



Università
degli Studi
di Perugia

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I raggi cosmici visti da AMS-02: principali risultati in ≈ 5 anni di volo

Maura Graziani



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Outline:

1. Raggi cosmici e la fisica di AMS-02
2. AMS-02: il rivelatore
3. AMS-02: Risultati
 - frazione di positroni $e^+/(e^++e^-)$
 - flussi e^+ , e^-
 - flusso $e^+ + e^-$
 - dipendenza temporale flussi e^+ , e^-
 - antiprotoni
 - flussi nucleari: p, He..Li, C



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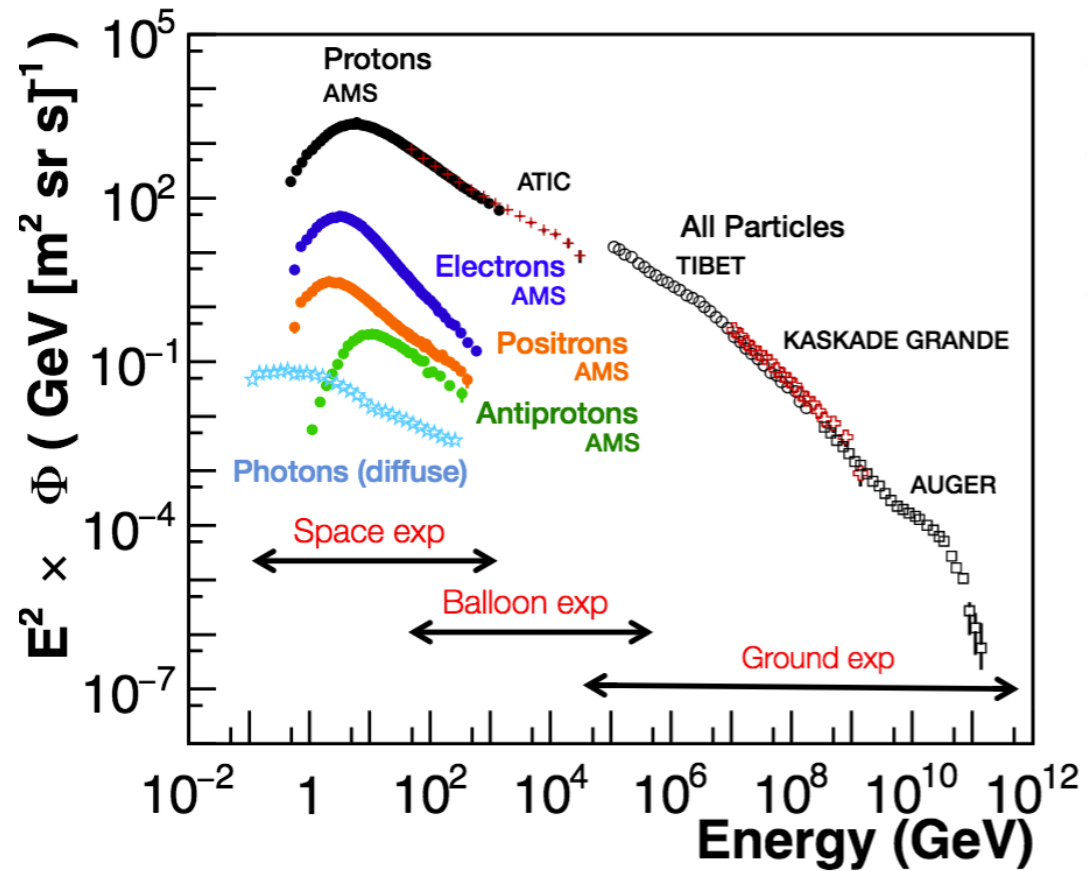
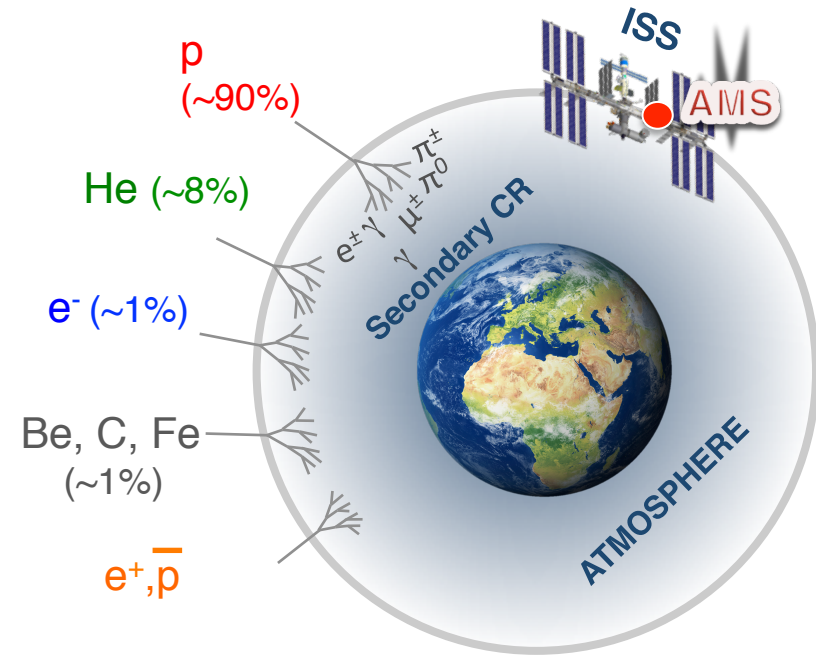
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Raggi Cosmici & fisica di AMS-02

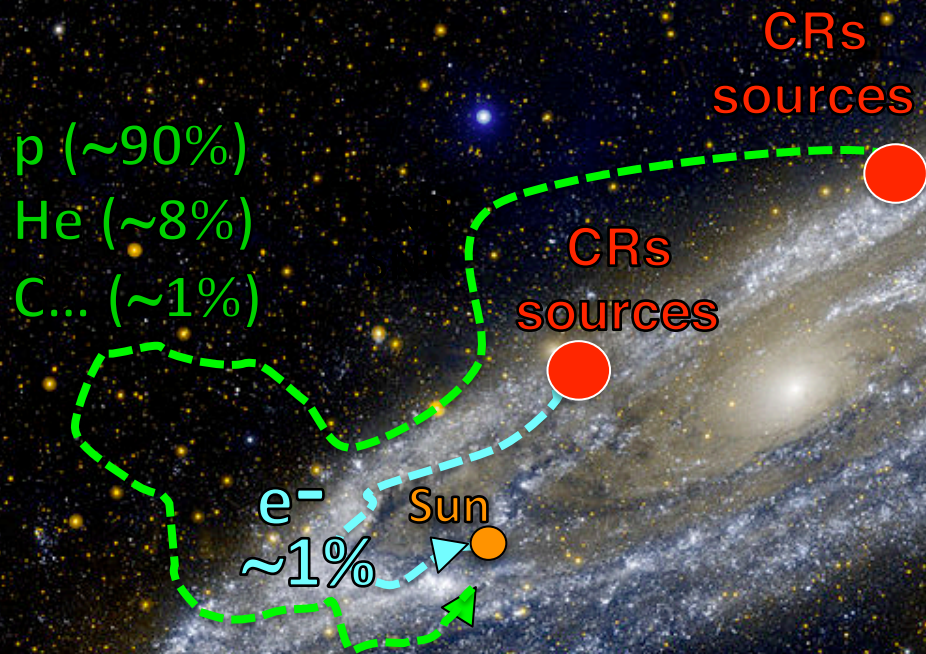


Raggi cosmici

- origine galattica ed extragalattica
- Spettro energetico ($dN/dE \sim E^{-\gamma}$) fino a 10^{20} eV
- principalmente composti da protoni
- trasportano importanti informazioni sull'universo.

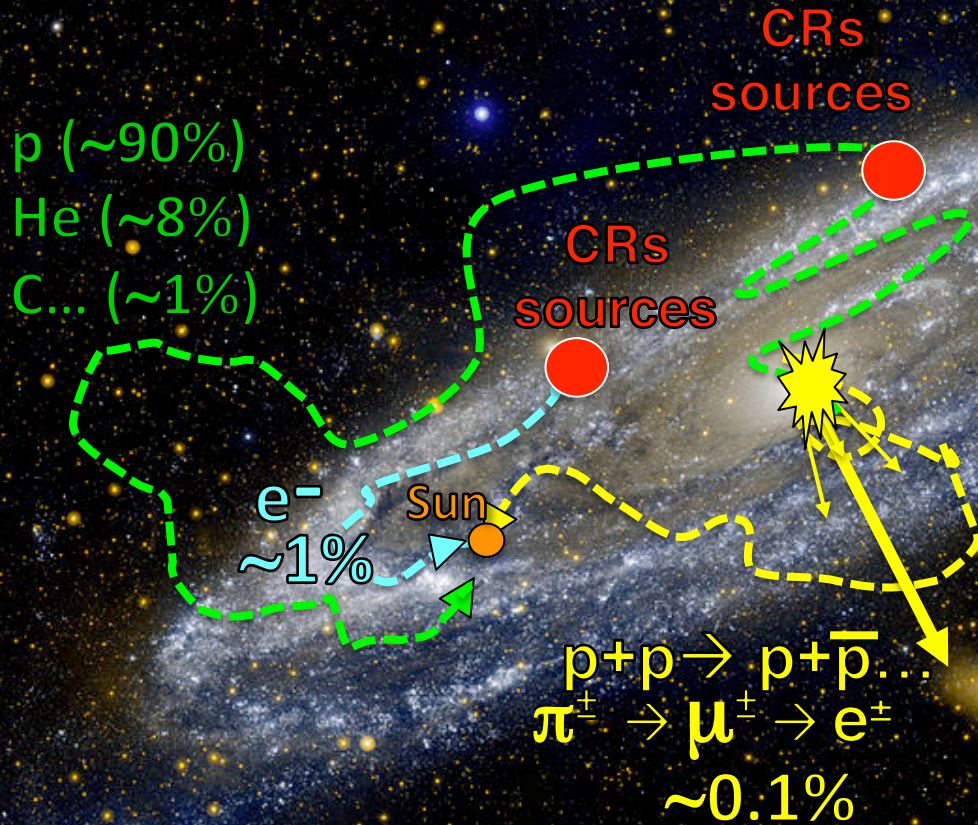
Raggi Cosmici & fisica di AMS-02

→ Modello standard dell'origine e della propagazione dei raggi cosmici



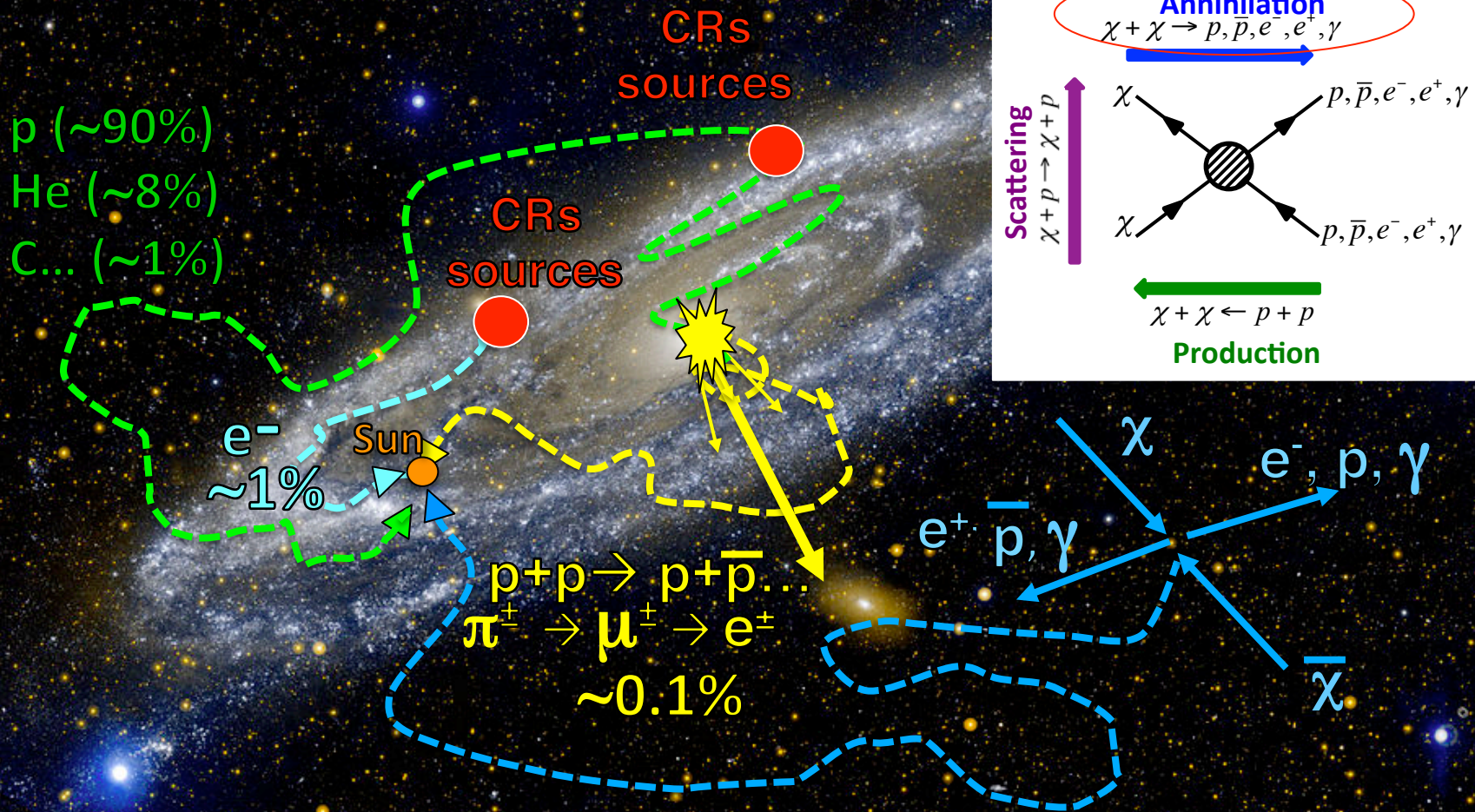
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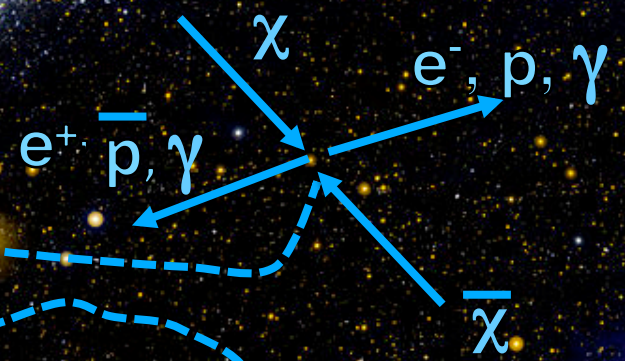
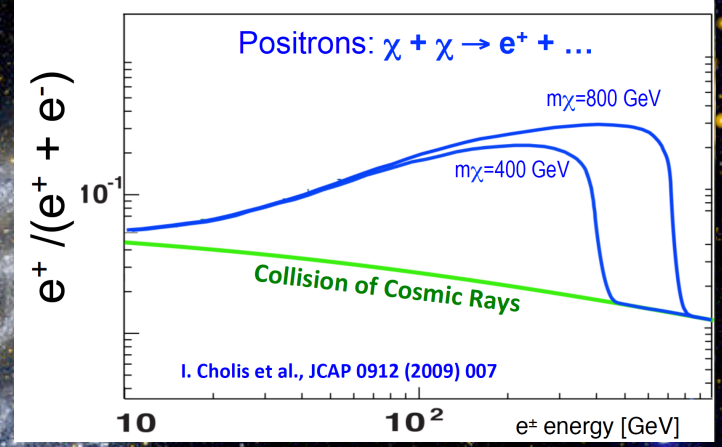
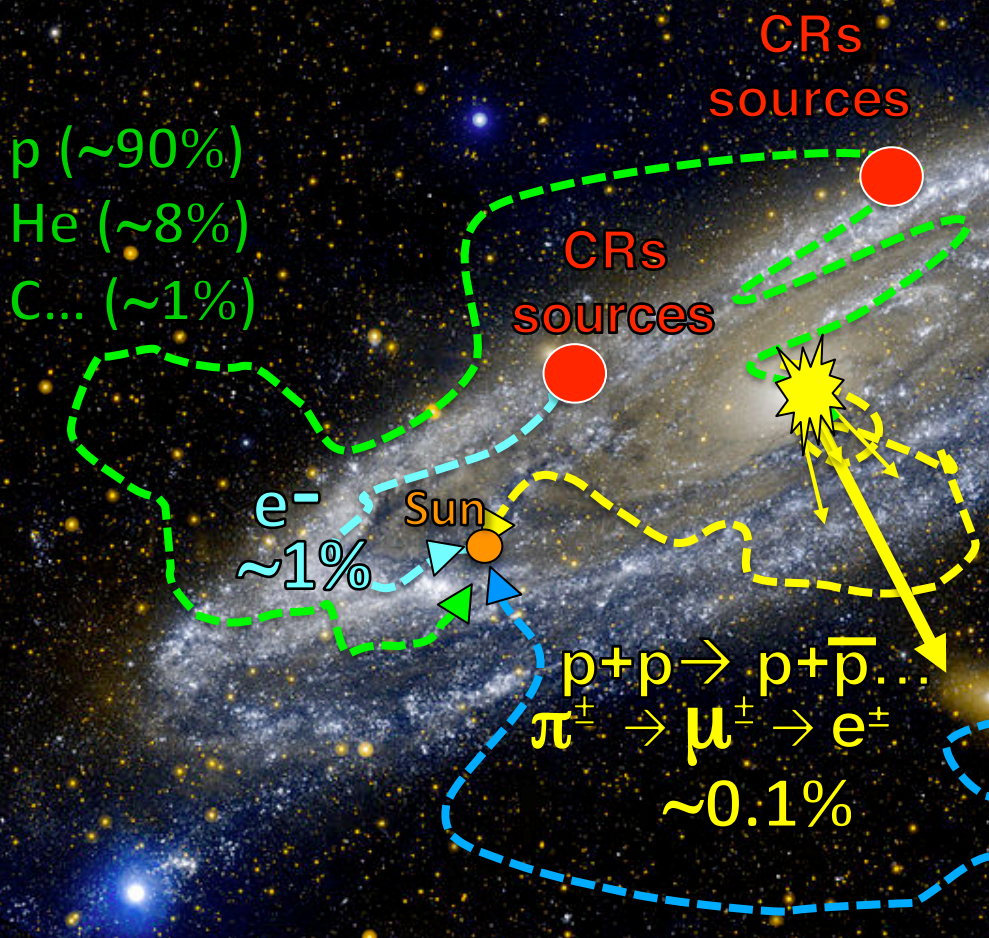
Raggi Cosmici & fisica di AMS-02

- Modello standard dell'origine e della propagazione dei raggi cosmici
- Ricerca indiretta di DM: studio delle componenti rare dei raggi cosmici



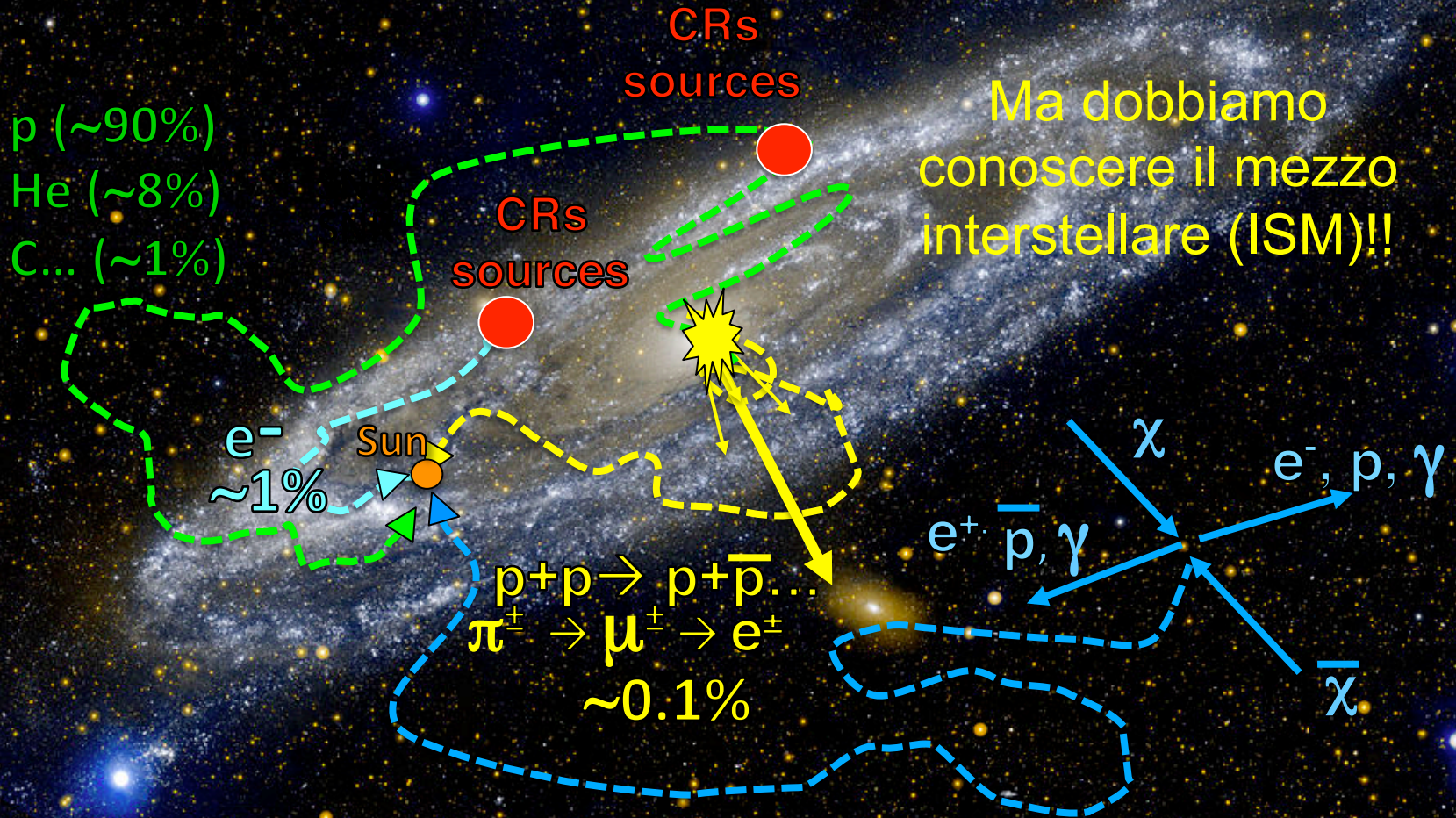
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Raggi Cosmici & fisica di AMS-02:

Misura accurata dello spettro energetico di

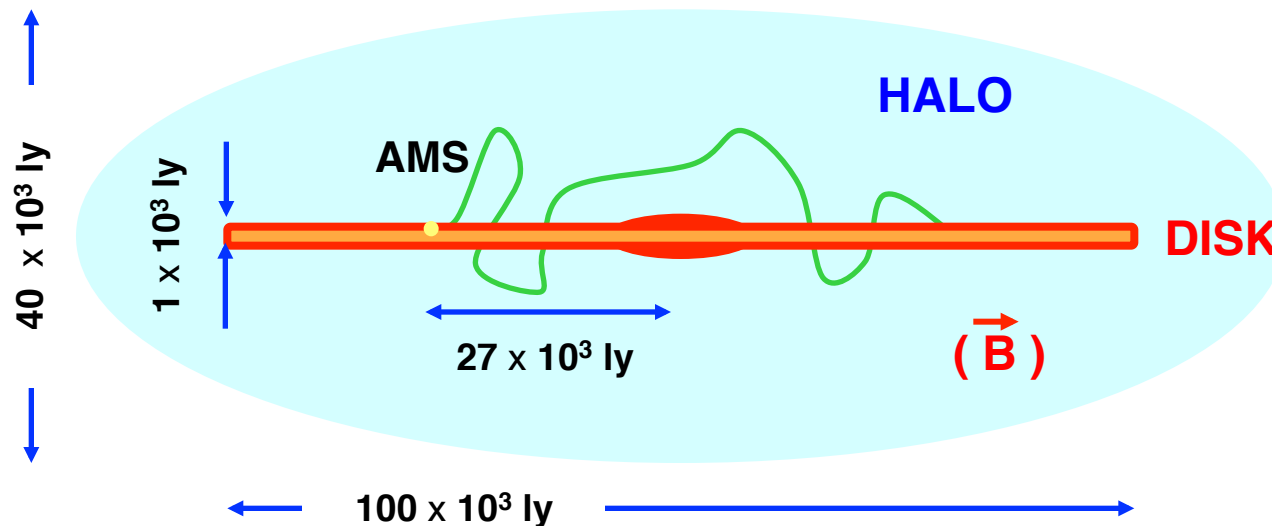
p, He, C, N, O ... Fe

→ informazioni sulle sorgenti e meccanismi di accelerazione

Li, Be, B, ...

→ informazioni sulle interazioni dei RC con il mezzo interstellare

→ informazioni sulla propagazione dei RC

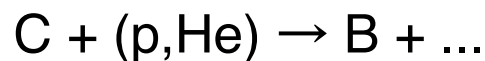


Diffusion
Convection
Reacceleration

Interactions with the
Interstellar Medium
(ISM):

- Fragmentation
- Secondaries
- Energy loss

Interazione con il mezzo interstellare:



Ricerca di antimateria di origine primordiale

→ Ricerca di anti-nuclei

Dirac's Nobel speech

“We must regard it rather as an accident that the Earth [...], contains a preponderance of negative electrons and positive protons. It is quite possible that for some of the stars it is the other way about”



Fisica fondamentale & Antimateria:

- ▶ Antimateria di origine primordiale con una sensibilità di 10^{-9}
- ▶ Ricerca indiretta di materia oscura (e^+ , p , ...)

La composizione e lo spettro energetico dei Raggi Cosmici:

- ▶ Sorgenti & Accelerazione
- ▶ Propagazione nel ISM: Abbondanze relative dei nuclei e isotopi nei Raggi Cosmici

Di cosa abbiamo bisogno?

→ **Identificazione particelle e misure di energia fino al TeV:**

- ▶ Segno della carica: separazione materia/anti-materia (campo magnetico!)
- ▶ separazione e/p al livello del 10^4 usando detector indipendenti
- ▶ Z: misure ridondanti per tener conto della frammentazione dei nuclei con il materiale del rivelatore

→ **Alta Statistica**

- ▶ Grande Accettanza & efficienza
- ▶ Lungo Tempo di esposizione.



*ISS - May 19, 2011
AMS installation completed*

Misura dei raggi cosmici carichi
(O(GV) - O(TV))

AMS in numeri:

- 5 m x 4 m x 3m
- 7.5 tonnellate
- 300k canali di lettura
- Più di 600 microprocessori riducono il rate di acquisizione da 7 Gb/s a 10 Mb/s
- Consumo totale < 2.5 kW



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AMS-02: il rivelatore

TRD, Transition Radiation Detector
Identificazione e^+ , e^-

Z, P sono misurate
indipendentemente dal
Tracker, RICH, TOF e ECAL

TOF
"Time of Flight"
 Z, E

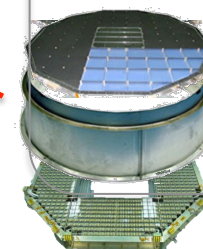
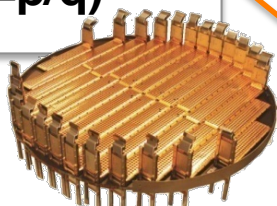
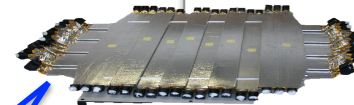
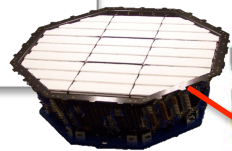
Tracciatore al silicio
 $Z, R(=p/q)$

Magnete Permanente
 $\pm Z$
(0.15 T)

**Sistema di
anticoincidenze
(ACC)**

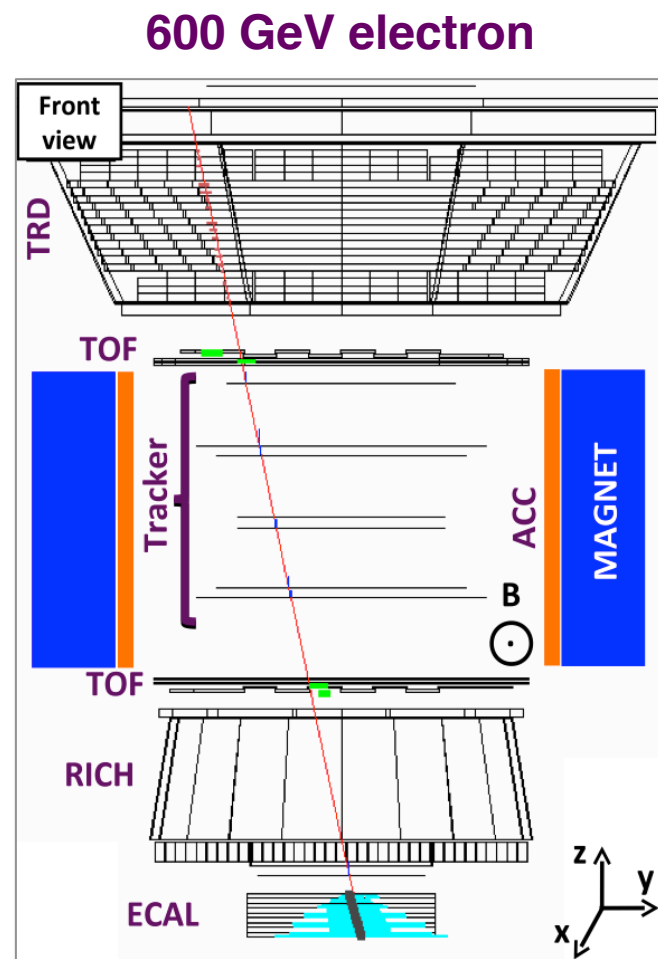
**ECAL, Calorimetro
Elettromagnetico**
 E of e^+ , e^- , γ

**RICH, Ring Imaging
Cherenkov**
 Z, E
($\sigma_\beta/\beta \sim 0.1\%$)



AMS-02: Identificazione particelle

	e^-	P	He, Li, Be,..Fe	γ	e^+	\bar{p}	\bar{He}, \bar{C}
TRD							
TOF							
Tracker +Magnet							
RICH							
ECAL							
Physics example	Cosmic Ray Physics				Dark matter		Anti matter



Maggiori dettagli in:

Poster: [Crispoltoni](#),

“Stato della misura della componente elettronica dei Raggi Cosmici con l’esperimento AMS-02”

Poster: [Donnini](#),

“Stato della misura delle componenti nucleari dei Raggi Cosmici con l’esperimento AMS-02”

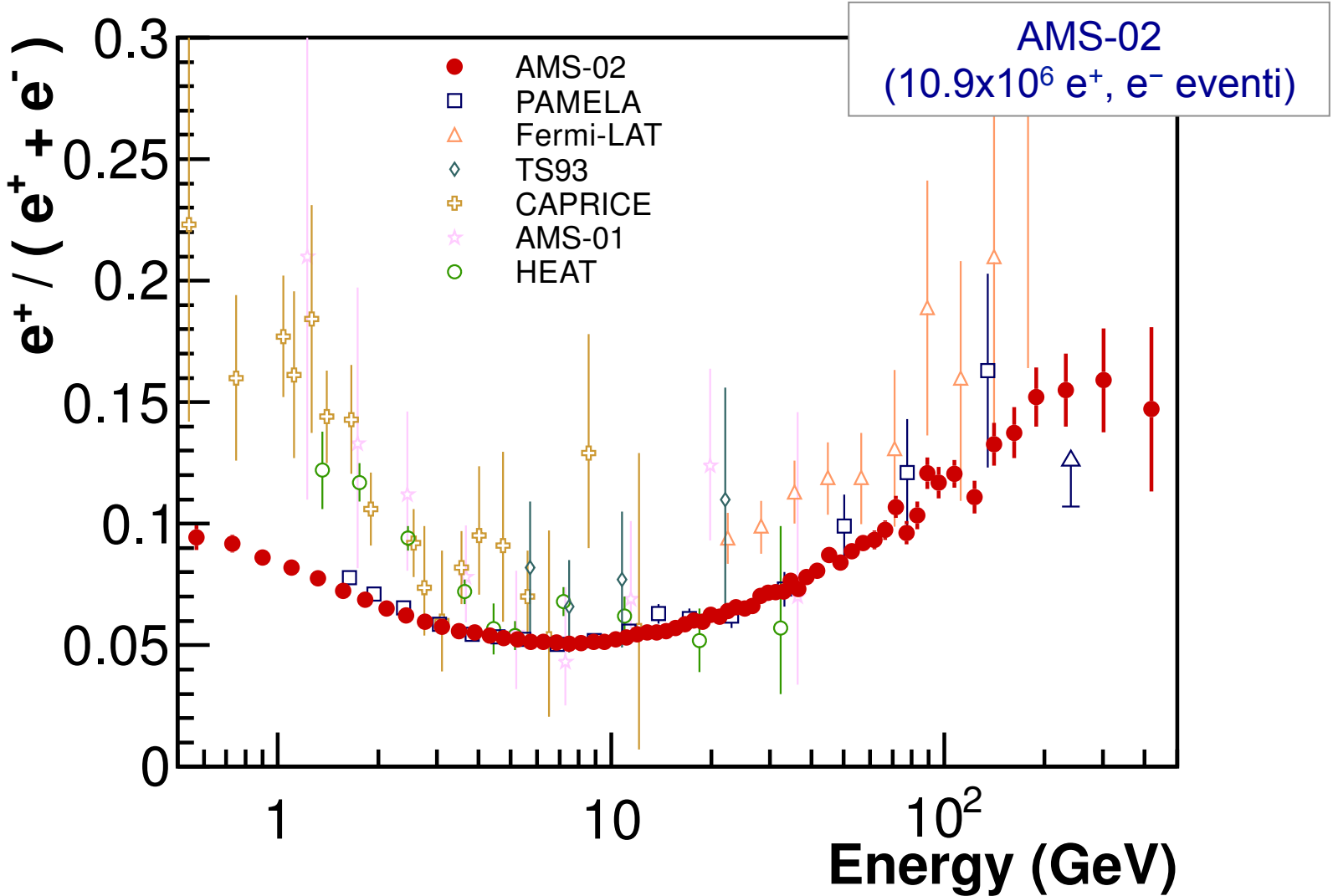


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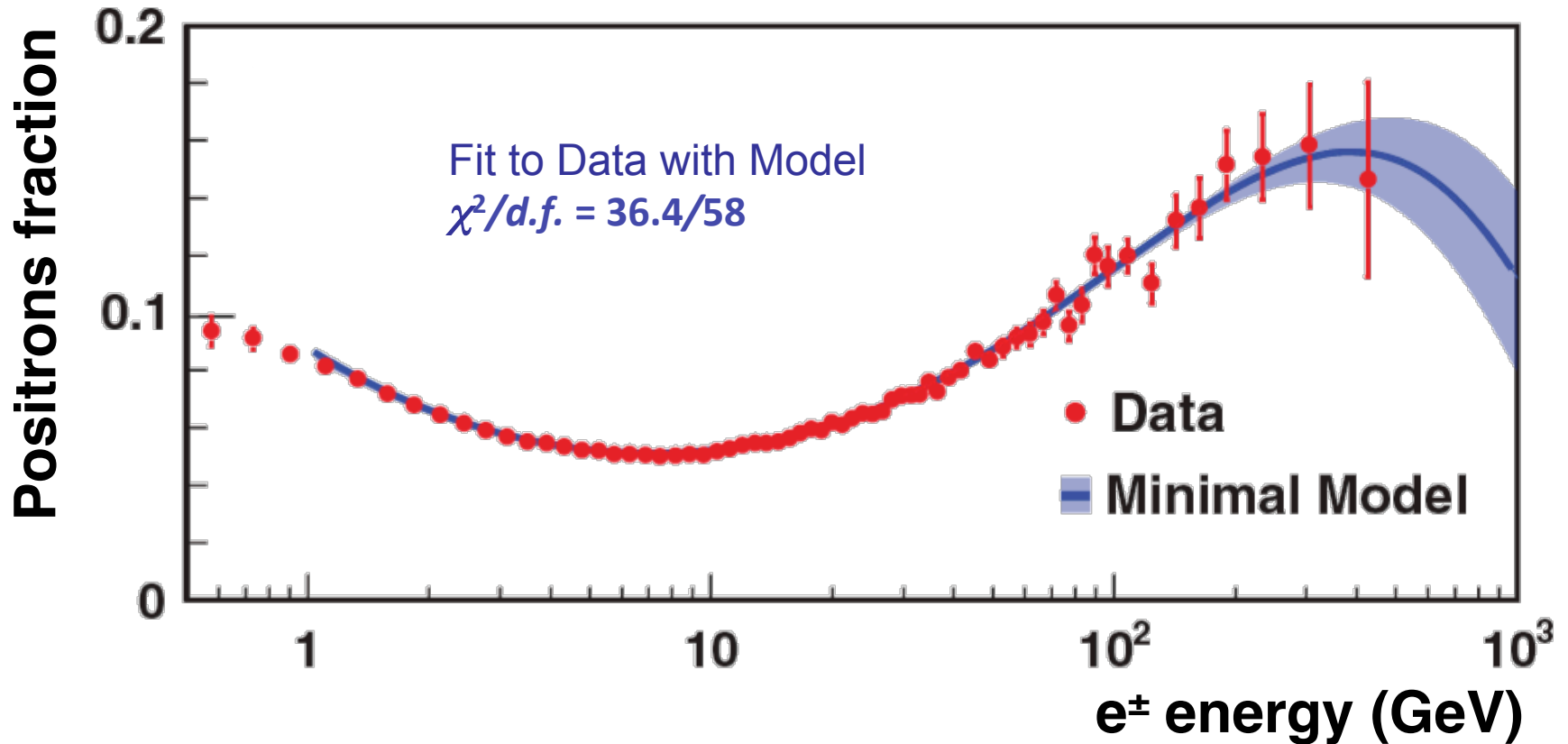
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 - **flussi e^+ , e^-**
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 - **dipendenza temporale flussi e^+ , e^-**
 - **antiprotoni**
 - **flussi nucleari: p, He..Li, C**

Positron fraction (0.5 – 500 GeV)



- Risalita non prevista in modelli di sola produzione secondaria



I flussi di elettroni e positroni vengono descritti come somma di una **componente diffusiva** e di una **sorgente comune** con un energia di cutoff :

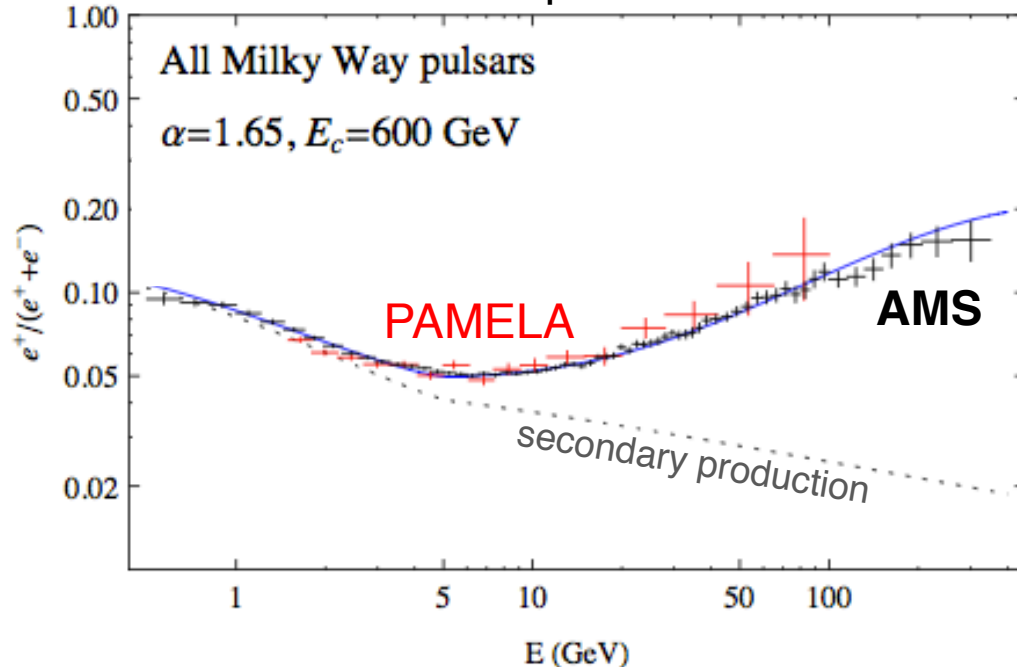
$$\Phi_{e^+} = C_{e^+} E^{-\gamma_{e^+}} + C_s E^{-\gamma_s} e^{-E/E_s}$$

$$\Phi_{e^-} = C_{e^-} E^{-\gamma_{e^-}} + C_s E^{-\gamma_s} e^{-E/E_s}$$

Origine dell'eccesso

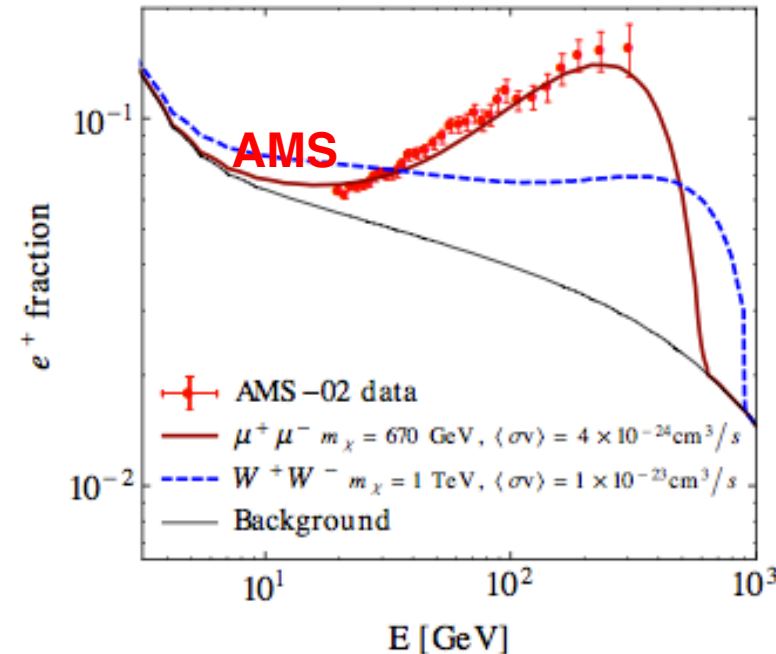
Astrophysical objects

Cholis arXiv: astro-ph/1304.1840



Dark Matter

Kopp hep-ph/1304.1184



Diversi andamenti con l'energia della positron fraction:

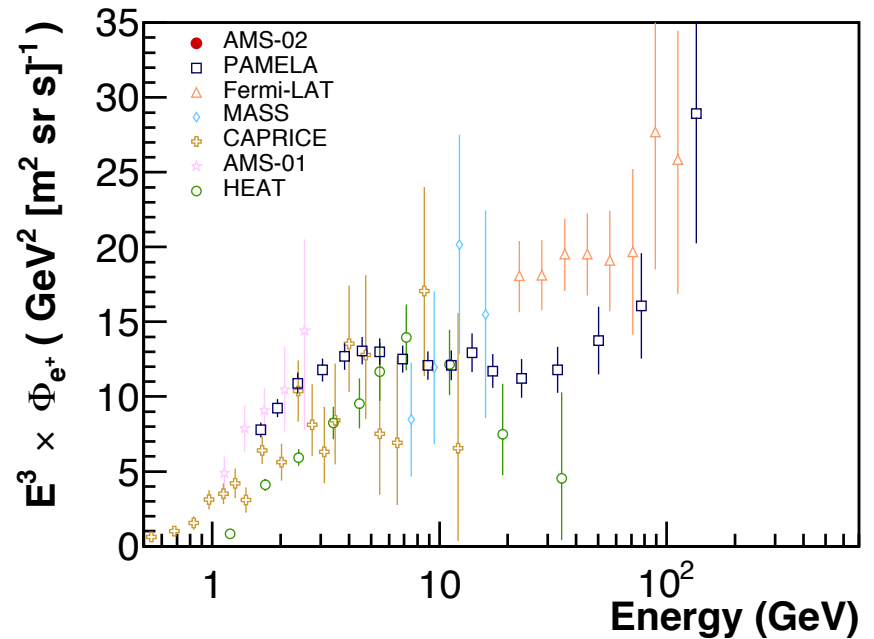
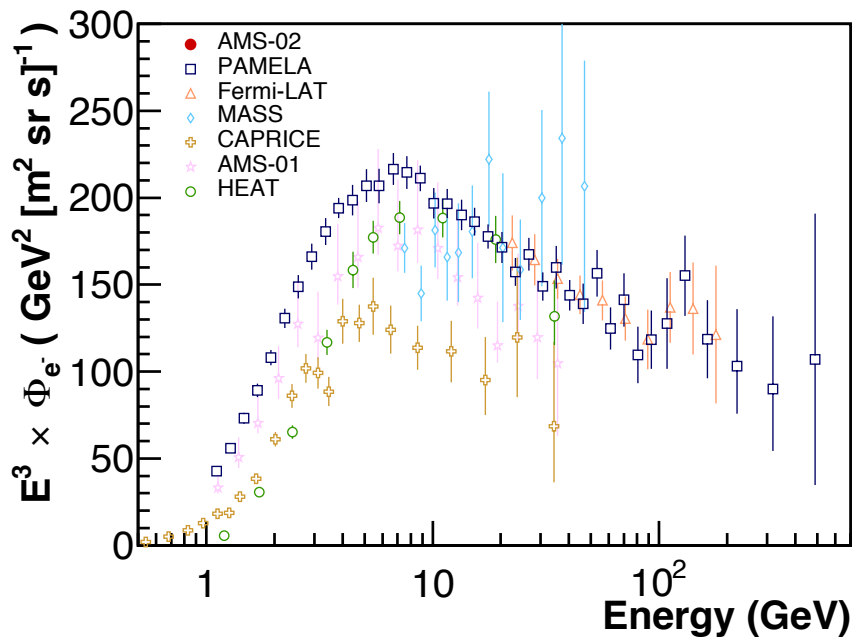
- **Pulsars:**

- **lenta decrescita ad alte energie**
- **anisotropia nel flusso di positroni**

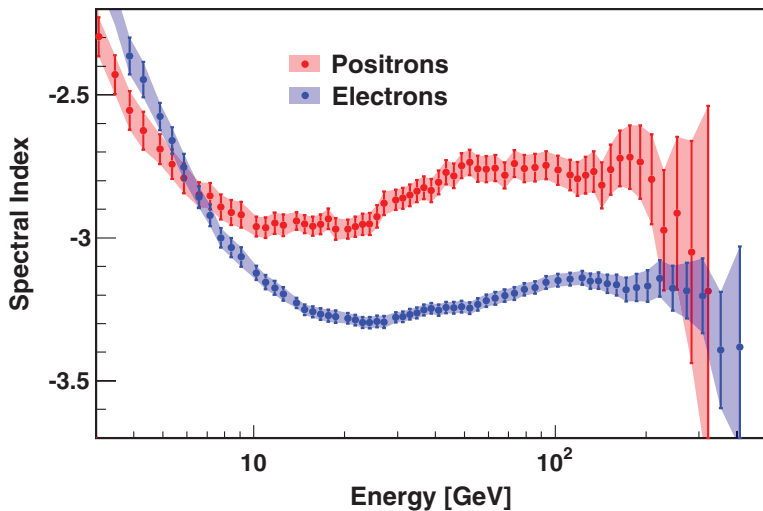
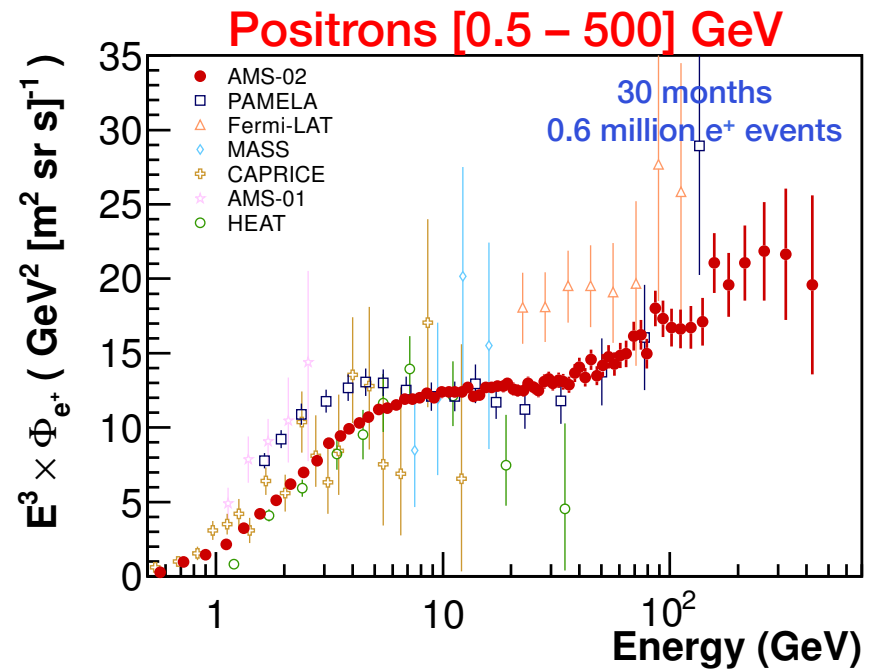
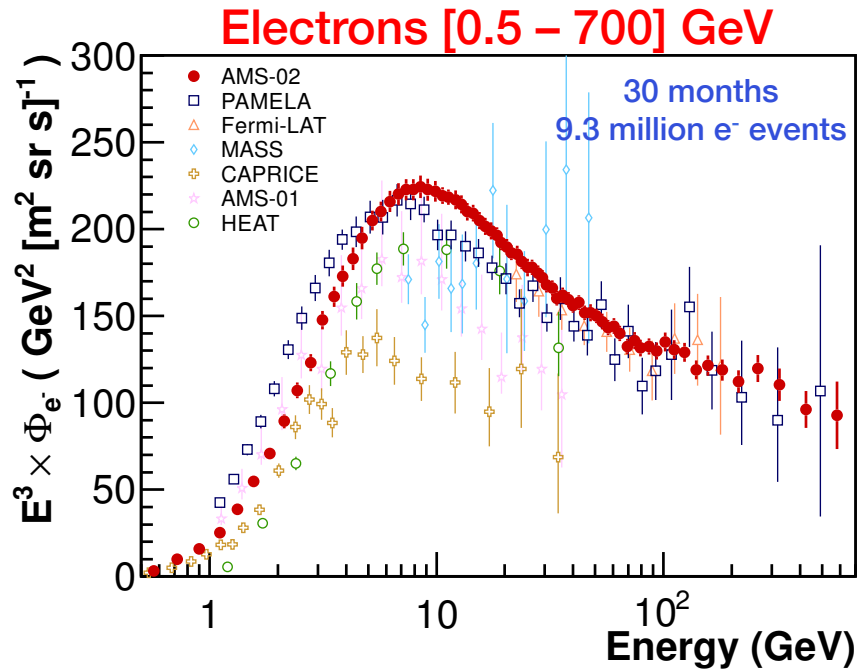
- **Dark Matter:**

- **veloce decrescita ad alte energie**
- **isotropia nel flusso di positroni**

Flussi di e^\pm - prima di AMS-02



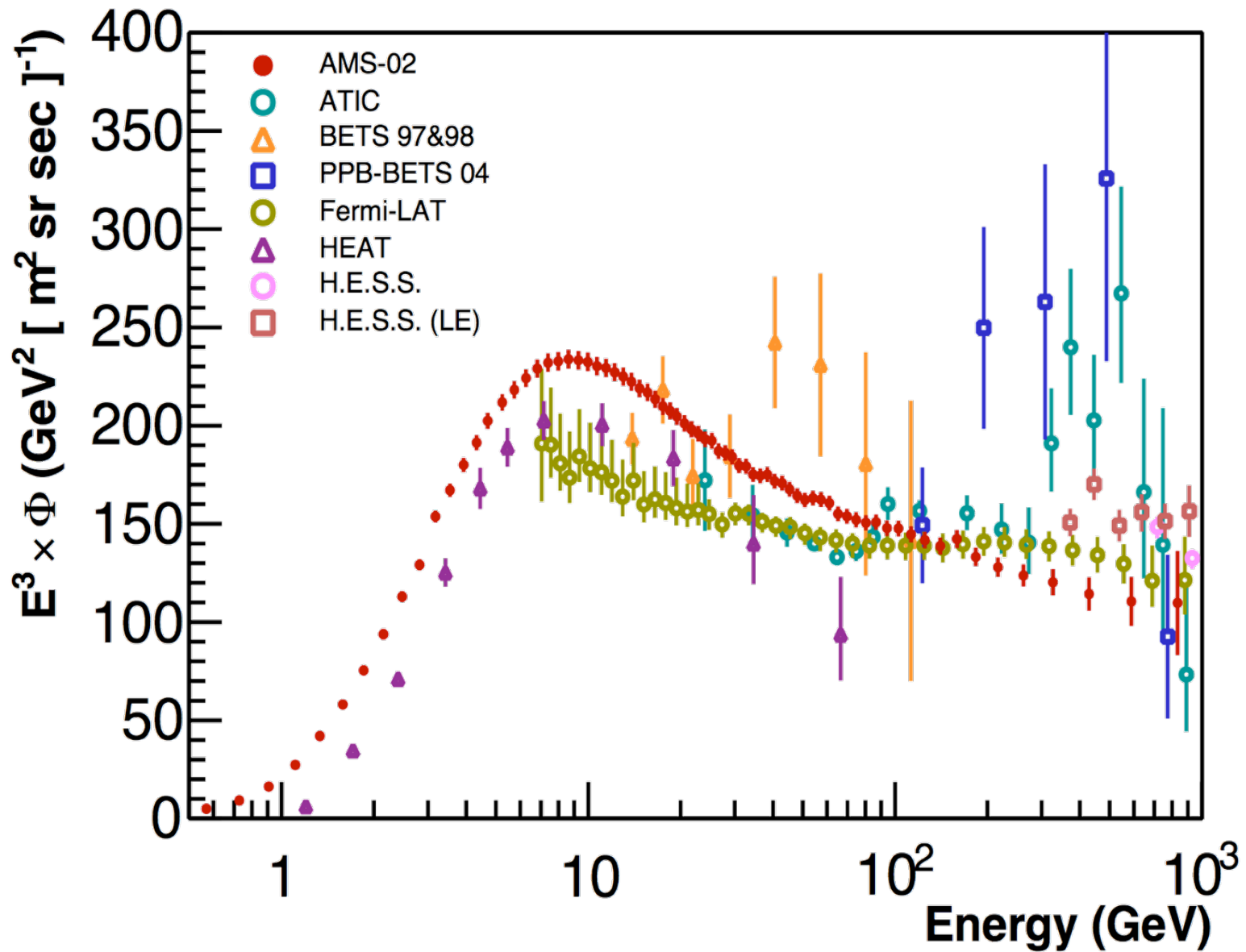
Flussi di e^\pm - dopo AMS-02



I flussi di elettroni e positroni sono **significativamente differenti** sia nel loro **valore assoluto** sia nella loro **dipendenza in energia**

La **risalita nella positron fraction** è dovuta ad un **eccesso di positroni** e non ad una decrescita nel flusso di elettroni.

Flusso All-electrons (e^+e^-) – dopo AMS-02



Flussi di e^\pm - modulazione solare

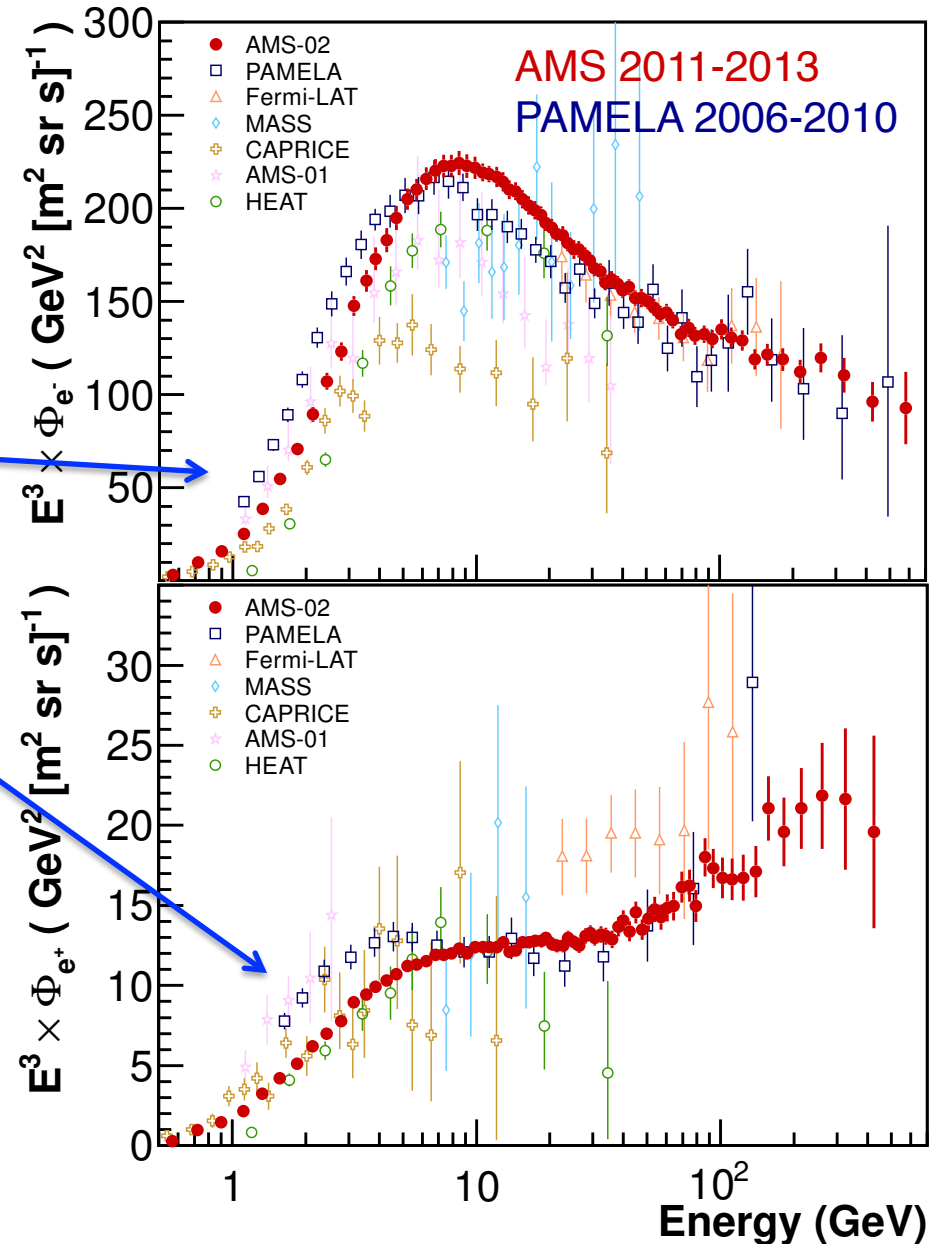
$E < 20$ GeV...

modulazione solare
dei raggi cosmici

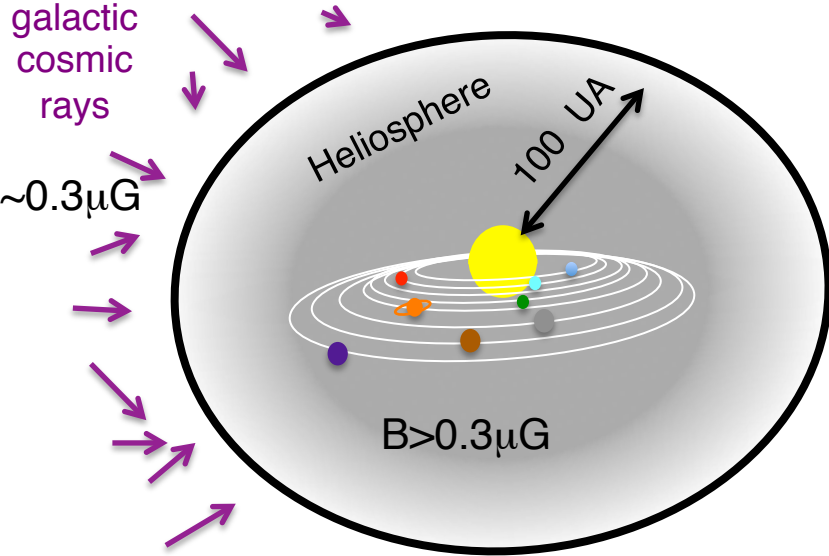
**Per una comprensione globale degli
spettri:**

→ Devono essere modellizzati gli effetti
della **modulazione solare**

→ Studio dei flussi nel tempo



Modulazione solare dei raggi cosmici



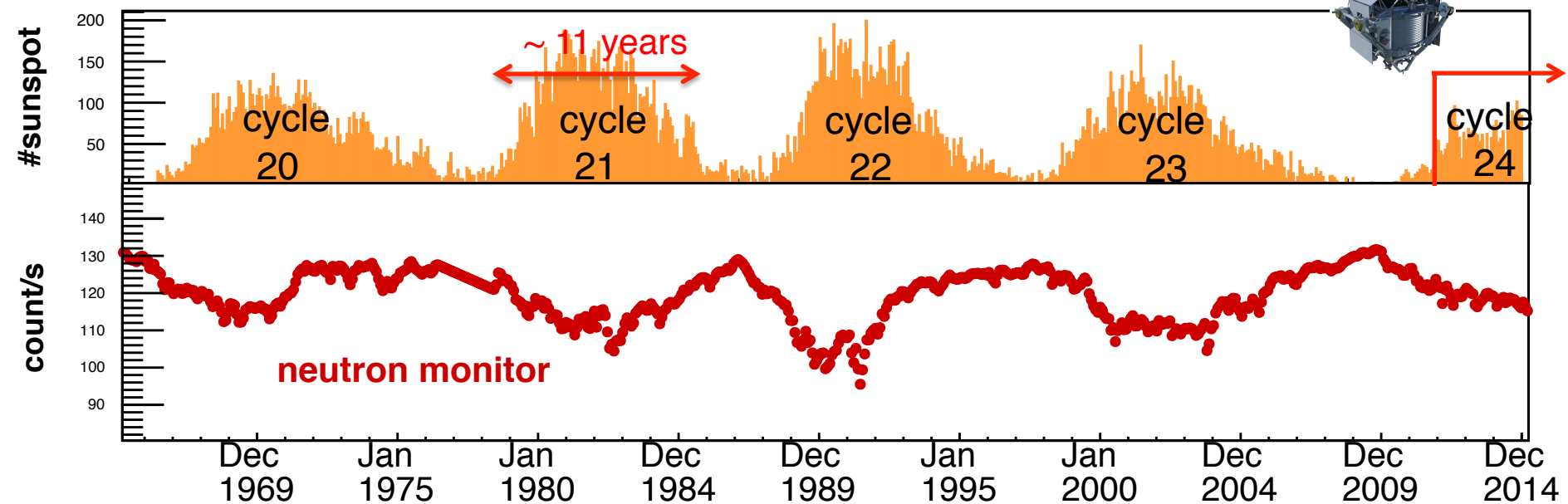
Effetti su larga scala temporale (~anni):

- variazione intensità dei RC
- dipendenza dal segno della carica:
 - al massimo: moto diffusivo
 - al minimo: deriva magnetica + moto diffusivo

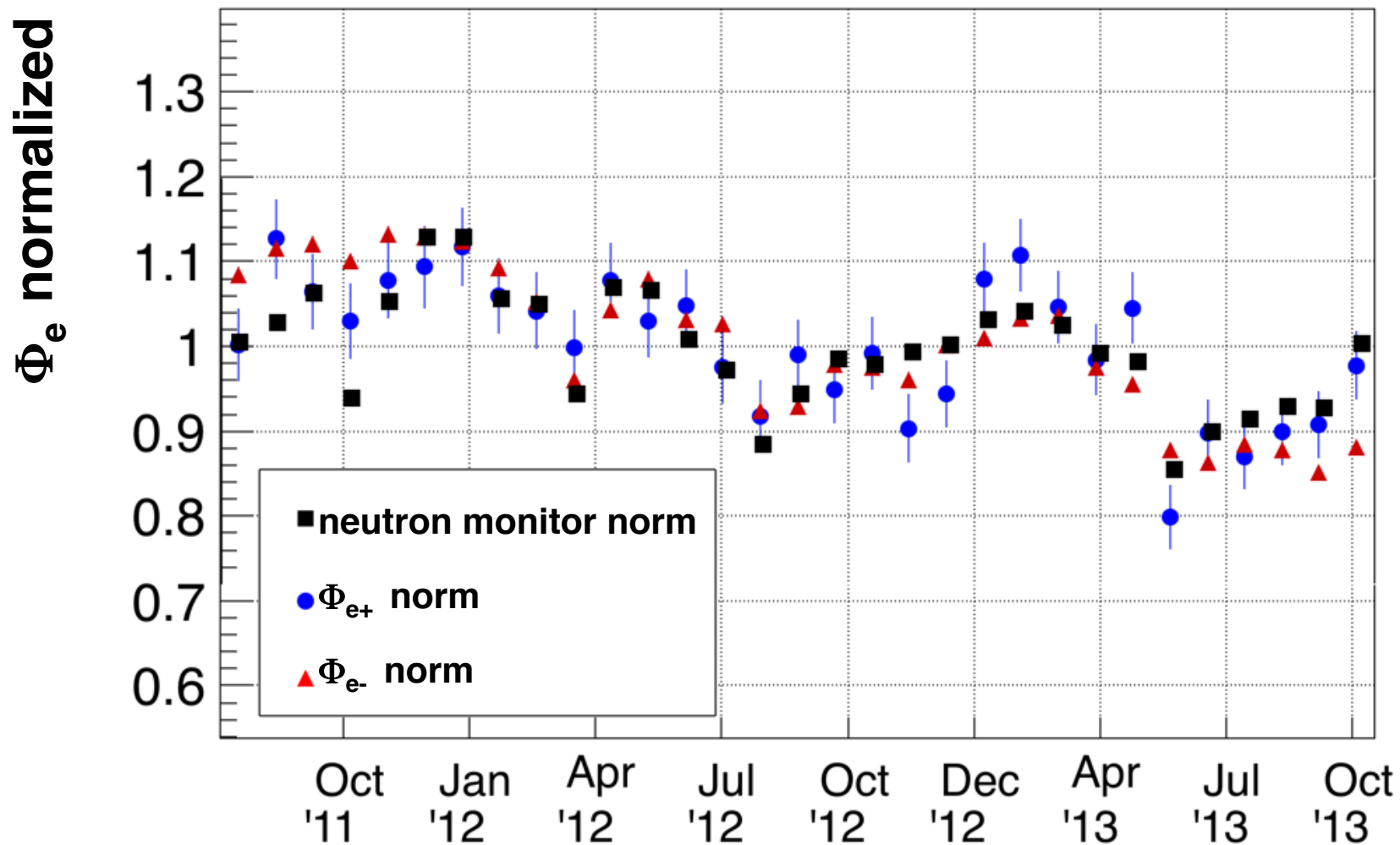
Effetti su piccola scala temporale (~giorni)

- Forbush decrease

AMS starts taking data

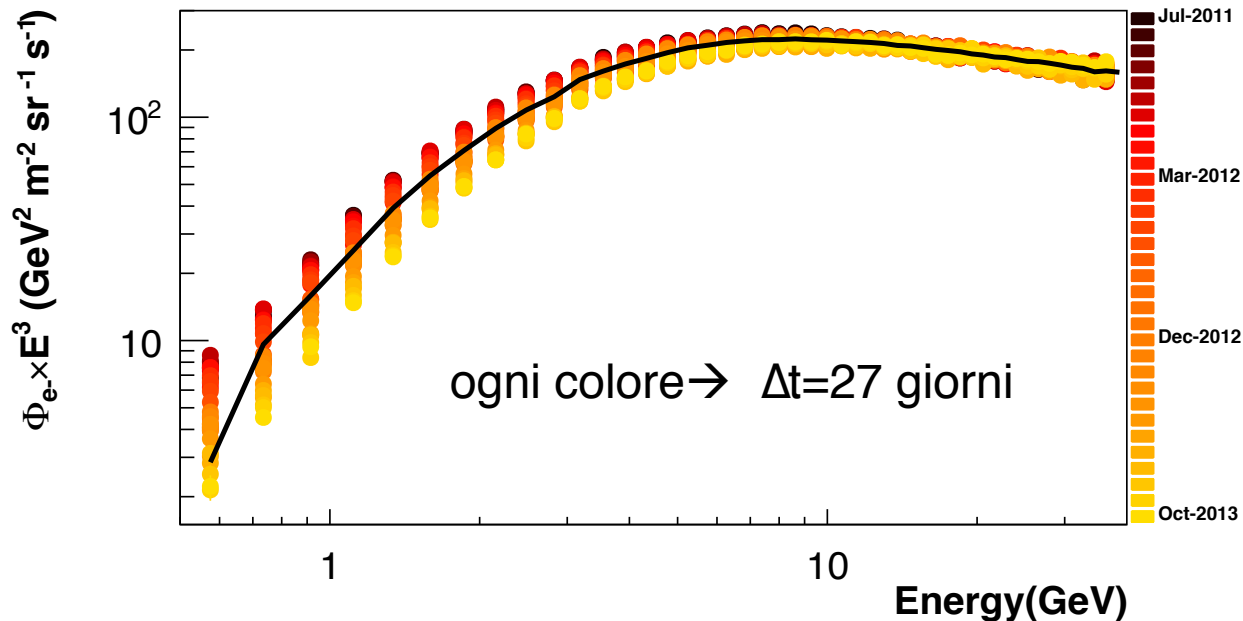


E= 4.12-4.54 (GeV)

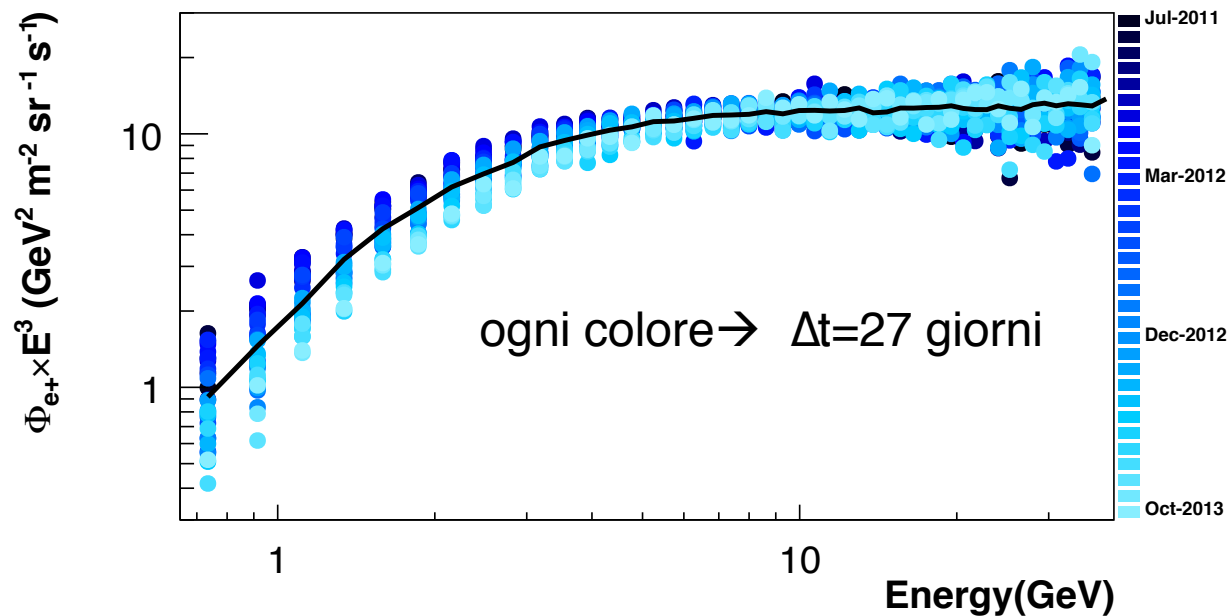


Flussi di e^\pm - modulazione solare (status report)

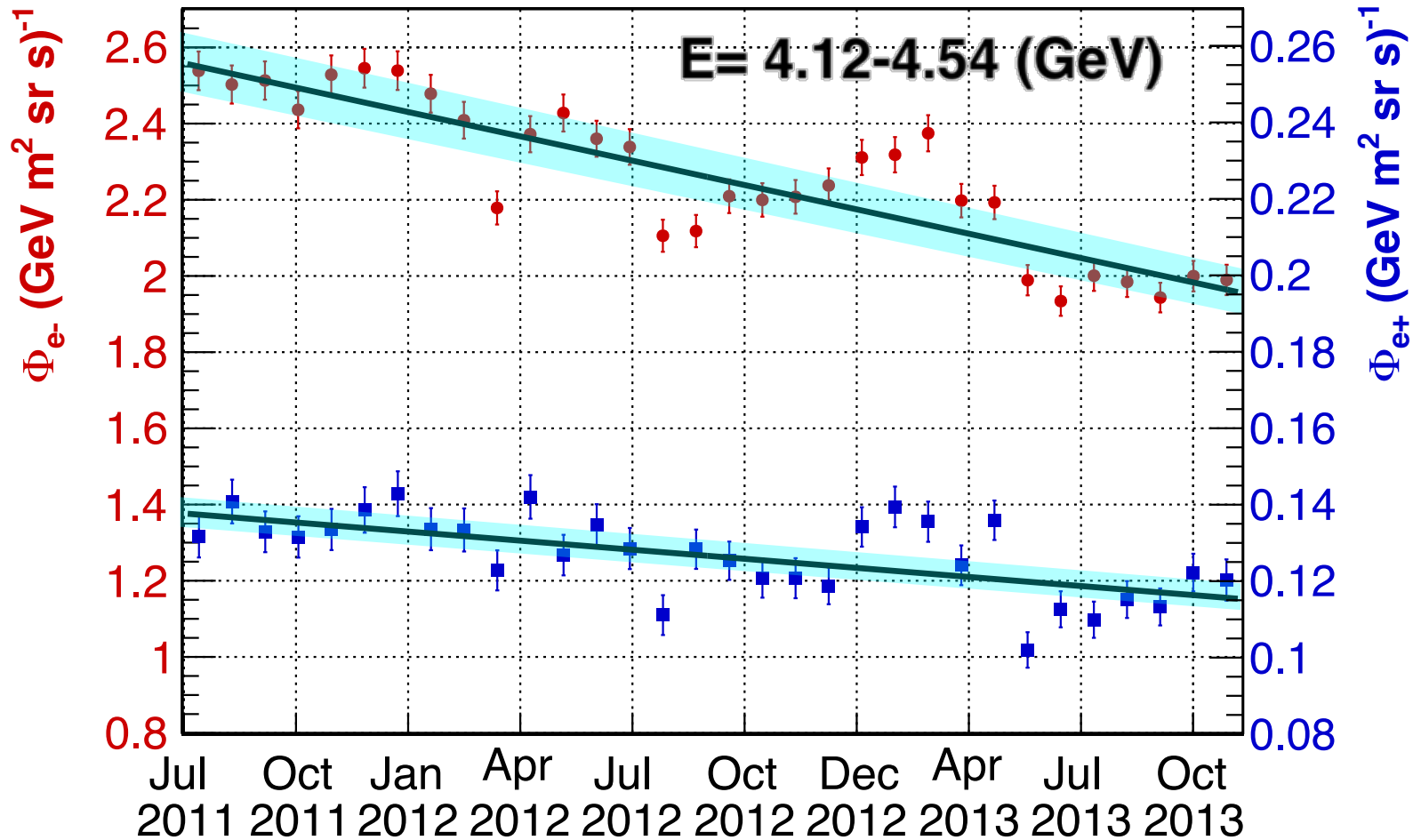
Flusso
elettroni



Flusso
positroni



Flussi di e^\pm - modulazione solare (status report)

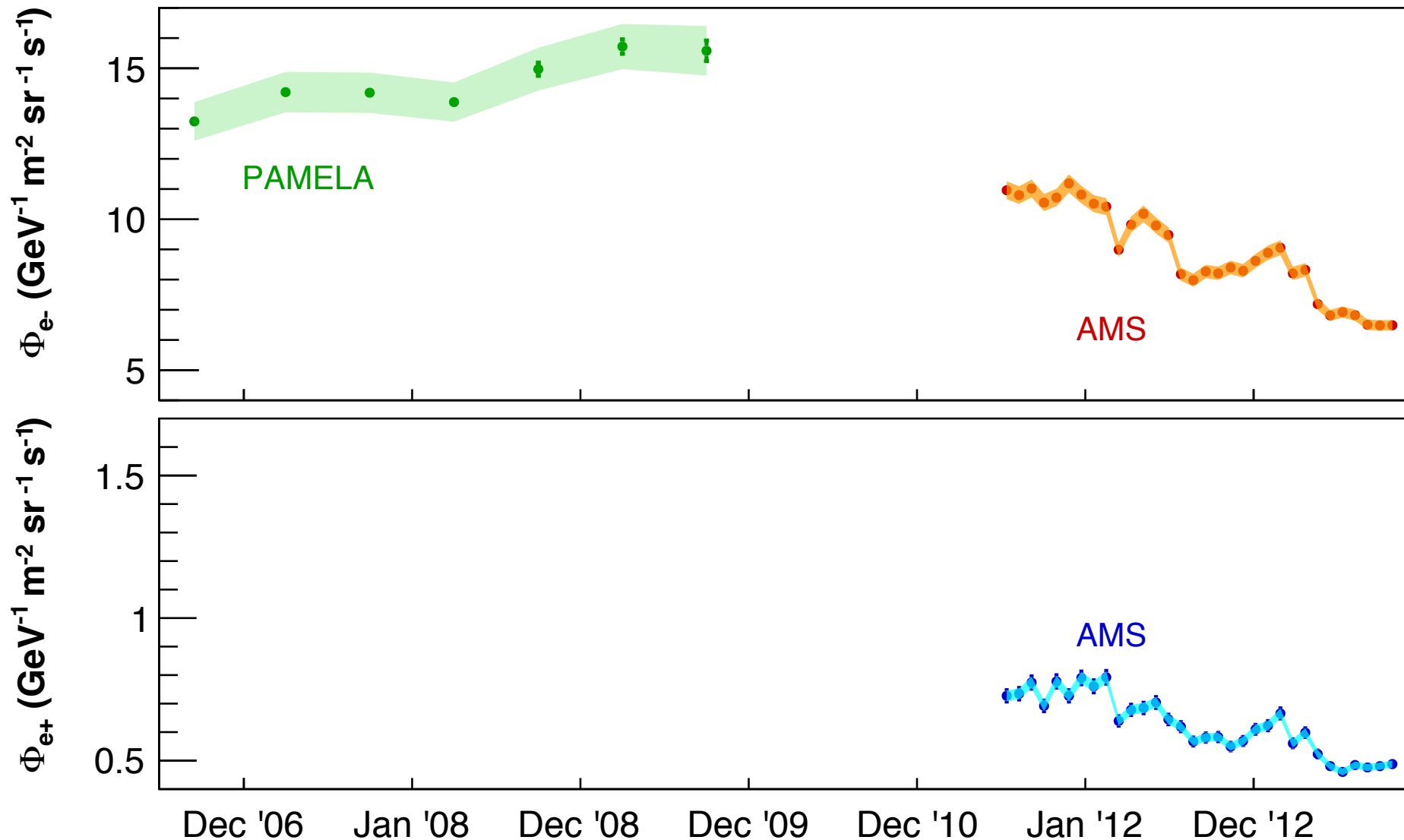


$$d\Phi_{e^-}/dt = (9.29 \pm 0.31)\%/year$$

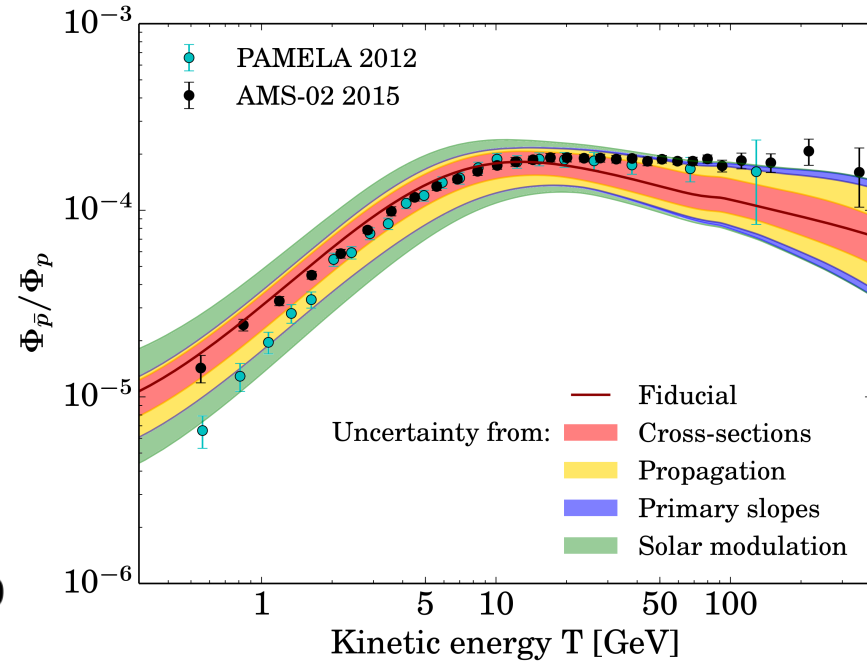
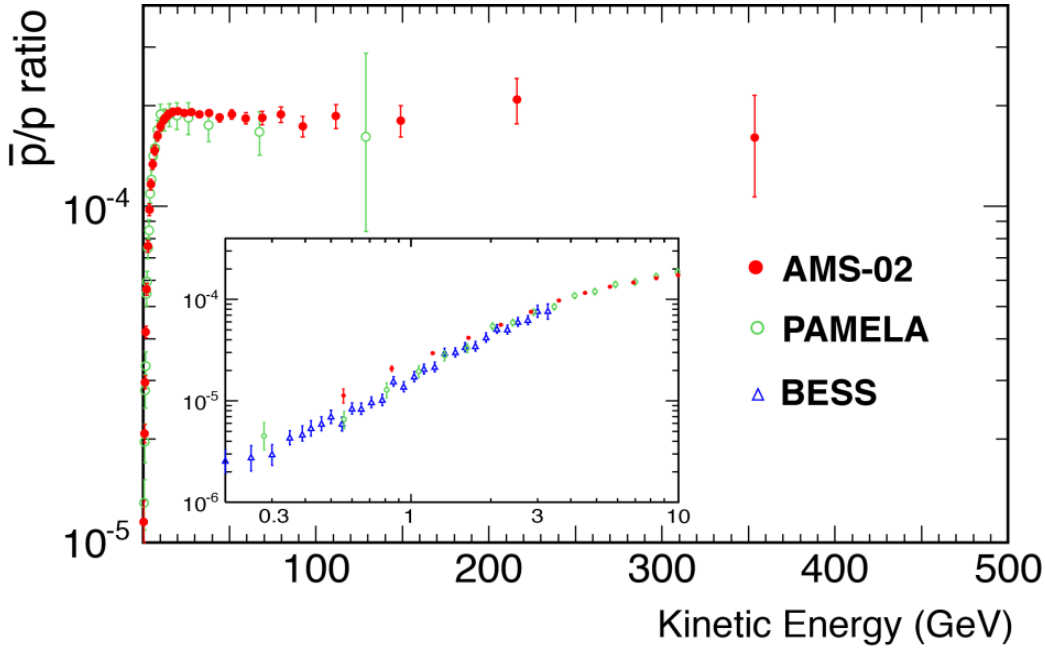
$$d\Phi_{e^+}/dt = (6.41 \pm 0.69)\%/year$$

Flussi di e^\pm - modulazione solare, prima e dopo AMS-02

$E = 2.00- 2.30 \text{ GeV}$



Antiprotoni: rapporto \bar{p}/p

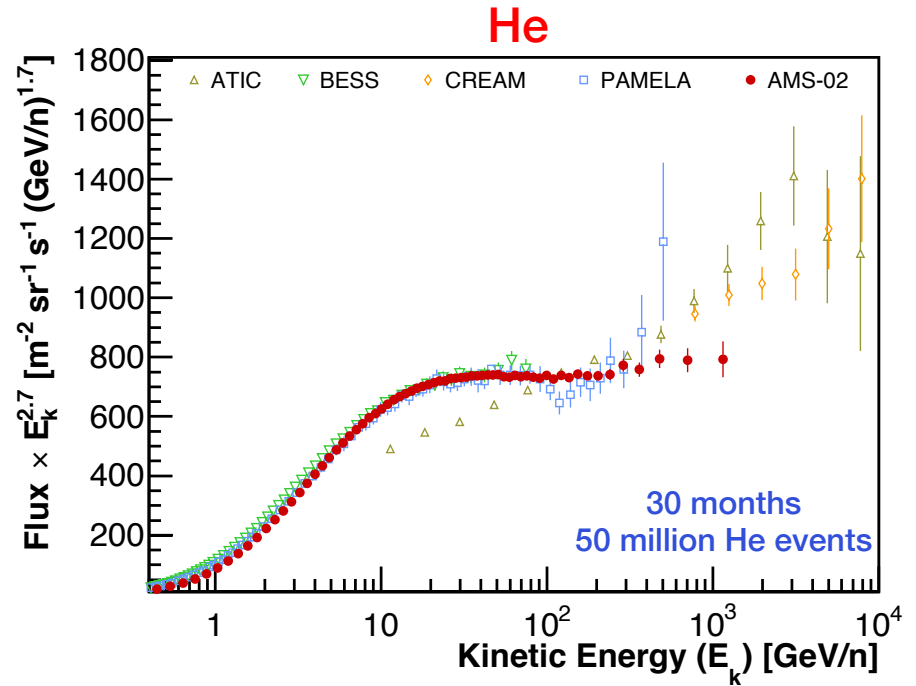
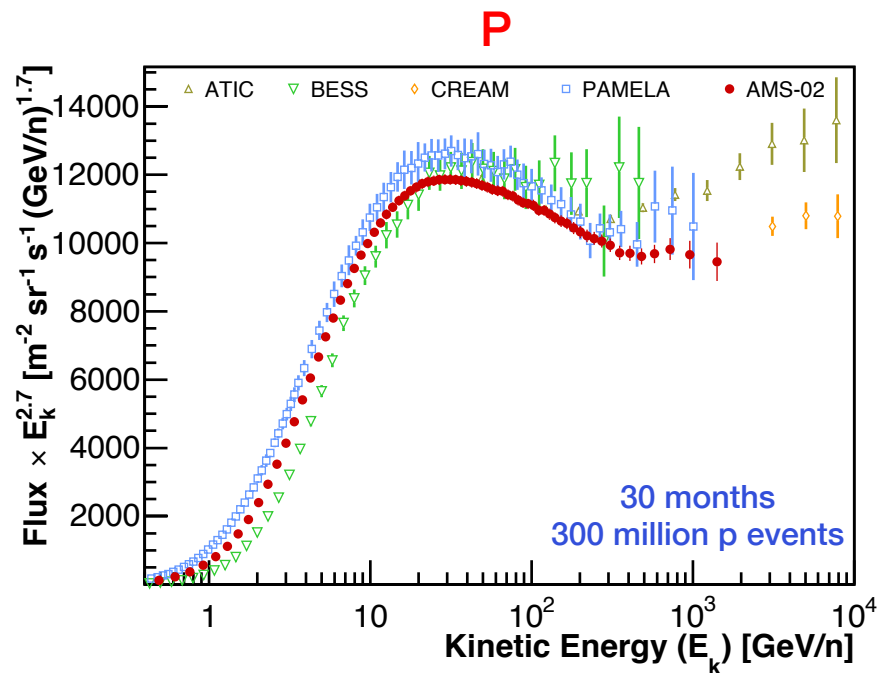


Giesen et al, 2015

Con AMS le **incertezze sui flussi attesi** da produzione secondaria nel mezzo interstellare sono diventate **maggiori di quelle sperimentali** !

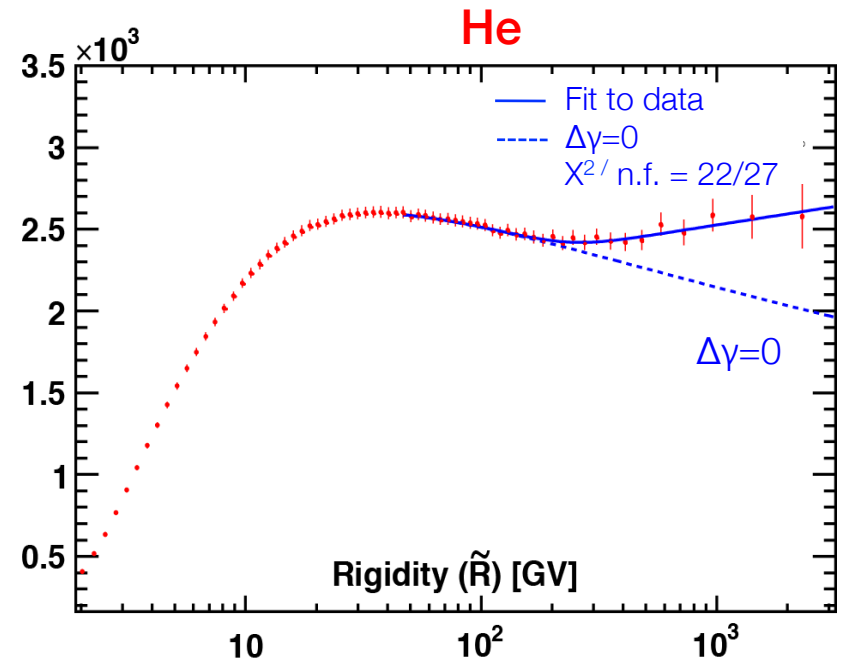
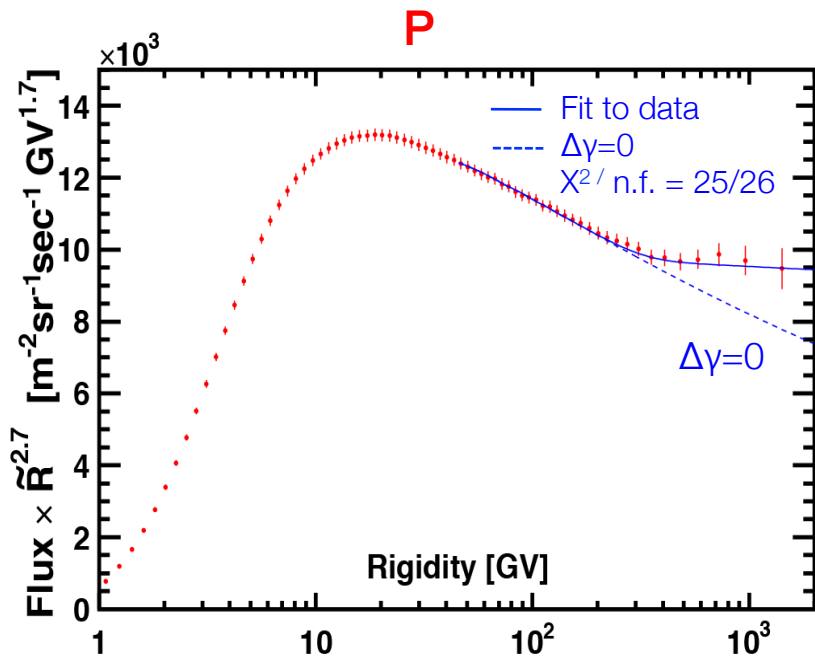
- **solar modulation**: da AMS
- **Propagation**: misure nuclei primari e secondari da AMS
- **Cross section** : misure ad acceleratori....

Flussi di protoni ed elio



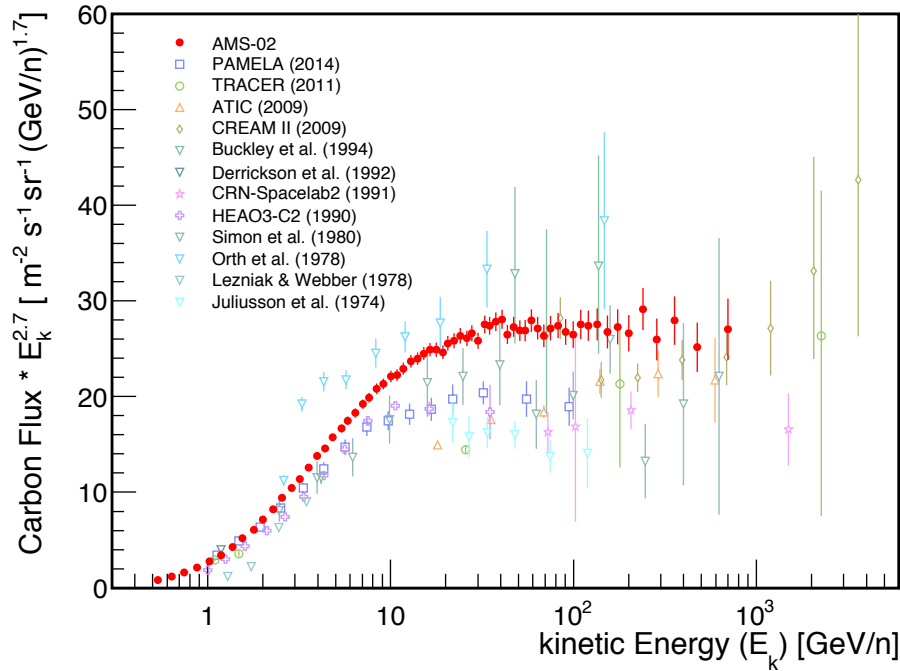
Flussi di protoni ed elio

$$\Phi = C \left(\frac{R}{45 \text{ GV}} \right)^\gamma \left[1 + \left(\frac{R}{R_0} \right)^{\Delta\gamma/s} \right]^s$$

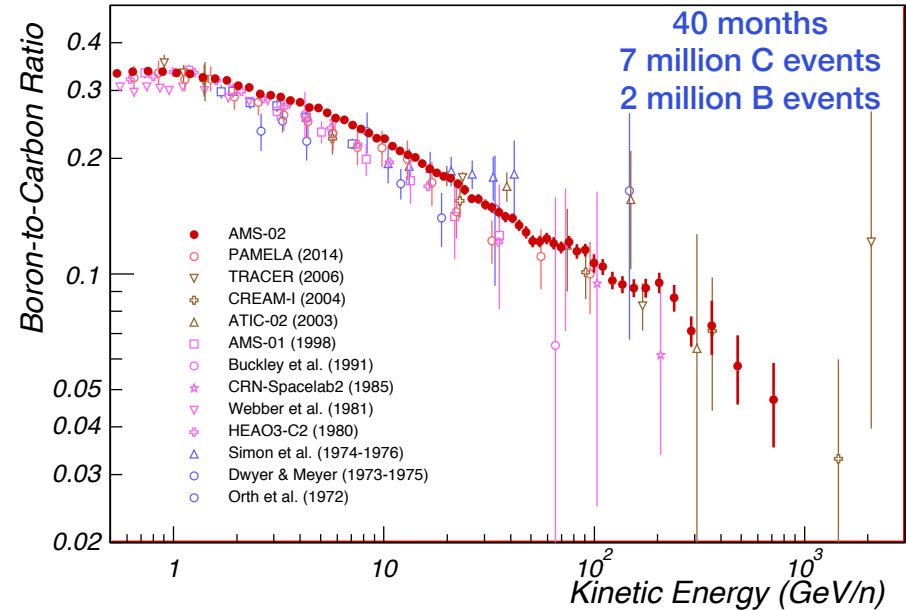


Entrambi i flussi possono essere descritti da una **legge di potenza** con un break a **$R \sim 300 \text{ GV}$** .

C

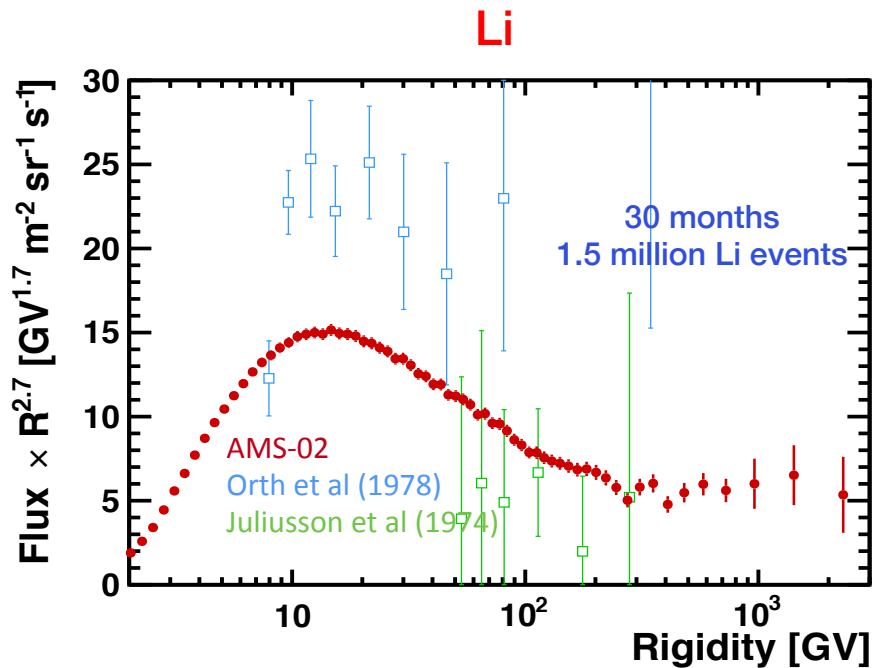


B/C



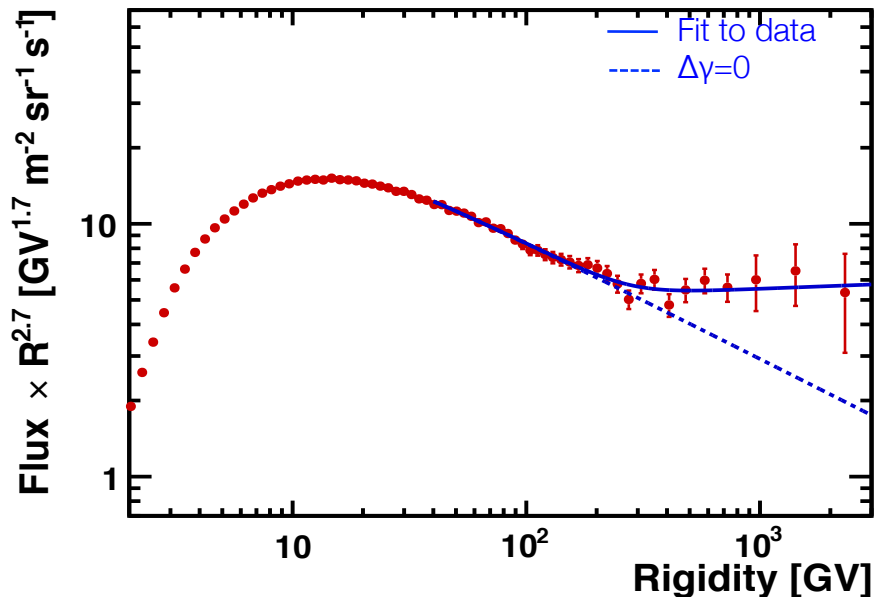
Non sono state osservate particolari strutture sia nel flusso di C che nel rapporto B/C.

+ statistica \rightarrow + informazioni ad alte energie



può essere descritto con una
broken power law

$$\Phi = C \left(\frac{R}{45 \text{ GV}} \right)^\gamma \left[1 + \left(\frac{R}{R_0} \right)^{\Delta\gamma/s} \right]^s$$



grande **numero** di eventi raccolti
+
grandi capacità di **identificazione
della carica**

→ Flusso di Litio misurato da AMS -02
ha una *precisione senza precedenti*

Conclusioni

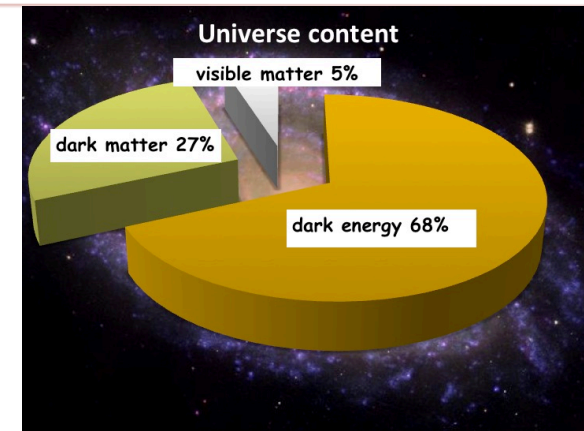
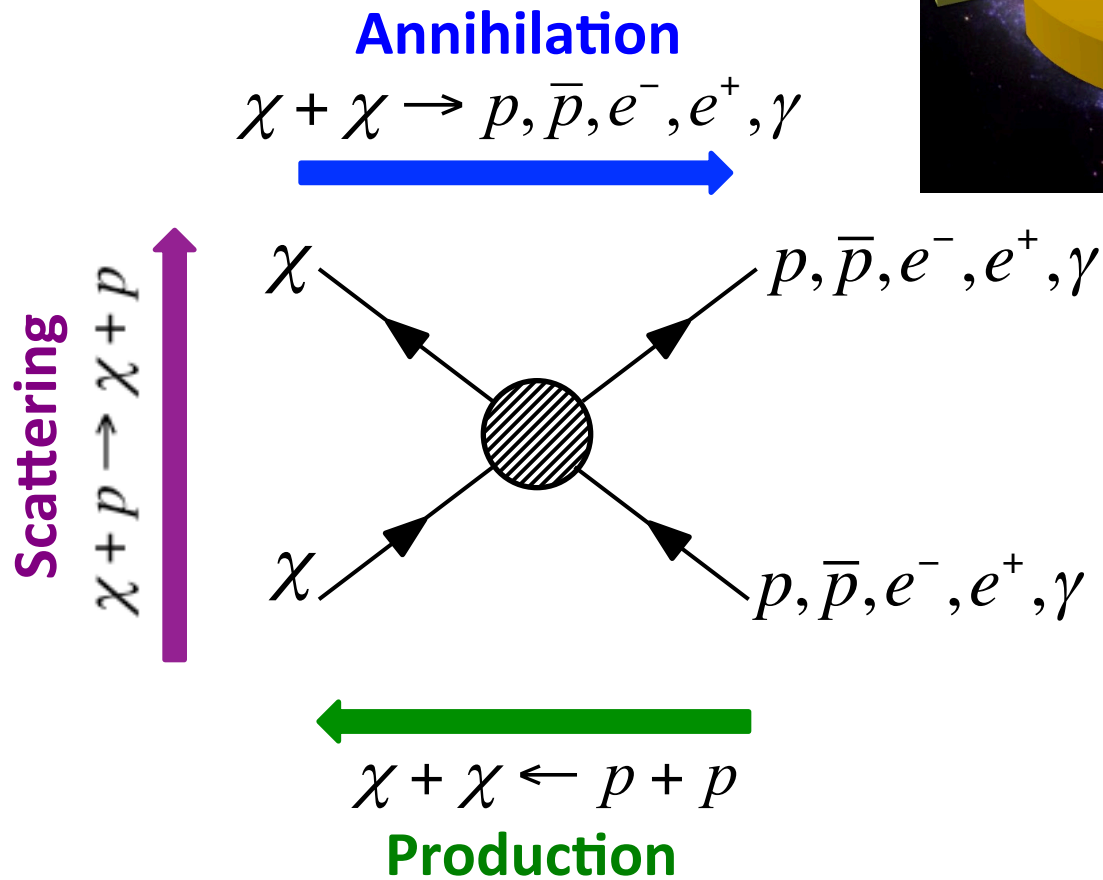
- ▶ AMS continuerà la sua missione fino a quando la ISS sarà operativa
→ osservatorio per Raggi Cosmici per il prossimo decennio
- ▶ La precisione/intervallo energetico delle misure di AMS di positroni e anti-protoni hanno le potenzialità di far luce sulla natura della materia oscura e costituiscono una sfida per i modelli teorici:
 - ▶ nuclei primari nei RC: origine e accelerazione
 - ▶ nuclei secondari nei RC: propagazione e proprietà del ISM
 - ▶ Misure dei flussi nel tempo: effetto della modulazione solare
- ▶ Nei prossimi anni:
+ statistica ad alte energie → + canali → + informazioni!

Grazie per l'attenzione
e STAY TUNED !!

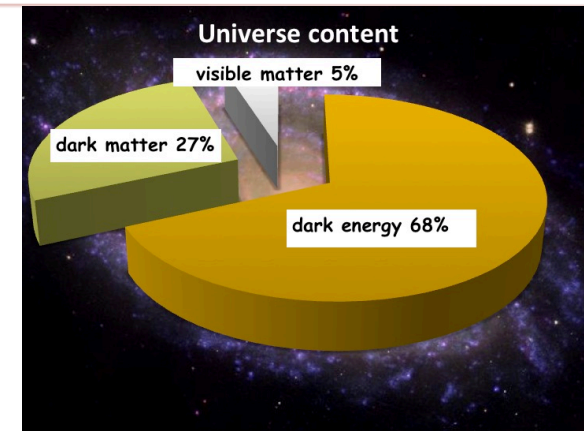
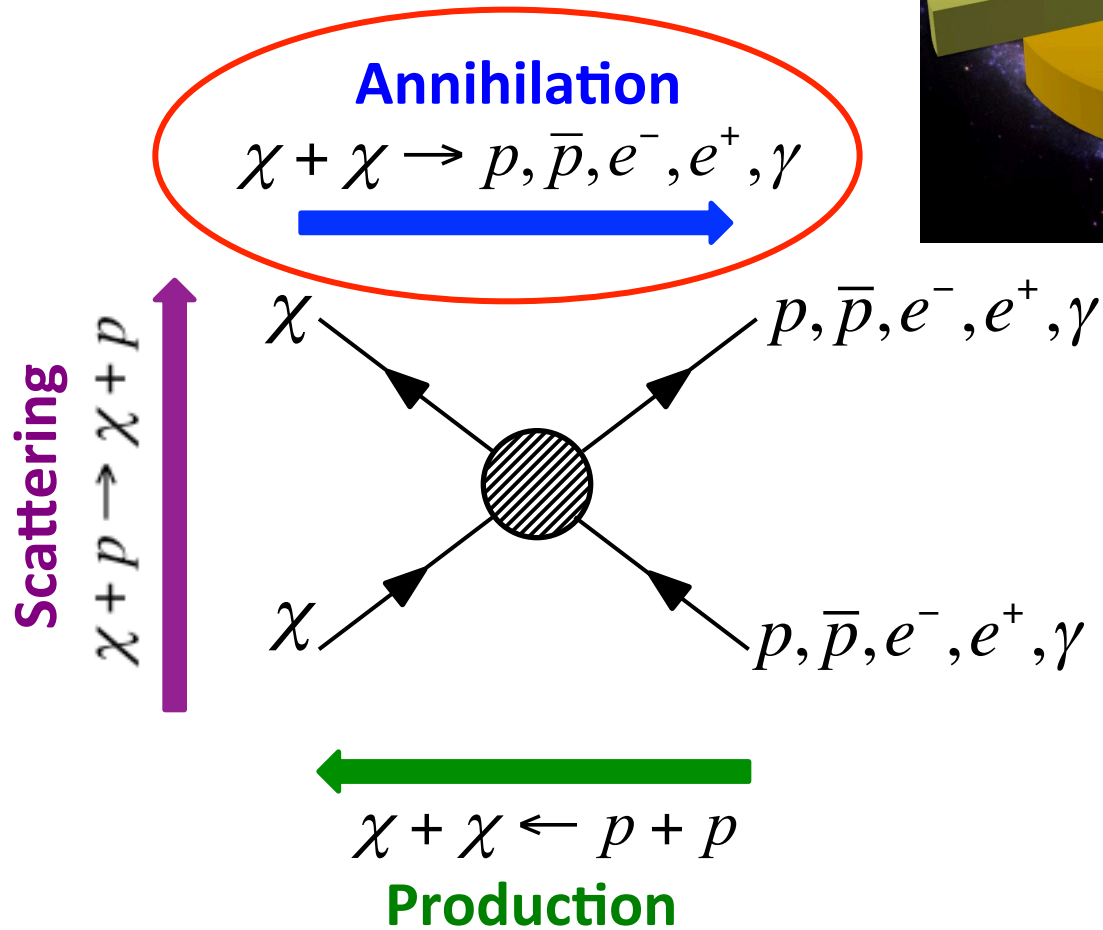


4. back up

The Physics: The quest for Dark Matter



The Physics: The quest for Dark Matter

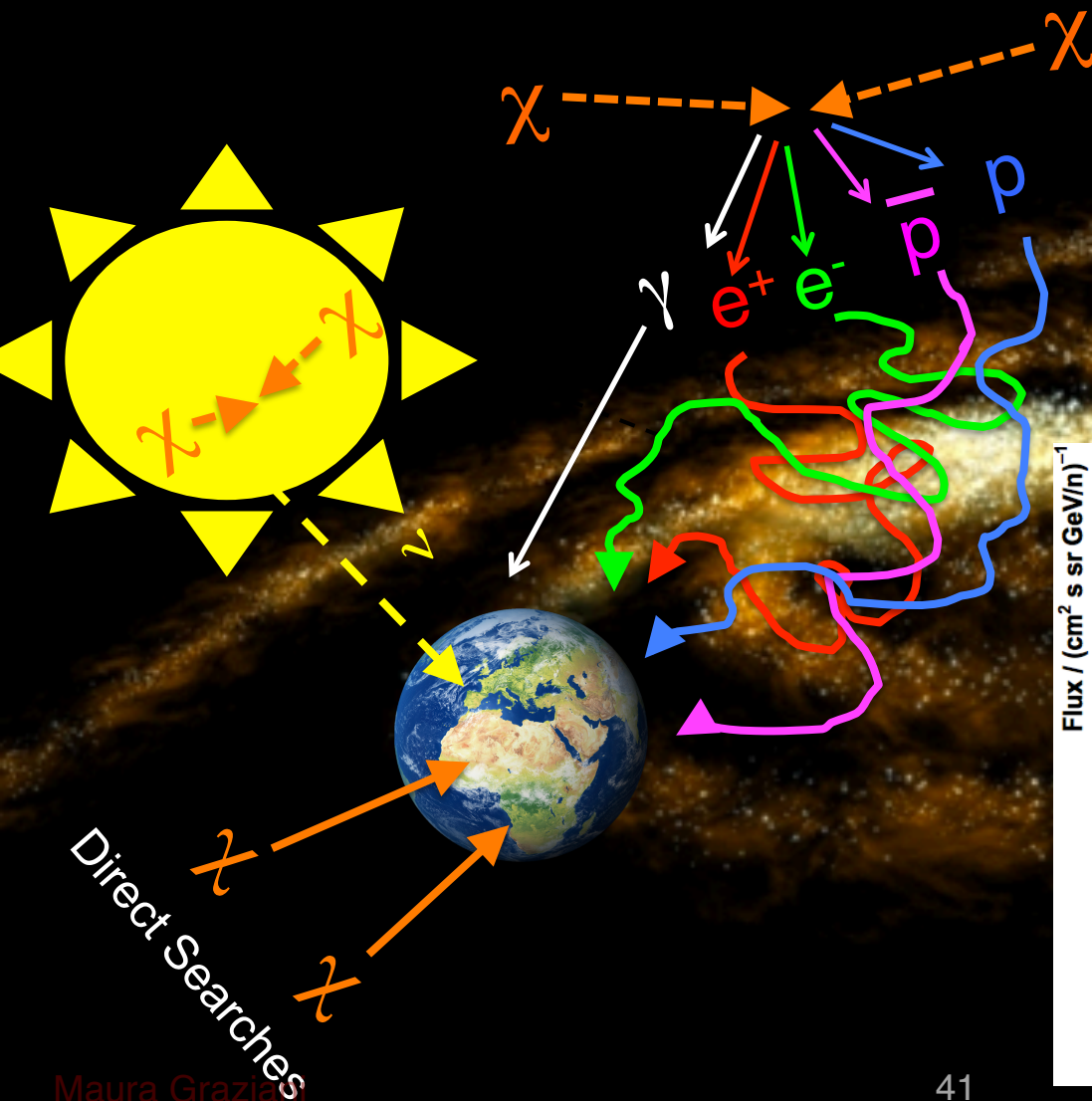


The Physics: Anti-Matter & Dark Matter

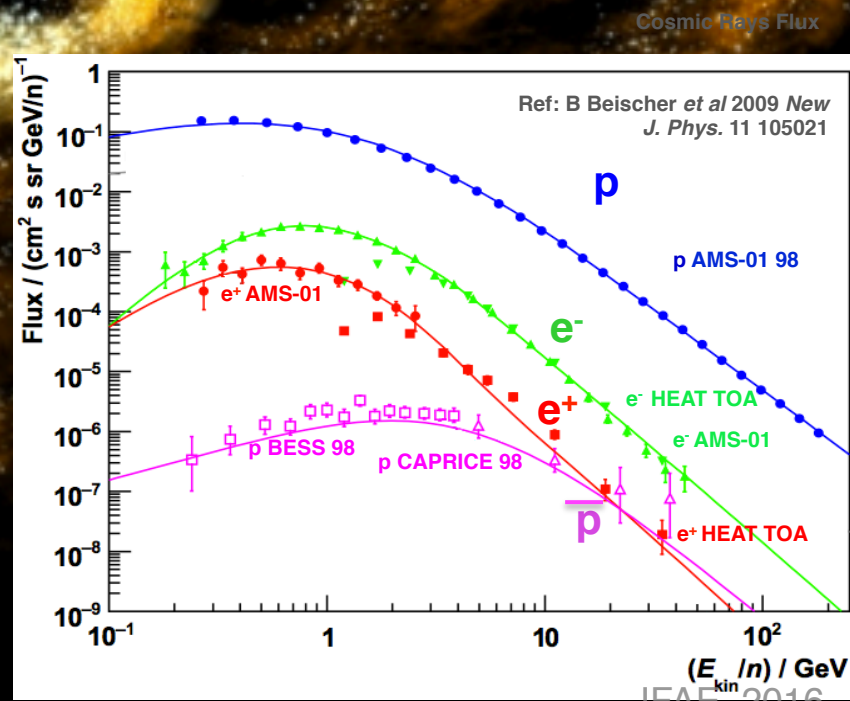
WIMP as the responsible of Dark Matter (?)

Direct Searches

Indirect DM search \rightarrow search for (RARE IN CR) products from their annihilation....



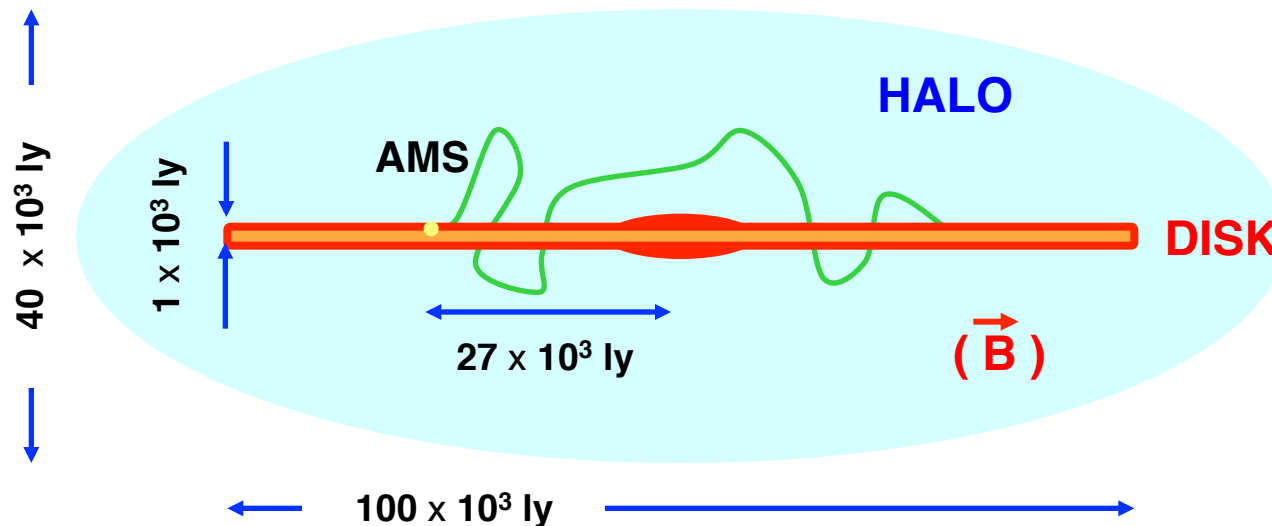
But you should know what you expect in the ISM !!



The Physics: Knowledge of cosmic background

**Precise measurement of the energy spectra of B, C ...
provides information on Cosmic Ray Interactions and Propagation**

Interactions with the Interstellar Medium:
 $C + (p, He) \rightarrow B + \dots$



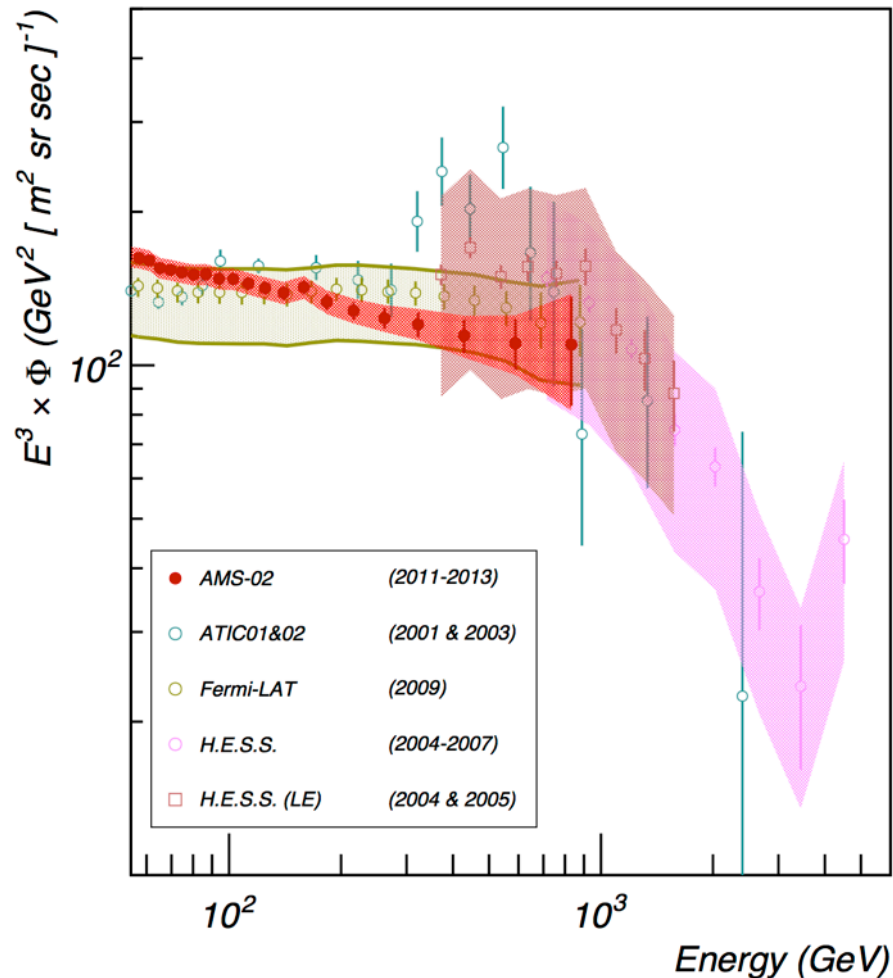
Diffusion
Convection
Reacceleration

Interactions with the
Interstellar Medium
(ISM):

- Fragmentation
- Secondaries
- Energy loss

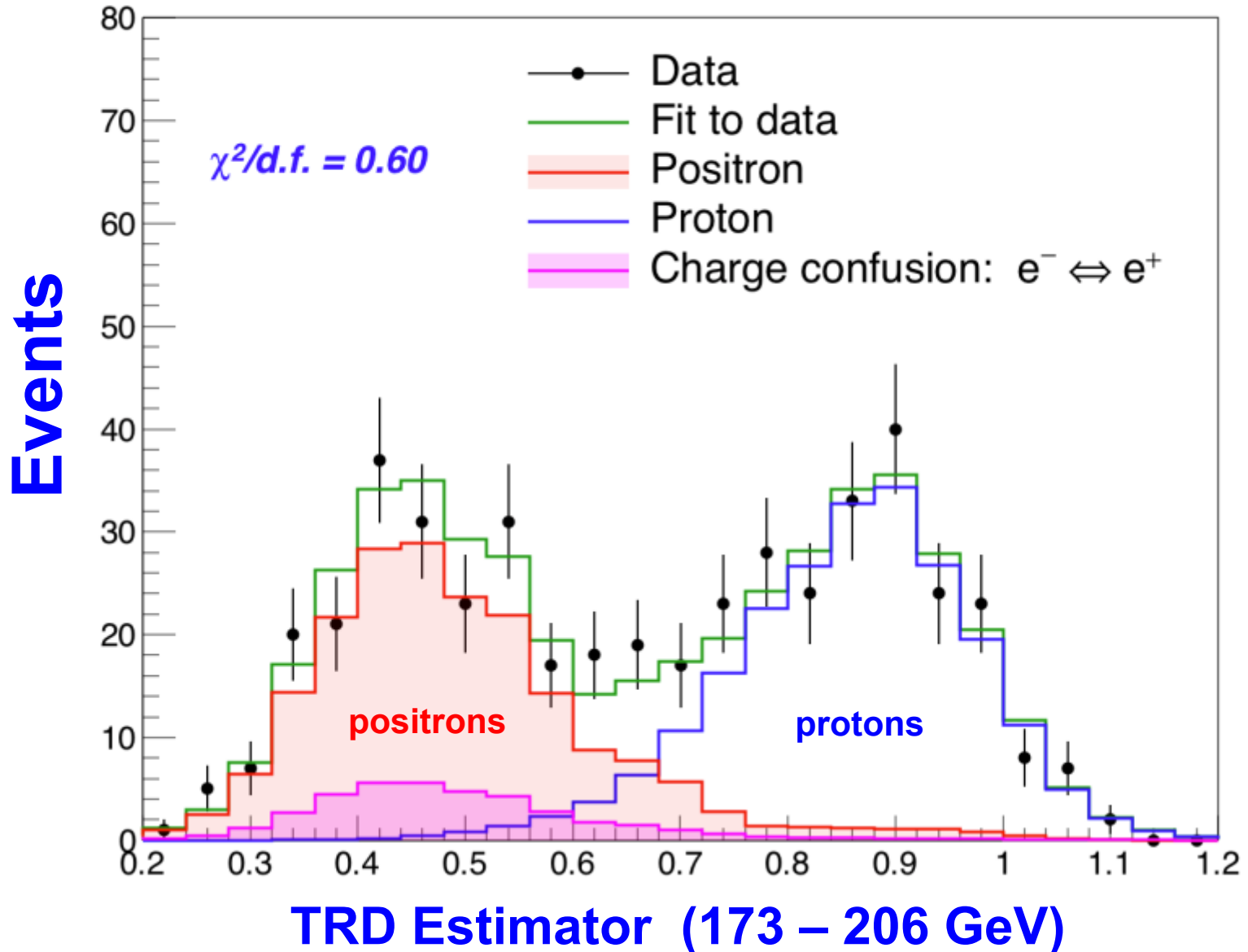
$e^+ + e^-$ flux measurements with AMS

..Taking into account also the knowledge of the energy scale....

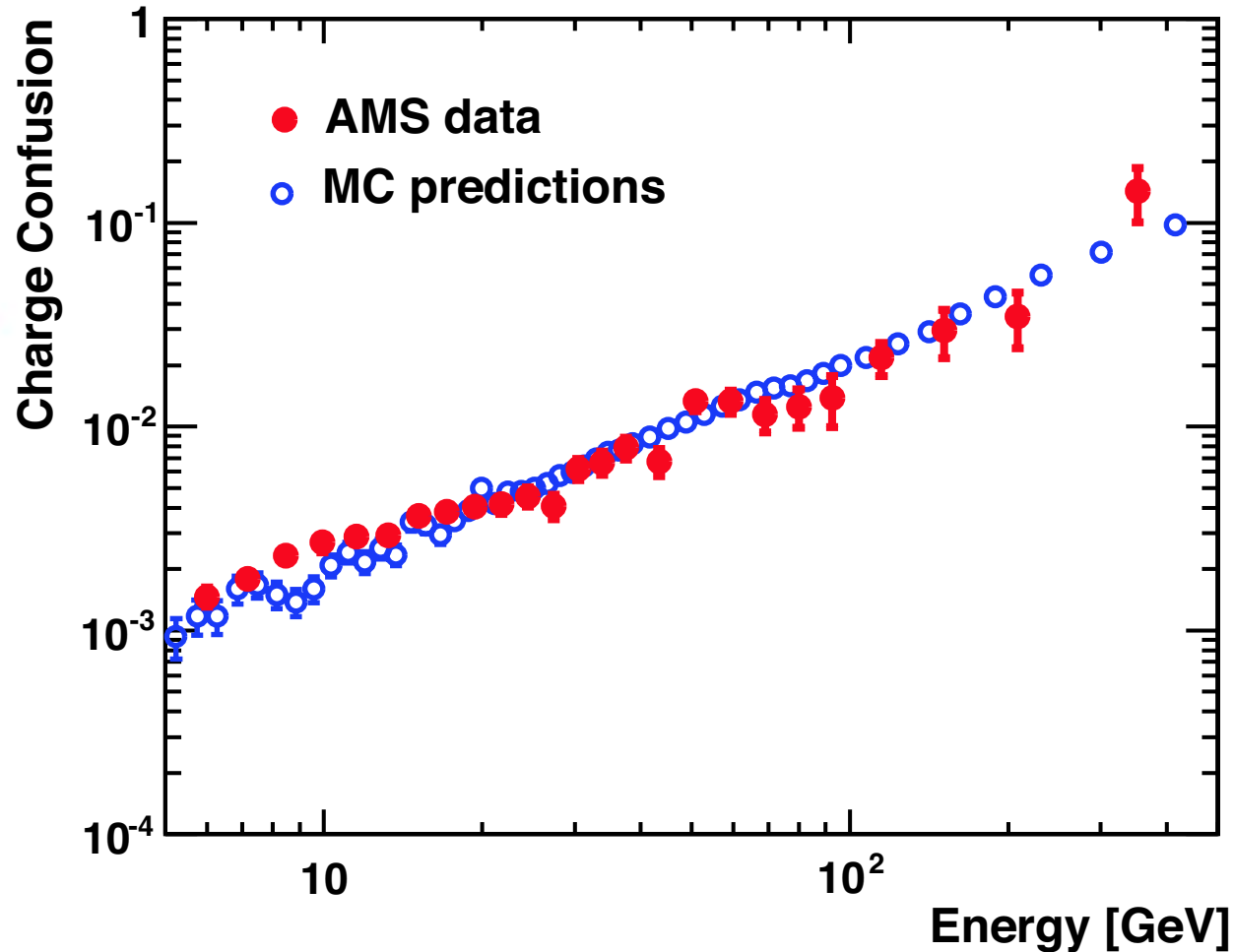
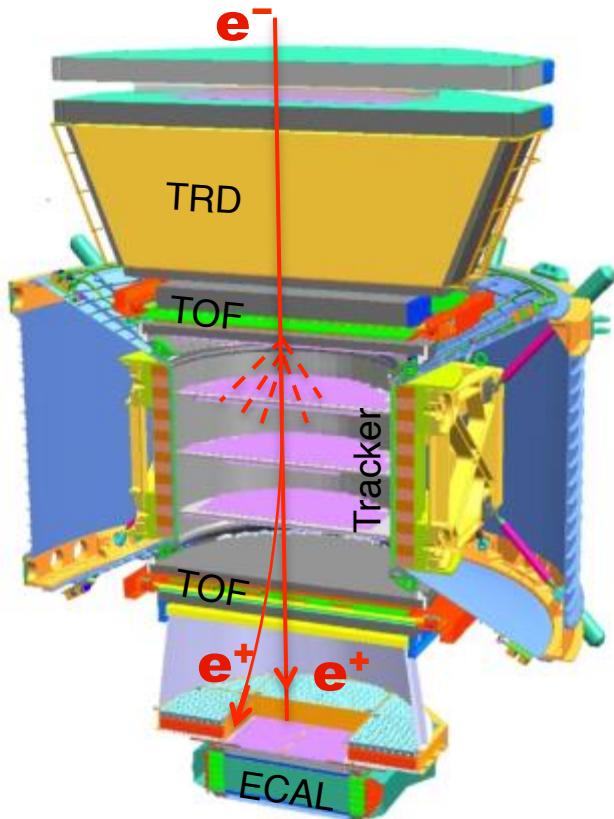


Example of Positron Selection:

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

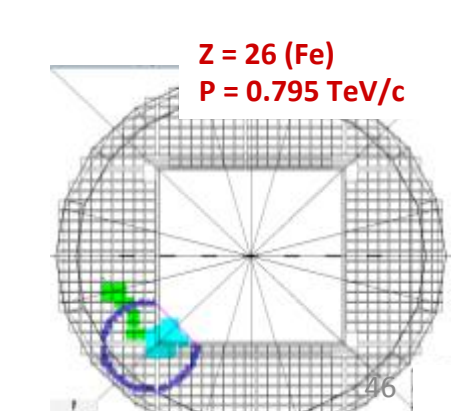
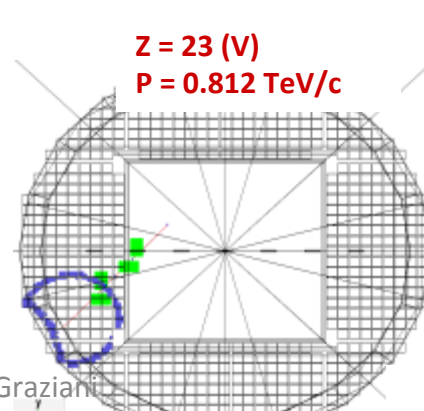
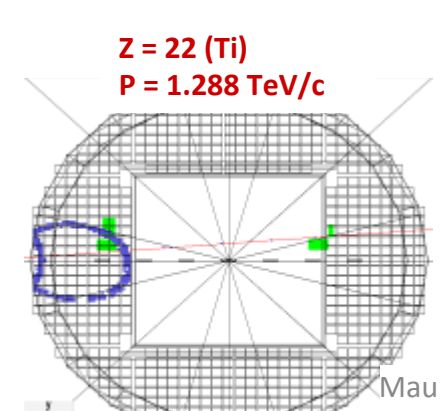
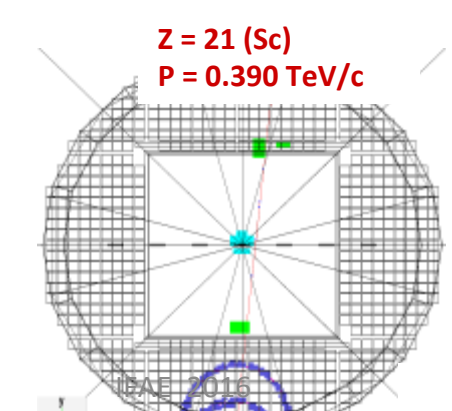
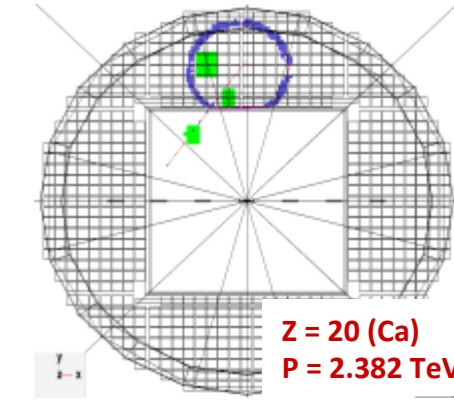
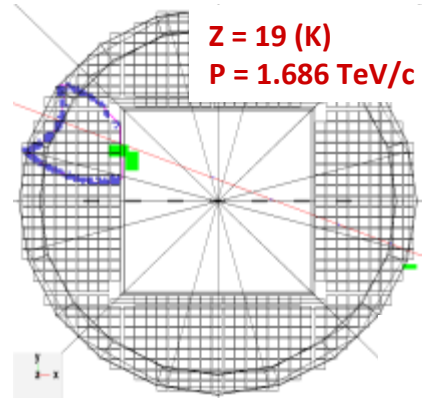
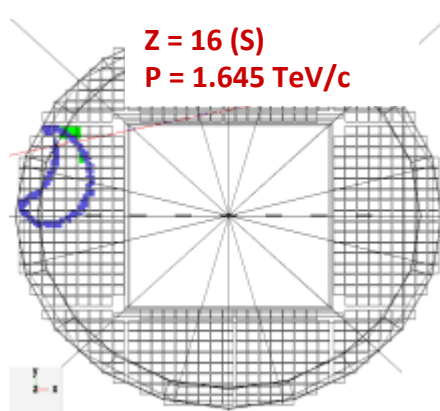
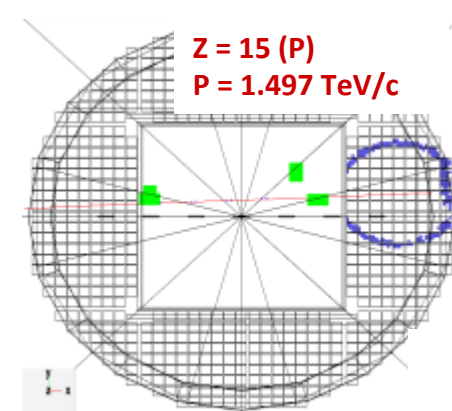
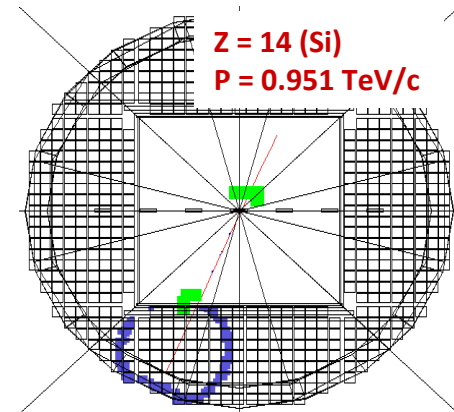
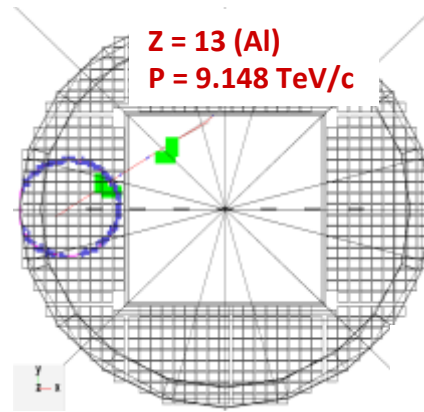
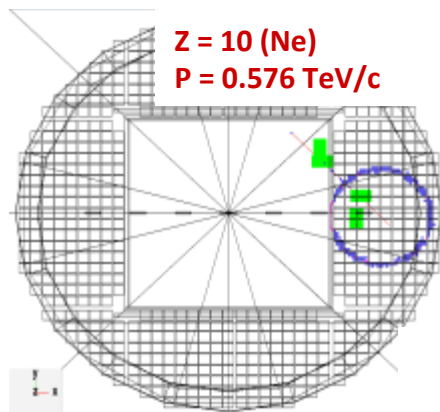
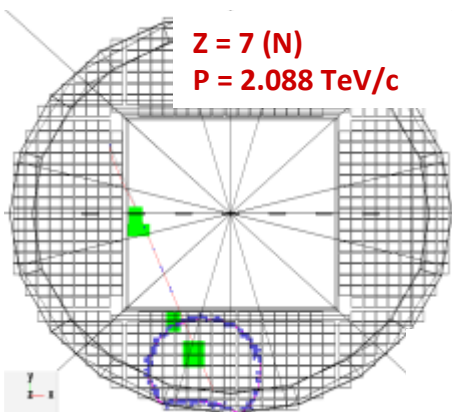


Systematic error on the positron fraction: 5. Charge confusion



Two sources: 1) large angle scattering and 2) production of secondary tracks along the path of the primary track. Both are well reproduced by MC. Systematic errors correspond to variations of these effects within their statistical limits and comparing the results with the Monte Carlo simulation

RICH performance on ISS

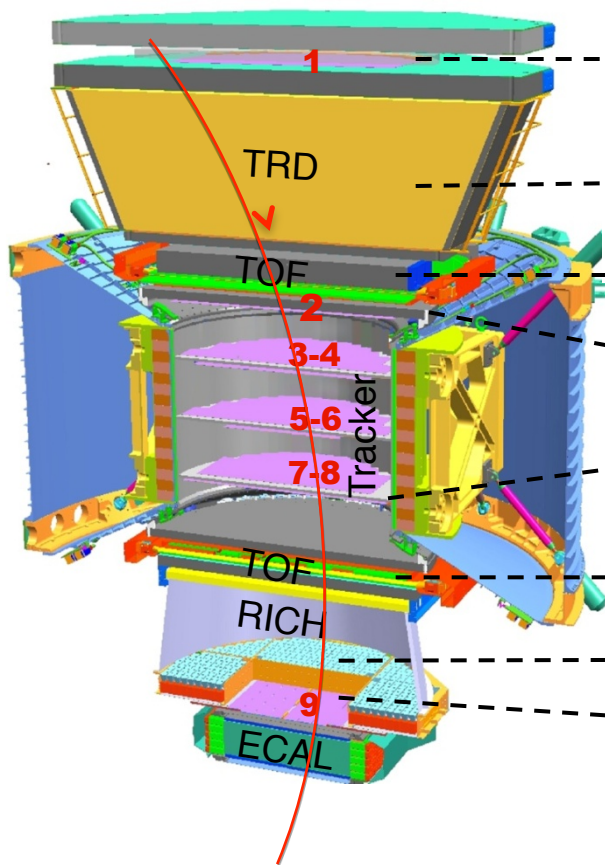




Particle Charge Measurement

Multiple Independent Measurements of $|Z|$

Carbon ($Z=6$)
 ΔZ (cu)



1. Tracker Plane 1

0.30

2. TRD

0.33

3. Upper TOF (1 counter)

0.16

4. Tracker Planes 2-8

0.12

5. Lower TOF (1 counter)

0.16

6. RICH

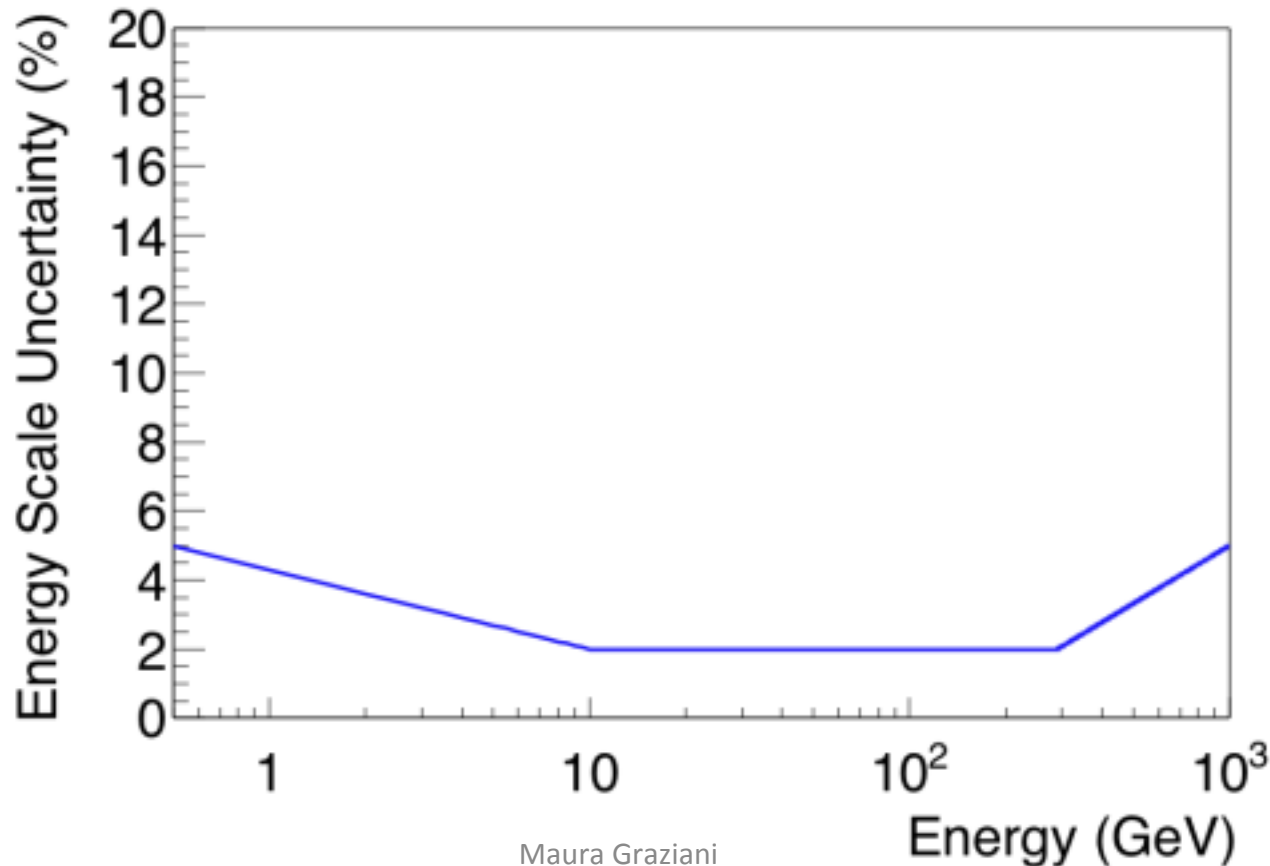
0.32

7. Tracker Plane 9

0.30

Absolute Energy Scale for e^\pm (at the top of AMS)

Verified using MIPs and E/p; compared to the test beam.
In the test beam range (10-290 GeV) the uncertainty is 2%.
It increases to 5% at 0.5 GeV and 1 TeV.

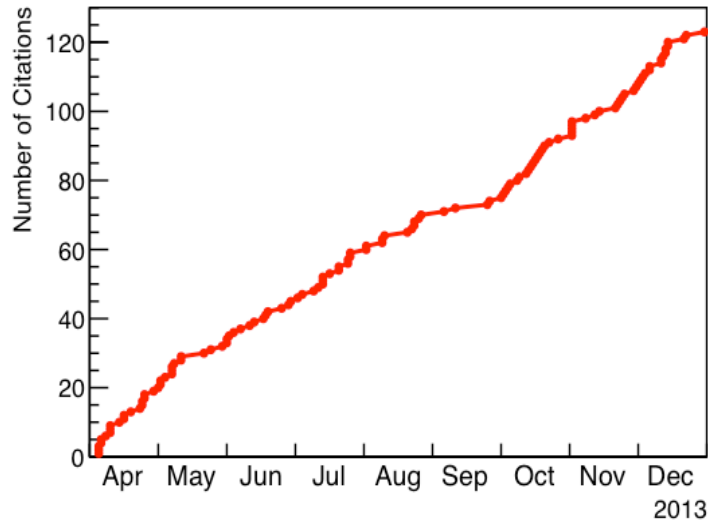
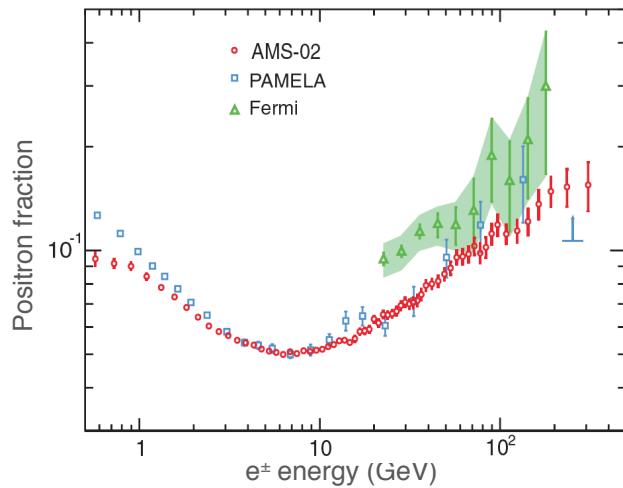


1. “First Result from the Alpha Magnetic Spectrometer on the International Space Station: Precision Measurement of the Positron Fraction in Primary Cosmic Rays of 0.5–350 GeV ” (*M. Aguilar et al.*) Physical Review Letters **PRL 110, 141102 (2013)**
2. “High Statistics Measurement of the Positron Fraction in Primary Cosmic Rays of 0.5–500 GeV with the Alpha Magnetic Spectrometer on the International Space Station” (*L. Accardo et al.*). Physical Review Letters **PRL 113, 121101 (2014)**
3. “Electron and Positron Fluxes in Primary Cosmic Rays Measured with the Alpha Magnetic Spectrometer on the International Space Station” (*M. Aguilar et al.*). Physical Review Letters **PRL 113, 121102 (2014)**
4. “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”, (*M. Aguilar et al.*). Phys. Rev. Lett. **PRL 113, 221102 (2014)**

1. “First Result from the Alpha Magnetic Spectrometer on the International Space Station: Precision Measurement of the Positron Fraction in Primary Cosmic Rays of 0.5–350 GeV ” (*M. Aguilar et al.*) Physical Review Letters **PRL 110, 141102 (2013)**
2. “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” (*L. Accardo et al.*). Physical Review Letters **PRL 113, 121101 (2014)**
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First Result from the AMS on the ISS

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



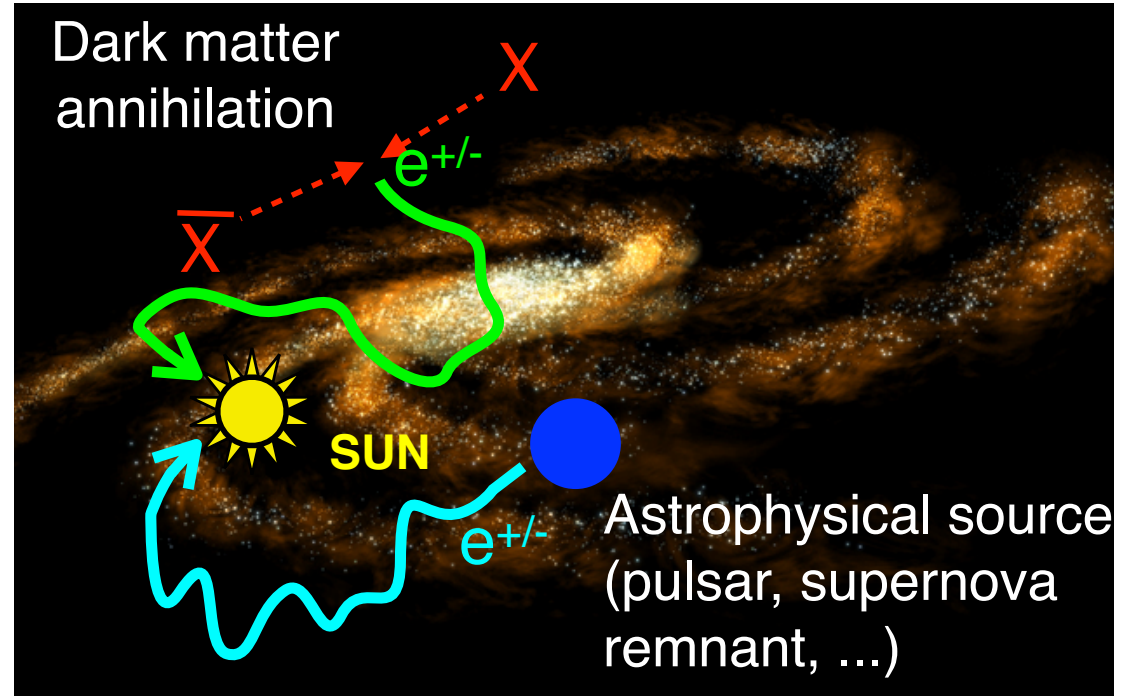
The cover of the journal *PHYSICAL REVIEW LETTERS*, Volume 110, Number 14, published by the American Physical Society. The cover features a green and white geometric design. The title "PHYSICAL REVIEW LETTERS" is prominently displayed in a serif font. Below the title, it states "Articles published week ending 5 APRIL 2013". A diagram of the AMS detector is shown, illustrating the "MAGNET" and "Tracker" components. The diagram includes a coordinate system with x, y, and z axes. The detector is shown in a cross-sectional view, with the magnet and tracker components clearly labeled. The diagram also shows the path of a particle through the detector, with numbered points (1-9) indicating the detector's layers. The American Physical Society logo and the APS physics logo are also visible on the cover.

The importance of electrons in CR

First results of AMS: e^\pm measurements

Why the electrons are so important?

Important physics information carried:



- 1. Information** about the **origin** and the **propagation of cosmic rays** complementary to the hadronic component ($m_e \ll m_p \rightarrow$ very different energy losses in the interaction with ISM);
- 2. possible indirect detection of dark matter.**

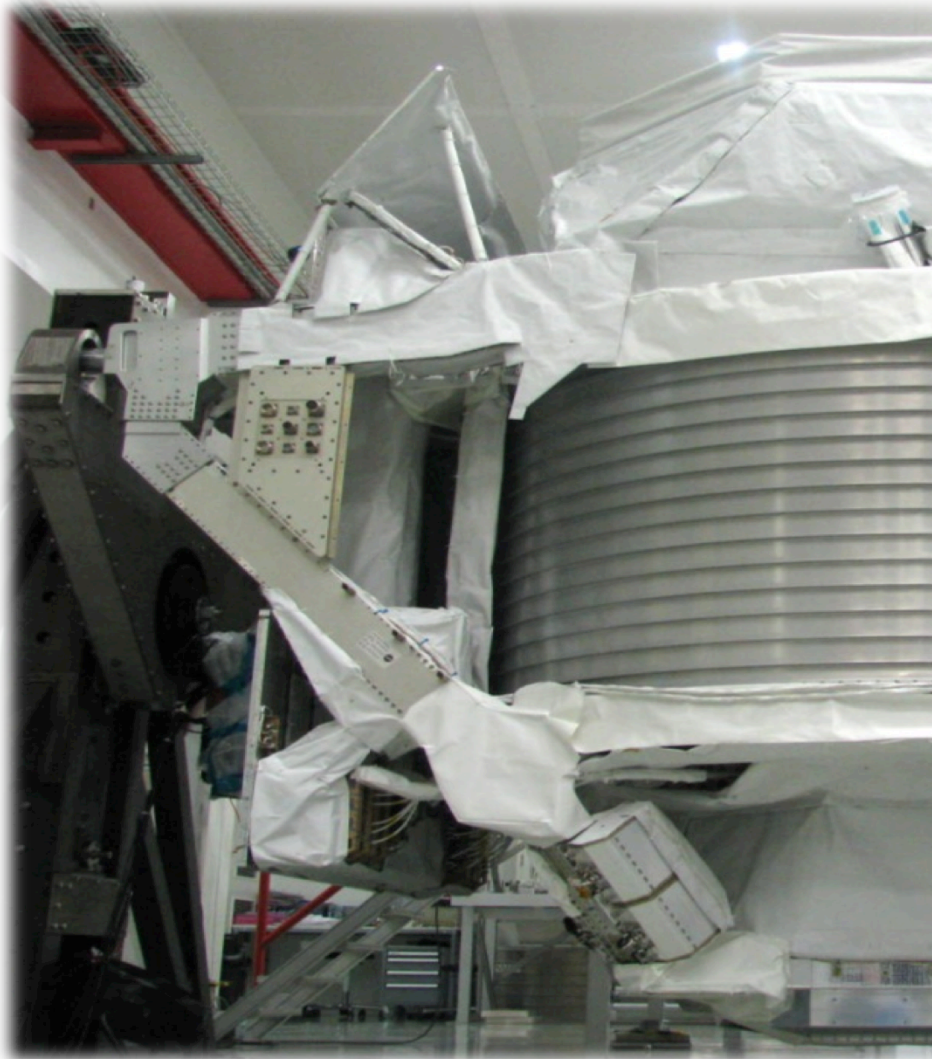
1. Physics of AMS

2. AMS-02: Detector & Operations

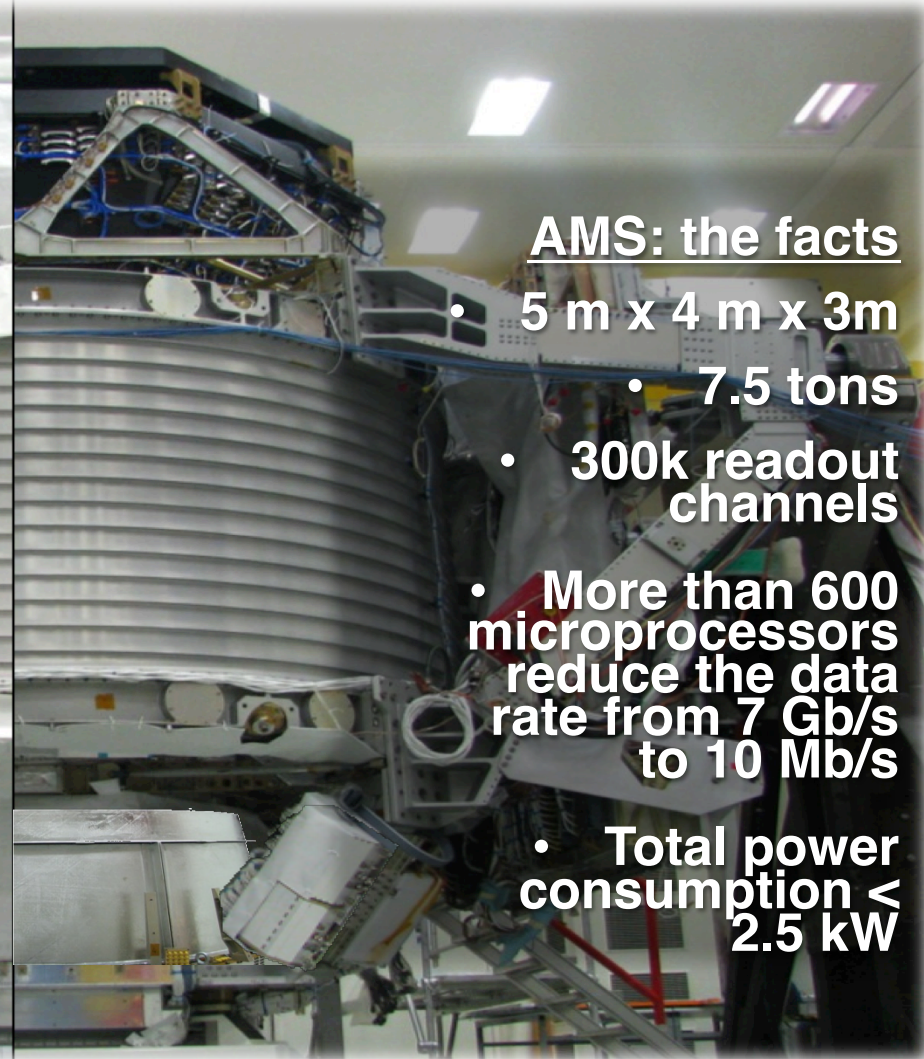
3. AMS-02: Results

AMS-02: The detector

AMS with MLI



AMS without MLI



AMS: the facts

- 5 m x 4 m x 3m
- 7.5 tons
- 300k readout channels
- More than 600 microprocessors reduce the data rate from 7 Gb/s to 10 Mb/s
- Total power consumption < 2.5 kW

AMS-02: the launch

May 16th 2011

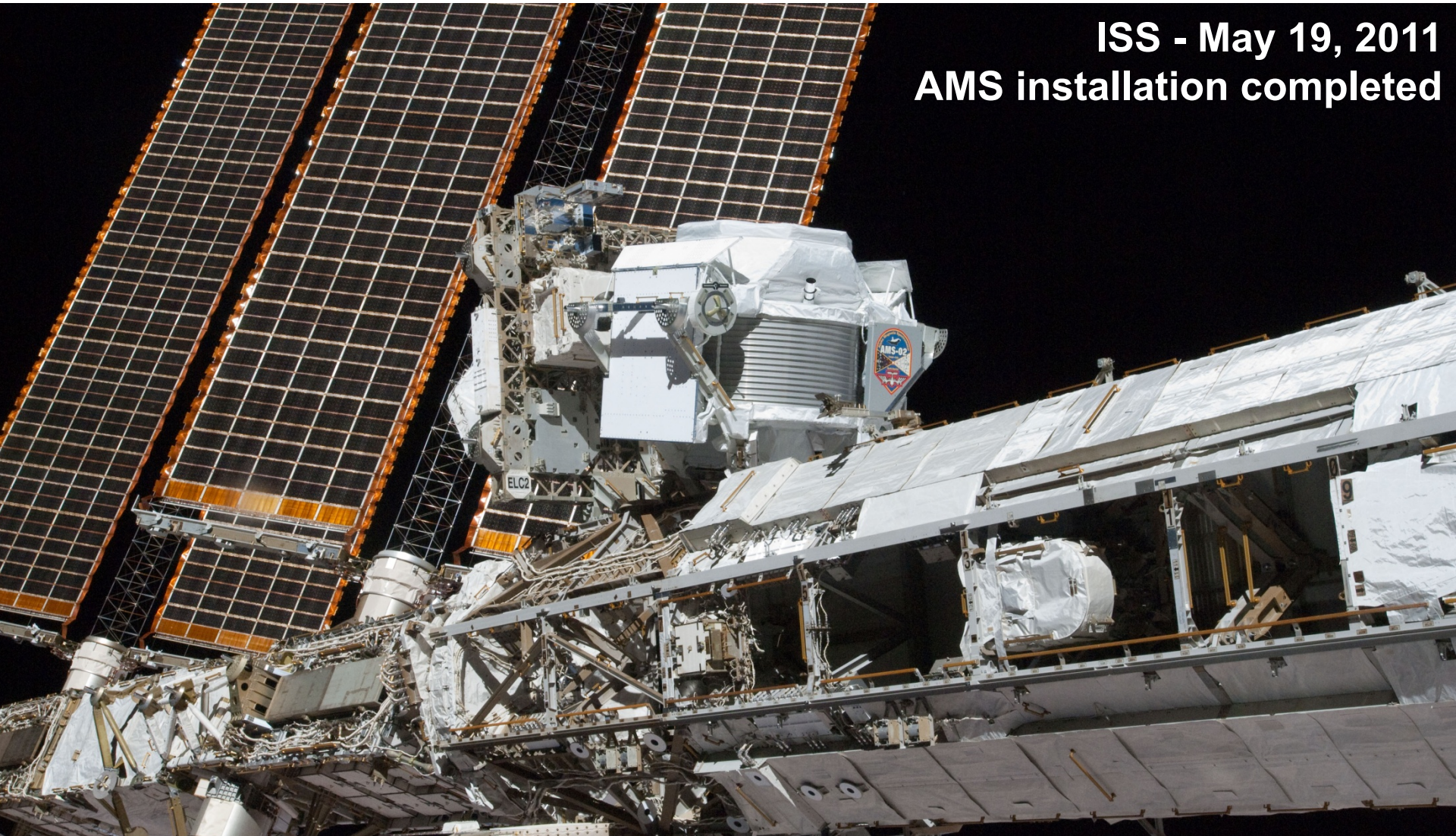


Cape Canaveral, KSC - May 16, 2011 @ 08:56 AM

AMS-02: the installation

May 19th 2011

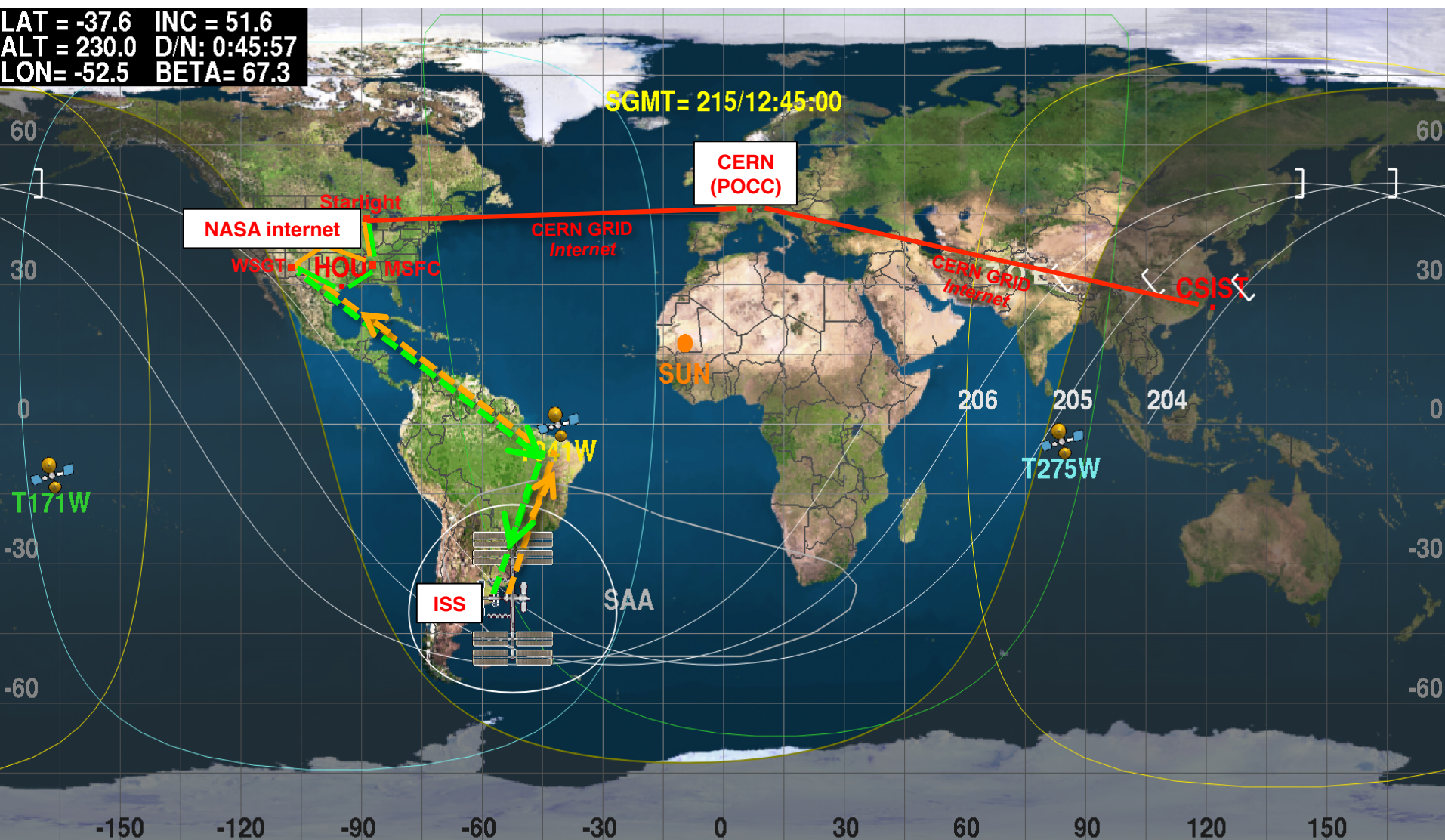
**ISS - May 19, 2011
AMS installation completed**



AMS on orbit @ 400 Km

1 orbit ~93 min

LAT = -37.6 INC = 51.6
ALT = 230.0 D/N: 0:45:57
LON = -52.5 BETA = 67.3



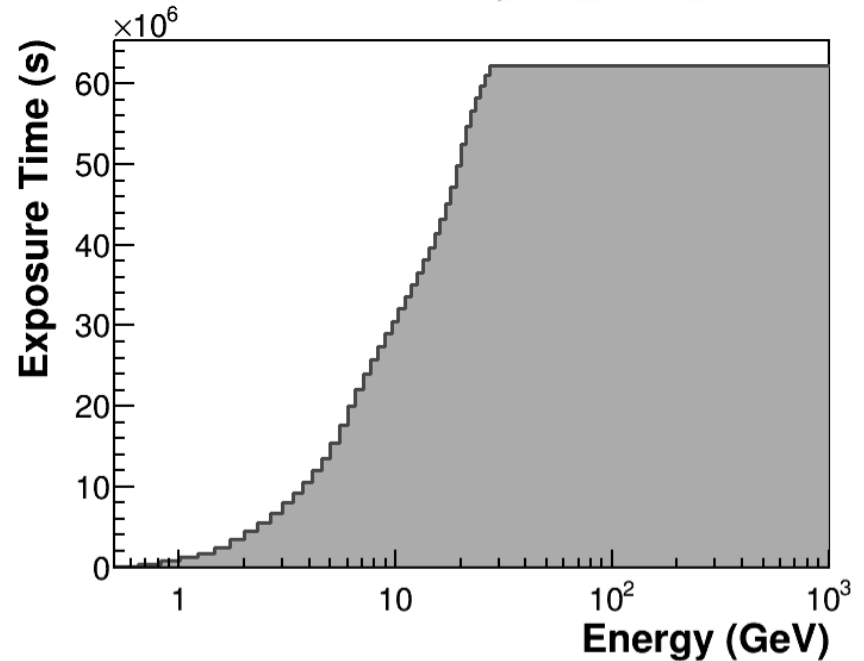
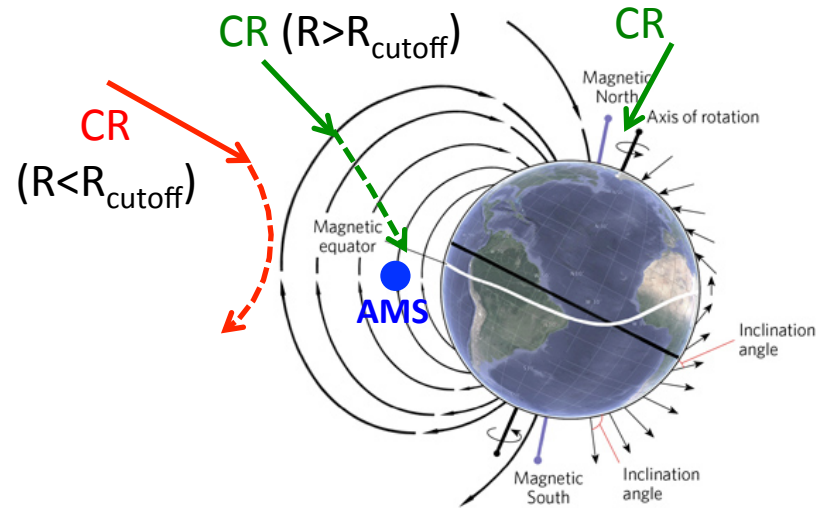
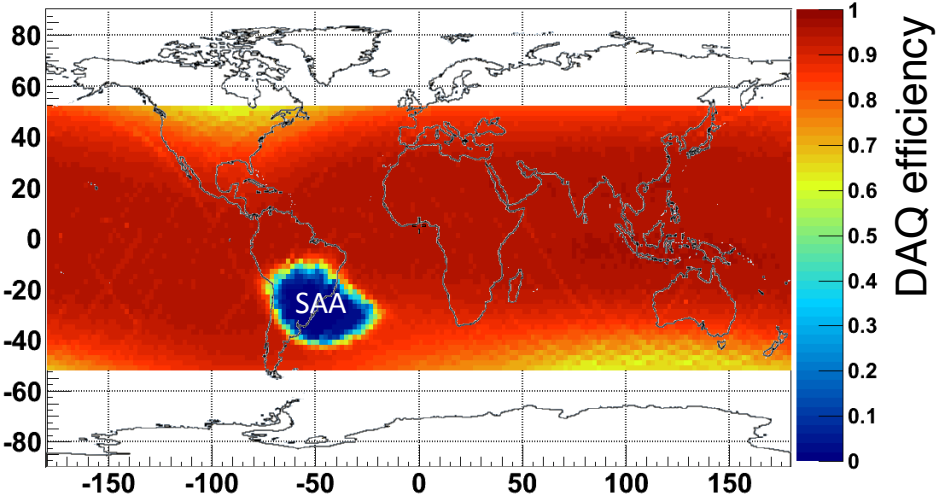
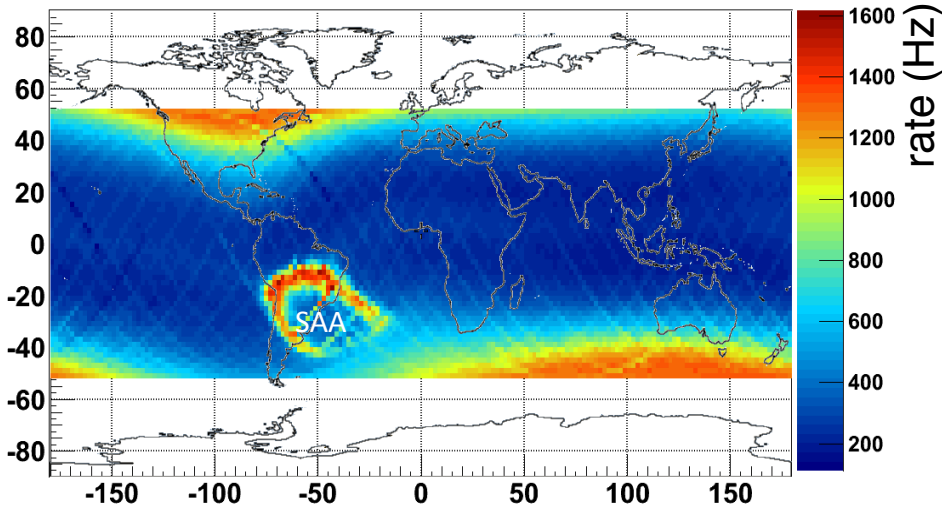
Payload Operation Control Center (POCC) @ CERN

24/24 hours
all days of the year



Orbital DAQ parameters

$\langle \text{Acquisition rate} \rangle \approx 500 \text{ Hz}$



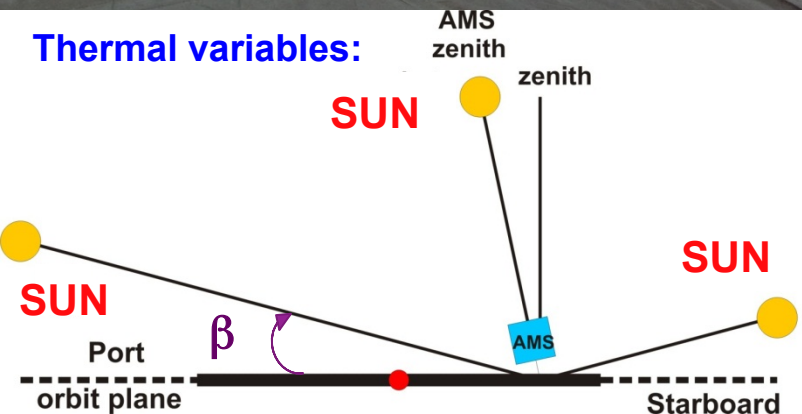
Cutoff & Orbit \rightarrow Average life time fraction $T_{\text{exp}}/44 \text{ months} \sim 80 \%$

The Thermal environment

AMS-02 is not a free-flyer attitude and sun exposition cannot be controlled!

- 70° C

+ 70° C



Thermal environment

TOF & ACC

64 Temperature Sensors

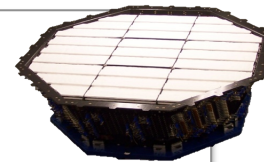


TRD

24 Heaters

8 Pressure Sensors

482 Temperature Sensors

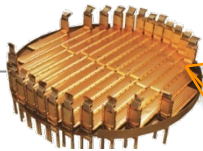


Silicon Tracker

4 Pressure Sensors

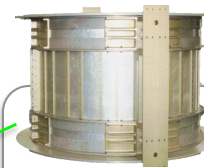
32 Heaters

142 Temperature Sensors



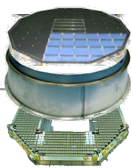
Magnet

68 Temperature Sensors



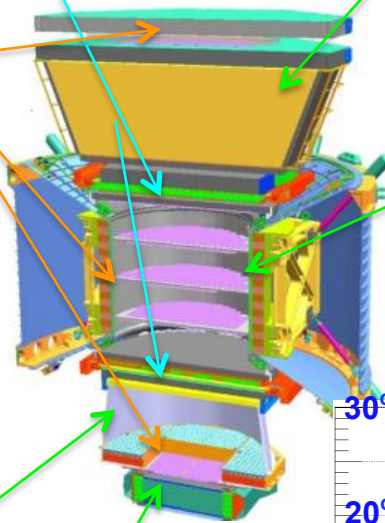
RICH

96 Temperature Sensors

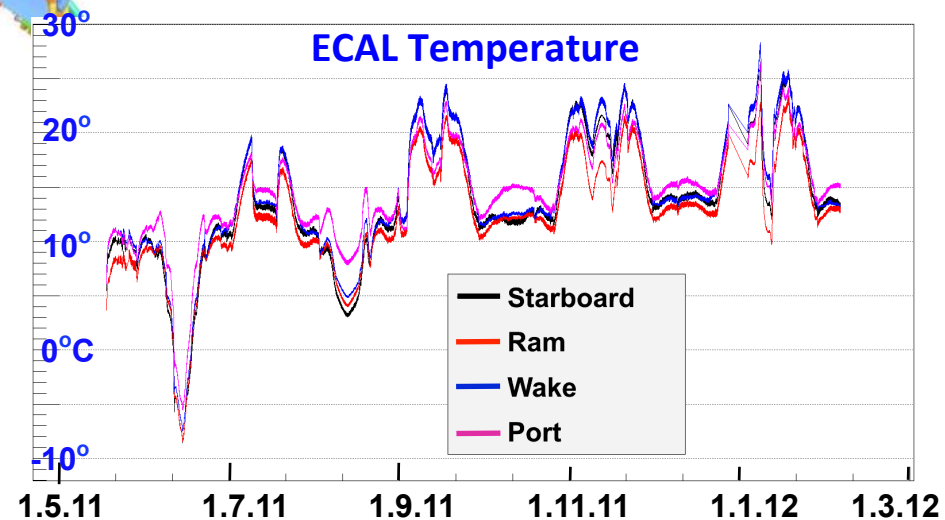


ECAL

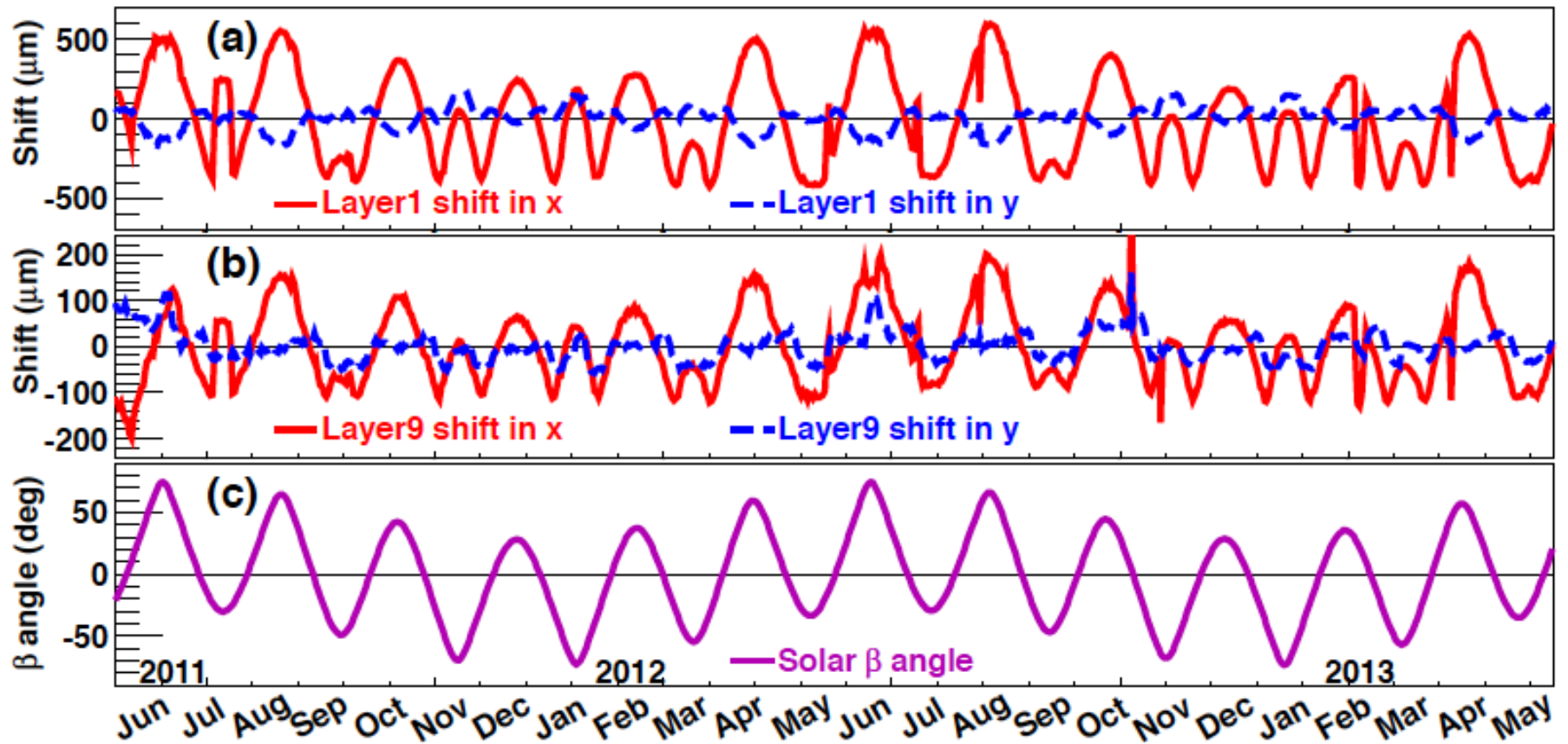
80 Temperature Sensors



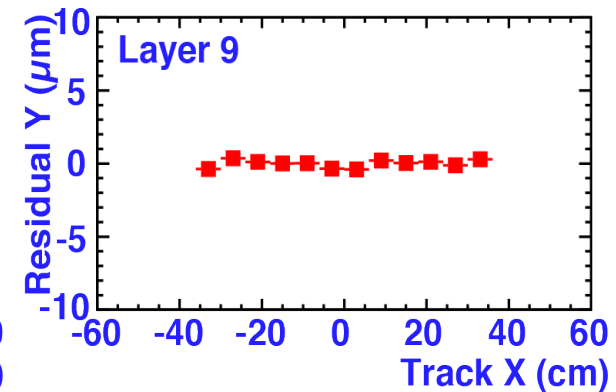
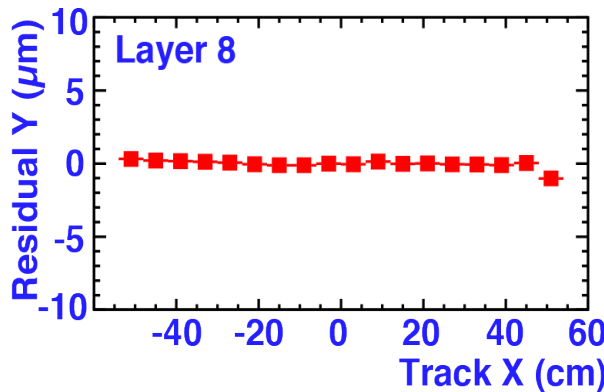
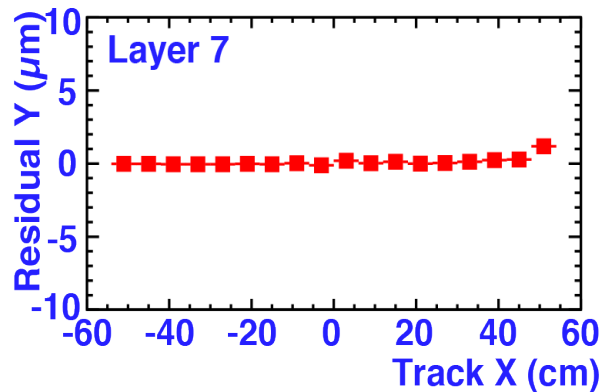
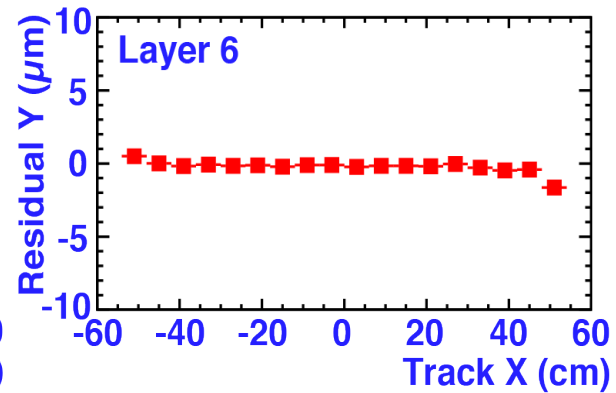
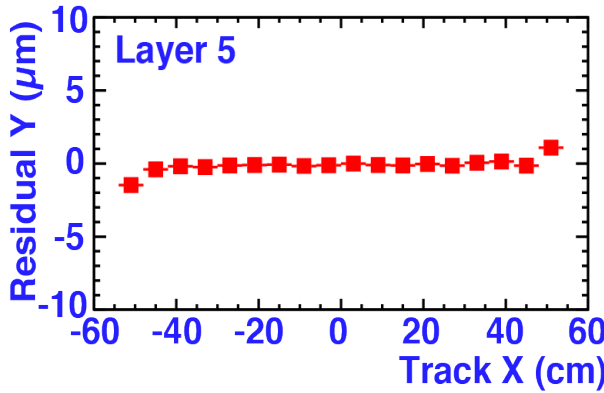
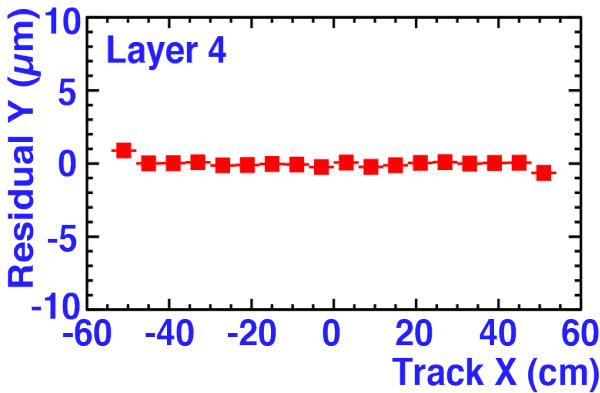
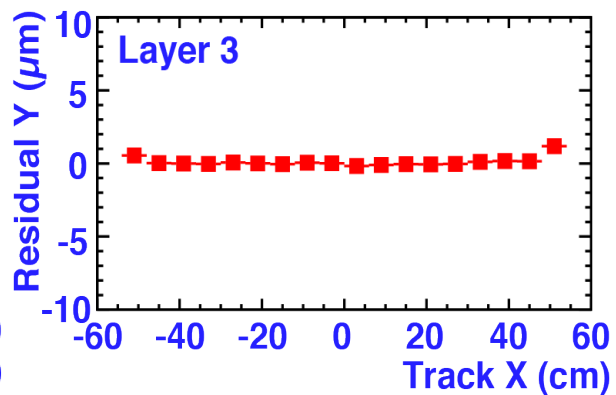
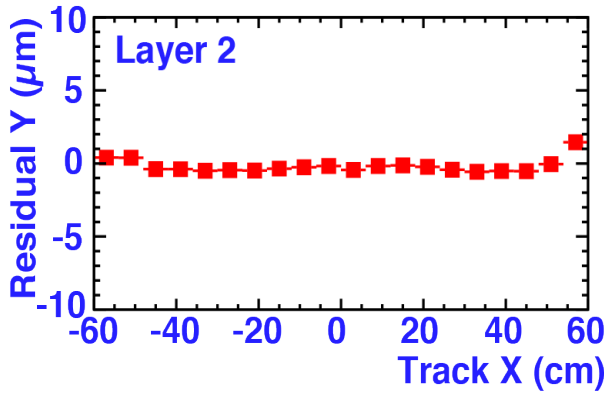
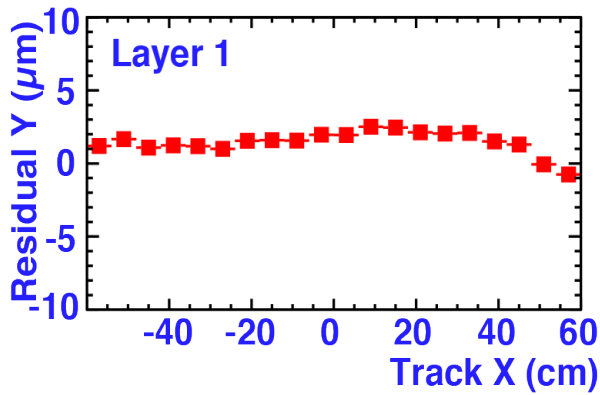
ECAL Temperature



Seasonal effects on Tracker

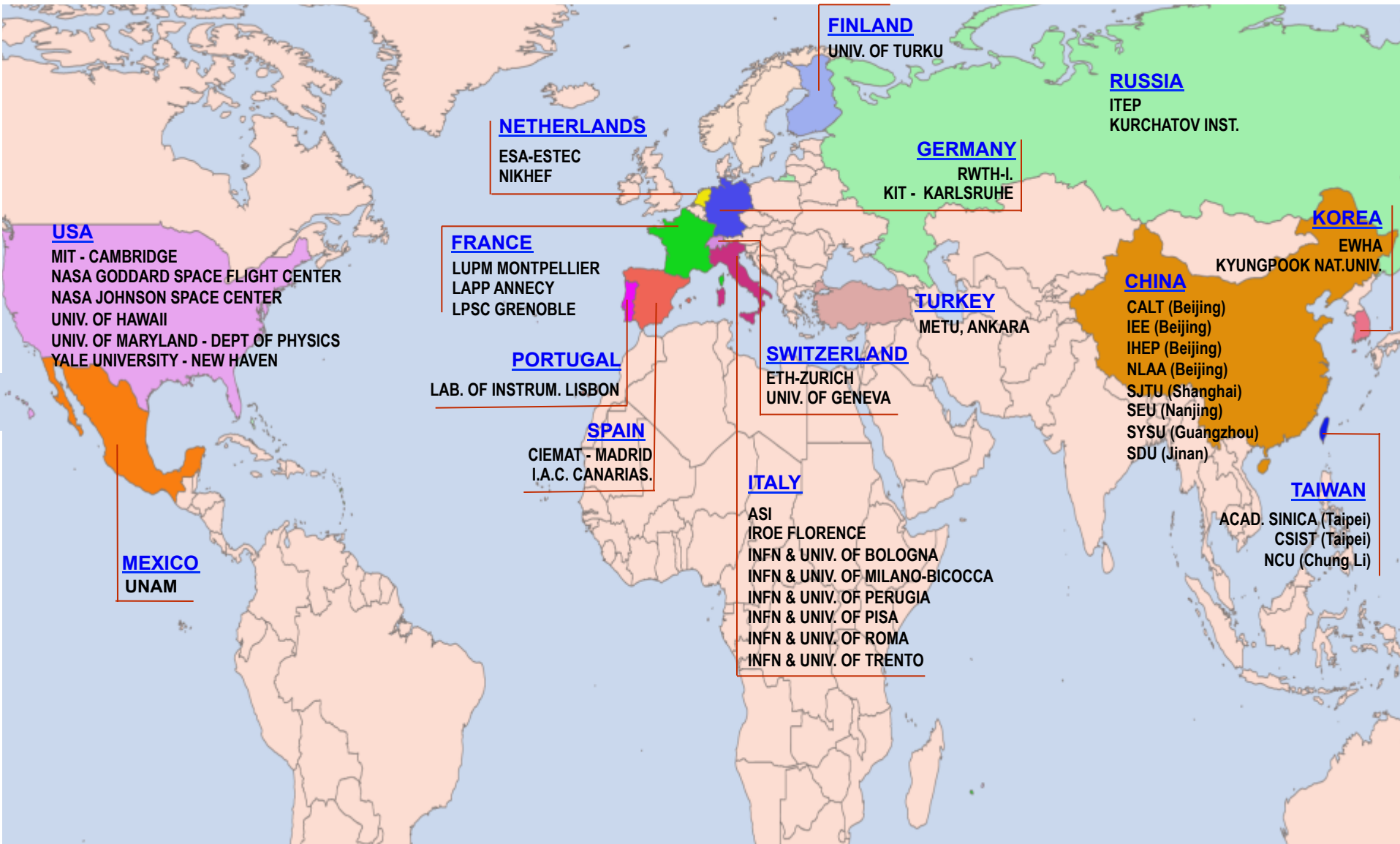


Alignment accuracy of the 9 Tracker layers over the full period



On behalf of the AMS-02 Collaboration

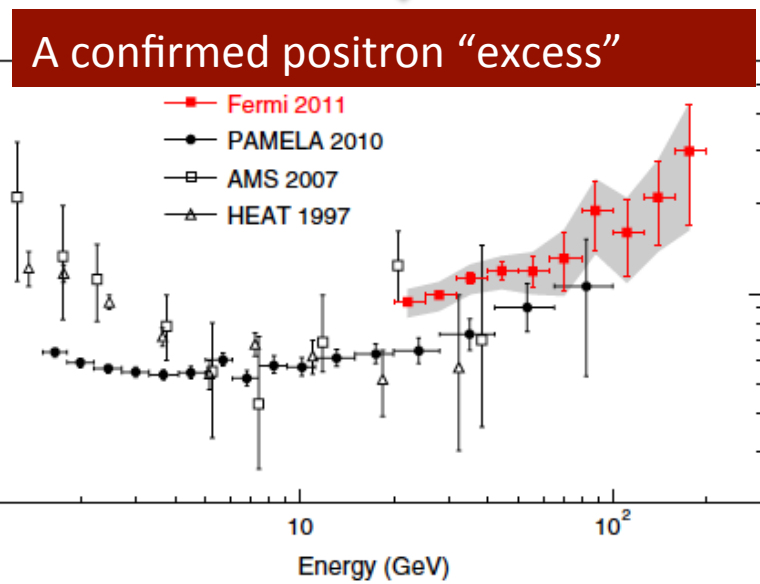
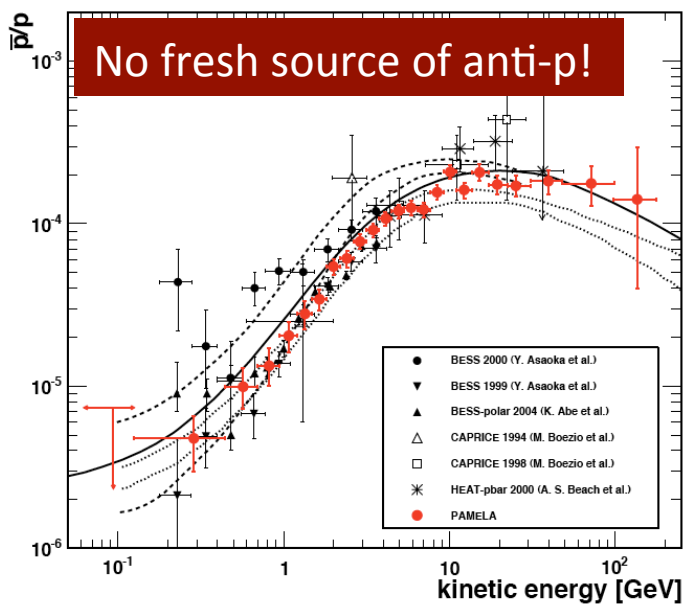
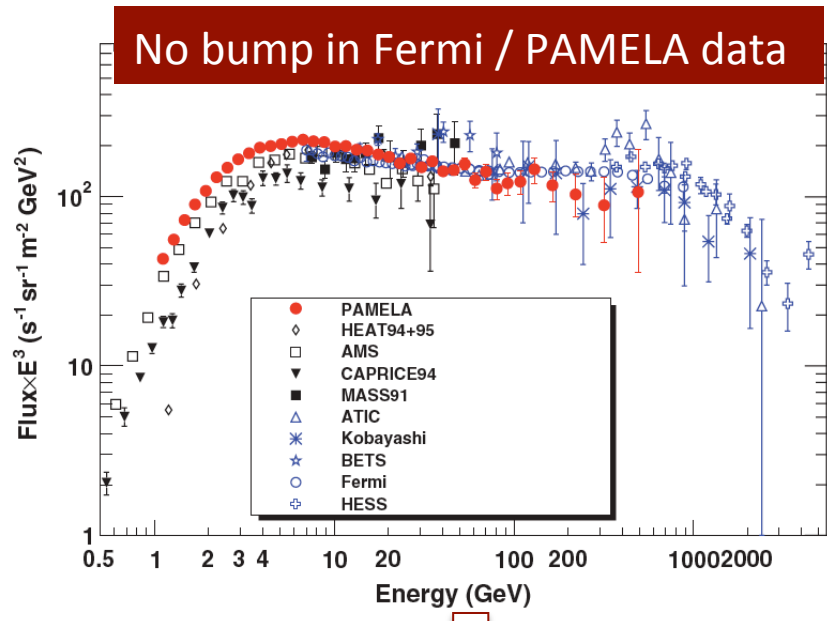
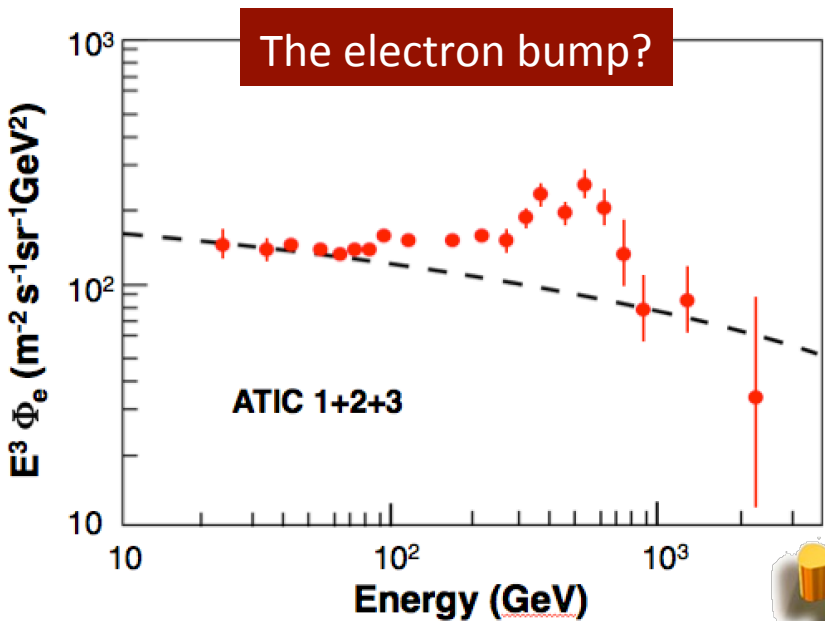
15 Countries, 44 Institutes and 600 Physicists



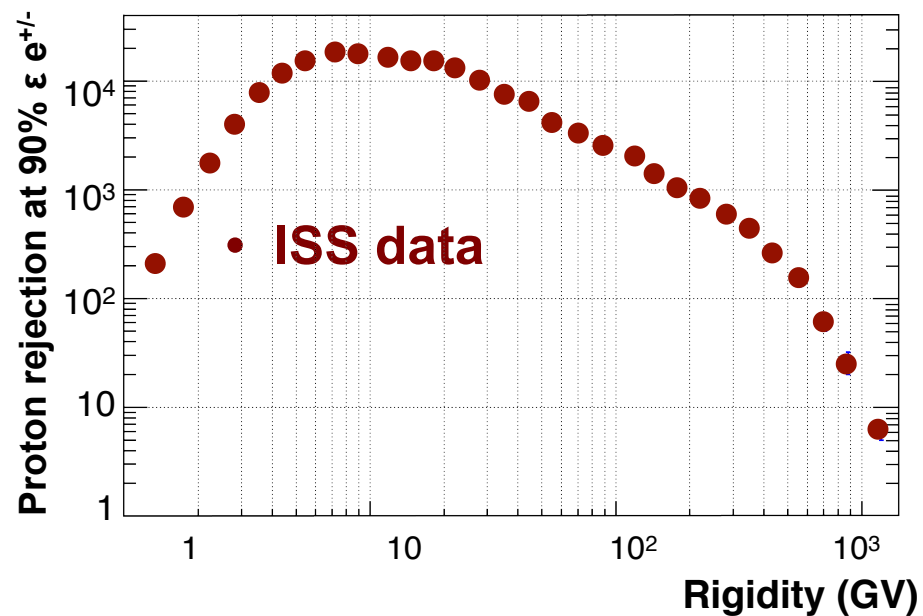
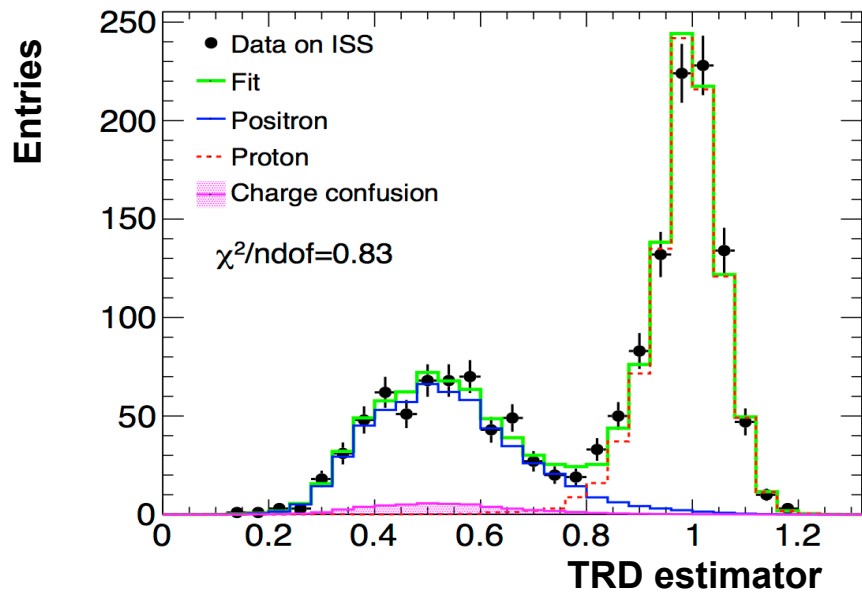
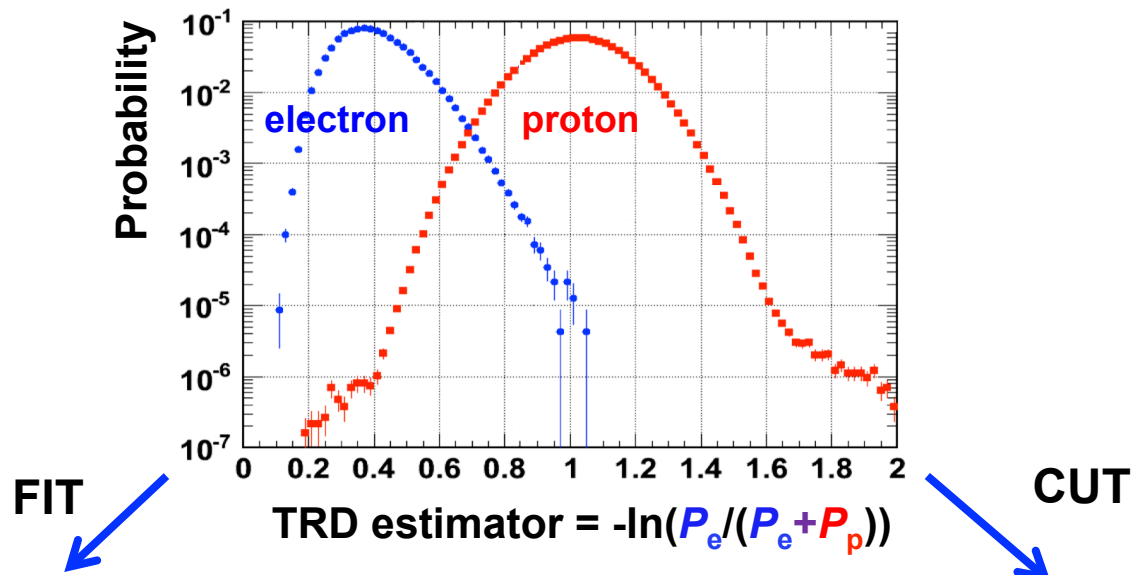
AMS-02: (part) of the Collaboration @ NASA-JSC



The Physics: DM/exotic sources

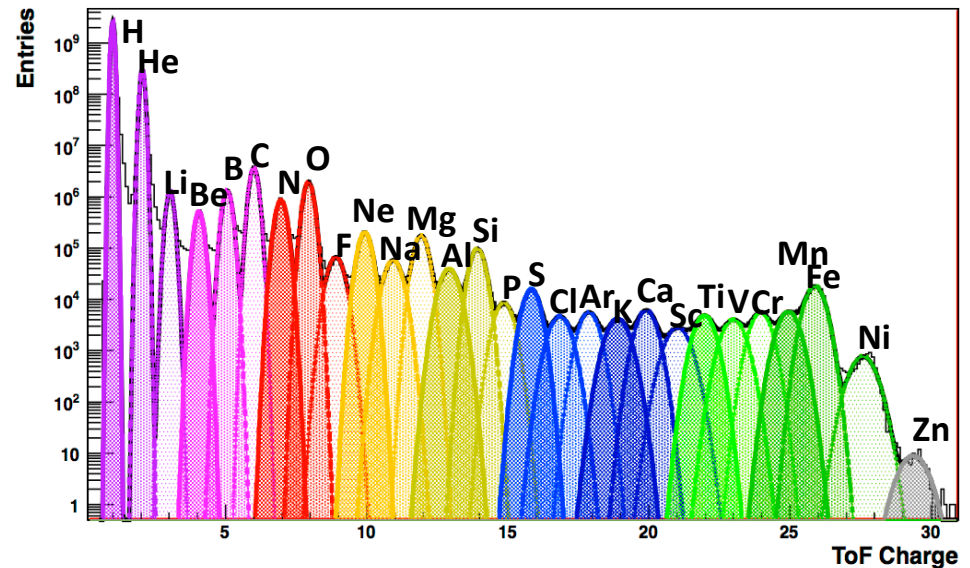
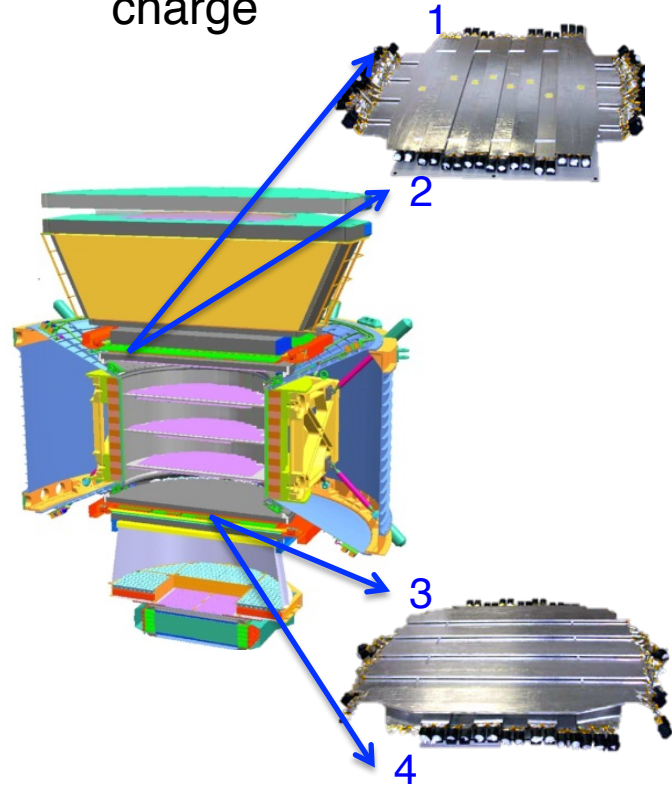
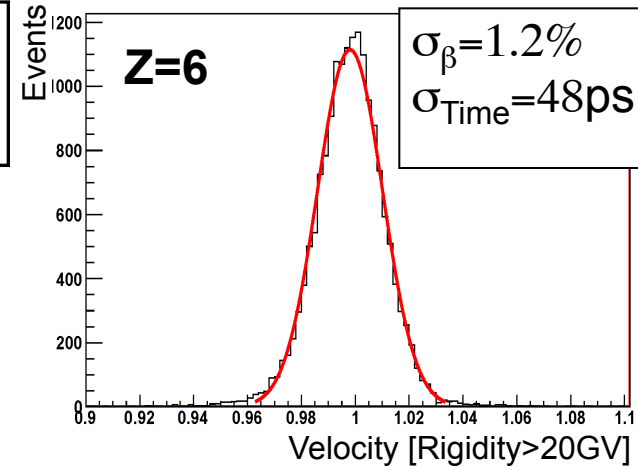
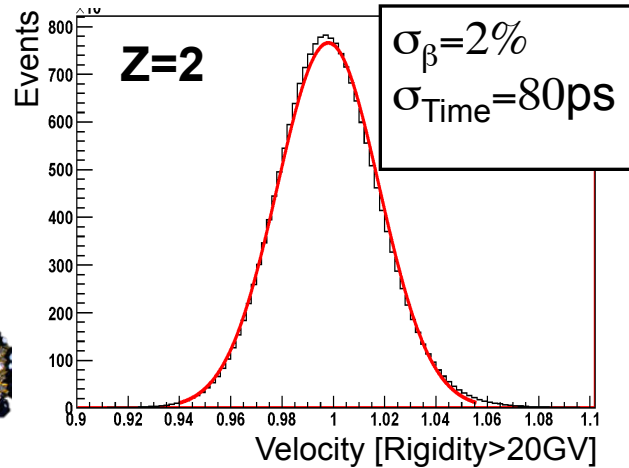


TRD e/p separation

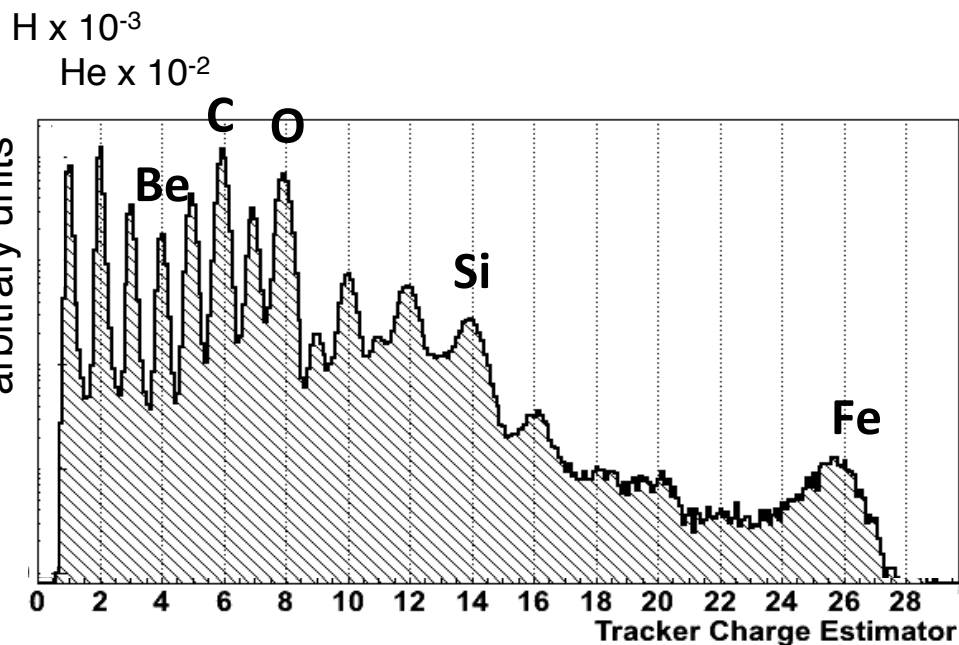


Time of Flight System

- ▷ 4 Layers of scintillation counter
- ▷ Main trigger
- ▷ Measurement of $\beta=v/c$ ($\Delta t \sim 180$ ps)
- ▷ Measurement of charge



Charge measurement :

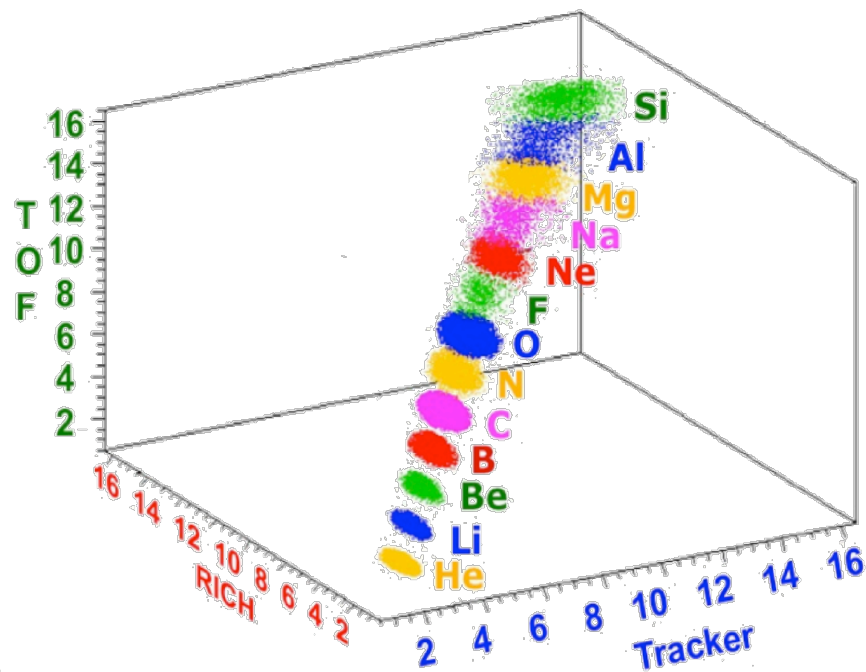


Redundant measurement of Z



dE/dx in each layer →

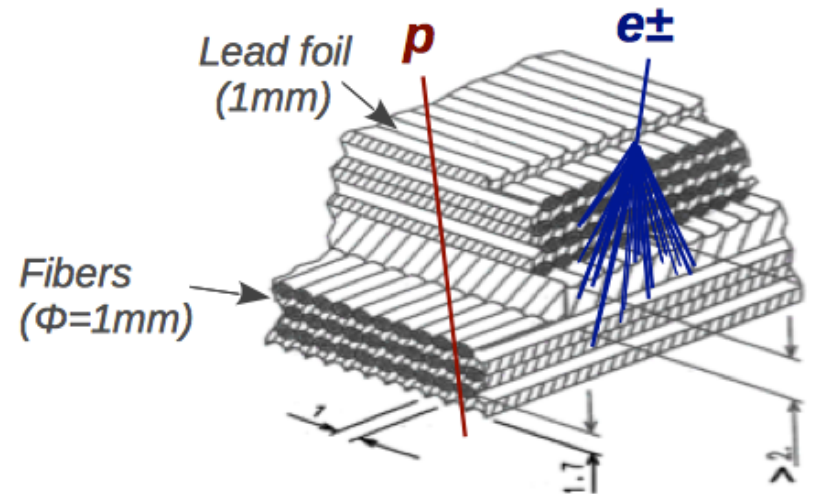
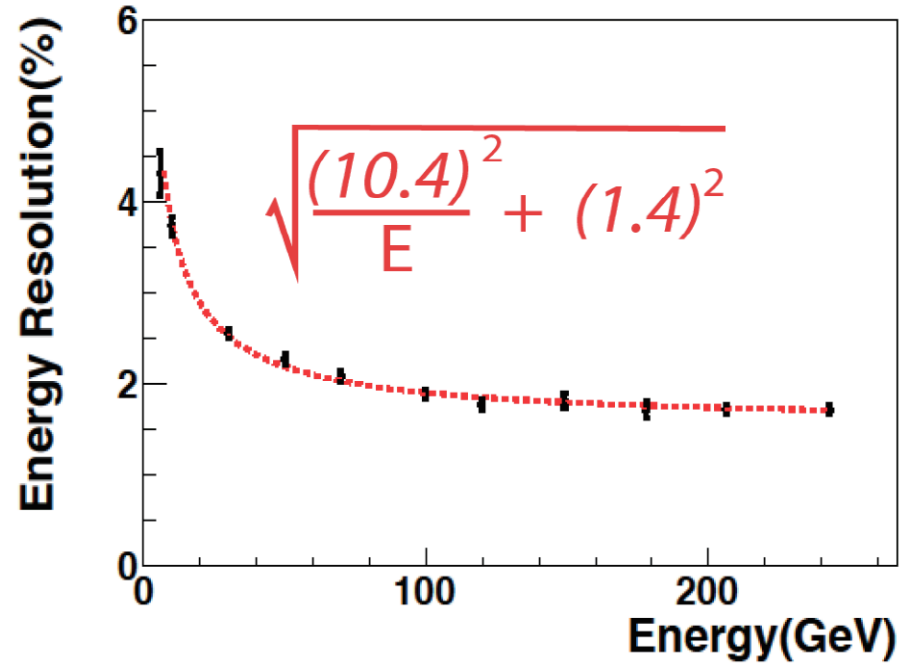
Silicon Tracker has a very accurate charge resolution (~ 0.1 c.u.)



3D Electromagnetic Calorimeter (ECAL)

- Measurement of e^\pm and γ energy ($\Delta E/E \sim 2\% @ 100 \text{ GeV}$).
- p/e rejection $> 10^4$
- 18 layers of lead and scintillating fiber

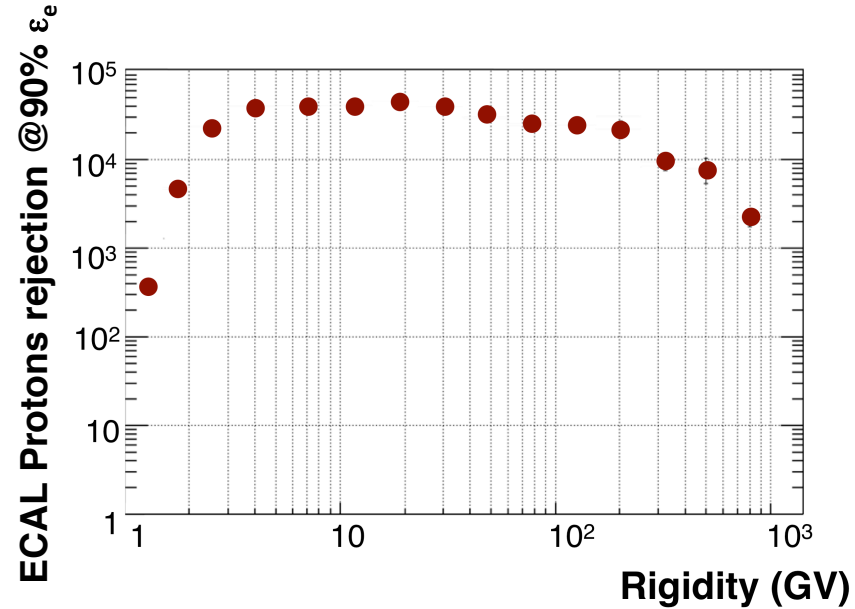
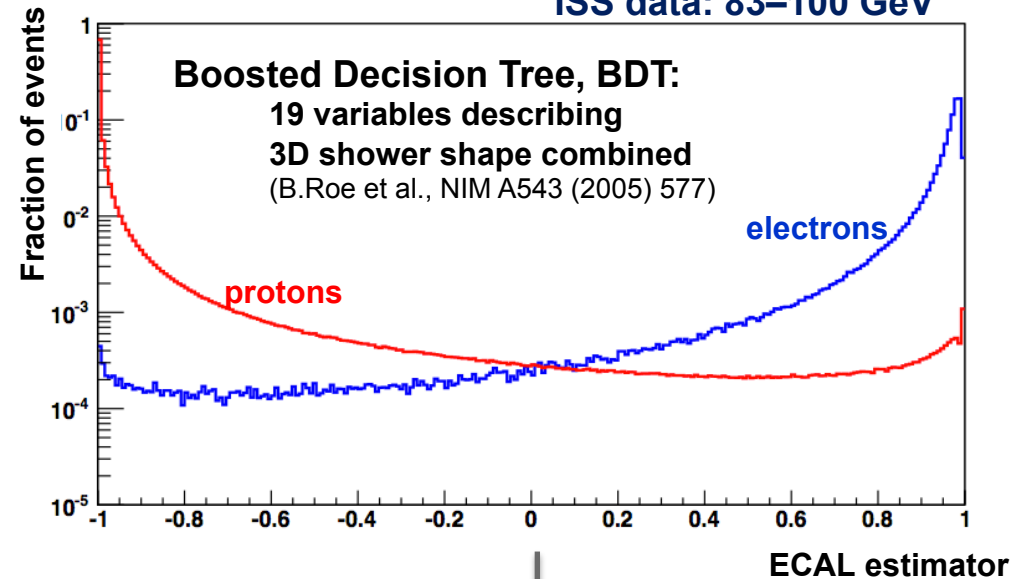
50,000 fibers, $\phi = 1 \text{ mm}$
 distributed uniformly inside 600 kg of
 lead: Total $\sim 17 X_0$



ECAL: e/p separation

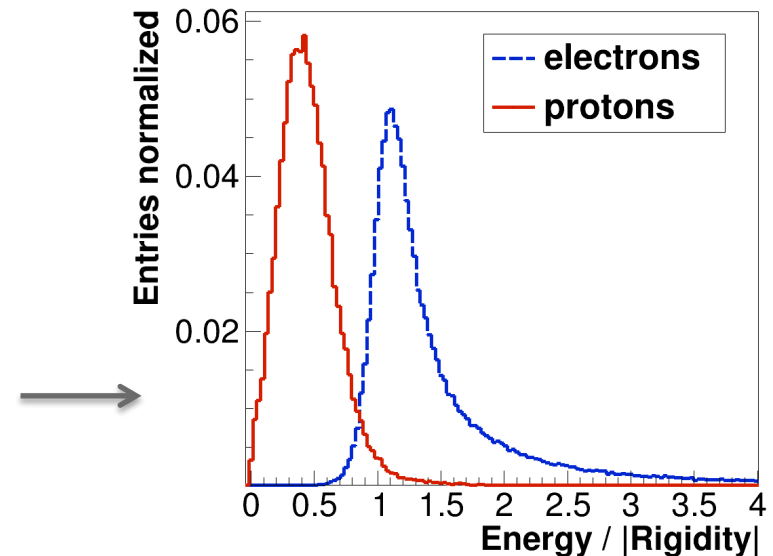
ISS data: 83–100 GeV

Boosted Decision Tree, BDT:
19 variables describing
3D shower shape combined
(B.Roe et al., NIM A543 (2005) 577)



Thanks to its shower **shape imaging capabilities** can **discriminate** very sensibly **electromagnetic from hadronic showers**

Combining the ECAL energy information with the Tracker Rigidity (E/R) the **e/p rejection** can be further **increased**



A 600 GeV electron in AMS

-TRD:

- identify the particle as e^+/e^- rejecting the hadronic hypothesis

-TOF:

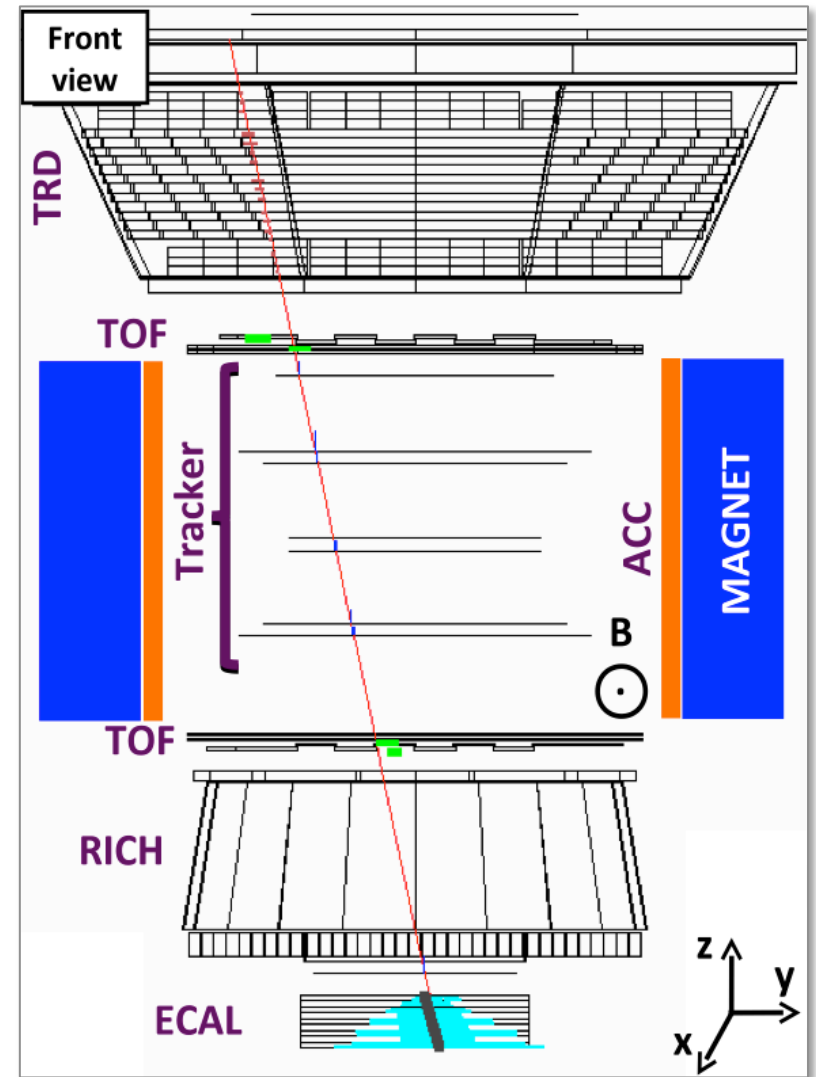
- main trigger
- down going relativistic particle
- $Z=1$

-TRACKER:

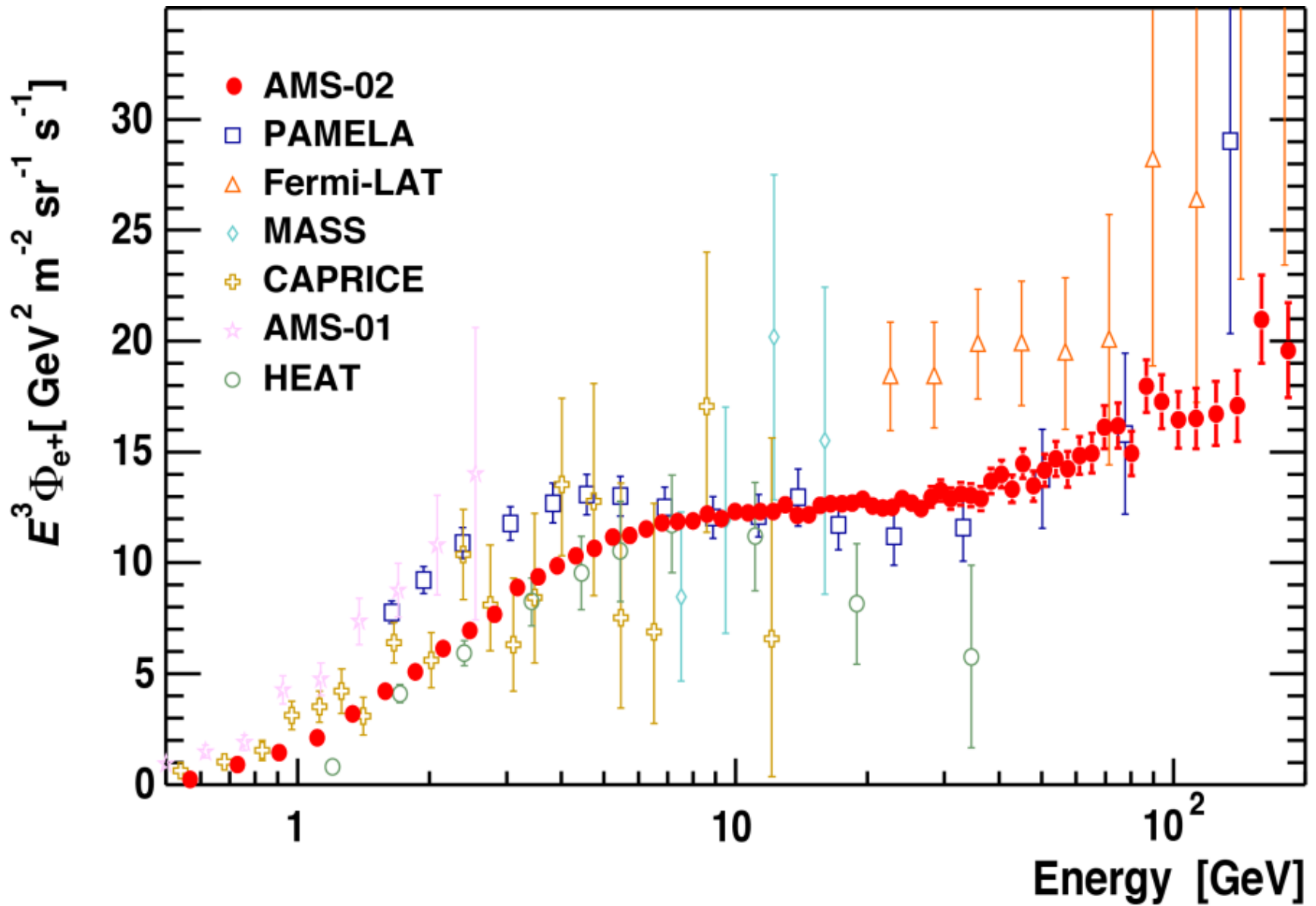
- identify negative charge (e^-)
- $Z=1$

-ECAL:

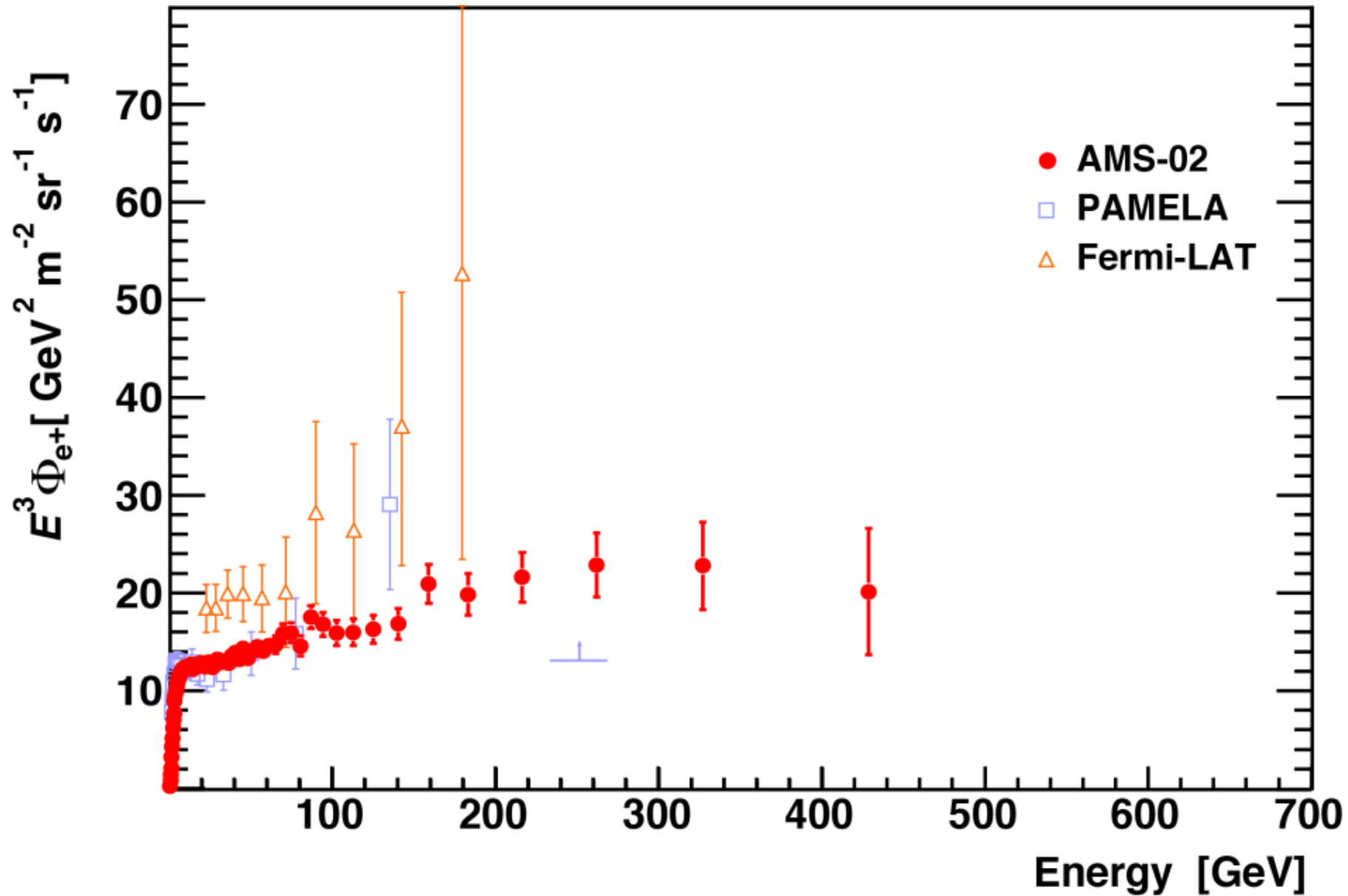
- identify the particle as $e^+/e^-/\gamma$ rejecting the hadronic hypothesis
- measurement of energy



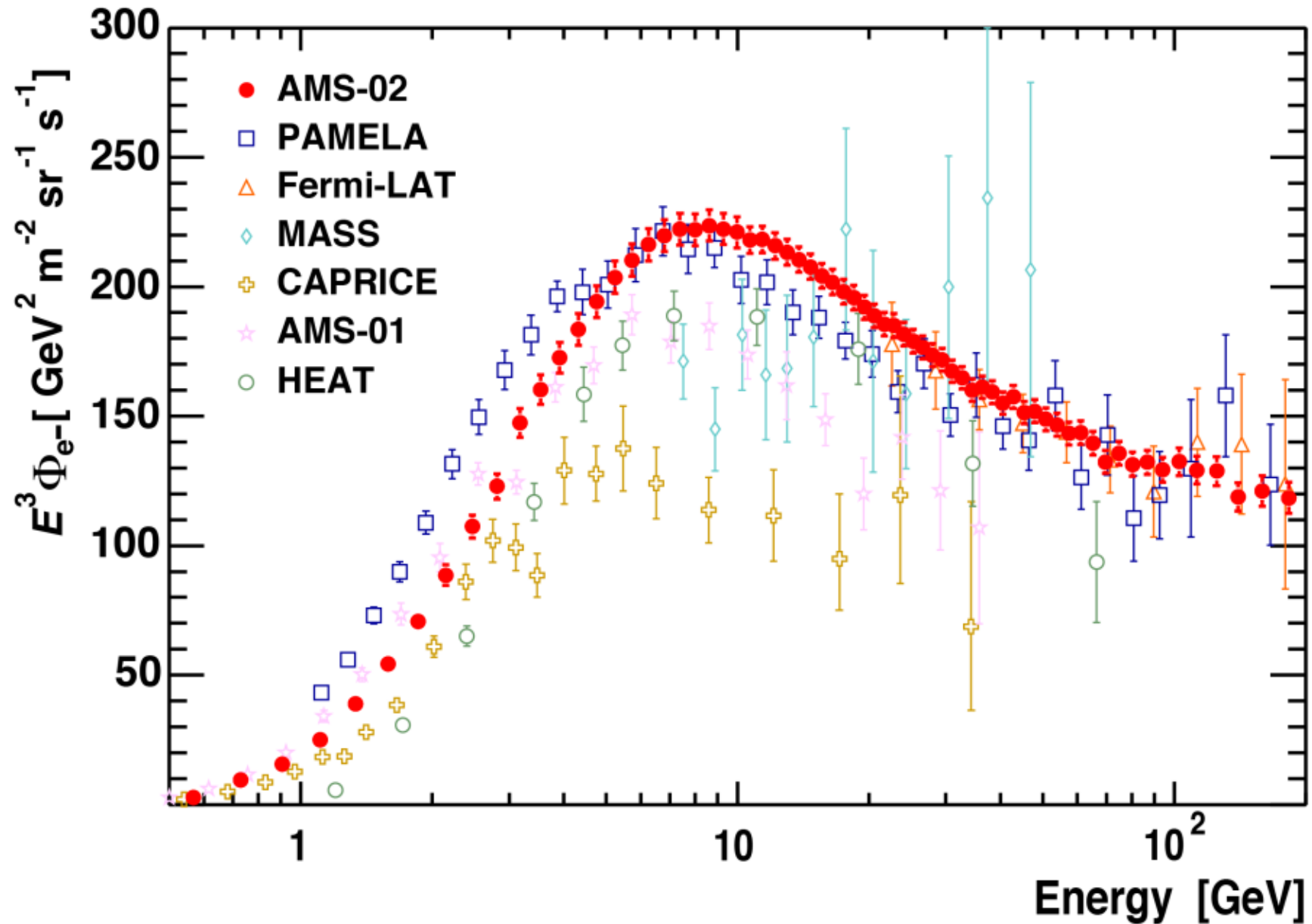
Positron (e^+) flux



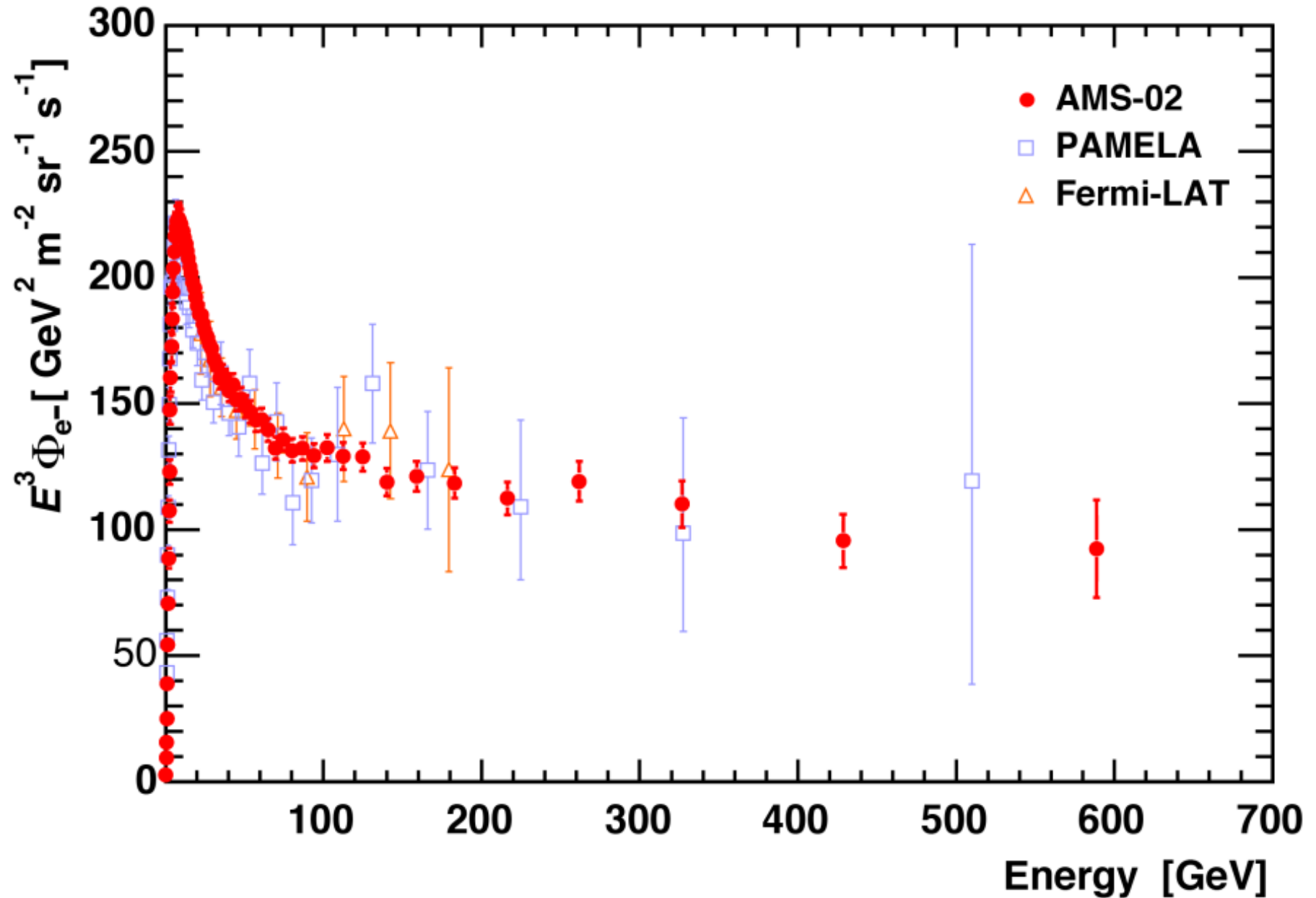
Positron (e^+) flux



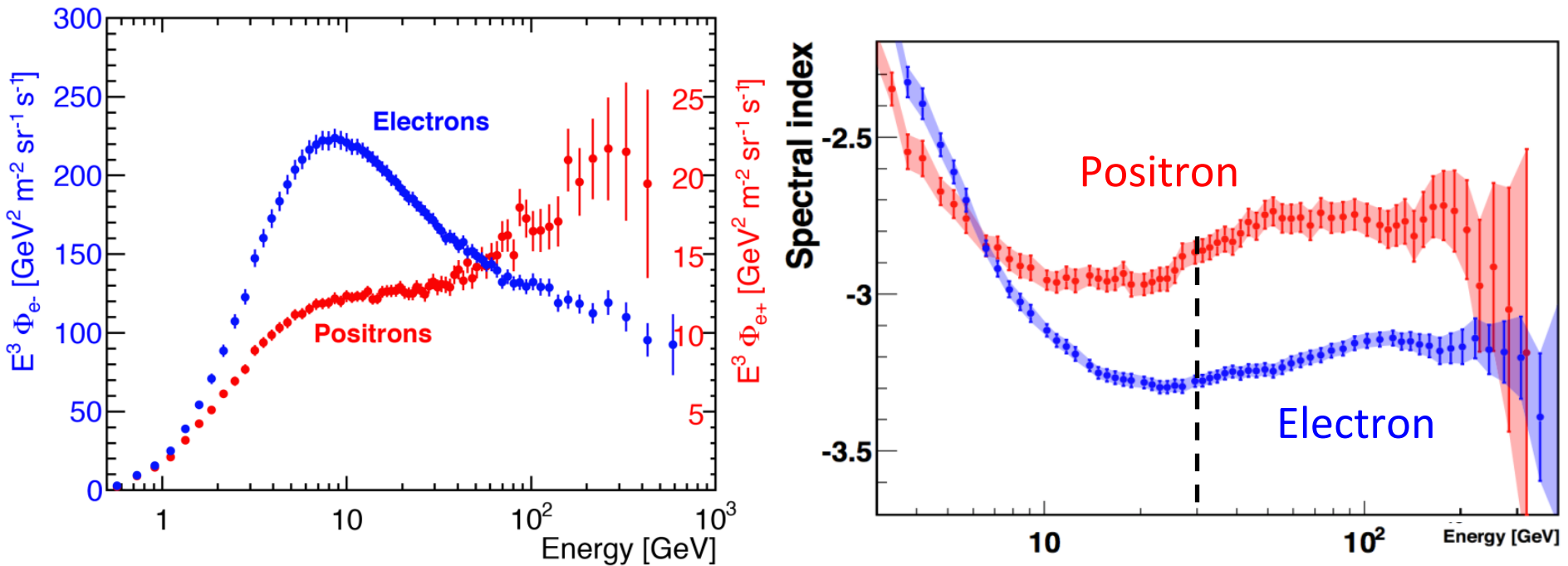
Electron (e^-) flux



Electron (e^-) flux



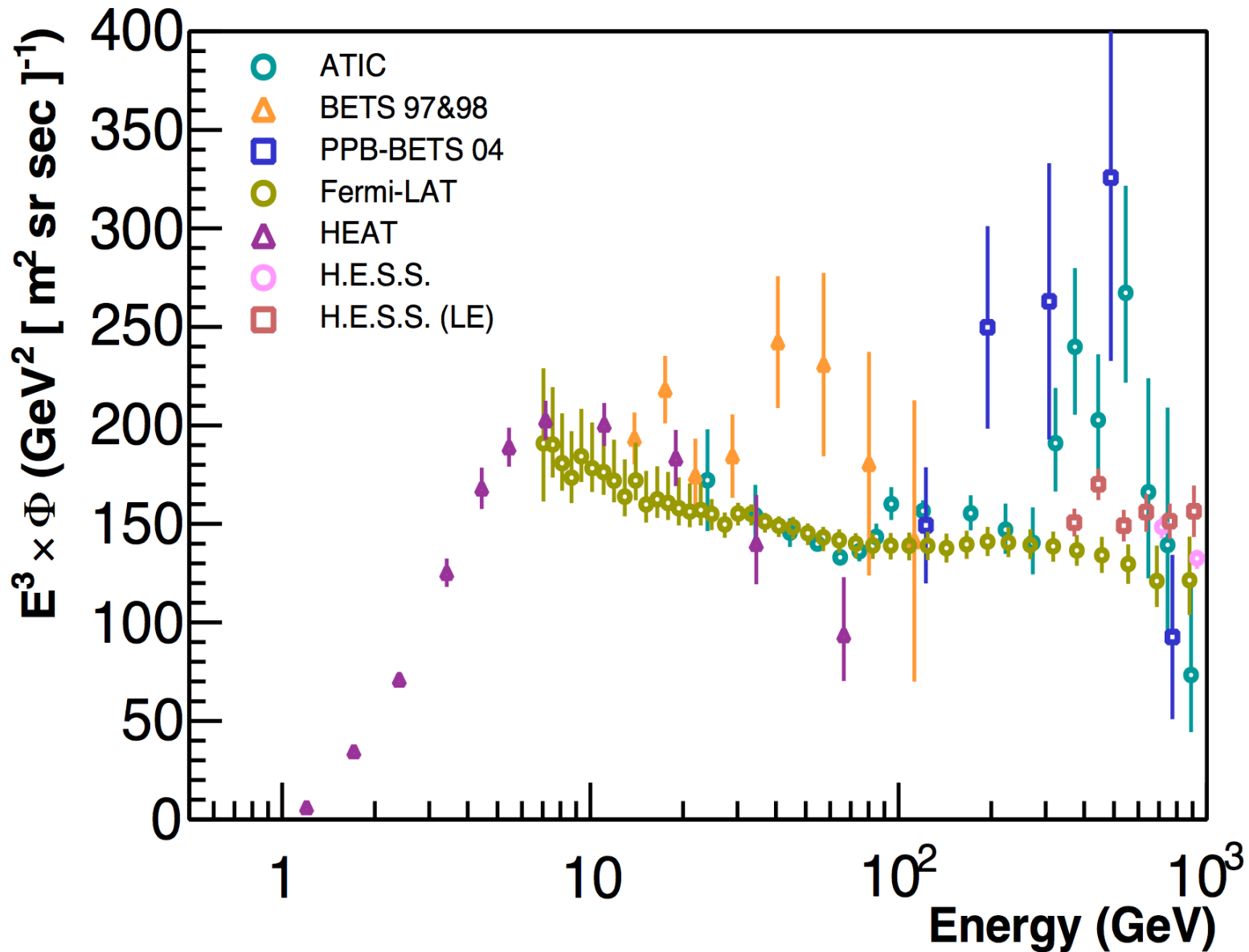
Observation on electrons and positrons fluxes



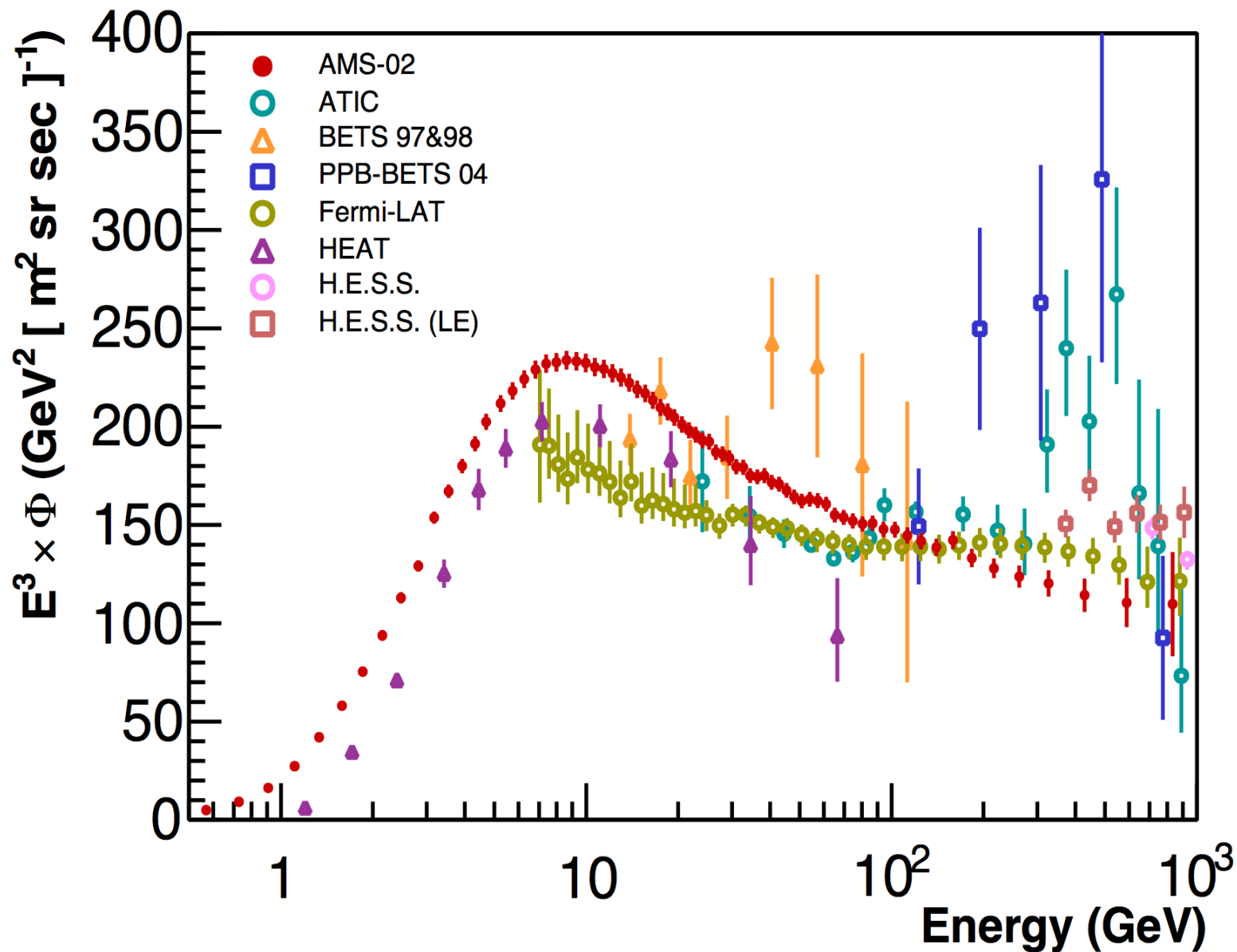
Observations:

1. Both the electron flux and the positron flux **are significantly different in their magnitude and energy dependence.**
2. Both spectra **cannot be described by single power laws.**
3. The **spectral indices** of electrons and positrons **are different.**
4. Both change their behavior at **~30GeV.**
5. The **rise in the positron fraction from 20 GeV is due to an excess of positrons,** not the loss of electrons (the positron flux is harder).

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

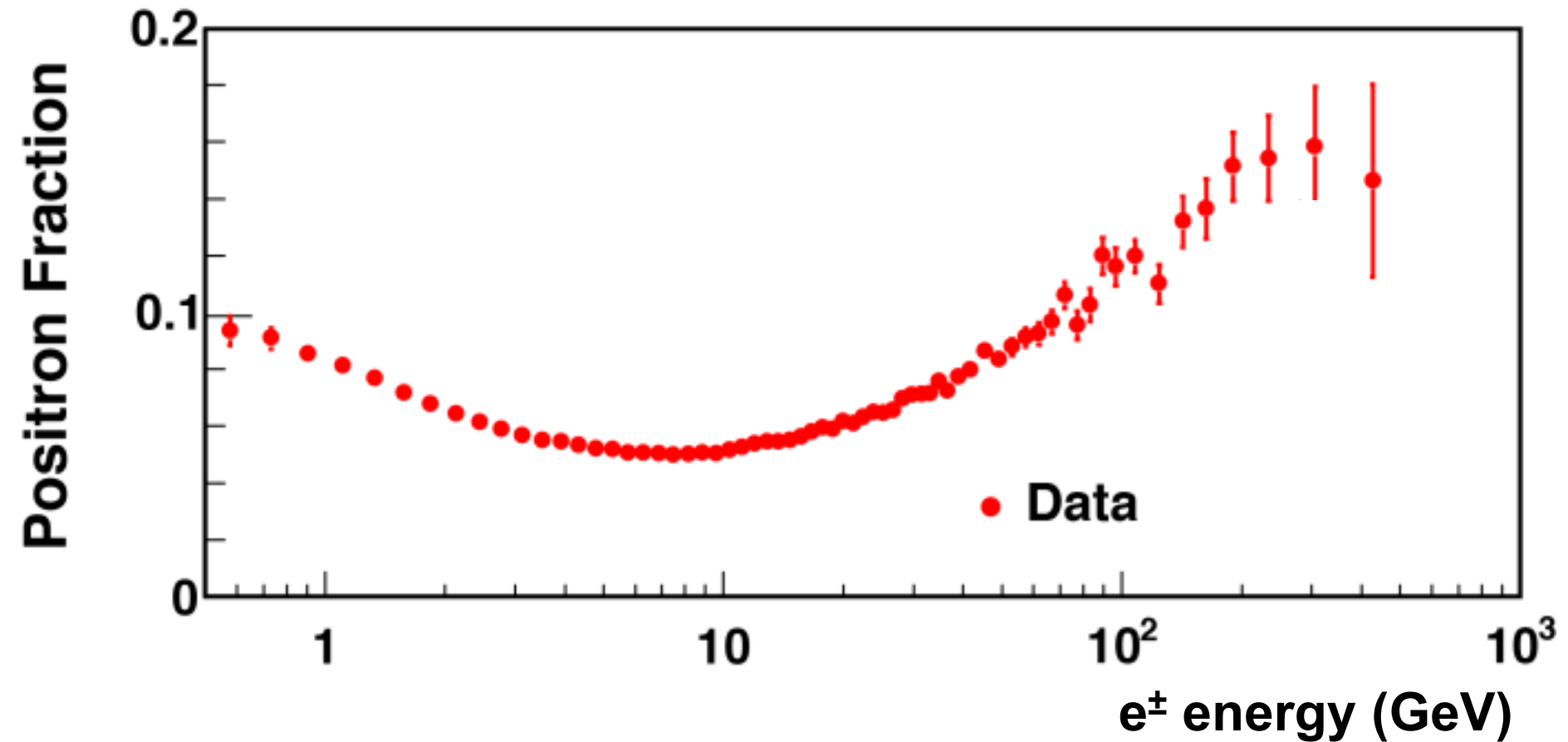


All-electrons (e^+e^-) flux – after AMS



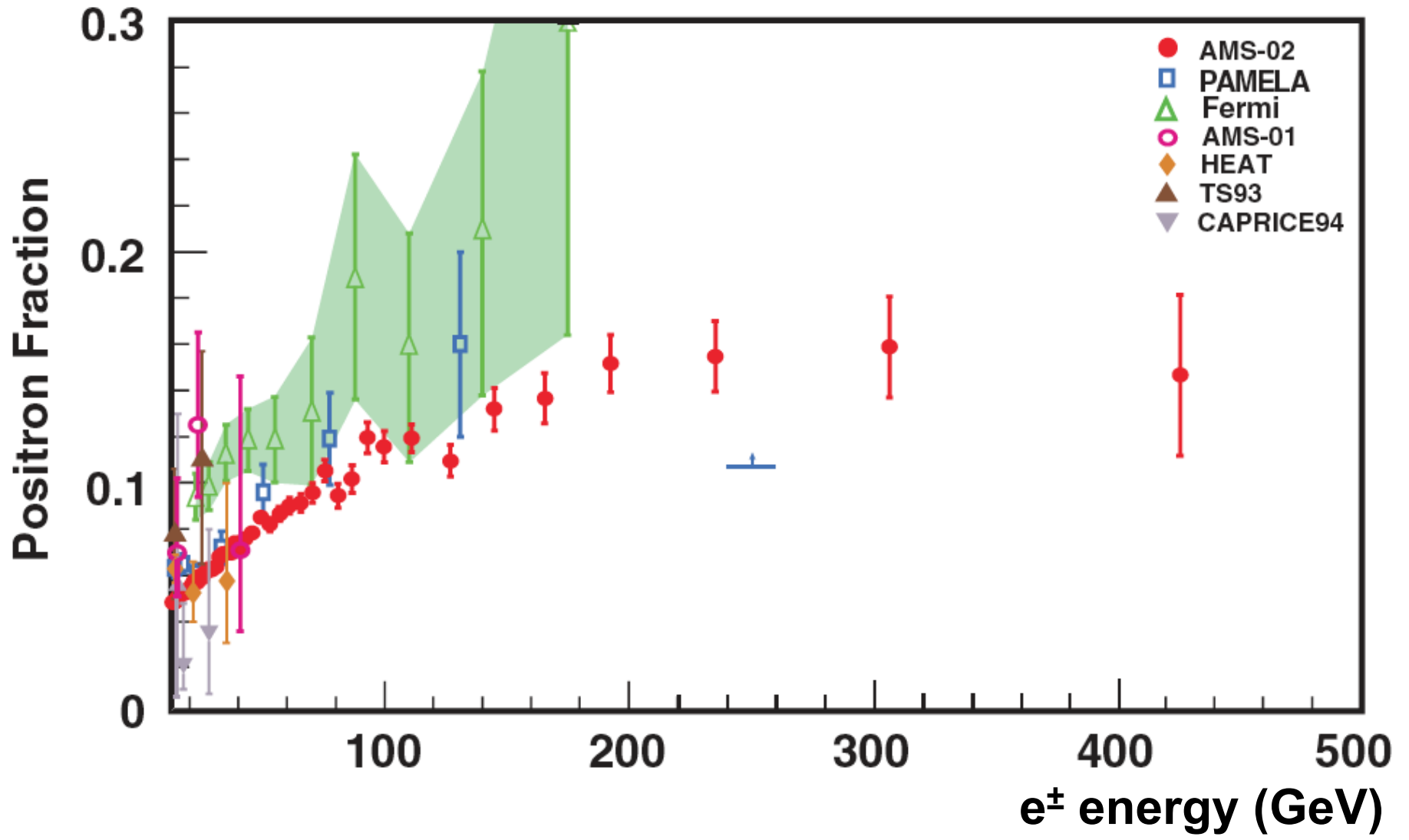
Positron fraction (0.5 – 500 GeV)

AMS-02
(10.9×10^6 e^+ , e^- events)

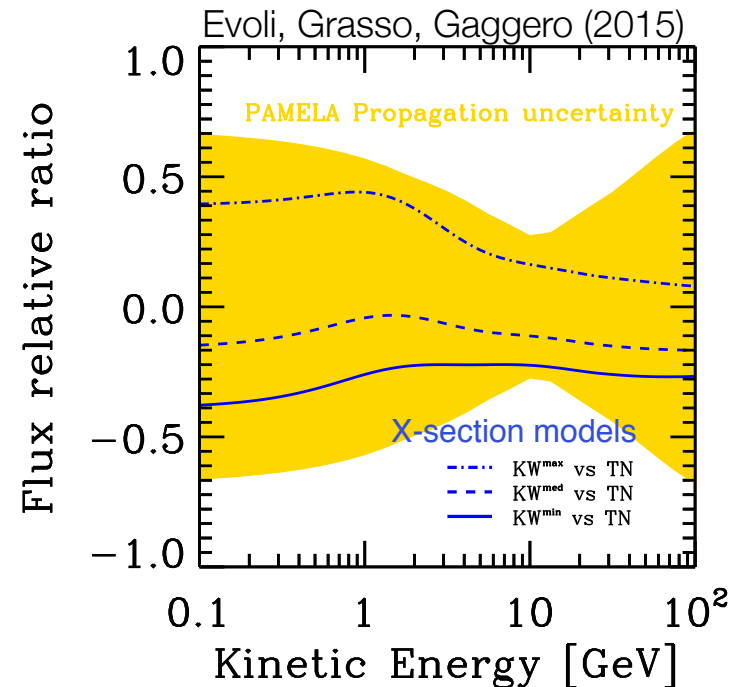
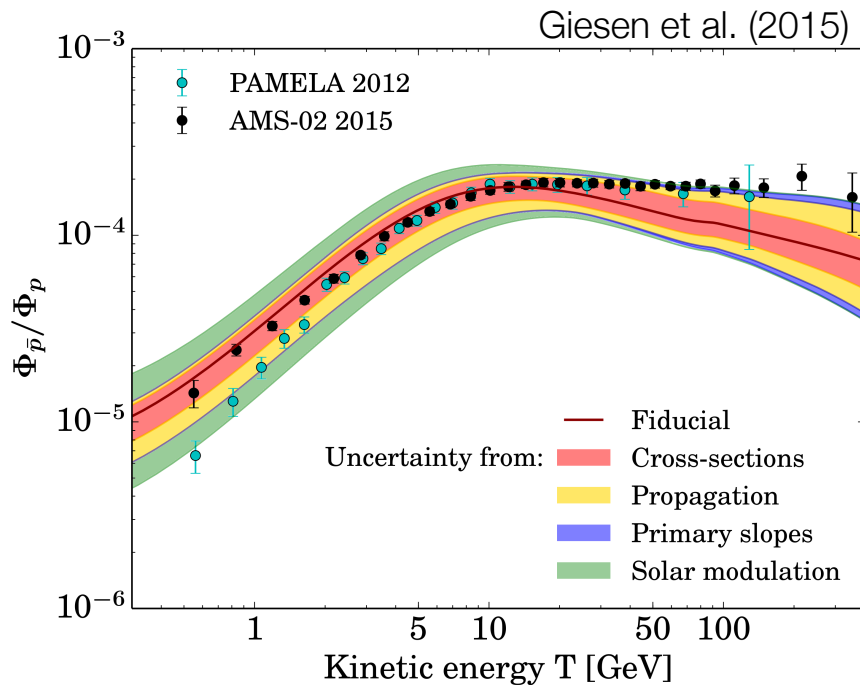


No fine structures are observed

Positron fraction @ high energies



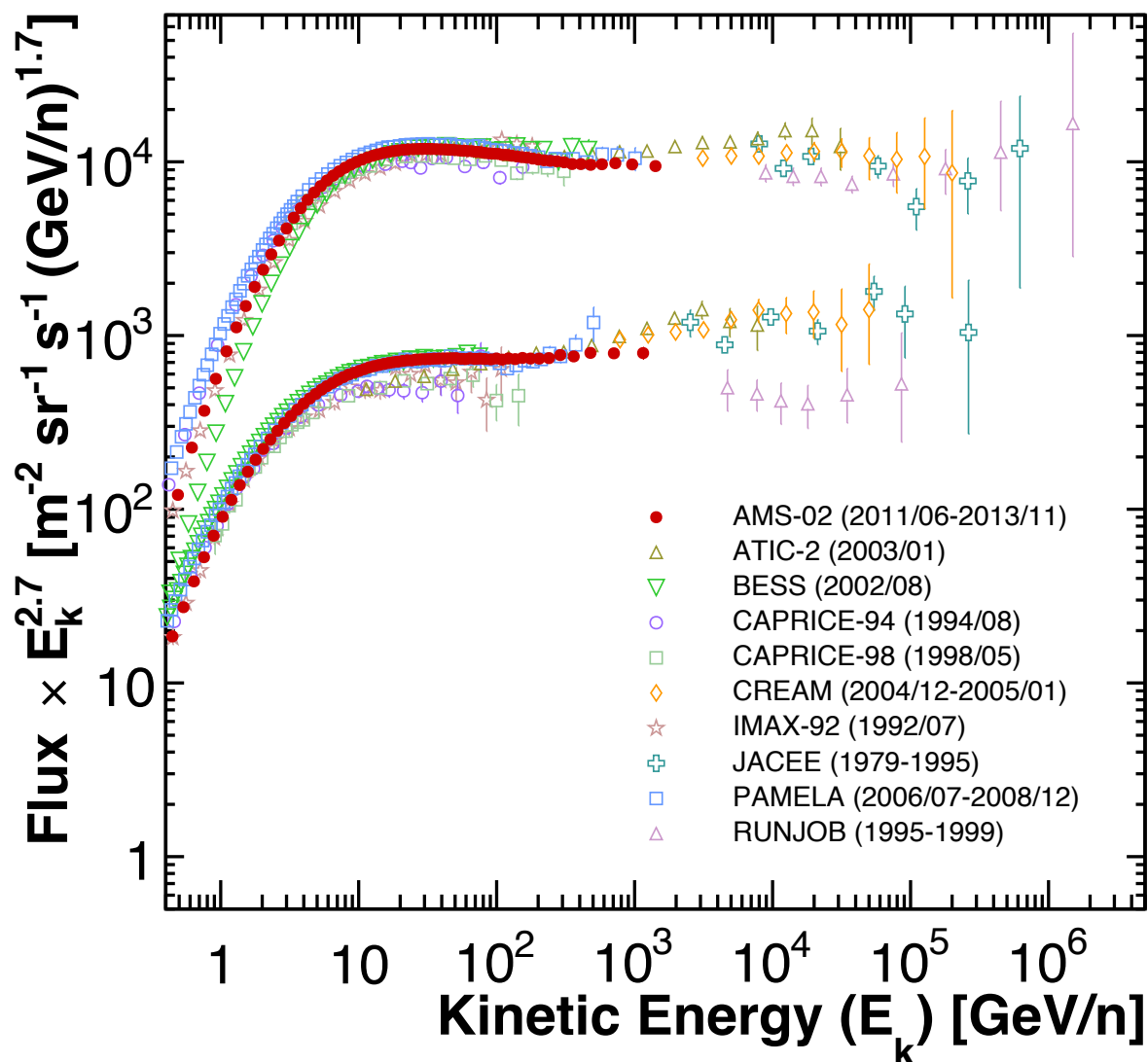
The accuracy of the AMS measurement challenges the current knowledge of cosmic background



Evoli, Grasso, Gaggero (2015)

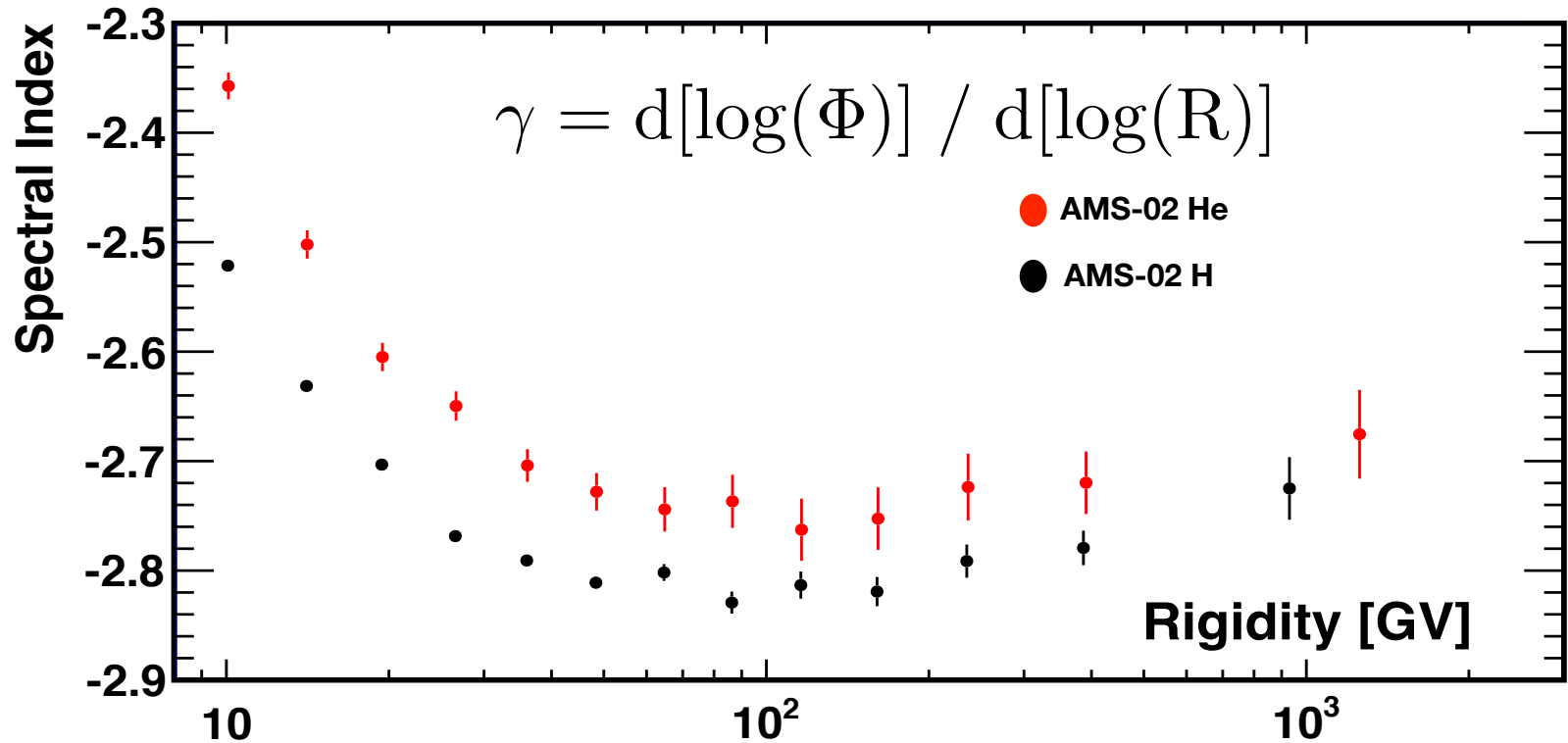
Upcoming measurements (in particular, from AMS-02 [1], CALET [54], and ISS-CREAM [49]) are expected to significantly improve our knowledge of propagation parameters and then to reduce the associated uncertainties. In that situation, antiproton production cross sections will prevent us to provide predictions for the astrophysical backgrounds as accurate as the forecasted sensitivities.

Proton and Helium Fluxes

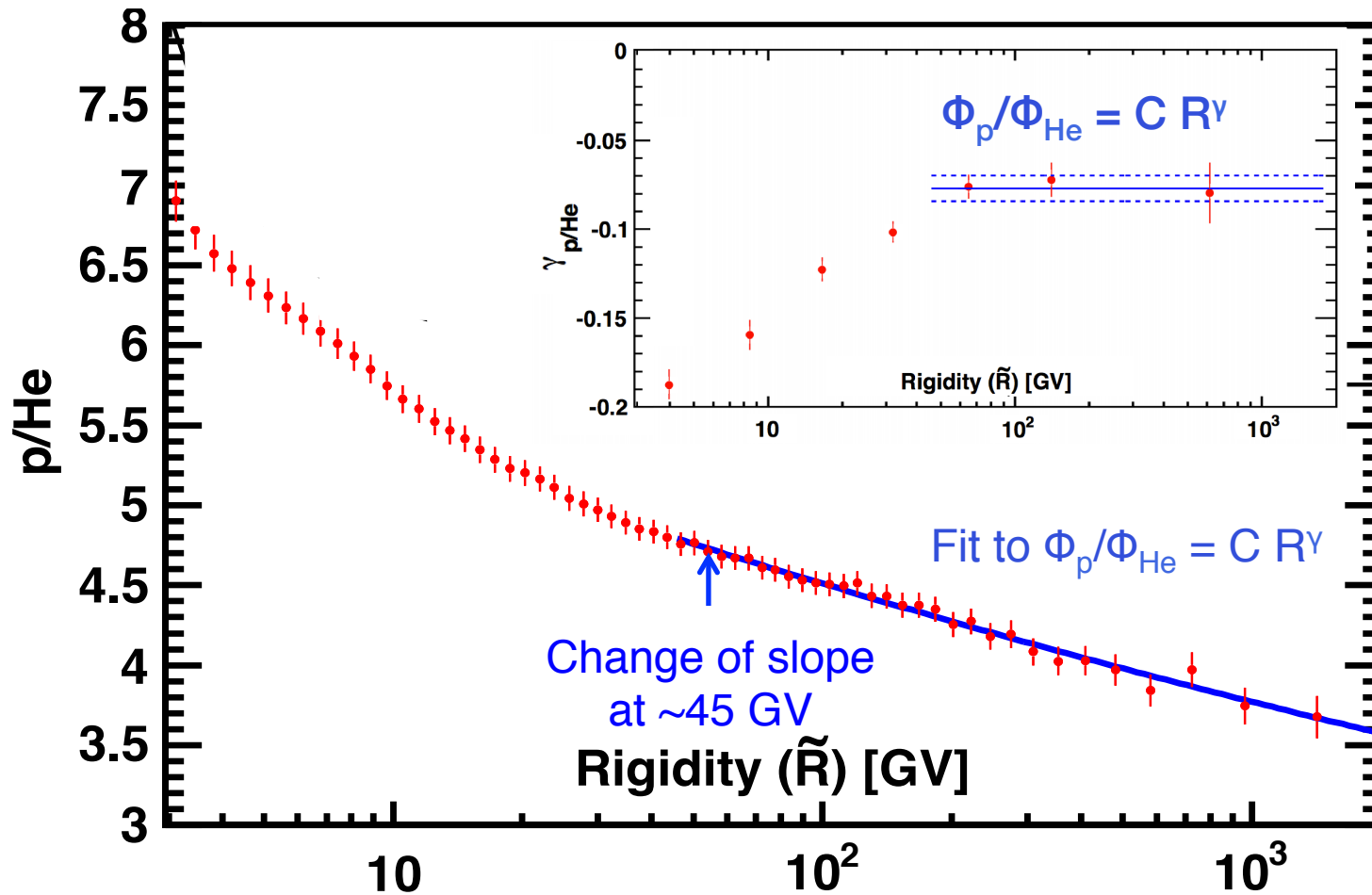


Proton and Helium Fluxes

Model independent spectral index analysis



Proton and Helium Fluxes



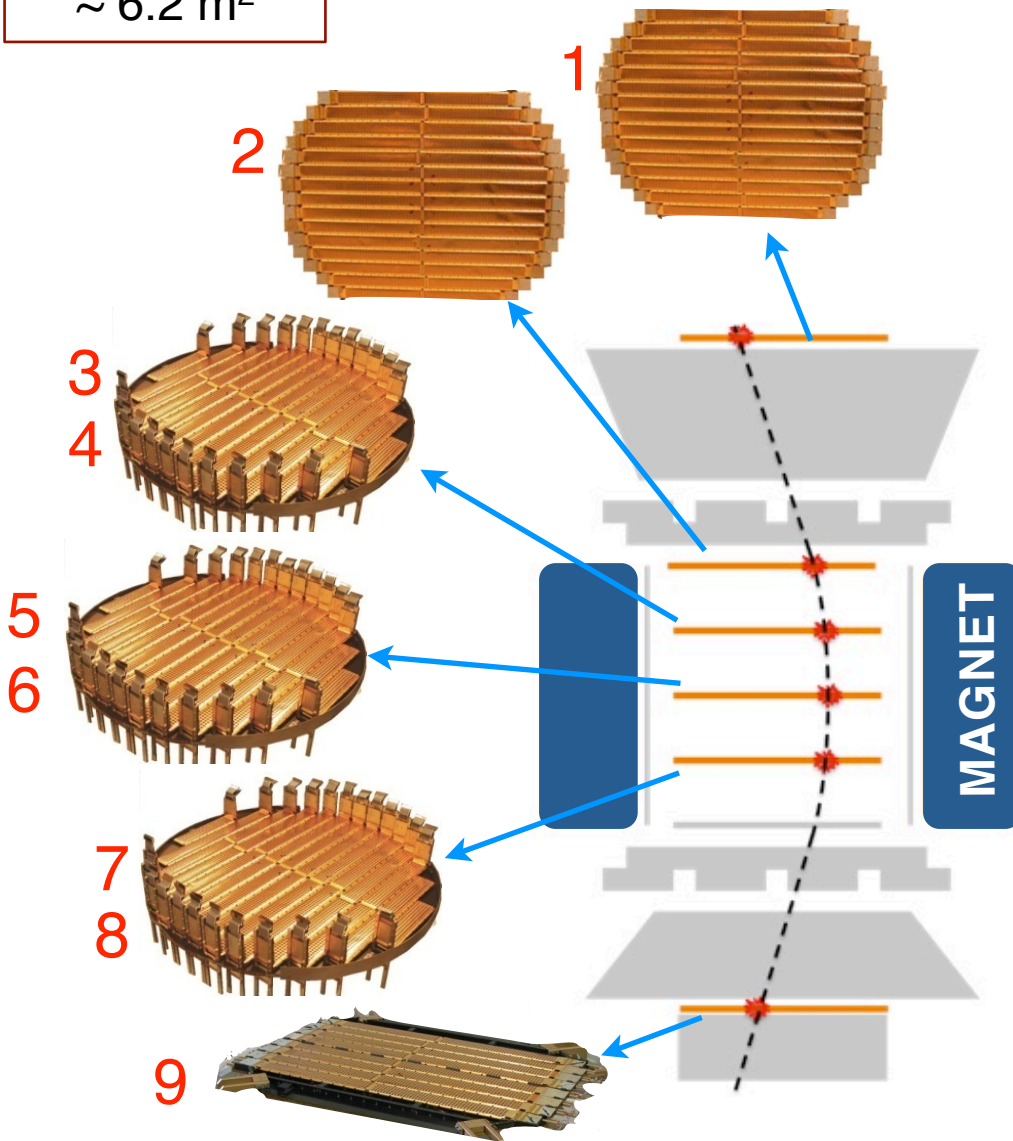
In 44 months, AMS has collected 60 billion cosmic rays.

This is much more than all the cosmic rays collected in the last 100 years.



AMS-02: Spettrometro magnetico

active area
 $\sim 6.2 \text{ m}^2$



Magnete Permanente:

- $B=0.15 \text{ T}$

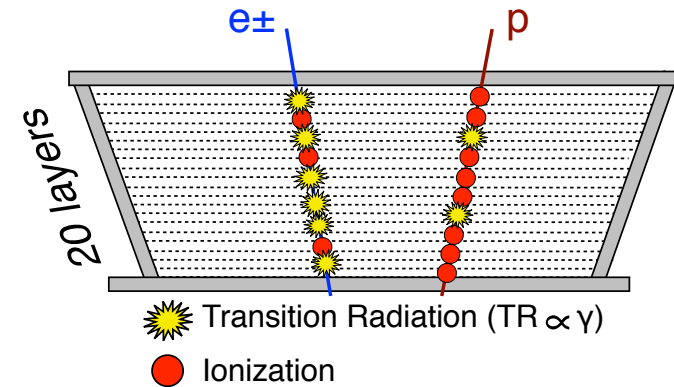
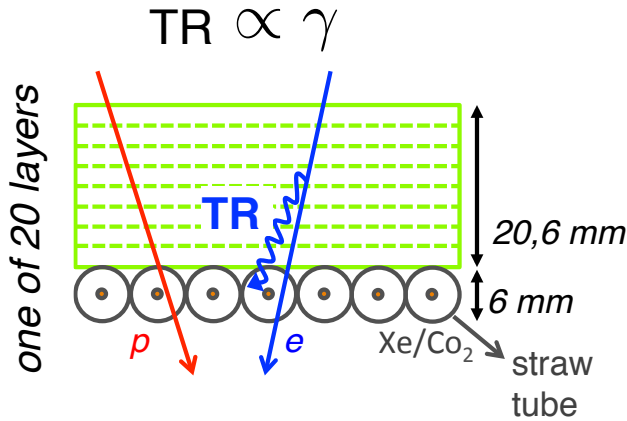
Tracciatore:

- 9 layers di microstrip di sensori al silicio a doppia faccia
- Accuratezza spaziale nella direzione di bending: $\sim 10 \mu\text{m}$

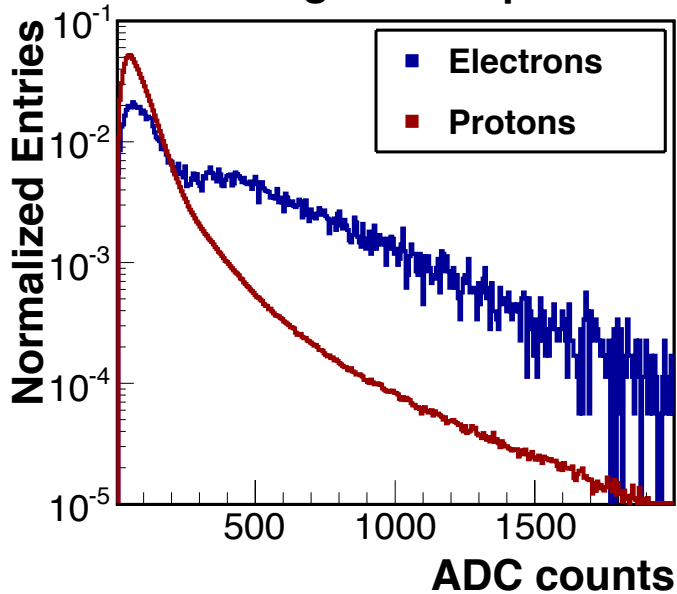
Scopo:

- *Misura della rigidità*
($R=p/q$) (MDR $\sim 2 \text{ TV}$)
- (+ToF) *Misura del segno della carica: **distinzione tra materia e anti-materia***
- *Misura della **carica** (dE/dx)*

20 layers di materiale radiante intervallati da piani di straw tube (90:10 Xe/Co₂)



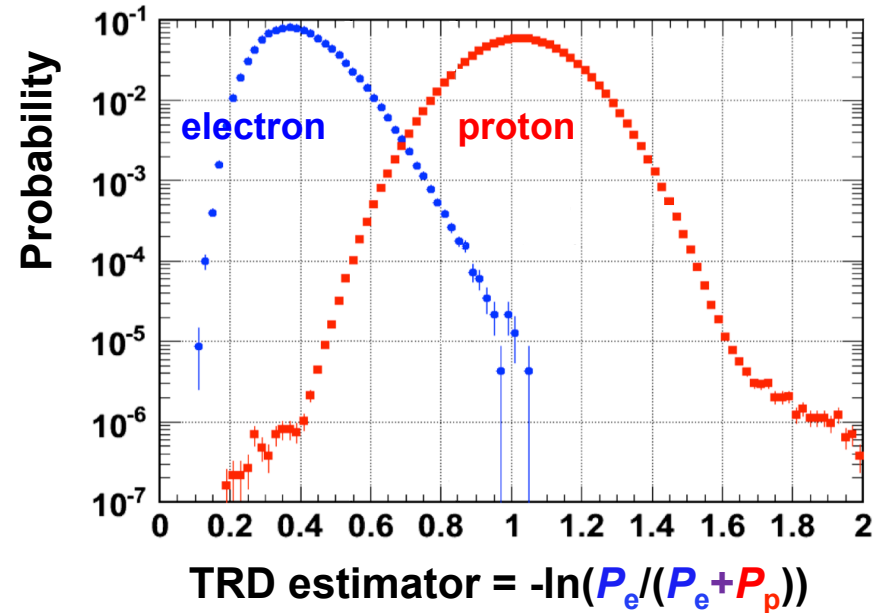
TRD - Single tube spectrum



su tutti i
20 layers:

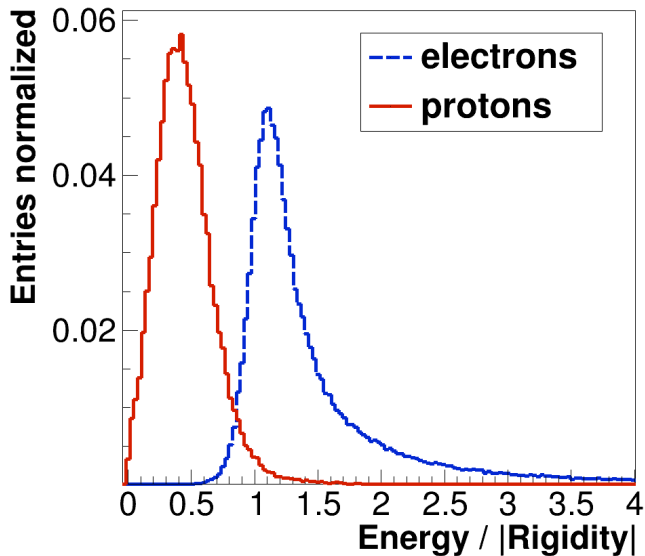
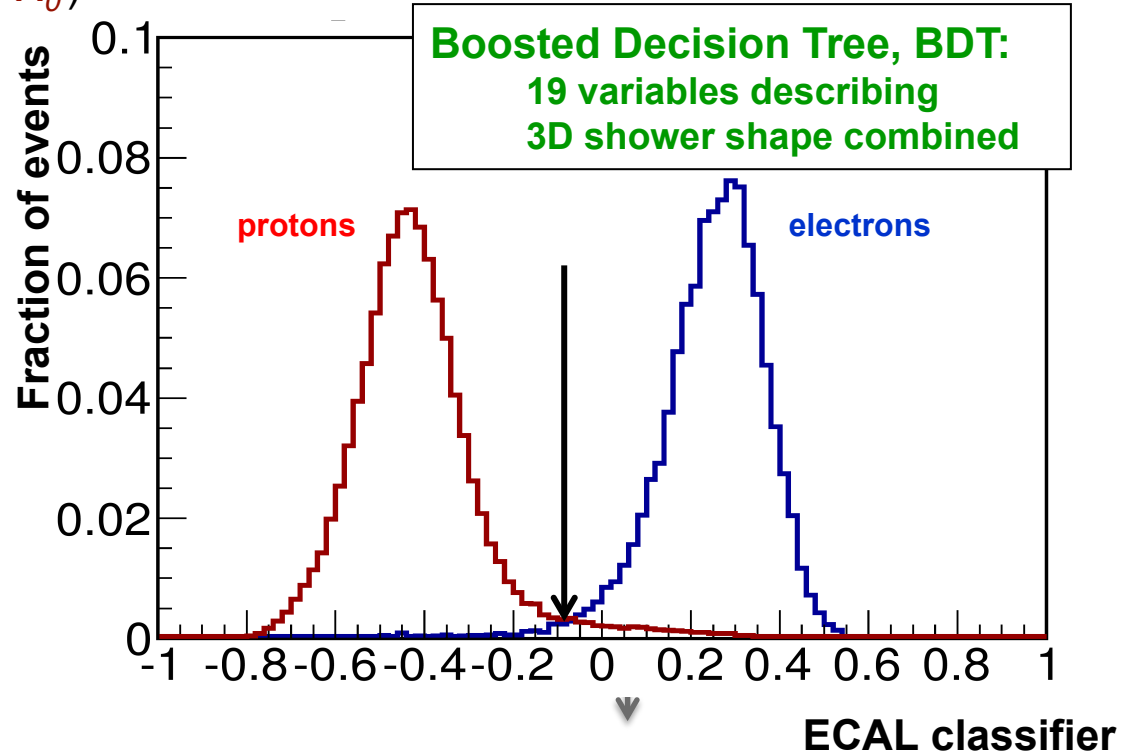
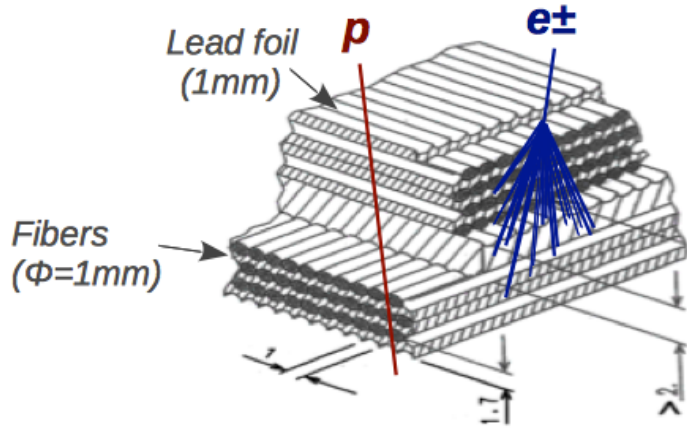
$$P_p = \sqrt[n]{\prod_i^n P_p^{(i)}(A)}$$

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



AMS-02: ECAL

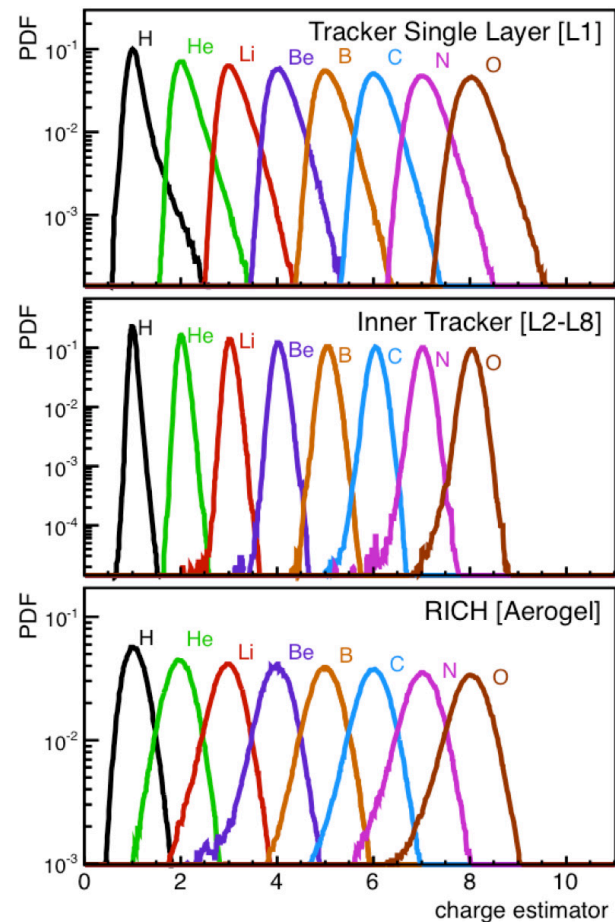
18 layers di piombo e fibre scintillanti ($\sim 17 X_0$)



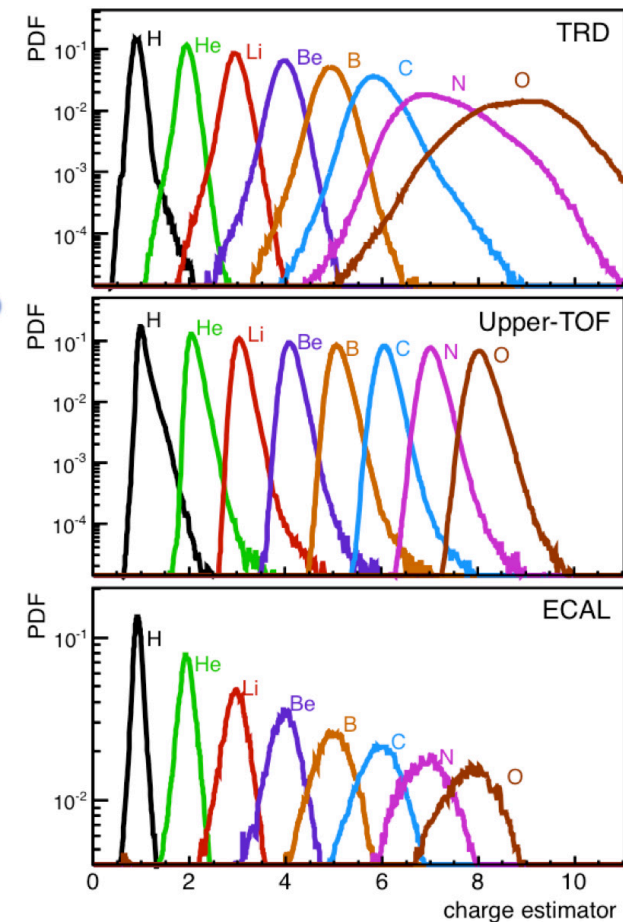
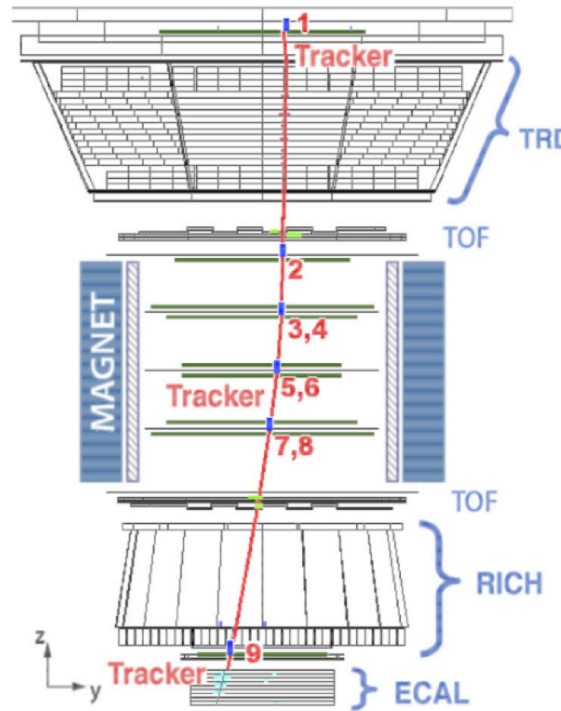
Grazie alle sue capacità di ricostruzione 3D degli sciami è possibile discriminare tra **sciame elettromagnetici e sciame adronici**

← **Combinando l'energia** misurata da ECAL con la **Rigidità** misurata dal Tracker (E/R) la **reiezione e/p** rejection può venire ulteriormente incrementata

AMS-02: Misura della carica



AMS-02 Charge Measurements of Light Cosmic-Ray Nuclei



Misure ridondanti della carica a differenti profondità lungo il rivelatore

→ Studio accurato della frammentazione dei nuclei nel materiale di AMS

TRD + ECAL + TRACKER:

