Leptonic Decays of the $B^{\pm}$

Results from the B factories

Roger Barlow
Manchester University

BELLE

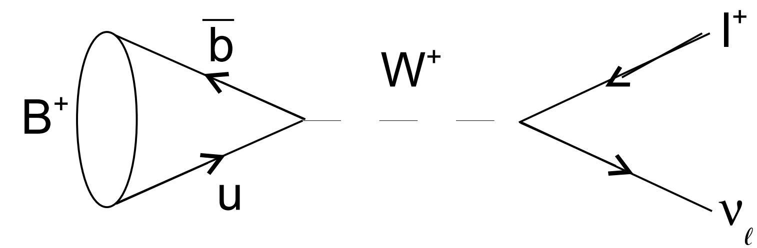
CKM 2010

Contents

- Theory – SM and beyond
- Limits on $B \to e\nu$, $B \to \mu\nu$
- Measurement of $B \to \tau\nu$
- Implications

The basics

$$Br(B\to l\nu)=\frac{G_F^2 m_B}{8\pi} m_l^2 \left(1-\frac{m_l^2}{m_B^2}\right)^2 f_B^2 |V_{ub}|^2 \tau_B$$

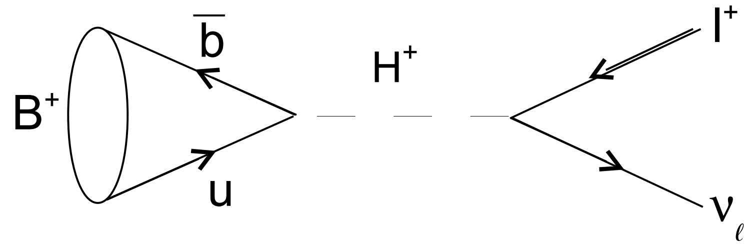


Expected BR ~10^{-4} for $B\to\tau\nu$

Much smaller for $B\to\mu\nu$, $B\to e\nu$ due to helicity suppression

Analyses use up to 468M $B\bar{B}$ pairs (BaBar), 657M pairs (Belle)

Higgs Models



2HDM (W S Hou PRD 48 (1993) 2342)

$$Br(B\to l\nu)=\frac{G_F^2 m_B}{8\pi} m_l^2\left(1-\frac{m_l^2}{m_B^2}\right)^2 f_B^2|V_{ub}|^2\tau_B\times\left(1-\tan^2\beta\,\frac{m_B^2}{m_H^2}\right)^2$$

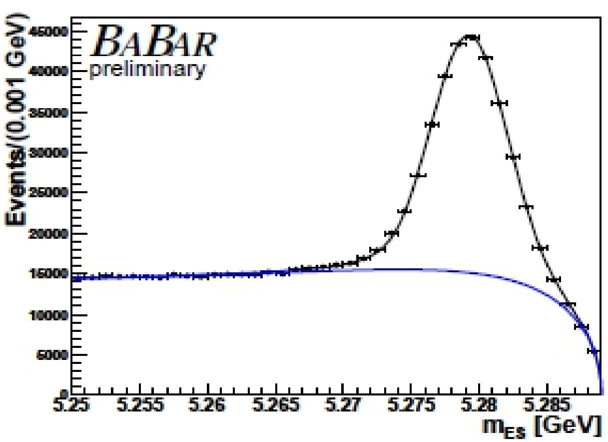
SUSY (A G Akeroyd and S Recksiegel, J Phys G 29 (2003) 2311)

$$Br(B\to l\nu)=\frac{G_F^2 m_B}{8\pi} m_l^2\left(1-\frac{m_l^2}{m_B^2}\right)^2 f_B^2|V_{ub}|^2\tau_B\times\left(1-\frac{\tan^2\beta}{1+\bar{\epsilon}_0\tan\beta}\,\frac{m_B^2}{m_H^2}\right)^2$$

B tagging

Final state neutrino(s) undetectable: Decays not reconstructable on their own.
Tagging technique: B mesons produced in pairs: reconstruct one, and the rest of the event must be a B

<u>Hadronic B decay tags</u>
Identify $K^{\pm}, \pi^{\pm}, K^0, \pi^0$
Construct D, D* or J/ψ
Reconstruct B mass
Efficiency ~ 10^{-3}



<u>Semileptonic B decay tags</u>
Identify $K^{\pm}, \pi^{\pm}, K^0, \pi^0$
Construct D^0 or D^{0*}
High momentum lepton(e or μ)
Efficiency ~ 10^{-2}

Both tag methods used

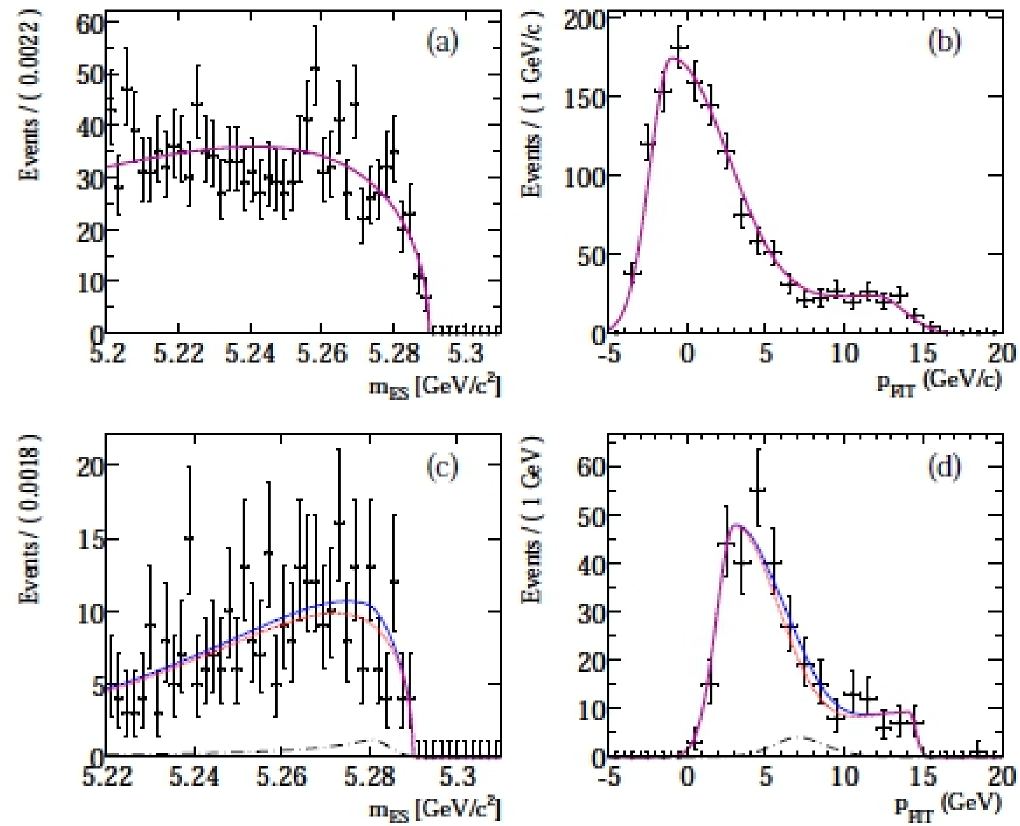
Details of cuts depend on analysis channel

Also whether tagging follows signal or signal follows tag

$B^\pm \to e^\pm \nu$ and $B^\pm \to \mu^\pm \nu$

No events seen
Limit (90% Bayesian CL)
1.0×10^{-6} for muons – above SM value 5×10^{-7}
1.9×10^{-6} for electrons – well above SM value 1×10^{-11}

Belle reports limits
1.7×10^{-6} for muons
0.98×10^{-6} for electrons



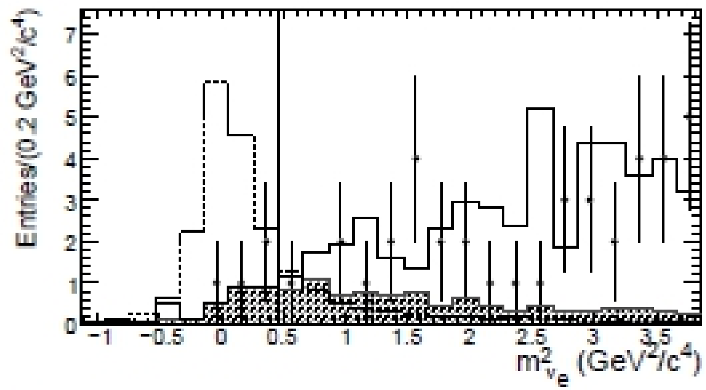
Hadronic tag: Phys.Rev.D79:091101,2009. arXiv:0903.1220
Semileptonic tag: Phys.Rev.D81:051101,2010 arXiv :0809.4027

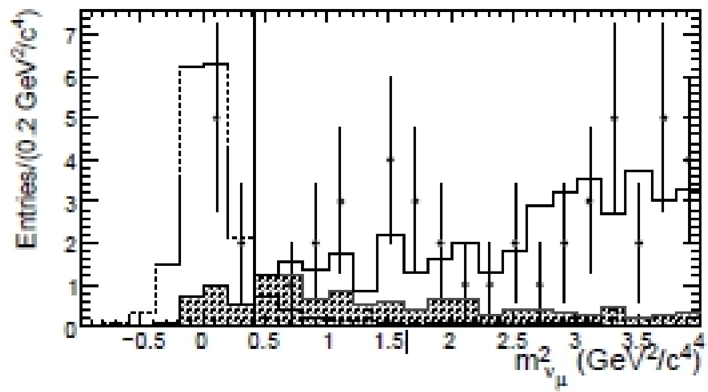
$B^\pm \to e^\pm \gamma \nu$ and $B^\pm \to \mu^\pm \gamma \nu$

Radiating a photon can evade the helicity suppression – but introduces an extra α_{EM}.

SM prediction of order 10^{-6}.

Find B tag
Require only one extra charged track, identified as e or μ
Search for high energy photon
Reconstruct neutrino mass





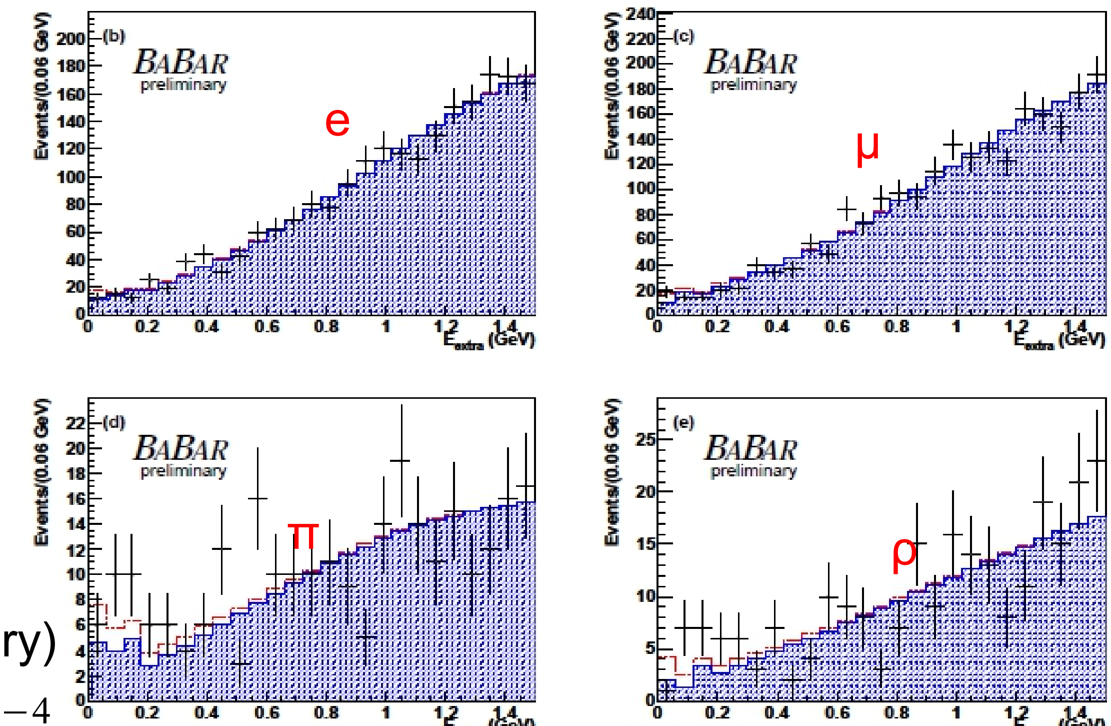
See 4 μγν and 7 eγν events – expected backgrounds 2.7 and 3.4
Combined model-independent 90% CL limit 15.6 x 10^{-6}

PhysRevD.80.111105 arXiv 0907.1681

$B^{\pm} \to \tau^{\pm} \nu$: BaBar results

Find tag (hadronic or semileptonic)
Identify tau remnant(s)
Look at the extra EM energy
Signal is excess near zero

Extra energy: Hadronic tag
For 4 separate tau decay modes



Chief systematic uncertainty:
Background PDF

Consistent Excess in all 4 channels

Combined hadronic tag result (preliminary)

$$Br(B \to \tau \nu) = \left(1.80^{+0.57}_{-0.54} \pm 0.26\right) \times 10^{-4}$$

arXiv1008.0104

Combined semileptonic tag result

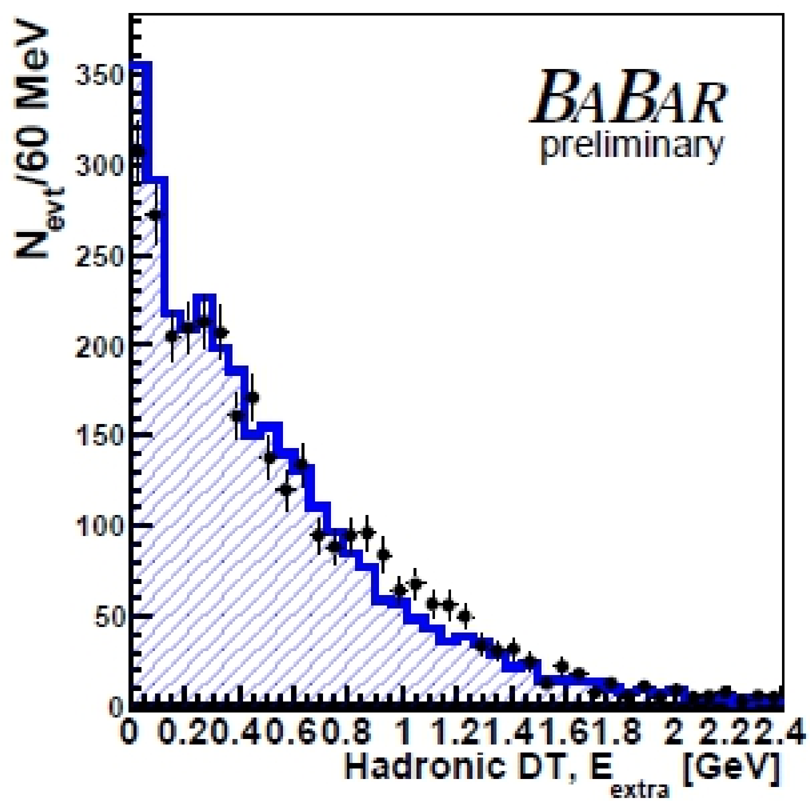
$$Br(B \to \tau \nu) = \left(1.7 \pm 0.8 \pm 0.2\right) \times 10^{-4}$$

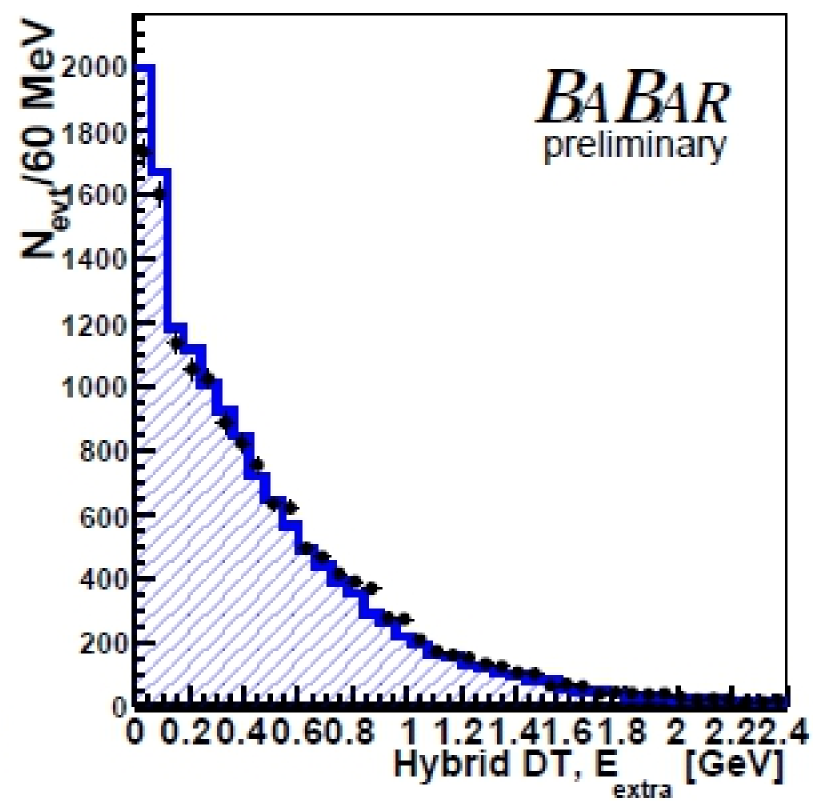
PRD81,051101(2010)

Mode	Value x 10^{-4}	Significance
e	$0.39^{+0.89}_{-0.79}$	0.5 σ
μ	$1.23^{+0.89}_{-0.80}$	1.6 σ
π	$4.0^{+1.5}_{-1.3}$	3.3 σ
ρ	$4.3^{+2.2}_{-1.9}$	2.6 σ
Total	$1.80^{+0.57}_{-0.54}$	3.6 σ

Consistency check

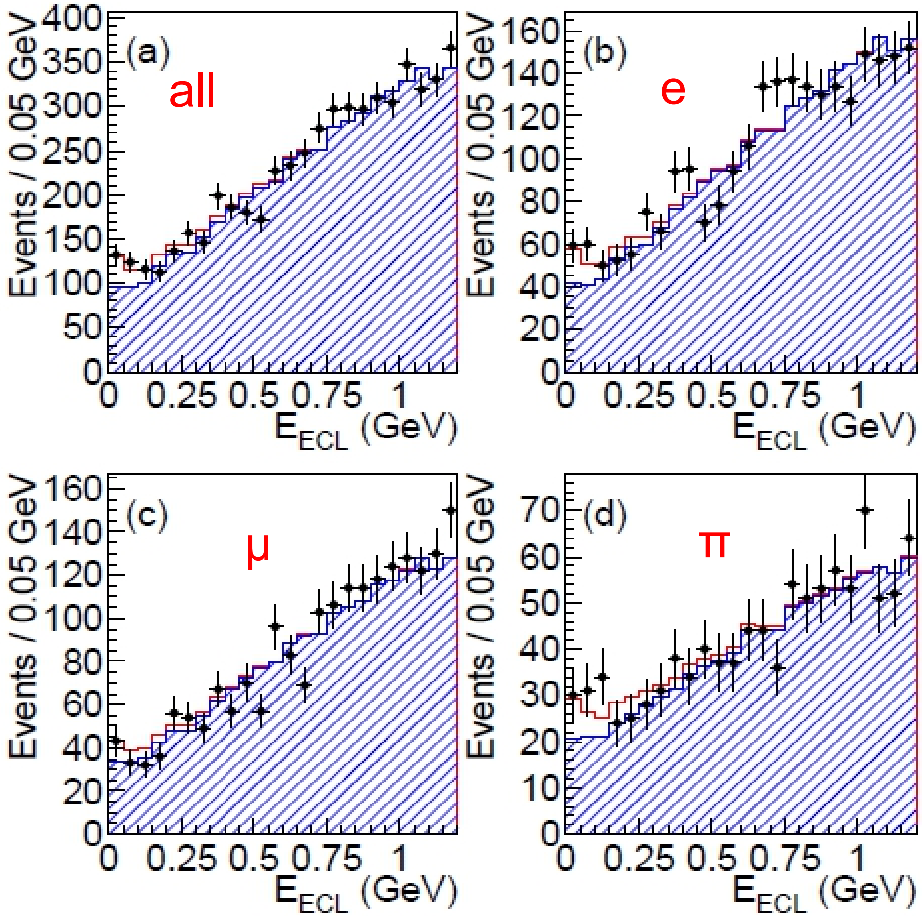
Extra EM energy for double-tagged events
Hadronic-hadronic and hadronic-semileptonic
Excellent data/MC agreement validates E_{extra} as a discriminator variable





Belle results

Plot shows excess energy for all taus and for decays to e, mu,pi channels with semileptonic tags



Combined hadronic tag result

$$Br(B\to\tau\nu)=\left(1.79^{+0.56\,+0.46}_{-0.49\,-0.51}\right)\times 10^{-4}$$

PRL97,251802(2006)

Combined semileptonic tag result

$$Br(B\to\tau\nu)=\left(1.54^{+0.38\,+0.29}_{-0.37\,-0.31}\right)\times 10^{-4}$$

arXiv 1006.4201

Combination

BaBar hadronic tag: $(1.80^{+0.57}_{-0.54} \pm 0.26) \times 10^{-4}$ Preliminary. NEW

BaBar semileptonic tag: $(1.7 \pm 0.87 \pm 0.2) \times 10^{-4}$

BaBar combined result: $(1.76 \pm 0.49) \times 10^{-4}$

Belle hadronic tag $(1.79^{+0.56}_{-0.49}\ {}^{+0.46}_{-0.51}) \times 10^{-4}$

Belle semileptonic tag $(1.54^{+0.38}_{-0.37}\ {}^{+0.29}_{-0.31}) \times 10^{-4}$ NEW

Combined result: $(1.64 \pm 0.34) \times 10^{-4}$ HFAG

Well established decay:
Consistent with SM prediction $(1.20 \pm 0.25) \times 10^{-4}$

$f_B = 190 \pm 13$ MeV (HPQCD)

$V_{ub} = (4.32 \pm 0.16 \pm 0.29) \times 10^{-3}$ (HFAG)

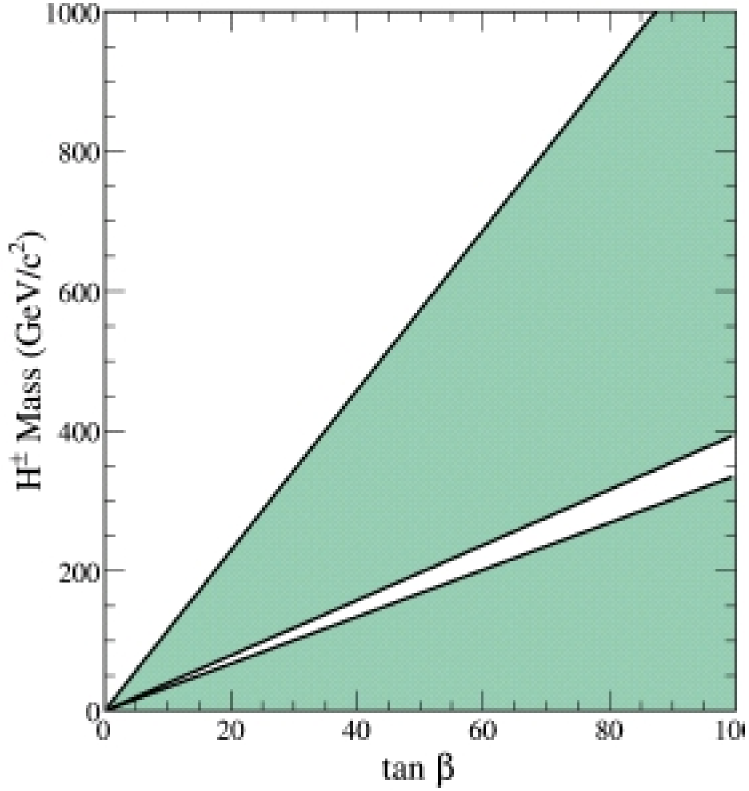
Higgs Limits

$$Br(B \rightarrow l\nu) = BR_{SM} \times \left(1 - \tan^2\beta \frac{m_B^2}{m_H^2}\right)^2$$

Simple 'Type II' 2HDM

Consistency means M_H is large or tan β is small
(Unless there is a quite implausible cancellation)

Other models are more complicated – but this result rules out large tan β values



Plot from Trabelsi @ ICHEP

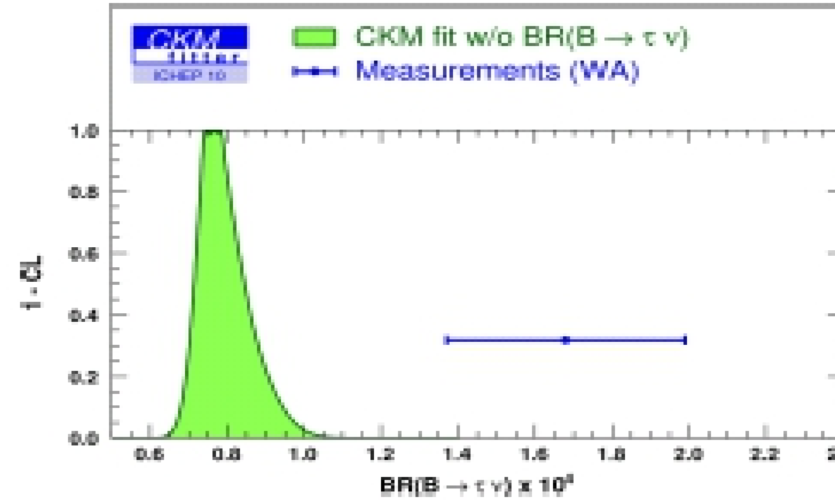
CKM results

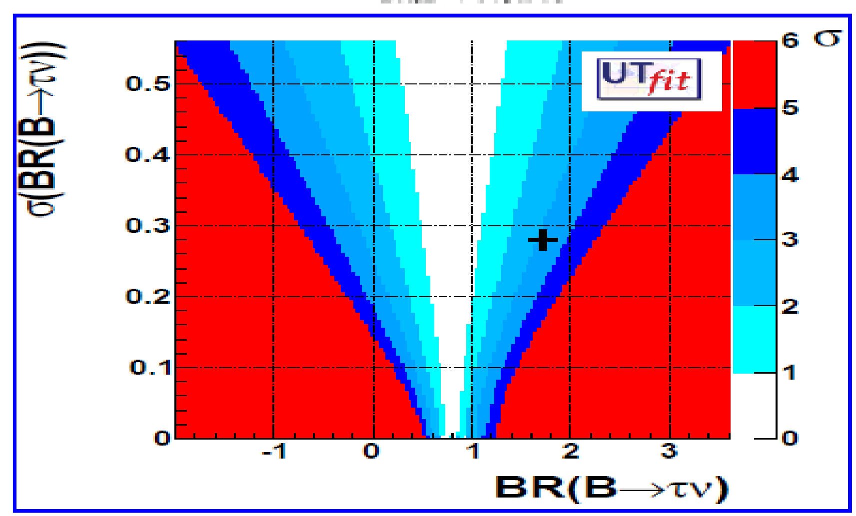
UTfit: prediction (Tarantino's ICHEP talk)
Br= $(0.805 \pm 0.071) \times 10^{-4}$

CKMfitter: prediction (T'Jampens ICHEP talk)
Br=$(0.763^{+0.114}_{-0.061}) \times 10^{-4}$

Fit to all measurements – f_B also fitted

Different statistical approach but similar message:
Tension between V_{ub} and sin 2β





Conclusions

Measurement of $B\rightarrow\tau\nu$ is a strong constraint on BSM models

<u>and</u> is a source of tension within the CKM fit

Measurements from BaBar and Belle will continue to improve somewhat – full dataset and improved techniques.

Super B factory will give 100 times the data, and make this a precision measurement.