Light Vector Meson Photoproduction off of ^{1}H at Jefferson Lab and ρ-ω Interference in the Leptonic Decay Channel

Chaden Djalali[1,a], Michael Paolone[a], Rakhsha Nasseripour[b], Michael Wood[c], Dennis Weygand[d], and the CLAS Collaboration
[a]*University of South Carolina, Columbia SC, USA*
[b]*George Washington University, Washington DC, USA*
[c]*Canisius College, Buffalo NY, USA*
[d]*Thomas Jefferson National Accelerator Facility, Newport News VA, USA*

Recent studies of light vector meson production in heavy nuclear targets has generated interest in ρ-ω interference in the leptonic e^+e^- decay channel. An experimental study of the elementary process provides valuable input for theoretical models and calculations. In experiment E04-005 (g12), high statistics photoproduction data has been taken in Jefferson Lab's Hall B with the Cebaf Large Acceptance Spectrometer (CLAS). The invariant mass spectrum is fitted with two interfering relativistic Breit-Wigner functions to determine the interference phase. Preliminary analysis indicate a measurable ρ-ω interference.

1 Introduction

Partial restoration of chiral symmetry in ordinary nuclear matter suggests the modification of properties of vector mesons, such as a shift in mass and/or a change of width. Recently, several experiments have studied the properties of the ρ, ω and ϕ mesons in the medium via their rare leptonic decay to e^+e^- pairs. The ρ meson has a very short lifetime leading to the largest probability of decaying in the medium, while the ω and ϕ mesons (with their longer lifetimes) will mostly decay outside the medium in which they are produced. In most experiments,the majority of the ω and ϕ mesons decay outside of the medium and therefore their mass spectra are consistent with their free-space properties. However the information on the in-medium widths of these mesons can be extracted from their interactions with the nucleons as the mesons escape the nucleus using transparency ratios. Reference [1] discusses and compares these studies. The JLab transparency ratios drop faster that the CBELSA-TAPS ratios indicating an even larger in-medium width ($\Gamma_\omega \geqslant 200$ MeV). The very large ω-meson absorption observed in the e^+e^- channel cannot be explained with the

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[1] djalali@sc.edu

current theoretical calculations. One explanation could be a destructive ρ-ω interference in nuclei. Interference due to ρ-ω mixing was first suggested by Glashow [2] in 1961. In the seventies, several experiments on C and Be targets and strong ρ-ω interference were observed in γA→ e^+e^-(X) reactions. [3–6]. Further motivation for the current study was based on calculations by Lutz and Soyeur [7] that predict relatively large ρ-ω interference in the γN→ e^+e^-N reaction (constructive interference on p, destructive interference on n).

2 The g12 experiment at JLab

The JLab E04-005 experiment (a.k.a. CLAS experiment g12) main purpose was to study exotic meson production and excited cascade states through photoproduction. The study of the vector mesons and their decays in e^+e^- was conducted in parallel. A tagged photon beam of energies up to 5.5 GeV was used on a liquid hydrogen target cell 40 cm in length and 4 cm in diameter. The target cell was placed 90 cm upstream from the CLAS center to increase coverage of very forward angle particles. The Electromagnetic Calorimeter (EC) and the Cherenkov Counter (CC) are the critical component of CLAS which lead to an e/π rejection factor better than 10^{-6} for di-lepton pairs. The experimental procedure is described in detail in Ref. [9].

In addition to the channels of interest ($\rho, \omega, \phi \rightarrow e^+e^-$), two other physical channels (treated as "background" in this study) are the Dalitz decays of mesons and the Bethe-Heitler pair production. For either of these channels, a simple cut on the opening angle of the e^+e^- pair significantly reduces their contributions. It almost eliminates all Dalitz decay events and substantially reduces the Bethe-Heitler "background". The remaining Bethe-Heitler contribution can be easily estimated and subtracted. If one looks at the inclusive reaction $\gamma p \rightarrow e^+e^-X$, one has to take into account the combinatorial e^+e^- background which arises from leptons from uncorrelated events. The magnitude and shape of this background can be determined from the data by measuring the amount of like charge lepton pairs (e^+e^+ and e^-e^-). This procedure is described in Ref. [9].

Additionally, a cut is made on the missing mass squared off of the dilepton pair, $(\gamma + p_{targ} - e^+ - e^-)^2$ around the mass of the proton squared. This cut eliminates higher mass baryon states in the final state and puts restrictions on the production mechanism (varying t-channel ρ-ω production processes). An additional benefit of this cut is the complete elimination of the combinatorial background.

3 ρ-ω interference

To describe the photoproduction of the vector mesons on the proton, the total amplitude F can be written as a combination of the ρ and ω meson amplitudes with a complex phase term: $F = f_\rho + ie^{i\phi_\rho} f_\omega$. f_ρ and f_ω are relativistic Breit-Wigner functions and ϕ_ρ is the interference phase. The cross section is obtained by squaring this amplitude.

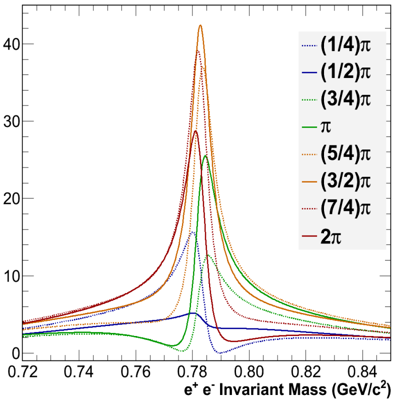

Figure 1: Predicted ρ-ω interference shape as a function of the phase ϕ_ρ

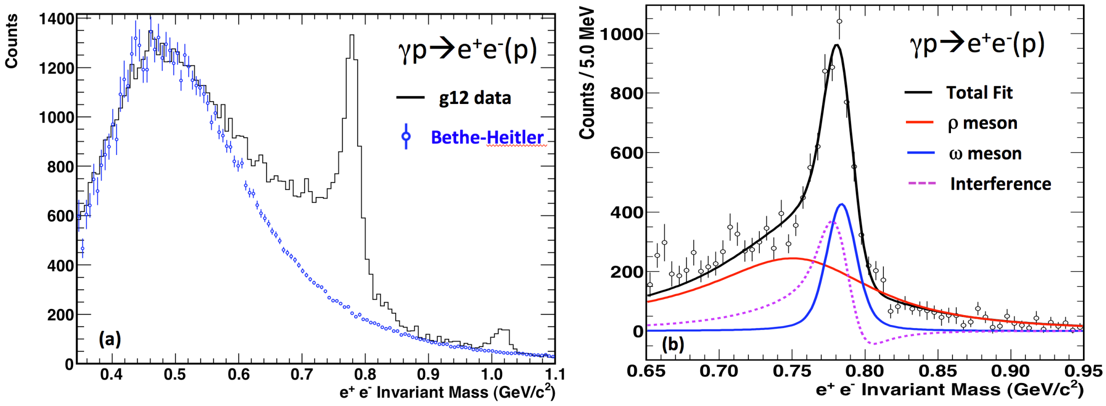

Figure 2: (a) Calculated Bethe-Heitler contribution (blue) compared to data (black); (b) Bethe-Heitler subtracted e^+e^- invariant mass spectrum fit showing the ρ, ω and interference term contributions

The ρ-ω interference as a function of the interference phase ϕ is shown in Figure 1. The Bethe-Heitler contribution is calculated and matches very well with the data (see Figure 2-(a)). Once the Bethe-Heitler contribution is subtracted, the e^+e^- invariant mass spectrum is fitted with two interfering relativistic Breit-Wigner functions. The ρ width in the Breit-Wigner function is set to be mass dependent [8]. Figure 2-(b) shows a typical fit with contributions from the ρ and ω mesons as well as the interference term. Different fits have been carried out with and without the interference. The interference term is required to substantially improve the chi-squared of the fit.

4 Summary and Conclusion

The g12 experiment at JLab has generated large statistics data in the e^+e^- decay channel. The ρ, ω and ϕ mesons are clearly observed. Selecting the γ N → e^+e^- (p) channel, the combinatorial background is suppressed. The Bethe-Heitler contribution has been calculated and subtracted from the e^+e^- invariant mass spectrum. Preliminary analysis show a ρ-ω interference. Further analysis is underway to estimate the uncertainties before extracting the final ρ-ω interference phase. The measured cross sections will be compared to Lutz and Soyeur predictions [7]. These studies will be extended to nuclei.

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