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K_L° production in 1-prong τ decays

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1 Introduction

K° production is usually investigated through the K_S° component in the $\pi^+\pi^-$ decay channel. Such an analysis was done in τ decays in ALEPH with 91 data [1] and some ongoing work is being performed for the 92 data. Due to the low multiplicity in τ decays and the good calorimetric granularity in ALEPH, it is possible, for the first time, to measure the K° rate through the K_L° component, detected via its interaction in HCAL.

The object of this note is to present the results of an analysis designed in this way. It should be pointed out that a calorimetric search for K_L°'s is completely orthogonal to other analyses relying only on charged particles and photons, involving the TPC and ECAL [2]. Such a perfect complementarity is exploited to measure the branching fractions for several new decay modes of the τ. This is useful (a) to understand experimentally the background in important channels like $\tau \to \nu_\tau K^-$ and $\tau \to \nu_\tau K^-\pi^\circ$ and (b) to improve our presently poor knowledge on the τ decays involving strange particles [3].

The results presented here are concerned with K_L° production in 1-prong τ decays possibly with additional π°'s. They provide measurements on the following decay modes :

$$\begin{aligned} \tau \to &\quad \nu_\tau h K^\circ \\ \tau \to &\quad \nu_\tau h \pi^\circ K^\circ \end{aligned}$$

In addition, the statistical analysis designed in Ref.[2] allows the separation of the K and π contributions to the total hadron rate.

2 Event selection

Events are selected using the $\tau^+\tau^-$ TAUSLT filter , an improved version of the earlier program described in [4] : its overall efficiency is 77.1%, while the background is reduced to only 1.3% , affecting mostly the leptonic decays (from $Z \to e^+e^-, \mu^+\mu^-, and\ \gamma\gamma \to leptons$) and to a lesser extent the multi-prong decays (from $Z \to q\bar{q}$).

Decays with only one 'good' track ($\geq$ 4 TPC pads, $|d_\circ| < 2cm$, $|z_\circ| < 10cm$) are kept with the following further requirements :

- P > 2 GeV
- identification as a hadron by TAUPID [4]

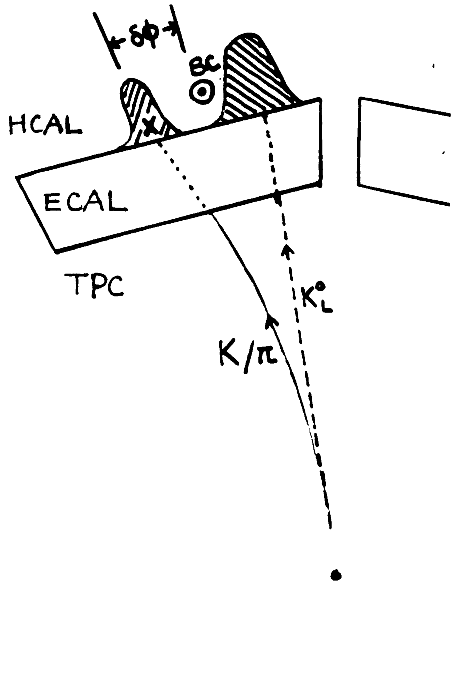
Photons are reconstructed with GAMPEX, with a threshold of 250 MeV, and π°'s are identified as usual (except for a tighter bound $0.09 < m_{\gamma\gamma} < 0.19$ GeV). This allows the decay data sample to be split in 2 classes :

'h' $\equiv$ $h + 0\gamma$ and $2 < P_h < 20\ GeV$
'$h\pi^\circ$' $\equiv$ $h + 1\pi^\circ$ or 1γ with E > 4 GeV and $2 < P_h + E_{\pi^\circ,\gamma} < 30\ GeV$

Data from 91 and 92 are used, yielding a sample of 7948 one-prong τ candidates.

3 Calorimetric selection

The characteristics of the events searched for in this analysis are illustrated in Fig.1 : an excess of HCAL energy compared to the amount expected from the charged hadron and a displacement of the energy barycenter compared to the impact of the track. This displacement is expected to occur mostly in the plane transverse to the beams, since the dominant effect is due to the track bending in the magnetic field (recall that typical angles in τ decays are of the order of only 1° at Z° energies, and therefore they do not provide enough separation in HCAL generally).



1. τ decay into a charged hadron and a K_L°.

Two calorimetric variables sensitive to the presence of a K_L° are defined along these lines :

(1)

$$\delta_E = \frac{E_{HCAL} - P_h}{\sigma_h}$$

where E_{HCAL} is the sum of the energy in HCAL clusters within a 30° cone around the charged hadron of momentum P_h and σ_h the expected fluctuation in the charged hadron energy in HCAL taken to be

$$\sigma_h = 0.9\sqrt{P_h} \;\; (GeV)$$

(2)

$$\delta\phi = |\phi_{barycenter} - \phi_{track\ impact}|\ \xi$$

with ξ=+1 if the shift in ϕ occurs towards a larger bending of the track and $\xi = -1$ in the opposite case.

Thus a K_L° signal should occur for δ_E positive and possibly large (δ_E measures the excess of HCAL energy in units of the expected fluctuation in the charged hadron energy) and for large negative $\delta\phi$ values.

Asymmetric fluctuations in the 'charged' hadronic shower could fake a K_L° contribution in practice : Figs.2 and 3 show the expected distributions in this case, with the resolution tails in δ_E and $\delta\phi$. It should be noticed, as expected, that the fluctuations leading to $\delta\phi$ tails are essentially symmetric around the track impact. This important observation leads to a direct way to limit systematic effects in the calorimetric selection, since the background from shower fluctuations can be directly estimated from the data, without having to rely on the precise Monte Carlo simulation of resolution tails and on the shower description, which are probably not accurate for atypical configurations.

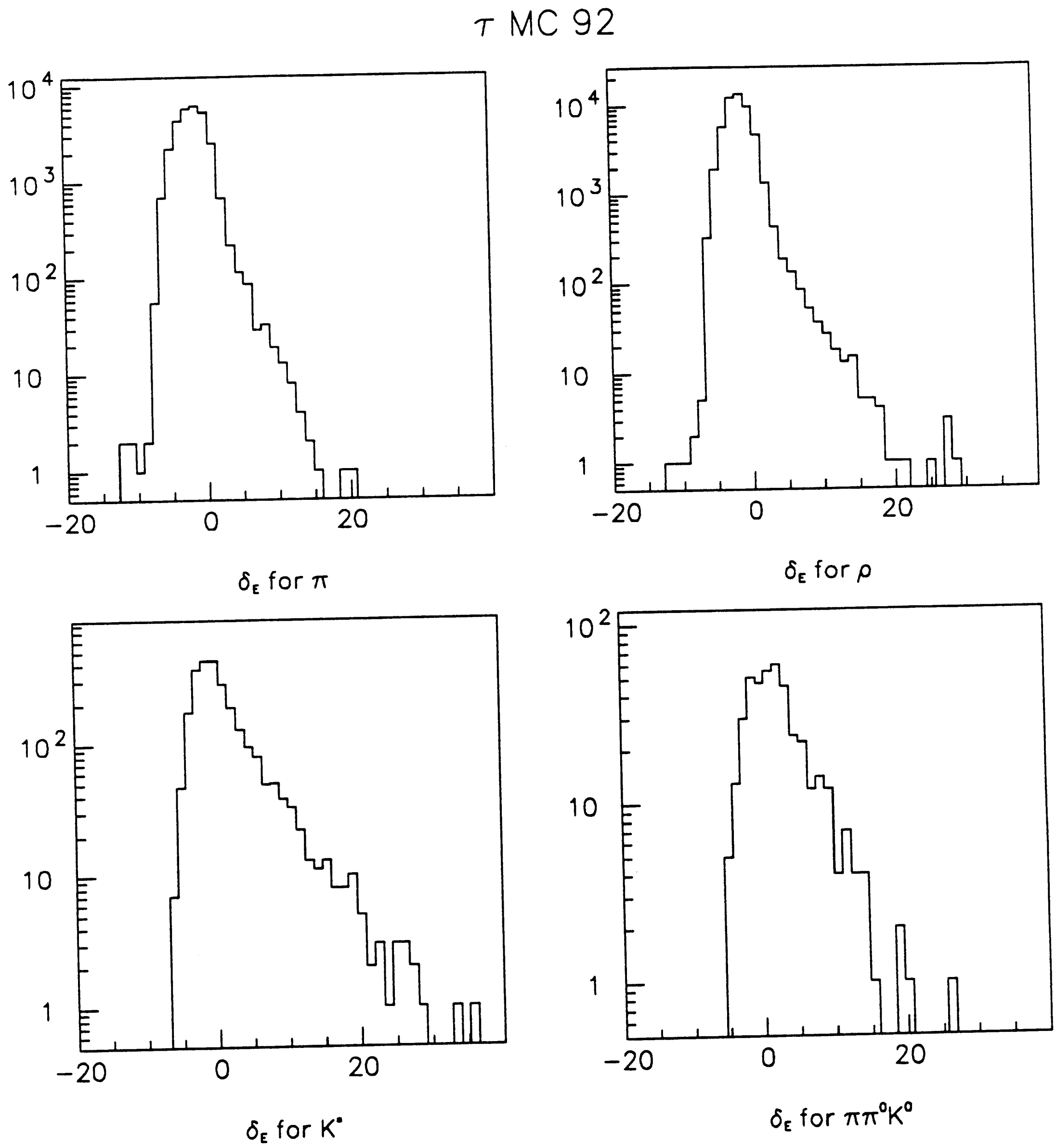
The final cuts are optimized using the Monte Carlo in the $(\delta_E, \delta\phi)$ plane to reduce the backgrounds at a negligible level while keeping a reasonable efficiency :

$$\delta_E > 0 \text{ and } \delta\phi < -1^\circ$$

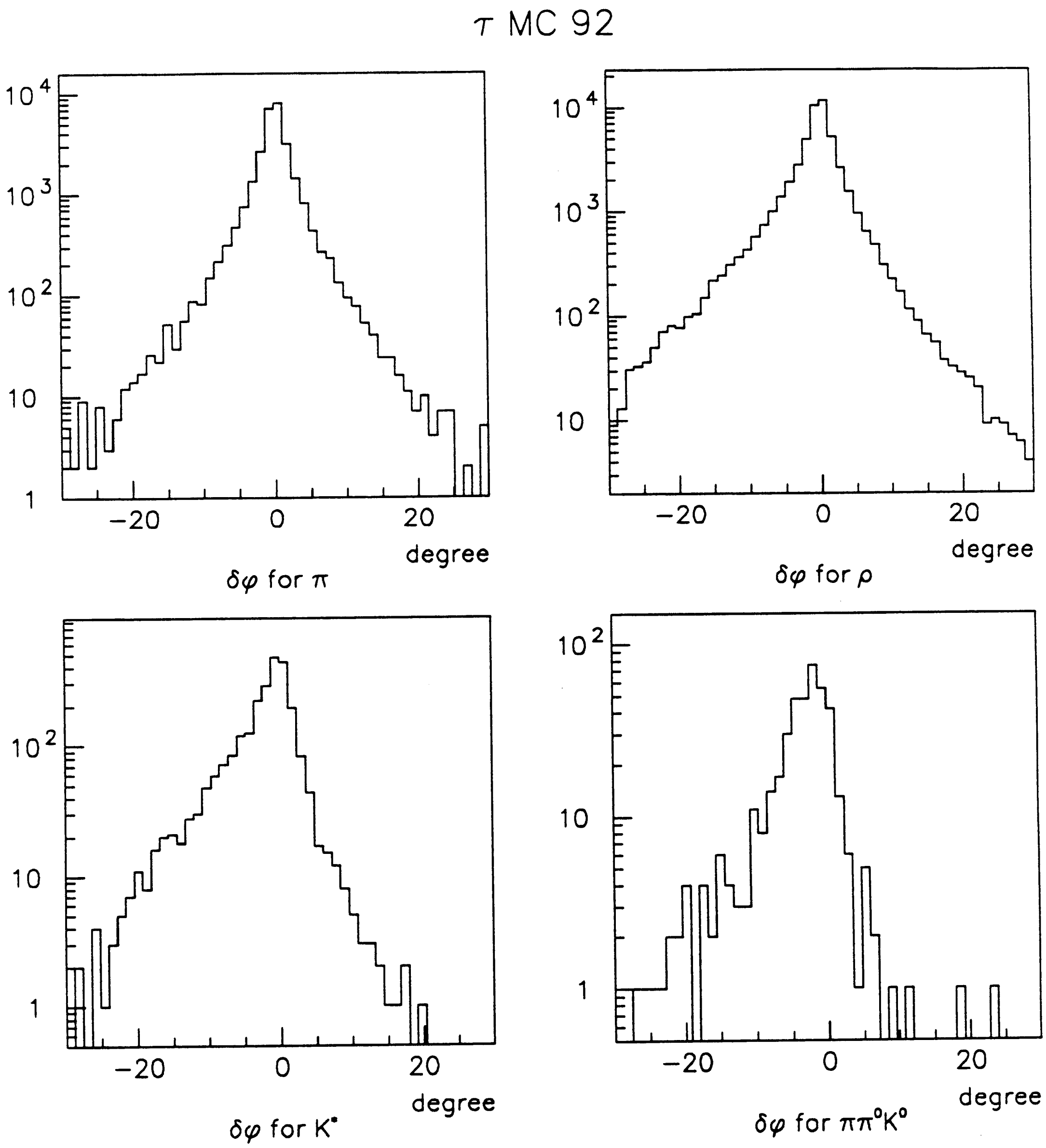
and

$$-7\delta_E + 8\delta\phi + 64 < 0$$

together with an absolute cut on the residual HCAL energy $E_{HCAL} - P_h > 4\ GeV$.



2. δ_E Monte-Carlo distributions.



3. $\delta\phi$ Monte-Carlo distributions.

Additional cuts are necessary to remove further backgrounds :

(1) $h + \pi^\circ$'s final states where some of the π° energy leaks into HCAL (through the ECAL cracks) can simulate a fake K_L° signal ; a cut on $\phi_{HCAL\ cluster}$ around the modules edges of ECAL is necessary.

(2) a small contribution from 3-prong events with only 1 (good) reconstructed track is also present. To reduce this effect a track with $2 < |d_\circ| < 50cm$ is counted as good track, and an event with more than 1 'good' track is discarded.

4 Results

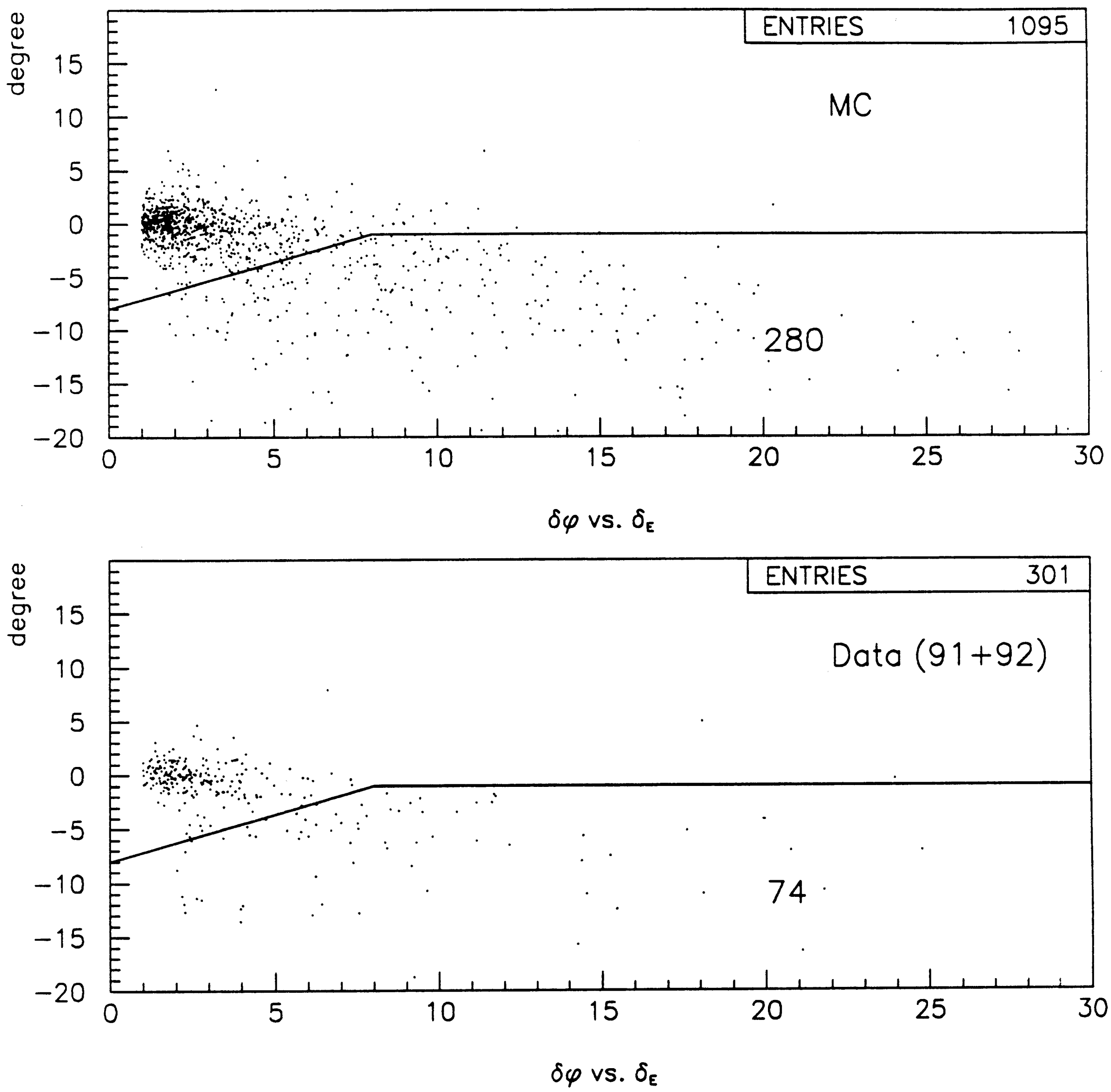
The effect of the final calorimetric cuts is shown in Fig.4 and Fig.6 for the hK_L° and $h\pi^\circ K_L^\circ$ samples, respectively. Clear tails, as from K_L°'s in the Monte-Carlo are observed in the data. Within the limited statistics of the data, the distributions of δ_E or $(E_{HCAL} - P_h)$, and $\delta\phi$ follow the expectations from the Monte-Carlo (Figs.5 and 7).

Whereas the analysis is dependent on the Monte-Carlo for the estimate of the background from $h+\pi^\circ$'s channels with π° leakage into HCAL through ECAL cracks, this is not the case for the h background which is substracted from the data (and the Monte-Carlo) taking symmetric cuts in $(\delta_E, \delta\phi)$ plane.

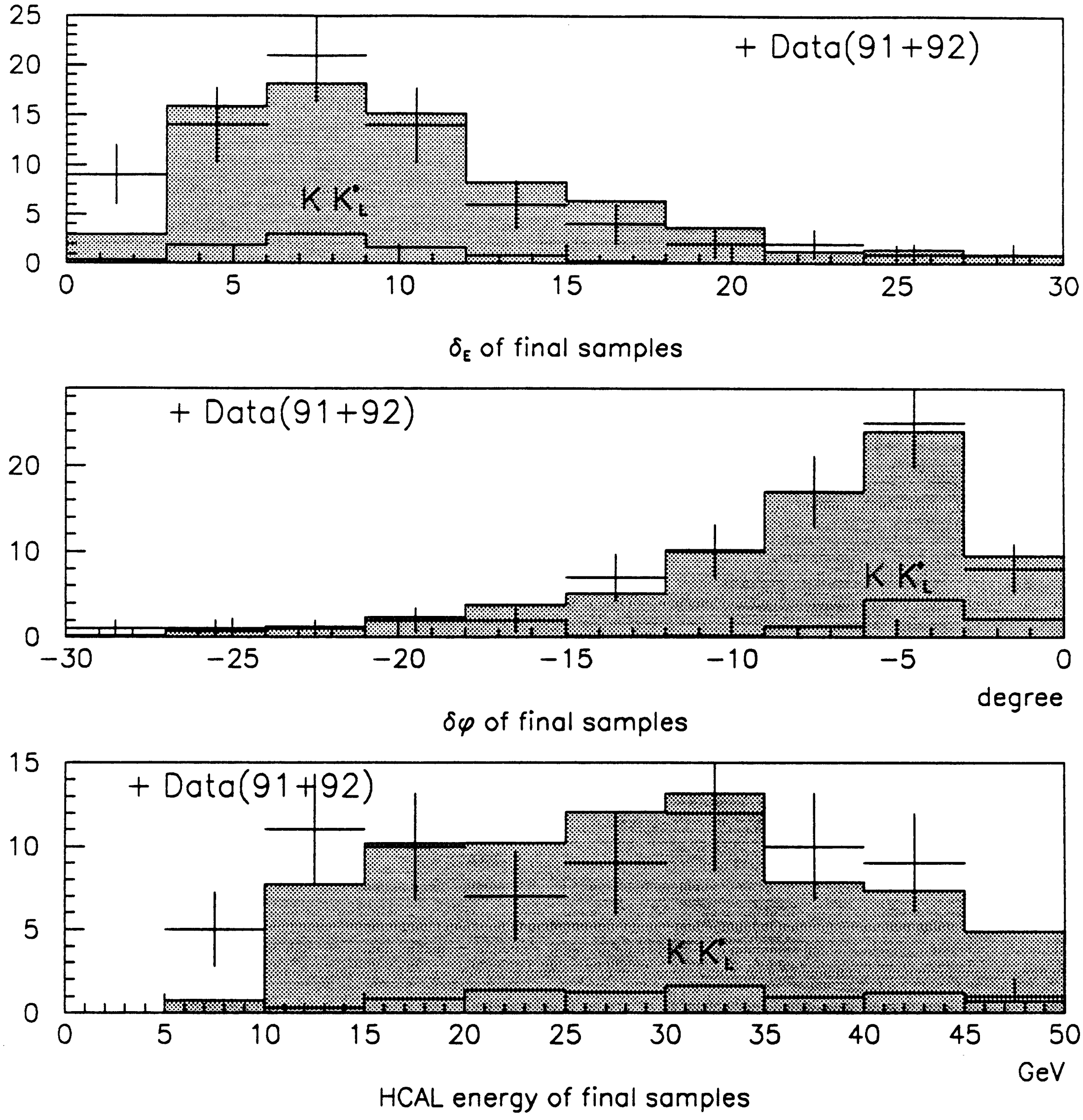
Finally, the charged hadrons are analyzed with dE/dx in order to statistically determine the π and K content [2]. The K probability distributions are given in Figs.8 and 9 : they show a clear evidence for the KK° channel and only an indication for through a maximum likelihood method, since the statistics is rather low.

Table 1: *Results on the final samples*

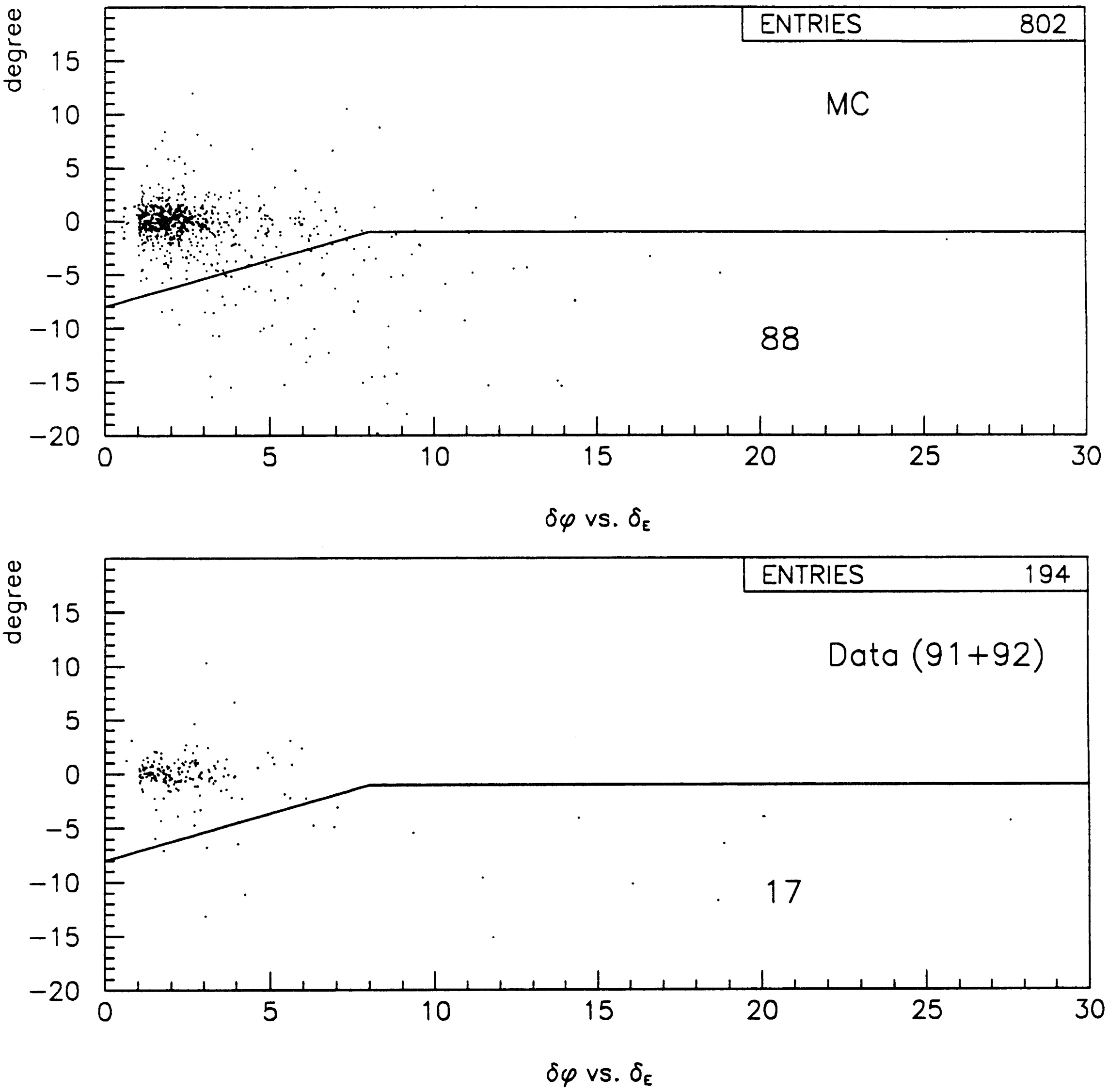
sample	hK°	$h\pi^\circ K^\circ$
selected events	74	17
h background	2	2
$N_K(dE/dx)$ fit	8.4±3.3	1.4±1.3



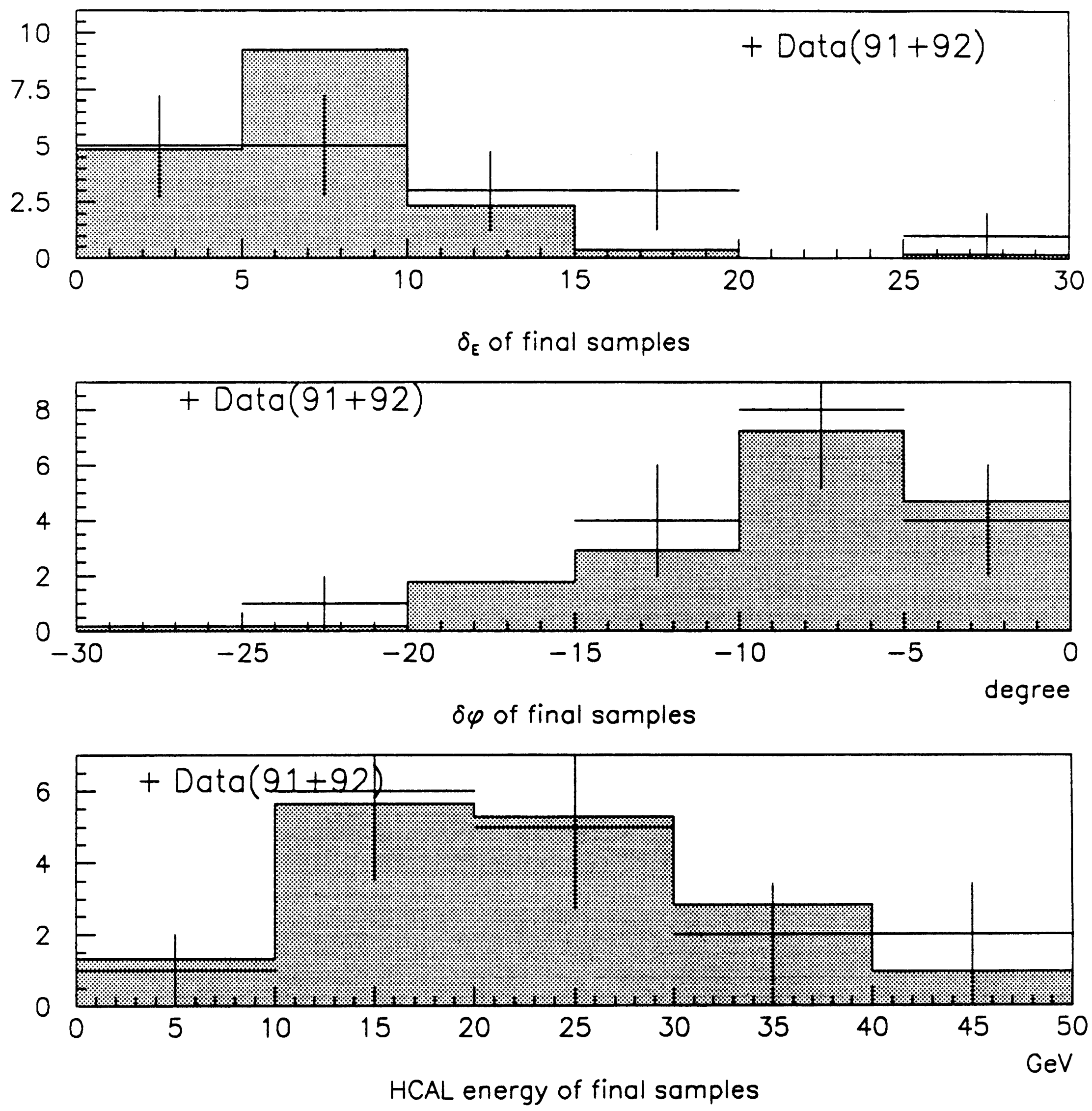
4. $(\delta_E, \delta\phi)$ distributions for Monte-Carlo and data : hK° sample.



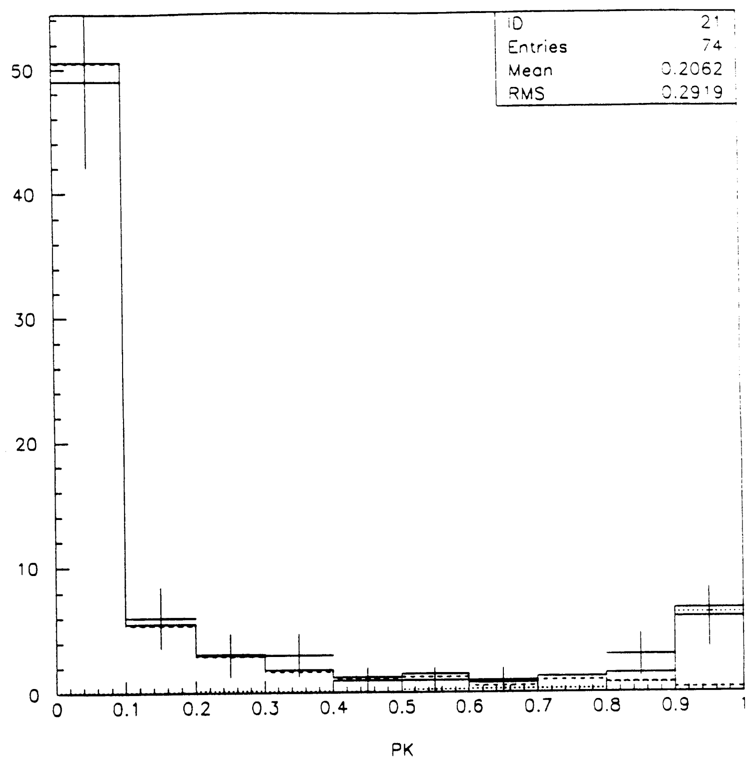
5. Distributions for selected hK° sample.



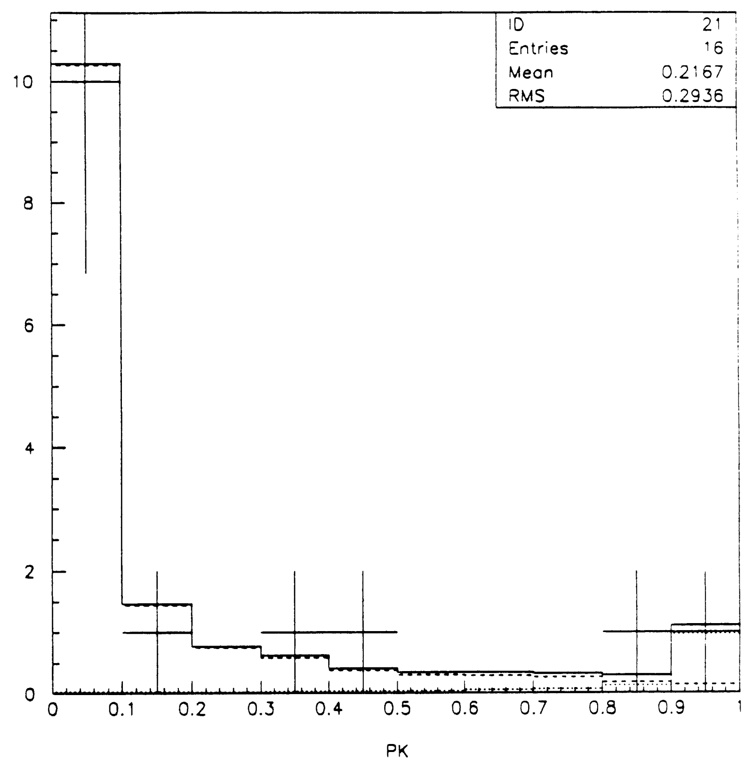
6. $(\delta_E, \delta\phi)$ distributions for Monte-Carlo and data : $h\pi^\circ K^\circ$ sample.



7. Distributions for selected $h\pi^\circ K^\circ$ sample.



8. dE/dx K probability distribution for selected hK° sample.



9. dE/dx K probability distribution for selected $h\pi^{\circ}K^{\circ}$ sample.

The corresponding efficiencies and purities are obtained from the Monte-Carlo. The πK°_L sample is expected to contain also events from the channel $\pi K^\circ_L \overline{K^\circ}$, which is estimated to contribute at the level 10% level (based on the measured $\pi K^+ K^-$ rate). An uncertainy of $\pm 5\%$ is introduced to take this effect into account. The final branching fractions are given in Table 2.

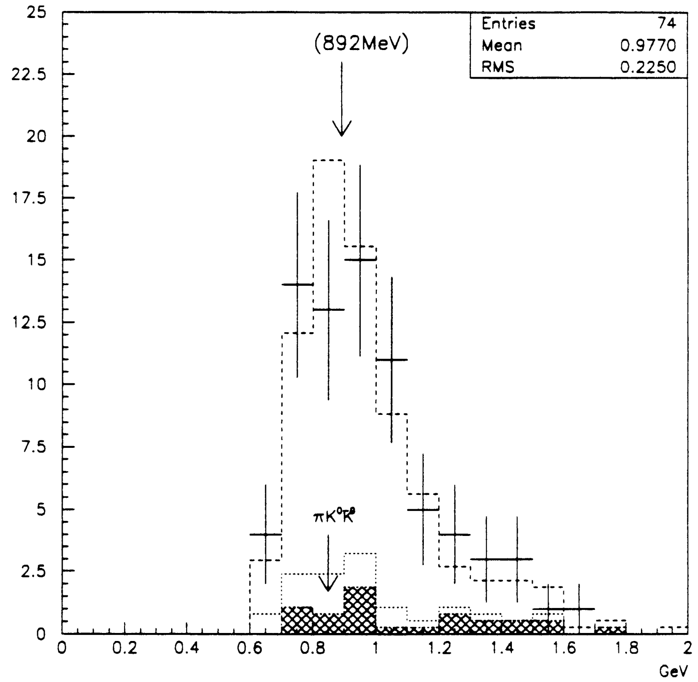
Table 2: *Results on branching fractions*

channel	πK°_L	$K K^\circ_L$	$\pi\pi^\circ K^\circ_L$	$K\pi^\circ K^\circ_L$
events	65.6	8.4	15.6	1.4
efficiency*(%)	12.3	6.0	5.7	5.8
background	10.8	0.1	4.4	0.0
channel	πK°	$K K^\circ$	$\pi\pi^\circ K^\circ$	$K\pi^\circ K^\circ$
$B \pm stat \pm sys(\%)$	1.39±0.24±0.16	0.28±0.12±0.03	0.41±0.15±0.09	0.05±0.05±0.01

* computed for both K°_L and K°_S and multiplied by 2

The systematic uncertainties are dominated by the calorimetric cut. Since the observed distributions do not show deviations when compared to the Monte-Carlo expectations, it is possible to place limits to systematic shifts in HCAL energies. These possible biases could change the efficiencies up to an estimated level of $\pm 7\%$.

The πK°_L final state is dominated as expected by the K^* resonance (Fig.10).



10. πK°_L mass distributions.

5 Summary

Through a calorimetric analysis in HCAL, the K_L^o component in 1-prong τ decays is measured and branching ratios are determined for 4 channels. The value for K^* mode is in agreement with measurements using the $K_S\pi$ [5] and the new ALEPH determination with $K\pi^o$ channel [2]. Averaging the two ALEPH results yields

$$B(\tau \rightarrow \nu_\tau K^{*-}) = (1.48 \pm 0.19)\%$$

The 3 other branching ratios are measured for the first time.

References

[1] A.Frey, ALEPH-note 92-137 , and M.Davier and H.J.Park , τ meeting

[2] M.Davier and H.J.Park, ALEPH-note 93 - 165

[3] For a recent review, see M.Davier, Summary Talk of the 2nd International Workshop on τ Lepton Physics, Colombus, K.K.Gan editor, ... (1993)

[4] A new version of TAUPID with improved performances has been developed and will be described shortly in an ALEPH-note (M.Davier and H.J.Park). The earlier version and the general method are presented in : M.Davier and Z.Zhang, ALEPH-note 91-93

[5] Paticle Data Group