The latest results from AMS

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Academia Sinica

AMS collaboration

From Asia, Europa, and America

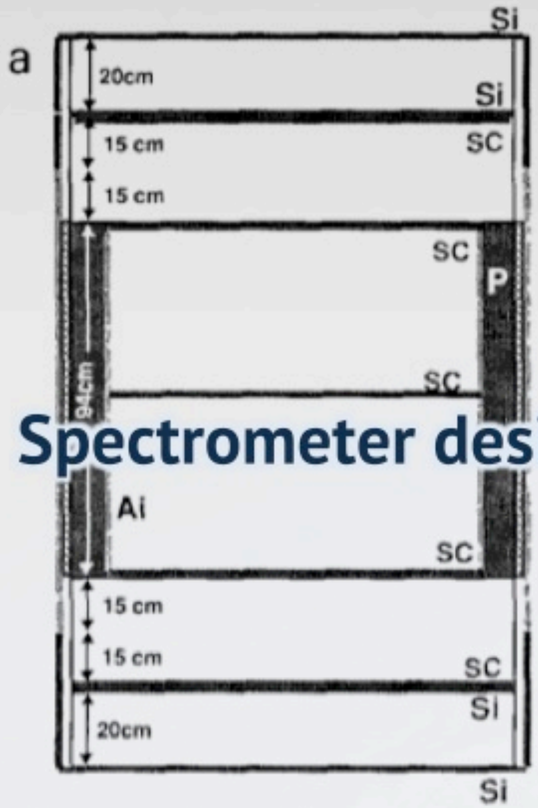
Spokesperson: S.C.C Ting

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
S scintillators for time of flight and $\frac{dE}{dX}$ (charge)
Ai veto scintillators

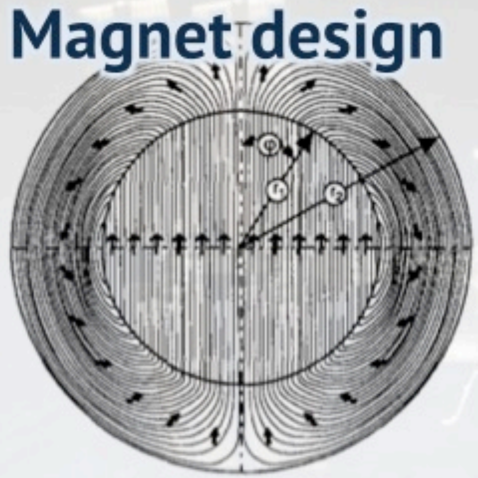


Fig. 6. Magnetic field distribution at a cross-section of the center of the magnet.

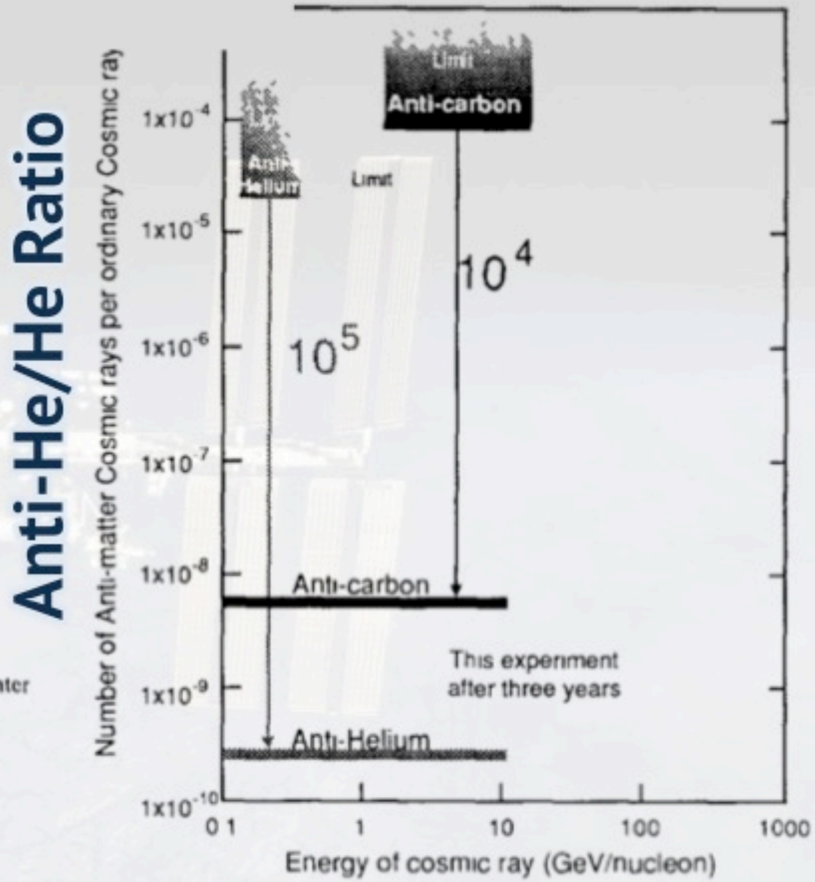


Fig. 30. Current limits and sensitivity of this experiment for antimatter. In addition to the search for antimatter, our detector could be easily modified (particularly for options 2 and 4) to explore the search of $\bar{p}$ and e^+.

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

It took ~18 years

For

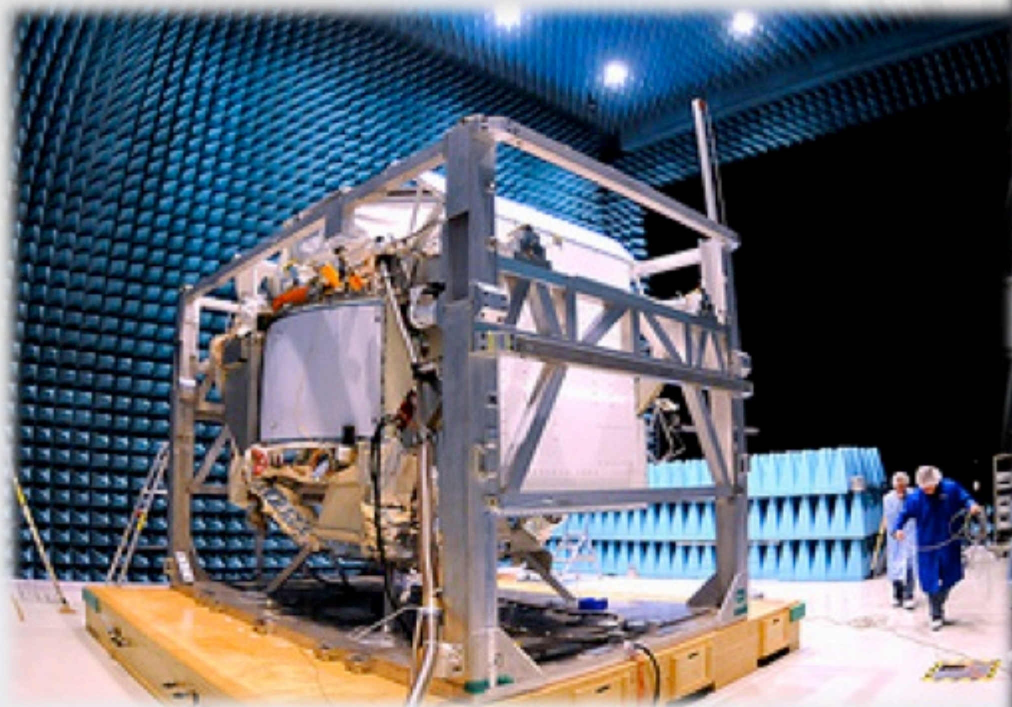
- Design
- Construction
- Space qualification tests
  of sub-systems

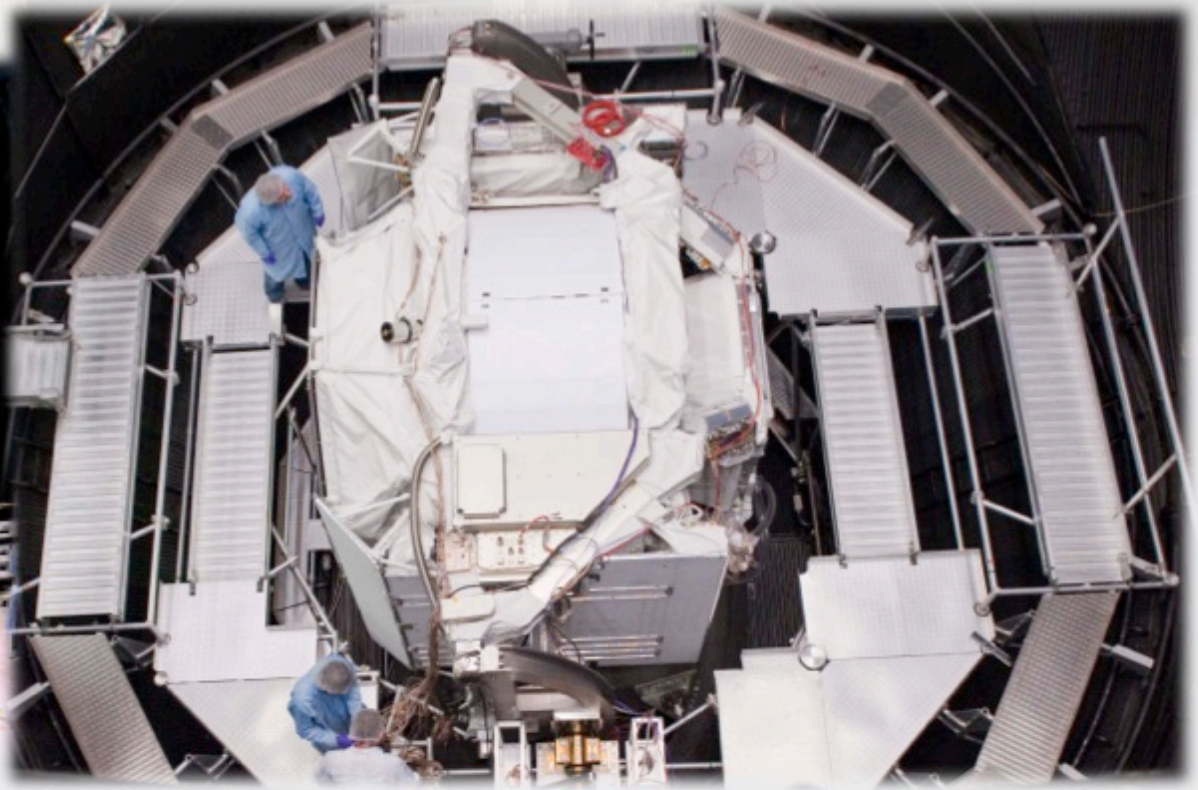
  and
- Integration of AMS-02

Space qualification at ESA

Mar~Apr/2010

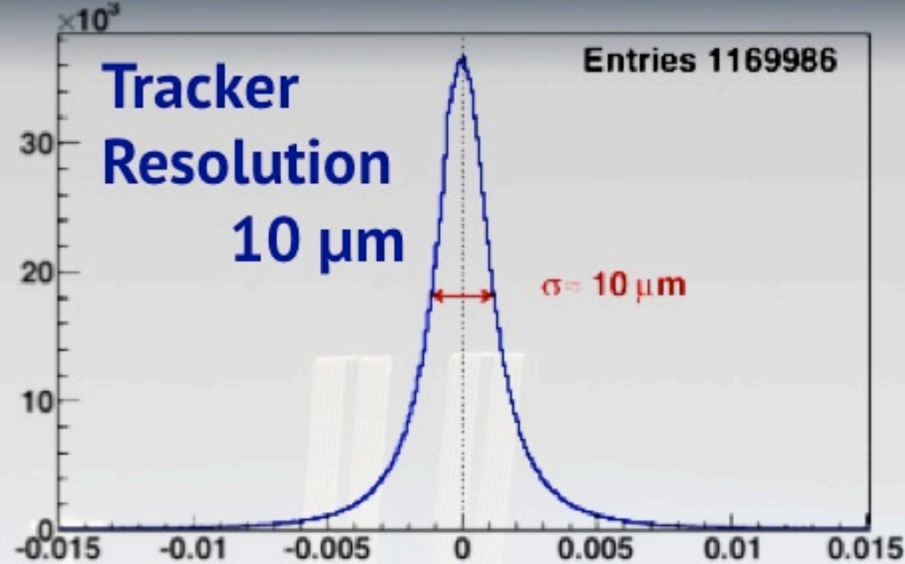
- **EMI (Electro Magnetic Interference) test**
- **Thermal Vacuum test**
  Pressure < 10^{-9} bar, Temperature -40 ~ +90 °C

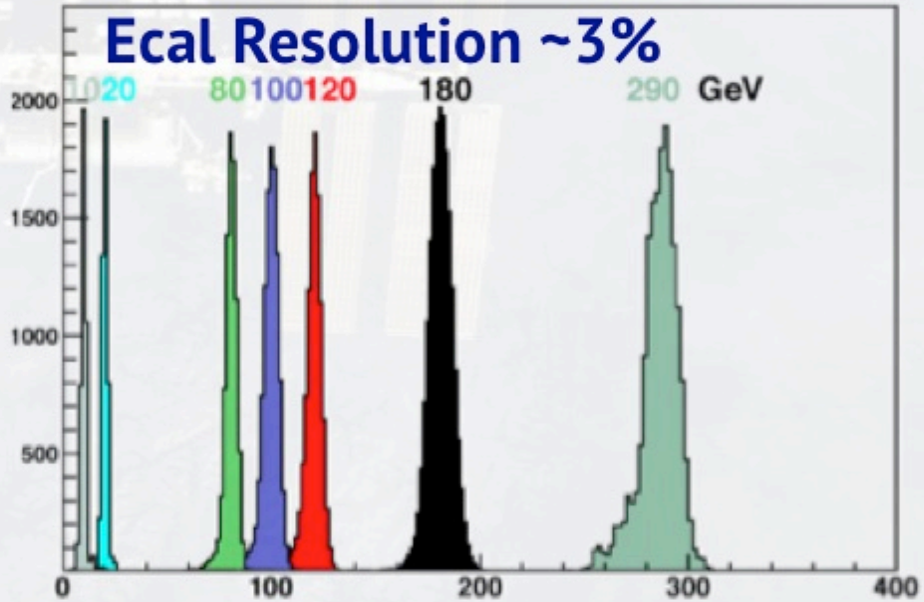




CERN beam test (2010)

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





AMS installed in Space Shuttle

Kennedy Space Center 2010~2011

Final inspection by S. Ting

Closing Endeavour's Payload Bay Doors at the Launch Pad

Launch of AMS-02

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

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...

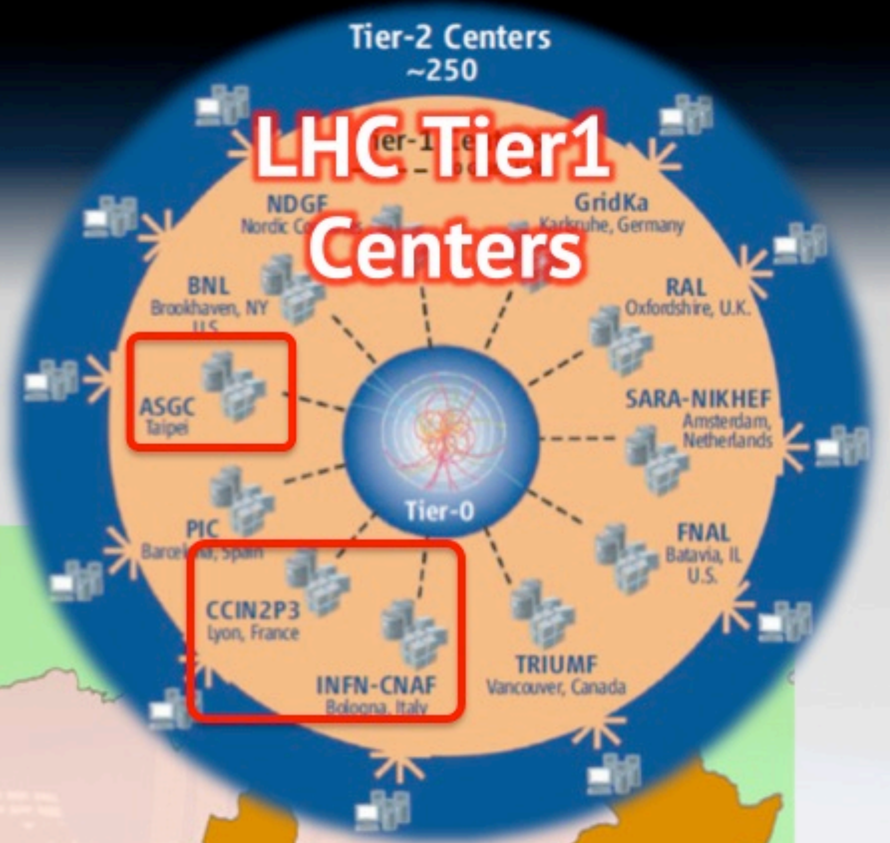
Operation and data link

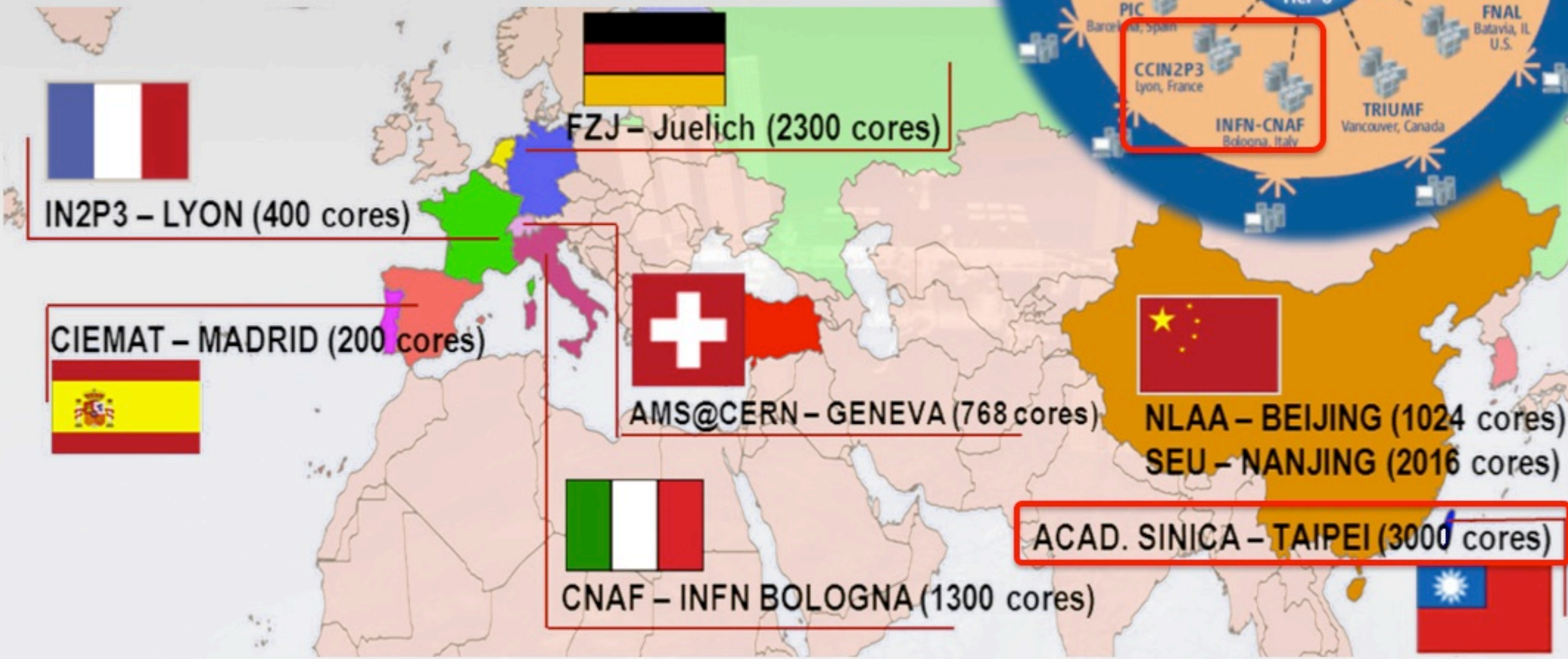
Ku-Band (down):
Events <10Mbit/s>

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

AMS computing

LHC Tier 1 : Academia Sinica, IN2P3, INFN



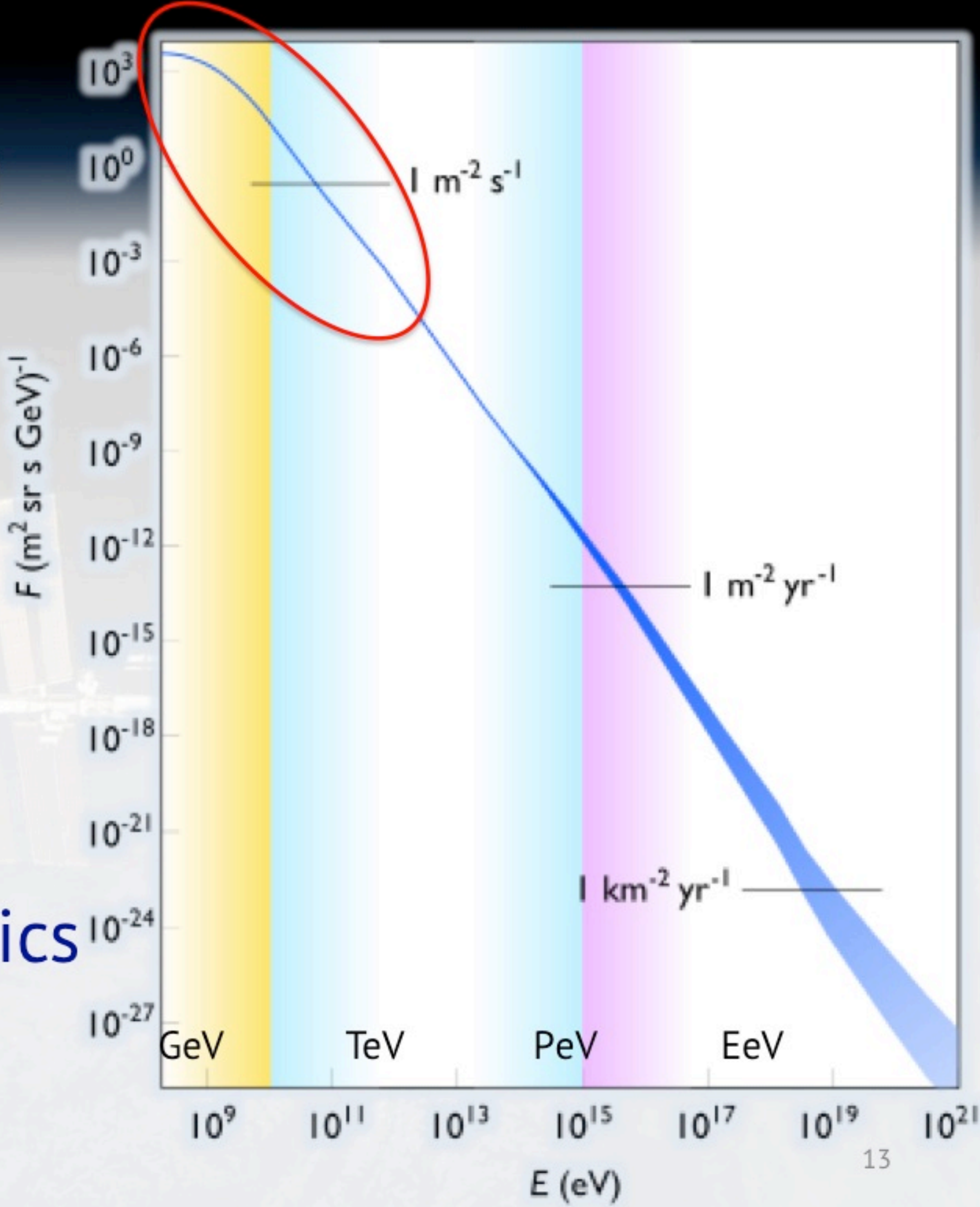


Cosmic-ray energy spectrum

GeV-TeV :

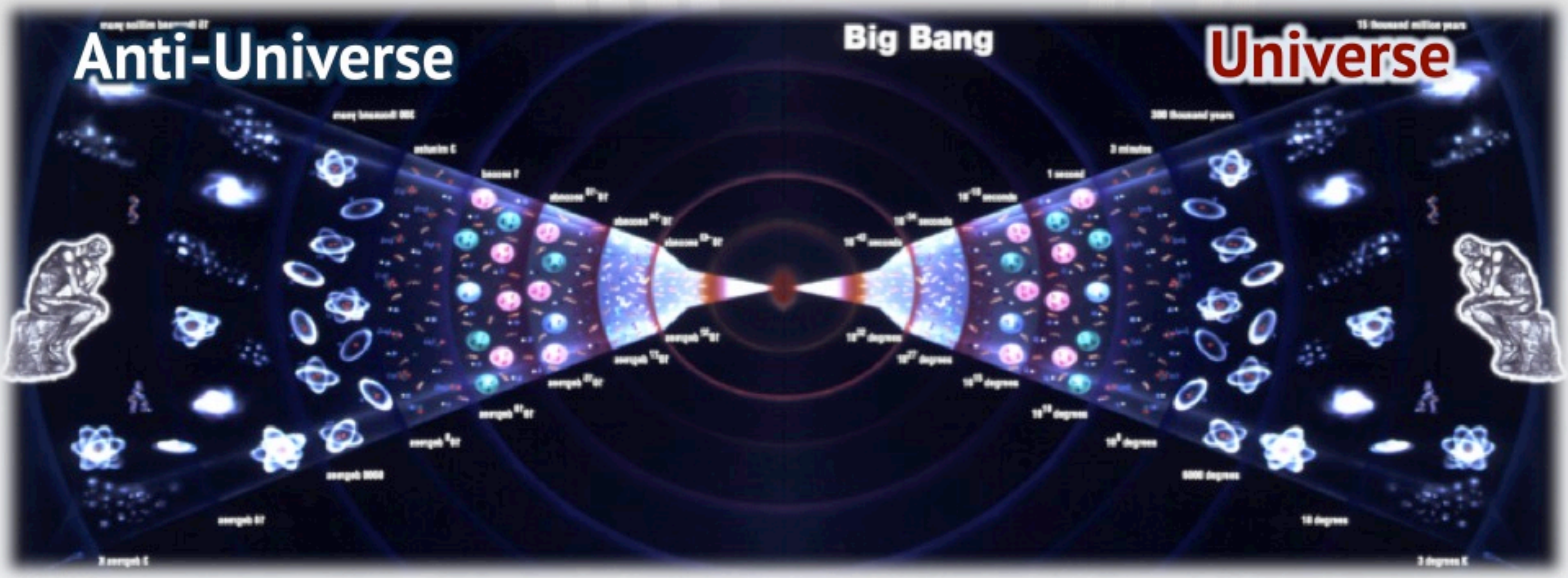
- Direct precision measurements of cosmic-ray energy spectra

- Fundamental physics with antiparticles



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



Matter/antimatter asymmetry

Direct search | **Search for Baryogenesis**

Sakharov conditions

CP Violation
BELLE, BaBar
KTeV, NA-48
CDF, D0

Proton decay
Super K
($\tau_p > 6.6 \times 10^{33}$ yr)

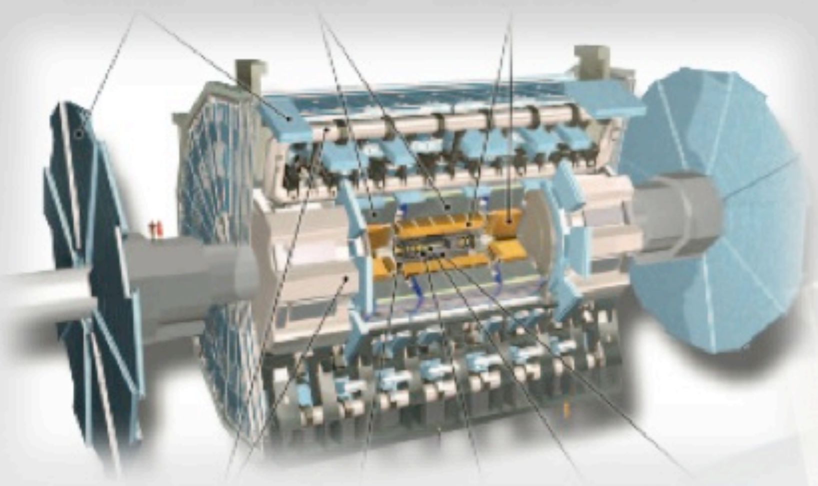
↓

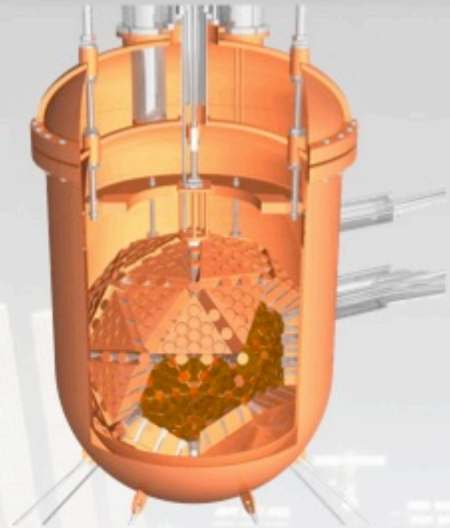
LHC-b, ATLAS, CMS

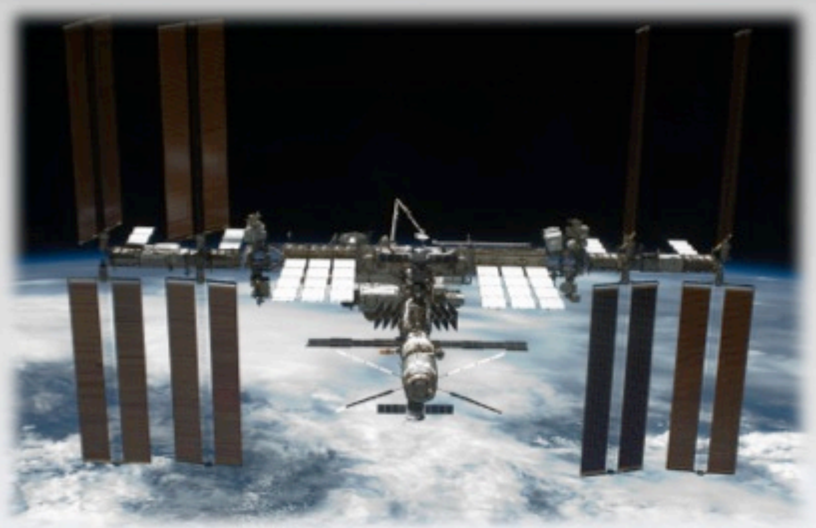
↓

Balloon and space (AMS, BESS, ...)

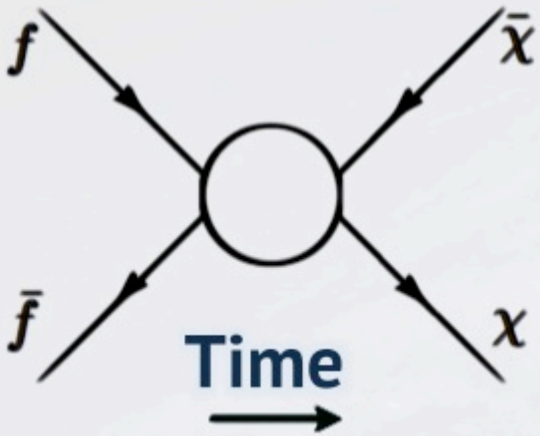
Dark Matter searches



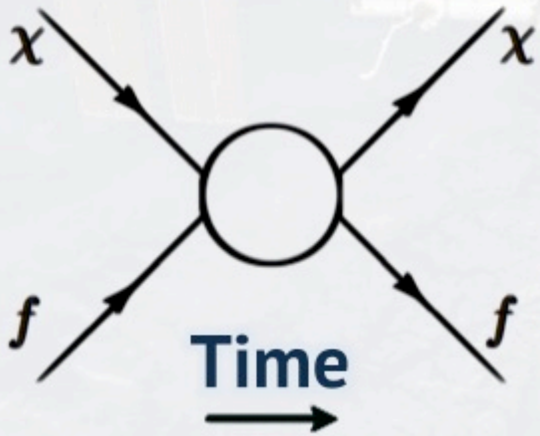




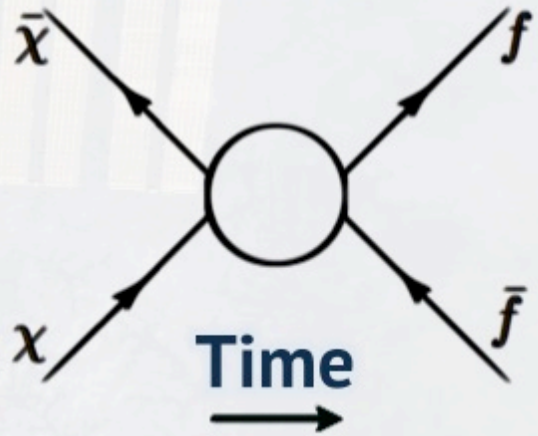
Colliders



Direct search

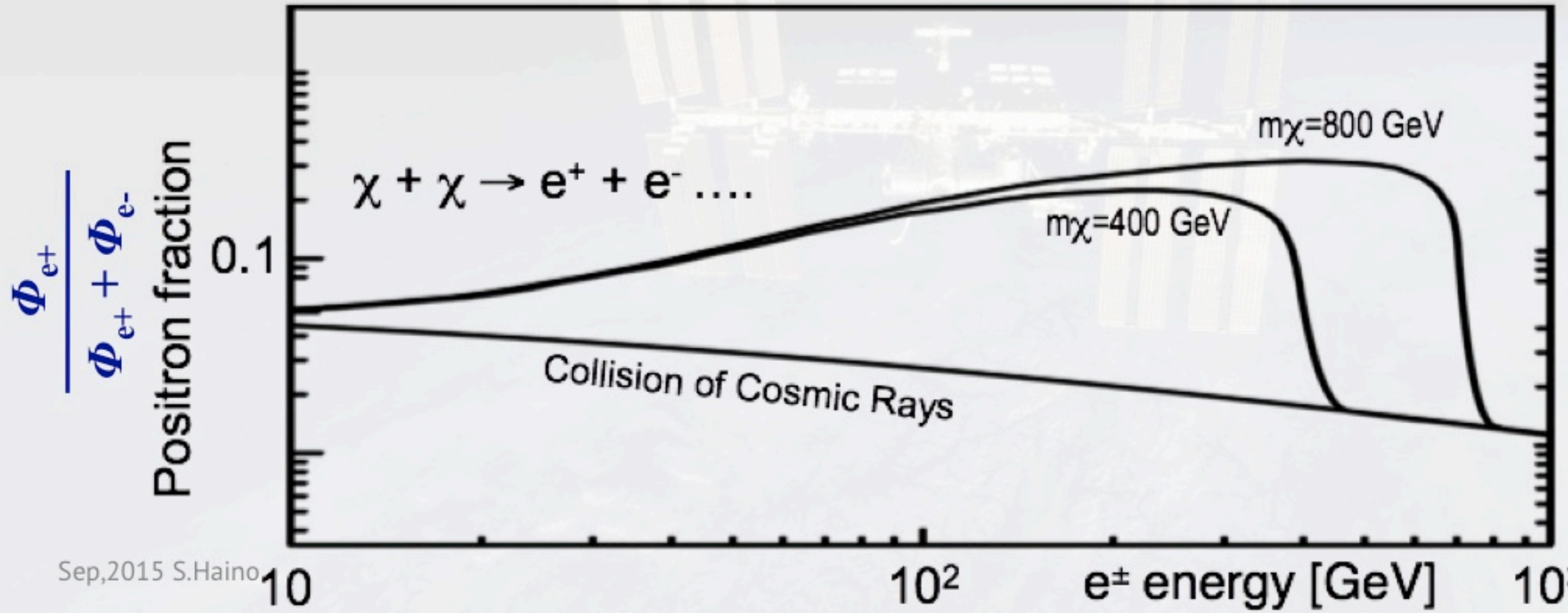


Indirect search



Cosmic-ray Positrons

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

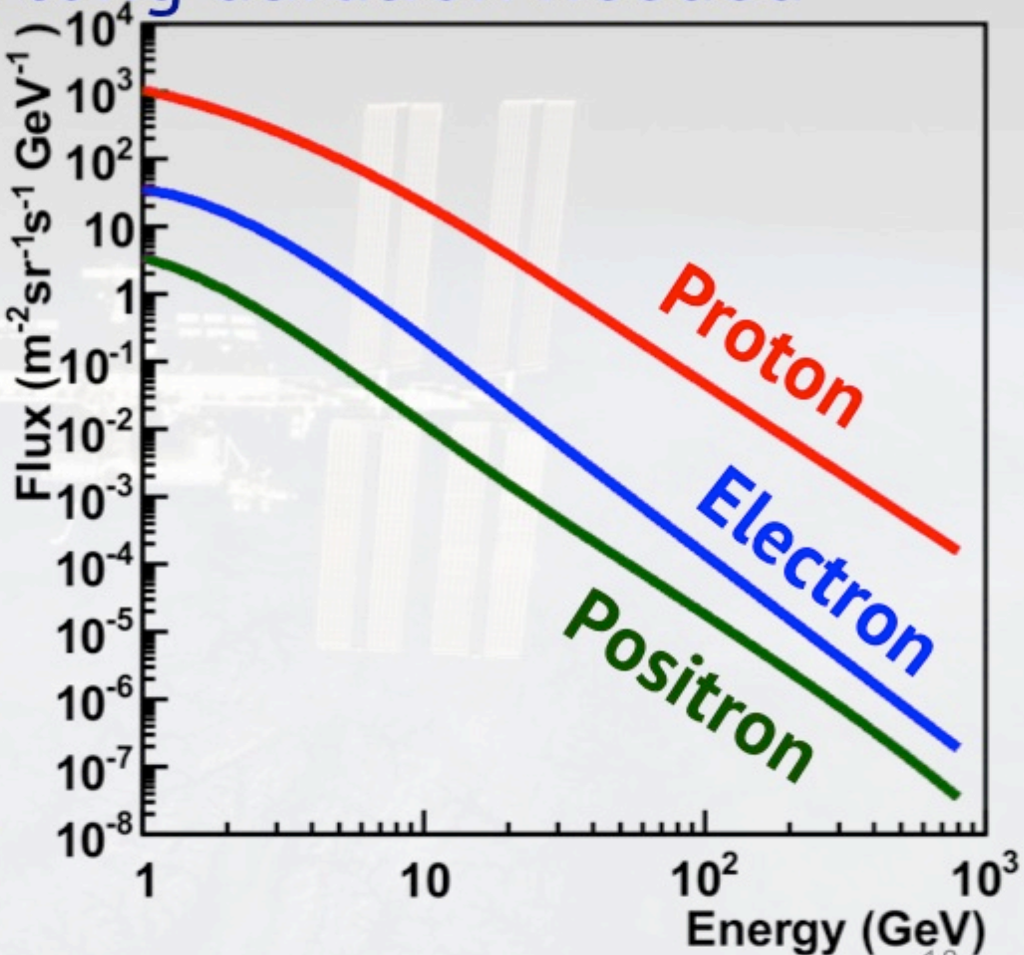


Difficulties – CR positron measurement

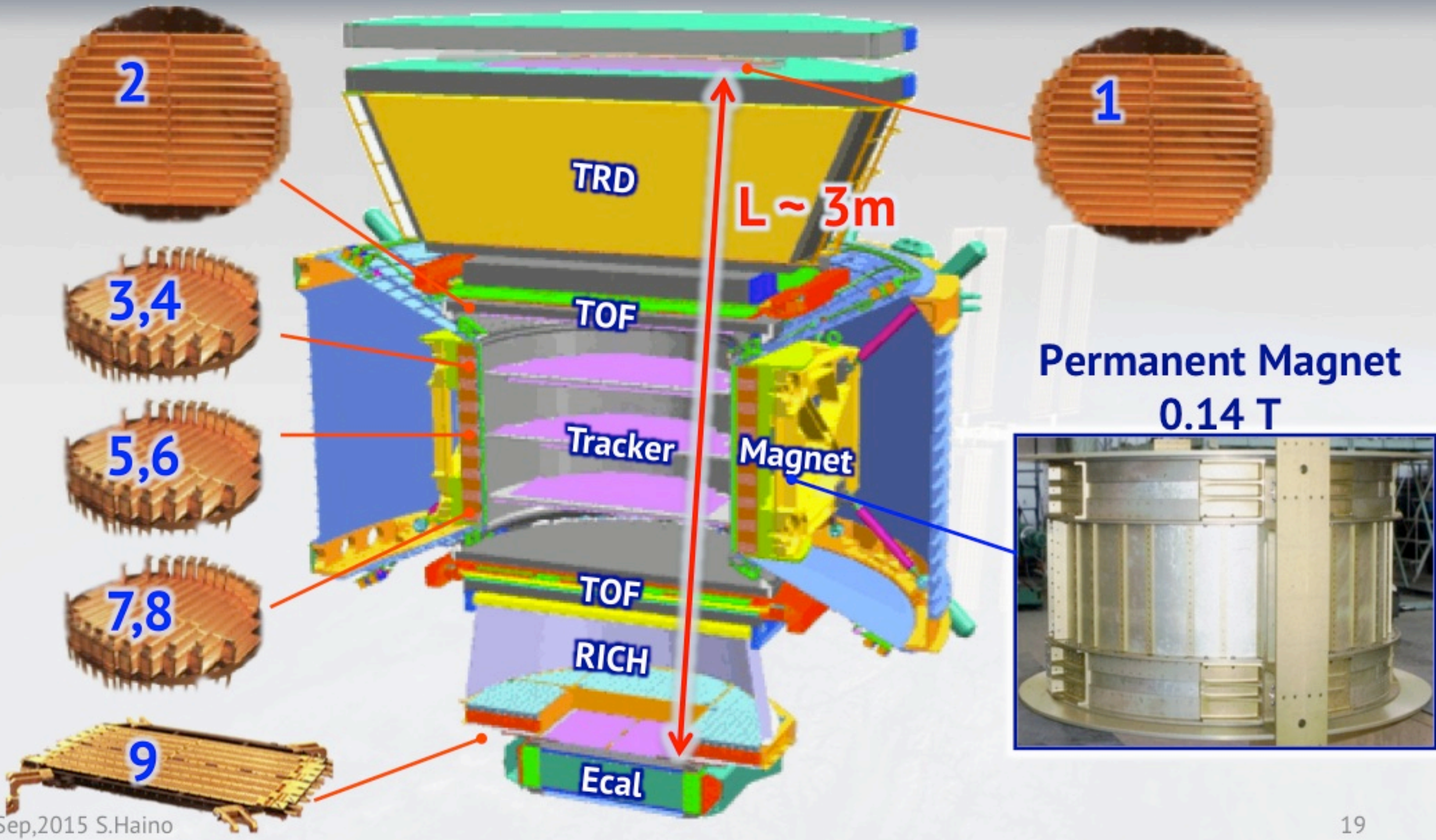
- **Low abundance : 0.01~0.1 % of Cosmic Rays**
  → Large acceptance and long duration needed
- **Large backgrounds**

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

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



AMS – 9 layers of silicon tracker

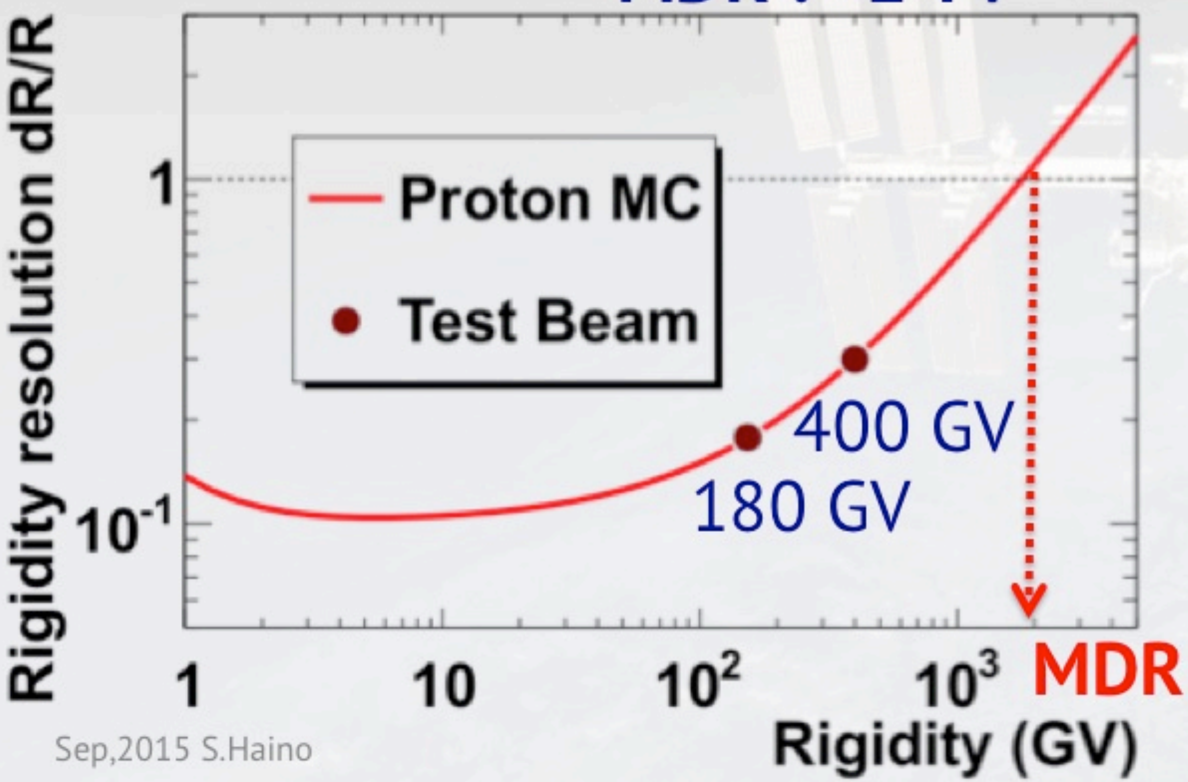


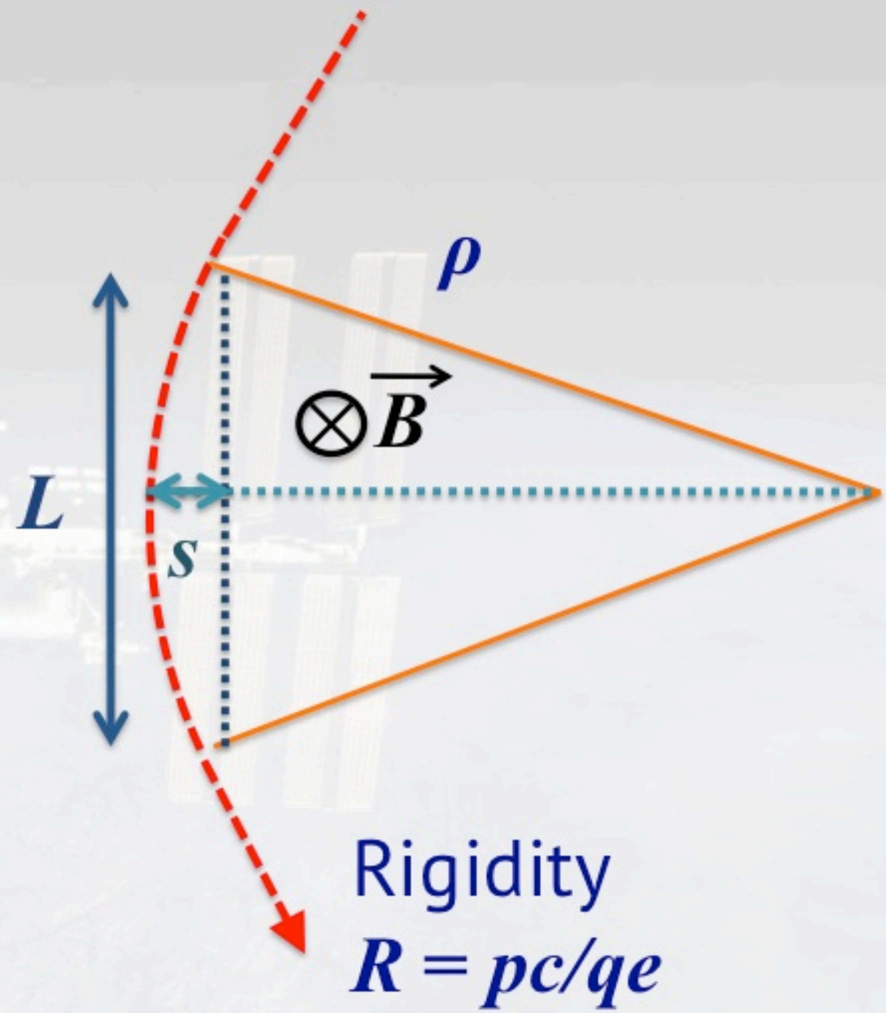
Magnetic Rigidity Measurement

$$\Delta(1/R) = \frac{\Delta R}{R^2} \approx \frac{8\Delta s}{0.3BL^2}$$

Maximum Detectable Rigidity

MDR : ~2 TV





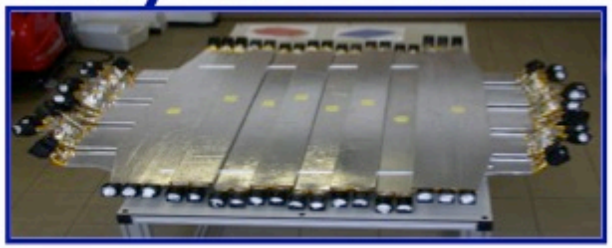
Rigidity

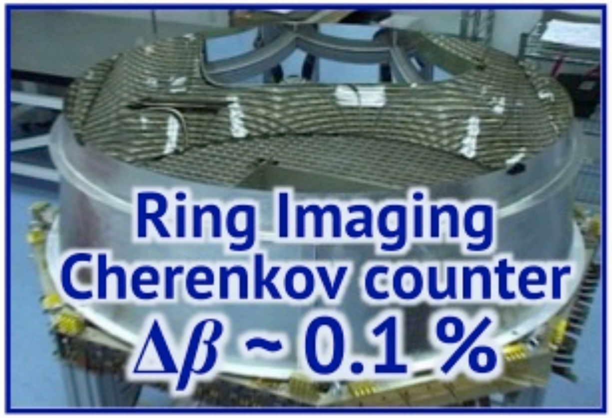
$R = pc/qe$

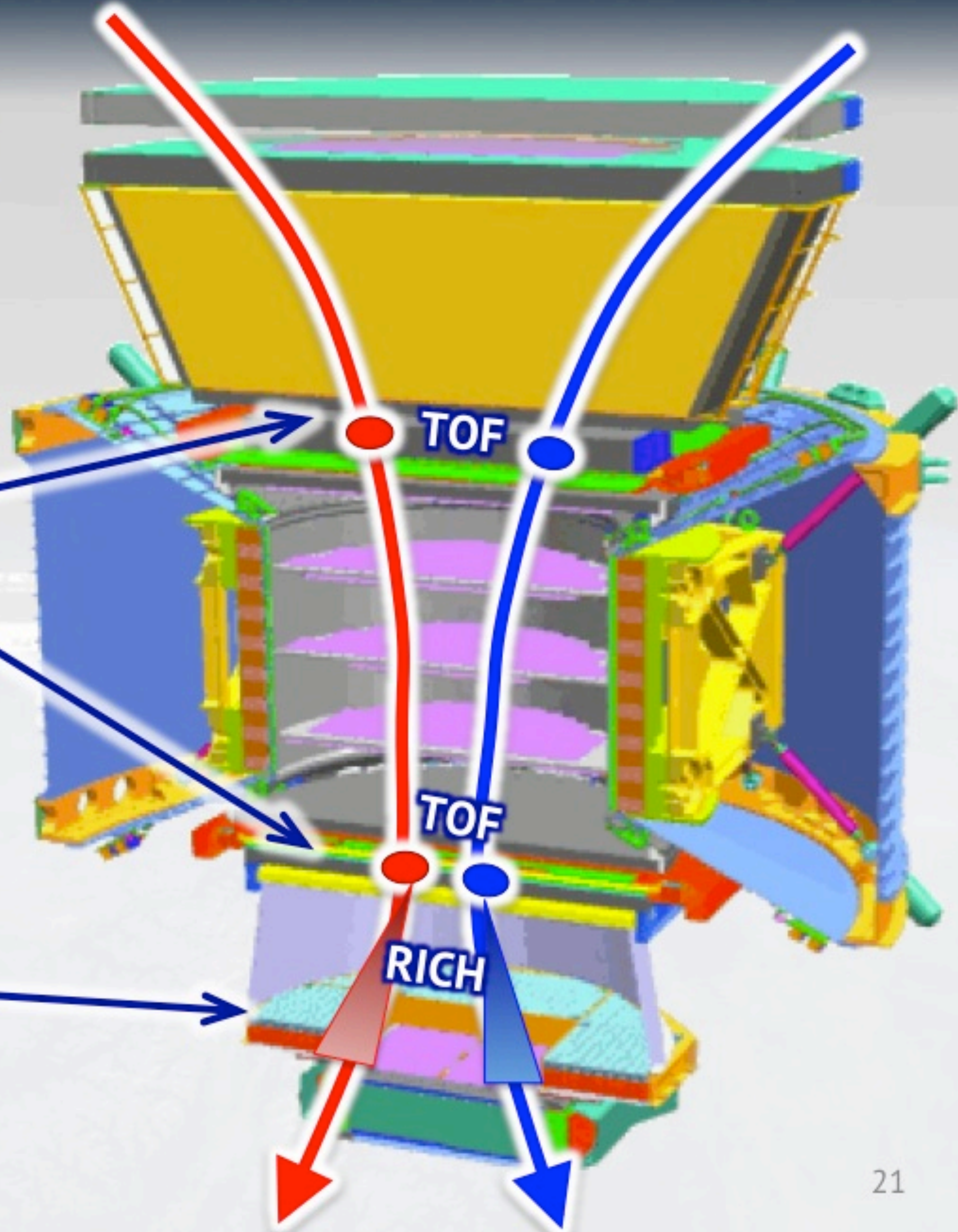
TOF and RICH

- **Determine direction and measure velocity**

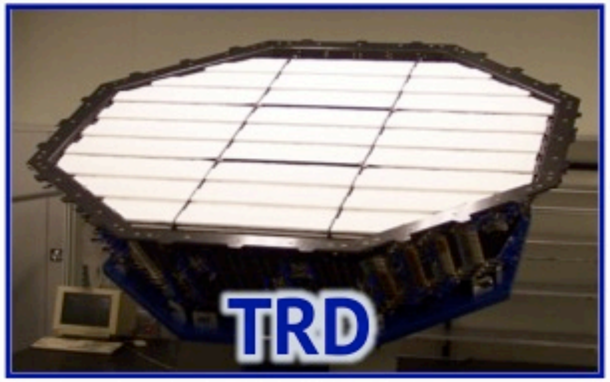
Time Of Flight
$\Delta\beta$: 1~ 2 %

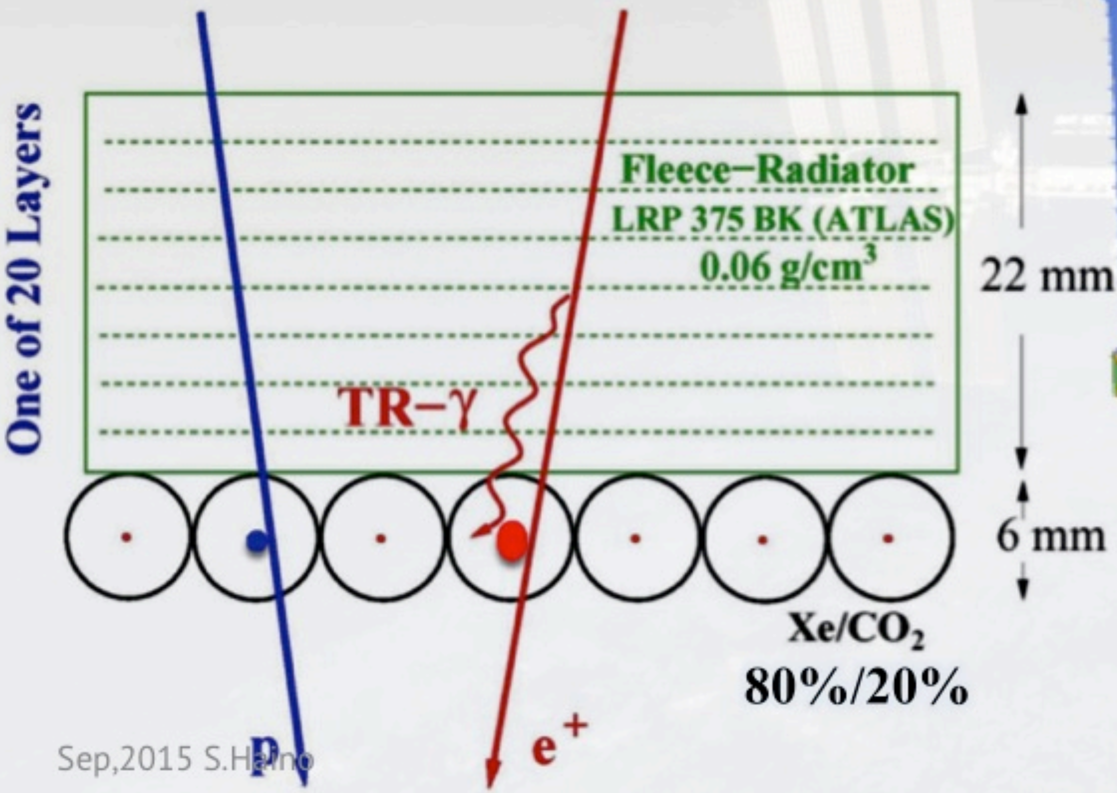


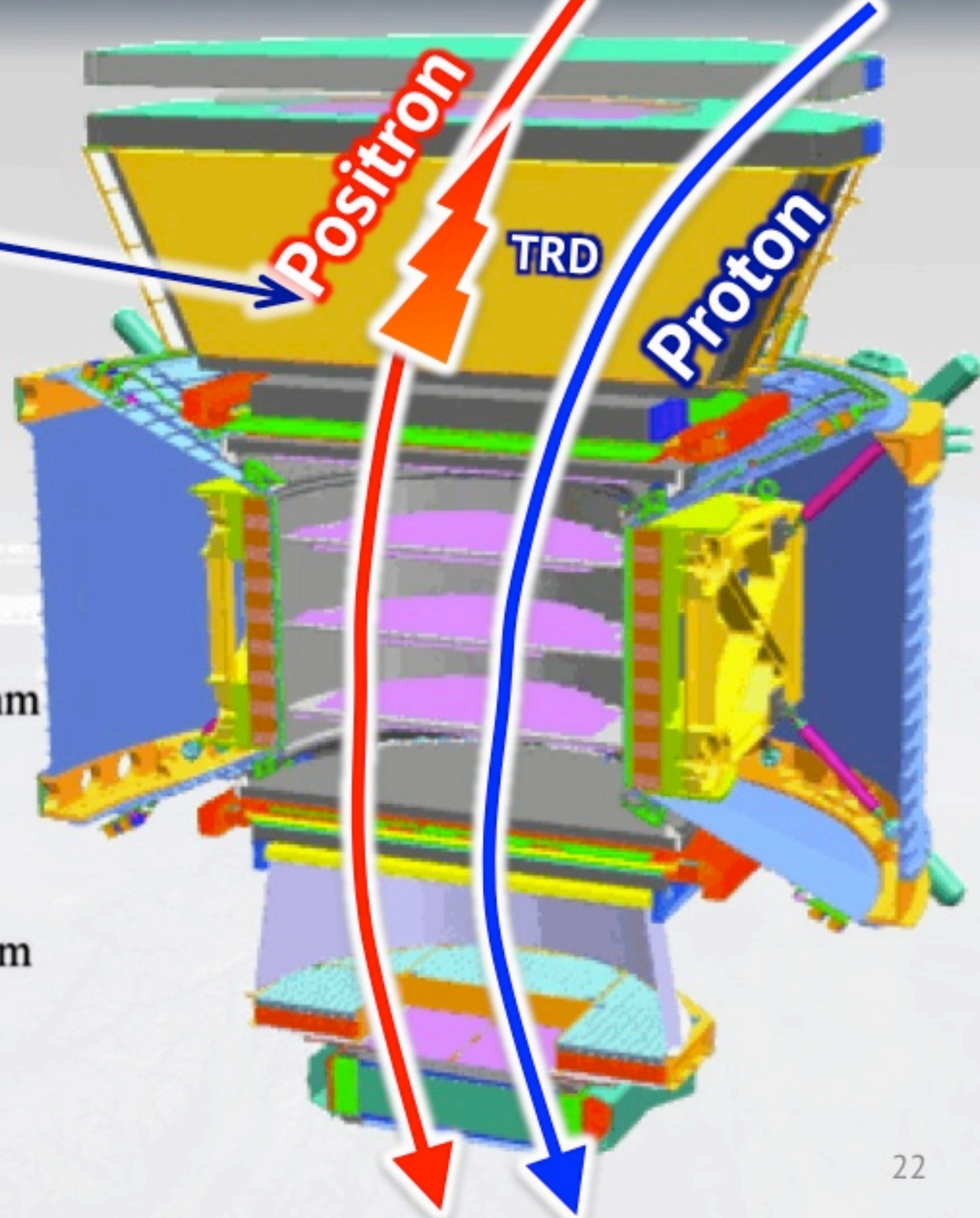




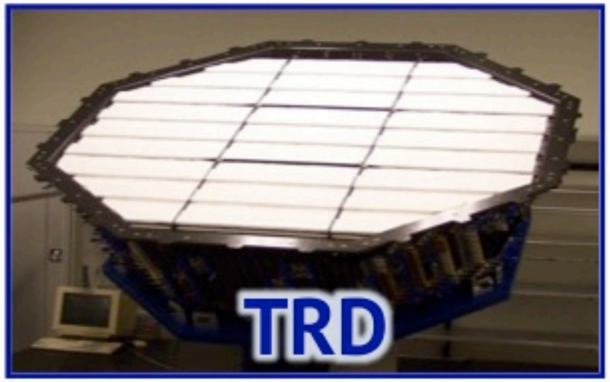
Transition Radiation Detector (TRD)

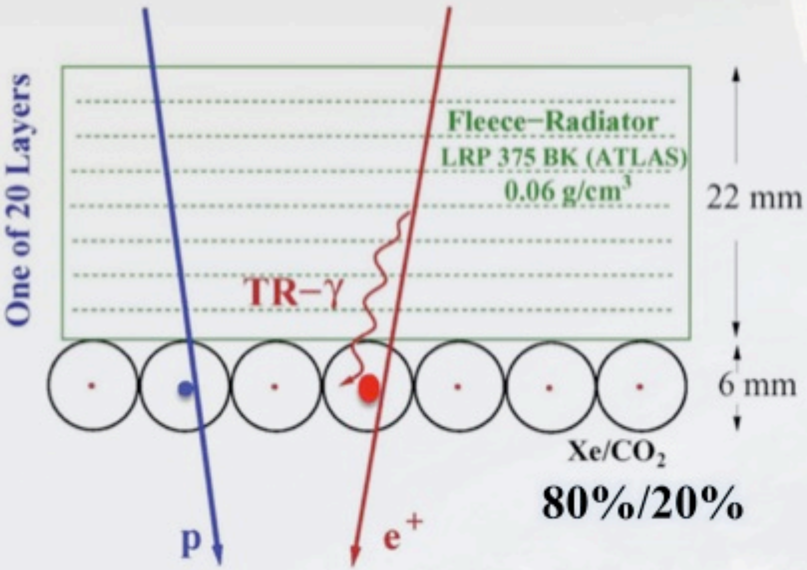


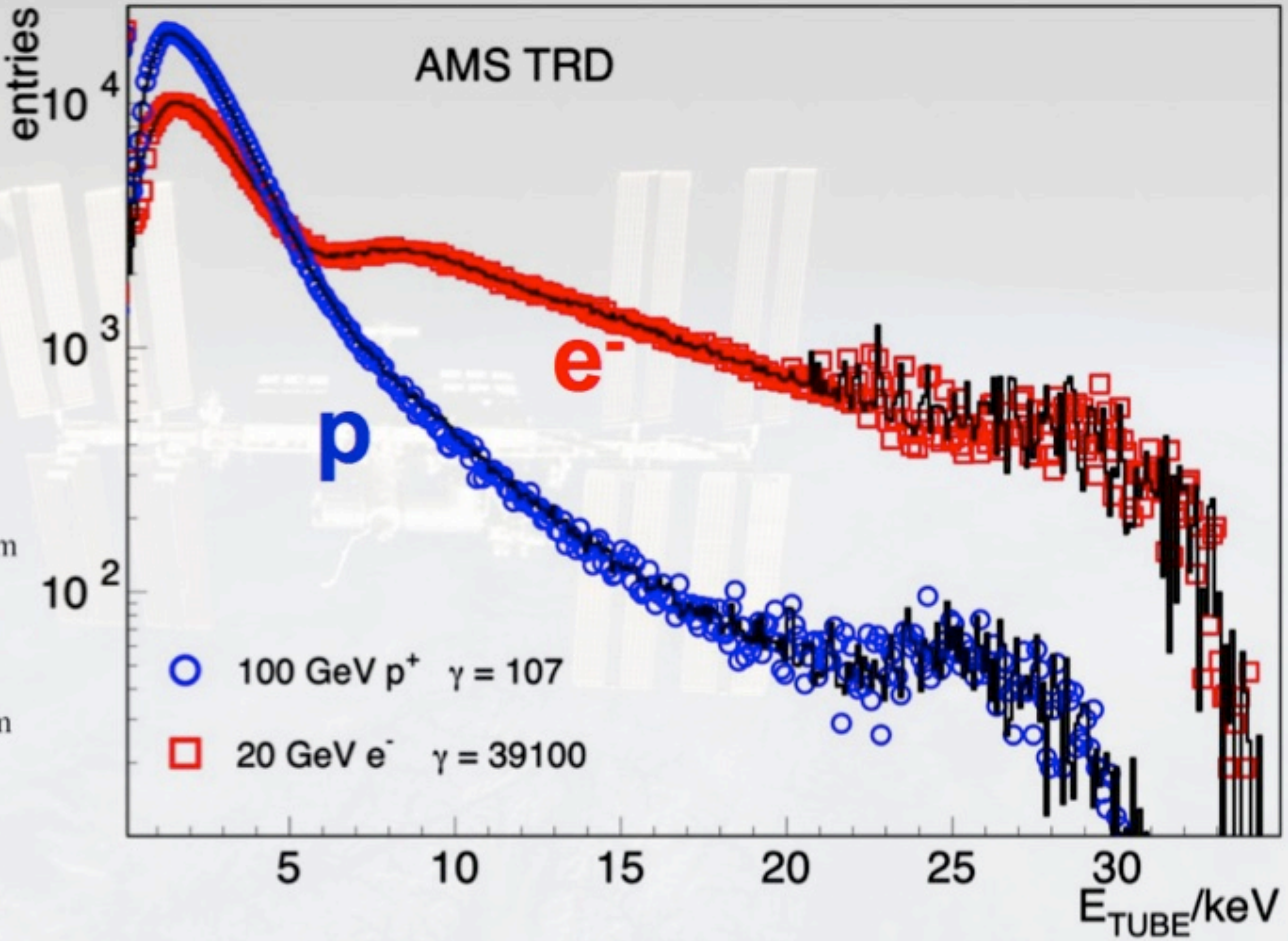




TRD signal


TRD

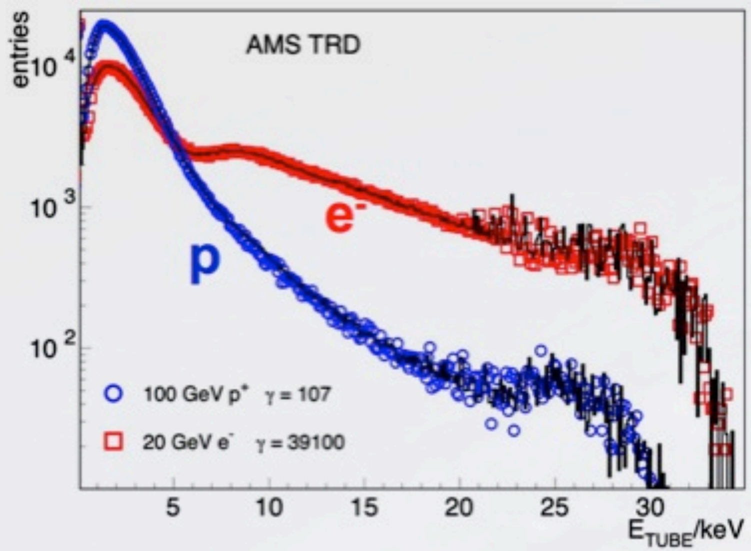

One of 20 Layers
Fleece−Radiator
LRP 375 BK (ATLAS)
0.06 g/cm³
22 mm
TR−γ
6 mm
Xe/CO₂
80%/20%
p
e⁺


AMS TRD
entries
10⁴
10³
10²
e⁻
p
100 GeV p⁺ γ = 107
20 GeV e⁻ γ = 39100
5
10
15
20
25
30
E_TUBE/keV

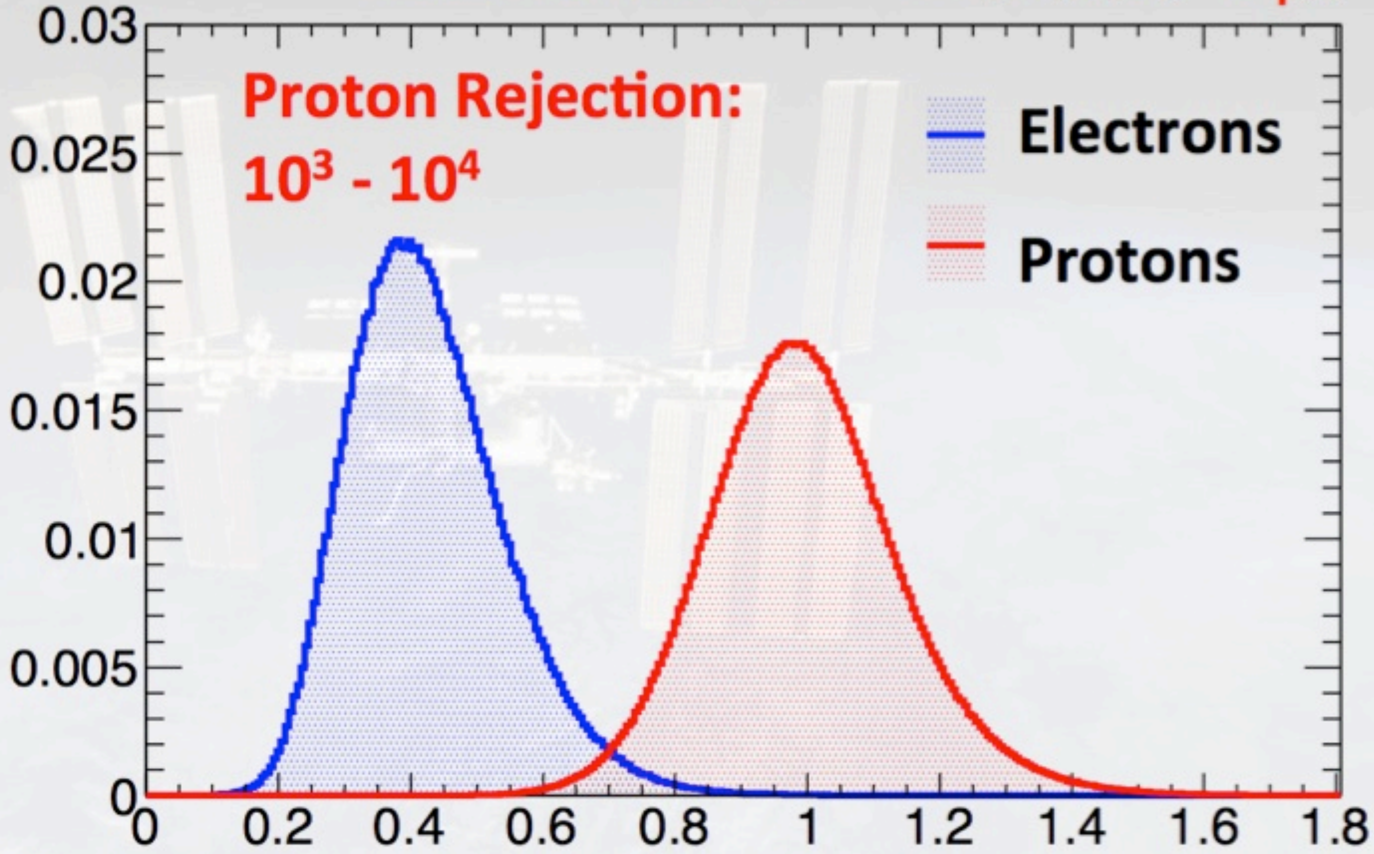
TRD estimator

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

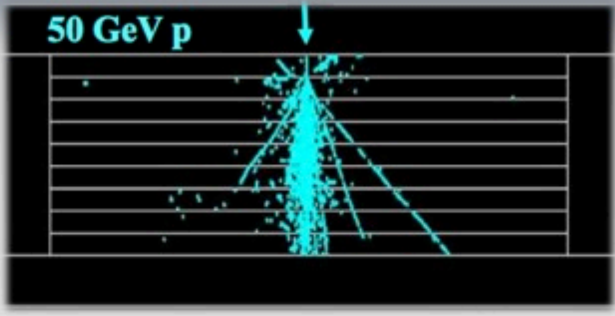
$$P_p = \sqrt[n]{\prod_i^n P_p^{(i)}(A)}$$

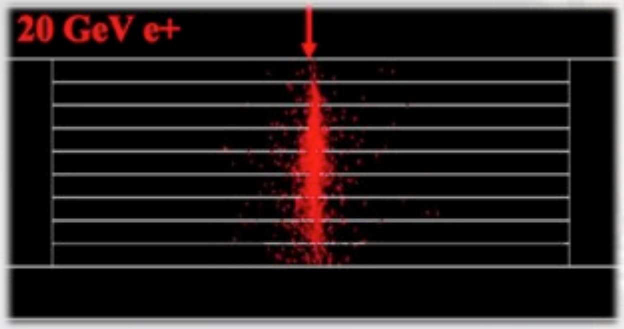


TRD estimator = $-\ln(P_e/(P_e+P_p))$

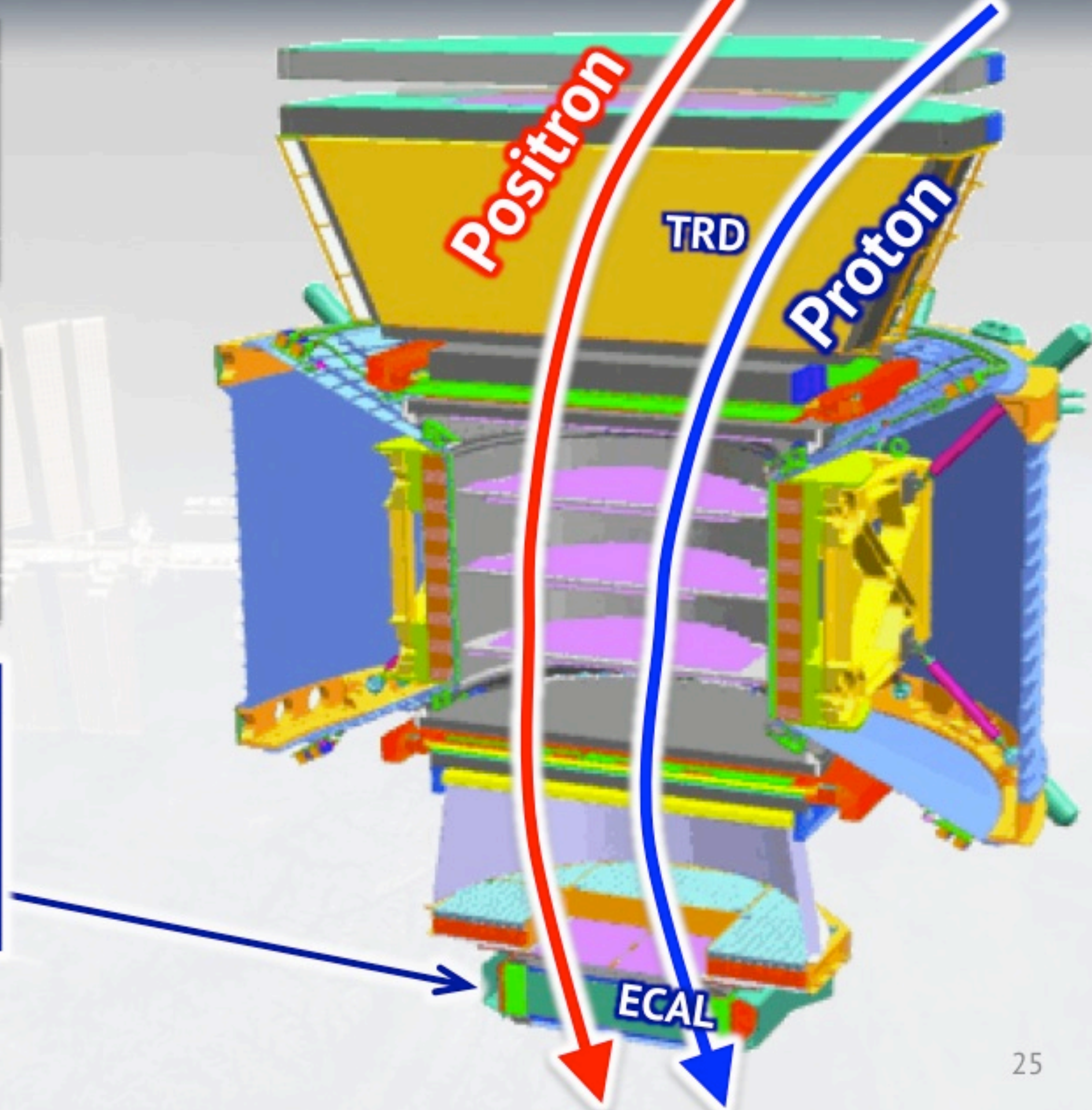


EM calorimeter (ECAL)

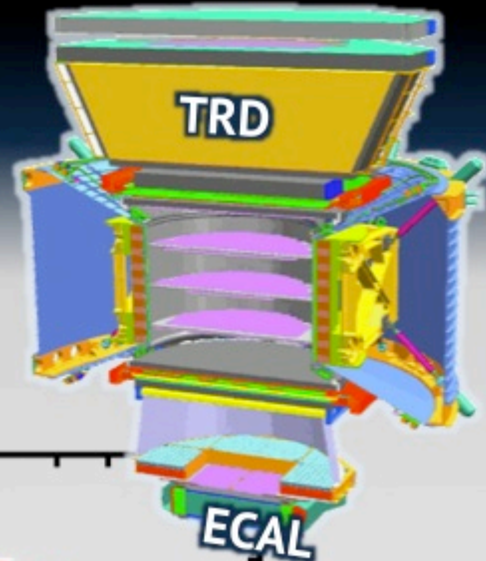




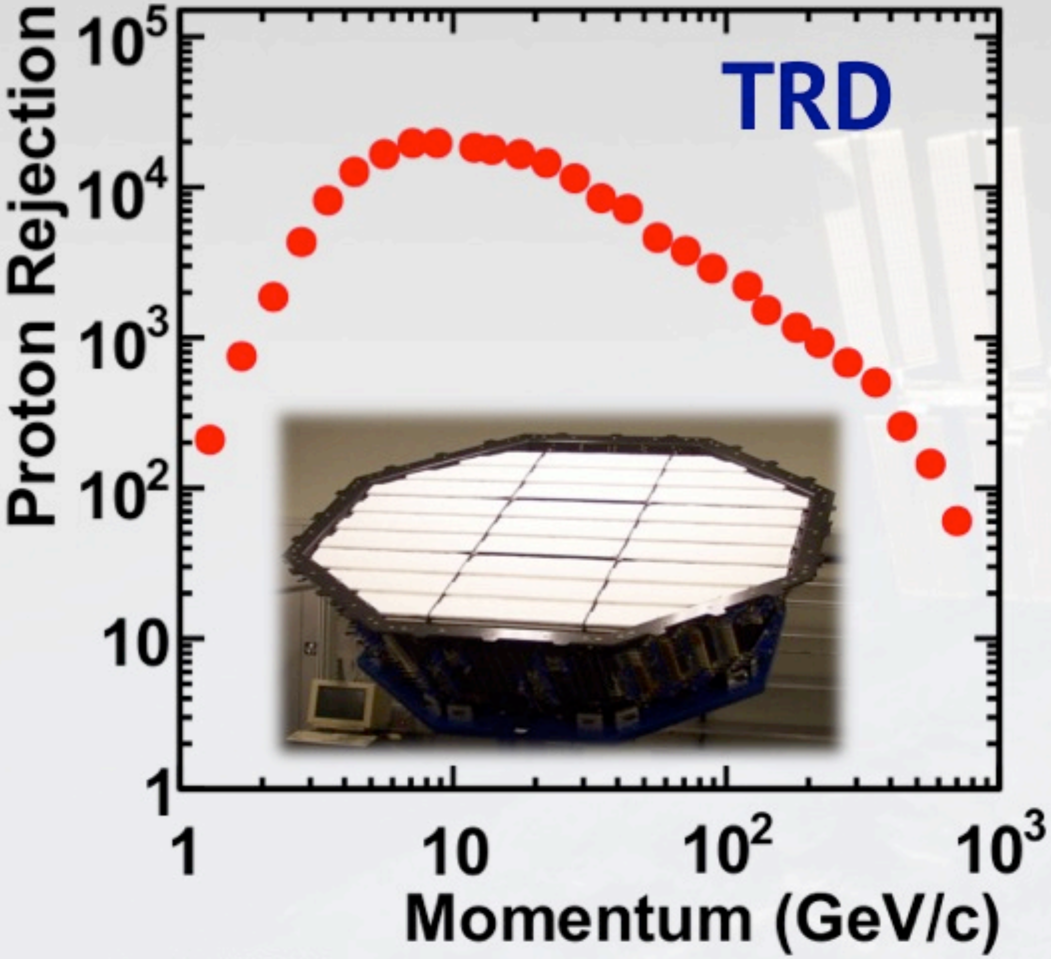
ECAL (17 X_0)

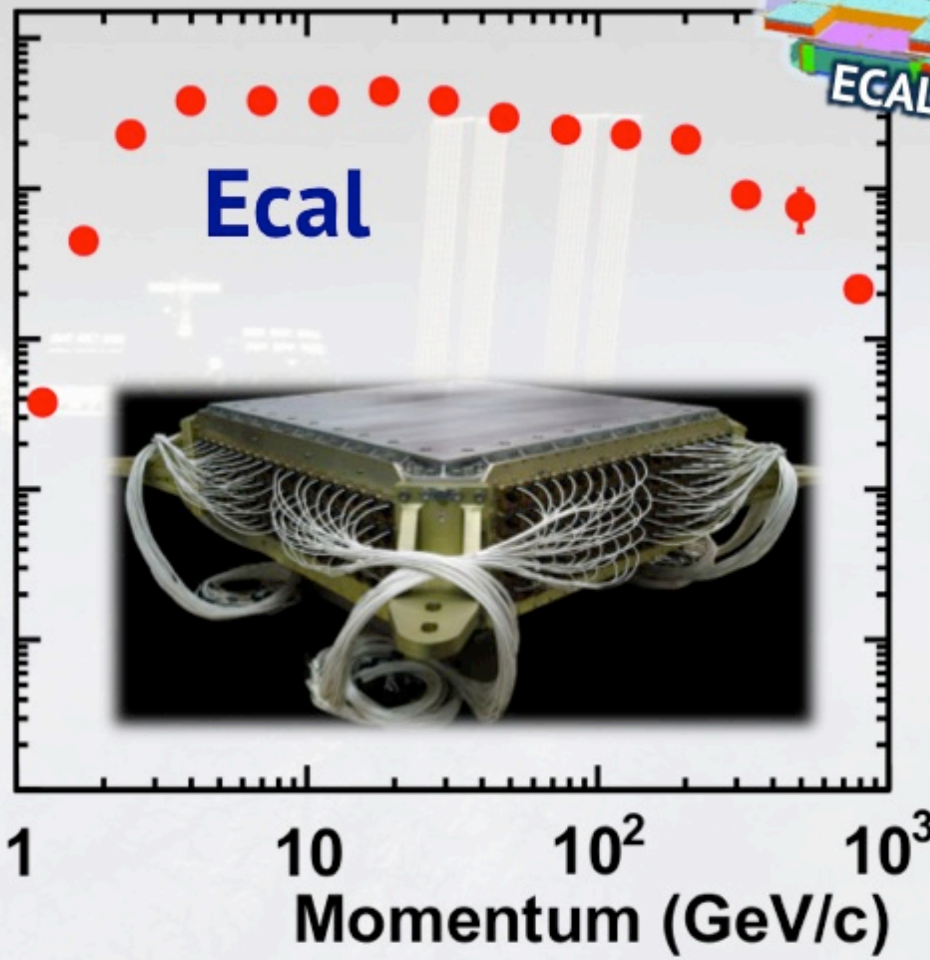


Proton rejection

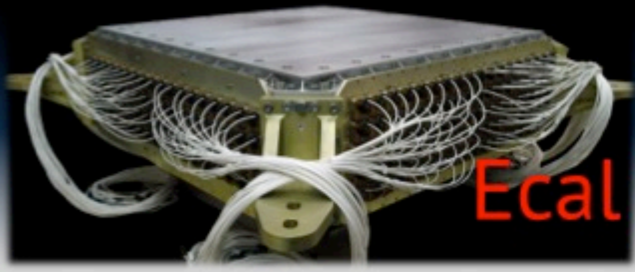


With 90 % e⁺ efficiency

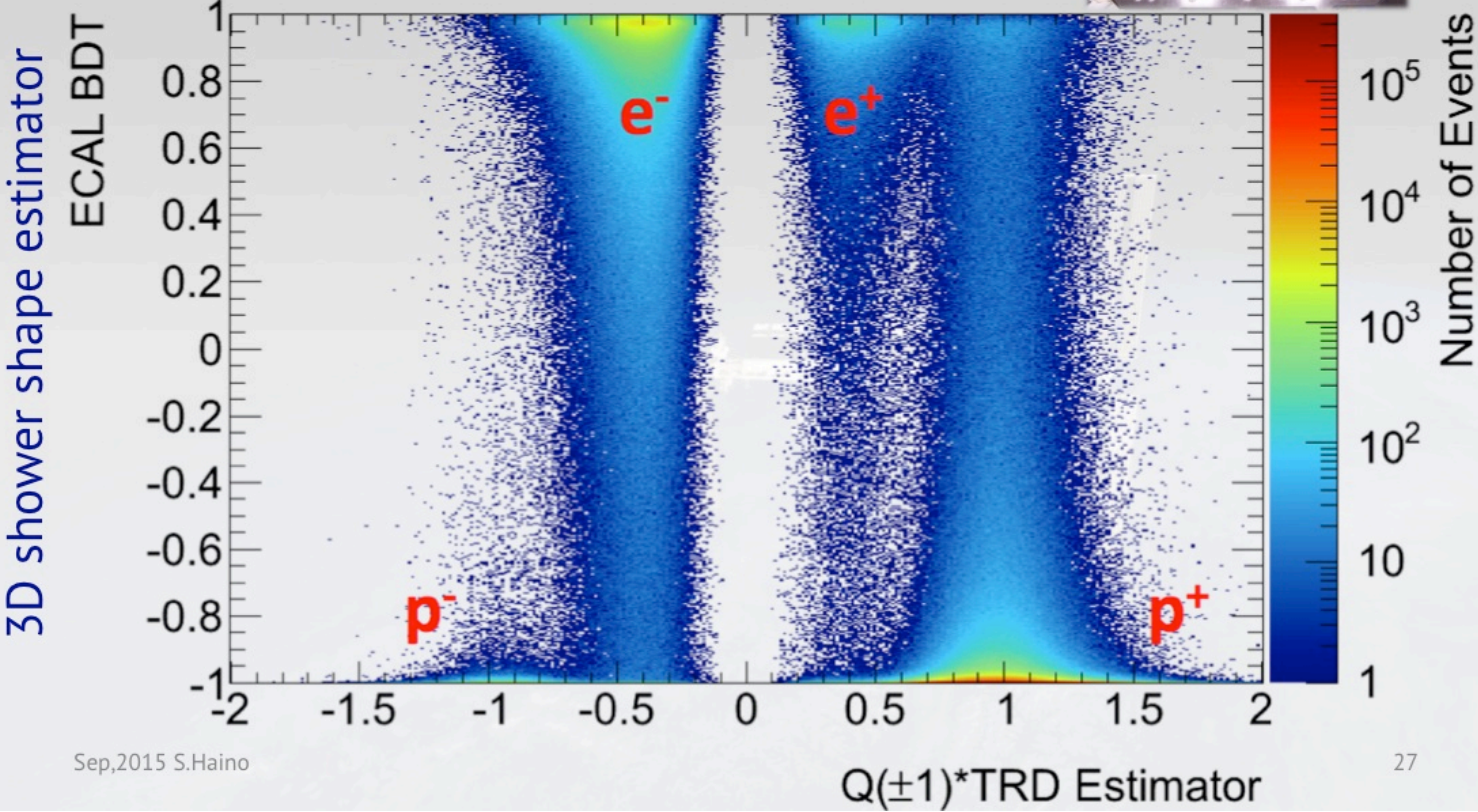




Particle ID


Ecal

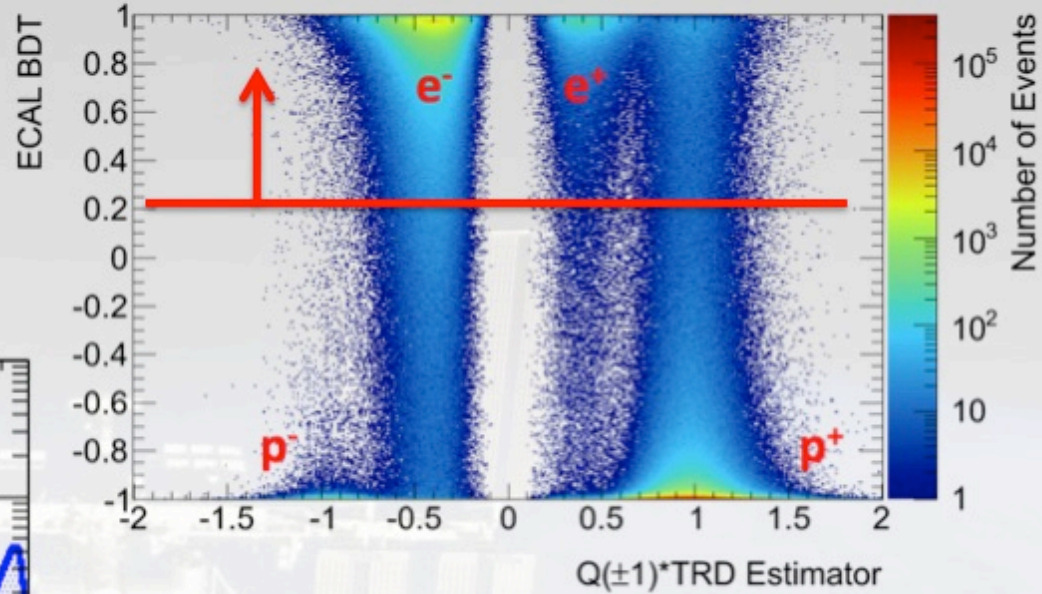

TRD
21/07/2005

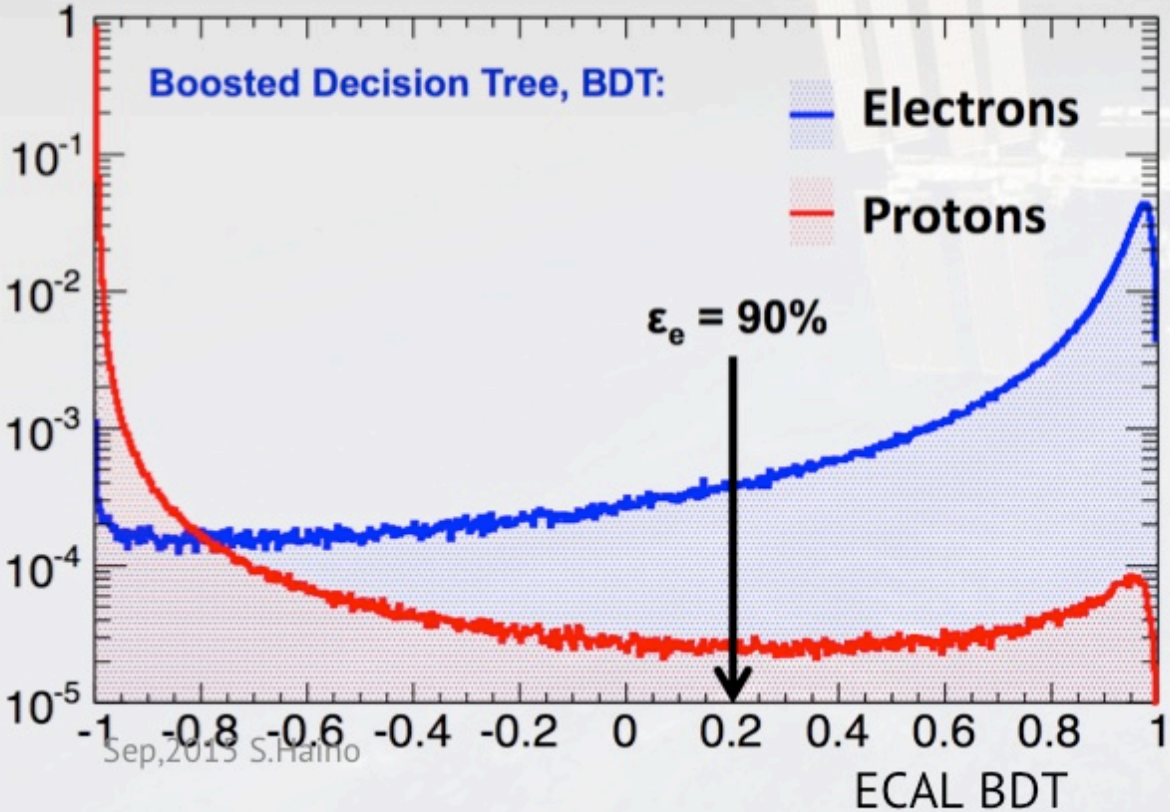

3D shower shape estimator
ECAL BDT
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
e-
e+
p-
p+
Number of Events
1
10
10^2
10^3
10^4
10^5
Q(±1)*TRD Estimator

Particle ID

Cut on ECAL BDT

- **Reduce proton BG**
- **Minimal effect on e^+ fraction**



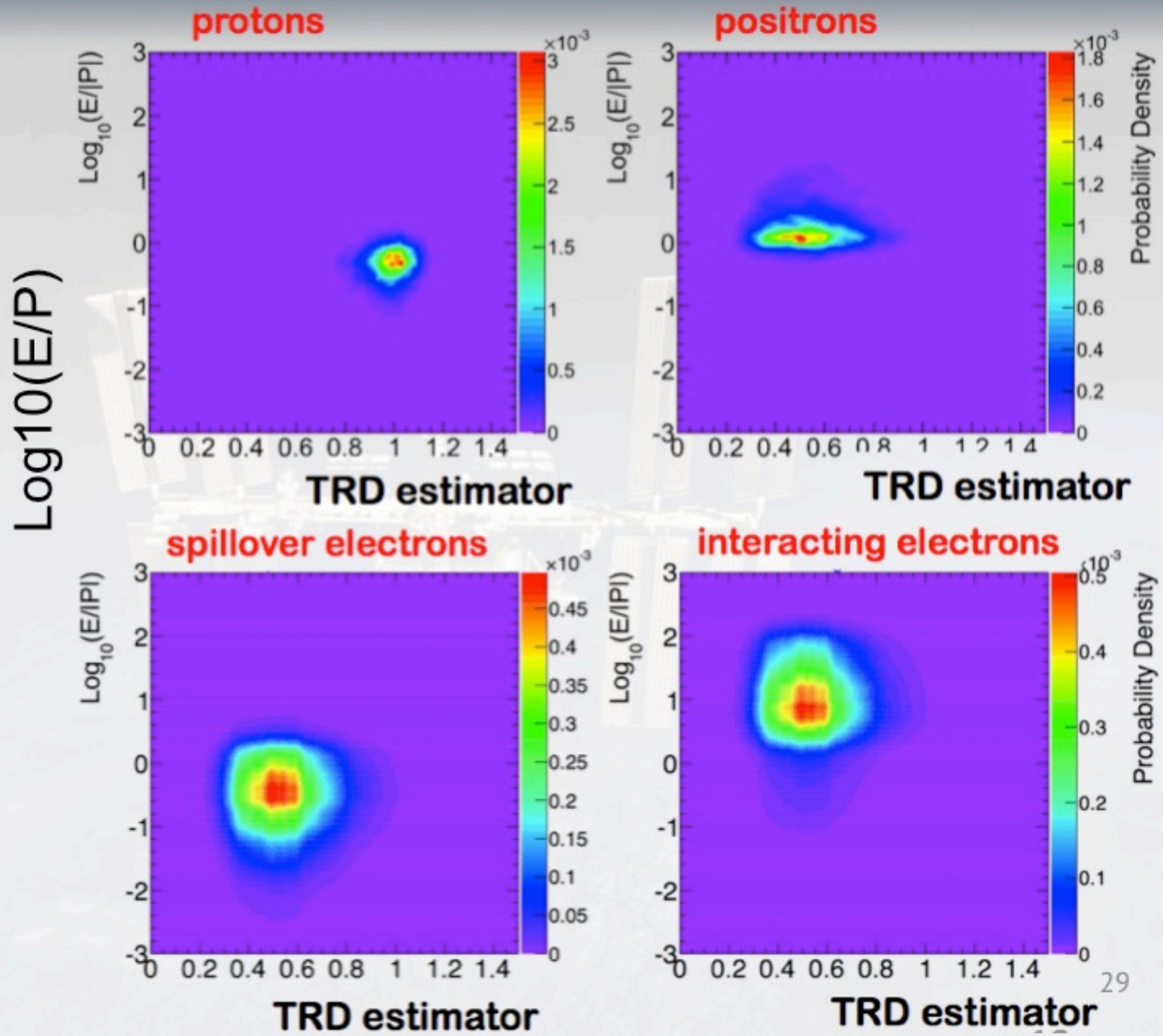


2D fitting

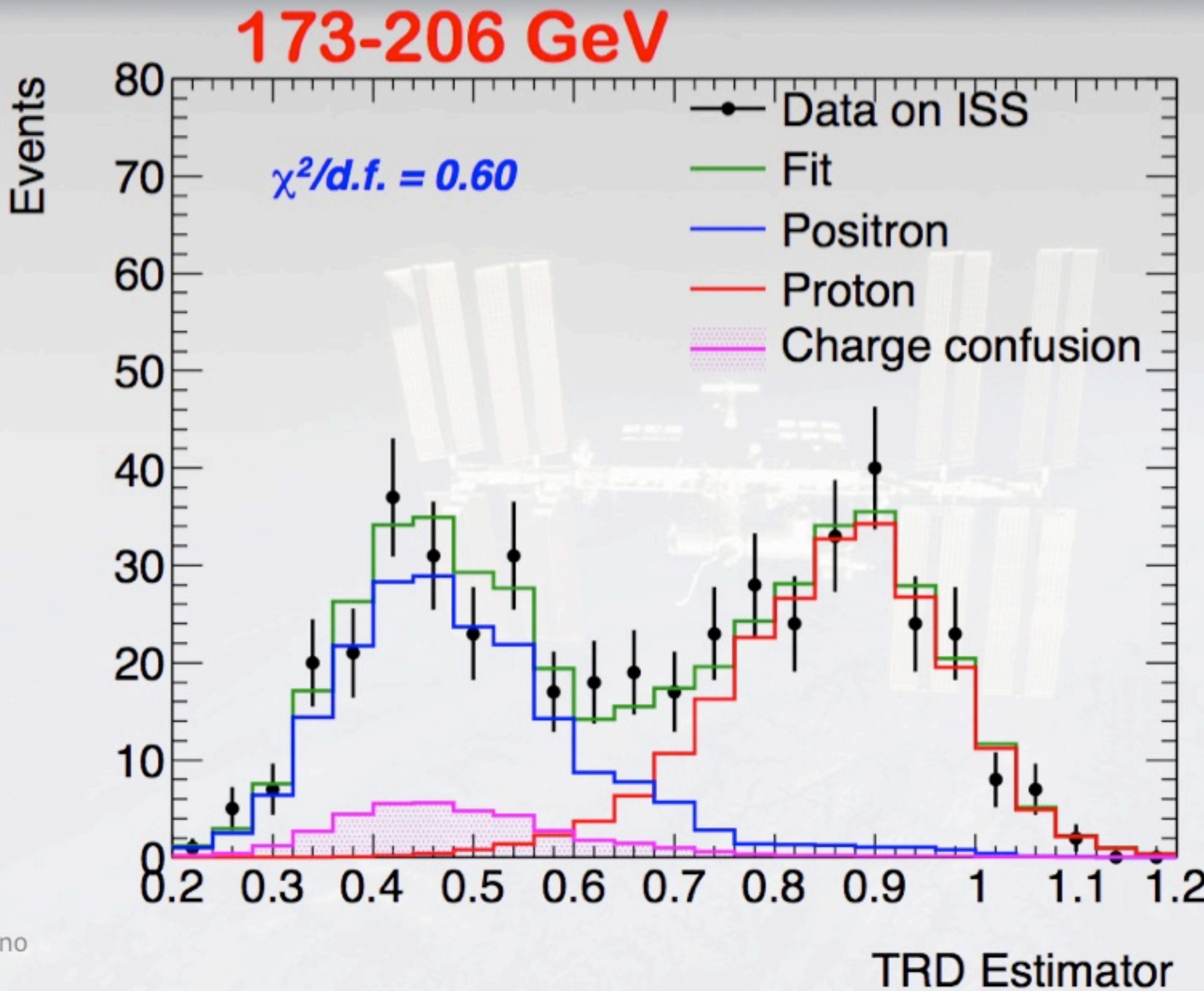
E: Energy
(ECAL)
P: Momentum
(Spetrometer)

Charge confusion:
(misidentified e-)

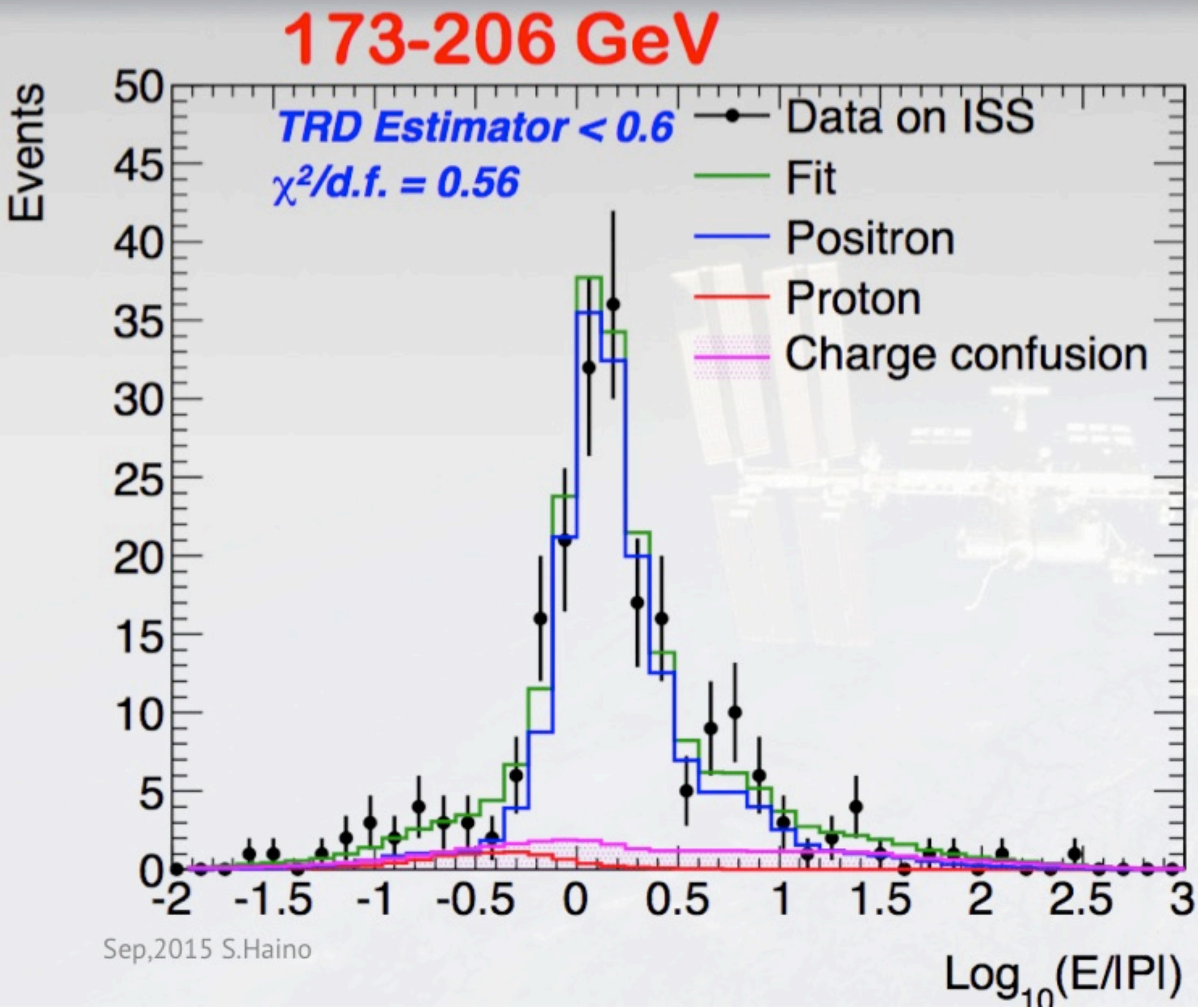
- **Spillover due to finite resolution**
- **Interacting e-**

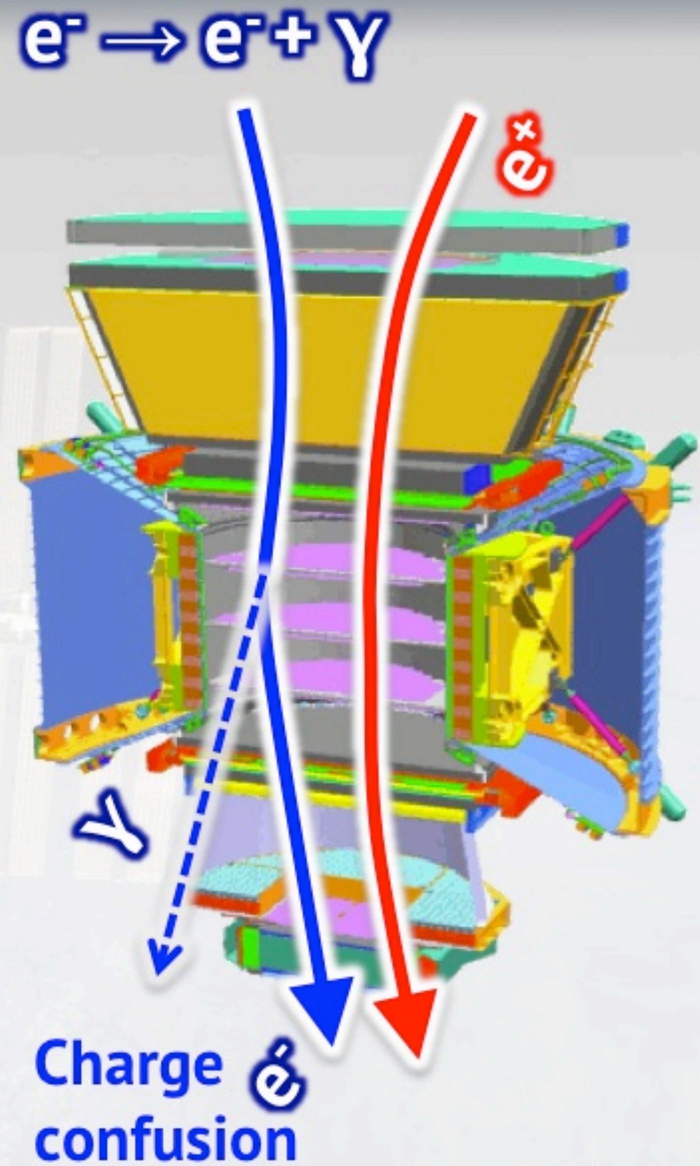


Projection (TRD estimator)



Projection (E/P)



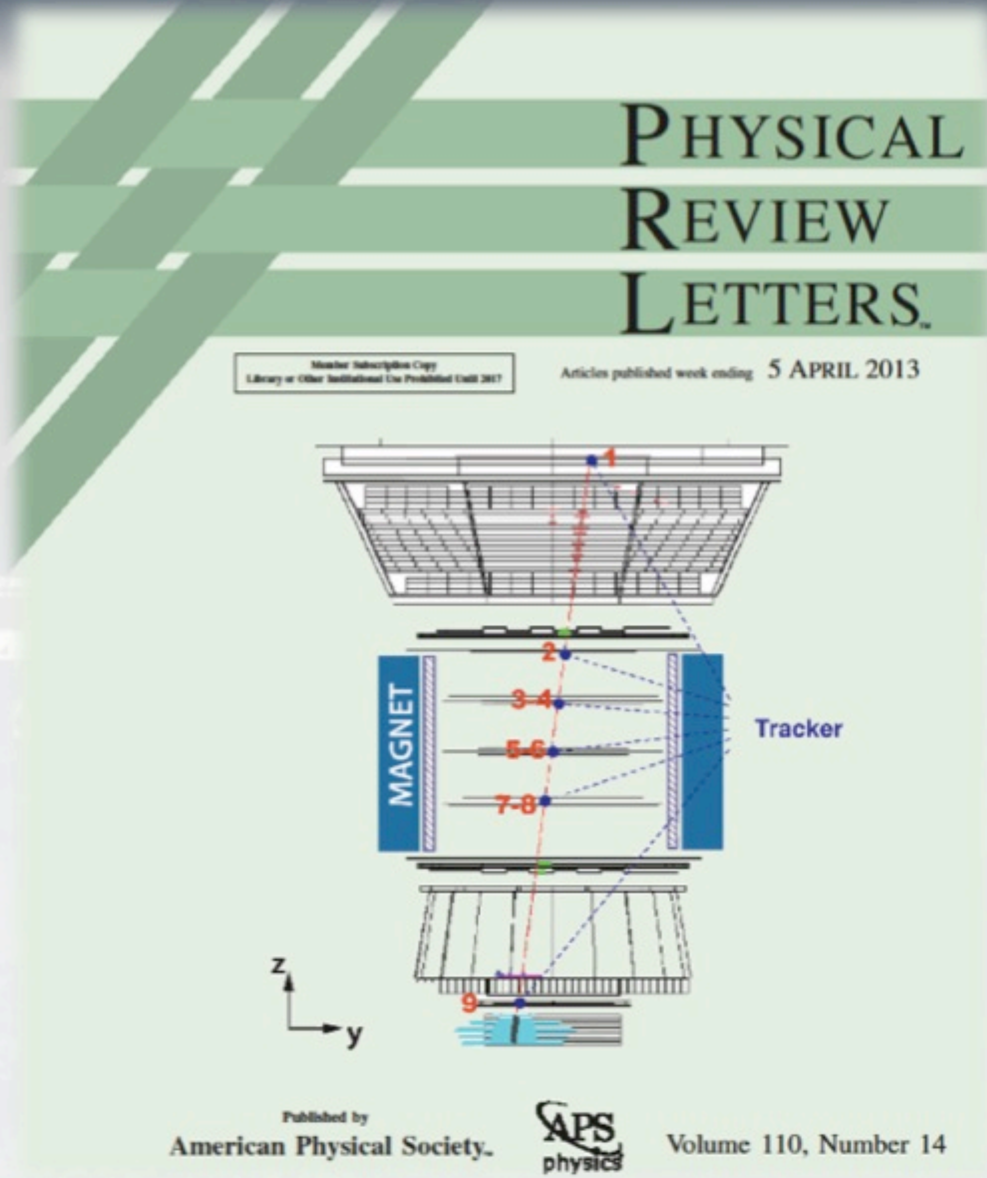


First results of AMS

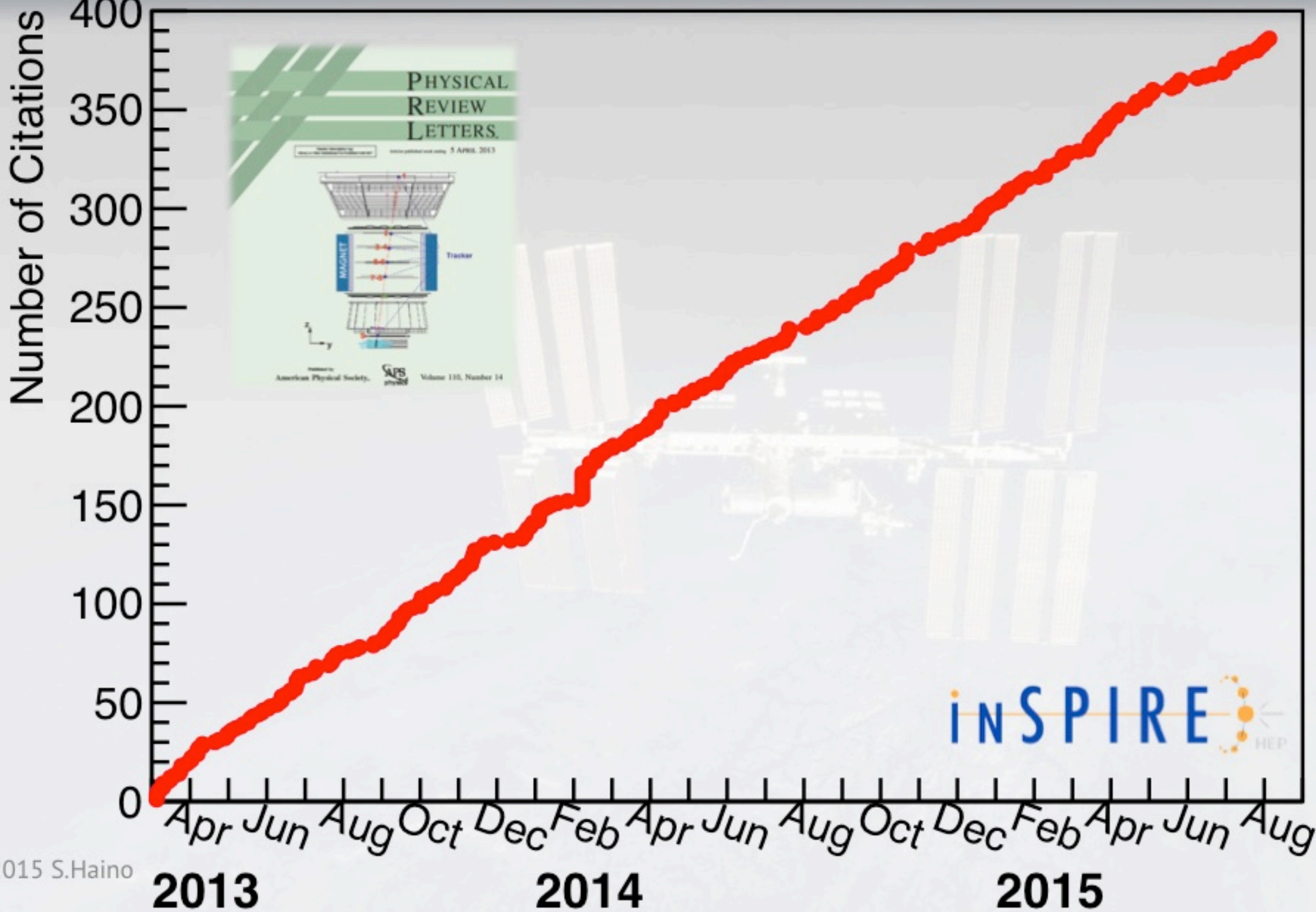
M. Aguilar *et al.*,
PRL 110, 141102 (2013)

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

(April/2013)



Citation increasing ...



New AMS Results (Sep. and Nov., 2014)

PRL **113,** 121101 (2014) PHYSICAL REVIEW LETTERS week ending 19 SEPTEMBER 2014

High Statistics Measurement of the Positron Fraction in Primary Cosmic Rays of 0.5–500 GeV with the Alpha Magnetic Spectrometer on the International Space Station

PRL **113,** 121102 (2014) PHYSICAL REVIEW LETTERS week ending 19 SEPTEMBER 2014

Electron and Positron Fluxes in Primary Cosmic Rays Measured with the Alpha Magnetic Spectrometer on the International Space Station

PRL **113,** 221102 (2014) PHYSICAL REVIEW LETTERS week ending 28 NOVEMBER 2014

Precision Measurement of the $(e^+ + e^-)$ Flux in Primary Cosmic Rays from 0.5 GeV to 1 TeV with the Alpha Magnetic Spectrometer on the International Space Station

Positron fraction data table

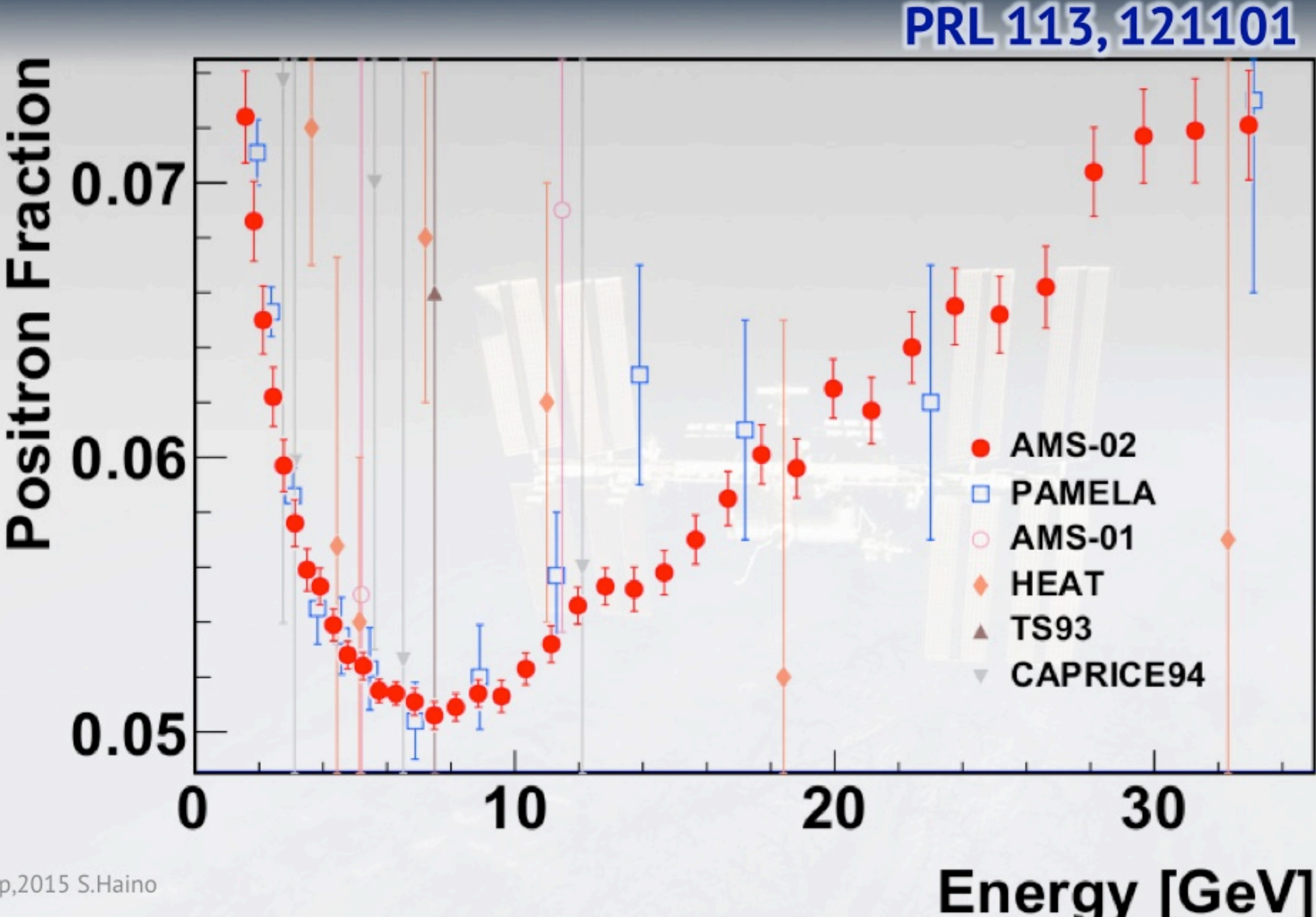
High Statistics Measurement of the Positron Fraction in Primary Cosmic Rays of 0.5–500 GeV with the Alpha Magnetic Spectrometer on the International Space Station

PRL **113,** 121101 (2014) PHYSICAL REVIEW LETTERS week ending 19 SEPTEMBER 2014

TABLE I. Positron fraction as a function of energy. The number of positrons, N_{e^+}, is corrected for charge confusion. Errors due to: statistical error (stat.), acceptance asymmetry (acc.), event selection (sel.), energy scale and bin-to-bin migration (mig.), reference spectra (ref.), charge confusion (c.c.), and total systematic error (syst.).

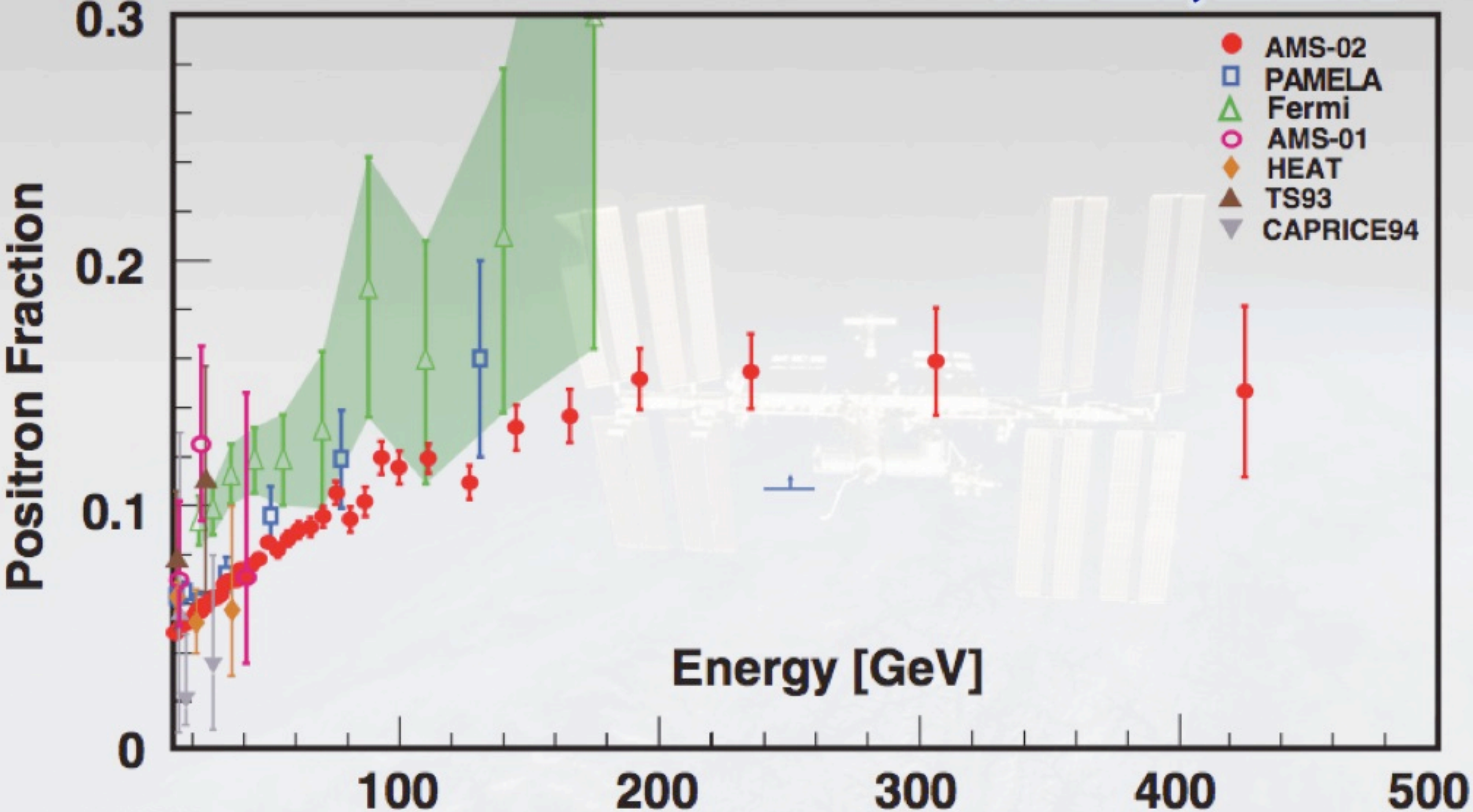
Energy [GeV]	N_{e^+}	Fraction	$\sigma_{stat.}$	$\sigma_{acc.}$	$\sigma_{sel.}$	$\sigma_{mig.}$	$\sigma_{ref.}$	$\sigma_{c.c.}$	$\sigma_{syst.}$
0.50–0.65	1242	0.0943	0.0027	0.0009	0.0034	0.0023	0.0003	0.0009	0.0043
0.65–0.81	5295	0.0917	0.0015	0.0008	0.0024	0.0020	0.0002	0.0008	0.0033
0.81–1.00	10 664	0.0862	0.0008	0.0007	0.0014	0.0018	0.0002	0.0007	0.0025
1.00–1.21	14 757	0.0820	0.0007	0.0006	0.0009	0.0016	0.0002	0.0006	0.0020
···	···	···	···	···	···	···	···	···	···
132.1–151.5	271	0.1327	0.0083	0.0002	0.0020	0.0007	0.0006	0.0024	0.0032
151.5–173.5	228	0.1374	0.0097	0.0002	0.0023	0.0007	0.0007	0.0031	0.0040
173.5–206.0	225	0.1521	0.0109	0.0002	0.0027	0.0007	0.0008	0.0044	0.0053
206.0–260.0	178	0.1550	0.0124	0.0003	0.0034	0.0007	0.0011	0.0076	0.0084
260.0–350.0	135	0.1590	0.0168	0.0003	0.0045	0.0007	0.0015	0.0123	0.0132
350.0–500.0	72	0.1471	0.0278	0.0003	0.0064	0.0007	0.0022	0.0182	0.0194

Positron fraction (low energy)



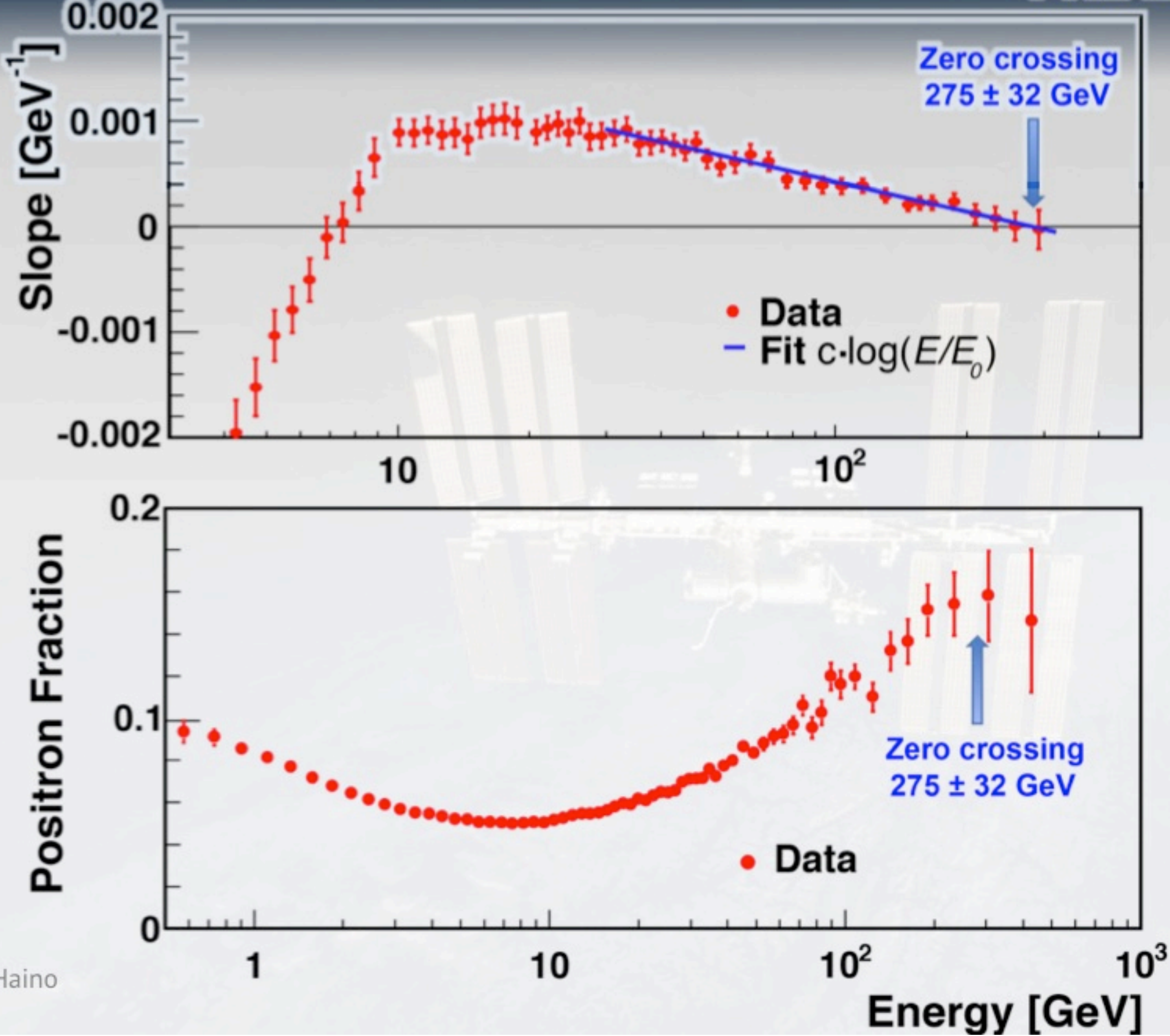
Positron fraction (high energy)

PRL 113, 121101

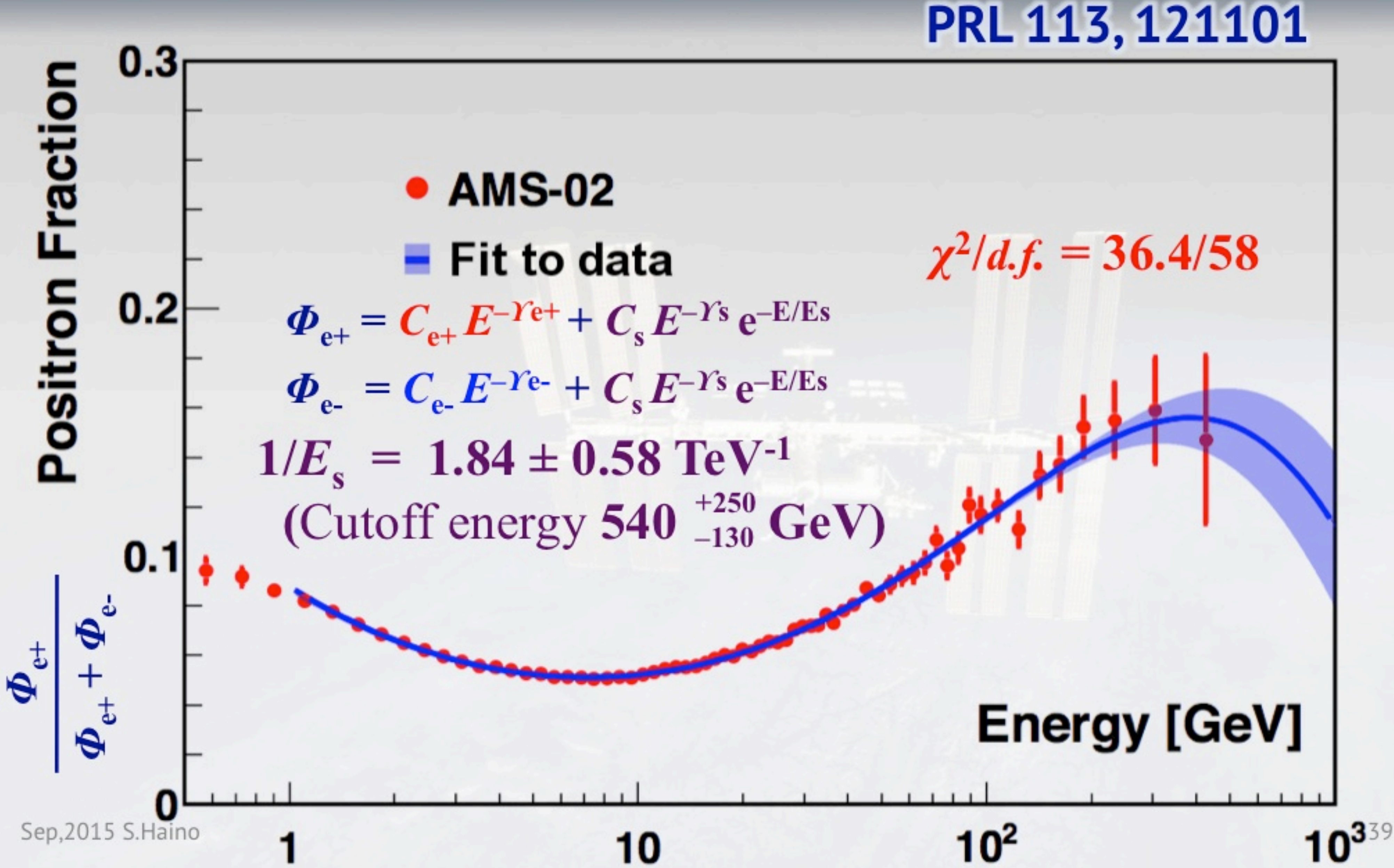


Positron fraction slope

PRL 113, 121101



Fit to data

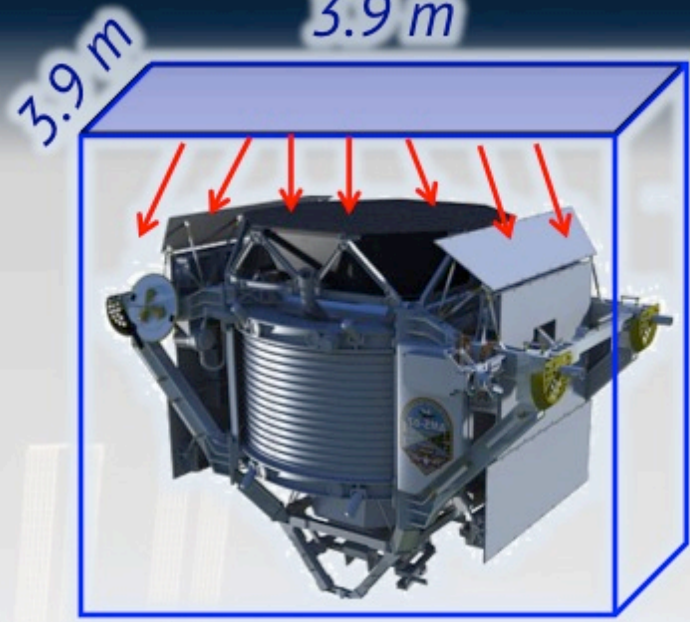

PRL 113, 121101
Positron Fraction
$\frac{\Phi_{e+}}{\Phi_{e+} + \Phi_{e-}}$
AMS-02
Fit to data
$\Phi_{e+} = C_{e+} E^{-\gamma_{e+}} + C_s E^{-\gamma_s} e^{-E/E_s}$
$\Phi_{e-} = C_{e-} E^{-\gamma_{e-}} + C_s E^{-\gamma_s} e^{-E/E_s}$
$1/E_s = 1.84 \pm 0.58 \text{ TeV}^{-1}$
(Cutoff energy 540 $^{+250}_{-130}$ GeV)
$\chi^2/d.f. = 36.4/58$
Energy [GeV]
0.3
0.2
0.1
0
1
10
10^2
10^3

Flux determination

$$\Phi(E) = \frac{N}{T \cdot A_{\mathrm{eff}} \cdot \varepsilon_{\mathrm{trig.}} \cdot \Delta E}$$

Φ	: Absolute differential flux	($m^{-2}sr^{-1}s^{-1}GeV^{-1}$)
E	: Measured energy	(GeV)
N	: Number of events after proton selection	
T	: Exposure life time	(s)
A_{eff}	: Effective acceptance	(m^2 sr)
$\varepsilon_{\mathrm{trg.}}$	: Trigger efficiency	
ΔE	: Energy bin	(GeV)

Acceptance



$$A_{eff} = A_{geom} \cdot \varepsilon_{sel} \cdot \varepsilon_{id} \cdot (1+\delta)$$

A_{eff} : Effective acceptance

A_{geom} : Geometrical acceptance (~550 cm^2 sr)

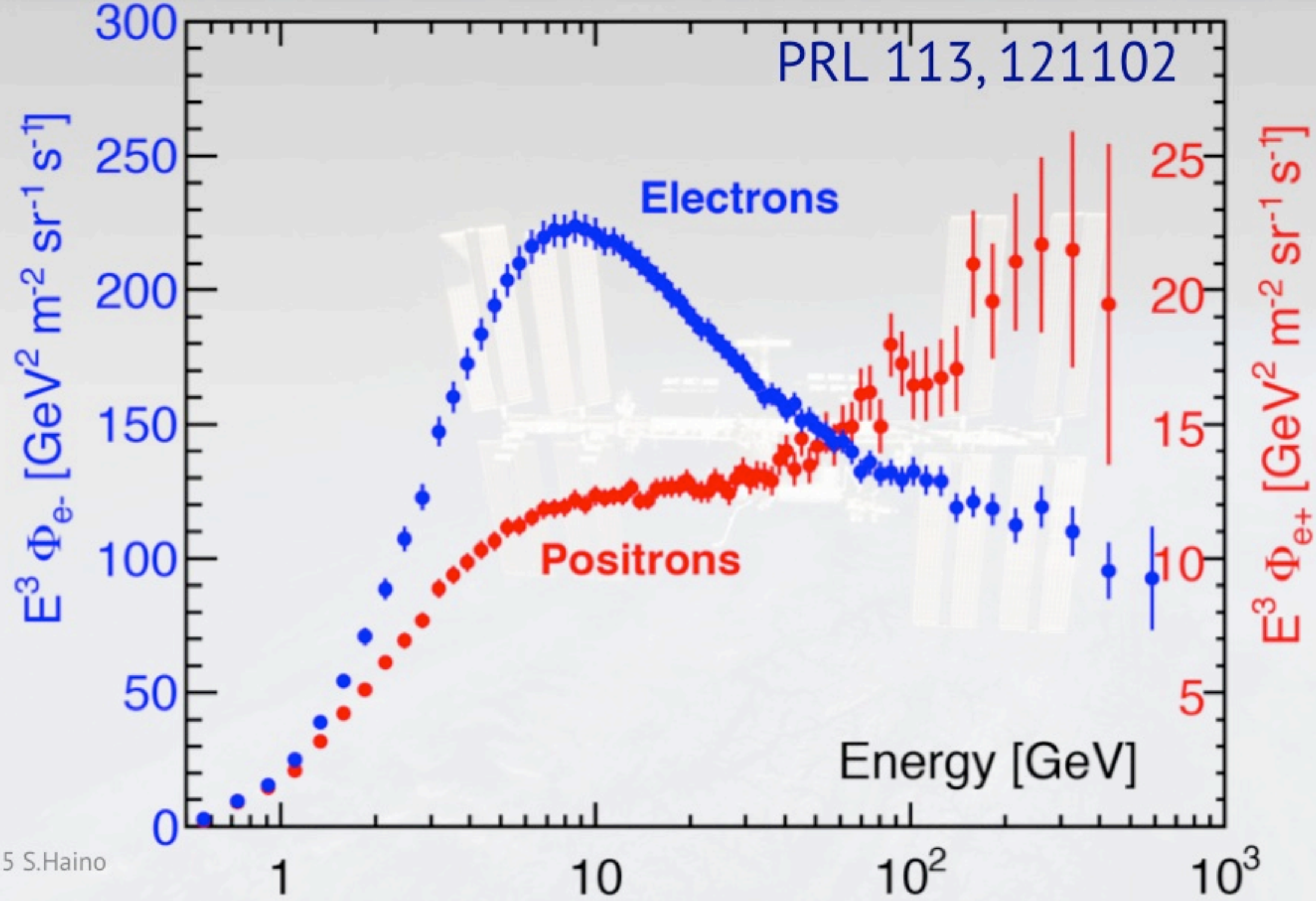
ε_{sel} : Selection efficiency

ε_{id} : $e^{\pm}$ identification efficiency

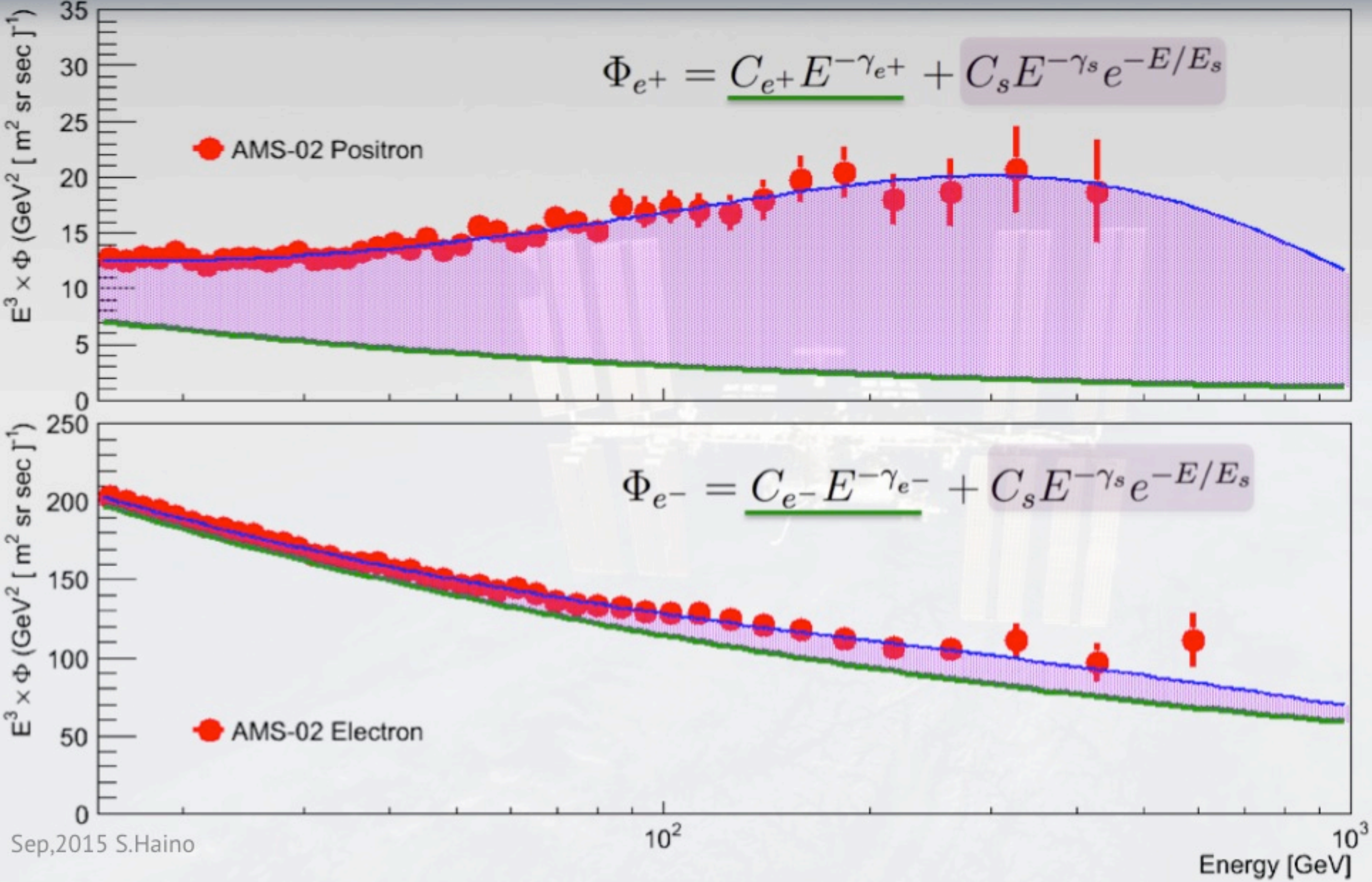
δ : Minor correction from Data/MC comparison

(2% at 10 GeV to 6% at 700 GeV)

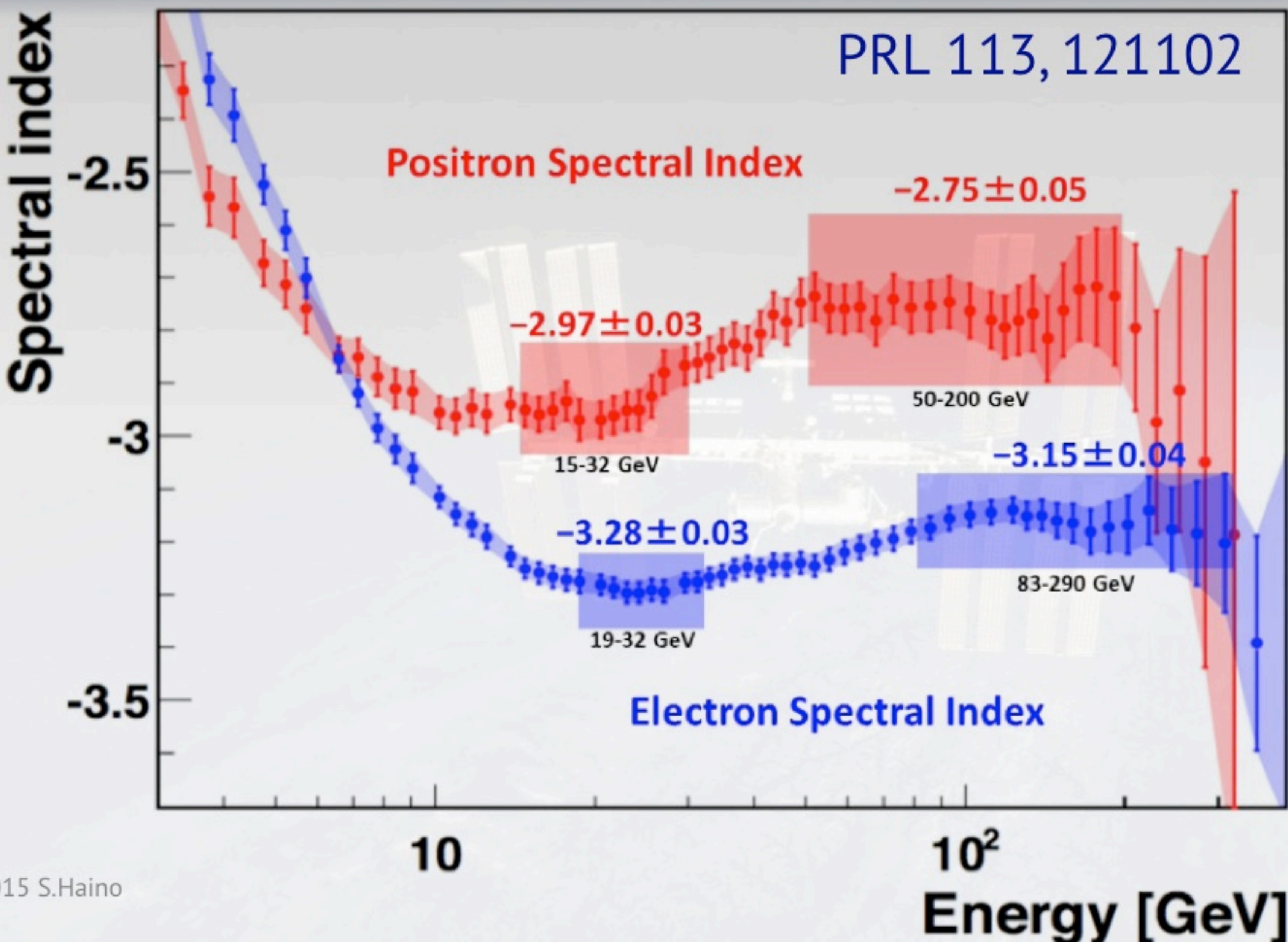
Flux measurement



Fit to e+ and e− flux

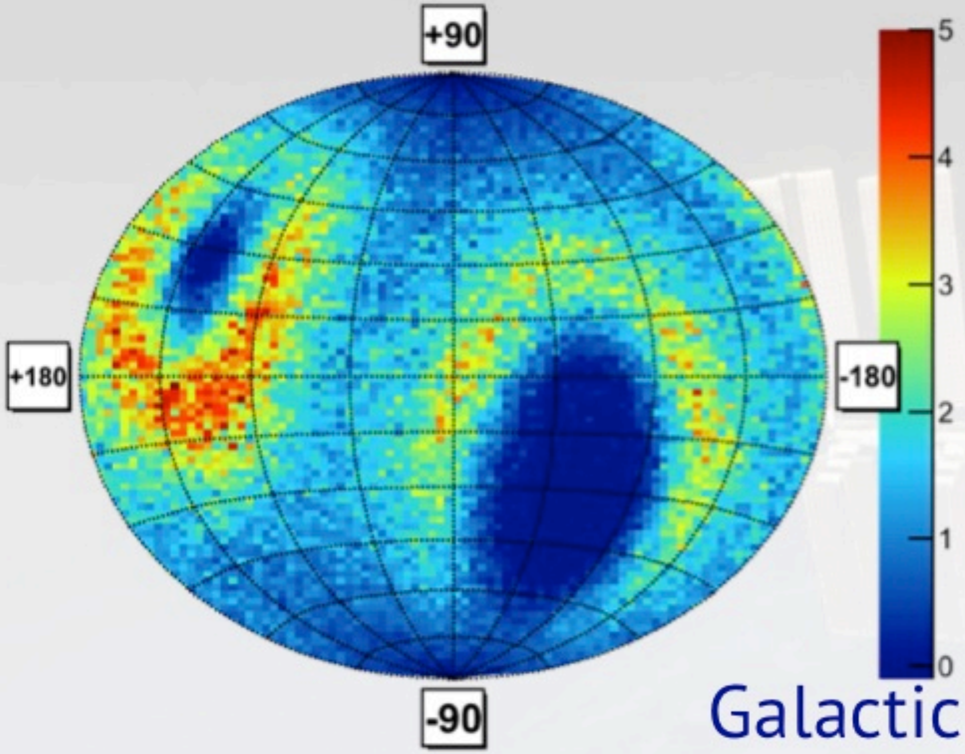


Spectral indices are not constant

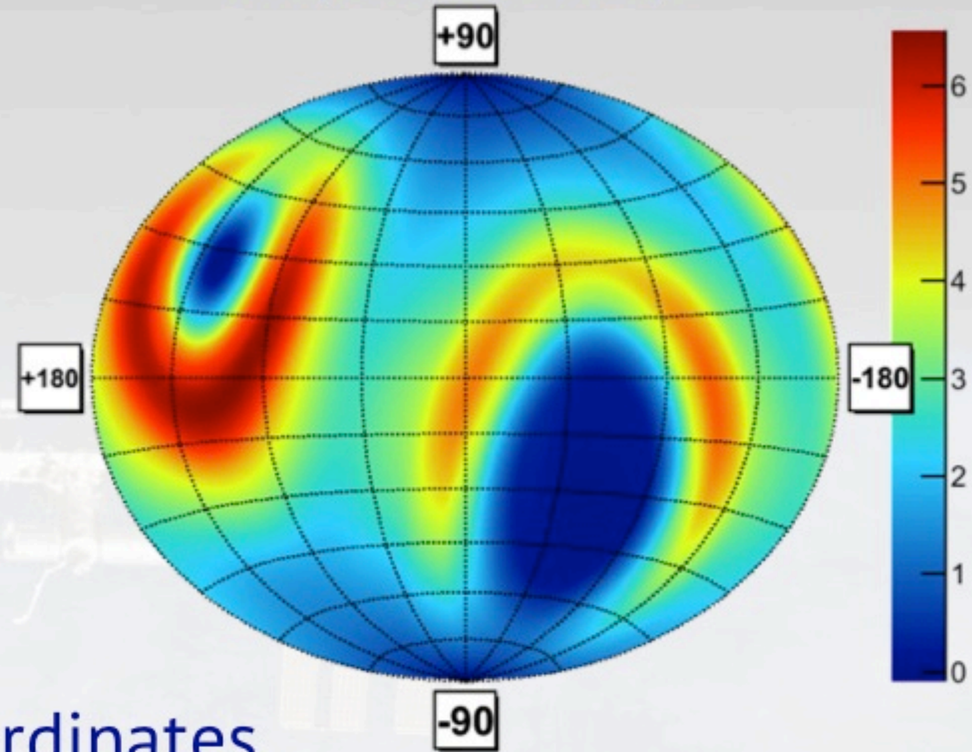


Electron/positron anisotropy

e+ Arrival direction



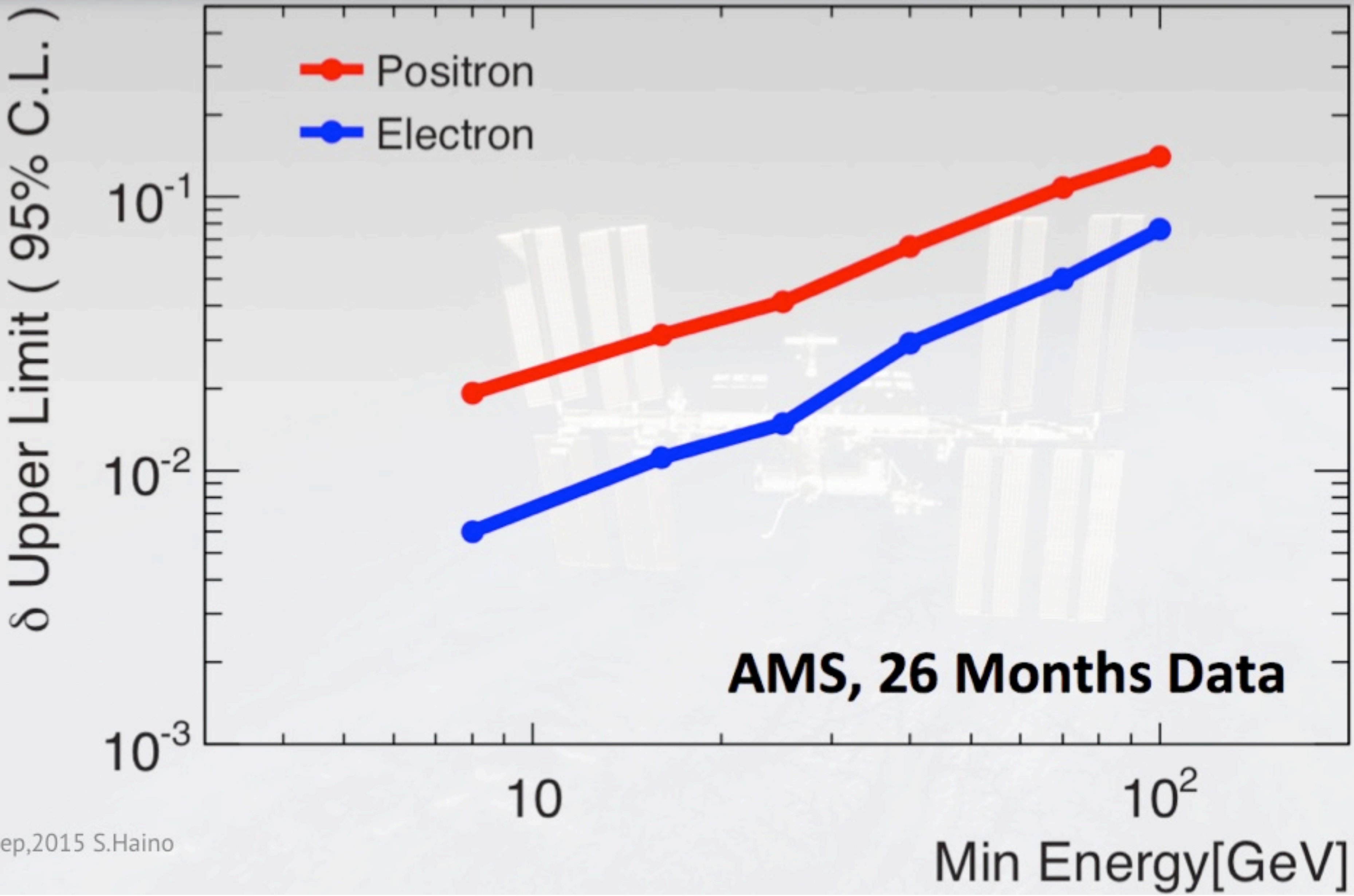
Exposure map



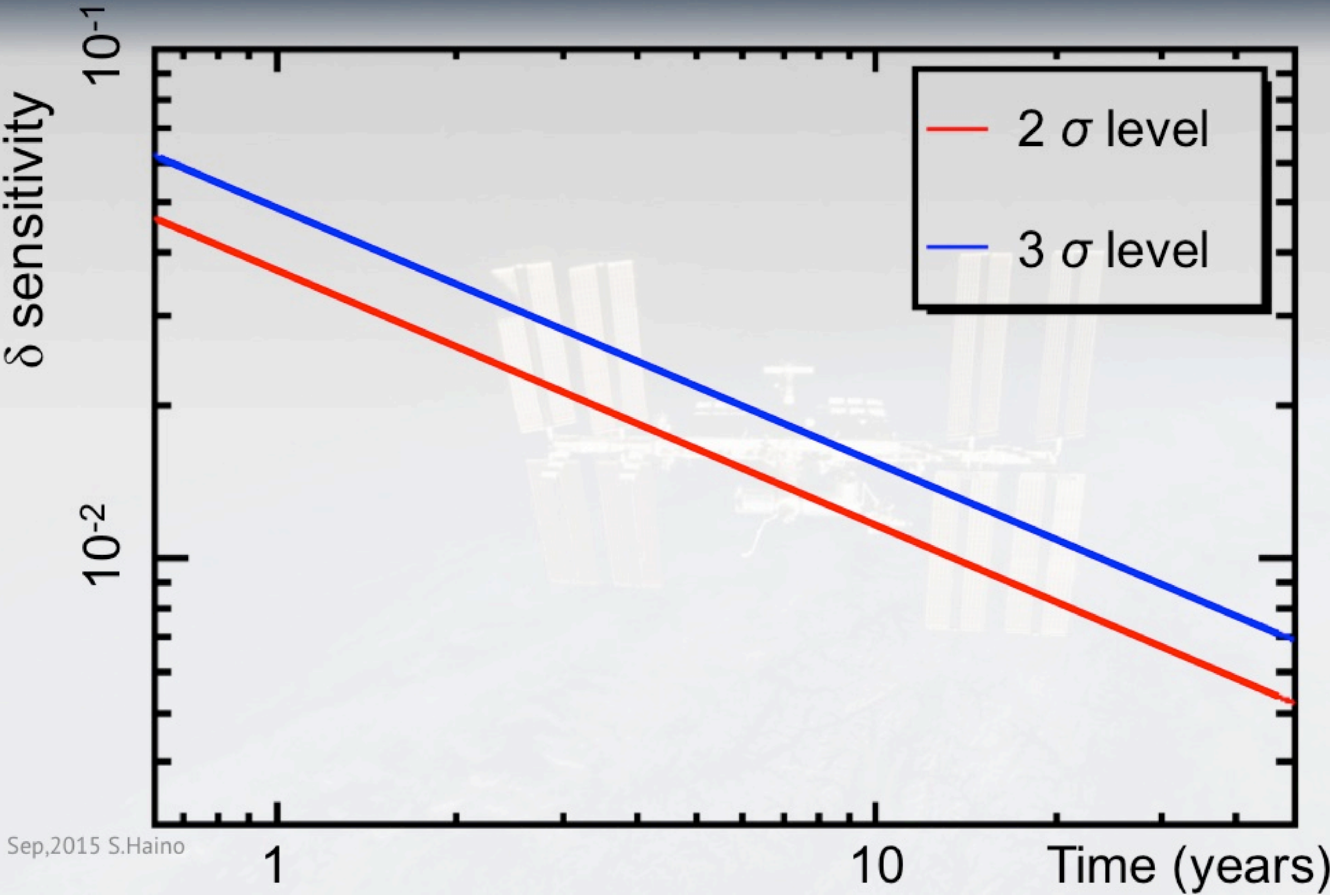
Galactic coordinates

$$N = \int_b \int_l J(b,l) \times AT(b,l) \times \sin b \times db\, dl$$

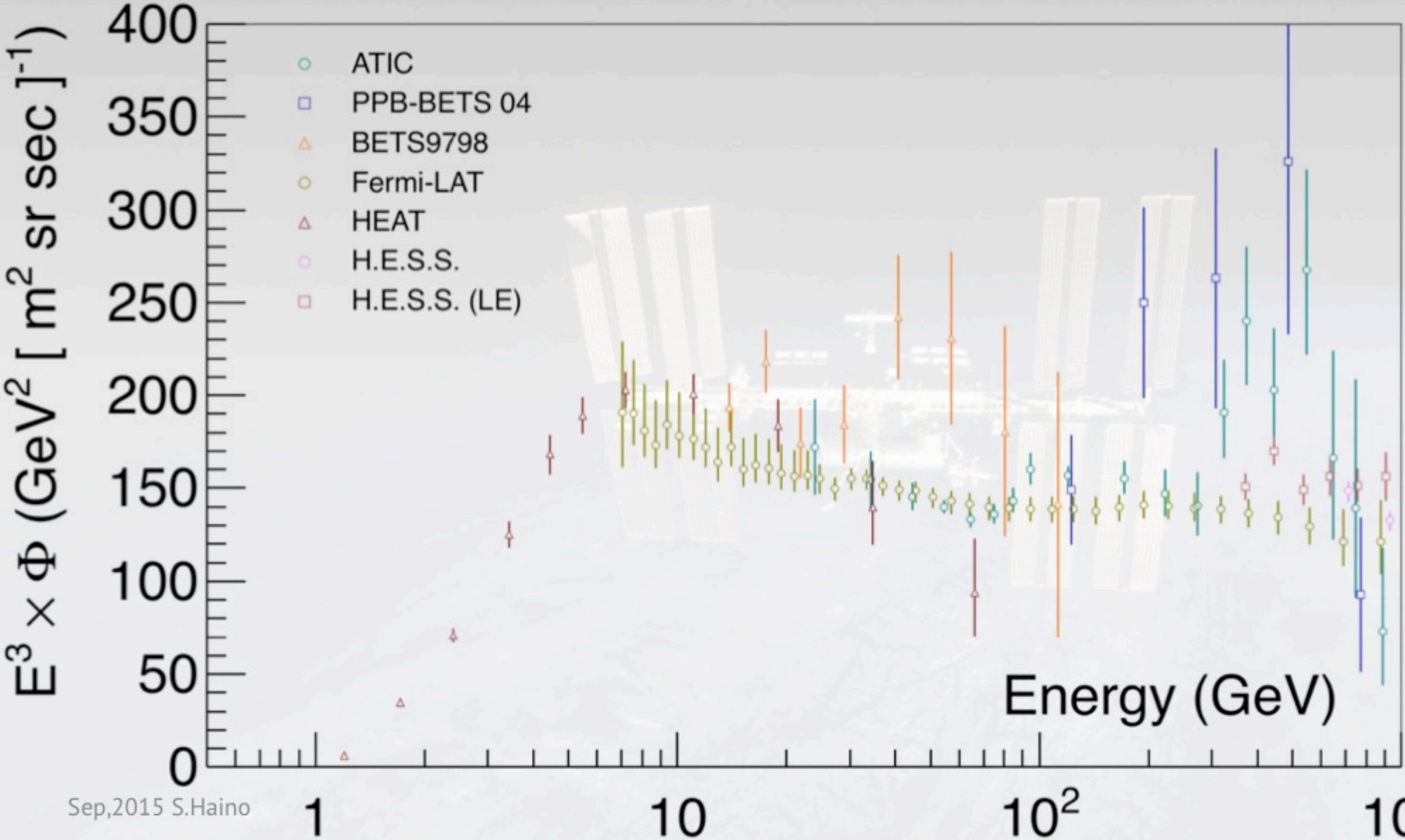
Upper limits of dipole anisotropy



Future sensitivity of e^+ anisotropy



All (e^++e^-) flux before AMS



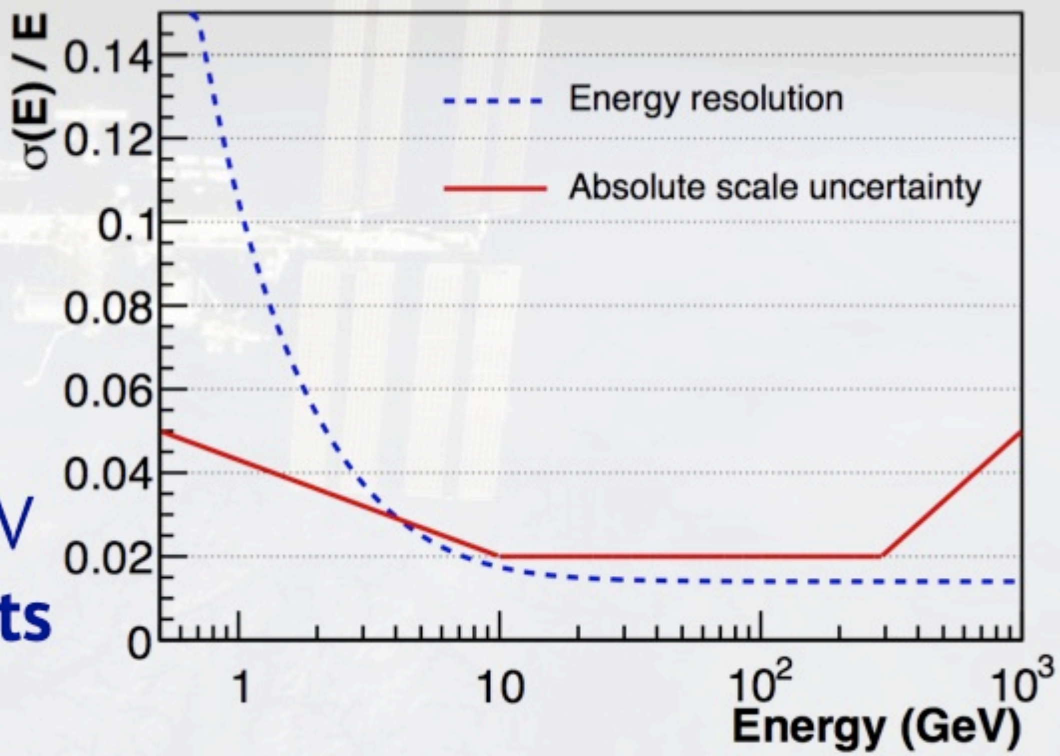
AMS all (e^++e^-) flux up to 1 TeV

PRL **113,** 221102 (2014) PHYSICAL REVIEW LETTERS week ending 28 NOVEMBER 2014

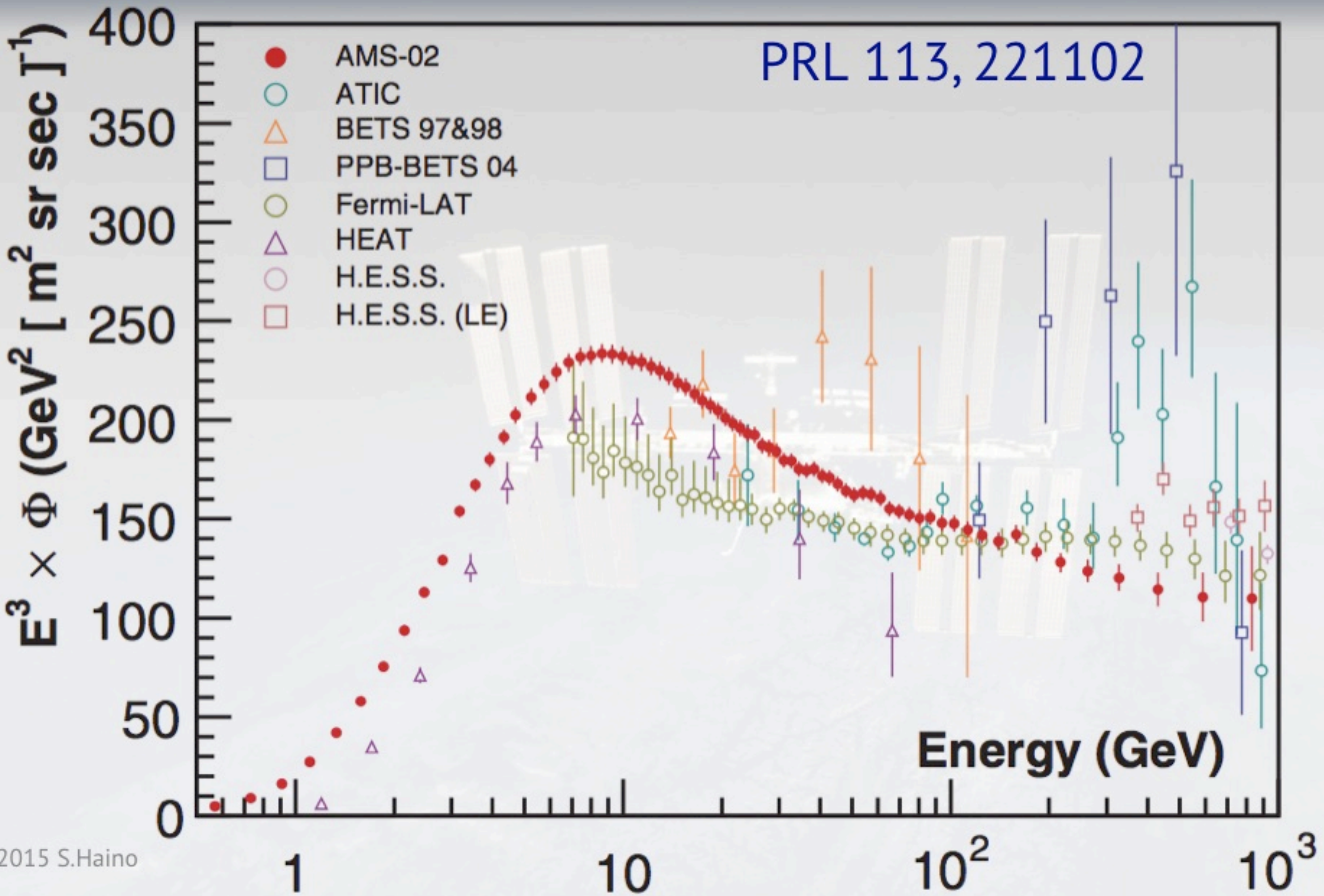
Precision Measurement of the $(e^+ + e^-)$ Flux in Primary Cosmic Rays from 0.5 GeV to 1 TeV with the Alpha Magnetic Spectrometer on the International Space Station

No need to separate charge sign
→ Loose cut and large acceptance
→ Higher statistics
→ Higher energy reach (> ~1 TeV)

Good energy resolution ~2% at 1TeV
Energy scale calibrated by beam tests



AMS all ($e^+ + e^-$) flux up to 1 TeV

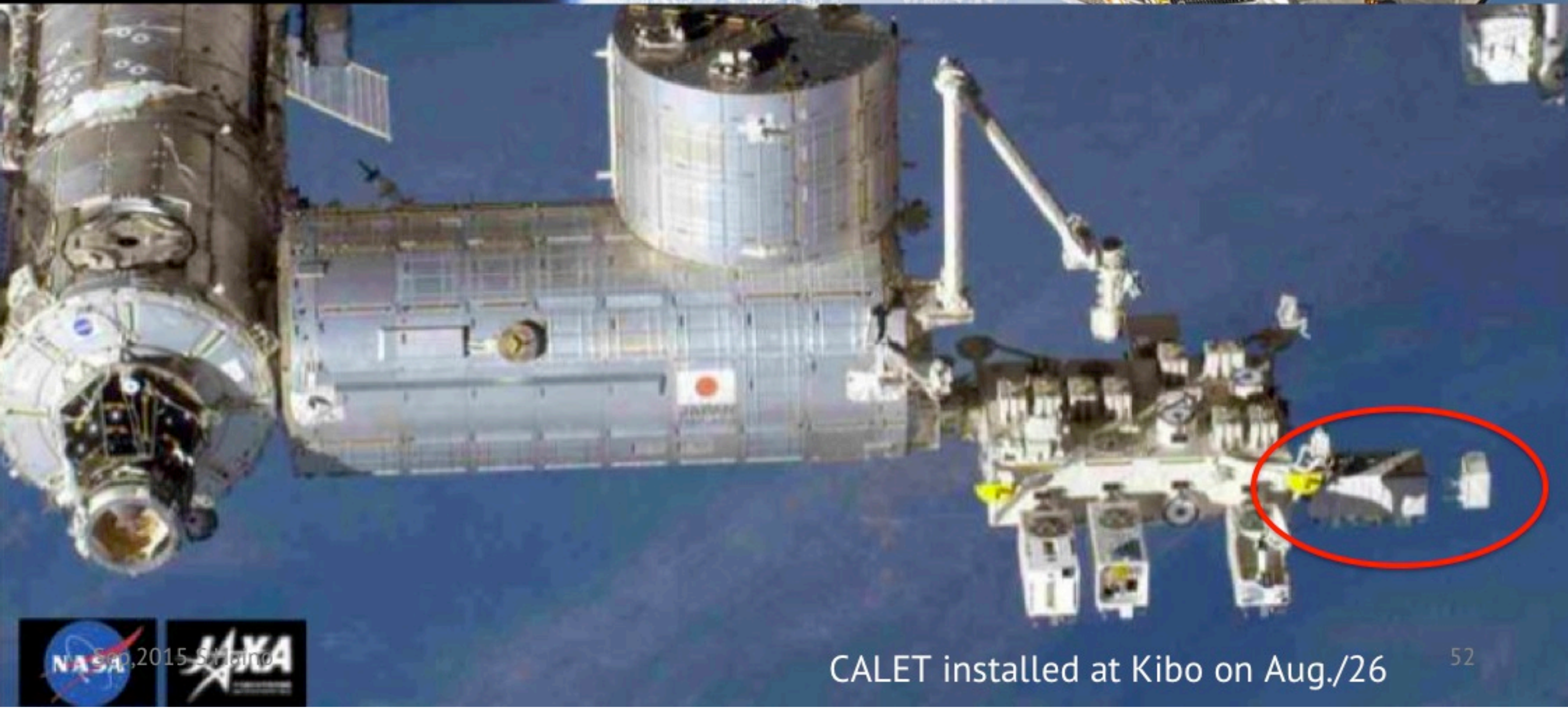


Coming experiments

Payload (Launching Date)	Energy Region (GeV)	Energy Resolution	e/p separation	Instruments*	Exposure in 5 years** (m^2 sr day)	Total Weight (kg)
AMS-02 (2011)	1-2,000 (~800)	~10 % @100 GeV	10^4 - 10^5	Magnet Spectrometer (0.15T) + Sampling Calorimeter (SciFi + Pb: 17X_0) +TOF+TRD+RICH	55@2TeV (170@800GeV)	7,000
CALET (2015)	1-20,000	~2 % (>10 GeV)	~10^5 Mostly Energy Independent	Imaging Calorimeter (W+SciFi: 3 X_0) + Total Absorption Cal. (PWO : 27 X_0) +Charge Detector (SCN)	220	650
DAMPE* (China : 2015?)	5-10,000	~1.5 %	~10^5	Silicon Tracker +Total Absorption Cal. (BGO: ~31 X_0) +ACD Detector +Neutron Detector	900	1,500
GAMMA-400* (Russia : 2017?)	1-sevral 10,000	~1 % (>100GeV)	~4x10^5	Imaging Calorimeter (2X_0) + Main Calorimeter- calocube (25 X_0)	730(vertical) x10 (all)	1,700

Table by S. Torii (CALET)

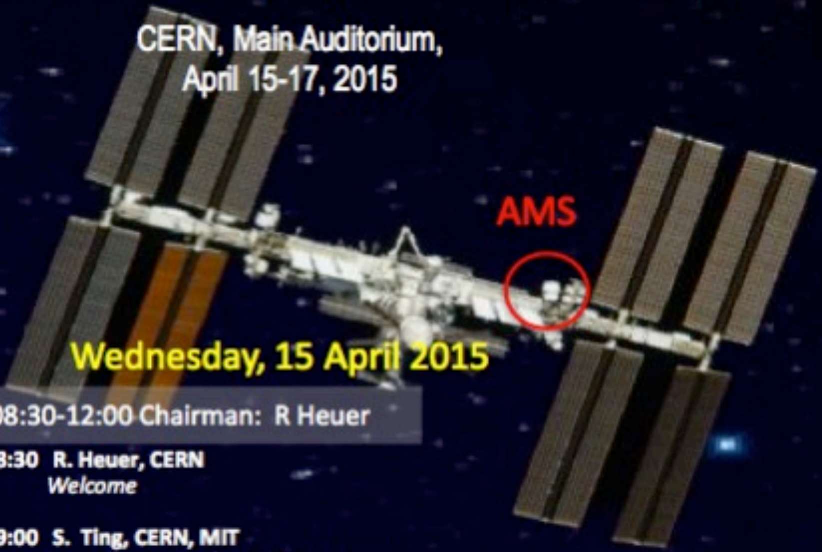
From jaxa.jp



CALET installed at Kibo on Aug./26

AMS Days at CERN
The Future of Cosmic Ray Physics and Latest Results

CERN, Main Auditorium,
April 15-17, 2015



Wednesday, 15 April 2015

08:30-12:00 Chairman: R Heuer

08:30 **R. Heuer, CERN**
Welcome

09:00 **S. Ting, CERN, MIT**
Introduction to the AMS Experiment
10:00 **A. Kounine, MIT**
Latest AMS Results: The Positron Fraction and the p-bar/p ratio
11:00 Break
11:15 **S. Schael, RWTH-Aachen**
The e⁻ Spectrum and e⁺ Spectrum from AMS

11:45 Lunch

13:00 - 16:15 Chairman: F. Ferroni

13:00 **F. Zwirner, Padova, CERN**
New Physics, Dark Matter and the LHC

14:00 **J. L. Feng, UC Irvine**
Complementarity of Indirect Dark Matter Detection
15:00 **I. V. Moskalenko, Stanford**
Cosmic Rays in the Milky Way and Other Galaxies
16:00 Break

16:15 - 18:15 Chairman: H. Schopper

16:15 **K. Blum, IAS, Princeton**
It's about time: interpreting AMS antimatter data in terms of cosmic ray propagation
17:00 **V. S. Ptuskin, IZMIRAN**
Acceleration and Transport of Galactic Cosmic R
18:00 Break

18:15 R. Heuer

18:15 **W. Gerstenmaier, NASA**
***Public Lecture:** Human Space Exploration*

Thursday, 16 April 2015

08:30-12:45 Chairman: F. Linde

08:30 **B. Bertucci, Perugia**
The (e⁻ plus e⁺) Spectrum from AMS
09:00 **V. Choutko, MIT**
The Proton Spectrum from AMS
09:30 **S. Haino, Academia Sinica, Taiwan**
The Helium Spectrum from AMS

10:00 Break
10:15 **L. Randall, Harvard**
Indirect Detection: Enhanced Density Models and Antideuteron Searches
11:15 **S. Sarkar, Oxford, Niels Bohr Inst.**
Background to Dark Matter Searches from Galactic Cosmic Rays

12:15 Lunch

14:00-18:15 Chairman: Y.F. Wang

14:00 **P. Picozza, INFN, Rome Tor Vergata**
The JEM-EUSO Program
15:00 **F. Halzen, Wisconsin**
Latest Results from Ice Cube

16:00 Break
16:15 **A. Watson, Leeds**
Latest Results from the Pierre Auger Observatory and Future Prospects in particle physics and high energy astrophysics with cosmic rays

17:15 **P. Michelson, Stanford**
Latest Results from Fermi-LAT

18:15 Break

18:15 S. Ting

18:30 **E. C. Stone, Caltech**
Public Lecture: The Odyssey of Voyager

Friday, 17 April 2015

08:00-10:15 Chairman: A. Yamamoto

08:00 **T. Slatyer, CTP, MIT**
Scrutinizing Possible Dark Matter Signatures with AMS, Fermi, and Planck
08:30 **J. R. Ellis, King's College, London, CERN**
Super-symmetric Dark Matter
09:30 **A. Oliva, CIEMAT**
AMS Results on Light Nuclei - B/C
09:45 **L. Derome, LPSC, Grenoble**
AMS Results on Light Nuclei - Li
10:00 **M. Heil, MIT**
AMS Results on Light Nuclei - C/He

10:15 Break

10:30-12:45 Chairman: F. Gianotti

10:30 **Y. L. Wu, UCAS/ITP, CAS**
Implications of AMS02 Experiment
11:15 **A. Olinto, Chicago**
The Highest Energy Cosmic Particles
12:15 **M. Fukushima, Tokyo**
Recent Results on Ultra-High Energy Cosmic Rays from the Telescope Array
12:45 Lunch

13:30-17:45 Chairman: J. Trümper

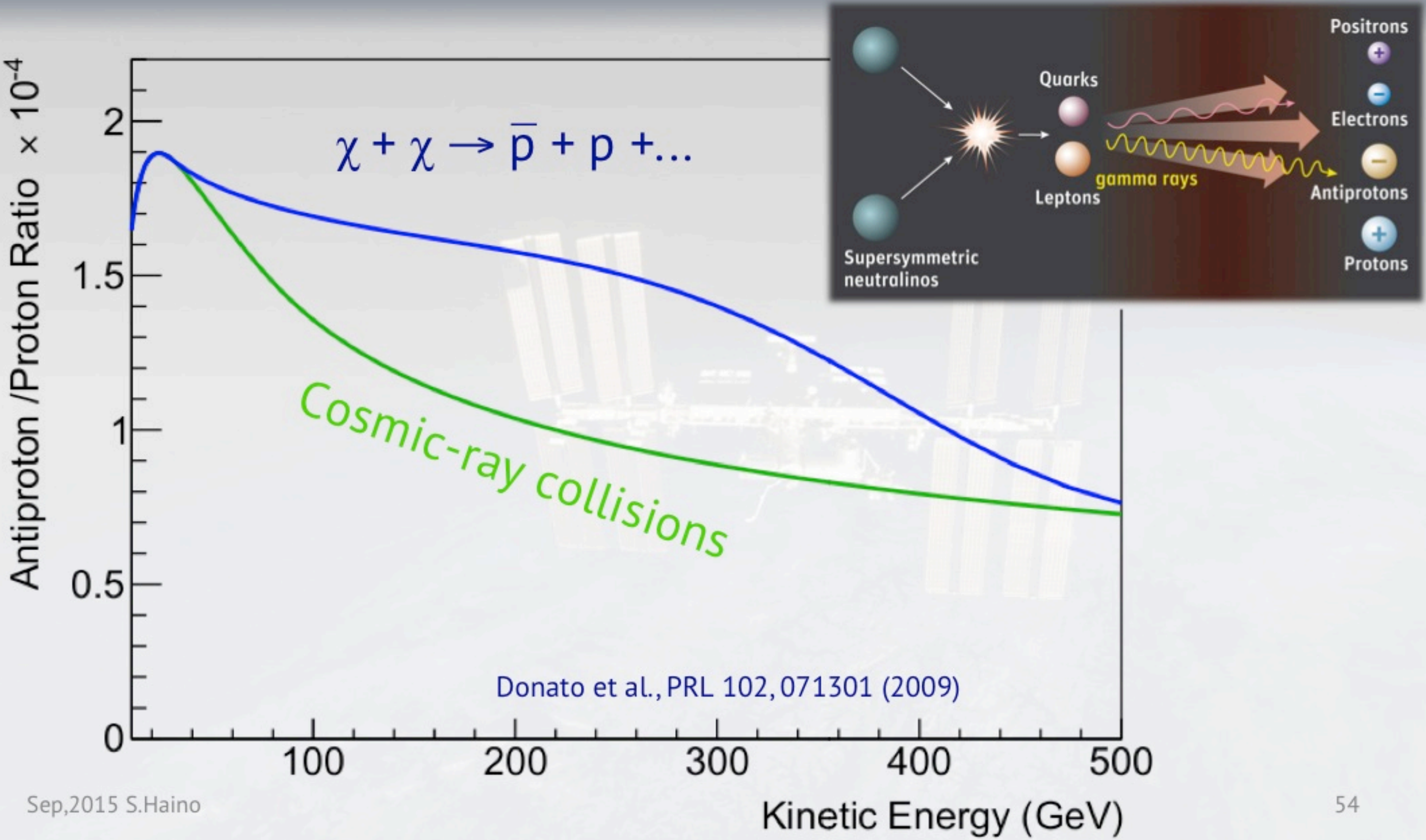
13:30 **E.-S. Seo, Maryland**
Cosmic Ray Energetics and Mass: From Balloons to the ISS
14:30 **W. Hofmann, MPI Heidelberg**
Latest Results from HESS and the Progress of CTA
15:30 **G. Kane, Michigan**
Are there currently well-motivated and phenomenologically allowed dark matter candidates (besides axions)

16:30 Break
16:45 **M. Salamon, DOE**
The Cosmic Frontier at DOE
17:15 **R. Battiston, ASI, Trento**
What next in fundamental and particle physics in space ?

17:45 **S. Ting, MIT, CERN**
Summary

Contact: Ms. Laurence Barrin
<laurence.barrin@cern.ch>

Antiprotons : another probe

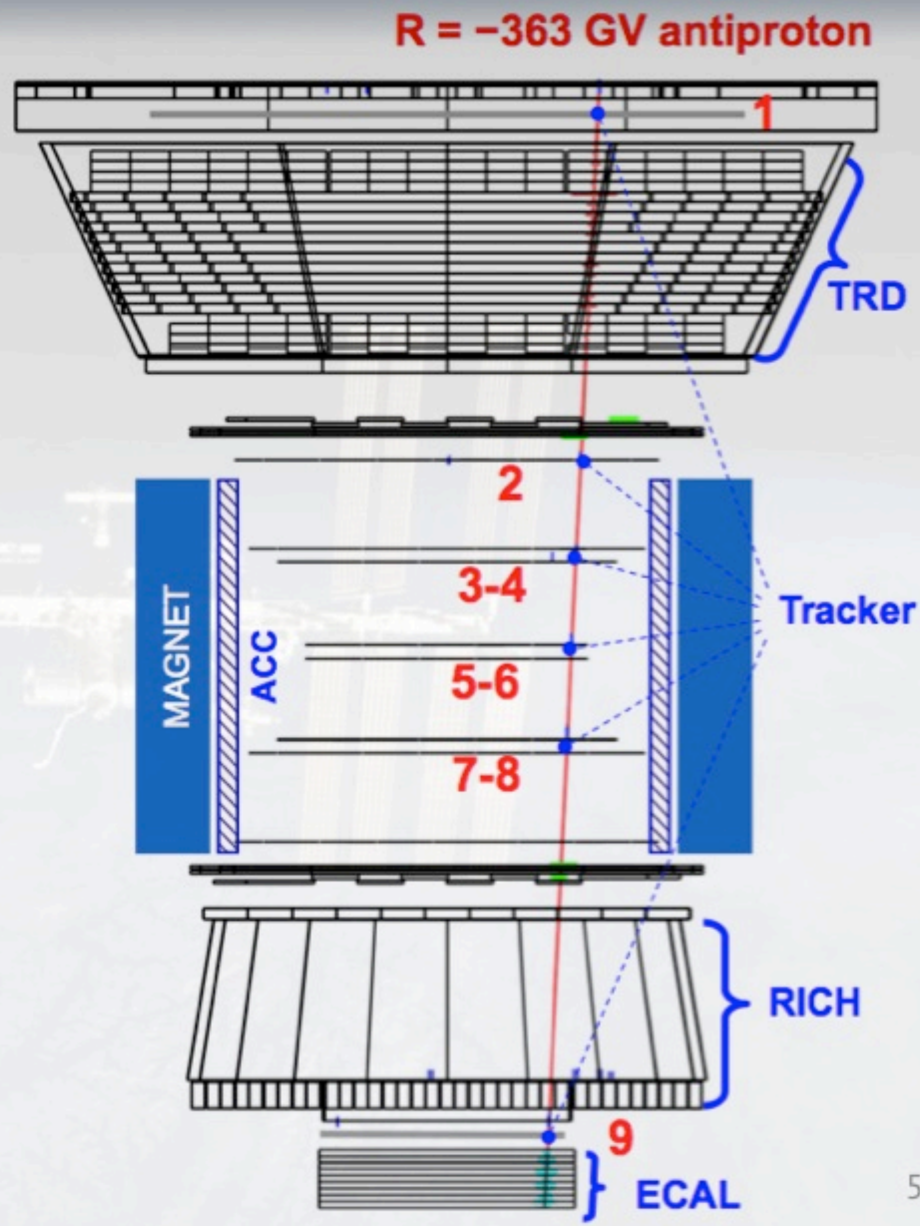


Antiproton analysis

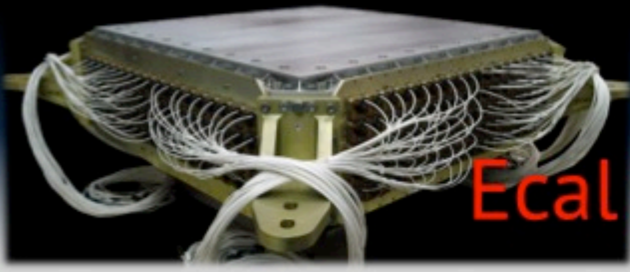
Low energy (R < 10 GV)
TRD (e⁻ B.G.)
TOF/RICH (π⁻ B.G.)

Middle energy (R < 50 GV)
TRD, Ecal (e⁻ B.G.)

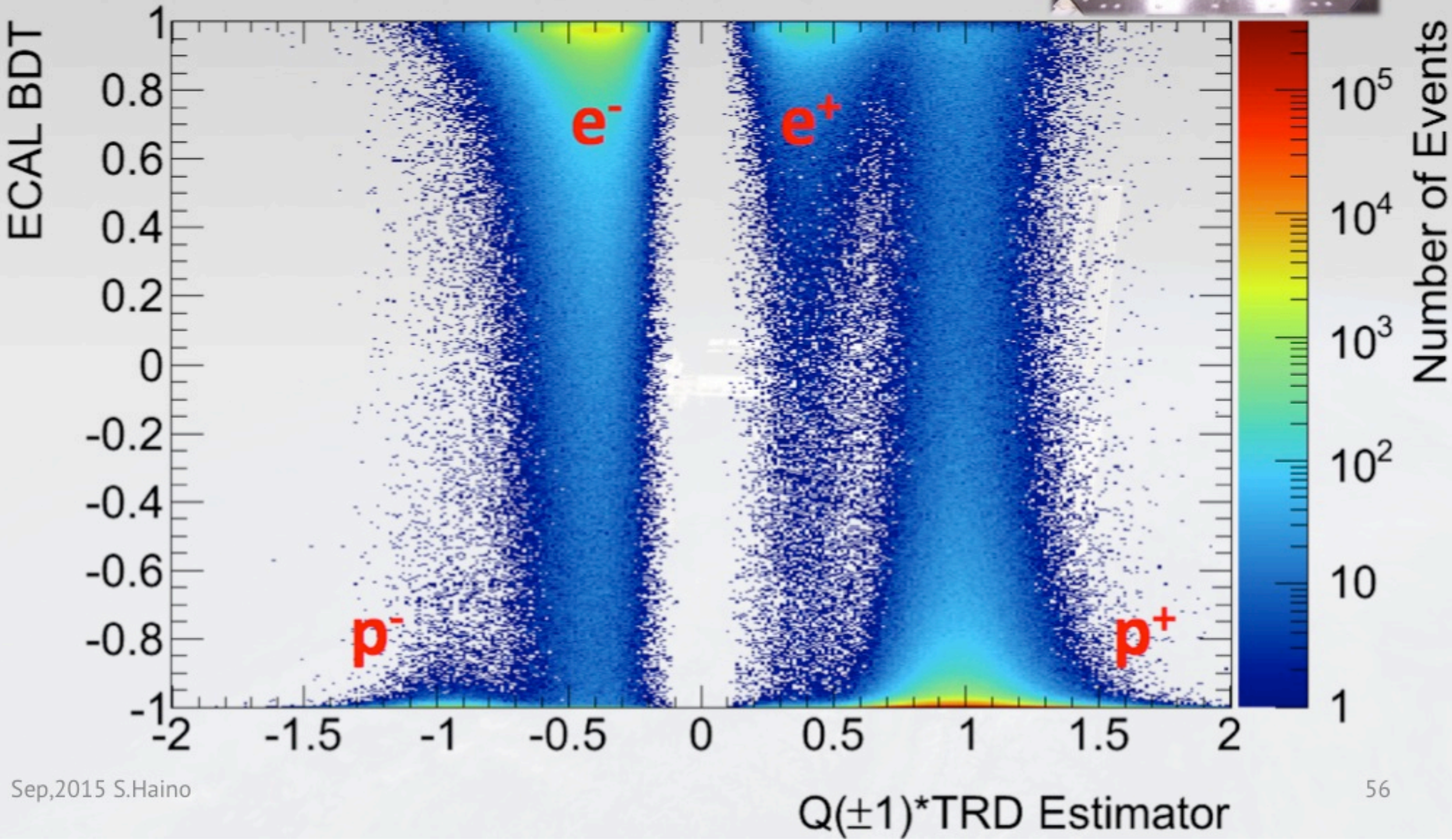
High energy (R > 50 GV)
TRD (e⁻ B.G.)
Tracker (p B.G.)



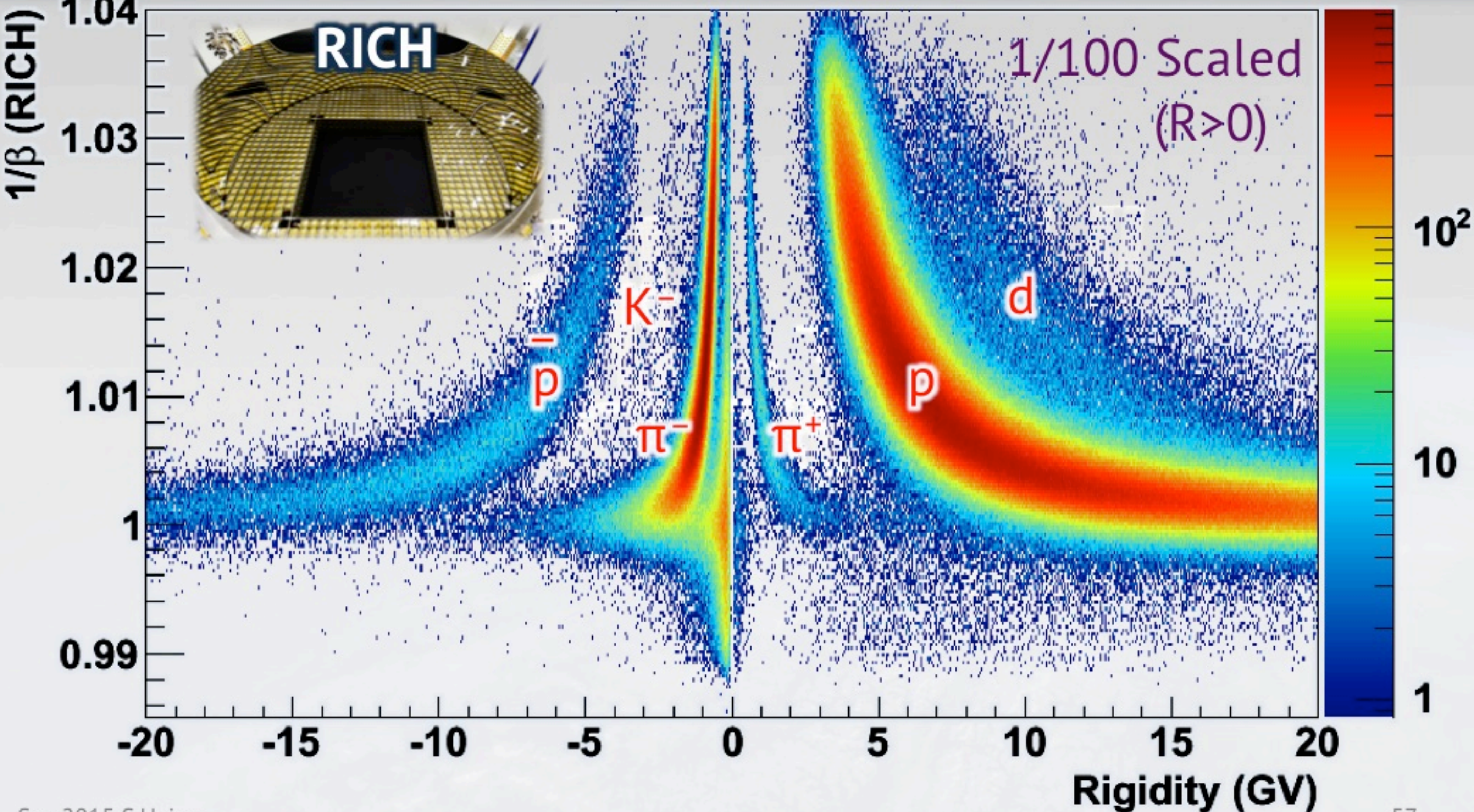
Particle ID


Ecal


TRD
21/07/2005

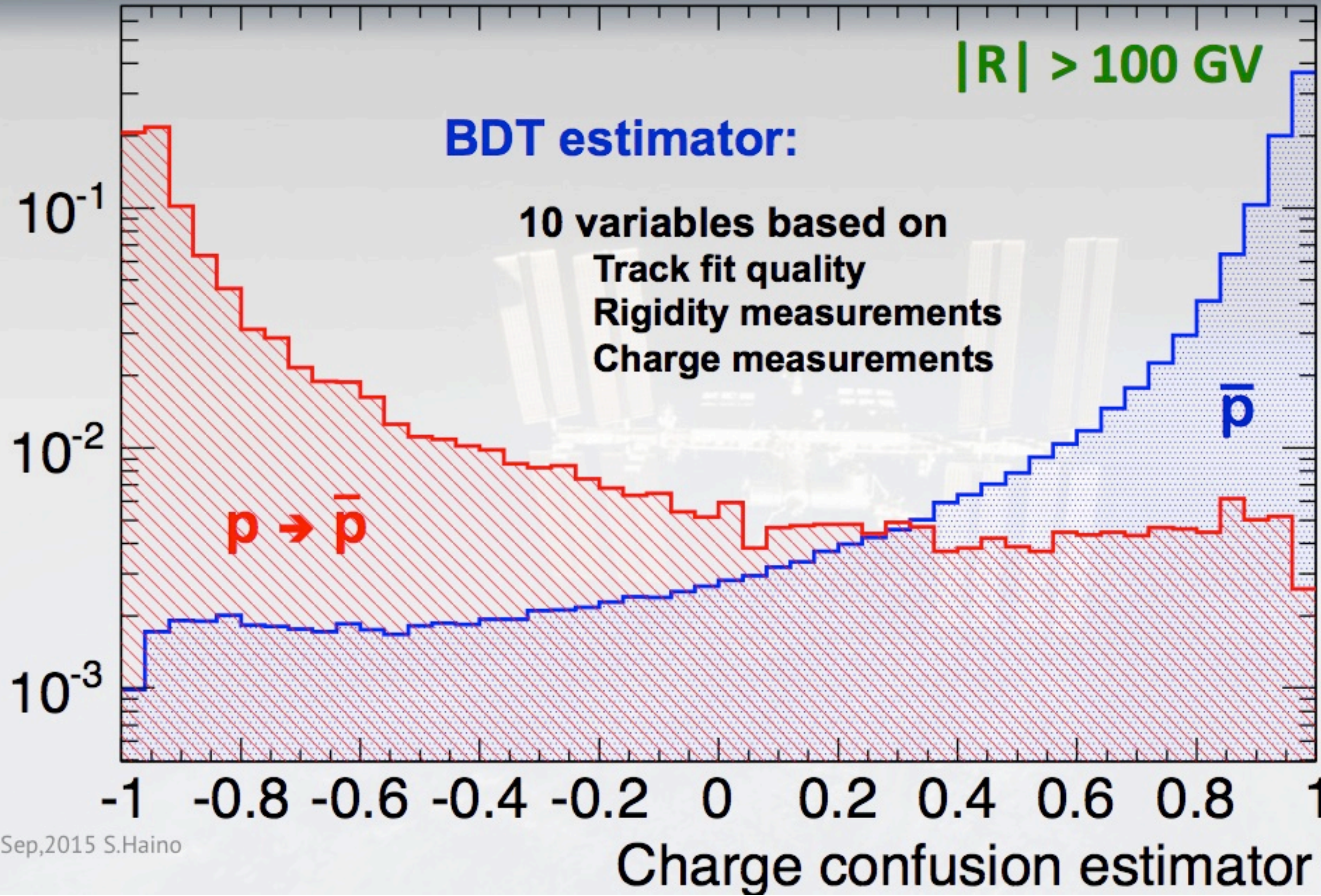

ECAL BDT
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
e-
e+
p-
p+
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
Q(±1)*TRD Estimator
Number of Events
10^5
10^4
10^3
10^2
10
1

Mass ID

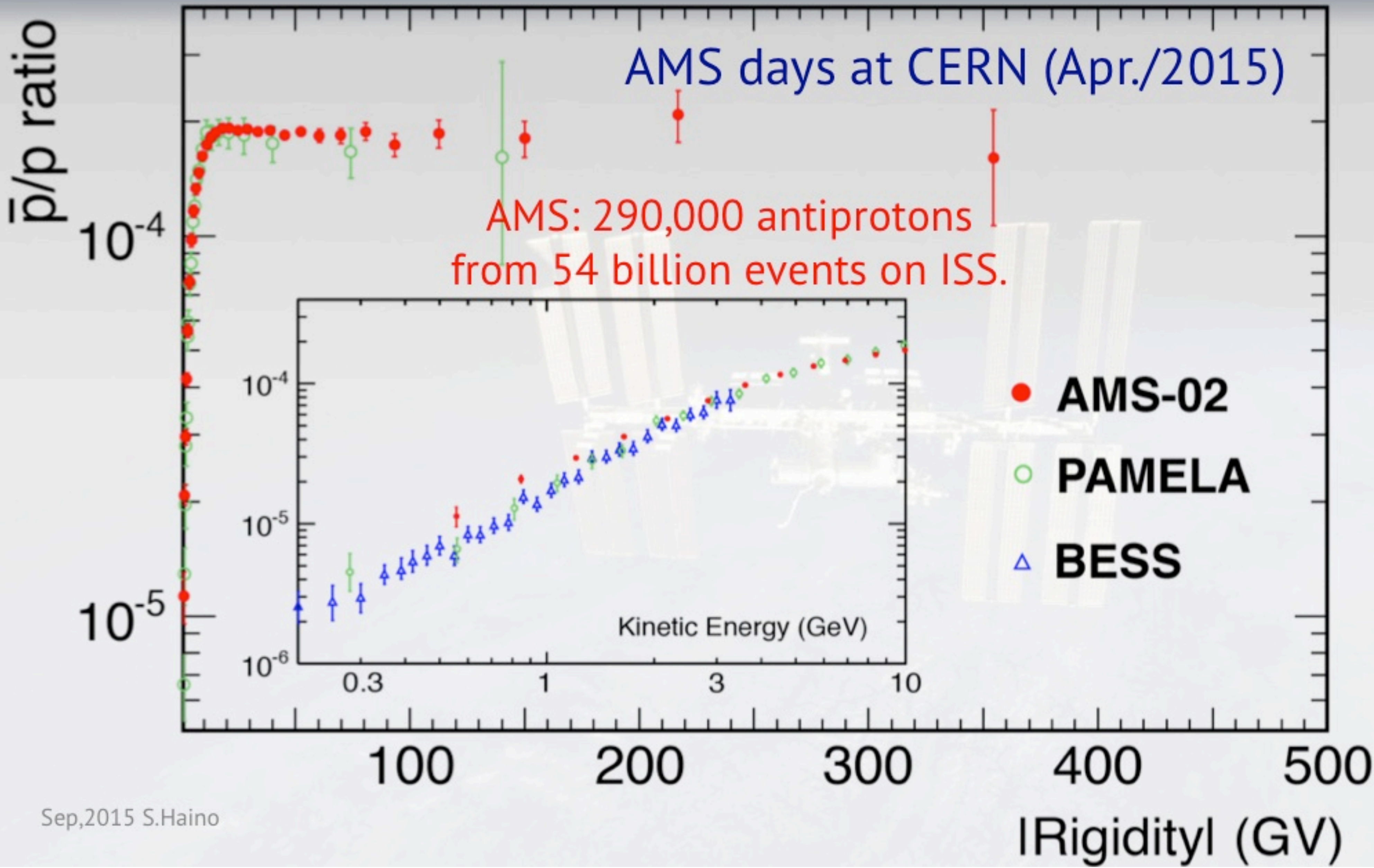


RICH
1/100 Scaled
(R>0)
1/β (RICH)
1.04
1.03
1.02
1.01
1
0.99
K⁻
p̄
π⁻
π⁺
p
d
-20
-15
-10
-5
0
5
10
15
20
Rigidity (GV)
10^2
10
1

Charge sign determination

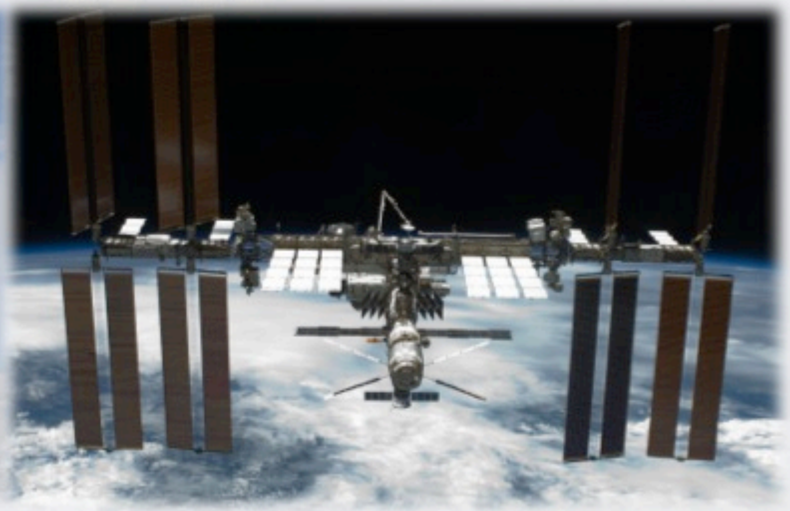


AMS Antiproton : current status

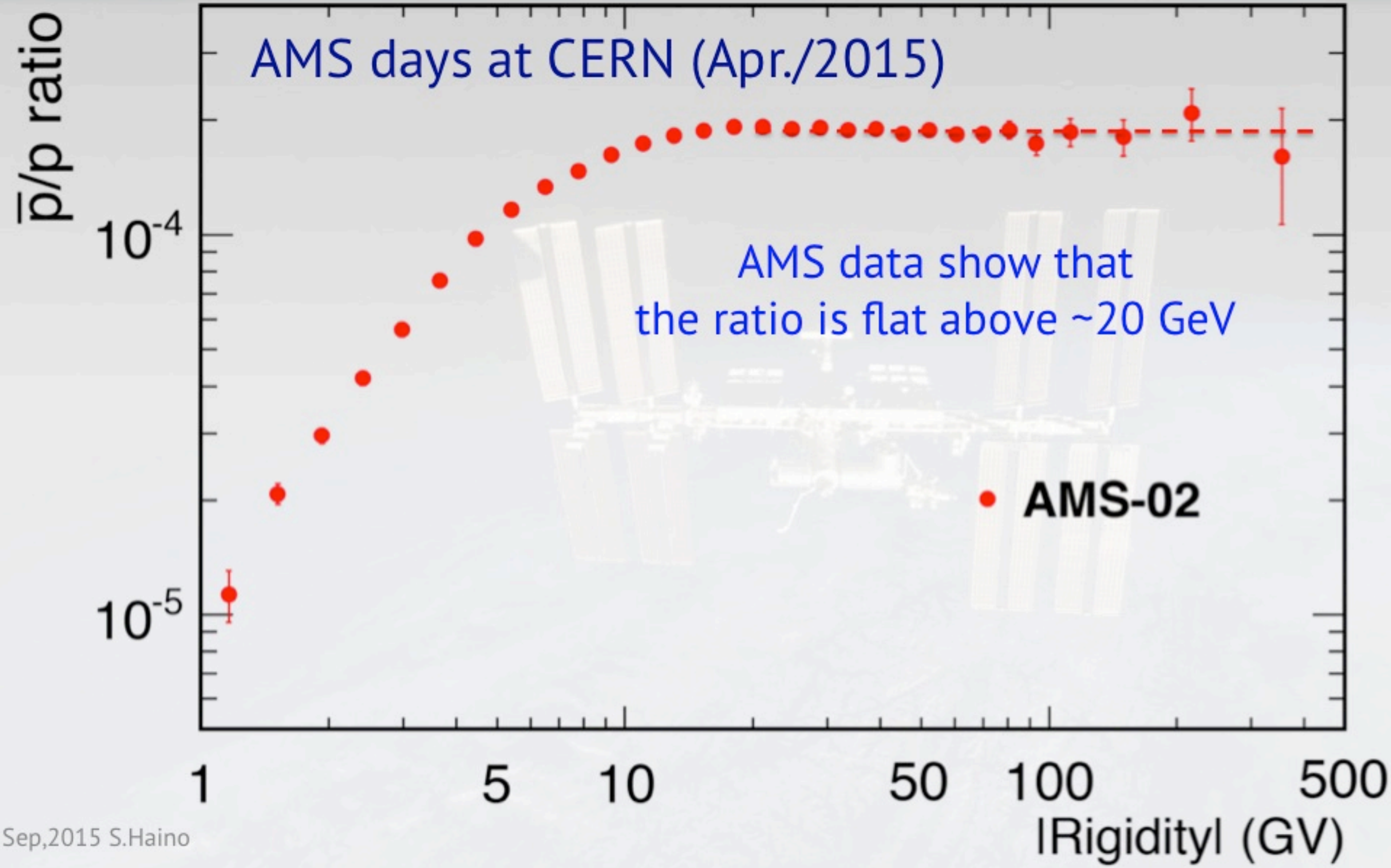


Antiprotons : history and future

Project	BESS-93	BESS-97	BESS-Polar I	BESS-Poalr II	AMS (current)	AMS (expected)
Year	1993	1997	2004	2007	2011-2014	2011-2024
$N\bar{p}$	4	415	1,520	7,886	~290,000	~1,100,000



AMS Antiproton : current status



Anti-deuterons

PRL **95,** 081101 (2005) PHYSICAL REVIEW LETTERS week ending 19 AUGUST 2005

Search for Cosmic-Ray Antideuterons

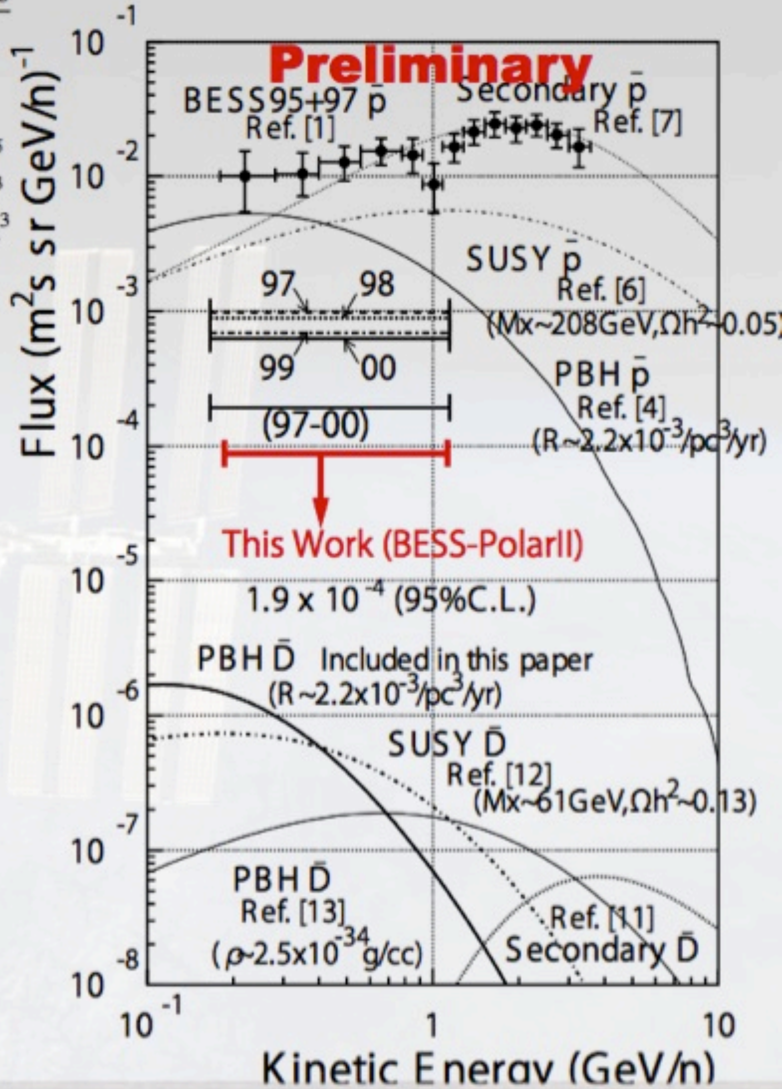
H. Fuke,[1,*] T. Maeno,[2,†] K. Abe,[2,‡] S. Haino,[3] Y. Makida,[3] S. Matsuda,[4] H. Matsumoto,[4] J. W. Mitchell,[5] A. A. Moiseev,[5] J. Nishimura,[4] M. Nozaki,[2] S. Orito,[4,§] J. F. Ormes,[5,‖] M. Sasaki,[5] E. S. Seo,[6] Y. Shikaze,[2,¶] R. E. Streitmatter,[5] J. Suzuki,[3] K. Tanaka,[3] K. Tanizaki,[2] T. Yamagami,[1] A. Yamamoto,[3] Y. Yamamoto,[4,**] K. Yamato,[2] T. Yoshida,[3] and K. Yoshimura[3]

[1]*Institute of Space and Astronautical Science (ISAS/JAXA), Sagamihara, Kanagawa 229-8510, Japan*
[2]*Kobe University, Kobe, Hyogo 657-8501, Japan*
[3]*High Energy Accelerator Research Organization (KEK), Tsukuba, Ibaraki 305-0801, Japan*
[4]*The University of Tokyo, Tokyo 113-0033, Japan*
[5]*NASA, Goddard Space Flight Center, Greenbelt, Maryland 20771, USA*
[6]*University of Maryland, College Park, Maryland 20742, USA*

(Received 16 April 2005; revised manuscript received 6 July 2005; published 16 August 2005)

We performed a search for cosmic-ray antideuterons using data collected during four BESS balloon flights from 1997 to 2000. No candidate was found. We derived, for the first time, an upper limit of 1.9×10^{-4} $(m^2 s\, sr\, GeV/nucleon)^{-1}$ for the differential flux of cosmic-ray antideuterons, at the 95% confidence level, between 0.17 and 1.15 GeV/nucleon at the top of the atmosphere.

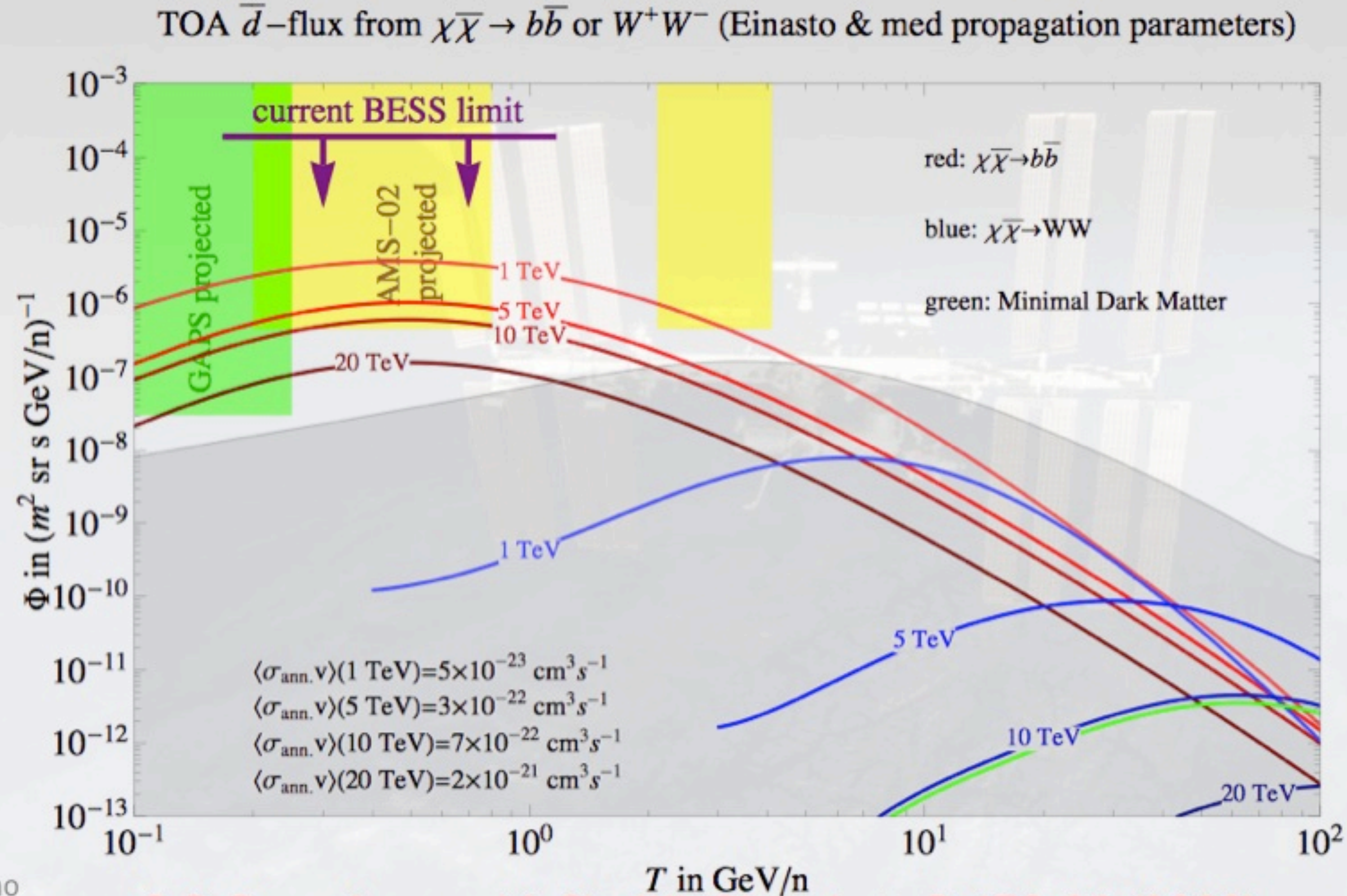
The first and only limit by BESS



BESS-Polar II
K. Yoshimura et al., COSPAR 2014

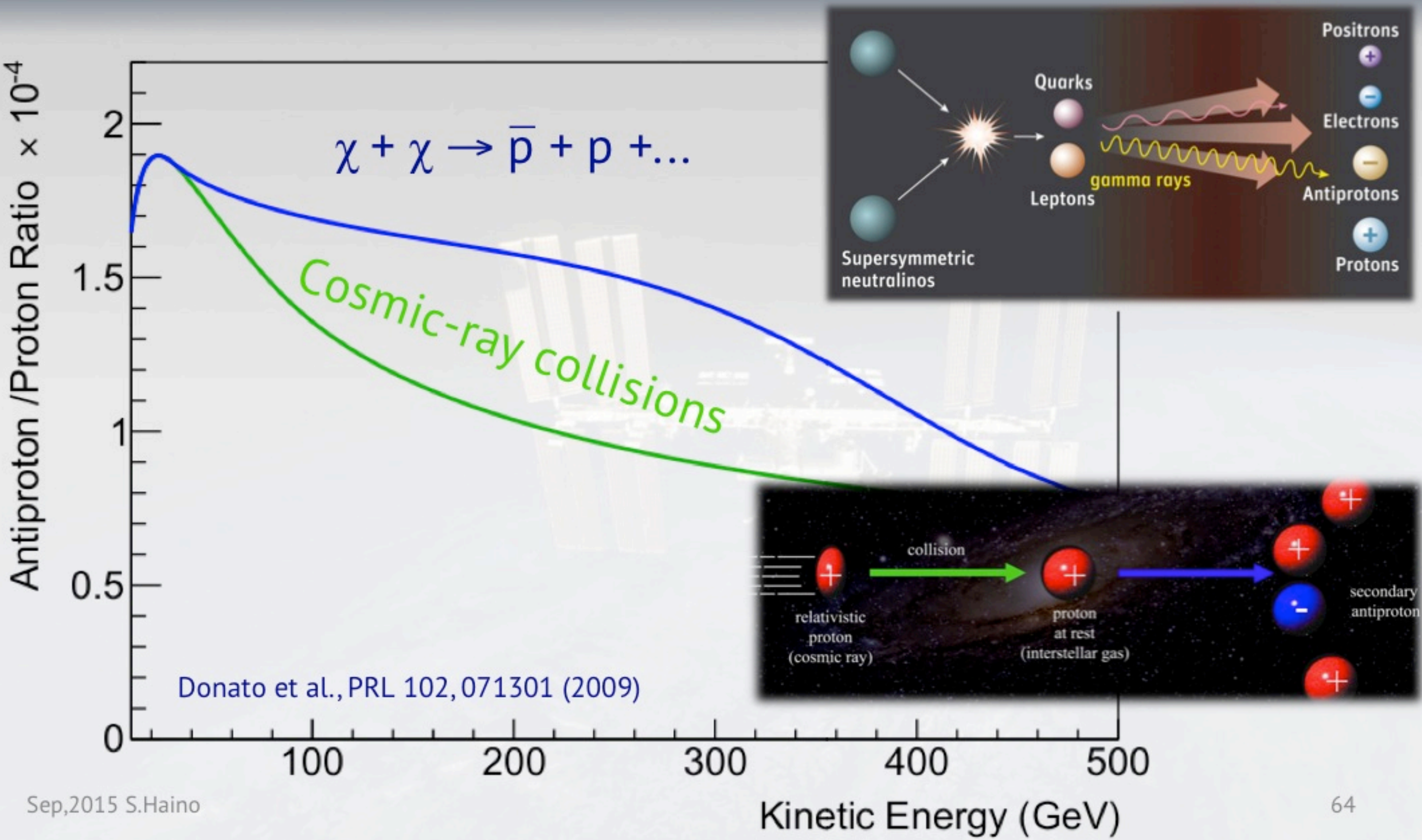
Anti-deuteron

Important probe complementary to e+ and antiproton with Astrophysical B.G. is much suppressed

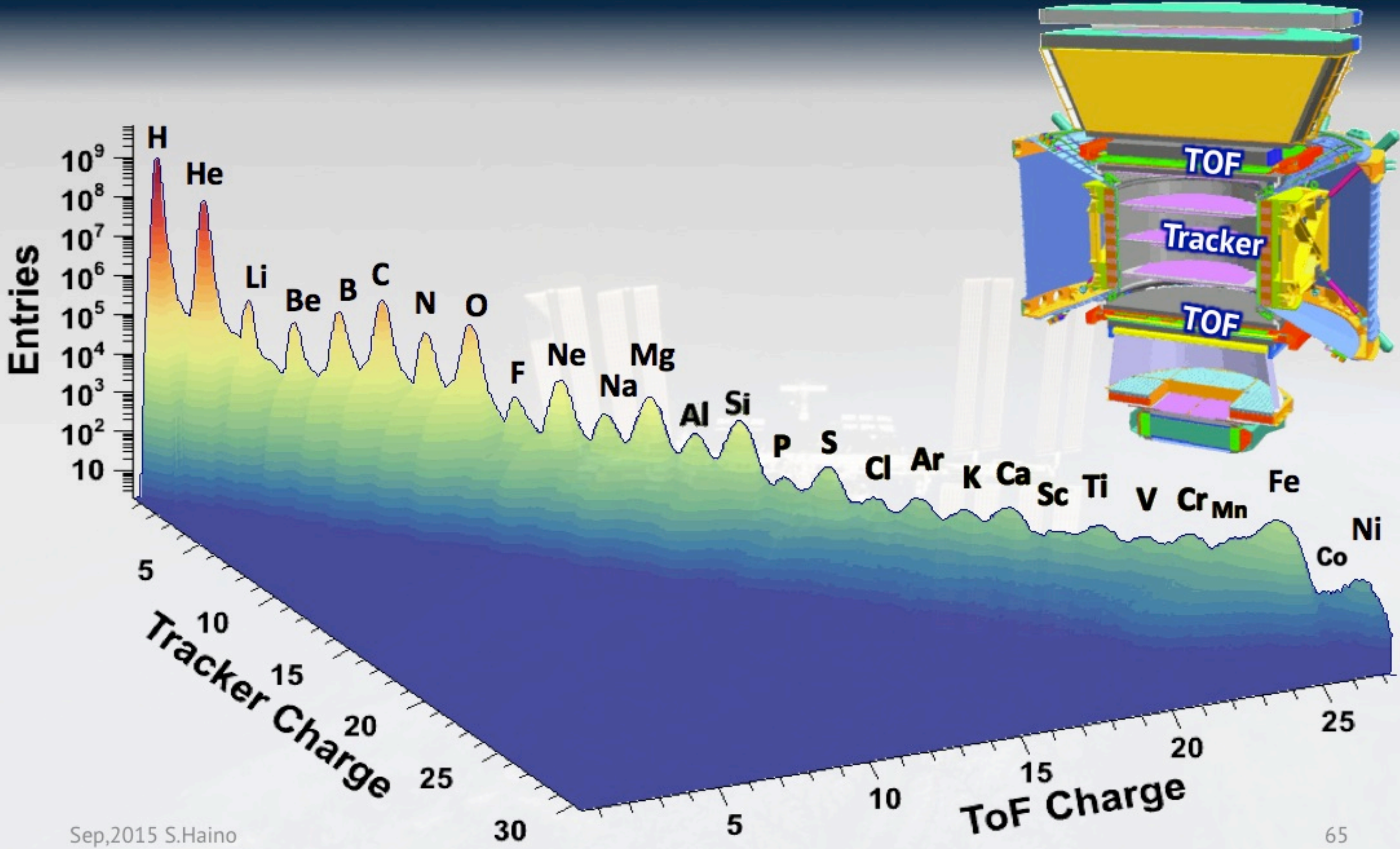


C. B. Brauningera, M. Cirellib Phys. Lett. B 678, 20 (2009)

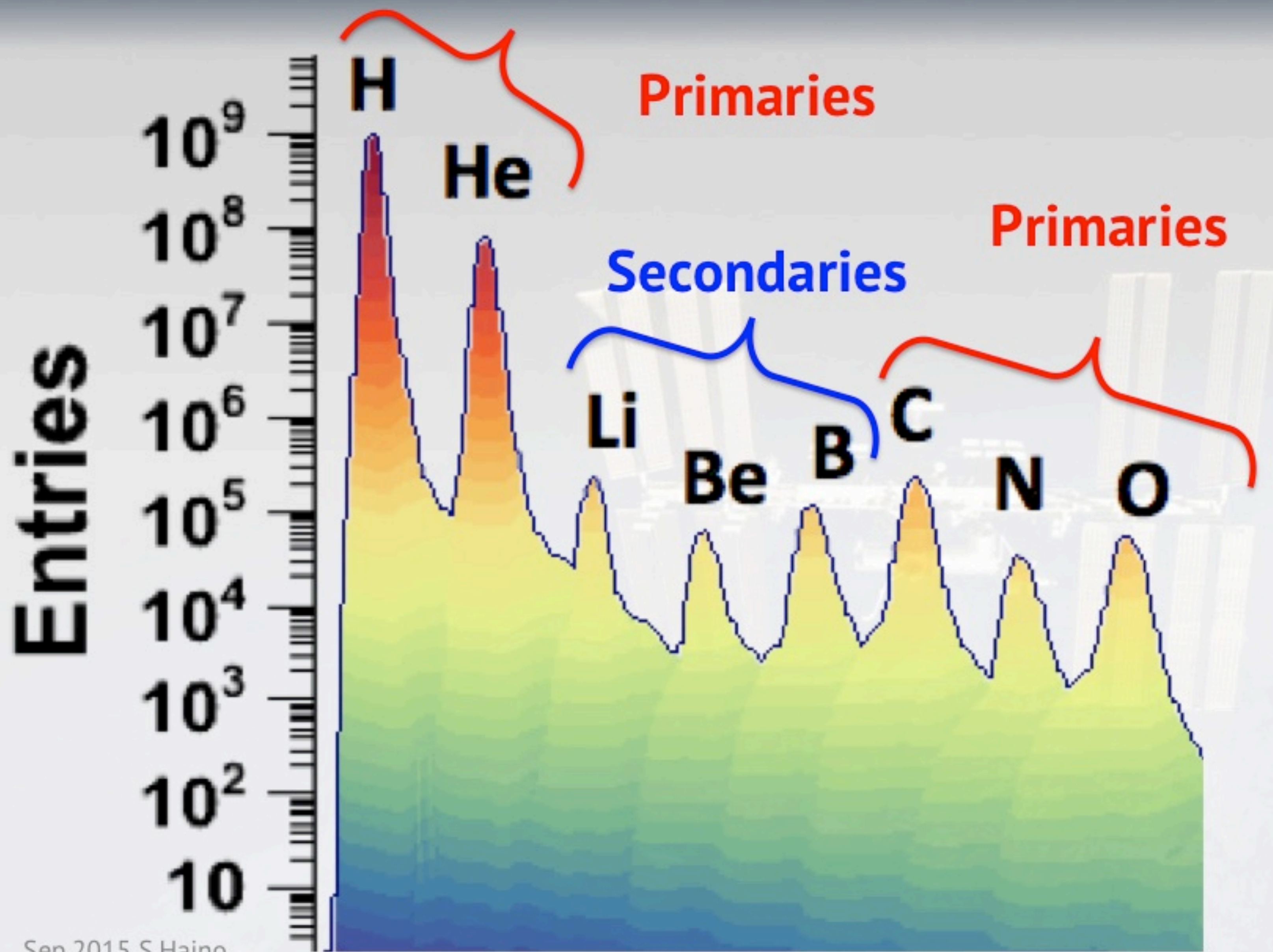
Understanding backgrounds



Nuclei identification in AMS



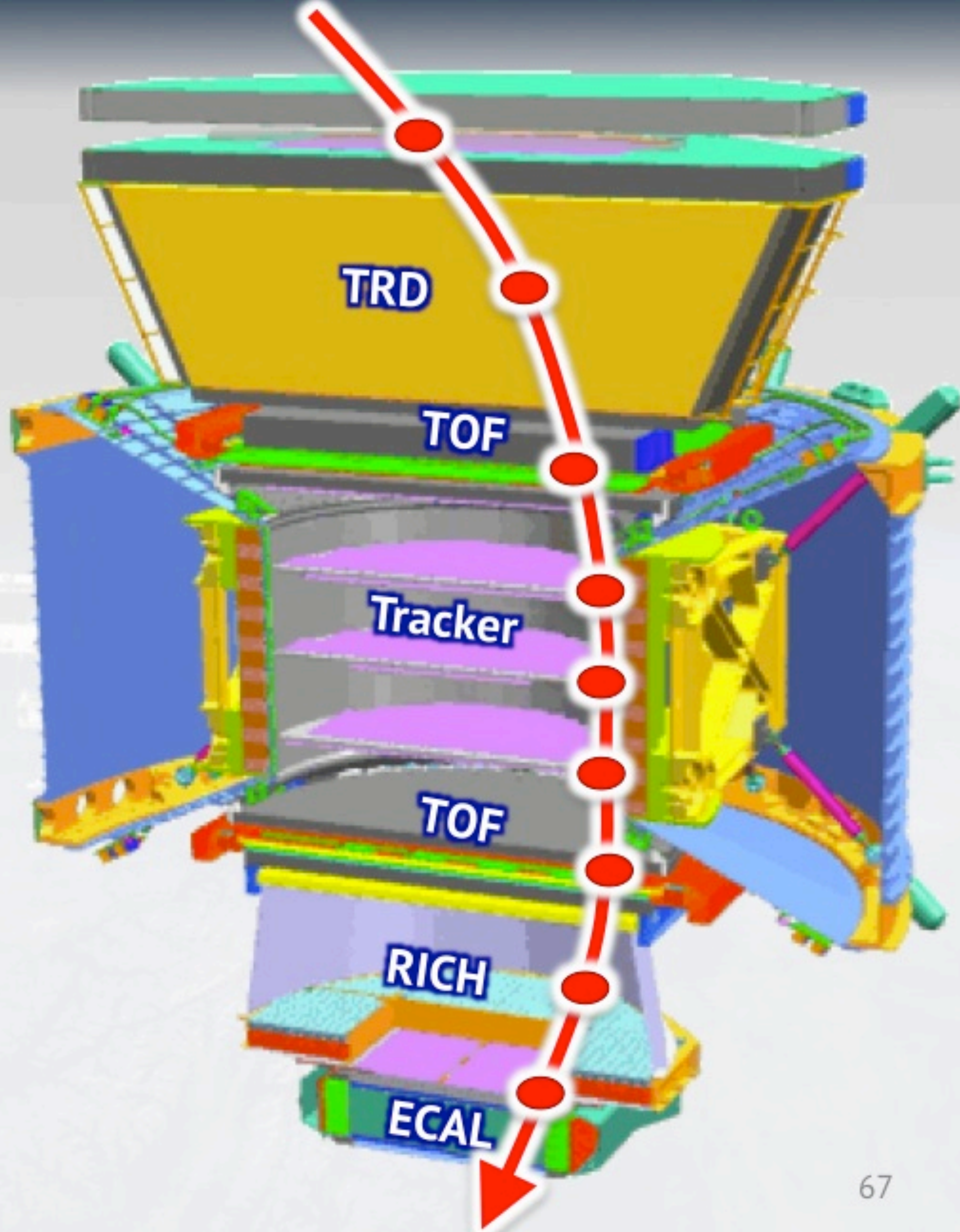
Cosmic-ray nuclei flux



Multiple charge measurements

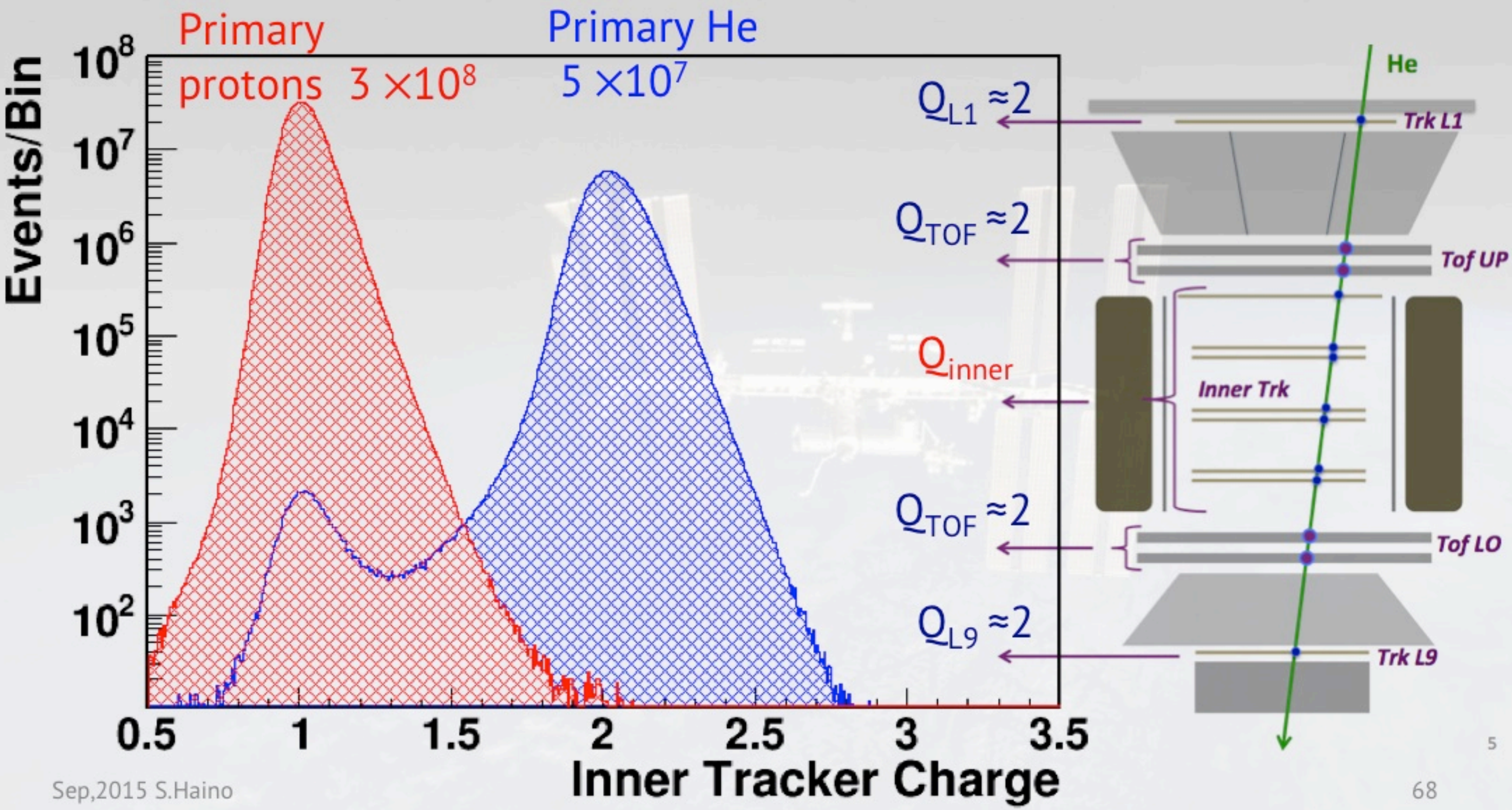
Charge resolution ΔZ (au) for Carbon (Z=6)

- **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**



Proton/He selection

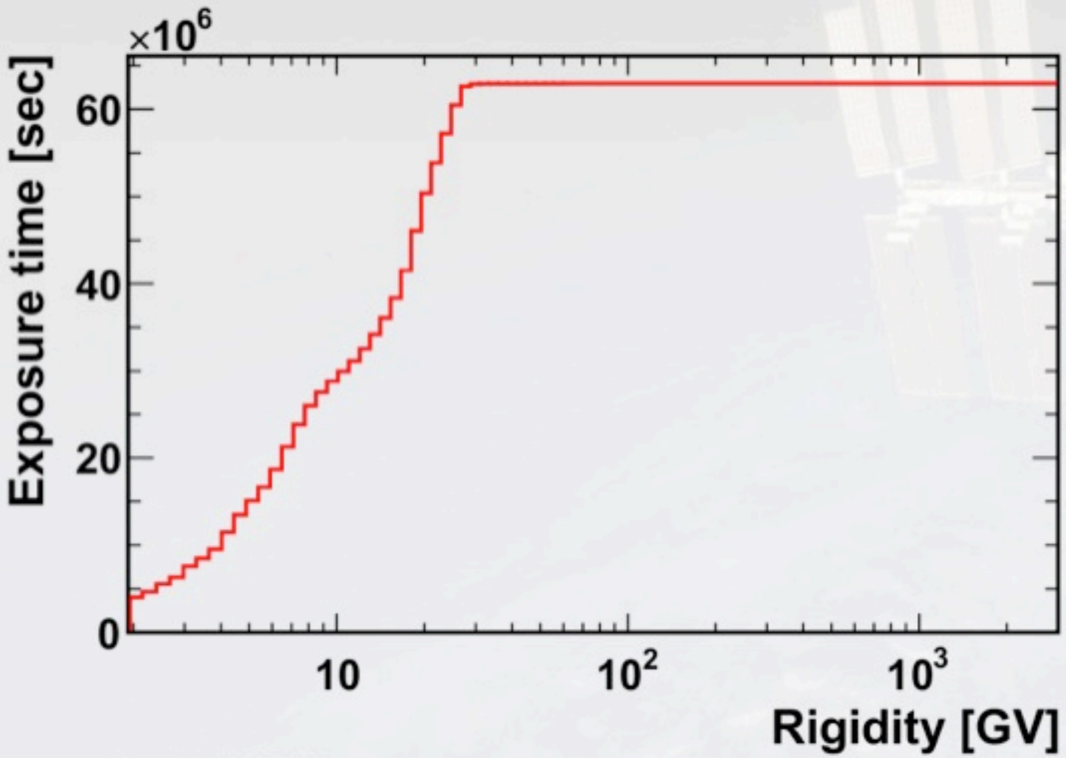
30 months ISS data (May/2011 ~ Nov/2013)



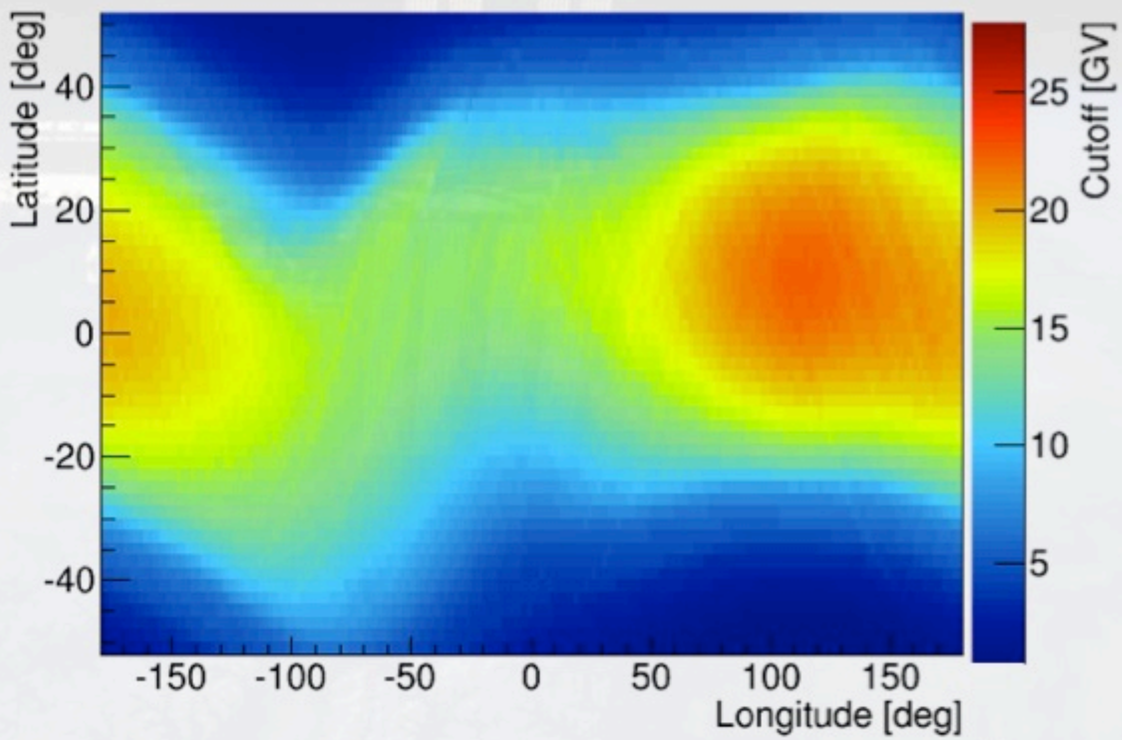
Flux determination : exposure time

$$\Phi_i(R_i) = \frac{N_i}{T_i\, \varepsilon_i\, A_i\, \Delta R_i}$$

T_i : Exposure time



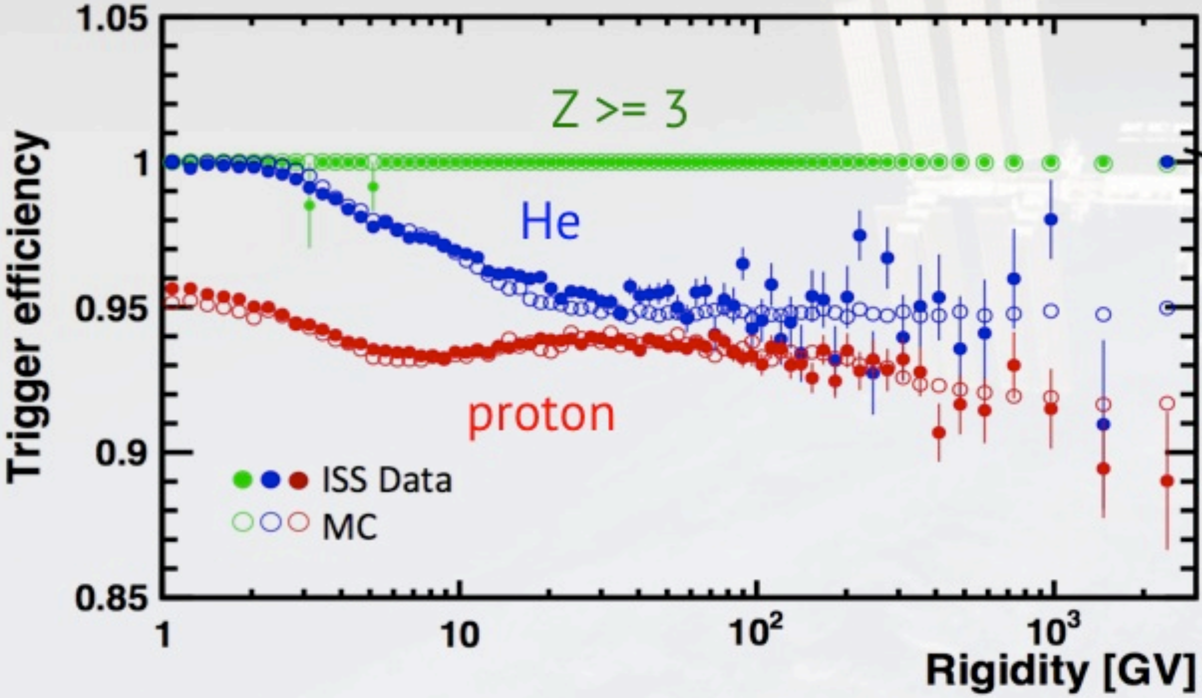
Cutoff Rigidity

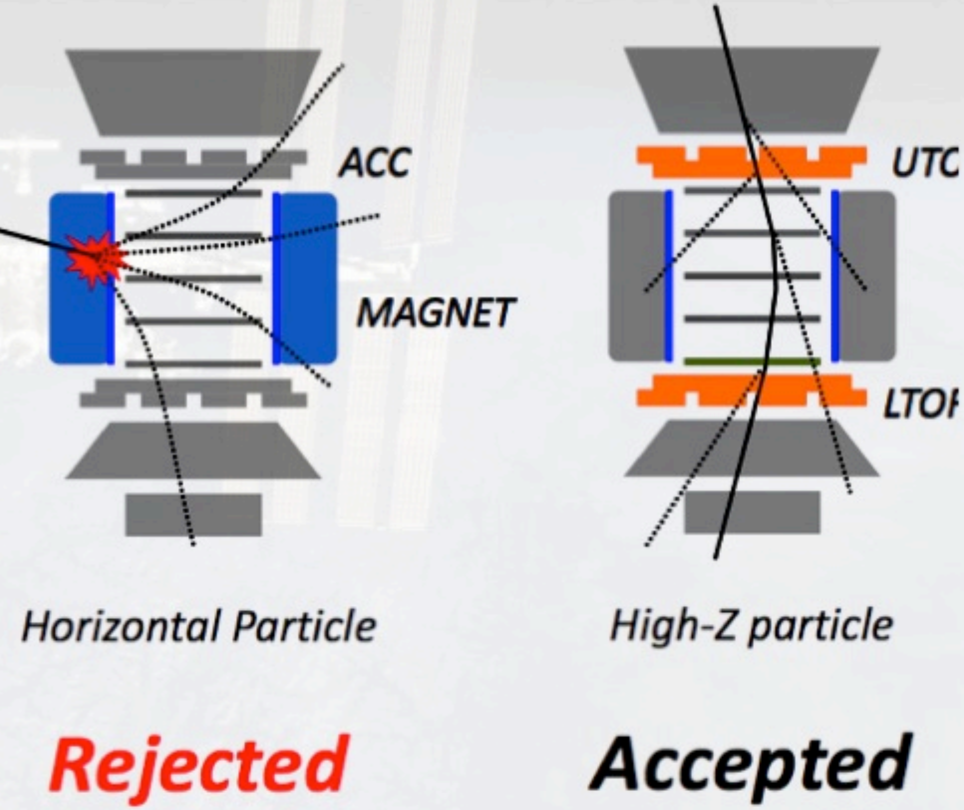


Flux determination : trigger efficiency

$$\Phi_i(R_i) = \frac{N_i}{T_i \, \varepsilon_i \, A_i \, \Delta R_i}$$

ε_i : Trigger efficiency





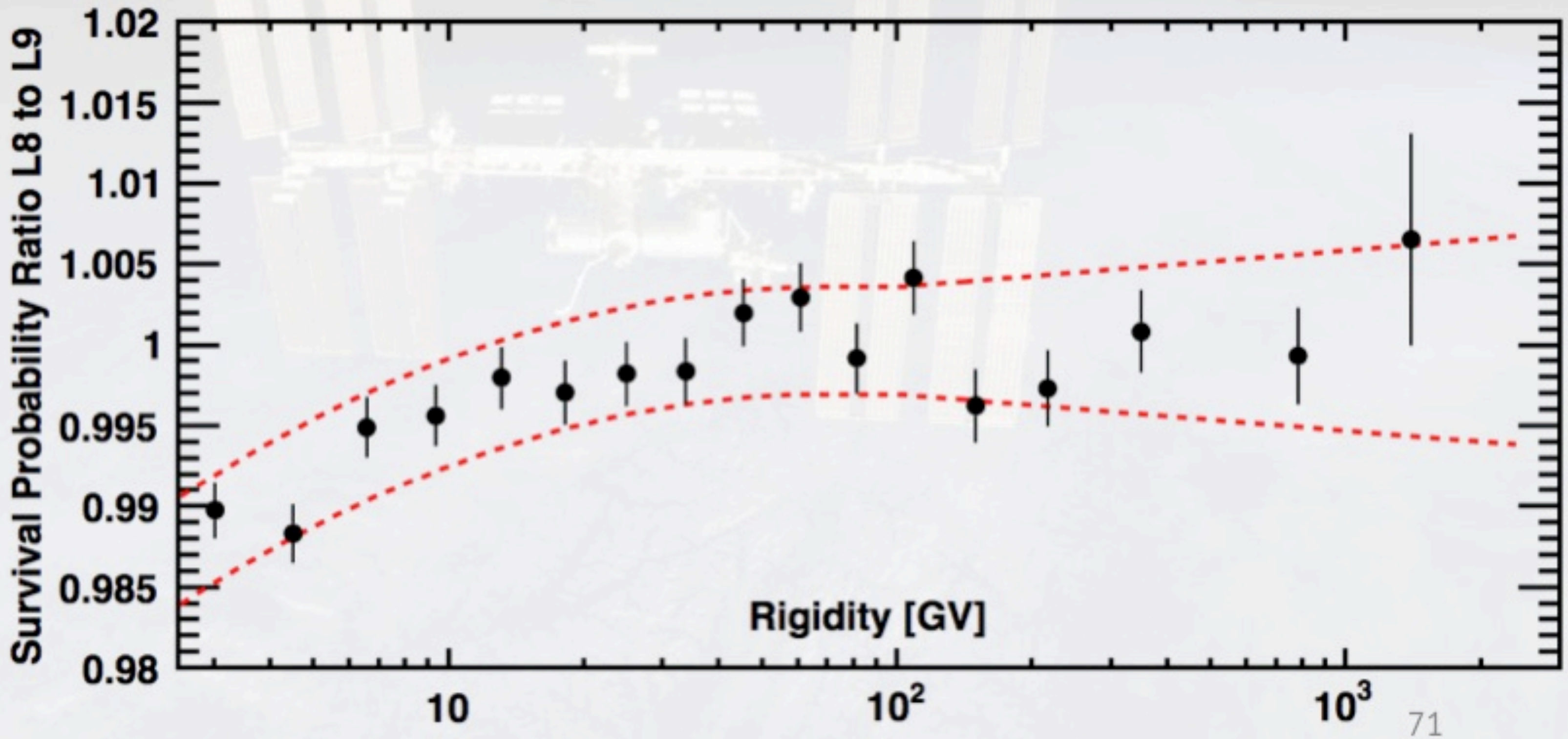
Flux determination : acceptance

$$\Phi_i(R_i) = \frac{N_i}{T_i\,\varepsilon_i\,A_i\,\Delta R_i}$$

A_i : Acceptance

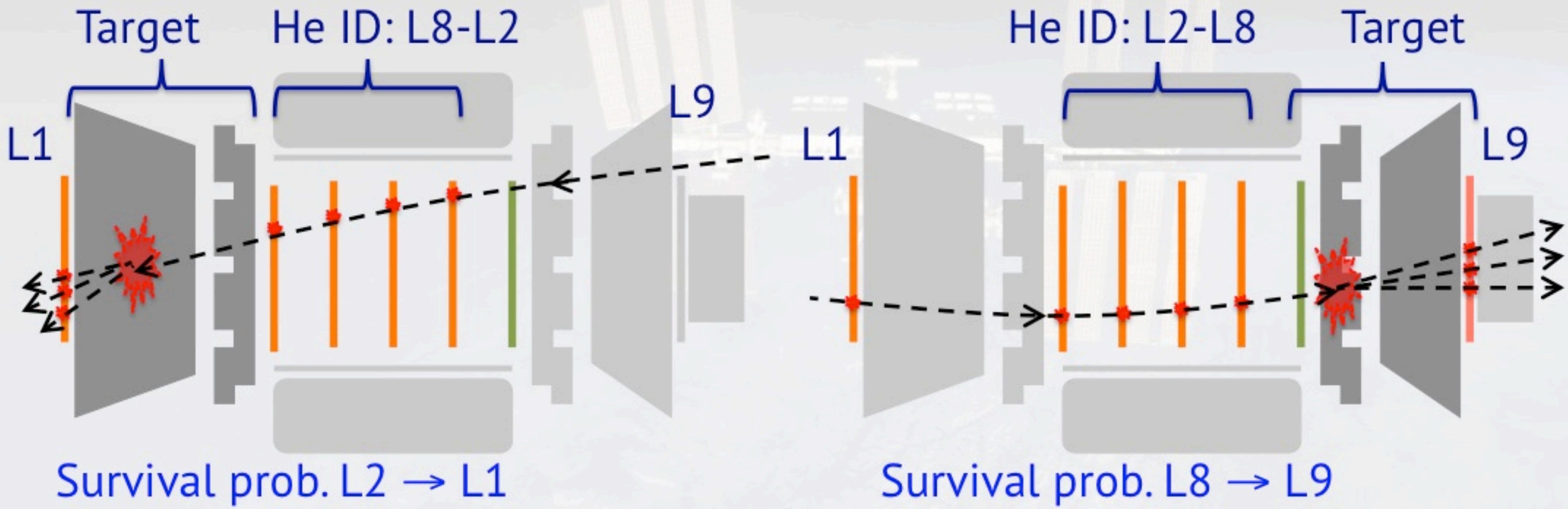
MC validation : MC/Data comparisons on

- Reconstruction efficiency
- Selection efficiency
- Survival probability
- ...



He survival probability measurement

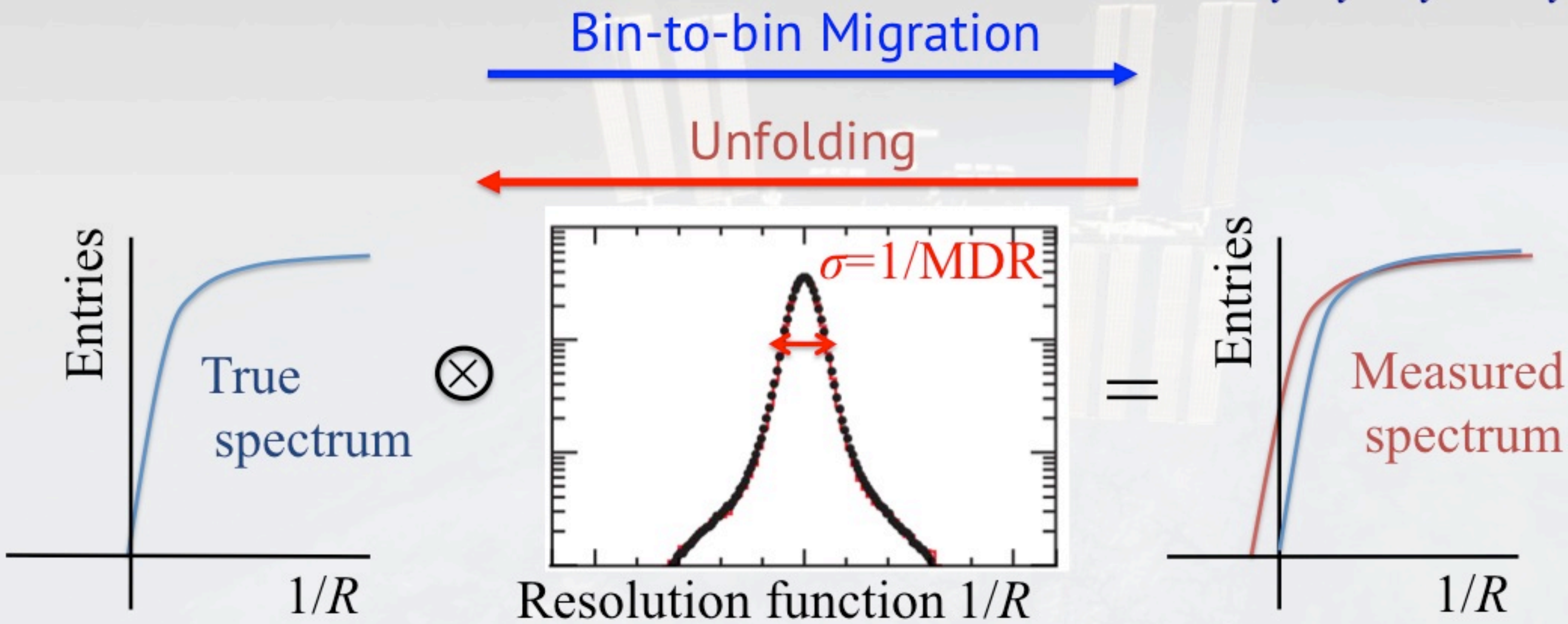
Direct determination with ISS data where AMS is pointing horizontal direction: 2 days in total (from 4 years on ISS)



Unfolding

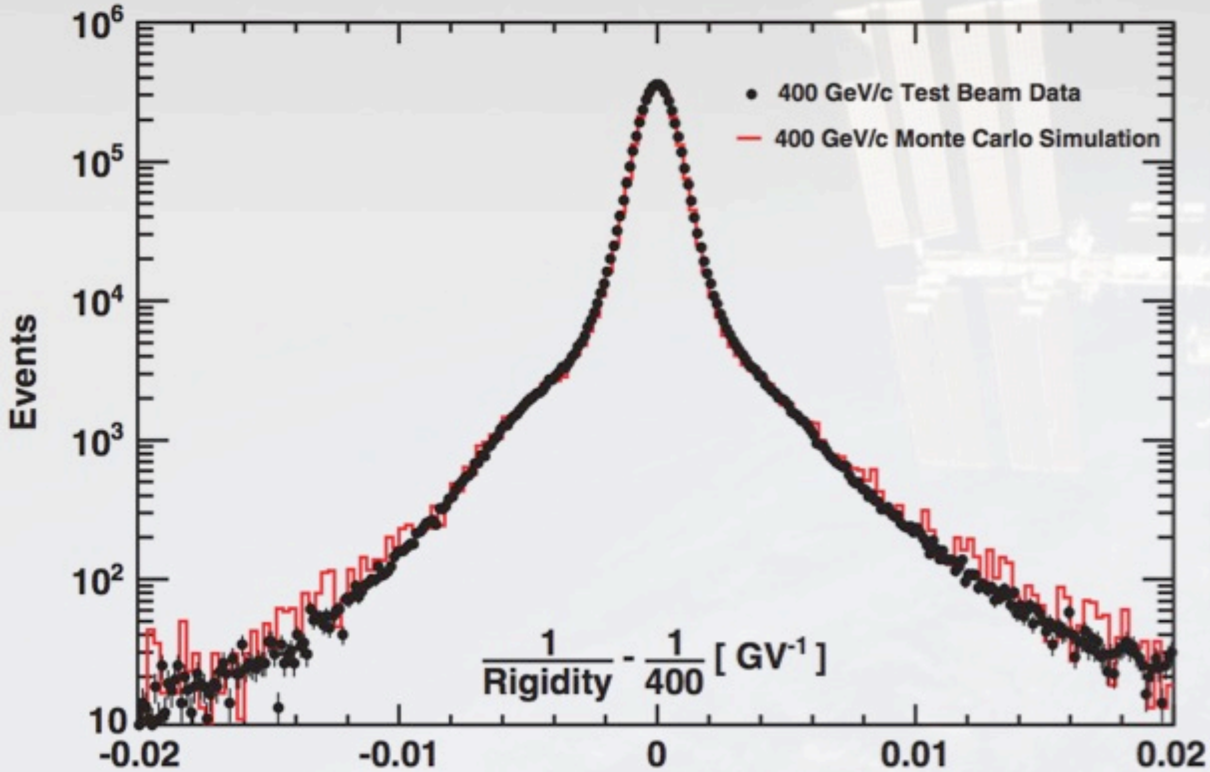
Correction of bin-to-bin migration due to the finite resolution function

$$\Phi_i(R_i) = \frac{N_i}{T_i\, \varepsilon_i\, A_i\, \Delta R_i}$$



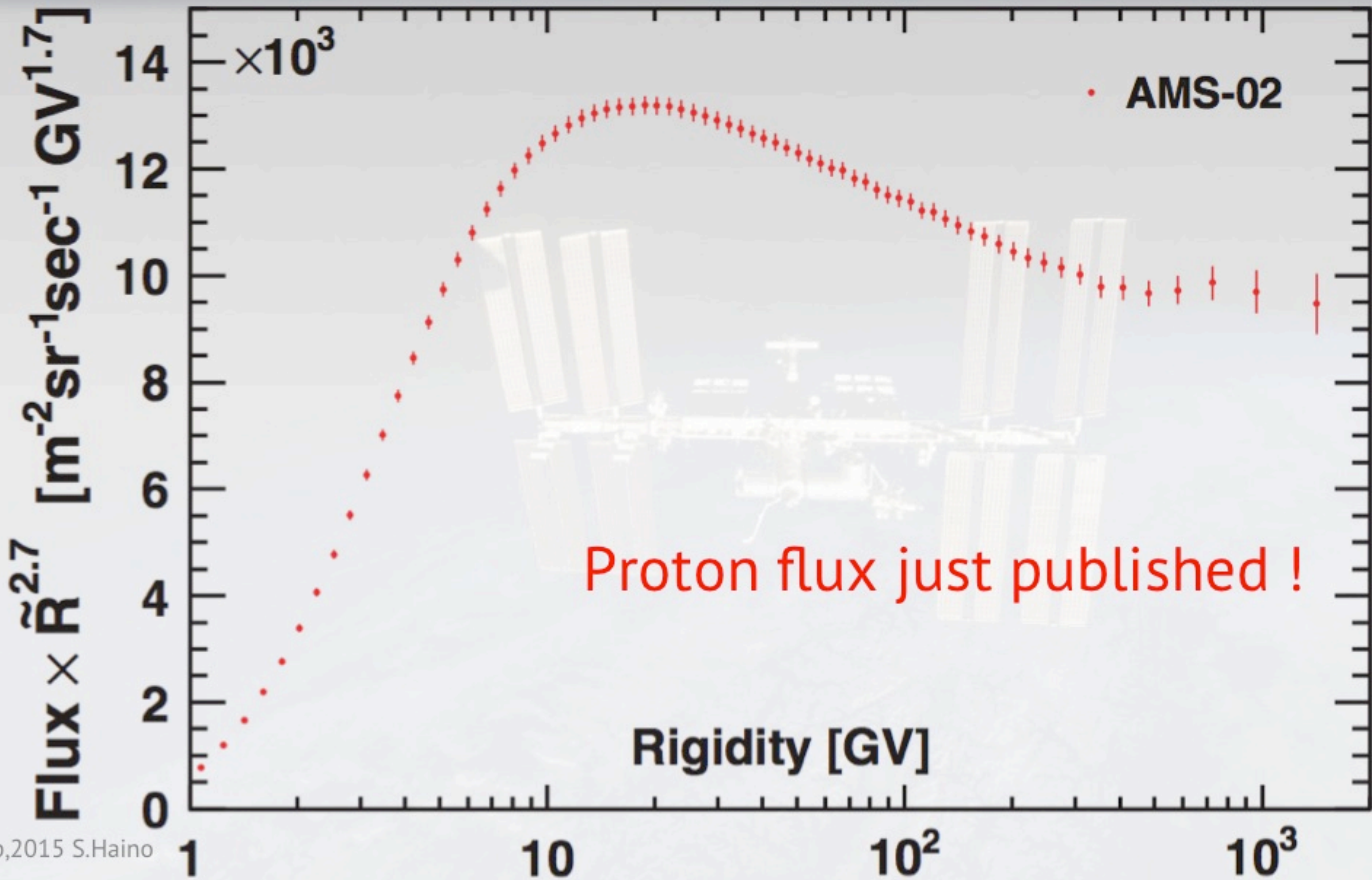
Resolution function

Proton : Calibration with CERN SPS 400 GeV primary beam
Aug. 2010 (just before the launch of AMS in May. 2011)



PRL 114, 171103 (2015) PHYSICAL REVIEW LETTERS week ending 1 MAY 2015

Precision Measurement of the Proton Flux in Primary Cosmic Rays from Rigidity 1 GV to 1.8 TV with the Alpha Magnetic Spectrometer on the International Space Station

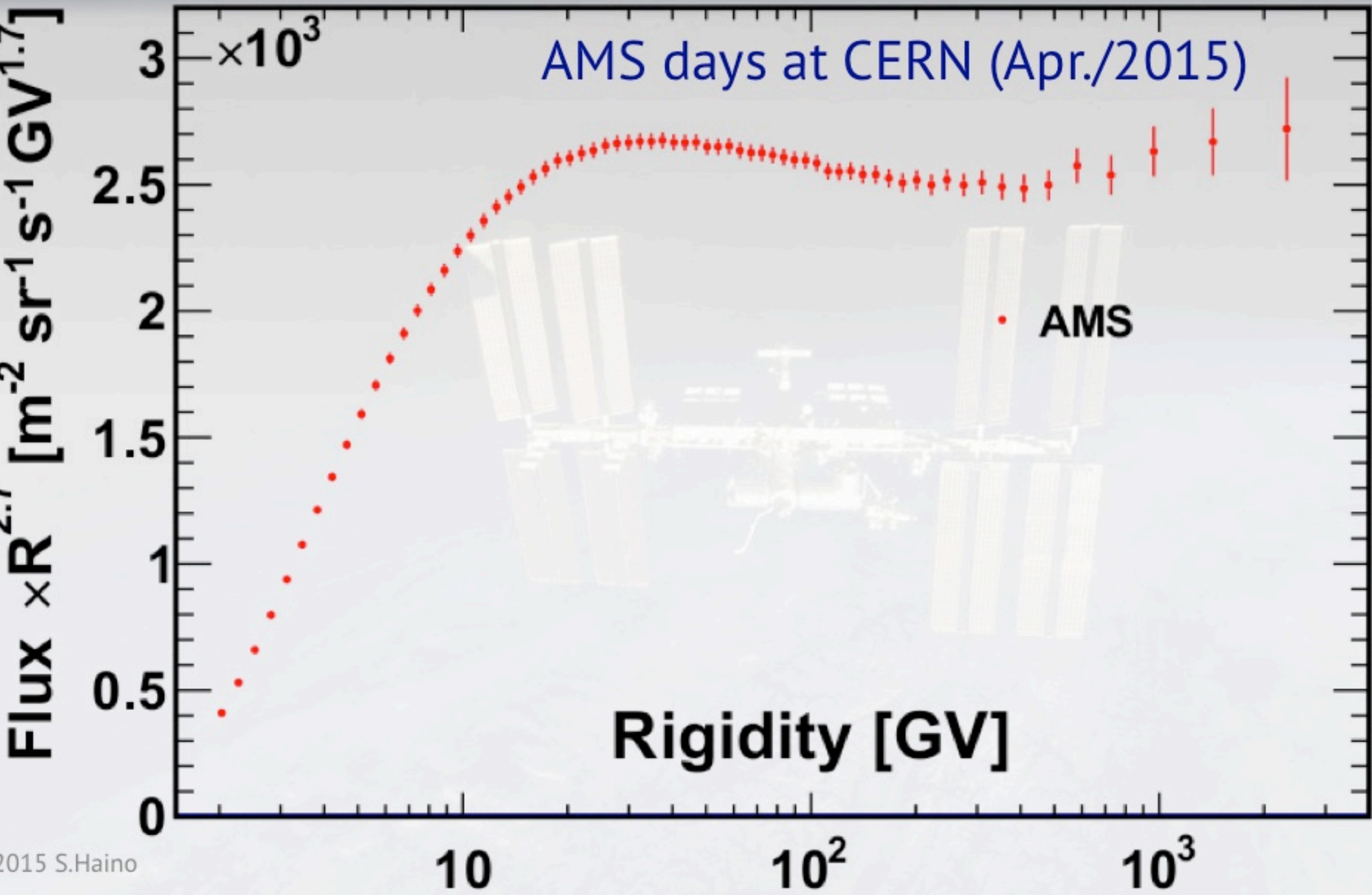


Precision Measurement of the Proton Flux in Primary Cosmic Rays from Rigidity 1 GV to 1.8 TV with the Alpha Magnetic Spectrometer on the International Space Station

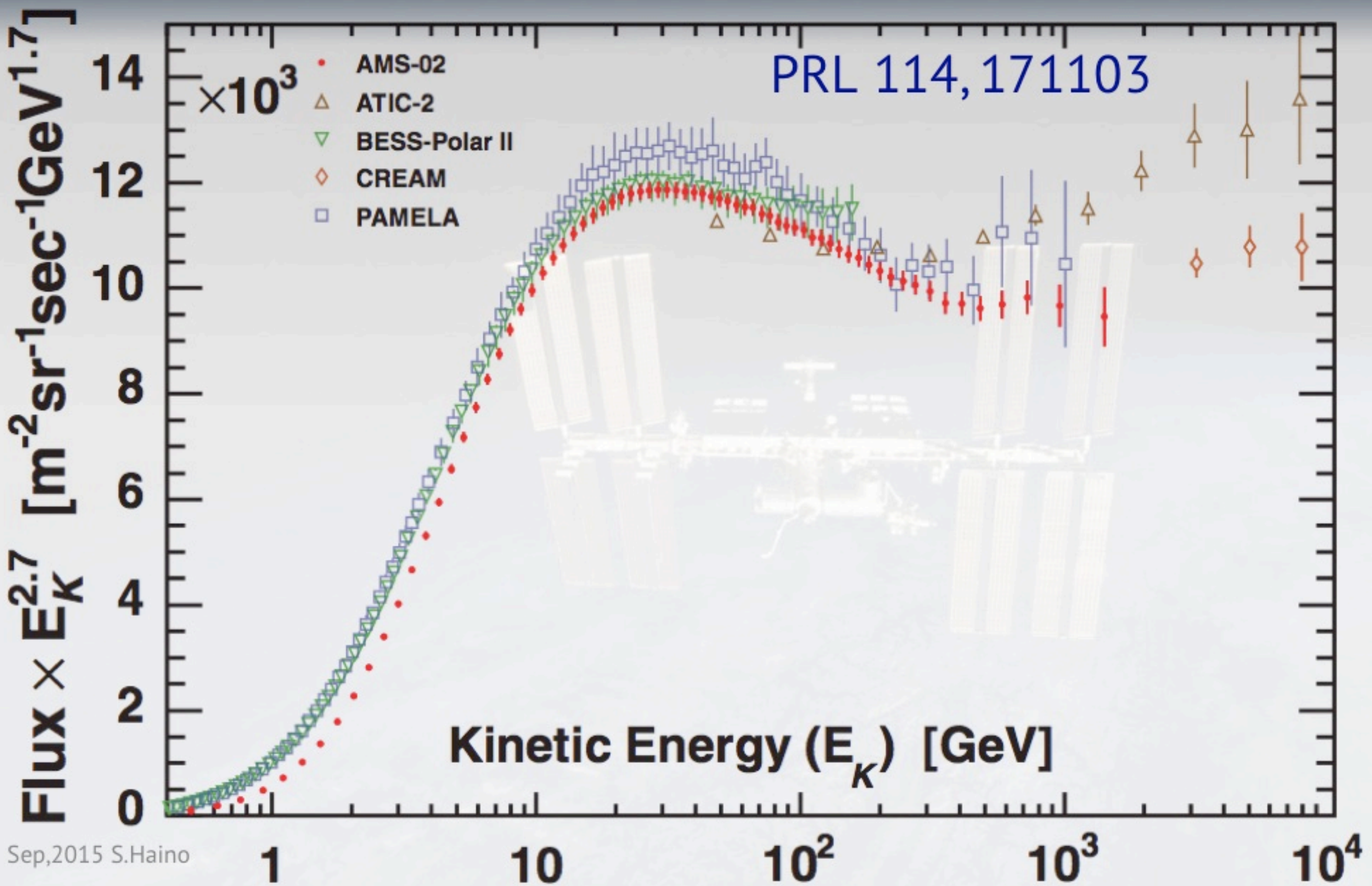
Supplemental Material

Rigidity [GV]	Φ	$\sigma_{stat.}$	$\sigma_{trig.}$	$\sigma_{acc.}$	$\sigma_{unf.}$	σ_{scale}	$\sigma_{syst.}$
100 – 108	(4.085	0.007	0.006	0.040	0.035	0.022	0.058) $\times 10^{-2}$
108 – 116	(3.294	0.007	0.005	0.033	0.028	0.018	0.047) $\times 10^{-2}$
116 – 125	(2.698	0.006	0.004	0.027	0.023	0.016	0.039) $\times 10^{-2}$
125 – 135	(2.174	0.005	0.004	0.022	0.019	0.013	0.032) $\times 10^{-2}$
135 – 147	(1.727	0.004	0.003	0.018	0.016	0.011	0.026) $\times 10^{-2}$
147 – 160	(1.358	0.003	0.003	0.014	0.013	0.009	0.021) $\times 10^{-2}$
...	...						
525 – 643	(3.357	0.017	0.018	0.047	0.052	0.057	0.092) $\times 10^{-4}$
643 – 822	(1.860	0.010	0.012	0.028	0.032	0.040	0.060) $\times 10^{-4}$
822 – 1130	(8.571	0.053	0.071	0.139	0.192	0.254	0.355) $\times 10^{-5}$
1130 – 1800	(2.933	0.021	0.035	0.055	0.092	0.130	0.173) $\times 10^{-5}$

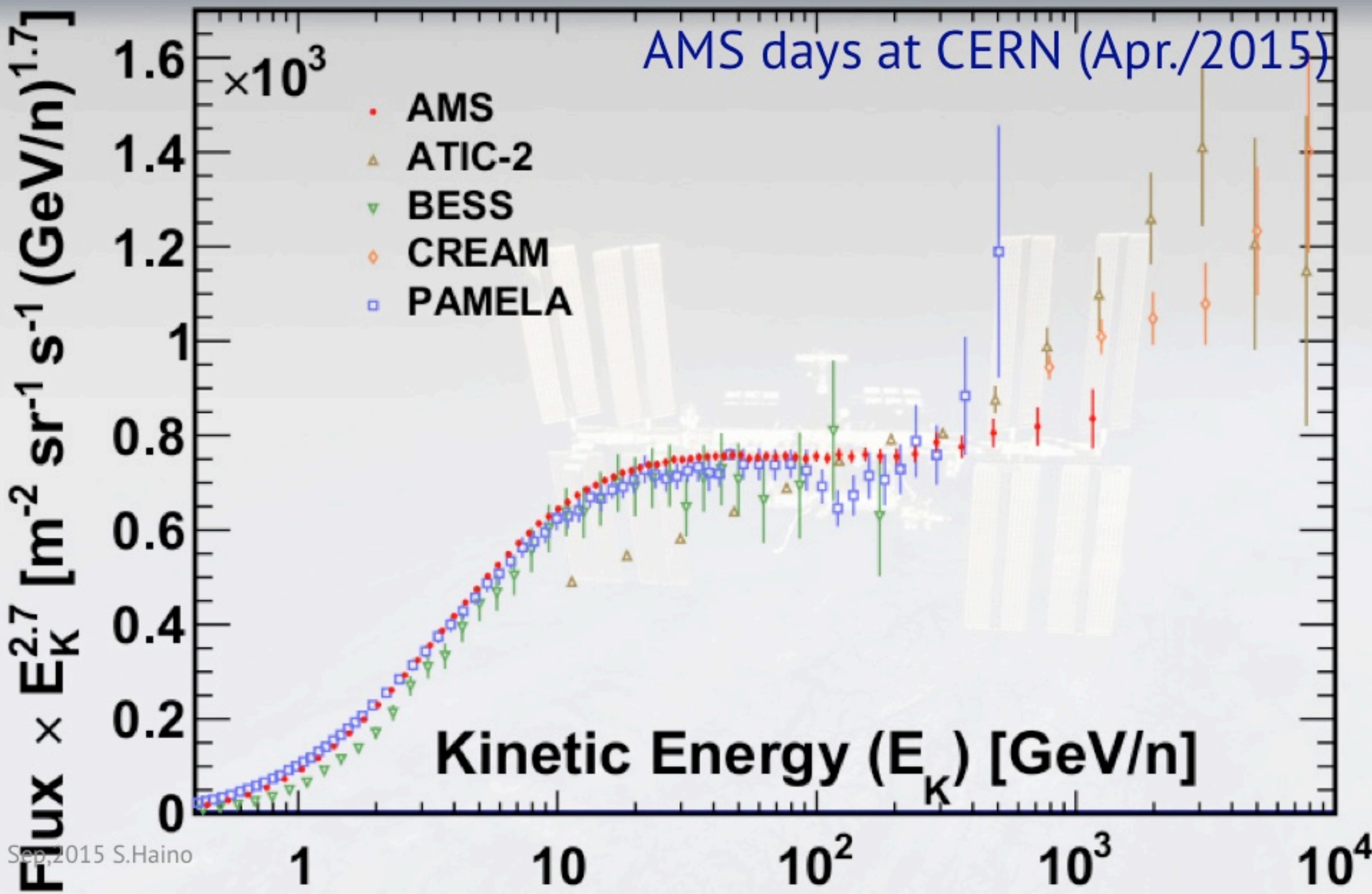
He flux is coming soon ...



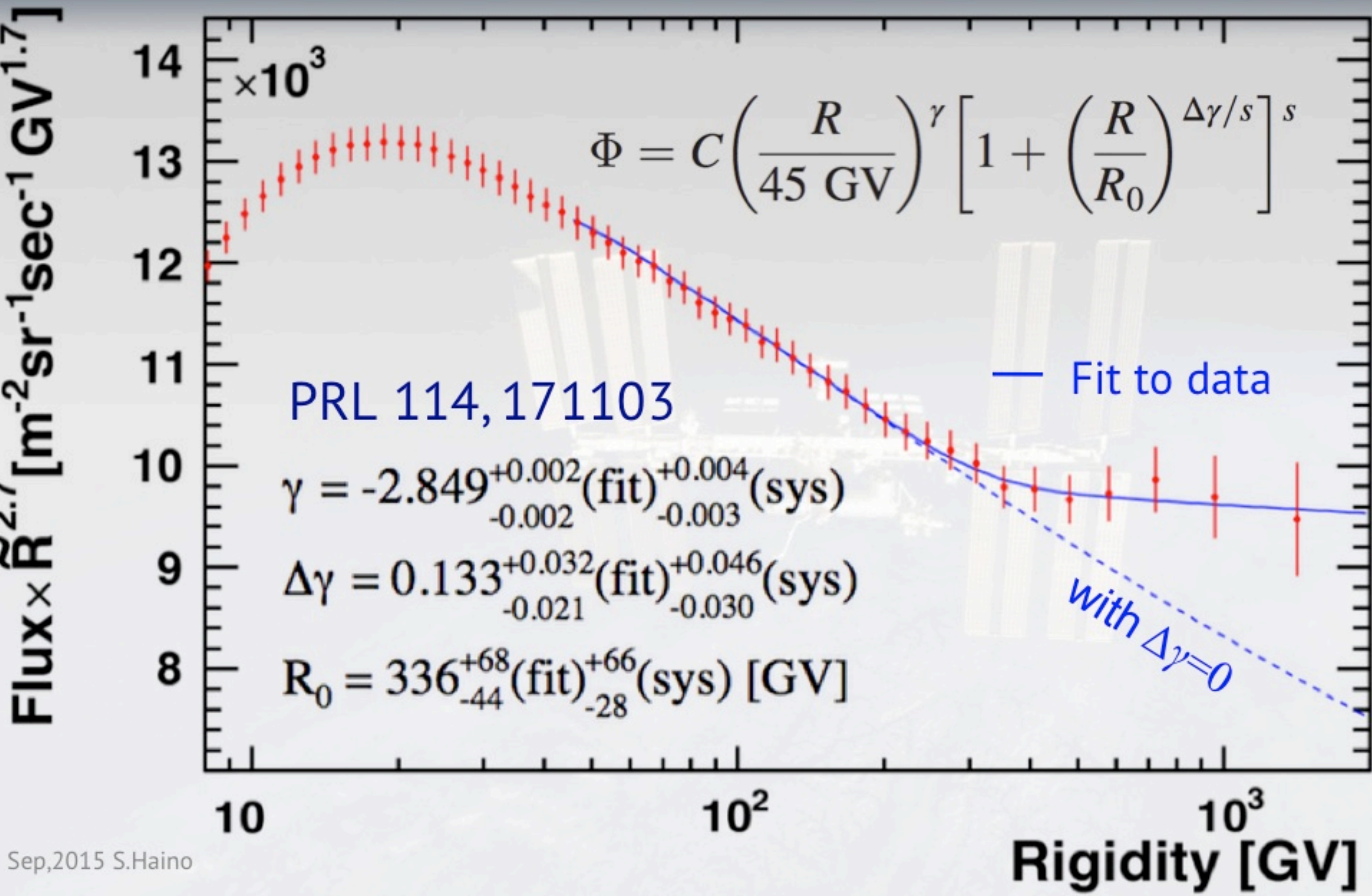
Proton flux with recent measurements



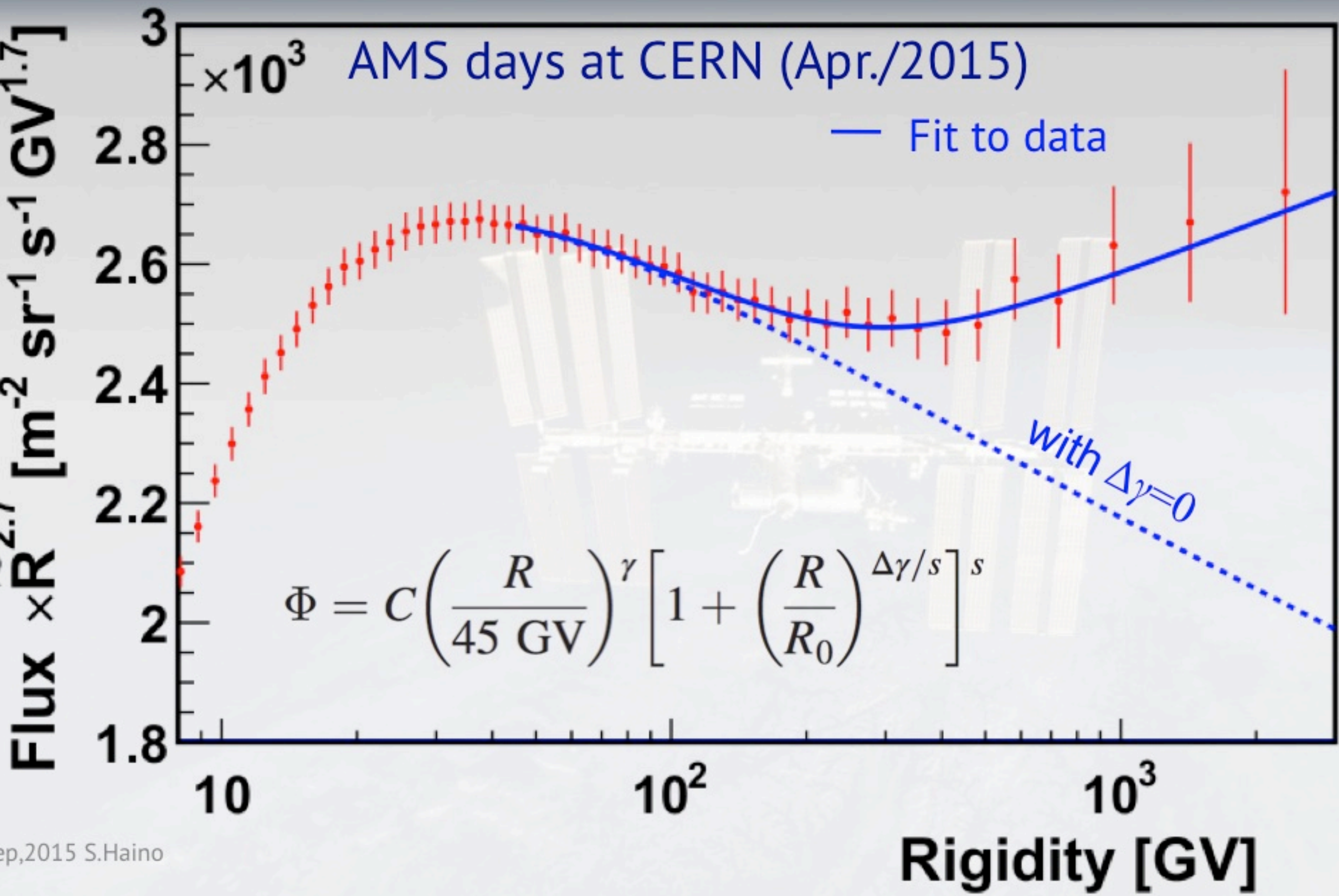
He flux with recent measurements



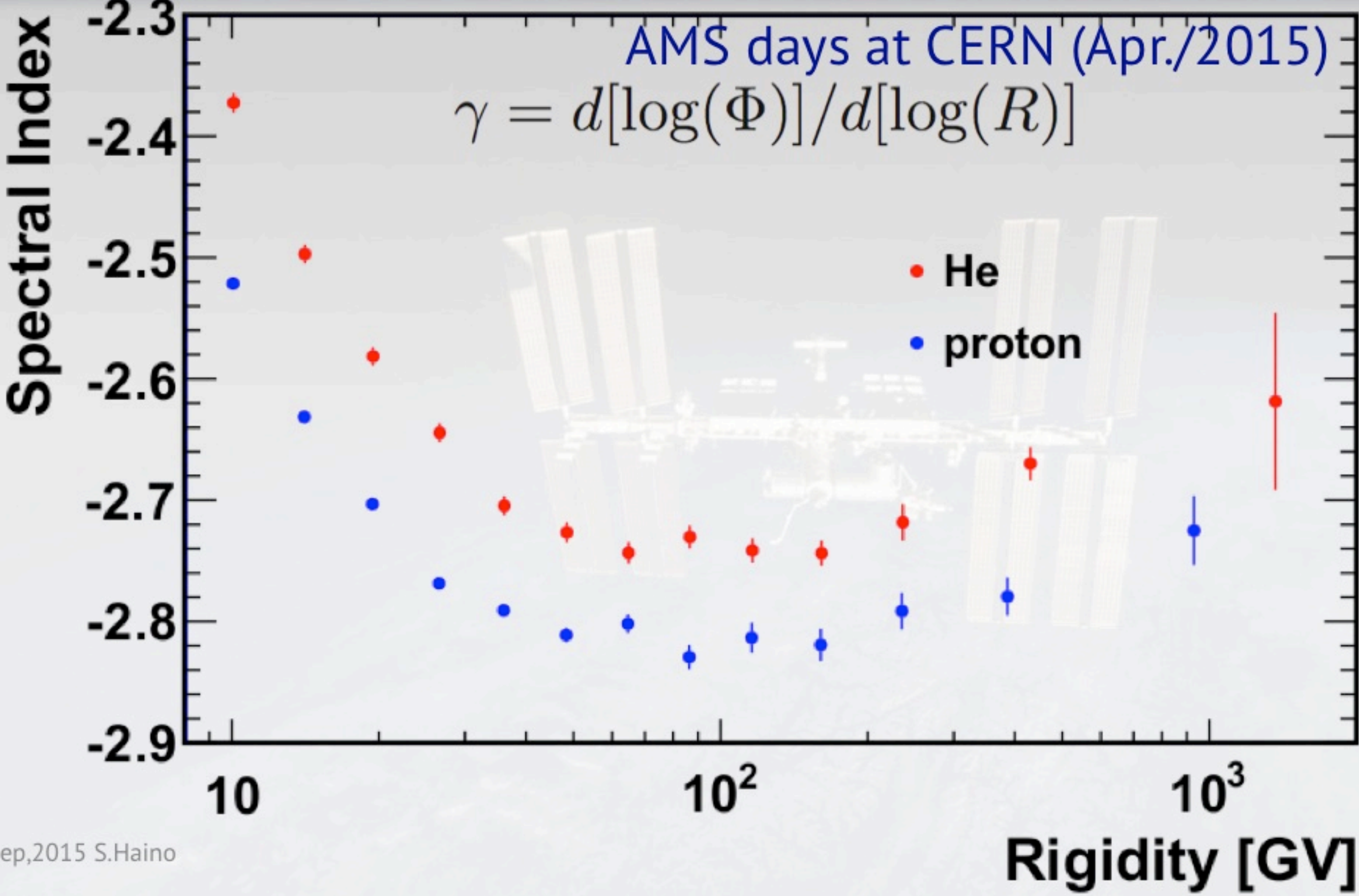
Proton flux fit with two power laws



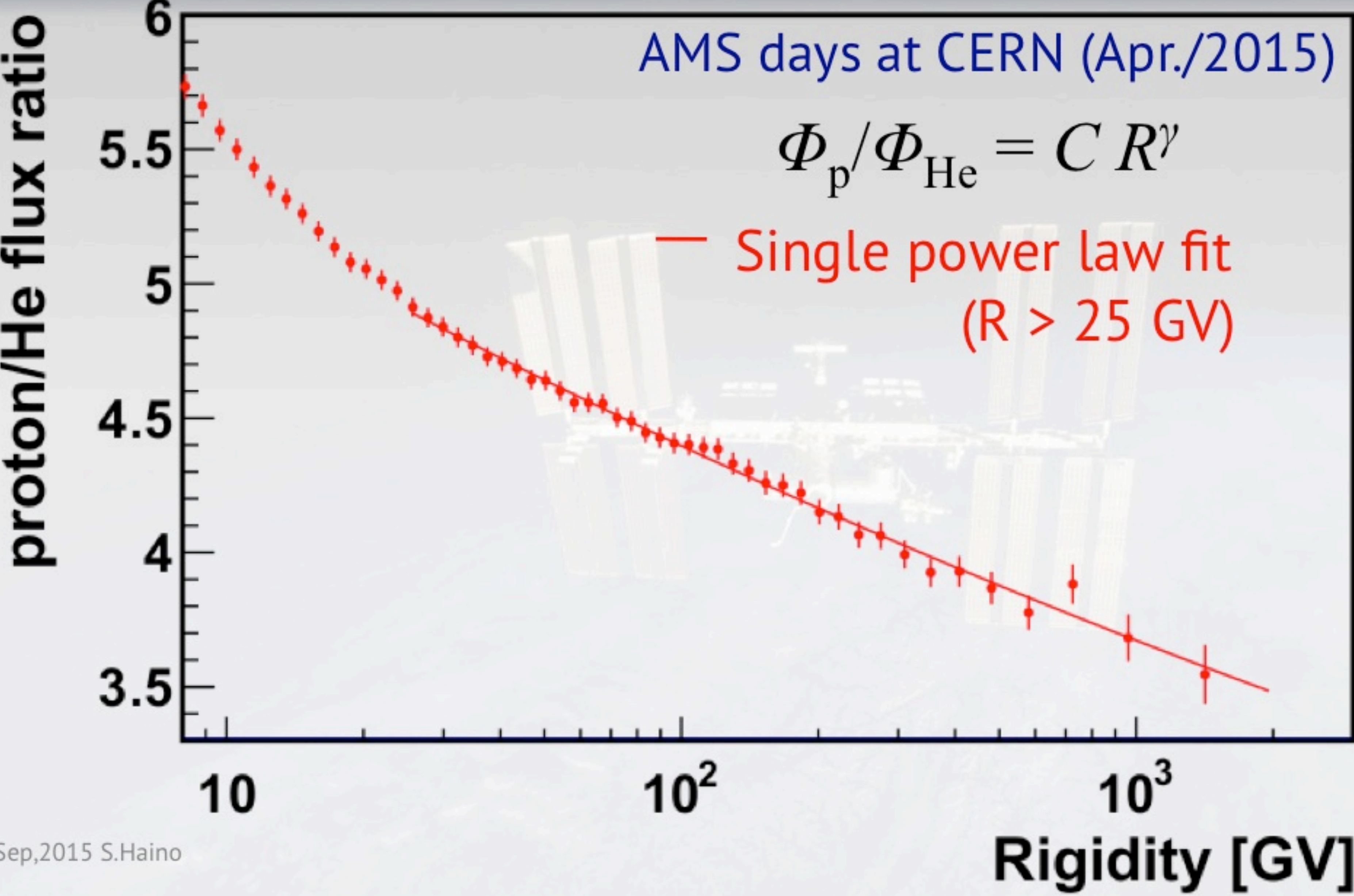
He flux fit with two power laws



Spectral indices for p and He



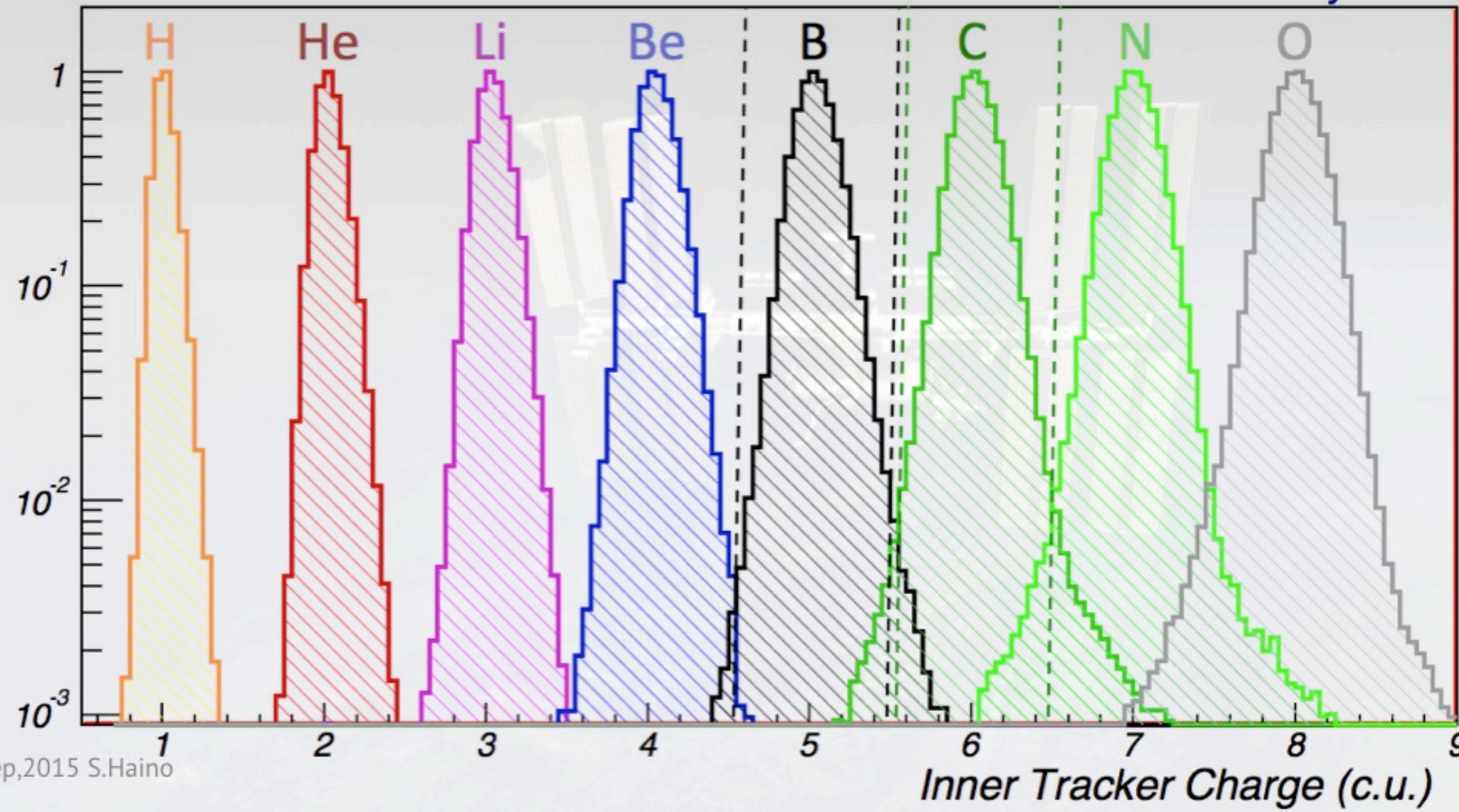
proton/He ratio



B/C selection

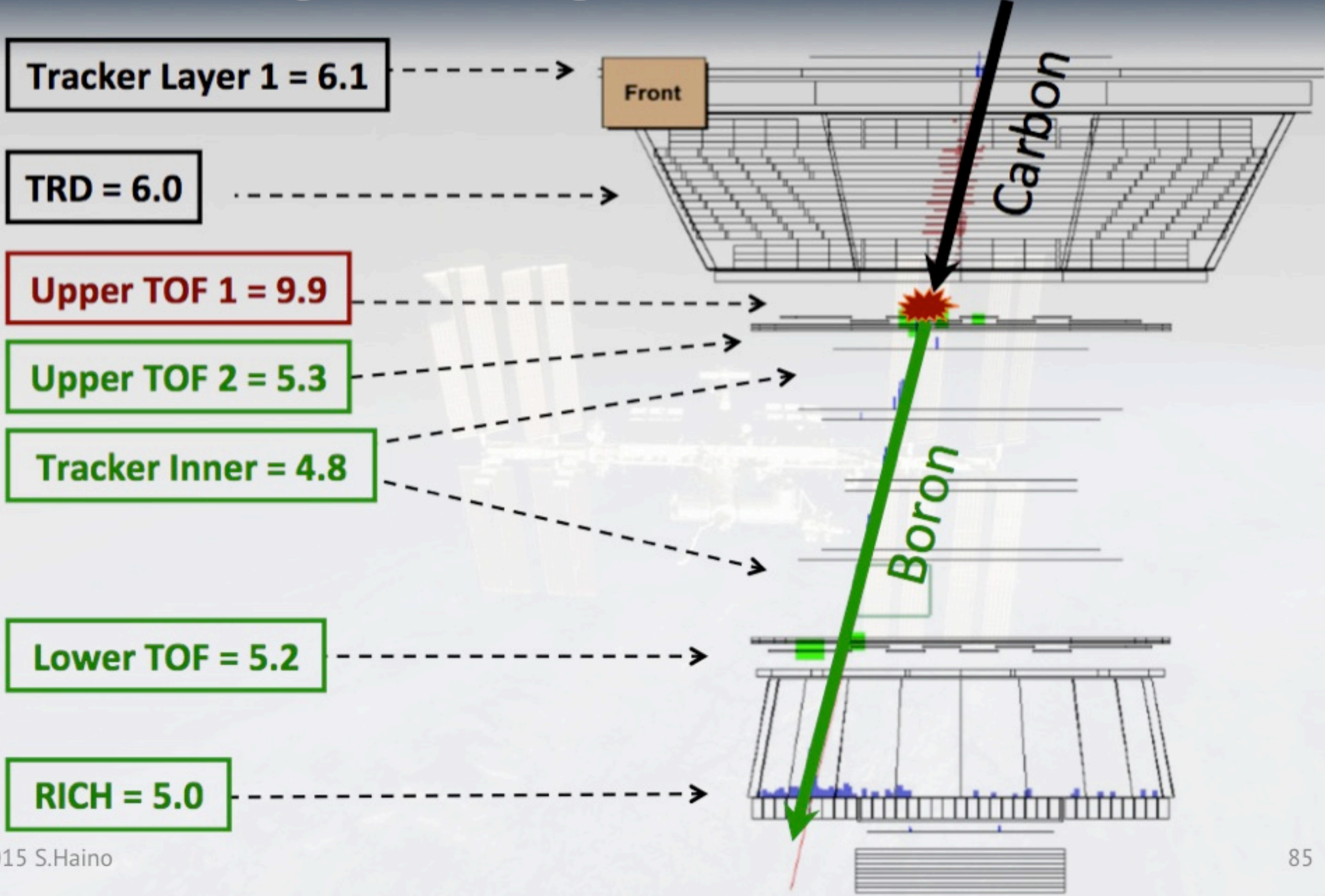
Truncated mean of Inner Tracker charge measurements

Misidentification < 0.1 % with > 98 % efficiency



B/C sample purity control

The main backgrounds: Fragmentation events in the detector



B/C sample purity control

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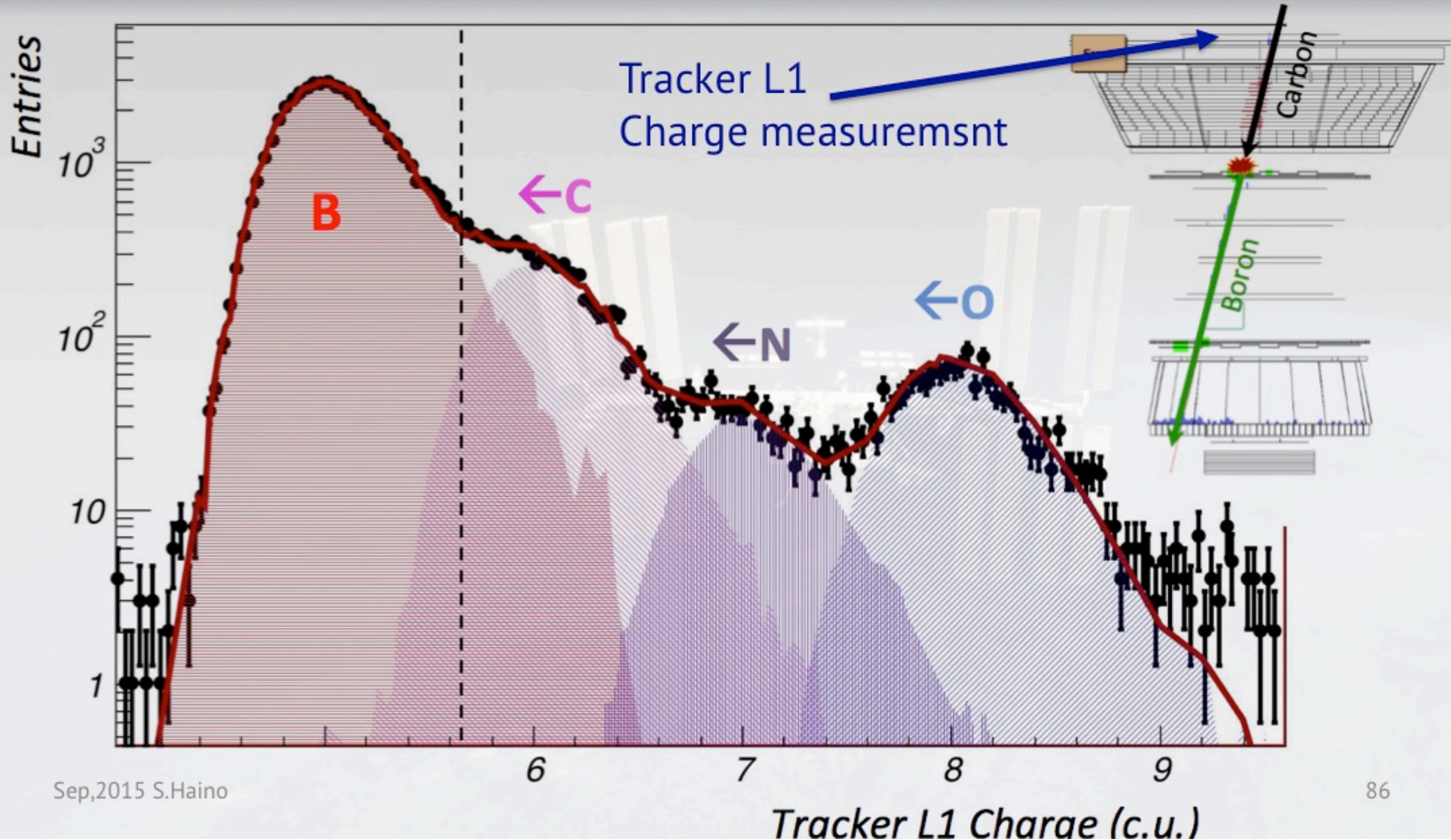
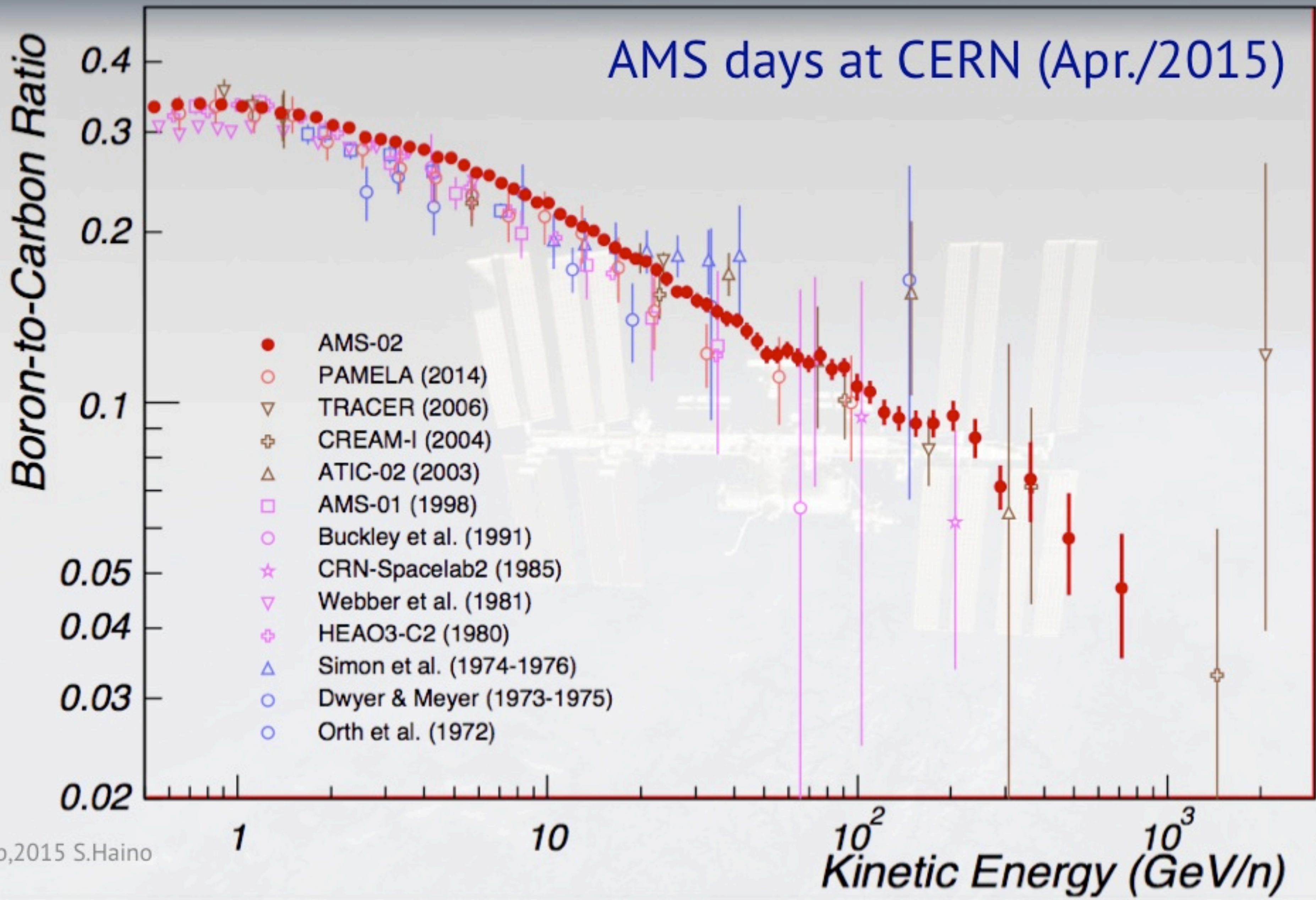
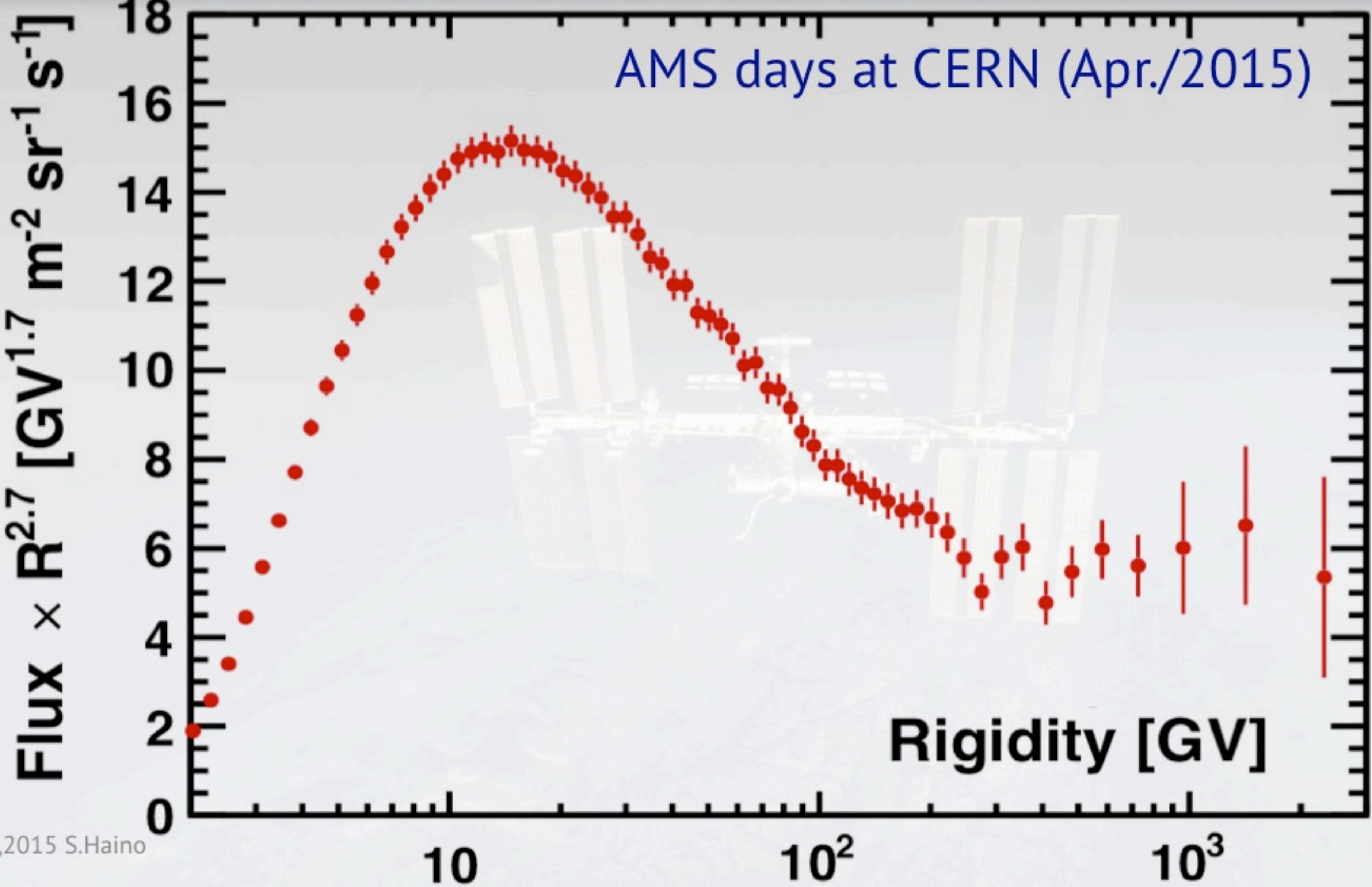


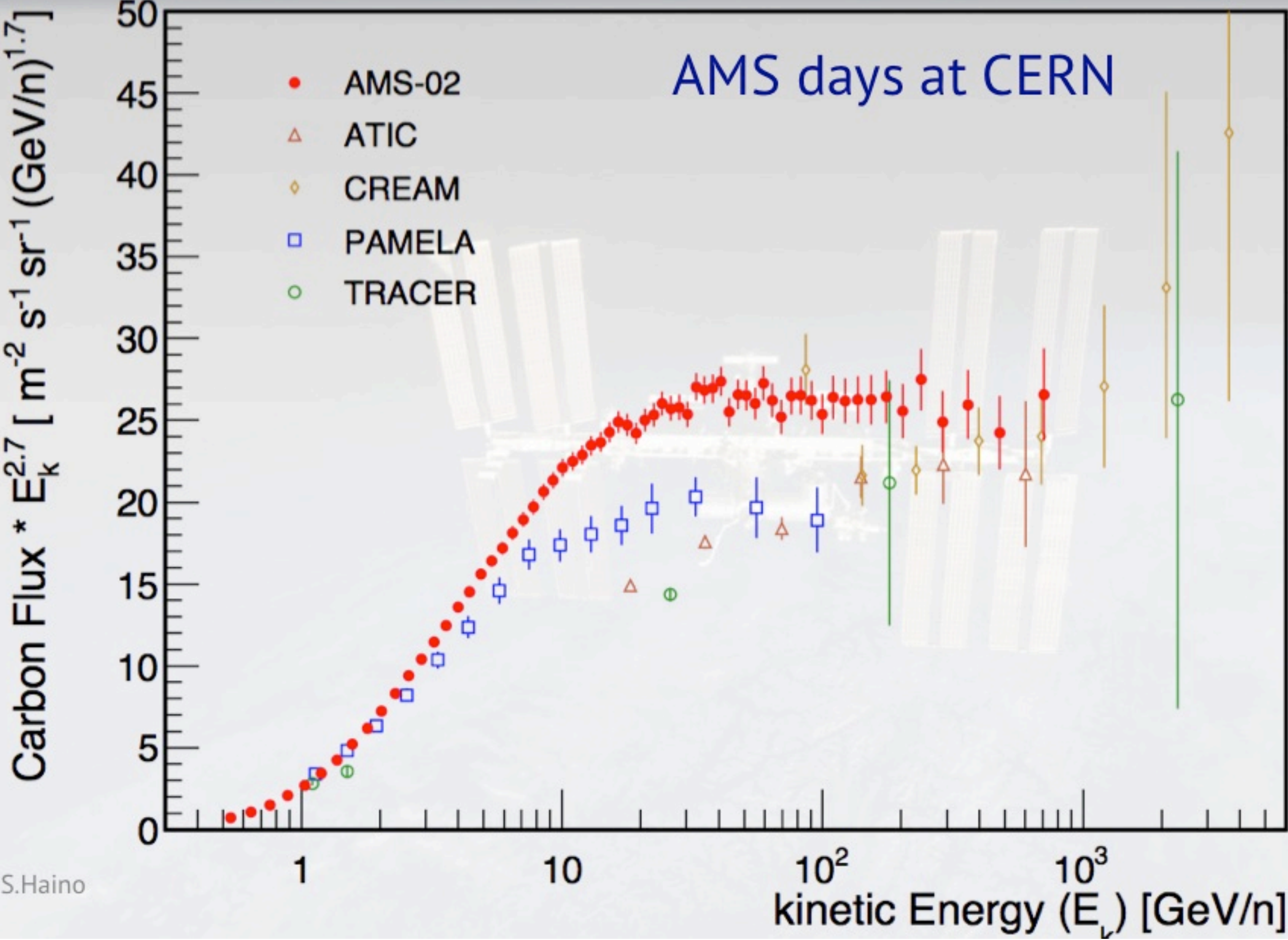
B/C compared with other measurements



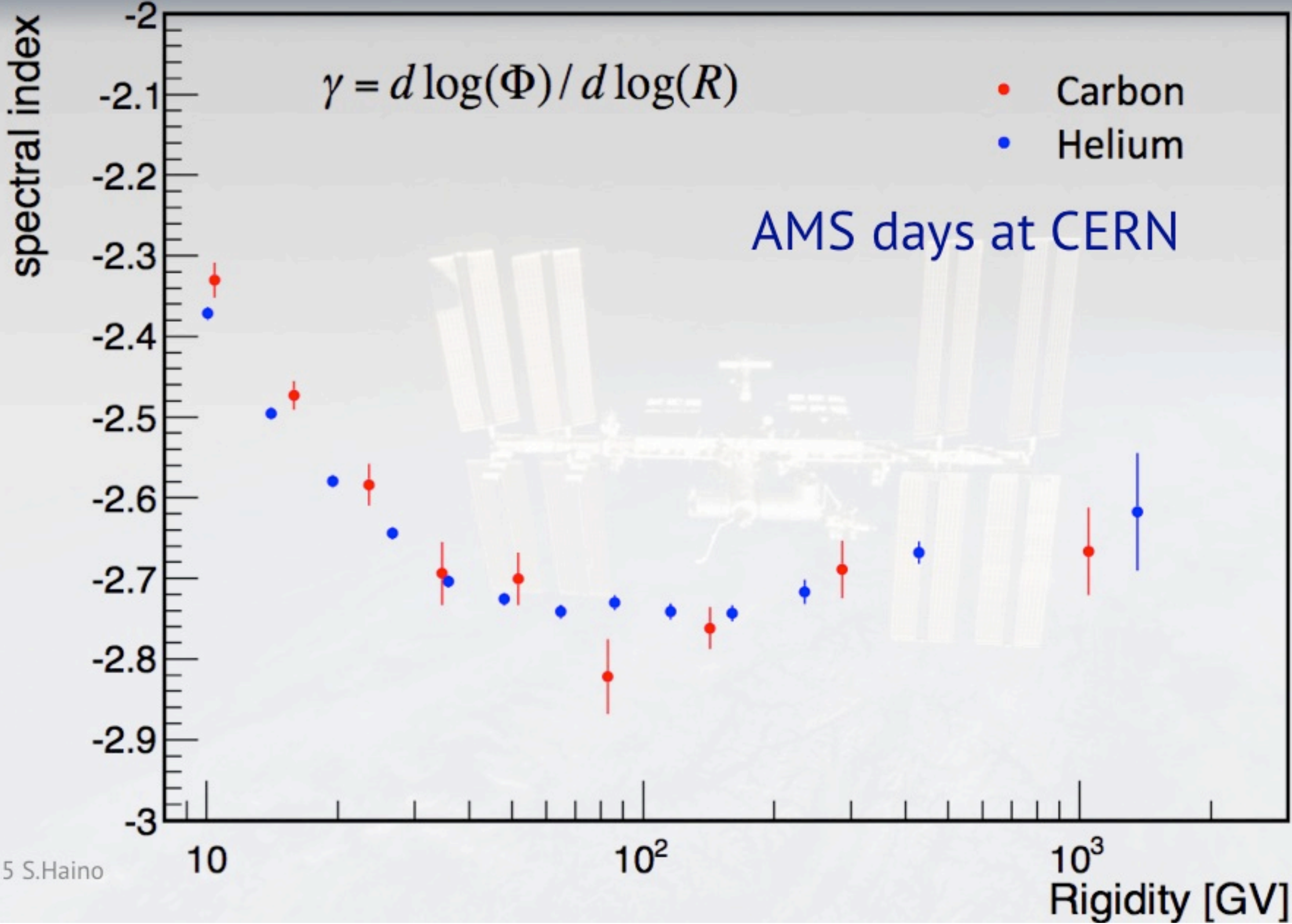
Li flux : current status



Carbon flux : current status



Carbon, Helium spectral index



The latest AMS measurements provide precise and unexpected information.
The accuracy and characteristics of the data, simultaneously from many different particles, require a comprehensive model to ascertain if their origin is Dark Matter, Astrophysical sources or a combination.