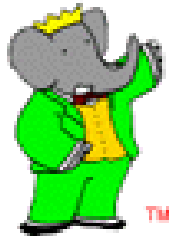
Hadronic Tau Decays at BaBar



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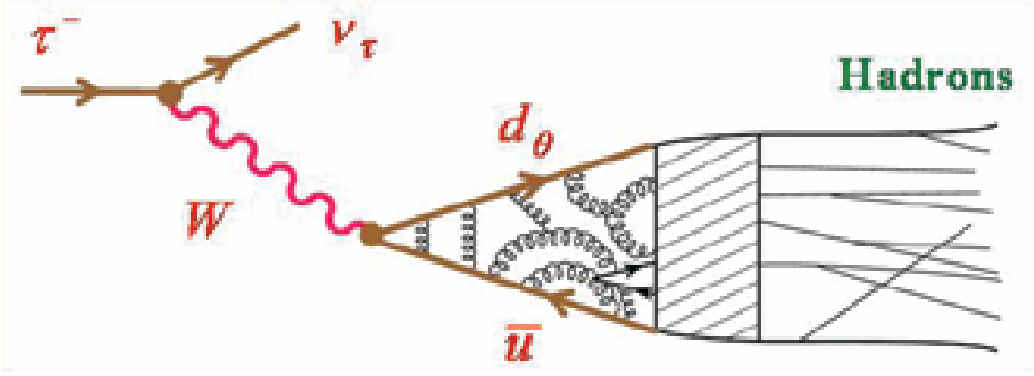
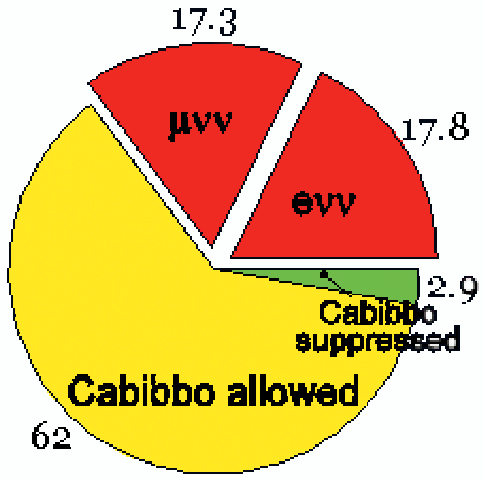
Hadronic τ decays

- Only lepton that decays into hadrons
  - Hadronic Branching Fraction $\sim$ 65%
- Initial state represents perfect QCD vacuum





- $\tau^- \to h^- \nu_\tau$ probes hadronic $V - A$ current:
  $\langle h^- | \bar{d_\theta} \gamma^\mu (1 - \gamma_5) u | 0 \rangle$, where $d_\theta = \cos\theta_C d + \sin\theta_C s$
  $\Rightarrow$ Cabibbo allowed and suppressed decays
- Ideal for measurements of fundamental quantities like V_{us}, m_s, α_s
- Several resonance (sub-)structure waiting to be observed

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Strange Spectral Function

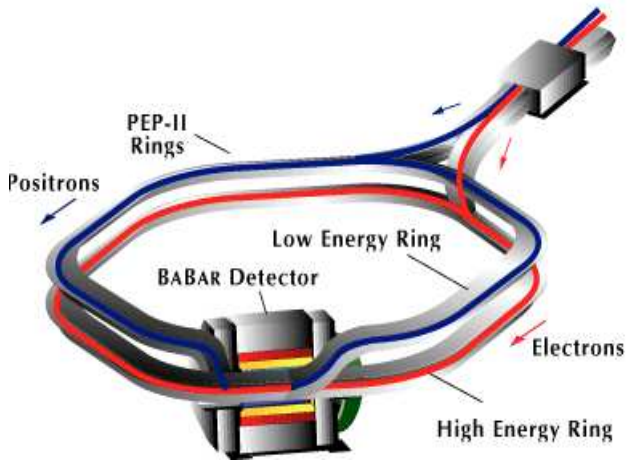
- Inclusive study of strange spectral functions from final states with net strangeness of unity $\Rightarrow$ world's best measurement of $|V_{us}|$, m_s

Branching Fractions ($\times 10^{-3}$) [PDG 2005]

$\mathcal{B}(\tau \to K\nu)$	6.86 ± 0.23
$\mathcal{B}(\tau \to K\pi^0\nu)$	4.50 ± 0.30
$\mathcal{B}(\tau \to K\eta\nu)$	0.27 ± 0.06
$\mathcal{B}(\tau \to K2\pi^0\nu)$	0.58 ± 0.23
$\mathcal{B}(\tau \to K3\pi^0\nu)$	0.38 ± 0.22
$\mathcal{B}(\tau \to \pi\bar{K}^0\nu)$	8.9 ± 0.4
$\mathcal{B}(\tau \to \pi\bar{K}^0\pi^0\nu)$	3.7 ± 0.4
$\mathcal{B}(\tau \to \pi\bar{K}^0 2\pi^0\nu)$	0.24 ± 0.24
$\mathcal{B}(\tau \to K\pi\pi \geq 0\pi^0\nu)$	3.9 ± 0.4
$\mathcal{B}(\tau \to X^{(S=-1)}\nu)$	29.3 ± 0.8

- Preliminary $\mathcal{B}(\tau^- \to K^-\pi^0\nu_\tau)$ and $\mathcal{B}(\tau^- \to K^-\pi^-\pi^+\nu_\tau)$ reported with better precision than the world average (TAU06, Pisa)

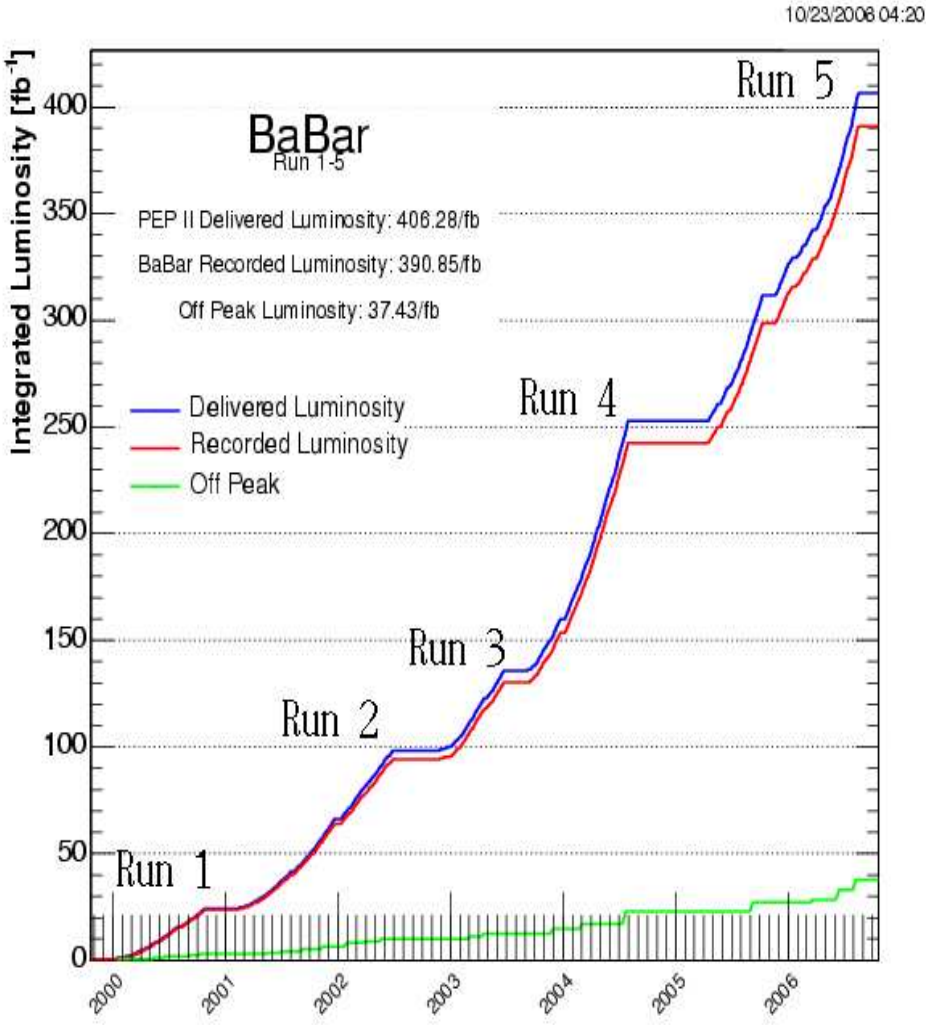
τ-factory



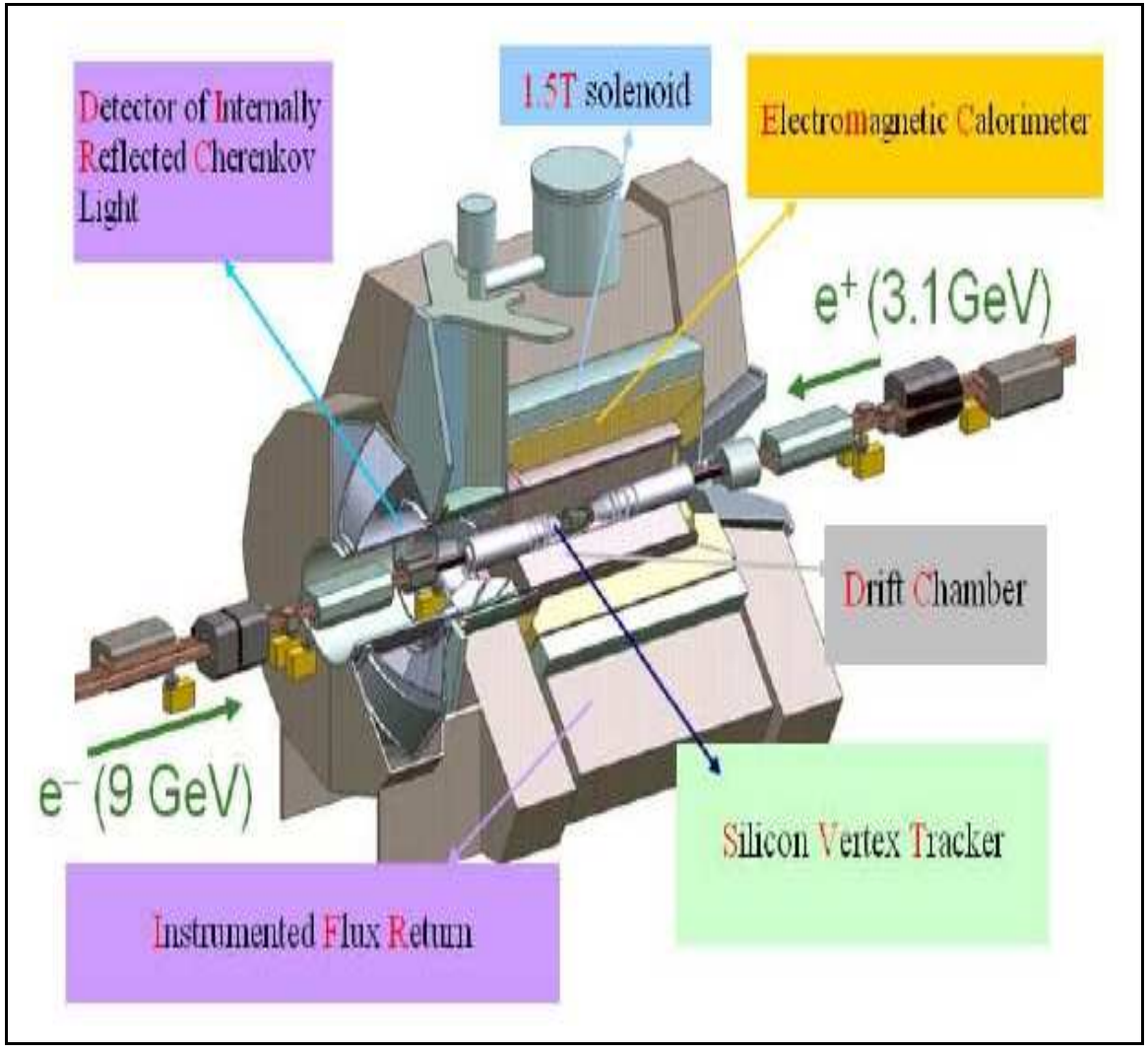
PEP-II B-factory: also a τ-factory

At $\Upsilon(4S)$: $\sqrt{s}$ = 10.58 GeV
$\sigma(e^+e^- \to B\overline{B})$ = 1.05 nb
$\sigma(e^+e^- \to \tau^+\tau^-)$ = 0.89 nb

Experiment	# of τ-pairs
LEP	3×10^5
CLEO	1×10^7
BABAR	3×10^8

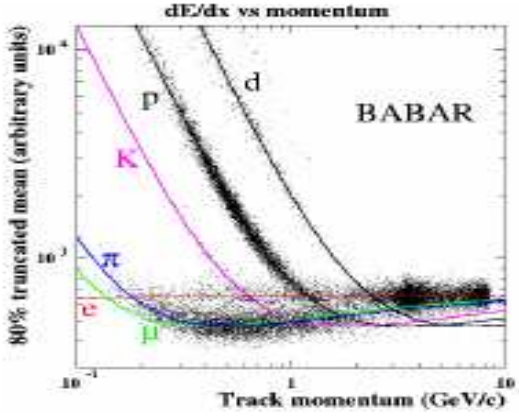


The BABAR Detector

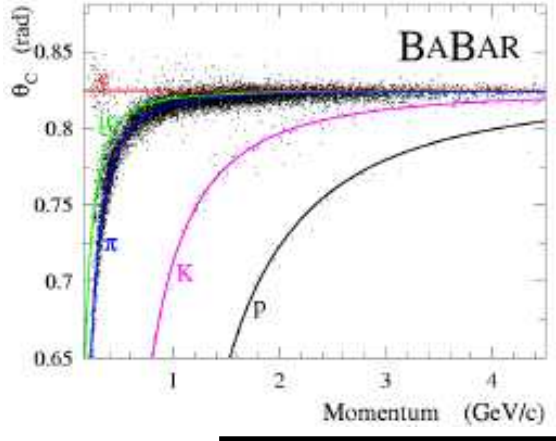


Excellent K/π separation

- dEdx



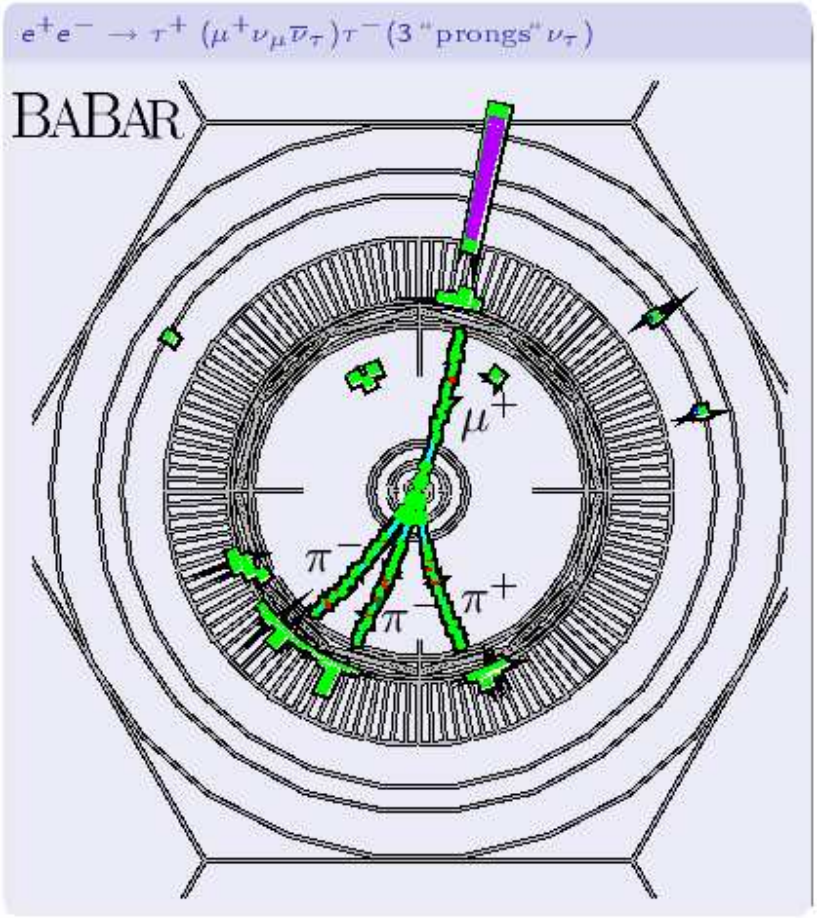
- Cherenkov angle



Recent Results from BABAR

- Runs 1-4 Data ($\mathcal{L} \sim 230$ fb^{-1})
  - $\tau^- \to \pi^- \underbrace{\pi^- \pi^+ \pi^0}_{\omega} \nu_\tau$
  - $\tau^- \to \pi^- \underbrace{\pi^- \pi^+ \eta}_{f_1(1285)} \nu_\tau$
  - $\tau^- \to \underbrace{K^- \pi^0}_{K^{*-}(892)} \nu_\tau$
- Runs 1-5 Data ($\mathcal{L} \sim 340$ fb^{-1})
  - $\tau^- \to \pi^- \pi^- \pi^+ \nu_\tau$
  - $\tau^- \to K^- \pi^- \pi^+ \nu_\tau$
  - $\tau^- \to \pi^- \underbrace{K^- K^+}_{\phi} \nu_\tau$
  - $\tau^- \to K^- \underbrace{K^- K^+}_{\phi} \nu_\tau$

Most analyses use leptonic tag



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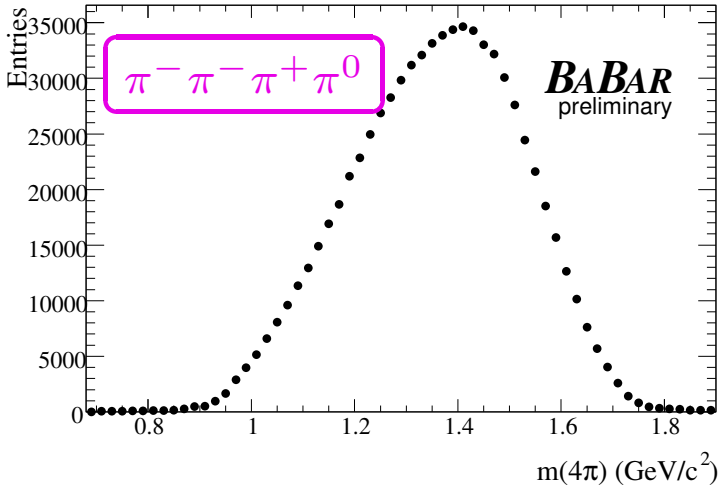
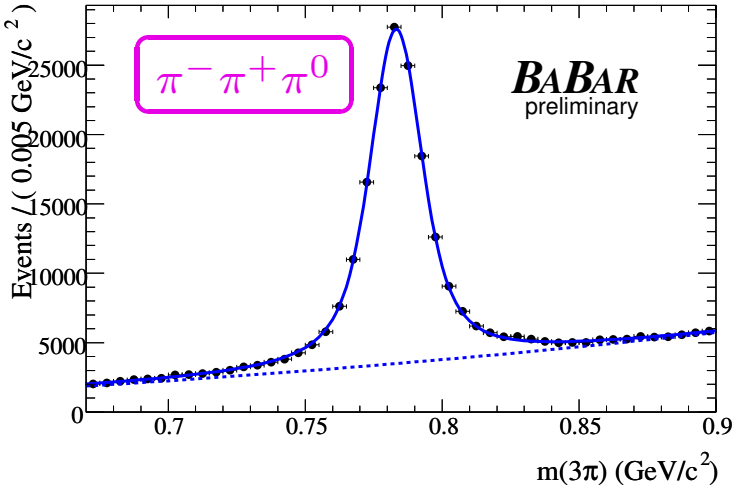
$\tau^- \longrightarrow \pi^-\pi^-\pi^+\pi^0\nu_\tau$

- 411K e-tagged events
  Background: 10%
  ($\tau^+\tau^-$ events with extra π^0)
  BABAR (Preliminary):
  $\mathcal{B}(\tau^- \longrightarrow \pi^-\pi^-\pi^+\pi^0\nu_\tau) =$
  $(4.39 \pm 0.01 \pm 0.21) \times 10^{-2}$
  PDG (Aleph, CLEO):
  $(4.46 \pm 0.06) \times 10^{-2}$



- Fit Breit-Wigner convoluted with Gaussian (resolution: 6.1 MeV) plus polynomial background
  ($\sim$ 6% from $\tau^+\tau^-$ with extra π^0)
  BABAR Preliminary:
  $\mathcal{B}(\tau^- \longrightarrow \pi^-\omega\nu_\tau) =$
  $(1.97 \pm 0.01 \pm 0.10) \times 10^{-2}$
  Aleph: $(1.91 \pm 0.07 \pm 0.06) \times 10^{-2}$



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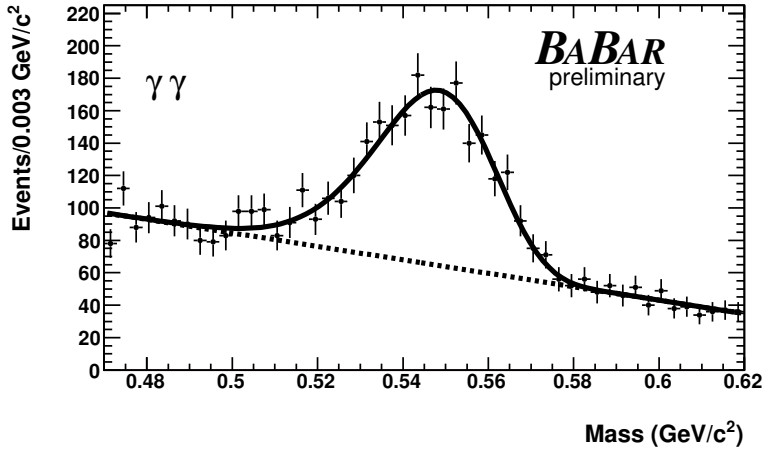
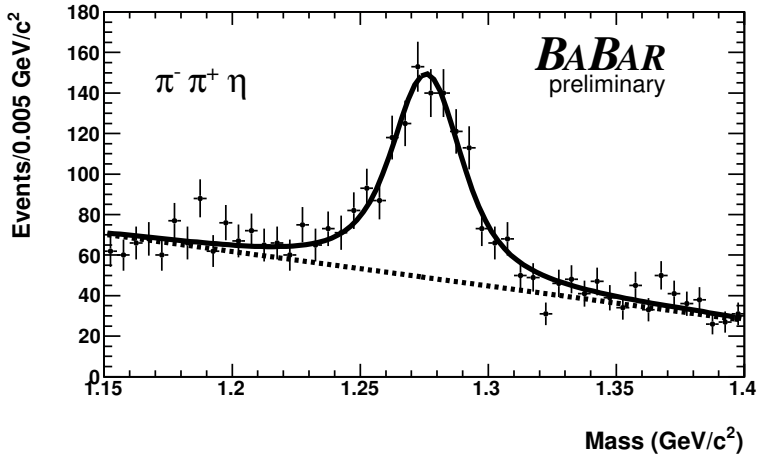
$\tau^- \to \pi^-\pi^-\pi^+\eta\nu_\tau$

- Fit with Novosibirsk function:
  (1260 ± 56) η candidates
  $q\bar{q}$ Background: (54 ± 16)
  BABAR (Preliminary):
  $\mathcal{B}(\tau^- \to \pi^-\pi^-\pi^+\eta\nu_\tau) =$
  $(1.84 \pm 0.09 \pm 0.13) \times 10^{-4}$
  PDG : $(2.3 \pm 0.5) \times 10^{-4}$



- Fit Breit-Wigner convoluted with Gaussian (resolution: 7 MeV)
  (951 ± 78) $f_1(1285)$ candidates
  BABAR (Preliminary):
  $\mathcal{B}(\tau^- \to \pi^- f_1\nu_\tau) =$
  $(3.83 \pm 0.32 \pm 0.20 \pm 1.18) \times 10^{-4}$
  BABAR: $(4.6 \pm 1.2 \pm 0.7) \times 10^{-4}$
  using $f_1(1285) \to \pi^-\pi^-\pi^+\pi^+$ decays

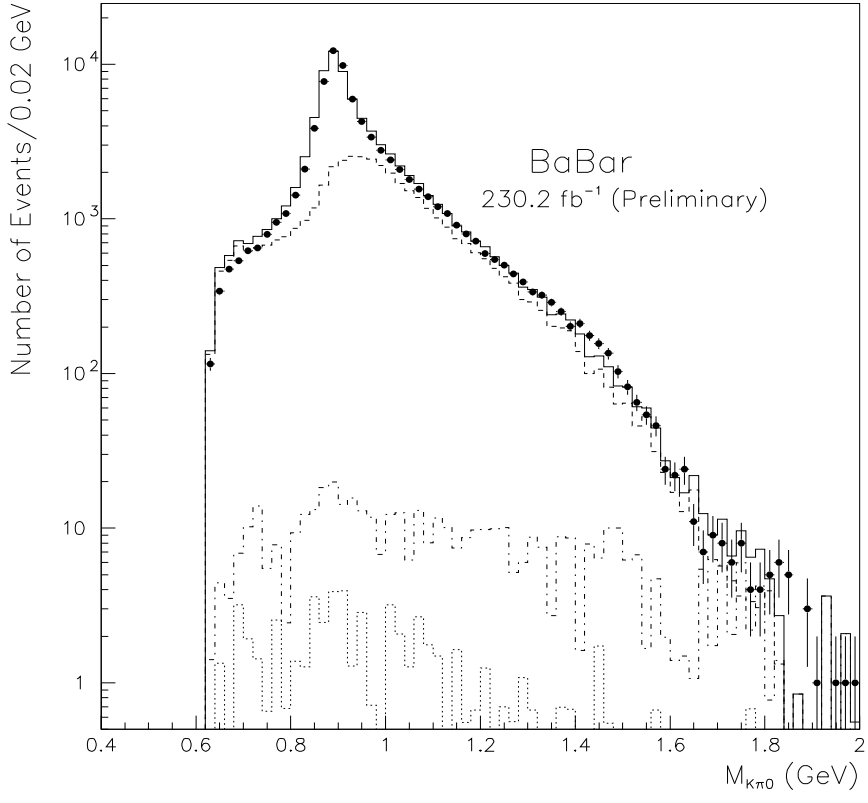


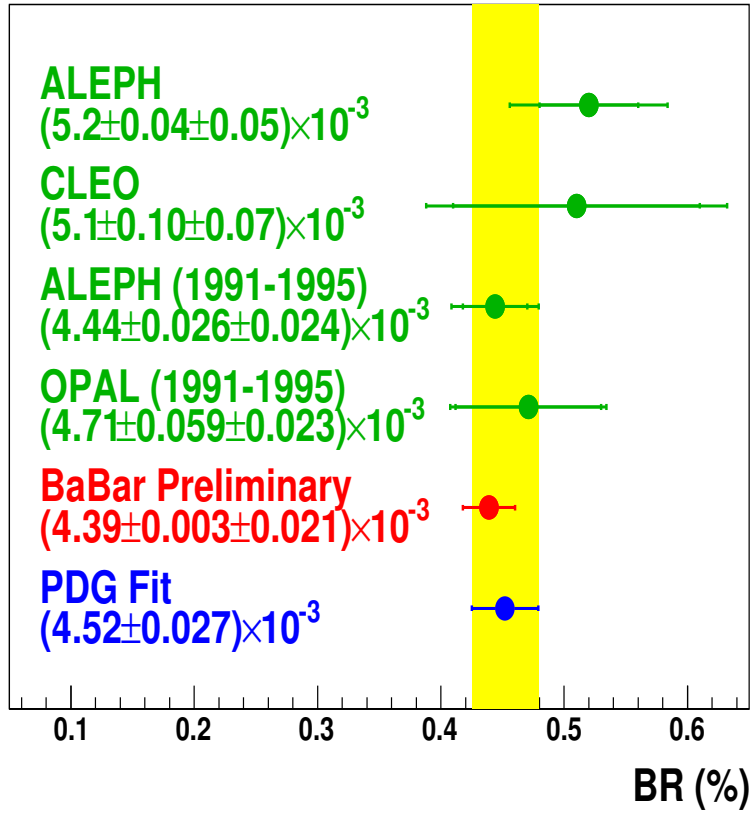
Resonant Contributions

- Ratio of Branching Fractions (BABAR Preliminary):
  - $R\left(\frac{\tau^- \to \pi^- \omega \to \pi^- \pi^- \pi^+ \pi^0 \nu_\tau}{\tau^- \to \pi^- \pi^- \pi^+ \pi^0 \nu_\tau}\right) = 0.400 \pm 0.002 \pm 0.006$
  - $R\left(\frac{\tau^- \to \pi^- f_1 \to \pi^- \pi^- \pi^+ \eta \nu_\tau}{\tau^- \to \pi^- \pi^- \pi^+ \eta \nu_\tau}\right) = 0.723 \pm 0.012 \pm 0.042$
- $\tau^- \to \pi^- \underbrace{\pi^- \pi^+ \eta}_{\eta'} \nu_\tau$ decays
  - Suppressed by G-parity (2^{nd} Class Current)
  - Expected at the level of isospin breaking $m_u \neq m_d$
  - We fit the region around $\eta'(958)$ and find no signal
  - BABAR (Preliminary):
    $\mathcal{B}(\tau^- \to \pi^- \eta' \nu_\tau) < 1.2 \times 10^{-5}$ @ 90% C.L.
    CLEO: Upper Limit = 7.4×10^{-5} @ 90% C.L.

$\tau^- \to K^-\pi^0\nu_\tau$

- 78K e/μ-tagged events: $\tau^+\tau^-$ mostly; $q\bar{q}$, $\mu^+\mu^-$ small
- Background sources: K/π mis-ID, π^0 reconstruction in-efficiency

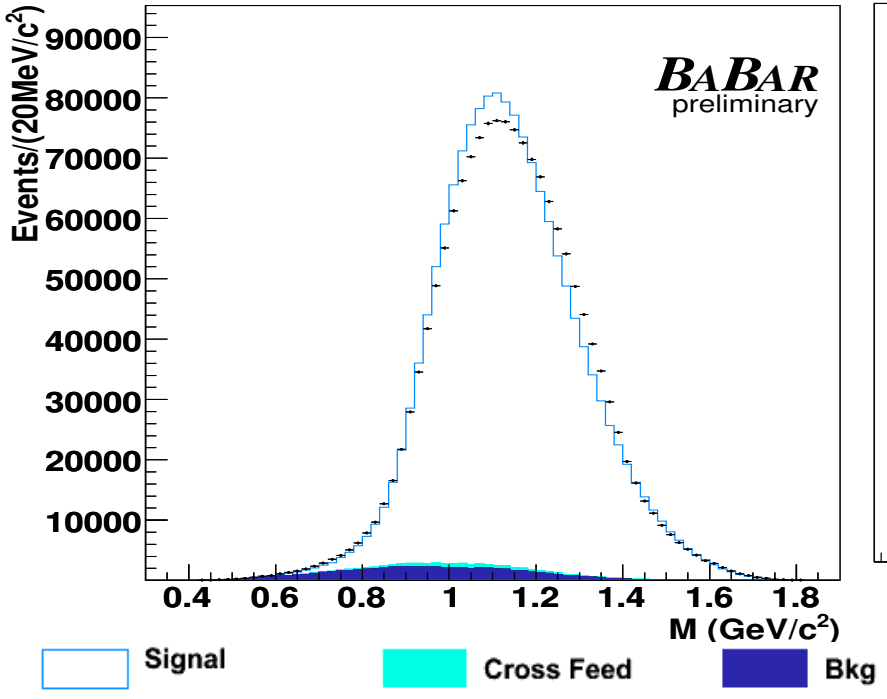


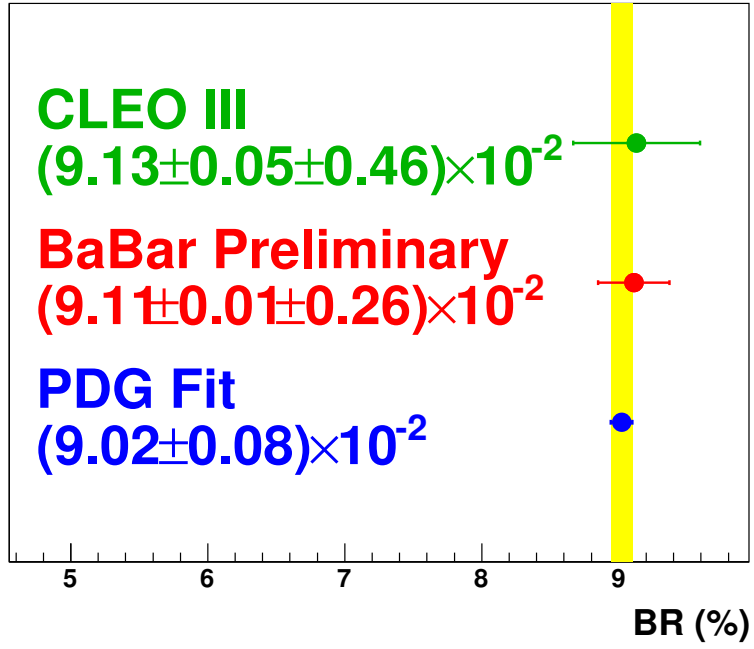


$\tau^- \longrightarrow \pi^-\pi^-\pi^+\nu_\tau$

- 1.6M e/μ-tagged events: $\tau^+\tau^-$ mostly (extra π^0); $q\bar{q} < 0.1\%$
- Particle-ID component of efficiency migration matrix:

$\pi^-\pi^-\pi^+$	$K^-\pi^-\pi^+$	$K^-\pi^-K^+$	$K^-K^-K^+$
97.7%	22.8%	4.8%	1.0%

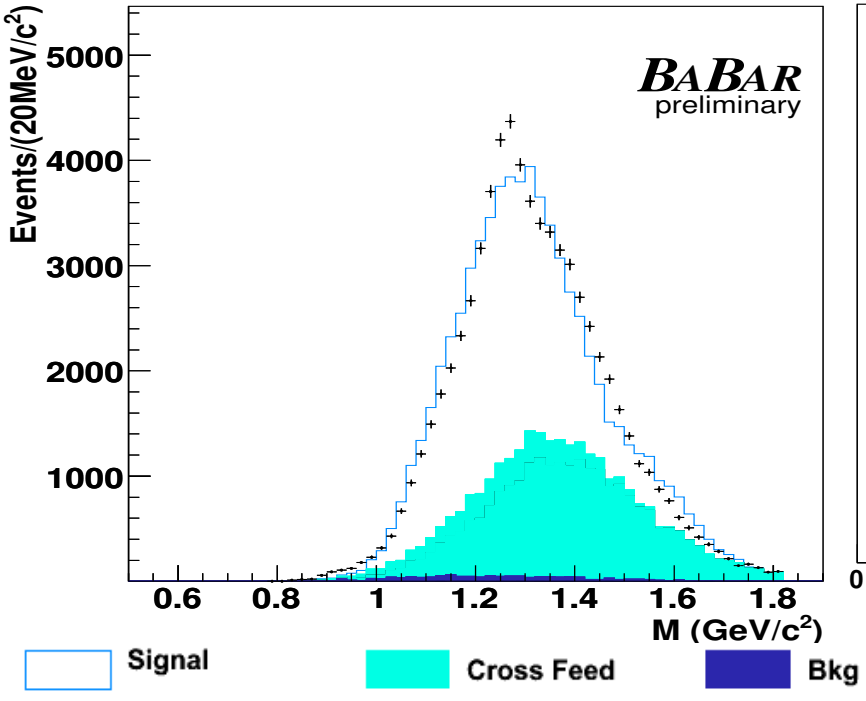


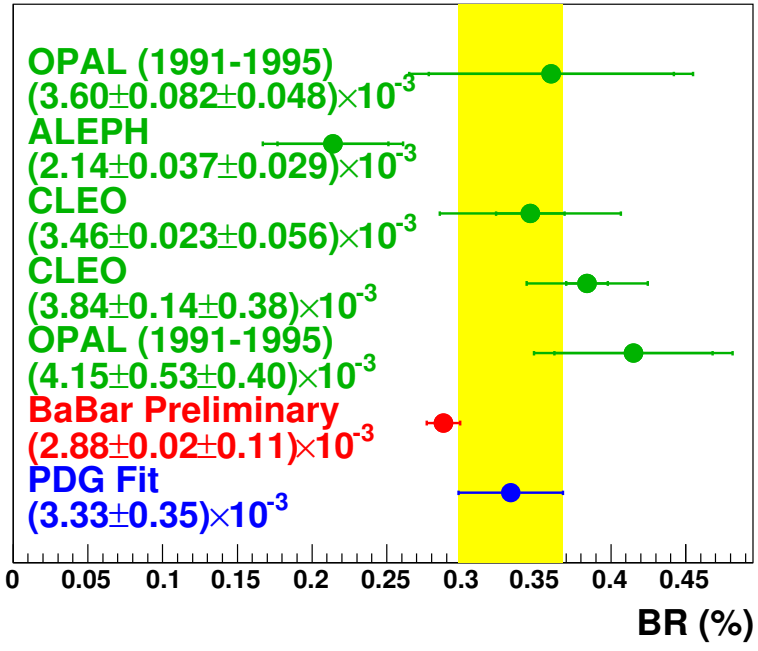


$\tau^- \to K^-\pi^-\pi^+\nu_\tau$

- 69K e/μ-tagged events: non-Cross-Feed background small
- Particle-ID component of efficiency migration matrix:

$\pi^-\pi^-\pi^+$	$K^-\pi^-\pi^+$	$K^-\pi^-K^+$	$K^-K^-K^+$
1.4%	74.7%	16.3%	6.5%

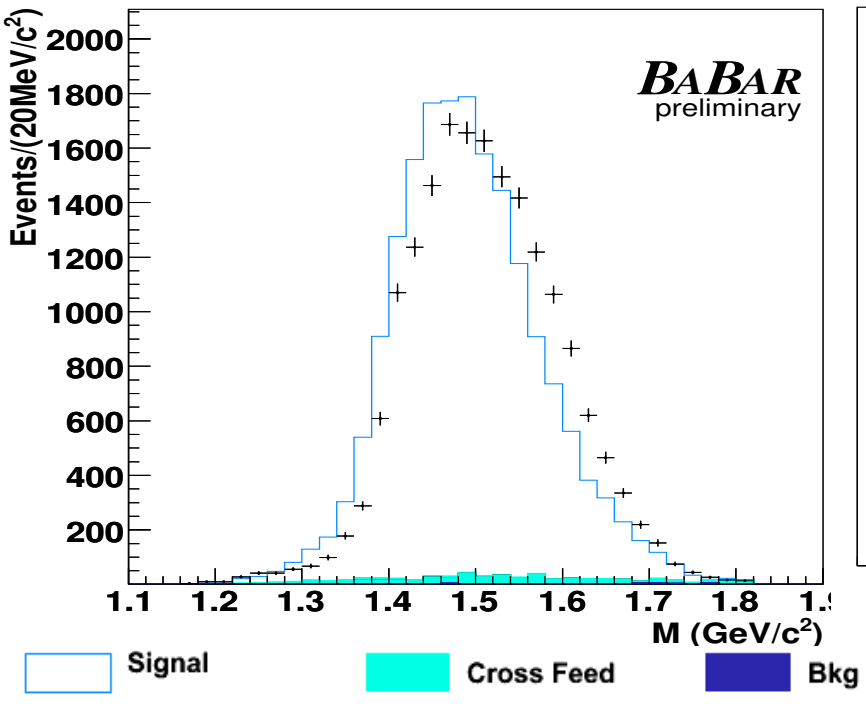


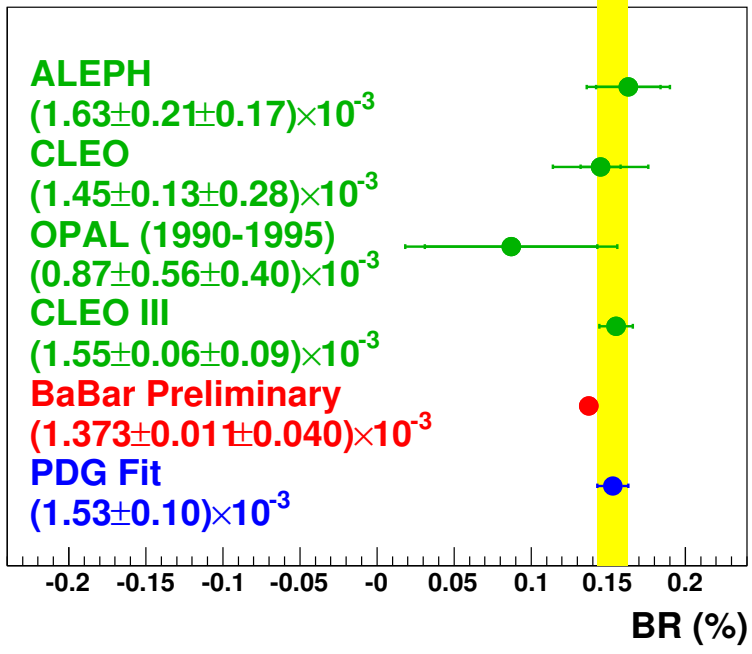


$\tau^- \to K^-\pi^-K^+\nu_\tau$

- 18K e/μ-tagged events: non-Cross-Feed background negligible
- Particle-ID component of efficiency migration matrix:

$\pi^-\pi^-\pi^+$	$K^-\pi^-\pi^+$	$K^-\pi^-K^+$	$K^-K^-K^+$
–	0.5%	60.1%	25.8%

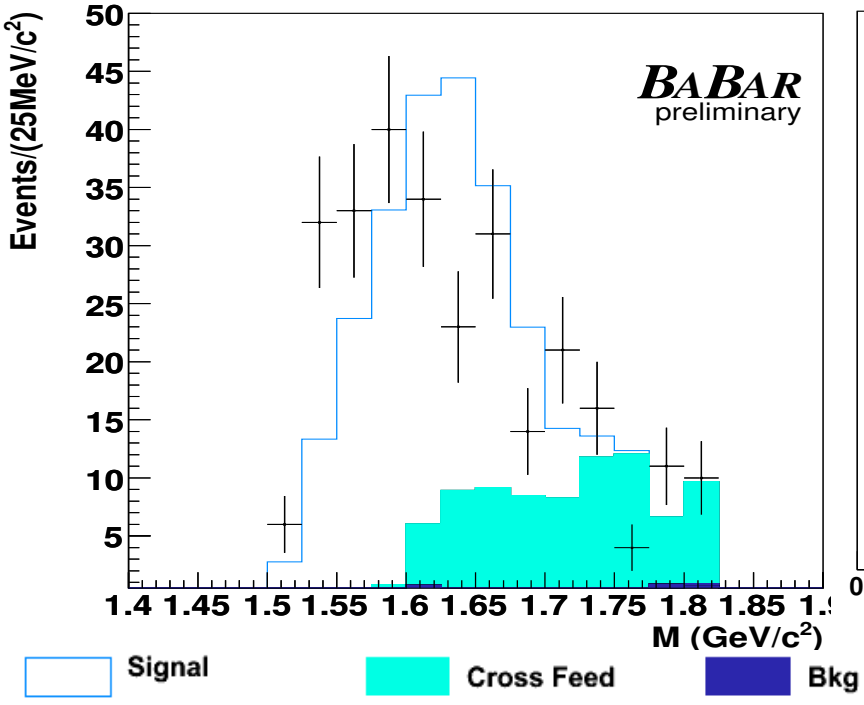


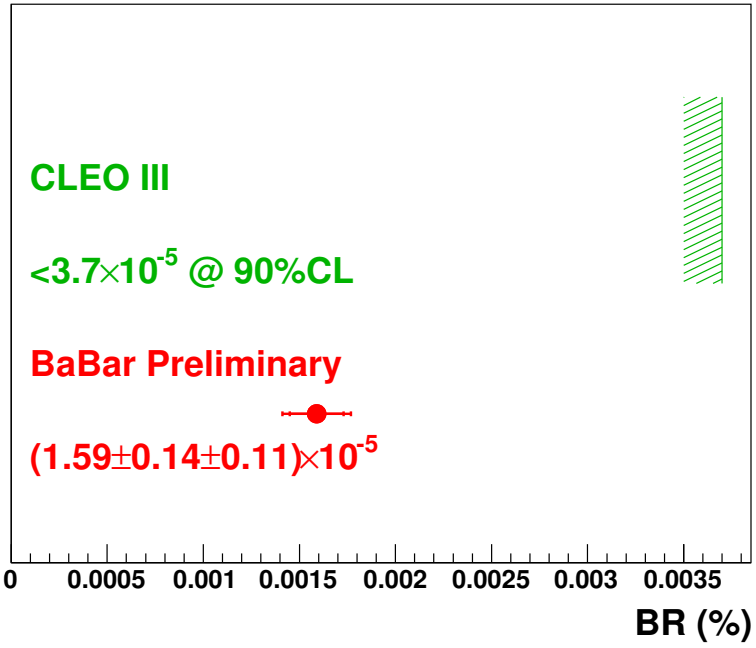


$\tau^- \to K^- K^- K^+ \nu_\tau$

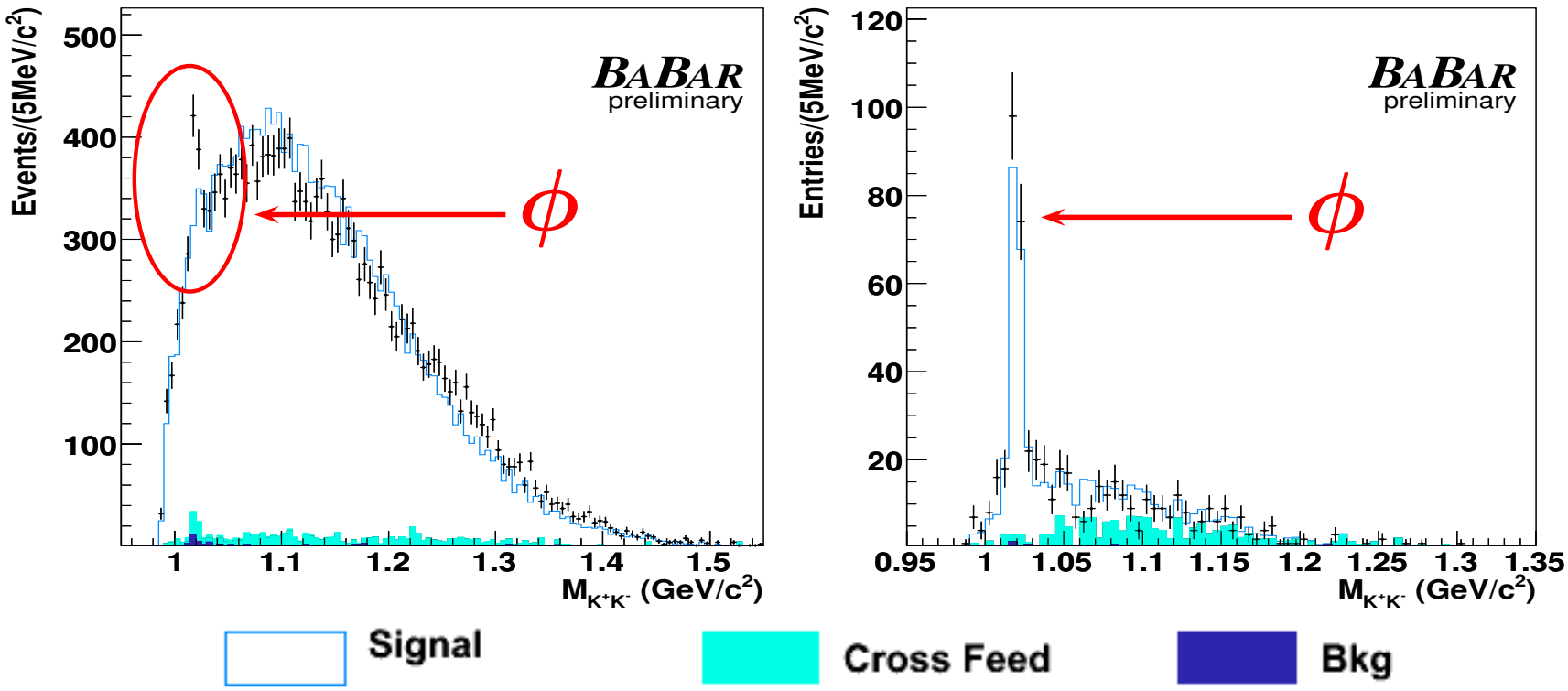
- (275 ± 17) e/μ-tagged events: non-Cross-Feed background $< 1\%$
- Particle-ID component of efficiency migration matrix:

$\pi^-\pi^-\pi^+$	$K^-\pi^-\pi^+$	$K^-\pi^-K^+$	$K^-K^-K^+$
–	–	0.3%	50.7%





New decay modes via ϕ resonance



- FIRST MEASUREMENTS of $\pi^-\phi$ and inclusive $K^-K^-K^+$ states:
  $\mathcal{B}(\tau^- \to \pi^-\phi\nu_\tau) = (3.49 \pm 0.55 \pm 0.32) \times 10^{-5}$ (Significance: 5.5σ)
  $\mathcal{B}(\tau^- \to K^-\phi\nu_\tau) = (3.48 \pm 0.20 \pm 0.26) \times 10^{-5}$ (Significance: 10.6σ)
- $\tau^- \to K^-\phi\nu_\tau$ consistent with saturating $\tau^- \to K^-K^-K^+\nu_\tau$ channel
- Consistent with Belle: $\mathcal{B}(\tau^- \to K^-\phi\nu_\tau) = (4.06 \pm 0.25 \pm 0.26) \times 10^{-5}$

Conclusions

- B-Factories are also τ-Factories
- On-going efforts to better understand systematic errors
  - π^0, η reconstruction efficiency
  - uncertainty in production cross-section $\sigma_{e^+e^-\to\tau^+\tau^-} \sim 2\%$
- BABAR dataset expected to be doubled by 2008
- Expect lots of more τ-physics in near future:
  - High precision tests of QCD
  - Measurements of fundamental quantities: V_{us}, m_s, α_s
  - Resonance sub-structure of hadronic final states
  - Search for second class currents
  - Search for violation of charge-parity symmetry in τ decays