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

CKM Workshop 2012

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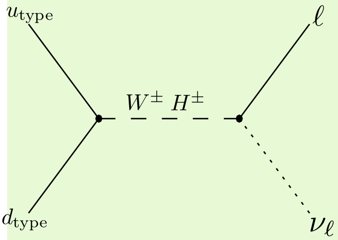
Motivation

Charged Higgs Effects



$$\mathcal{H}_{\text{eff}} = \frac{G_F}{\sqrt{2}} V_{qb} \left\{ [\bar{q}\gamma^u(1-\gamma_5)b][\bar{\tau}\gamma_\mu(1-\gamma_5)\nu_\tau] - \frac{\bar{m}_b m_\tau}{m_B^2} \bar{q}[\boldsymbol{g_S} + g_P\gamma_5]b[\bar{\tau}(1-\gamma_5)\nu_\tau] \right\}$$

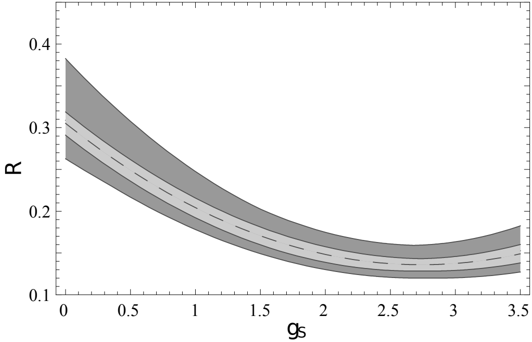
- Observables:

$$R = \frac{\mathcal{B}(B \to D\tau\nu_\tau)}{\mathcal{B}(B \to D\ell\nu_\ell)} \overset{SM}{\approx} 0.297 \qquad R^* = \frac{\mathcal{B}(B \to D^*\tau\nu_\tau)}{\mathcal{B}(B \to D^*\ell\nu_\ell)} \overset{SM}{\approx} 0.251$$

Effects of Charged Higgs

- MSSM with Minimal Flavor Violation:

$$g_S = g_P = \frac{m_B^2}{M_{H^+}^2} \frac{\tan^2\beta}{(1+\tilde{\epsilon}_0 \tan\beta)(1+\epsilon_\tau \tan\beta)}$$



Nierste, Trine, Westhoff, arXiv:0801:4938

- In the type-II 2HDM: $\tilde{\epsilon}_0 = \epsilon_\tau = 0$
- **Charged Higgs contribution (g_S) can have large impact on branching ratios**

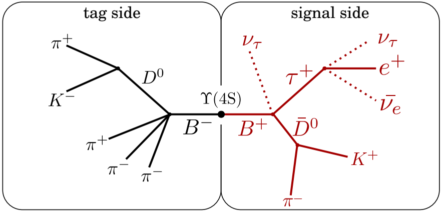
Missing Neutrinos

Exemplary decay: $B^0 \to D^- \tau^+ (\to e^+ \nu_e \bar{\nu}_\tau) \nu_\tau$

Problem: Three neutrinos in the final state

- $\boxed{B \to D\tau(\to \ell\nu_\ell\nu_\tau)\nu_\tau}$ signal contains three-neutrino system with unknown momentum.
- Without further information ...
  - ... no useful kinematic constraints to obtain a clean signal
  - ... not distinguishable from $B \to D\ell\nu_\ell$

Solution: Tagging



Tagging Methods

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Hadronic Tagging

- Full Reconstruction of as many purely hadronic $b \to c$ decays as reasonably possible.
- Tag Side, then Signal Side
- Efficiency $\sim 0.1 - 0.2\%$
- Combined with signal side: **Usually manageable background levels**

Inclusive Tagging

- Signal Side, then Tag Side
- Remaining particles in the detector form the tag side B_{tag}
- Efficiency typically larger than for hadronic tagging
- **Much higher background levels**

Overview

Tagging	Measurement	Data Sample
Inclusive	$\mathcal{B}(B^0 \to D^{*-}\tau^+\nu_\tau)$	535×10^6 $B\bar{B}$
Inclusive	$\mathcal{B}(B^+ \to \overline{D}^0\tau^+\nu_\tau)$	657×10^6 $B\bar{B}$
Inclusive	$\mathcal{B}(B^+ \to \overline{D}^{*0}\tau^+\nu_\tau)$	657×10^6 $B\bar{B}$
Hadronic	R, R^*	657×10^6 $B\bar{B}$
Hadronic	$B \to D\tau\nu_\tau$	657×10^6 $B\bar{B}$
Hadronic	$B \to D^*\tau\nu_\tau$	657×10^6 $B\bar{B}$

Overview

Tagging	Measurement	Data Sample
Inclusive	$\mathcal{B}(B^0 \to D^{*-}\tau^+\nu_\tau)$	$535 \times 10^6\ B\bar{B}$
Inclusive	$\mathcal{B}(B^+ \to \overline{D}^0\tau^+\nu_\tau)$	$657 \times 10^6\ B\bar{B}$
Inclusive	$\mathcal{B}(B^+ \to \overline{D}^{*0}\tau^+\nu_\tau)$	$657 \times 10^6\ B\bar{B}$
Hadronic	R, R^*	$657 \times 10^6\ B\bar{B}$
Hadronic	$B \to D\tau\nu_\tau$	$657 \times 10^6\ B\bar{B}$
Hadronic	$B \to D^*\tau\nu_\tau$	$657 \times 10^6\ B\bar{B}$

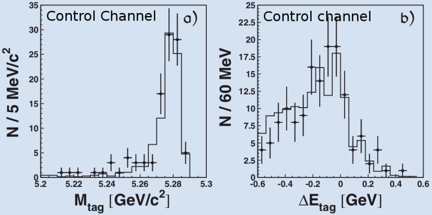
$\mathcal{B}(B^0 \to D^{*-}\tau^+\nu_\tau)$ - Inclusive Tagging

Description

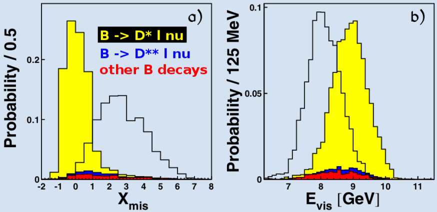
- Inclusive tagging
- **535×10^6 $B\bar{B}$ pairs**
- Channels:
  - $B^0 \to D^{*-}\tau^+\nu_\tau$
  - $D^{*-} \to \bar{D}^0\pi^-$
  - $D^0 \to K^-\pi^+$ (and $D^0 \to K^-\pi^+\pi^0$ for electron mode)
  - $\tau^+ \to e^+\nu_e\bar{\nu}_\tau$
  - $\tau^+ \to \pi^+\bar{\nu}_\tau$
- Reference: **A. Matyja, M. Rozanska et al. (Belle Collaboration), Phys. Rev. Lett. 99, 191807 (2007).**

Inclusive Tagging

- **Tag side improvement**: zero total event charge, no (additional) $\mu/e/p$, residual E in ECL< 0.35 GeV and $N_{\pi^0 \text{and} \gamma} < 5$ (on tag side)



Validation sample $B^0 \to D^{*-}\pi^+$

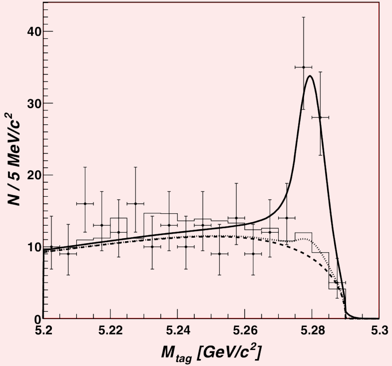


Signal (blank) BG (shaded)

- $E_{vis} = \sum E(\text{particle}_i)$, $E_{mis} = E_{beam} - E_{D^*} - E_{e/\pi}$, $X_{mis} = (E_{mis} - |\vec{p_{D^*}} + \vec{p_{e/\pi}}|)/\sqrt{E_{beam}^2 - m_{B^0}^2}$
- $X_{mis} > 2.75$, 1.9GeV$< E_{mis} < 2.6$GeV and $E_{vis} < 8.3$ GeV. (e mode)
- $X_{mis} > 1.50$, $M_W^2 - M_{mis}^2 - m_\tau^2 + m_\pi^2 > 0$, $E_{vis} < 8.3$ GeV, $p(\pi_{prompt}) > 0.6$ GeV, no K_L and < 4 non-IP tracks (π mode)

$\mathcal{B}(B^0 \to D^{*-}\tau^+\nu_\tau)$ - Inclusive Tagging

Results



- Signal: Crystal Ball line shape (CB)
- Background: ARGUS (combinatorial BG) and CB (peaking $B^0 \to D^{*-}e^+\nu_e$ events)

$\mathcal{B}(B^0 \to D^{*-}\tau^+\nu_\tau)$ - Inclusive Tagging

Subchannel	N_s	N_{obs}	$\mathcal{B}(\%)$	Σ
$\bar{D}^0 \to K^+\pi^-,\ \tau^+ \to e^+\nu_e\bar{\nu}_\tau$	$19.5^{+5.8}_{-5.0}$	40	$2.44^{+0.74}_{-0.65}$	5.0σ
$\bar{D}^0 \to K^+\pi^-\pi^0,\ \tau^+ \to e^+\nu_e\bar{\nu}_\tau$	$11.9^{+6.0}_{-5.2}$	60	$1.69^{+0.84}_{-0.74}$	2.6σ
$\bar{D}^0 \to K^+\pi^-,\ \tau^+ \to \pi^+\bar{\nu}_\tau$	$29.9^{+10.0}_{-9.1}$	148	$2.02^{+0.68}_{-0.61}$	3.8σ
Combined	60^{+12}_{-11}	248	$2.02^{+0.40}_{-0.37}$	6.7σ

Systematic Uncertainties

- Parametrization of signal and background
- B_{tag} efficiency
- Tracking, neutral reconstruction and PID efficiency
- Intermediate branching fraction $(\mathcal{B}(D^{*-} \to \bar{D}^0\pi^-) \times \mathcal{B}(\bar{D}^0 \to i) \times \mathcal{B}(\tau^+ \to j))$
- **Sum: 18.5%** $\Rightarrow \Sigma = 5.2\sigma$

First observation of $B^0 \to D^{*-}\tau^+\nu_\tau$!

Overview

Tagging	Measurement	Data Sample
Inclusive	$\mathcal{B}(B^0 \to D^{*-}\tau^+\nu_\tau)$	$535 \times 10^6\ B\bar{B}$
Inclusive	$\mathcal{B}(B^+ \to \overline{D}^0\tau^+\nu_\tau)$	$657 \times 10^6\ B\bar{B}$
Inclusive	$\mathcal{B}(B^+ \to \overline{D}^{*0}\tau^+\nu_\tau)$	$657 \times 10^6\ B\bar{B}$
Hadronic	R, R^*	$657 \times 10^6\ B\bar{B}$
Hadronic	$B \to D\tau\nu_\tau$	$657 \times 10^6\ B\bar{B}$
Hadronic	$B \to D^*\tau\nu_\tau$	$657 \times 10^6\ B\bar{B}$

$\mathcal{B}(B^+ \to \bar{D}^{(*)0}\tau^+\nu_\tau)$ - Inclusive Tagging

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Description

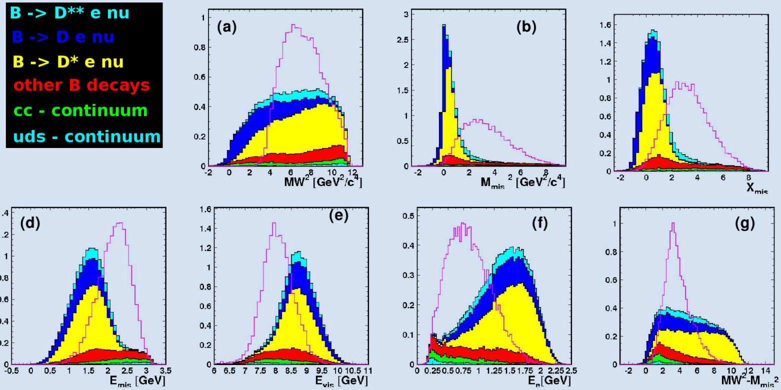
- Inclusive tagging
- **657×10^6 $B\bar{B}$ pairs**
- Channels:
  - $B^+ \to \bar{D}^0\tau^+\nu_\tau$
  - $B^+ \to \bar{D}^{*0}\tau^+\nu_\tau$
  - $D^{*0} \to D^0\pi^0$
  - $D^0 \to (K^-\pi^+), (K^-\pi^+\pi^0)$
  - $\tau^+ \to e^+\nu_e\bar{\nu}_\tau$
  - $\tau^+ \to \mu^+\nu_\mu\bar{\nu}_\tau$
  - $\tau^+ \to \pi^+\bar{\nu}_\tau$
- Reference: **A. Bozek, M. Rozanska et al. (Belle Collaboration), Phys. Rev. D 82, 072005(R) (2010).**

$\mathcal{B}(B^+ \to \bar{D}^{(*)0}\tau^+\nu_\tau)$ - Inclusive Tagging

- **Tag side improvement:** zero total event charge, no (additional) $\mu/e/p$, residual E in ECL$< 0.35(0.25)(0.20)$ GeV (depending on the mode), $N_{\pi^0\text{and}\gamma} < 6$ and $N_\gamma < 3$ (on tag side), < 4 non-IP tracks (π mode), depending on mode also no K_L.
- Variables for signal side:
  - $\boldsymbol{E}_{\text{miss}} = E_{\text{beam}} - E_{D^{(*)0}} - E_{e/d_\tau}$
  - $\boldsymbol{E}_{\text{vis}} = \sum E(\text{particle}_i)$
  - $\boldsymbol{M}^2_{\text{miss}} = E^2_{\text{miss}} - (\vec{p}_{\text{sig}} - \vec{p_{D^{(*)0}}} - \vec{p_{d_\tau}})^2$
  - $\boldsymbol{X}_{\text{mis}} = (E_{\text{miss}} - |\vec{p_{D^*}} + \vec{p_{e/\pi}}|)/\sqrt{E^2_{\text{beam}} - m^2_{B^0}}$
- $E_{\text{vis}} > 8.3 - 8.5$ GeV, $E_{\text{miss}} > 1.5 - 1.9$ GeV, $X_{\text{mis}} > 2.0 - 2.75$ GeV (leptonic τ-decays), $X_{\text{mis}} > 1.0 - 1.5$ GeV (pionic τ-decays), neutrino angle (calculated from M^2_{miss} and q^2) in $[-1, 1]$ and $q^2 < 9.5$ GeV^2
- BG estimation by simultaneous fits to M_{tag}, ΔE_{tag}, E_{D_τ}, X_{mis}, E_{vis}, q^2 and R_2 (ratio of FWM)

$\mathcal{B}(B^+ \to \bar{D}^{(*)0}\tau^+\nu_\tau)$ - Inclusive Tagging

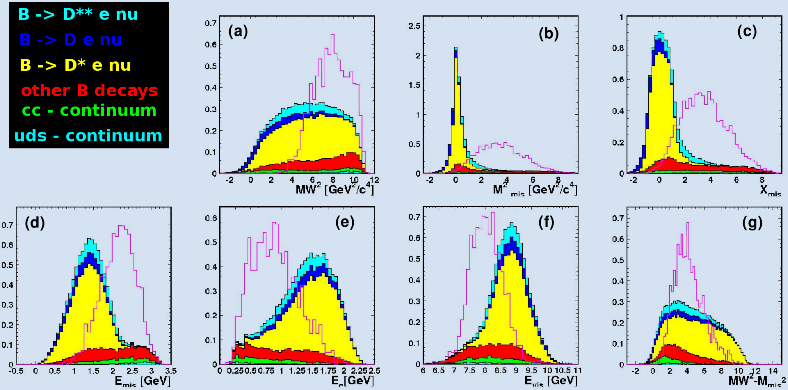
$B^+ \to \bar{D}^0\tau^+(\to e^+\nu_e\bar{\nu}_\tau)\nu_\tau$ sample



Signal (blank) BG (shaded)

$\mathcal{B}(B^+ \to \bar{D}^{(*)0}\tau^+\nu_\tau)$ - Inclusive Tagging

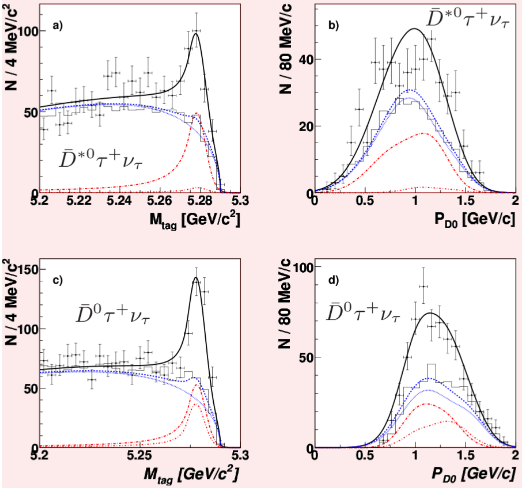
$B^+ \to \bar{D}^{*0}\tau^+(\to e^+\nu_e\bar{\nu}_\tau)\nu_\tau$ sample



Signal (blank) BG (shaded)

$\mathcal{B}(B^+ \to \bar{D}^{(*)0}\tau^+\nu_\tau)$ - Inclusive Tagging

Results



M_{tag}

- Signal: Crystal Ball line shape
- Background: ARGUS

P_{D^0}

- All components: Sum of two Gaussians

$\mathcal{B}(B^+ \to \bar{D}^{(*)0}\tau^+\nu_\tau)$ - Inclusive Tagging

Mode	N_s	$\mathcal{B}(\%)$	$\Sigma(\sigma)$
$\bar{D}^{*0}\tau^+\nu_\tau$	$446^{+58}_{-56}(226)$	$2.12^{+0.28}_{-0.27}$	8.8
$\bar{D}^{0}\tau^+\nu_\tau$	$146^{+42}_{-41}(15)$	0.77 ± 0.22	3.6

Numbers in parantheses: D (D^*) signal events extracted from D^* (D) sample.

Source	$\bar{D}^{*0}\tau^+\nu_\tau$	$\bar{D}^{0}\tau^+\nu_\tau$
$N_{B\bar{B}}$	$\pm1.4\%$	$\pm1.4\%$
Reconstruction of B_{tag} and B_{sig}	$\pm12.9\%$	$\pm12.8\%$
Lepton-id and signal selection	$^{+1.5}_{-1.6}\%$	$^{+4.4}_{-4.5}\%$
Shape of the signal PDF's	$\pm2.5\%$	$\pm6.0\%$
Comb. and peaking backgrounds	$\pm3.3\%$	$\pm2.7\%$
Fitting procedure	$\pm0.8\%$	$\pm1.5\%$
Total	$\pm13.9\%$	$\pm15.2\%$

$\Sigma = 8.1\sigma(D^*)$ and
$\Sigma = 3.5\sigma(D)$

First evidence for $B^+ \to \bar{D}^0\tau^+\nu_\tau$!

Overview

Tagging	Measurement	Data Sample
Inclusive	$\mathcal{B}(B^0 \rightarrow D^{*-}\tau^+\nu_\tau)$	535×10^6 $B\bar{B}$
Inclusive	$\mathcal{B}(B^+ \rightarrow \overline{D}^0\tau^+\nu_\tau)$	657×10^6 $B\bar{B}$
Inclusive	$\mathcal{B}(B^+ \rightarrow \overline{D}^{*0}\tau^+\nu_\tau)$	657×10^6 $B\bar{B}$
Hadronic	R, R^*	657×10^6 $B\bar{B}$
Hadronic	$B \rightarrow D\tau\nu_\tau$	657×10^6 $B\bar{B}$
Hadronic	$B \rightarrow D^*\tau\nu_\tau$	657×10^6 $B\bar{B}$

$B \to D^{(*)}\tau\nu_\tau$, hadronic tagging

Description

- Hadronic tagging
- Efficiency $\sim 0.1\%$
- **657×10^6 $B\bar{B}$ pairs**
- Channels:
  - $B^0 \to D^-\tau^+\nu_\tau$, $B^0 \to D^{*-}\tau^+\nu_\tau$
  - $B^+ \to \overline{D}^0\tau^+\nu_\tau$, $B^+ \to \overline{D}^{*0}\tau^+\nu_\tau$
  - $D^{*0} \to D^0\pi^0, D^0\gamma$ and $D^{*+} \to D^+\pi^0, D^0\pi^+$
  - $D^0 \to K^-\pi^+, K^-\pi^+\pi^0, K^-\pi^+\pi^+\pi^-, K^-\pi^+\pi^+\pi^-\pi^0$, $K_S^0\pi^0, K_S^0\pi^+\pi^-, K_S^0\pi^+\pi^-\pi^0$
  - $D^- \to K^+\pi^-\pi^-, K^+\pi^-\pi^-\pi^0, K_S^0\pi^-$
  - $\tau^+ \to e^+\nu_e\bar{\nu}_\tau, \tau^+ \to \mu^+\nu_\mu\bar{\nu}_\tau$
- Reference: **I. Adachi et al. (Belle Collaboration), arXiv:0910.4301.**

$B \to D^{(*)}\tau\nu_\tau$, hadronic tagging

Optimization of the Selection

- Cut on $P_\ell^{\text{in } B \text{ frame}}$
- Requirement of no additional tracks and π^0

$B \to D\ell\nu_\ell$ and $B \to D^*\ell\nu_\ell$ components ...

- are used to calibrate the background MC simulation
- are used to normalize the extracted signal yields

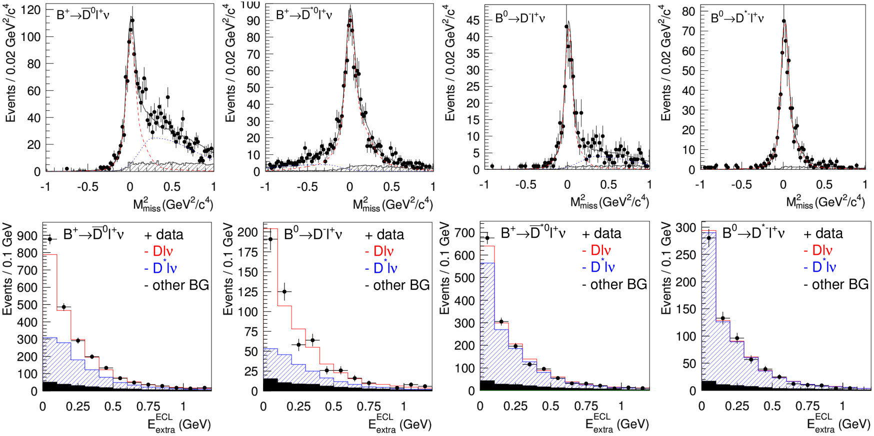
Fitting variables ...

- $M_{\text{miss}}^2 = \left[p(\text{Beam}) - \left(p(B_{\text{tag}}) + p(D^{(*)}) + p(\ell)\right)\right]^2$
- $E_{\text{extra}}^{\text{ECL}} = \sum E_{\text{Calor.}} - \left(\sum E_{\text{tag}} + \sum E_{\text{signal}}\right)$

$B \to D^{(*)}\tau\nu_\tau$, hadronic tagging

Normalization Sample - 2D fits

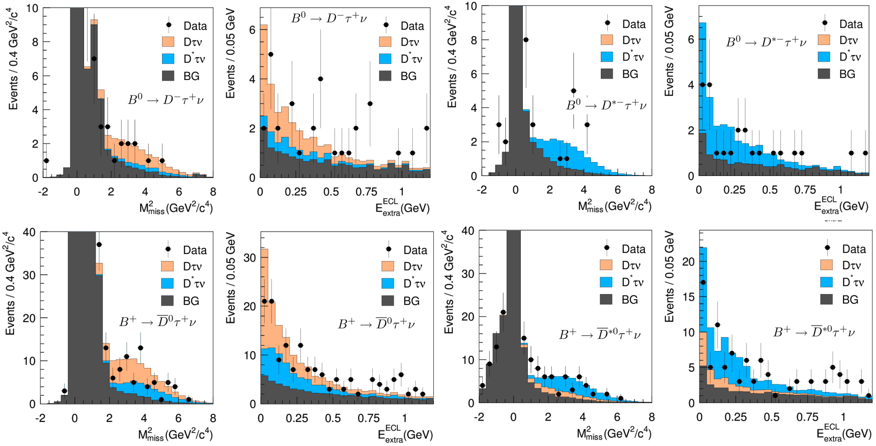
$B^+ \to \overline{D}^0\tau^+\nu_\tau$ $B^+ \to \overline{D}^{*0}\tau^+\nu_\tau$ $B^0 \to D^-\tau^+\nu_\tau$ $B^0 \to D^{*-}\tau^+\nu_\tau$



$B \to D^{(*)}\tau\nu_\tau$, hadronic tagging

Full Signal Sample - 2D fits

$B^0 \to D^-\tau^+\nu_\tau$ $\qquad$ $B^0 \to D^{*-}\tau^+\nu_\tau$



$B^+ \to \overline{D}^0\tau^+\nu_\tau$ $\qquad$ $B^+ \to \overline{D}^{*0}\tau^+\nu_\tau$

$B \to D^{(*)}\tau\nu_\tau$, hadronic tagging

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Results

Quantity	$\overline{D}^0\tau^+\nu$	$\overline{D}^{*0}\tau^+\nu$
$N(\overline{D}^{(*)}\tau^+\nu)$	$98.6^{+26.3}_{-25.0}$	$99.8^{+22.2}_{-21.3}$
$\epsilon(\overline{D}^{(*)}\tau^+\nu)$ [%]	6.20 ± 0.08	3.86 ± 0.08
R[%]	$70.2\ ^{+18.9}_{-18.0}\ ^{+11.0}_{-9.1}$	$46.8\ ^{+10.6}_{-10.2}\ ^{+6.2}_{-7.2}$
$\Sigma(\Sigma_{stat})$	3.8 (4.4)	3.9 (5.2)
$\mathcal{B}$ [%]	$1.51\ ^{+0.41}_{-0.39}\ ^{+0.24}_{-0.19} \pm 0.15$	$3.04\ ^{+0.69}_{-0.66}\ ^{+0.40}_{-0.47} \pm 0.22$
Quantity	$D^-\tau^+\nu$	$D^{*-}\tau^+\nu$
$N(\overline{D}^{(*)}\tau^+\nu)$	$17.2^{+7.7}_{-6.9}$	$25.0^{+7.2}_{-6.3}$
$\epsilon(\overline{D}^{(*)}\tau^+\nu)$ [%]	6.86 ± 0.09	2.09 ± 0.04
R[%]	$47.6\ ^{+21.6}_{-19.3}\ ^{+6.3}_{-5.4}$	$48.1\ ^{+14.0}_{-12.3}\ ^{+5.8}_{-4.1}$
$\Sigma(\Sigma_{stat})$	2.6 (2.8)	4.7 (5.9)
$\mathcal{B}$[%]	$1.01\ ^{+0.46}_{-0.41}\ ^{+0.13}_{-0.11} \pm 0.10$	$2.56\ ^{+0.75}_{-0.66}\ ^{+0.31}_{-0.22} \pm 0.10$

$B \to D^{(*)}\tau\nu_\tau$, hadronic tagging

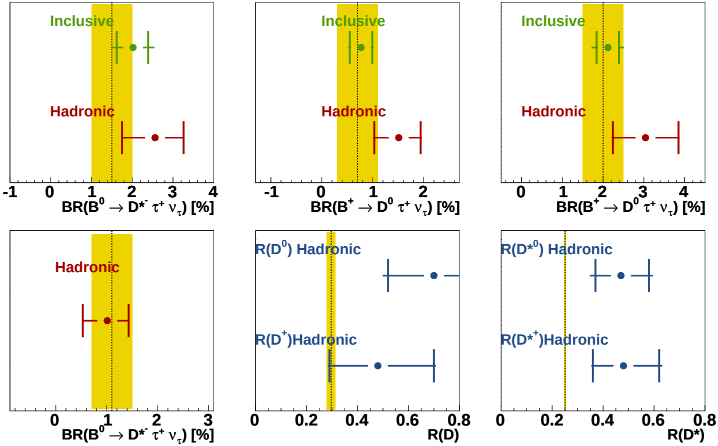
Systematic Errors

Source	$\overline{D}^0\tau^+\nu[\%]$	$\overline{D}^{*0}\tau^+\nu[\%]$	$D^-\tau^+\nu[\%]$	$D^{*-}\tau^+\nu[\%]$
M^2_{miss} shape	+9.10/-7.89	+9.86/-10.7	+6.39/-5.78	+5.80/-6.12
$E^{\text{ECL}}_{\text{extra}}$ shape	+10.6/-7.58	+7.01/-9.73	+9.03/-7.27	+9.84/-4.97
$D^{**}\ell\nu$	+0.35/-0.41	+0.75/-0.02	+4.50/-2.56	+0.58/-0.28
$D \leftrightarrow D^*$ cross-feed	+7.05/-6.86	+5.12/-5.34	+5.77/-6.01	+3.48/-3.37
$\mathcal{B}(\tau \to \ell\nu\nu)$	±0.3	±0.3	±0.3	±0.3
Total	+15.7/-12.9	+13.2/-15.4	+13.3/-11.4	+12.0/-8.58

Conclusion

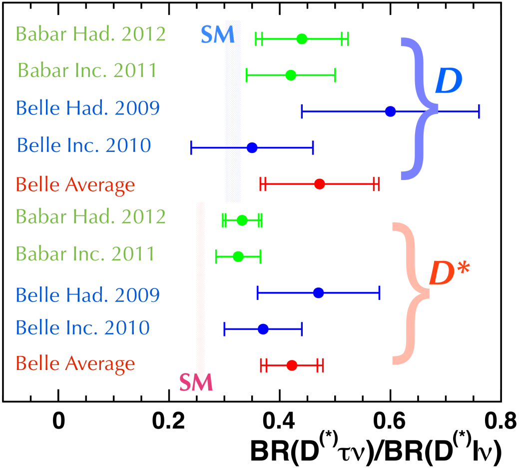
Tagging	Measurement	Result
Inclusive	$\mathcal{B}(B^0 \to D^{*-}\tau^+\nu_\tau)$	$(2.02^{+0.40}_{-0.37} \pm 0.37)\%$
Inclusive	$\mathcal{B}(B^+ \to \overline{D}^0\tau^+\nu_\tau)$	$(0.77 \pm 0.22 \pm 0.12)\%$
Inclusive	$\mathcal{B}(B^+ \to \overline{D}^{*0}\tau^+\nu_\tau)$	$(2.12^{+0.28}_{-0.27} \pm 0.29)\%$
Hadronic	$R(D^0)$, $R(D^+)$	$0.70^{+0.19+0.11}_{-0.18-0.9}$, $0.48^{+0.22+0.06}_{-0.19-0.05}$
Hadronic	$R(D^{*0})$, $R(D^{*+})$	$0.47^{+0.11+0.06}_{-0.10-0.07}$, $0.48^{+0.14+0.06}_{-0.12-0.04}$
Hadronic	$B^+ \to \overline{D}^0\tau^+\nu_\tau$	$(1.51^{+0.41+0.24}_{-0.39-0.19} \pm 0.15)\%$
Hadronic	$B^+ \to \overline{D}^{*0}\tau^+\nu_\tau$	$(3.04^{+0.69+0.40}_{-0.66-0.47} \pm 0.22)\%$
Hadronic	$B^0 \to D^-\tau^+\nu_\tau$	$(1.01^{+0.46+0.13}_{-0.41-0.11} \pm 0.10)\%$
Hadronic	$B^0 \to D^{*-}\tau^+\nu_\tau$	$(2.56^{+0.75+0.31}_{-0.66-0.22} \pm 0.10)\%$

Conclusion



Dotted Line: Current WA, Yellow Bands: Uncertainty on current WA

Conclusion



Isospin invariance assumed

Conclusion

- The branching ratios
  - $B^+ \to \overline{D}^0 \tau^+ \nu_\tau$
  - $B^+ \to \overline{D}^{*0} \tau^+ \nu_\tau$
  - $B^0 \to D^- \tau^+ \nu_\tau$
  - $B^0 \to D^{*-} \tau^+ \nu_\tau$

  are measured.
- The ratios $R(D^0)$, $R(D^{*0})$, $R(D^+)$ and $R(D^{*+})$ have been measured.
- The current precision does not allow to rule out the Standard Model yet.
- With more statistics, the result may be improved further.

Outlook

Description

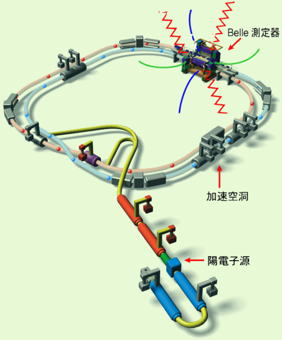
- Improved hadronic tagging
- Efficiency $\sim 0.1\% \rightarrow \sim 0.2\%$ (see M. Feindt et al., Nucl. Instr. and Meth. A (2011), doi:10.1016/j.nima.2011.06.008)
- **657 $\rightarrow$ 771 $\times$ 10^6 $B\bar{B}$ pairs**
- 2D signal extraction: M^2_{miss} and the output of a Neural Network with negligible correlations.
- Reference: **Work in progress, no publication yet.**

BACKUP

KEK & Belle

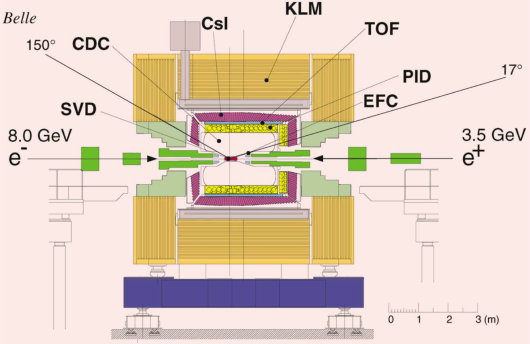
KEK-B

Asymmetrical e^+e^- collider with $\sqrt{s} = 10.58$ GeV

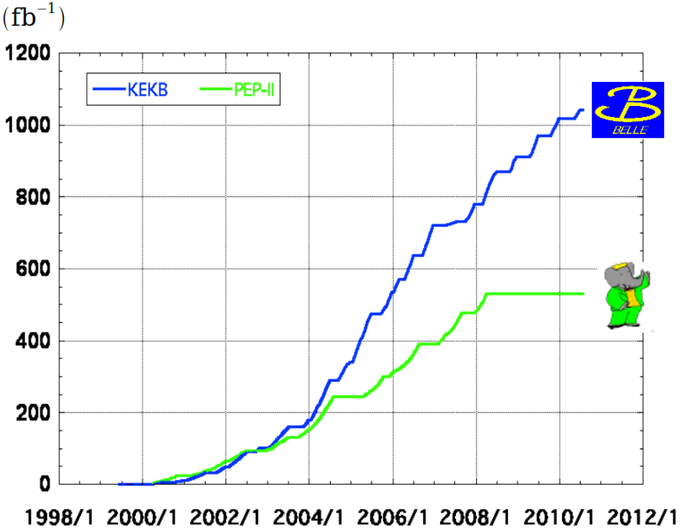


Belle

Only experiment at the KEK-B collider, upgrade scheduled for 2015



Integrated Luminosity



> 1 ab^{-1}

On resonance:

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

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

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

$\Upsilon(2S)$: 25 fb^{-1}

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

Off reson./scan:

$\sim$ 100 fb^{-1}

$\sim$ 550 fb^{-1}

On resonance:

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

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

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

Off resonance:

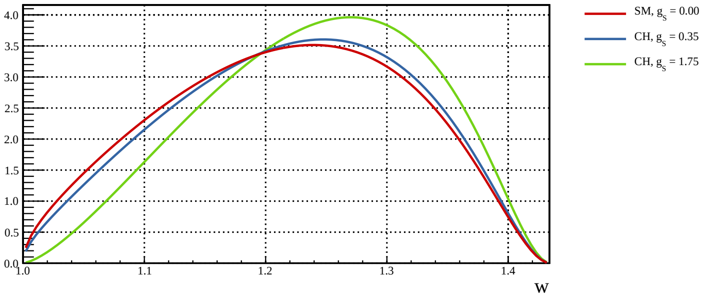
$\sim$ 54 fb^{-1}

Effects of Charged Higgs

Decay kinematics

- Described by

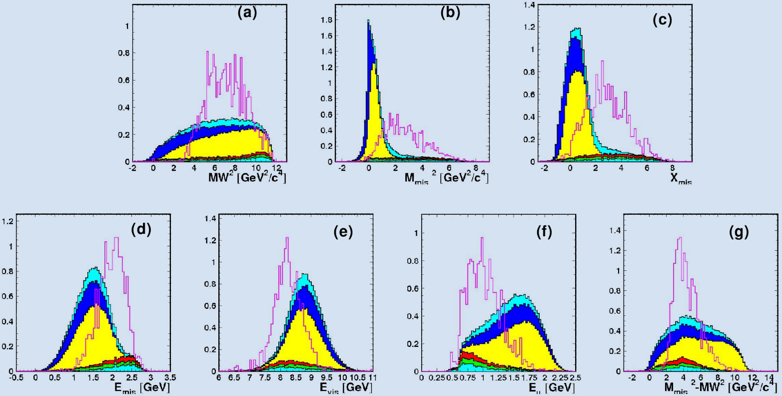
$$w = \left(1 + r^2 - \frac{q^2}{m_B^2}\right)/r^2, \quad \text{with} \quad r = m_D/m_B$$



$B^+ \rightarrow \bar{D}^{(*)0}\tau^+\nu_\tau$

Phys. Rev. D82, 072005(R) (2010)

Inclusive Tagging

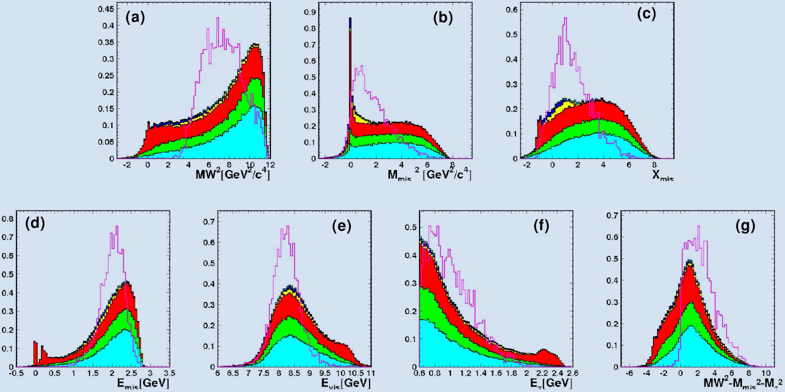


$B^+ \rightarrow \bar{D}^0\tau^+(\rightarrow \mu^+\nu_\mu\bar{\nu}_\tau)\nu_\tau$ Signal (blank) BG (shaded)

$B^+ \to \bar{D}^{(*)0}\tau^+\nu_\tau$

Phys. Rev. D82, 072005(R) (2010)

Inclusive Tagging

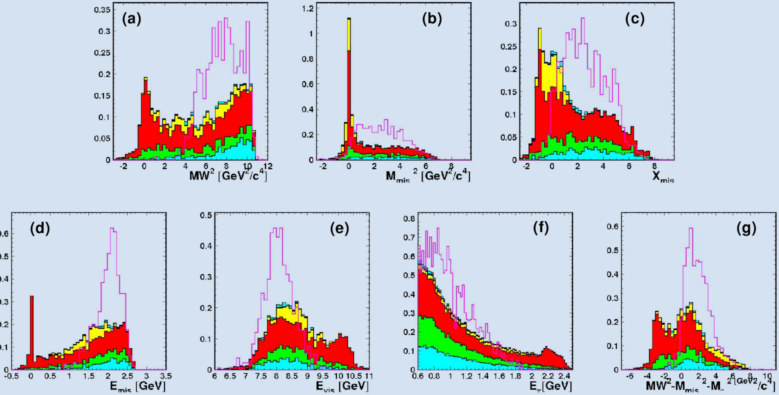


$B^+ \to \bar{D}^0\tau^+(\to \pi^+\bar{\nu}_\tau)\nu_\tau$ Signal (blank) BG (shaded)

$B^+ \to \bar{D}^{(*)0}\tau^+\nu_\tau$

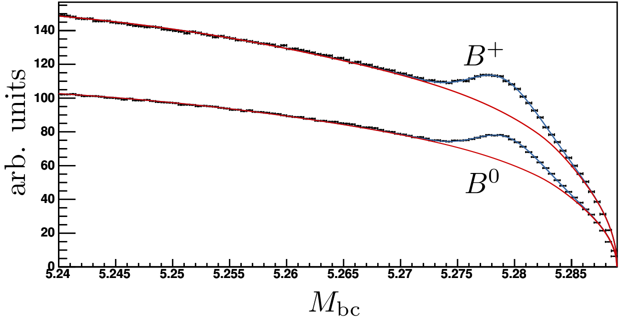
Phys. Rev. D82, 072005(R) (2010)

Inclusive Tagging



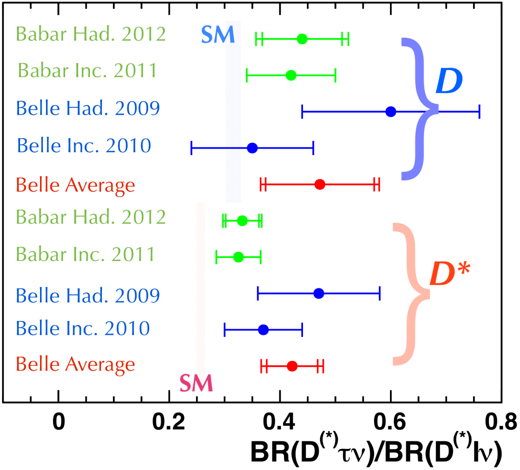
$B^+ \to \bar{D}^{*0}\tau^+(\to \pi^+\bar{\nu}_\tau)\nu_\tau$ Signal (blank) BG (shaded)

Tagging Methods



- Typical hadronic tag side without any signal side selection

Measurements

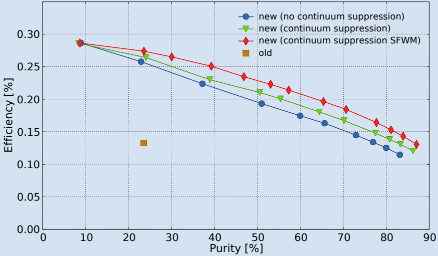


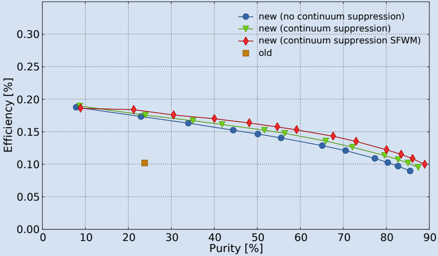
Isospin invariance assumed

Outlook

New Full Reconstruction algorithm

- Increased efficiency and purity





Outlook

Fit Procedure and Expected Sensitivity

- Do be done . . .