Positrons, antiprotons, nuclei and prospects with AMS-02

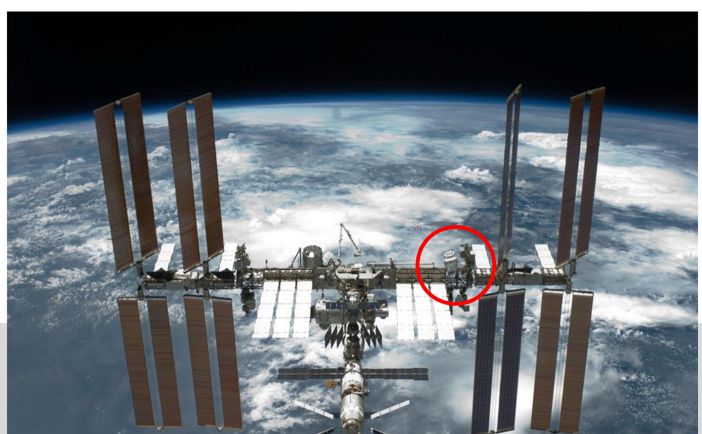
September, 23rd, 2015

Iris Gebauer for the AMS collaboration

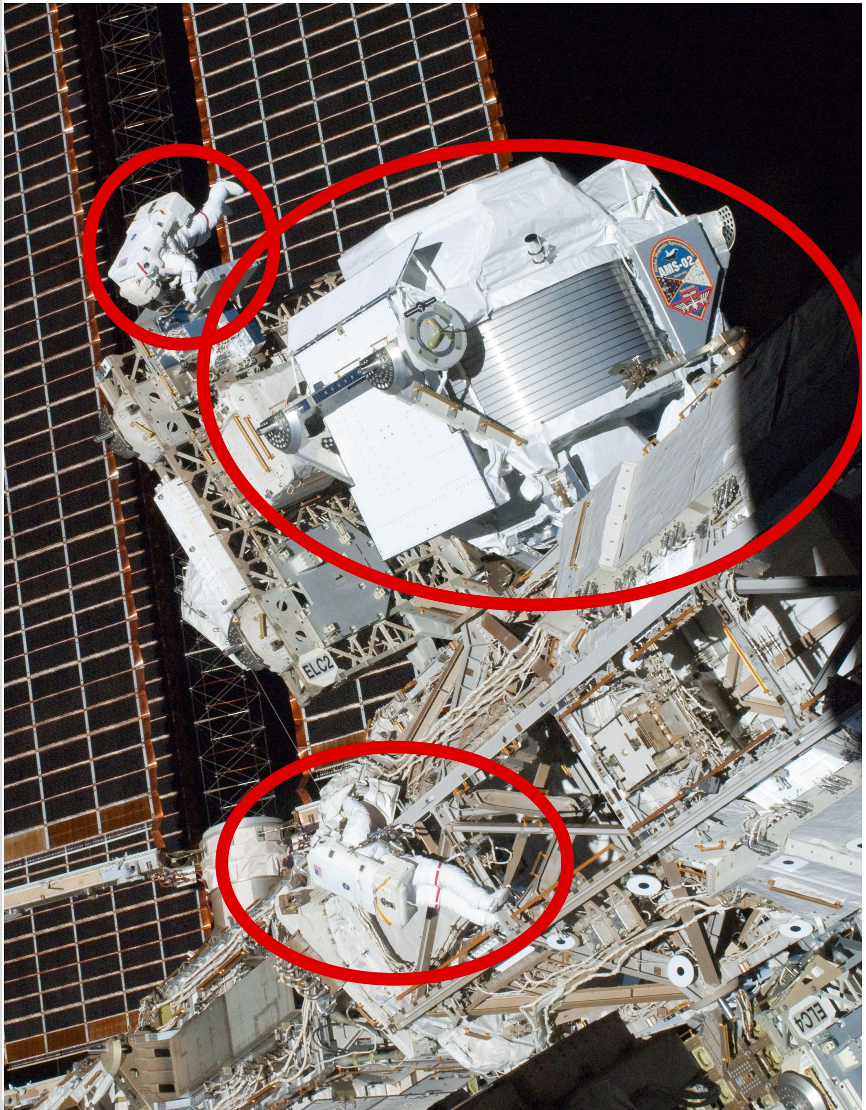
INSTITUT FÜR EXPERIMENTELLE KERNPHYSIK


16th May 2011


19th May 2011

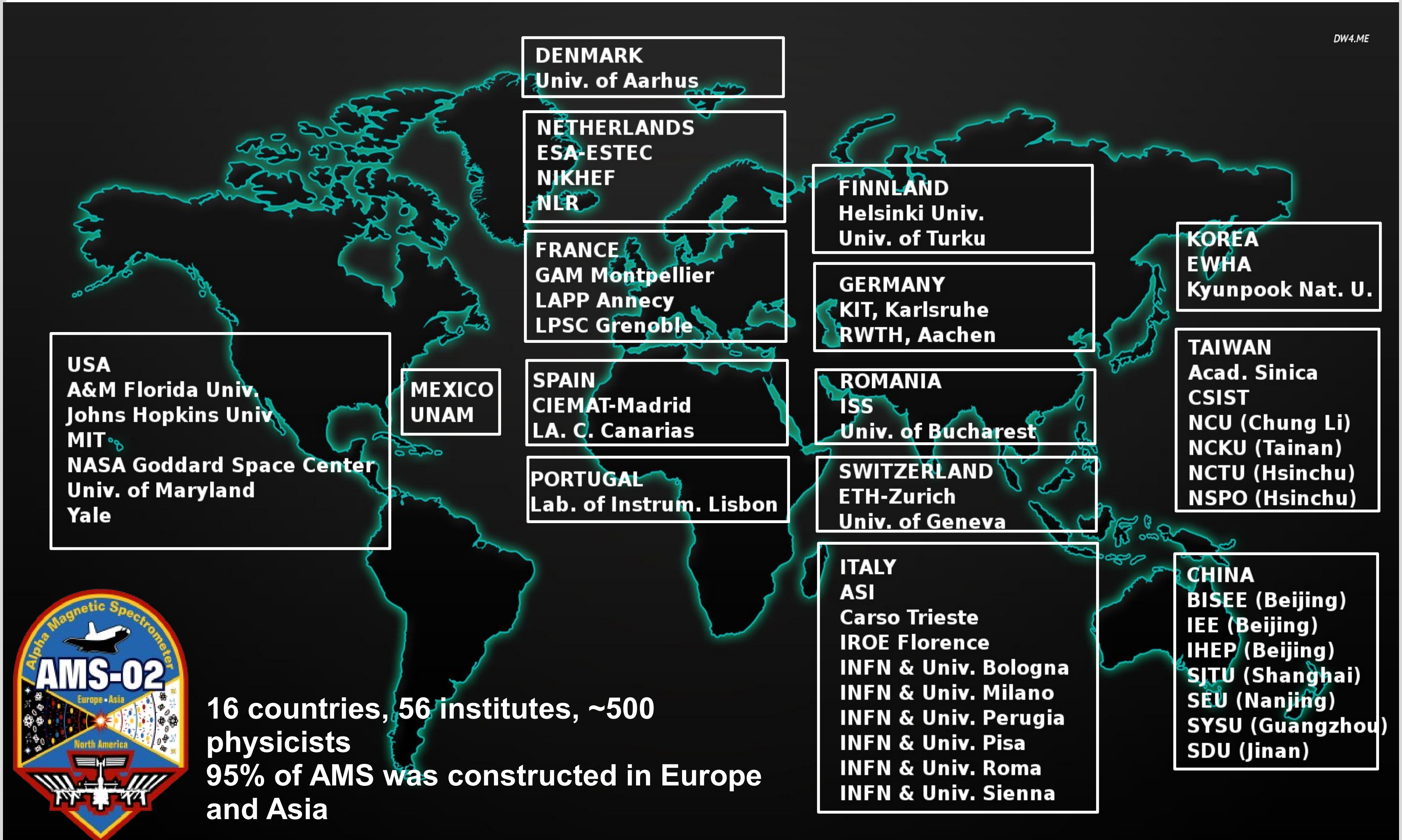


AMS-02: THE ALPHA MAGNETIC SPECTROMETER 02



- **Volume** 64 m^3, height 4 m
- **Weight** 8500 kg
- **Power** 2500 W
- **Data downlink** 9 Mbps (minimum)
- **Magnetic field** 0.15 T (400 x Earth, PAMELA: 0.4 T, but H=44.5 cm)
- **Launch** May 16th, 2011 (Endeavour)
- **Data taking** as of May 19th, 2011
- **Construction** 1999-2010 (>3 PhD generations)
- **Mission duration:** until the end of ISS operation (currently 2024)

AMS-02 COLLABORATION



16 countries, 56 institutes, ~500 physicists
95% of AMS was constructed in Europe and Asia

POCC: PAYLOAD OPERATIONS CONTROL CENTER

POCC
Payload **O**perations **C**ontrol **C**enter

Monitoring + Commanding

Communication with NASA

4 positions monitoring
11 Subdetectors (24/7)

LEAD position monitoring the entire system

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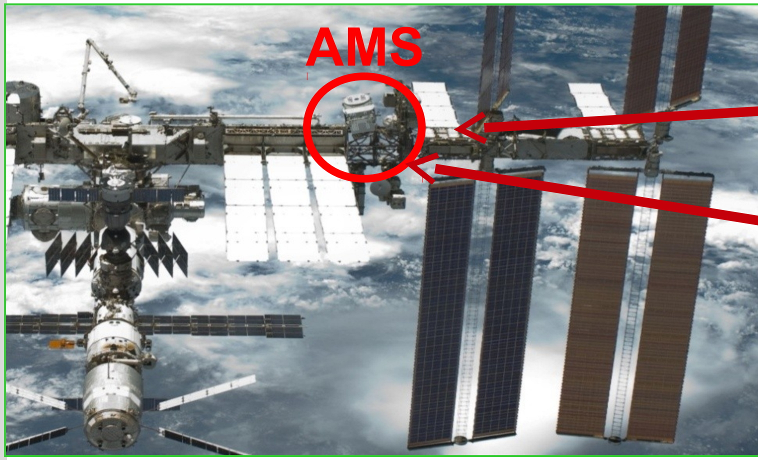
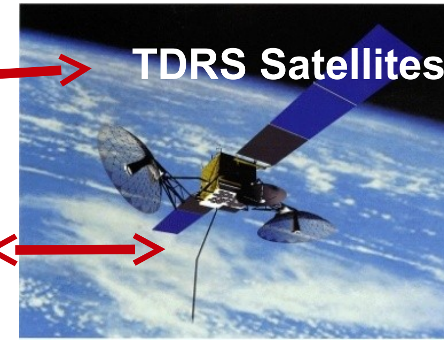
AMS-02 ↔ GROUND





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

Flight Operations

Ground Operations

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

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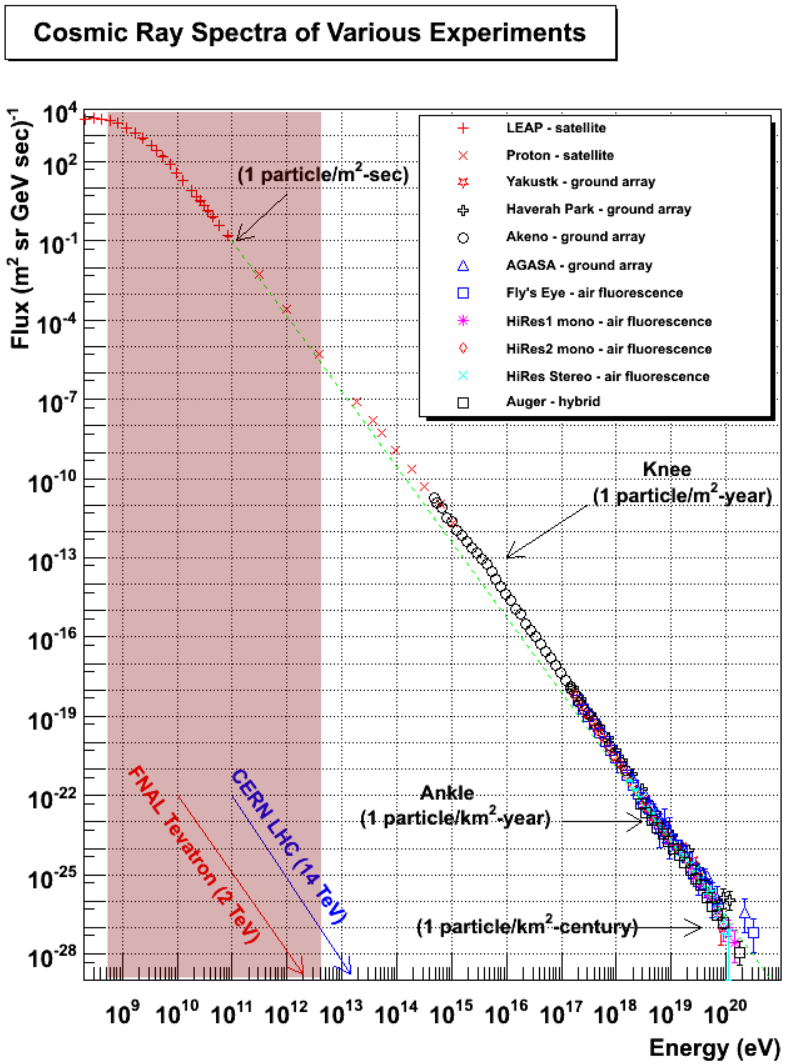
Cosmic ray spectra up to TeV energies
Indirect Dark Matter search: e^+, $\bar{p}$, γ, …
Direct search for primordial antimatter: $\overline{He}$, $\overline{C}$, ….
Solar physics effects over 11 years solar cycle

Pulished results:
Positron fraction
Combined electron+positron flux
Positron and electron flux
Proton flux

Currently ongoing analyses:
He, B/C, Li, C/O…., $\bar{p}$/p
Solar activity

CHARGED **COSMIC RAYS** (CRs)



Primary cosmic rays (from SNRs):

- Protons ~89%
- He ~10%
- heavy nuclei (mainly C) ~1%
- e^- ~1%

Secodary cosmic rays (from interactions):

- traces of e^+
- traces of $\bar{p}$
- traces of nuclei

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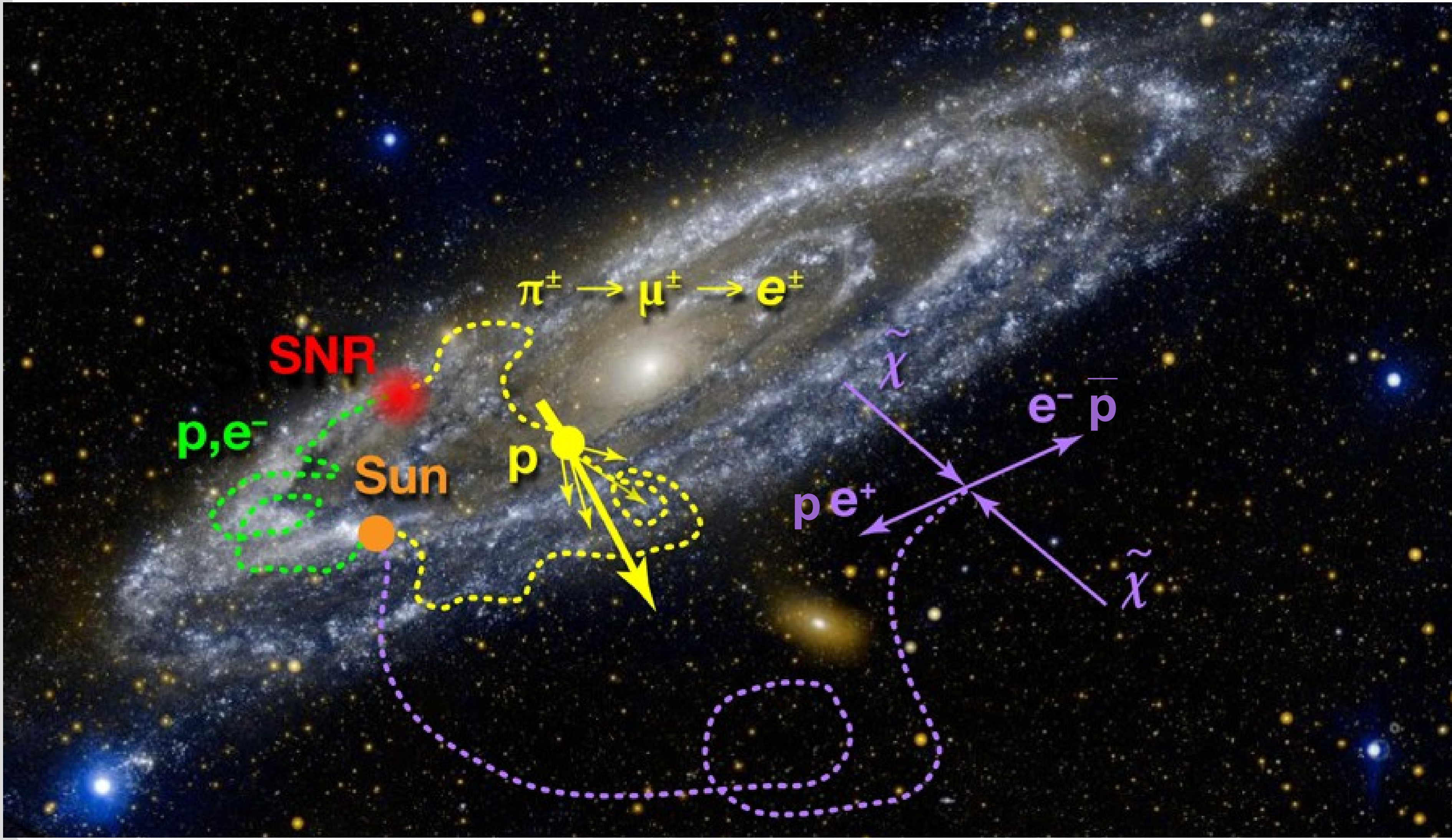
GALACTIC COSMIC RAYS: SOURCE → US



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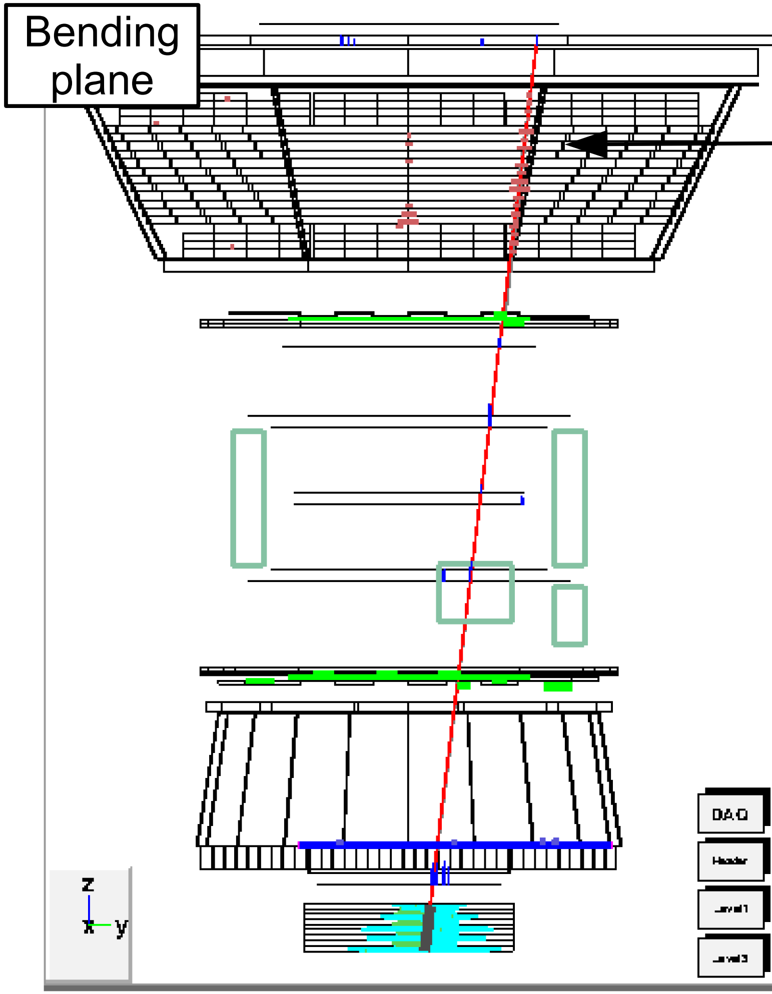
TRANSITION RADIATION DETECTOR



320 GeV positron

Transition Detector Radiation TRD
Identifies e+/e- (Xrays)

Time Of Flight TOF
Trigger / Charge Q / Flight direction / Velocity β

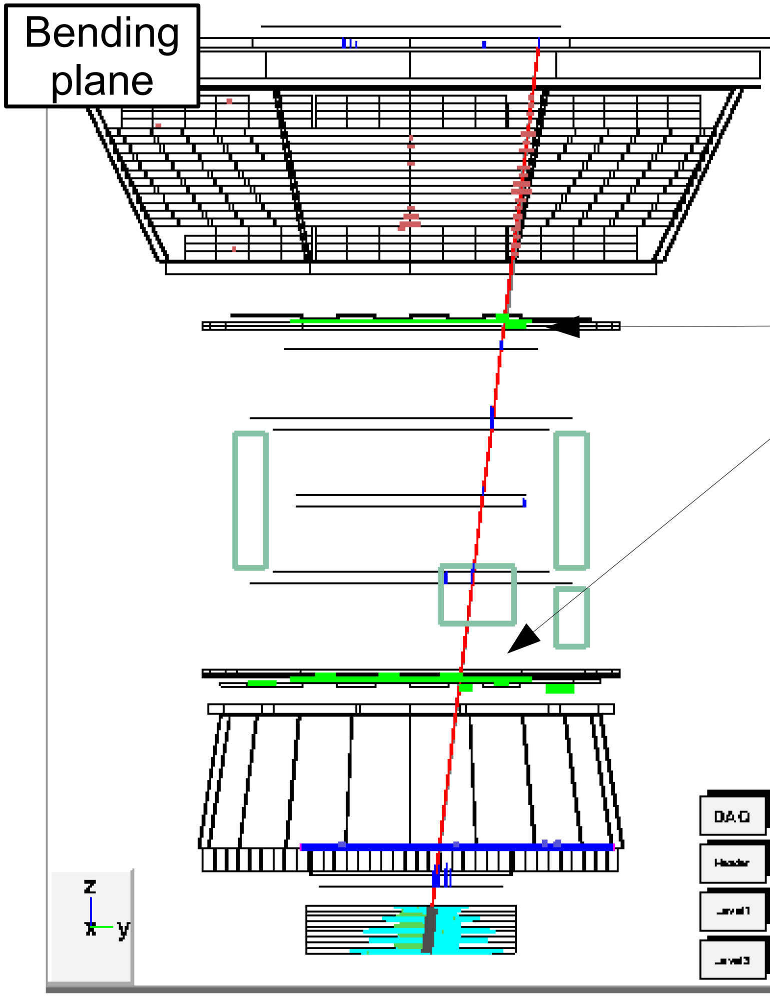
Magnet + Silicon Tracker TRK
Measure momentum / sign(Q) / Charge Q

Ring Imaging Cherenkov RICH
Velocity β / Charge Q /

Electromagnetic Calorimeter ECAL
Measure energy / Identifies e+/e- (shower shape)

Most particle properties are measured redundantly

TIME OF FLIGHT



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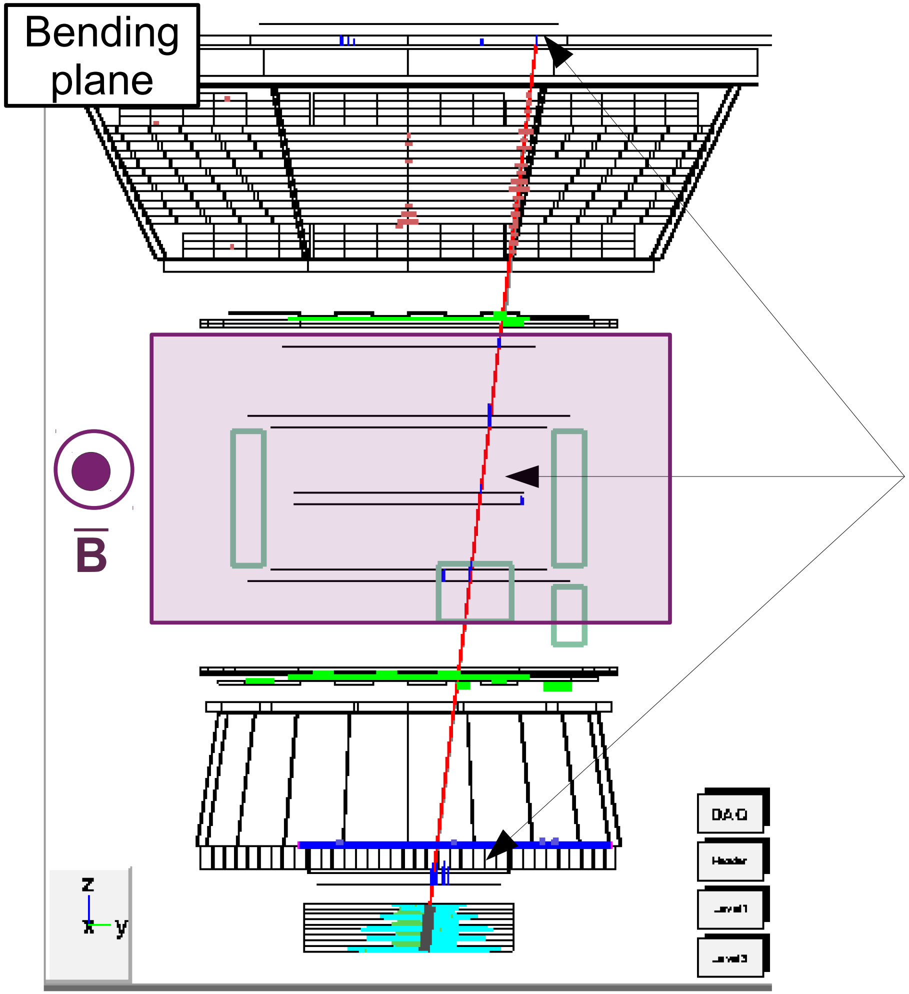
SILICON TRACKER AND MAGNET



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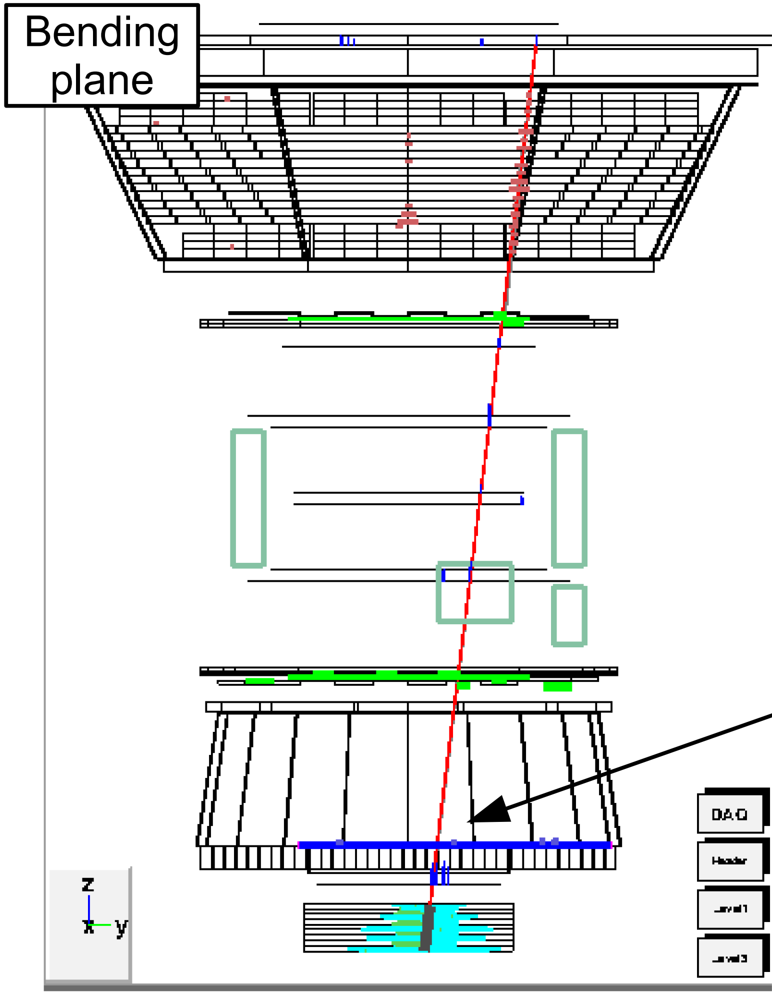
RING IMAGING CHERENKOV DETECTOR



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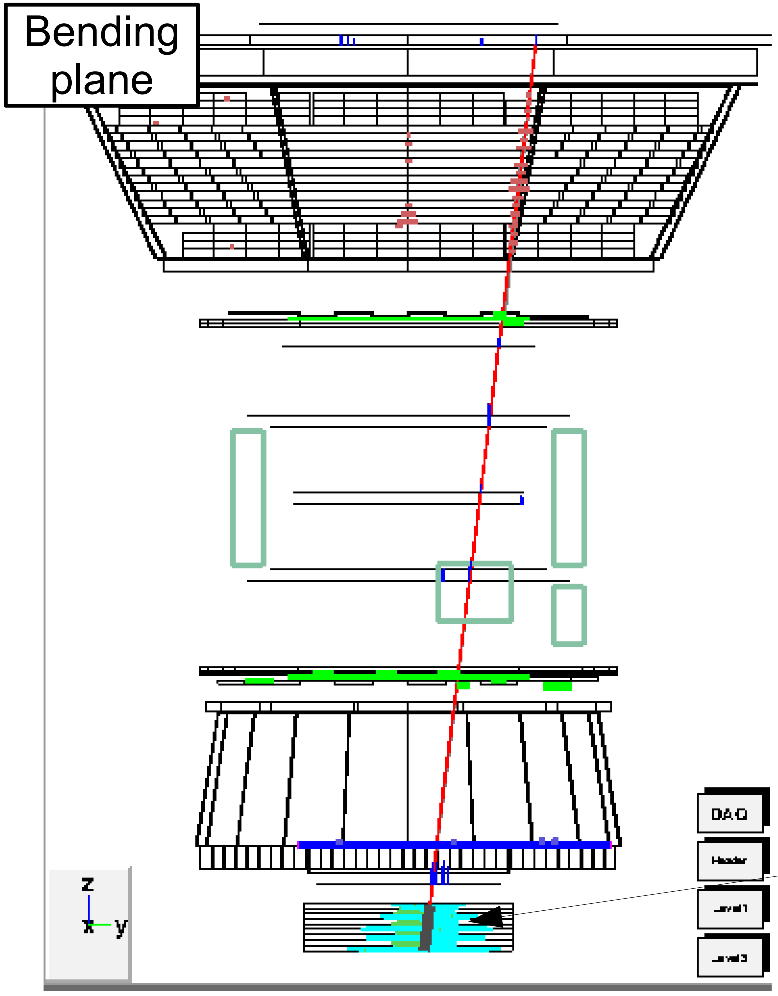
Most particle properties are measured redundantly /

ELECTROMAGNETIC CALORIMETER



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Velocity β / Charge Q /

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Measure energy / Identifies e+/e- (shower shape)

Most particle properties are measured redundantly

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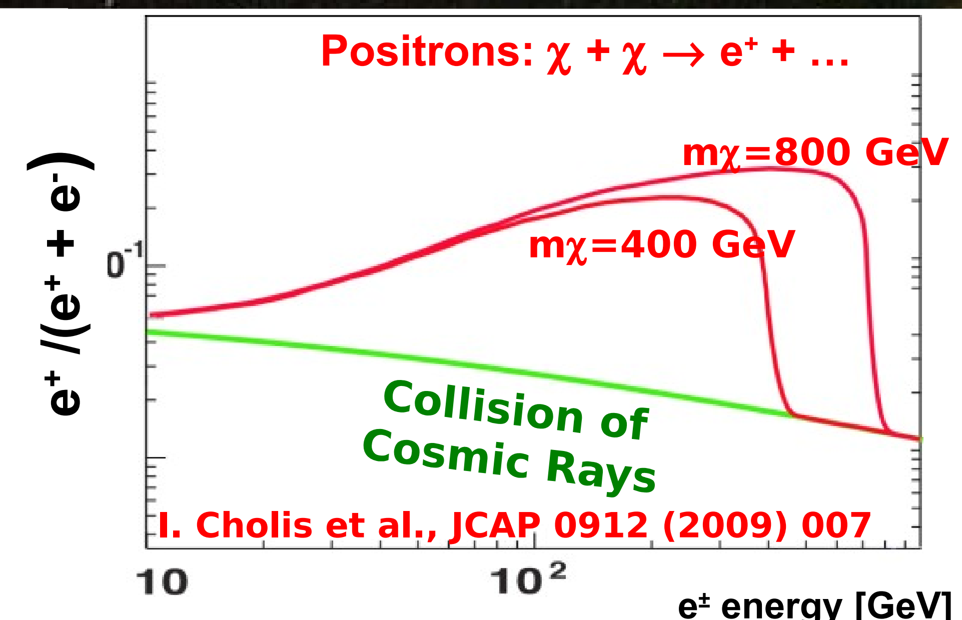
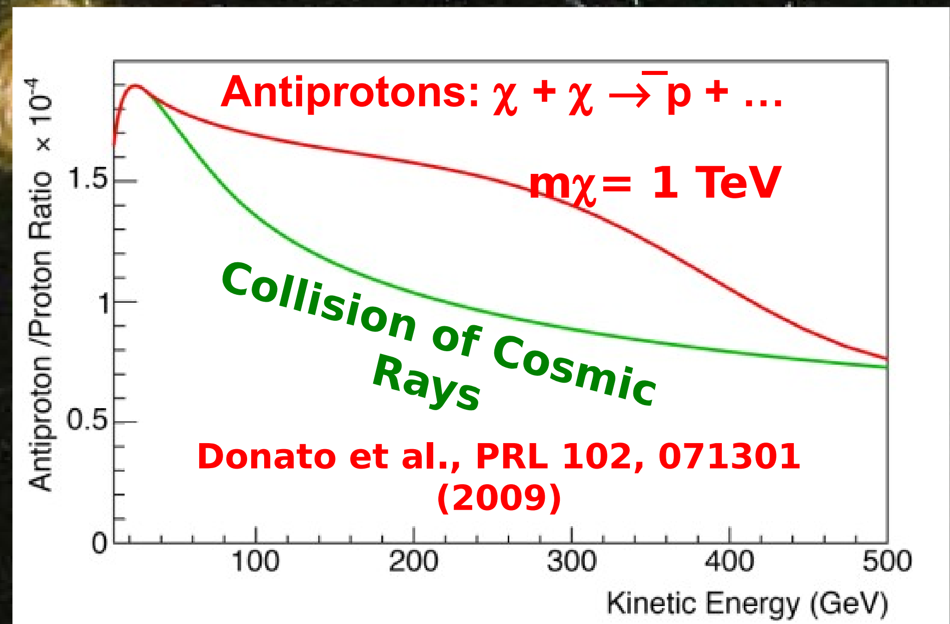
THE SEARCH FOR DARK MATTER SIGNALS

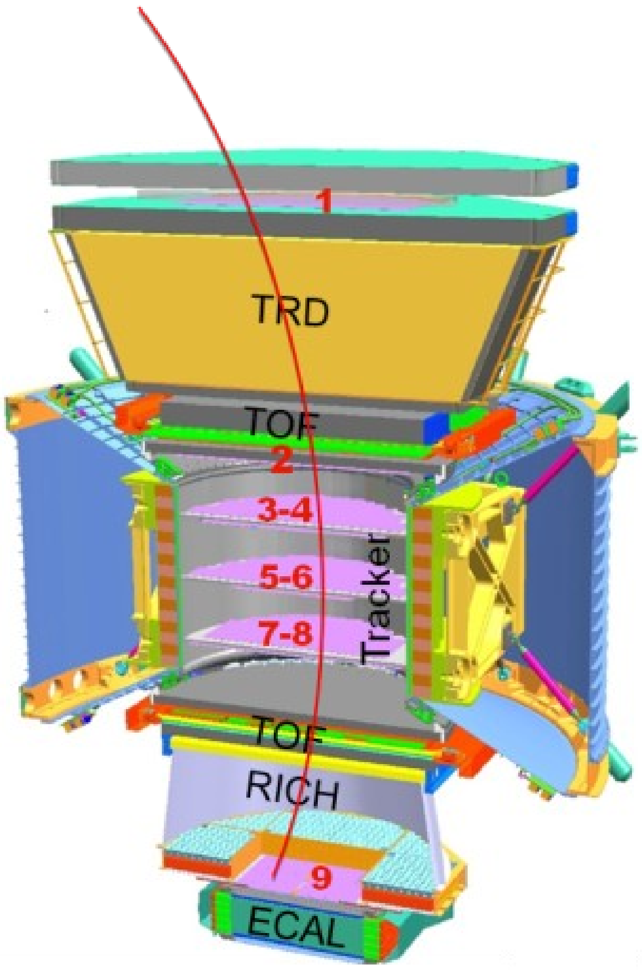
Annihilation of Dark Matter will produce p, $\bar{p}$, e^+, e^-, γ.

Possibly visible above background of “ordinary” cosmic rays.





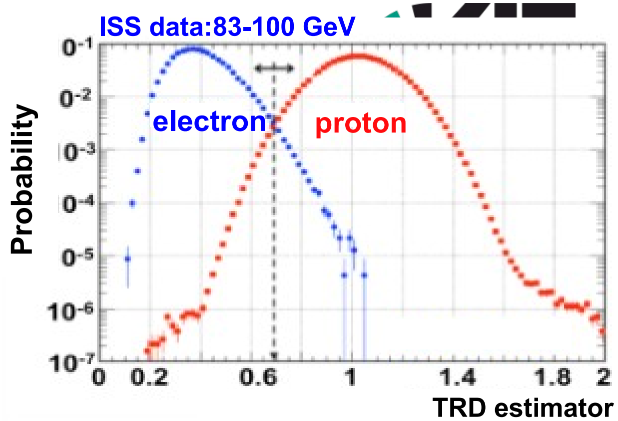
MEASURING ELECTRONS AND POSITRONS

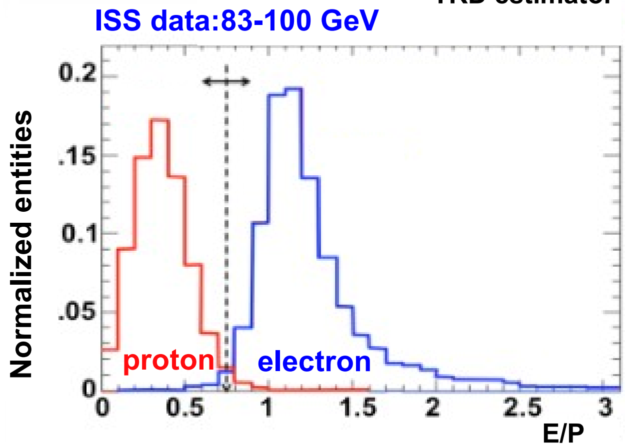


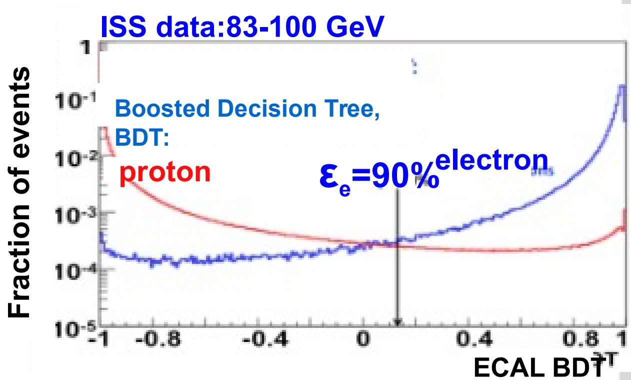
TRD identifies e±

TRACKER measures P
ECAL measures E
e±: E=P
proton: E<P

ECAL measures E and shower shape to separate e± from protons







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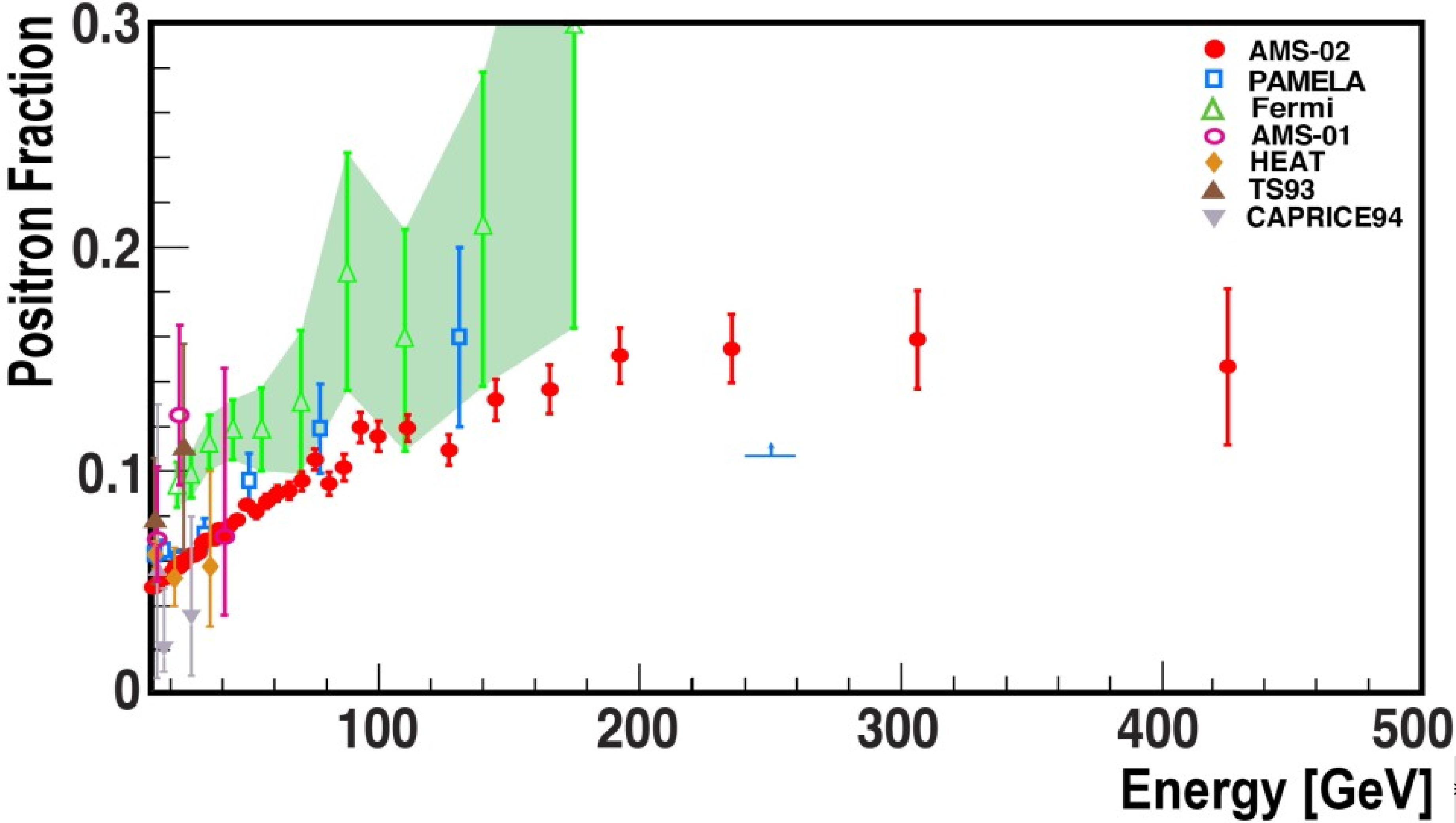
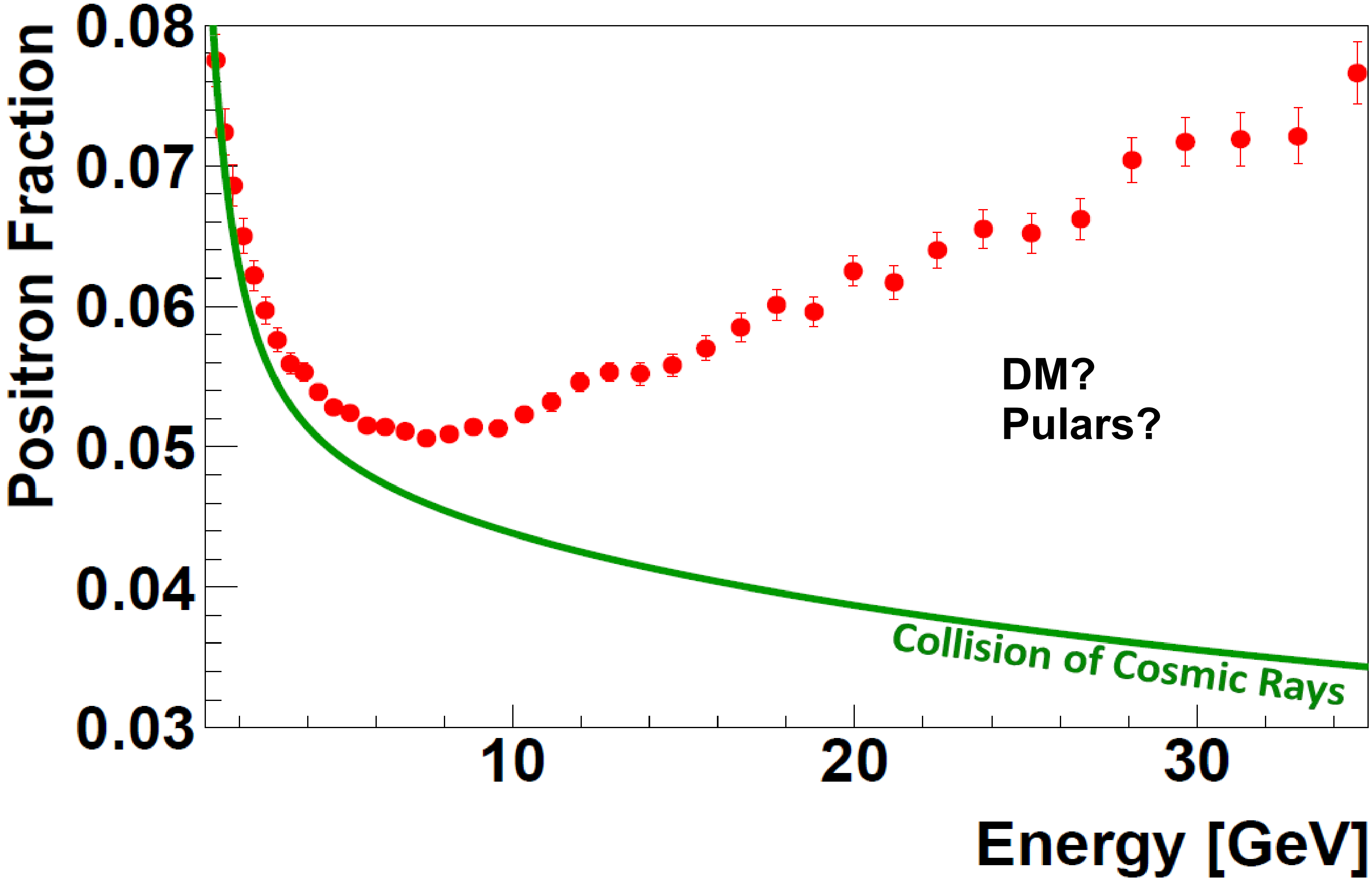
PRL 113, 121101 (2014) PHYSICAL REVIEW LETTERS week ending 19 SEPTEMBER 2014

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

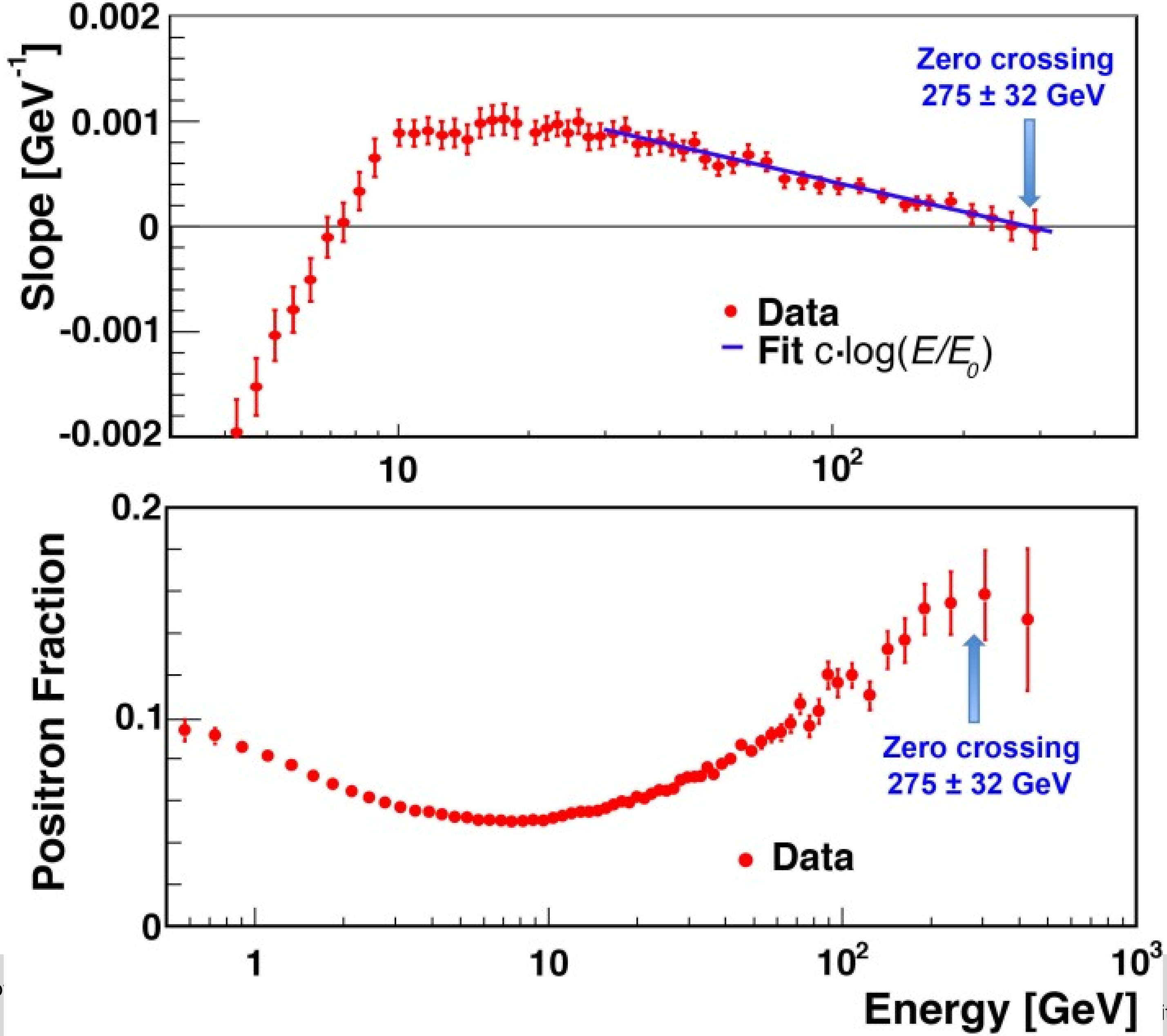
10.9 million e+ and e- events



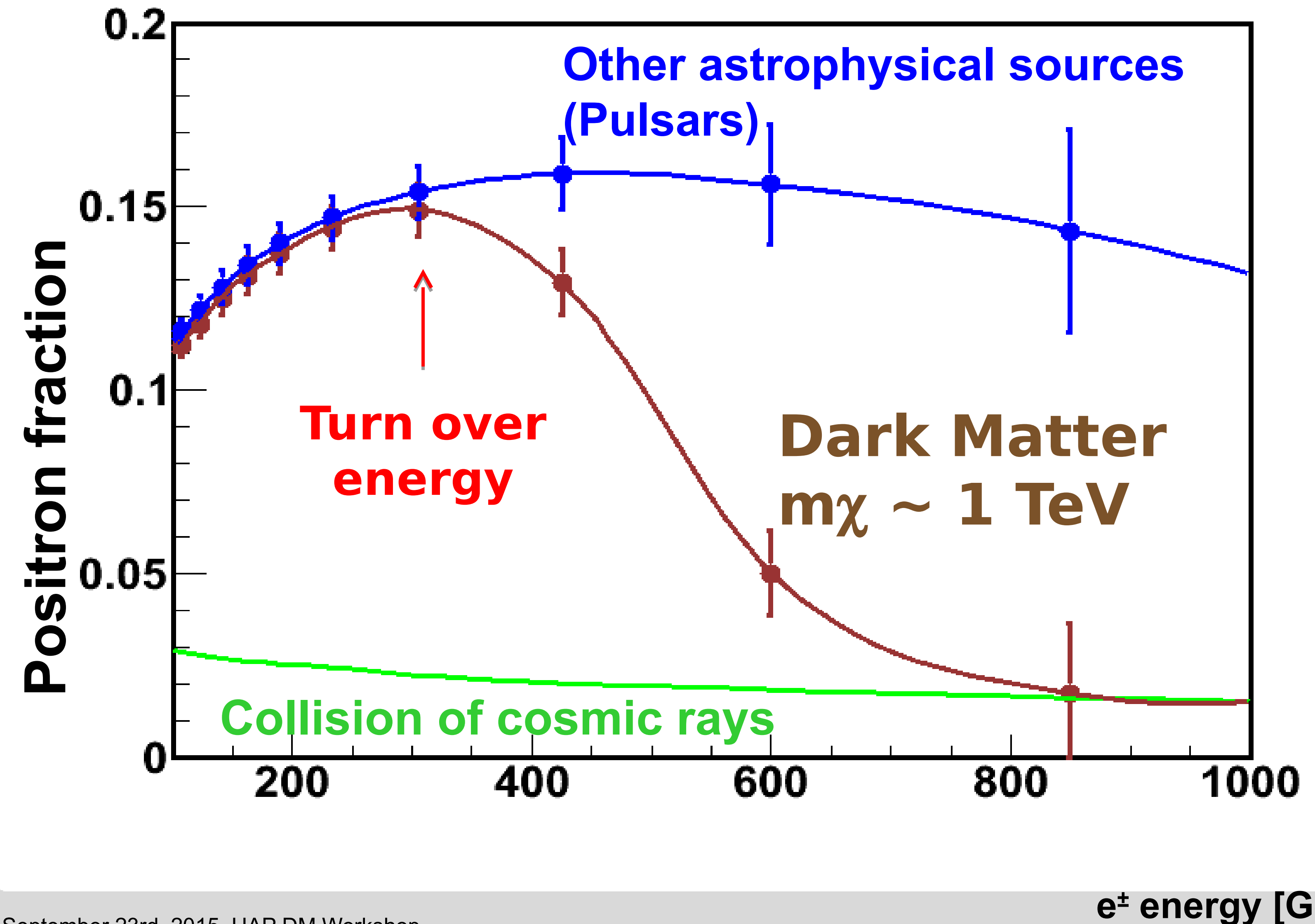
THE ENERGY AT WHICH IT BEGINS TO INCREASE



THE ENERGY BEYOND WHICH IT CEASES TO INCREASE



THE EXPECTED RATE AT WHICH IT FALLS BEYOND THE TURNING POINT



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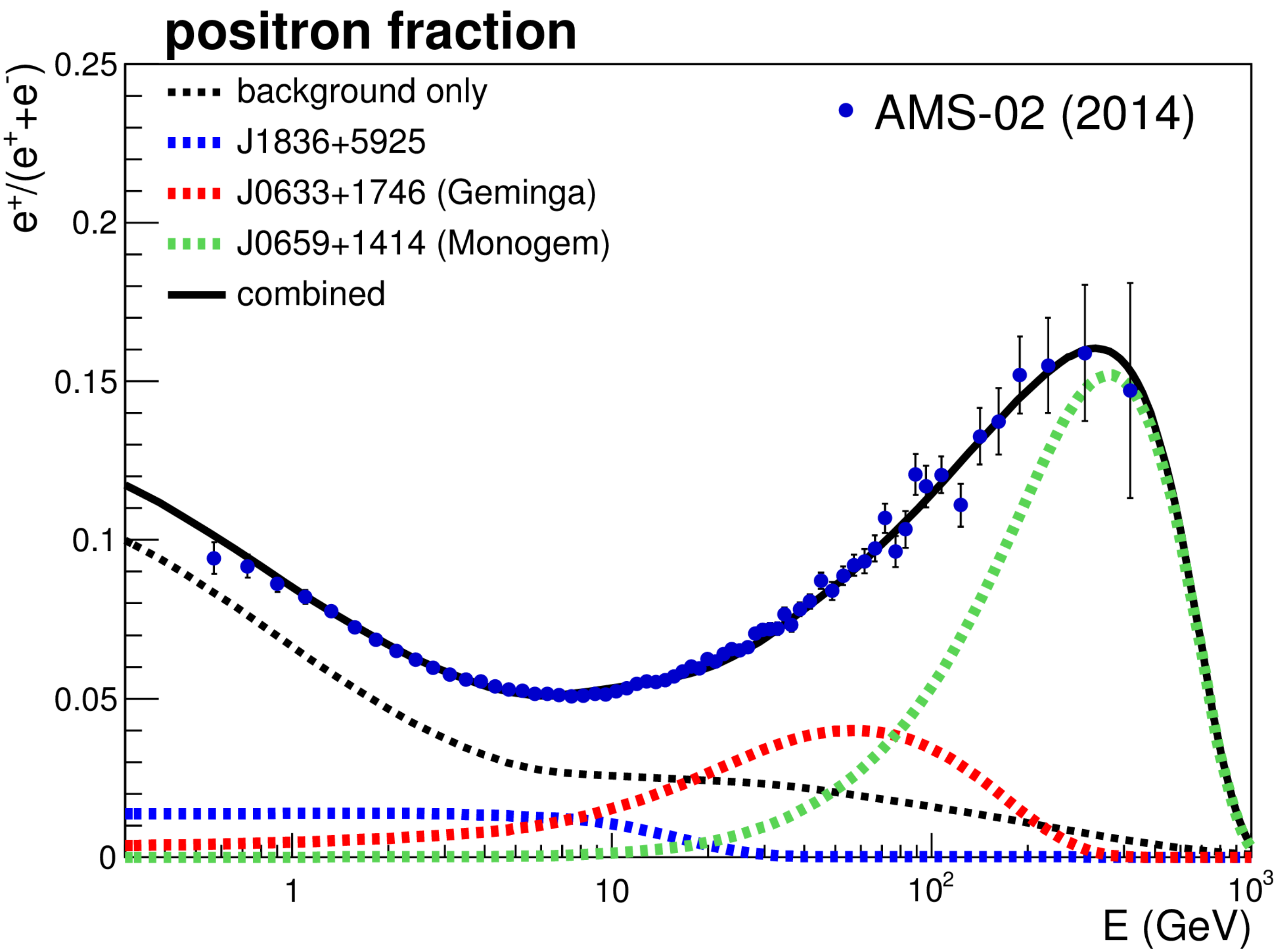
IT'S NOT THAT EASY: PULSARS AS A POSSIBLE SOURCE



Pulsars tuned to AMS data.

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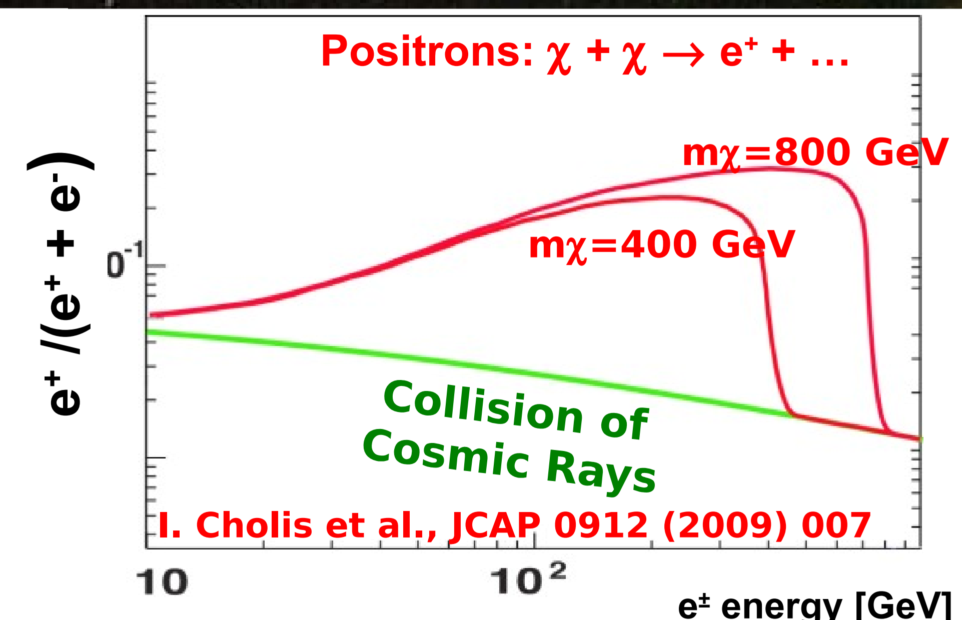
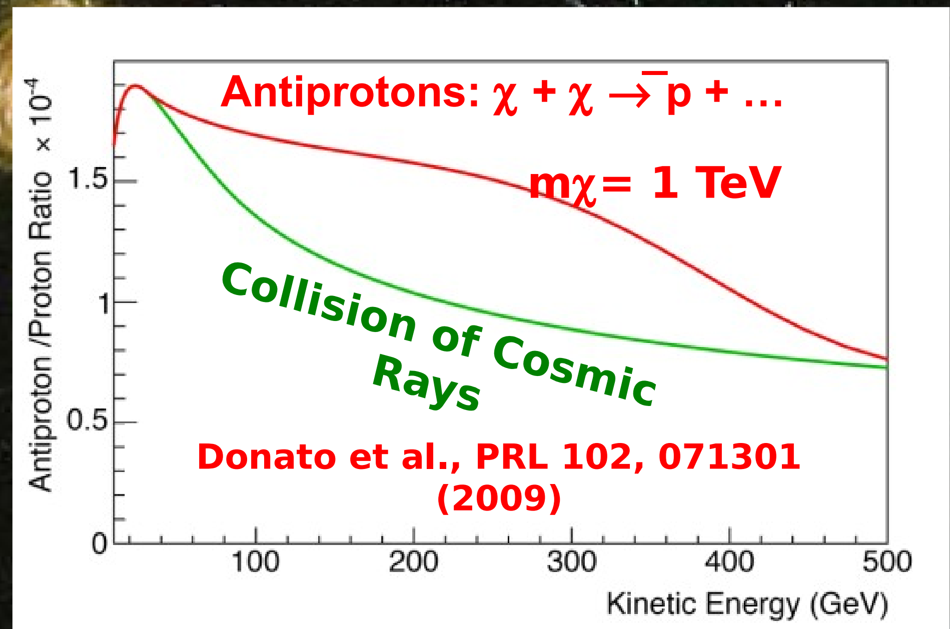
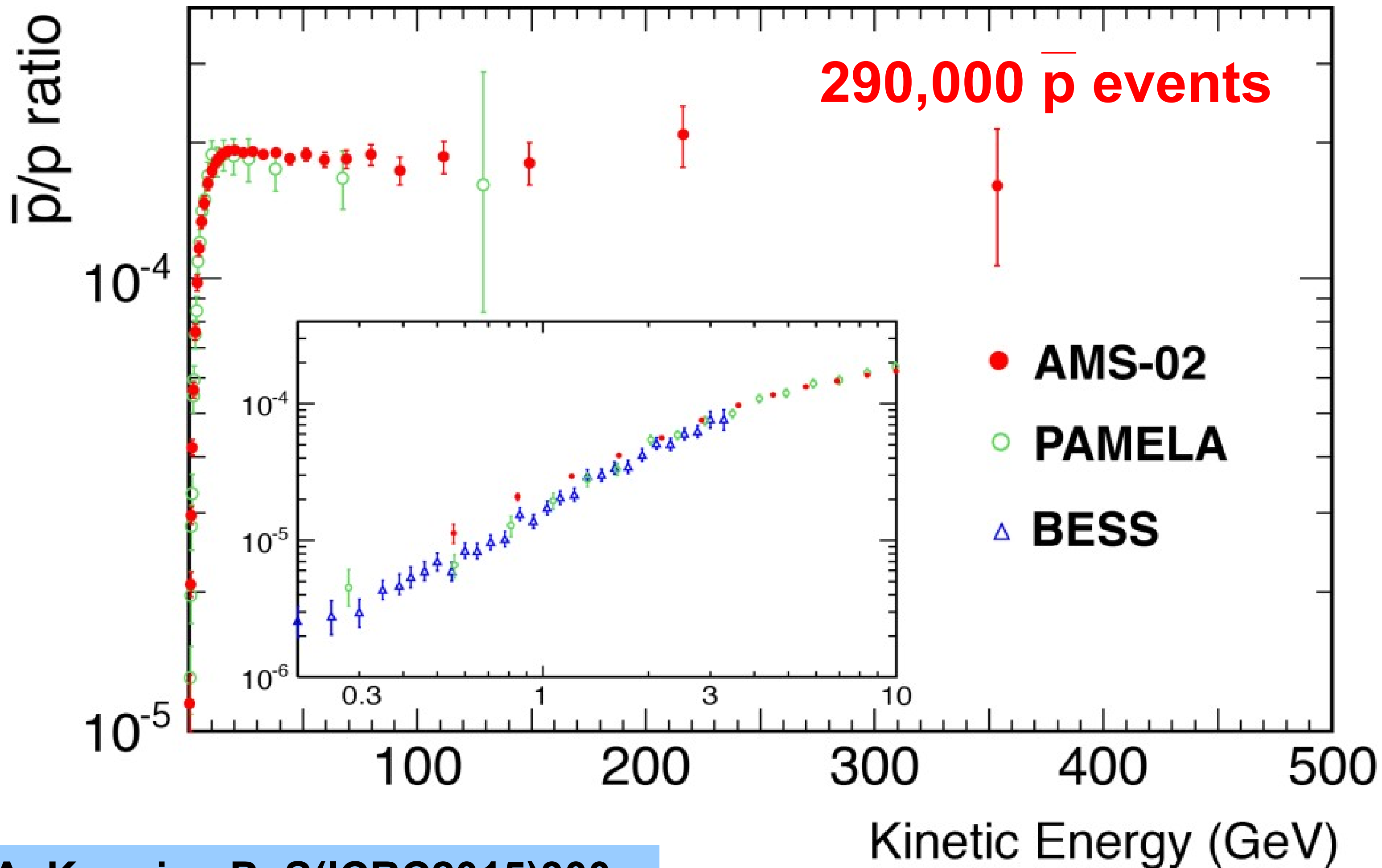


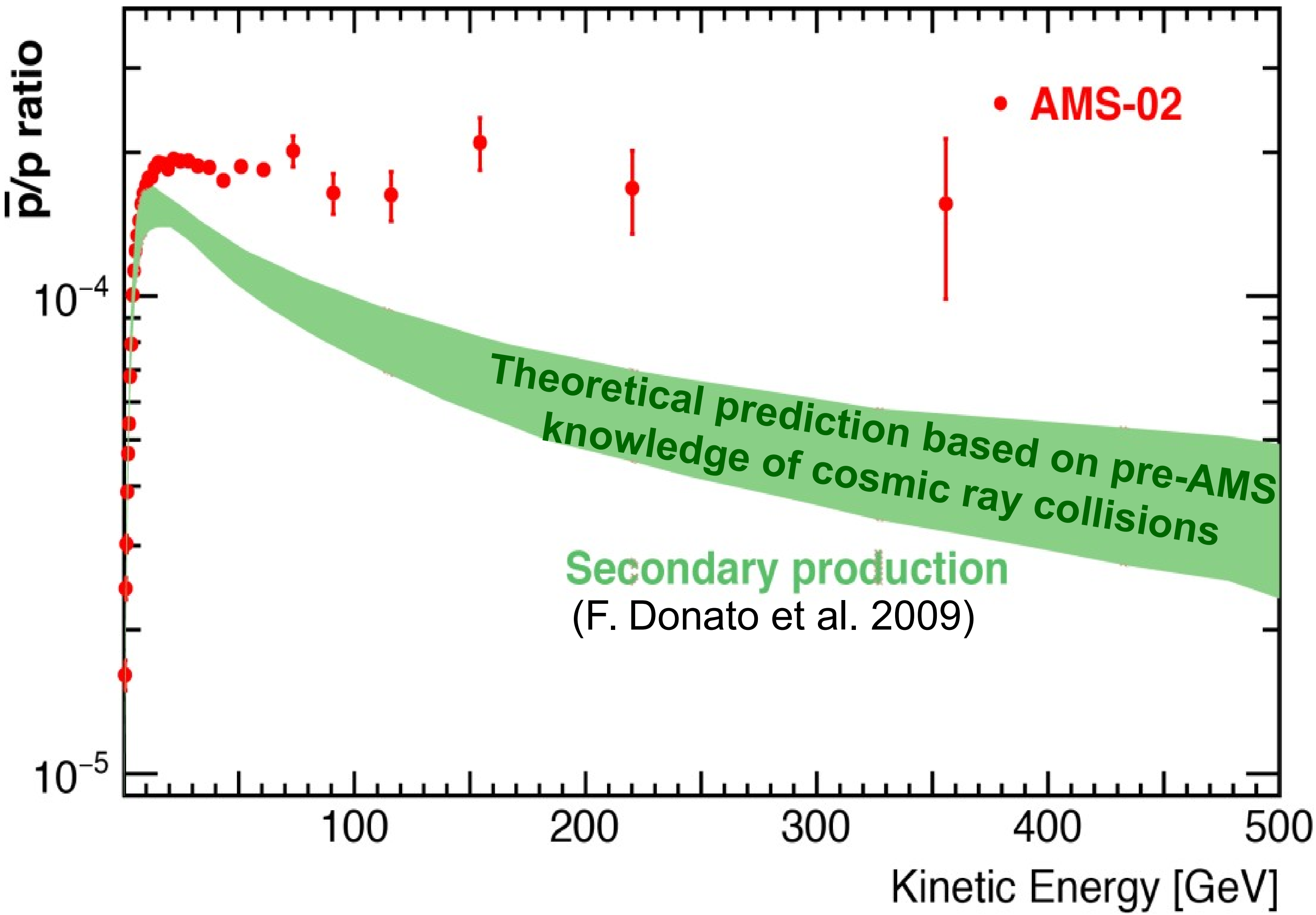


AMS p/$\bar{p}$ RESULTS

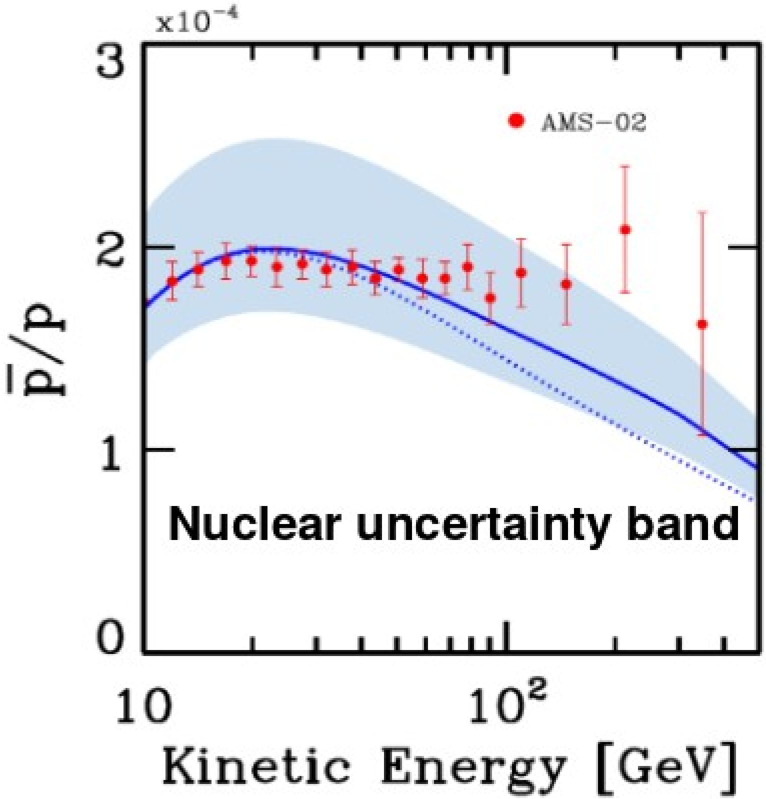


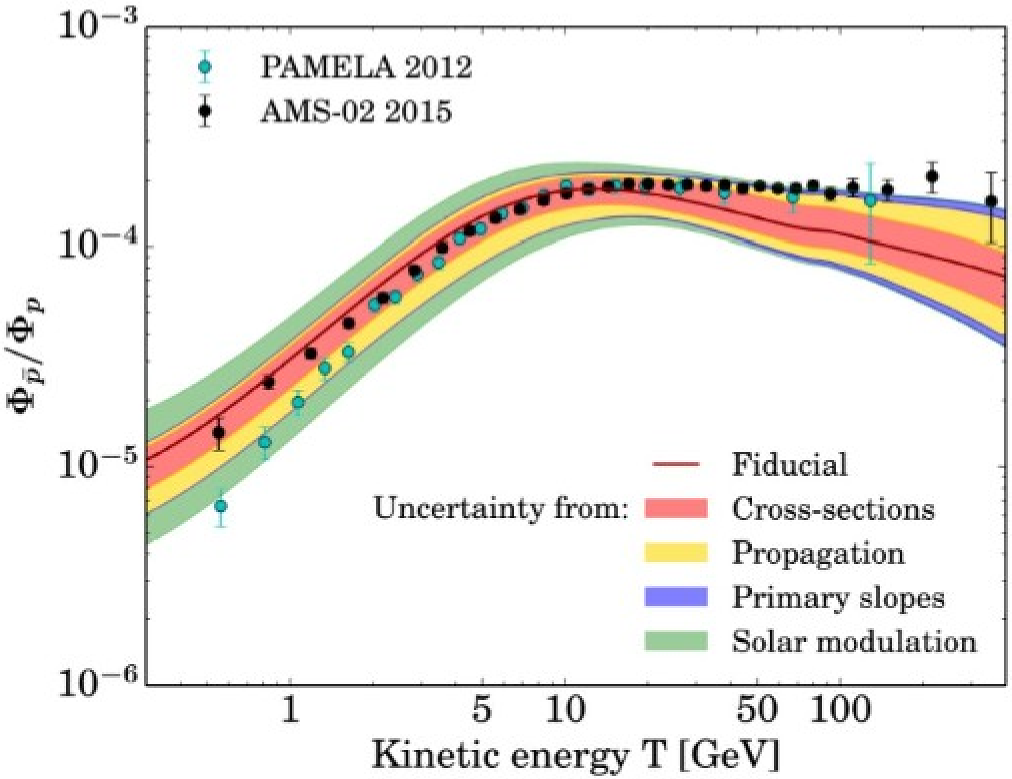
A. Kounine PoS(ICRC2015)300

AMS p/$\bar{p}$ RESULTS



IS THERE ROOM FOR DARK MATTER?





Secondary antiprotons as a Dark Matter probe
arXiv:1504.05175
C. Evoli, D. Gaggero, D. Grasso

AMS-02 antiprotons at last!

arXiv:1504.04276
G. Giesen et al.

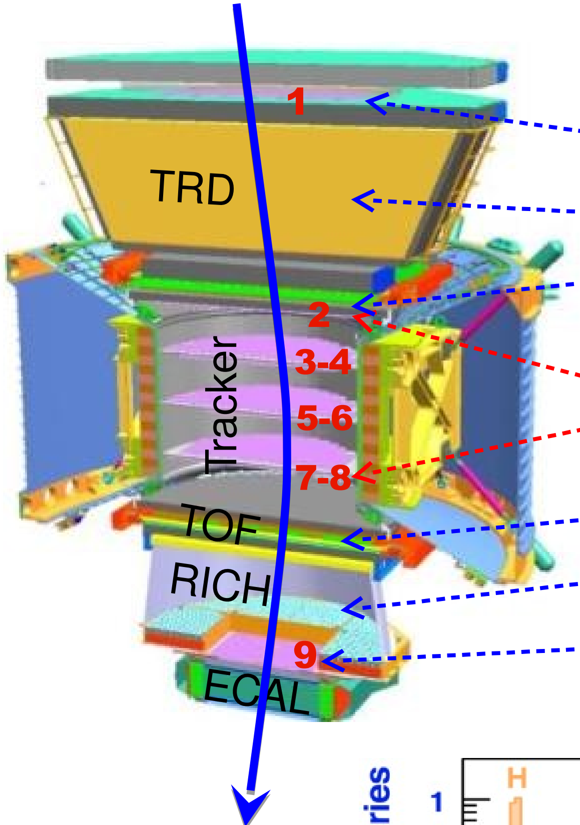
CAVEAT: THESE MODELS ARE BASED ON PRE-AMS DATA FITS

To understand the astrophysical background, we need precise knowledge of:

1. The cosmic ray fluxes at Earth (p, He, C, …)

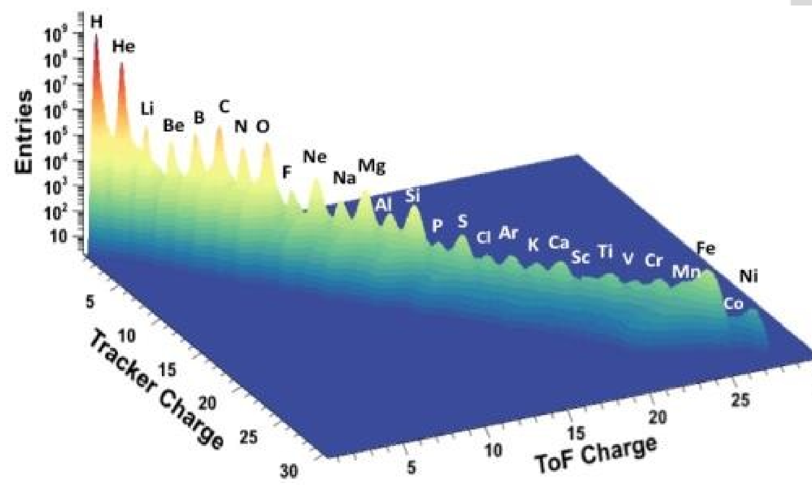
2. Propagation and acceleration in the galaxy (Li, B/C, …)

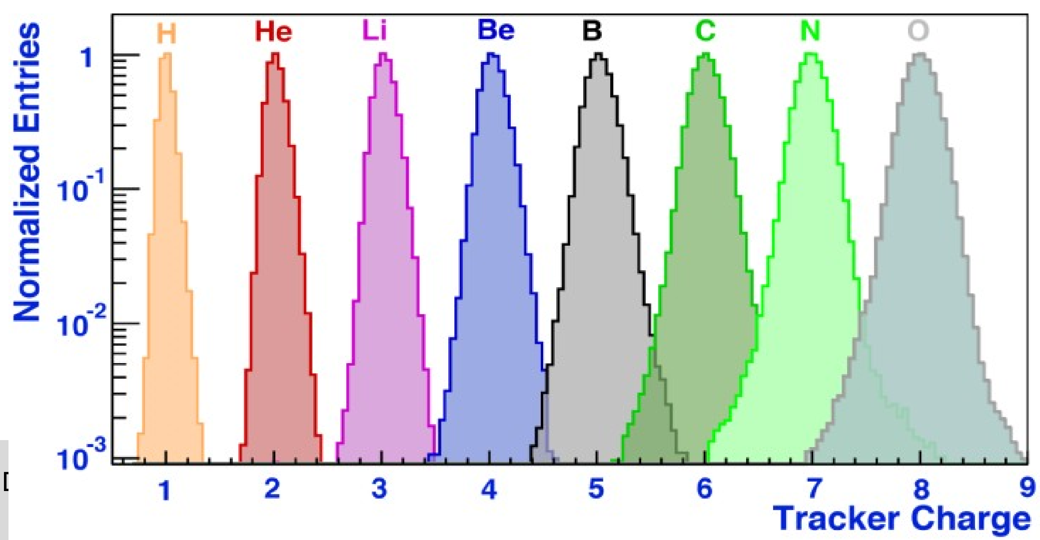
MULTIPLE MEASUREMENTS OF NUCLEAR CHARGE



Charge Resolution (Z=6)

Tracker Plane 1	0.30
TRD	0.33
Upper TOF	0.16
Inner Tracker 2-8	0.12
Lower TOF	0.16
RICH	0.32
Tracker Plane 9	0.30





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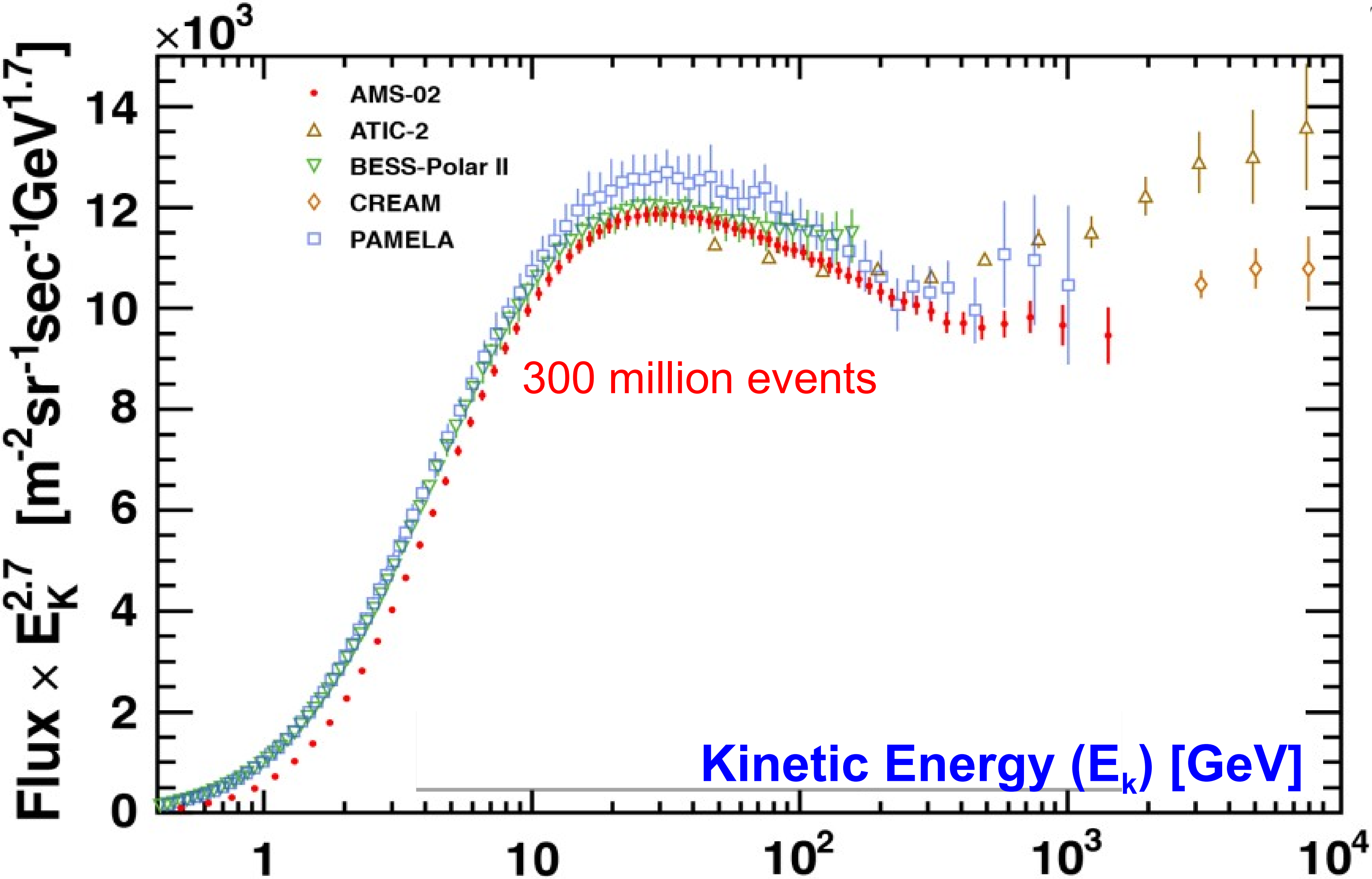
AMS PROTON FLUX



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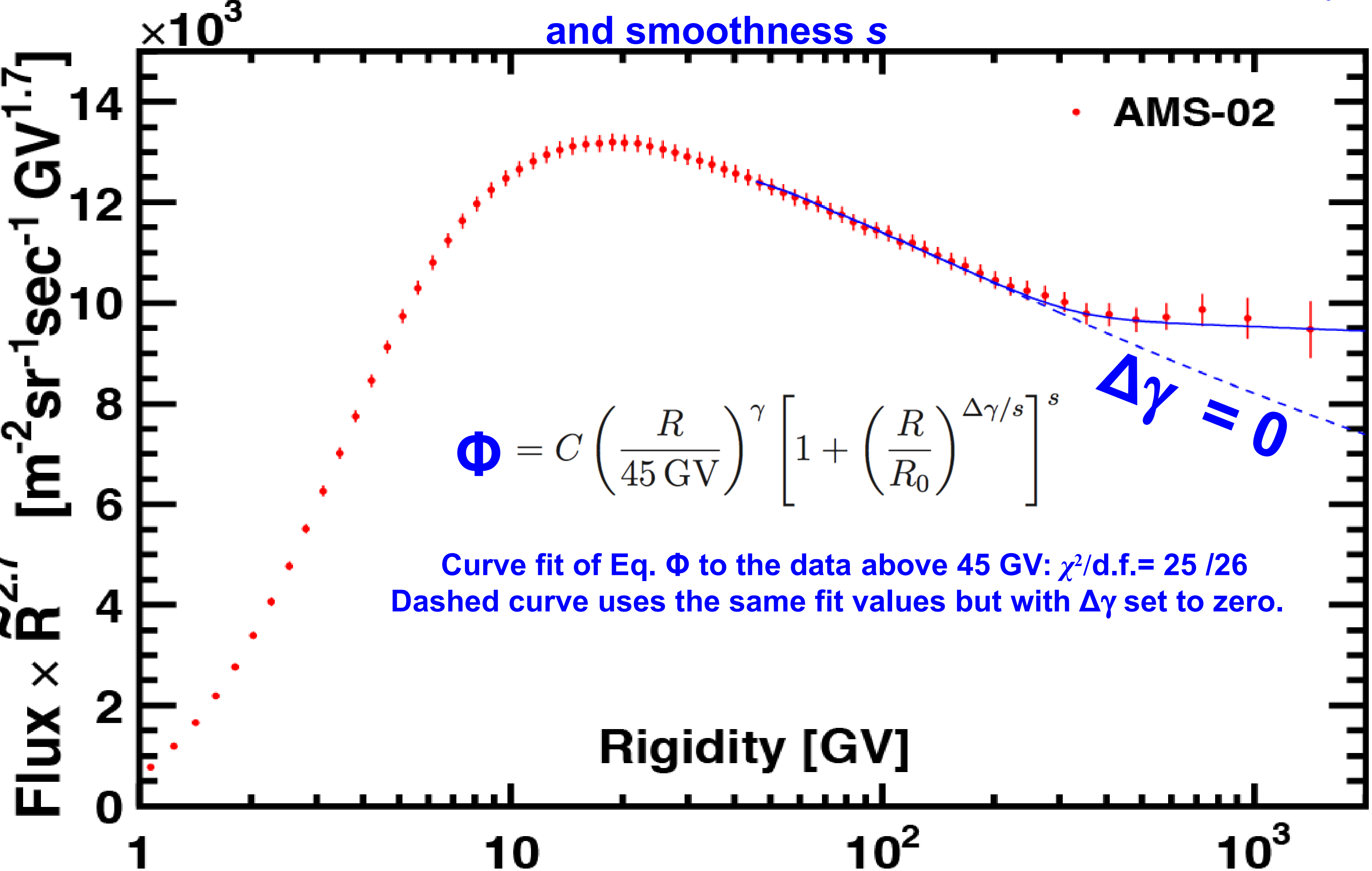
AMS PROTON FLUX

two power laws: R^{γ}, $R^{\gamma+\Delta\gamma}$ with a characteristic transition rigidity R_0 and smoothness s



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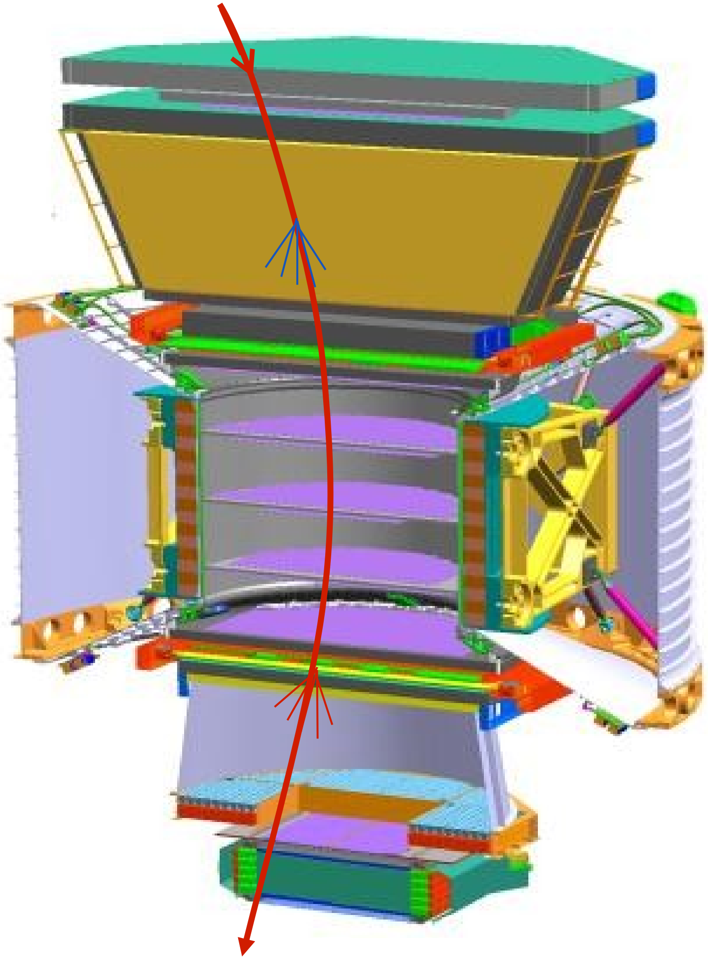
ACCURATE MEASUREMENT OF NUCLEI FLUXES ON ISS

To measure the flux of nuclei (He, Li, Be, B, C, O, …) accurately, we need to know the interaction cross section of these nuclei with the materials in AMS.



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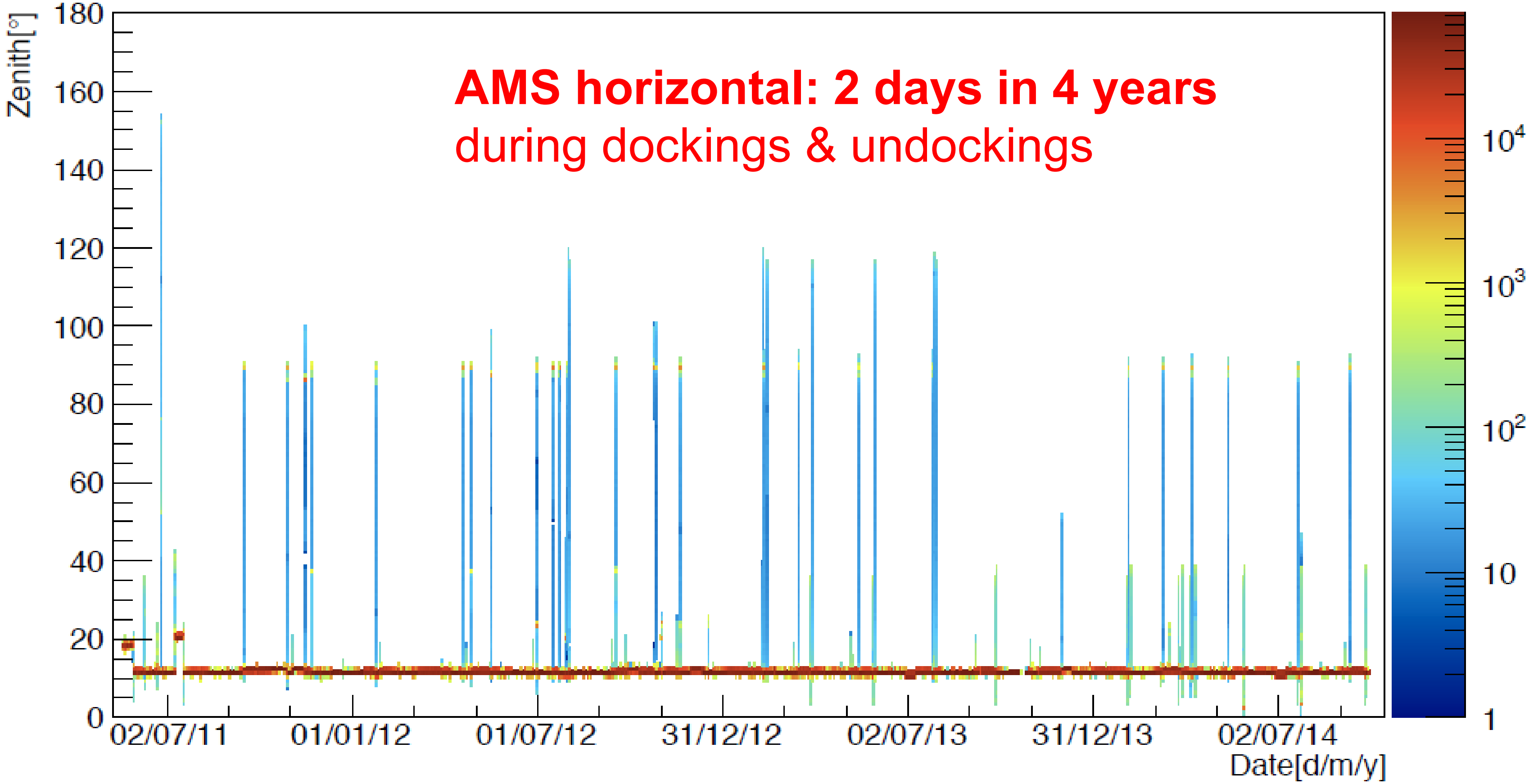
requires horizontal particles, which are detected when the ISS flies with AMS horizontal



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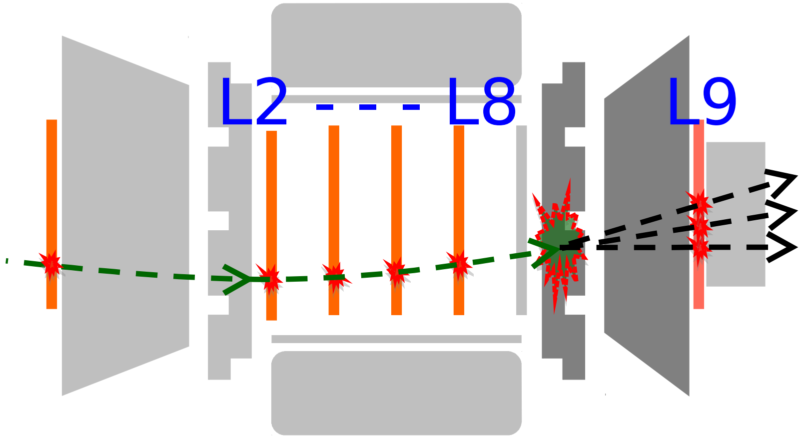
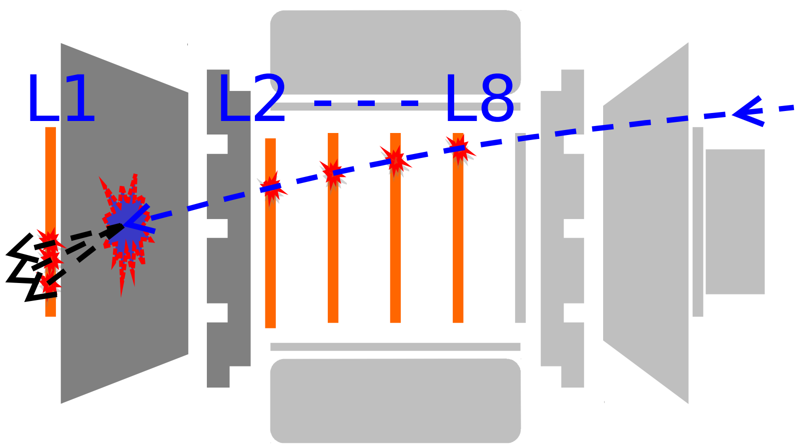
MEASURING THE INTERACTIONS OF NUCLEI WITHIN AMS

when AMS is flying horizontal



First, we use the seven inner tracker layers, L2-L8, to define beams of nuclei: He, Li, Be, B, …

Second, we use left-to-right particles to measure the nuclear interactions in the lower part of the detector.



Third, we use right-to-left particles to measure the nuclear interactions in the upper part of detector.

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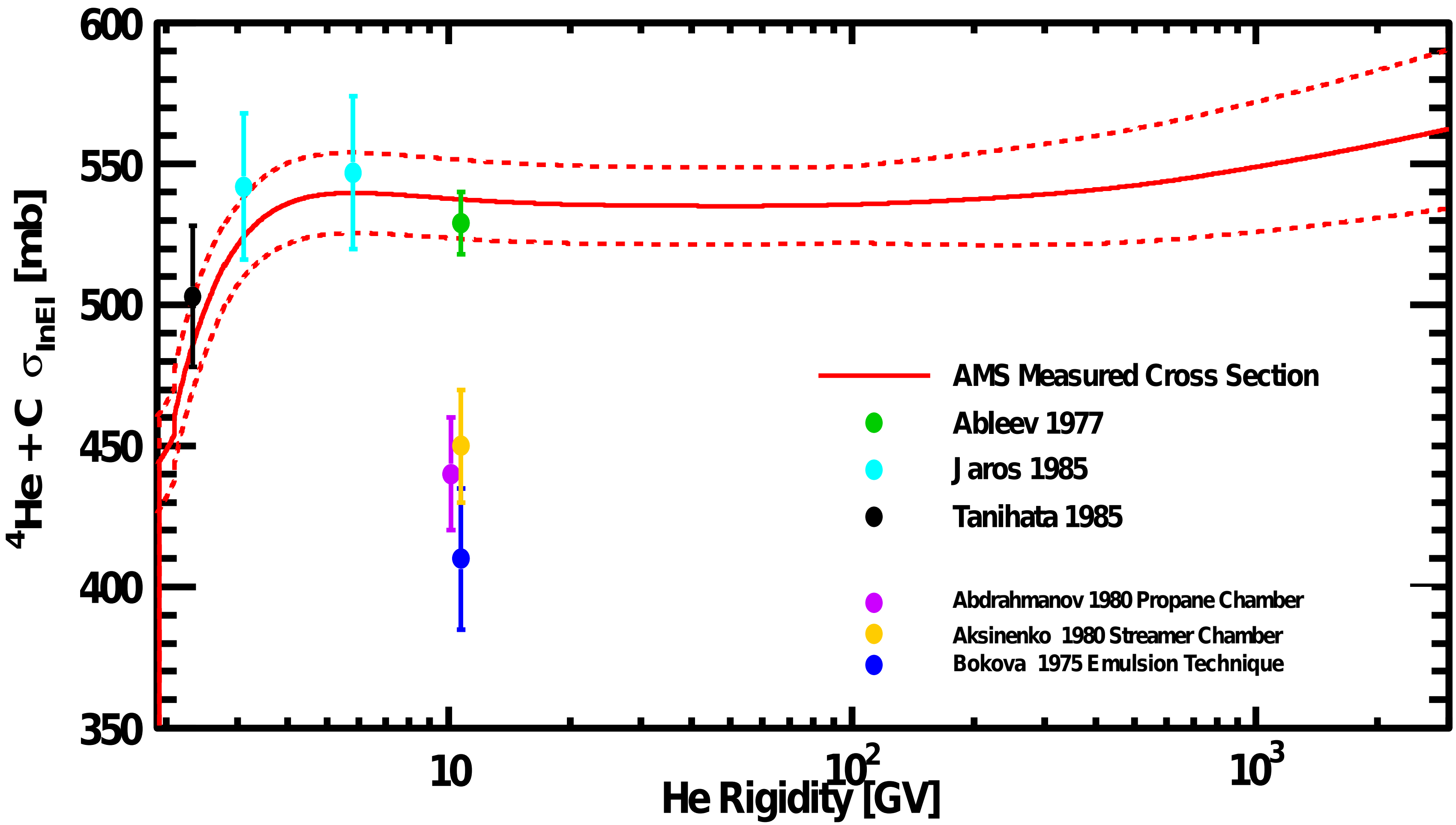
MEASUREMENT OF THE He+C CROSS SECTION



Helium

Primary+secondary isotopes

→ information about CR injection (+ propagation)

Lithium

C, N, O,…Fe + ISM -> Li
B, Be + ISM -> Li

Secondary: produced by the spallation of heavier nuclei during their propagation.
→ information about propagation parameters (diffusion, convection, reacceleration…).

Carbon

Primary, about 10% secondary contribution

→ information about CR injection

Boron/Carbon

C, N, O,…Fe + ISM -> B
Be → B

Secondary/primary ratio

→ information about CR interaction rate and energy dependence of CR escape

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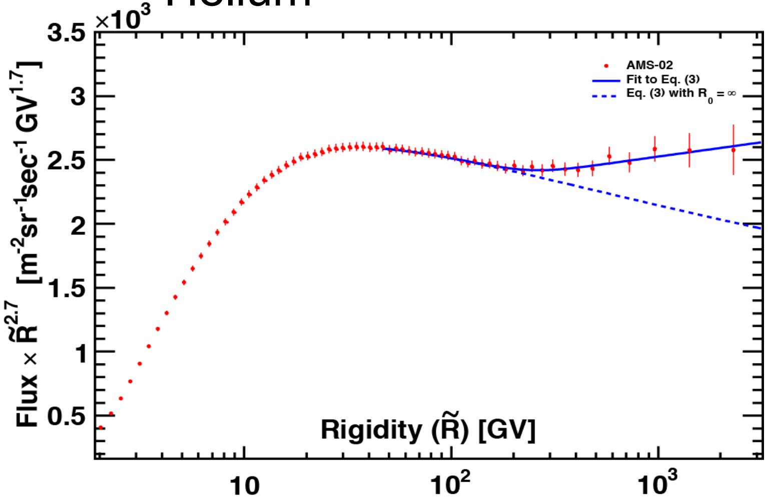
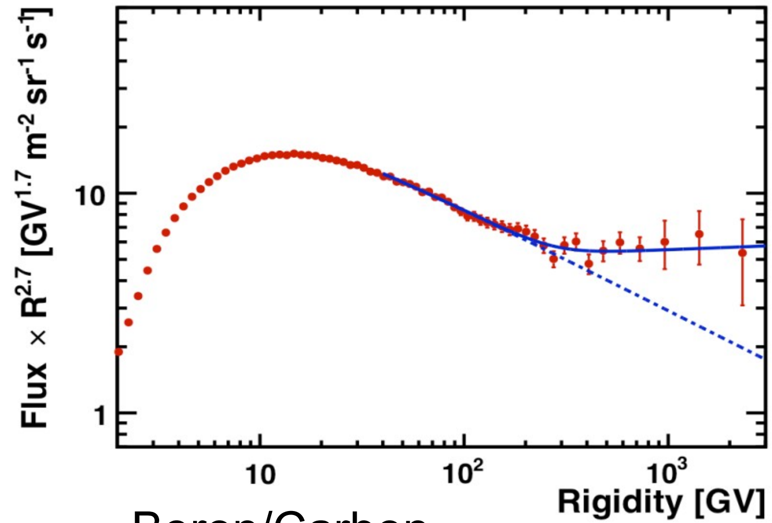
Helium



S. Haino PoS(ICRC2015)236

Lithium



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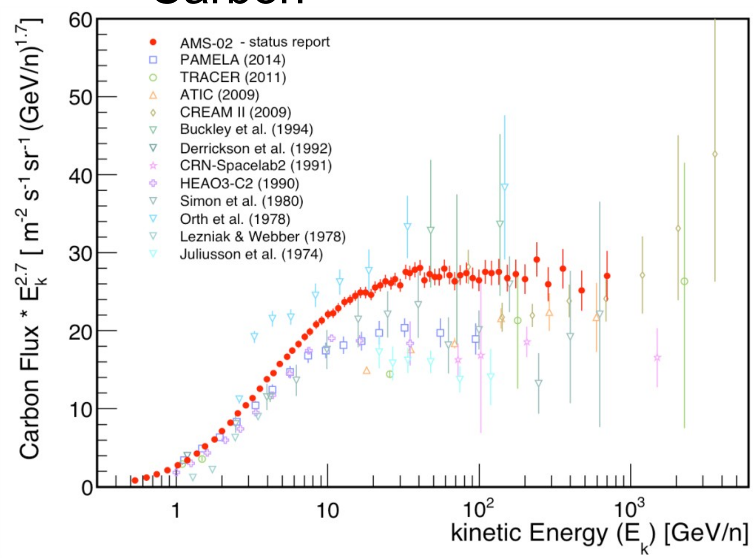
Carbon



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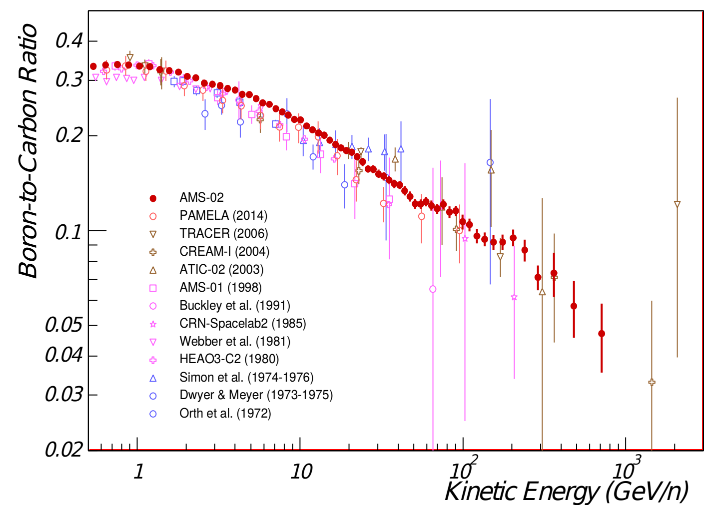
Boron/Carbon



A. Oliva PoS(ICRC2015)265

SUMMARY

In 4 years on ISS, AMS has collected >68 billion cosmic rays.

The accuracy of the AMS data is tremendously improving our understanding of cosmic ray transport and will help to shed a light on the nature of dark matter.

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