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RECOIL POLARIZATION MEASUREMENTS WITH CB@MAMI

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Abstract

The photoproduction of mesons from a nucleon target is a valuable tool for investigating the underlying structure of the nucleon. Many of the available tagged photon facilties are prioritising the measurement of double polarization observables, in particular experiments with a polarized beam and polarized target. Additionally, measurements of the recoil hadron polarization have been successfully achieved for kaon production, where the weak decay of the produced hyperon contains information on its polarization. For π and η photoproduction the situation is less favourable and a subsequent nuclear scattering interaction is required to deduce the recoiling proton polarization. This talk describes a novel technique to measure recoil polarization using the upgraded Glasgow tagger along with the Crystal Ball detector systems currently in place in the A2 hall at MAMI.

1 Introduction

The last ten years has seen a huge advance in the quantity and quality of photoproduction data from a variety of different labs. Facilities such as MAMI, ELSA, JLAB, GRAAL and LEPS have contributed greatly to this progress utilising high duty factor tagged photon beams and high quality polarized beam and targets. Despite these advances the current experimental situation for recoil polarization observables is much less favourable, due to the requirement of a secondary scattering interaction. However without this crucial information the photoproduction amplitudes and the wealth of information therein, relating to couplings and resonances, cannot be fully constrained in a model independent analysis. Measurement of the recoil polarization in photoproduction reactions is therefore both necessary and timely.

1.1 Pseudoscalar meson photoproduction

The photoproduction of pseudoscalar mesons from a nucleon target, fig. (1), can be described by 16 observables: the differential cross section, 3 single polarization observables (recoil polarization P, target polarization T , beam asymmetry Σ) and a further 12 double polarization observables with combinations of beam, target and recoil polarizations. For these proceedings we will focus on observables that can be measured with a polarized beam and recoil polarization. The differential cross section for such measurements can be written as [1],

$$\rho_f \frac{d\sigma}{d\Omega} = \frac{1}{2}\frac{d\sigma}{d\Omega}_{un} \left\{1 - P_\gamma^T \Sigma \cos 2\phi - \sigma_{x'}\left(P_\gamma^T O_x \sin 2\phi + P_\gamma^C C_x\right) + \sigma_{y'}\left(P - P_\gamma^T T \cos 2\phi\right) - \sigma_{z'}\left(P_\gamma^T O_z \sin 2\phi + P_\gamma^C C_z\right)\right\} \quad (1)$$

where O_x, C_x, O_z and C_z are the relevant double polarization observables and P_γ^T and P_γ^C the beam linear and circular polarization respectively. The matrices $\sigma_{i'}$ refer to the hadron quantisation axis of fig. (1) and ρ_f its density matrix. The proposed experiment will potentially allow measurement of 4 observables O_x, C_x,P and T. Together with previous and ongoing measurement of $\frac{d\sigma}{d\Omega}$, Σ, and the beam target observables G and E they will provide the 8 observables necessary to fully constrain the photoproduction amplitudes for the first time [2].

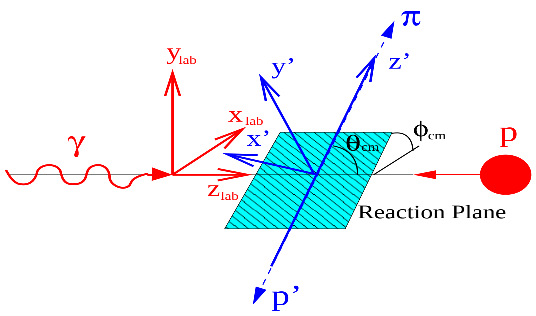

Figure 1: Reference frames in pion photoproduction.

2 Polarimetry with the Crystal Ball/TAPS

2.1 Nucleon Polarimetery

Nucleon polarimeters typically employ nucleon-nucleus scattering interactions which, due to the spin-orbit potential, produce asymmetries proportional to the transverse polarization of the nucleon. This naturally leads to a new reference frame (double primed) with the z-axis along the nucleon momentum direction and y-axis perpendicular to the reaction plane, both in the lab. The resulting azimuthal scattering distribution is then given by,

$$n(\phi_{sc}) = n_o\{1 + A[P''_y \cos\phi_{sc} - P''_x \sin\phi_{sc}]\} \tag{2}$$

where ϕ_{sc} is the azimuthal scattering angle and A the analysing power. This allows the polarization components to be extracted from fits to the $n(\phi_{sc})$ distribution after modeling the detector acceptance, or in the case of polarized beam experiments from fits to spin flip asymmetries where the acceptance cancels.

2.2 Polarization Components

Eq. 1 allows us to determine the polarization of the recoiling nucleon in terms of the photoproduction observables. These are found to be for the different beam polarizations,

Circularly Polarized beam

$P_x = P^C_\gamma C_x, \qquad P_y = P, \qquad P_z = -P^C_\gamma C_z$

Linearly Polarized beam

$P_x = \frac{-P^T_\gamma O_x \sin 2\phi}{\left(1-P^T_\gamma \Sigma \cos 2\phi\right)}, \qquad P_y = \frac{P-P^T_\gamma T \cos 2\phi}{\left(1-P^T_\gamma \Sigma \cos 2\phi\right)}, \qquad P_z = \frac{-P^T_\gamma O_z \sin 2\phi}{\left(1-P^T_\gamma \Sigma \cos 2\phi\right)}$

These polarizations must be rotated around the y-axis into the double-primed frame to compare to the polarizations seen by the polarimeter in eqn. (2).

2.3 The Crystal Ball Polarimeter

The Crystal Ball (CB), is an electromagnetic calorimeter comprising 672 NaI crystals arranged spherically and covering 94% of 4π. The forward beam exit hole of the CB is instrumented by the TAPS BaF_2 detector array. Such an arrangement is ideal for detecting the decay photons of neutral mesons such

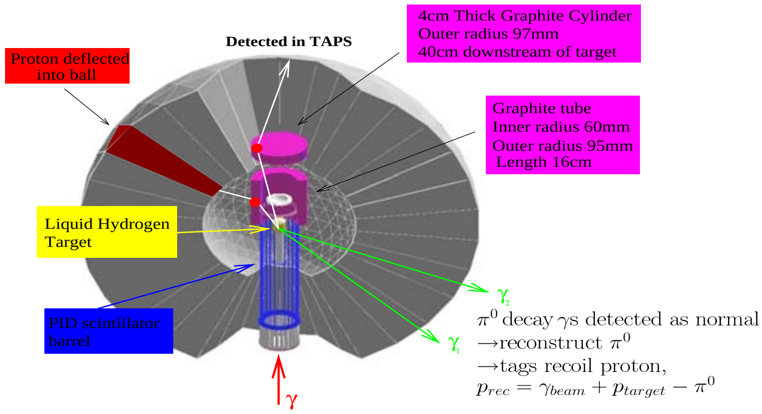

Figure 2: Proposed Crystal Ball polarimeter

as the π^0 and η and the high segmentation allows accurate reconstruction of the meson 4-vectors. In addition as the incident photon 4-vector is accurately determined by the Glasgow photon tagger, the reaction kinematics of meson photoproduction allows accurate reconstruction of the recoil proton 4-vector.

Now, placing a tube of graphite around the proton target at the centre of the ball and a disc of graphite at forward angles shadowing TAPS, as shown in fig. (2), allows the protons to undergo polarized scattering reactions. Subsequent detection of the scattered nucleons in either the CB or TAPS allows reconstruction of the scattered proton direction given its initial momentum from the previous π^0-tagger analysis. In this way azimuthal scattering asymmetries can be produced and thus the polarizations extracted.

The design illustrated in fig. 2, will be tested in October 2007. The proposed device will allow a full programme of measurements to be undertaken in the coming years on a variety of photoproduction reactions, giving new measurements of polarization observables in π, η and 2π production while taking full advantage of the upgraded MAMI-C facility.

References

[1] I.S. Barker, A. Donnachie and J.K. Storrow, *Nuc. Phys. B* **95**, 347 (1975).

[2] Wen-Tai Chiang and Frank Tabakin, *Phys. Rev. C* **55**, 2054 (1975).