Hadronic decays of the ω meson

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Abstract. The WASA-at-COSY collaboration has collected a high statistics data set of ω mesons produced through the $p + d \rightarrow {}^3\text{He} + \omega$ reaction. This article presents the status of the ongoing studies of two ω decay channels. The decay dynamics of the $\omega \rightarrow \pi^+\pi^-\pi^0$ channel is investigated by means of a Dalitz plot distribution and the $\omega \rightarrow \pi^+\pi^-$ channel is examined to search for a possible manifestation of $\rho - \omega$ interference in hadronic production.

1 Introduction

Decay studies of the ω, a light vector meson, covers a span of interesting physics including 3π decay dynamics, the $\rho - \omega$ mixing and the $\omega - \pi^0$ transition form factor. The ongoing study presented here covers the first two mentioned topics through measurements of the $\omega \rightarrow \pi^+\pi^-\pi^0$ ($BR = 89.2\%$) and $\omega \rightarrow \pi^+\pi^-$ ($BR = 1.53\%$) channels.

For decays into three final state particles, the dynamics can be studied using a Dalitz plot. In case of the $\omega \rightarrow \pi^+\pi^-\pi^0$ reaction, a Dalitz plot was already used to establish the P-wave state of the three pions and therefore the spin of the ω meson [1]. The low statistics of previous Dalitz plot studies has not allowed any further experimental observation of decay dynamics, such as an intermediate ρ or the shape distortions due to $\pi - \pi$ final state interactions. Two recent theoretical models [2, 3] have made predictions of the shape of the $\omega \rightarrow \pi^+\pi^-\pi^0$ Dalitz plot where such effects are included. It is therefore exceedingly interesting to provide a high statistics Dalitz plot for experimental verification.

The isospin breaking $\omega \rightarrow \pi^+\pi^-$ decay may provide insight to the behaviour of the $\rho - \omega$ mixing. This channel has already been widely studied in e^+e^- collisions where the interference has been conclusively shown to be destructive [4]. Only a few measurements with limited statistics have been performed for hadronic production of the ω meson with hints of a possible constructive interference [5]. The aim of this study is to investigate the structure of the $\omega \rightarrow \pi^+\pi^-$ signal in proton on deuteron collisions.

2 Status of experimental studies

2.1 The experiment

The WASA detector is a near-4π detector optimised for studying production and decays of light mesons. A unique pellet generator provides frozen pellets of hydrogen and deuterium as an internal

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fixed target. The central part of the detector can detect both charged and neutral particles. The forward part is designed to detect scattered projectiles and charged recoil particles like protons, deuterons and ^{3}He nuclei.

The WASA-at-COSY collaboration has performed experiments dedicated to the ω meson production. The data in the analysis presented in this paper was produced in the $p + d \rightarrow {}^3\text{He} + \omega$ reaction, at two beam energies close to threshold: $T_{beam} = 1.45$ GeV and $T_{beam} = 1.5$ GeV. A separate data set has also been collected for the $p + p \rightarrow p + p + \omega$ process and is currently being analysed by S. Sawant [6].

2.2 $\omega \rightarrow \pi^+\pi^-\pi^0$

The normalised Dalitz plot variables are constructed from the kinetic energies (T) of the outgoing pions in the ω rest frame, $X = \sqrt{3}\frac{T_+ - T_-}{Q}$ and $Y = \frac{(m_+ + m_- + m_0)T_0}{m_+ Q} - 1$ where $Q = T_+ + T_- + T_0$. Due to the symmetric shape of the distribution for this reaction, one can instead use the polar variables $Z = X^2 + Y^2$ and $\Phi = \arctan\frac{Y}{X}$. A proposed parametrisation of the Dalitz plot distribution is given by

$$F(Z, \Phi) = \frac{1}{(2\pi)^3 m_\omega^3 32} \cdot \mathcal{P} \cdot \left\{ 1 + 2\alpha Z + 2\beta Z^{3/2} \sin 3\Phi + 2\gamma Z^2 + O(Z^{5/2}) \right\}, \quad (1)$$

where $\mathcal{P}$ is the phase space factor, which accounts for the P-wave state of the pions, and $\alpha, \beta, \gamma, \ldots$ are the Dalitz plot parameters. The aim of this study is to provide experimental values of these parameters.

A clean data set of the $\omega \rightarrow \pi^+\pi^-\pi^0$ decay is obtained by requiring full reconstruction of all the final state particles $^3\text{He}\pi^+\pi^-\gamma\gamma$. The two photons come from the $\pi^0 \rightarrow \gamma\gamma$ decay. A constrained fit of the kinematic variables of the final state particles is performed to ensure conservation of energy and momentum of the full reaction. The number of signal events belonging to each bin in the Dalitz plot is extracted by subtracting continuum background from the distribution formed by the missing mass to the initial proton and deuteron and the created ^{3}He, see Figure 1. The preliminary Dalitz plot distribution from this analysis is estimated to contain 27 370(380) events. This is nearly a factor 6 larger data sample than used in the previous studies.
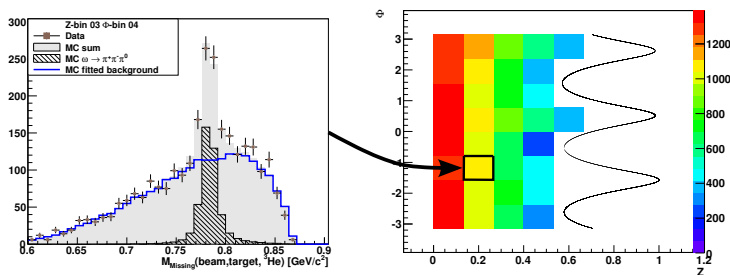

Figure 1. The missing mass distribution (left panel) illustrates the background subtraction made in order to extract the amount of $\omega \rightarrow \pi^+\pi^-\pi^0$ events in each Dalitz plot bin. The number of events in the shaded area fills the bin indicated by the arrow in the Dalitz plot (right panel). The black line in the Dalitz plot shows the kinematical limit of the phase space.

As a measurement of the expected experimental accuracy provided by this study, the estimated statistical errors of α, β and γ are presented in Table 1. To obtain these a simulated data set has been used with statistics comparable to the experimental results above.

Table 1. σ_X gives the estimated statistical errors expected for the final experimental Dalitz plot parameters. Three different fits of the function given in equation (1) has been performed using only one, two or three respectively of the Dalitz plot parameters.

Parameters used in fit	$\sigma_\alpha \times 10^3$	$\sigma_\beta \times 10^3$	$\sigma_\gamma \times 10^3$
α	20	-	-
α, β	23	27	-
α, β, γ	80	29	147

2.3 $\omega \to \pi^+\pi^-$

To reduce the large $^3\text{He}\pi^+\pi^-\pi^0$ background a strict cut on the invariant mass of the two charged pions is imposed. For further background reduction, a cut is performed on the probability of the constrained fit of kinematic variables where total energy and momentum conservation is assumed. The fit of the kinematic variables also improves the resolution of the final state particles. Shown in Figure 2 are the missing mass distributions to the initial proton and deuteron and the created ^3He for the entire available data set. Currently no clear signal of the $\omega \to \pi^+\pi^-$ channel is visible, but improvements of the kinematic fit is ongoing.
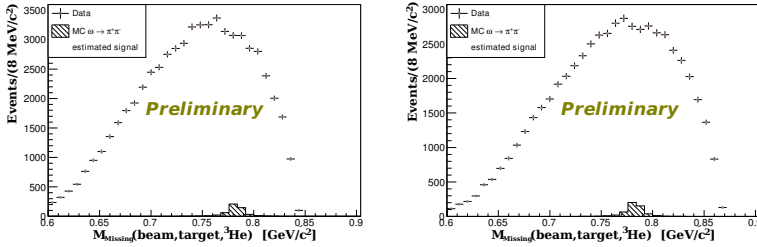

Figure 2. The missing mass distributions of the full data set collected at $T_{beam} = 1.45$ GeV (left panel) and $T_{beam} = 1.5$ GeV (right panel). The size of the shaded peaks illustrates the expected amount of $\omega \to \pi^+\pi^-$ events existing in data, as estimated from MC-simulation and value of $BR(\omega \to \pi^+\pi^-)$ taken from PDG [7].

The goal of the studies is to provide estimate of the $\rho - \omega$ mixing with help of a suitable parametrisation which include the $\rho - \omega$ interference.

Acknowledgements

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