Eur Phys J A (2005) **24,** s2, 129–130
DOI: 10.1140/epjad/s2005-04-030-2

EPJ A direct
electronic only

The transmission Compton polarimeter of the A4 experiment

A simple simultaneous monitor for the longitudinal electron beam polarisation

Christoph Weinrich[a], for the A4 Collaboration

Johannes-Gutenberg-Universtität, Institut für Kernphysik, J.-J.-Becher-Weg 45, 55099 Mainz, Germany

Received: 1 November 2004 / Published Online: 8 February 2005

Abstract. A transmission Compton polarimeter as a simultaneous, relative monitor for the longitudinal polarisation of a stabilised, polarised electron beam (polarisation degree ∼ 80 %) has been constructed in a new design. It is located in the vacuum between the target and the beam dump of the A4 parity violation experiment at MAMI. The analysing power is ∼ 80 ppm at 854 MeV and ∼ 115 ppm at 570 MeV. The measurement precision for the polarimeter asymmetry (which is proportional to the longitudinal beam polarisation degree) is ∼ 3 ppm within 5 min. at 854 MeV and ∼ 7 ppm within 5 min. at 570 MeV and the systematical error is about 0.5 ppm + 1 - 2 %. This simple polarimeter consists mainly of two graphite scatterers, a water-cooled Samarium-Cobalt permanent magnet, an aluminum secondary electron emission monitor, an understructure and electronics.

PACS. 29.27.Hj Polarized beams – 29.27.Fh Beam characteristics

1 Introduction

The A4 collaboration at MAMI measures (parity violating) beam spin asymmetries in elastic electron-nucleon scattering. The transmission Compton polarimeter serves as a relative monitor for the longitudinal polarisation between the absolute Møller polarimeter measurements and for spin angle measurements.

2 Functionality and setup

In a transmission Compton polarimeter the polarised electron beam (with flipping polarisation direction) produces proportionally polarised bremsstrahlung in some target. The polarisation of the bremsstrahlung beam is then analysed by measuring the asymmetry in its transmission through a magnet, arising from the polarisation dependence of Compton scattering. The beam electrons superposing the bremsstrahlung beam have to be diminished in front of the magnet because they dilute the measured asymmetry. The quantitatively unknown background from electromagnetic shower production by the photons (and electrons) in the magnet make the polarisation measurement only relative.

The A4 transmission Compton polarimeter is located in the 60 cm wide exit beam pipe between the target and the beam dump. Its compact design allows the beam to pass by and reach the beam dump without beeing dissipated too much. Electron background diminution is achieved by scattering, i.e. spreading the electron beam to a limited extent. For space saving and background minimisation, a permanent magnet is used as analysing magnet and secondary electron emission for the transmission measurement. Dimensions and positions of the main polarimeter parts were optimised on the basis of calculations of electron scattering, bremsstrahlung and pair production and Compton scattering. Figure 1 shows the design of the polarimeter. Polarised bremsstrahlung is produced in the liquid hydrogen target and in two graphite scatterers. These also spread the electron beam and strongly reduce the number of electrons impinging the magnet. The analysing magnet is an axially magnetised Sm_2Co_{17} (Vacomax 225 HR^{TM}) permanent magnet. It is highly remanent and coercive and heat-proof. The estimated electron polarisation in the magnet is about 3.2 % [1]. The length of the magnet has been chosen in order to nearly minimise the relative error for the measured asymmetry. The magnet is cooled by water of the beam dump cooling water circuit. A copper/CuFeP body is shrink-fitted to the magnet and conducts the heat to the cooling pipes. The aluminum converter is used to measure the photons transmitted through the magnet. Therein the photons produce electron-positron pairs, which generate a secondary electron emission signal. The signal of the 1st scatterer is used as the reference (normalising) signal for the calculation of the transmission (which is the ratio of the photon flux in front of and behind the magnet). To allow the measurement of secondary electron emission currents, the scatterers, the magnet and the converter are electrically isolated by an aluminum shielded ceramic isolator. The

[a] comprises part of PhD thesis

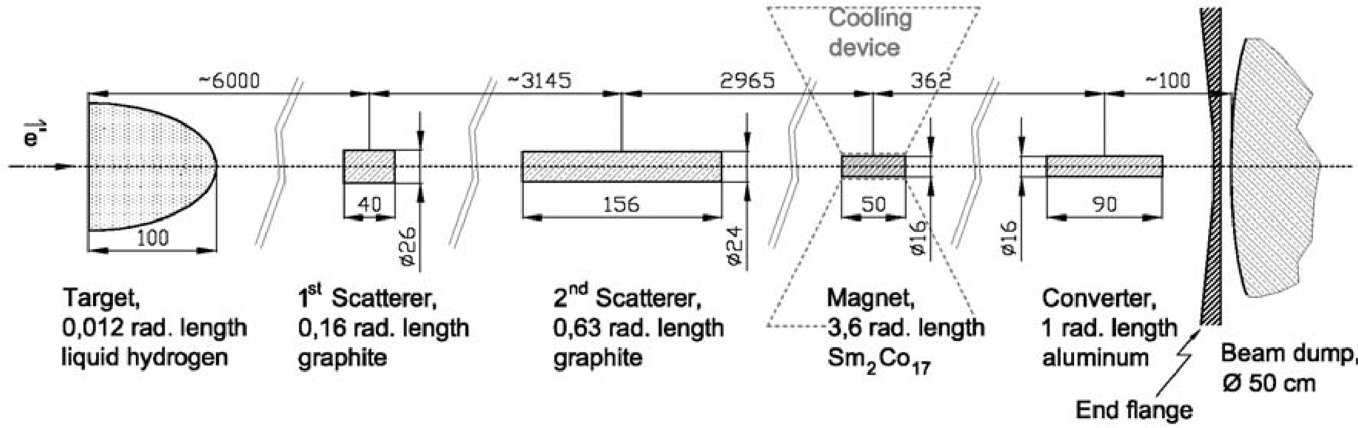

Fig. 1. The design of the A4 transmission Compton polarimeter (all parts are symmetric around the axis)

2nd scatterer, the magnet and the converter are mounted on one adjustable (MayTek™) aluminum carriage which can be rolled into the exit beam pipe and is kept in position by pins. The 1st scatterer is mounted on a proper frame. The rods holding the scatterers are made of titanium for heat resistance. The signal cables that are connected to the polarimeter pieces to conduct the secondary electron emission currents are radiation resistant in the rear ("hot") region. The polarimeter electronics consists of MAMI and A4 standard parts: amplifying current-voltage converters close to the signal source with differential output and integration-ADC- and histogramming-modules as designed for the A4 beam monitors (histogramming modules are used in timing mode). The signals are integrated over the 20 ms measurement gates between which the polarisation is flipped in the pattern (+P,-P,-P,+P), the sign of P beeing chosen pseudo-randomly before repetition. The transmission asymmetry $A^{Pola} = (T^+ - T^-)/(T^+ + T^-)$ with $T = S_C/S_{S1}$ ($S_{C/S1}$: converter/1. scatterer signal; +/-: polarisation state) is calculated offline using the timings of the (pedestal corrected) signals. A challenge was the pedestal correction of the converter signal. This pedestal is strongly drifting probably caused by activation of the material. We solved this problem by measuring the signal ratio of the converter and 1st scatterer signals $c = \Delta S_C/\Delta S_{S1}$ in switching off the beam. The converter pedestal is then calculated as $S_C^0 = \bar{S}_C - c \cdot \bar{S}_{S1}$ ($\bar{S}_{C/S1}$: signal averages over polarisation 4-tuple). Since the signal ratio is drifting slowly as well it has to be measured regularly in order to keep the systematical error small.

3 Results

The measured analysing power of the polarimeter is about 80 ppm at 854 MeV and $\sim$ 115 ppm at 570 MeV beam energy. The variance (precision) of the measured polarimeter asymmetry (for 5 min. runs) is $\sim$ 3 ppm at 854 MeV and $\sim$ 7 ppm at 570 MeV. Sensitivity to helicity correlated beam parameters was found to be $\lesssim 30$ ppm/μm for position differences (at target), $\lesssim 0.015$ ppm/ppm for current asymmetries and negligible for energy (preliminary, probably overestimated values at 570 MeV). Averaged over a data sample ($\sim$ 500 runs) typical position differences are $\sim$ 50 nm, typical current asymmetries are less than 1 ppm. The signal ratio measurement error (used for pedestal correction) contributes as a systematical error of 1-2 % of the measured asymmetry. Runwise decorrelation of the measured polarimeter asymmetry of the beam parameters (based on the polarisation 4-tuples) had negligible effect under normal beam conditions. Figure 2 shows the result of a spin rotation measurement using a Wien filter. Spin rotation measurements were also used to determine the spin angle at the experiment.

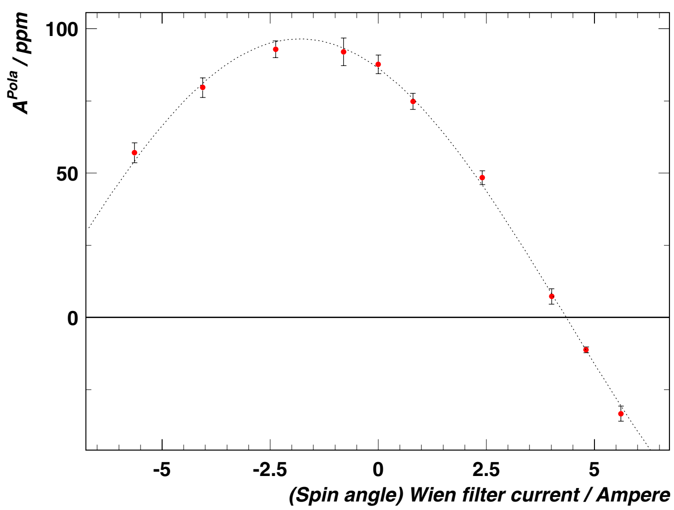

Fig. 2. Result of the spin rotation measurement at 570 MeV with a cosine-fit. The ordinate is the current of the Wien filter dipole which is proportional to the spin angle. The abscissa is the polarimeter asymmetry

References

1. M. Huth: personal communication