MEGA: measuring polarization in γ-rays

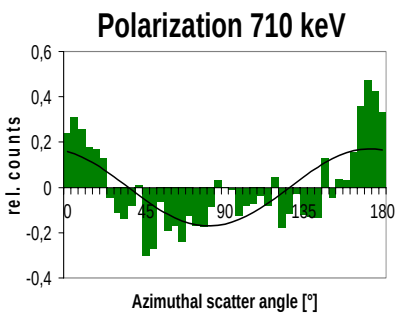
The prototype instrument MEGA, a combined Compton scattering and pair creation telescope, was calibrated with monoenergetic and 100% polarized photons in beams generated at Duke University's FELL HIγS facility. Polarization signatures are detected from 710 keV up to 5 MeV in agreement with expectations from Geant4 simulations. These properties demonstrate that Compton telescopes suitable for recording large angle scattering events, like MEGA, are ideal instruments to measure polarization in low energy γ-rays from astronomical objects. We know from tantalizing first observations (*RHESSI*) that gamma-ray bursts and solar flares are strongly polarized at MeV energies. It is to be expected that polarization in other sources like pulsars, binaries, and AGNs, where radiation processes of relativistic particles in strong magnetic fields or beamed geometries play an important role, will also provide decisive new insights into the physics of cosmic high-energy sources.

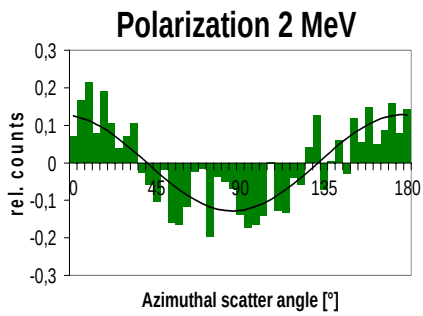
Most processes in high-energy astrophysics, such as synchrotron radiation, bremsstrahlung, Compton scattering, etc. generate polarized gamma-rays. Therefore, polarization measurements are of great value to understand the emission mechanisms of gamma-rays.

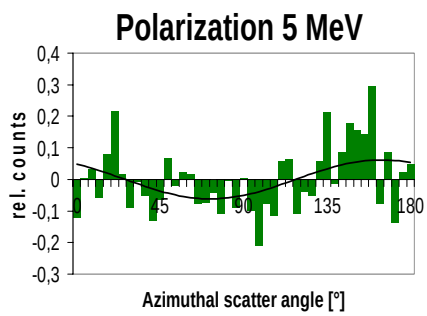
The polarization preserving properties of the Compton cross-section (right) result in a cosine shaped modulation of the azimuthal scatter angle of the Compton process. The maximum of the modulation is perpendicular to the original polarization vector.

$$\frac{\partial\sigma}{\partial\Omega} = \frac{r_e^2}{2}\left(\frac{E_g}{E_i}\right)^2\left(\frac{E_g}{E_i}+\frac{E_i}{E_g}-2\sin^2\varphi\cos^2\chi\right)$$

MEGA calibration: Azimuthal scatter angle distributions (geometry and efficiency corrected) for measurements at 0.71, 2.0 and 5.0 MeV. As expected, the maxima of the modulation are found at ~0° and ~180°, perpendicular to the horizontal polarization vector of the incident beam. The amplitudes of the detected modulations are in agreement with Geant4 simulations.

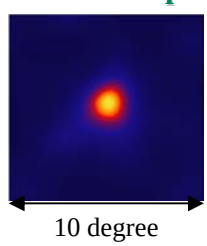


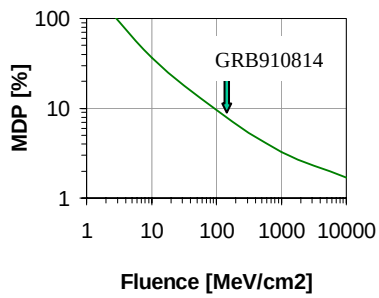




Simulation of a gamma-ray burst with a MEGA satellite telescope:

The high-energy burst GRB910814, the second brightest GRB in the first year of COMPTEL, was used as a template for a simulated observation with a MEGA satellite configuration. Imaging to a sub-degree accuracy and a minimum detectable polarization (MDP) of 8% are found for this average GRB. MEGA with its wide field-of-view should register many such events.





Reference: Zoglauer A. et al., poster 5th Integral Workshop, München, 2004

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