B^+ leptonic decays: review and prospects for Belle II

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Challenges in Semileptonic B decays @ MITP, Mainz

Outline

- Motivations and features
  - To tag, or not to tag
- $B^+ \to \tau^+ \nu$
- $B^+ \to \ell^+ \nu(\gamma)$
- Prospects (Belle II)

Features of $B^+ \to \ell^+\nu$

SM predictions

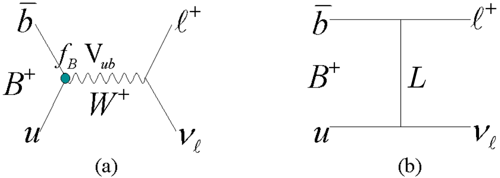
$$\Gamma(B^+ \to \ell^+\nu) = \frac{G_F^2 m_B m_\ell^2}{8\pi}\left(1 - \frac{m_\ell^2}{m_B^2}\right)^2 f_B^2 |V_{ub}|^2$$

- $\mathcal{B}(B^+ \to \tau^+\nu) \sim 10^{-4}$
- $\mathcal{B}(B^+ \to \mu^+\nu) \sim \mathcal{B}(B^+ \to \tau^+\nu)/300$
- $\mathcal{B}(B^+ \to e^+\nu) \sim \mathcal{B}(B^+ \to \tau^+\nu)/10^7$

Experimental features

- $B^+ \to \tau^+\nu$ — large BF, but multiple ν's
- $B^+ \to \ell^+\nu$ $(\ell \neq \tau)$ — $E_\ell \sim M_B/2$, but small BF

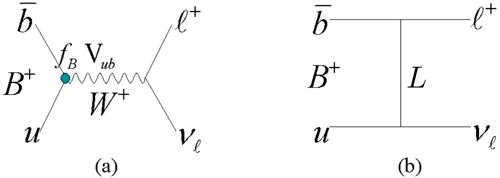
Motivations for $B^+ \to \ell^+ \nu$



$$\Gamma(B^+ \to \ell^+ \nu) = \frac{G_F^2 m_B m_\ell^2}{8\pi} \left(1 - \frac{m_\ell^2}{m_B^2}\right)^2 f_B^2 |V_{ub}|^2$$

- very clean place to measure $f_B |V_{ub}|$
  and/or search for new physics (e.g. H^+, LQ)

Motivations for $B^+ \to \ell^+ \nu$

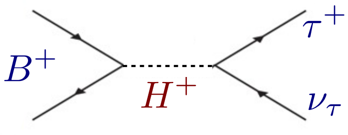


$$\Gamma(B^+ \to \ell^+ \nu) = \frac{G_F^2 m_B m_\ell^2}{8\pi} \left(1 - \frac{m_\ell^2}{m_B^2}\right)^2 f_B^2 |V_{ub}|^2$$

- very clean place to measure $f_B|V_{ub}|$
  and/or search for new physics (e.g. H^+, LQ)

- ultimate test of **LUV**
  $\Gamma(B^+ \to \ell^+ \nu)/\Gamma(B^+ \to \tau^+ \nu) = f(m_\ell^2, m_\tau^2)$,
  and all other parameters cancel!

$B^+ \to \tau^+\nu$ by new physics, e.g. H^+



- $B^+ \to \tau^+\nu$ can be affected by new physics effects
  For instance, H^+ of 2-Higgs doublet model (type II)

$$\mathcal{B}(B^+ \to \tau^+\nu) = \mathcal{B}_{\rm SM}(B^+ \to \tau^+\nu) \times r_H$$

where $r_H = \left[1 - (m_B^2/m_H^2)\tan^2\beta\right]^2$ W.S. Hou, PRD 48, 2342 (1993)

$B^+ \to \tau^+\nu$ for new physics

Two useful (*for NP*) ratios

$$R_{\rm ps} = \frac{\tau_{B^0}}{\tau_{B^+}} \frac{\mathcal{B}(B^+ \to \tau^+\nu)}{\mathcal{B}(B^0 \to \pi^-\ell^+\nu)}$$

$$R_{\rm pl} = \frac{\mathcal{B}(B^+ \to \tau^+\nu)}{\mathcal{B}(B^+ \to \mu^+\nu)}$$

$$R_{\rm ps}^{\rm NP} = (0.539 \pm 0.043)\left|1 + r_{\rm NP}^{\tau}\right|^2,$$

$$R_{\rm pl}^{\rm NP} = \frac{m_\tau^2}{m_\mu^2}\frac{(1 - m_\tau^2/m_B^2)^2}{(1 - m_\mu^2/m_B^2)^2}\left|1 + r_{\rm NP}^{\tau}\right|^2 \simeq 222.37\left|1 + r_{\rm NP}^{\tau}\right|^2$$

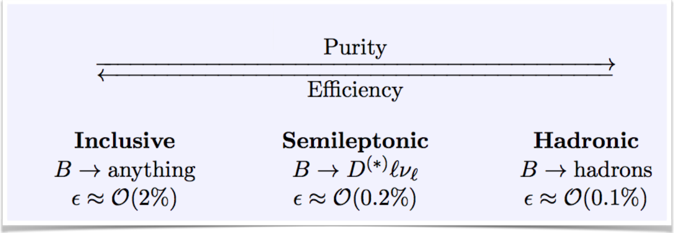
Tanaka & Watanabe, PTEP (2017), 1608.05207

To tag, or not to tag

- Why bother?
  - $B^+ \to \tau^+ \nu$ has multiple ν's in the final state
  - need extra kinematic constraints to improve sensitivity
  - exploit $\Upsilon(4S)$ producing $B\bar{B}$ and nothing else

$$e^+e^- \to \Upsilon(4S) \to B_{\text{sig}}\overline{B}_{\text{tag}}$$

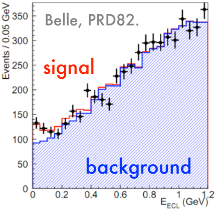
- How to tag?
  - "**hadronic tagging**" – full reconstruction of the decay chain of B_{tag}
  - "**semileptonic tagging**" – use $B^+ \to \overline{D}^{(*)}\ell^+\nu$



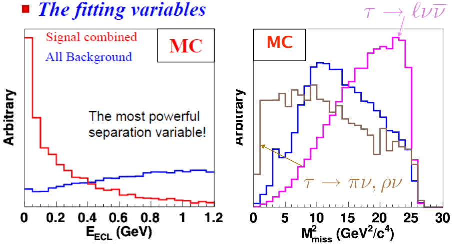
$B^+ \to \tau^+\nu$ (Belle, had) – signal extraction

- Signal τ modes: $\tau^+ \to e^+\nu_e\overline{\nu}_\tau,\ \mu^+\nu_\mu\overline{\nu}_\tau,\ \pi^+\overline{\nu}_\tau,\ \rho^+\overline{\nu}_\tau$
- π^0, K_L^0 veto – demand no trace of π^0, K_L^0 after reconstructing $B_{\rm tag}$ and $B_{\rm sig}$
  - K_L^0 gives $\sim 5\%$ improvement in the expected sensitivity
- 2D fitting to $E_{\rm ECL}$ & $M^2_{\rm miss}$
  - improve sensitivity by $\sim 20\%$; more robust against peaking backgs. in $E_{\rm ECL}$

previous analyses
($E_{\rm ECL}$ only)



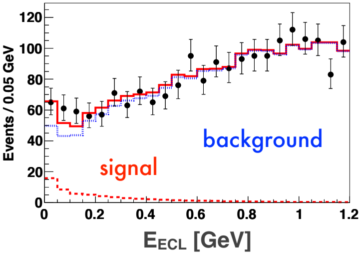
■ ***The fitting variables***



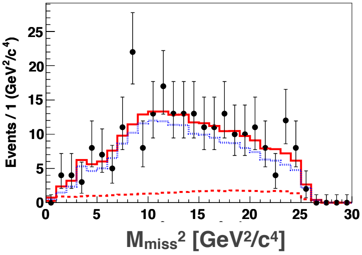
$E_{\rm ECL}$ = residual energy in the EM calorimeter (ECL) that has not been attributed to either $B_{\rm sig}$ or $B_{\rm tag}$

$B^+ \to \tau^+\nu$ (Belle, had) – Result

- Simultaneous fit to different τ decay modes
  Figures below shown for the sum of different τ decay modes



(Projection for all M_{miss}^2 region.)

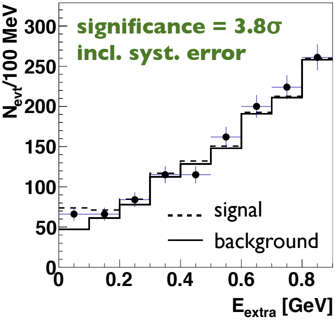


(Projection for E_{ECL} < 0.2 GeV)

- Signal yield: $62^{+23}_{-22} \pm 6$ significance $= 3.0\sigma$ incl. systematic error
  Major sources of systematic error are: background PDF (8.8%), K_L^0 efficiency (7.3%), and B_{tag} efficiency (7.1%).
- $\mathcal{B}(B^+ \to \tau^+\nu) = \left(0.72^{+0.27}_{-0.25} \pm 0.11\right) \times 10^{-4}$ PRL 110, 131801 (2013)

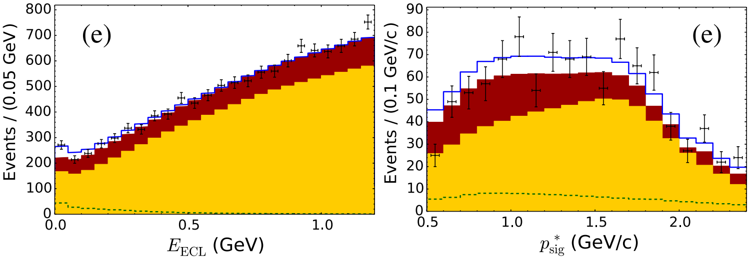
$B^+ \to \tau^+\nu$ (BABAR, had) – Result

- Hadronic B-tagging analysis with $N_{B\bar{B}} = 468 \times 10^6$
- Signal τ modes: $\tau^+ \to e^+\nu_e\overline{\nu}_\tau,\ \mu^+\nu_\mu\overline{\nu}_\tau,\ \pi^+\overline{\nu}_\tau,\ \rho^+\overline{\nu}_\tau$
- Signal extraction via $E_{\rm extra}$ $(= E_{\rm ECL})$
  $N_{\rm sig} = 62.1 \pm 17.3$
  from simultaneous fit to the four τ modes
- $\mathcal{B}(B^+ \to \tau^+\nu) = (1.83^{+0.53}_{-0.49} \pm 0.24) \times 10^{-4}$
- Major systematic uncertainties are from
  background PDF's (10%), B-tag efficiency (5%), etc.



PRD 88, 031102(R) (2013)

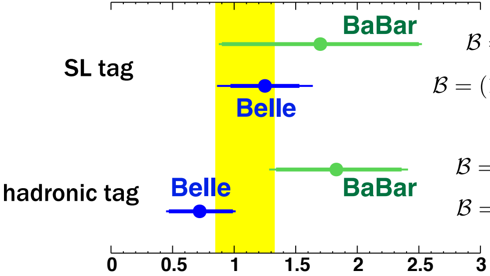
$B^+ \to \tau^+\nu$ (Belle, SL-tag)



- tagged by $B^- \to D^{(*)0}\ell^-\overline{\nu}$
- Signal extraction by 2D-fitting $(E_{\rm ECL}, p^*_{\rm sig})$
  $N_{\rm sig} = 222 \pm 50$ events
- $\mathcal{B}(B^+ \to \tau^+\nu) = (1.25 \pm 0.28 \pm 0.27) \times 10^{-4}$
  4.6σ significance by combining had-tag and SL-tag analyses of Belle

PRD 92, 051102(R) (2015)

$B^+ \to \tau^+\nu$ Summary



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

$\mathcal{B} = (1.25 \pm 0.28 \pm 0.27) \times 10^{-4}$

$\mathcal{B} = (1.83^{+0.53}_{-0.49} \pm 0.24) \times 10^{-4}$

$\mathcal{B} = (0.72^{+0.27}_{-0.25} \pm 0.11) \times 10^{-4}$

Belle combined: $\mathcal{B}(B^+ \to \tau^+\nu) = (0.91 \pm 0.22) \times 10^{-4}$

BABAR combined: $\mathcal{B}(B^+ \to \tau^+\nu) = (1.79 \pm 0.48) \times 10^{-4}$

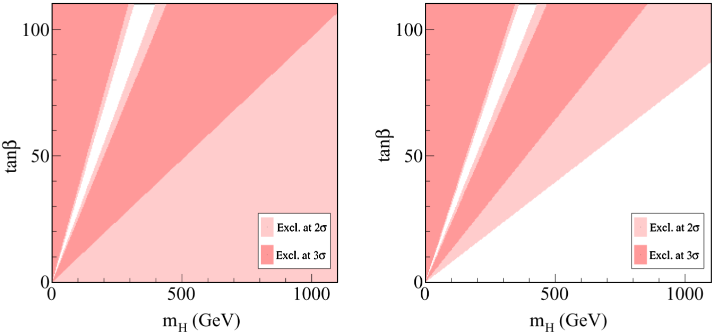
World avg: $\mathcal{B}(B^+ \to \tau^+\nu) = (1.06 \pm 0.19) \times 10^{-4}$ HFLAV (2017)

- Belle vs. BABAR – consistent within $\sim 1.7\sigma$
- The average is consistent with SM

$B^+ \to \tau^+\nu$ constraints on charged Higgs

- With 2-Higgs doublet model (type II),

$$\mathcal{B}(B^+ \to \tau^+\nu) = \mathcal{B}_{\rm SM}(B^+ \to \tau^+\nu) \times \left[1 - (m_B^2/m_H^2)\tan^2\beta\right]^2$$



Plots are from PRD 88, 031102(R) (2013), by *BABAR*, based on *BABAR*'s combined $\mathcal{B}(B^+ \to \tau^+\nu)$.

Search for $B^+ \to \ell^+ \nu$

- (*experimental*) very clean
  - just a mono-energetic charged lepton and nothing else
- (*theoretical*) very small branching fraction compared to $B^+ \to \tau^+ \nu$
  - helicity suppression: $\Gamma \propto m_\ell^2$
- Tagged vs. Untagged for $B^+ \to \ell^+ \nu$,
  - tagging is not really necessary $\because$ mono-energetic ℓ^+ in the final state
  - Nonetheless, analyses with tagging have also been tried

$\Gamma(B^+ \to e^+\nu_e)/\Gamma_{total}$

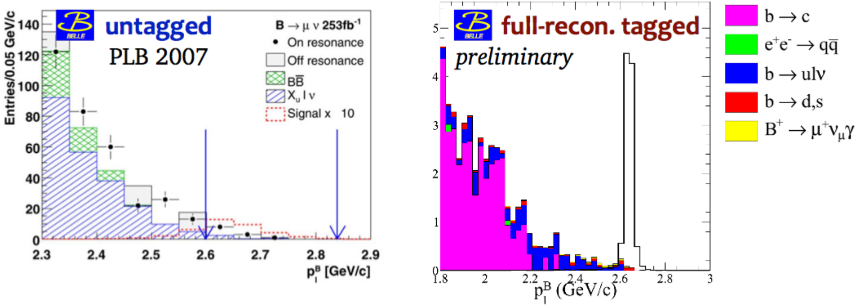
VALUE (10^{-6})	CL%	DOCUMENT ID		TECN	COMMENT	
< 0.98	90	[1] SATOYAMA	2007	BELL	$e^+ e^- \to \Upsilon(4S)$	untagged
*** We do not use the following data for averages, fits, limits, etc ***						
<3.5	90	[2] YOOK	2015	BELL	$e^+ e^- \to \Upsilon(4S)$	had tag
<8	90	[1] AUBERT	2010E	BABR	$e^+ e^- \to \Upsilon(4S)$	SL tag
<1.9	90	[1] AUBERT	2009V	BABR	$e^+ e^- \to \Upsilon(4S)$	untagged
<5.2	90	[1] AUBERT	2008AD	BABR	$e^+ e^- \to \Upsilon(4S)$	had tag

$\Gamma(B^+ \to \mu^+\nu_\mu)/\Gamma_{total}$

	VALUE (10^{-6})	CL%	DOCUMENT ID		TECN	COMMENT
untagged	**< 1.0**	90	[1] AUBERT	2009V	BABR	$e^+ e^- \to \Upsilon(4S)$
	*** We do not use the following data for averages, fits, limits, etc ***					
had tag	<2.7	90	[2] YOOK	2015	BELL	$e^+ e^- \to \Upsilon(4S)$
SL tag	<11	90	[1] AUBERT	2010E	BABR	$e^+ e^- \to \Upsilon(4S)$
had tag	<5.6	90	[1] AUBERT	2008AD	BABR	$e^+ e^- \to \Upsilon(4S)$
untagged	<1.7	90	[1] SATOYAMA	2007	BELL	$e^+ e^- \to \Upsilon(4S)$

Why then bother with 'tagged' for $B^+ \to \ell^+\nu$?

- The signal lepton candidate's momentum in B_{sig} rest frame. -



- much better resolution of p_ℓ^B with the full-recon. tagging
- But, does it make a case for 'full-recon-tagged' analysis of $B^+ \to \ell^+\nu$?

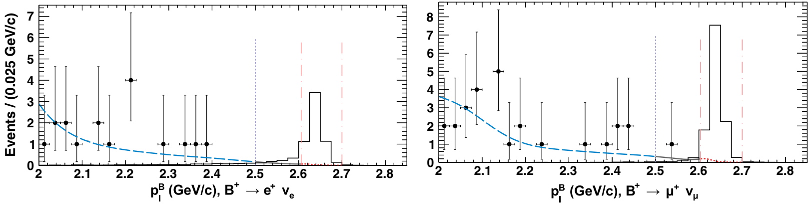
Why then bother with 'tagged' for $B^+ \to \ell^+\nu$?

- Note: $\mathcal{B}_{\rm SM}(B^+ \to e^+\nu) \sim 10^{-11}$ and $\mathcal{B}_{\rm SM}(B^+ \to \mu^+\nu) \sim 3 \times 10^{-7}$

  $\Rightarrow$ Any signal for $B^+ \to e^+\nu$ at the Belle sensitivity is way beyond the SM
- In that case, are we *sure* what we see is *really* $B^+ \to e^+\nu$?

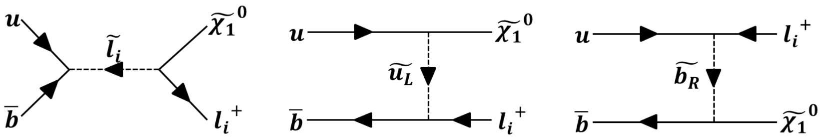
  What about $B^0 \to e^+\tau^-$? How about $B^+ \to e^+X^0$ where X^0 is any unknown particle from NP?
- With full-recon., we can use p_ℓ^B to discern many such cases
- Belle analysis with hadronic B-tagging

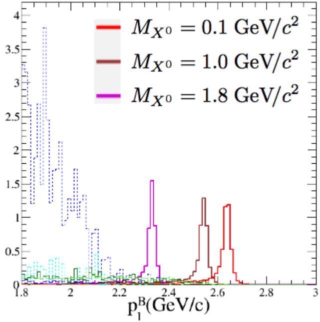
PRD 91, 052016 (2015)



Mode	ϵ_s [%]	$N_{\rm obs}$	$N_{\rm exp}^{\rm bkg}$	$\mathcal{B}$ (in 10^{-6})
$B^+ \to e^+\nu_e$	0.086 ± 0.007	0	0.10 ± 0.04	**< 3.5**
$B^+ \to \mu^+\nu_\mu$	0.102 ± 0.008	0	$0.26^{+0.09}_{-0.08}$	**< 2.7**

$B^+ \to \ell^+ X^0$ (Belle)



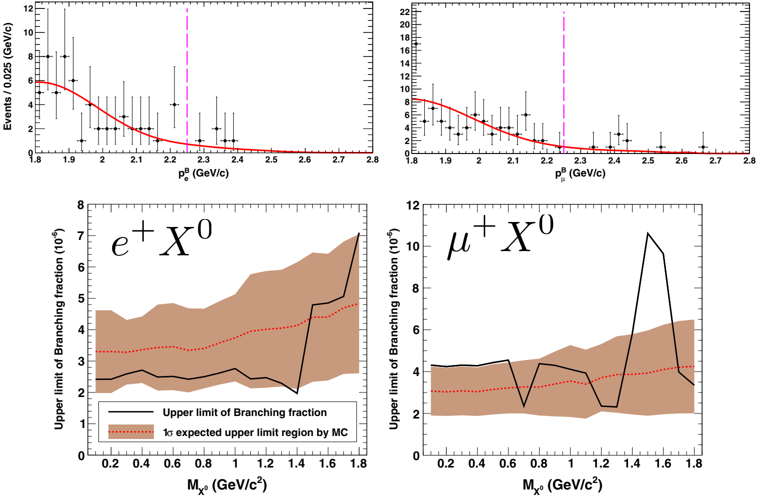


- Search for massive neutral invisible fermion "X^0"

  a heavy neutrino, or an LSP in RPV models, or whatever

- Very similar experimental signature to $B^+ \to \ell^+ \nu$
- But, p_ℓ^B gives a handle on M_X

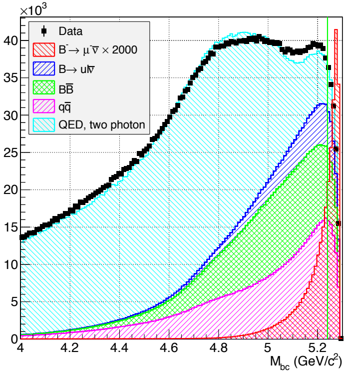
$B^+ \to \ell^+ X^0$ (Belle)

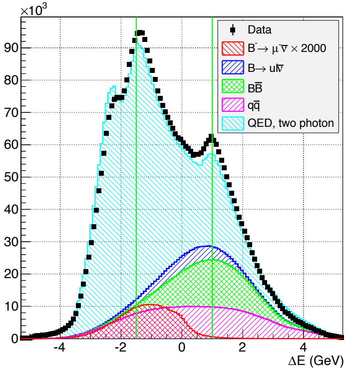


PRD 94, 012003 (2016)

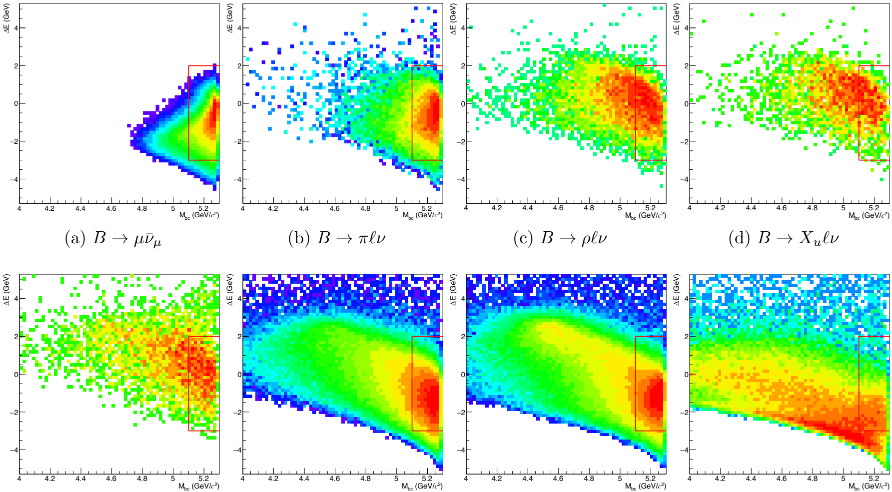
new *untagged* $B^+ \to \mu^+\nu$ (Belle)

- all particles except for the μ^+ are to come from the other B, but its decay chain is not explicitly reconstructed (*hence, untagged*)
- require $M_{\rm bc} > 5.1$ and $-3.0 < \Delta E < +2.0$





new *untagged* $B^+ \to \mu^+\nu$ (Belle)



(a) $B \to \mu\bar{\nu}_\mu$ (b) $B \to \pi\ell\nu$ (c) $B \to \rho\ell\nu$ (d) $B \to X_u\ell\nu$

(e) $B\bar{B}$ (f) $c\bar{c}$ (g) $u\bar{u}$, $d\bar{d}$, $s\bar{s}$ (h) $e^+e^- \to \tau^+\tau^-$

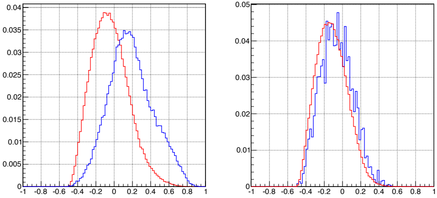
new *untagged* $B^+ \to \mu^+\nu$ (Belle)

- all particles except for the μ^+ are to come from the other B, but its decay chain is not explicitly reconstructed (*hence, untagged*)
- require $M_{\rm bc} > 5.1$ and $-3.0 < \Delta E < +2.0$
- In the B^+ rest frame, $p_\mu = 2.64$ GeV (*sharp!*), but in the CM frame, $2.45 < p^*_\mu < 2.85$ GeV
- Use p^*_μ and neural net (NN) for signal extraction (2D fit)

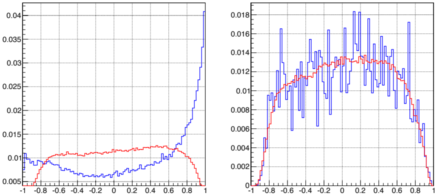
NN variables

- $R_1^{\mu o}/R_0^{\mu o}$, $R_2^{\mu o}/R_0^{\mu o}$, $R_3^{\mu o}/R_0^{\mu o}$ – where $R_i^{\mu o} = \sum_j$ in the cm frame, $\vec{p}_j$ is in the cm frame and j the muon, and $P_i(x)$ is the i^{th} Legendre polynoı 17b, 17c.
- R_1^{oo}/R_0^{oo} – where $R_i^{oo} = \sum_k \sum_j |\vec{p}_k||\vec{p}_j|P_i(\cos\theta_{kj})$,
- $R_1^{\text{KFW}} = \sum_k \sum_{j>k} |\vec{p}_k||\vec{p}_j|P_i(\cos\theta_{kj})$, the first Kakı cm frame, see Fig. 17e.
- $\cos(\theta_{\text{miss}})$ – angle of missing momentum in the
- $\sqrt{\sqrt{\sqrt{\Delta Z^2}}}$ – distance between reconstructed z- transformation tries to make the strongly peak the neural net catch the small difference betw shown in Fig. 17g. The square root function se discriminating variable away from zero.
- $\frac{\vec{n}_{\text{t}} \cdot \vec{p}_\mu}{|\vec{n}_{\text{t}}||\vec{p}_\mu|}$ – angle between thrust and muon
- $s = 1 - \vec{n}_{\text{t}}^2$ – sphericity, see Fig. 17i
- ΔE – difference between the sum of energ signal muon and expected energy of B mes
- $\frac{\vec{n}_{\text{t}}^{\text{ECL}} \cdot \vec{p}_\mu}{|\vec{n}_{\text{t}}^{\text{ECL}}||\vec{p}_\mu|}$ – where the thrust vector $\vec{n}_{\text{t}}^{\text{ECL}}$ i and calculated in the lab frame, $\vec{p}_\mu$ is in th
- $(q_\mu + q_{\text{tag}}) \times q_\mu$ – charge balance, see Fig.
- $\frac{\vec{p}_\mu \cdot \vec{p}_{B_{\text{tag}}}}{|\vec{p}_\mu||\vec{p}_{B_{\text{tag}}}|}$ – angle between muon and tag ı
- $\cos\theta_\mu$ – muon angle in the cm frame, see F

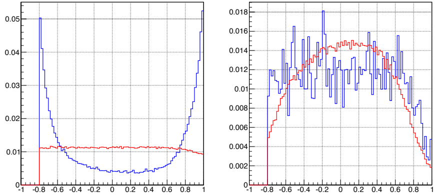
NN variables



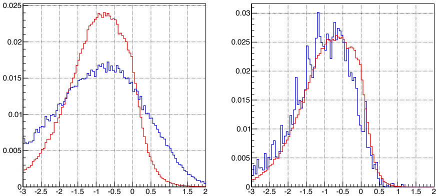
(b) $R_2^{\mu o}/R_0^{\mu o}$



(f) $\cos(\theta_{\rm miss})$

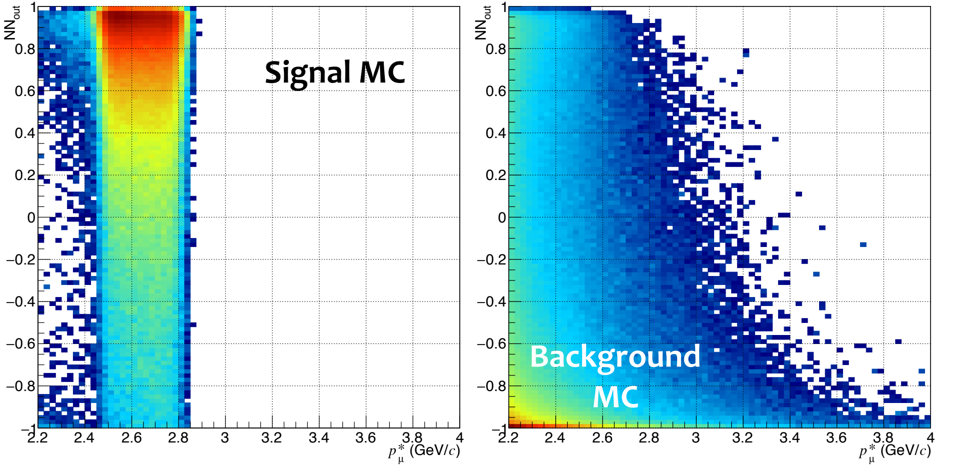


(h) $\dfrac{\vec{n}_{\rm t}\cdot\vec{p}_\mu}{|\vec{n}_{\rm t}||\vec{p}_\mu|}$

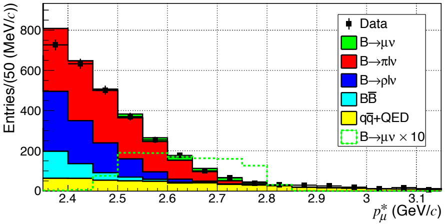


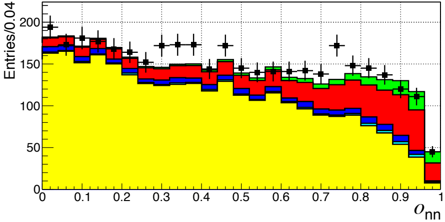
(j) ΔE (GeV)

2D distributions (MC) for signal fit



new *untagged* $B^+ \to \mu^+\nu$ **Result**





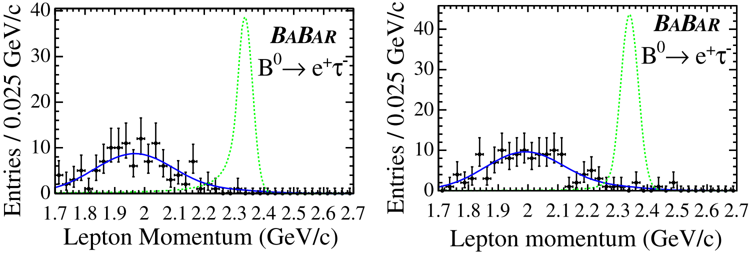
- $B \to \pi\ell\nu$, $\rho\ell\nu$, studied in detail by FF variation
- measure $R \equiv N_{B\to\mu\nu}/N_{B\to\pi\ell\nu}$ for (partial) cancellation of syst. error
- most significant (2.4σ), and consistent with SM

$$\mathcal{B}(B^+ \to \mu^+\nu) = (6.46 \pm 2.22 \pm 1.60) \times 10^{-7}$$
$$\in [2.9, 10.7] \times 10^{-7} \text{ @ 90\% C.L.}$$

arXiv:1712.04123, *submitted to* PRL

$B^0 \to \ell^\pm \tau^\mp$ (BABAR)

PRD 77, 091104(R) (2008)



- In a hadronic B-tagging analysis very similar to $B^+ \to \ell^+\nu$, BABAR also searched for $B^0 \to \ell^\pm\tau^\mp$.
- Background suppression using $m_{\rm ES}$ and $E_{\rm extra}$
- Signal extraction by unbinned max. likelihood fit to p_ℓ^B

$$\mathcal{B}(B^0 \to e^\pm\tau^\mp) < 2.8 \times 10^{-5}$$
$$\mathcal{B}(B^0 \to \mu^\pm\tau^\mp) < 2.2 \times 10^{-5}$$

$B^+ \to \ell^+\nu\gamma$

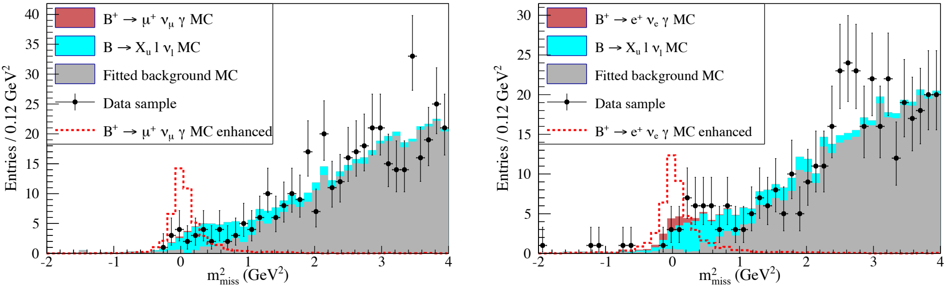
- Helicity suppression (of $B^+ \to \ell^+\nu$) is avoided by γ.

$$\Gamma(B^+ \to \ell^+\nu\gamma) \propto \frac{\alpha_{\rm EM}(G_{\rm F} m_B^2 |V_{ub}| f_B)^2}{\lambda_B^2}$$

- λ_B is needed for QCDF to calculate, e.g., charmless hadronic B decays
- SM expectation: $\mathcal{B}(B^+ \to \ell^+\nu\gamma) \sim \mathcal{O}(10^{-6})$
  - * Calculation is reliable only for $E_\gamma > 1$ GeV
- Most stringent limits from Belle (2015) with hadronic B-tagging
  - * using neural net to suppress the most significant background $B^+ \to \pi^0\ell^+\nu$

$B^+ \to \ell^+ \nu \gamma$ (Belle)

PRD 91, 112009 (2015)



$B^+ \to \mu^+ \nu_\mu \gamma$ $\qquad$ $B^+ \to e^+ \nu_e \gamma$

Enhanced signal MC portions in the figures correspond to $\mathcal{B} = 30 \times 10^{-6}$.

$B^+ \to \ell^+\nu\gamma$ (Belle)

PRD 91, 112009 (2015)

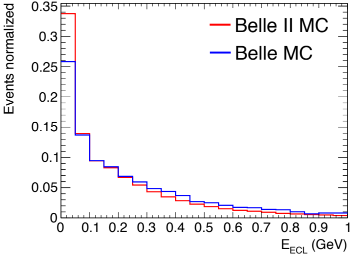
- Signal yields and partial $\mathcal{B}$ for $E_\gamma > 1$ GeV

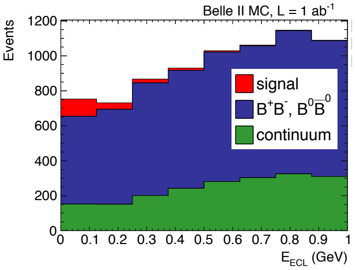
Mode	Signal yield	$\mathcal{B}$ (10^{-6})	Significance (σ)	$\mathcal{B}$ limit (10^{-6})
$B^+ \to e^+\nu_e\gamma$	$6.1\,^{+4.9}_{-3.9}\,^{+1.0}_{-1.3}$	$3.8\,^{+3.0}_{-2.4}\,^{+0.7}_{-0.9}$	1.7	< 6.1
$B^+ \to \mu^+\nu_\mu\gamma$	$0.9\,^{+3.6}_{-2.6}\,^{+1.0}_{-1.5}$	$0.6\,^{+2.1}_{-1.5}\,^{+0.7}_{-1.1}$	0.4	< 3.4
$B^+ \to \ell^+\nu_\ell\gamma$	$6.6\,^{+5.7}_{-4.7}\,^{+1.6}_{-2.2}$	$2.0\,^{+1.7}_{-1.4}\,^{+0.6}_{-0.7}$	1.4	< 3.5

- From the partial $\mathcal{B}$, we set $\lambda_B(E_\gamma > 1\text{ GeV}) > 238$ MeV
  By varying input parameters, we obtain $\lambda_B > (172, 410)$ MeV
- 2nd analysis with looser cut ($E_\gamma > 0.4$ GeV) also gives no signal and consistent results

BABAR result: $\mathcal{B}(B^+ \to \ell^+\nu\gamma) < 15.6 \times 10^{-6}$, PRD 80, 111105(R) (2009)

$B^+ \to \tau^+\nu$ Prospects for Belle II





- $E_{\rm ECL}$ is crucial for $B^+ \to \tau^+\nu$ study
  * In Belle II, beam background is much higher
  * But such backgrounds can be rejected by tighter selection based on ECL cluster's energy, timing, shape, etc.
- Expected precision at 1 $\mathrm{ab}^{-1} \sim 29\%$ (stat.)
- Major systematic sources (bkg. PDF, K_L^0 veto eff., $B_{\rm tag}$ eff., etc.) can be improved with more data

	Integrated Luminosity (ab^{-1})	1	5	50
hadronic tag	statistical uncertainty (%)	29	13	4
	systematic uncertainty (%)	13	7	5
	total uncertainty (%)	32	15	6
semileptonic tag	statistical uncertainty (%)	19	8	3
	systematic uncertainty (%)	18	9	5
	total uncertainty (%)	26	12	5

$B^+ \to \tau^+\nu$ Prospects for Belle II

Two useful (*for NP*) ratios

$$R_{\rm ps} = \frac{\tau_{B^0}}{\tau_{B^+}} \frac{\mathcal{B}(B^+ \to \tau^+\nu)}{\mathcal{B}(B^0 \to \pi^-\ell^+\nu)}$$

$$R_{\rm pl} = \frac{\mathcal{B}(B^+ \to \tau^+\nu)}{\mathcal{B}(B^+ \to \mu^+\nu)}$$

$$R_{\rm ps}^{\rm NP} = (0.539 \pm 0.043)\left|1 + r_{\rm NP}^{\tau}\right|^2 ,$$

$$R_{\rm pl}^{\rm NP} = \frac{m_\tau^2}{m_\mu^2}\frac{(1 - m_\tau^2/m_B^2)^2}{(1 - m_\mu^2/m_B^2)^2}\left|1 + r_{\rm NP}^{\tau}\right|^2 \simeq 222.37\left|1 + r_{\rm NP}^{\tau}\right|^2$$

Luminosity	$R_{\rm ps}$	$R_{\rm pl}$
$5\,{\rm ab}^{-1}$	$[-0.22, 0.20]$	$[-0.42, 0.29]$
$50\,{\rm ab}^{-1}$	$[-0.11, 0.12]$	$[-0.12, 0.11]$

Expected sensitivity @ 95% CL.
Assumed: NP contribution is real and $|r_{\rm NP}^{\tau}| < 1$

NP contributions to $B^+ \to \tau^+\nu$ with $|r_{\rm NP}| > \mathcal{O}(0.1)$ can be tested at 95% CL.

$B^+ \to \mu^+\nu$ Prospects for Belle II

- By scaling the FoM of Belle new untagged analysis (arXiv:1712.04123),

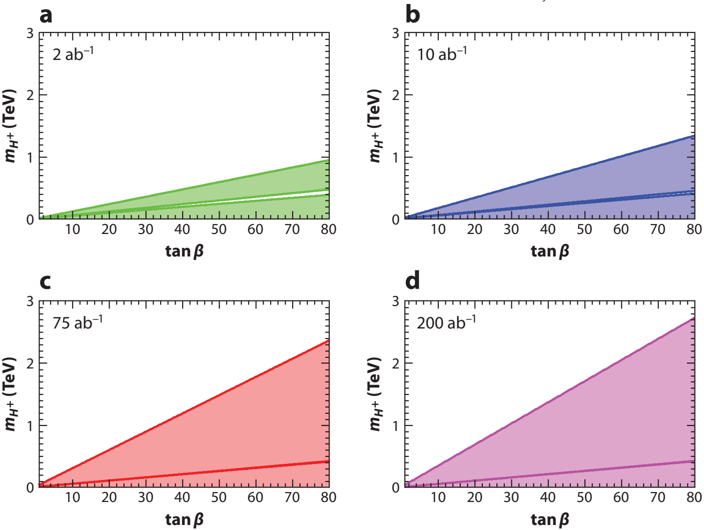
$$\mathcal{F}_{\rm B2} = \mathcal{F}_{B1} \times \sqrt{50\ \mathrm{ab}^{-1}/0.711\ \mathrm{ab}^{-1}} \sim 14.5\%$$

  corresponding to $\sim 7\%$ statistical precision

- naive expectation (Ref. B2TiP draft)
  - $B^+ \to \mu^+\nu$ can reach 5σ with ~ 6 ab^{-1}
  - 5% statistical precision, with full 50 ab^{-1}

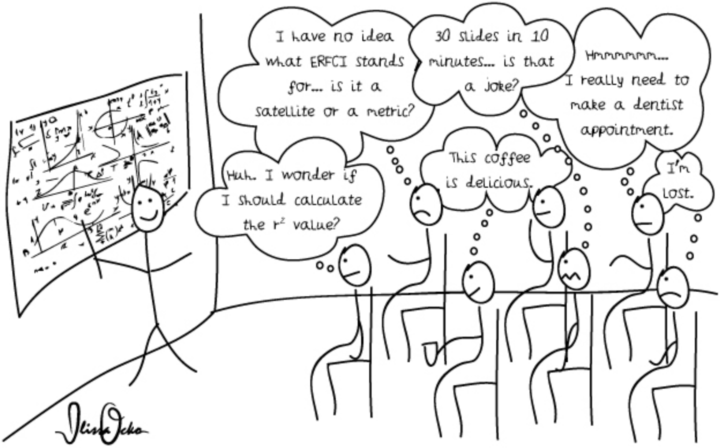
$B^+ \to \ell^+\nu$ Prospects beyond 50 ab^{-1}

from Ciuchini & Stocchi, Ann. Rev. Nucl. Part. Sci. 61 (2011) 491



Concluding Remarks

- Leptonic B decays, in particular $B^+ \to \ell^+ \nu$ ($\ell = e, \mu, \tau$), provide powerful probe for new physics beyond the SM.
- $B^+ \to \tau^+ \nu$ decays have been measured at nearly 5σ significance, and new physics models such as 2HDM (II) have been tested.
- With hadronic B-tagging, Belle has searched for *invisible, massive, lepton-like neutral* particle X^0 in $B^+ \to \ell^+ X^0$ for the first time.
- Belle II with $\int \mathcal{L}\, dt = 50$ ab^{-1} branching fractions for both $B^+ \to \tau^+ \nu$ and $B^+ \to \mu^+ \nu$ are expected to be measured with precision of $\sim 5\%$.


I have no idea what ERFCI stands for... is it a satellite or a metric?
30 slides in 10 minutes... is that a joke?
Hmmmmmm... I really need to make a dentist appointment.
Huh. I wonder if I should calculate the r² value?
This coffee is delicious.
I'm lost.

Thank you!