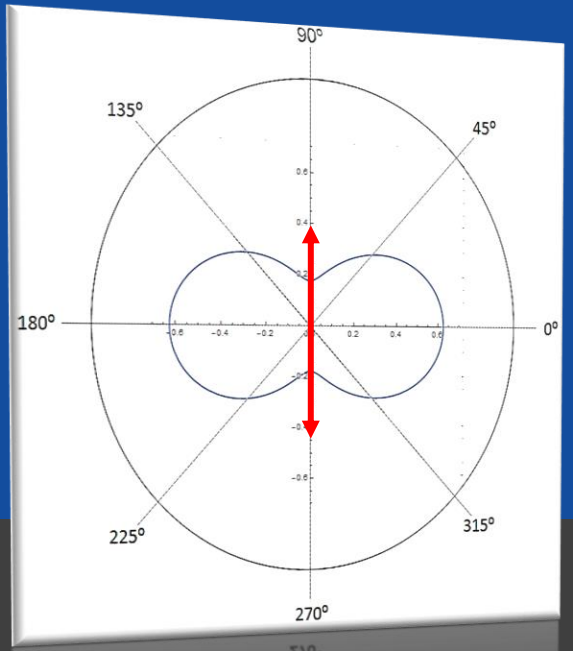


COMCUBE Part 3: polarimetric technical challenges and optimization

H. Neves, R. M. Curado Silva, J. Maia, F. P. Santos

LABORATÓRIO DE INSTRUMENTAÇÃO
E FÍSICA EXPERIMENTAL DE PARTÍCULAS
partículas e tecnologia

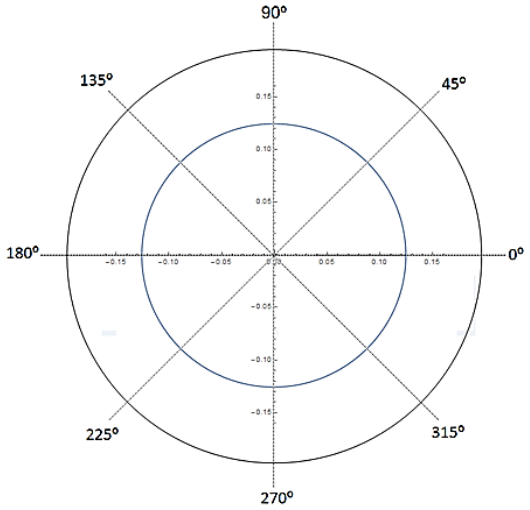
October 2nd, 2020, Coimbra Progress Meeting on Space Experiments for HE Astrophysics & Multi-messenger Astronomy

1.
A Few Polarimetry Concepts

Compton Polarimetry

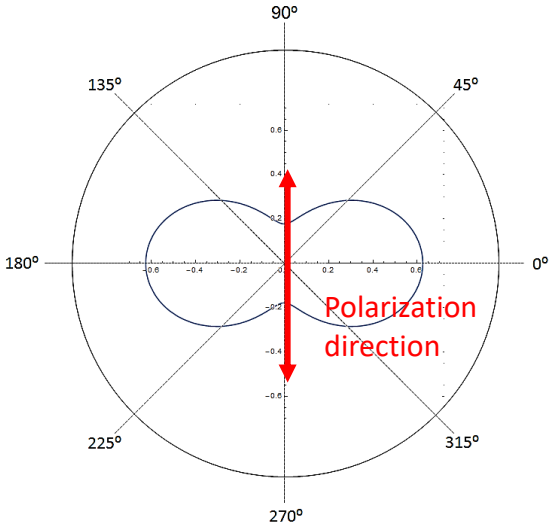
Unpolarized Beam

$$\frac{d\sigma_{KN,U}}{d\Omega} = \frac{1}{2} r_0^2 \varepsilon^2 [\varepsilon + \varepsilon^{-1} - \sin^2\theta]$$



Polarized Beam

$$\frac{d\sigma_{KN,P}}{d\Omega} = \frac{1}{2} r_0^2 \varepsilon^2 [\varepsilon + \varepsilon^{-1} - 2\sin^2\theta \cos^2\eta]$$

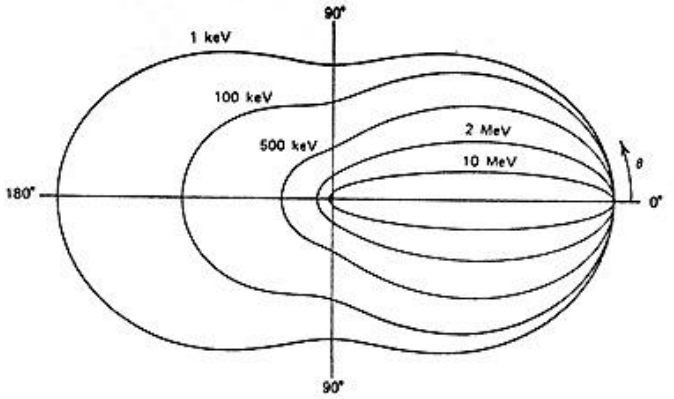


100%

Compton Polarimetry

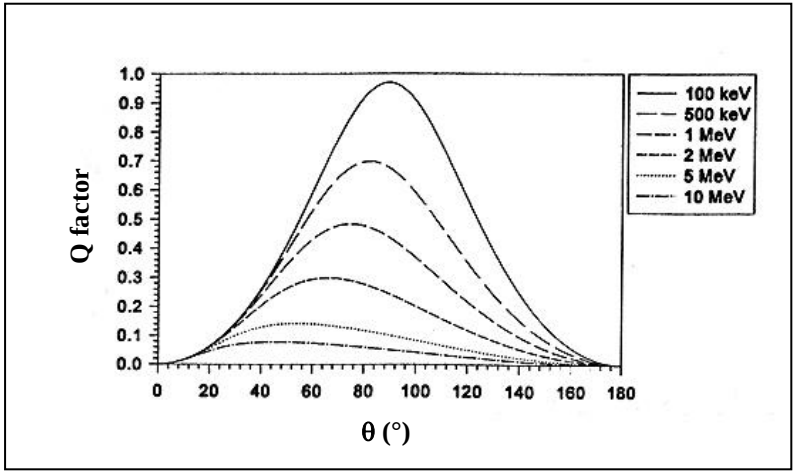
Klein-Nishina cross-section for linearly polarized photons:

$$\frac{d\sigma}{d\Omega} = \frac{r_0^2}{2}\left(\frac{E'}{E}\right)^2\left[\frac{E'}{E} + \frac{E}{E'} - 2\sin^2\theta\cos^2\varphi\right]$$

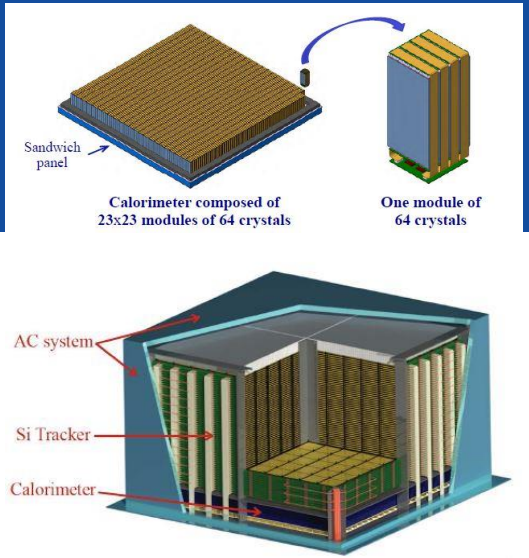


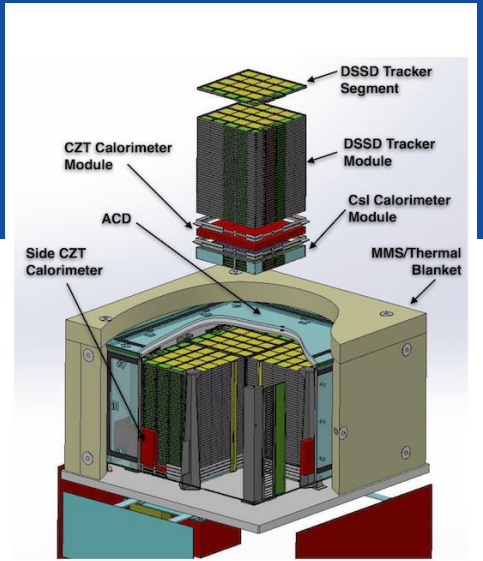
$$Q = \frac{N_\perp - N_\parallel}{N_\perp + N_\parallel} \qquad Q = \frac{d\sigma(\varphi = 90) - d\sigma(\varphi = 0)}{d\sigma(\varphi = 90) + d\sigma(\varphi = 0)}$$

$$Q = \frac{\sin^2\theta}{\frac{E'}{E} + \frac{E}{E'} - \sin^2\theta}$$



2.
Polarimetric heritage





Experimental and simulations heritage

$$MDP_{99\%} = \frac{4.29}{A \cdot \boldsymbol{\varepsilon} \cdot S_F \cdot \boldsymbol{Q_{100}}} \sqrt{\frac{A \cdot \boldsymbol{\varepsilon} \cdot S_F + B}{\Delta T}}$$

Conceptual simulations and experiments

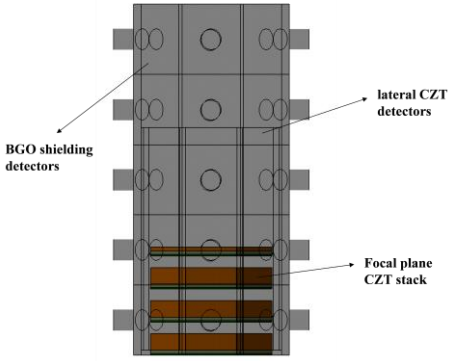
- Modulation vs Detection Plane Thickness → ~ 90°
- Modulation vs Pixelization level (pixels/cm^2)
- Modulation vs Incidence Angle and Polarization Angle

Gamma-Ray Imager (GRI)

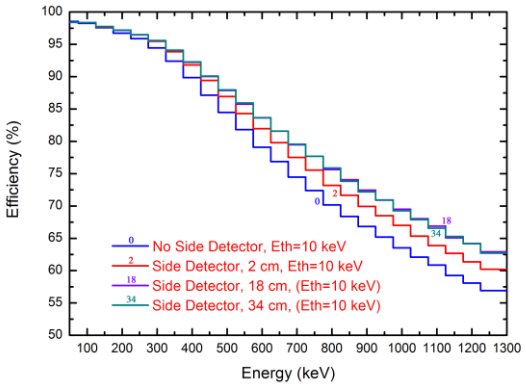
- Side detetectors
- Multi-layers

e-Astrogam

- Tracker Multi-layers thickness, inter-layer distance, pixelization level and reconstruction
- Calorimeter contribution thickness, inter-layer distance, pixelization level



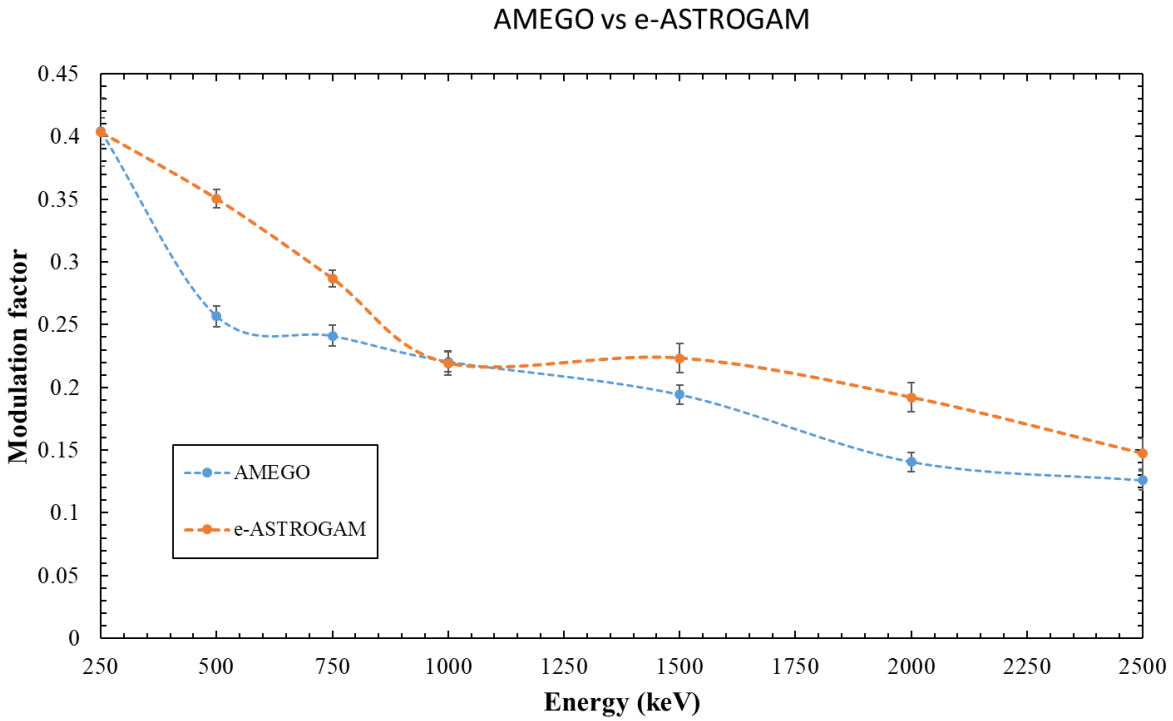
GRI



e-ASTROGAM vs AMEGO

- **e-ASTRO Si Tracker**:
  Thickness - 500 µm
  Nlayers - 56
  Spacing 1.00 cm
  5x5 DSSD arrays
  each 9.5 cm^2

- **AMEGO Si Tracker**:
  Thickness - 500 µm
  Nlayers - 60
  Spacing 1.00 cm
  4x4 DSSD arrays
  each 9.5 cm^2



e-ASTROGAM vs AMEGO

Spectrum: Crab Source
Energy Range: 0.2-2 MeV
Beam: FarFieldPointSource

- **e-ASTRO Si Tracker**:
  Thickness - 500 µm
  Nlayers - 56
  Spacing 1.00 cm
  5x5 DSSD arrays
  each 9.5 cm^2

- **AMEGO Si Tracker**:
  Thickness - 500 µm
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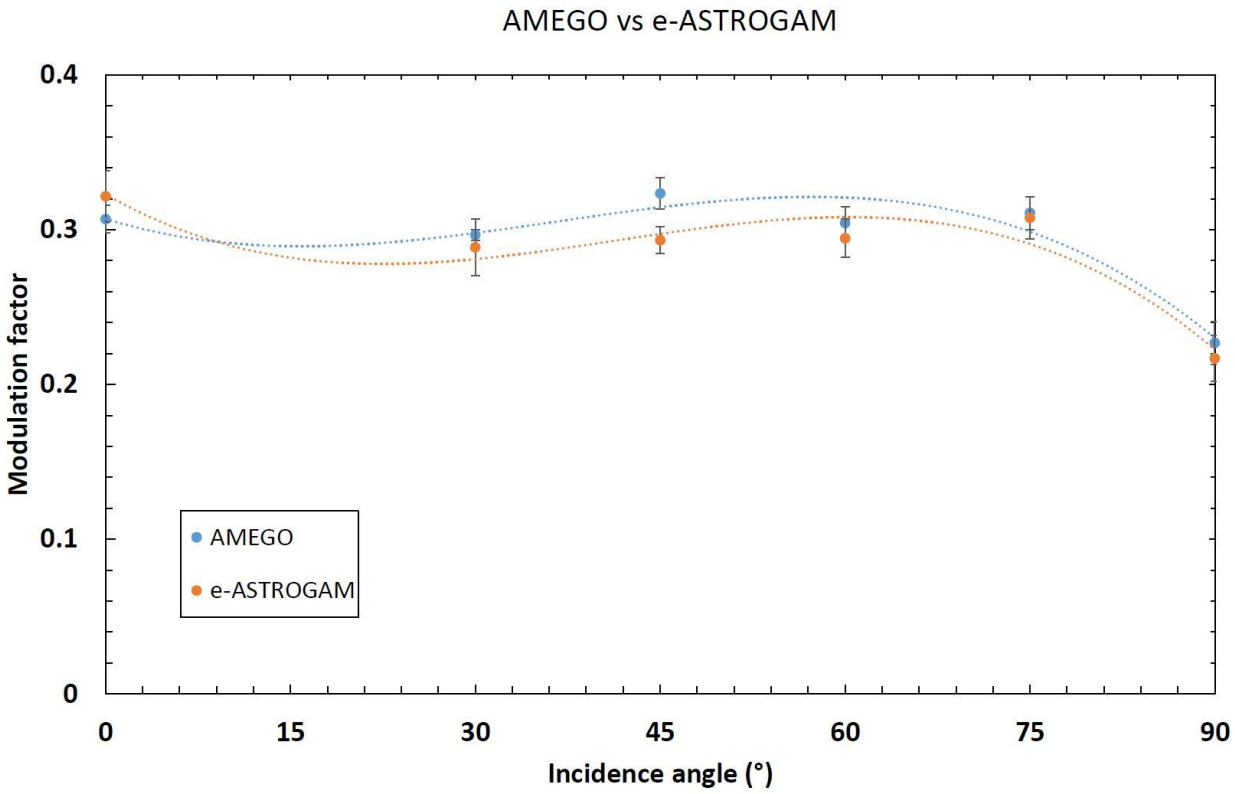
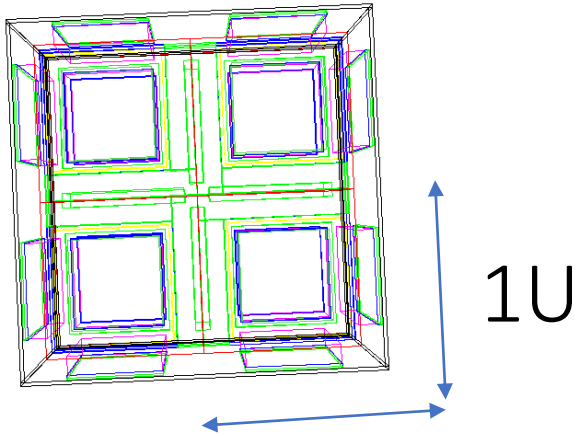


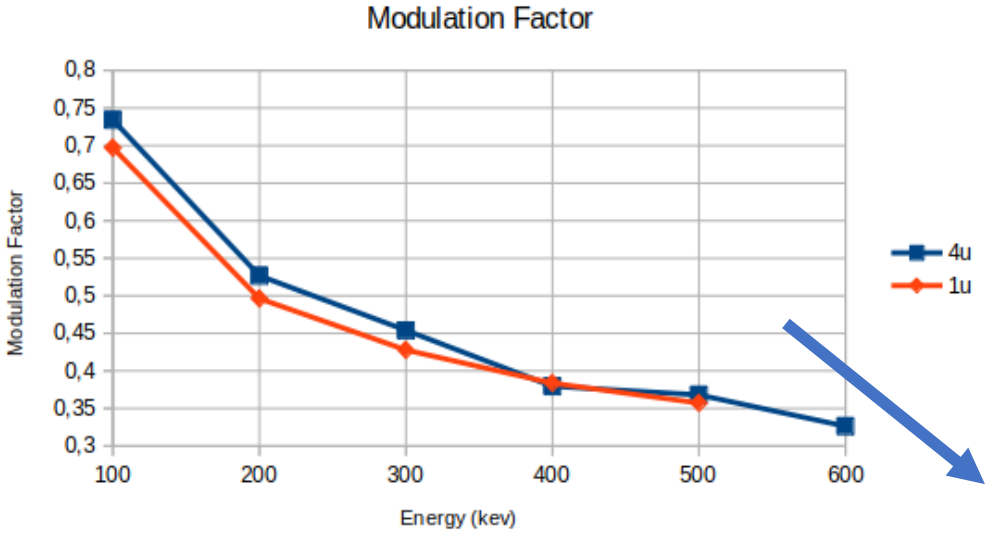
3.
COMCUBE Polarimetric Optimization

Coimbra Progress Meeting on Space Experiments for HE Astrophysics & Multi-messenger Astronomy October 1-2, 2020

Polarimetry and Sensitive Volume



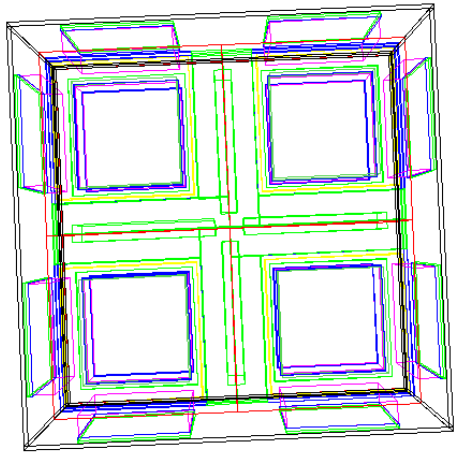
V 1.3.1



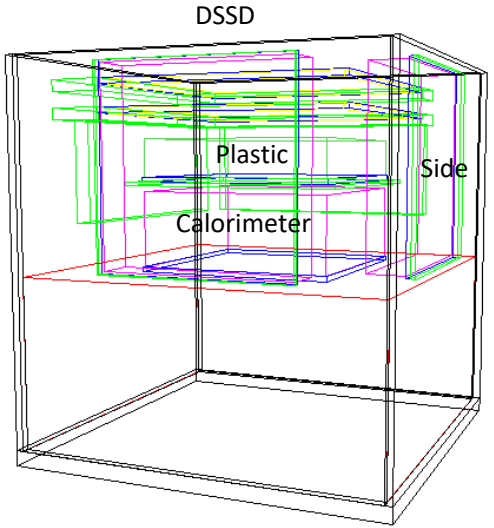
$$MDP_{4U} \approx (Q_{1U} / Q_{4u}) * MDP_{1U} / 2$$

Polarimetric contribution
by group of sensors

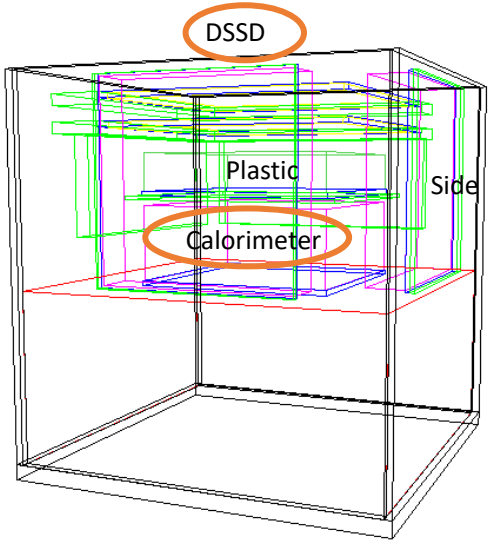
4U
Version 1.3.1

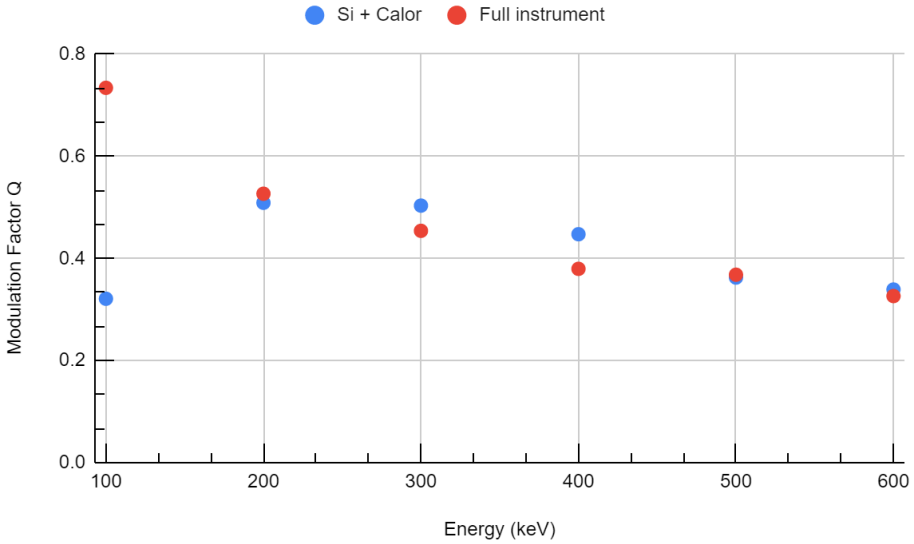


- DSSD: Fine first interaction position resolution
- Calorimeter: detection efficiency
- Side detectors: ~90° scattering double events
- Reconstruction

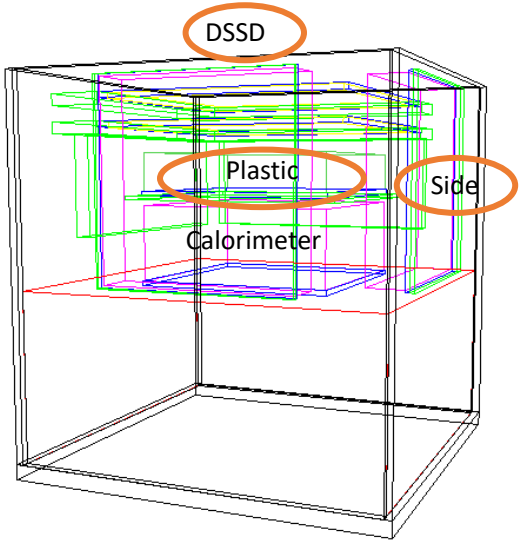


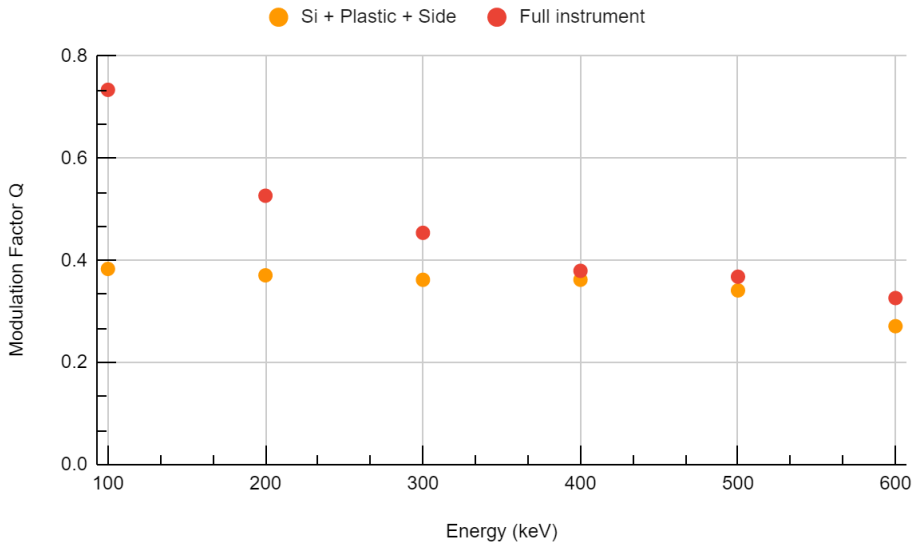
Polarimetric contribution
by group of sensors





Polarimetric contribution
by group of sensors



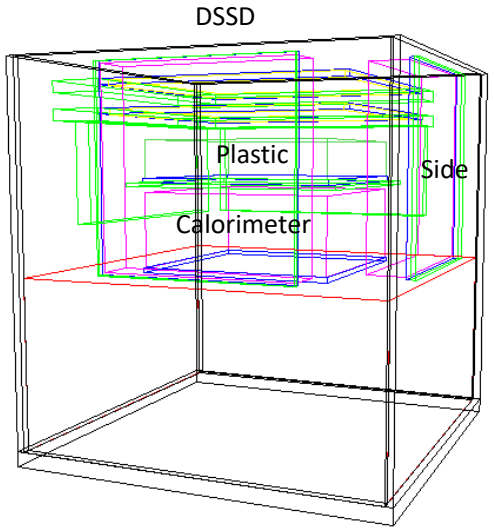


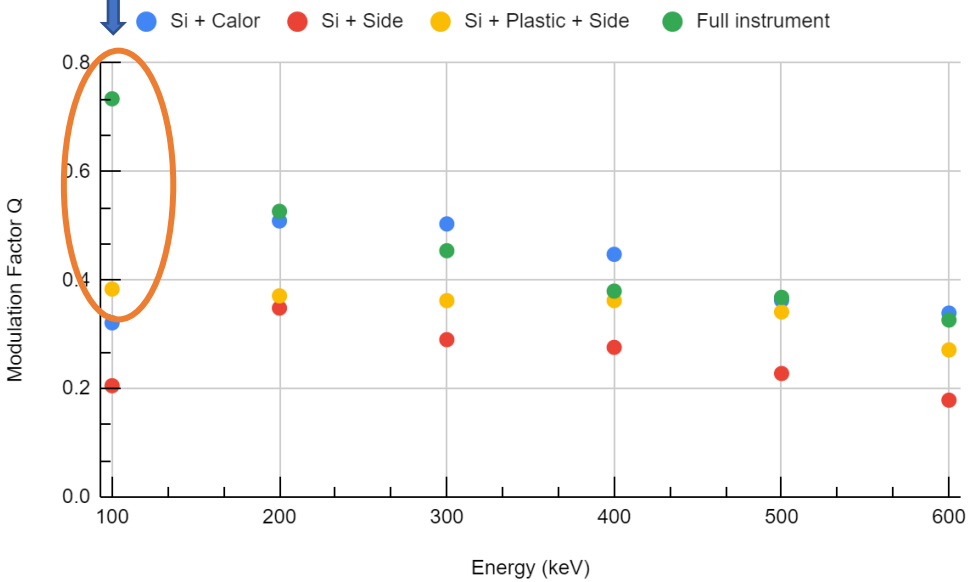
Polarimetric contribution
by group of sensors

Minor Improvement Possibilities
- Side detectors vs non Si double events
- Contribution of double events without Si

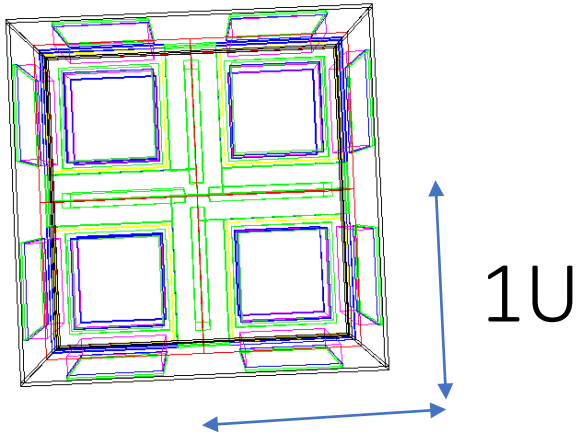
Plastic scintillator relevant for low energies ~ 100 keV

Calorimeter dominant contribution for higher energies ≥ 200 keV

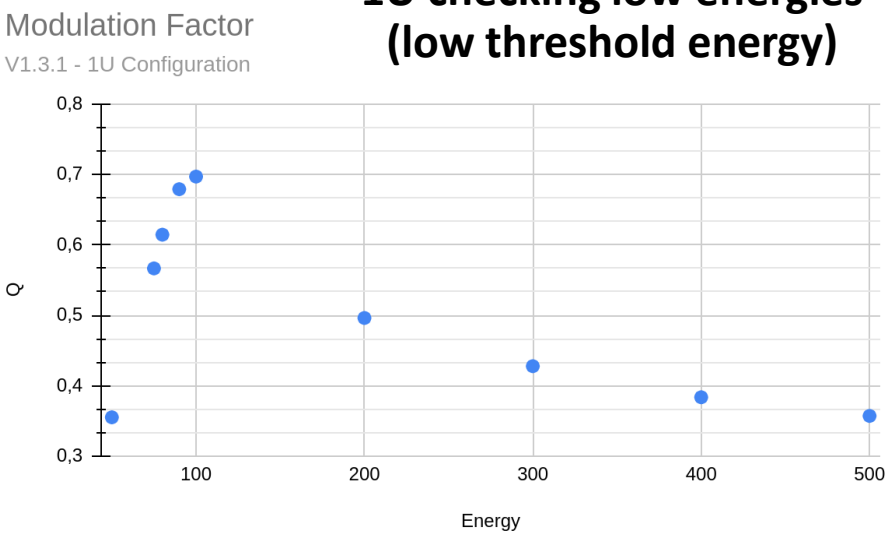




Polarimetric
low energy limit

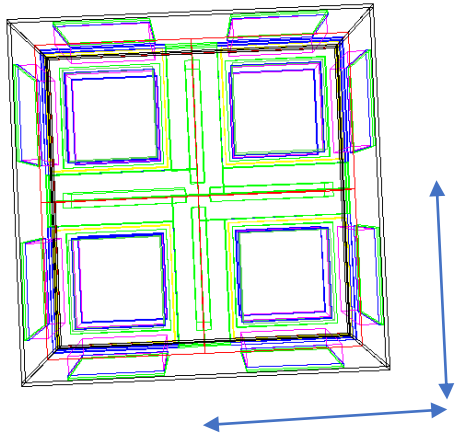


1U checking low energies (low threshold energy)

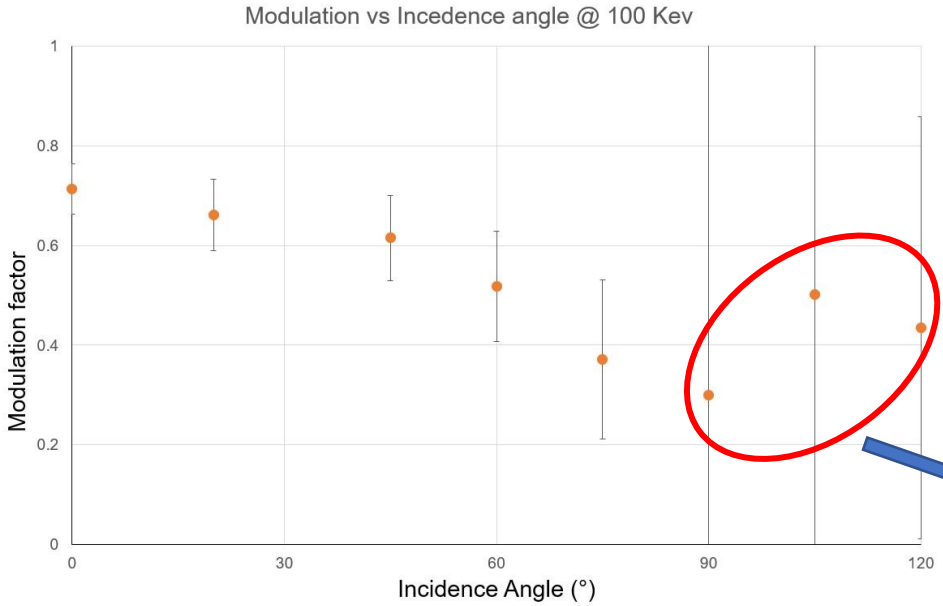


V 1.3.1

Polarimetric
low energy limit

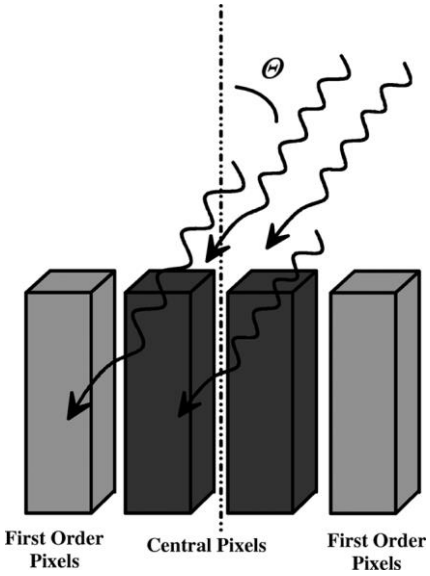


V 1.3.1



Very low double event efficiency > 75° @ 100 keV

Modulation vs Incidence angle



No correction with unpolarized beam case

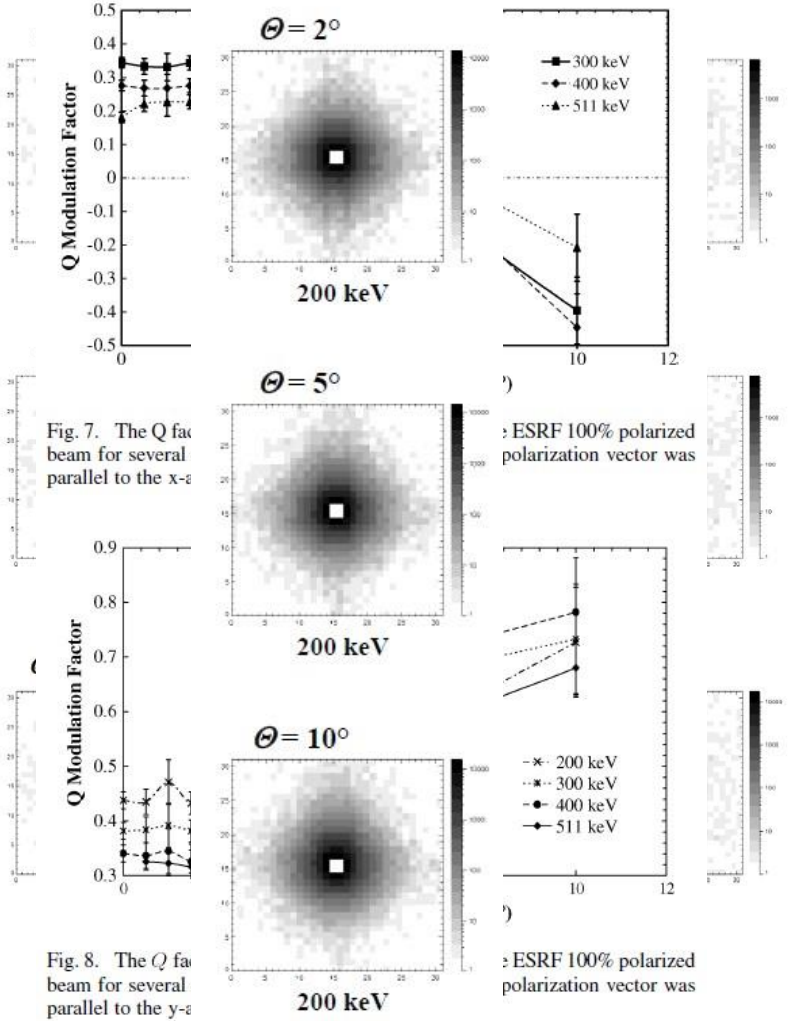
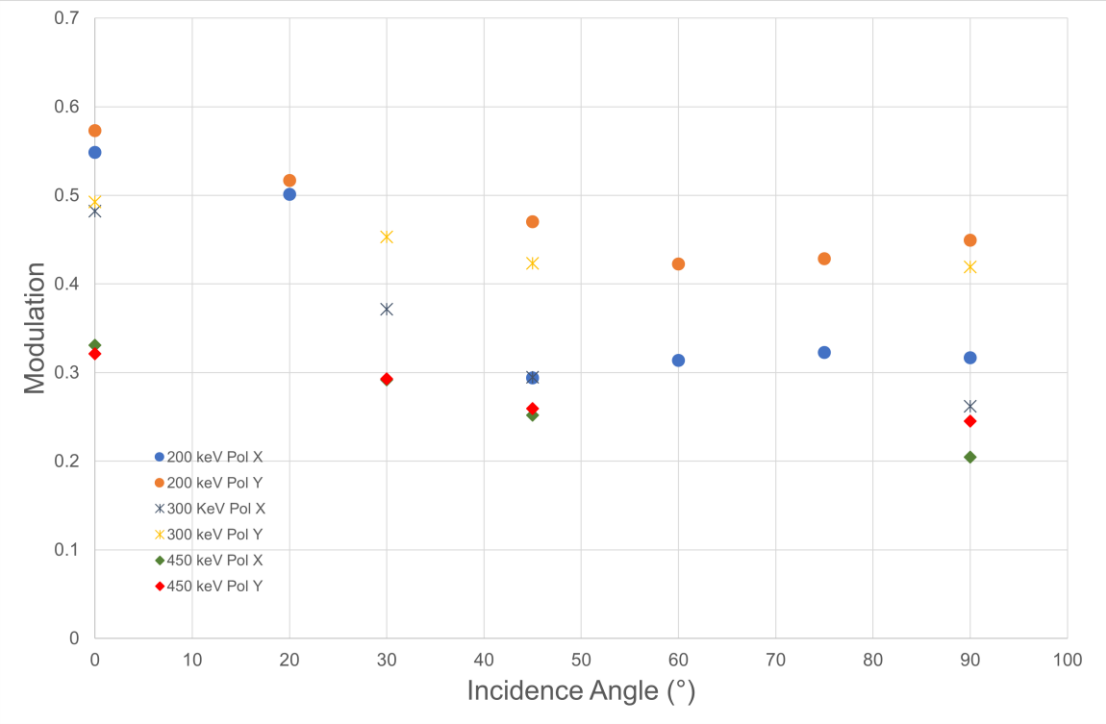


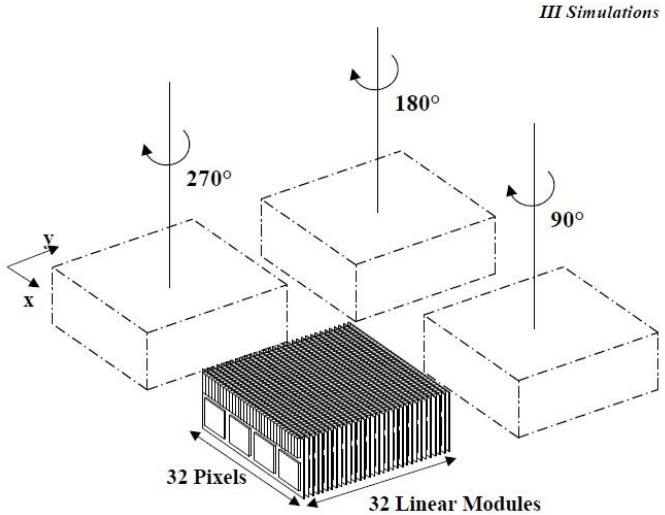
Fig. 7. The Q fa
beam for several
parallel to the x-a
ESRF 100% polarized
polarization vector was

Fig. 8. The *Q* fa
beam for several
parallel to the y-a
ESRF 100% polarized
polarization vector was

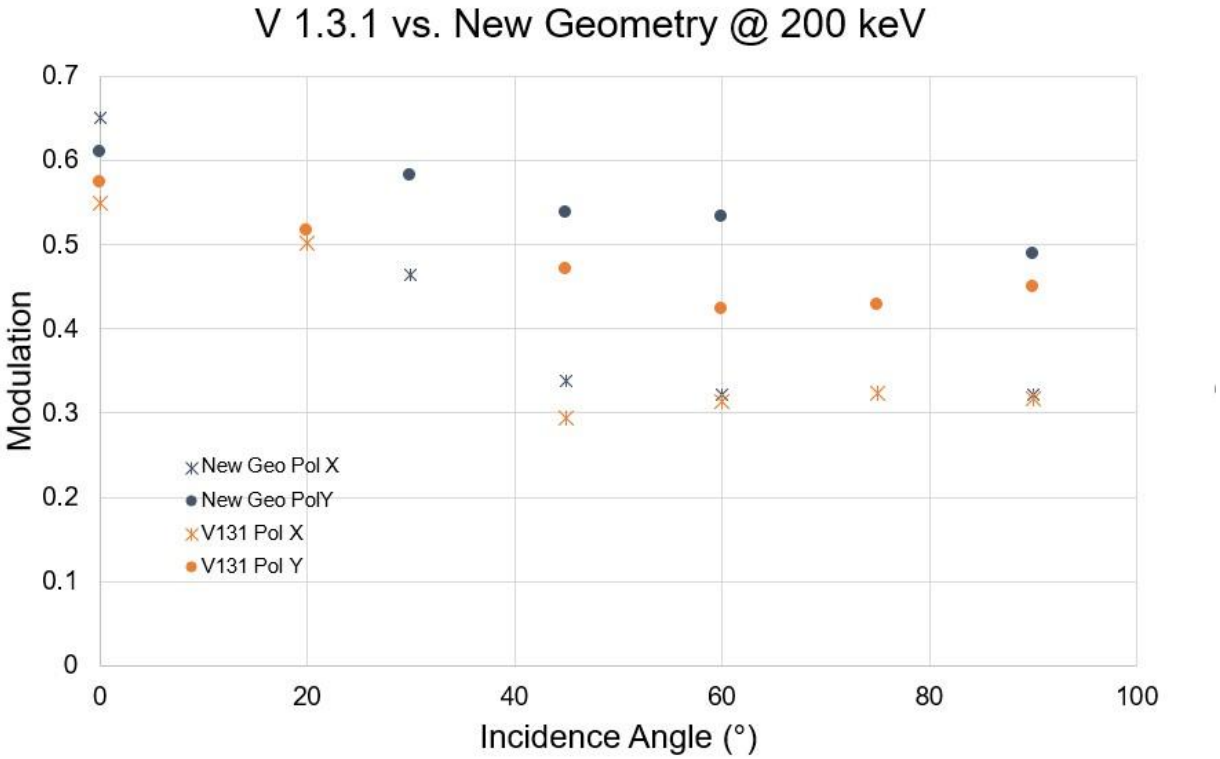
Modulation vs
Incidence angle and polarization angle



Unpolarized beam correction method has its limits: Revan cone of probabilities.



Modulation vs
Incidence angle and polarization angle



Conclusions & Next steps...

- Simulated COMCUBE polarimetric performances show a good potential for GRB polarimetry. Furthermore see Alexei's talk.
- Simulations show a good agreement with precedent simulations and experimental work on Compton polarimetry;
- Real design improvements have been made during the simulation task with multiple contributions, wit positive impact on instrument polarimetric potential
- Further detailed studies on possible trigger modes might indicate design or operation modes' adjustments that can contribute to optimize the instrument performance.
- Henrique's master thesis on Cubesats for Multimessenger Astrophycis.