Letter of intent

SPCHP SPin Control for Hadron Physics-experiments

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1. Research objective

The goal of the project is to offer better knowledge and control of the electron-spin-vector in scattering experiments for hadron physics, i.e. knowing its length (known as "spin-polarization") and the values of its individual spatial components. This is intended to act as service provision for the TNA-activities at the MAMI/MESA facilities in Mainz. It will allow the international groups working at the P2-experiment at MESA to increase the accuracy of their results.

A chain of polarimeters is available for MESA so that a statement of polarisation accuracy of an experiment will be based on at least two independently calibrated devices.

The project will aim at the improvement of accuracy for one of the polarimeters, namely the 5 MeV Mott-polarimeter whereas the optimization of a second – a Möller-polarimeter - will be pursued simultaneously from other resources. Based on the result from this project, it will provide sufficient accuracy - at least until the end of the decade - for the experiments of the P2-collaboration where parity violating observables will be measured by the international groups (from France, USA and Canada and, of course, Mainz). Whereas an accuracy below 1% is obtainable as start of the art, 0.5% is preferable. In the long range, i.e. beyond 2030, 0.2% must be achieved.

The deliverable is a quantitative determination of the contribution of radiative corrections to the Mott polarimeter analyzing power which will serve to fulfill the needs mentioned above. It will be achieved by the following approach: One of the main error sources in Mott-polarization measurements is the theoretical prediction of the analyzing power (S) of the scattering process. Theoretically, polarization (P) is extracted from the observed scattering rate asymmetry A=S*P. In reality, the experimental asymmetry is reduced compared to the theoretically expected by multiple scattering effects. These can be controlled by a series of measurements on targets of different thicknesses. The achieved result can be compared with Monte Carlo-modelling of spin dependent multiple scattering which eliminates this uncertainty at about 0-1-0.2% level. Therefore, the main limiting factor is the theoretical uncertainty in calculation of radiative corrections for S, which is presently estimated to be around 0.5% [1].

Recent theoretical studies in non-perturbative QED quote a considerably reduced uncertainty because the radiative corrections have been treated with improved models [2]. We propose to test these statements by examining the observed asymmetry for different beam energies, on which these corrections have sensitivity. Our polarimeter is equipped with a target station that can hold a wide variety of targets, addressing the above mentioned question of multiple scattering effects. Therefore, the technical conditions are given, but the measurements must be done with great care by experienced personnel. If a coherent picture of radiative corrections can be obtained, the accuracy of the polarimeter may be improved considerably, i.e. well below 0.5%.

The theoretical work of [2] predicts a change of the relative contribution to the analyzing power of Mott-scattering if the input beam energy is varied. This change ranges from 0.2% to 0.8% for a heavy nucleus like gold if the input beam energy is varied from 2 to 5 MeV at a scattering angle of 173 degree which is the angle chosen for our Mott-polarimeter

We will use several gold targets of variable thickness. Measuring the experimental asymmetry will allow disentangling the effects of spin diffusion during multiple scattering and radiative effects. By varying the energy of the MESA pre-accelerator within the mentioned range we can extract the contribution of radiative contributions quantitatively. The first measurement campaigns can be started immediately after project starts since the polarimeter is presently installed at the MAMI 3.5 MeV stage. During the funding period it will be moved to MESA where the full energy range will be covered. The polarimeter also allows measuring the in-plane polarization components – these must be checked to be sufficiently small.

The total amount of beamtime needed is less than 10 days since statistics is not a problem even at such extreme backward angles. Nevertheless, determination of aspects like acceptance or detector dead time requires careful analysis and control by a scientist at the Post-Doc level.

If the result of theoretical calculations can be confirmed by these measurements an accuracy below 0.5% of polarization will be achieved. This will not only be sufficient for the first round of the experiments at this TNA-infrastructure but will also be an important contribution regarding the accuracy needed for the upcoming experiments at MESA in the 2030's.

References:

[1] J. Grames et al PHYSICAL REVIEW C 102, 015501 (2020) DOI: 10.1103/PhysRevC.102.015501

[2] D. H. Jakubassa-Amundsen: J. Phys. G: Nucl. Part. Phys. 51 (2024) 035105

2. Connection to Transnational Access infrastructures (TAs) and / or Virtual Access projects (VAs)

The project acts as service provision for the TNA -activities at the MAMI/MESA facilities in Mainz. It will serve the international groups working at the P2-experiment at MESA to increase the accuracy of their results. The most striking example is parity violating scattering on Carbon-12 where the systematic error - and therefore the impact of the achieved result - will be dominated by the uncertainty of spin-polarization.

3. Estimated budget request

1 ½ year Post-Doc salary German level EG13 – based on 76 k€ salary /year

Personnel:	124k€
Travel (conferences, workshops)	6 k€
Total Direct costs:	**120k€**
Overhead 25% of direct costs: :	30k€
Total:	**150k€**

4. Participating and partner institutions

Johannes Gutenberg University Mainz – Institute of Nuclear Physics

Partners - P2-project: University Paris/Saclay (France); University of Manitoba (Canada); University of Massachussets (USA)