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Mainz Microtron MAMI

Collaboration A1: "Virtual Photons"

Spokesperson: R. Neuhausen

Proposal for an experiment

Separation of transverse and longitudinal structure functions in $p(e, e'\pi^+)n$ at $W = 1125\,\mathrm{MeV}$, $Q^2 = 0.07\,(\mathrm{GeV/c})^2$ in parallel kinematics

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Abstract:

We request 96 hours of beam-time for a measurement of the transverse and longitudinal structure functions for the reaction $^1H(e, e'\pi^+)n$. The measurements will be carried out at a pion-nucleon centre-of-mass energy of 1125 MeV, at four-momentum transfer of $Q^2 = 0.07\,(\mathrm{GeV/c})^2$. Pions will be measured in the direction of the virtual photon.

1. Introduction and motivation

For unpolarised electrons and unpolarised target, the differential cross section for $p(e, e'\pi^+)n$ can be written in the following form [1]:

$$\frac{d\sigma}{d\Omega dE' d\Omega_\pi^*} = \Gamma \frac{d\sigma_v}{d\Omega_\pi^*} \tag{1.1}$$

where

$$\frac{d\sigma_v}{d\Omega_\pi^*} = \frac{d\sigma_T}{d\Omega_\pi^*} + \epsilon_L \frac{d\sigma_L}{d\Omega_\pi^*} + \sqrt{2\epsilon_L(1+\epsilon)}\,\frac{d\sigma_{LT}}{d\Omega_\pi^*}\cos\phi_\pi^* + \epsilon\frac{d\sigma_{TT}}{d\Omega_\pi^*}\cos 2\phi_\pi^* \,. \tag{1.2}$$

The virtual photon flux per scattered electron in $dE'd\Omega$ is given by the expression

$$\Gamma = \frac{\alpha}{2\pi^2}\frac{E'}{E}\frac{k_\gamma}{Q^2}\frac{1}{1-\epsilon} \,. \tag{1.3}$$

where the transverse and longitudinal polarisation of the virtual photon are denoted by ϵ and ϵ_L, respectively:

$$\epsilon = \left(1 + 2\frac{|\vec{k}|^2}{Q^2}\tan^2\frac{\theta_e}{2}\right)^{-1} \quad \text{and} \quad \epsilon_L = \epsilon\frac{Q^2}{\omega^{*2}} \,. \tag{1.4}$$

The pion angles θ_π^* and ϕ_π^* given in the centre-of-mass system. In parallel kinematics ($\theta_\pi^* = 0$) the interference terms σ_{LT} and σ_{TT} vanish due to their $\sin\theta_\pi^*$ and $\sin^2\theta_\pi^*$ dependence, respectively.

By variation of ϵ_L, the longitudinal and transverse contributions can be disentangled by Rosenbluth separation. This method was successfully applied to our previous measurement [2, 3] which aimed at a precise extraction of the axial mass parameter M_A from the transverse cross section (figure 1.1).

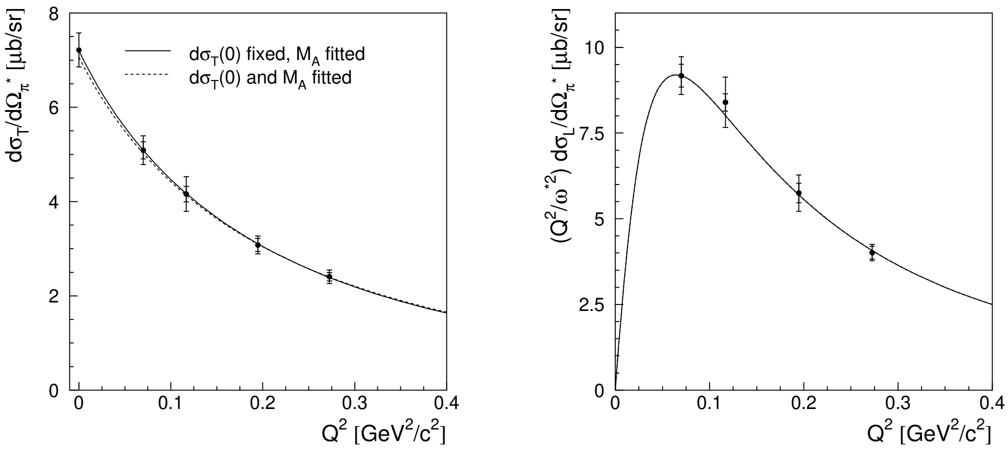

Figure 1.1: Separated transverse and longitudinal cross sections for $p(e, e'\pi^+)n$ from a previous measurement [3]. The solid line shows the theoretical fit with $d\sigma_T/d\Omega_\pi^*(Q^2 = 0)$ fixed to (7.22 ± 0.36) μb/sr; the dotted line is the unconstrained fit. The smaller error bars correspond to statistical, the larger ones to the sum of statistical and systematical errors. The data points at $Q^2 = 0.07\,(\text{GeV}/c)^2$ represent expected values and their uncertainties.

To pin down the low-Q^2 end of the transverse cross section, however, a rather imprecise value of $d\sigma_T$ at $Q^2 = 0$ had to be adopted from available (scarce) low-energy photo-production data [5, 6]. From the viewpoint of the axial mass parameter, an additional data point in the vicinity of the photon point would significantly improve the reliability of the extraction since the theoretical fit is most sensitive to data points at lower values of Q^2. We expect to achieve a total uncertainty on both $d\sigma_T$ and $d\sigma_L$ below 6 %, so the statistical and the systematical uncertainty of the measurement at the proposed value of Q^2 could be reduced with respect to the lowest existing data point at $Q^2 = 0.117\,(\mathrm{GeV}/c)^2$ by at least 3 %.

2. Experimental requirements

The standard setup of the three-spectrometer facility at MAMI can be used. We require an unpolarised electron beam with 25 μA current. A liquid hydrogen target will be used with the extended target cell of 5 cm length and with walls of 10 μm Havar.

Spectrometer A will be used for detection of the scattered electrons, and spectrometer B for the detection of pions. In addition, the kinematical setting at the highest ϵ will be *also* performed by measuring electrons in spectrometer B and pions in spectrometer A to get a better grip on the systematical uncertainty due to the muon contamination. Spectrometer C will detect elastic electron scattering at a constant backward angle and will be used as a luminosity monitor.

3. Kinematics and counting rate estimates

We choose an invariant mass of $W = 1125\,\mathrm{MeV}$ and a four-momentum transfer of $Q^2 = 0.07\,(\mathrm{GeV}/c)^2$. For performing a longitudinal-transverse separation, it is important to have the lever arm in ϵ as large as possible. According to the experience of the previous experiments [4, 3], the lever arm for the chosen value of Q^2 appears to be sufficient. In table 3.1 the kinematic variables are listed in detail.

Q^2	ϵ	E	E'	$\theta_{e'}$	θ_π	p_π	$\exp(-\Delta t/\gamma\tau)$	$d\sigma/dE'd\Omega d\Omega_\pi$
$(\mathrm{GeV}/c)^2$		MeV	MeV	$^\circ$	$^\circ$	MeV/c		pb/MeV sr^2
0.07	0.887	855	612.4	21.1	37.8	174.4	0.313	95.0
	0.887	855	612.4	21.1	37.8		0.273	95.0
	0.571	465	222.4	48.6	27.6		0.273	13.0
	0.277	360	117.4	80.2	18.7		0.273	3.84

Table 3.1: Kinematic parameters for the measurement at $W = 1125\,\mathrm{MeV}$. The cross sections were calculated by the MAID program [6]. The pion survival fractions were calculated by an exponential decay formula averaged over the pion flight lengths. For $\epsilon = 0.887$, spectrometers A and B will be used interchangeably as the electron and the pion spectrometer.

With the standard liquid hydrogen target and a 5 cm extended target cell a luminosity of $115\,\mathrm{fb}^{-1}\mathrm{h}^{-1} = 3.2 \cdot 10^{37}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$ is attainable, assuming a beam current of 25 μA. For a satisfactory Rosenbluth separation, 10000 true coincidences per measuring point will be necessary [3]. A simulation then gives the coincidence counting rates as in table 3.2.

Q^2	ϵ	rate	measuring time
$(\mathrm{GeV/c})^2$		s^{-1}	h
0.07	0.887	2.5	3
	0.887	1.6	3
	0.571	0.21	16
	0.277	0.059	57
Σ			79

Table 3.2: Expected coincidence counting rates and proposed measuring times for $\geq$ 10000 events per setting. Rates are for the 5.6 msr collimator in spectrometer B and for the 21 msr collimator in spectrometer A.

4. Beam-time request

We request 96 hours of beam-time, according to the following schedule:

▷ Before the run we need about 3 working days to install the cryogenic target.

▷ We intend to collect at least 10000 true coincidences per point, which is estimated to require 79 hours, in total.

▷ Calibration runs will add another 2 hours per ϵ setting, i. e. 8 hours in total.

▷ In addition, we need 3 changes of our spectrometer setup (magnetic field, spectrometer angles) or of MAMI beam energy, requiring 9 hours.

References

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