AMS-01 on the shuttle

analysis of light nuclei and interactions

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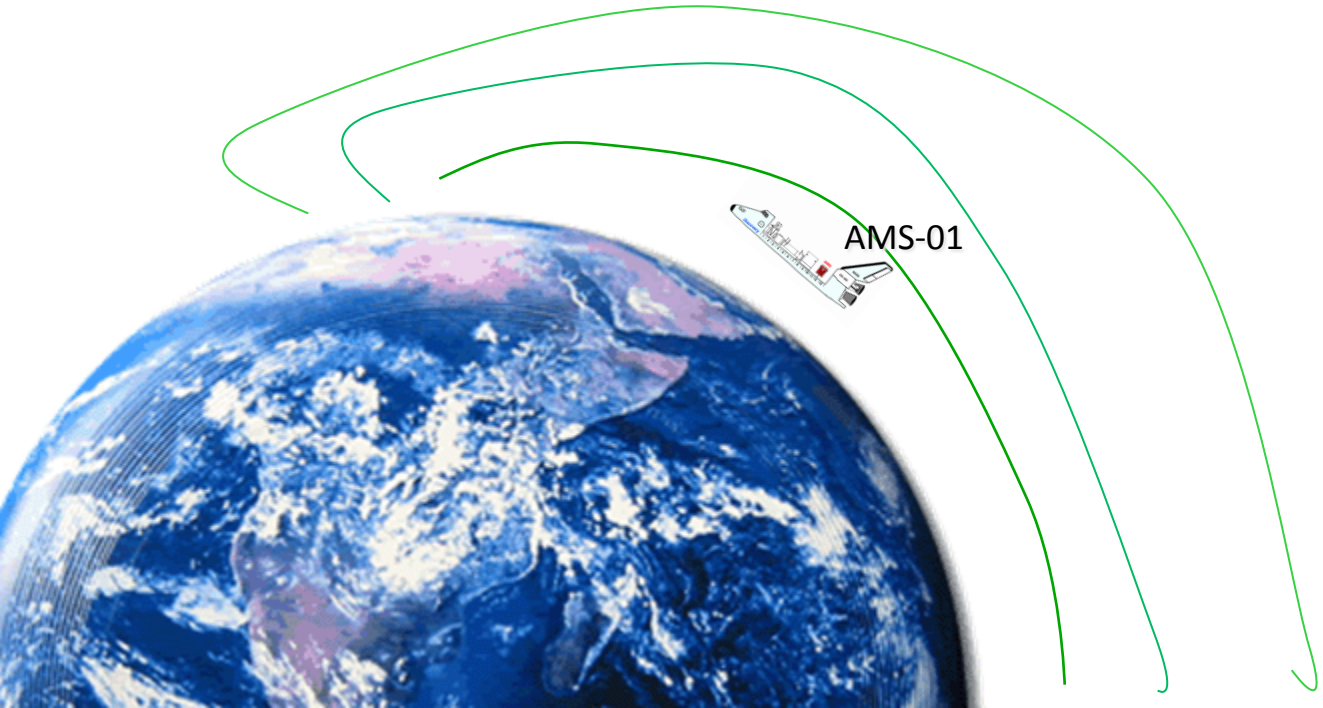
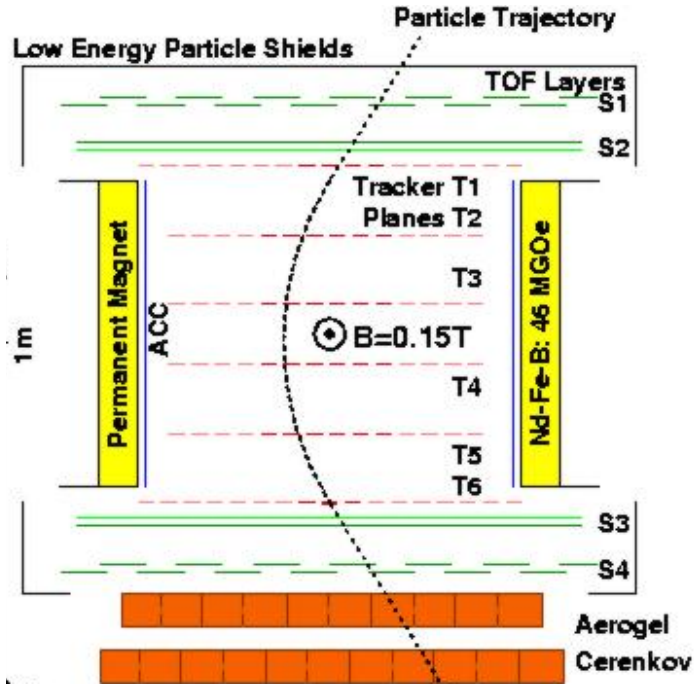


Flux Measurement with AMS-01

AMS-01



The Instrument

- Magnet: dipole field; $BL^2 = 0.14\ Tm^2$
- TOF: 4 layers of scintillators; fast trigger + β + dE/dx
- Tracker: 6 layers of 2-sided Si; p/Z + dE/dx + Z/|Z|
- ATC: aerogel threshold Cerenkov; e/p up 3 GeV
- ACC: veto against multiparticle events;

$$\phi^Z(E) \approx \frac{\Delta N^Z(E)}{\Delta E \cdot G \cdot \varepsilon^Z(E) \cdot T^Z(E)}$$

detector counts

species

bin width

geom factor 0.3 m² sr

detection efficiency

$$\varepsilon^Z_{TOT} = \varepsilon^Z_{SEL} \cdot \varepsilon^Z_{REC} \cdot \varepsilon^Z_{TRIG}$$

effective exposure time

Event reconstruction

- Velocity and direction: by timing (TOF)
- Rigidity R=p/Z: by the reco trajectory (TRACKER)
- Charge: by multiple dE/dx (TOF & TRACKER)

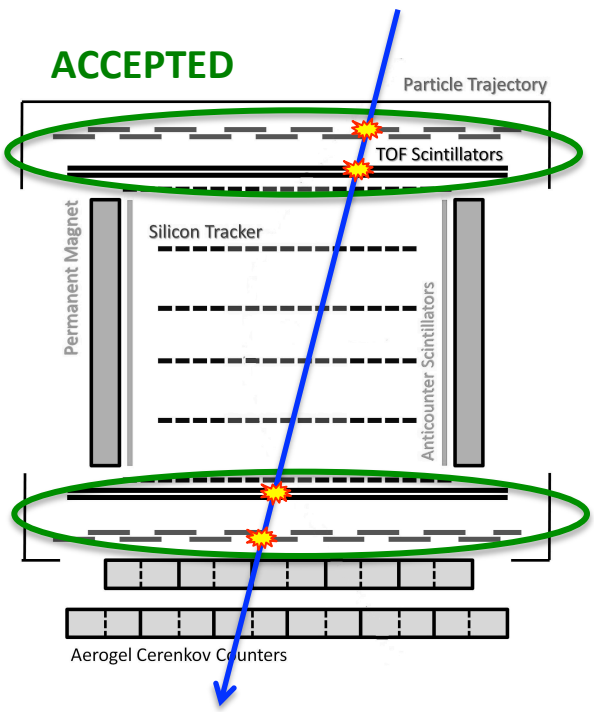
Enter in the flux normalization.

Not canceled out for ratios:

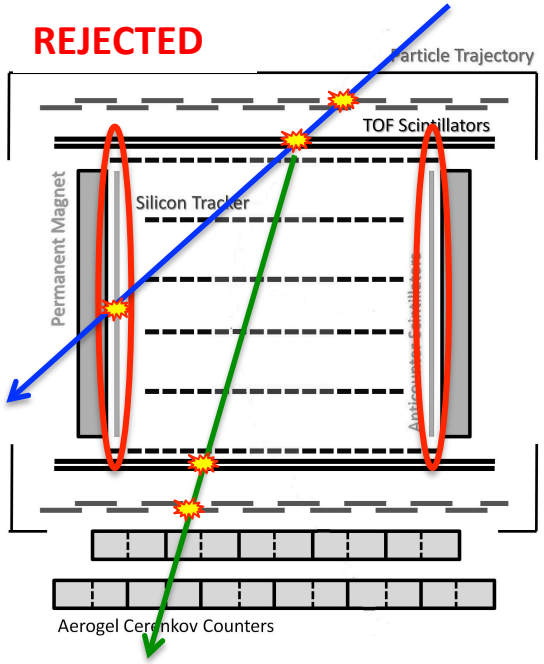
$$B / C \propto \varepsilon^C / \varepsilon^B$$

Trigger logic

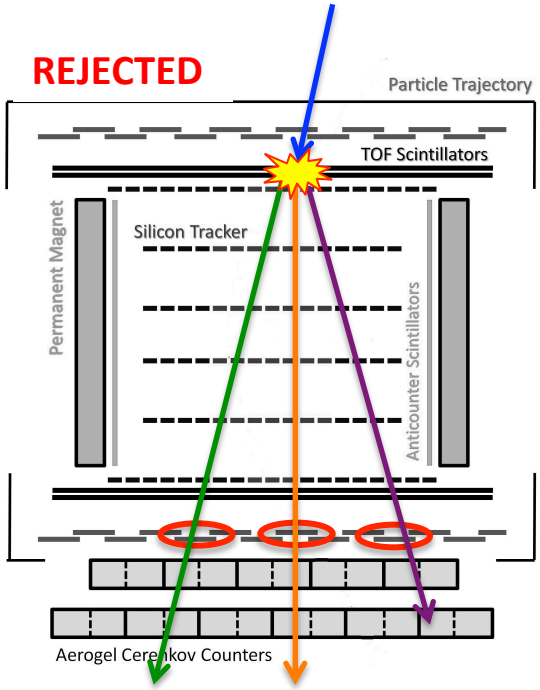
The AMS-01 trigger was designed to reject multi-particle events. 3 requirements:



(1) TOF 4/4 planes fired



(2) No ACC counters fired



(3) No Multiple TOF hits

Minimum bias trigger: *for efficiency studies*

1 out of 1000 events recorded without the application of (2) and (3).

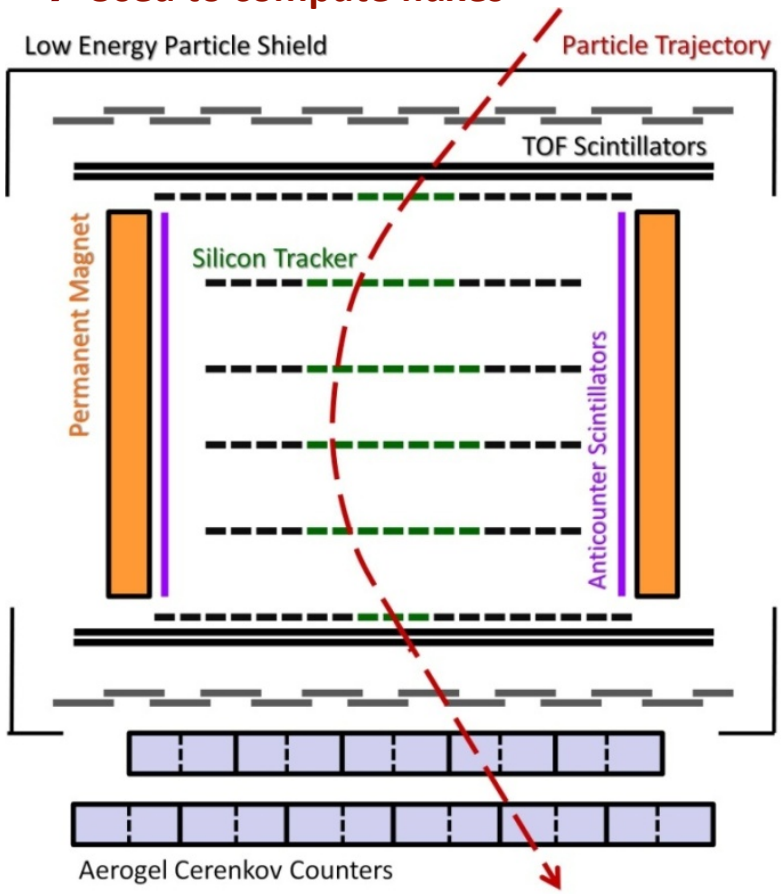
→ Allow to study/validate trigger efficiency with data.

→ Prescaling factor 1/1000 was too small for Z>2 nuclei

Some examples

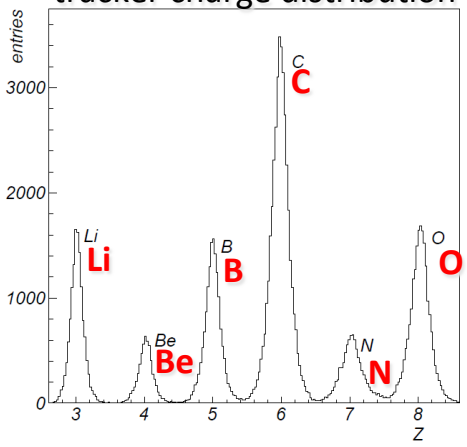
THE GOOD EVENTS

→ **Used to compute fluxes**

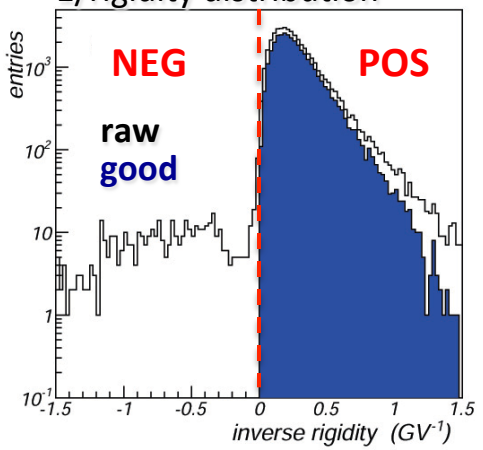


- Ideal event: a CR particle traverses AMS, giving a clean track. All active layers are fired.

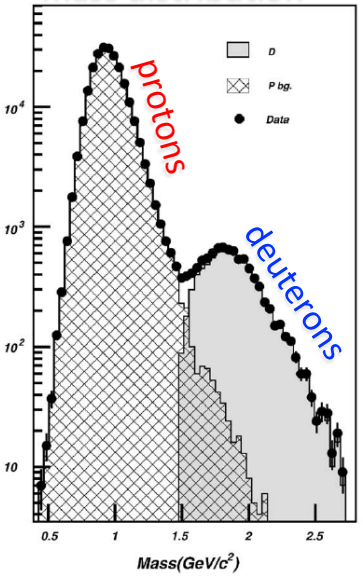
tracker charge distribution



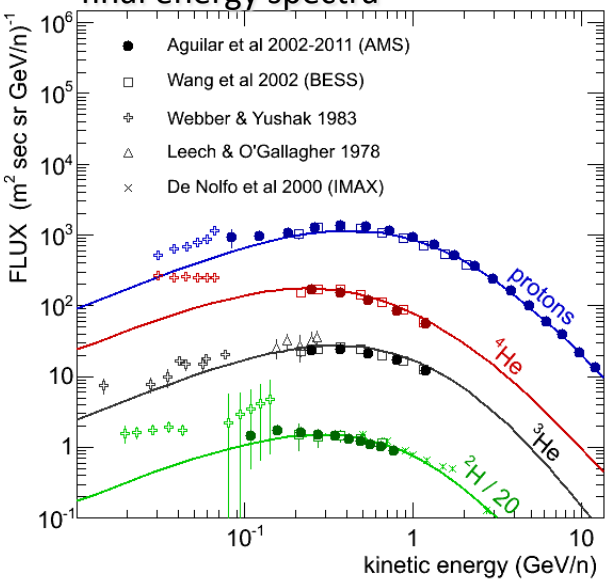
1/rigidity distribution



mass distribution

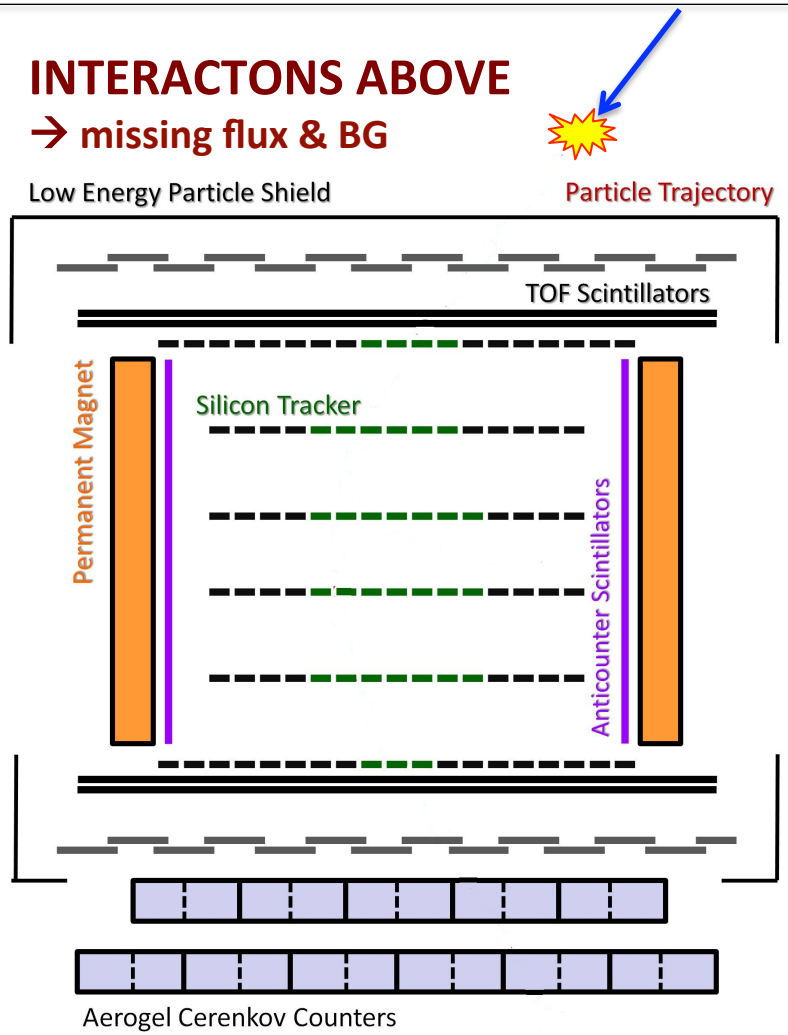


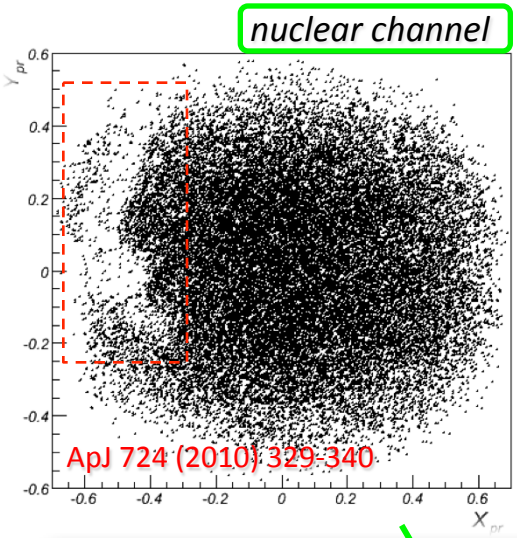
final energy spectra

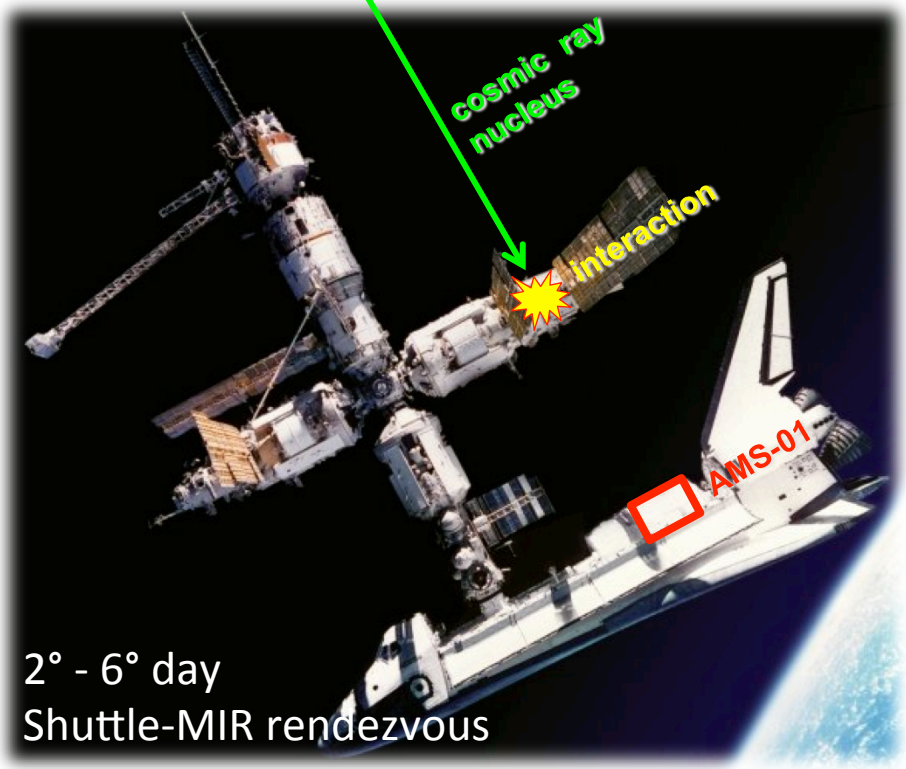


Some examples

INTERACTONS ABOVE
→ missing flux & BG







- Balloons: atmospheric attenuation/BG
- AMS-01: MIR modules (while docked)
- AMS-02: ISS solar arrays (when pass)

Some examples

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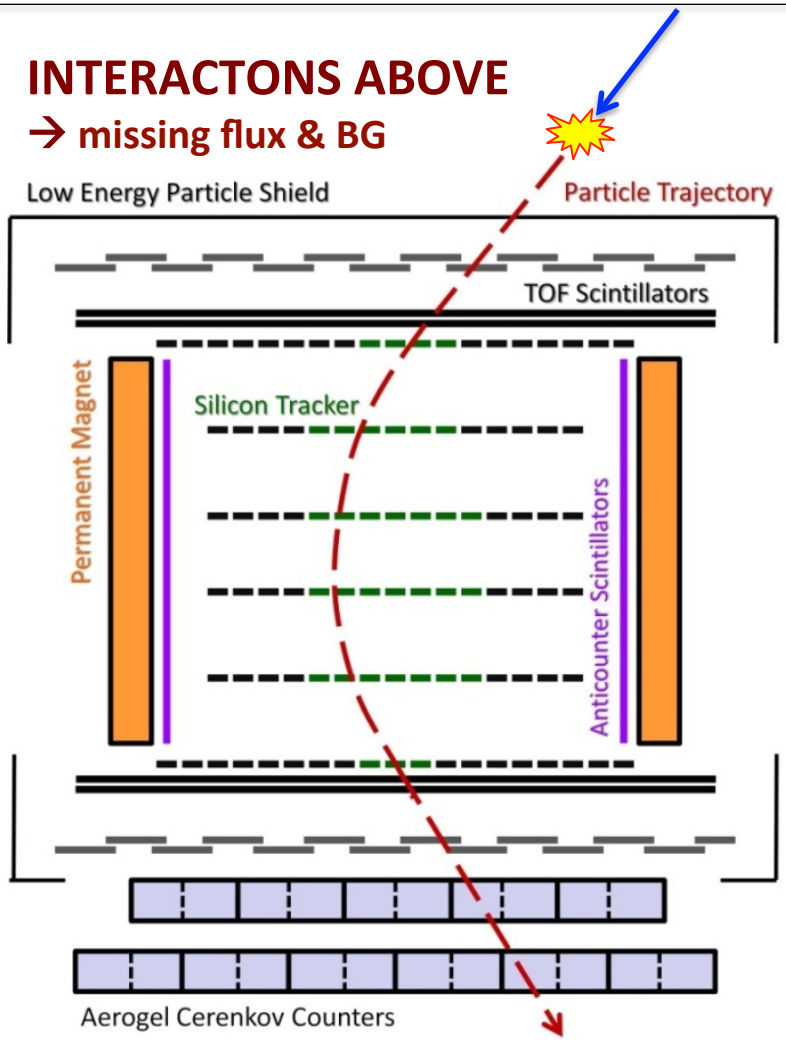
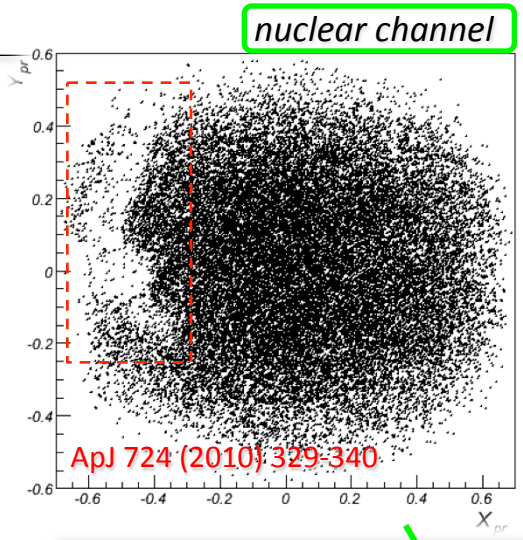
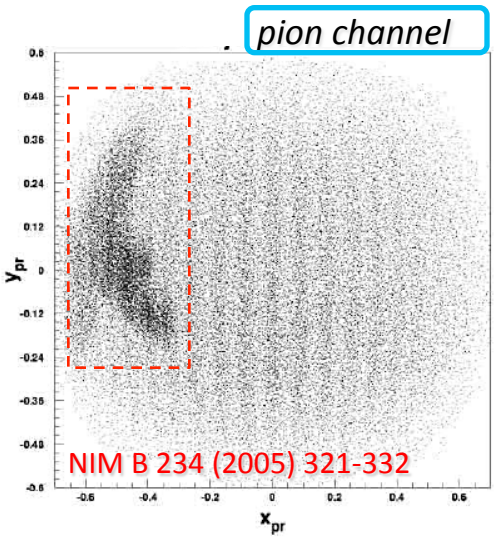
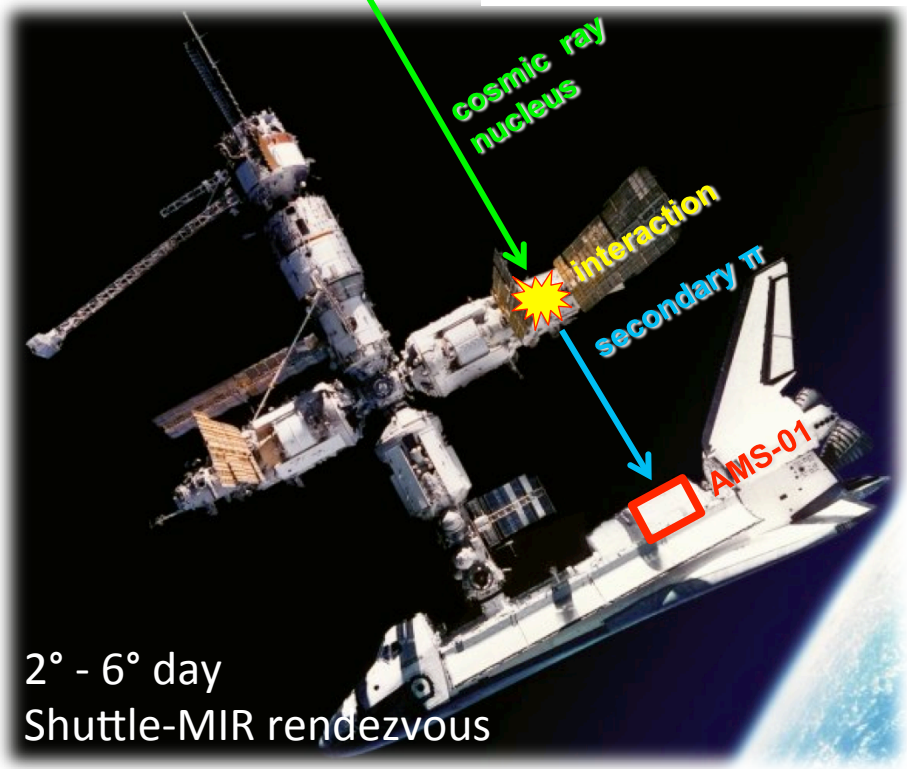
→ missing flux & BG









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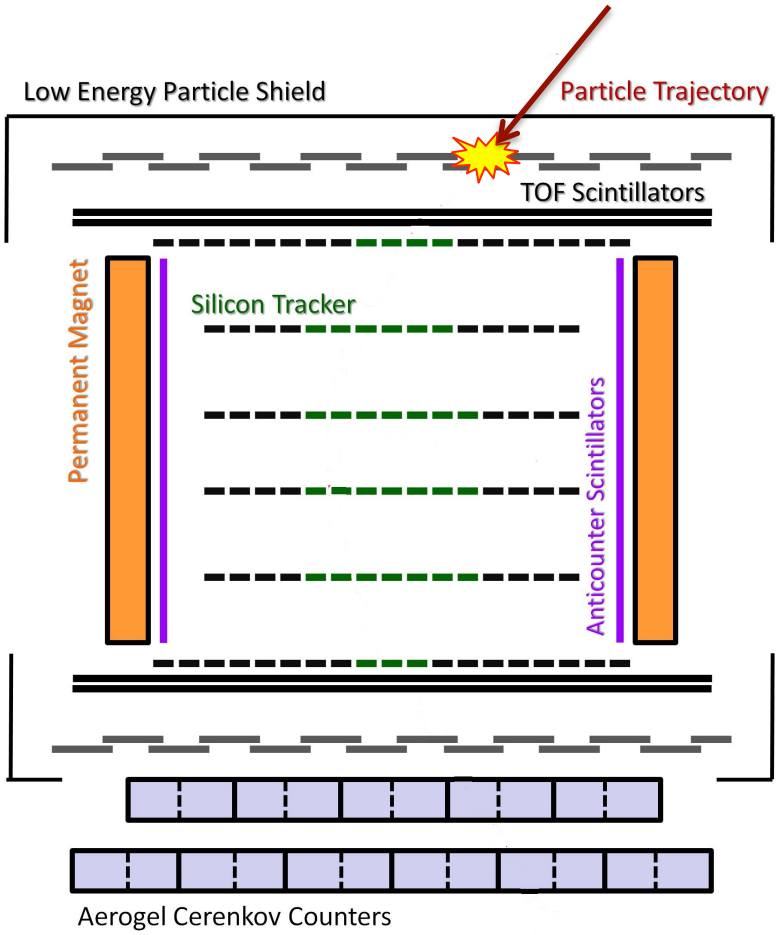
Some examples

TOI INTERACTIONS



TOI interactions (above tracking volume)

→ Absorption -> missed event

→ Secondary production -> rejected evt

Survival fraction

$$P = e^{-x/\lambda} \approx 90\%$$

$$\begin{cases} \lambda_{He} \sim \dfrac{M_{He}}{\sigma_{He}} \sim 50\, g/cm^2 \\ x \sim 5\, g/cm^2 \end{cases}$$

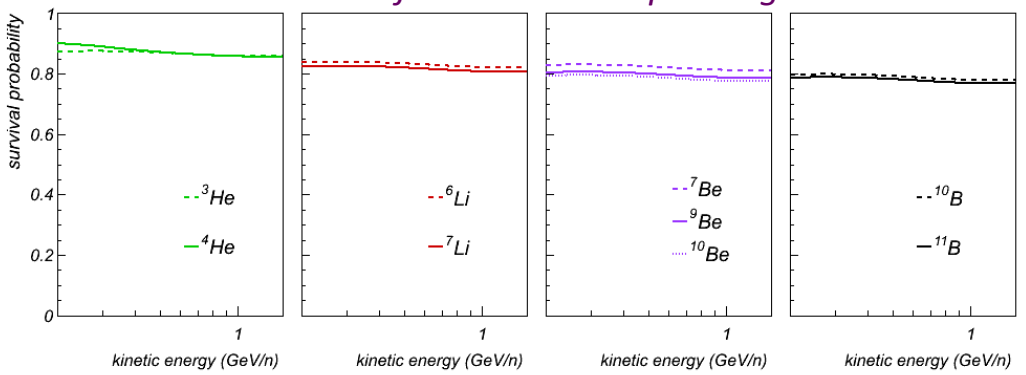
Uncertainty for He

$$\frac{\delta P}{P} \approx \frac{x/\lambda}{1 - x/\lambda}\left(\frac{\delta\sigma}{\sigma}\right) \approx 1\%$$

~10%

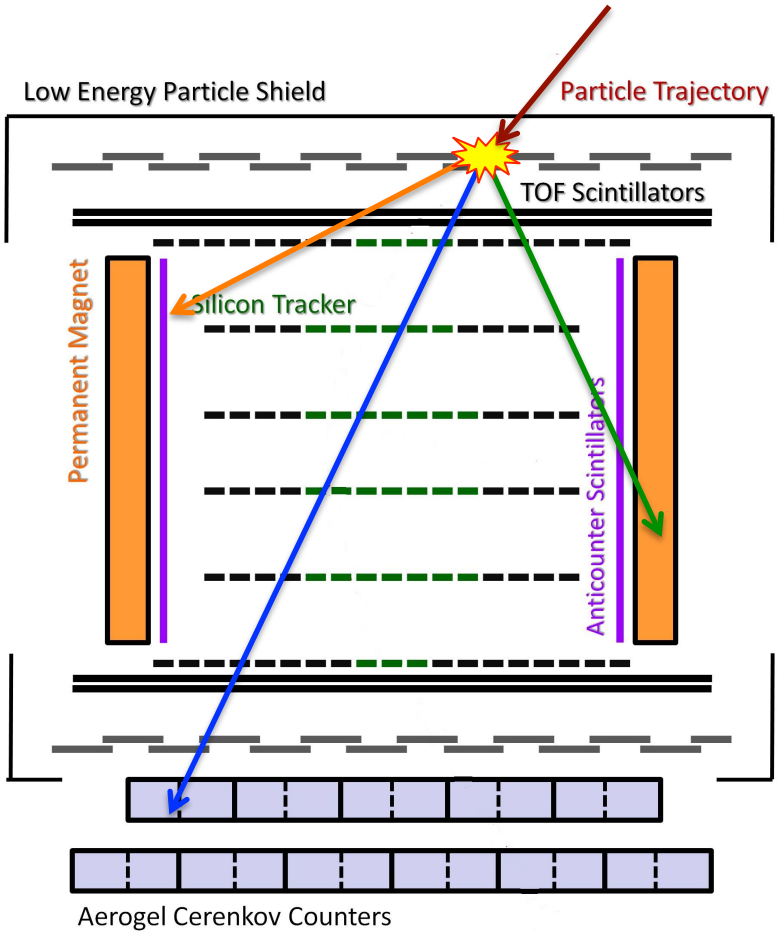
	IMAX	BESS	AMS-01
MASS RESOLUTION	<12%	<12%	12-14%
MASS PDF MODEL	semi empirical	double gaussian	full MC
TOI MATERIAL	12 g/cm^2	9 g/cm^2	4 g/cm^2
ATMOSPHERE	5 g/cm^2	5 g/cm^2	0 g/cm^2
EVENTS/BINS	47,650/10	29,937/7	18,035/5

AMS-01 TOI Survival fraction – G4TripathiLightCrossSection



Some examples

TOI INTERACTIONS



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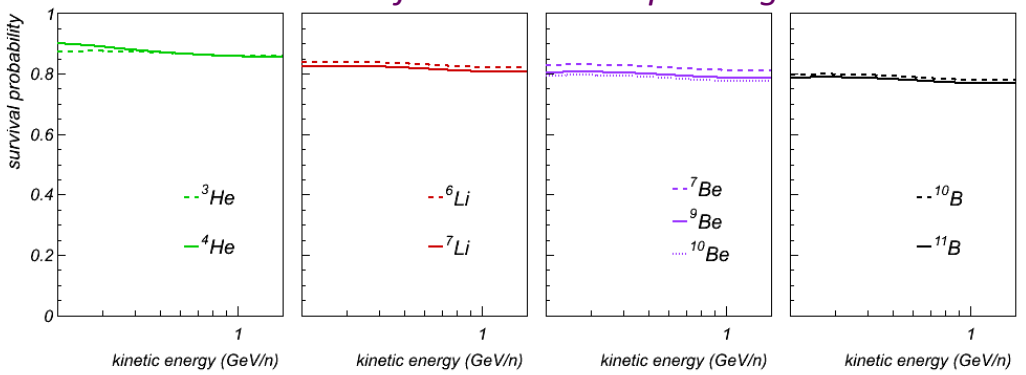
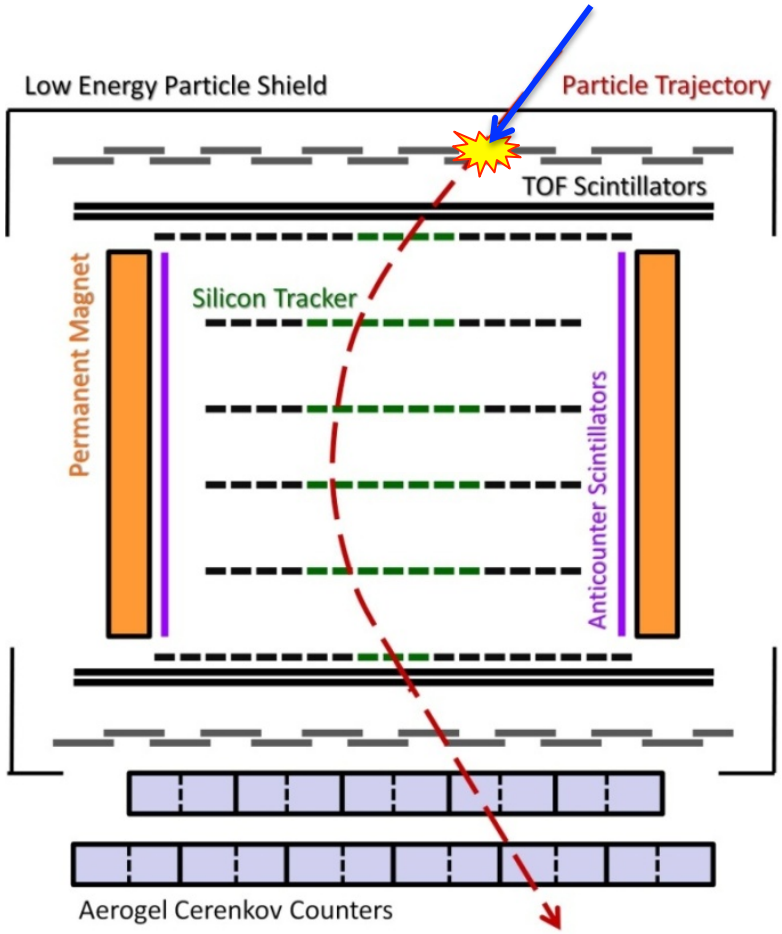


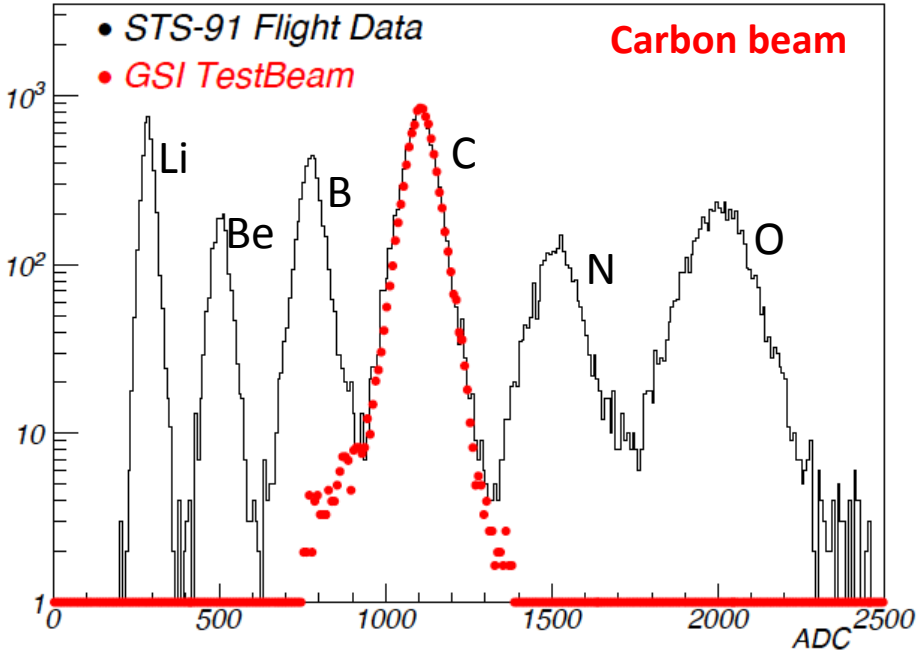
Some examples

TOI CHARGE-CHANGING



fragmentation matrix: $P(Z_{rec}|Z_{true})$

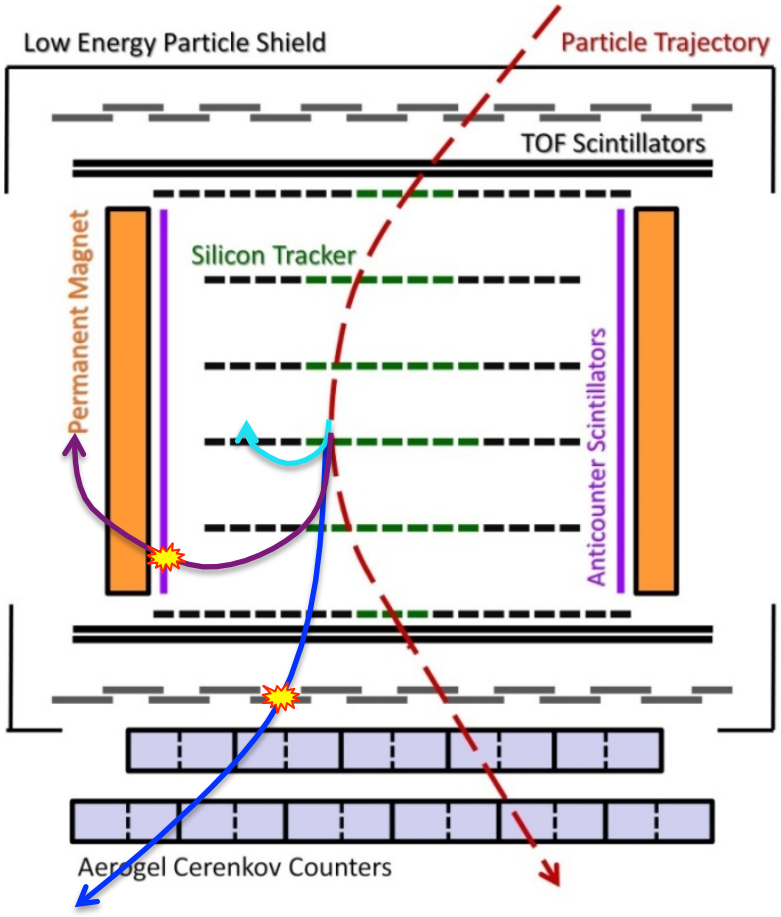
Z rec \ Z true	Li	Be	B	C	N	O
Li	99.99	0.12	0.06	0.02	0.01	0.01
Be		99.88	0.36	0.10	0.08	0.07
B			99.58	0.53	0.15	0.08
C				99.24	5.31	4.07
N					94.44	0.01
O						95.77



TOI charge-changing processes
Clean track reconstructed. Wrong Z.

Some examples

DELTA-RAY EMISSION



High-energy delta-ray emission.
Event may (or may not) be rejected by trigger.
Strongly dependent on primary Z and Energy.

Number of delta-rays emitted at energy T

$$\frac{dN}{dT} \propto \frac{Z^2}{T^2}$$

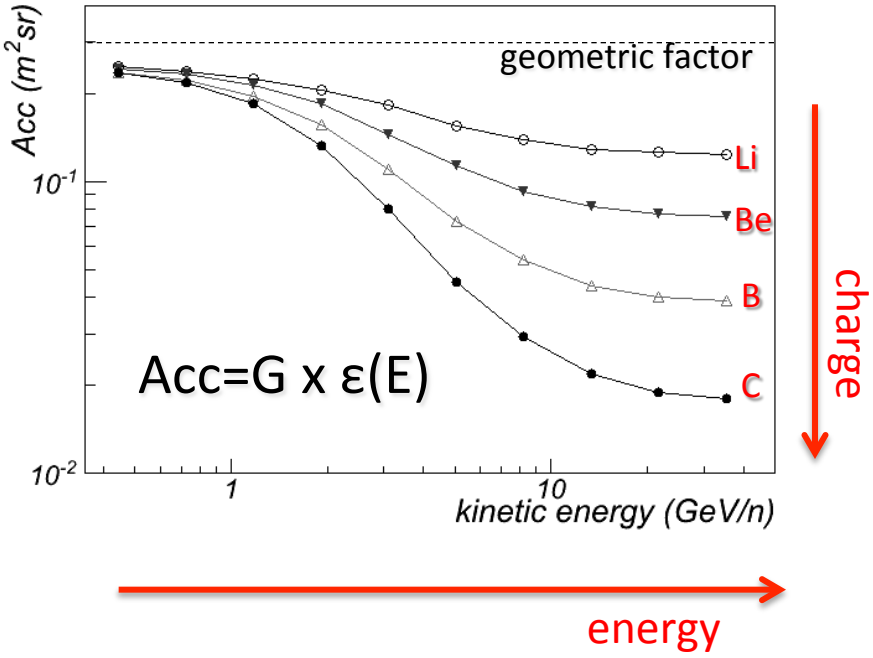
→ *increases with Z*

→ *high energy tails*

Maximum energy of delta-rays

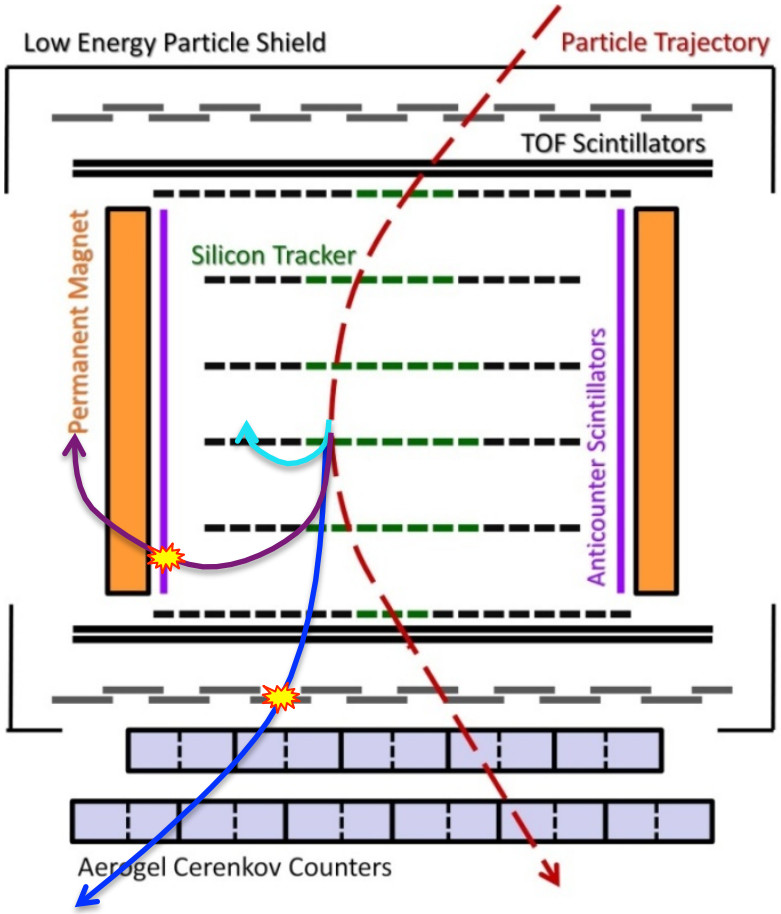
$$T_{Max} \approx 2m_e\beta^2c^2\gamma^2$$

increases with the primary CR energy

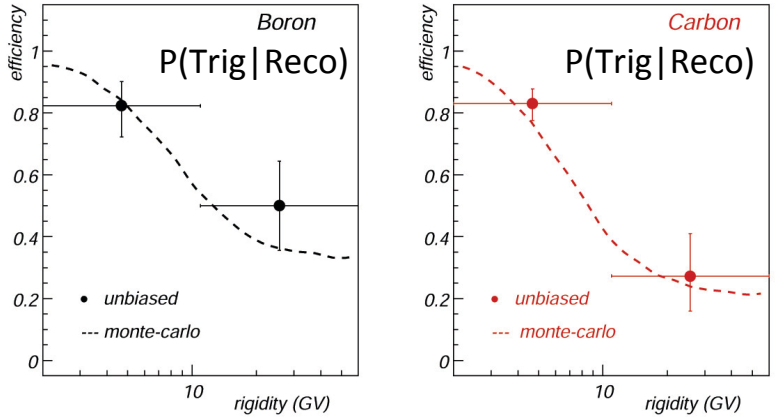


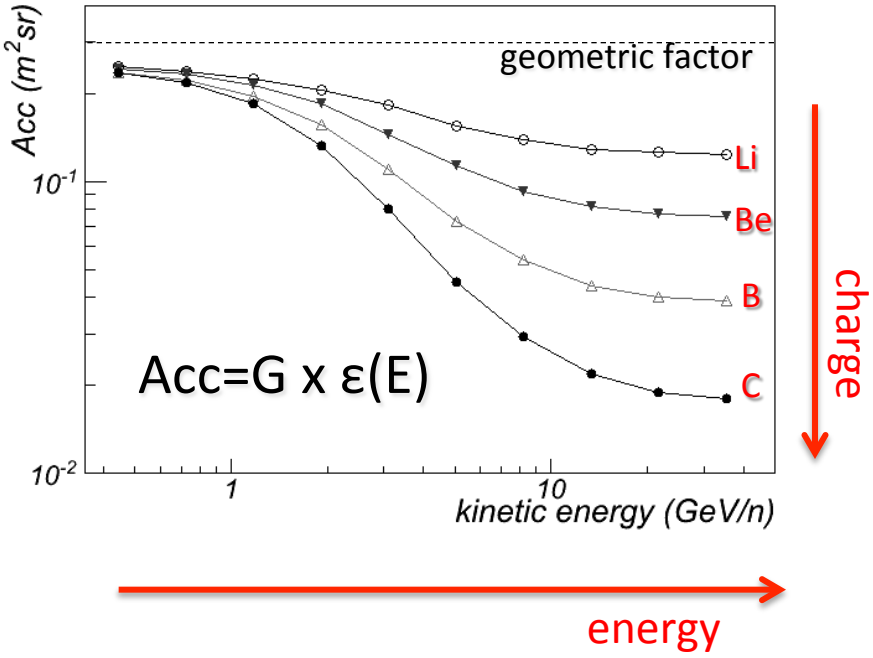
Some examples

DELTA-RAY EMISSION



Trigger eff. with minimum-bias data



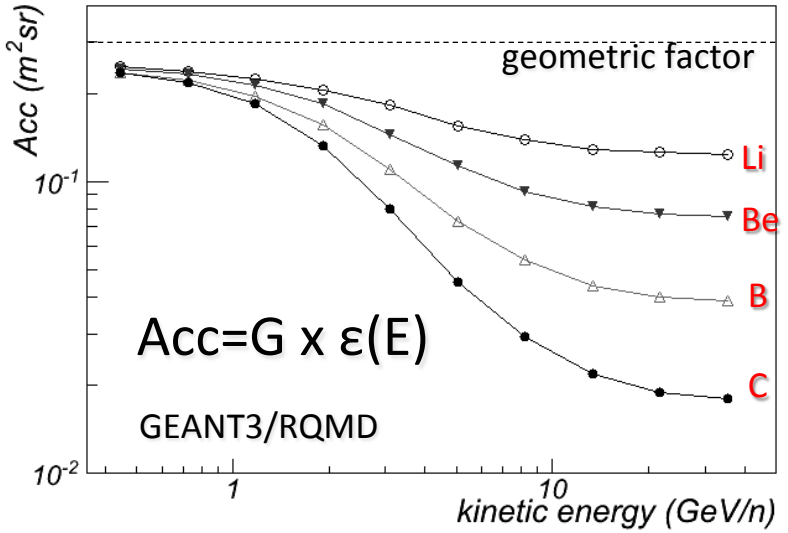


High-energy delta-ray emission.
Event may (or may not) be rejected by trigger.
Strongly dependent on primary Z and Energy.

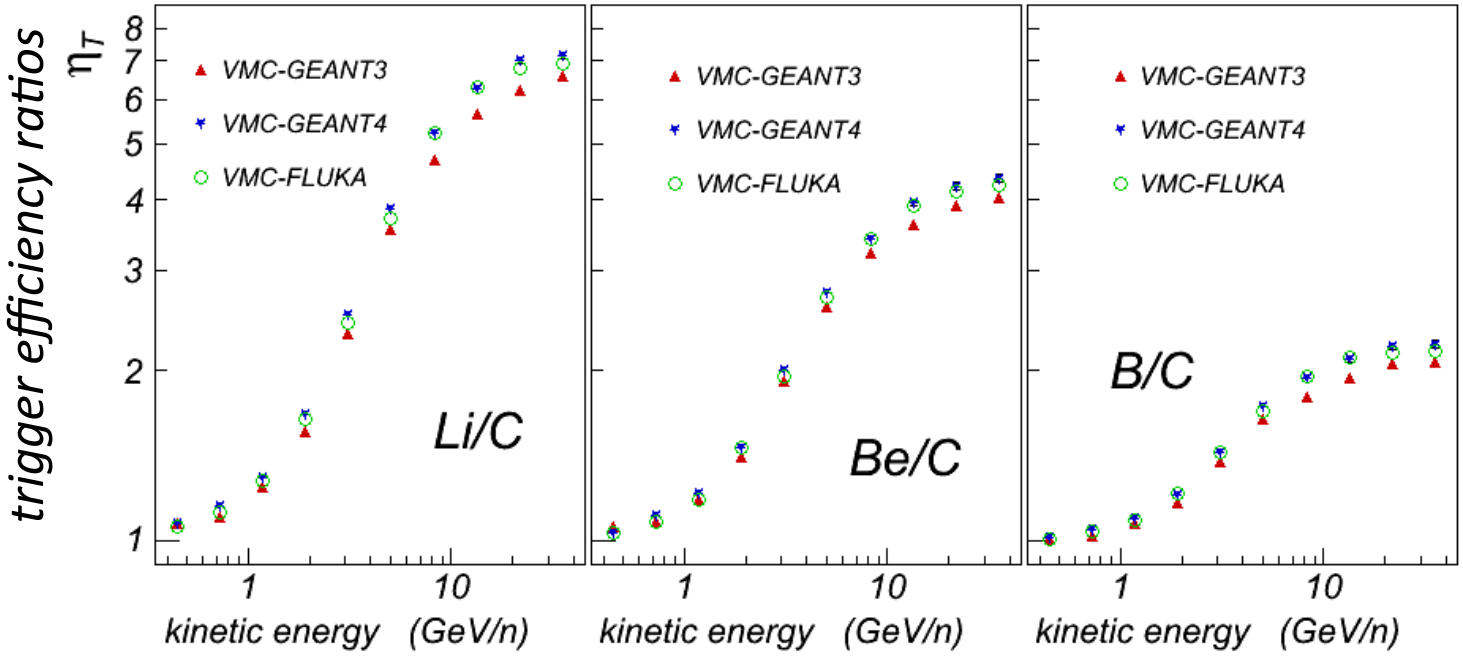
Trigger Efficiency

MC estimations were performed with three different simulations codes of particle interactions.

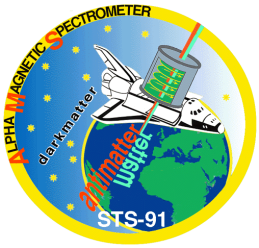
GEANT3 **GEANT4** **FLUKA**



$$\eta^{Z}_{TRIG} = \varepsilon^{Z}_{TRIG} / \varepsilon^{6}_{TRIG}$$



Summary



CR interactions in material affect the flux measurements.

1. Inefficiency due to missing flux.
   → Increases with CR mass number A (~ Z) and TOI material thickness
   → Requires reliable estimate of destruction cross-sections

2. Background due to charge- (mass-) changing processes
   → Complex hadronic MC simulation needed.
   → Can be minimized with analysis cuts.
   → Can be studied with DATA, using redundant Z-evaluations.

Limitations with AMS-01

1. Tot optimized for Z>2 nuclei. Strong E-Z-dependent trigger efficiency.
2. Minium-bias DATA not sufficient to validate the MC efficiencies
3. Lack of statistics for high-energy and high-charge nuclei

The main goal of the AMS-01 mission was to gain experience and knowledge for the final design of the AMS-02 project.

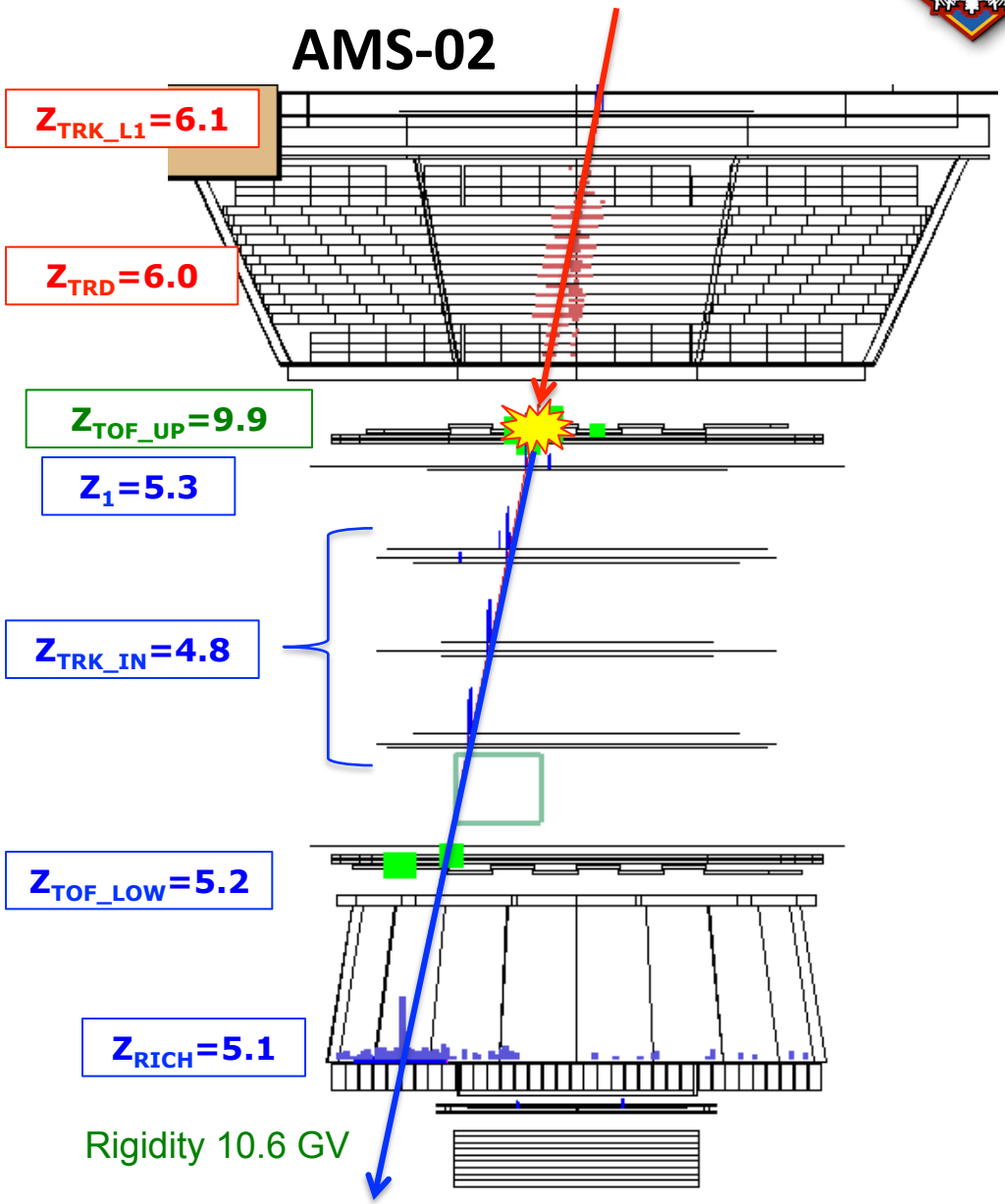
AMS-02 : Evidence of fragmentation Carbon → Boron

Carbon → Boron in Upper TOF

Optimized for high-Z measurements
-Large dinamical range: Z~ 1 - 30
-Many layers of active material.
-Many independent evaluations of Z.

Dedicated Trigger for Z>1:
-4/4 TOF planes fired
-Multiple TOF hits allowed
-NACC <5

Minimum bias trigger:
-1/100 prescaling!!
-3/4 TOF fired
-No conditions on NACC

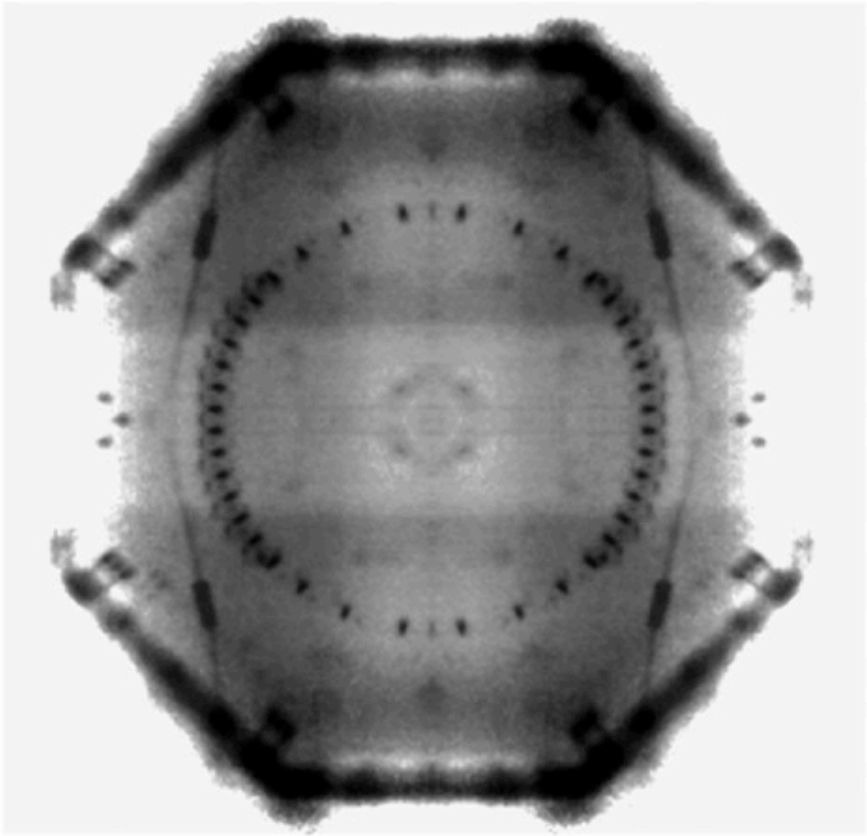


AMS-02 : Evidence of fragmentation He absorption in TOI

AMS Hadronic Tomography

with the cosmic-ray p/He ratio

Exposure Time: May 20 2011 – May 20 2012	
Number of Protons:	3,676,863,217
Number of Helium nuclei:	620,303,906
Rigidity range:	2 GV – 2000 GV
Tomographic plane:	Z = +165 cm
XY pixel area:	1 cm^2



Operating in the International Space Station since May 2011, AMS is performing very accurate measurements of cosmic ray (e.g. Proton and Helium nuclei) with unprecedent sensitivity. This picture represents a “tomographic” reconstruction of the AMS top-of-instrument material obtained using the Proton-to-Helium flux ratio. Tiny changes of the interaction probabilities of these nuclei with different materials are used to trace the material inhomogenities. Detector elements such as screws, electronics boards, and mechanical interfaces are clearly recognizable.