Cosmic Antiproton Sensitivity for the GAPS Experiment

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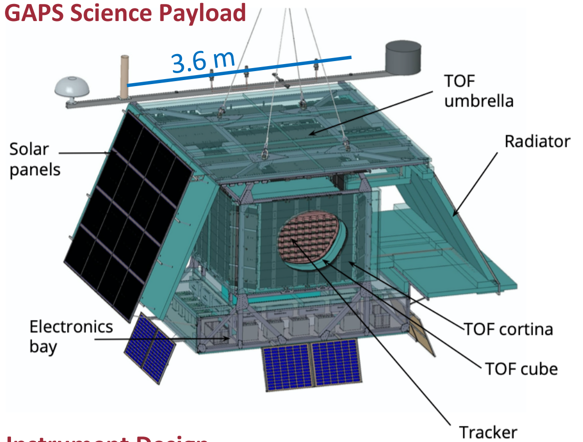
The GAPS Experiment

GAPS [i] is a balloon payload optimized to detect low-energy (KE < 0.25 GeV/n) cosmic antinuclei as probes of dark matter annihilation or decay [1] in three Antarctic flights (~37 km float altitude)

- Leading sensitivity to $\overline{\text{D}}$ and $^3\overline{\text{He}}$ [ii,2] in 3 flights
- Precision $\overline{\text{p}}$ spectrum [3] in first flight (~late 2022)

GAPS Science Payload



Instrument Design

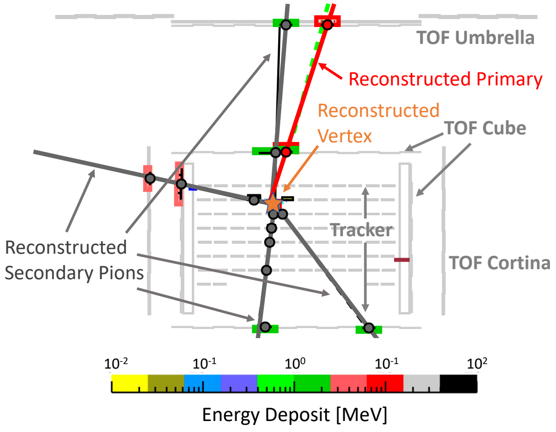
Exotic atom-based particle identification facilitates a large-acceptance balloon payload to detect rare cosmic particles [iii]

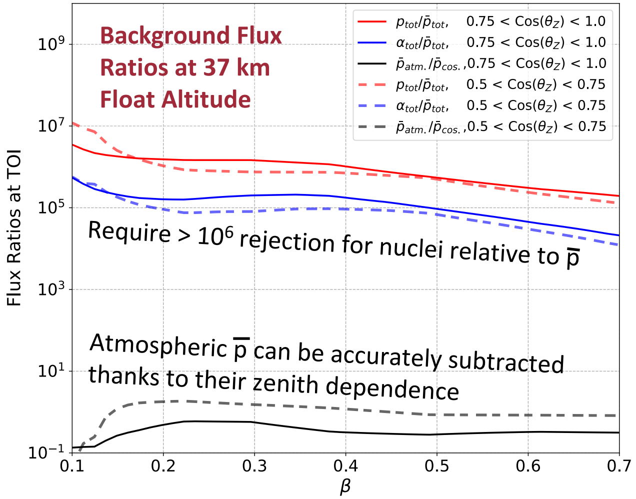
- Plastic scintillator-based TOF system measures β with $\sigma_\beta/\beta \sim 5-10\%$ and provides the trigger.
- ~1000 2.5 mm-thick silicon detectors in 10 layers serve as tracker, target material, and X-ray spectrometer.
- Novel oscillating head pipe thermal system
- No magnet, cryostat, or pressure vessel required!

High Statistics Antiproton Identification

A simulated, reconstructed [iv, v] $\overline{\text{p}}$ shows:

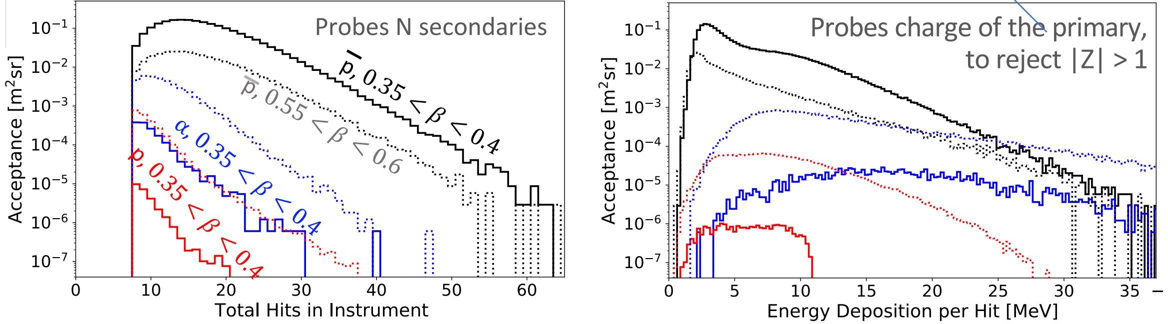
- Primary slows down in tracker layers and is captured into an exotic atom
- Annihilation "star" of secondary tracks from the exotic atom annihilation vertex





- ➢ Positively-charged nuclei do not form exotic atoms.
- ➢ Rare hard interactions produce secondaries and thus mimic exotic atom annihilation

Sample Event Variables Identify Antinucleus Annihilation from Nucleus Hard Interactions



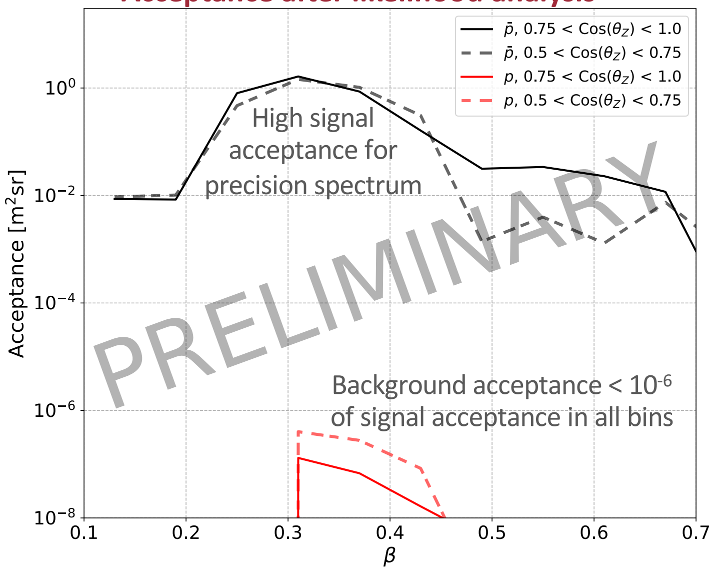
- Nucleus hard interactions, and thus the trigger rate, are elevated with increasing β
- Compared to exotic atom annihilations, hard interactions produce fewer, slower secondaries with larger energy depositions per hit
- Select |Z| = 1 particles based on energy deposition on the primary track

Cosmic Antiproton Measurement

The number of particles of a given species identified as signal in a β and zenith analysis bin depends on the flight time and:

- β- and zenith-dependent flux at float altitude
- β- and zenith-dependent instrument acceptance after cuts

Acceptance after likelihood analysis



- Precision spectrum for $0.25 < \beta < 0.65$ at float altitude in one 35-day flight
- Translates ~0.1 – 0.35 GeV/n at the top of the atmosphere
- Sensitive to the falling low-energy edge of the possible AMS $\overline{\text{p}}$ excess [5], Hawking radiation from local evaporating primordial black holes [5], and Galactic propagation models

References

[1] von Doetinchem+ JCAP08 (2020) [2002.04163]
[2] Saffold+ Astropart. 130 (2021) [2012.05834]
[3] Aramaki+ Astropart. 59 (2014) [1401.8245]
[4] Aguilar+ Phys. Rev. Lett. 117 (2016)
[5] Barrau+ A&A 388 (2002) [astro-ph/0112486]

GAPS at ICRC 2021

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