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

CLEO III Collaboration

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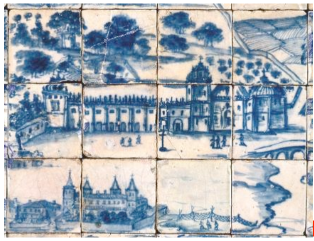

Outline

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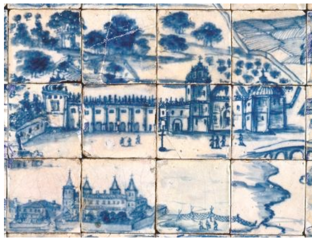
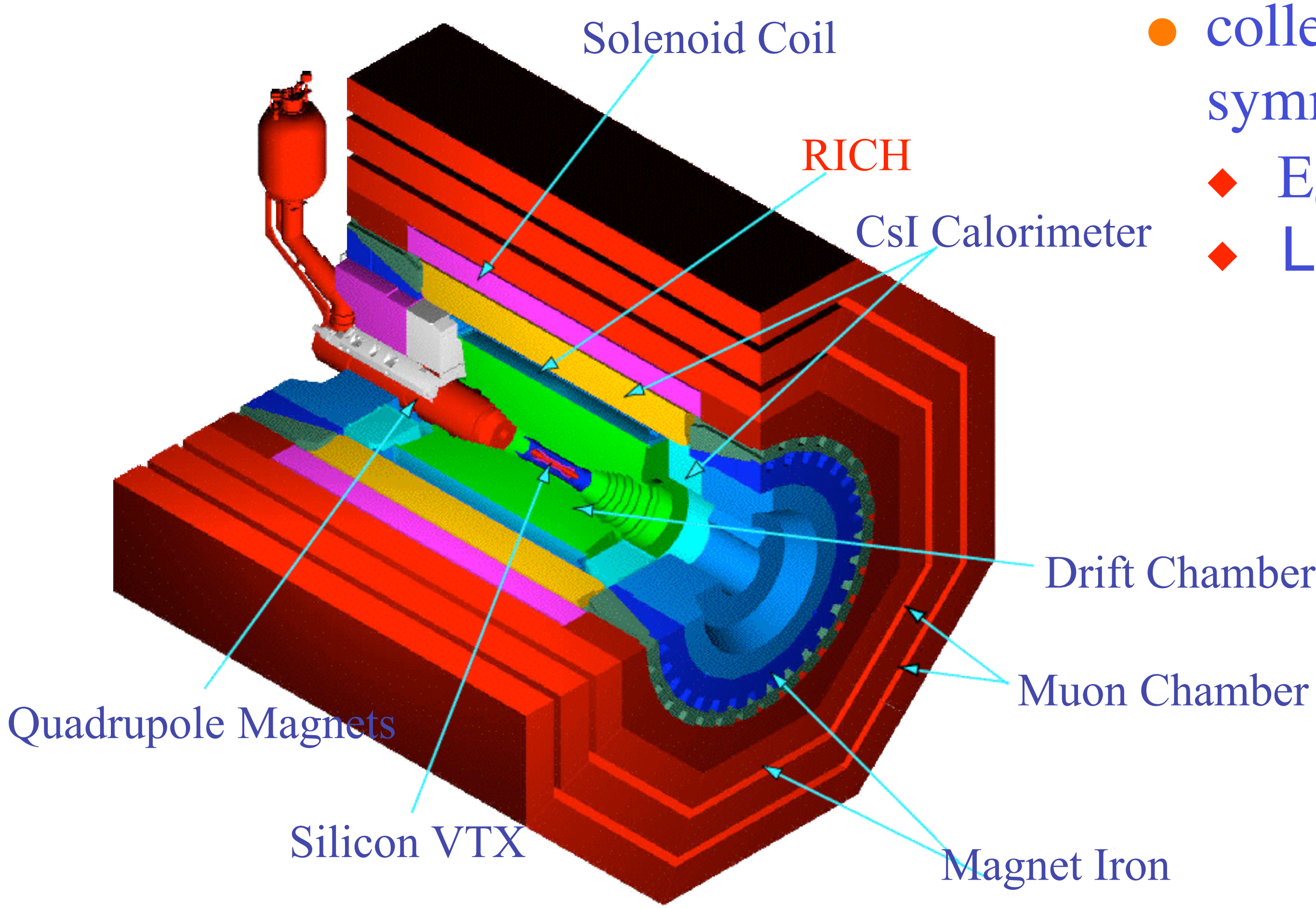
- K/π identification/cross check
- results
- summary



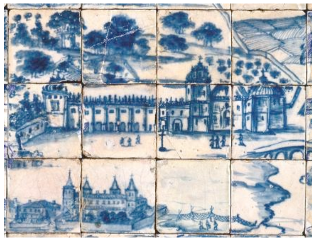
Motivations

- 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 $\tau^- \to K^-\pi^+\pi^-\pi^0\nu_\tau$ & $K^-K^+\pi^-\pi^0\nu_\tau$
  - ■ search for $\tau^- \to K^-\omega\nu_\tau$ and $K^-K^+K^-\pi^0\nu_\tau$

CLEO III Experiment



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

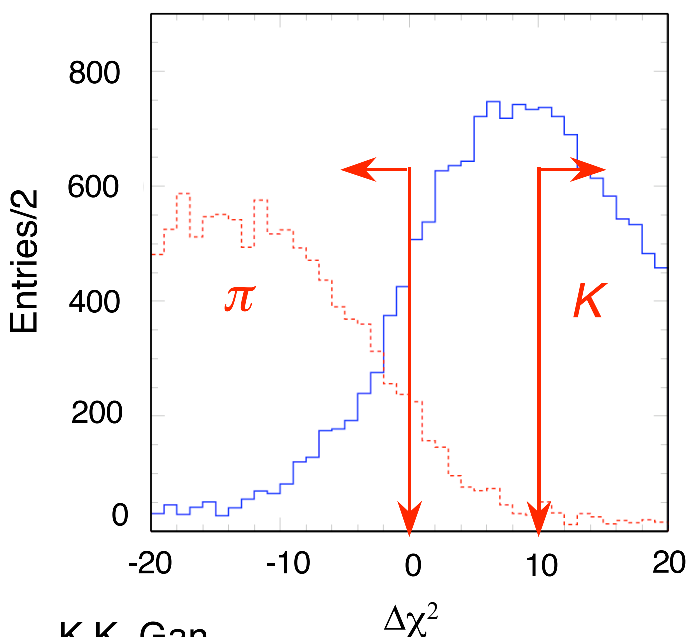


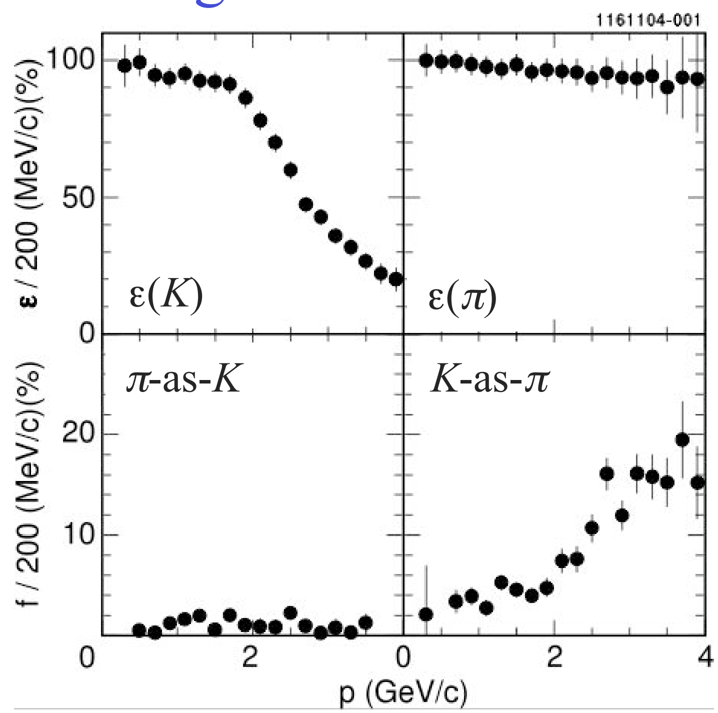
K/π Identification

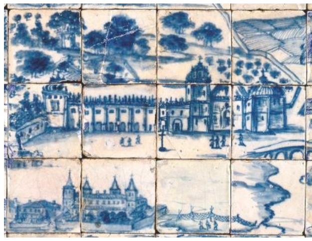
- combine RICH & dE/dx:

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

  - strict kaon ID to reduce large π backgrounds
  - calibrate efficiencies and fake rates using $D^* \to D^0\pi_s^+ \to K^-\pi^+\pi_s^+$





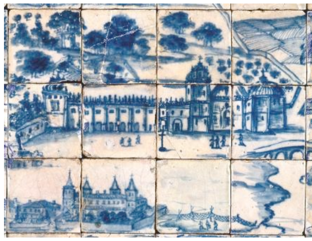


Fake Rate Cross-Check

- cross check fake rate with wrong sign decays:

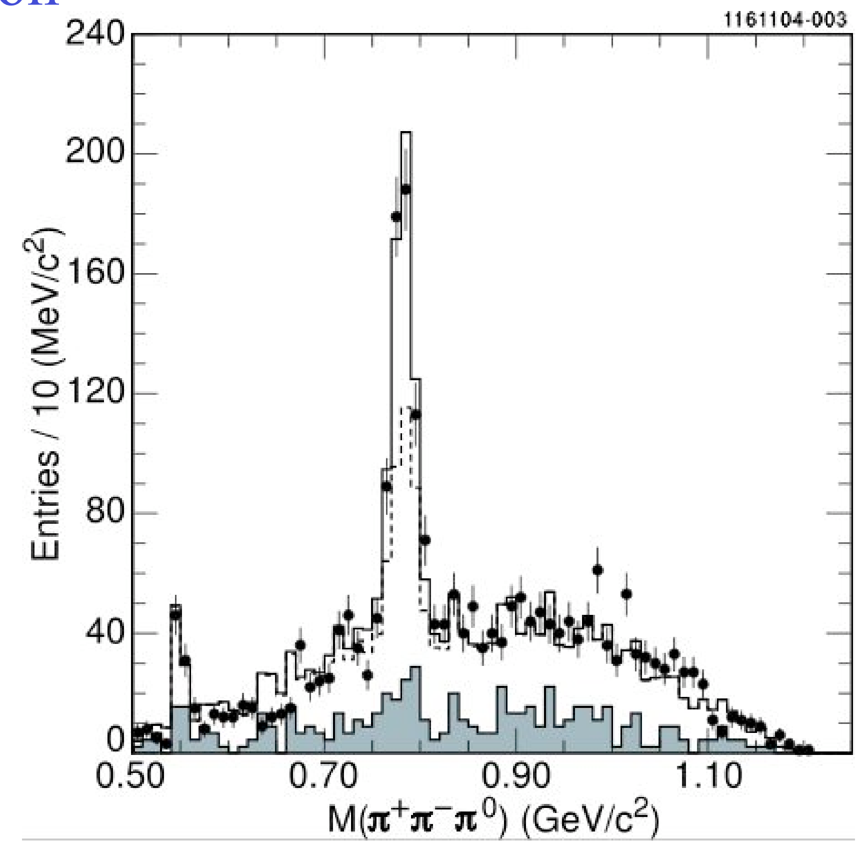
decay	data	prediction	$\tau^+\tau^-$	$q\bar{q}$
$\tau^- \to K^+\pi^-\pi^-\pi^0\nu_\tau$	633 ± 25	609 ± 23	465 ± 15	144 ± 18
no angular correction	–	568 ± 23	424 ± 14	–
$\tau^- \to K^-K^-\pi^+\pi^0\nu_\tau$	11 ± 3	9 ± 3	9 ± 2	0 ± 2

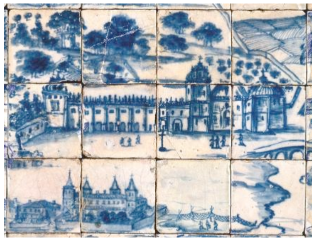
- no excess of events
  - ⇨ fake rate estimation is reliable



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

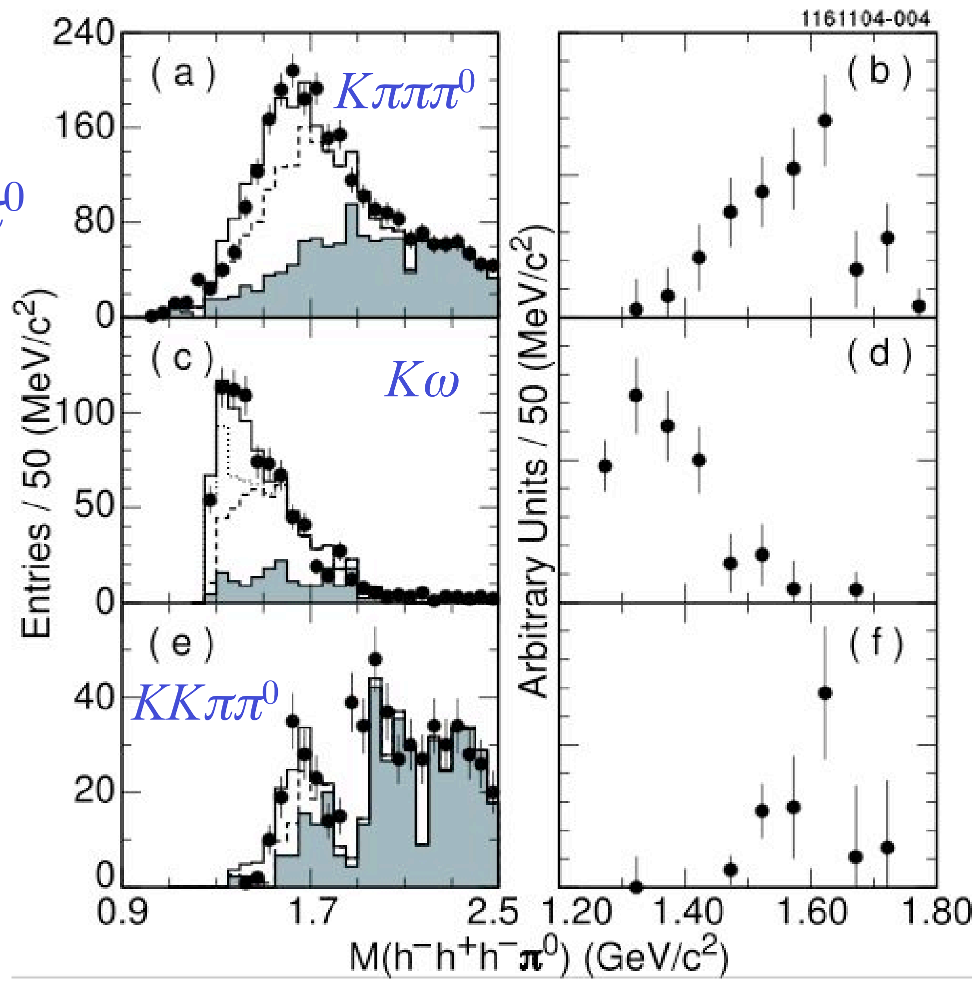
- η peak consistent with expectation
- clear ω signal over background





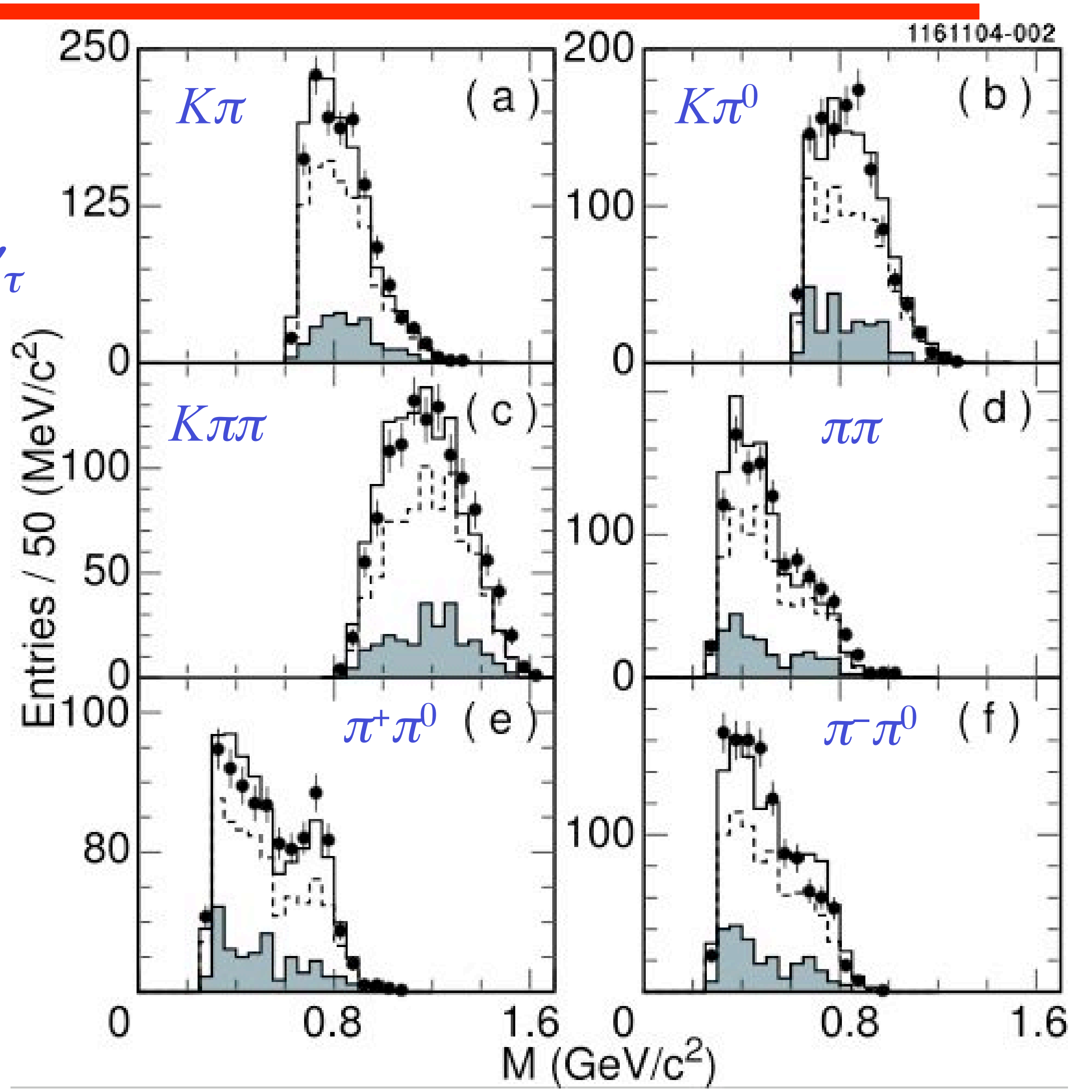
Measurements of $\tau^- \rightarrow K^-\pi^+\pi^-\pi^0\nu_\tau$ & $K^-K^+\pi^-\pi^0\nu_\tau$

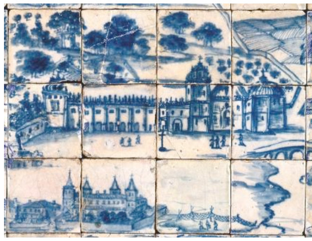
- background above τ mass well reproduced
- clear excess of $K\pi\pi\pi^0$ & $KK\pi\pi^0$ events over background
- 50/50 $K_1(1270)$+$K_1(1400)$ describes M($K\omega$) well
- efficiency/background corrected mass spectra can be used to extract spectral functions for measuring m_S & $\sin\theta_C$



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%

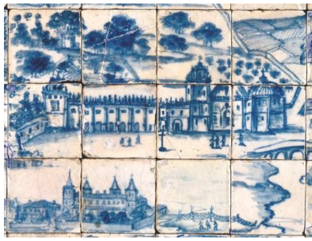




Results

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

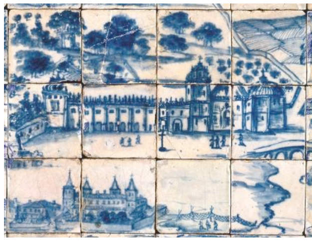
- 1st observation of $\tau^- \to K^-\omega\nu_\tau$
- 1st statistically significant measurement of $\boldsymbol{B}(\tau^- \to K^-K^+\pi^-\pi^0\nu_\tau)$ and $\boldsymbol{B}(\tau^- \to K^-\pi^+\pi^-\pi^0\nu_\tau$, ex. $K_s) = (7.4 \pm 0.8 \pm 1.1) \times 10^{-4}$
- 1st limits on $\boldsymbol{B}(\tau^-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



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

- 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)

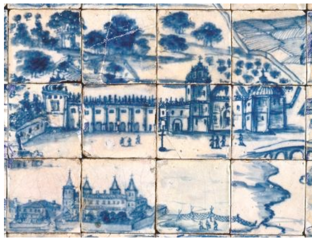
- CLEO III measurement is consistent with earlier results but significantly more precise



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

- 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

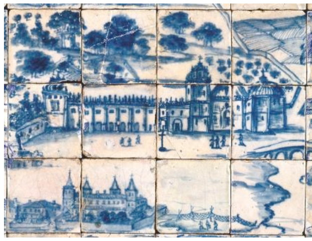


$B(\tau^- \to K^-\omega\nu_\tau)$

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

- $B(\tau^- \to K^-\omega\nu_\tau)$ disagrees with Li's predictions
  - $B(\tau^- \to K^-\omega\nu_\tau)$ is ~ 2 × lower than predicted
  - $B(\tau^- \to K^-\omega\nu_\tau)/B(\tau^- \to K^-\rho\nu_\tau)$ is ~ 4 × lower than predicted

- B.A. Li, PRD **55**, 1436 (1997)



Summary

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

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