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Mainz Microtron MAMI

Collaboration A2: "Real Photons"
Spokesperson: A. Thomas

Proposal for an Experiment

"The Reaction $\gamma p \rightarrow \eta\gamma' p$ and the magnetic Moment of the $S_{11}^{+}(1535)$ Resonance"

Collaborators :
CrystalBall@MAMI collaboration

Spokespersons for the Experiment :
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Abstract of Physics :
Static properties of baryons carry important information about the baryonic structure. In particular, the magnetic moment is a valuable observable for testing QCD-inspired models in the non-perturbative region and the $S_{11}(1535)$ is especially interesting since the possibly non-qqq nature of this hadronic system remains a controversial issue. The magnetic dipole moment of a resonance with a full width of ≈ 100 MeV can be accessed by measuring an internal photon transition (R→Rγ') via radiative meson photoproduction. This technique has been successfully used for the $\Delta^{++}(1232)$ and $\Delta^{+}(1232)$ using the reactions $\pi^+ p \rightarrow \pi^+\gamma' p$ and $\gamma p \rightarrow \pi^0\gamma' p$. Additionally we propose a pilot experiment to study the feasibility of the magnetic moment measurement for the $S_{11}^{0}(1535)$ resonance using a deuteron target.

Abstract of Equipment :
The measurement requires a high intensity (circularly polarized) photon beam in the energy range of 850-950 MeV. The available target setup for liquid hydrogen (the target length is 5cm) will be used with liquid hydrogen and liquid deuterium. All measurements require the combined setup of the Crystal Ball and TAPS detectors as a 4π photon spectrometer for the detection of the $\eta\gamma'$ final state ($\eta \rightarrow 3\pi^0 \rightarrow 6\gamma$ and $\eta \rightarrow 2\gamma$). Furthermore, in case of the deuterium target, particle discrimination in forward direction between neutrons, protons and photons is necessary in order to identify the recoil nucleon. The ideal trigger is a combination of conditions on the number of clusters (≥ 3 clusters) and on the total energy in the event (energy sum ≥ 400 MeV).

MAMI–Specifications :

beam energy	LH_2 1500 MeV, LD_2 1500 MeV
beam current	< 100nA
time structure	cw
polarization	circularly polarized photons

Experiment–Specifications :

experimental hall/beam	A2
detector	Crystal Ball, TAPS, MWPC, PID
target material	liquid hydrogen, liquid deuterium

Beam Time Request :

set–up/tests with beam	48h each (24h LD_2 in parallel with)
data taking	500 hours (LH_2 target)
	500 hours (LD_2 target in parallel with)

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1 Introduction

The complex structure of the nucleon is reflected in its rich excitation spectrum. Attempts to unravel the baryon structure have led to an impressive set of measurements of the properties of the nucleon, e.g. polarizabilities, magnetic moments, and more general form factors. Different (QCD inspired) models try to explore the internal effective degrees of freedom of the nucleon by predicting the excitation spectrum and the static properties. In this context, the knowledge of the nucleon's excited states is limited to the mass of the lowest resonances and their (iso)spin quantum numbers. However, to test the modeling of internal degrees of freedom of the excited states, measurements of static properties of the baryonic resonances are required. In particular, the $S_{11}(1535)$ is of considerable interest, because of the large mass splitting between the ground state $N(939)J^P = \frac{1}{2}^+$ and the state with negative parity, the $S_{11}(1535)J^P = \frac{1}{2}^-$. If the two-flavor chiral symmetry were exact and preserved by the QCD vacuum, QCD would predict parity partners degenerate in mass. In recent years, new techniques have become available to perform numerical calculations of the properties of nucleon excited states using lattice QCD. Furthermore, the next generation of lattice QCD calculations will study the change of the nucleon and resonance properties by varying the quark mass parameter from the large regime down to sufficiently small quark mass values, where chiral symmetry could be used to extrapolate to the chiral limit [Tho03]. These important advances in theoretical technique must be tested experimentally, but to date quantitative measurements of the properties of nucleon resonances are extremely scarce due to their extremely short lifetimes.
The magnetic dipole moment (MDM) is a particularly useful observable to study baryonic structure and for the SU(3) ground state these are well known, agreeing astonishingly well with the predictions of the non-relativistic constituent quark model. Recently, the ratio of the proton and neutron magnetic moment has been studied by exploiting chiral symmetry in the extrapolation of lattice data with large quark masses down to the physical value. In particular, it has been noted that the apparent success of the non-relativistic quark model in the description of the ratio of proton to neutron MDM seems to be rather fortuitous [Lei01]. Therefore, it is essential to extend such studies to MDMs of nucleon resonances, where the $\Delta(1232)$ and the $S_{11}(1535)$ are experimentally the best accessible resonances because of their characteristic decays into $N\pi$ and $N\eta$, respectively. Moreover, a significant motivation is to clarify the nature of the $S_{11}(1535)$ resonance: whether it is a traditional qqq state or a dynamically generated meson baryon resonance ($K\Sigma$ molecule) as was first claimed in [Kai95].
It has been proposed to determine the electromagnetic structure of a broad resonance by measuring a γ-transition within the resonance [Kon68]. In case of the Δ^+ nucleon is excited by absorption of a 400 MeV photon turning the nucleon into a heavy Δ state. This heavy Δ can

$/ \mu_N$	$(qqq)S_{11}^+(1535)$	$(qqq)S_{11}^0(1535)$
CQM [Chi03]	1.89	-1.28
χUM [Hyo03]	1.1	-0.25
OPE [Liu05]	-0.45	0.95
OPsE [Liu05]	-0.35	0.85
GBE [Liu05]	1.55	-1.0
OGE [Liu05]	1.65	-1.15

Table 1: Predictions for the magnetic moment of the $S_{11}(1535)$ resonance from different quark models. The latter values ([Liu05]) are averages between results in a CQM and a χQM since these differences are negligible but with large differences resulting from the hyperfine interactions (one pion exchange OPE, only pseudoscalar meson exchange OPsE, Goldstone boson exchange GBE, one gluon exchange OGE).

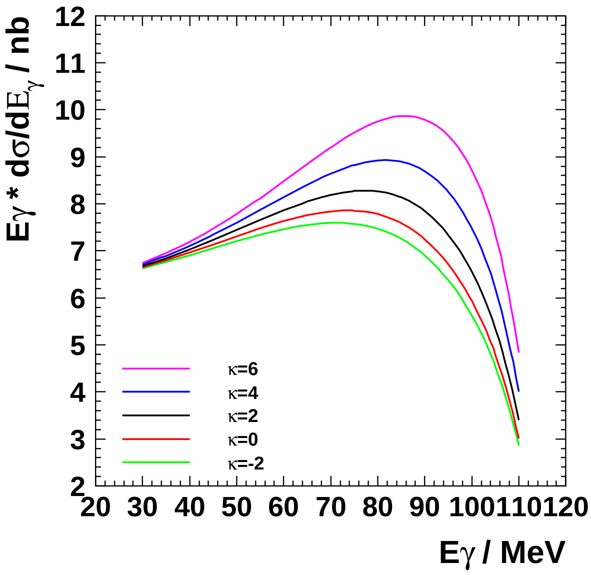

Figure 1: Energy differential cross section with respect to $E_{\gamma'}$ in the γp CM system [Chi03]. The cross section is shown for $\kappa_{S_{11}(1535)}$ = -2, 0, 2, 4 and 6 (these values correspond to $\mu_{S_{11}(1535)}$= -0.61, 0.61, 1.84, 3.06 and 4.28 μ_N).

decay into a lighter Δ by emission of a single photon (generally R$\rightarrow$Rγ'). Subsequently the lighter Δ will decay into a nucleon and a π meson. Spin and parity conservation require that the lowest order electromagnetic transition is magnetic dipole (M1) radiation. This R$\rightarrow$Rγ' amplitude is proportional to μ_R. The magnetic moment of the Δ^{++} isobar was extracted in a similar way from the reaction $\pi^+ p \rightarrow \pi^+\gamma' p$. Two experiments at the University of California (UCLA) [Nef78] and the Schweizerisches Institut für Nuklearforschung (SIN, now called PSI) [Bos91] have been performed and as a result of many theoretical analyses of these data the Particle Data Group [Eid04] quotes a range of $\mu_{\Delta^{++}}$ = 3.7–7.5 μ_N (where μ_N is the nuclear magneton). The large uncertainty in the extraction of $\mu_{\Delta^{++}}$ is due to the strong contribution of π^+ bremsstrahlung and model dependencies. Recently, a pilot experiment to extract the MDM of the Δ^+ resonance via the reaction $\gamma p \rightarrow \pi^0\gamma' p$ was performed by the TAPS/A2 collaborations at the MAMI tagged photon facility [Mac99, Dre01, Kot02]. This channel has the advantage that the bremsstrahlung contribution of the proton is much smaller than that of the charged pion. The result of this experiment is $\mu_{\Delta^+} = 2.7 \pm 2.5(\text{exp}) \pm 3(\text{model})\ \mu_N$. A dedicated next generation experiment with much improved statistics [Bec02] has been finished and is presently being analyzed. This measurement was accomplished using the Crystal Ball and TAPS detectors located at the MAMI accelerator. At the same time, the description of the reaction $\gamma p \rightarrow \pi^0\gamma' p$ has been improved [Pas05]. The calculation is done within the chiral effective field theory ansatz to minimize the model error significantly.

The MDM of the $S_{11}(1535)$ can be extracted in a similar way, by measuring the reaction $\gamma p \rightarrow \eta\gamma' p$. Recently, two papers reported on the feasibility of this method [Chi03, Hyo03]. The prominent dominance of the $S_{11}(1535)$ resonance in the η photoproduction channel compared to contributions of other resonances or background terms ([Dre05]) makes the $S_{11}(1535)$ the only N* state, where such studies are possible. Table 1 shows predictions for the magnetic moment of the two charge states of the $S_{11}(1535)$ resonance assuming a (qqq)-state. The deviations in the various predictions are not only large, they even differ in sign. This situation calls for an experimental verification. Furthermore, the authors of [Chi03, Hyo03] calculated the magnetic moment in a simple model assuming a KΣ nature of the $S_{11}(1535)$. Their results for the magnetic

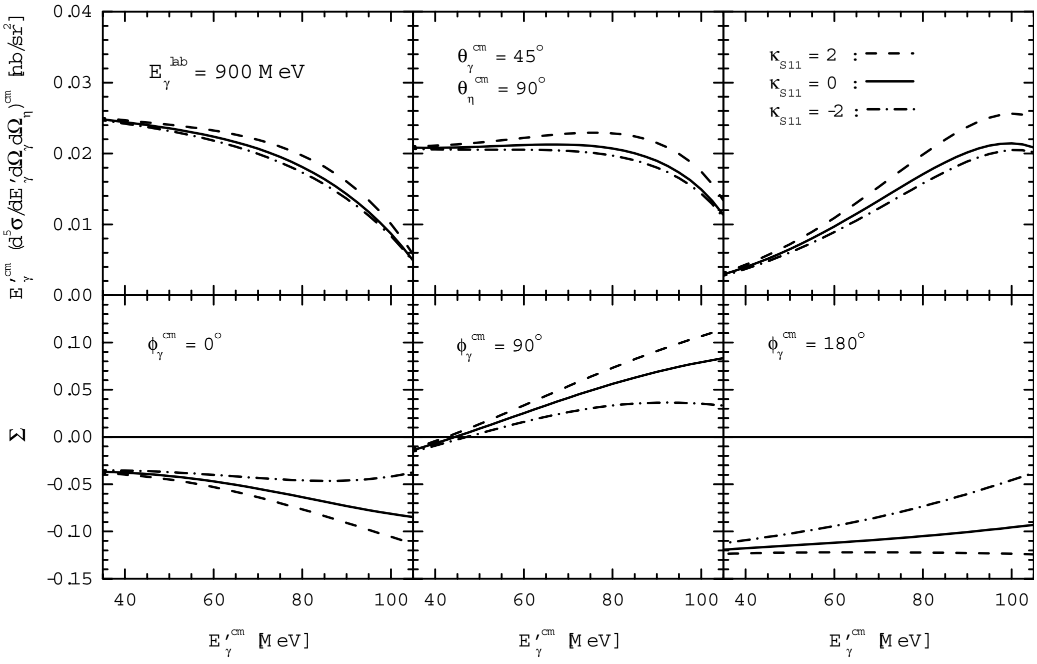

Figure 2: Five-fold differential cross section (upper row) and photon beam asymmetry Σ (lower row) for fixed polar angles $\theta_\eta^{cm} = 90°$ and $\theta_\gamma^{cm} = 45°$, and varying the azimuthal angle $\phi_\gamma^{cm} = 0°, 90°, 180°$ [Chi03].

moment are 1.86, -0.56 μ_N [Chi03] and 1.55, -0.74 μ_N [Hyo03], respectively for the charged and neutral state of the $S_{11}(1535)$.

2 Extraction of the magnetic moment of the $S_{11}(1535)$ resonance

The MDM of the $S_{11}(1535)$ can be extracted from a measurement of the reaction $\gamma p \to \eta\gamma' p$. In [Chi03] an effective Lagrangian model was used to investigate the sensitivity to $\mu_{S_{11}(1535)}$ in this reaction. The energy distribution of the radiated photon γ' is shown in Fig. 1, where it has been multiplied by $E_{\gamma'}$ to factor out the trivial $1/E$ dependence arising from bremsstrahlung. The various curves show the sensitivity to the value of the anomalous magnetic moment $\kappa_{S_{11}(1535)}$, which is related to $\mu_{S_{11}(1535)}$ via:

$$\mu_{S11} = (1 + \kappa_{S_{11}}) \cdot \frac{e}{2m_{S_{11}}} = (1 + \kappa_{S_{11}}) \cdot \frac{m_N}{m_{S_{11}}} \cdot \mu_N \quad (1)$$

where m_N and $m_{S_{11}}$ denote the masses. The quantitative correspondence of values expressed in $\kappa_{S_{11}(1535)}$ and in $\mu_{S_{11}(1535)}$ is given in the caption of Fig. 1. The sensitivity can be increased by measuring a higher differential cross section, as it is shown in the upper row of Fig. 2, where the variation of the five-fold differential cross section for the values of $\kappa_{S_{11}(1535)}$= -2, 0, 2 is at the 20-25% level. The total cross section integrating $E_{\gamma'}$ from 30 MeV up to 110 MeV is of the order of 10 nb at an incident beam energy of 900 MeV.

Moreover, we plan to measure the reaction $\gamma p \to \eta\gamma' p$ using a circularly polarized photon beam and an unpolarized target. In this case, there is a non-vanishing asymmetry Σ_{circ} defined for a three body final state like the $\eta\gamma' p$ final state. We will measure this asymmetry simultaneously to exploit its sensitivity to $\mu_{S_{11}(1535)}$. The observable Σ_{circ} has turned out to be very sensitive to μ_{Δ^+} in case of the $\Delta^+(1232)$ [Pas05]. The circular polarized photon beam is produced by scattering longitudinally polarized e^- on a radiator foil. The accelerator MAMI-B delivers routinely e^- with a polarization of 75%. The polarization transfer from the longitudinally

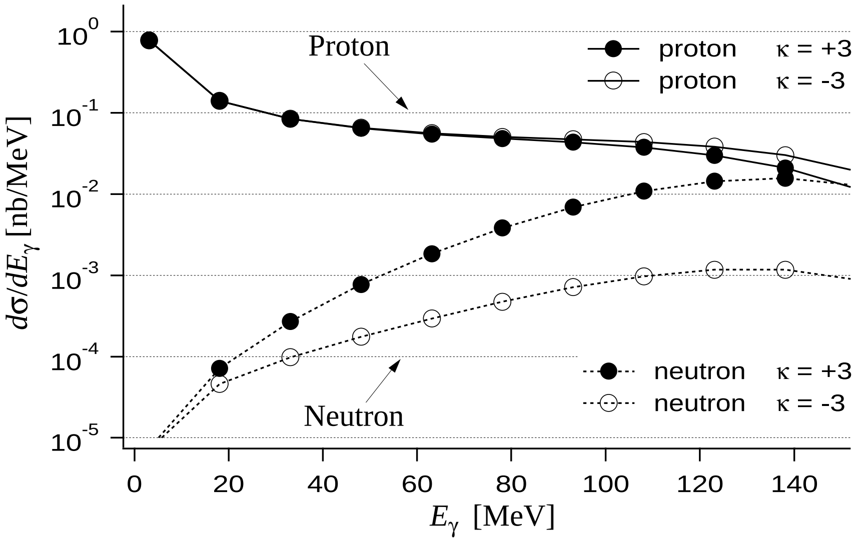

Figure 3: Energy differential cross section for the reactions $\gamma p \to \eta\gamma' p$ and $\gamma n \to \eta\gamma' n$ with respect to $E_{\gamma'}$ in the γp CM system at an incident beam energy of 1000 MeV [Hyo03].

polarized e^- to the circularly polarized photons is almost 100% close to the maximum energy. Therefore, a circular polarization of 57% will be achieved at 900 MeV by using an incident beam energy of 1500 MeV.

Furthermore, it is very important to measure the photon beam asymmetry Σ in the radiative η photoproduction ($\gamma p \to \eta\gamma' p$). The measurement of the photon beam asymmetry in the non-radiative η photoproduction gave the very surprising result of $\Sigma = 0.4$ at 90° η scattering angle ([Aja98, Tia99]). This large asymmetry is a result of an interference between the $D_{13}(1520)$ and the $S_{11}(1535)$. It is a priori not evident how this strong effect in the observable Σ for the non-radiative η production might be translated to the radiative case. The ideal setup for such an experiment is the Crystal Barrel / TAPS detector at ELSA. A degree of linear polarization of $\geq$65% can be reached at the energy range of interest due to the high incident beam energy of 3.2 GeV available at this laboratory. We would like to propose such an experiment at a later date.

The rather low sensitivity to the MDM in the reaction $\gamma p \to \eta\gamma' p$ is caused by the dominance of the ordinary bremsstrahlung radiation in a process where e.g. the excited $S_{11}(1535)$ first decays emitting an η meson into an off-shell proton, which subsequently radiates the γ'. Thus, a measurement on the neutron would omit this ordinary nucleon bremsstrahlung since the neutron carries no charge. Consequently, a measurement of the reaction $\gamma n \to \eta\gamma' n$ would be much more sensitive to the magnetic moment of the neutral charge state of the $S_{11}(1535)$. The first calculation of the reaction $\gamma n \to \eta\gamma' n$ was recently done by Hyodo et al. [Hyo03] using the chiral unitary model. The comparison of the energy differential cross section in Fig. 3 shows that the sensitivity to the anomalous magnetic moment $\kappa_{S_{11}(1535)}$ is very large for the production on the neutron, accompanied by a lower total cross section in case of the neutron. Fig. 3 shows the cross section for an incident beam energy of 1000 MeV, where the total cross section on the proton is roughly a factor of 2 smaller than at 900 MeV.

Since the extraction of the MDM relies not only on the measured experimental data, but also on a model for $\gamma p \to \eta\gamma' p$ or $\gamma n \to \eta\gamma' n$, it is crucial that the model reliably describes the underlying reaction properties. Such models could be tested in describing the non-radiative processes like $\gamma p \to \eta p$ and then be extended to the radiative case without introducing any further unknown parameters [Chi03].

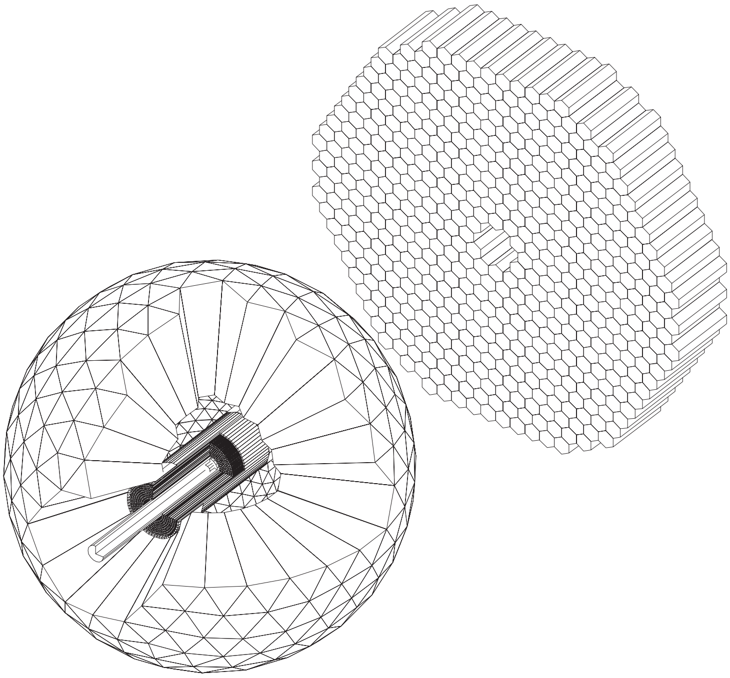

Figure 4: The Crystal Ball and TAPS detectors as they were used for experiments in 2004/2005. The hydrogen target and one cylindrical plastic detector and two MWPCs are located in the central region of the Crystal Ball.

3 Experimental Issues

We propose to measure the reaction $\gamma p \rightarrow \eta\gamma' p$ using a liquid hydrogen target. The experiment requires the detection of the $\eta\gamma'$ in the final state. The detection of the η meson is best done in its neutral decay channels, so that a 4π photon spectrometer is necessary to optimize detection efficiency and minimize systematic effects. We propose to use the Crystal Ball in combination with the TAPS detector at MAMI as shown in Fig. 4 which proved extremely successful in a series of experiments performed 2004/2005. A major focus of this programme was the $\gamma p \rightarrow \pi^0\gamma' p$ reaction to access the Δ^+ MDM, which in terms of apparatus and data analysis was very similar to the present proposed setup. The detection of the η meson is realized in its $3\pi^0$ and 2γ decay modes. The 4π coverage of the phase space is vital to suppress background from other reactions which generate e.g. 8 photons ($\eta\pi^0$ channel) and can be misinterpreted as 7 photons ($3\pi^0\gamma'$) if one photon is missed. Furthermore, positive identification of the rare $\eta\gamma' p$ final state requires measurement of proton momentum, which enables cross checking of correlated kinematic variables in the overdetermined kinematics. A 2mm-thick cylinder of plastic scintillator around the target provides charged particle identification in the CB by ΔE-E and a further two layers of cylindrical MWPC provide charged-particle tracking. For TAPS particle ID is done by time of flight, pulse shape and ΔE-E which is available from the new 5mm plastic scintillator tiles located in front of each TAPS crystal. Photon detection in the present segmented electromagnetic calorimeter relies on the identification of clusters of hits generated by the electromagnetic showers and occasionally a single γ shower may produce two (or more) apparently unconnected clusters. The minor cluster, the so called split off, can be mistaken for a γ'. Since the cross section of the non-radiative η photoproduction is almost three orders of magnitude larger than the radiative process this channel is the source of the split off background. Cuts on the opening angles between the clusters as well as on the measured energy reduces this background. The calculation of the missing mass from the measured proton can be used independently to identify

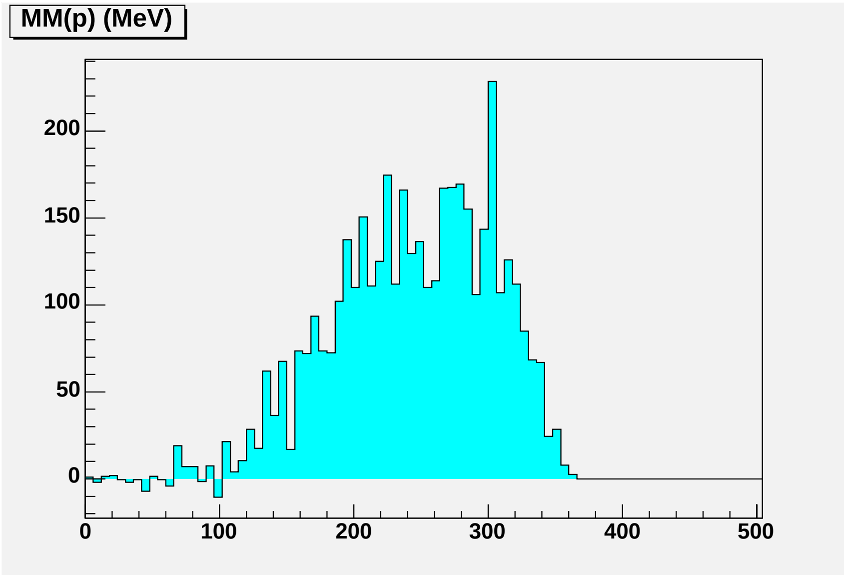

Figure 5: (Data from the 2004/2005 $\Delta^+(1232)$ MDM measurement [Dow05].) Missing mass calculated only from the detected proton for $\gamma p \to \pi^0 \gamma' p$ candidates. Any split off contamination from the reaction $\gamma p \to \pi^0 p$ would show up as a peak at the π^0 invariant mass of 135 MeV.

any split off contamination which arises from the non-radiative channel. Fig. 5 is taken from the current analysis of the $\Delta^+(1232)$ MDM data and shows that the contamination from split offs can be very effectively suppressed. Finally the reaction $\gamma p \to \eta\gamma' p$ will be identified by calculating the missing mass from the measured proton and the η meson in the final state. The information of the measured photon γ' will not be used directly. Fig. 6 shows as an example the recently measured data for the similar case of the Δ^+.
The measurement on the deuterium target of the reaction $\gamma n \to \eta\gamma' n$ is much more ambitious as measurement of the neutron momentum is less precise than for a proton and the reaction kinematics are smeared by nucleon Fermi motion in the deuterium target. This channel requires the detection of the participant nucleon. In this case, the TAPS detector could be used, since it has an excellent time-of-flight resolution and particle recognition capabilities (pulse shape, charged particle veto detectors). The neutron detection characteristics of the Crystal Ball / TAPS setup are being explored in the analysis of the 2004/2005 data. Furthermore, the quasi-free nature of the reaction will be exploited. Detecting the participant nucleon, the four-momentum of the undetected spectator nucleon could be calculated (see Fig. 7). Above 750 MeV the momentum components of the spectator nucleon are all very well centered around zero indicating the dominance of the quasi-free nature of the reaction process. Applying a cut on the three-momentum in each direction around zero, the selection of the quasi-free reaction process can be ensured. As a result, bound state effects or final state interaction is minimized, which makes the application of a reaction model for the production on the deuteron feasible. Furthermore, the radiative η production in coincidence with a proton could be measured and compared to the results from the measurement on the liquid hydrogen target. From this comparison any effect from final state interaction could be identified.
The trigger will be based on a combination of a total energy sum threshold which will be set to ca. 400 MeV and a cluster multiplicity condition ($\geq$ 3 clusters) with individual energy thresholds. This combination will efficiently eliminate background from electromagnetic processes and greatly reduce the dominant hadronic background like single meson photoproduction which ensures a high live time for the data acquisition system without reduction of the available phase space for the $\eta\gamma'$p final state.

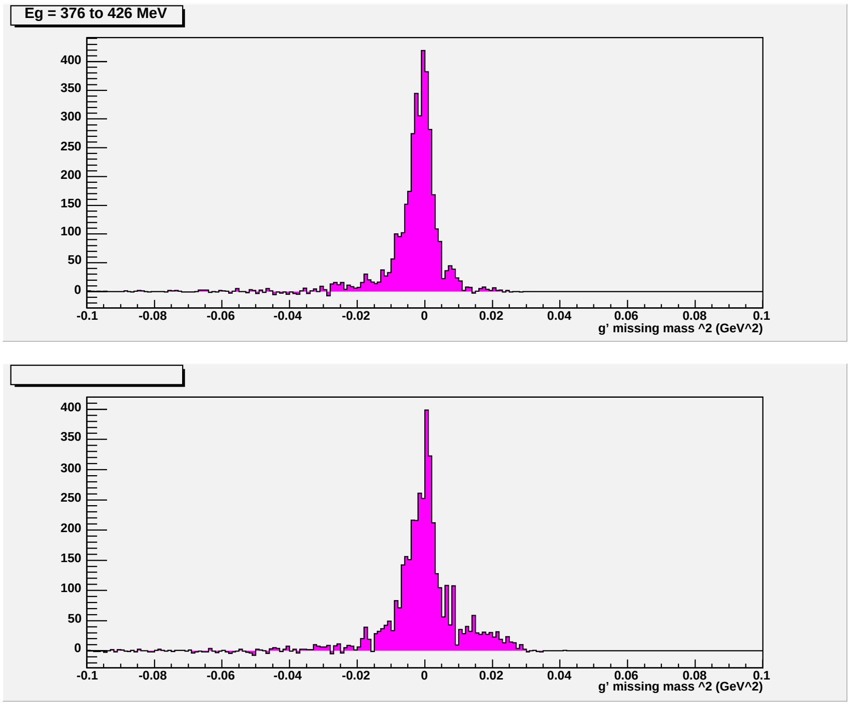

Figure 6: (Data from the 2004/2005 $\Delta^+(1232)$ MDM measurement [Dow05].) Missing mass calculated only from the detected proton and the π^0 meson. The information of the detected γ' is not used. The candidates for $\gamma p \to \pi^0\gamma' p$ show up at a missing mass of 0 GeV^2. At higher incident beam energy (lower picture) a small contribution from the reaction $\gamma p \to 2\pi^0 p$ is visible at a missing mass of $m_{\pi^0}^2 = 0.018$ GeV^2.

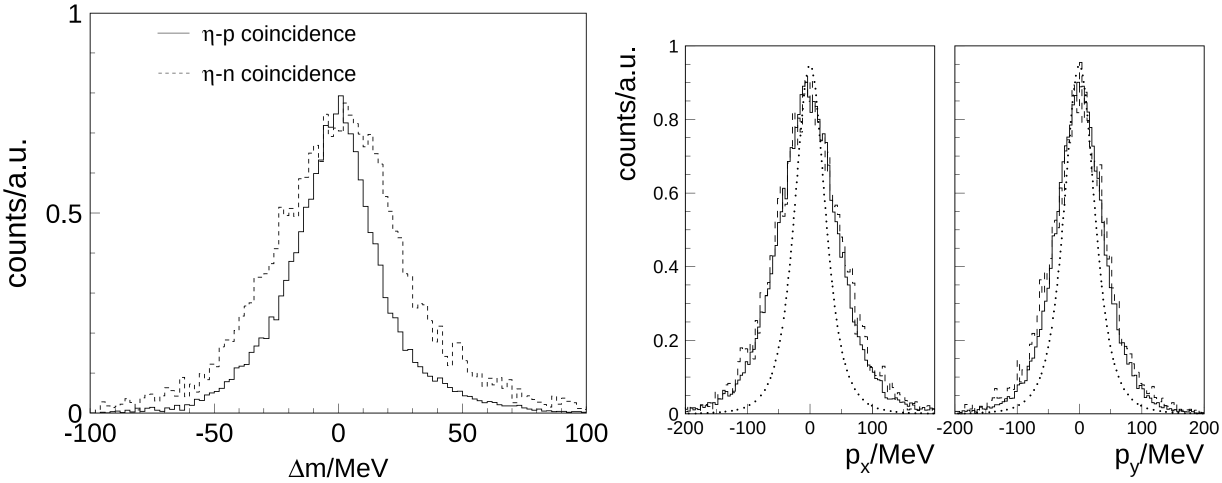

Figure 7: Left: missing mass for the coincident η nucleon system. The mass of the spectator nucleon (939 MeV) is subtracted. Right: Momentum distributions of the (undetected) reconstructed spectator nucleon (solid: proton, dashed: neutron). The dotted curve shows the expectation from the deuteron wave function without taking resolution effects into account. The picture is taken from a measurement of quasi-free η photoproduction on deuterium by Weiss et al. [Wei03].

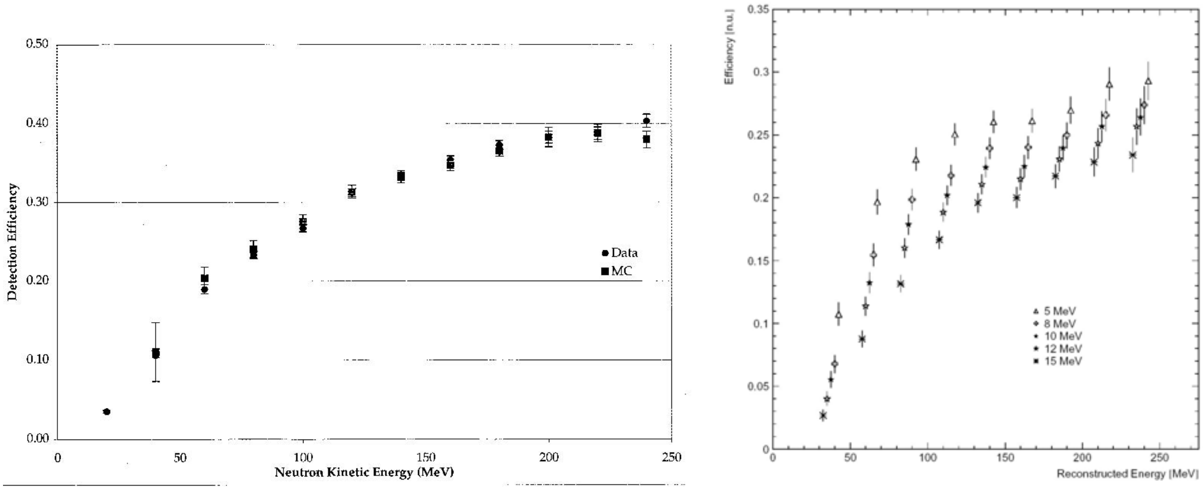

Figure 8: Left: neutron efficiency for the Crystal Ball detector [Sta01]. Right: Neutron efficiency for the TAPS detector as function of the energy threshold [Kot97].

4 Event Rates

The count rate estimate is based on an integrated flux of 55 MHz available at the MAMI accelerator system (a tagging range of 23% - 93% is assumed). This flux was already achieved during the rare η decay beam time end of 2004. This estimate is rather conservative, since the performance of the data acquisition system will be improved. An increase of the flux would directly increase the estimated rates. The required beam energy is available using the upgraded MAMI-C accelerator. The parameters entering the count rate estimate are:

- Incoming electron beam energy: $E_0 = 1.5$ GeV.
- Photon energy range of interest: $E_\gamma^t = 800 - 950$ MeV.
- Integrated photon count rate in the tagger (23%-93%): $N_\gamma = 5.5 \times 10^7\ \frac{1}{s}$.
- Number of protons in a 5 cm long LH_2 target: $N_t = 2.1 \times 10^{23}\ \frac{1}{cm^2}$.
- Average photon efficiency: $\varepsilon_{\eta\gamma} \approx (26\% \times \Gamma_{\eta\to 3\pi^0} + 64\% \times \Gamma_{\eta\to 2\gamma}) \times 0.8 = 27\%$.
- Proton detection efficiency: $\varepsilon_p \approx 90\%$
- Data acquisition system live time: $\varepsilon_{DA} \approx 70\%$.

4.1 Measurement on the Proton

We consider the following properties in the beam energy range of 850-950 MeV. Although we will measure the reaction $\gamma p \to \eta\gamma' p$ over a wider beam energy range, we expect the highest sensitivity for the proton target in that interval.

- Average photon count rate in the tagger 850-950 MeV: $N_\gamma = 5 \times 10^4\ \frac{1}{s}\ \frac{1}{MeV}$.
- Degree of circular polarization $P_\gamma = 57\%$ (assuming 75% polarization of the e^- beam available at MAMI-B)
- Total cross section for $\gamma p \to \eta\gamma' p$ ($E_{\gamma'} \geq 30$ MeV): $\sigma \sim 10$ nb.

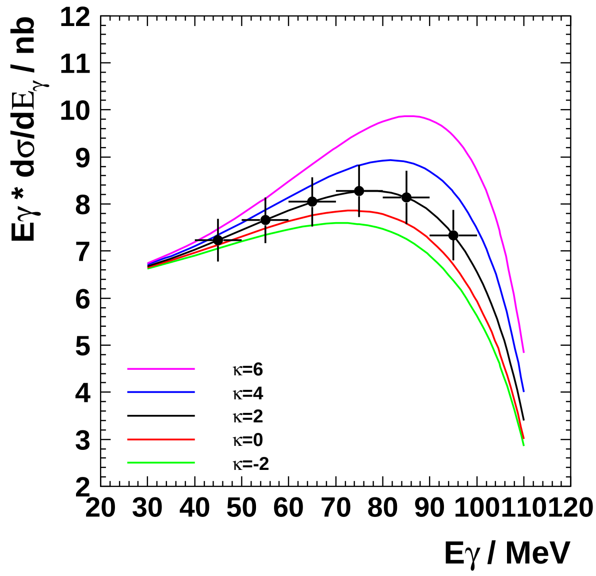

Figure 9: Energy differential cross section with respect to $E_{\gamma'}$ in the γp CM system [Chi03]. The sensitivity of this cross section is shown for an estimated yield of 3200 counts and includes a systematic error of 5%.

The resulting number of events expected per hour for the beam energy range of 850-950 MeV is:

$$N_{\eta\gamma' p} = N_\gamma \; \sigma \; N_t \; \varepsilon_{\eta\gamma} \; \varepsilon_p \; \varepsilon_{DA} \approx 6.4 \; h^{-1}. \tag{2}$$

A beam time of 500 hours would provide about 3200 -$\eta\gamma' p$ events in the incident beam energy range of 850-950 MeV. We have estimated the sensitivity to the magnetic moment within the model [Chi03] from the energy differential cross section solely. For this purpose an anomalous magnetic moment of $\kappa = 2.0$ ($\mu = 1.8\mu_N$) has been chosen, a quadratically combined error of the statistical uncertainty (3200 counts) and a systematic error of 5% has been assumed. A χ^2-test yields a very promising accuracy of $1.8^{+0.56}_{-0.58}\mu_N$. Moreover, other observables (angular differential cross section and the helicity asymmetry Σ_{circ}) will add further non-redundant sensitivity. Therefore, we expect that this measurement will yield a significant result.

4.2 Measurement on the Neutron

We consider the following properties in the beam energy range of 800-950 MeV. We expect a constant large sensitivity in case of the neutron at smaller beam energy (and therefore smaller $E_{\gamma'}$) since the $1/E_\gamma$ bremsstrahlung from the nucleon is greatly suppressed.

- Average photon count rate in the tagger 800-950 MeV: $N_\gamma = 5 \times 10^4 \; \frac{1}{s} \; \frac{1}{MeV}$.
- Total cross section for $\gamma p \to \eta\gamma' p$ ($E_{\gamma'} \geq 30$ MeV): $\sigma \sim 0.5 - 5$ nb ($\kappa_{S_{11}(1535)} = -3 \ldots 3 \; \mu_N$, compare Fig. 3).
- Neutron detection efficiency of 25% (see Fig. 8)

The resulting number of events expected per hour for the beam energy range of 800-950 MeV is:

$$N_{\eta\gamma' p} = N_\gamma \; \sigma \; N_t \; \varepsilon_{\eta\gamma} \; \varepsilon_n \; \varepsilon_{DA} \approx 0.14...1.4 \; h^{-1}. \tag{3}$$

A beam time of 500 hours would provide about 70. . . 700-$\eta\gamma' n$ events in the incident beam energy range of 800-950 MeV. This rather small number should be compared to the very large sensitivity in case of the neutron, since the bremsstrahlung contribution from charged particles is absent (compare Fig. 3). In other words our experiment will be able to determine the cross section for the production on the neutron. Additionally, we expect the same statistics for the -$\eta\gamma' p$ channel from the deuteron target as measured on the liquid hydrogen target. Consequently, a detailed comparison can be made between the $\eta\gamma'$ off the proton and the quasi-free $\eta\gamma'$ production on the deuteron, allowing to demonstrate the feasibility of this method, which is based on the quasi-free nature of the process and the absence of final state effects.

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