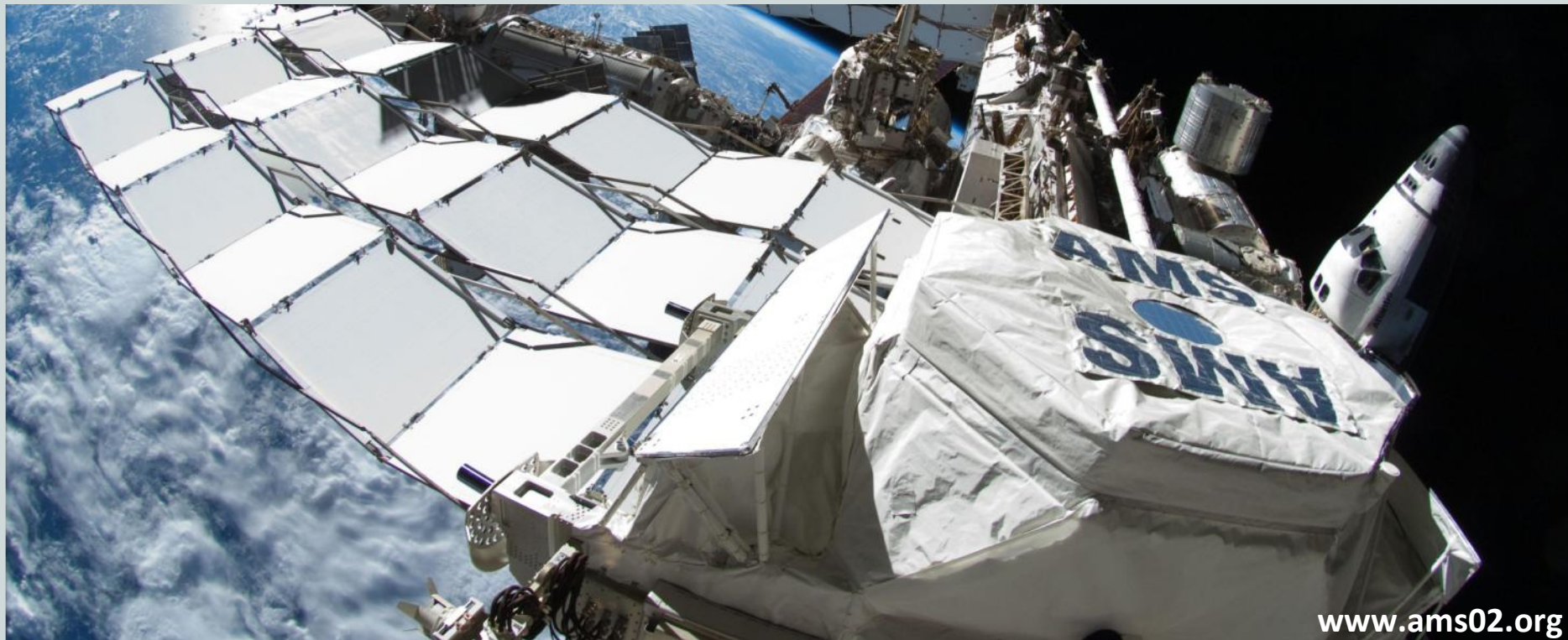




Risultati scientifici dell'esperimento AMS-02 dopo 6 anni in orbita sulla Stazione Spaziale Internazionale

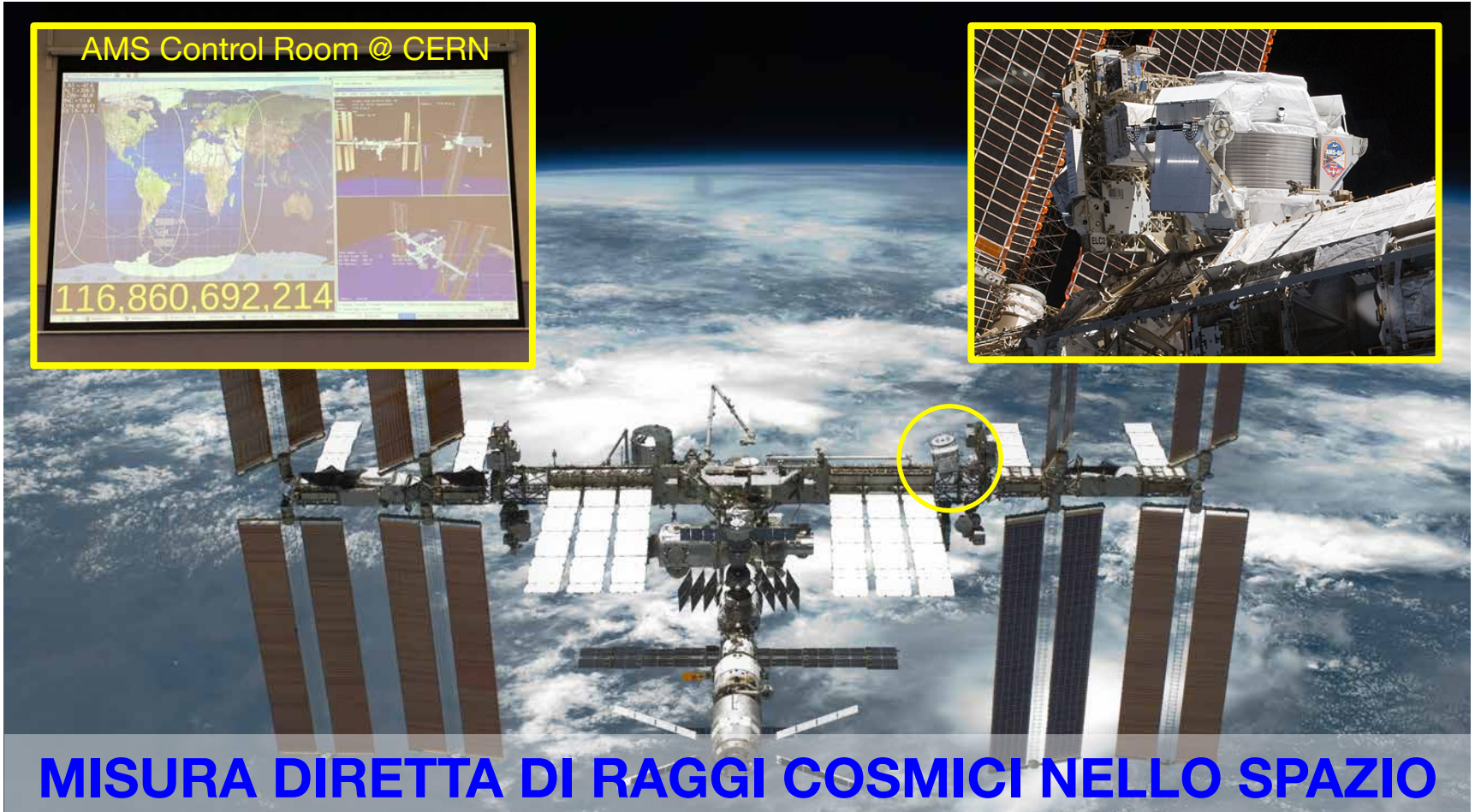
Valerio Vagelli **Università degli studi di Perugia - I.N.F.N. Perugia (IT)**
Incontri di Fisica delle Alte Energie – IFAE 2018, Milano





AMS-02 sulla ISS

In orbita da più di 6 anni



MISURA DIRETTA DI RAGGI COSMICI NELLO SPAZIO

- **Ricerca indiretta di Materia Oscura (e^{\pm} , anti-p,....)**
 - **Ricerca di antimateria primordiale (anti-He)**
- **Composizione dei raggi cosmici (H, He, Li, B, C, ...)**



AMS: spettrometro a energie TeV



TRD

Riv. di radiazione di transizione



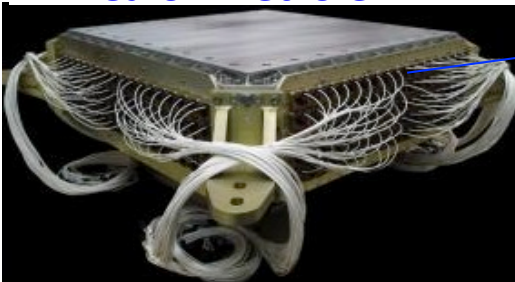
TRK

Tracciatore



ECAL

Calorimetro e.m.

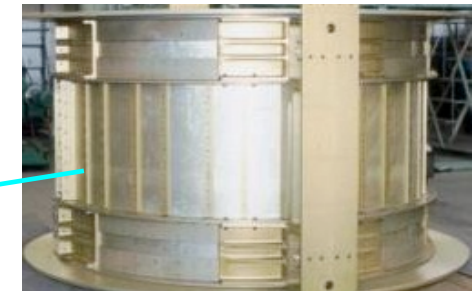


TOF

Tempo di volo

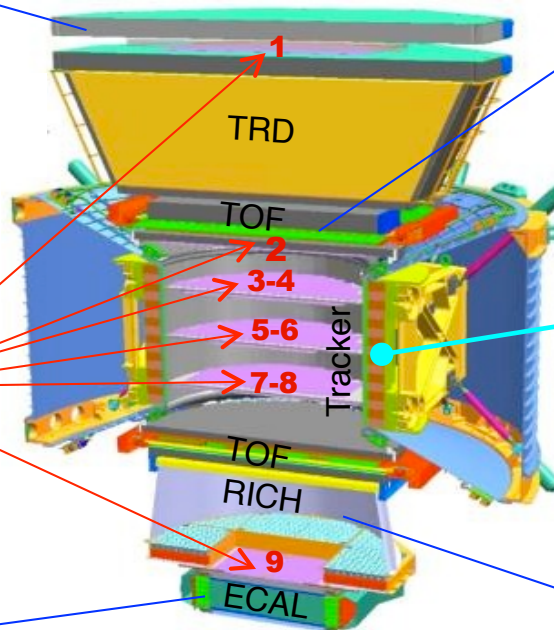
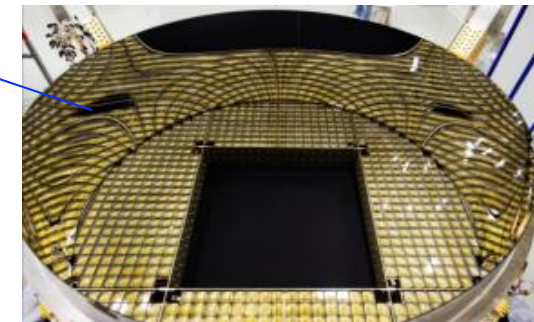


MAGNETE



RICH

Riv. Cherenkov ad anello

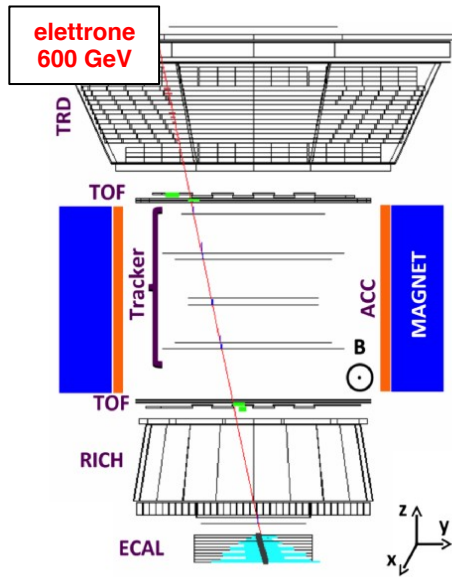




AMS: spettrometro a energie TeV



Identificazione precisa delle proprietà dei RC con **misure multiple e ridondanti dei diversi sottorivelatori**



	e^+	e^-	p	\bar{p}	He	$\bar{\text{He}}$
TRD 20 piani						
TOF 4 piani						
TRK 9 piani						
RICH						
ECAL 18 piani						

separazione e/p
carica ($|Z|$)

trigger
velocità (β)
carica ($|Z|$)

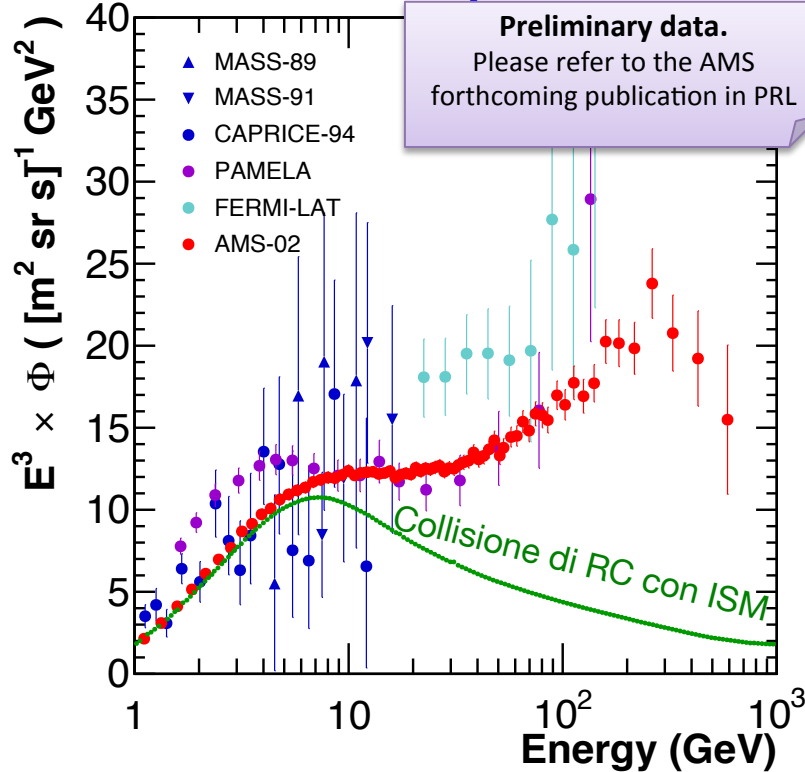
rigidità (p/Q)
segno ($\pm Q$)
carica ($|Z|$)

velocità (β)
carica ($|Z|$)

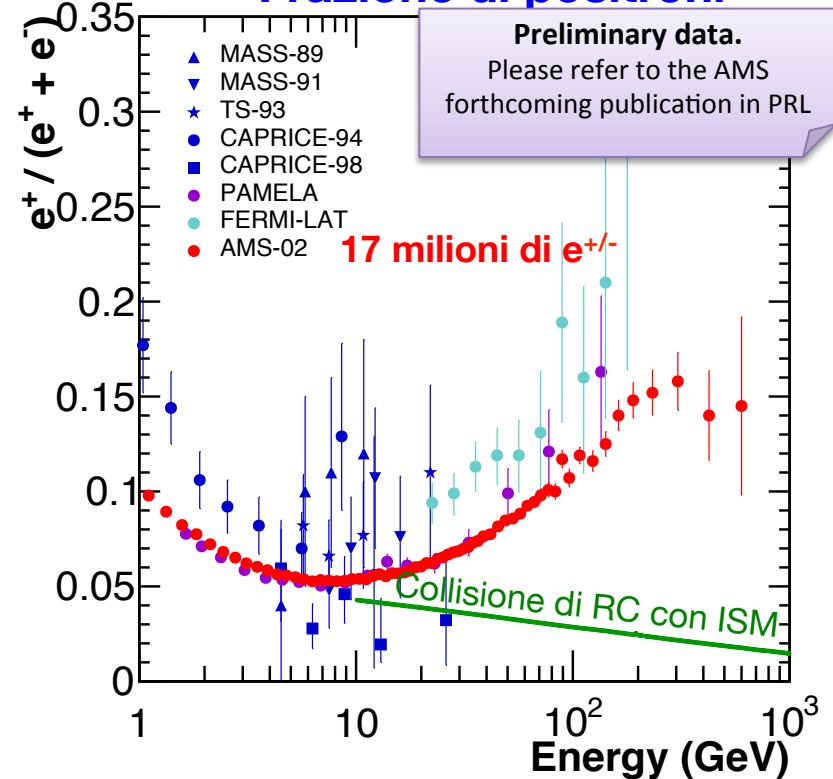
energia e^\pm
separazione e/h
misura fotoni

Antimateria: positroni

Flusso di positroni



Frazione di positroni



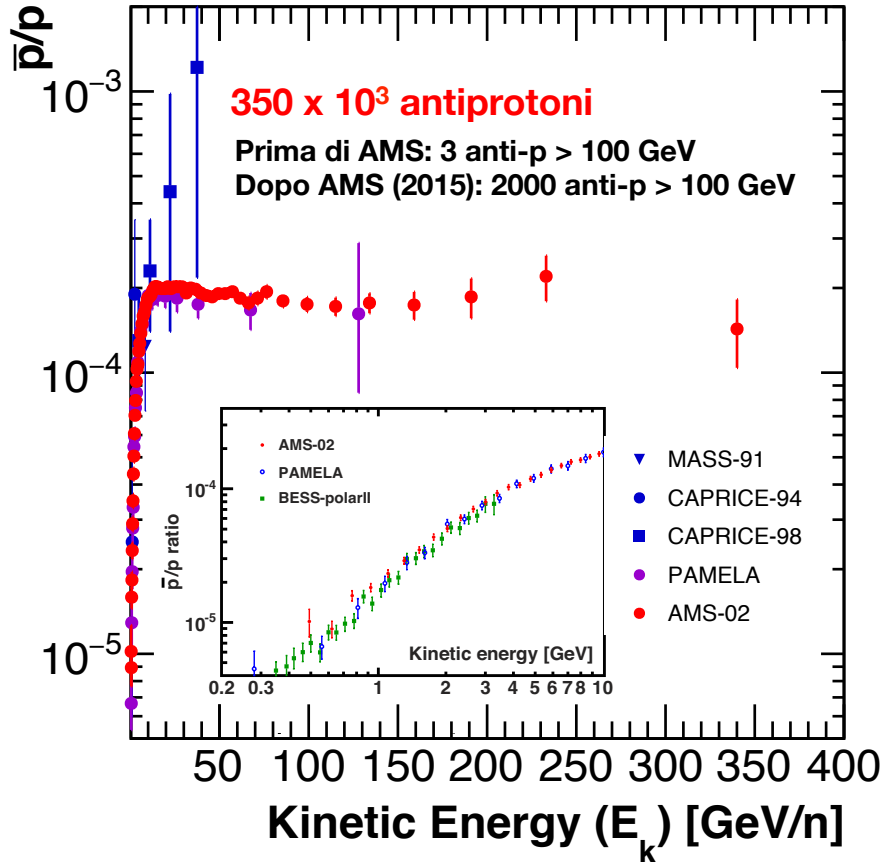
Eccesso di positroni: sorgente aggiuntiva di $e^{+/-}$

- Annichilazione Materia Oscura?
- Produzione coppie e^+/e^- in sorgenti astrofisiche?
 - Meccanismi di propagazione?



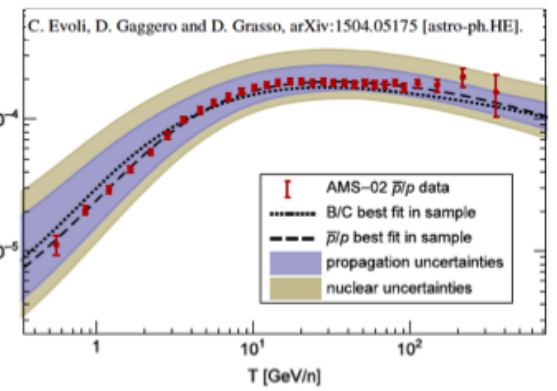
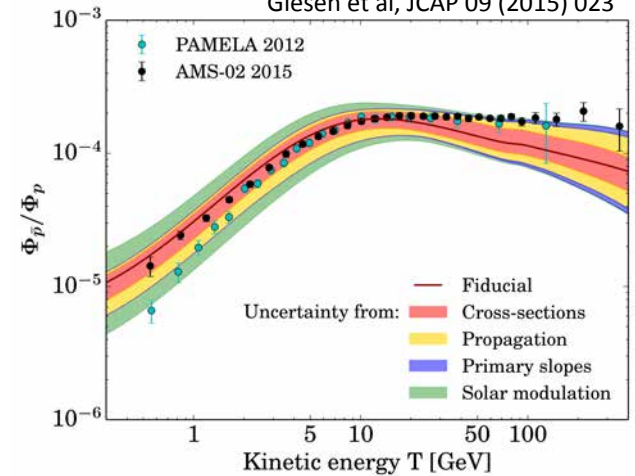
Antimateria: antiprotoni

Phys. Rev. Lett. 117, 091103



1103

Giesen et al, JCAP 09 (2015) 023

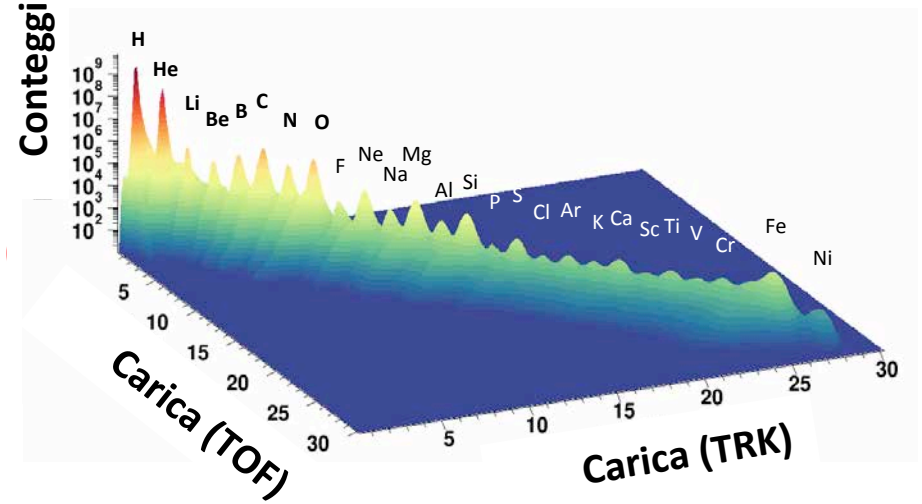
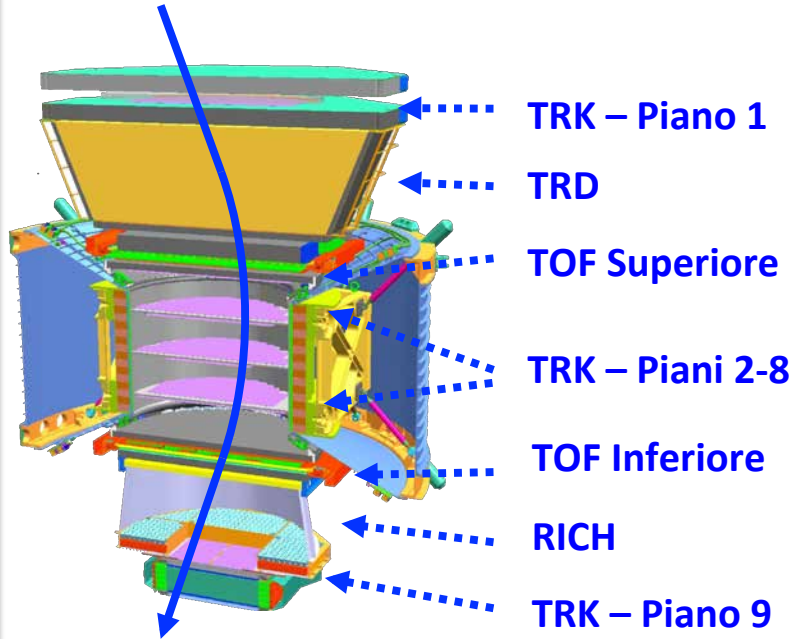


Misura al limite delle predizioni senza contributo Materia Oscura

Incertezze teoriche dominanti:

- **Meccanismi di propagazioni dei RC**
 - **Sezioni d'urto di produzione**
- **Fisica solare, propagazione in eliosfera**

Misura di carica



Carica campionata a diverse profondità del rivelatore

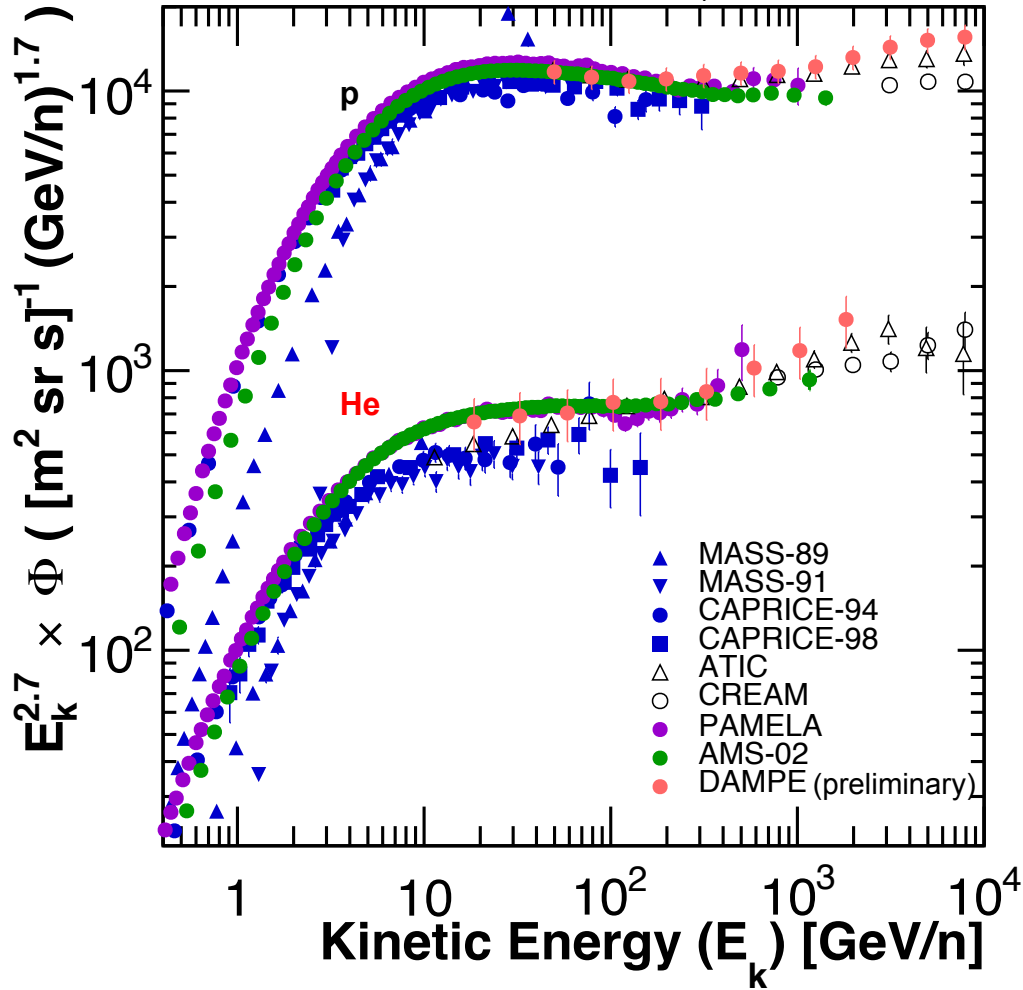
Misura “diretta” della contaminazione dovuta alla frammentazione delle specie nucleari pesanti

Controllo e verifica delle incertezze sistematiche

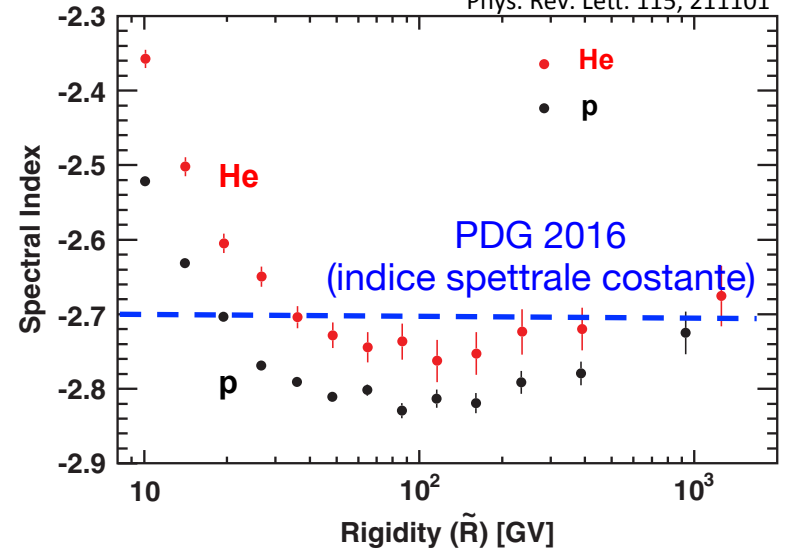


Protoni e Nuclei di Elio

Phys. Rev. Lett. 114, 171103
Phys. Rev. Lett. 115, 211101



Phys. Rev. Lett. 115, 211101



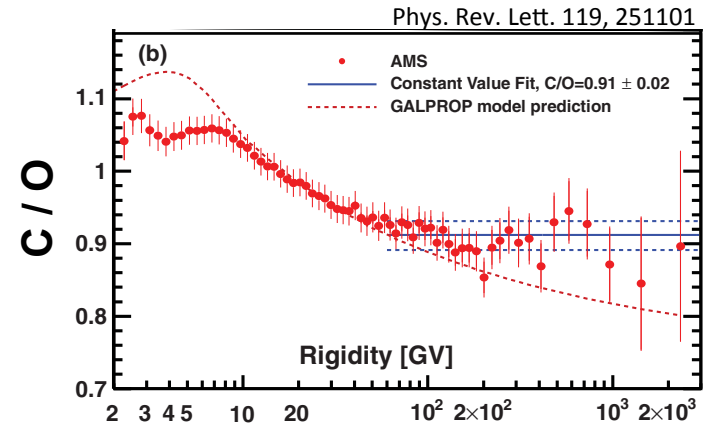
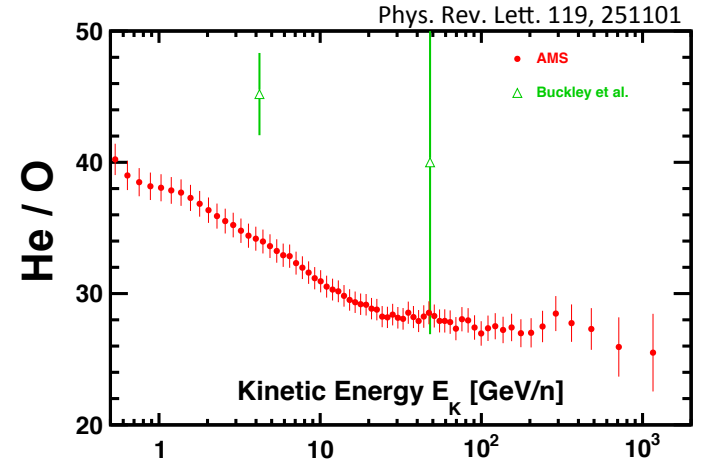
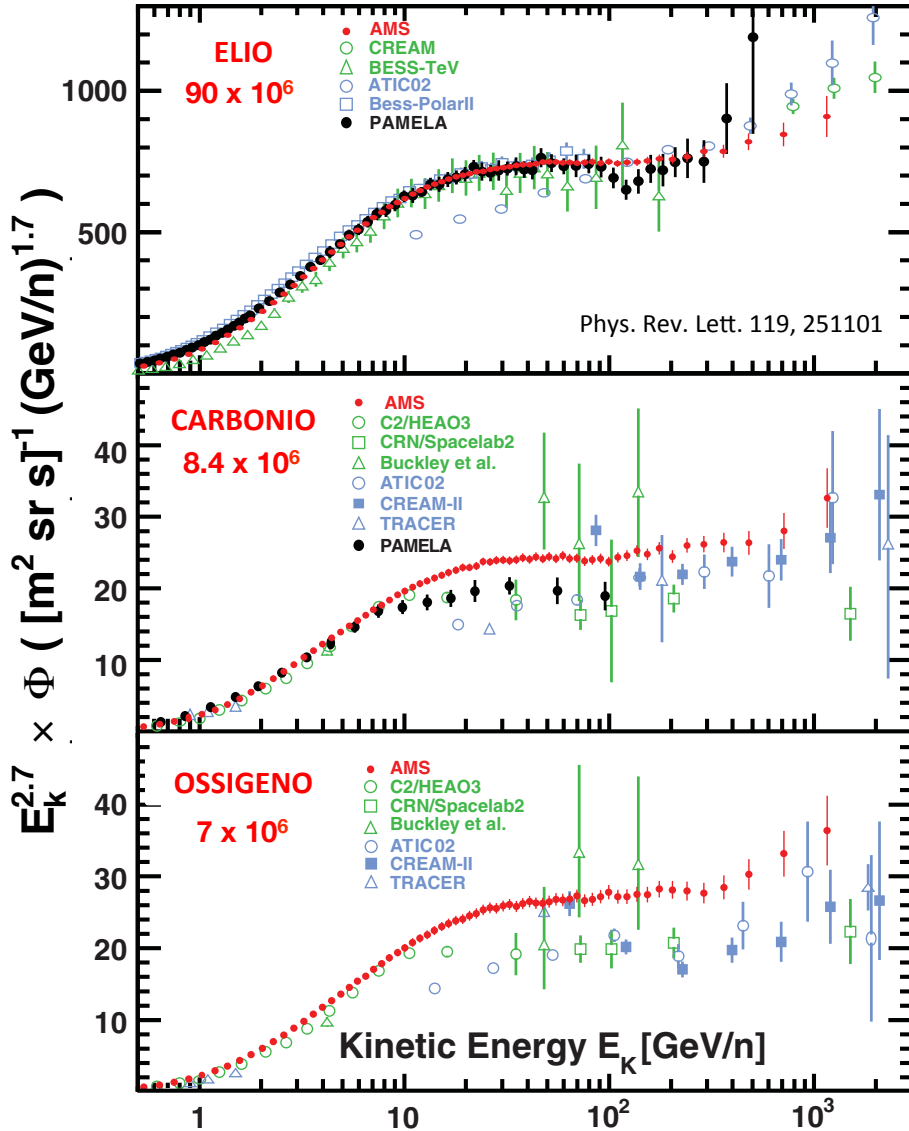
**Indurimento dello spettro
sopra 200 GV**

- Nuove sorgenti?
- Meccanismi di propagazione?



RC Primari: He-C-O

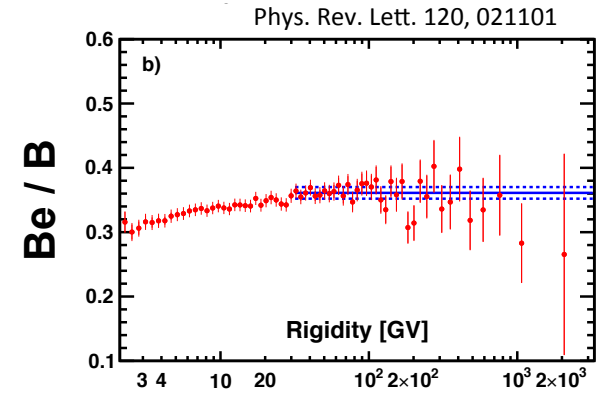
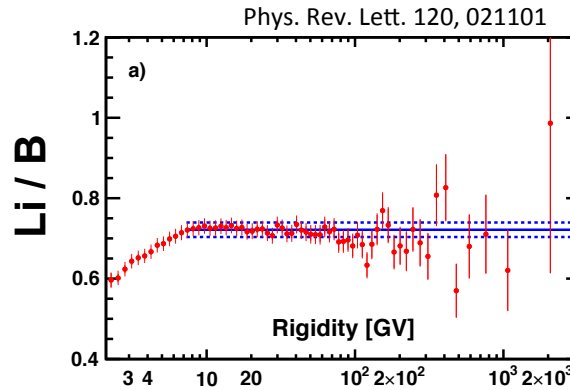
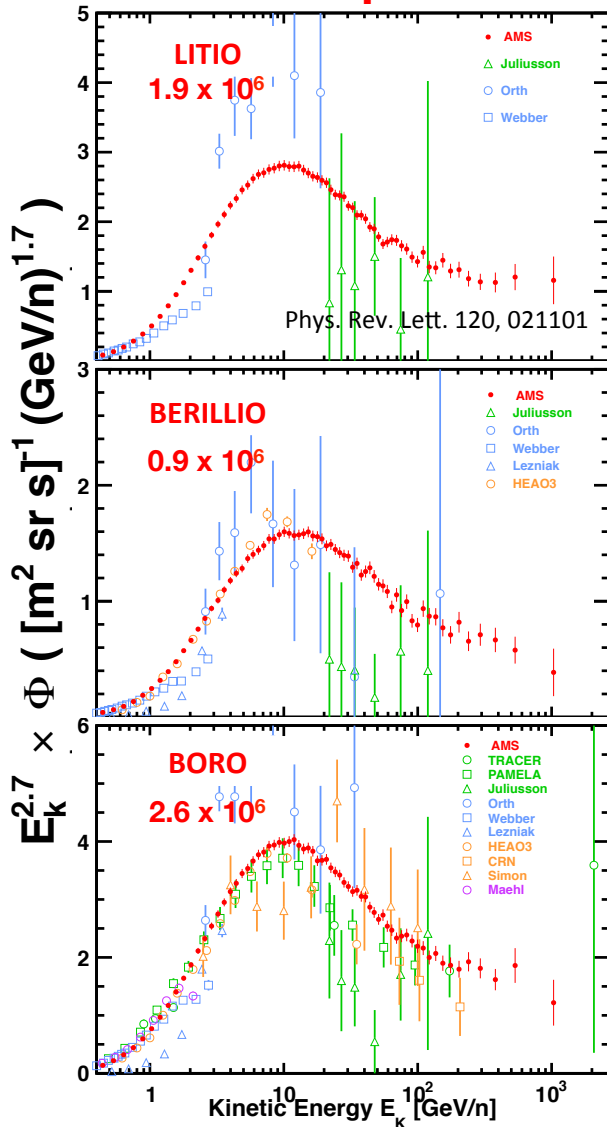
5 anni di presa dati



Indurimento dello spettro in comune a c.a. 200 GV. Stessa dipendenza spettrale sopra 60 GV.

RC Secondari: Li-Be-B

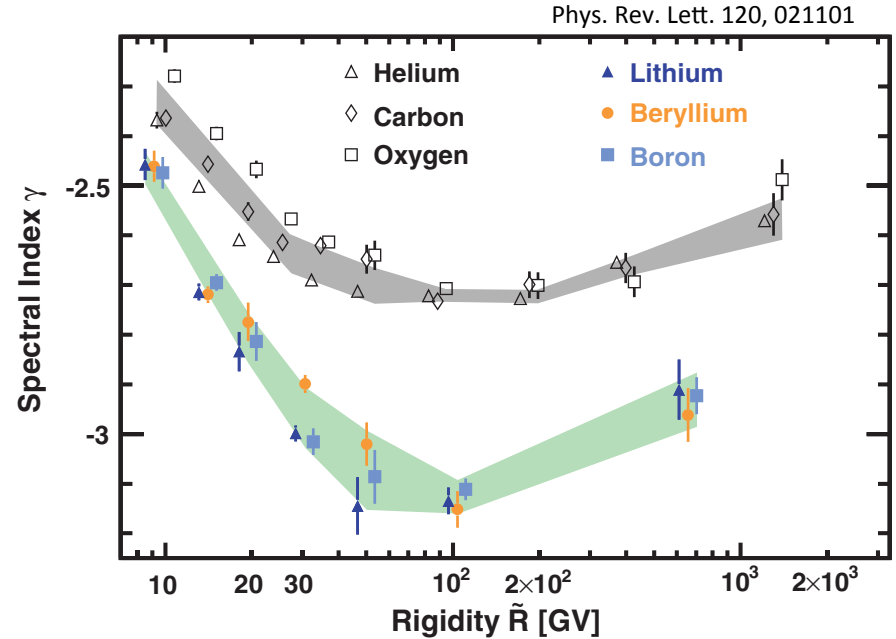
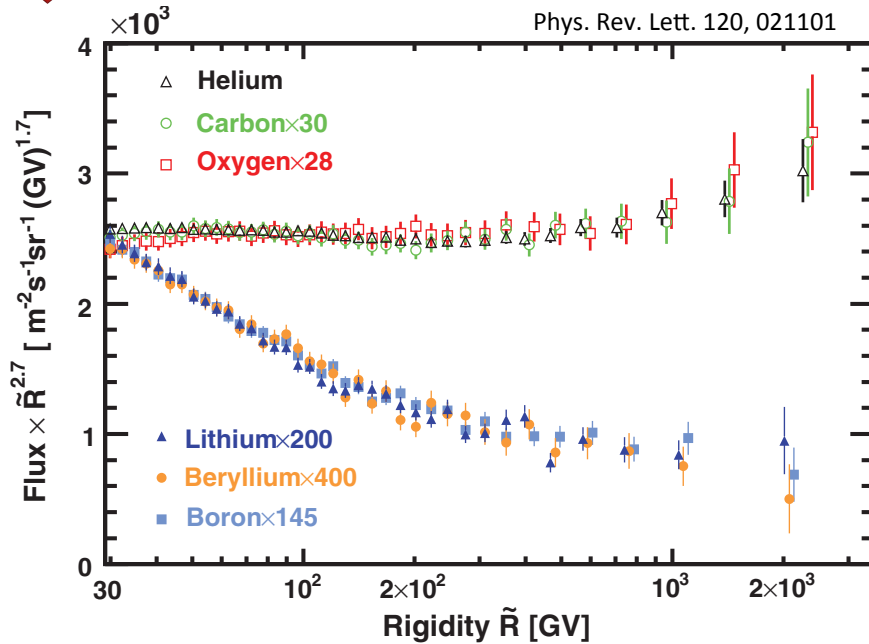
5 anni di presa dati



Indurimento dello spettro in comune a c.a. 200 GV. Stessa dipendenza spettrale sopra 30 GV.

Dipendenza spettrale per RC primari e secondari: studio dei meccanismi di propagazione dei RC

RC Primari e Secondari

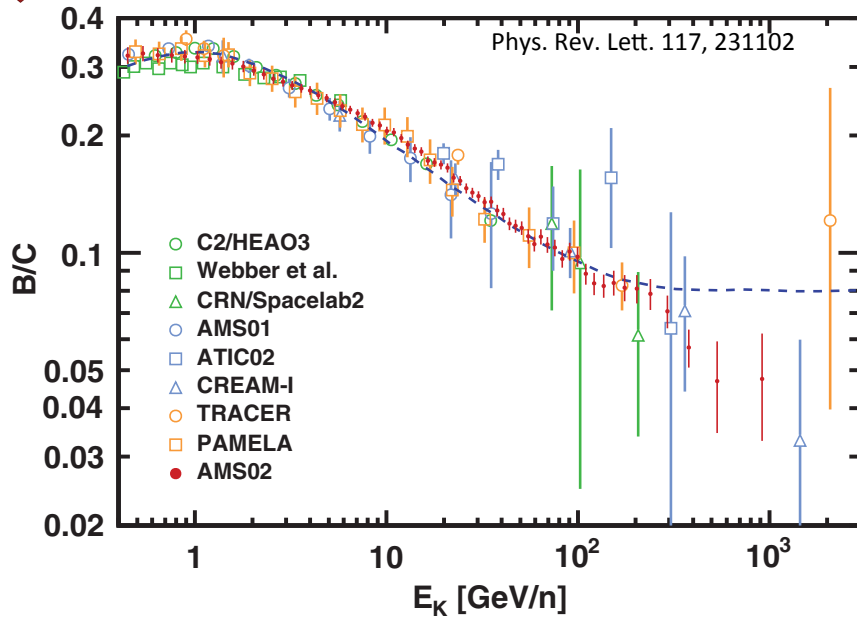


Indurimento dello spettro in comune tra primari e secondari, ma diversa dipendenza spettrale.

Favoriti i modelli in cui l'indurimento dello spettro è dovuto a variazioni nel coefficiente di diffusione.

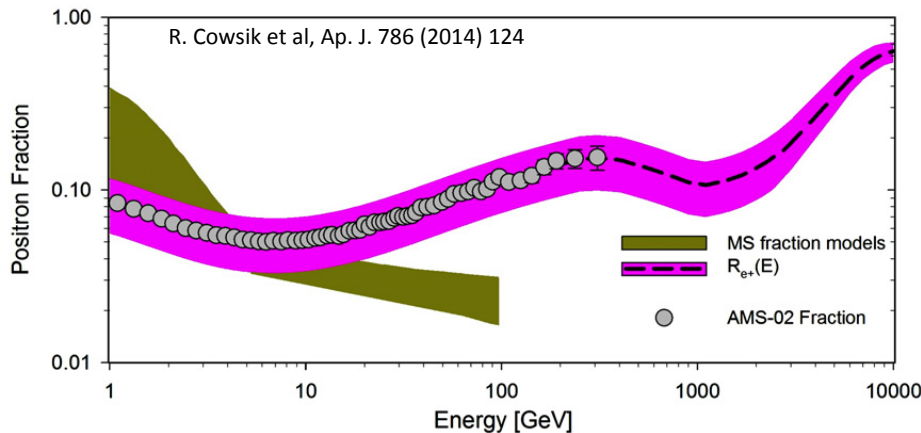


RC Primari e Secondari

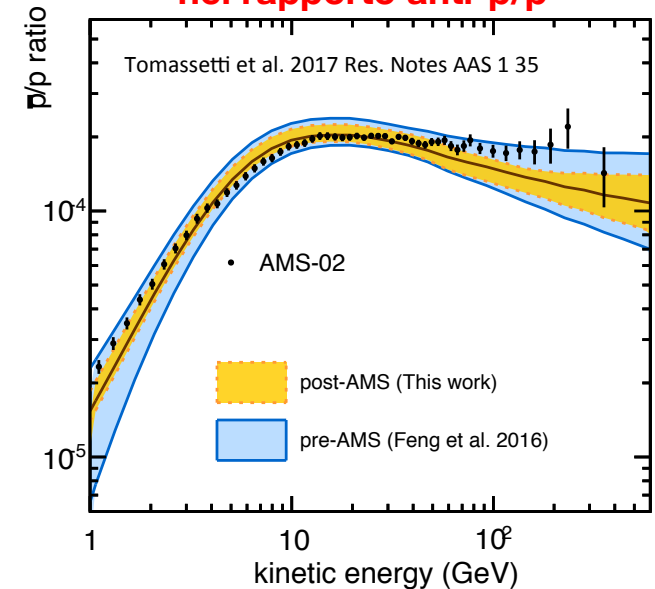


**Rapporto Secondari/Primari
pone vincoli sulla propagazione
(diffusione/interazioni) dei RC
nella galassia**

**Sfavorisce modelli con produzione in eccesso di e^+ in
interazioni con mezzo interstellare**



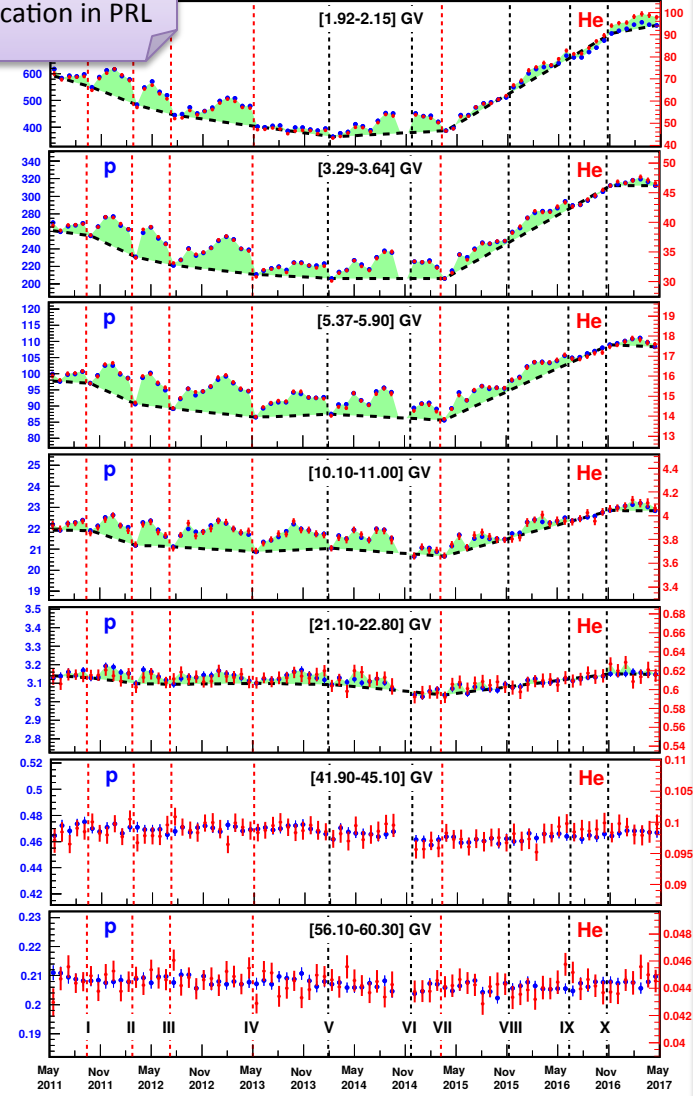
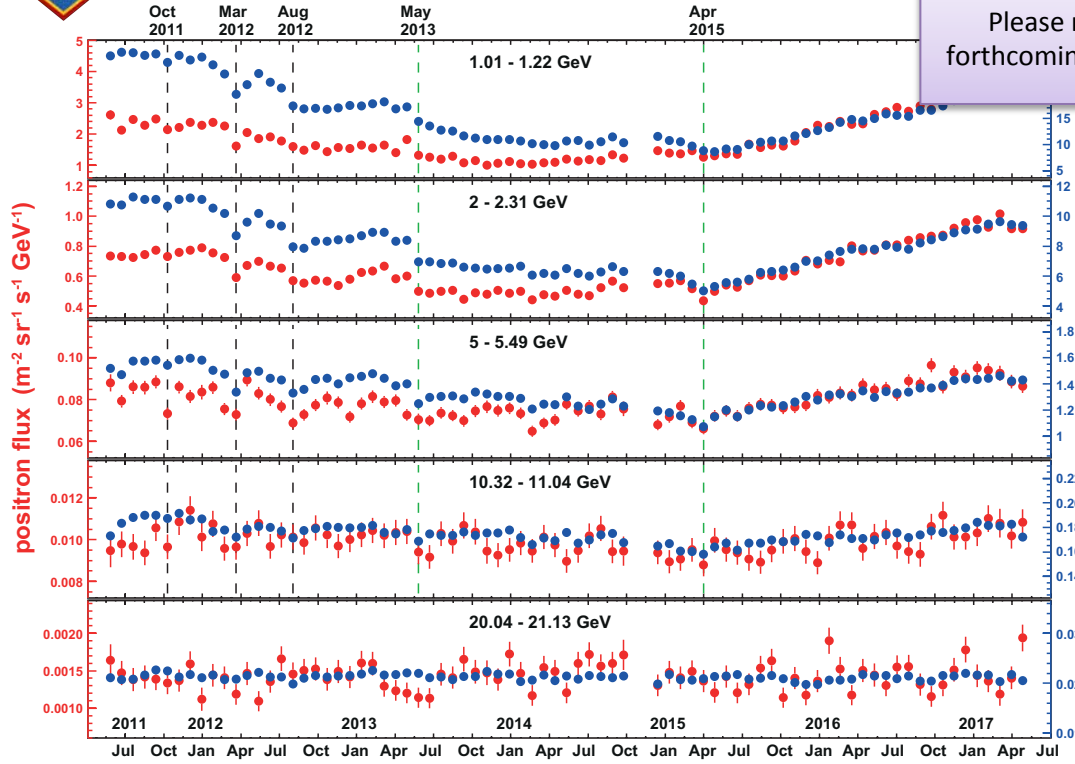
**Riduzione delle incertezze astrofisiche
nel rapporto anti-p/p**





Variazioni Temporali

Preliminary data.
Please refer to the AMS
forthcoming publication in PRL

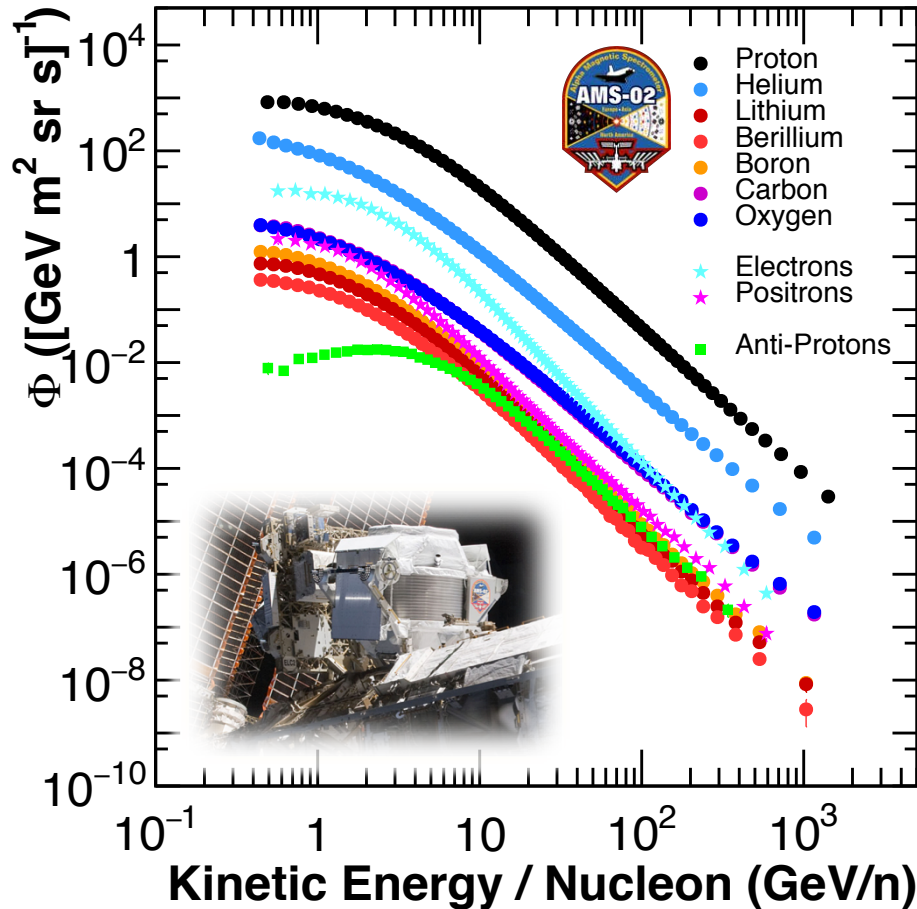


Analisi dettagliata della variazione temporale dei raggi cosmici su corta e lunga scala e transienti

(Poster: S. Della Torre, Misure di precisione sulle variazioni temporali del flusso di raggi cosmici con AMS-02)



Stato attuale (2018)



Misure di precisione del flusso di raggi cosmici e rapporti materia/antimateria nell'intervallo [GeV-TeV]

elettroni, positroni, antiprotoni e nuclei fino all'ossigeno.

Misure sperimentali con incertezze tipicamente inferiori a quelle dei modelli di origine e propagazione.

Misure complementari e aggiornamenti con maggiore statistica per investigare origine e propagazione dei RC

LAVORI IN CORSO: Flusso di azoto (componente primaria + secondaria), abbondanze di isotopi ($^3\text{He}/^4\text{He}$, $^2\text{H}/^1\text{H}$, ...), anisotropia, antimateria nucleare, ...

(Presentazione: F. Dimiccoli, Misure di deuterio e ^3He con AMS-02)

AMS ha inaugurato un'epoca di misure di precisione dei raggi cosmici necessarie per poter comprendere la dinamica nell'ambiente galattico e l'origine delle abbondanze di antimateria.

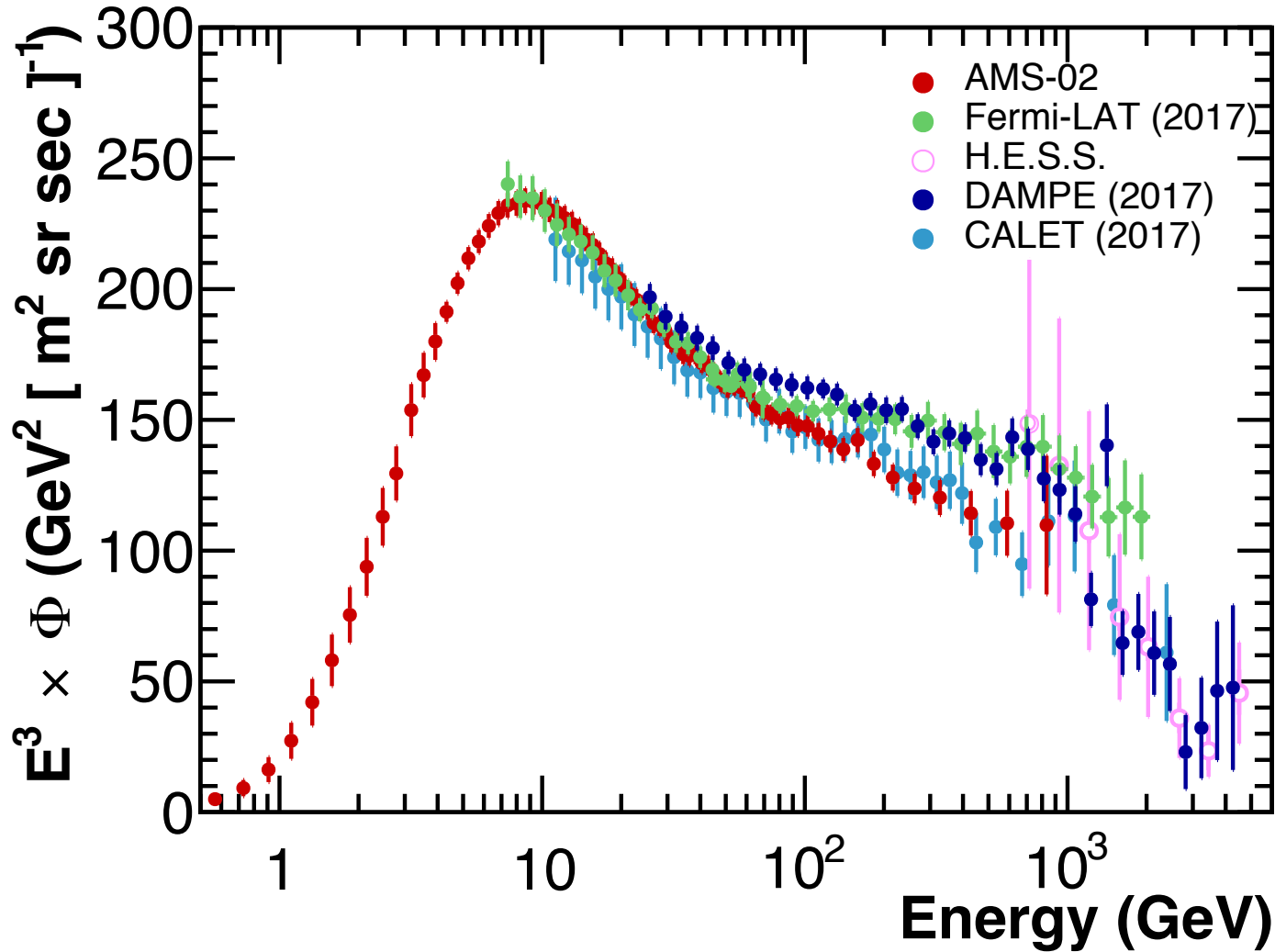
Il rivelatore è completamente attivo e continuerà a raccogliere dati fino alla fine della missione ISS.

Il meglio deve ancora venire!



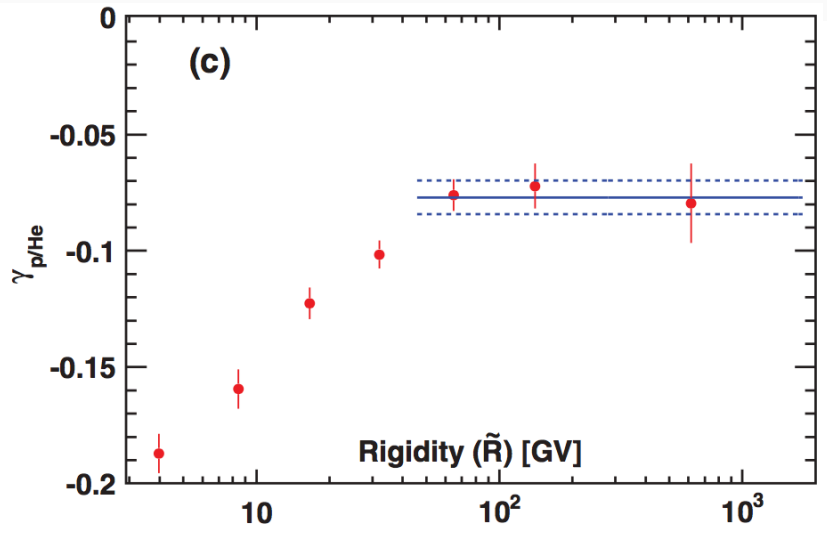
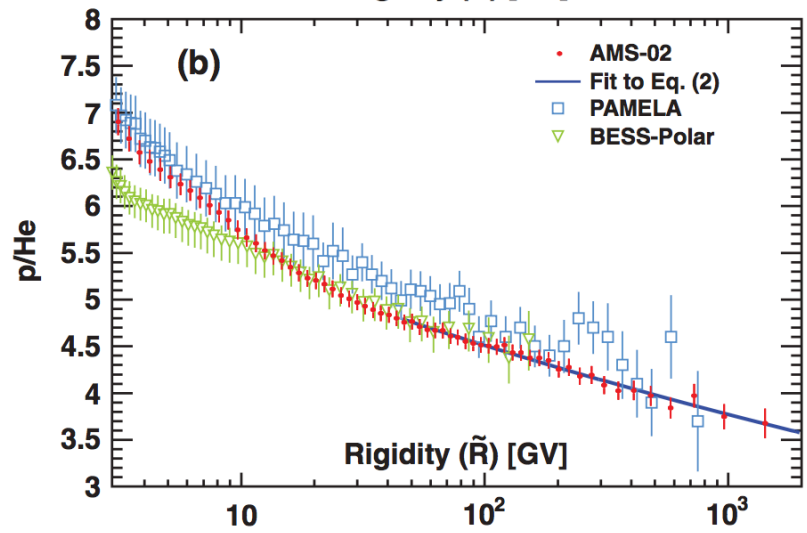
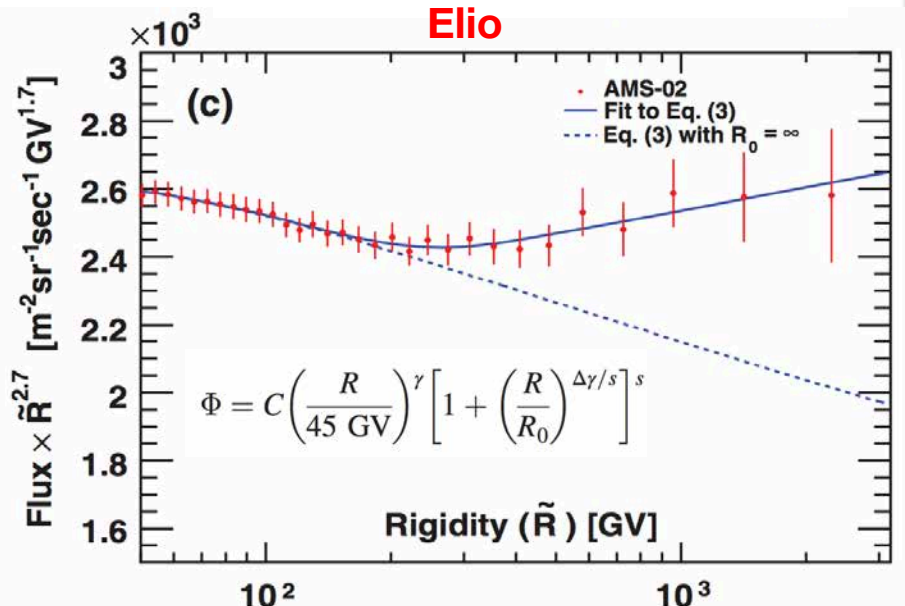
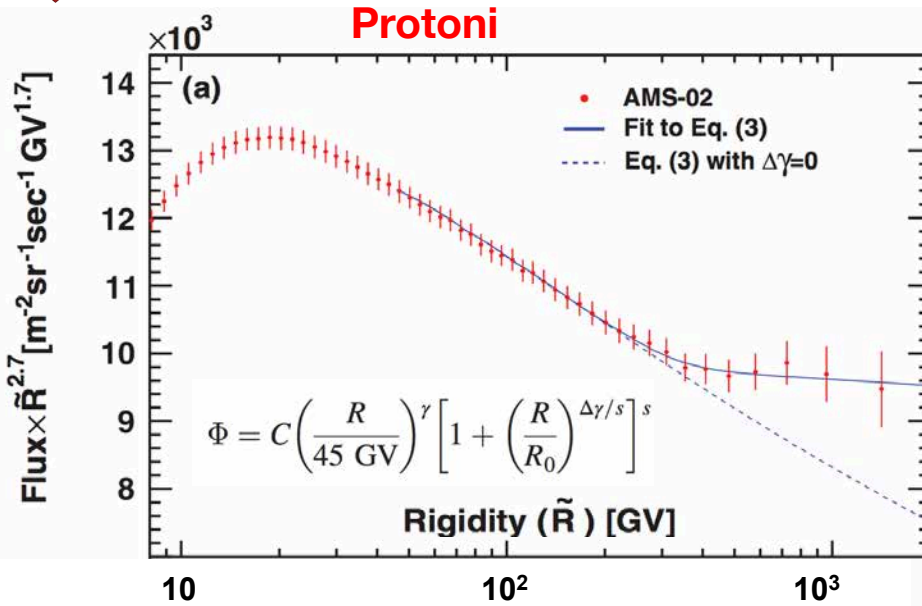


(e^+e^-) : Stato attuale

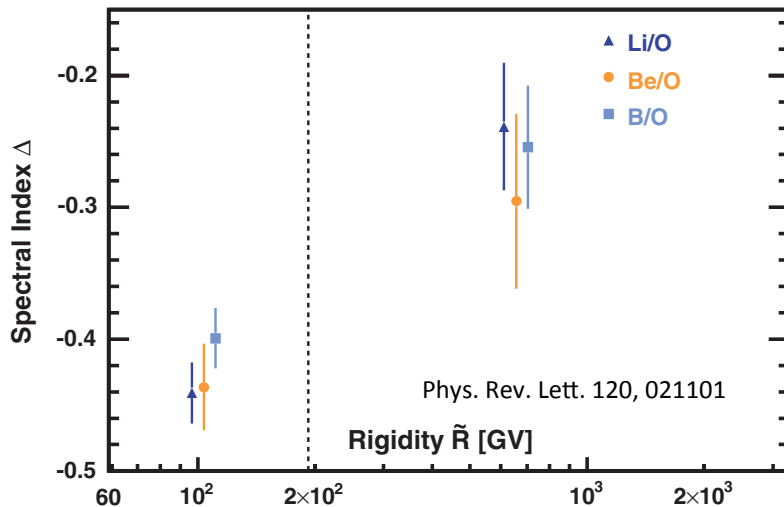
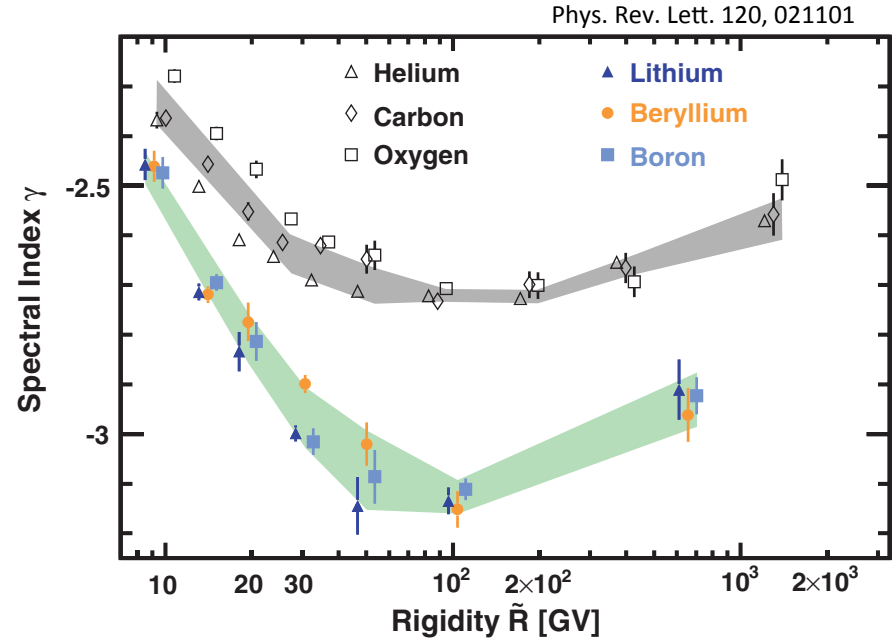
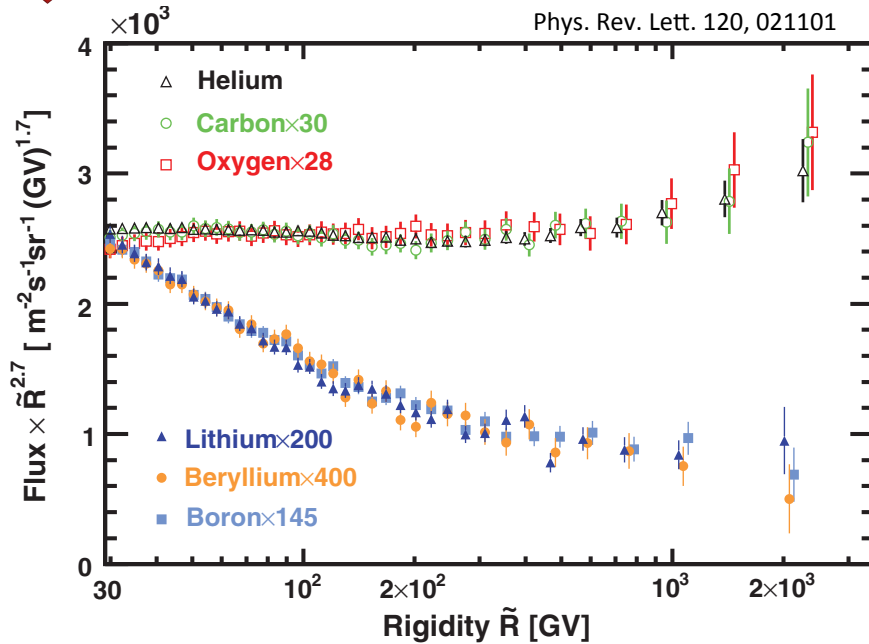




Protoni e Elio



RC Primari e Secondari



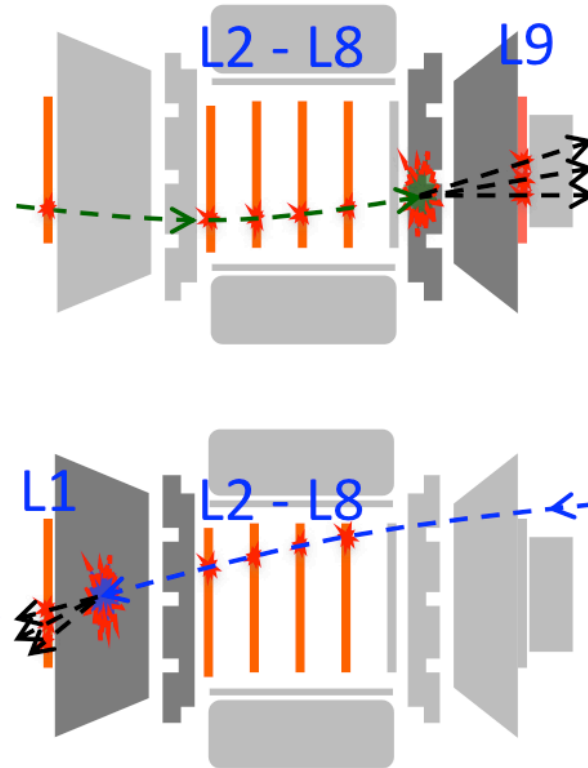
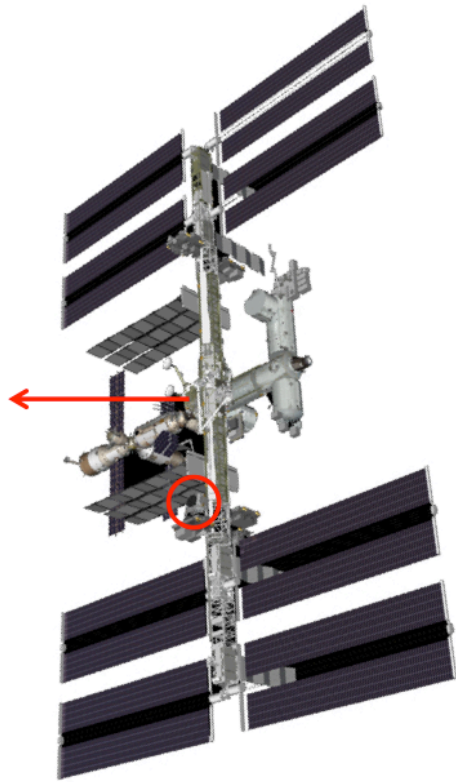
Indurimento dello spettro in comune tra primari e secondari, ma diversa dipendenza spettrale.

Favoriti i modelli in cui l'indurimento dello spettro è dovuto a variazioni nel coefficiente di diffusione.



Misura diretta delle interazioni

Measuring the interactions of nuclei within AMS AMS horizontal

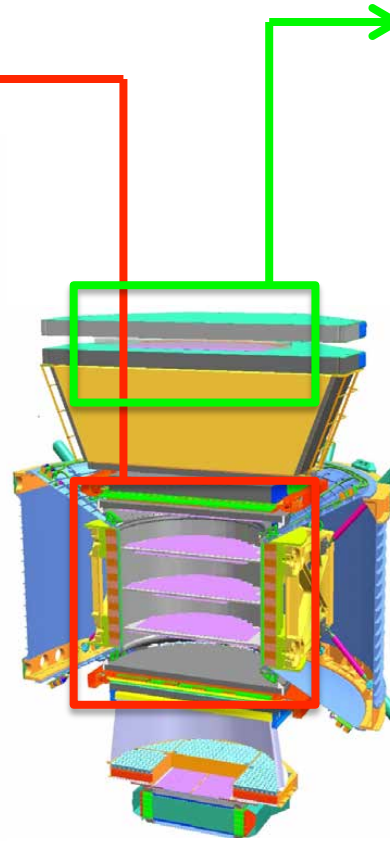
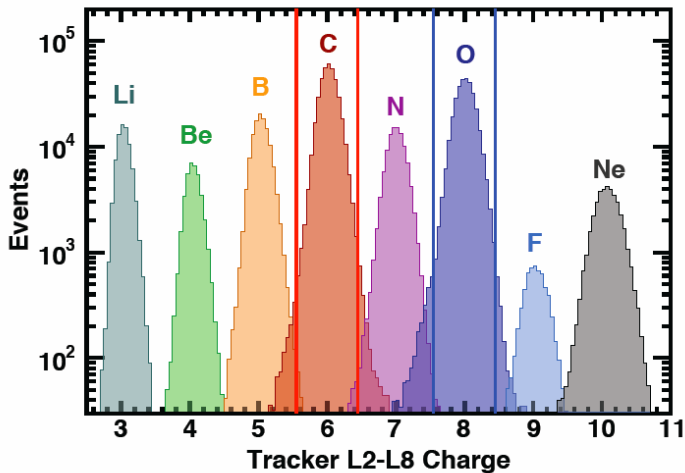
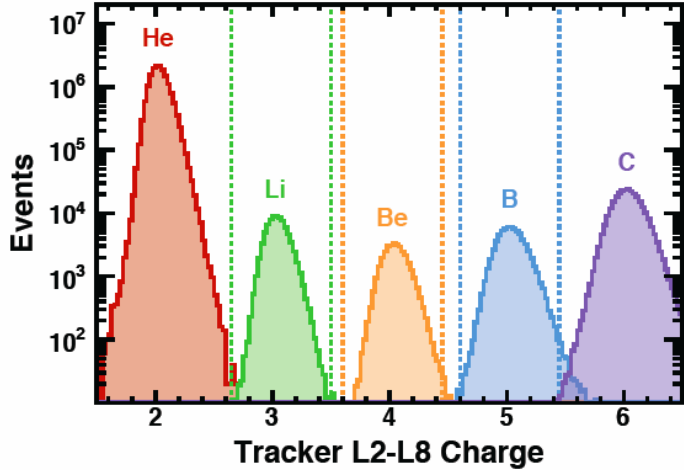


First, we use the seven inner tracker layers, L2-L8, to define beams of nuclei: Li, Be, B, ...

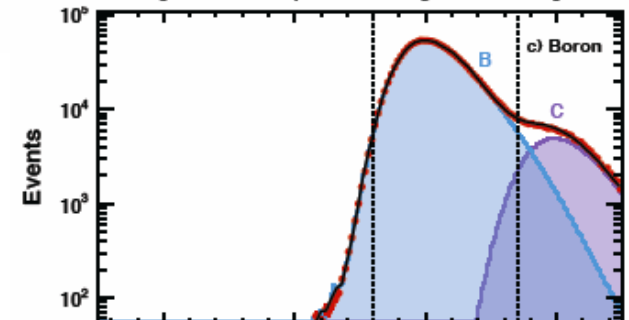
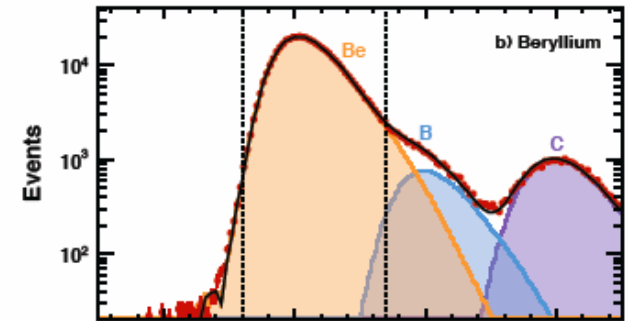
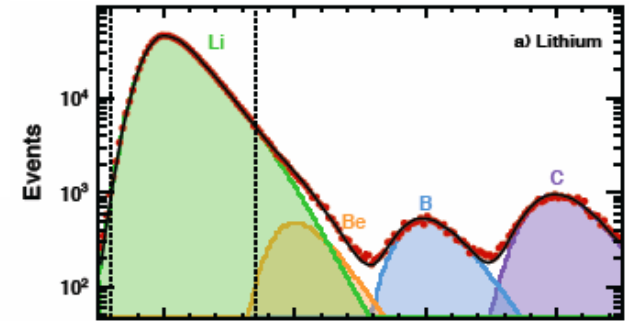
Second, we use left-to-right particles to measure the nuclear interactions in the lower part of the detector.

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

Selezione del campione con TRK – Piani 2-8



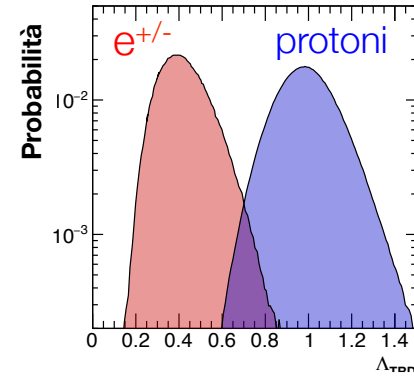
Verifica delle frammentazioni con TRK – Piano 1



Identificazione di $e^{+/-}$

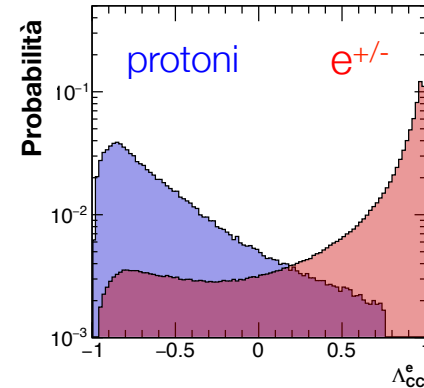
TRD

Rad. di transizione
 identificazione $e^{+/-}$



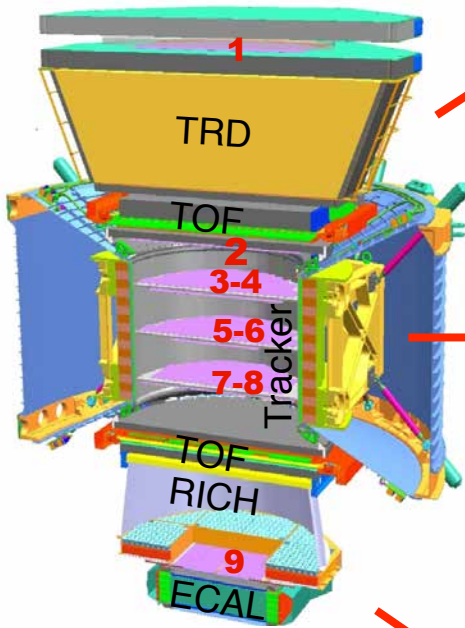
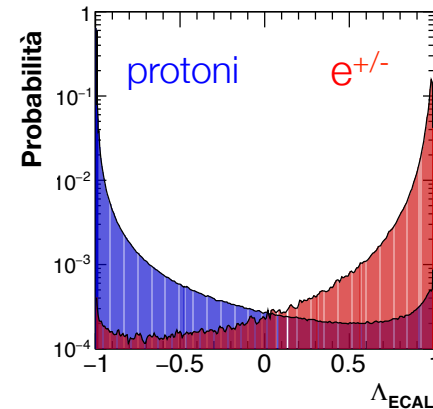
TRK

Rigidità R
 sistematica di
 ricostruzione del segno
 della carica



ECAL

Topologia dello sciame
 separazione $e^{+/-}$ / protoni





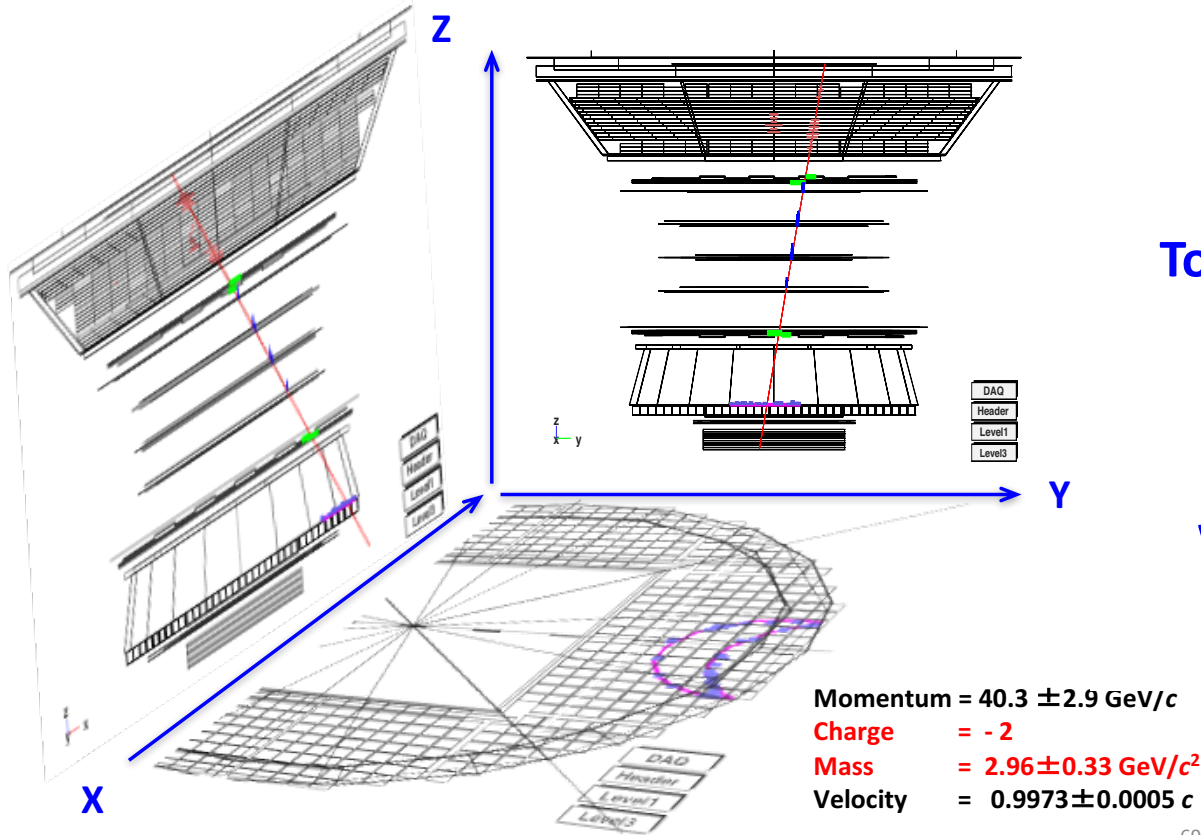
Ricerca di Antielio

(S. J. Ting, “The first five years of the AMS on the ISS: Unlocking the secrets of the cosmo”, 2016)

Antihelium and AMS

At a signal to background ratio of $1/10^9$, detailed understanding of the instrument is required.

An anti-Helium candidate:



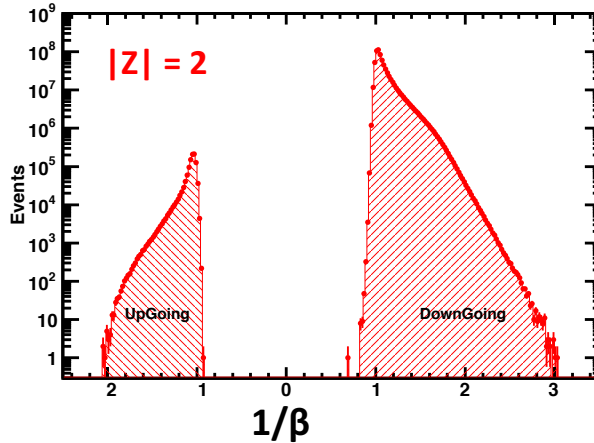
To date we have observed
a few events
with $Z = -2$ and
with mass around ^3He .

Ricerca di Antielio

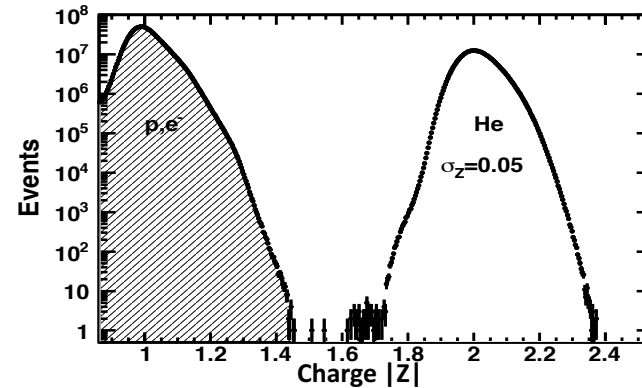
(S. J. Ting, “The first five years of the AMS on the ISS: Unlocking the secrets of the cosmo”, 2016)

Identification of antihelium

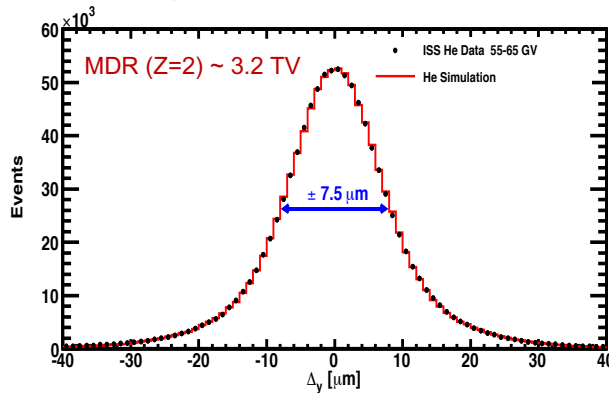
1. Determine direction with TOF.



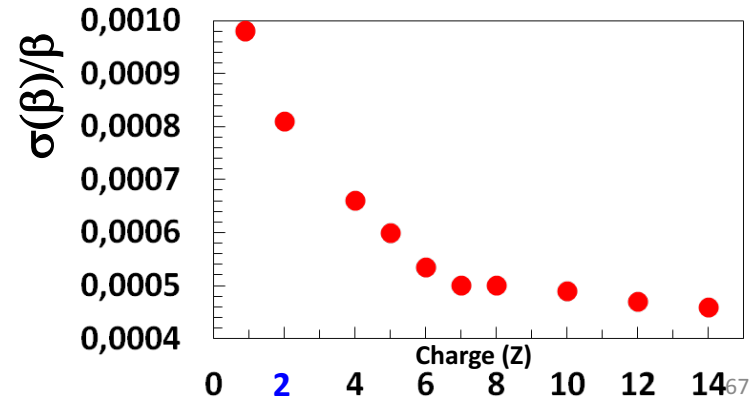
2. To measure $|Z|$, use the TOF+Tracker+RICH to separate p, e^\pm from He



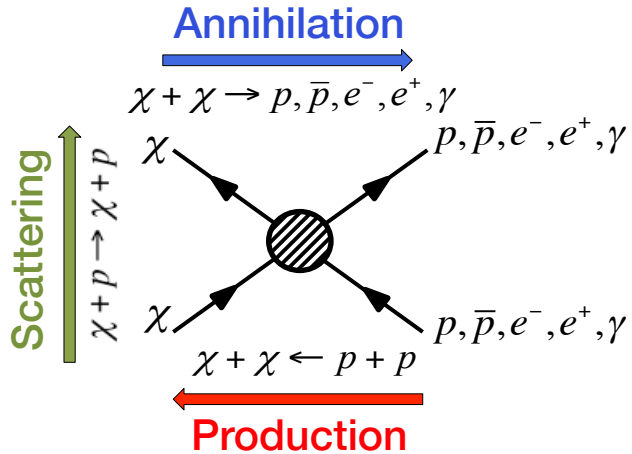
3. To measure momentum and sign of the charge, use Tracker



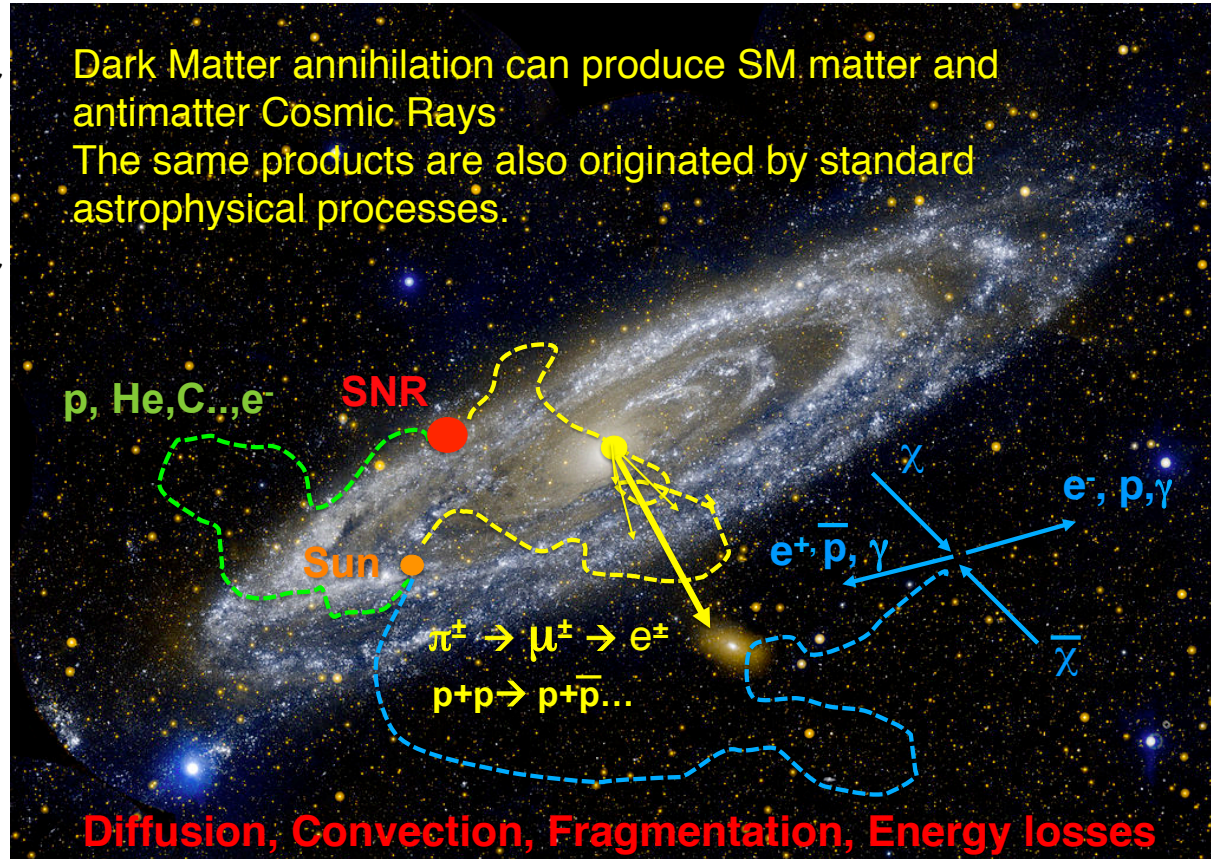
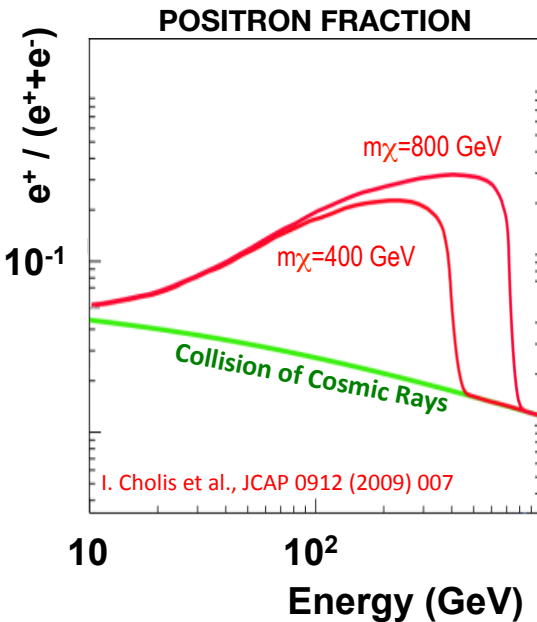
4. To determine mass, use the RICH to measure the velocity.



The quest for Dark Matter



Dark Matter annihilation can produce SM matter and antimatter Cosmic Rays
 The same products are also originated by standard astrophysical processes.

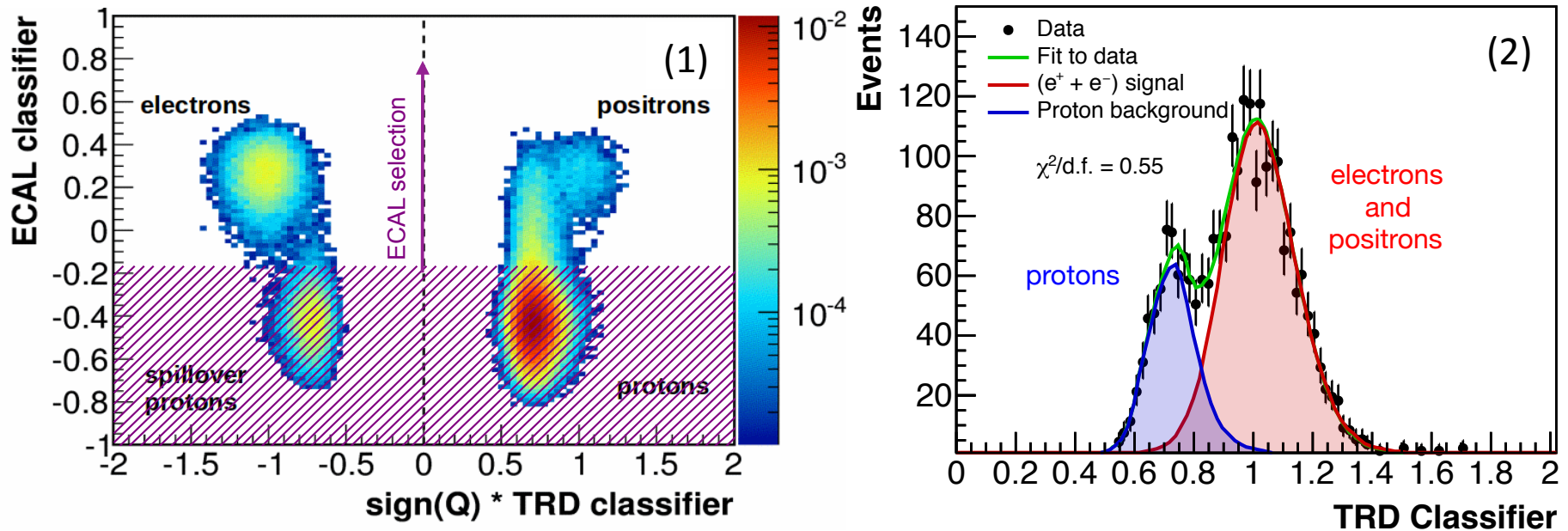


A comprehensive *standard model* of CR origin, acceleration and propagation is mandatory to search for antimatter excesses in CRs.

Identification of $e^{+/-}$

Data driven $e^{+/-}$ identification

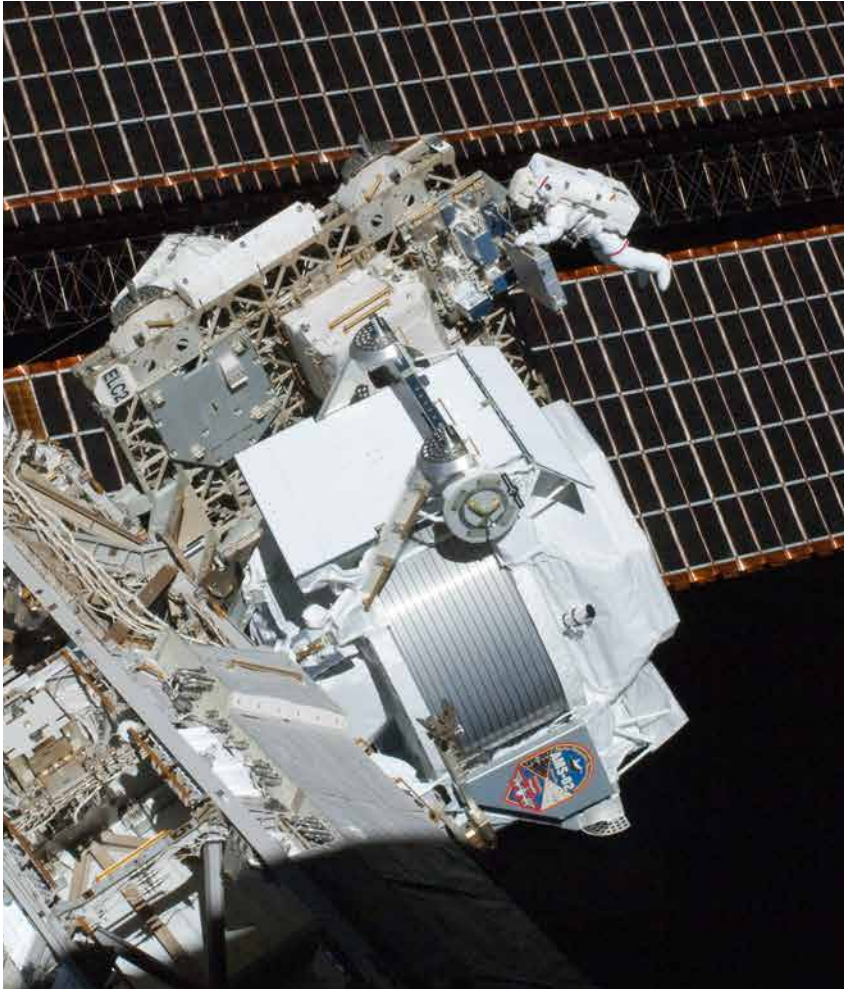
Reference spectra for the signal and the background are fitted to data as a function of the TRD Classifier for different cuts on the ECAL Classifier



1. **ECAL** efficiently removes the majority of background protons
2. **TRD** independently evaluates the tiny remaining proton background

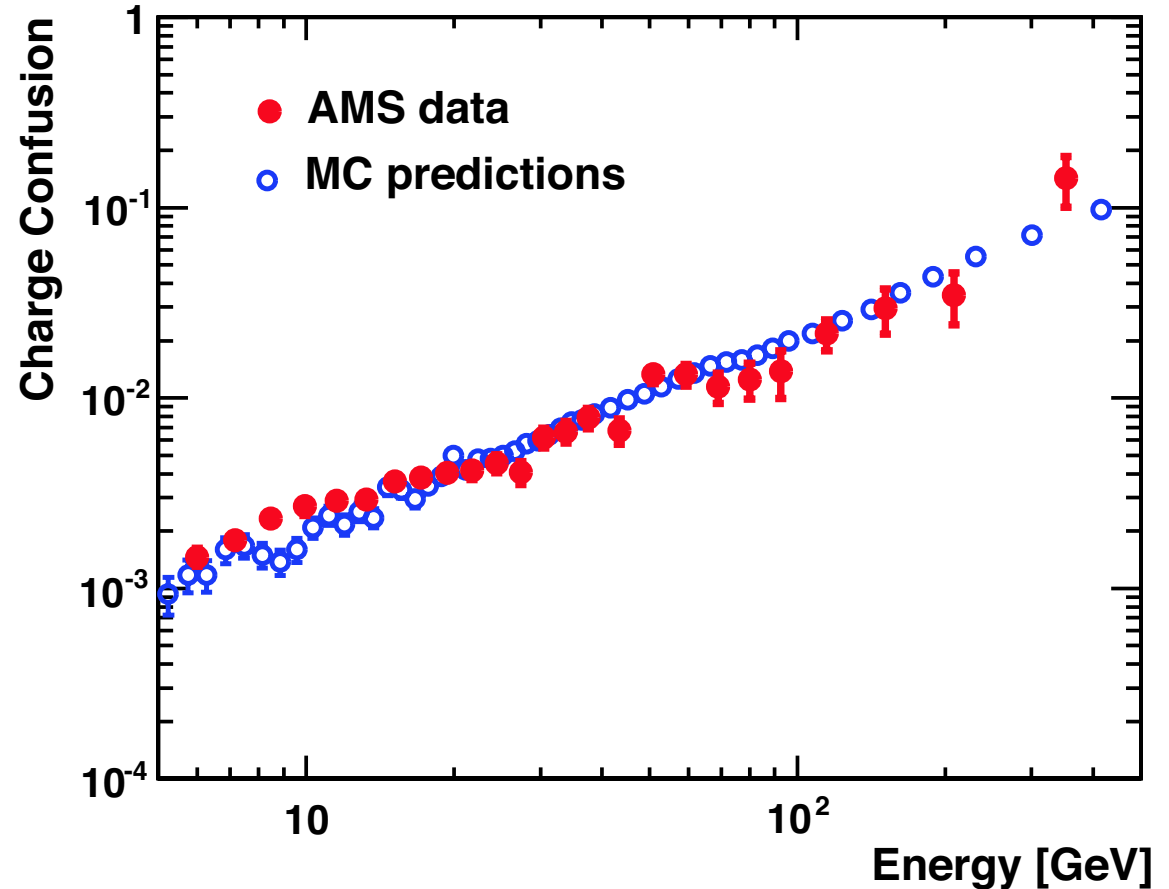
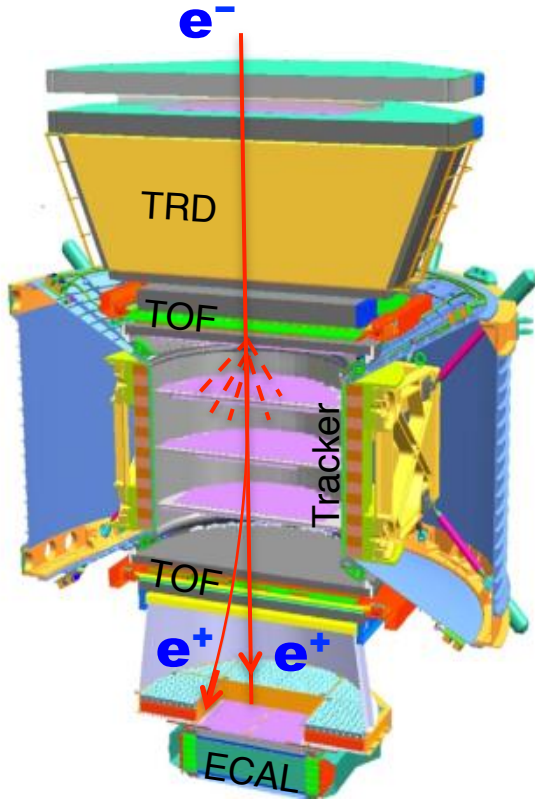


The AMS-02 detector



- **Size** 5 x 4 x 4 m, 7500 kg
 - **Power** 2500 W
- **Data Readout** 300,000 channels
- **<Data Downlink>** ~ 12 Mbps
 - **Magnetic Field** 0.14 T
- **Mission duration** until the end of the ISS operations (currently 2024)

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

Charge Confusion

