Exclusive branching fraction measurements of semileptonic τ decays into three charged hadrons, $\tau \to \phi\pi\nu$ and $\tau \to \phi K\nu$.

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BaBar Collaboration

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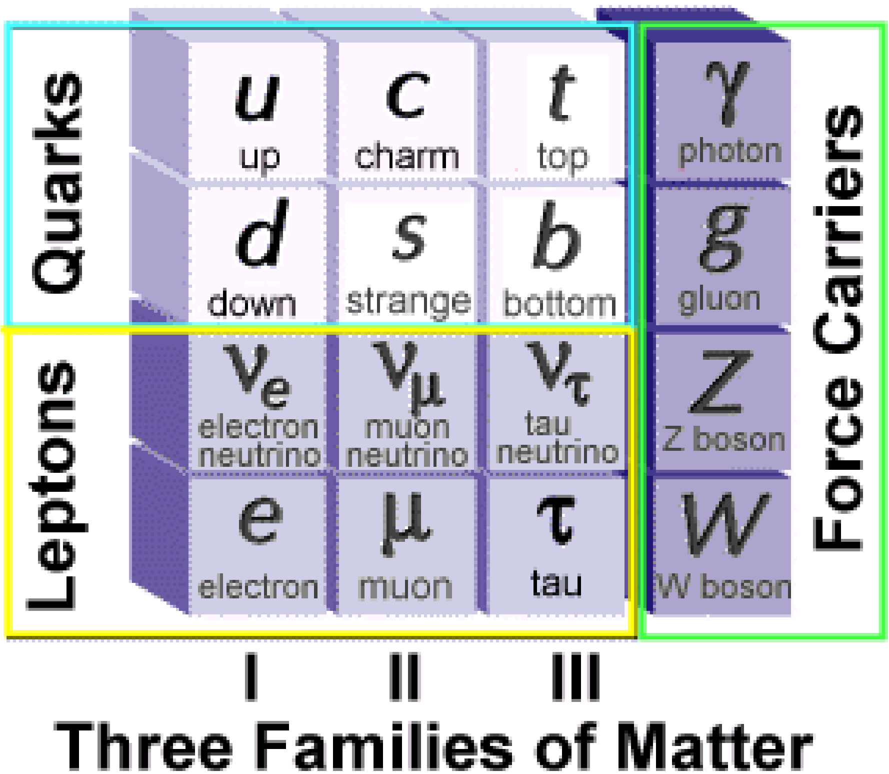
Importance of $|V_{us}|$ and m_s

Elementary Particles



Cabibbo-Kobayashi-Maskawa Matrix

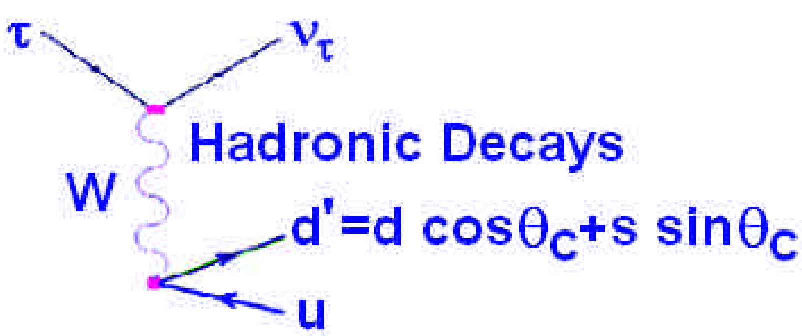
Is a unitary transform matrix that relates quark mass eigenstates to the weak eigenstates.

$$\begin{pmatrix} d_w \\ s_w \\ b_w \end{pmatrix} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \begin{pmatrix} d_m \\ s_m \\ b_m \end{pmatrix}$$

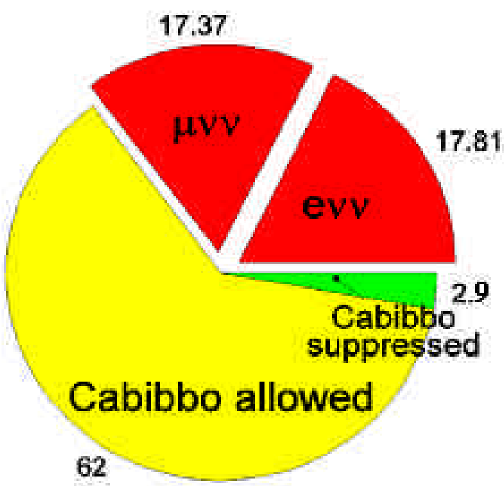
$$|V_{ud}|^2 + |V_{us}|^2 + |V_{ub}|^2 = 1$$

Strange and non-Strange τ-Decays

$$B_{had} = 1 - B_e - B_\mu$$



$$R_{\tau,\mathrm{Strange}} = R_\tau - R_{\tau,\mathrm{non-Strange}}$$



Strange τ Decays:

Mode	$\mathcal{B}(10^{-3})$
K^-	6.81 ± 0.23
$K^-\pi^0$	4.54 ± 0.30
$\bar{K}^0\pi^-$	8.78 ± 0.38
$K^-\pi^0\pi^0$	0.58 ± 0.24
$\bar{K}^0\pi^-\pi^0$	3.60 ± 0.40
$K^-\pi^+\pi^-$	3.30 ± 0.28
$K^-\eta$	0.27 ± 0.06
$(\bar{K}3\pi)^-$ (estimated)	0.74 ± 0.30
$K_1(1270)^- \to K^-\omega$	0.67 ± 0.21
$(\bar{K}4\pi)^-$ (estimated) and $K^{*-}\eta$	0.40 ± 0.12
Sum	29.69 ± 0.86

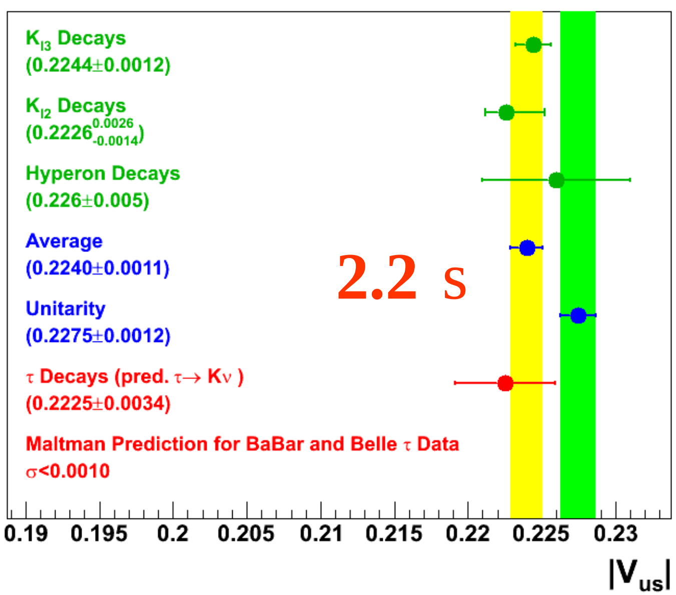
Davier, Hocker, Zhang(RMP 78, 1043, 2006)

t-Spectral Density

Hadronic Width: $R_\tau = \dfrac{\Gamma(\tau^- \to \upsilon_\tau \text{hadrons}^-)}{\Gamma(\tau^- \to \upsilon_\tau \overline{\upsilon}_e e^-)}$

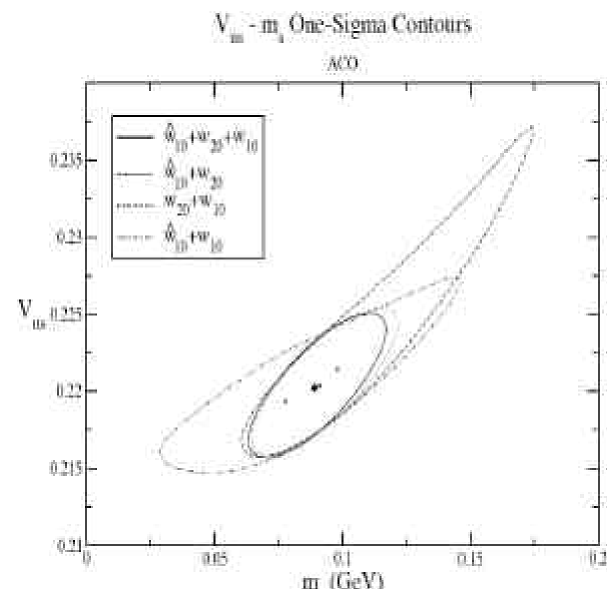
Flavour SU(3) Breaking: $\delta R^{kl}_{\tau,\text{Theory}}(m_s) = \dfrac{R^{kl}_{\tau,\text{non-Strange}}}{|V_{ud}|^2} - \dfrac{R^{kl}_{\tau,\text{Strange}}}{|V_{us}|^2}$

Extract |Vus| with Fixed m_s



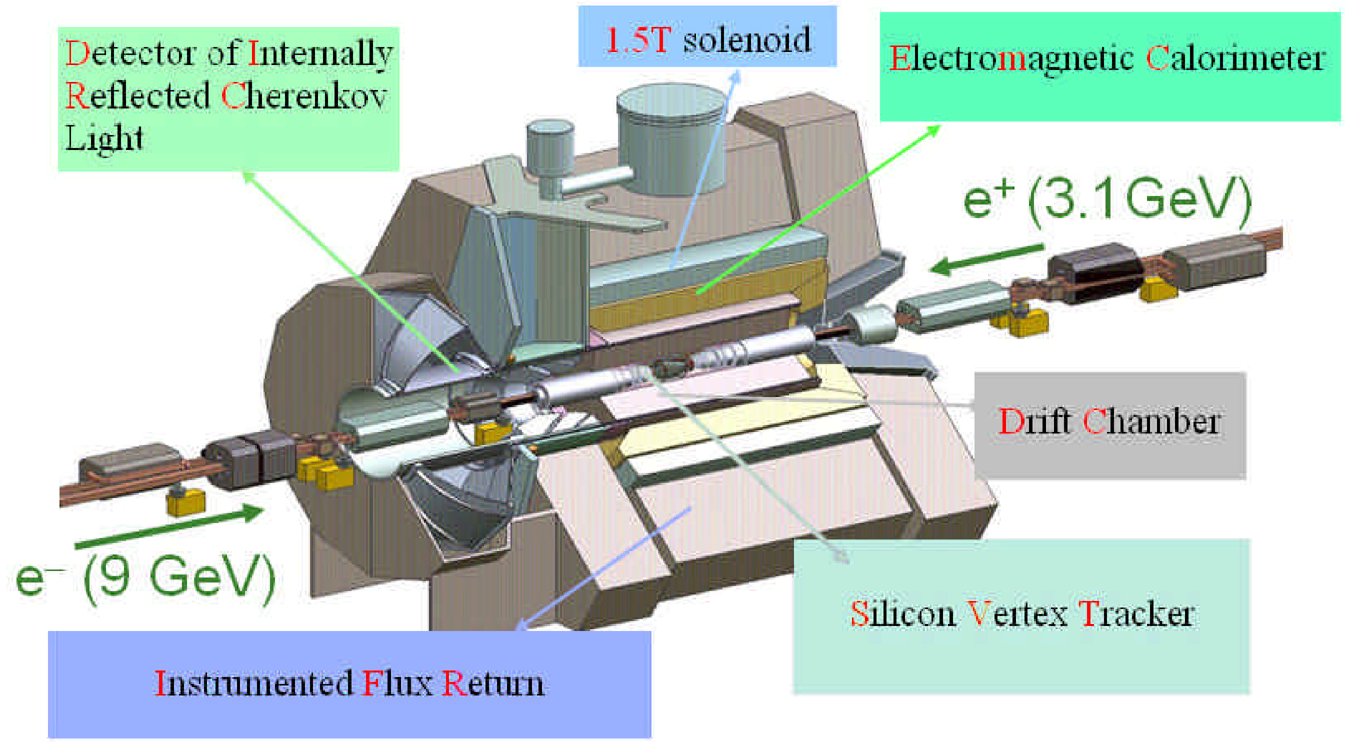
Jamin, Moriond EW 2007 and Maltman, hep-ph/0703314v1

Simultaneously extract |Vus| and m_s



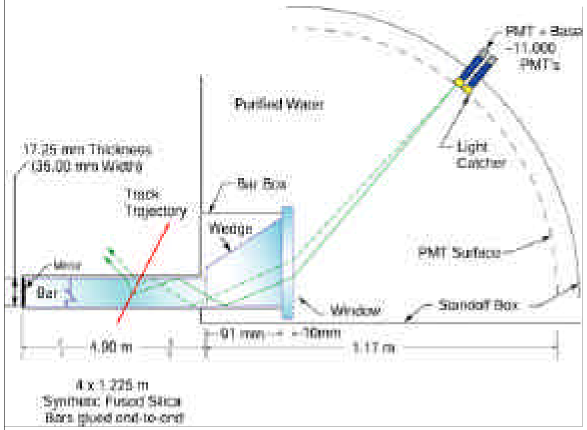
Maltman, Wolfe (Tau06) hep-ph/0611180

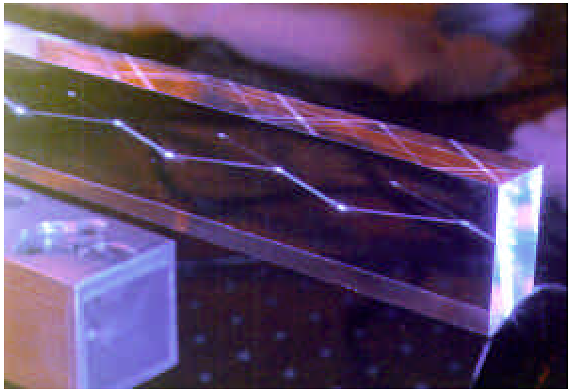
The BaBar Detector at SLAC



Tau Energy = ~5.29GeV

DIRC used for K/p separation



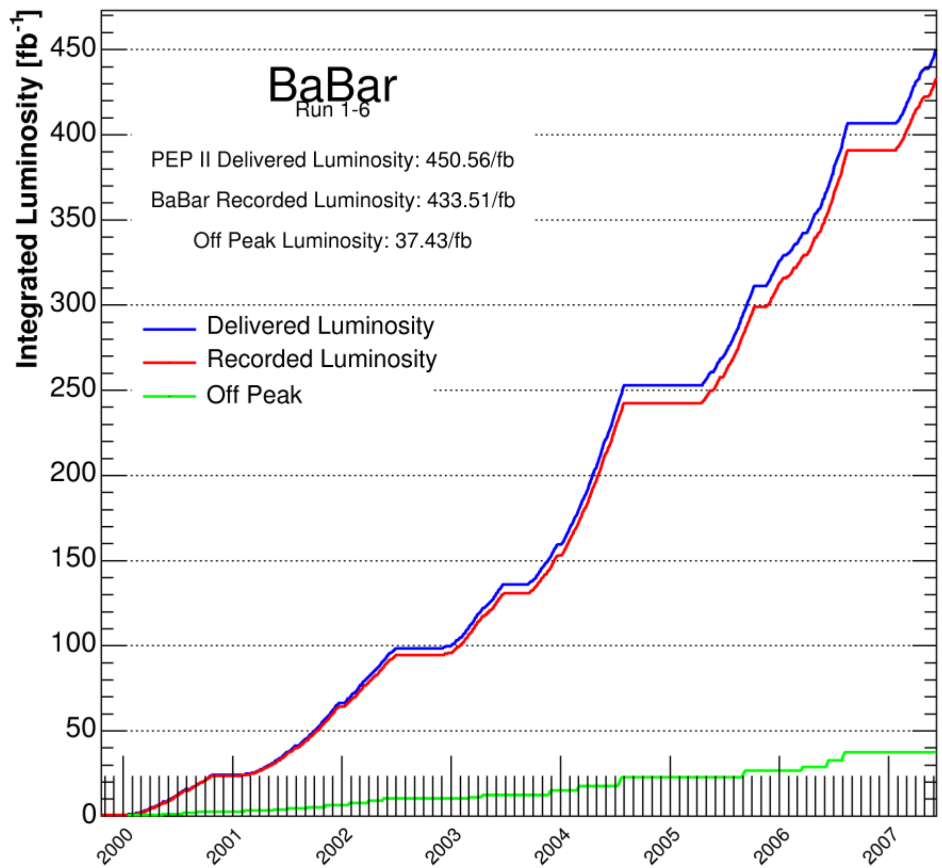


The Number of τ's at BaBar

The $\tau^- \rightarrow h^-h^-h^+\nu$ analysis uses **344fb^{-1}** Data (on-peak and off-peak)

Cross Section at BaBar
$\sigma(\tau^+\tau^-)=0.9\text{nb}$

Experiment	Number of τ Pairs
LEP	$\sim 3\times10^5$
CLEO	$\sim 1\times10^7$
BaBar	$\sim 4\times10^8$
This Analysis	$\sim 3\times10^8$
Belle	$\sim 7\times10^8$



Selection for t ® $h^-h^-h^+$n

Events are split into 2 hemispheres from the thrust in the CM.

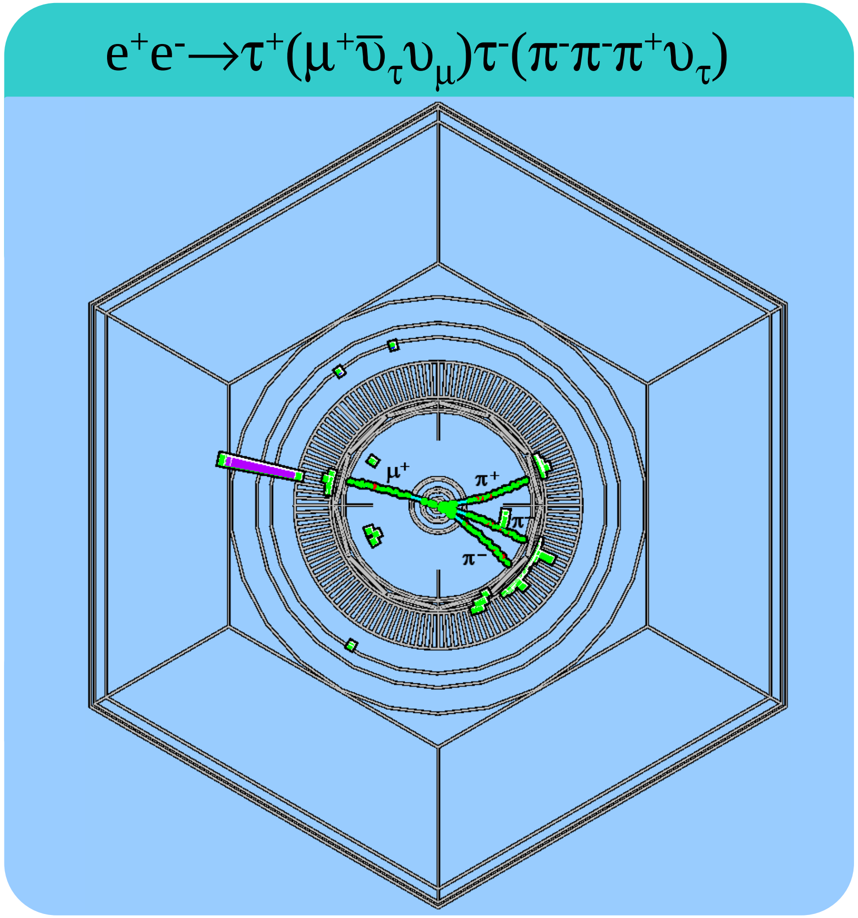
- Require 1-3 topology with net charge 0
- Require tracks are within acceptance of DIRC and Calorimeter for particle identification
- Veto conversions ($\gamma \to e^+e^-$)

Non-τ Background Suppression

- Require missing P_t in event
- Thrust
- Tag tracks require e/μ ID and have upper limit on momentum in CM.

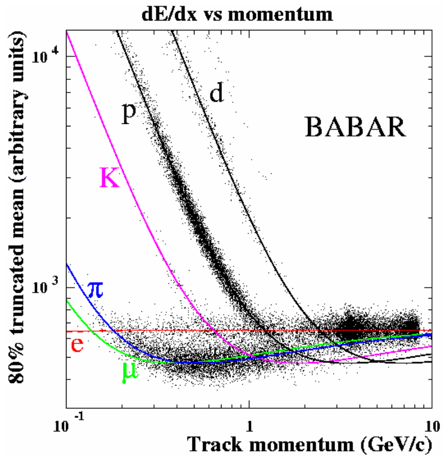
τ Background suppression

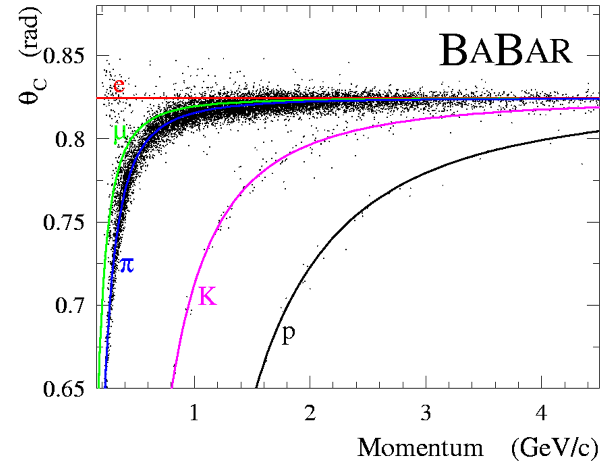
- Veto on π^0 and large unassociated net neutral energy
- Reject K_s
- No electrons on signal side



K/p Separation and Efficiency

Use dE/dx and Cherenkov angle for K/p separation





Candidates	Decay Modes (Truth)	(Preliminary)		
	p⁻p⁻p⁺u	K⁻p⁻p⁺u	K⁻p⁻K⁺u	K⁻K⁻K⁺u
p⁻p⁻p⁺u	97.68%	22.81%	4.79%	1.02%
K⁻p⁻p⁺u	1.42%	74.72%	16.29%	6.50%
K⁻p⁻K⁺u	0.01%	0.52%	60.08%	25.78%
K⁻K⁻K⁺u			0.27%	50.72%

Charge conjugation is implied and wrong signs are used as control samples for determining the systematic uncertainty on the PID.

Branching Ratios for t^{-} ® $h^{-}h^{-}h^{+}n$

$$\sum_j M_{ij} N_j^{Sig} = (N_i^{Data} - N_i^{Bkg(MC)})$$

$$\Rightarrow N_j^{Sig} = \sum_i \left(M^{-1}\right)_{ij} (N_i^{Data} - N_i^{Bkg(MC)})$$

$$Br_j = \frac{1}{2L\sigma_{\tau^+\tau^-}} \frac{N_j^{Sig}}{\varepsilon_{TFS,j}}$$

i=Channels Selected

j=Decay Mode

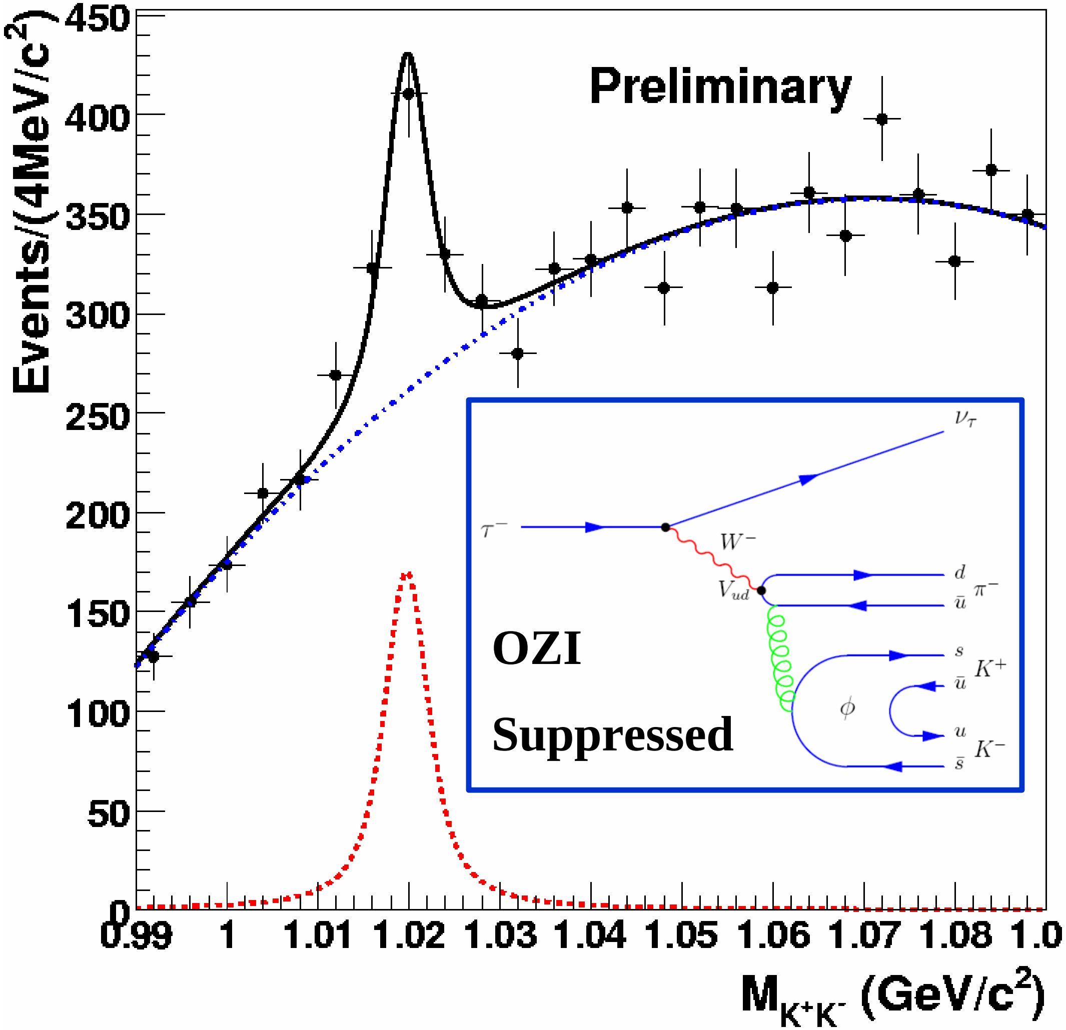
	Decay Modes	**(Preliminary)**		
	$p^-p^-p^+u$	**K**$^-p^-p^+u$	**K**$^-p^-$**K**^+u	**K**$^-$**K**$^-$**K**^+u
e	2.8%	3.2%	3.5%	3.9%
Br	**(9.11±0.01±0.26)´10^{-2}**	**(2.88±0.02±0.11)´10^{-3}**	**(1.371±0.011±0.040)´10^{-3}**	**(1.59±0.14±0.11)´10^{-5}** **8.9s Significance**
Br$_{PDG}$	(9.02±0.08)×10^{-2}	(3.33±0.35)×10^{-3}	(1.53±0.10)×10^{-3}	<(3.7)×10^{-5} @ 90% CL

Systematic Uncertainties for $\tau^- \to h^- h^- h^+ \nu$

	Decay Modes (Preliminary)			
	$\pi^-\pi^-\pi^+\nu$	$K^-\pi^-\pi^+\nu$	$K^-\pi^-K^+\nu$	$K^-K^-K^+\nu$
$L\sigma_{e^+e^- \to \tau^+\tau^-}$	2.4%	2.4%	2.4%	2.4%
MC stat and PID	0.4%	2.5%	0.8%	4.4%
Kinematics	1.2%	1.1%	0.9%	4.0%
EMC and DCH	0.8%	0.8%	0.8%	1.2%
Trigger	0.1%	0.1%	0.1%	0.1%
Backgrounds	0.4%	1.4%	0.4%	2.5%
Total	2.9%	3.8%	2.8%	6.9%

Fitting the f Peak in KpKn

To increase statistics for fitting the φ peak, the kaon selector was loosened.



The φ peak was fitted with a Breit-Wigner convoluted with a Gaussian (σ=1.3MeV) while the background was modeled with a 3rd order polynomial.

Results

χ^2/n.d.f.=26.8/21

N^{Sig}=344±42

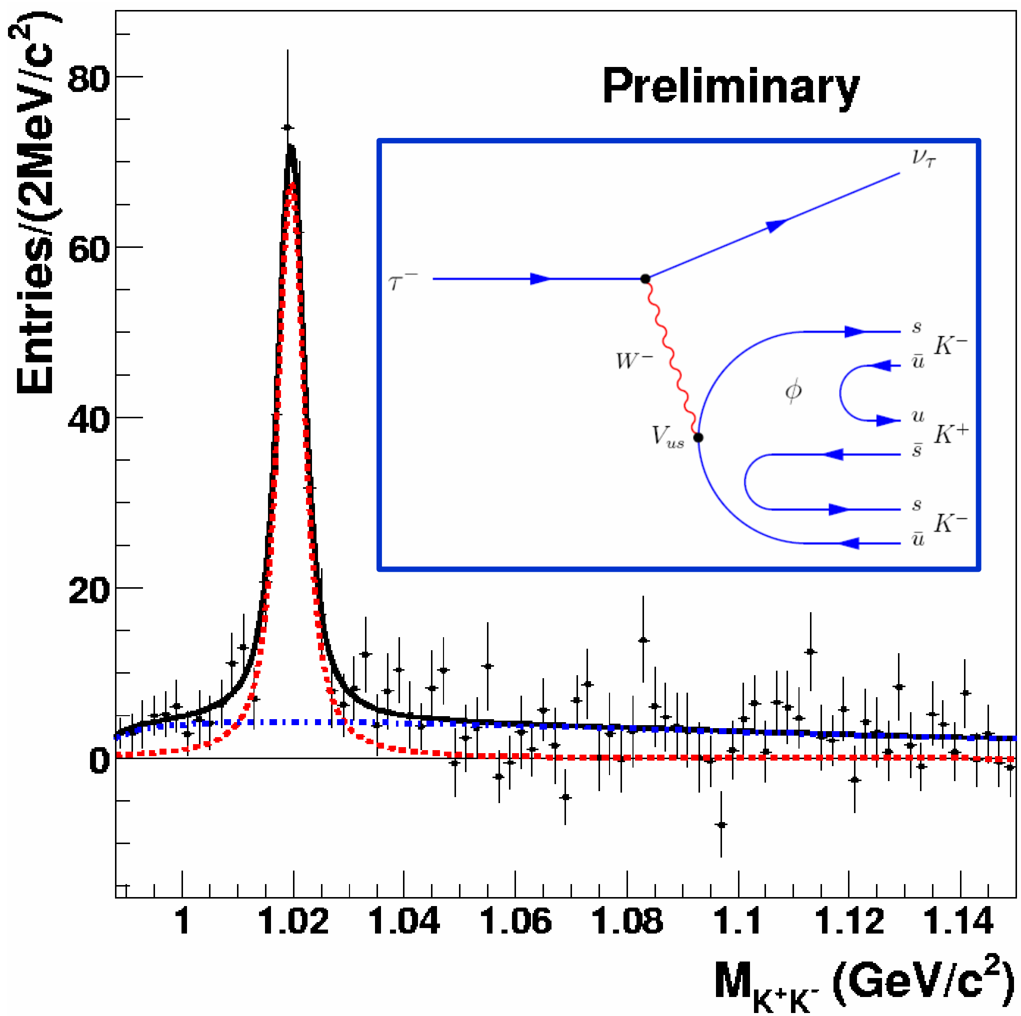
⇒**BR(p f n)=(3.49±0.55±0.32)x10^{-5}**

5.5 s Significance

Fitting the f Peak in KKKn

To increase statistics for fitting the ϕ peak, the kaon selector was loosened. The ϕ peak was fitted with a Breit-Wigner convoluted with a Gaussian (σ=1.3MeV) while the background was modeled with a “ARGUS-Like” function.

In the M_{K+K-} plot both combinations of the K^+K^- are included.



Results

χ^2/n.d.f.=140/176

N^{Sig}=274±16

N^{Bkg}=281±17

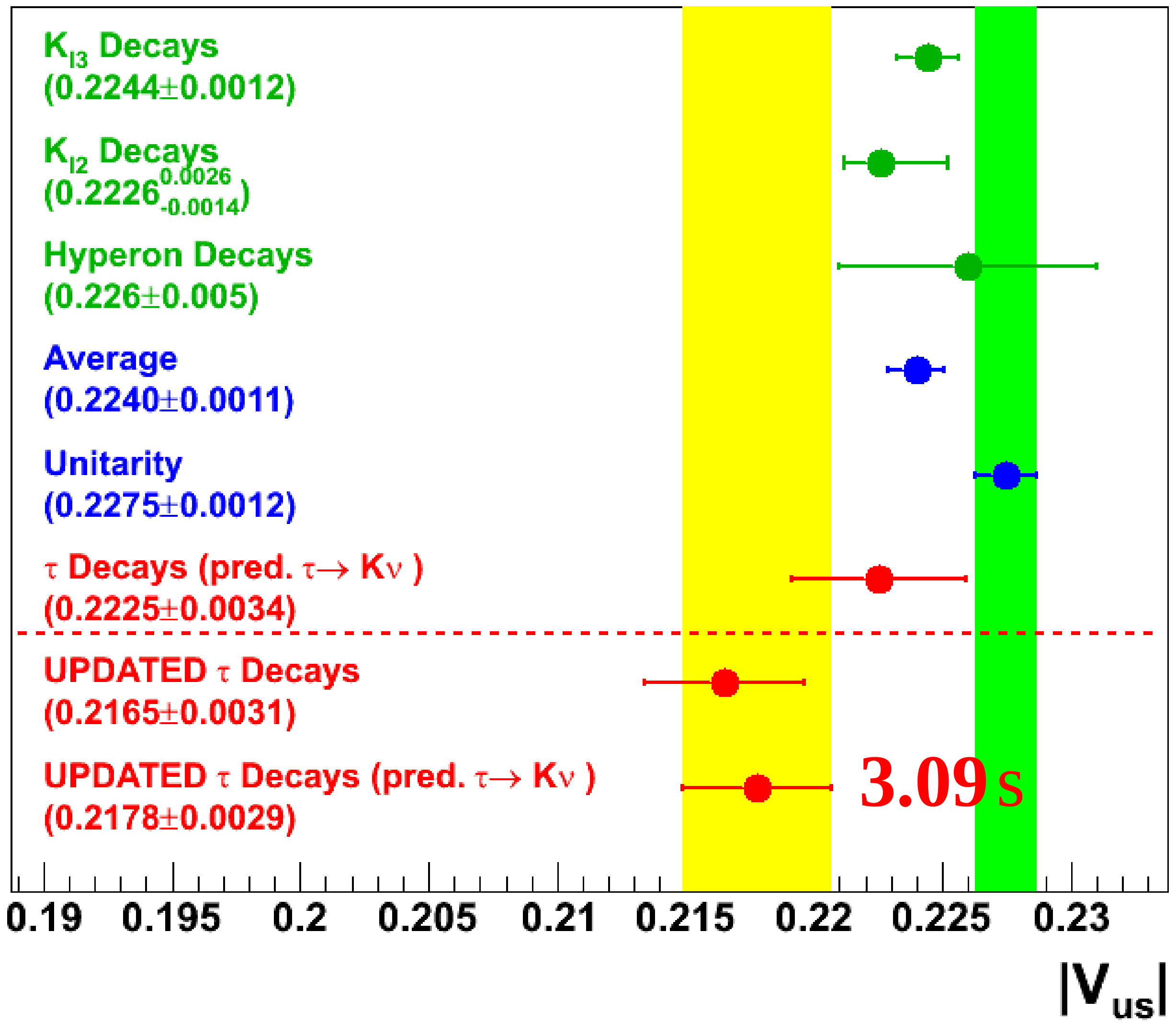
⇒**BR(Kfn)=(3.48±0.20±0.26)x10^{-5}**

10.6s Significance

BR(Kfn)/ BR(pfn)~1

Lopez Castro

Update to $|V_{us}|$



Jamin, Moriond EW 2007 and Swagato Banerjee, Kaon 2007

UPDATED

t^{-} ® $K^{-}p^{0}u$

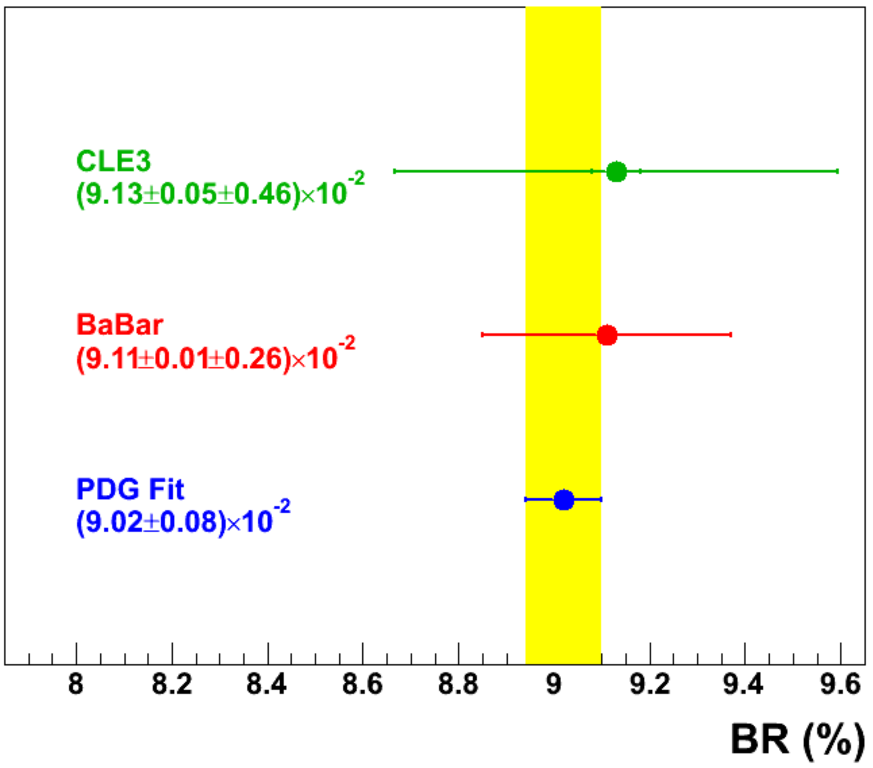
t^{-} ® $K^{-}p^{-}p^{+}u$

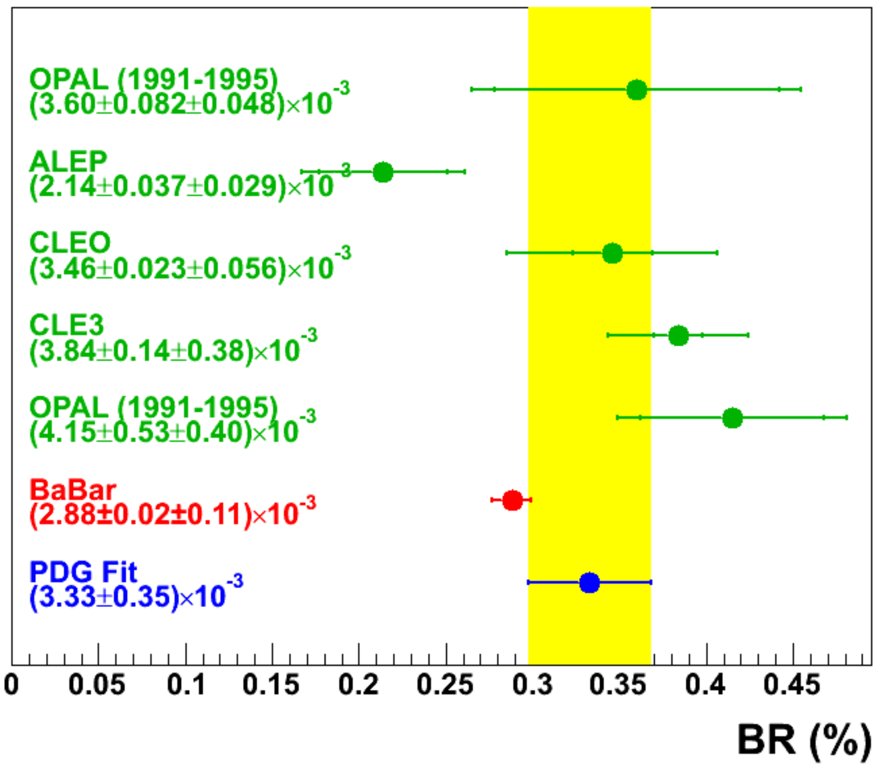
t^{-} ® $K^{0}p^{-}u$

Conclusion

$\tau^- \to \pi^- \pi^- \pi^+ \upsilon$ (ex Ks) measured more precisely than the previous exclusive measurement directly identifying pions

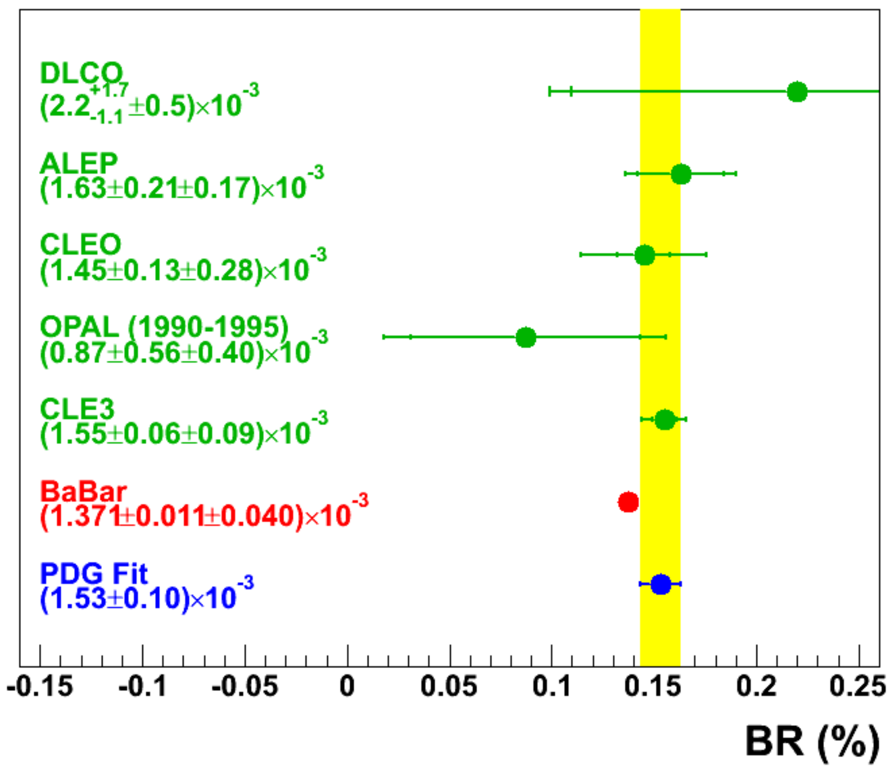
$\tau^- \to K^- \pi^- \pi^+ \upsilon$ has been measured more precisely then the world average.





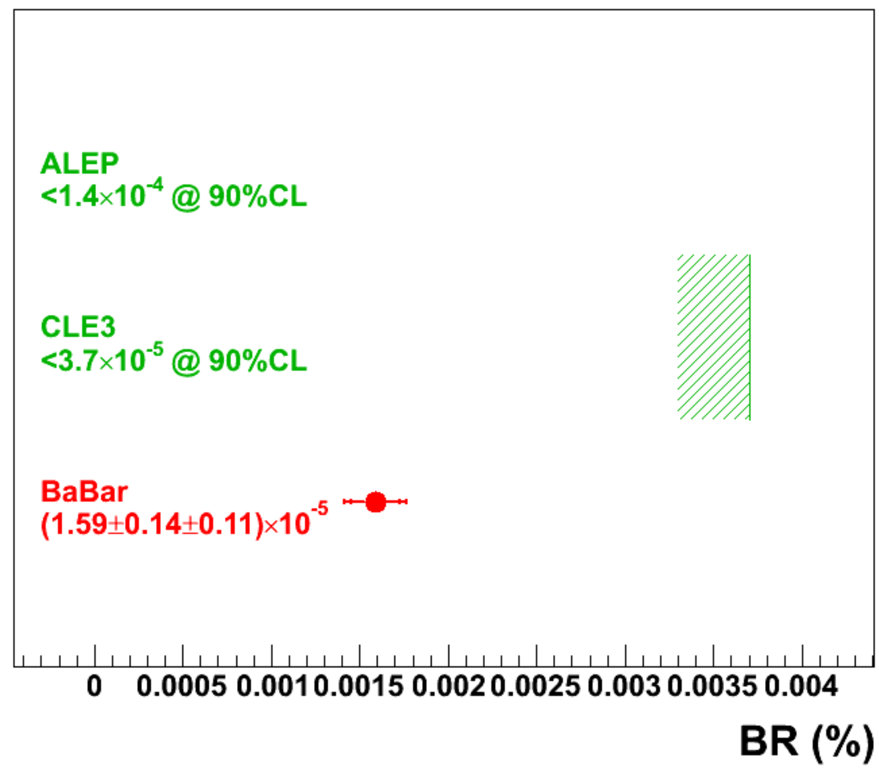
Conclusion

$\tau^- \to K^- \pi^- K^+ \upsilon$ has been measured more precisely then the world average.

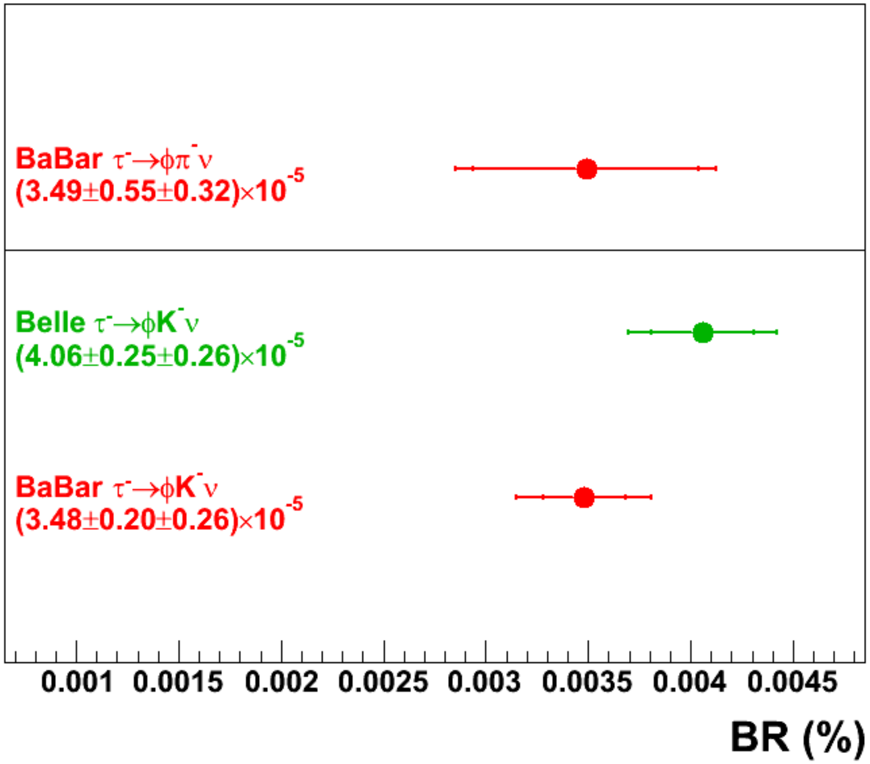


$\tau^- \to K^- K^- K^+ \upsilon$

FIRST MEASURMENT!



Conclusion



$\tau^- \to \phi\pi^-\upsilon$ FIRST MEASURMENT

$\tau^- \to \phi K^-\upsilon$ is consistent with saturating $\tau^- \to K^-K^-K^+\upsilon$ decay channel. This measurement is also compatible with Belle measurement.