HELICITY DEPENDENT PHOTO-PRODUCTION IN THE GDH EXPERIMENT

A. Thomas[1†] for the GDH-Collaboration

(1) *Institut für Kernphysik, Universität Mainz*
† *E-mail: thomas@kph.uni-mainz.de*

Abstract

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 at MAMI and ELSA to check this sum rule experimentally to do a further progress in the investigation of the spin structure of the nucleon. In addition partial reaction channels like pion and eta production were determined. In this talk the experimental results from the proton runs were presented.

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:

$$\frac{\pi e^2}{2M^2}\kappa^2 = \int_0^\infty \frac{d\nu}{\nu}\,(\sigma_{3/2} - \sigma_{1/2}). \qquad (1)$$

Effectively the lower integration limit is the π-production threshold energy and ν denotes the photon energy. The GDH sum rule was derived under very general assumptions (Lorentz and gauge invariance, causality, relativity, unitarity and the no-substraction hypothesis) in 1966 by Gerasimov, Drell and Hearn [1, 2], but is has not been checked experimentally. Some authors [3, 4] have tried to calculate the right hand side of eq.1 using partial wave analyses of single π-photoproduction experiments and rough estimates for the double π contribution. They always maintained a discrepancy with the left side of eq.1, which yields 205 μb for the proton. Interest in the GDH sum rule was renewed with the measurements of the longitudinal spin structure functions for proton and neutron in deep inelastic lepton scattering. The GDH sum rule can be interpreted as the extrapolation from the Bjorken- and the Ellis-Jaffe-sum rules to the real photon limit [5].
Nowadays, improved technologies for polarized photon beams and polarized targets allow us to check this sum rule performing a dedicated double polarization experiment directly. The goal of the GDH-collaboration is to measure the energy dependence of the helicity dependent total absorption cross sections as well as partial reaction channels on proton and neutron targets to determine the dominant contributions to equation 1 and to extract new information about the nucleons excitation spectrum.

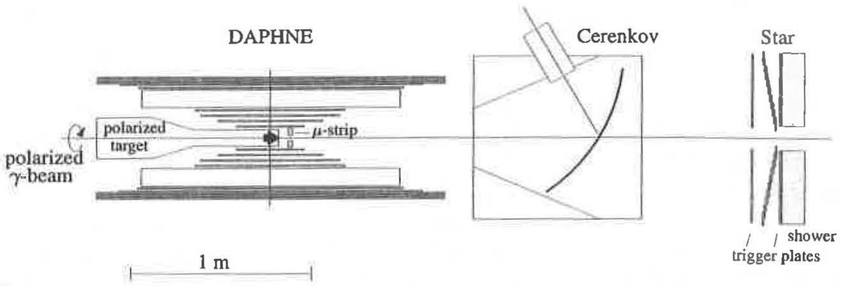

Figure 1: The experimental setup at MAMI.The polarized photon beam is coming along the axis of the ^{3}He/^{4}He refrigerator of the polarized 'frozen spin' target.

2. Experimental Setup

Experimental Setup at MAMI: The MAMI accelerator with its source of polarized electrons, based on the photoeffect on a strained GaAs crystal, routinely delivers polarized beams with a degree of polarization of about 75% and a maximum energy of 855 MeV. The photons were produced by bremsstrahlung in the A2-Glasgow-Mainz tagging facility, which firstly determines the photon energy and secondly measures the degree of polarization of the electrons by detecting the asymmetry in the Møller process. This Møller polarimeter allows an online monitoring of the degree of electron beam polarization. The statistical error is in the order of 2% for a measuring time of 4 hours. The energy dependent helicity transfer to the photon can be calculated reliably [6]. In order to achieve a high degree of photon beam polarization we used as primary electron beam energies 525MeV and 855MeV.

A solid state 'frozen spin' polarized target [7] was used. The target material butanol (C_4H_9OH), which had been chemically doped with paramagnetic radicals to allow the process of 'Dynamic Nuclear Polarization', was cooled in a ^{3}He/^{4}He dilution refrigerator. The polarizing magnetic field of 2.5T was produced by an external superconducting solenoid. After 4 hours values for the degree of proton polarization of 80% - 85% were reached by irradiation with microwaves of a frequency near to the electron spin resonance (70GHz). The external solenoid was moved on a specially adapted 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 a thin superconducting solenoid that was integrated into the refrigerator and operates at 1.2K [8]. The relaxation time for the proton spins was 200 hours; consequently we could take data for typically 2 days before repolarizing the target.

The cylindrical detector DAPHNE [9] was especially designed for handling multi particle final states by provision of a large solid angle (94% of 4π), particle identification and moderate efficiency for neutral particles. It consists of three multi-wire proportional chambers and six layers of plastic scintillators. New forward detection components (silicon μ-strip- and Čerenkovdetectors and scintillation counter array) and the ring shaped STAR detector have been added to expand the angular acceptance.

Experimental Setup at ELSA: In Bonn the same solid state 'frozen spin' polarized target was used. The primary aim of the experimental conception here was to measure the total photoabsorption cross section difference as a function of the photon energy with a minimal systematic error. The polarization of the electrons delivered by ELSA was typically 70% at a maximum extracted beam current of 2 nA and was permanently measured by the GDH-Møller polarimeter. The tagging system [10] covers an energy range of 68% to 97% of the primary electron energy. Three settings (1.0, 1.4, and 1.9 GeV) were necessary to cover the photon energy range from 0.68 to 1.82 GeV. At the higher ELSA photon energy, photoabsorption processes lead to multi particle final states which are hard to detect all individually with full acceptance and efficiency. To avoid systematic uncertainties arising from unobserved final states, the total photoabsorption cross section was measured inclusively. The concept of the GDH detector [11] is to observe at least one reaction product of all possible hadronic final states with almost complete acceptance as far as solid angle and efficiency are concerned.

3. Results

3.1 Results on partial reaction channels

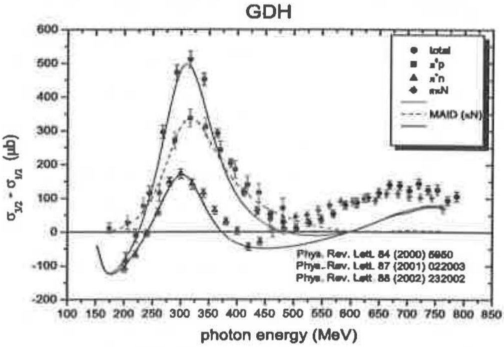

Figure 2: Overview on the helicity dependent partial photoabsorption cross sections measured at MAMI.

We have published our results from the Mainz part of the experiment up to a photon energy of 450MeV for the single pion production channels on the proton [12] and a second paper on the total photoabsorption cross section for energies up to 800MeV [13]. Beside the importance of this data to check the GDH sum rule experimentally and to measure the forward spin polarizibility, new information about the nucleon's excitation spectrum can be extracted. In the $\Delta(1232)$ resonance region the determination of the double polarization observable E has provided new complementary information about the EMR ratio. At higher energies our data were used to determine with the help of the multipole analysis MAID2000 the parametrisation of the multipoles E_{2-} and M_{2-} that drive the D_{13}-excitation. A detailed discussion can be found in [14, 15]. In the MAMI energy range up to 800MeV we are analyzing our data for the asymmetry $\sigma_{3/2} - \sigma_{1/2}$ for the double pion production channels [16, 17]. Comparing our results with predictions from different theoretical models[18, 19] will give a new insight into the double pion production mechanism, specially the role of the $D_{13}(1520)$ and the $\Delta(1700)$ is under discussion. The asymmetry for the η photoproduction, dominated by the $S_{11}(1535)$ resonance had been reported in [20].

3.2. Results on the GDH sum rule

In a recent paper [21] the data taken at ELSA from 0.7 to 1.8GeV have been published. Together with the previously measured data at MAMI (see table 1), the photon energy interval covered experimentally is broader, so this can be used to check the validity of the GDH sum rule. A reasonable estimate of its value can be deduced by using the contributions predicted by existing models for the missing energy range: The unitary isobar model MAID2002 [22] gives a contribution of $(-27.5 \pm 3)\mu b$ for photon energies below 0.20 GeV [23]. This gives a value for the GDH integral between 0.14 and 1.82 GeV of $228\mu b$. The Regge approaches from [24, 25] predict a negative contribution above 1.82 GeV of $-22\mu b$ [24] and $-13\mu b$ [25], respectively. The combination of our combined experimental results from MAMI and ELSA with these predictions yields an estimate $(206 - 215)\mu b$ which within the experimental errors is consistent with the GDH sum rule value. Our measurements up to 2.9 GeV at ELSA will finally clarify the validity of Regge predictions in this energy regime and will give a more definitive answer to the question whether the GDH sum rule holds or not.

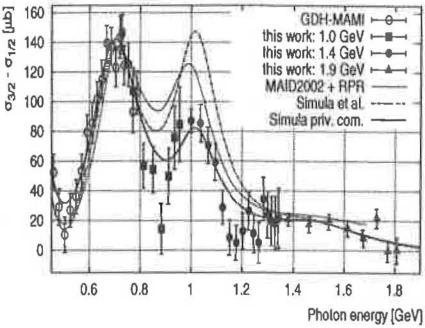

Figure 3: The helicity dependent total photoabsorption cross section difference measured at MAMI and ELSA.

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	$\nu[GeV]$	GDH-Integral μb
ELSA	0.8 − 1.82	$29.1 \pm 1.9 \pm 1.3$
MAMI	0.2 − 0.8	$226 \pm 5 \pm 12$
combined	0.2 - 1.82	$255 \pm 5 \pm 12$

Table 1: Measured values of the GDH integral in various photon energy intervals.

Discussion

Q. (A. Deshpande, BNL, Upton): I was surprised by the "low" value of theoretical uncertainty assigned to the GDH integral from the high ν region extrapolation. What value of the ν_{high} would be ideal for future measurements?

A. The "low" value of theoretical uncertainty assigned to the GDH integral from the high ν region extrapolation comes from the energy weighting of the GDH integrand. Since above the resonance region no energy dependent structures in the helicity dependent total photo absorption cross sections are expected, no special energy is ideal. It would be of course good to have a measurement around 3-10 GeV to test Regge models and in addition at much higher energies to cover a broad energy range.

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