Commissioning of a Si(Li) Compton Polarimeter

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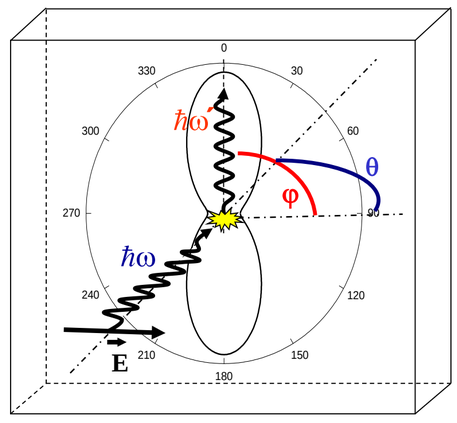
Motivation and Introduction

A detailed polarization measurement of photons in the x-ray regime gives insights into many properties in atomic physics, such as the relativistic particle dynamics and QED effects of radiative processes in highly charged heavy ions [1].

The Compton scattering process can be described using the Klein-Nishina equation: $\frac{d\sigma}{d\Omega} = \frac{1}{2}r_0^2 \left(\frac{\hbar\omega'}{\hbar\omega}\right)^2 \left(\frac{\hbar\omega'}{\hbar\omega} + \frac{\hbar\omega}{\hbar\omega'} - 2\sin^2\theta\cos^2\varphi\right)$

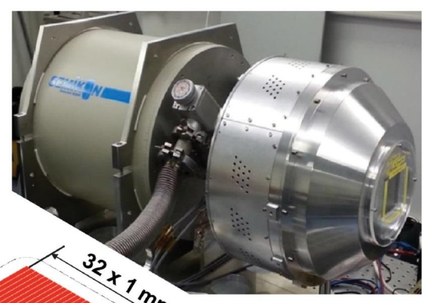
As can be seen, the scattered photon is more likely to be emitted perpendicular to the electric field vector of the incoming photon. Therefore, the degree of linear polarization as well as the orientation of the polarization ellipse can be obtained from the azimuthal scattering distribution.

To utilize this effect, many double sided segmented detectors have been built and improved within the SPARC collaboration [2,3,4] within the last years. Recently a new 2D Si(Li) detector system with a cooled first stage of the preamplifiers has been built and commissioned [5]. This work is funded by the German Federal Ministry of Education and Research within the Verbundprojekt "05P2015 – APPA R&D: Licht-Materie-Wechselwirkung mit hochgeladenen Ionen".

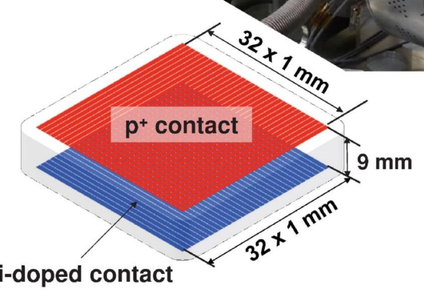


Schematic drawing of the Compton scattering process

Polarimeter



Si(Li)-Compton polarimeter with cryogenic preamplifiers and schematic drawing of the detector crystal

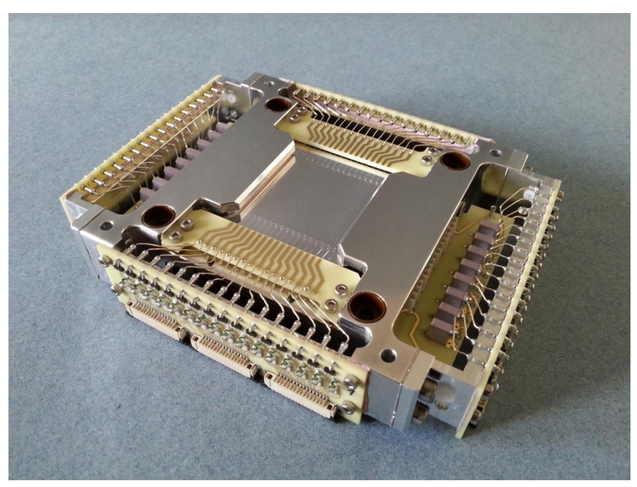


To improve the energy resolution by reducing the electronic noise, the first stage of the preamplifiers was mounted in the cryogenic environment of the detector crystal.

To investigate the characteristics of this new 2D Si(Li) Compton polarimeter, we participated in an experiment at the ESR storage ring located at GSI Darmstadt. The detector system was placed next to the internal gas target at an angle of 90° with respect to the beam axis.

The projectile beam consisted of bare xenon ions at an energy of ≈ 31 MeV/u and hydrogen at a density of 3×10^{13} cm^{-3} was used as target.

Beforehand the detector was calibrated and tested using an ^{241}Am sample.



P+ side of the mounted detector crystal with the preamplifier FETs on printed circuit boards

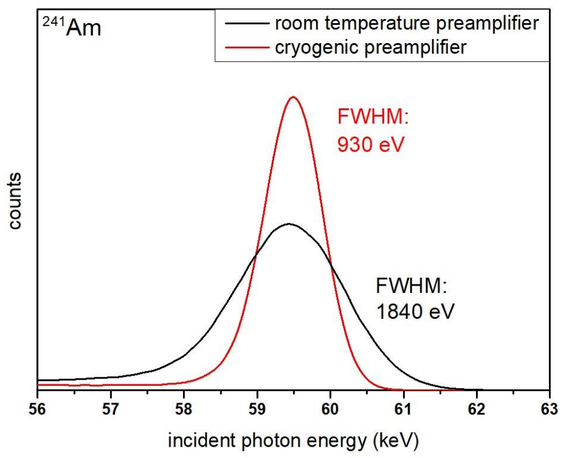
Results

Due to the LN2 cooling of the preamplifiers, the energy resolution is increased by about a factor 2, compared to previous measurements, leading to a FWHM across the p+- and ground-side of ≈ 900 eV at 60 keV (^{241}Am decay; picture on the right side) [5].

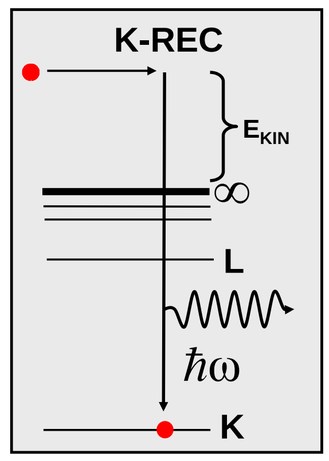
Furthermore the lower limit of accessible energy was lowered to about 8 keV due to the cryogenic preamplifiers.

The experimental data employing the xenon beam (picture bottom left) is clearly showing the K- (56 keV) and L-REC (26 keV) transitions as well as the characteristic lines of xenon (30 keV, 35 keV, 37 keV).

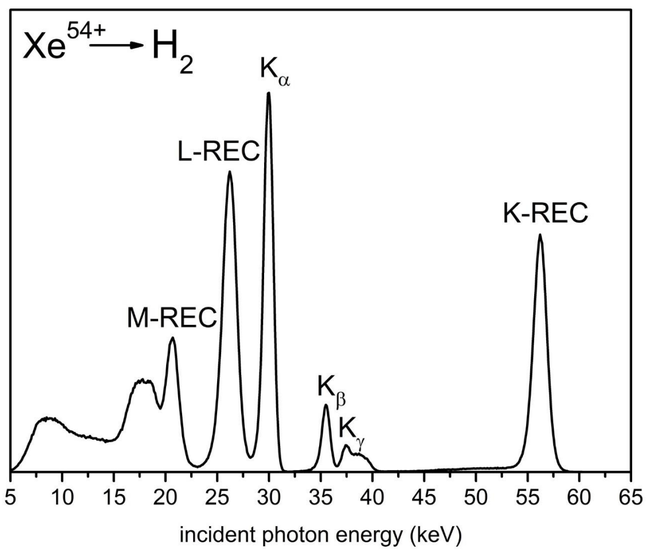
As expected, the degree of linear polarization of the K-REC radiation is very high, resulting in a highly anisotropic distribution of the Compton scattering events across the detector (picture bottom middle and right). The analysis is still ongoing, but first results indicate values of close to full linear polarization.



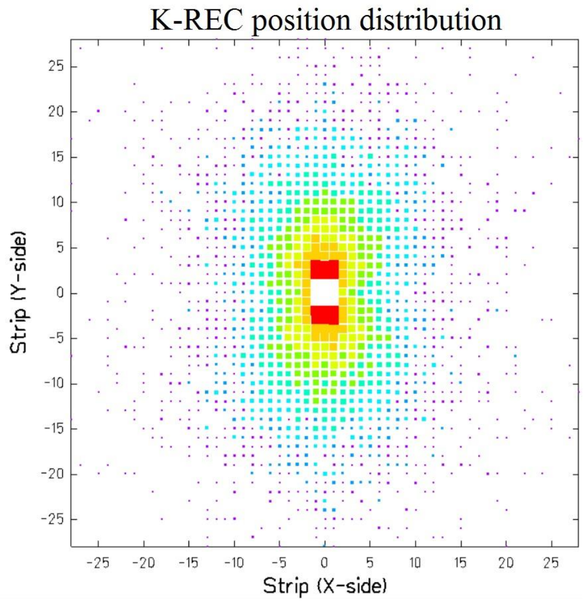
Spectra of an ^{241}Am source compared for the new detector with cryogenic preamplifier (red) and another detector with room temperature preamplifier (black).



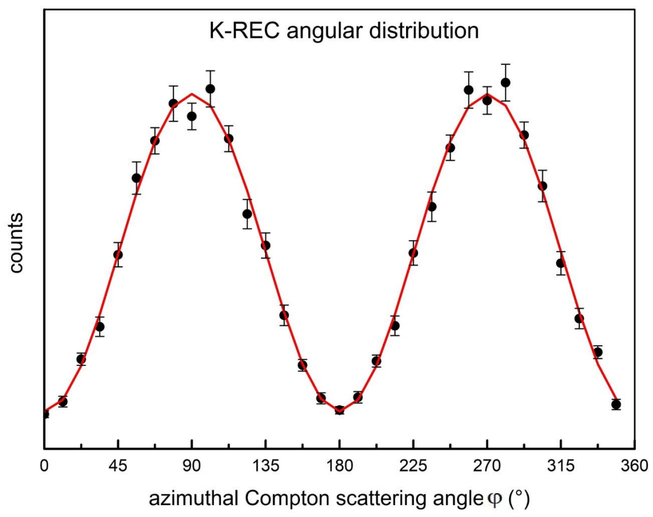
Schematic drawing of the radiative electron capture (REC) into the K-shell. It can be considered the time-inverse process of photoionization



Spectrum of a beam of bare xenon at 31 MeV/u on a hydrogen target. K-REC, L-REC, and characteristic lines are clearly visible



2D plot of the detected Compton scattered photons for the K-REC peak at 56 keV. The strong asymmetry indicates a high degree of polarization. Red zones indicate a high count rate.



Detected Compton scattering events as polar plot (black dots) and a least-squares fit of the Klein-Nishina equation with the degree of polarization as free parameter (red line). Polarization analysis is still ongoing.

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