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Study of the $\eta \to \pi^+\pi^-\pi^0$ Dalitz plot with the KLOE detector

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Abstract. In this article we present the status of an ongoing analysis of the $\eta \to \pi^+\pi^-\pi^0$ Dalitz plot based on data taken with the KLOE detector at the DAFNE ϕ factory.

1 Theoretical Motivation

The study of the $\eta \to \pi^+\pi^-\pi^0$ Dalitz plot has two main reasons. Firstly, the experimental decay width ($\Gamma_{exp} = 296 \pm 16$ eV) is not well described by leading or next to leading order χPT ($\Gamma_{LO} \sim 70$ eV, $\Gamma_{NLO} = 160 \pm 50$ eV). Secondly, this Dalitz plot can be used to extract Q, defined as:

$$Q^2 = \frac{m_s^2 - \hat{m}^2}{m_d^2 - m_u^2} \tag{1}$$

with

$$\hat{m} = \frac{1}{2}(m_d + m_u) \tag{2}$$

which provides the elliptic constraint seen in figure1 for the light quark mass ratios.

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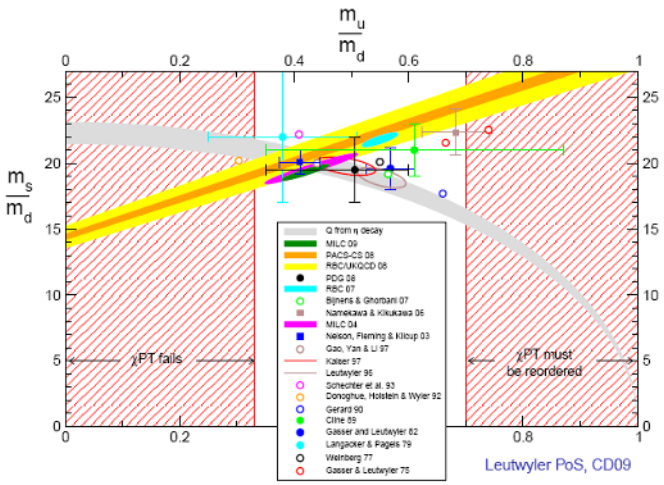

Fig. 1. Constraints on the light quark mass ratios, the ellipse is calculated with $Q = 22.3 \pm 0.8$ [1].

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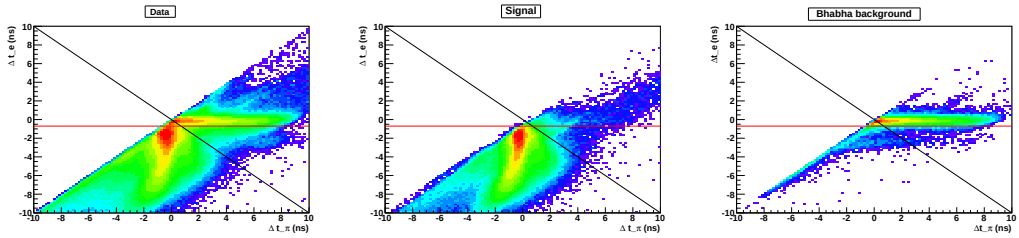

Fig. 2. Δt_e *vs* Δt_π for data (left), MC signal (middle) and MC Bhabha background (right).

Q is calculated from:

$$\Gamma = \left(\frac{Q_D}{Q}\right)^4 \bar{\Gamma} \tag{3}$$

where Γ is the experimental decay width, $\bar{\Gamma}$ is the theoretical decay width in the Dashen limit[2] and Q_D is Q in the Dashen limit. To evaluate $\bar{\Gamma}$ one can use χPT or dispersive analysis [3]. In the first case, comparison to the experimental Dalitz plot serves to validate the result, in the second case the Dalitz plot can also be used as input for the calculations.

2 KLOE data analysis

The KLOE detector is located at the DAFNE electron positron collider, in Frascati, Italy. It consists of a large drift chamber and an electromagnetic calorimeter, both inserted inside a superconducting coil providing an axial magnetic field of ~ 0.5 T.

In 2008, the KLOE collaboration has presented a Dalitz plot analysis of $\eta \to \pi^+\pi^-\pi^0$, based on ~ 450 pb^{-1} of data collected in 2001-2002 [4]. The new analysis in progress is done on a different and larger data set (~ 2.0 fb^{-1} from 2004-2005 run) with the aim to reduce systematic errors, by using a different analysis scheme, improved MC description, and a better understanding of the event classification procedure. Until now, the analysis is performed on only 560 pb^{-1} from 2005.

The decay chain studied is $e^+e^- \to \phi \to \eta\gamma_{rec} \to \pi^+\pi^-\pi^0\gamma_{rec} \to \pi^+\pi^-\gamma\gamma\gamma_{rec}$. Events selected have at least 3 prompt neutral clusters in the calorimeter and at least a positive and a negative track in the drift chamber. The most energetic photon is assumed to be the recoil photon γ_{rec} and its energy is calculated from the 2-body ϕ decay kinematics (this gives a better resolution than using the EMC information alone). The π^0 four-momentum is calculated from η decay kinematics and the photons from the π^0 decay are selected by transverse opening angle in the π^0 rest frame.

To improve the signal bo background ratio, several selection cuts are made. A time of flight cut permits the rejection of electrons, especially from Bhabha scattering. The time of flight variable is calculated as $\Delta t = t_{track} - t_{cluster}$ for $\pi^{+/-}$ and $e^{+/-}$ hypothesis. For each track, the event is discarded if $\Delta t_e > -\Delta t_\pi$ or $\Delta t_e > -0.7$ ns (black and red line, respectively, in figure 2). To reject more of these events, an angle cut is made. As seen in figure 3, the minimum angle between the positive track and the π^0 decay photons is plotted against the minimum angle for the negative track. The boxes in the corners are cut away.

A cut on the invariant mass M($\phi - \pi^- - \pi^+ - \gamma_{rec}$) around the π^0 mass, as shown in figure 4 on the left, is made to reject background. On the right of figure 4 another cut is shown. This plot is the transverse angle between the two photons from the π^0 decay, in the π^0 rest frame (the photons go back to back). These figures also show the good agreement between data and MC. After all these cuts there are $1.7275 \cdot 10^6$ MC signal events left and the background is $\sim 1\%$.

The final result of this analysis will be the Dalitz plot parameters when the Dalitz density is fitted by

$$|A(X,Y)|^2 \simeq 1 + aY + bY^2 + cX + dX^2 + eXY + fY^3 + \ldots \tag{4}$$

where

$$X = \sqrt{3}\frac{T_+ - T_-}{Q_\eta} \qquad Y = 3\frac{T_0}{Q_\eta} - 1 \qquad Q_\eta = T_0 + T_- + T_+ \tag{5}$$

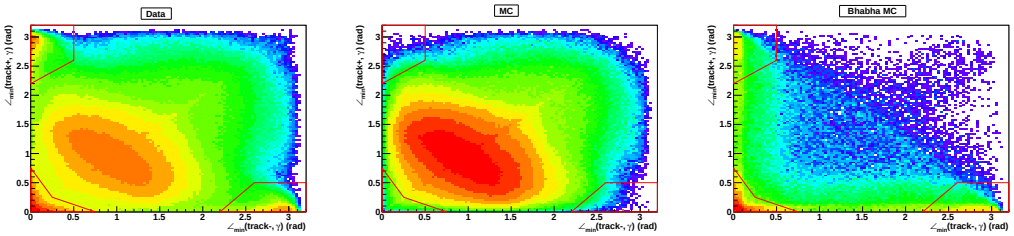

Fig. 3. Angle plots, for data (left), MC excluding Bhabha (middle) and MC Bhabha background (right).

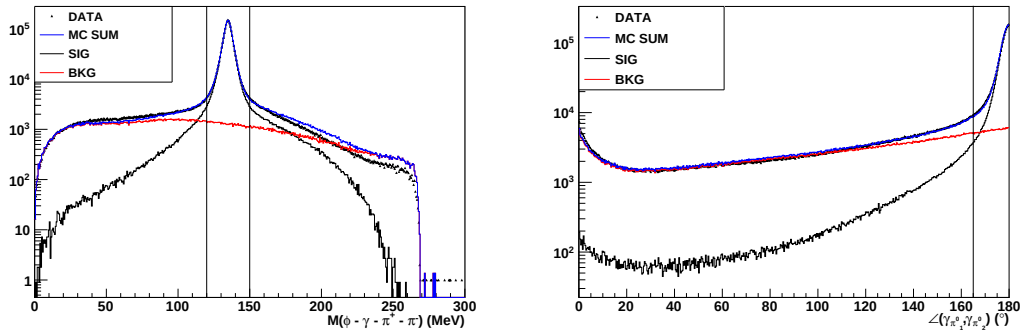

Fig. 4. On the left the invariant mass of π^0, on the right the tranverse angle between π^0 decay photons, in π^0 rest frame. Black triangles are data, blue line the MC signal+background, black line MC signal, and red line MC background.

and T_0, T_- and T_+ are the kinetic energies of the pions in the η rest frame.

To extract the parameters $(a, b, \ldots)$ a fit to the data will be done, minimizing:

$$\chi^2 = \sum_{i=1}^{Nb} \left(\frac{N_i - \sum_{j=1}^{Nb} \epsilon_j S_{ij} N^j_{theory}}{\sigma_i} \right)^2 \tag{6}$$

where Nb 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 4 and σ_i the error in bin i. The fit procedure is at the moment being checked with MC, and so far there is good agreement between the results of the fit and the MC input.

At KLOE-2 [5] with an improved reconstruction of charged tracks coming from the interaction region, thanks to the new inner tracker detector, and more integrated luminosity, further significant improvements in this analysis are expected.

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