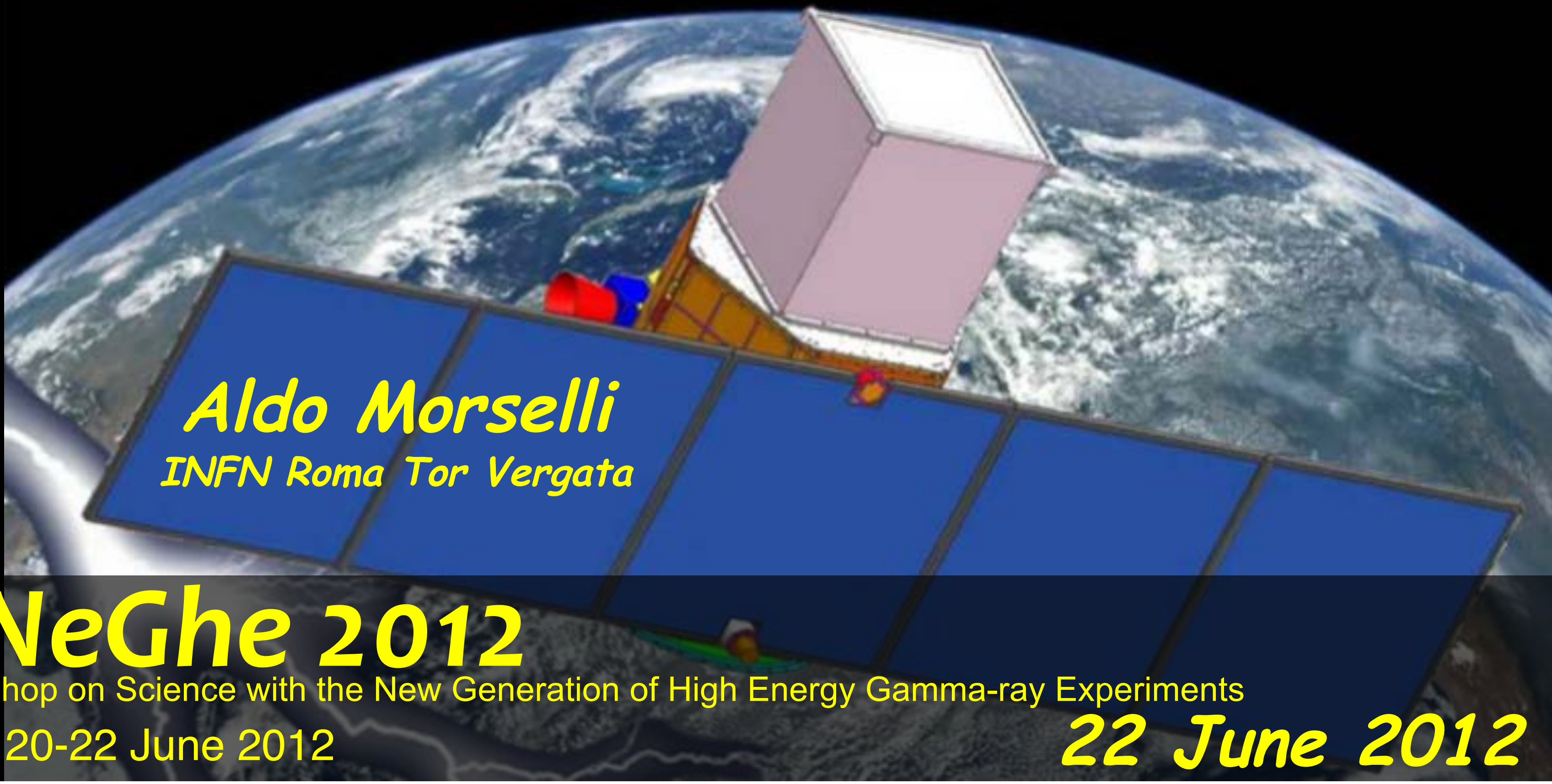
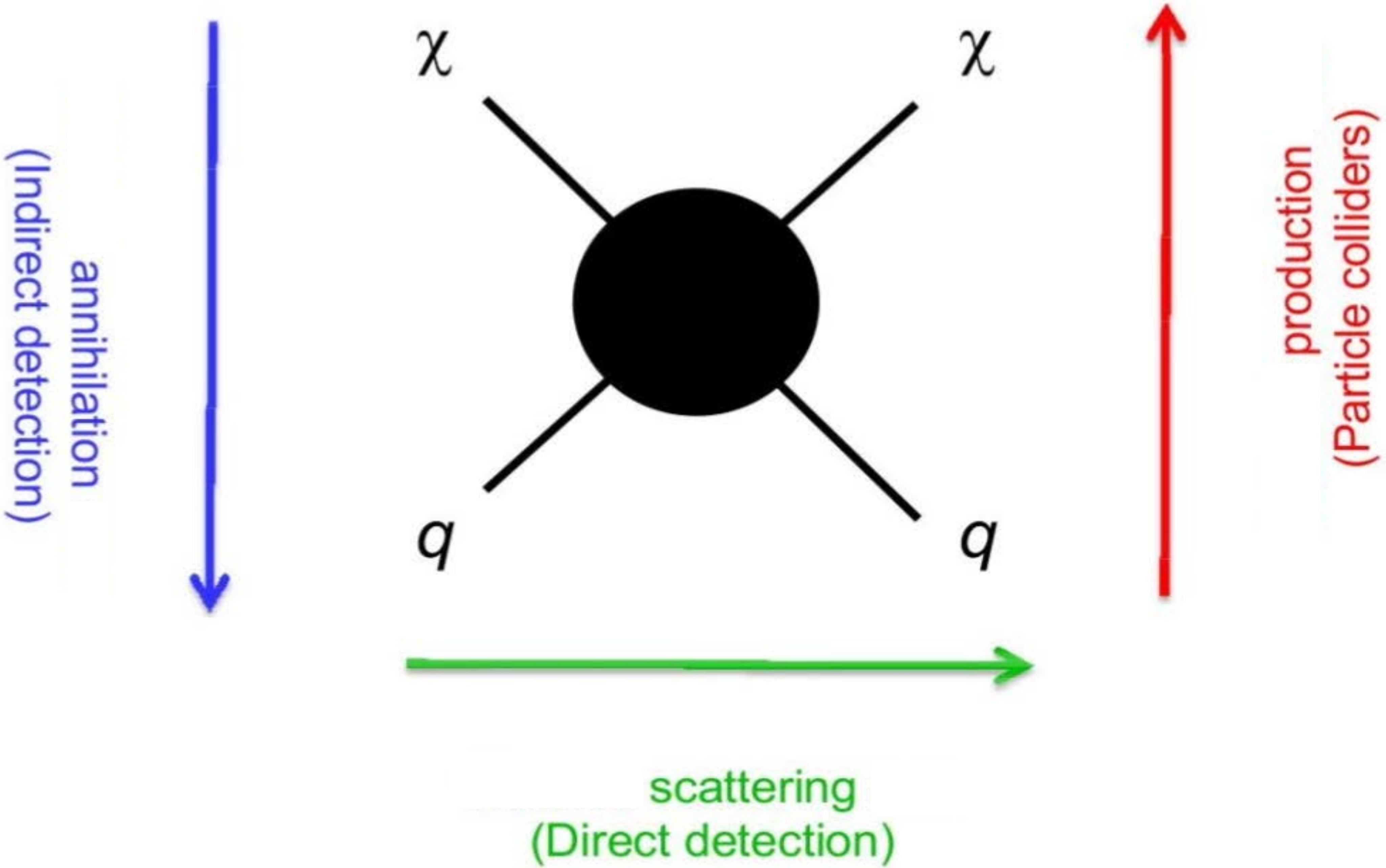
Gamma-Light



Aldo Morselli
INFN Roma Tor Vergata

SciNeGhe 2012
9th Workshop on Science with the New Generation of High Energy Gamma-ray Experiments
Lecce, 20-22 June 2012

22 June 2012

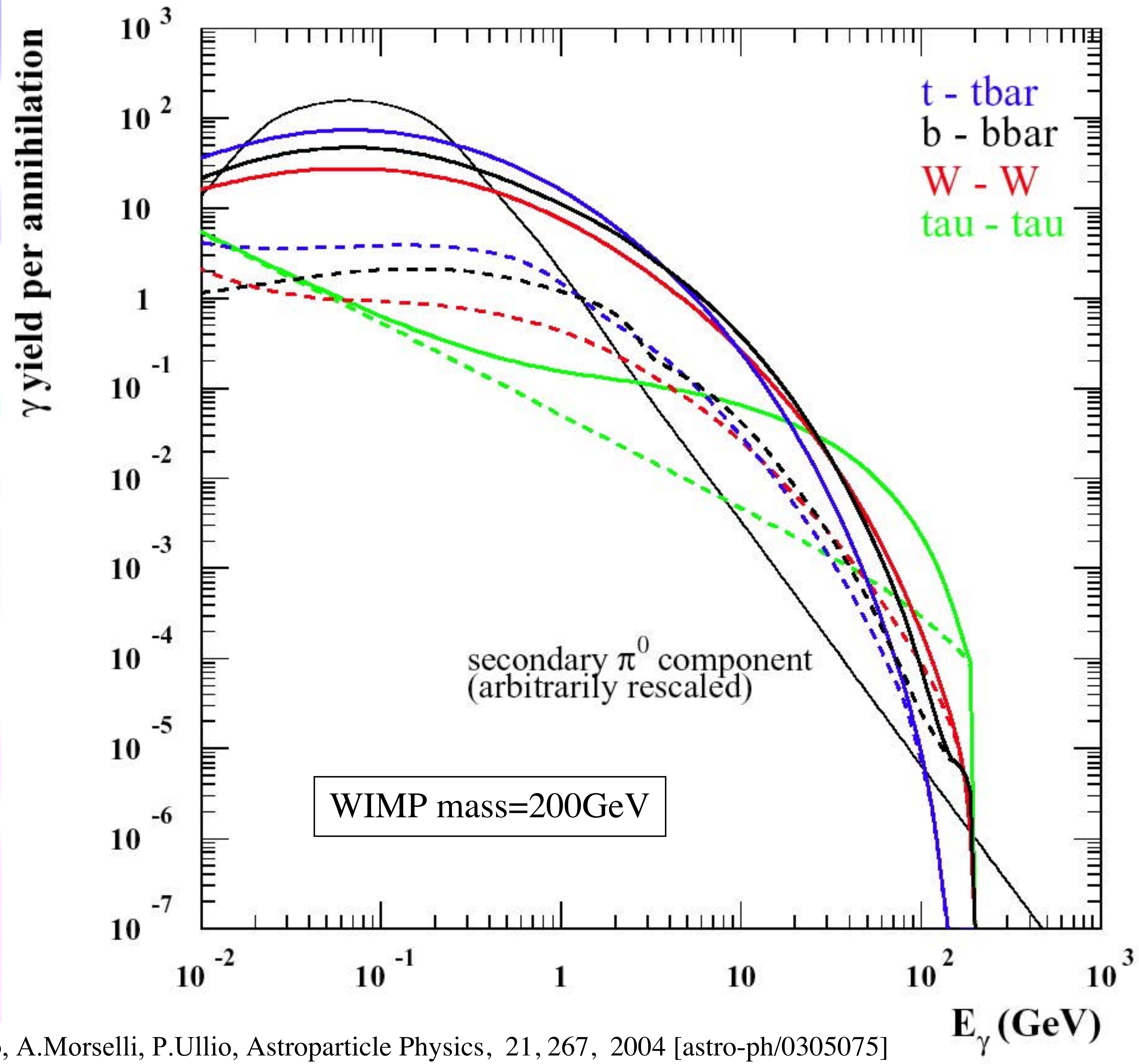

χ
χ
q
q
annihilation
(Indirect detection)
production
(Particle colliders)
scattering
(Direct detection)

Neutralino WIMPs

Assume χ present in the galactic halo

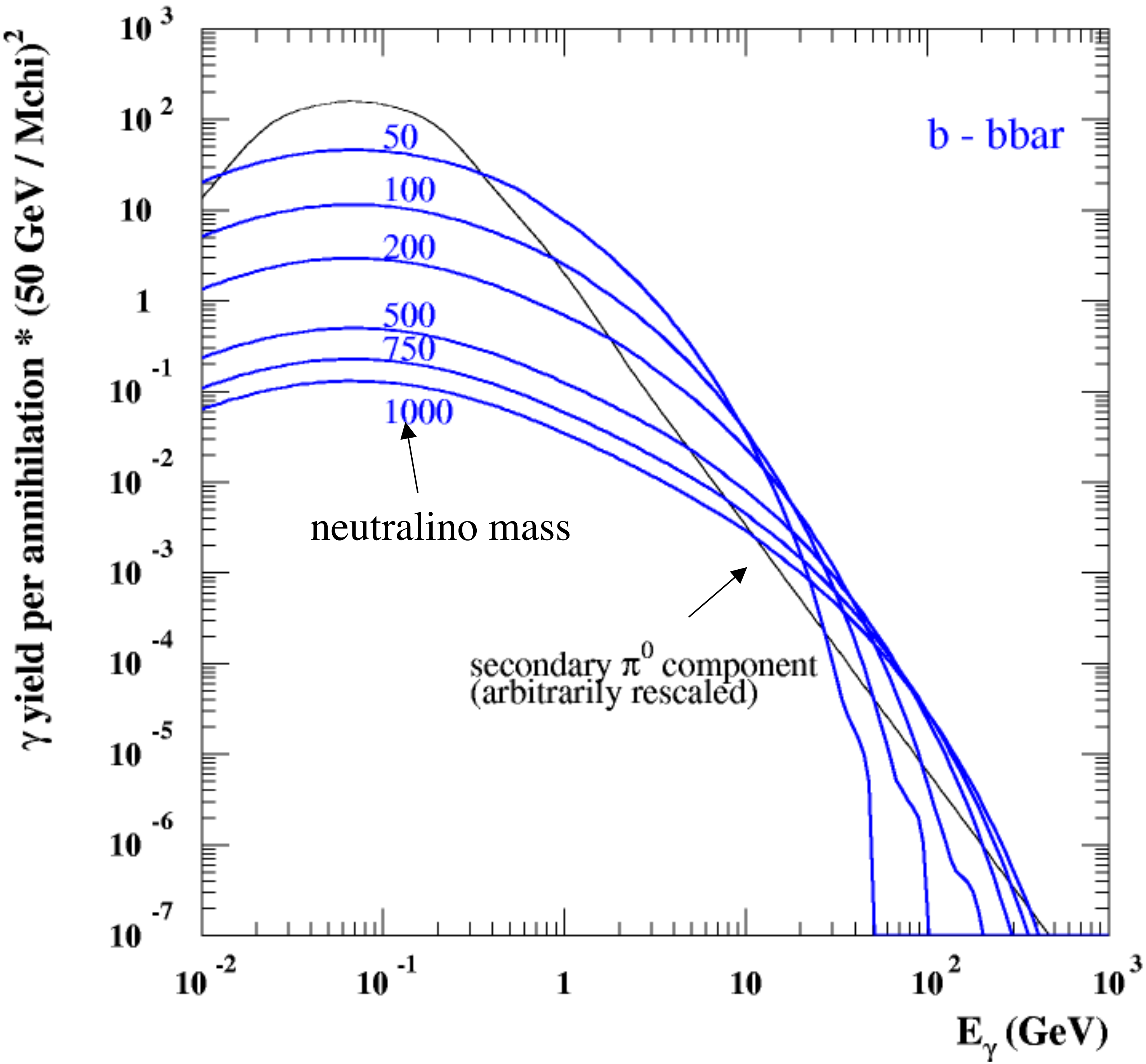
- χ is its own antiparticle **=>** can annihilate in galactic halo producing gamma-rays, antiprotons, positrons….
- Antimatter not produced in large quantities through standard processes (secondary production through p + p **-->** anti p + X)
- So, any extra contribution from exotic sources ($\chi\,\chi$ annihilation) is an interesting signature
- ie: $\chi\,\chi$ --> anti p + X
- Produced from (e. g.) $\chi\,\chi$ **-->** q / g / gauge boson / Higgs boson and subsequent decay and/ or hadronisation.

Differential yield for each annihilation channel



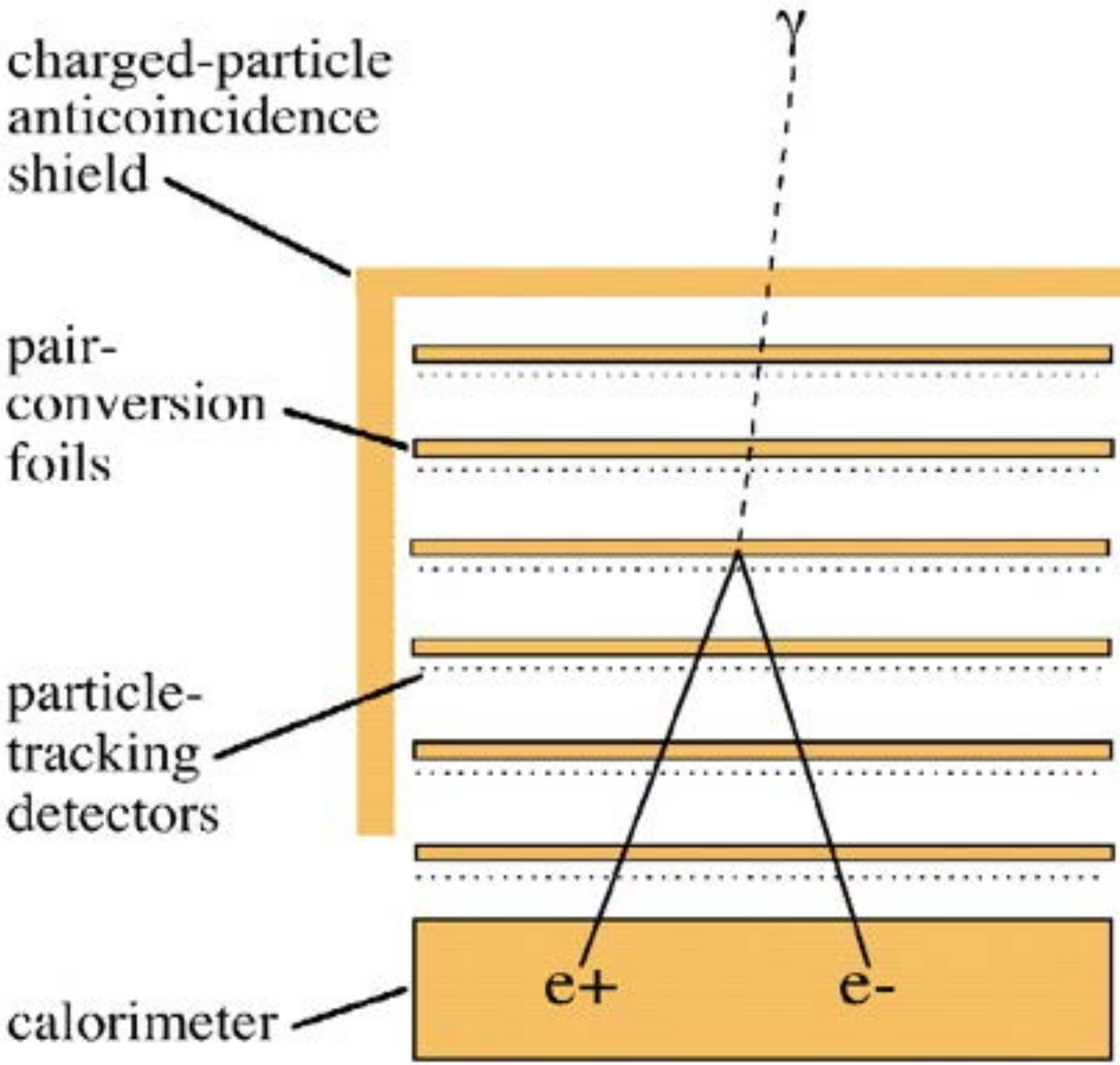
A.Cesarini, F.Fucito, A.Lionetto, A.Morselli, P.Ullio, Astroparticle Physics, 21, 267, 2004 [astro-ph/0305075]

Differential yield for b bar



A.Cesarini, F.Fucito, A.Lionetto, A.Morselli, P.Ullio, Astroparticle Physics, 21, 267-285, 2004 [astro-ph/0305075]

Elements of a pair-conversion telescope



(energy measurement)

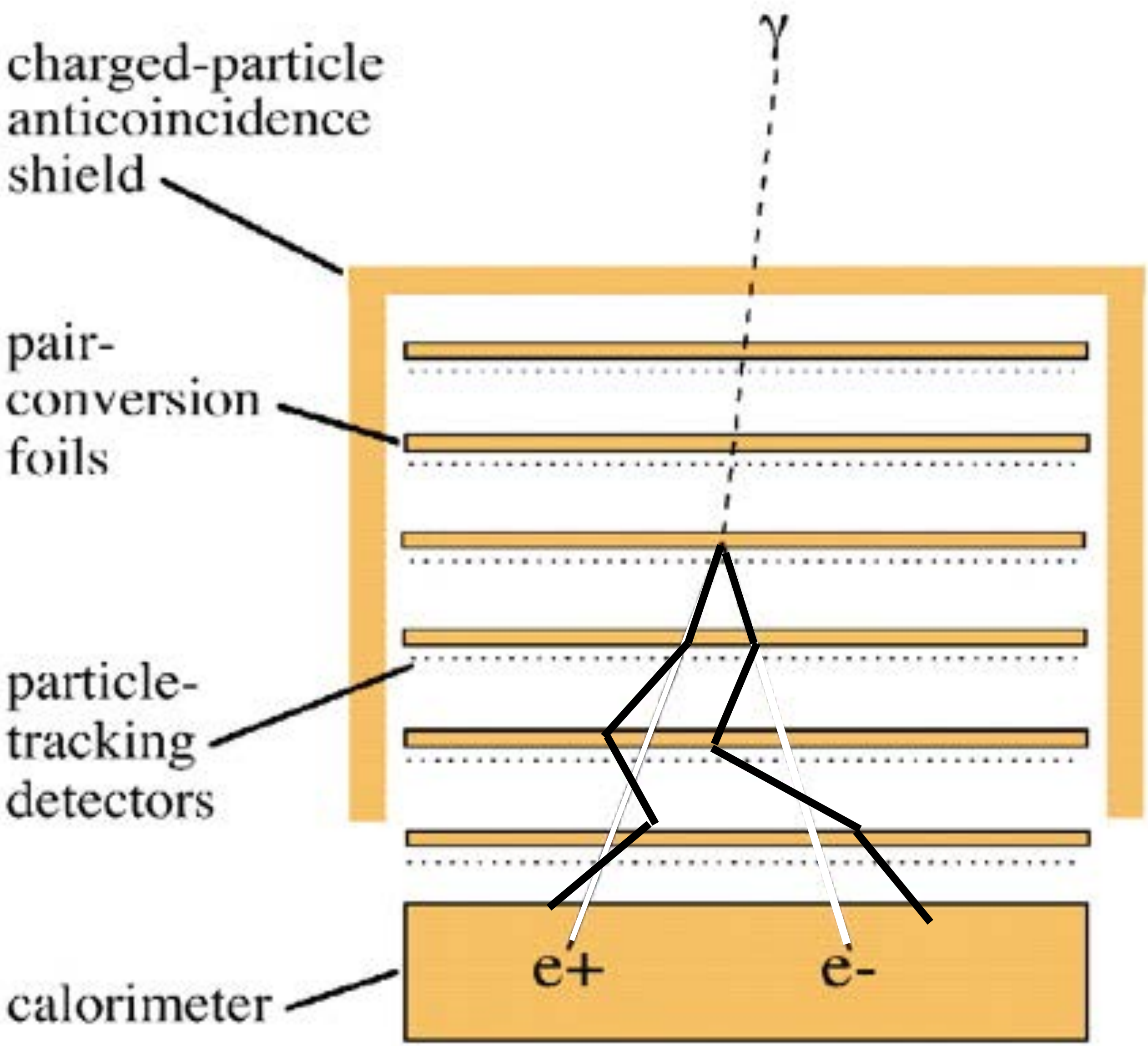
- photons materialize into matter-antimatter pairs:

  $E_\gamma \;\text{-->}\; m_{e^+}c^2 + m_{e^-}c^2$

- electron and positron carry information about the direction, energy and polarization of the γ-ray

Elements of a pair-conversion telescope

(more realistic scheme)



(energy measurement)

- photons materialize into matter-antimatter pairs:

  $E_\gamma \; \text{-->} \; m_{e^+}c^2 + m_{e^-}c^2$

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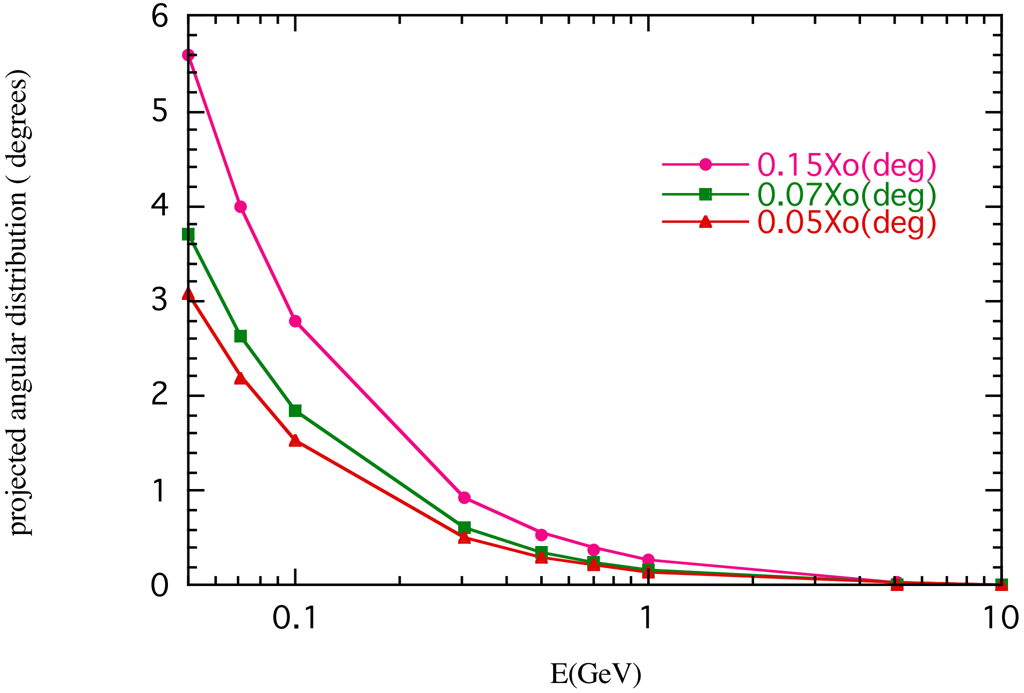
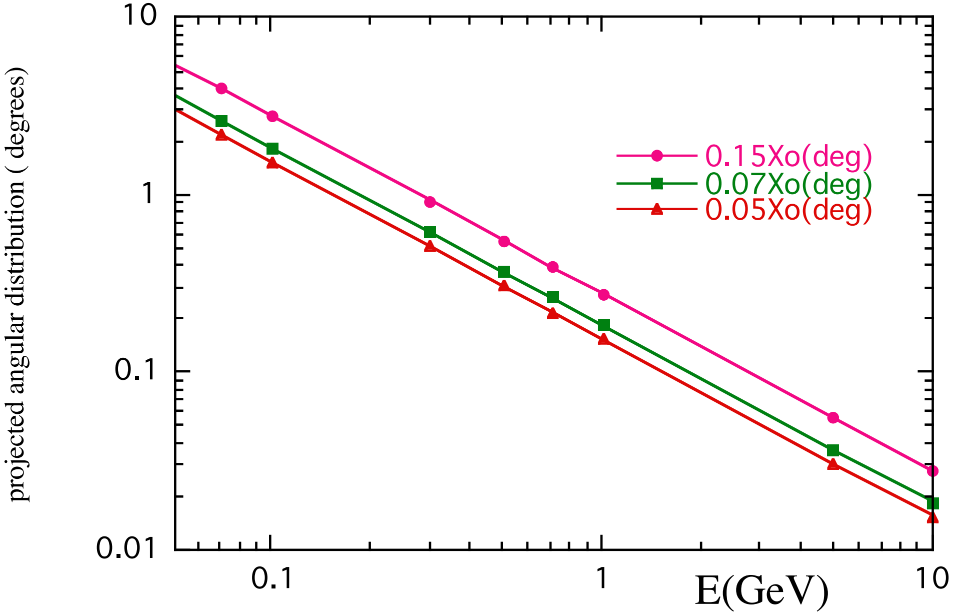


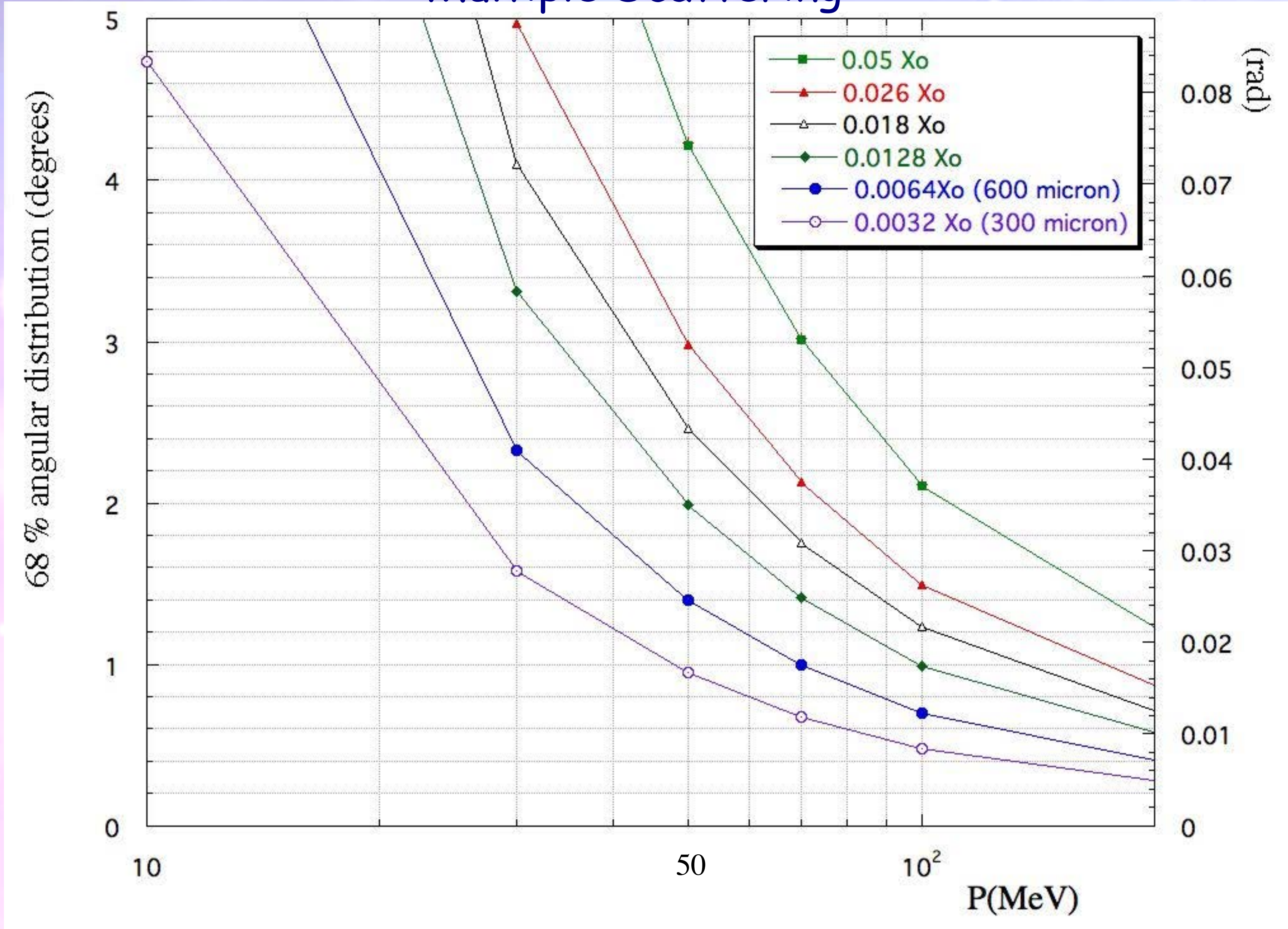
Multiple Scattering



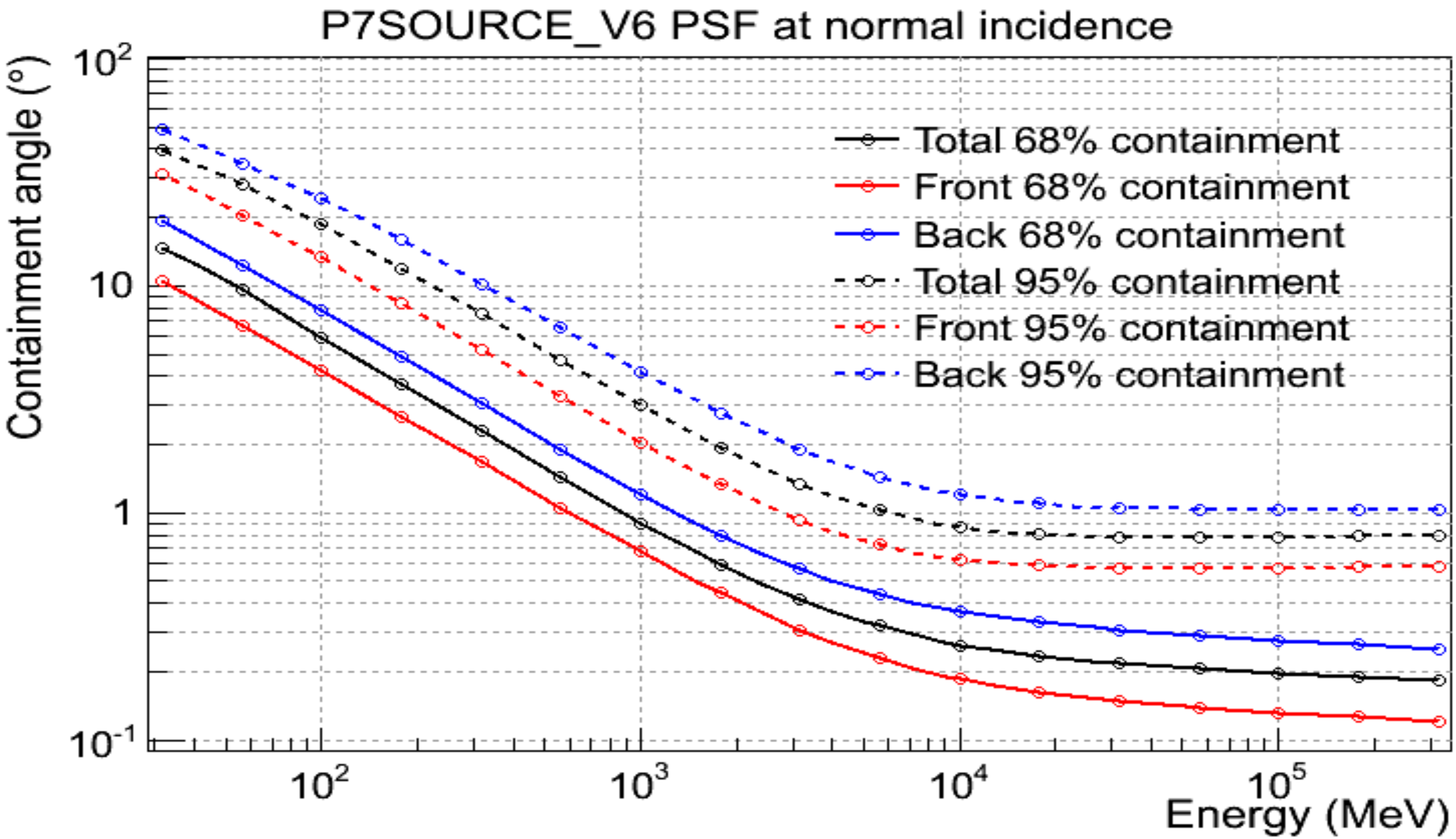
$$\theta_0 = \theta^{rms}_{plane} = \frac{1}{\sqrt{2}}\theta^{rms}_{space}$$

$$\theta_0 = \frac{13.6MeV}{\beta cp} z\sqrt{x/X_0}\left[1 + 0.038\ln(x/X_0)\right]$$

Multiple Scattering

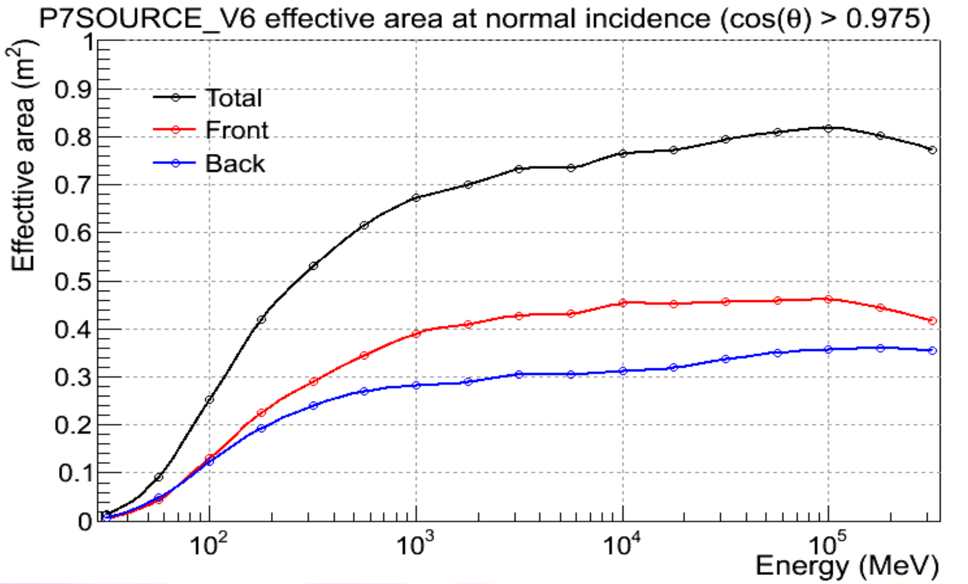


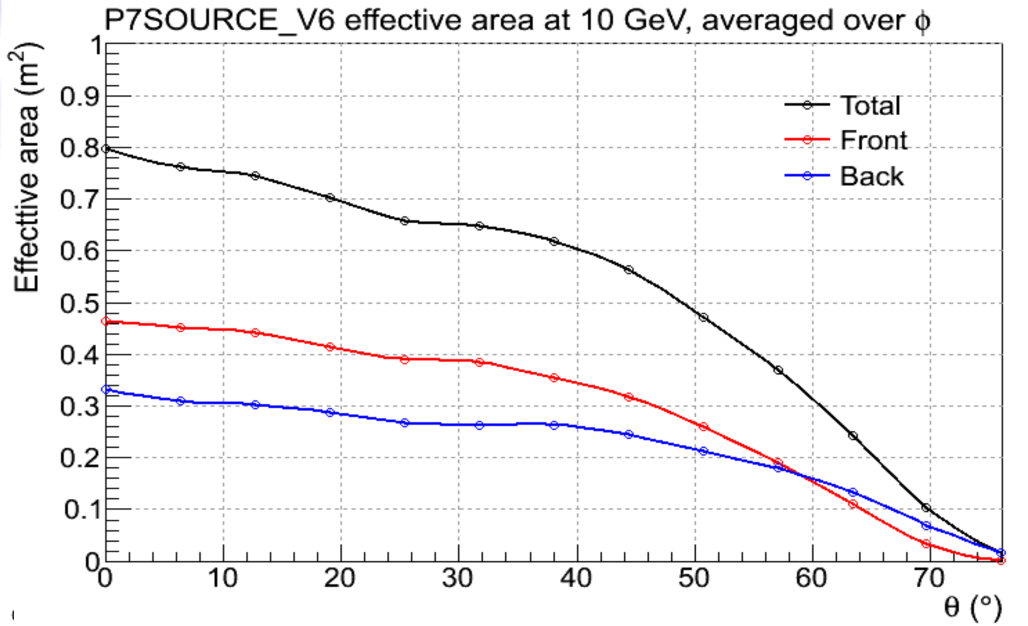
Fermi Instrument Response Function

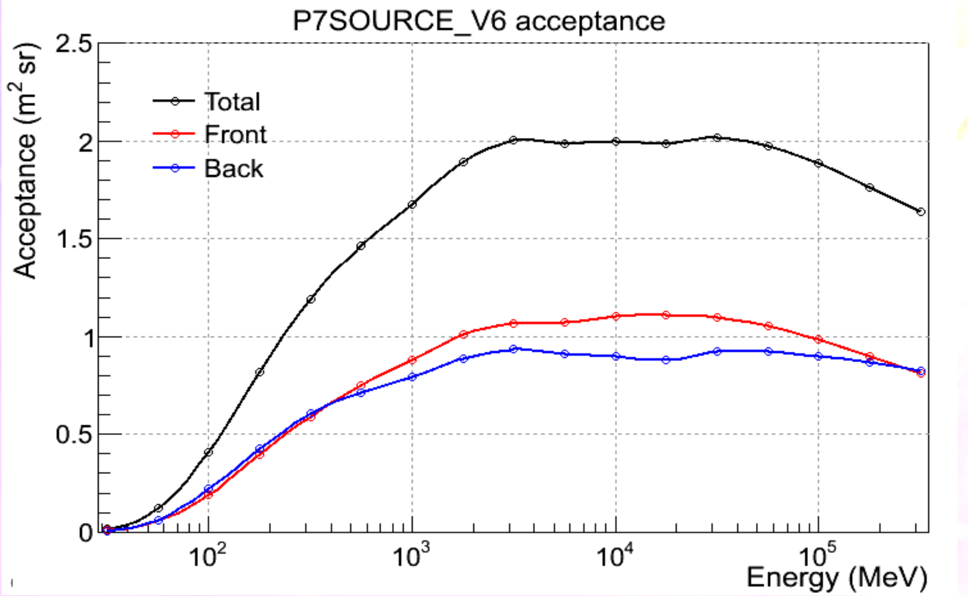


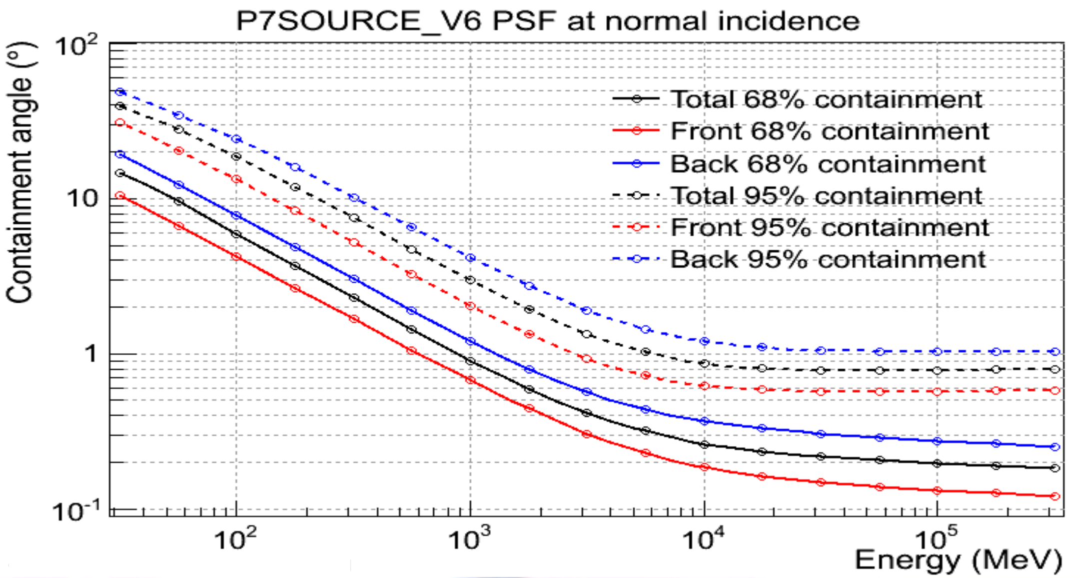
http://www.slac.stanford.edu/exp/glast/groups/canda/lat_Performance.htm

Fermi Instrument Response Function







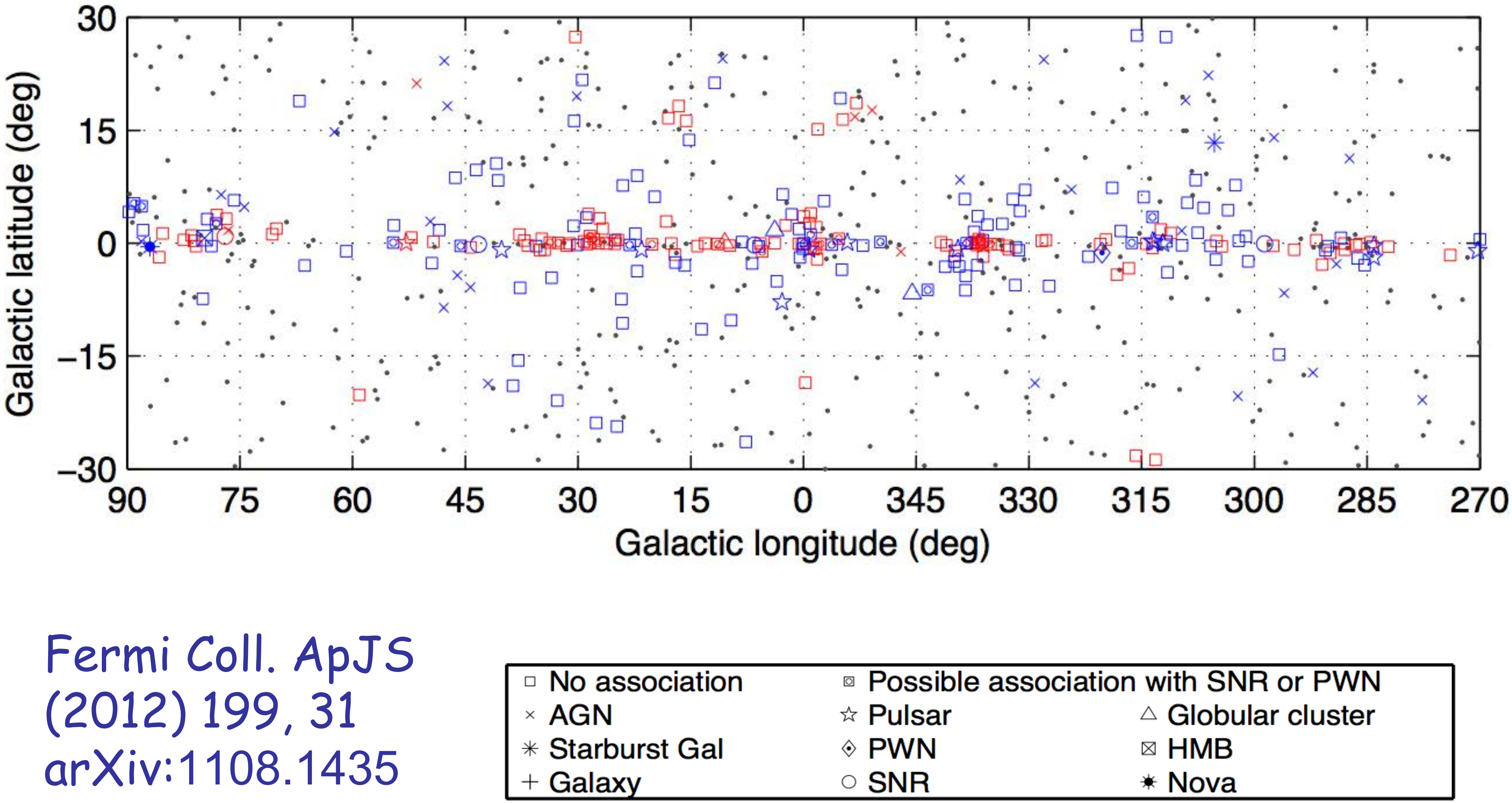


http://www.slac.stanford.edu/exp/glast/groups/canda/lat_Performance.htm

The Fermi LAT 2FGL Inner Galactic Region

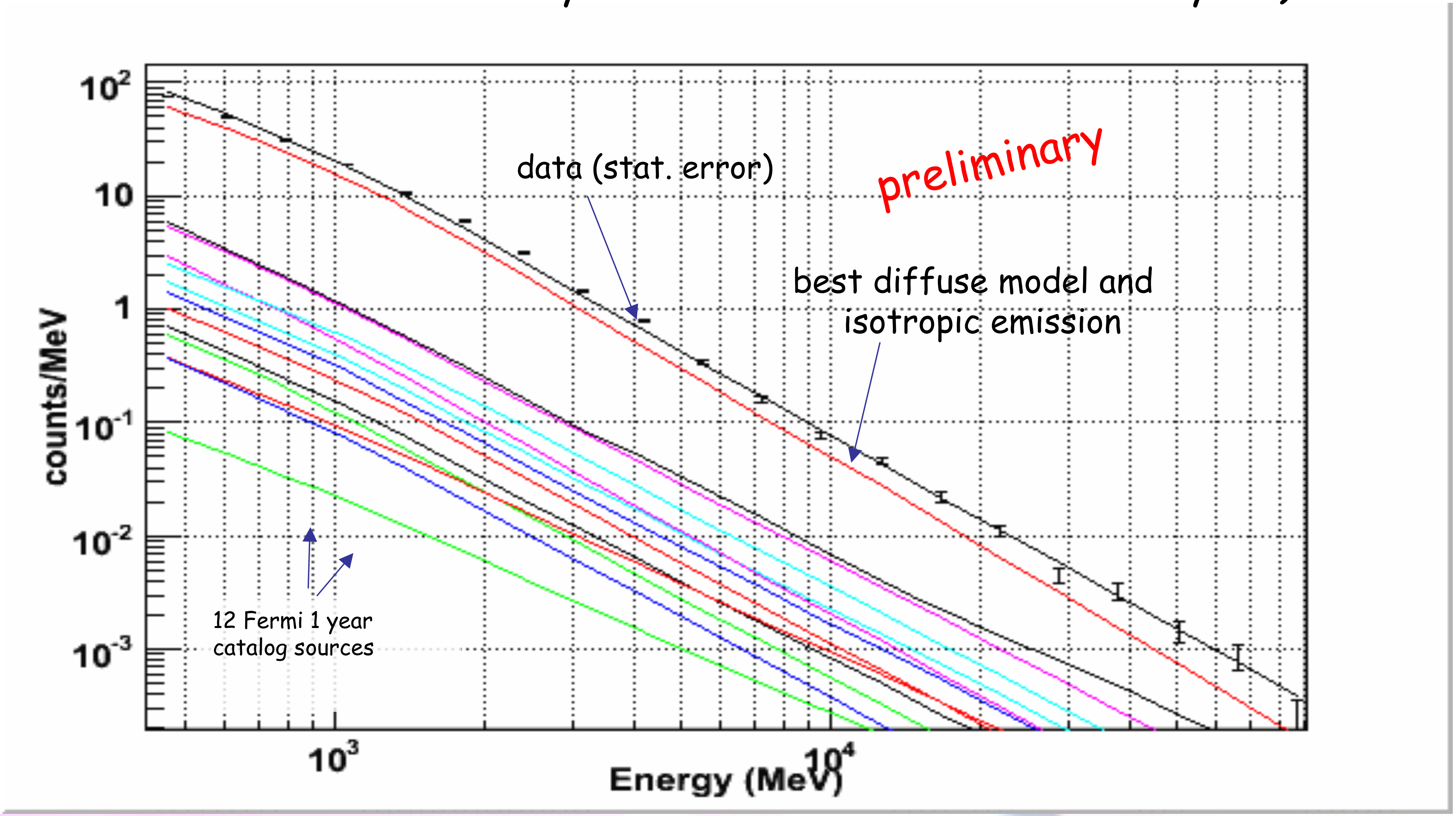
August 4, 2008, to July 31, 2010

100 MeV to 100 GeV energy range



Fermi Coll. ApJS (2012) 199, 31
arXiv:1108.1435

Spectrum (E> 400 MeV, 7°x7° region centered on the Galactic Center analyzed with binned likelihood analysis)

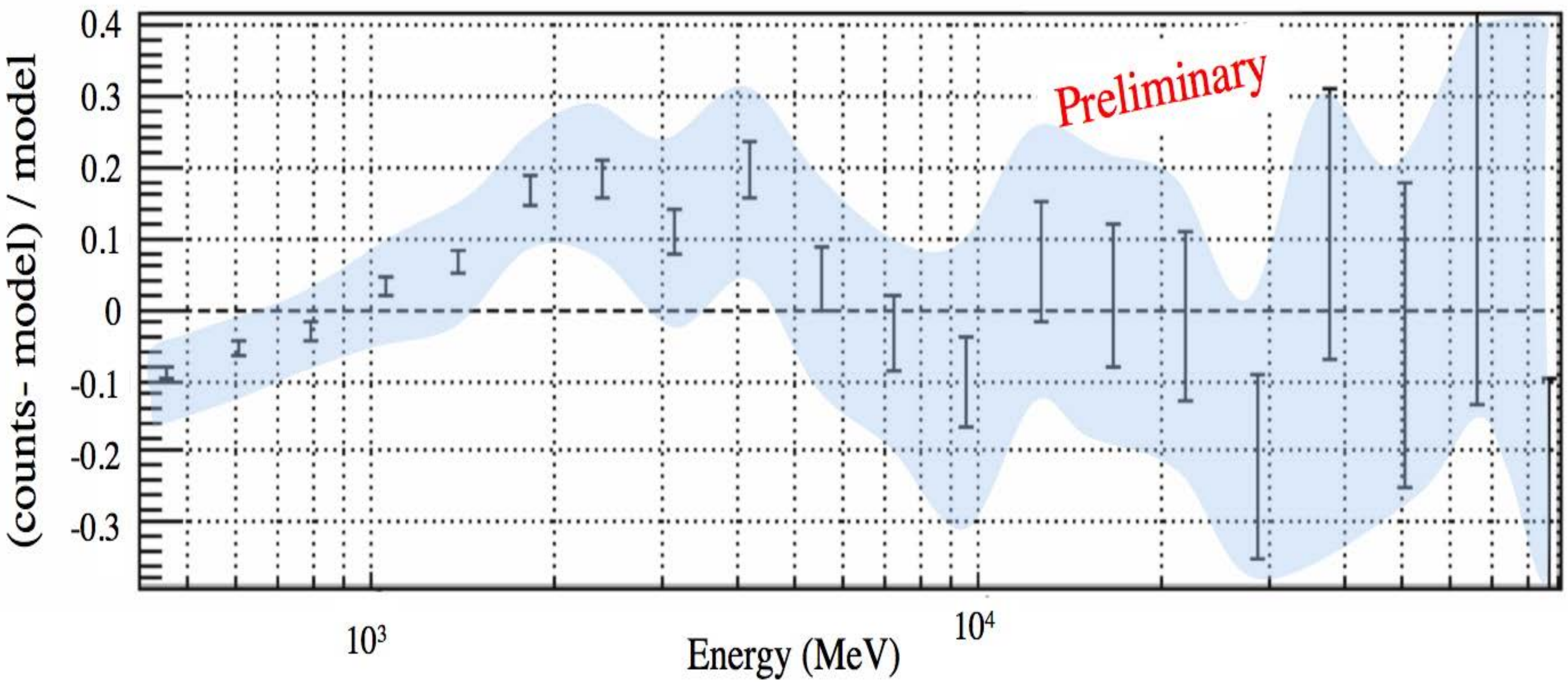


Morselli et al. for the Fermi Coll. 2011, Il Nuovo Cimento Vol. 34 C, N. 3

GC Residuals 7°x7° region centered on the Galactic Center

11 months of data, E >400 MeV, front-converting events analyzed with binned likelihood analysis)

- The systematic uncertainty of the effective area (blue area) of the LAT is ~10% at 100 MeV, decreasing to 5% at 560 MeV and increasing to 20% at 10 GeV



Morselli et al. for the Fermi Coll. 2011, Il Nuovo Cimento Vol. 34 C, N. 3

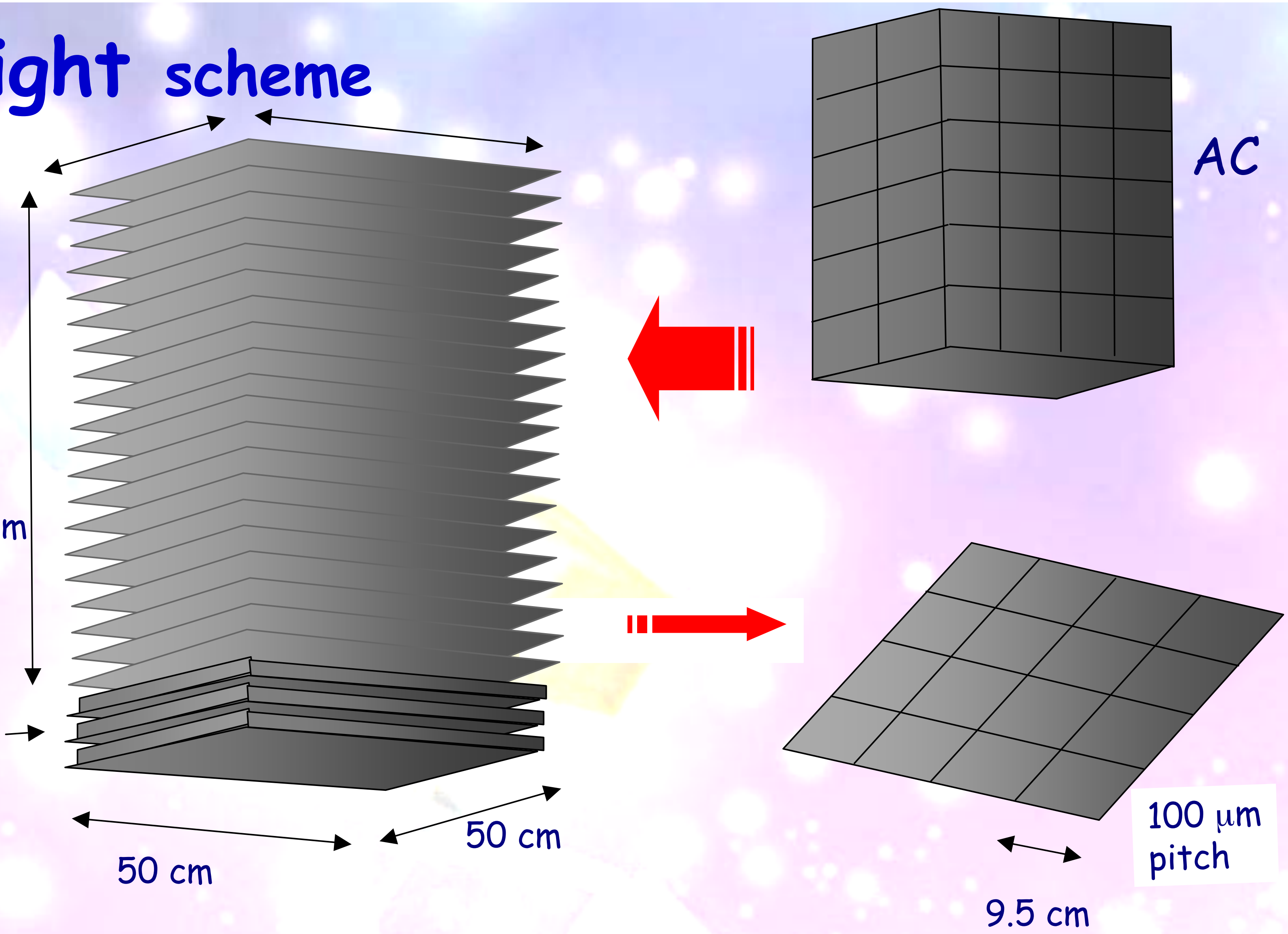
Gamma-light scheme

40+1 x-y planes
100 μm pitch
each
~0.025 X_0

Tot~ 1 X_0

height of a plane 1.3 cm

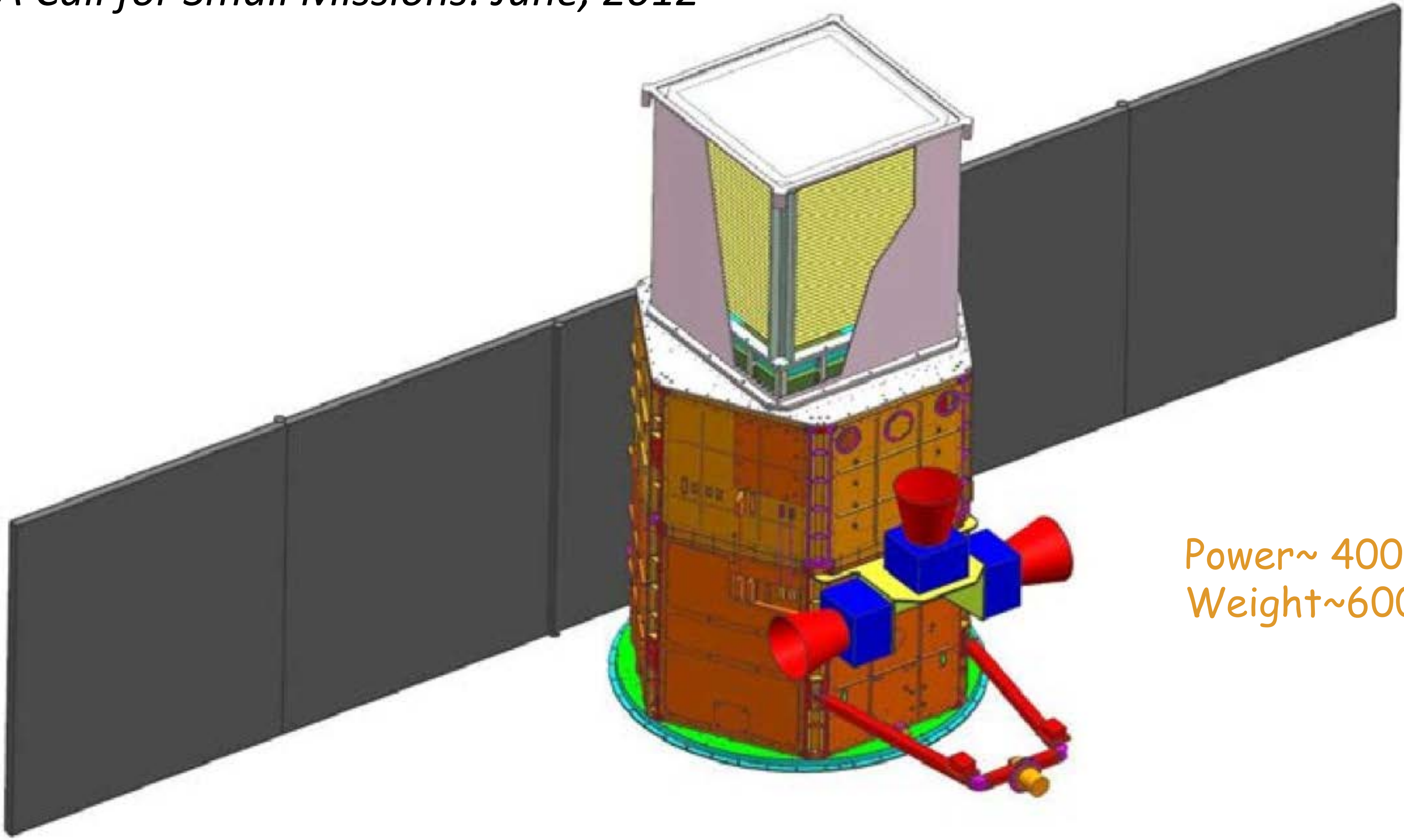
2 Xo Calorimiter



*Compton scattering **and** pair production telescope*

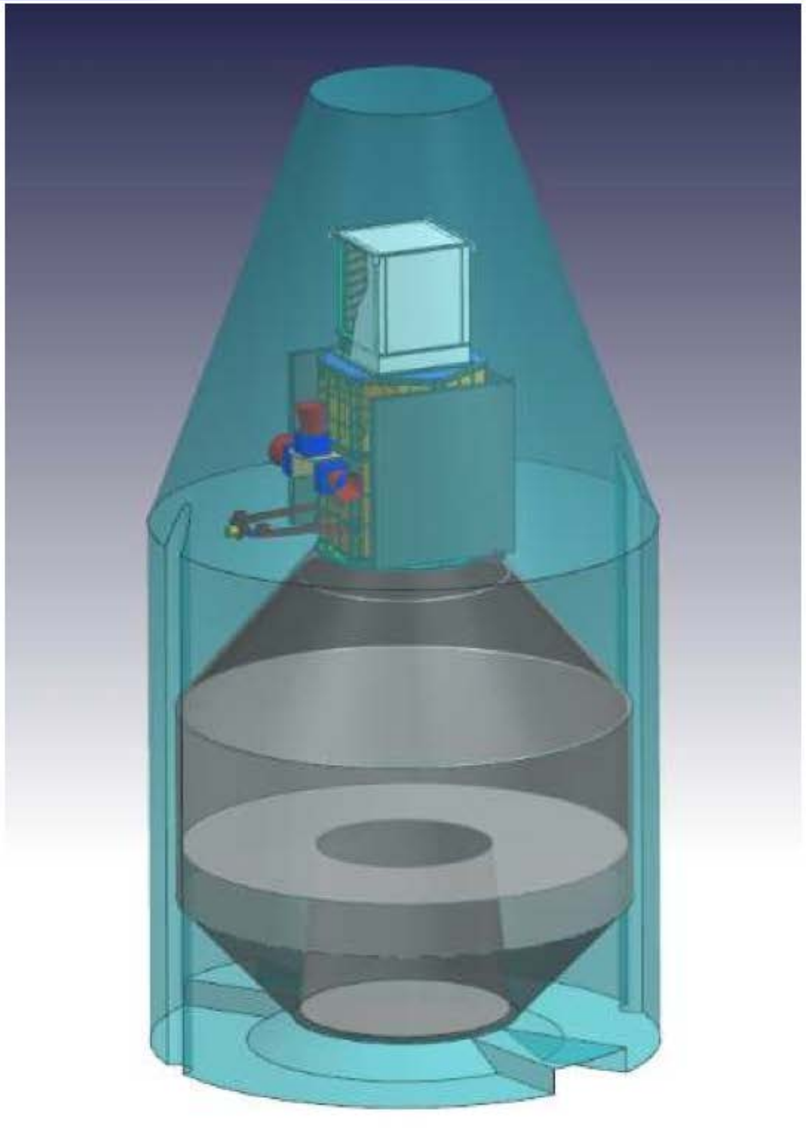
Gamma-light payload

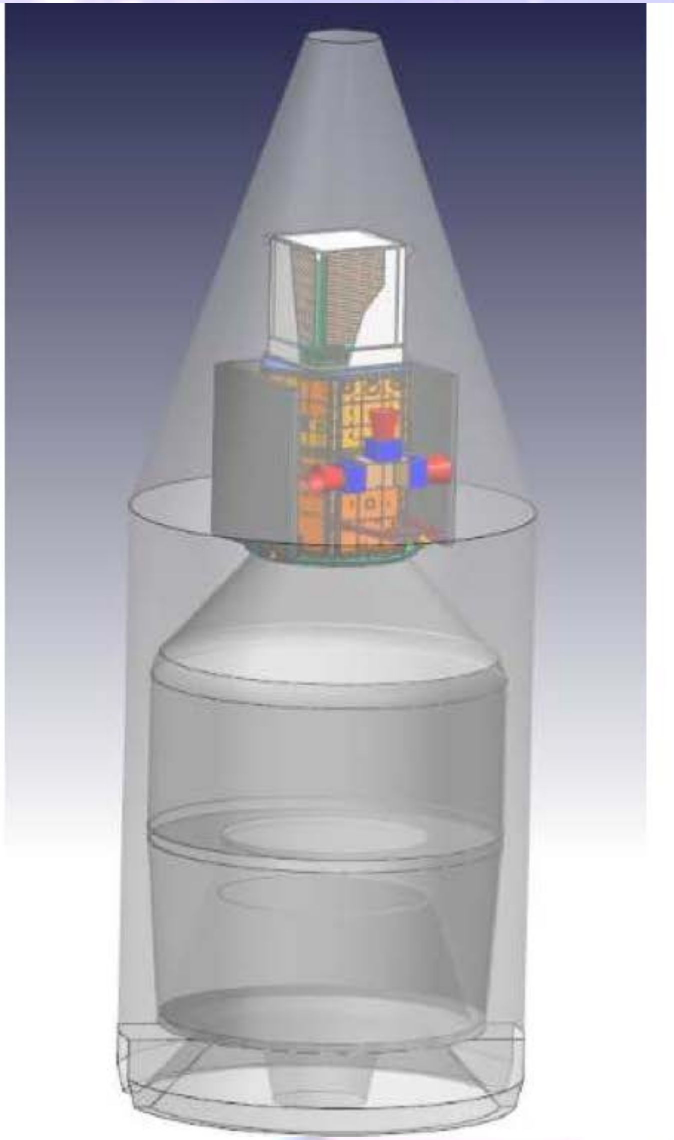
ESA Call for Small Missions: June, 2012



Power~ 400 W
Weight~600 Kg

GAMMA-LIGHT satellite launch configurations for the PSLV and VEGA





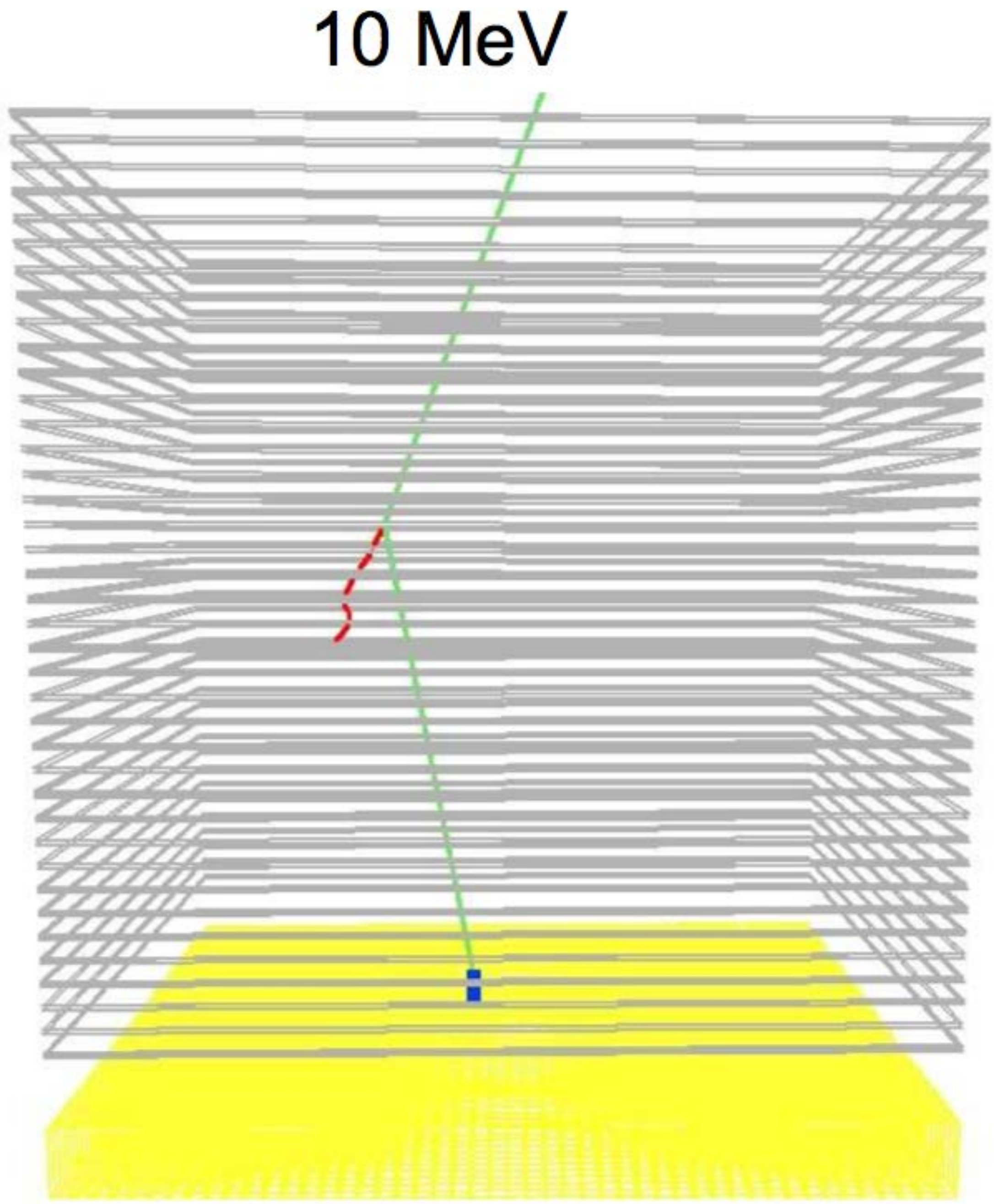
- a companion satellite similar to G-LIGHT can be accomodated.

Gamma-light Participants

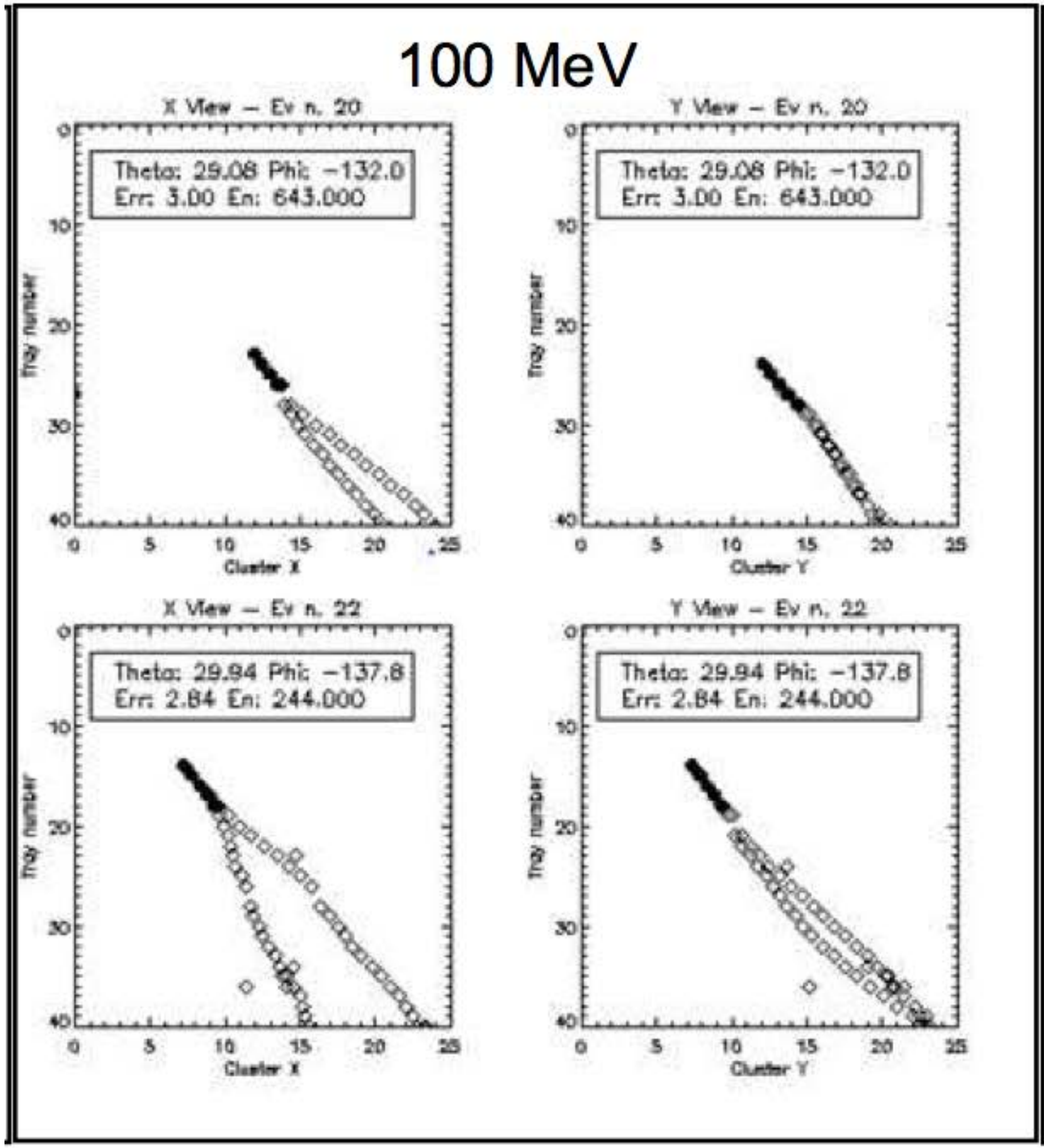
- INAF Italian Institute of Astrophysics (INAF) Italy
- INFN Italian Institute of Nuclear Physics Italy
- ASDC ASI Science Data Center Italy
- SRC PAS Space Research Center of Polish Academy of Sciences Poland
- NCAC Nicolaus Copernicus Astronomical Center, Warsaw Poland
- University of Barcelona Spain
- DTU Space Denmark
- UIB University of Bergen Norway
- TOV University of Rome Tor Vergata Italy
- TUR University of Turin Italy
- YAL Yale UniversityUSA
- SAP University of Rome "La Sapienza"Italy
- MAD University of Madrid Spain
- University of Salamanca Spain
- TRI University of TriesteItaly
- ENEA Italy

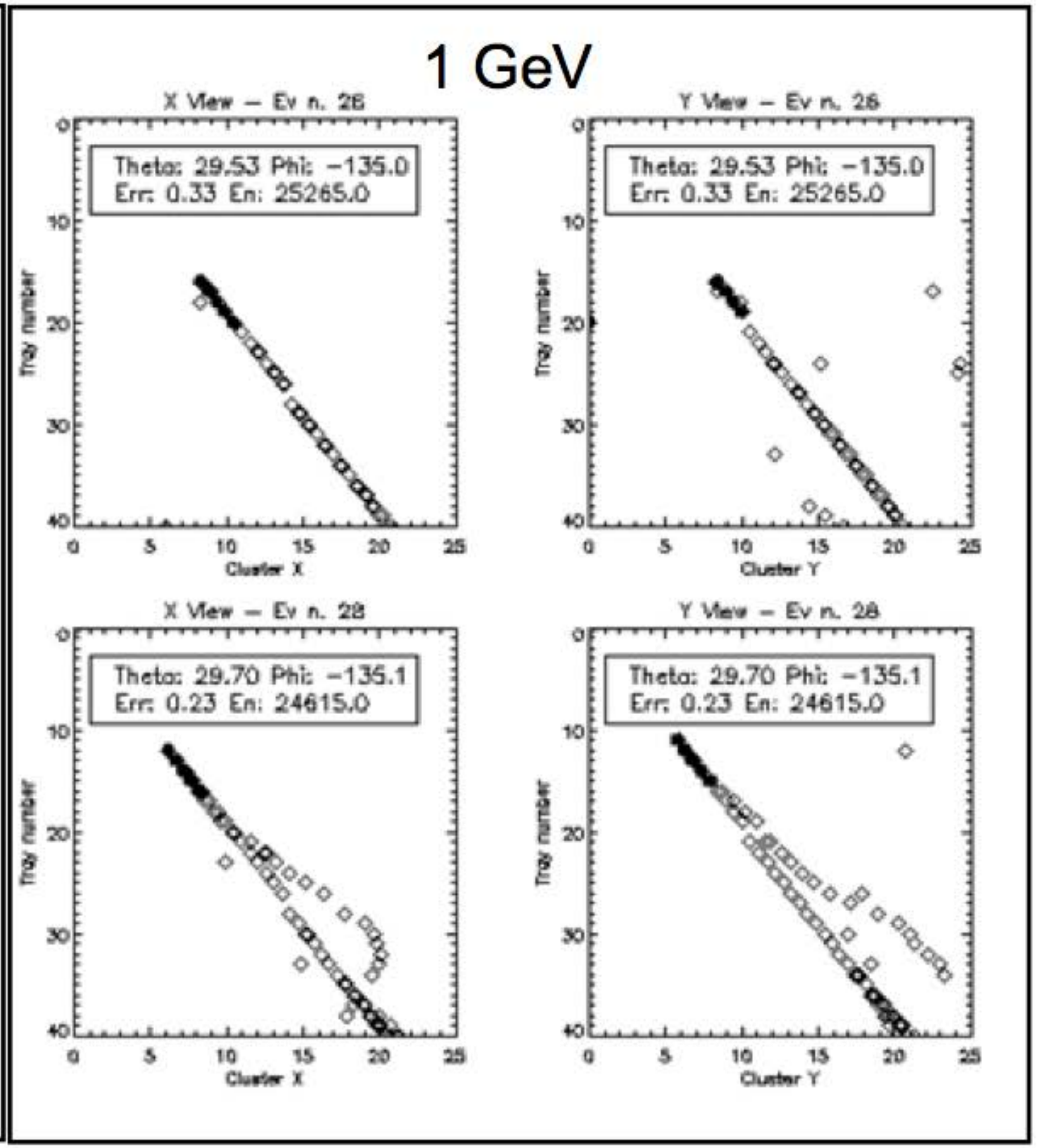
G-LIGHT Simulation

Compton interaction of a 10 MeV photon producing a low-energy single-track electron, and depositing energy in the Calorimeter for a 30^0 incidence

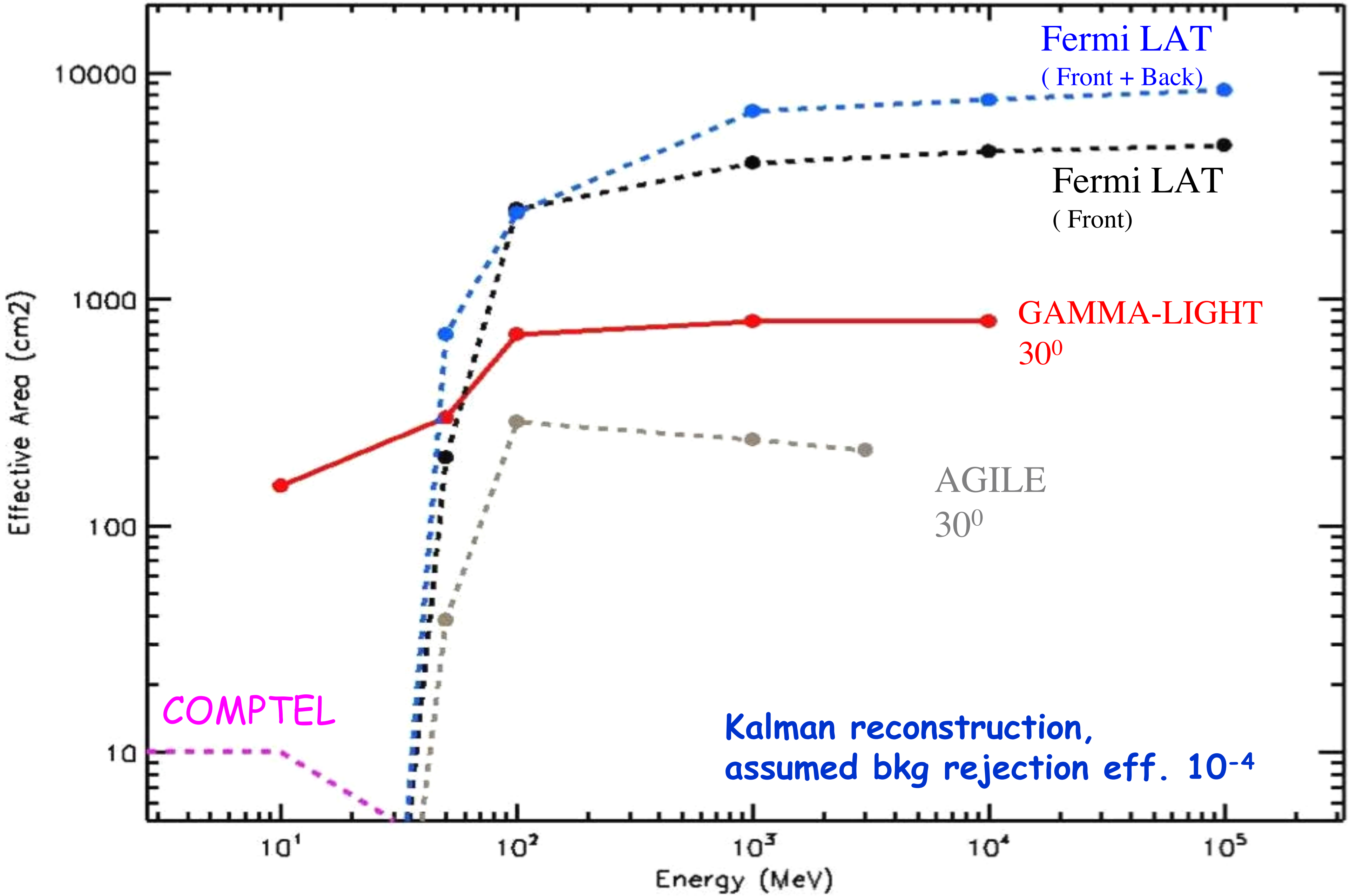


Gamma-light *Simulation*

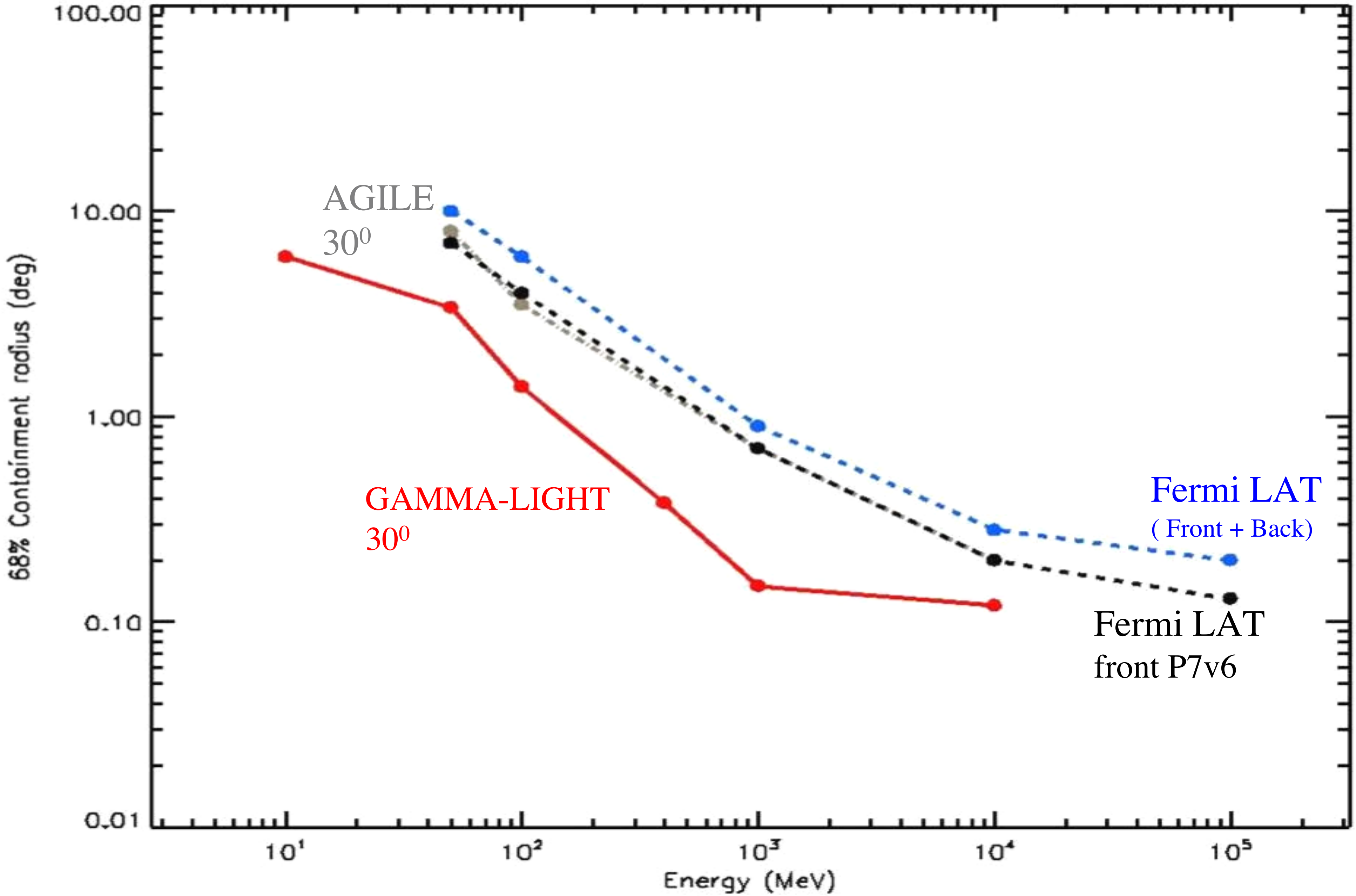


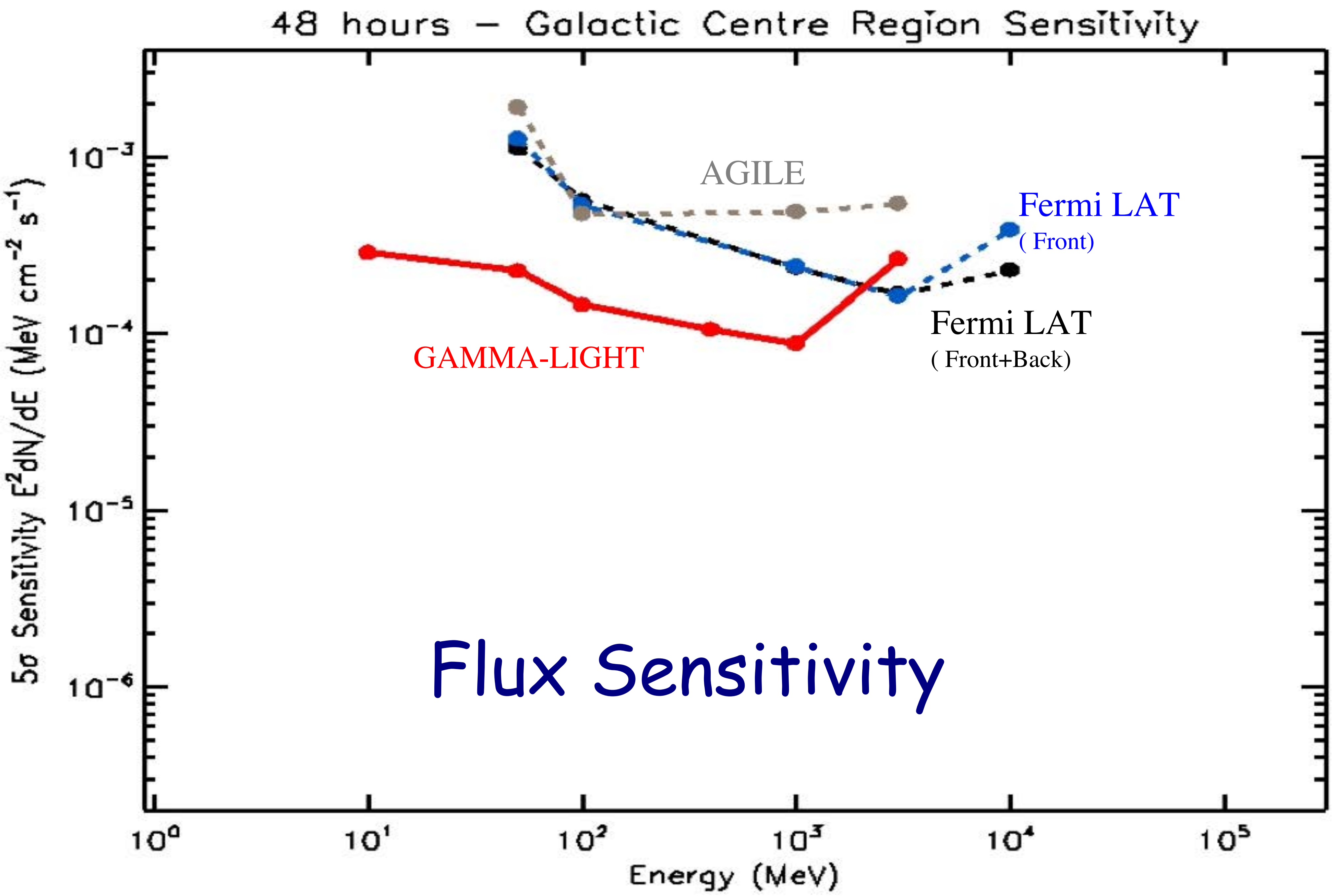


Effective area

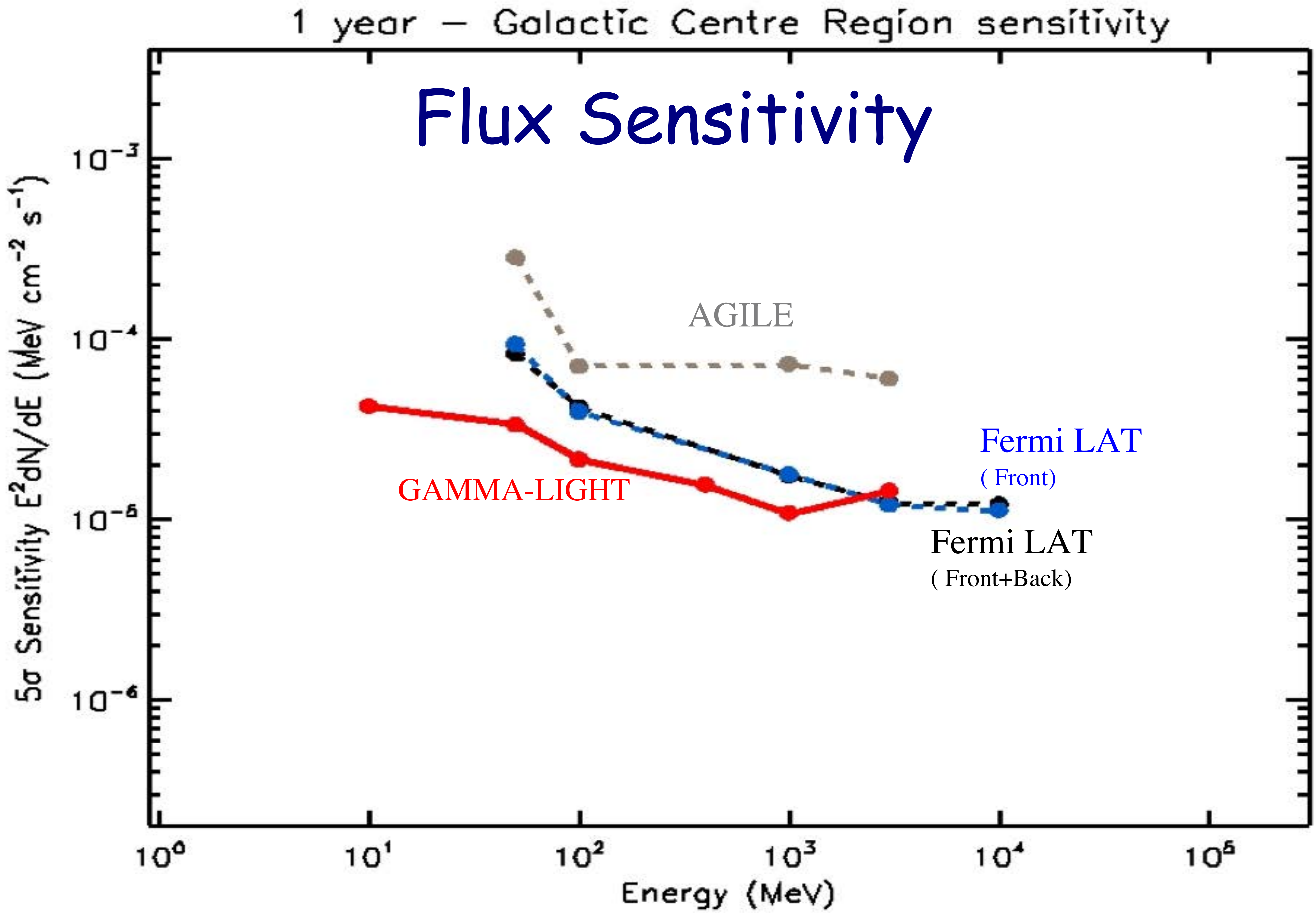


PSF (68% containment radius)




48 hours - Galactic Centre Region Sensitivity
AGILE
Fermi LAT
(Front)
Fermi LAT
(Front+Back)
GAMMA-LIGHT
Flux Sensitivity
5σ Sensitivity E²dN/dE (MeV cm⁻² s⁻¹)
Energy (MeV)
10⁻³
10⁻⁴
10⁻⁵
10⁻⁶
10⁰
10¹
10²
10³
10⁴
10⁵

Flux Sensitivity



Astrophysics Objectives of GAMMA-LIGHT

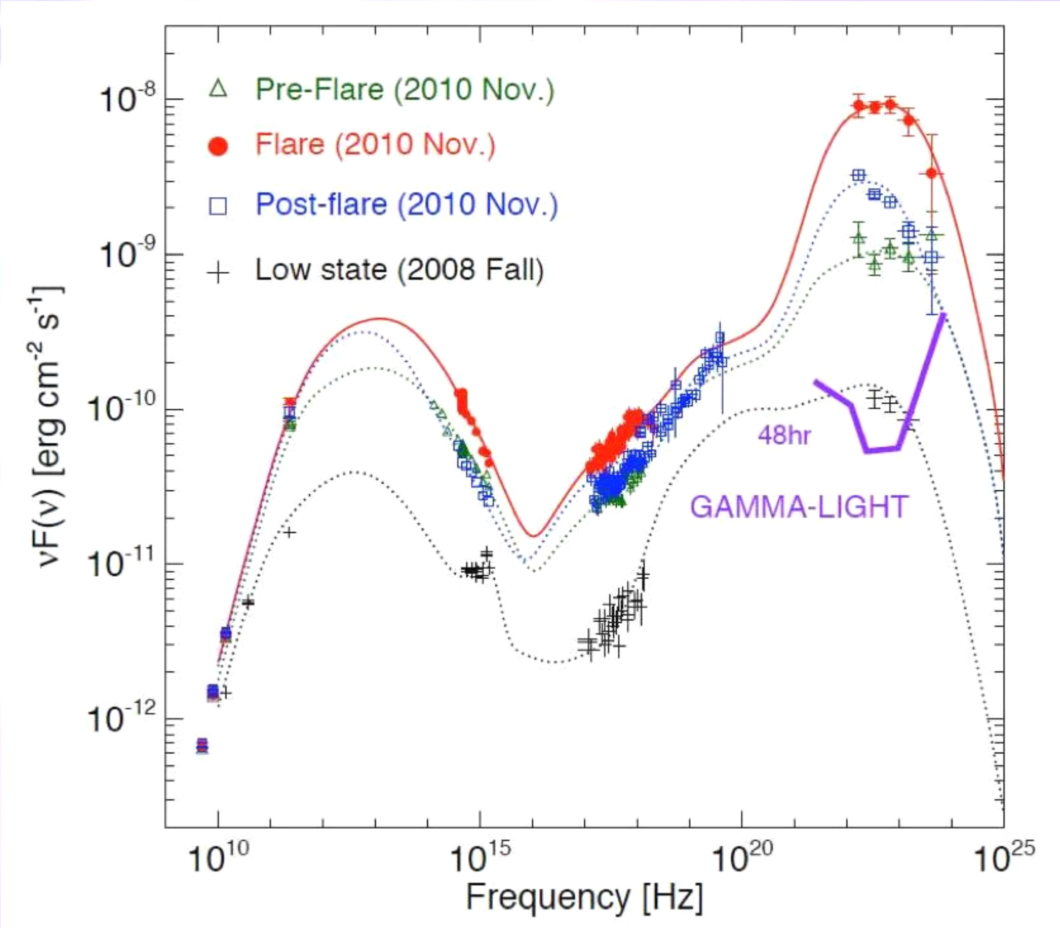
- 1. Search of Dark Matter gamma-ray signatures in the Galaxy and in particular in the Galactic Center region;
- 2. Resolving the Galactic Center region in gamma-rays: the central BH region, GeV and TeV sources, nebulae, compact sources, SNRs;
- 3. Resolving the diffuse emission in the Galactic plane, relation with cosmic-ray propagation, star forming regions in the Galactic plane; extending the cosmic-ray propagation and emission properties of the "Fermi bubbles" to the lowest energies below 100 MeV;
- 4. Resolving spatially and spectrally SNRs and addressing the origin and propagation of cosmic- rays;
- 5. Polarization studies of gamma-ray sources;

Astrophysics Objectives of GAMMA-LIGHT (cont.)

- 6. Detection of soft gamma-ray pulsars in the range 10-100 MeV, and pulsar wind nebulae studies;
- 7. Detection of compact objects, microquasars, relativistic jets in the range 10 MeV - 1 GeV resolving the issue of hadronic vs. leptonic jets for a variety of sources (e.g., Cyg X-3);
- 8. Detection and localization of transients and exotic sources with much improved sensitivity;detection of Crab Nebula gamma-ray flares with excellent sensitivity down to 10 MeV;
- 9. Blazar studies down to 10 MeV, excellent positioning resolving source confusion;
- 10. GRB excellent capability in the range 10 MeV - 5 GeV; sub-millisecond timing capability in the range 0.3-100 MeV.

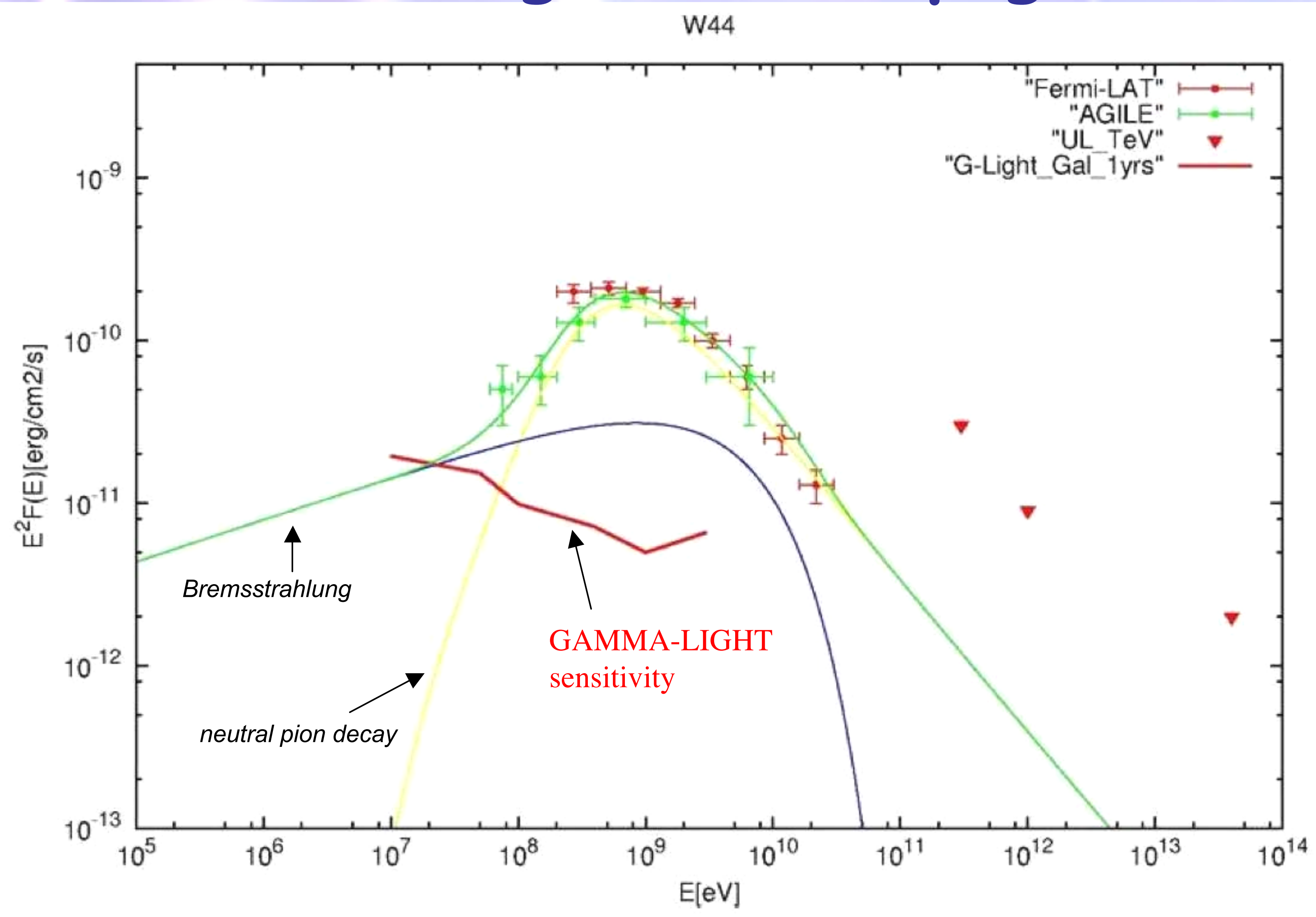
Extragalactic Sources, Blazars, MeV Blazars

Multi-epoch SEDs of the FSRQ 3C454.3



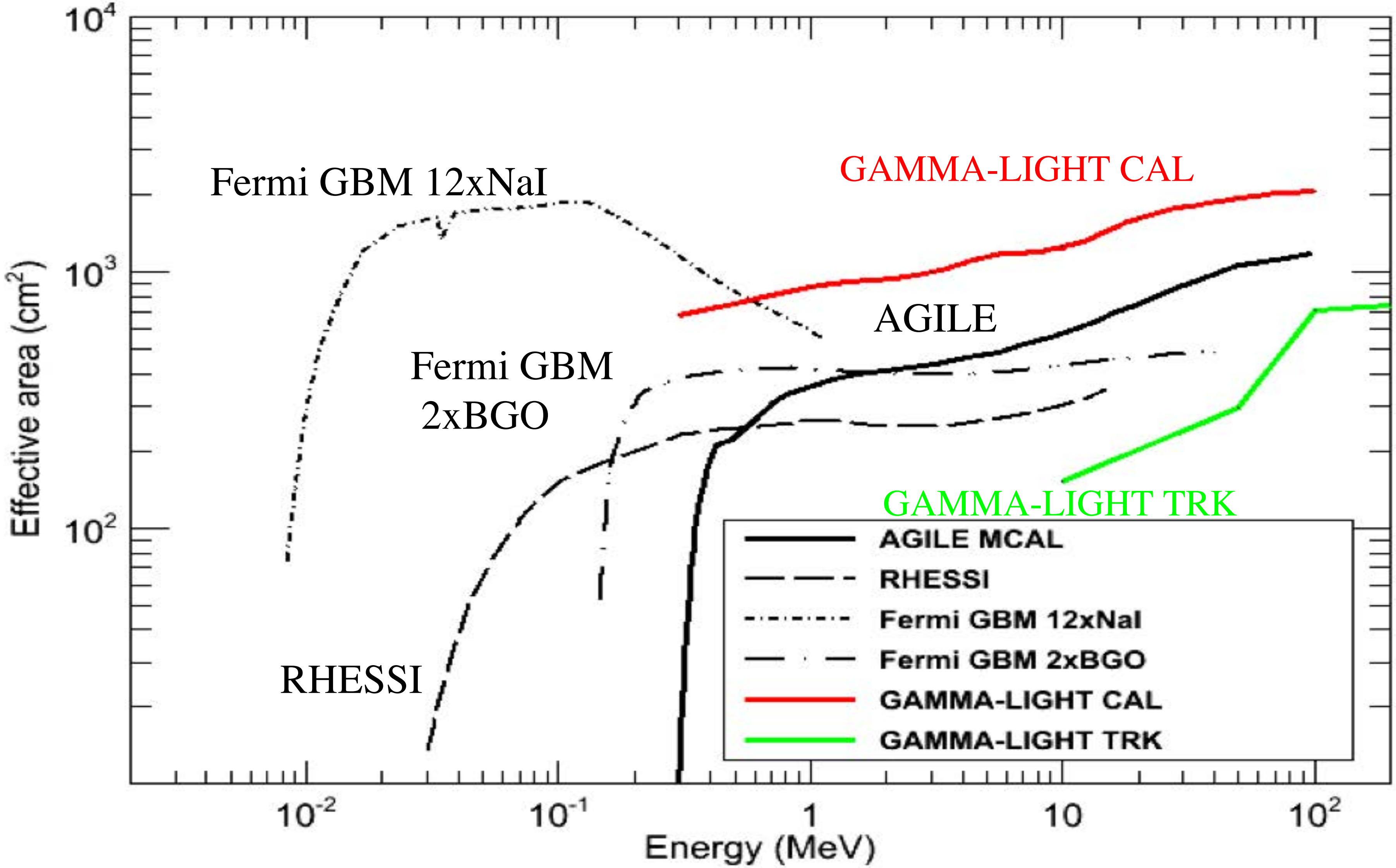
G-LIGHT will allow us to investigate daily (or sub-daily) SEDs during gamma-ray super- flares. The 5-sigma G-LIGHT differential sensitivity (purple line) is computed for an integration time of 48 hours

SNRs and the Origin and Propagation of CRs



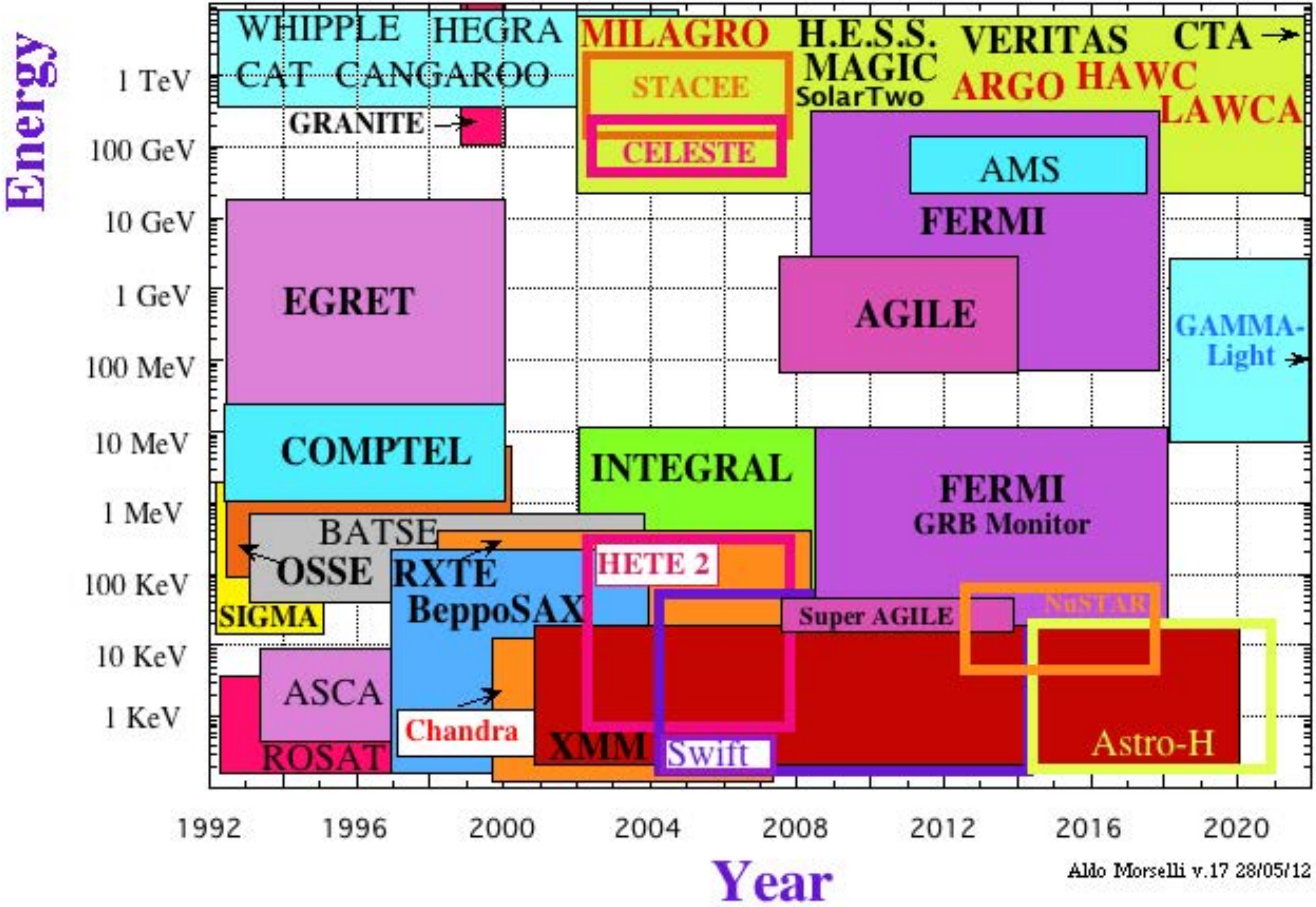
- *gamma-ray spectrum of SNRs W44. The red curve shows the expected GAMMA-LIGHT sensitivity for a 1-year effective time integration.*

Earth Studies Objectives of GAMMA-LIGHT: Terrestrial Gamma-Ray Flashes



Earth Studies Objectives of GAMMA-LIGHT: Terrestrial Gamma-Ray Flashes

- G-LIGHT will fill this observational gap and contribute to TGF science with the following points:
- 1) detection of Terrestrial Gamma-Ray Flashes (TGFs) with extended energy range and imaging capability obtained by a new strategy for Earth albedo background rejection;
- 2) correlating high-energy TGFs with local and global meteorological data, addressing local climate and Climate Change issues;
- 3) studying the impact of TGFs and "high-energy"-TGFs for the atmospheric chemistry and particle transport including gamma-ray and neutron generation and atmospheric propagation to the ground;
- 4) maintaining an updated TGF archive, available to ESA and meteorological institutions.


Energy
1 TeV
100 GeV
10 GeV
1 GeV
100 MeV
10 MeV
1 MeV
100 KeV
10 KeV
1 KeV
WHIPPLE
HEGRA
CAT
CANGAROO
GRANITE
MILAGRO
STACEE
CELESTE
H.E.S.S.
MAGIC
SolarTwo
VERITAS
ARGO
HAWC
CTA
LAWCA
AMS
FERMI
EGRET
AGILE
GAMMA-Light
COMPTEL
INTEGRAL
FERMI
GRB Monitor
BATSE
OSSE
RXTE
BeppoSAX
HETE 2
SIGMA
Super AGILE
NuSTAR
ASCA
Chandra
XMM
Swift
Astro-H
ROSAT
1992
1996
2000
2004
2008
2012
2016
2020
Year
Aldo Morselli v.17 28/05/12

thank you for the attention