The Mini Astrophysical MeV Background Observatory (MAMBO): A CubeSat Mission for Gamma-Ray Astronomy

P. F. Bloser[1], W. T. Vestrand[1], M. P. Hehlen[1], K. Katko[1], L. Parker[1], D. Beckman[1], J. Sedillo[1], J. McGlown[1], J. Michel[1], R. Scobie[1], T. Nelson[1], D. Poulson[1], T. Roth[1], C. Fryer[1], A. Hungerford[1], M. Mumpower[1], M. Rasmussen[1], S. Anandagoda[2], M. Ajello[2], D. Hartmann[2]

[1]Los Alamos National Laboratory, Los Alamos, NM 87545
[2]Clemson University, Clemson, SC 29634

Introduction

The **Mini Astrophysical MeV Background Observatory (MAMBO)** is an innovative gamma-ray astrophysics investigation that will answer three decades-old questions about the mysterious Cosmic Diffuse Gamma-ray (CDG) background:

- What is the detailed spectral shape of the CDG from 0.3 – 10 MeV?
- Is the MeV CDG truly isotropic across the sky?
- What is the contribution of nuclear processes over the history of the Universe to the MeV CDG?

The MAMBO mission represents a new way of doing MeV astronomy and will demonstrate a flexible new paradigm for rapid, inexpensive science missions.

SCIENTIFIC MOTIVATION

- The origin of the CDG background in the MeV band remains a mystery over 40 years after the first measurements by Apollo 15 & 16 [1]
- More recent observations (1990s) by COMPTEL [2] suffered from large systematic errors due to instrumental background, and SMM [3] was constrained to observe the Sun
- Up-to-date theoretical modeling indicates that the contributions of radio-quiet AGNs, flat-spectrum radio quasars (FSRQs), supernovae (both Type Ia and core collapse), and NS mergers ***fall below the data*** $\lesssim$ ***1 MeV*** (Figure 1; [4])

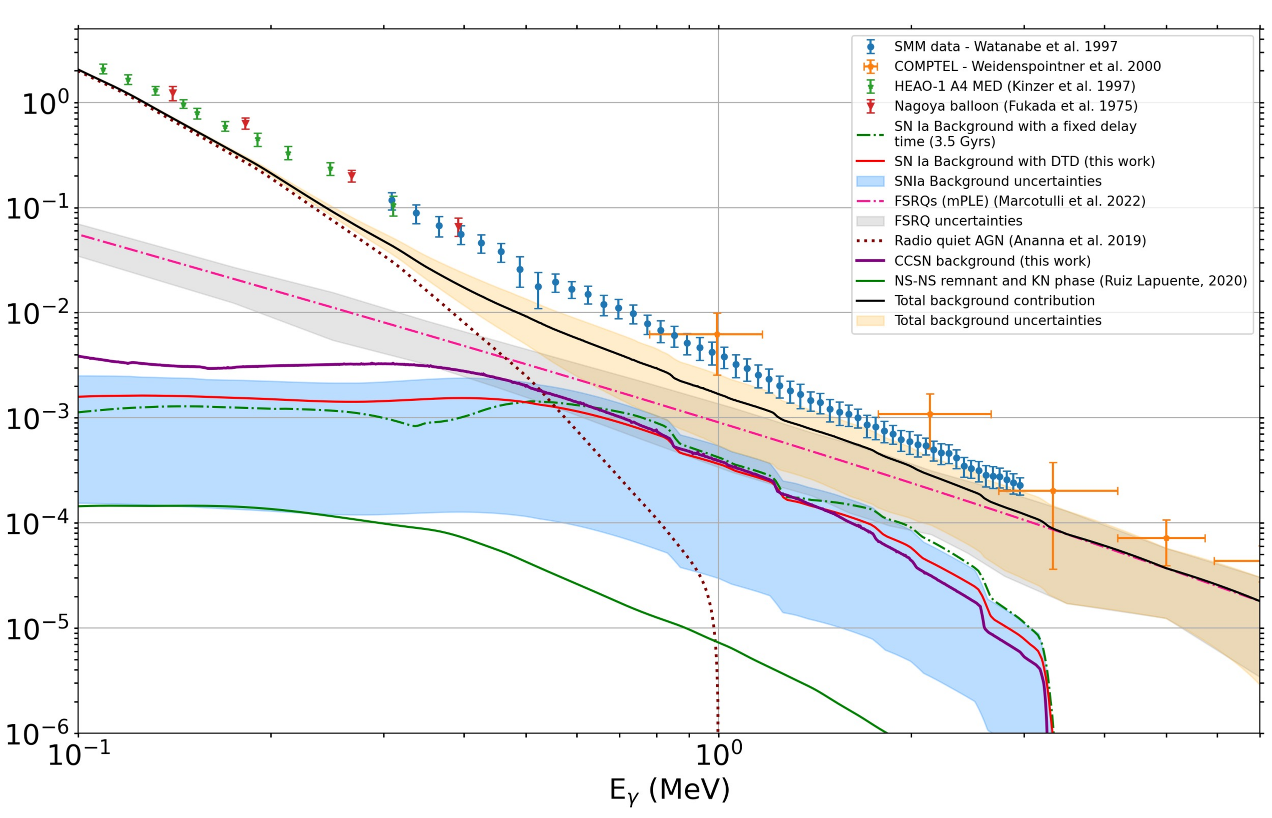

Figure 1. The latest theoretical models of the CDG in the MeV band do not agree with the COMPTEL and SMM observations [4]. This could indicate that other sources are necessary, or could be the result of residual instrumental background still contaminating the data.

LOW-BACKGROUND OBSERVATIONS FROM A CUBESAT

- **The Problem:** The sensitivity of space-based gamma-ray instruments is severely limited by ***locally generated instrumental backgrounds***
  - Energetic particles in space interact in spacecraft materials to produce both prompt and delayed (activation) background signals in the MeV band
  - As a result, ***previous measurements of the MeV CDG suffer from large systematic errors*** due to subtraction of instrumental backgrounds
- **The MAMBO Approach:** To significantly reduce background, mass must be dramatically reduced
  - The CDG is relatively bright, so only a small detector needed
  - MAMBO utilizes a ***12U CubeSat bus = 25 kg total***
  - Will experience an order of magnitude less instrumental background than COMPTEL on CGRO (Figure 2)

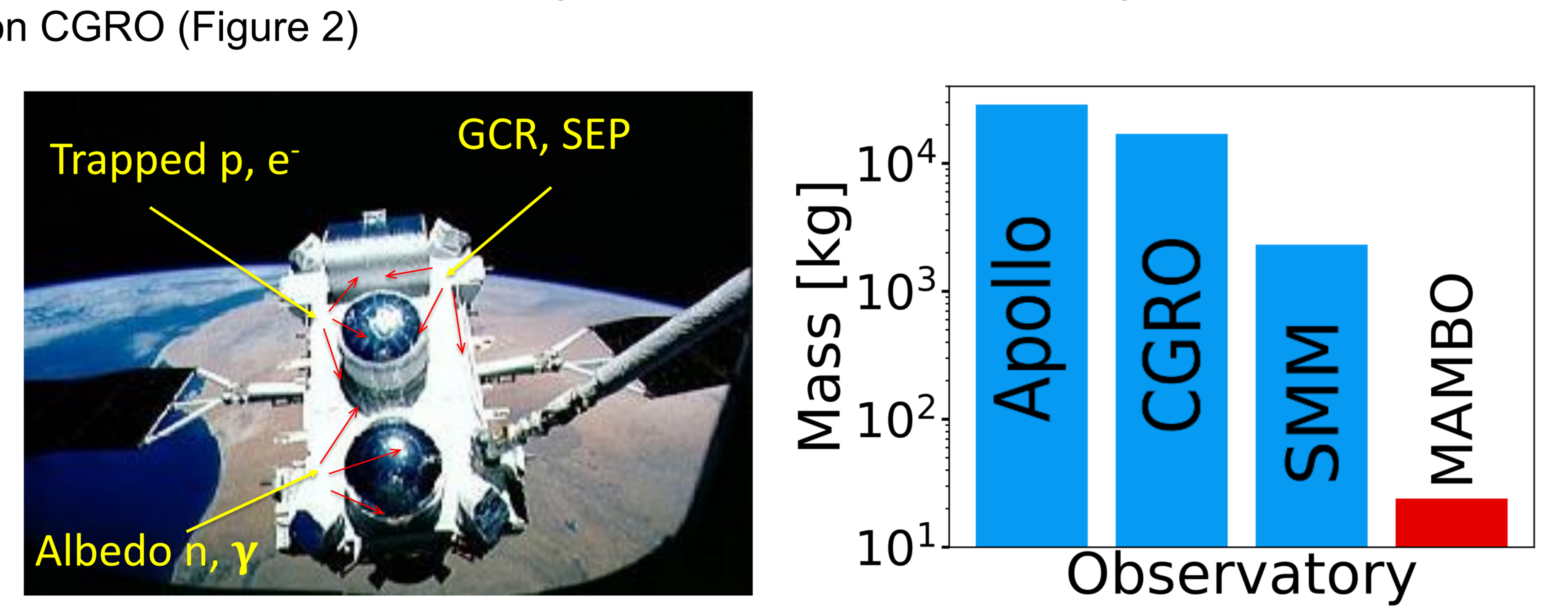

Figure 2. Massive structures (CGRO: 17,000 kg) in space are subjected to intense radiation fields that generate instrumental background. On a 12U CubeSat platform, MAMBO will experience roughly an order of magnitude lower instrumental background.

REFERENCES

[1] Trombka, J. I., et al., 1977, ApJ, 212, 925. [2] Weidenspointner, G., et al., 2000, AIP Conf. Proc. 510, 581. [3] Watanabe, K., et al., 2000, AIP Conference Proceedings 510, 471. [4] Anandagoda et al. 2023 (submitted to ApJ)

The MAMBO Instrument & Mission

- MAMBO achieves high efficiency and exceptional background rejection using an innovative shielding configuration (Figure 3)
- The **Primary Detector** (BGO scintillator) is exposed to the CDG
- The **Background Monitor** (identical BGO) is shielded from the CDG by the Primary, but exposed to the identical instrumental background from the sides
- Gains are kept the same using a **tagged ^{60}Co calibration source**
- ***Instrumental background is thus directly measured and subtracted***
- Close spacing is enabled by the use of **silicon photomultipliers (SiPMs)**

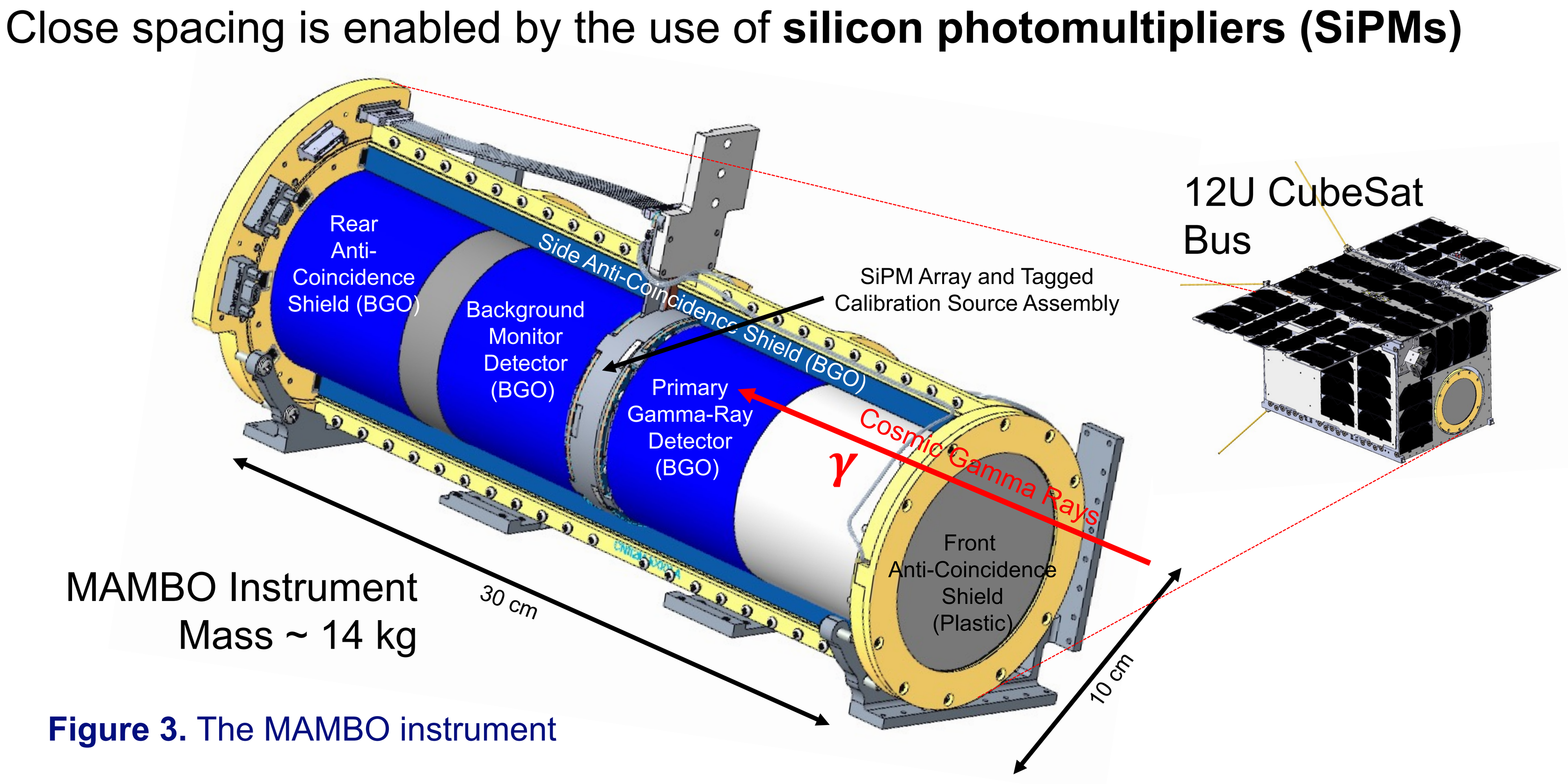

Figure 3. The MAMBO instrument

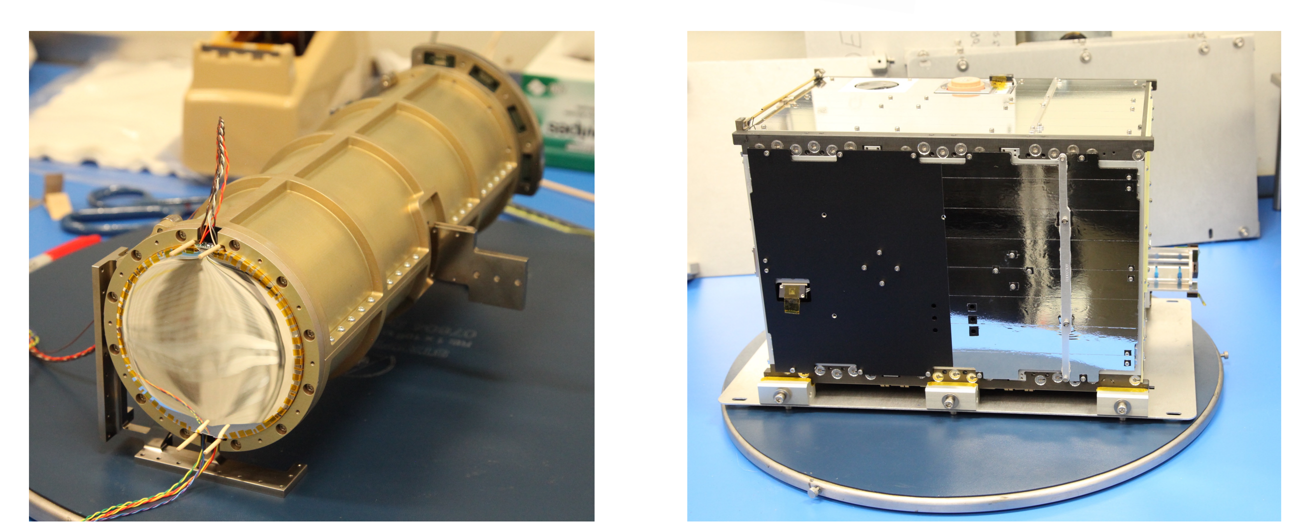

Figure 4. The instrument mechanical qualification unit (left) and 12U bus from NanoAvionics (right)

HARDWARE

- Mechanical qualification unit (Figure 4) successfully passed vibration test
- Flight electronics boards are currently being tested and integrated
- 12U CubeSat bus (Figure 4) provided by commercial partner, **NanoAvionics**
- Mass is just within 25 kg limit

MISSION

- Anticipate Low Earth Orbit, 55º inclination, 500 km altitude
- Launch to be provided by DoD's Space Test Program in **October 2024**
- Commercial ground station network for telemetry and commanding
- Point at high-Galactic-latitude fields and extrapolate backgrounds to zero

Expected Performance

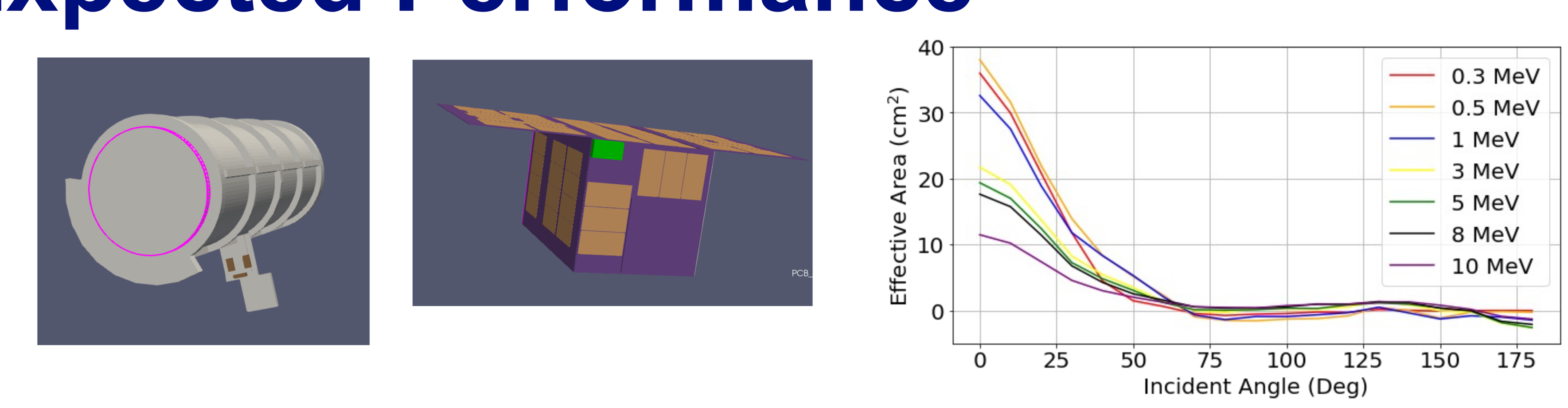

Figure 5. Geant4-based simulation models (left) and simulated effective area vs. incidence angle (right)

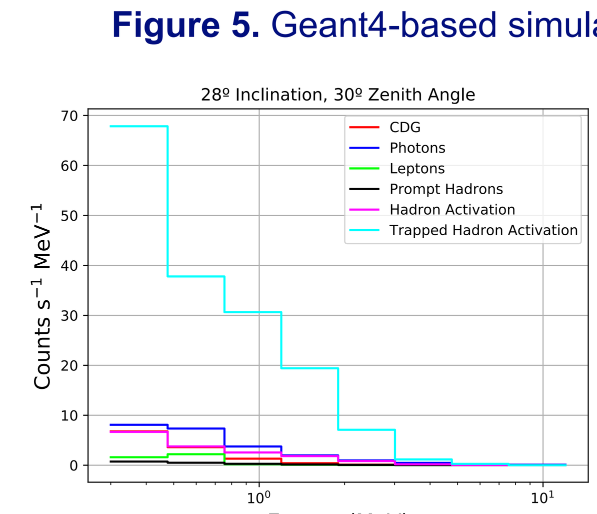

Figure 6. Simulated spectra in Primary Detector using other scintillators as shields only.

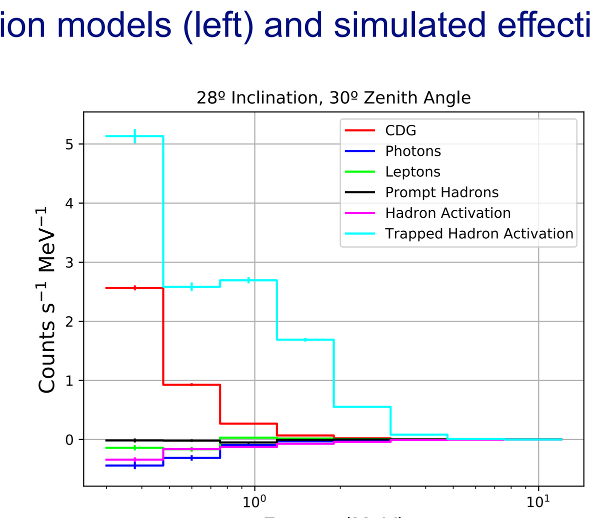

Figure 7. Simulated spectra using MAMBO background subtraction technique. The CDG (red) is much more prominent.

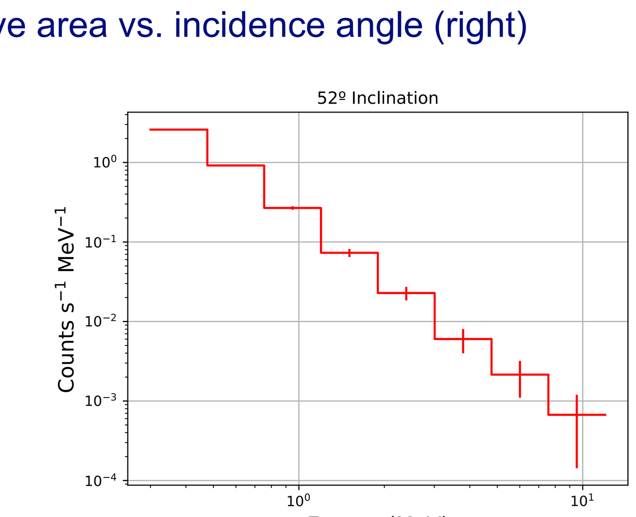

Figure 8. Simulated CDG spectrum in 10^6 s observing time, assuming background components properly subtracted.