One-prong τ Decays with Neutral Kaons

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Representing the
L3 collaboration

Introduction

For an integrated luminosity of $69\ \mathrm{pb}^{-1}$

taken during 1991, 1992, and 1993

We have gathered

$$\approx 43\ 500\ \mathrm{Z} \rightarrow \tau\tau(\gamma)$$

We present here our study of

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

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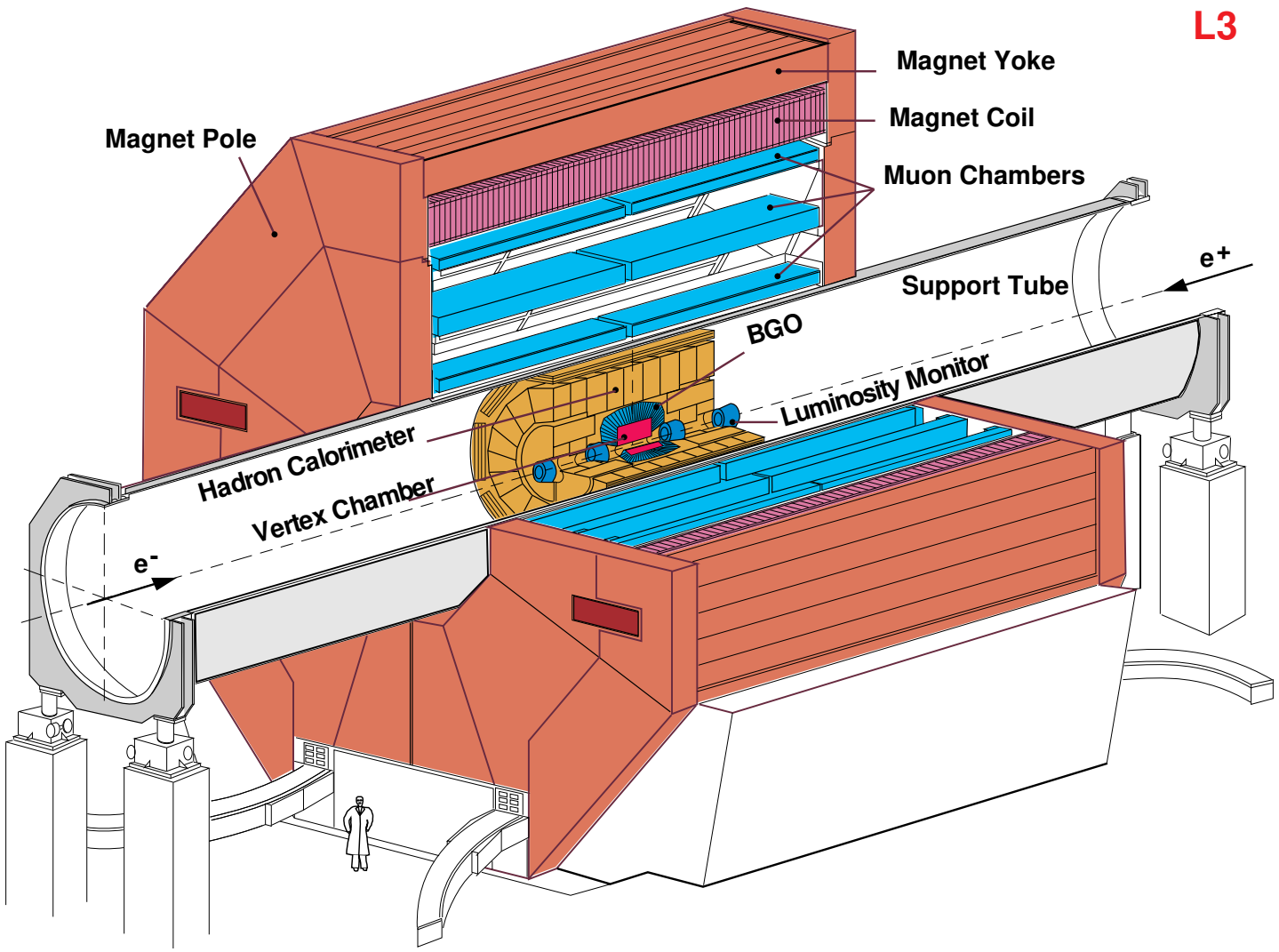
$$\tau^- \rightarrow \nu_\tau \pi^- \bar{K}^0 K^0$$

Motivation

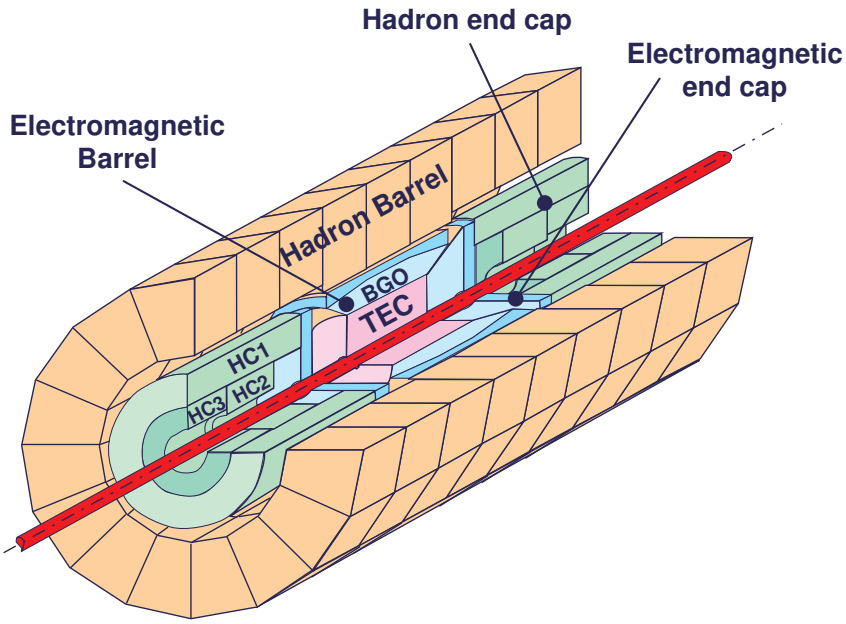
Why are the decays of τ-leptons involving neutral kaons important?

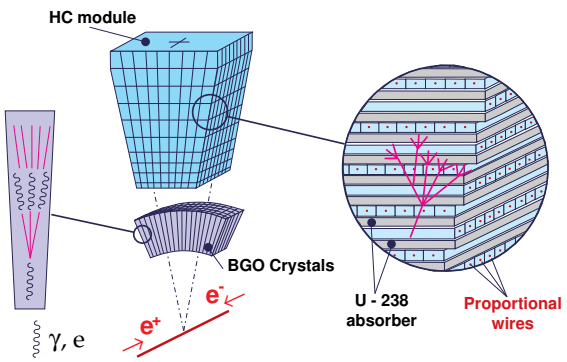
- **one-prong branching ratio problem**
- **theoretical uncertainties due to the combined effects of**
  - ◇ **Cabibbo-suppression of odd numbers of kaons**
  - ◇ **limited phase space for two kaon modes**
  - ◇ **QCD anomalies**
  - ◇ **uncertainties in the resonant structure**

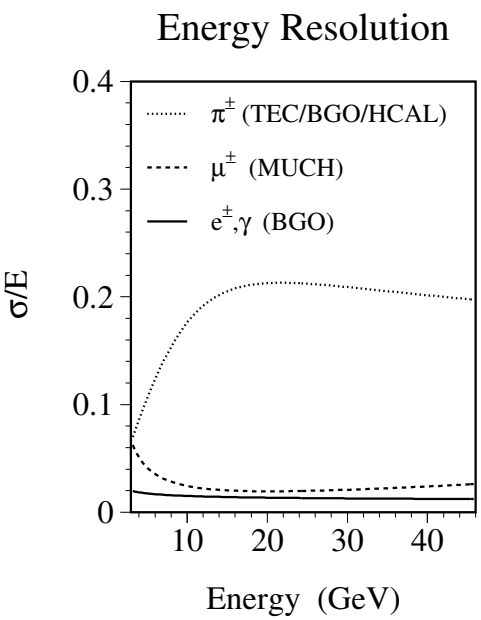
The L3 detector



The Hadron Calorimeter







Selection Criteria

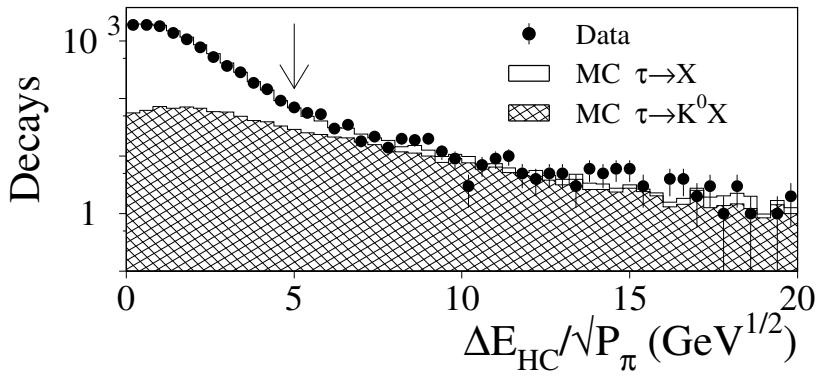
Selection of $\tau^- \to \nu_\tau \bar{K}^0 X^-$

- Begin with approximately 43 500 $Z \to \tau\tau(\gamma)$ events.
- Require one track in the hemisphere that originates at the vertex.
- Require a hadronic shower in the HCAL.

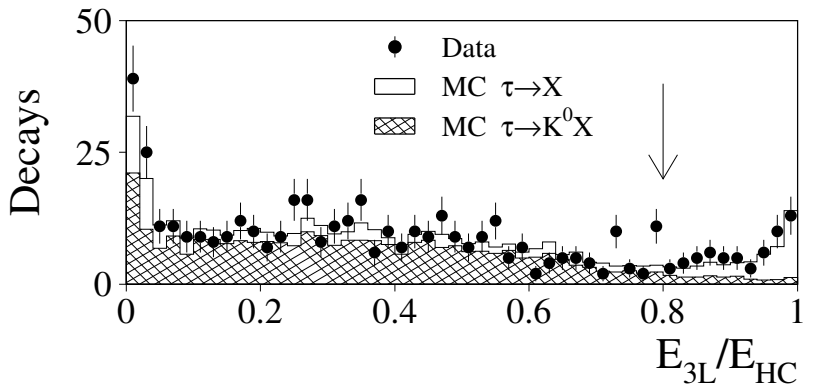
At this point we have a sample of hadronic, one-prong decays of the τ. The isolation of $\tau^- \to \nu_\tau \bar{K}^0 X^-$ begins.

Selection Criteria

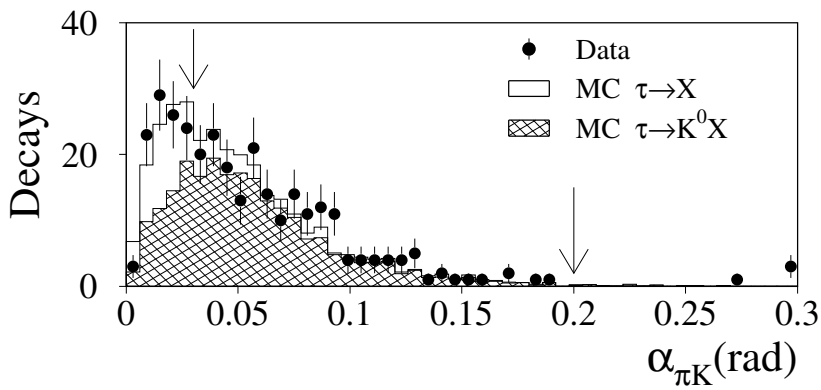
- **Require $\Delta E_{HC}/\sqrt{P_\pi} > 5$.**



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



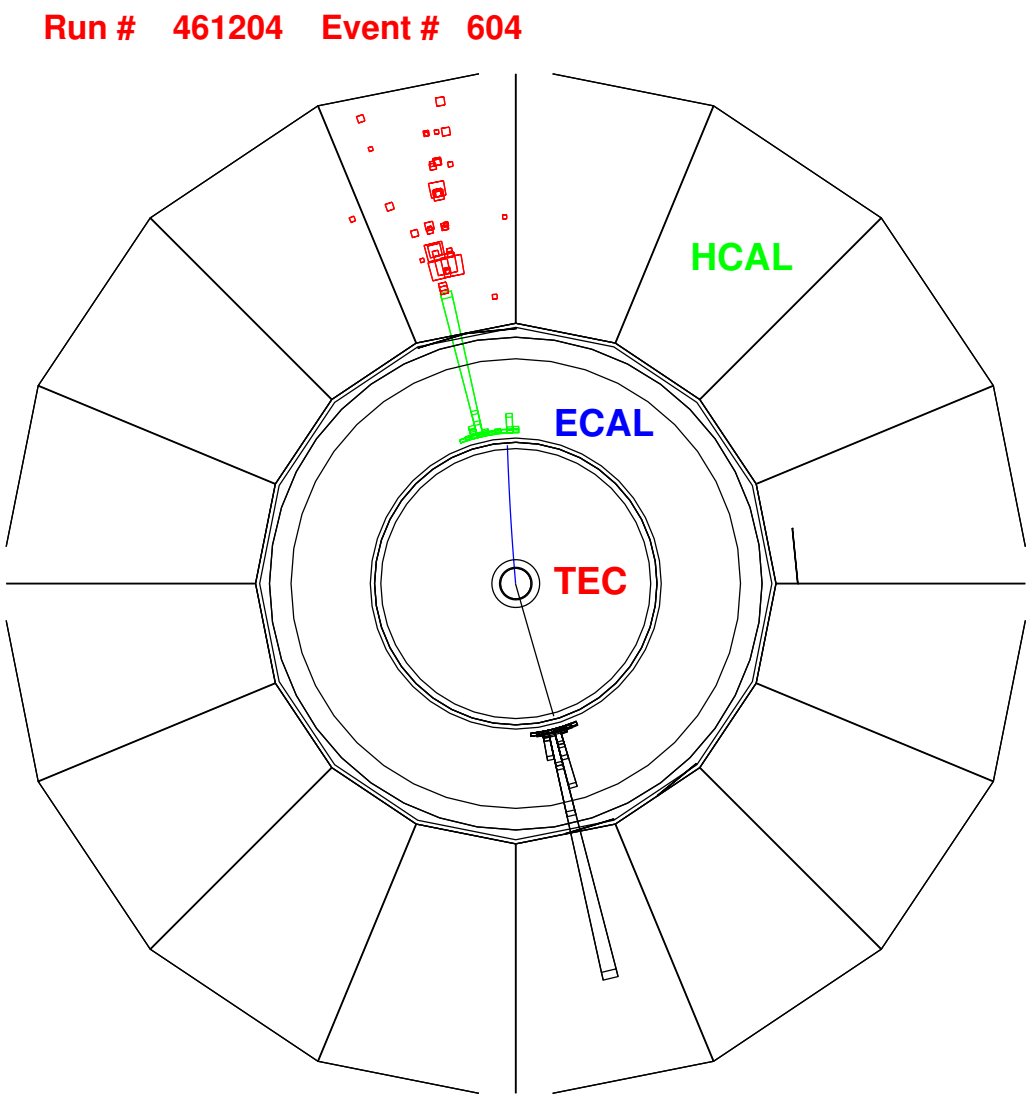
- **Require $0.03 < \alpha_{\pi^- \bar{K}^0} < 0.2$ rad.**



Final Separation

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.

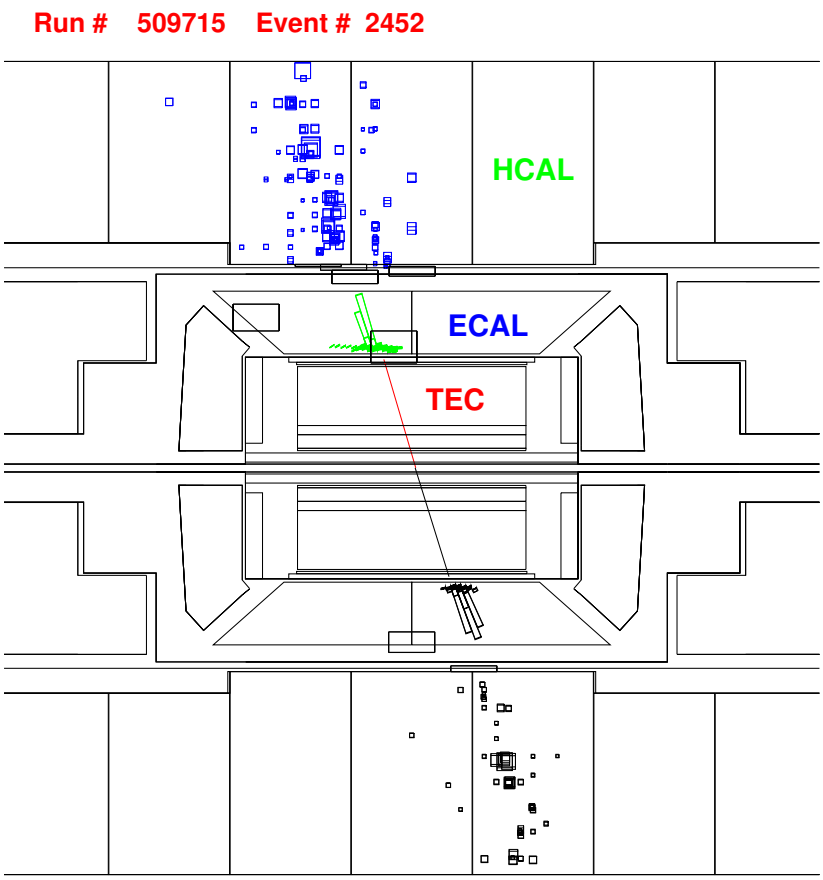


Final Separation

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.

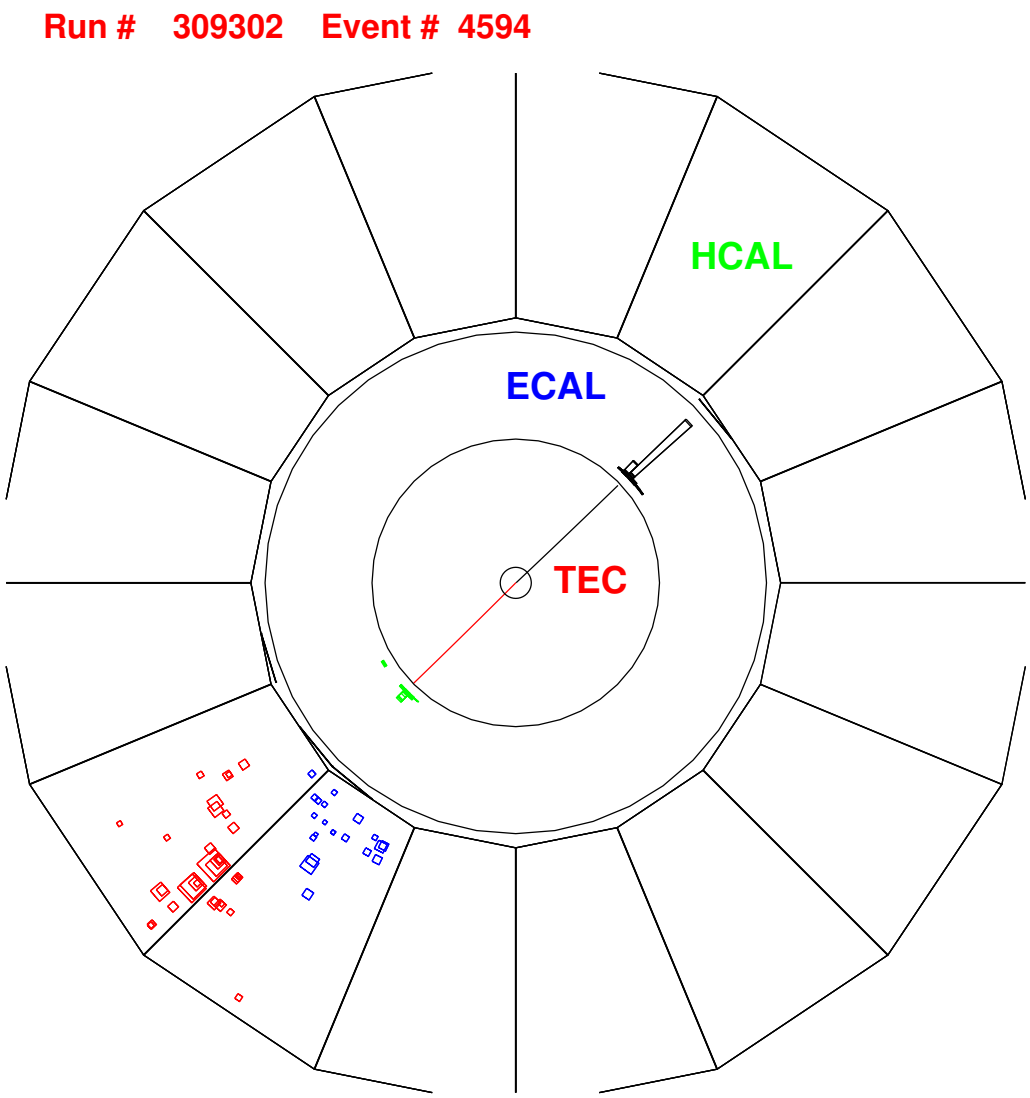
The $K^0 \bar{K}^0$, while not separated in angle, are often separated by depth in the HCAL.



Final Separation

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

Binned maximum likelihood which accounts for the finite statistics in data and Monte Carlo to the linear combination

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

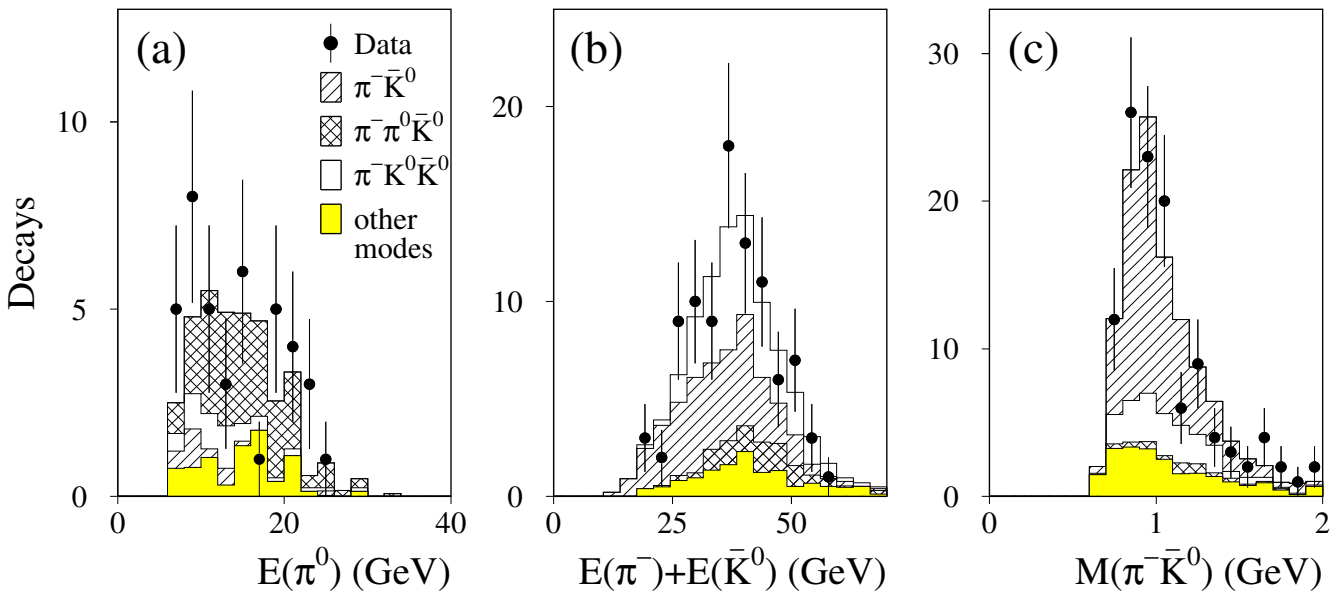
Only the coefficients of the three π^- modes are allowed to vary.

The two K^- modes are fixed to previously measured values:[1] $\mathcal{B}(\tau^- \to \nu_\tau K^- \bar{K}^0) = 0.0029 \pm 0.0012$ and $\mathcal{B}(\tau^- \to \nu_\tau K^- \pi^0 \bar{K}^0) = 0.0005 \pm 0.0005$.

[1] ALEPH Collaboration, D. Busklulic *et al.*, *Phys. Lett.* B332 (1994) 219.

Branching Fractions

$$\mathcal{N}(\tau^- \to \nu_\tau \pi^- \bar{K}^0) = 112.0 \pm 17.7$$
$$\mathcal{N}(\tau^- \to \nu_\tau \pi^- \pi^0 \bar{K}^0) = 33.1 \pm 9.7$$
$$\mathcal{N}(\tau^- \to \nu_\tau \pi^- K^0 \bar{K}^0) = 55.8 \pm 21.4$$



Systematic Uncertainties

Efficiencies

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

We vary our energy scales for TEC, ECAL, and HCAL within the limits of our understanding of their resolutions. We vary backgrounds, including the K^- modes. We vary the theoretical uncertainties. The following changes were observed in our measurement:

Source	$\Delta\mathcal{N}_{\pi^-\bar{\mathrm{K}}^0}$	$\Delta\mathcal{N}_{\pi^-\pi^0\bar{\mathrm{K}}^0}$	$\Delta\mathcal{N}_{\pi^-\mathrm{K}^0\bar{\mathrm{K}}^0}$
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

Conclusion

Our final branching ratios

$$\mathcal{B}(\tau^- \to \nu_\tau \pi^- \bar{\mathrm{K}}^0) = 0.0095 \pm 0.0015 \pm 0.0006$$

$$\mathcal{B}(\tau^- \to \nu_\tau \pi^- \pi^0 \bar{\mathrm{K}}^0) = 0.0041 \pm 0.0012 \pm 0.0003$$

$$\mathcal{B}(\tau^- \to \nu_\tau \pi^- \mathrm{K}^0 \bar{\mathrm{K}}^0) = 0.0031 \pm 0.0012 \pm 0.0004$$