Reconstruction of antinucleus-annihilation events in the GAPS experiment

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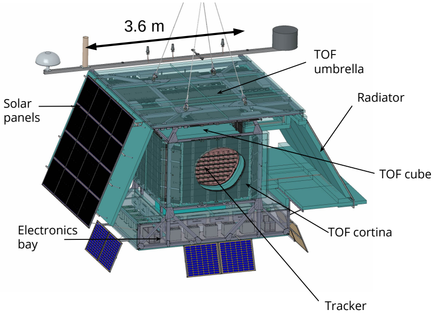
The GAPS experiment [1,2]

- Measurement of antinuclei as as a signature of dark matter annihilation or decay.
- Predicted flux of antideuteron and antihelium-3 from dark matter is two orders of magnitude above the astrophysical background below 0.25 GeV/n.

~background-free measurement

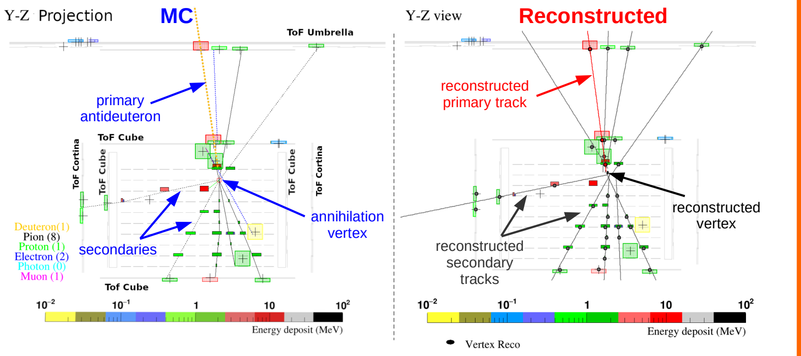
- Time-of-Flight (ToF) system surrounding a tracker.
- ToF: plastic scintillator paddles (6.35 mm x 16 cm x 1.5−1.8 m) [3].
- Tracker: Si(Li) cylindrical detectors with ~10 cm diameter and ~2.5 mm thickness, segmented into 8 strips [4].



- Antinucleus detection based on the observation of the particles produced in the annihilation of the antinucleus in the tracker volume [5,6]

Event reconstruction

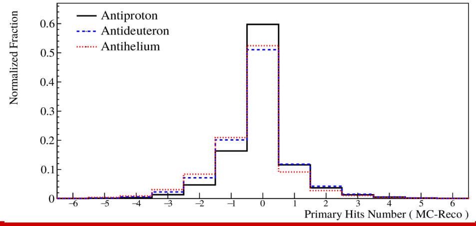
- Two algorithms developed for the reconstruction of the annihilation event: a method based on the Hough-3D transform [7] and a custom algorithm specific for the experiment ("Star Finding")
- **Star Finding algorithm:**
  - **Primary particle reconstruction:** identified from first hits in the ToF, then other consistent hits are searched along the extrapolated track.
  - **Secondaries reconstruction:** a scan is done along the extrapolation of the primary track in the tracker volume. Trajectories that intercept hits are searched isotropically over the solid angle. The secondary tracks are selected from the point where the minimum number of trajectories intercepts the maximum number of hits.



- **Vertex Reconstruction:** identified as the point that minimizes the distance with all the reconstructed tracks.
- The search for secondary tracks and vertex is iterated again after some clean-up of the tracks (e.g., rejecting tracks far from the vertex and excluding primary hits beyond the found vertex).

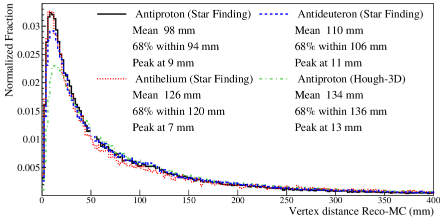
Primary reconstruction performance

- **50-60%** of the events reconstructed with the correct number of primary hits, **~85%** of the events with no more than one hit wrongly associated
- β resolution: **~5%** for antinuclei coming from the top ToF, **~20%** for antinuclei from side ToF. (difference due to the different distance between outer and inner ToF: ~90 cm and ~35 cm for the top and side ToF, respectively).



Annihilation vertex reconstruction performance

- Vertex reconstruction efficiency in the β range of interest:
  - Star Finding: **~90%** for antiprotons, antideuterons, and antihelium-3.
  - Hough-3D: **~75%** for antiprotons
- Vertex position resolution:
  - Star Finding: peak at **~1 cm**, 68% of events within **9-12 cm**.
  - Hough-3D: peak at **~1.3 cm**, 68% of events within **~14 cm**.



Conclusions

- Two algorithms developed, one based on the Hough transform and the other specifically developed for the experiment
- The custom algorithm ("Star Finding") exhibits better performances with respect to the Hough-3D.
- Most of the hits are correctly associated to the primary track
- Vertex reconstruction performances satisfy the requirements for the discrimination between different antinuclei (e.g., an antideuteron vertically incident with β < 0.4 stops >12 cm deeper with respect to an antiproton with same β).

References
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