Belle II first results and prospects for LFU tests

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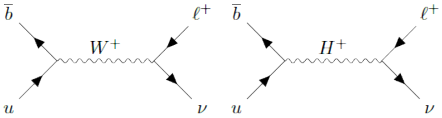
for the Belle II Collaboration

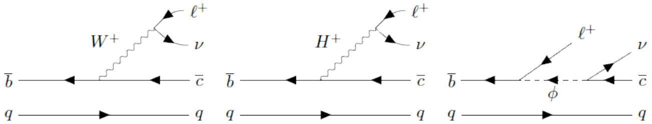
HC2NP
Tenerife, 23-28 September 2019

B decays and LFV/LFU

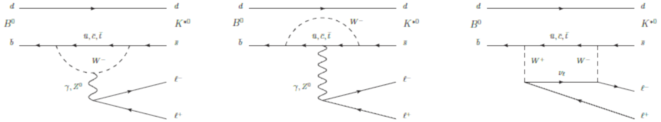
- Leptonic decays $B^{\pm} \to \ell^{\pm}\nu$



- Semileptonic decays $B \to X\ell\nu$



- FCNC processes $B \to X_{s(d)}\ell^+\ell^-$.



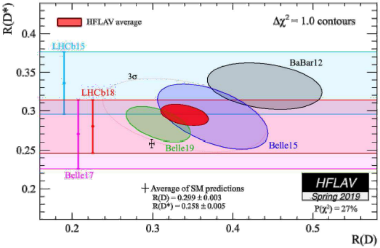
Current status of LFV/LFU in B-factories

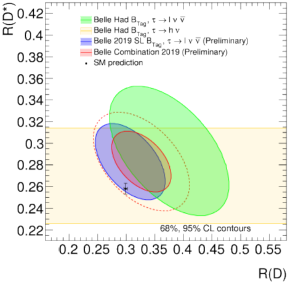
Belle: Semileptonic decays R_D and R_{D^*}

Exp.	Tag method	τ^- decays	Observables	Fit variables
Belle PRL 99, 191807 (2007)	Hadronic Inc.	$e^-\nu_\tau\bar{\nu}_e, \pi\nu_\tau$	$\mathcal{B}(\bar{B}^0 \to D^{*+}\tau^-\bar{\nu}_\tau)$	$M_{\rm bc}^{\rm comp}$
Belle PRD 82, 072005 (2010)	Hadronic Inc.	$\ell^-\nu_\tau\bar{\nu}_\ell, \pi\nu_\tau$	$\mathcal{B}(B^- \to D^{(*)0}\tau^-\bar{\nu}_\tau)$	$M_{\rm bc}^{\rm comp}$ and p_{D^0}
Belle PRD 92, 072014 (2015)	Hadronic	$\ell^-\nu_\tau\bar{\nu}_\ell$	$R_D, R_{D^*}, q^2, \lvert p_\ell^*\rvert$	$M_{\rm miss}^2$ and O_{NB}†
Belle PRL 118, 211801 (2017)	Hadronic	$h^-\nu_\tau$	$R_{D^*}, P_\tau(D^*)$	$E_{\rm ECL}$ and $\cos\theta_{\rm hel}$
Belle PRD 94, 072007 (2016)	Semileptonic	$\ell^-\nu_\tau\bar{\nu}_\ell$	$R_{D^*}, \lvert p_\ell^*\rvert\,\lvert p_{D^*}^*\rvert$	$E_{\rm ECL}$ and O'_{NB}‡
Belle preliminary conf-1902	Semileptonic FEI	$\ell^-\nu_\tau\bar{\nu}_\ell$	R_D, R_{D^*}	$E_{\rm ECL}$ and O_{BDT}

- experimental method depends on what we measure
  - tagging,
  - signal reconstruction (τ decay channels)
- $q^2 \equiv M_W^2$ - effective mass squared of the $\tau\nu$ system
- $R_D = \frac{\mathcal{B}(B\to D\tau\nu)}{\mathcal{B}(B\to D\ell\nu)}$
- $R_D^* = \frac{\mathcal{B}(B\to D^*\tau\nu)}{\mathcal{B}(B\to D^*\ell\nu)}$

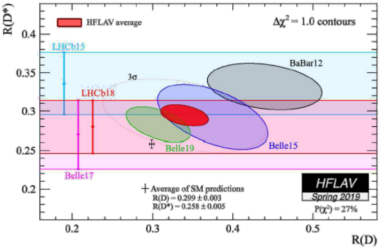
R_D and R_{D^*} current status

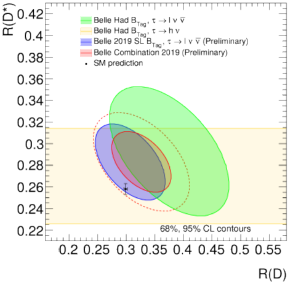




- New perliminary semileptonic tag based measurement of R_D, R_D^* is consistent with the old result, more precise.
- Recent measurements from Belle and LHCb reduce tensions with SM
- Combined Belle result is consistent with SM at 2σ level

R_D and R_{D^*} current status





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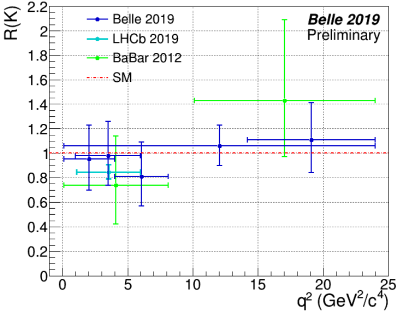
- Combined Belle result is consistent with SM at 2σ level

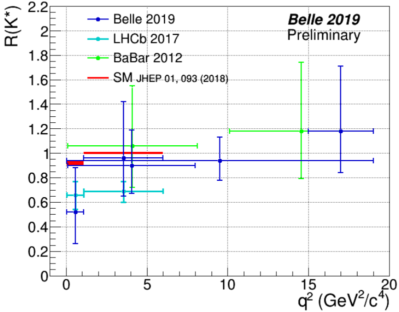
The dynamics of these decays can be probed with differential distributions q^2, τ and D^* polarizations ...

Recent R_K and R_{K^*}

$$R_K = \frac{\mathcal{B}(B \to K\mu\mu)}{\mathcal{B}(B \to K\ell\ell)}$$



$$R_{K^*} = \frac{\mathcal{B}(B \to K^*\mu\mu)}{\mathcal{B}(B \to K^*\ell\ell)}$$



- Recent preliminary results for both R_K and R_K^* from Belle (arXiv:1904.02440)
- Belle measured R_K^{*+} and R_{K_S} for first time,
- Allow measurement of CP averaged isospin asymmetry

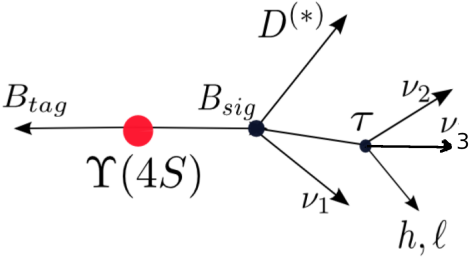
$$A_| = \frac{(\tau_{B^+}/\tau_{B^0}) \times \mathcal{B}(B^0 \to K^0\ell\ell) - \mathcal{B}(B^+ \to K^+\ell\ell)}{(\tau_{B^+}/\tau_{B^0}) \times \mathcal{B}(B^0 \to K^0\ell\ell) + \mathcal{B}(B^+ \to K^+\ell\ell)}$$

- New measurements are closer to the SM (and consistent with LHCb)

Belle II first results

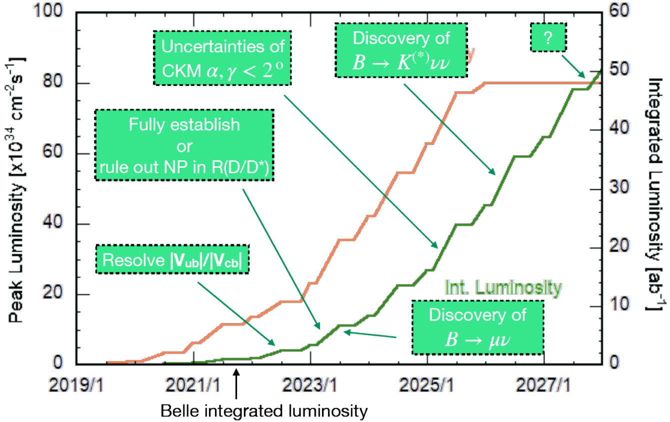
The Belle II experiment

- The Belle II experiment is an upgrade of Belle detector
- Electron-positron collisions
- $E_{\mathrm{CM}} \approx m_{\Upsilon(4s)}$
- $\Upsilon(4s) \rightarrow \bar{B}B$, quantum-entangled
- Particulary well adapted to study B decays with missing energy; especially with multiple ν in final state
- Target plan 55 billion B meson pairs decays recorded
- Sensitivity in B, charm and τ to $O(10^{-9}) - O(10^{-11})$ branching fractions



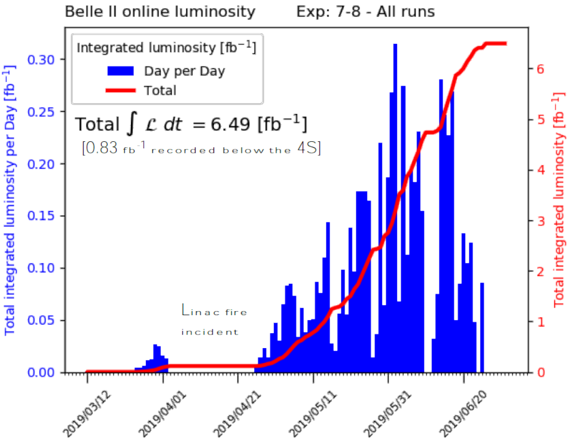
SuperKEKB/BElle II Luminosity profile

Belle/KEKB recorded $\approx 1000\ \mathrm{fb}^{-1}$



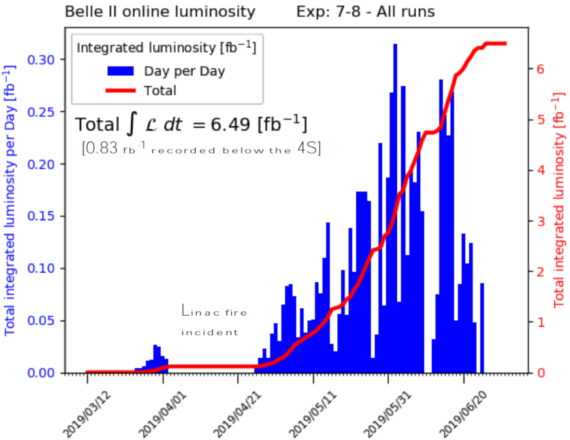
- Beam currents only a factor of two higher then KEKB ($\approx$ PEPII)
- “nano-beams” are the key; vertical beam size is 50nm at the IP

Spring 2019, First Physics Run with full Detector



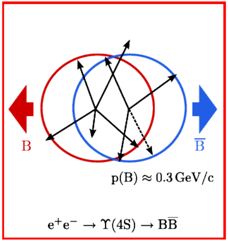
- only 2 months of collisions
- L(peak)$\approx$ $5.5 \times 10^{33}/cm^2/s$

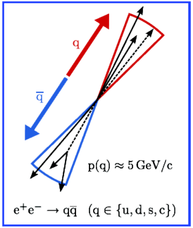
Spring 2019, First Physics Run with full Detector



- only 2 months of collisions
- L(peak)$\approx$ $5.5 \times 10^{33}/cm^2/s$
- L(SuperKEKB)$\approx$ $1.2 \times 10^{34}/cm^2/s$
- Luminosity comparable to PEP-II records
- background to large to turn Belle II

B meson counting

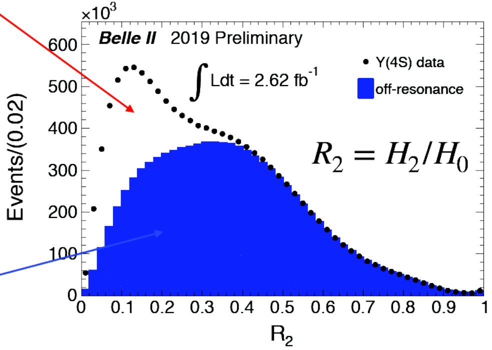




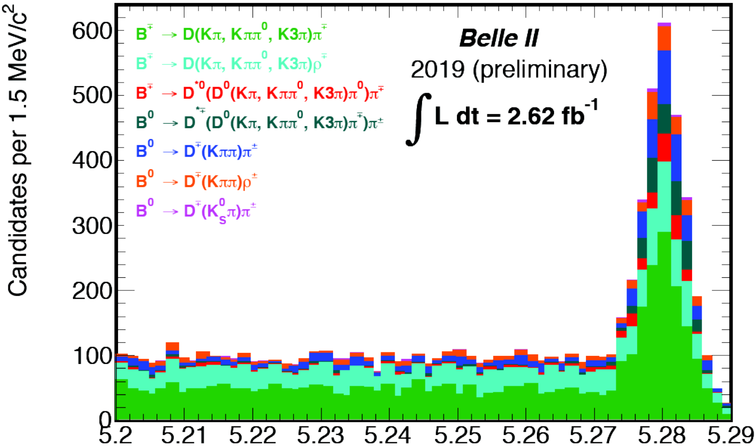
$$H_l = \sum_{i,j} \frac{|P_i||P_j|}{E_j^{vis}} P_l(cos\theta_{ij})$$

P : Momentum of charged tracks or Energy neutral clusters

θ_{ij} : Opening angle between *ith* and *jth* particle

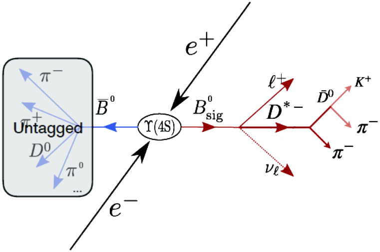


Rediscovery of $B \to D^{(*)}\pi^{\pm}.\rho^{\pm}$ $\mathcal{B} \approx$ few 0.1%



$$m_{bc} = \sqrt{E_{\rm beam}^2 - p_B^{*2}} \simeq m_B^2$$

Rediscovery of $B^0 \to D^{*-}\ell^+\nu_\ell$ $\mathcal{B} \approx 11\%$



Particle	Selection
Tracks	IP in $z < 2$ cm
Tracks	IP in r-ϕ plane < 0.5 cm
ℓ	$1.2 < p^*_\ell < 2.4$ GeV/c
e	Electron likelihood > 0.85
μ	Muon likelihood > 0.9
slow π	$p^*_\pi < 0.5$ GeV/c
D^0	$1.85 < M_D < 1.88$ GeV/c^2
D^*	$0.144 < M_{D^*} - M_D < 0.148$ GeV/c^2
D^*	$p_{D^*} < 2.5$ GeV/c

$$m^2_{\text{miss}} = \left((\frac{1}{2}E_{\text{beam}}, 0,0,0) - p^*_{D^*\ell} \right)^2 \approx p^2_\nu = 0\,\text{GeV}^2$$

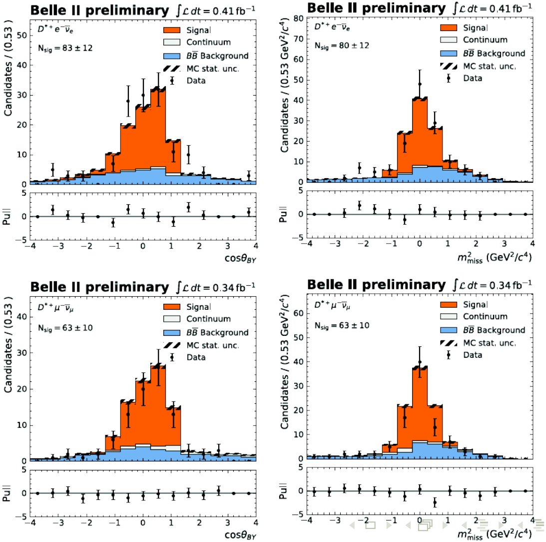
$$\cos\theta_{B,D^*\ell} = \frac{2E_B E_{D^*\ell} - m^2_B - m^2_{D^*\ell}}{2|\vec{p}^{\,*}_B||\vec{p}_{D^*\ell}|}$$

Rediscovery of $B^0 \to D^{*-}\ell^+\nu_\ell$

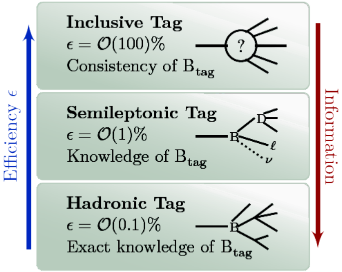
$\cos\theta_{B,D^*\ell}$ m^2_{miss}

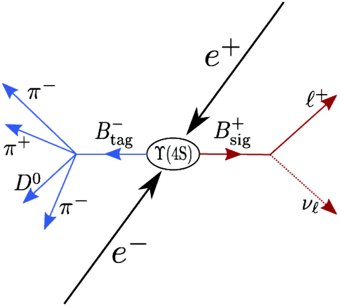
$\ell = e$

$\ell = \mu$



Hadronic Tagging with the Full Event Interpretation





$$p_\nu = \left(p_{e^+e^-} - p_{B_{tag}} - p_\ell\right)$$

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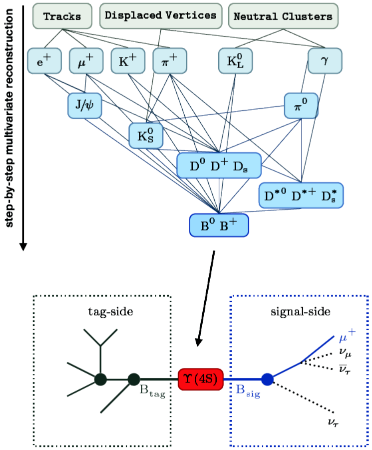

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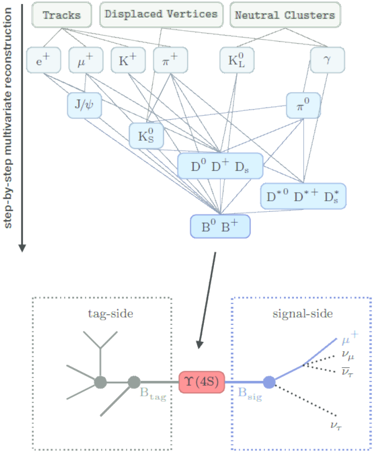
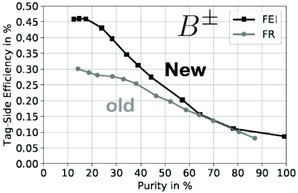


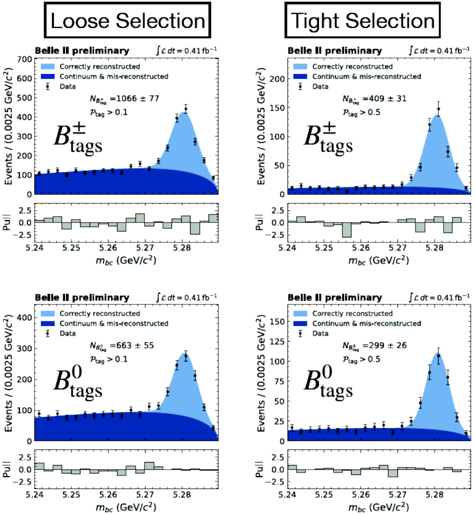
Thomas Keck et al, arXiv:1807.08680
Published in Computing and Software for Big Science

	FEI			old algorithms	
	$B^\pm$	B^0		$B^\pm$	B^0
Hadronic			Hadronic		
FEI with FR channels	0.53 %	0.33 %	FR	0.28 %	0.18 %
FEI	0.76 %	0.46 %	SER	0.4 %	0.2 %
Semileptonic			Semileptonic		
FEI	1.80 %	2.04 %	FR	0.31 %	0.34 %
			SER	0.3 %	0.6 %

- Significant improvement of performance



Full Event Interpreter (FEI) at Belle II



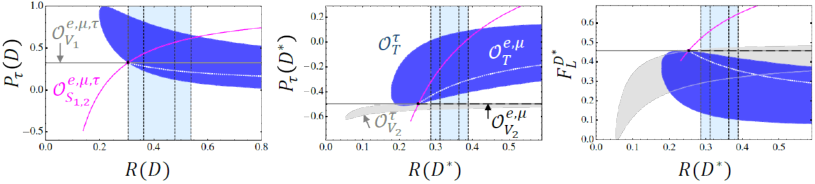
Belle II prospects for LFU tests

D^* and τ polarizations in $B \to D^* \tau \nu_\tau$

Observables that can give a better insight into the dynamics of $b \to c\tau\nu$ transitions: q^2, longitudinal and transverse polarizations of τ and D^*.
So far experiments measured q^2 distributions (and lepton spectra)
Belle measured longitudinal polarizations:

- $P_\tau(D^*) = \frac{\Gamma^+(D^*) - \Gamma^-(D^*)}{\Gamma^+(D^*) + \Gamma^-(D^*)}$ $\quad\Gamma^\pm(D^*)$: decay rate with τ helicity $\lambda_\tau = \pm\frac{1}{2}$
- $F_L^{D^*} = \frac{\Gamma(D_L^*)}{\Gamma(D_L^*) + \Gamma(D_T^*)}$ $\quad\Gamma(D^*_{L(T)})$: decay rate of longitudinally (transversely) polarized D^*

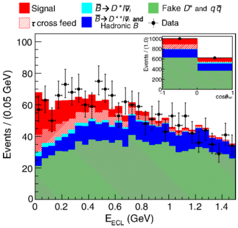
New physics scenarios [Phys. Rev. D 87, 034028 (2013)]

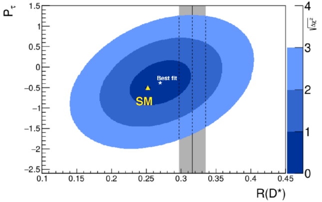


$B \to \bar{D}^{*}\tau^{-}\nu_{\tau}$ distribution : τ polarisation

Pioneered by Belle Phys. Rev. Lett. **118**, 211801 (2017); Phys. Rev. D **97**, 012004 (2018)

Measured from the two body semileptonic τ ($\to \pi\nu, \to \rho\nu$) decays -experimentally challenging

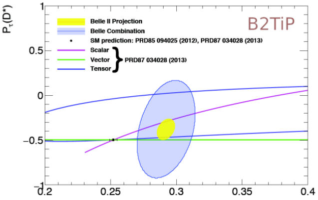




$$P_{\tau}(D^{*}) = -0.38 \pm 0.51(\text{stat})^{-0.16}_{+0.21}(\text{syst})$$

Belle II perspectives :

	5 ab^{-1}	50 ab^{-1}
$P_{\tau}(D^{*})$	$\pm 0.18 \pm 0.08$	$\pm 0.06 \pm 0.04$

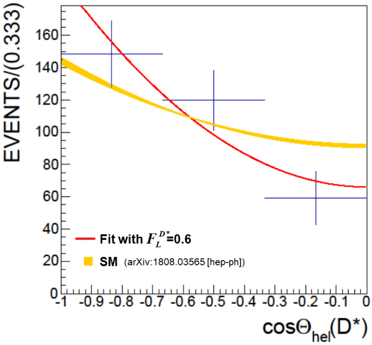


$B \to \bar{D}^* \tau^- \nu_\tau$ distribution : D^* polarisation

$$\frac{1}{\Gamma}\frac{d\Gamma}{d\cos\theta_{\rm hel}(D^*)} = \frac{3}{4}[2F_L^{D^*}\cos^2(\theta_{\rm hel}(D^*)) + (1-F_L^{D^*})\sin^2(\theta_{\rm hel}(D^*))]$$

All τ decays are usable.

Preliminary Belle result arXiv:1903.03102



Large efficiency variation $\to$ experimentally dificult

Belle: $F_L^{D^*} = 0.60 \pm 0.08$(stat)$\pm$0.04(sys)

$F_L^{D^*} = 0.60 \pm 0.08(stat.) \pm 0.035(syst.)$

SM: $F_L^{D^*} = 0.46 \pm 0.03$ (Phys. Rev. D **95**, 115038 (2017), A.K. Alok, et al) $(1.5\ \sigma)$

SM: $F_L^{D^*} = 0.441 \pm 0.006$ (arXiv:1808.03565, Z-R. Huang, et al) $(1.8\ \sigma)$

Expected number of events for $F_L^{D^*}$ in full data set is ~ 15000.

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

Composition of the systematic uncertainties in each Belle analysis

	Belle (Had, ℓ^-)	Belle (Had, ℓ^-)	Belle (SL, ℓ^-)	Belle (Had, h^-)
Source	R_D	R_{D^*}	R_{D^*}	R_{D^*}
MC statistics	4.4%	3.6%	2.5%	$^{+4.0}_{-2.9}$%
$B \to D^{**}\ell\nu_\ell$	4.4%	3.4%	$^{+1.0}_{-1.7}$%	2.3%
Hadronic B	0.1%	0.1%	1.1%	$^{+7.3}_{-6.5}$%
Other sources	3.4%	1.6%	$^{+1.8}_{-1.4}$%	5.0%
Total	7.1%	5.2%	$^{+3.4}_{-3.5}$%	$^{+10.0}_{-9.0}$%

"The Belle II Physics Book", arXiv:1808.10567

- The uncertainty due to MC statistic is reducible
  - MC statistic affects the estimation of the reconstruction efficiency, understanding of the cross-feed components and PDFs for the fit
- Efficiency is model dependent: q^2 and others distributions with used model. Belle II will reduce model dependency by measureing differential distribution.
- The uncertainties from $\mathcal{B}(B \to D^{**}\ell\nu_\ell)$, D^{**} decays and hadronic B decays have to be reduced.
  - Need for dedicated measurements of $B \to D^{**}\ell\nu_\ell$ and hadronic B decays with a large data sample.

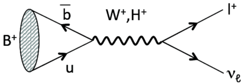
Testing lepton flavor universality with leptonic B decays

Very clean theoretically, hard experimentally SM is helicity suppressed
Sensitive to NP contribution (charged Higgs)

$$R^{\tau\mu} = \frac{\Gamma(B \to \mu\nu)}{\Gamma(B \to \tau\nu)}$$

$$R^{\tau e} = \frac{\Gamma(B \to e\nu)}{\Gamma(B \to \tau\nu)}$$

$$R^{\tau\pi} = \frac{\Gamma(B \to \tau\nu)}{\Gamma(B \to \pi l\nu)}$$



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

SM test in $\mathcal{B}$ measurement

Mode	SM BR	Current meas.	Belle II 5 ab-1	Belle II 50 ab-1
τν	10^{-4}	20% uncertainty	15%	6%
μν	10^{-6}	40% uncertainty*	20%	7%
eν	10^{-11}	Beyond reach	-	-

* arxiv:1712.04123 2.4σ excess $[2.9,10.7]\times10^{-7}$ at 90% C.L.

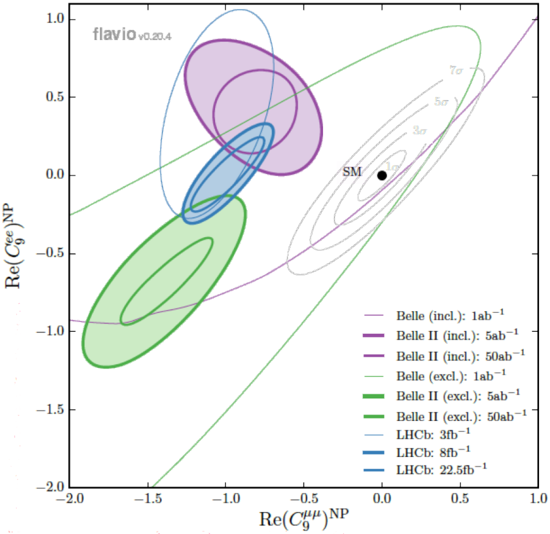
Belle II Full simulation with expected background conditions (hadronic tags only)
S.L. tag expected to have similar sensitivity

Extrapolation of Belle Analysis

Semileptonic B decays with $b \to s\ell^+\ell^-$ transitions

- reconstruction of exclusive decays is very straight forward and well established at Belle
  - improvement in reconstruction possible at Belle II
- Belle II have tools (FEI) for fully inclusive measurement; unique position for measurement with different systematic errors.
- $\mathcal{B}$ and q^2 distributions are already systematic dominated at LHCb
  - still we can test the deficit of muon modes observed by LHCb
  - and recheck the region of higher charmonium contributions of $q^2 > 14.4 Gev^2$
- Belle measurement of $A_{|}(B \to K\ell^+\ell^-)$ lead to isospin violation check
- angular analysis is avery important topic at Belle II

New Physics in $b \to s\ell^+\ell^-$

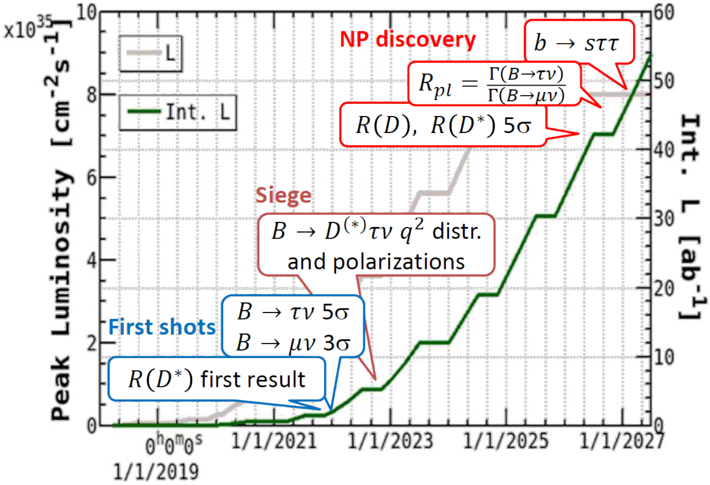


NP in b→s l⁺l⁻

Prepared by D. Straub et al. for the Belle II Physics Book (edited by P. Urquijo and E. Kou)

Belle II can do both inclusive and exclusive. Equally strong capabilities for electrons and muons.

Prospects on LFU

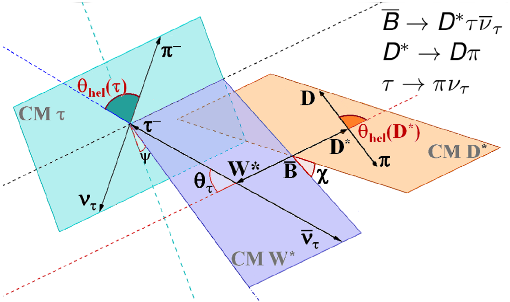


Summary

- Belle II experiment has started physics runs and expect to accumulate ≈ 50 times larger data sample then previous B-factories, which will be crucial for rare and decays with missing energy
- Belle II is an excellent detector for lepton universality studies, especially for the channels involving missing energy. Same is true for *ee* vs $\mu\mu$ channels, due to similar reconstruction efficiency.
- The $B \to D^{(*)}\ell\nu$ channels at Belle II are statistically limited, however for $R_{D^{(*)}}$ better modeling of $B \to D^{**}\ell\nu$ and generaly hadronic B decays is necessary.
- Belle II ML-based full event interpretation tagging method improves B meson tagging compared to Belle.

Backup

Kinematic variables describing $B \to \bar{D}^{(*)}\tau^-\nu_\tau$



$\overline{B} \to D^* \tau \overline{\nu}_\tau$
$D^* \to D\pi$
$\tau \to \pi\nu_\tau$

$q^2 \equiv M_W^2$ - effective mass squared of the $\tau\nu$ system
θ_τ - angle between τ&B in W^* rest frame
χ - angle between the $\tau\nu$ and D^* decay planes

$\theta_{\rm hel}(D^*)$ - angle between D&B in D^* rest frame
$\theta_{\rm hel}(\tau)$ - angle between π& direction opposite to W^* in τ rest frame

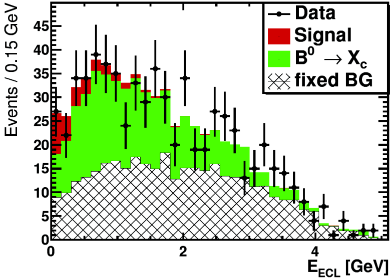
$$\frac{d\Gamma}{d\cos\theta_{hel}(\tau)} = \frac{1}{2}(1 + \alpha P_\tau \cos\theta_{hel}(\tau))$$
$$\alpha = 1.0 \text{ for } \tau \to \pi\nu; \quad \alpha = 0.45 \text{ for } \tau \to \rho\nu$$

$$\frac{1}{\Gamma}\frac{d\Gamma}{d\cos\theta_{\rm hel}(D^*)} = \frac{3}{4}[2F_L^{D^*}\cos^2(\theta_{\rm hel}(D^*)) + (1 - F_L^{D^*})\sin^2(\theta_{\rm hel}(D^*))]$$

q^2, $\cos\theta_{\rm hel}(\tau)$ and $\cos\theta_{\rm hel}(D^*)$ can be reconstructed at B-factories with hadronic decays of $B_{\rm tag}$

Testing lepton flavor universality in $b \to u$ semileptonic decays

$$R(\pi) = \frac{\mathcal{B}(B\to\pi\tau^+\nu_\tau)}{\mathcal{B}(B\to\pi\ell^+\nu_\tau)}$$



Feasibility already demonstrated with Belle. No statistically significant signal was observed $\mathcal{B}(B \to \pi\tau^+\nu_\tau) < 2.5 \times 10^{-4}$

Phys. Rev. Lett. 118, 211801 (2017)

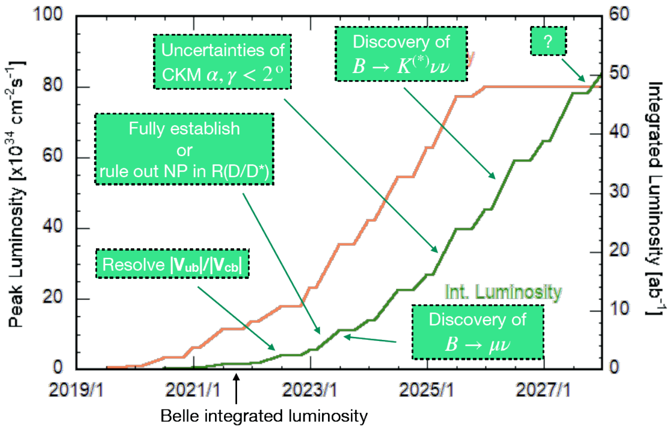
Central value:

$\mathcal{B}(B \to \pi\tau^+\nu_\tau) =$
$(1.52 \pm 0.72 \pm 0.13) \times 10^{-4}$

Belle II extrapolation of uncertainty

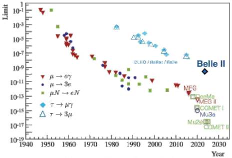
$R_\pi^{5ab^{-1}} \pm 0.23$ or $R_\pi^{50ab^{-1}} \pm 0.09$

General Outlook for next years



Lepton Flavor Violation in τ Decays at Belle II

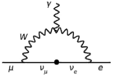
- **Super B-Factory, and τ factory too!**
  σ(e+e- –> Υ(4s)) = 1.05 nb
  σ(e+e- –> $\tau\tau$) = 0.92 nb



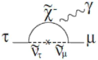
Talk by Ami Rostomyan at TAU 2018

- Charged LPV process occur oscillations in loops. In SM, small rate is immeasurable (10^{-49}~10^{-54}) for all LFV decays.

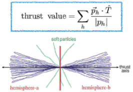
$$B(l_1 \to l_2\gamma) = \frac{3\alpha}{32\pi}\left|\sum_{i=2,3} U^*_{l_1,i} U_{l_2,i} \frac{\Delta m^2_{i1}}{M_W^2}\right|^2$$



- Charged LFV enhanced in many NP models (10^{-7}~10^{-10})



Thrust axis ($\vec{T}$) is maximising the event shape variable



Thrust and visible energy are useful variables in analysis.[24]

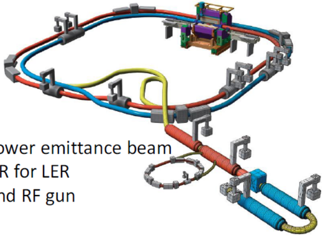
Belle II physics

Observables	Expected the. accuracy		Expected exp. uncertainty	Facility (2025)
UT angles & sides				
ϕ_1 [°]	***	CKM	0.4	Belle II
ϕ_2 [°]	**		1.0	Belle II
ϕ_3 [°]	***		1.0	LHCb/Belle II
$\|V_{cb}\|$ incl.	***		1%	Belle II
$\|V_{cb}\|$ excl.	***		1.5%	Belle II
$\|V_{ub}\|$ incl.	**		3%	Belle II
$\|V_{ub}\|$ excl.	**		2%	Belle II/LHCb
CP Violation				
$S(B \to \phi K^0)$	***	CPV	0.02	Belle II
$S(B \to \eta' K^0)$	***		0.01	Belle II
$\mathcal{A}(B \to K^0 \pi^0)[10^{-2}]$	***		4	Belle II
$\mathcal{A}(B \to K^+ \pi^-)$ $[10^{-2}]$	***		0.20	LHCb/Belle II
(Semi-)leptonic				
$\mathcal{B}(B \to \tau\nu)$ $[10^{-6}]$	**	(Semi) LEPTONIC	3%	Belle II
$\mathcal{B}(B \to \mu\nu)$ $[10^{-6}]$	**		7%	Belle II
$R(B \to D\tau\nu)$	***		3%	Belle II
$R(B \to D^*\tau\nu)$	***		2%	Belle II/LHCb
Radiative & EW Penguins				
$\mathcal{B}(B \to X_s\gamma)$	**	EWP	4%	Belle II
$A_{CP}(B \to X_{s,d}\gamma)$ $[10^{-2}]$	***		0.005	Belle II
$S(B \to K_S^0\pi^0\gamma)$	***		0.03	Belle II
$S(B \to \rho\gamma)$	**		0.07	Belle II
$\mathcal{B}(B_s \to \gamma\gamma)$ $[10^{-6}]$	**		0.3	Belle II
$\mathcal{B}(B \to K^*\nu\bar{\nu})$ $[10^{-6}]$	***		15%	Belle II
$\mathcal{B}(B \to K\nu\bar{\nu})$ $[10^{-6}]$	***		20%	Belle II
$R(B \to K^*\ell\ell)$	***		0.03	Belle II/LHCb
Charm				
$\mathcal{B}(D_s \to \mu\nu)$	***	CHARM	0.9%	Belle II
$\mathcal{B}(D_s \to \tau\nu)$	***		2%	Belle II
$A_{CP}(D^0 \to K_S^0\pi^0)$ $[10^{-2}]$	**		0.03	Belle II
$\|q/p\|(D^0 \to K_S^0\pi^+\pi^-)$	***		0.03	Belle II
$\phi(D^0 \to K_S^0\pi^+\pi^-)$ [°]	***		4	Belle II
Tau				
$\tau \to \mu\gamma$ $[10^{-10}]$	***	TAU	< 50	Belle II
$\tau \to e\gamma$ $[10^{-10}]$	***		< 100	Belle II
$\tau \to \mu\mu\mu$ $[10^{-10}]$	***		< 3	Belle II/LHCb

E. Kou, P Urquijo et al. Belle II Physics book, arXiv: 1808.10567 (Accepted to PTEP)

Very Rich Physics Program!

SuperKEKB: the nano beam scheme



Lower emittance beam
DR for LER
and RF gun

Beam current

Beam-beam parameter

$$L = \frac{\gamma_{e\pm}}{2er_e}\left(1+\frac{\sigma_y^*}{\sigma_x^*}\right)\left(\frac{I_{e\pm}\xi_y^{e\pm}}{\beta_y^*}\right)\left(\frac{R_L}{R_{\xi_y}}\right)$$

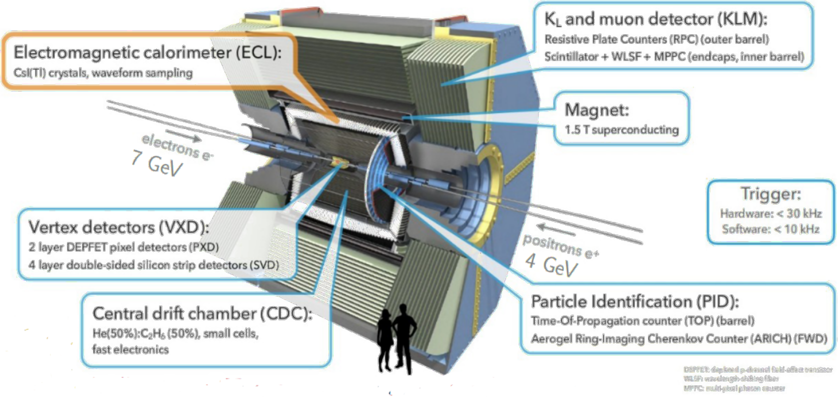
σ: beam size

β function

		KEKB		SuperKEKB		units	
		LER	HER	LER	HER		
Beam energy	E_b	**3.5**	**8**	**4**	**7.007**	**GeV**	
Beam crossing angle	φ	**22**		**83**		**mrad**	
β function @ IP	β_x^*/β_y	**1200/5.9**		**32/0.27**	**25/0.30**	**mm**	X 20
Beam current	I_b	**1.64**	**1.19**	**3.6**	**2.6**	**A**	X 2
Luminosity	L	2.1×10^{34}		8×10^{35}		$cm^{-2}s^{-1}$	X 40

Belle II detector

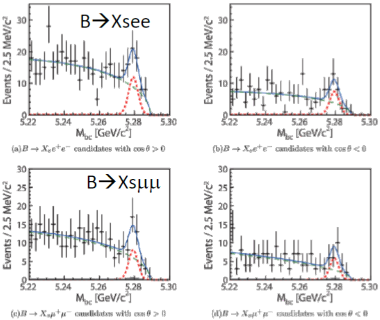
- The Belle II detector has better resolution, PID and capability to cope with higher background



New Physics in $b \to s\ell^+\ell^-$

- Dilepton
  - Electron selected from dE/dx in CDC and ECL
  - Muon from KLM
  - We might be able to use TOP and ARICH for low momentum region which improve efficiency for low q^2 region
- Xs
  - is reconstructed from $K n\pi$ ($0<=n<=4$).
  - We can add three kaon modes and η modes (two pi0 modes?)
- Backgrounds
  - Dominated by B→Xlν and B→Ylν
    - Second largest is ee→cc but event shape information can suppress the background.
  - Can be suppressed with missing energy and vertex information.

Y. Sato, Phys.Rev. D93 032008 (2016)



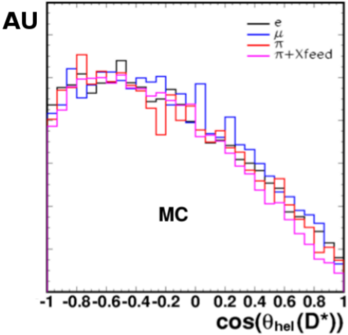
Forward event backward event

[1,6]GeV²

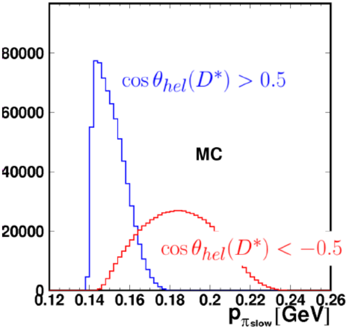
Challenges for D^* polarisation measurement

Main experimental problem:
strong acceptance effects for $\cos\theta_{\rm hel}(D^*) \geq 0.0$

efficiency



distribution of slow $\pi^{\pm}$ from D^*



Effectively only $\cos\theta_{\rm hel}(D^*) < 0$ is useful for $F_L^{D^*}$ measurement

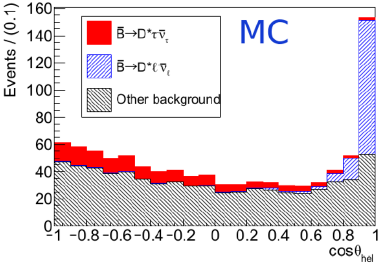
Measurement of τ polarization in B decays

- **both $\bar{B}^0$ and B^- decays are used; only 2 body τ decays: $\tau \to \pi\nu, \rho\nu$**
- sample divided into two bins of $cos\theta_{\rm hel}$: I: $-1 < cos\theta_{\rm hel} < 0$; II: $0 < cos\theta_{\rm hel} < 0.8$ (for $\tau \to \pi\nu$)

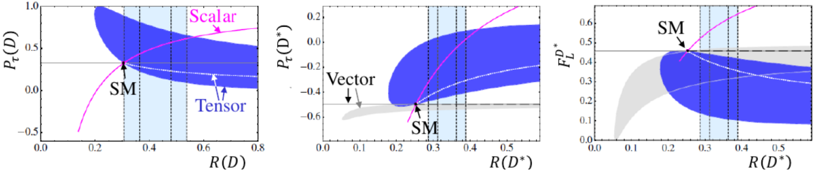
$$P_\tau = \frac{2}{\alpha}\frac{\Gamma_{cos\theta_{\rm hel}>0} - \Gamma_{cos\theta_{\rm hel}<0}}{\Gamma_{cos\theta_{\rm hel}>0} + \Gamma_{cos\theta_{\rm hel}<0}}$$

Experimental challenges

- Distribution of $\cos\theta_{hel}(\tau)$ is modified by:
  - cross-feeds from other τ decays (contribute mainly in the region of $\cos\theta_{hel}(\tau) < 0$)
  - peaking background (concentrated around $\cos\theta_{hel}(\tau) \approx 1$)
- corrections for detector effects: acceptance, asymmetric $cos\theta_{\rm hel}$ bins, crosstalks between different τ decays
- for $\tau \to \pi(\rho)\nu$ modes combinatorial background from poorly known hadronic B decays



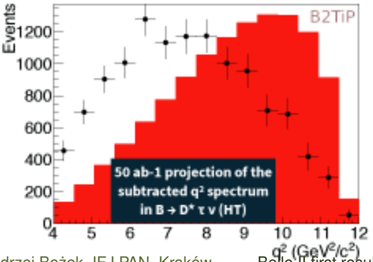
$B \to \bar{D}^{*}\tau^{-}\nu_{\tau}$ differential distribution : q^2



M.Tanaka,R.Watanabe - arXiv:1212.1878v1

Differential distribution can be measured to constrain NP contributions

Detailed measurement of q^2 and other kinematic distributions including polarization of the τ and D^*



Belle II MC are generated in the SM hypothesis

Block histograms is a 2HDM-type II benchmark