Antideuterio: resoconto del workshop "Antideuterons 2014" @ UCLA

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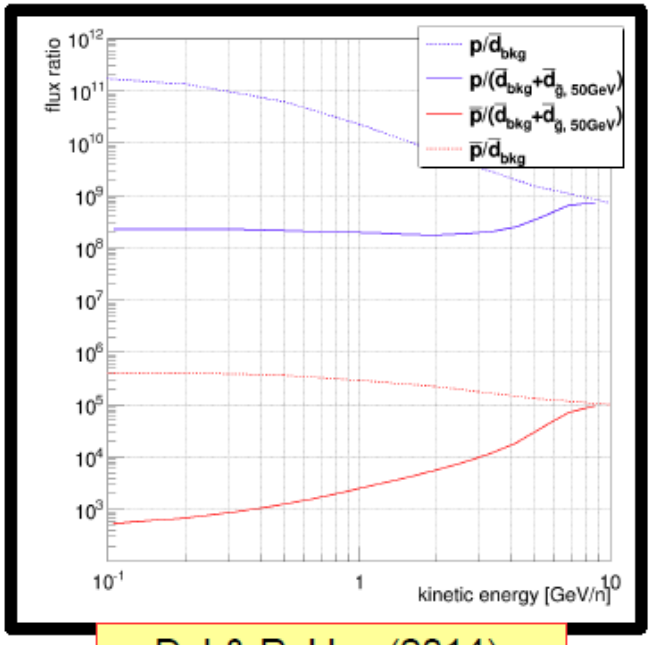
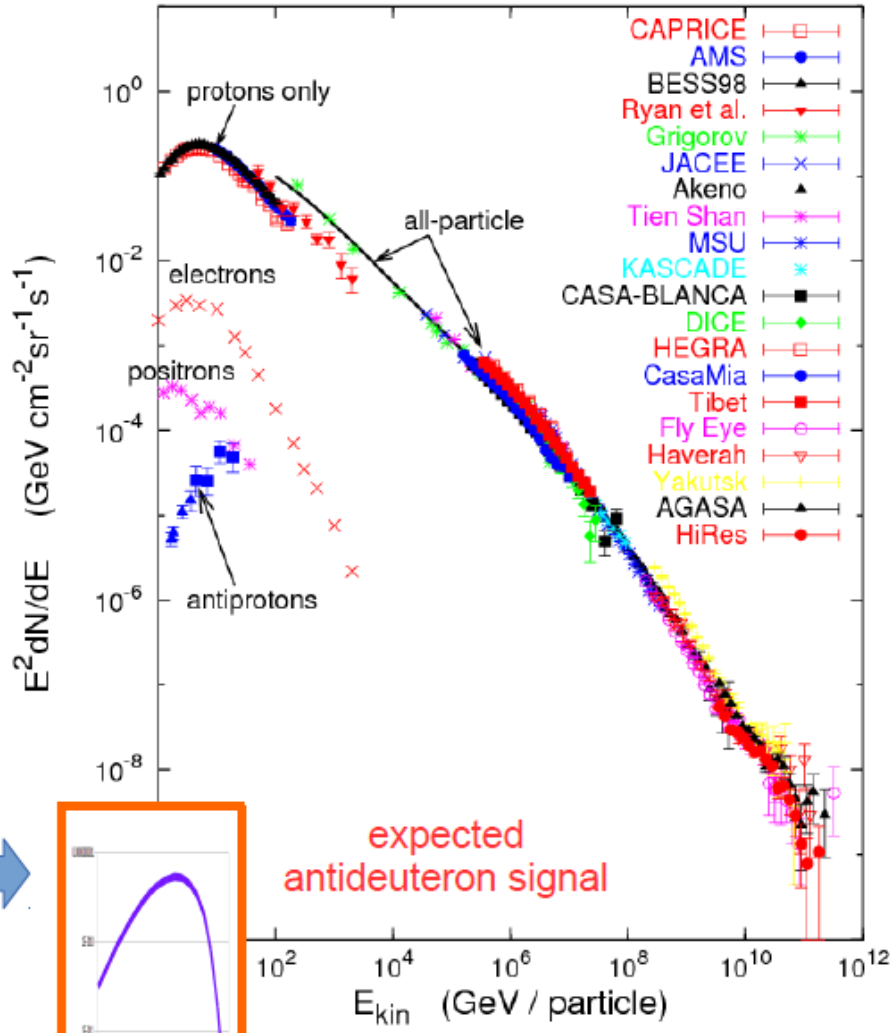
What Next DM
10 *Luglio 2014*

Cosmic-ray spectrum

- Required rejections for antideuteron detection:
  - **protons**: > 10^8 - 10^{10}
  - **He-4**: > 10^7 - 10^9
  - **electrons**: > 10^6 - 10^8
  - **positrons**: > 10^5 - 10^7
  - **antiprotons**: > 10^4 - 10^6



Dal & Raklev (2014), arXiv:1402.6259



BESS Program

- Balloon-borne Experiment
  - Steady improvement
    - Continuously upgrade and modify detector components
    - Various new scientific subjects
  - Long period of successive observations
    - Cover more than full cycle (11 years) of solar activity
  - Education/Training
    - Young people can be responsible for essential parts of the experiment (24 students/engineers awarded with Ph.D)

with a

- Superconducting Spectrometer
  - Large acceptance
    - High statistics
  - Uniform magnetic field
    - High resolution MDR 200 – 1400 GV
  - Transparent
    - Thin Solenoid 4.4 g/cm^2 (2.2 g/cm^2)
  - Definitive mass ID

BESS-Polar Program

	BESS	BESS-Polar
Geom. Acceptance:	0.3	0.3 $m^2 \cdot sr$
Material for trigger:	18 g/cm^2	4.5 g/cm^2
Magnetic field	1.0 T	0.8 T
Weight	2.2	2.0 tons
Power	Battery	Solar-panel
Comsumption	1.2 kW	450 W
Cryogen life	5.5	20 days

BESS-Polar II Antideuteron Search

Single Track Selection

- Track Quality
  - No. of Hit, $\chi 2$ of fitting
  - Consistensy of Track and TC

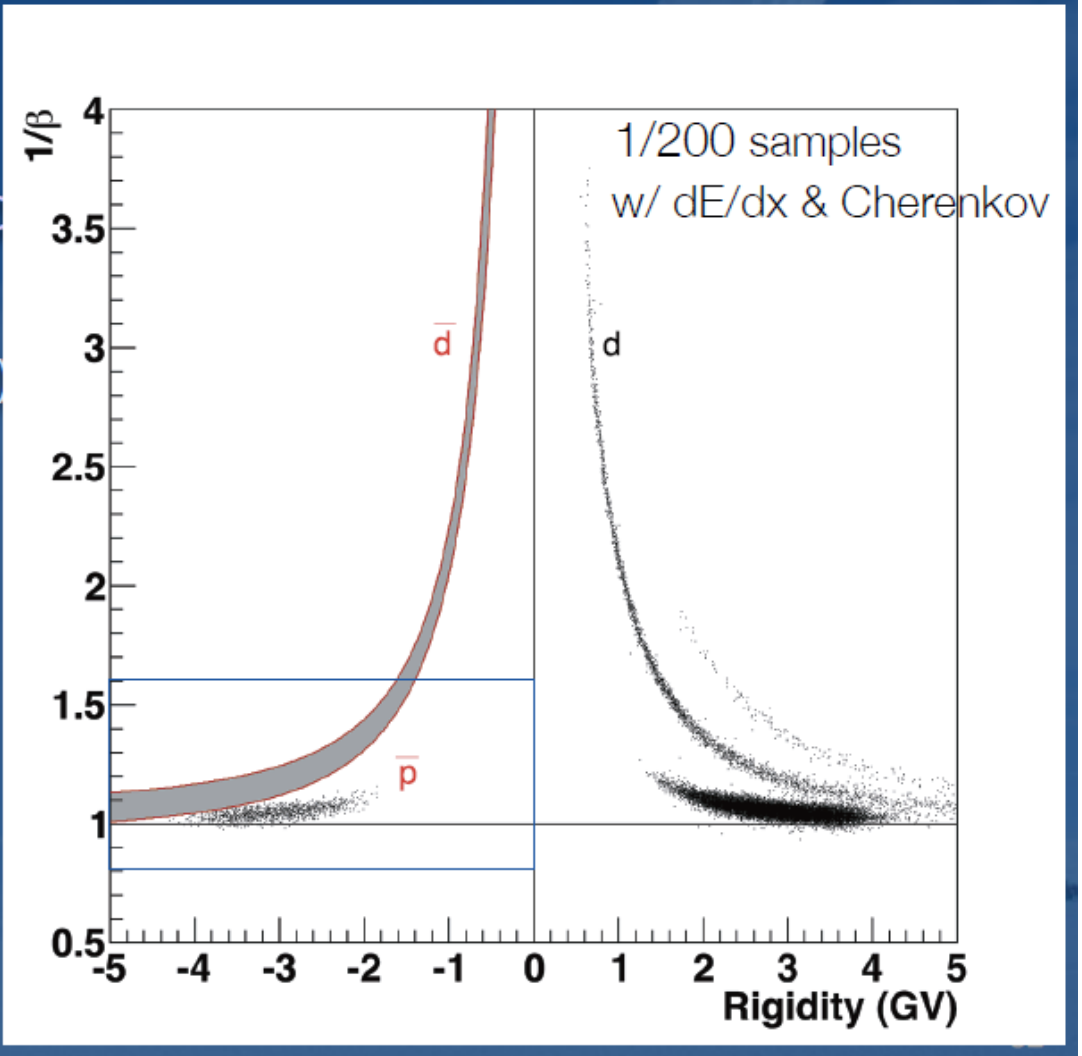
Extract (anti)deuterons

- dE/dX (UTOF, LTOF, MTOF, JET)
- Beta U-L
- Cherenkov

Optimize selection using positive curvature events

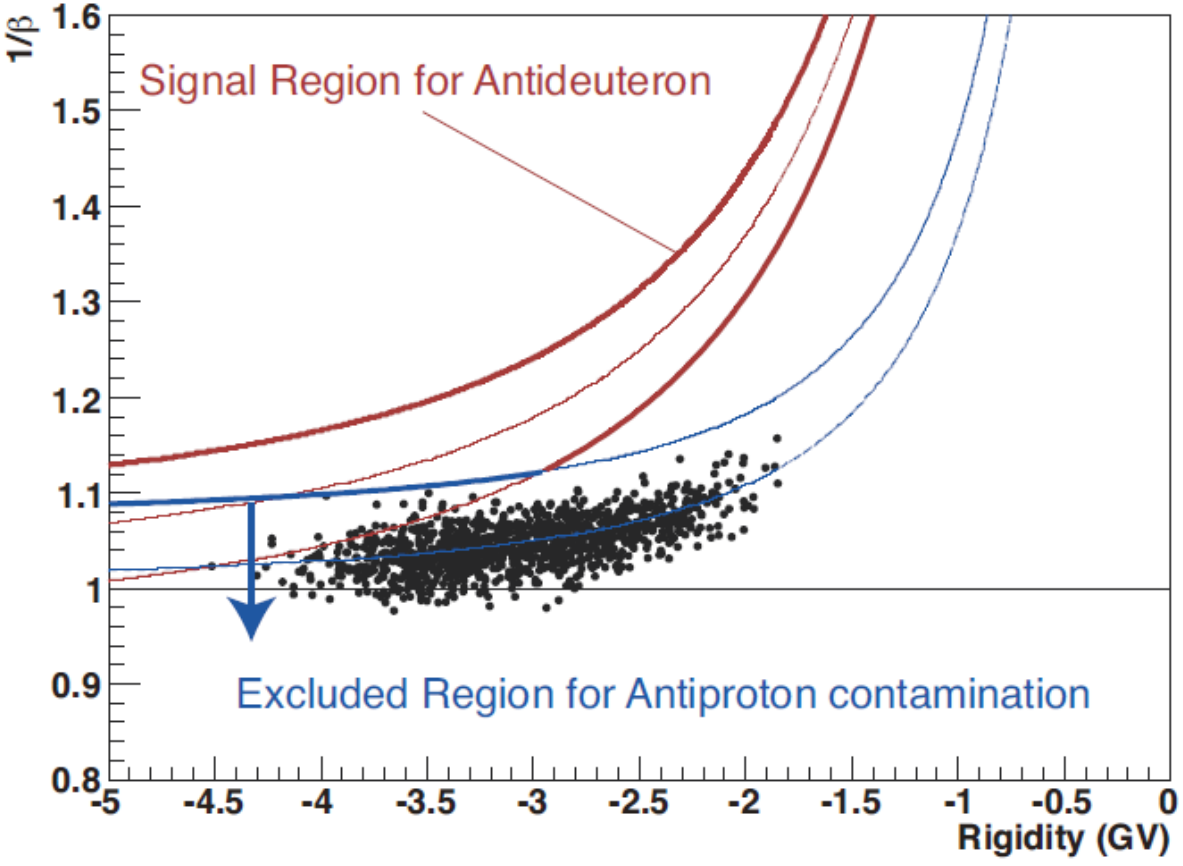
- wider energy range
- good rejection while keeping efficiency

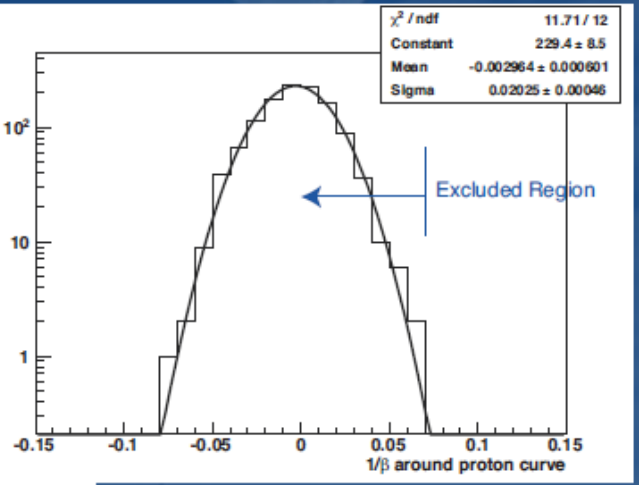
$\bar{d}$ (d) are clearly extracted in the band
$\bar{p}$ (p) contaminate the $\bar{d}$(d) region



BESS-Polar II Antideuteron Search

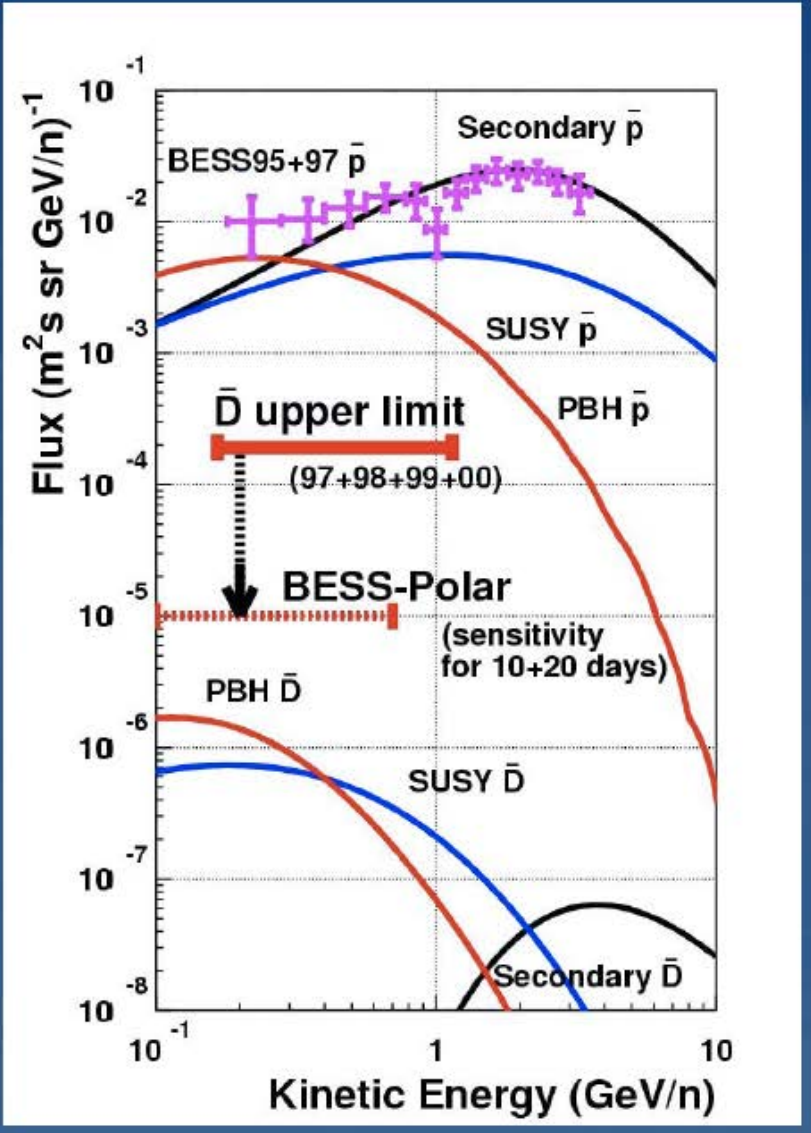
No antideuteron was found below 5 GeV/c rigidity.





Excluded region
< 0.1 event

Antideuteron Search



- Secondary $\bar{D}$ probability is negligible at low energies due to kinematics
- Any observed $\bar{D}$ almost certainly has a primary origin!
- $\bar{D}$ 95% C.L. upper limit (first reported) **1.92×10^{-4}** $(m^2\,s\,sr\,GeV/n)^{-1}$ from BESS97+98+99+00.
- BESS-Polar II flight accumulated cosmic-ray data in near solar minimum conditions with more than 10~20 times the statistics of BESS97.

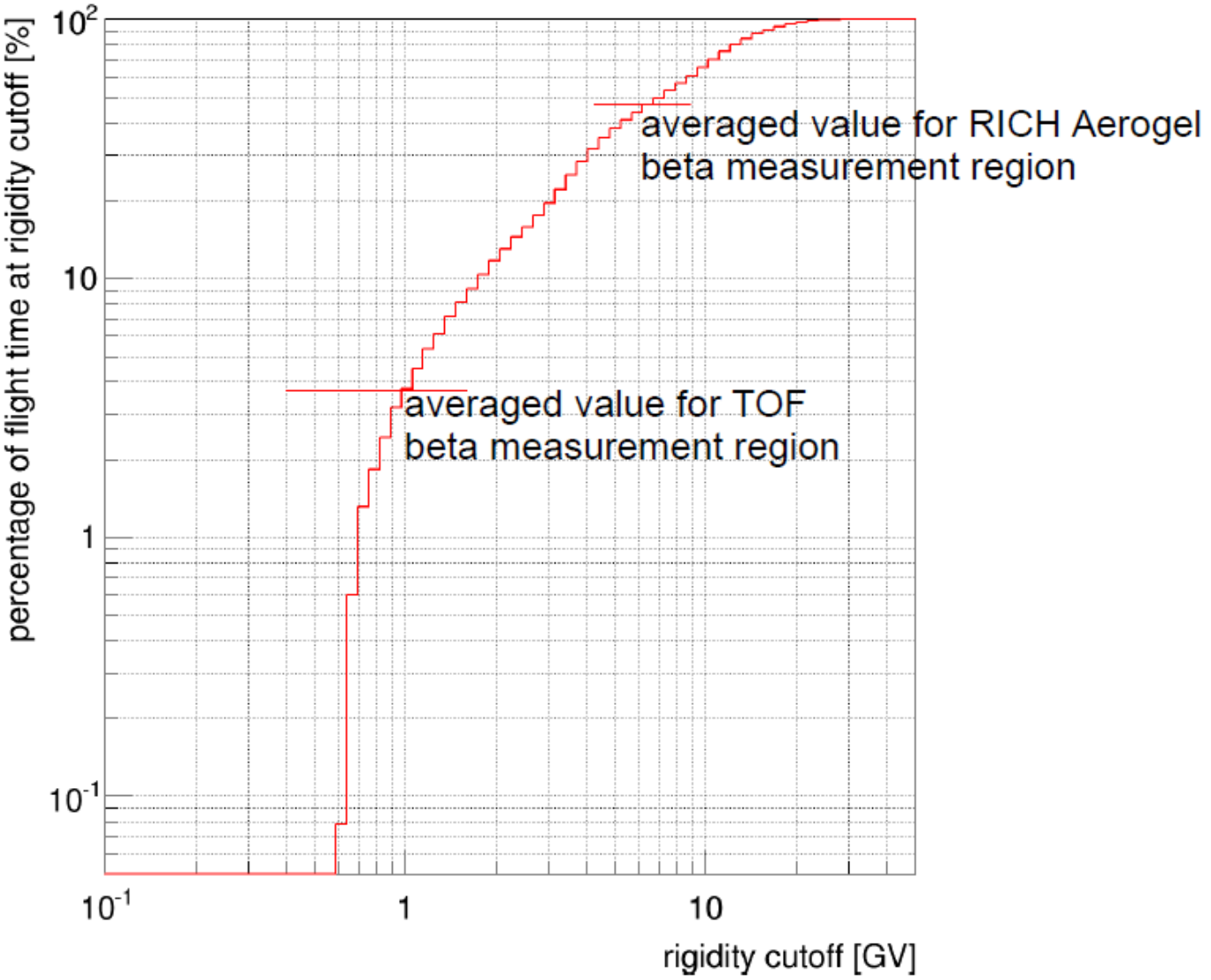
AMS-02 antideuteron search

- Antideuteron identification requires reliable measurement of:
  - **Charge** magnitude (=1) & sign (negative)
  - **Mass**, from **velocity/momentum** combination:

$$m = \frac{p}{Z}\frac{\sqrt{1-\beta^2}}{\beta}$$

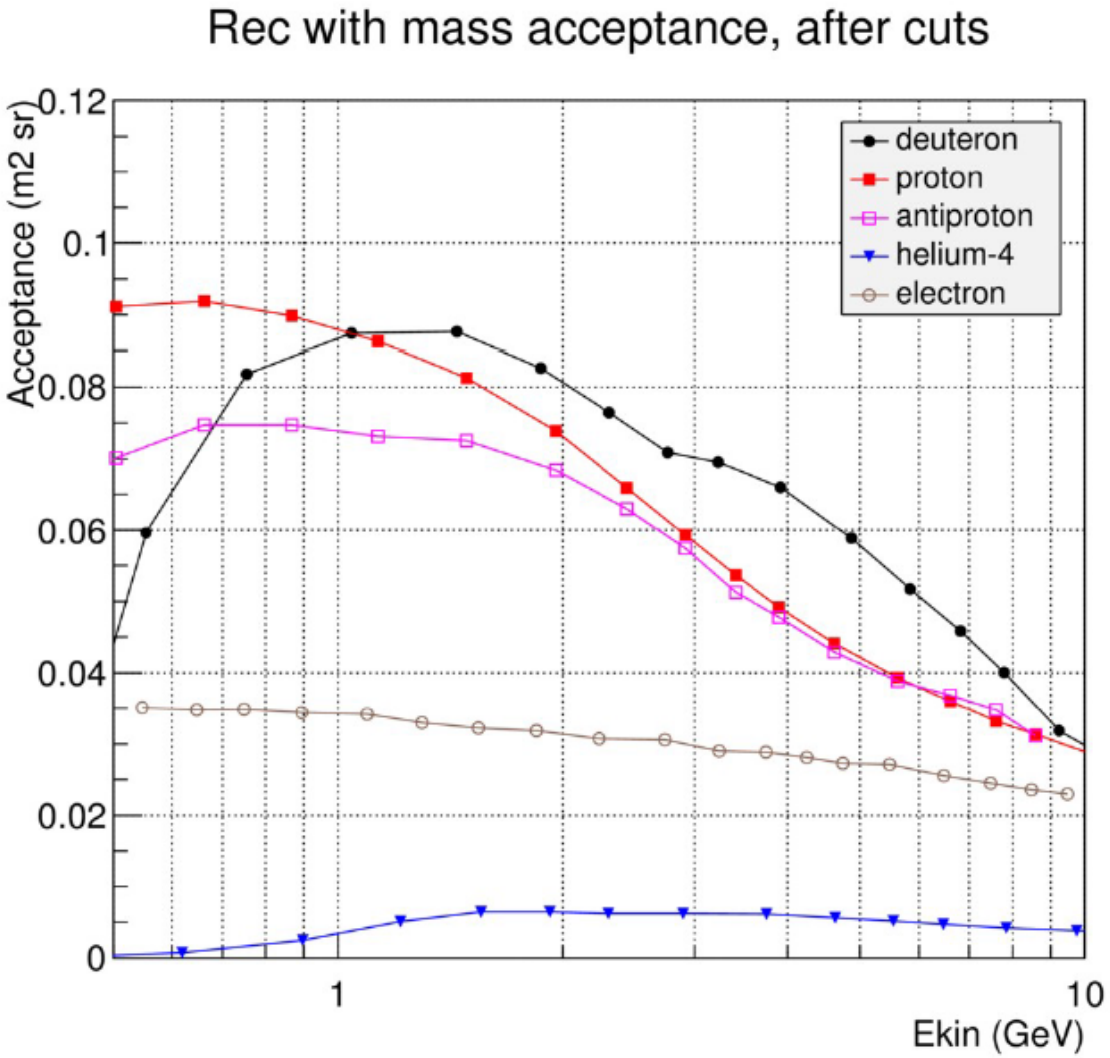
    - Momentum measured in the form of rigidity (R=p/Z)
    - Methods for velocity measurement:
      - up to ~1 GeV/nuc: **TOF** (directy from Δt between upper/lower planes)
      - at ~1 GeV/nuc: **RICH**, ***NaF radator*** (limited by very small acceptance)
      - at ~5 GeV/nuc: **RICH**, ***aerogel radiator***
        (RICH velocity comes from Cherenkov cone aperture)
- Discreteness of charge, mass values is helpful
  - broad windows may be used
  - closest charges are 100% away, closest masses 50% away
- Existing studies on AMS-02 antideuteron sensitivity were based on superconducting magnet configuration
  - **NEW ANALYSIS NEEDED FOR PERMANENT MAGNET SETUP**

Average time spent at low rigidity cutoffs



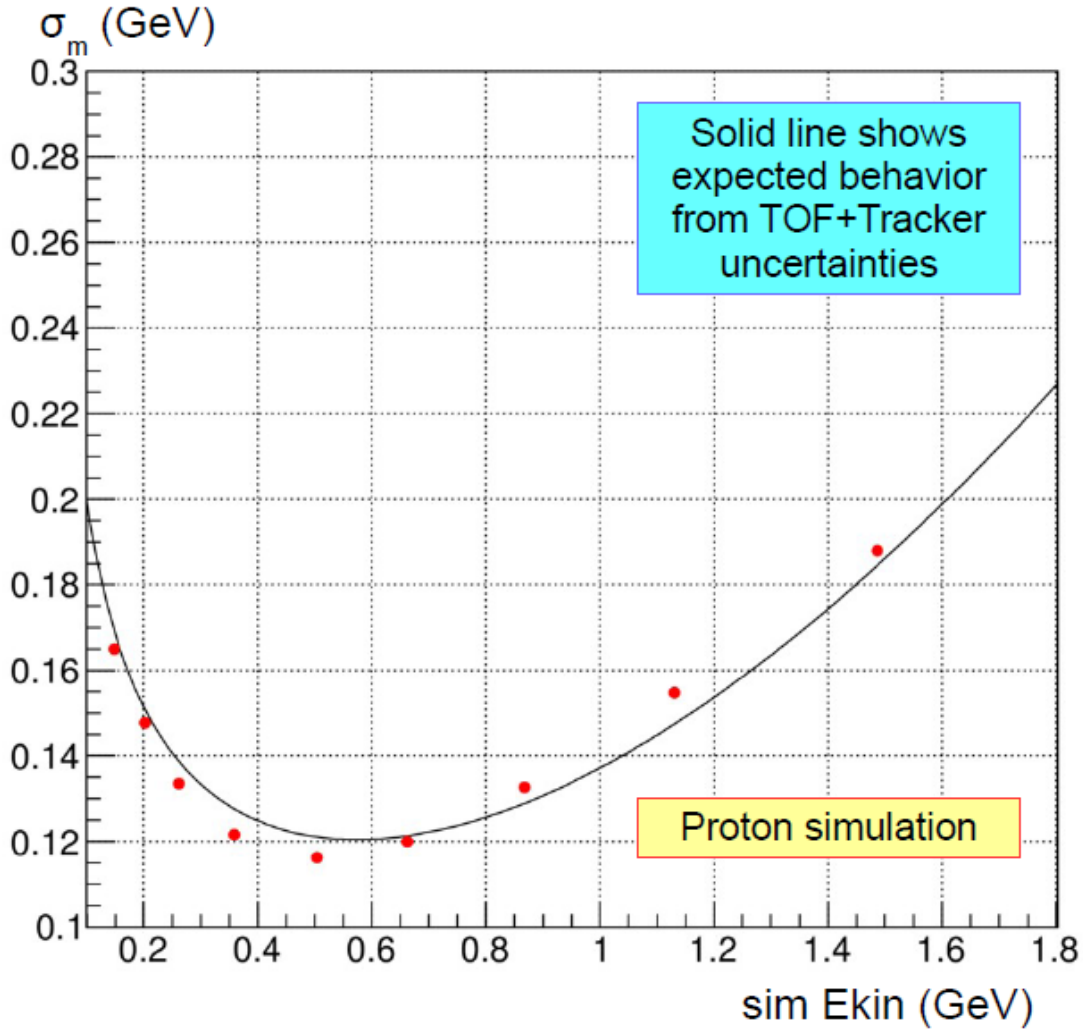
Acceptance after cuts

- Acceptance after cuts at 1 GeV:
  - ~0.08 m^2sr for hadrons
  - ~0.03 m^2sr for electrons
  - Large electron fraction excluded due to $\beta > 1$ reading
- Much smaller value for helium
  - restriction to $Z = 1$ included in quality cuts
- Quality cuts tend to exclude noisy events (detected as ACC clusters, extra TOF clusters...)
  - higher energy means more interactions
  - also explains why antiprotons (where annihilation is possible) are clearly below protons at low energy



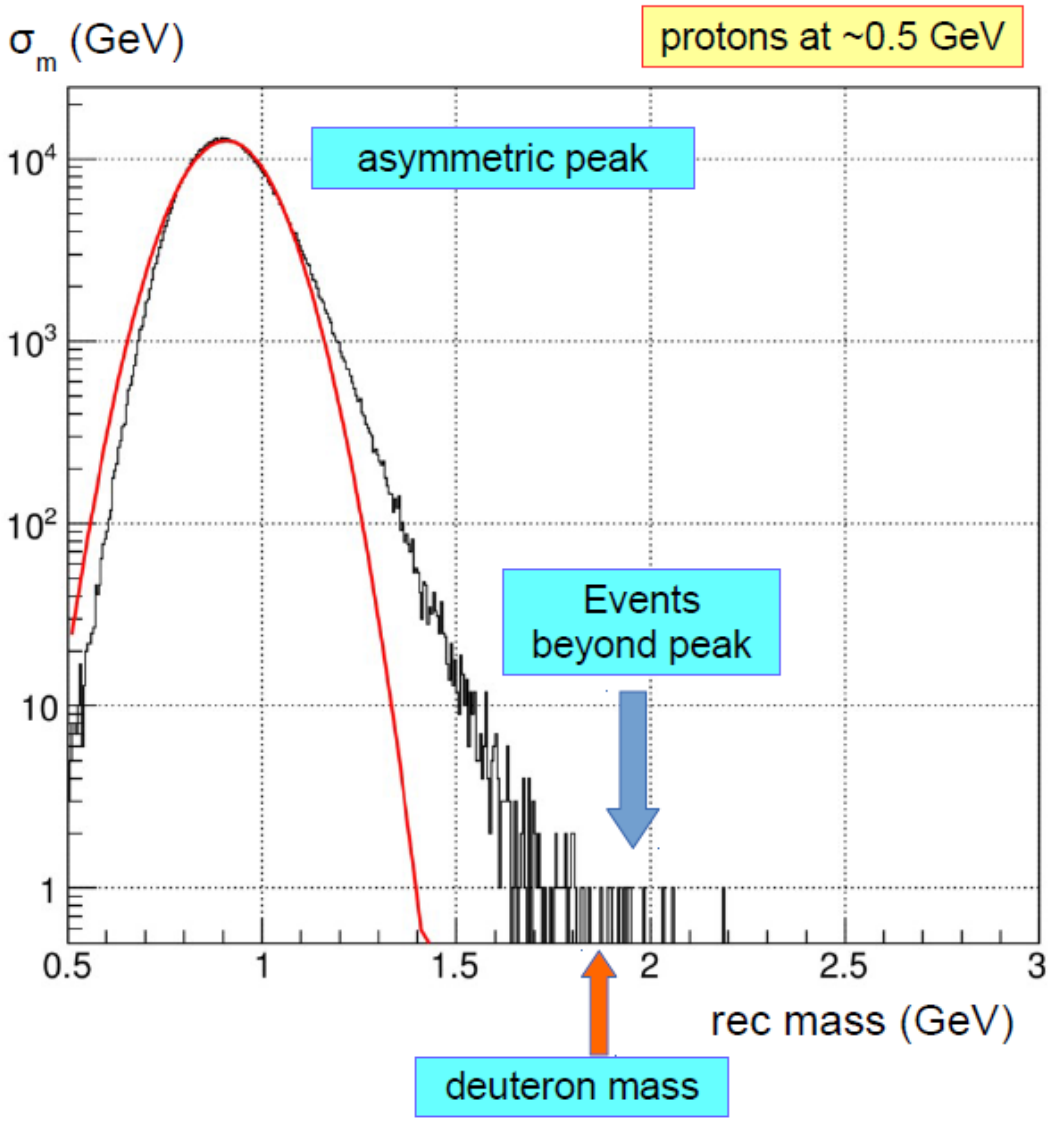
Mass resolution

- Proton results show mass resolution of 12% at ~0.5 GeV after quality cuts are applied
  - Should be enough for good d/p separation if tails were fully Gaussian...



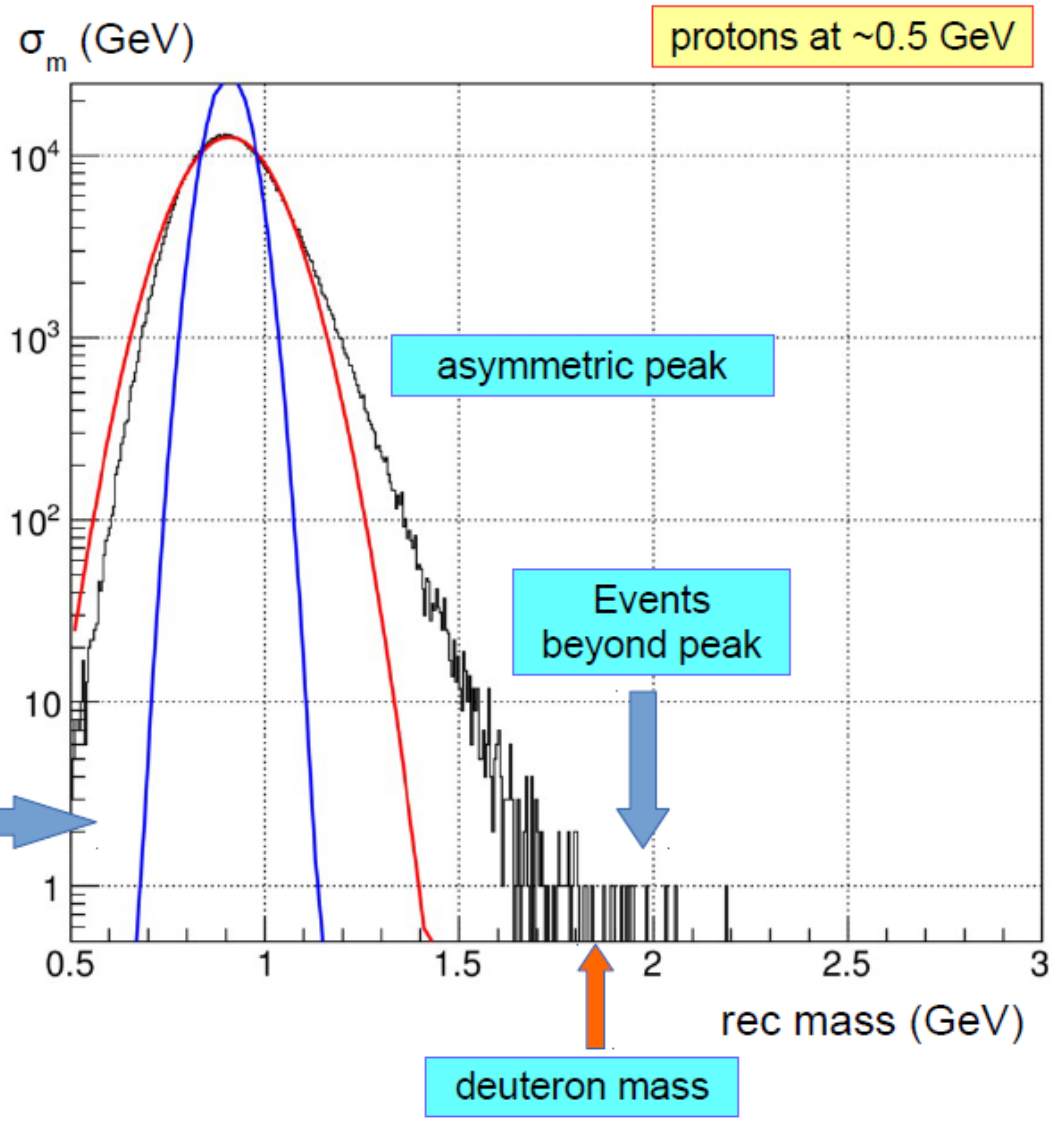
Mass resolution

- Unfortunately, as expected, that is not exactly the case
  - Gaussian curve shown matches top of mass peak
  - Mass peak is slightly asymmetric, with larger tail on the right
  - A tiny, but non-zero fraction of events lies beyond the peak
- Ongoing work to improve reconstruction results



Mass resolution

- Superconducting magnet configuration would have been better
  - Example for ~0.5 GeV: mass resolution would be 5% instead of 12%



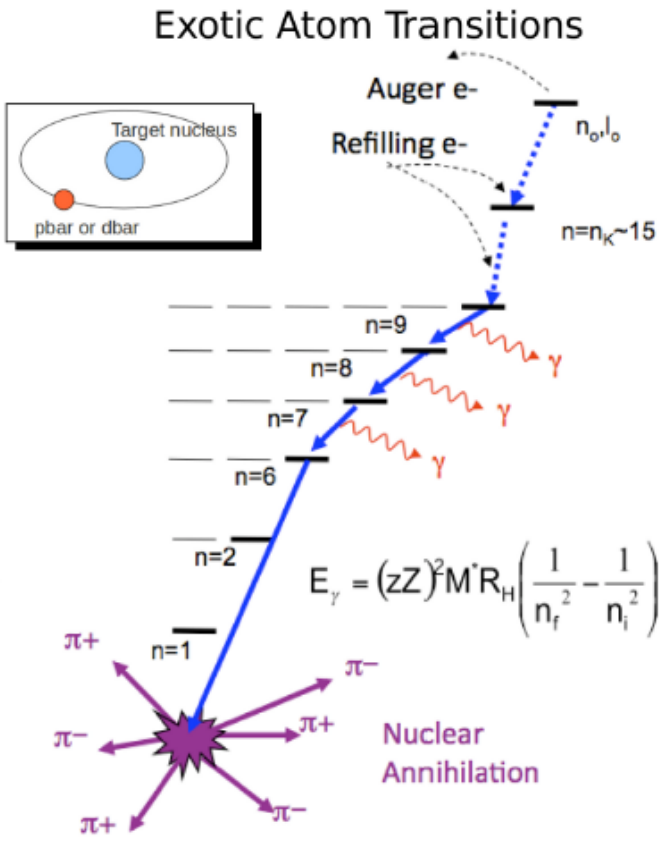
The GAPS Collaboration

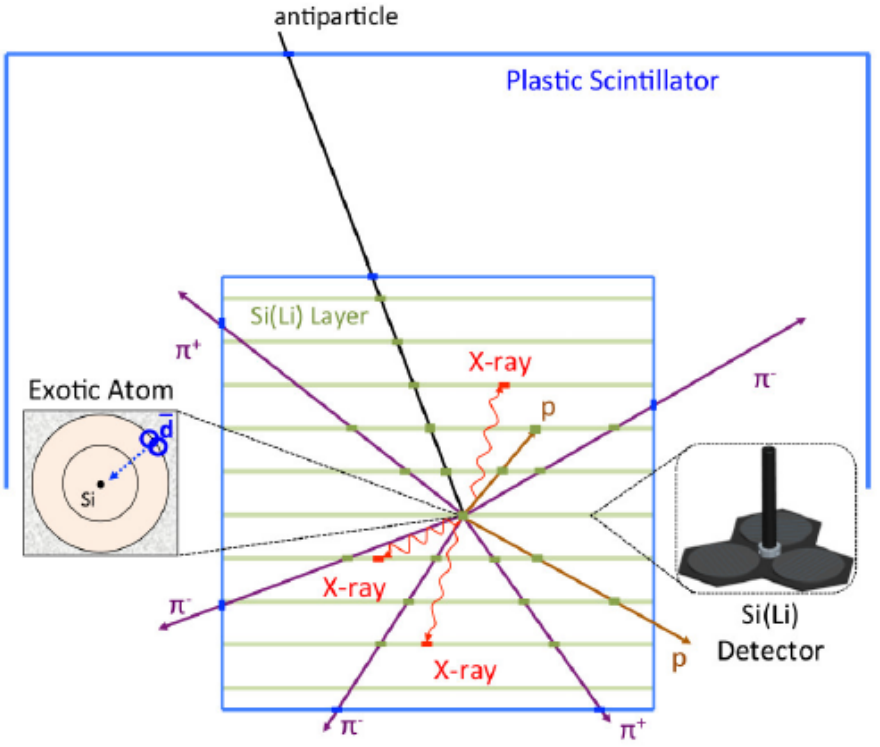
- JAXA / ISAS: Fuke, Bando, Takada, Yoshida
- Columbia Univ.: Aramaki, Hailey, Perez, Madden, Mori
- UC Berkeley: Boggs
- Hawaii: von Doetinchem
- UCLA: Mognet, Ong, Zweerink
- Univ. of Latvia: Gahbauer

pGAPS is funded by NASA grants in the US and by MEXT-KAKENHI grants in Japan.

GAPS: The General Antiparticle Spectrometer

Light antinuclei can form excited *exotic atom* states with normal matter.





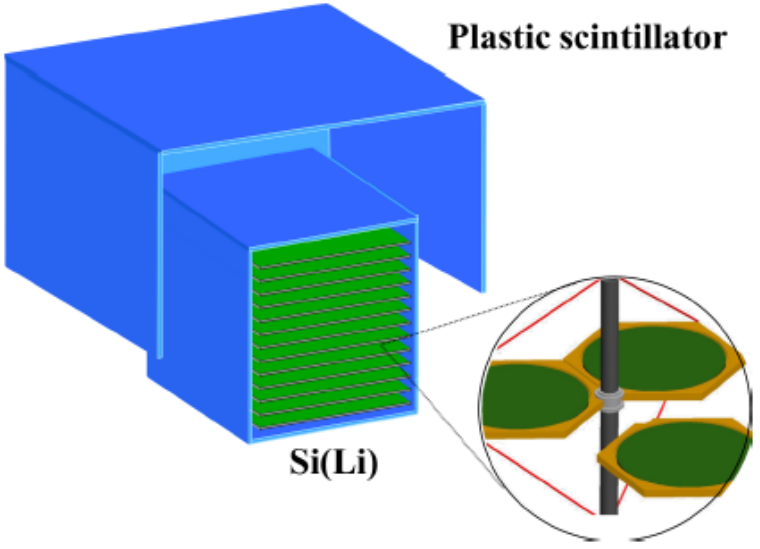
GAPS with Si target material.

Atomic transition x-rays, charged pion multiplicity, and other products provide distinct signature for antinuclei.

The GAPS Project

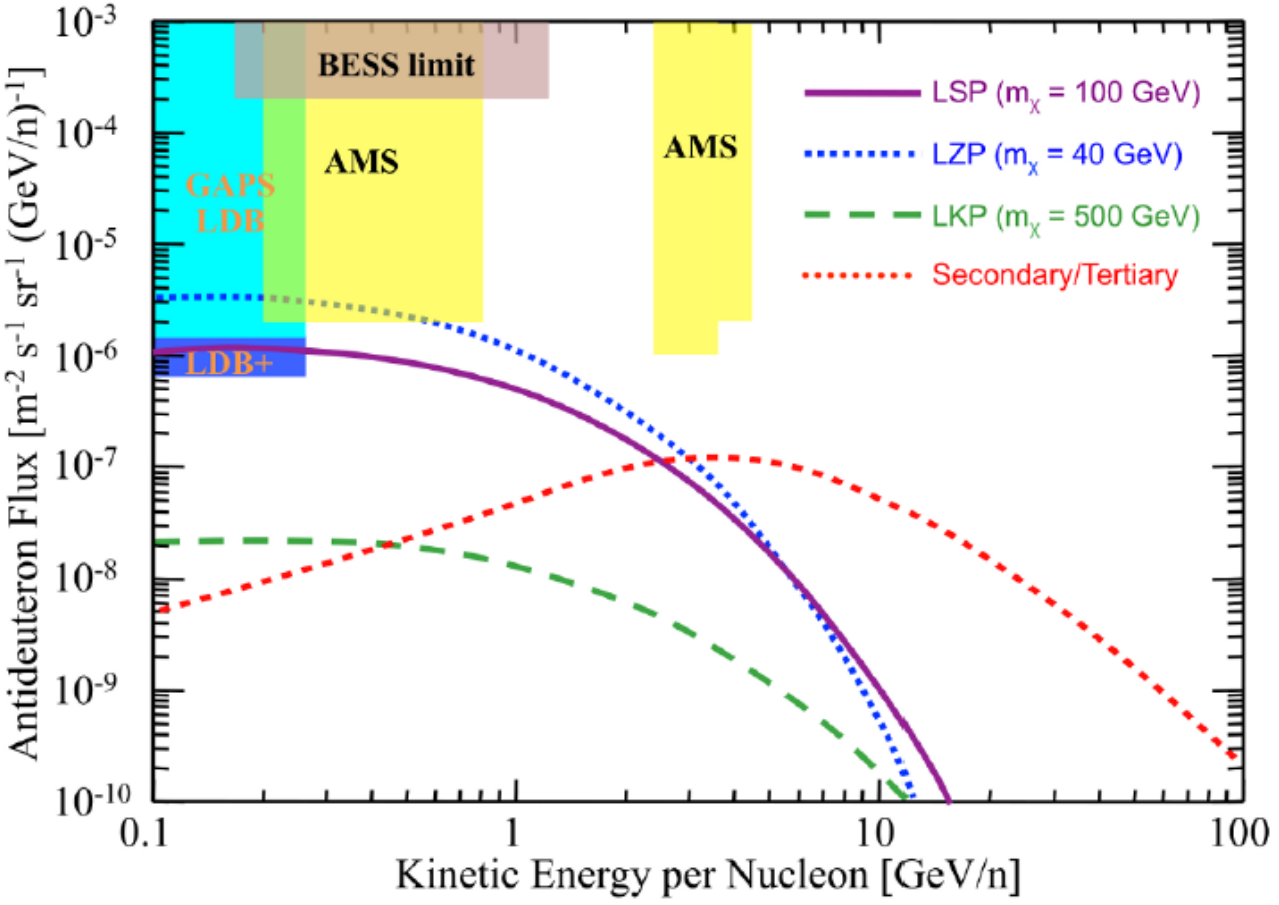
Proposed Antarctic flight at the end of 2018.

Geometrical Acceptance	18 $m^2 sr$
Energy	0.05-0.25 GeV/n
Exposure Target	105 days (3 LDB flights)
Sensitivity (CL)	2.0×10^6 $(m^2 * sr * s * GeV/n)^{-1}$
Expected Bkgd Events	0.009



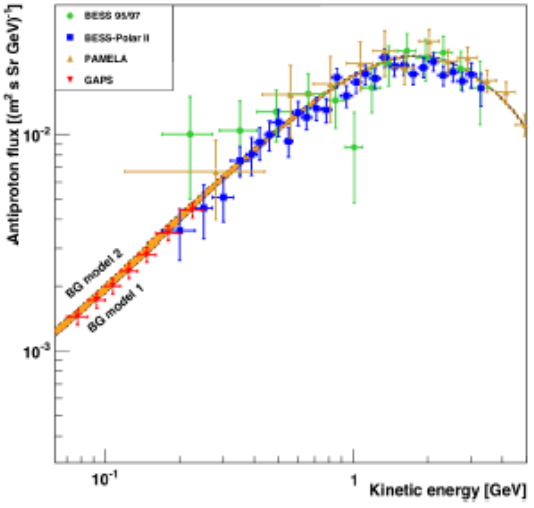
- Overall width of $\sim$ 3.6 m.
- $\sim$ 1440 Si(Li) detectors in 10 layers (70 kg of silicon).
- OHP cooling system
- Plastic scintillator based time-of-flight system (60 m^2).

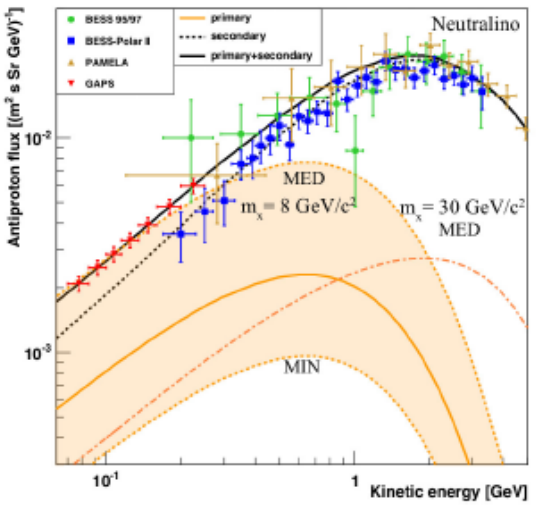
GAPS and AMS Sensitivity

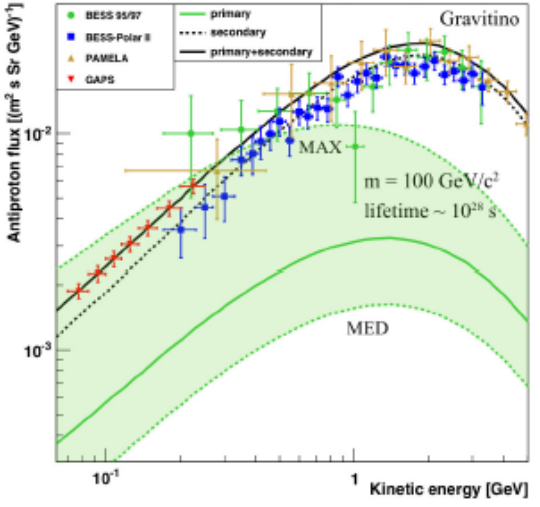


(Potentially) an essentially background free channel for dark matter detection.

Precision Antiproton Measurements with GAPS



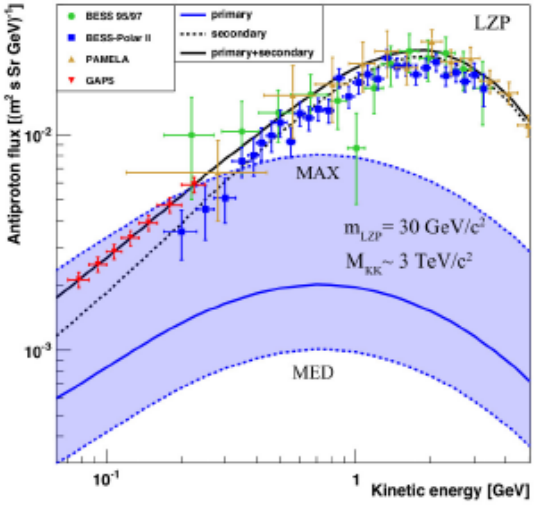


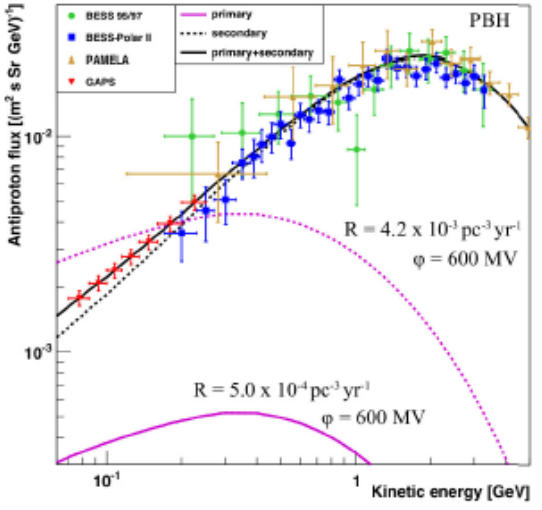


Antiproton sensitivity for 40 day GAPS flight:

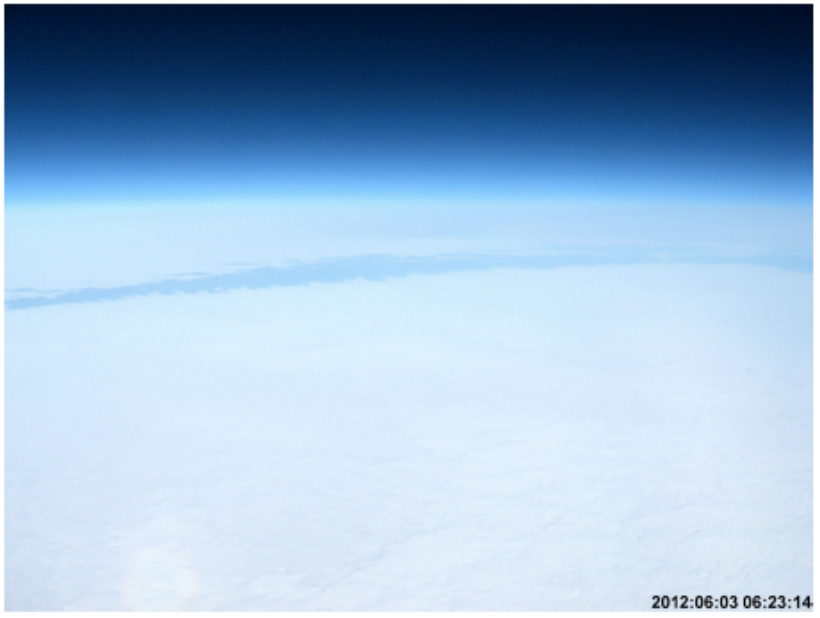
- Secondary background
- Neutralino (8 and 30 GeV/c^2)
- Gravitino
- Right-handed KK neutrino (30 GeV/c^2)
- Evaporating primordial black holes

See arXiv:1401.8245v1





The Flight



Instrument Paper

S. A. I. Mognet et al.
http://arxiv.org/abs/1303.1615

Flight Paper

P. von Doetinchem et al.
http://arxiv.org/abs/1307.3538v2

- Both TOF and Si(Li) systems worked very well.
- Rotator failed so no pointing (no active cooling available).
- Si(Li) operated for duration of flight from initial ground cooling (64% of strips still depleted at termination).
- OHP test very successful (first operation in a balloon flight).
- Thermal model fully validated (with pointing, active cooling would have worked).

The pGAPS flight was a great success!