Feasibility studies of the polarisation of photons with the J-PET detector

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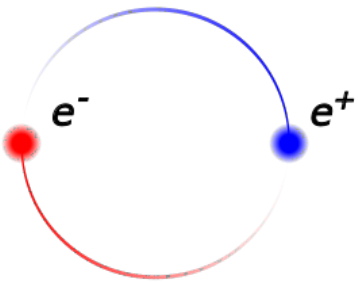
Before annihilation
Para-positronium



Total spin $S = 0$
Parity $P = -1$

After annihilation
Two photons

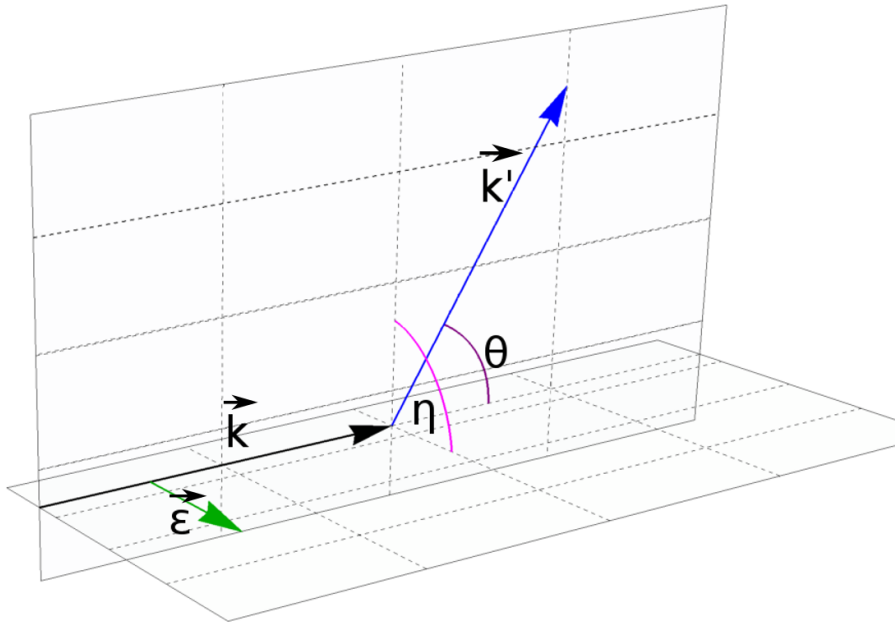
Due to spin and parity conservation final state is:

$$|\psi\rangle = |HV\rangle + |VH\rangle$$

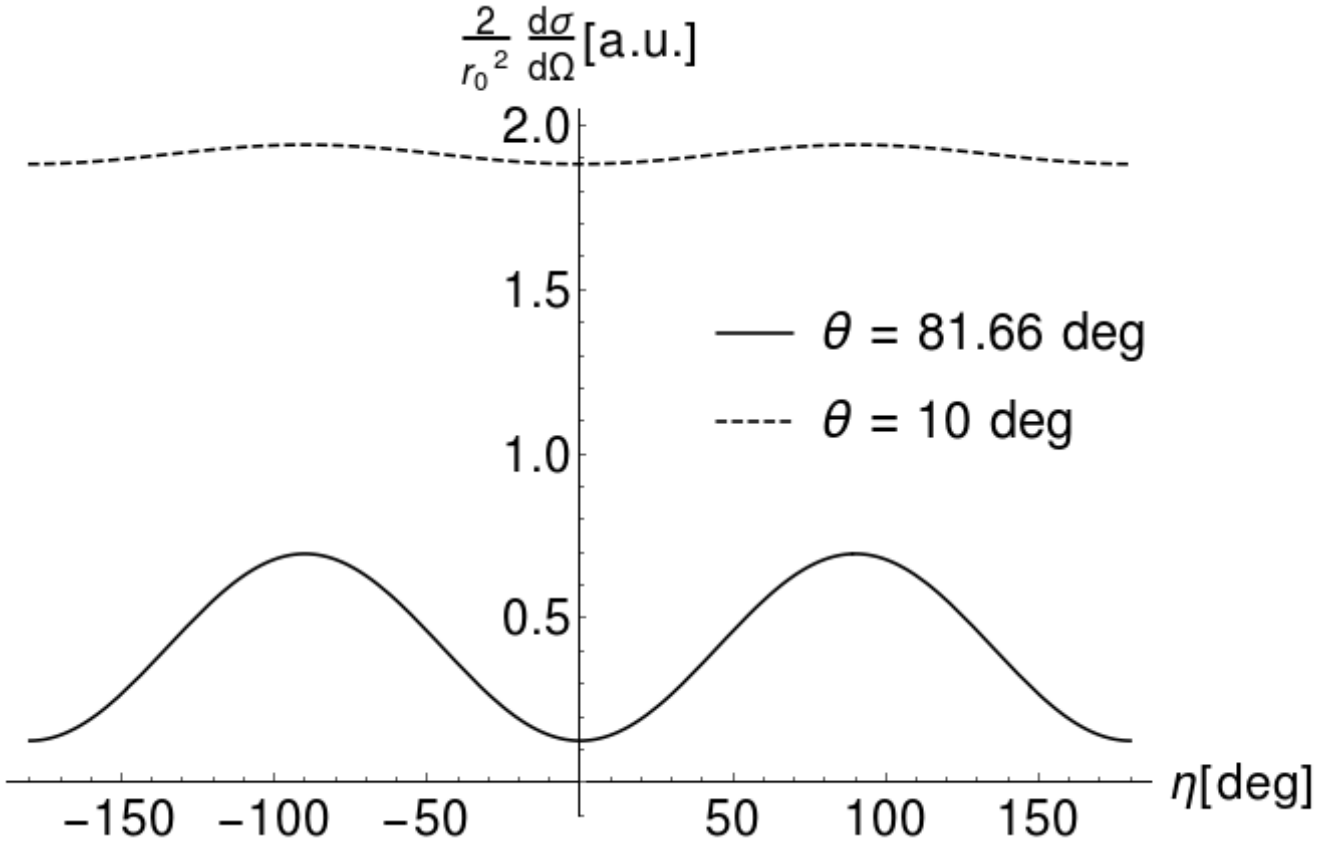
Klein Nishina differential cross section

Gamma particles interact with scintillators by Compton scattering. That interaction is described by Klein-Nishina differential cross section:

$$\frac{d\sigma}{d\Omega}(E,\theta,\eta) = \frac{r_0^2}{2}\left(\frac{E'}{E}\right)^2 \cdot \left(\frac{E}{E'} + \frac{E'}{E} - 2\sin^2\theta\cos^2\eta\right)$$

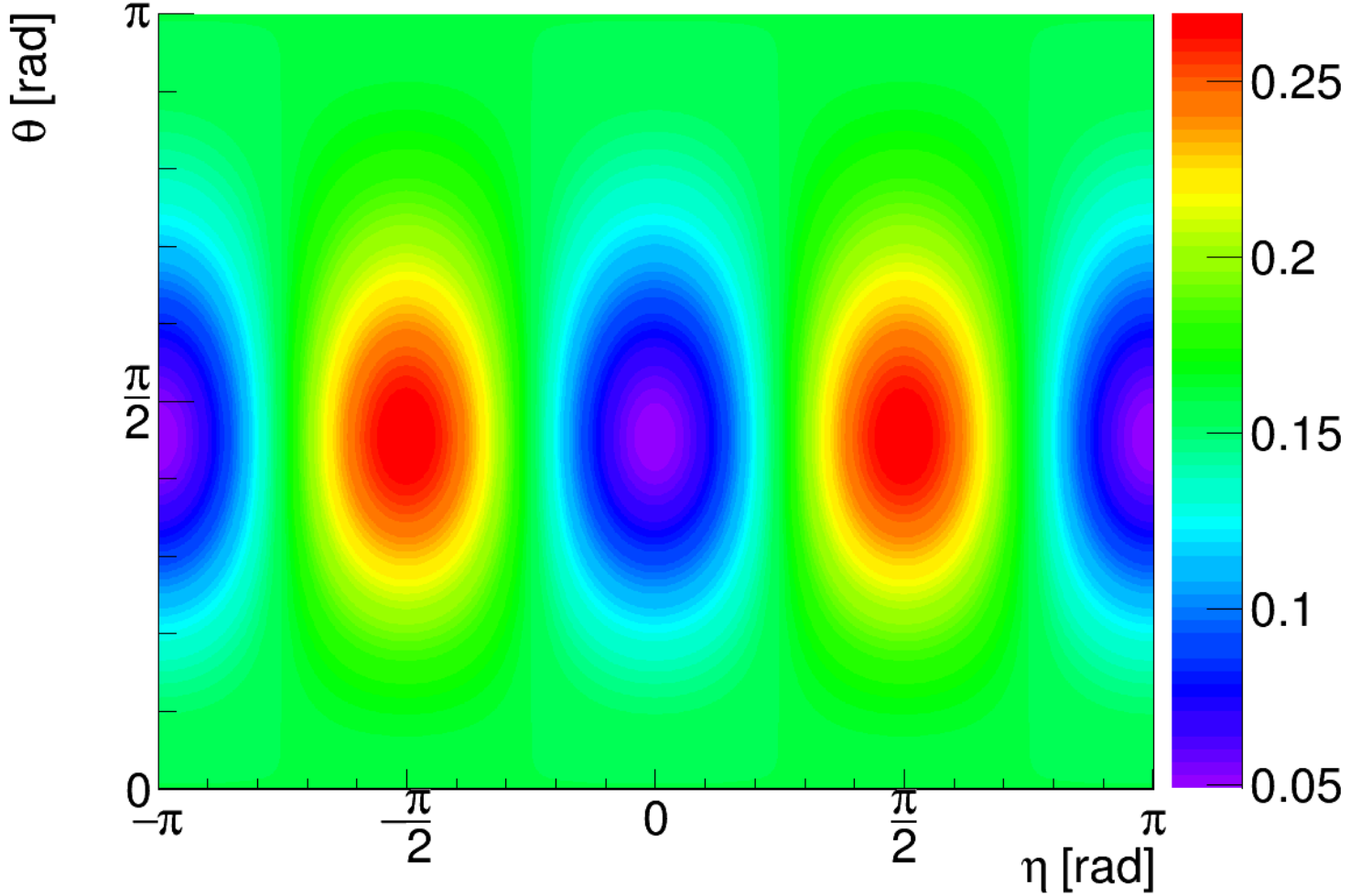


Klein-Nishina differential cross section

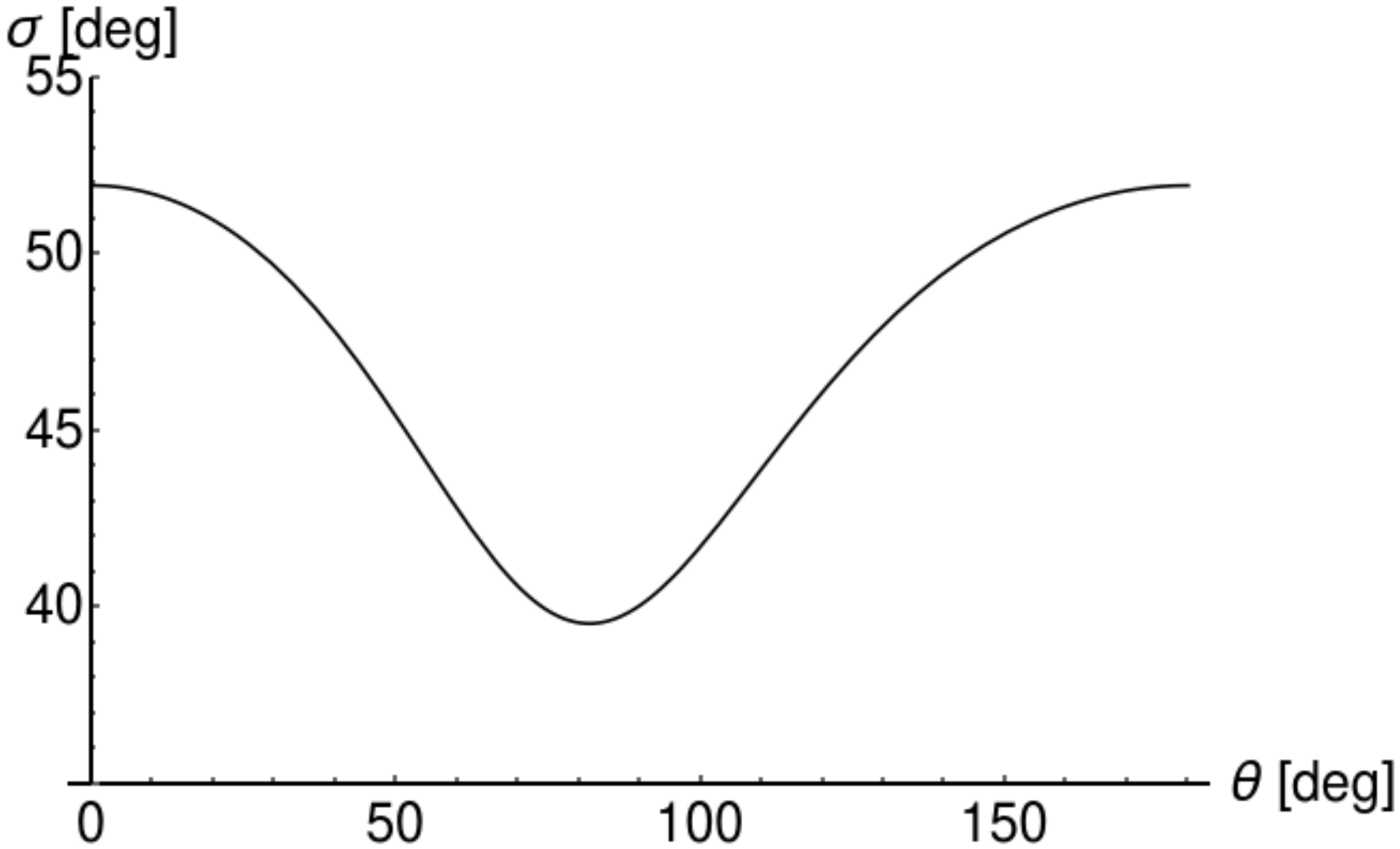


Normalized Klein-Nishina differential cross section

$$P(E,\theta,\eta) = N(E,\theta) \cdot \frac{d\sigma(E,\theta,\eta)}{d\Omega}$$

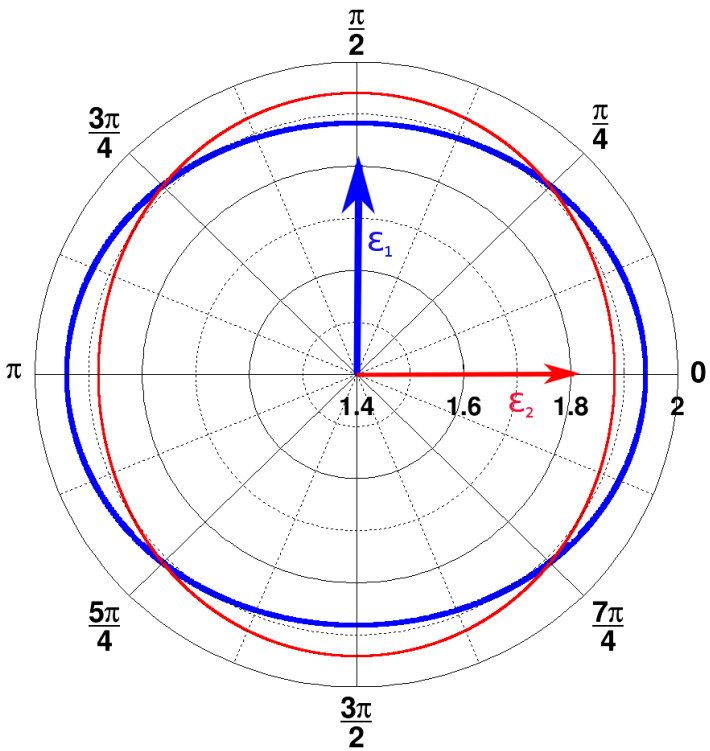


Standard deviation of the distribution $P(E, \theta, \eta)$

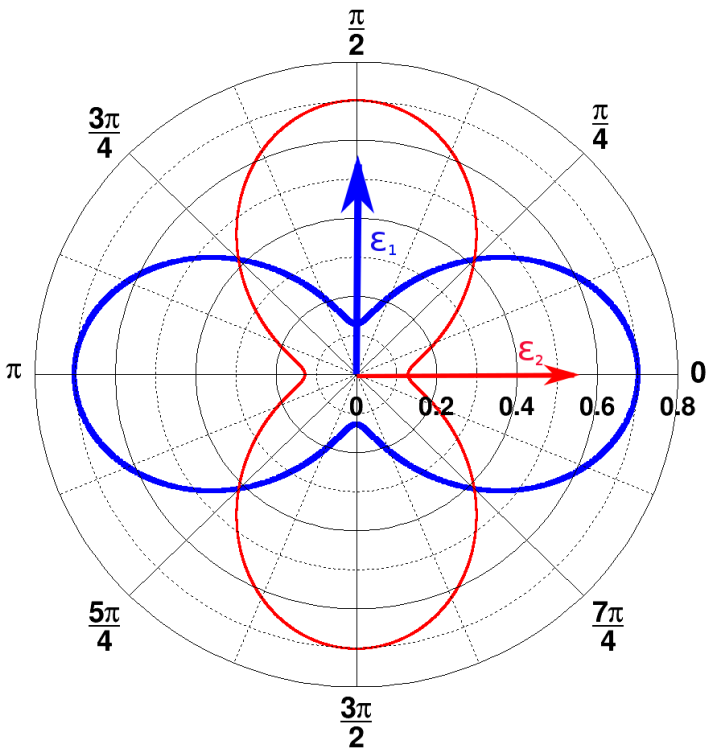


Expected distribution of angle between scattering planes

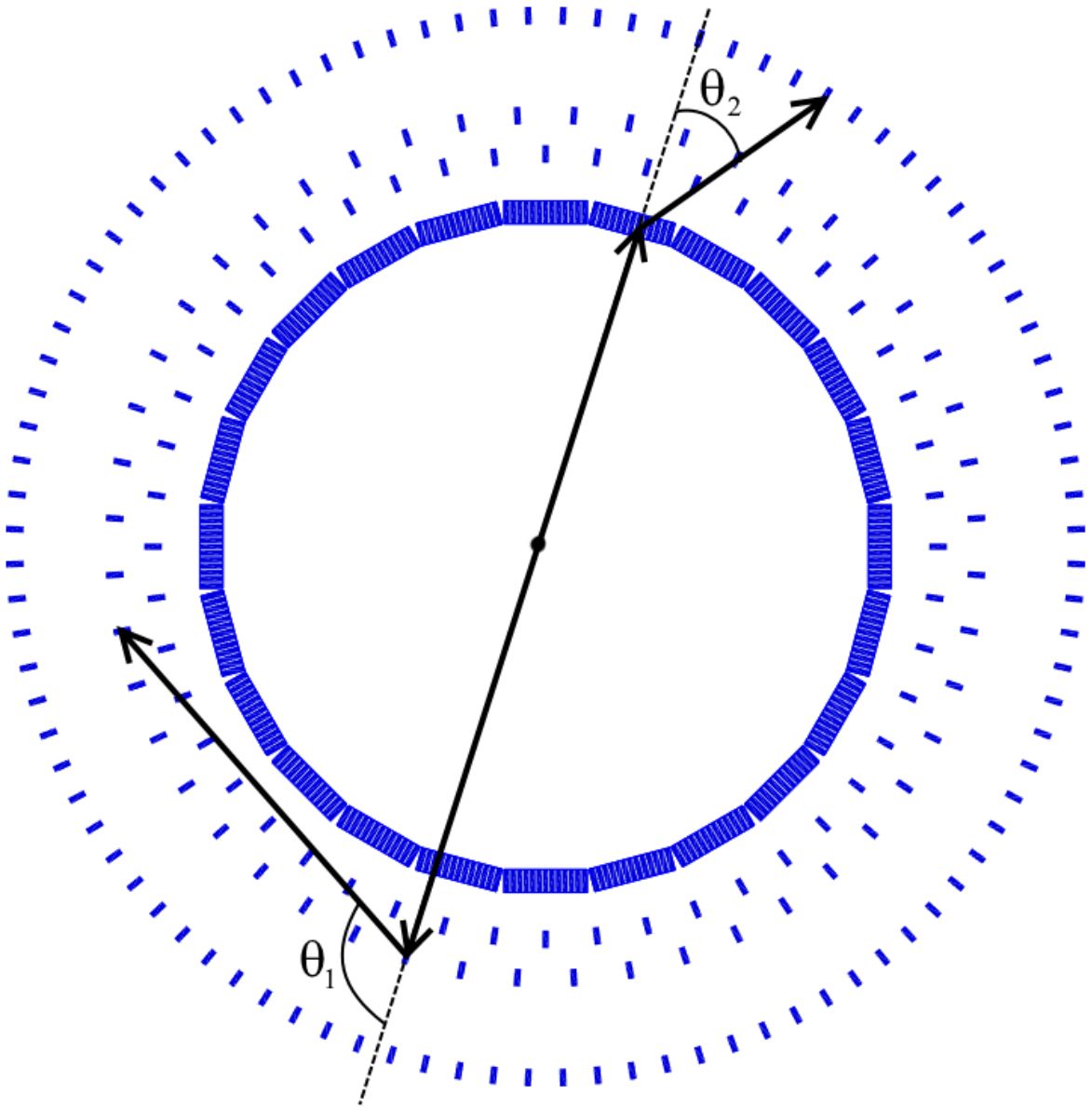
$\theta = 10°$



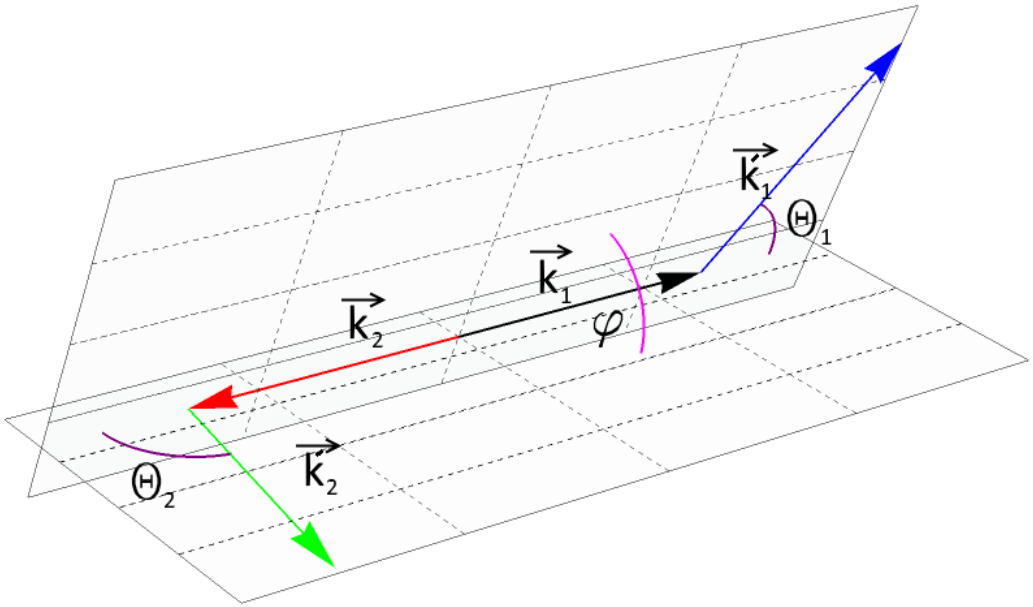
$\theta = 82°$



Two photons decay



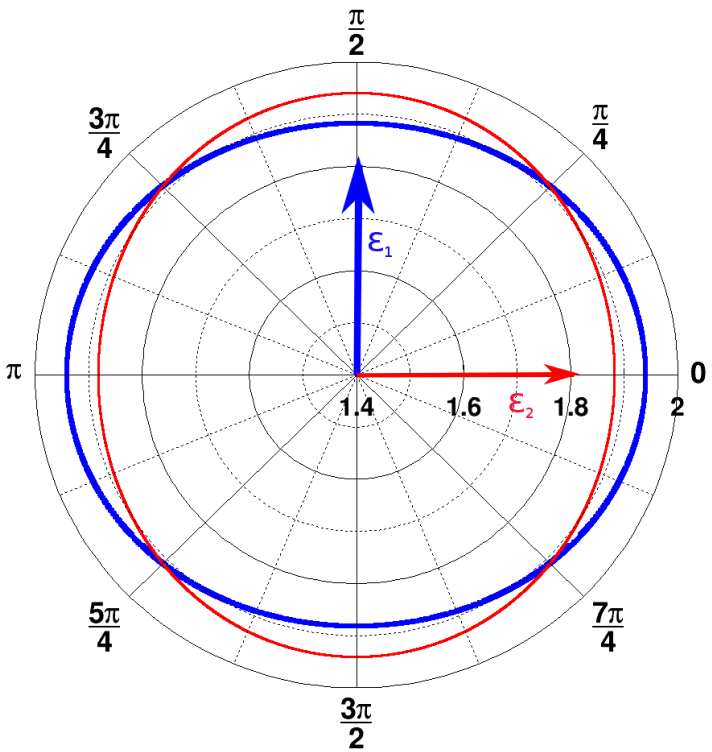
Two photons decay



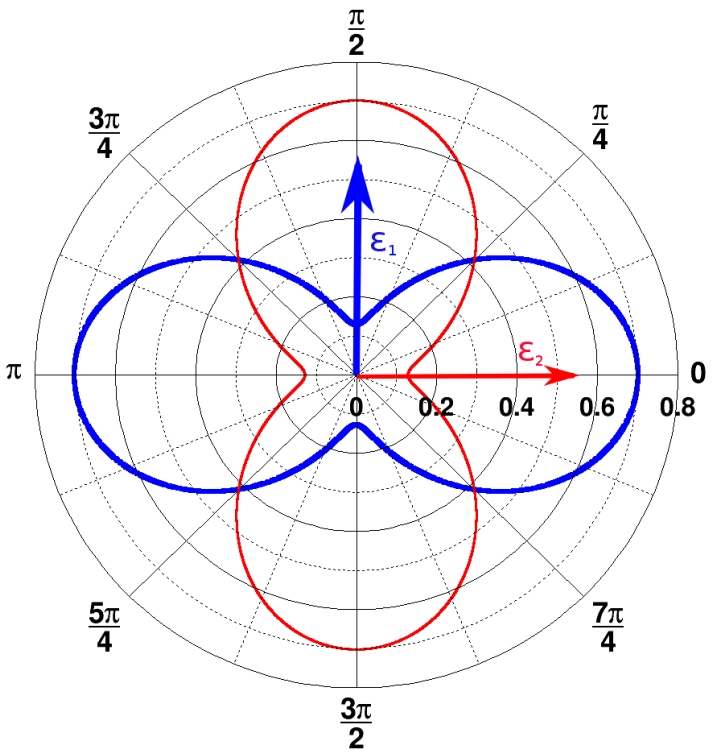
θ_1, θ_2 - Compton scattering angles
k_1, k_2 - momenta directions
k_1', k_2' - directions of scattered momenta
φ - angle between scattering planes

Radial distrubution of scattered radiation

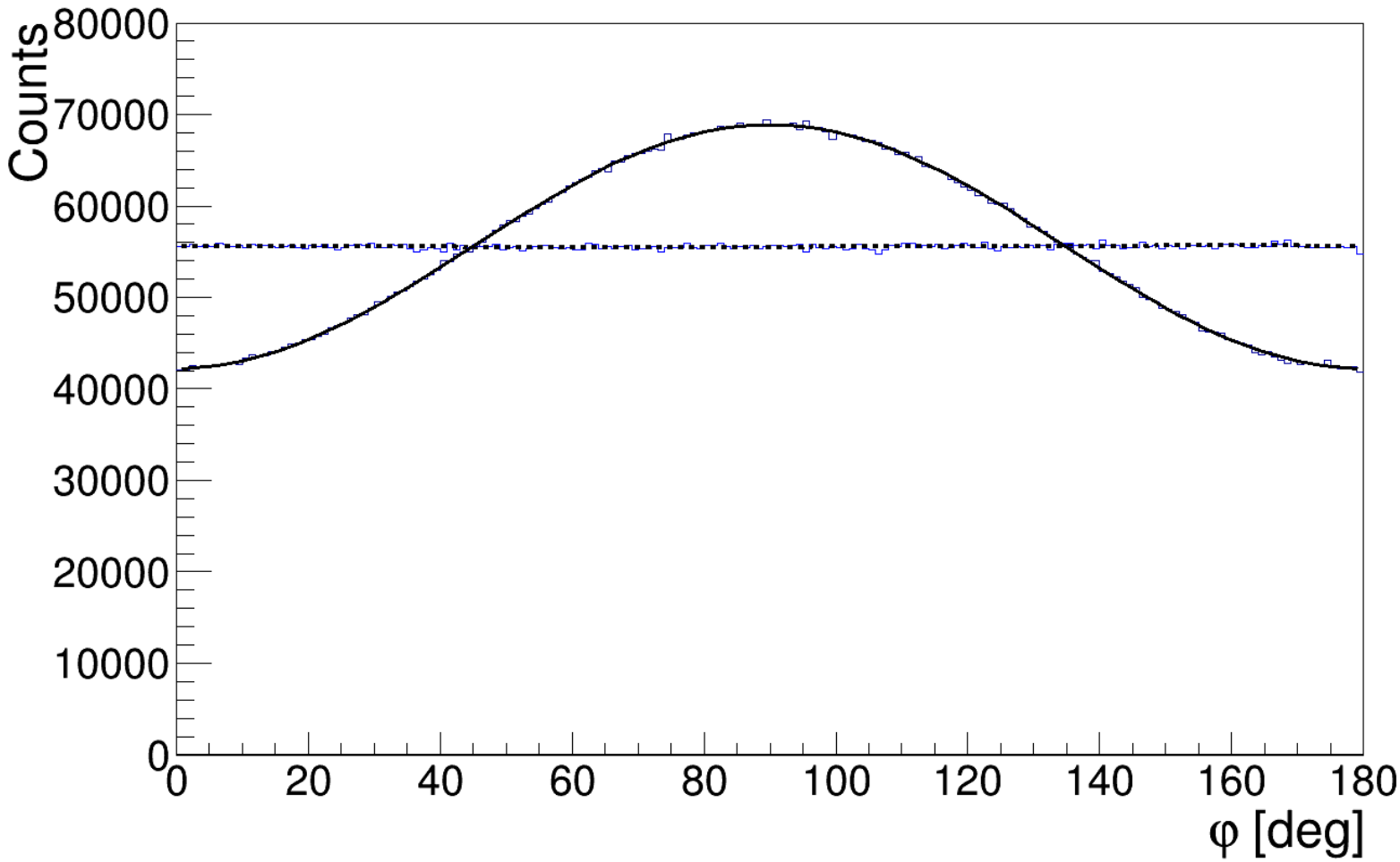
$\theta = 10°$



$\theta = 81.66°$



Distribution of angle between scattering planes φ for $\theta = 10^\circ$ and $\theta = 82.66^\circ$



Shape of the φ distribution

Following function was fitted to every histogram:

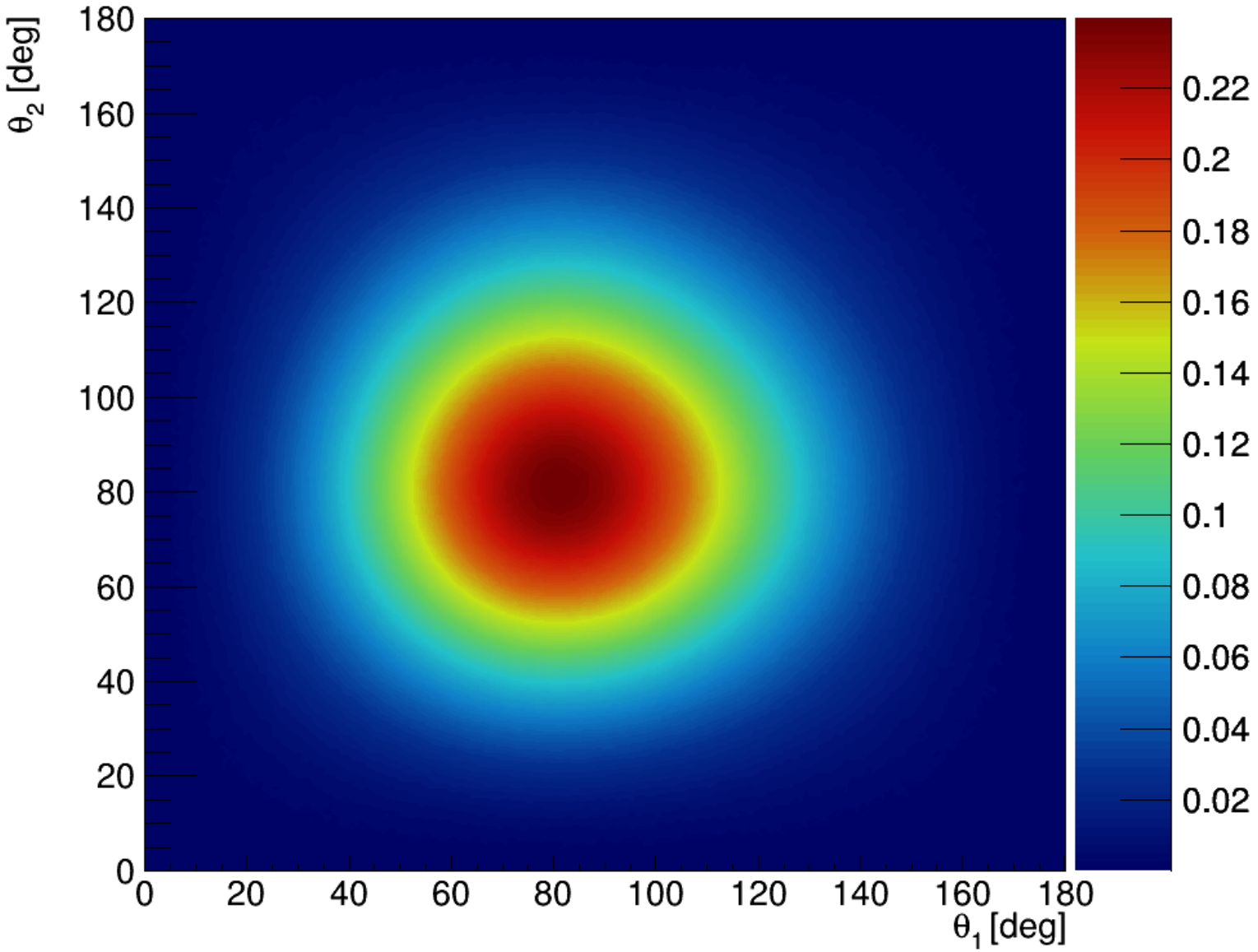
$$f(\varphi) = A \cdot \cos^2(\varphi - \delta) + B,$$

where δ describes position of the maximum

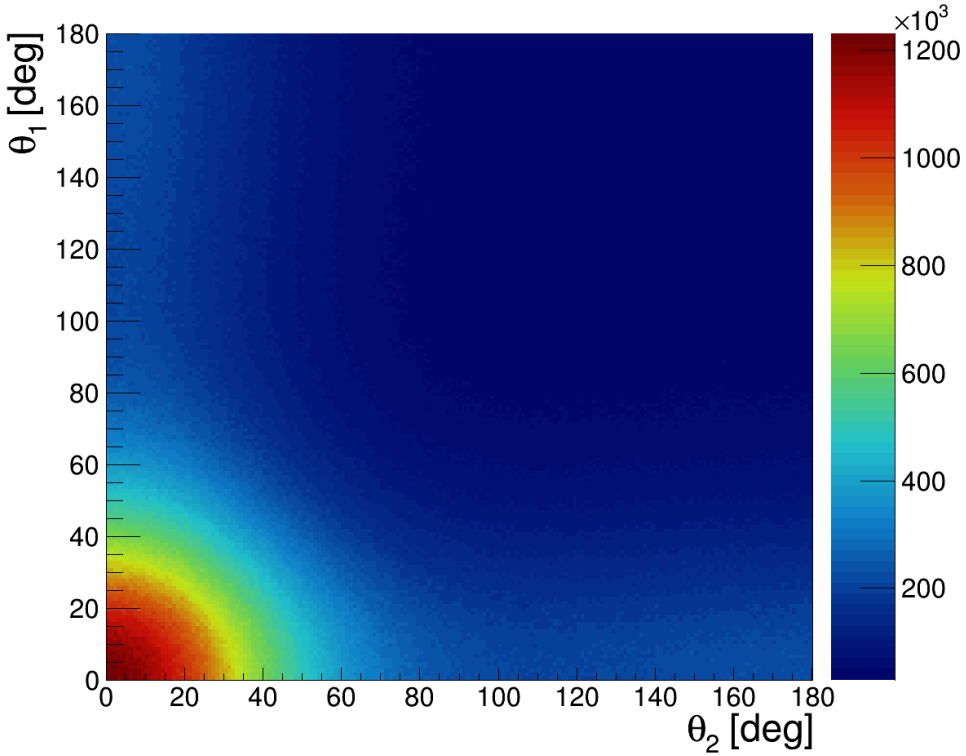
We can also introduce visibility squared (interference contrast of the oscillations):

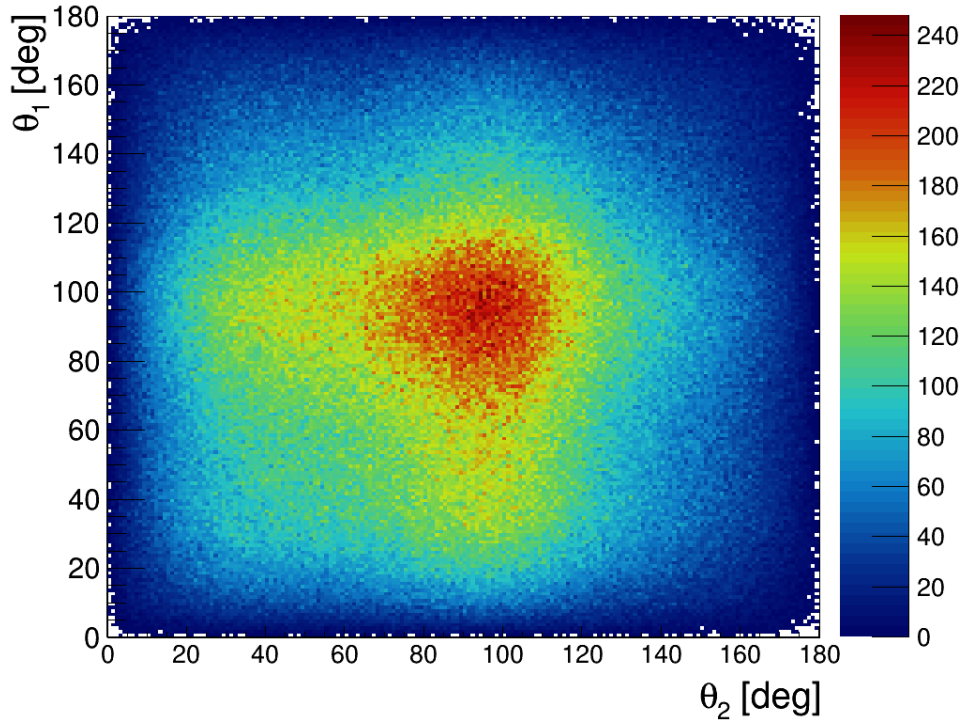
$$\mathcal{V}^2 = \frac{A}{2B + A}$$

Visibility squared

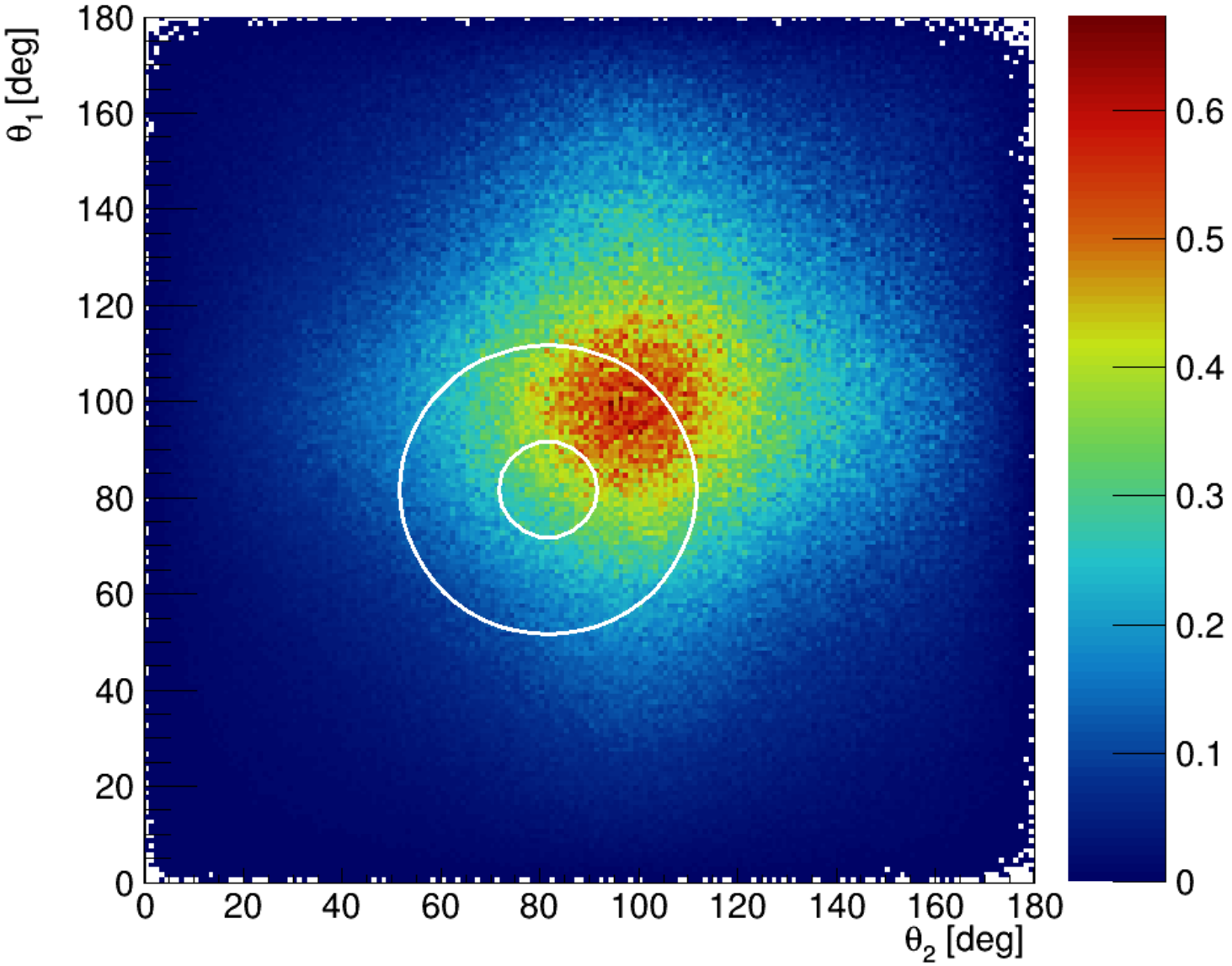


Event distribution as a function of Compton scattering angles θ_1 and θ_2

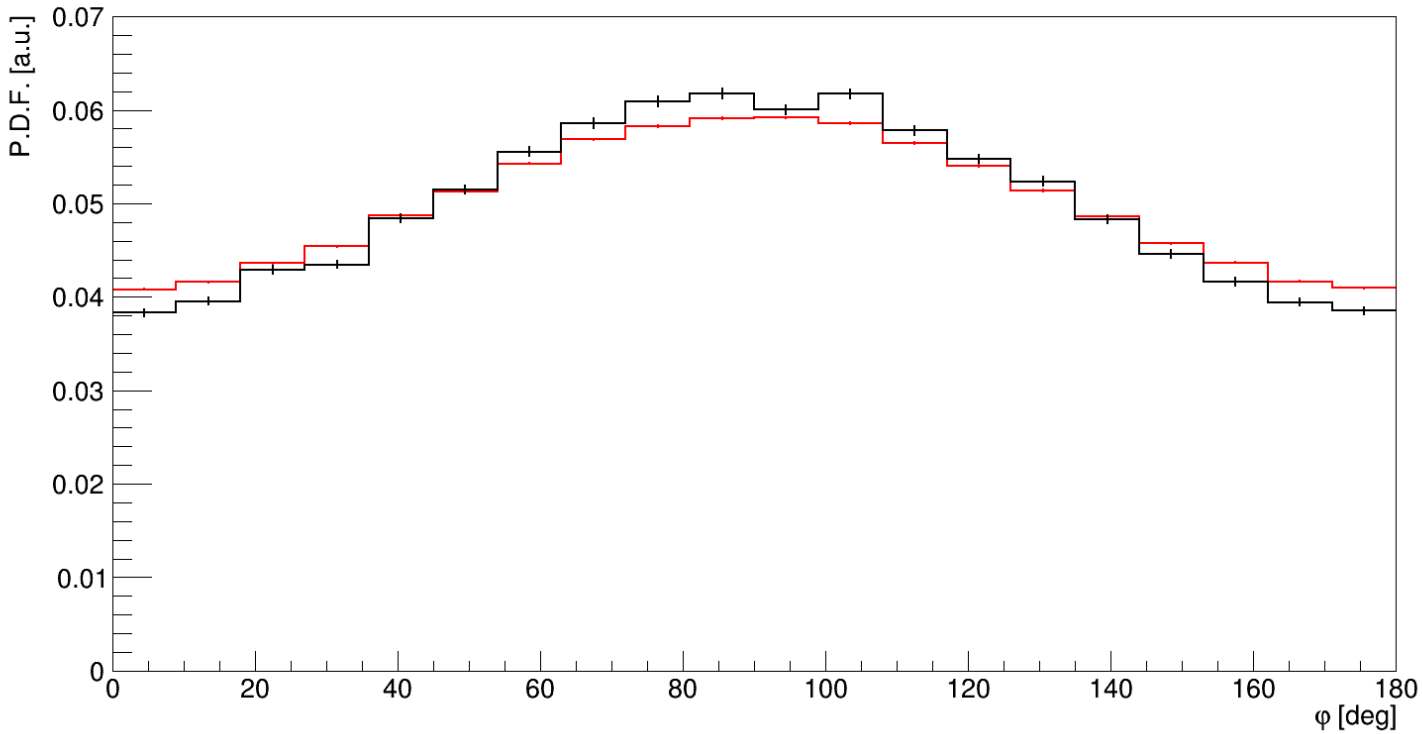




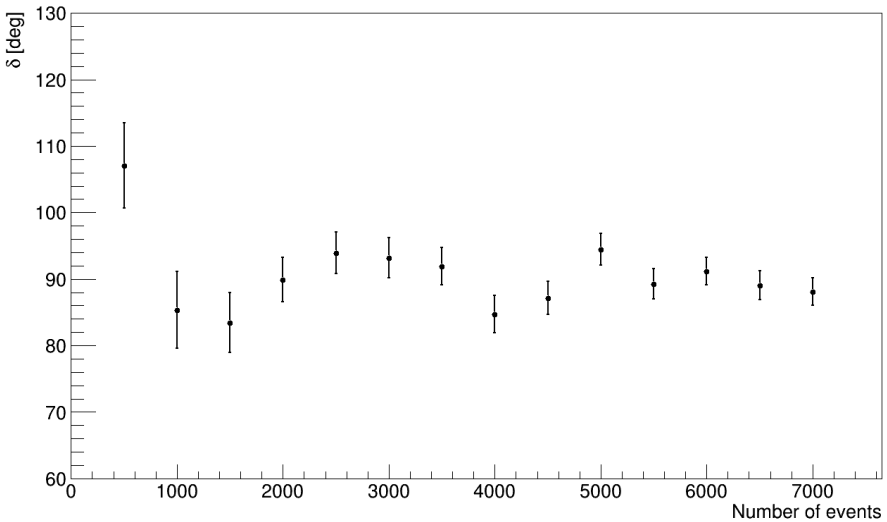
Efficiency of measuring events

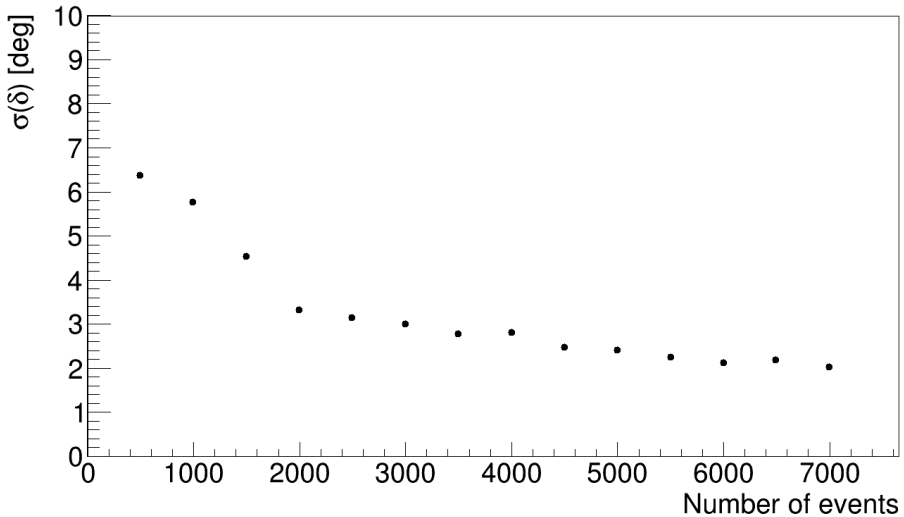


Distribution of angle between scattering planes φ for $R = 10^\circ$ and $R = 30^\circ$



Position of maximum (δ parameter) and it's uncertainty of the determination of the relative angle between the photons polarization directions





Thank you for your attention.