Design and Detection Mechanism for Gamma Rays and Antimatter Particles by a LArTPC Detector Towards Future GRAMS Mission

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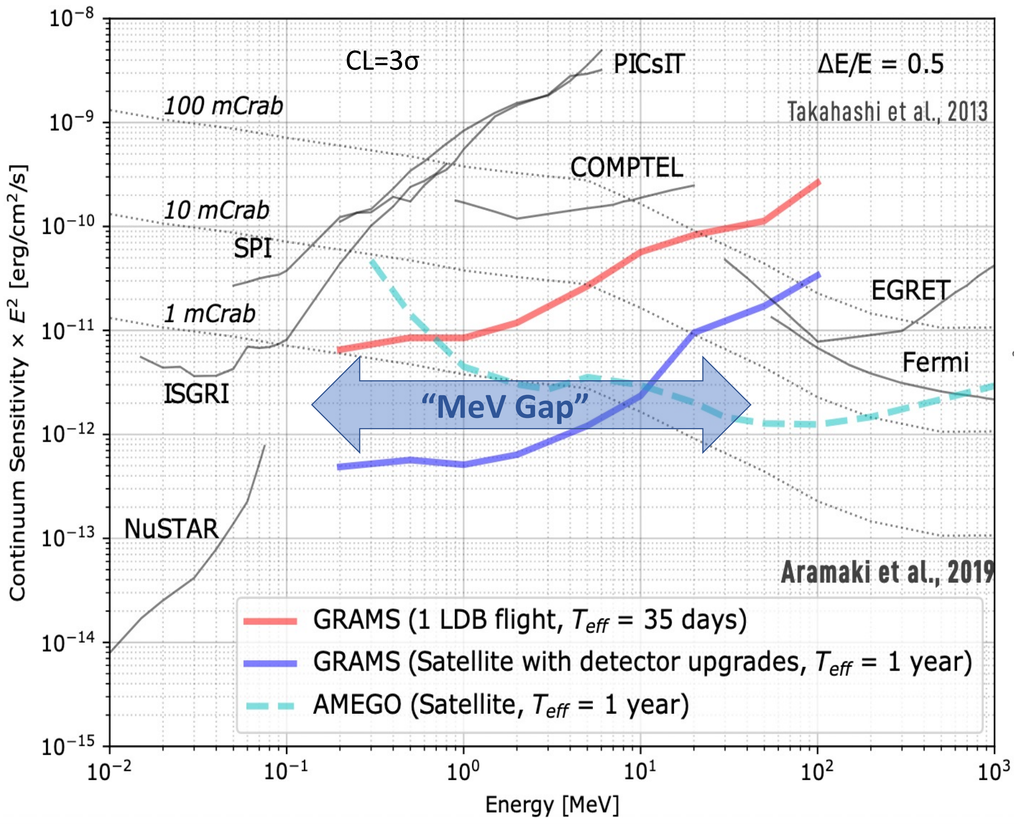
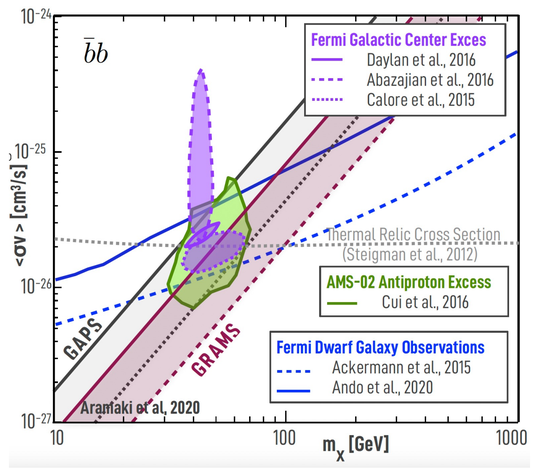
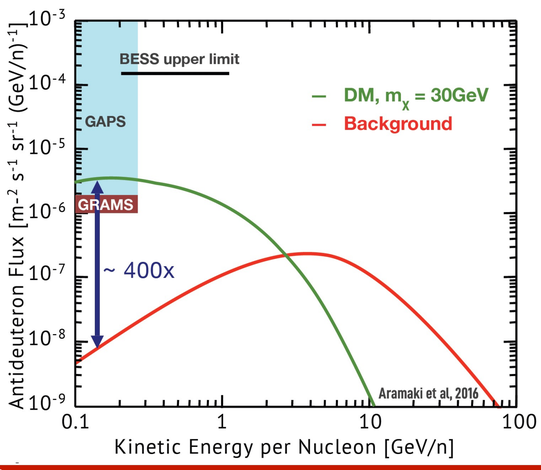
Introduction

The upcoming GRAMS (Gamma-Ray and AntiMatter Survey) experiment aims to provide unprecedented sensitivity to a poorly explored region of the cosmic gamma-ray spectrum from 0.1-100 MeV, often referred to as the "MeV gap". In addition to gamma rays, the ability to detect cosmic antimatter makes GRAMS an excellent candidate for a nearly 'background free' indirect dark matter search. Utilizing Liquid Argon Time Projection Chamber (LArTPC) technology to detect MeV gamma rays and antimatter, GRAMS has the potential to uncover crucial details behind a variety of processes in multi-messenger astrophysics.

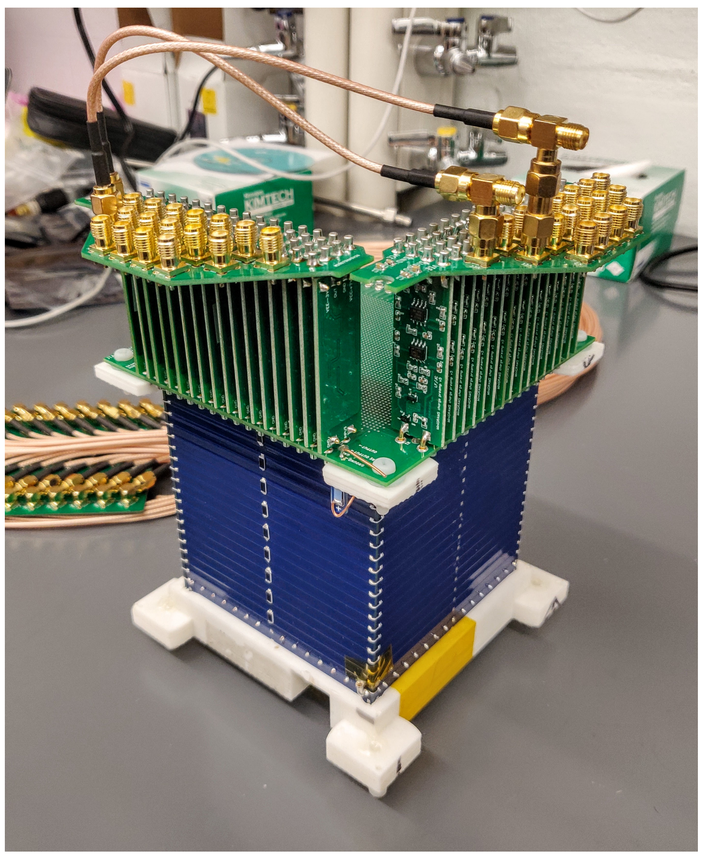
GRAMS Mission Projected Sensitivity in MeV Band

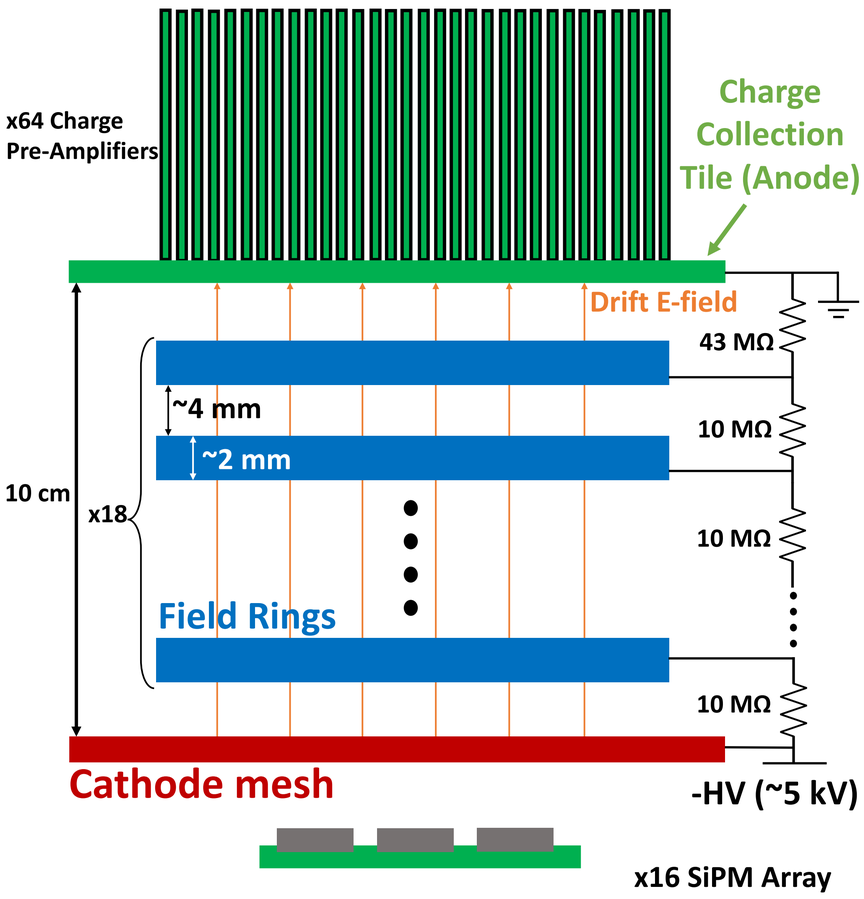




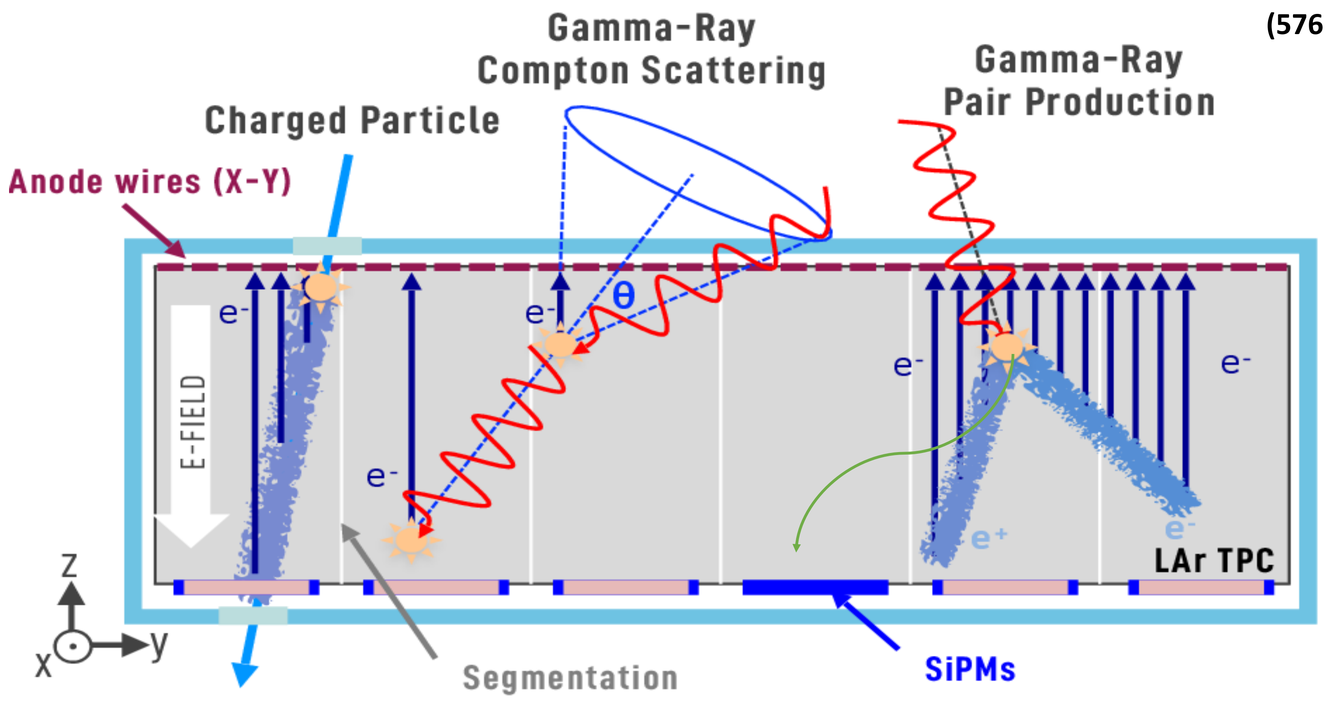


Liquid Argon Time Projection Chamber

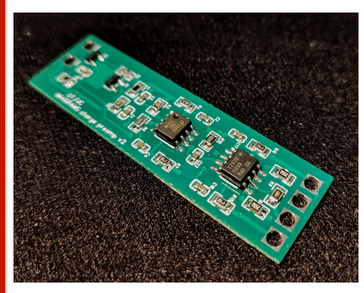


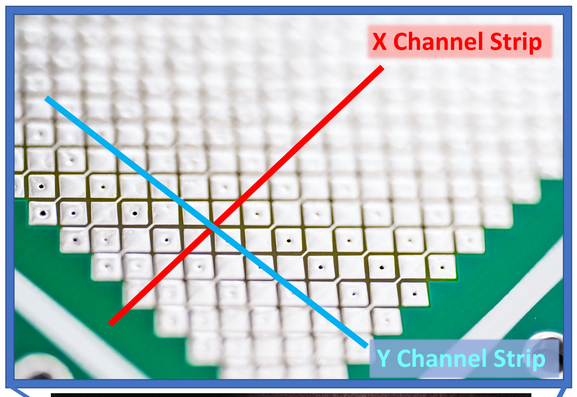


x16 SiPM Array (576 mm²)

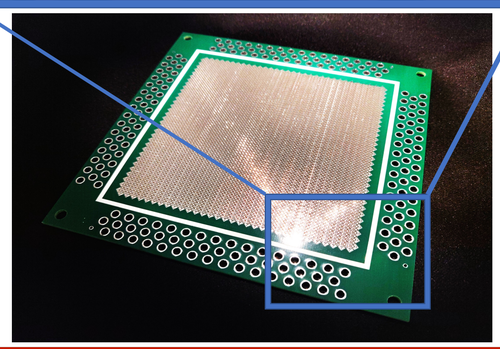


Ionization Signal – Anode Tile and Charge Pre-Amplifier



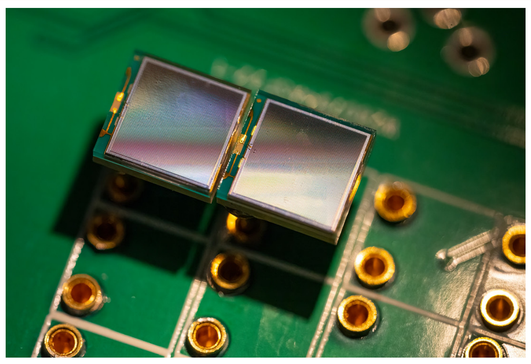


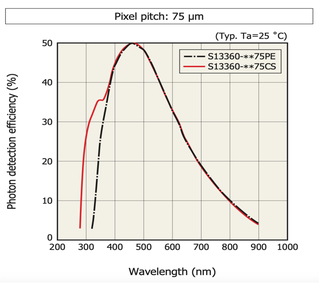
- x64 detector strips for X-Y directions
  - ~220 µm pixel separation
- Each strip readout by dual stage charge sensitive pre-amplifier
  - Data acquisition and processing by CAEN 64-Ch. Digitizer
    - 125 MSa/s (8 ns/pt)
    - 16-bit ADC resolution
- ~15 keV energy resolution

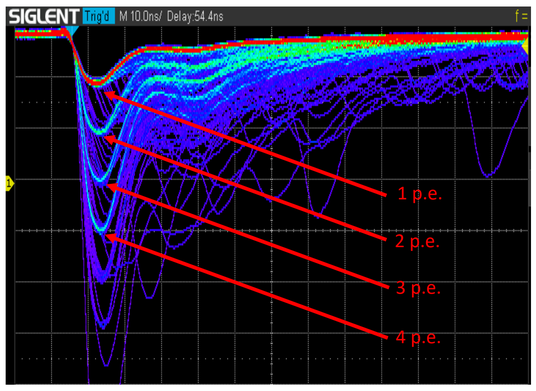


Scintillation Signal - SiPM Light Collection System

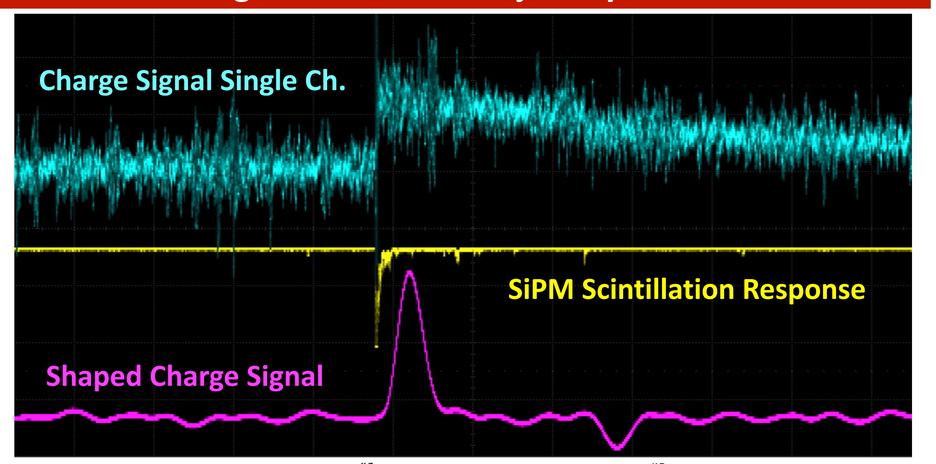
- Hamamatsu S13360-6075PE
- 4x4 SiPM array implemented for light collection system
  - 36 mm² / SiPM
- Readout by transimpedance amplifier using Texas Inst. LMH6629
- Single photon sensitivity tested and confirmed in LAr
- Current SiPM's most sensitive to ~480 nm
  - Future plans to implement new generation VUV SiPMs



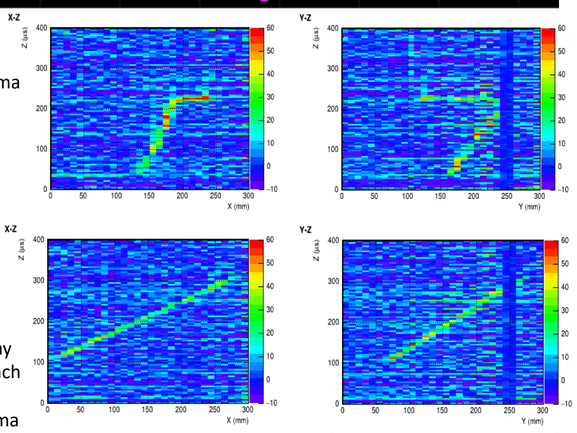




Coincident Signals & Particle Trajectory Reconstruction



- Gamma ray reconstruction
  - Compton camera
    - ML methods to locate gamma source
- Charged Particle track reconstruction possible using ionization & light combination signal
- **Future Plans**
  - MicroGRAMS used for proof of concept and engineering flight
  - Next generation design underway for 30 x 30 x 30 cm³ balloon launch
  - Largest effective area MeV gamma ray detector launched



Particle trajectory reconstruction from GRAMS Japan Team [2]

References

[1] T. Aramaki, P. Adrian, G. Karagiorgi, et al. Astroparticle Physics, 2020, 114: 107-114.

[2] K. Yorita, T. Aramaki, G. Karagiorgi, J. Mitchel, J-PARC Proposals P98, 35th PAC meeting, Jan. 2023

[3] Scott LeyVa Photography, Aramaki Lab - GRAMS Northeastern Team

[4] GRAMS Web: https://grams.sites.northeastern.edu/

[5] M. Aguilar et al. (AMS Collaboration)
Antiproton Flux, Antiproton-to-Proton Flux Ratio, and Properties of Elementary Particle Fluxes in Primary Cosmic Rays Measured with the Alpha Magnetic Spectrometer on the International Space Station