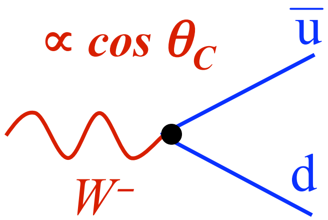
Sixth International Workshop on Chiral Dynamics
Bern, July 6 - 10, 2009

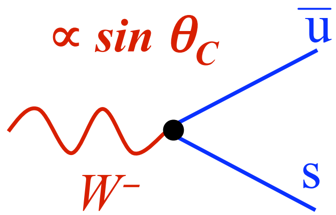
Experimental Information on V_{us}

Achim Denig (BaBar)
Institut für Kernphysik, Johannes Gutenberg-Universität Mainz

The CKM Matrix - Element V_{us}



$$\begin{pmatrix} u \\ d_c = d \cdot \cos\theta_c + s \cdot \sin\theta_c \end{pmatrix}$$



VOLUME 10, NUMBER 12—PHYSICAL REVIEW LETTERS—15 JUNE 1963

UNITARY SYMMETRY AND LEPTONIC DECAYS

Nicola Cabibbo
CERN, Geneva, Switzerland
(Received 29 April 1963)

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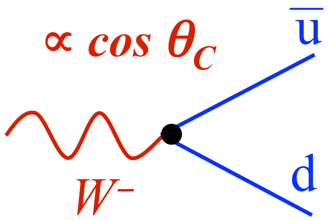

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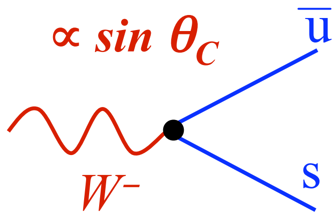

VOLUME 10, NUMBER 12 — PHYSICAL REVIEW LETTERS — 15 JUNE 1963

$V_{us} = sin\ \theta_C$ with θ_C = Cabibbo Angle

UNITARY SYMMETRY AND LEPTONIC DECAYS

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First Row CKM Unitarity Relation

$$V_{CKM} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \sim \begin{pmatrix} 1 & \lambda & \lambda^3 \\ \lambda & 1 & \lambda^2 \\ \lambda^3 & \lambda^2 & 1 \end{pmatrix}$$

$$|V_{ud}|^2 + |V_{us}|^2 + \cancel{|V_{ub}|^2} = 1 - \Delta$$

negligible

$|V_{ub}| = (3.93 \pm 0.36) \cdot 10^{-3}$

Δ was $\sim 2\sigma$ up to 2004

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***V_{ud}*:**

- Super-allowed $0^+ \rightarrow 0^+$ Nucleus-Decays
- Neutron β-Decay measurement
  Neutron lifetime measurements
- Pion β-Decay measurement

$|V_{ud}| = 0.97425 \pm 0.00022$
Phys.Rev.C79 (2009) 055502
Towner - Hardy

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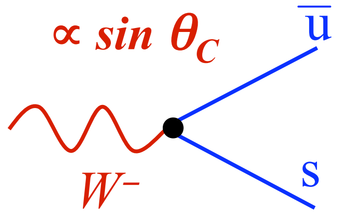
V_{us}:

- Semileptonic kaon decays
- Leptonic kaon decays
- Tau decays into kaon final states
- Improved theory (lattice, χPT, OPE, ...)

$\Delta = 0 \rightarrow |V_{us}| = 0.2255 \pm 0.0010$
Most precise test of CKM Unitarity

Outline



$|V_{us}|$

Kaon Decays
- Semileptonic K_{l3}
- Leptonic K_{l2}/π_{l2}

FlaviAnet Kaon WG

➔ **see M. Antonelli talk!**

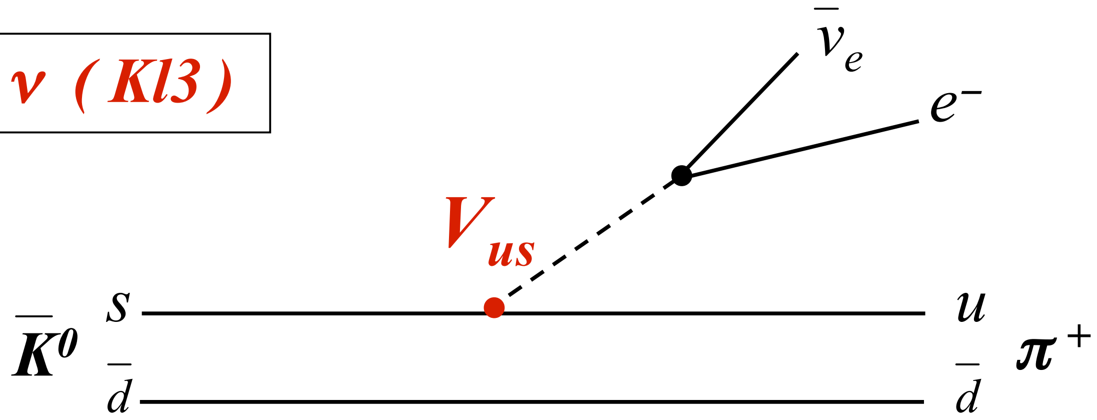
➔ **see Ch. Sachrajda, J. Bijnens, U. Heller, I. Rosell, H. Neufeld talks!**

Tau Decays
- Inclusive using OPE
- Exclusive $\tau \to K\nu/\pi\nu$

V_{us} from Kaon Decays

V_{us}: The Master - Formula for $K \to \pi\, l\, \nu$

$K \to \pi\, l\, \nu$ (Kl3)

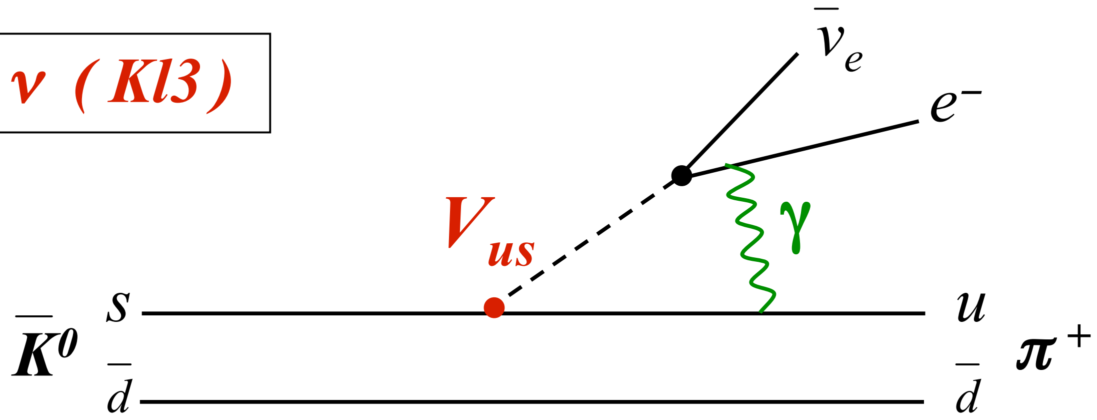


$$\Gamma_{Kl3} = \frac{G_F^2 \cdot M_K^5}{192\,\pi^3}\; S_{EW}\; |V_{us}|\; f_+^2(0) \cdot I^{Kl}(\lambda_I) \cdot (1+\delta_{EM})$$

Partial Decay Width
(Experiment)
→ BR's
→ Lifetimes

V_{us}: The Master - Formula for $K \to \pi\, l\, \nu$

$K \to \pi\, l\, \nu$ (Kl3)



Short Distance Electroweak Radiative corrections (Theory)

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Partial Decay Width (Experiment)
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→ Lifetimes

Electromagnetic corrections and SU(2) correct. (Theory)

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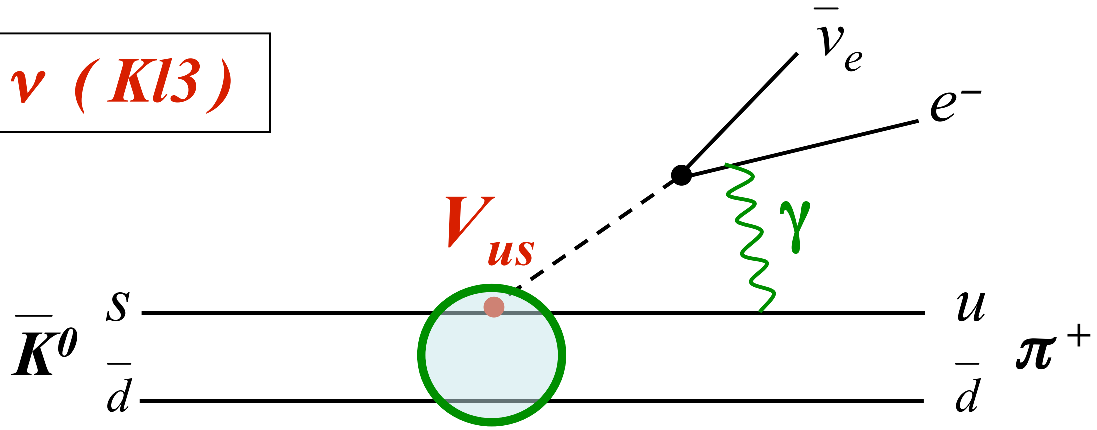
$K \to \pi\, l\, \nu$ ($Kl3$)



Short Distance Electroweak Radiative corrections (Theory)

Form Factor at $t=0$ (Theory)

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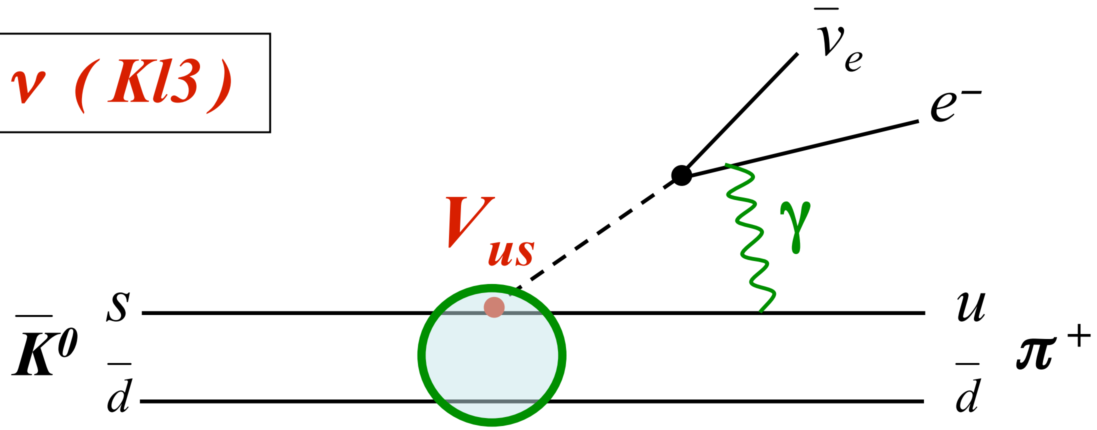

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Partial Decay Width (Experiment)
→ BR's
→ Lifetimes

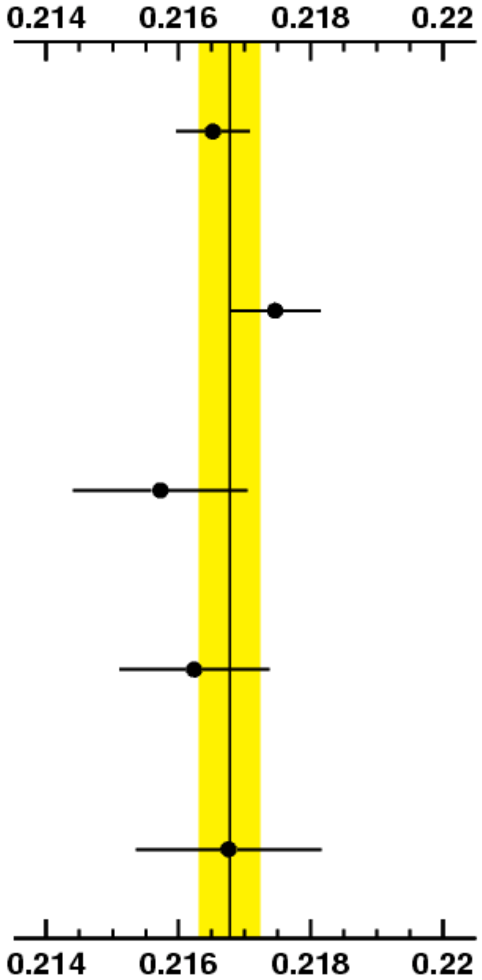
Integral over the momentum dependence of the form factors (Experiment)

Electromagnetic corrections and SU(2) correct. (Theory)

Experimentally extracted: $|V_{us}|f_+(0)$

FlaviA net Kaon WG

$|V_{us}|\,f_+(0)$



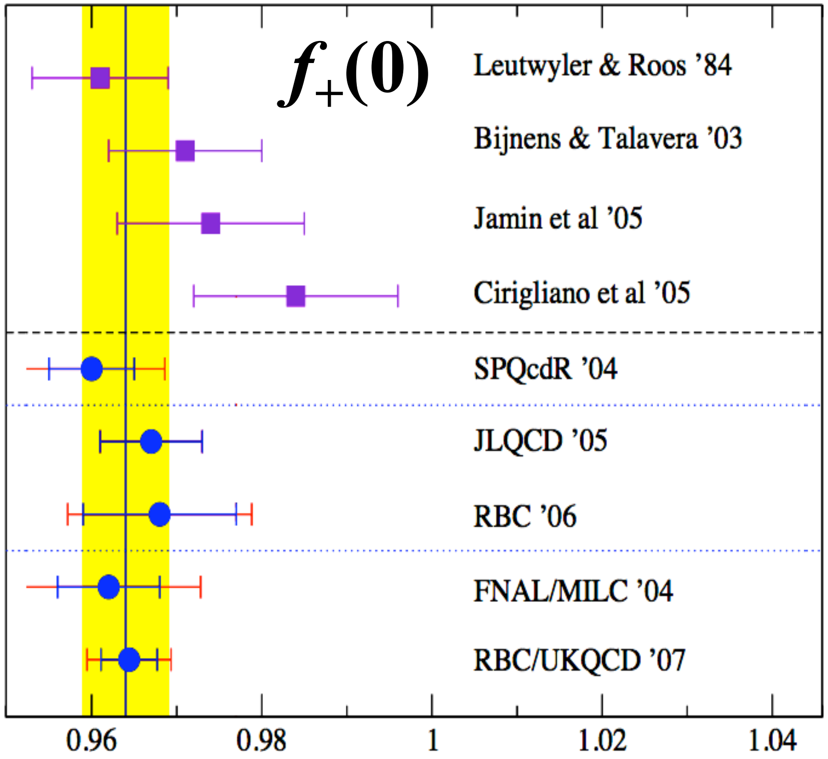
Approx. contrib. to % error from:

		% err	BR	τ	δ	I^{Kl}
$K_L e3$	**0.21652(56)**	**0.25**	0.11	**0.20**	0.11	0.10
$K_L \mu 3$	**0.21746(69)**	**0.32**	0.17	**0.19**	0.11	0.15
$K_S e3$	**0.21572(132)**	**0.61**	**0.60**	0.03	0.11	0.10
$K^{\pm} e3$	**0.21624(113)**	**0.52**	**0.31**	0.06	**0.41**	0.09
$K^{\pm} \mu 3$	**0.21676(141)**	**0.65**	**0.48**	0.06	**0.41**	0.15

Theoretical challenge: $f_+(0)$

FlaviA net Kaon WG

Compilations: L. Lellouch, Lattice '08



- Discrepancy btw. Lattice and ChPT, which tends to give higher values for $f_+(0)$
- Trend is to use lattice results,
  FLAVIANET FLAG recommendation: $f_+(0) = 0.9644(49)$ **RBC/UKQCD '07**

Summary V_{us} from K_{l3} Decays

FlaviA net Kaon WG

K_{l3} average: $|V_{us}| f_+(0)$ = 0.21660(47)

With **$f_+(0)$ = 0.9644(49)** from lattice QCD:

K_{l3} average: $|V_{us}|$ = 0.2246(12)

Using **$|V_{ud}|$ = 0.97425(22)** (Towner-Hardy '09)

$V_{ud}^2 + V_{us}^2 - 1$ = –0.0004(7)
Compatibility with unitarity –0.6σ

was 0.031(15) in PDG04

V_{us} from K_{l2} Decays

FlaviA net Kaon WG

$$\frac{\Gamma(K_{\mu 2(\gamma)})}{\Gamma(\pi_{\mu 2(\gamma)})} = \frac{|V_{us}|^2}{|V_{ud}|^2} \frac{f_K^2}{f_\pi^2} \frac{m_K(1-m_\mu^2/m_K^2)^2}{m_\pi(1-m_\mu^2/m_\pi^2)^2} [1+\alpha(C_K - C_\pi)]$$

f_K^2/f_π^2: **[1.189(7)]^2** HPQCD/UKQCD 08

$1+\alpha(C_K - C_\pi)$: **0.9930(35)** Marciano '04

Inputs from experiment:

KLOE:

BR($K^{\pm}_{\mu 2(\gamma)}$) = 0.6347(18)

$\tau_{K\pm}$ = 12.384(15) ns

PDG: BR($\pi^{\pm}_{\mu 2(\gamma)}$) = 0.9999

$\tau_{\pi\pm}$ = 26.033(5) ns

$|V_{us}|/|V_{ud}|$ = 0.2319(15)

$|V_{us}|$ = 0.2259(15)

V_{us} from K_{l2} Decays

FlaviA net Kaon WG

[1.189(7)]² HPQCD/UKQCD 08

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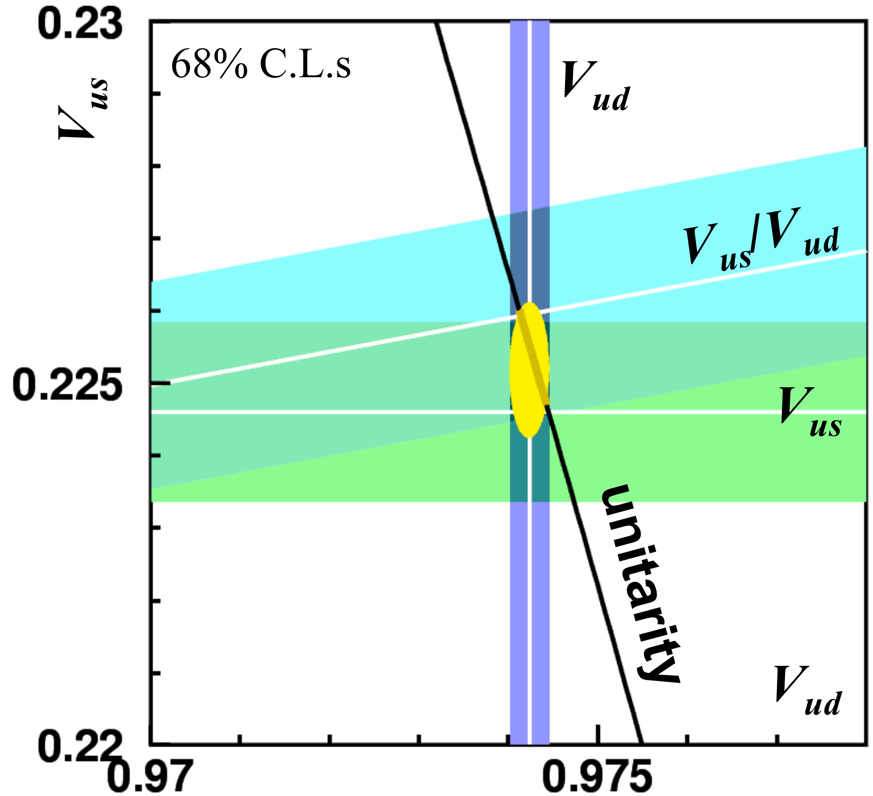
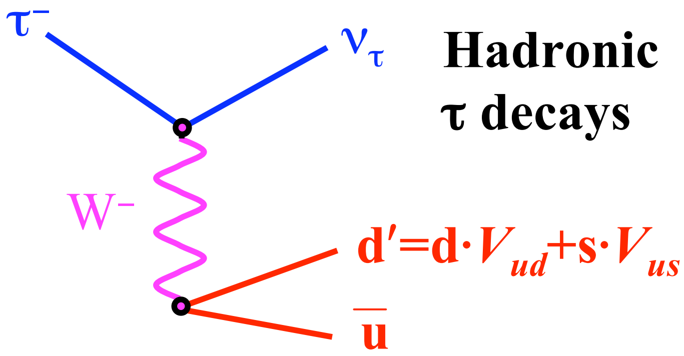


V_{us} from Tau Decays

V_{us}: *The Master - Formula for τ - Decays*

Hadronic τ decays



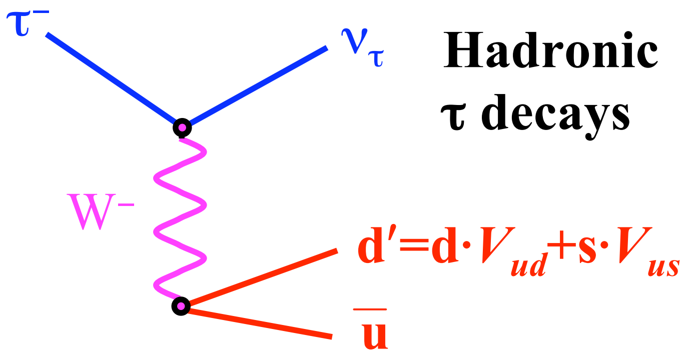
$$|V_{us}|^2 = \frac{R^{w}_{\tau,\text{strange}}}{R^{w}_{\tau,\text{non-strange}} / |V_{ud}|^2 + \delta R^{w}_{OPE}}$$

$$R_\tau = \frac{\Gamma(\tau^- \to [\text{hadrons}]^- \, \nu_\tau)}{\Gamma(\tau^- \to e^- \bar{\nu}_e \nu_\tau)} = R_{\tau,\text{non-strange}} + R_{\tau,\text{strange}}$$

The branching fractions and invariant mass distributions are the experimental input to determine V_{us} from τ.

V_{us}: The Master - Formula for τ - Decays

Hadronic τ decays



δR is a SU(3) symmetry breaking correction; obtained from OPE/FESR; small, $< 0.1 \cdot R_{\tau,ns}/|V_{ud}|^2$

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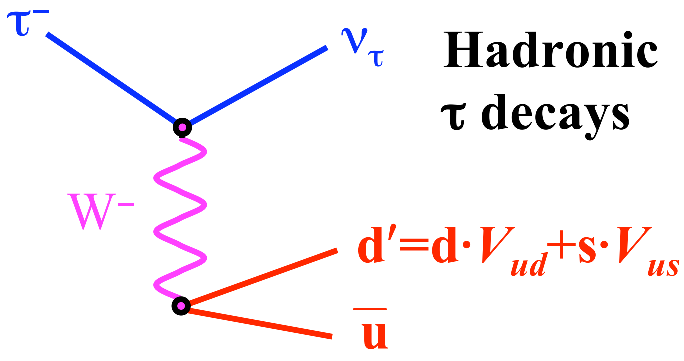

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The branching fractions and invariant mass distributions are the experimental input to determine V_{us} from τ.

Strange τ Decays:

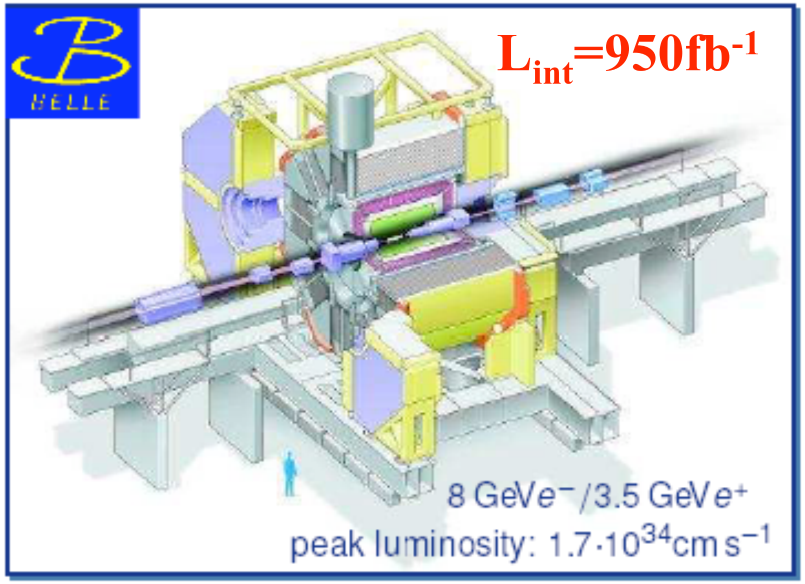
Mode	$\mathcal{B}(10^{-3})$
K^-	6.81 ± 0.23
$K^-\pi^0$	4.54 ± 0.30
$\bar{K}^0\pi^-$	8.78 ± 0.38
$K^-\pi^0\pi^0$	0.58 ± 0.24
$\bar{K}^0\pi^-\pi^0$	3.60 ± 0.40
$K^-\pi^+\pi^-$	3.30 ± 0.28
$K^-\eta$	0.27 ± 0.06
$(\bar{K}3\pi)^-$ (estimated)	0.74 ± 0.30
$K_1(1270)^- \to K^-\omega$	0.67 ± 0.21
$(\bar{K}4\pi)^-$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

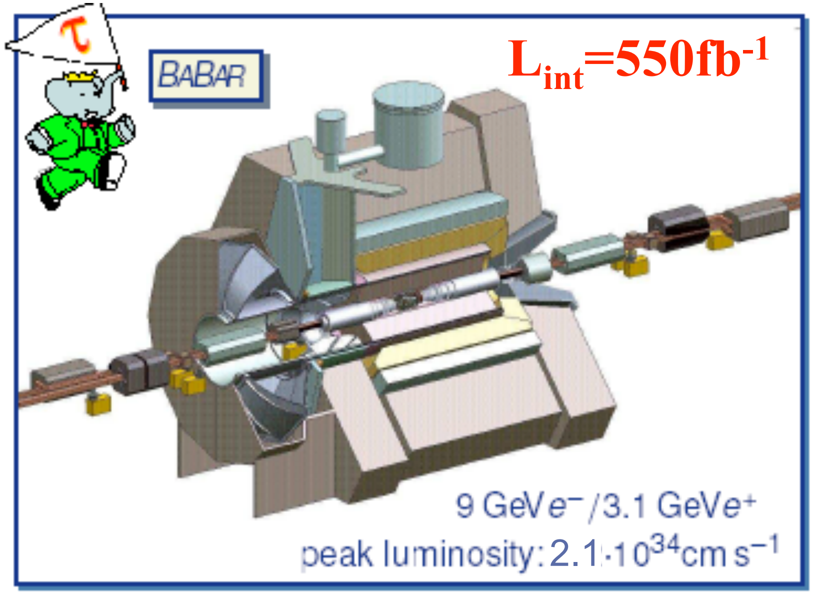
Davier, Hocker, Zhang(RMP 78, 1043, 2006)

B - Factories are also τ - Factories

At $\Upsilon(4S)$ energies: $\sigma(e^+e^- \to \tau^+\tau^-) \sim \sigma(e^+e^- \to B\bar{B}) \sim 0.9$ nb ➔ Huge tau rates

➔ Tagging





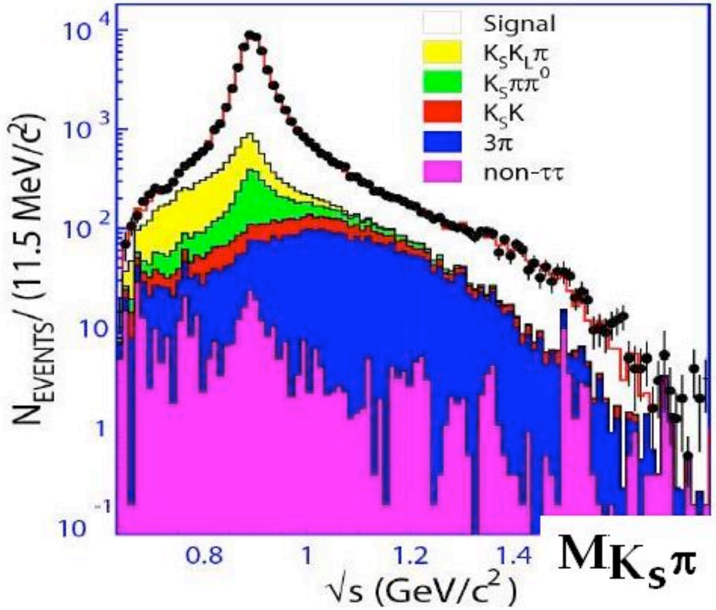
- Both experiments have a very large ($\sim 10^9$) sample of tau events
- Detectors are well matched to do tau physics:
  - K/π particle ID, γ/π^0 reconstruction, charged particle tracking, etc.
- Can reduce most non-tau backgrounds to ≤ 1%:
  - Bhabhas, μ-pairs, $e^+e^- \to q\bar{q}$

Recent τ Results relevant for V_{us}

Mode	**BaBar**		**Belle**	
$\tau^- \to \pi^- \nu$	Preliminary ICHEP08	467 fb^{-1}		
$\tau^- \to K^- \nu$	Preliminary ICHEP08	467 fb^{-1}		
$\tau^- \to \bar{K}^0 \pi^- \nu$	Preliminary ICHEP08	385 fb^{-1}	PLB654(2007) 65	351 fb^{-1}
$\tau^- \to K^- \pi^0 \nu$	PRD76(2007)051104	230 fb^{-1}		
$\tau^- \to \pi^- \pi^- \pi^+ \nu$	PRL100(2008)011801	342 fb^{-1}		
$\tau^- \to K^- \pi^- \pi^+ \nu$	PRL100(2008)011801	342 fb^{-1}	Preliminary ICHEP08	500 fb^{-1}
$\tau^- \to K^- \pi^- K^+ \nu$	PRL100(2008)011801	342 fb^{-1}	Preliminary ICHEP08	500 fb^{-1}
$\tau^- \to K^- K^- K^+ \nu$	PRL100(2008)011801	342 fb^{-1}	Preliminary ICHEP08 **$\tau^- \to K^- \phi \nu$, PL B643 (2006) 5**	500 fb^{-1}
$\tau^- \to K^-/K^{*-} \eta\, \nu$			Preliminary EPS07 arXiv:0708.0733	485 fb^{-1}

$BR(\tau^- \to K_s \pi^- \nu_\tau)$

PL B654:65-73, 2007



$$B(\tau^- \to K_S^0 \pi^- \nu) = (0.404 \pm 0.002 \pm 0.013)\%$$

$$B(\tau^- \to \overline{K^0} \pi^- \nu) = 2 \times B(\tau^- \to K_S^0 \pi^- \nu)$$

$$= (0.808 \pm 0.004 \pm 0.026)\%$$

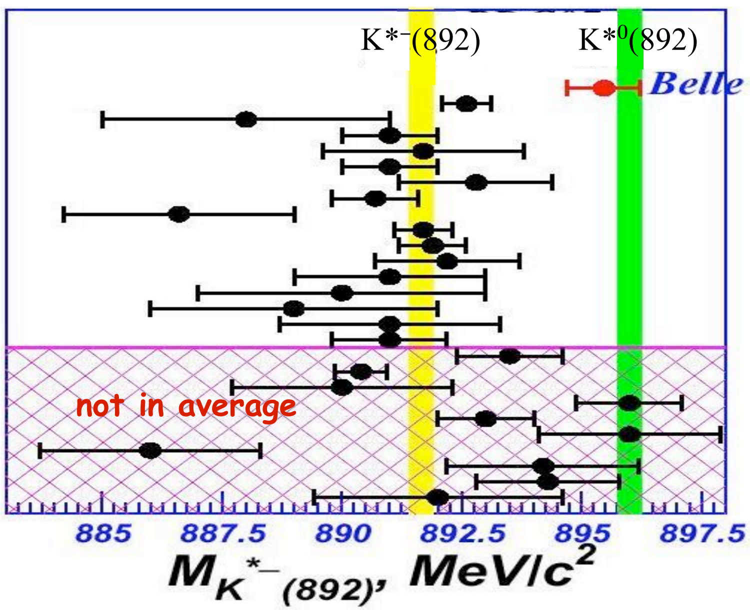
PDG 07 $= (0.90 \pm 0.04)\%$

Fitted values for K*⁻(892):

$M = (892.47 \pm 0.20_{stat} \pm 0.44_{syst})$ MeV/c^2

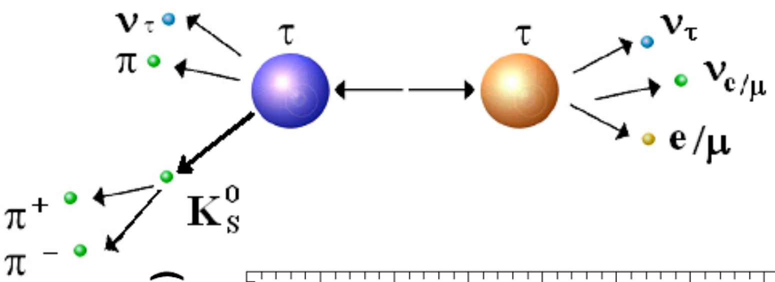
$\Gamma = (42.2 \pm 0.6_{stat} \pm 1.0_{syst} \pm 0.7_{mod.})$ MeV

Fits include K*(800), K*(890), K*(1410), K*(1430)

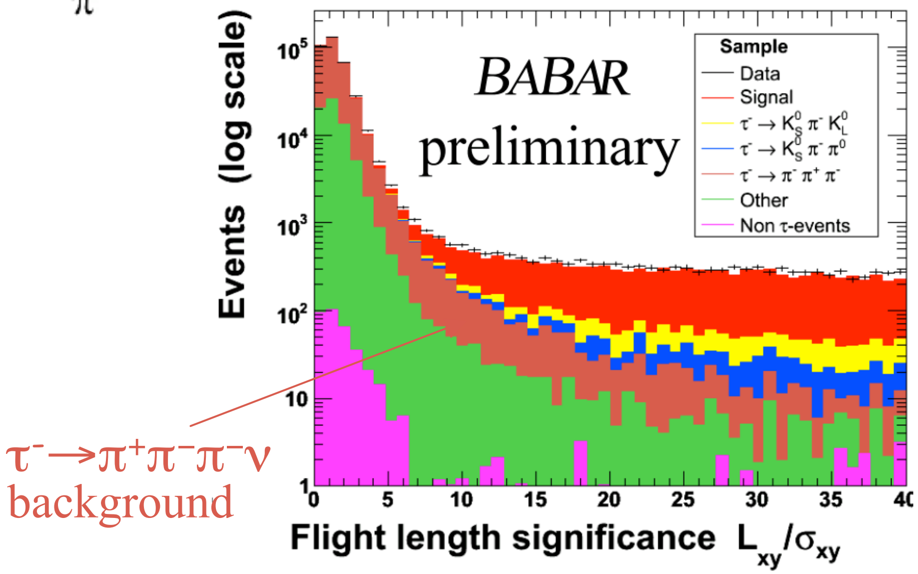


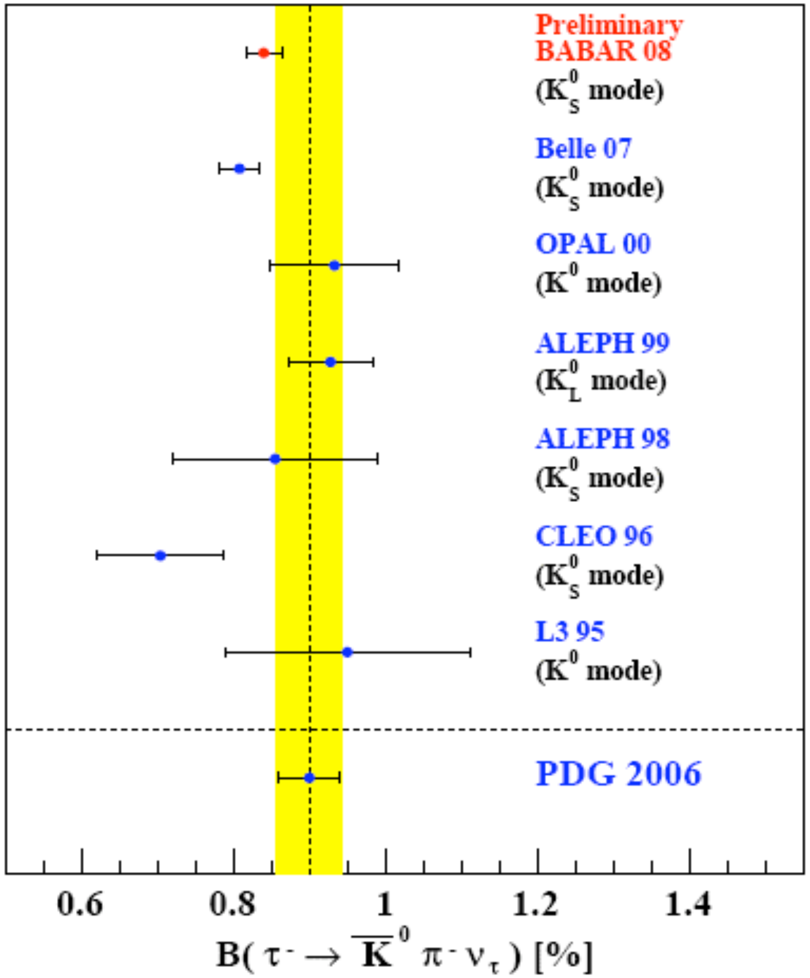
$BR(\tau^- \to K_s \pi^- \nu_\tau)$ preliminary

ICHEP08
arXiv:0811.1429



BaBar (385 fb^{-1}):
$BF(\tau \to K^0 \pi^- \nu) = (0.840 \pm 0.004 \pm 0.023)\%$

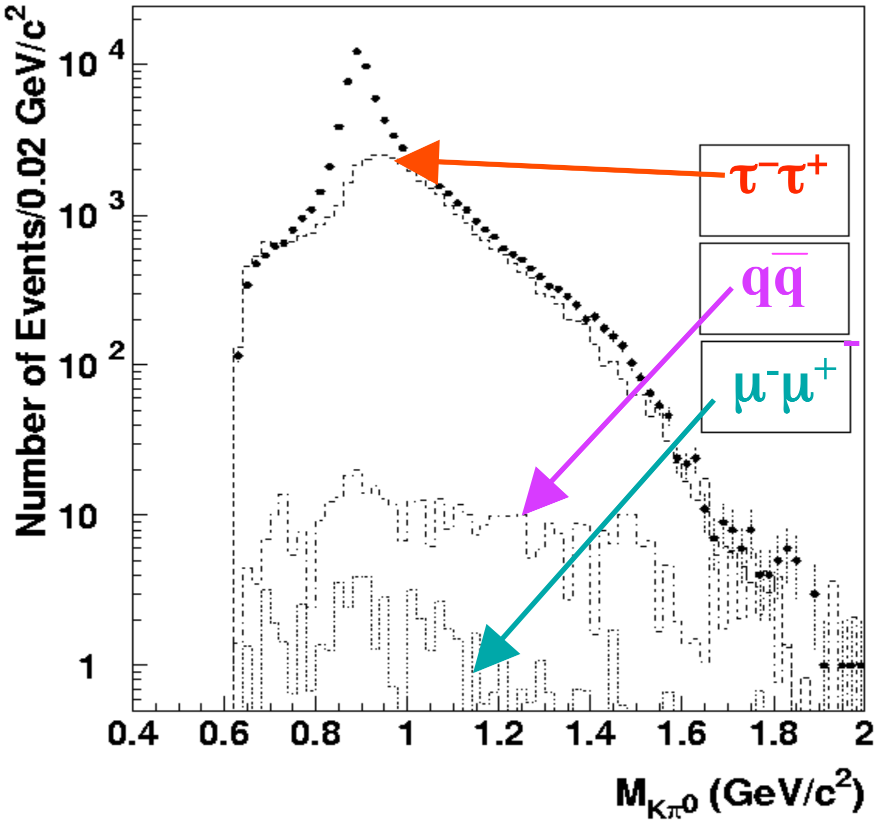


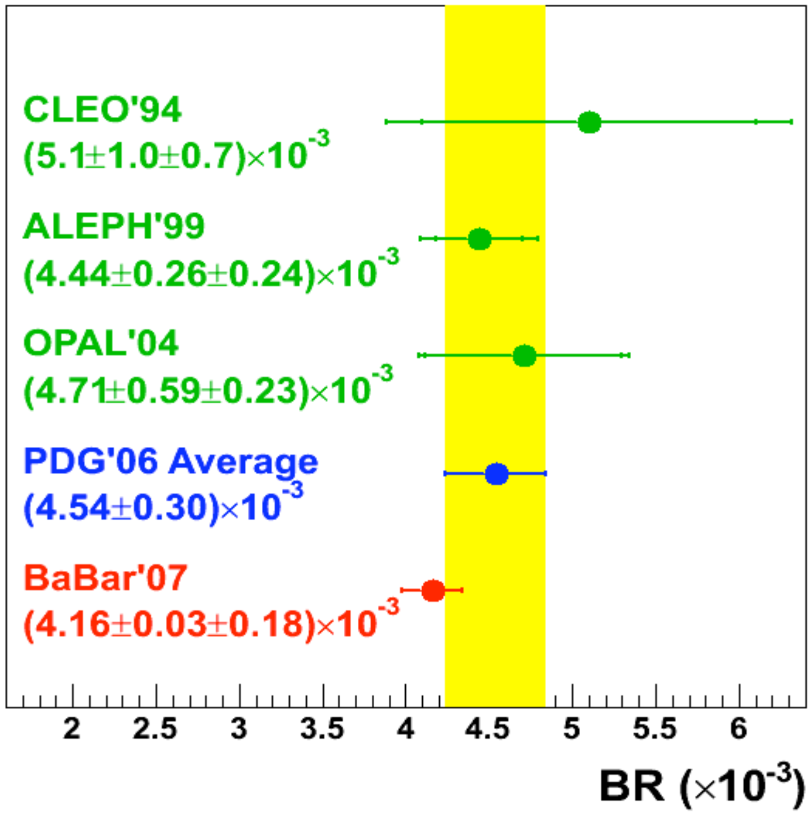


New World Average with BABAR+BELLE:
$BF(\tau \to K^0 \pi^- \nu) = (0.835 \pm 0.022)\%$
(combination includes 'PDG scale factor' of 1.4)

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

PRD 76:051104, 2007



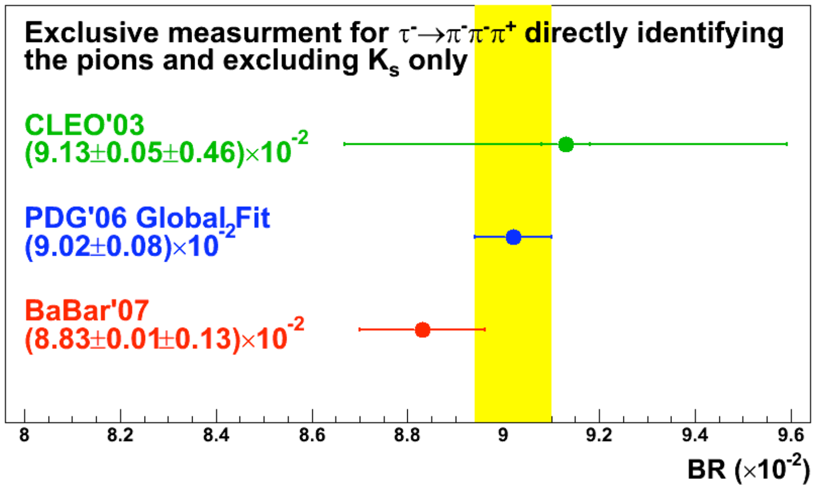


ε	(2.267±0.008)%
N^{Data}	78,112±280
N^{Bkg}	38,247±159

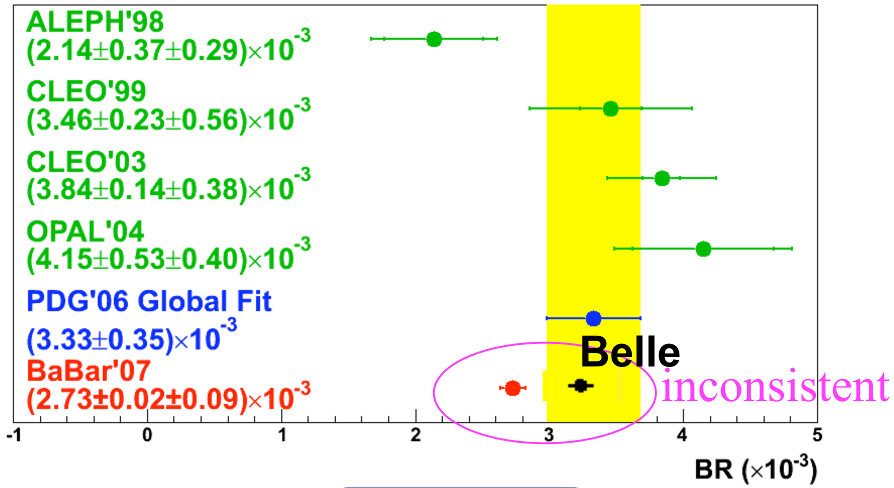
$BR(\tau^- \rightarrow h^- h^+ h^- \nu_\tau)$

BaBar: PRL 100 011801, 2008
Belle: ICHEP2008, arXiv:0810.3464

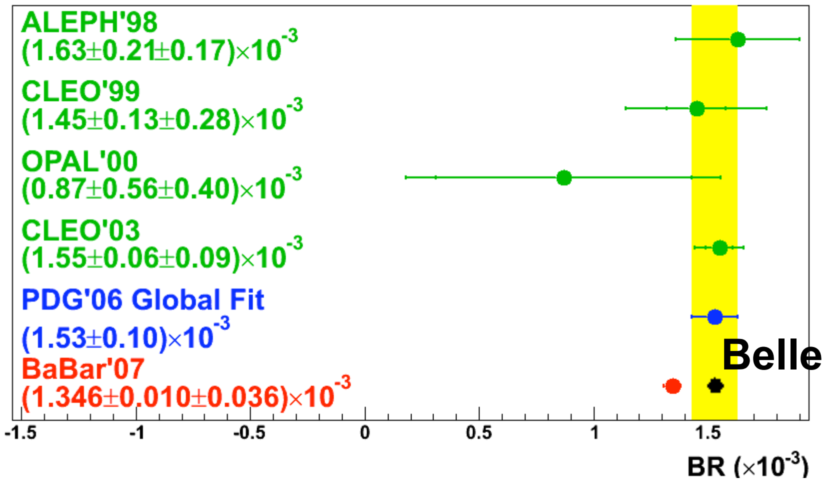
$\pi^-\pi^-\pi^+$



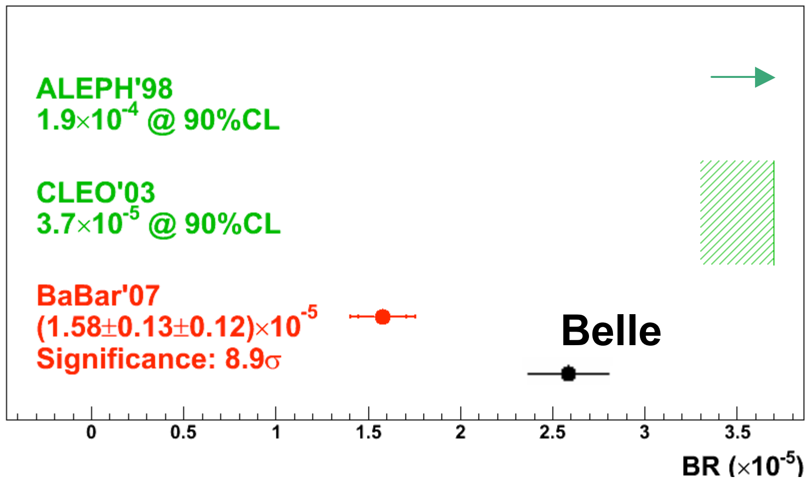
$K^-\pi^-\pi^+$



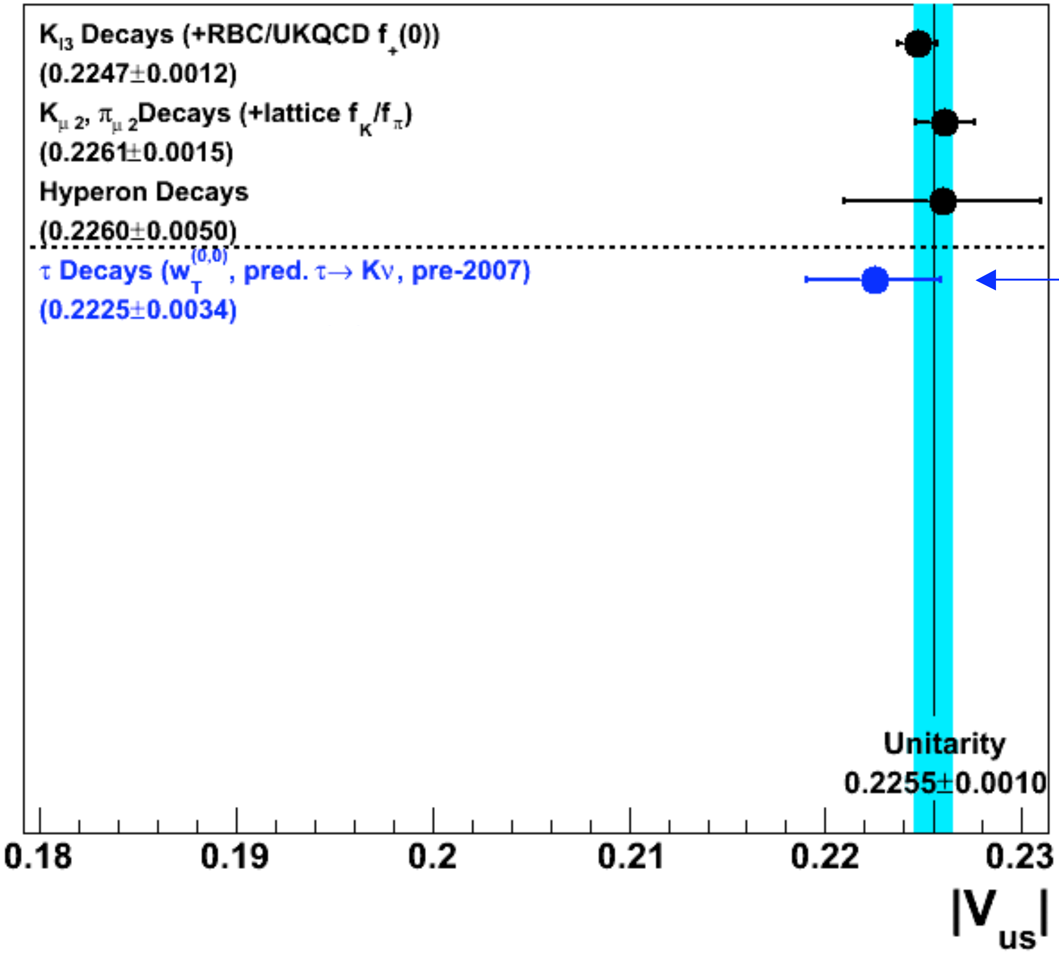
$K^-\pi^-K^+$



$K^-K^-K^+$

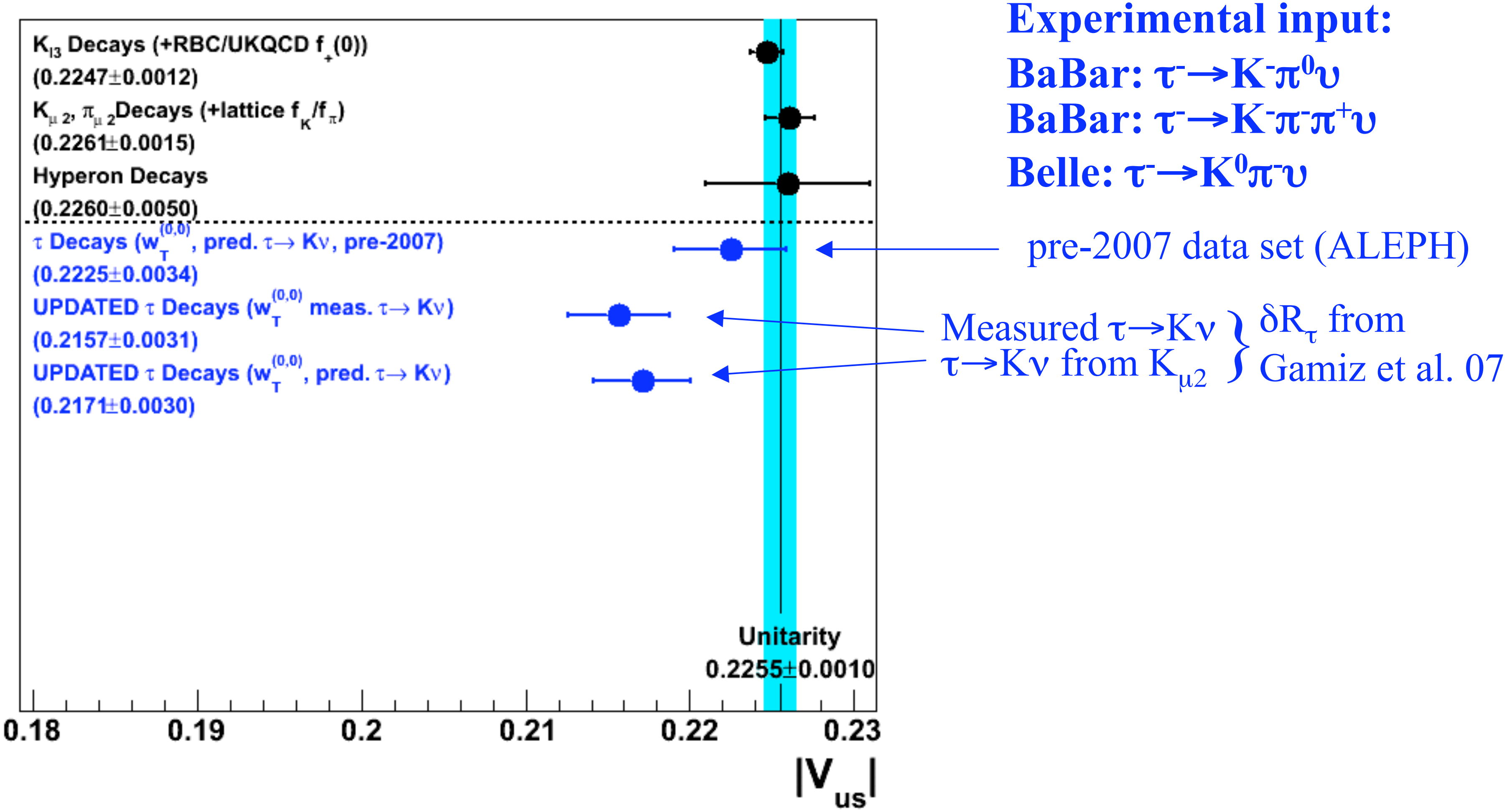


Extraction of V_{us} using τ - Data



pre-2007 data set (ALEPH)

Extraction of V_{us} using τ - Data



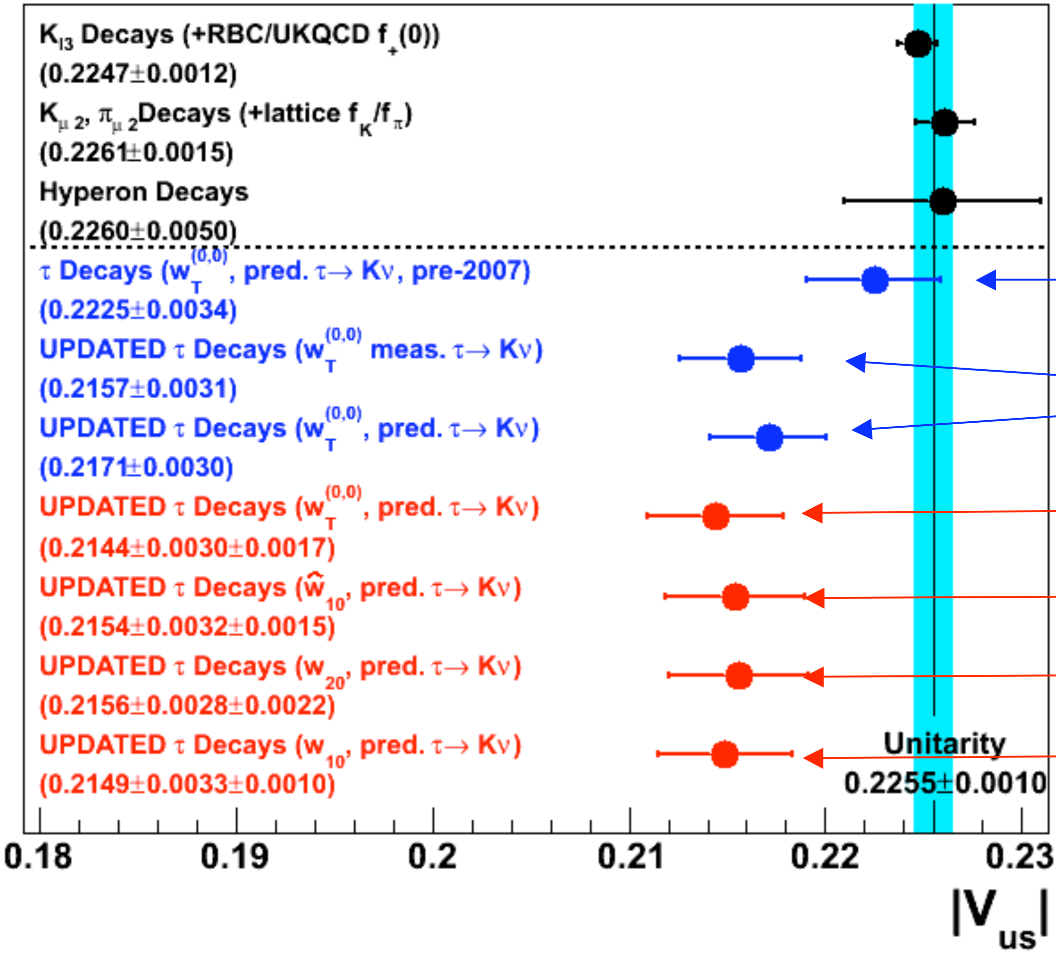
Experimental input:

BaBar: $\tau^- \to K^- \pi^0 \upsilon$

BaBar: $\tau^- \to K^- \pi^- \pi^+ \upsilon$

Belle: $\tau^- \to K^0 \pi^- \upsilon$

Extraction of V_{us} using τ - Data



Updated exptl. input:

BaBar: $\tau^- \to K^- \pi^0 \nu$

BaBar: $\tau^- \to K^- \pi^- \pi^+ \nu$

Belle: $\tau^- \to K^0 \pi^- \nu$

pre-2007 data set (ALEPH)

Measured $\tau \to K\nu$ } δR_τ from
$\tau \to K\nu$ from $K_{\mu 2}$ } Gamiz et al. 07

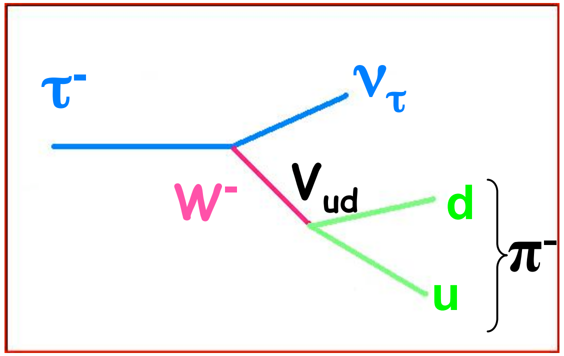
Same data set, but different weights including non-spectral weights based on ALEPH data+updated BFs (FESR, Maltman et al. 08, 09)

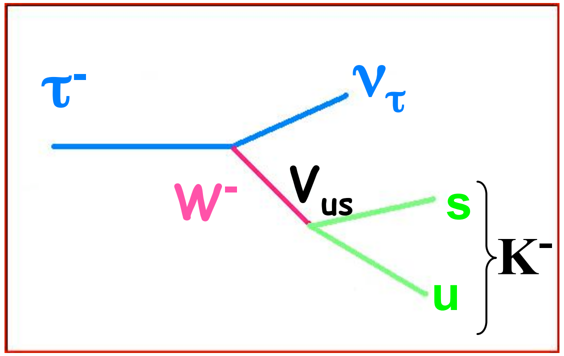
$$|V_{us}|^2 = \frac{R^w_{us}(s_0)}{R^w_{ud}(s_0)/|V_{ud}|^2 - \delta R^w_{OPE}(s_0)}$$

K. Maltman et al. arXiv:0807.3195
Finite Energy sum Rules FESR

$|V_{us}|$ from τ is ~3σ lower than unitarity

V_{us} from $\tau \to K\nu$, $\tau \to \pi\nu$





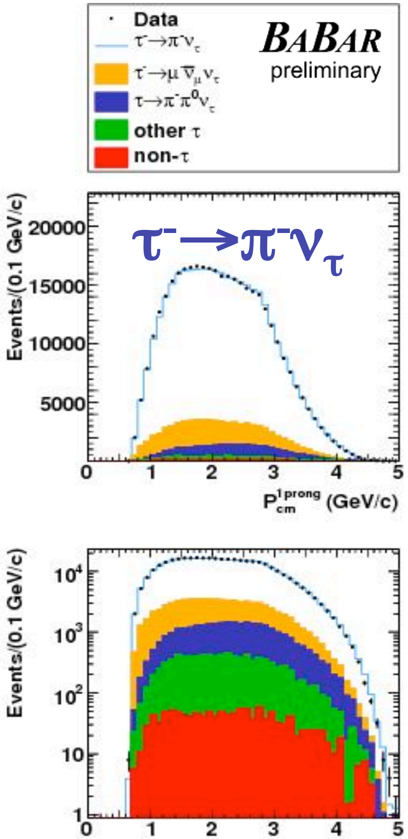
$$\frac{\Gamma(\tau \to K\nu)}{\Gamma(\tau \to \pi\nu)} = \frac{|V_{us}|^2}{|V_{ud}|^2} \frac{f_K^2}{f_\pi^2} \left(\frac{1 - m_K^2 / m_\tau^2}{1 - m_\pi^2 / m_\tau^2} \right)^2 \left(1 + \delta_{RC}^\tau\right)$$

- Assume universality of couplings
- EW corrections cancel (apart from known long distance corrections δ_{RC}^{τ})
- Take f_K/f_π from Lattice QCD
  $f_K/f_\pi = 1.189 \pm 0.007$ HPQCD/UKQCD 08
- $|V_{ud}|$ known
- **Determine $B(\tau^- \to K^-\nu)/B(\tau^- \to \pi^-\nu)$**

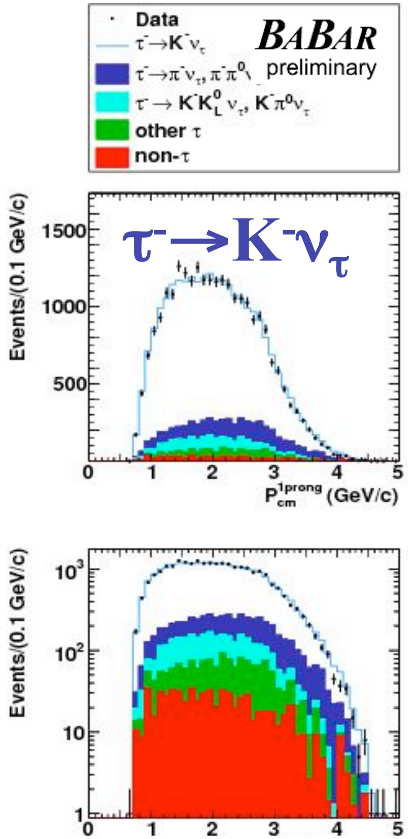
Preliminary $\tau \to K\nu$, $\tau \to \pi\nu$

ICHEP08
arXiv:0811.1429

$$\frac{B(\tau^- \to \mu^- \nu_\tau \bar{\nu}_\mu)}{B(\tau^- \to e^- \nu_\tau \bar{\nu}_e)} \quad \frac{B(\tau^- \to \pi^- \nu_\tau)}{B(\tau^- \to e^- \nu_\tau \bar{\nu}_e)} \quad \frac{B(\tau^- \to K^- \nu_\tau)}{B(\tau^- \to e^- \nu_\tau \bar{\nu}_\mu)} \quad \boxed{\frac{B(\tau^- \to K^- \nu_\tau)}{B(\tau^- \to \pi^- \nu_\tau)}}$$



p_π (GeV/c) in C.M.

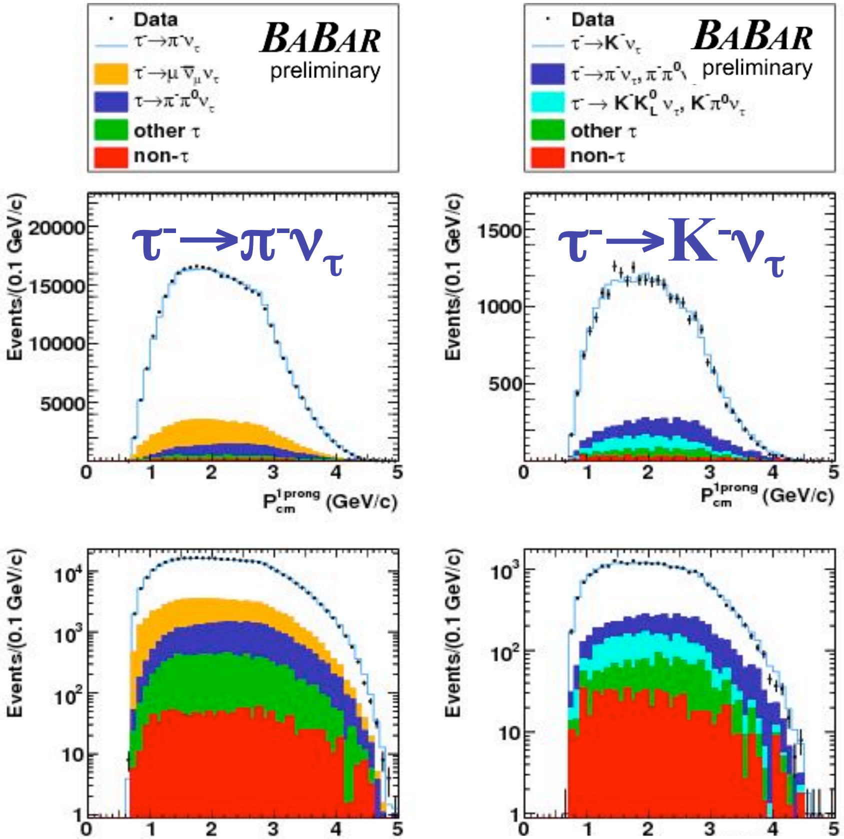


p_K (GeV/c) in C.M.

Preliminary $\tau \rightarrow K\nu$, $\tau \rightarrow \pi\nu$

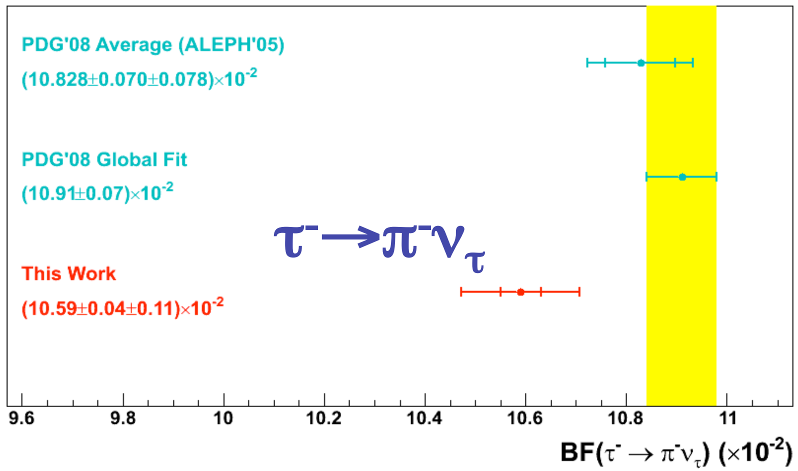
ICHEP08
arXiv:0811.1429

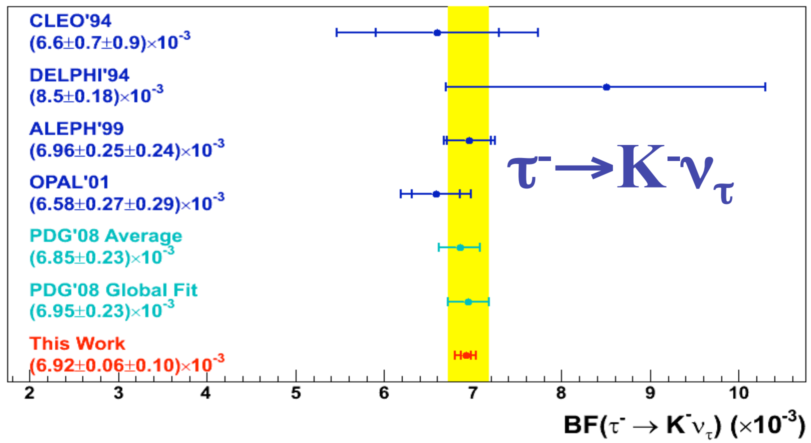
$$\frac{B(\tau^- \rightarrow \mu^- \nu_\tau \bar{\nu}_\mu)}{B(\tau^- \rightarrow e^- \nu_\tau \bar{\nu}_e)} \qquad \frac{B(\tau^- \rightarrow \pi^- \nu_\tau)}{B(\tau^- \rightarrow e^- \nu_\tau \bar{\nu}_e)} \qquad \frac{B(\tau^- \rightarrow K^- \nu_\tau)}{B(\tau^- \rightarrow e^- \nu_\tau \bar{\nu}_e)} \qquad \boxed{\frac{B(\tau^- \rightarrow K^- \nu_\tau)}{B(\tau^- \rightarrow \pi^- \nu_\tau)}}$$



p_π (GeV/c) in C.M. $\qquad$ p_K (GeV/c) in C.M.

Use PDG08 $B(\tau^- \rightarrow e^- \nu_\tau \nu_e) = (17.82 \pm 0.05)\%$

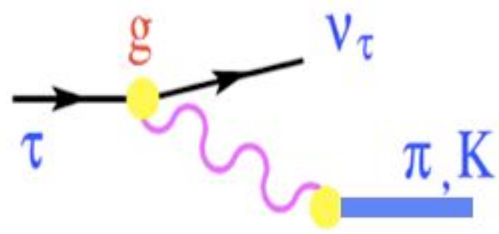




Preliminary V_{us} from $\tau \to K\nu$, $\tau \to \pi\nu$

B(τ→K⁻ν)/B(τ→π⁻ν)=0.06531±0.00056±0.00093

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



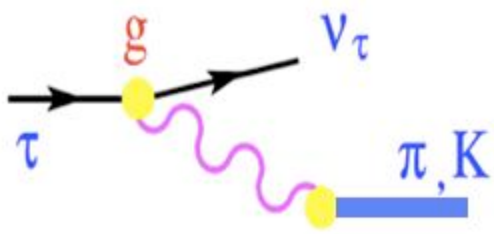
$|V_{us}|$ = 0.2255±0.0019±0.0014
Perfect agreement with Unitarity

BaBar prel.

Preliminary V_{us} from $\tau \to K\nu$, $\tau \to \pi\nu$

$B(\tau \to K^-\nu)/B(\tau \to \pi^-\nu) = 0.06531 \pm 0.00056 \pm 0.00093$

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



$|V_{us}| = 0.2255 \pm 0.0019 \pm 0.0014$
Perfect agreement with Unitarity

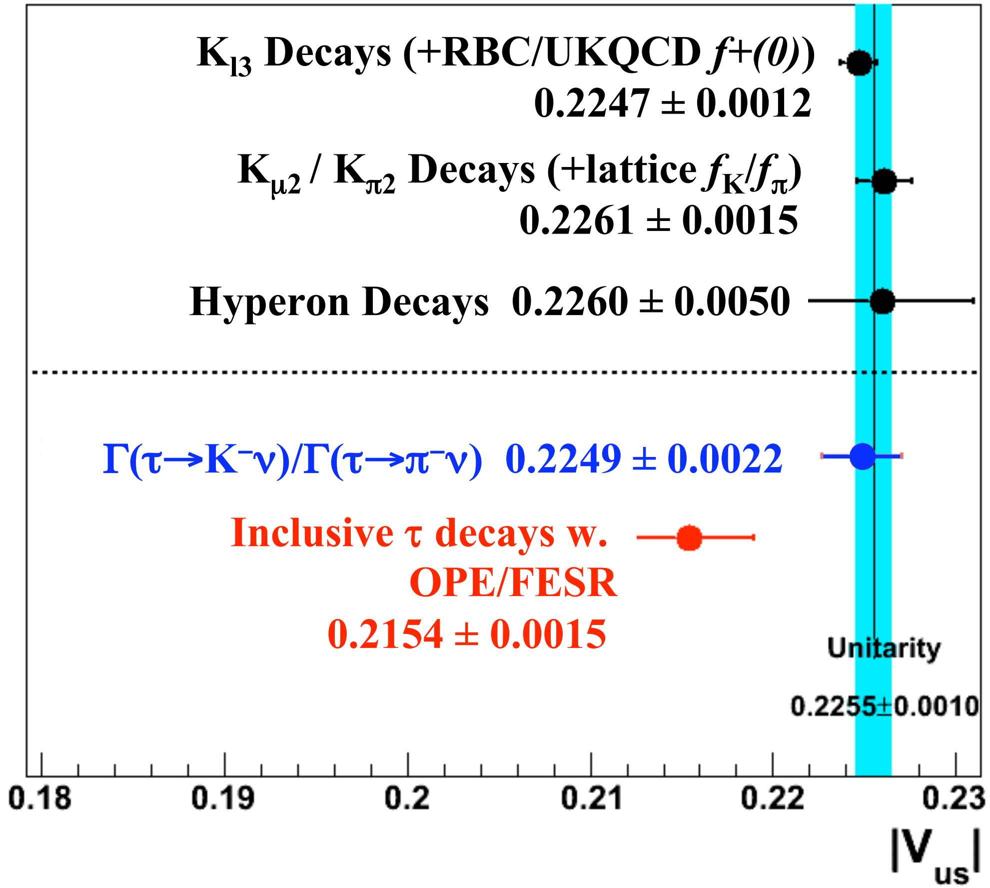
BaBar prel.

- However:
  $|V_{us}| = 0.2227 \pm 0.0037 \pm 0.0014$ from ratios of PDG08 fit values for $\tau \to K\nu$ and $\tau \to \pi\nu$
  combining these with BaBar value gives: $0.2249 \pm 0.0017 \pm 0.0014$

- With a Belle measurement of same precision as BaBar, can expect error to decrease to $\pm 0.0013 \pm 0.0014$

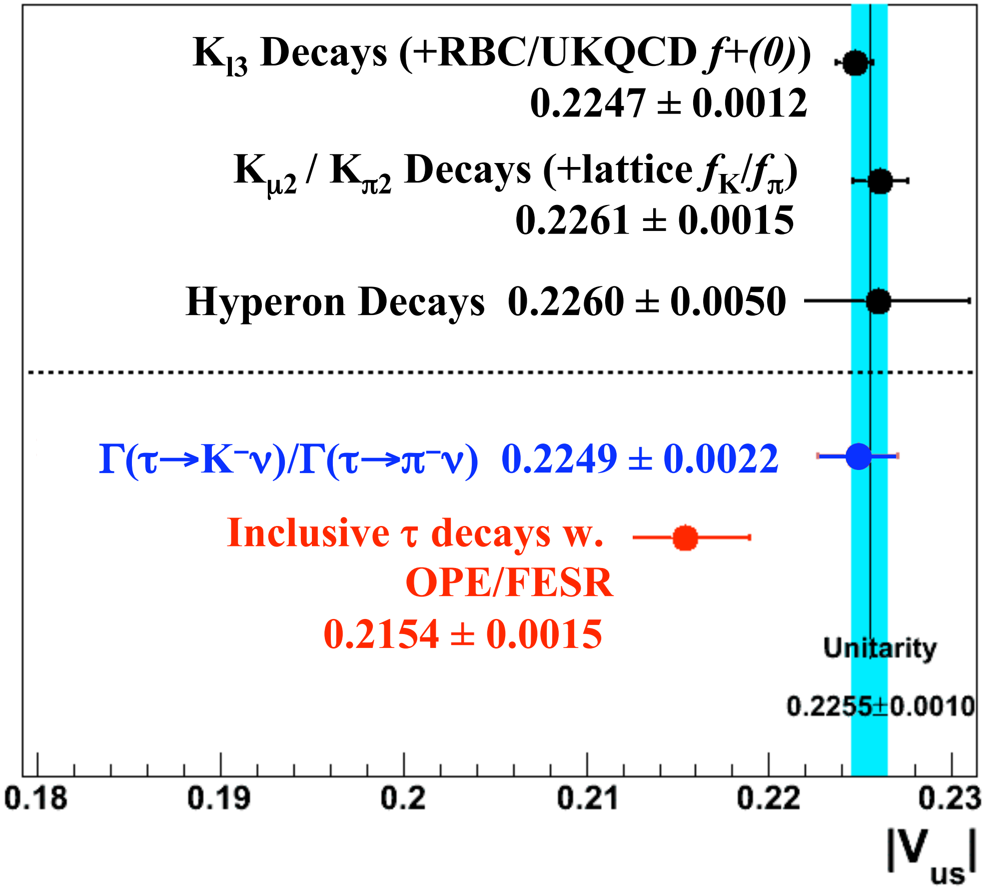
Conclusions

Experimental Information on V_{us}



Summer 2009 knowledge of V_{us}

Experimental Information on V_{us}

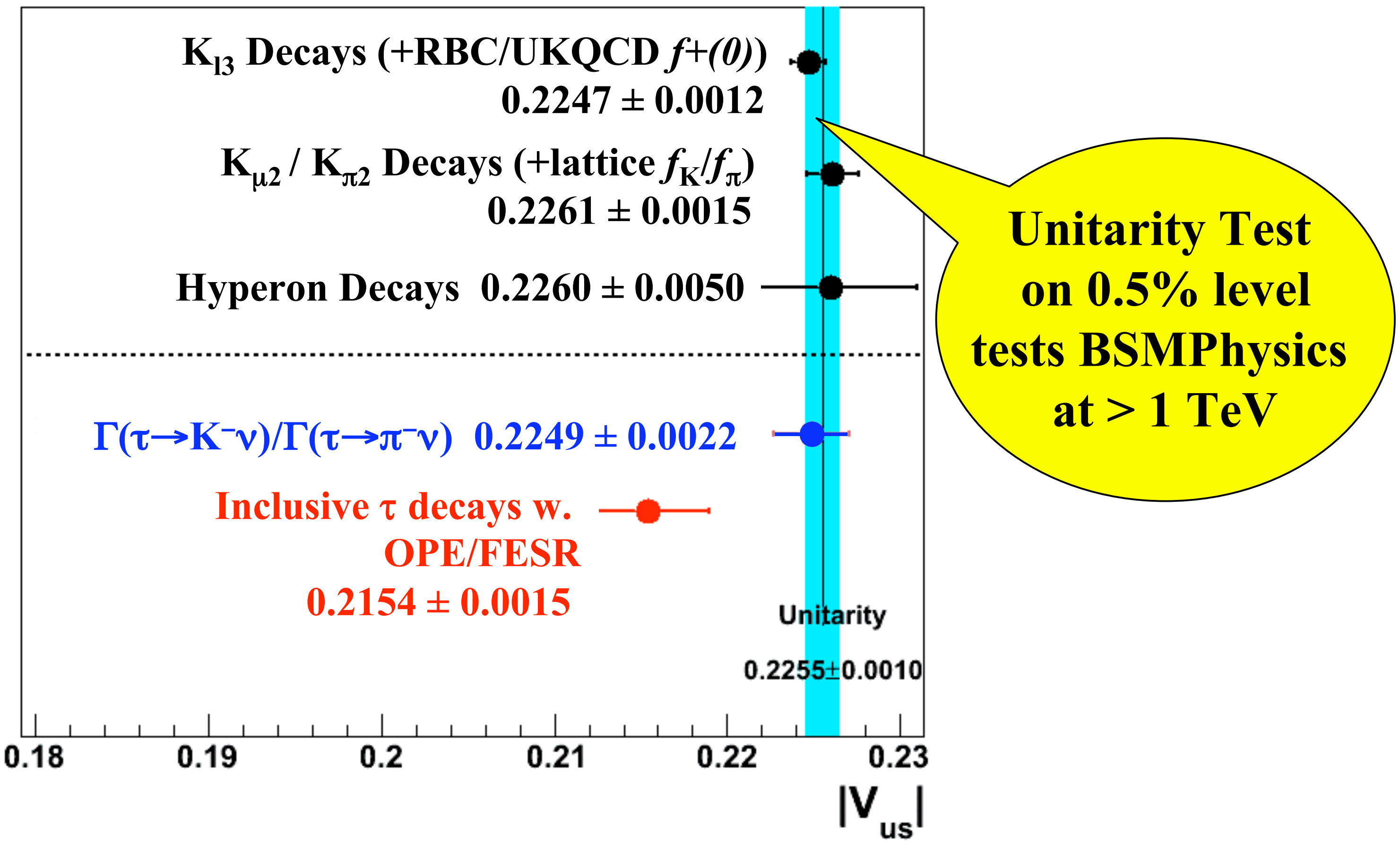


V_{us} determination using τ has potential to get sensitivity of K_{l3} and K_{l2}

➔ Completion of the τ strange decay experimental programme

➔ Understand potential issues related to δR_τ (OPE) and $f_+(0)$ for K_{l3}

Experimental Information on V_{us}



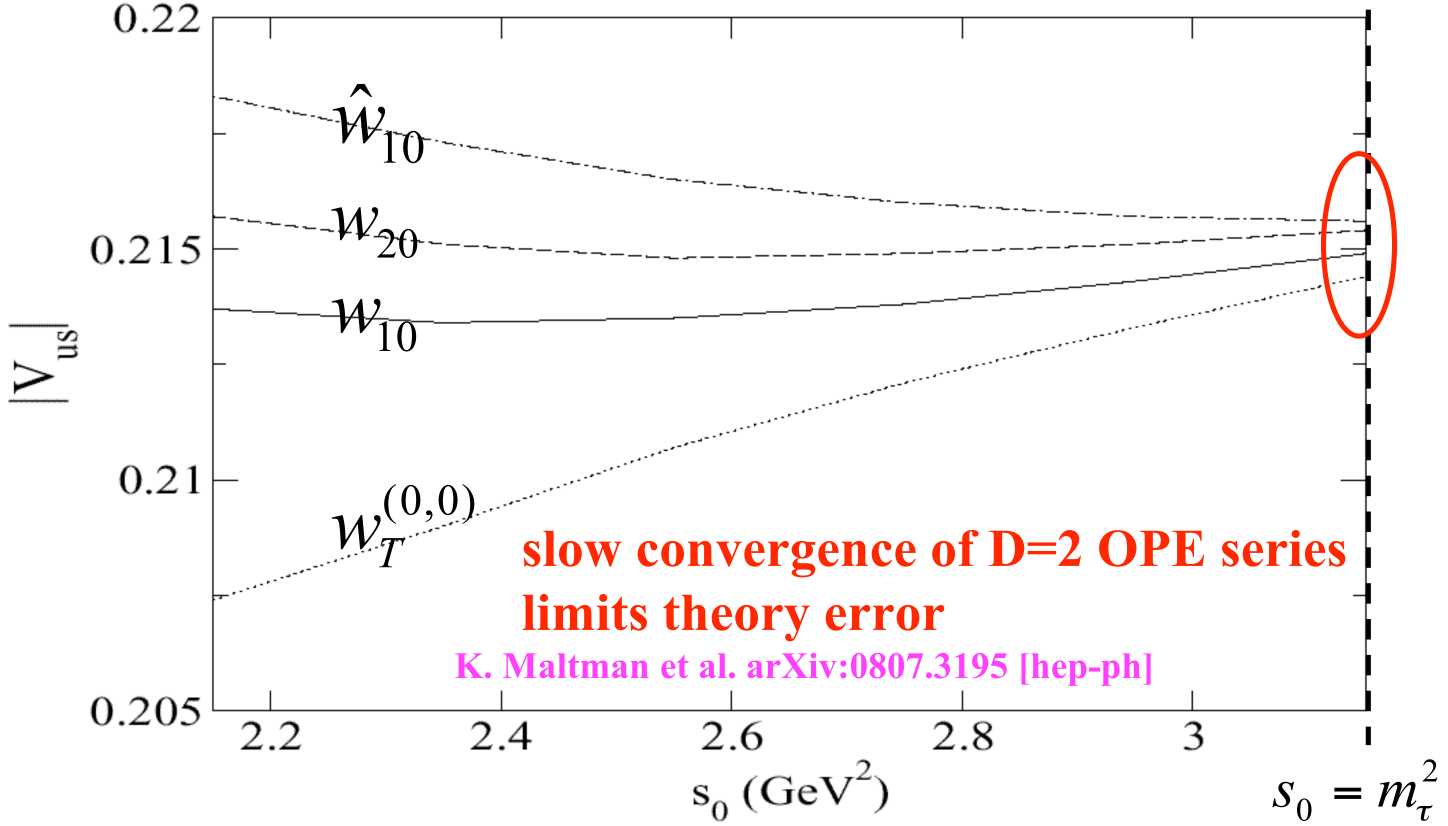
V_{us} determination using τ has potential to get sensitivity of K_{l3} and K_{l2}

➔ Completion of the τ strange decay experimental programme

➔ Understand potential issues related to δR_τ (OPE) and $f_+(0)$ for K_{l3}

Additional Material

$|V_{us}|$ using different weight functions in FESR to provide δR^{w}_{OPE}

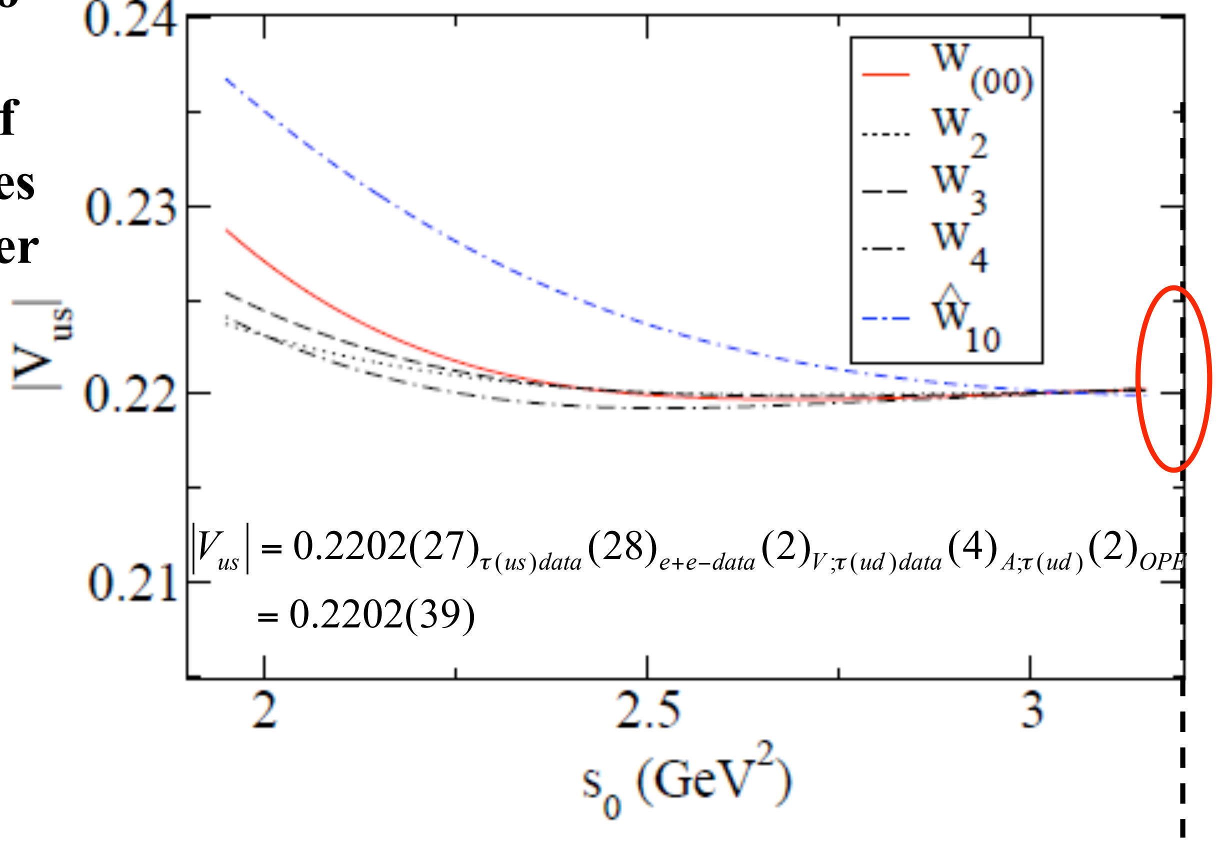


Use various weight factors including non-spectral weights, based on ALEPH data + updated τ BFs.

Combination of tau and e+e- data in FESR

K. Maltman, Phys.Lett.B672:257-263,2009

less sensitive to slow convergence of D=2 OPE series yielding smaller theory error



$s_0 = m_\tau^2$

Use various weight factors including non-spectral weights, uses ALEPH tau spectral functions + updated τ BFs and e+e-→ hadron data

Comments on 3 Sigma Tension in FESR τ

- Still need to complete the programme of measurements – so ~3σ discrepancy in FESR $|V_{us}|$ most probably will go away
- If 3σ discrepancy in FESR $|V_{us}|$ increases in significance, may need to consider theories/models that accommodate a tau FESR $|V_{us}|$ different from the pseudo-scalar ratio determination of $|V_{us}|$
- Perhaps a 3rd generation lepton coupling that cancels in the pseudoscalar ratio(?)
- Perhaps something that is more sensitive to final state hadronic system with spin=1(?)
- Lepto-quarks come to mind (?)

Callan - Treiman Relation

$t_{CT} = m_K^2 - m_\pi^2$

Δ_{CT} = $SU(2)$-breaking correction
= $-(3.5 \pm 8.0) \times 10^{-3}$
in NLO ChPT $(m_u = m_d)$

Callan-Treiman relation:

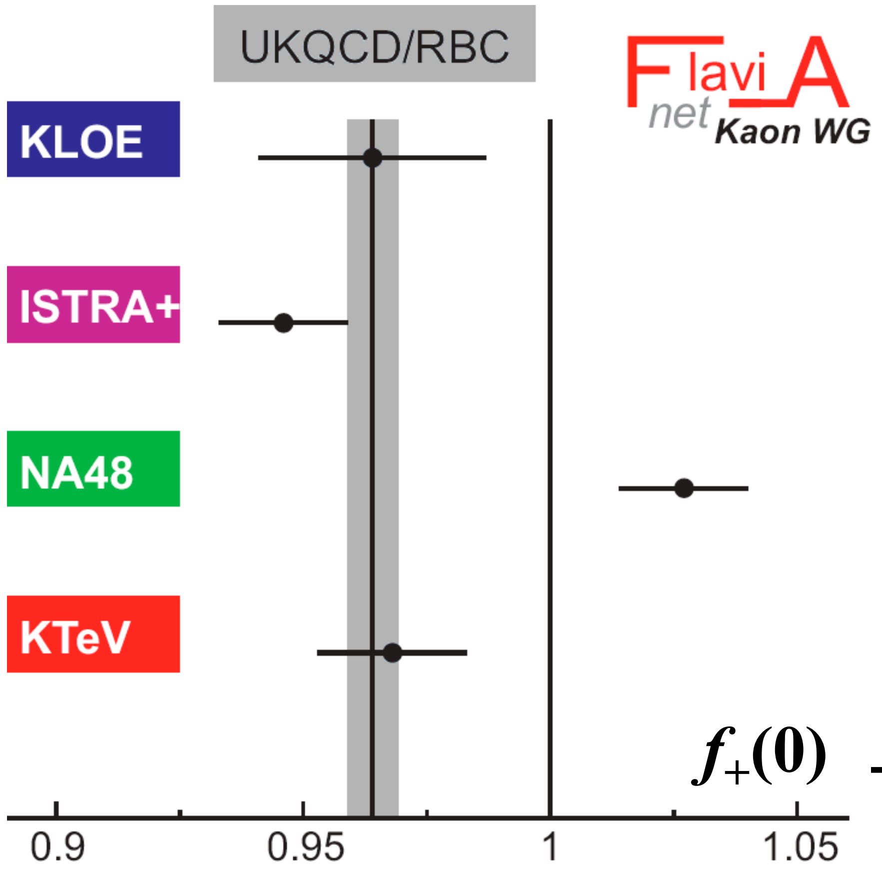
$$\tilde{f}_0(t_{CT}) = \frac{f_K}{f_\pi}\frac{1}{f_+(0)} + \Delta_{CT}$$

Use dispersive parameterization of $f_0(t)$

KLOE $K_{e3\text{-}\mu3}$ data:
$\lambda_0^C = (14.0 \pm 2.1) \times 10^{-3}$
$\rightarrow f_+(0) = 0.968(28)$

NA48 $K_{\mu3}$ data:
$\ln C = 0.1438(138)$
$\rightarrow f_+(0) = 1.027(20)$

Lattice QCD $f_+(0) = 0.964(5)$



Extracting $|V_{us}|$

The weighted spectral functions $R^w_{\tau,ij}(s_0) = \int_0^{s_0} ds\; w(s) \frac{dR_{\tau,ij}}{ds} \quad (ij = ud \text{ or } us)$ may be written as:

$$R^w_{\tau,ij}(s_0) = 3S_{EW}\left\{\left(|V_{ud}|^2 + |V_{us}|^2\right)\left(1+\delta^{kl(0)}\right) + \sum_{D\geq 2}\left(|V_{ud}|^2\,\delta^{kl(D)}_{ud} + |V_{us}|^2\,\delta^{kl(D)}_{us}\right)\right\}$$

When one takes the flavour breaking difference,

$$\delta R^w_\tau(s_0) = \frac{R^w_{\tau,ud}(s_0)}{|V_{ud}|^2} - \frac{R^w_{\tau,us}(s_0)}{|V_{us}|^2}$$

the D=0 terms cancel leaving D$\geq$ 2. Thus:

$$|V_{us}| = \sqrt{\frac{R^w_{us}(s_0)}{\left(R^w_{ud}(s_0)/|V_{ud}|^2\right) - \delta R^w_{OPE}(s_0)}}$$

where $\delta R^w_{OPE}(s_0)$ must be calculated and $R^w_{ij}(s_0)$ measured

Note: Because the D=0 term is significantly greater than the D=2 term, a large uncertainty on the OPE expansion still yields a small uncertainty on $|V_{us}|$

Extracting $|V_{us}|$ from τ-Spectral Function

Strange and non-strange Hadronic Width

$$R_{\tau,ij} = \frac{Br\left(\tau^- \to \nu_\tau hadrons_{ij}^-\right)}{Br\left(\tau^- \to \nu_\tau \bar{\nu}_e e^-\right)} \quad \text{where } ij = ud \text{ or us}$$

May be written in terms of the spectral density function

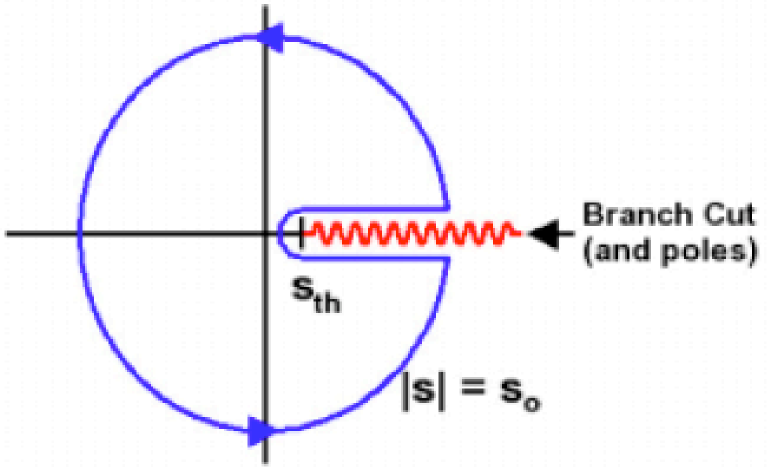
$$R_{ij} = 12 S_{EW} \pi^2 \left|V_{ij}\right|^2 \int_0^{m_\tau^2} \left(1 - \frac{s}{m_\tau^2}\right)^2 \left[\left(1 + \frac{2s}{m_\tau^2}\right)\rho_{ij}^{(1)}(s) + \rho_{ij}^{(0)}(s)\right]\frac{ds}{m_\tau^2}$$

or in terms of the 2 point correlator function

$$R_{ij} = 12 S_{EW} \pi \left|V_{ij}\right|^2 \; \frac{-1}{2\pi i} \oint_{|s|=m_\tau^2} \left(1 - \frac{s}{m_\tau^2}\right)^2 \left[\left(1 + \frac{2s}{m_\tau^2}\right)\Pi_{ij}^{(1)}(s) + \Pi_{ij}^{(0)}(s)\right]\frac{ds}{m_\tau^2}$$

Extracting $|V_{us}|$

$$\Pi(s) \sim \int_{s_{th}}^{\infty} \frac{\rho(s)}{s-q^2} ds \Rightarrow \int_{s_{th}}^{s_0} w(s)\rho(s)ds = -\frac{1}{2\pi i} \oint_{|s|=s_0} w(s)\Pi(s)ds$$

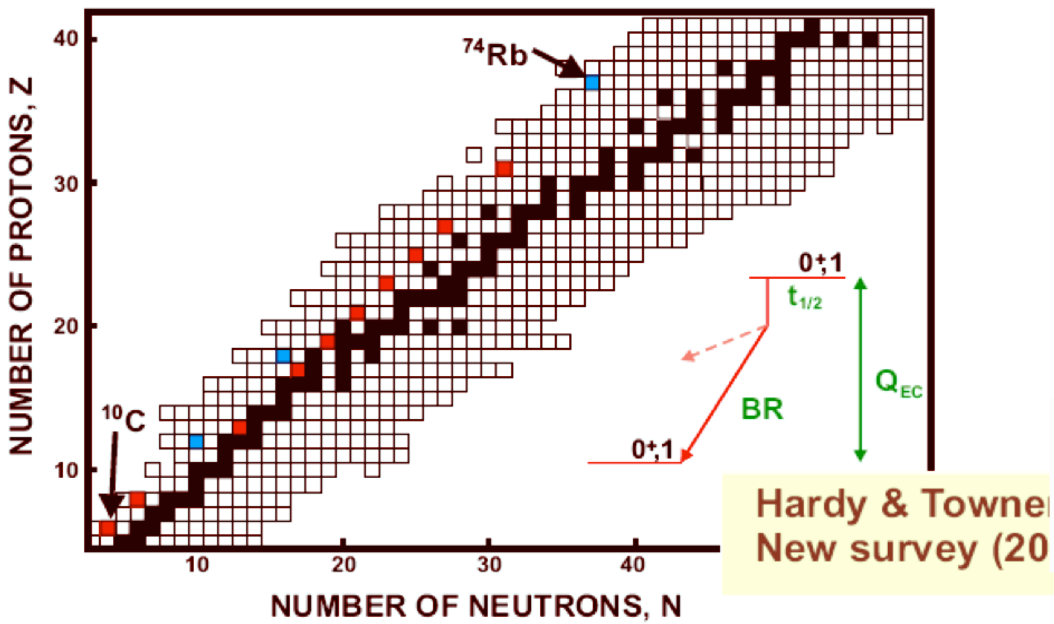


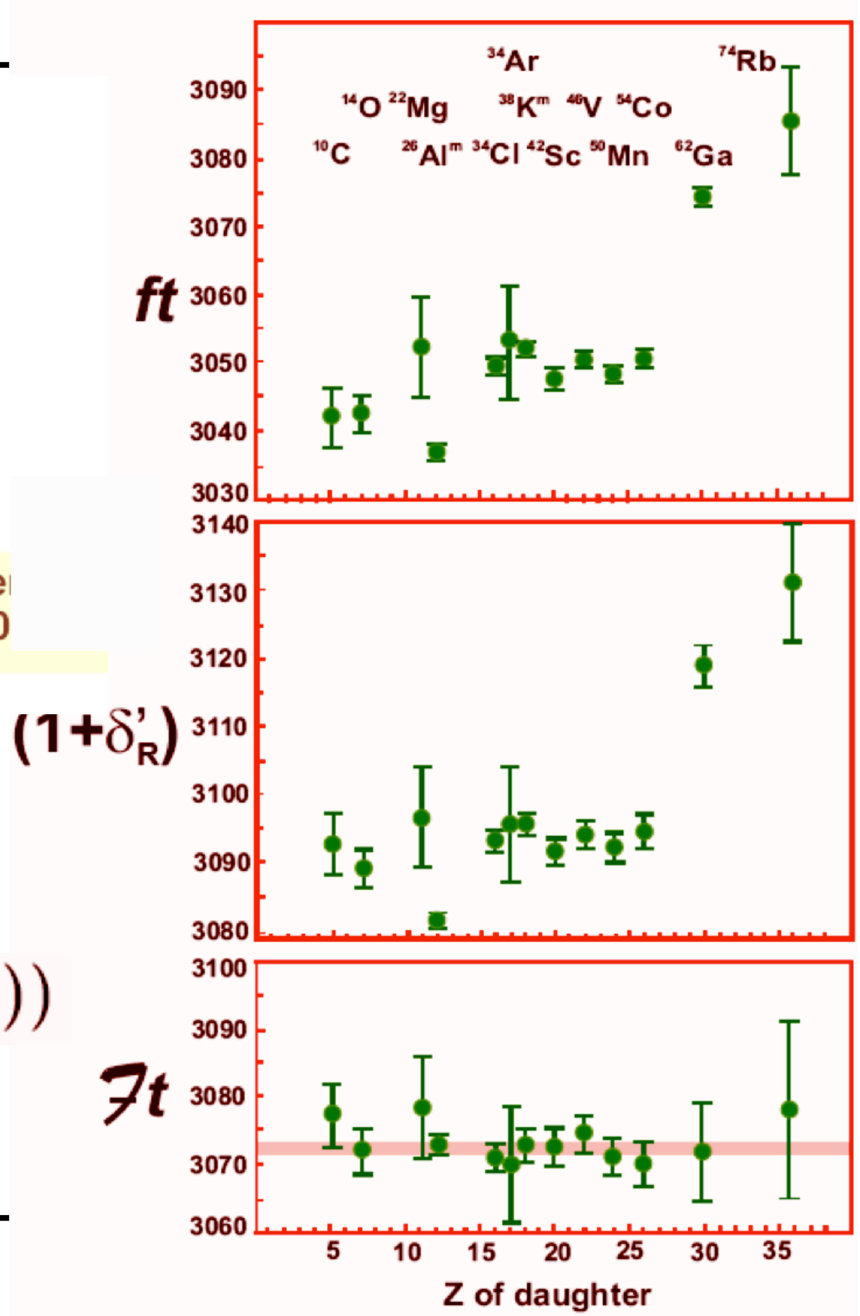
e.g. A set of 'spectral moments' has been used in the FESR as the particular weight functions w

$$R_{\tau,ij}^{kl} = \int_0^{s_0} ds \left(1 - \frac{s}{m_\tau^2}\right)^k \left(\frac{s}{m_\tau^2}\right)^l \left(\frac{dR_{\tau,ij}}{ds}\right)$$

For (k,l)=(0,0), R^{00} is obtained from the BR of strange decays

V_{ud} from 0+ → 0+



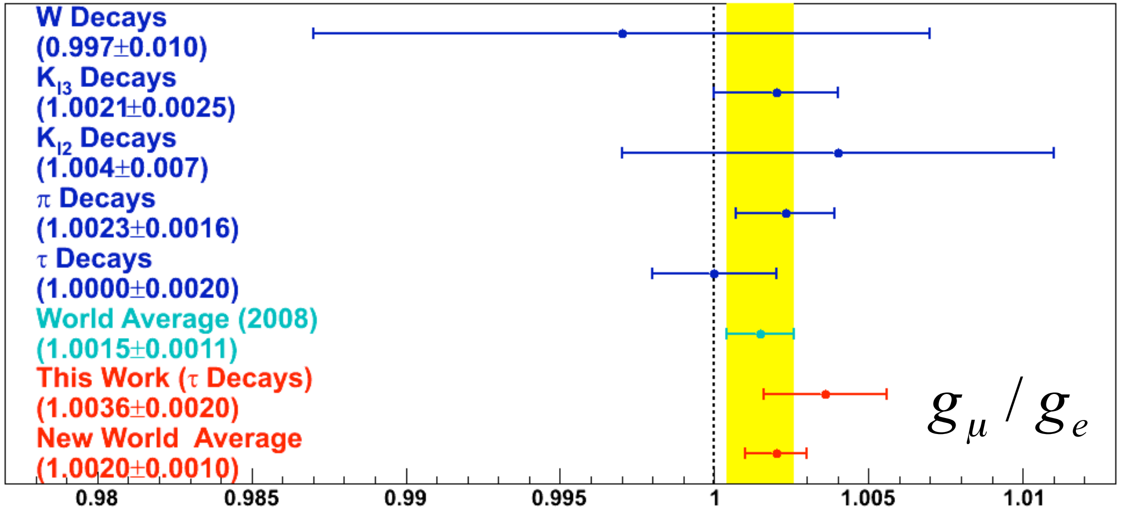


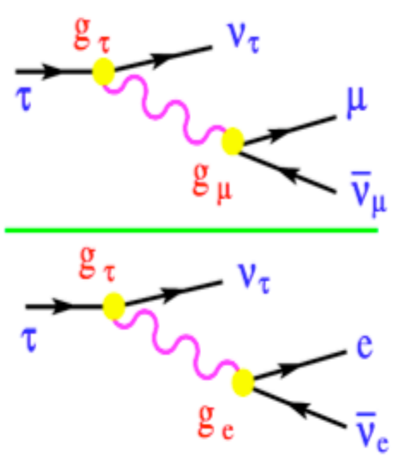
10 cases with *ft*-values measured to **~0.1% precision**; 3 more cases with **<0.3% precision**

$$\mathcal{F}t = ft(1+\delta'_R)(1-(\delta_C-\delta_{NS}))$$

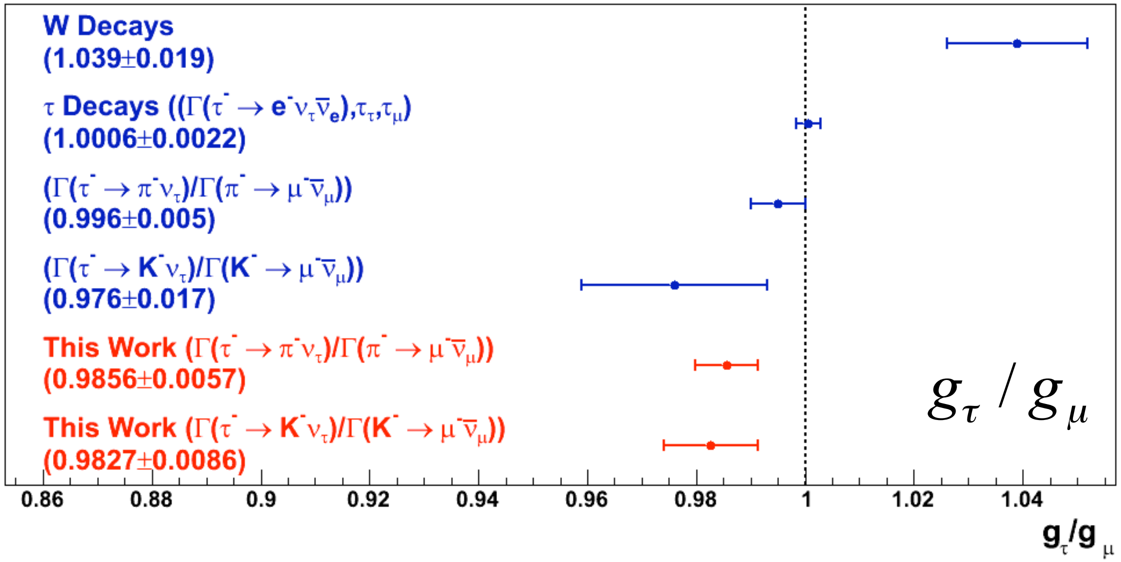
$$V_{ud}^2 = \frac{K}{2G_F^2\overline{\mathcal{F}t}(1+\Delta_R)}$$

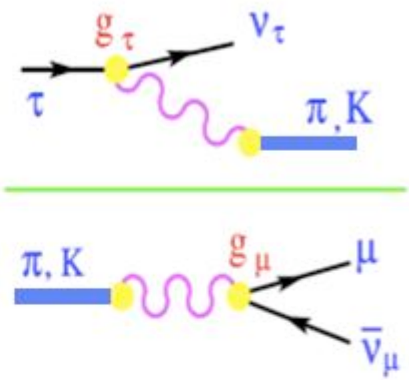
Lepton Universality from prel. BaBar result





$$\frac{\mathcal{B}(\tau^- \to \mu^- \overline{\nu}_\mu \nu_\tau)}{\mathcal{B}(\tau^- \to e^- \overline{\nu}_e \nu_\tau)}$$





$$\frac{\mathcal{B}(\tau^- \to K^- \nu_\tau)}{\mathcal{B}(K^- \to \mu^- \overline{\nu}_\mu)}$$

$$\frac{\mathcal{B}(\tau^- \to \pi^- \nu_\tau)}{\mathcal{B}(\pi^- \to \mu^- \overline{\nu}_\mu)}$$

Measurement of Slope Parameters

FlaviA net Kaon WG

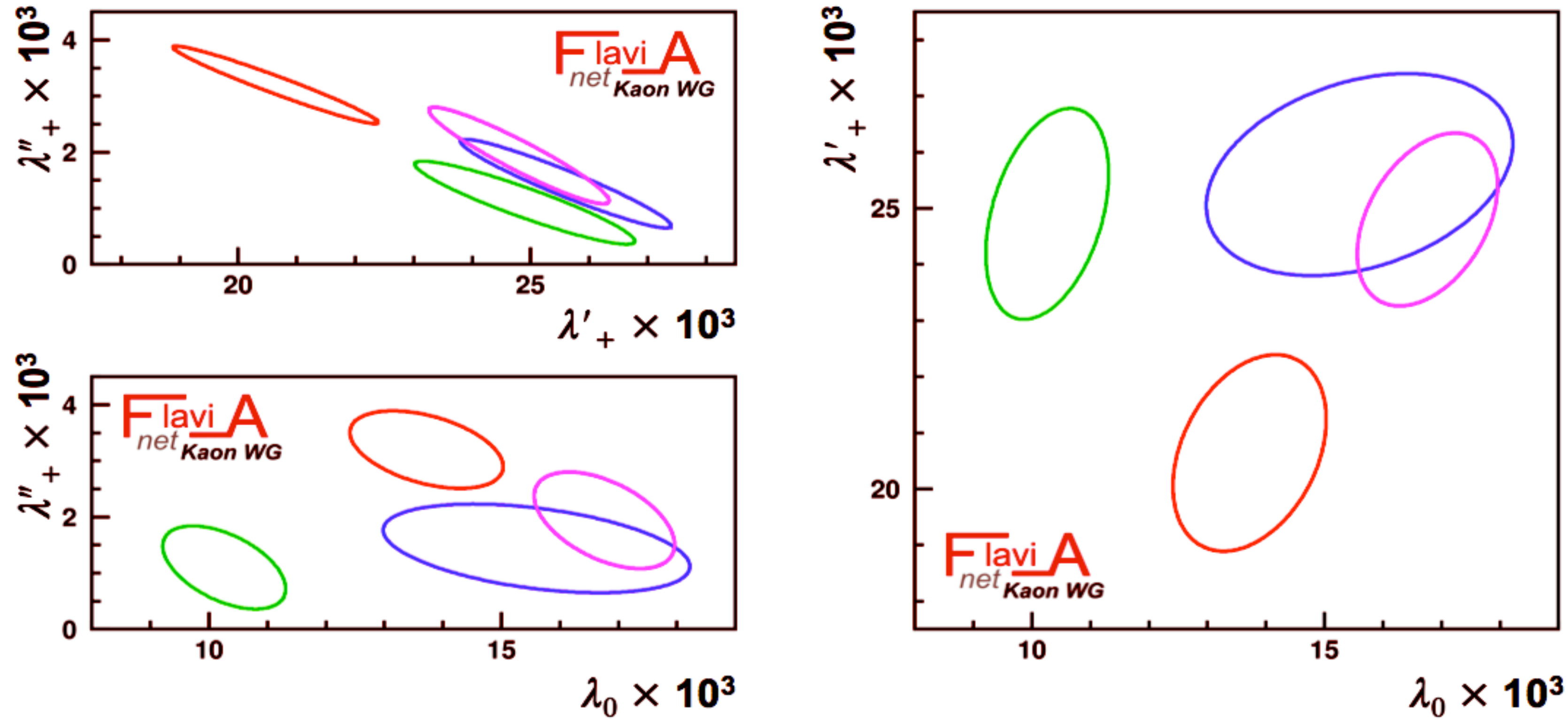
For phase space integral need to parameterize and measure *FF*-dependence on *t*

$$f_+(t) = f_+(t=0)\cdot\left(1+\lambda'_+\cdot t/M_\pi^2+\lambda''_+\cdot t^2/2M_\pi^4\right)$$

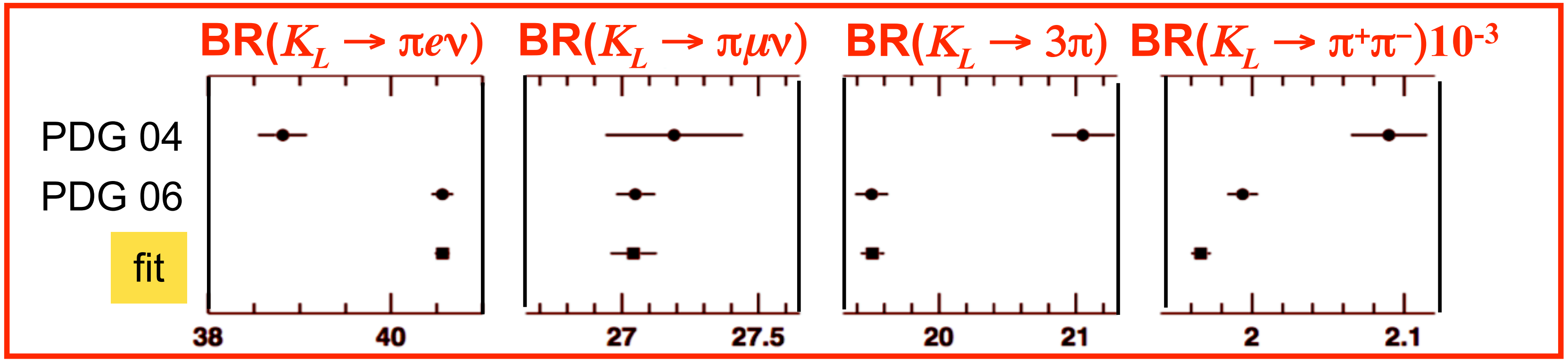
$$f_0(t) = f_+(t=0)\cdot\left(1+\lambda_0\cdot t/M_\pi^2\right)$$

***e*3-μ3 averages from**

KTeV | KLOE | ISTRA+ | NA48



The 2004 Kaon Revolution: K_{l3} BR's



FlaviA net Kaon WG

- **BRs, lifetimes, FF slopes**
- **High statistics experiments**
- Importance **radiat. corrections**
- **Correlations** btw. measurements
- **Fits to data**

ISTRA+

KTEV Kaons at the Tevatron

BNL-E865