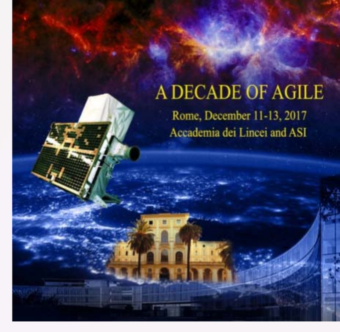
GAMMA-400: extension to study low-energy gamma rays (20 MeV -100 MeV)



Simulation environment: GEANT4 (4.10.01p02)

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According the Russian Federal Space Program 2016-2025 GAMMA-400 continues to be funded by Roscosmos and the GAMMA-400 space observatory is scheduled to launch in 2025-2026.

GAMMA-400 scientific goals

-Searching for gamma-ray lines for the energy range of 20 MeV - 20 TeV in the discrete source, diffuse, and isotropic gamma-ray emission when annihilating or decaying dark matter particles;
-Searching for new and study of known Galactic and extragalactic discrete high-energy gamma-ray sources: supernova remnants, pulsars, accreting objects, microquasars, active galactic nuclei, blazars, quasars; studying their structure with high angular resolution and measuring their energy spectra and luminosity with high energy resolution;
-Identifying discrete gamma-ray sources with known sources in other energy ranges.

Motivation of this study

Improve physical characteristics of the GAMMA-400 gamma-ray telescope in the energy range of ~20-100 MeV, most unexplored range today. Such observations are crucial today for a number of first-rank problems faced by modern astrophysics and fundamental physics.

MeV gamma ray measurement s will clarify:

Re-acceleration models in Galaxy Clusters ;
The origin of the Extragalactic MeV background;
Leptonic or lepto-hadronic models for the high energy emission in Active Galactic Nuclei;
Physical origin of the high-energy gamma rays during the prompt emission of GRBs;
Cosmic-ray production in star-forming regions;
Understanding the nature of gamma-ray emission of the Fermi Bubbles;
CR propagation and interactions in the inner Galaxy;
The interplay between cosmic rays and the interstellar medium;
Sub-GeV dark matter hypothesis in the Galactic Center;
Polarization characteristics of the gamma - ray emission from pulsars;
The characteristics of gamma-ray emission from solar flares;
Galactic center gamma-ray excess;
The understanding of soft γ-ray pulsars.

Realization

Physical scheme modification while maintaining physical characteristics for high-energy (> 1 GeV) gammas.

MAIN TRIGGER (MT): not AC × S1 × S2

AC: $AC_{TOP} \times AC_{LEFT} \times AC_{RIGHT} \times AC_{FRONT} \times AC_{BACK}$

double layer $AC_{TOP,\ LEFT,\ RIGHT,\ FRONT,\ BACK}$: $(AC)_{UP}$ | $(AC)_{DOWN}$

$(AC)_{UP,\ DOWN}$: $(AC)_{UP,\ DOWN}{}^{TILE1} > (E_{RELEASE})^{THRESHOLD}$ |……| $(AC)_{UP,\ DOWN}{}^{TILE10} > (E_{RELEASE})^{THRESHOLD}$

double layer S1: $(S1)_{UP}$ | $(S1)_{DOWN}$

double layer S2: $(S2)_{UP}$ | $(S2)_{DOWN}$

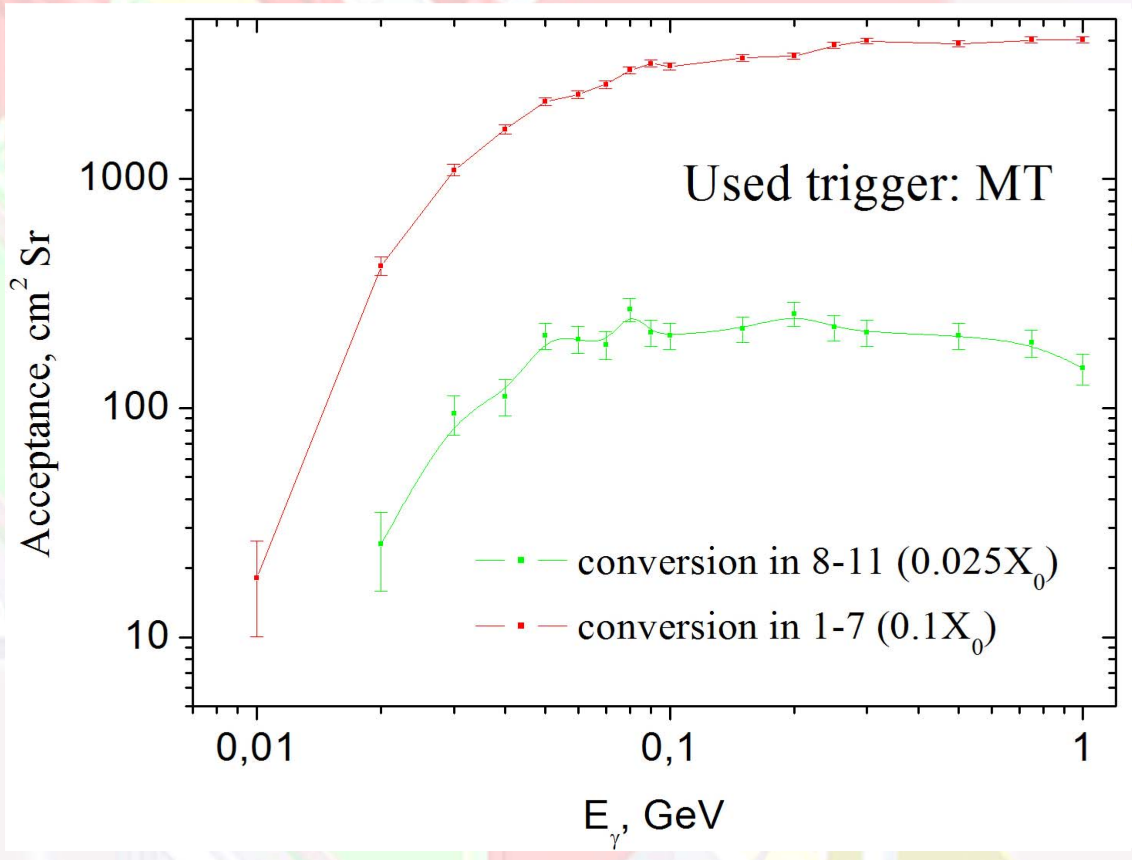
$(S1,2)_{UP,\ DOWN}$: $(S1,2)_{UP,\ DOWN}{}^{TILE1} > (E_{RELEASE})^{THRESHOLD}$ |……| $(S1,2)_{UP,\ DOWN}{}^{TILE10} > (E_{RELEASE})^{THRESHOLD}$

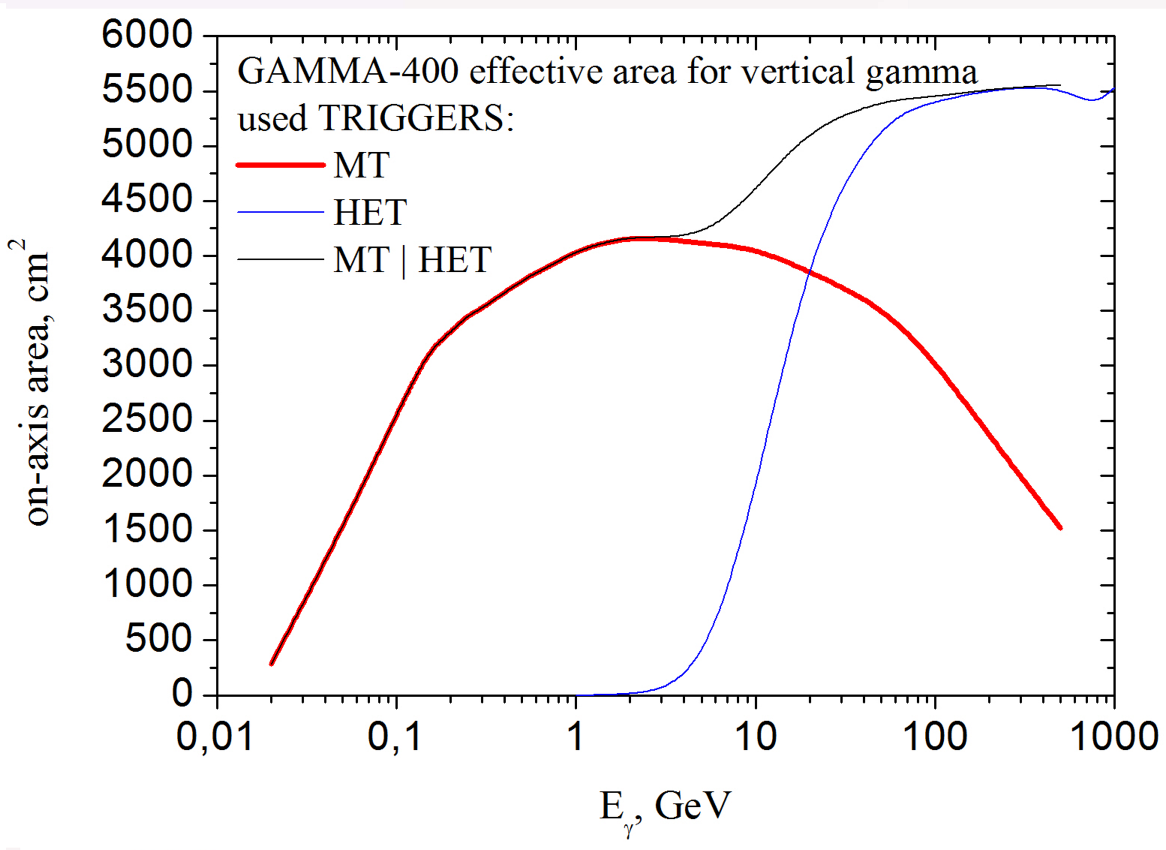
$(E_{RELEASE})^{THRESHOLD}$=0.3 MIP

HIGH ENERGY TRIGGER (HET): S1 × S2 × $S3^{HE}$

double layer $S3^{HE}$: $(S3)_{UP}$ | $(S3)_{DOWN}$
$(S3)_{UP,\ DOWN}$: $(S3)_{UP,\ DOWN}{}^{TILE1} > 0.5 \times (E_{RELEASE})^{THRESHOLD\ HE}$ |…..| $(S3)_{UP,\ DOWN}{}^{TILE10} > 0.5 \times (E_{RELEASE})^{THRESHOLD\ HE}$

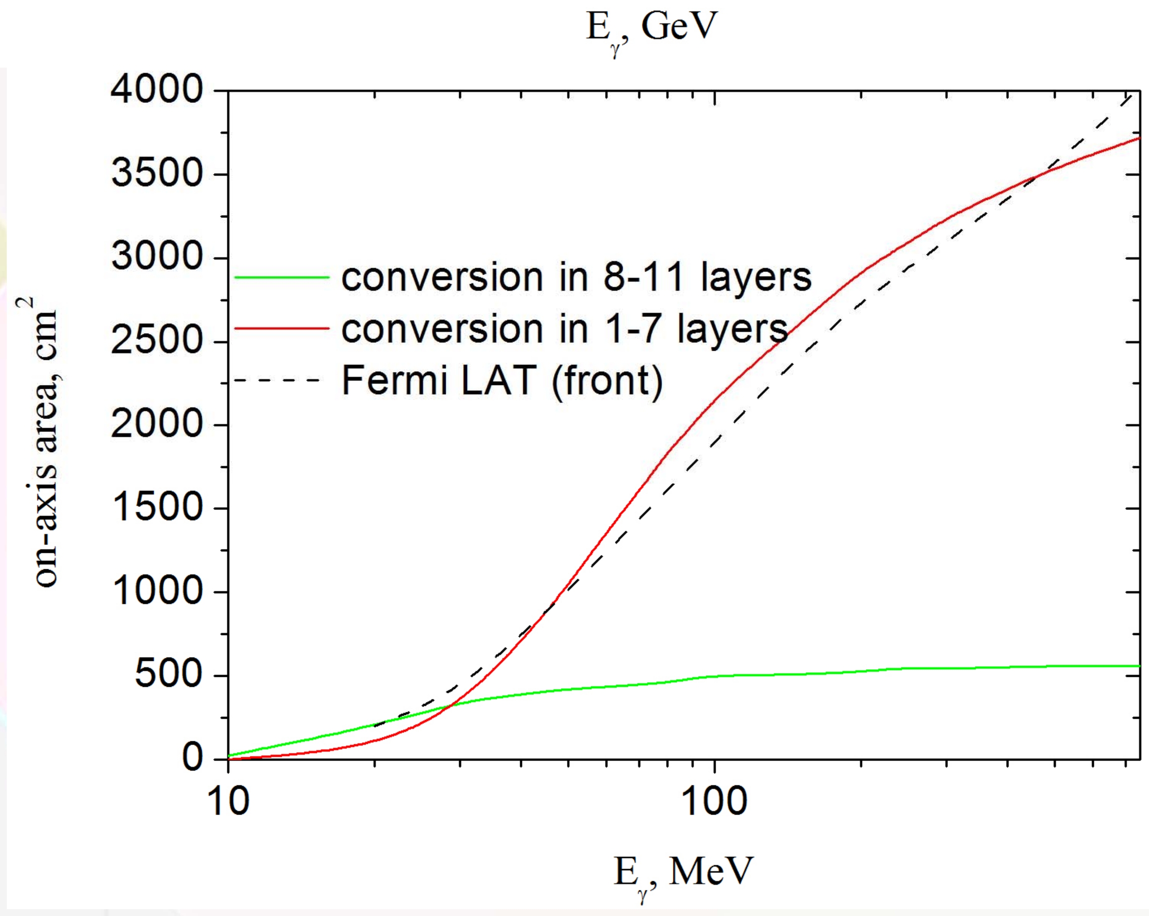
$(E_{RELEASE})^{THRESHOLD\ HE}$=100 MeV





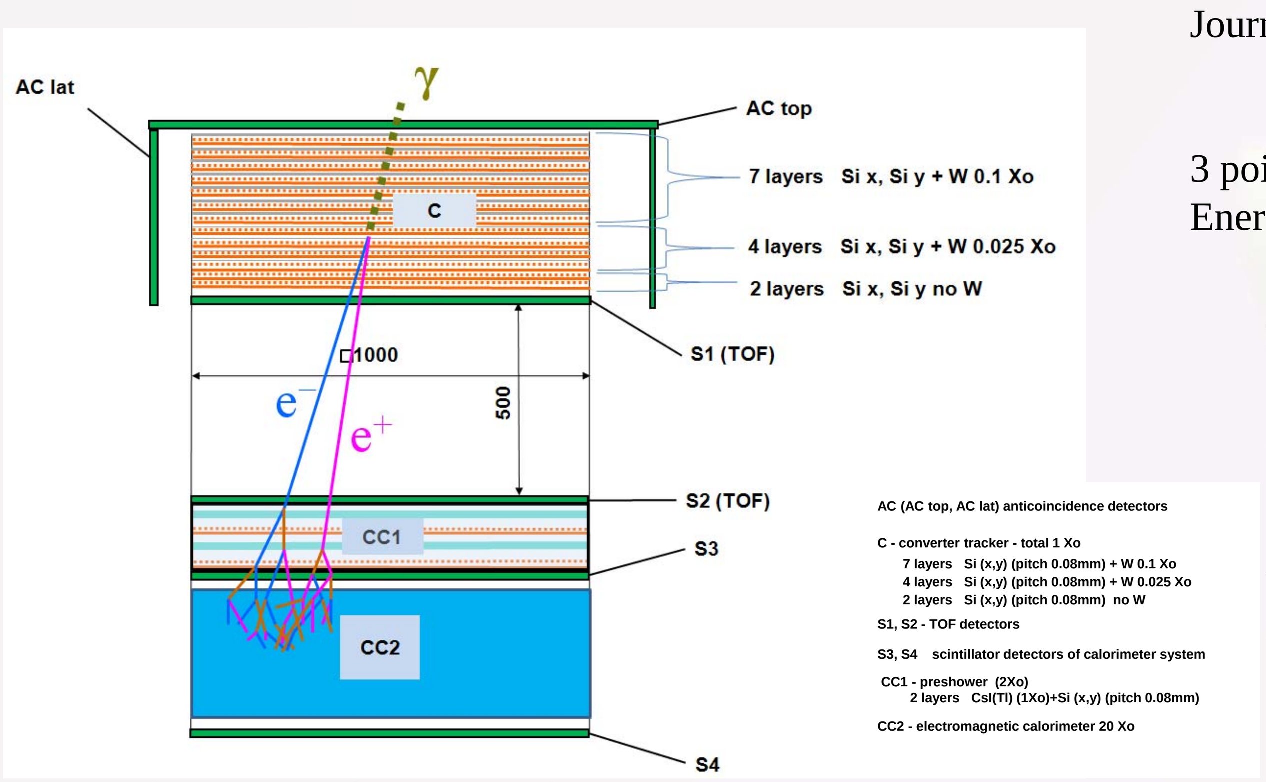
Science with e-ASTROGAM
A space mission for MeV-GeV gamma-ray astrophysics
Cosmic rays interactions
E. Orlando, A. Strong, I. A. Grenier, A. Bykov,
Gamma rays from the interstellar medium: probing cosmic rays throughout the Galaxy, Figure 1, Spectrum of the **inner Galaxy**.

GAMMA-400 will detect from inner Galaxy:
~10^7 gamma/per year (conversion in 1÷7 layers)
~8×10^5 gamma/per year (conversion in 8÷11 layers)
in the energy range from 20 MeV to 100 MeV

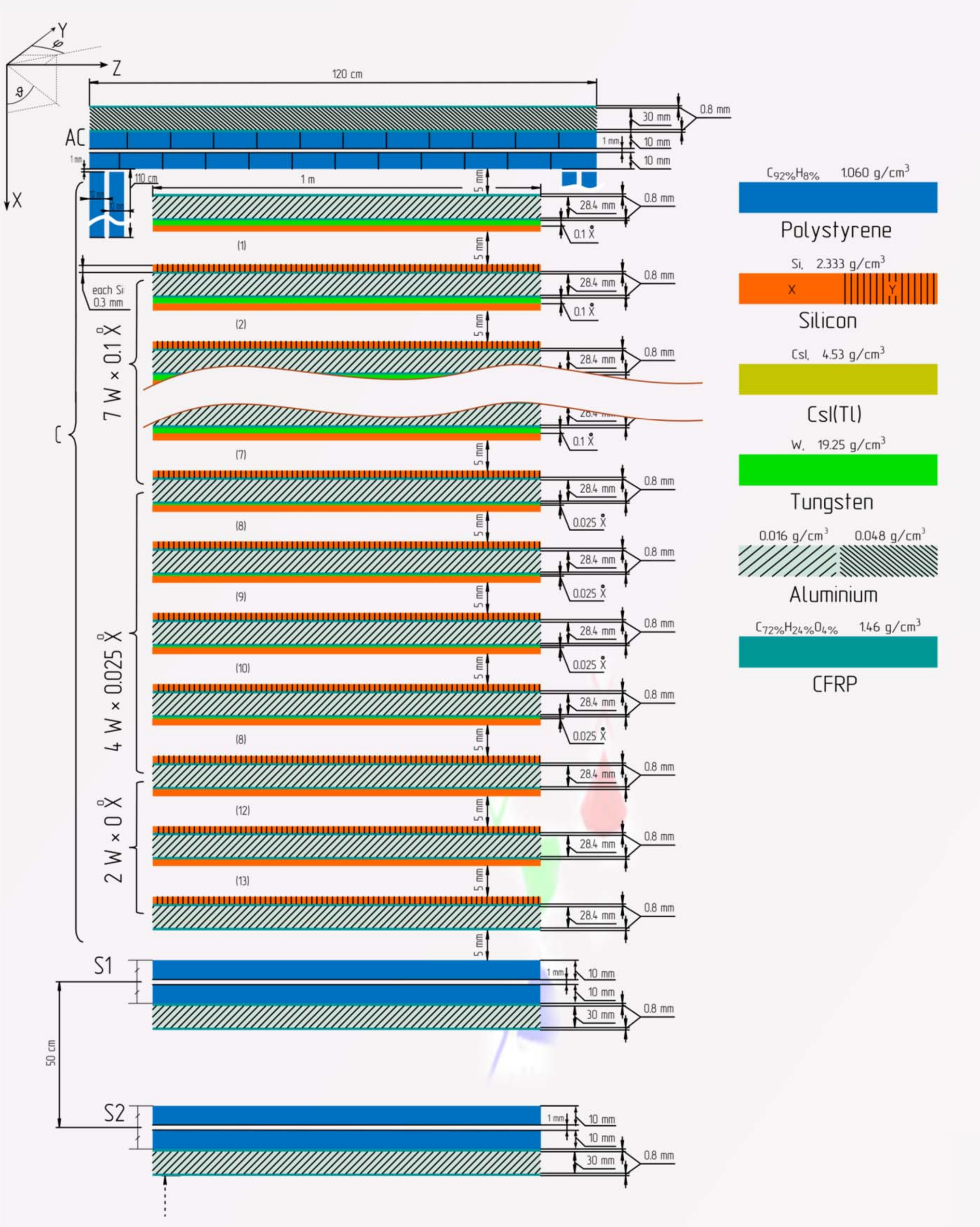


GAMMA-400 physical scheme

Total mass ~ 3500 kg
13 layers in converter
7 top layers with tungsten 0.1 X_0
4 intermediate layers with tungsten 0.025 X_0
2 last layers without tungsten



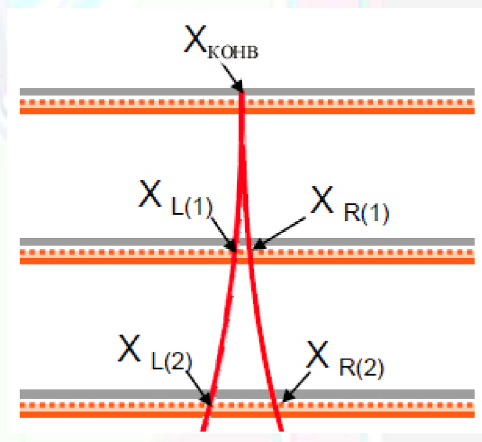
Magnified view of top part of GAMMA-400 layers



Angular resolution for low energy gamma:

Method to restore incident angle of low energy (< 300 MeV) gamma.

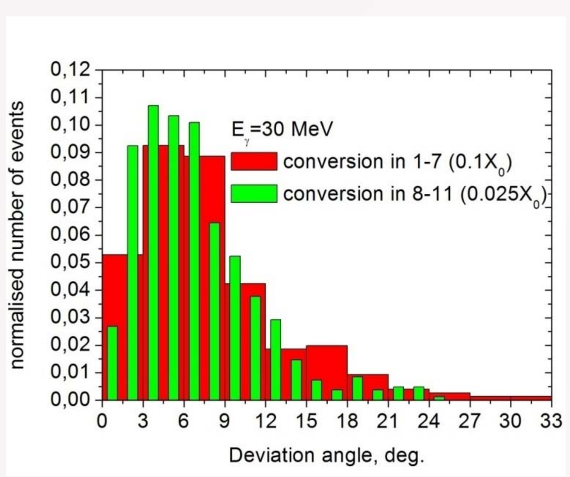
Imaginary curvature method
M.D. Kheymits, et al., Method of incident low energy gamma-ray direction reconstruction in the GAMMA-400 gamma-ray space telescope, Journal of Physics: Conference Series 675 , 2016

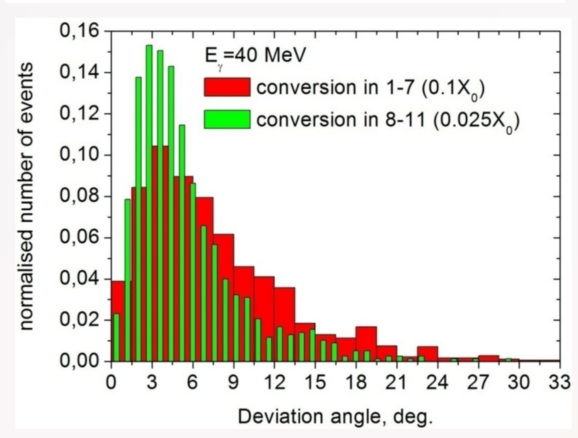


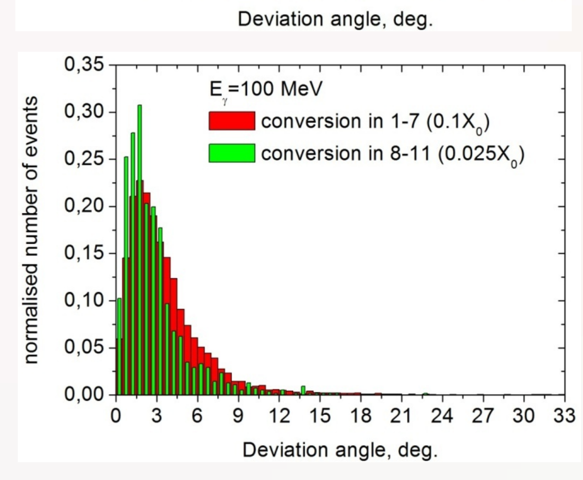
Basic method:
3 points per track for each pair component.
Energy estimation for bisector correction.

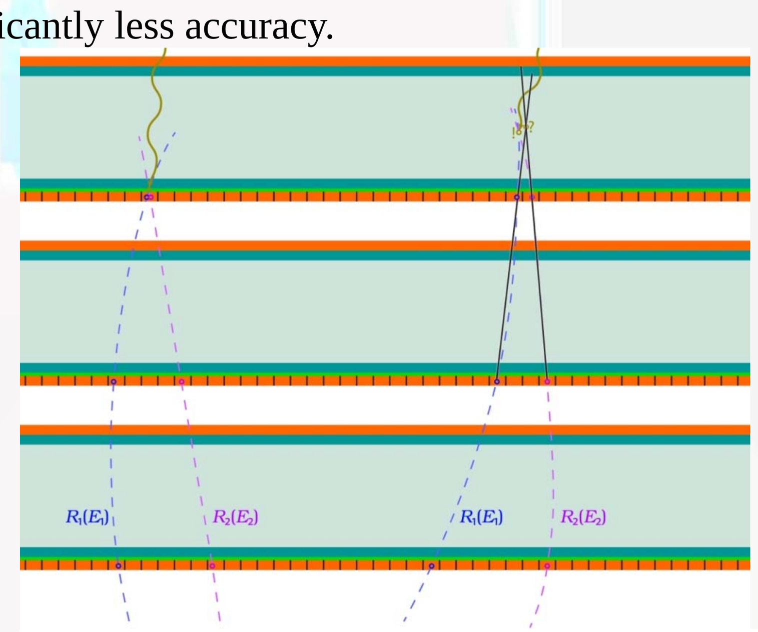
Modified method.

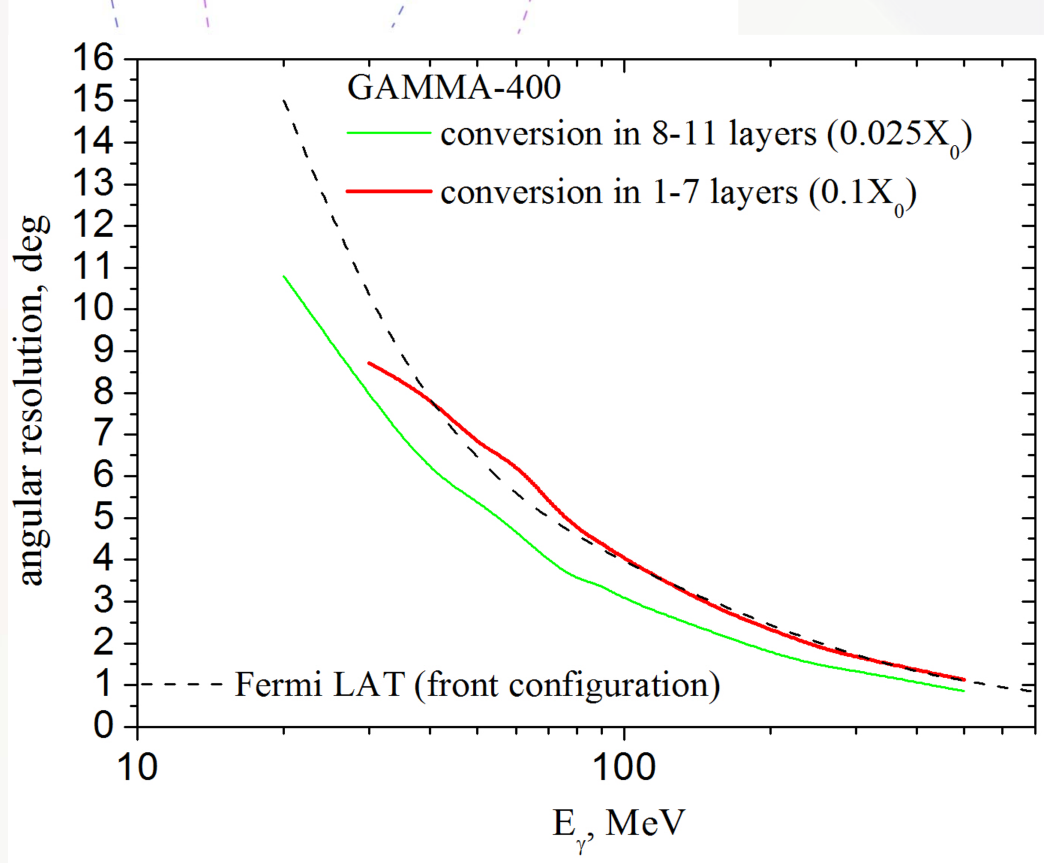
The gamma conversion events topology can be separated into the following two samples. The first one presents the conversion in tungsten layer, which is shown in left part of the figure. For such events the pair components release the energy (mainly) in one strip just under the tungsten plane. The second sample corresponds to the conversion in support matter just upper the tungsten plane, which is shown in right part of the figure. For such events the pair components release the energy (mainly) in different strips. The vertical localization of conversion point in this case has significantly less accuracy.











Energy resolution for low energy gamma: