Test of AGATA modules as polarization analyzers

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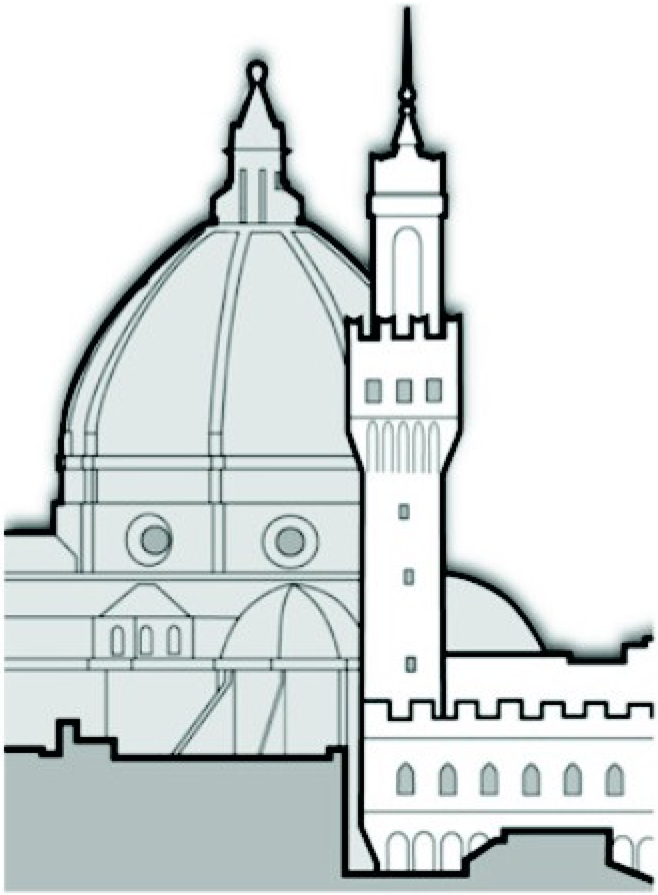

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Linear polarization measurements

- Measurements of the linear polarization can provide information on the type of multipolarity (electric or magnetic) of γ transition hence on the parity of the deexciting nuclear level.
- The angular distribution of Compton scattering is sensitive to the linear polarization of the incoming radiation:

$$\frac{d\sigma}{d\Omega} = \frac{r_0^2}{4}\left(\frac{k}{k_0}\right)^2\left[\frac{k_0}{k} + \frac{k}{k_0} + 2\left(\cos^2\theta - P\sin^2\theta\cos 2\Phi\right)\right]$$

where P is the polarization and Φ is the azimuthal angle

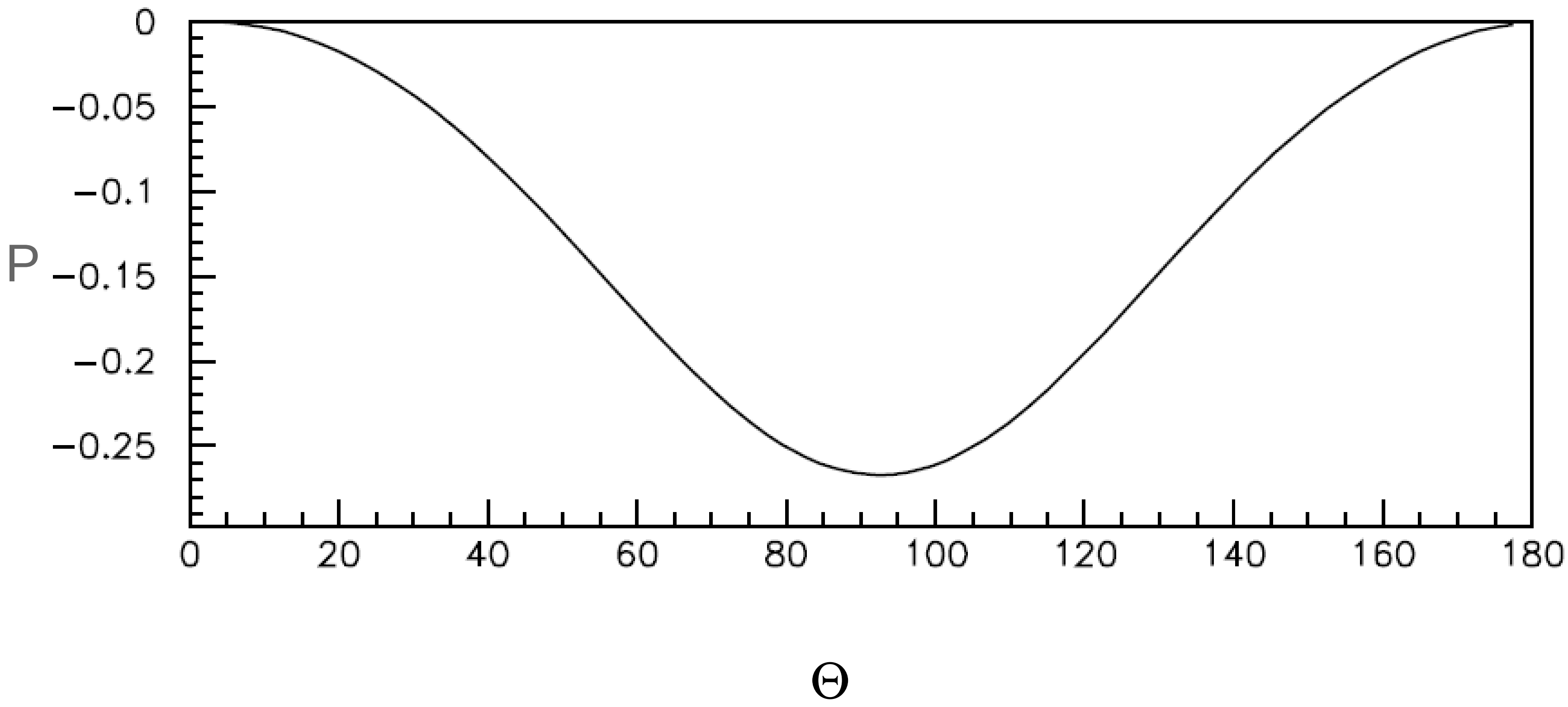
- In the usual Compton polarimeters, the cross section is measured only at a few values of ϕ . With the tracking of the Compton scattering, the complete angular distribution can be measured
- The advent of the AGATA array offers the possibility of detecting linear polarization with hight efficiency

Test of AGATA modules as Compton polarimeters

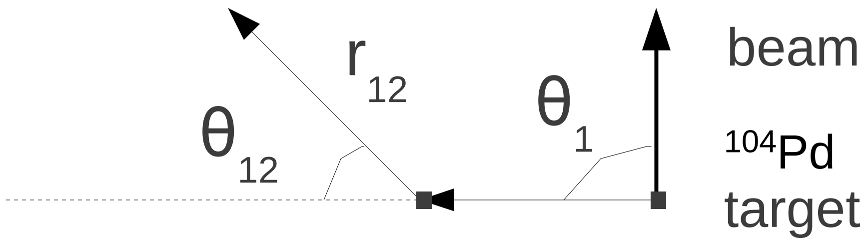
Experimental setup

- Two AGATA Demonstrator modules (six counters) positioned in a way to select γ not far from 90º with respect to the beam direction
- Reaction: ^{12}C beam @ 32MeV onto enriched 1 mg/cm^2 ^{104}Pd and ^{108}Pd targets
- Partially polarized γ rays are produced by CE of the first excited states in ^{104}Pd and ^{108}Pd, which deexcite by emission of 555.8keV and 433.9keV γ rays, respectively .
- Measurement of the distribution of unpolarized γ rays with a ^{137}Cs source have also been performed

Expected linear polarization of gamma rays from Coulomb excitation of the lowest 2^+ of ^{104}Pd, as function of the emission angle Θ



Preliminary analysis in ^{104}Pd



$\theta_1 \approx 90°$

θ_{12} → from the position of the 1st and 2nd interaction points → θ_G

θ_{12} → from the energy released to the e- → θ_E

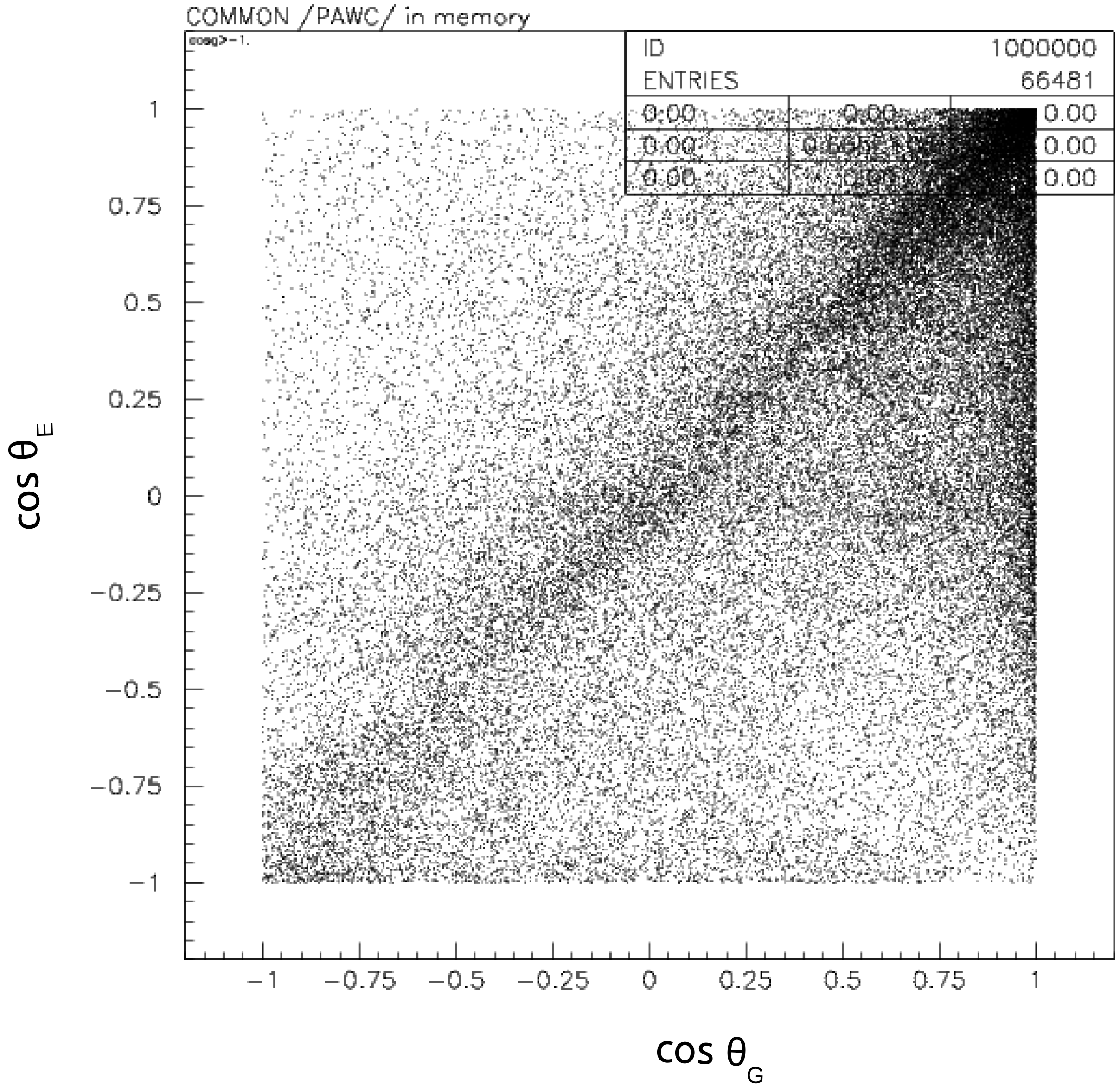
$$\Delta = |\cos\theta_E - \cos\theta_G|$$

The angular distribution in φ are built setting cuts:

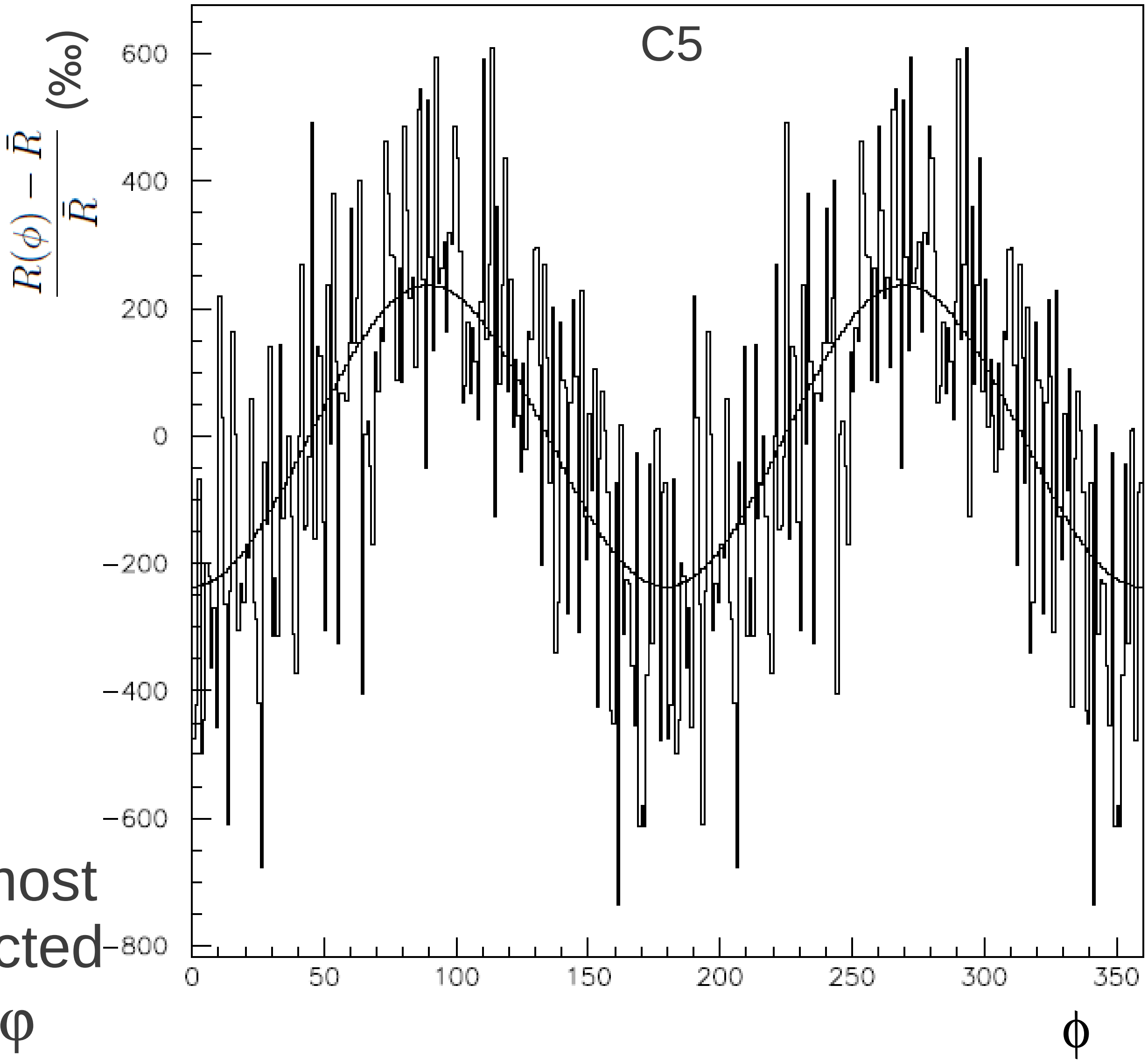
- on the distance between the 1st and 2nd interaction point ($r_{12} \geq 10$mm)
- on the difference Δ
- on the value of $\cos\theta_{12}$ (excluding values close to 1)

Note: we have accepted only those events for which the 1st and 2nd interaction points are in the same counter

Scatter plot of the cos θ_E vs cos θ_G



Problems: We found distortions in the φ distributions in both CE and with ^{137}Cs measurements



However, in the ratio

$$R(\phi) = \frac{F_{CE}(\phi)}{F_{Cs}(\phi)}$$

distortions cancel almost exactly and the expected dependence on cos2φ appears

$$\Delta = | \cos\theta_E - \cos\theta_G |$$

N	θ	Δ ≤0.02	Δ ≤0.05	Δ ≤0.15	No cut
3	104	0.36(17)	0.33(11)	0.30(8)	0.17(4)
4	103.1	0.15(17)	0.18(12)	0.25(8)	0.17(4)
5	90.7	0.60(11)	0.45(7)	0.37(4)	0.23(3)
6	117	0.27(14)	0.34(8)	0.36(6)	0.22(4)
7	128	0.20(19)	0.39(10)	0.36(8)	0.25(5)
8	112	0.31(14)	0.39(9)	0.32(9)	0.20(4)
best av.		**0.36(6)**	**0.37(4)**	**0.34(3)**	**0.21(2)**

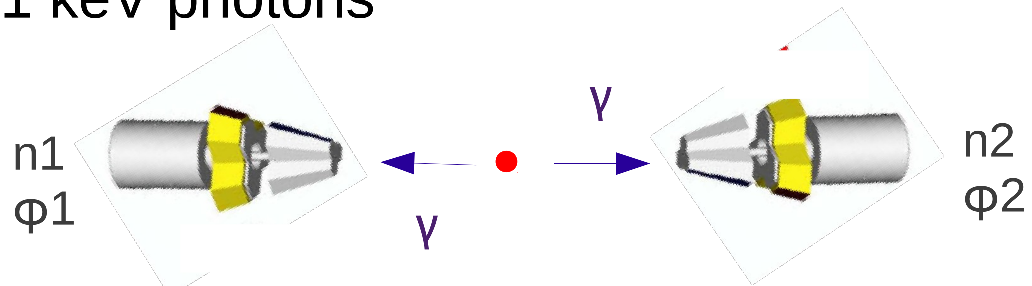
for Δ ≤ 0.15 the ratios at different angles of the measured polarization to the calculated one are consistent

The measured polarization in smaller than the calculated one due to the fact that a certain number of excited nuclei are able to recoil into vacuum and the hyperfine interaction of the nucleus with the surrounding electrons “destroy” the polarization

Quantum entanglement of annihilation photons

We have proposed to measure (LOI) the linear polarization correlations of two entangled photons produced from a s-state $e^+ e^-$ annihilation

- Two AGATA modules mounted positioned symmetrically at opposite sides with respect to the annihilation source to detect the coincidences of the two 511 keV photons



- The singlet positronium $e^+ e^-$ provides a clean source of pair of entangled photons (back to back emission)

- Since the position of the first interaction of the two photons are known to be collinear with the annihilation source, the tracking is expected to be easier than for a single photon of the same energy

  - $F(\theta 1,\varphi 1;\theta 2,\varphi 2) = A(\theta 1,\theta 2) + B(\theta 1,\theta 2) \cos 2(\varphi 1-\varphi 2)$
  - N true coincidences (n1= n2) will show expected angular dependence
  - N(N-1) random pairs (n1≠ n2) will provide a reference distribution to correct for distortion effects

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