The All-sky Medium Energy Gamma-ray Observatory eXplorer (AMEGO-X) Mission Concept

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AMEGO-X Team

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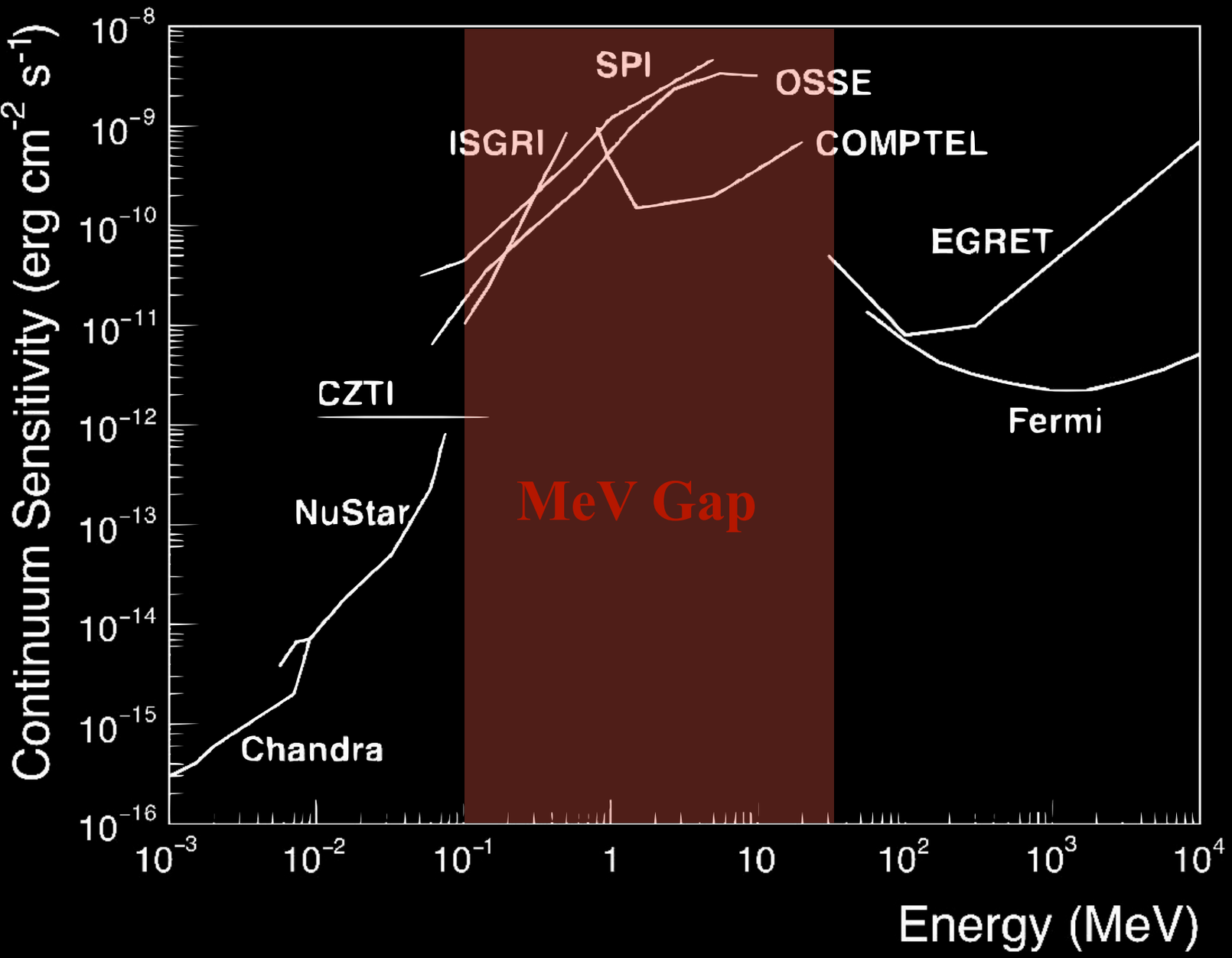
Also with collaborators at INFN, U. Hiroshima, U. Johannesburg, KIT, U. Western Australia, Georgia Tech, Drexel, UNH.
And members of
LIGO, IceCube, CTA.

Overview

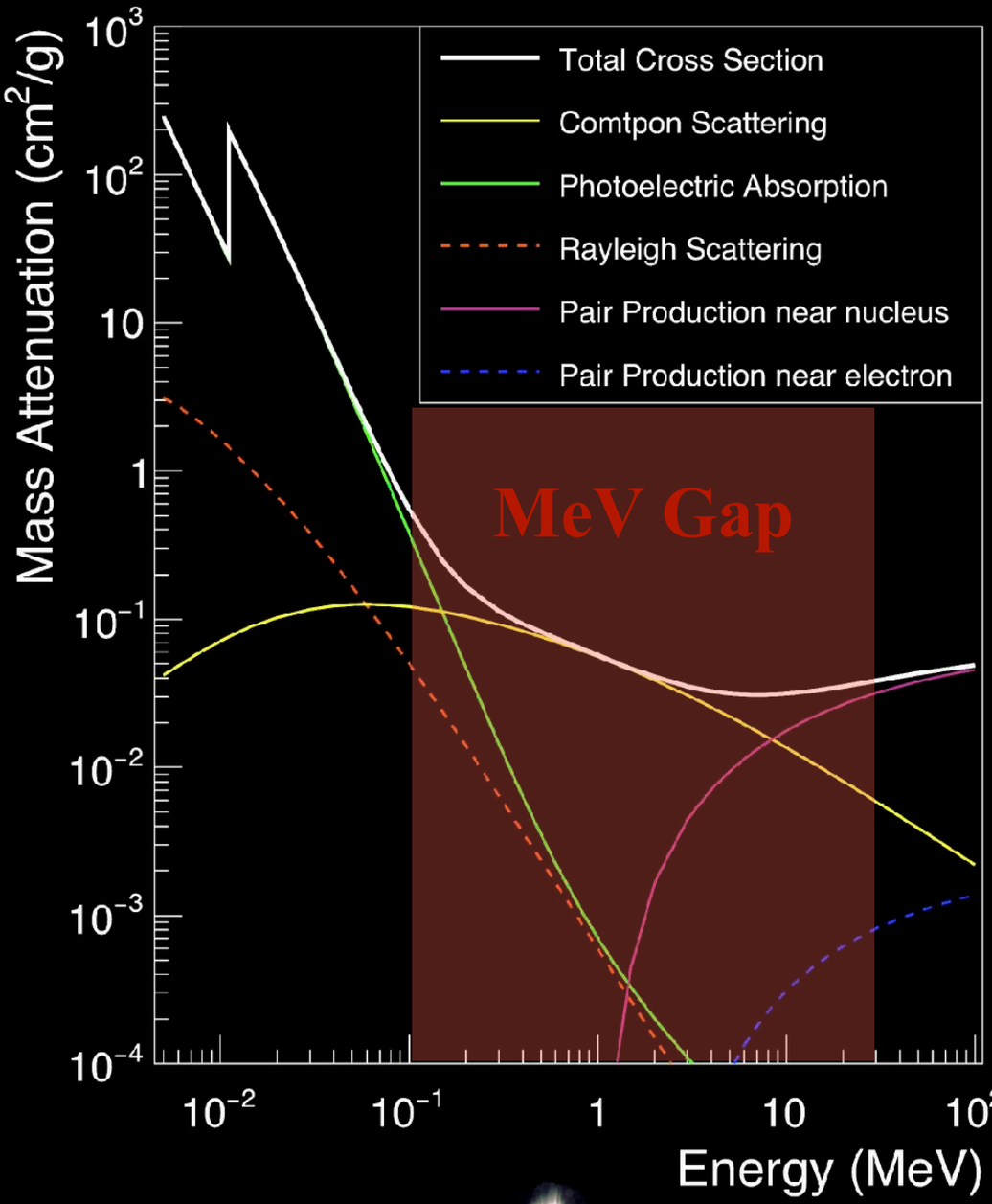
- This talk is primarily based on Caputo+22: arXiv:2208.04990
- The MeV Gap
- AMEGO-X Mission, Instrument, Detectors, and Performance
- Primary Science Goals
- Current Status
- Summary

The MeV Gap



The MeV gap is one of the least explored regions in the electromagnetic spectrum

The MeV Gap

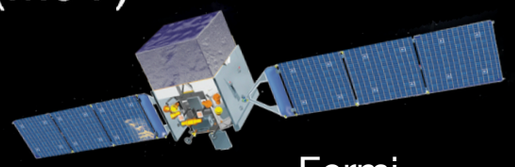


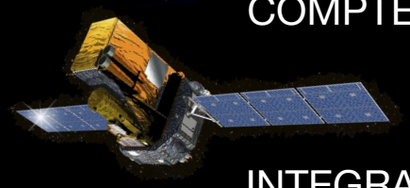
Main limiting factors in the MeV Gap:

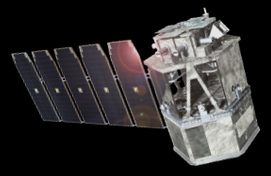
1. Compton scattering is the dominant interaction.
2. High instrumental background.
3. Technological constraints in terms of both hardware and software.


NuStar

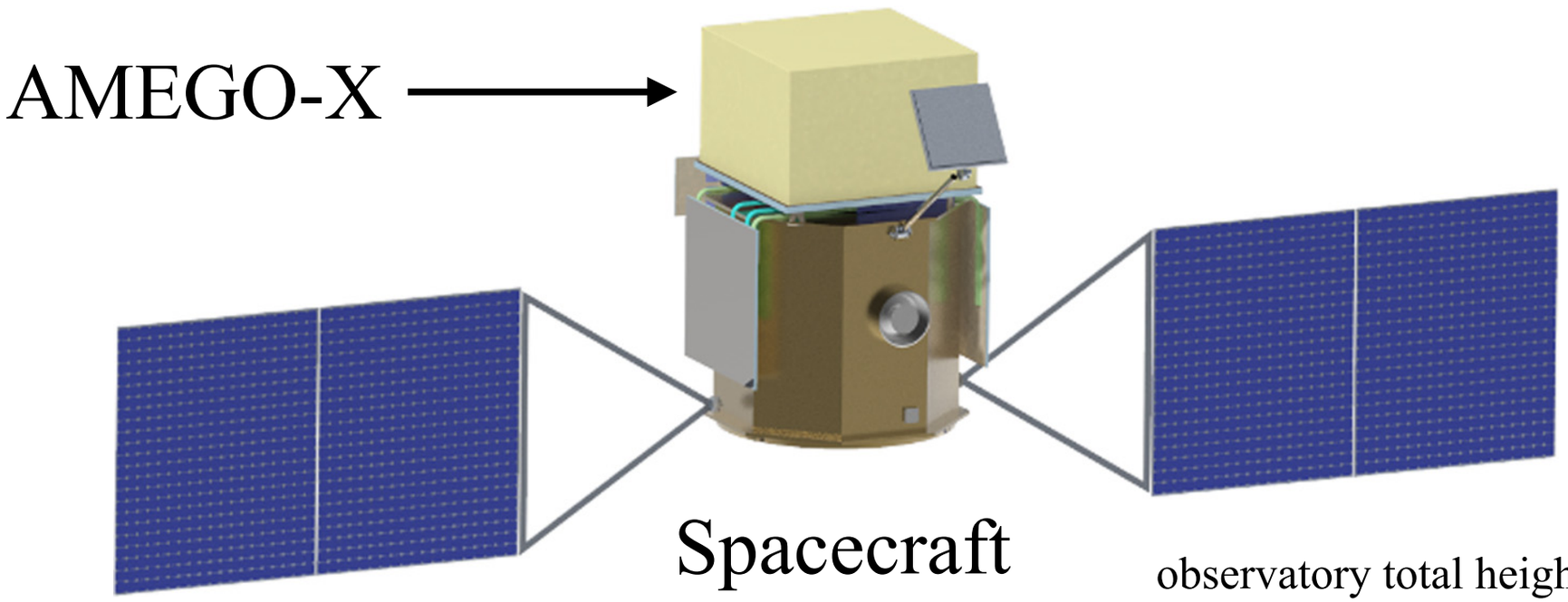

COMPTEL


Fermi


INTEGRAL


COSI

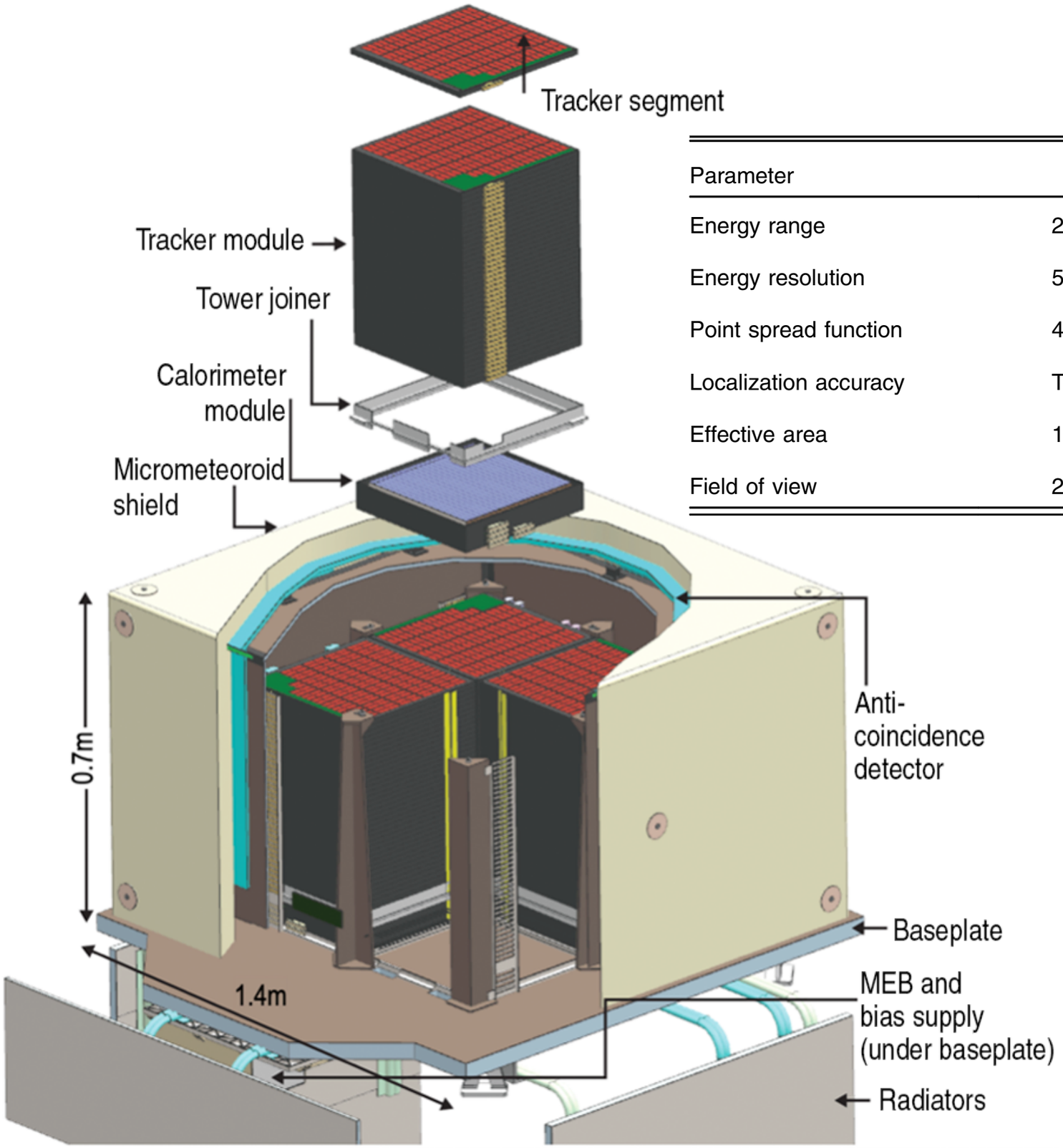
AMEGO-X Mission



observatory total height: 109 inch (2.8 m)
end-to-end width: ~11 m
observatory total mass: 857.9 kg

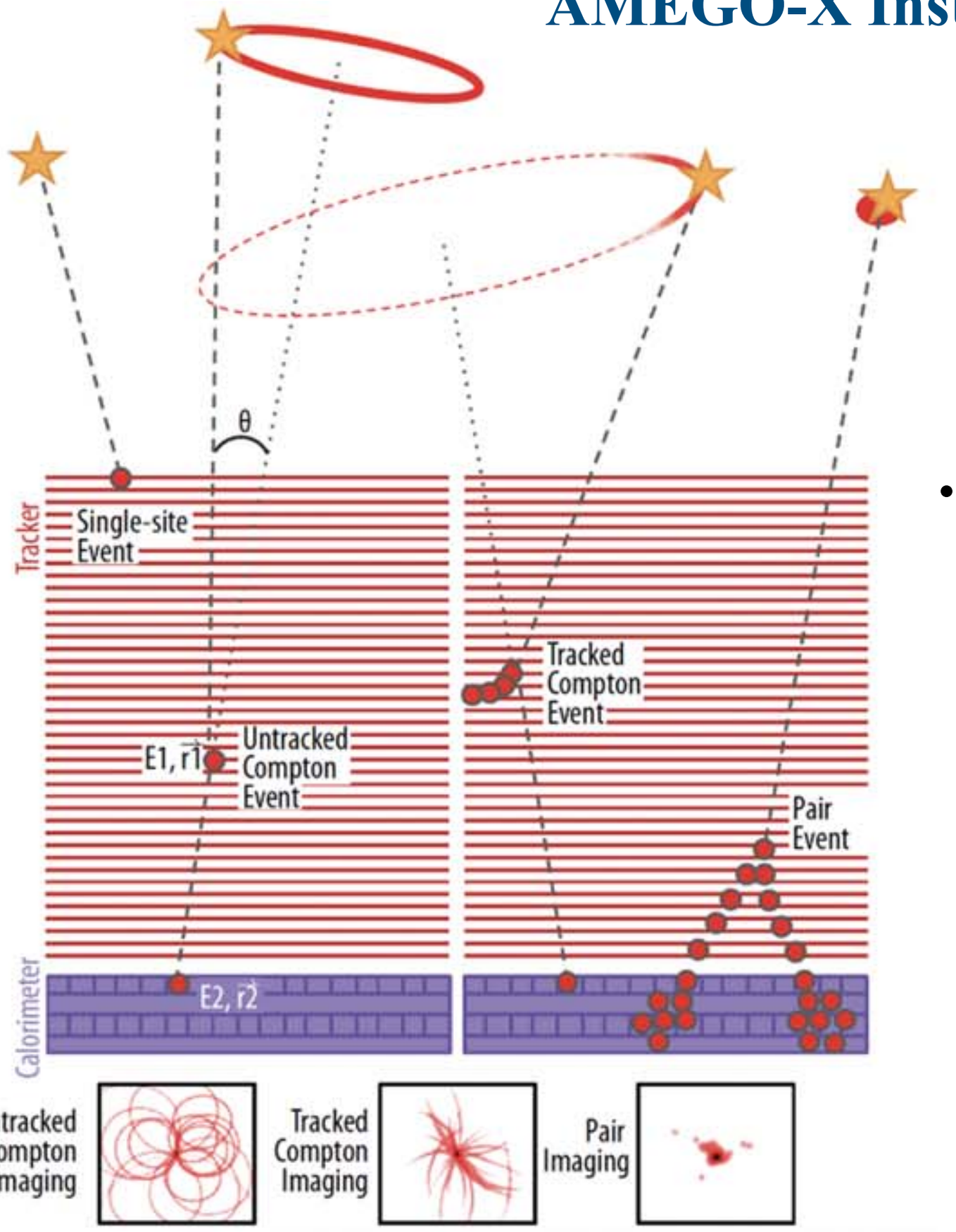
- AMEGO-X is a Medium Explorer satellite mission concept: $300M and 3-year mission lifetime.
- Will have broad MeV continuum, transient, and polarization capabilities.
- Low inclination (5°) low-Earth (600 km) orbit
- All sky coverage: full sky every 3 hours
- Openly distributed transient alerts and localization within 30 seconds.
- Addresses two themes and priorities from NASA's Decadal Survey (Astro2020):
  - New Messengers and New Physics: New Windows in the Dynamic Universe
  - Cosmic Ecosystems: Unveiling the Drivers of Galaxy Growth

AMEGO-X Instrument



Parameter	
Energy range	25 keV to 1 GeV
Energy resolution	5% FWHM at 1 MeV, 17% (68% containment half width) at 100 MeV
Point spread function	4 deg FWHM at 1 MeV, 3 deg (68% containment) at 100 MeV
Localization accuracy	Transient: 1 deg (90% CL radius), persistent: 0.6 deg (90% CL radius)
Effective area	1200 cm^2 at 100 keV, 500 cm^2 at 1 MeV, 400 cm^2 at 100 MeV
Field of view	2π sr (<10 MeV), 2.5 sr (>10 MeV)

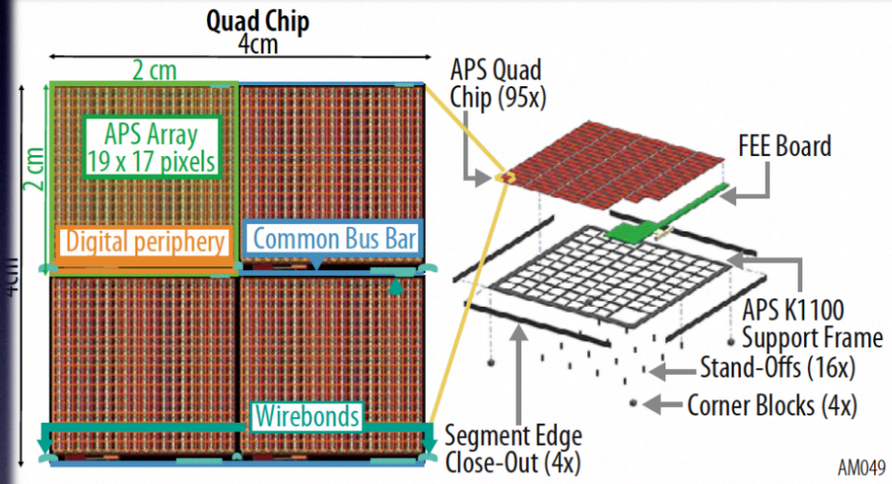
AMEGO-X Instrument

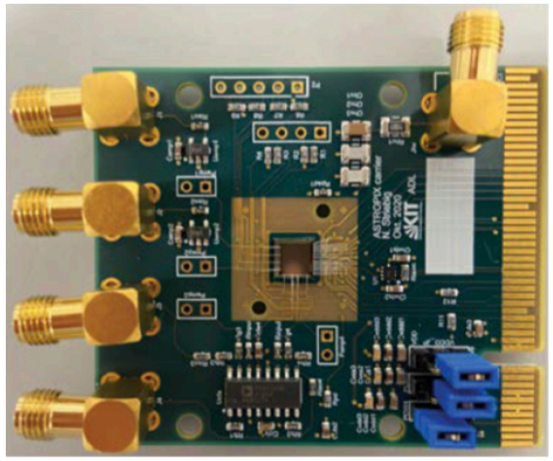


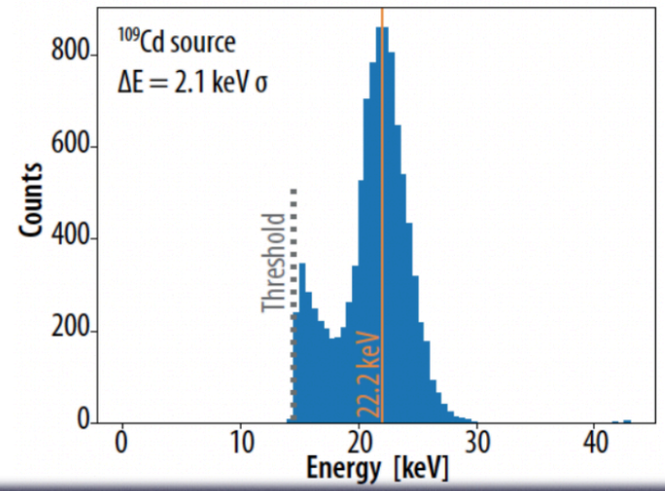
- AMEGO-X is a highly versatile instrument, sensitive to 3 types of interactions: single-site, Compton, and pair-production.

AMEGO-X Detectors

Silicon Pixel tracker: AstroPix



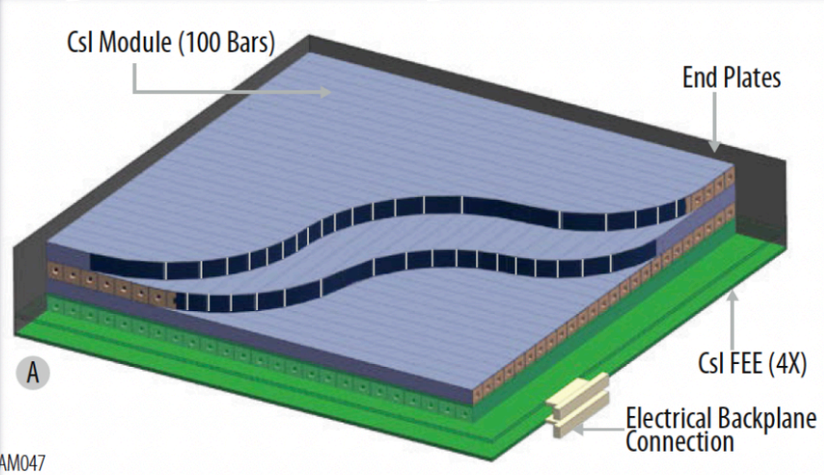


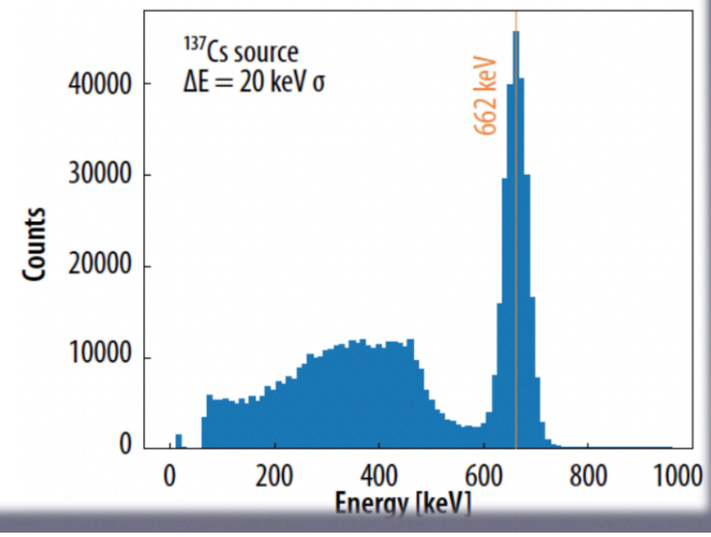


A. Steinhebel et al., SPIE 2022; arXiv: 2209.02631

High-heritage Calorimeter

Caputo+22: arXiv:2208.04990

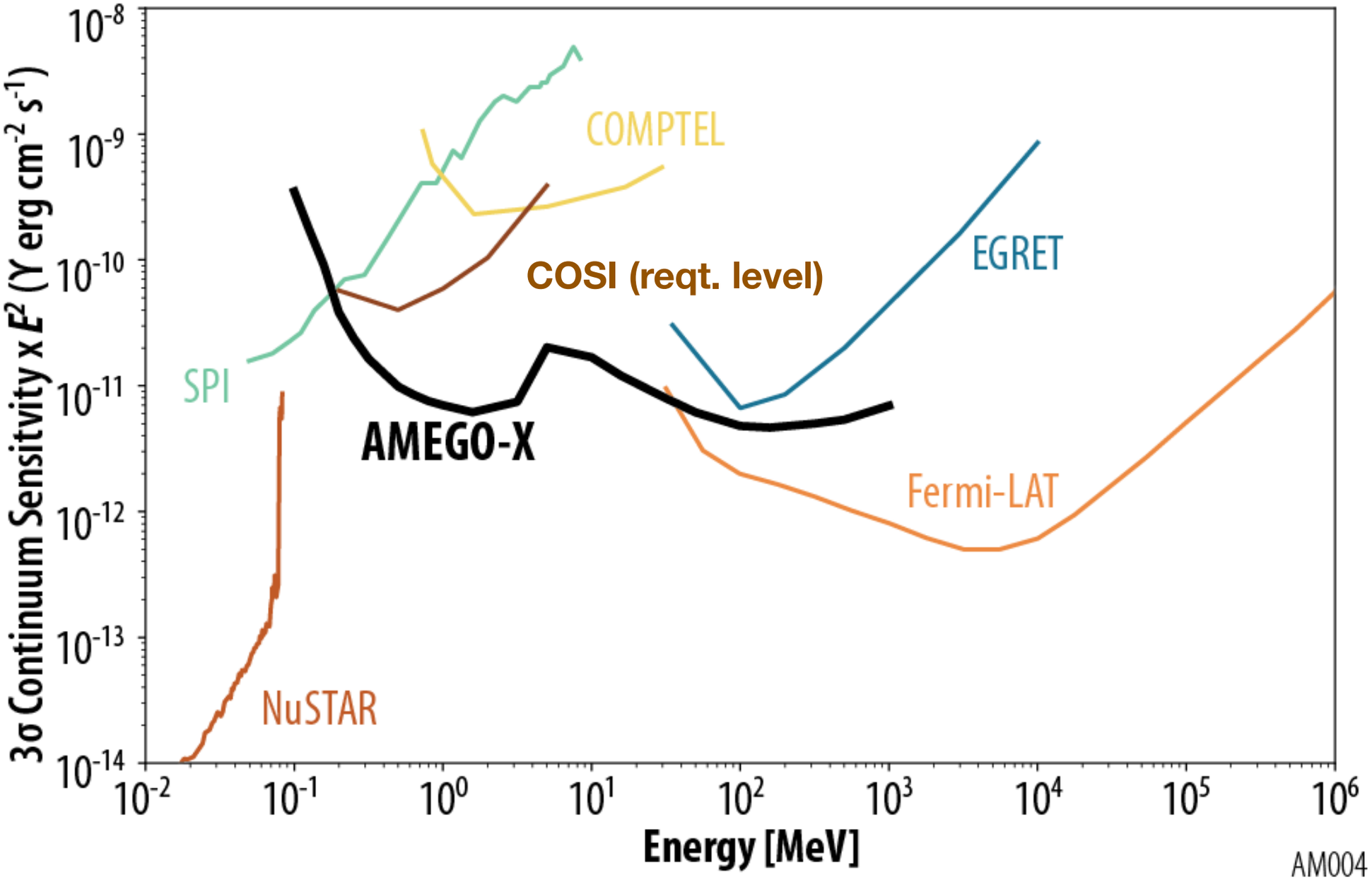




Slide credit: Regina Caputo

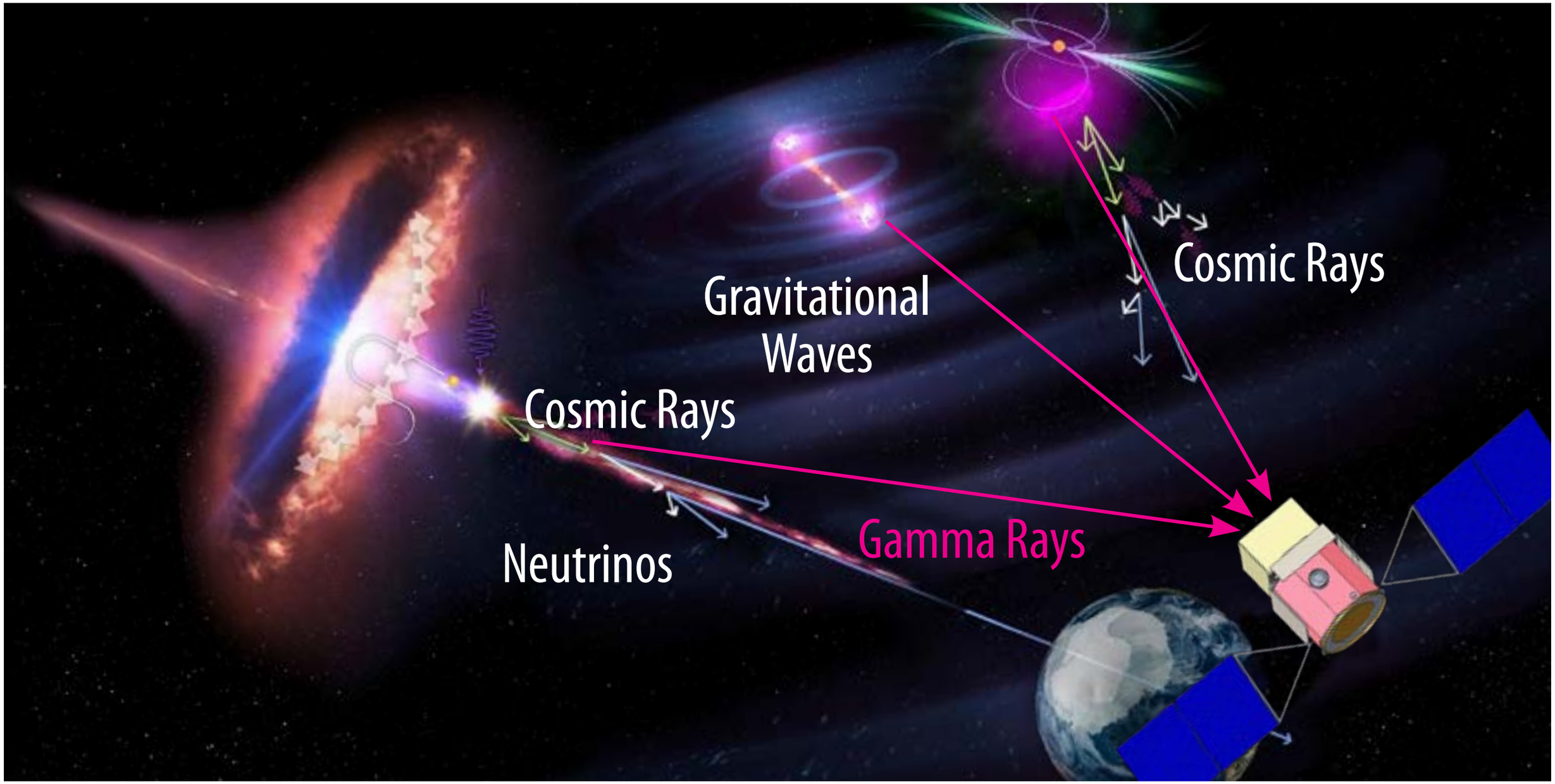
- Silicon Pixel tracker: 40 layers, 95 quad chips/layer.
- The AstroPix detectors enable observations at lower photon energies, achieve an overall increase in sensitivity, and are simpler to integrate compared with previous silicon detector technologies.
- CsI Calorimeter: 4 layers, 25 bars per layer read out by SiPMs
- The AMEGO-X calorimeter utilizes a design based on Fermi-LAT. The team is based out of NRL.

AMEGO-X Performance



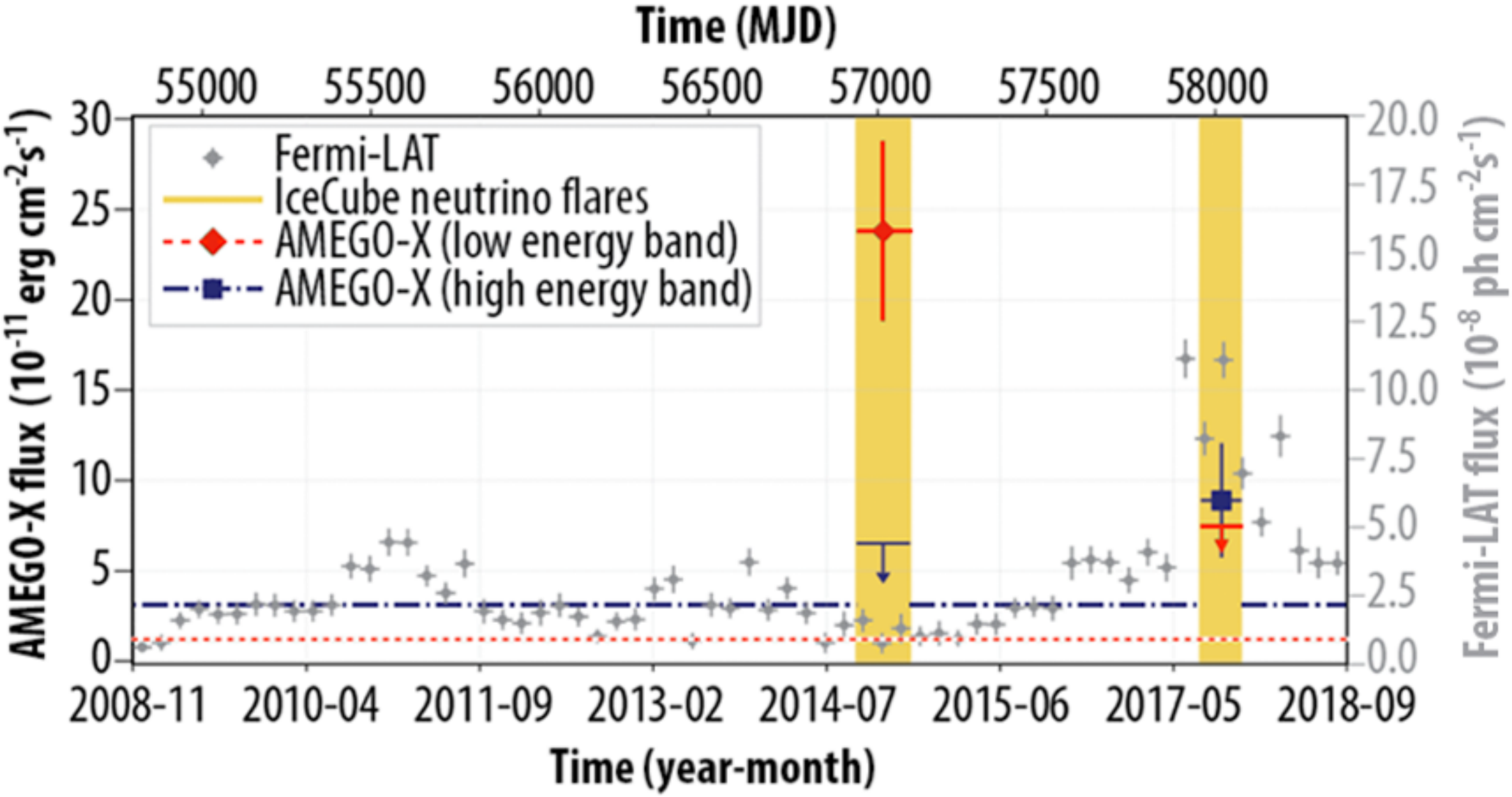
- Will also have sensitivity to single-site events for transients between 25 - 100 keV (see Martinez-Castellanos+21).
- See extra slides for angular resolution and effective area.

Primary Science Goals



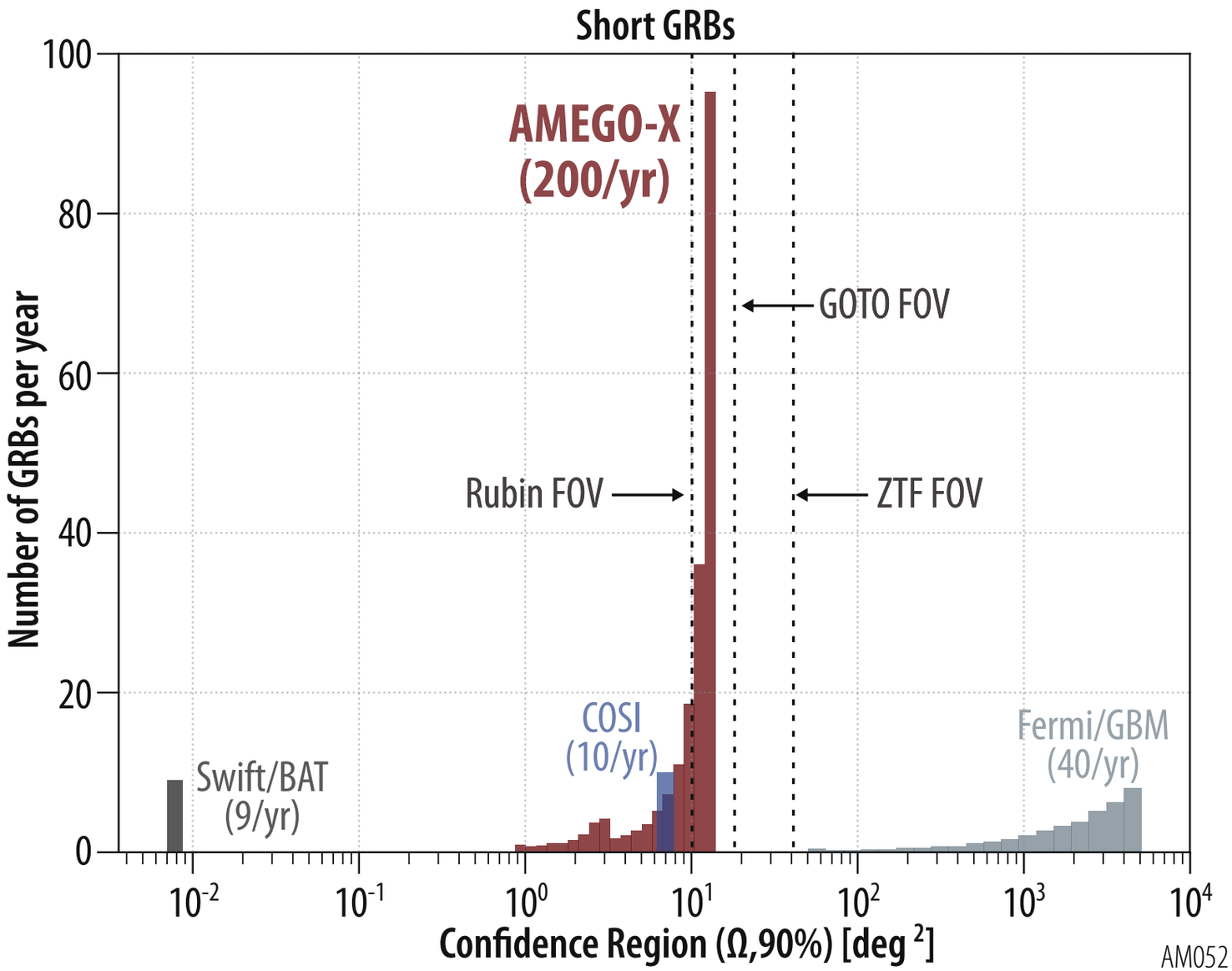
1. **Gamma-rays, Cosmic rays, and neutrinos**: Do supermassive black holes accelerate cosmic rays and produce neutrinos?
2. **Gamma-rays and Gravitational Waves:** How do binary neutron star mergers produce relativistic jets and what is the structure of those jets?
3. **Gamma-rays and Cosmic rays:** Where are cosmic rays accelerated in the Galaxy?

Gamma-rays, Cosmic rays, and neutrinos



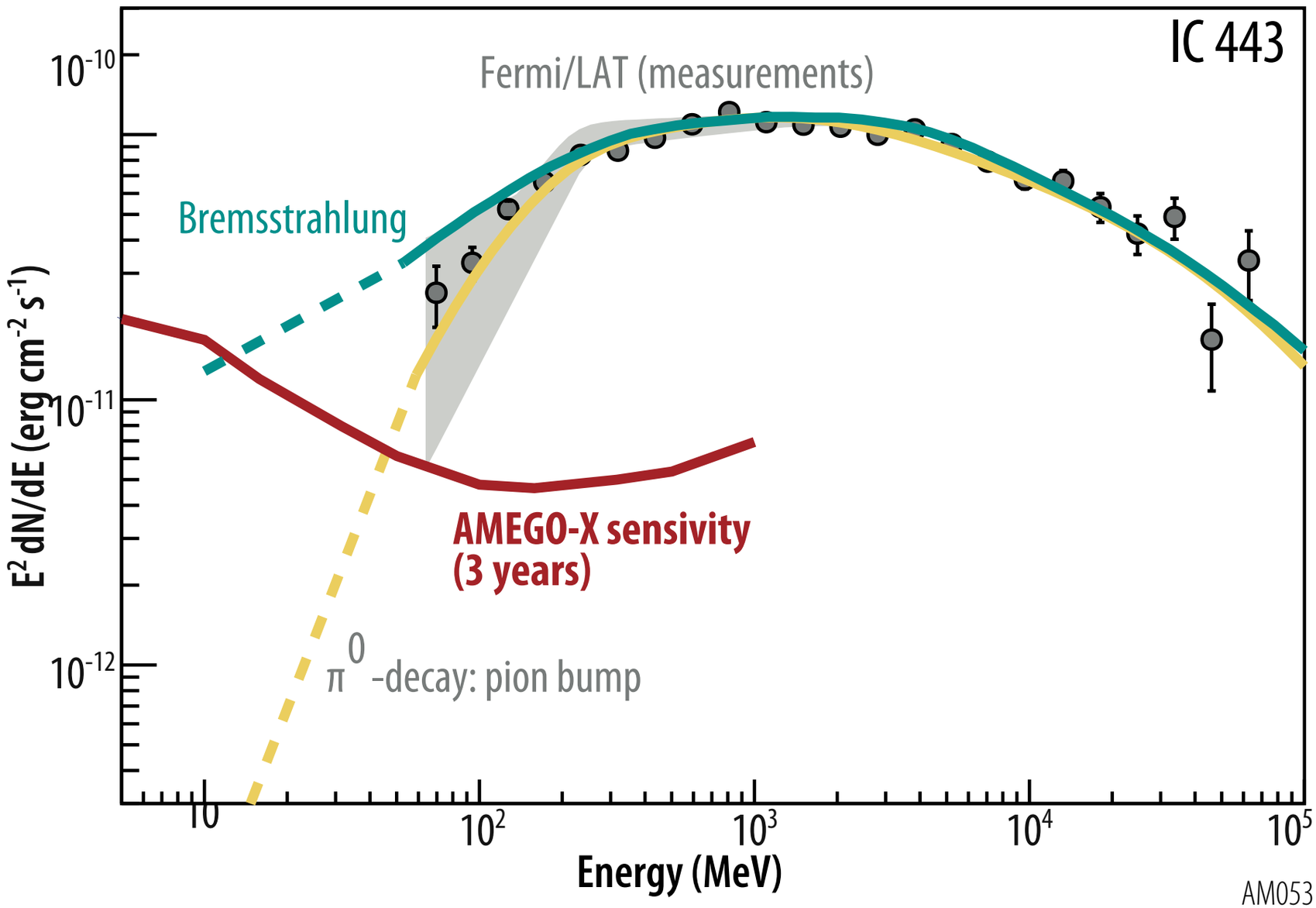
- Based on current flare data, both hadronic and leptonic models are consistent with observed blazer spectra.
- By monitoring the entire medium-energy gamma-ray sky every 3 hours, AMEGO-X will observe in real-time the potential sources of IceCube neutrinos and correlate the timing between gamma-ray and neutrino flares.

Gamma-rays and Gravitational Waves



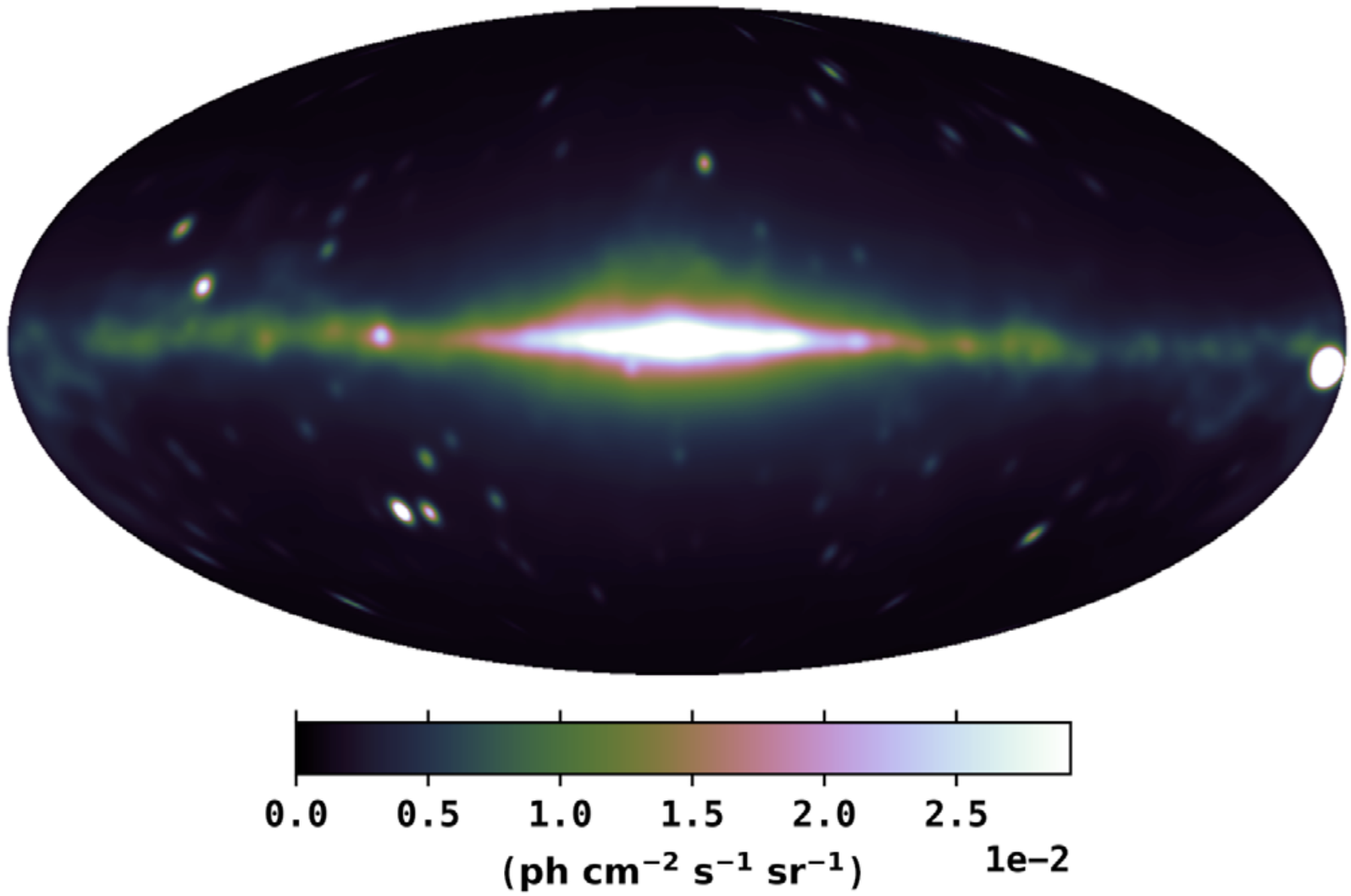
- SGRBs are brightest in the AMEGO-X energy band, and thus AMEGO-X will provide unique insight into the physics of BNS mergers.
- AMEGO-X will detect >200 SGRBs per year with the ideal combination of sensitivity and localization accuracy.
- A smaller localization uncertainty will dramatically decrease the time needed to search for and precisely localize the SGRB afterglow or kilonova emission via X-ray, optical, and radio follow-up.

Gamma-rays and Galactic Cosmic Rays



- AMEGO-X will detect supernova remnants, such as IC 443, between 30 MeV and 1 GeV, enabling identification of proton acceleration.

The MeV Sky



- With an order of magnitude increase in sensitivity in this energy band, AMEGO-X will deliver science results of significant and varying interest, including a multiyear catalog of the the full medium-energy gamma-ray sky, as well as unprecedented measurements of the Galactic diffuse continuum emission and extragalactic gamma-ray background.

Current Status

- Developing AstroPix detectors.
- Submitted proposal to increasing the technical readiness level of the hardware by building a prototype AMEGO-X tower with flight-like AstroPix detector.
- Implement novel event identification and reconstruction techniques to improve the predicted performance
- Resubmit in next MIDEX call ~2025-26

Summary

- Extreme processes that produce gravitational waves and accelerate neutrinos and cosmic rays also produce gamma rays.
- Multimessenger astrophysics needs a wide-field, all-sky, sensitive gamma-ray telescope.
- AMEGO-X will provide this, and address three primary science goals connecting to all four cosmic messengers.

Thank You!