

Study of τ Decays to Four-Hadron Final States with Kaons

CLEO III Collaboration

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Outline

- motivations
- K/π identification/cross check
- results
- summary

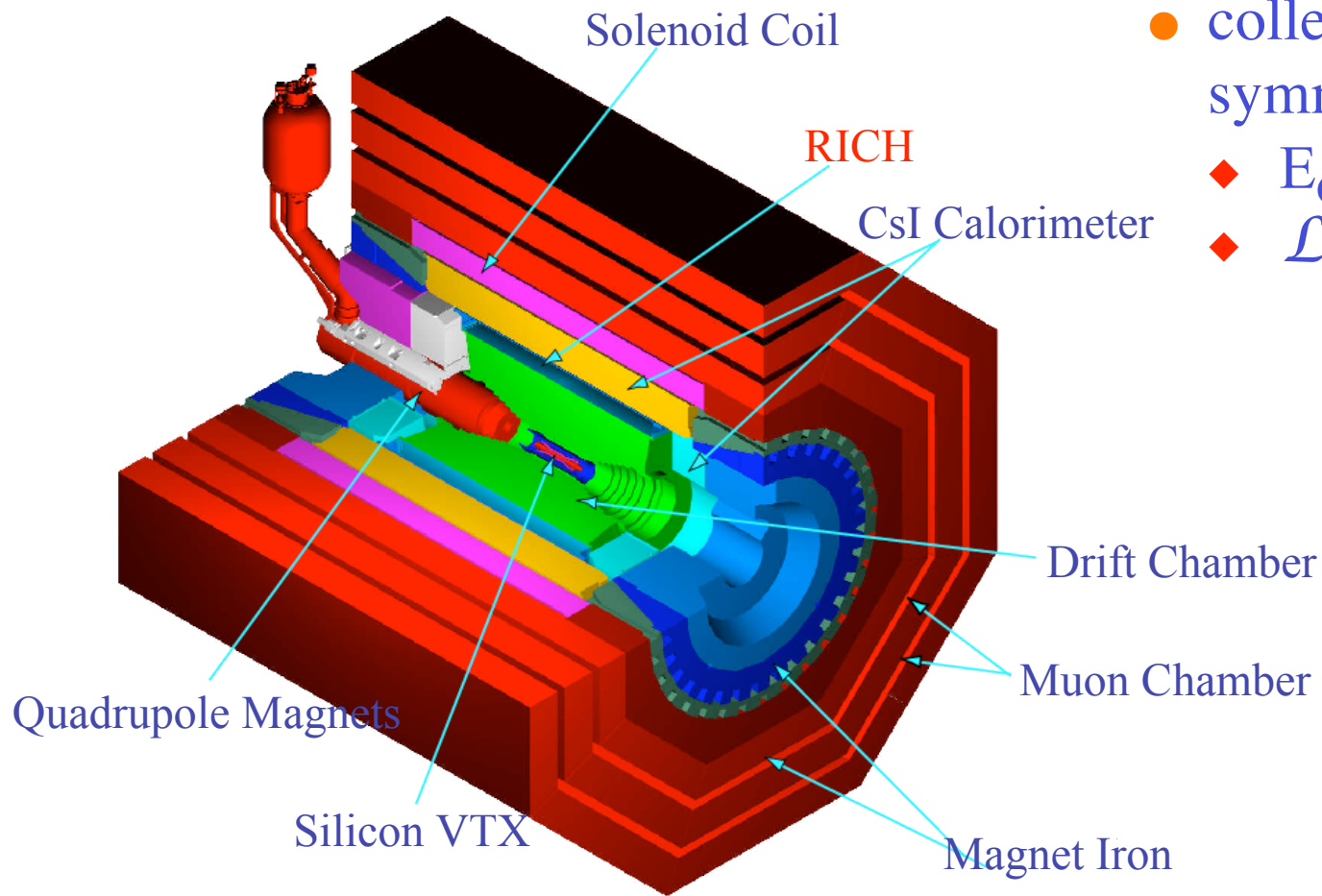


Motivations

- study of τ decay to four hadrons with kaons:
 - ☆ provide better knowledge of high-mass strange τ decays
 - ◆ improve measurements of m_S & $\sin\theta_C (V_{us})$
 - ◆ sensitive to τ neutrino mass
 - improve measurements of $\tau^- \rightarrow K^- \pi^+ \pi^- \pi^0 \nu_\tau$ & $K^- K^+ \pi^- \pi^0 \nu_\tau$
 - search for $\tau^- \rightarrow K^- \omega \nu_\tau$ and $K^- K^+ K^- \pi^0 \nu_\tau$



CLEO III Experiment



- collect data at Cornell symmetric e^+e^- collider
- ◆ $E_{\text{CM}} \sim 10.6 \text{ GeV}$
- ◆ $\mathcal{L} = (7.56 \pm 0.15) \text{ fb}^{-1}$



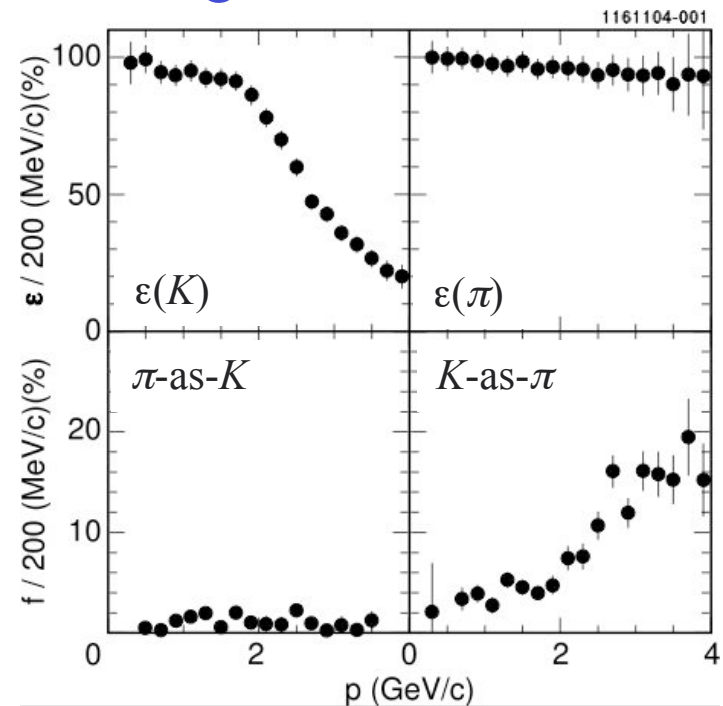
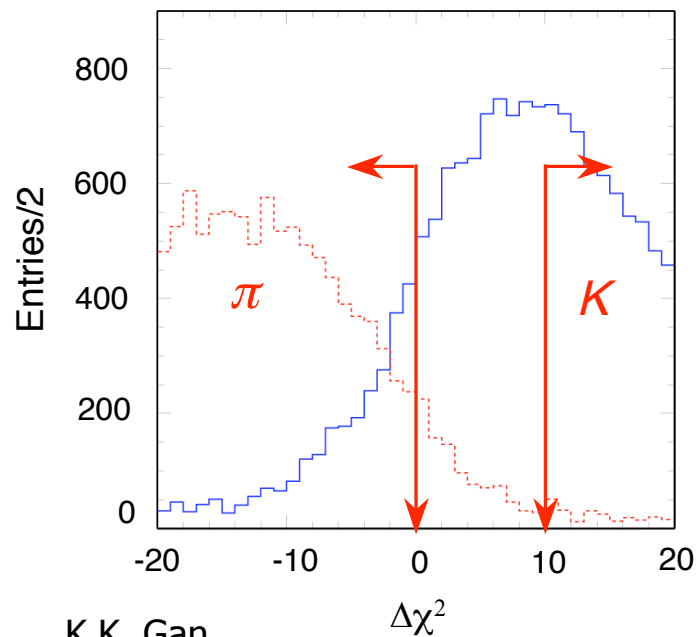
K/π Identification

- combine RICH & dE/dx:

$$\Delta\chi^2 = \chi_\pi^2 - \chi_K^2 + \sigma_\pi^2 - \sigma_K^2$$

- strict kaon ID to reduce large π backgrounds
- calibrate efficiencies and fake rates using

$$D^* \rightarrow D^0 \pi_s^+ \rightarrow K^- \pi^+ \pi_s^+$$





Fake Rate Cross-Check

- cross check fake rate with wrong sign decays:

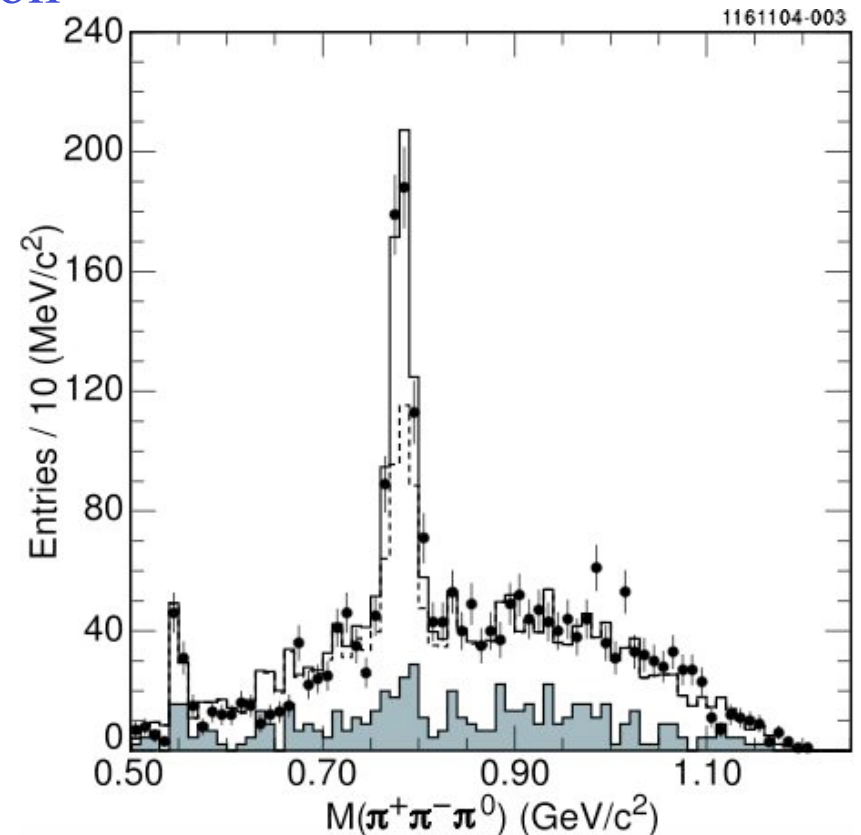
decay	data	prediction	$\tau^+\tau^-$	$q\bar{q}$
$\tau^- \rightarrow K^+\pi^-\pi^-\pi^0\nu_\tau$	633 ± 25	609 ± 23	465 ± 15	144 ± 18
<i>no angular correction</i>	–	568 ± 23	424 ± 14	–
$\tau^- \rightarrow K^-K^-\pi^+\pi^0\nu_\tau$	11 ± 3	9 ± 3	9 ± 2	0 ± 2

- no excess of events
⇒ fake rate estimation is reliable



First Observation of $B(\tau^- \rightarrow K^- \omega \nu_\tau)$

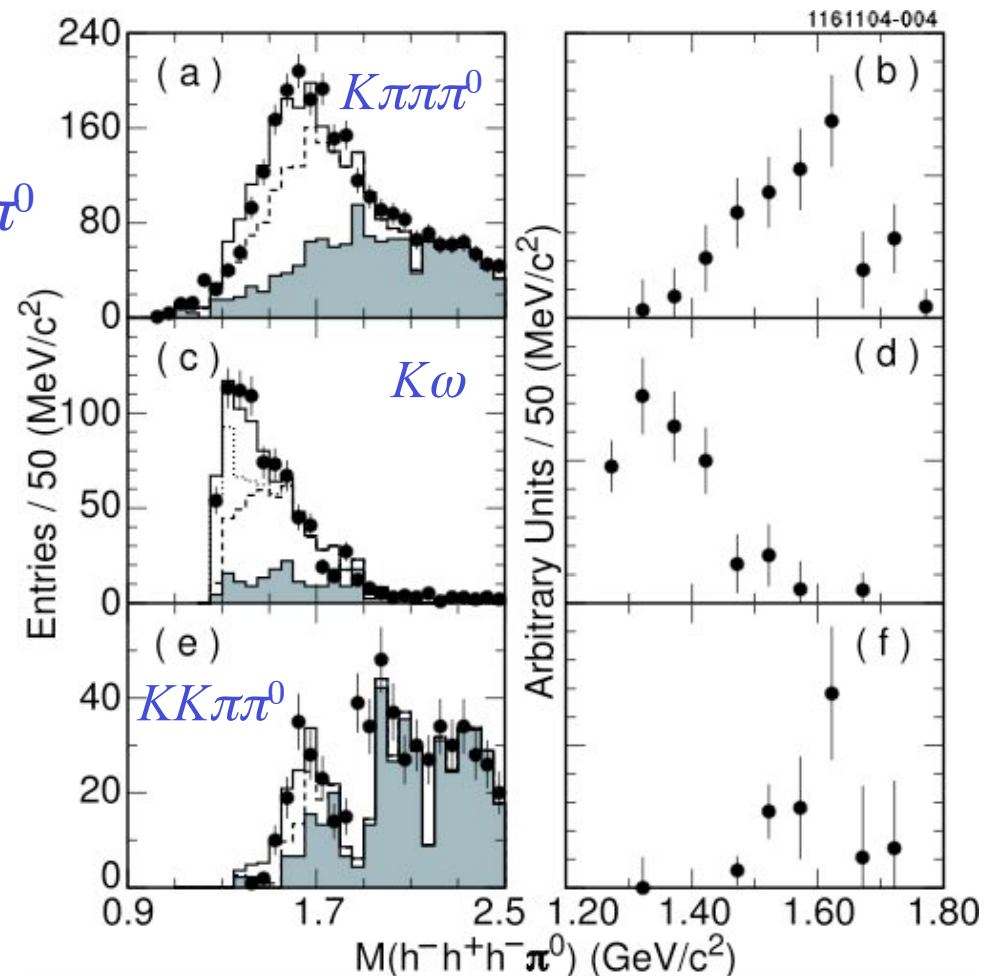
- η peak consistent with expectation
- clear ω signal over background





Measurements of $\tau^- \rightarrow K^- \pi^+ \pi^- \pi^0 \nu_\tau$ & $K^- K^+ \pi^- \pi^0 \nu_\tau$

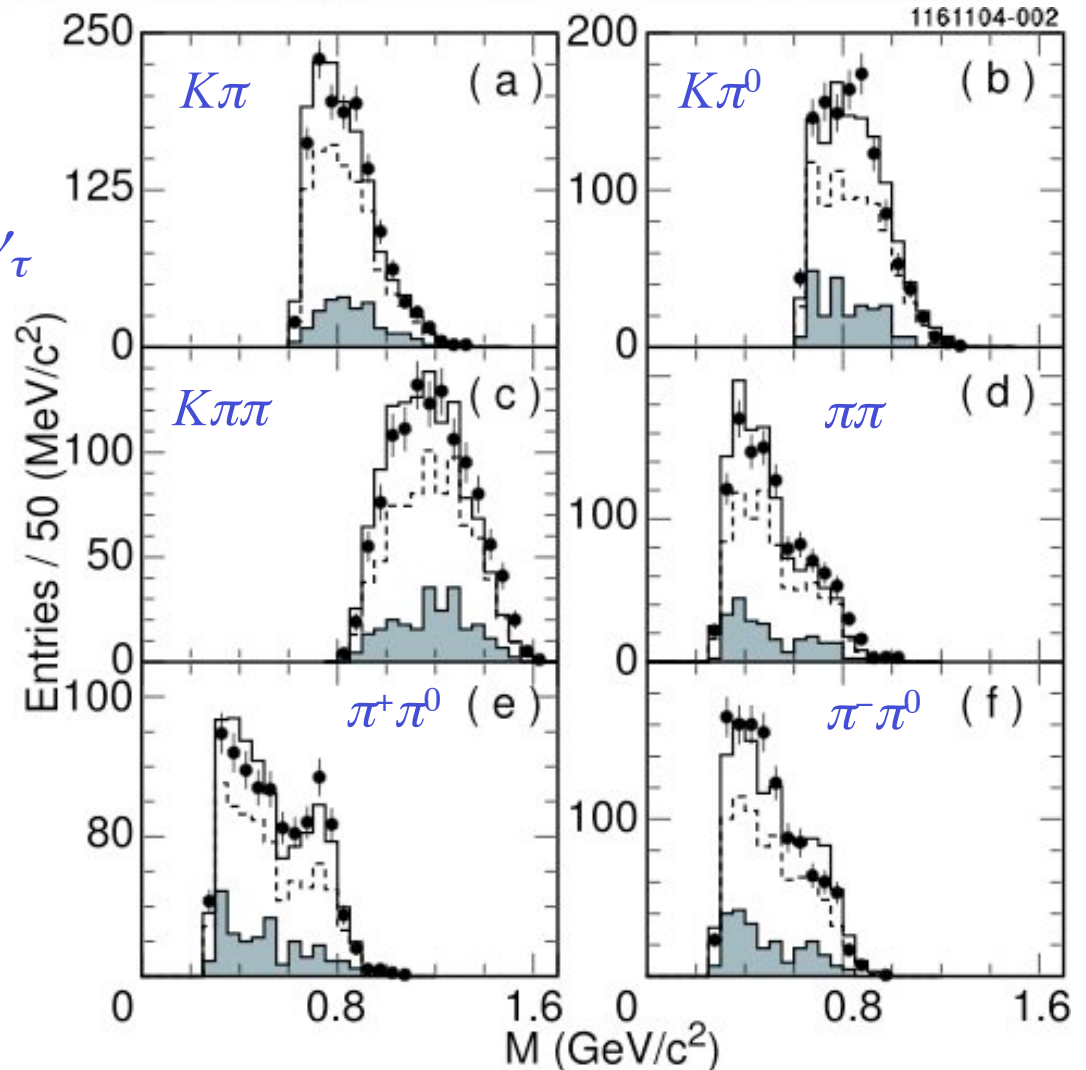
- background above τ mass well reproduced
- clear excess of $K\pi\pi\pi^0$ & $KK\pi\pi^0$ events over background
- 50/50 $K_1(1270)+K_1(1400)$ describes $M(K\omega)$ well
- efficiency/background corrected mass spectra can be used to extract spectral functions for measuring m_S & $\sin\theta_C$





Search for Substructures in $K\pi\pi\pi^0$

- no evidence for K^* , K_1 , ρ^0
- presence of ρ^+
consistent with $\tau \rightarrow K^- a_1 \nu_\tau$
- no indication of ρ^- but
not inconsistent with $K^- a_1$:
CL = 2.3%





Results

decay	data	$\tau^+\tau^-$	$q\bar{q}$	ε (%)	$\mathbf{B} (\times 10^{-4})$
$K\omega$	500 ± 35	194 ± 12	64 ± 20	5.61 ± 0.09	$4.1 \pm 0.6 \pm 0.7$
$K\pi\pi\pi^0$ (ex. ω)	833 ± 36	434 ± 14	153 ± 25	5.68 ± 0.17	$3.7 \pm 0.5 \pm 0.8$
$KK\pi\pi^0$	48 ± 9	1 ± 1	9 ± 7	5.89 ± 0.12	$0.55 \pm 0.14 \pm 0.12$
$KKK\pi^0$	0	0	0	4.36 ± 0.10	< 0.048 @ 90% CL

- 1st observation of $\tau^- \rightarrow K^- \omega \nu_\tau$
- 1st statistically significant measurement of $\mathbf{B}(\tau^- \rightarrow K^- K^+ \pi^- \pi^0 \nu_\tau)$ and $\mathbf{B}(\tau^- \rightarrow K^- \pi^+ \pi^- \pi^0 \nu_\tau, \text{ex. } K_s) = (7.4 \pm 0.8 \pm 1.1) \times 10^{-4}$
- 1st limits on $\mathbf{B}(\tau^- \rightarrow K^- K^+ K^- \pi^0 \nu_\tau)$



$$B(\tau^- \rightarrow K^- \pi^+ \pi^- \pi^0 \nu_\tau)$$

- ◆ CLEO III : $(7.4 \pm 0.8 \pm 1.1) \times 10^{-4}$ PRL **94**, 241802 (2005)
- ◆ CLEO II : $(7.5 \pm 2.6 \pm 1.8) \times 10^{-4}$ PRD **60**, 112002 (1999)
- ◆ ALEPH : $(6.1 \pm 3.9 \pm 1.8) \times 10^{-4}$ EPJ **1**, 65 (1998)
- CLEO III measurement is consistent with earlier results
but significantly more precise



$$B(\tau^- \rightarrow K^- K^+ \pi \pi^0 \nu_\tau)$$

- ◆ CLEO III : $(0.55 \pm 0.14 \pm 0.12) \times 10^{-4}$
- ◆ CLEO II : $(3.3 \pm 1.8 \pm 0.7) \times 10^{-4}$
- ◆ ALEPH : $(7.5 \pm 2.9 \pm 1.5) \times 10^{-4}$
- CLEO III result is ~ 10 x smaller than previous results



$$B(\tau \rightarrow K^- \omega \nu_\tau)$$

	prediction	measurement
$B(\tau \rightarrow K^- \omega \nu_\tau)$	7.5×10^{-4}	$(4.1 \pm 0.6 \pm 0.7) \times 10^{-4}$
$\frac{B(\tau \rightarrow K^- \omega \nu_\tau)}{B(\tau \rightarrow K^- \rho \nu_\tau)}$	1	0.26 ± 0.11

- $B(\tau \rightarrow K^- \omega \nu_\tau)$ disagrees with Li's predictions
 - ◆ $B(\tau \rightarrow K^- \omega \nu_\tau)$ is $\sim 2 \times$ lower than predicted
 - ◆ $B(\tau \rightarrow K^- \omega \nu_\tau)/B(\tau \rightarrow K^- \rho \nu_\tau)$ is $\sim 4 \times$ lower than predicted
- B.A. Li, PRD **55**, 1436 (1997)



Summary

- 1st observation of $\tau^- \rightarrow K^- \omega \nu_\tau$
 - ◆ measurement disagrees with Li's predictions
- 1st statistically significant measurement of $\tau^- \rightarrow K^- \pi^+ \pi^- \pi^0 \nu_\tau$ (ex. K_S) and $K^- K^+ \pi^- \pi^0 \nu_\tau$
- 1st limits for $\tau^- \rightarrow K^- K^+ K^- \pi^0 \nu_\tau$

- K. Arms et al., Phys. Rev. Lett. **94**, 241802 (2005)