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MEASUREMENT OF THE $\eta \to \pi^+\pi^-\pi^0$ DECAY WITH WASA-at-COSY DETECTOR

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FOR THE WASA-at-COSY COLLABORATION

One of the objectives of the physics programme of the WASA-at-COSY facility is to study the isospin violating η hadronic decays into $\pi^+\pi^-\pi^0$ systems driven by the term of QCD Lagrangian which depends on the d and u quark mass difference. These studies can be made in terms of the Dalitz plot parameters describing the density population which is proportional to the square of the amplitude $|A(x,y)|^2$. This contribution describes the current status of the analysis of the $\eta \to \pi^+\pi^-\pi^0$ decay in the $pd \to^3 He\eta$ and as well in the $pp \to pp\eta$ reaction with WASA-at-COSY.

Keywords: Meson production; hadronic decays; ChPT; WASA-at-COSY.

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1. Motivation

The isospin violating strong decay $\eta \to \pi^+\pi^-\pi^0$ allows access to light quark mass ratios. At lowest order of chiral perturbation theory (ChPT) the amplitude is proportional to the light quark mass difference $(m_d - m_u)$ and may be written as

$$A \propto \frac{m_d - m_u}{F_\pi^2}\left(1 + \frac{3(s - s_0)}{m_\eta^2 - m_\pi^2}\right), \tag{1}$$

where F_π is the pion decay constant, $s = (p_{\pi^+} + p_{\pi^-})^2 = (p_\eta - p_{\pi^0})^2$ and $s_0 = \frac{1}{3}(m_\eta^2 + 2m_{\pi^+}^2 + m_{\pi^0}^2)$. At higher order of ChPT it has been found that final state pion interaction contribute to the decay width.[1,2] The decay width scales as $\Gamma = \left(\frac{Q_D}{Q}\right)^4 \bar{\Gamma}$, where $Q^2 = \frac{m_s^2 - \hat{m}^2}{m_d^2 - m_u^2}$, $\hat{m} = \frac{1}{2}(m_u + m_d)$, and the decay width $\bar{\Gamma}$ and $Q_D = 24.2$ are calculated in the Dashen limit.[3] This scaling works under the pre-requisite that $\bar{\Gamma}$ is understood reliably. To test this, theoretical predictions and experimental measurements of pion kinematical distributions may be compared in a Dalitz plot, where the axes are defined as $x = \sqrt{3}\frac{T_+ - T_-}{Q_\eta}$, $y = \frac{3T_0}{Q_\eta} - 1$. Here T_+,

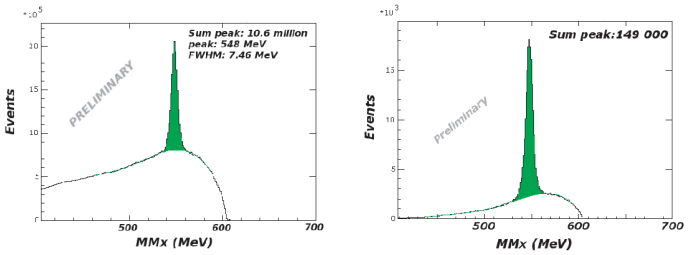

Fig. 1. (**left**) Missing mass for the 2008 data calculated from the identified ^3He. (**right**) Missing mass after selecting 3π candidates and including a cut on $MM(^3He\pi^+\pi^-)$ and $MM(^3He\pi^0)$.

T_- and T_0 denote the kinetic energies of pions in the rest frame of the η meson, and $Q_\eta = T_+ + T_- + T_0 = m_\eta - 2m_{\pi^+} - m_{\pi^0}$. The standard way to parametrize the Dalitz plot density is a polynomial expansion around the center point: $|A(x,y)|^2 \propto 1 + ay + by^2 + dx^2 + fy^3 + ...$ where a, b, d, f are the Dalitz plot parameters. The experimental results are dominated by KLOE with a Dalitz plot containing $1.34{\cdot}10^6$ events.[4] This result shows a significant deviation of parameters b and f in comparison to the theoretical predictions based on ChPT. It is therefore important to perform an independent measurement, which is one of the aims of the WASA-at-COSY.

2. $pd \to^3 He\eta$ measurement

In 2008 and 2009 WASA-at-COSY[5] measured $pd \to^3 HeX$ reaction at beam energy 1 GeV, collecting 10^7 and $2 \cdot 10^7$ η mesons respectively. The missing mass with respect to ^3He is used to tag the η meson (Fig. 1 left). In addition two tracks of opposite charge are required in the Mini Drift Chamber in the angular range $30.5° < \theta < 150°$. Furthermore two γ with an invariant mass close to π^0 are required. The $pd \to^3 He\pi\pi$ reaction is reduced by imposing conditions on the missing mass calculated for $^3He\pi^+\pi^-$ and the missing mass calculated for $^3He\pi^0$. The preliminary analysis yields 149 000 $\eta \to \pi^+\pi^-\pi^0$ candidates from the 2008 data, shown in Fig. 1 right. The experimental resolution is better for the η four-momenta from ^3He compared to the information derived from the η decay products. Therefore a kinematical fit for the reaction $pd \to^3 He\pi^+\pi^-\pi^0$ has been used with ^3He observables fixed and a cut on the 1% level of the probability density function. To estimate the η content in each Dalitz plot bin, a four-degree polynomial fit is performed over the background region. The preliminary experimental results for the x,y projections of the Dalitz plot are compared in Fig. 2 to Monte Carlo simulations of the $\eta \to \pi^+\pi^-\pi^0$ weighted with the tree-level prediction (Eq. (1)).

3. $pp \to pp\eta$ measurement

The measurement of the $pp \to ppX$ reaction was conducted in 2008 and in 2010 at beam kinetic energy 1.4 GeV. The collected sample of data yields about 10^8 produced η mesons. Protons and charged pions were detected using scintillators

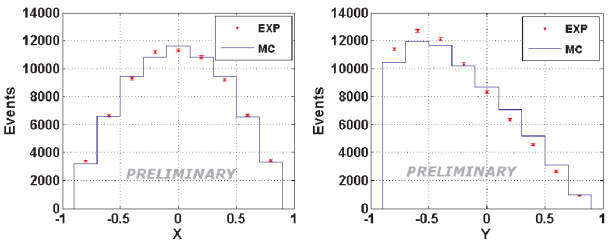

Fig. 2. Projections of Dalitz Plot, not corrected for acceptance and normalized to sum of experimental data: **(left)** X-projection **(right)** Y-projection. Solid line indicates MC data and points with error bars experimental values.

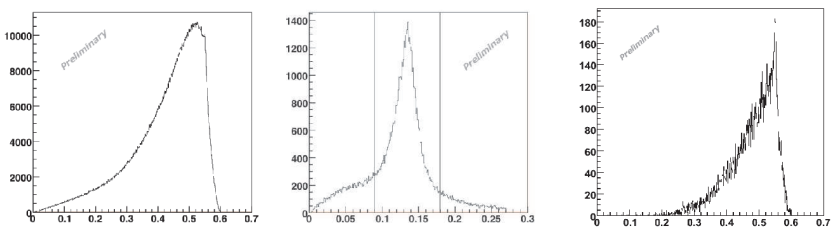

Fig. 3. **(left)** Missing mass of the $pp \to ppX$ reaction. **(middle)** Invariant mass ot two γ with cut lines. **(right)** Missing mass of two protons with the requirement of two γ in coincidence.

and straw tube trackers (FPC and MDC). Two protons were used to tag the η meson in the missing mass plot showed in Fig. 3 left (here we present data only from one run). The two γ originating from the π^0 meson decay were registered in the electromagnetic calorimeter. The invariant mass of theseγ is required to be close to the mass of the π^0 (Fig. 3 middle). Requiring two γ in coincidence with the two protons gives the missing mass as shown in Fig. 3 right.

4. Outlook

The work for both *pd* and *pp* data will be continued in order to obtain two independent determinations of the Dalitz plot density for the $\eta \to \pi^+\pi^-\pi^0$. This includes estimating systematical errors as well as tuning Monte Carlo simulation.

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