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LETTER TO THE EDITOR

ELECTRON BEAM MØLLER POLARIMETER AT JLAB HALL A

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As part of the spin-physics program at Jefferson Laboratory (JLab), a Møller polarimeter was developed to measure the polarization of electron beam of energies 0.8 to 5.0 GeV. A unique signature for Møller scattering is obtained using a series of three quadrupole magnets which provide an angular selection, and a dipole magnet for energy analysis. The design, commissioning and the first results of the polarization measurements of this polarimeter will be presented as well as future plans to use its small scattering angle capabilities to investigate physics in very low Q^2 regime.

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Møller polarimeters are widely used for electron-beam polarization measurements in the GeV energy range. The high quality of polarization experiments anticipated at new-generation CW multi-GeV electron accelerators, such as Jefferson Laboratory (JLab), require precise measurements of electron-beam parameters. One of the parameters is the electron-beam polarization. The Hall A beam line at

JLab is equipped with a Møller polarimeter. It was designed and constructed in collaboration of Jefferson Laboratory, the Kharkov Institute of Physics and Technology and the University of Kentucky.

The polarimeter is schematically presented in Fig. 1. The horizontal plane in Hall A is in accordance to the polarimeter reaction plane. The polarimeter consists of a polarized electron target, three quadrupole magnets, a dipole magnet and a detector. The polarimeter quadrupole magnets make it possible to keep the position of all polarimeter elements unchanged within the whole range of JLab energies. Their primary purpose is to focus the divergent trajectories of Møller electrons in the scattering plane into paired trajectories aligned with the axis of the beam at the exit of the last quadrupole. The dipole is the main element of the polarimeter magnetic system. It provides the energy analysis, thus separating the Møller scattered electrons ($E_o/2$, Θ_{Moll}) from electrons coming from the Mott scattering peak ($E \approx E_o$, $\Theta \approx \Theta_{Moll}$)) and thereby suppressing the background. It also bends the Møller electrons from the reaction plane, allowing their detection away from the electron beam. The dipole has a magnetic shielding insertion in the center of the magnetic gap. The Møller electrons pass through the dipole on the left and right sides of this shielding insertion. The primary electron beam passes through the 4 cm diameter hole bored in the shielding insertion letting its passage to the Hall A beam dump with small influence of the dipole magnetic field.

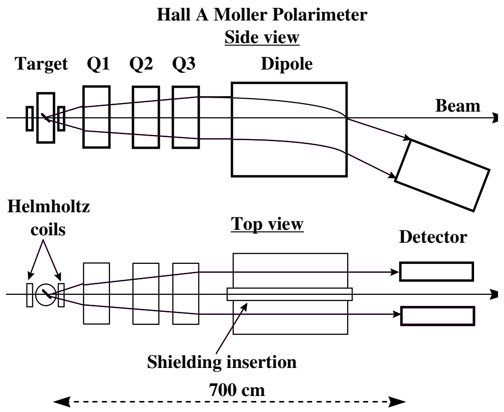

Fig. 1. Hall A Møller polarimeter set-up.

The Møller polarimeter detector is located in the shielding box downstream of the dipole and consists of two modules (left and right) for coincidence measurements. Each part of the detector includes an aperture detector made of plastic scintillator and four blocks of lead glass.

The polarized electron target chamber contains two target frames with different ferromagnetic foils:

1) 99.95% pure iron foil 10.9 μm thick with an effective polarization of 7.12% in an applied magnetic field of about 28 mT ;

2) foil of Supermendur 13.9 μm thick with an effective polarization of 7.6% in

an applied magnetic field of about 28 mT.

The targets are mounted on a vertical ladder and are cooled with liquid nitrogen down to 115 K. They can be rotated in an angular range ± (20° to 160°). The beam-polarization measurements are made with one or the other foil in the beam (*TOP* or *BOTTOM* target positions). The third position (*HOME*) is used whem beam-polarization measurement is not in progress. The target foil magnetization is measured by a series of pickup coils. The first polarization measurement with the Hall A Møller polarimeter was done in June 1997. From April 1998, regular measurements with the polarimeter are made. Results of a measurement are shown in Fig. 2.

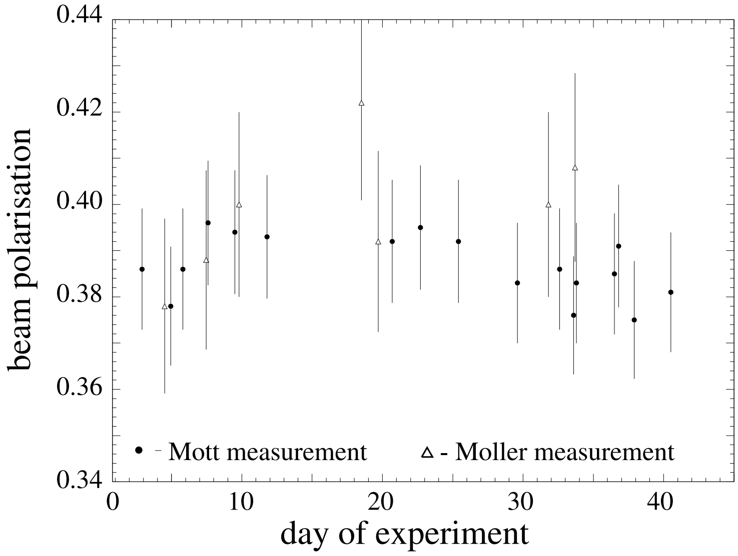

Fig. 2. Results of the Hall A electron beam polarization measurements with Møller and Mott polarimeters for experiment E-93-027.

The Hall A Møller polarimeter covers the energy range 0.8 to 5.0 GeV and can be used for measurements with beam currents from 0.5 – 5.0 μA. About twenty minutes of measurement time is needed to take data with a statistical error of less than 1%. Although the polarimeter quadrupole magnets are part of the regular Hall A beam transport, it is not necessary to change the quadrupole magnet settings or the primary beam trajectory in switching from data taking with the Hall A physics target to a polarization measurement. Also, the polarization measurements can be done with the Hall A fast raster on.

A typical beam current for the polarization measurement is 1.5 μA when the iron target heats up to 150 K. This target heating provides a relative target depolarization of 0.3%. The Helmholtz coils provide a 28 mT magnetic field in the area in which the electron beam passes through the target. The experimentally-measured target polarization is 7.6% for the Supermendur foil and 7.12% for the iron foil. The background in coincidence measurements is neglible. The typical detector acceptance angle in the reaction plane for an energy range of 2 – 5 GeV is $\Delta\Theta_{Moll} \approx \pm 14^\circ$ in c.m. and is about 0.76 in analysing power. The Levchuk effect [2,3] is estimated to be about 2% and was not observed at the $\approx 3\%$ level of the systematic error of our measurements. Other sources of systematic errors were considered and are summarized in Table 1.

TABLE 1. Systematic errors in beam-polarization measurements.

Parameter	$< A_{zz} >$	$\cos\Theta_{targ}$	P_{targ}	**Total:**
Error	0.25%	$\leq 1\%$	$\leq 3\%$	$\approx$ **3%**

In addition to being a part of the standard beam-line instrumentation in Hall A, the small scattering angle capabilities of the Møller polarimeter, coupled with the momentum analyzing capabilities of its dipole, present unique opportunities to do physics in the very low Q^2 regime. The QQQD design of the Møller spectrometer will make possible the electron scattering experiments at electron scattering angles ranging from about three degrees to less than one degree with $\Delta p'/p'$ of about 10^{-3}. As an initial area of investigation, we intend to measure the neutral pion form factor, $F_{\gamma^*\gamma\pi^\circ}$, at low Q^2 via the virtual Primakoff effect [4], i.e., π° electroproduction in the Coulomb field of heavy nucleus. The slope of this form factor in the low Q^2 range to be measured (0.005 $(\mathrm{GeV/c})^2$ to 0.04 $(\mathrm{GeV/c})^2$) gives a measure of the mean square $\gamma^*\gamma\pi^\circ$ interaction radius and is sensitive to the constituent quark mass. Such an experiment can be performed by removing the third quadrupole magnet, installing position-sensitive detectors in the focal plane, and placing a series of lead glass photon detectors upstream of the dipole to measure the π° decay photons from the Pb(e,e$'\pi^\circ$)Pb reaction.

A double-arm Møller polarimeter, used to measure the polarization of 0.8 – 5.0 GeV primary electron beam in Hall A of JLab, has been described. It is used for the extensive planned spin-physics program in Hall A. The polarimeter has been found to be robust and stable. Statistical errors of between 0.2 and 0.8% per measurement have made precision tests of possible systematic shifts in the data possible. Combining the systematic uncertainties leads to a final determination of the beam polarization with a relative uncertainty of $\leq 3\%$. More detailed information about the polarimeter design, status and current measurements is available at http://www.jlab.org/∼moller/.

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MØLLEROV POLARIMETAR ZA ELEKTRONE U DVORANI A U JLABU

Kao dio programa istraživanja spinske fizike, u Jeffersonovom se laboratoriju sagradio Møllerov polarimetar radi mjerenja polarizacije elektrona energije 0,8 do 5,0 GeV. Jedinstven signal za Møllerovo raspršenje se postiže nizom od tri kvadrupolna magneta koji određuju kut, te dipolnim magnetom za analizu impulsa elektrona. Opis, preuzimanje i prva mjerenja s tim polarimetrom se izlažu, kao i planovi za buduću upotrebu mogućnosti sustava za mjerenja na malim kutovima raspršenja radi istraživanja fizike za vrlo male Q^2.