Nuclear interaction studies with AMS-02

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Introduction

$\overline{p}/p$ theoretical prediction is dominated by two kind of uncertainties:

- $\overline{p}$ production cross section
- propagation model

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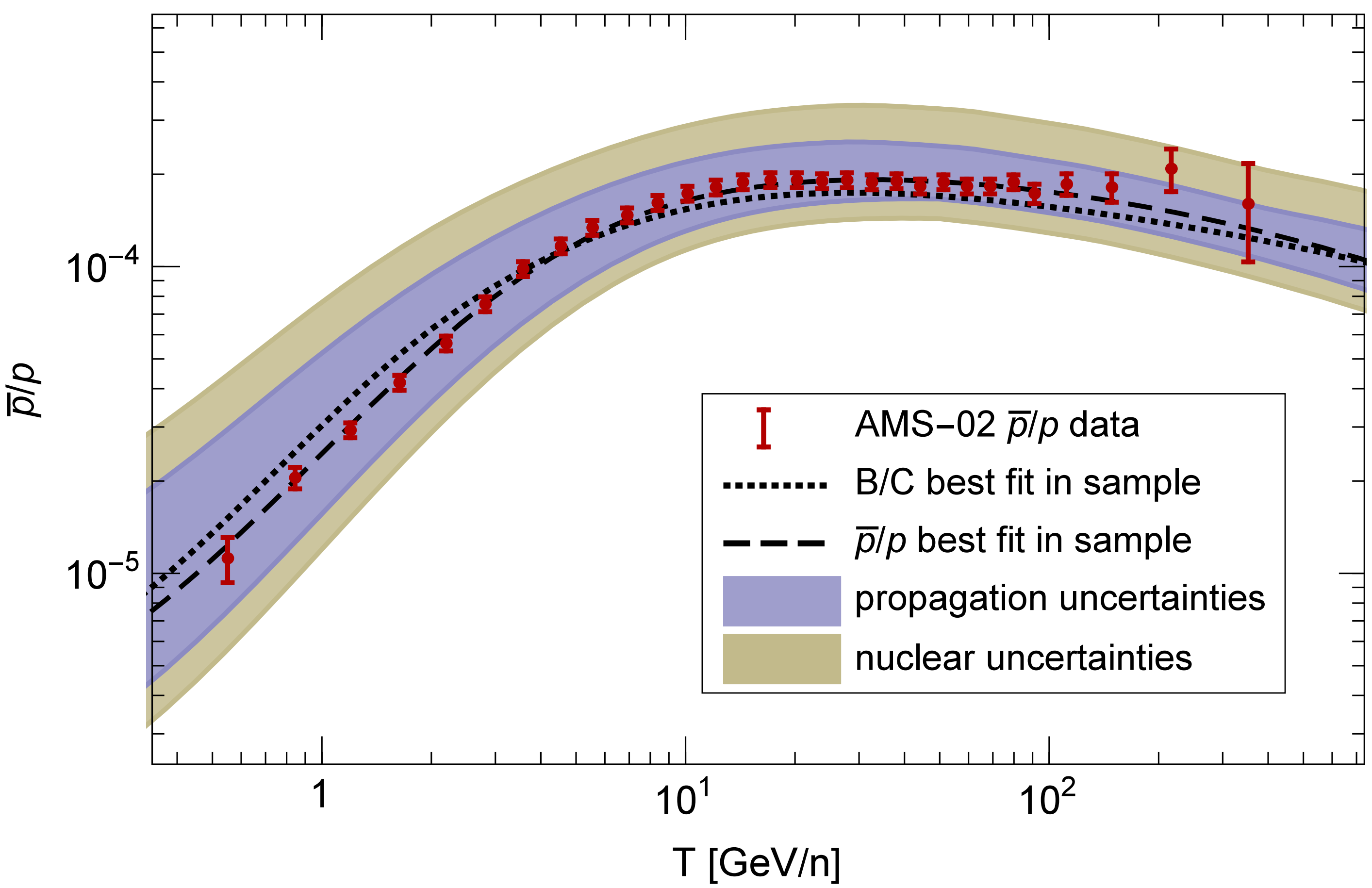
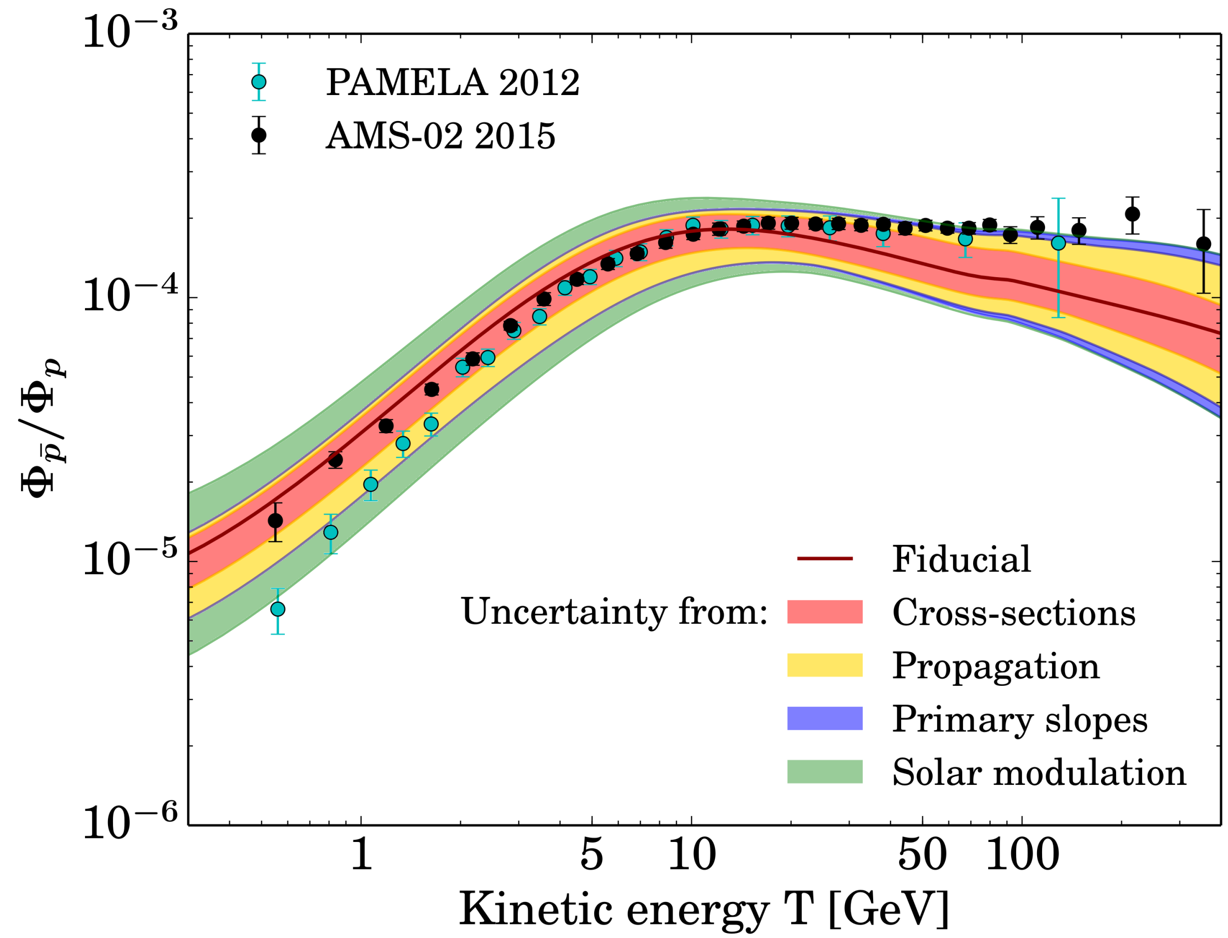
Precision measurements of the nuclear component of cosmic rays may help reducing the latter.





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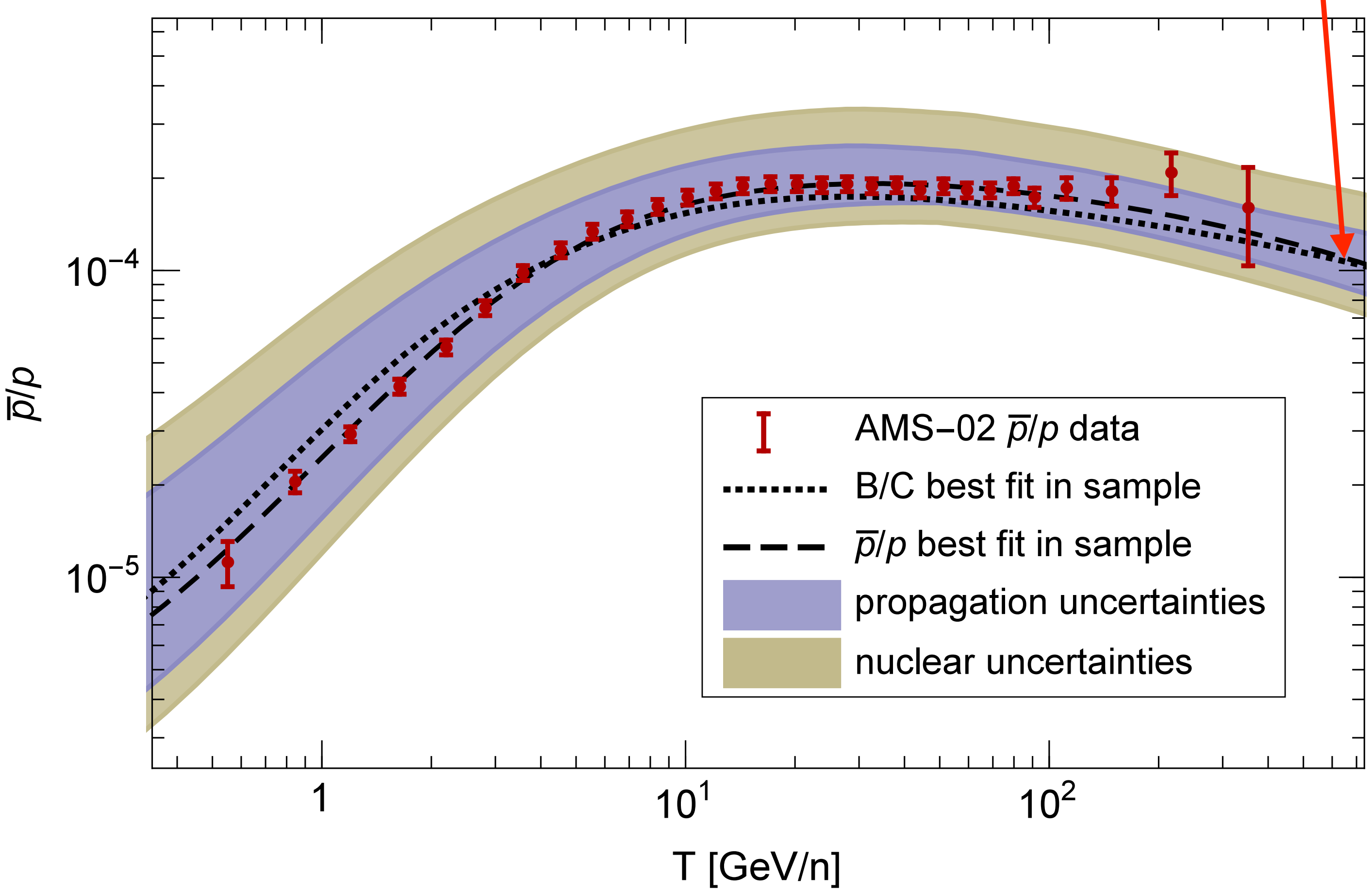
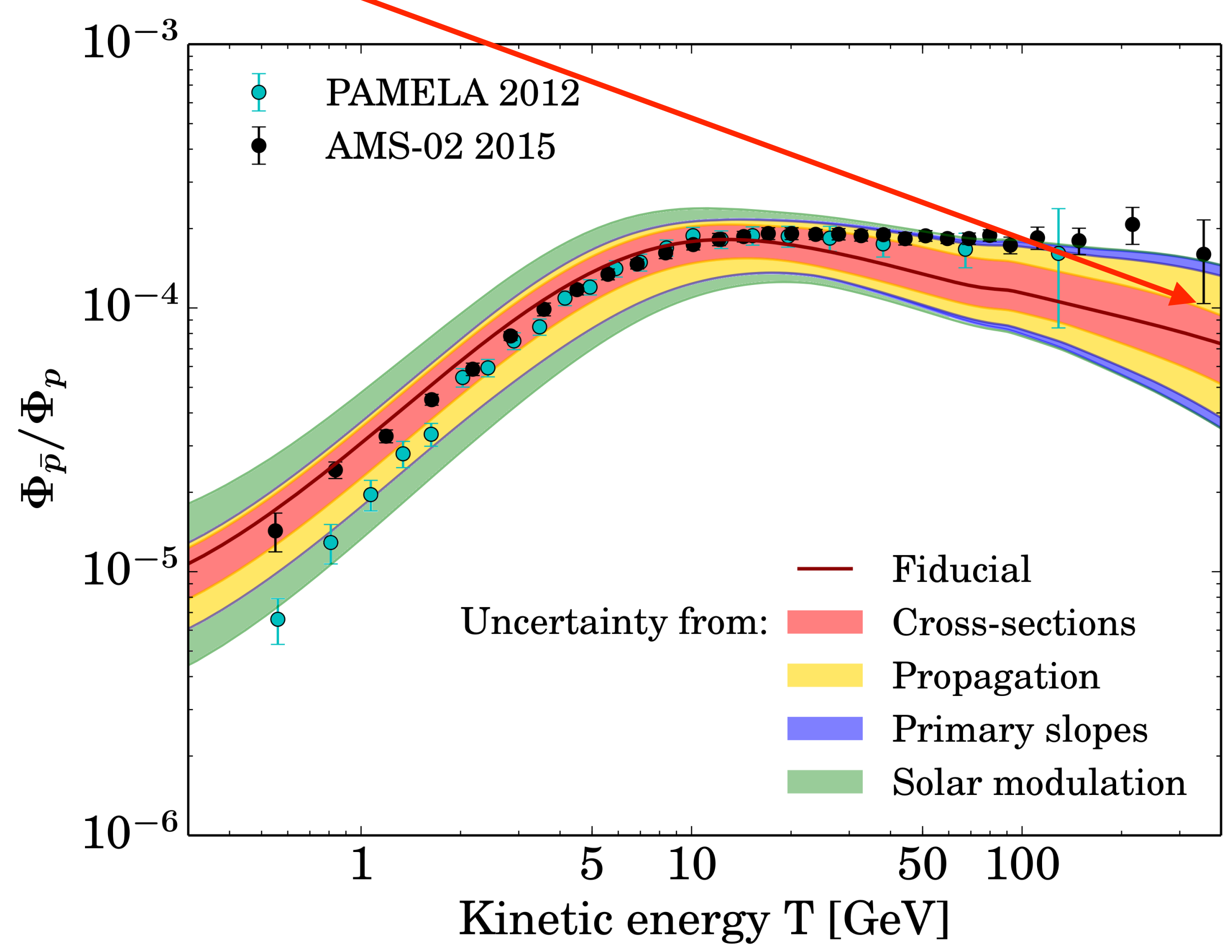
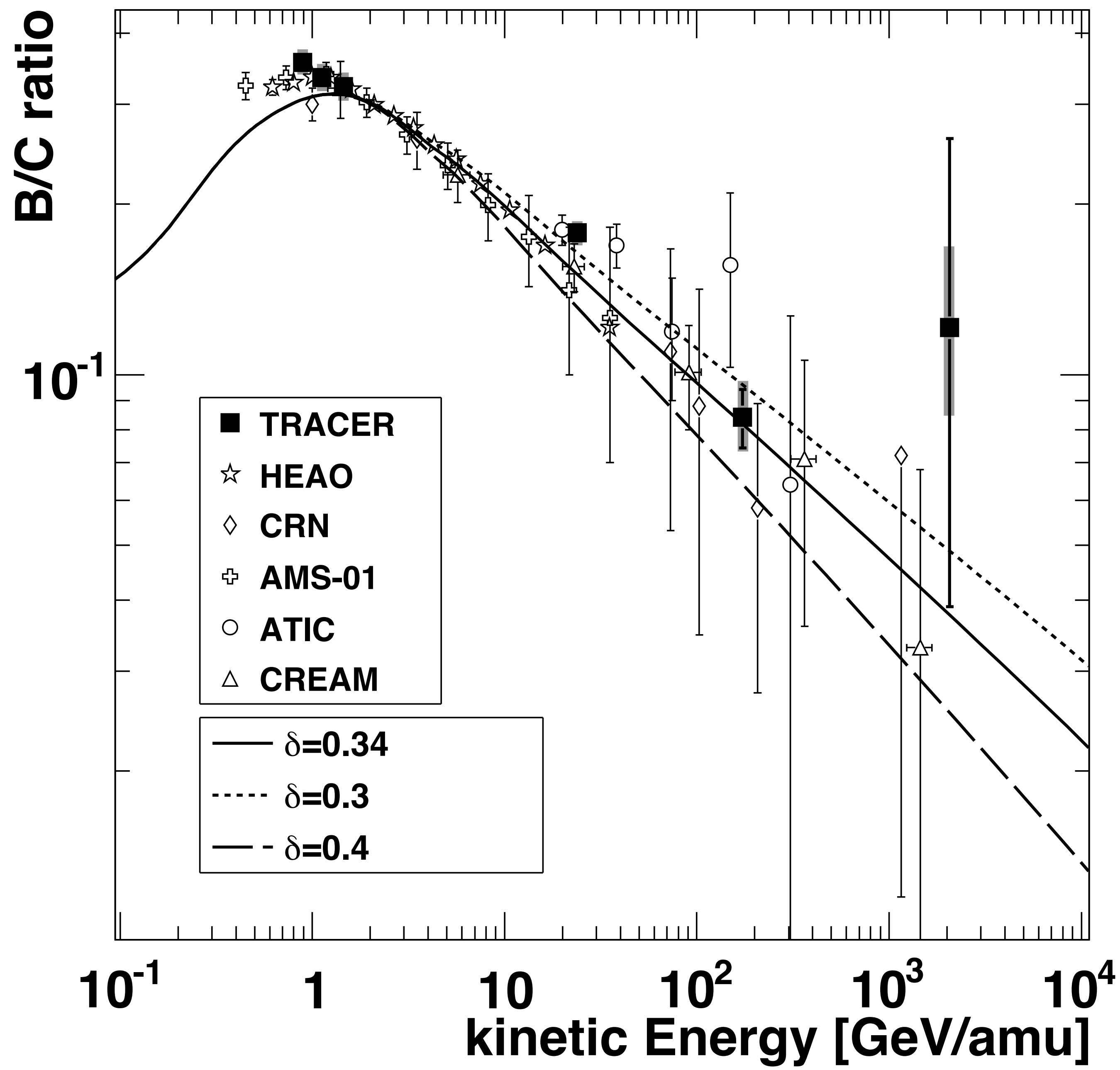




Introduction

This uncertainty comes from the estimation of the various parameters that define a given propagation environment for cosmic rays.

Usually these parameters are extracted from a comparison with experimental data and carry an uncertainty which reflects the precision of current data available.



AMS-02

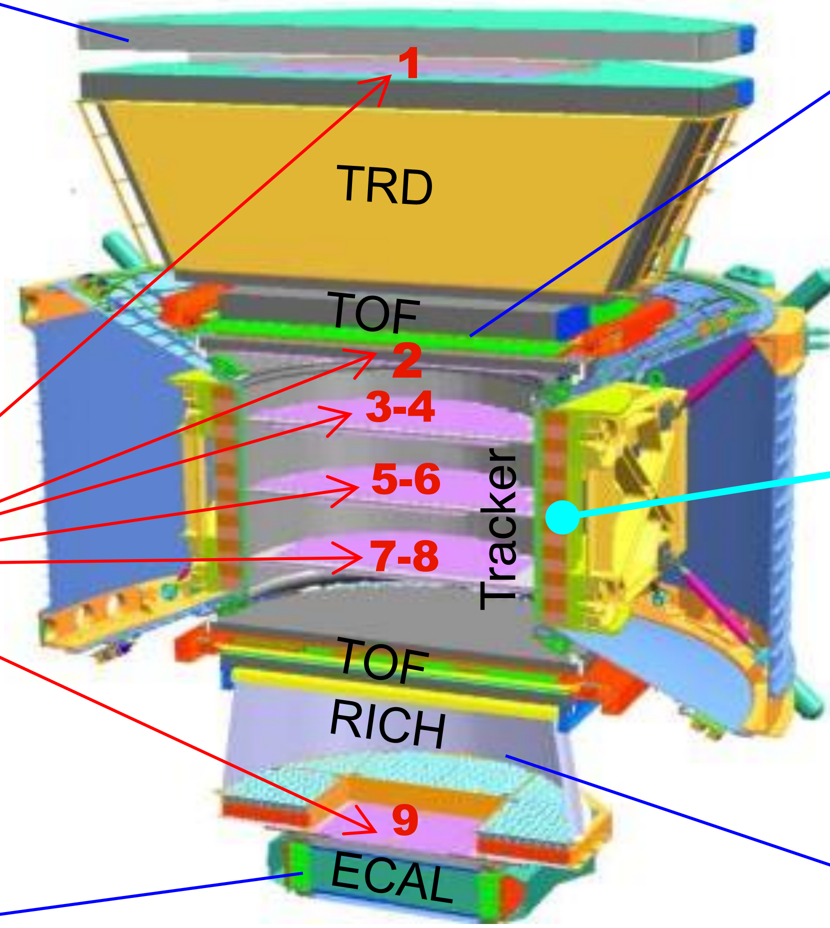
TRD
Identify e^+, e^-

Particles and nuclei are defined by their charge (Z) and energy (E ~ P)

TOF
Z, E

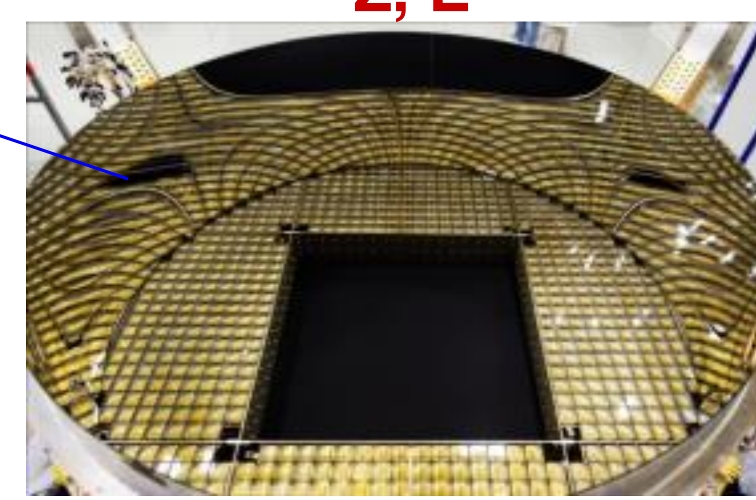
Magnet
±Z

Silicon Tracker
Z, P



ECAL
E of e^+, e^-

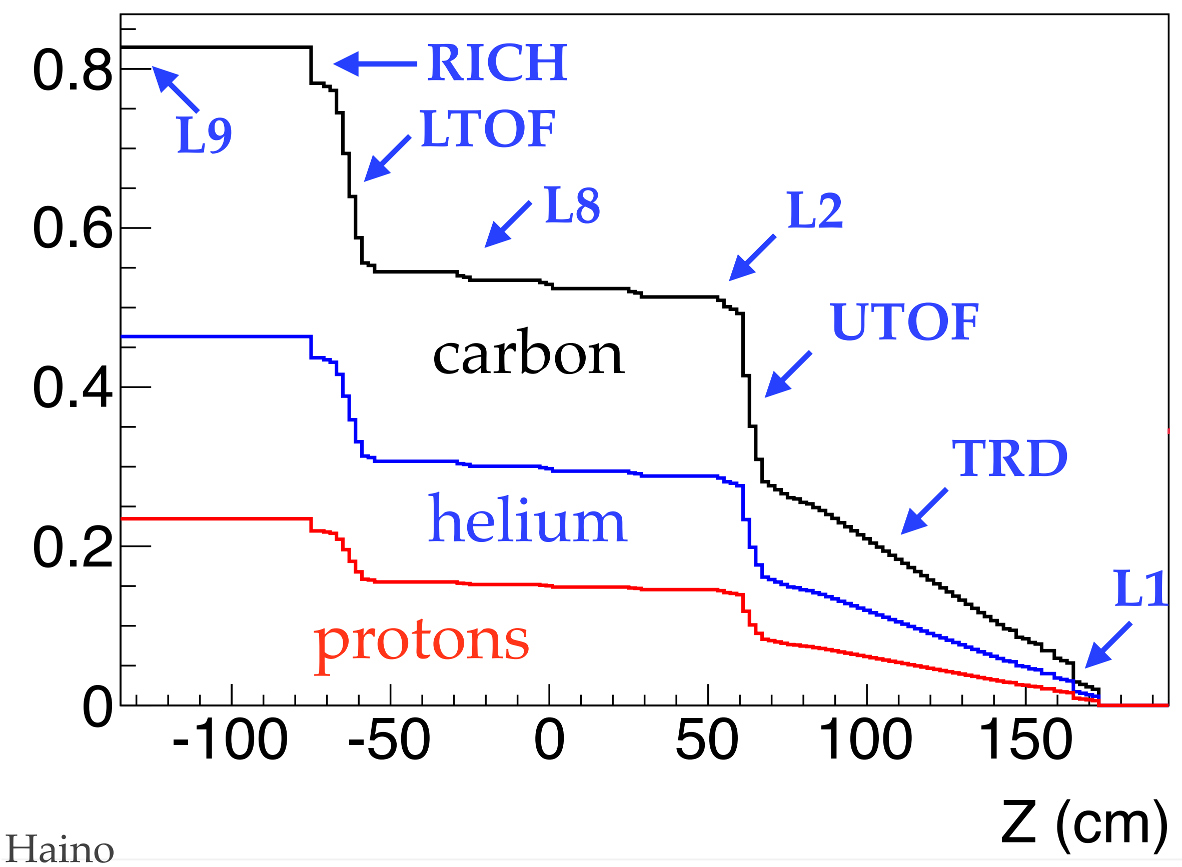
RICH
Z, E



Z and P

are measured independently by the Tracker, RICH, TOF and ECAL

Cross section systematics

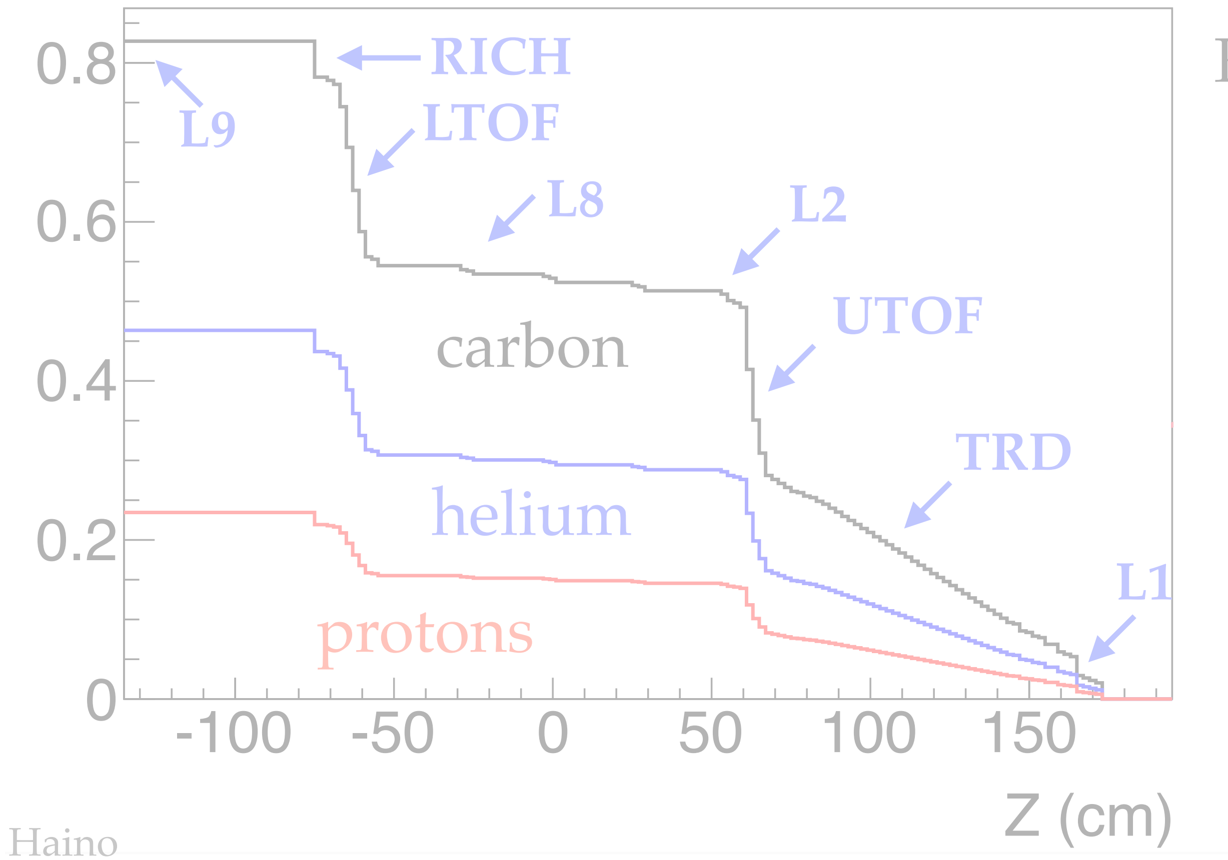


Haino

From the interaction length the uncertainty on a measured flux due to the cross section is obtained as

$$\frac{1}{2} \cdot \frac{e^{-L(1-\Delta\sigma)} - e^{-L(1+\Delta\sigma)}}{e^{-L}}$$

Cross section systematics



From the interaction length the uncertainty on a measured flux due to the cross section is obtained as

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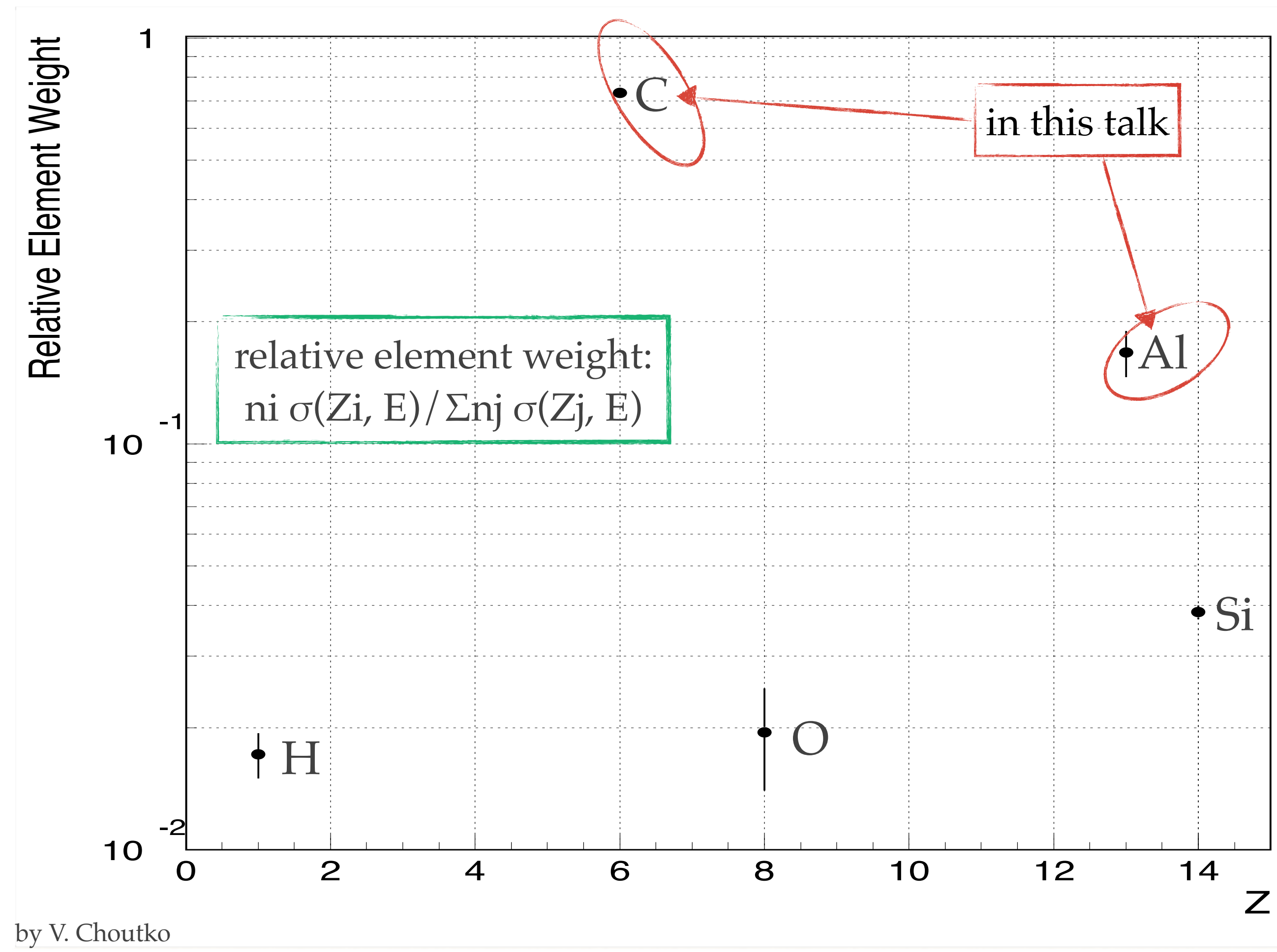
But in the detector many materials are present, for each one a different cross section is involved.



A caveat for flux measurement

- AMS analyses need proper estimation of cross section for particles like proton, helium, carbon, etc. on the detector material.

- The current estimation of interaction and survival probability comes from models encoded in Geant4.

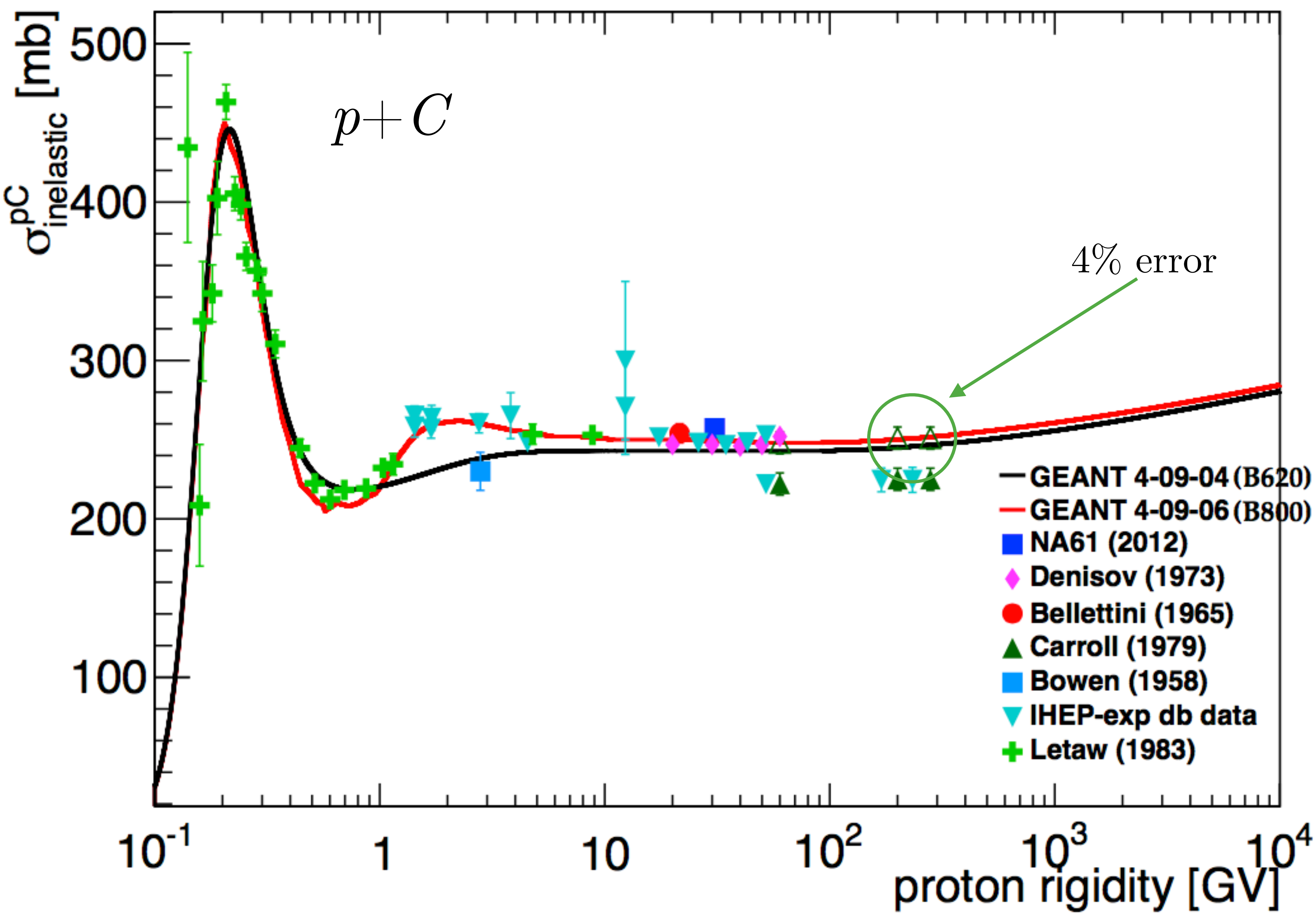
- The models are partially verified by experimental data, mostly in low-energy region (with the exception of p-p data).

- There is an effort by the AMS-02 collaboration to estimate high energy projectile cross sections for current analyses of interest.

- With 5-10% uncertainty on the cross-section we can get :
  - 1-2% syst. error on p flux,
  - 2-5% syst. error for He flux,
  - 4-8% syst. error for C flux.

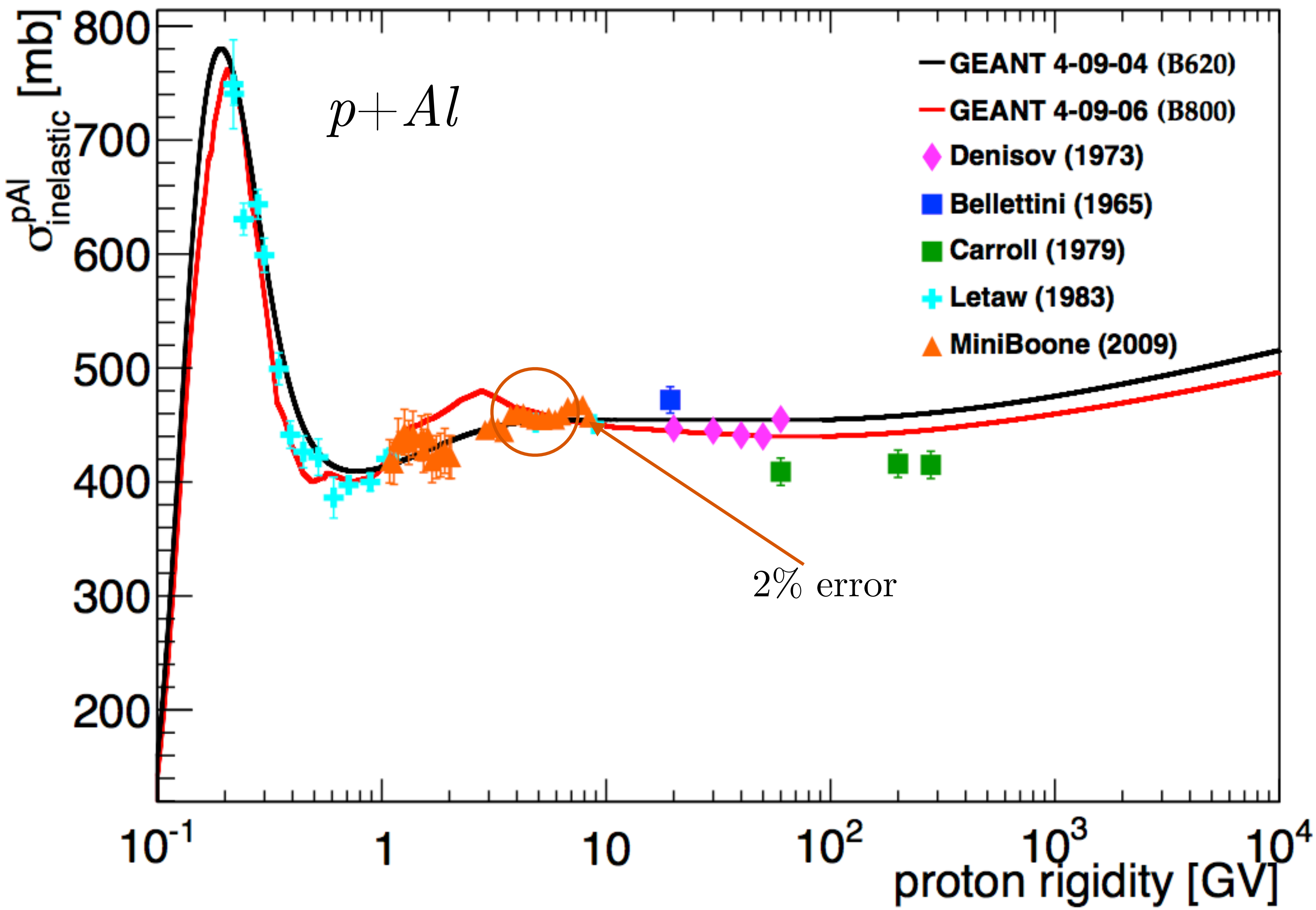
A sample of cross sections

(Models may differ up to 14%)



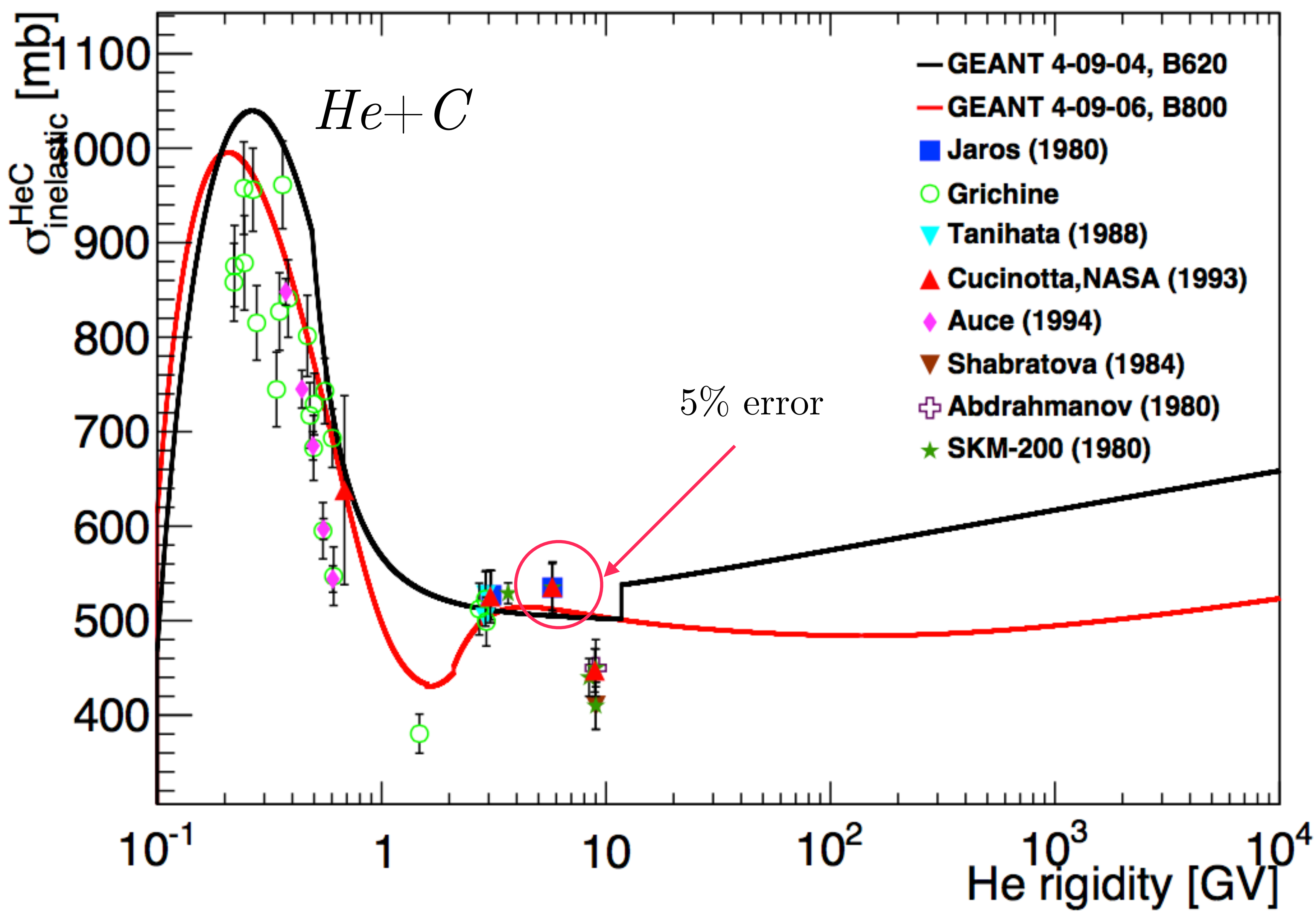
A sample of cross sections

(Models may differ up to 9%)



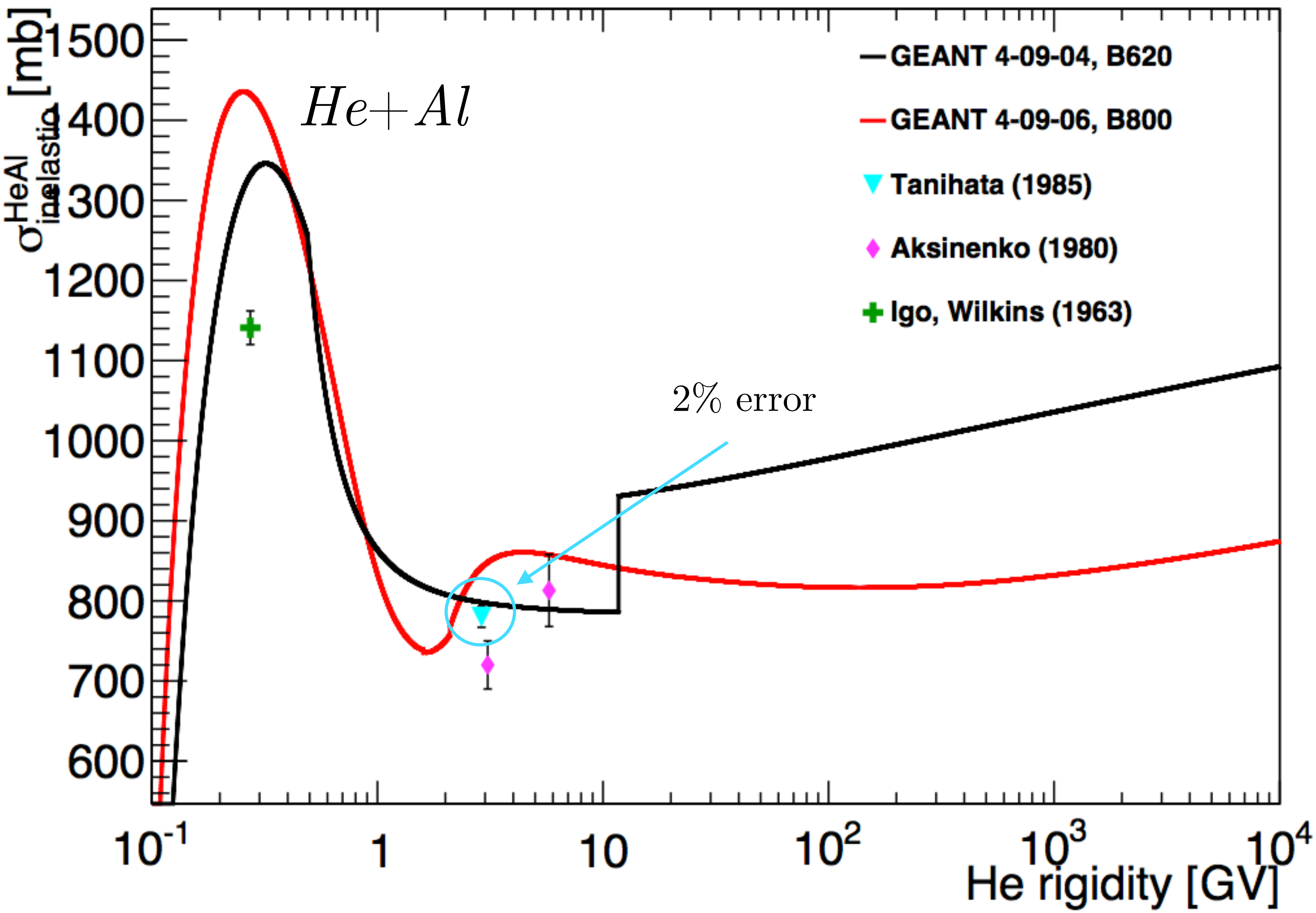
A sample of cross sections

(Models may differ up to 20%)



A sample of cross sections

(Models may differ up to 25%)



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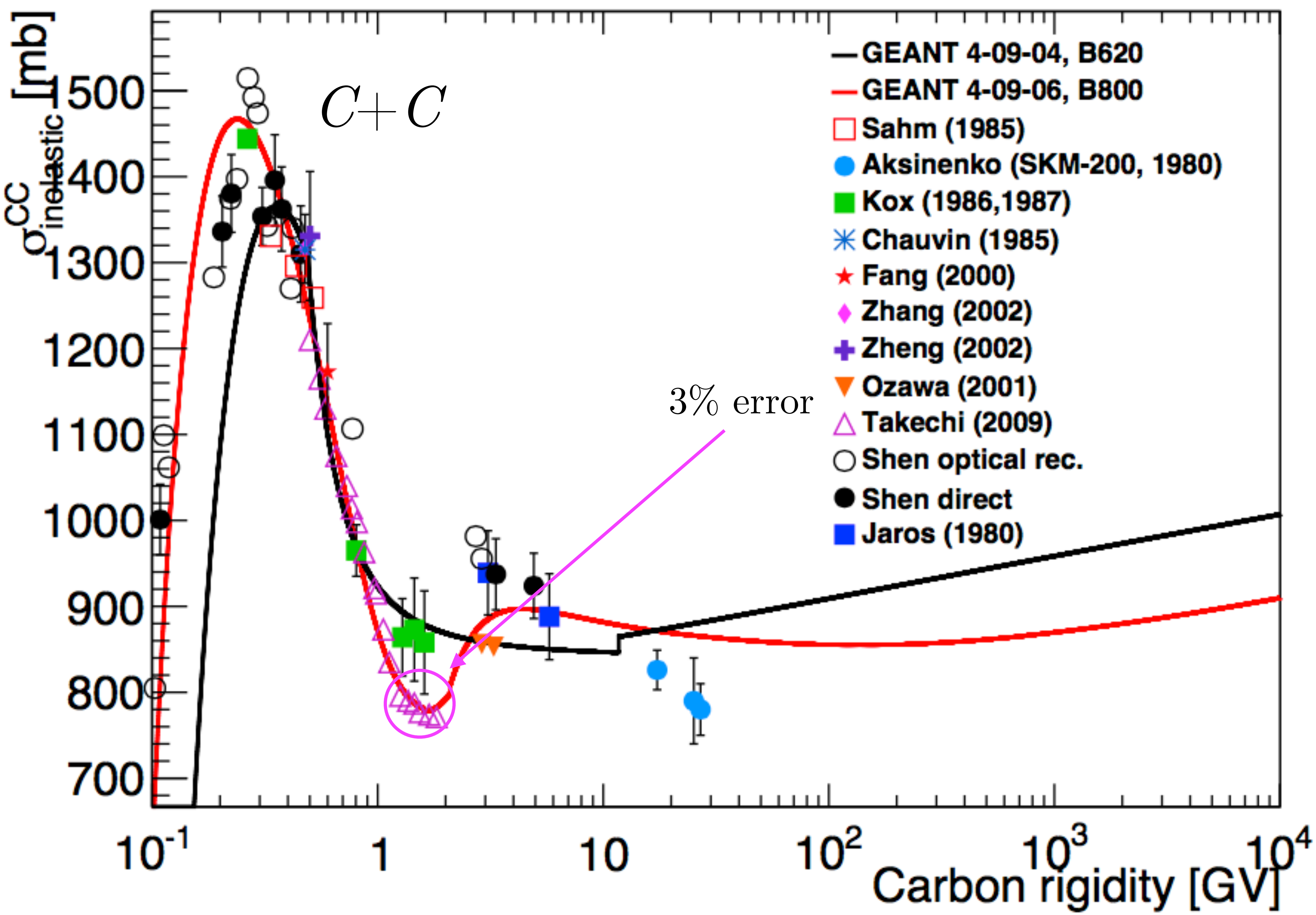

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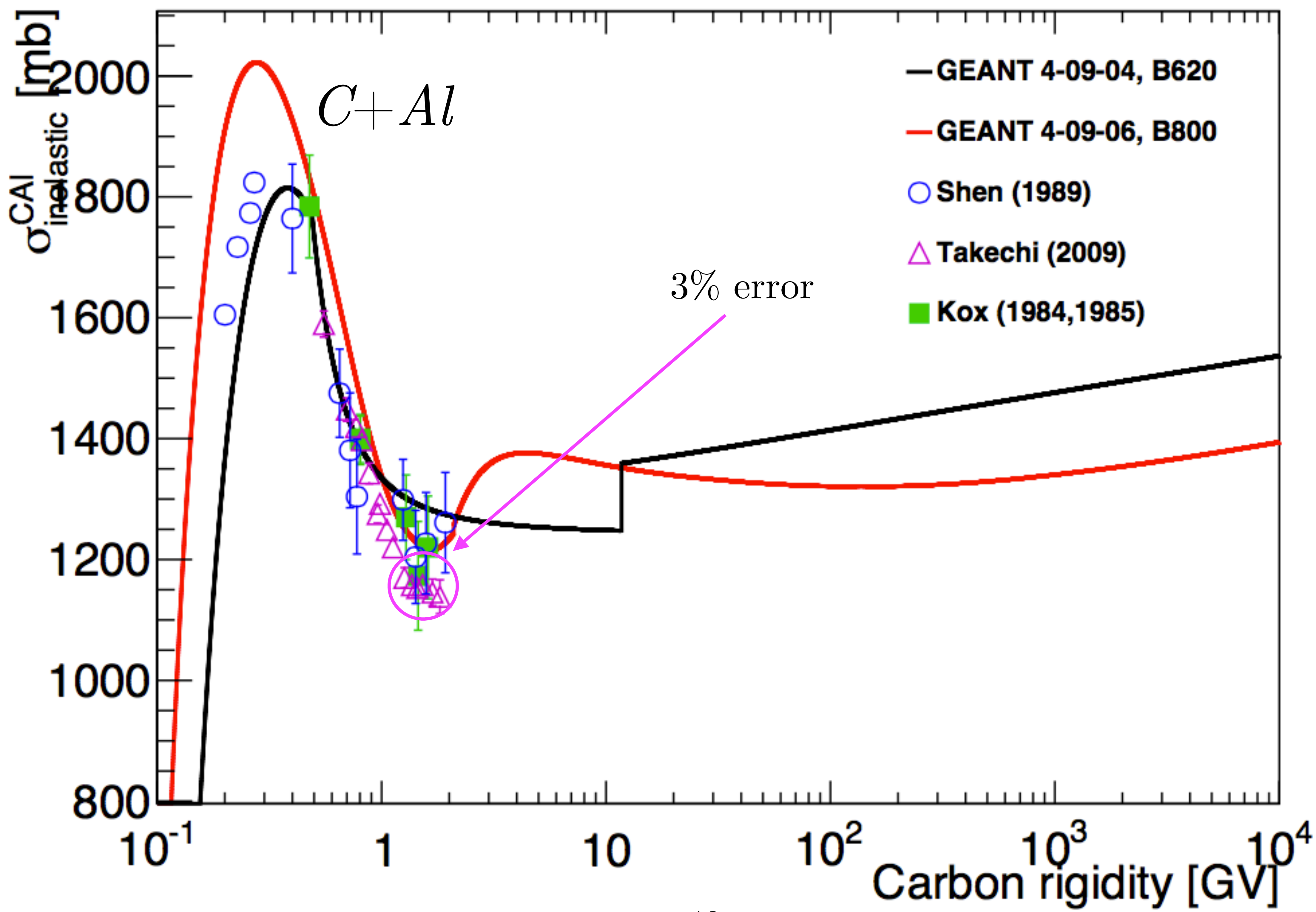
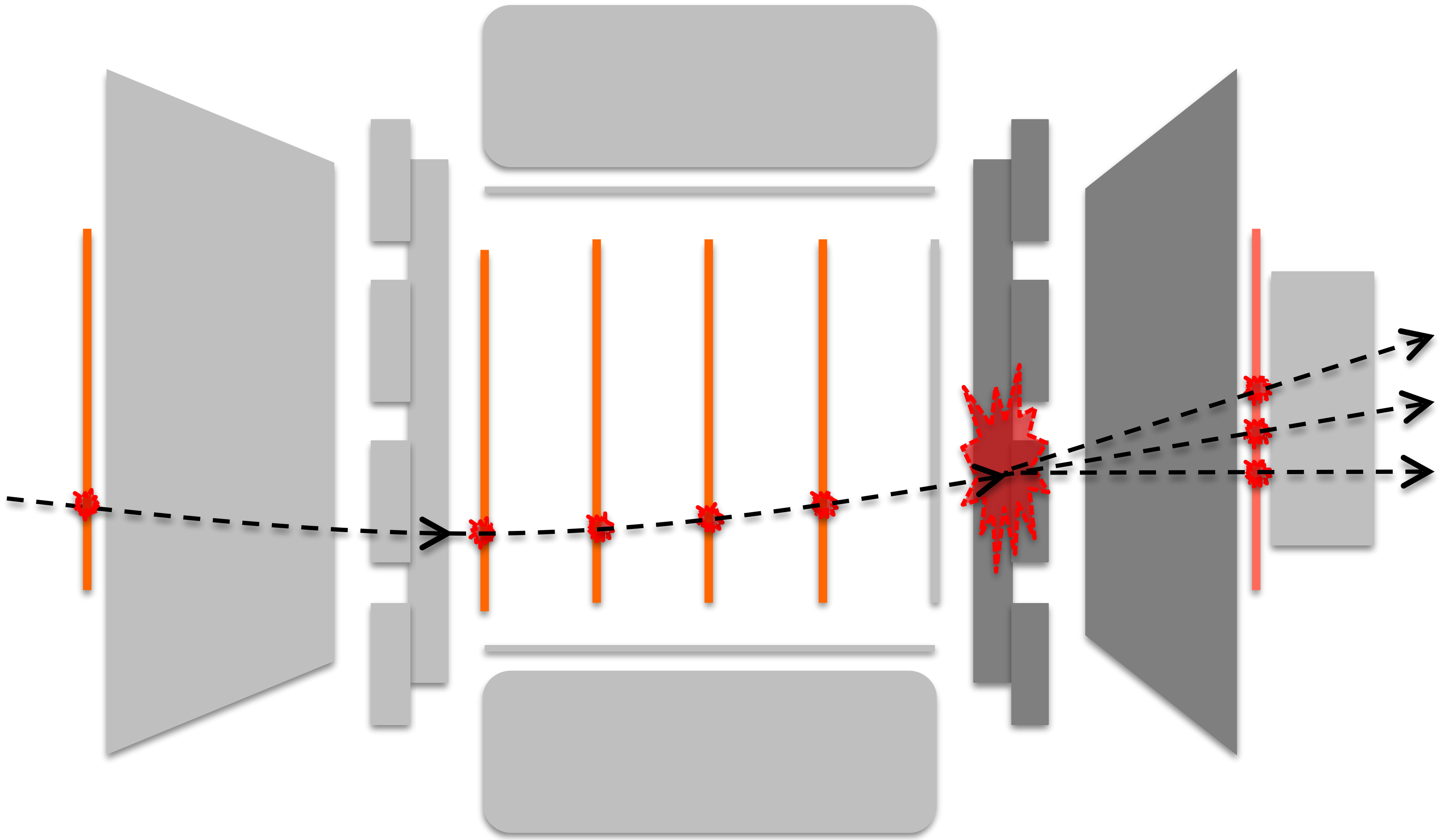


AMS-02

AMS is a particle detector in space. It can try to address the problem.
Repurpose part of the detector as a target, use the rest for up(down)stream ID.

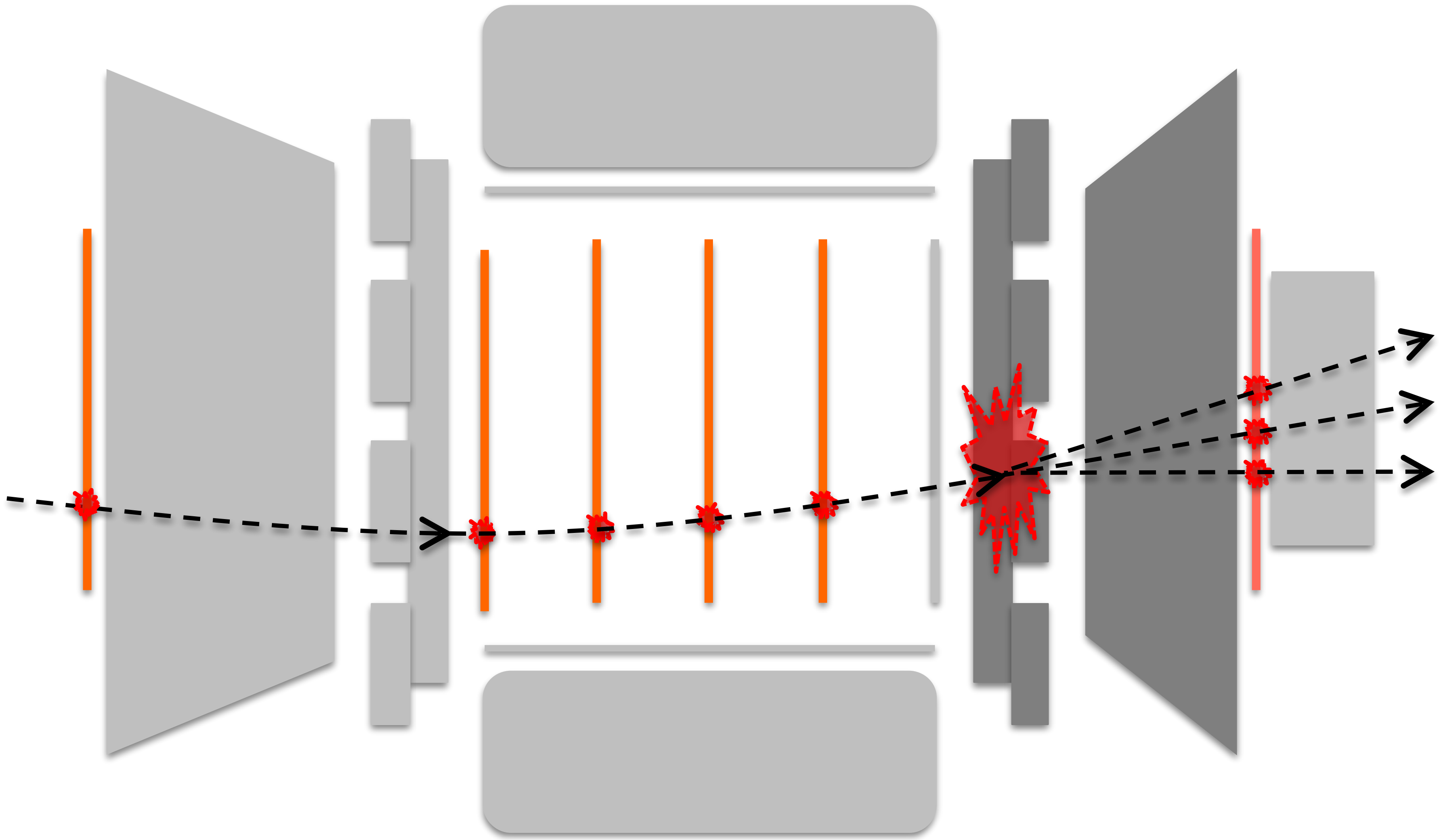


"Survival probability"

Preselect particles with upper part of detector (N_p)

Select surviving particles with charge cut on Layer 9 (N_s)

Use particles not interacting in ECAL to estimate charge efficiency ($\boldsymbol{\varepsilon}_\mathrm{c}$)



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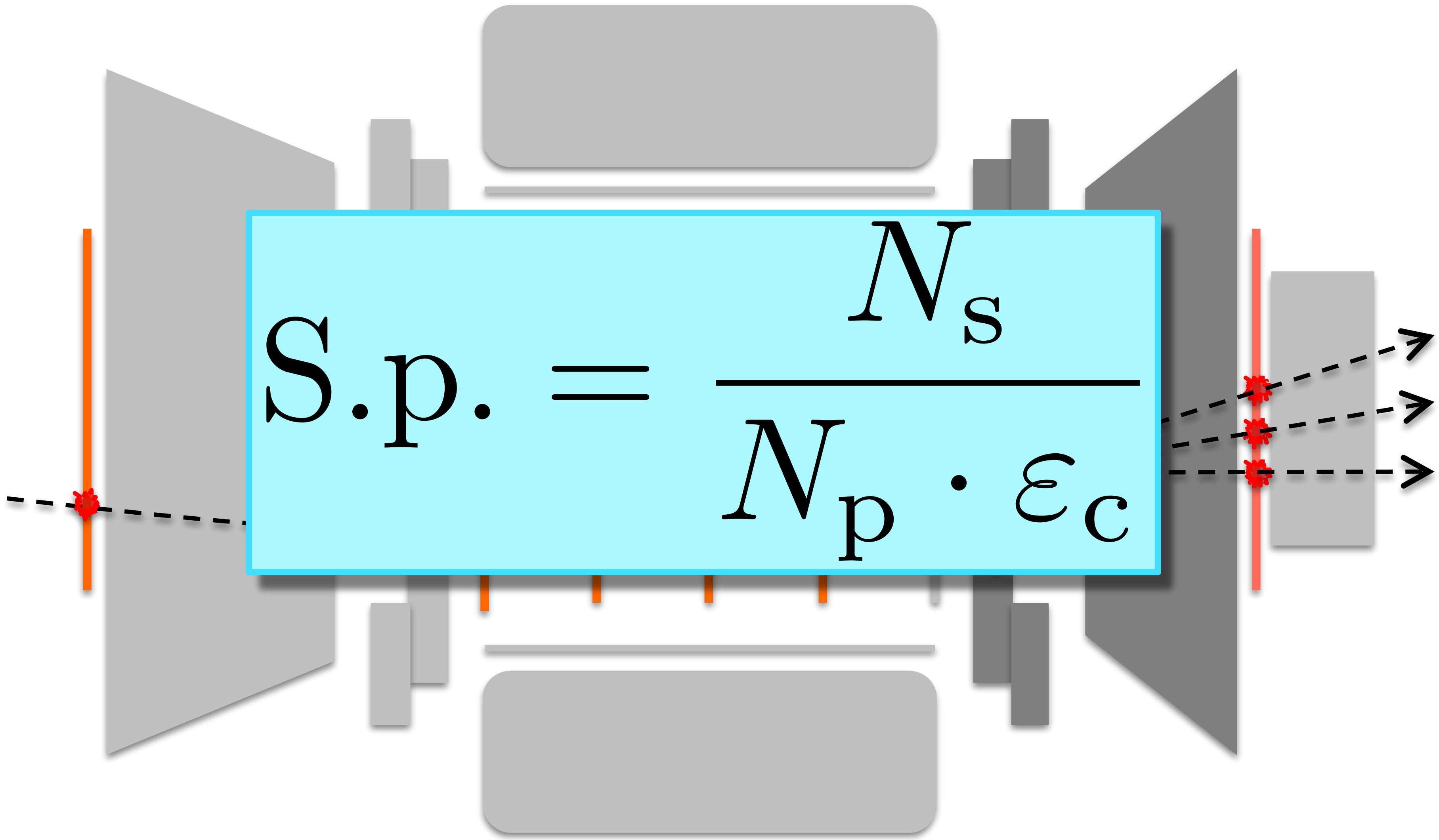


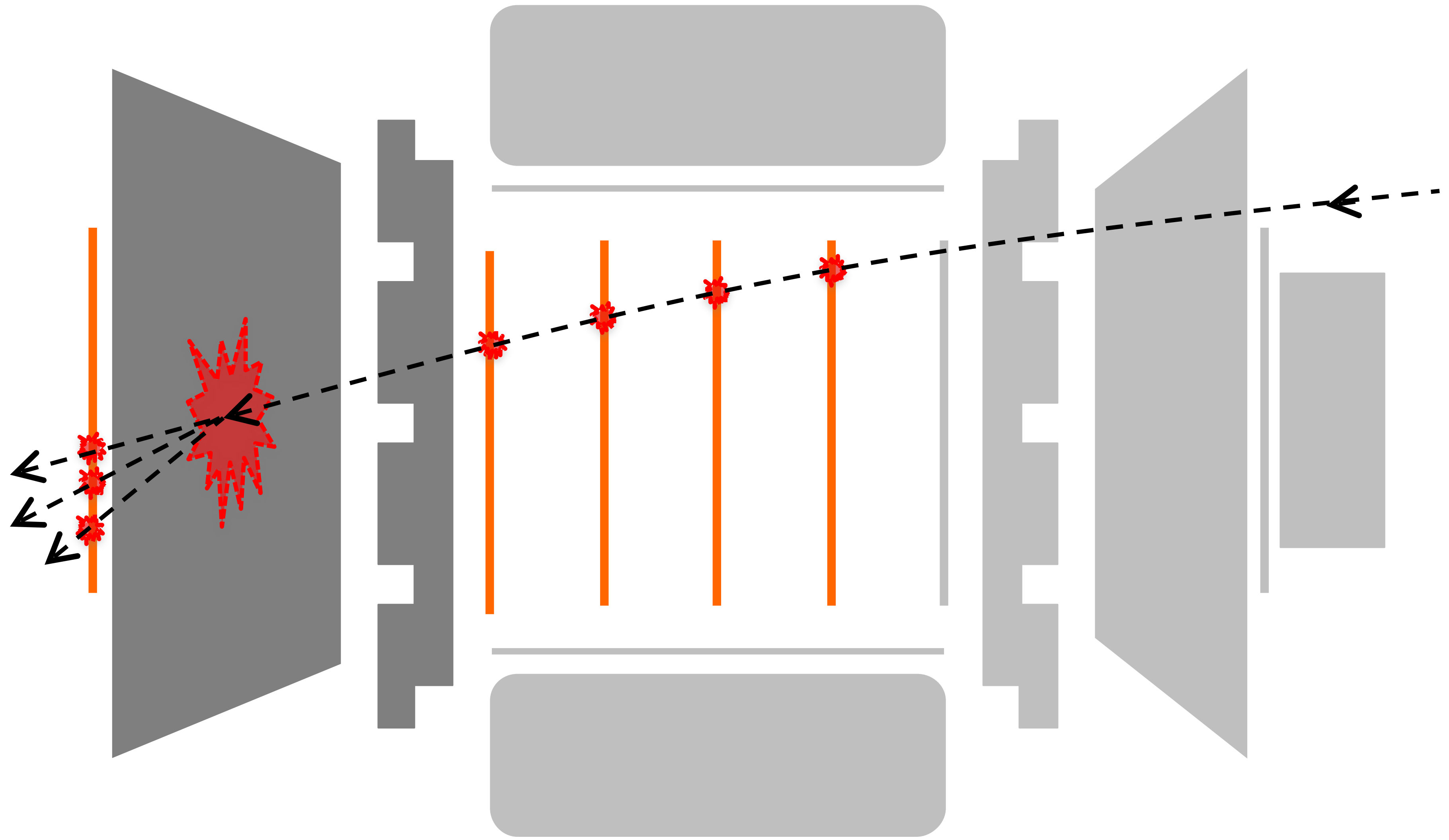
$$\text{S.p.} = \frac{N_s}{N_p \cdot \varepsilon_c}$$

The same game can be played upside-down

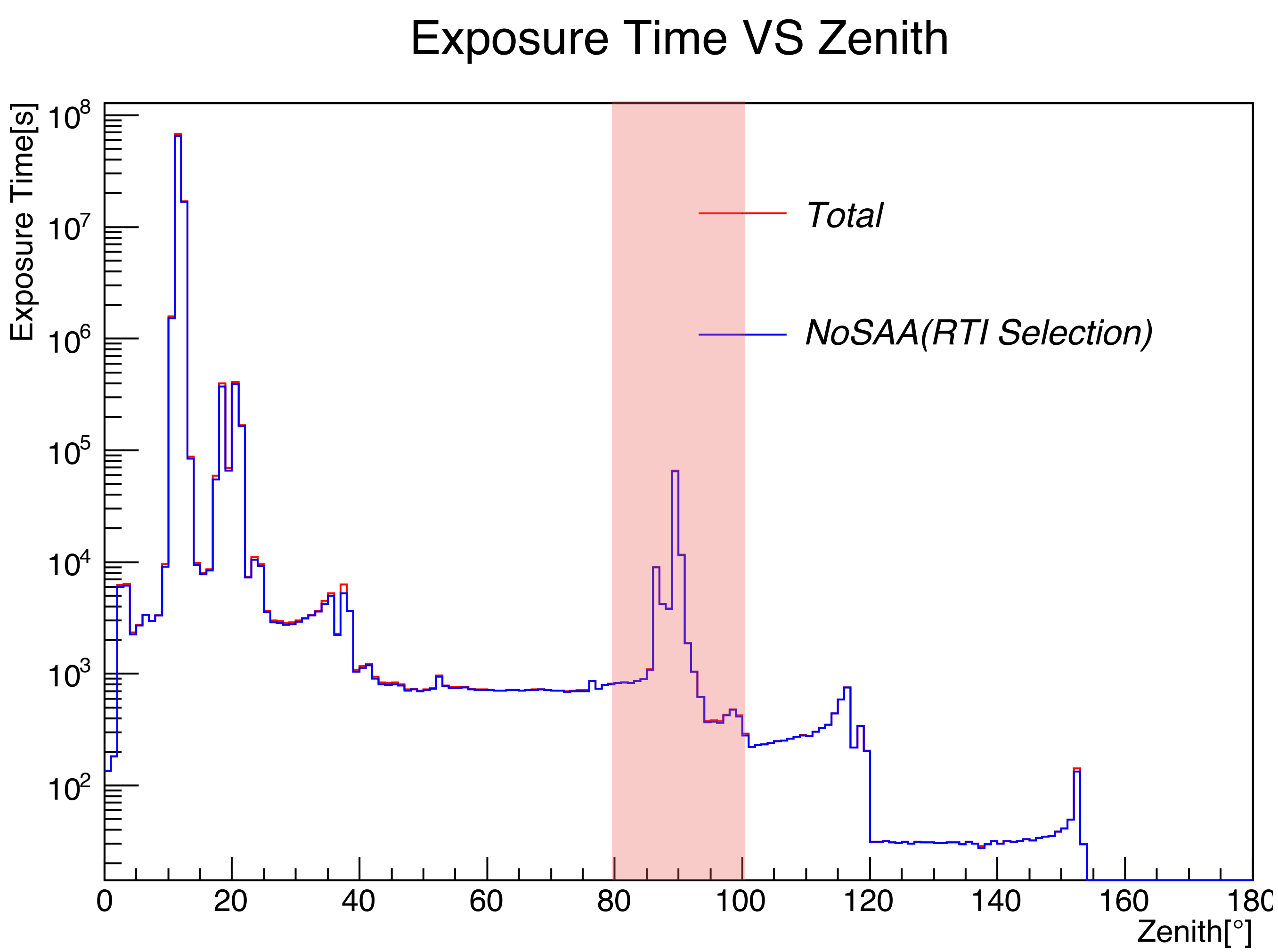
Preselect particles with inner tracker coming from below (N_p)

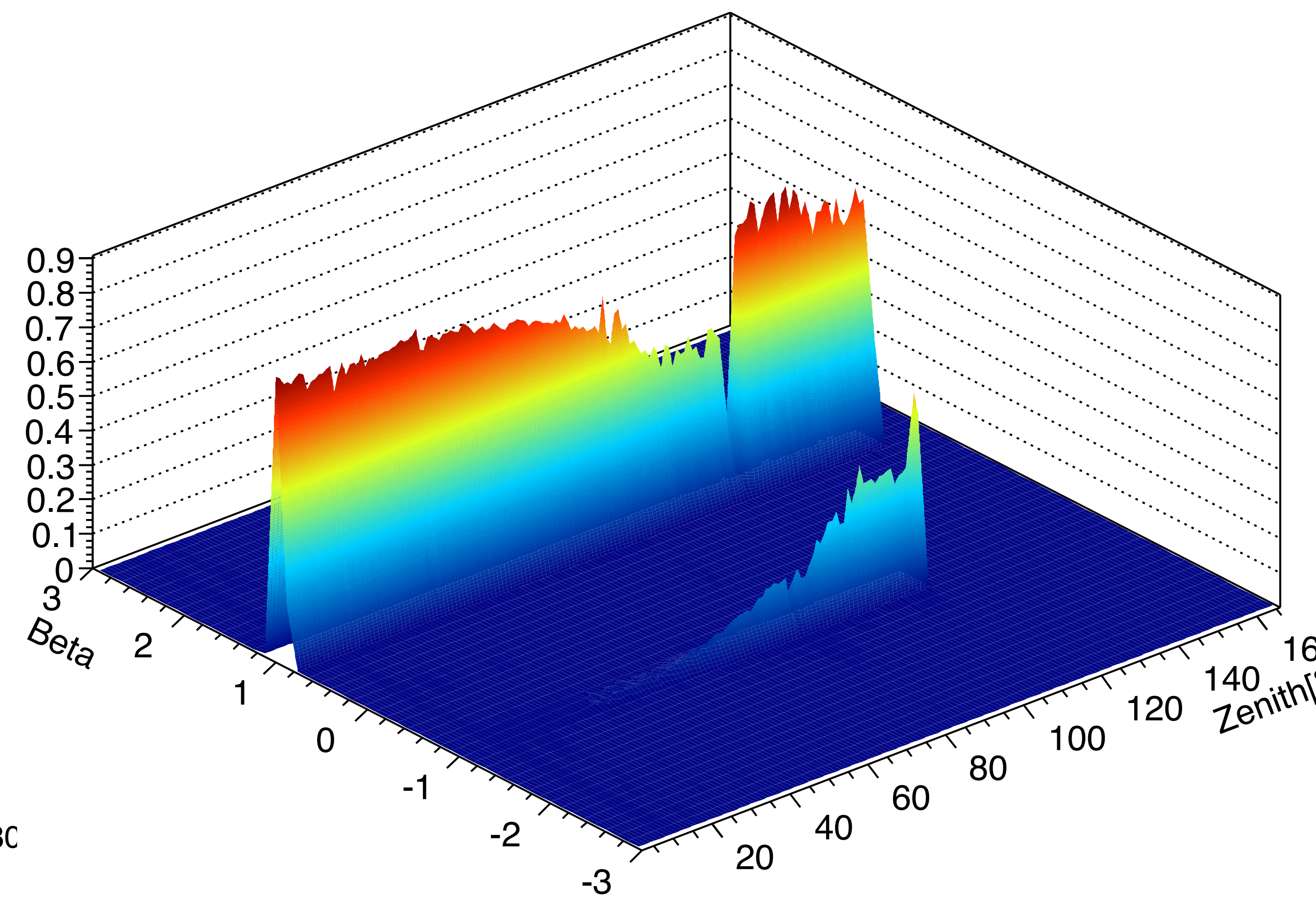
Select surviving particles with charge cut on Layer 1 (N_s)

Use particles coming from above to estimate charge efficiency ($\boldsymbol{\varepsilon}_\mathrm{c}$)



So far AMS-02 has spent 2 days in "horizontal" position.
With 80<zenith<100 the data sample is enriched in particles coming from below.
Compare downward and upward efficiencies after sample reweighing (because of different angular distribution)

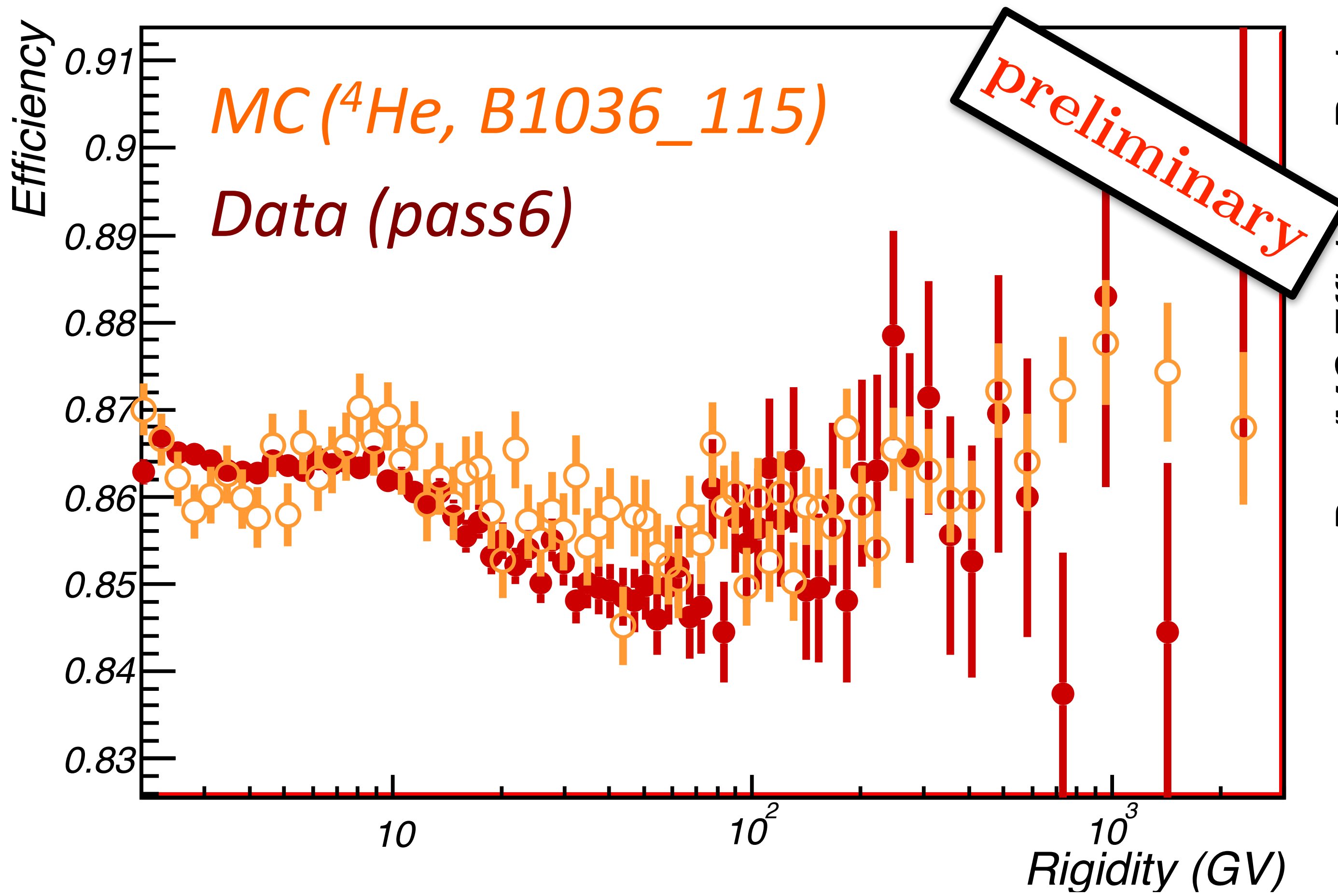


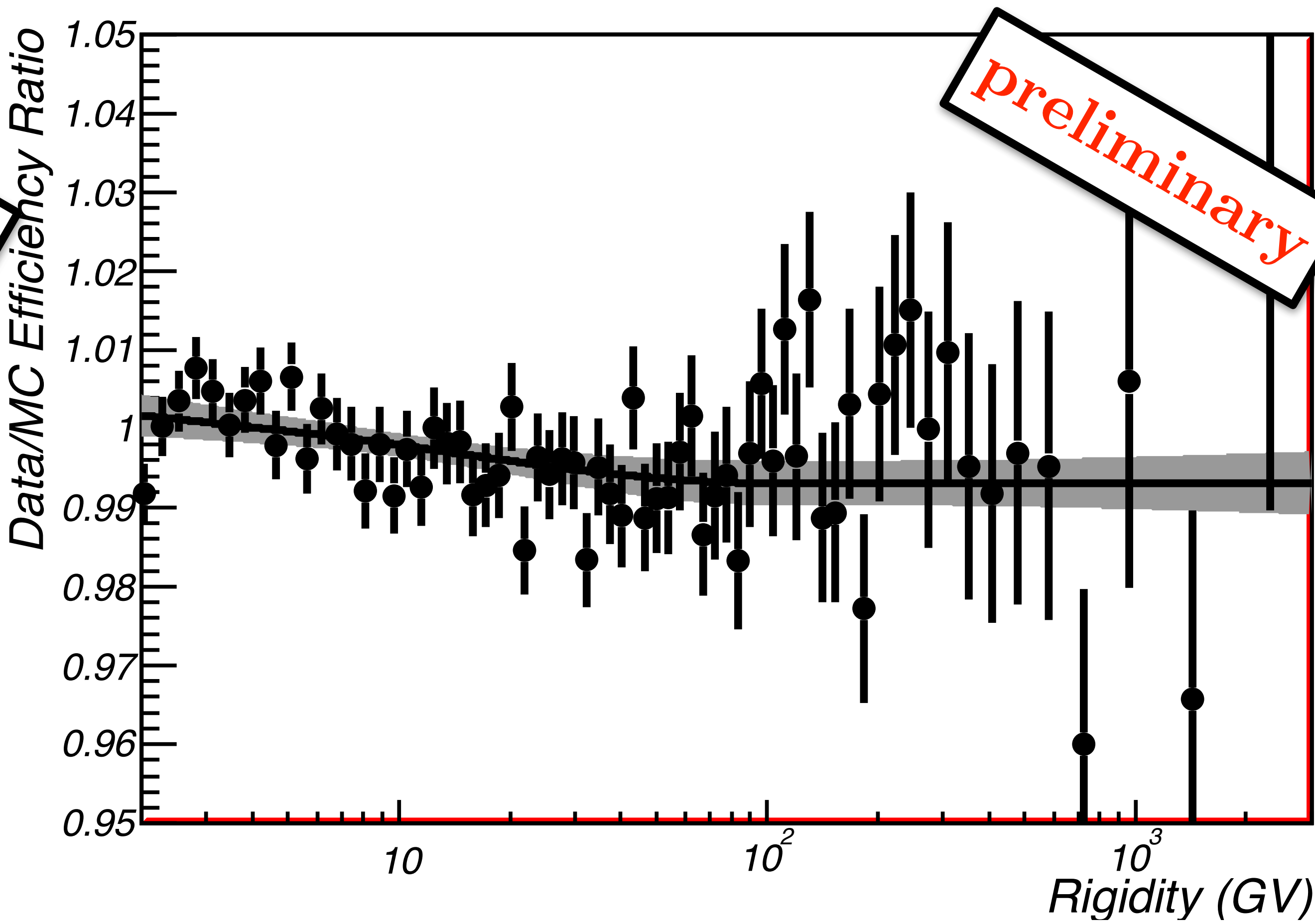


Helium S.p.

Best data/MC agreement if interaction probability is tuned up by 15%. This tuning is preliminarily done with cross section but it's only part of this game

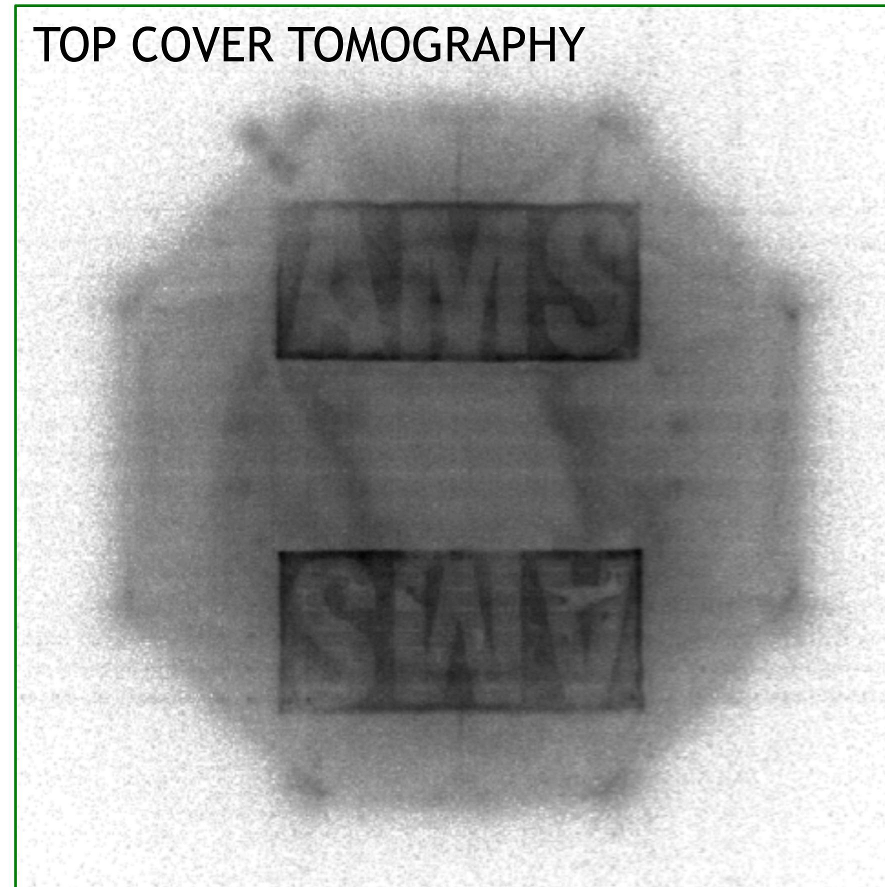
(Remember, $He+C$ and $He+Al$ models at high energies may differ by more than 20%)

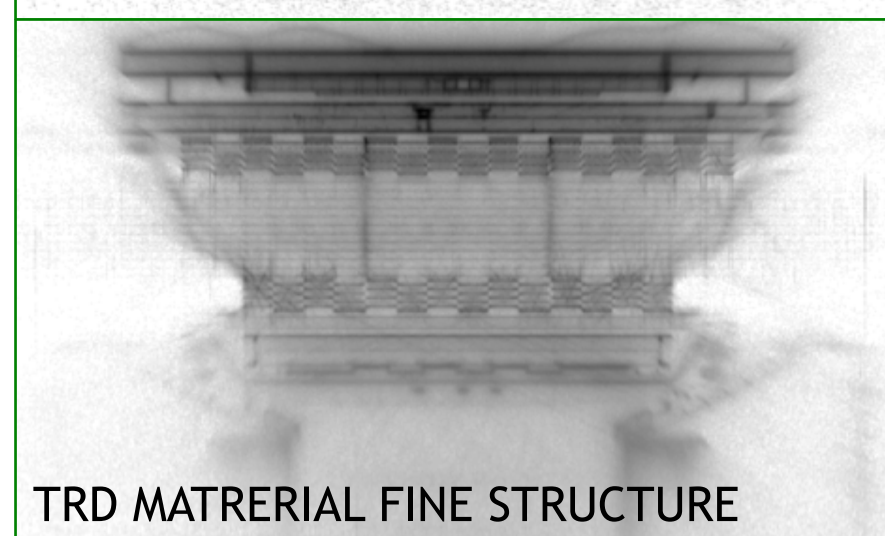




Interaction tomography

MATERIAL RECONTRUCTION USING INTERACTION VERTICES RECONSTRUCTED BY TRD



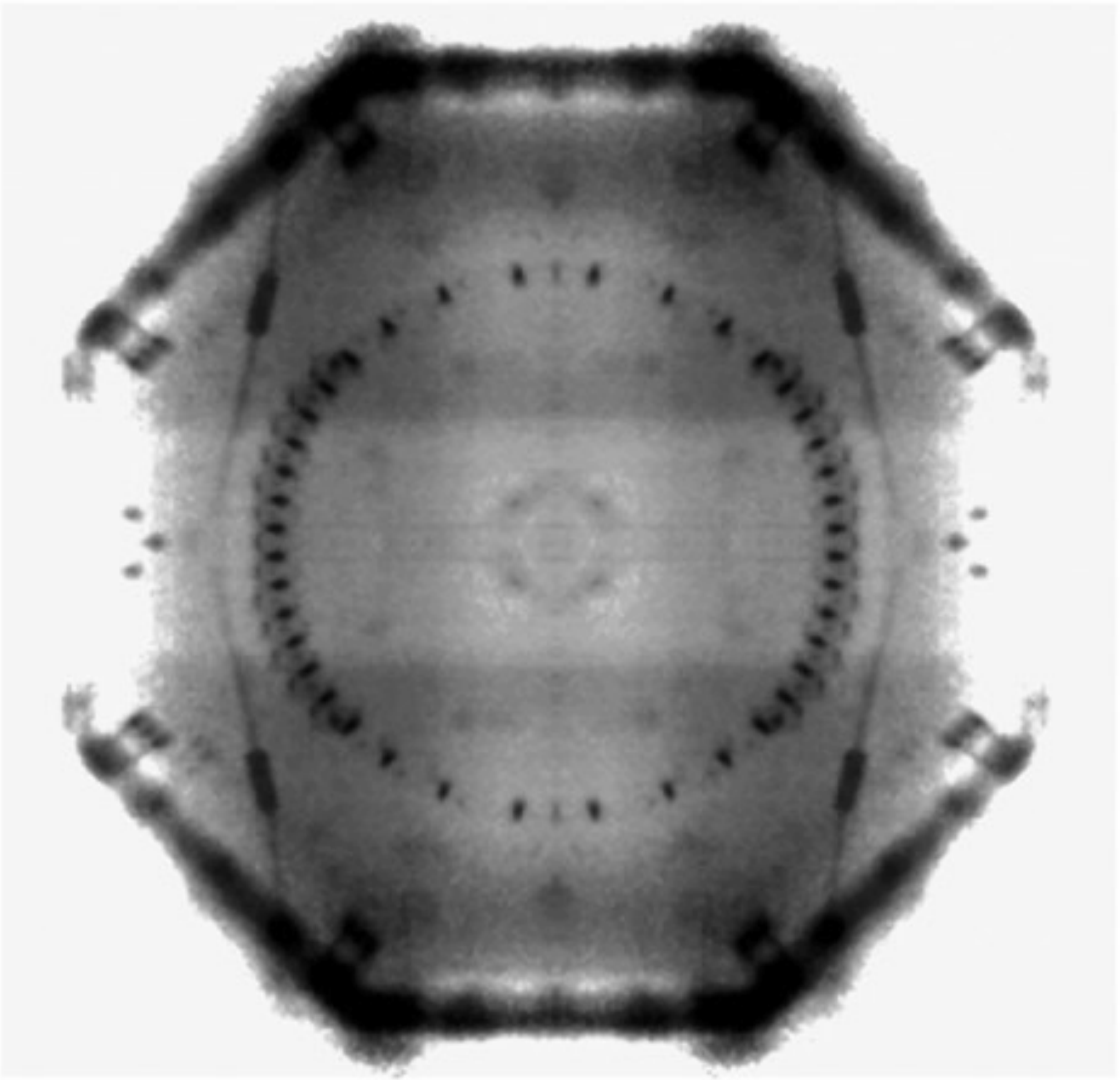


Interaction tomography

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



Tomographic reconstruction of the AMS top-of-instrument material obtained using the Proton-to-Helium flux ratio. Tiny differences in the interaction cross-section of proton and He are used to trace the material inhomogeneities. Several detector elements such as screws, electronics boards, and mechanical interfaces are clearly recognisable.

Charge-changing processes

$$C \to B$$

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

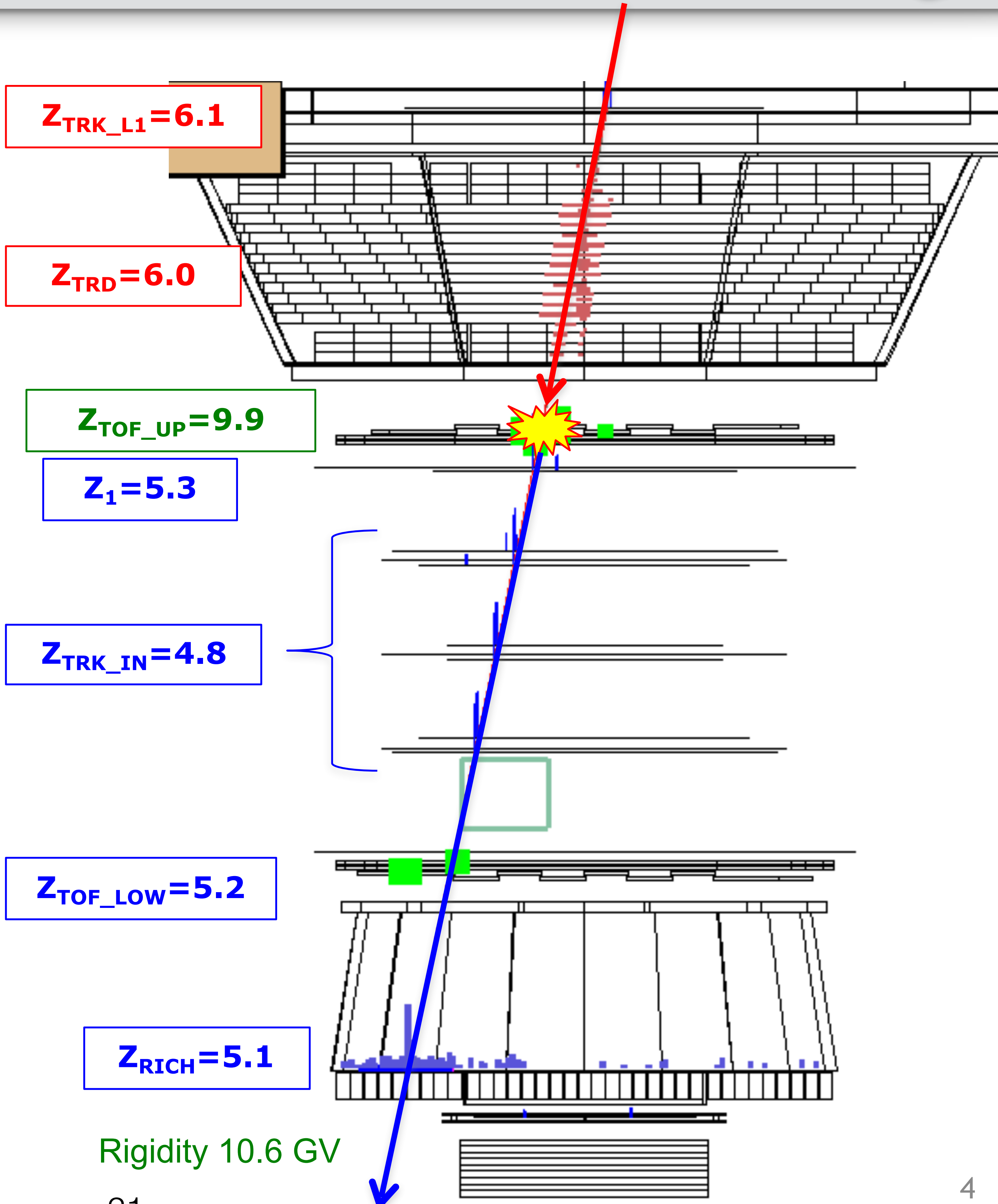
-NACC < 5

Minimum bias trigger:

-1/100 prescaling!!

-3/4 TOF fired

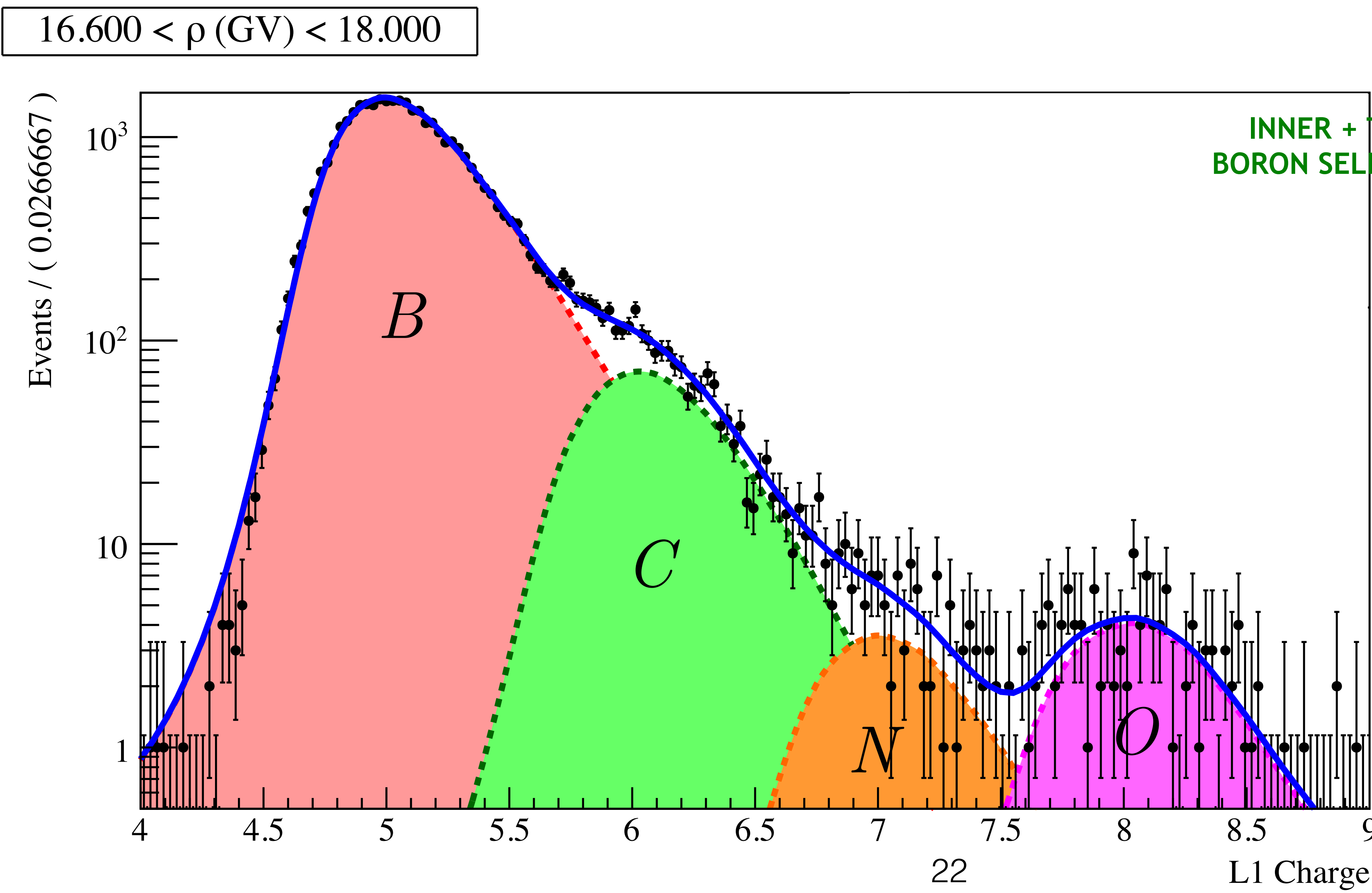
-No conditions on NACC

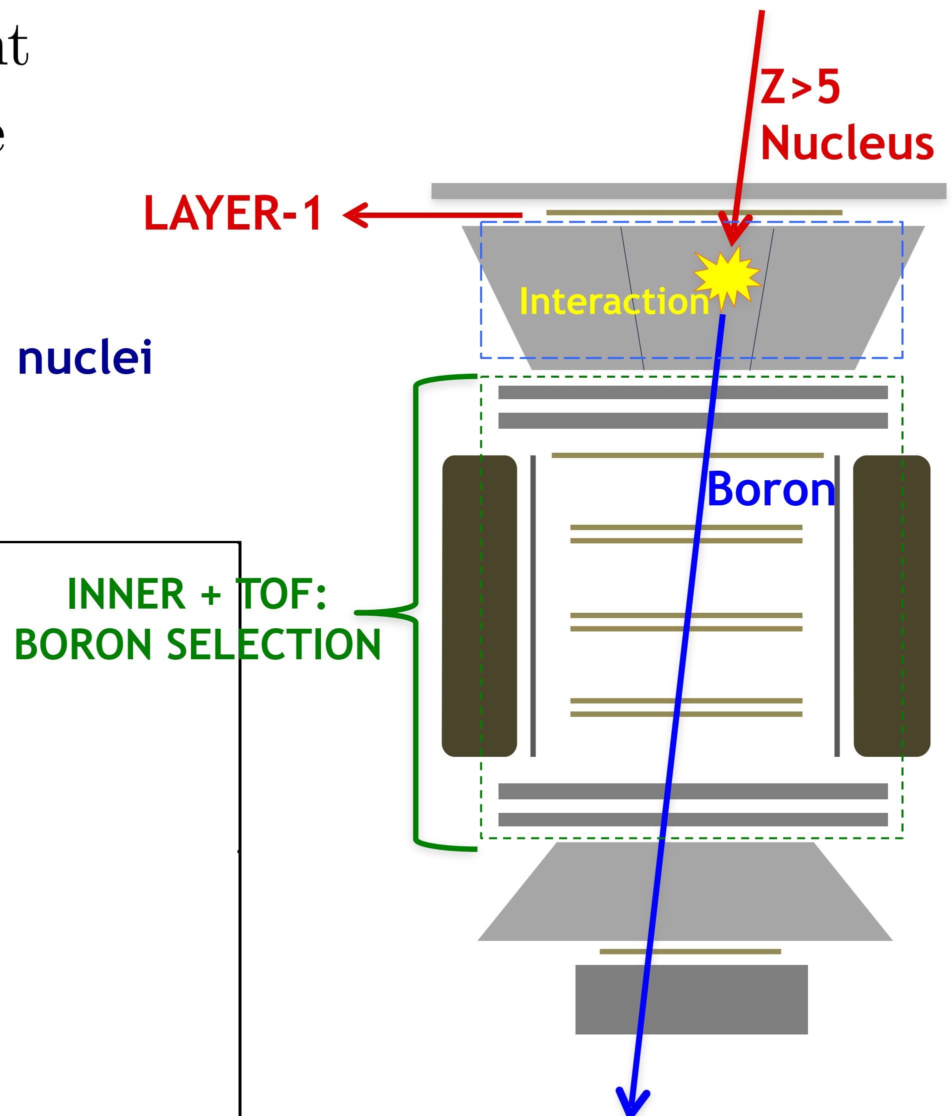


Charge-changing process

Redundancy in Z-measurements allows us to study different fragmentation processes appearing at different levels in the detector.

Example: secondary production of Boron in TRD material by Z>5 nuclei





Conclusions

- Almost 50% of the uncertainty on $\bar{p}$ theoretical prediction comes from the propagation environment
- Precision measurements of the nuclear component of cosmic rays is crucial to narrow down propagation parameters
- AMS-02 is capable of performing such measurement, provided we can increase our knowledge of high-energy ions inelastic cross sections.
- AMS-02 shows also sensitivity to the cross section value in some key observables (and has a lot of data!). Also, sensitivity to exclusive (charge-changing) cross sections.
- AMS-02 (like many other CR experiments) can benefit from some new measurements of cross sections for heavy ions.

Thanks