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

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Abstract. We present the status of an ongoing analysis of the $\eta \to \pi^+\pi^-\pi^0$ Dalitz plot, as well as preliminary results for the Dalitz plot parameters. The analysis is based on data taken at the DAΦNE ϕ-factory with the KLOE detector.

1 Motivation

The experimental decay width of $\eta \to \pi^+\pi^-\pi^0$ ($\Gamma_{exp} = 296 \pm 16$ eV [1]) is not well described by leading or next to leading order Chiral Perturbation Theory (χPT) ($\Gamma_{LO} \sim 70$ eV, $\Gamma_{NLO} = 160 \pm 50$ eV). This points towards strong pion rescattering effects in the final state, which can be treated by means of dispersion relations [2]. Since the $\eta \to \pi^+\pi^-\pi^0$ decay is isospin violating, it is sensitive to the light quark mass ratio:

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

A good, quantitative understanding of this decay allows for the extraction of Q and thus a constraint in the quark masses (exemplified by the grey elliptical band in figure 1).

The KLOE collaboration has in 2008 published the Dalitz plot analysis of $\eta \to \pi^+\pi^-\pi^0$ with the largest statistics to date [4]. The results have been used in dispersive calculations following two different methods ([5], [6]). More data is needed to understand the tension between experimental results and χPT calculations.

A new analysis of KLOE data is in progress, with a larger, independent data set to overcome some limitations of the previous analysis. For this, a new selection scheme is used. To reduce systematic effects, the Monte Carlo description of the detector has been improved and any possible bias due to the event classification filter, that organizes data in different output files, is studied on prescaled, unclassified events.

2 Analysis

The new analysis is performed on ~ 1.7 fb^{-1} collected in 2004-2005. The η meson is produced by the radiative decay of ϕ: $e^+e^- \to \phi \to \eta\gamma_{rec} \to \pi^+\pi^-\pi^0\gamma_{rec} \to \pi^+\pi^-\gamma\gamma\gamma_{rec}$. The final state thus has 3 photons and two charged tracks with opposite charge. Events are selected by requiring at least 3 prompt neutral clusters in the calorimeter and at least a positive and a negative track in the drift chamber. Several cuts are used to improve the signal to background ratio, based on time-of-flight to

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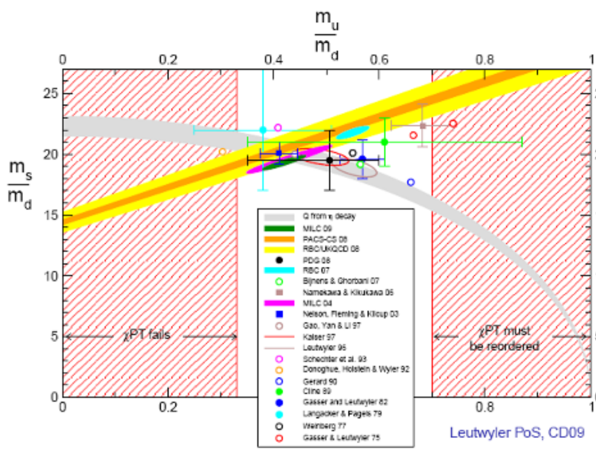

Figure 1. Constraints on the light quark mass ratios. The ellipse is calculated with $Q = 22.3 \pm 0.8$, the points are from lattice calculations. [3]

the calorimeter and kinematic variables. In figure 2, the sqared missing mass $\mathrm{MM}^2(\phi - \pi^- - \pi^+ - \gamma_{rec})$ and the opening angle of the π^0 decay photons in the π^0 rest frame are shown. Cuts on these variables are also shown. After all cuts the signal efficiency is 37.6% with a background contamination of 0.96%.

The two variables shown in figure 2 are also used to fix scaling factors of the background contribution from Monte Carlo. As can be seen, there is good agreement between data and simulations, especially in the selected region.

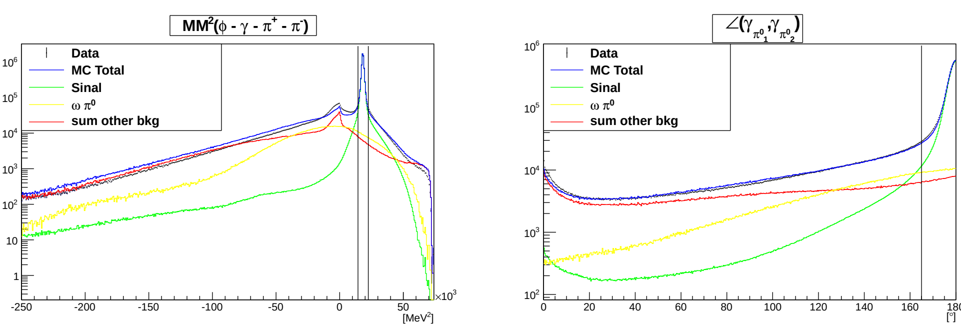

Figure 2. Comparison of data and Monte Carlo simulation. On the left, the squared missing mass, with the selected region between the two lines ($(m_{\pi^0} - 15) < \mathrm{MM} < (m_{\pi^0} + 15)$ MeV). On the right, the opening angle between π^0 photons, with the selected region to the right of the line at 165°.

2.1 Dalitz plot

Dalitz plot of $\eta \to \pi^+\pi^-\pi^0$ is built using the X and Y variables, defined in the η-rest frame as:

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

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 resulting Dalitz plot (see figure 3) is fit with a polynomial expansion around $X = 0, Y = 0$:

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

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

The fit is performed by minimizing:

$$\chi^2 = \sum_{i=1}^{N_b} \left(\frac{N_i - \sum_{j=1}^{N_b} \epsilon_j S_{ij} N^j_{theory}}{\sigma_i} \right)^2 \quad (4)$$

where N_b is the number of bins of the Dalitz plot, N_i is the number of data events in bin i, ϵ_j is the efficency for bin j, S_{ij} the smearing matrix from bin j to bin i, N^j_{theory} the theoretical number of events in bin j calculated with equation 3 and σ_i the error in bin i.

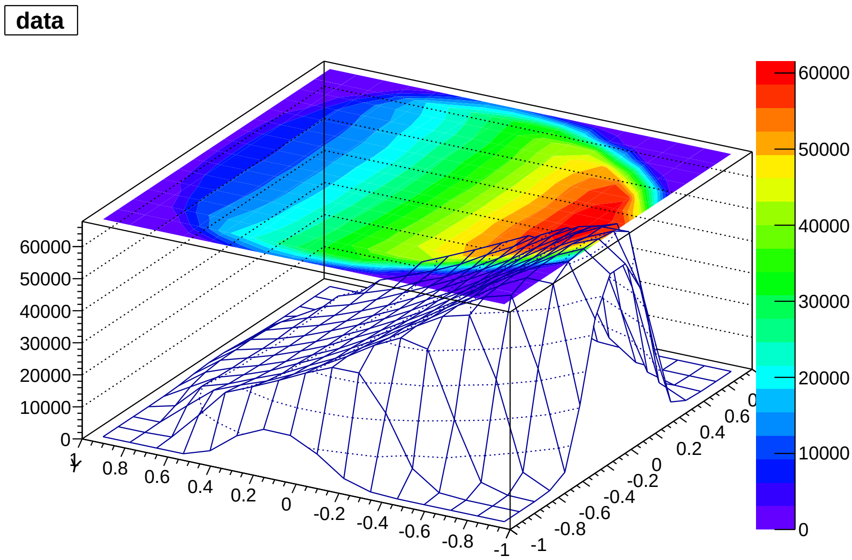

Figure 3. Dalitz plot for data, at the end of the analysis.

3 Results

The preliminary results are shown in table 1, compared to the results of the previous analysis. In both analyses, c and e are found consistent with zero and in the presented results these parameters are fixed to zero. For the new analysis, the fit is done with 143 degrees of freedom, resulting in $\chi^2 = 164.2$ and $\chi^2_\nu = 1.148$. The possibility to include the g parameter is currently being investigated.

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

Experiment	$-a$	b	d	f
KLOE 08[4]	$1.090(5)(^{+8}_{-19})$	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)

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