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Dalitz plot analysis for $\eta \to \pi^+\pi^-\pi^0$ at KLOE

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Abstract. Based on $1.6\,\mathrm{fb}^{-1}$ of data taken with the KLOE detector at the DAϕNE ϕ-factory, we present the status of the ongoing analysis of the $\eta \to \pi^+\pi^-\pi^0$ Dalitz plot. With $4.48 \cdot 10^6$ events in the Dalitz plot, the preliminary results for the Dalitz plot parameters are: $a = 1.104(3)$, $b = 0.144(3)$, $d = 0.073(3)$ and $f = 0.155(6)$.

1. Introduction

Chiral Perturbation Theory (χPT) calculations for the decay width the of $\eta \to \pi^+\pi^-\pi^0$ process, at leading order $\Gamma_{LO} \sim 70$ eV and next to leading order $\Gamma_{NLO} = 160 \pm 50$ eV, do not agree with the experimental value $\Gamma_{exp} = 296 \pm 16$ eV [1]. This points towards important effects from pion rescattering in the final state, which can be treated by means of dispersion relations [2].

A good understanding of the $\eta \to \pi^+\pi^-\pi^0$ decay can set a constraint on the light quark masses, as exemplified by the grey band in figure 1. As this decay is isospin violating, it is sensitive to the light quark mass ration Q:

$$Q^2 = \frac{m_s^2 - \hat{m}^2}{m_d^2 - m_u^2} \qquad \hat{m} = \frac{1}{2}(m_d + m_u). \tag{1}$$

The Dalitz plot of $\eta \to \pi^+\pi^-\pi^0$ shows the dymanics of the decay and can be used either to compare to χPT calculations, or as input to dispersive analysis calculations with the aim of extracting Q ([3], [4]).

In 2008, the KLOE collaboration published a Dalitz plot analysis of this decay performed on $450\,\mathrm{pb}^{-1}$, with the largest statistics to date, $1.34 \cdot 10^6$ events in the Dalitz plot [5], but more data is needed to understand the tension between experimental results and χPT calculations. Therefore, the KLOE-2 collaboration is performing a new analysis of $\eta \to \pi^+\pi^-\pi^0$ decay with a larger ($\sim 1.6\,\mathrm{fb}^{-1}$), independent dataset and a new selection scheme. We expect to reduce the systematic errors since the Monte Carlo description of the detector has been improved and the effect of the event classification filter (which organizes the data in different output files) can now be studied on prescaled, unclassified events.

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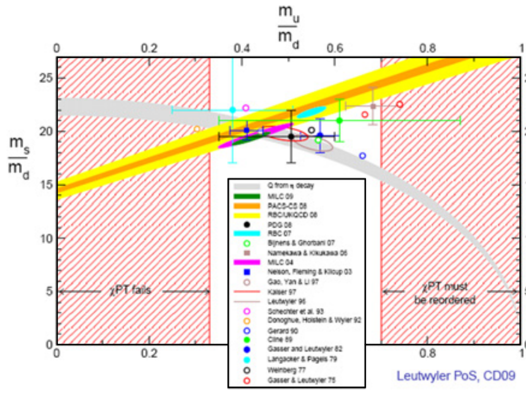

Figure 1. Constraints on the light quark mass ratios. The ellipse is calculated with $Q = 22.3 \pm 0.8$, the points are from lattice calculations [6].

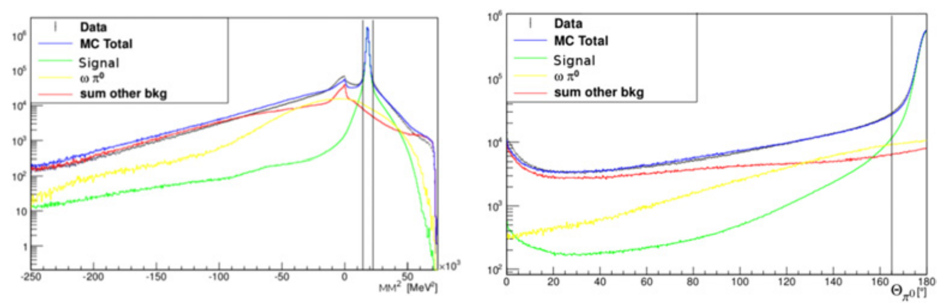

Figure 2. Comparison of data and Monte Carlo simulation. On the left, the squared missing mass, with the selected region between the two lines. On the right, the opening angle between π^0 photons, with the selected region to the right of the line.

2. Analysis

The new analysis is based on $\sim 1.6\,\text{fb}^{-1}$ of data collected in 2004-2005. The desired reaction is $e^+e^- \to \phi \to \eta\gamma_{rec} \to \pi^+\pi^-\pi^0\gamma_{rec} \to \pi^+\pi^-\gamma\gamma\gamma_{rec}$. Events are selected by requiring at least 3 prompt neutral clusters[1] in the calorimeter and at least two charged secondary tracks in the drift chamber, with positive and negative curvature. To reject background, several cuts are applied using: 1) the angle between tracks and prompt neutral clusters, 2) time-of-flight to the calorimeter ($\Delta t_e \leq -0.7$ ns and $\Delta t_e \leq -\Delta t_\pi$[2]), 3) missing mass, MM, ($(m_{\pi^0} - 15) <$ MM $< (m_{\pi^0} + 15)$ MeV, see Fig. 2 left) and 4) the angle, Θ_{π^0} between the π^0 decay photons in the π^0 rest frame ($\Theta_{\pi^0} \geq 165^\circ$, see Fig. 2 right). After all cuts, the signal efficiency is 37.6% and the background contamination 0.96%.

With the variables MM^2 and Θ_{π^0}, shown in Fig. 2 we calculate scaling factors for the different MC background contributions. As can be seen, the data – MC simulation agreement is quite good.

[1] Clusters with no associated track from the drift chamber and with $|t - \frac{r}{c}| < 5\sigma_t$, where t is the arrival time at the calorimeter, r the distance from the interaction point to the cluster, c the speed of light and $\sigma_t = 54\text{ps}/\sqrt{E(\text{GeV})} \oplus 147\text{ps}$ [7].

[2] Where $\Delta t = t_{track} - t_{cal}$, t_{track} is the time to the calorimeter calculated from the track momentum for e or π hypotheses and t_{cal} is the time measured at the calorimeter.

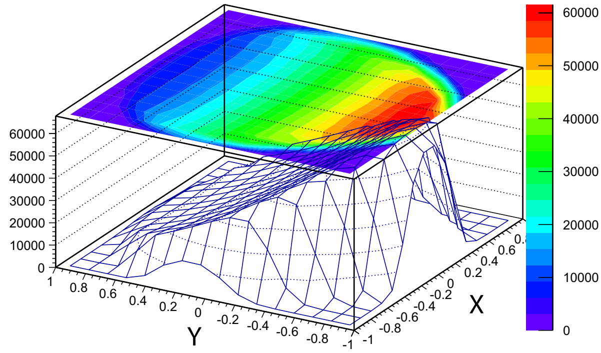

Figure 3. Dalitz plot obtained with $\eta \rightarrow \pi^+\pi^-\pi^0$ data sample selected using cuts described in the text.

Table 1. Preliminary results from this analysis together with the previous KLOE result.

Experiment	$-a$	b	d	f
KLOE 08[5]	$1.090(5)(^{+8}_{-19})$	0.124(6)(10)	$0.057(6)(^{+7}_{-16})$	0.14(1)(2)
New KLOE, prel.	1.104(3)	0.144(3)	0.073(3)	0.155(6)

2.1 Dalitz plot

The $\eta \rightarrow \pi^+\pi^-\pi^0$ Dalitz plot is presented in the X and Y variables, defined in the η-meson rest frame:

$$X = \sqrt{3}\frac{T_+ - T_-}{Q_\eta} = \frac{\sqrt{3}}{2m_\eta Q_\eta}(u-t) \qquad Y = \frac{3T_0}{Q_\eta} - 1 = \frac{\sqrt{3}}{2m_\eta Q_\eta}\left[\left(m_\eta - m_{\pi^0}\right)^2 - s\right] - 1 \tag{2}$$

where T_+,T_-, T_0 are the kinetic energies of the π^+, π^-, π^0, $Q_\eta = T_+ + T_- + T_0$ and s, u, t are the Mandelstam variables.

The Dalitz plot (see figure 3) is fit with a polynomial expansion by minimizing:

$$\chi^2 = \sum_{i=1}^{N_b}\left(\frac{N_i - \sum_{j=1}^{N_b}\epsilon_j S_{ij} N^j_{theory}}{\sigma_i}\right)^2 \tag{3}$$

where N_b is the number of bins of the Dalitz plot, N_i is the number of background subtracted data events in bin i, ϵ_j is the efficency for bin j, S_{ij} the smearing matrix from bin j to bin i, σ_i the error in bin i and N^j_{theory} the theoretical number of events in bin j calculated with:

$$\begin{aligned} N_{theory} &= \int |A(X,Y)|^2 dPh(X,Y) \\ &\sim \int N(1 + aY + bY^2 + cX + dX^2 + eXY + fY^3 + gX^2Y)dPh(X,Y) \end{aligned} \tag{4}$$

where $dPh(X,Y)$ indicates the integral is over the phase space in the X and Y variables.

The fit gives the Dalitz plot parameters a, b, c, d, e, f. To conserve charge conjugation c and e must be zero.

3. Results

Table 1 shows the preliminary results of the reported analysis together with the previous KLOE results[5]. Letting the parameters c and e vary, both analysis found them consistent with zero, and therefore the reported results are obtained with these parametes fixed to zero. The fit has 143 degrees

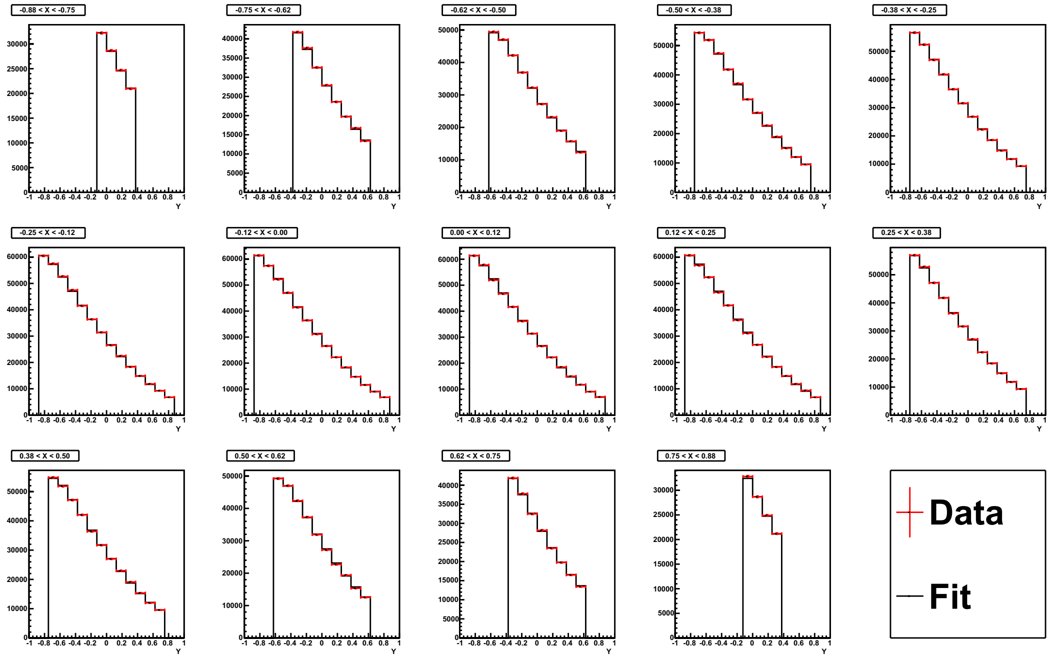

Figure 4. Dalitz plot depence on the Y variable, for each bin in the X variable. In red the background subtracted data and in black the smeared fit result are shown.

of freedom, giving $\chi^2 = 164.2$ and $\chi^2_\nu = 1.148$. In figure 4 the Dalitz plot depence on the Y variable for each bin in the X variable can be seen, as well as the good agreement between data distributions and fit result.

We are currently evaluating systematic uncertainties and investigating wether we can include g in the fitting function (see Eq. (4)).

References

[1] K. Nakamura *et al.* (Particle Data Group), Journal of Physics G **37**, 075021 (2010)
[2] G. Colangelo, S. Lanz and E. Passemar, Proceedings of Science CD **09**, 047 (2009)
[3] G. Colangelo, S. Lanz, H. Leutwyler, E. Passemar, Proceedings of Science **EPS-HEP2011**, 304 (2011)
[4] M. Zdráhal, Nuclear Physics B (Proceedings Supplements), 219 (2011)
[5] F. Ambrosino *et al.* (The KLOE collaboration), Journal of High Energy Physics **5**, 006 (2008)
[6] H. Leutwyler, Proceedings of Science CD **09**, 005 (2009)
[7] M. Adinolfi *et al.* (The KLOE collaboration), Nucl. Instrum. Meth. A **461**, 344 (2001)