Microstrip detectors for compton polarimetry

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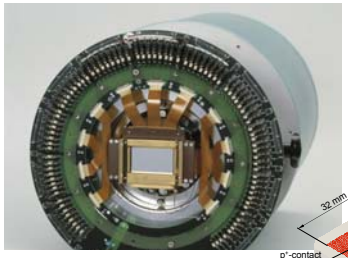
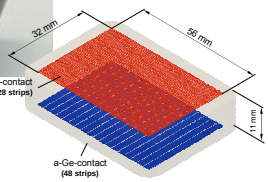
Abstract

Novel energy dispersive and position sensitive solid state detectors play an important role for accurate x-ray spectroscopy of exotic atomic systems such as hydrogenlike uranium [1]. Besides applications in x-ray spectroscopy and time-resolved x-ray imaging, the polarization sensitivity for hard x-rays is a further important feature of such devices. It allows to address experimentally the polarization properties of radiation from elementary processes such as electron bremsstrahlung, recombination or photonic processes in warm dense plasmas.
Here we report on a performance test of a prototype 2D Ge(i) detector and give an outlook for a new Si(Li) Compton polarimeter. Both systems have been developed at IKP Jülich.

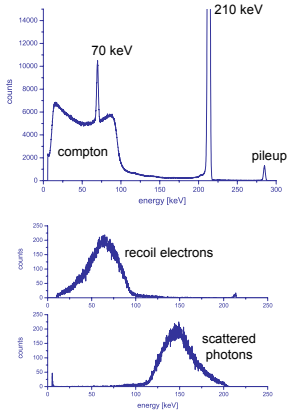


Microstrip 2D Ge(i) detector
active area: 32 x 56 mm
thickness: 36mm
128x48 strips
corresponding to 6144 effective Pixels
250 / 1167µm pitch



The tests have been performed at beamline ID15 at the European Synchrotron Facility, Grenoble

Performance test of the Ge(i) detector

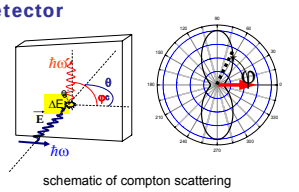


At ESRF, Grenoble, a beam of 98% linearly polarized photons with 210 keV energy was focused to a size close to 50 x 50 µm on the detector. The beam was centered on one strip on the front and the back side. The upper left plot shows the raw spectrum of the central backside strip.

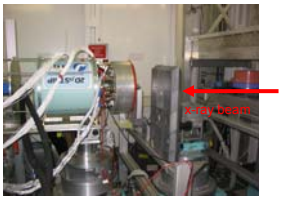
The lower plot shows the coincident distributioins of recoil electrons and compton scattered photons. Since the energy transfer to the electron is determined by

$$\Delta E = \hbar\omega \frac{\frac{\hbar\omega}{mc^2}(1-\cos(\vartheta))}{1+\frac{\hbar\omega}{mc^2}(1-\cos(\vartheta))} \qquad (1)$$

we can select the scattering angle by setting energy windows on the energy



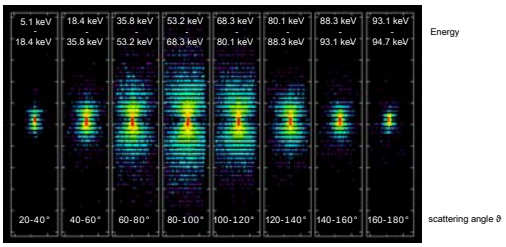
schematic of compton scattering



experimental setup

distribution of the recoil electrons. Therefore we can extract the angular distributions which are determined by the Klein-Nishina function:

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



distributions of compton scattered photons at different scattering angles ϑ from 0° to 180°

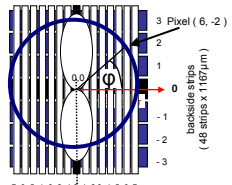
Polarization Measurements

Sorting the events pixelwise and extracting only those pixels within a certain distance from the central Pixel, we can extract the azimuthal angular distributions. For demonstration purposes, we introduced an overeall multiplication factor for the Klein-Nishina function which then has been fitted to the angular distributions at different radii. As shown in the third graph, the fitted multiplication factor decreases exponentially. Thereby we obtain an attenuation coefficient of 0.13 mm^{-1}. This is in agreement with the NIST data for the expected absorption in the germanium crystal.

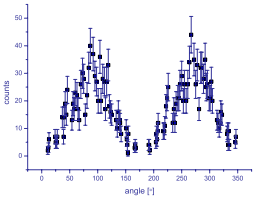
The modulation coefficient is given by:

$$Q = \frac{N_\perp - N_\parallel}{N_\perp + N_\parallel} \qquad (3)$$

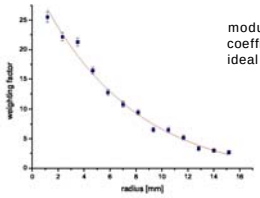
While $N_\perp$ and $N_\parallel$ are the compton events perpendicular and parallel to the polarization vector. We obtained a Q value of 0.896 ± 0.007. Furthermore we present the Q values for different acceptance windows for ϑ. While the Q value decreases only slightly, the relative efficiency of the detector can be increased dramatically.



schematic of detector geometry

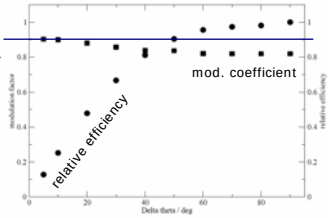


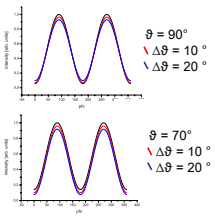
azimuthal angluar distribution of pixels with central distances between 4.4mm t 5.5mm.



fitting weighting factors at different radii

modulation coefficient of ideal detector

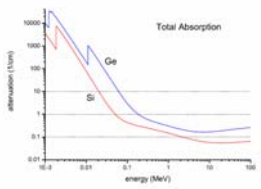


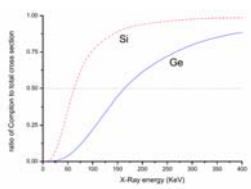


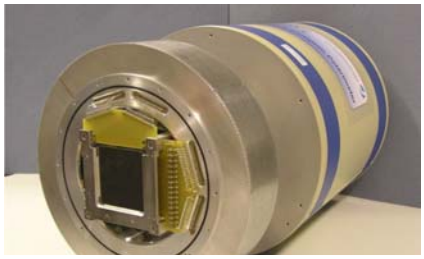
theoretical Klein – Nishina differential cross sections

A new Si(Li) detector for low energy polarization studies

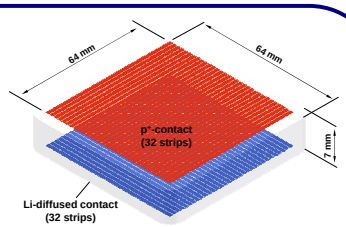
The germanium detector has an excellent performance as a polarimeter for photon energies above 120 keV and is therefore well suited for the investigation of electron bremsstrahlung and recombination processes. In contrast, due to the relatively low-Z of the crystal, a Si(Li) 2D detector can already be used as a polarimeter for energies as low as 50 keV. Therefore with the new Si(Li) detector system which is currently being commissioned even the polarization of characteristic atomic transitions can now be addressed in experiments.







2D Si(Li) strip detector
active area: 64 x 64 mm
thickness: 7mm
32x32 strips
2 / 2mm pitch



Acknoledgements:
European Synchrotron Radiation Facilty,
6 rue Jules Horowitz, 38000 Grenoble, France

References:

[1] J. Eichler, Th. Stöhlker, Phys. Rep. 2007
[2] http://www.gsi.de/sparc/
[3] D. Protic et. al., IEEE 52, 3194 2005