Advances in modeling High-Energy Astrophysical Sources – Sexten (BZ) – 30 June, 4 July 2025

SEXTEN CENTER FOR ASTROPHYSICS RICCARDO GIACCONI

The Antarctic Demonstrator for the Advanced Particle-astrophysics Telescope (ADAPT), overview and project status

P. Loizzo [1,2], E. Bissaldi [2,3], G. De Palma [2,3] , L. Di Venere [2], F. Gargano [2], F. Licciulli [2], M.N. Mazziotta [2], D. Serini [2] on behalf of the ADAPT collaboration

[1] University of Trento, Italy
[2] INFN Sezione di Bari, Italy
[3] Politecnico di Bari, Italy

ADAPT
ANTARCTIC DEMONSTRATOR for the ADVANCED PARTICLE-ASTROPHYSICS TELESCOPE
OSU · INFN · ECAP · NRL · WashU · LSU · UH · NASA

PhD SST Space Science and Technology

UNIVERSITY OF TRENTO

INFN BARI
Istituto Nazionale di Fisica Nucleare Sezione di Bari

The Advanced Particle-astrophysics Telescope (APT) mission concept

Gamma and cosmic ray observatory in an orbit around L2

Combine Compton and pair telescope in single monolithic design

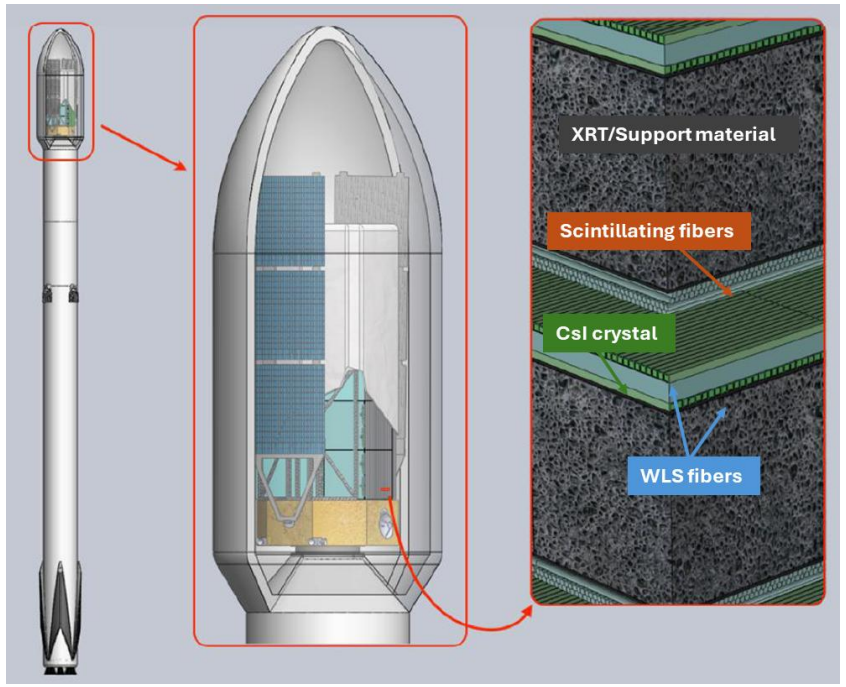
Cheap, low complexity but with improved sensitivity compared to existing experiments in the MeV-GeV range

- Indirect search of Dark Matter
- Prompt localization for gamma-ray transients
- Understanding heavy elements origin

Scientific Goals

Link to collaboration page: [ADAPT: Antarctic Demonstrator for the Advanced Particle-astrophysics Telescope]

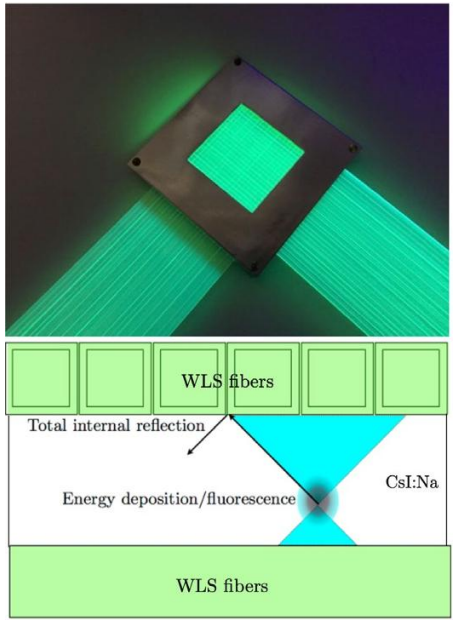
The Advanced Particle-astrophysics Telescope (APT) mission concept



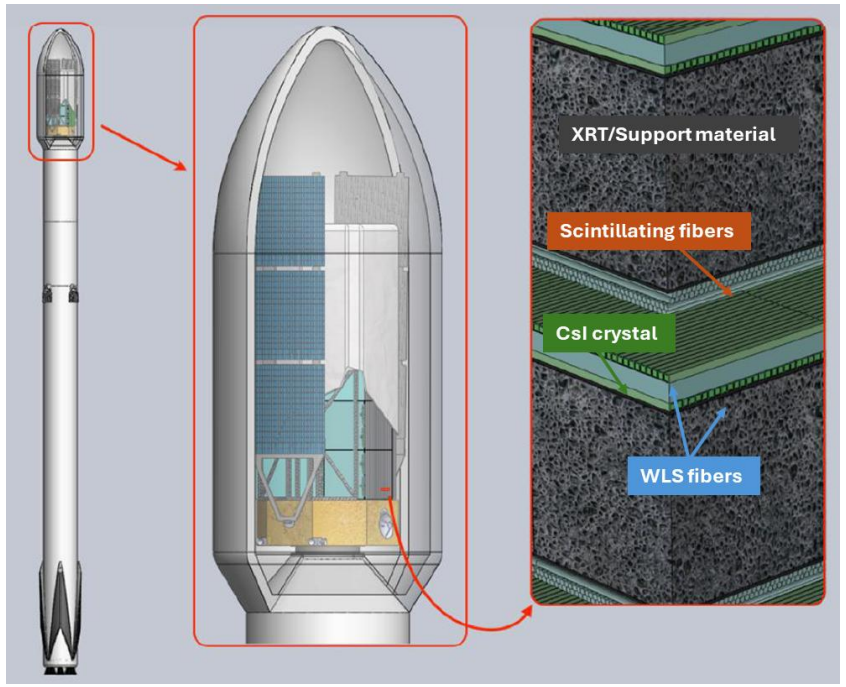
3m x 3m x 2.5m single module detector surrounded by an ACD made of plastic scintillators

20 X-Y tracker and active converter layers. Each layer with:

- CsI (Na) detector as active pair converter
- Staggered green squared WLS fibers (2mm) used to convert and guide the photons emitted in the CsI to SiPMs
- 2 close-packed, staggered layers of 1.5mm diameter round scintillating fibers for tracking



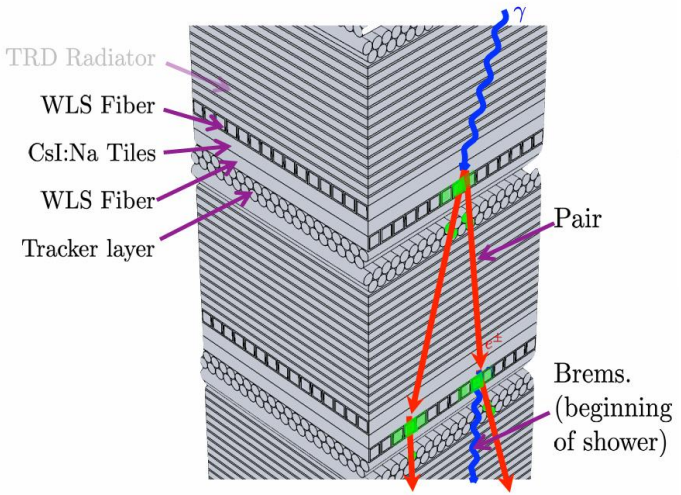
The Advanced Particle-astrophysics Telescope (APT) mission concept



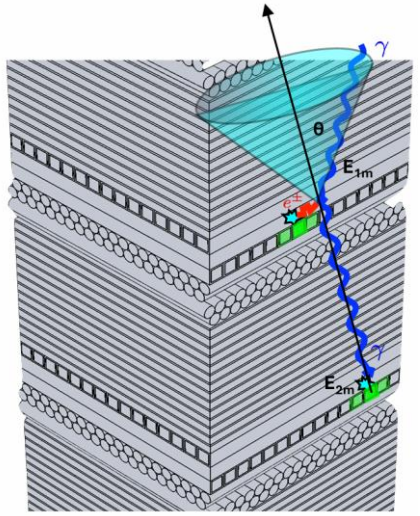
3m x 3m x 2.5m single module detector surrounded by an ACD made of plastic scintillators

Combine Compton and pair telescope in single monolithic design

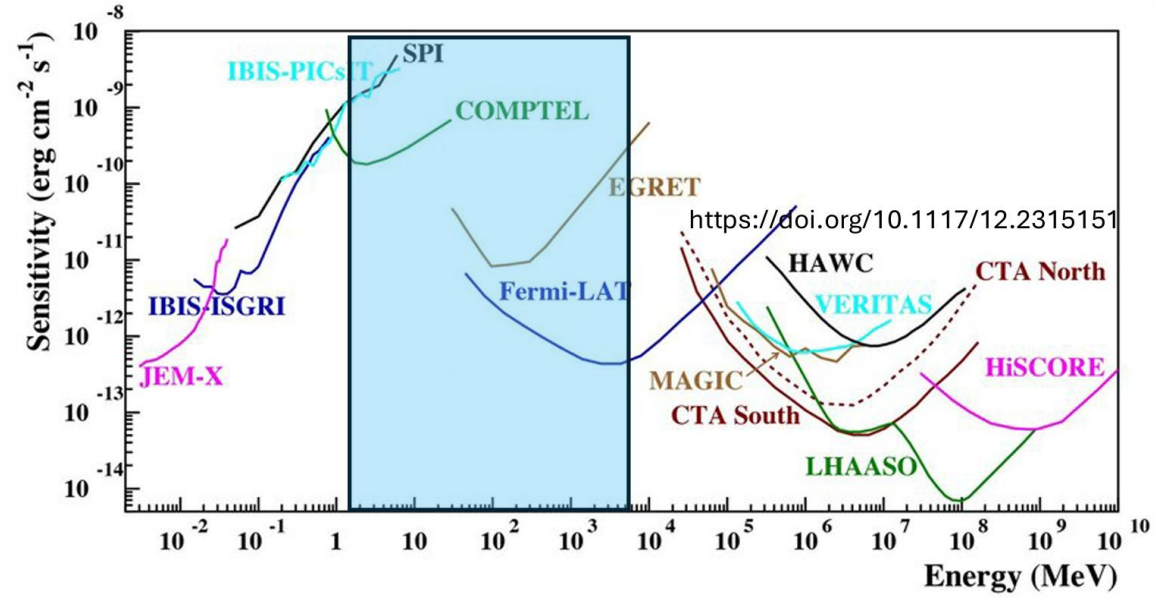
Pair telescope



Compton telescope

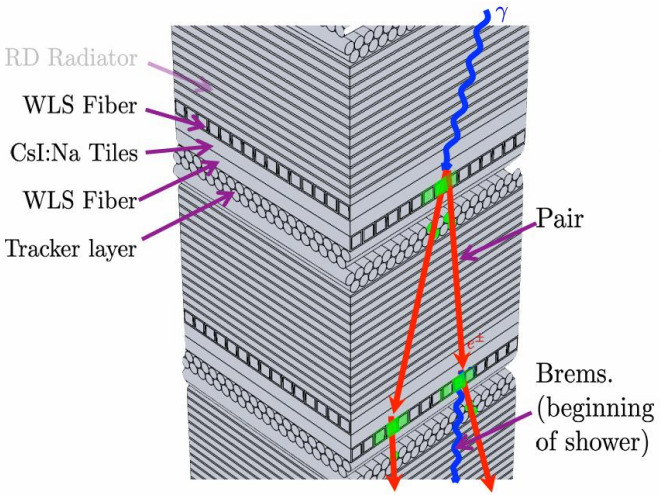


The Advanced Particle-astrophysics Telescope (APT) mission concept

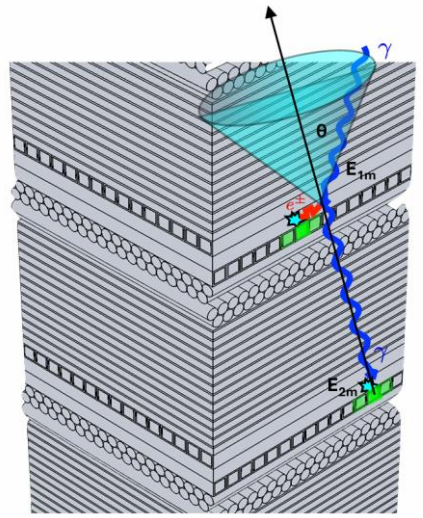


Combine Compton and pair telescope in single monolithic design

Pair telescope



Compton telescope



- **Effective area**: 1 m^2 (1 MeV) – 8 m^2 (1 GeV)
- **Field of view**: ~1.8 π (x2)
- **Energy resolution**: ~ 10% (1 MeV) – ~20% (1 GeV)
- **Angular resolution**: ~ 10° (1 MeV) – ~1° (1 GeV)

The Antarctic Demonstrator for APT (ADAPT)

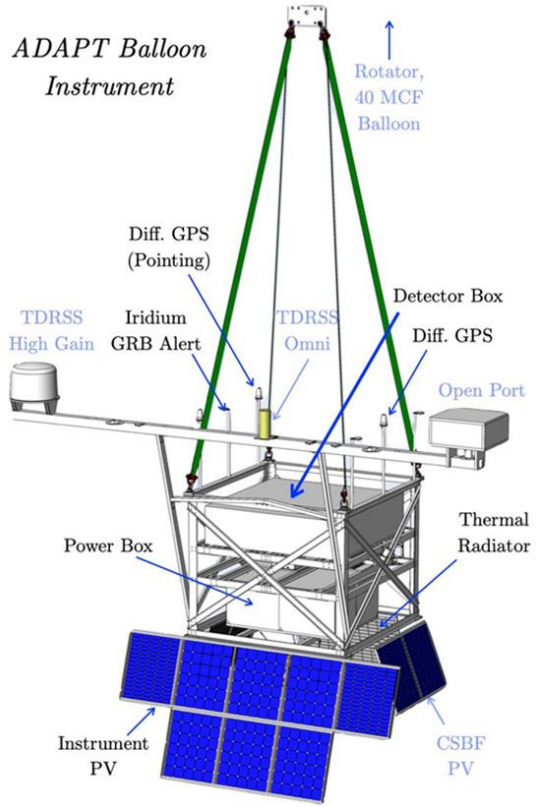
NASA suborbital mission that will fly for 36 days over Antarctica during the 2026-2027 season

Goals

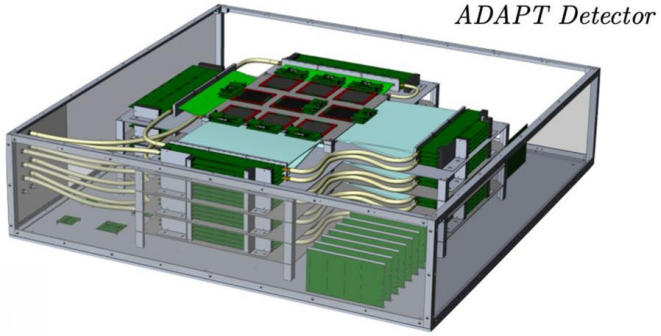
Demonstrate APT key detector technologies and functionalities on a long duration flight (*with only 1% total amount of sensitive materials wrt APT*)

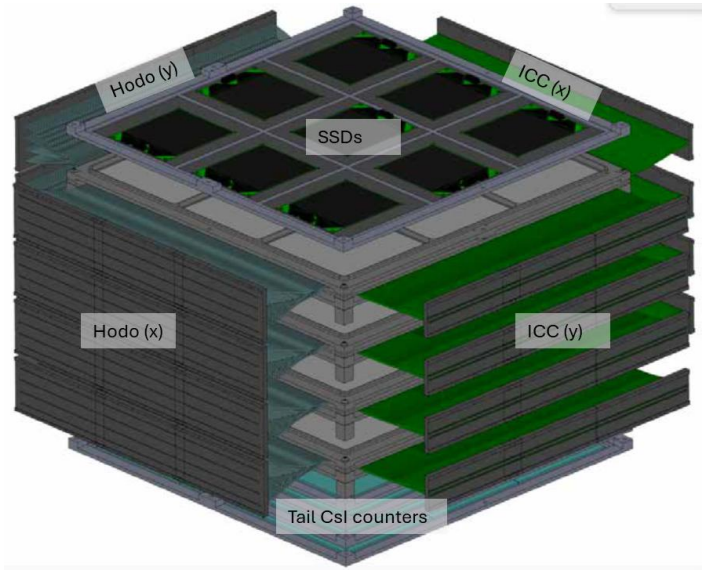
Validate detection capabilities and Compton reconstruction mechanism

If any during the flight (*few expected*), testing a real-time positional alert for gamma-ray transients



ADAPT detector schematic



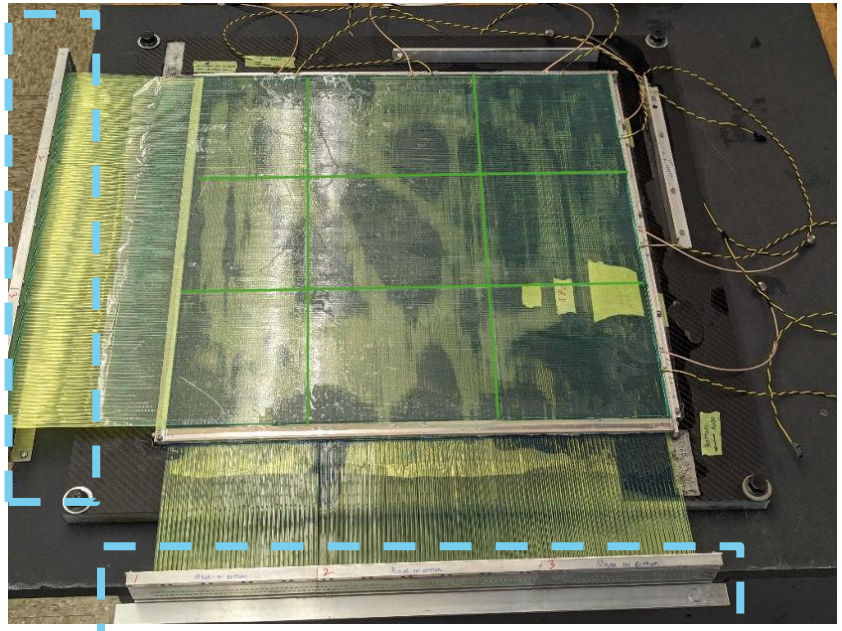


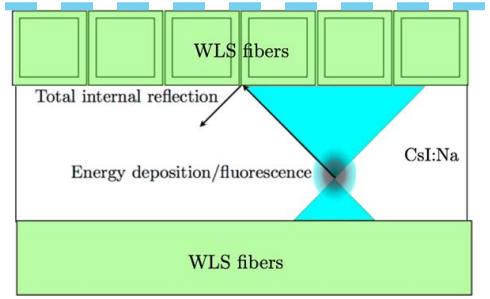
- SSDs: Silicon Strip Detectors for Cosmic Ray charge identification (*not covered here*)
- Imaging CsI Calorimeter (ICC) module.
  - CsI detector with SiPMs on two sides as edge detectors
  - Staggered 2mm WLS fibers + SiPMs reading CsI scintillation light
- Hodoscope (Hodo) of 1.5 mm scintillating fibers + SiPMs readout
- CsI crystals only with edge SiPMs as Tail Counters for calorimetry
- Anti Coincidence Detector (ACD) made of plastic scintillators and surrounding the whole detector

4 layers

Imaging CsI Calorimeter (ICC) module

ICC SiPM carrier board (WLS fibers)

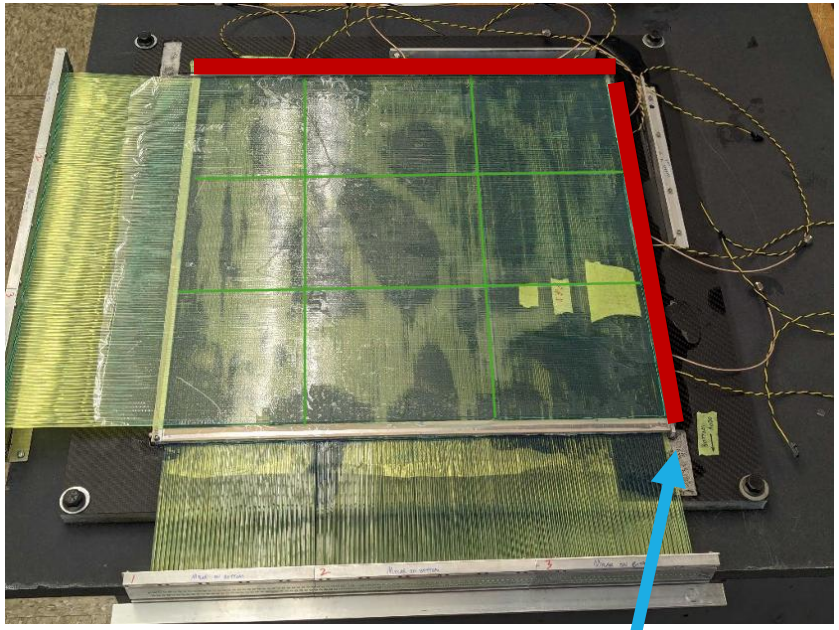




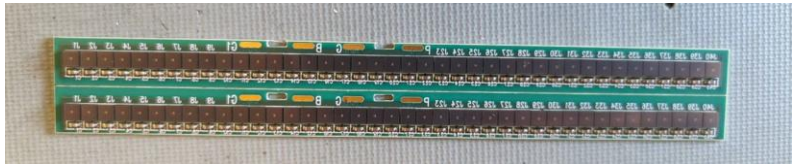
- Each plane is made by 9 CsI 15x15 cm^2 modules
- Each plane is readout by 480 WLS Kuraray fibres (240 X and 240 Y)
- Each fiber is directly coupled to a single Hamamatsu 3x3 mm^2 SiPM (S13360-3050VE)
- To reduce the number of readout channel a 3-Fold SiPMs merge is done (80ch X and 80ch Y)
- SiPMs signals are pre-amplified by SMART ASIC and then sent to ALPHA ASIC for trigger and charge measurements

Imaging CsI Calorimeter (ICC) module

ICC SiPM carrier board (WLS fibers)



ICC SiPM Edge detector

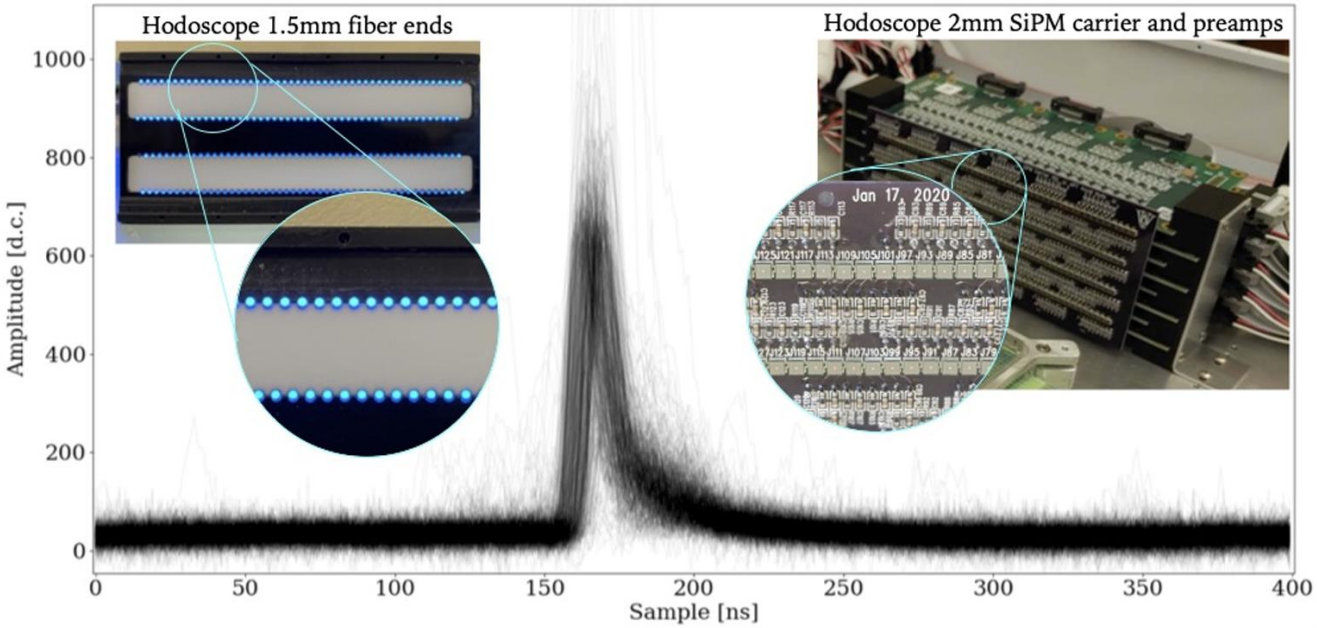


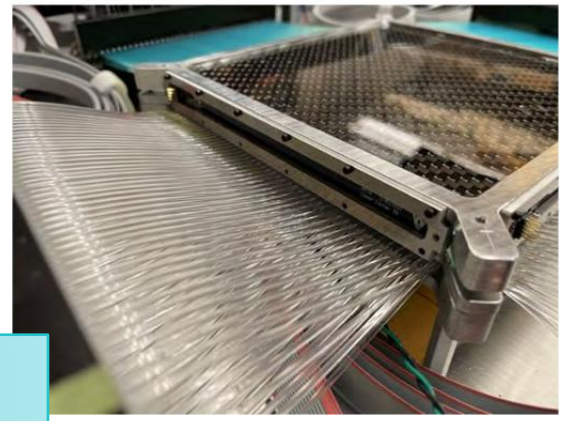
- Each plane is made by 9 CsI 15x15 cm^2 modules
- The two sides of the CsI:Na plane without WLS fibers are readout by a set of 3 Edge Detector each
- Each Edge Detector carries 40 SiPMs (S13360-3050VE)
- All the 40SiPMs are passively connected to a low- and high gain preamplifier stages + ALPHA ASIC (trigger/charge measurements)

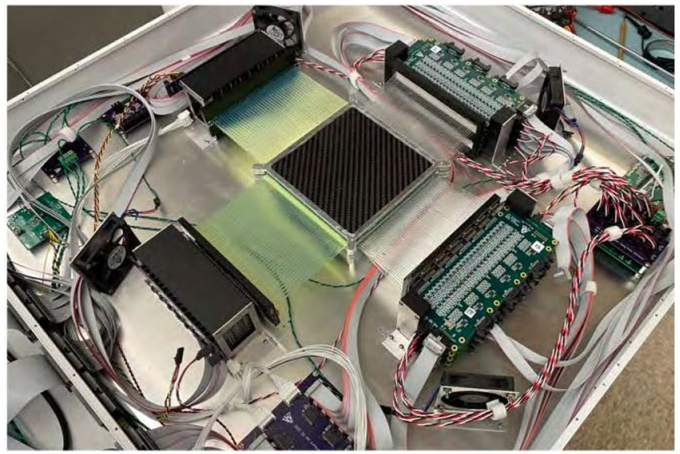
Hodoscope (Hodo)

- Scintillating Fiber (SciFi) tracker
- SiPM carrier boards designed to match the fiber geometry 2x2 mm^2 SiPM (Hamamatsu S13360-2050VE TSV)
- Each SiPM is directly coupled to a single 1.5mm diameter St. Gobain SciFi for an easier position reconstruction
- 3-fold merge of SiPM signals

Muon MIP event in the Hodo tracker prototype

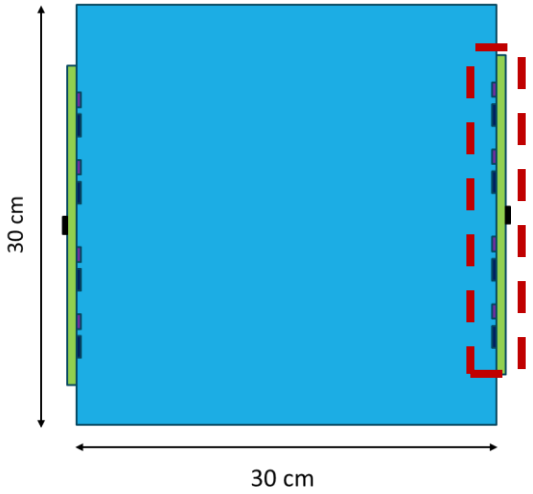




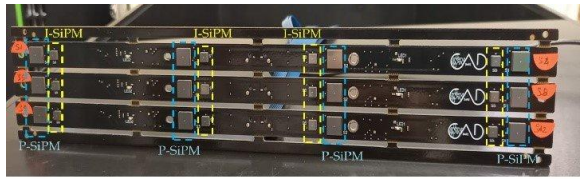


Small Hodo module
15 cm^2 x 15 cm^2

Anti-Coincidence Detector (ACD)

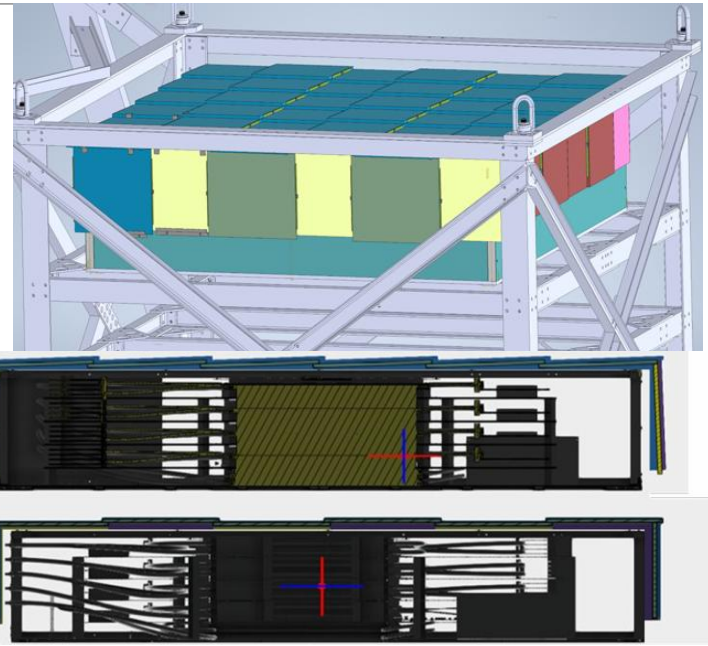


SiPM edge carrier boards with two SiPM sizes

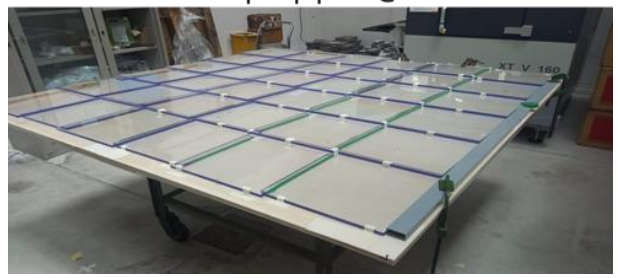


- ACD will provide both **veto** against charged particles and **trigger** for cosmic ray nuclei (Z>2) + complementary charge measurements
- 60 tiles between top (180 x 180 cm^2) and lateral plane (partial coverage)
- Overlap to ensure hermeticity

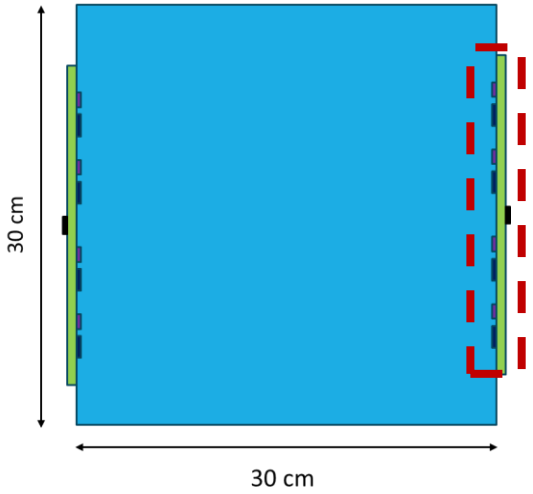
Tile's prototype with black Tedlar wrapping.



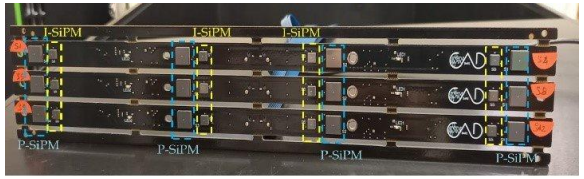
Mockup top plan @ INFN Bari



Anti-Coincidence Detector (ACD)

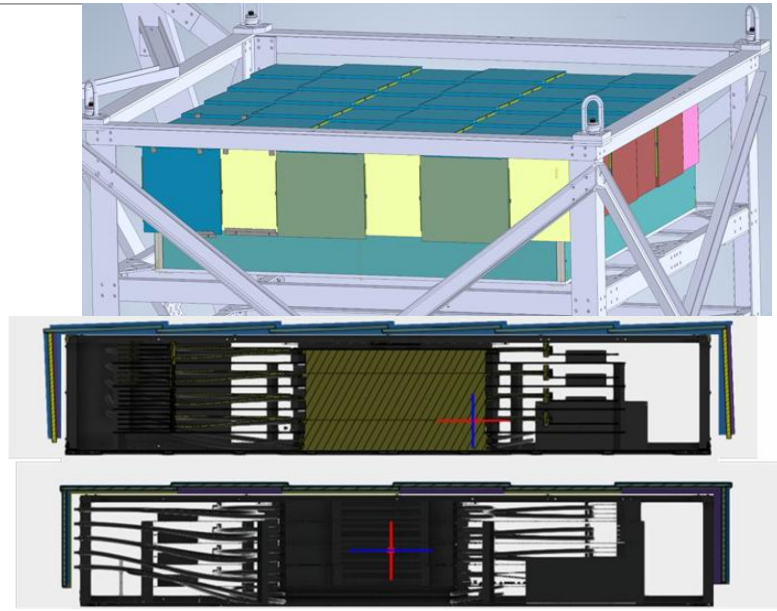


SiPM edge carrier boards with two SiPM sizes

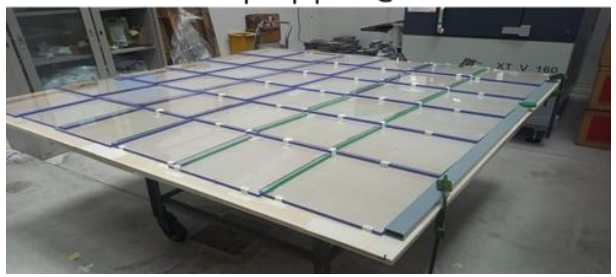


- 30x30x1 cm^3 EJ-200 scintillator tiles
- Each tile with 2 edge carrier boards:
  - 4 SiPMs (Veto) S14160-6050HS
  - 4 SiPMs (Ion trigger) S14160-3050HS
- Tile wrapped with AlMylar + black tedlar
- 3D printed black mask for the edge SiPM carrier board placement and light tightness
- SiPM readout based on BETA ASIC (ICCUB)

Tile's prototype with black Tedlar wrapping.



Mockup top plan @ INFN Bari



Project status

- ❑ Hodo electronics (MUX + Carrier + SMART) produced and tested, ready for integration
- ❑ ICC electronics similar to Hodo, prototype boards produced and test ongoing
- ❑ ICC first small prototype tested, ADAPT flight prototype tests ongoing
- ❑ ACD single tile tested at BT. Full ACD is being populated in these days
- ❑ Progress on simulations and real-time computational pipeline

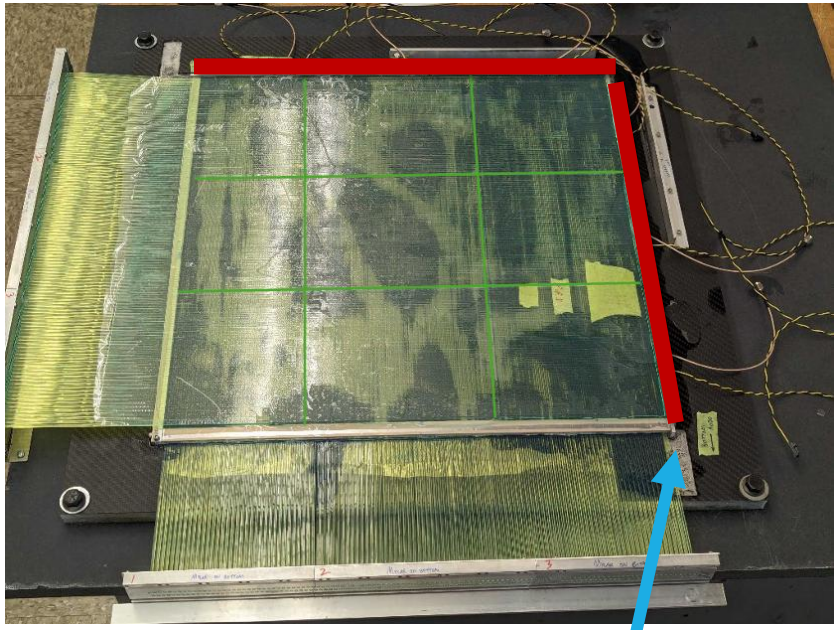
- First expected to be launched in 2025.
- A problem with the launch of a previous balloon has forced a **one-year delay** in the launch schedule

Thank you for your attention

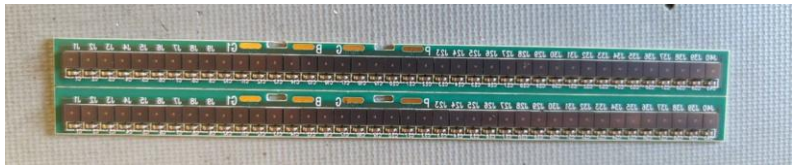
Backup

Imaging CsI Calorimeter (ICC) module

ICC SiPM carrier board (WLS fibers)

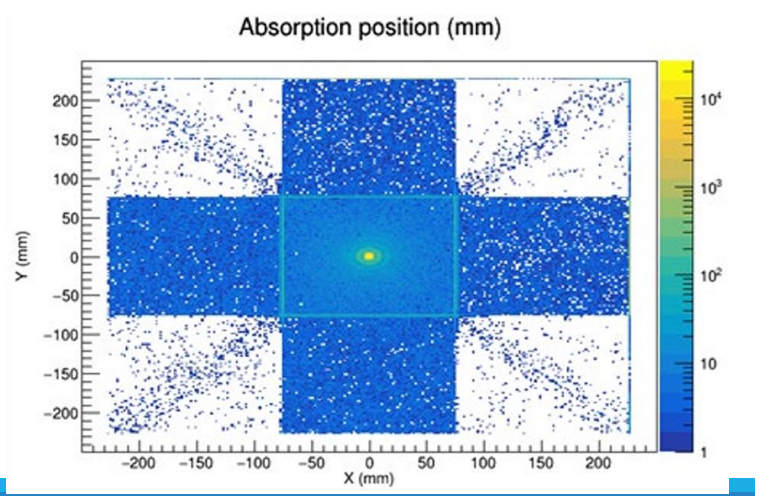


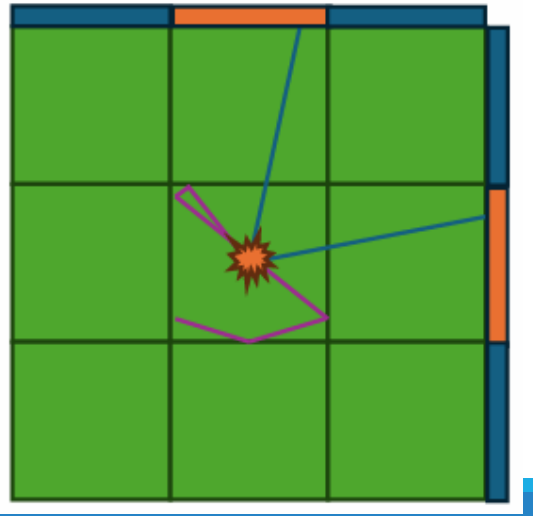
ICC SiPM Edge detector



- Each plane is made by 9 CsI 15x15 cm2 modules
- The two sides of the CsI:Na plane without WLS fibers are readout by a set of 3 Edge Detector each

Since the WLS fibers SiPM are connected in a 3-fold way we need another information to help in resolving the ambiguity

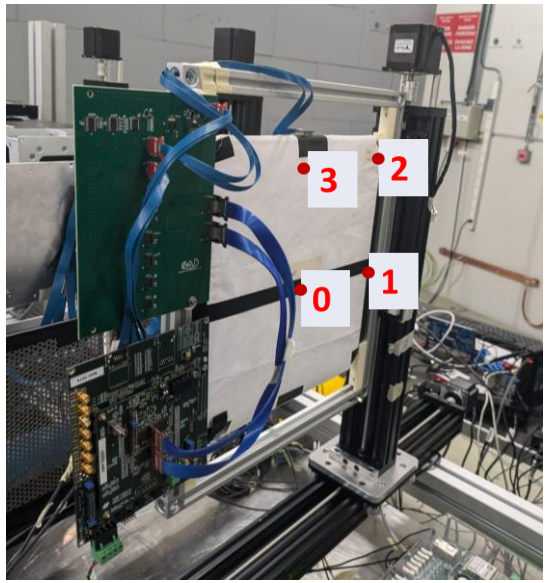




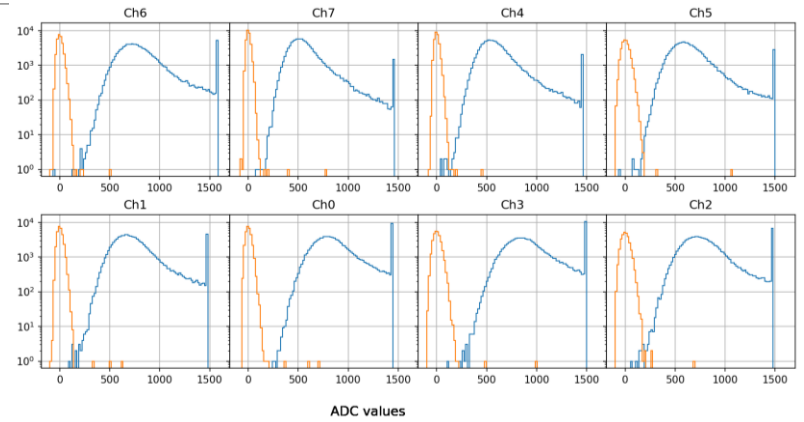
Anti-Coincidence Detector (ACD)

ACD tile and readout capability to detect charged particles has been investigated in a beam test at CERN Proton Synchrotron (PS) in 2024.

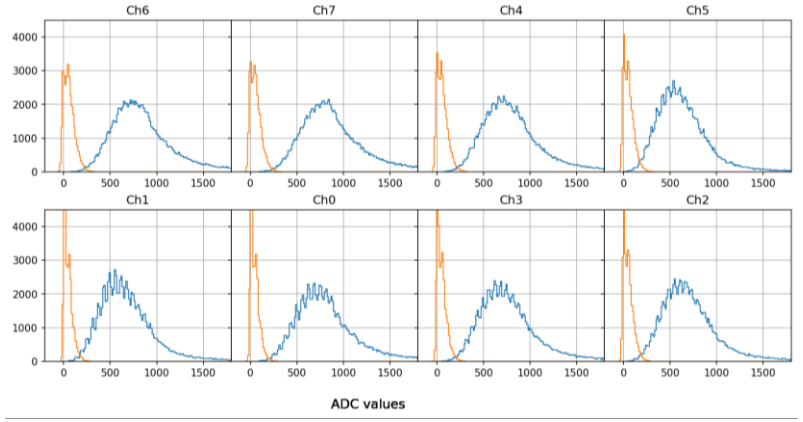
Position	Efficiency (1/3 MIP equivalent)	95% confidence interval
0	99.996 %	99.992% - 99.999%
1	99.997 %	99.991% - 100%
2	99.985 %	99.971% - 99.997%
3	99.985 %	99.970% - 99.997%

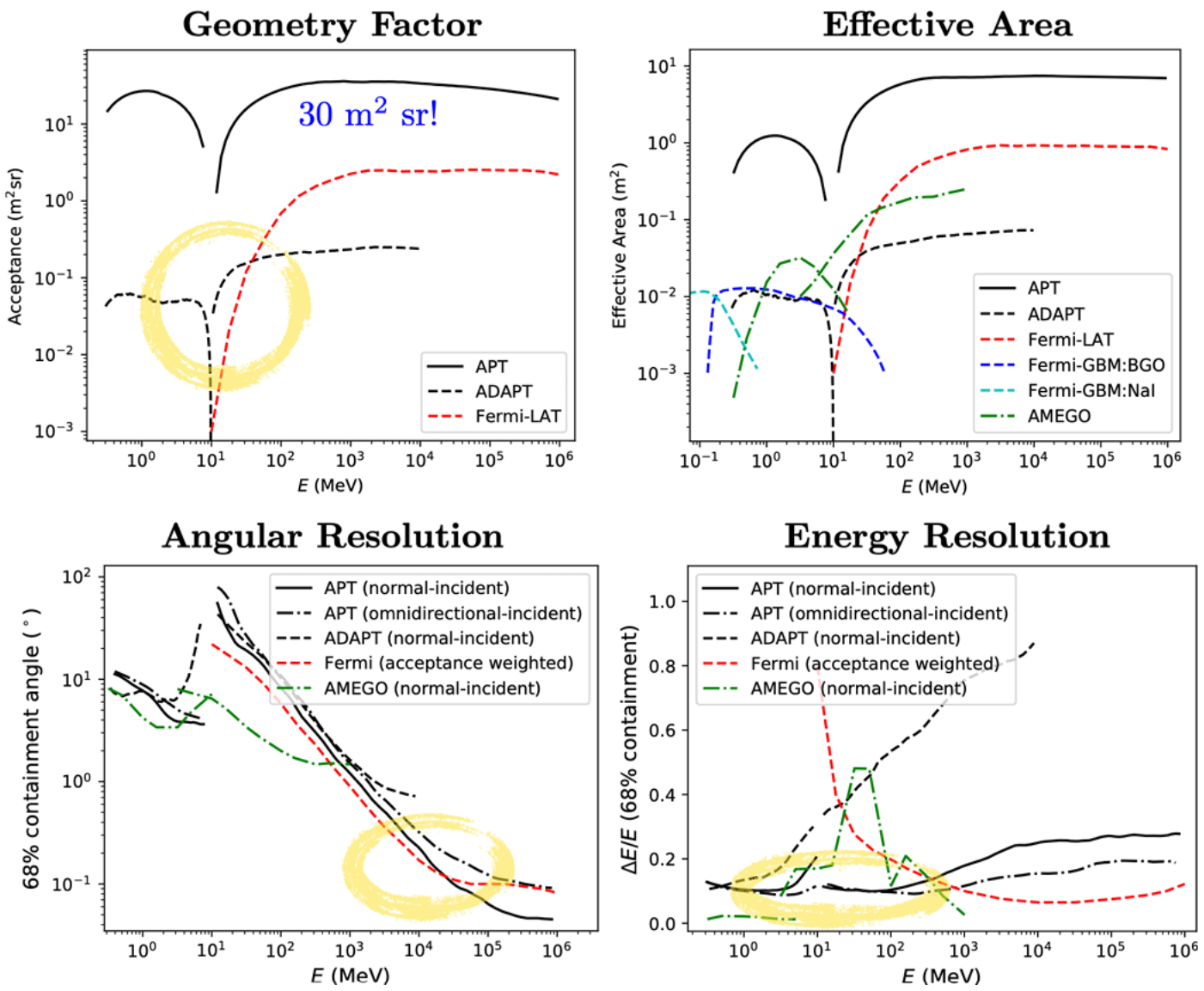


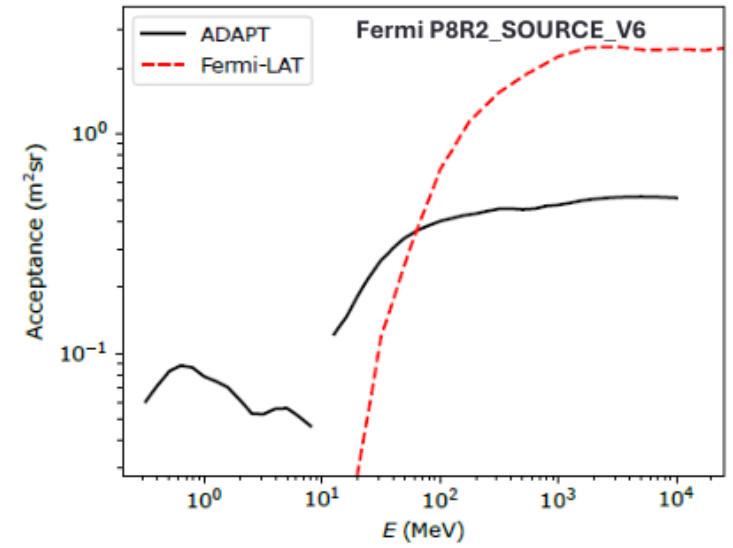
6x6 mm² SiPMs

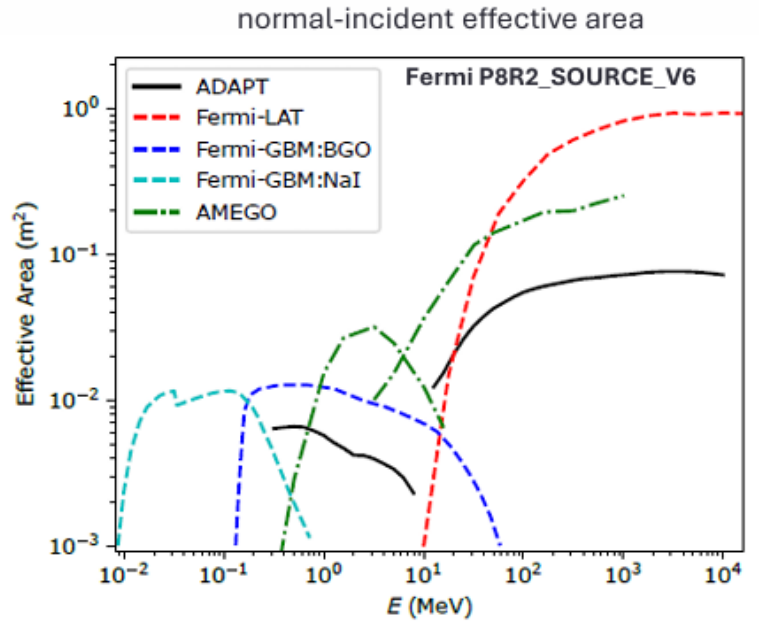


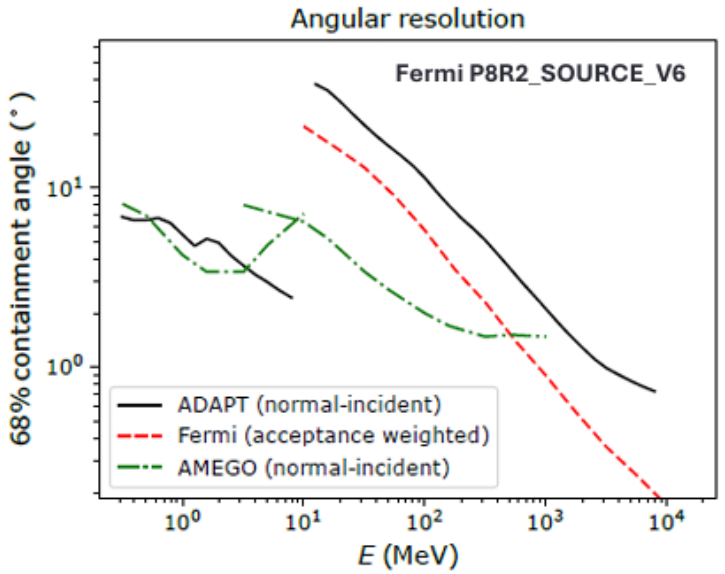
3x3 mm² SiPMs

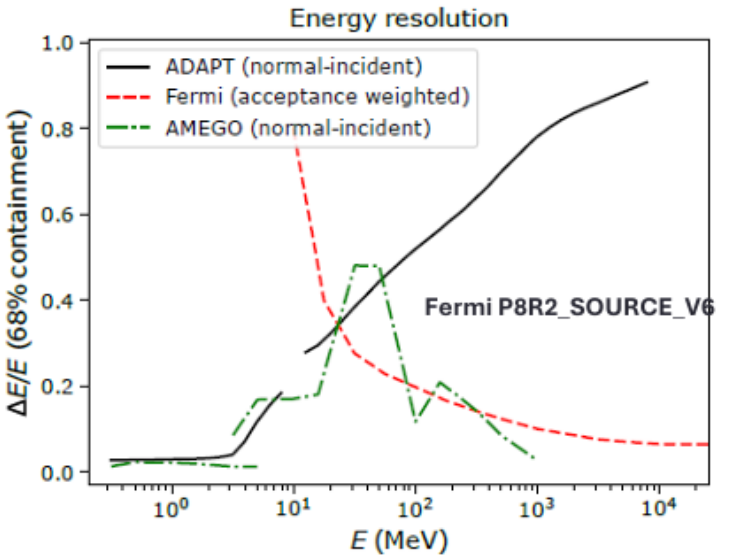



Geometry Factor
30 m² sr!
Acceptance (m²sr)
E (MeV)
APT
ADAPT
Fermi-LAT
Effective Area
Effective Area (m²)
E (MeV)
APT
ADAPT
Fermi-LAT
Fermi-GBM:BGO
Fermi-GBM:NaI
AMEGO
Angular Resolution
68% containment angle (°)
E (MeV)
APT (normal-incident)
APT (omnidirectional-incident)
ADAPT (normal-incident)
Fermi (acceptance weighted)
AMEGO (normal-incident)
Energy Resolution
ΔE/E (68% containment)
E (MeV)
APT (normal-incident)
APT (omnidirectional-incident)
ADAPT (normal-incident)
Fermi (acceptance weighted)
AMEGO (normal-incident)


ADAPT
Fermi-LAT
Fermi P8R2_SOURCE_V6
Acceptance (m²sr)
E (MeV)


normal-incident effective area
ADAPT
Fermi-LAT
Fermi-GBM:BGO
Fermi-GBM:NaI
AMEGO
Fermi P8R2_SOURCE_V6
Effective Area (m²)
E (MeV)


Angular resolution
Fermi P8R2_SOURCE_V6
ADAPT (normal-incident)
Fermi (acceptance weighted)
AMEGO (normal-incident)
68% containment angle (°)
E (MeV)


Energy resolution
ADAPT (normal-incident)
Fermi (acceptance weighted)
AMEGO (normal-incident)
Fermi P8R2_SOURCE_V6
ΔE/E (68% containment)
E (MeV)