Vector polarimetry at MAMI

Measurements of tensor correlation coefficients in e^- bremsstrahlung processes

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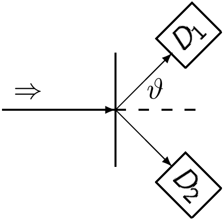
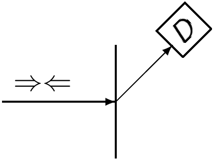
1. Introduction
   - How to measure polarisation
   - The correlation tensor
   - Measuring principle
2. Setup and measurements
   - Experimental setup
   - Energy resolved measurement of the longitudinal polarisation via C_{32}
   - First energy resolved measurement of the transverse polarisation via C_{12}
3. Summary & Outlook

Polarisation is measured by an asymmetry:

- either $A = \frac{N_1 - N_2}{N_1 + N_2} = S_\vartheta \cdot P$ with a pair of two detectors, D_1 and D_2
- or by switching the polarisation and receiving different counting rates $N^{\Rightarrow}$ and $N^{\Leftarrow}$ in a single detector





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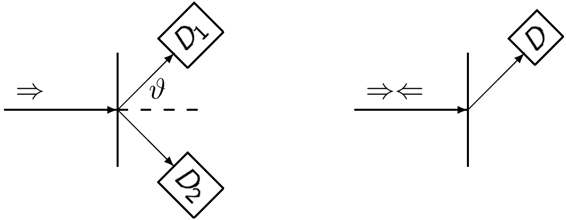
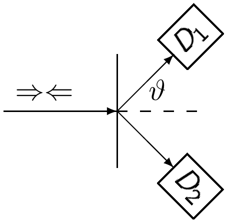


Why not use both techniques?

Measuring a polarisation with the super ratio:

- using two detectors
- switching the polarisation
- measuring four rates $N_1^{\Rightarrow}$, $N_2^{\Rightarrow}$, $N_1^{\Leftarrow}$ and $N_2^{\Leftarrow}$.



$$\mathcal{A} = \frac{1 - \sqrt{\frac{N_1^{\Rightarrow} \cdot N_2^{\Leftarrow}}{N_1^{\Leftarrow} \cdot N_2^{\Rightarrow}}}}{1 + \sqrt{\frac{N_1^{\Rightarrow} \cdot N_2^{\Leftarrow}}{N_1^{\Leftarrow} \cdot N_2^{\Rightarrow}}}}$$

$$N_\mathrm{m} = N_\mathrm{t} \cdot f$$

Tseng and Pratt[1] introduced a correlation tensor between the incoming electrons and the emitted photons $C_{\mu\nu}(\mathrm{Z}, \vartheta, \mathrm{E})$.

- The first μ index represents the polarisation of the electrons:
  - $\mu = 0$: intensity
  - $\mu = 1$: transverse in the emission plane
  - $\mu = 2$: perpendicular to the emission plane
  - $\mu = 3$: longitudinal
- The second ν index describes the properties of the emitted photons
  - $\nu = 0$: intensity
  - $\nu = 1$: linear polarisation diagonal to emission plane (45° & 135°)
  - $\nu = 2$: circular polarisation
  - $\nu = 3$: linear polarisation respective to the emission plane (x & y)

[1] H. K. Tseng and R. H. Pratt, Phys. Rev. A 7, 1502 (1973)

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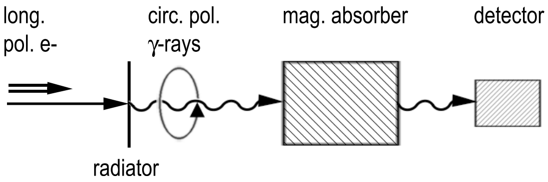
How to measure circular polarised photons?

1. electrons produce photons in bremsstrahlung processes
2. spin dependency of the compton cross section



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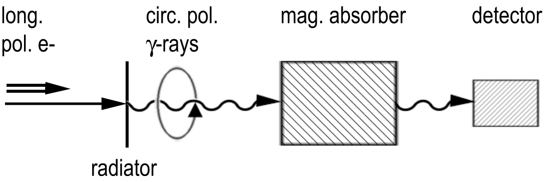
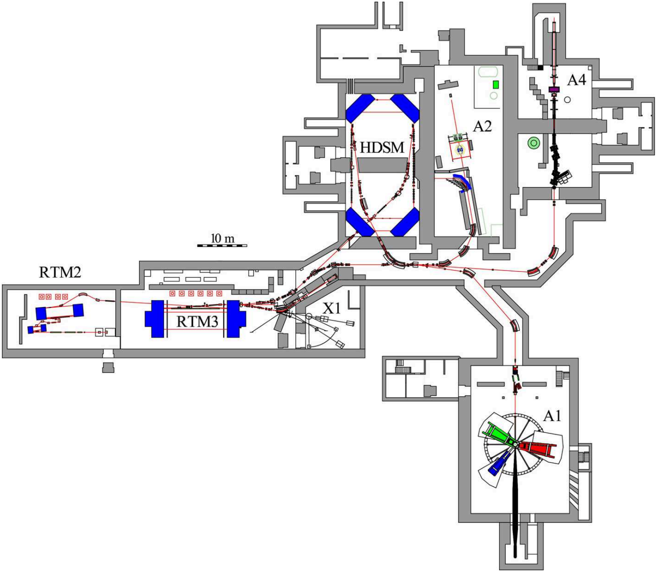
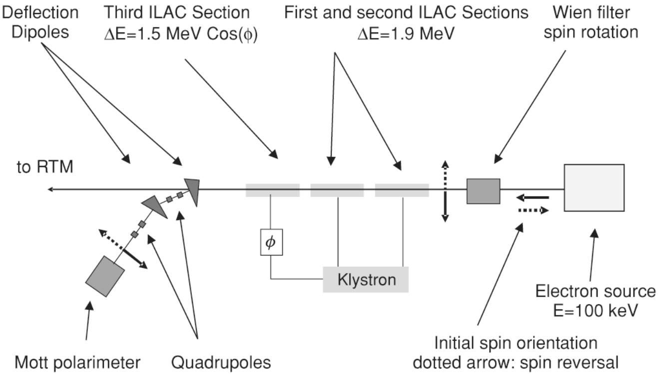


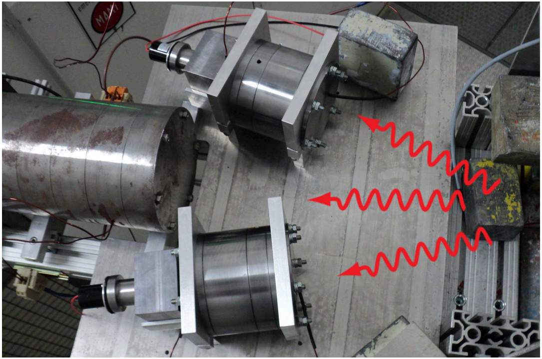
This design is also known as a compton absorption polarimeter.

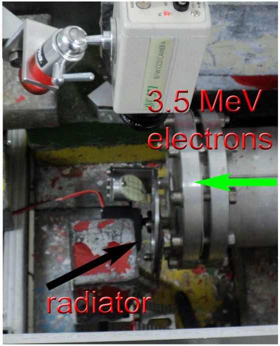
$$A_{full}(E_\gamma) = \frac{e^{-\sigma_p Z N_A \rho d/B} - e^{+\sigma_p Z N_A \rho d/B}}{e^{-\sigma_p Z N_A \rho d/B} + e^{+\sigma_p Z N_A \rho d/B}} = -\tanh\left(\frac{\sigma_p Z N_A \rho d}{B}\right)$$

$$\begin{aligned}
A(E_\gamma) &= -P_e C_{32}(E_\gamma) \tanh\left(\sigma_p(E_\gamma)\frac{2N_A\rho d}{B}\right) \\
&\approx -P_e C_{32}(E_\gamma)\, \sigma_p(E_\gamma)\frac{2N_A\rho d}{B} \\
\sigma_p &= \text{cross section sensitive to polarisation} \\
Z &= \text{atomic number} \\
B &= \text{baryon number} \\
P_e &= \text{polarisation of the electron beam} \\
N_A &= \text{Avogadro number} \\
d &= \text{absorber length} \\
\rho &= \text{density}
\end{aligned}$$

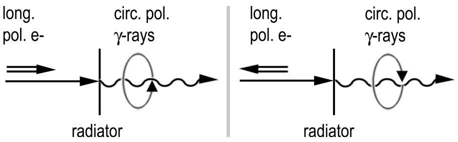

A4
A2
HDSM
10 m
RTM2
RTM3
X1
A1


Deflection
Dipoles
Third ILAC Section
ΔE=1.5 MeV Cos(ϕ)
First and second ILAC Sections
ΔE=1.9 MeV
Wien filter
spin rotation
to RTM
ϕ
Klystron
Electron source
E=100 keV
Initial spin orientation
dotted arrow: spin reversal
Mott polarimeter
Quadrupoles



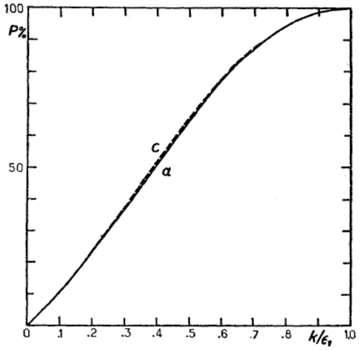

3.5 MeV
electrons
radiator

C_{32} describes the correlation between the longitudinal polarisation of the electrons and the circular polarisation of the outgoing photon.



C_{32}

The circular polarisation of bremsstrahlung from longitudinal polarised electrons for relativistic electrons was calculated by H. Olsen and L. C. Maximon[2] for 50 MeV ($\gamma = 101$).

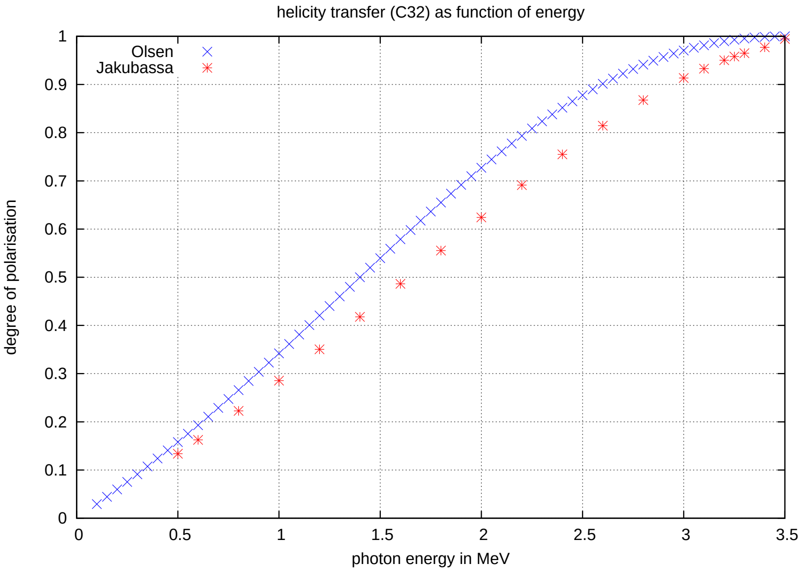


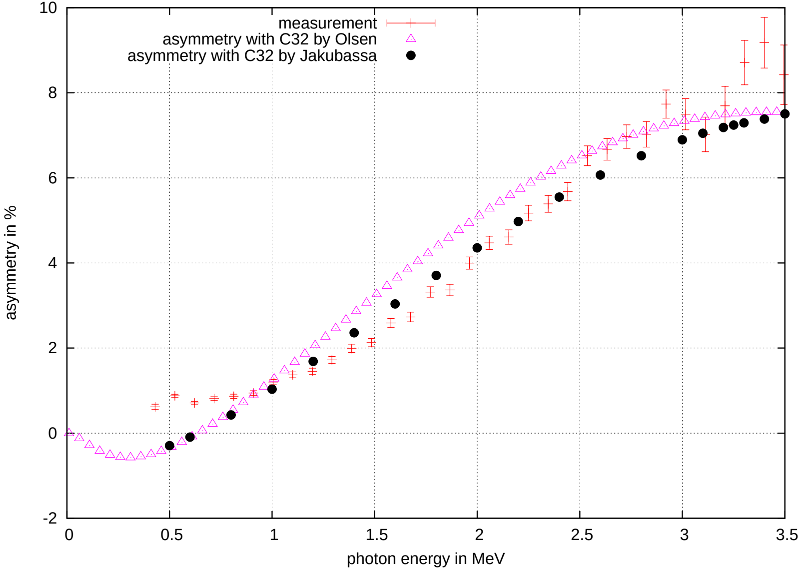
But what does this look like for

$$\gamma \not\gg 1$$

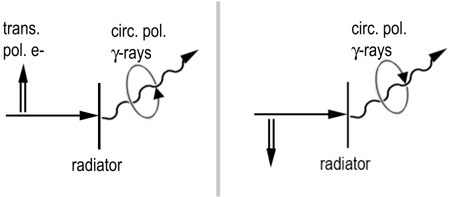
e. g. 8?

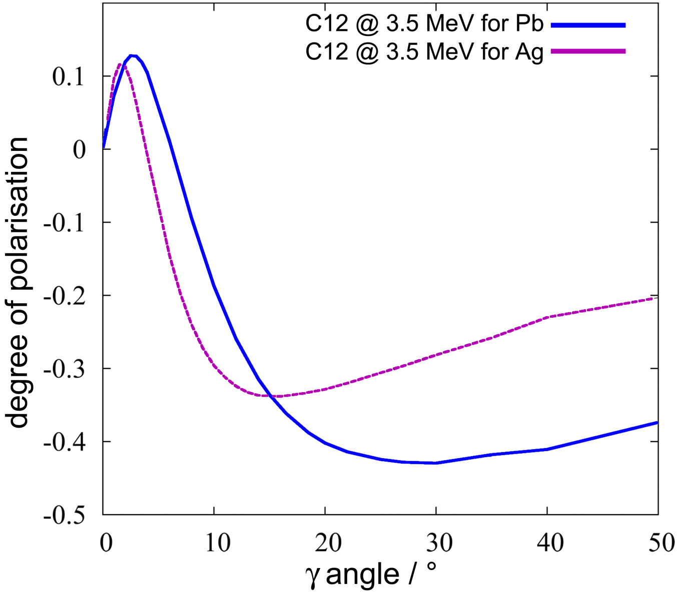
[2] H. Olsen and L. C. Maximon, Phys. Rev. 114, 887 (1959)

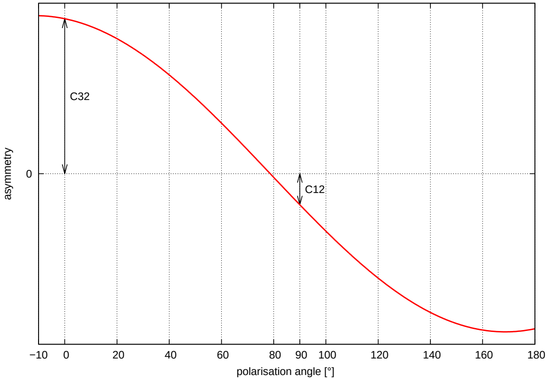

helicity transfer (C32) as function of energy
Olsen
Jakubassa
degree of polarisation
photon energy in MeV
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
0.5
1
1.5
2
2.5
3
3.5


measurement
asymmetry with C32 by Olsen
asymmetry with C32 by Jakubassa
asymmetry in %
photon energy in MeV
10
8
6
4
2
0
-2
0
0.5
1
1.5
2
2.5
3
3.5

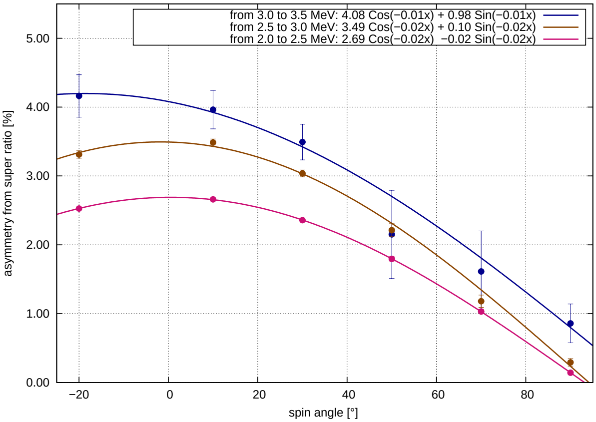
C_{12} describes the correlation between the transverse polarisation of the electrons and the circular polarisation of the outgoing photon.

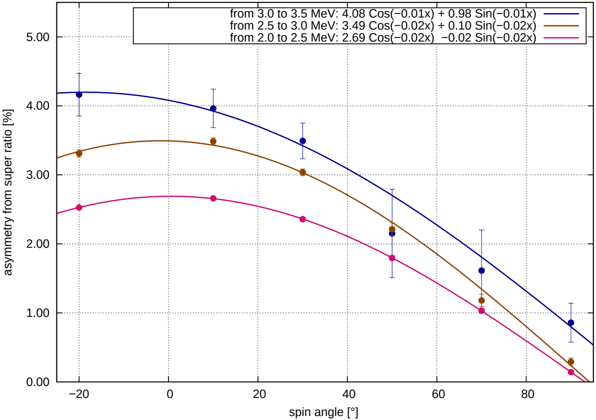



C12 @ 3.5 MeV for Pb
C12 @ 3.5 MeV for Ag
degree of polarisation
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
0
10
20
30
40
50
γ angle / °



$$A(\phi_{\mathrm{Pol}}) = \chi\left(C_{32}\cos(\phi_{\mathrm{Pol}}) + C_{12}\sin(\phi_{\mathrm{Pol}})\right)$$


from 3.0 to 3.5 MeV: 4.08 Cos(−0.01x) + 0.98 Sin(−0.01x)
from 2.5 to 3.0 MeV: 3.49 Cos(−0.02x) + 0.10 Sin(−0.02x)
from 2.0 to 2.5 MeV: 2.69 Cos(−0.02x) −0.02 Sin(−0.02x)
asymmetry from super ratio [%]
spin angle [°]
0.00
1.00
2.00
3.00
4.00
5.00
−20
0
20
40
60
80



$$\left(\frac{C_{32}}{C_{12}}\right)_{exp} = 4.163 \qquad \left(\frac{C_{32}}{C_{12}}\right)_{theo} = 4.086$$

Summary

- setup for measuring C_{32} and C_{12} installed
- energy resolved measurements concerning C_{32} and C_{12} have been obtained
- difference between theory of Olsen and Jakubassa can be seen

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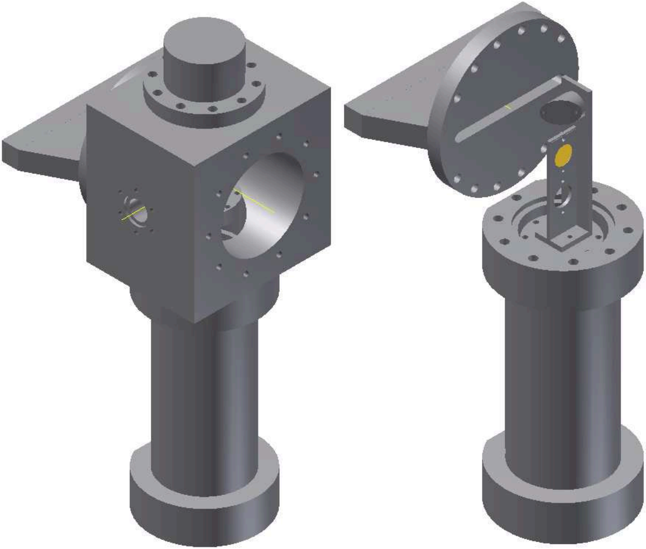
  - degree of polarisation
  - magnetisation
  - energy resolution
  - background
- measurements for different γ-angles
- improved experimental setup



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