Commissioning of a 2D Si(Li) Compton polarimeter

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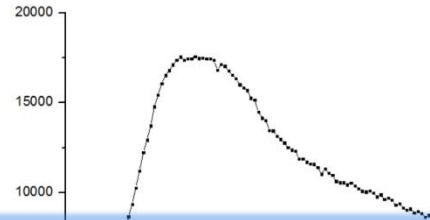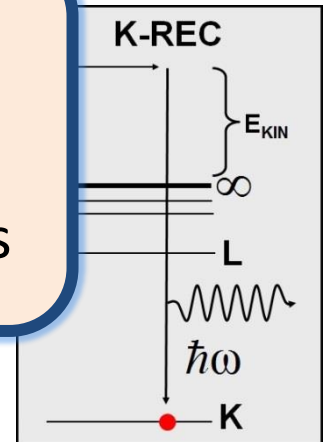FAIRNESS workshop – 02.06.2017

Sources of polarized x-rays
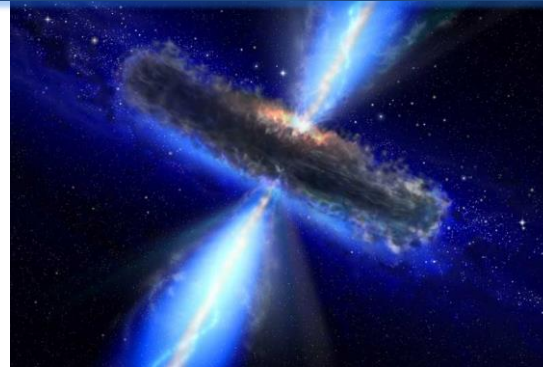
Synchrotron radiation

Bremsstrahlung

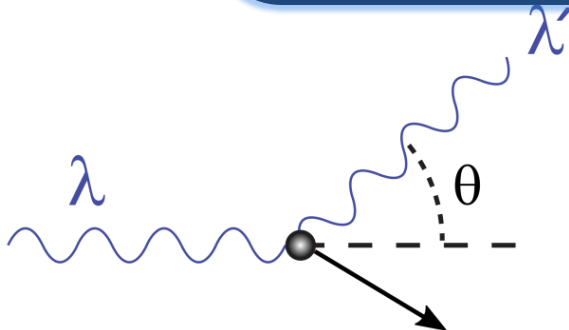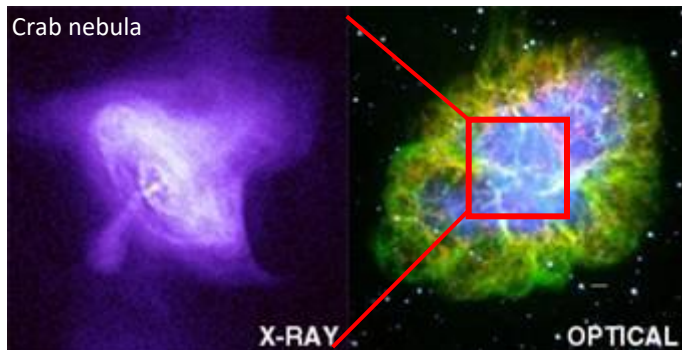Recombination processes

Scatter

→ towards "complete" measurement

→ test of theory (QED, astrophysical models)
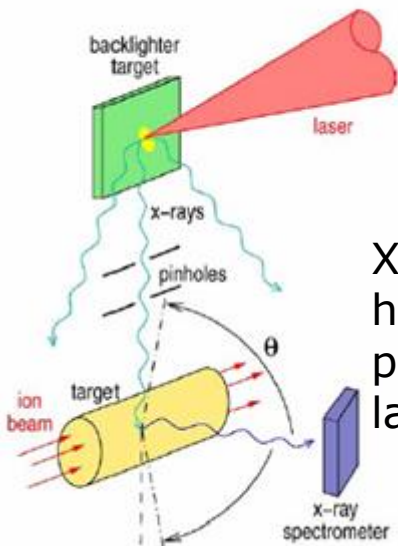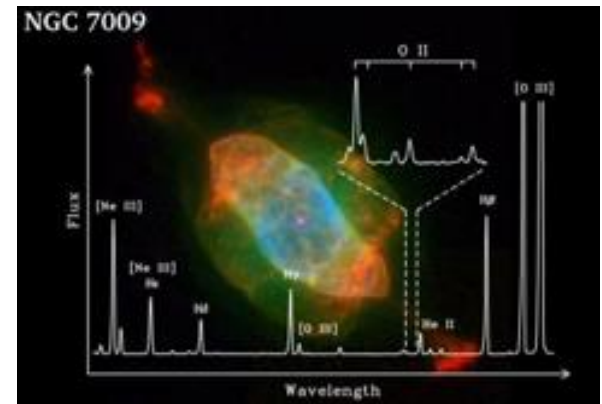
→ diagnostic of spin polarized particle beams

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Laboratory Astrophysics

Crab nebula

X-RAY · OPTICAL
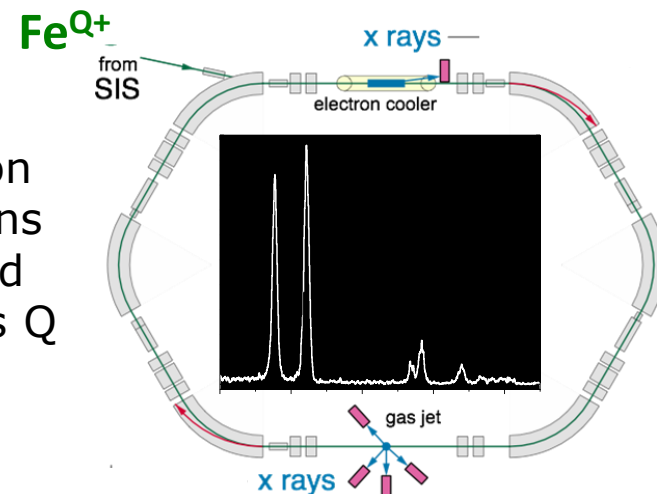
⬌ Direct insight into celestial plasmas

Spectra provide knowledge of temperature, density, element abundance, etc.

NGC 7009

⬌

X-Ray Spectroscopy / Polarimetry

X-ray emission of hot plasmas produced by intense laser and ion beams

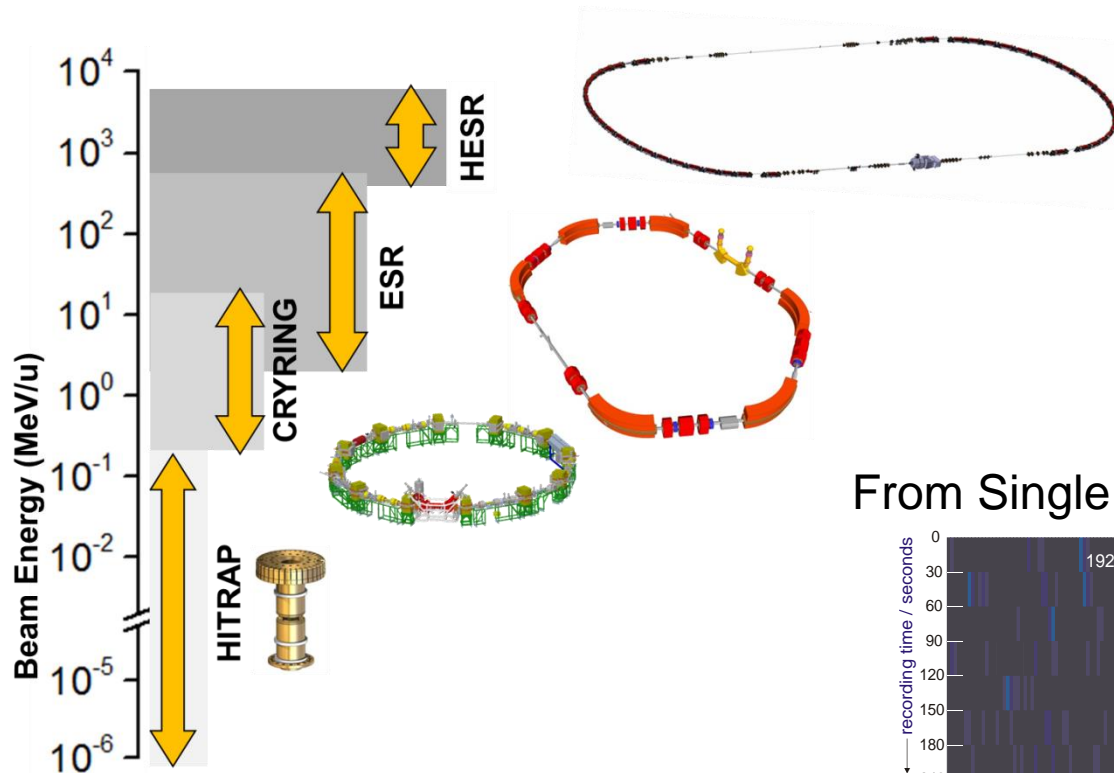X-ray emission studies for ions in well defined charge-states Q

Fe^{Q+} from SIS

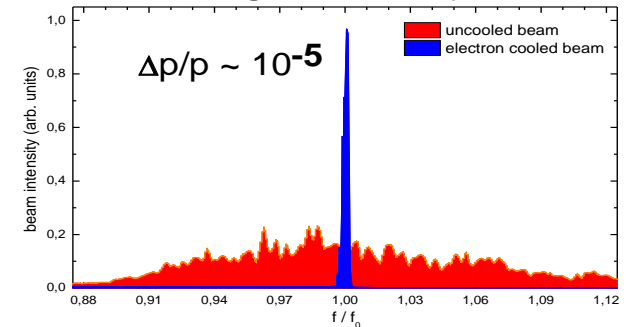x rays

electron cooler

gas jet

x rays

Worldwide Unique

Stored and Cooled
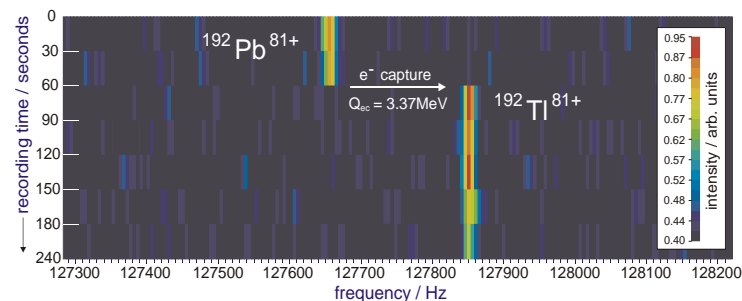**Highly-Charged Ions (e.g. U^{92+}) and Exotic Nuclei**
From Rest to Relativistic Energies (up to 4.9 GeV/u)

Cooling: The Key for Precision

$\Delta p/p \sim 10^{-5}$

uncooled beam
electron cooled beam

From Single Ions to Highest Intensities

$^{192}Pb^{81+}$

e^- capture
$Q_{ec} = 3.37\text{MeV}$

$^{192}Tl^{81+}$

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Compton scattering
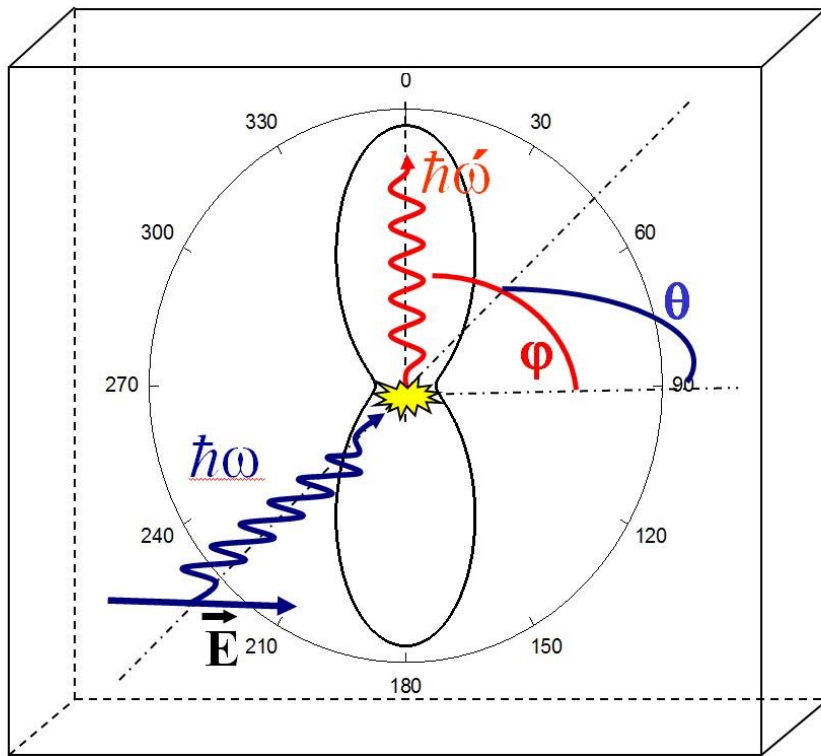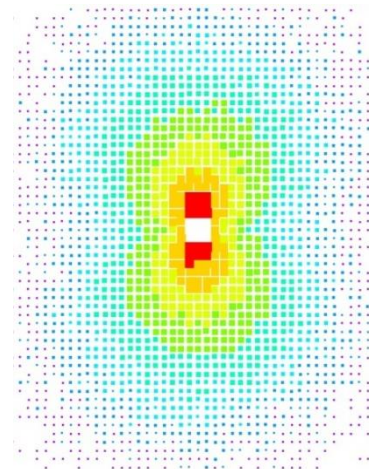

$$20 \; keV \lesssim \hbar\omega \lesssim 1 \; MeV$$

Klein-Nishina formula:

$$\frac{d\sigma}{d\Omega} = \tfrac{1}{2}r_0^2 \left(\frac{\hbar\omega'}{\hbar\omega}\right)^2 \left(\frac{\hbar\omega'}{\hbar\omega} + \frac{\hbar\omega}{\hbar\omega'} - 2\sin^2\theta\cos^2\varphi\right)$$

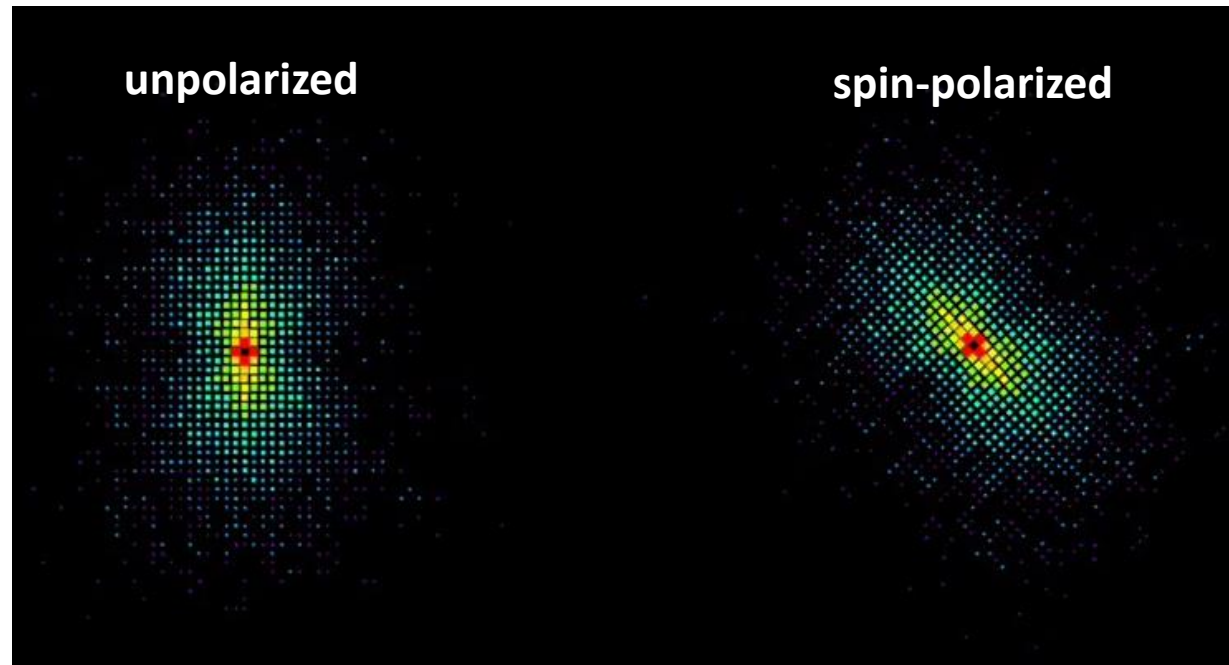Anisotropy of the azimuthal scattering distribution is highly sensitive to the polarization of the incoming photon!

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Spin Polarized Ion Beams

for spin polarized ions, the polarization plane and scattering plane are not equal.

A.Surzhykov et al.,
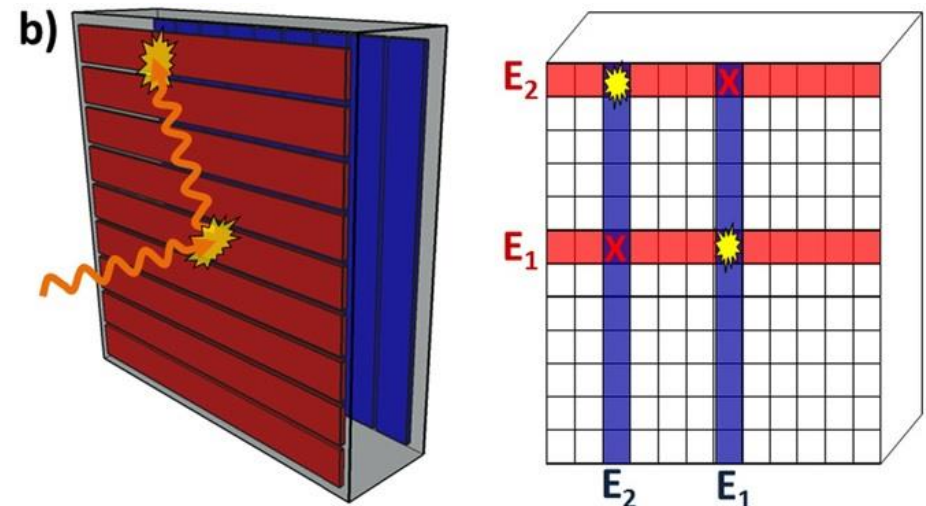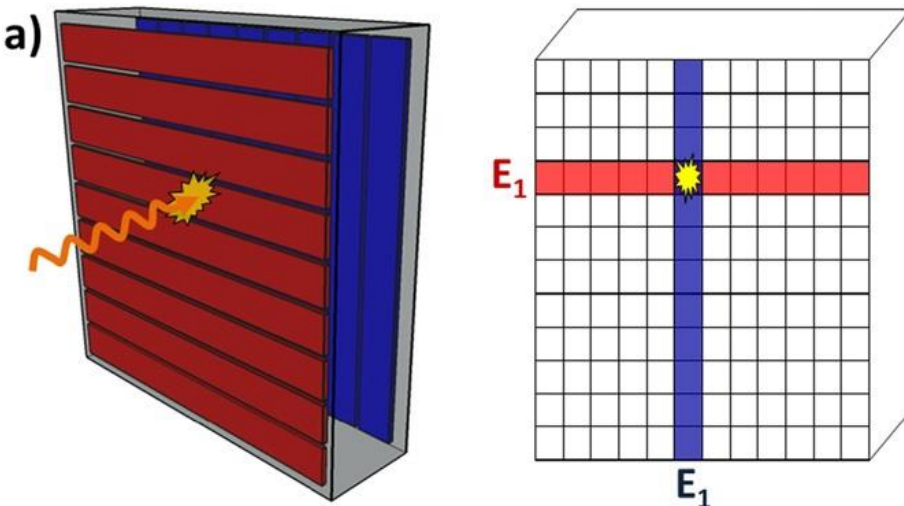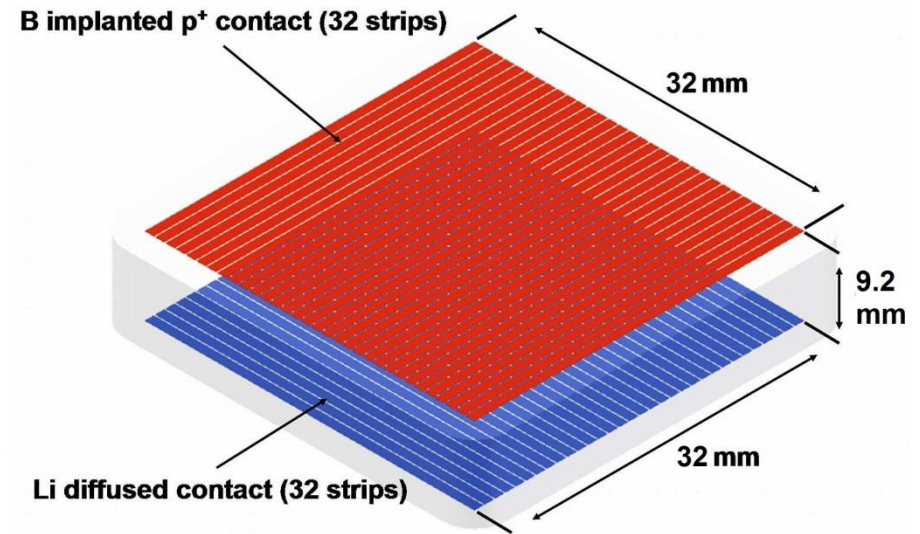PRL 94, 203202 (2005)

unpolarized   spin-polarized

control over the spin-polarization of stored ions:
required for the search of the electric-dipole momentum of elementary particles and for atomic PNC experiments.

Recombination would be a possible tool:
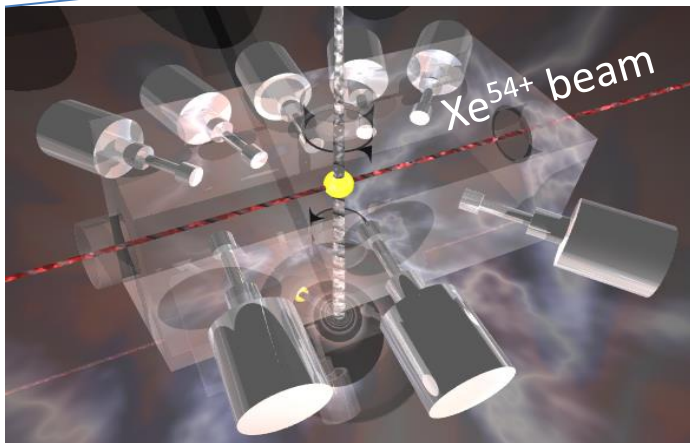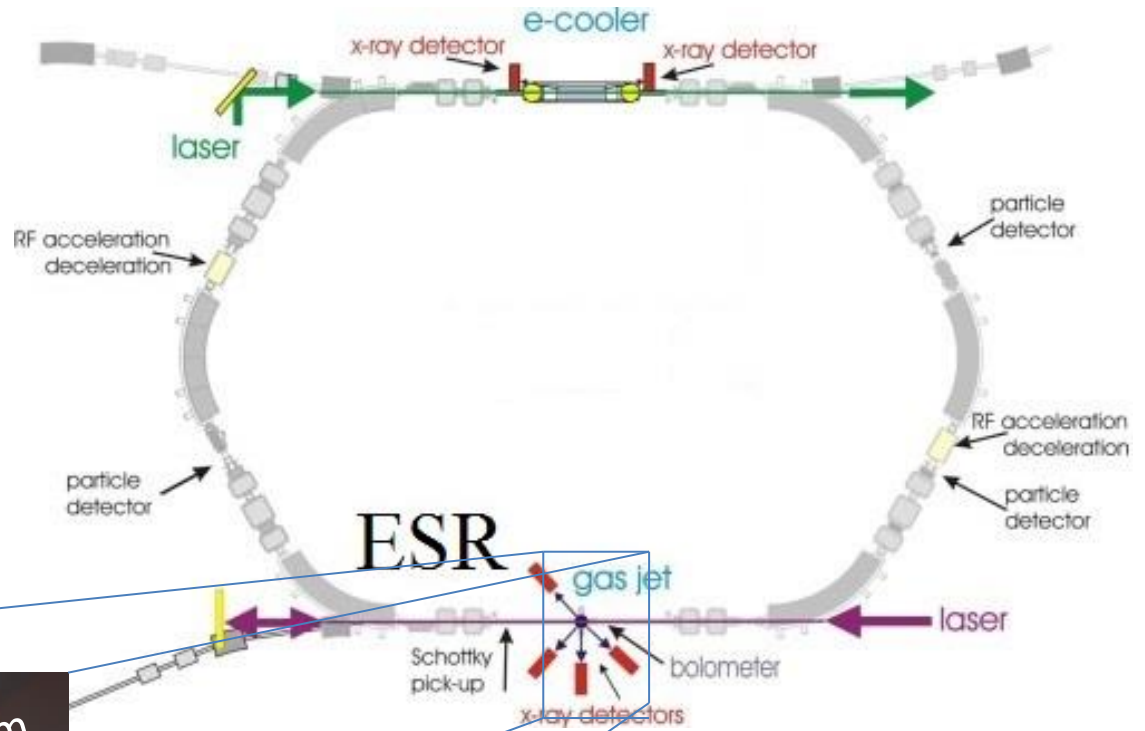Polarization transfer from the particles to the photons !

Micro-strip Si(Li) detector

→ energy resolution + position sensitivity

ESR @ GSI

H$_2$, He, N$_2$, ..., Xe gas target

Xe^{54+} beam

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continuum

E_{KIN} electron
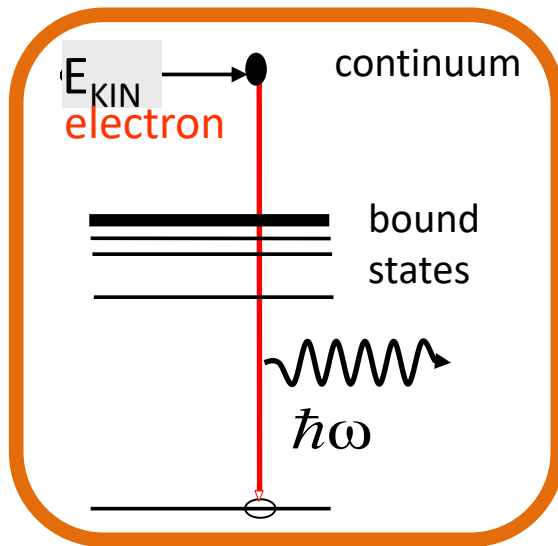
bound states

$\hbar\omega$

Radiative Recombination

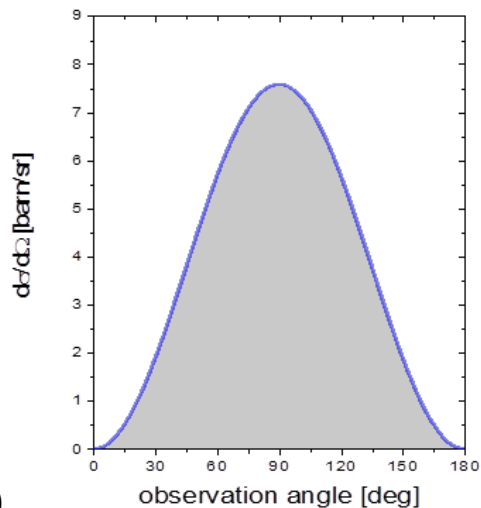Electron capture into a bound ionic state by emission of a photon

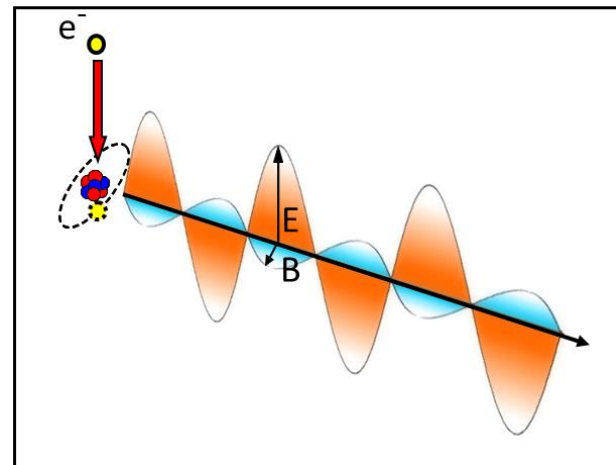$$\hbar\omega = \mathrm{E_B} + \mathrm{E}_{KIN}$$

Time-reversed photonization

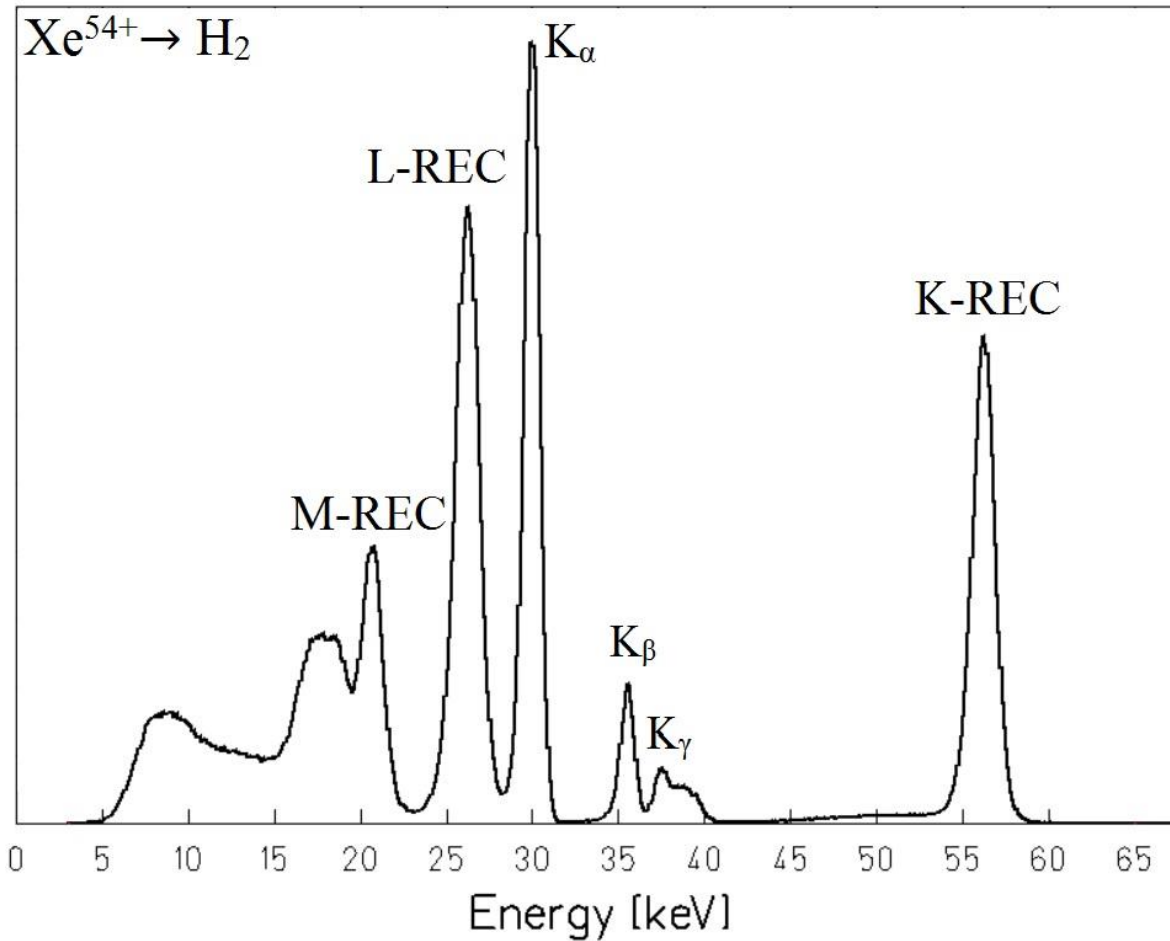Schnopper et al., PRL 29, 898 (1972)

angular distribution

$d\sigma/d\Omega$ [barn/sr]

observation angle [deg]

Polarization

e^-

E

B

Spindler et al., 42, 832 (1979)

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Spectra obtained at ESR/GSI

$Xe^{54+} \rightarrow H_2$

K$_\alpha$
L-REC
K-REC
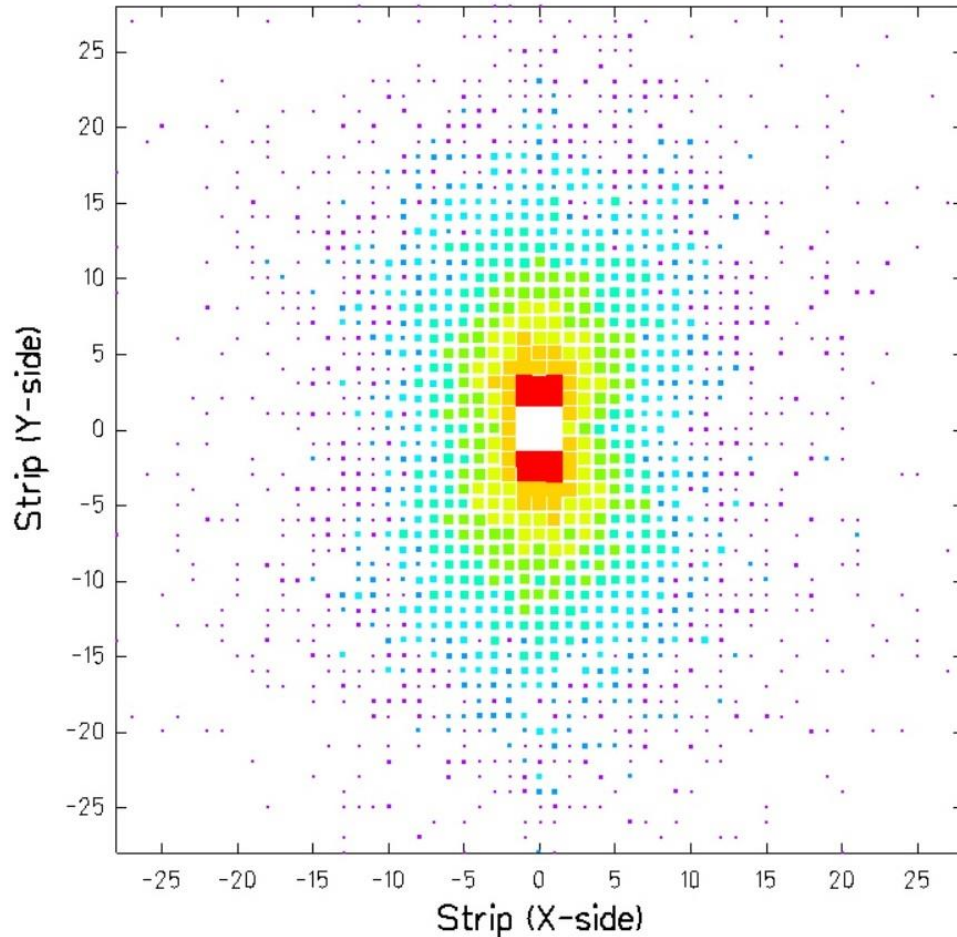M-REC
K$_\beta$
K$_\gamma$

Energy [keV]

beam energy: 31 MeV/u

Energy resolution of roughly up to 1 keV at 60 keV photon energy.

K-REC

E_{KIN}

∞

L

$\hbar\omega$

K

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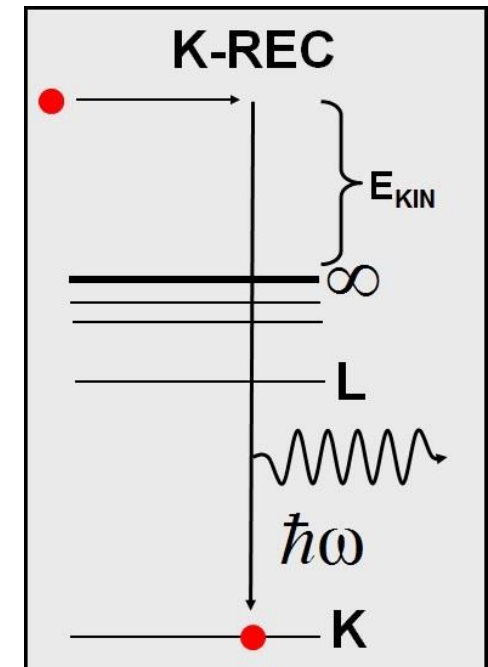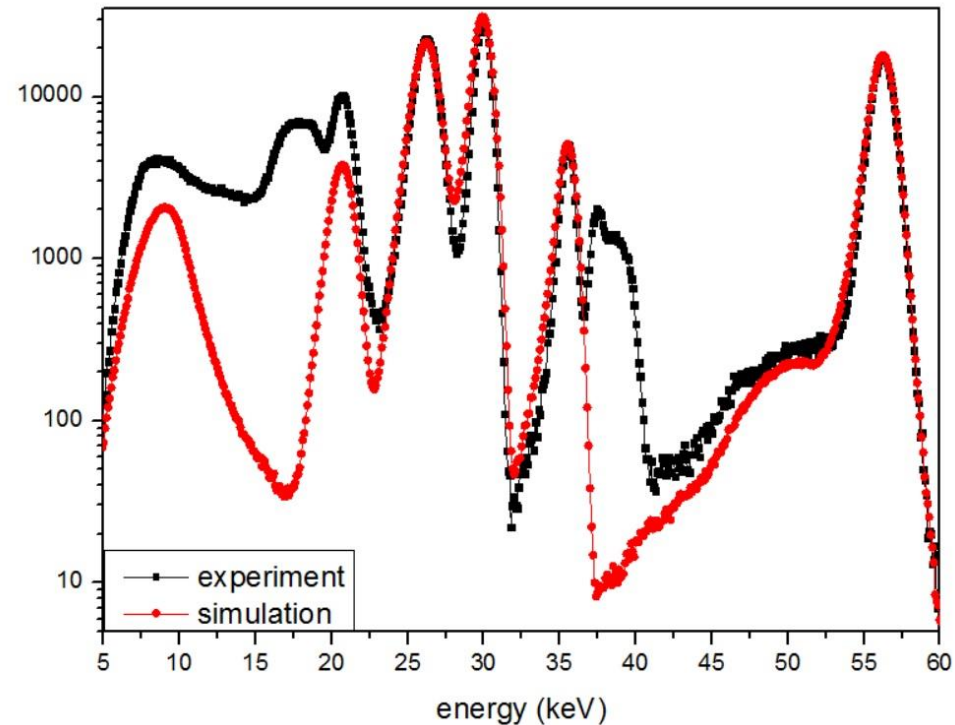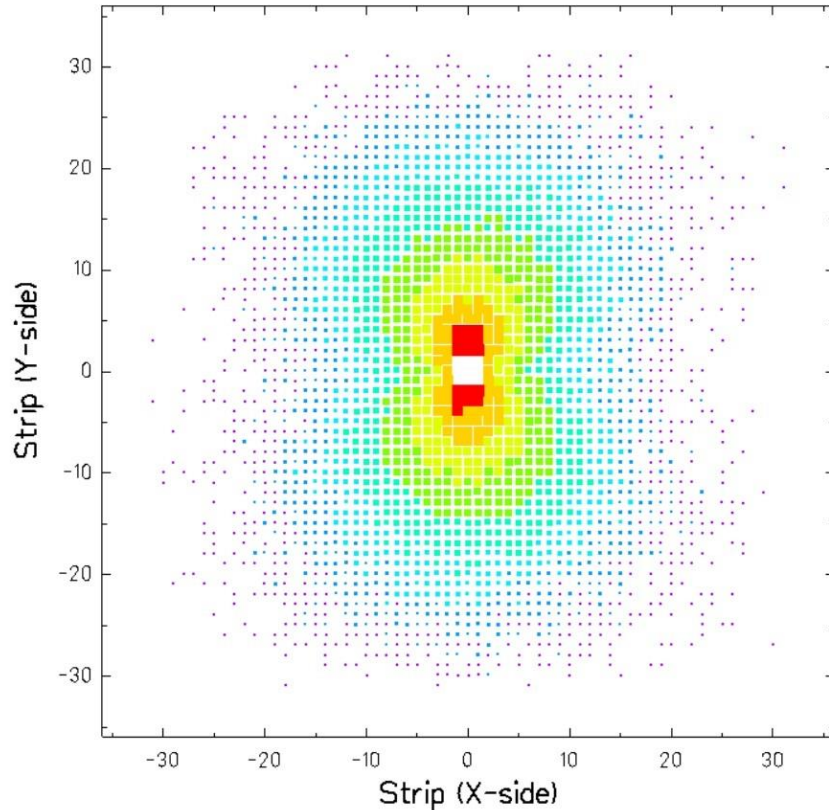
K-REC Scattering distribution

The strong anisotropy indicates a high degree of linear polarization.
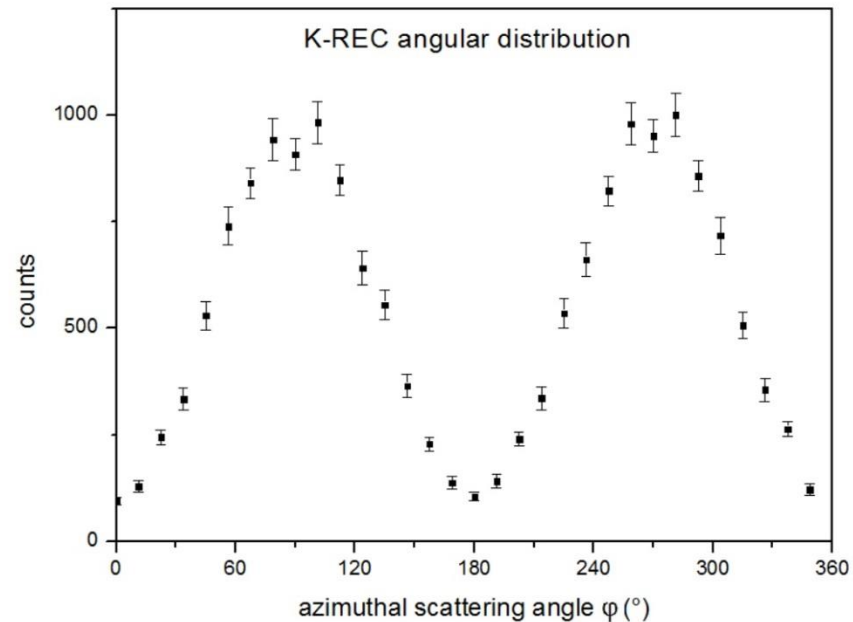
Simulation

Good agreement with experimental data
→ Get rid of some detector effects in analysis

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Polarization

K-REC angular distribution
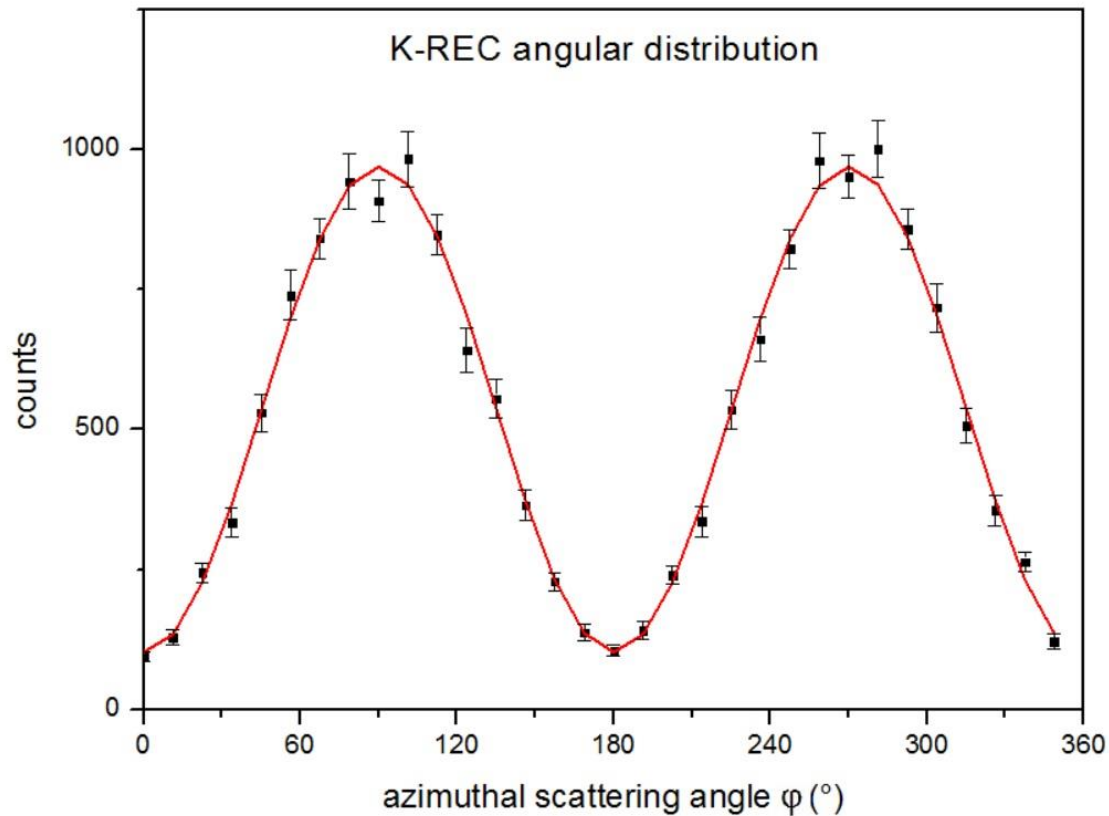
Degree of linear polarization in K-REC peak is about 99% (preliminary)

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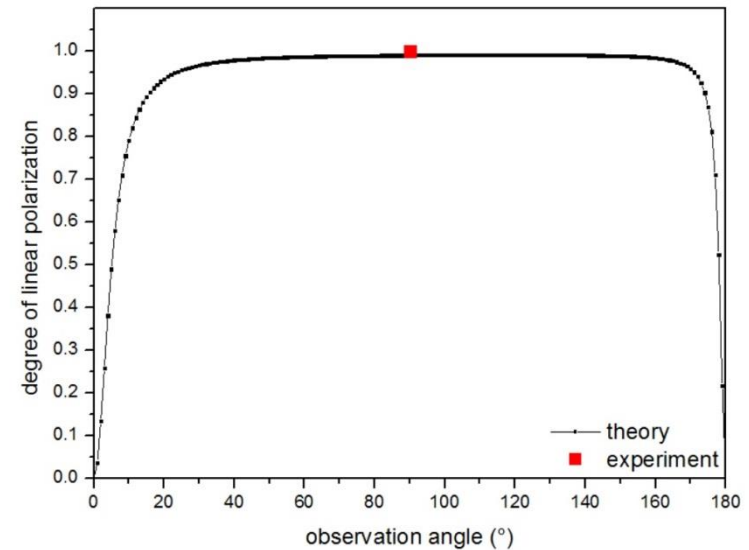
Summary

- Segmentation and energy resolution result in the possibility to measure the polarization of x-rays in a broad energy regime.

- The energy resolution was significantly improved by also cooling the first stage of the preamplifiers.

- The simulation of the detector features fits well with the experimental results.

- Using this setup, the degree of linear polarization can with this setup be determined with an accuracy of a few percent only.

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Thank you for your attention!