B decays at e^+e^- colliders

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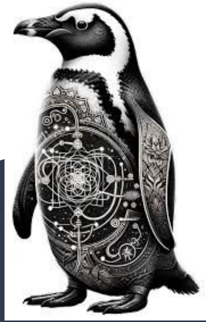
On behalf of the Belle & Belle II Collaborations



22nd Conference on Flavour physics and CP violation (FPCP 2024)

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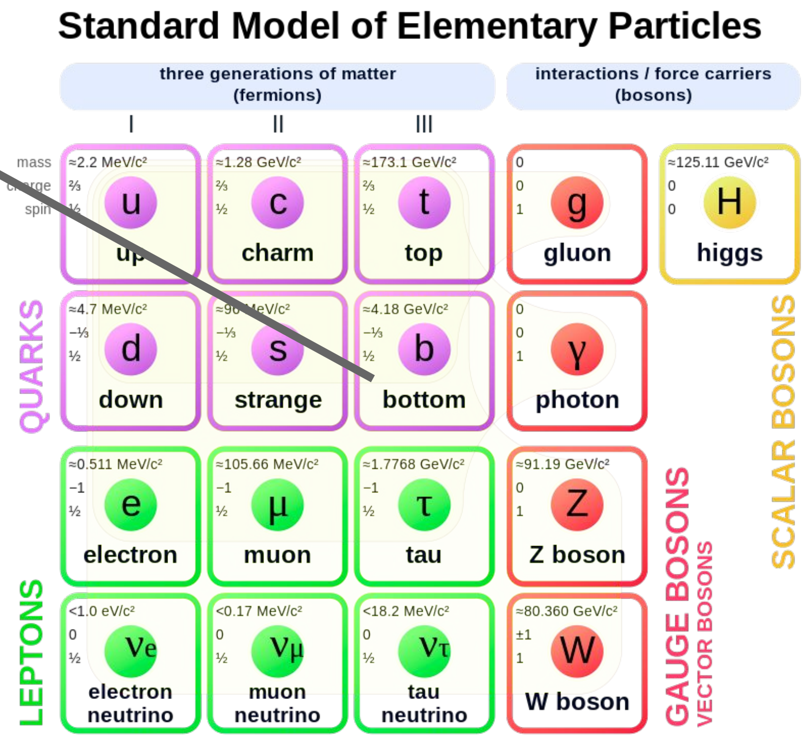
Outline

- Motivation
- Overview of B factories
- Probing $B \to K\nu\bar{\nu}$ at Belle II
- First measurement of $B \to K^*(892)\gamma$ at Belle II
- Results for exclusive $B \to \rho\gamma$ study using Belle + Belle II data
- Search for double radiative $B \to \gamma\gamma$ using Belle + Belle II data
- Summary

Motivation

The beautiful *b* quark

- Light enough to be produced abundantly
- Heavy enough to have many decays
- Myriad of final states and interactions to probe from
- Well known Standard Model predictions



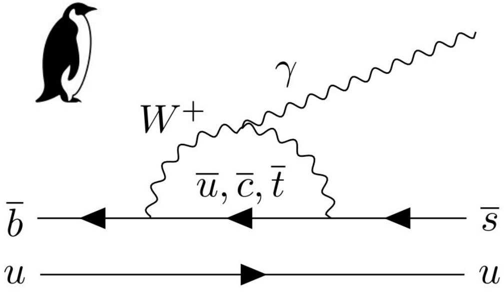
One of the main missions of B -factories is to perform searches for physics beyond SM in rare B decays

Rare B decay: branching fraction $\mathcal{B} < 5 \times 10^{-5}$
→ less than 5 in 100000 B-hadrons decay in this way

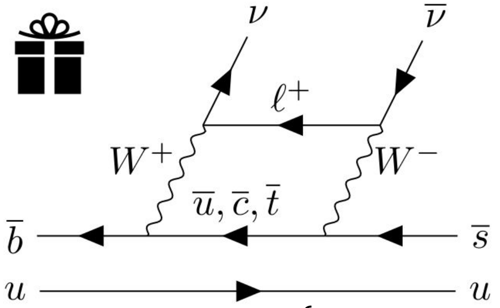
Rare decays!!!

Flavour changing neutral currents (FCNC) decays of *B* mesons

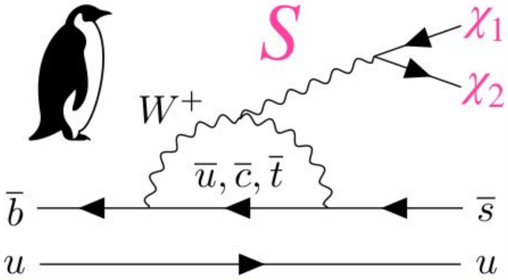
- Forbidden at tree level, allowed at loop level [PRD 2 (1970) 1285]
- Standard Model (SM) contribution is small, sensitive to beyond SM
- BSM particles can contribute in the loop (eg. charged Higgs) or mediate the process at the tree level (eg leptoquarks).

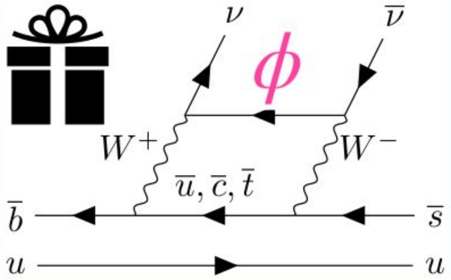


$\mathcal{B} \sim 10^{-5}$



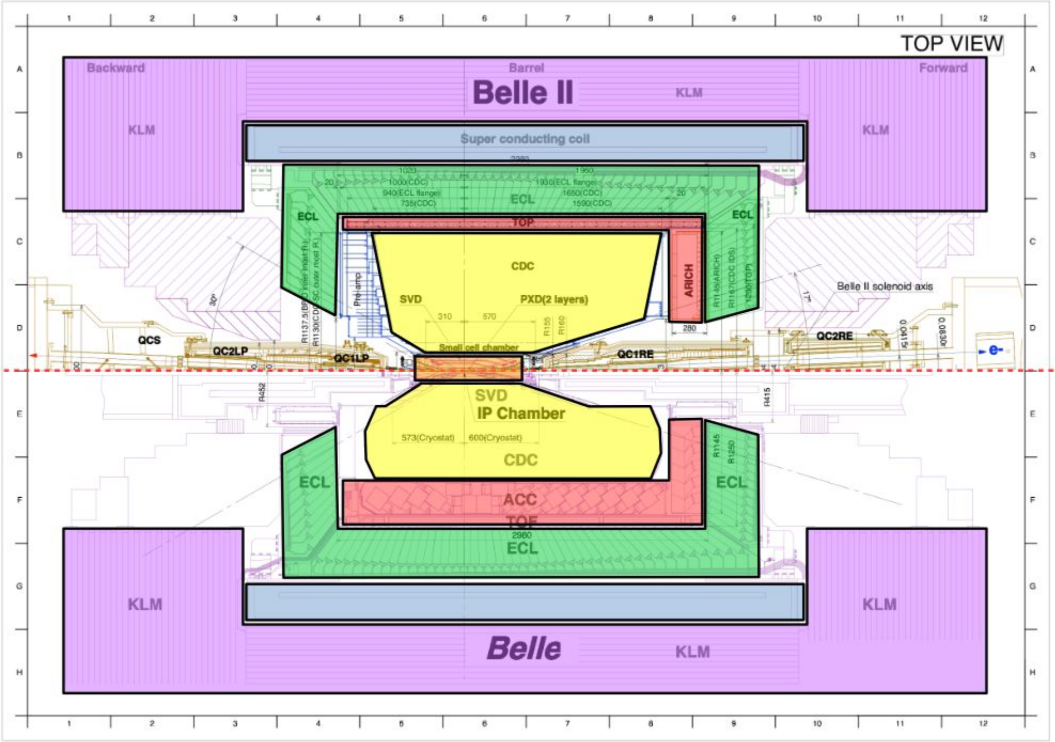
$\mathcal{B} \sim 10^{-6}$





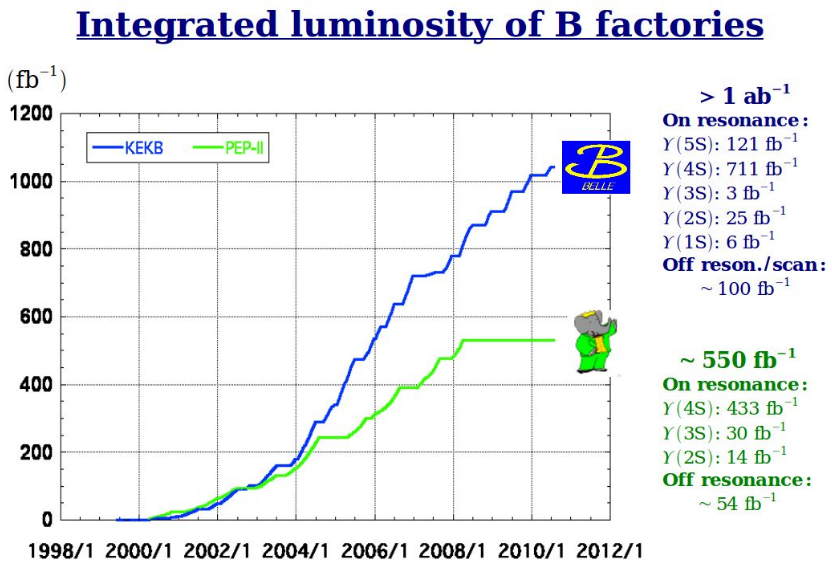
Belle & Belle II

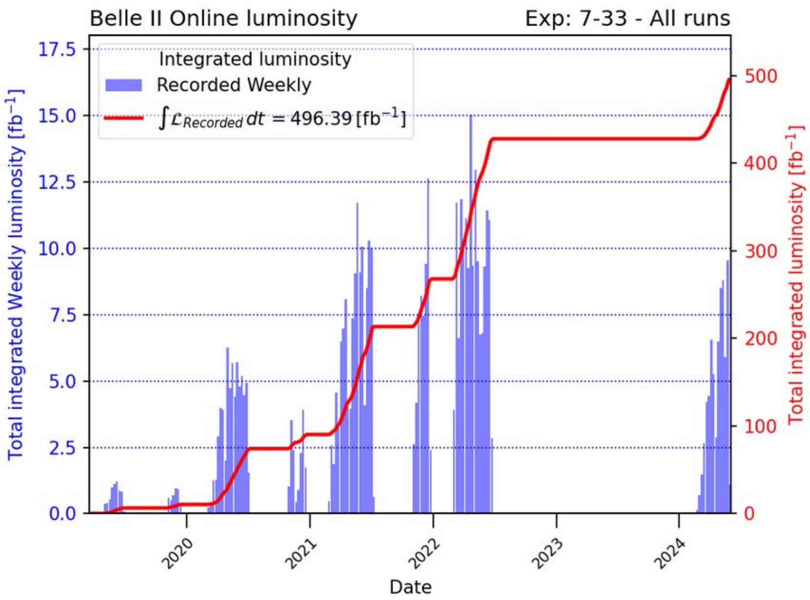
	Belle	Belle II
Vertexing	SVD	PXD + SVD
Tracking	CDC	CDC
K and π	ACC + TOF	ARICH + TOP
γ and e	ECL	ECL
μ and K^0_L	KLM	KLM



Belle TDR: NIM A **479** 117 (2002)
Belle II TDR: arXiv:1011.0352 (2010)

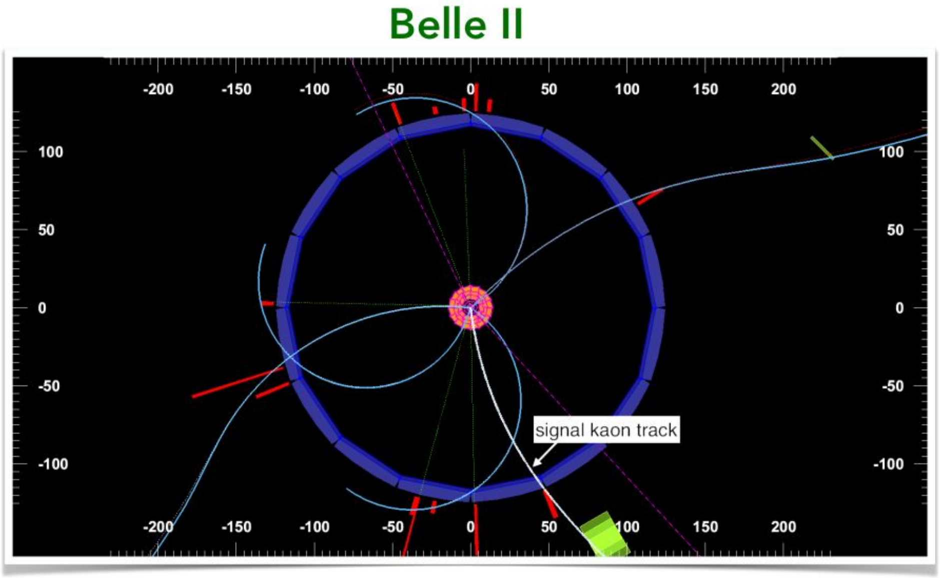
Belle/Belle II status





Belle II collected 362 fb-1 at Υ(4S) — equivalent to BaBar and ~1/2 of Belle sample (Today's results: 362 fb-1)
Belle II collected 42 fb-1 of off-resonance data [60 MeV below Υ(4S)] compared to ~90 fb-1 from Belle

Events at B factories



$$B^+B^-(51.4 \pm 0.6)\%, \ B^0\overline{B}^0(48.6 \pm 0.6)\%$$

$$\sigma(e^+e^-) \rightarrow \Upsilon(4S) = 1.1\,nb$$

$$\sigma(e^+e^-) \rightarrow c\bar{c}(g) = 1.6\,nb$$

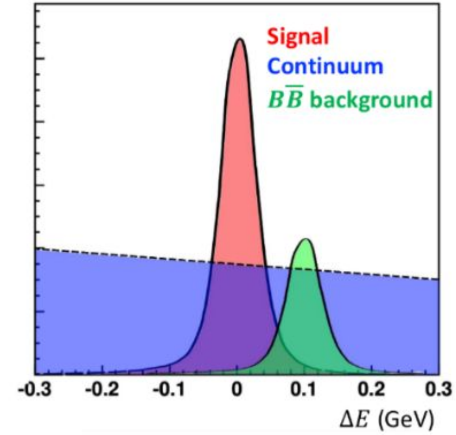
$$\sigma(e^+e^-) \rightarrow u\bar{u}(\gamma) = 1.3\,nb$$

- Principal background from light quark (continuum)
- Near 100% efficiency for B decays

- Clean environment with on average ~10-15 tracks, 3-4 π^0
- Known initial state kinematics

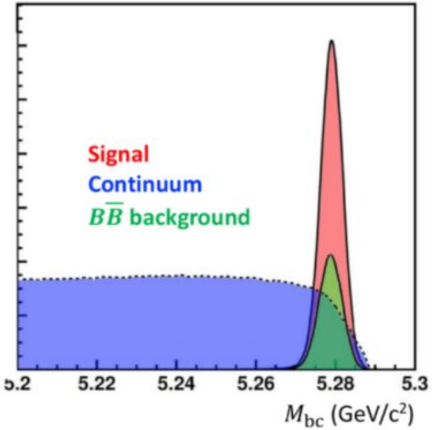
Event kinematics

$$\Delta E = E_B^* - \sqrt{s}/2$$

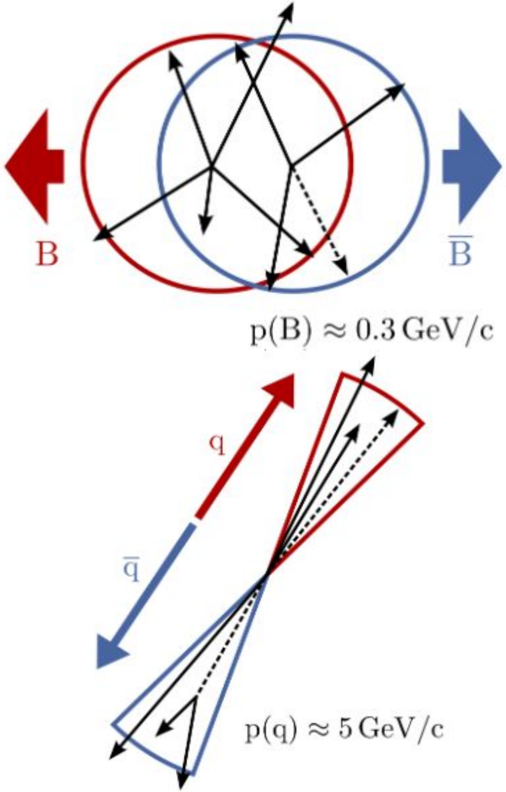


Expected $\Delta E \simeq 0$

$$M_{bc} = \sqrt{(\sqrt{s}/2)^2 - |\vec{p}_B^{\,*2}|}$$



Expected $M_{bc} \simeq m_B$



- B factory specific variables to exploit information on initial kinematics
- Different event shape to separate B events from continuum background

$B \to K \nu \bar{\nu}$: Motivation

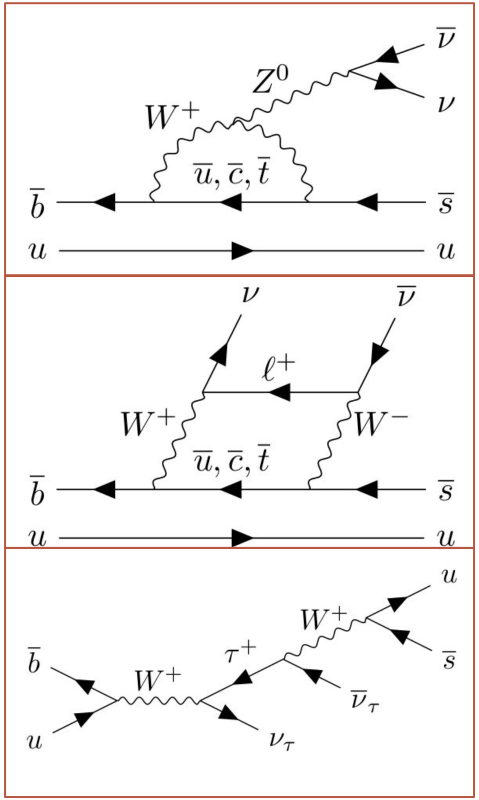
- $B^+ \to K^+ \nu\bar{\nu}$ is a challenging ⇒ single charged track in the final state
- $\mathcal{B}$(SM) = (5.58 ± 0.37) x 10^{-5} [PRD 107, 014511]
- New physics could alter the rate (also angular observables for $B \to K^* \nu\bar{\nu}$)

Advantages at Belle II:

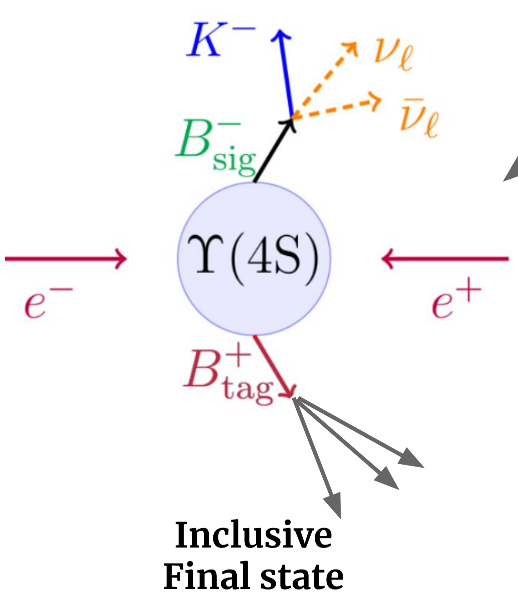
- Constraints from well-known initial state kinematics;
- Lower average multiplicity at the Y(4S) compared to hadronic collisions.

NP scenarios:

- **Light** : axions [PRD 102, 015023 (2020)],
- dark scalars [PRD 101, 095006 (2020)],
- axion-like particles [JHEP 04 (2023) 131]
- **Heavy** : Z' [PL B 821 (2021) 136607],
- leptoquarks [PRD 98, 055003 (2018)]



$B \to K \nu \bar{\nu}$: Reconstruction

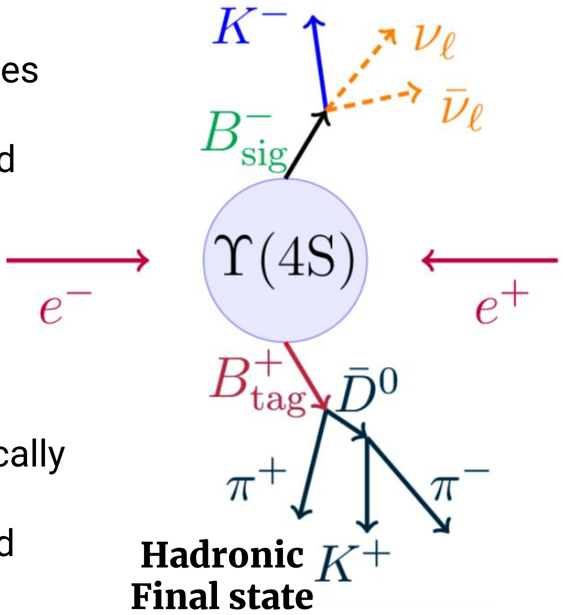


Inclusive tag analysis (ITA)

- Select first signal kaon that minimizes q^2_{rec} (computed as K^+ recoil)
- Nested BDT to suppress background
- Fit q^2_{rec} and BDT output

Hadronic tag analysis (HTA)

- Select first tag B decaying hadronically [[Comput Softw Big Sci 3, 6 (2019)]]
- Single BDT to suppress background
- Fit BDT output

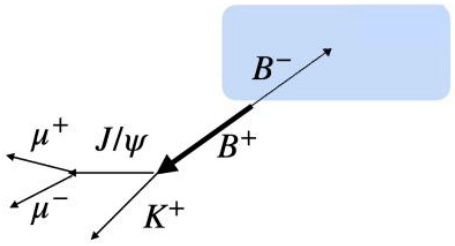


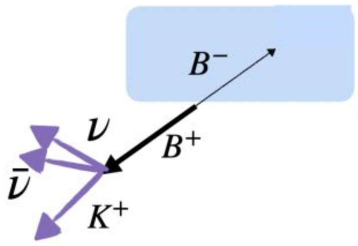
signal efficiency = 8%; purity = 0.9%

signal efficiency = 0.4%; purity = 3.5%

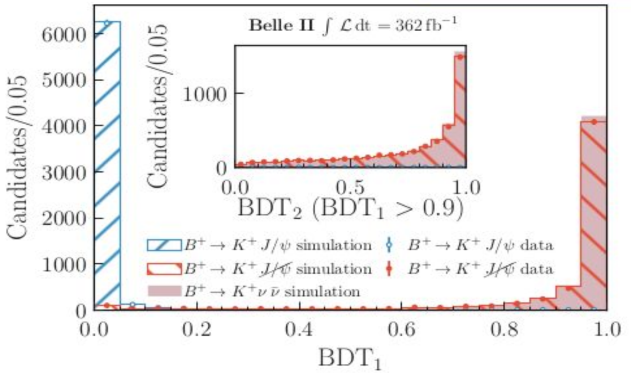
$B \to K\nu\bar{\nu}$: Validation

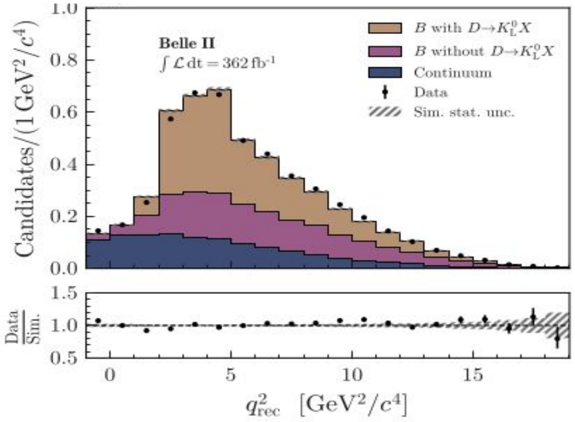
- Signal efficiency checked with signal embedded $B \to K\, J/\psi(\to \mu\,\mu)$
  Remove J/ψ and correct the kaon kinematics to match that of signal





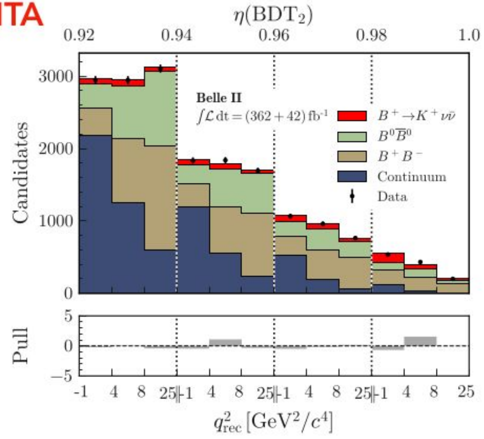
- Continuum validated with off-resonance
- $B \to X_c(\to K^0_L)$ validated from pion enriched sideband
- Signal like $B \to K^+ K^0_L K^0_L$ checked with $B \to K^+ K^0_S K^0_S$ [PRD 85 11201
- Similar treatment for $B \to K^+ K^0_S K^0_L$ and $B \to K^+ nn$
- Closure test: $\mathcal{B}(K^0\pi^+) = (2.5 \pm 0.5)\times10^{-5}$ compatible with the World average: $(2.38 \pm 0.08)\times10^{-5}$





$B \to K \nu \bar{\nu}$: Results

ITA



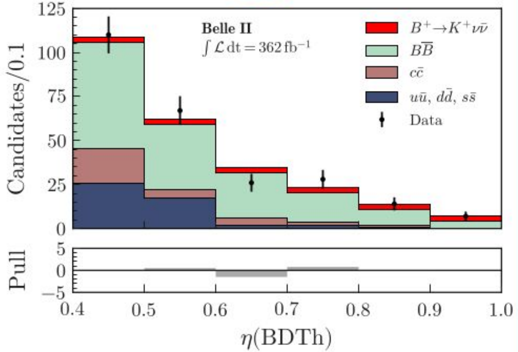
$\mu = 5.4 \pm 1.0(\mathrm{stat}) \pm 1.1(\mathrm{syst})$

corresponding to

$\mathscr{B}(B^+ \to K^+ \nu\bar{\nu}) = 2.7 \pm 0.5(\mathrm{stat}) \pm 0.5(\mathrm{syst}) \times 10^{-5}$

- 3.5 σ compatibility wrt bkg only
- 2.9 σ compatibility wrt to the SM

HTA



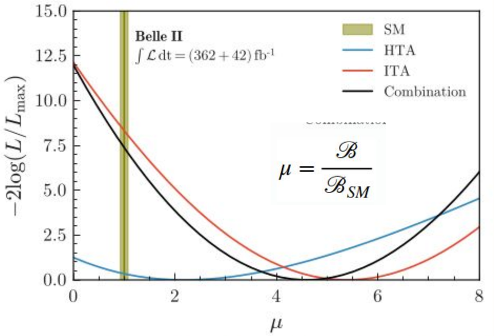
$\mu = 2.2^{+1.8}_{-1.7}(\mathrm{stat})^{+1.6}_{-1.1}(\mathrm{syst})$

corresponding to

$\mathscr{B}(B^+ \to K^+ \nu\bar{\nu}) = [1.1^{+0.9}_{-0.8}(\mathrm{stat})^{+0.8}_{-0.5}(\mathrm{syst})] \times 10^{-5}$

- 1.1 σ compatibility wrt bkg only
- 0.6 σ compatibility wrt to the SM

Combination



$\mu = 4.6 \pm 1.0(\mathrm{stat}) \pm 0.9(\mathrm{syst})$

corresponding to

$\mathscr{B}(B^+ \to K^+ \nu\bar{\nu}) = [2.3 \pm 0.5(\mathrm{stat})^{+0.5}_{-0.4}(\mathrm{syst})] \times 10^{-5}$

- Combination improves the ITA-only precision by 10%
- 3.5 σ significance wrt bkg
- 2.7 σ significance wrt SM

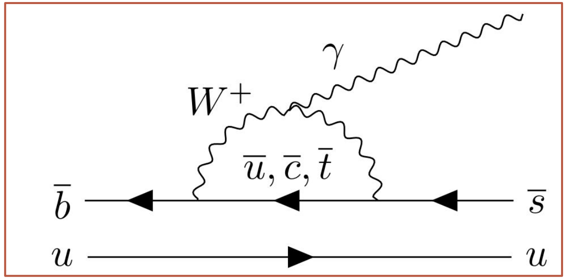
First measurement of B->K*(892)γ at Belle II

- Flavour changing neutral current decays sensitive to new physics
- First observed FCNC decay [PRL 71 (1993) 674]
- CP (A_{CP}) and isospin (Δ_{+0}) asymmetries are theoretically clean thanks to form factor cancellations
- Asymmetries are ideal for BSM searches [PRD 88 (2013) 094004] [PRL 106 (2011) 141801]
- Belle measurement found evidence of isospin asymmetry at 3.1σ [PRL 119 (2017) 191802]

$$A_{CP} = \frac{\Gamma(\bar{B} \to \overline{K^*}\gamma) - \Gamma(B \to K^*\gamma)}{\Gamma(\bar{B} \to \overline{K^*}\gamma) + \Gamma(B \to K^*\gamma)}$$

SM prediction is small (~1%)

$$\Delta A_{CP} = A_{CP}(B^0 \to K^{*0}\gamma) - A_{CP}(B^+ \to K^{*+}\gamma)$$



$$\Delta_{+0} = \frac{\Gamma(B^0 \to K^{*0}\gamma) - (B^+ \to K^{*+}\gamma)}{\Gamma(B^0 \to K^{*0}\gamma) + (B^+ \to K^{*+}\gamma)}$$

SM prediction: 4.9 ± 2.6% [PRD 88 (2013) 094004]

B->K*(892)γ: Analysis

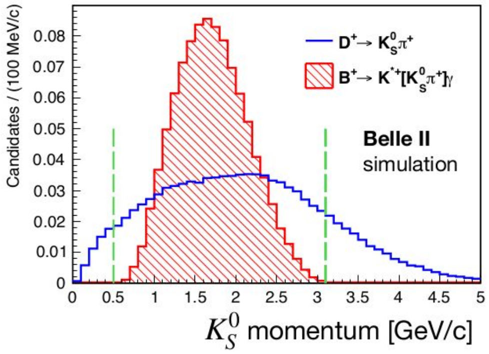
- Analysis based on run 1 data (362 fb^{-1})
- Reconstruct $K^* \to K^+ \pi^-$, $K^0_S \pi^0$, $K^+ \pi^0$, $K^0_S \pi^-$
- Combine K* with a prompt photon to get B candidate
- Dedicated BDTs to suppress continuum, $\pi \to \gamma\gamma$, and $\eta \to \gamma\gamma$ decays

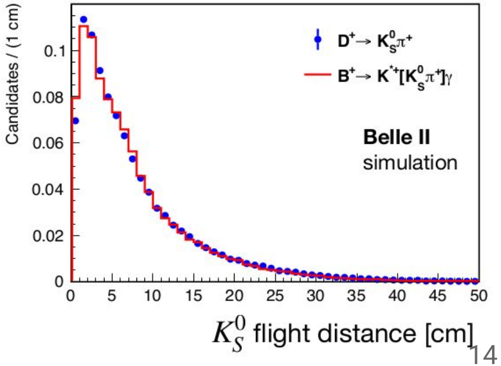
Fit strategy

- Perform 2D fit to ΔE and M_{bc} to extract signal yield

Control sample study

- Employed $B \to D^0 [D^0 \to K^- \pi^+]\pi^-$ to calibrate the BDTs (continuum, $\pi \to \gamma\gamma$, and $\eta \to \gamma\gamma$)
- Significant effort towards K^0_S systematics using $D^+ \to K^0_S \pi^+$





B->K*(892)γ : Results

- Consistent with World average and SM
- Asymmetries are statistically limited
- Similar sensitivity to Belle result despite half the data
  Δ_{0+}= 6.2 ± 1.5 (stat) ± 0.6 (sys) ± 1.2 (f_{+-}/f_{00}) [PRL 119, 191802 (2017)]
  (Thanks to improved K^0_S efficiency, continuum suppression, and addition of ΔE to fit model)

$$\mathcal{B}[B^0 \to K^{*0}\gamma] = (4.16 \pm 0.10 \pm 0.11) \times 10^{-5},$$

$$\mathcal{B}[B^+ \to K^{*+}\gamma] = (4.04 \pm 0.13 \pm 0.13) \times 10^{-5},$$

$$\mathcal{A}_{CP}[B^0 \to K^{*0}\gamma] = (-3.2 \pm 2.4 \pm 0.4)\%,$$

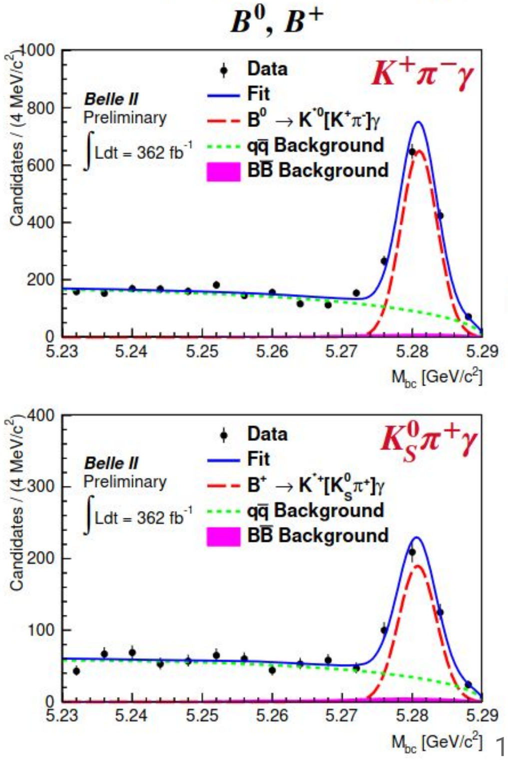
$$\mathcal{A}_{CP}[B^+ \to K^{*+}\gamma] = (-1.0 \pm 3.0 \pm 0.6)\%,$$

$$\Delta\mathcal{A}_{CP} = (2.2 \pm 3.8 \pm 0.7)\%,$$

$$\Delta_{0+} = (5.1 \pm 2.0 \pm 1.0 \pm 1.1)\%$$

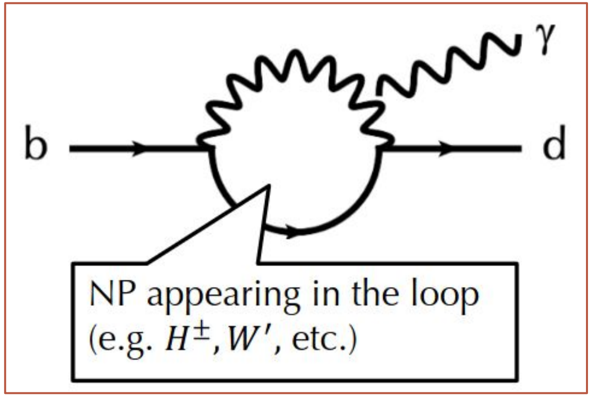
Uncertainty:
stat. + sys. + f_{+-}/f_{00} (for Δ_{0+})

⇒ Scope to improve results which are statistically limited



Exclusive measurement of B→ργ at Belle and Belle II

- Flavor changing neutral current with b → d transition
- Independent search for NP [PRD 88 (2013) 094004]
- SM branching fraction suppressed by |Vtd /Vts | ~ 0.04 with respect to B->K*(892)γ
- The first "charmless" study with Belle and Belle II joint data
- Earlier results from Belle [Phys. Rev. Lett. 101, 111801] and BaBar [Phys. Rev. D 78, 112001].



$$\Delta_{0+} = \frac{2 \times \Gamma(B^0 \to \rho^0\gamma) - \Gamma(B^+ \to \rho^+\gamma)}{2 \times \Gamma(B^0 \to \rho^0\gamma) + \Gamma(B^+ \to \rho^+\gamma)}$$

SM prediction: 5.2 ± 2.8% [PRD 88 (2013) 094004]

Current world average deviates by 2σ from SM

$$\mathcal{A}_{CP} = \frac{\Gamma(B \to \rho\gamma) - \Gamma(\bar{B} \to \bar{\rho}\gamma)}{\Gamma(B \to \rho\gamma) + \Gamma(\bar{B} \to \bar{\rho}\gamma)}$$

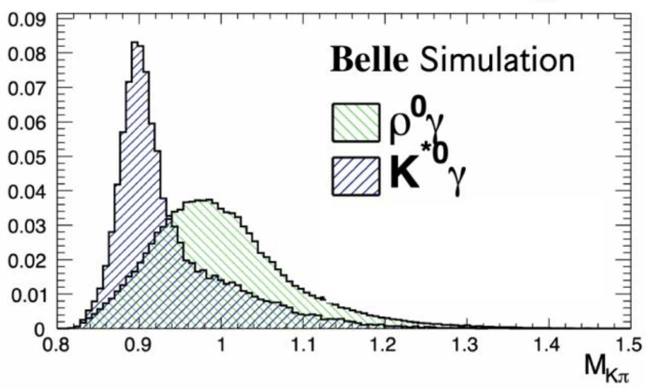
B→ργ : Analysis

- Analysis based on Belle (711 fb^{-1}) + Belle II (362 fb^{-1}) data
- Reconstruct $\rho^0 \to \pi^+\pi^-$ and $\rho^+ \to \pi^+\pi^0$, combine with prompt photon
- Define $M_{K\pi}$ as the invariant mass calculated assuming π^+ is K^+
- The $M_{K\pi}$ helps separate $K^*\gamma$ background better compared to $M_{\pi\pi}$
- Dedicated BDTs to suppress continuum, $\pi \to \gamma\gamma$, and $\eta \to \gamma\gamma$ decays

Fit Strategy

- Perform Belle+Belle II simultaneous 3D fit of M_{bc}, ΔE and $M_{K\pi}$

- **Control sample study**
- Employed $B \to K^{*0} [K^-\pi^+]\gamma$ to calibrate the BDTs (continuum, $\pi \to \gamma\gamma$, and $\eta \to \gamma\gamma$) and signal PDF modelling

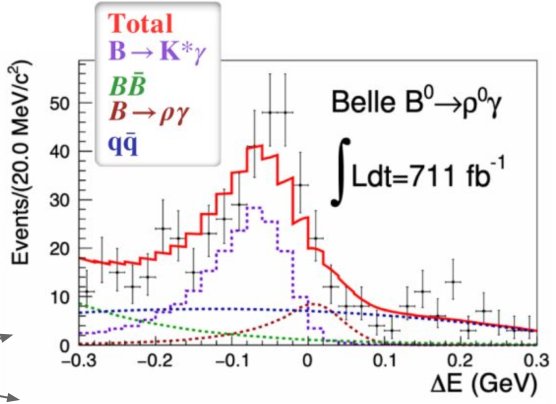


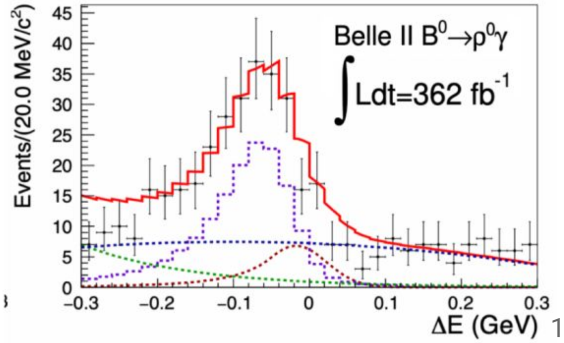
Impact of $M_{K\pi}$

B→ργ : Results

- Result for the isospin asymmetry consistent with the SM
- All measured observables are the most precise to date
- Results supersede previous Belle measurement [PRL 101 111801 (2008)]

Signal enriched projections
$M_{\mathrm{bc}} > 5.27$ GeV/c^2
$M_{K\pi} > 0.92$ GeV/c^2





$$\mathcal{B}\left(B^+ \to \rho^+\gamma\right) = \left(12.9^{+2.0+1.3}_{-1.9-1.2}\right) \times 10^{-7},$$
$$\mathcal{B}\left(B^0 \to \rho^0\gamma\right) = \left(7.5^{+1.3+1.0}_{-1.3-0.8}\right) \times 10^{-7},$$
$$A_{\mathrm{CP}}\left(B^+ \to \rho^+\gamma\right) = \left(-8.4^{+15.2+1.3}_{-15.3-1.4}\right)\%,$$
$$A_{\mathrm{I}}\left(B \to \rho\gamma\right) = \left(11.0^{+11.2+7.1+3.8}_{-11.7-6.3-3.9}\right)\%,$$

Uncertainty:
stat. + sys. + f_{+-}/f_{00} (for A_I)

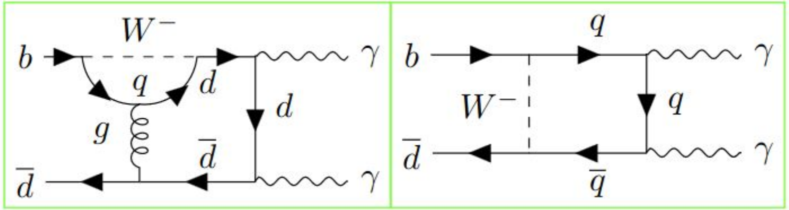
Double radiative $B^0 \to \gamma\gamma$ at Belle + Belle II

- Very rare decay with $\mathcal{B}$(SM) = $(1.4^{+1.4}_{-0.8}) \times 10^{-8}$ [JHEP 12, 169 (2020)]
- Highly CKM suppressed relative to Bs → γγ
- Challenging due to the presence of two photons in the final state; large backgrounds

Previous searches:

- PLB 363 (1995) 137-144
- PRD 73, 051107 (2006)
- PRD 83, 032006 (2011)

Experiment	Integrated Luminosity ($\int \mathcal{L}\, dt$)	Limit @ 90 C.L.
L3	73 pb^{-1}	3.9×10^{-5}
Belle	104 fb^{-1}	6.2×10^{-7}
Babar	426 fb^{-1}	3.2×10^{-7}



$B^0 -> \gamma\gamma$: Analysis

- Analysis based on combined Belle (694 fb^{-1}) + Belle II (362 fb^{-1}) data
- Reconstruct signal from two prompt photons
- Peaking background in M_{bc} due to back-to-back off time photons
  => Suppressed using photon timing cuts
- Dedicated BDTs to suppress continuum, $\pi \rightarrow \gamma\gamma$, and $\eta \rightarrow \gamma\gamma$ decays

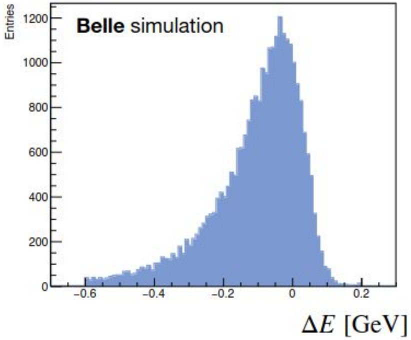
Fit strategy

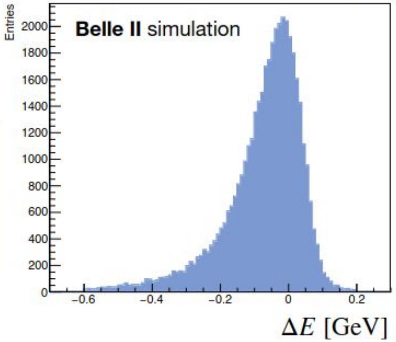
- 3D fit to ΔE, M_{bc} and transformed continuum BDT output (C'_{BDT})
- Use $B^0 -> K^*(892)[K^+\pi^-]\gamma$ as control sample

Belle vs **Belle II**

- Improved signal efficiency per fb^{-1} bkg
- Improved ΔE resolution

	Belle	Belle II
Sig efficiency	23%	31%
Exp. bkg/fb^{-1}	~ 0.8	





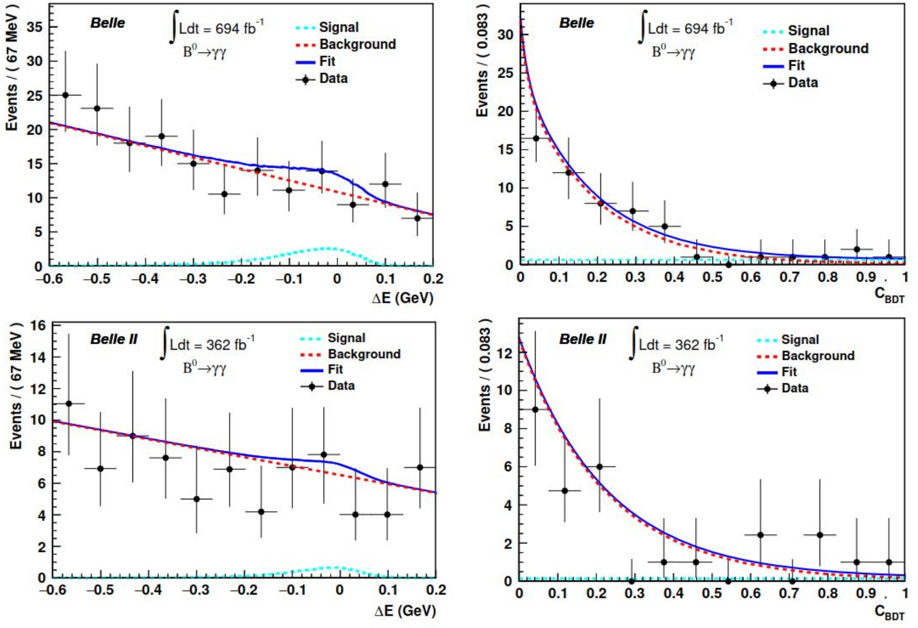
$B^0 -> \gamma\gamma$: Results

- Combined signal yield = $11.0^{+6.5}_{-5.5}$
- Since no significant signal ⇒ set 90% C.L. limits
- Sensitivity approaching SM prediction

→ **best upper limit with Belle II data**

	$\mathcal{B}(B^0 \to \gamma\gamma)$	$\mathcal{B}(B^0 \to \gamma\gamma)$ (at 90% CL)
Belle	$(5.4^{+3.3}_{-2.6} \pm 0.5) \times 10^{-8}$	$< 9.9 \times 10^{-8}$
Belle II	$(1.7^{+3.7}_{-2.4} \pm 0.3) \times 10^{-8}$	$< 7.4 \times 10^{-8}$
Combined	$(3.7^{+2.2}_{-1.8} \pm 0.7) \times 10^{-8}$	$< 6.4 \times 10^{-8}$

Expected 90 C.L. 4.4×10^{-8}



ΔE

C'_{BDT}

- Uncertainties are comparable between Belle and Belle II, despite Belle II having a smaller dataset.
- 5x improvement over previous best UL by Babar [PRD 83 (2011) 032006]

Summary

- FCNC's are attractive to probe SM and physics beyond.
- First evidence for $B^+ \rightarrow K^+ \nu\bar{\nu}$ decay with 2.7σ compatibility with SM [arxiv: 2311.14647, to appear in PRD]
- World's most precise measurement of $B \rightarrow \rho\gamma$ decays using Belle + Belle II data.
- First measurement of $B \rightarrow K^*(892)\gamma$ at Belle II
- Best upper limit for $B^0 \rightarrow \gamma\gamma$ rarest decay measured with Belle + Belle II data so far

Backup

B→γγ : Systematics

Signal yield

Source	Belle (%)	Belle II (%)
Photon Detection Efficiency	4.0	2.7
Reconstruction Efficiency (ϵ_{rec})	0.6	0.5
Number of $B\overline{B}$	1.3	1.5
f^{00}	2.5	2.5
C_{BDT} requirement	0.4	0.9
π^0/η veto	0.3	0.4
Timing requirement efficiency	2.8	–
Total (sum in quadrature)	5.7	4.1

Signal efficiencies

Source	Belle (events)	Belle II (events)
Fit bias	+0.16	+0.12
PDF parameterization	$^{+0.56}_{-0.48}$	$^{+0.30}_{-0.32}$
Shape Modeling	+0.06	+0.04
Total (sum in quadrature)	$^{+0.58}_{-0.48}$	$^{+0.30}_{-0.32}$

B->K*(892)γ : Systematics

Belle II

$\mathscr{B}$

Source	$K^{*0}[K^+\pi^-]\gamma$	$K^{*0}[K_S^0\pi^0]\gamma$	$K^{*+}[K^+\pi^0]\gamma$	$K^{*+}[K_S^0\pi^+]\gamma$
B counting	1.5	1.5	1.5	1.5
$f^{\pm}/f^{00}$	1.6	1.6	1.6	1.6
γ selection	0.9	0.9	0.9	0.9
π^0 veto	0.7	0.7	0.7	0.7
η veto	0.2	0.2	0.2	0.2
Tracking efficiency	0.5	0.5	0.2	0.7
π^+ selection	0.2	–	–	0.2
K^+ selection	0.4	–	0.4	–
K_S^0 reconstruction	–	1.4	–	1.4
π^0 reconstruction	–	3.9	3.9	–
χ^2 selection	0.2	1.0	0.2	1.0
CSBDT selection	0.3	0.4	0.4	0.3
Candidate selection	0.1	1.0	0.6	0.2
Fit bias	0.1	0.9	0.5	0.2
Signal PDF model	0.1	0.4	0.3	0.2
KDE PDF model	0.1	0.8	0.6	0.2
Simulation sample size	0.2	0.8	0.4	0.5
Misreconstructed signal	–	1.0	1.0	–
Total	2.6	5.4	4.9	3.2

A_{CP}

Source	$K^{*0}[K^+\pi^-]\gamma$	$K^{*+}[K^+\pi^0]\gamma$	$K^{*+}[K_S^0\pi^+]\gamma$
Fit bias	0.1	0.2	0.2
Signal PDF model	0.1	0.1	0.1
KDE modelling	0.1	0.4	0.2
BCS	0.1	0.5	0.2
K^+ asymmetry	–	0.6	–
π^+ asymmetry	–	–	0.6
$K^+\pi^-$ asymmetry	0.3	–	–
Total	0.4	0.9	0.7

$B \to K \nu \bar{\nu}$: Systematics

TABLE I. Sources of systematic uncertainty in the ITA, corresponding correction factors (if any), their treatment in the fit, their size, and their impact on the uncertainty of the signal strength μ. The uncertainty type can be "Global", corresponding to a global normalization factor common to all SR bins, or "Shape", corresponding to a bin-dependent uncertainty. Each source is described by one or more nuisance parameters (see the text for more details). The impact on the signal strength uncertainty σ_μ is estimated by excluding the source from the minimization and subtracting in quadrature the resulting uncertainty from the uncertainty of the nominal fit.

Source	Correction	Uncertainty type, parameters	Uncertainty size	Impact on σ_μ
Normalization of $B\overline{B}$ background	—	Global, 2	50%	0.90
Normalization of continuum background	—	Global, 5	50%	0.10
Leading B-decay branching fractions	—	Shape, 5	$O(1\%)$	0.22
Branching fraction for $B^+ \to K^+ K^0_L K^0_L$	q^2 dependent $O(100\%)$	Shape, 1	20%	0.49
p-wave component for $B^+ \to K^+ K^0_S K^0_L$	q^2 dependent $O(100\%)$	Shape, 1	30%	0.02
Branching fraction for $B \to D^{**}$	—	Shape, 1	50%	0.42
Branching fraction for $B^+ \to K^+ n\bar{n}$	q^2 dependent $O(100\%)$	Shape, 1	100%	0.20
Branching fraction for $D \to K^0_L X$	+30%	Shape, 1	10%	0.14
Continuum-background modeling, BDT$_c$	Multivariate $O(10\%)$	Shape, 1	100% of correction	0.01
Integrated luminosity	—	Global, 1	1%	< 0.01
Number of $B\overline{B}$	—	Global, 1	1.5%	0.02
Off-resonance sample normalization	—	Global, 1	5%	0.05
Track-finding efficiency	—	Shape, 1	0.3%	0.20
Signal-kaon PID	p, θ dependent $O(10-100\%)$	Shape, 7	$O(1\%)$	0.07
Photon energy	—	Shape, 1	0.5%	0.08
Hadronic energy	−10%	Shape, 1	10%	0.37
K^0_L efficiency in ECL	−17%	Shape, 1	8%	0.22
Signal SM form-factors	q^2 dependent $O(1\%)$	Shape, 3	$O(1\%)$	0.02
Global signal efficiency	—	Global, 1	3%	0.03
Simulated-sample size	—	Shape, 156	$O(1\%)$	0.52

B→ργ : Systematics

Source	$\mathcal{B}_{\rho^+\gamma} \times 10^8$	$\mathcal{B}_{\rho^0\gamma} \times 10^8$	A_{I}	A_{CP}
Particle detection	4.1	1.3	1.4%	0.5%
Selection efficiencies	9.0	3.4	4.0%	0.5%
Fixed fit parameters	1.1	2.7	1.8%	0.2%
Signal shape	4.7	3.0	3.1%	0.5%
Histogram PDFs	1.0	0.6	0.5%	0.1%
Peaking $K^*\gamma$ bkg	3.4	5.4	3.1%	0.1%
Other peaking $B\overline{B}$ bkgs	2.2	0.8	0.9%	0.2%
Peaking $B\overline{B}$ A_{CP}	0.1	<0.1	0.1%	1.0%
Number of $B\overline{B}$'s	1.7	1.4	0.3%	0.1%
$\tau_{B^\pm}/\tau_{B^0}$	0.1	<0.1	0.2%	<0.1%
f_{+-}/f_{00}	4.0	3.6	3.8%	<0.1%
Total	12.5	8.6	7.5%	1.4%

$b \to d \ell^+ \ell^-$ with Belle

- $\mathscr{B}_{SM} \leq \mathcal{O}(10^{-8})$
- Probe lepton flavour universality
- LHCb ($3\ fb^{-1}$) observed final states with $\pi^{\pm}$ in muon modes
  JHEP10(2015)034
- Suppress peaking J/ψ and $\psi(2S)$ background and fit to ΔE and M_{bc}

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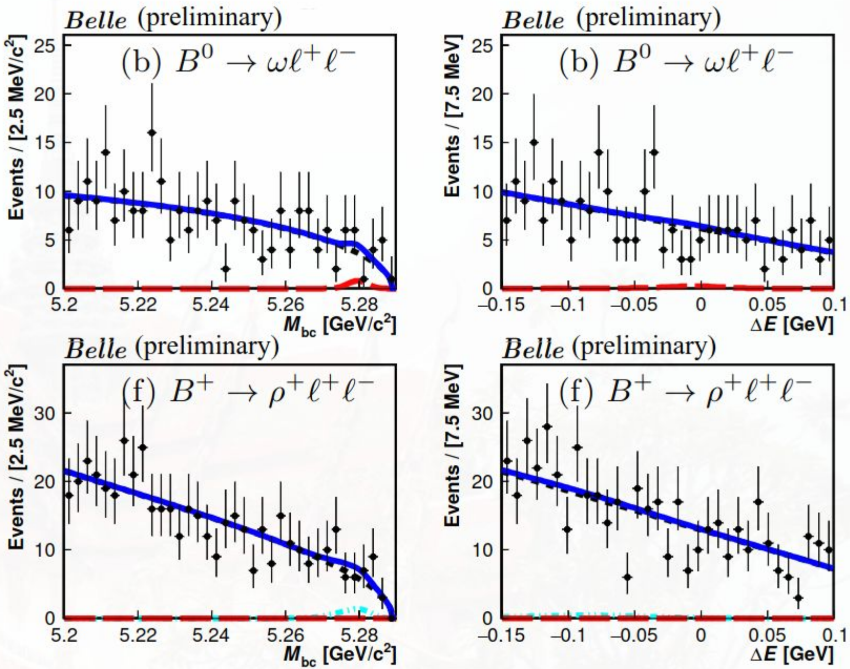
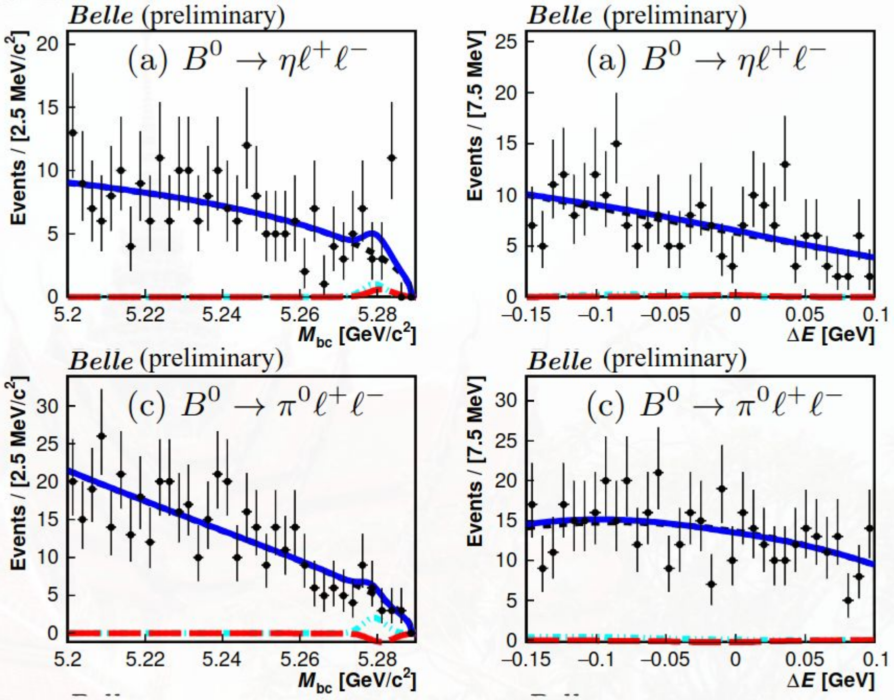


$b \to d \ell^+ \ell^-$ with Belle *(submitted to PRL ; arXiv:2404.08133)*

	$\mathcal{B}^{UL}$ (10^{-8})	$\mathcal{B}$ (10^{-8})
$B^0 \to \eta e^+ e^-$	< 10.5	$0.0^{+4.9}_{-3.4} \pm 0.1$
$B^0 \to \eta \mu^+ \mu^-$	< 9.4	$1.9^{+3.4}_{-2.5} \pm 0.2$
$B^0 \to \eta \ell^+ \ell^-$	< 4.8	$1.3^{+2.8}_{-2.2} \pm 0.1$
$B^0 \to \omega e^+ e^-$	< 30.7	$-2.1^{+26.5}_{-20.8} \pm 0.2$
$B^0 \to \omega \mu^+ \mu^-$	< 24.9	$7.7^{+10.8}_{-7.5} \pm 0.6$
$B^0 \to \omega \ell^+ \ell^-$	< 22.0	$6.4^{+10.7}_{-7.8} \pm 0.5$
$B^0 \to \pi^0 e^+ e^-$	< 7.9	$-5.8^{+3.6}_{-2.8} \pm 0.5$
$B^0 \to \pi^0 \mu^+ \mu^-$	< 5.9	$-0.4^{+3.5}_{-2.6} \pm 0.1$
$B^0 \to \pi^0 \ell^+ \ell^-$	< 3.8	$-2.3^{+2.1}_{-1.5} \pm 0.2$
$B^+ \to \pi^+ e^+ e^-$	< 5.4	$0.1^{+2.7}_{-1.8} \pm 0.1$
$B^0 \to \rho^0 e^+ e^-$	< 45.5	$23.6^{+14.6}_{-11.2} \pm 1.1$
$B^+ \to \rho^+ e^+ e^-$	< 46.7	$-38.2^{+24.5}_{-17.2} \pm 3.4$
$B^+ \to \rho^+ \mu^+ \mu^-$	< 38.1	$13.0^{+17.5}_{-13.3} \pm 1.1$
$B^+ \to \rho^+ \ell^+ \ell^-$	< 18.9	$2.5^{+14.6}_{-11.8} \pm 0.2$



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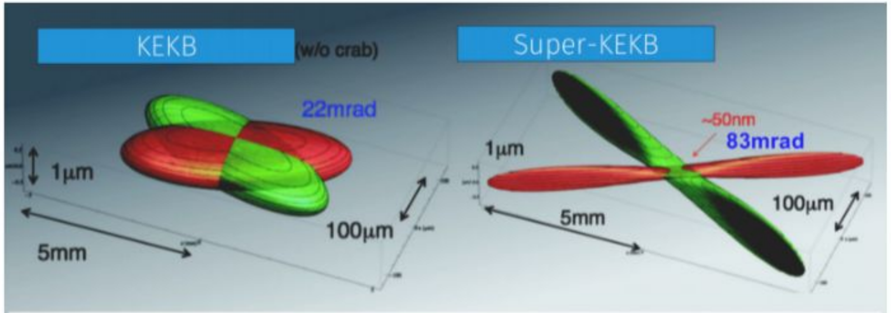
World's best limits in all channels. First search for $\omega\ell^+\ell^-$, $\rho^0 e^+ e^-$, $\rho^\pm \ell^+ \ell^-$ modes

SuperKEKB vs KEKB



	E (GeV) LER/HER	β^*_y (mm) LER/HER	β^*_x (cm) LER/HER	φ (mrad)	I (A) LER/HER	L ($cm^{-2}s^{-1}$)
KEKB	3.5/8.0	5.9/5.9	120/120	11	1.6/1.2	2.1 x 10^{34}
SuperKEKB	4.0/7.0	0.27/0.30	3.2/2.5	41.5	3.6/2.6	80 x 10^{34}

factor 20 · factor 2-3

	KEKB		**SuperKEKB (Juni 2022)**		SuperKEKB Ziel	
	LER	HER	**LER**	**HER**	LER	HER
Energie [GeV]	3.5	8	**4**	**7**	4	7
#Bunches	1584		**2249**		1800	
β^*_x/β^*_y [mm]	1200/5.9	1200/5.9	**80/1.0**	**60/1.0**	32/0.27	25/0.3
I [A]	1.64	1.19	**1.46**	**1.15**	2.8	2.0
Luminosität [10^{34} $cm^{-2}s^{-1}$]	2.1		**4.65** (Rekord!)		60	
Int. Luminosität [ab^{-1}]	1		**0.43**		50	