DESIGN OF A VERY COMPACT 130 MeV MØLLER POLARIMETER FOR THE S-DALINAC*

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Abstract

At the **S**uperconducting **Da**rmstadt **Lin**ear **Ac**celerator S-DALINAC [1] it is possible to accelerate electron beams to a maximum energy of up to 130 MeV with a beam current of up to 20 μA. In the **S**-DALINAC **P**olarized **In**jector SPIN [2] polarized electrons with a polarization of up to 86% can be produced. The polarization can be measured with two already mounted Mott polarimeters in the injector beam line, where the electrons can have energies of up to 10 MeV. To allow a polarization measurement behind the main accelerator a Møller polarimeter suitable for energies between 50 MeV and 130 MeV is currently being developed. The rather low and variable beam energies and the resulting big and also variable scattering angle distribution combined with very strict spatial boundary conditions at the designated mounting area necessitate a very compact set-up for the polarimeter.

S-DALINAC

The S-DALINAC is a recirculating linear electron accelerator capable of producing cw electron beams with a maximum energy of 130 MeV and beam currents of up to 20 μA. Its floor plan is shown in Fig. 1. In order to provide electrons with polarizations of over 80%, inside the spin-polarized injector a special GaAs cathodes is illuminated with a laser beam to produce polarized electrons via the photo effect. These electrons are preaccelerated to an energy of 100 keV by a static electric field. To manipulate the spatial spin orientation, the electrons pass a wien filter and solenoid allowing the operator to align the spin orientation to the preferences of the experiment or polarimetry setups. In front of the s.c. injector beam line there is a low energy Mott-Polarimeter usable with electron energies between 100 keV and 250 keV for an incident measurement of the absolute polarization. Additionally there is a Mott-Polarimeter optimized for energies up to 10 MeV behind the s.c. injector and a mountable Compton-Transmission-Polarimeter at the first experimental area. After passing the s.c. main accelerator, it is at this time not possible to measure the polarization until now. Therefore a Møller-Polarimeter for electron energies between 50 MeV and 130 MeV is currently being developed and will be installed at the marked position shown in Fig. 1.

MØLLER POLARIMETRY

For electron energies of more than 10 MeV Mott polarimetry is not applicable any more. To measure the polarization Møller polarimeters are commonly used for high energy electron beams. Although the Møller scattering crossection is not directly dependent of the participants' spin, one can exploit Pauli's principle that suppresses scattering events with the same orientation of the two involved electrons' spins. It can be shown that this suppression is maximal for a center-of-momentum frame scattering angle of 90° resulting in a maximal analyzing power of the polarimeter if this angle is used. Of course the laboratory frame scattering angle strongly depends on the incident energy of the electrons, what has to be taken into account when positioning the detectors. In Møller Polarimeters the electron beam of unknown absolute polarization scatter on a longitudinally polarized ferromagnetic target. In a first measurement the target material is polarized parallel to the beams polarization and the detected events produced by symmetrical scattered electrons is accumulated. In a second measurement either the target polarization, or the beam polarization is flipped to produce antiparallel spin orientations. The amount of detected events is expected to increase since no Pauli suppression is expected to occur. By comparing the amount of events of both measurements, it is possible to calculate the beams polarization. Generally one finds two different types of Møller polarimeters: One-arm polarimeters only detect and count one of the two scattered electrons making it necessary to strongly collimate the scattered beam. Background radiation represents a big problem for this type of polarimeter making it necessary to shield the detectors very well. Two-armed polarimeters on the other hand detect and count both scattered electrons coincidentally, strongly reducing the random background from the primary beam and activated material in close distance. This allows greater angle acceptances and therefore higher counting rates. The Møller Polarimeter that is currently being designed for the S-DALINAC will be such a two-armed type using coincidence counters.

POLARIMETER FLOORPLAN

As depicted in Fig. 2 the Møller Polarimeter will be placed right next to the high energy scraper system of the S-DALINAC leaving an area of about two by three meters for scattering, beam separation, detection and dumping. It is not possible to separate the Møller electrons horizontally due to the scraper system blocking the left hand side of the polarimeter. Therefore the Møller electrons have to be separated vertically and additionally be steered further to the right. Since both, target chamber and beam dump, produce a lot of background radiation the detectors have to be positioned carefully to minimize underground events.

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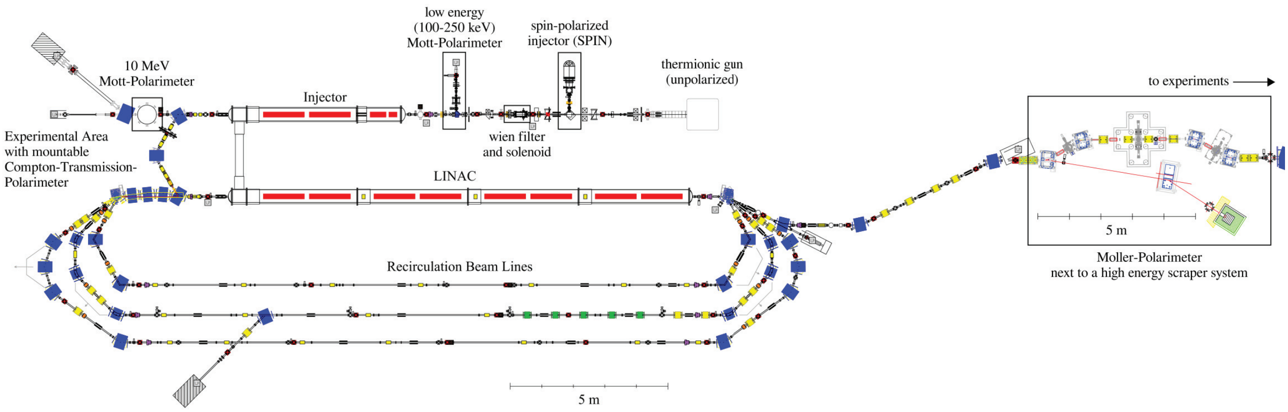

Figure 1: floorplan of the S-DALINAC with highlighted polarimetry setups.

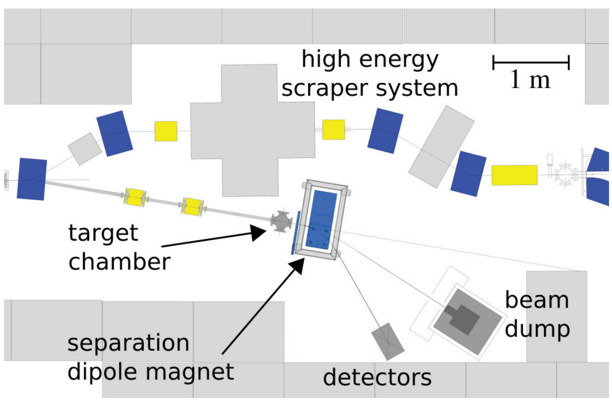

Figure 2: floorplan of the Moeller Polarimeter.

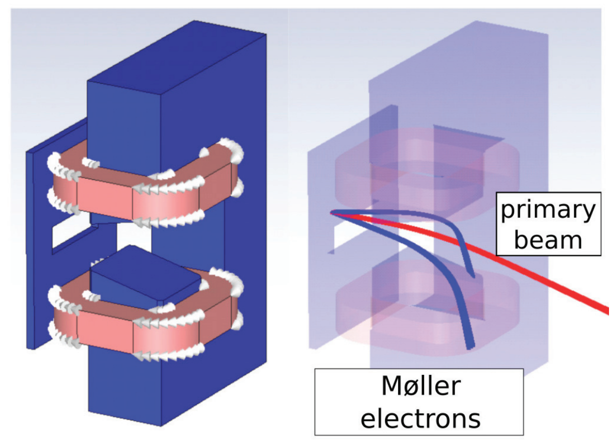

Figure 3:
left: yoke of the separation dipole magnet with its mirror plates (blue) and excitation coils (light red).
right: trajectories of a 50 MeV primary beam and Møller scattered electrons for a COM scattering angle of (90 ± 5) degree.

BEAM SEPARATION

Due to strict geometrical boundary conditions the separation of the Møller scattered electrons from the primary beam and the focusing of the scattered electrons have to be accomplished within two meters of the beamline. Additionally the low incident energy and therefore big scattering angles and the big energy acceptance this polarimeter has to provide necessitates a combined function separation dipole magnet with a wide gap as shown in Fig. 3. The divergence angle of the gap is 13°, allowing the deflection and focusing of all relevant Møller scattered electrons within the energy range of 50 MeV (6° to 10°) to 130 MeV (4° to 6°). By adjusting the transverse entrance position of the incident beam it was possible to reduce the vertical divergence angle of the scattered electrons to nearly zero creating two nearly horizontal Møller electron beams. This allows an arbitrary placement of the detectors in longitudinal direction without introducing additional geometric challenges.

TARGET CHAMBER

To exploit Møller scattering to measure the polarization of the electron beam the target polarization has to be well known. Furthermore this polarizable target has to be sufficiently thin to avoid multi-scattering. Therefore one has the options to use a ferromagnetic foil that is polarized perpendicular to the foils face or one that is polarized in-plane. Since the perpendicular polarization would require a magnetic excitation that could only be provided by s.c. coils, in this setup the in-plane polarization is preferred. To be able to still hit a target that is aligned to the beam direction, a target angle of 20° has to be introduced. In order to avoid systematical errors caused by the target tilt, the target frame provides two target foils with a 20° and a −20° tilt angle. Additionally the target frame provides a BeO-target that can be observed by a camera to adjust the beam position. The Møller target material is a soft-magnetic alloy called *Vacoflux50* which consists of 50% Iron and 50% Cobalt and saturates at a magnetic excitation of approximately 40 A/cm. Outside the target chamber a pair of Helmholtz coils provides excitation parallel to the incident beam direction. The target frame and the corresponding vacuum chambers are shown in Fig. 4 (side view) and Fig. 5 (top view).

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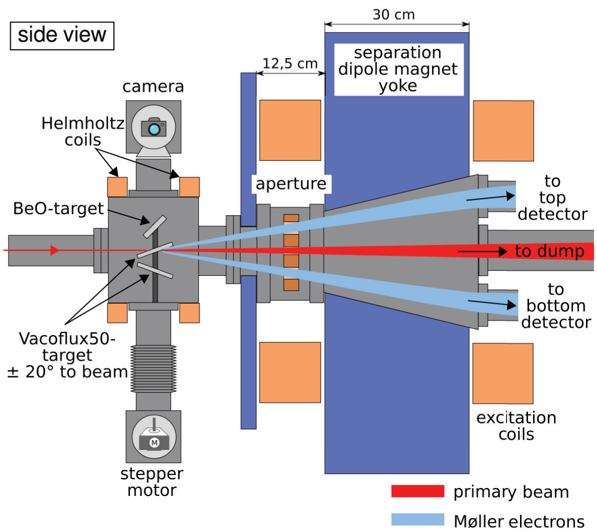

Figure 4: side view of the Møller target chamber and the yoke chamber demonstrating the beam separation.

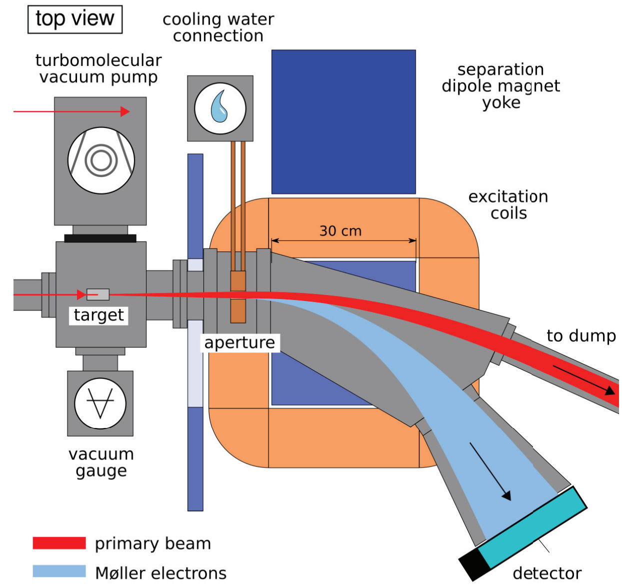

Figure 5: top view of the Møller target chamber and the yoke chamber demonstrating the beam separation.

Aperture

In order to reduce background events generated by scattered electrons hitting the inner walls of the yoke chamber due to their random energies the installation of a special aperture as shown in Fig. 4 and Fig. 5 is currently being studied. The aperture consist of a copper block with a hole for the primary electrons that still have approximately their incident energy and are dumped in the Faraday cup behind the separation dipole as shown in Fig. 2. Two additional slits on the top and bottom of the aperture filter the symmetrical scattered Møller electrons in the vertical direction within a precisely defined acceptance in respect to the scattering angle and the azimuthal angle. This aperture geometry of course has to be adjusted to the particular beam energy being used for the experiment due to the corresponding Møller scattering angle. At this time it is still unclear if the introduction of a aperture increases the analyzing power of the polarimeter by increasing the counting rate asymmetry, due to reduced background or if the background from the surrounding will make it neccessary to maximize the absolute counting rate by removing the aperture and therefore maximizing the angle acceptance of the polarimeter. Detailed simulations are currently being evaluated.

DETECTOR

With this polarimeter setup the dispersion of the separation dipole filters all incoming scattered electrons with respect to their energy. Therefore the used detector does not need to provide information about the detected energy rendering its task to be a pure counter. Furthermore it should be fast to measure with high counting rates to accumulate good statistics in a shorter period of time. Furthermore only electrons should be detected, since only the scattered electrons provide information about the polarization. All these criteria lead to a detector system consisting of a cherenkov counter which is both fast and insensitive to gamma radiation. In this setup, several stripes of quartz glass are used in combination with photo diodes. The top and bottom detector count coincidentally detected electrons and accumulate the absolute amount of detected electrons.

CONCLUSION AND OUTLOOK

To introduce a possibility to measure the electron beam polarization after the passage of the main accelerator of the S-DALINAC a new Møller polarimeter has been designed. The targets consists of two Vacoflux50 foil targets tilted by ±20° and are polarized in-plane by a pair of Helmholtz coils. This two-arm polarimeter setup separates the Møller scattered electrons vertically and counts them using several cherenkov detectors in a coincidence circuit. The benefits of a specialized collimator is still being investigated. A complete three dimensional model of the polarimeter has already been created using CAD software and is currently being used for detailed particle tracking simulations.

REFERENCES

[1] A. Richter, EPAC '96, Sitges (1996) 110.

[2] J. Enders, AIP Conf. Proc. 1563, 223 (2013).

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