The GAPS Experiment: Hunting for Dark Matter with Antideuterons

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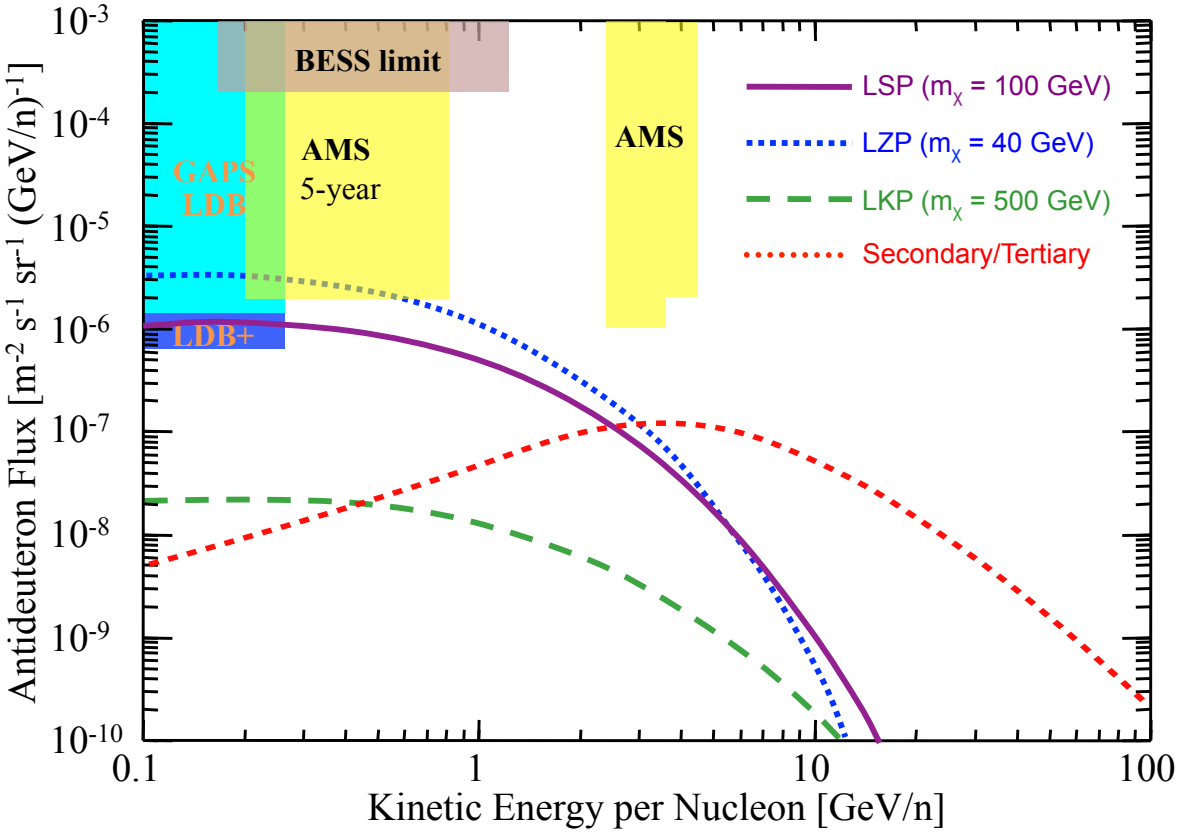
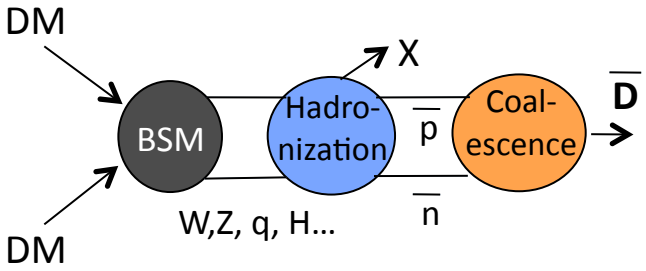
GAPS and Antideuterons

GAPS will look for DM particles self-annihilating in Galactic Halo to form **low-energy antideuterons**

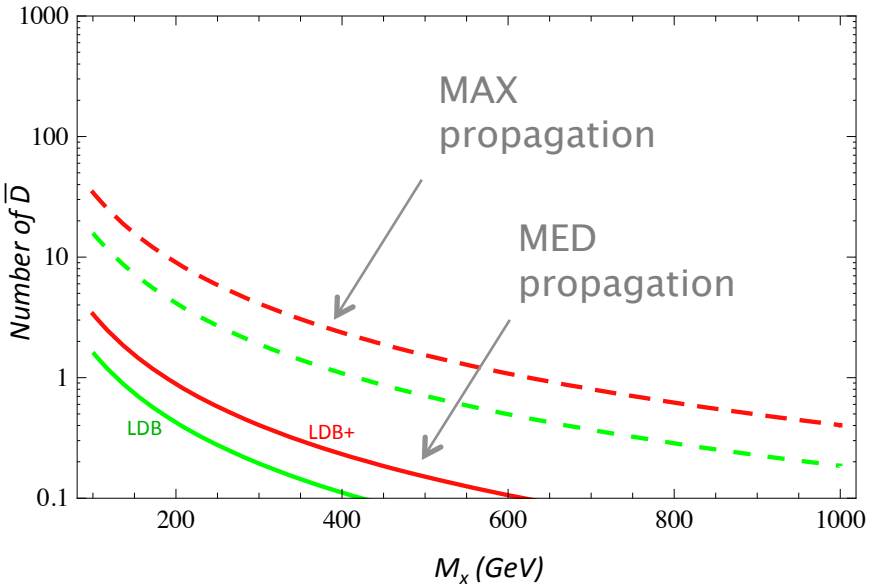




A generic BSM signature with essentially zero conventional astrophysical background

* Primary flux: Baer and Profumo, JCAP 12, 008 (2005), with updated p_0.
** Secondary/Tertiary: Salati, Donato, and Fornengo, Particle Dark Matter, pp. 521-546, (2010). Ibarra and Wild, arXiv:1301.3820v1 (2013)
*** AMS: N. Fornengo et al. (2013) arXiv:1306.4171

Antideuteron Searches



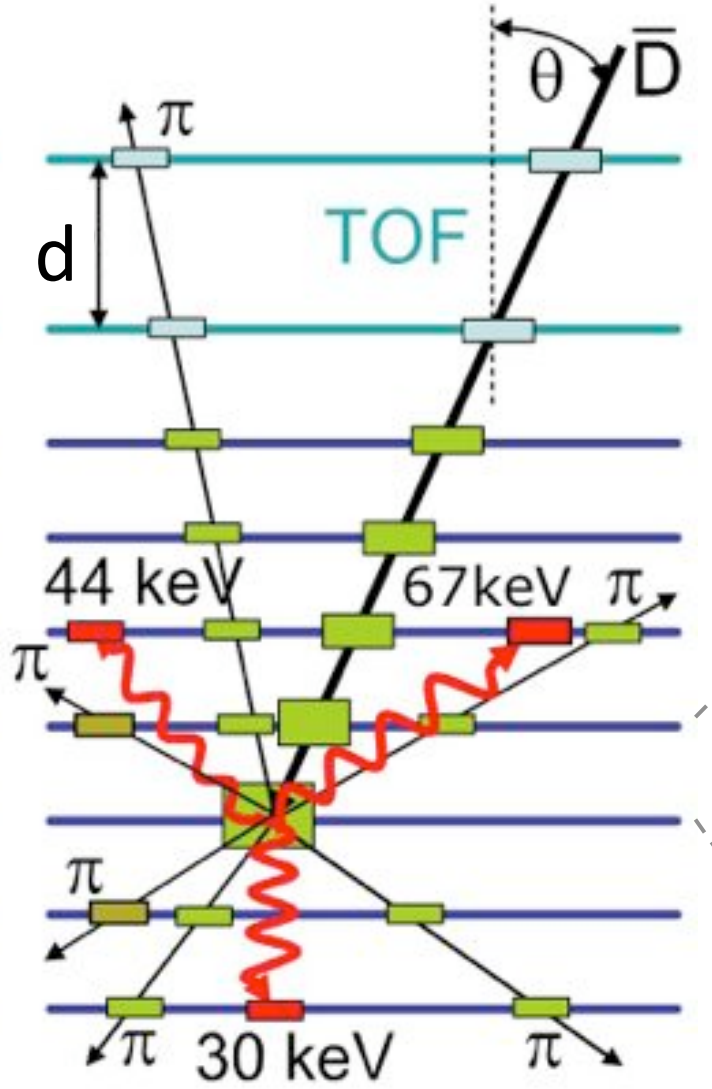
Neutralino fluxes from Cui, Mason, and Randall, J. High Energy Phys. 11, 017 (2010).

- Antideuteron detection = rare-event search
- Flux uncertainties due to:
  - propagation model *up to factor x10 for signal, much less for background!*
  - hadronization and coalescence models *factor x0.8-10, depending on annihilation channel*

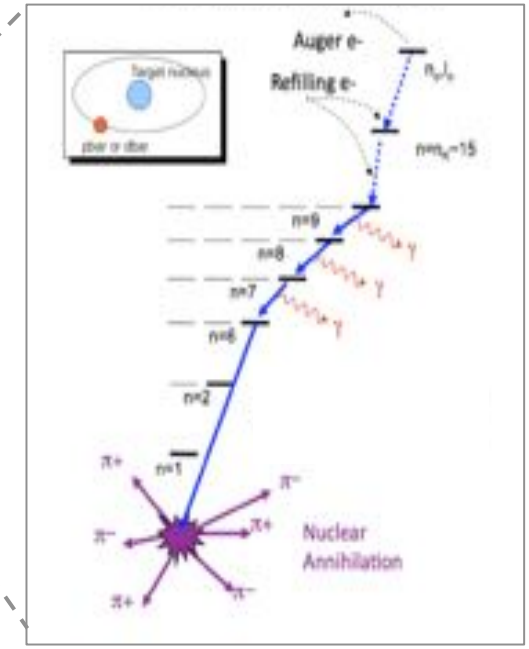
    i.e. N. Fornengo et al. (2013) arXiv:1306.4171
  - boost factor $f \approx 1$-10
  - DM halo density *up to factor x2*
- Analogy to direct search experiments:
  - handful of signal events
  - background dominated
  - long integration times
  - different technologies

Small expected signal flux and multiple uncertainties
highlight need for multiple experiments, complementary sensitivities

GAPS Detection Concept

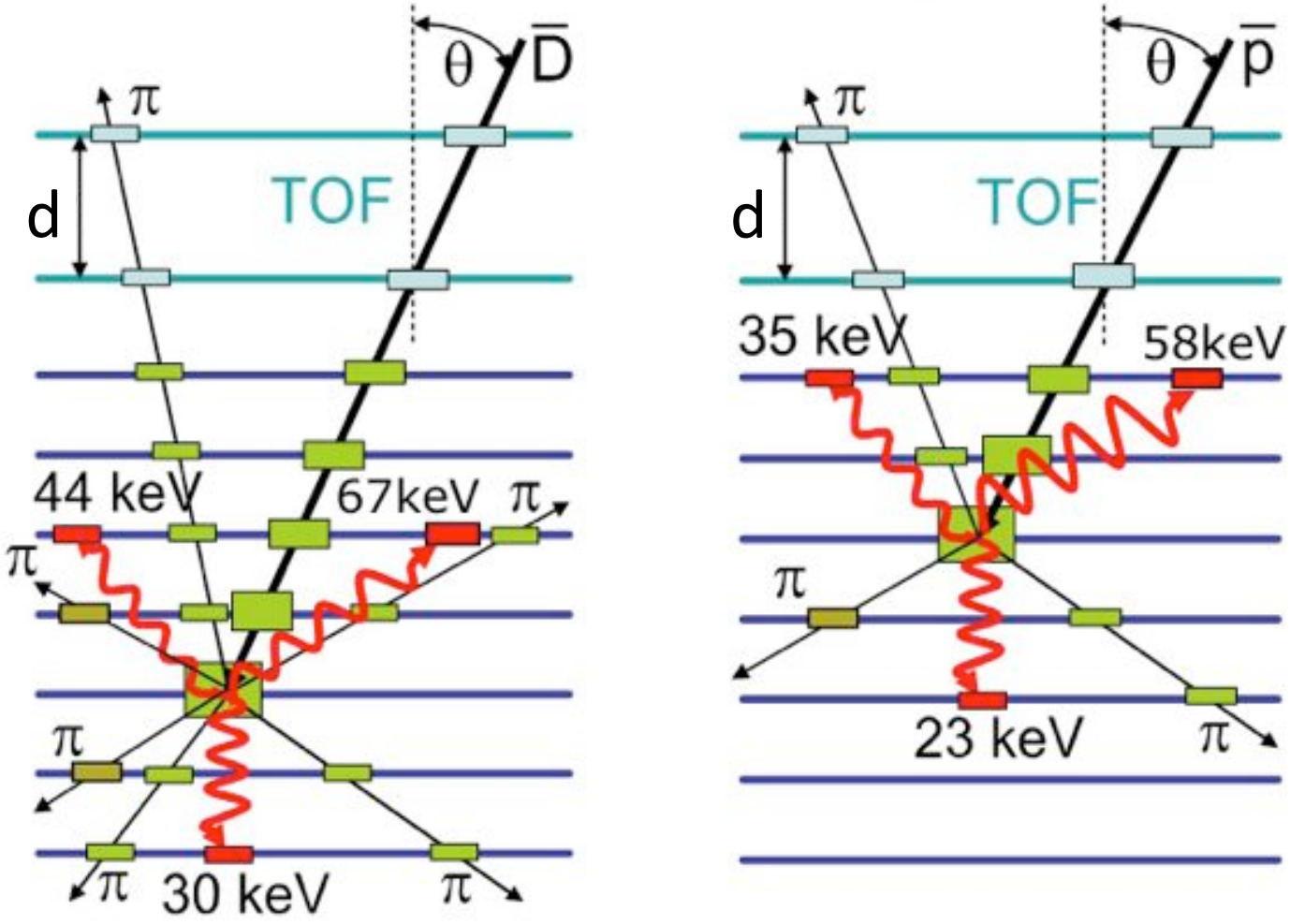


- **TOF** system measures velocity
- Loses energy in layers of semiconducting **Si(Li) target/detector**
- Stops, forming exotic excited atom
- Atom de-excites, emitting **x-rays**
- Remaining nucleus annihilates, emitting **pions and protons**



T. Aramaki et al., http://arxiv.org/abs/1303.3871

GAPS Background Rejection

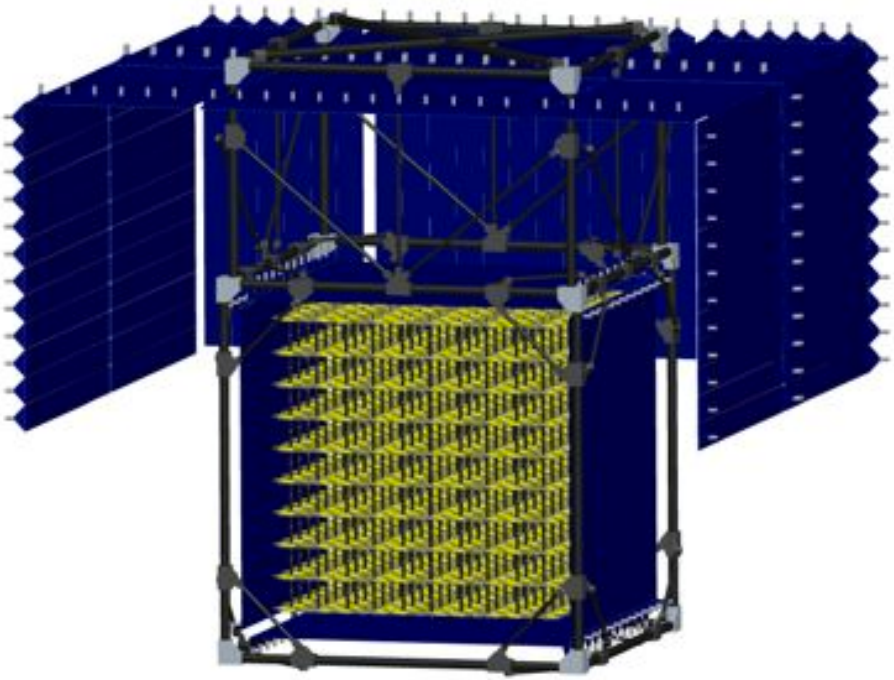


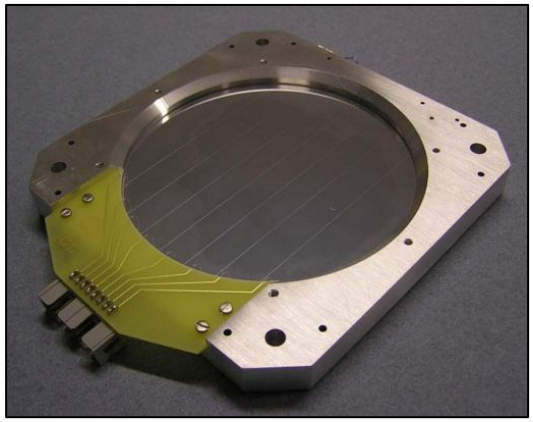
Combination of TOF, depth-sensing, X-ray, and π/proton detection yield rejection >10^5

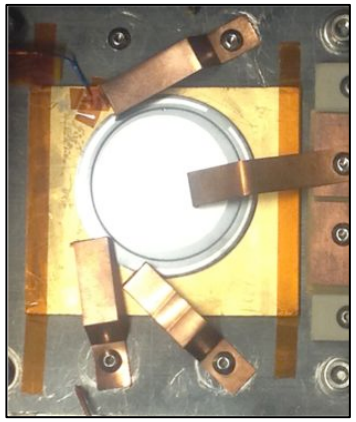
GAPS Detector Design

Plastic scintillator TOF

- high-speed trigger and veto
- 2 m long, 0.5 cm thick
- read out both ends
- ~500 ps timing resolution



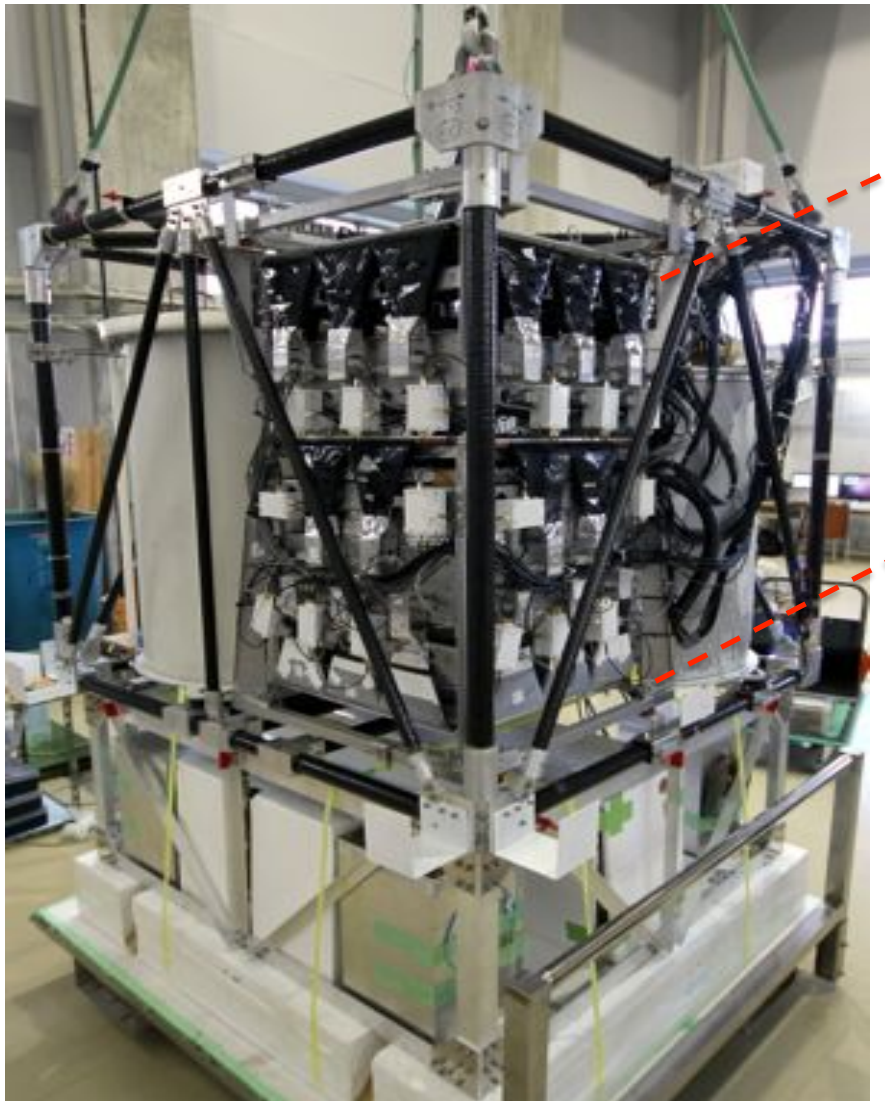


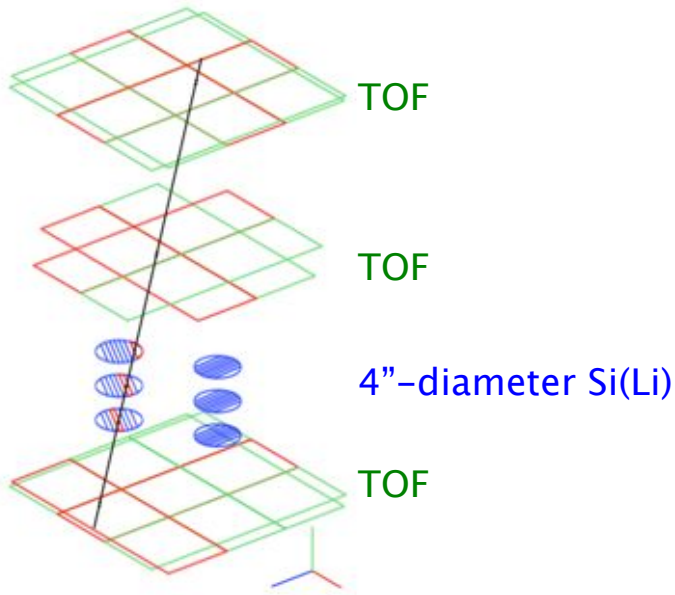


Si(Li) targets/detectors

- X-ray identification, dE/dx, stopping depth, and shower particle multiplicity
- 2.5 mm thick, 4" (or 2") diameter
- 3 keV resolution for X-rays

pGAPS: a Prototype GAPS Flight





S. A. I. Mognet, et al. (2013) arXiv:1303.1615

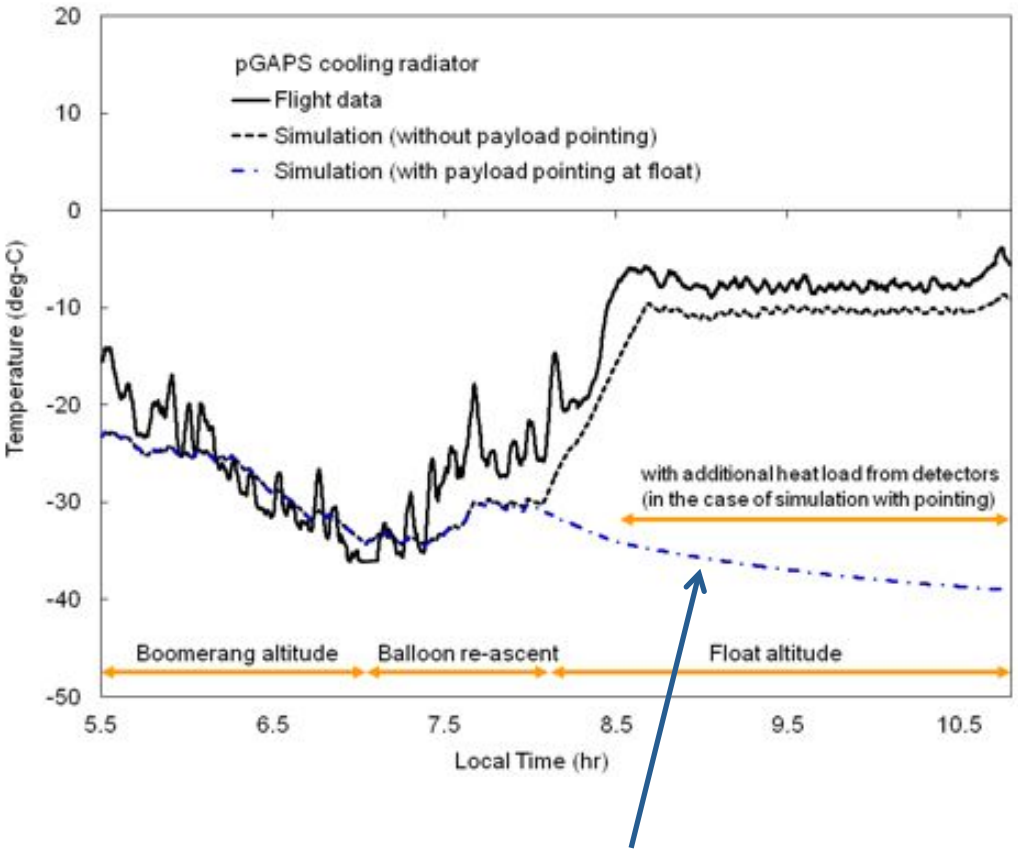
100% of flight goals met!

(1) verify stable, low-noise operation of Si(Li) detectors at ambient flight pressure
(2) validate the cooling system and thermal model for the Si(Li) system
(3) measure the background levels at flight altitude to validate simulation codes

pGAPS: a Prototype GAPS Flight

Taiki, Japan

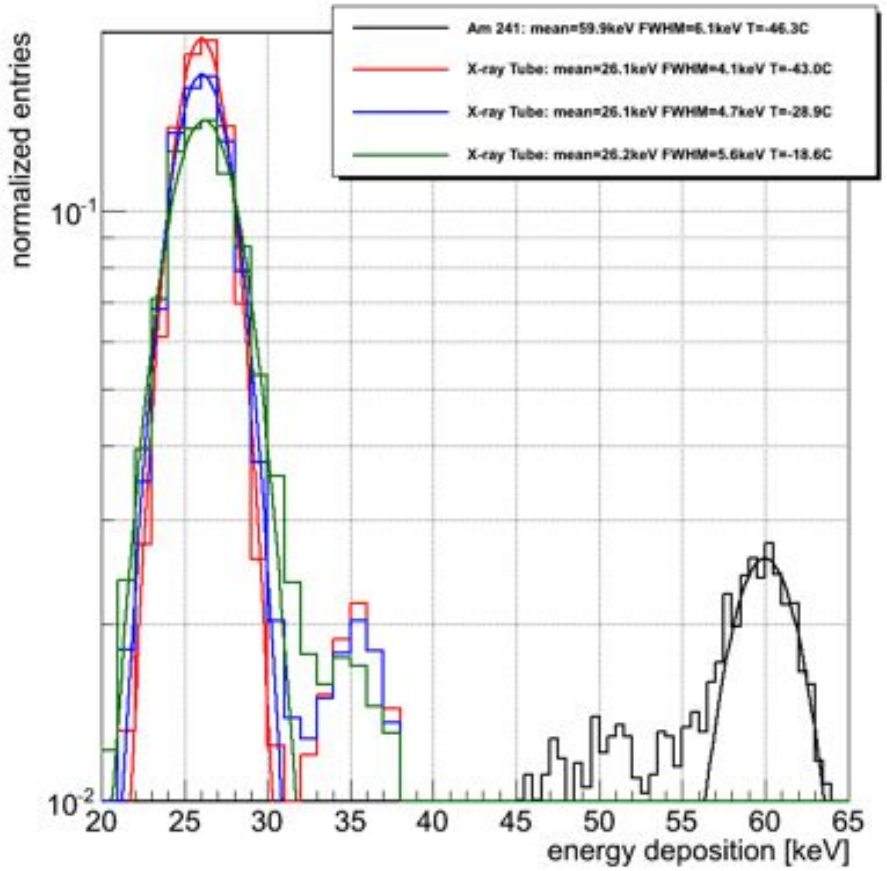
pGAPS Cooling Results



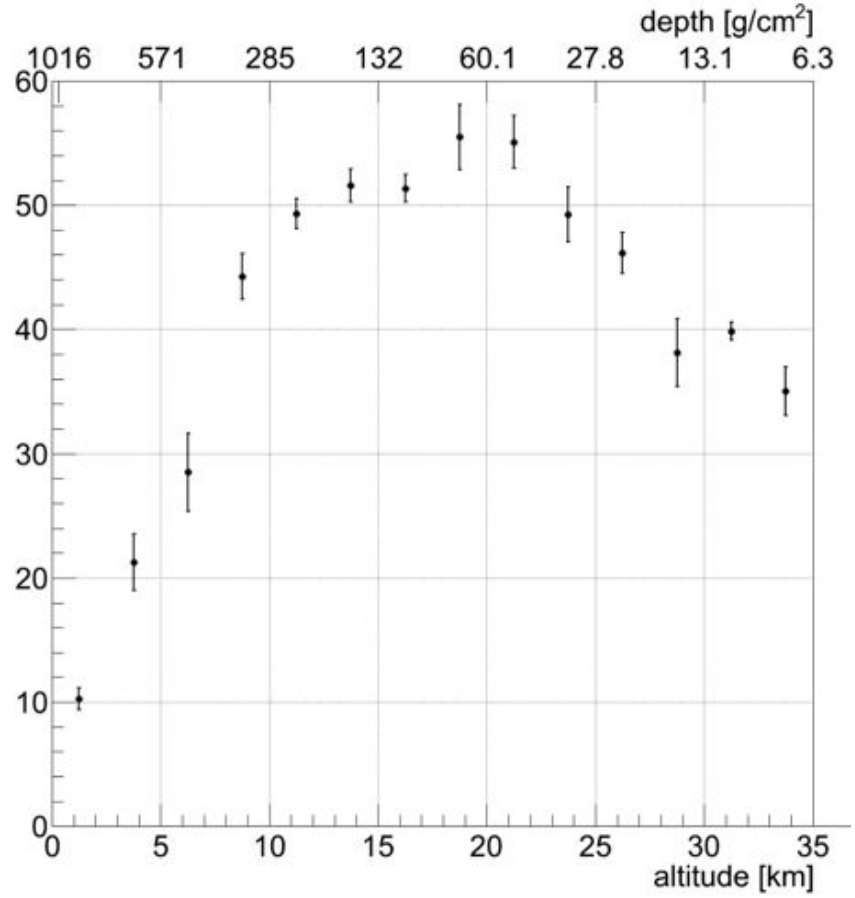
Cooling performance confirms thermal model

- With proper pointing, cooling system allows optimal Si(Li) operation
- Oscillating heat pipe (OHP) system also validated with thermal simulation

pGAPS Detector Results

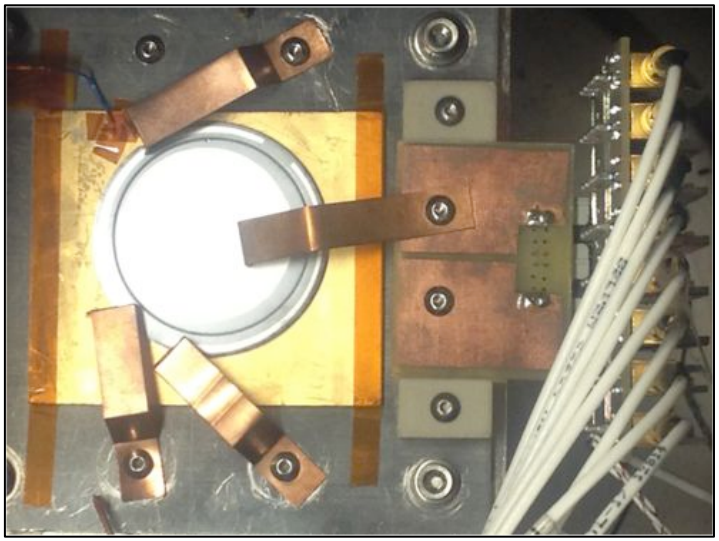


Si(Li) resolution consistent with temperature-dependent predictions



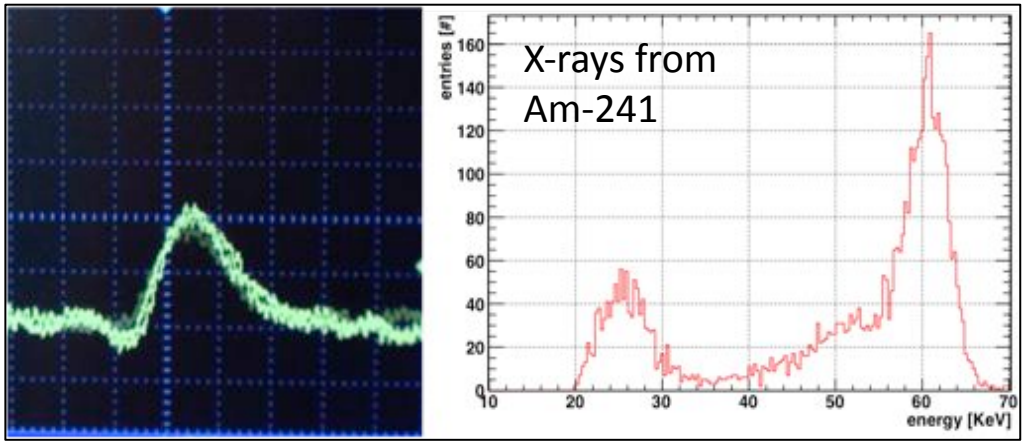
TOF trigger rates in good agreement with other measurements and air shower simulations

Onward! – Si(Li) Detector Production



- GAPS will use 2875 4” Si(Li) detectors (or 11500 2” detectors)
- 2”-diameter detectors being produced at Columbia U. using simple fabrication scheme
- Successfully drifted diameters from 1” to 2” with >90% yield, both 1.25 mm (prototype) and 2.5 mm thick

- Leakage current <10 nA at -35 C
- Confirmed performance with cosmic rays (MIPs) and Am-241 source (X-rays)
- 4” detector development underway!



Onwards to GAPS!

- **Exciting time for antideuteron searches!**
- If AMS sees signal, GAPS will verify and strengthen confidence
- If AMS reports limit, GAPS prepared to search deeper
    - Lower energies and different detection technique
- **Development ongoing!**
    - 4” Si(Li) detector development and facility for batch processing of all flight detectors
    - increase TOF paddle length and verify mechanical integrity, signal size, and timing performance
    - based on existing prototypes, develop ASICs for both Si(Li) and TOF systems and a custom pre-amplifier for Si(Li)

Building on experience from successful pGAPS and Si(Li) development, plan for an initial GAPS flight in winter 2017/2018