

GAPS: A SEARCH FOR DARK MATTER SIGNALS IN COSMIC RAY ANTINUCLEI

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for the GAPS collaboration
TAUP 2017 · July 27, 2017

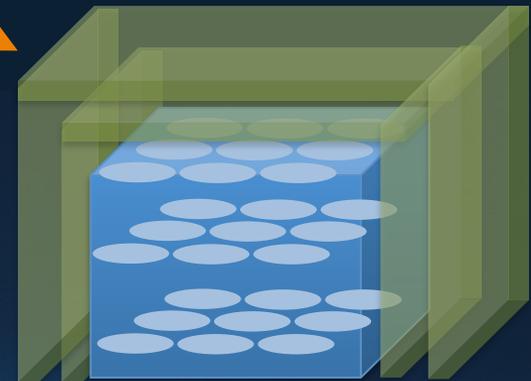


Low-energy (< 1 GeV) cosmic ray antinuclei, namely **ANTIDEUTERONS**, ANTIPROTONS, ...

are a low-background, largely unexplored indirect signal from dark matter

The General Antiparticle Spectrometer (**GAPS**)

will perform the first dedicated search for this signal



Low-energy antideuterons are rarely produced from standard astrophysics
→ LOW BACKGROUND FOR ANTIDEUTERONS FROM NEW PHYSICS

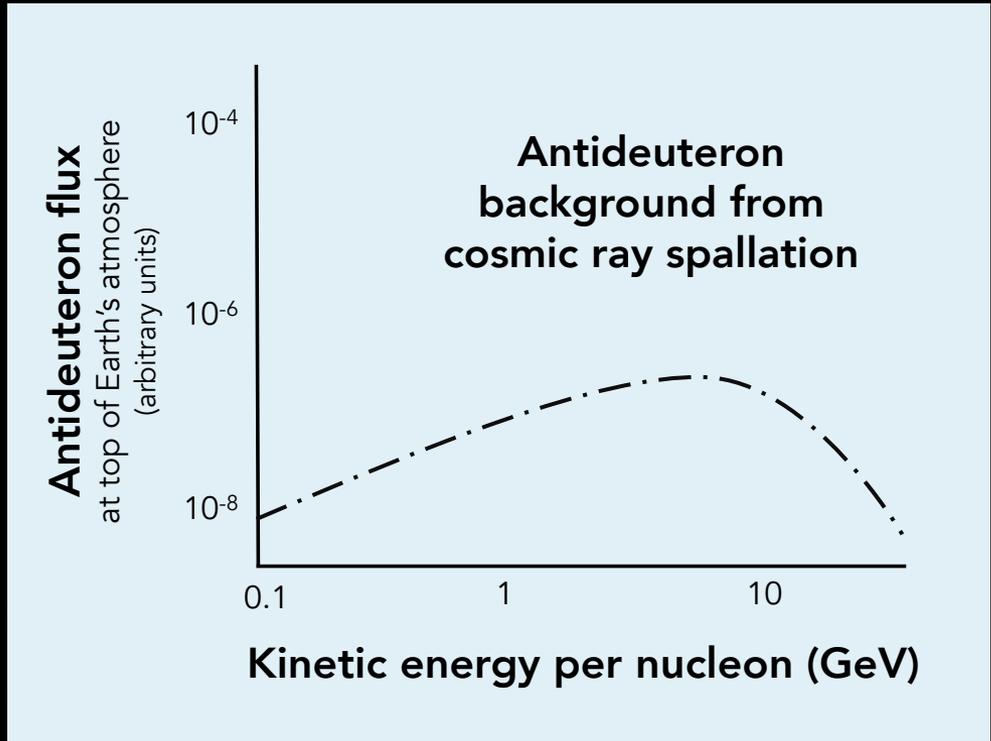
Primary
cosmic ray
proton

Interstellar
medium

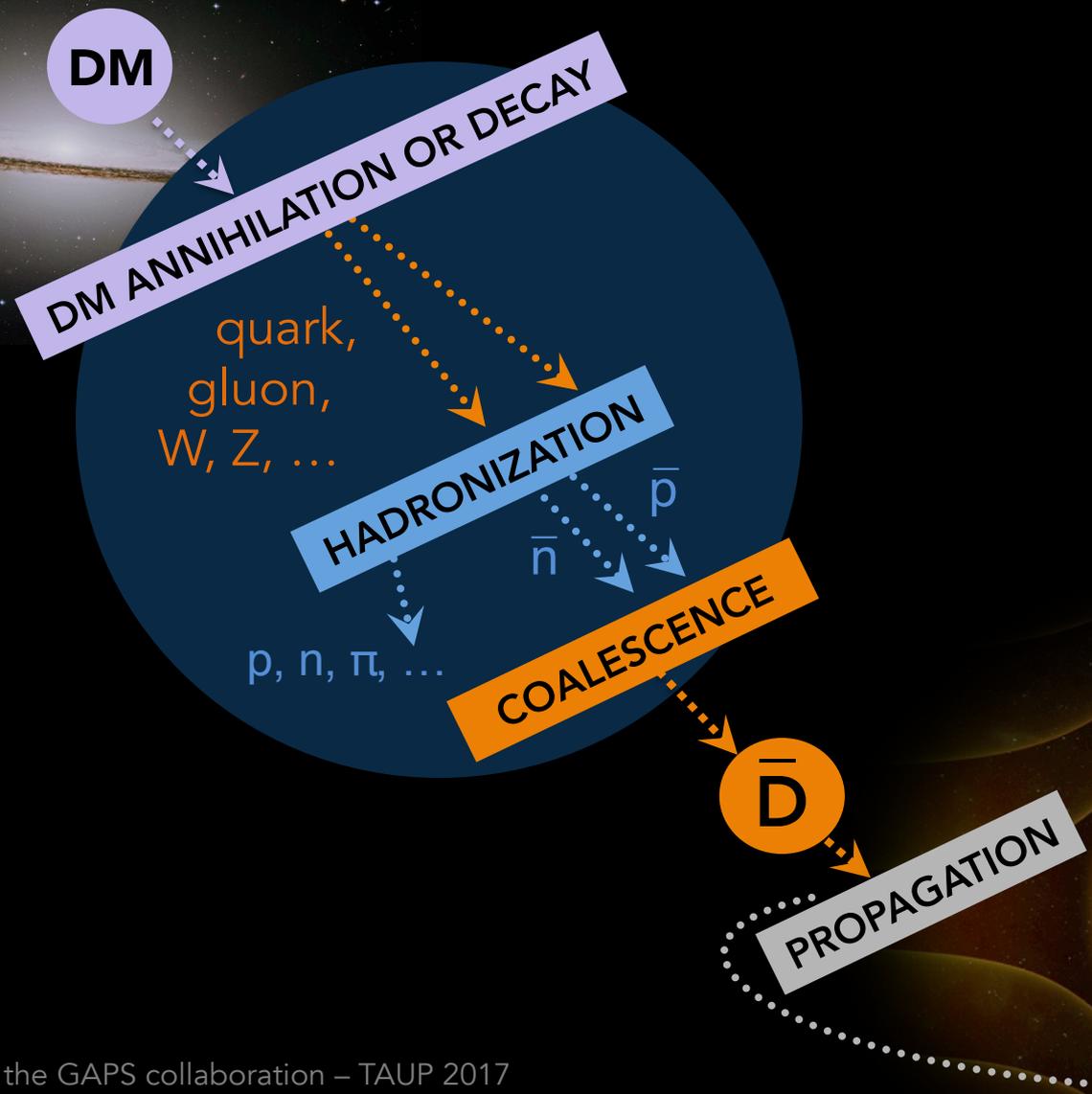
SPALLATION

COALESCENCE

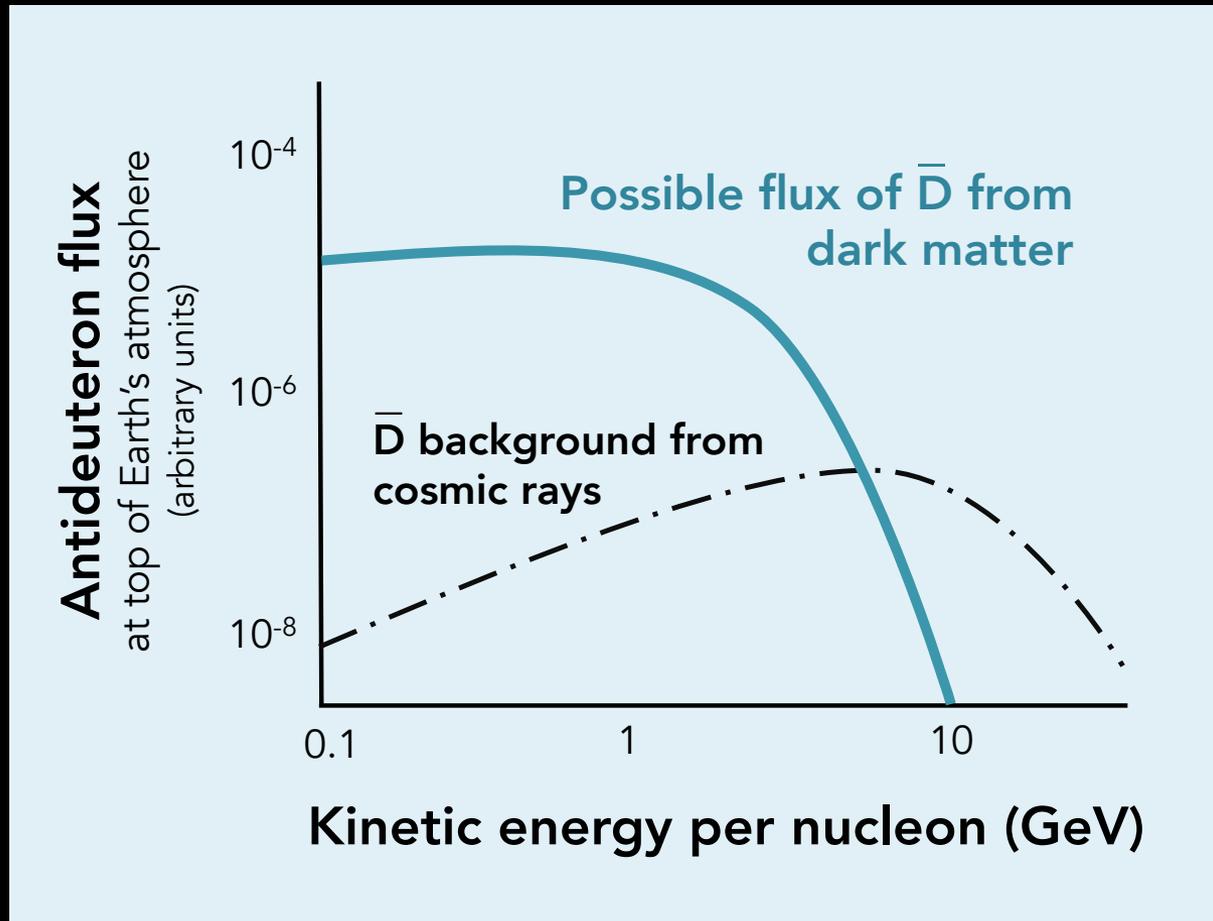
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ANTIDEUTERON production by self-annihilation or decay of DARK MATTER (e.g., WIMPs, gravitinos)

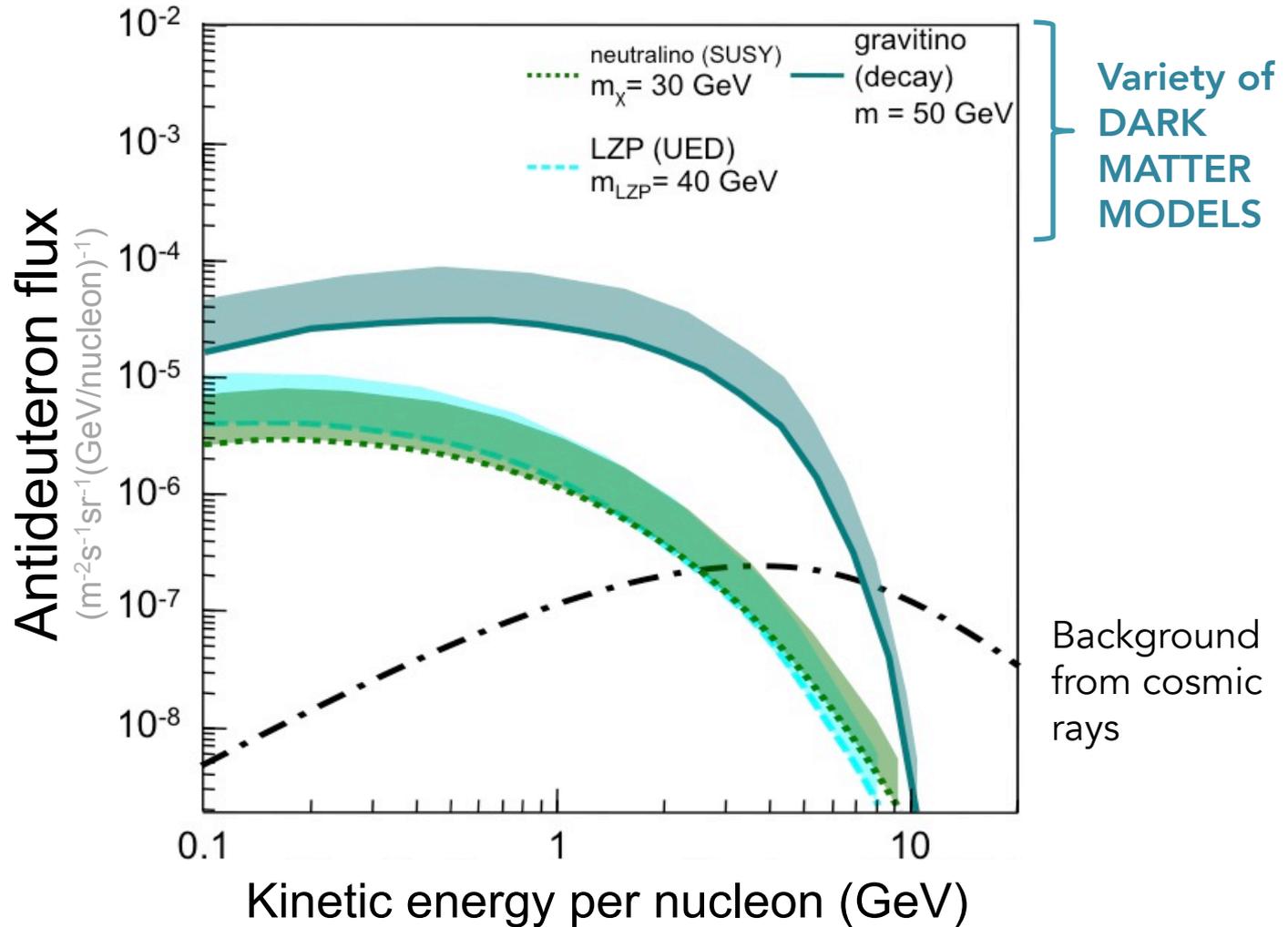


ANTIDEUTERON production by self-annihilation or decay of DARK MATTER (e.g., WIMPs, gravitinos): far above background at low energies

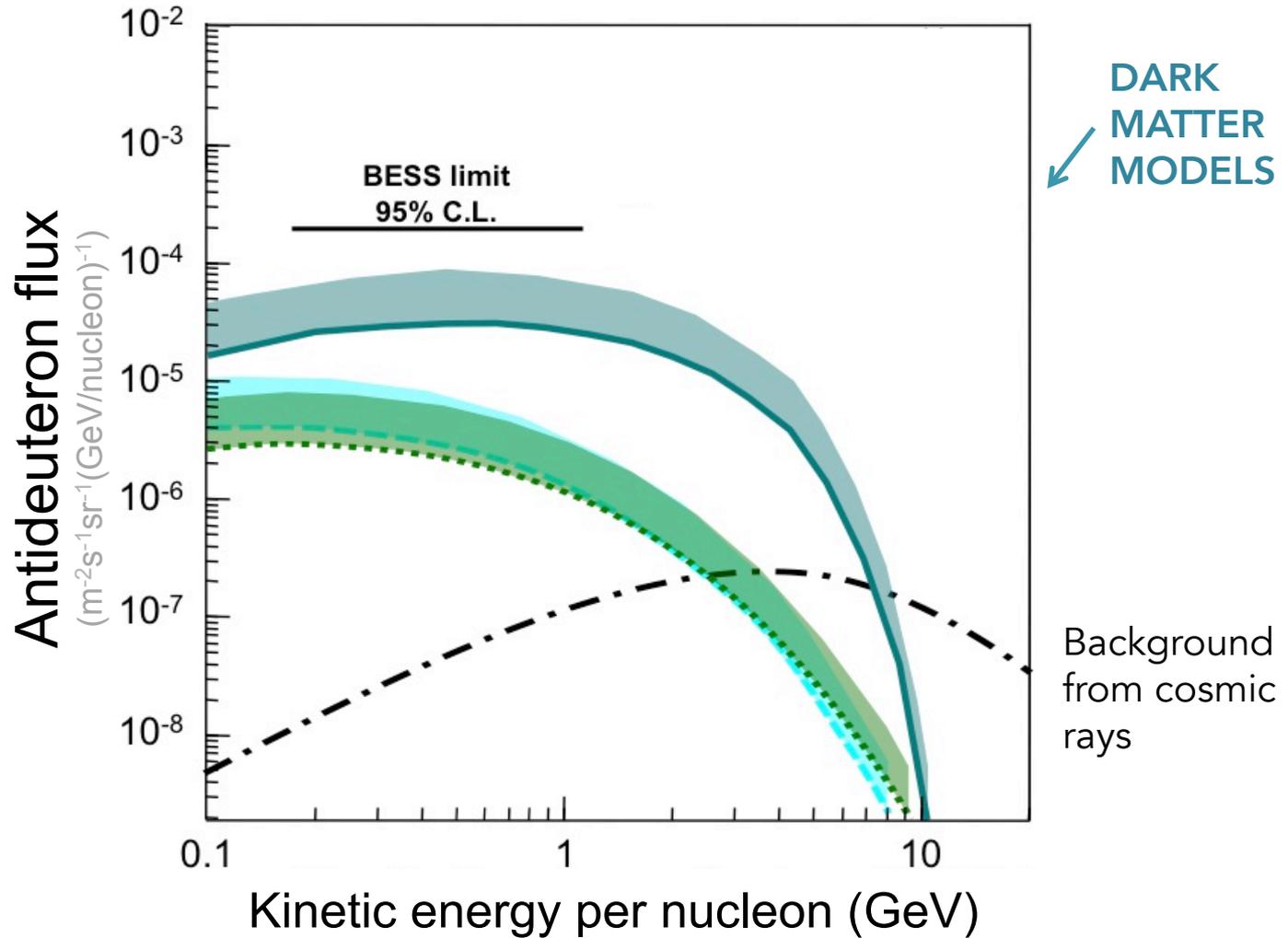


EXPECTED ANTIDEUTERON FLUX AT TOP OF EARTH'S ATMOSPHERE

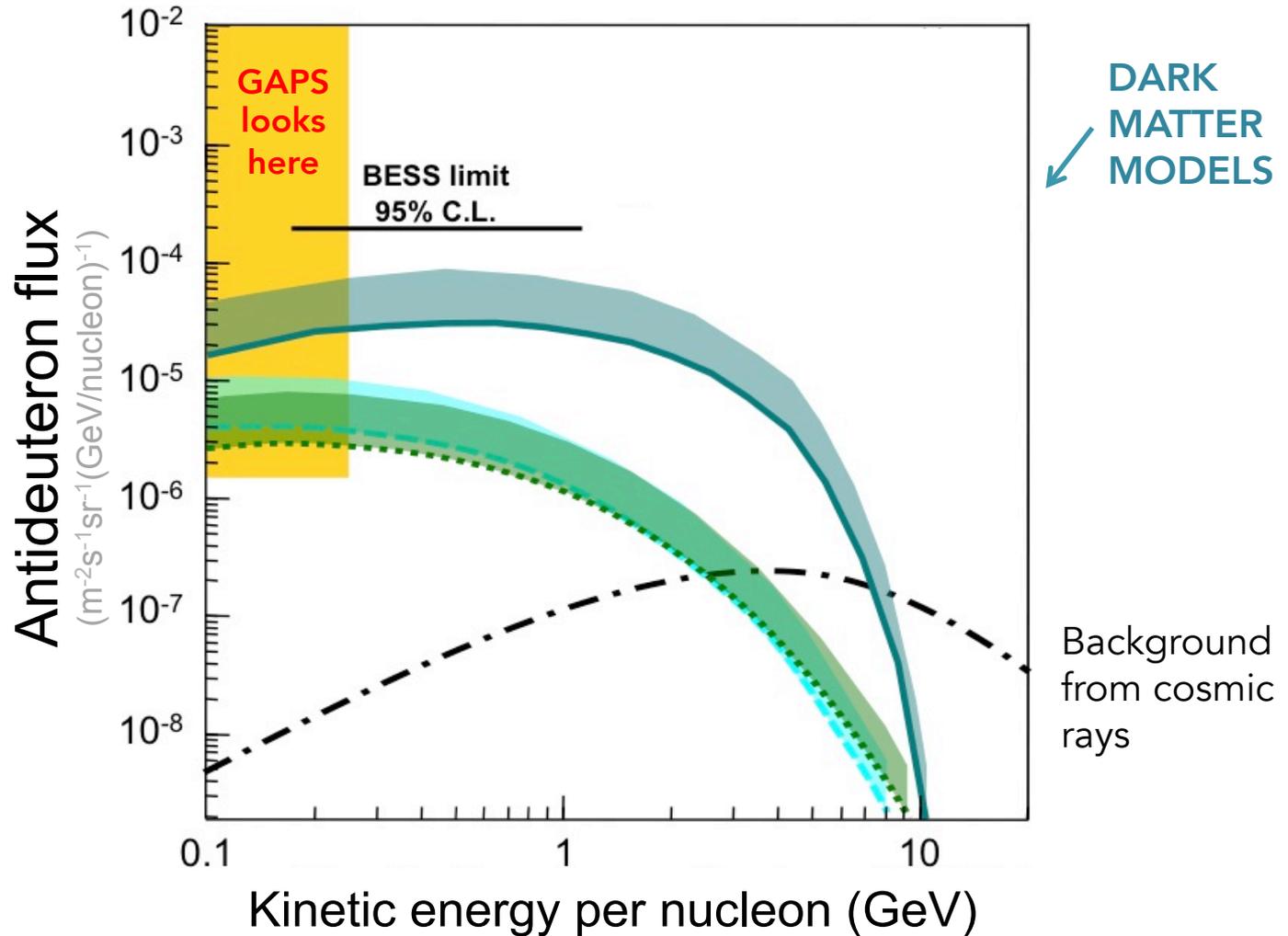
estimated for solar modulation minimum (i.e., before 2021)



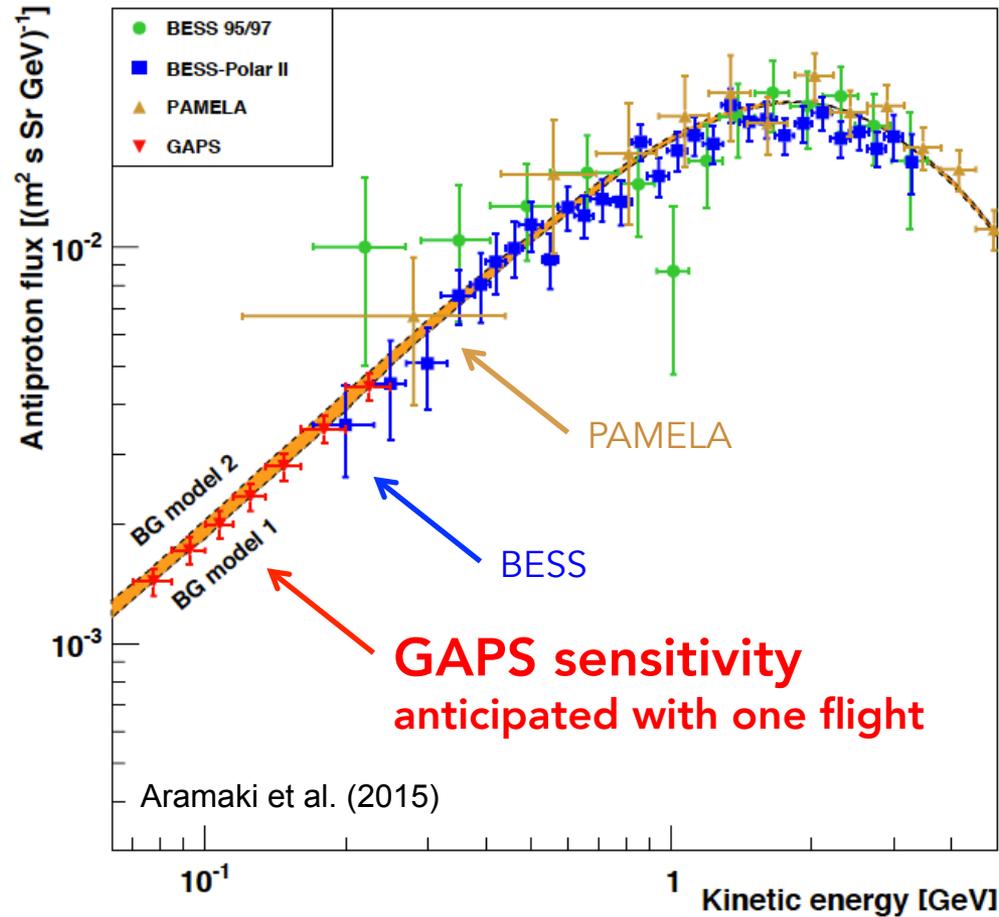
ANTIDEUTERONS HAVE NEVER BEEN SEEN IN COSMIC RAYS



GAPS WILL MAKE THE FIRST DEDICATED SEARCH FOR LOW-ENERGY ANTIDEUTERONS



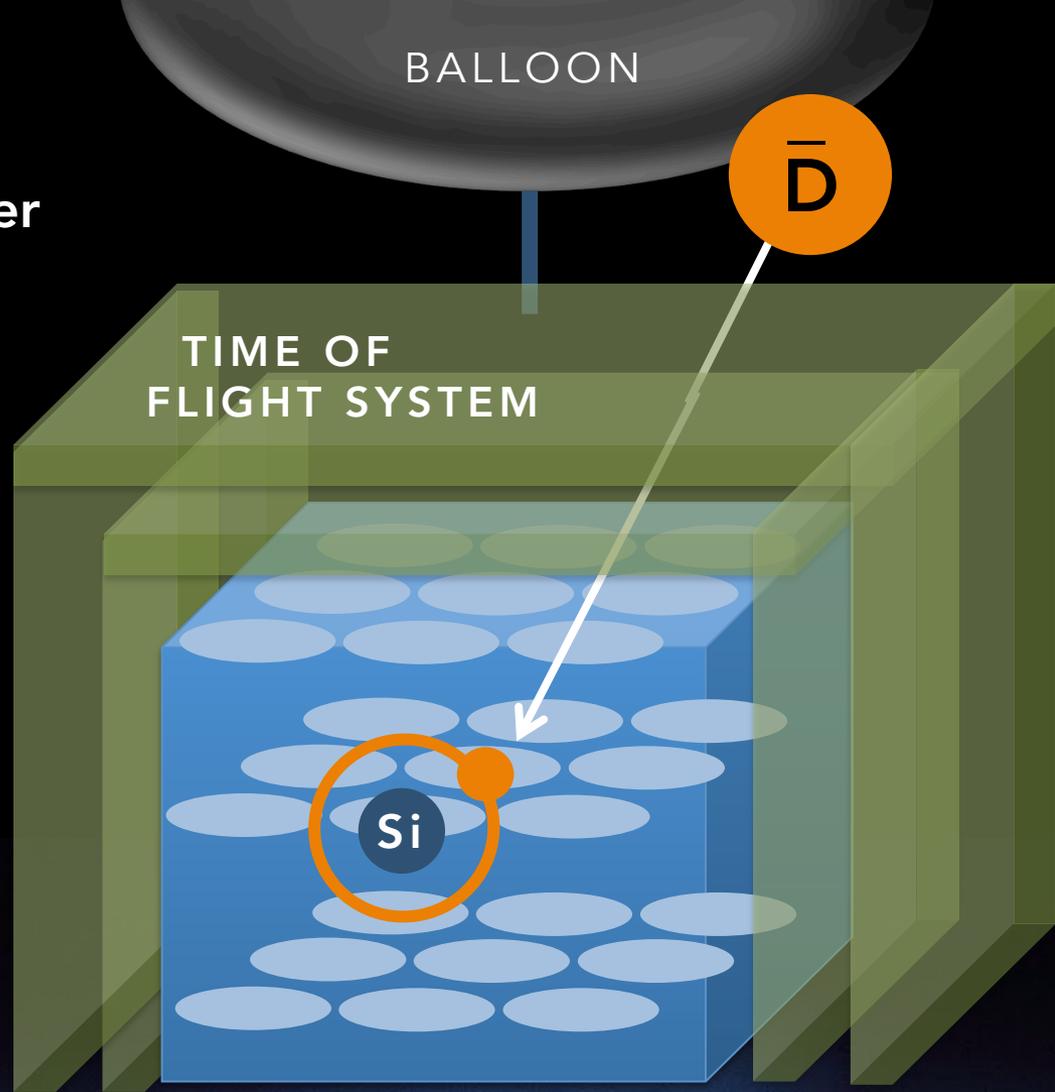
ALSO FROM GAPS: FIRST PRECISION MEASUREMENT OF **LOW-ENERGY ANTIPROTONS**



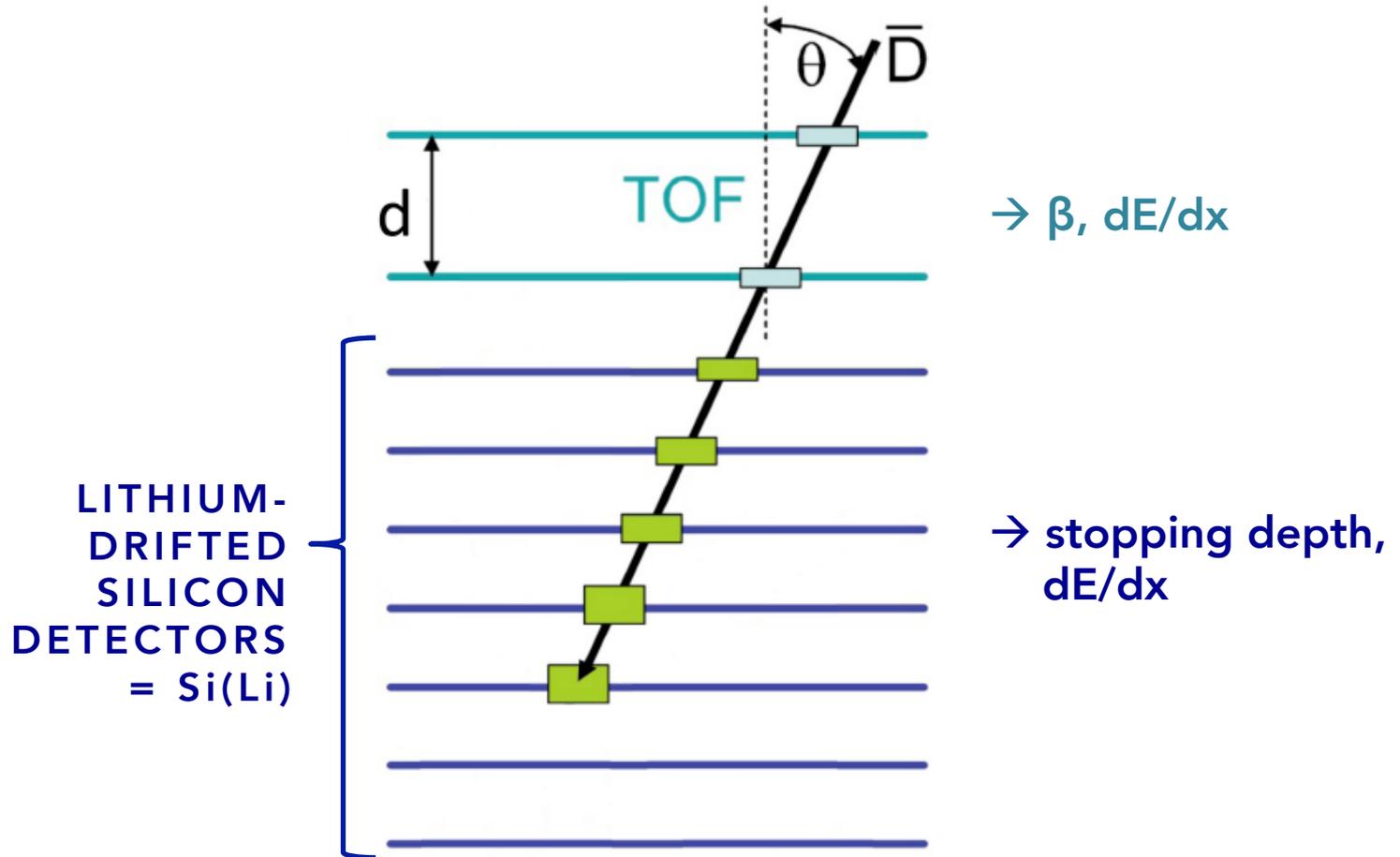
- Constraints on cosmic ray propagation models
- Constraints on light DM and primordial black holes

GAPS: a new type of antiparticle spectrometer based on EXOTIC ATOM DETECTION

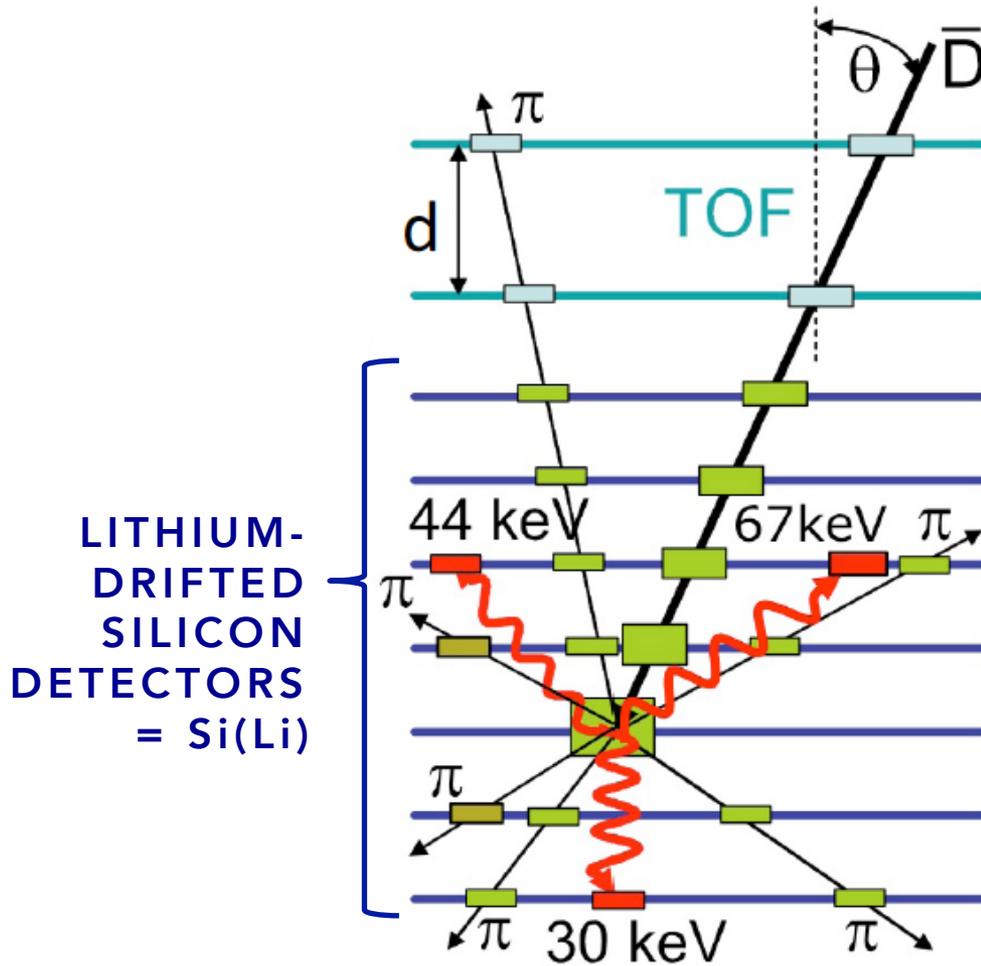
LITHIUM-DRIFTED SILICON DETECTORS (~10 m²)



ANTIDEUTERON INTERACTION IN GAPS



ANTIDEUTERON INTERACTION IN GAPS



EXOTIC ATOM
DECAY:

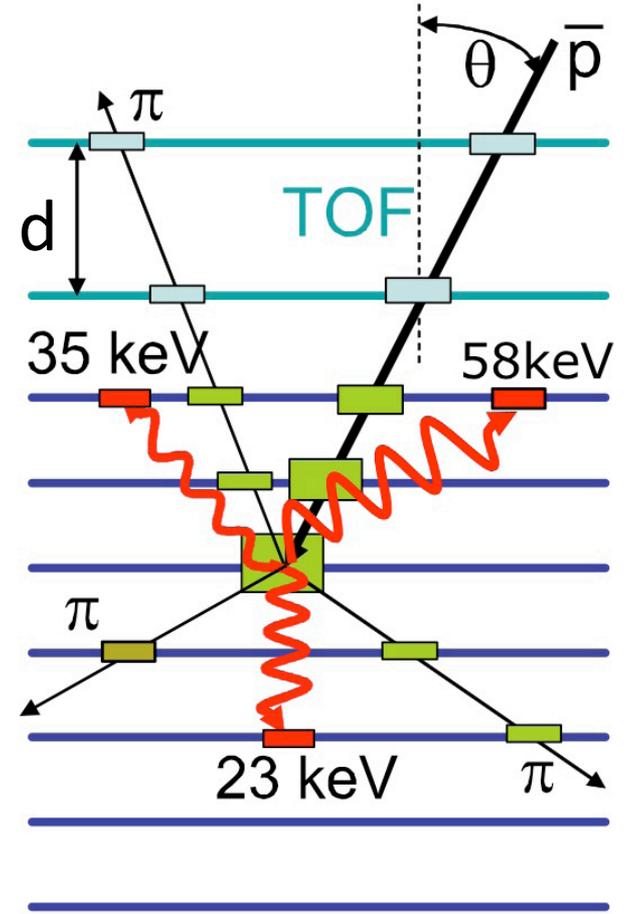
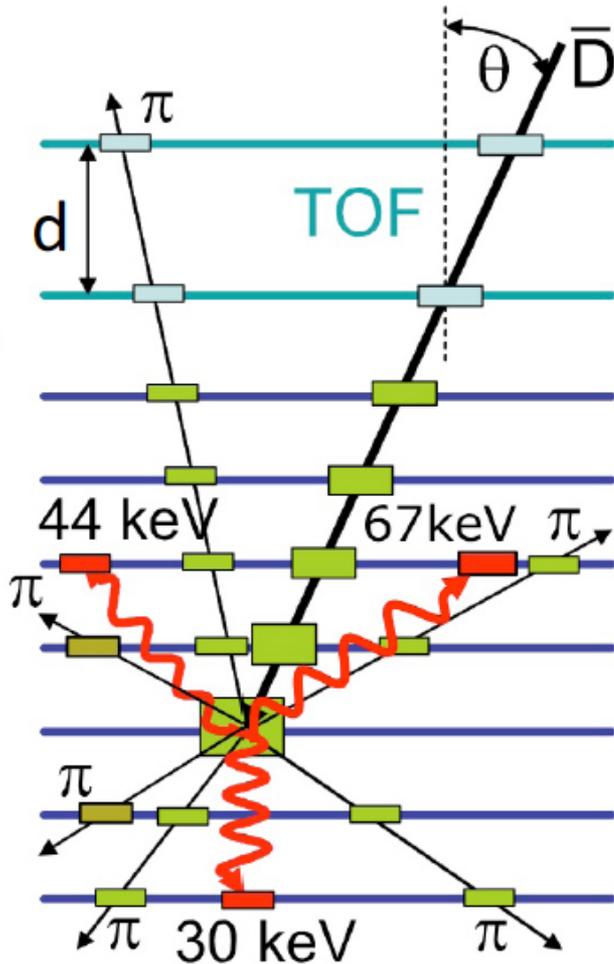
→ Characteristic
X-ray energies

→ pion, proton
multiplicities

Exotic atom
signature →
> 10^9 rejection of
proton cosmic rays

ANTIDEUTERON vs. ANTIPROTON

(same incident velocity)



\bar{D} and \bar{p} have different:

- Stopping depths**
($\rightarrow 10^3$ rejection of antiprotons)
- X-rays**
($\rightarrow 10^1$ rejection)
- Pion, proton multiplicity**
($\rightarrow 10^1$ rejection)

GAPS INSTRUMENTATION

PLASTIC SCINTILLATOR TOF

→ Rough tracking, master trigger

Strips: 1.8m x 0.18m x 0.5cm

Read out both ends with PMTs/SiPMs

500 ps timing resolution

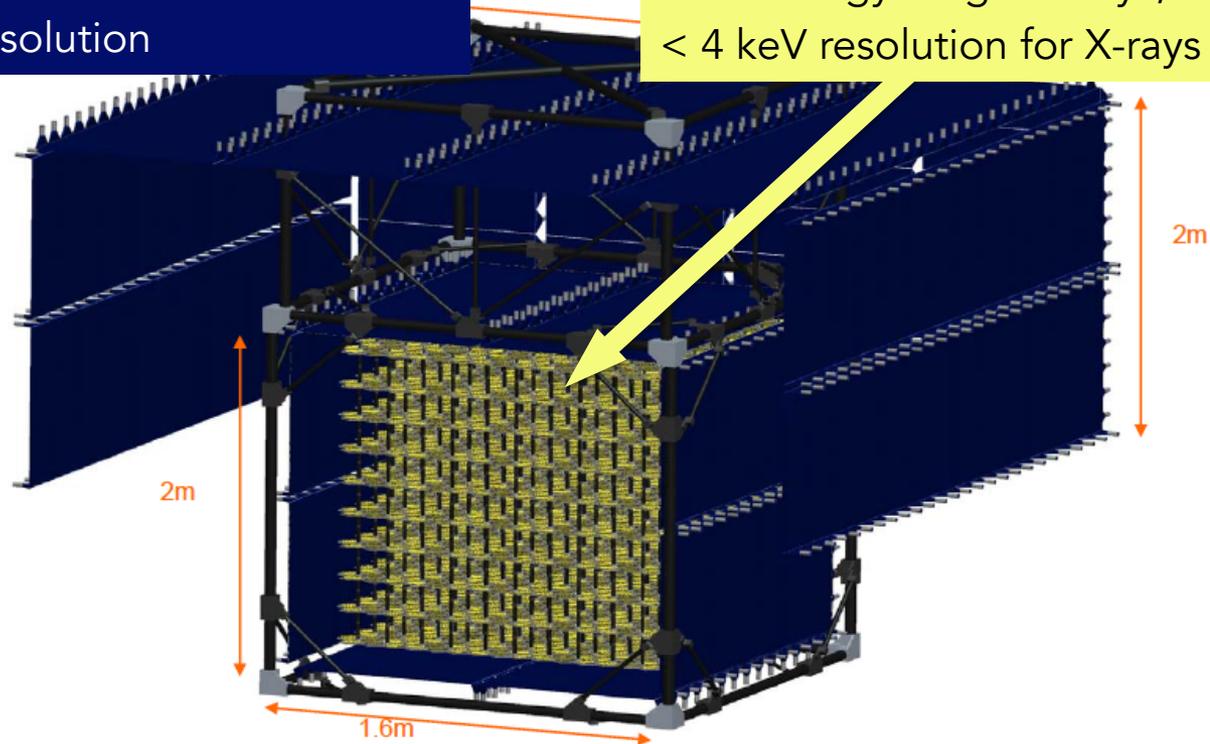
Si(Li) DETECTORS (1000+)

→ Exotic atom ID, tracking

Discs: 2.5 mm thick, 10 cm diameter

Dual energy range: X-rays, MIPs

< 4 keV resolution for X-rays

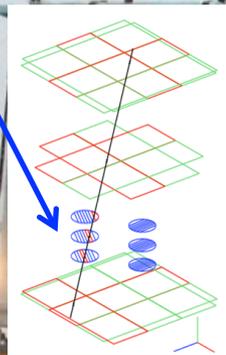


SUCCESSFUL PROTOTYPE FLIGHT (pGAPS) 2012



Taiki, Japan

3 time-of-flight planes
+ 6 Si(Li)
detectors



- ✓ Demonstrated Si(Li), TOF, and cooling system during flight
- ✓ Measured backgrounds



科研費
KAKENHI

GAPS
COLLABORATION



Massachusetts
Institute of
Technology

UC San Diego



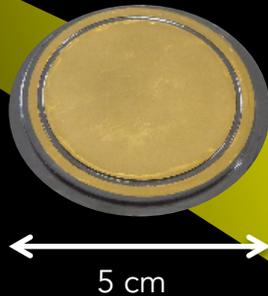
UNIVERSITY
of HAWAII®
MĀNOA



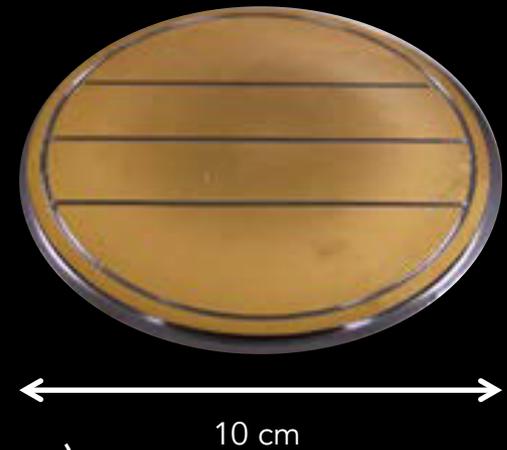
ONGOING DEVELOPMENT OF LARGE SI(LI) DETECTORS



Si(Li) technology established for small detectors...



✓ Required energy resolution achieved on custom-made intermediate-size detectors



GAPS requires > 1000 large Si(Li) detectors

Now optimizing fabrication at MIT/Columbia

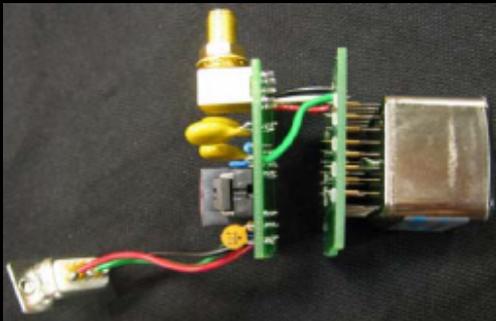
Detectors will be produced at Shimadzu Corp. (Japan)

ONGOING WORK ON TOF SYSTEM

225 scintillation counters, read out on both sides using custom ASIC boards



← Prototype 120 cm paddles →



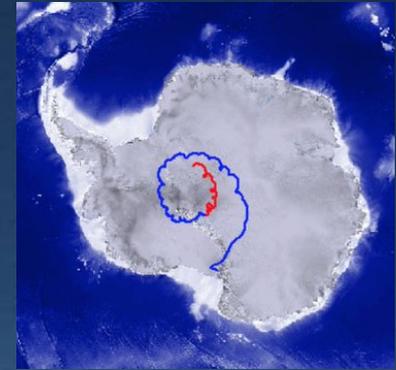
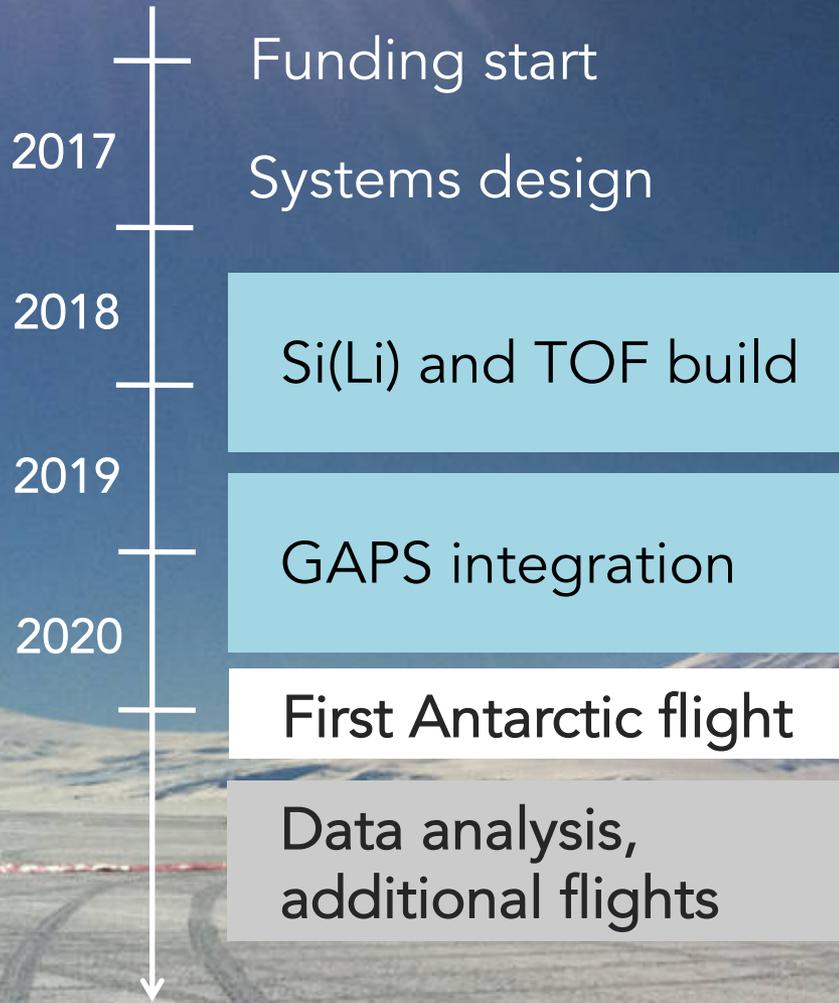
Currently determining:

PMT vs. SiPM



TOF-based trigger scheme under development

PREPARING TO LAUNCH IN 2020



Long duration (~30 day) flight, Antarctica





GAPS RESULTS BY 2021:

Potential for first detection of antideuterons in cosmic rays

First precision measurement of low-energy antiprotons

→ **Unique probes of a variety of dark matter models**