MeV Gamma-Ray
Mini-Workshop

6/20, 2022

GRAMS PROJECT OVERVIEW

Tsuguo Aramaki
Northeastern University

GRAMS = Gamma-Ray and AntiMatter Survey

A newly proposed project with an international collaboration

First balloon/satellite mission with a low-cost, large-scale LArTPC detector

First experiment to target both astrophysical observations with MeV gamma rays and dark matter searches with antimatter

GRAMS Collaboration

Multidisciplinary team with different backgrounds/expertise

Gamma-rays, X-rays, Cosmic-rays, Neutrinos,
Direct DM search, Indirect DM search

USA

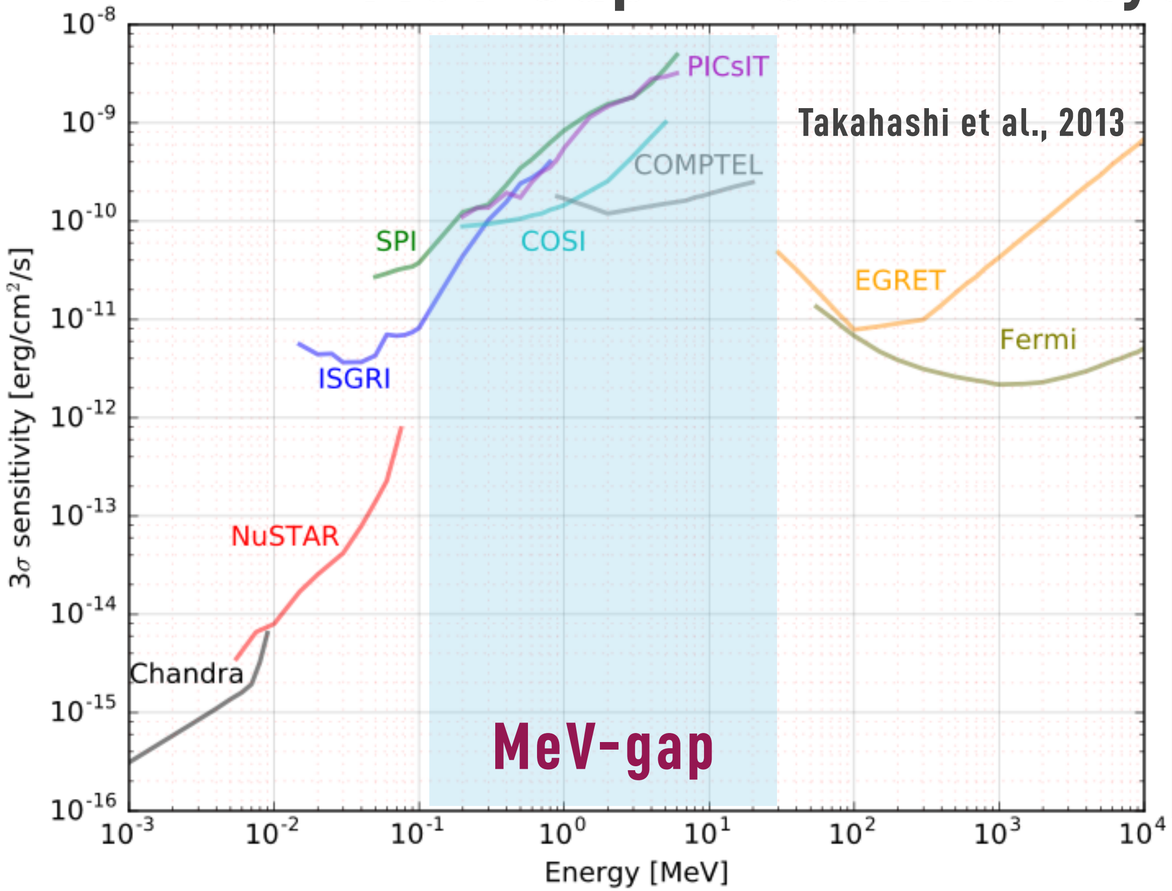
- Barnard College
- Columbia University
- MIT
- NASA GSFC
- Northeastern University
- Oak Ridge National Lab
- UT Arlington

International (Japan)

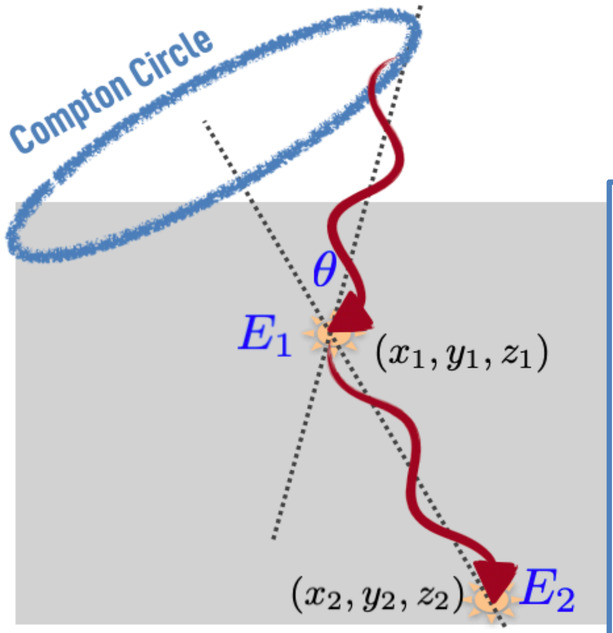
- Hiroshima University
- Kanagawa University
- Osaka University
- RIKEN
- Rikkyo University
- University of Tokyo/NDA
- Waseda University

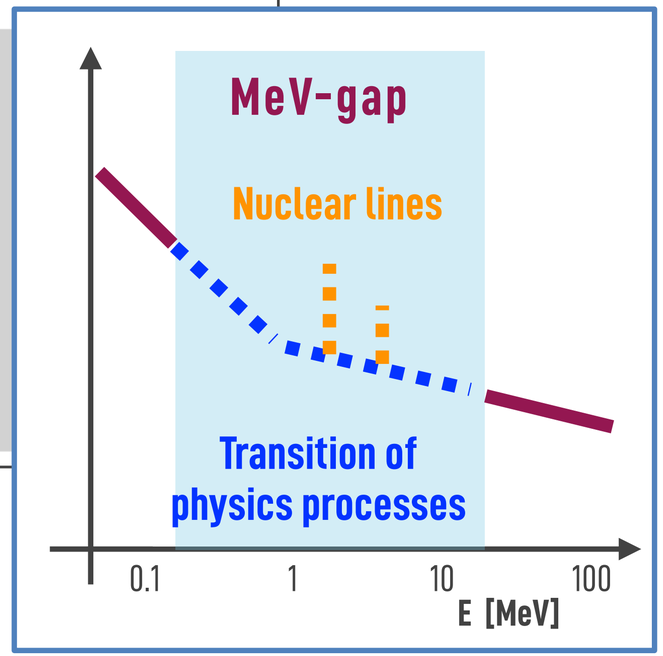
MeV Gamma-Ray Observations

"MeV Gap" = Gamma-rays in MeV region poorly explored



Compton scattering process dominates in MeV range
Good energy & spatial resolution required





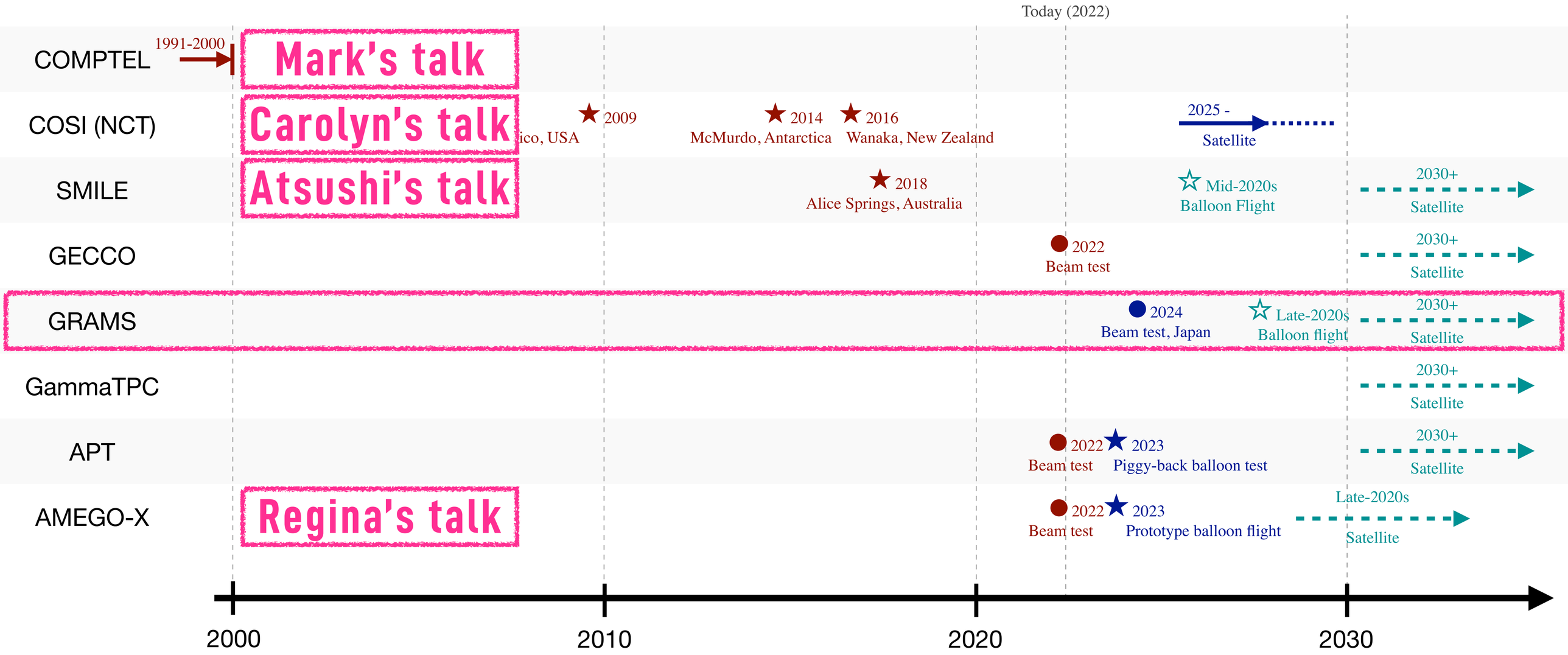
MeV gamma-ray spectrum/lines

- Physics processes/nucleosynthesis
- Multi-messenger astronomy
- Indirect dark matter searches/PBH searches

Naomi's talk

MeV Gamma-ray missions

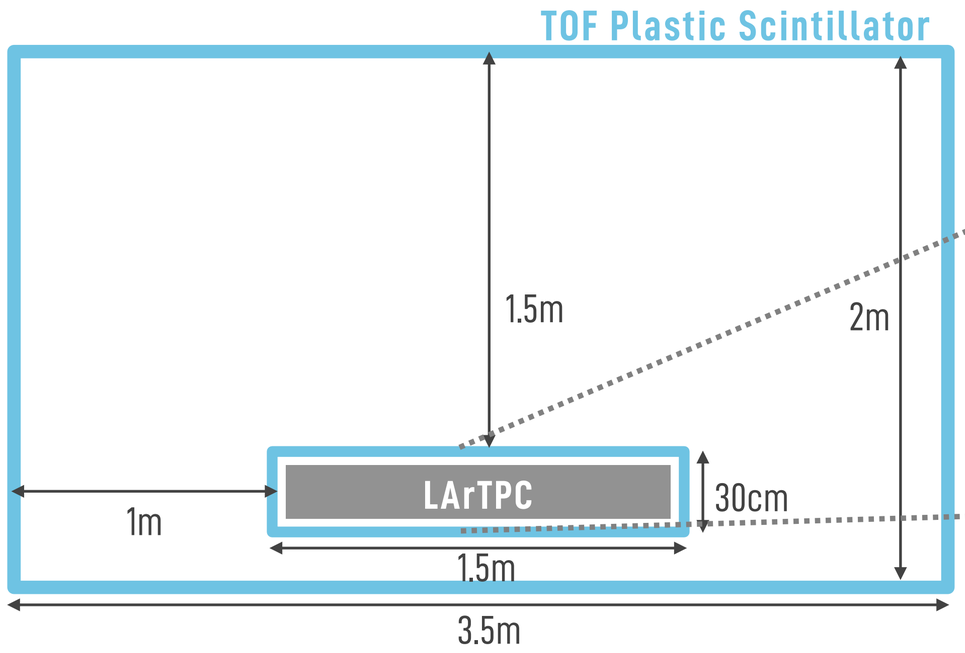
Past, near-term, and long-term future plans (Snowmass2022 WP5)

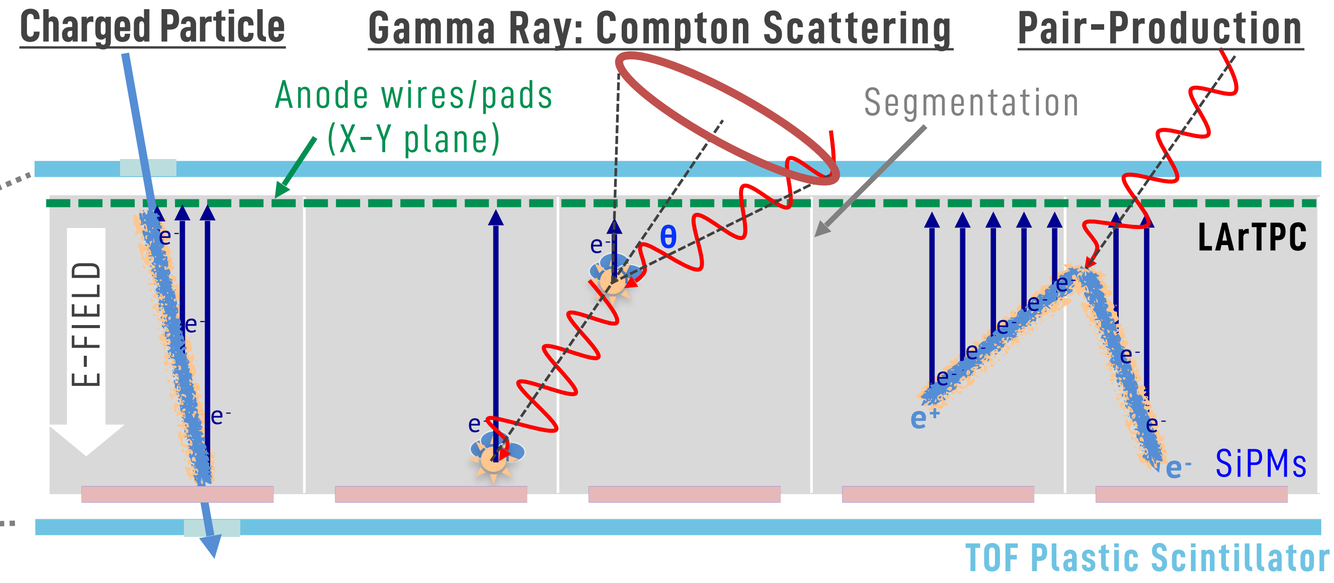


GRAMS Detector Design

LArTPC detector surrounded by plastic scintillators
LArTPC measures scintillation light and ionization electron

	Antimatter	Gamma Rays
Plastic Scintillators	Time of Flight to measure velocity	VETO Counters to reject charged particles
LArTPC	Particle Tracker, Calorimeter	Compton Camera, Calorimeter

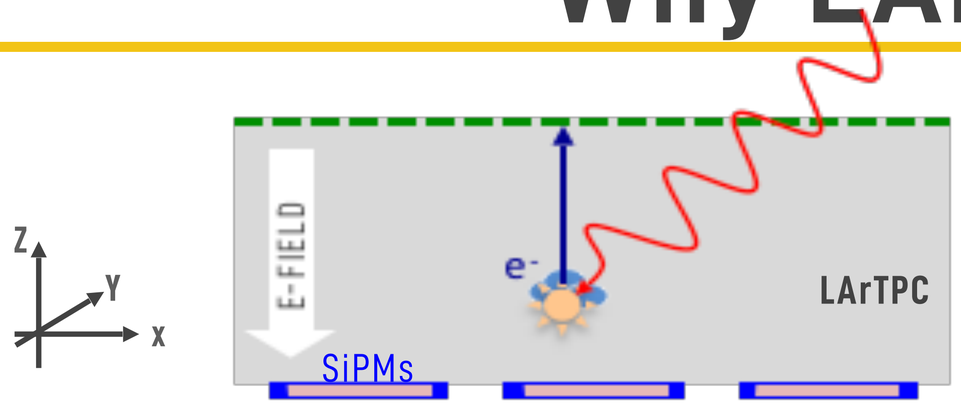




LArTPC segmented into "cells" to minimize coincident background

Large-scale, low-energy threshold LArTPC has been well-studied/ widely-used in dark matter/neutrino underground experiments

Why LArTPC?

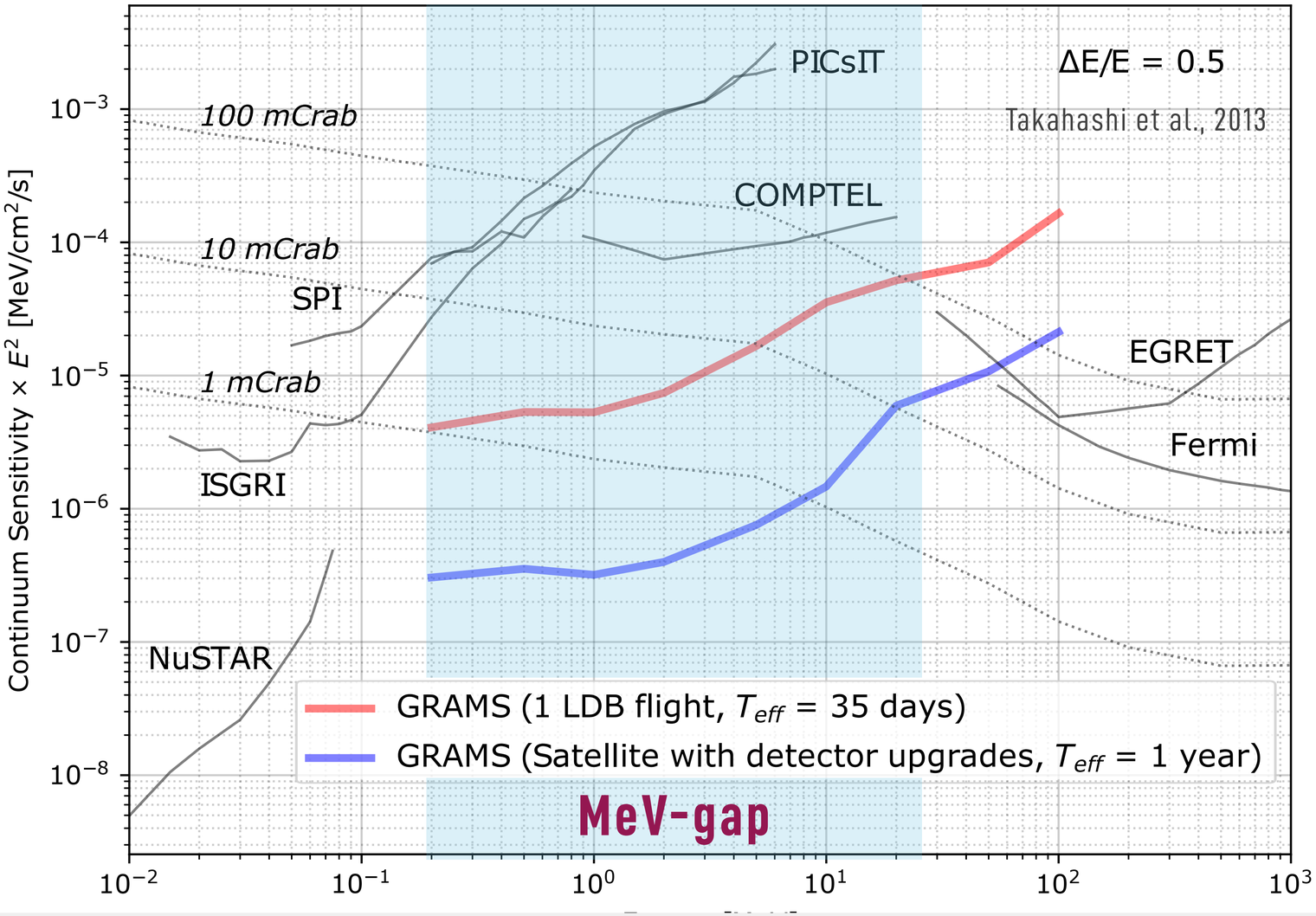


	LArTPC	Semiconductor/Scintillator
ρ (g/cm^3)	1.4	2.3/5.3 (Ge/Si)
$T_{operation}$	~80K	~240K/~80K
Cost	**$**	$$$
Signals	scintillation light + ionization electrons	electrons, holes
X, Y Positions	wires on anode plane (X-Y)	double-sided strips
Z Position	from drift time	from layer #
# of Layers	**1 layer**	multi-layers
# of Electronics	**#**	###
Dead Volume	**almost no dead volume**	detector frame, preamps
Neutron bkg	**identified with pulse shape**	no rejection capability

Gerogia's talk

LArTPC is cost-effective and almost no dead volume, easily expandable to a larger scale with high detection efficiency

MeV Gamma-ray Observations

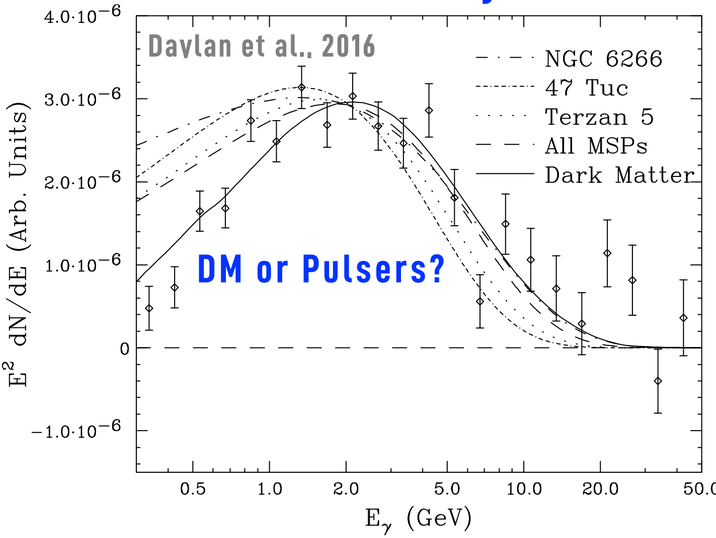


Balloon flight: an order of magnitude improved

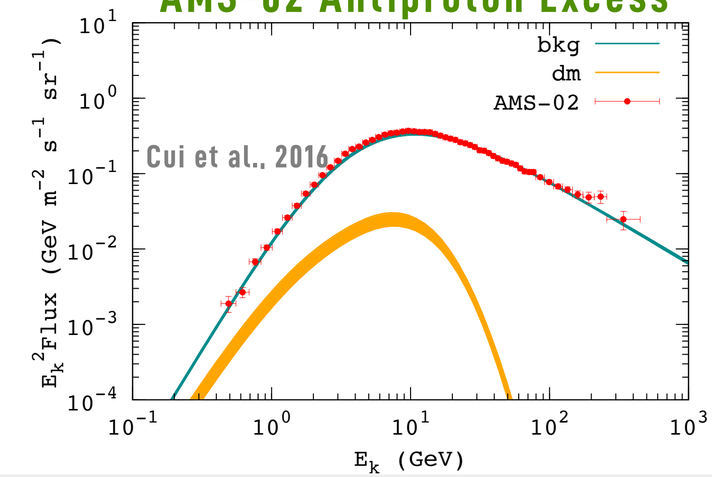
Satellite mission: comparable to future missions

Indirect DM Searches with Antinuclei

Fermi Gamma-ray Excess



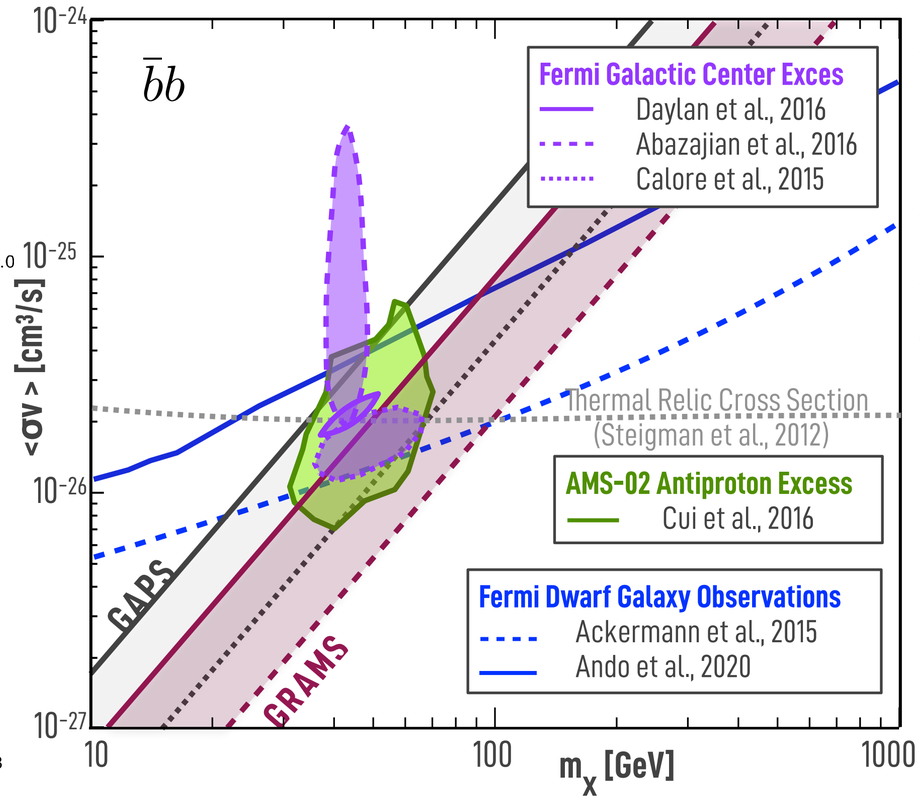
AMS-02 Antiproton Excess

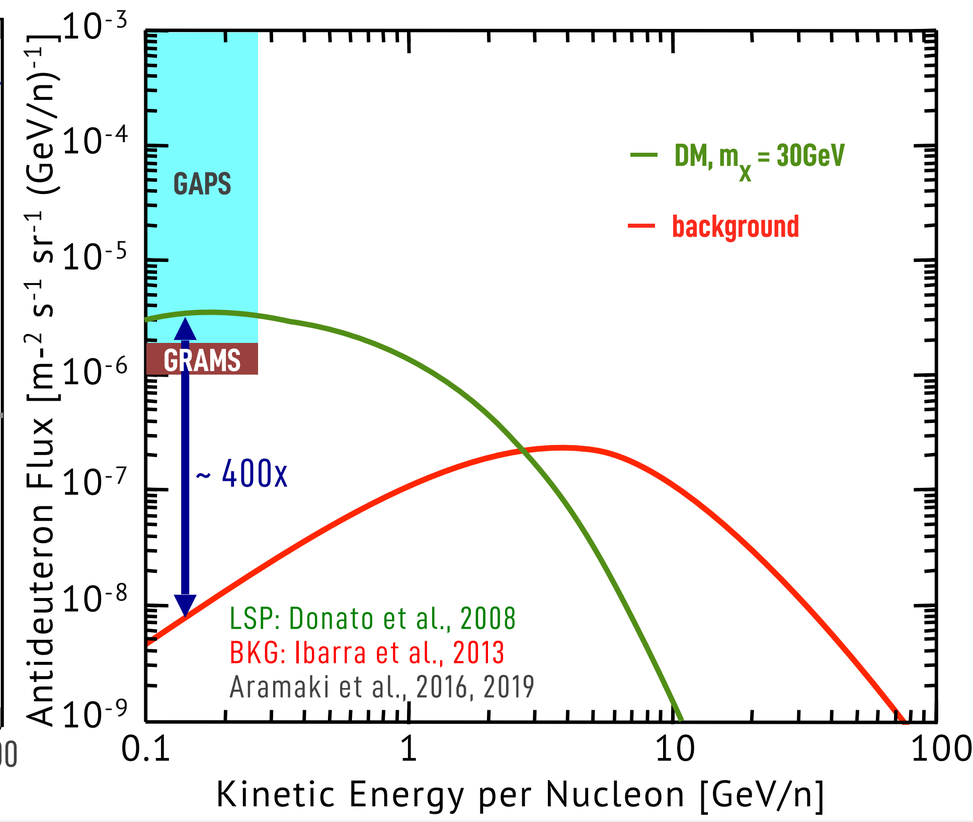


Possible DM signature in FERMI GCE, AMS-02 antiproton excess

AMS-02 detected antihelium-like events

How do we validate these results?

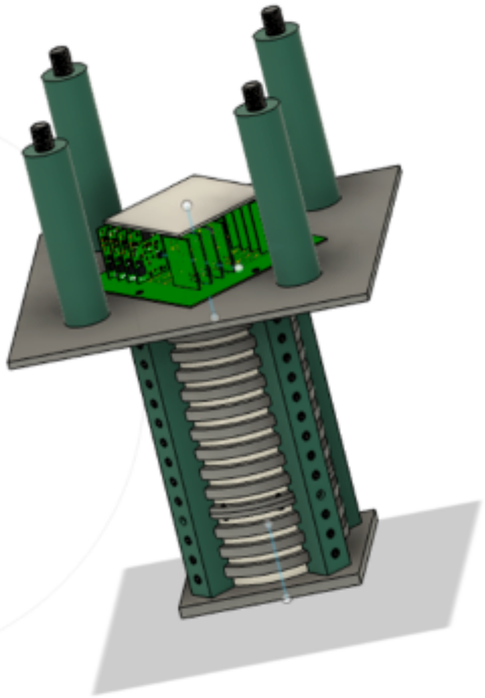




Background-free DM search with low-energy antideuterons

GRAMS can extensively explore DM parameter space

Curren Status



MiniGRAMS construction: Northeastern

- TPC: 10 x 10 x 20 cm^3 (**UTA** test-stand design)
  -> 30 x 30 x 20 cm^3 with segmentation
- PCB tile instead of wires (nEXO prototype)
  - nEXO preamp for charge signal (**ORNL**)

Readout system: Columbia

- MicroBooNE ADC/digitizer

MPPC development: NASA GSFC

- VIS/VUV SiPMs, reflector material, etc.

U Tokyo

- Currently building MiniGRAMS with **ASICs** developed for ASTRO-H SGD
- Developed **event reconstruction algorithms** (neural network, probabilistic methods)

Waseda

- LArTPC development for the **ANKOK direct DM search experiments**
- Optimization of **TPB evaporation** for high light-yield **-> Beam test at J-Park in 2024**

Summary

- GRAMS is a proposed next-generation mission to target both **gamma-ray observations** in the **poorly explored MeV energy band** and **indirect dark matter searches with antimatter**.
- The Project will begin with a **balloon experiment** as **a step forward to** a **satellite mission**.
- With a **cost-effective, large-scale LArTPC** detector, the sensitivity to **MeV gamma rays** can be more than **an order of magnitude improved** compared to previous experiments with a single balloon flight.
- We have developed the **event reconstruction algorithms** for multiple Compton scattering events, based on multi-task neural network/physics-based probabilistic methods.
- GRAMS antideuteron measurements can be essentially **background-free dark matter searches** while investigating and validating the possible dark matter detection indicated in **Fermi GCE** and **AMS-02 antiproton excess**.
- We are currently building **a small-scale** LArTPC detector, **MiniGRAMS** that can be deployed in the beam test (2024) and the prototype flight (TBD).