Studies of hadronic states containing kaons in τ decays at BaBar

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(on behalf of the BaBar collaboration)

Outline

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

publication in preparation

BABAR preliminary

Presented at TAU2008:

→ Measurement of $B(\tau^- \to \bar{K}^0 \pi^- \nu_\tau)$

Since TAU2008:

→ Measurement of $B(\tau^- \to \bar{K}^0 \pi^- \pi^0 \nu_\tau)$

→ Measurement of mass and width of K*(892)

- Study of $\tau^- \to K^- (/\pi / e / \mu) \nu_\tau$

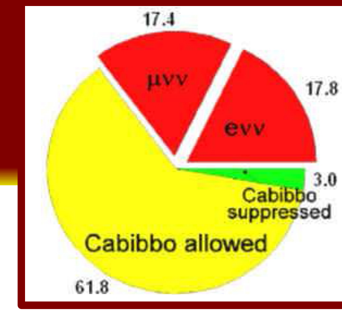
published in
Phys. Rev. Lett 105, 051602 (2010)

→ Measurement of $B(\tau^- \to K^- \nu_\tau)$ and $\dfrac{B(\tau^- \to K^- \nu_\tau)}{B(\tau^- \to \pi^- \nu_\tau)}$

→ Determination of $|V_{us}|$

Analysis presented today in lepton universality session:
Measurement of one-prong tau branching fractions to e, mu, pi and K at BaBar – R. Sobie (University of Victoria)

Strange τ Decays



ICHEP 2010 $\tau \to X_s \nu$

- Sensitive to |Vus| and ms
- Access to K/π form factors
- Largest branching fractions:

$$B(\tau^- \to \bar{K}^0 \pi^- \nu_\tau)$$

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

hadronic system in $\tau \to X_s \nu$	BF [%]	B-factories contributions
K^-	0.696 ± 0.010	BABAR 2010
$K^-\pi^0$	0.431 ± 0.015	BABAR 2007
$K^-\pi^0\pi^0(ex.K^0)$	0.060 ± 0.022	
$K^-\pi^0\pi^0\pi^0(ex.K^0, \eta)$	0.044 ± 0.022	
$\bar{K}^0\pi^-$	0.827 ± 0.018	Belle 2008, BABAR 2008
$\bar{K}^0\pi^-\pi^0$	0.349 ± 0.015	BABAR 2009 prelim.
$\bar{K}^0\pi^-\pi^0\pi^0$	0.023 ± 0.023	
$K^0h^-h^+h^-$	0.023 ± 0.020	
$K^-\pi^-\pi^+(ex.K^0)$	0.294 ± 0.007	BABAR 2008, Belle 2010
$K^-\pi^-\pi^+\pi^0(ex.K^0, \eta)$	0.075 ± 0.012	
$K^-\eta$	0.016 ± 0.001	Belle 2009
$K^-\eta\pi^0$	0.0048 ± 0.0012	Belle 2009
$\bar{K}^0\eta\pi^-$	0.0094 ± 0.0015	Belle 2009
$K^-K^+K^-$	0.0022 ± 0.0001	Belle 2006, BABAR 2007
$K^-K^0\bar{K}^0$ from $K^-K^+K^- \cdot \frac{\phi \to K^0\bar{K}^0}{\phi \to K^+K^-}$	0.0015 ± 0.0001	($K^-\phi, \phi \to K^+K^-$ saturates $K^-K^+K^-$)
TOTAL using only tau's	2.8570 ± 0.0582	error also depends on correlations
(BRs obtained by HFAG unconstrained fit **(ICHEP2010)**		χ^2/d.o.f = 155/114)

τ dataset at BaBar:

$\sigma_{\tau\tau}$ = 0.9 nb,

(σ_{BB} = 1.1 nb)

$\mathcal{L}$ = 531 fb^{-1}

→ 488 million ττ pairs

Study of $\tau^- \rightarrow \bar{K}_s^0 \pi^- \nu_\tau$: Motivation

- A BaBar measurement of the branching fraction of $\tau^- \rightarrow \bar{K}^0 \pi^- \nu_\tau$ was presented at the TAU08 (arxiv:0808.1121v2 [hep-ex]):

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$$B = (0.840 \pm 0.004\ (\text{stat.}) \pm 0.023\ (\text{syst.})\ )\ \%$$

publication in preparation

which is consistent with the PDG 2009 value:

$$B_{pdg} = (0.831 \pm 0.030)\%$$

- A fit to the $K_S\pi$ mass spectrum allows a precise measurement of the mass and width of the dominant vector resonance K*(892).

- Belle measured the $K^*(892)^-$ mass and width, including two further resonances ($K^*_0(800)$ and K*(1410)) in the fit.
(Phys.Lett.B 654:65-73, 2007)

Study of $\tau^- \to \bar{K}^0_s \pi^- \nu_\tau$: Overview

- Reconstruct $\tau^- \to \bar{K}^0_S \pi^- \nu_\tau$ decay

  → lepton tag

  → displaced vertex of Ks

  → veto neutral deposits larger than 0.1 GeV in signal hemisphere

- The $\tau^- \to \bar{K}^0_S \pi^- \pi^0 \nu_\tau$ decay is a peaking background in the K*(892) mass region in the $\tau^- \to \bar{K}^0_S \pi^- \nu_\tau$ mass spectrum

  → measure $\tau^- \to \bar{K}^0_S \pi^- \pi^0 \nu_\tau$ hadronic mass spectra

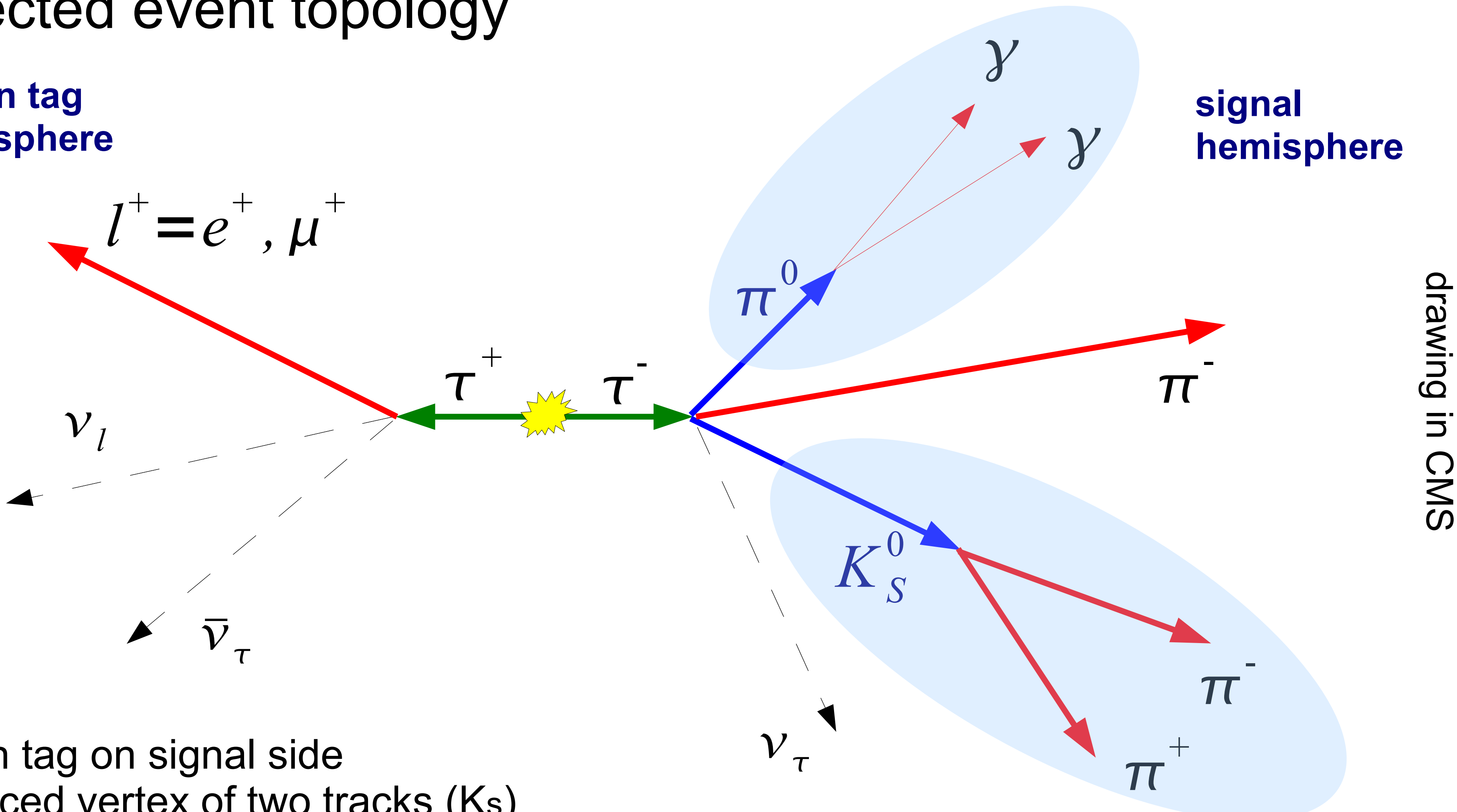
  → tune MC to describe the spectra

  → use tuned MC in $\tau^- \to \bar{K}^0_S \pi^- \nu_\tau$ measurement

- Perform a fit to the hadronic mass spectrum of $\tau^- \to \bar{K}^0_S \pi^- \nu_\tau$

Measurement of $\tau^- \to \bar{K}^0_s \pi^- \pi^0 \nu_\tau$

Selected event topology



- Lepton tag on signal side
- Displaced vertex of two tracks (Ks)
- π^0 trajectory within 90° of $K^0_S\pi^-$ momentum

Red arrows:
particles reconstructed with the BaBar detector

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

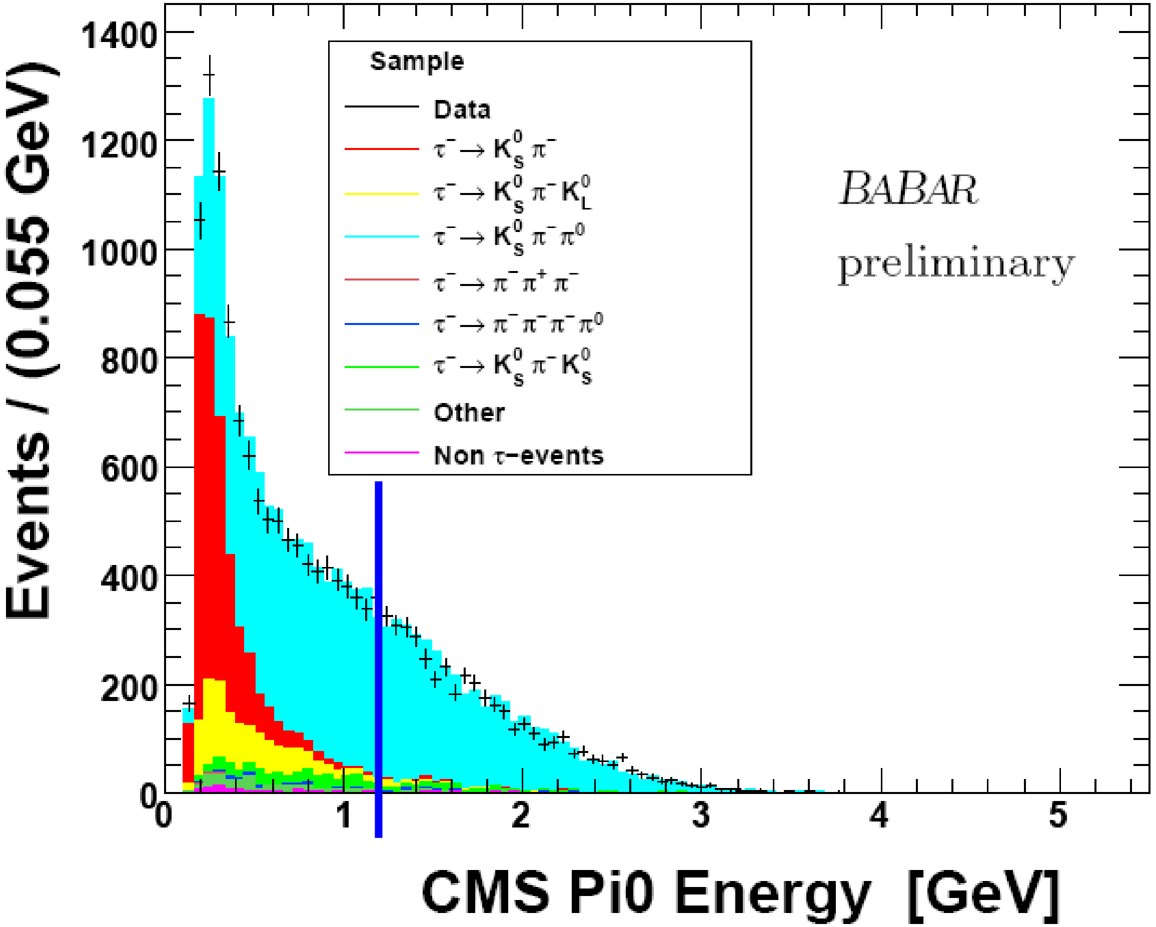
384 fb^{-1}

arXive:0910.2884v1
(S.Paramesvaran, DPF2009)

Stringent π^0 selection to obtain high purity:

- exactly one π^0
- high π^0 energy required in CMS (>1.2GeV)

→ signal purity: 93%

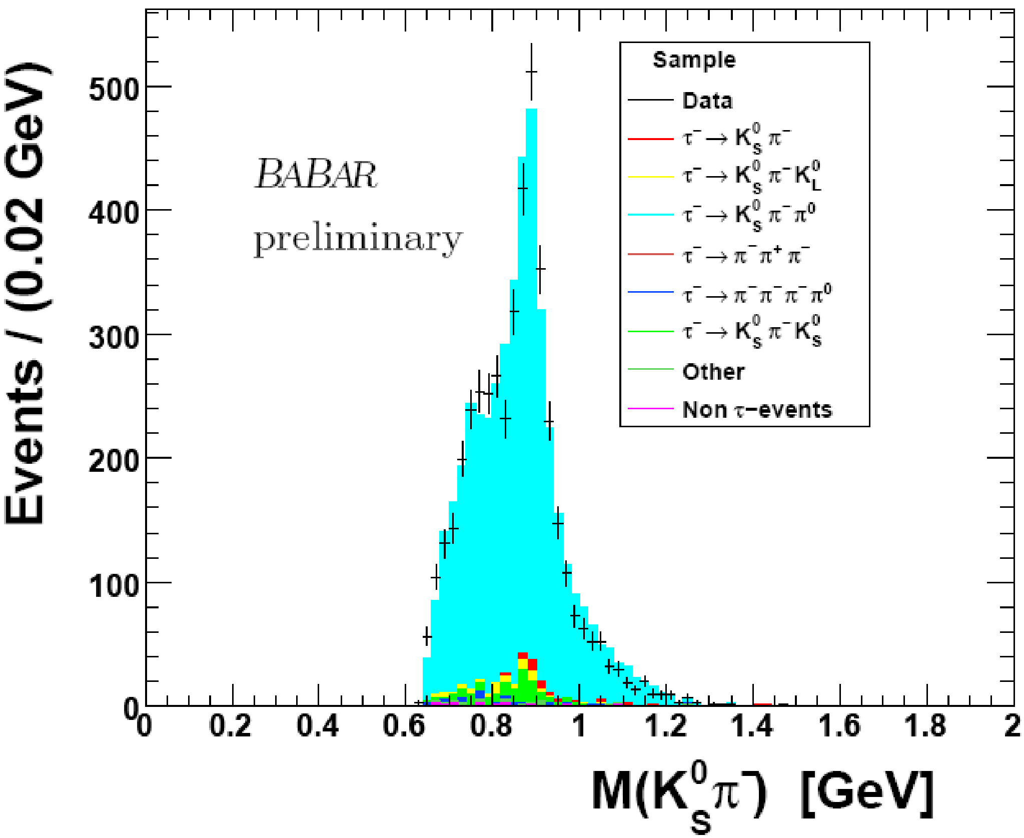


Measurement of $\tau^- \to \bar{K}^0_s \pi^- \pi^0 \nu_\tau$

- τ Monte Carlo hadronic mass distribution tuned with data
- Dominant systematic uncertainty:

  π^0 reconstruction efficiency

  → contribution to uncertainty on branching fraction:
  0.011% (rel. 3.2%)



arXiv:0910.2884v1

BABAR preliminary

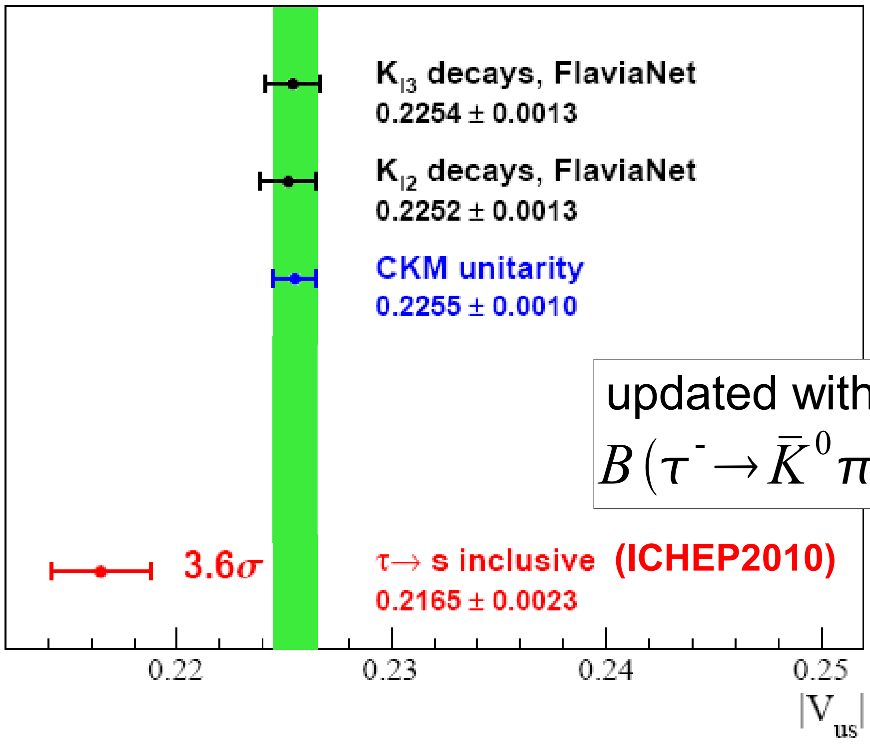
$$B(\tau^- \to \bar{K}^0 \pi^- \pi^0 \nu_\tau) = [0.342 \pm 0.006(stat.) \pm 0.015(syst.)]\%$$

Uncertainty improved by a factor of 2 with respect to PDG 2009 value
($\sigma_{rel.}$(this) = 4.7%, $\sigma_{rel.}$(PDG2009) = 11.1%)

$|V_{us}|$ from inclusive $\tau \to s$

$$|V_{us}|^2 = \frac{R_{\tau,\,strange}}{\dfrac{R_{\tau,\,non\,strange}}{|V_{ud}|^2} - \delta R_{OPE}}$$

ICHEP 2010



updated with new $B(\tau^- \to \bar{K}^0 \pi^- \pi^0 \nu_\tau)$

- |Vus| from K,Hyp,Uni. (PDG2009)
- m_s(2GeV) = 94 ± 6 MeV (M.Jamin et al., 2006)
- δR_{OPE} = 0.240 ± 0.032 (Gamiz et al., 2007)
- |Vud| (Towner, Hardy 2009)
- B(τ → s) from ICHEP2010

|Vus| precision:
→ ICHEP2008: 1.39%
→ ICHEP2010: 1.06%

the HFAG-tau group will present new |Vus| results at this workshop

Fit to mass spectum of $\tau^- \rightarrow \bar{K}_s^0 \pi^- \nu_\tau$

Method:

- Tuned $\tau^- \rightarrow \bar{K}_S^0 \pi^- \pi^0 \nu_\tau$ MC is used
- A function which reflects the limited resolution and efficiency of the detector is convoluted with the signal PDF
- Several different fit models are investigated
- Terms to include uncertainties in rates and shapes of background are included in the χ^2-minimization

  → background shapes/rates differ in each fit model

  → background subtracted data spectra are different in each fit model

Signal PDF

Same PDF as Belle (Phys.Lett.B 654:65-73, 2007)

$$f(m;\vec{\theta}) \propto \frac{1}{s}\left(1-\frac{s}{{m_\tau}^2}\right)\left(1+2\frac{s}{{m_\tau}^2}\right)P\left(P^2|F_V|^2+\frac{3({m_K}^2-{m_\pi}^2)^2}{4s(1+2\frac{s}{{m_\tau}^2})}|F_S|^2\right)$$

s = m^2

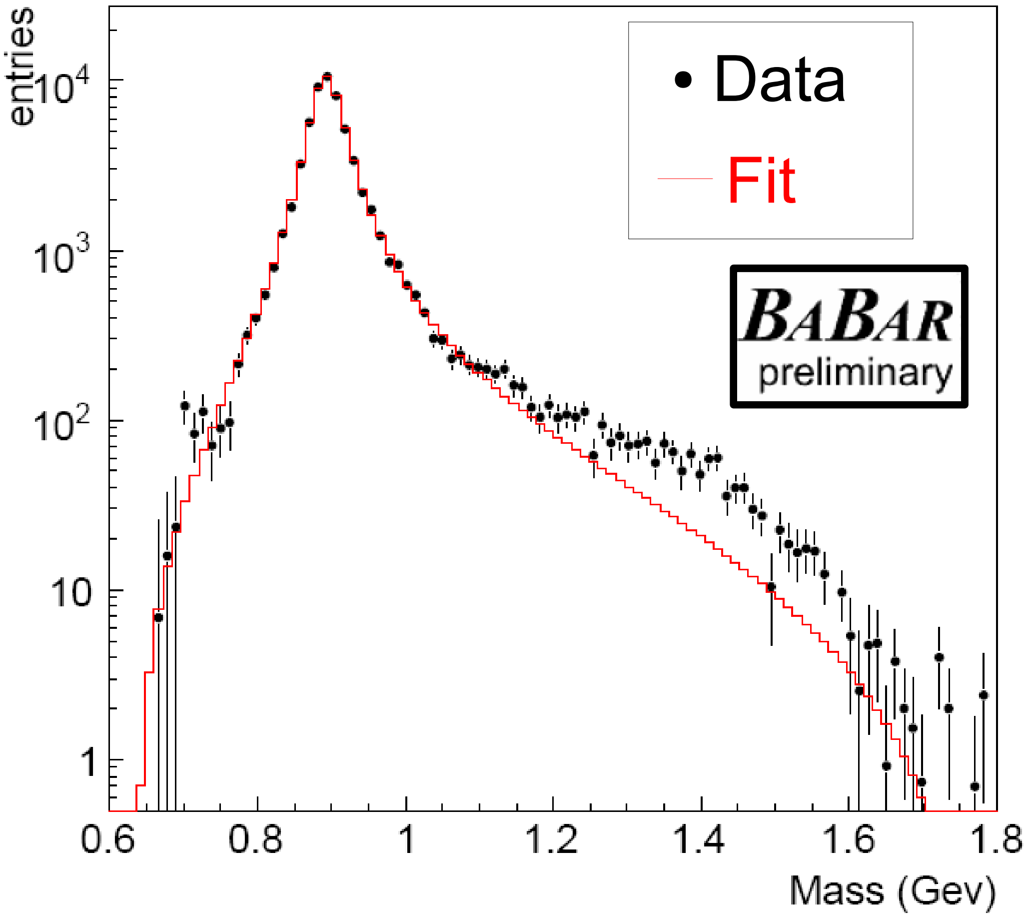
Vector form factor

$$F_V = \frac{1}{1+\beta+\gamma+\cdots}[BW_{K^1}(s)+\beta BW_{K^2}(s)+\gamma BW_{K^3}(s)+\cdots]$$

Scalar form factor

$$F_S = \varkappa\frac{s}{M^2_{K_0^*(800)}}BW_{K_0^*(800)}(s)+\lambda\frac{s}{M^2_{K_0^*(1430)}}BW_{K_0^*(1430)}(s)$$

Fit to mass spectrum (I)



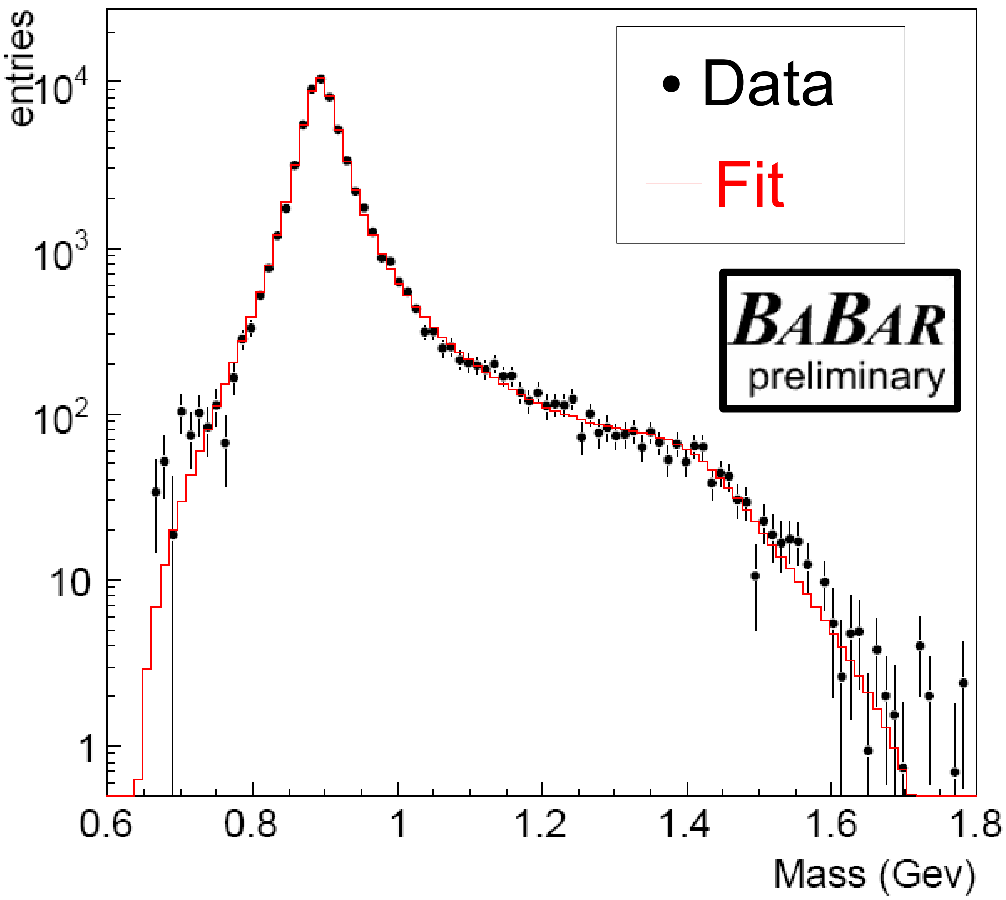
Fit model:

K*(892)

$$\chi^2/ndf = 399.8/97$$

$$Prob. < 0.0001$$

Fit to mass spectrum (II)



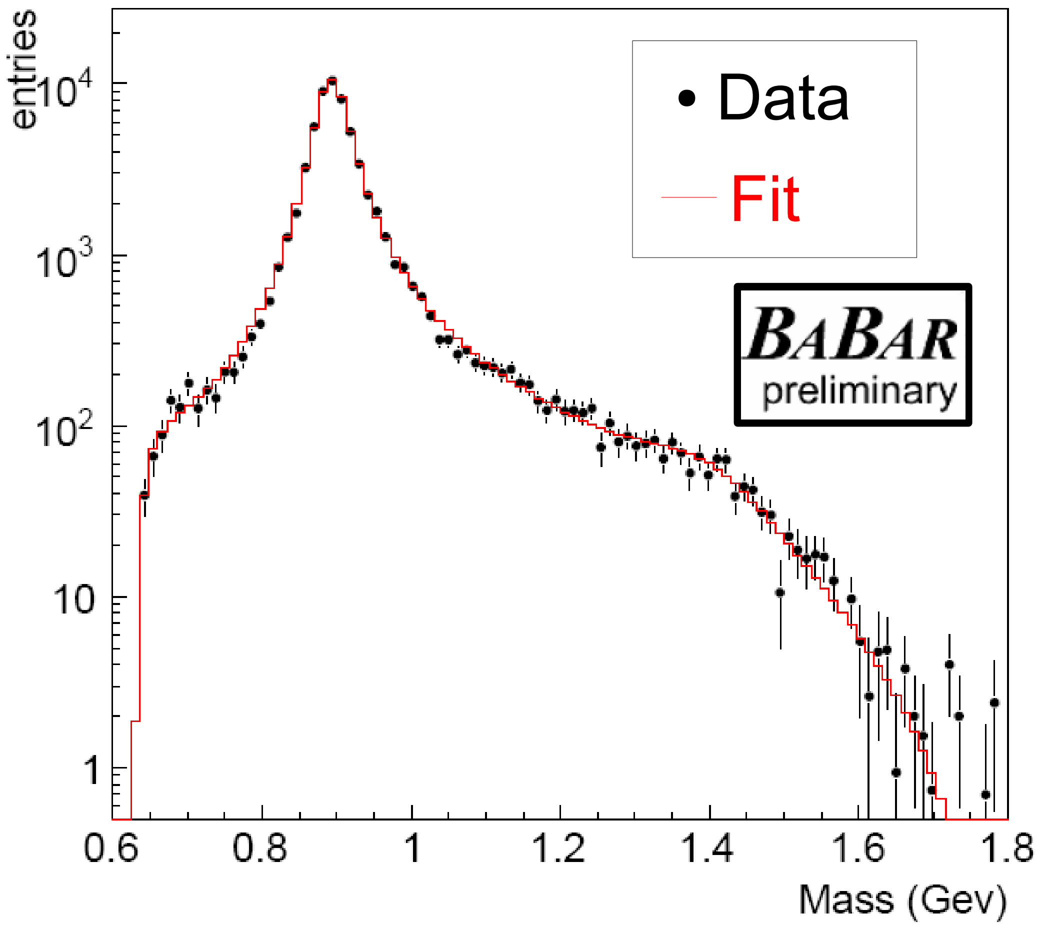
Fit model:

K*(892) + K*(1410)

$$\chi^2 / ndf = 130.0/95$$

$$Prob. = 0.0098$$

Fit to mass spectrum (III)



K*(800) mass and width from BES collaboration (Phys.Lett.B633:681-690,2006)

Fit model:

K*(892) + K*(1410) + K*(800)

$$\chi^2 / ndf = 113.0/94$$

$$Prob. = 0.0880$$

Best fit

Sytematic uncertainties

- Fit method (dominant for mass measurement) :
  → check method by fit to signal MC
  → resulting mass and width differ slightly from input values
  → additive correction
  → statistical error of correction contributes to systematic uncertainty

- Fit model:
  Differences between models with different resonances,
  and similar fit goodness are taken as source of systematic uncertainties

- Detector response matrix:
  → parameters are varied

- Uncertainties in background rates
- Shape parameters for $\tau^- \rightarrow K_S^0 K_L^0 \pi^- \nu_\tau$

} enter the statistical uncertainty of the fit

Results

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arXive:0910.2884v1

- Best fit model: K*(892) + K*(1410) + K*(800)
- Measured mass and width with best fit model

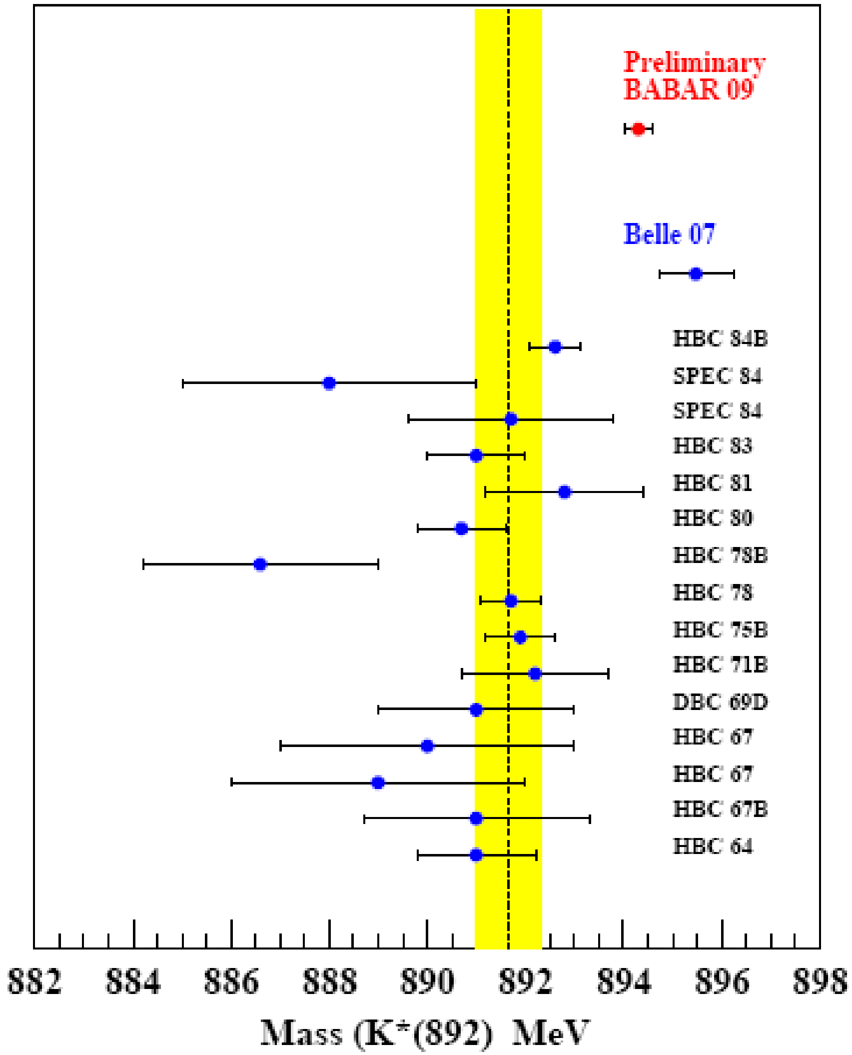
$M(K^*(892)^-) = 894.30 \pm 0.19$ (stat.) $\pm$ 0.19 (syst.) MeV/c2

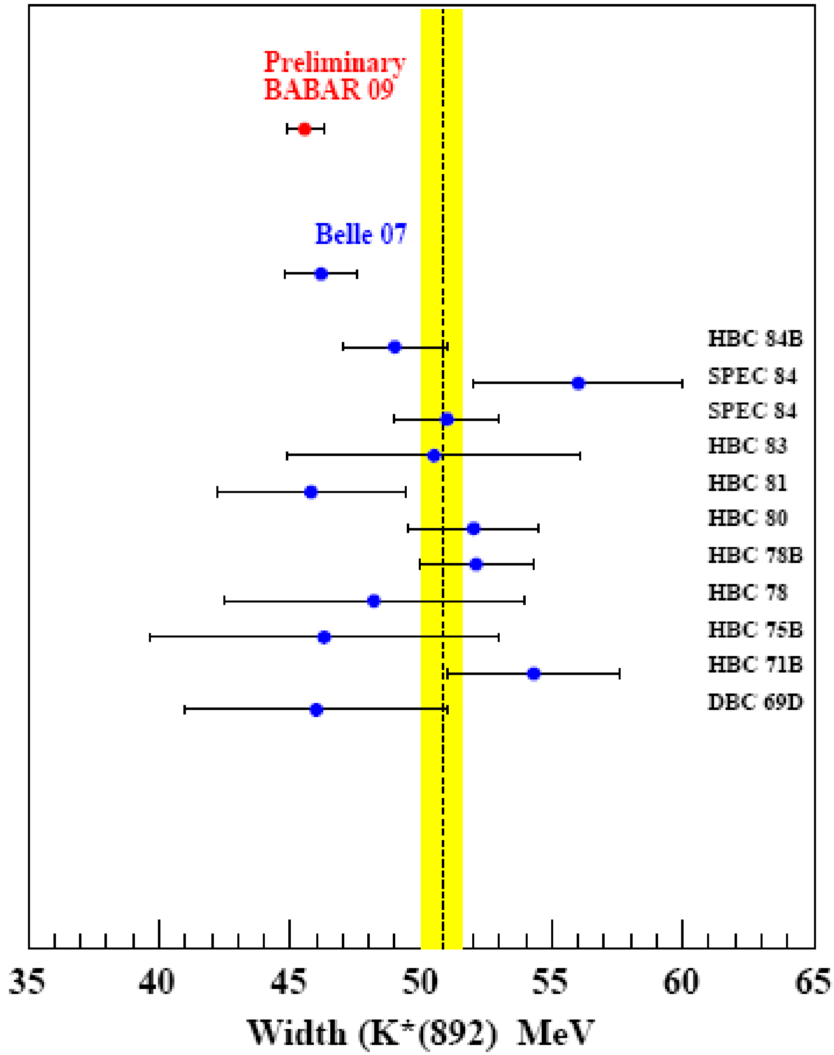
$\Gamma(K^*(892)^-) = 45.56 \pm 0.43$ (stat.) $\pm$ 0.57 (stat.) MeV/c

- Same model as Belle (Phys.Lett.B 654:65-73, 2007)
- Further study of background processes is ongoing

Comparison with other measurements

Babar09, Belle07 and measurements included in PDG2008





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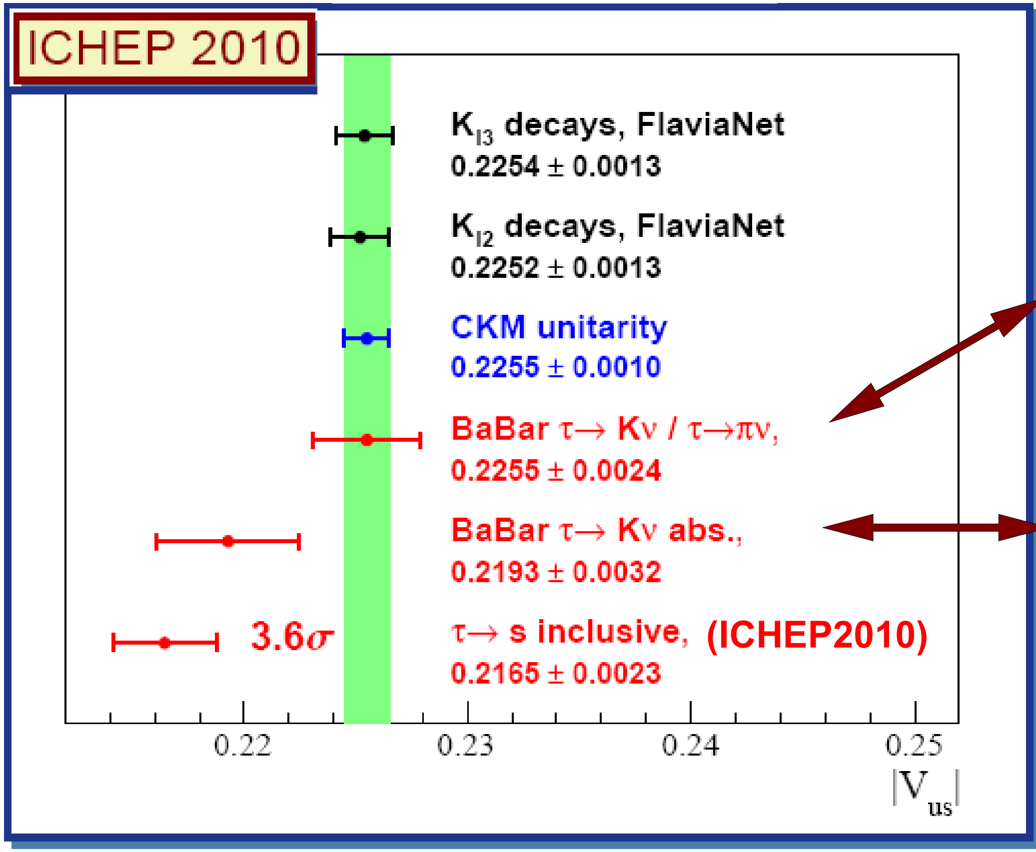
|V_{us}| from $B(\tau^- \to K^- \nu_\tau)$ and $\frac{B(\tau^- \to K^- \nu_\tau)}{B(\tau^- \to \pi^- \nu_\tau)}$

Analysis presented today in lepton universality session:
Measurement of one-prong tau branching fractions to e, mu, pi and K at BaBar – R. Sobie (University of Victoria)

$$B(\tau^- \to K^- \nu_\tau) = (0.692 \pm 0.006(stat.) \pm 0.010(syst.)) \times 10^{-2}$$

$$\frac{B(\tau^- \to K^- \nu_\tau)}{B(\tau^- \to \pi^- \nu_\tau)} = (6.531 \pm 0.056(stat.) \pm 0.093(syst.)) \times 10^{-2}$$



$$\frac{BF(\tau \to K\nu)}{BF(\tau \to \pi\nu)} = \frac{|V_{us}|^2}{|V_{ud}|^2} \frac{f_K^2}{f_\pi^2} \left(\frac{1 - m_K^2 / m_\tau^2}{1 - m_\pi^2 / m_\tau^2} \right)^2 (1 + \delta_{LD}^\tau)$$

|V_{us}| consistent with unitarity

$$B(\tau^- \to K^- \nu_\tau) = \frac{G_F^2 f_K^2 |V_{us}|^2 m_\tau^3 \tau_\tau}{16 \pi \hbar} \left(1 - \frac{m_K^2}{m_\tau^2}\right)^2 S_{EW}$$

|V_{us}| within 2σ of unitarity, and consistent with |V_{us}| from K/π ratio

Phys. Rev. Lett 105, 051602 (2010)

Summary

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

publication in preparation

BABAR preliminary

→ Measurement of the $B(\tau^- \rightarrow \bar{K}^0 \pi^- \pi^0 \nu_\tau)$

- uncertainty improvement by a factor of two compared with PDG2009

→ Measurement of mass and width of K*(892)

- Best fit model: K*(892) + K*(1410) + K*(800)
- Measured mass and width consistent with Belle (2007)

Measurement of $\frac{B(\tau^- \rightarrow K^- \nu_\tau)}{B(\tau^- \rightarrow \pi^- \nu_\tau)}$ and $B(\tau^- \rightarrow K^- \nu_\tau)$

published in Phys. Rev. Lett 105, 051602 (2010)

- Determination of |Vus| independent of OPE framework

Backup slides

Constants for $|V_{us}|$ determination

- δ_{LD} = (0.03 ± 0.44)% (arXiv:0811.1429)
- |Vud|= 0.97425 ± 0.00022 (Towner, Hardy 2009)
- f_K / f_π = 1.189 ± 0.007 (E. Follana et al. PRL 100)
- f_K = 157 ± 2 MeV (E. Follana et al. PRL 100)
- S_{EW} = 1.0201 ± 0.0003 (J.Erler, Rev. Mex. Fis 50, 200(2004))

Fit to mass spectrum

Alternative Models: (S.Paramesvaran, DPF2009)

- K*(800) + K*(892) + K*(1430) – $\chi^2/dof = 114.1/94$
- K*(800) + K*(892) + K*(1680) – $\chi^2/dof = 144.71/94$
- K*(892) + LASS – $\chi^2/dof = 148.38/94$