

Measurement of Polarization Transfer in Møller Scattering

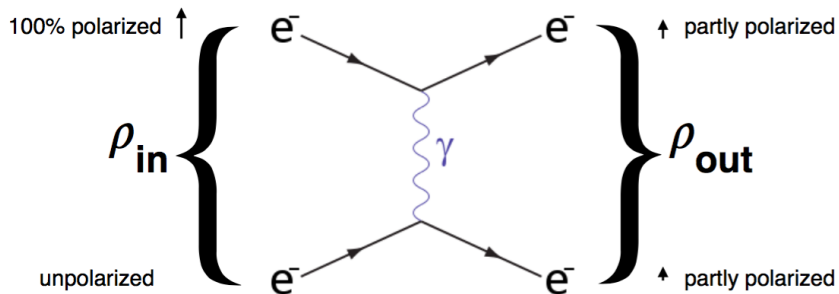
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J. Enders Y. Fritzsche V. Tioukine

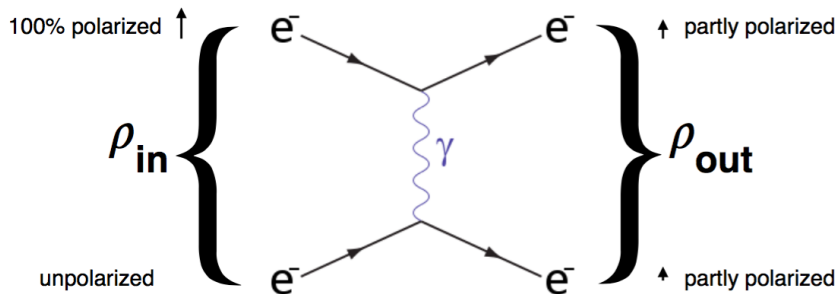
24th International Spin Symposium, October 20, 2021



Polarization transfer in Møller scattering

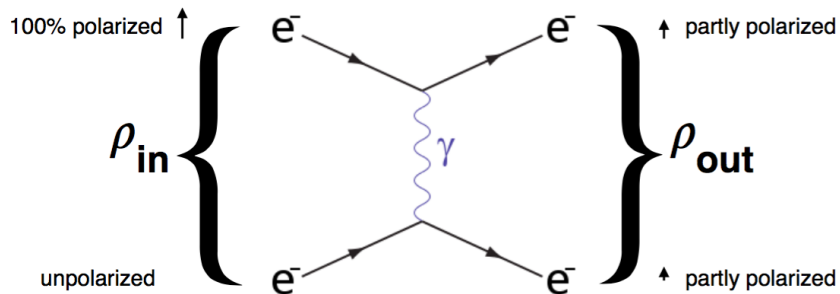


Polarization transfer in Møller scattering



statistical mixture of singlet and triplet state

Polarization transfer in Møller scattering

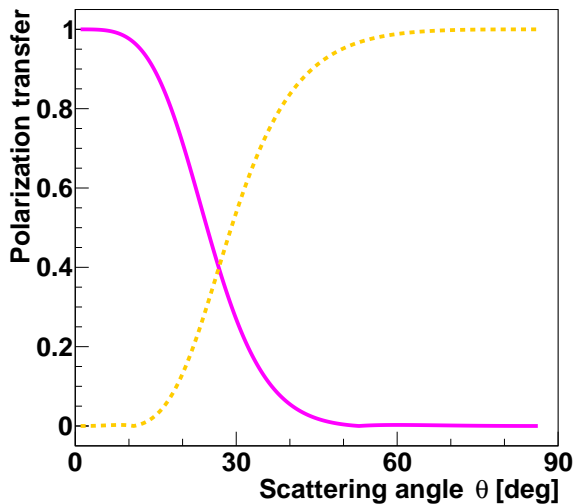


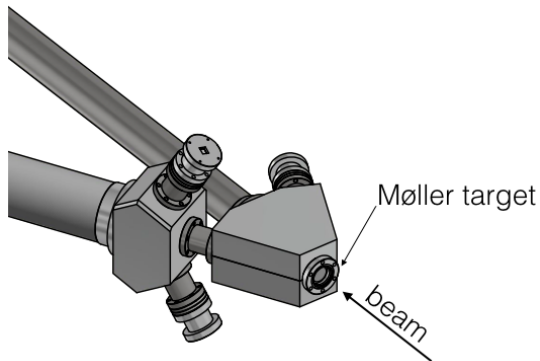
statistical mixture of singlet and triplet state

$$\rho_i = \text{Tr}_j \rho_{out}, \quad i, j = 1, 2$$

$$\vec{P}_i = \text{Tr}(\rho_i \cdot \boldsymbol{\sigma}), \quad \boldsymbol{\sigma} = (\sigma_1, \sigma_2, \sigma_3)$$

Polarization transfer in Møller scattering (3 MeV)





Møller scattering:

- 3 MeV polarized beam from MAMI
- Møller scattering off atomic electrons in 100 μm Be target

Polarization measurement:

- Mott polarimetry
- 10 μm Au target
- scattering angle $120^\circ \pm 5^\circ$
- detectors: scintillator + SiPM



scattering amplitudes imported from ELSEPA at initialization

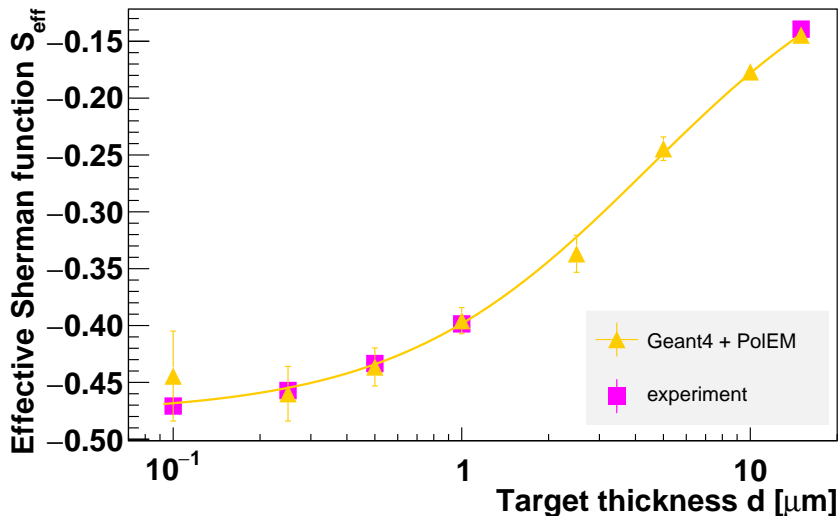
interaction model to replace the default Coulomb scattering model

cross section, momentum and polarization change calculated
for given energy, momentum and polarization

M. Drągowski, *Simulation of Polarized Electron Interactions with Matter in the MeV Energy Range*, 23rd International Spin Symposium (2018)

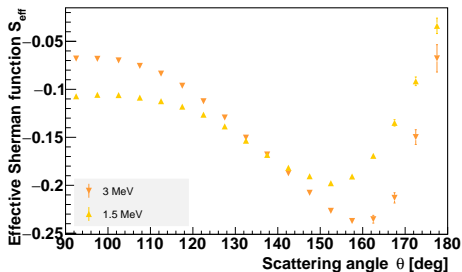
M. Drągowski, M. Adamus, G. Weber, and M. Włodarczyk, Nucl. Instrum. Methods Phys. Res. B 488, 37 (2021)

Simulation — comparison with experiment

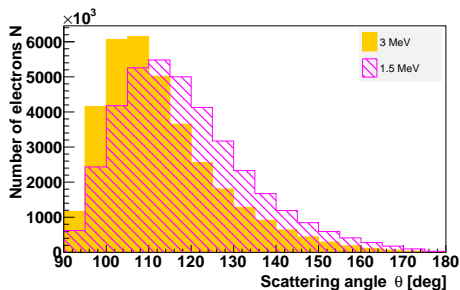


MAMI Mott polarimeter; 3 MeV, 164° , Au targets

Simulation — experiment optimization

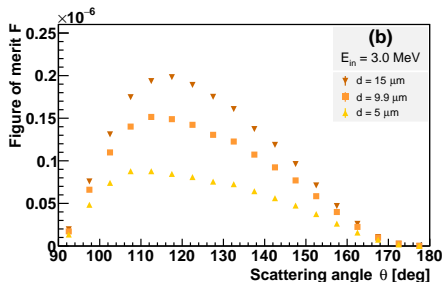
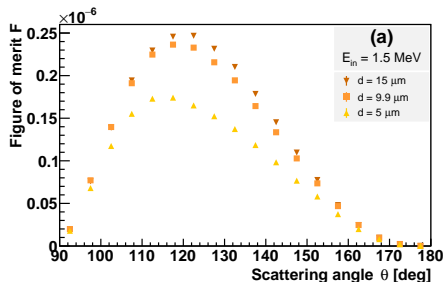


5 μm Au target



finding an optimal combination of analyzing power and sample size

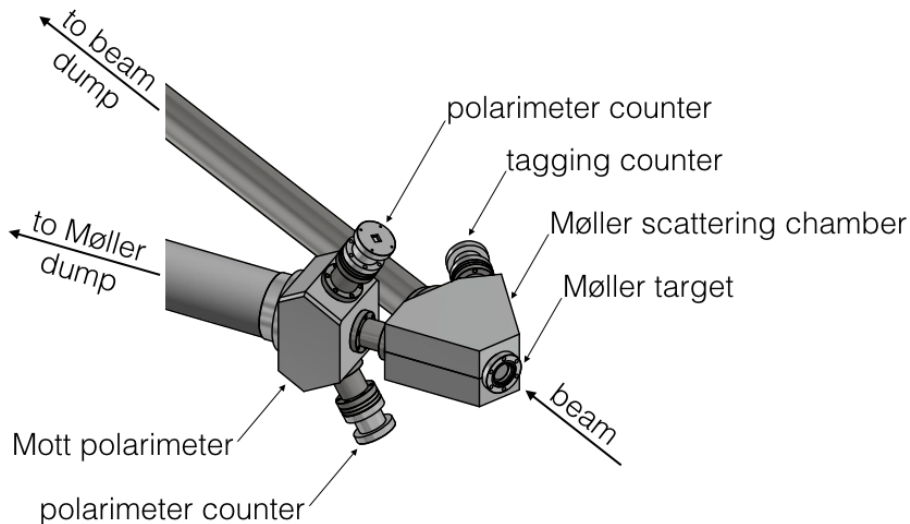
Simulation — experiment optimization



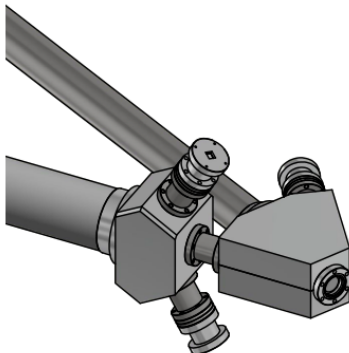
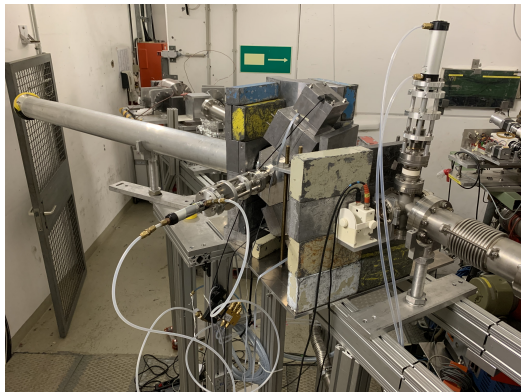
maximizing the figure of merit

$$F = S_{eff}^2 N$$

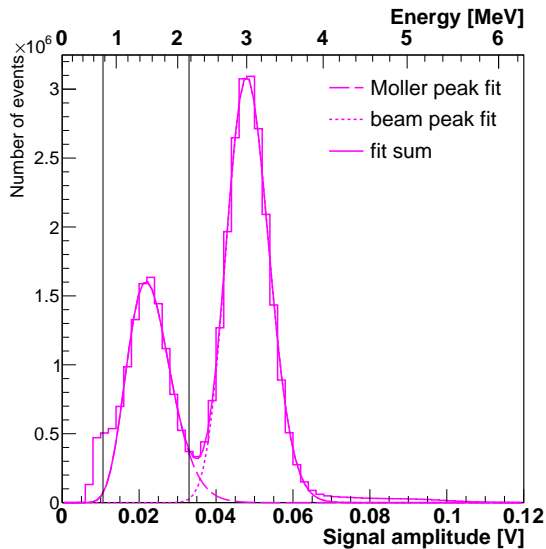
Experimental setup



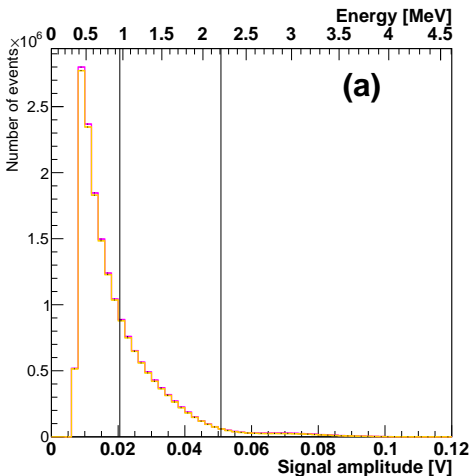
Experimental setup



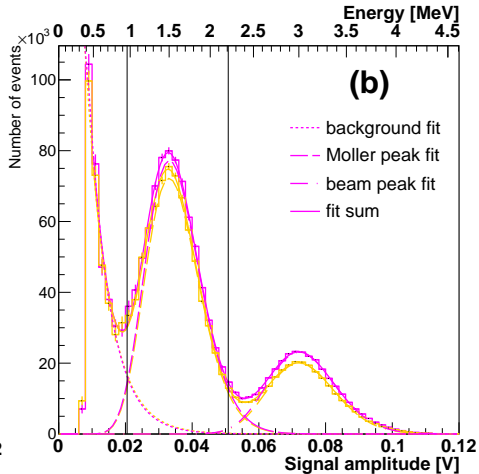
Energy spectrum in the tagging counter



Møller electrons — background subtraction

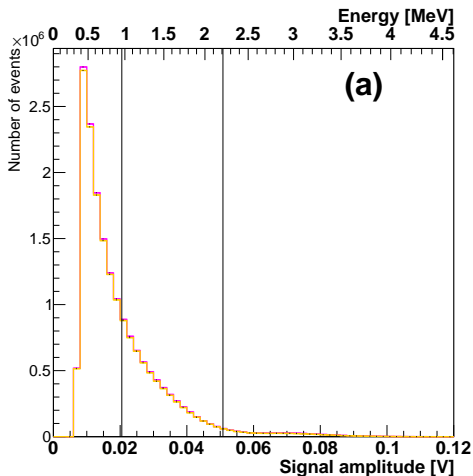


raw coincidence data

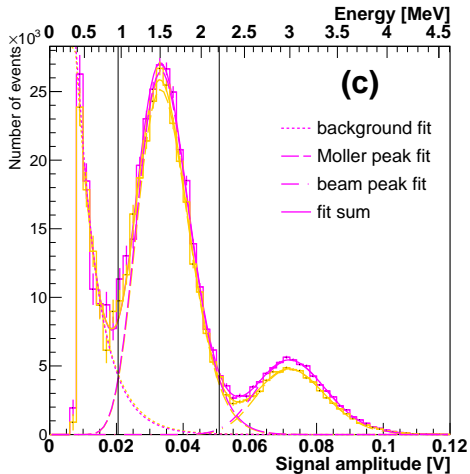


background subtraction

Møller electrons — energy selection

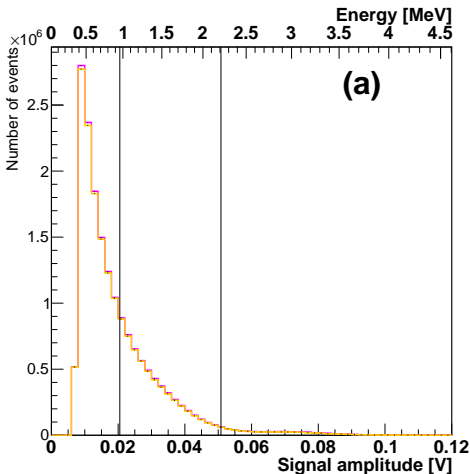


raw coincidence data

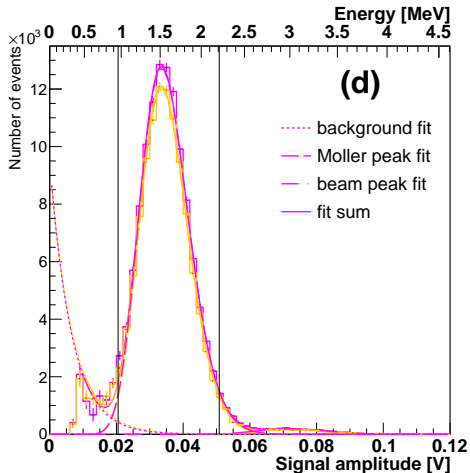


background subtraction & energy
selection

Møller electrons — timing selection

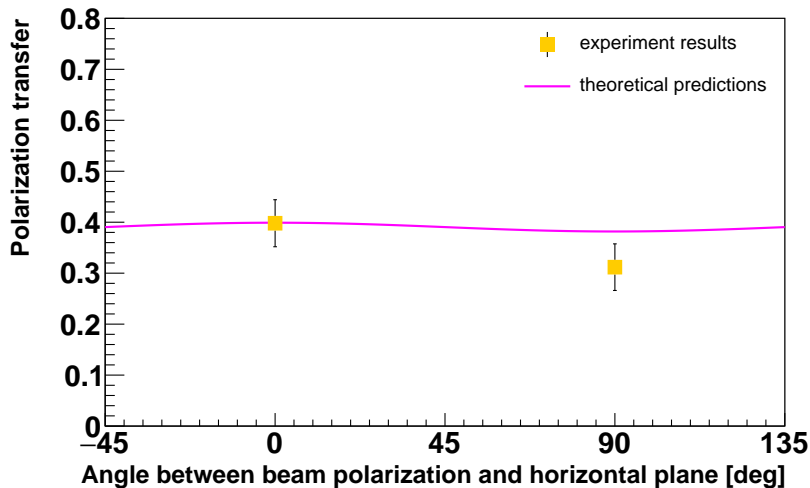


raw coincidence data



background subtraction & energy +
timing selection

Polarization transfer results



Spin correlation experiments with massive particles

- correlation function:

$$C(\vec{a}, \vec{b}) = P_{++} + P_{--} - P_{+-} - P_{-+}$$

spin projections on given directions (\vec{a} and \vec{b}) measured for both electrons

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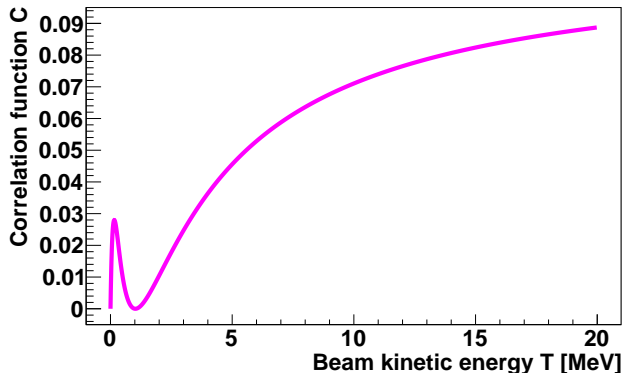
spin projections on given directions (\vec{a} and \vec{b}) measured for both electrons

- experiments with protons:

Lamehi, Rachti, Mittig	1976	Saclay (France)
Hamieh <i>et al.</i>	2004	KVI (Holland)
Sakai <i>et al.</i>	2006	RIKEN (Japan)

- measurement of correlation function and violation of Bell inequalities for massive non-relativistic particles
- non-relativistic quantum mechanics only (too low energies)

Spin correlations in Møller scattering



- polarized beam, unpolarized target
- \vec{a} i \vec{b} in Møller scattering plane
- symmetric scattering
- C does not depend on beam polarization, but $P_{\pm\pm}$ do

P. Caban, J. Rembieliński and M. Włodarczyk, Phys. Rev. A 88, 032116 (2013)

M. Drągowski, *Study of quantum spin correlations of relativistic electrons*, 2019 Workshop on Polarized Sources, Targets, and Polarimetry

Summary

- ① Successful elimination of false coincidences with energy and timing selection.
- ② Polarization of Møller electrons in agreement with the theoretical predictions.

Requirements for a correlation experiment:

- ① Performing Mott-polarimetry measurements on a divergent stream of secondary Møller electrons.
- ② Achieving sufficient statistical accuracy:
not possible with a basic Mott-polarimeter layout,
signal to background ratio can be improved with veto and/or tracking.