VIRTUAL COMPTON SCATTERING AND NEUTRAL PION ELECTRO-PRODUCTION FROM THE PROTON IN THE NUCLEON RESONANCE REGION

L.TODOR

Carnegie Mellon University, Pittsburgh, PA 15213

VCS COLLABORATION

Jefferson Lab, Newport News, VA 23606

The Experiment (E93-050) at Jefferson Lab measured the $ep \rightarrow ep\gamma$ and $ep \rightarrow ep\pi^0$ cross sections in the nucleon resonance region, from threshold to $W = 1.9$ GeV at $Q^2 = 1$ GeV² for backward emission of the γ or π^0 .

1 Introduction

The electro-production of resonances from the proton followed by photo-decay, known as Virtual Compton Scattering (VCS) is a necessary element of the study of resonances together with the meson decaying channels. The $p(e, e'p')\gamma$ amplitude is the coherent sum of VCS and Bethe-Heitler (BH) amplitudes. In the BH process, the final real photon is emitted by the electron either before or after the interaction with the proton. The BH amplitude peaks in the directions of the incident and scattered electron. The experimental kinematics were chosen such that for the VCS reaction, the virtual photon and the final photon were back to back. In this case the BH amplitude is minimized¹.

2 Experimental Details

The experiment ran in March-April 1998 and used the TJNAF 4 GeV electron beam incident on Hall A liquid hydrogen target with a luminosity $\geq 4 \cdot 10^{38}$ cm⁻² s⁻¹. The scattered electron and proton were detected in coincidence with the two Hall A high resolution spectrometers (HRS). Each HRS consists of a QQDQ magnetic system and a detection package with scintillators, wire chambers, and a electromagnetic calorimeter. The electron spectrometer was set to detect scattered electrons corresponding at a fixed 4-momentum transfer of $Q^2 = 1$ GeV². The energy transfer from the electron was varied so that for the VCS reaction, the invariant mass for the virtual photon plus proton system ranged from 1.0 GeV to 1.9 GeV. We identified the true coincidences using both time and space coincidence. For the coincidence time-of-flight resulting

from back-projecting the detected particles to the target we reconstruct the true coincidence with a FWHM of 1.2 ns. Comparing the transverse vertex position as determined from the crossing of the detected charged particles trajectories with the instantaneous beam position we reconstruct the true coincidence with a FWHM of 2.0 mm. We identified the undetected particle in the final state (π^0 or γ) using the missing mass technique. Although the purpose of the experiment was to measure the $p(e, e'p')\gamma$ cross-section, within the acceptance we measured the $p(e, e'p')\pi^0$ cross-section in a kinematic region poorly covered previously.

3 $p(e, e'p')\gamma$ Cross-section

Figure 1. $p(e, e'p')\gamma$ cross-section function of center of mass energy W for $Q^2 = 1 \text{ GeV}^2$, and $\cos \theta_{cm} = -0.975$. Φ is the azimuthal angle between the leptonic and hadronic scattering planes. θ_{cm} is the polar angle between the emitted photon and the direction of momentum transfer from the electron. The black curves represent the calculated BH+Born cross-section and the blue are the values calculated with the dispersion relation formalism.

The 5-fold differential cross section was evaluated in the phase-space W , Q^2 , ϕ_e , θ_{cm} , Φ . We compared our results with the model prediction using

dispersion relation formalism² and the BH plus Born (proton in intermediate state) calculation. We note at $\Phi = 15^\circ$ and 165° , the destructive and constructive interference, respectively, of the BH and VCS amplitudes near $W = 1$ GeV. At large W we also note the agreement between the data and the BH+Born calculation, suggesting a cancellation of the contributions of excited intermediate states.

4 $p(e, e'p')\pi^0$ Cross-section

The 5-fold differential cross section is usually described (Hand convention) as a product between a photon flux and the 2-fold differential cross section. Using the angular distribution we extract the transverse and longitudinal terms of the cross section.

$$\frac{d^5\sigma}{dk_e \cdot d\Omega_e \cdot d\Omega_p} = \frac{\alpha_{QED}}{2\pi^2} \frac{k_{e'}}{k_e} \frac{W^2 - M_p^2}{2M_p \cdot Q^2} \frac{1}{1 - \epsilon} \cdot \left[\frac{d^2\sigma_T}{d\Omega_p} + \epsilon \cdot \frac{d^2\sigma_L}{d\Omega_p} + \sqrt{2\epsilon(1 + \epsilon)} \cdot \frac{d^2\sigma_{LT}}{d\Omega_p} \cos \Phi + \epsilon \cdot \frac{d^2\sigma_{TT}}{d\Omega_p} \cos 2\Phi \right]$$

We used the MAID2000 (Unitary Isobar Model) parametrisation³ in our simulation to extract the $p(e, e'p')\pi^0$ differential cross-sections. From our results, the MAID photon point parameters were readjusted; substantial differences were noticed for $S_{11}(1535)$, $S_{31}(1620)$ and $D_{33}(1700)$ parameters (Fig. 4). Similar comparison was performed for SAID model.

5 Conclusion

The π^0 and γ electro-production reactions were measured simultaneously, in the $H(e, e'p)X$ at $Q^2 = 1$ GeV², with the proton detected parallel to the virtual photon direction. These are the first ever measurements of the excitation function of the VCS process in the resonance region. The VCS data show a strong interference between the Compton and Bethe-Heitler processes at low W , and a smooth convergence towards the Born cross-section at high W . In the π^0 electroproduction case, the three cross sections $d\sigma_T + \epsilon d\sigma_L$, $d\sigma_{TL}$, and $d\sigma_{TT}$ are separated. Above the Δ resonance, there are strong disagreements between the data and the MAID2000, and SAID parameterizations. This reflects the limited previous data set on π^0 electroproduction.

Acknowledgments

The collaboration thanks to Hall A technical staff for their support during this experiment. The Southern Universities Research Association (SURA)

Figure 2. $p(e, e'p')\pi^0$ separated cross-sections as functions of center of mass energy W , at $Q^2 = 1 \text{ GeV}^2$, and $\cos\theta_{cm} = -0.975$.

operates the Thomas Jefferson National Accelerator Facility for the United States Department of Energy under contract DE-AC05-84ER40150.

References

1. P.Y. Bertin, C. Hyde-Wright and P.A.M. Guichon, Jefferson Lab PR93050, (1993).
2. B. Pasquini et al., *Phys. Rev. C* **62**, 052201 (2001).
3. D. Drechsel et al., *Nucl. Phys. A* **645**, 145 (1999).