

COHERENT PHOTOPRODUCTION OF ϕ MESONS FROM DEUTERONS NEAR THRESHOLD

W.C. Chang
Institute of Physics, Academia Sinica,
Taipei 11529, Taiwan, Republic of China

Abstract

We measured coherent ϕ -meson photo-production from deuterons at forward angles by using linearly polarized photons with $E_\gamma = 1.5\text{-}2.4$ GeV. The decay asymmetries show a dominance of the natural-parity exchange process. The energy dependence of cross sections will explore the behavior of Pomeron exchange at low energies.

1 Introduction

The photoproduction of vector mesons from hadrons has been a valuable tool to study the dynamics of Pomeron exchange at high energies and the resonance channels at low energies [1]. Because of the dominant $s\bar{s}$ quark component in the ϕ meson, quark-exchange (or meson-exchange) mechanisms, and s-channel resonance production are strongly suppressed by the Okubo-Zweig-Iizuka (OZI) rule, compared to the cases of ρ and ω production. This feature makes the photoproduction of ϕ mesons at low energies a unique tool for the study of Pomeron exchange near threshold and multigluon exchange processes other than baryon and meson exchange [2]. Especially the measurement of decay angular distributions of ϕ -meson with the use of linearly-polarized-photon beam can be used to decompose the scattering amplitude into a natural-parity-exchange (Pomeron and glueball) part and an unnatural-parity-exchange (π, η) part.

In the intermediate range of photon energies to the threshold, the coherent vector-meson photoproduction from deuterons filters out the isovector π -meson exchange in t -channel because both the beam and target are isoscalar [3]. The isovector π -meson exchange is the leading component in the unnatural-parity processes because the other channel of η -exchange is

suppressed by the smallness of ηNN coupling and large mass in the exchange propagator. Therefore the study of the coherent ϕ -meson production from deuterons provides the cleanest way to explore the contributions purely from natural-parity processes at low energies.

2 $\gamma d \rightarrow \phi d$

The LEPS experiment measured the ϕ -meson photoproduction from liquid hydrogen and deuterium near threshold in the very forward direction with linearly polarized photons by LEPS experiment [4,5]. Polarized photons were produced by backward Compton scattering with an ultra-violet Ar laser from 8 GeV electrons in the storage ring of SPring-8, Japan. The typical photon flux was about 10^6 s^{-1} . Within the acceptance of the tagger counter, the polarization of the photon beam was 95% at 2.4 GeV and decreased down to 55% at 1.5 GeV. More experimental details are referred to Ref. [6].

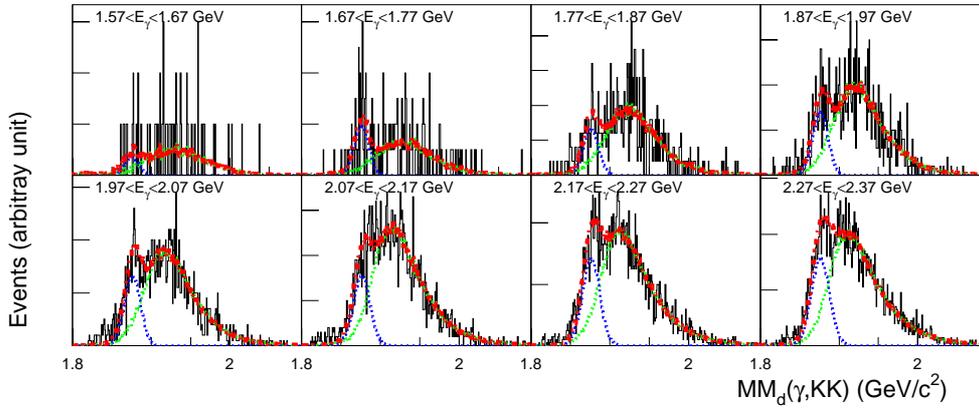


Figure 1: The distributions of missing mass $MM_d(\gamma, KK)$ assuming deuteron target overlapped with the fit (red lines) of MC-simulated coherent (blue lines) and incoherent (green lines) components.

For the interactions with liquid deuterium target [7], we identified the production of ϕ mesons via the charged decay mode with the detection of two tracks K^+ and K^- in the final state. The vertex positions of K^+K^- tracks were required within the target position. A cut on the invariant mass, $|M(KK) - M_\phi| < 0.01 \text{ GeV}/c^2$, was applied to select the ϕ -meson events, either

through coherent or incoherent production. The coherent ϕ production from deuterons, $\gamma d \rightarrow \phi d$, was characterized by the distribution with a peak at the mass of deuterons $1.875 \text{ GeV}/c^2$ in the spectra of missing mass ($\text{MM}_d(\gamma, \text{KK})$) assuming deuteron as the rest target. The $\text{MM}_d(\gamma, \text{KK})$ spectra at various photon energy bins were shown in the Fig. 1.

Our acceptance sat mainly at the very forward direction of $|t - t_{min}^d| < 0.1$ where t_{min}^d is the minimum four-momentum transfer assuming deuteron as the rest target in the reaction. To disentangle the yields of coherent and incoherent interactions, the $\text{MM}_d(\gamma, \text{KK})$ spectra was fitted by the sum of the individual distributions obtained by Monte-Carlo simulation [7]. As seen in Fig. 1 the missing mass spectra of real data were nicely reproduced by MC simulation.

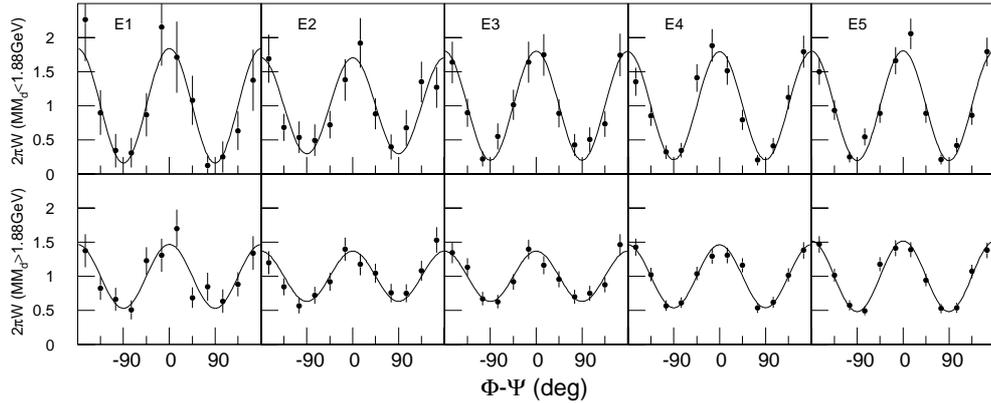


Figure 2: The distributions of $W(\Phi-\Psi)$ in the Gottfried-Jackson frame at the forward angles ($|t - t_{min}^d| < 0.1 \text{ GeV}^2$) for five energy bins of $1.9 < E_\gamma < 2.4 \text{ GeV}$. The E_γ binning starts from E1=(1.87,1.97) GeV and ends at E5=(2.27,2.37) GeV. The top and bottom panel are for the events whose missing-mass values are less than or larger than $1.88 \text{ GeV}/c^2$.

For the measurements of decay asymmetry of coherent and incoherent interactions from the decay angular distributions of $W(\Phi - \Psi)$ in the Gottfried-Jackson frame [8], two sets of distributions of $W(\Phi - \Psi)$ were in five energy regions of $1.9 < E_\gamma < 2.4 \text{ GeV}$. As shown in Fig. 2 with a division at missing mass value of $1.88 \text{ GeV}/c^2$, a larger decay asymmetry was seen for the group of events with smaller missing mass. It was understood in the sce-

nario of different mixing percentage of coherent and incoherent events distributed in the regions of $MM_d(\gamma, KK)$ and their different decay asymmetries. Hence the individual decay asymmetry was disentangled under the assumption of a relationship of linearly weighting from each component. A very large decay asymmetry close to the maximum value corresponding to pure exchange of natural-parity processes was found for the coherent component and this means that the exchange processes for the coherent ϕ production from deuteron are mainly of natural parity, agreeing with the theoretical expectation of an absence of π -exchange together with a small contribution of η -exchange in the sector of unnatural-parity exchanges.

3 Summary

In summary, photoproduction of ϕ mesons from deuterons at forward angles in the low energy region of $E_\gamma=1.5-2.4$ GeV was measured by SPring-8/LEPS experiment with the use of linearly polarized photons. The coherent interactions with deuterons were disentangled from the incoherent ones via the missing mass spectra. A complete dominance of helicity-conserving natural-parity exchange processes were seen from the decay angular distributions of this reaction. The energy dependence of the cross sections to be finalized will be extremely valuable to determine the behavior of Pomeron exchange at low energies and explore the existence of additional significant natural-parity processes beyond the Pomeron exchange.

References

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