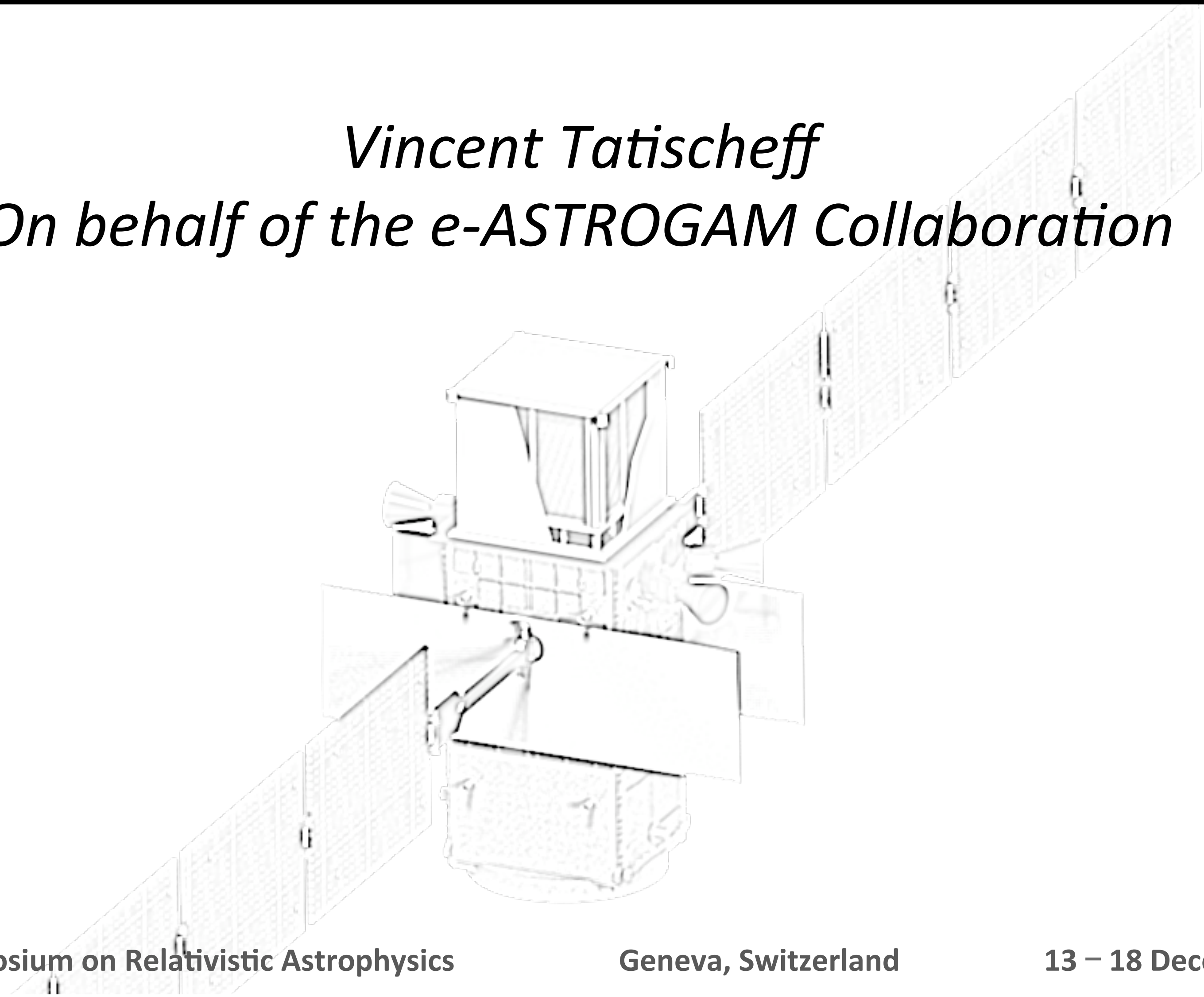
The e-ASTROGAM mission

A wide-field observatory for the MeV / sub-GeV band

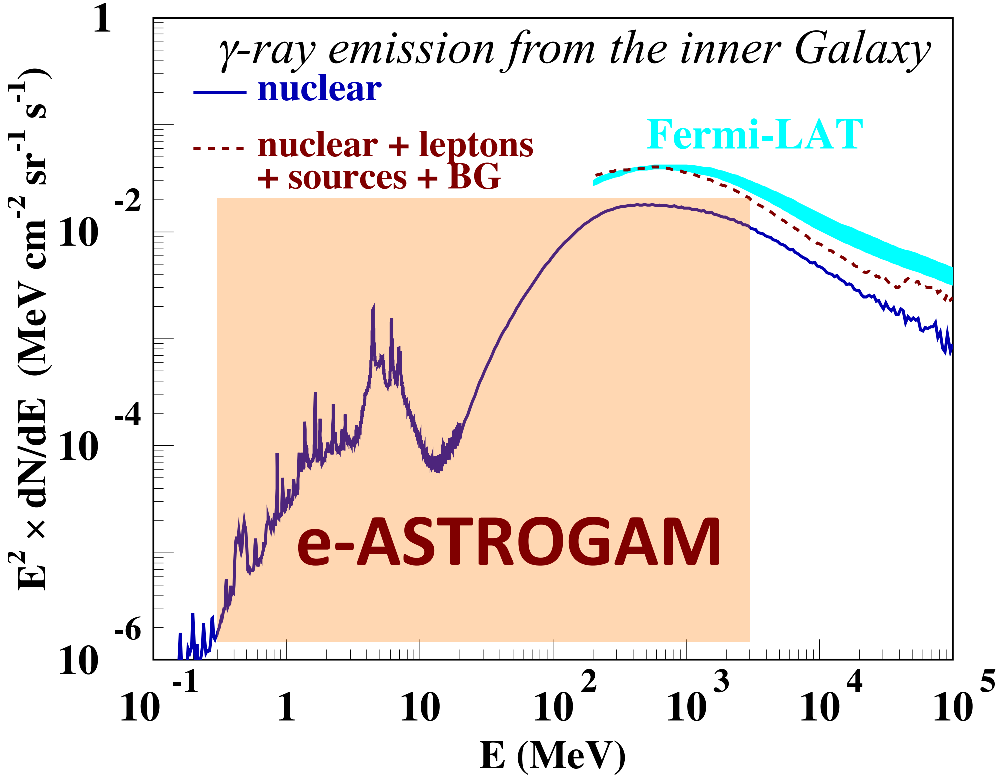
Vincent Tatischeff
On behalf of the e-ASTROGAM Collaboration

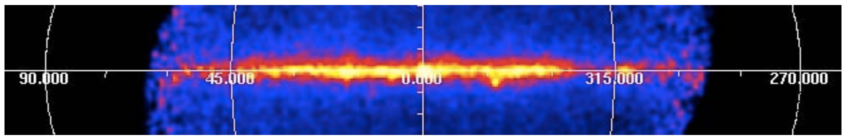


28th Texas Symposium on Relativistic Astrophysics Geneva, Switzerland 13 – 18 December 2015

e-ASTROGAM The MeV/sub-GeV domain

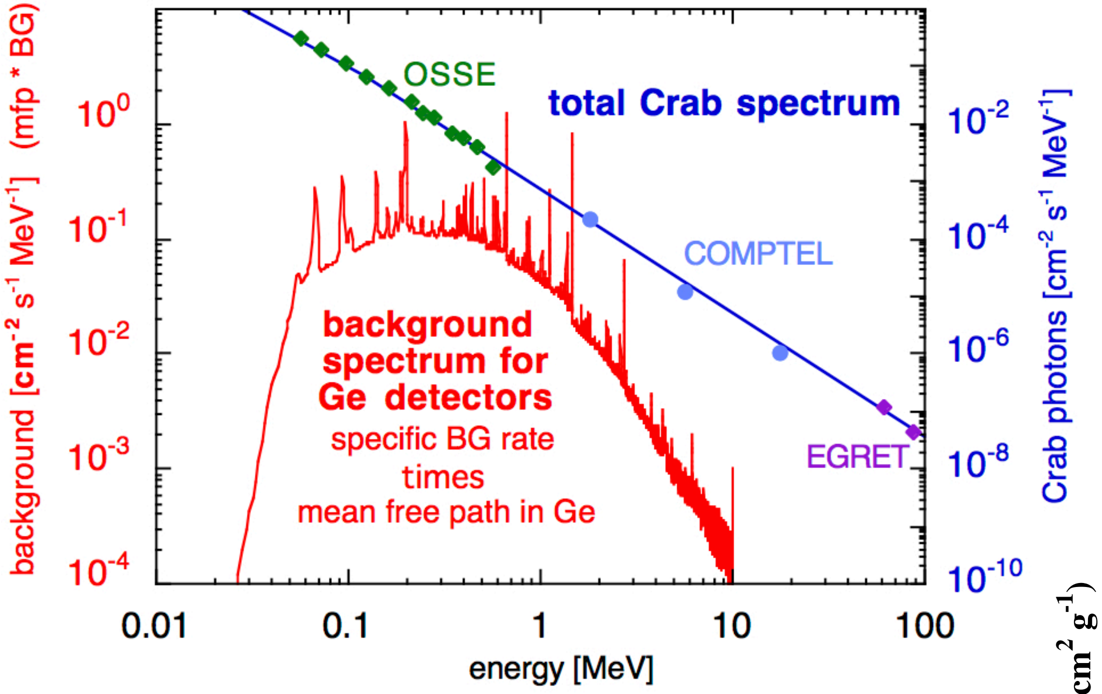
- Cosmic accelerators (thermal/non thermal transition, jet launching…): active galactic nuclei, SNRs, accreting stellar black holes and neutron stars…





- Nuclear spectroscopy (independent of ionization state and temperature): nucleosynthesis (γ-ray radioactivities), low-energy cosmic-ray physics, high-energy solar physics…

e-ASTROGAM Observational challenges

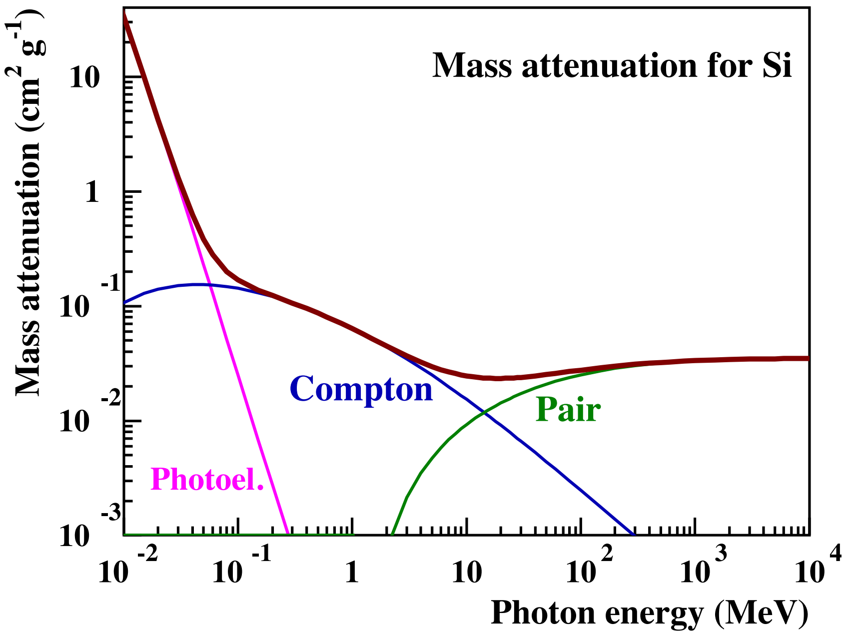


- The MeV range is the domain of nuclear γ-ray lines

⇒ Strong instrumental background from activation of space-irradiated materials

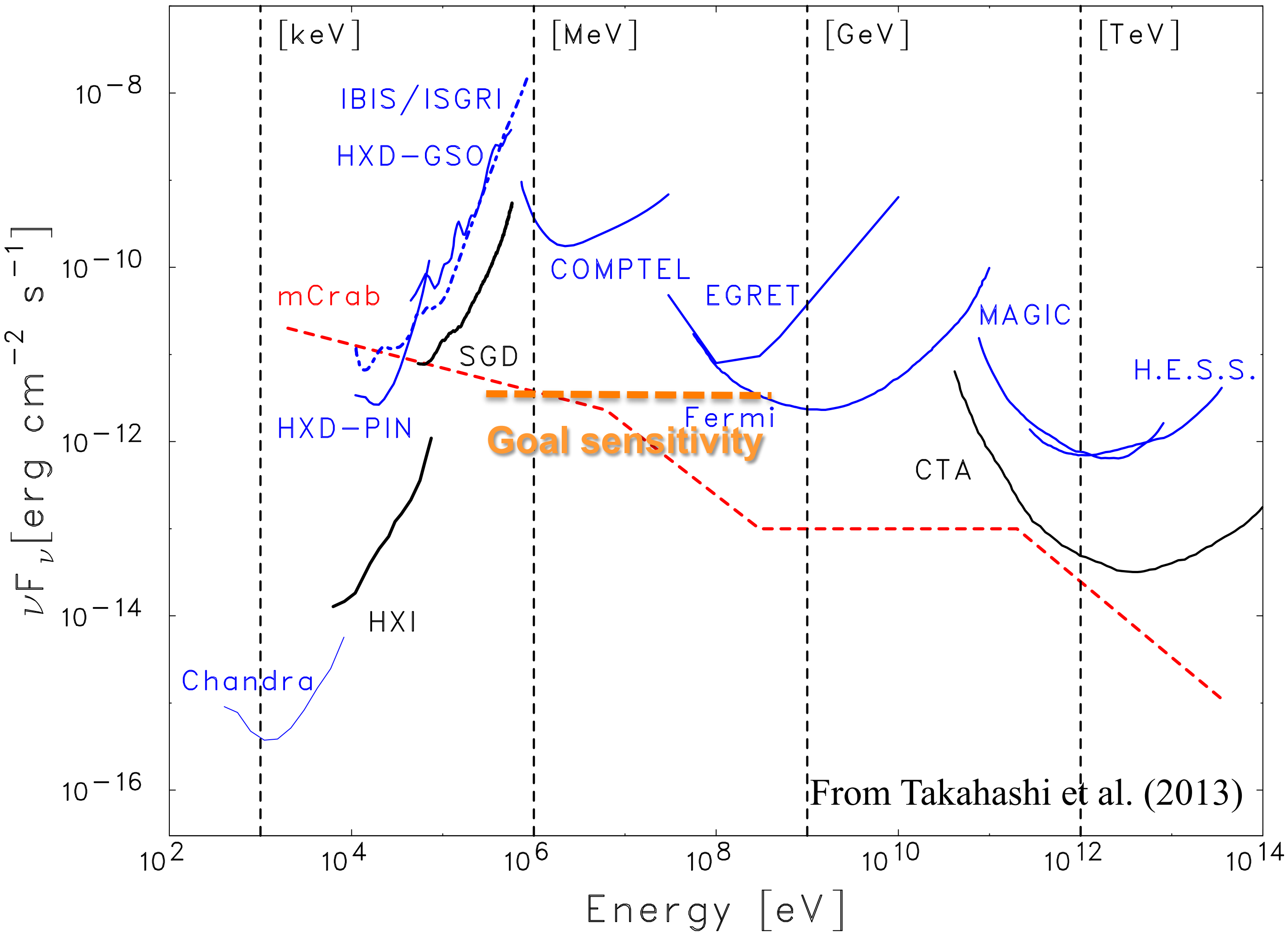
- Photon interaction probability reaches a minimum at ~ 10 MeV
- Three competing processes of interaction, Compton scattering being dominant around 1 MeV

⇒ Difficult to reconstruct the events



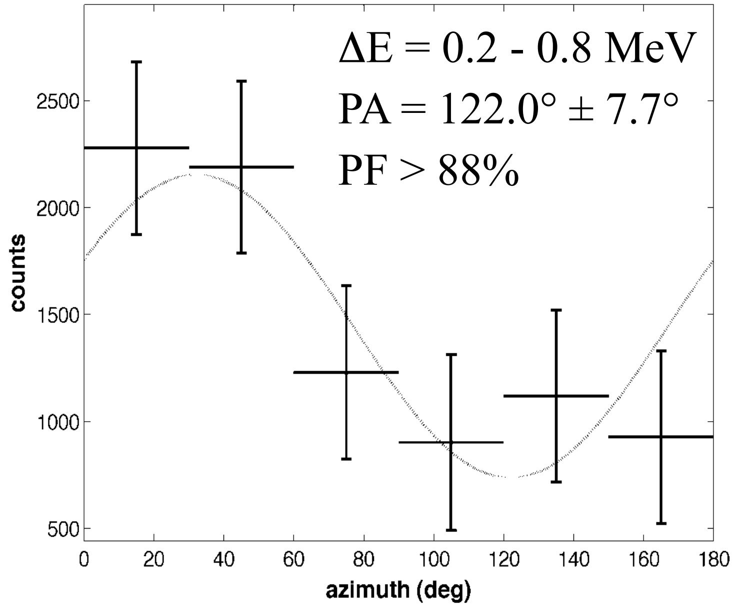
e-ASTROGAM Sensitivity requirement

- Improve sensitivity by a factor of about 50 in the **mostly unexplored energy range 0.3 - 100 MeV** (continuum and line detection)

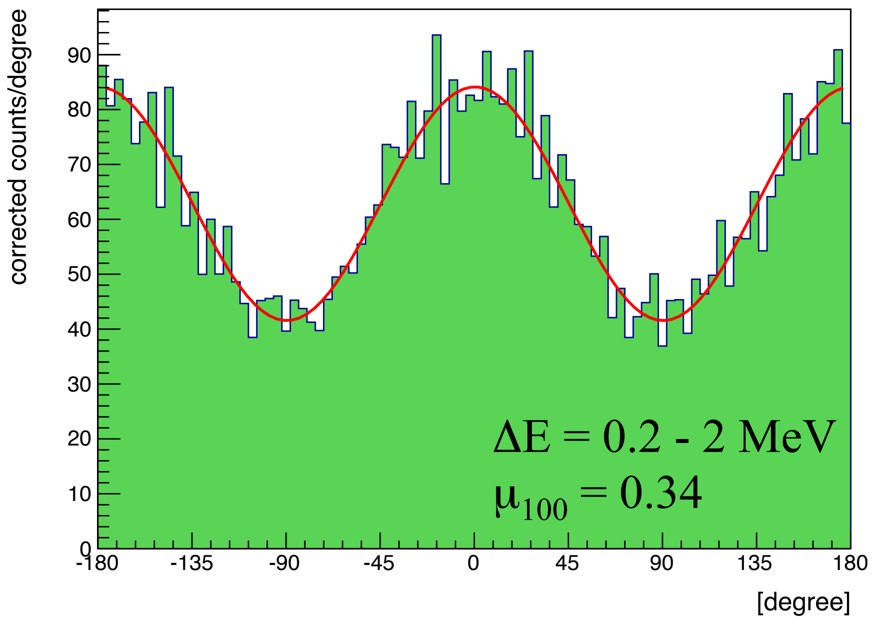


e-ASTROGAM Gamma-ray polarization

- γ-ray polarization in **objects emitting jets** (Blazars, GRBs, X-ray binaries) or with **strong magnetic field** (pulsars, magnetars) can pose strong constraints on the magnetic field structure and the nature of the γ-ray emission process
- γ-ray polarization from **cosmological sources** (Blazars, GRBs) will address fundamental questions related to Lorentz Invariance (vacuum birefringence)



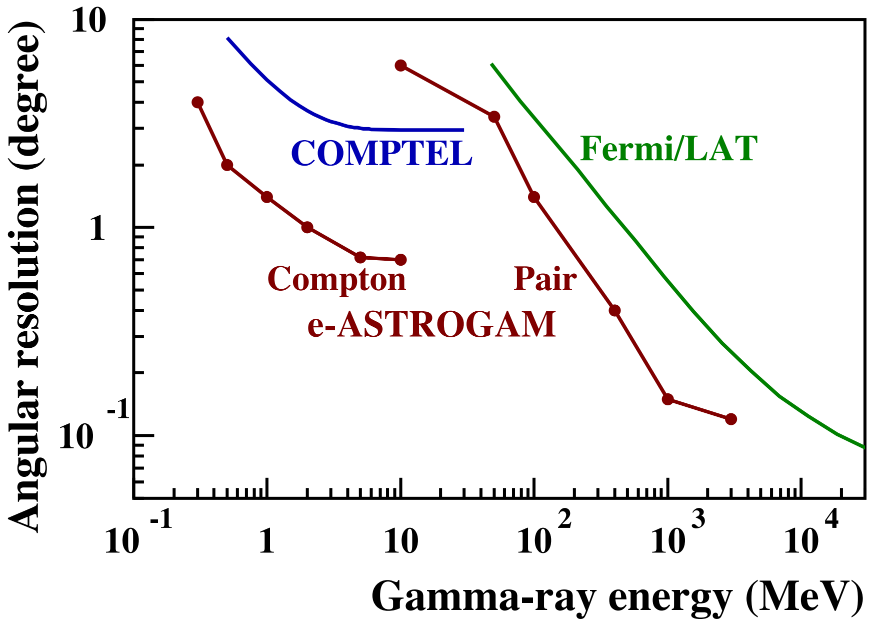
INTEGRAL/IBIS *polarigramme for the* ***Crab*** *emission in the off-pulse and bridge intervals (Forot et al. 2008)*



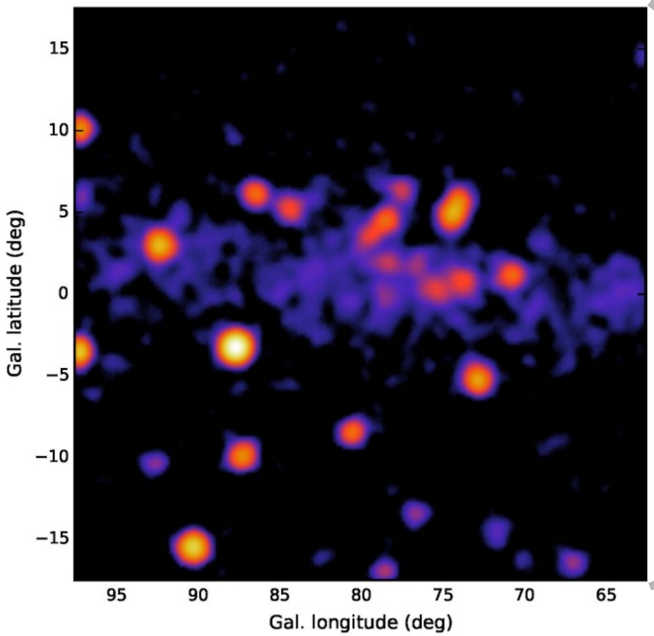
e-ASTROGAM *polarization response for a 100% polarized,* ***10 mCrab-like*** *source observed on axis for 10^6 s*

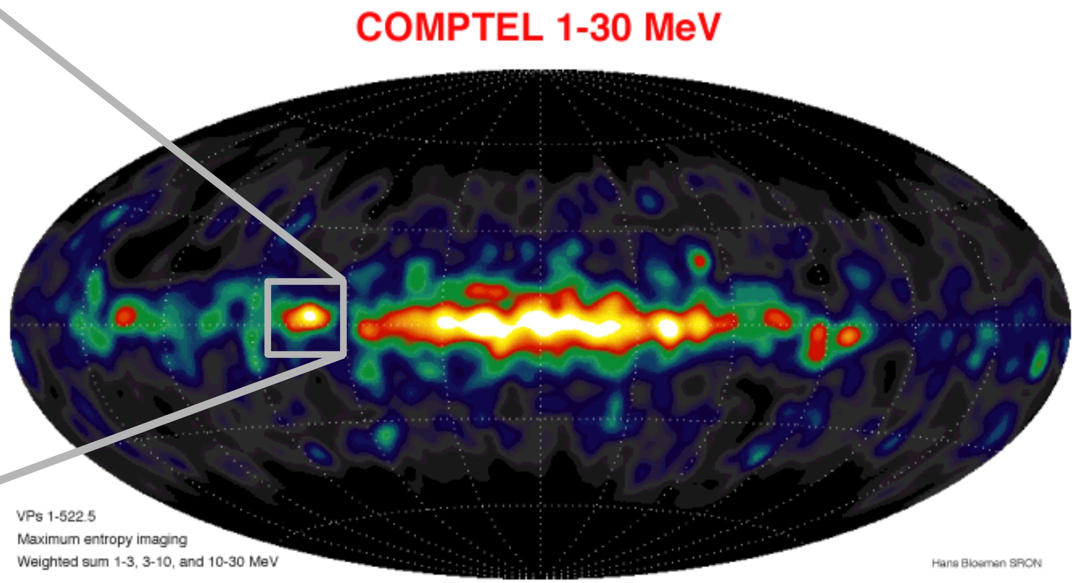
e-ASTROGAM Angular resolution

- Improve angular resolution close to the Compton physical limits

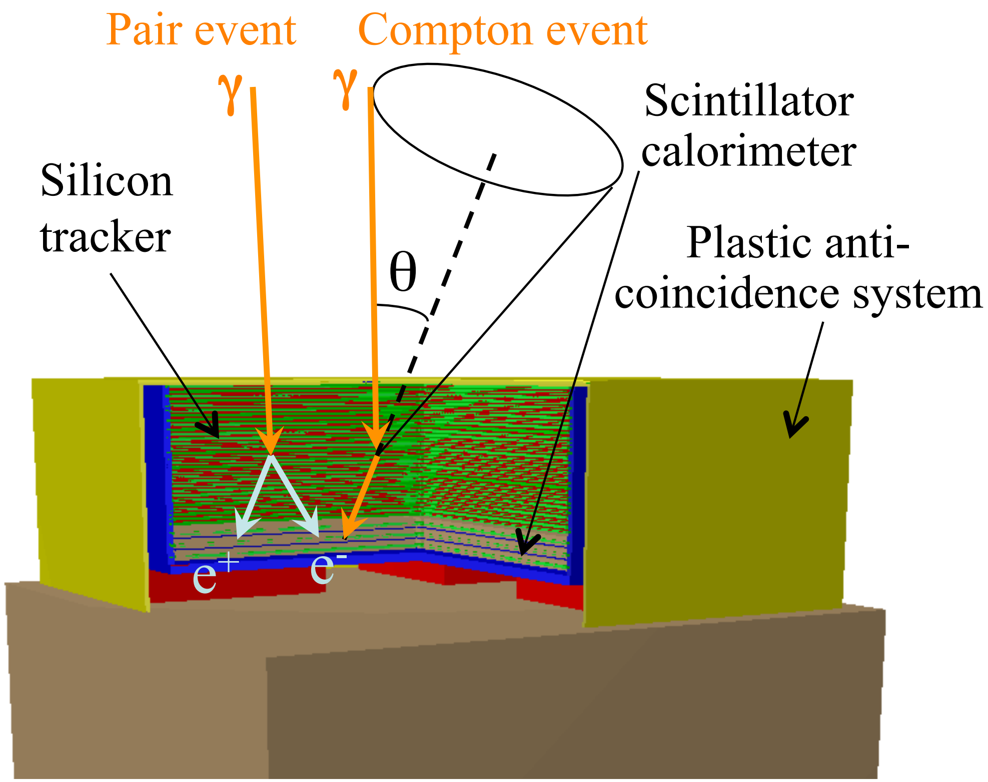


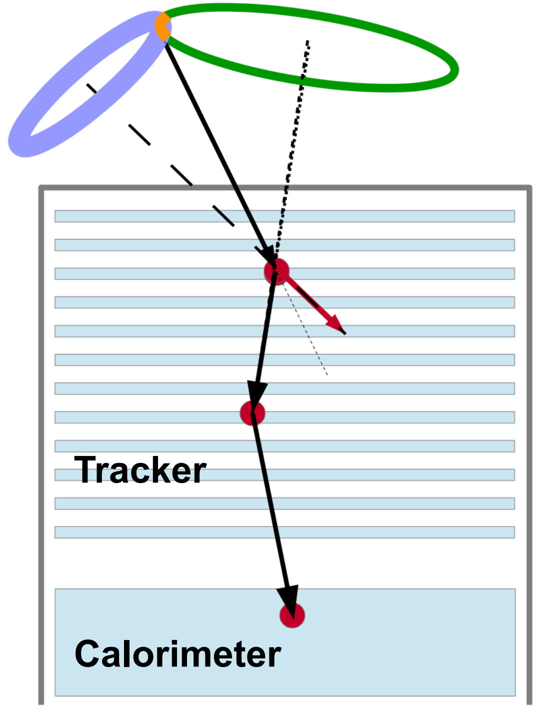
Simulation of the Cygnus region in the 1 – 3 MeV energy band using the e-ASTROGAM PSF, from an extrapolation of the 3FGL source spectra to low energies





e-ASTROGAM Measurement principle



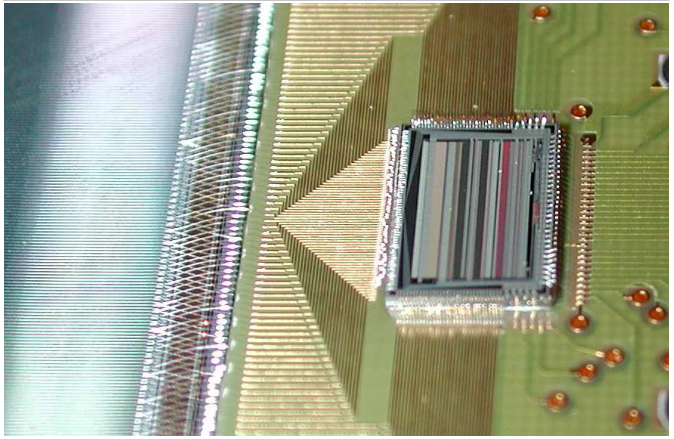


Tracked Compton event

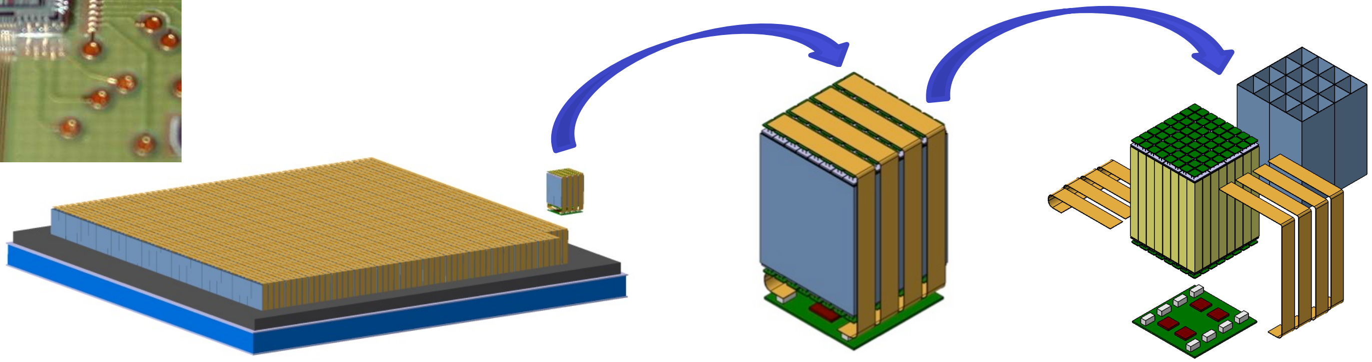
- **Tracker** – Double sided Si strip detectors (DSSDs) for excellent spectral resolution and fine 3-D position resolution
- **Calorimeter** – High-Z material for an efficient absorption of the scattered photon ⇒ CsI(Tl) scintillation crystals readout by Si Drift Diodes for better energy resolution
- **Anticoincidence detector** to veto charged-particle induced background ⇒ plastic scintillators readout by Si photomultipliers

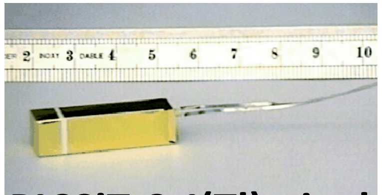
Payload

Detail of the detector-ASIC bonding in the AGILE Si Tracker

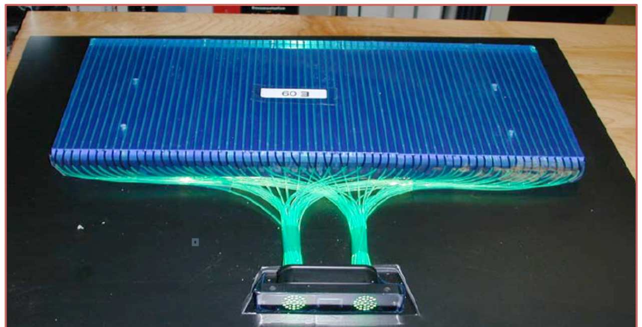


- **Tracker**: 56 layers of 4 times 5×5 DSSDs (5 600 in total) of 500 μm thickness and 240 μm pitch
- DSSDs bonded strip to strip to form 5×5 ladders
- Light and stiff mechanical structure
- Ultra low-noise front end electronics





PICSiT CsI(Tl) pixel

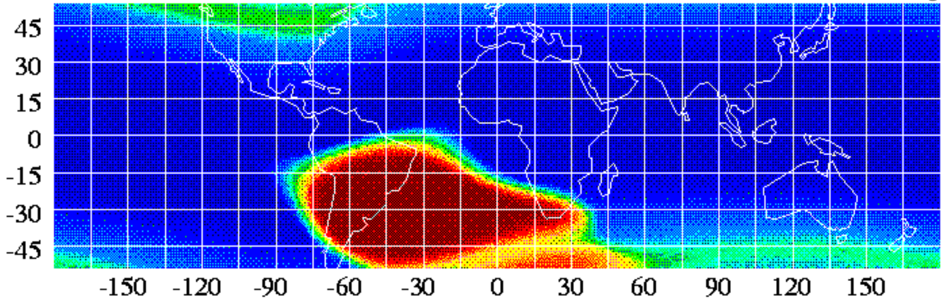


Fermi/LAT AC system

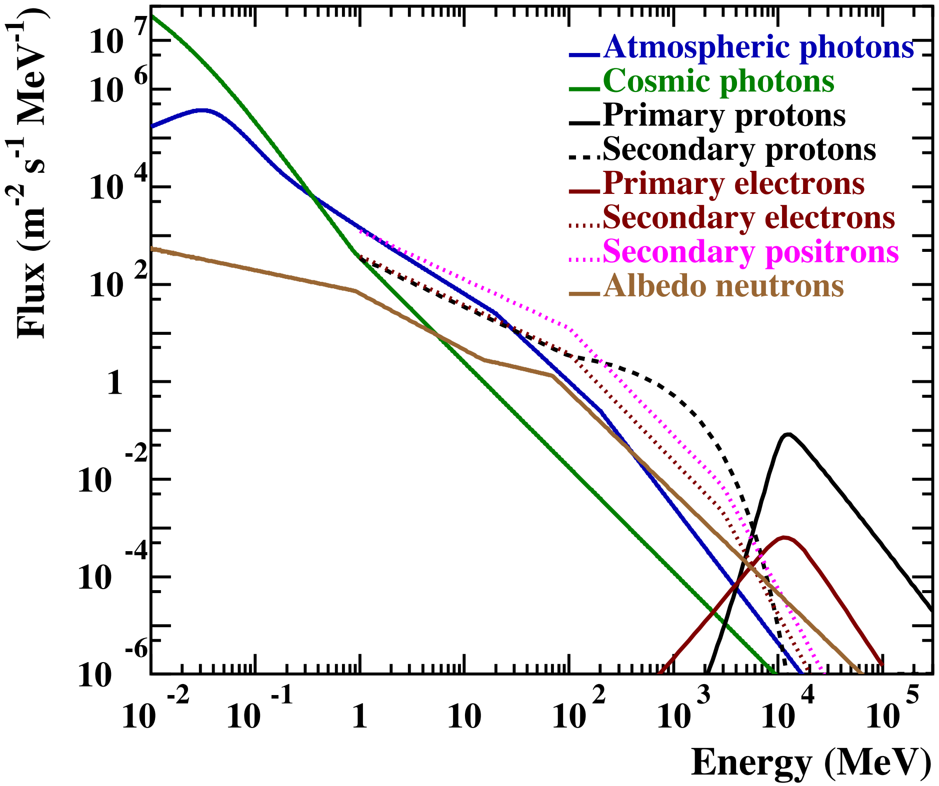
- **Calorimeter**: 8 464 CsI(Tl) bars coupled at both ends to low-noise Silicon Drift Detectors
- **ACD**: segmented plastic scintillators coupled to SiPM by optical fibers
- **Heritage**: AGILE, Fermi/LAT, AMS-02, INTEGRAL, LHC/ALICE…

e-ASTROGAM Mission profile

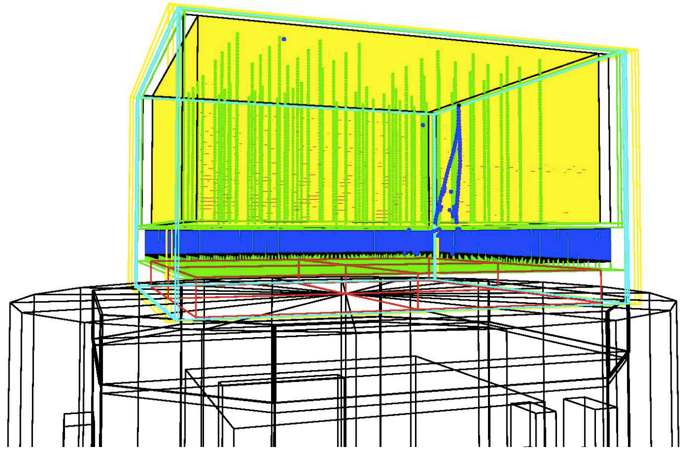
- **Orbit** – Equatorial (inclination *i* < 2.5°, eccentricity *e* < 0.01) low-Earth orbit (altitude in the range 550 - 600 km)
- **Launcher** – Ariane 6.2 (TBC)
- **Satellite communication** – ESA ground station at Kourou + ASI Malindi station (Kenya)
- **Data transmission** – via X-band (available downlink of 10 Mbps)
- **Observation modes** – (i) zenith-pointing sky-scanning mode, (ii) nearly inertial pointing, and (iii) fast repointing to avoid the Earth in the field of view
- **In-orbit operation** – 5 years duration + provisions for a 2+ year extension (TBC)

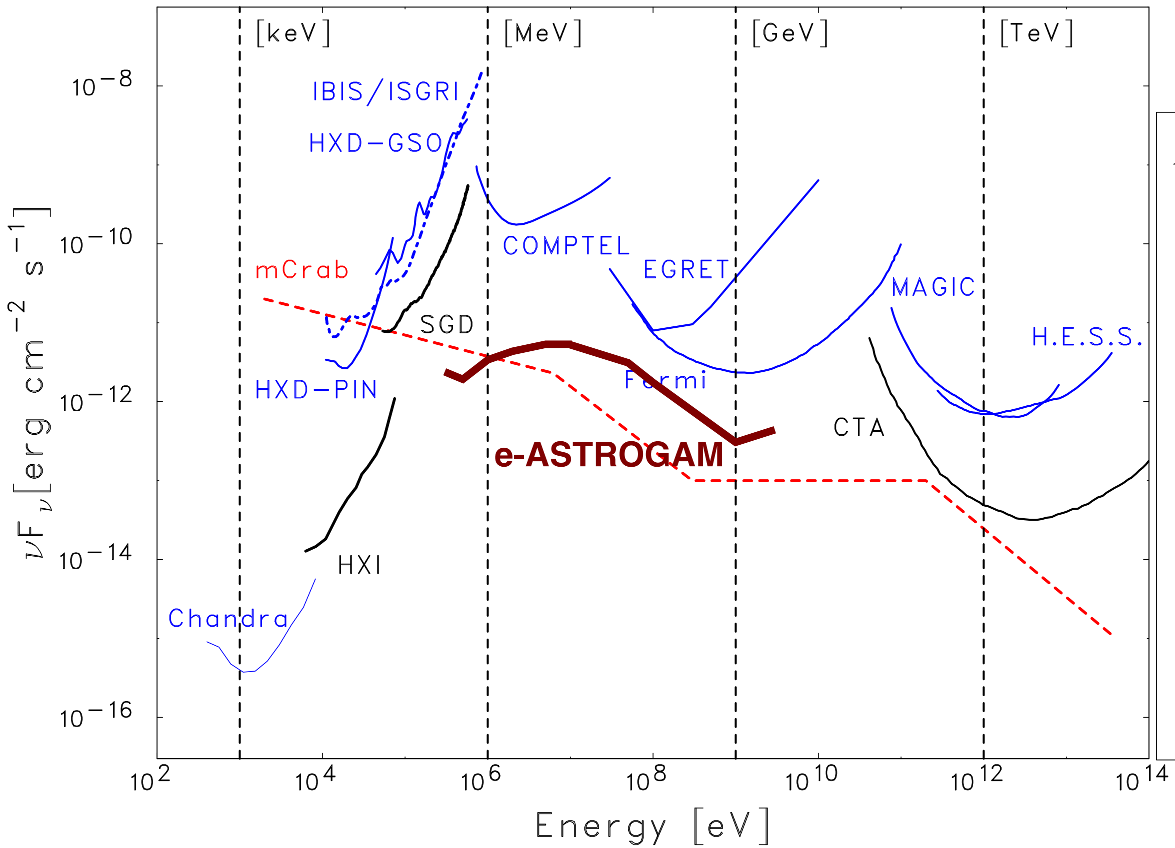


Background environment in an ELEO



- e-ASTROGAM performance evaluated with **MEGAlib** and **Bogemms** (both based on Geant4) and a detailed mass model of the instrument





Adapted from Takahashi et al. (2013)

- **ASTRO-H/SGD**: S(3σ) for 100 ks exposure of an isolated point source
- **COMPTEL and EGRET**: sensitivities accumulated during the whole duration of the CGRO mission (9 years)
- **Fermi/LAT**: 5σ sensitivity for a high Galactic latitude source and after 1 year observation in survey mode
- **e-ASTROGAM** − 3σ/5σ sensitivity for a 1-year effective exposure of a high Galactic latitude source

e-ASTROGAM Core science

1. High-energy mysteries of the Galactic center and inner Galaxy (supermassive black hole activity, Fermi bubbles, Galactic positrons, dark matter…)

2. Nucleosynthesis and propagation of heavy elements in our Galaxy and beyond (nova and supernova physics, long-term radioactivities…)

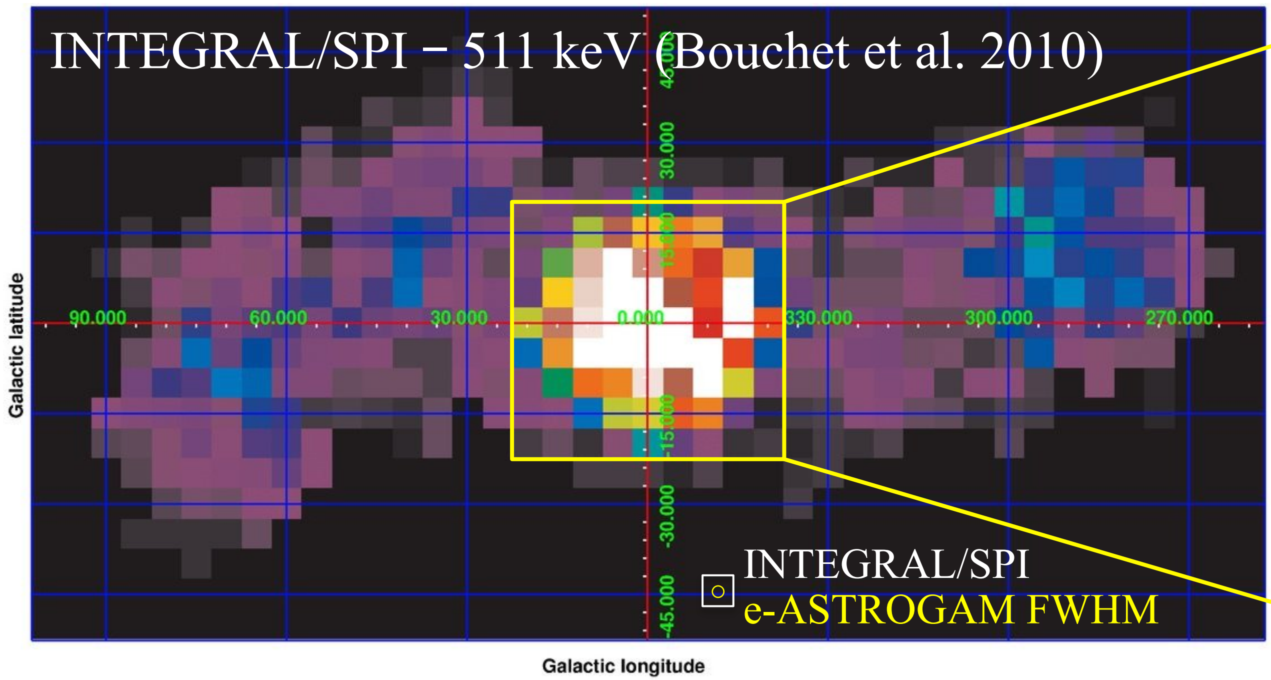
3. Activity from extreme particle accelerators (disk-jet transitions in active galactic nuclei, origin of the extragalactic gamma-ray background…)

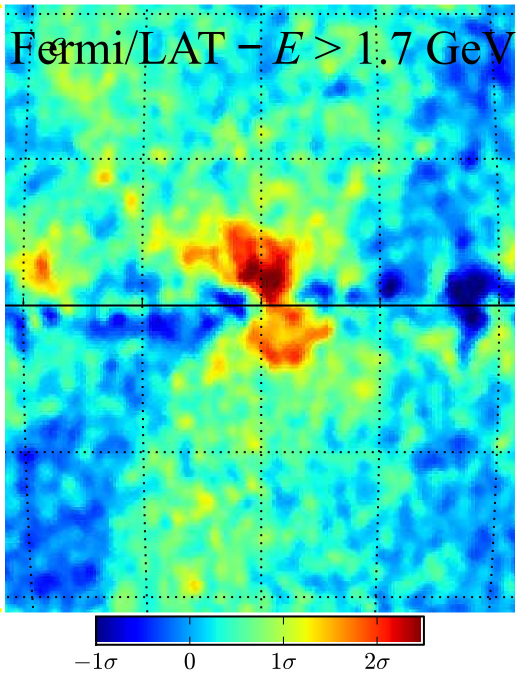
Antimatter in the Galactic bulge

- The 511 keV emission from the Galactic center is still a mystery after more than 40 yr of observations (Johnson et al. 1972)
- The **bulge emission** can be explained by the injection of 10^{58} - 10^{60} positrons in the Galactic center some millions years ago

⇒ Supermassive black hole activity? Related to the Fermi bubbles?

- e-ASTROGAM will produce much better maps of the 511 keV radiation



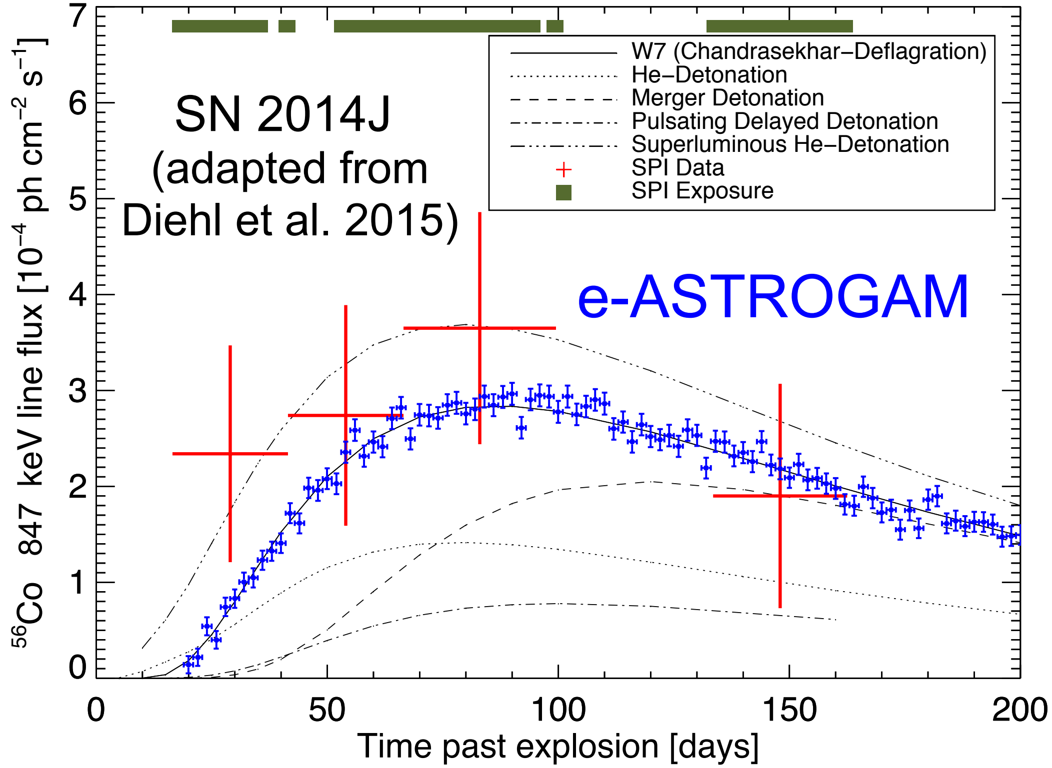


Thermonuclear supernovae

- Type Ia SNe are key tools for modern cosmology, yet we do not understand their progenitor systems, as well as the initiation and propagation of the thermonuclear burning

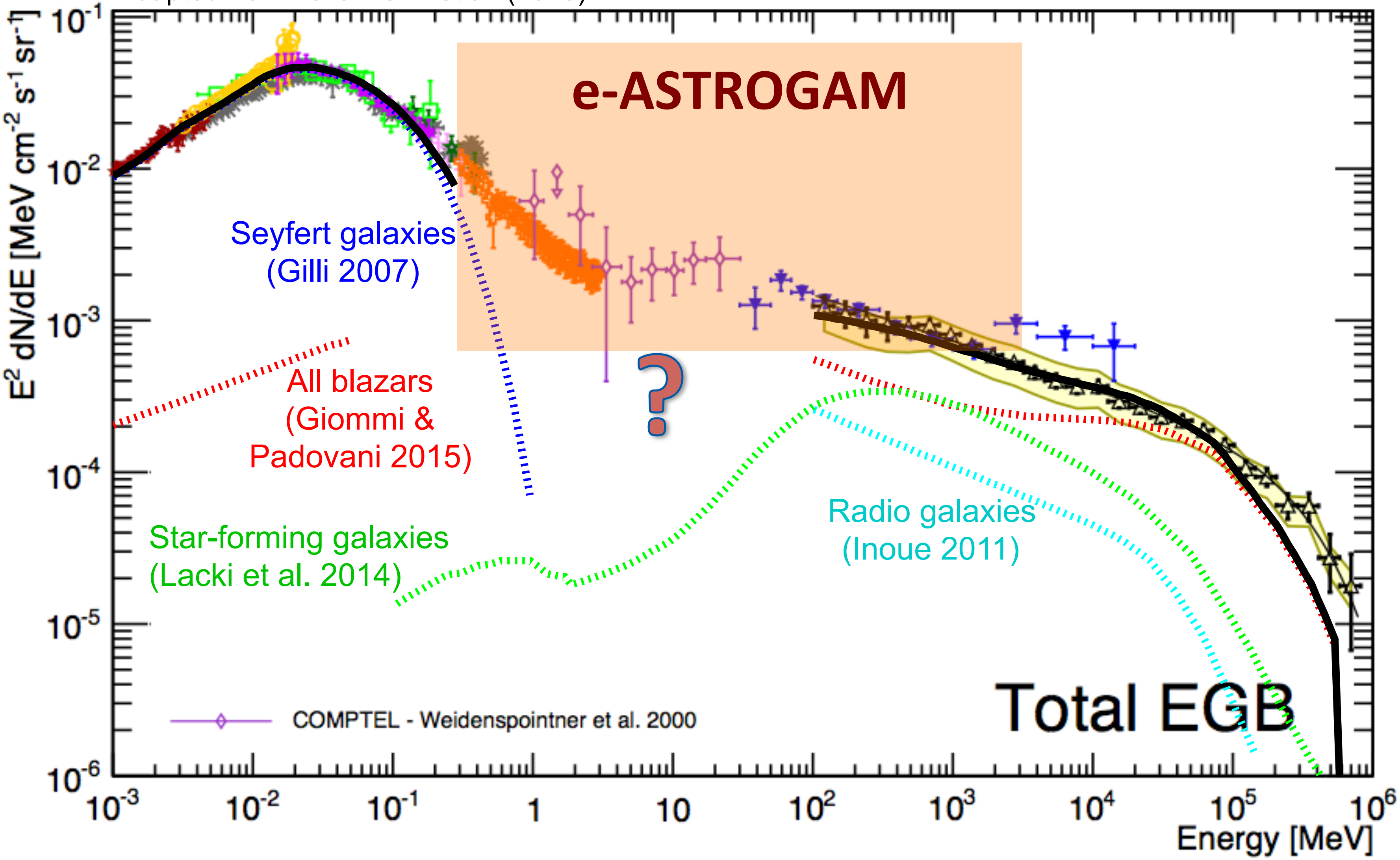
- INTEGRAL results for the nearby (*D* = 3.3 Mpc) supernova SN 2014J show the potential of γ-ray spectroscopy to study the explosion process of SN Ia

- e-ASTROGAM should detect 8 – 10 Type Ia SNe in 5 yr up to a distance of about 30 Mpc



e-ASTROGAM Extragalactic γ-ray background

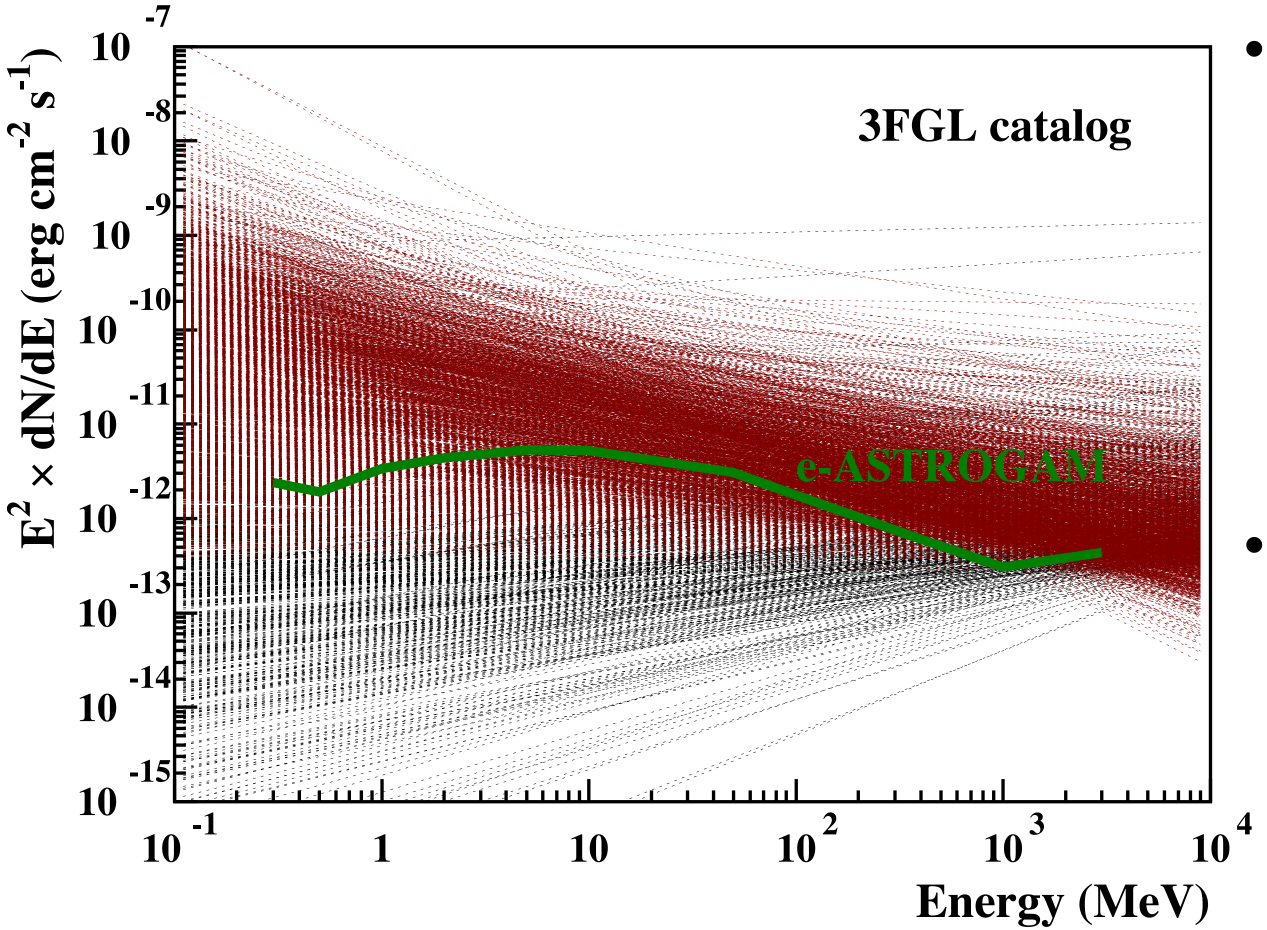
Adapted from Ackermann et al. (2015)



- Origin of the EGB in the 0.3 - 100 MeV range? Dark matter contribution?

e-ASTROGAM Predictions from 3FGL

- Over 3/4 of the sources from the 3rd Fermi LAT Catalog (3FGL), 2415 sources over 3033, have power-law spectra (E_γ > 100 MeV) steeper than E_γ^{-2}, implying that their peak energy output is below 100 MeV



- These includes more than 1200 (candidate) blazars (mostly FSRQ), about 150 pulsars, and nearly 900 unassociated sources
- Most of these sources will be detected by e-ASTROGAM ⇒ large discovery space

e-ASTROGAM Collaboration

INAF, INFN, University of Rome 2

CSNSM, IRAP, APC, CEA, LUPM, IPNO

ICE (CSIC-IEEC), IMB-CNM (CSIC)

University College Dublin

MPE, University of Mainz, University of Wuerzburg

DTU

University of Geneva

Jagiellonian University, CBK, NCAC

University of Tokyo

Ioffe Institute

NASA GSFC, NRL, Clemson Un., UC at Berkeley

Summary

- The MeV / sub-GeV band is potentially one of the richest energy domain of astronomy

- Thanks to its unprecedented sensitivity and groundbreaking capability for measuring γ-ray polarization, the e-ASTROGAM observatory has the potential for many foundational discoveries

- The e-ASTROGAM payload is innovative in many respects, but the technology is ready

- e-ASTROGAM will be proposed in 2016 as ESA's M5 Medium-size mission