Prospect for measurements of heavy antimatter in space (ID 223)

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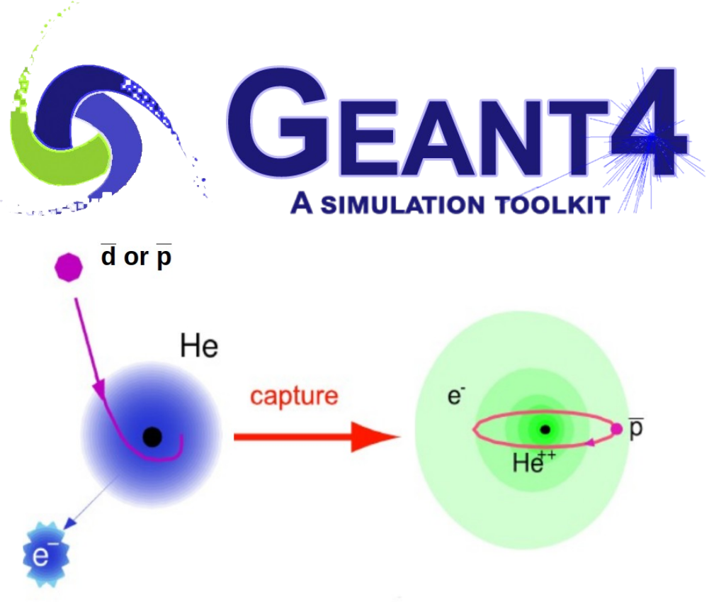
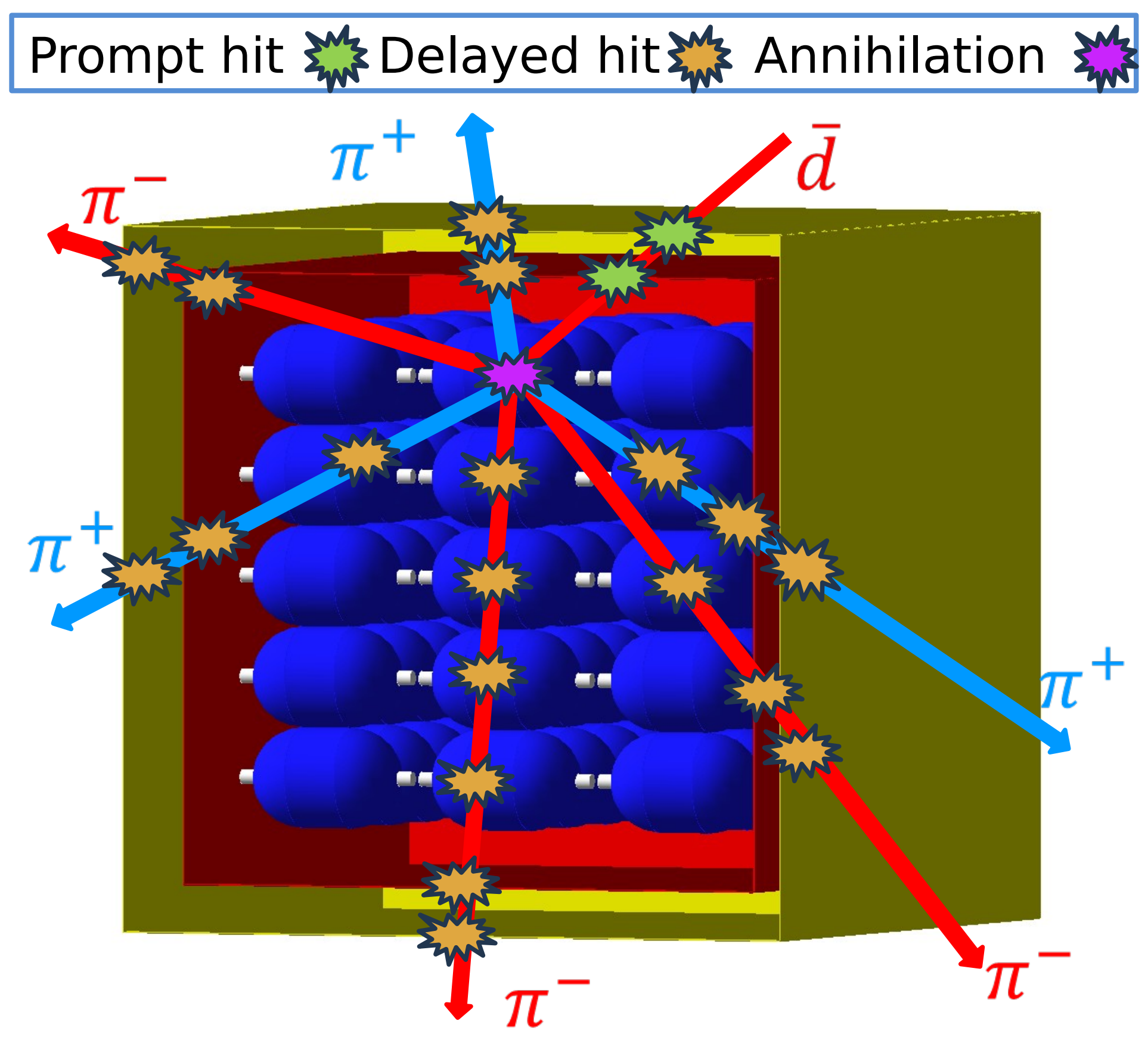
Metastable states in Helium and the PheSCAMI detector



An **Helium atom can capture antiparticles** as antiprotons and antideuterons stopping nearby. The atom looses an electron and the captured antiparticle occupies a large orbit (**n~38**). **Auger and collisional Stark effect are suppressed**. The ground state can be reached **only** through **radiative transitions**. The metastable states increase the annihilation lifetime from **~ps** to **~μs**. Such increment has been observed in **antiprotons**, **π^-** and **K^-**.



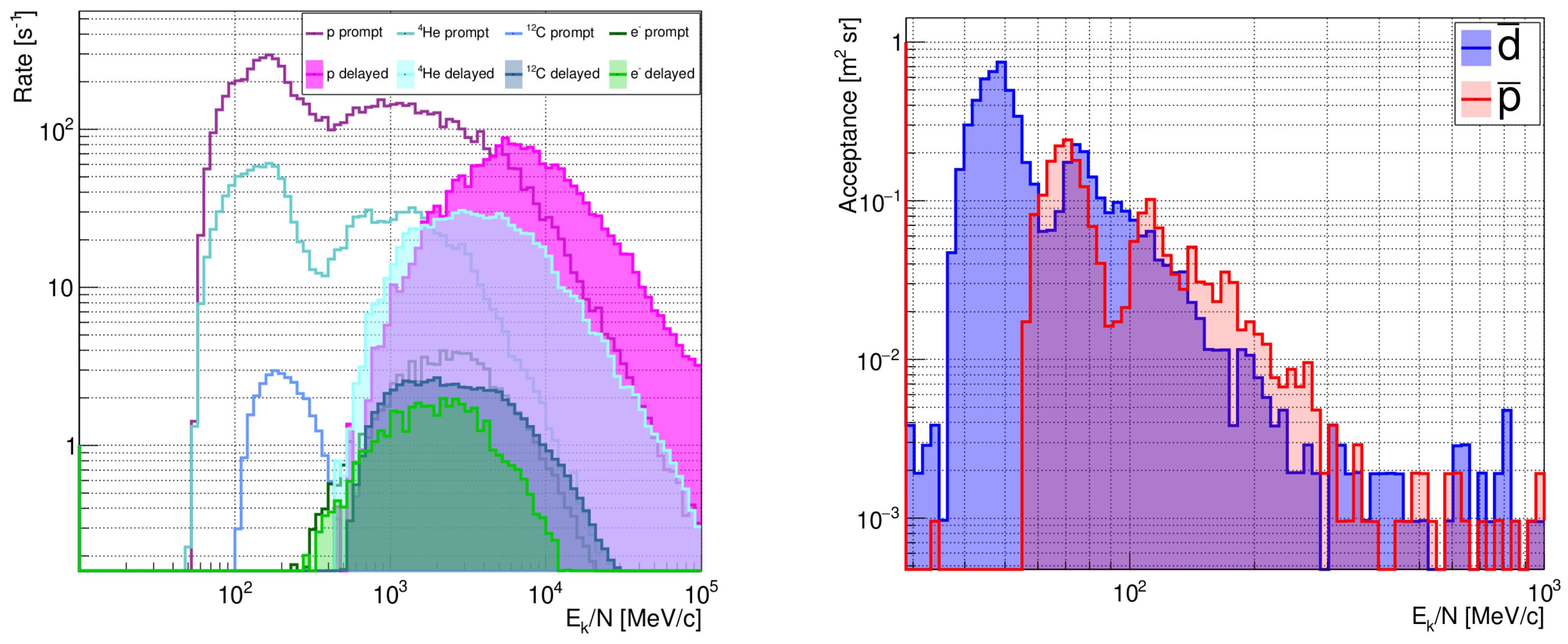
The PheSCAMI project aims to identify **low energy antideuterons inside the cosmic rays** (CRs), measuring the delayed annihilations within the pressurized Helium target.
The detectors has two systems: the **Time of Flight (TOF)** and the **Helium calorimeter (HeCal)**.
The **TOF** is composed of **segmented plastic scintillator** (44 mm X 54 m²) with resolution of: **σ_β = 5%** and **σ_E = 5%**.
The **HeCal** is made of 75 **Helium tanks** (75 L and 310 bar) with the following resolutions: **σ_t ~ ns and σ_E = 10%.**
Those tanks are **space qualified** and will be used by ESA.

Trigger logic, rates and acceptances

The **trigger logic has two selection: prompt and delayed**. The **prompt** selection **rejects** minimum ionizing particles (**MIPs**), while the **delayed** selection **search for signs of a delayed annihilation**.

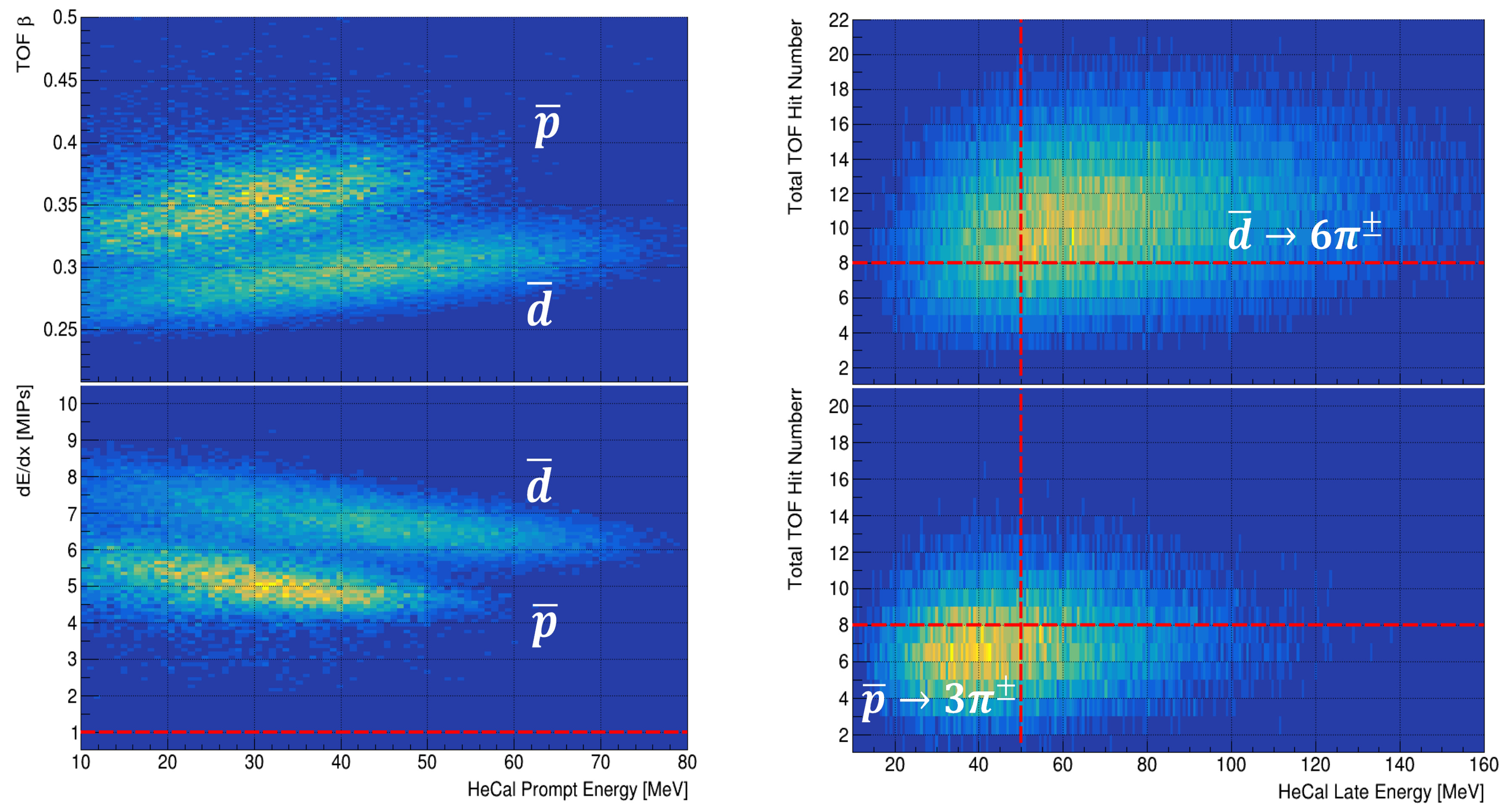
PROMPT (0, 50 ns)	**DELAYED (50 ns, 4'000 ns)**
Max E_{dep} TOF > 2 MIP_{TOF}	Max E_{dep} TOF > 1 MIP_{TOF}
Max E_{dep} HeCal > 1.3 MIP_{HeCal}	Max E_{dep} HeCal > 1.3 MIP_{HeCal}
Number of TOF prompt hit ≤ 3	Number of TOF delayed hit > 4

The trigger logic has been applied to the most common particle and nuclei in CRs (**p, e^-, ^{4}He, ^{12}C**) obtaining the expected rate. The **acquisition rate for ordinary matter is ~ 100 Hz**. The geometric acceptances have been obtained considering the probability of create a metastable state and to observe the delayed annihilation within 4 μs. **The expected sensibility to an antideuterons flux** with three circumpolar flight **is ~10^{-5} [GeV m² sr s]$^{-1}$**.



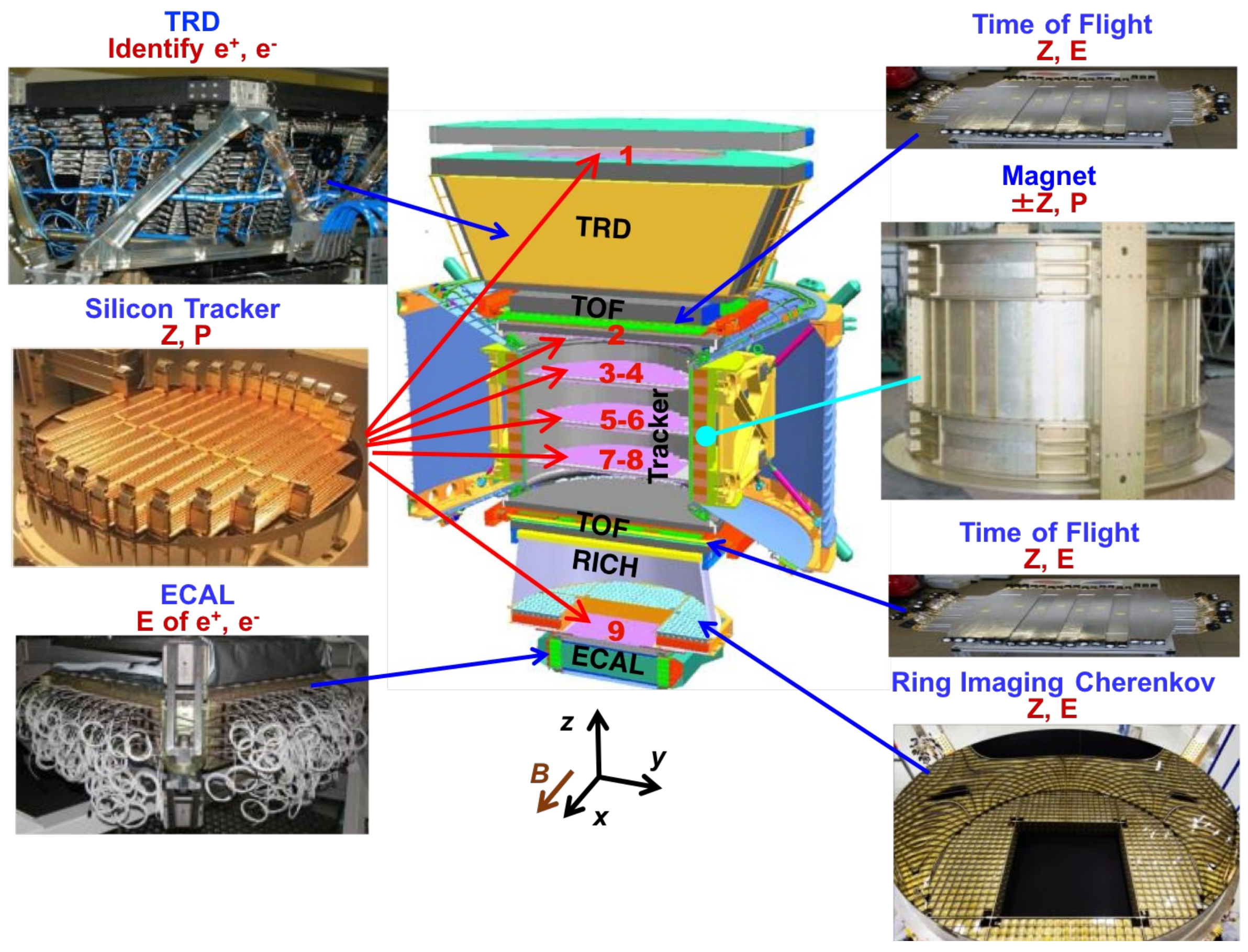
Antideuterons identification

The **left plots** show two different variables as a function of **the prompt energy** released **in the HeCal**. The **upper-left** plot shows the **TOF β**, while the **bottom left** plot shows the **energy deposit in the out TOF layer**, normalized on a MIP scale (2 MeV/cm).
The **right plots** shows the **hits number in the TOF as a function of the delayed energy** release **in the HeCal** on the x-axis. **The upper-right** plot is for **antideuterons**, while **antiprotons** are reported on **the bottom-right plot**.



The Alpha Magnetic Spectrometer (AMS-02)

The **Alpha Magnetic Spectrometer** is a state-of-the-art particle physics detector designed to operate as an external module on the International Space Station (**ISS**). The objectives of AMS-02 are the **precise measurement of cosmic rays** (CRs) composition and the search for **antimatter in space**.



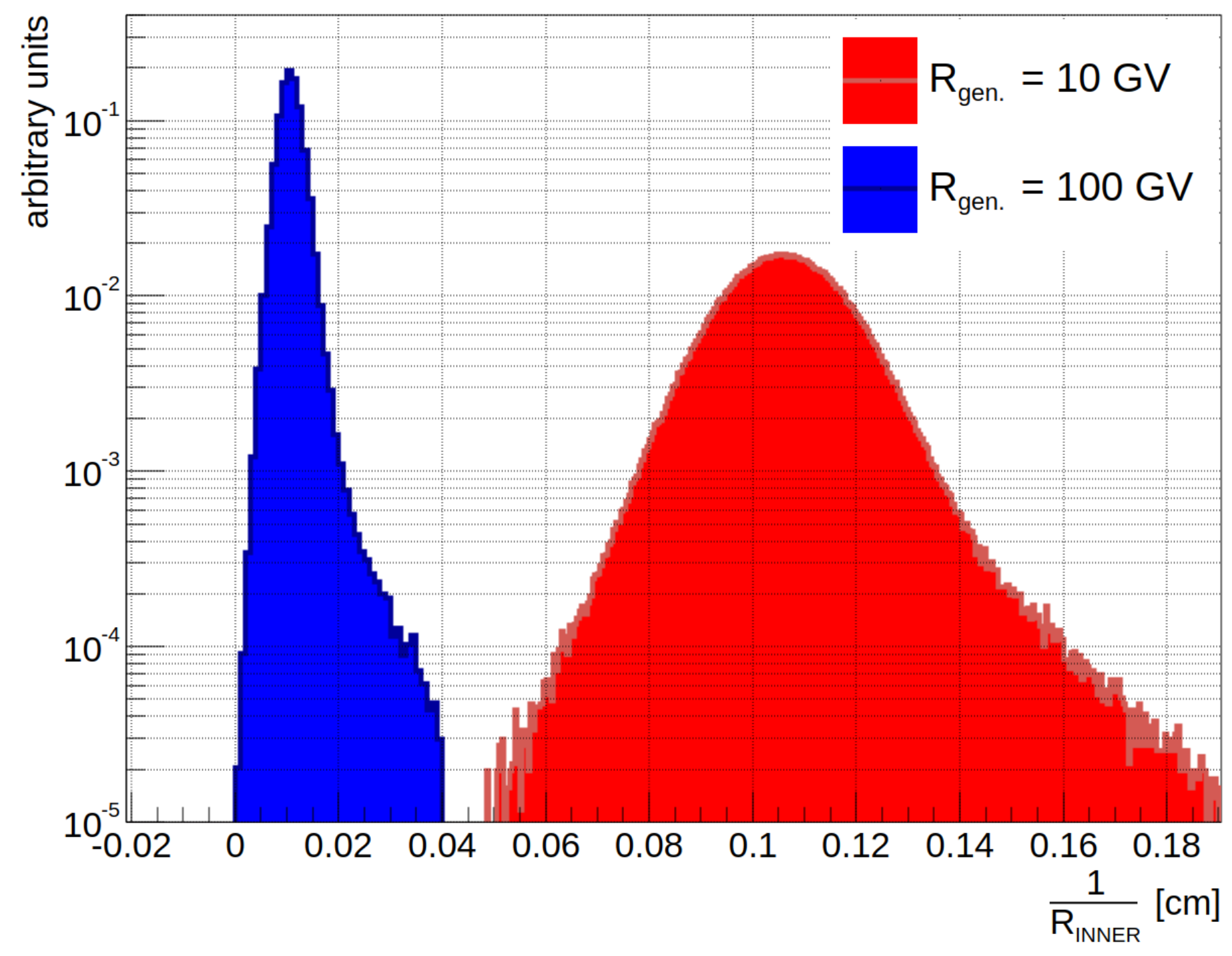
AMS consists of **a permanent magnet** surrounded by an array of particle detectors to measure momentum and charge of the passing particles and nuclei. The core of AMS is the **silicon tracker** composed by **nine silicon layers**, seven of them are within the magnet bore and the total lever arm is 3 m.
The coordinate system of AMS is concentric with the center of the magnet, with the **y-z plane as the bending plane**.

Monte Carlo toy

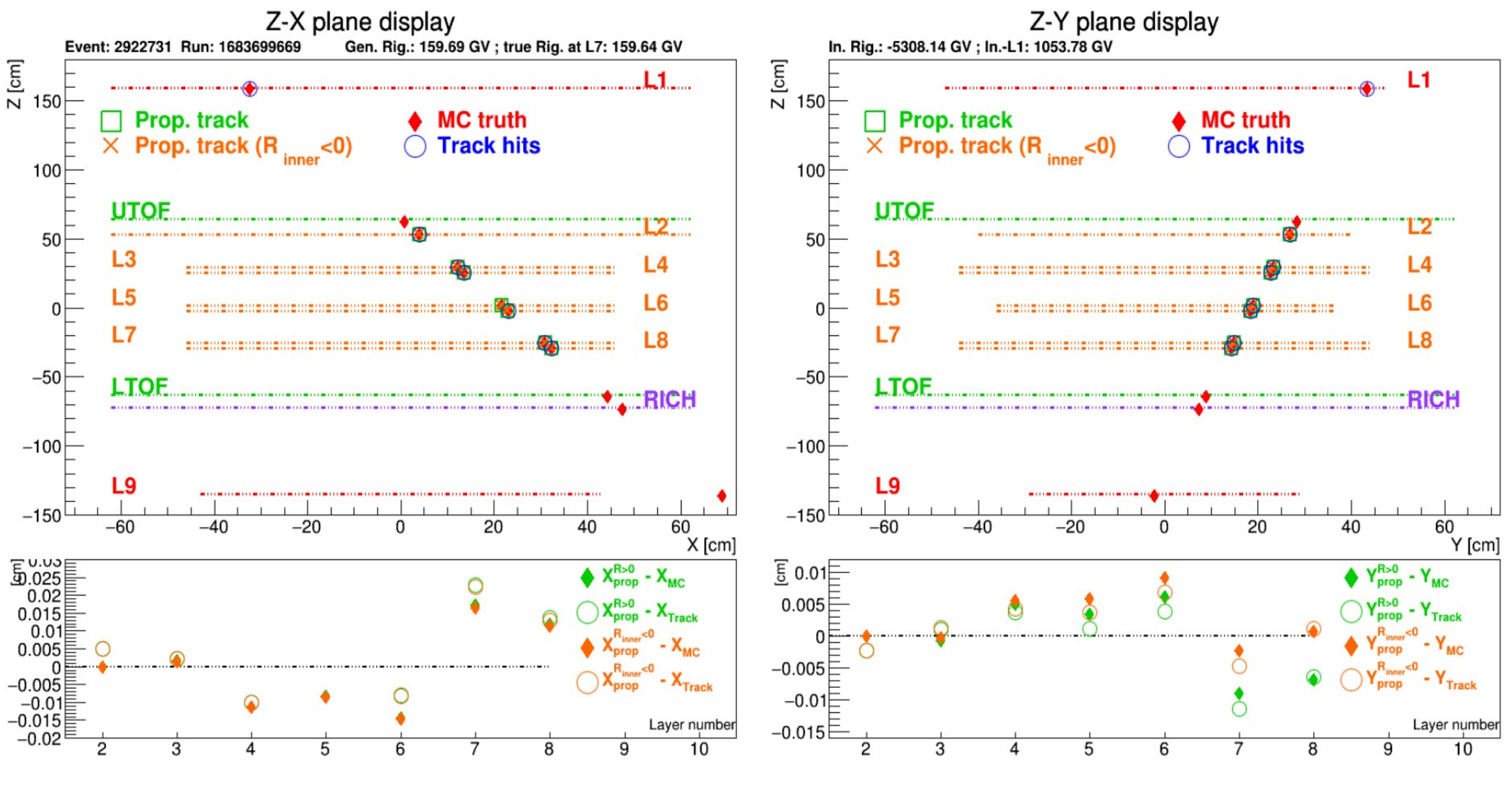
The particle and antiparticle behave the same way in the detector, except for the rigidity (p/Z) curvature. The response of an AMS-02 like detector is implemented in **a Monte Carlo simulation**. The aim is to identify several sources of charge confusion that can lead to misidentification of an He as anti-He. The selection applied to the **simulated ^{4}He events** aims to obtain a well reconstructed Helium sample.

Charge confusion sources

Using the MC simulation **four different sources of charge confusion have been identified**. The first three corresponds to interactions that the primary particle can do within the inner tracker: hadronic **inelastic scattering**, hadronic **elastic scattering** and **large angle scattering** (Coulomb scattering). The fourth source is due to the finite resolution of the detector and is called **spillover**.



The figure shows the distribution of the **reconstructed 1/R** using the **inner span** for **generated rigidities of 10 and 100 GV**. The width and mean of the distributions decreases with an increasing $R_{gen.}$.
Requiring **R_{UH}, R_{LH} > 0**, **no interaction within the inner tracker** and **R_{INNER} < 0** a pure **sample of spillover can be selected**. Figure below shows one event of such sample.
Select pure sample for each charge confusion source is important to develop a machine learning technique to quantify the reconstruction quality of an event.



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