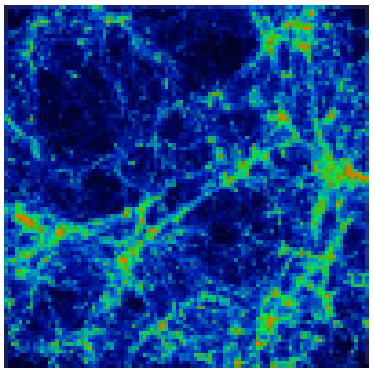
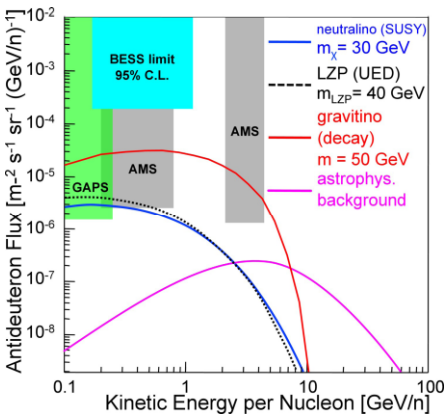
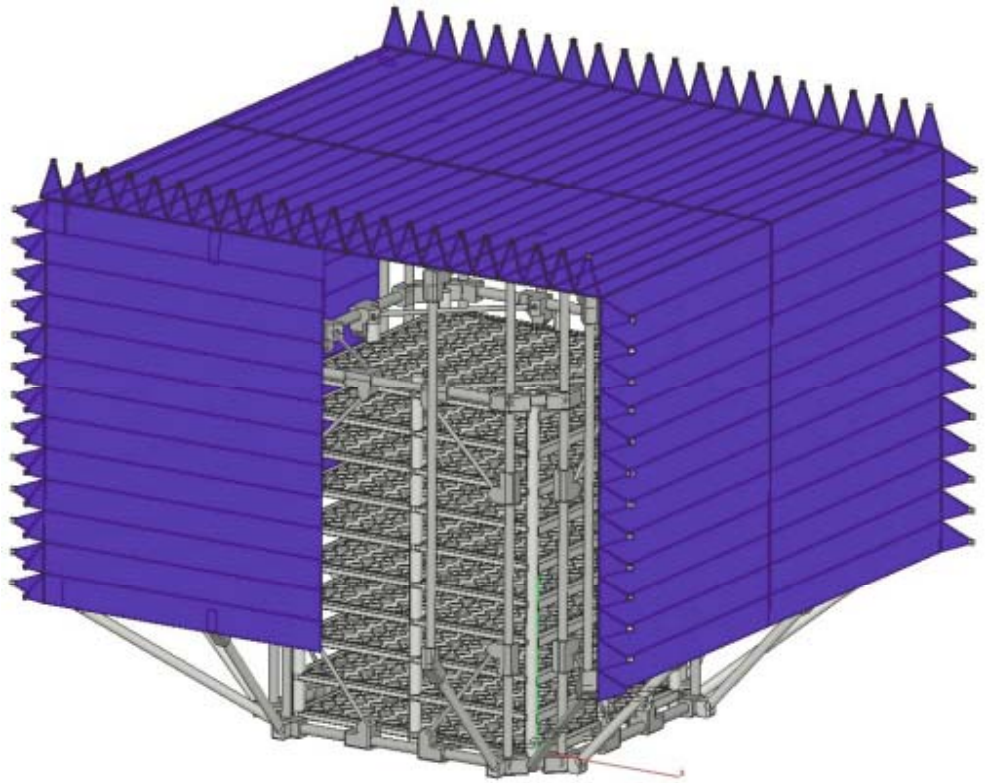
ICRC2017
35th International Cosmic Ray Conference

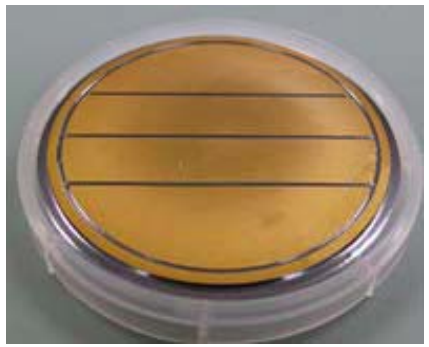
GAPS – Dark matter search using low-energy antimatter

Rene A. Ong, for the GAPS Collaboration
University of California, Los Angeles, CA 90095, USA



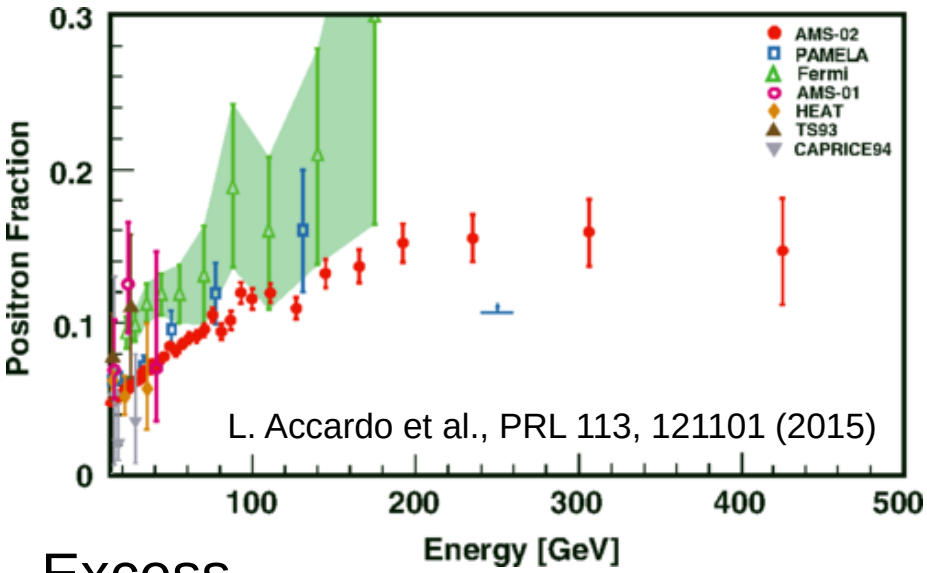






Cosmic Ray Anomalies

There are a variety of puzzles in cosmic rays:



Excess Positrons

Cosmic Ray Anomalies

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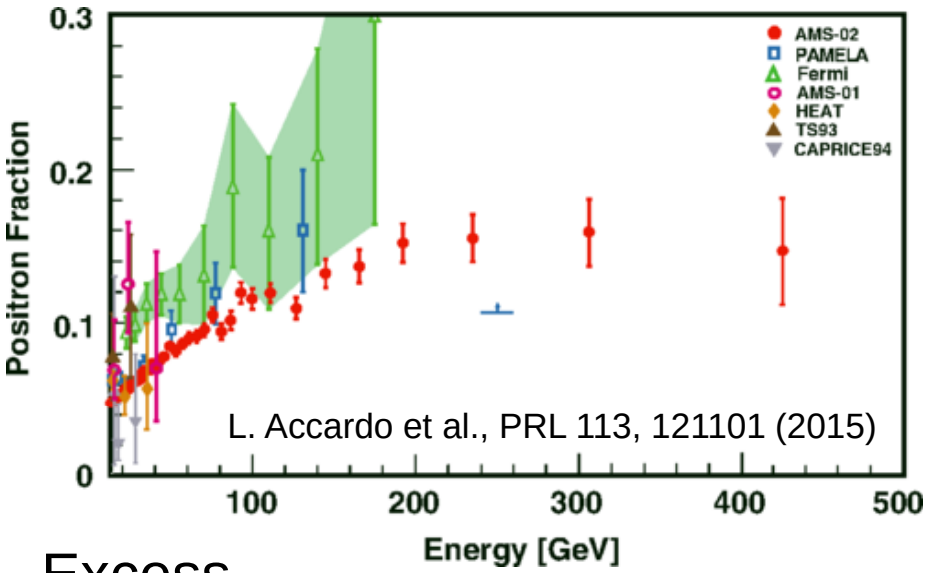
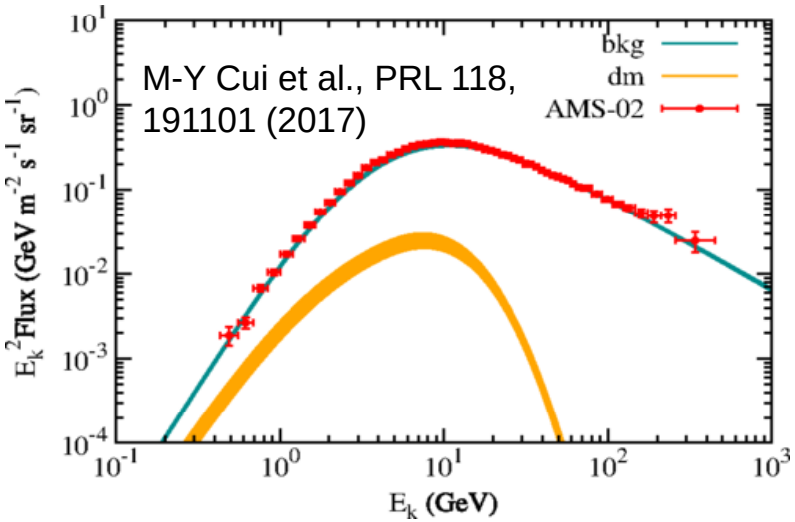


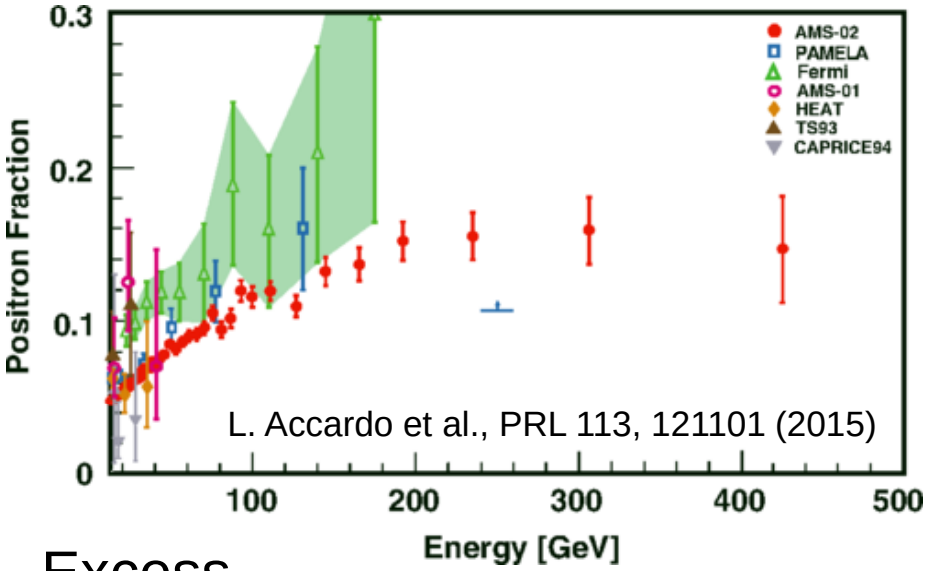
Excess Positrons



Antiproton Spectrum

Cosmic Ray Anomalies

There are a variety of puzzles in cosmic rays:



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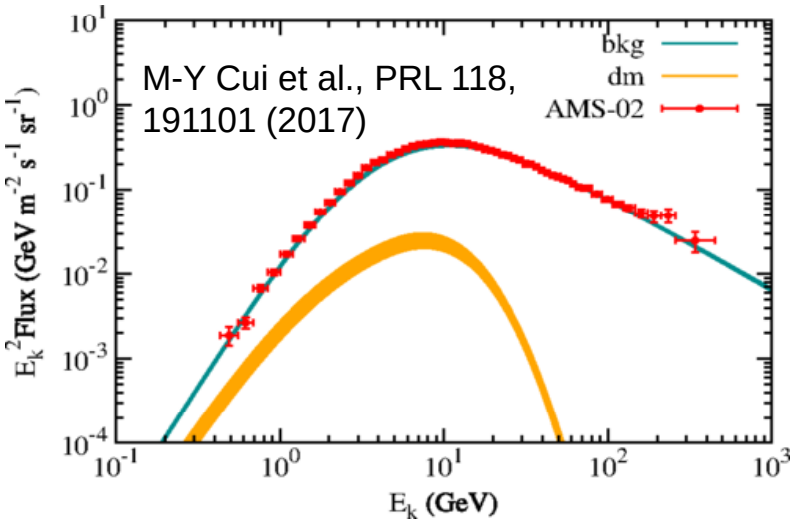
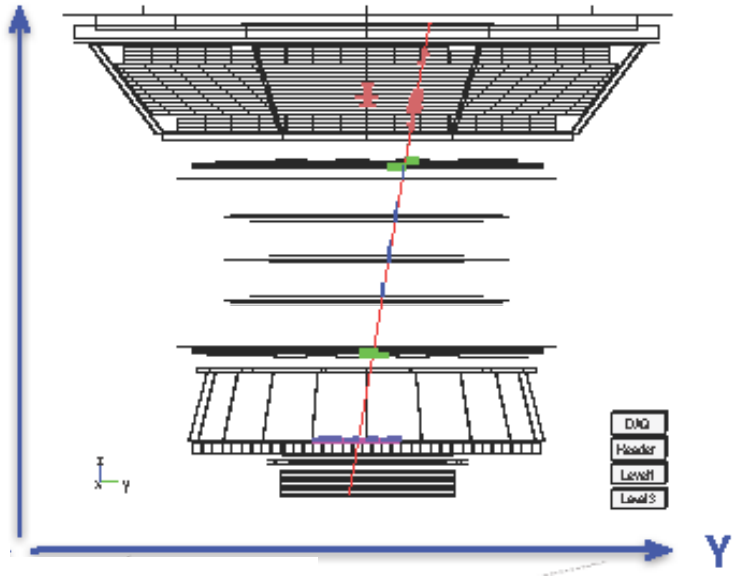


Antiproton Spectrum

AMS Anti-He Candidate Events

S.C.C. Ting, CERN Colloquium, https://indico.cern.ch/event/592392/



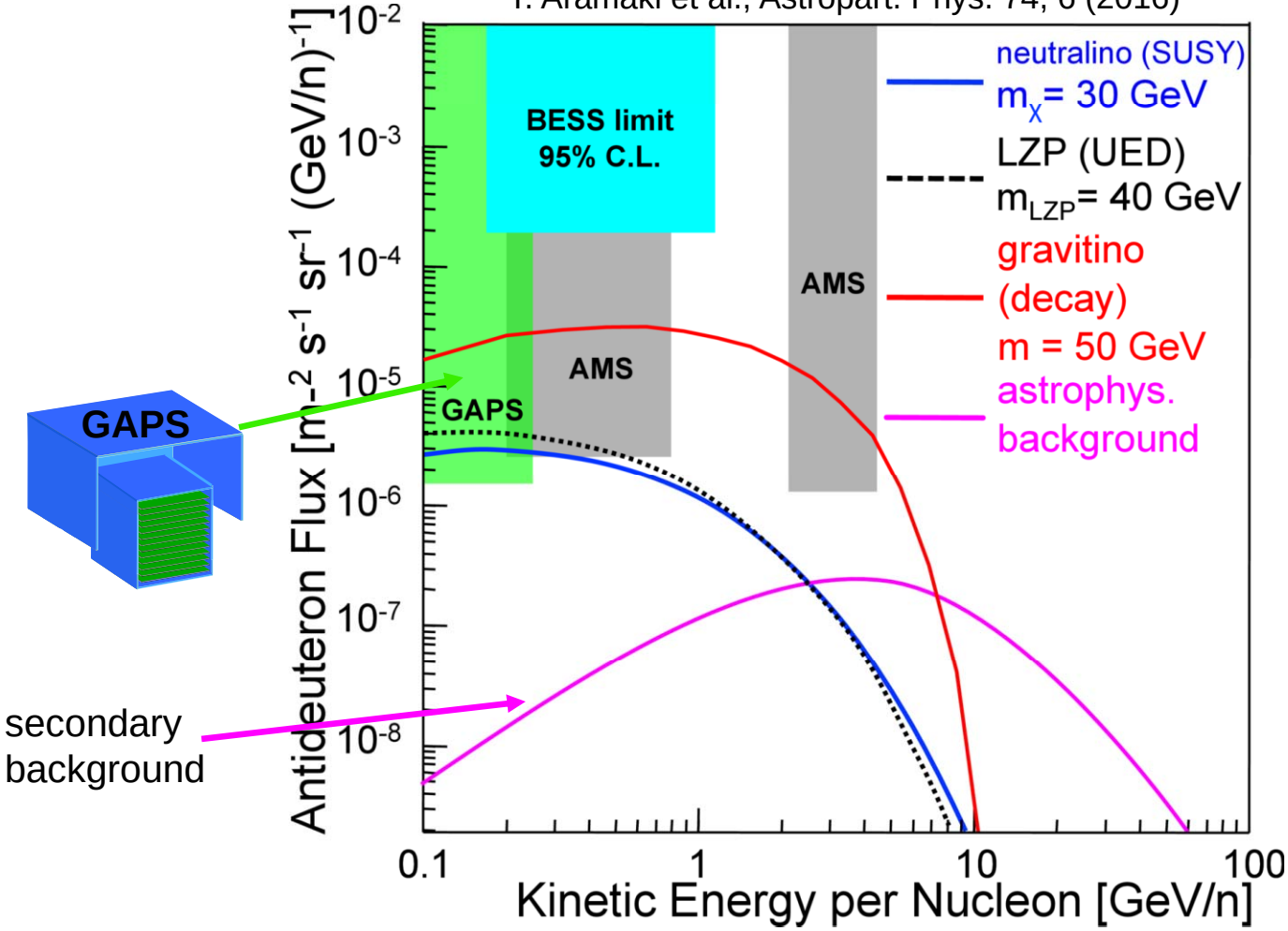
+ γ-rays from Galactic Center …

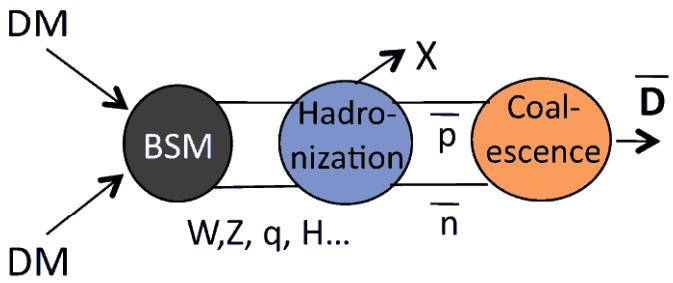
Are these signs for DM annihilation ??

Antideuteron Searches

Anti-D's can be produced by BSM dark matter, and unlike e^-, e^+, $\bar{p}$, they are essentially background free:

T. Aramaki et al., Astropart. Phys. 74, 6 (2016)



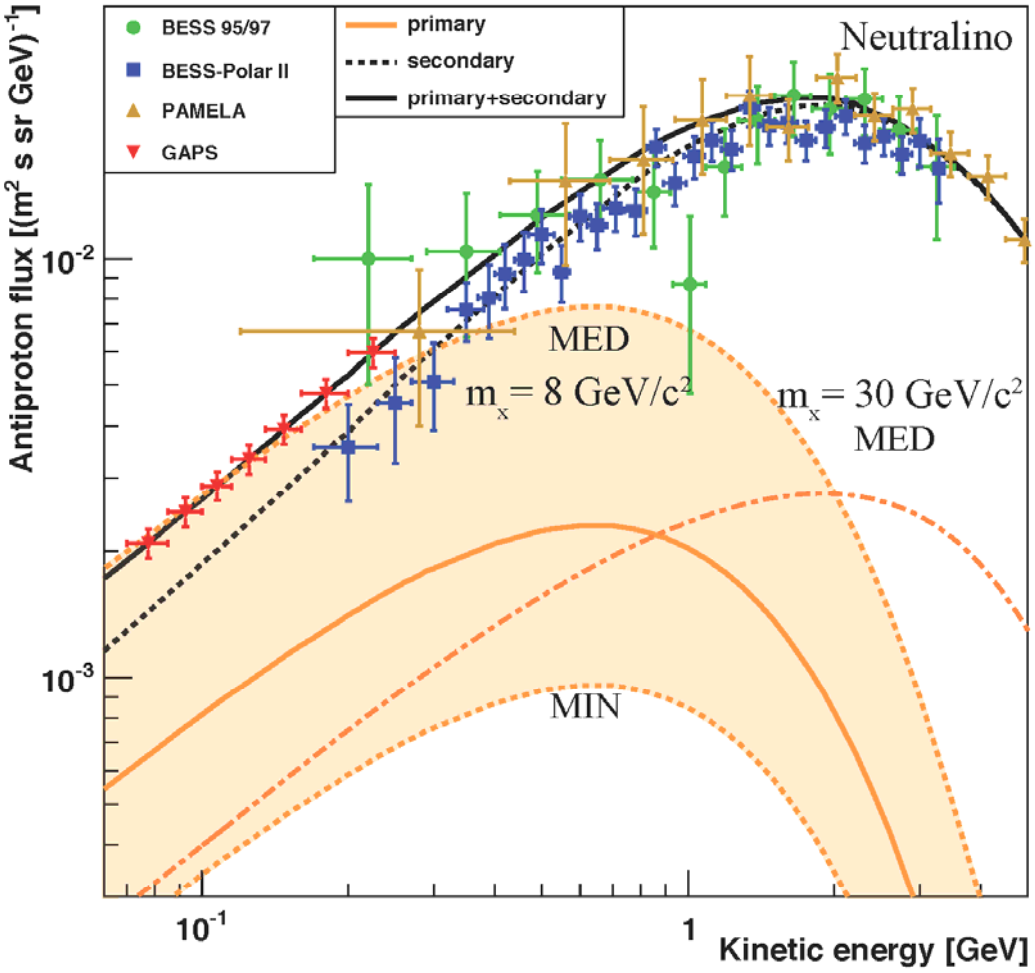


Anti-D's are the most important unexplored indirect detection technique !

Low-Energy Antiprotons

GAPS will make precision flux measurement of low-energy antiprotons – strong constraints on DM, PBH models:

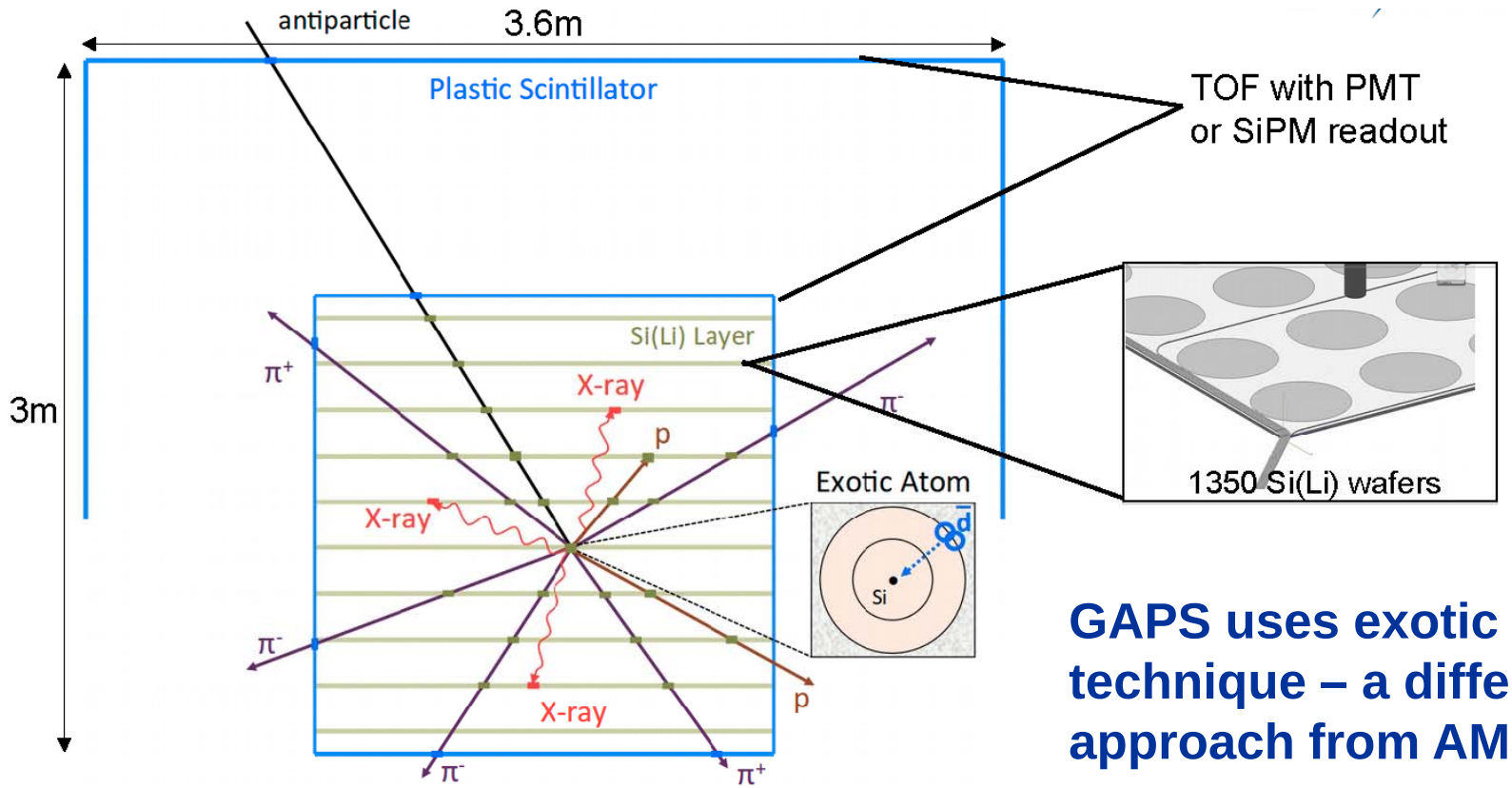
T. Aramaki et al., Astropart. Phys. 59, 12 (2014)



- Complementary to direct/indirect searches and collider expts.
- x10 more statistics @ 0.25 GeV than BESS/PAMELA/AMS
- Search for light DM, gravitino DM, LZP in extra dimension theories, and PBHs

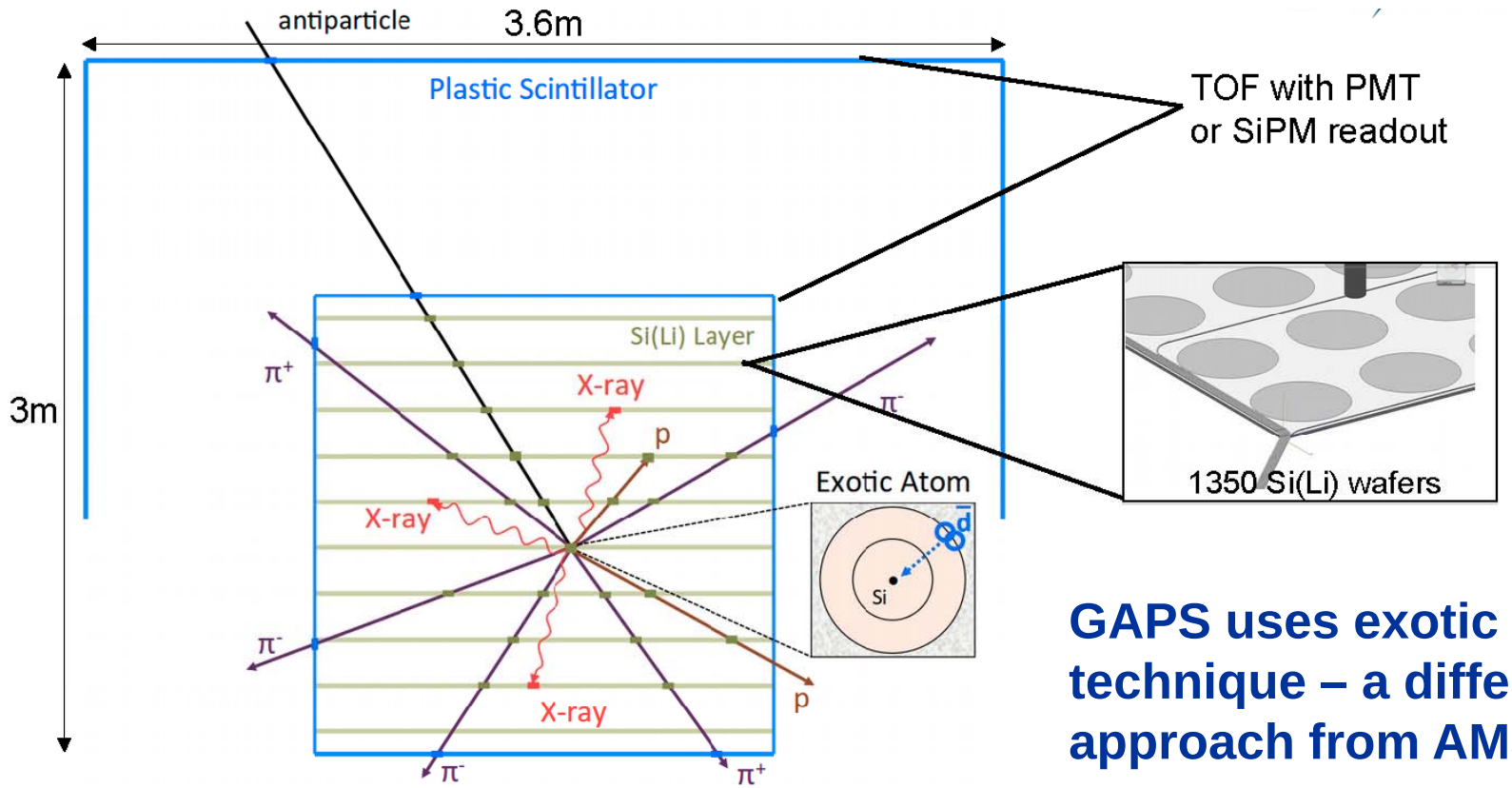
GAPS also has capability for detection of anti-He, using the exotic atom technique
→ studies ongoing to estimate the sensitivity

The GAPS Experiment



GAPS uses exotic atom technique – a different approach from AMS, BESS…

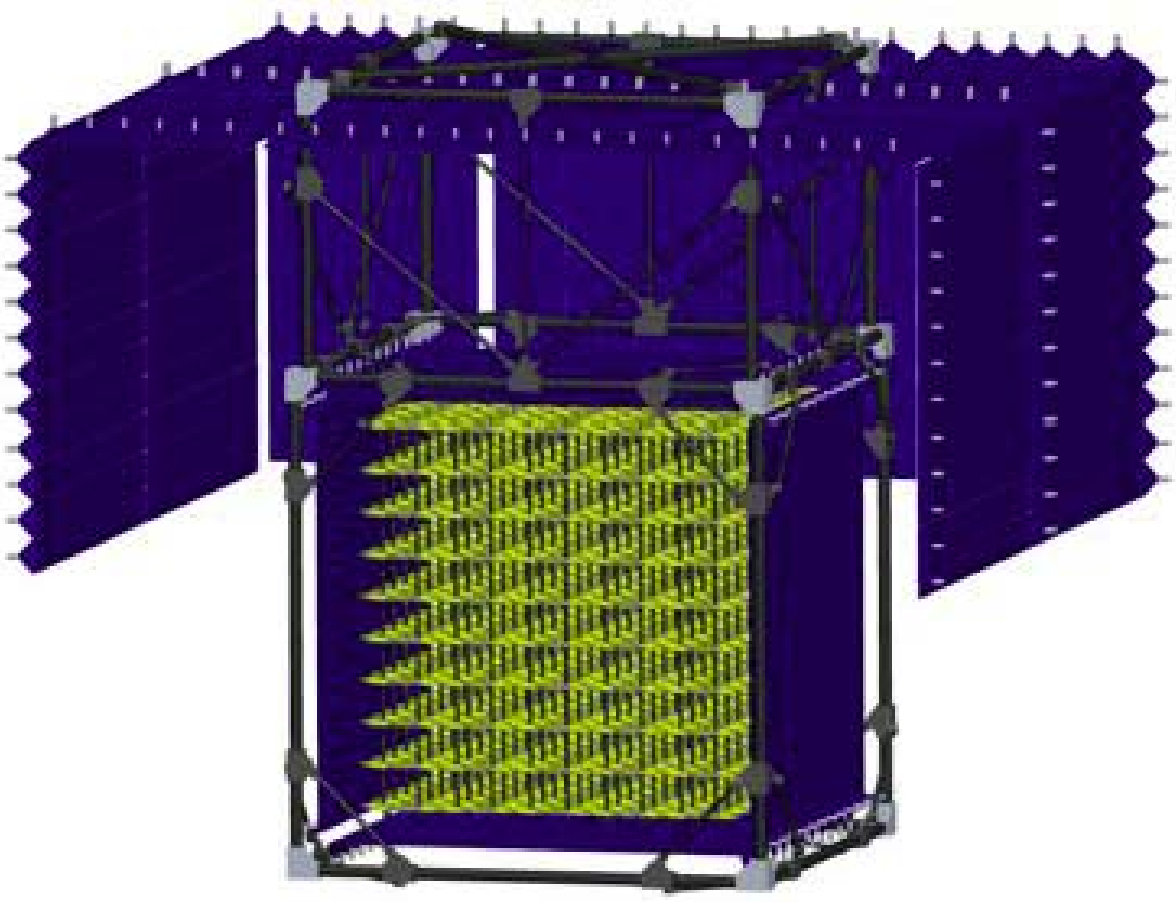
The GAPS Experiment



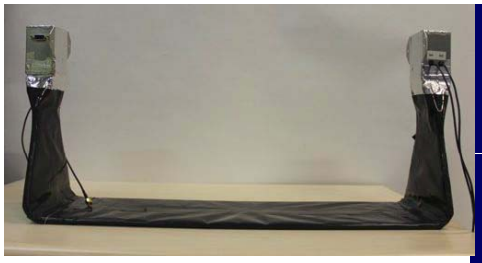
GAPS uses exotic atom technique – a different approach from AMS, BESS…

- General AntiParticle Spectrometer (GAPS): specifically designed for low-energy antideuterons and antiprotons
- Long-duration balloon (LDB) flight in Antarctic – *low geomagnetic cutoff*
- Now approved by NASA for funding and launch in late 2020
- Strong international participation with Japan (JAXA) and Italy (INFN)

GAPS Instrument Design

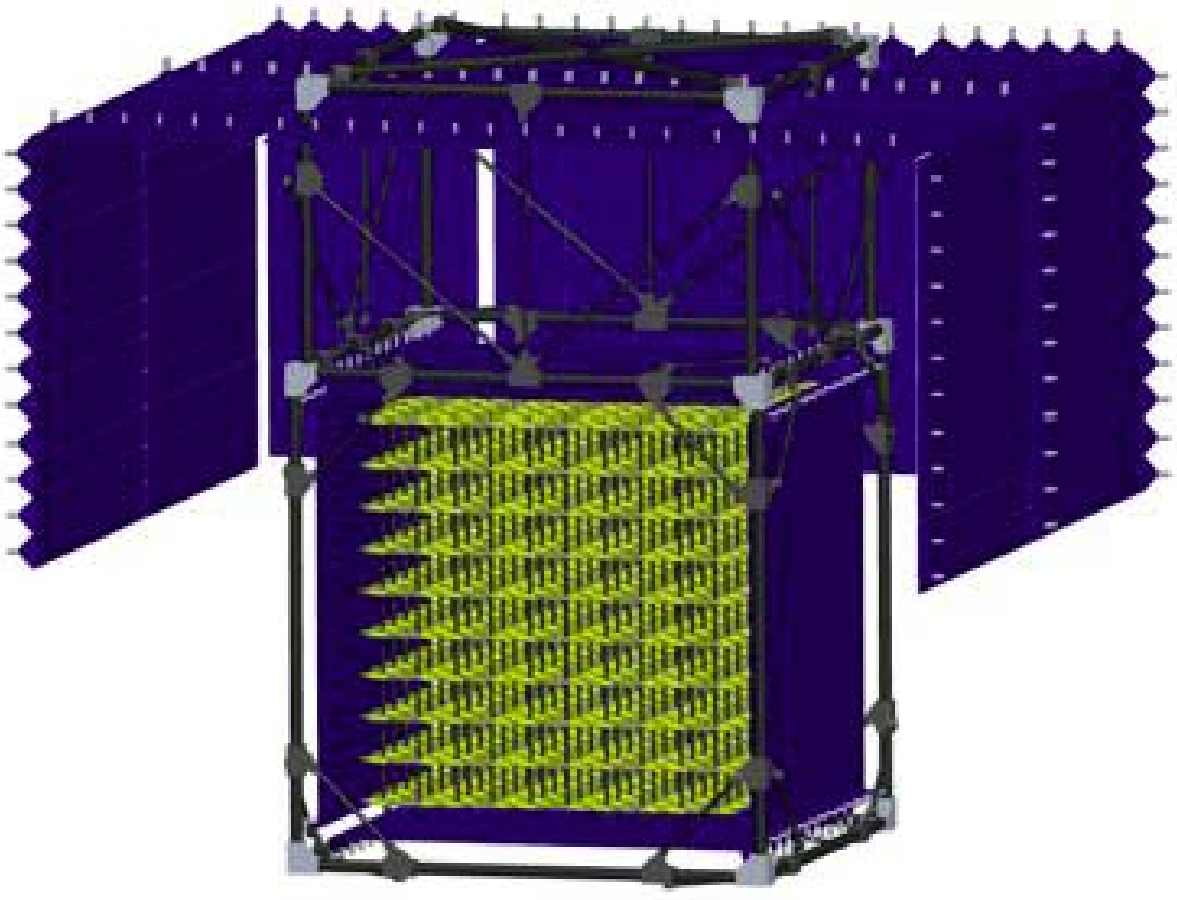


GAPS Instrument Design



Time of Flight (TOF)

- Plastic scintillator 1.8m x 0.18m x 0.5cm
- Read out on both ends using PMTs/Si-PMs
- 500ps timing resolution



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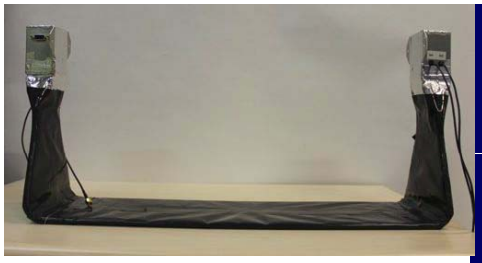

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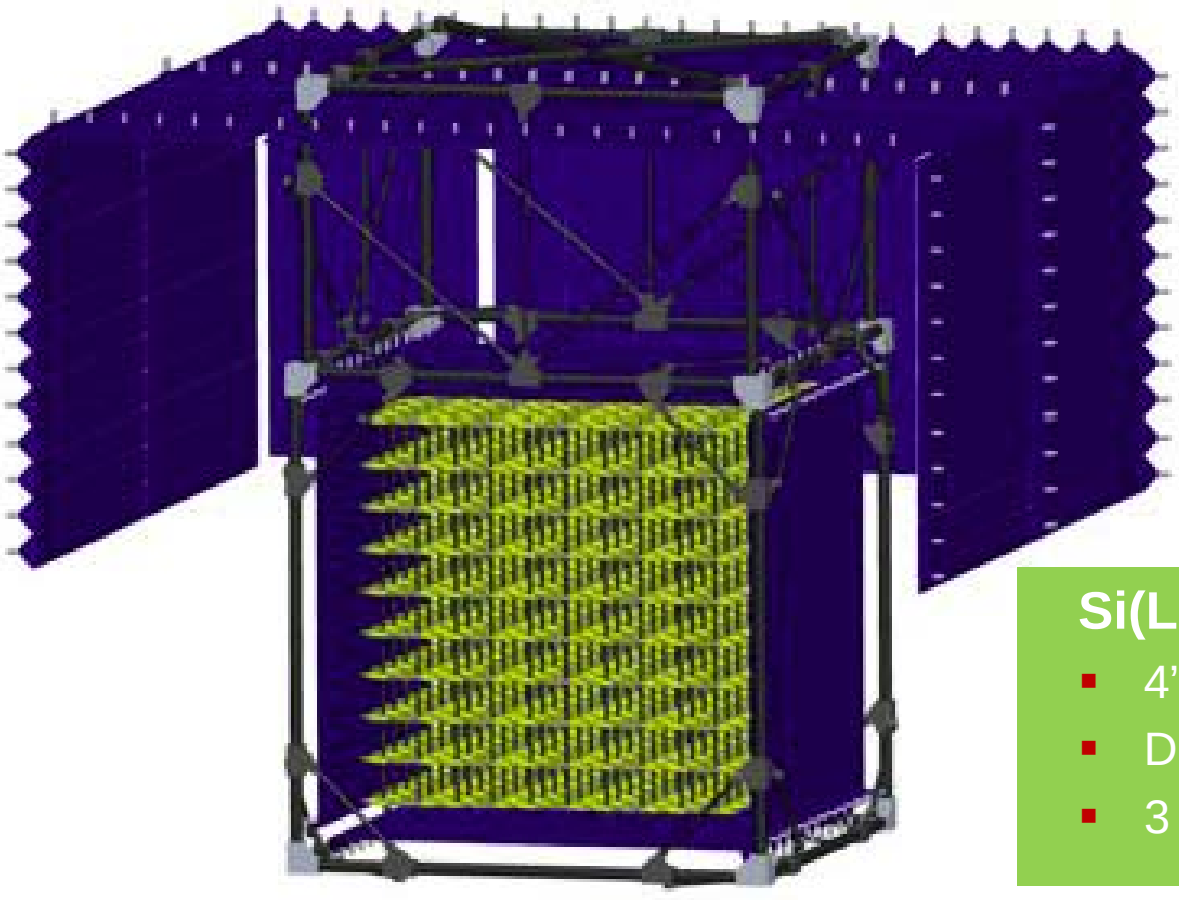
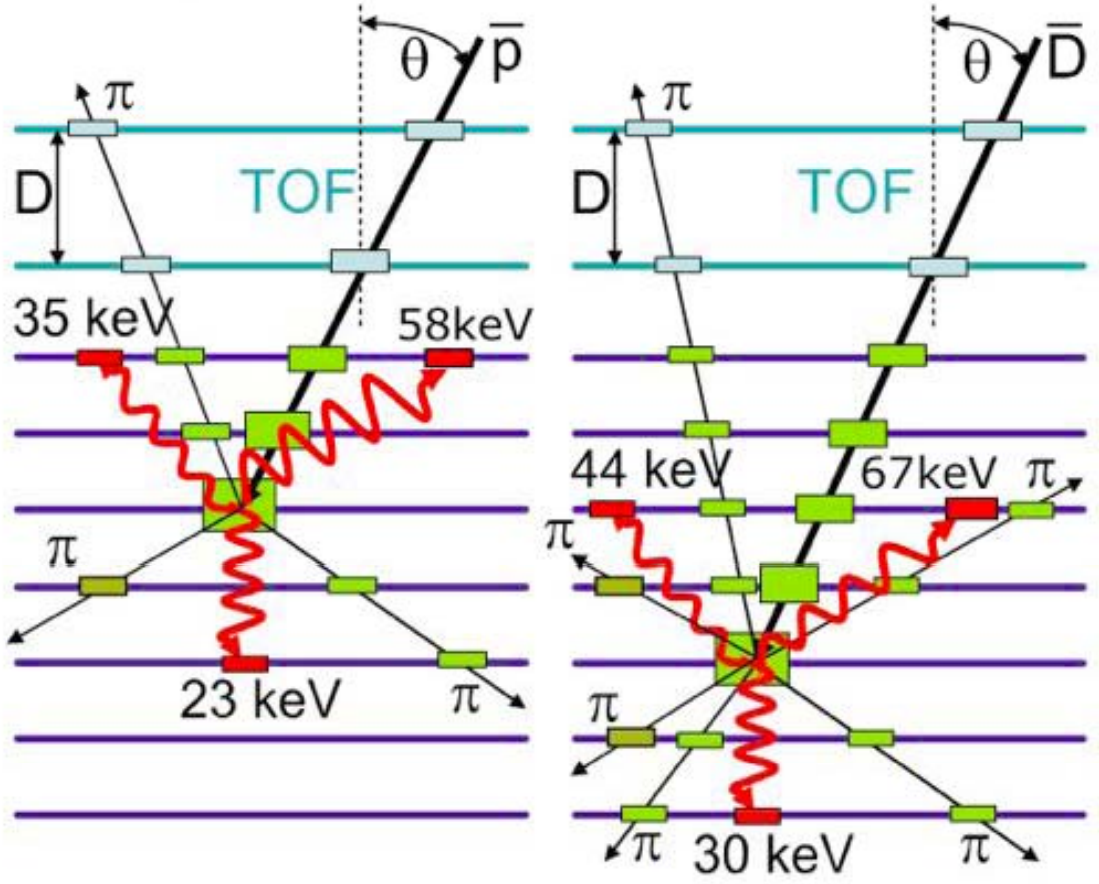


Si(Li) Target/Tracker

- 4” Si(Li) disks, 2.5mm thick
- Dual energy range (X-rays, min-I)
- 3 keV energy resolution

GAPS Background Rejection

Rare event search required good particle ID and excellent background rejection:



- Combination of: TOF velocity (β), dE/dx, and depth, combined with unique X-ray emission and π/p from nuclear annihilation → strong rejection power

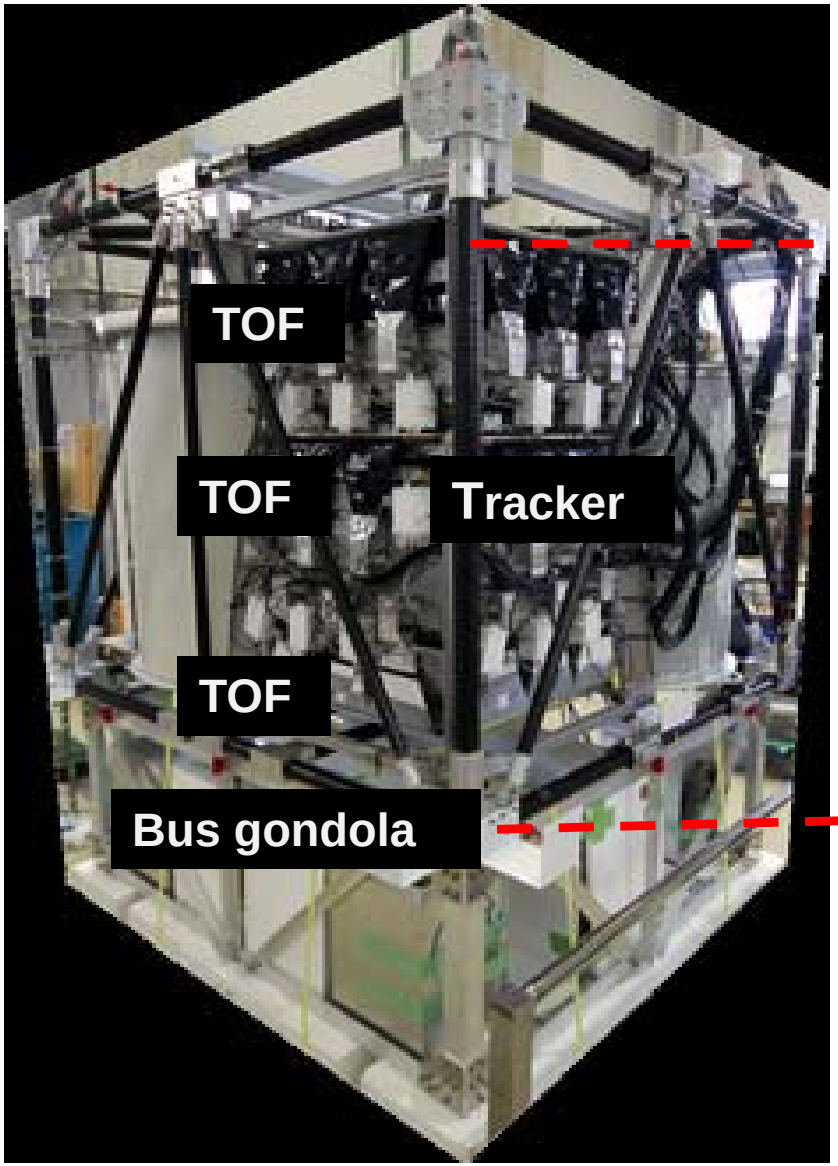
The GAPS Team

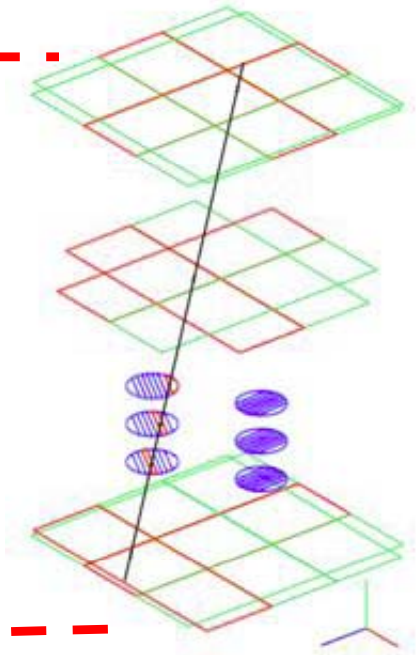
GAPS Team @UCLA March 2017

T. Aramaki[1], R. Bird[2], M. Boezio[3], S.E. Boggs[4], R. Carr[5], W.W. Craig[5], P. von Doetinchem[7], L. Fabris[8], F. Gahbauer[9], C. Gerrity[7], H. Fuke[10], C.J. Hailey[9], C. Kato[11], A. Kawachi[12], M. Kozai[12], S.I. Mognet[13], K. Munakata[11], S. Okazaki[10], R.A. Ong[2], G. Osteria[14], K. Perez[5], V. Re[15], F. Rogers[5], N. Saffold[9], Y. Shimizu[16], A. Yoshida[17], T. Yoshida[10], G. Zampa[3], and J. Zweerink[2]

[1]SLAC National Accelerator Laboratory
[2]University of California, Los Angeles
[3]INFN, Sezione di Trieste
[4]University of California, San Diego
[5]Massachusetts Institute of Technology
[6]Lawrence Livermore National Laboratory
[7]University of Hawaii at Manoa
[8]Oak Ridge National Laboratory
[9]Columbia University
[10]Japan Aerospace Exploration Agency
[11]Shinshu University
[12]Tokai University
[13]Pennsylvania State University
[14]INFN, Sezione di Napoli
[15]Università di Bergamo
[16]Kanagawa University
[17]Aoyama Gakuin University

pGAPS – Successful prototype flight





Event in pGAPS

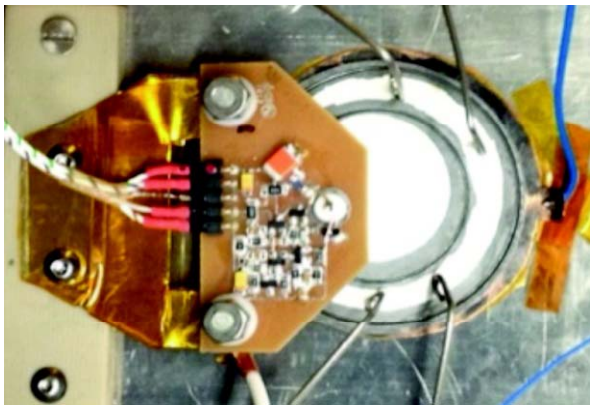
June 2012 launch, Taiki, Japan

- Demonstrated stable operation of Si(Li) and TOF detectors during flight
- Studied Si(Li) cooling approach
- Measured background levels

S.A.I. Mognet et al., NIM A735, 24 (2014)
P. von Doetinchem et al., Astropart. Phys. 54, 93 (2014)

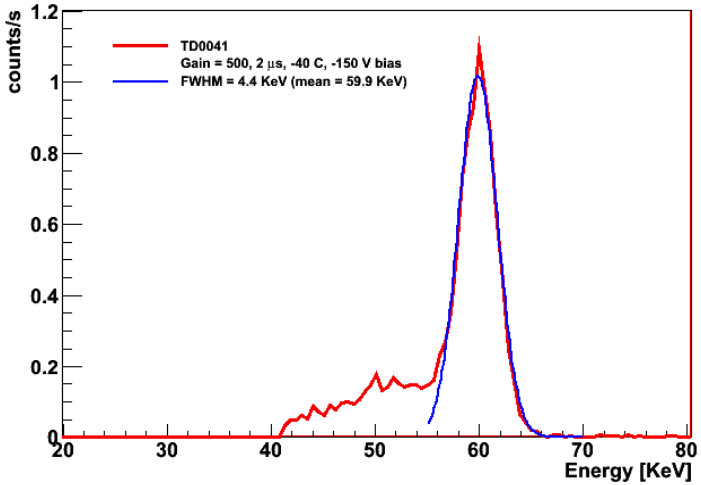
Current Work: Si(Li) Detectors

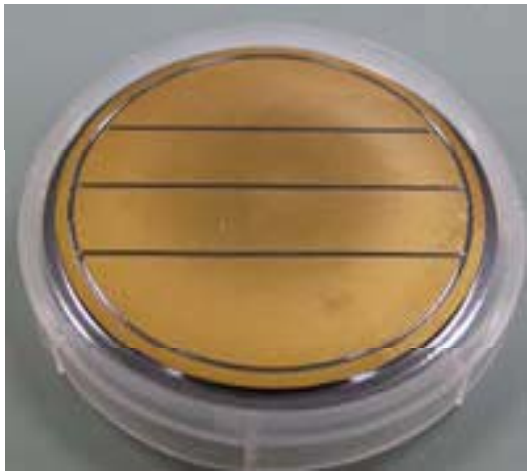
- GAPS will use 1350 4-inch, 4-strip Si(Li) detectors, 2.5mm thick
- Fabrication scheme developed at Columbia University; plan to have detectors produced by commercial company – Shimadzu in Japan.
- Confirmed leakage current and performance with cosmic rays and X-ray source



Prototype single-strip 2-inch detector with guard ring and pre-amplifier

Am-241 source
FWHM: 4.4 keV @ 59 keV



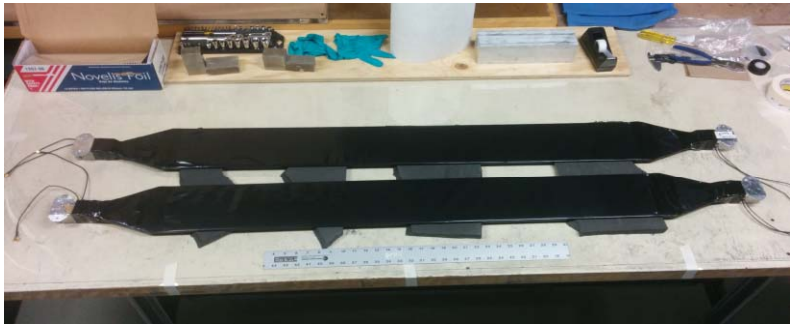


Prototype 4-inch,4-strip detector
(courtesy Shimadzu Corp)

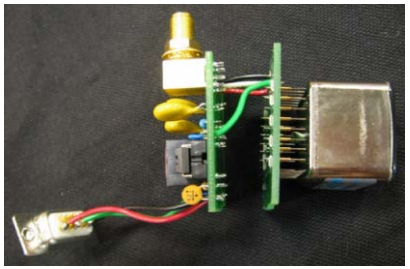
Currently optimizing fabrication; ramp up to trial production runs in early 2018

Current Work: TOF Detector

- The TOF will consist of 225 scintillation counters, read out on both ends
- PMTs (used in pGAPS) and Si-PMs being considered
- Custom board for readout using DRS-4 ASIC @ 2 GS/s
- TOF will measure particle β, dE/dx, provide rough tracking and master trigger

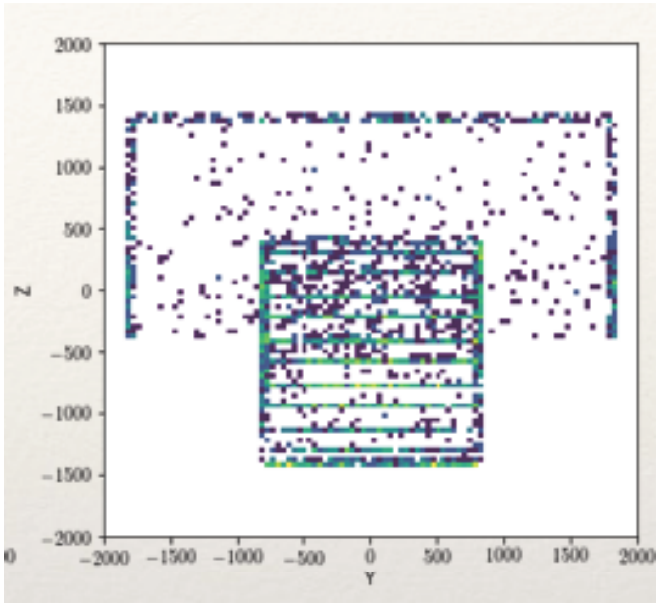


Prototype 1.2m paddles



R7600-UBA PMT and base

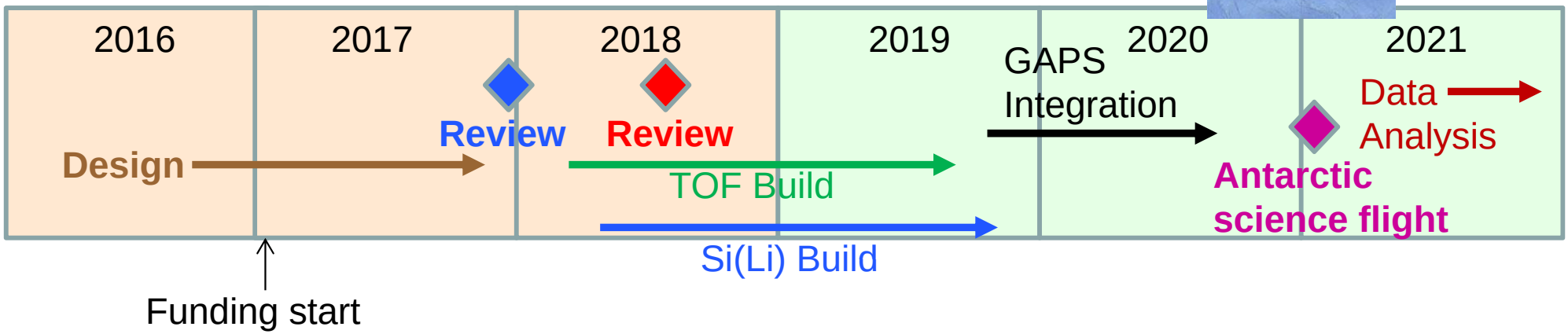
Si-PM testing



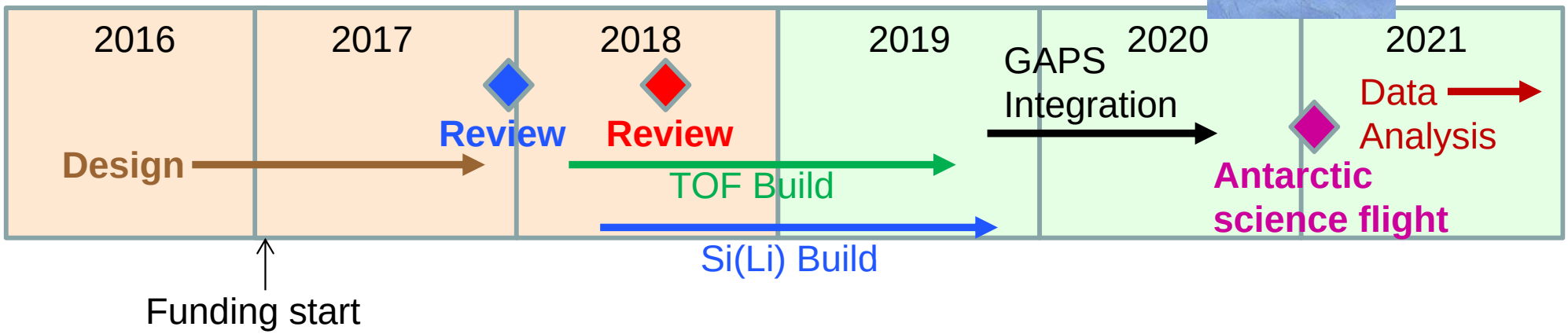
Stopping depth simulations
(100 MeV antideuterons)

Major tasks: PMT/Si-PM decision, determining trigger algorithm

Timeline & Summary



Timeline & Summary



- Discovery of antideuterons in cosmic rays would a very significant result.
- GAPS is specifically designed for low-energy anti-D's and antiprotons
- Technique is different and complementary to AMS; if AMS sees some events, GAPS can confirm and go deeper.
- Prototype GAPS flight – completely successful, verified detector operation
- Rapid timeline from funding start to GAPS construction, integration and first science flight in late 2020

Note: Two advertised postdoctoral positions, see:
https://inspirehep.net/record/1505690 https://inspirehep.net/record/1495582

Backup

Si(Li) Electronics