Experimental Gamma-Ray Astronomy at Los Alamos National Laboratory

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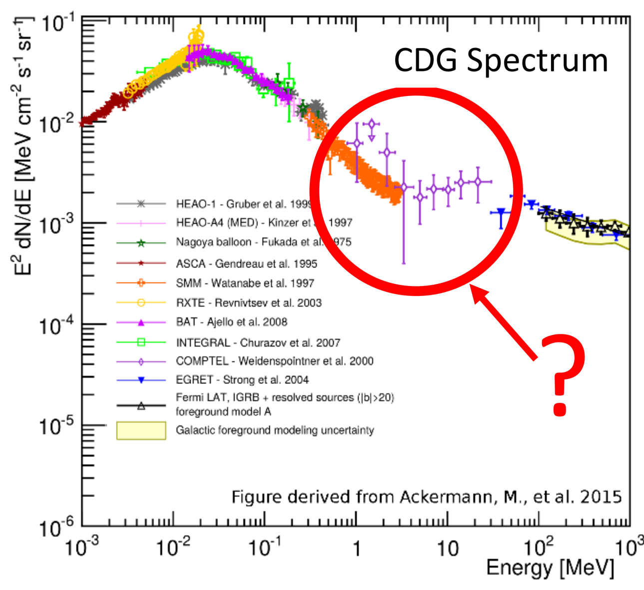
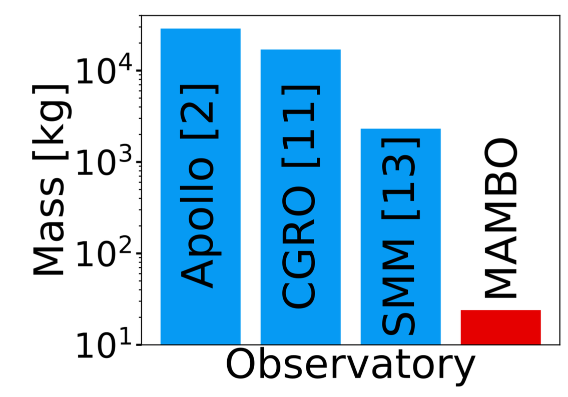
Los Alamos National Laboratory has a long history of discovery in gamma-ray astronomy, from the first detection of gamma-ray bursts by the Vela satellites to extensive involvement in NASA's highly successful Swift and Fermi missions. Looking to the future, several exciting new opportunities are being pursued, leveraging Los Alamos's unique expertise in space-based gamma-ray detector development and data analysis. We describe current experimental efforts at Los Alamos, including: 1) a concept for a CubeSat mission, MAMBO, to measure the cosmic diffuse gamma-ray background in the MeV band; 2) development of an advanced Compton telescope based on diamond detectors and fast scintillators; 3) a high-altitude ballooning program to test advanced detector technologies in a near-space environment; and 4) contributions to AMEGO, a concept for NASA's next large-scale gamma-ray astronomy mission.

MAMBO CubeSat Mission

The **Mini Astrophysical MeV Background Observatory (MAMBO)** is a concept for a CubeSat mission with the objective of performing a greatly improved measurement of the cosmic diffuse gamma-ray (CDG) background in the MeV energy band. This measurement will help differentiate and clarify the evolution of nuclear (e.g., supernovae) vs. accretion (e.g., active galactic nuclei) processes over the history of the Universe.

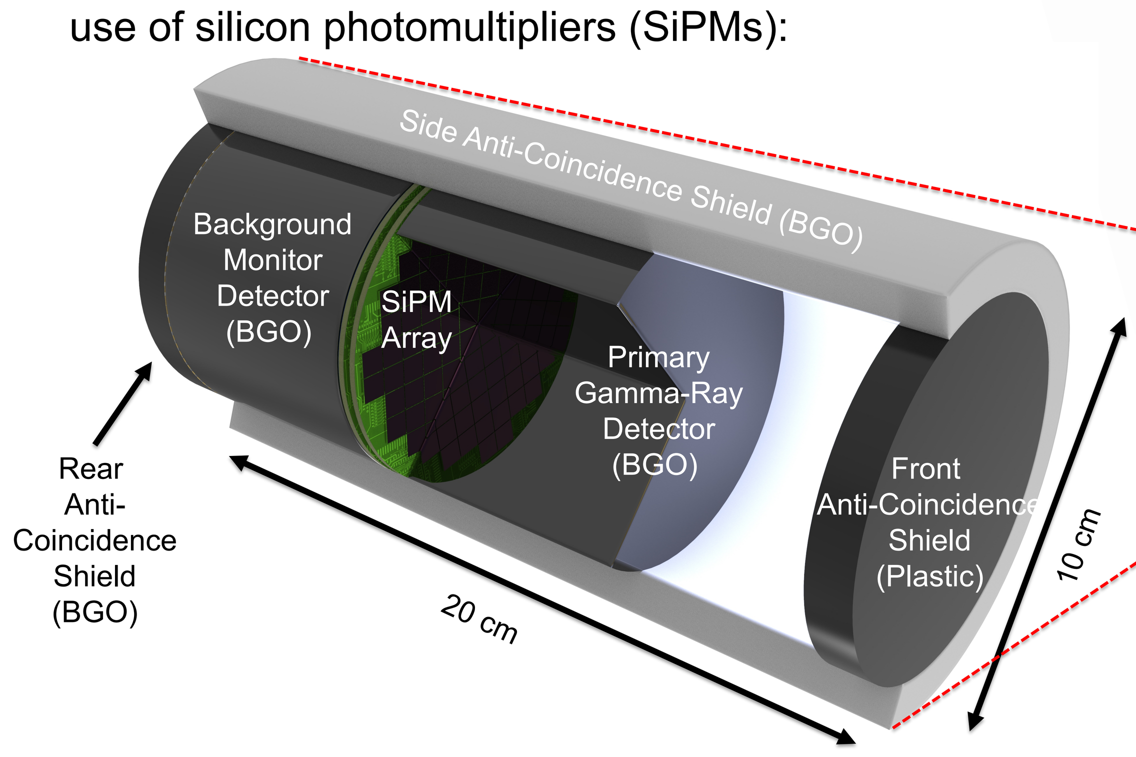


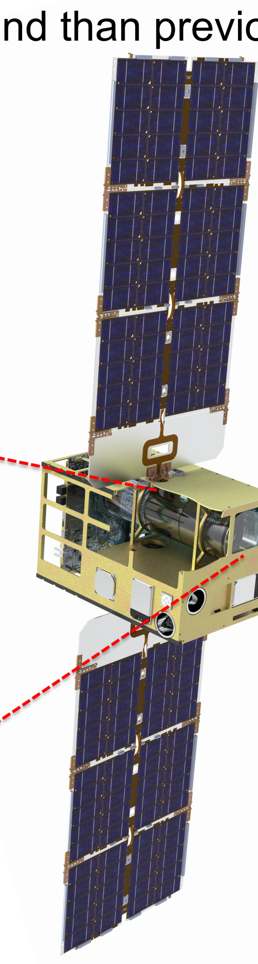
Previous measurements by COMPTEL and SMM suffered from large systematic errors due to immense instrumental background.



Instrumental background scales with observatory mass. MAMBO will be subjected to orders of magnitude less background than previous instruments.

MAMBO achieves high efficiency and exceptional background rejection using an innovative shielding configuration. The close spacing is enabled by the use of silicon photomultipliers (SiPMs):

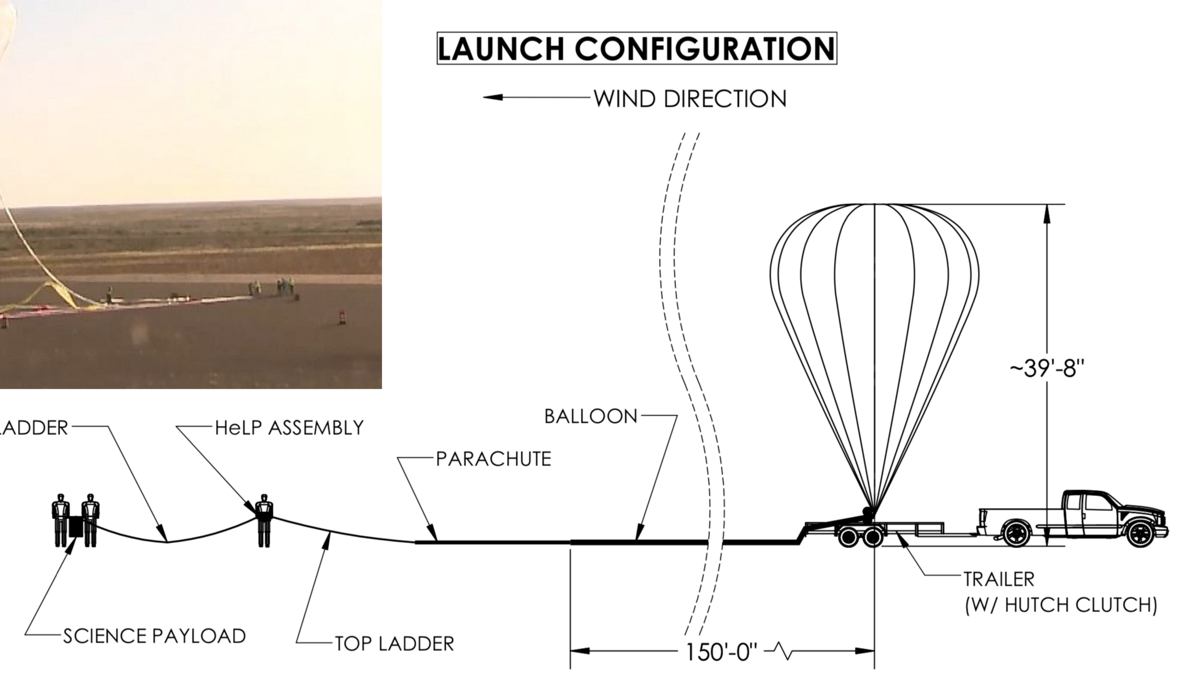




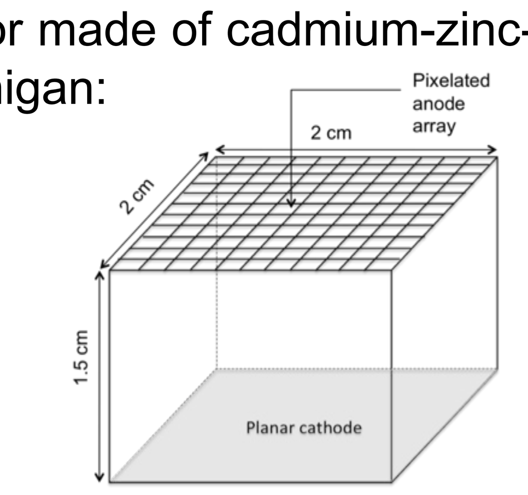
A 12U CubeSat (mass < 24 kg) flying in LEO produces very little local instrumental background

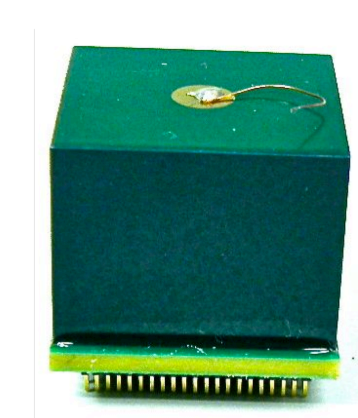
High-Altitude Balloon Program

High-altitude ballooning offers a cost-effective way to test new technologies in an environment similar to outer space. NASA's Columbia Scientific Balloon Facility (CSBF) has flown large (a few tons) scientific payloads from **Fort Sumner, NM**, for many decades. Recently, CSBF introduced a capability to "hand launch" relatively small (< 60 lbs) payloads, which offers a more streamlined process and cleaner environment for testing advanced detector concepts in near-space conditions:



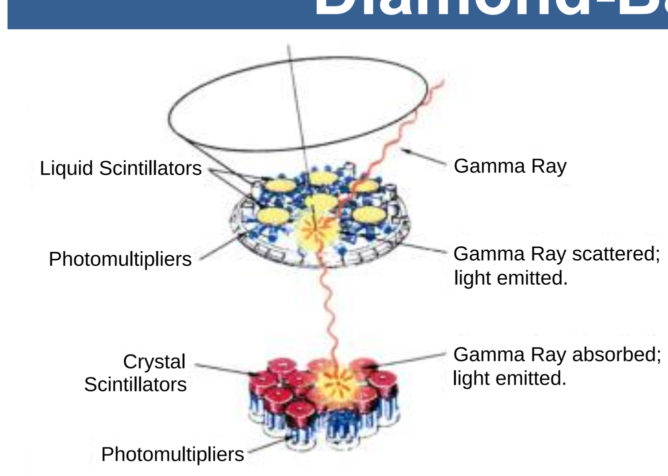
Los Alamos is currently developing a dedicated small balloon platform for use with CSBF's hand-launch capability. The inaugural flight is planned for August of 2020 from Fort Sumner, where we will test an advanced imaging gamma-ray detector made of cadmium-zinc-telluride (CZT) in collaboration with the University of Michigan:





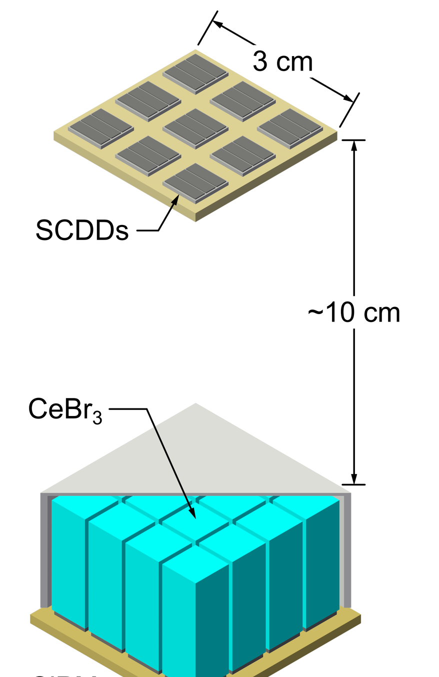
Pixelated CZT gamma-ray detectors offer excellent energy and position resolution. Los Alamos will test them on a balloon flight as a precursor to future space mission proposals.

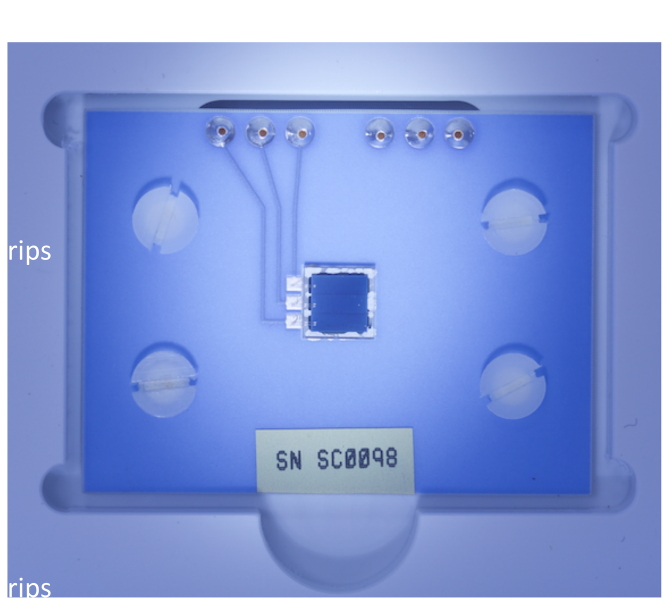
Diamond-Based Compton Telescope



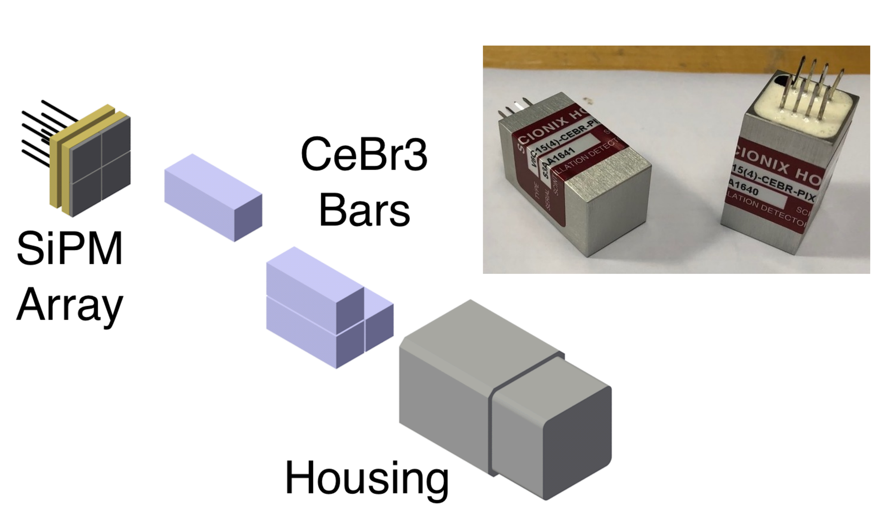
A Compton telescope takes advantage of Compton scattering to form images in the difficult MeV gamma-ray range. The only successful astronomical Compton telescope, COMPTEL, relied on time-of-flight (ToF) measurements between two scintillator detector layers to reject background.

Single-crystal diamond detectors (SCDDs) offer superior efficiency, position resolution, and energy resolution to organic scintillators for Compton scattering, while retaining fast timing for ToF. We are investigating whether SCDDs combined with modern fast scintillators with SiPM readouts could be formed into a superior Compton telescope for MeV gamma-ray astronomy.





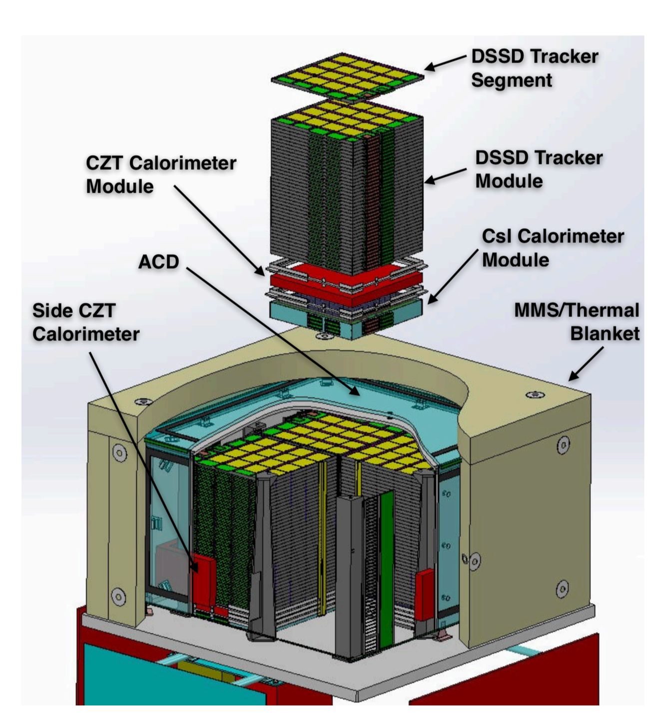
The SCDDs are being developed at Southwest Research Institute. Each is 4.5 × 4.5 × 0.5 mm^3 and patterned with 3 readout strips per side. A custom readout board provides position, energy, and timing signals.

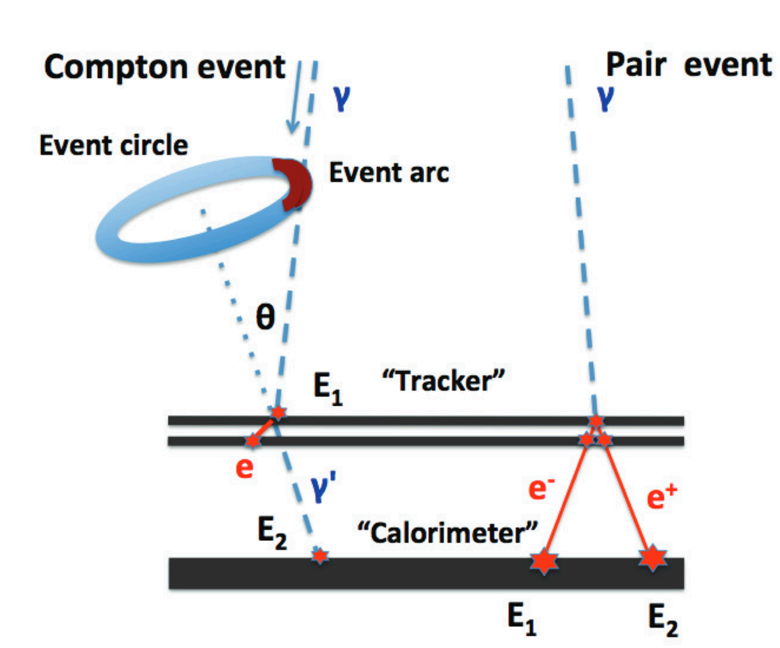


The calorimeters are being tested at Los Alamos. Each contains a 2 × 2 matrix of Cerium Bromide scintillator read by one pixel of a 2 × 2 SiPM array. The signals will be recorded using a commercial ASIC.

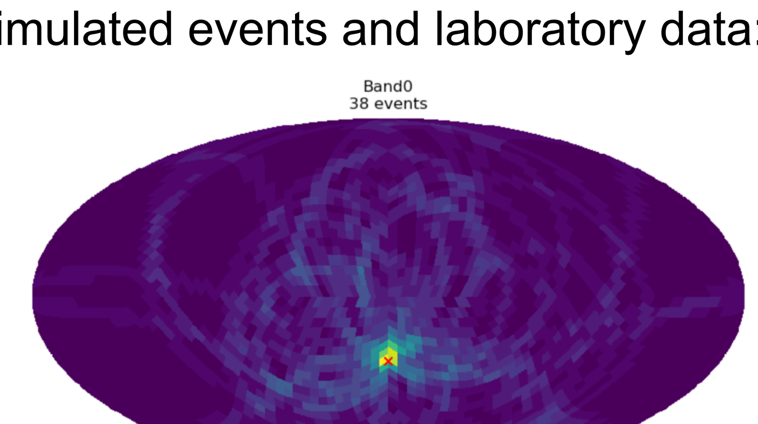
Contributions to AMEGO

The **All-sky Medium Energy Gamma-ray Observatory (AMEGO)** is a concept for a large, probe-class NASA mission, led by NASA's Goddard Space Flight Center. It covers the energy range 200 keV – 10 GeV by imaging both Compton scatter and pair production interactions. AMEGO utilizes a silicon particle tracker and two calorimeters made of cadmium-zinc-telluride (CZT) and Cesium Iodide scintillator, all surrounded by a plastic anti-coincidence detector.

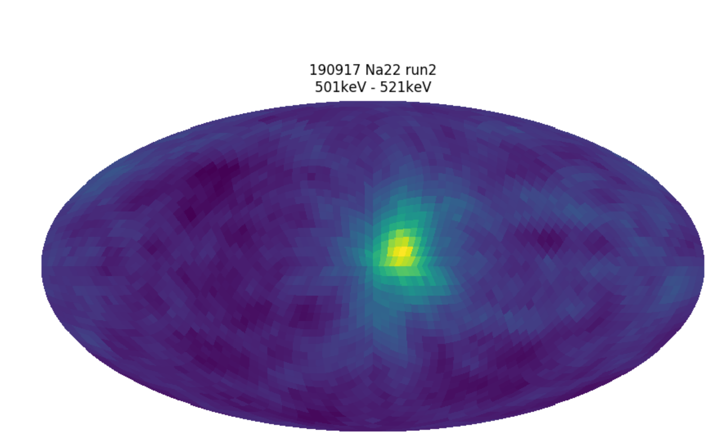




Los Alamos is a member of the AMEGO collaboration and will contribute expertise in on-board data analysis in order to reduce the enormous data downlink requirements. We have implemented Compton imaging on a field-programmable gate array (FPGA) suitable for space flight and demonstrated it using both simulated events and laboratory data:



FPGA-generated Compton map of simulated AMEGO events



FPGA-generated Compton map of 511 keV photons recorded with laboratory CZT detector