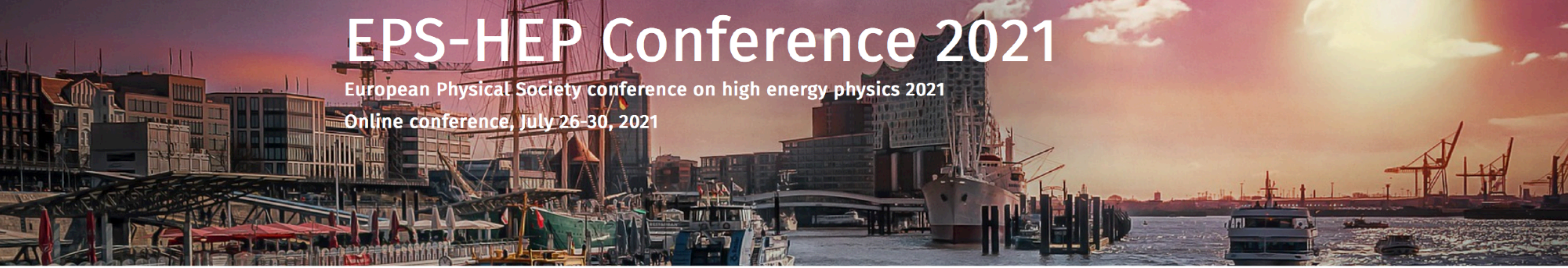
Dear Belle II colleagues,

As some of you already heard through media, Professor Toshihide Maskawa passed away on July 23, at the age of 81.
His great work on the CP violation problem motivated us to do the B-factory experiments, and then led us together here to go beyond the Standard Model by Belle II.
It is really sad news, but let's keep in mind his encouragement and push forward to the success of the project.
I would like to express the deepest condolences on behalf of the Belle II collaboration.

— Toru Iijima

Toshihide Maskawa 1940-2021



Highlights from the Belle II Experiment and Flavour Physics in e^+e^-

EPS-HEP Hamburg, July 30, 2021

Carsten Niebuhr, DESY

BELLE

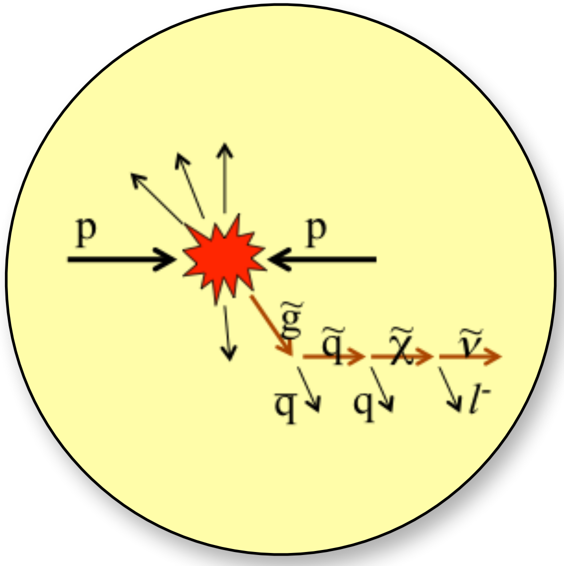
Belle II

DESY.

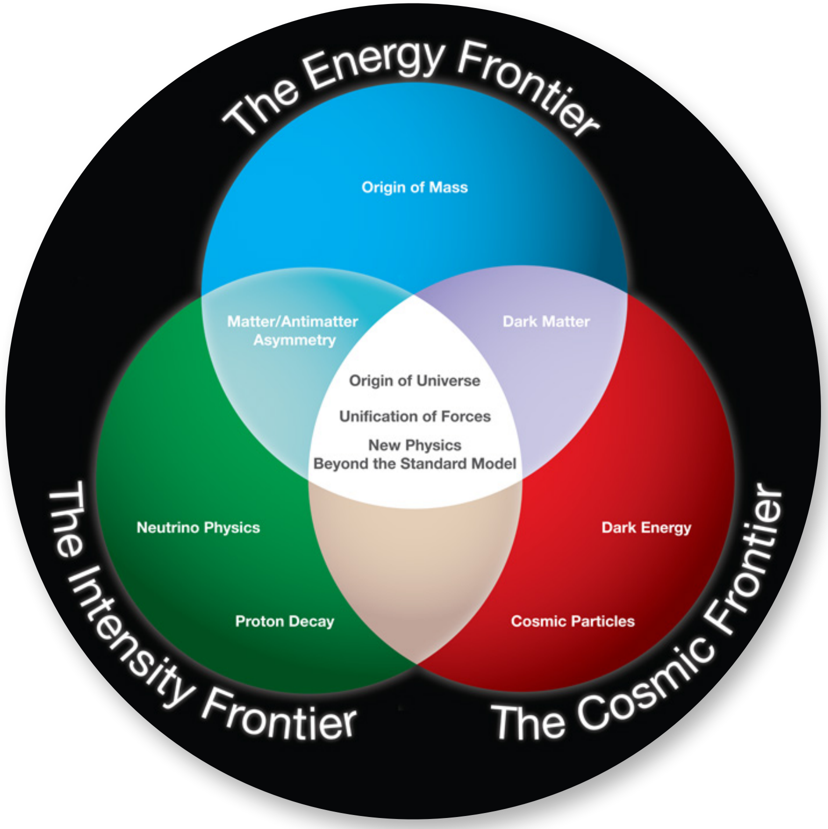
BESIII

Complementary Pathways to New Physics

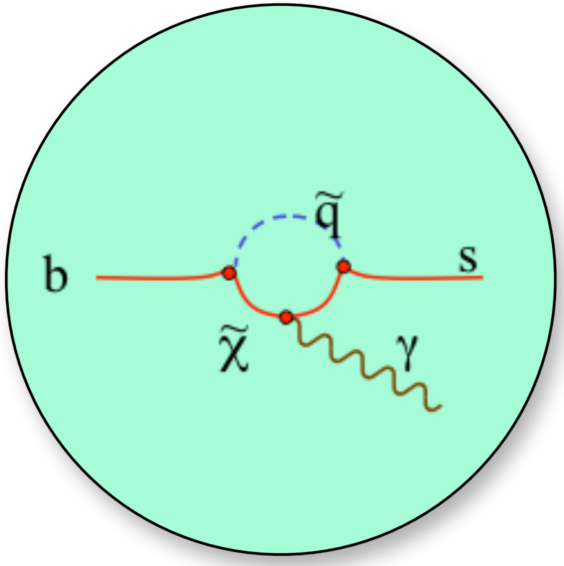
Energy frontier



Direct production of new particles



Intensity frontier

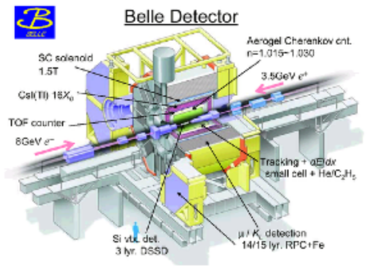


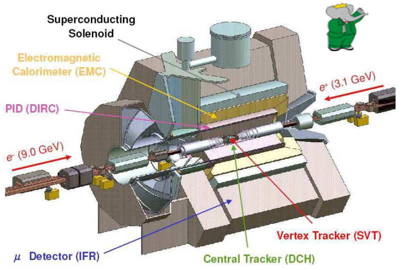
Indirect sensitivity through loops

- Presently no unambiguous evidence for Beyond Standard Model (BSM) physics at the high energy frontier
- Intensity frontier offers indirect sensitivity to very high scales: recent observation of **"Flavour Anomalies"**

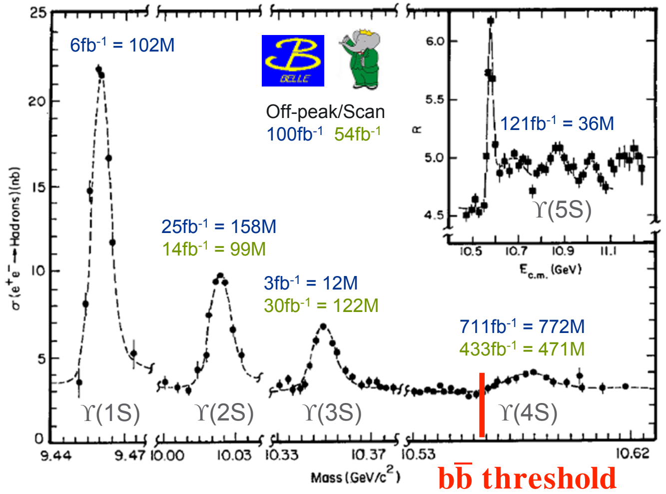
Pre-Belle II Experiments and Data Sets

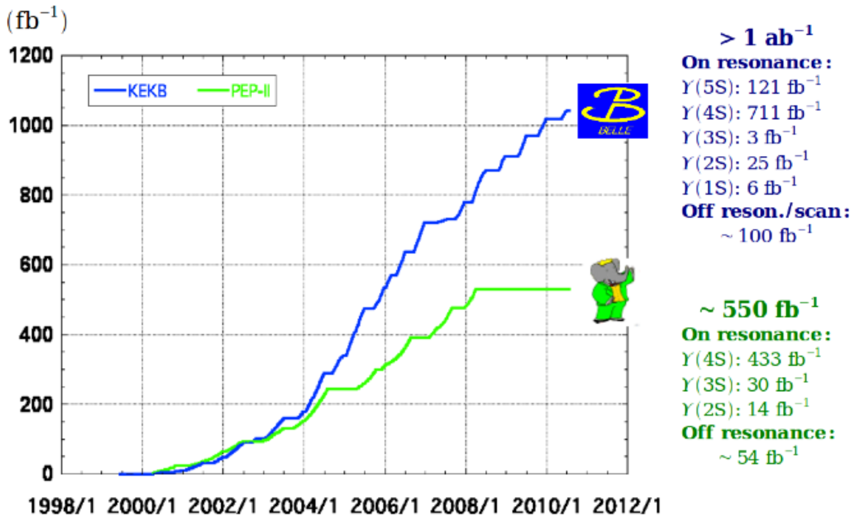
B factories





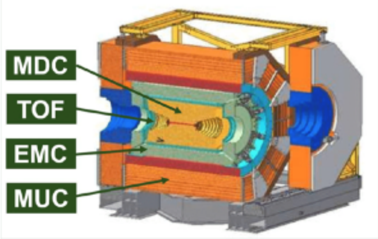
- Flavor physics: CKM/UT, CPV in B decays
- Hints for New Physics in rare processes
- New particle discoveries: "XYZ" states





τ-charm factory

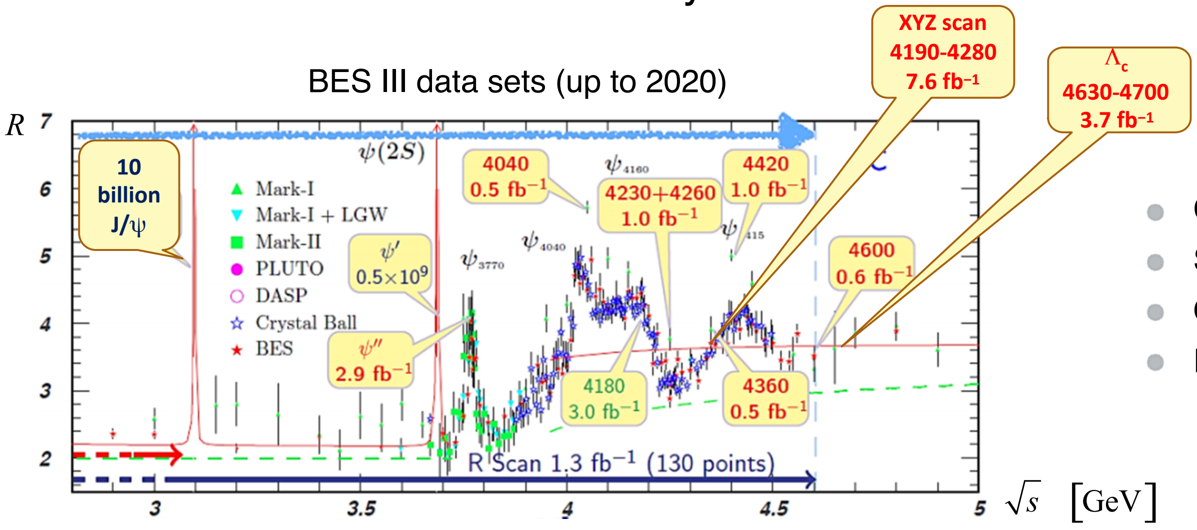
BESIII



BES III @ BEPC II, IHEP China: 2009 - ongoing

- Energy range $\sqrt{s}$ = 2.0 - 4.6 GeV (~5 GeV since 2019)
- Design luminosity achieved: 1x10[33] cm[-2]s[-1] (at ψ(3770))

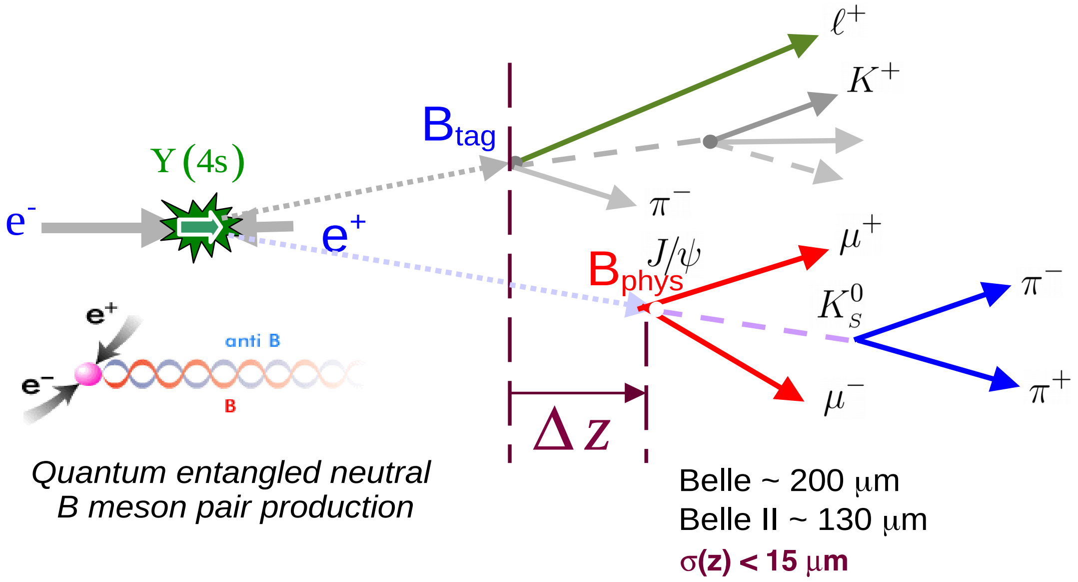
BES III data sets (up to 2020)



- Charmonium physics
- Spectroscopy of light-hadron states
- Open charm physics
- Probing QCD predictions and New Physics

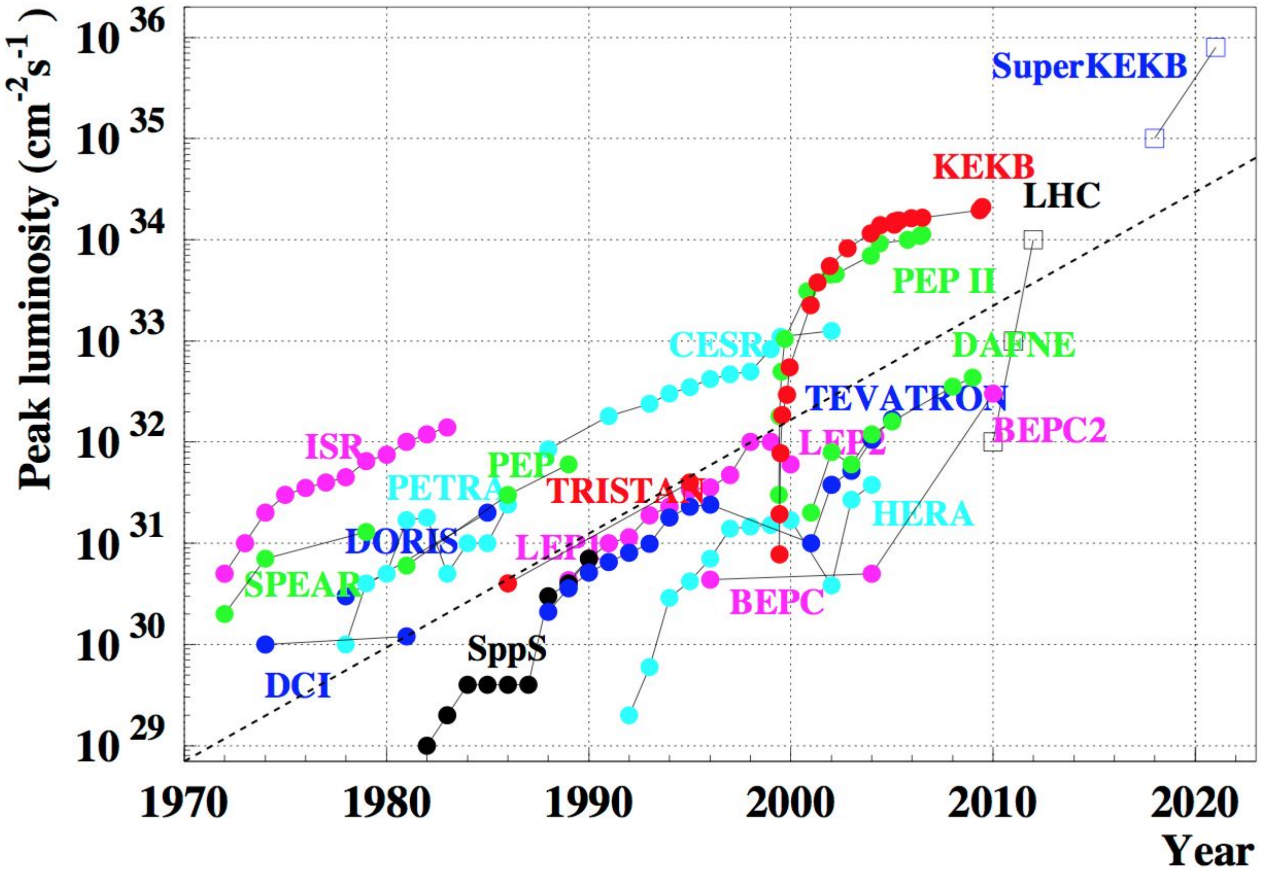
Advantages of Flavor Production in e^+e^- Collisions

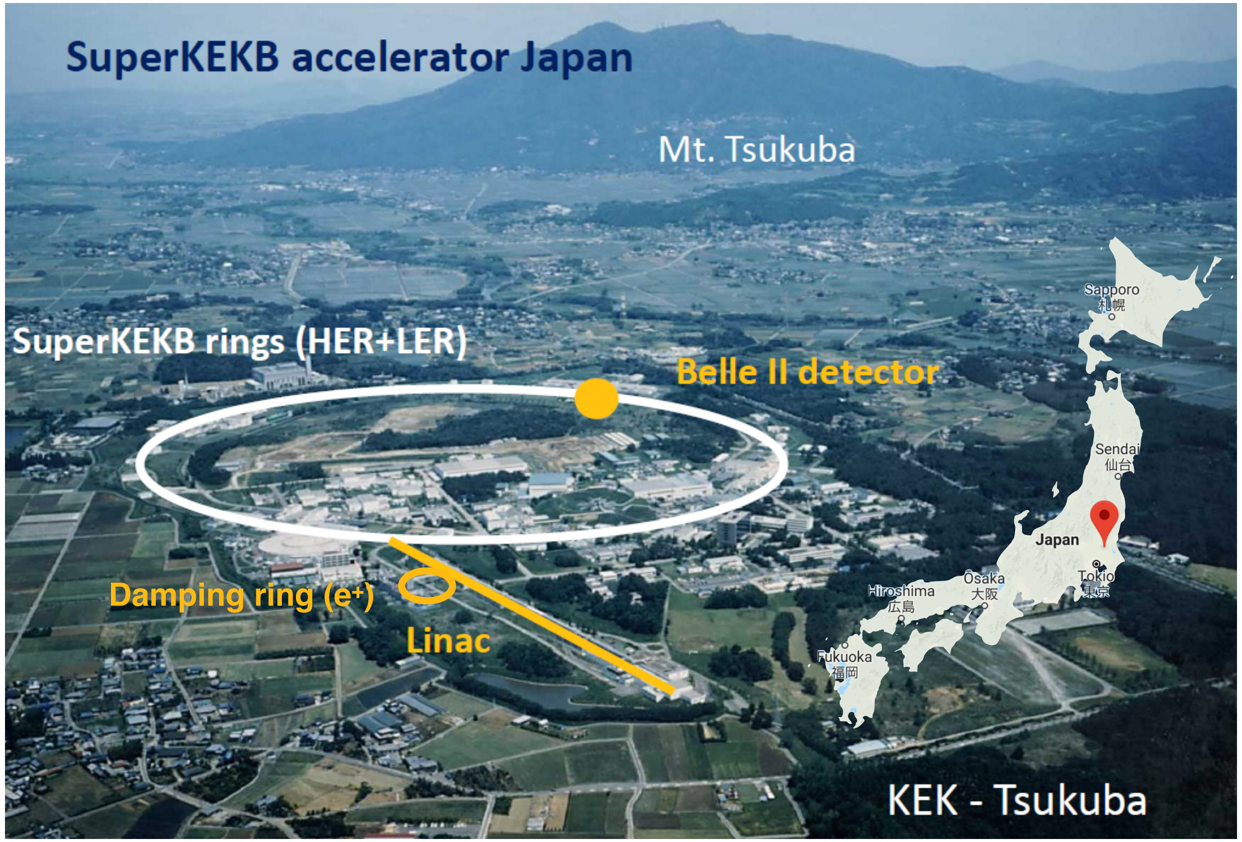
- High luminosity can be achieved more easily
- Coherent and well defined initial state without additional interactions
- Low (physics) backgrounds, high trigger efficiency, little bias
- Excellent neutral reconstruction (γ, π^0, η, K_S, K_L)
- Rather uniform efficiency in Dalitz plot
- Good kinematic and vertex resolution
- High flavor-tagging efficiency with low dilution
- Many channels are unique to e^+e^- flavor factories
- Absolute branching fractions can be measured
- Can study
  - rare and forbidden decays, invisible decays (incl. tau decays)
  - asymmetries (CP, isospin)
  - angular distributions
- Systematics quite different from hadron machines ⇒ in many areas complementary to LHCb



F.Muheim: Highlights from the LHCb Experiment

Ambitious Next Step at Luminosity Frontier: SuperKEKB



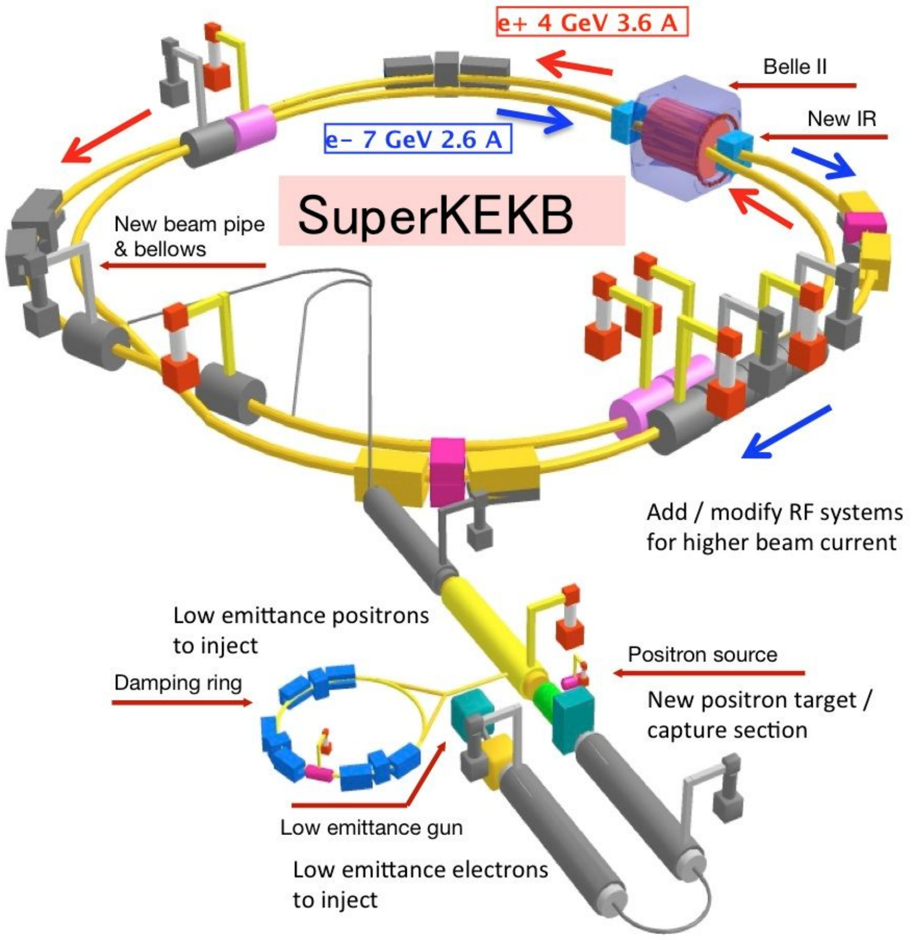


SuperKEKB and Nano-Beam Scheme

beam current **x1.5** — beam-beam param. **x1**

$$L = \frac{\gamma_\pm}{2 e r_e}\left(1+\frac{\sigma_y^*}{\sigma_x^*}\right)\frac{R_L}{R_\xi}\frac{I_\pm \xi_{y\pm}}{\beta_{y\pm}^*}$$

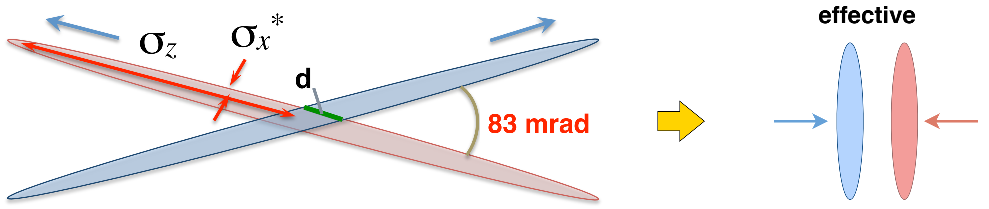
vertical beta function **x 1/20**



Y. Ohnishi: Status and perspectives of the SuperKEKB project

LER / HER	KEKB	SuperKEKB	Effect
Energy [GeV]	3.5 / 8	4.0 / 7.0	boost x 2/3
Crossing angle $2\phi_x$ [mrad]	22	**83**	
β_y^* [mm]	5.9 / 5.9	**0.27 / 0.30**	**L x 20**
$I_\pm$ [A]	1.64 / 1.19	**2.8 / 2.0**	**L x ~1.5**
$\varepsilon_y = \sigma_y \times \sigma_{y'}$ [pm]	140 / 140	**13 / 16**	
$\xi_y \sim (\beta_y^*/\varepsilon_y)^{1/2} / \sigma_x^*$	0.129 / 0.09	**0.09 / 0.09**	**L x 1**
Luminosity [10^{34} cm^{-2} s^{-1}]	2.1	**60**	**L x 30**

Nano-Beam scheme (P. Raimondi):
Squeeze beta function at the IP (β_x^*,β_y^*) and minimize longitudinal size of overlap region to avoid hourglass effect

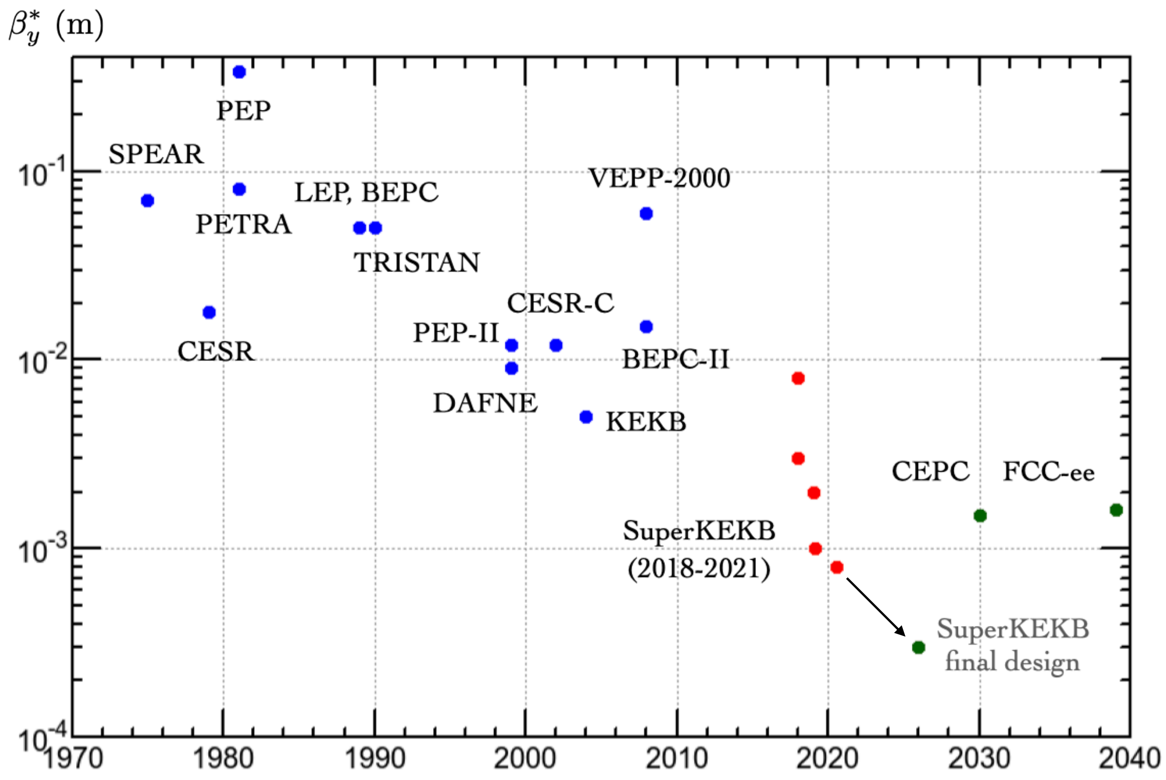


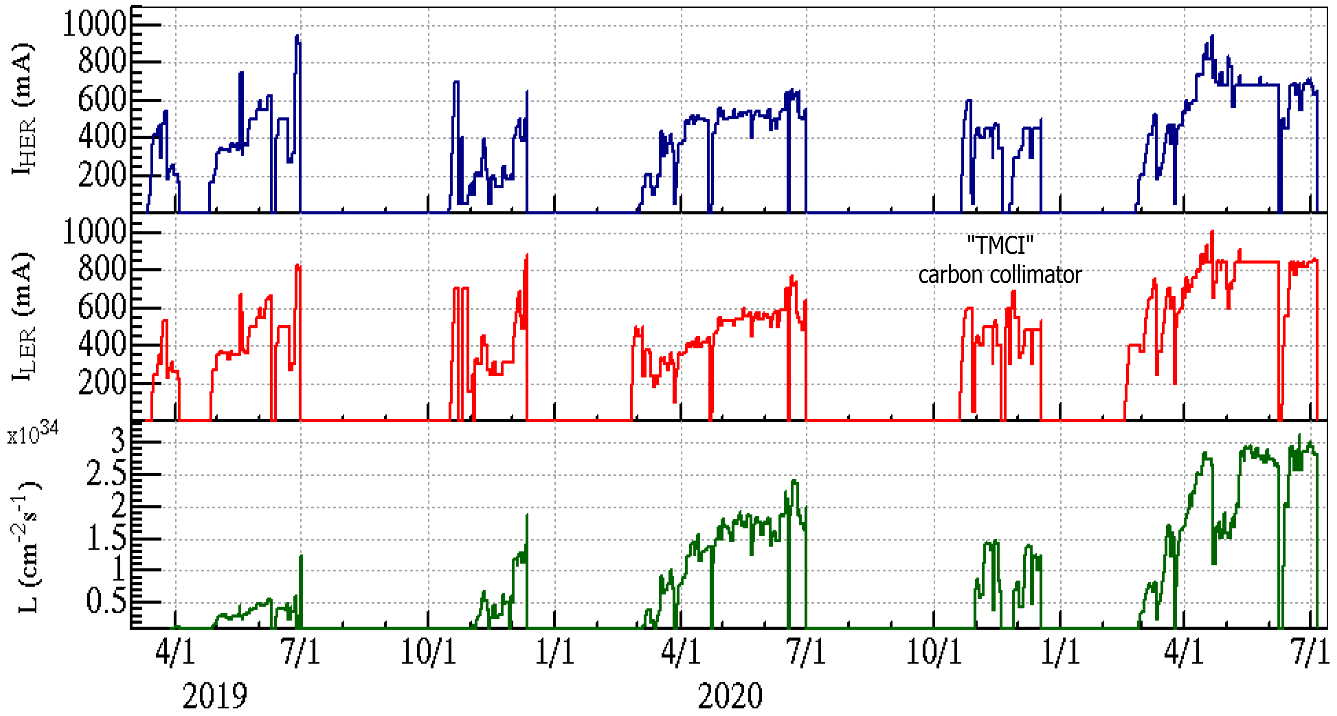
$$\sigma_z^{\text{eff}} = \frac{\sigma_x^*}{\phi_x} < \beta_y^*$$

Strong focusing of beams down to vertical size of ~ **50 nm** requires **very low emittance beams** and **large crossing angle (83 mrad)**
$\Rightarrow$ Need **powerful** and **sophisticated final focus** system (QCS)

SuperKEKB Achievements

Y. Ohnishi: Status and perspectives of the SuperKEKB project





- Ramping up machine performance proved more challenging than initially hoped for
  - vertical beam size blow-up due to beam-beam effect (→crab-waist scheme)
  - shorter than expected beam lifetime – limitations of injector power
  - lower than expected bunch-current limit due to Transverse Mode Coupling Instabilities (TMCI)
  - abnormal beam aborts, sometimes leading to damage of collimators
- Despite these difficulties: **world record** reached in instantaneous luminosity of **$3.12 \times 10^{34} cm^{-2}s^{-1}$** on June 22nd

Belle II Detector

Taken over from Belle

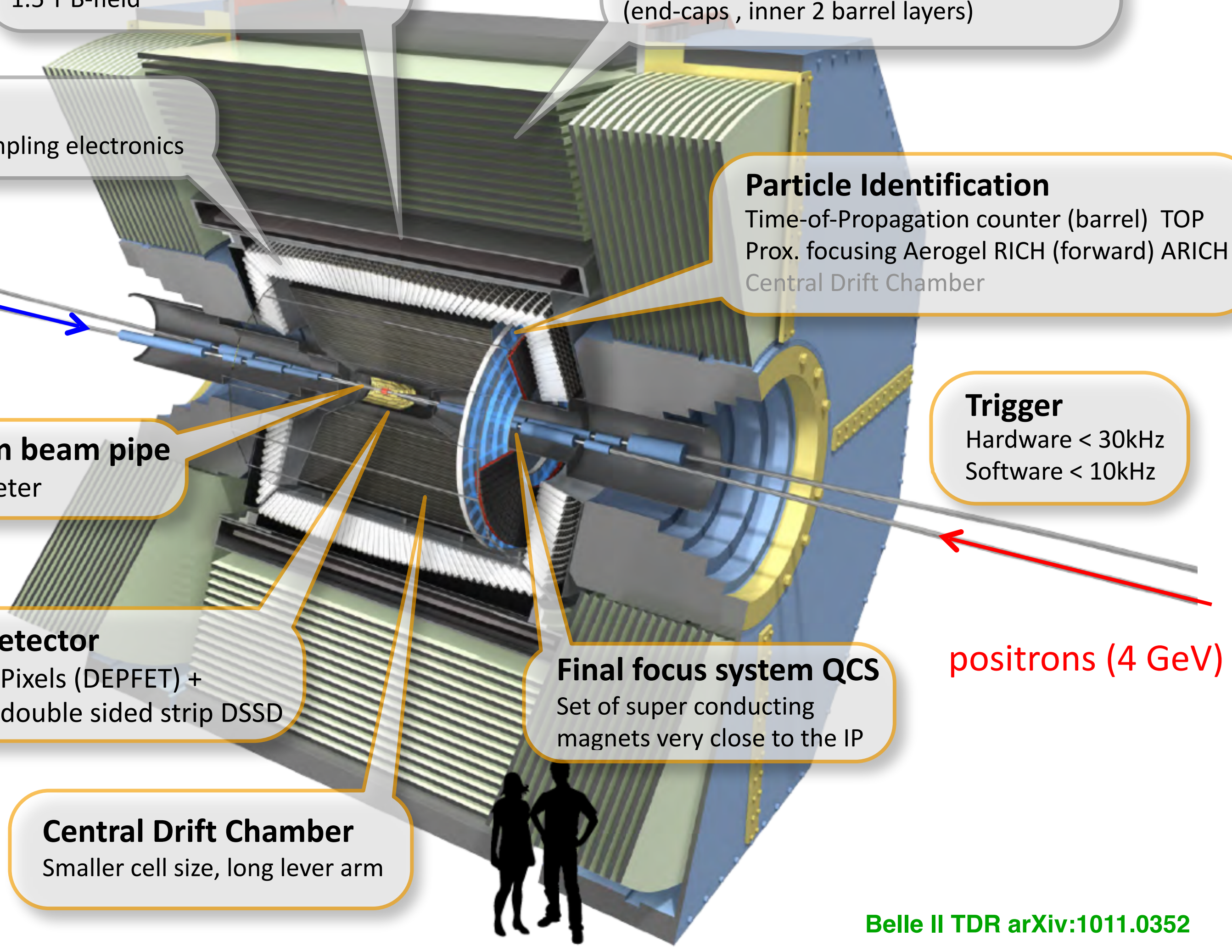
New for Belle II

Super conducting solenoid
1.5 T B-field

EM Calorimeter
CsI(Tl), waveform sampling electronics

KL and muon detector
Resistive Plate Counter (barrel outer layers)
Scintillator + WLSF + MPPC
(end-caps , inner 2 barrel layers)

Particle Identification
Time-of-Propagation counter (barrel) TOP
Prox. focusing Aerogel RICH (forward) ARICH
Central Drift Chamber



electrons (7 GeV)

positrons (4 GeV)

Beryllium beam pipe
2cm diameter

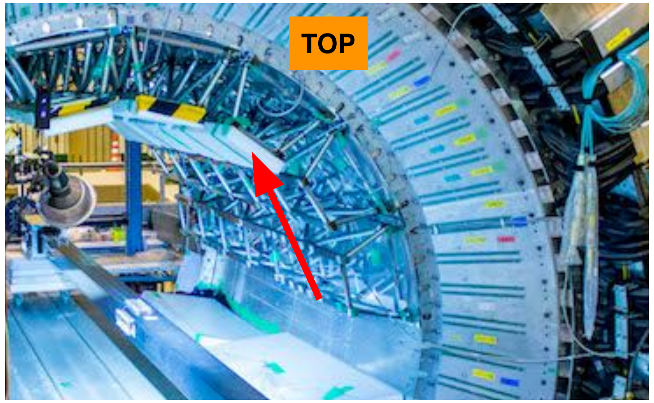
Trigger
Hardware < 30kHz
Software < 10kHz

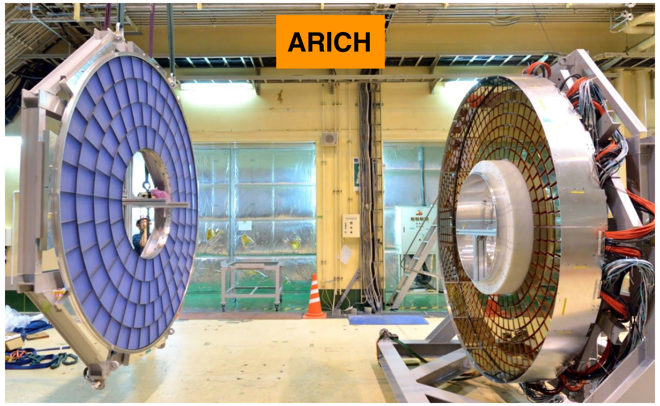
Vertex Detector
2 layers Si Pixels (DEPFET) +
4 layers Si double sided strip DSSD

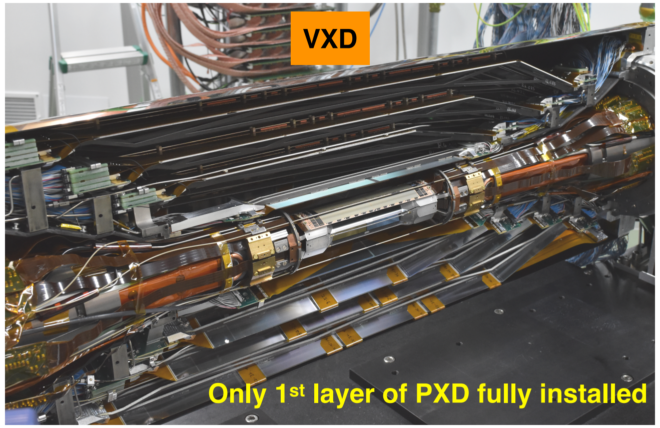
Final focus system QCS
Set of super conducting
magnets very close to the IP

Central Drift Chamber
Smaller cell size, long lever arm

Belle II TDR arXiv:1011.0352

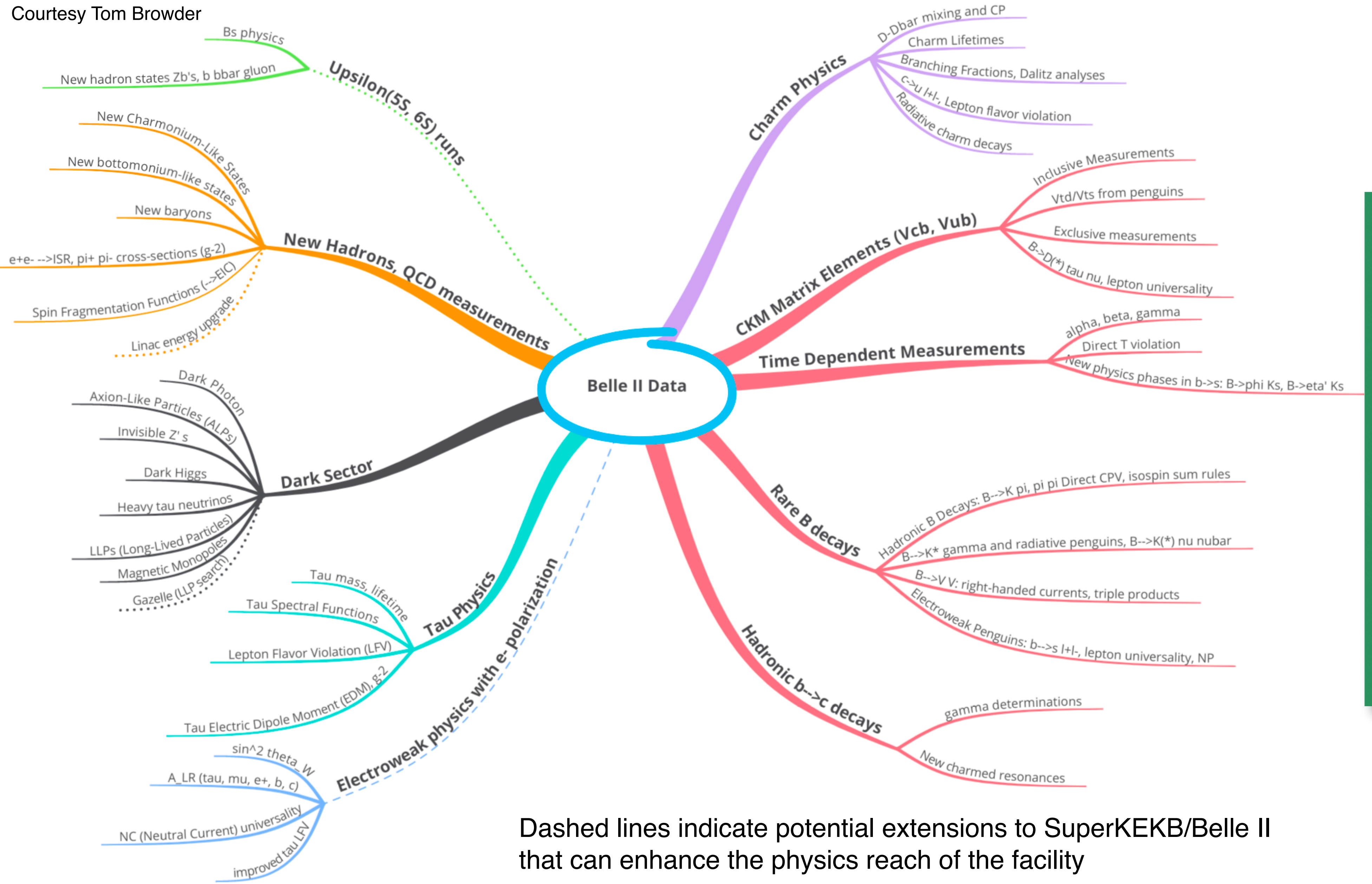


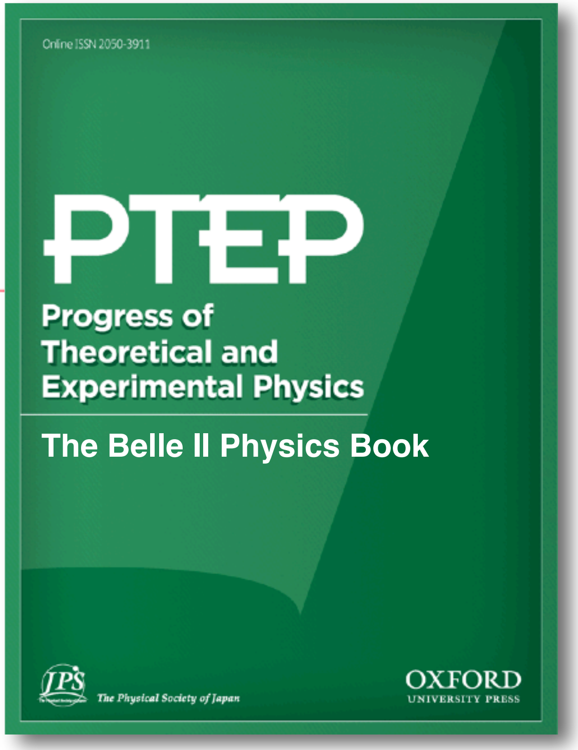




Very Diverse Belle II Physics Program

Courtesy Tom Browder

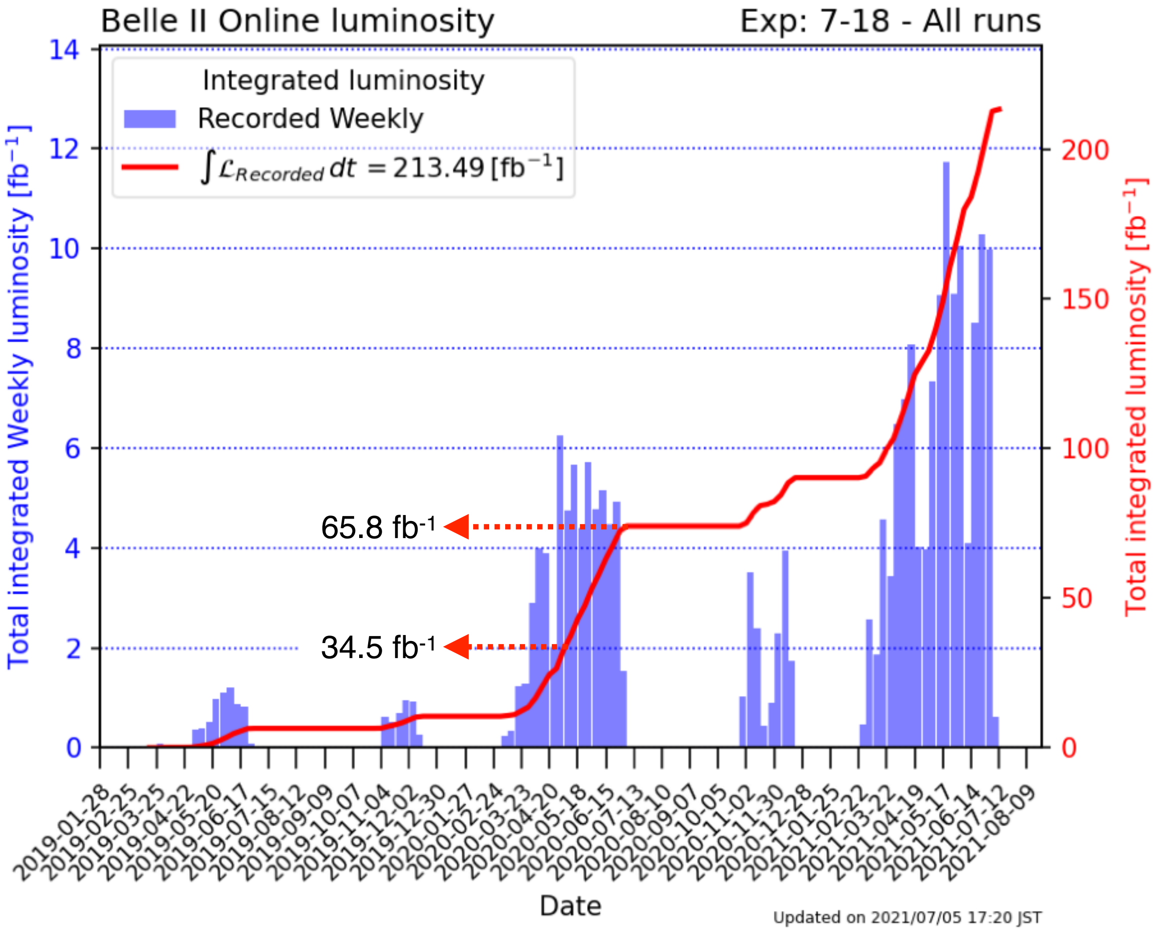


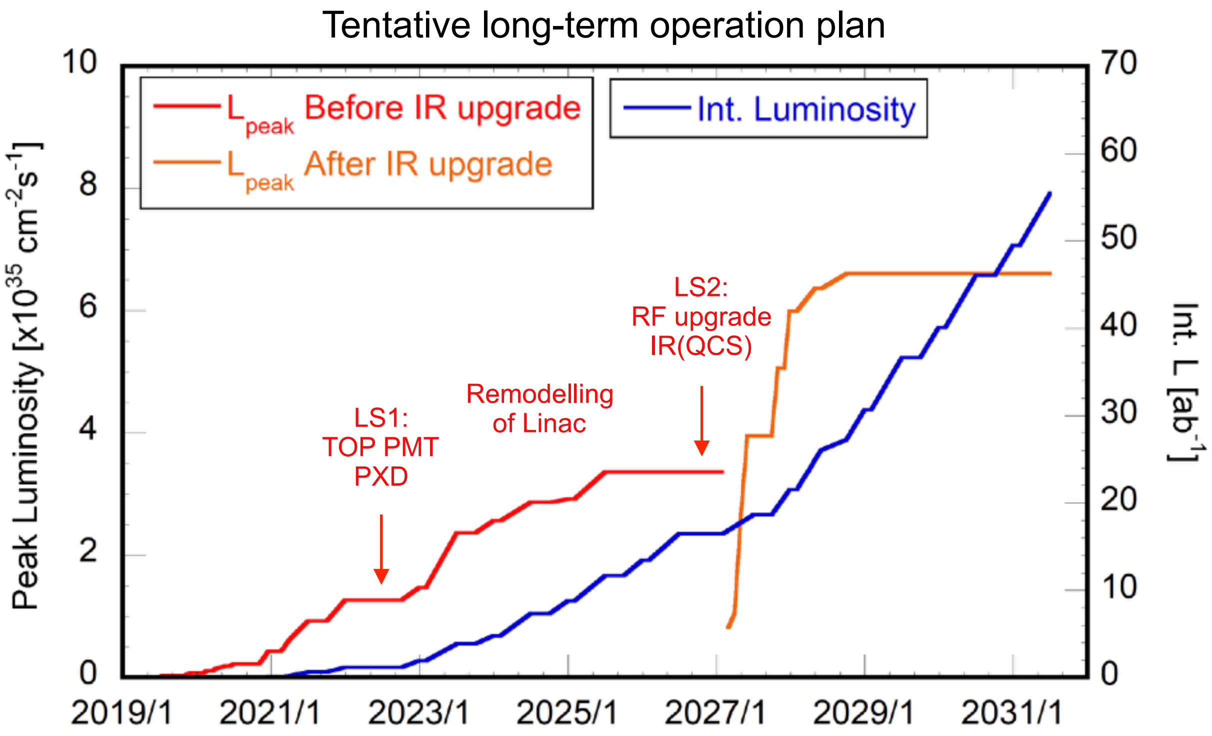


Prog. Theor. Exp. Phys. 2019, 123C01
arXiv:1808.10567

Dashed lines indicate potential extensions to SuperKEKB/Belle II that can enhance the physics reach of the facility

Status of Integrated Luminosity and Long-term Operation Plan

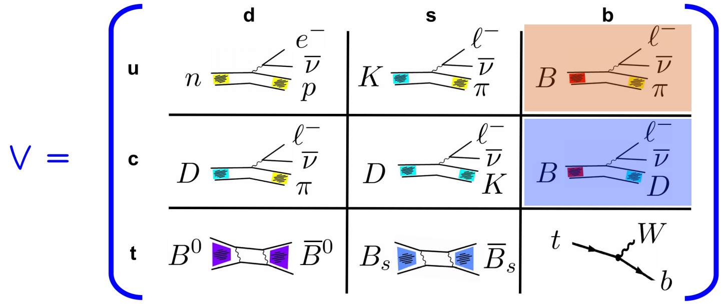




- Very successful data taking throughout the pandemic
  - overall data taking efficiency of **89.5%**
  - collected up to 12 fb^{-1} per week: Super-B factory mode
- Current working plan follows the KEK Roadmap2020
  - LS1 in 2022 for PXD & TOP-PMT replacement
  - options for a possible IR upgrade ≳2026 under study

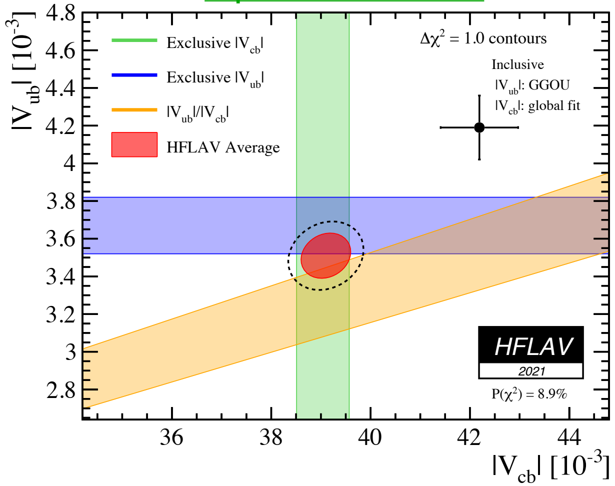
Towards Measurements of CKM Matrix Elements $|V_{ub}|$ and $|V_{cb}|$

- Long-standing discrepancy between inclusive and exclusive determinations of CKM matrix elements $|V_{ub}|$ and $|V_{cb}|$

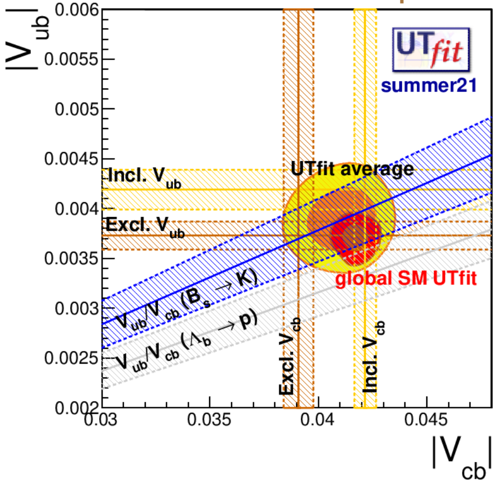


- Analysis of inclusive and exclusive semi-leptonic B decays using both tagged and untagged approach
  - $|V_{ub}|$: $B \to X_u \ell \nu$, $B \to \pi(\rho,\eta)\ell\nu$ $(\ell = e, \mu)$
  - $|V_{cb}|$: $B \to X_c \ell \nu$, $B \to D^{(*)}\ell\nu$ $(\ell = e, \mu)$

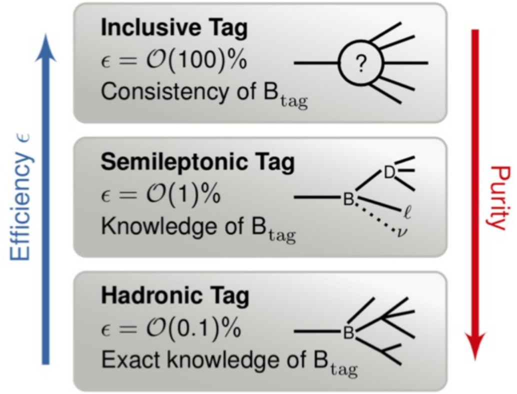
https://hflav.web.cern.ch

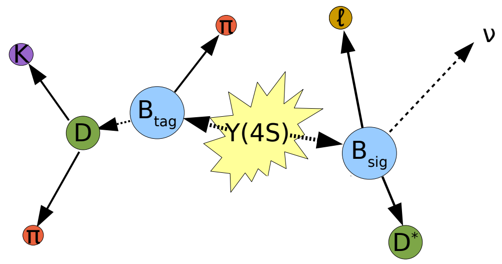


M.Bona: UTfit 2021 SM update



- Tagged approach exploits Belle II **F**ull **E**vent **I**nterpretation (FEI) algorithm Comput Softw Big Sci 3, 6 (2019)
  - hierarchical multivariate technique (>200 BDTs) to reconstruct the B-tag side (semi-leptonic or hadronic) through $\mathcal{O}(10^3)$ different decay modes
  - results in significantly increased tagging efficiency compared to Belle





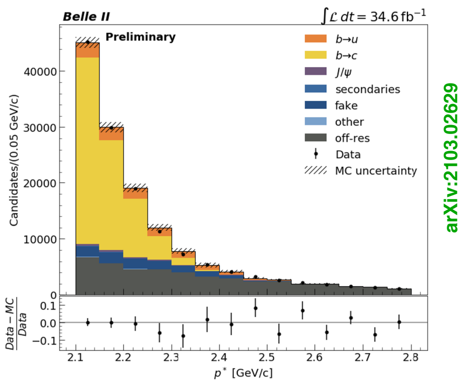
Inclusive and Exclusive $b \to (c,u)\ell\nu$ Branching Fractions

M.Merola: Towards first Vub and Vcb measurements at the Belle II experiment

- A large variety of different analysis strategies will help to resolve the remaining discrepancies

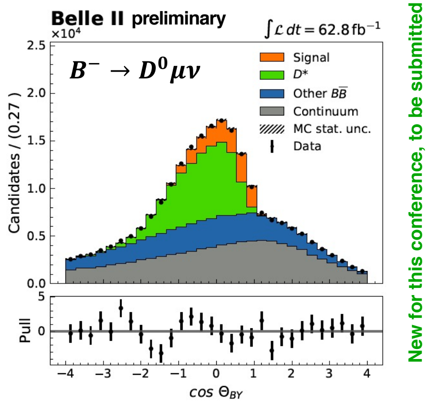
- Alternative approaches, such as the recently proposed use of inclusive q^2-moments, are expected to further enhance sensitivity to V_{cb}

Untagged inclusive $X_u \ell \nu$



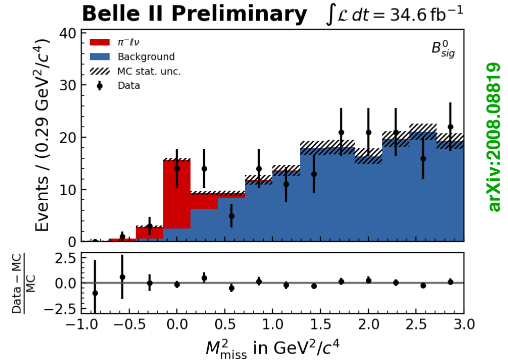
3σ significance for b-u

Untagged exclusive $B \to D^0 \ell \nu$



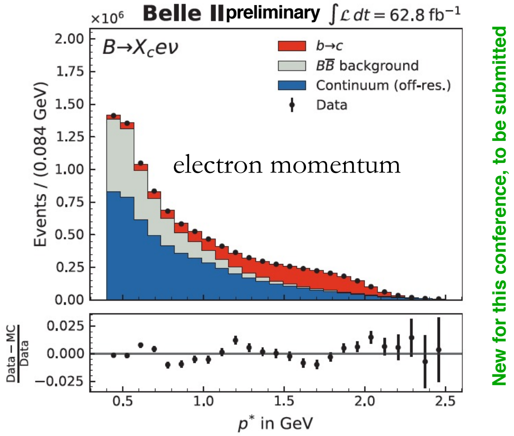
$$\mathcal{B}(B^- \to D^0 \ell^- \overline{\nu}_l) = (2.293 \pm 0.053_{\text{stat}} \pm 0.084_{\text{syst}})\%$$

FEI hadronic tag excl. $B^0 \to \pi^- \ell \nu$



$$\mathcal{B}(B^0 \to \pi^- \ell^+ \nu_\ell) \;|\; (1.58 \pm 0.43_{\text{stat}} \pm 0.07_{\text{sys}}) \times 10^{-4}$$

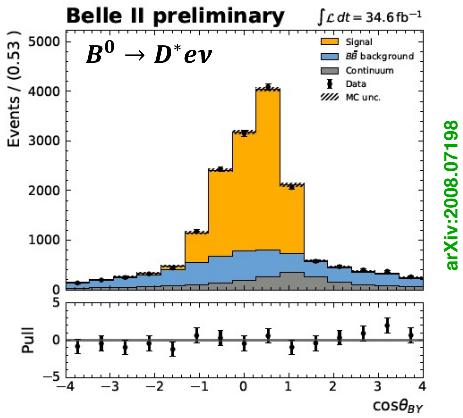
Untagged inclusive $X_c \ell \nu$



$$\mathcal{B}(B \to X_c \ell\nu) = (9.75 \pm 0.03(stat) \pm 0.47(syst))\%$$

Lepton momentum p* in the CMS

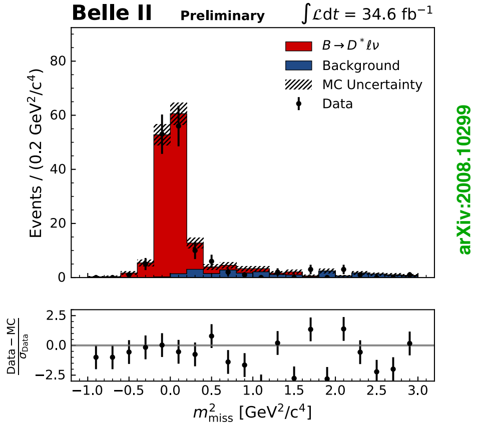
Untagged exclusive $B^0 \to D^* \ell \nu$



$$\mathcal{B}(\overline{B}^0 \to D^{*+} \ell^- \overline{\nu}_l) = (4.60 \pm 0.05_{\text{stat}} \pm 0.17_{\text{syst}} \pm 0.45_{\pi_s})\%$$

θ_{BY} angle between B and Dℓ system

FEI hadronic tag excl. $B^0 \to D^* \ell \nu$



$$\mathcal{B}(\overline{B}^0 \to D^{*+} \ell^- \overline{\nu}_l) = (4.51 \pm 0.41_{\text{stat}} \pm 0.27_{\text{syst}} \pm 0.45_{\pi_s})\%$$

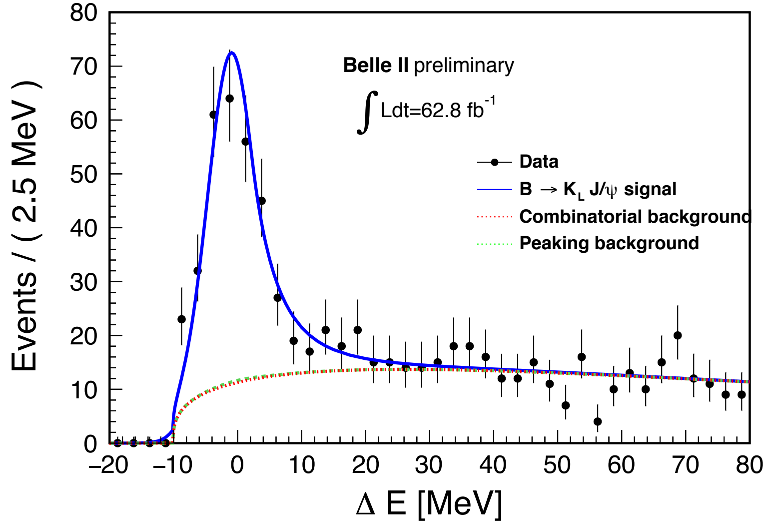
$$m^2_{\text{miss}} = \left(p_{e^+e^-} - p_{B_{\text{tag}}} - p_{D^*} - p_\ell\right)^2$$

Rediscoveries of B→J/ψK^0_L and B → η′K

- The measurement of sin(2ϕ$_1$/β) using B^0→J/ψK^0_L complements the one from B^0→J/ψK^0_S
  - signal yield compatible with Belle result (no sys. error yet)
  - next to come: precise measurement of B^0 lifetime and mixing frequency
- First Belle II measurement of rare charmless hadronic penguin diagram mediated decay B → η′K
  - particularly sensitive to new physics in the hadronic loop
  - measured branching ratio in good agreement with world average

arXiv:2106.13547

Rediscovery of B→J/ψK^0_L

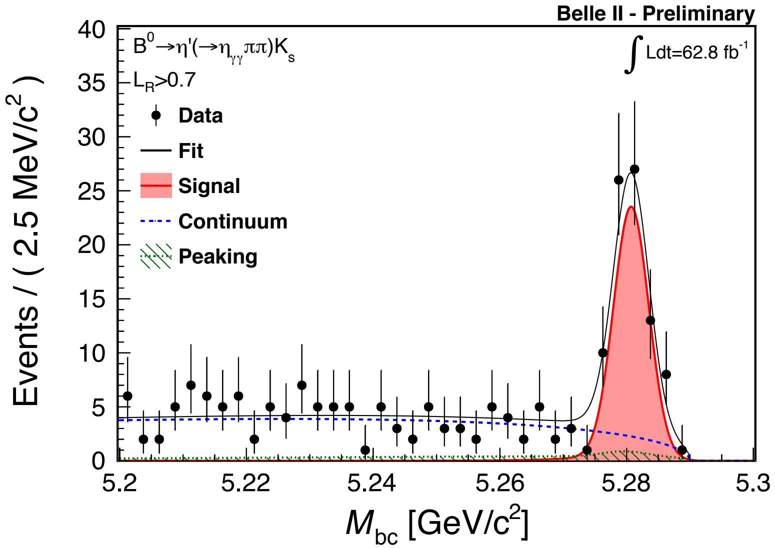


$$\Delta E = E_B^* - E_{beam}$$

$$N_{sig}\ (\mu^+\mu^-) = 267 \pm 21(\text{stat}) \pm 28(\text{peaking})$$
$$N_{sig}\ (e^+e^-) = 226 \pm 20(\text{stat}) \pm 31(\text{peaking})$$

arXiv:2104.06224

Rediscovery of B→η′K



$$M_{bc} = \sqrt{E_{beam}^{*2}c^4 - p_B^{*2}c^2}$$

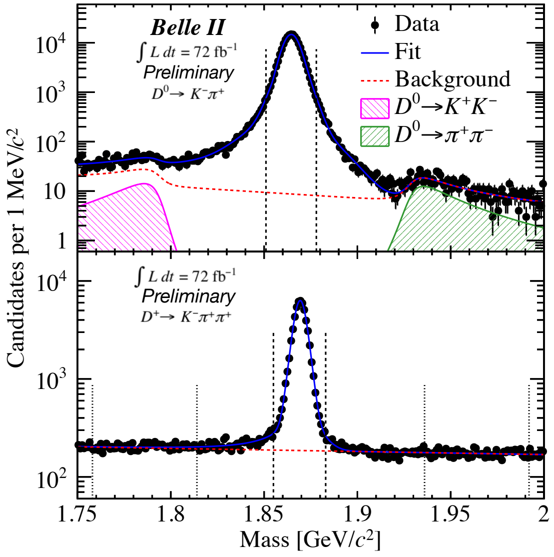
Channel	This analysis	World average [9]
	$\mathcal{B}\ (\times 10^6)$	
$B^{\pm} \to \eta' K$	$63.4\ ^{+3.4}_{-3.3}(\text{stat}) \pm 3.4(\text{syst})$	70.4 ± 2.5
$B^0 \to \eta' K^0$	$59.9\ ^{+5.8}_{-5.5}(\text{stat}) \pm 2.7(\text{syst})$	66 ± 4

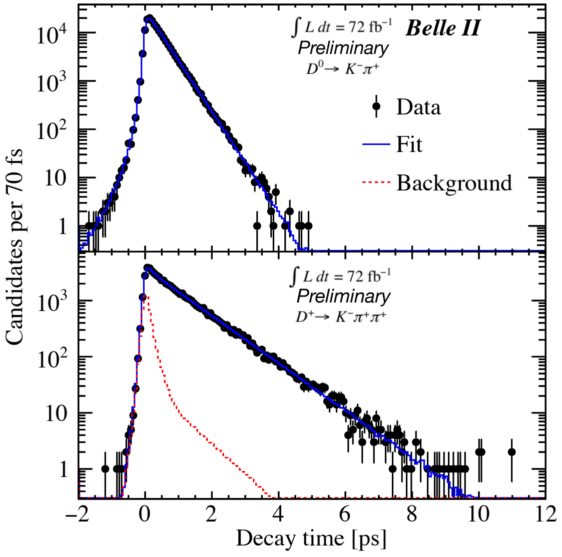
S.Duell: Measurement of χ_d and other time-dependent B decay measurements at the Belle II experiment

D^0 and D^+ Lifetime Measurements

New for this conference, to be submitted to PRL

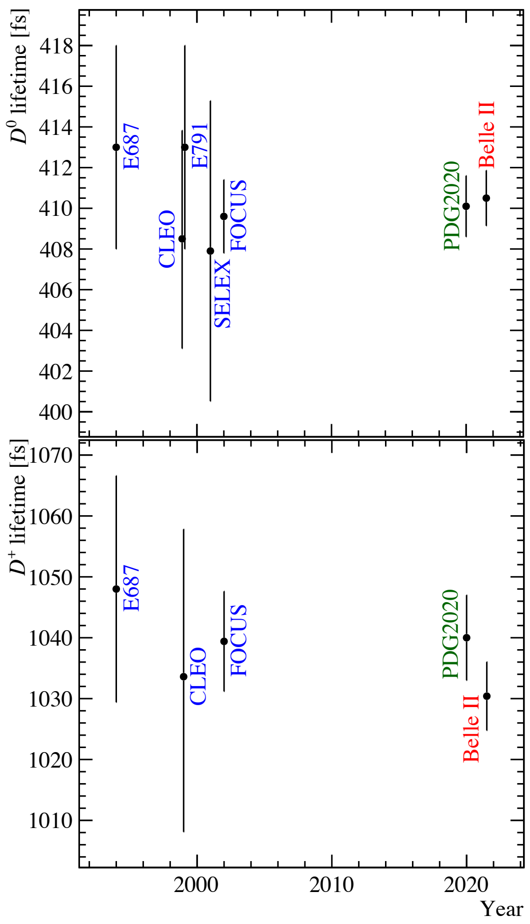
M.Dorigo: Charm Status and Prospects at Belle II





Source	Uncertainty (fs)	
	$D^0 \to K^-\pi^+$	$D^+ \to K^-\pi^+\pi^+$
Statistical	1.1	4.7
Resolution model	0.16	0.39
Backgrounds	0.24	2.52
Detector alignment	0.72	1.70
Momentum scale	0.19	0.48
Total systematic	0.8	3.1

	Belle II	World average
	$\tau(D^0) = (410.5 \pm 1.1 \pm 0.8)$ fs	(410.1 ± 1.5) fs
	$\tau(D^+) = (1030.4 \pm 4.7 \pm 3.1)$ fs	(1040 ± 7) fs



- Select high-purity samples of D^*-tagged $D^0 \to K^-\pi^+$ and $D^+ \to K^-\pi^+\pi^+$ decays
- Fit the distribution of the decay time with accurate modelling of the resolution
  - dominant systematic uncertainties come from residual mis-alignment (D^0) and from background modelling (D^+)
  - results not yet limited by systematics
- Preliminary results consistent with, and more precise than, respective world averages
- Demonstration of excellent vertexing capabilities of Belle II

Expected Impact of Belle II on the Longstanding “Kπ” Puzzle

- A significant difference is seen between direct CP asymmetry in $B^0 \to K^+\pi^-$ and $B^+ \to K^+\pi^0$ decays: $\Delta A_{CP} = 0.124 \pm 0.021$
- An Isospin sum rule has been proposed which provides a sensitive null-test: PLB 627, 82 (2005)

$$I_{K\pi} = \mathcal{A}_{K^+\pi^-} + \mathcal{A}_{K^0\pi^+}\frac{\mathcal{B}(K^0\pi^+)}{\mathcal{B}(K^+\pi^-)}\frac{\tau_{B^0}}{\tau_{B^+}} - 2\mathcal{A}_{K^+\pi^0}\frac{\mathcal{B}(K^+\pi^0)}{\mathcal{B}(K^+\pi^-)}\frac{\tau_{B^0}}{\tau_{B^+}} - 2\mathcal{A}_{K^0\pi^0}\frac{\mathcal{B}(K^0\pi^0)}{\mathcal{B}(K^+\pi^-)}$$

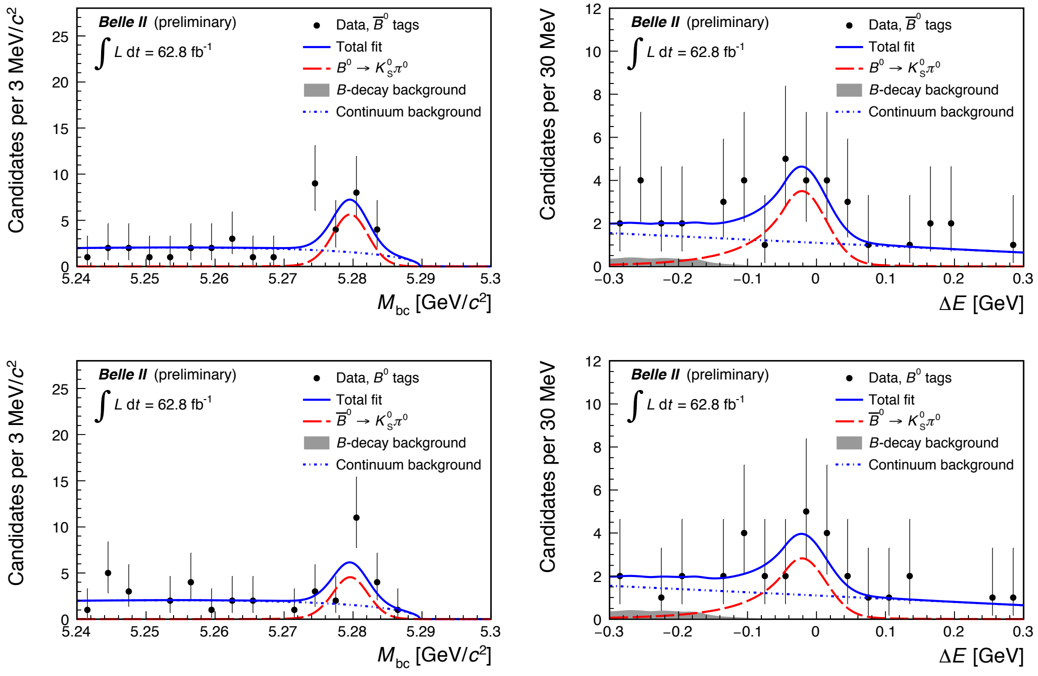
arXiv:2104.14871

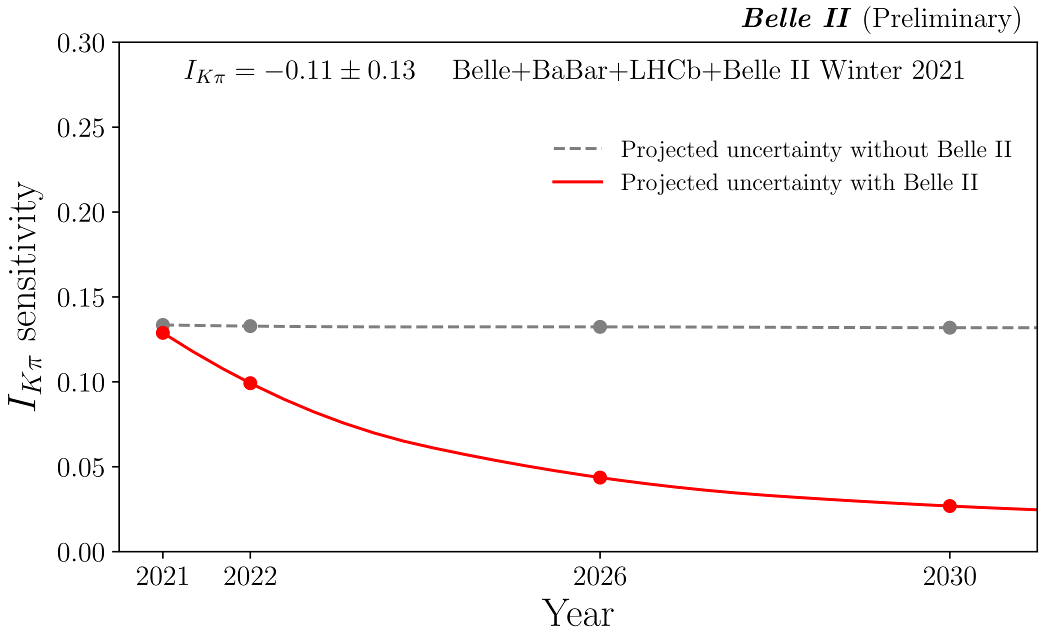
  - a violation of the sum rule would be evidence for New Physics
  - precision on $A_{K^0\pi^0}$ is the most limiting input for test of sum rule

$$\mathcal{A}_{K^0\pi^0} = -0.40^{+0.46}_{-0.44}(\text{stat}) \pm 0.04(\text{syst}), \text{ and}$$
$$\mathcal{B}(B^0 \to K^0\pi^0) = [8.5^{+1.7}_{-1.6}(\text{stat}) \pm 1.2(\text{syst})] \times 10^{-6}$$

$\overline{B}^0$ tag

B^0 tag



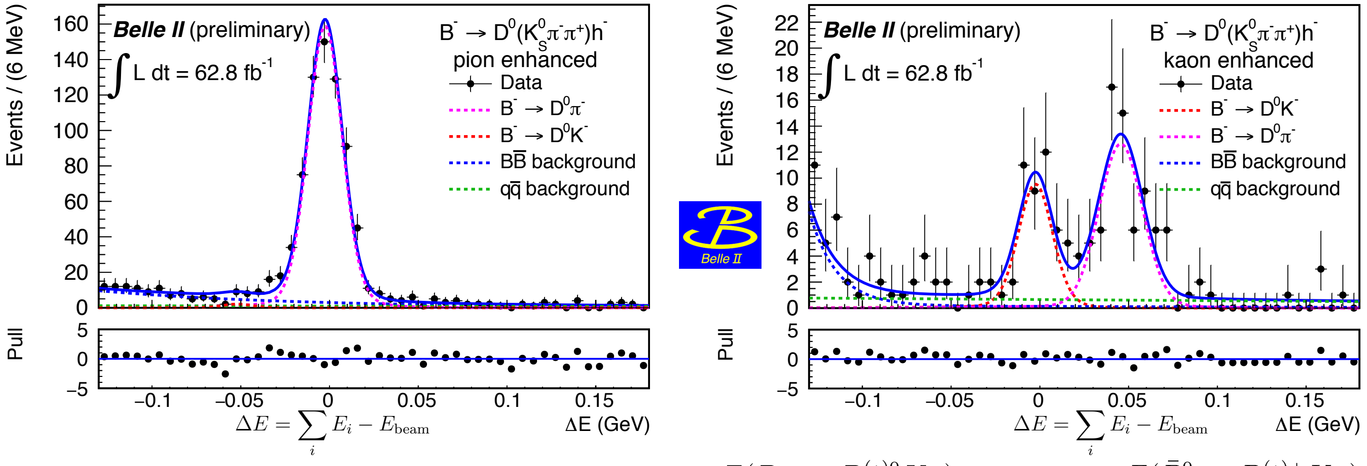


B.Wach: Measurements of $B \to D(*)h$ and charmless B-decays at Belle II

Towards Belle II Measurement of ϕ_3 /γ with $B \to D^{(*)}K/\pi$ Transitions

- $B^- \to D^{(*)0}\pi^-$ and $\bar{B}^0 \to D^{(*)+}\pi^-$ are the most abundant hadronic B decays
- $B^- \to D^{(*)0}K^-$ are sensitive to CKM unitarity-triangle angle ϕ_3 (or γ)
  - "golden" mode: $B^- \to D^0(K^0_S\pi^+\pi^-)K^-$
- Many systematic uncertainties cancel in the ratio of decay rates
- Results agree with world average (LHCb)

B.Wach: Measurements of B→D(*)h and charmless B-decays at Belle II arXiv:2104.03628

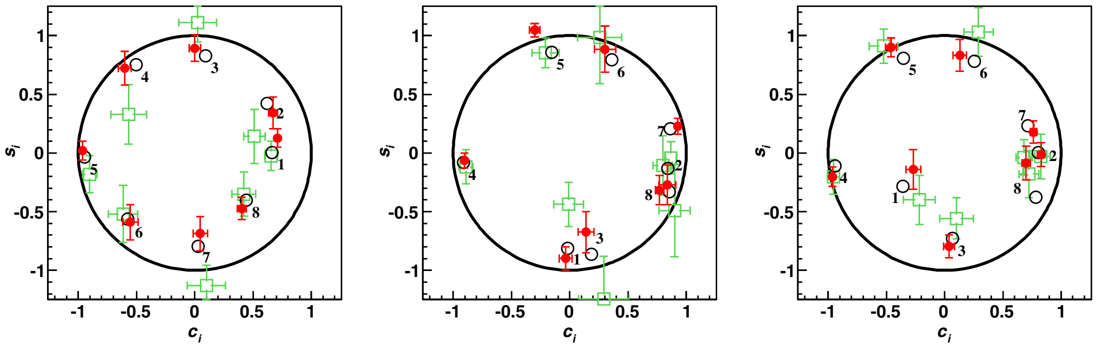


Ratio between decay rates $R^{(*)0} = \frac{\Gamma(B^- \to D^{(*)0}K^-)}{\Gamma(B^- \to D^{(*)0}\pi^-)}$ $R^{(*)+} = \frac{\Gamma(\bar{B}^0 \to D^{(*)+}K^-)}{\Gamma(\bar{B}^0 \to D^{(*)+}\pi^-)}$

	$B^- \to D^0(K^-\pi^+)h^-$	$B^- \to D^0(K^0_S\pi^+\pi^-)h^-$	$\bar{B}^0 \to D^+h^-$
Belle II $R^{+/0}$ $(\times 10^{-2})$	$7.66 \pm 0.55\ ^{+0.11}_{-0.08}$	$6.32 \pm 0.81\ ^{+0.09}_{-0.11}$	$9.22 \pm 0.58 \pm 0.09$
LHCb $R^{+/0}$ $(\times 10^{-2})$	$7.77 \pm 0.04 \pm 0.07$ [24]	$7.77 \pm 0.04 \pm 0.07$ [24]	$8.22 \pm 0.11 \pm 0.25$ [25]

- Re-optimization of Belle ϕ_3-analysis ongoing
  - precision of favoured BPGGSZ method strongly depends on recent BES III results on strong phases between D^0 and $\bar{D}^0$ decays to $K^0_S\pi\pi$
  - aiming for first Belle+Belle II combined result by end of summer

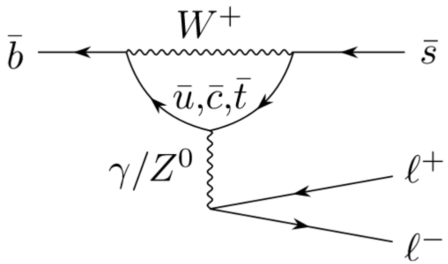
Phys. Rev. Lett. 124.241802 (2020); Phys. Rev. D 101, 112002 (2020)



A.Lavania: Measurements of strong-phase parameters at BESIII

Test of Lepton Flavor Universality in $b \to s\ell\ell$ Transitions

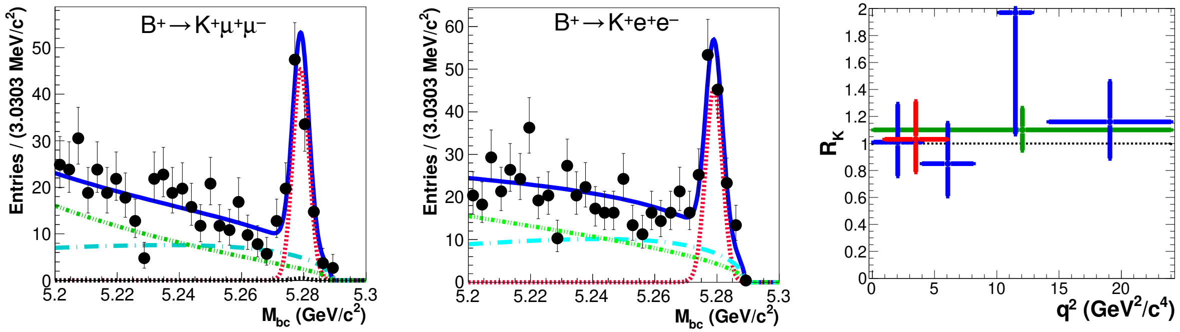
Flavor-Changing Neutral Current (FCNC)



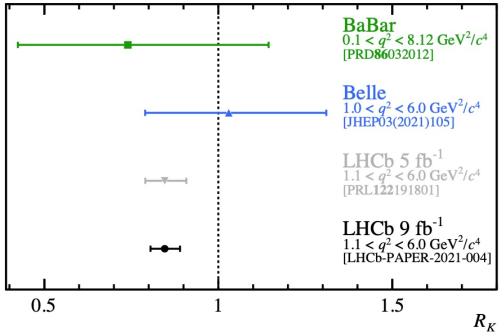
$$R_{K^{(*)}} = \frac{\mathcal{B}(B \to K^{(*)}\mu^+\mu^-)}{\mathcal{B}(B \to K^{(*)}e^+e^-)}$$

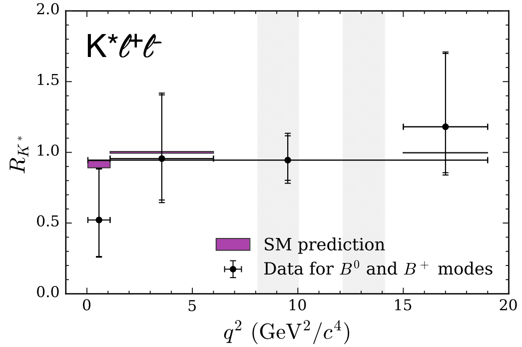
- Belle
  - charged and neutral mode are analysed
  - similar performance for electron and muon channel
  - R_K-values for various choices of q²-binning in agreement with SM predictions
  - $R_{K^{*+}}$ measured for the first time
- Belle II
  - rediscovery in first small dataset
  - exploit complementarity with LHCb: long term focus on e- and τ-channels

JHEP 2103, 105 50 (2021) B→Kll

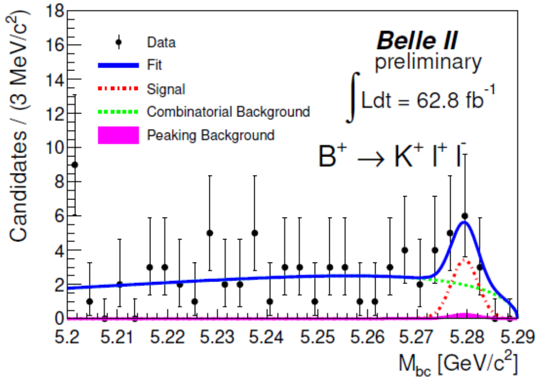


Phys. Rev. Lett. 126, 161801 (2021)

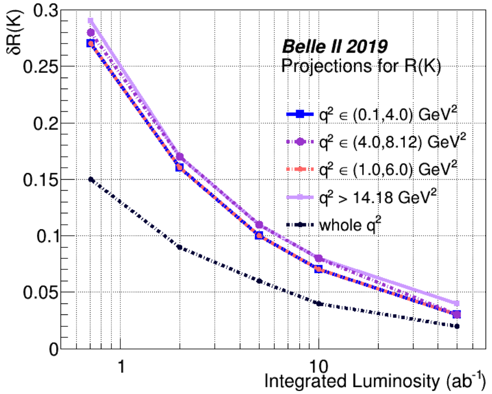




S.Kurz: Search for B → Kνν and other electroweak/radiative penguin processes at Belle II



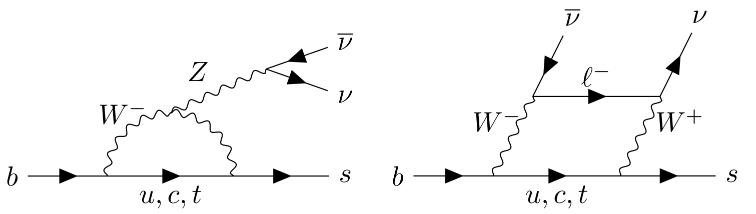
https://docs.belle2.org/record/1906/files/Approved_Plots_BptoKpll.pdf

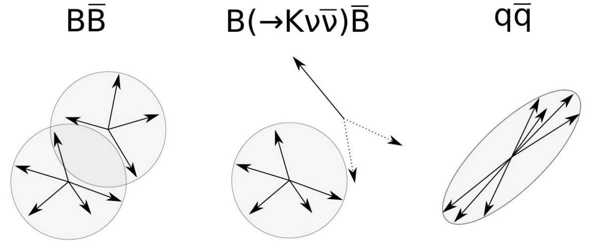


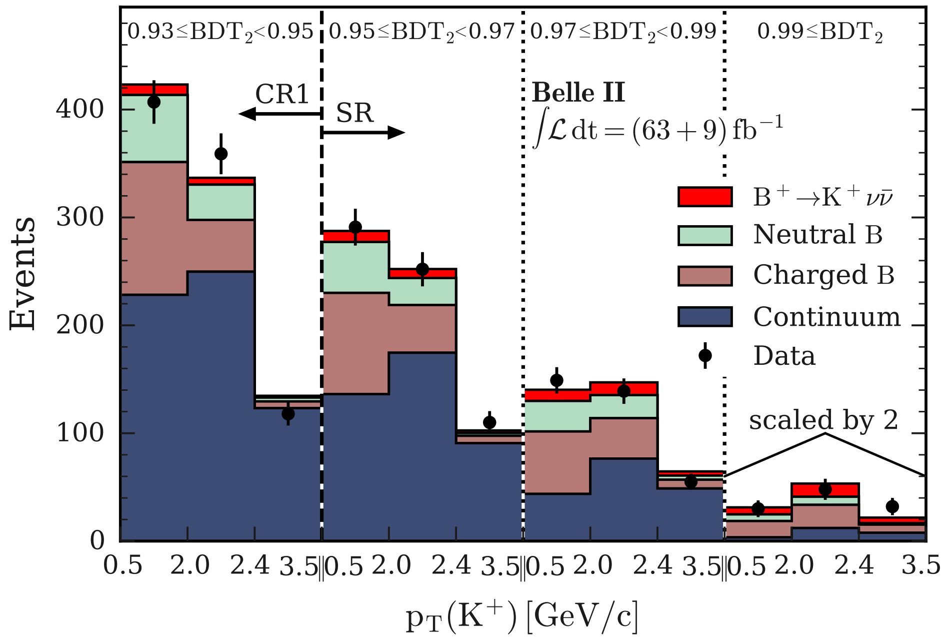
Search for $B^\pm \to K^\pm \nu\bar{\nu}$

S.Kurz: Search for B → Kνν and other electroweak/radiative penguin processes at Belle II

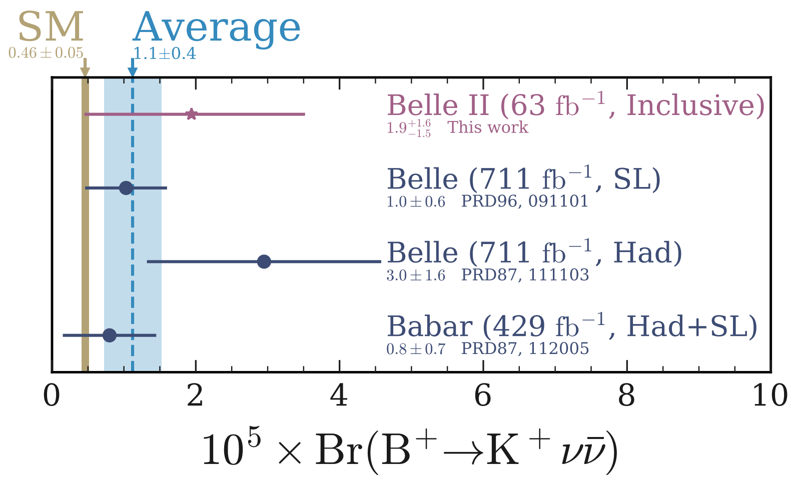
arXiv: 2104.12624, submitted to PRL







- Flavour-Changing Neutral Current process that has not yet been observed
  - no photon contribution → much cleaner theoretical prediction $\mathcal{B}(B^\pm \to K^\pm \nu\bar{\nu}) = (4.6 \pm 0.5) \times 10^{-6}$
- Previous searches based on tagged analyses
  - semi-leptonic tag: $\varepsilon_{sig} \sim 0.2\%$ (Belle)
  - hadronic tag: $\varepsilon_{sig} \sim 0.04\%$ (BaBar)
- New approach by Belle II based on an inclusive tag
  - no explicit reconstruction of the second B-meson
  - use BDTs to exploit distinctive topological features of $B^\pm \to K^\pm \nu\bar{\nu}$
  - much higher efficiency of $\varepsilon_{sig} \sim 4.3\%$ resulting in increased sensitivity per luminosity
- Further improvements are underway
  - more data (already have 3x more on tape)
  - additional channels ($B^0 \to K^{*0}\nu\bar{\nu}$, $B^0 \to K_S^0\nu\bar{\nu}$, …)
  - improved/extended classifiers (neural networks)
- Events of different tagging methods are statistically independent and can be combined

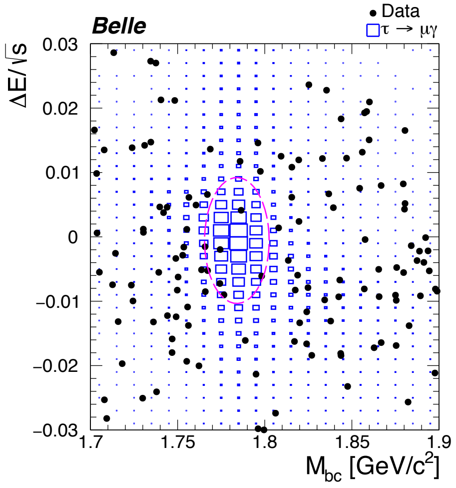


Search for Lepton Flavor Violation in Tau Decays

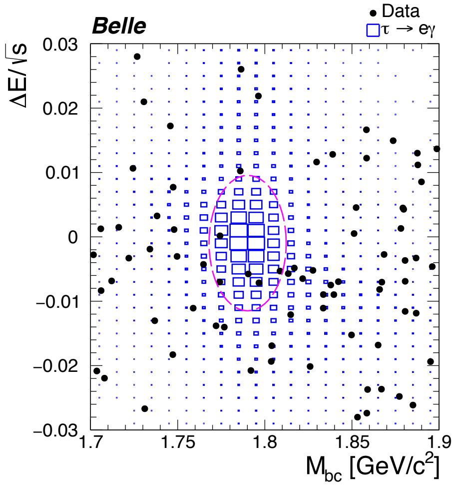
S.Patra: New physics searches through τ decays at Belle

arXiv:2103.12994, submitted to JHEP

- Search for LFV decays $\tau^{\pm} \to \ell^{\pm}\gamma$ ($\ell = e, \mu$) using full Belle data set (988 fb^{-1})
- Improvements compared to previous Belle analysis
  - about twice more data than previous analysis
  - new requirements on observables energy asymmetry and beam-energy-constrained mass
  - photon energy calibrated using radiative muon events
- Perform unbinned maximum-likelihood fit to
  - $M_{\rm bc} = \sqrt{(E^{\rm CM}_{\rm beam})^2 - |\vec{p}^{\,\rm CM}_{\ell\gamma}|^2}$
  - $\Delta E/\sqrt{s} = (E^{\rm CM}_{\ell\gamma} - \sqrt{s}/2)/\sqrt{s}$
- Upper limits are set on branching fractions: $\mathscr{B}(\tau^{\pm} \to \mu^{\pm}\gamma) < 4.2 \times 10^{-8}$ and $\mathscr{B}(\tau^{\pm} \to e^{\pm}\gamma) < 5.6 \times 10^{-8}$ at 90% confidence level
  - the $\tau^{\pm} \to \mu^{\pm}\gamma$ limit is the most stringent to date
- Another search for lepton-number- and baryon-number-violating tau decays, such as $\tau \to p\ell\ell'$, improves existing LHCb limits or even yields first-ever limits for some channels

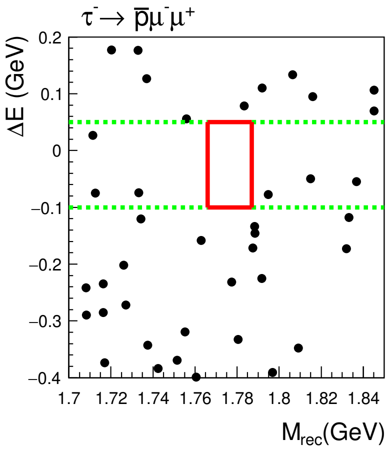


(a) $\tau^{\pm} \to \mu^{\pm}\gamma$



(b) $\tau^{\pm} \to e^{\pm}\gamma$

Channel	$\tau \to \mu\gamma$	$\tau \to e\gamma$
Signal efficiency	3.7%	2.9 %
Exp. # bkgs.	5.8 ± 0.4	5.1 ± 0.4
Obs. event	5	5
$N^{\rm UL}_{\rm sig}$	2.8	3.0



PRD 102, 111101(R) (2020)

Channel	ϵ (%)	$N_{\rm bkg}$	$N_{\rm obs}$	$N^{\rm UL}_{\rm sig}$	$\mathcal{B}\,(\times 10^{-8})$
$\tau^- \to \bar{p}e^+e^-$	7.8	0.50 ± 0.35	1	3.9	< 3.0
$\tau^- \to pe^-e^-$	8.0	0.23 ± 0.07	1	4.1	< 3.0
$\tau^- \to \bar{p}e^+\mu^-$	6.5	0.22 ± 0.06	0	2.2	< 2.0
$\tau^- \to \bar{p}e^-\mu^+$	6.9	0.40 ± 0.28	0	2.1	< 1.8
$\tau^- \to p\mu^-\mu^-$	4.6	1.30 ± 0.46	1	3.1	< 4.0
$\tau^- \to \bar{p}\mu^-\mu^+$	5.0	1.14 ± 0.43	0	1.5	< 1.8

Probing τ-μ Universality and LFV in Υ(3S) Decays

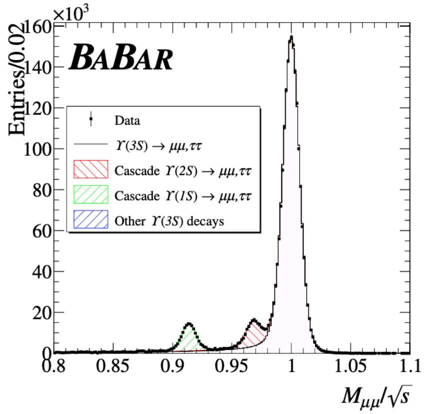
- The decay widths of a $q\bar{q}$ bound state into a pair of leptons can be precisely calculated
- The ratio of decay widths in τ pairs and μ pairs, $R_{\tau\mu}$, is therefore a sensitive probe for New Physics, such as
  - light CP-odd Higgs in 2HDM (Type-II) models with large tanβ
  - New Physics contributions that might resolve tensions in R(D*) measurements
- Based on Υ(3S), Υ(4S) and off-resonance data the Babar analysis exploits differences between resonant and off-resonant di-muon processes to improve the precision
- The result of $R_{\tau\mu}^{\Upsilon(3S)} = \Gamma_{\tau^+\tau^-}/\Gamma_{\mu^+\mu^-} = 0.966 \pm 0.008_{\rm stat} \pm 0.014_{\rm syst}$ is six times more precise than previous measurement and agrees with the SM prediction of 0.9948 within ± 2σ
- The data are also used to derive a preliminary first upper limit on electron-muon flavor violation in Υ(3S) decays: $\mathscr{B}(\Upsilon(3S) \to e^{\pm}\mu^{\mp}) < 3.6 \times 10^{-7}$ at 90% CL
  or, if interpreted as a limit on the scale of New Physics: $\Lambda_{\rm NP}/g^2_{\rm NP} \geq 80$ TeV at 90% CL

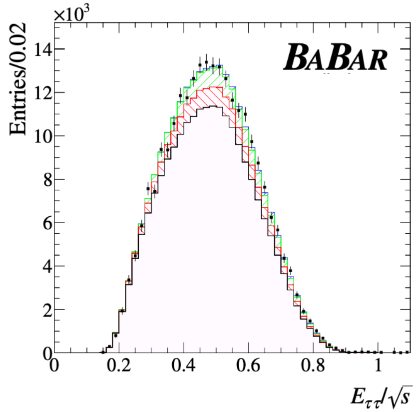
$$\Gamma_{\Upsilon\to\ell\ell} = 4\alpha^2 e_q^2 \frac{|\Psi(0)|^2}{M^2}(1+2m_\ell^2/M^2)\sqrt{1-4m_\ell^2/M^2}$$

$$R_{\tau\mu} = \frac{\Gamma_{\Upsilon\to\tau\tau}}{\Gamma_{\Upsilon\to\mu\mu}} = \frac{(1+2m_\tau^2/M^2)\sqrt{1-4m_\tau^2/M^2}}{(1+2m_\mu^2/M^2)\sqrt{1-4m_\mu^2/M^2}}$$

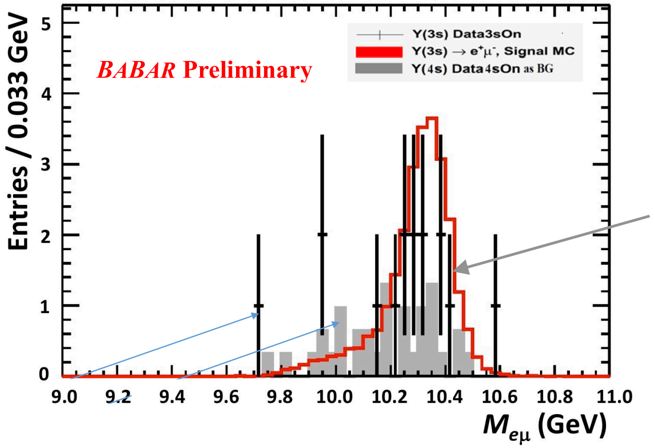
$V(nS)$	SM prediction
$\Upsilon(1S)$	$0.9924 \pm \mathcal{O}(10^{-5})$
$\Upsilon(2S)$	$0.9940 \pm \mathcal{O}(10^{-5})$
$\Upsilon(3S)$	$0.9948 \pm \mathcal{O}(10^{-5})$

Phys. Rev. Lett. 125.241801





Result of template fit after continuum background subtraction



Data driven background estimate based on Υ(4S) data

N.Tasneem: Tests of the Standard Model by means of Υ(3S) meson decays with the BABAR detector

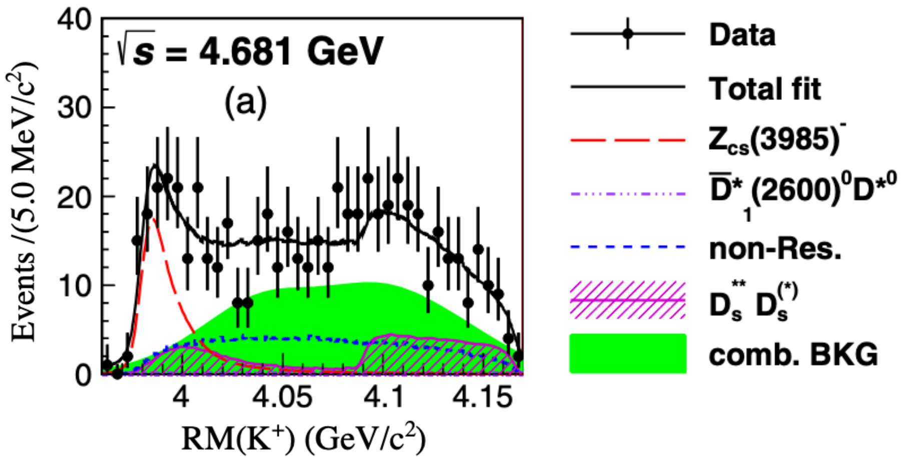
First observation of Z_{cs} (3985) in $e^+e^- \rightarrow K^+D^-_sD^{*0}$, $K^+D^{*-}_sD^0$

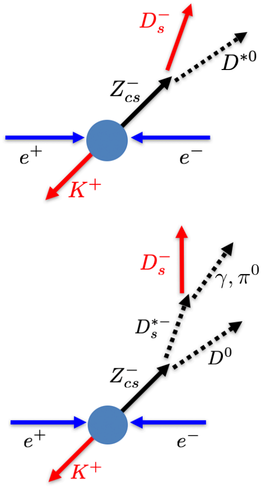
BESIII

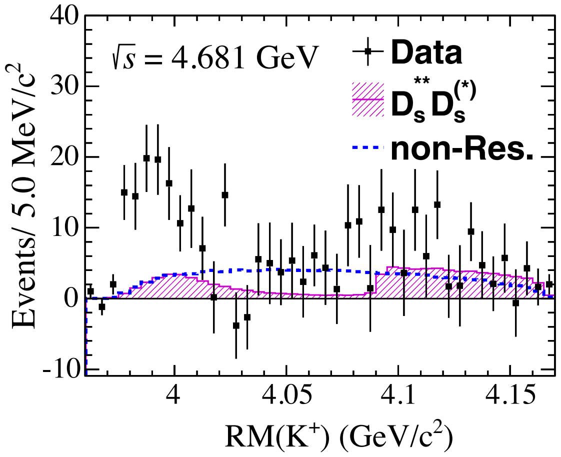
- Recent observations of nonstrange hidden-charm tetra-quark candidates with quark content $c\bar{c}q\bar{q}'$ (Z_c states) have opened a new chapter in hadron spectroscopy
- BESIII reported on the first candidate for a charged hidden-charm tetraquark with strangeness, decaying into $D^-_sD^0$ and $D^{*-}_sD^0$
- A number of different explanations for this new state have been proposed
- However, the properties of the excess need further exploration with more statistics
  - relation to the ~10x broader $c\bar{c}u\bar{s}$ state decaying to $J/\psi K^+$, reported by LHCb, still needs to be understood

Phys. Rev. Lett. 126, 102001 (2021)

K+ recoil mass spectrum







$$M = 3982.5^{+1.8}_{-2.6} \pm 2.1 \text{ MeV}$$
$$\Gamma = 12.8^{+5.3}_{-4.4} \pm 3.0 \text{ MeV}$$

Significant (5.3σ) enhancement at threshold over estimated backgrounds at 4.681 GeV

Conclusions

- Flavor physics in e^+e^- collisions offers an extremely rich physics program with many opportunities to probe New Physics
- The first generation B-factory experiments Belle and BaBar and the Tau-charm factory experiment BES III continue to deliver first quality and highly relevant physics results
- SuperKEKB has set a new world record in peak luminosity and is entering the regime of a „Super B factory“
- The Belle II detector is working very well and is producing very promising physics results
- Looking forward to an exciting era of discoveries and a healthy competition and complementarity of Belle II and LHCb

Backup

LHCb-Belle II Comparison

Observable	Current Belle/ Babar	2019 LHCb	Belle II ($5\ ab^{-1}$)	Belle II ($50\ ab^{-1}$)	LHCb ($23\ fb^{-1}$)	Belle II Upgrade ($250\ ab^{-1}$)	LHCb upgrade II ($300\ fb^{-1}$)
CKM precision, new physics in CP Violation							
$\sin 2\beta/\varphi_1$ ($B\to J/\psi\ K_S$)	0.03	0.04	0.012	0.005	0.011	0.002	0.003
γ/φ_3	13º	5.4º	4.7º	1.5º	1.5º	0.4º	0.4º
α/φ_2	4º	–	2	0.6º	–	0.3º	–
$\lvert V_{ub}\rvert$ (Belle) or $\lvert V_{ub}\rvert/\lvert V_{cb}\rvert$ (LHCb)	4.5%	6%	2%	1%	3%	<1%	1%
φ_s	–	49 mrad	–	–	14 mrad	–	4 mrad
$S_{CP}(B\to\eta'\ K_S$, gluonic penguin)	0.08	○	0.03	0.015	○	0.007	○
$A_{CP}(B\to K_S\pi^0)$	0.15	–	0.07	0.04	–	0.02	–
New physics in radiative & EW Penguins, LFUV							
$S_{CP}(B_d\to K^*\gamma)$	0.32	○	0.11	0.035	○	0.015	○
$R(B\to K^* l^+ l^-)$ ($1<q^2<6\ GeV^2/c^2$)	0.24	0.1	0.09	0.03	0.03	0.01	0.01
$R(B\to D^*\tau\nu)$	6%	10%	3%	1.5%	3%	<1%	1%
$Br(B\to\tau\nu)$, $Br(B\to K^*\nu\nu)$	24%, –	–	9%, 25%	4%, 9%	–	1.7%, 4%	–
$Br(B_d\to\mu\mu)$	–	90%	–	–	34%	–	10%
Charm and τ							
$\Delta A_{CP}(KK-\pi\pi)$	–	8.5×10^{-4}	–	5.4×10^{-4}	1.7×10^{-4}	2×10^{-4}	0.3×10^{-4}
$A_{CP}(D\to\pi^+\pi^0)$	1.2%	–	0.5%	0.2%	–	0.1%	–
$Br(\tau\to e\gamma)$	$<120\times10^{-9}$	–	$<40\times10^{-9}$	$<12\times10^{-9}$	–	$<5\times10^{-9}$	–
$Br(\tau\to\mu\mu\mu)$	$<21\times10^{-9}$	$<46\times10^{-9}$	$<3\times10^{-9}$	$<3\times10^{-9}$	$<16\times10^{-9}$	$<0.3\times10^{-9}$	$<5\times10^{-9}$

arXiv: 1808.08865 (Physics case for LHCb upgrade II), PTEP 2019 (2019) 12, 123C01 (Belle II Physics Book)