Searches for Leptonic B-decays and $B\to D^{(*)}\tau\nu$ at the B-factories

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Heavy Quarks & Leptons
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Outline

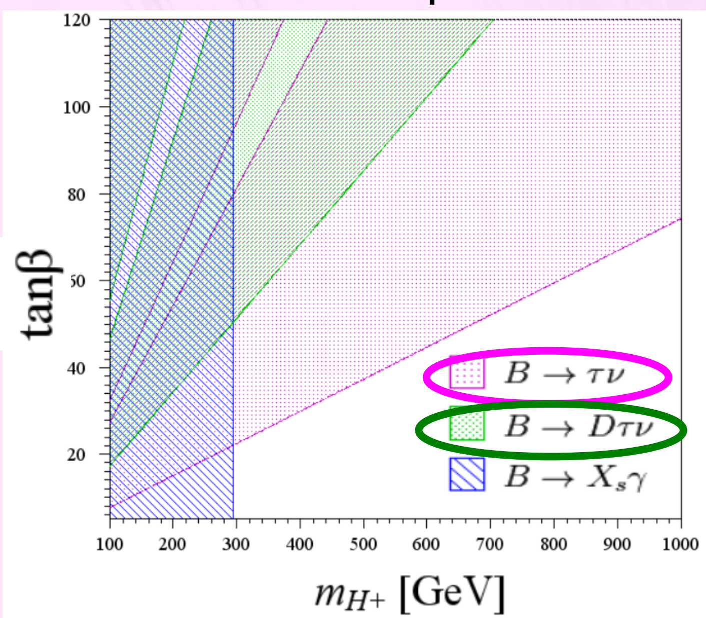
- Introduction & Motivation
- B Reconstruction Methodology
- Updates on BaBar and Belle searches for:
  - $B \to \tau\nu$
  - $B \to \ell\nu(\gamma)$
  - $B \to D^{(*)}\tau\nu$

Search for New Physics (NP)

Standard Model (SM) predictions in flavor sector successfully confirmed by B-factories!

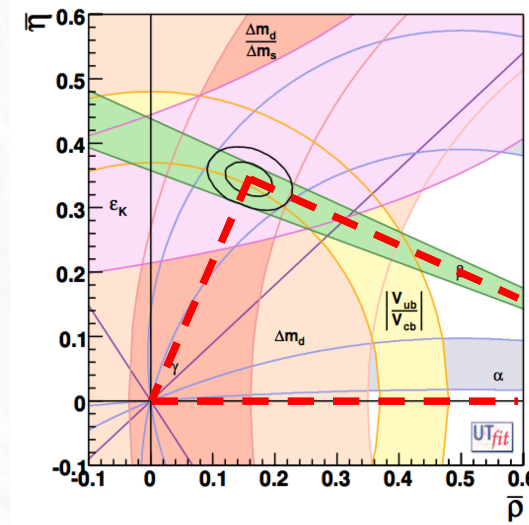
But discrepencies exist – is there a NP model that's better?

Goal: Compare experimental results with SM predictions to hopefully find evidence of NP and constrain NP parameters.

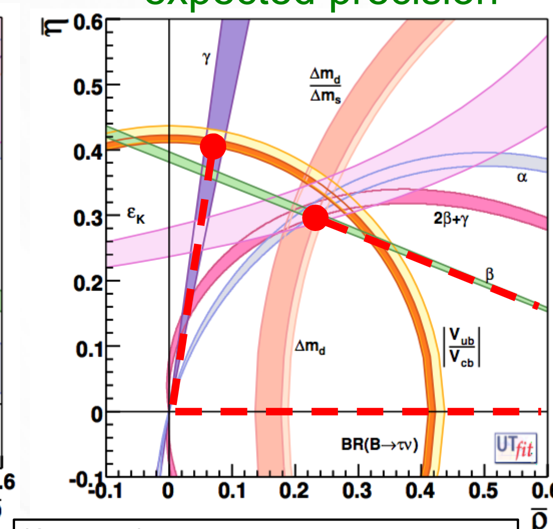


(UTfit) arXiv:0908:3470 [hep-ph]

Current Unitarity Triangle Fits: No major deviation from SM observed

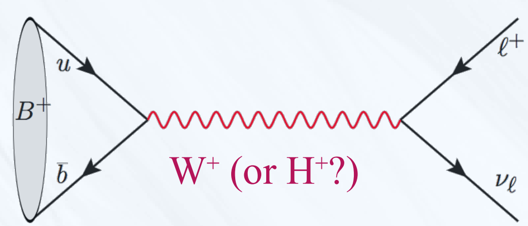


Current central values, with next generation B-factory expected precision

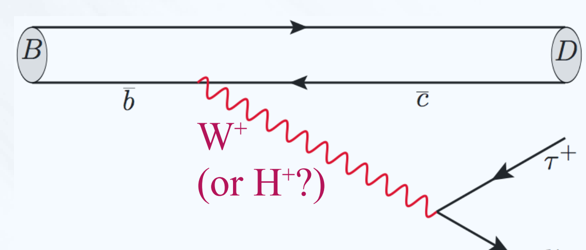


(SuperB) arXiv:0709.0451 [hep-ex]

- Non-SM particles can contribute at the same order as SM particles!



$B \to \ell\nu$



$B \to D^{(*)}\tau\nu$

- Hbu ($\tau\nu$) and Hbc ($D\tau\nu$) searches are complimentary to Htb searches at the LHC

Reconstruction Methods

Since both $B \to D^{(*)}\tau\nu$ and $B \to \ell\nu$ have (several) final-state neutrinos, we exploit our $\Upsilon(4S) \to B\bar{B}$ production by reconstructing a "B_{tag}" in two ways:

"Exclusive" Analysis

1. Fully reconstruct B_{tag} via $B \to D^{(*)0} X$
2. Check if remaining particles are consistent with signal decay

Provides a clean sample

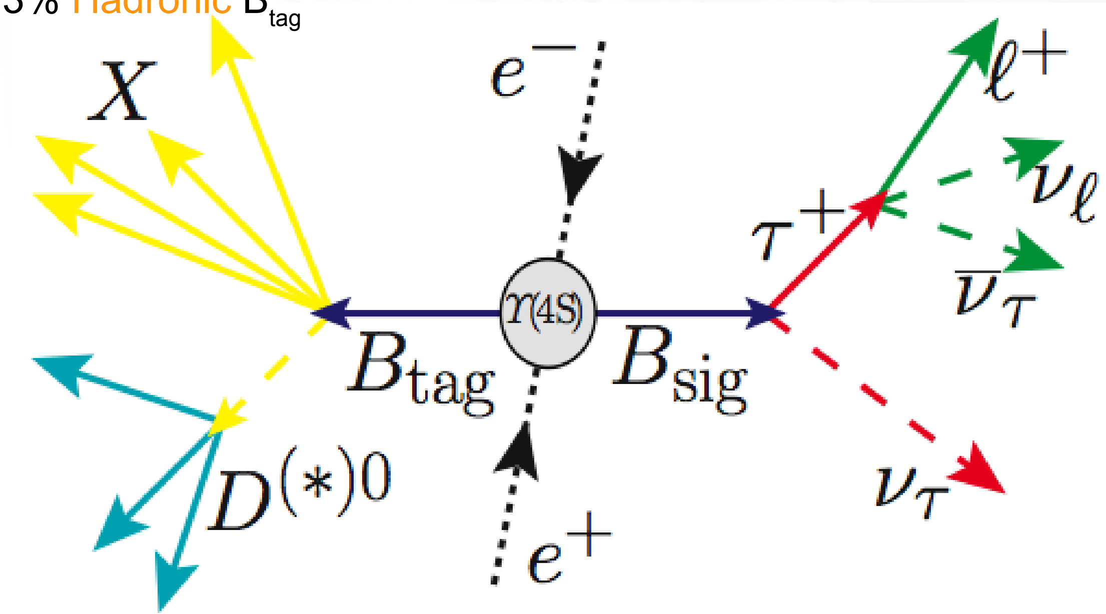
Low reconstruction efficiency
~1% Semi-Leptonic B_{tag}
~0.3% Hadronic B_{tag}

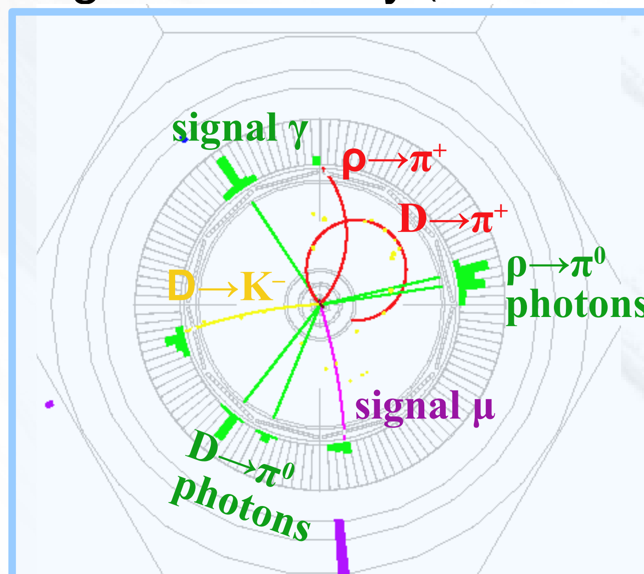
"Inclusive" Analysis

1. Select signal decay products
2. Check if remaining particles are consistent with B_{tag}

Larger backgrounds

Higher signal efficiency (~5% for $B \to \ell\nu$)





MC Signal event in BaBar detector:
$B^{+}_{sig} \to \mu^{+}\nu\gamma$ *and* $B^{-}_{tag} \to D^{0} \rho^{-}$

Reconstruction Methods (II)

Since both $B \to D^{(*)}\tau\nu$ and $B \to \ell\nu$ have (several) final-state neutrinos, we exploit our $\Upsilon(4S) \to B\bar{B}$ production by reconstructing a "B_{tag}" in two ways:

"Exclusive" Analysis

1. Fully reconstruct B_{tag} via $B \to D^{(*)0} X$
2. Check if remaining particles are consistent with signal decay

X=K's & π's → Hadronic B_{tag}; X=ℓν → Semi-leptonic B_{tag}

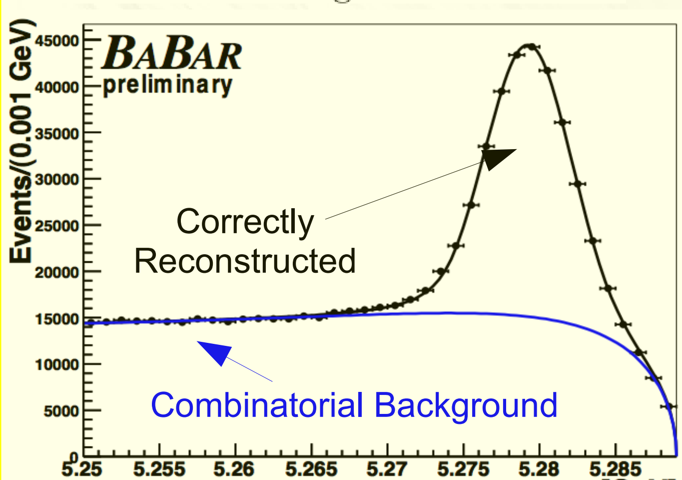
"Inclusive" Analysis

1. Select signal decay products
2. Check if remaining particles are consistent with B_{tag}

Hadronic B_{tag} (& Inclusive)

$$m_{ES} \equiv \sqrt{E^2_{\rm beam} - \vec{p}^{\,2}_{\rm B_{tag}}}$$

$$\Delta E \equiv E_{\rm B_{tag}} - E_{\rm beam}$$

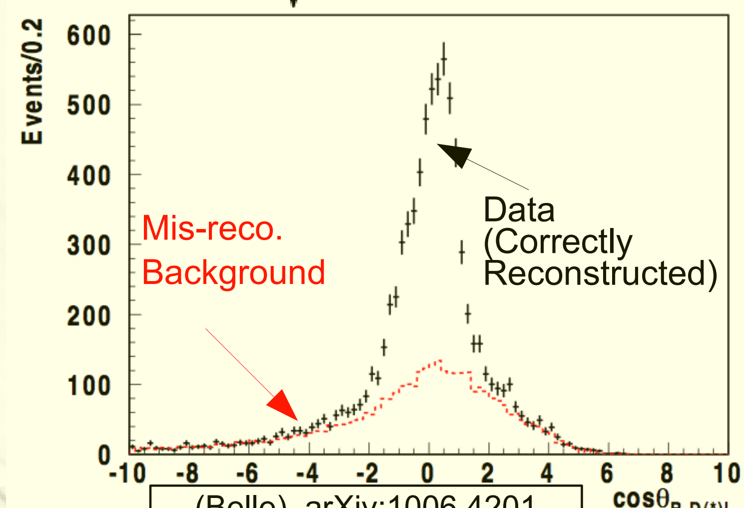


(BaBar) arXiv:1008.0104

Semi-leptonic B_{tag}

$$\cos\theta_{B,D\ell} = \frac{2E_{\rm beam}E_{D\ell} - m_B^2 - m_{D\ell}^2}{2|\vec{p}_{B_{\rm tag}}| \cdot |\vec{p}_{D^{(*)}\ell}|}$$

$$|\vec{p}_{B_{\rm tag}}| = \sqrt{E^2_{\rm beam} - m^2_{B_{\rm tag}}}$$



(Belle) arXiv:1006.4201

Search for $B \to \tau\nu$

B→τν: Theoretical Motivation

Provides clean predictions of SM parameters without hadronic (QCD) final-state uncertainties

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

Helicity suppression

$$\mathcal{B}(B \to \mu\nu)_{\mathrm{SM}} \approx 10^{-7}$$

$$\mathcal{B}(B \to e\nu)_{\mathrm{SM}} \approx 10^{-11}$$

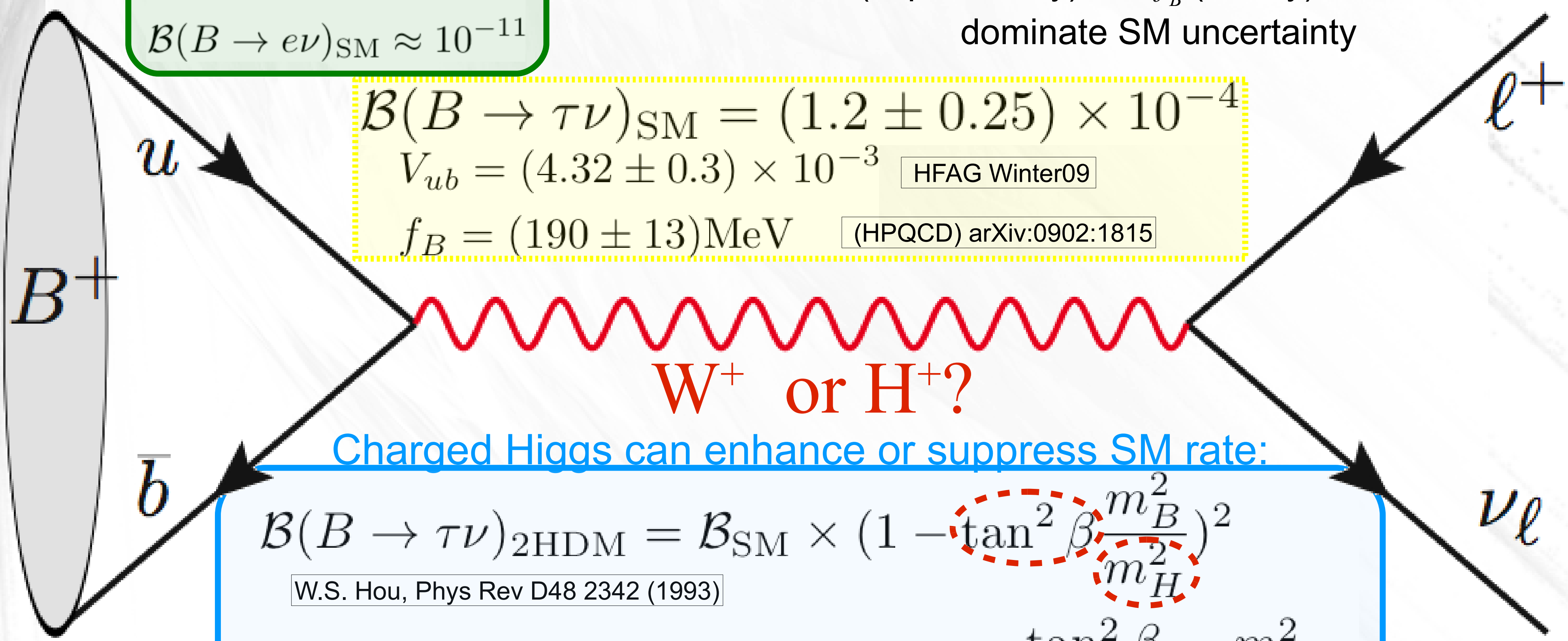
Experimental sensitivity to f_B assuming Vub

Vub (exp + theory) and f_B (theory) uncertainties dominate SM uncertainty

$$\mathcal{B}(B \to \tau\nu)_{\mathrm{SM}} = (1.2 \pm 0.25) \times 10^{-4}$$

$V_{ub} = (4.32 \pm 0.3) \times 10^{-3}$ HFAG Winter09

$f_B = (190 \pm 13)\mathrm{MeV}$ (HPQCD) arXiv:0902:1815



Charged Higgs can enhance or suppress SM rate:

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

W.S. Hou, Phys Rev D48 2342 (1993)

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

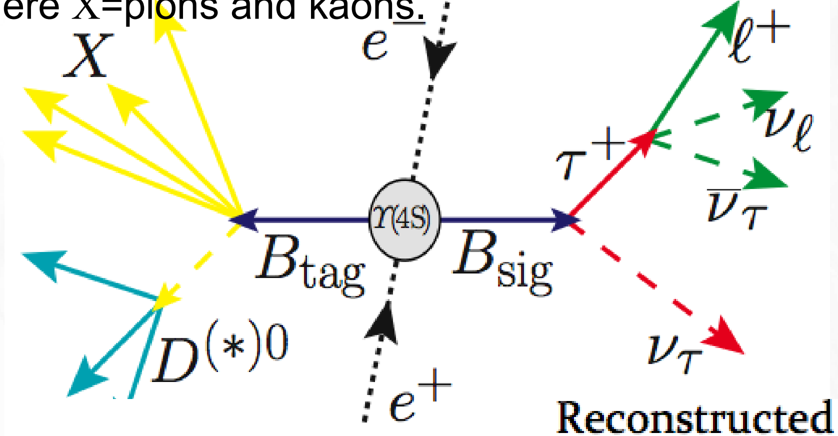
A.G. Akeroyd and S. Recksiegel, J. Phys G29 2311 (2003)

arXiv:1008.0104 (2010)
468 x10^6 $B\bar{B}$

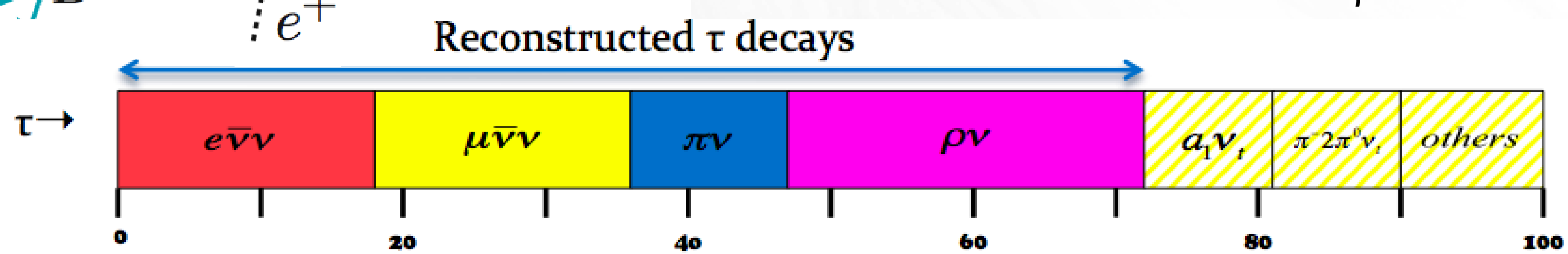
BaBar $B\to\tau\nu$ with Hadronic Tag

Reconstruct this side using $B_{tag}\to D^{(*)0}X$ and $B_{tag}\to J/\psi X$ where X=pions and kaons.

Find signal in this side

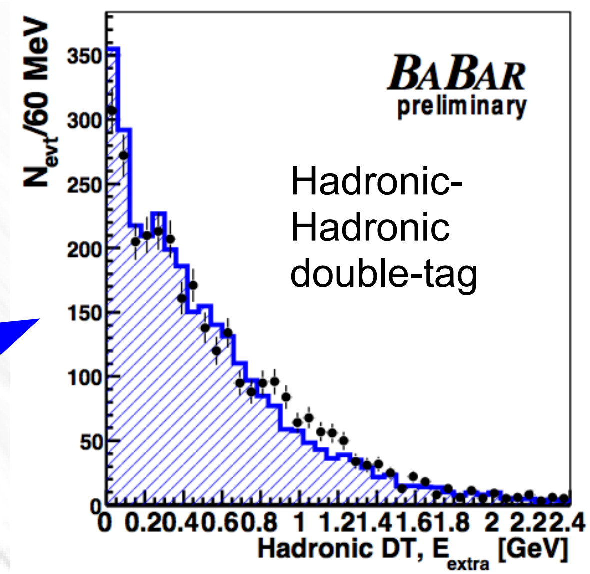


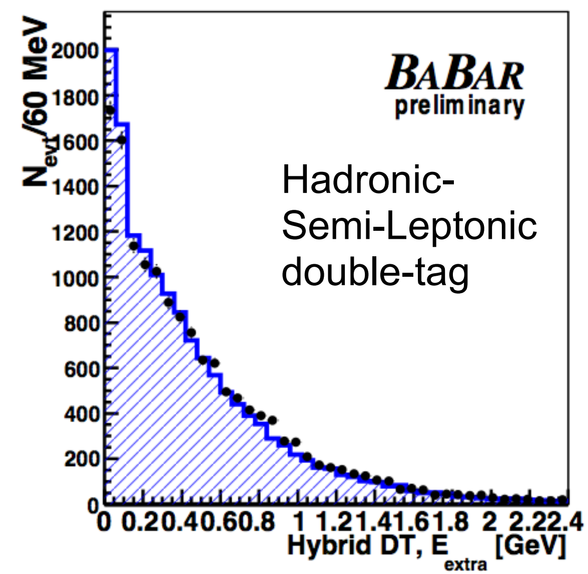
- Suppress continuum bkg using LHR of 3 event-shape variables
- Reconstruct ~70% of τ decay modes: $e\nu\bar{\nu}$, $\mu\nu\bar{\nu}$, $\pi\nu$, and $\rho\nu\to\pi^+\pi^0\nu$
  - Exactly 1 track, with requirements on its CM momentum for $e\nu\bar{\nu}$, $\mu\nu\bar{\nu}$, $\pi\nu$, and a 4-variable LHR for $\rho\nu$



Most discriminating variable:
E_{extra}

- Sum of all remaining energy in calorimeter should be zero!
- Validate E_{extra} with data using double-tagged samples

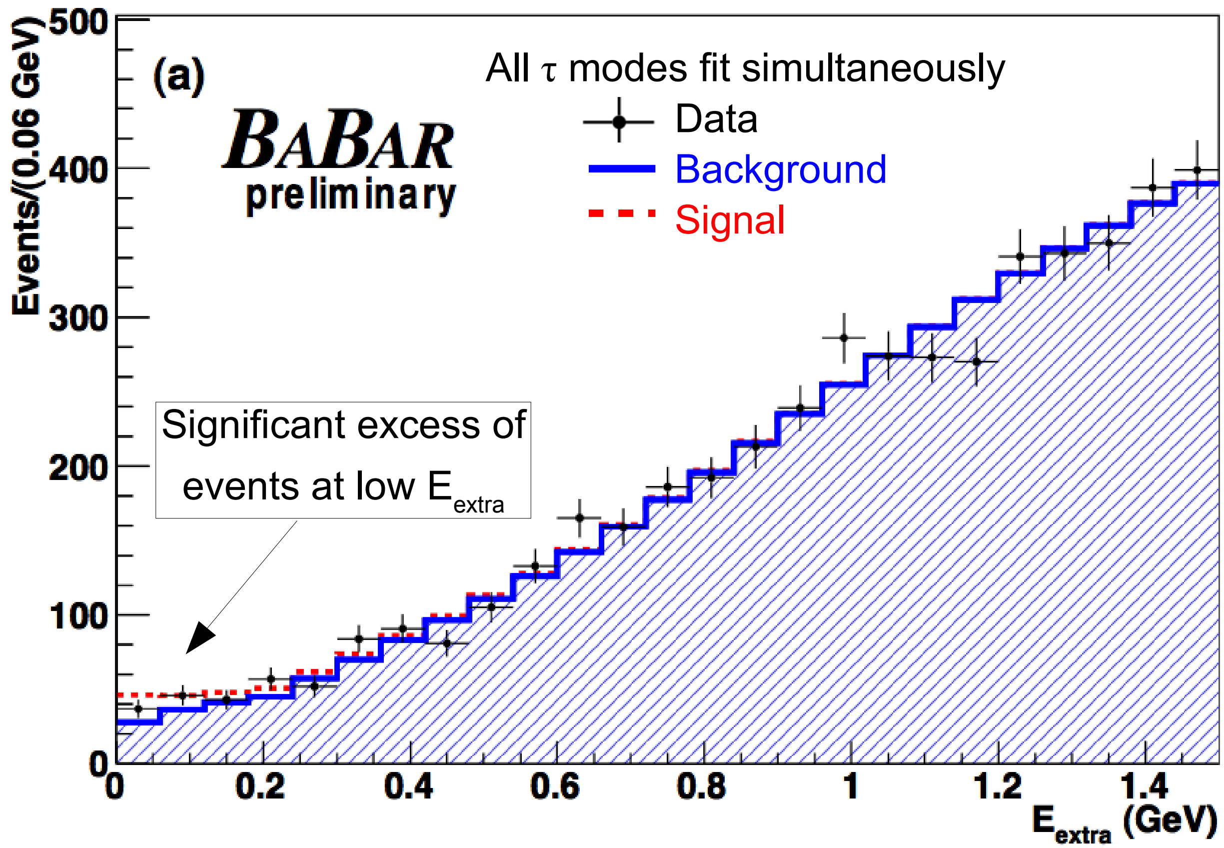




arXiv:1008.0104 (2010)
468 x10[6] $B\bar{B}$

BaBar $B\to\tau\nu$ with Hadronic Tag: Results

- Extract BF using unbinned maximum likelihood fit to E_{extra}
- Signal and peaking bkg PDFs from MC corrected for data/MC ratio using m_{ES} distribution. Combinatorial bkg PDF from m_{ES} sidebands in on-resonance data



Source of systematics	BF uncertainty (%)
B counting	0.5
Tag B efficiency	5.0
Background PDF	12
Signal PDF	1.7
MC statistics	0.8
Electron identification	2.6
Muon identification	4.7
Kaon identification	0.4
Tracking	1.4
Total	14

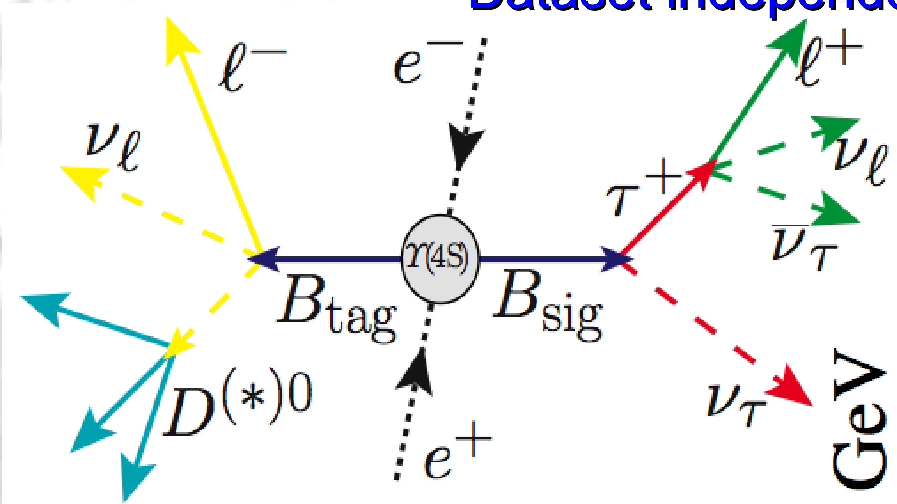
$$\mathcal{B}(B\to\tau\nu) = (1.80^{+0.57}_{-0.54} \pm 0.26)\times 10^{-4}$$

Exclusion of null hypothesis at 3.3 σ

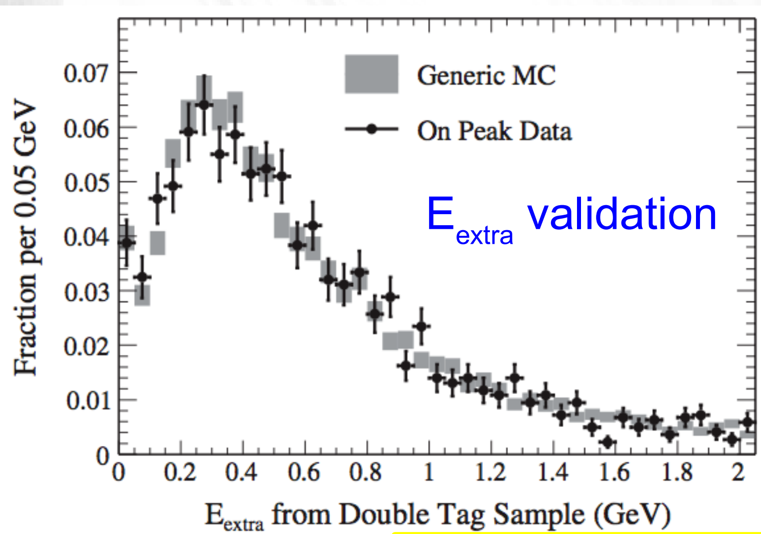
PRD81:051101 (2010)
459 x10^6 $B\overline{B}$

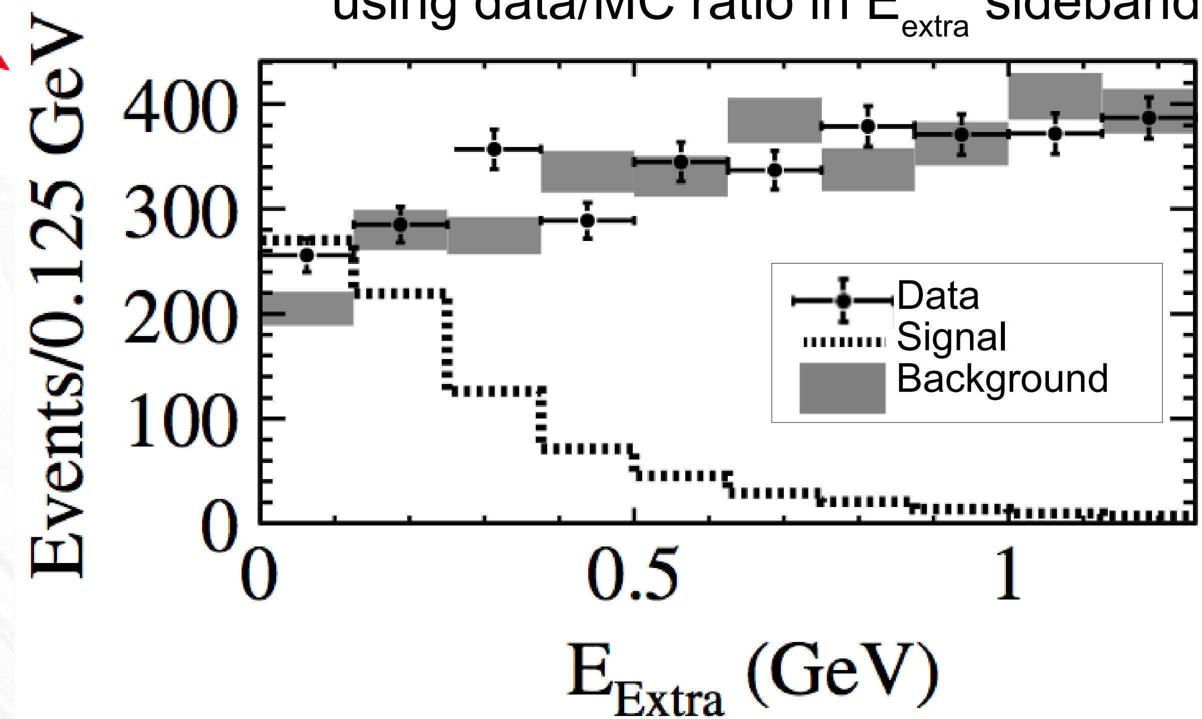
BaBar $B \to \tau\nu$ Semi-Leptonic Tag

Dataset independent from hadronic analysis!



- Reconstruct same 4 τ modes
- Applies signal, continuum and $B\overline{B}$ bkg LHR of many variables in MC
- Background prediction calibrated using data/MC ratio in E_{extra} sideband





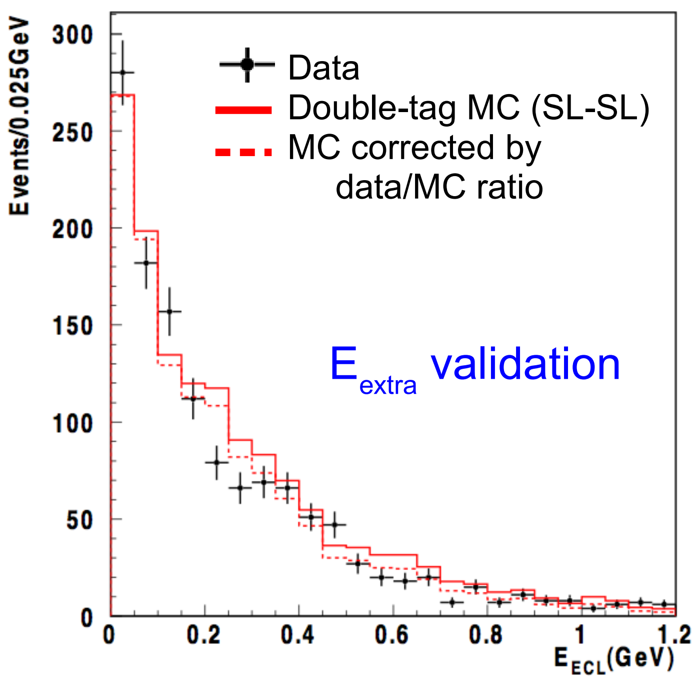
$$\mathcal{B}(B \to \tau\nu) = (1.7 \pm 0.8 \pm 0.2) \times 10^{-4}$$

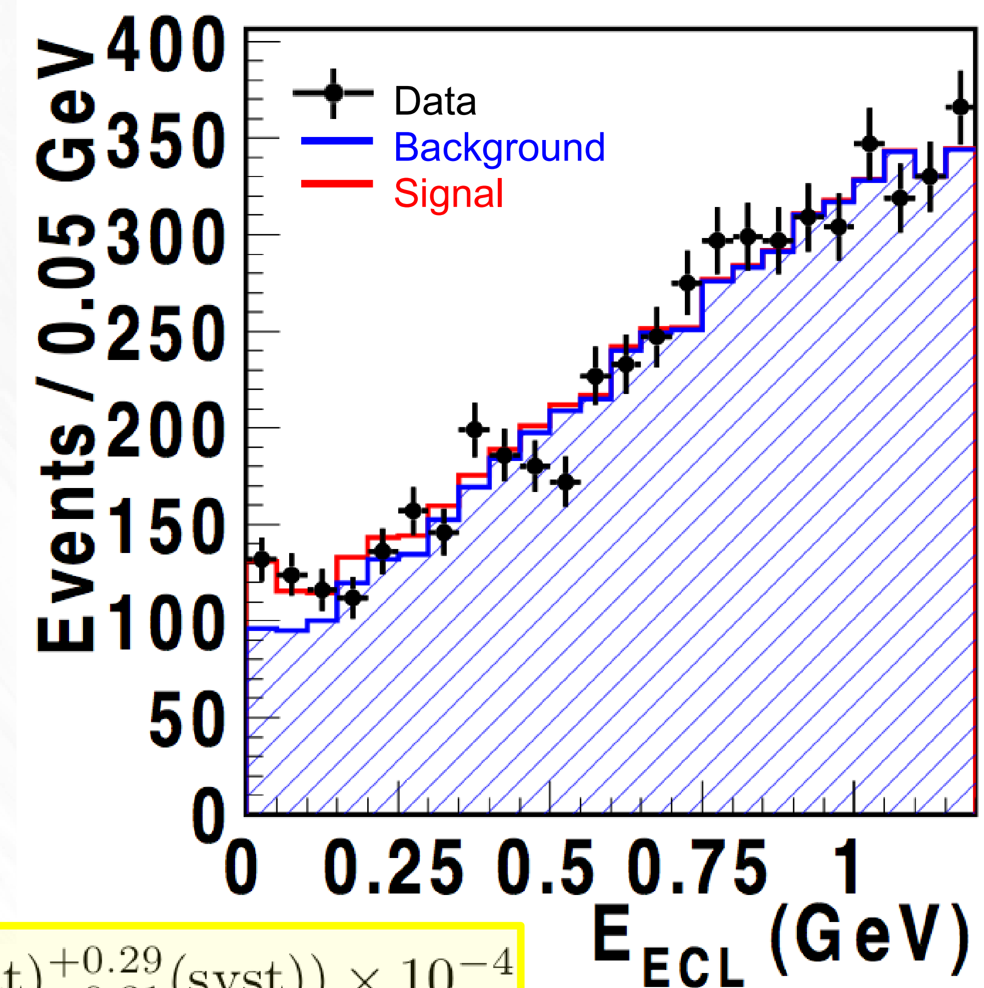
Exclusion of null hypothesis at 2.3 σ

arXiv:1006.4201 (2010)
657 x10⁶ B$\bar{B}$

Belle B→τν Semi-Leptonic Tag

- Reconstruct $e\nu\bar{\nu}$, $\mu\nu\bar{\nu}$, and $\pi\nu$ (50% of τ modes)
- Requirements on τ momentum and $\cos\theta_{B,D\ell}$
- MC corrected for data/MC ratio using double-tagged E_{extra}
- Signal and bkg PDFs from MC. Continuum MC corrected using off-resonance data



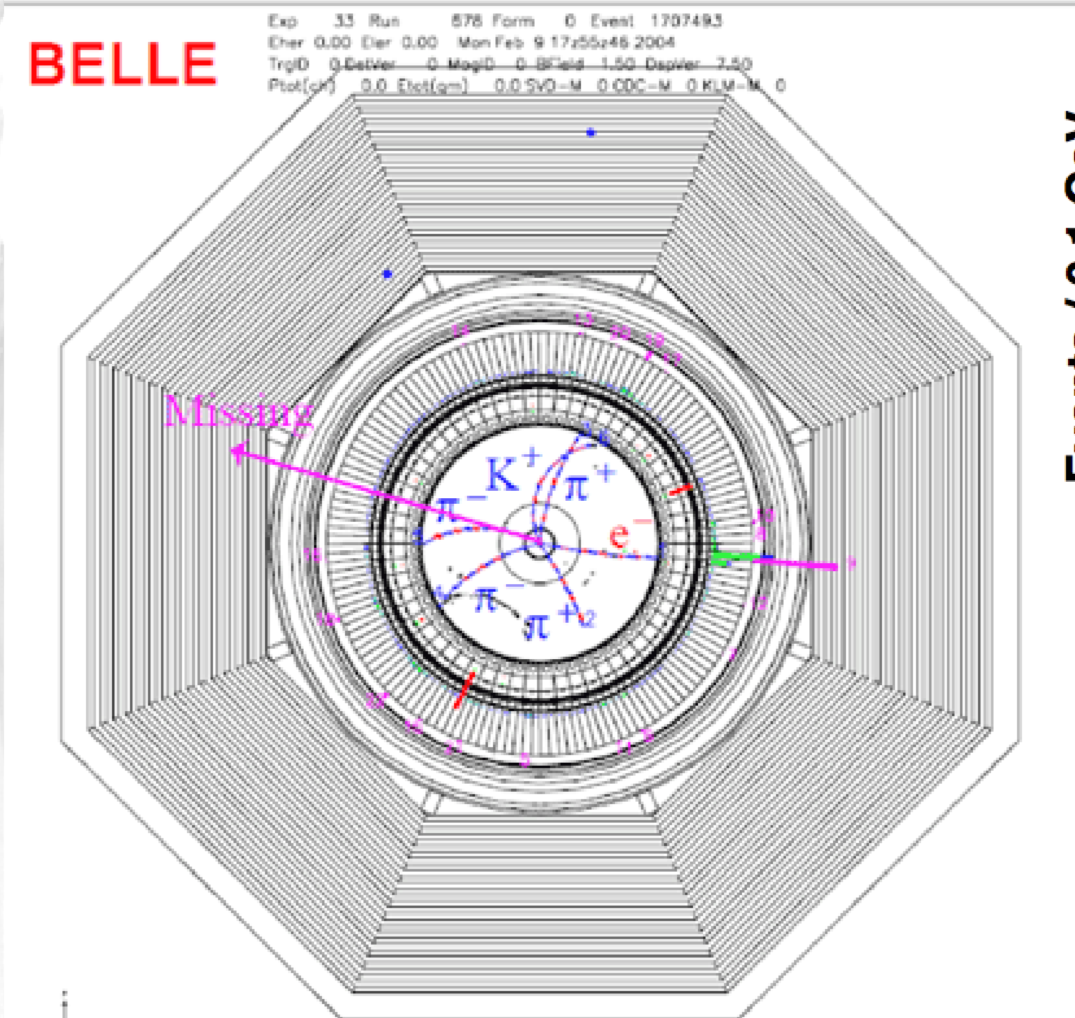


$$\mathcal{B}(B \to \tau\nu) = (1.54^{+0.38}_{-0.37}(\text{stat})^{+0.29}_{-0.31}(\text{syst})) \times 10^{-4}$$

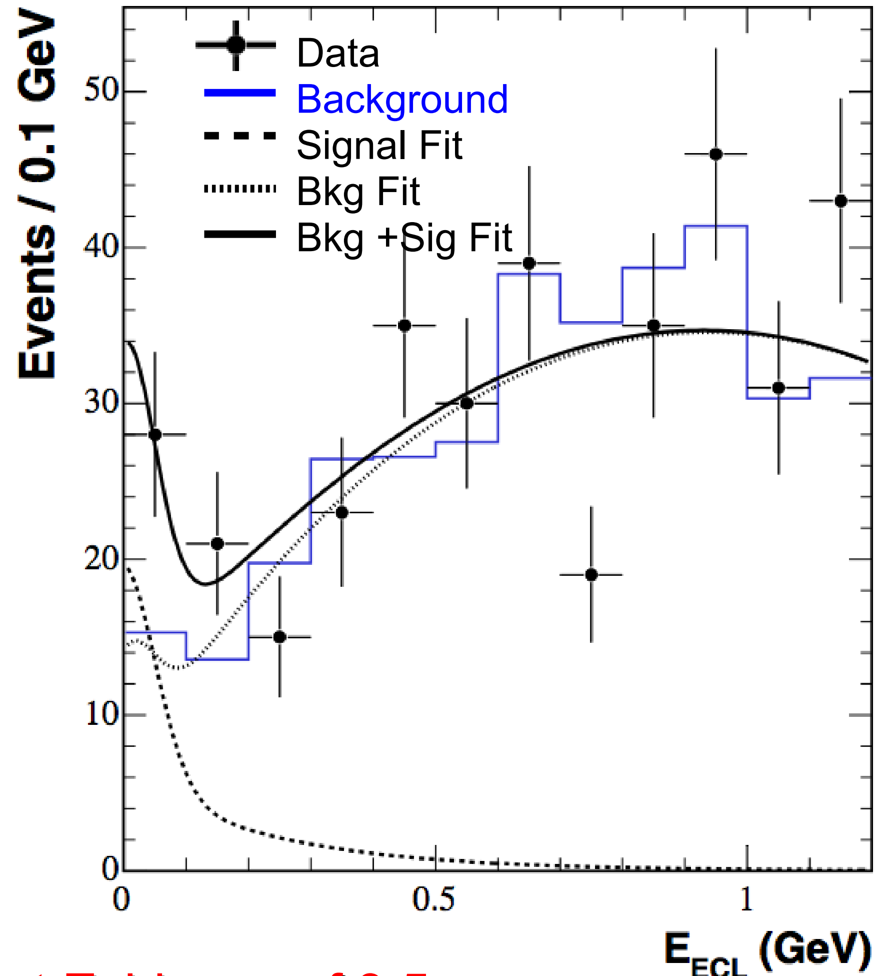
Exclusion of null hypothesis at 3.6 σ

Belle B→τν with Hadronic Tag (2006)

PRL 97 251802 (2006)
449 x10⁶ $B\bar{B}$



http://www.kek.jp/intra-e/press/2006/BellePress8e.html (2006)



First Evidence of 3.5σ

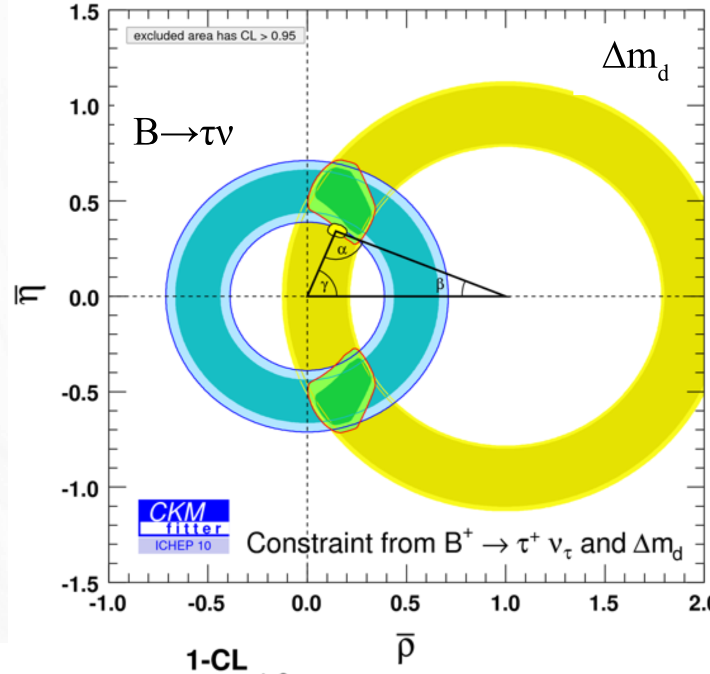
$$\mathcal{B}(B \to \tau\nu) = (1.79^{+0.56}_{-0.49}(\text{stat})^{+0.46}_{-0.51}(\text{syst})) \times 10^{-4}$$

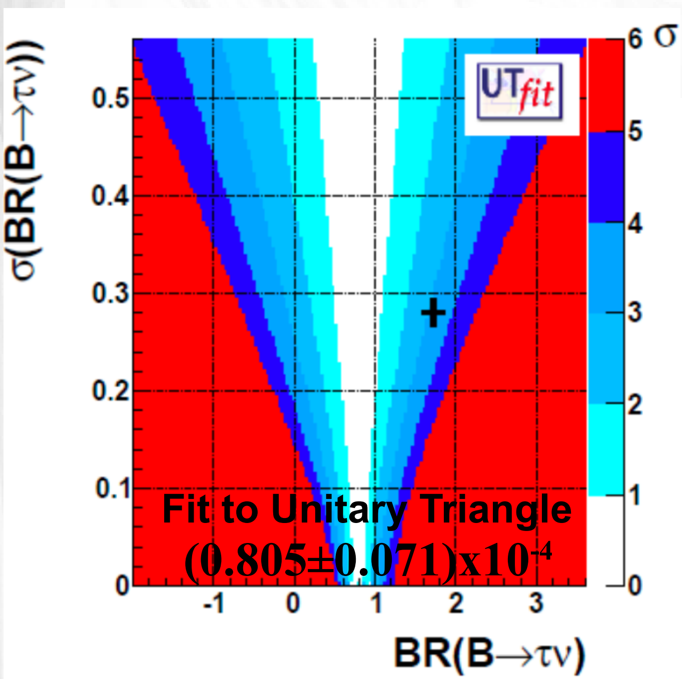
B→τν: Comparison of Results

	$\mathcal{B}(B \to \tau\nu)$
Belle (combined)	$(1.62 \pm 0.40) \times 10^{-4}$
BaBar (combined)	$(1.76 \pm 0.49) \times 10^{-4}$
HFAG Ave (Aug'10)	$(1.64 \pm 0.34) \times 10^{-4}$
Standard Model	$(1.2 \pm 0.25) \times 10^{-4}$

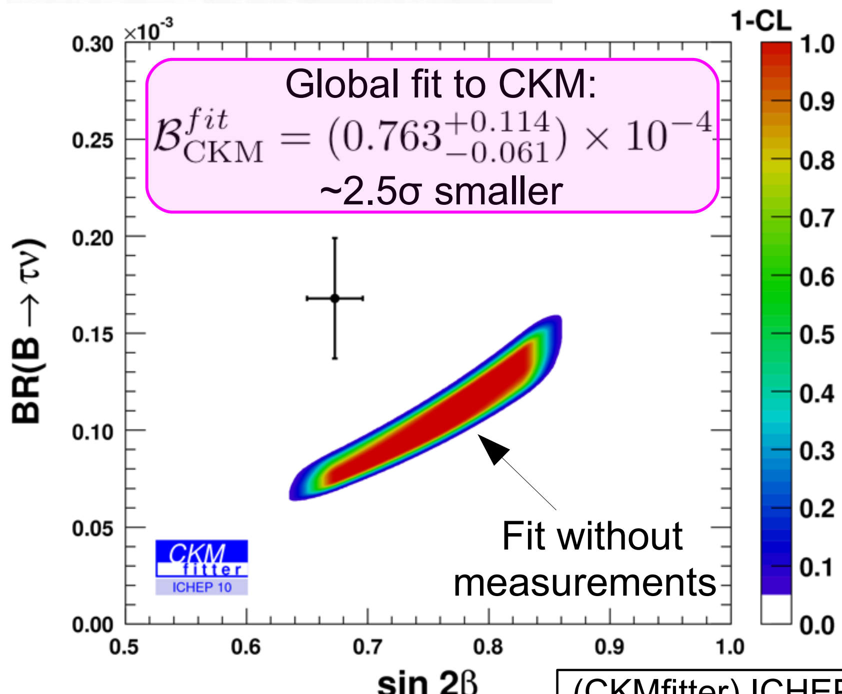
(V_{ub}=(4.32±0.3)x10^{-3}, f_B=190±13MeV)

SM prediction is ~2σ smaller than experiments!





(UTfit) Tarantino, ICHEP10, update of arXiv:0908.3470



(CKMfitter) ICHEP10

Possible sources of CKM discrepencies:
- Stat. Fluctuations in measurements
- Lattice estimate of f_B
- New Physics in B→τν or sin(2β)

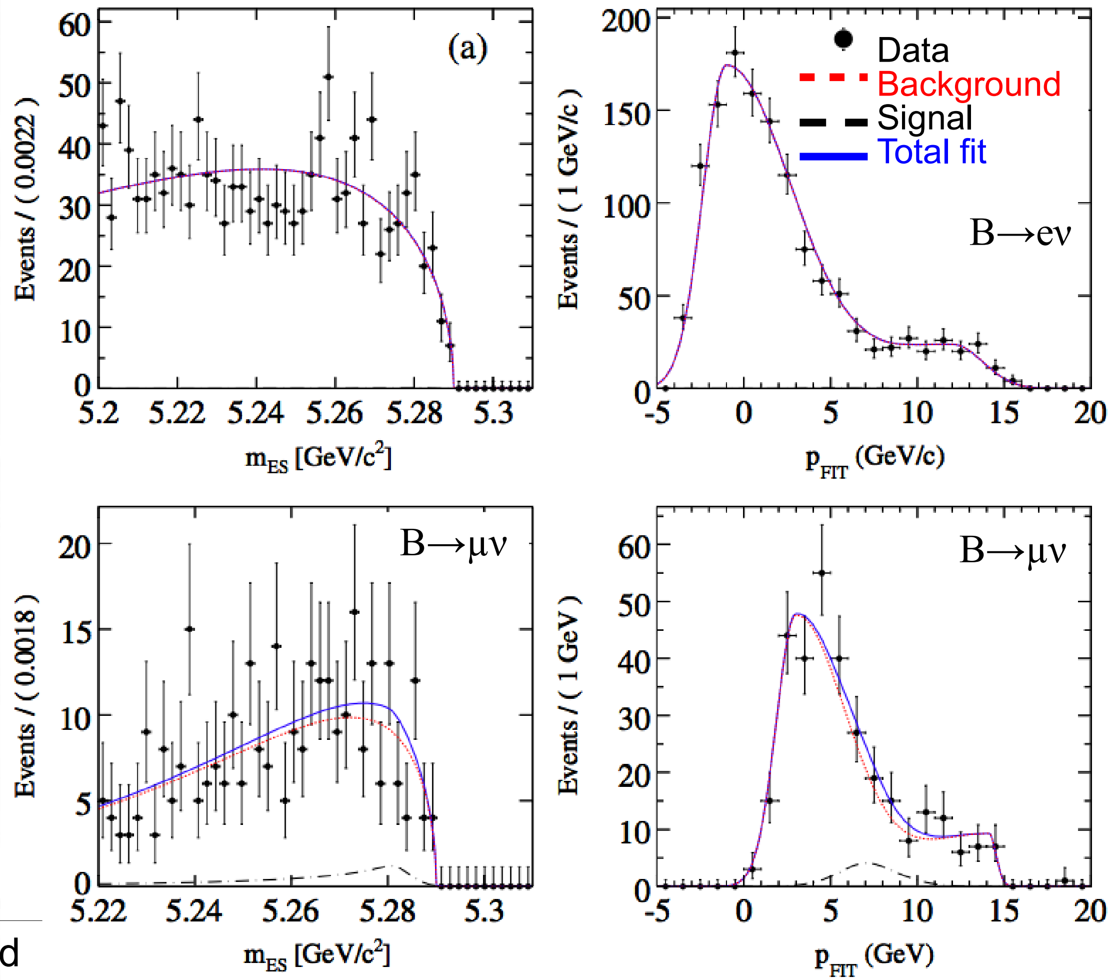
Search for
$B \rightarrow \ell\nu(\gamma)$
(where $\ell = e, \mu$)

PRD79:091101 (2009)
468 x10^6 BB̄

BaBar $B \to \ell\nu$ Inclusive Analysis

Helicity suppressed but clean decay with monoenergetic lepton (2.64 GeV/c)

- Assign high momentum lepton (particle ID) and missing energy as signal decay
- Reject events with more leptons.
- Assign B_{tag} as rest of event with requirements on its ΔE and p_T
- Suppress background using Fisher discriminant of kinematic and event-shape variables.
- Extract yield from 2D fit to m_{ES} and $p_{FIT} = a_0 + a_1 p_\ell^{CM} + a_2 p_\ell^{B\_rest}$
- No signal decays were observed.

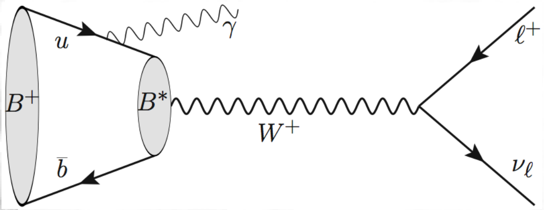


90% CL	BaBar Inclusive	Belle (Phys Lett B 647, 67 (2007))	Standard Model
$B \to e\nu$	$< 1.9\times10^{-6}$	$< 0.98\times10^{-6}$	$\sim1\times10^{-11}$
$B \to \mu\nu$	$< 1.0\times10^{-6}$	$< 1.7\times10^{-6}$	$\sim5\times10^{-7}$

PRD80:111105 (2009)
465 x10[6] $B\bar{B}$

BaBar $B\to\ell\nu\gamma$ with Hadronic Tag

No helicity suppression and clean decay providing λ_B



$$\mathcal{B}(B\to\ell\nu\gamma)\approx\frac{\alpha_{em}G_F^2}{288\pi^2}|V_{ub}|^2 f_B^2 m_B^5\tau_B\left(\frac{Q_u}{\lambda_B}+\frac{Q_b}{m_b}\right)^2$$

Korchemsky, Pirjol, & Yan, PRD 61 114510 (2000).

1[st] inverse moment of B wave function, present in $B\to\pi$ transitions, theoretically uncertain

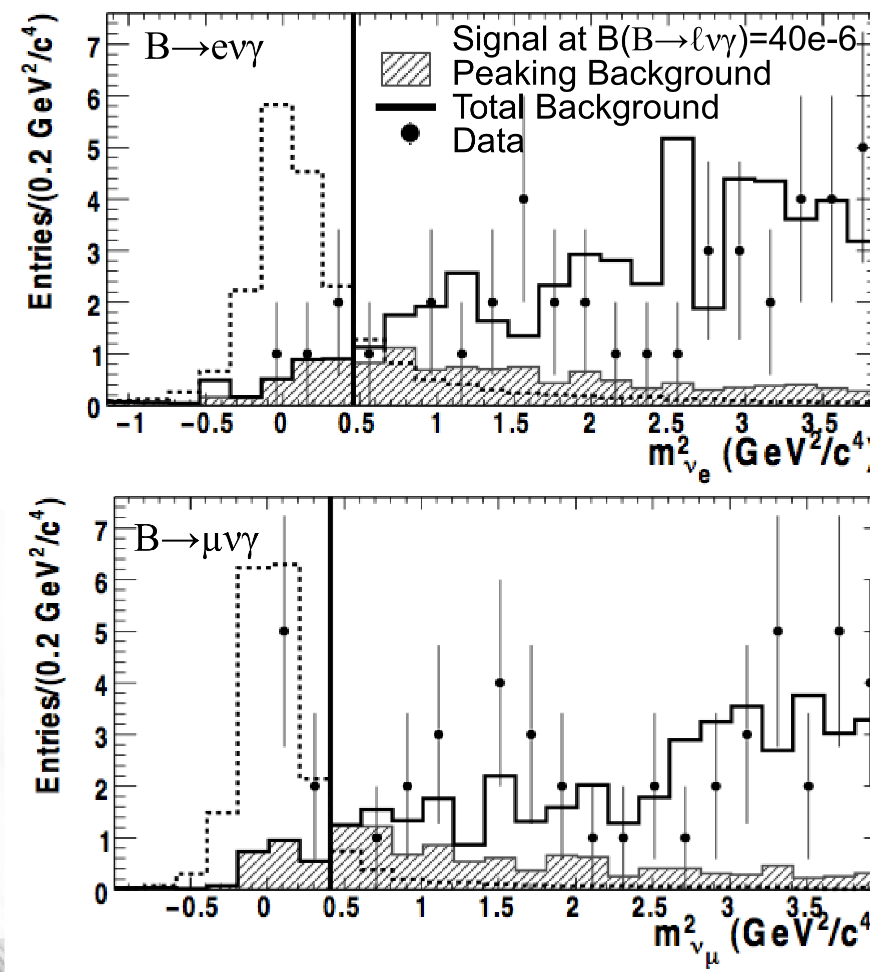
- Reconstruct B_{tag} and suppress continuum using event-shape variables
- Require 1 track, choose highest energy photon, apply π^0 vetos, restrict ν-ℓ angle
- Restrict neutrino mass $m^2_\nu=|p_B-p_\ell-p_\gamma|^2$
- No requirements on lepton/photon kinematics provides first measurement independent of $B\to\gamma$ form-factor models

$$\mathcal{B}(B\to\ell\nu\gamma)=(6.5^{+7.6+2.8}_{-4.7-0.8})\times10^{-6}\text{ at }2.1\sigma$$

$B\to e\nu\gamma$	$B\to\mu\nu\gamma$	$B\to\ell\nu\gamma$	SM
$< 17\times10^{-6}$	$< 26\times10^{-6}$	$< 15.6\times10^{-6}$	10^{-6}

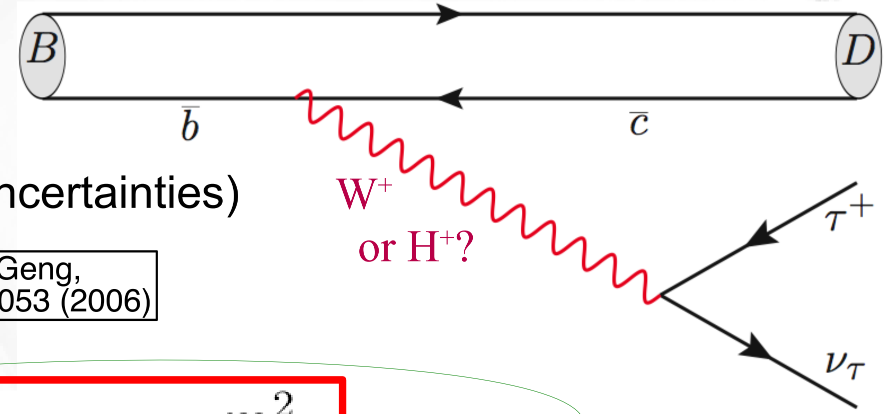
Most stringent reported limits (90% CL) to date

- Also provides model-dependent results by restricting γ-ν and γ-ℓ angles



Search for
$B \to D^{(*)} \tau \nu$

$B \to D^{(*)}\tau\nu$: Theoretical Motivation



- Sensitive to charged Higgs couplings at the tree level
- Complementary to $B \to \tau\nu$ but:
  - Larger rates and more precision (no f_B and Vub uncertainties)

$$\mathcal{B}(B^0 \to D^- \tau\nu)_{\rm SM} = 0.69 \pm 0.04$$
$$\mathcal{B}(B^0 \to D^{*-} \tau\nu)_{\rm SM} = 1.41 \pm 0.07$$

Chen &Geng, JHEP 0610, 053 (2006)

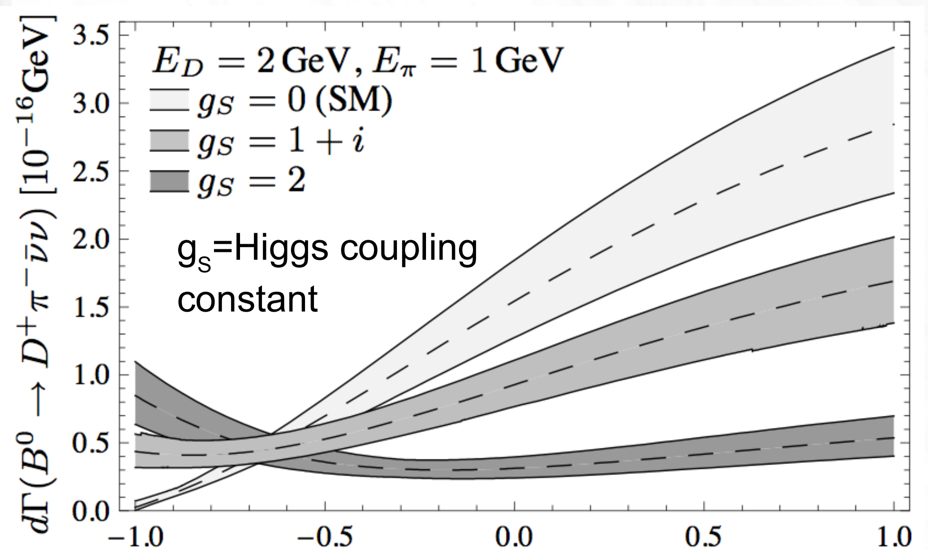
$$\mathcal{B}(B \to D\tau\nu)_{\rm 2HDM} = G_F^2 \tau_B |V_{cb}|^2 f(F_V, F_S, \tan^2\beta \frac{m_B^2}{m_H^2})$$

Form factor measured from $B \to D\ell\nu$ — constrained by HQET

better known than Vub, cancels out in ratio

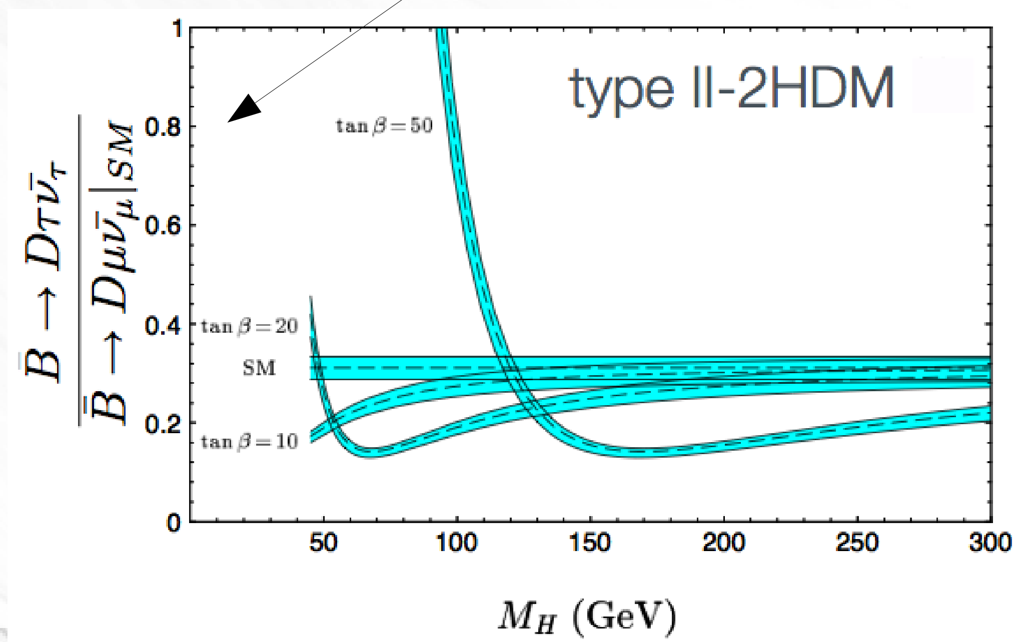
$$R(D) \equiv \frac{\mathcal{B}(B \to D\tau\nu)}{\mathcal{B}(B \to D\ell\nu)}$$

  - 3 body decay permits study of other observables sensitive to NP (q^2 distributions, D* and τ polarization)



$$\cos\theta = \frac{(m_B - E_D - E_\pi)^2 - 2(E_D^2 - m_D^2) - m_{\rm miss}^2}{2(E_D^2 - m_D^2)}$$

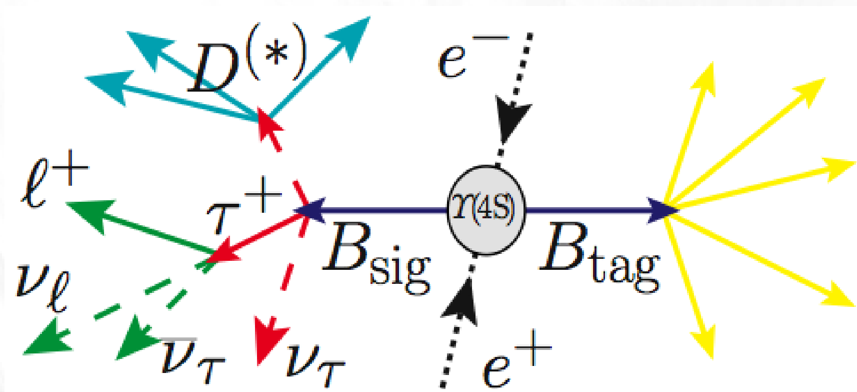
Nierste, et al, PRD78:015006 (2008)



Tanaka, Z Phys C37, 321 (1995)

Belle $B \to D^{(*)}\tau\nu$ Inclusive Analyses

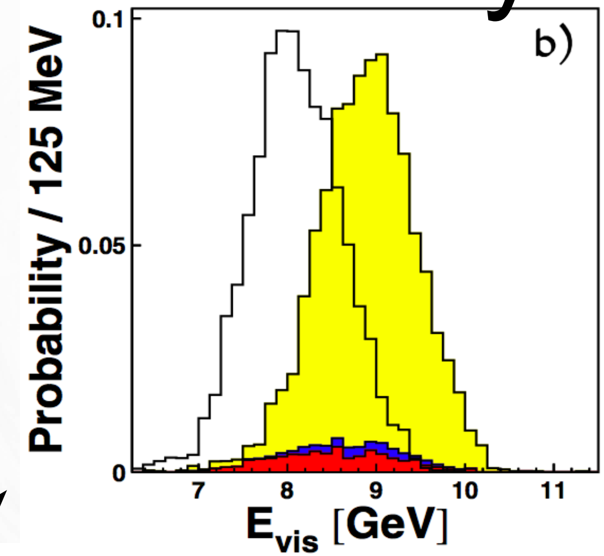
- Reconstruct $D^0 \to K^+\pi^-(\pi^0)$, and $D^* \to D^0\pi$. Select e, μ, or π for τ decays.

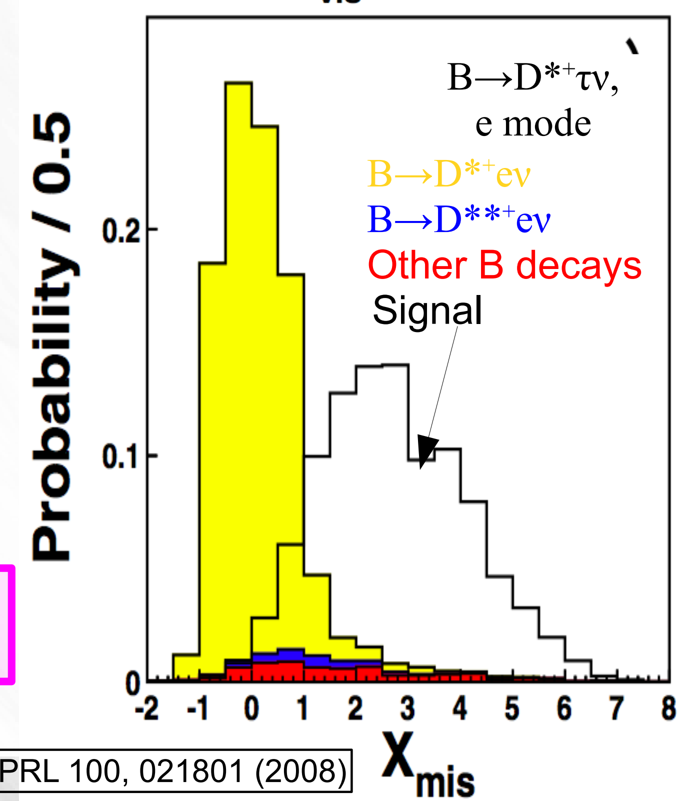


- Apply requirements on ΔE and m_{ES} for rest of event (B_{tag})
- Restrict E_{miss}, m^2_{miss}, q^2, $E_{vis(ible)}$
- Most disriminating variable to separate $B \to D^{(*)}\tau\nu$ (2-3 ν) from $B \to D^{(*)}\ell\nu$ (1 ν) background:

$$X_{\rm miss} \equiv (E_{\rm miss} - |\vec{p}_{D^{(*)}} + \vec{p}_{\ell,\pi}|)/|\vec{p}_B|$$

(Like m_{miss} but no dependence on m_{ES})





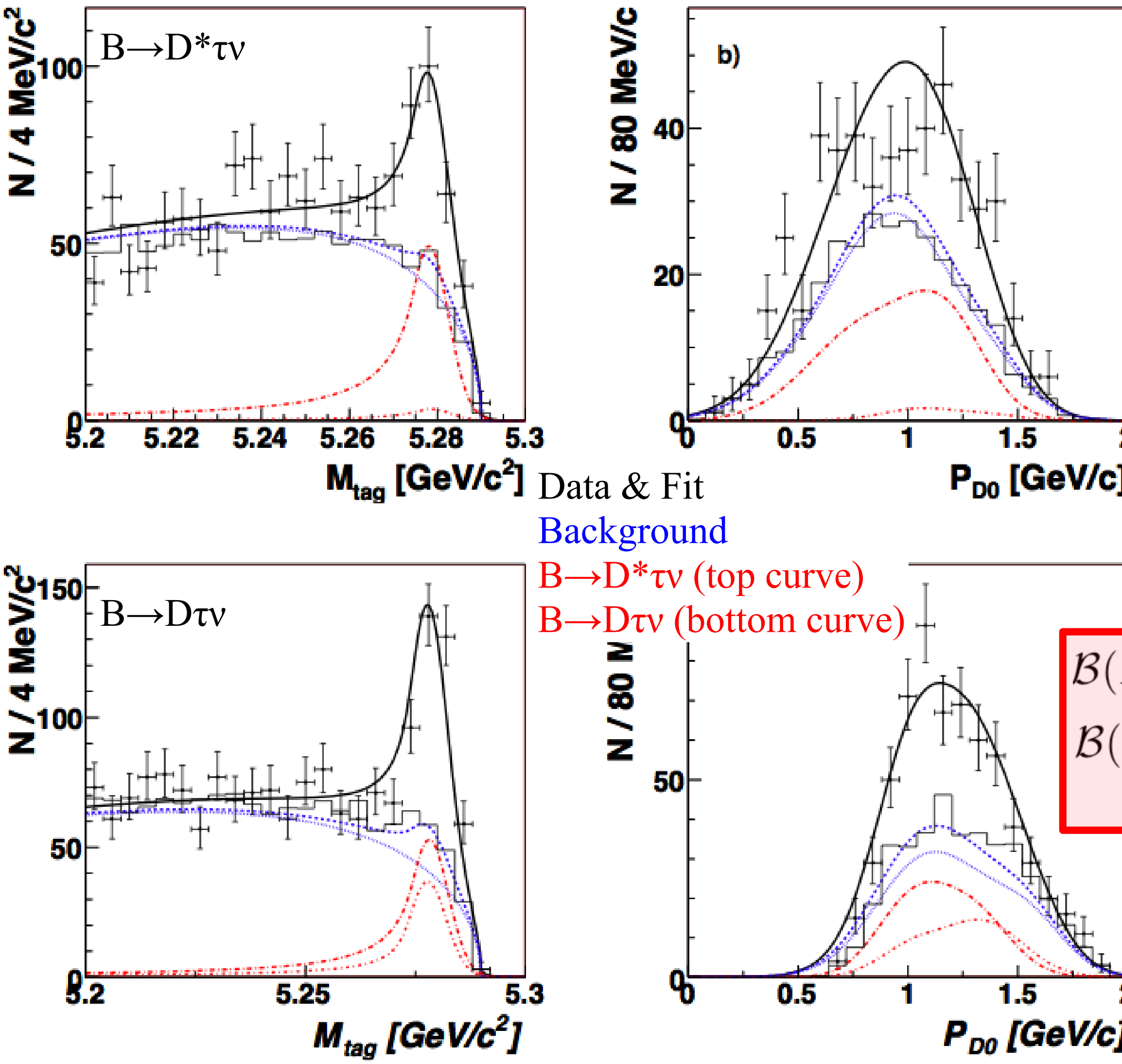
PRL 100, 021801 (2008)

arXiv: 1005.2302 (2010)
675x10⁶ $B\bar{B}$

Belle $B \to D^{(*)}\tau\nu$ Inclusive Results

- Fit to m_{ES} and $|p_{D0}|$ in CM frame

Fit accounts for cross-feed between signal modes



PRL 100, 021801 (2008), 535x10⁶ $B\bar{B}$

(only fit to m_{ES}, not p_D)

$$\mathcal{B}(B^0 \to D^{*-}\tau\nu) = 2.02^{+0.40}_{-0.37} \pm 0.37$$

5.2σ: **First obsersvation** of an exclusive $b \to c\tau\nu$ decay

TABLE II. Summary of the systematic uncertainties.

Source	$\bar{D}^{*0}\tau^+\nu_\tau$	$\bar{D}^0\tau^+\nu_\tau$
$N_{B\bar{B}}$	±1.4%	±1.4%
Reconstruction of $B_{\rm tag}$ and $B_{\rm sig}$	±12.9%	±12.8%
Lepton-id and signal selection	$^{+1.5}_{-1.6}$%	$^{+4.4}_{-4.5}$%
Shape of the signal PDF's	±2.5%	±6.0%
Comb. and peaking backgrounds	±3.3%	±2.7%
Fitting procedure	±0.8%	±1.5%
Total	±13.9%	±15.2%

Determined from data control samples $B^+ \to D^{*0}\pi^+$ and $B^+ \to D^0\pi^+$

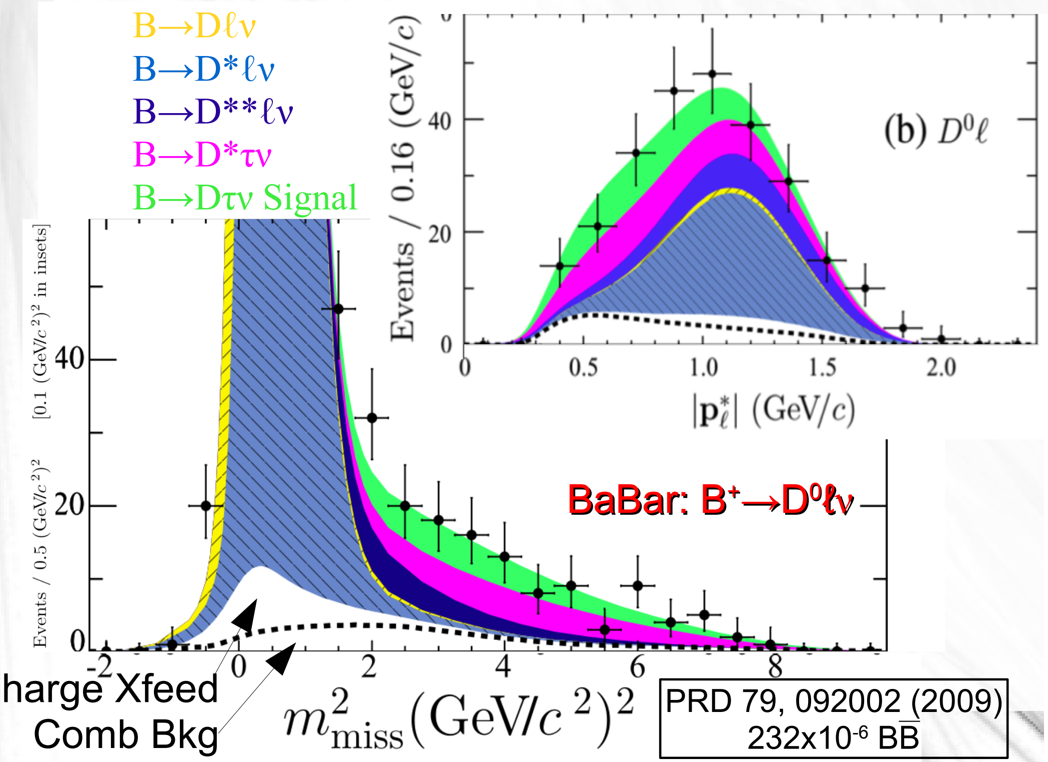
$$\mathcal{B}(B^- \to D^{*0}\tau\nu) = 2.12^{+0.28}_{-0.27} \pm 0.29 \quad (8.1\sigma)$$

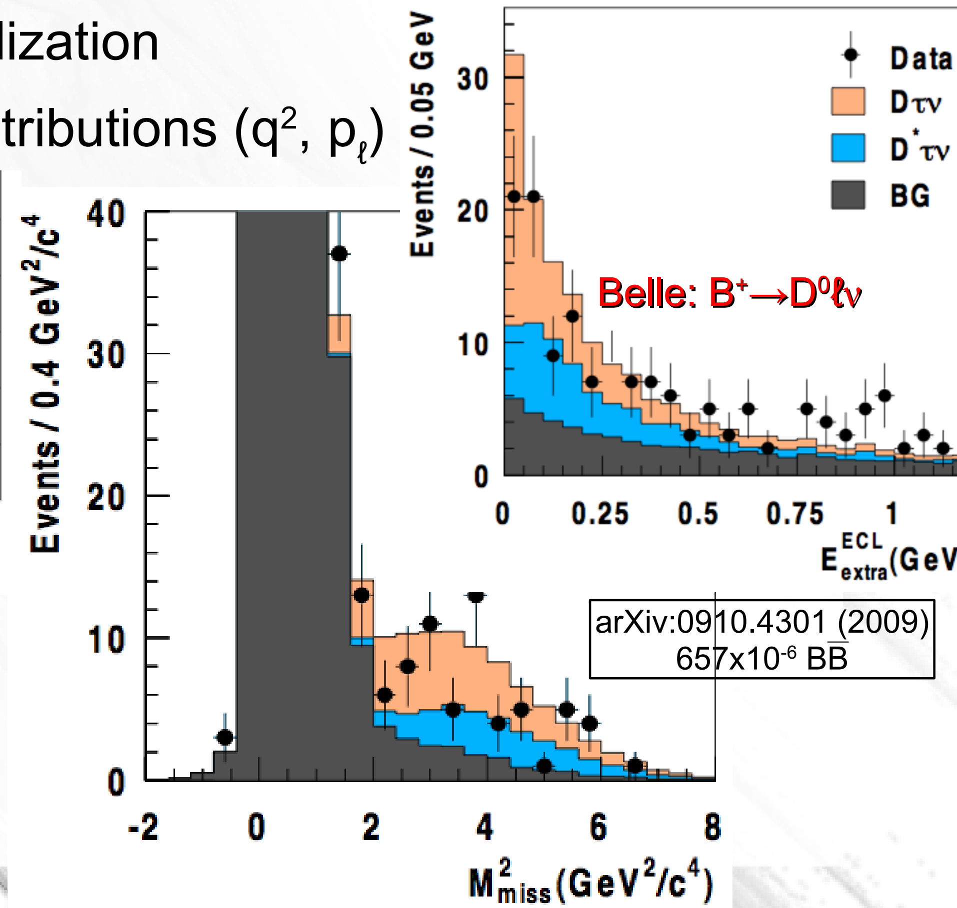
$$\mathcal{B}(B^- \to D^0\tau\nu) = 0.77 \pm 0.22 \pm 0.12 \quad (3.5\sigma)$$

First Observation

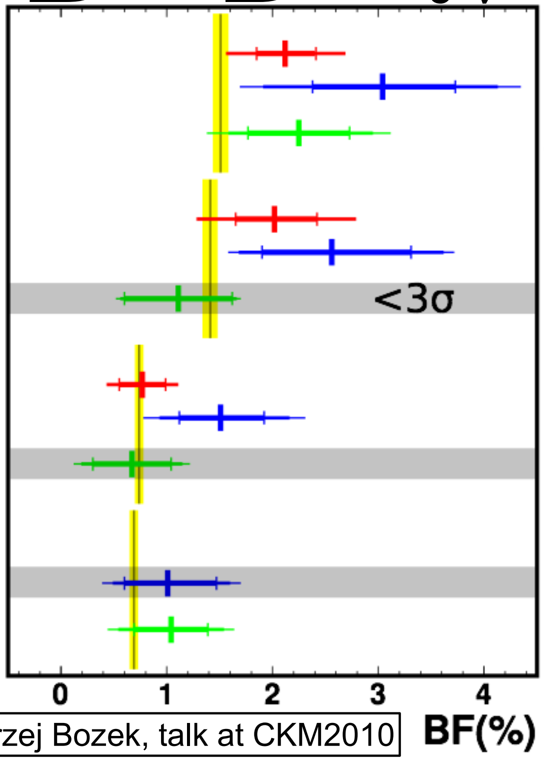
$B \to D^{(*)}\tau\nu$ Hadronic Tag

- After B_{tag}, reconstruct $D^{(*)}$ through ~10 modes. Require exactly 1 lepton: e or μ.
- Suppress combinatorial bkg using E_{extra} and p_ℓ (and for BaBar: q^2 and p_{miss})
- Simultaneous extract all modes from 2D fit to m^2_{miss} and { $p_\ell^{B\_rest}$ (BaBar), E_{extra} (Belle) }
where $m^2_{\rm miss} \equiv p_{beam} - p_{B_{\rm tag}} - p_{D^{(*)}} - p_\ell$ peaks at 0 for $B \to D^{(*)}\ell\nu$ (1 ν) bkd
  - BaBar: also simultaneously fit to $B \to D^{**}\ell\nu$ control samples
- $B \to D^{(*)}\ell\nu$ samples used for yield normalization
- BaBar: 1st measurement of kinematic distributions (q^2, p_ℓ)





$B\to D^{(*)}\tau\nu$ Comparison of Results



Andrzej Bozek, talk at CKM2010

$B^+ \to \overline{D}^{*0}\tau^+\nu_\tau$
- $[2.12^{+0.28}_{-0.27} \pm 0.29]\%$ 8.1σ
- $[3.04^{+0.69}_{-0.66}{}^{+0.40}_{-0.47}]\%$ 3.9σ
- $[2.25 \pm 0.48 \pm 0.22]\%$ 5.3σ

$B^0 \to D^{*-}\tau^+\nu_\tau$
- $[2.02^{+0.40}_{-0.37} \pm 0.37]\%$ 5.2σ
- $[2.56^{+0.75}_{-0.66}{}^{+0.31}_{-0.22}]\%$ 4.7σ
- $[1.11 \pm 0.51 \pm 0.04]\%$ 2.7σ

$B^+ \to \overline{D}^{0}\tau^+\nu_\tau$
- $[0.77 \pm 0.22 \pm 0.12]\%$ 3.5σ
- $[1.51^{+0.41}_{-0.39}{}^{+0.24}_{-0.19}]\%$ 3.8σ
- $[0.67 \pm 0.37 \pm 0.11]\%$ 1.8σ

$B^0 \to D^{-}\tau^+\nu_\tau$
- $[1.01^{+0.46}_{-0.41}{}^{+0.13}_{-0.11}]\%$ 2.6σ
- $[1.04 \pm 0.35 \pm 0.15]\%$ 3.3σ

– Belle Inclusive
PRL99, 191807 (2007)
arXiv:1005.2302(2010)

– Belle Hadronic
arXiv:0910.4301 (2009)

– BaBar Hadronic
PRD79, 092002 (2009)
PRL100, 021801 (2008)

– Standard Model
Chen &Geng,
JHEP 0610, 053 (2006)

Ratio R(D(*)) was extracted from Hadronic Tag fits:

$$R(D)_{\rm SM} = 0.30 \pm 0.024$$

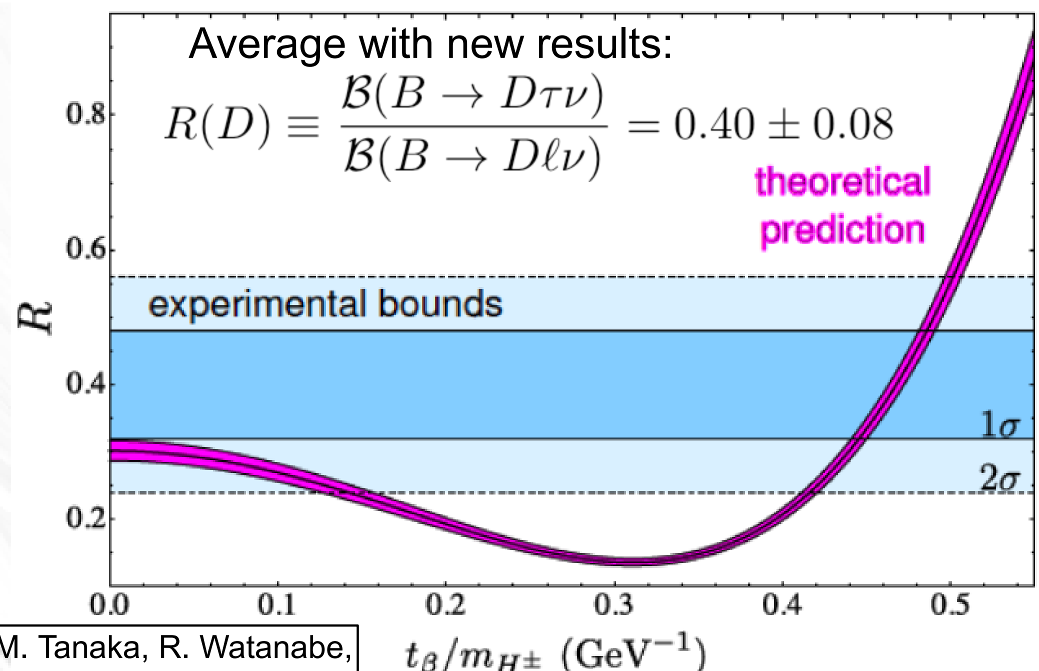
$$R(D^*)_{\rm SM} = 0.25 \pm 0.018$$

$$R(D) = (41.6 \pm 11.7 \pm 5.2)\%,$$
$$R(D^*) = (29.7 \pm 5.6 \pm 1.8)\%,$$

$$R(\overline{D}^0) = 0.70 {}^{+0.19}_{-0.18} {}^{+0.11}_{-0.09}$$
$$R(D^-) = 0.48 {}^{+0.22}_{-0.19} {}^{+0.06}_{-0.05}$$
$$R(\overline{D}^{*0}) = 0.47 {}^{+0.11}_{-0.10} {}^{+0.06}_{-0.07}$$
$$R(D^{*-}) = 0.48 {}^{+0.14}_{-0.12} {}^{+0.06}_{-0.04}$$

Average with new results:

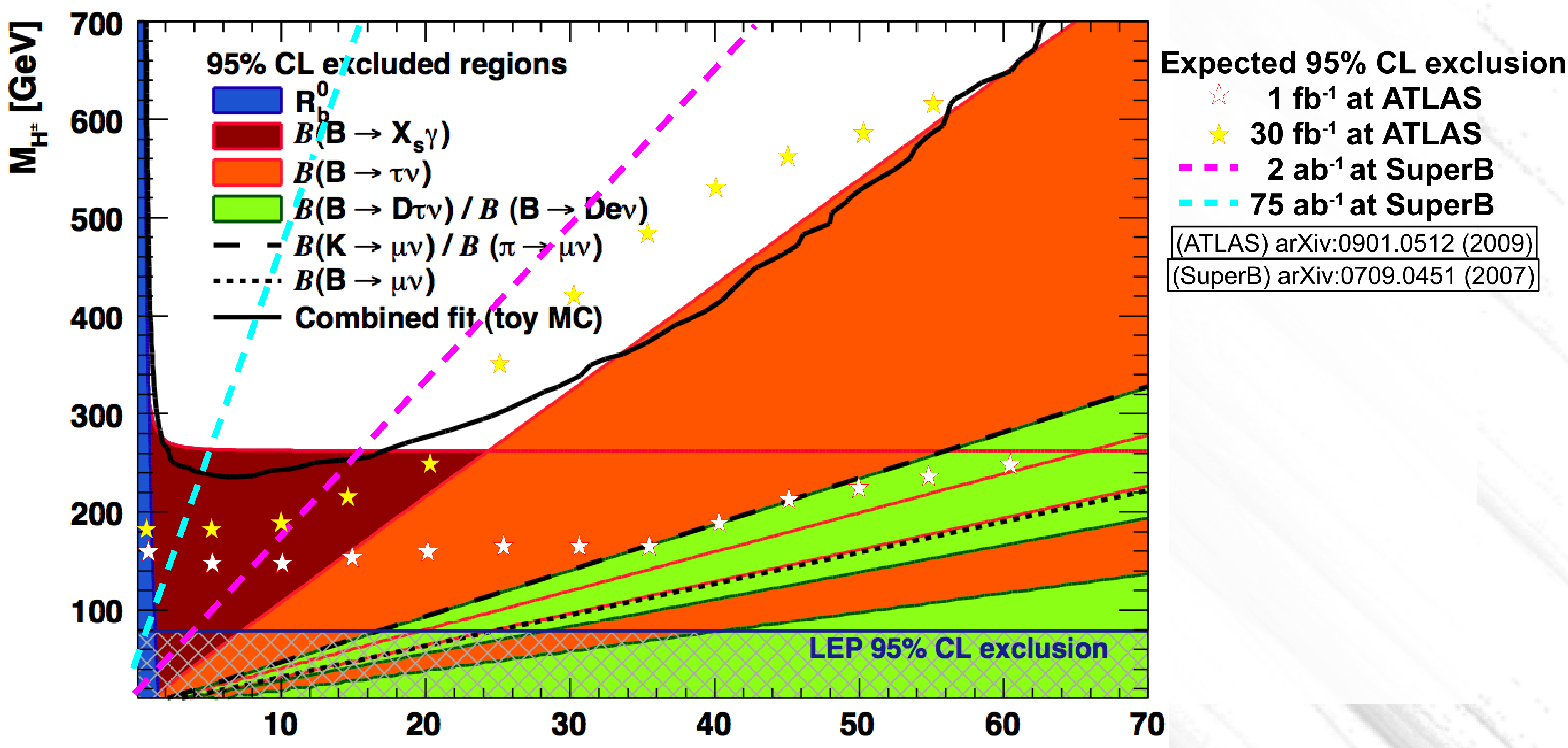
$$R(D) \equiv \frac{\mathcal{B}(B\to D\tau\nu)}{\mathcal{B}(B\to D\ell\nu)} = 0.40 \pm 0.08$$



M. Tanaka, R. Watanabe, arXiv:1005.4306

Conclusions

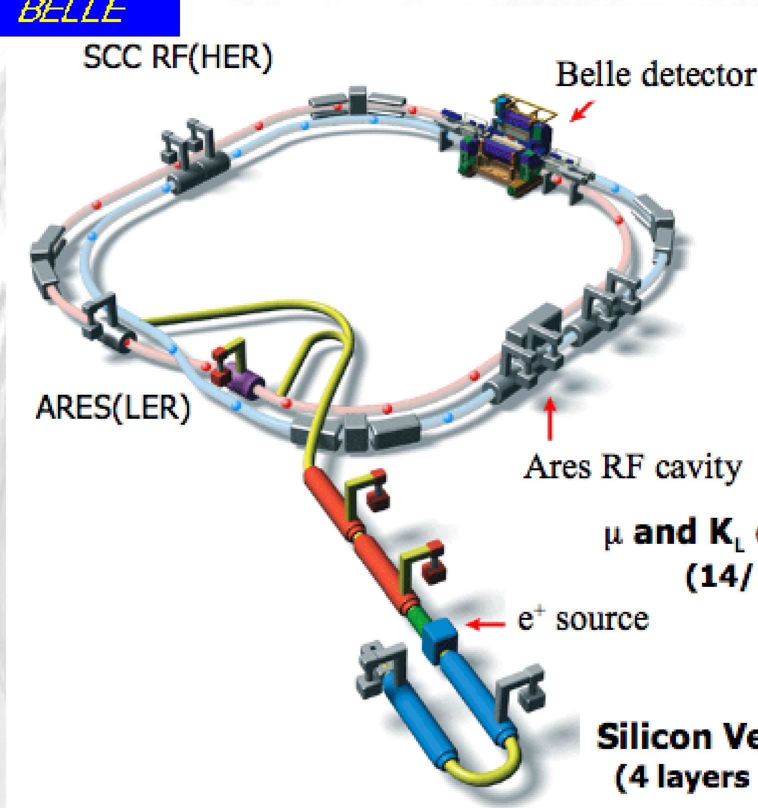
- $B\rightarrow\tau\nu$ and $B\rightarrow D^{(*)}\tau\nu$: now well-established decays, observed at both BaBar and Belle
- $B\rightarrow\mu\nu$ and $B\rightarrow\ell\nu\gamma$: not yet observed, but sensitivity near SM expectations! Observations expected at next generation B-factories
- Measured BFs and SM expectations consistent within uncertainties, but room for NP!
- $B\rightarrow\tau\nu$ and $B\rightarrow D\tau\nu$ already provide exclusion in plane of 2HDM parameters m_H x tanβ. B-factory sensitivity is competitive with direct searches at LHC!



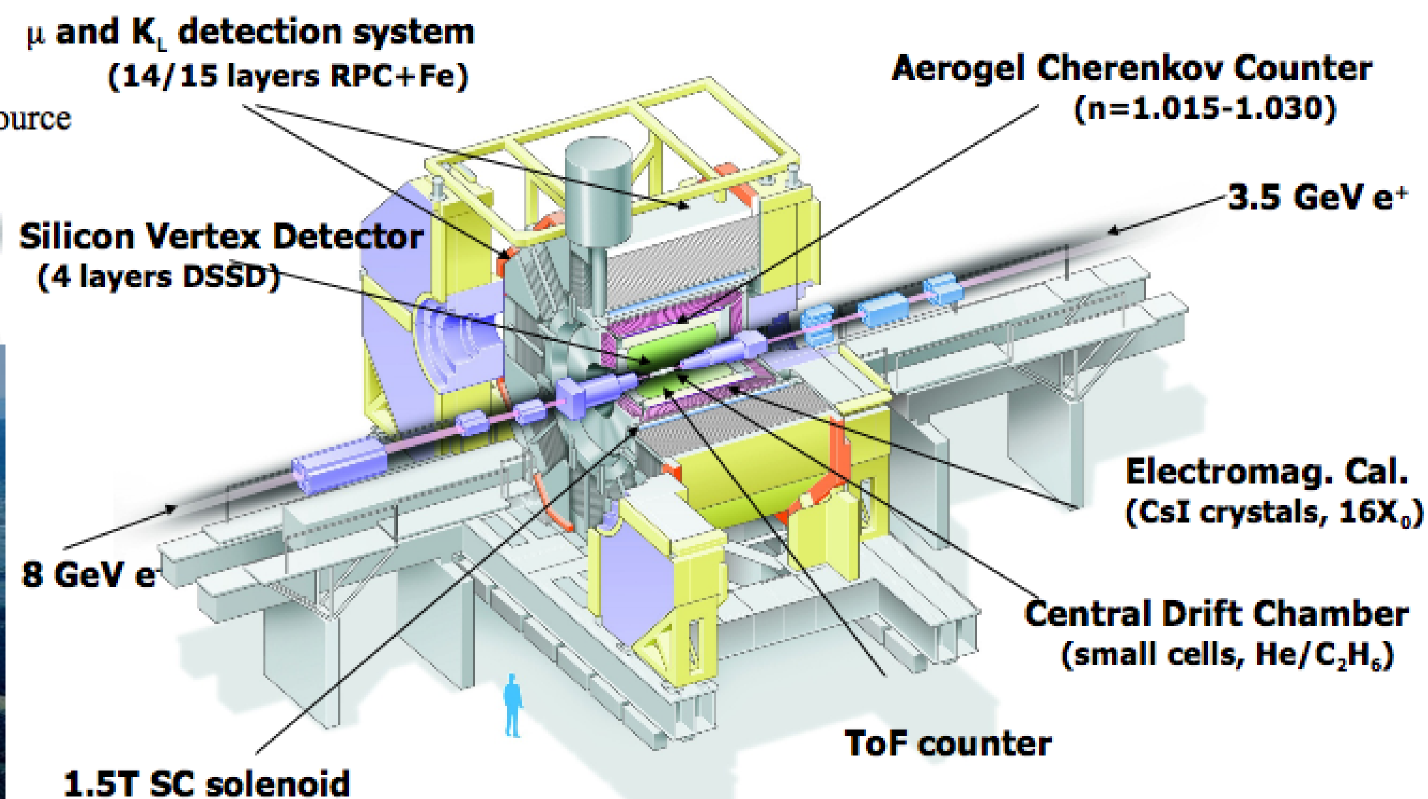
Flaecher, et al, Eur.Phys.J.C60:543 (2009)

Extra Slides

KEKB Collider/ Belle Spectrometer

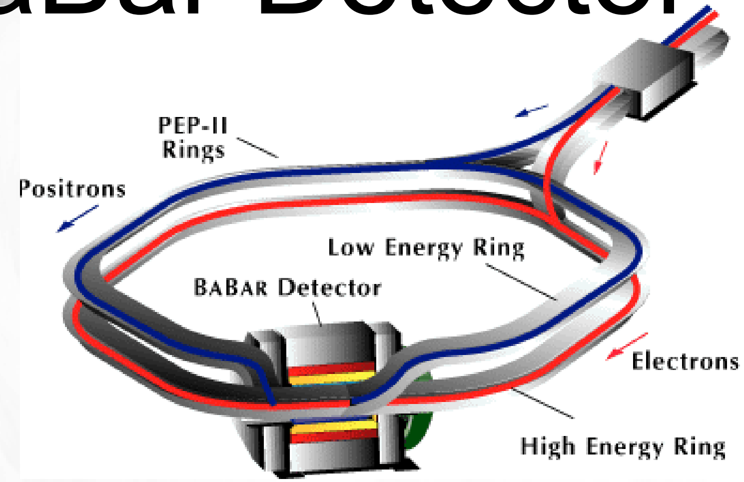


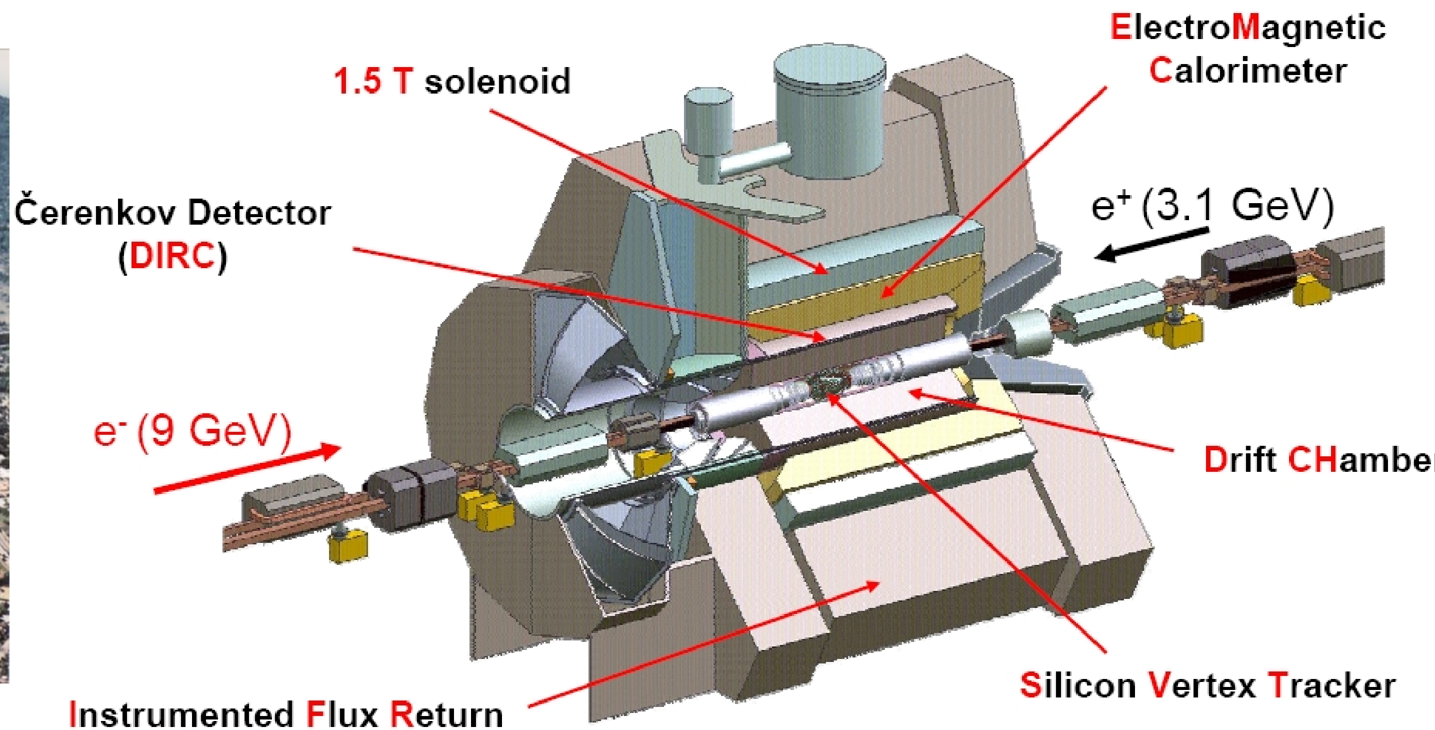
High Energy Ring:	8.0 GeV electrons
Low Energy Ring:	3.5 GeV positrons
Design luminosity:	$1 \times 10^{34}\ cm^{-2}s^{-1}$
Peak luminosity:	$1.71 \times 10^{34}\ cm^{-2}s^{-1}$
Beam Crossing angle:	22mrad



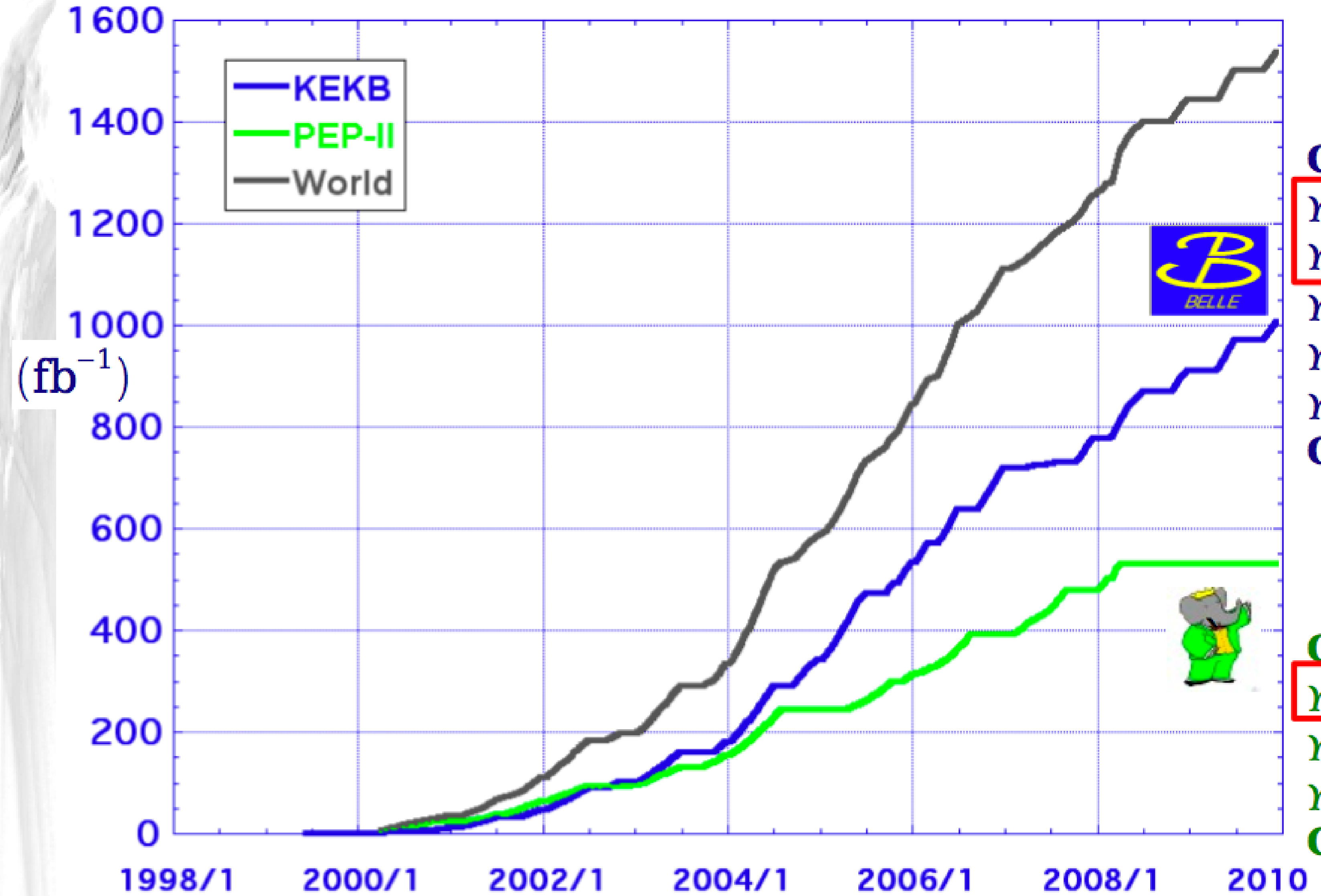
PEP-II B Factory/BaBar Detector

High Energy Ring (HER): 9.0 GeV electrons
Low Energy Ring (LER): 3.1 GeV positrons
Design luminosity: $3 \times 10^{33}\ cm^{-2}s^{-1}$
Peak luminosity: $1.207 \times 10^{34}\ cm^{-2}s^{-1}$
CM Energy: 10.58 GeV
Boost of $\beta\gamma$=0.56 in lab frame





Luminosities



> 1 ab^{-1}

On resonance:

$\Upsilon(5S)$: 121 fb^{-1}

$\Upsilon(4S)$: 711 fb^{-1}

$\Upsilon(3S)$: 3 fb^{-1}

$\Upsilon(2S)$: 24 fb^{-1}

$\Upsilon(1S)$: 6 fb^{-1}

Off reson./scan

~ 100 fb^{-1}

~ 550 fb^{-1}

On resonance:

$\Upsilon(4S)$: 433 fb^{-1}

$\Upsilon(3S)$: 30 fb^{-1}

$\Upsilon(2S)$: 14 fb^{-1}

Off resonance:

~ 54 fb^{-1}

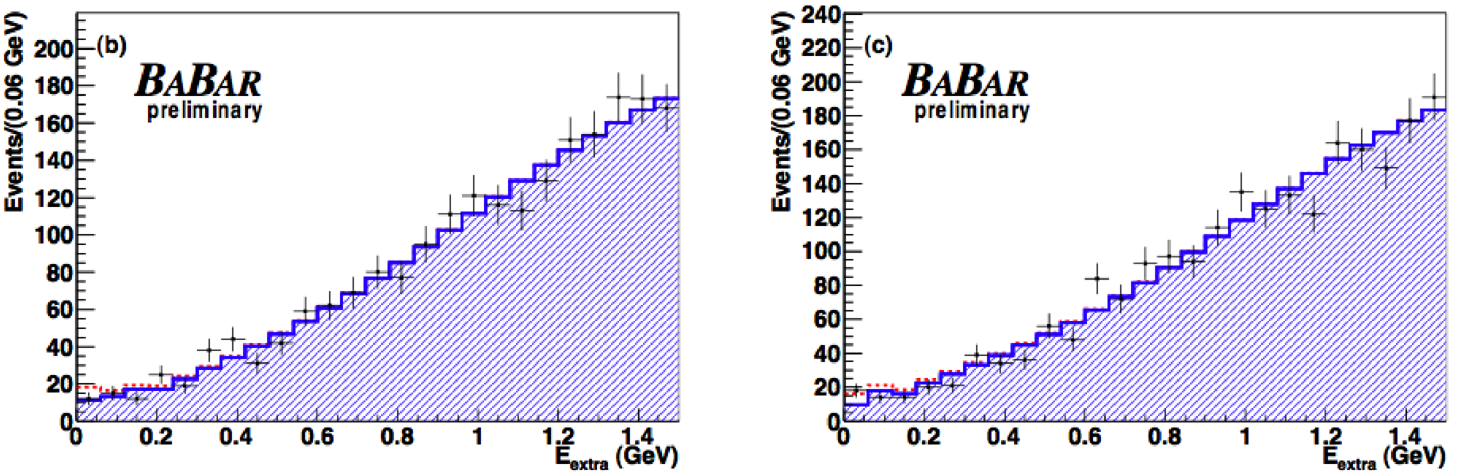
Trabelsi @ ICHEP'10

~770 M$B\bar{B}$ for Belle, ~ 470 M$B\bar{B}$ for BaBar

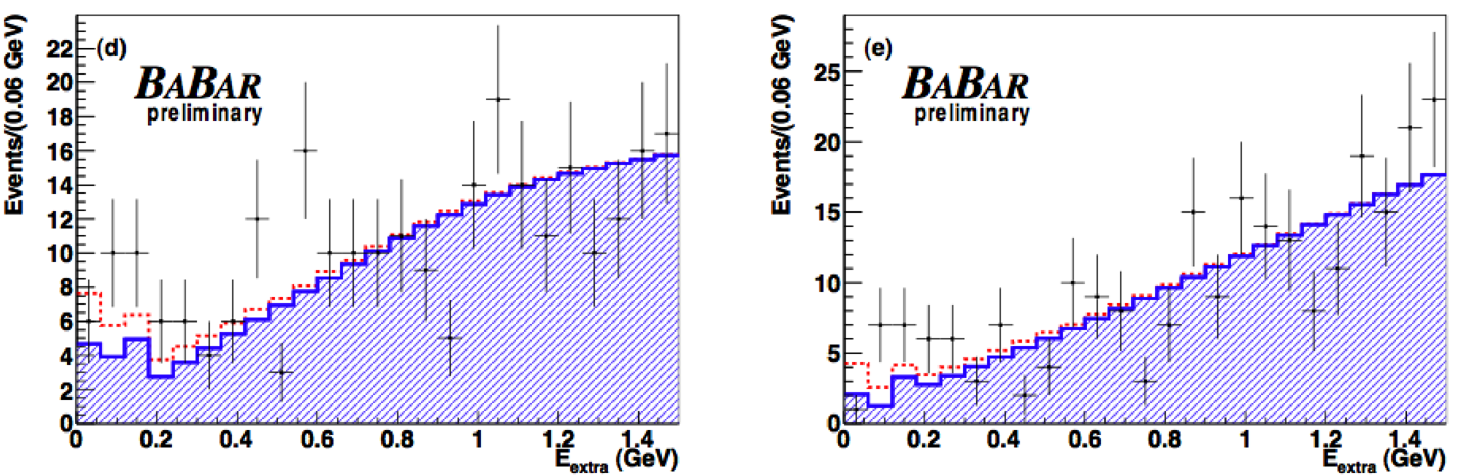
arXiv:1008.0104 (2010)
468 x10^6 $B\bar{B}$

BaBar B→τν Hadronic Tag

Decay Mode	$\epsilon \times 10^{-4}$	Branching Fraction ($\times 10^{-4}$)	Significance σ
$\tau^+ \to e^+ \nu \bar{\nu}$	2.73	$0.39^{+0.89}_{-0.79}$	0.5
$\tau^+ \to \mu^+ \nu \bar{\nu}$	2.92	$1.23^{+0.89}_{-0.80}$	1.6
$\tau^+ \to \pi^+ \nu$	1.55	$4.0^{+1.5}_{-1.3}$	3.3
$\tau^+ \to \rho^+ \nu$	0.85	$4.3^{+2.2}_{-1.9}$	2.6
combined	8.05	$1.80^{+0.57}_{-0.54}$	3.6



(b) τ+→e+νν, (c)τ+→μ+νν, d)τ+→π+ν, (e)τ+→ρ+ν

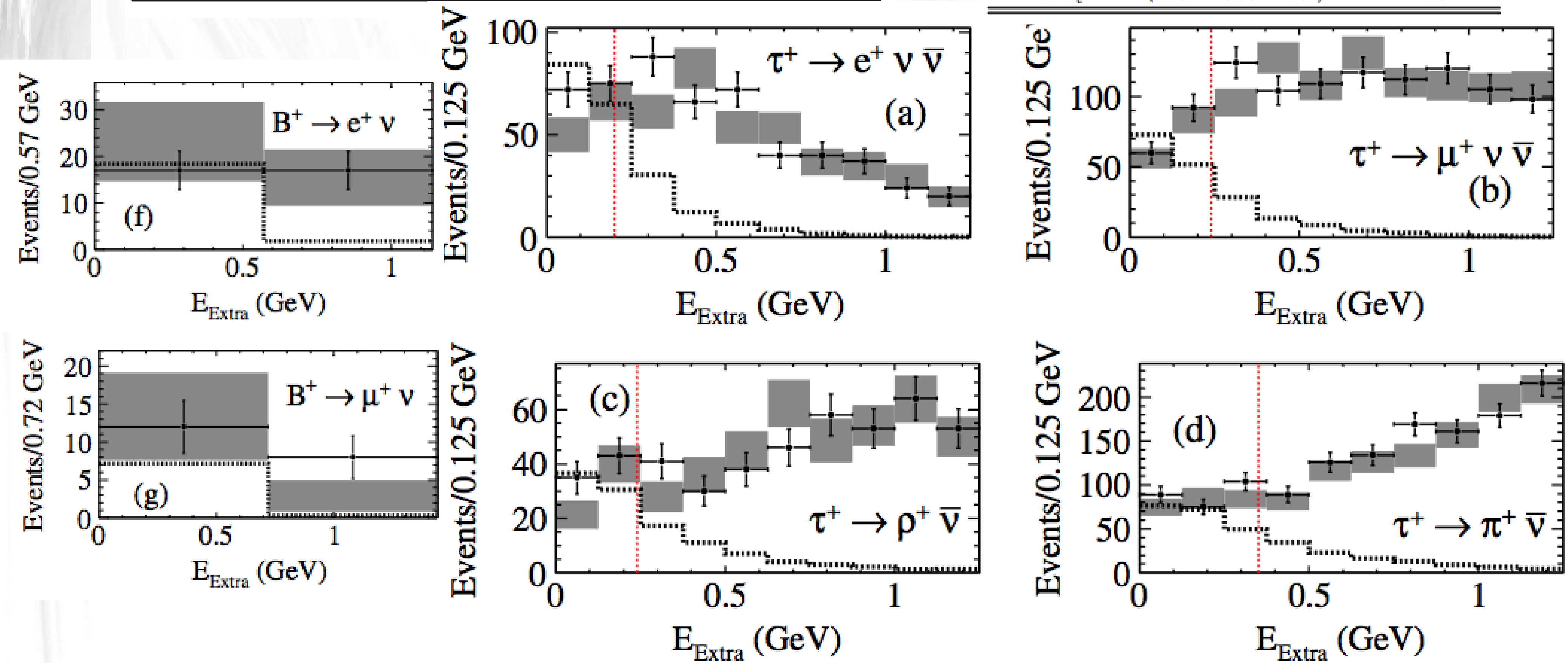


PRD81:051101 (2010)
459 x10^6 $B\bar{B}$

BaBar $B\to\tau\nu$ Semi-Leptonic Tag

Mode	$\mathcal{N}_{bg}^{data}$	N_{obs}	Branching fraction ($\times10^{-4}$)
$\tau^+\to e^+\nu_e\bar{\nu}_\tau$	81 ± 12	121	(3.6 ± 1.4)
$\tau^+\to\mu^+\nu_\mu\bar{\nu}_\tau$	135 ± 13	148	$(1.3^{+1.8}_{-1.6})$
$\tau^+\to\rho^+\bar{\nu}_\tau$	59 ± 9	71	$(2.1^{+2.0}_{-1.8})$
$\tau^+\to\pi^+\bar{\nu}_\tau$	234 ± 19	243	$(0.6^{+1.4}_{-1.2})$
$B^+\to\tau^+\nu_\tau$	509 ± 30	583	(1.7 ± 0.8 ± 0.2)
$B^+\to\mu^+\nu_\mu$	13 ± 8	12	<0.11 (90% C.L.)
$B^+\to e^+\nu_e$	24 ± 11	17	<0.08 (90% C.L.)

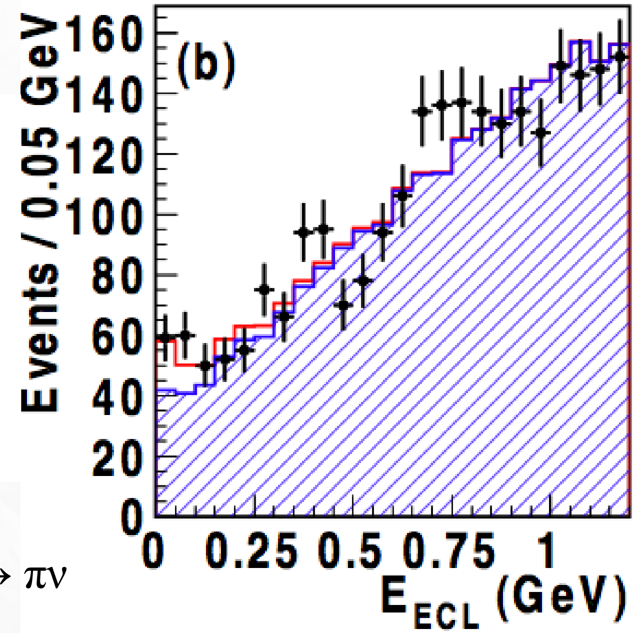
Channel	Efficiency (%)	Uncertainty (%)
Tag efficiencies		
$B^+\to\tau^+\nu_\tau$	(1.514 ± 0.003 ± 0.107)	7.1
$B^+\to\mu^+\nu_\mu$	(0.937 ± 0.003 ± 0.066)	7.1
$B^+\to e^+\nu_e$	(0.974 ± 0.003 ± 0.069)	7.1
Signal efficiencies		
$\tau^+\to e^+\nu_e\bar{\nu}_\tau$	(1.58 ± 0.04 ± 0.07)	4.5
$\tau^+\to\mu^+\nu_\mu\bar{\nu}_\tau$	(1.45 ± 0.03 ± 0.11)	7.4
$\tau^+\to\pi^+\bar{\nu}_\tau$	(2.44 ± 0.05 ± 0.11)	4.5
$\tau^+\to\rho^+\bar{\nu}_\tau$	(0.83 ± 0.03 ± 0.05)	5.4
$B^+\to\tau^+\nu_\tau$	(6.31 ± 0.07 ± 0.34)	5.4
$B^+\to\mu^+\nu_\mu$	(28.65 ± 0.34 ± 1.75)	6.1
$B^+\to e^+\nu_e$	(37.01 ± 0.38 ± 1.84)	5.0



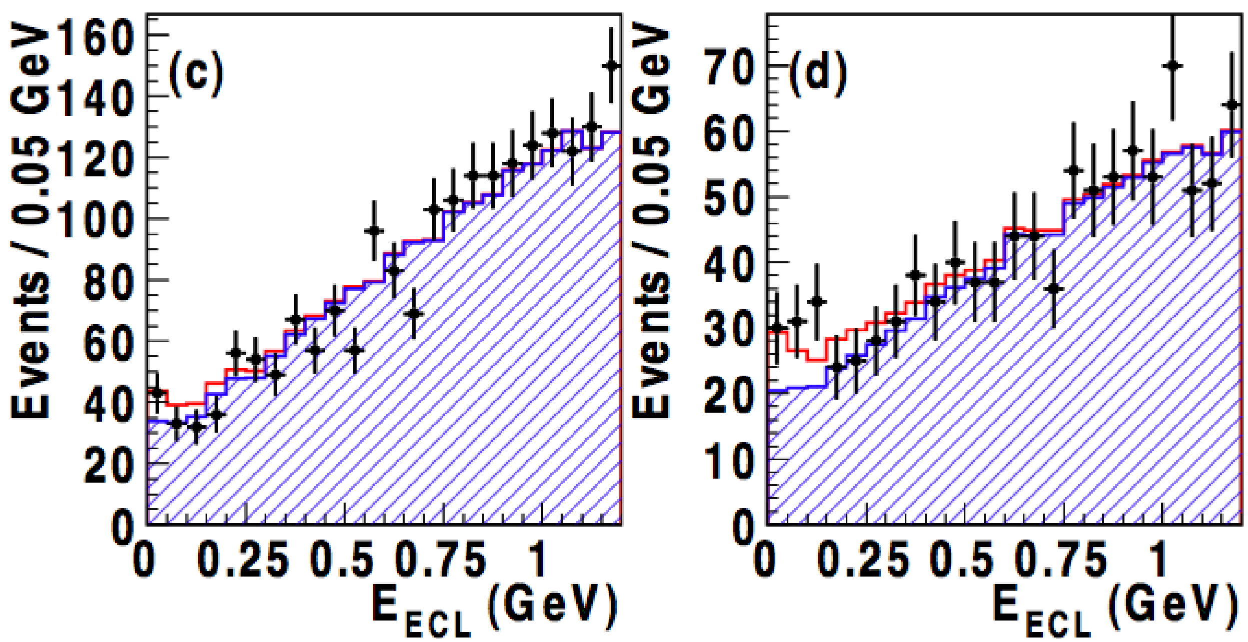
Belle B→τν Semi-Leptonic Tag

arXiv:1006.4201 (2010)
657 x10[6] $B\bar{B}$

Decay Mode	Signal Yield	ε, 10^{-4}	$\mathcal{B}$, 10^{-4}
$\tau^- \to e^- \overline{\nu}_e \nu_\tau$	73^{+23}_{-22}	5.9	$1.90^{+0.59+0.33}_{-0.57-0.35}$
$\tau^- \to \mu^- \overline{\nu}_\mu \nu_\tau$	12^{+18}_{-17}	3.7	$0.50^{+0.76+0.18}_{-0.72-0.21}$
$\tau^- \to \pi^- \nu_\tau$	55^{+21}_{-20}	4.7	$1.80^{+0.69+0.36}_{-0.66-0.37}$
Combined	143^{+36}_{-35}	14.3	$1.54^{+0.38+0.29}_{-0.37-0.31}$



(b) τ → eνν , (c) τ→ μνν and (d) τ → πν



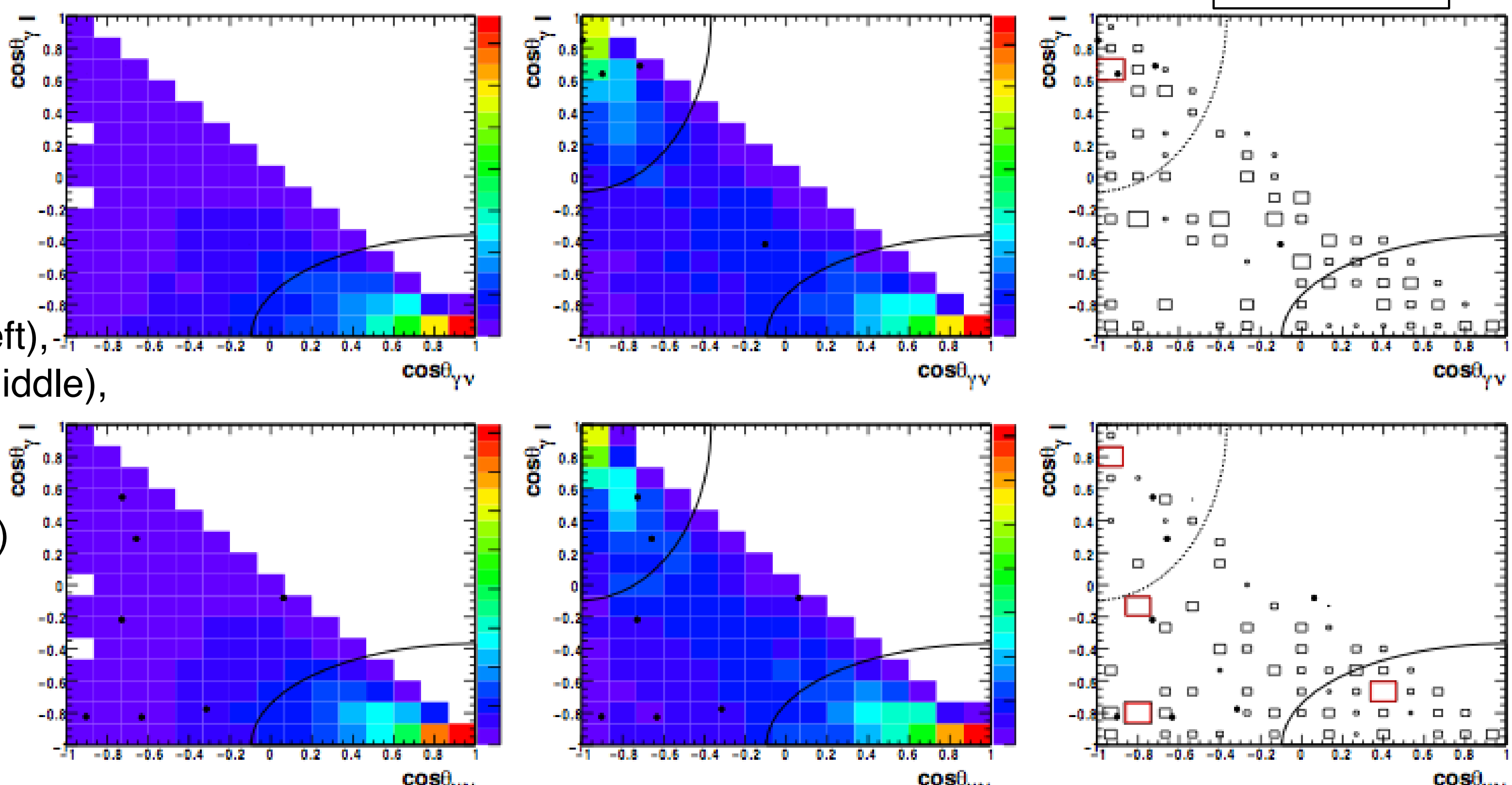
BaBar B→ℓνγ Hadronic Tag

PRD80:111105 (2009)
465 x10^6 $B\bar{B}$

	$B^+\to e^+\nu_e\gamma$	$B^+\to \mu^+\nu_\mu\gamma$	$B^+\to \ell^+\nu_\ell\gamma$
$N_\ell^{\rm comb}$	$0.3 \pm 0.3 \pm 0.1$	$1.2 \pm 0.6 \pm 0.6$	
$N_\ell^{\rm peak}$	$2.4 \pm 0.3 \pm 0.4$	$2.1 \pm 0.3 \pm 0.3$	
$N_\ell^{\rm bkg}$	$2.7 \pm 0.4 \pm 0.4$	$3.4 \pm 0.7 \pm 0.7$	
$\epsilon_\ell^{\rm sig}$	$(7.8 \pm 0.1 \pm 0.3)\times10^{-4}$	$(8.1 \pm 0.1 \pm 0.3)\times10^{-4}$	
$N_\ell^{\rm obs}$	4	7	
$\mathcal{B}_{\rm combined}$			$(6.5^{+7.6+2.8}_{-4.7-0.8}) \times 10^{-6}$
Model-independent limits	$< 17\times10^{-6}$	$< 26\times10^{-6}$	$< 15.6 \times 10^{-6}$
$f_A = f_V$ limits	$< 8.4 \times 10^{-6}$	$< 6.7 \times 10^{-6}$	$< 3.0 \times 10^{-6}$
$f_A = 0$ limits	$< 29 \times 10^{-6}$	$< 22 \times 10^{-6}$	$< 18 \times 10^{-6}$

$$\frac{d\Gamma}{dE_\gamma} = \frac{\alpha G_F^2}{48\pi^2}|V_{ub}|^2 m_B^4 \left(f_A^2(E_\gamma) + f_V^2(E_\gamma)\right) x(1-x)^3$$

arXiv:0909.5689



f_A=f_V signal model (left),
f_A=0 signal model (middle),
N_{bkg} (right),
electron mode (top),
muon mode (bottom)

Belle $B \to D^{(*)} \tau \nu$ Inclusive

arXiv: 1005.2302 (2010)
PRL 100, 021801 (2008)

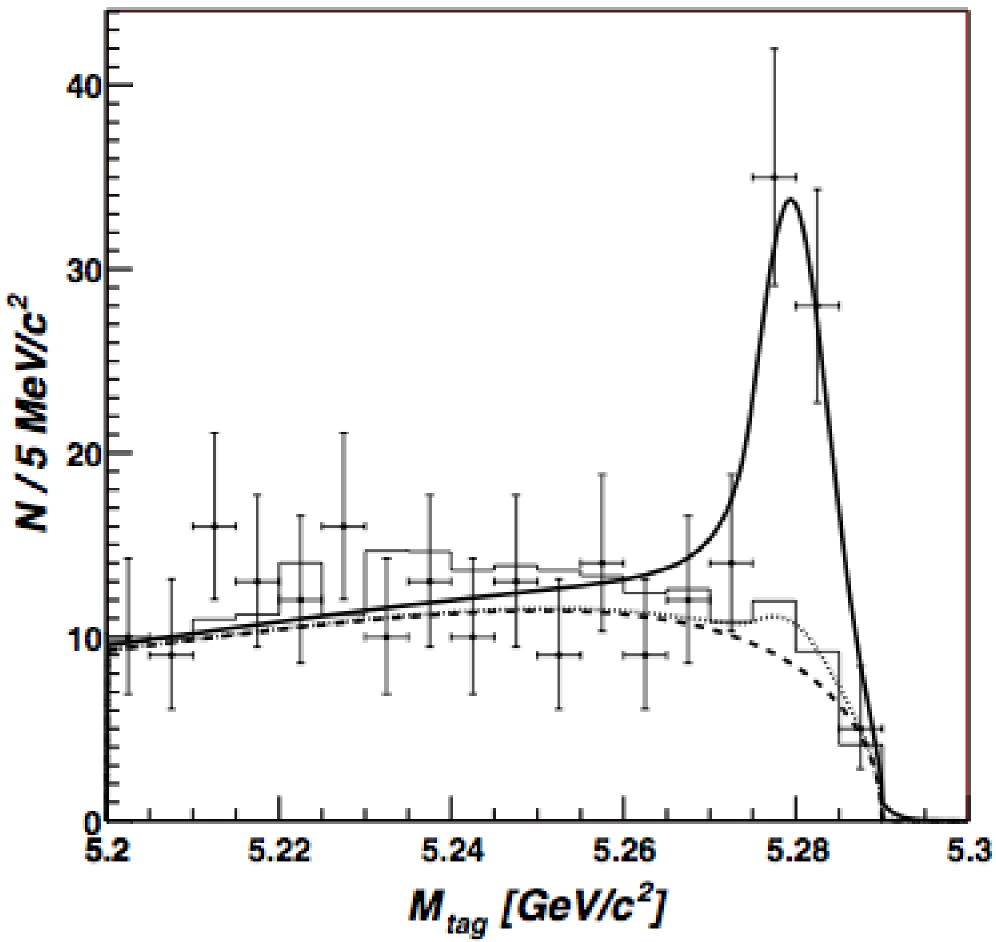


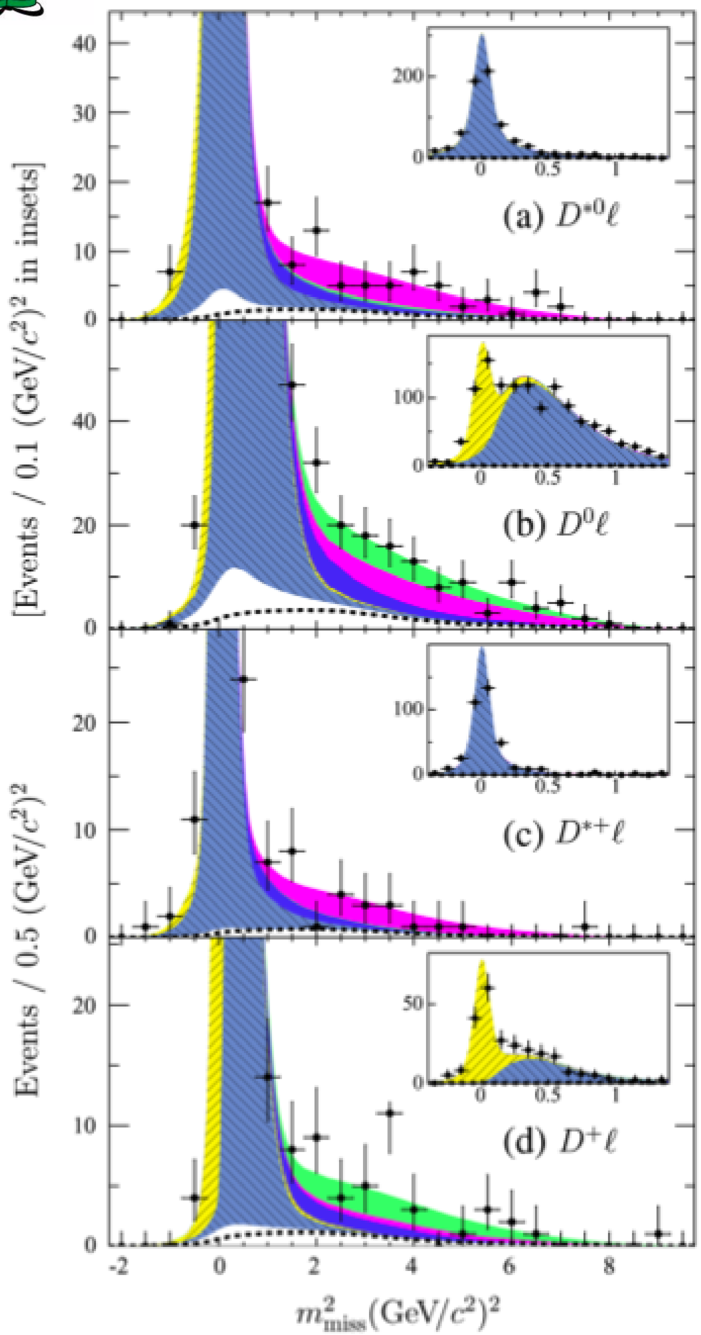
TABLE II. Summary of the systematic uncertainties.

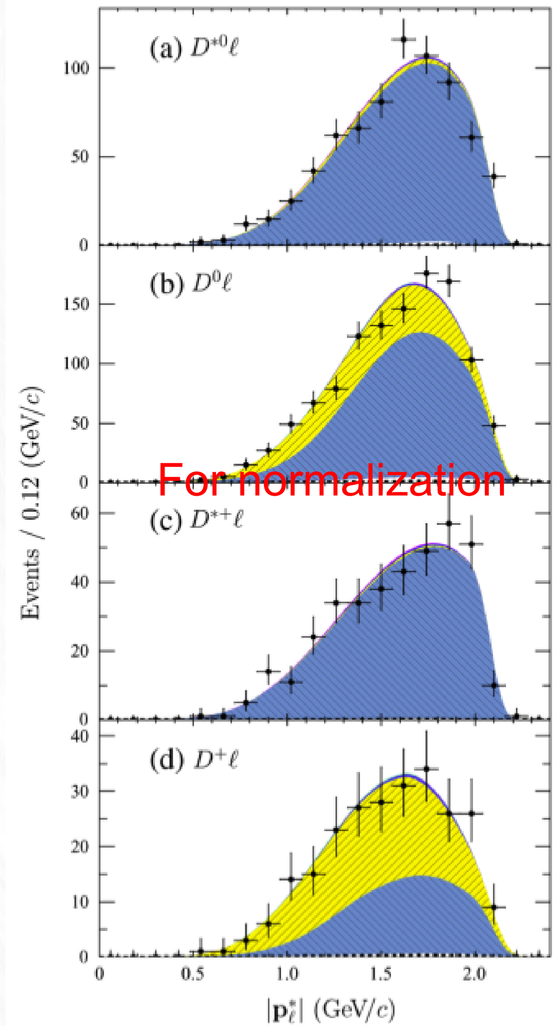
Source	$\bar{D}^{*0}\tau^+\nu_\tau$	$\bar{D}^0\tau^+\nu_\tau$
$N_{B\bar{B}}$	$\pm 1.4\%$	$\pm 1.4\%$
Reconstruction of $B_{\rm tag}$ and $B_{\rm sig}$	$\pm 12.9\%$	$\pm 12.8\%$
Lepton-id and signal selection	${}^{+1.5}_{-1.6}\%$	${}^{+4.4}_{-4.5}\%$
Shape of the signal PDF's	$\pm 2.5\%$	$\pm 6.0\%$
Comb. and peaking backgrounds	$\pm 3.3\%$	$\pm 2.7\%$
Fitting procedure	$\pm 0.8\%$	$\pm 1.5\%$
Total	$\pm 13.9\%$	$\pm 15.2\%$

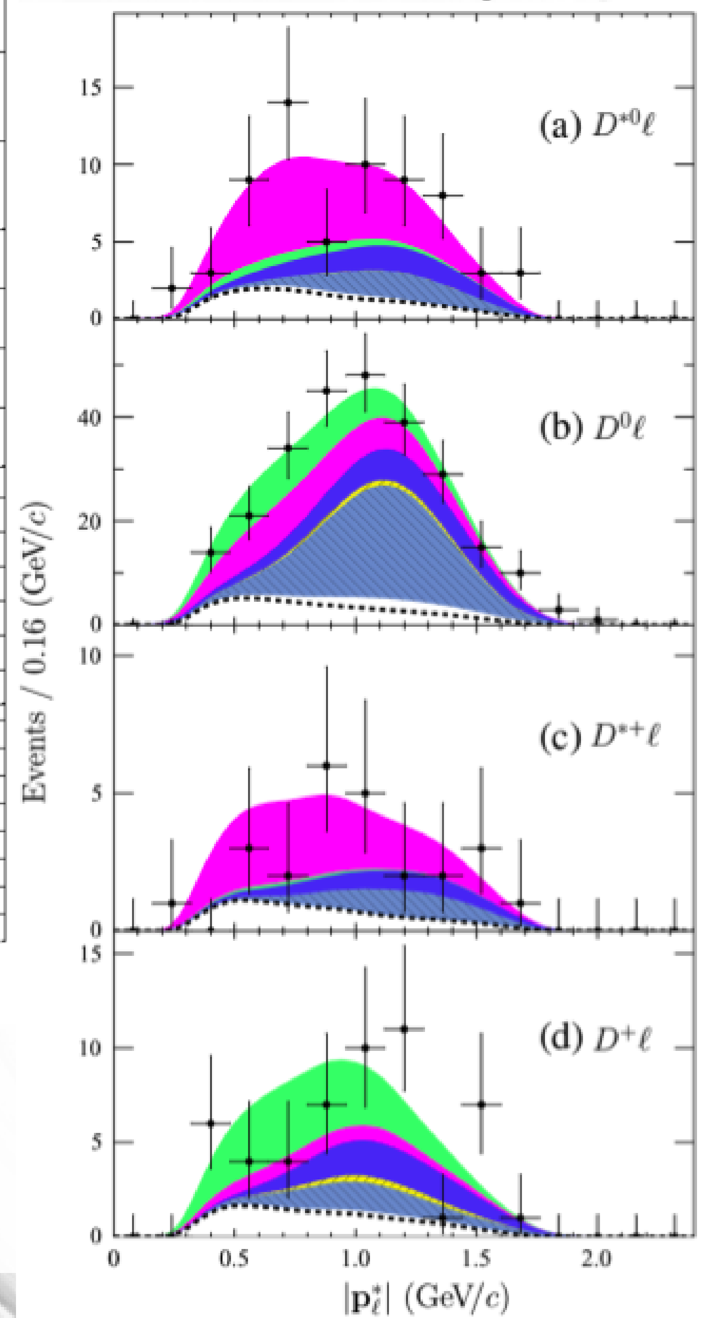
Subchannel	$N_b^{\rm MC}$	N_p	N_s	N_b	$N_{\rm obs}$	$\epsilon \times 10^{-4}$	$B \times 10^{-3}$	$\mathcal{B}(\%)$	Σ	S
$\bar{D}^0 \to K^+\pi^-$, $\tau^+ \to e^+\nu_e\bar{\nu}_\tau$	$26.3^{+5.4}_{-3.7}$	$1.2^{+1.6}_{-1.5}$	$19.5^{+5.8}_{-5.0}$	$19.4^{+5.8}_{-5.0}$	40	3.25 ± 0.11	4.59	$2.44^{+0.74}_{-0.65}$	5.0σ	0.79
$\bar{D}^0 \to K^+\pi^-\pi^0$, $\tau^+ \to e^+\nu_e\bar{\nu}_\tau$	$50.8^{+5.5}_{-5.1}$	$5.0^{+2.6}_{-2.2}$	$11.9^{+6.0}_{-5.2}$	$43.1^{+8.0}_{-7.2}$	60	0.78 ± 0.07	17.03	$1.69^{+0.84}_{-0.74}$	2.6σ	0.50
$\bar{D}^0 \to K^+\pi^-$, $\tau^+ \to \pi^+\bar{\nu}_\tau$	$138.0^{+9.2}_{-8.8}$	$-1.0^{+3.6}_{-3.2}$	$29.9^{+10.0}_{-9.1}$	$118.0^{+14.0}_{-13.0}$	148	$1.07^{+0.17}_{-0.15}$	25.72	$2.02^{+0.68}_{-0.61}$	3.8σ	0.48
Combined	215^{+12}_{-11}	$6.2^{+4.7}_{-4.2}$	60^{+12}_{-11}	182^{+15}_{-14}	248	$1.17^{+0.10}_{-0.08}$	47.34	$2.02^{+0.40}_{-0.37}$	6.7σ	0.57

PRD 79, 092002 (2009)

BaBar B→D$^{(*)}\tau\nu$ Hadronic Tag



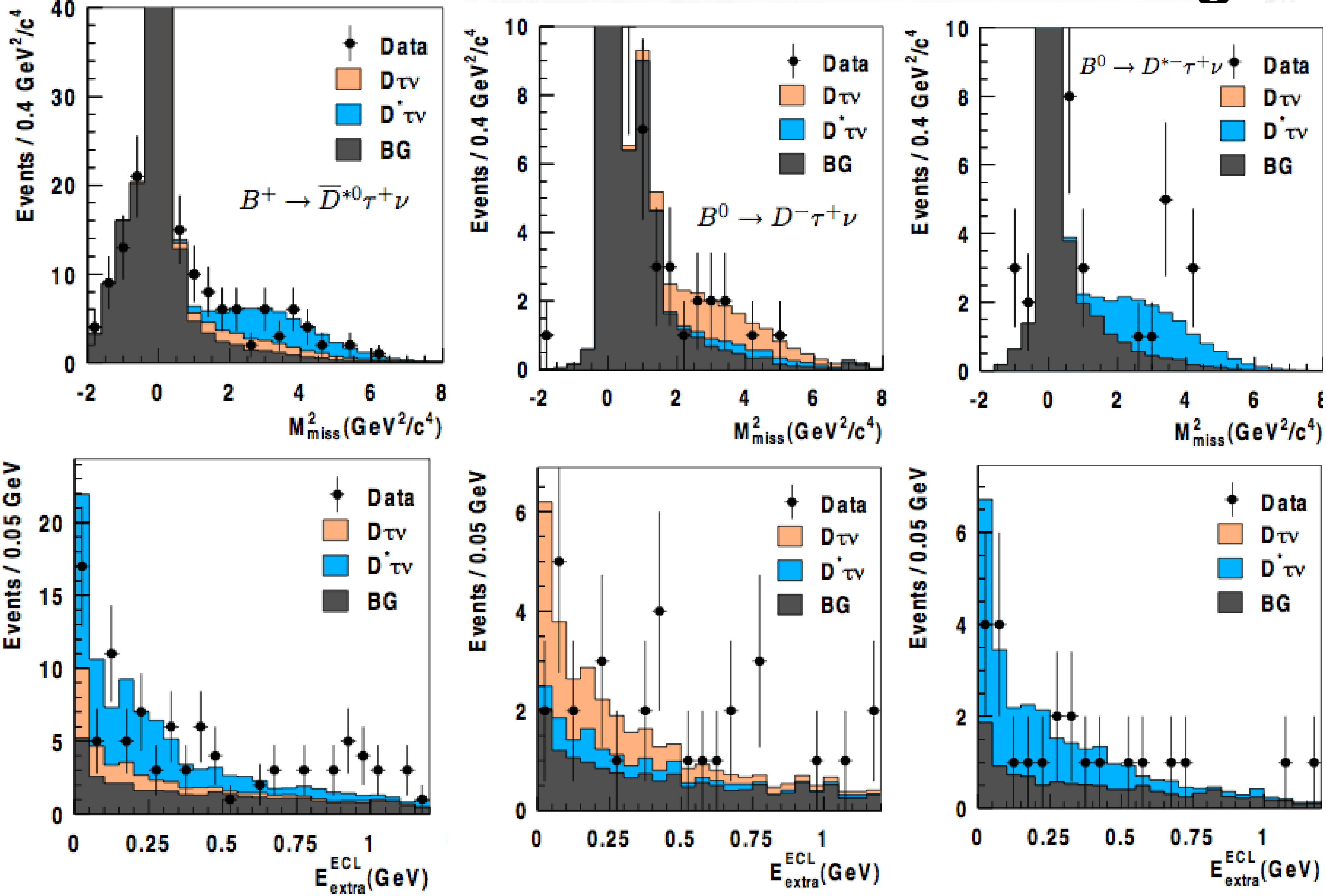




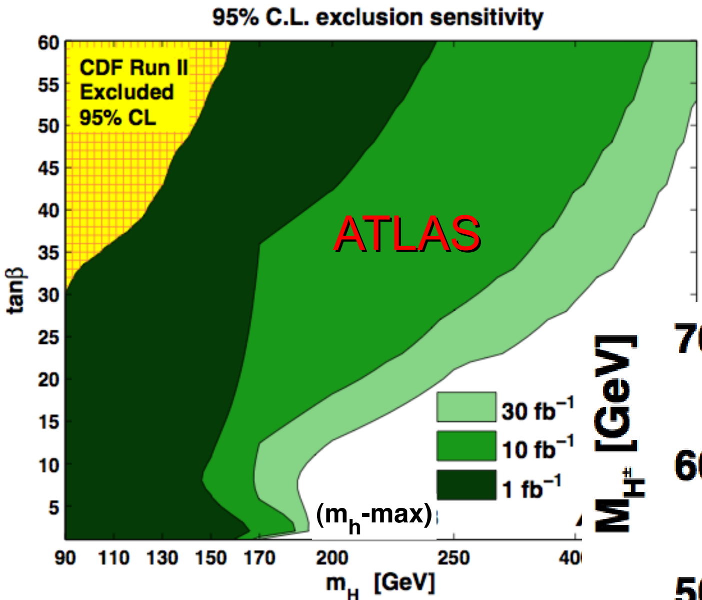
Signal mode	$\varepsilon_{\rm sig}/\varepsilon_{\rm norm}$
$B^- \to D^0\tau^-\bar{\nu}_\tau$	1.85 ± 0.02
$B^- \to D^{*0}\tau^-\bar{\nu}_\tau$	0.99 ± 0.01
$\bar{B}^0 \to D^+\tau^-\bar{\nu}_\tau$	1.83 ± 0.03
$\bar{B}^0 \to D^{*+}\tau^-\bar{\nu}_\tau$	0.91 ± 0.01

arXiv:0910.4301 (2009)

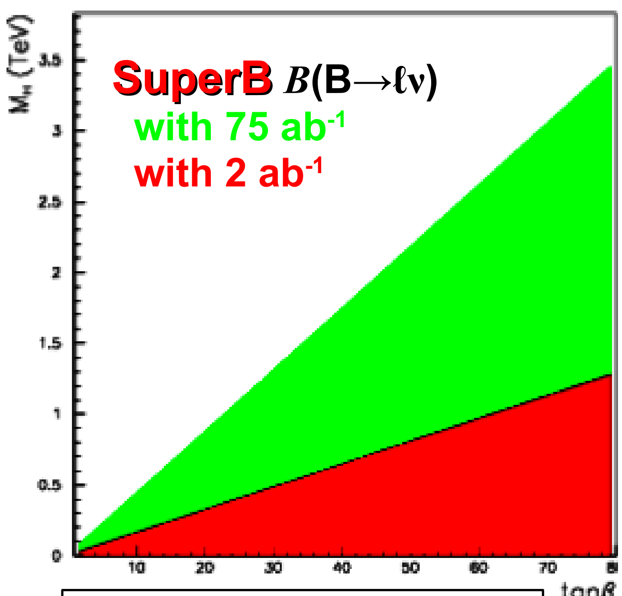
Belle $B \to D^{(*)}\tau\nu$ Hadronic Tag



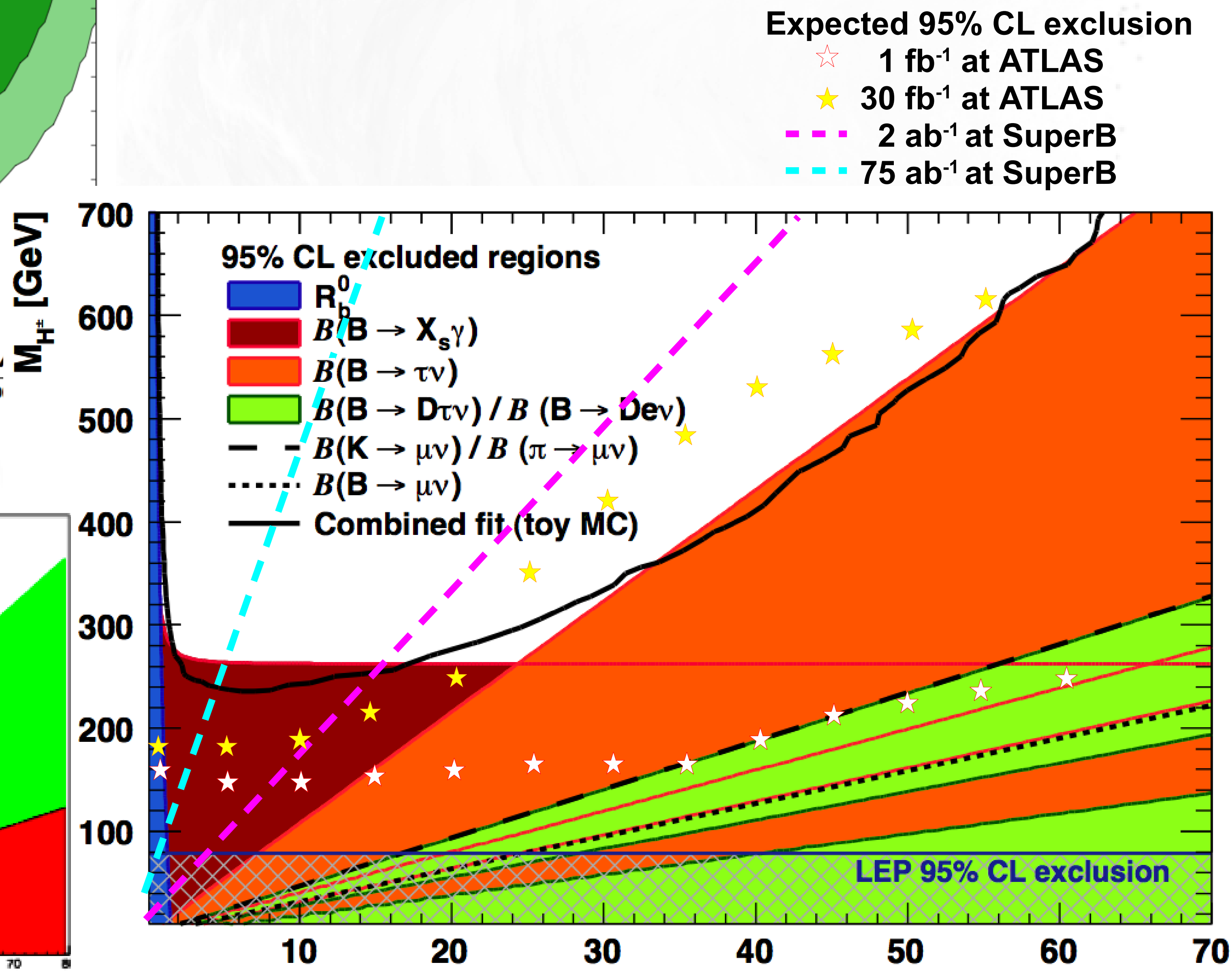
B-Factory Sensitivity



(ATLAS) arXiv:0901.0512 (2009)



(SuperB) arXiv:0709.0451 (2007)



Flaecher, et al, Eur.Phys.J.C60:543 (2009)