Hard Exclusive and Semi-exclusive Vector Meson Production

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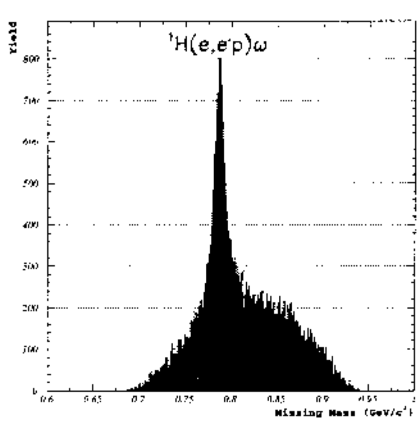
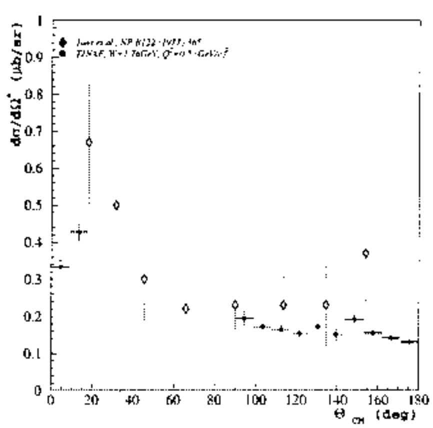
1. Electroproduction of Vector Mesons

Electroproduction of vector mesons is a sensitive tool for probing hadronic structure. Diffractive production is sensitive to both the nucleon and meson structures. Non-diffractive production is sensitive to not only the nucleon structure but also to s-channel decays of N^*-resonances into the ωp final state.[1]

Experimentally, such studies are well suited to Jefferson Lab. Of particular interest regarding the energy upgrade is the ability to exploit small angles (*i.e.*, with the septa magnets in Hall A) and/or spin degrees of freedom (with polarized electron beams and either target polarization or recoil proton polarization using the Hall A FPP).

Here we report on the $^1\mathrm{H}(\mathrm{e},\mathrm{e}'\mathrm{p})\omega$ reaction. The data were taken in Hall C during the fall of 1996 during E91-016 (B. Zeidman, Spokesperson) and E93-018 (O.K. Baker, Spokesperson). Electrons of energy upto 4 GeV were incident on a 4 cm liquid hydrogen target. Scattered electrons were detected in the HMS spectrometer, and the scatterered hadrons (p, π, or K) were detected in the SOS spectrometer. $^1\mathrm{H}(\mathrm{e},\mathrm{e}'\mathrm{p})\omega$ data were obtained parasitically to $^1\mathrm{H}(\mathrm{e},\mathrm{e}'\mathrm{K})\mathrm{Y}$ data. The missing mass technique identified the unobserved particle in $^1\mathrm{H}(\mathrm{e},\mathrm{e}'\mathrm{p})\mathrm{X}$ as the ω-vector meson. As seen in Figure 1a, the missing mass spectrum also has multi-particle continuum states (the "2π" final states) underneath the ω peak.



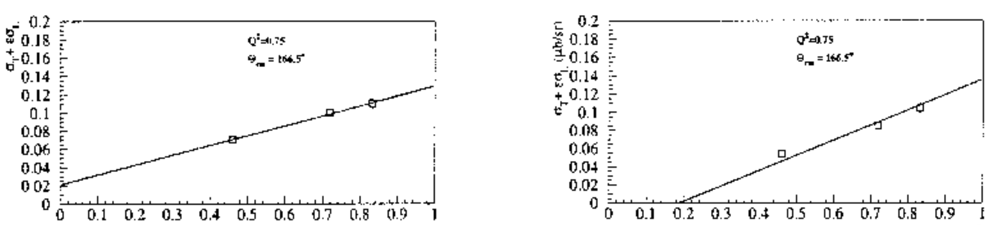


As part of a general program, ω production may isolate the isoscalar structure of the nucleon in the same way that ϕ production may isolate the $s\bar{s}$ structure. However such interpretations are model dependent. The present data set can be used to test the methodology of proposed measurements of observables in ϕ electroproduction where the cross sections, polarizations and angular distributions are not well known. Such measurements on the ϕ are the subject of an LOI submitted to TJNAF PAC14 by the FIU group.

Important production mechanisms for the ω include diffractive production (which in electroproduction is a subset of VMD, where the virtual photon fluctuates to a vector meson with the same quantum numbers which then scatters hadronically from the proton). The Q^2 dependence of the cross section should then exhibit a monopole dependence, $\sigma \sim (\frac{m_v^2}{m_v^2+Q^2})^2$. Additionally several resonances are predicted to have large branching ratios to the ωN-channel. Diffractive production is expected to dominate at forward COM angles, dropping off exponentially with the center-of-mass angle. At intemdiate angles the s-channel resonances should be important and at backward angles the u-channel production is important.

The current data cover the threshold region ($1.72 < W < 1.9$) and 4-momentum transfers of $Q^2 = 0.376, 0.5, 0.75, 1.0, 1.5, 2.0$ with a complete angular distribution at $Q^2 = 0.5$ and partial distributions at the other Q^2 values. At $Q^2 = 0.5, 0.75, 1.0, 2.0$ there is also an L/T separation for the backward angles. To analysize the data, it was binned in Q^2, W, Ω_ω^* (the center-of-mass angle), and M_x. After correcting for inefficiencies and deadtimes, the accidental coincidences were subtracted. The data was normalized by the luminosity and divided by the Monte Carlo-calculated acceptance. The multi-particle background was subtracted by using the Monte Carlo-calculated shape, normalized to the data. The integrated missing mass was divided by the virtual photon flux to extract the virtual photoproduction cross section: $\frac{d^5\sigma}{d\Omega_e dE' d\Omega_h} = \Gamma \frac{d\sigma}{d\Omega^*}$.

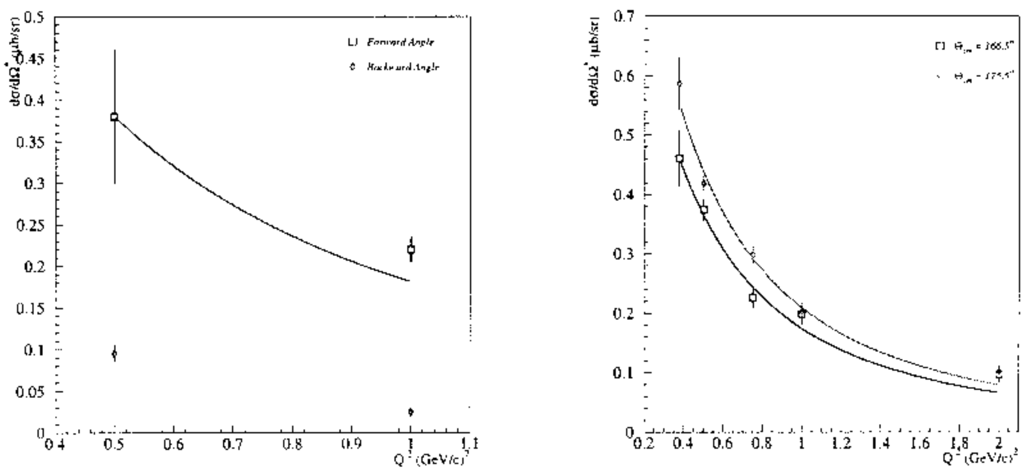
The $\frac{d\sigma}{d\Omega^*} = \sigma_T + \varepsilon\sigma_L$ cross section shows a rapid rise with W at threshold. Figure 1b shows some of the data for $W = 1.76 \pm .045$ GeV and $Q^2 = 0.5$ (GeV/c)^2 along with previous data. No radiative corrections have been done. The statistical uncertainty and the angular range of the new data are improved (the W and Q^2 bins are significantly smaller) and the data is also consistent with the previous data[2].



At $Q^2 = 0.75$, a L/T separation has been done for the backward angles. Although no radiative corrections were yet applied to the data, the bin size in Q^2, W and t was kept the same between forward and backward angles in order to ensure that the size of the correction would be the same. Plotted in Figures 2a and 2b are the reduced cross section versus ε, the virtual photon polarization for Θ_{CM}= 166.5 and 175.5 degrees. As seen, the cross section at the backward angles is mainly longitudinal. The diffractive production is mainly transverse at this Q^2.

At the forward angles, the cross section should be diffractive, with a form given by: $\sigma(Q^2, W) = \frac{P(0)}{P(Q^2)}(1+\epsilon R)(\frac{m_V^2}{m_V^2+Q^2})^2 9.3 e^{bt}(1+\frac{1.4}{E_\gamma})$[1]. Figure 3a shows 'forward' (i.e., $\Theta_C M = 4.5 \pm 4.5$ degree) and 'backward' ($\Theta_C M = 175.5 \pm 4.5$ degree) data for $Q^2 = 0.5, 1.0$ and $W = 1.76$. The forward data agrees well with a monopole form factor (shown by the red curve). However, the forward data is corrected in t (Q^2 =0.5 and 1.0 were both taken at $t = t_{min}$ but the value of t_{min} increases with Q^2). The t-dependence is given in diffractive VMD.

Figure 3b shows the backward data versus Q^2. Again the unseparated cross section is plotted (only $Q^2 = 0.75$ has so far had an L/T separation done). The value of t_{max} also increases with Q^2. However no correction was done for these different values of t. [Since the L/T separation shows that the backward data is not described by diffractive production, there is no guide how to correct the data.] The uncorrected data follow a monopole form factor (as seen by the curves), indicating that some form of VMD may be the dominant mechanism (although not diffraction).



Remaining analysis includes extrapolating the forward angle data to find the exponential slope (the b parameter), a detailed angular dependence as a function of W, and L/T separations at the other momentum transfers (which will enable a Q^2 study of σ_L and σ_T. The large data set (> 70K ω's) and precise kinematics will give a detailed study of the production mechanism at threshold will yield new information on vector meson electroproduction.

References

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[2] P. Joos, et. al., Nucl. Phys. **B113** (1976) 93.