Rayleigh scattering in X-ray polarimetry

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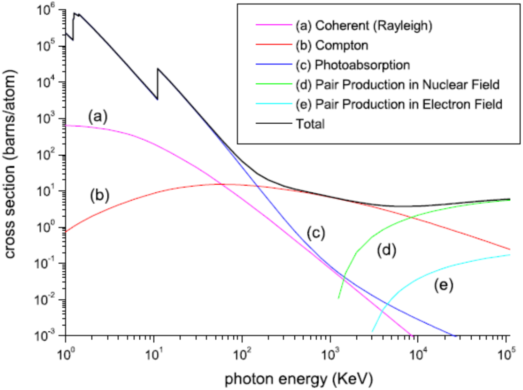
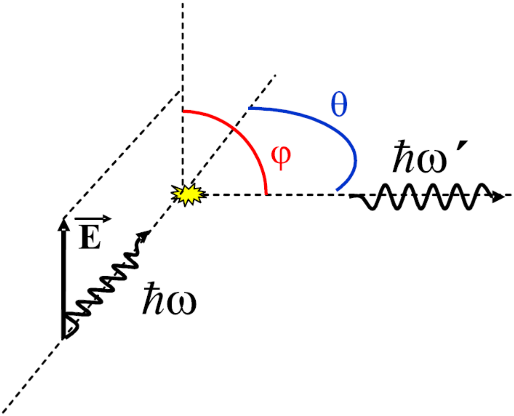


Cross-section for the main interaction processes of hard X-rays with germanium atoms.

The differential cross-section for scattering depends on the direction of the electric field vector of the incident photon.



Kinematical relation between the scattered photon energy $\hbar\omega'$ and the scattering angle θ:

$$\hbar\omega' = \hbar\omega \frac{1}{1 + \frac{\hbar\omega}{m_e c^2}(1 - \cos\theta)}, \qquad (1)$$

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Klein-Nishina equation

$$\frac{d\sigma}{d\Omega} = \frac{r_e}{2}\left(\frac{\hbar\omega'}{\hbar\omega}\right)^2\left(\frac{\hbar\omega'}{\hbar\omega} + \frac{\hbar\omega}{\hbar\omega'} - 2\sin^2\theta\cos^2\varphi\right) \tag{2}$$

$$I(\varphi) \sim M \cdot P \cdot \sin^2 \varphi + (1/2)(1 - M \cdot P). \tag{3}$$

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$$M = \frac{I(90) - I(0)}{I(90) + I(0)}. \tag{4}$$

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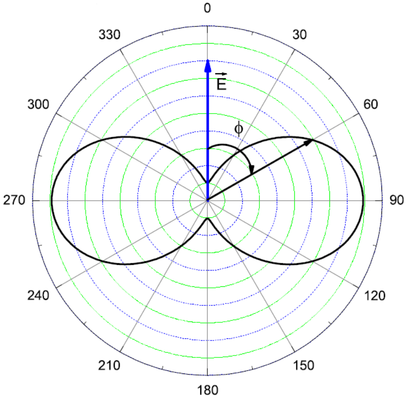
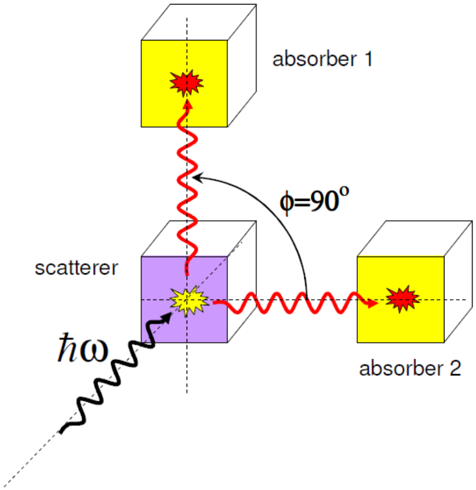
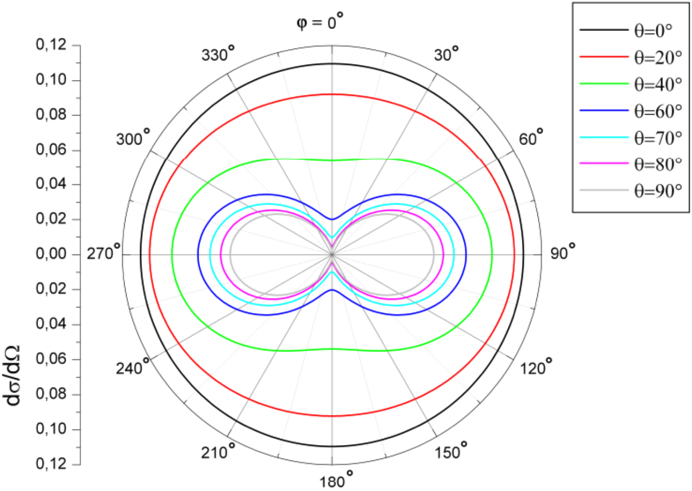
Here the ϕ-distribution for a vertically aligned photon polarization $\vec{E}$ is displayed.



Basic scheme of a scattering polarimetry experiment. One detector serves as a scatterer and one or more as absorbers. The angular distribution of the scattered photons delivers the information about the incident photon polarization.

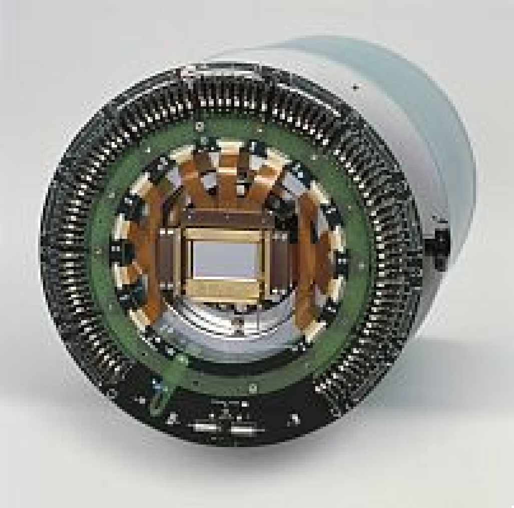


Cross-section depends on scattering angle θ too.

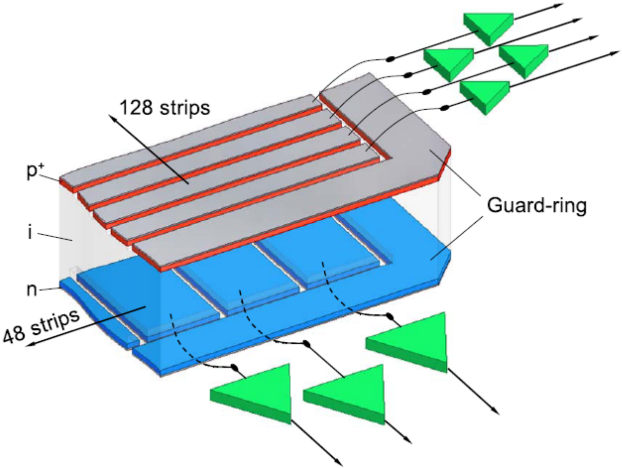


We used almost 100% polarized radiation from the European Synchrotron Radiation Facility in Grenoble

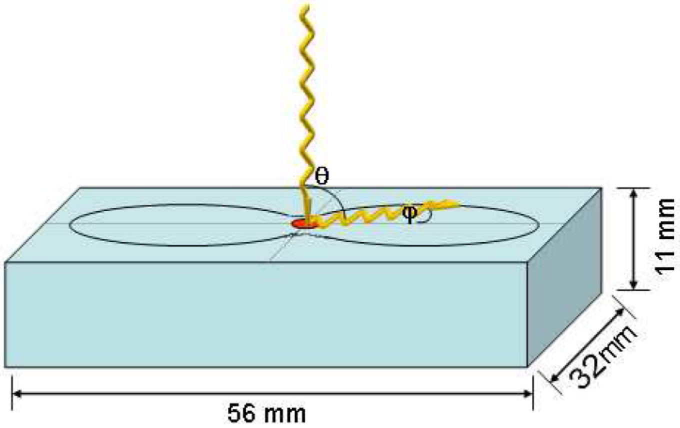
and 2D position sensitive microstrip Ge(i) detector.



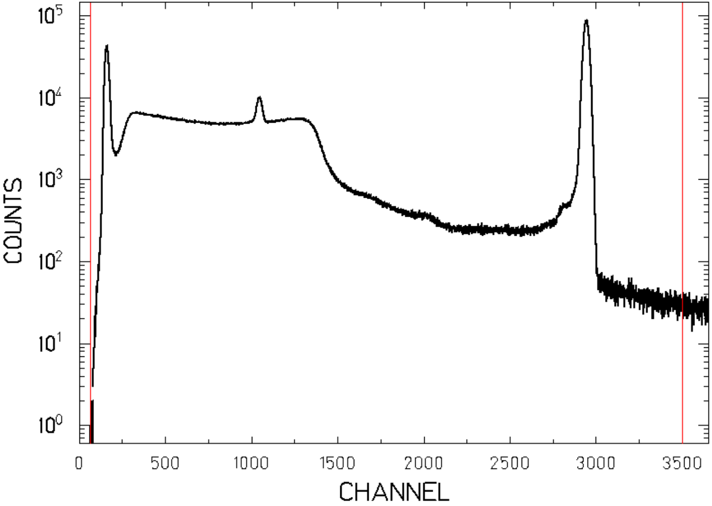
Schematic drawing of a small section of the Ge(i) crystal with etched orthogonal strips on front (p) and back (n) sides surrounded by a guard ring. Each strip is furnished with a separate readout.



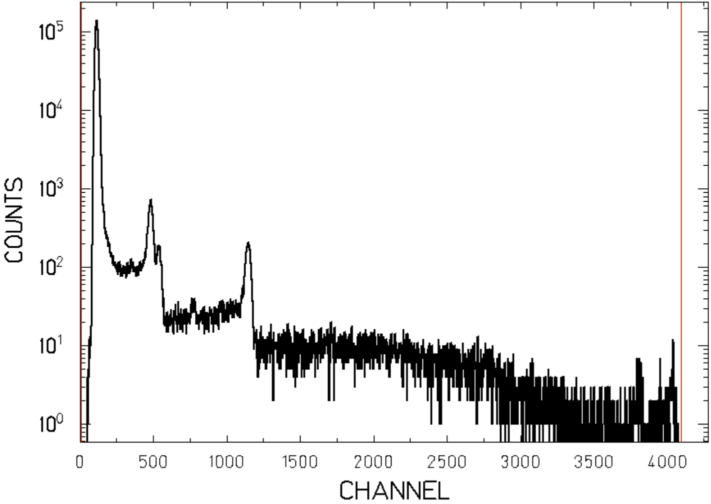
The geometry of the detector.



Uncalibrated energy spectrum of synchrotron radiation received by the 2D detector.



Energy spectum of $^{133}_{56}$Ba using for the detector's calibration.



Obtained data was analyzed by means of a special package SATAN (System for the analysis of tremendous amounts of nuclear data).

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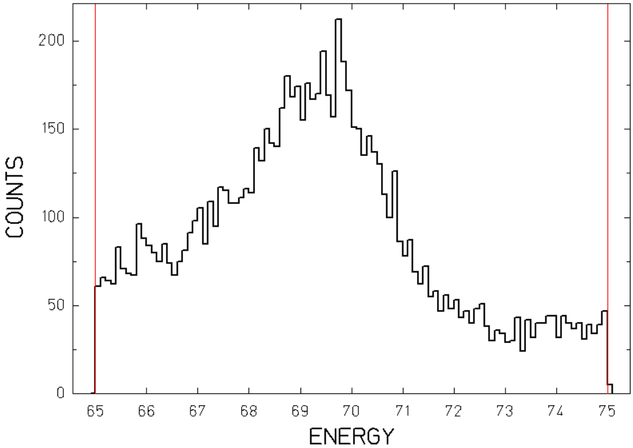
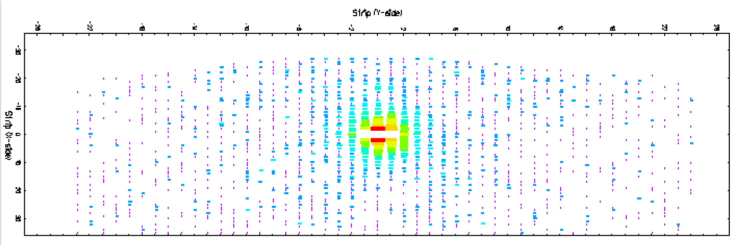
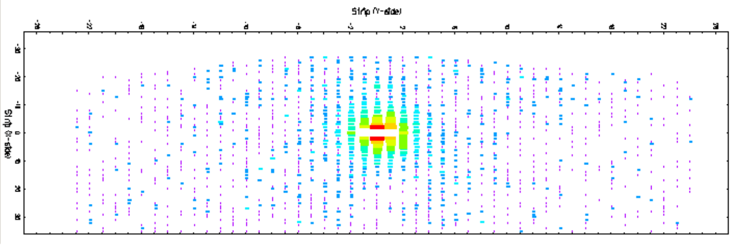


The peak corresponds to Rayleigh scattering of 70 keV photons in our detector.

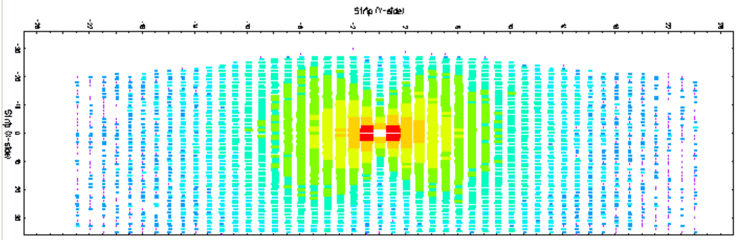
Position distribution of Rayleigh scattered photons for energy range 70 keV ± 5 keV.



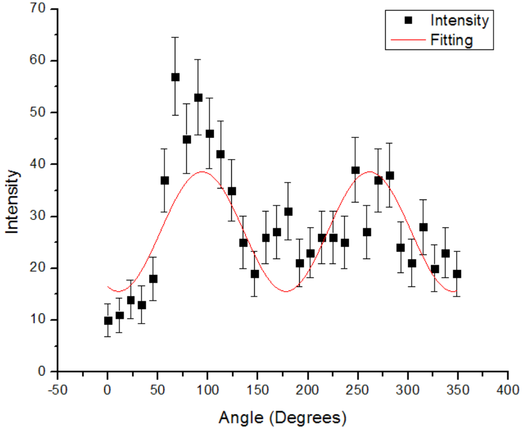
Position distribution of Rayleigh scattered photons for energy range 70 keV $\pm$ 5 keV.



And of Compton scattered photons for energy range 210 keV $\pm$ 10 keV and at the angle $\theta = 90^\circ \pm 15^\circ$.

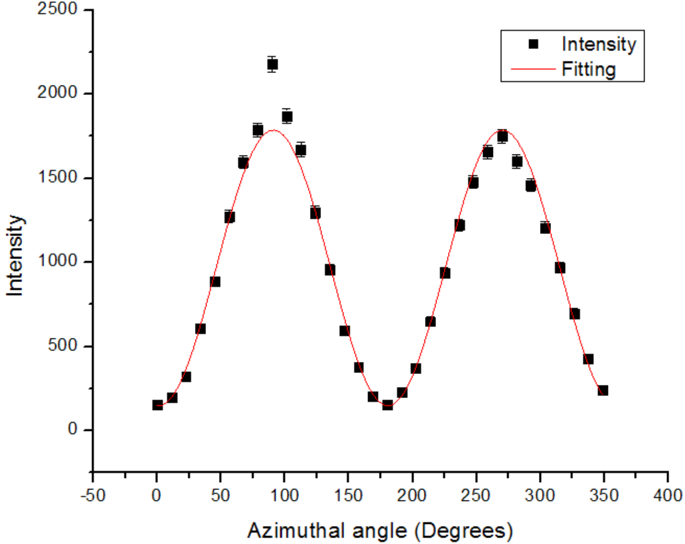


Projection of the position distribution on the φ-axis together with the least square fit of eq. 5: $M = 0.45 \pm 0.06$.



$$I(\varphi) = A \cdot (M \cdot \sin^2 \varphi + (1/2)(1 - M)) \quad (5)$$

Projection of the 2D position distribution for Compton scattering at the angle $\theta = 90^\circ \pm 15^\circ$ on the φ-axis together with the least square fit of eq. 5: $M = 0.86 \pm 0.01$.



- A 2D distribution of Rayleigh scattered photons in our microstrip detector has been obtained.
- Usefulness of the Rayleigh scattering process for X-ray polarimetry is addressed as well.
- Since the Rayleigh scattering can influence identification of events in Compton polarimetry, its investigation is also important for determination of the accuracy of polarization measurements.

Thanks for your presence!