Review of Experimental CP-Conserving Processes in Heavy Flavour Physics

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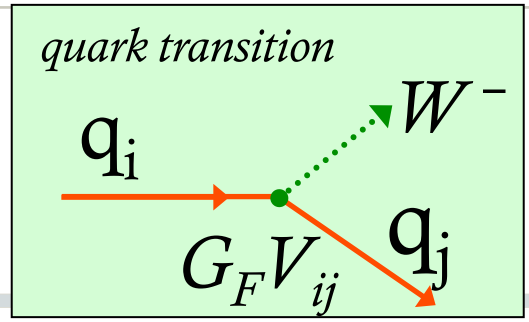
standard model's flavour sector

~two dozen fundamental SM parameters

- Couplings of EW and strong interactions
- Weak mixing angle, Z boson mass
- Masses of quarks and leptons
- Matrix characterizing the mixing of weak and mass eigenstates of quarks and, recently in extended SM, leptons
- Higgs mass, strong-CP angle

Heavy flavour sector primarily touches on the Cabibbo-Kobayashi-Maskawa (CKM) matrix

CKM Matrix



In SM weak charged transitions mix quarks of different generations

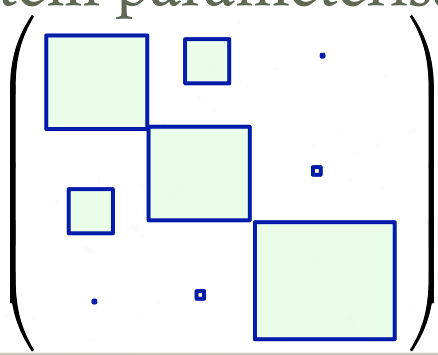
Encoded in unitary CKM matrix

$$\begin{pmatrix} d' & s' & b' \end{pmatrix} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \begin{pmatrix} d \\ s \\ b \end{pmatrix}$$

Unitarity ➔ 4 independent parameters, one of which is the complex phase and sole source of CP violation in SM

Wolfenstein parameterisation:

$\mathbf{V}_{CKM} =$



$$= \begin{pmatrix} 1-\lambda^2/2 & \lambda & A\lambda^3(\rho - i\eta) \\ -\lambda & 1-\lambda^2/2 & A\lambda^2 \\ A\lambda^3(\rho - i\eta) & -A\lambda^2 & 1 \end{pmatrix} + O(\lambda^4)$$

CKM Unitarity Triangle

Physics beyond the SM signaled by breakdown of unitarity of CKM matrix

Wolfenstein parameterisation defined to hold to all orders in $\lambda \sim 0.2$ and rephasing invariant

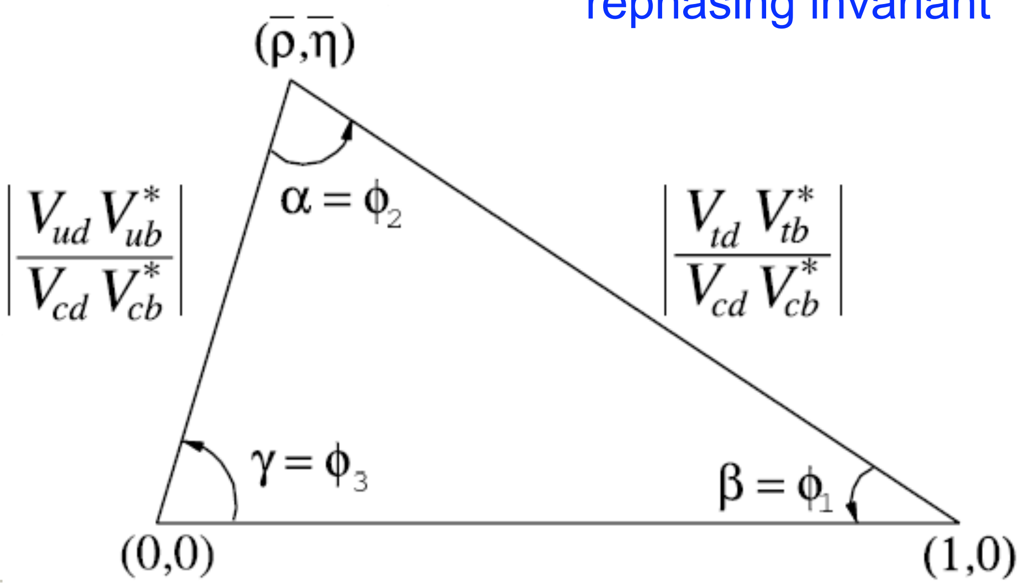
$$\lambda^2 = \frac{|V_{us}|^2}{|V_{ud}|^2 + |V_{us}|^2}; \quad A^2\lambda^4 = \frac{|V_{cb}|^2}{|V_{ud}|^2 + |V_{us}|^2}; \quad \bar{\rho} + i\bar{\eta} = -\frac{V_{ud}V_{ub}^*}{V_{cd}V_{cb}^*}$$

$$V_{ud}V_{ub}^* + V_{cd}V_{cb}^* + V_{td}V_{tb}^* = 0$$

$$\alpha = \arg\left(-\frac{V_{td}V_{tb}^*}{V_{ud}V_{ub}^*}\right) \quad \beta = \arg\left(-\frac{V_{cd}V_{cb}^*}{V_{td}V_{tb}^*}\right)$$

$$\gamma = \arg\left(-\frac{V_{ud}V_{ub}^*}{V_{cd}V_{cb}^*}\right) \quad \beta_s = \arg\left(-\frac{V_{ts}V_{tb}^*}{V_{cs}V_{cb}^*}\right)$$

Area of Δ~CP violation



CKM experimental programme

•Make as many precision measurements as possible that overconstrain the four CKM parameters (A, λ , ρ , η)

•New Physics would be revealed in discrepancies between measurements

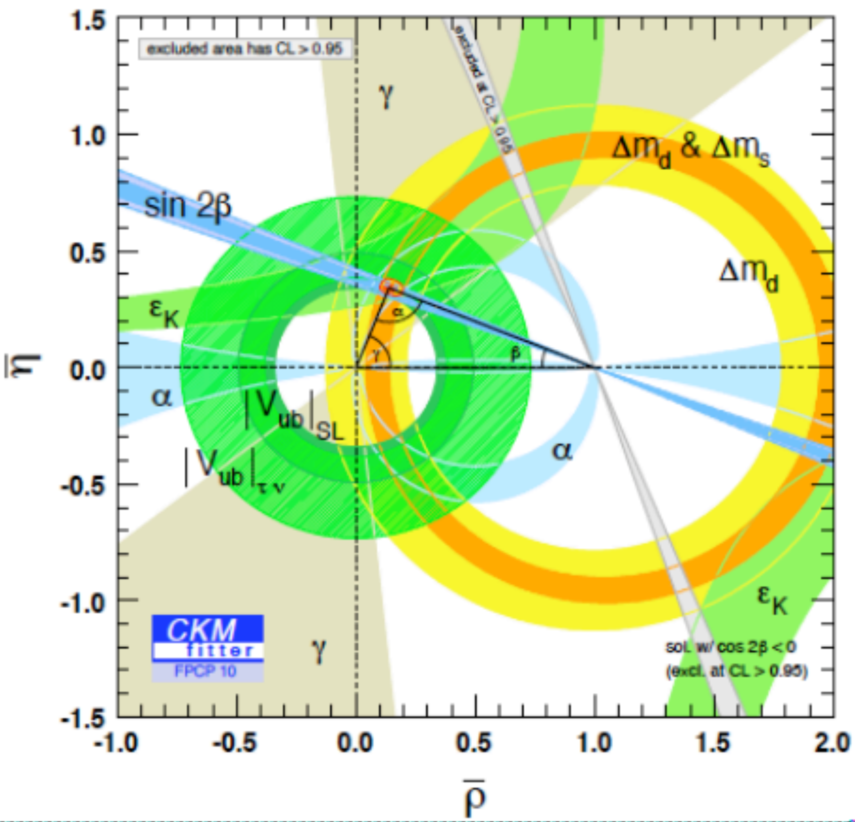
•Generally requires non-perturbative QCD input to convert measurements to a SM CKM interpretation

Programme: Over constrain CKM with broad set of measurements

Quantity	Sample Measurement(s)
$\|V_{ud}\|$	superallowed β decays
$\|V_{us}\|$	$K_{\ell 3} \to \pi \ell \nu; K_{\ell 2} \to \ell \nu /$
ε_K	CPV in K^0
$\|V_{ub}\|$	$b \to u \ell \nu$; $B \to (\pi / \rho) \ell \nu; B \to \tau \nu$
$\|V_{cb}\|$	$B \to D^{(*)} \ell \nu$
Δm_d	$B_d^0 - \overline{B_d^0}$ mixing
Δm_s	$B_s^0 - \overline{B_s^0}$ mixing
β	$B^0 \to J/\psi K^{(*)}$
α	$B^0 \to \pi\pi / \pi\rho / \rho\rho$
γ	$B^0 \to D^{(*)} K^{(*)}$
$\|V_{td}\| / \|V_{ts}\|$	$b \to d\gamma / b \to s\gamma; B_d^0$ & B_s^0 mixing

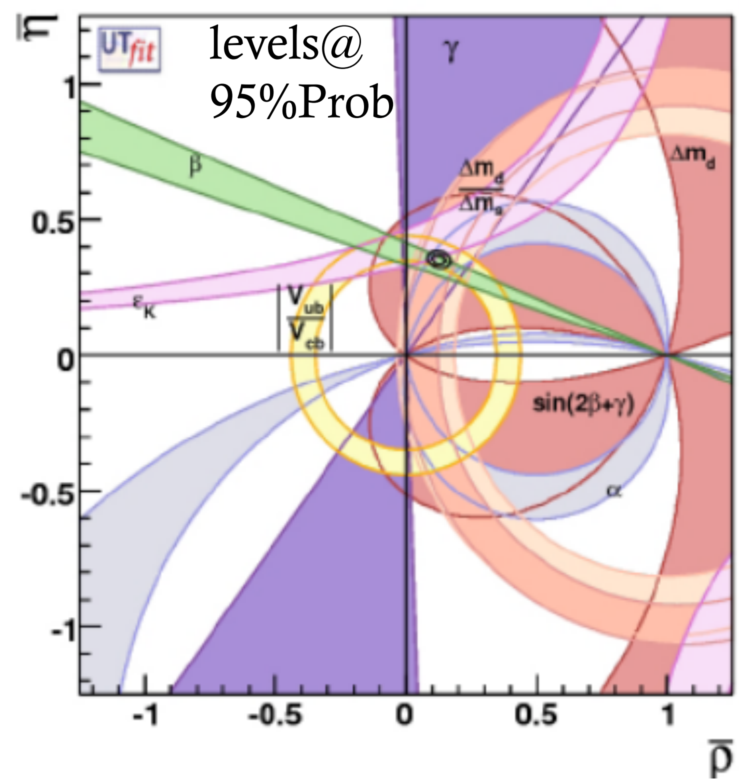
Although we probe the charged weak interaction, we need input from strong interaction calculations, which are difficult and often need data

Graphically present results as overconstrained Unitarity Triangle



CKM Fitter group uses frequentist framework

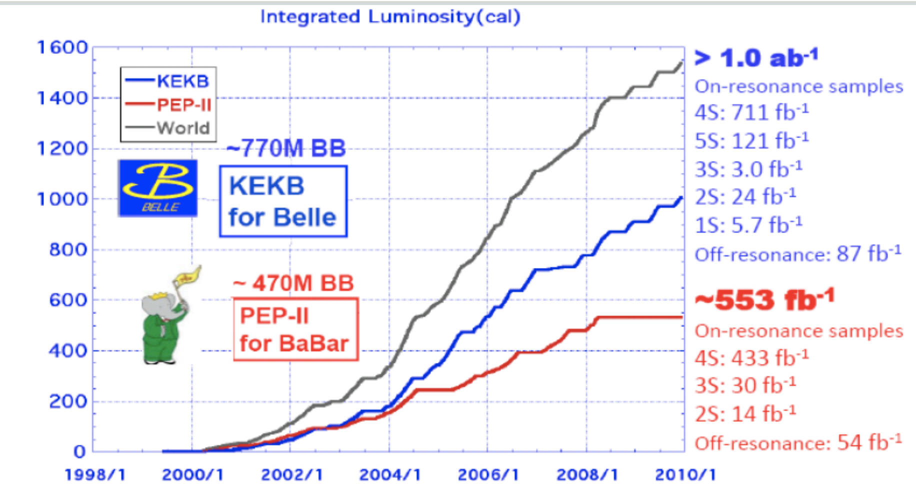
$\bar{\rho} = 0.139^{+0.027}_{-0.023}$ $\bar{\eta} = 0.342^{+0.016}_{-0.015}$

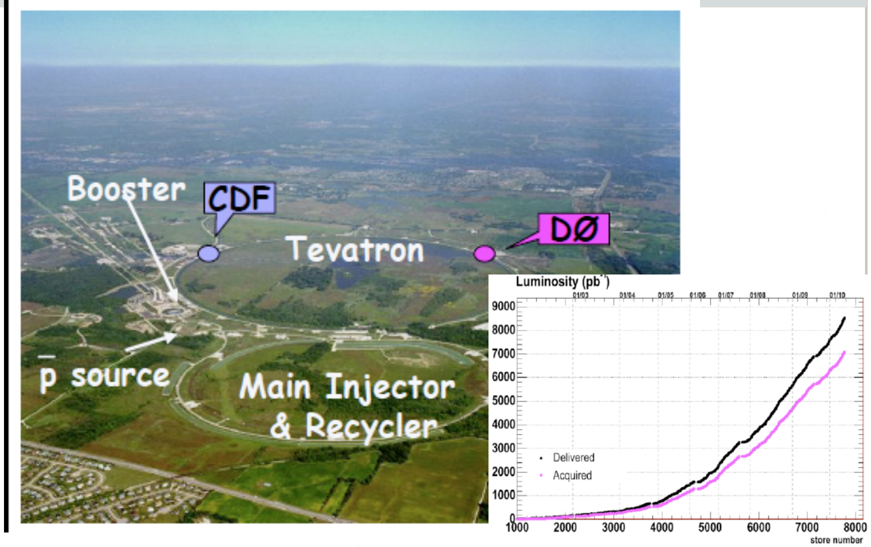


UTFit uses Bayesian framework

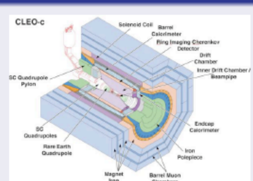
$\bar{\rho} = 0.130 \pm 0.020$ $\bar{\eta} = 0.355 \pm 0.013$

Major experiments providing flavour data… so far

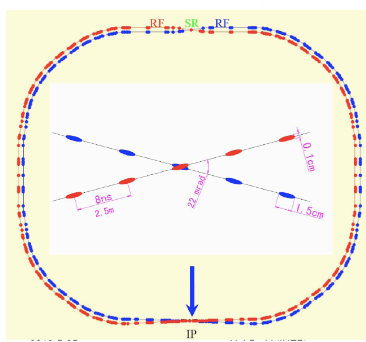




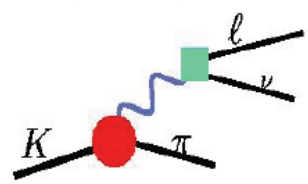
Cleo-c



- 0.818/fb at $\psi(3770)$
  - ⋆ 2.4×10^6 D^+D^- pairs
- 0.586/fb at $\psi(4170)$
  - ⋆ 0.54×10^6 $D_s^{*\pm}D_s^{\mp}$ pairs



BESIII @ BEBC II



KLOE, BNL-E865, KTeV, ISTRA+ and NA48

Related Parallel Session talks

Semi-leptonic and Leptonic B Decays at B Factories - Elisabetta Barberio (Melbourne)

Recent B Physics Results from the Tevatron - Karen Gibson (Case Western)

Evidence for Significant Matter-Antimatter Asymmetry at DZero - Derek Strom (UIC)

Recent Charm Physics Results from e+e- B Factories - Rolf Andreassen (Cincinnati)

Recent Quarkonium Results from the e+e- B Factories - Simone Stracka (Milan)

Recent Tau Decay Results at B Factories - Kiyoshi Hayasaka (Nagoya)

Recent Results from CLEO - David Cassel (Cornell)

Single Top and V_tb at the Tevatron - Reinhard Schwienhorst (Michigan State)

Constraints on Quark and Neutrino 4th Generation SM Mixing Matrix - Heiko Lacker (Berlin)

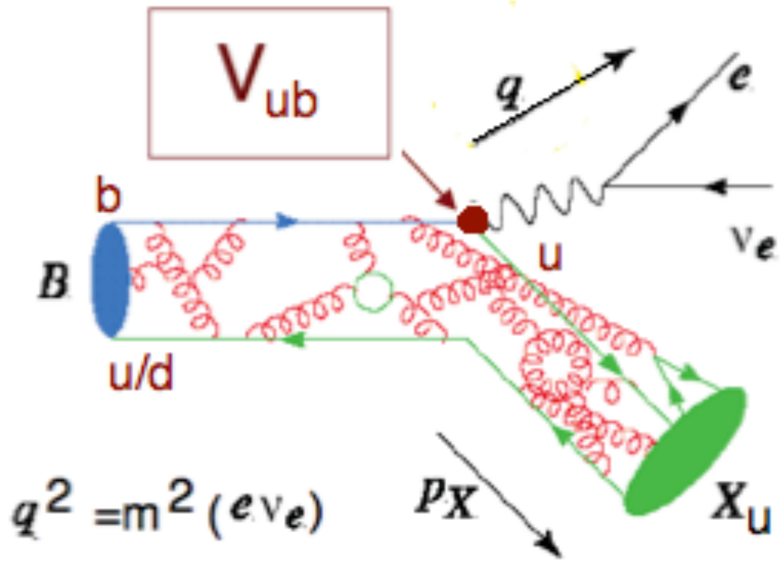
Highlights of Flavour Violation in the Presence of a 4th Generation - Tillmann Heidsieck (Munich)

Sample of recent measurements

- CP violating measurements will be discussed in the next presentation
- Here I'll address a few recent CP-conserving heavy flavour measurements
  - $|V_{ub}|$ from Semileptonic B decays
  - B leptonic decays
  - $|Vus|$ measurements

$|V_{ub}|$ from Semileptonic B Decays

measurements based on
decays with large
branching fractions

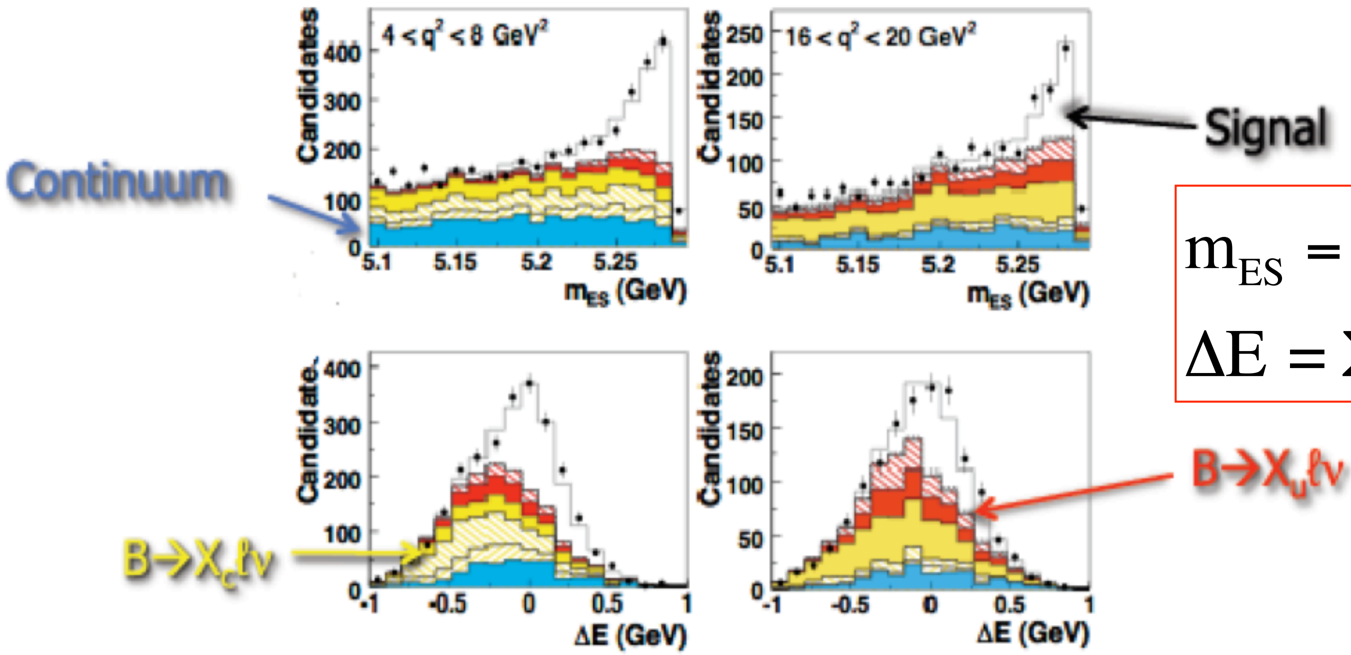


Two experimental approaches:

- Inclusive $b \to u\, l\, \nu$
  - Weak Quark decay + QCD
- Exclusive $B \to X_u\, l\, \nu$
  - QCD handled via Form factors with non-perturbative input from e.g. lattice QCD

Address experimental issues, such as charm background, differently and have different QCD correction issues

Example: recent BaBar result on untagged $B \to \pi \ell \nu$ and $B \to \rho \ell \nu$



$$m_{ES} = \sqrt{E_{beam}^2 - (\Sigma p_i)^2}$$

$$\Delta E = \Sigma E_i - E_{beam}$$

Simultaneous fit to $\pi^+\ell\nu$, $\pi^0\ell\nu$, $\rho^+\ell\nu$, $\rho^0\ell\nu$

$BF(B \to \pi^+\ell\nu) = (1.41 \pm 0.05 \pm 0.07) * 10^{-4}$

$BF(B \to \rho^+\ell\nu) = (1.75 \pm 0.15 \pm 0.27) * 10^{-4}$

$|V_{ub}|$ from $B \to \pi \ell \nu$

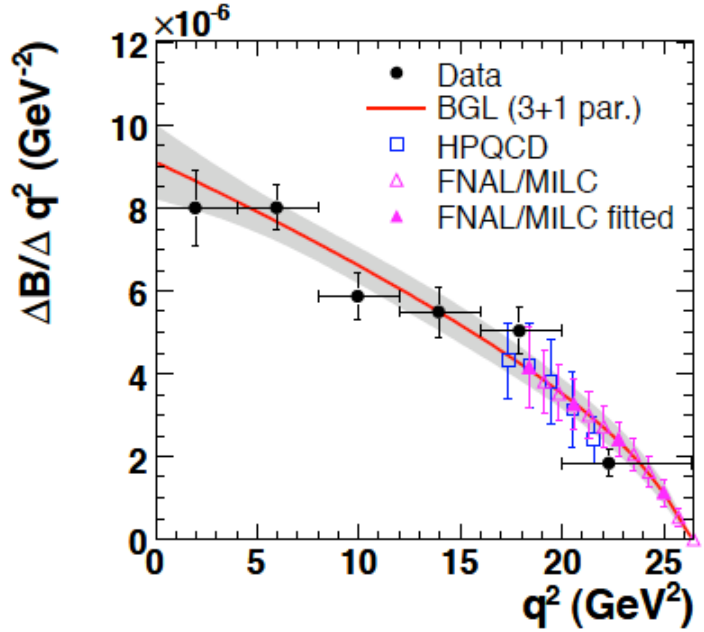
(*BABAR* arXiv:1005.3288)

Determine |Vub| from simultaneous fit to calculated (lattice QCD) and measured values of partial decay rate as function of q^2

Latest *BABAR* measured q^2 spectrum yields a value of:

$$|V_{ub}| = (2.95 \pm 0.31) \times 10^{-3}$$

Total error has similar contributions from lattice and experimental uncertainties



$|V_{ub}|$ comparisons

Latest combined fit to data,lattice $B \to \pi \ell \nu \quad (2.95 \pm 0.31) \times 10^{-3}$

Inclusive, PDG2010 average: $b \to u \ell \nu \quad (4.37 \pm 0.39) \times 10^{-3}$

(difference: 2.7σ)

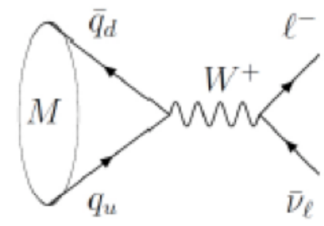
Difference is a problem and perhaps should be identified as an unattributed uncertainty

- work of multiple experiments, multiple theoretical groups.
- exclusive result relies on non-perturbative normalization input
- inclusive result uses m_b, non-perturbative extrapolations and perturbative corrections

Predictions from CKM fits:

UTFit	**3.48±0.16**	**(ICHEP 2008)**
CKMFitter	**$3.51\pm^{0.15}_{0.16}$**	**(Beauty 2009)**

Leptonic Decays



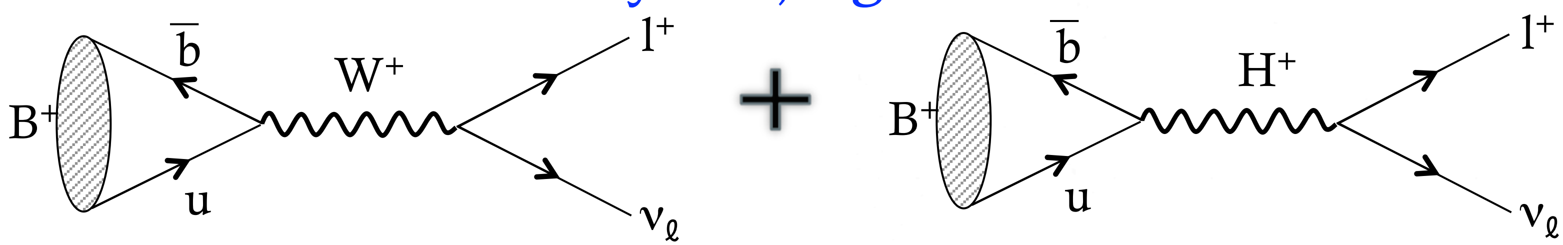
Remarkably simple pseudo-scalar (spin = 0, Parity is negative) decays carry information about CKM elements, but come with a 'decay constant' factor which accounts for the strong interaction component

- $B \to \tau\ \nu$ rate of decay α $(f_B |V_{ub}|)^2$
- $Ds \to \tau\ \nu$ or $Ds \to \mu\ \nu$ rate α $(f_{Ds} |V_{cs}|)^2$
- $K \to \mu\ \nu$ rate α $(f_K |V_{us}|)^2$

$$\mathcal{B}[M \to \ell\nu_\ell]_{\mathrm{SM}} = \frac{G_F^2 m_M m_\ell^2}{8\pi}\left(1 - \frac{m_\ell^2}{m_M^2}\right)^2 |V_{q_u q_d}|^2 f_M^2 \tau_M (1 + \delta_{EM}^{M\ell 2})$$

Leptonic decays

Particularly interesting because some New Physics theories have charged Higgs which contributed to the observed decay rate, e.g.



- Additional tree level contribution from a charged Higgs
  - It does not suffer from helicity suppression, but gets the same m_l dependence from Yukawa coupling
  - Branching fraction theoretical expression depends on the NP model

$$\mathcal{B}(B \to l\nu)_{2HDM} = \mathcal{B}(B \to l\nu)_{SM} \times (1 - tan^2\beta \frac{m_B^2}{m_H^2})^2$$

W. S. Hou, Phys. Rev. D 48 (1993) 2342.

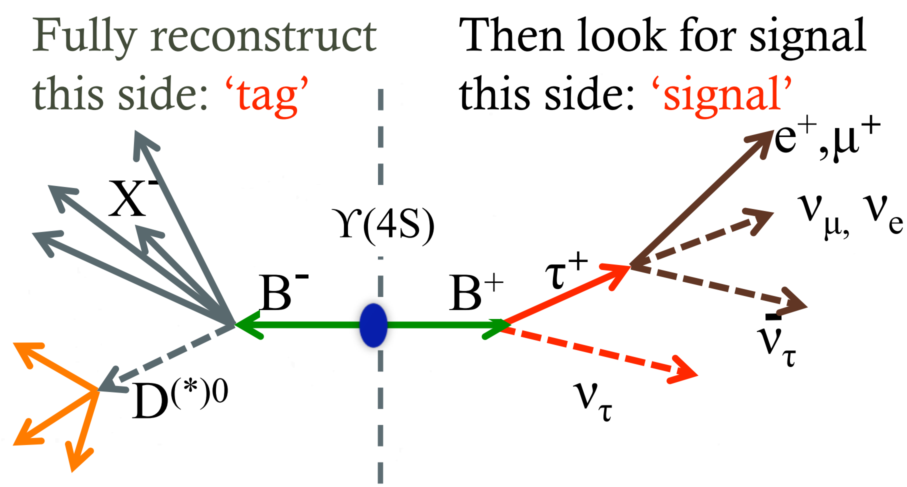
$$\mathcal{B}(B \to l\nu)_{SUSY} = \mathcal{B}(B \to l\nu)_{SM} \times (1 - \frac{tan^2\beta}{1 + \epsilon_0 tan\beta} \frac{m_B^2}{m_H^2})^2$$

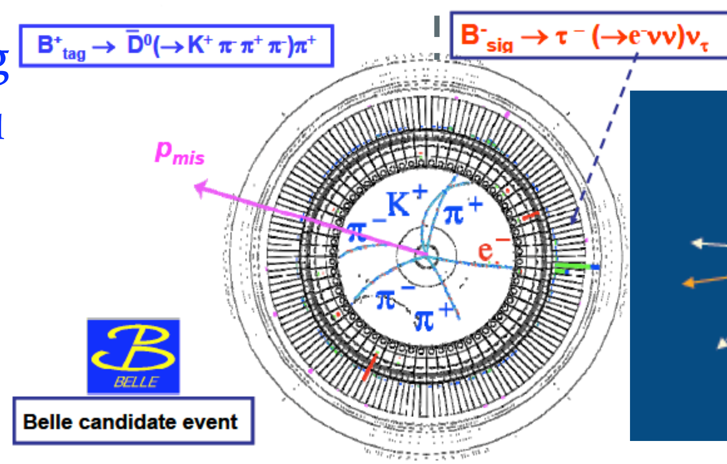
A.G. Akeroyd and S.Recksiegel J.Phys.G29:2311-2317,2003

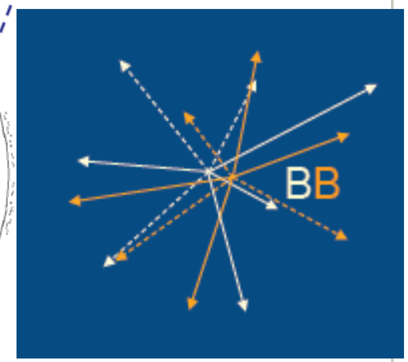
$B^+ \to \tau^+ \nu_\tau$ Experimental method

Two approaches to reconstruct the 'tag', which are classified as hadronic or semileptonic

1. select signal candidate and check that remaining particles consistent with B decay (inclusive B_{tag} reco)
2. Reconstruct B_{tag} in exclusive modes and check if remaining particles consistent with B_{signal}







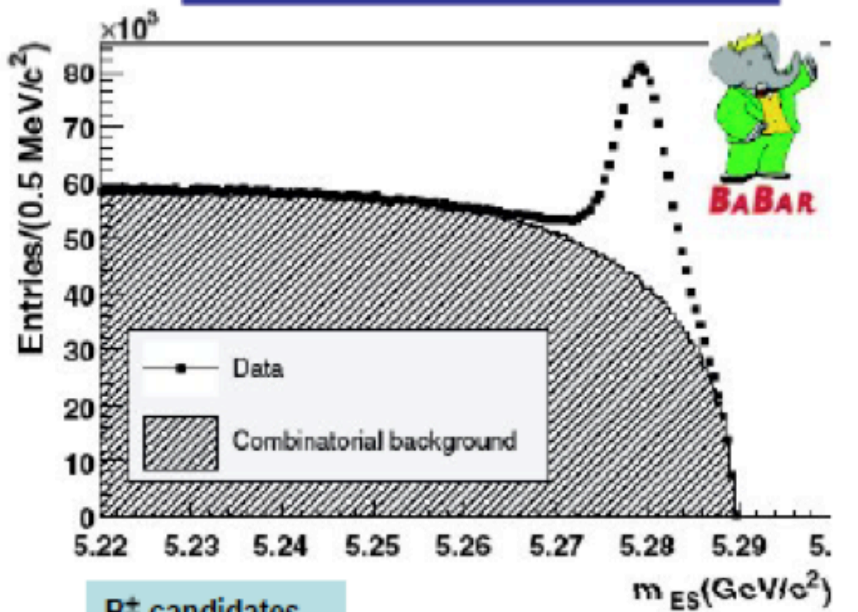
In reality at the Υ(4S) the B^+ and B^- decay products all overlap

Reconstruct event to select B^- events from background…

Reconstruct B_{tag} in hadronic mode:

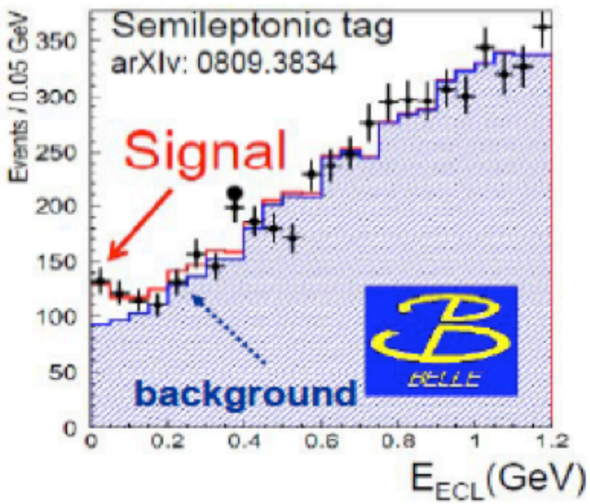
$\Delta E = \Sigma E_i - E_{beam}$

$M_{ES} = \sqrt{E^2_{beam} - (\Sigma p_i)^2}$



B± candidates

….and look for excess of missing energy associated with the neutrino



D(*)l ν tag

$B^- \to D^{*0} l^+ \nu$, $D^0 l \nu$
$D^{*0} \to D^0 \pi^0$, $D^0 \gamma$
$D^0 \to K^- \pi^+, K^- \pi^+ \pi^- \pi^+, K^- \pi^+ \pi^0$

657 M $\bar{B}B$

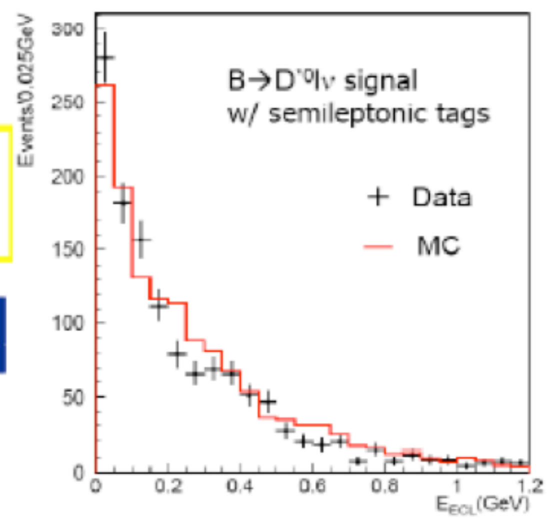
hep-ex/0809.3834

Preliminary

visible products of τ decay

$h = \pi^\pm, l = e^\pm, \mu^\pm$

$B \to D^{*0} l \nu$ control sample



$N_{sig} = 154^{+36}_{-35}$ (stat) $^{+20}_{-22}$ (syst)

$\Rightarrow \mathcal{B}(B \to \tau\nu) = (1.65^{+0.38}_{-0.37}{}^{+0.35}_{-0.37}) \times 10^{-4}$

3.8σ

Obtained $Br(B^- \to D^{*0} l \nu) = 6.0 \pm 0.2$ (stat) %

$B^+ \rightarrow \tau^+ \nu_\tau$ Results

BABAR Hadronic

$$\mathcal{B}(B \rightarrow \tau\nu) = (1.8^{+0.9}_{-0.8}(\text{stat.}) \pm 0.4 \pm 0.2) \times 10^{-4}$$

Phys. Rev. D 77, 011107(R) (2008)

BABAR Semi-leptonic

$$\mathcal{B}(B \rightarrow \tau\nu) = (1.7 \pm 0.4(\text{stat.}) \pm 0.2) \times 10^{-4}$$

Phys. Rev. D 81,051101(R) (2010)

BELLE Hadronic

$$\mathcal{B}(B \rightarrow \tau\nu) = (1.79^{+0.56}_{-0.49}(\text{stat.})^{+0.46}_{-0.51}) \times 10^{-4}$$

Phys. Rev. Lett. 97, 261802 (2006)

BELLE Semi-leptonic

$$\mathcal{B}(B \rightarrow \tau\nu) = (1.54^{+0.38}_{-0.37}(\text{stat.})^{+0.29}_{-0.31}) \times 10^{-4}$$

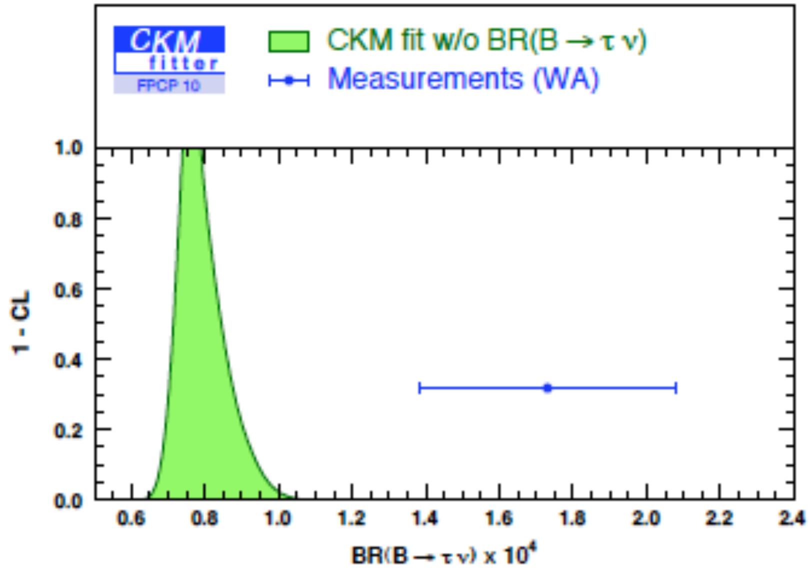
arXiv:1006.4201[hep-ex]

$B^+ \to \tau^+ \nu_\tau$ Results

world average:

$B(B^+ \to \tau^+ \nu) = (1.73 \pm 0.35) \times 10^{-4}$

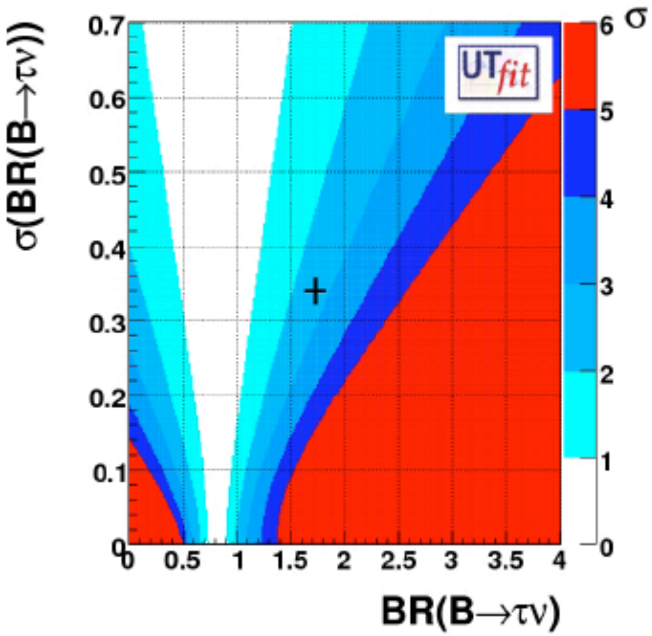
~2.5 σ higher than expected from CKM fit excluding $B^+ \to \tau^+ \nu$



$Br(\tau\nu)_{CKM\ fit} = \left[0.786^{+0.179}_{-0.083}\right] \times 10^{-4}$

$B^+ \rightarrow \tau^+ \nu_\tau$ Results

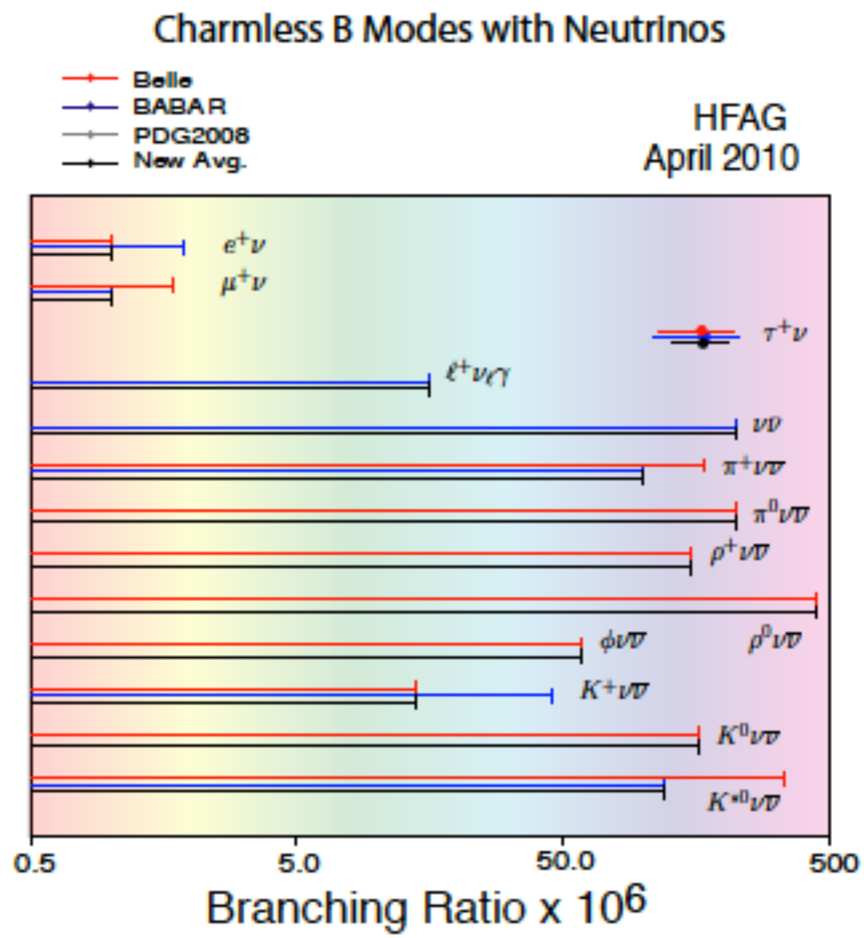
same conclusion from UTfit analysis Phys.Lett.B 687, 61 (2010)



$BR(B\rightarrow\tau\nu)_{exp} = (1.74 \pm 0.34)\cdot 10^{-4}$

$BR(B\rightarrow\tau\nu)_{UTfit} = (0.79 \pm 0.07)\cdot 10^{-4}$

Summary of leptonic B decay results



Most precise CKM test is from the unitarity condition:

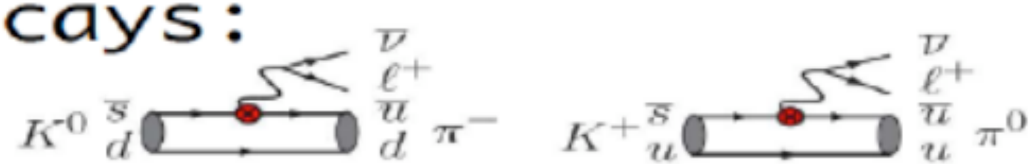
$$|V_{ud}|^2 + |V_{us}|^2 + |V_{ub}|^2 = 1$$

From the 1st row of the CKM matrix

- $|V_{ub}|$ is negligible in comparison to $|Vud|$ ~1 and $|V_{us}|$ ~0.2
- $|V_{ud}|$=0.97425(22) is most precisely obtained from super-allowed nuclear beta decay
- $|V_{us}|$ is most precisely obtained from Kaon decays

$|V_{us}|$ from kaons

Kl3 decays:



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

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

$$\Gamma_{K_{\ell 3}} = \frac{G_F^2 m_K^5}{192\pi^3} C_K^2 S_{\rm EW} \left(|V_{us}| f_+^{K^0\pi^-}(0)\right)^2 I_{K\ell}\left(1 + \delta_{\rm EM}^{K\ell} + \delta_{\rm SU(2)}^{K\pi}\right)^2$$

Kl2 decays:

$\Rightarrow \frac{|V_{us}|}{|V_{ud}|} \frac{F_K}{F_\pi}$

- $|V_{us}|/|V_{ud}| \times f_K/f_\pi$.

$$\frac{\Gamma_{K_{\ell 2}}}{\Gamma_{\pi_{\ell 2}}} = \frac{|V_{us}|^2}{|V_{ud}|^2} \frac{f_K^2}{f_\pi^2} \frac{m_K(1 - m_\ell^2/m_K^2)^2}{m_\pi(1 - m_\ell^2/m_\pi^2)^2} (1 + \delta_{\rm EM})$$

$|V_{us}|$ from kaons

KLOE, BNL-E865, KTeV, ISTRA+ and NA48

$$|V_{us}| = 0.2254(13), \quad |V_{us}|/|V_{ud}| = 0.2312(13), \quad |V_{ud}| = 0.97425(22)$$

Fit with no CKM unitarity constraint:

$$|V_{us}| = 0.2253(9), \quad |V_{ud}| = 0.97425(22)$$

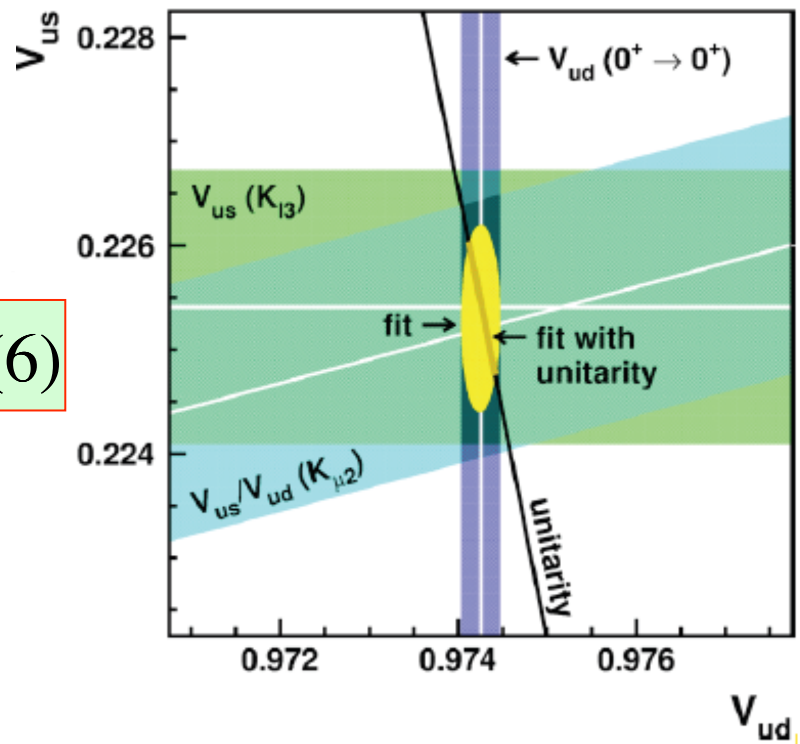
$$\chi^2/\text{dof} = 0.014/1 \ (91\%)$$

$$|V_{us}|^2 + |V_{us}|^2 + |V_{us}|^2 - 1 = -0.0001(6)$$

Fit with CKM unitarity constraint:

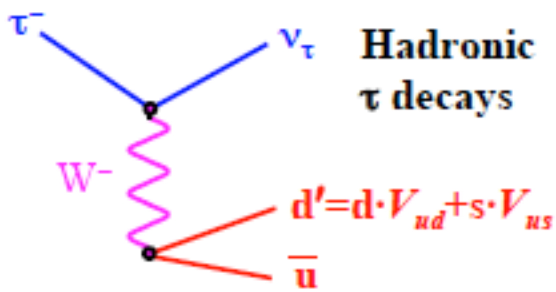
$$|V_{us}| = 0.2254(6)$$

$$\chi^2/\text{dof} = 0.024/2 \ (99\%)$$



this analysis from **Antonelli et al arXiv:1005.2323** (hep-ph 2010)
(uses f_K/f_π = 1.193(6))

$|V_{us}|$ from inclusive tau decays to kaons: $\tau^{+} \rightarrow X_s \nu_\tau$



Hadronic τ decays

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

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

OPE = Operator Product Expansion

FESR = Finite Energy Sum Rules

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

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

$|V_{us}|$ from inclusive tau decays to kaons: $\tau^+ \to X_s \nu_\tau$

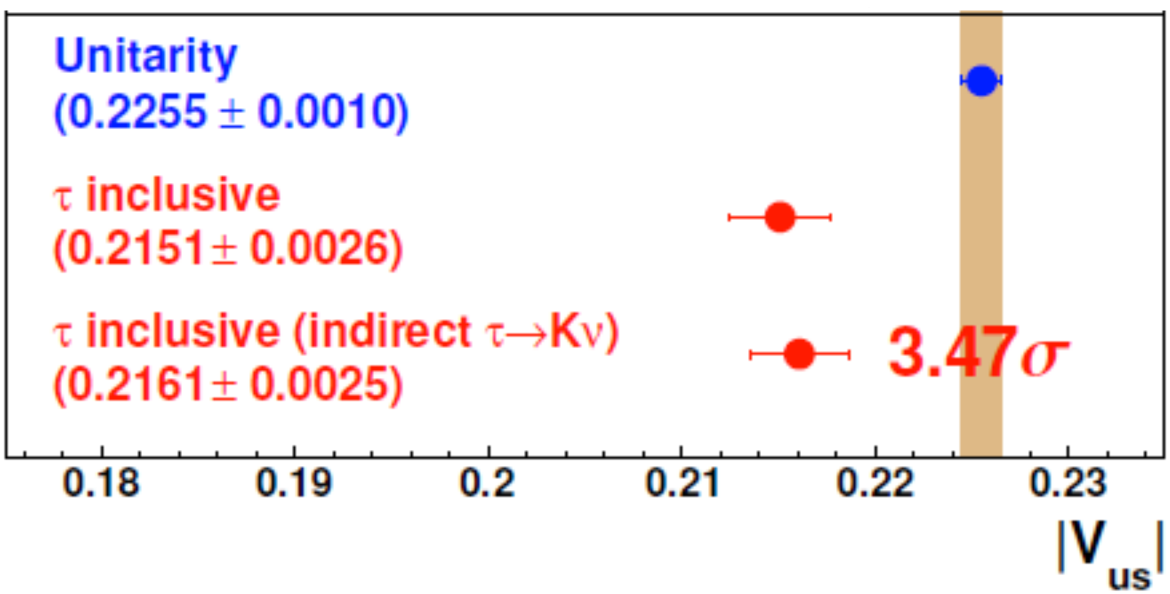
Decay Mode	Experiment	Reference	Result
$(\tau^- \to K^- \nu)/(\tau^- \to e^- \bar{\nu} \nu)$	BaBar	arXiv:0912.0242 [hep-ex]	$(0.03882 \pm 0.00032 \pm 0.00057)$
			$\mid g_\tau / g_\mu \mid = (0.9836 \pm 0.0087)$
$\tau^- \to K^- \pi^0 \nu$	BaBar	Phys.Rev.D76:051104,2007	$(0.416 \pm 0.003 \pm 0.018) \times 10^{-2}$
$\tau^- \to \bar{K}^0 \pi^- \nu$	BaBar	arXiv:0808.1121 [hep-ex]	$(0.840 \pm 0.004 \pm 0.023) \times 10^{-2}$
	Belle	Phys.Lett.B654:65-73,2007	$(0.808 \pm 0.004 \pm 0.026) \times 10^{-2}$
$\tau^- \to \bar{K}^0 \pi^- \pi^0 \nu$	BaBar	arXiv:0910.2884 [hep-ex]	$(0.342 \pm 0.006 \pm 0.015) \times 10^{-2}$
$\tau^- \to K^- \pi^- \pi^+ \nu$ (excl. K_S^0)	BaBar	Phys.Rev.Lett.100:011801,2008	$(0.273 \pm 0.002 \pm 0.009) \times 10^{-2}$
	Belle	arXiv:1001.0083 [hep-ex]	$(0.330 \pm 0.001 {}^{+0.016}_{-0.017}) \times 10^{-2}$
$\tau^- \to K^- \pi^- K^+ \nu$	BaBar	Phys.Rev.Lett.100:011801,2008	$(1.346 \pm 0.010 \pm 0.036) \times 10^{-3}$
	Belle	arXiv:1001.0083 [hep-ex]	$(1.55 \pm 0.01 {}^{+0.06}_{-0.05}) \times 10^{-3}$
$\tau^- \to K^- K^- K^+ \nu$	BaBar	Phys.Rev.Lett.100:011801,2008	$(1.58 \pm 0.13 \pm 0.12) \times 10^{-5}$
	Belle	arXiv:1001.0083 [hep-ex]	$(3.29 \pm 0.17 {}^{+0.19}_{-0.20}) \times 10^{-5}$
$\tau^- \to K^- \phi \nu$	BaBar	Phys.Rev.Lett.100:011801,2008	$(3.39 \pm 0.20 \pm 0.28) \times 10^{-5}$
	Belle	Phys.Lett.B643:5-10,2006	$(4.05 \pm 0.25 \pm 0.26) \times 10^{-5}$
$\tau^- \to K^{\bullet} K^- \nu$	Belle	arXiv:0808.1059 [hep-ex]	$(1.56 \pm 0.02 \pm 0.09) \times 10^{-3}$
$\tau^- \to K^{\bullet} K^- \pi^0 \nu$	Belle	arXiv:0808.1059 [hep-ex]	$(2.39 \pm 0.46 \pm 0.26) \times 10^{-5}$
$\tau^- \to K^- \eta \nu$	Belle	Phys.Lett.B672:209-218,2009	$(1.58 \pm 0.05 \pm 0.09) \times 10^{-4}$
$\tau^- \to K^- \pi^0 \eta \nu$	Belle	Phys.Lett.B672:209-218,2009	$(4.6 \pm 1.1 \pm 0.4) \times 10^{-5}$
$\tau^- \to K_S^0 \pi^- \eta \nu$	Belle	Phys.Lett.B672:209-218,2009	$(4.4 \pm 0.7 \pm 0.2) \times 10^{-5}$
$\tau^- \to K^{\bullet -} \eta \nu$	Belle	Phys.Lett.B672:209-218,2009	$(1.34 \pm 0.12 \pm 0.09) \times 10^{-4}$

Belle and BaBar measured many modes with significantly higher precision than previous world averages from LEP and CLEO. Measurements are consistent with previous measurements, but slightly lower.

$|V_{us}|$ from inclusive tau decays to kaons: $\tau^+ \to X_s \nu_\tau$

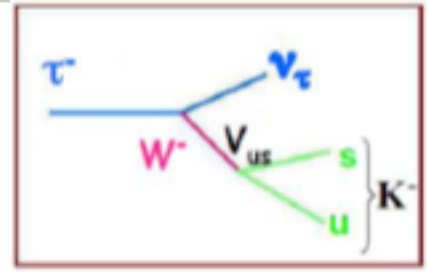
Use $\delta R^{00} = 0.240 \pm 0.032$ (Gamiz et al., 2007)

$$|V_{us}| = 0.2151 \pm 0.0026$$



$|V_{us}|$ from $\tau^- \to K^- \nu_\tau$

BABAR (arXiv:0912.0242)



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

$f_K = 157 \pm 2$ MeV

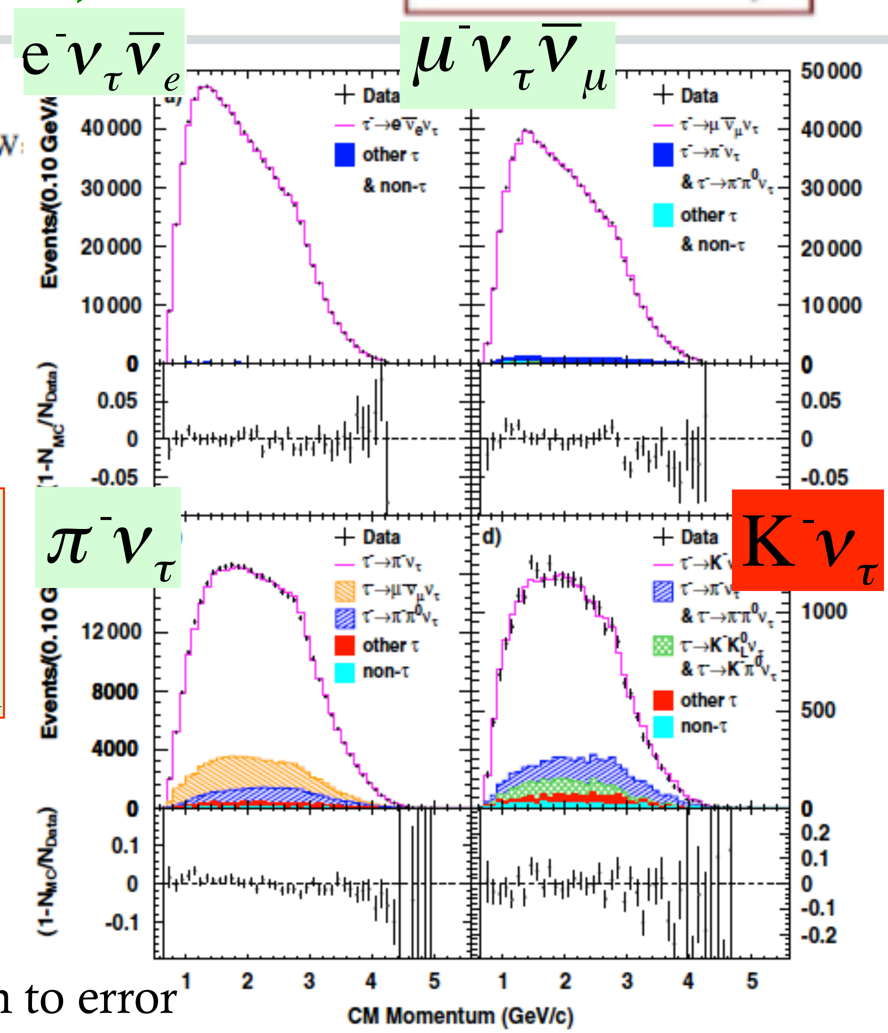
E. Follana, et al, PRL 100, 062002 (2008).

Branching Ratios
$B(\tau\to\pi\nu_\tau)/B(\tau\to e\nu_\tau\bar{\nu}_e)$
$(5.945\pm0.014\pm0.061)\times10^{-1}$
$B(\tau\to K\nu_\tau)/B(\tau\to e\nu_\tau\bar{\nu}_e)$
$(3.882\pm0.032\pm0.056)\times10^{-2}$
$B(\tau\to K\nu_\tau)/B(\tau\to\pi\nu_\tau)$
$(6.531\pm0.056\pm0.093)\times10^{-2}$

← 1.8σ lower than $\pi \to \mu\nu$ prediction

← 1.8σ lower than $K \to \mu\nu$ prediction

$|V_{us}| = 0.2193 \pm 0.0032$



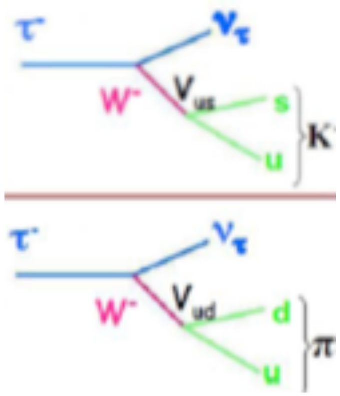
lattice and experimental: similar contribution to error

Value within 1 σ of exclusive |Vus| and within 2 σ of unitarity

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

BABAR (arXiv:0912.0242)

Improve lattice error by taking ratio:



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

Using : $f_K / f_\pi = 1.189 \pm 0.007$ MeV

E. Follana, et al, PRL 100, 062002 (2008)

$|V_{ud}| = 0.97425\ (22)$

$$|V_{us}| = 0.2255 \pm 0.0024$$

Consistent with unitarity

Summary and Prospects

- Flavour sector provides a means of probing physics beyond the SM at the precision frontier
- The SM describes the flavour data, but there are seen a few 'tensions' in the flavour sector requiring attention
- Looking forward to new data from LHCb and in the future SuperB and SuperKEKB