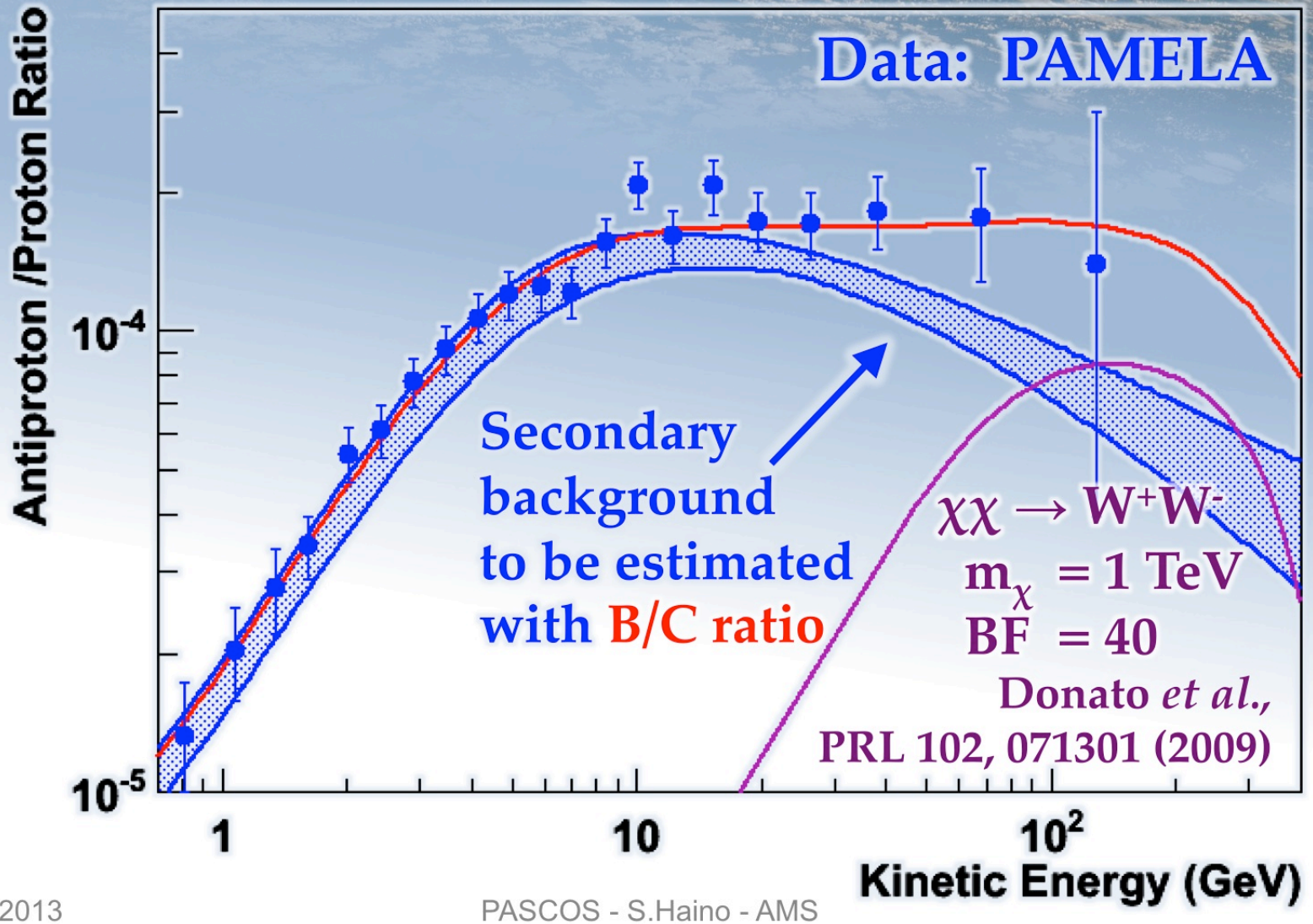


# B/C ratio

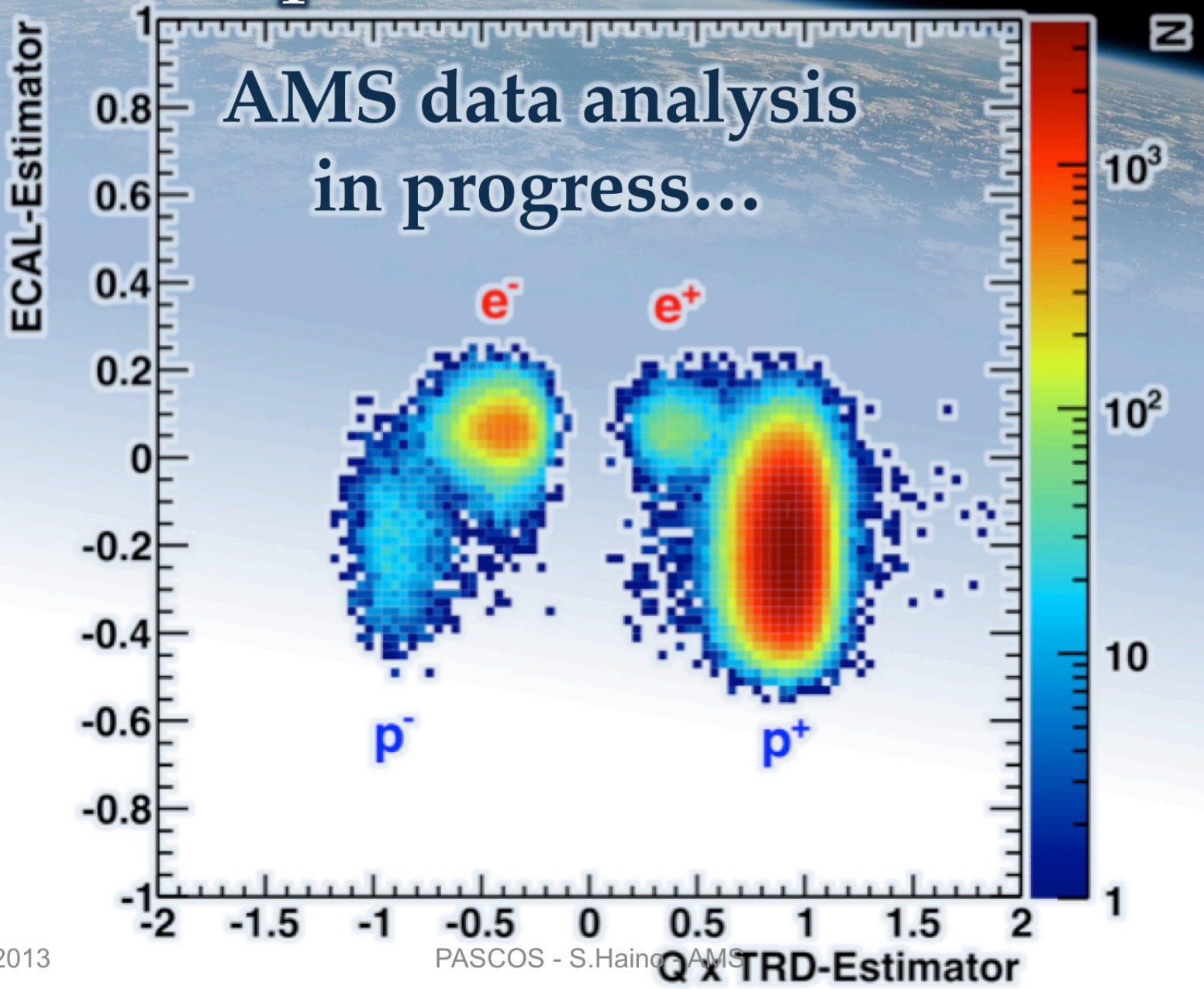
ICRC 2013



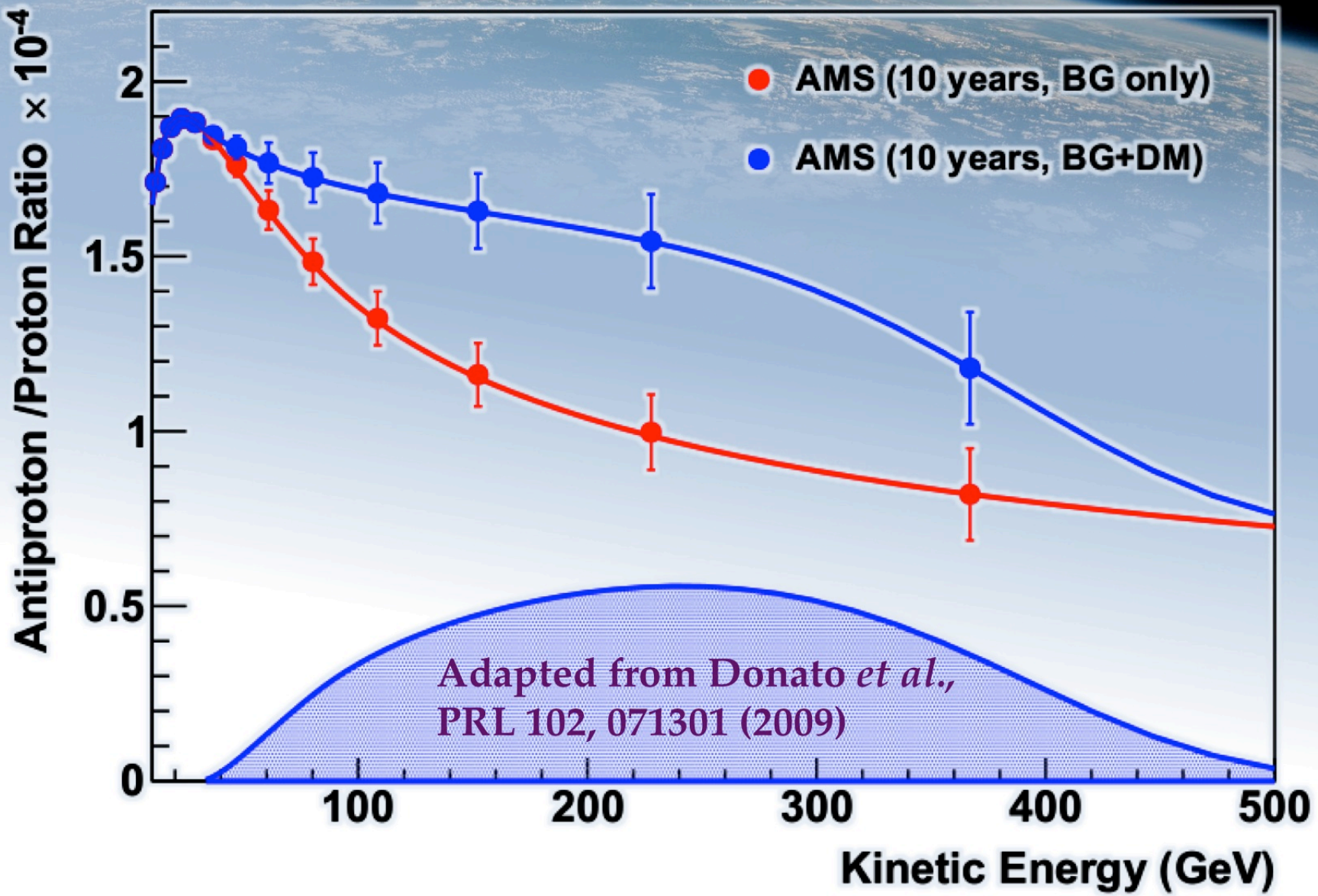
# DM search with antiprotons



# Antiproton identification



# AMS Potential of DM search



# The Cosmos is the Ultimate Laboratory.

The most exciting objective of AMS is to probe the unknown; to search for phenomena which exist in nature that we have not yet imagined nor had the tools to discover ...

S.Ting