CP/NFS/007
June 1, 1994

OFFLINE NOTE

To: CPLEAR Collaboration

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Subject: Status of the $\pi^o\pi^o$-analysis using Dalitz decays and converted photons

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1 Introduction

A short report about the status of the analysis of $K^o \rightarrow \pi^o\pi^o \rightarrow Xe^+e^-$ is presented. The K^o decay vertex is reconstructed by using the direction of the missing momentum given by primary tracks and the direction of the secondary tracks. The advantage of using e^+e^--pairs compared to the standard analysis using four reconstructed showers in the calorimeter is the better K^o lifetime resolution at short lifetimes. Therefore no dilution of the asymmetry due to short lifetime events is expected. In addition all the non-golden background events ($\pi^+\pi^- n\pi^o$, $K^+K^- n\pi^o$) are expected to be concentrated at zero lifetime.

All the available data up to the half of P25 were used for the analysis. About 108000 events with lifetimes greater than 1 τ_s survived after all the cuts.

2 Preselection

The events with Dalitz decays or γ-conversion are preselected by requiring four tracks where two tracks have opposite charge and an opening angle smaller than 16^o. About 650 of such events are found on a MINRAW tape. The distribution of the opening angle for Dalitz decays and γ-conversion is shown in figure 1 for MC and data.

3 Cuts

The following cuts were applied in order to select the $K^o \rightarrow \pi^o\pi^o \rightarrow Xe^+e^-$ events:

• number of tracks	$N = 4$
• primary vertex	$r < 2$ cm
• primary tracks with hits in PC's	$N_{tr} \geq 2$
• primary tracks identified as Kaons	$N = 1$
• opening angle of secondary tracks (removes the $K^o \rightarrow \pi^+\pi^-$ events)	$\cos\theta > 0.96$
• probability of 1C-fit (missing K^o mass) (enriches golden K^o channel)	$p > 10\%$
• probability of 1C-fit (invariant e^+e^- mass) (reduces the $K^o \rightarrow \pi^+\pi^-\pi^o$ and semileptonic background)	$p > 1\%$
• angle between K^o direction and γ^* (improves the vertex reconstruction resolution)	$-0.8 < \cos\theta < 0.992$
• number of neutral clusters (reduces the semileptonic background)	$N_\gamma \geq 1$
• energy of converted photon (reduces the $K^o \rightarrow \pi^o\pi^o\pi^o$ background)	$E_{\gamma^*} > 100MeV$
• K^o decay vertex	$r < 50$ cm

4 Lifetime reconstruction

The lifetime reconstruction is performed in the transverse plane only. A 1C-fit (missing K^o mass) is applied to the two primary tracks first of all to reject non golden background and also to improve the K^o momentum reconstruction. The e^+e^--vertex is reconstructed by using the intersection of a line which connects the two centers of the circle of each track and the circles. This implies implicitly a zero opening angle at the vertex.

The K^o decay vertex is found as the intersection of the K^o flight direction and the e^+e^--pair momentum direction. In order to have a reasonable estimation of the intersection of the two lines an angle larger than 7.3^o ($\cos\theta < 0.992$) between the two lines is required. The K^o decay length is given by the distance between the primary vertex and the K^o decay vertex. The K^o lifetime is obtained using the transverse K^o momentum from the 1C-fit.

The resolution achieved with this method is shown in figure 2 for different lifetime regions. The resolution becomes worse for events with longer lifetime.

The e^+e^--vertex distribution in the transverse plane is shown in figure 3. Clear signs for γ-conversion at the places with thick material (walls of PC1, PC2, DC1...) can be seen. Evidence for Dalitz decays is seen by looking at the distance between the e^+e^--vertex and the reconstructed K^o-decay vertex.

5 Background

The Monte Carlo studies show that the major source of background is the $K^o \to \pi^o\pi^o\pi^o \to Xe^+e^-$ channel (see fig. 5). $K^o \to \pi^+\pi^-\pi^o$ with two pions misidentified as electrons is another decay channel, which significantly contributes to the background. The other background sources are negligible. The two background sources mentioned above have a flat lifetime distribution and an efficiency very similar to that of the desired events. The method of estimating the background level used in this analysis is a fit to the efficiency corrected lifetime distribution (fig. 4). The fit is performed in the $[3.4\tau_s, 15\tau_s]$ lifetime interval, since the Monte Carlo simulation does not reproduce well the efficiency for the short lifetimes. Assuming a flat background with the same efficiency as for the golden events yields about $2.9\% \pm 0.3\%$ background events in the $[0, 15\tau_s]$ lifetime region.

6 Normalisation

The fig. 6 shows the $\overline{K^o}$ and K^o momentum distributions and the $\overline{K^o}/K^o$ ratio as a function of the K^o momentum for the lifetime region $[1\tau_S - 4\tau_S]$. The distributions are corrected for CP violation effects. The resulting $\overline{K^o}/K^o$ ratio is flat as a function of K^o momentum and the obtained normalisation is $\alpha = 1.188 \pm 0.008$.

7 Asymmetry

The decay rate asymmetry of K^0 and $\overline{K^o}$ decays to $\pi^o\pi^o$ is shown in fig. 7. The fit function uses the theoretical rates convoluted with the resolution obtained from the Monte Carlo. The background is assumed to be dominated by $K_L^o \to 3\pi^o$ with the same relative efficiency as a function of lifetime as the desired events.

$$A(t) = \frac{\alpha R(\overline{K}^0 \to \pi^o\pi^o)(t) - R(K^0 \to \pi^o\pi^o)(t) + (\alpha - 1) \cdot bckg.}{\alpha R(\overline{K}^0 \to \pi^o\pi^o)(t) + R(K^0 \to \pi^o\pi^o)(t) + (\alpha + 1) \cdot bckg.}$$

with

$$\begin{aligned} R(K^0 \to \pi^o\pi^o)(t) &= (1 - 2 \cdot Re(\varepsilon)) \\ &\quad \cdot \left(e^{-t/\tau_s} + |\eta_{oo}|^2 e^{-t/\tau_l} + 2 \cdot |\eta_{oo}| \cos(\Delta m \cdot t - \varphi_{oo}) e^{-\frac{1}{2}(1/\tau_s + 1/\tau_l)t}\right) \end{aligned}$$

$$
\begin{aligned}
R(\overline{K}^0 \to \pi^o\pi^o)(t) &= (1 + 2 \cdot Re(\varepsilon)) \\
&\cdot \left(e^{-t/\tau_s} + |\eta_{oo}|^2 e^{-t/\tau_l} - 2 \cdot |\eta_{oo}| \cos(\Delta m \cdot t - \varphi_{oo}) e^{-\frac{1}{2}(1/\tau_s + 1/\tau_l)t}\right)
\end{aligned}
$$

The value of $|\eta_{oo}|$ is fixed at $2.253 \cdot 10^{-3}$, which is the present world average value. The following results are obtained from the fit to the lifetime dependent asymmetry:

- normalisation $\alpha = 1.187 \pm 0.008$
- background in the $[0, 15\tau_s]$ lifetime region $Bck = 0.8\% \pm 0.4\%$
- phase of η_{oo} $\varphi_{oo} = (60 \pm 12)^o$

The normalisation obtained here is in a very good agreement with the one obtained from the $\overline{K^o}/K^o$ ratio. The background level obtained by fitting the asymmetry is only about 1/3 of the background found from the fit to the lifetime distribution. This is for a moment an open problem and further investigations are necessary.

By fixing the background level at the value obtained from the fit to the efficieny corrected lifetime distribution and performing once more the asymmetry fit we obtain a similar result for the phase $\varphi_{oo} = (55 \pm 15)^o$ as leaving the background as a free fit variable (see fig. 8).

8 Estimated error at the full expected statistics

For the analysis presented above all data up to to the first half of P25 were used. This corresponds to about 20% of the full expected statistics at the end of 1995. Scaling our result to the final statistics we estimate the expected precision of our φ_{oo} measurement:

- no improvements in the analysis $\Delta\varphi_{oo} = 6^o$
- total background rejection $\Delta\varphi_{oo} = 4.5^o$
- total background rejection and the perfect lifetime resolution (the only limit is a statistics) $\Delta\varphi_{oo} = 4^o$

This shows, that the background reduction improves the precision to a greater extend than improving the lifetime resolution.

9 Future Work

The asymmetry is diluted due to the background which reduces the precision of the φ_{oo} measurement. The background, mostly $K^o \to \pi^o\pi^o\pi^o$, might be reduced by using the neutral showers in the calorimeter to identify the events. A neural network can be used to improve the cuts quality. Also the usage of the PID information for the π/e separation might reduce the $K^o \to \pi^+\pi^-\pi^o$ background.

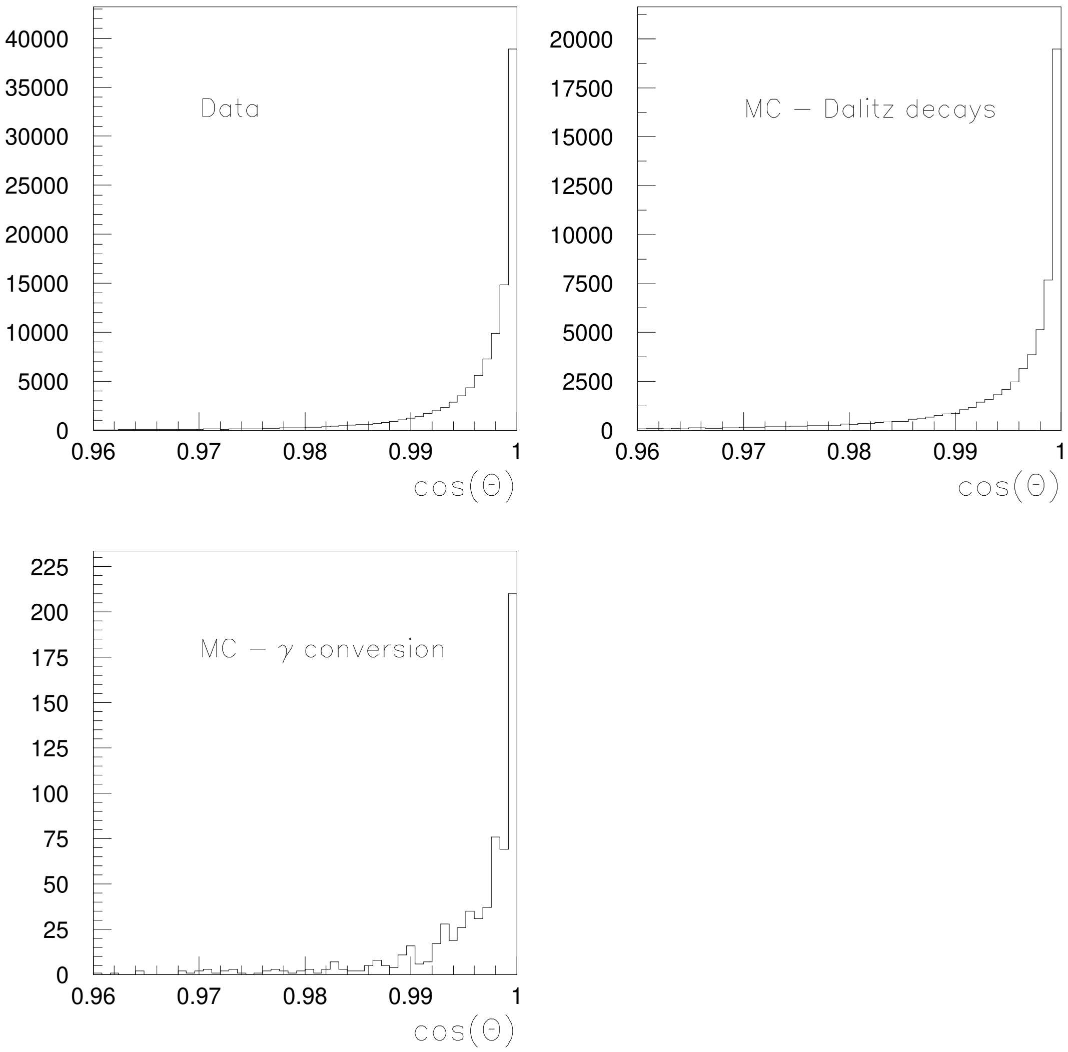

Figure 1: Opening angle for Dalitz decays and γ-conversion found with MC and data.

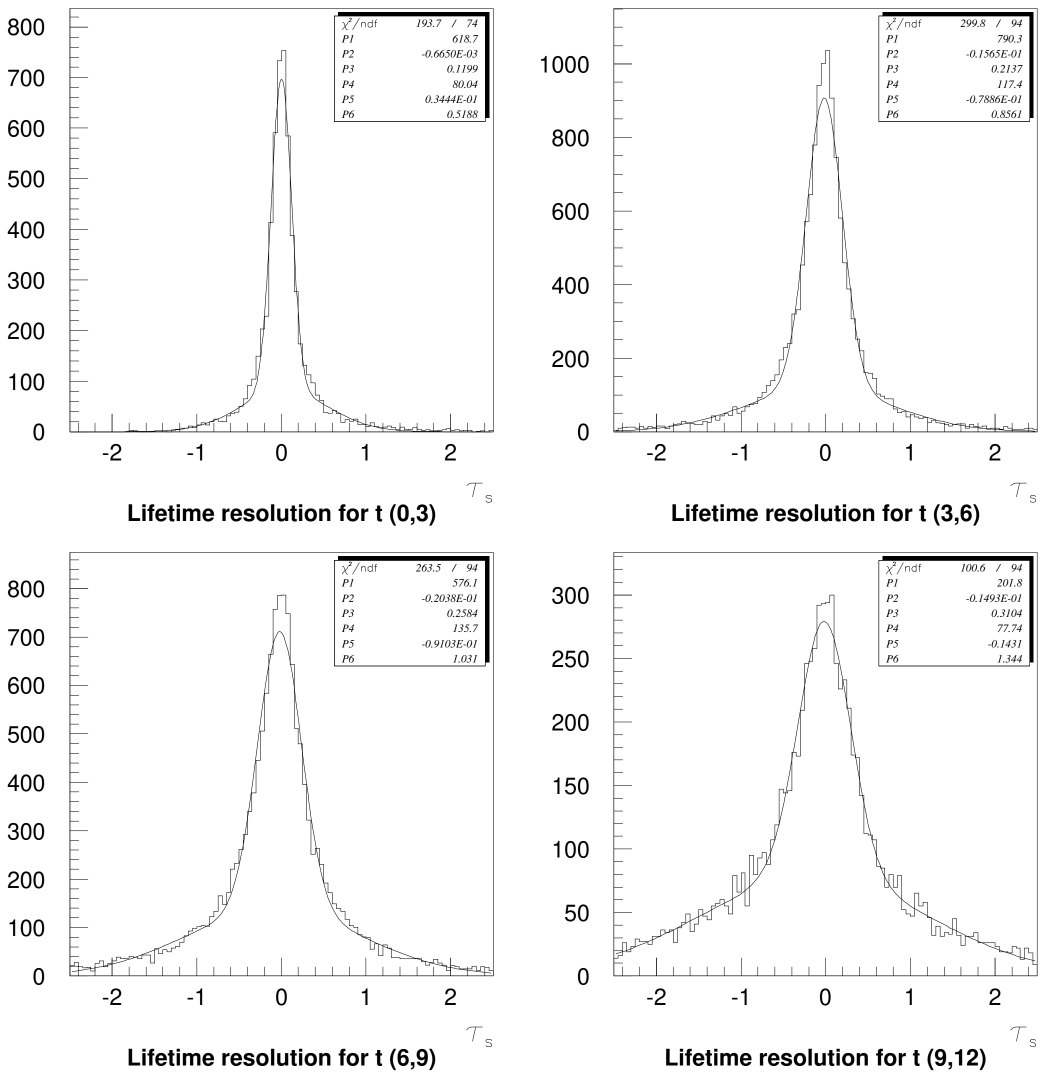

Figure 2: Lifetime resolution for different lifetime regions.

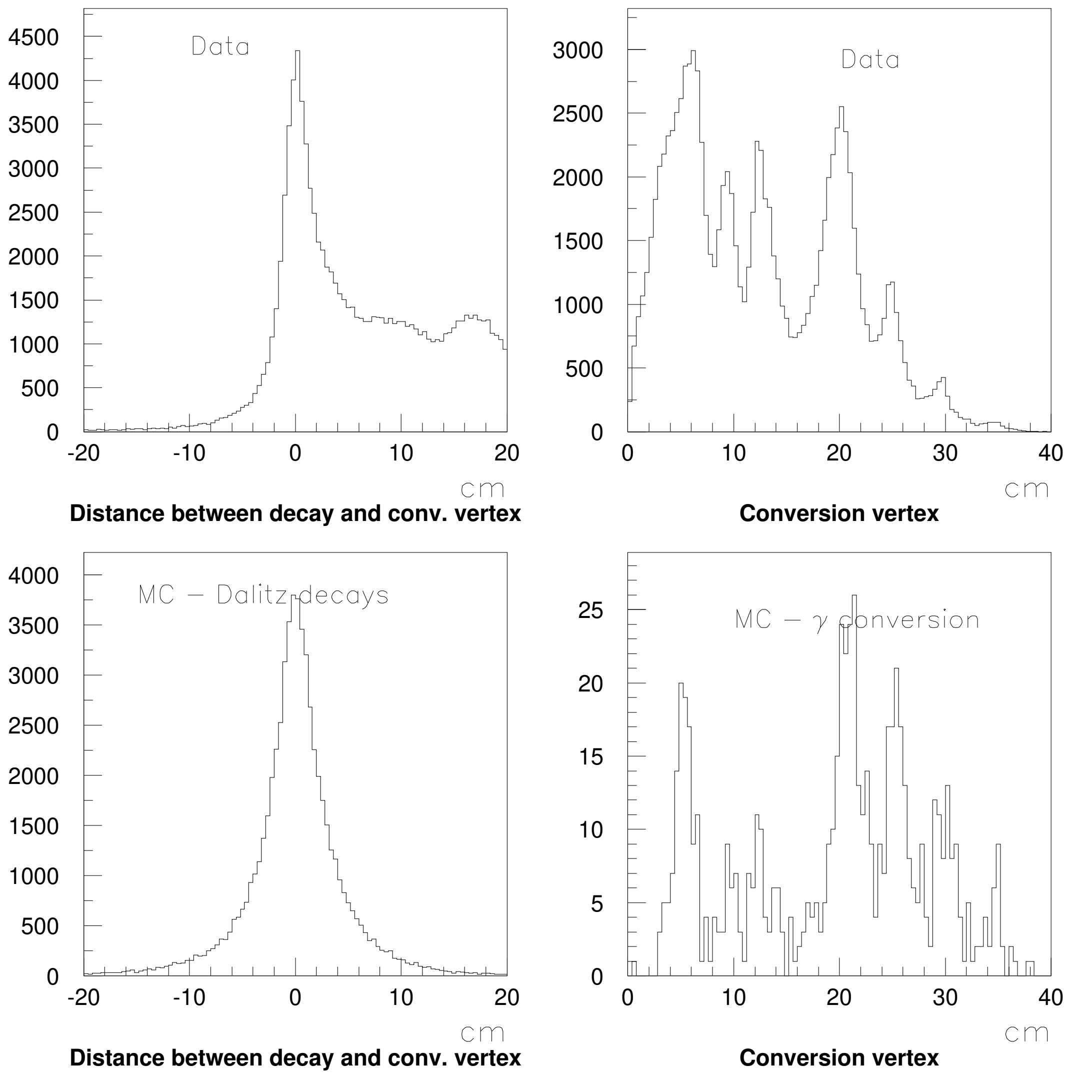

Figure 3: Differences between Dalitz decays and γ-conversion.

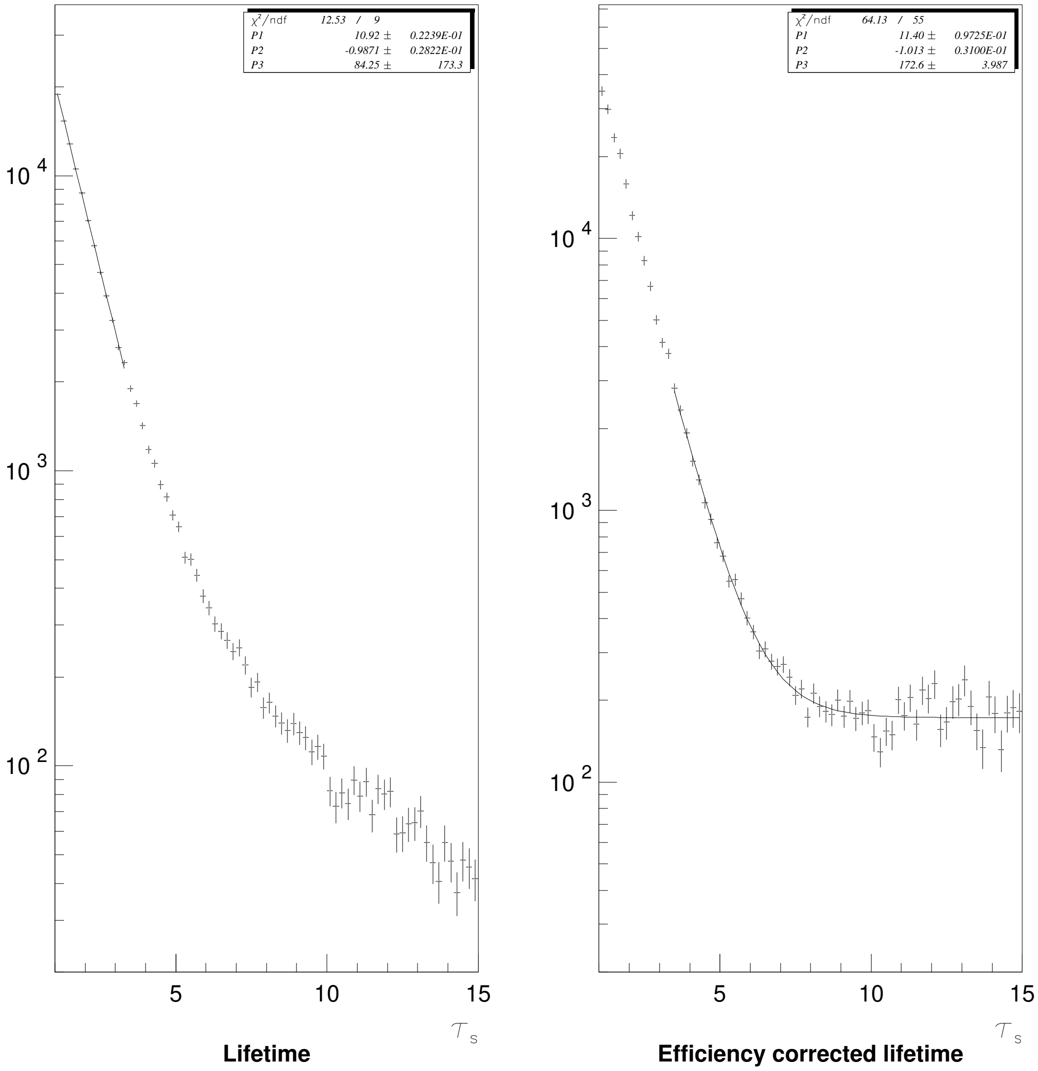

Figure 4: Lifetime distribution with and without efficiency correction. The fit to the efficiency corrected lifetime distribution is performed starting from $3.4\tau_S$ since for the shorter lifetimes Monte Carlo simulation doesn't reproduce well the efficiency.

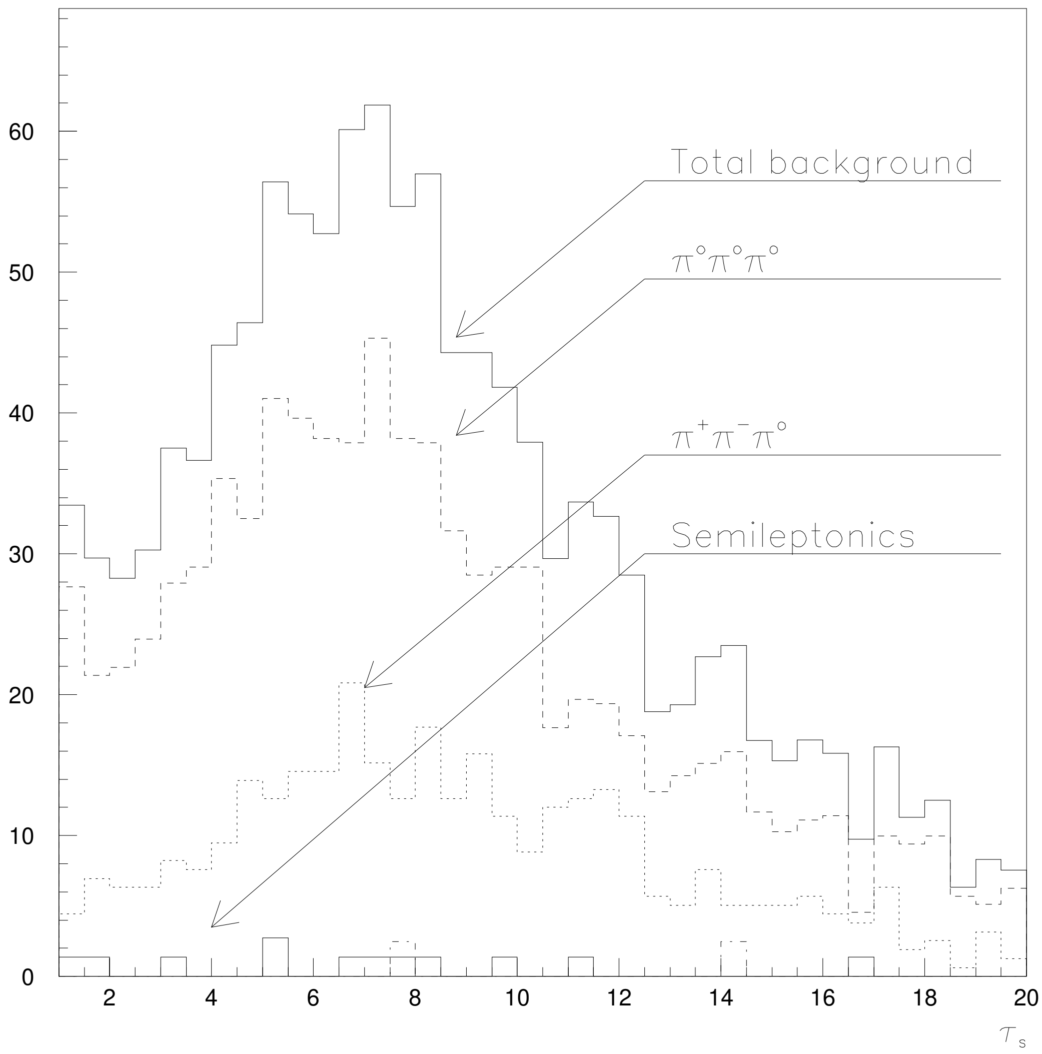

Figure 5: Background sources.

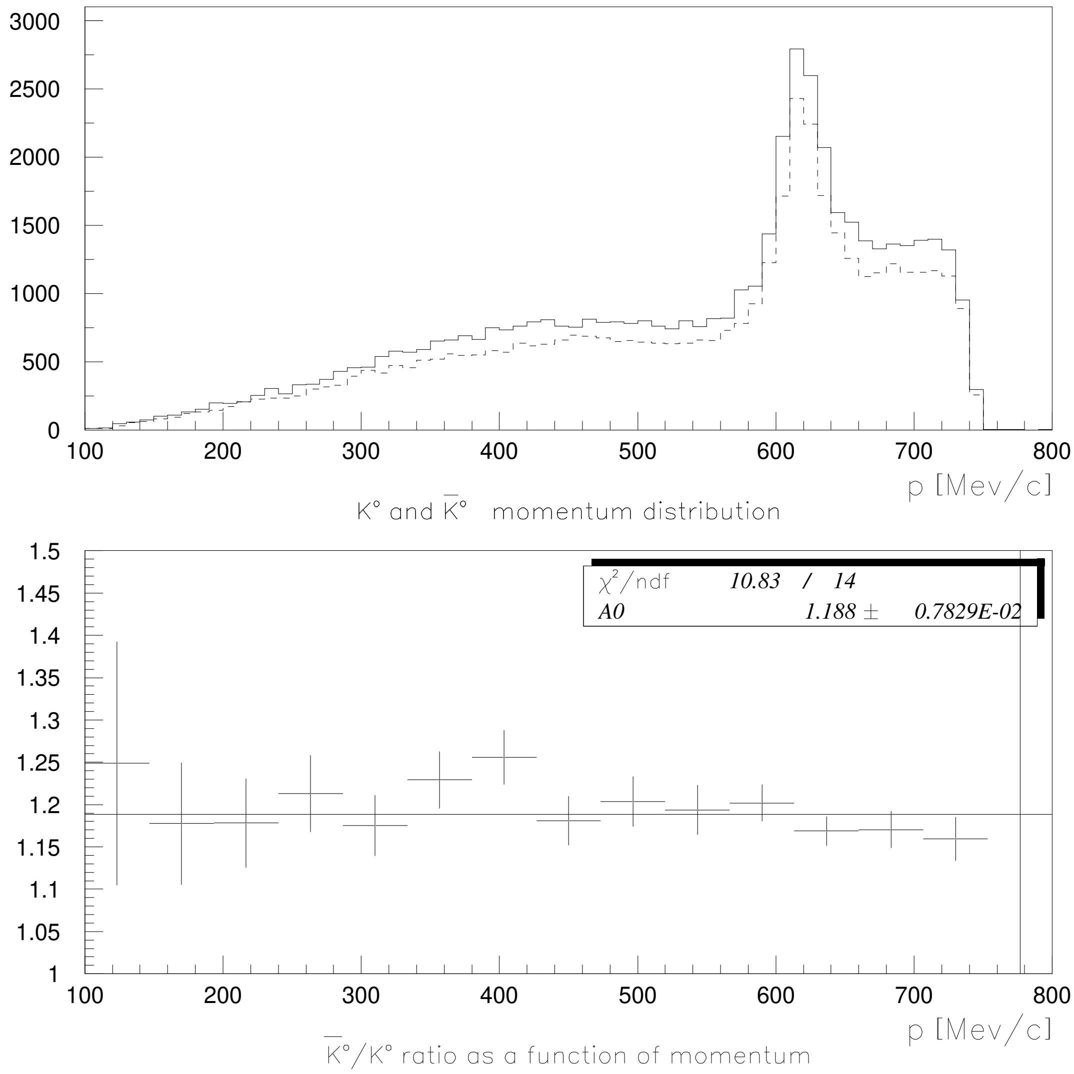

Figure 6: $\overline{K^o}$ and K^o momentum spectra and a $\overline{K^o}/K^o$ ratio. The $\overline{K^o}/K^o$ ratio is flat with the K^o momentum.

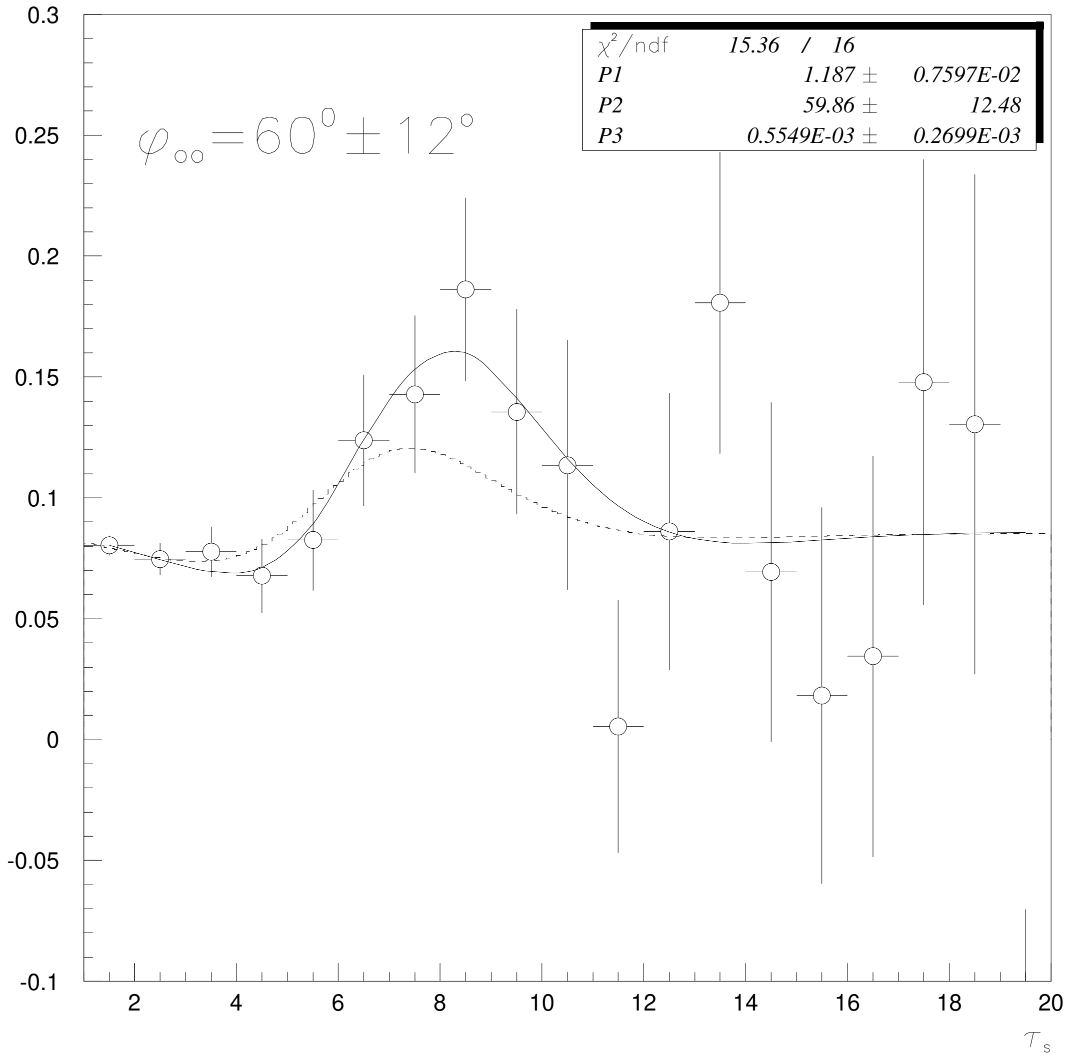

Figure 7: K^o and $\overline{K}^o$ decay asymmetry fitted with a free phase, normalisation and background. The dotted line shows the simulated asymmetry with the $\varphi_{oo} = 44.3^o$ and the background level 2.9% in the $[0, 15\tau_s]$ lifetime region, namely the background level obtained from the the fit to the lifetime distribution. The simulated asymmetry fits quite well to the data points ($\chi^2/ndf = 19.9/19$).

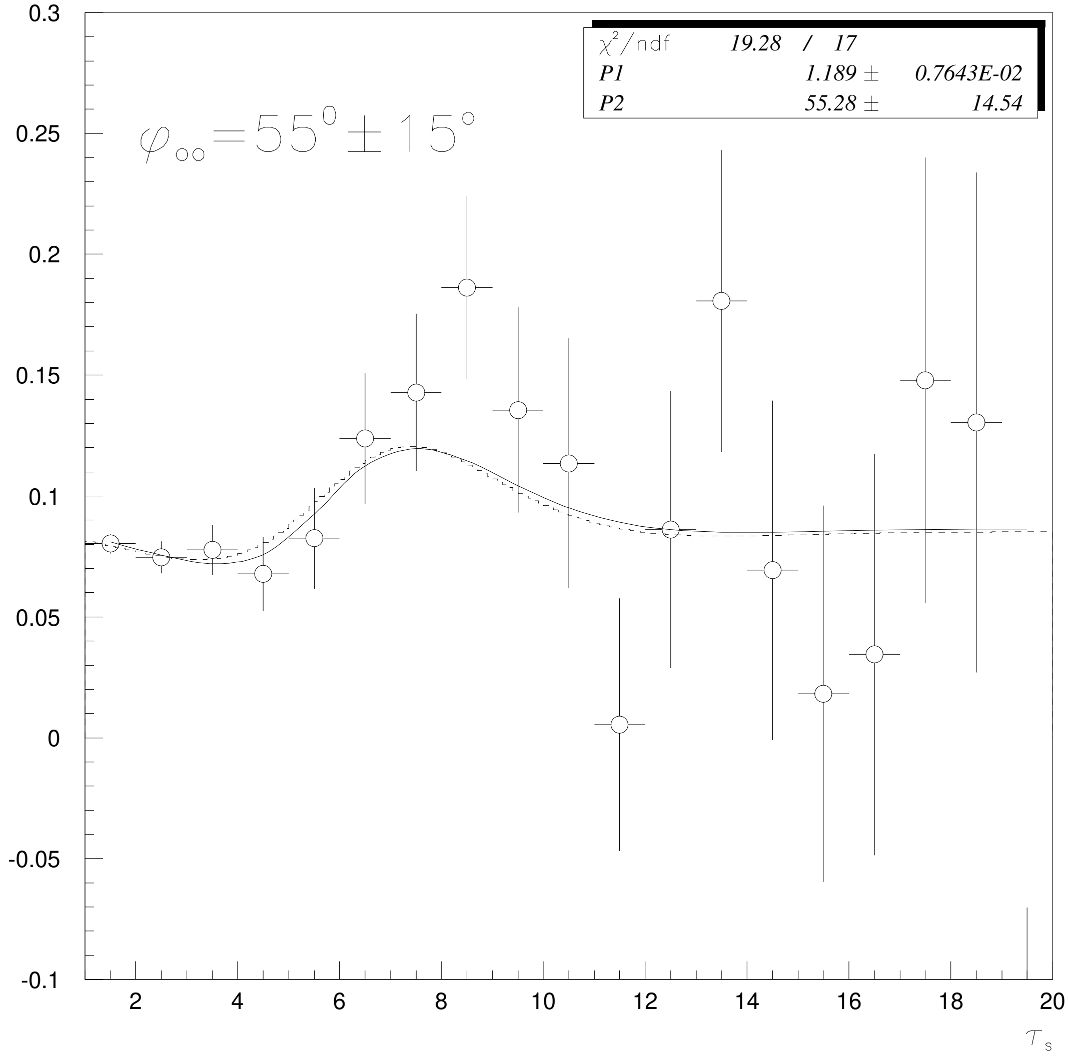

Figure 8: K^o and $\overline{K}^o$ decay asymmetry. Fitted with a free phase and normalisation. The background level is fixed at 2.9%. The dotted line shows the simulated asymmetry.