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Belle II

Recent Belle II results on electroweak and radiative penguins

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On behalf of the Belle II collaboration

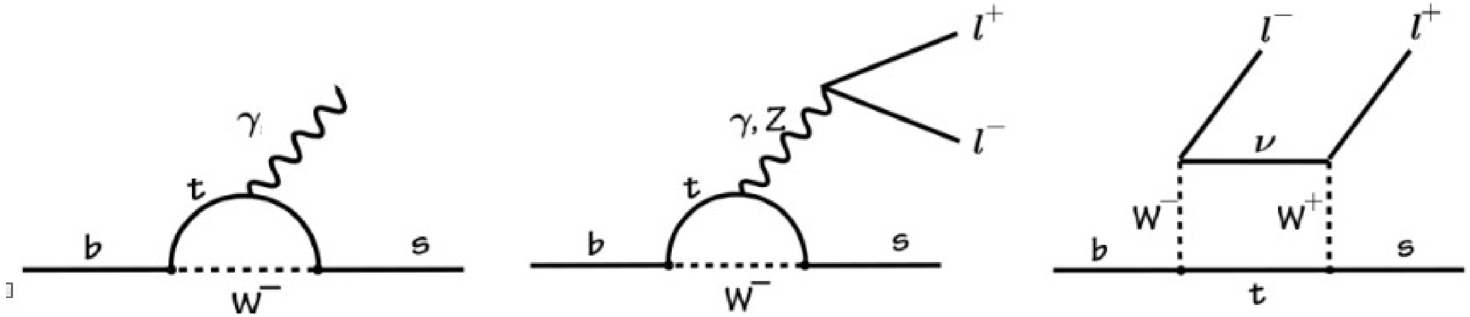
Quirks in Quark Flavor Physics

Zadar, 14-17.6. 2022

NP in radiative and EW penguins

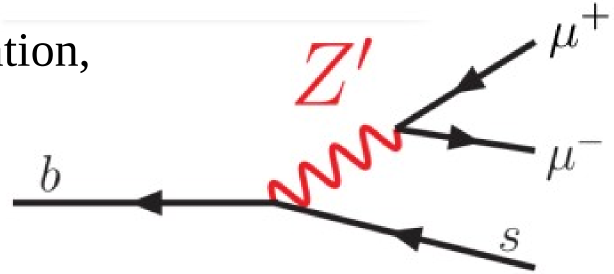
- FCNC processes: suppressed in the SM; only via loop and box diagrams

$b \to s\gamma$ $b \to sl^+l^-$ $b \to s\nu\nu$ $\mathcal{B} \sim 10^{-5}$ and less



- High sensitivity to potential NP contributions in loops or new tree diagrams

→ enhancing/suppressing decay rates, inducing lepton flavor violation, affecting angular observables, etc.



NP in radiative and EW penguins

- Effective field theory description (NP model independent):

$$\mathcal{L}_{\rm eff} = \frac{4G_F}{\sqrt{2}} V_{ts} V_{tb}^{*} \sum_i \underbrace{C_i \mathcal{O}_i}_{\text{left-hand}} + \underbrace{C_i' \mathcal{O}_i'}_{\text{right-hand}}$$

$\mathcal{C}_i$ - Wilson coefficients → short distance

$\mathcal{O}_i$ - operator matrix elements → long dist.

- radiative and EW penguins sensitive to

$\mathcal{C}_7^{(\prime)}, \mathcal{O}_7 \sim (s_L \sigma^{\mu\nu} b_R) F_{\mu\nu}$ **Photon penguin**

$\mathcal{C}_9^{(\prime)}, \mathcal{O}_9 \sim (\bar{s}_L \gamma_\mu b_L)(\bar{l}\gamma^\mu l)$ **EW vector**

$\mathcal{C}_{10}^{(\prime)}, \mathcal{O}_{10} \sim (\bar{s}_L \gamma_\mu b_L)(\bar{l}\gamma_5\gamma^\mu l)$ **EW axial-vector**

- NP can contribute in $\mathcal{C}_i \rightarrow \mathcal{C}_i^{SM} + \mathcal{C}_i^{NP}$ $\mathcal{C}_i' \rightarrow \mathcal{C}_i'^{SM} + \mathcal{C}_i'^{NP}$

↳ m_s/m_b suppressed

- different observables sensitive to different combinations of $\mathcal{C}_i$‘s

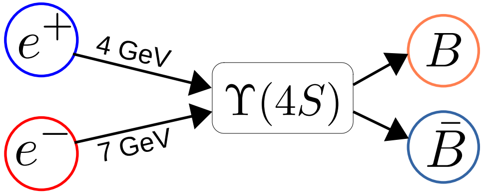
→ pinpoint NP contributions by measuring many observables

→ exploit the power of global fits to understand its nature

Belle II @ SuperKEKB – B factory of 2nd generation

Belle II @ SuperKEKB – B factory of 2nd generation

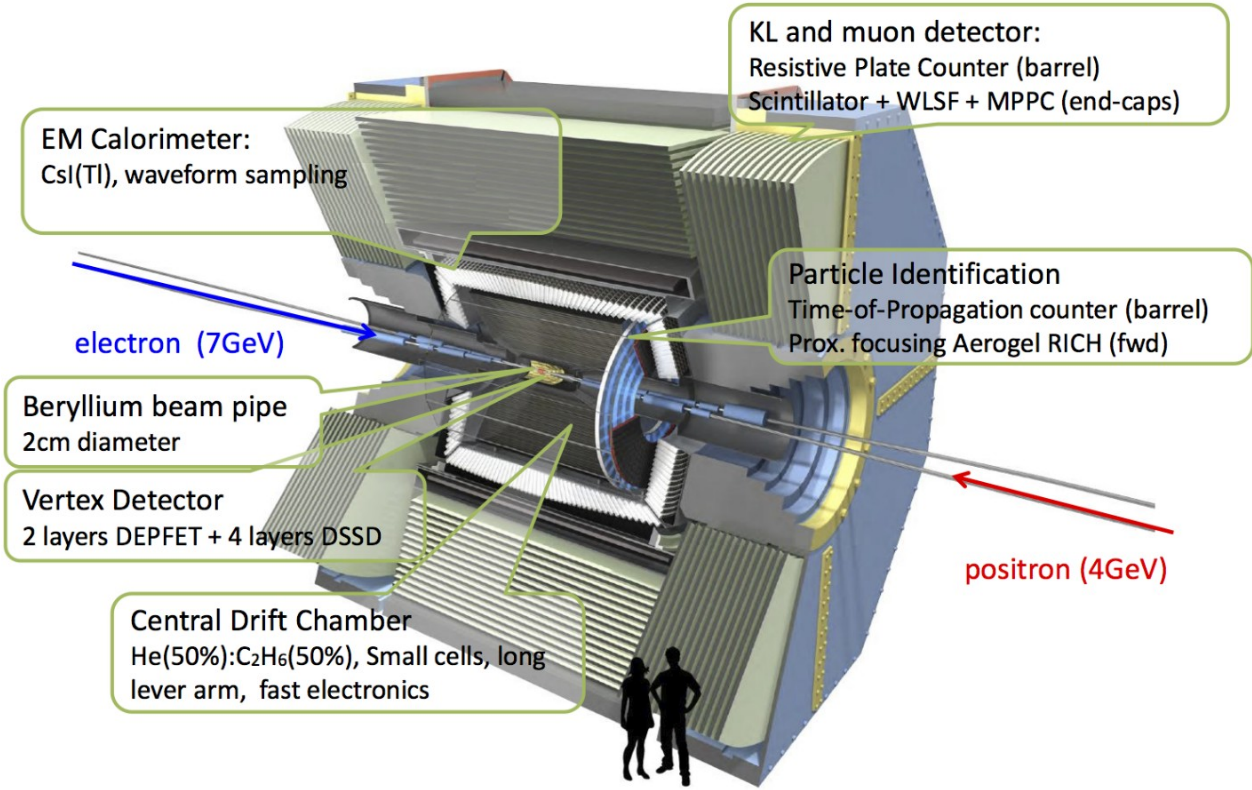
- **SuperKEKB:** asymmetric e^+e^- collider operating nominally at $\Upsilon(4S) = 10.58\ \mathrm{GeV}$



(+ large number of D, τ !)

Design luminosity: $6.5 \times 10^{35}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$

30 x higher than KEKB



- **Belle II:** general purpose spectrometer

→ 4π coverage
→ clean e^+e^- environment with known initial state!
→ good charged track reconstruction efficiency, particle identification, gamma reconstruction
→ excellent vertexing ($\sigma \sim 60\mu\mathrm{m}$, for B,D vertices)

So far collected data

- **SuperKEKB** achieved world record instantaneous luminosity of

$$4.65 \times 10^{34}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$$

$2.1 \times 10^{34}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$ @ KEKB
$1.2 \times 10^{34}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$ @ PEP-II

- **Belle II** data taking efficiency ~ 90%

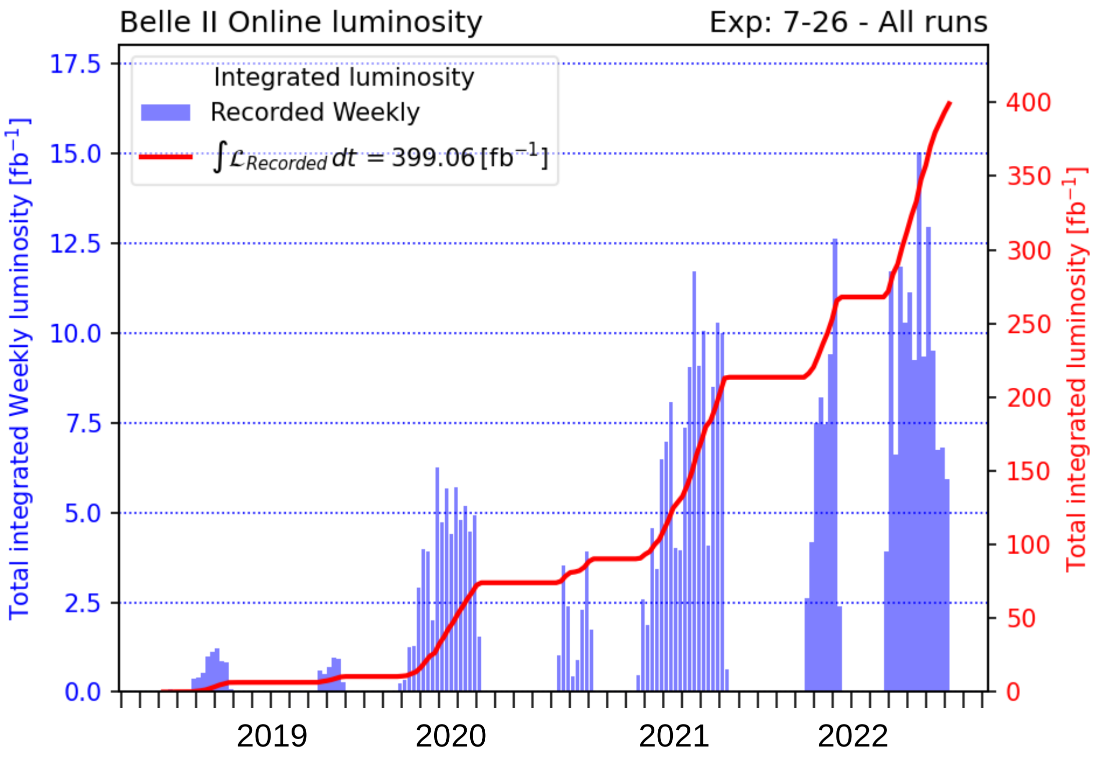
- Recorded luminosity @ Belle II

$$> 400\ \mathrm{fb}^{-1}$$

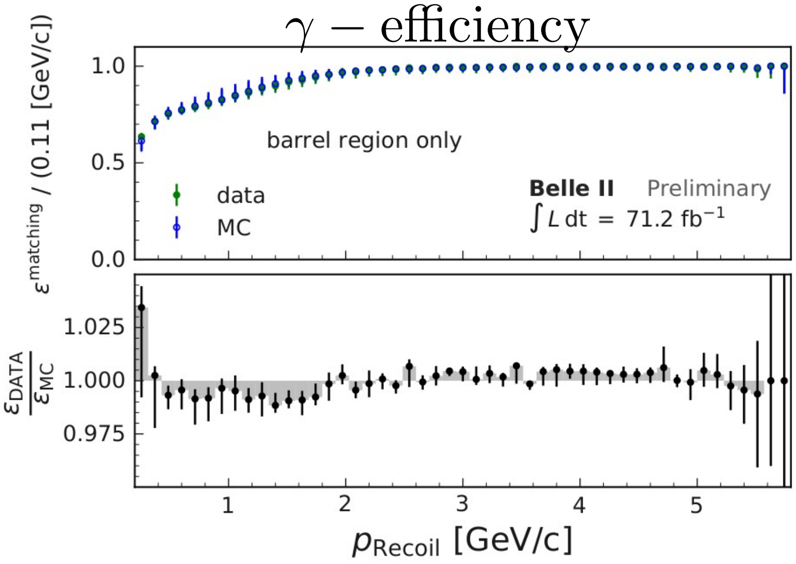
$988\ \mathrm{fb}^{-1}$ @ Belle
$513\ \mathrm{fb}^{-1}$ @ BaBar

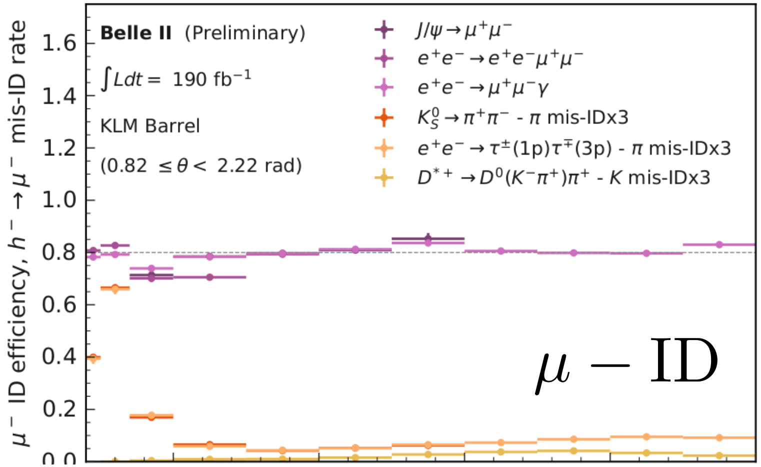
- After LS1 boost in instantaneous luminosity

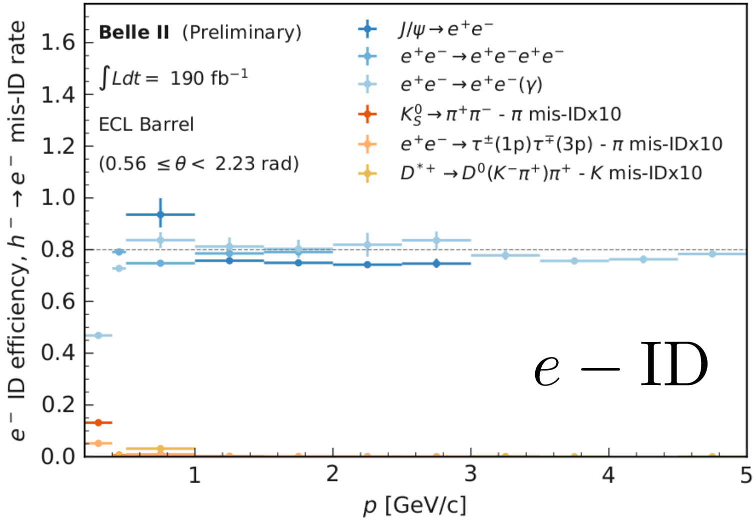
→ expect $50\ \mathrm{ab}^{-1}$ in the next 10 years



Belle II performance







- excellent and well understood γ reconstruction efficiency (important also for π^0, η reconstruction)

- excellent lepton ID (both, e and μ)

- good hadron ID

- improved reconstruction algorithms w.r.t. Belle (e.g. Full-Event-Interpretation)

Rare radiative B decays ($b \to s\gamma$)

- variety of techniques and observables accessible at Belle II

inclusive / exclusive

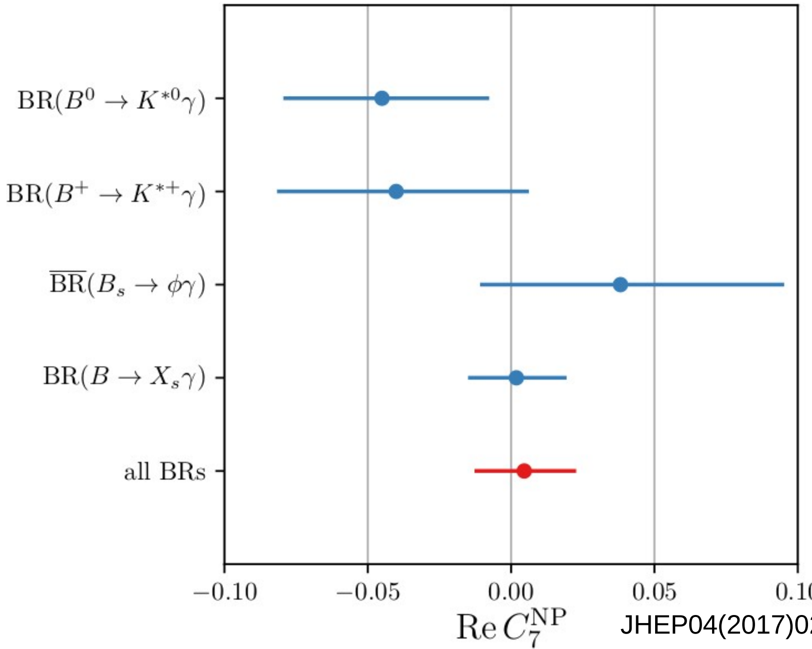
Branching fractions, Isospin asymmetries, CP asymmetries
Inclusive spectrum parameters: m_b, μ_π^2 → inputs for inclusive $|V_{ub}|$

- most precise measurements available from Belle

	B → K* γ	B → X_s γ
BF Precision	3% [3]	10% [2] b → s γ inclusive BF theoretically well described in SM[5], [6]
A_{CP}	consistent with 0 and SM predictions [1], [3], [4]	
Δ_{0+}	first evidence for isospin violation @ 3.1 σ [3]	consistent with 0 [1]

[1] Phys.Rev.D 99 (2019) 3, 032012
[2] Phys.Rev.D 91 (2015) 5, 052004
[3] Phys.Rev.Lett. 119 (2017) 19, 191802
[4] hep-ph/1608.02556
[5] Phys.Rev.Lett. 98 (2007) 022002
[6] Phys.Rev.Lett. 98 (2007) 022003

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

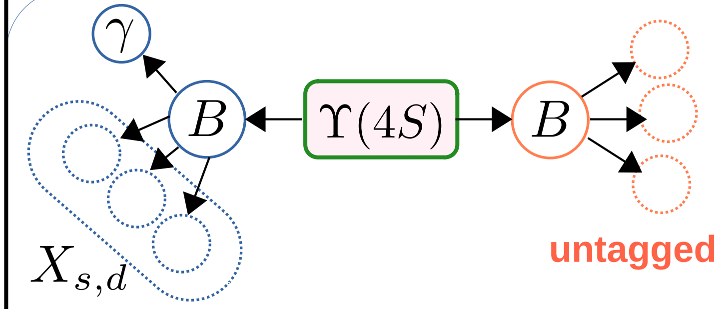


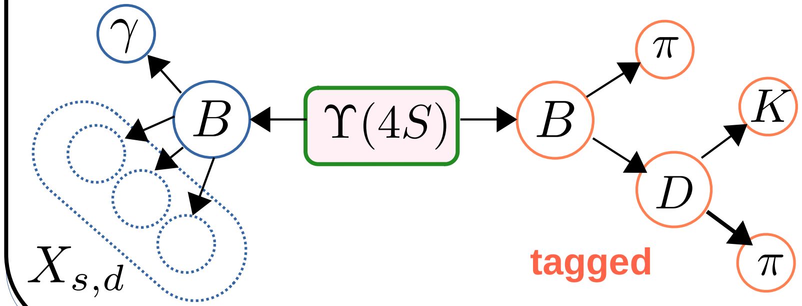
JHEP04(2017)027

Rare radiative B decays – measurement techniques

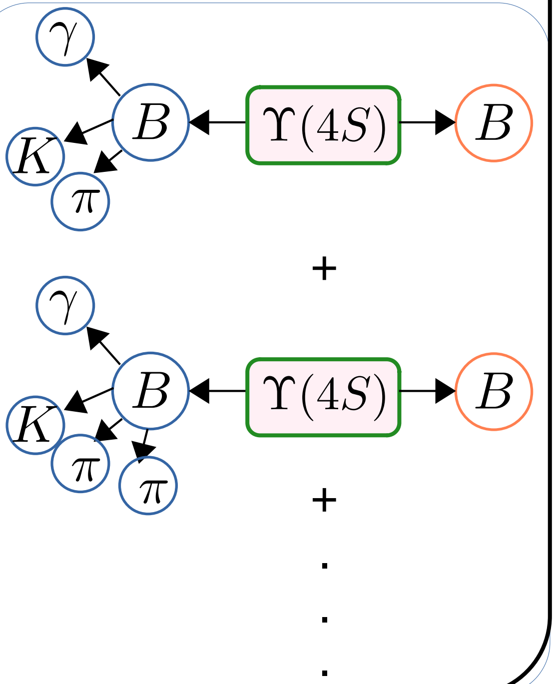
Inclusive $B \to X_{s,d}\gamma$

fully inclusive



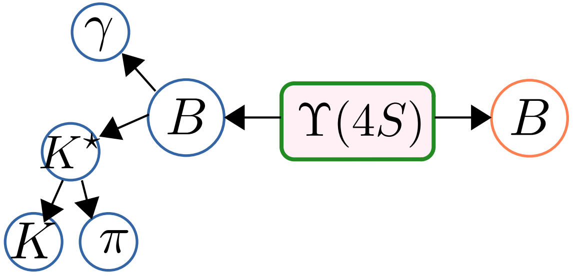


sum-of-exclusive



Exclusive measurements

e.g. $B \to K^{\star}\gamma, \; B \to \rho\gamma$



experimental challenge ←

theory challenge →

Branching fraction of $B \to K^\star \gamma$

[hep-ex:2110.08219]

- signal fully reconstructed: $B^0 \to K^{*0}[K^+\pi^-]\gamma$
  $B^0 \to K^{*0}[K^0_S\pi^0]\gamma$
  $B^+ \to K^{*+}[K^+\pi^0]\gamma$
  $B^+ \to K^{*+}[K^0_S\pi^+]\gamma$

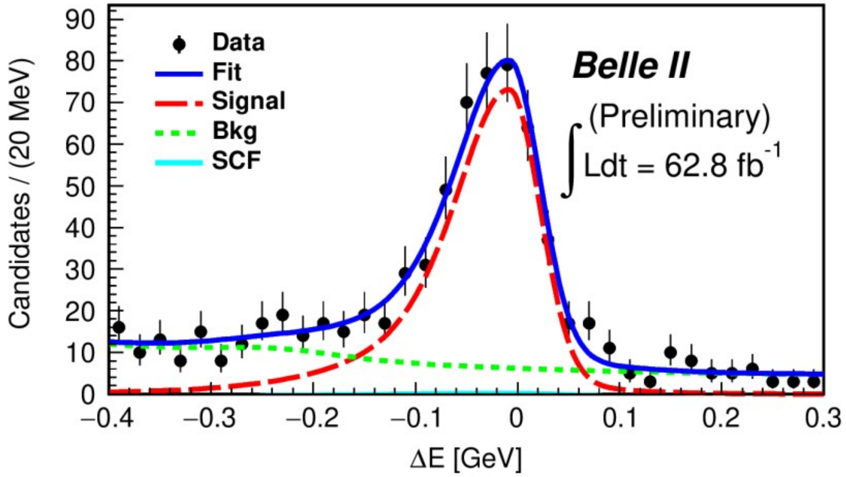
  $2.25 < E^*_\gamma < 2.85$ GeV

- large background from continuum events suppressed BDT based on the event shape variables

- signal extracted by an unbinned maximum likelihood fit to ΔE distribution ($\Delta E = E^\star_B - \sqrt{s}/2$)

Mode	$\mathcal{B}_{\text{meas}}$ $[10^{-5}]$	$\mathcal{B}_{\text{PDG}}$ $[10^{-5}]$
$B^0 \to K^{*0}\gamma$	$4.5 \pm 0.3 \pm 0.2$	4.18 ± 0.25
$B^+ \to K^{*+}\gamma$	$5.2 \pm 0.4 \pm 0.3$	3.92 ± 0.22

- Main systematics contributions:
  → fit modelling
  → mis-modelling of π^0 /η veto
  and selection variables in simulation



(a) $B^0 \to K^{*0}[K^+\pi^-]\gamma$

- In the pipeline:

  → update, including isospin & CP asymmetry

  → measurement of $B \to \rho\gamma$ based on the full Belle + Belle II dataset

First inclusive measurements: $B \to X_s\gamma$

[BELLE2-NOTE-PL-2021-004]

- measurement with **untagged** approach

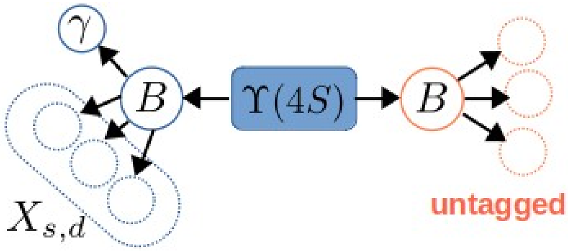
  → only high E gamma reconstructed

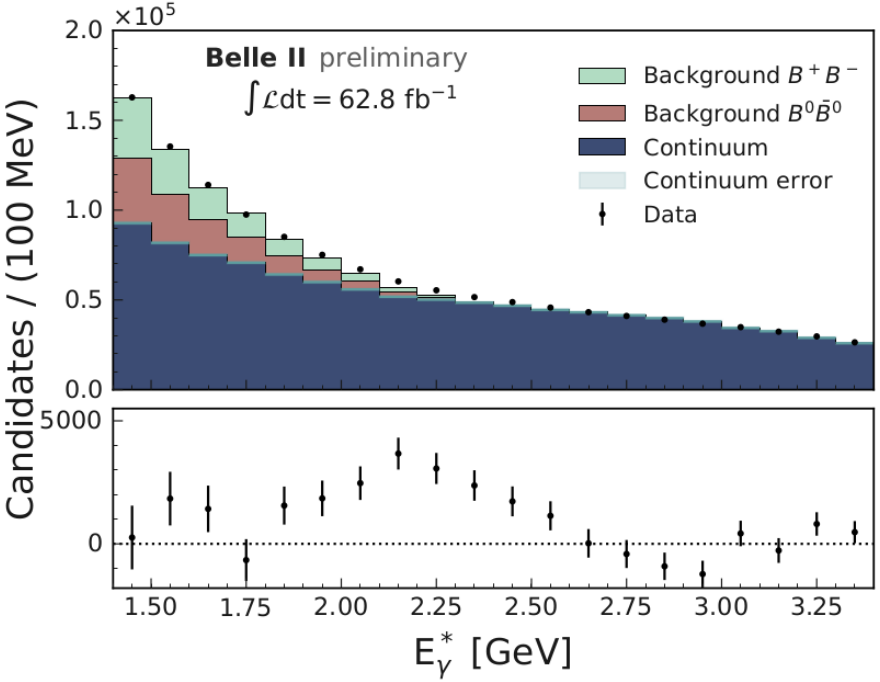
  → photon spectrum obtained by subtracting expected backgrounds:

  * continuum ($q\bar{q}$) from the off-resonance data
  * BB from the MC

  → clear excess consistent with $B \to X_{s,d}\gamma$ observed

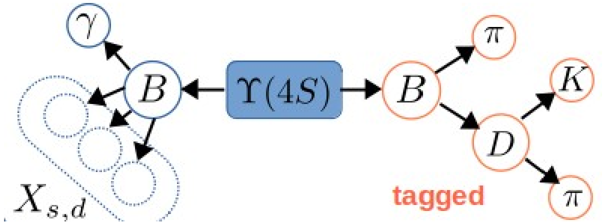
  → aim to provide competitive physics result using $\sim 0.5\ \mathrm{ab}^{-1}$





First inclusive measurements: $B \to X_s\gamma$

- in the pipeline measurements with:

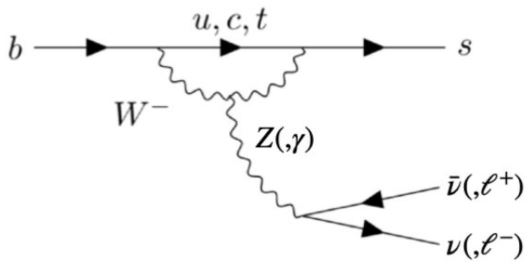


→ **hadronic tag** (FEI) approach: - lower statistics
- but independent systematics from other
- only used by BaBar → provide competitive measurement

Year	Experiment	Tag type	Data on res	$\mathcal{B}(B \to X_s\gamma) \times 10^{-4}$	Threshold
2007	**BaBar**	**Hadronic**	**210 fb^{-1}**	$3.66 \pm 0.85(\text{stat.}) \pm 0.60(\text{syst.})$	$E_\gamma^* > 1.9$ GeV
2009	Belle	No-tag/lepton	605 fb^{-1}	$3.45 \pm 0.15(\text{stat.}) \pm 0.40(\text{syst.})$	$E_\gamma^B > 1.7$ GeV
2012	BaBar	lepton	347 fb^{-1}	$3.21 \pm 0.15(\text{stat.}) \pm 0.29(\text{syst.})$	$E_\gamma^B > 1.7$ GeV
2012	BaBar	Sum-of-exclusive	429 fb^{-1}	$3.29 \pm 0.19(\text{stat.}) \pm 0.48(\text{syst.})$	$E_\gamma^B > 1.7$ GeV
2016	Belle	lepton	711 fb^{-1}	$3.12 \pm 0.10(\text{stat.}) \pm 0.19(\text{syst.})$	$E_\gamma^B > 1.6$ GeV

→ **semi-leptonic tag:** - not used before

Electroweak penguin B decays



LFU in $b \to s\ell^+\ell^-$

→ excellent electron identification (nearly symmetric e, μ performance)

→ provide independent test of anomalies with few ab^{-1} of data

→ able to measure $R(X_s)$

→ provide independent measurement of absolute BR for e, μ modes

EWP with missing energy

→ known initial state allows accessing decay modes with ν in the final state

→ $b \to s\nu\bar{\nu}$ - sensitive probe of the SM

→ $b \to s\tau\tau$ - test of LFU (increased sensitivity to NP with enhanced coupling to heavier particles)

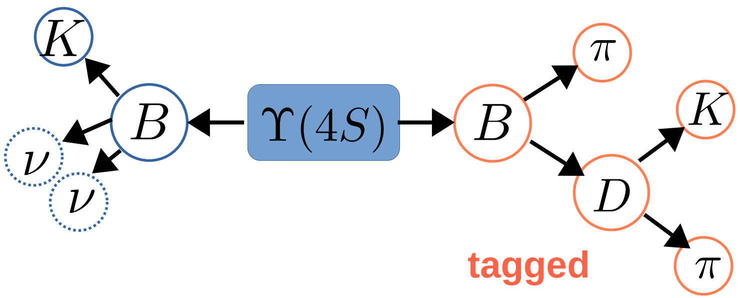
→ $b \to s\tau\ell$ - test of LFV (if LFU is indeed violated, LFV is allowed)

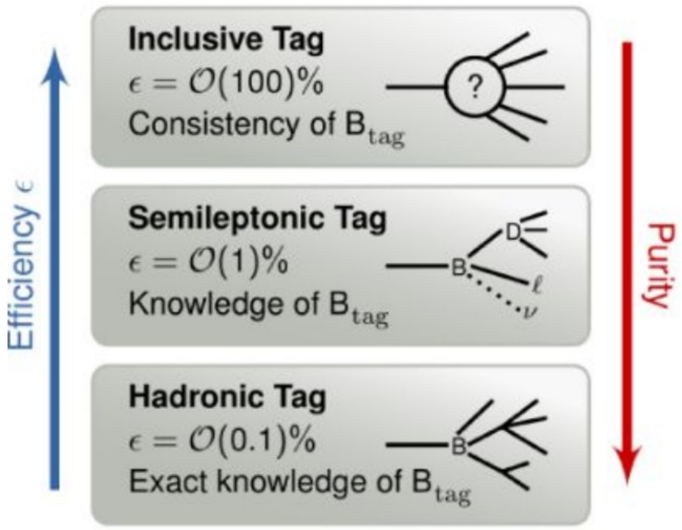
Search for $B^+ \to K^+ \nu\bar{\nu}$

Phys.Rev.Lett. 127 (2021) 18, 181802

Belle II

- clean SM prediction $\mathcal{B} = (4.6 \pm 0.5) \times 10^{-6}$
  [J. High Energ. Phys. 2015, 184 (2015)]
- not yet observed!
- uniquely accessible at B factories:
  - → traditionally searched for with explicit B_{tag} recontruction
  - → low reconstruction efficiency: ~0.2% (Phys. Rev. D 87, 112005 (2013); Phys. Rev. D 96, 091101 (2017))
  - → most stringent limit from BaBar: $\mathcal{B} < 1.6 \times 10^{-5}$@ 90% CL





Search for $B^+ \to K^+\nu\bar{\nu}$ @ Belle II

Phys.Rev.Lett. 127 (2021) 18, 181802

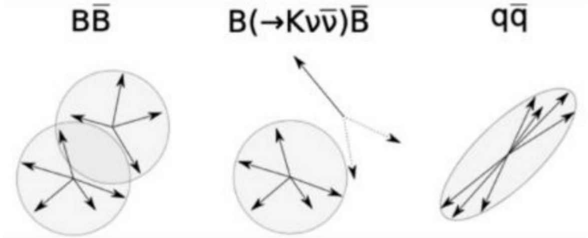
- this measurement uses novel method with no explicit B_{tag} reconstruction

- it exploits distinct signal kinematics:

 → select highest p_T kaon kandidate

 → all other tracks associated to B_{tag}

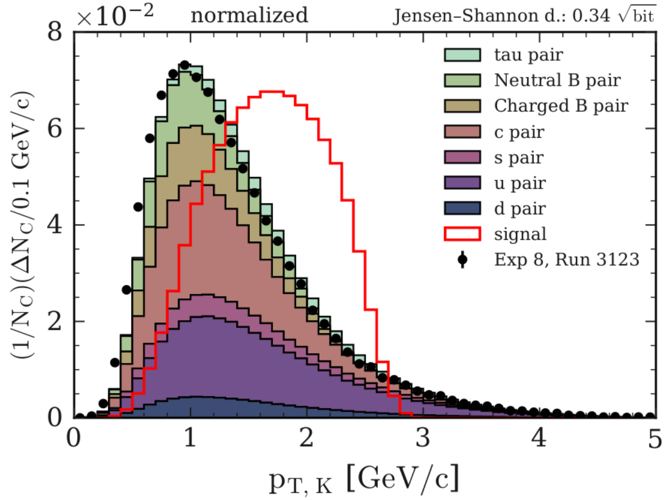
→ minimizing the background contamination with constraints on event topology, missing energy and vertex separation

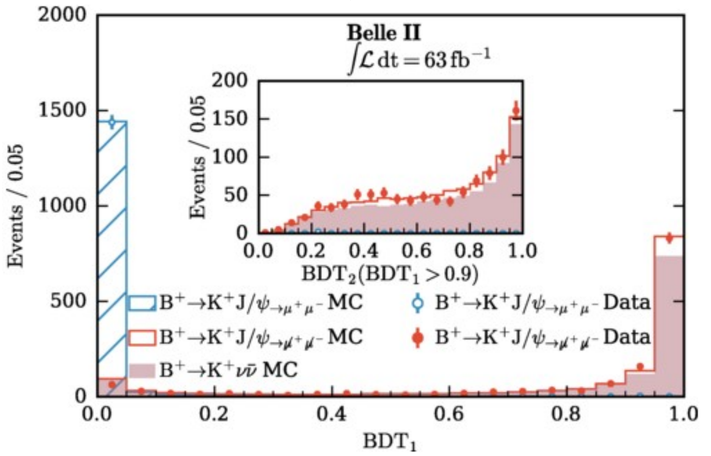


51 discriminating variables included into two step BDT

→ signal reconstruction eff. of ~4%

→ validated using $B^+ \to J/\psi(\to \mu^+\mu^-)K^+$ with removal of di-muon





Search for $B^+ \to K^+\nu\bar{\nu}$ @ Belle II

- signal yiels is extracted from simultaneous maximum likelihood fit to on-resonance and off- resonance data in bins of $p_T(K^+)$and second BDT

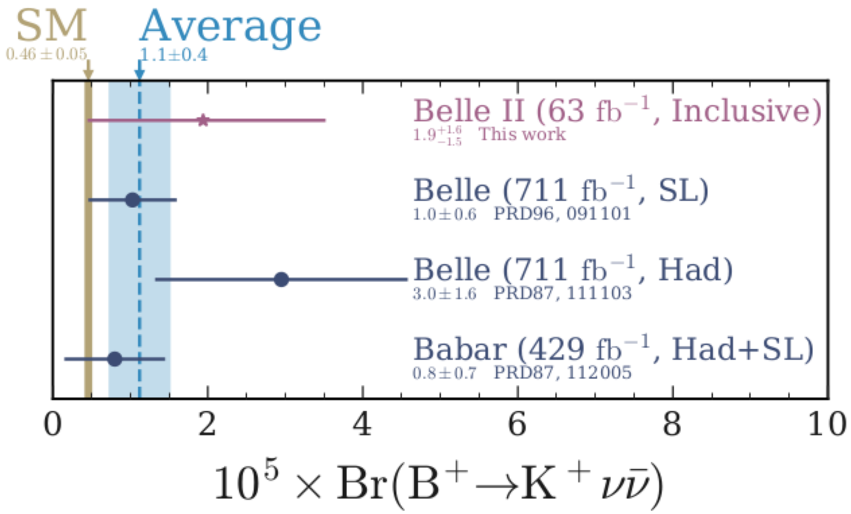
- the method provides sensitivity comparable to the SL taging! (but independent sample)

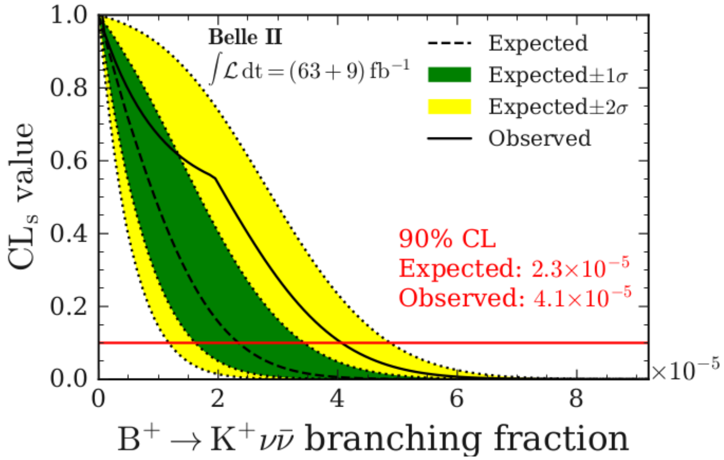
- based on only $63\ \mathrm{fb}^{-1}$ of collected data, much larger sample already collected

- other modes to be included $B^0 \to K^0_S\nu\bar{\nu}$, $B^0 \to K^{*0}(\to K^+\pi^-)\nu\bar{\nu}$, and $B^+ \to K^{*+}(\to K^+\pi^0)\nu\bar{\nu}$

- hadronic and SL tag measurements on-going.

- watch this space!





Other upcoming measurements

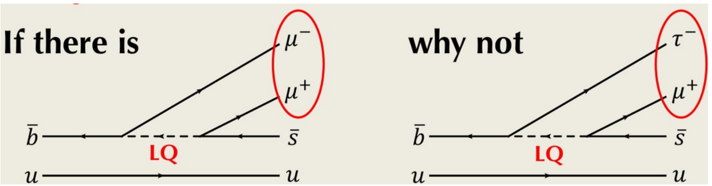
- $B \to X_s \nu \bar{\nu}$ with hadronic tag (sum-of-exclusive)

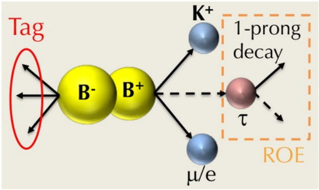
Clean SM prediction
$\mathcal{B} = (2.7 \pm 0.2) \times 10^{-5}$

ALEPH collaboration
$\mathcal{B} < 6.4 \times 10^{-4}$@90% CL

Belle II @ 300 fb^{-1}
$\mathcal{B} \sim 10^{-4}$

- $B^+ \to K^+ \tau \ell$ with hadronic tag @ Belle





Expect much improved limits w.r.t. existing

Mode	BaBar (90% C.L.)	LHCb (90% C.L.)
$B^+ \to K^+ \tau^+ \mu^-$	2.8×10^{-5}	3.9×10^{-5}
$B^+ \to K^+ \tau^- \mu^+$	4.5×10^{-5}	
$B^+ \to K^+ \tau^+ e^-$	1.5×10^{-5}	
$B^+ \to K^+ \tau^- e^+$	4.3×10^{-5}	

- $B \to K^\star \tau \tau$ @ Belle II and $B \to K \tau \tau$ @ Belle

Suppressed in the SM
$\mathcal{B} \sim 10^{-7}$

Can reach up to $\sim 10^{-4}$
in some NP models

Aim to improve the existing limits

$\mathcal{B}(B^0 \to K^{*0} \tau^+ \tau^-) < 2.0 \times 10^{-3}$ (Belle)

$\mathcal{B}(B^+ \to K^+ \tau^+ \tau^-) < 2.3 \times 10^{-3}$ (BaBar)

→ according to MC studies much improved sensitivity @ Belle II → competitive results

Summary

- $b \to s$ transitions are powerful probes of physics beyond the SM.

- Belle II has so far collected $> 400\ \mathrm{fb}^{-1}$ (~equiv. to BaBar datased) of high quality data.

  → unique access to several inclusive modes and modes with missing energy

- first published measurements using $< 100\ \mathrm{fb}^{-1}$ show Belle II can already provide competitive results in many areas, including measurements of radiative and EW penguins.

- demonstrated ability to perform inclusive and exclusive measurements of $b \to s\gamma$

- limit on $B^+ \to K^+\nu\bar{\nu}$ competitive with Belle/BaBar already with ~1/10 of data sample size.

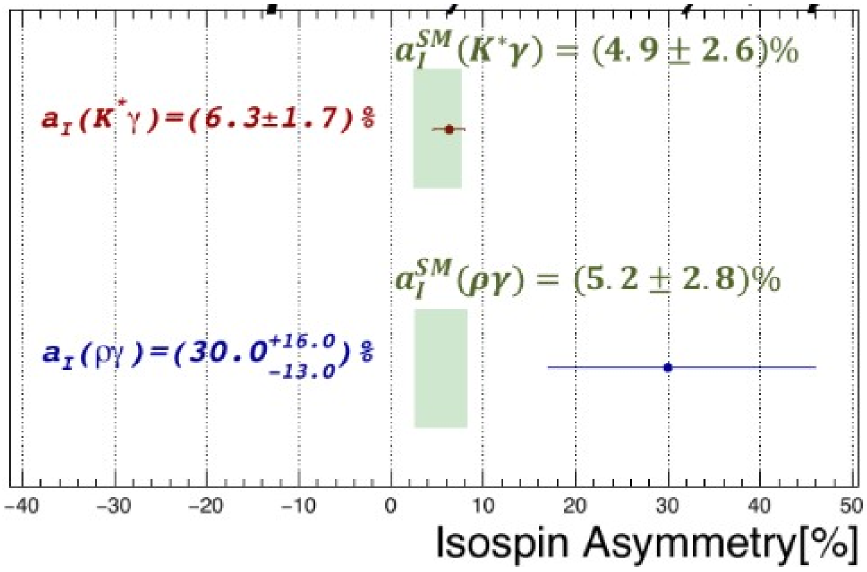
- many updates and new results to follow soon.

backup

$b \to s\gamma$

systematics sources

Source	$K^{*0}[K^+\pi^-]\gamma$	$K^{*0}[K^0_S\pi^0]\gamma$	$K^{*+}[K^+\pi^0]\gamma$	$K^{*+}[K^0_S\pi^+]\gamma$
No. of $B\overline{B}$ events	1.6	1.6	1.6	1.6
Photon selection	$^{+0.2}_{-0.4}$	$^{+0.2}_{-0.4}$	$^{+0.2}_{-0.4}$	$^{+0.2}_{-0.4}$
π^0/η veto	3.8	3.8	3.8	3.8
Pion identification	0.6	—	—	0.6
Kaon identification	0.8	—	0.8	—
K^0_S reconstruction	—	2.4	—	2.4
π^0 selection	—	3.4	3.4	—
Tracking efficiency	1.4	1.4	0.7	1.4
MVA selection	2.0	6.0	2.0	4.0
MC statistics	0.2	0.5	0.3	0.3
PDF shape parameters	1.0	$^{+7.4}_{-5.4}$	$^{+2.4}_{-3.1}$	$^{+0.6}_{-1.4}$
Misreconstructed signal	1.5	$^{+6.8}_{-7.2}$	$^{+4.7}_{-5.9}$	$^{+2.5}_{-3.1}$
Total	5.3	$^{+13.2}_{-12.4}$	$^{+7.9}_{-8.9}$	$^{+7.0}_{-7.3}$



$b \to s\gamma$

TABLE VII. Systematic uncertainties (%) in each M_{X_s} mass bin.

M_{X_s} bin (GeV/c^2)	$B\overline{B}$ counting	Detector response	Background rejection	Signal PDF	Cross-feed PDF	Peaking BG PDF	$q\bar{q}$ BG PDF	Frag.	Missing proportion	Total
0.6-0.7	1.4	2.7	3.4	0.0	0.0	0.0	0.0	-	-	4.5
0.7-0.8	1.4	2.6	3.4	0.1	12.2	7.8	0.0	-	-	15.3
0.8-0.9	1.4	2.6	3.4	0.2	0.4	0.5	0.0	-	-	4.5
0.9-1.0	1.4	2.6	3.4	0.1	0.5	0.4	0.0	-	-	4.5
1.0-1.1	1.4	2.6	3.4	0.1	2.9	1.1	0.3	-	-	5.4
1.1-1.2	1.4	3.0	3.4	0.4	3.1	1.7	0.2	32.1	1.2	32.1
1.2-1.3	1.4	3.2	3.4	0.2	1.6	0.9	0.0	2.1	1.0	5.6
1.3-1.4	1.4	3.2	3.4	0.2	1.6	0.2	0.0	2.6	1.9	6.0
1.4-1.5	1.4	3.1	3.4	0.2	2.0	0.1	0.0	4.0	1.3	6.7
1.5-1.6	1.4	3.3	3.4	0.6	2.2	0.1	0.0	2.4	1.3	6.1
1.6-1.7	1.4	3.5	3.4	0.1	1.7	2.1	0.2	2.8	1.9	6.7
1.7-1.8	1.4	3.6	3.4	0.1	2.2	1.7	0.2	3.4	1.0	6.8
1.8-1.9	1.4	3.7	3.4	0.1	1.9	2.0	0.1	3.6	2.1	7.2
1.9-2.0	1.4	3.7	3.4	0.1	4.2	4.0	0.1	3.7	1.6	8.8
2.0-2.1	1.4	3.8	3.4	0.1	5.6	0.6	0.2	17.8	2.2	19.5
2.1-2.2	1.4	3.8	3.4	0.3	3.7	2.5	0.4	21.9	1.9	23.1
2.2-2.4	1.4	3.8	3.4	0.1	7.4	7.1	0.0	25.5	1.6	28.0
2.4-2.6	1.4	3.8	3.4	0.1	11.5	21.8	0.3	29.6	1.0	38.9
2.6-2.8	1.4	3.8	3.4	0.1	44.7	101.0	0.9	29.4	2.0	113.9

Belle coll, Phys.Rev.D 91 (2015) 5, 052004, untagged $X_s\gamma$ sum of exclusive, 711 fb-1

$$\mathcal{B}(\overline{B} \to X_s\gamma) = (3.51 \pm 0.17 \pm 0.33) \times 10^{-4}$$

Belle coll, Phys.Rev.Lett.103:241801,2009, untagged $X_s\gamma$ inclusive, 605 fb-1

	BF$(B \to X_s\gamma)$ (10^{-4})			
$E^{\mathrm{B}}_{\gamma-\mathrm{Low}}$ [GeV]	1.70	1.80	1.90	2.00
Value	3.45	3.36	3.21	3.02
$\pm$statistical	0.15	0.13	0.11	0.10
$\pm$systematic	0.40	0.25	0.16	0.11
				Syst
1. Continuum	0.26	0.16	0.10	0.07
2. Selection	0.15	0.12	0.10	0.08
3. π^0/η	0.07	0.05	0.04	0.02
4. Other B	0.25	0.14	0.06	0.02
5. Beam bkgd.	0.03	0.02	0.02	0.01
6. Unfolding	0.01	0.01	0.02	0.02
7. Model	0.01	0.01	0.00	0.01
8. Resolution	0.05	0.03	0.01	0.00
9. γ Detection	0.03	0.02	0.00	0.00
10. $B \to X_d\gamma$	0.01	0.01	0.01	0.01
11. Boost	0.01	0.01	0.02	0.02

$$\mathrm{BF}\,(B \to X_s\gamma) = (3.45 \pm 0.15 \pm 0.40) \times 10^{-4}$$

Table 6: Projected statistical and systematic (absolute) uncertainties of relevant observables from $B \to K^*\gamma$ decays.

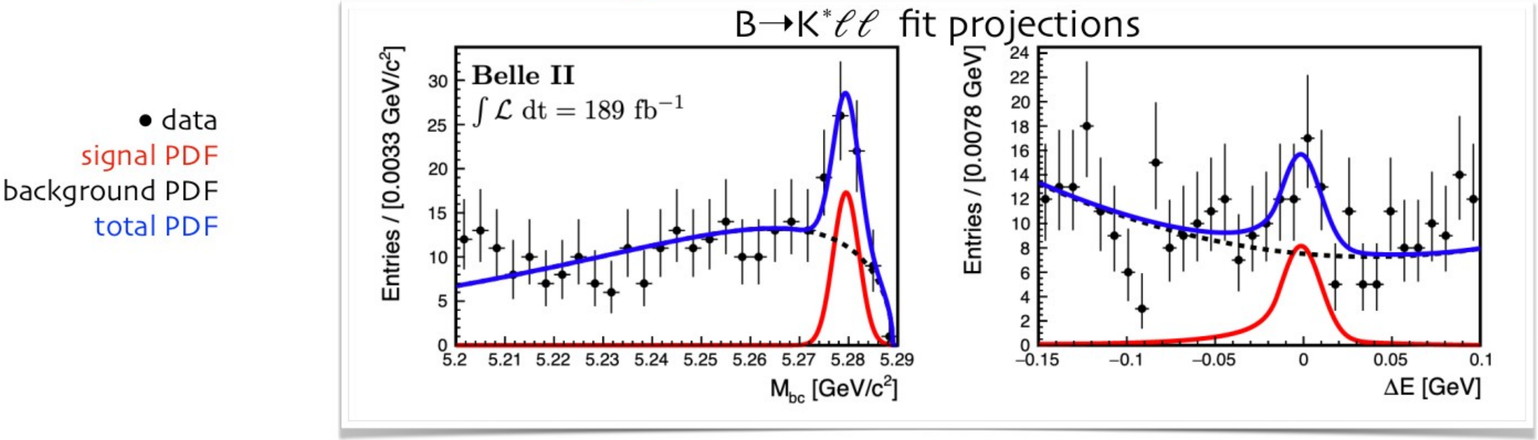
Observable	1 ab^{-1}	5 ab^{-1}	10 ab^{-1}	50 ab^{-1}	Systematic uncertainty
$\Delta_{0+}(B \to K^*\gamma)$	1.3%	0.6%	0.4%	0.2%	1.2%
$A_{CP}(B^0 \to K^{*0}\gamma)$	1.4%	0.6%	0.5%	0.2%	0.2%
$A_{CP}(B^+ \to K^{*+}\gamma)$	1.9%	0.9%	0.6%	0.3%	0.2%
$\Delta A_{CP}(B \to K^*\gamma)$	2.4%	1.1%	0.7%	0.3%	0.3%

Table 5: Projected fractional uncertainties of the $B \to X_s\gamma$ branching fraction measurement for various E_γ^B thresholds. The systematic uncertainty is presented for a baseline scenario when the remaining background is known to the 10% level, and an improved scenario, when the background is known to the 5% level.

Lower E_γ^B threshold	Statistical uncertainty				Baseline (improved)
	1 ab^{-1}	5 ab^{-1}	10 ab^{-1}	50 ab^{-1}	syst. uncertainty
1.4 GeV	10.7%	6.4%	4.7%	2.2%	10.3% (5.2%)
1.6 GeV	9.9%	6.1%	4.5%	2.1%	8.5% (4.2%)
1.8 GeV	9.3%	5.7%	4.2%	2.0%	6.5% (3.2%)
2.0 GeV	8.3%	5.1%	3.8%	1.7%	3.7% (1.8%)

$R(K^{(\star)})$

- Signal yield extracted from 2D fit to M_{bc} and ΔE



- Branching fraction in entire q^2 range excluding J/ψ and $\psi(2S)$ resonances:

$$\mathcal{B}(B \to K^*\mu\mu) = (1.19 \pm 0.31 \pm^{+0.08}_{-0.07}) \times 10^{-6},$$
$$\mathcal{B}(B \to K^*ee) = (1.42 \pm 0.48 \pm 0.09) \times 10^{-6},$$
$$\mathcal{B}(B \to K^*\ell\ell) = (1.25 \pm 0.30 \pm^{+0.08}_{-0.07}) \times 10^{-6},$$

PDG averages

$(1.06 \pm 0.09) \times 10^{-6}$

$(1.19 \pm 0.20) \times 10^{-6}$

$(1.05 \pm 0.10) \times 10^{-6}$

- Precision for electron and muon channels in the same ballpark
- Limited by sample size
- Electron channel "only" 2.5σ worst wrt PDG, expected to became competitive with 1 ab^{-1}

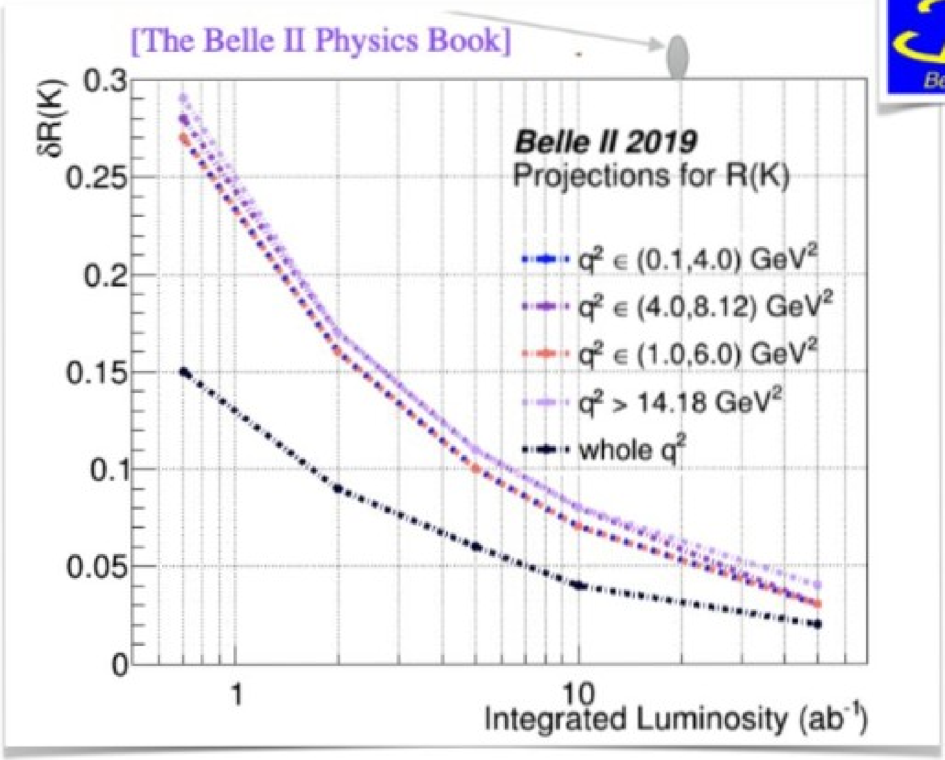
- Will provide essential independent check of anomalies with few 1/ab

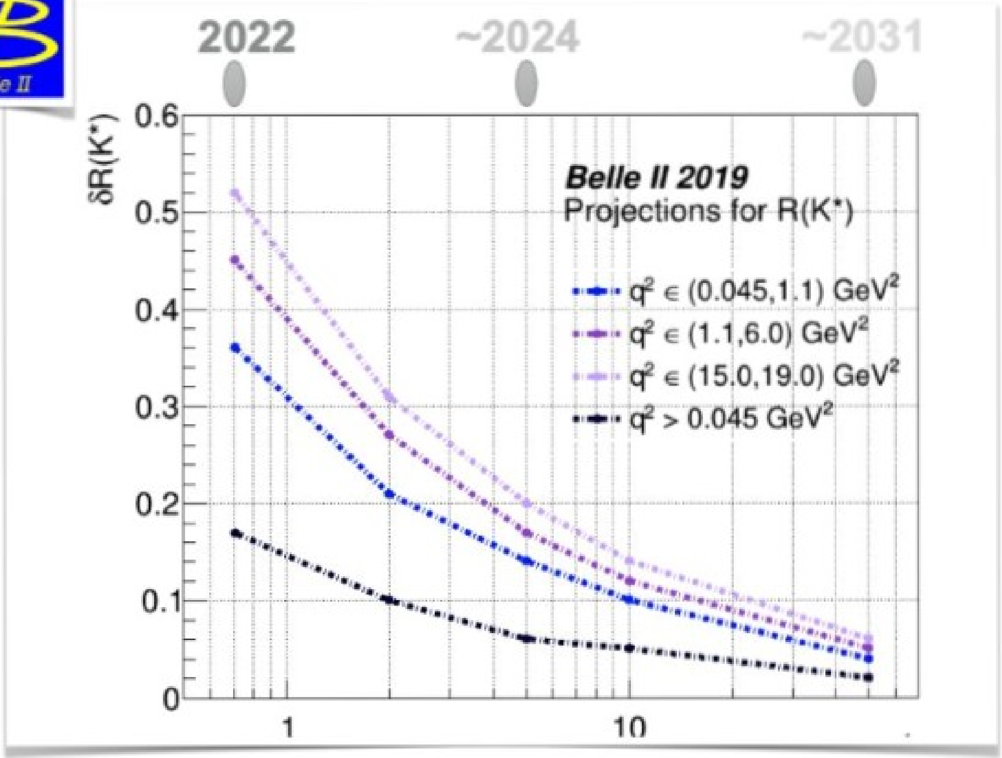
$B \to K^* \ell\ell$ systematics table

Source	Systematic (%)
signal shape	~ 1.0
muon identification	$^{+1.9}_{-0.8}$
electron identification	$^{+0.9}_{-0.5}$
kaon identification	0.4
pion identification	2.5
K^0_S identification	2.0
π^0 identification	3.4
FastBDT	1.3 – 1.7
limited MC statistics	< 0.5
signal cross feed	$\sim 1\%$
tracking	1.2 – 1.5
$f^{+-(00)}$	1.2
number of $B\bar{B}$ pairs	2.9
Total	$^{+6.7}_{-6.0}$

$R(K^{(\star)})$

The Belle II Physics Book, PETP 2019, 123C01 (2019)



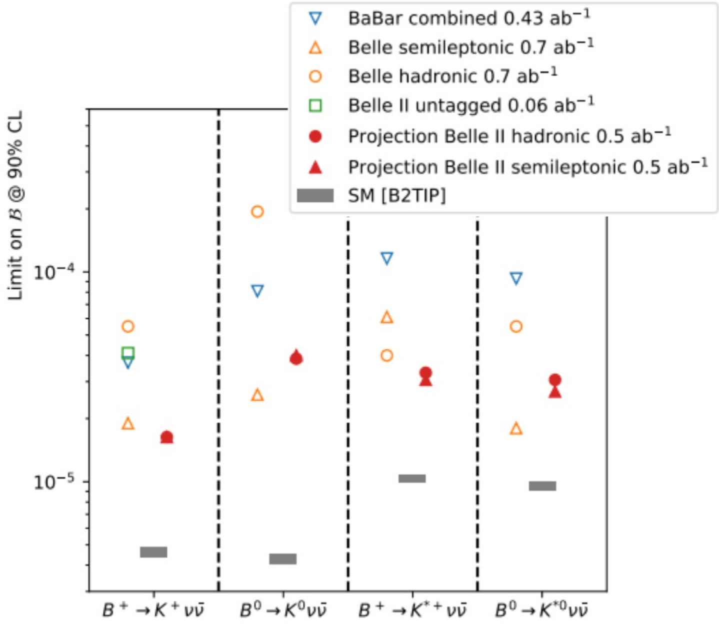


$B^+ \to K^+\nu\bar{\nu}$

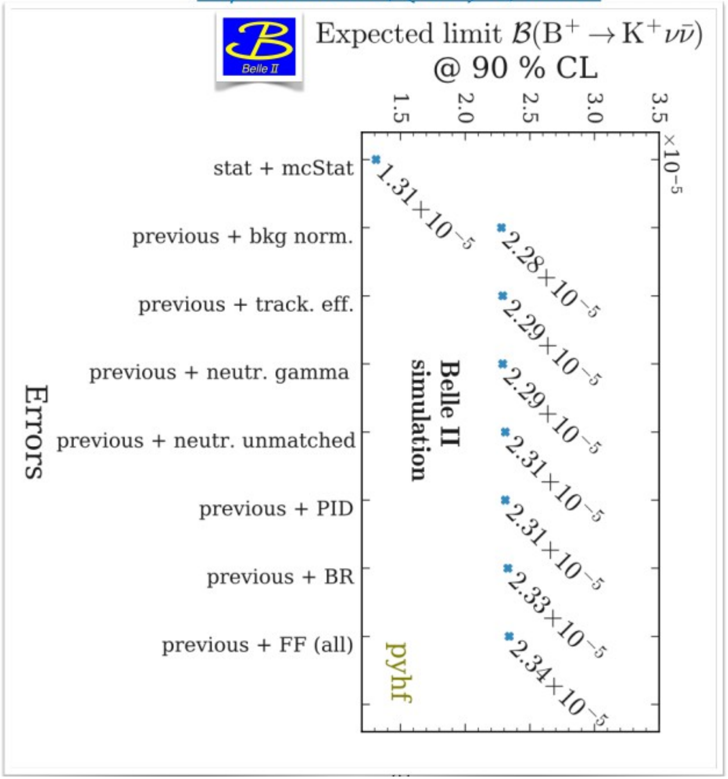
FF in MC model
arXiv:1409.4557

Table 3: Baseline (improved) expectations for the uncertainties on the signal strength μ (relative to the SM strength) for the four decay modes as functions of data set size.

Decay	$1\,\text{ab}^{-1}$	$5\,\text{ab}^{-1}$	$10\,\text{ab}^{-1}$	$50\,\text{ab}^{-1}$
$B^+ \to K^+\nu\bar{\nu}$	0.55 (0.37)	0.28 (0.19)	0.21 (0.14)	0.11 (0.08)
$B^0 \to K^0_S\nu\bar{\nu}$	2.06 (1.37)	1.31 (0.87)	1.05 (0.70)	0.59 (0.40)
$B^+ \to K^{*+}\nu\bar{\nu}$	2.04 (1.45)	1.06 (0.75)	0.83 (0.59)	0.53 (0.38)
$B^0 \to K^{*0}\nu\bar{\nu}$	1.08 (0.72)	0.60 (0.40)	0.49 (0.33)	0.34 (0.23)



Phys.Rev.Lett. 127 (2021) 18, 181802



Projections – radiative

Observables	Belle $0.71\,\mathrm{ab}^{-1}$	Belle II $5\,\mathrm{ab}^{-1}$	Belle II $50\,\mathrm{ab}^{-1}$
$\mathrm{Br}(B \to X_s\gamma)^{\text{lep-tag}}_{\text{inc}}$	5.3%	3.9%	3.2%
$\mathrm{Br}(B \to X_s\gamma)^{\text{had-tag}}_{\text{inc}}$	13%	7.0%	4.2%
$\mathrm{Br}(B \to X_s\gamma)_{\text{sum-of-ex}}$	10.5%	7.3%	5.7%
$\Delta_{0+}(B \to X_s\gamma)_{\text{sum-of-ex}}$	2.1%	0.81%	0.63%
$\Delta_{0+}(B \to X_{s+d}\gamma)^{\text{had-tag}}_{\text{inc}}$	9.0%	2.6%	0.85%
$A_{CP}(B \to X_s\gamma)_{\text{sum-of-ex}}$	1.3%	0.52%	0.19%
$A_{CP}(B^0 \to X_s^0\gamma)_{\text{sum-of-ex}}$	1.8%	0.72%	0.26%
$A_{CP}(B^+ \to X_s^+\gamma)_{\text{sum-of-ex}}$	1.8%	0.69%	0.25%
$A_{CP}(B \to X_{s+d}\gamma)^{\text{lep-tag}}_{\text{inc}}$	4.0%	1.5%	0.48%
$A_{CP}(B \to X_{s+d}\gamma)^{\text{had-tag}}_{\text{inc}}$	8.0%	2.2%	0.70%
$\Delta A_{CP}(B \to X_s\gamma)_{\text{sum-of-ex}}$	2.5%	0.98%	0.30%
$\Delta A_{CP}(B \to X_{s+d}\gamma)^{\text{had-tag}}_{\text{inc}}$	16%	4.3%	1.3%

Observables	Belle $0.71\,\mathrm{ab}^{-1}$ $(0.12\,\mathrm{ab}^{-1})$	Belle II $5\,\mathrm{ab}^{-1}$	Belle II $50\,\mathrm{ab}^{-1}$
$\Delta_{0+}(B \to K^*\gamma)$	2.0%	0.70%	0.53%
$A_{CP}(B^0 \to K^{*0}\gamma)$	1.7%	0.58%	0.21%
$A_{CP}(B^+ \to K^{*+}\gamma)$	2.4%	0.81%	0.29%
$\Delta A_{CP}(B \to K^*\gamma)$	2.9%	0.98%	0.36%
$S_{K^{*0}\gamma}$	0.29	0.090	0.030

Projections – EW penguin

The Belle II Physics Book, PETP 2019, 123C01 (2019)

Observables	Belle $0.71\,\mathrm{ab}^{-1}$ $(0.12\,\mathrm{ab}^{-1})$	Belle II $5\,\mathrm{ab}^{-1}$	Belle II $50\,\mathrm{ab}^{-1}$
$\mathrm{Br}(B^+ \to K^+\tau^+\tau^-)\cdot 10^5$	< 32	< 6.5	< 2.0
$\mathrm{Br}(B^+ \to K^+\tau^\pm e^\mp)\cdot 10^6$	–	–	< 2.1
$\mathrm{Br}(B^+ \to K^+\tau^\pm \mu^\mp)\cdot 10^6$	–	–	< 3.3

tagged analysis ONLY!

Observables	Belle $0.71\,\mathrm{ab}^{-1}$ $(0.12\,\mathrm{ab}^{-1})$	Belle II $5\,\mathrm{ab}^{-1}$	Belle II $50\,\mathrm{ab}^{-1}$
$\mathrm{Br}(B^+ \to K^+\nu\bar{\nu})$	$< 450\%$	30%	11%
$\mathrm{Br}(B^0 \to K^{*0}\nu\bar{\nu})$	$< 180\%$	26%	9.6%
$\mathrm{Br}(B^+ \to K^{*+}\nu\bar{\nu})$	$< 420\%$	25%	9.3%
$F_L(B^0 \to K^{*0}\nu\bar{\nu})$	–	–	0.079
$F_L(B^+ \to K^{*+}\nu\bar{\nu})$	–	–	0.077

Observables	Belle $0.71\,\mathrm{ab}^{-1}$	Belle II $5\,\mathrm{ab}^{-1}$	Belle II $50\,\mathrm{ab}^{-1}$
R_K ($[1.0, 6.0]\,\mathrm{GeV}^2$)	28%	11%	3.6%
R_K ($> 14.4\,\mathrm{GeV}^2$)	30%	12%	3.6%
R_{K^*} ($[1.0, 6.0]\,\mathrm{GeV}^2$)	26%	10%	3.2%
R_{K^*} ($> 14.4\,\mathrm{GeV}^2$)	24%	9.2%	2.8%
R_{X_s} ($[1.0, 6.0]\,\mathrm{GeV}^2$)	32%	12%	4.0%
R_{X_s} ($> 14.4\,\mathrm{GeV}^2$)	28%	11%	3.4%

Belle II luminosity projection