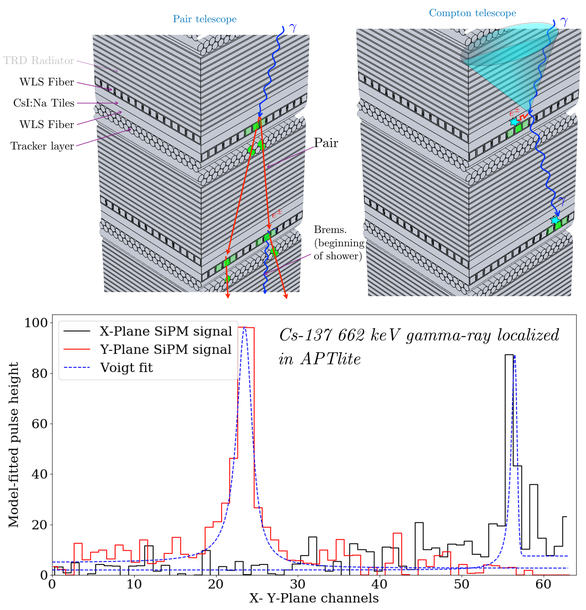
The ADAPT Mission: The Antarctic Demonstrator for the Advanced Particle Astrophysics Telescope

James Buckley [1] for the APT Collaboration

[1]Department of Physics and McDonnell Center for the Space Sciences, Washington University, St. Louis, MO 63130, USA

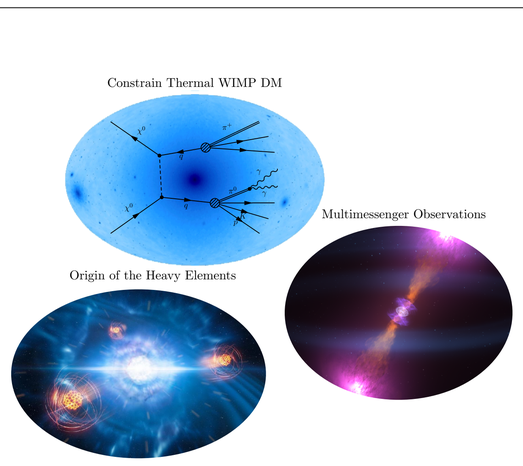
Abstract

ADAPT is a suborbital pathfinder for the future gamma-ray/cosmic-ray mission concept called the Advanced Particle-astrophysics Telescope (APT). The ADAPT instrument is scheduled for an Antarctic flight in 2025. Like the larger APT instrument, ADAPT combines a pair tracker and Compton telescope in a single monolithic design. By using scintillating fibers for the tracker and wavelength-shifting fibers to readout Na-doped CsI detectors, the APT instrument could achieve an order of magnitude improvement in sensitivity compared with Fermi at GeV energies, and several orders of magnitude improvement in MeV sensitivity compared with existing experiments. ADAPT combines 4 layers of CsI:Na imaging calorimeter (ICC) detectors with 4 layers of Scintillating fiber tracker (hodoscope) followed by an electromagnetic tail counter consisting of 4 additional layers of integrating CsI counters. ADAPT has an active cross-sectional area of 0.45m×0.45m that is partially covered with a layer of Silicon Strip Detectors to provide CR charge measurements through wide-dynamic range readout on the Ohmic side as well as a low-noise readout (based on NRL ASICs). The instrument makes use of a new low-power ASICs to readout Silicon photomultipleirs (SiPMs) including the SMART preamplifiers and new ALPHA ASICs that use a switched capacitor array for waveform capture from the ICC and tracker SiPMs. With 2.2 radiation lengths of CsI:Na



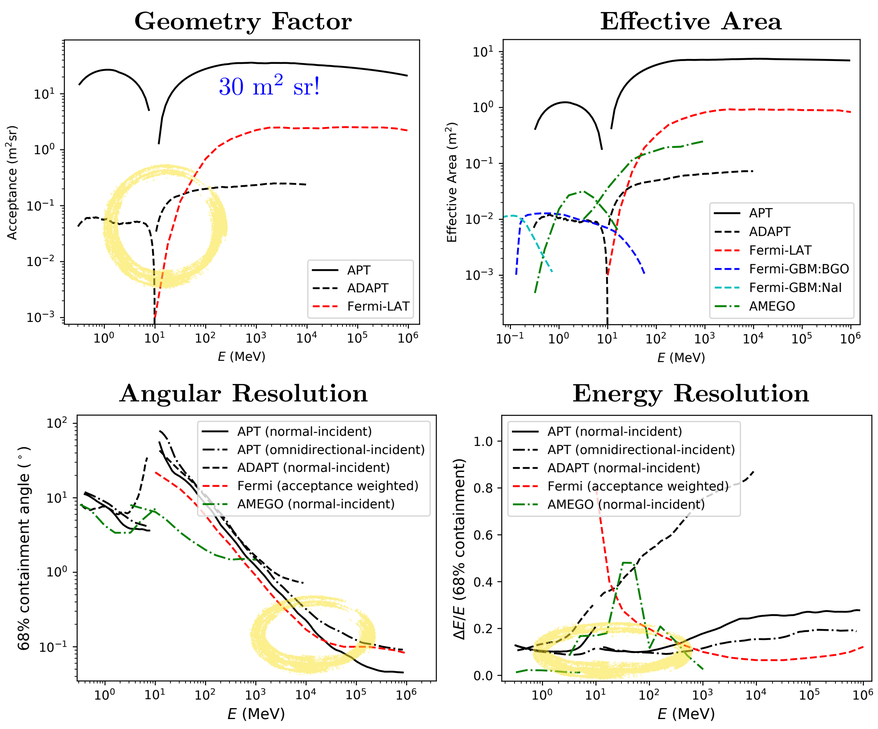
the instrument will provide some sensitivity up to GeV energies for pair-production event reconstruction. While smaller than Fermi, the use of all-active converter layers provides higher instantaneous sensitivity at tens of MeV for transients (e.g., low-energy peaked Blazars). The primary objective of the flight is to demonstrate prompt localization of several GRBs during a (nominal) 30 day flight. A real-time computational pipeline will be used to provide prompt localizations to ground-based telescopes. Measurements could provide new polarization and spectral measurements of several bright bursts.

APT and ADAPT Science



The APT mission would: (1) Either detect or constrain WIMP dark matter over the entire natural parameter space, extending Fermi Dwarf galaxy limits from 100 GeV up to TeV energies. (2) Provide an all-sky MeV-TeV instrument with 20 times the geometry factor of Fermi in the GeV-TeV range and a nearly 4Π-str instantaneous field of view to provide prompt localizations of MeV transients for multimessenger astrophysics. ADAPT, like the larger APT mission, will demonstrate the multi-messenger capabilities by providing real-time localizations of GRBs with degree-scale uncertainty.

Simulation Results

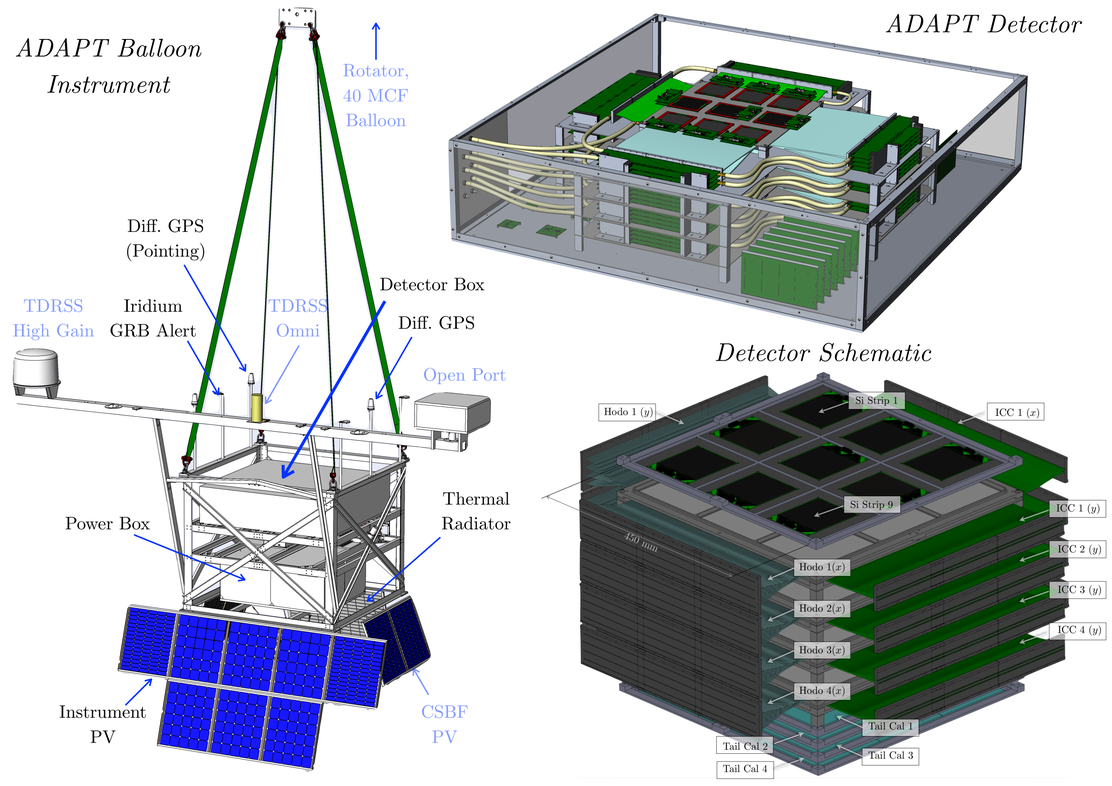


The above simulations were obtained using GEANT4 and detailed model of the APT and ADAPT instruments. The circled regions on these plots indicate the improved performance of ADAPT over Fermi in the sensitivity of transients and energy resolution at 10s of MeV.

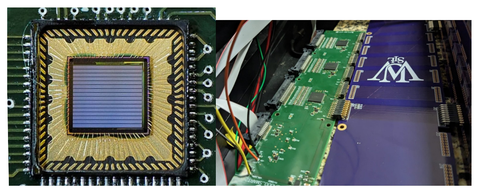
APT Collaboration

C. Altomare[2], Z. Andrew[3], B. Bal, [3],R.G. Bose[3], D. Braun[3], J.H. Buckley[3], J. D. Buhler[4], E. Burns[4], R. D. Chamberlain[4], W. Chen[5], M. L.Cherry[1], S. Funk[6], P. Gosh, F. Giordano[7,2], J. Hoffman[3], Y. Htet[4], Z. Hughes[3], A. Jung, P. L. Kelly[5], J. F. Krizmanic[8,9,10], M. Kuwahara[11], F. Licciulli[2], G. Liu[12], L. Lorusso[2], M. N. Mazziotta[2], J. W. Mitchell[9], J.W. Mitchell, G. A. de Nolfo[13], G. Panzarini, R. Peschke[12], R. Paoletti[14], R. Pillera[15,2], B. F. Rauch[3], D. Serini[2]2, G. Simburger[3], M. Sudvarg[4], G. Suarez, T. Tatoli, G. S. Varner[12], L. Di Venere[7,2], E. A. Wulf[16], A. Zink[6], W. V. Zober[3] [1]Dept. of Physics and Astronomy, LSU, Baton Rouge, Louisiana, [2]INFN, Sezione di Bari, I-70126 Bari, Italy, [3]Department of Physics and MCSS, Washington U., St. Louis, MO [4]Dept. of Computer Science & Engineering, Washington U., St. Louis, MO, [5]Dept. of Physics and Astronomy, U. of Minnesota, Minneapolis, MN, [6]Friedrich-Alexander-Universität Erlangen-Nürnberg, ECAP, Erlangen, Germany, [7]Dipartimento di Fisica "M. Merlin" dell'Università e del Politecnico di Bari, Bari, Italy, [8]Center for Space Sciences and Technology, University of Maryland Baltimore County, Baltimore, Maryland, [9]Astroparticle Phys. Lab., NASA/GSFC, Greenbelt, Maryland, [10]CRESST, NASA/GSFC, Greenbelt, Maryland, [11]Dept. of Engineering, University of Hawai'i at Manoa, Honolulu, HI, [12]Dept. of Physics and Astronomy, University of Hawai'i at Manoa, Honolulu, HI, [13]Heliospheric Physics Laboratory, NASA/GSFC, Greenbelt, Maryland, [14]Università di Siena and INFN Pisa, Siena, Italy, [15]Politecnico di Bari, Department of Mechanics, Mathematics and Management, via Orabona, Bari, Italy,. [16]Naval Research Laboratory, Washington, DC.

ADAPT Instrument

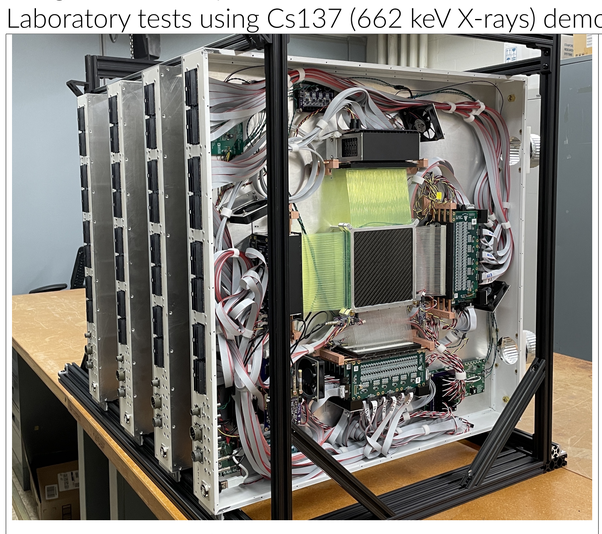


The ADAPT instrument is currently under construction, with the second version of the ALPHA ASIC under production (right), and the readout electronics (consisting of SiPM carrier boards, 3:1 passive multiplexers, and SMART-ASIC preamplifiers) have been produced and testing, and ready for production. Other significant progress has been made on the real-time Compton reconstruction including both front-end (FPGA-based calculation) and higher level source reconstruction (see Posters "Design of Front-end Signal Processing for the Advanced Particle-astrophysics Telescope", 103.27, "Prompt, Accurate Localization of Gamma-Ray Bursts in the Advanced Particle-astrophysics Telescope" 103.29, and "The Advanced Particle-astrophysics Telescope: Reconstruction of the MeV gamma-ray sky and estimation of point-source sensitivity in the presence of the background" 103.32.

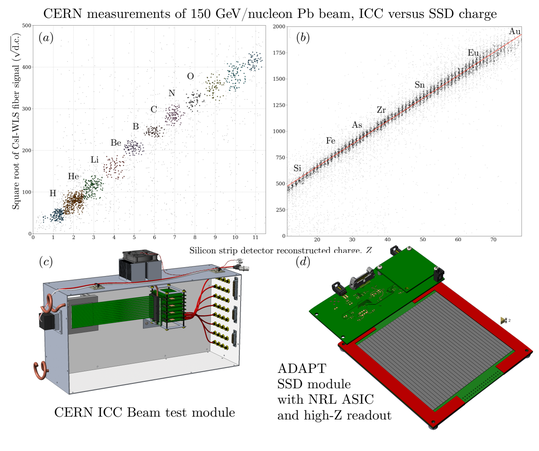


ADAPT Hardware Development

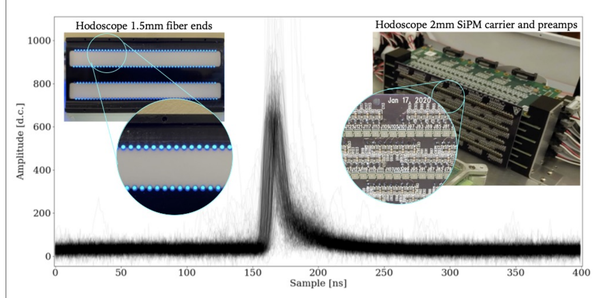
In 2018 a prototype of the ICC and silicon strip detector was tested at CERN, using fragmentation of a 150 GeV/N Pb beam to show the charge resolution for ultraheavy cosmic rays (upper right panel). A piggyback Antarctic flight (2019) of the APTlite instrument demonstrated the performance of a larger ICC module, with a 150mm square CsI tile, readout by 64 2mm WLS fibers and SiPMs in the x and y directions. Each channel was readout by a CTC 1 Gsps analog pipeline ASIC (the predecessor of the ALPHA developed for the CTA project). Results from CR events showed the position reconstruction of the ICC module, and the ability to use waveform data to reconstruct charge for saturated events to extend dynamic. A 4-layer prototype instrument was constructed and taken to the Fermilab MTEST facillity, using a 120 GeV proton beam to demonstrate both the tracker and ICC for event reconstruction. Laboratory tests using Cs137 (662 keV X-rays) demonstrate the performance in the Compton regime.



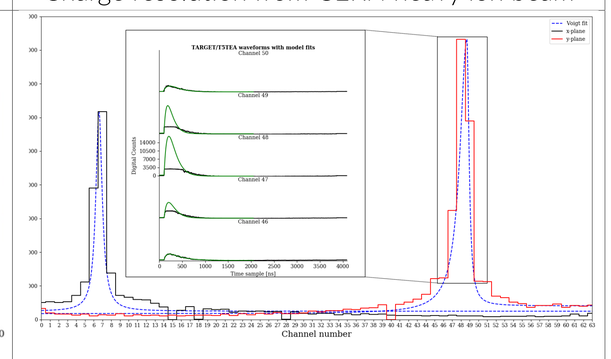
Fermilab beam test instrument



Charge resolution from CERN heavy ion beam



Muon events (MIPs) in tracker fiber



Cosmic ray event from APTlite Antarctic flight

References

[1] J.H. Buckley 2021 for the APT collaboration "The Advanced Particle-astrophysics Telescope (APT) Project Status" in Proceedings of 37th International Cosmic Ray Conference — PoS(ICRC2021), 395, 655. [2] W. Chen, J.H. Buckley for the APT collaboration, "The Advanced Particle-astrophysics Telescope: Simulation of the Instrument Performance for Gamma-Ray Detection" in Proc. of 37th ICRC — PoS(ICRC2021), 395, 590:1–590:9. [3] M. Sudvarg, J. Buhler, J.H. Buckley, W.Chen, et al. 2021. "A Fast GRB Source Localization Pipeline for the Advanced Particle-astrophysics Telescope", in Proc. of 37th ICRC— PoS(ICRC2021), 395, 588.

Acknowledgements

This work was supported by NASA grants 80NSSC19K0625 and 80NSSC21K1741, as well as generous support from the Washington University McDonnell Center for the Space Sciences.