General AntiParticle Spectrometer (GAPS) Dark matter search with low-energy cosmic-ray antideuterons and antiprotons

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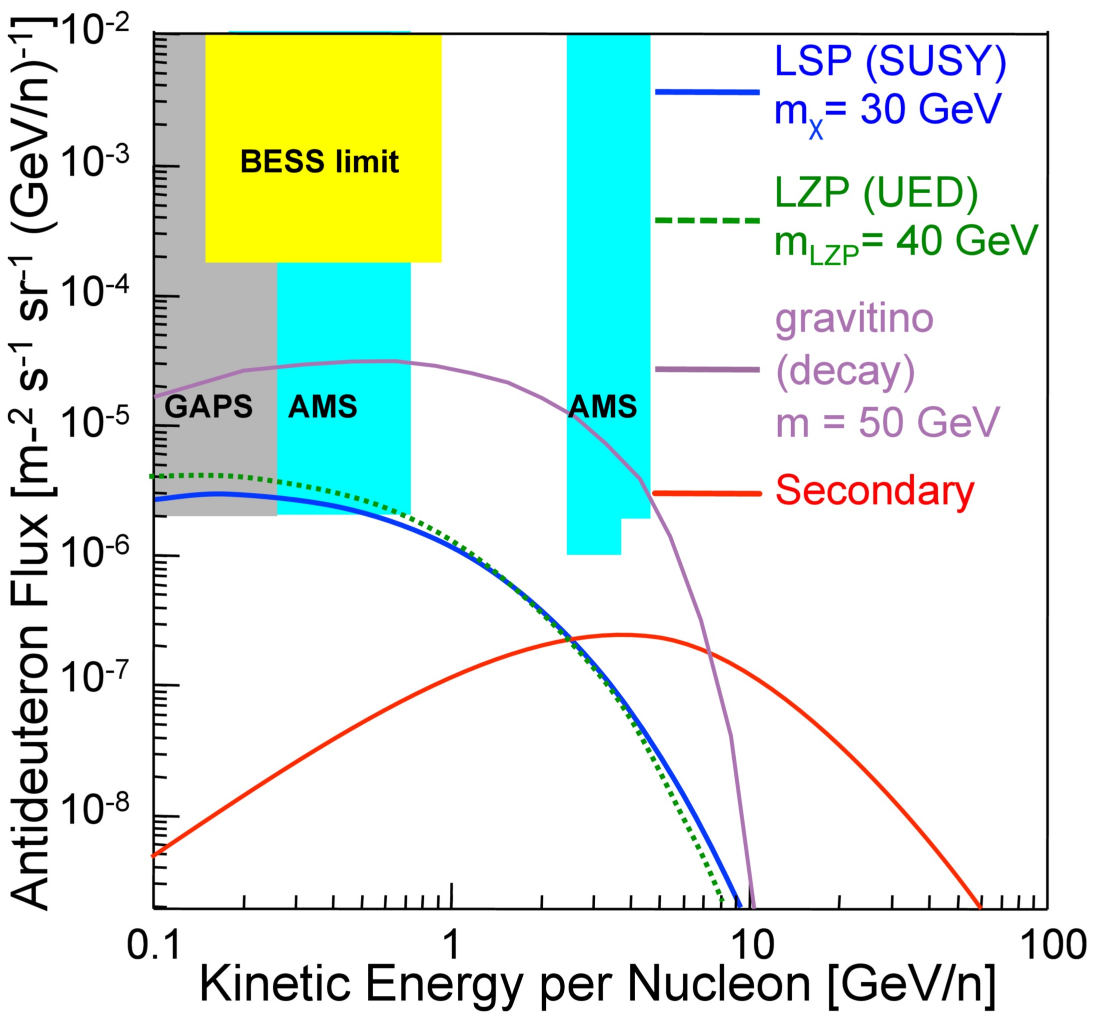
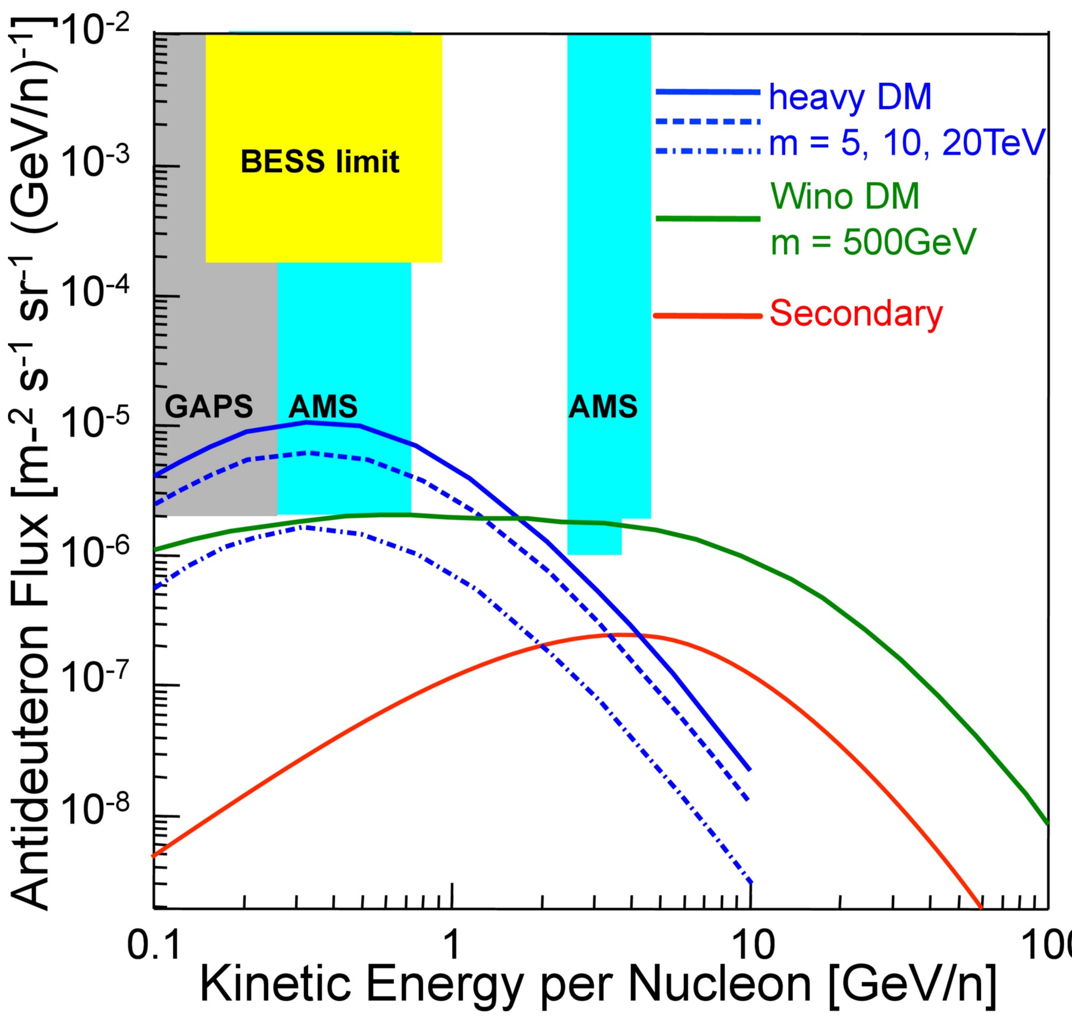
The GAPS experiment is foreseen to carry out a dark matter search by measuring low-energy cosmic-ray antideuterons and antiprotons with a novel detection approach. It will provide a new avenue to access a wide range of different dark matter models and masses from about 10GeV to 1TeV. The theoretically predicted antideuteron flux resulting from secondary interactions of primary cosmic rays is very low. Well-motivated theories beyond the Standard Model contain viable dark matter candidates, which could lead to a significant enhancement of the antideuteron flux due to annihilation or decay of dark matter particles. This flux contribution is believed to be especially large at low energies, which leads to a high discovery potential for GAPS. The GAPS low-energy antiproton search will provide some of the most stringent constraints on ~30GeV dark matter, will provide the best limits on primordial black hole evaporation on galactic length scales, and explore new discovery space in cosmic-ray physics. GAPS is designed to achieve its goals via long duration balloon flights at high altitude in Antarctica. The detector itself will consist of 10 planes of Si(Li) solid state detectors and a surrounding time-of-flight system. Antideuterons and antiprotons will be slowed down in the Si(Li) material, replace a shell electron and form an excited exotic atom. The atom will be deexcited by characteristic X-ray transitions and will end its life by the formation of an annihilation pion/proton star. This unique event structure will deliver a nearly background free detection possibility. In June 2012, a successful prototype balloon flight from the balloon base in Taiki, Japan was carried out.

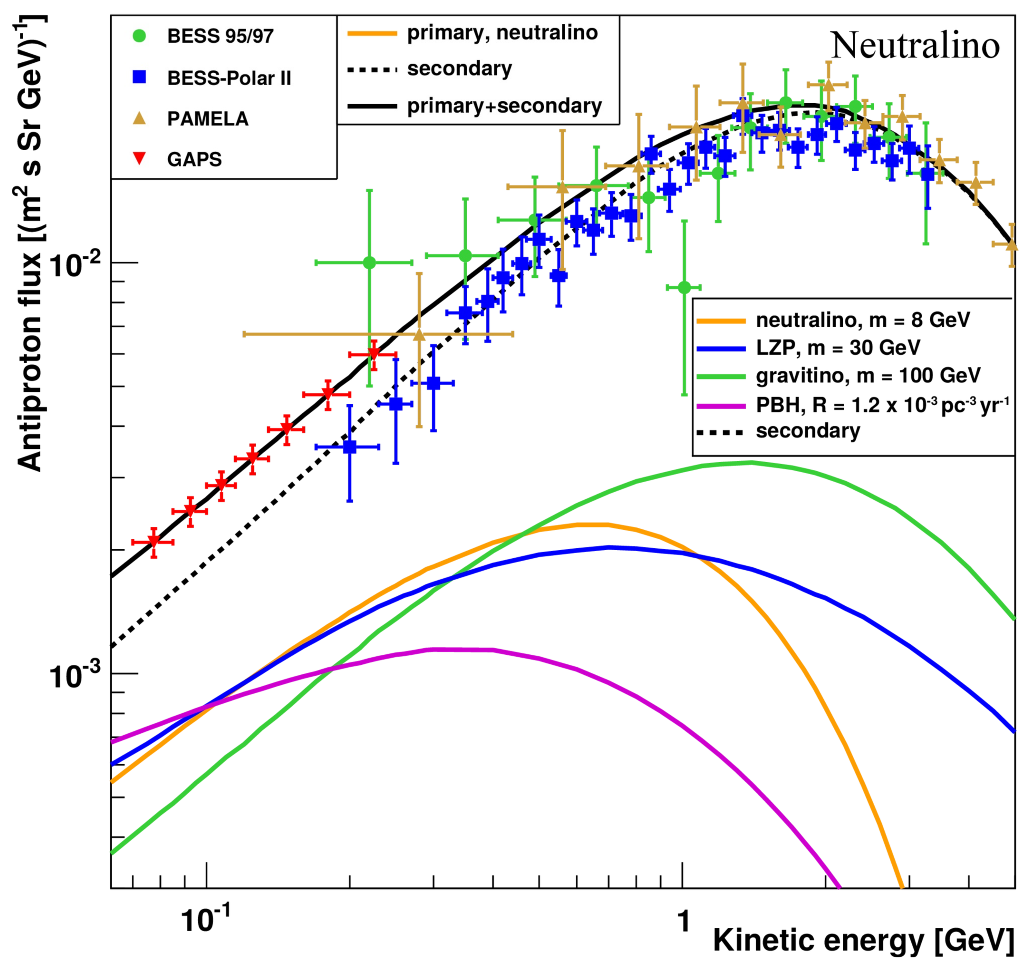
Motivation



LSP, LZP, and gravitino models along with the antideuteron background and sensitivity of GAPS, BESS and AMS (for five years of operation)

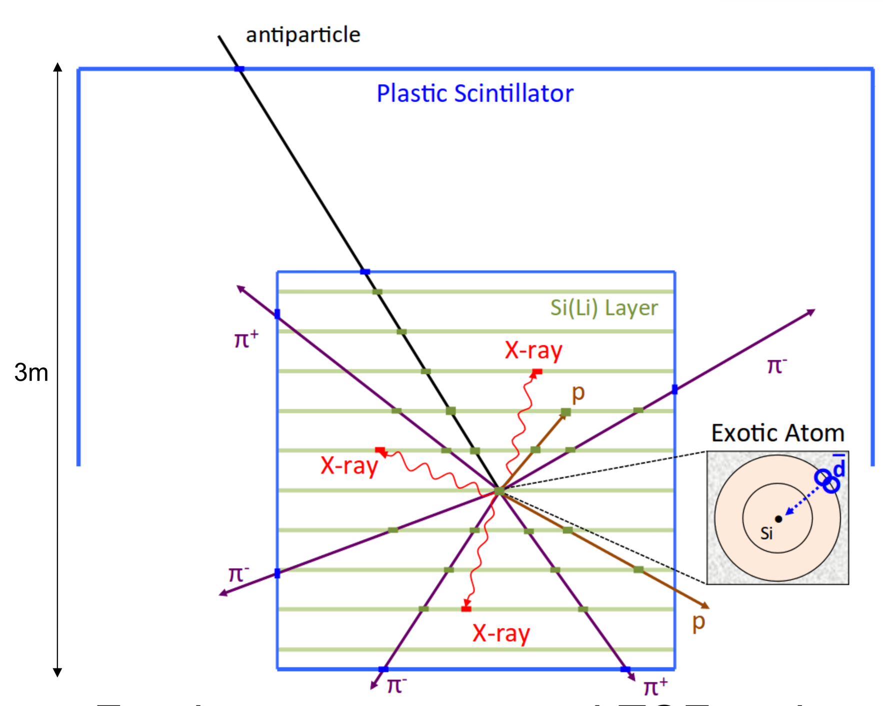


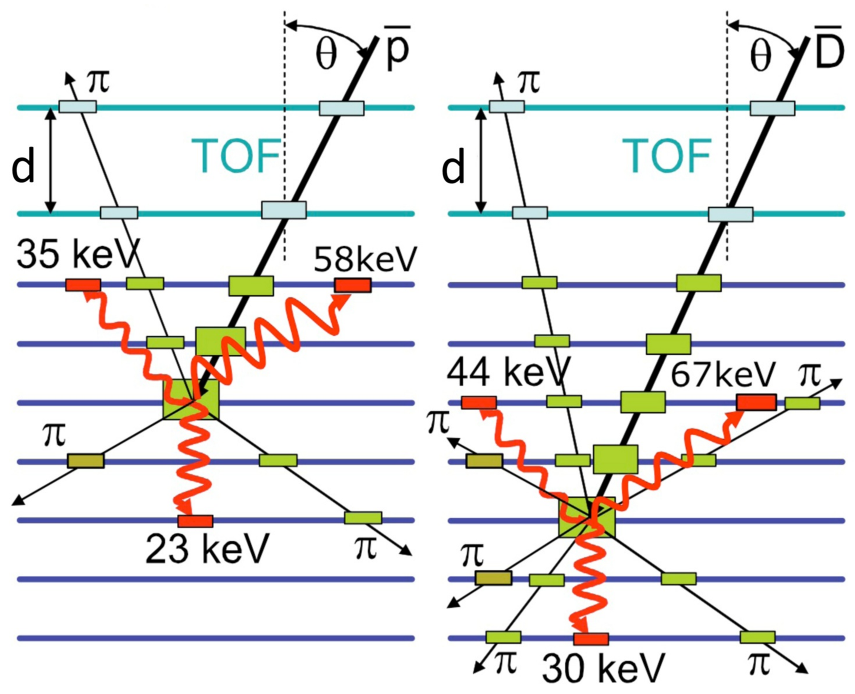
Sensitivity of antideuteron searches for heavy DM annihilation with representative propagation uncertainty indicated



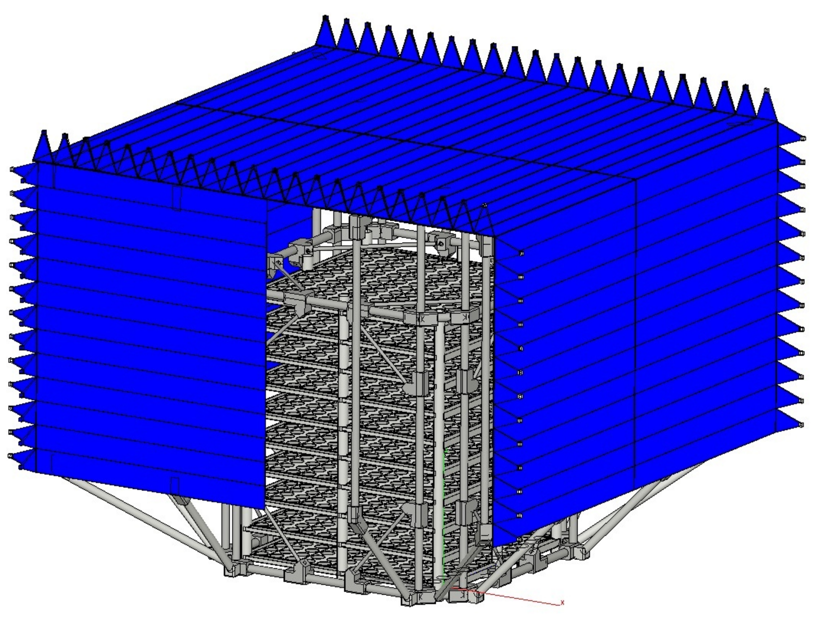
Predicted primary antiproton fluxes at TOA from neutralinos, LZPs, gravitinos, or PBHs, along with neutralino signals as seen by 1 GAPS LDB flight.

GAPS instrument





For the same measured TOF and angle (i.e., particle velocity), an antideuteron (right) will penetrate deeper, typically emit twice as many annihilation pions and protons and emit X-rays of different well-defined energies than an antiproton.



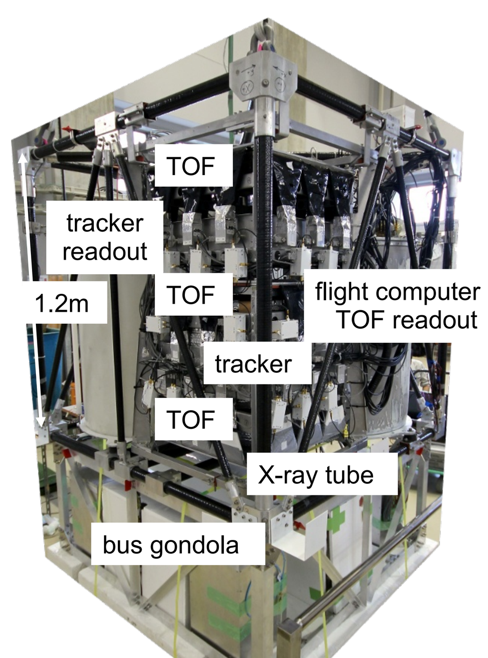
	1LDB	3LDB
Energy range:	0.05-0.25GeV/n	
Geometric acceptance (w/o efficiencies):	22m²sr	
Observation time:	~35days	~105days
Antideuteron sensitivity (CL>99%) (m²sr s GeV/n)⁻¹:	$4.8\cdot10^{-6}$	$2\cdot10^{-6}$
Antiproton events:	~1500	~4500

GAPS balloon long duration flights are proposed from Antarctica for the 2019/20 ballooning season

GAPS will:

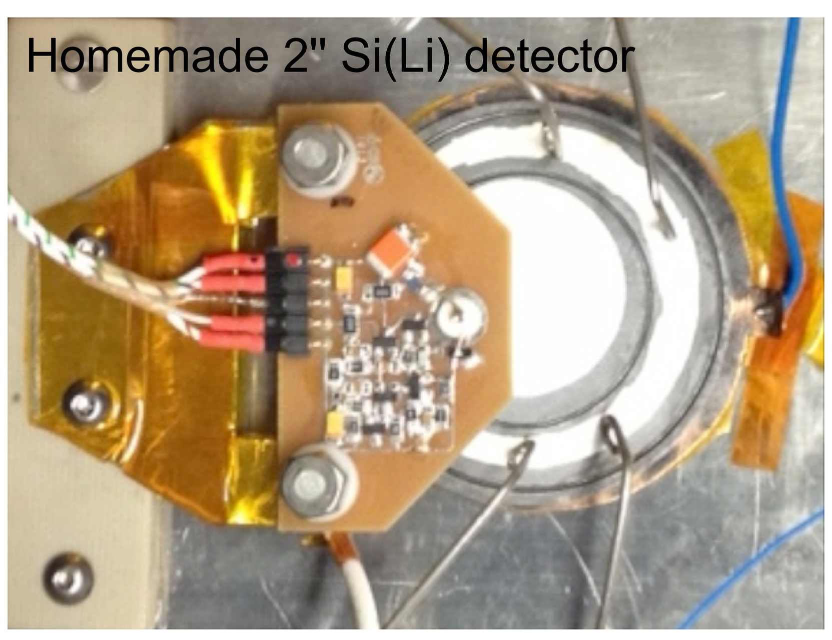
- use antideuterons to search for DM from supersymmetric (SUSY) and extra dimension theories, with particular relevance to light DM, where positive detection is claimed and direct searches are in conflict, and to heavy DM, where direct searches are ineffective,
- search for decaying gravitino DM, which is inaccessible to direct searches but detectable by antideuterons over a broad mass range, and
- use precision ultra-low energy antiproton spectroscopy to provide stringent constraints on models of ~30GeV DM, provide the best limits on primordial black hole evaporation on Galactic length scales and explore new discovery space in cosmic-ray physics.

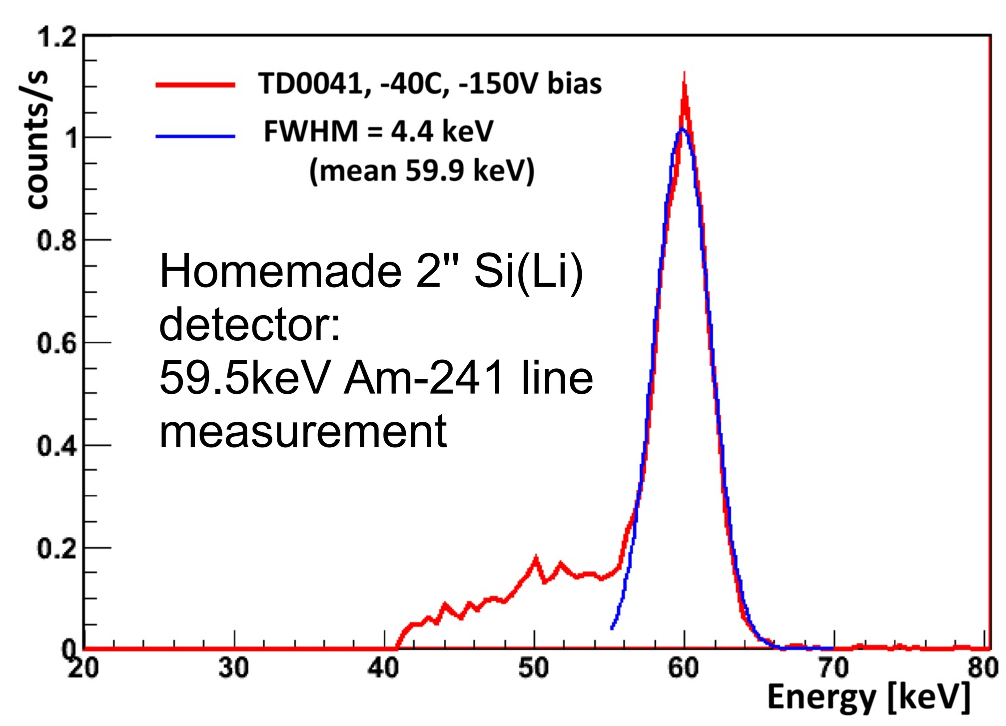
GAPS technology



GAPS prototype

- GAPS prototype flight in 2012 met 100% of its goals and demonstrated all key technologies
- Si(Li) detector fabrication well understood
- homemade Si(Li) detectors show good resolution





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