Polarization response of the MEGA medium energy gamma-ray telescope

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A prototype instrument for a potential future satellite telescope sensitive from 0.4 to >50 MeV has been calibrated with completely polarized beams at energies from 0.7 MeV to 50 MeV.

The modulation expected in the azimuthal distribution of Compton scattering was clearly detected below 5MeV in agreement with simulations.

The MEGA collaboration:

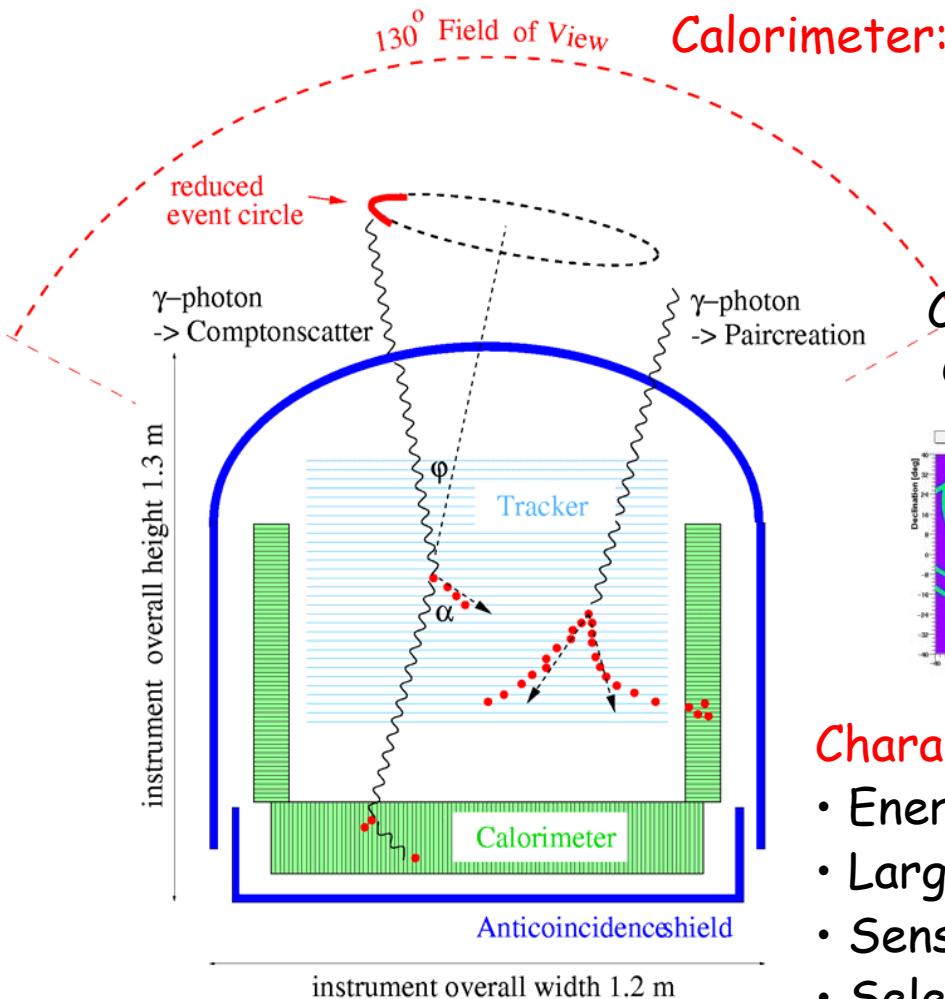
Europe: MPE, Garching, GACE, Valencia, IASF, Bologna, CESR, Toulouse,

U.S.A.: UNH, GSFC, NRL , Columbia U. , U of Alabama, U. of Lousiana, IGPP-UCR, LANL, Clemson U.

MEGA Principle of detecting Compton and pair-creation events:
two detector subsystems in ‚flexible' coincidence

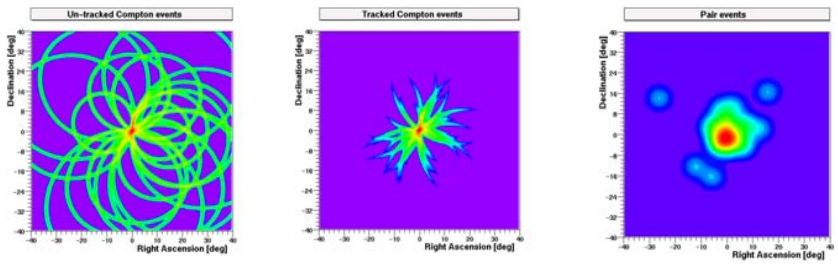
Tracker: double sided Si strip detectors

Calorimeter: 2(3)D resolving CsI/PIN diode arrays



Imaging

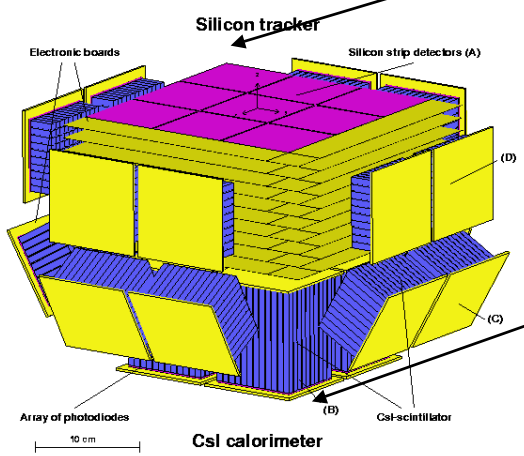
Classical Compton | Tracked Compton | Pairs



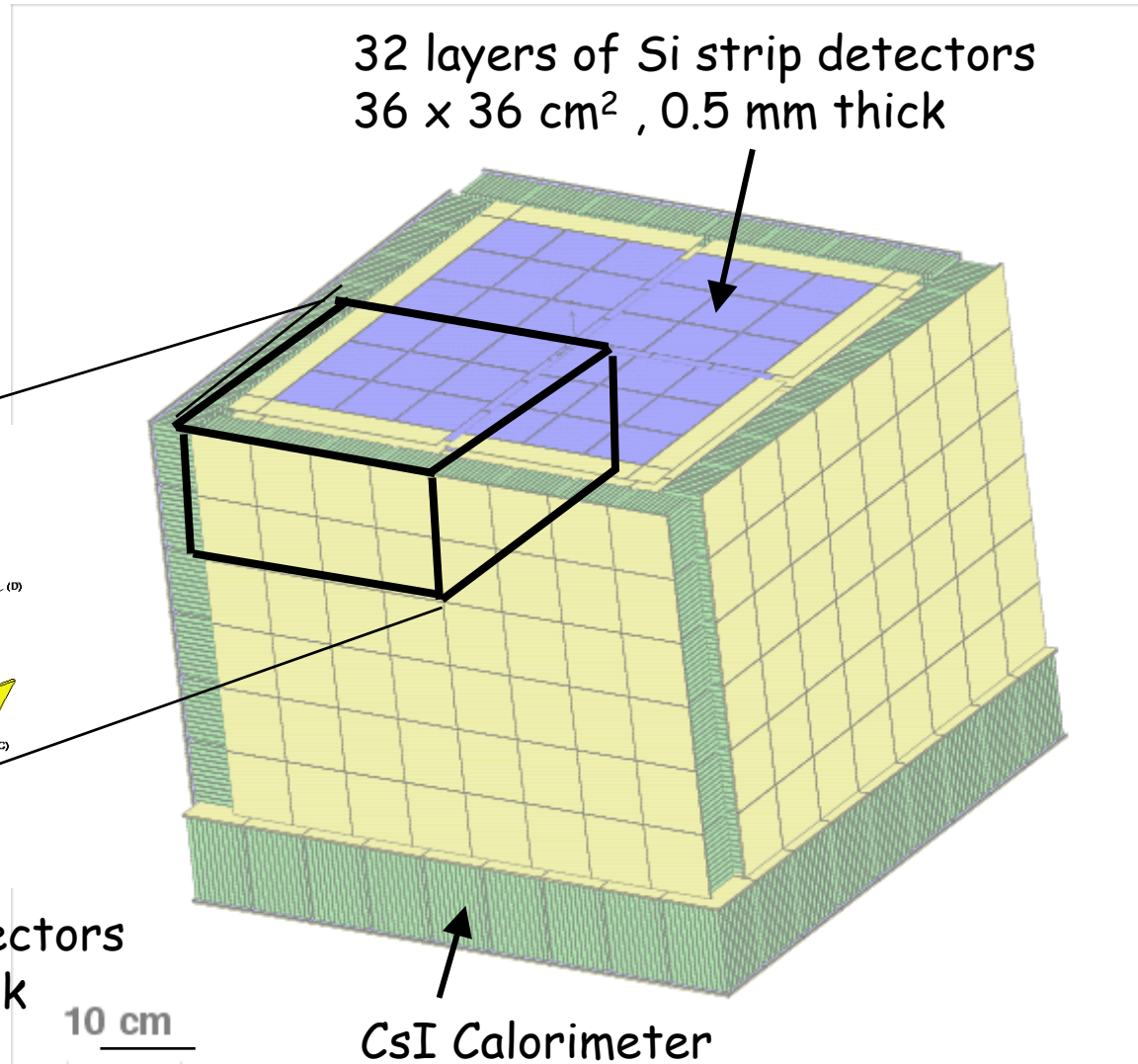
Characteristics:

- Energy range spanning Compton-Pair range
- Large field of view and good Sensitivity
- Sensitive to Polarization below ~5 MeV
- Selective / good Background Suppression

Prototype and Full-size Instrument

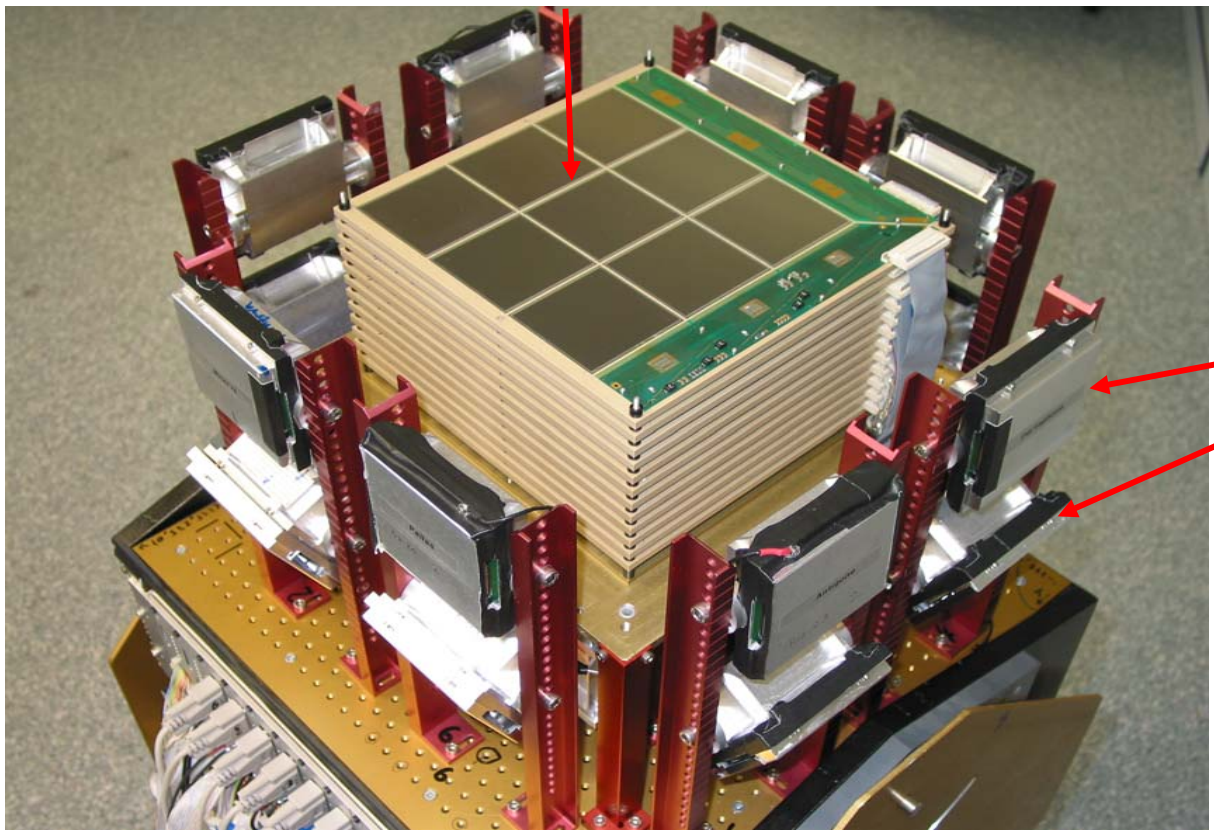


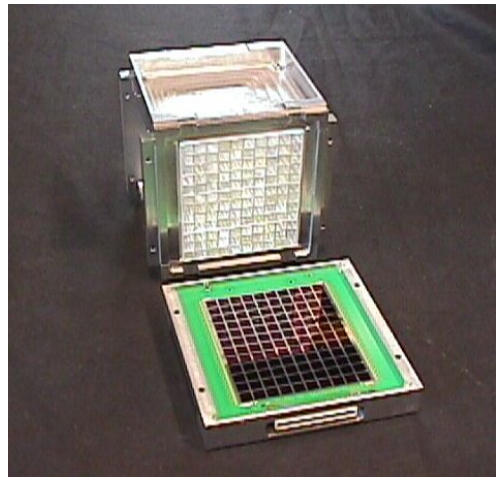
10 layers of Si strip detectors
18 x 18 cm^2 , 0.5 mm thick



Prototype

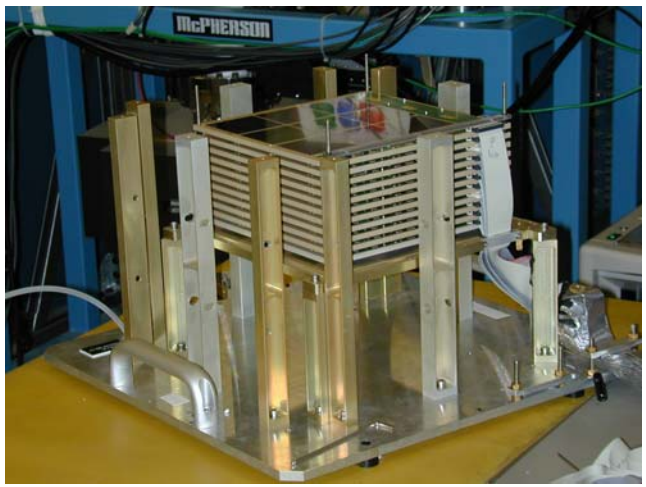
Tracker:
10 (+1) layers of Silicon stripdetectors (wafers 6x6cm^2)

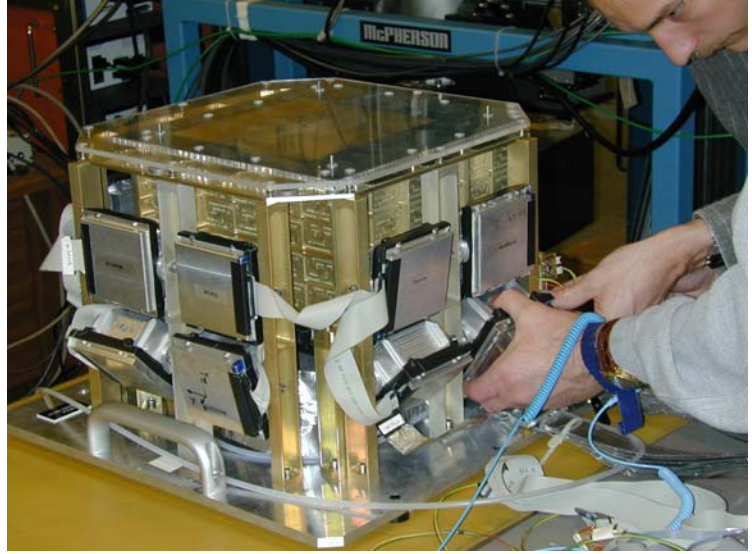


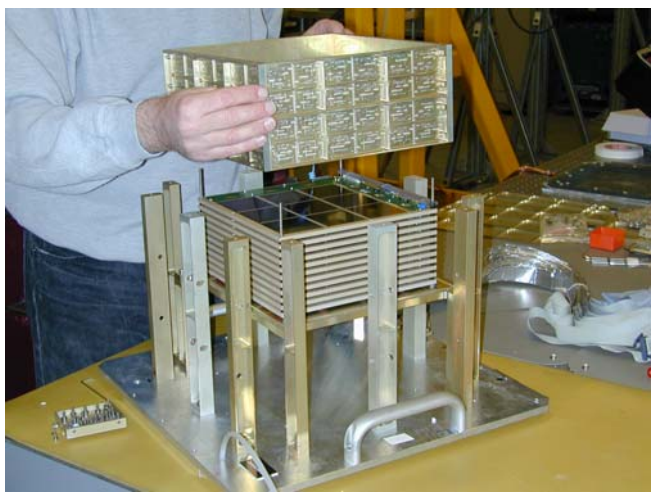


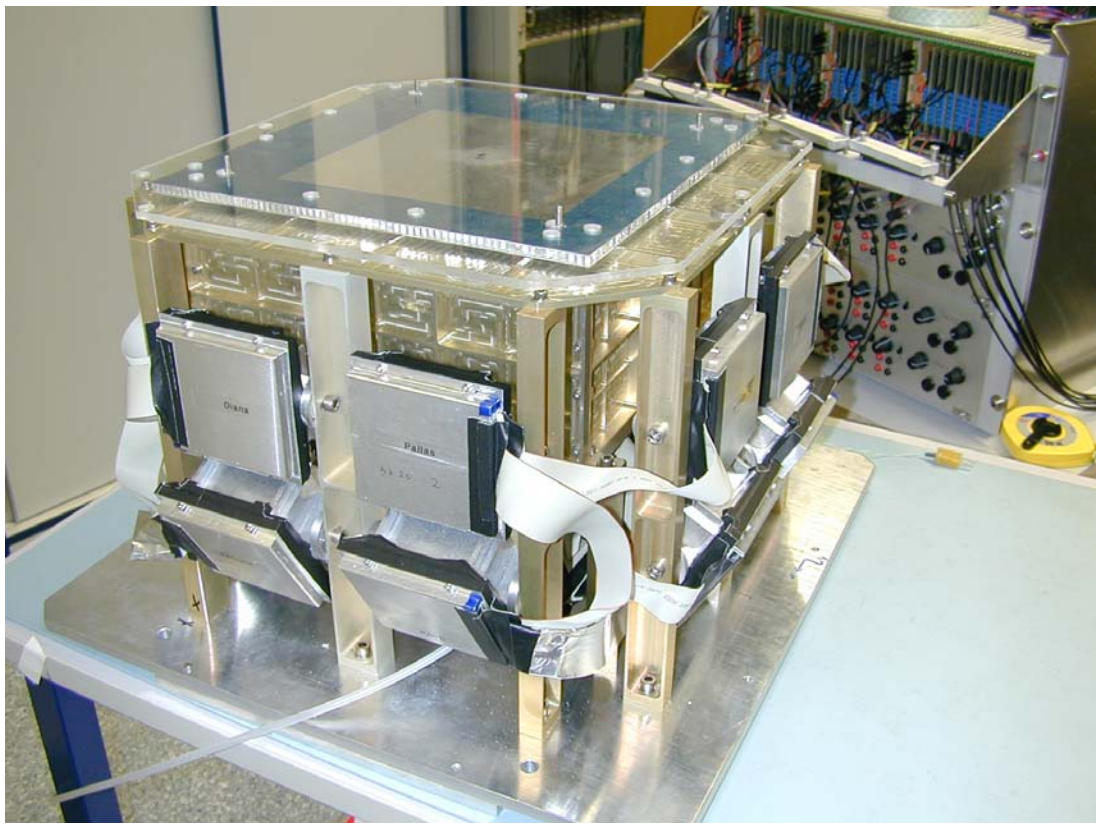
Calorimeter:
pixellated CsI(Tl)/
PIN diode arrays

Integration of Prototype Detector









Beam Calibration Measurements (April/May 2003)

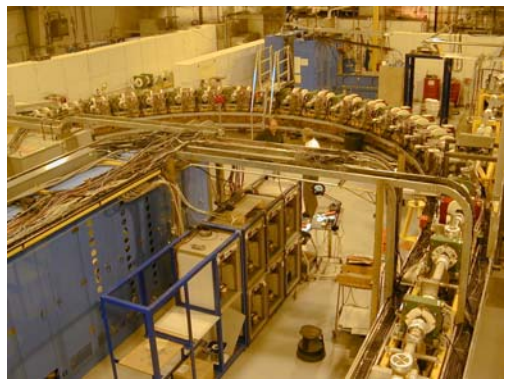
High Intensity Gamma-Ray Source (HIGS) at
Duke University, Durham, N.C.

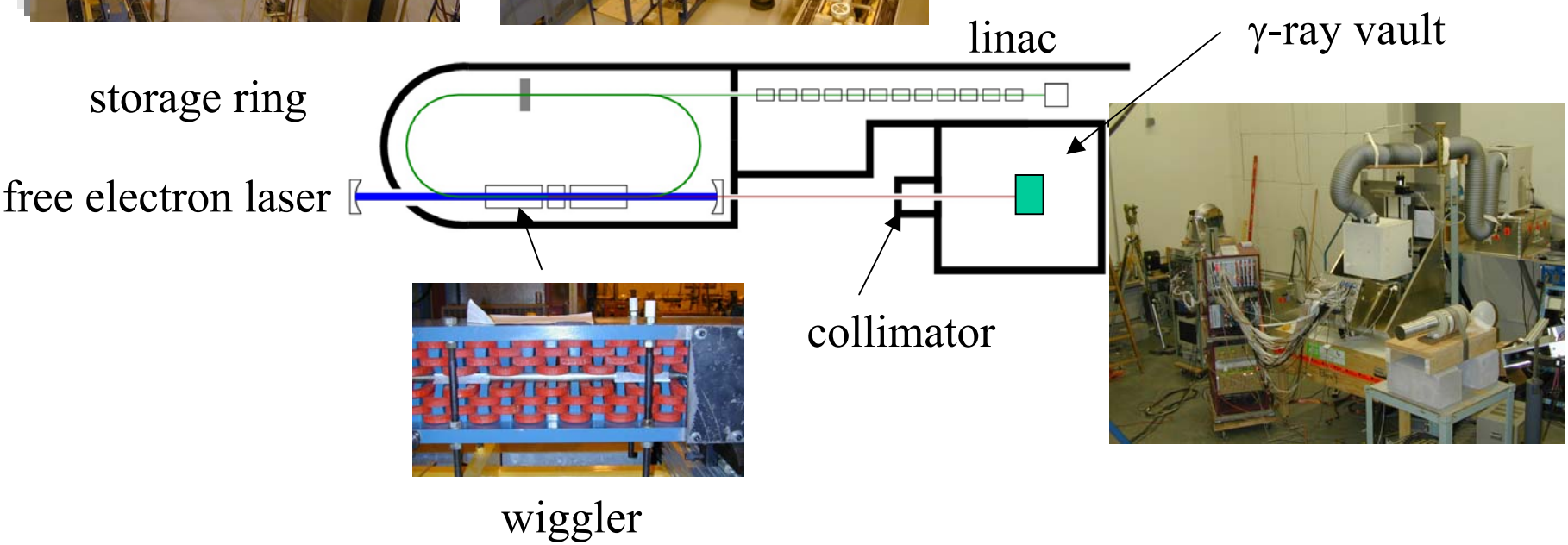
Type: Free electron laser + inverse Compton scattering

Monoenergetic photons from 0.7 to 50 MeV
~100% polarized

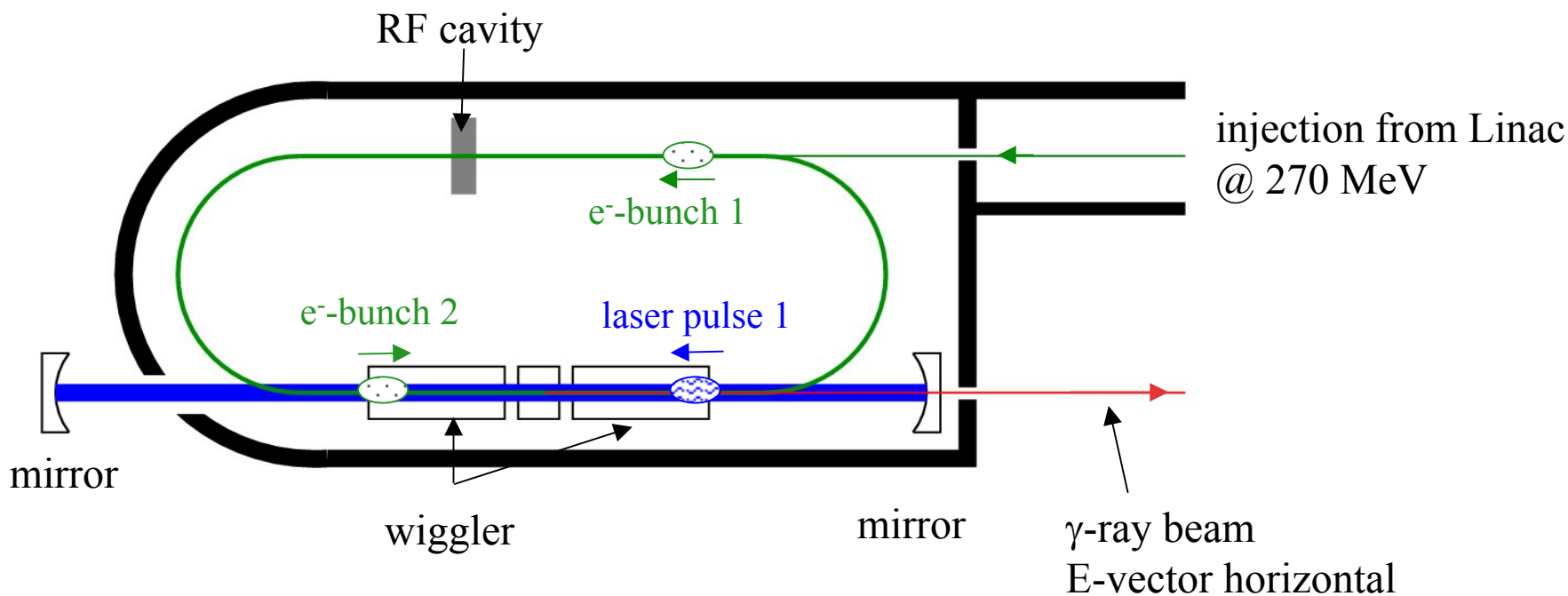
Recorded ~ 15 Mio events

The Duke FEL High Intensity γ-ray Source (HIγS)





Storage Ring, Free Electron laser, Inverse Compton Beam



$$\gamma = \frac{E_e}{m_e c^2}; \quad E_{ph} = \frac{2\gamma^2 hc}{\lambda_w (1 + K_w^2/2)}; \quad K_w = \frac{eB_w \lambda_w}{2\pi m_e c}; \quad E_\gamma \cong \frac{4\gamma^2 E_{ph}}{1 + (\gamma\theta)^2 + 4\gamma \frac{E_{ph}}{m_e c^2}};$$

electron energy

laser photon energy (UV-IR)

IC gamma-ray energy

Measured Energies and Angles

Energies [MeV]

Angles	0.7	2	5	8	10	12	17	25	37	50
0°	300	400	345	255	435	435	435	345	435	1095
30°	246		345		525	525	525	390	480	390
60°			480		525	705	570	570	570	570
80°						480		570	480	480
120°			120			165		165	120	165
180°			120		165	120			220	240
$\sum$	546	400	1410	255	1650	2430	1530	2040	2305	2940

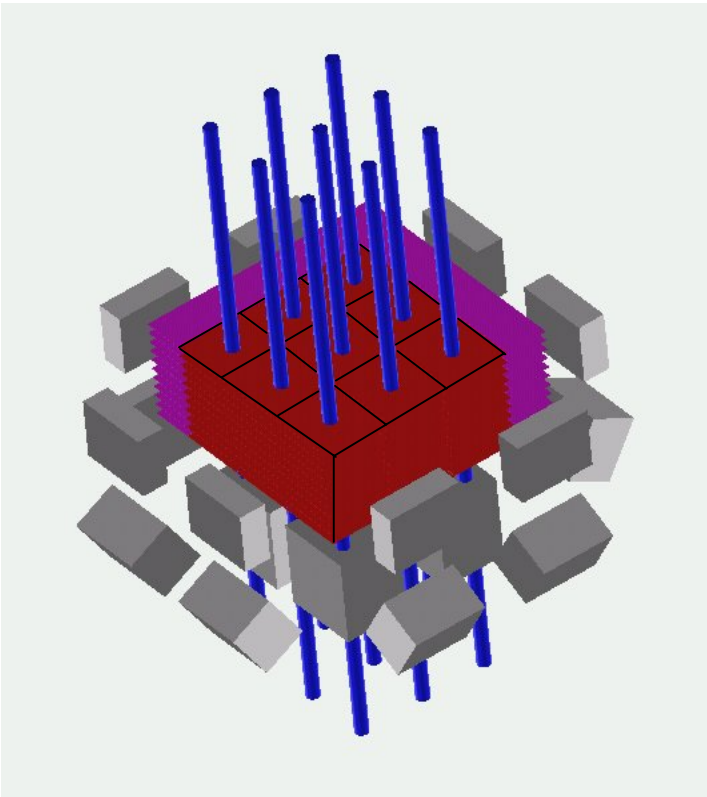
$\cdot 10^3$ events

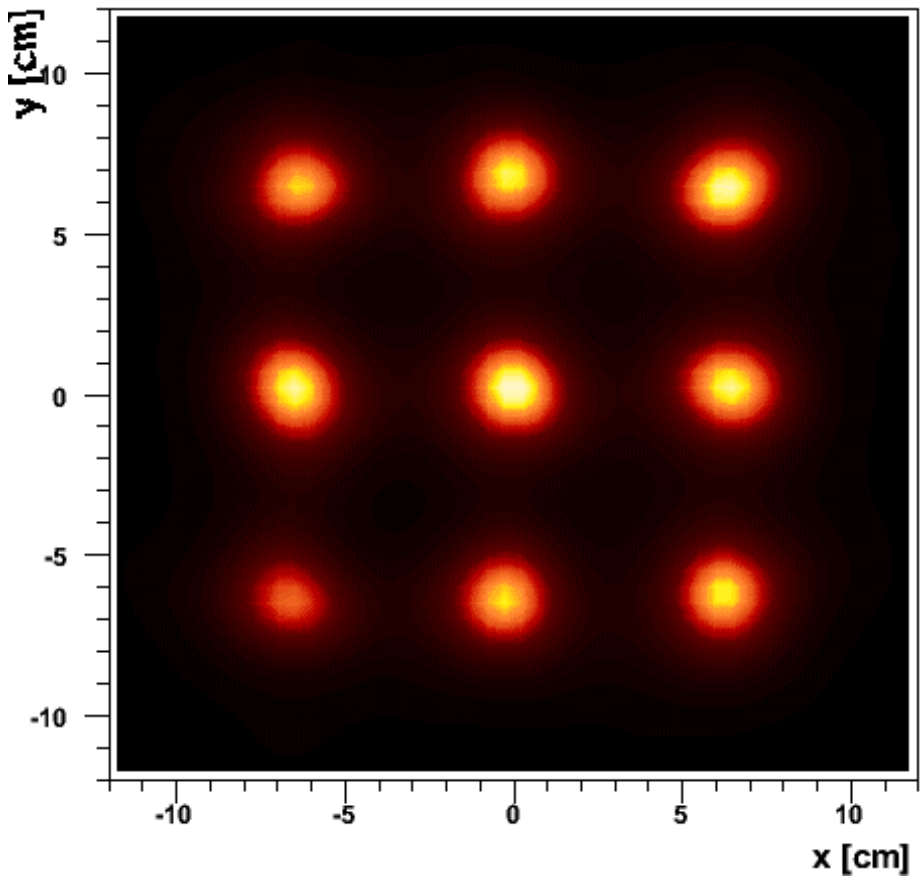
IR-mirrors (1. week)
≈ 45 % beam time

UV-mirrors
≈ 70 - 80 % beam time

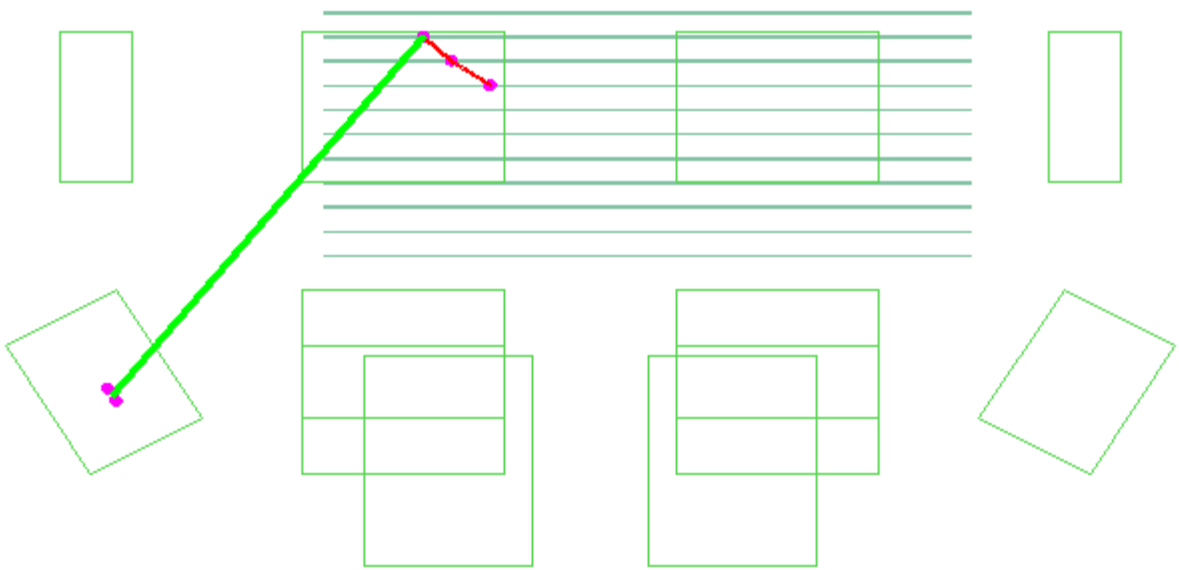
Total: $15.5 \cdot 10^6$ triggered events

Calibration Beams incident on MEGA

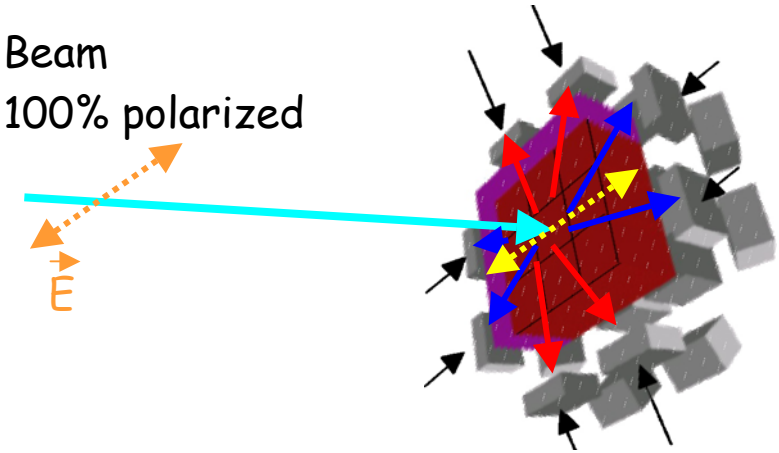




Typical Compton Events: @ 2 MeV

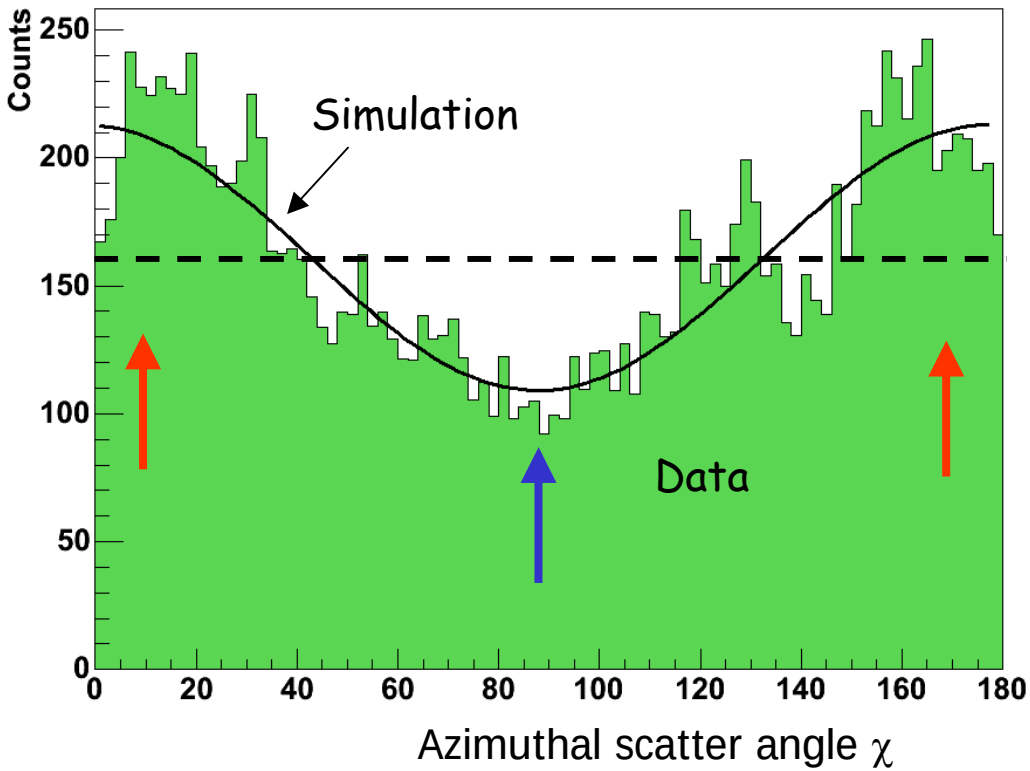


Polarization: Measurement & Simulation

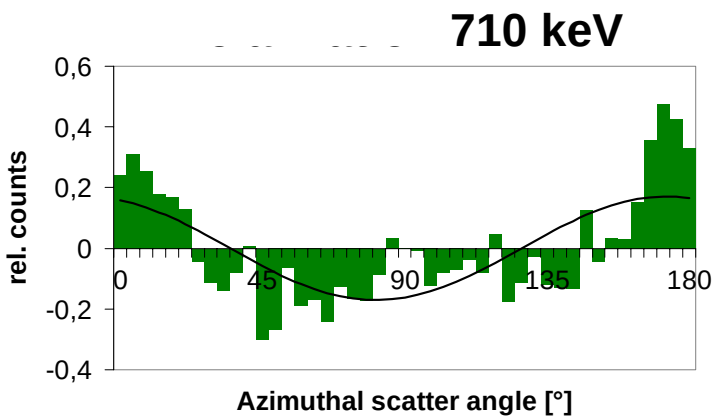


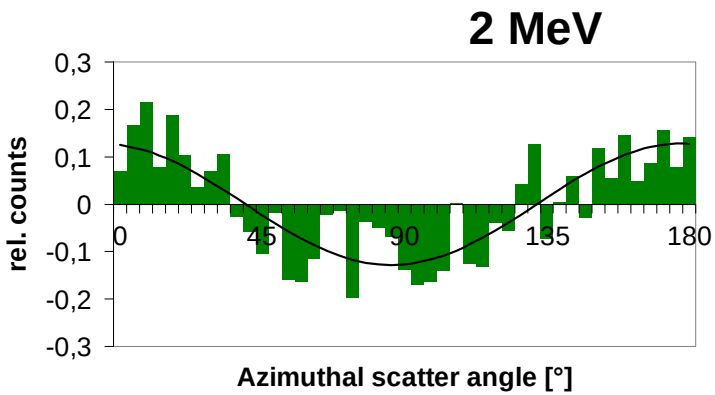
$$\frac{\partial\sigma}{\partial\Omega} = \frac{r_e^2}{2}\left(\frac{E_g}{E_i}\right)^2\left(\frac{E_g}{E_i} + \frac{E_i}{E_g} - 2\sin^2\varphi\cos^2\chi\right)$$

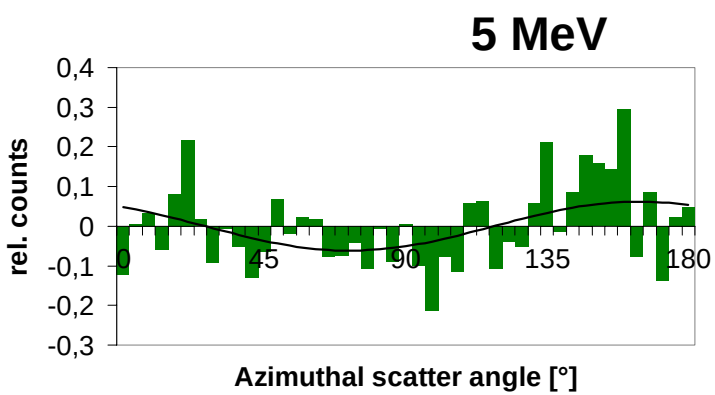
Azimuthal distribution: $a*\cos(2(\chi+\chi_0))+c$



Polarization Signatures at:



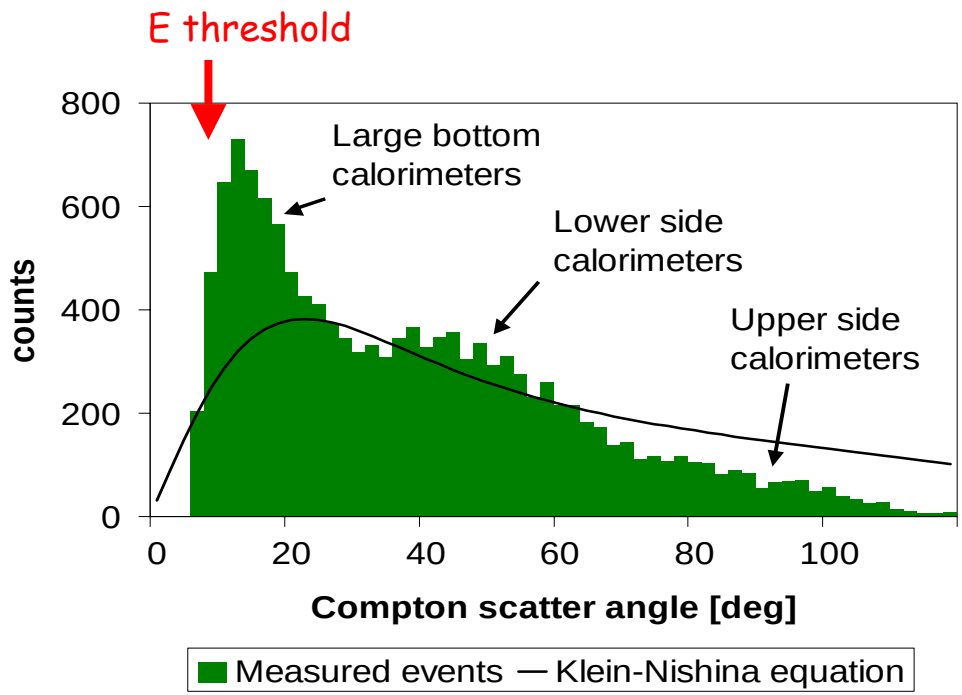




Modulation p_{100} [%] measured	sim	Angle [°] (180°)
17± 4	19± 1	172
13± 3	14± 1	176
6± 3	3± 2	164

(all scattering angles used)

Scattering Angle Distribution @ 2MeV



p_{100} as a function of scattering angle @ 2MeV