FIRST RESULTS
WITH THE NEW GDH-POLARIZED TARGET

Ch. Bradtke, W. Meyer, G. Reicherz
Institut für Experimentalphysik der Ruhr-Universität Bochum
Universitätsstraße 150, 44780 Bochum, Germany

H. Dutz, H. Peschel, Ch. Rohlof
Physikalisches Institut der Universität Bonn, Nussallee 12, 53115 Bonn, Germany

For the measurement of the Gerasimov-Drell-Hearn sum rule with real photons at the Mainz accelerator facility MAMI a new horizontal, polarized frozen-spin target has been built by the Bonn polarized target group. The horizontal ^{3}He/^{4}He-dilution refrigerator includes an internal superconducting holding coil to maintain the polarization in the frozen-spin mode longitudinal to the incoming γ-beam. Here we will describe the components of the target set-up and will report on first measurements of the GDH sum rule and the performance of the target during the data taking.

1 Introduction

The Gerasimov-Drell-Hearn sum rule relates static properties of the nucleon - its anomalous magnetic moment and its mass - to an integral that runs over all energies and contains the energy weighted helicity asymmetry of the total photoabsorption cross section:

$$\int_0^\infty \frac{d\nu}{\nu}(\sigma_{3/2} - \sigma_{1/2}) = \frac{2\pi^2\alpha}{m^2}\kappa^2$$

The GDH sum rule is based on fundamental physics principles such as causality, unitarity, gauge invariance and Lorentz invariance. It also can be related to the polarized structure function g_1:

$$I(0) = \frac{m^2}{8\pi^2\alpha}\int_0^\infty \frac{d\nu}{\nu}(\sigma_{1/2} - \sigma_{3/2}) = -\frac{\kappa^2}{4}$$

A derivation of this sum rule was first published in 1965, but more than thirty years passed before the demands for a direct experimental check could be fulfilled. Now in spring 1998 a first measurement for the GDH sum rule was performed at MAMI in Mainz for photons of energy up to 800 MeV. The test of the sum rule will be completed using a further measurement next year at the Bonn accelerator facility ELSA with electrons of energy between 550 MeV and 3400 MeV[1]. In this paper we present the new GDH-target BICEPS that made it possible for the first time to measure a total cross section in combination with a polarized solid state target.

2 Set-up at Mainz

For an experimental check of the GDH sum rule the total cross section of circularly polarized photons on longitudinally polarized nucleons has to be measured. Circularly polarized photons are obtained by the bremsstrahlung process of longitudinally polarized electrons and energy tagged in the GEM-tagger of the A2-collaboration with a resolution of 2 MeV. The beam polarization is determined by a Møller polarimeter and the photon flux is about 500 kHz. Under these conditions it is necessary to use a solid state target with its high density of polarized nucleons. The DAPHNE detector represents the central part of the detector and covers 94 % of $4\,\pi$. It is complemented in the forward region by microstrip detectors (MIDAS) and a forward wall consisting of the STAR-detector and Showercounter. A Çerenkov detector is used for the suppression of the electromagnetic background.

3 Polarized Target

A polarized solid state target uses the principle of Dynamic Nuclear Polarization (DNP) in which a target material - butanol (C_4H_9OH) - is doped with a dilute assembly of paramagnetic radicals by chemical techniques. The material is cooled to about 300 mK in a magnetic field of 2.5 Tesla and then irradiated by microwaves near to the electron spin resonance frequency to drive the hyperfine transitions, which allow the nucleon spin to be aligned parallel or antiparallel to the applied magnetic field. For the cooling of the target material a horizontal $^3He/^4He$ dilution refrigerator was built, the outer dimensions of which were determined by the inner dimensions of the DAPHNE detector and by the warm bore of the polarizing magnet. Two precooling stages, a separator and an evaporator, and several counter current heat exchangers provide the precooling and the liquefaction of the $^3He/^4He$ gas mixture. The dilution unit consisting of the still, the final heat exchanger and the mixing chamber permits cooling to temperatures below 50 mK. The cryogenic components of the refrigerator are placed symmetrically around the beamline tubing, which is the central part of the refrigerator and serves also as an internal isolation vacuum to reduce the thermal heat load. For the same purpose the refrigerator is also enclosed by an isolation vacuum and surrounded by two heat shields. For the DNP process a magnetic field of 2.5 Tesla with a homogeneity of $\frac{\Delta B}{B} < 10^{-4}$ over the target area is required. This can only be provided by a huge magnet that surrounds the target completely, resulting in a reduction of angular acceptance. To increase the acceptance to a totally open geometry for the scattered particles the 'frozen spin' technique with an internal holding coil is used [2]. In this technique the nucleon polarization is preserved after the polarization process at a temperature of about 50-60 mK and a magnetic field of 0.4 Tesla with a relaxation time of more than one week. This magnetic field is provided by a superconducting, internal holding coil that is integrated in the refrigerator. It consists of four layers of NbTi wire wound on a 300 μm copper layer, which results in a total thickness of 700 μm, such that a significant loss of scattered particles occurs only close to the threshold. As a result of its compact design (length 120 mm, diameter 44 mm) the coil has a weak outer fringe field, so that the influence on the detectors located close to the target area is very small in comparison to that of the outer holding coils formerly used. The coil is cooled to a temperature below 1.2 K by a thermal contact to the liquid helium of the still. At this temperature a maximum field of 0.48 Tesla at 12 A was achieved. The homogeneity of the magnetic field over the target area ($< 5 \cdot 10^{-3}$) allows for the first time an online polarization measurement during 'frozen spin mode' (data taking), so that the systematic error of the polarization measurement is considerably lowered. The degree of the nucleon polarization is determined by the NMR technique with a systematic error of less than 2 %.

4 Data taking

Between May and August 1998 the GDH collaboration has taken data on the proton for more than 400 hours. The electron beam polarization was 70 – 75 %, so that the photon polarization exceeded 50 % in the upper half of the bremsstrahlung spectrum. To use this energy range the experiment ran at three different electron energy settings: 850, 525, 300 MeV. The starting value of the proton polarization in 'frozen spin mode' was 80 – 85 % with a relaxation time of more than 200 hours. The target polarization was refreshed every two days and reversed for consistency checks. In preliminary analyses based on 10 % of the total data the GDH-integral between 200 and 800 MeV was determined to be 230$\pm$20 μbarn.

References

1. J. Ahrends et al., Proposal to the PAC MAMI Mainz (1992).
   G. Anton et al., Proposal to the PAC ELSA Bonn (1992)
2. H. Dutz et al., NIM **A 340** (1994) 272