One-prong τ Decays with Neutral Kaons

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- **Selection of τ Decays with Neutral Kaons**
- **Classification of the Decay**
- **Fitting Procedure**
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Introduction

Study of tau decay modes involving

neutral kaons

using the L3 detector at LEP

$$\tau^- \rightarrow \nu_\tau \pi^- \bar{K}^0$$

$$\tau^- \rightarrow \nu_\tau \pi^- \pi^0 \bar{K}^0$$

$$\tau^- \rightarrow \nu_\tau \pi^- \bar{K}^0 K^0$$

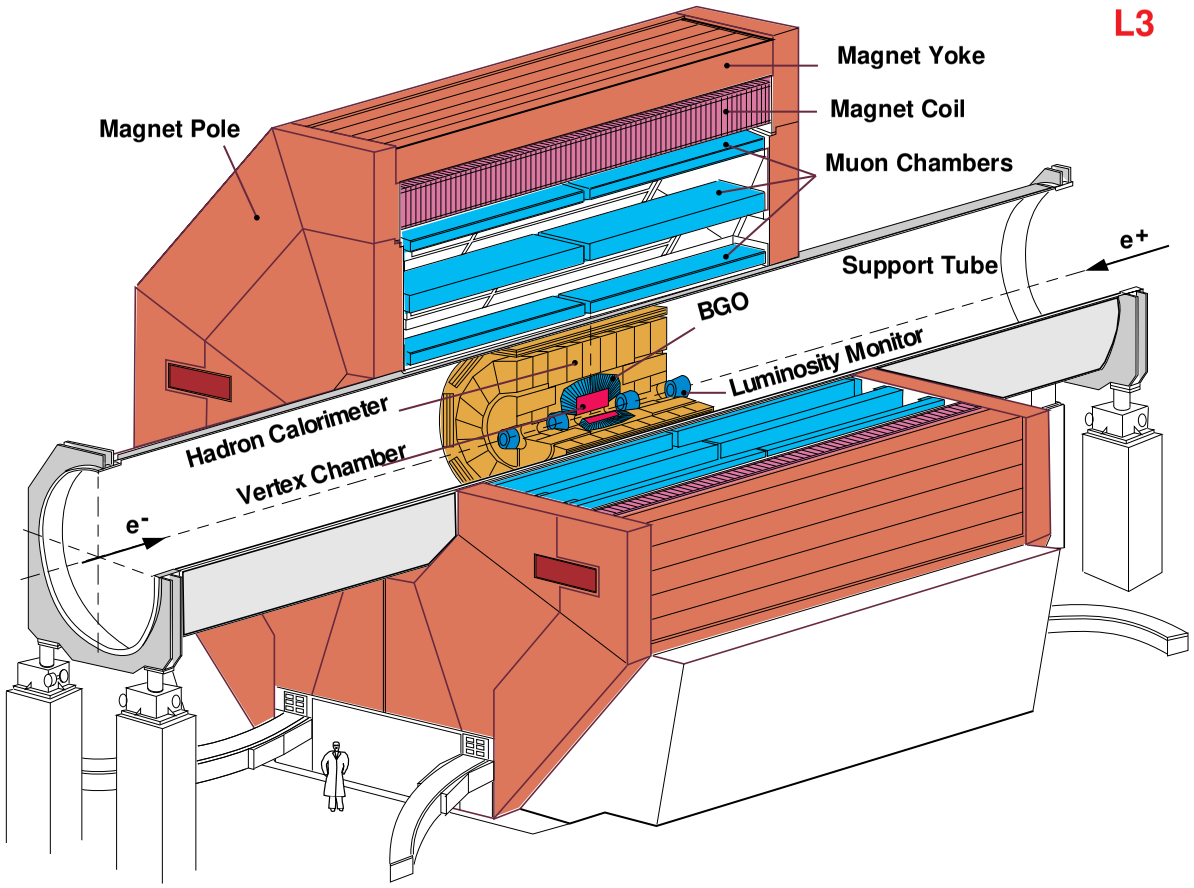
Statistics collected in 1991-1993

corresponding to an integrated luminosity of 69 pb^{-1}

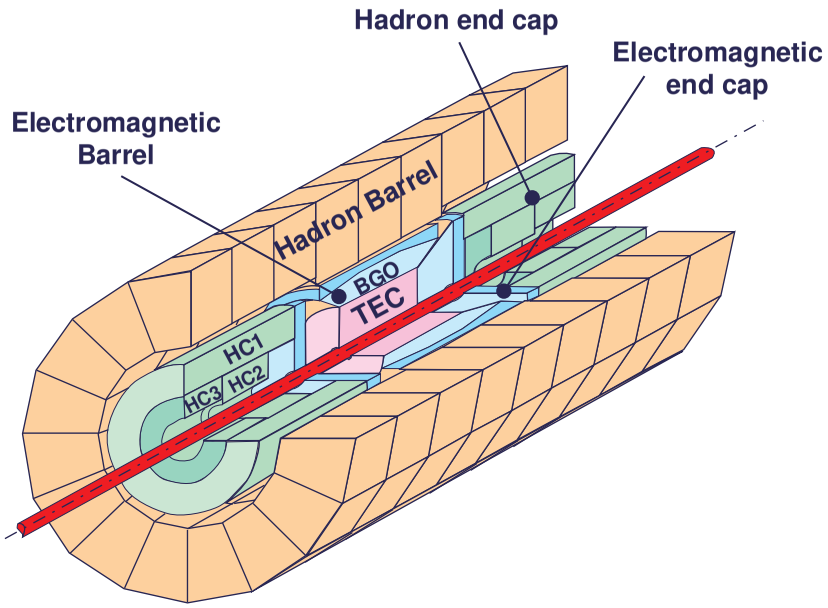
$\approx$ 43 500 Z $\rightarrow \tau\tau(\gamma)$

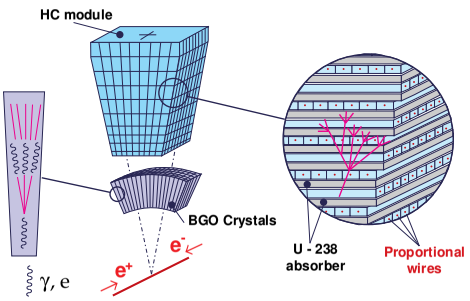
Selection Strategy

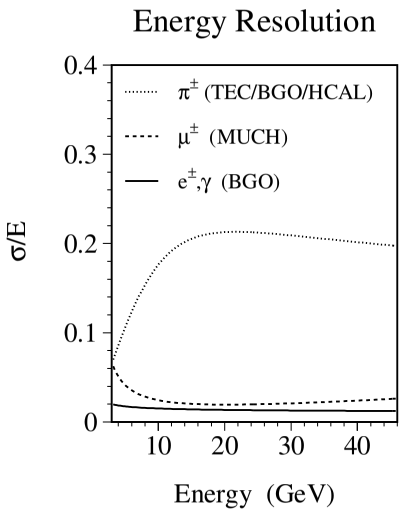
- Neutral Kaons measured in the hadron calorimeter
- General idea: high energy deposition in hadron calorimeter and low momenum charged track in the central tracker
- Small decay volume gives comparable efficiencies for K_L and K_S



The Hadron Calorimeter







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Selection Criteria

Selection of $\tau^- \to \nu_\tau \bar{K}^0 X^-$

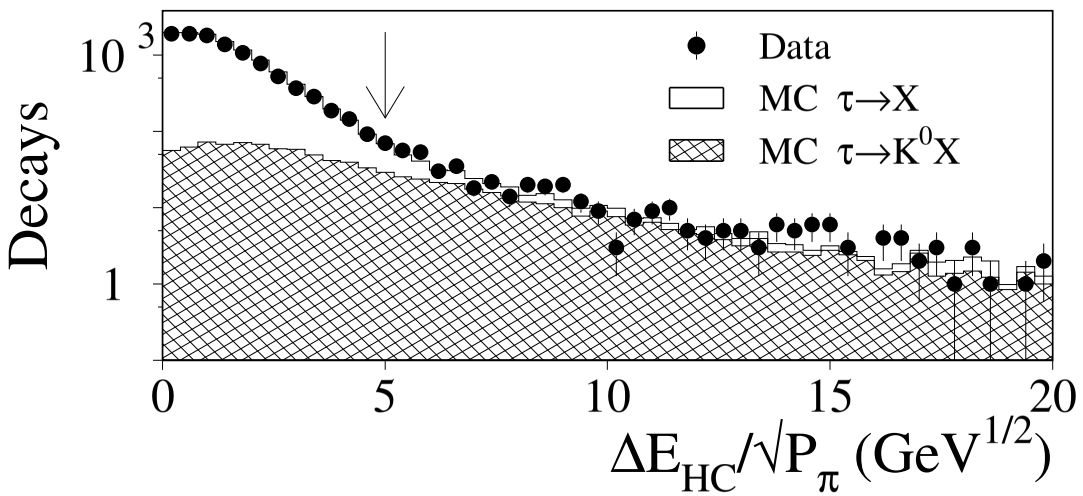
- **Require one charged track in the hemisphere**

- **Require an energy deposition in HCAL exceeding the estimated release due to the charged track.**

$\triangle E_{HC} = E_{HC}^{tot} - E_{HC}^{\pi^-} > 0$

To suppress fluctuations in the charged hadron shower

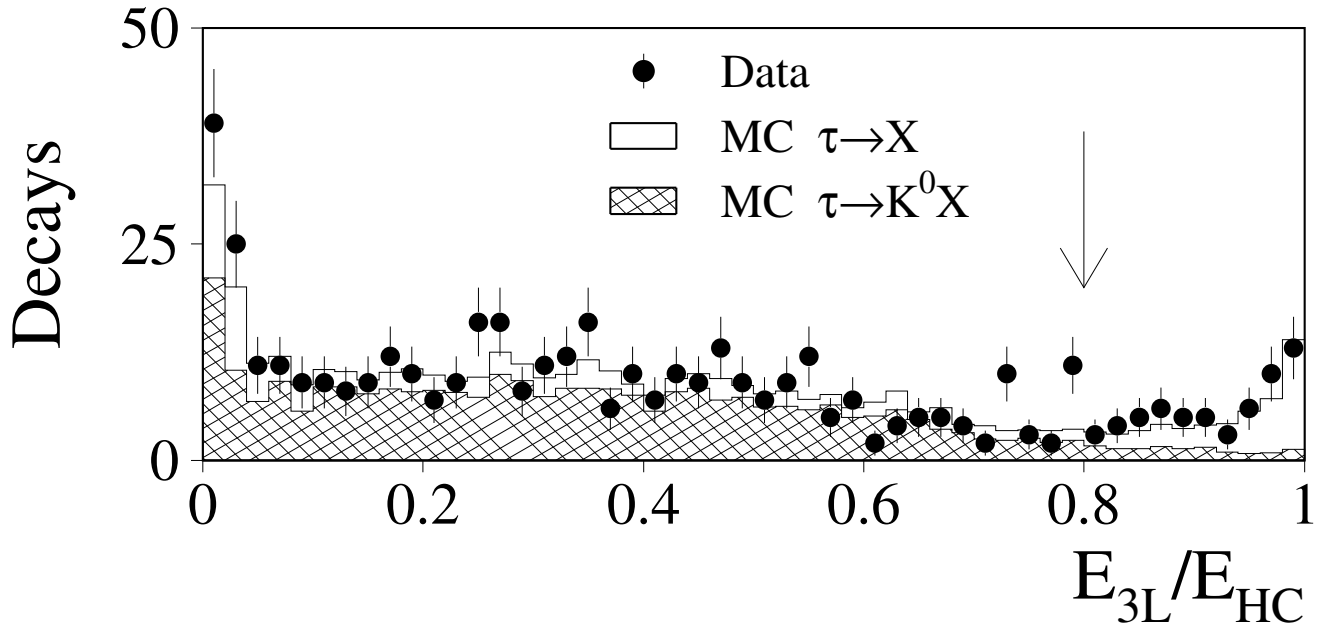
$\triangle E_{HC}/\sqrt{P_\pi} > 5$ **GeV**$^{1/2}$



Selection Criteria

- **Require the energy deposited in the first three layers of the HCAL to be less than 80% of the total.**

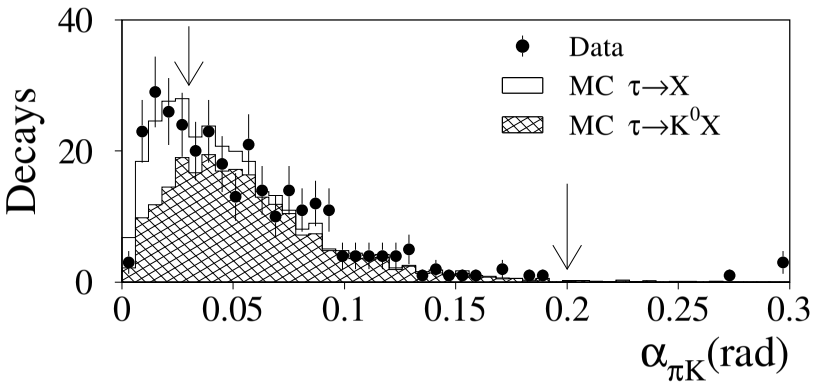
(to suppress decays with π^0 leakage from ECAL to HCAL)



Selection Criteria

- **Require angular separation**

$0.03 < \alpha_{\pi - \bar{K}^0} < 0.2$ rad.



After these cuts 247 candidate decays are selected

27.7 decays expected from non-K^0 decays.

Efficiencies

$\tau^- \to \nu_\tau \pi^- \bar{K}^0$	13.0%
$\tau^- \to \nu_\tau K^- K^0$	5.3%
$\tau^- \to \nu_\tau \pi^- \pi^0 \bar{K}^0$	8.8%
$\tau^- \to \nu_\tau K^- \pi^0 K^0$	3.7%
$\tau^- \to \nu_\tau \pi^- K^0 \bar{K}^0$	19.8%

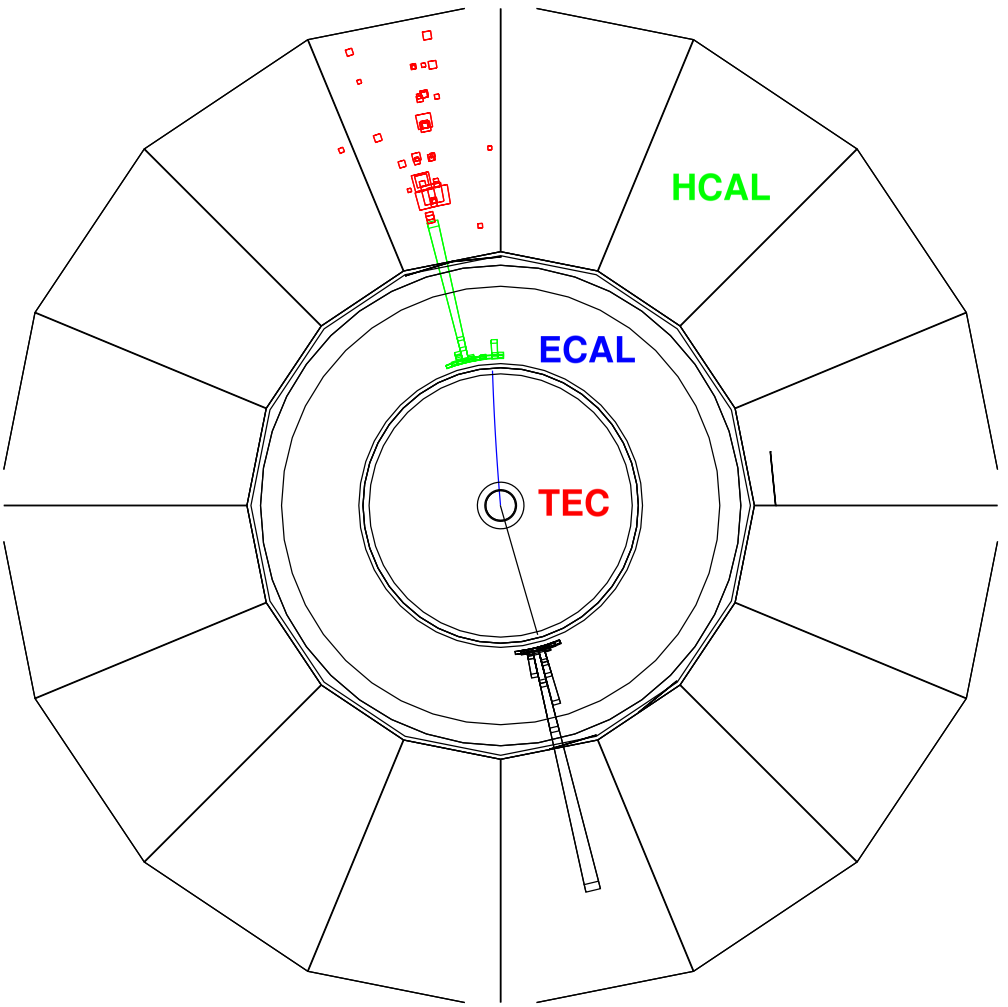
Events are classified in three different categories

Classification of the Decay

1. Events with a π^0 candidate ($\tau^- \to \nu_\tau \pi^- \pi^0 \bar{K}^0$)

- Require ECAL cluster with more than 6 GeV and a shape consistant with a π^0.

Run # 461204 Event # 604

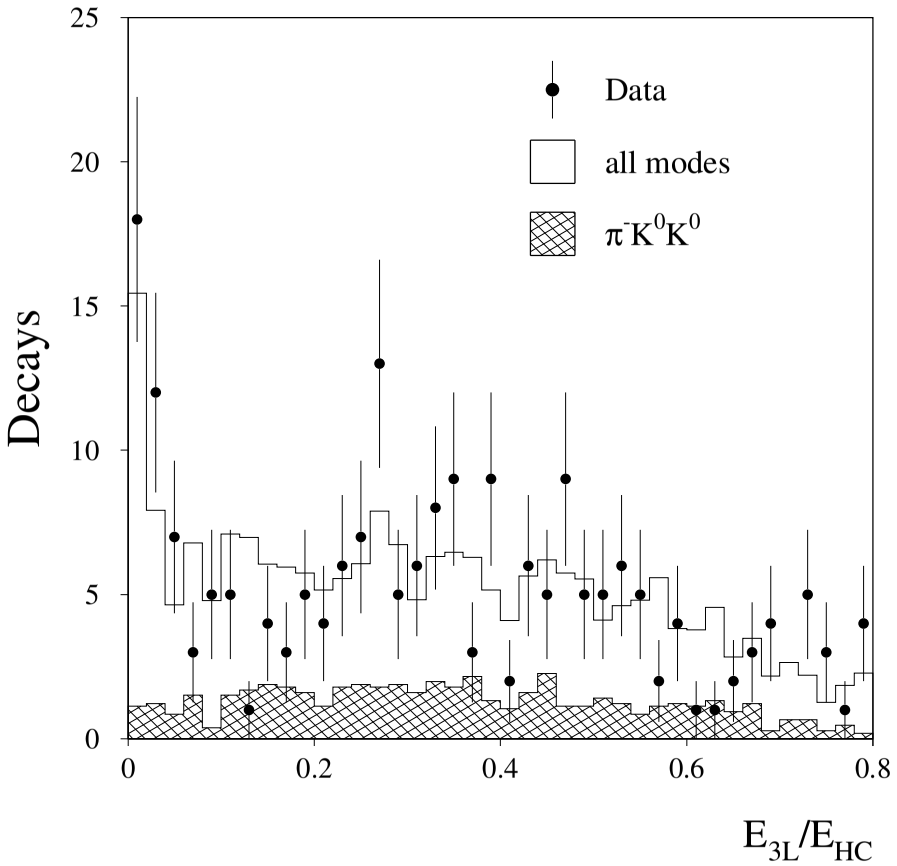


Classification of the Decay

2. Events with extra neutral hadronic energy ($\tau^- \to \nu_\tau \pi^- K^0 \bar{K}^0$)

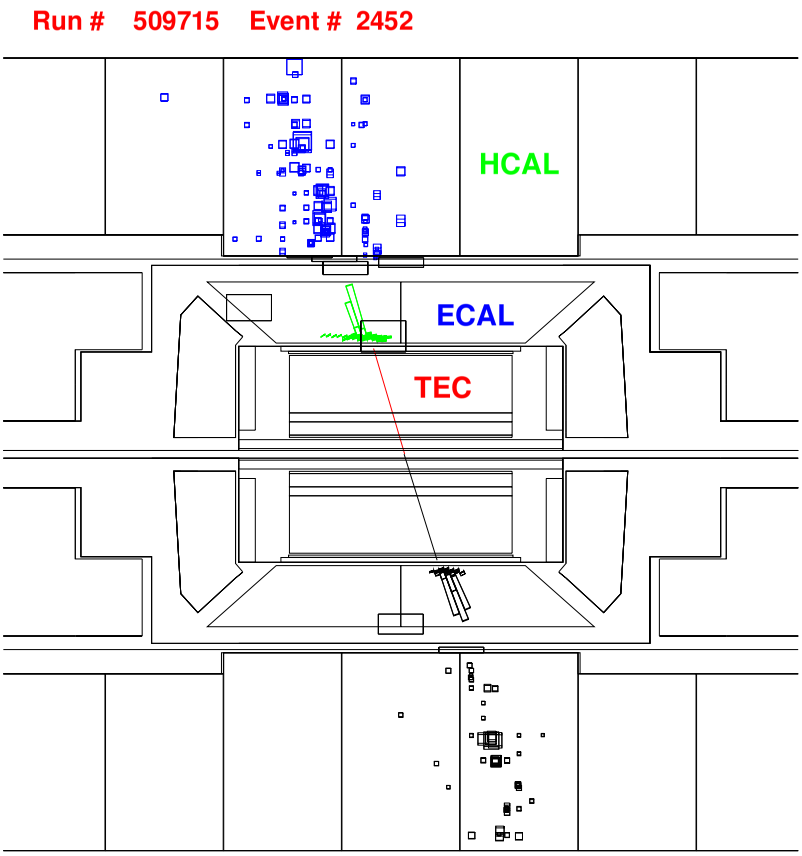
- **Require energy deposited in the ECAL and the front and back parts of the HCAL to each exceed 10% of total associated with neutral kaons.**

The $K^0\bar{K}^0$, while not separated in angle, are often separated by depth in the HCAL.



Classification of the Decay

$\tau^- \to \nu_\tau \pi^- K^0 \bar{K}^0$ candidate



3. Remaining events ($\tau^- \to \nu_\tau \pi^- \bar{K}^0$)

- Require that the event not be selected as one of the other modes.

Fitting Procedure

The total number of decays per each category is a linear combination of the signals and backgroud channels

$$N_{\pi^-\bar{K}^0}\,\mathcal{H}(\tau^- \to \nu_\tau \pi^- \bar{K}^0) + N_{K^-K^0}\,\mathcal{H}(\tau^- \to \nu_\tau K^- K^0) + N_{\pi^-\pi^0\bar{K}^0}\,\mathcal{H}(\tau^- \to \nu_\tau \pi^- \pi^0 \bar{K}^0) + N_{K^-\pi^0K^0}\,\mathcal{H}(\tau^- \to \nu_\tau K^- \pi^0 K^0) + N_{\pi^-K^0\bar{K}^0}\,\mathcal{H}(\tau^- \to \nu_\tau \pi^- K^0 \bar{K}^0) + N_b\,\mathcal{H}(background)$$

Coefficients extracted from a binned maximum likelihood fit to

π^0 energy	$\tau^- \to \nu_\tau \pi^- \pi^0 \bar{K}^0$
total energy vs invariant mass	$\tau^- \to \nu_\tau \pi^- \bar{K}^0$
	$\tau^- \to \nu_\tau \pi^- K^0 \bar{K}^0$

Only the coefficients of the three π^- modes are allowed to vary. The two K^- modes are fixed to previously measured values[a]

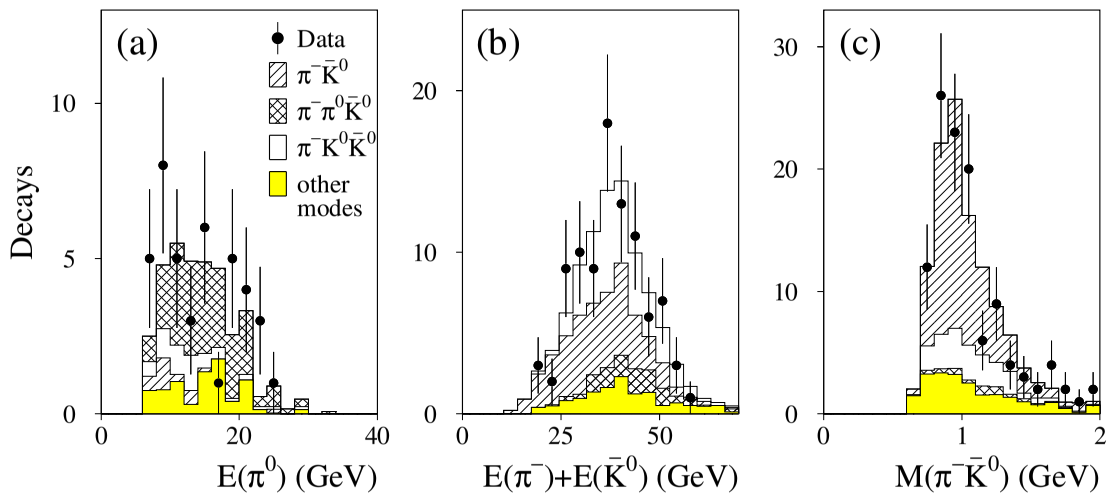
[a] ALEPH Collaboration, D. Busklulic *et al.*, *Phys. Lett.* B332 (1994) 219.
$\mathcal{B}(\tau^- \to \nu_\tau K^- K^0) = 0.0029 \pm 0.0012$ and $\mathcal{B}(\tau^- \to \nu_\tau K^- \pi^0 K^0) = 0.0005 \pm 0.0005$.

Branching Fractions

$$\mathcal{N}(\tau^- \to \nu_\tau \pi^- \bar{\mathrm{K}}^0) = 112.0 \pm 17.7$$

$$\mathcal{N}(\tau^- \to \nu_\tau \pi^- \pi^0 \bar{\mathrm{K}}^0) = 33.1 \pm 9.7$$

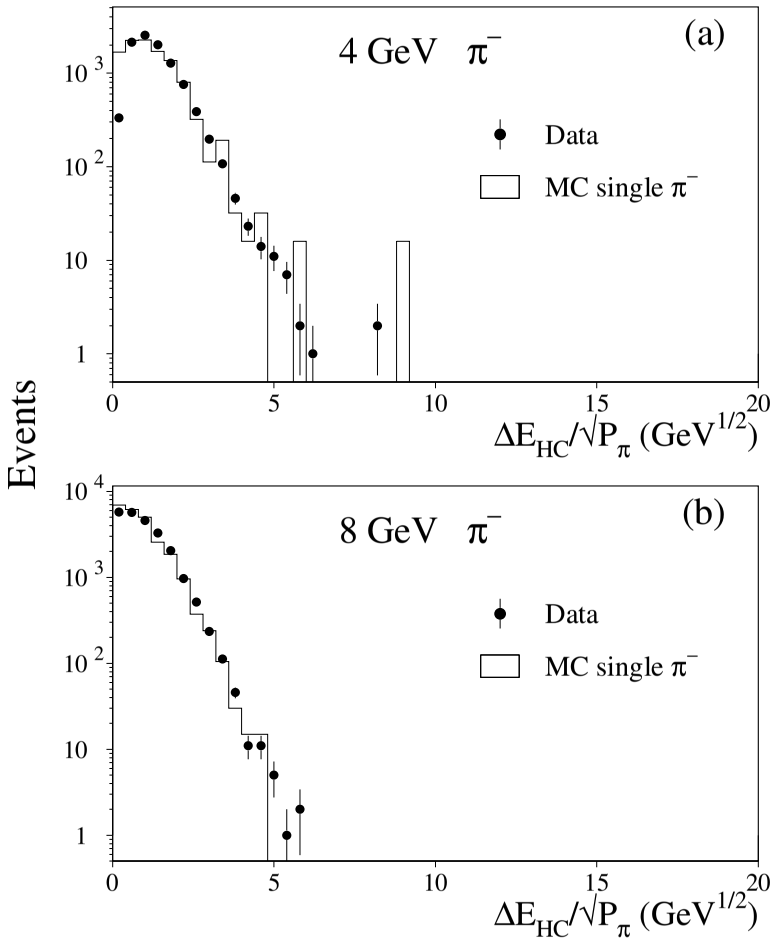
$$\mathcal{N}(\tau^- \to \nu_\tau \pi^- \mathrm{K}^0 \bar{\mathrm{K}}^0) = 55.8 \pm 21.4$$



Systematic Uncertainties

- **Variation of energy scales and resolution functions for TEC, ECAL, and HCAL within the limits of our understanding of their resolutions.**

e.g.: HCAL resolution function



Systematic Uncertainties

- Uncertainties from the background estimation: variation of the branching ratios within the uncertainties of the measurements. (if we fit the $\mathcal{B}(\tau^- \to \nu_\tau K^- K^0)$, we obtain 0.0023$\pm$0.0045)

- Systematic error from theoretical uncertainties:
  - ◇ variation of the assumptions on the matrix element $\to \simeq 10\%$ change in the efficiencies
  - ◇ uncertainty from the CP phase of the $K^0 K^0$ system in $\tau^- \to \nu_\tau \pi^- K^0 \bar{K}^0$

◇ Contributions to the systematic error:

Source	$\Delta\mathcal{N}_{\pi^-\bar{K}^0}$	$\Delta\mathcal{N}_{\pi^-\pi^0\bar{K}^0}$	$\Delta\mathcal{N}_{\pi^-K^0\bar{K}^0}$
Energy Scale	3.8	2.0	5.0
Background	4.2	1.3	2.7
Theory	3.9	1.2	4.8
Total	6.9	2.6	7.4

Conclusions

Results for the branching ratios

$$\begin{aligned}
\mathcal{B}(\tau^- \to \nu_\tau \pi^- \bar{\mathrm{K}}^0) &= 0.0095 \pm 0.0015 \pm 0.0006 \\
\mathcal{B}(\tau^- \to \nu_\tau \pi^- \pi^0 \bar{\mathrm{K}}^0) &= 0.0041 \pm 0.0012 \pm 0.0003 \\
\mathcal{B}(\tau^- \to \nu_\tau \pi^- \mathrm{K}^0 \bar{\mathrm{K}}^0) &= 0.0031 \pm 0.0012 \pm 0.0004
\end{aligned}$$

$$\begin{aligned}
\mathcal{B}(\tau^- \to \nu_\tau \mathrm{K}^{*-}) &= 0.0142 \pm 0.0022 \pm 0.0009 \\
\mathcal{B}(\tau^- \to \nu_\tau \pi^- \bar{\mathrm{K}}^0)_{\text{nonresonant}} &< 0.0017 \quad 95\%\text{CL} \\
\mathcal{B}(\tau^- \to \nu_\tau \pi^- \bar{\mathrm{K}}^0)_{K^{*-}(1430)} &< 0.0011 \quad 95\%\text{CL}
\end{aligned}$$