Super KEKB and Belle II: status and plans

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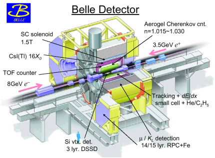
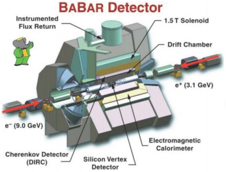
Fudan University

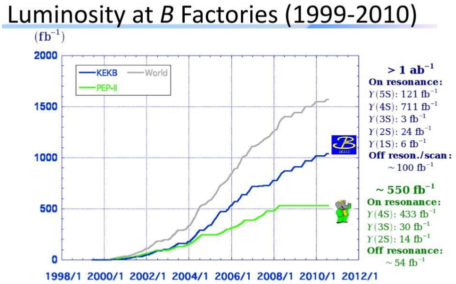
International Workshop on e^+e^- collisions from ϕ to ψ
Budker INP，25 February 2019

Achievements from B factories

Before LHCb

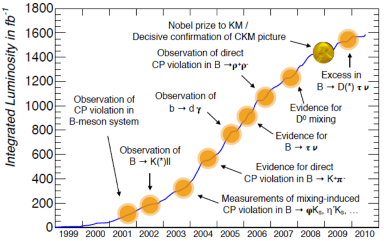


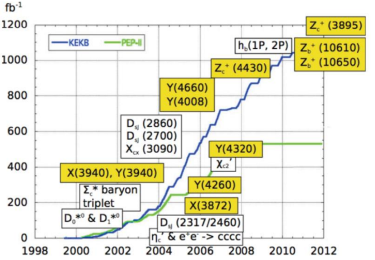




- Two e^+e^- B factories: Belle/KEKB at KEK and BaBar/PEP-II at SLAC
- 1.5 ab^{-1} data, 1.25×10^9 $B\bar{B}$.

Achievements at Flavor Physics and Exotics:

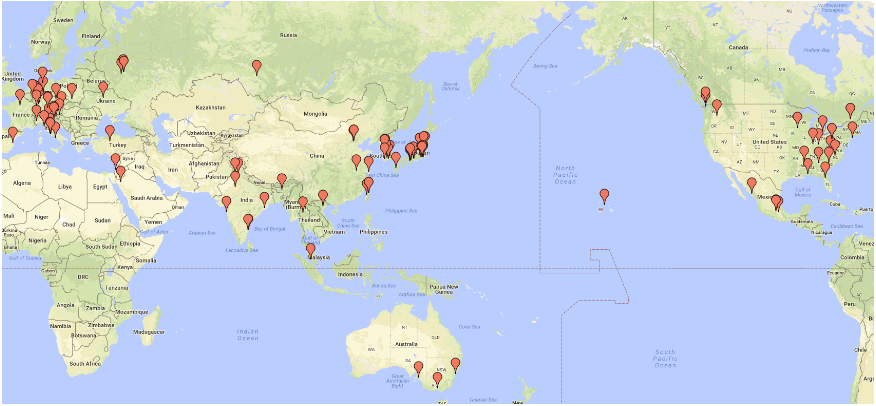




From Belle to Belle II

- Accelerator: KEKB→SuperKEKB, $\mathcal{L} \times 40$!
- Detector: Belle→Belle II, a new detector with great improved performance.

Belle II Collaboration

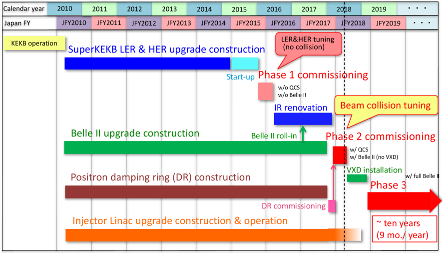


- 26 counties/regions
- 113 institutions
- $\sim$ 900 collaborators

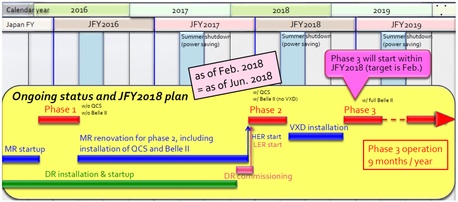
Part I. Status of SuperKEKB and Belle II

SuperKEKB/Belle II schedule

- Overall schedule



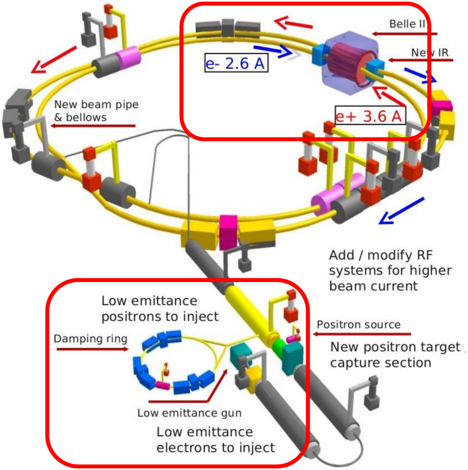
- Current schedule

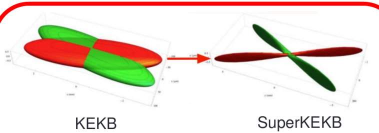


- First collisions on 4/26/2018, 8 years after KEKB and Belle being shut down.
- Phase 2 until July 17th, without inner vertex detector.
- On the way to Phase III: Physics Run will start on 11 March, 2019!

The SuperKEKB accelerator

A lot of new designs





"nano-beam" scheme

Beam squeezing: x20 smaller at IR

x2

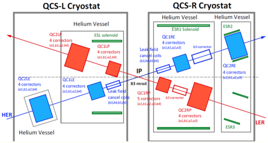
$$\text{Luminosity} = \frac{\gamma_\pm}{2er_e}\left(1+\frac{\sigma_y^*}{\sigma_x^*}\right)\frac{I_\pm \zeta_{\pm y}}{\beta_y^*}\frac{R_L}{R_y}$$

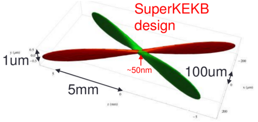
X1/20

Target luminosity: 8x10^{35}cm^{-2}s^{-1}
KEKB x 40!

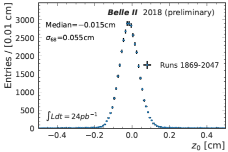
The final focus: Key of achieving the goal of $L = 0.8 \times 10^{36}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$

The superconducting final focus system



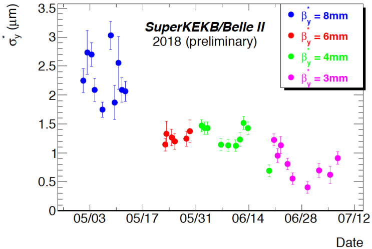


Large cross angle:
22 mrad (KEKB) → 83 mrad (SKB).



- Effective bunch length is reduced from $\sim$ 10 mm (KEKB) to 0.5 mm (SuperKEKB).
- Measured the bunch length in two track events.

- The record the vertical spot size is 400nm with $I \sim 15$ mA, goal is $\mathcal{O}(50\ \mathrm{nm})$ with full capability of the QCS system.
- Early Phase 3 will continue with $\beta^* = 3$ mm, goal is $\beta^* \sim 0.3$ mm.
- Struggling with beam-beam blow-up, a major issue for Phase3.

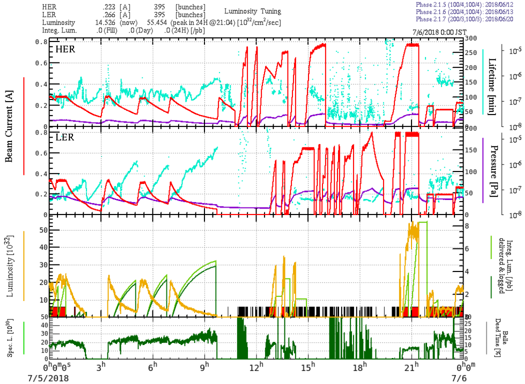


SuperKEKB achievements at Phase II

Keep on squeezing the two beams with the superconducting final focus $\beta_y^* = 3$ mm.

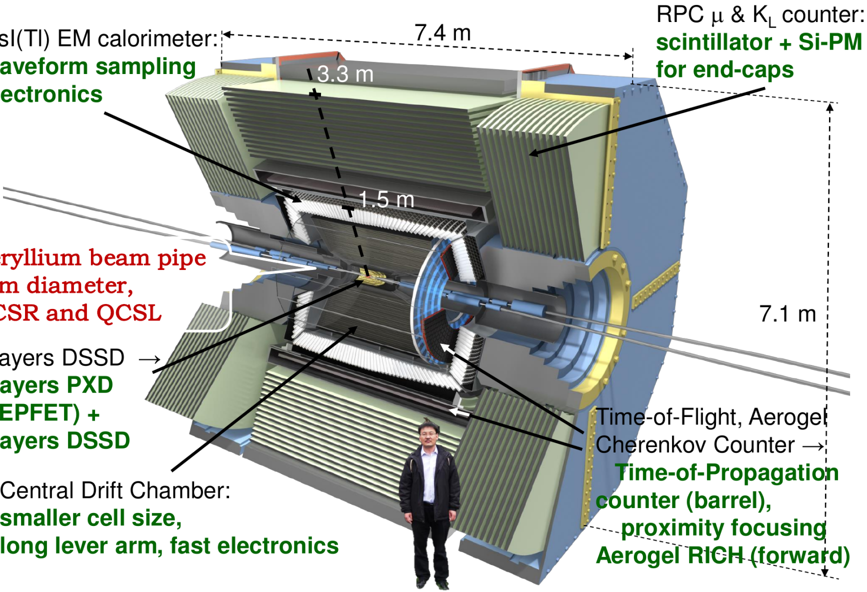
L_{peak} = 5.5 ´ $10^{33} / cm^2$ / sec

Phase 2,
July 2018



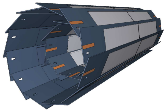
- A long way to go with the superconducting final focus (one order of magnitude in β_y^*)
- Luminosity tuning had priority. When accelerator physicists became tired, Belle II took data (usually owl shift). Only able to record $0.5\ \text{fb}^{-1}$.
- $L_{max} = 2.1 \times 10^{34}\ \text{cm}^{-2}\text{s}^{-1}$ was recorded by KEKB.

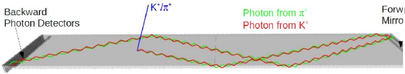
Cut view of Belle II detector

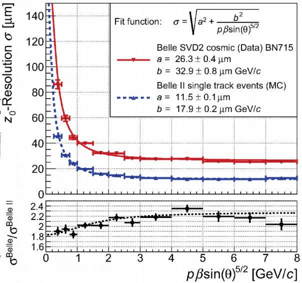


Detector highlights

PXD and iTOP

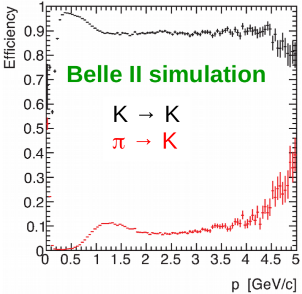






Vertex detectors:

- spatial resolution has a factor $\sim$ 2 than Belle;
- despite lower Lorentz boost, $O(30\%)$ improvement in separating the B decay vertices!
- $\sim 30\%$ larger acceptance for K_s reconstruction

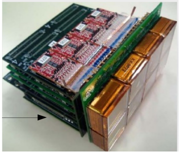
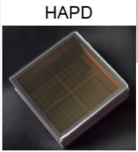


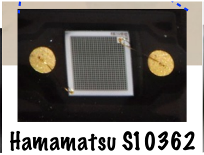
Particle Identification (PID):

- $K - \pi$ separation is fundamental to distinguish among important final states and bkgs;
- crucial ingredient for B flavor tagger;
- expected performance: $K(\pi)$ efficiency $> 90\%$, with $\pi(K)$ fake rate $< 10\%$ for $p < 4$ GeV$/c$.

Advanced & Innovative Technologies used in Belle II

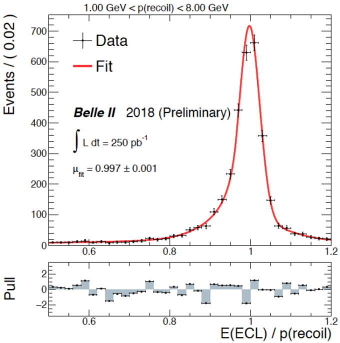
- Pixelated photo-sensors play a central role. Collaboration with Industry
  1. MCP-PMTs in the iTOP
  2. HAPDs in the ARICH
  3. SiPMs in the KLM
  4. DEPFET pixel sensors!
- Waveform sampling with precise timing. Front-end custom ASICs (Application Specific Integrated Circuits) for all subsystems.
  1. KLM: TARGETX ASIC
  2. ECL: New waveform sampling backend with good timing
  3. TOP: IRSX ASIC
  4. ARICH: KEK custom ASIC
  5. CDC: KEK custom ASIC
  6. SVD: APV2.5 readout chip adapted from CMS
- DAQ with high performance network switches, large HLT software trigger farm
- a 21^{th} century HEP experiment.

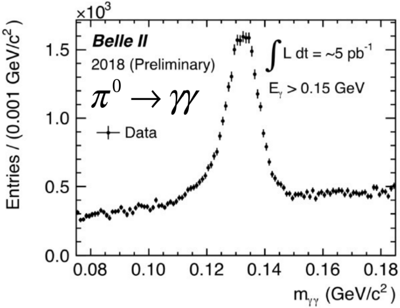





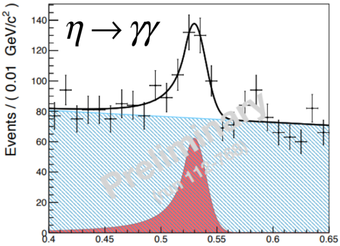
Signals involving photons (ECL)

$$e^+e^- \to \mu^+\mu^-\gamma$$





Single Photon Lines



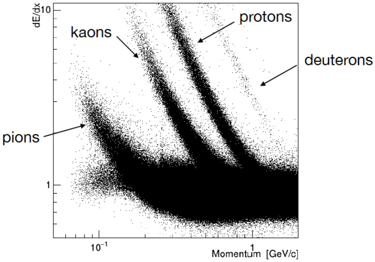
Ready for the dark sector !

$$e^+e^- \to \gamma X$$

$$e^+e^- \to \gamma ALPS \to \gamma(\gamma\gamma)$$

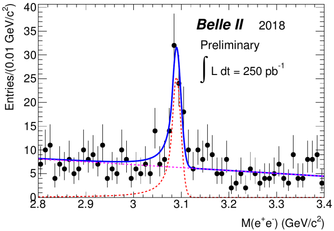
Signals involving charged tracks

$\frac{dE}{dx}$ from CDC for PID

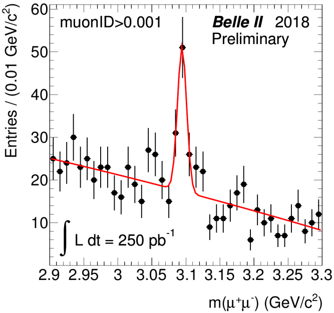


Extra cuts:
- |d0| < 1
- |dz| < 3
- # layers hit > 20

$J/\psi \to e^+e^-$

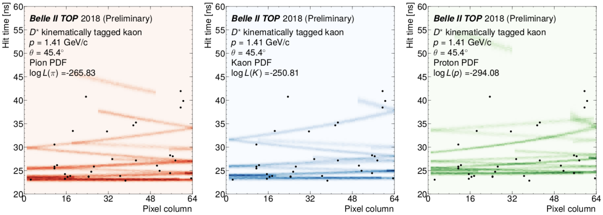


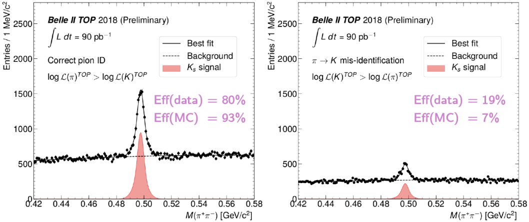
$J/\psi \to \mu^+\mu^-$



TOP for Particle Identification: $K^{\pm}$, p and $\pi^{\pm}$

- The charged correlation with the slow pion determines which track is the kaon (or pion)
- Kinematically identified kaon from a D^{*+} in the TOP.
- Cherenkov x vs. t pattern (mapping of the Cherenkov ring):



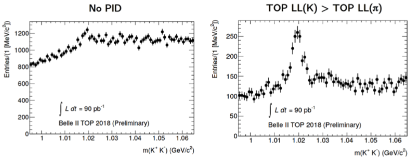


$$K_S^0 \to \pi^+\pi^-$$

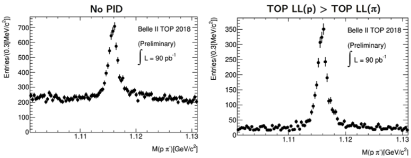
More examples about iTOP

- K-ID and p-ID

$\phi \to K^+K^-$ with both the tracks in the TOP acceptance



$\Lambda \to p\pi$ with the **proton candidate** in the TOP acceptance



- Rediscovery of $D_s \to \phi\pi^+$ with $\phi \to K^+K^-$

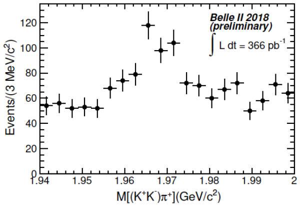


FIG. 1: This figure shows M[$(K^+K^-)\pi^+$] distribution, which was produced using phase-II 366 pb^{-1} hadron skim data. No PID criteria are applied to any of the charged tracks ($K^\pm\pi^+$). Selection criteria and further details are described in the internal note BELLE2-NOTE-PH-2018-026.

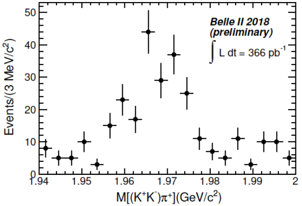
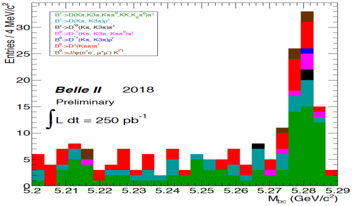


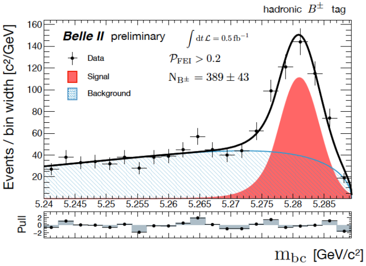
FIG. 2: This figure shows M[$(K^+K^-)\pi^+$] distribution, which was produced using phase-II 366 pb^{-1} hadron skim data. Combined PID criteria, Prob(K:π) >0.5 for $K^\pm$ tracks and Prob(π:K) >0.5 for π^+ tracks are applied. Selection criteria and further details are described in the internal note BELLE2-NOTE-PH-2018-026.

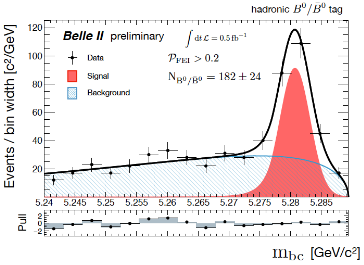
B mesons from Belle II

- Rediscovery of B mesons in June, shown at ICHEP2018.



- Use the full Phase 2 dataset and apply the FEI (Full Event Interpretation) technique based on boosted decision trees (BDTs, a machine learning technique).





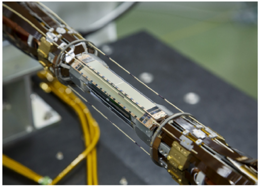
Onwards to Phase 3 and the Physics Run

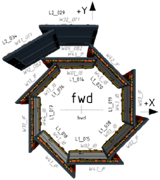
Inner detector: VXD = PXD+SVD

- PXD installation at KEK around Oct. 2018

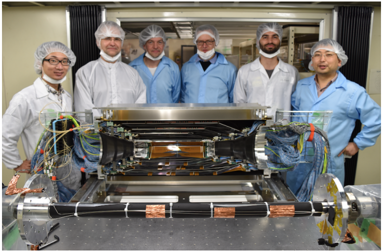
PXD Readiness for Phase 3

PXD geometry for Phase 3

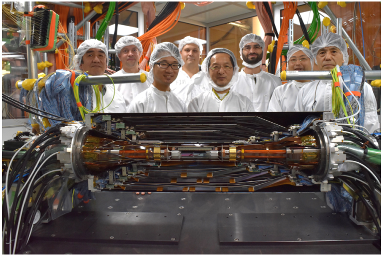




- SVD installation, finished in July, 2018



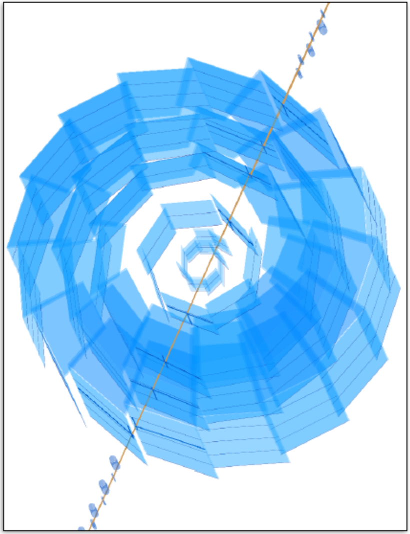
- Successful marriage of the PXD and SVD.



VXD & Endcap Installation and RVC Closure

VXD installation on Nov 21

FWD Endcap push-in on Jan 25



Very good consistency with previous alignment data but bowing of L2 ladders slightly increased after installation

Part II. Prospects of Belle II

- CMK-related Physics
- Search for New Physics
  - $B \to \tau \nu_\tau$
  - $B \to D^{(*)} l \nu$
  - $b \to s$ transitions
- LFV in τ decays
- XYZ particles
- ...

Luminosity Profile Updated

Last updated: Jan/29 2019

Assumption:

(1) $8\text{x}10^{35}$ will be achieved during 4 years (4 x 8 months = 32 months). -> $\Delta L_{peak} = 2.5\text{x}10^{34}$ per month

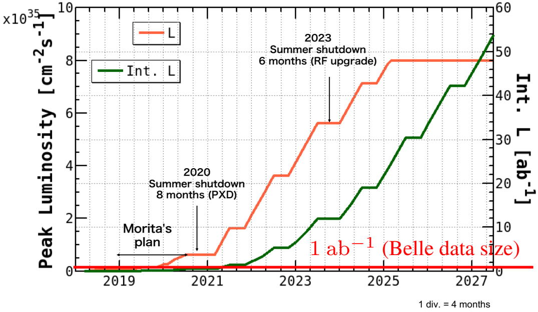
(2) Luminosity upgrade plan obeys Morita's plan until 2020 Summer.

(3) Learning curve is a straight line from 2021 (resolution is one month).

(4) Efficiency of integrated luminosity is 70 % (includes recorded/delivered, maintenance days, etc.).

(5) 8 months operation per year except for FY2019.

(6) 8 months shutdown in 2020 for PXD and 6 months in 2023 for RF upgrade(from 70 % to 100 %).



Belle II Physics Book

Belle II Theory Interface Platform (B2TIP)
Workshop series, 2015-2018:

WG1
Semileptonic & Leptonic B decays

WG2
Radiative & Electroweak Penguins

WG3
α/φ_2 β/φ_1

WG4
γ/φ_3

WG5
Charmless Hadronic B Decay

WG6
Charm

WG7
Quarkonium(-like)

WG8
Tau, low multiplicity

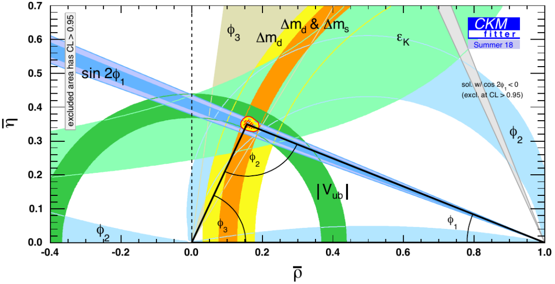
WG9
New Physics

The Belle II Physics Book
Emi Kou and Phill Urquijo, editors

689 pages
arXiv: 1808.10567
submitted to PTEP

… a fruitful collaboration among theorists and experimentalists

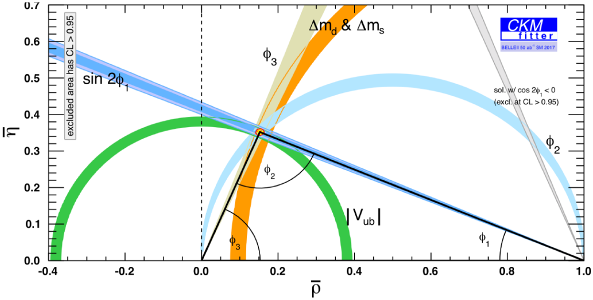
Precise measurements of CKM unitarity triangle



Now

$\phi_1 \leftrightarrow \beta$
$\phi_2 \leftrightarrow \alpha$
$\phi_3 \leftrightarrow \gamma$

with 50 ab^{-1}

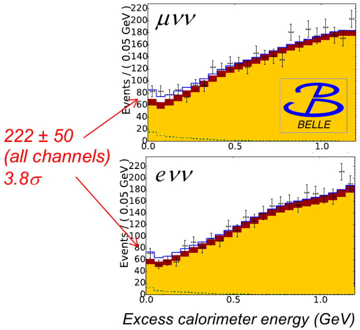


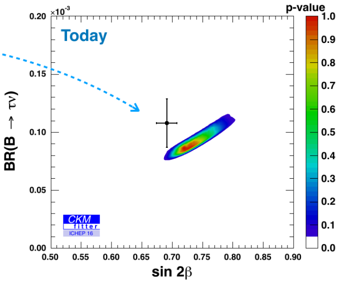
Measuring $|V_{ub}|$ via $B^+ \to \tau^+ \nu_\tau$

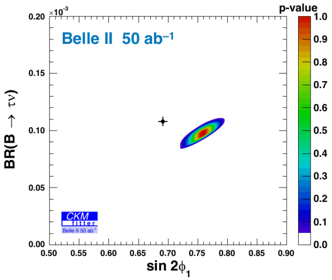
A missing-energy mode

- There is some **tension** at the CKM triangle apex from this measurement vs $\sin 2\phi_1$
- Leveraging fully-reconstructed tag-B, there should be **zero excess energy** in the calorimeter

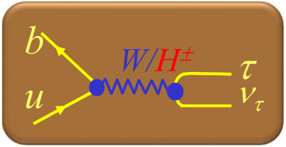
PRD **92**, 051102 (2015)



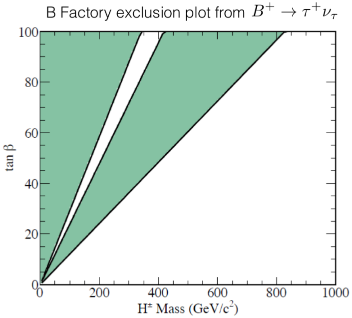


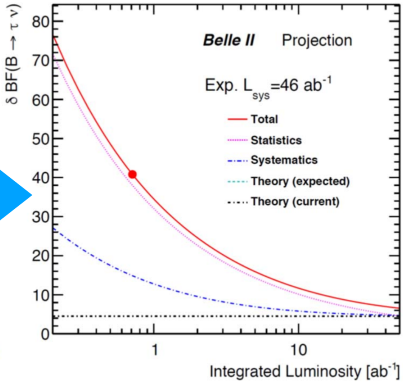


Search for New-Physics (e.g., charged Higgs) in $B^+ \to \tau^+ \nu_\tau$



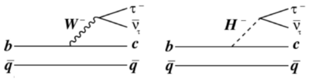
$$r = \frac{\mathcal{B}_{\text{meas}}(B \to \tau\nu)}{\mathcal{B}_{\text{SM}}(B \to \tau\nu)} = \left(1 - \frac{m_B^2}{m_H^2}\tan^2\beta\right)$$



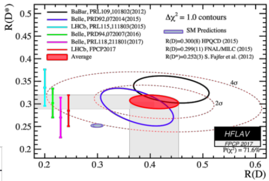


$B \to D^{(*)} l\nu$: challenge to lepton universality

- Theoretically clean channel in SM
- Charged Higgs can contribute to the decay
- $R(D^{(*)})$ is sensitive parameter to BSM!

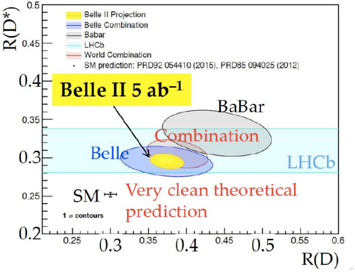


$$R(D^{(*)}) = \frac{\mathrm{Br}(B \to D^{(*)}\tau\nu)}{\mathrm{Br}(B \to D^{(*)}\mu\nu)}$$



	Exp	SM
$R(D^*)$	0.304±0.013±0.007	0.252±0.003
$R(D)$	0.407±0.039±0.024	0.300±0.008

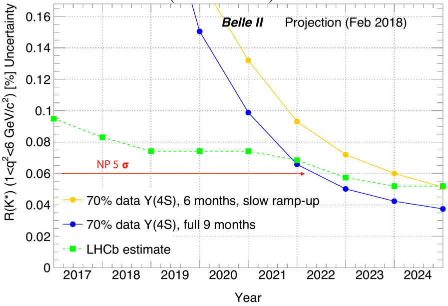
4.1σ away from the SM



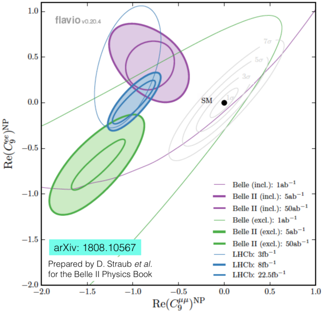
Belle II should be able to confirm the excess with ~5ab^{-1} data

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

$$\mathcal{R}(K^{(*)}) = \frac{\mathcal{B}\left(B \to K^{(*)}\mu\mu\right)}{\mathcal{B}\left(B \to K^{(*)}ee\right)}$$



Note: LHCb value is extrapolated from run-1 result



Lepton-universality test

$\ell \in \{e,\ \mu\}$

Belle II has strong capabilities for electrons and muons.

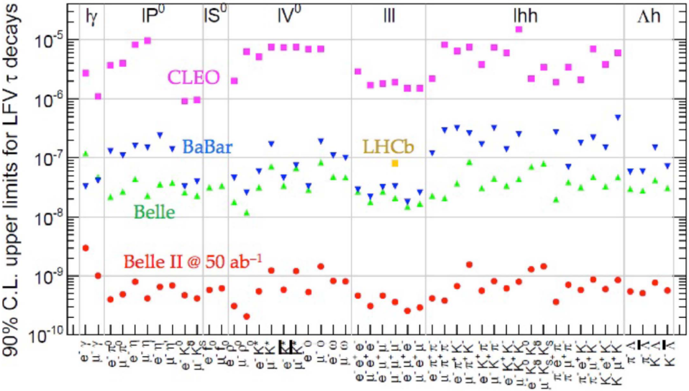
inclusive modes

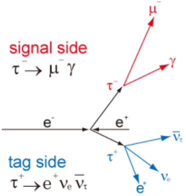
exclusive modes

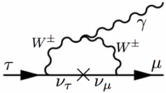
Belle II: good electron identification

- $K^* e^+ e^-$: $\sim$ 200 events/ab^{-1}
- $K^* \mu^+ \mu^-$: $\sim$ 280 events/ab^{-1}

Belle II will improve sensitivity for many LFV τ decays







- Two orders lower, down to 10^{-9} or 10^{-10} level
- Improve the sensitivity for search for LFV, which may be related to some experiments like neutrinoless double-beta decays.

Processes for XYZ

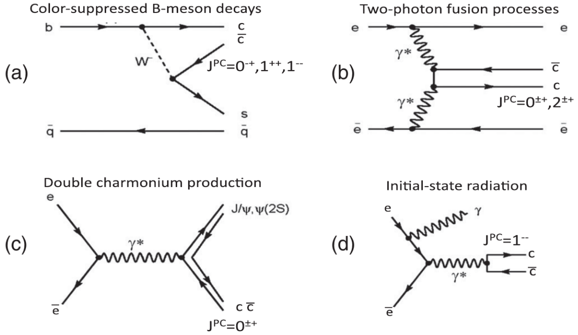
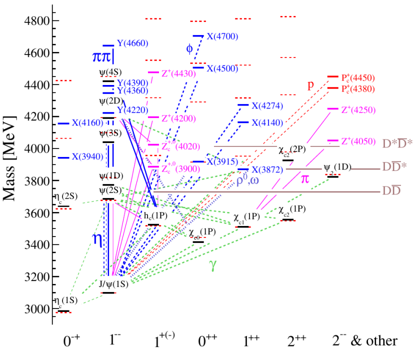
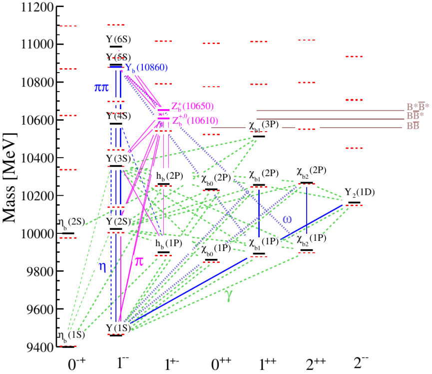


FIG. 12. Processes that produce $c\bar{c}$ pairs in e^+e^- collisions near $E_{\text{c.m.}} = 10.6$ GeV: (a) $B \to K(c\bar{c})$ decays, (b) two-photon fusion processes, (c) e^+e^- annihilation into $c\bar{c}c\bar{c}$, and (d) initial state radiation.

- $\Upsilon(1, 2, 3S)$ decays, continuum productions and energy scan can be used to study XYZ too.
- Uniquely measurable at Belle II: Two-photon fusion, Double-charmonium production, and Initial-state radiation

Current heavy quarkonium(-like) spectroscopies





Summary

- Belle II has finished the detector construction.
- Belle II had the first collisions on April 26, 2018, and the Phase 2 was until July 17th.
- The Phase 2 got very impressive results from both the SuperKEKB accelerator and the Belle II detector.
- $L_{peak} = 0.55 \times 10^{34}$ cm^{-2}s^{-1} was achieved in Phase II.
- The nano-beam scheme is working well and the Belle II detector has very good performance!
- Belle II is going to start physics running in 2019, coming back the game.
- 0.8×10^{36} cm^{-2}s^{-1} will make Belle II a luminosity revolution experiment, and open new windows for various physics topics.
  - Search for New-Physics in $B \to \tau\nu_\tau$, $B \to D^{(*)}l\nu$, $b \to s$ transitions and LFV, etc.
  - Figure out the nature of exotic states, charmonium-like and bottomonium-like states.

Thank you!

Back-up

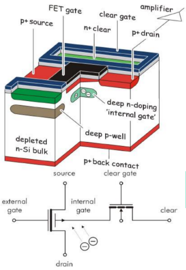
Nano-beam parameters of SuperKEKB

		LER (e+)	HER (e-)	units
Beam Energy	E	4	7	GeV
Half Crossing Angle	ϕ	41.5		mrad
Horizontal Emittance	ε_x	3.2(2.7)	2.4(2.3)	nm
Emittance ratio	$\varepsilon_y/\varepsilon_x$	0.40	0.35	%
Beta Function at the IP	β_x^*/β_y^*	32 / 0.27	25 / 0.41	mm
Horizontal Beam Size	σ_x^*	10.2(10.1)	7.75(7.58)	μm
Vertical Beam Size	σ_y^*	59	59	nm
Betatron tune	ν_x/ν_y	45.530/45.570	58.529/52.570	
Momentum Compaction	α_c	2.74×10^{-4}	1.88×10^{-4}	
Energy Spread	σ_ε	$8.14(7.96) \times 10^{-4}$	$6.49(6.34) \times 10^{-4}$	
Beam Current	I	3.60	2.62	A
Number of Bunches/ring	n_b	2503		
Energy Loss/turn	U_0	2.15	2.50	MeV
Total Cavity Voltage	V_c	8.4	6.7	MV
Synchrotron Tune	ν_s	-0.0213	-0.0117	
Bunch Length	σ_z	6.0(4.9)	5.0(4.9)	mm
Beam-Beam Parameter	ξ_y	0.0900	0.0875	
Luminosity	L	8×10^{35}		$\mathrm{cm}^{-2}\mathrm{s}^{-1}$

	KEKB Achieved	SuperKEKB
Energy (GeV) (LER/HER)	3.5/8.0	4.0/7.0
ξ_y	0.129/0.090	0.090/0.088
β_y^* (mm)	5.9/5.9	0.27/0.41
I (A)	1.64/1.19	3.60/2.62
Luminosity ($10^{34}\mathrm{cm}^{-2}\mathrm{s}^{-1}$)	2.11	80

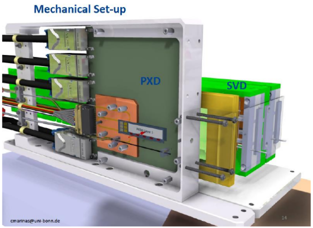
Pixel Vertex Detector(PXD)

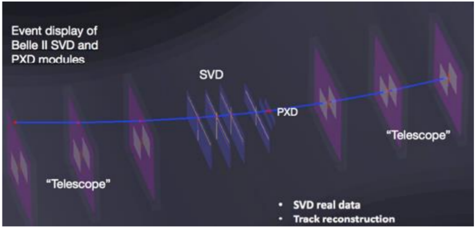
DEpleted P-channel FET



DEPFET pixel sensor

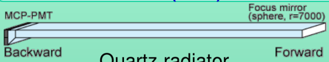
- PXD:
  - Excellent spatial granularity ($\sigma \sim 15\mu m$), low material (0.16% X_0 for layer_1)
  - **But**, significant amount of background hits, huge data rate.
- SVD:
  - Precise time ($2 \sim 3$ ns RMS)
  - **But**, has ambiguities in space due to 1D strip.
- Combining both yields a very powerful device!





Particle Identification in Belle II

Barrel PID: Time of Propagation Counter (iTOP)



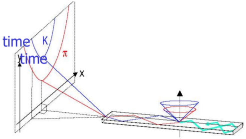
Quartz radiator

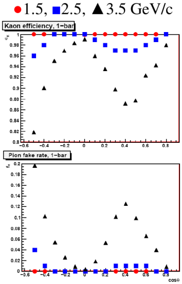
Focusing mirror

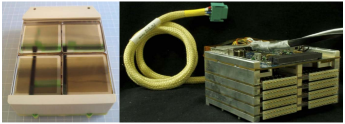
Small expansion block

Hamamatsu MCP-PMT (measure t, x and y)

- Cherenkov ring imaging with precise time measurement.
- Device uses internal reflection of Cherenkov ring images from quartz like DIRC of BaBar
- Cherenkov angle reconstruction from two hit coordinates and time of propagation of photons







16 Quartz radiators

2.6m^L x 45cm^W x 2cm^T

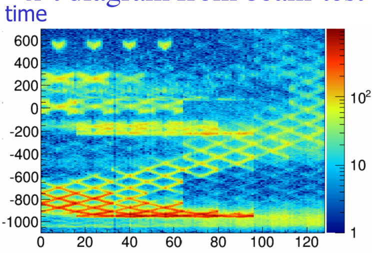
Excellent surface accuracy

MCP-PMT

Hamamatsu 16ch MCP-PMTGood TTS (<35ps) & enough lifetime

Multialkali photo-cathode → SBA

x-t diagram from beam-test



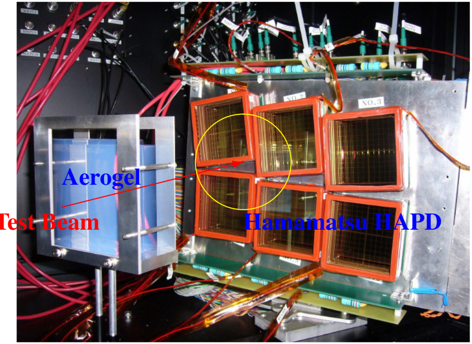
coordinate

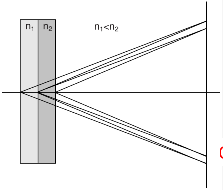
Table 7.1: Baseline quartz bar specifications.

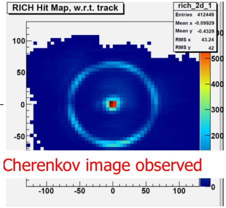
Size	$(440 \pm 0.15) \times (1200 \pm 0.5) \times (20 \pm 0.10)$ mm^3
Material	Synthetic fused silica (e.g., Corning 7980, Shin-etsu Suprasil)
Index tolerance	± 0.001
Flatness	10λ over full aperture
Roughness (r.m.s.)	5 Å
Angle between planes	$(90 \pm 1/60)$ degree
Chamfer size	< 0.20 mm

Aerogel RICH

Endcap PID

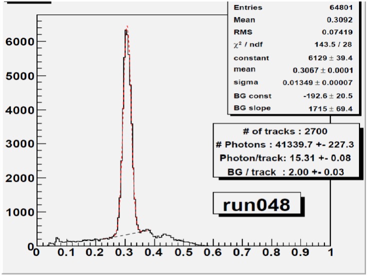






- RICH with a novel "focusing" radiator
- Two layer radiator
  - Employ multiple layers with different n $\rightarrow$
  - Cherenkov images from individual layers overlap on the photon detector

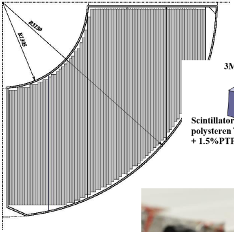
Cherenkov angle distribution

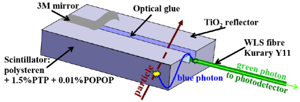


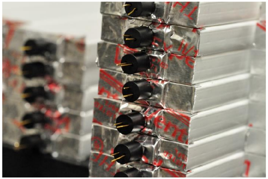
6.6 σ π/K at 4 GeV/c !

K_L & Muon detector (KLM)

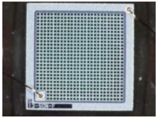
RPC → Scintillator (Endcap)
also inner 2 layers of Barrel(TBD)





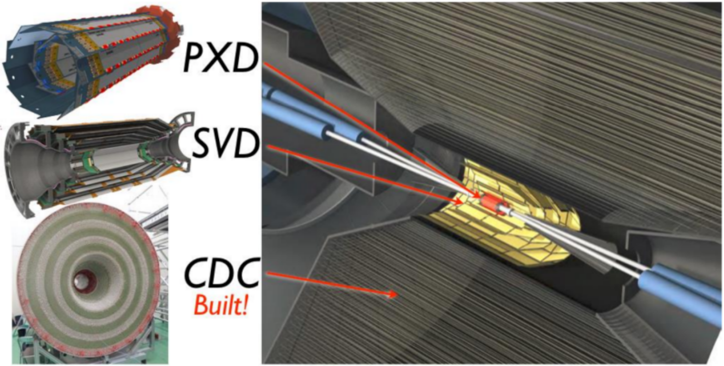


- WLS fiber in each strip
- Hamamatsu MPPC at one fiber end
- Mirrored far fiber end
- Endcap:
  - One layer: 75 strips (4cm)/sector
  - 5 segments ($\times$15 strips)
  - Two orthogonal layer = superlayer
  - Total area $\sim$ 1400m^2
- Barrel:
  - Two superlayers
  - Each layer has two modules: forward and backward
  - Each module has 80 $\sim$ 100 strips
  - 32 modules totally.



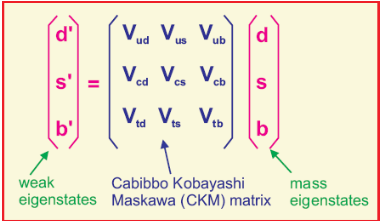
MPPC: Hamamatsu 1.3 × 1.3 mm 667 pixels (used in T2K Near Detector)

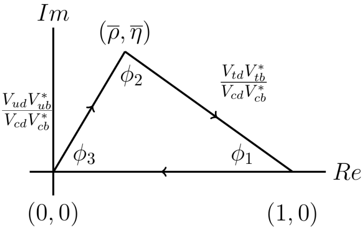
The tracking system



Component	Type	Configuration	Readout	Performance
Beam pipe	Beryllium double-wall	Cylindrical, inner radius 10 mm, 10 μm Au, 0.6 mm Be, 1 mm coolant (paraffin), 0.4 mm Be		impact parameter resolution $\sigma_{z_0} \sim 20\ \mu$m (PXD and SVD)
PXD	Silicon pixel (DEPFET)	Sensor size: 15×100 (120) mm^2 pixel size: 50×50 (75) μm^2 2 layers: 8 (12) sensors	10 M	
SVD	Double sided Silicon strip	Sensors: rectangular and trapezoidal Strip pitch: 50(p)/160(n) - 75(p)/240(n) μm 4 layers: 16/30/56/85 sensors	245 k	
CDC	Small cell drift chamber	56 layers, 32 axial, 24 stereo r = 16 - 112 cm - 83 $\leq z \leq$ 159 cm	14 k	$\sigma_{r\phi} = 100\ \mu$m, $\sigma_z = 2$ mm $\sigma_{p_t}/p_t = \sqrt{(0.2\% p_t)^2 + (0.3\%/\beta)^2}$ $\sigma_{p_t}/p_t = \sqrt{(0.1\% p_t)^2 + (0.3\%/\beta)^2}$ (with SVD)

CKM and Unitarity Triangle from B Decays





- Flavor physics described by the CKM unitary matrix V_{ckm}
- Standard parametrisation in complex plane
  - Sides→Amplitudes→Branching fractions
  - Angle→Phase→CPV
- All angles can be accessed at B-factories→ precise determination of unitary triangle

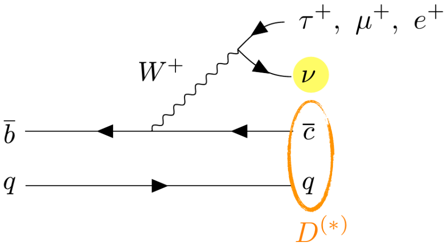
- $\phi_1 = \beta$: $b \to c\bar{c}s,\ q\bar{q}s$
  - $B^0 \to J/\psi K_s^0$
  - $B^0 \to \phi K_s^0$
  - $B^0 \to \eta' K_s^0$
- $\phi_2 = \alpha$: $b \to u\bar{u}d$
  - $B^0 \to \pi\pi$
  - $B^0 \to \rho\rho$
  - $B^0 \to \rho\pi$
- $\phi_3 = \gamma$: $b \to c\bar{u}s$
  - $B^\pm \to DK^\pm$

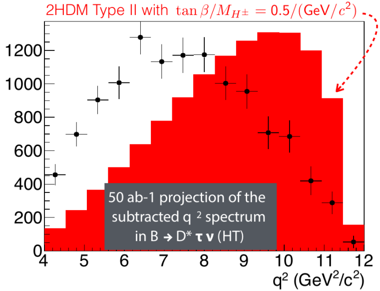
Is there NP in $B \to D^{(*)} l\nu$?

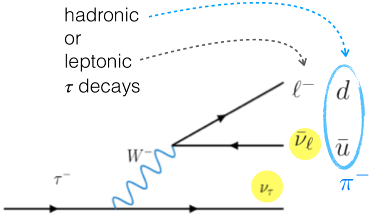
Missing-energy mode; multiple neutrinos in final state

Tagged analysis:

- full or partial reconstruction
- measure q^2 distribution, angular distribution, τ polarization, ...





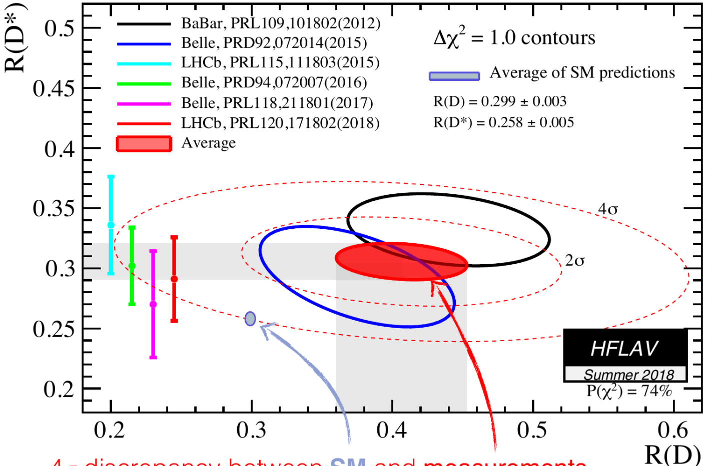


Standard Model:

- lepton universality
- hadronic uncertainties $\approx$ cancel (manageable)

Is there NP in $B \to D^{(*)} l\nu$?

$$\mathcal{R}(D^{(*)}) = \frac{\mathcal{B}\left(\bar{B} \to D^{(*)}\tau^-\bar{\nu}_\tau\right)}{\mathcal{B}\left(\bar{B} \to D^{(*)}\ell^-\bar{\nu}_\ell\right)}$$



4σ discrepancy between **SM** and **measurements**

Belle II prospects for New Physics (I)

Process	Observable	Theory	Sys. limit (Discovery) [ab^{-1}]	vs LHCb	vs Belle	Anomaly	NP
$B \to \pi \ell \nu_l$	$\|V_{ub}\|$	⋆⋆⋆	10-20	⋆⋆⋆	⋆⋆⋆	⋆⋆	⋆
$B \to X_u \ell \nu_\ell$	$\|V_{ub}\|$	⋆⋆	2-10	⋆⋆⋆	⋆⋆	⋆⋆⋆	⋆
$B \to \tau \nu$	$Br.$	⋆⋆⋆	>50 (2)	⋆⋆⋆	⋆⋆⋆	⋆	⋆⋆⋆
$B \to \mu \nu$	$Br.$	⋆⋆⋆	>50 (5)	⋆⋆⋆	⋆⋆⋆	⋆	⋆⋆⋆
$B \to D^{(*)} \ell \nu_\ell$	$\|V_{cb}\|$	⋆⋆⋆	1-10	⋆⋆⋆	⋆⋆	⋆⋆	⋆
$B \to X_c \ell \nu_\ell$	$\|V_{cb}\|$	⋆⋆⋆	1-5	⋆⋆⋆	⋆⋆	⋆⋆	⋆⋆
$B \to D^{(*)} \tau \nu_\tau$	$R(D^{(*)})$	⋆⋆⋆	5-10	⋆⋆	⋆⋆⋆	⋆⋆⋆	⋆⋆⋆
$B \to D^{(*)} \tau \nu_\tau$	P_τ	⋆⋆⋆	15-20	⋆⋆⋆	⋆⋆⋆	⋆⋆	⋆⋆⋆
$B \to D^{**} \ell \nu_\ell$	$Br.$	⋆	-	⋆⋆	⋆⋆⋆	⋆⋆	-

Process	Observable	Theory	Sys. limit (Discovery) [ab^{-1}]	vs LHCb	vs Belle	Anomaly	NP
$B \to K^{(*)} \nu \nu$	$Br., F_L$	⋆⋆⋆	>50	⋆⋆⋆	⋆⋆⋆	⋆	⋆⋆
$B \to X_{s+d} \gamma$	A_{CP}	⋆⋆⋆	>50	⋆⋆⋆	⋆⋆⋆	⋆	⋆⋆
$B \to X_d \gamma$	A_{CP}	⋆⋆	>50	⋆⋆⋆	⋆⋆⋆	-	⋆⋆
$B \to K_S^0 \pi^0 \gamma$	$S_{K_S^0 \pi^0 \gamma}$	⋆⋆	>50	⋆⋆	⋆⋆⋆	⋆	⋆⋆⋆
$B \to \rho \gamma$	$S_{\rho\gamma}$	⋆⋆	>50	⋆⋆⋆	⋆⋆⋆	-	⋆⋆⋆
$B \to X_s l^+ l^-$	$Br.$	⋆⋆⋆	>50	⋆⋆⋆	⋆⋆	⋆⋆	⋆⋆⋆
$B \to X_s l^+ l^-$	R_{X_s}	⋆⋆⋆	>50	⋆⋆⋆	⋆⋆⋆	⋆⋆	⋆⋆⋆
$B \to K^{(*)} e^+ e^-$	$R(K^{(*)})$	⋆⋆⋆	>50	⋆⋆	⋆⋆⋆	⋆⋆⋆	⋆⋆⋆
$B \to X_s \gamma$	$Br.$	⋆⋆	1-5	⋆⋆⋆	⋆	⋆	⋆⋆
$B_{d,(s)} \to \gamma\gamma$	$Br., A_{CP}$	⋆⋆	> 50(5)	⋆⋆	⋆⋆	-	⋆⋆
$B \to K^* e^+ e^-$	P_5'	⋆⋆	>50	⋆⋆⋆	⋆⋆	⋆⋆⋆	⋆⋆⋆
$B \to K \tau l$	$Br.$	⋆⋆⋆	>50	⋆⋆	⋆⋆⋆	⋆⋆	⋆⋆⋆

- $B \to \tau\nu + \tau$
- $B \to D^{(*)} l\nu$
- $b \to s$ transitions

Belle II New-Physics potential in $b \to s$ transitions

Observables	Experimental Sensitivity	Multi-Higgs Models (§17.2)	generic SUSY	MFV (§17.3)	Z' models (§17.6.1)	gauged flavour (§17.6.2)	3-3-1 (§17.6.3)	left-right (§17.6.4)	leptoquarks (§18.2.1)	compositeness (§17.7)	dark sector (§16.1)	Sum
$B \to K^{(*)}\ell\ell$ angular	⋆⋆	×	×	⋆⋆	⋆⋆	×	⋆⋆	×	⋆⋆⋆	⋆⋆	×	13
$R(K^*)$, $R(K)$	⋆⋆	×	×	×	⋆⋆	×	⋆⋆	×	⋆⋆⋆	⋆⋆	×	11
$\mathcal{B}(B \to X_s\ell\ell)$	⋆⋆⋆	×	×	⋆⋆⋆	⋆⋆	×	⋆⋆	×	⋆⋆⋆	⋆⋆	×	15
$R(X_s)$	⋆⋆⋆	×	×	×	⋆⋆	×	⋆⋆	×	⋆⋆⋆	⋆⋆	×	12
$\mathcal{B}(B \to K^{(*)}\tau\tau)$	⋆⋆⋆	⋆⋆⋆	×	⋆	⋆	×	⋆	×	⋆⋆⋆	⋆	×	13
$\mathcal{B}(B \to X_s\tau\tau)$	□	⋆⋆⋆	×	⋆	⋆	×	⋆	×	⋆⋆⋆	⋆	×	10
$\mathcal{B}(B \to K^{(*)}\nu\nu)$	⋆⋆⋆	×	×	⋆	⋆	×	⋆	×	⋆⋆⋆	⋆	×	10
$\mathcal{B}(B \to X_s\nu\nu)$	□	×	×	⋆	⋆	×	⋆	×	⋆⋆⋆	⋆	×	7

⋆⋆⋆ Belle II   × unlikely

⋆⋆ Belle II + LHCb   □ not studied

⋆ LHCb