The GDH Experiment at MAMI

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The Gerasimov-Drell-Hearn (GDH) sum rule connects the helicity dependent photoabsorption cross section with the anomalous magnetic moment of the nucleon. The GDH-collaboration is measuring the total cross section of circularly polarized photons with longitudinally polarized protons to check this sum rule experimentally to do a further progress in the investigation of the spin structure of the nucleon. The experiment has been started using the polarized electron beam of the Mainz electron accelerator MAMI in the energy range 200 - 800 MeV and will be continued at the Bonn accelerator ELSA up to an energy of about 3 GeV. We have finished the data taking period at MAMI for the proton in august 98. A frozen spin target has been integrated into the 4π-detector DAPHNE. The experimental setup at MAMI will be described and first preliminary results will be shown.

1. INTRODUCTION

The GDH sum rule connects static properties of the nucleon like the anomalous magnetic moment κ, the nucleon mass M and charge e, with the helicity dependent total absorption cross sections $\sigma_{1/2}$ and $\sigma_{3/2}$, which are related to the dynamics of the excitation spectrum:

$$\frac{\pi e^2}{2M^2}\kappa^2 = \int_{m_\pi}^{\infty} \frac{d\omega}{\omega}\,(\sigma_{3/2}-\sigma_{1/2}), \qquad (1)$$

where ω denotes the photon energy and the lower integration limit is the π production threshold energy. Another characteristic property of the nucleon is the forward spin polarizability γ_0

$$\gamma_0 = \frac{1}{4\pi^2}\int_{m_\pi}^{\infty} \frac{d\omega}{\omega^3}\,(\sigma_{3/2}-\sigma_{1/2}). \qquad (2)$$

The GDH sum rule was derived in 1966 by Gerasimov, Drell and Hearn [1], [2], but is has not been checked experimentally. A new interest in the GDH sum rule came up with the measurements of the longitudinal spin stucture functions for proton and neutron in deep inelastic lepton scattering (DIS), which lead to the so called 'spin crisis of the proton'. The GDH sum rule for the proton and the neutron can be interpreted as the extrapolation from the Bjorken- and the Ellis-Jaffe-sum rule for DIS to the real photon limit [3]. Nowadays, improved technologies for polarized photon beams and polarized targets allow us to check this sum rule experimentally. The goal of the GDH collaboration is to measure the helicity dependent total absorption cross sections as well as partial reaction channels on proton and neutron targets.

2. EXPERIMENTAL SETUP

The experiment was performed at MAMI for the photon energy from π production threshold up to a maximum photon energy of 800 MeV. Here a source of polarized electrons, based on the photoeffect on a strained GaAs crystal, delivers routinely electrons with a degree of polarization of about 75% and a maximum energy of 855 MeV. The photons were produced via the bremsstrahlung process in the Glasgow Mainz tagging facility, which is used twofold. First it determines the energy of the photon that has been produced in the bremsstrahlung process and secondly the degree of circular polarization of the electrons is measured by detecting the two electrons which are produced in the Møller process. The Møller polarimeter allows an online monitoring of the degree of electron beam polarization. The statistical error is in the order of 2% for a measurement time of 4 hours.The helicity transfer to the photon can be calculated [4] .

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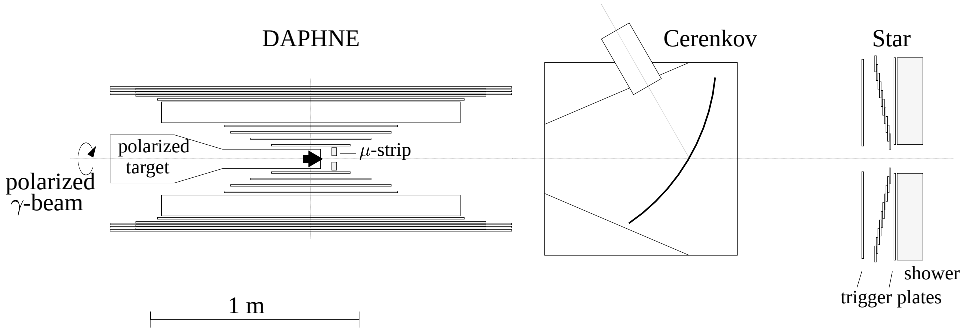

Figure 1. The experimental setup at MAMI. The polarized photon beam is coming along the axis of the $^{3}He/^{4}He$ refrigerator of the polarized 'frozen spin' target. The target is inserted into the cylindrical detector DAPHNE. The forward detectors (μ-strip detector MIDAS, Čerenkovdetector and scintillation counter array (STAR)) expand the angular acceptance.

The target protons were polarized in a solid state 'frozen spin' target [5]. We used as target material Butanol (C_4H_9OH) which had been chemically doped with paramagnetic radicals to allow the process of 'Dynamic Nuclear Polarization'. The $^{3}He/^{4}He$ dilution refrigerator cooled down the material to a temperature of 300mK in a magnetic field of 2.5T produced by an external superconducting polarizing solenoid. Irradiation by microwaves of a frequency near to the electron spin resonance (70GHz) led to an alignment parallel or antiparallel to the magnetic field, after 4 hours degrees of proton polarization of 80% - 85% were reached. Then the external solenoid was removed on a specially adopted rail system and the polarization was maintained in the 'frozen spin' mode at 50 mK and 0.4 T. This holding field was produced by an superconducting solenoid that was integrated into the refrigerator and operates at 1.2K[6]. The DAPHNE detector was moved in position and data could be taken for typically 44 hours, the relaxation times for the proton spins were 200 hours. The target material was stored in a 2 cm long 2 cm diameter teflon container which was surrounded by a NMR coil. The homogeneity of the holding field was sufficient to allow an online NMR polarization measurement during the 'frozen spin' (data taking) mode with a 2% error.

3. PRELIMINARY RESULTS

There was done a preliminary analysis of a small (10%) subset of our data taken in May 98. Only statistical errors were taken into account and a preliminary normalization of the photon flux, the degrees of beam and target polarization and detector efficiencies were used. Fig.2 shows the missing energy for protons detected in DAPHNE. It is assumed that they stem from π^0 production on a free proton. Events from the only chemically bound polarized protons can be clearly assigned to the peak at missing energy equal zero. Events from the unpolarized carbon give a broad background.This background cancels in the lowest spectrum for the difference of the count rates of both helicity states. In Fig.3 we have plotted our preliminary data for the difference of the total absorption cross sections $\sigma_{3/2} - \sigma_{1/2}$ from 200 to 800 MeV in comparison with two curves which were taken from the VPI multipole analysis SAID (solution SP97K) and a dispersion theoretical analysis (HDT) [7], both for single pion production only . From π production threshold up to 230 MeV this quantity is negative due to

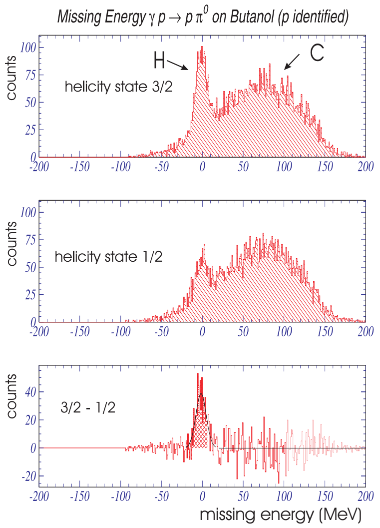

Figure 2. Missing energy spectra for the reaction $p(\gamma, p)\pi^0$

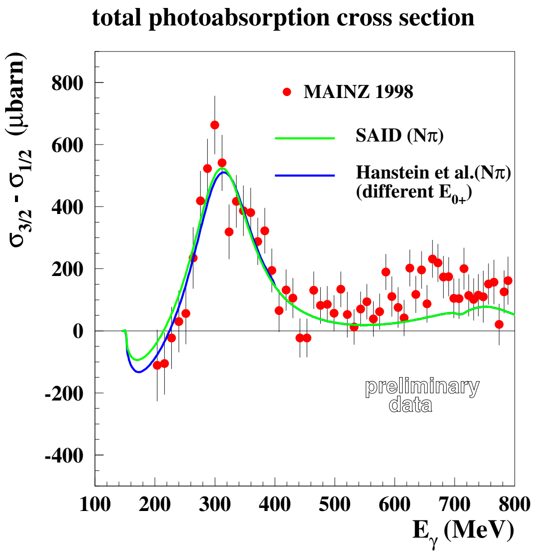

Figure 3. The total photoabsorption cross section difference $\sigma_{3/2} - \sigma_{1/2}$

the E_{0+} multipole for π^+ production. In the Δ resonance region (spin 3/2) the $\sigma_{3/2}$ cross section dominates because of the strong positive contribution of the M_{1+} multipole. In our data clearly the positive contribution of double π production for higher energies can be seen. The difference in the indicated two curves mainly comes from different threshold values for the E_{0+} multipole for π^+ production [8].

We have used this preliminary data to estimate the GDH integral in the energy range 200 to 800 MeV according to equation 1 and obtained a value of $(230 \pm 20)\mu b$. Taking into account the not measured low energy ($< 200 MeV$) and high energy ($> 800 MeV$) contribution using the HDT model we get $(225 \pm 20)\mu b$ which is compatible with the GDH value of $204\mu b$. Doing the integration of our data according to Eq.2 and again doing the correction using the HDT model we get as value for the spin polarizibility $(72 \pm 30) \cdot 10^{-6} fm^4$.

A more detailed analysis of our complete data set, which includes a pilot measurement on deuterated butanol, with a dedicated investigation of the partial reaction channels is in progress. This will lead to more precise results for the forward spin polarizibility and the GDH sum rule value. We have started to extend the accessible energy range to 3 GeV at the Bonn accelerator ELSA.

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