Purely leptonic decays of beauty and charm mesons at e^+e^- colliders

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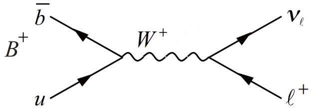
Leptonic decays in the Standard Model

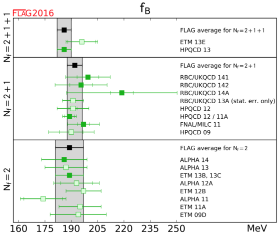
- Leptonic decay of B^+ meson
  $\hookrightarrow$ via annihilation of meson's constituent quarks to a W^+ boson



$$\mathcal{B}(B^+ \to \ell^+\nu_\ell) = \frac{\Gamma(B^+ \to \ell^+\nu_\ell)}{\Gamma(B^+ \to \mathrm{all})} = \frac{G_F^2}{8\pi}\tau_B f_B^2 |V_{ub}|^2 m_B^3 \left(1 - \frac{m_\ell^2}{m_B^2}\right)^2 \left(\frac{m_\ell}{m_B}\right)^2$$

- Helicity suppression factor
  - favors decays to τ over μ and e
- CKM (suppression) factor
- Phase-space factor
- Decay constant
  - calculated on the Lattice

Flag averages:



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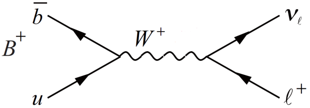

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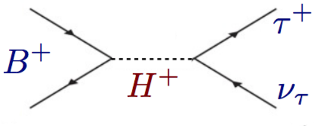
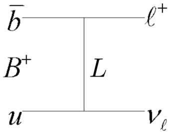
Standard Model Predictions

Mode	$\mathcal{B}(B^+ \to \ell^+\nu_\ell)$	
$\tau\nu_\tau$	$(1.03 \pm 0.2) \times 10^{-4}$	*Accessible with current data sets*
$\mu\nu_\mu$	$\sim 0.47 \times 10^{-6}$	*Need Belle II statistics*
$e\nu_e$	$\sim 1.1 \times 10^{-11}$	*Beyond the reach of experiments*

New Physics in leptonic decays

Purely leptonic B-meson decays can be by new physics effects, e.g.:





- Interference from charged Higgs can suppress or enhance SM decay rate:

$$\mathcal{B} = \mathcal{B}^{SM} \times \underbrace{\left(1 - m_B^2 \frac{tan^2\beta}{m_{H^\pm}^2}\right)^2}_{\equiv r_H}$$

Effect independent of lepton flavor!

- Test of Lepton Flavour Universality

$$R = \frac{\mathcal{B}(B^- \to \tau^- \bar{\nu}_\tau)}{\mathcal{B}(B^- \to \mu^- \bar{\nu}_\mu)} = \frac{m_\tau^2}{m_\mu^2} \frac{(1 - m_\tau^2/m_B^2)^2}{(1 - m_\mu^2/m_B^2)^2} \left|1 + r_{NP}^\tau\right|^2 \simeq 222.37 \left|1 + r_{NP}^\tau\right|^2$$

Experimental techniques

- Decay modes with neutrino(s) in the final state
  - offer no or very little kinematic constraints to separate signal from background
    - e.g. invariant mass of decaying particle
  - can be studied, if
    1. initial state is known **B-factory**

       $\overline{B}$

       $\nwarrow$

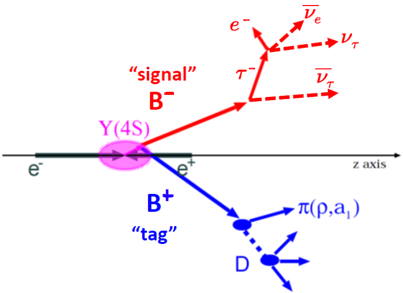
       $e^{+}(4.0\text{GeV}) \rightarrow$ BANG $\longleftarrow e^{-}(7.0\text{GeV})$ collider

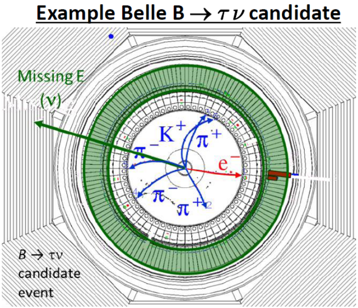
       $\searrow$

       B

    2. detector encloses interaction region hermetically **B-factory**

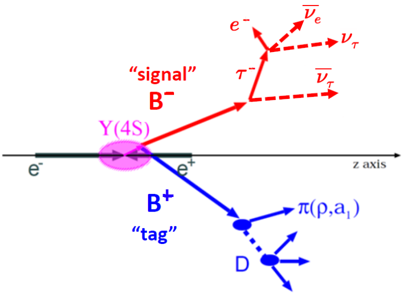
Tools of the trade – *Recoil B-meson reconstruction*



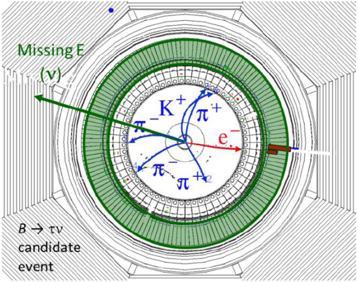


1. Reconstruct one of the B mesons ($B_{\rm tag}$) in the event

Tools of the trade – *Recoil B-meson reconstruction*



Example Belle B → τν candidate



1. Reconstruct one of the B mesons ($B_{\rm tag}$) in the event
2. All remaining particle(s) in the detector originate from the decay of other B

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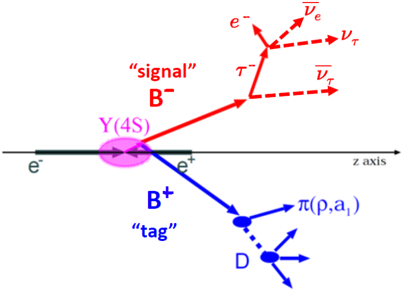

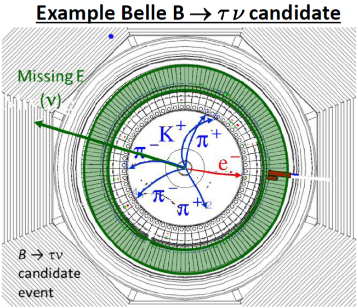

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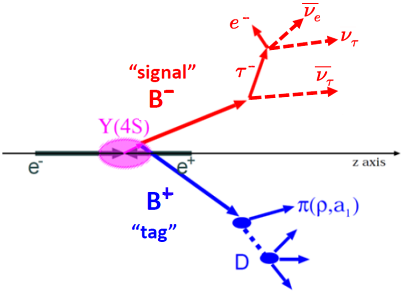

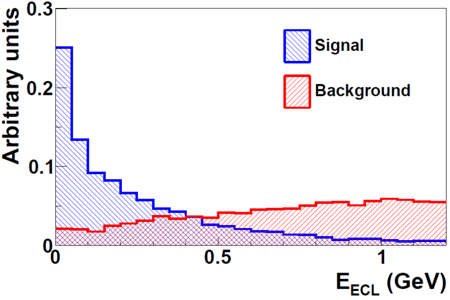

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2. All remaining particle(s) in the detector originate from the decay of other B
   - What is the number of remaining charged tracks?
   - Is it kaon, pion, electron, or ....?
   - What is its charge?
   - Is there any additional activity in the calorimeter?

Reconstruction of $B_{\rm tag}$

- need to reconstruct tagging B mesons in as many modes as possible in order to increase overall number of reconstructed events

$$N(B_{\rm tag}B_{\rm sig}) = N_{B\overline{B}}\left(\sum_f \mathcal{B}(B_{\rm tag}\to f)\varepsilon_f\right)\mathcal{B}(B_{\rm sig})\varepsilon_{\rm sig}$$

Reconstruction of B_{tag}

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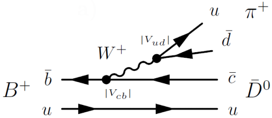
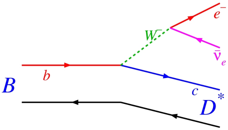
- Most probable B meson decay chains involve $b \to c \to s$ transitions





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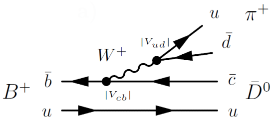
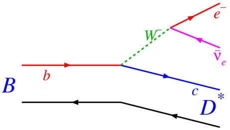




- **Hadronic B_{tag} recon.:** $B \to D^{(*)}n\pi$, $B \to D_s^{(*)}D^{(*)}$, $B \to J/\psi K n\pi$ $\quad \mathcal{B} \sim 10\%$
- **Semileptonic B_{tag} recon.:** $B \to D^{(*)}\ell\nu_\ell$ $(\ell = e, \mu)$ $\quad \mathcal{B} \sim 15\%$

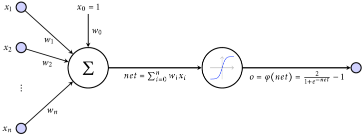
$\hookrightarrow D \to K n\pi$ $\quad \mathcal{B} \sim 1/3$

Reconstruction of B_{tag} – Belle's solution

- hierarchical reconstruction procedure and probabilistic calculus instead of classical selection cuts

Input variables:

- topological
- decay dynamics
- signal probabilities of children particles
- ...



signal probability

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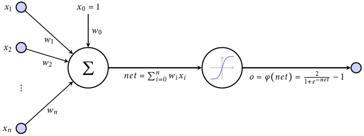
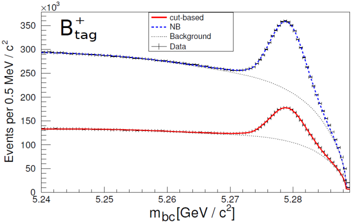
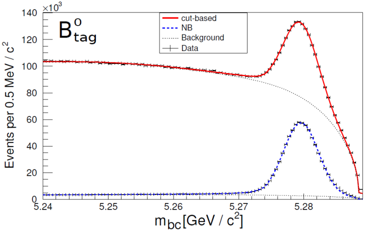


signal probability

Comparison of neural-net-based selection vs. cut-based selection:



B^+: same purity $\Rightarrow$ $\varepsilon(\text{NN}) \approx 2 \times \varepsilon(\text{cut})$



B^0: same efficiency $\Rightarrow$ reduction of background by factor of 20!

Reconstruction of B_{tag} – Belle's solution

- hierarchical reconstruction procedure and probabilistic calculus instead of classical selection cuts

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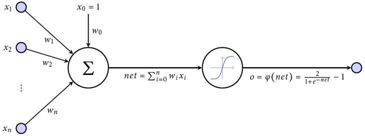
- ...



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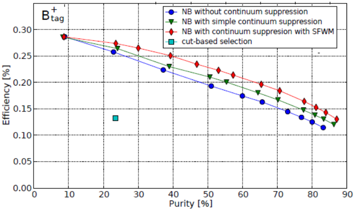
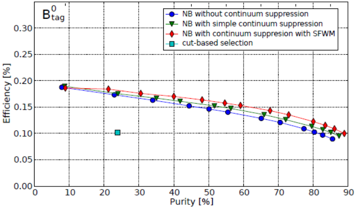




Around 2.1 million $B^{\pm}_{\mathrm{tag}}$ and 1.4 million $B^0(\overline{B}^0)_{\mathrm{tag}}$ reconstructed in 700 fb^{-1}!

B_{tag} reconstruction at Belle II

- Similar reconstruction approach as in case of the Belle
- Includes more B, D meson decay modes
- Results in around factor of two improvement in the reconstruction efficiency

Maximum reconstruction efficiency

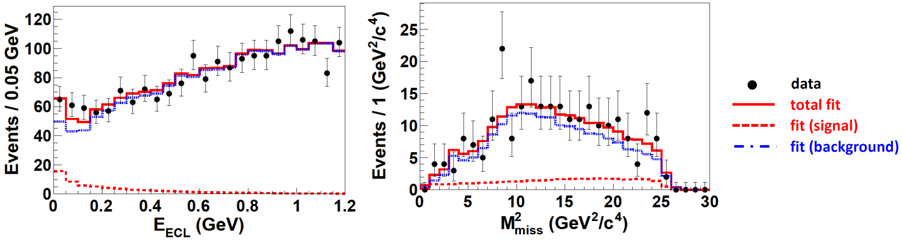
Tag	FR @ Belle	FEI @ Belle	FEI @ Belle II
Hadronic B^+	0.28 %	0.49 %	0.61 %
Semileptonic B^+	0.67 %	1.42 %	1.45 %
Hadronic B^0	0.18 %	0.33%	0.34 %
Semileptonic B^0	0.63 %	1.33%	1.25 %

$B^+ \to \tau^+\nu_\tau$ at Belle (with hadronic $B_{\rm tag}$)

Results using Belle's full data sample and improved $B_{\rm tag}$ reconstruction:

- $\tau^+ \to e^+\nu_e\overline{\nu}_\tau,\ \mu^+\nu_\mu\overline{\nu}_\tau,\ \pi^+\overline{\nu}_\tau,\ \pi^+\pi^0\overline{\nu}_\tau$ 70% of all τ decays

K.Hara et al. [Belle Collaboration] PRL 110, 131801 (2013)



Sub-mode	$N_{\rm sig}$	ϵ (10^{-4})	$\mathcal{B}$ (10^{-4})
$\tau^- \to e^-\bar{\nu}_e\nu_\tau$	16^{+11}_{-9}	3.0	$0.68^{+0.49}_{-0.41}$
$\tau^- \to \mu^-\bar{\nu}_\mu\nu_\tau$	26^{+15}_{-14}	3.1	$1.06^{+0.63}_{-0.58}$
$\tau^- \to \pi^-\nu_\tau$	8^{+10}_{-8}	1.8	$0.57^{+0.70}_{-0.59}$
$\tau^- \to \pi^-\pi^0\nu_\tau$	14^{+19}_{-16}	3.4	$0.52^{+0.72}_{-0.62}$
Combined	62^{+23}_{-22}	11.2	$0.72^{+0.27}_{-0.25}$

$\mathcal{L} = 711\ \mathrm{fb}^{-1}$

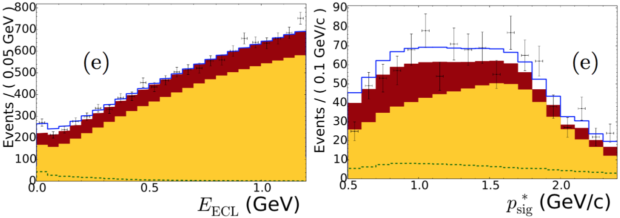
$$\boxed{\mathcal{B}(B^+ \to \tau^+\nu_\tau) = (0.72^{+0.27}_{-0.25} \pm 0.11) \times 10^{-4}}$$

Significance: 3σ

$B^+ \to \tau^+\nu_\tau$ at Belle (with semileptonic $B_{\rm tag}$)

Full Belle data sample:

- $\tau^+ \to e^+\nu_e\overline{\nu}_\tau,\ \mu^+\nu_\mu\overline{\nu}_\tau,\ \pi^+\overline{\nu}_\tau,\ \pi^+\pi^0\overline{\nu}_\tau$ 70% of all τ decays



Decay mode	$N_{\rm sig}$	$\mathcal{B}(10^{-4})$
$\tau^+ \to \mu^+\bar{\nu}_\tau\nu_\mu$	13±21	0.34±0.55
$\tau^+ \to e^+\bar{\nu}_\tau\nu_e$	47±25	0.90±0.47
$\tau^+ \to \pi^+\bar{\nu}_\tau$	57±21	1.82±0.68
$\tau^+ \to \rho^+\bar{\nu}_\tau$	119±33	2.16±0.60
Combined	222±50	1.25±0.28

$\mathcal{L} = 711\ \mathrm{fb}^{-1}$

$$\boxed{\mathcal{B} = (1.25 \pm 0.28(\mathrm{stat.}) \pm 0.27(\mathrm{syst.})) \times 10^{-4}}$$

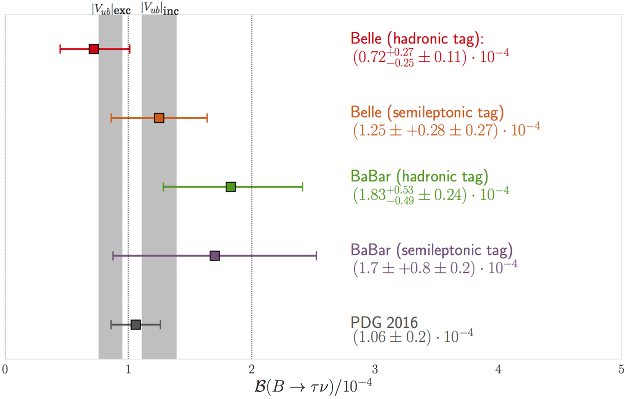
Significance: 3.8σ

4.6σ **when combined with had-tag result**

- Major systematic uncertainties are the continuum background description (14%) and efficiency calibration (13%) – data driven and scale with luminosity.

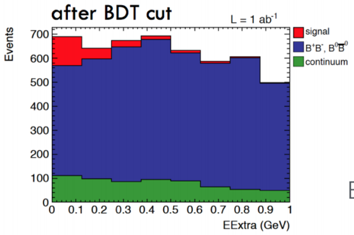
$B^+ \to \tau^+ \nu_\tau$ (World average)

T.Keck



- The average is consistent with the SM prediction
- Important input in future to resolve the $V_{\rm ub}$ *puzzle*

$B^+ \to \tau^+\nu_\tau$ at Belle II



$E_{extra} < 1$ GeV	Babar PRD 88, 031102 (2013)	Belle PRL 110, 131801 (2013)	Belle II (this study)
Signal Efficiency (‰)	**0.72**	**1.1**	**2.5**

Expected Belle II sensitivity @ 1 ab^{-1}: **~30%**

$$\mathcal{B}(B^+ \to \tau^+\nu_\tau) = (0.83 \pm 0.22) \times 10^{-4}$$

[NB: No KL veto applied in the study; 1D fit only;
Only hadronic reconstruction of the companion B;]

Guess-estimate of systematics

Integrated Luminosity (ab^{-1})	1	5	50
statistical uncertainty (%)	29.2	13.0	4.1
systematic uncertainty (%)	12.6	6.8	4.6
total uncertainty (%)	31.6	14.7	6.2

- A lot of sources of systematic scale with luminosity (sig./bkg. PDF), tagging efficiency;
- Peaking backgrounds will have to be measured more precisely

M.Merola (Napoli)

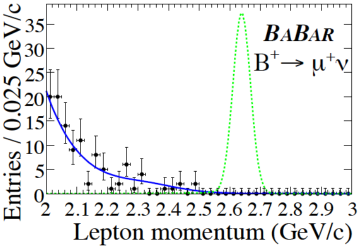
$B \to \mu\nu$ at Belle and BaBar

- Measurement of $B \to \mu\nu$ can provide an independent consistency check of $B \to \tau\nu$ measurement
- Interesting also in the context of recent hints of Lepton Flavour Universality Violation

Tagged method

- $B_{\mathrm{tag}}+\mu$
- better knowledge of signal kinematics and better continuum background rejection

B. Aubert et al. [Babar collab.] PRD77, 091104 (2008)

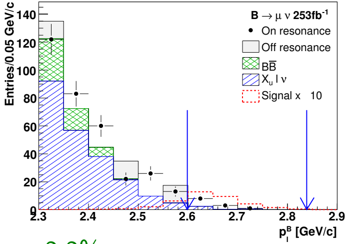


- $\varepsilon = 0.12\%$ $[\mathcal{L} = 342\ \mathrm{fb}^{-1}]$
- $\mathcal{B}(B^+ \to \mu^+\nu_\mu) < 5.6 \times 10^{-6}$ @ 90% C.L.

Untagged method

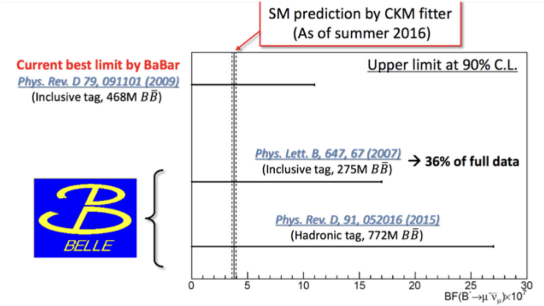
- Single high momentum muon
- almost mono-energetic ($p_B^* \approx 380$ MeV)
- infer $p(B_{\mathrm{sig}})$ from all other detected p.

N. Satoyama et al. [Belle collab.] PLB 647, 67 (2007)



- $\varepsilon = 2.2\%$
- $\mathcal{B}(B^+ \to \mu^+\nu_\mu) < 1.7 \times 10^{-6}$ @ 90% C.L.

$B \to \mu\nu$ at Belle II



- Upper limits approaching SM expectation
- Inclusive tag analysis with the full Belle data sample is ongoing
- Belle II expectations are
  - observation at SM level with 5 ab^{-1}
  - $\sigma(\mathcal{B})/\mathcal{B} \sim 7\%$ at 50 ab^{-1}
- theory free LFU violation test $R = \mathcal{B}(B \to \tau\nu)/\mathcal{B}(B \to \mu\nu)$

Charm tagging at B-factories

Reconstruction of charm hadron recoiling against $\overline{D}_{\rm tag}X_{\rm frag}$ in events of type:

$$e^+e^- \to c\overline{c} \to \overline{D}_{\rm tag}X_{\rm frag}D^{(*)}_{\rm recoil}$$

($X_{\rm frag}$ additional particles produced in fragmentation of $c\overline{c}$)

Provides

- knowledge of $D^{(*)}_{\rm recoil}$ momentum

  $\hookrightarrow$ $p_{D^{(*)}_{\rm recoil}} = p_{e^+e^-} - p_{\overline{D}_{\rm tag}} - p_{X_{\rm frag}}$

- knowledge of decay products of $D^{(*)}_{\rm recoil}$

  $\hookrightarrow$ all remaining tracks/energy deposits not associated to $\overline{D}_{\rm tag}$ or $X_{\rm frag}$

Charm tagging at B-factory vs. charm factory

B-factory

$$e^+e^- \to \overline{D}_{\rm tag} X_{\rm frag} D^{(*)}_{\rm recoil}$$

- low tagging efficiency ($\mathcal{O}(0.1-1\%)$) due to $X_{\rm frag}$
- access to all charm hadrons $D^{(*)}_{\rm recoil} = D^{(*)0}, D^{(*)+}, \Lambda_c^{(*)+}$
- large sample of continuum events $\int \mathcal{L}dt = 1 \to 50\ {\rm ab}^{-1}$ @ Belle II $\sigma(e^+e^- \to c\bar{c}) = 1.30$ nb

Charm factory

$$e^+e^- \to \overline{D}_{\rm tag} D_{\rm recoil} \quad @ \sqrt{s} = 3.77\ {\rm GeV}$$
$$e^+e^- \to \overline{D}_s^{\rm tag} D_s^{\rm recoil} \quad @ \sqrt{s} = 4.17\ {\rm GeV}$$

- high tagging efficiency ($\mathcal{O}(10\%)$)
- cleaner events (no additional particles)
- need to take data at different energies
- $\int \mathcal{L}dt = 10 - 20\ {\rm fb}^{-1}$ @ BESIII
  $\sigma(e^+e^- \to \psi(3770)) = 6$ nb
  $\sigma(e^+e^- \to D_s^* D_s) = 1$ nb @ 4.17 GeV

Method and Motivation

2 step reconstruction:

1. Recoil reconstruction of charm hadrons (for normalization)
2. Within the recoil sample search for $D \to f$ decays

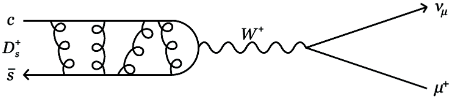
enables measurements of absolute branching fractions and studies of decays with missing energy:

$$\mathcal{B}(D \to f) = \frac{N^{\rm excl}_{D\to f}}{N^{\rm recoil}_{D} \cdot \varepsilon(D \to f | D_{\rm recoil})}$$

- $\mathcal{B}$ of *normalization* modes
  - $D_s \to KK\pi$
  - $D \to K\pi\pi$
  - $\Lambda_c \to pK\pi$
  - ...
- CKM matrix elements
  - $D_{(s)} \to \ell\nu$

- Searches for rare decays with missing energy:
  - $D^0 \to \mathrm{invisible}(\gamma)$
  - $D \to X_u \nu\bar{\nu}$
  - ...

Leptonic D_s decays in the Standard Model



$$\mathcal{B}(D_s^+ \to \ell^+ \nu_\ell) = \frac{G_F^2}{8\pi} f_{D_s}^2 |V_{cs}|^2 \tau_{D_s} M_{D_s} m_\ell^2 \left(1 - \frac{m_\ell^2}{M_{D_s}^2}\right)^2$$

- Unlike $B \to \ell\nu$ the $D_s \to \ell\nu$ decays are not CKM suppressed
  - $\mathcal{B}(B \to \tau\nu) \sim 1 \times 10^{-4}$ vs. $\mathcal{B}(D_s \to \tau\nu) \sim 5 \times 10^{-2}$
- Extract D_s decay constant, f_{D_s}, by measuring $\mathcal{B}(D_s \to \ell\nu)$
  - to test lattice QCD calculations (needed in extraction of the SM parameters from measurements in $B_{(s)}$ meson system)
  - Measurements of D^+ and D_s^+ decay constants provide the $SU(3)$ flavor breaking ratio f_{D_s}/f_D
    - To good approximation $f_{B_s}/f_B = f_{D_s}/f_D$
      [see Grinstein '93 and JHEP,1112,(2011)088 and references therein]
- Could receive contributions from New Physics...

Effect of charged Higgs (2HDM)

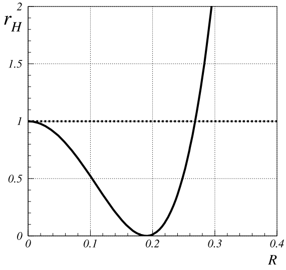
Akeroyd and Chen, PRD75, 075004 (2007)

$B \to \ell\nu$

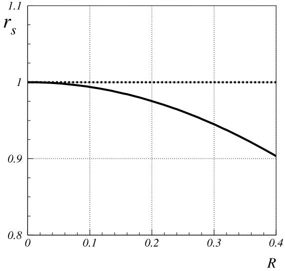
$$\mathcal{B} = \mathcal{B}^{SM} \times \underbrace{\left(1 - m_B^2 \frac{\tan^2\beta}{m_{H^\pm}^2}\right)^2}_{\equiv r_H}$$

$D_{(s)} \to \ell\nu$

$$\mathcal{B} = \mathcal{B}^{SM} \times \underbrace{\left(1 - m_{D_{(s)}}^2 \frac{\tan^2\beta}{m_{H^\pm}^2} \cdot \left[\frac{m_{d(s)}}{m_c + m_{d(s)}}\right]\right)^2}_{\equiv r_{(s)}}$$



$$R = \frac{\tan\beta}{m_{H^\pm}}$$



Large effect possible on $\mathcal{B}(B \to \ell\nu)$ but only small perturbation to the $\mathcal{B}(Ds \to \ell\nu)$ and no effect on $\mathcal{B}(D \to \ell\nu)$.

Recoil D_s reconstruction

$$e^+e^- \to c\bar{c} \to \overline{D}_{\rm tag} X_{\rm frag} K D_s^{*+} \left(\to \boxed{D_s^+} \gamma \right)$$

- $\overline{D}_{\rm tag} = \overline{D}^0,\ D^-,\ \Lambda_c^- p,\ D^{*-},\ \overline{D}^{*0}$

D^0	$\mathcal{B}$ [%]
$K^-\pi^+$	3.9
$K^-\pi^+\pi^0$	13.9
$K^-\pi^+\pi^+\pi^-$	8.1
$K^-\pi^+\pi^+\pi^-\pi^0$	4.2
$K_S^0\pi^+\pi^-$	2.9
$K_S^0\pi^+\pi^-\pi^0$	5.4
Sum	38.4

D^+	$\mathcal{B}$ [%]
$K^-\pi^+\pi^+$	9.4
$K^-\pi^+\pi^+\pi^0$	6.1
$K_S^0\pi^+$	1.5
$K_S^0\pi^+\pi^0$	6.9
$K_S^0\pi^+\pi^+\pi^-$	3.1
$K^+K^-\pi^+$	1.0
Sum	28.0

Λ_c^+	$\mathcal{B}$ [%]
$pK^-\pi^+$	5.0
$pK^-\pi^+\pi^0$	3.4
pK_S^0	1.1
$\Lambda\pi^+$	1.1
$\Lambda\pi^+\pi^0$	3.6
$\Lambda\pi^+\pi^+\pi^-$	2.6
Sum	16.8

$D^{*+} \to D^0\pi^+,\ D^+\pi^0;\ D^{*0} \to D^0\pi^-,\ D^0\gamma;$

- Strangeness balancing kaon: $K = K^\pm,\ K_S^0$
- Fragmentation system:

$$X_{\rm frag} = \text{nothing},\ \pi^\pm,\ \pi^0,\ \pi^\pm\pi^\pm,\ \pi^\pm\pi^0,\ \pi^\pm\pi^\pm\pi^\pm,\ \pi^\pm\pi^\pm\pi^0$$

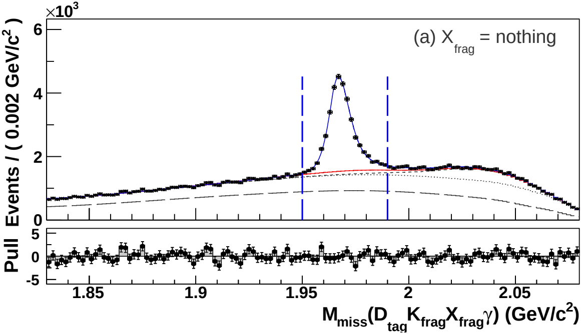
- Kinematic fit to improve resolution of $p_{D_{\rm recoil}}$
  - mass constrained vertex fit to $D^*_{s\ \rm recoil}$
- Recoil $D_{s\ \rm recoil}$ candidates identified in missing (recoil) mass

$$M_{\rm miss}(\overline{D}_{\rm tag} K X_{\rm frag}\gamma) = \sqrt{|p_{e^+e^-} - p_{\overline{D}_{\rm tag}} - p_K - p_{X_{\rm frag}} - p_\gamma|^2}$$

Recoil D_s yield

- $$e^+e^- \to c\bar{c} \to \overline{D}_{\rm tag} X_{\rm frag} K D_s^{*+} \left(\to \boxed{D_s^+} \gamma \right)$$

Belle, JHEP09(2013)139



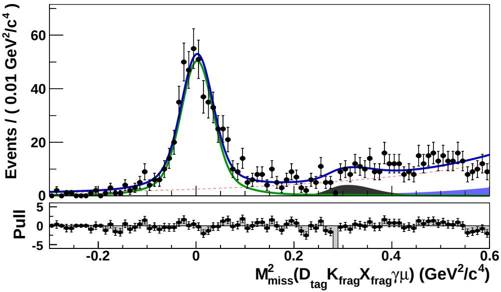
NOTE: only part of the sample shown

		Yield per luminosity
B-factory (Belle)		$100{\cdot}10^3$ per ab^{-1}
Charm-factory (CLEO-c)	$\sqrt{s} = 4.17$ GeV	$73{\cdot}10^3$ per fb^{-1}
Charm-factory (BESIII)	$\sqrt{s} = 4.01$ GeV	$22{\cdot}10^3$ per fb^{-1}

NOTE: $\sigma(D_s D_s)$ @ 4.01 GeV $\sim \frac{1}{3}\sigma(D_s D_s^*)$ @ 4.17 GeV

$D_s^+ \to \mu^+\nu_\mu$

- 1 charged track pointing to the IP passing muon PID requirements
- Fit to the $M^2_{\rm miss}(D_{\rm tag}KX_{\rm frag}\gamma\mu^\pm) = \sqrt{|p_{e^+e^-} - p_{D_{\rm tag}} - p_K - p_{X_{\rm frag}} - p_\gamma - p_\mu|^2}$



$N^{\rm excl}_{D_s\to\mu\nu} = 492 \pm 26$

Belle @ 913 fb^{-1}

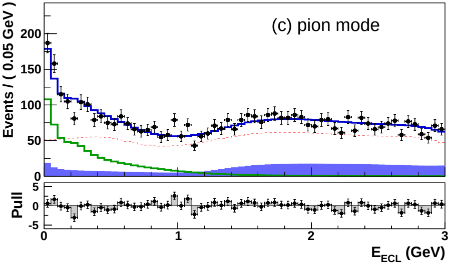
$$\boxed{\mathcal{B}(D_s^+ \to \mu^+\nu_\mu) = (0.531 \pm 0.028({\rm stat.}) \pm 0.020({\rm syst.}))\%}$$

$D_s \to \tau^+\nu_\tau$

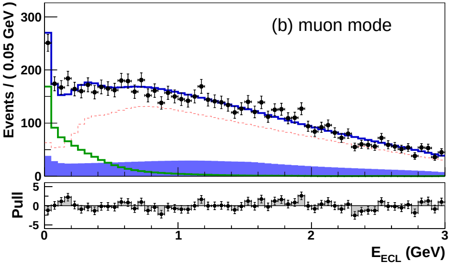
Fit to E_{ECL}:

- Signal
  $\hookrightarrow$ τ cross-feed between modes, e.g. $\tau(\rho) \to \tau(\pi)$, is part of signal PDF and fixed
- True D_s background is fixed
  $\hookrightarrow$ ℓ modes: dominantly $D_s \to X\ell\nu$
  $\hookrightarrow$ π mode: $D_s \to K^0K$, $\eta\pi$, ρK
- Combinatorial background

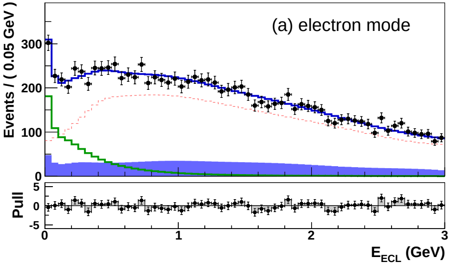
$N^{\mathrm{excl}}_{D_s\to\tau(\pi)\nu_\tau} = 496 \pm 35$



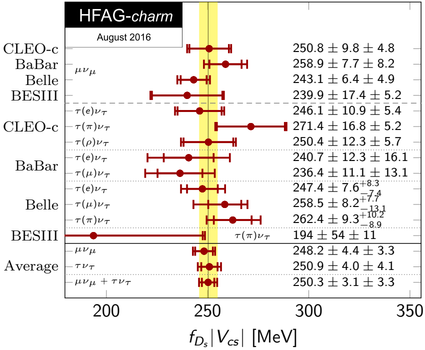
$N^{\mathrm{excl}}_{D_s\to\tau(\mu)\nu_\tau} = 758 \pm 48$

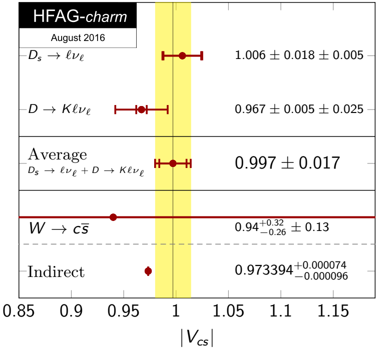


$N^{\mathrm{excl}}_{D_s\to\tau(e)\nu_\tau} = 952 \pm 59$



Extraction of V_{cs} and Comparison





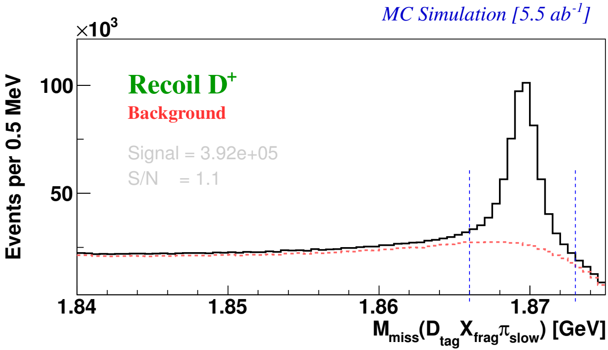
- Lepton Flavour Universality test

$$R^{\text{exp}} = \mathcal{B}(D_s \to \tau\nu)/\mathcal{B}(D_s \to \mu\nu) = 9.95 \pm 0.57 \quad \text{vs.} \quad R^{\text{SM}} = 9.76 \pm 0.03.$$

  - significant improvement at Belle II possible since most of the systematics cancels in the ratio ($\sigma(R^{\text{exp}})/R^{\text{exp}} \sim 1\%$)

Recoil D^+ yield

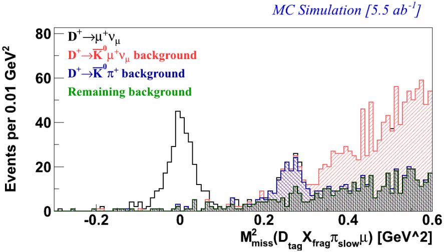
- $$e^+e^- \to c\bar{c} \to \overline{D}_{\rm tag} X_{\rm frag} D^{*+} \left(\to \boxed{D^+} \; \pi^0_{\rm slow} \right)$$



	Yield per luminosity
B-factory (Belle)	$71{\cdot}10^3$ per ab^{-1}
Charm-factory (BESIII)	$550{\cdot}10^3$ per fb^{-1}

$D^+ \to \mu^+\nu_\mu$ and $f_D|V_{cd}|$

- 1 charged track pointing to the IP passing muon PID requirements



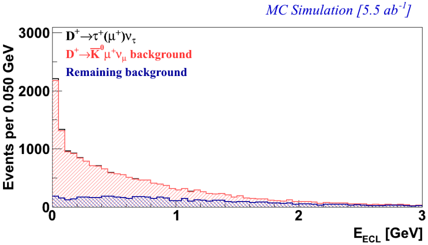
	Yield per luminosity
B-factory (Belle)	25 per ab^{-1}
Charm-factory (BESIII)	140 per fb^{-1}

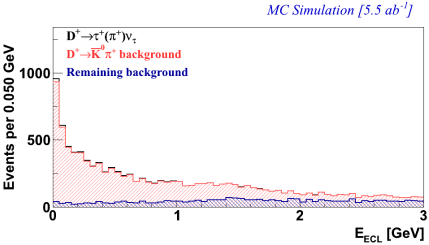
Assuming similar systematics as in $D_s^+ \to \mu^+\nu_\mu$ measurement:

- $\mathcal{B}$: $\sigma(\text{stat.})/\mathcal{B} \sim 4.5\ (3)\%$ at 20 (50) ab^{-1} and $\sigma(\text{syst.})/\mathcal{B} \sim 3\%$
- BESIII (PRD89,051104) @ 2.9 fb^{-1}: $\sigma/\mathcal{B} \sim 5.1(\text{stat.}) \pm 1.6(\text{syst.})\%$

$D^+ \to \tau^+\nu_\tau$ and $|V_{cd}|$

- 1 charged track pointing to the IP passing muon ($\tau(\mu)\nu$ mode) or pion ($\tau(\pi)\nu$ mode) PID requirements



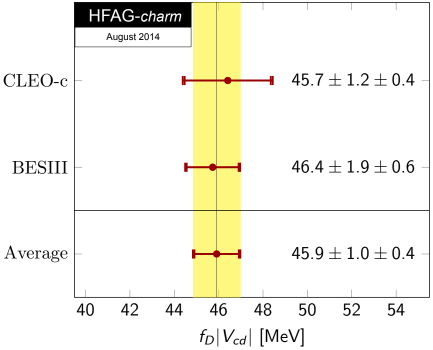


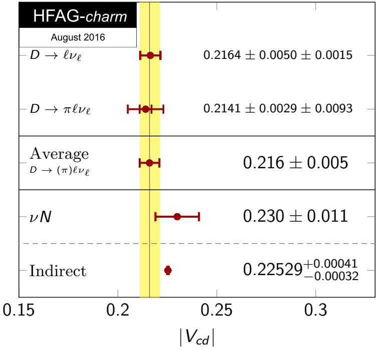
Signal and Peaking background yield per ab^{-1}

Mode	Signal Yield	Peaking background
$\tau(e)\nu$	15	3200 $K^0(\to K^0_L)e\nu$
$\tau(\mu)\nu$	10	4200 $K^0(\to K^0_L)\mu\nu$
$\tau(\pi)\nu$	10	1500 $K^0(\to K^0_L)\pi$

Dominated by the SL $D^+ \to K^0_L\ell^+\nu_\ell$ decays, however no K_L rejection attempted, yet. To use these modes further K_L reconstruction/rejection to be studied.

Extraction of V_{cd} and Comparison





- Expected precision of $f_D|V_{cd}|$ with full Belle II sample is around 2-3%

Conclusions

- A lot of effort at Belle II invested into improvement of tag reconstruction algorithm and understanding the beam background induced background on measurements with missing energy
- Leptonic decays of B and D meson decays will enter precision era with Belle II sample
  - provide important input to global CKM fits ($|V_{ub}|$)
  - sensitive to new physics
- Measurements will become systematically limited and the key will be to have excellent calibration of the tag reconstruction efficiency