Anticipated precision and sensitivity at Belle II

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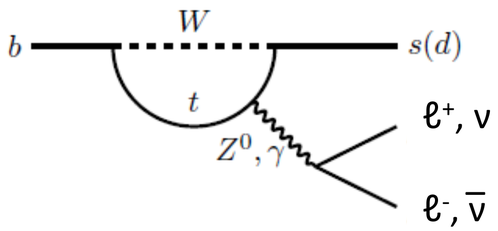
Mini-workshop on missing particle signatures and new physics at Belle II and LHCb
July 2021

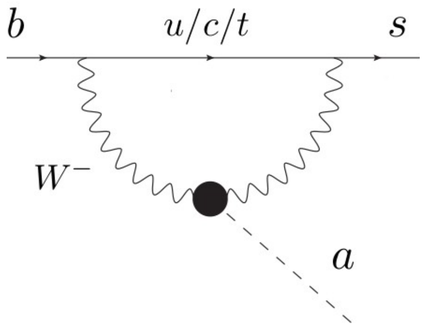
Missing particle and (semi)leptonic signatures

Flavour changing neutral currents



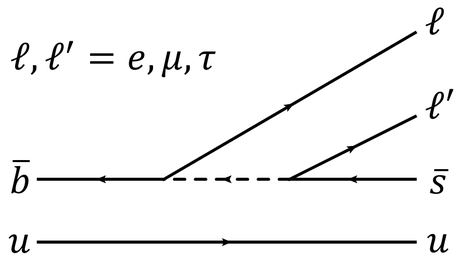
- $B \to X_s l^+ l^-$
- Loop in SM
- Rare at BR < ~10^{-6}

New particle searches



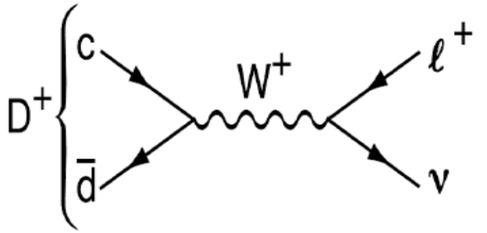
- ALPs (Pseudoscalars)
- Higgs-like (Scalars)
- Dark photons (Vector)

Forbidden decays



- Lepton flavour violating
- Lepton number violating
- Forbidden or very highly suppressed

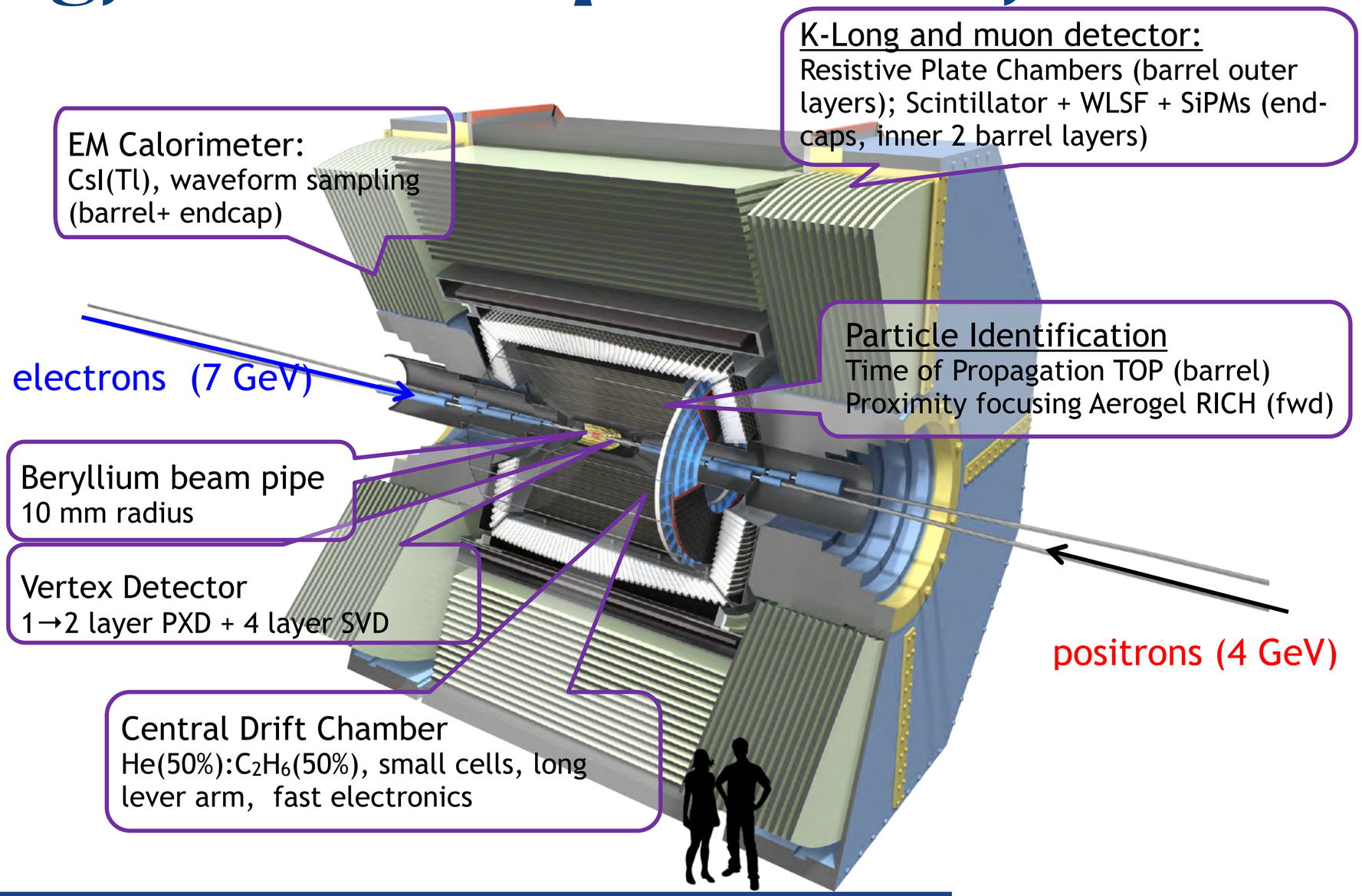
Tests of lepton flavour universality



- Semileptonic or leptonic
- BR ratios with τ/μ, τ/e, μ/e
- Tree or loop

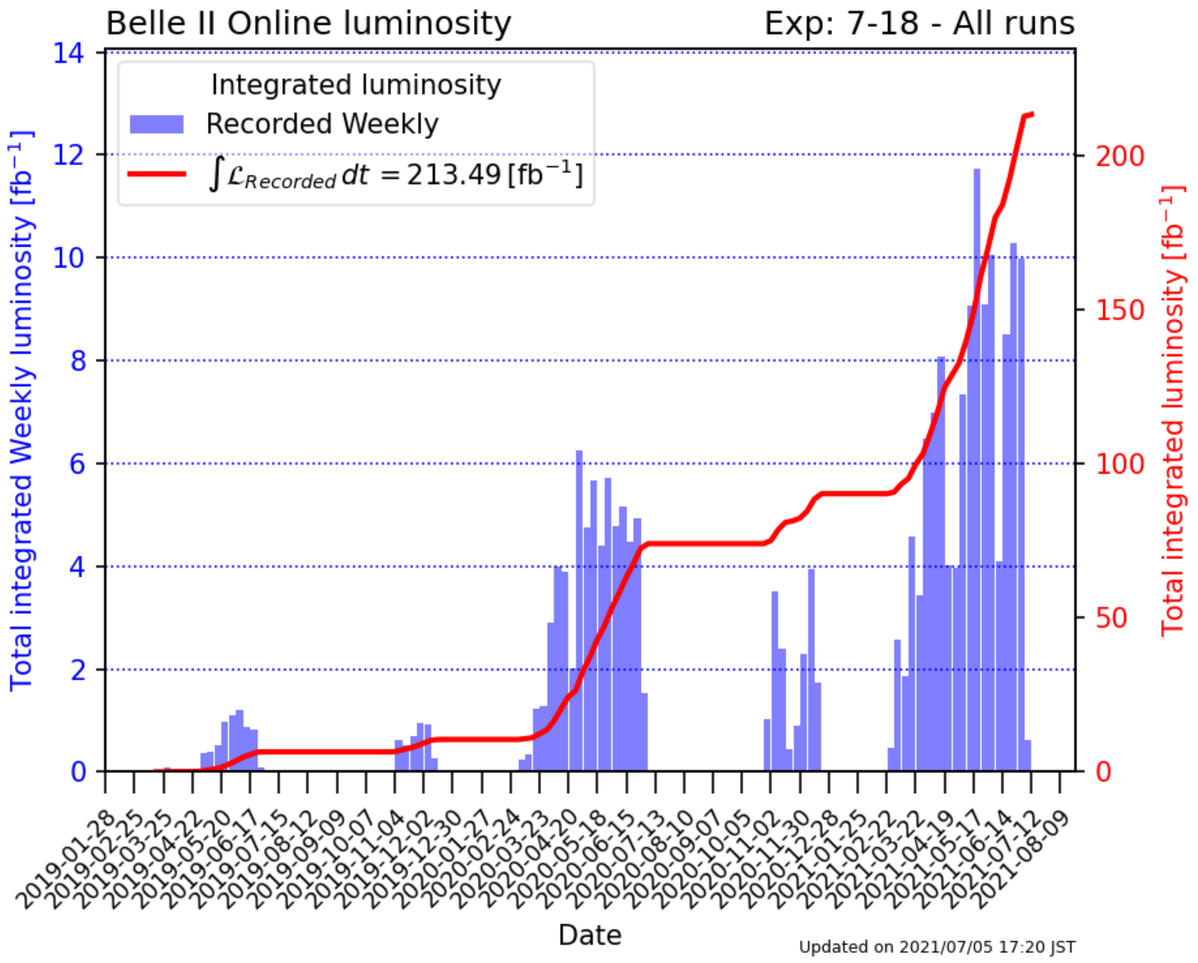
Missing energy and semileptonic analyses

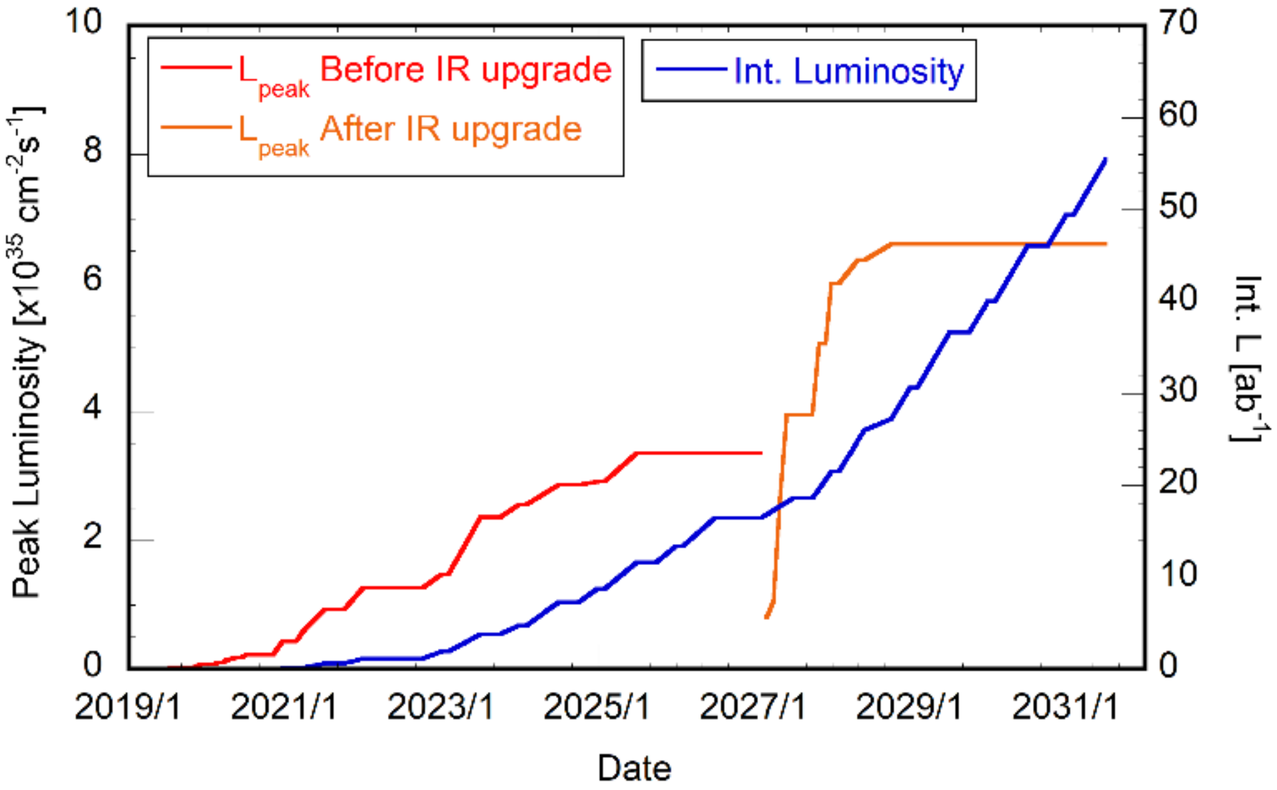
- Low lepton fake rates, good electron momentum resolution.
- High hadronic and semileptonic tag full reconstruction efficiencies.
- Hermetic coverage for vetoes and inclusive tagging.
- Background robustness at high luminosity.



To project to future capacity we must look at current detector performance!

(Anticipated) SuperKEKB/Belle II Luminosity Profile





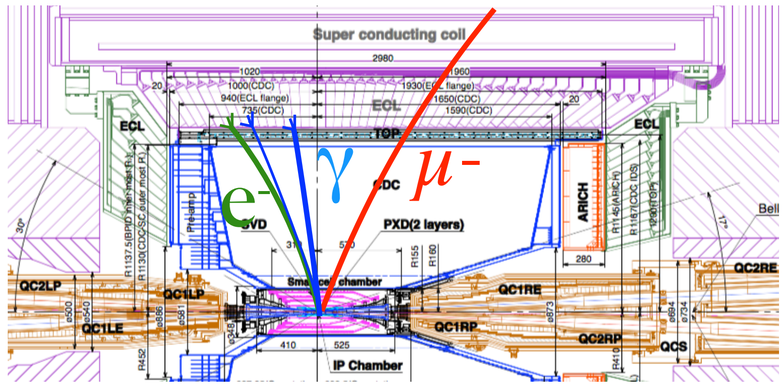
~90% data taking efficiency

	KEKB	SuperKEKB	**Achievements**
β^*_y(mm)	5.9/5.9	0.3/0.27	**1/1** **
I_{beam}(A)	1.19/1.65	2.6/3.6	**0.7/0.8** **
L(cm^{-2}s^{-1})	2.11x10^{34}	65x10^{34}	**3.12x10^{34}**

** for this Lumi.

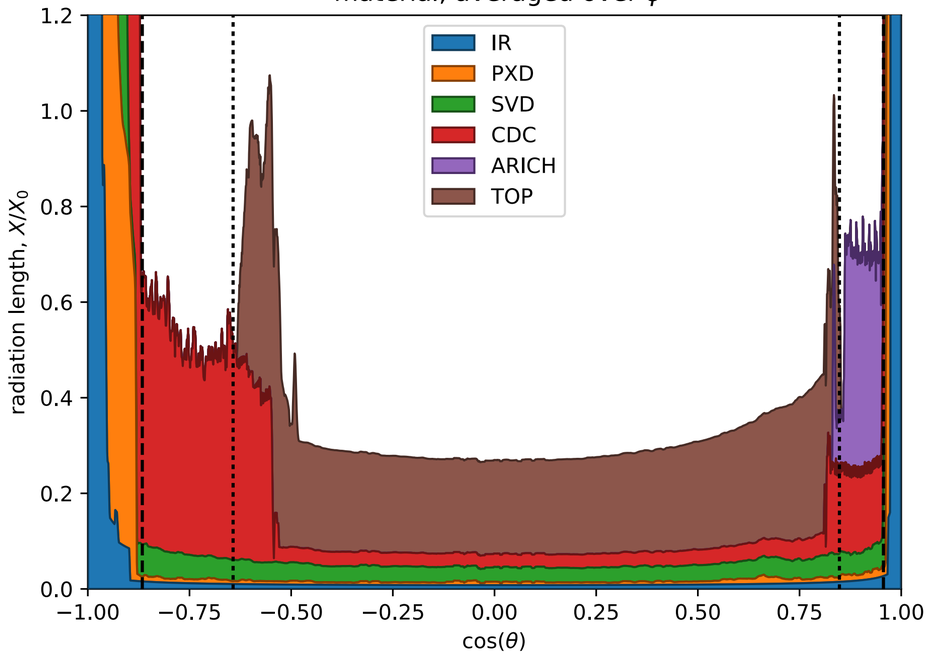
Lepton reconstruction

- Good universality in efficiency, and in resolution after bremsstrahlung corrections.

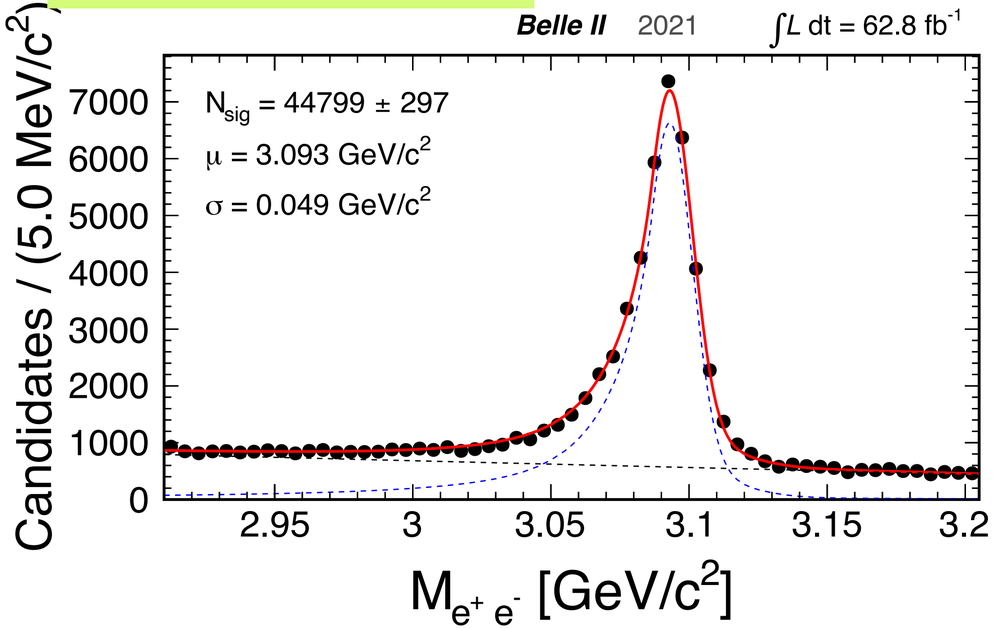


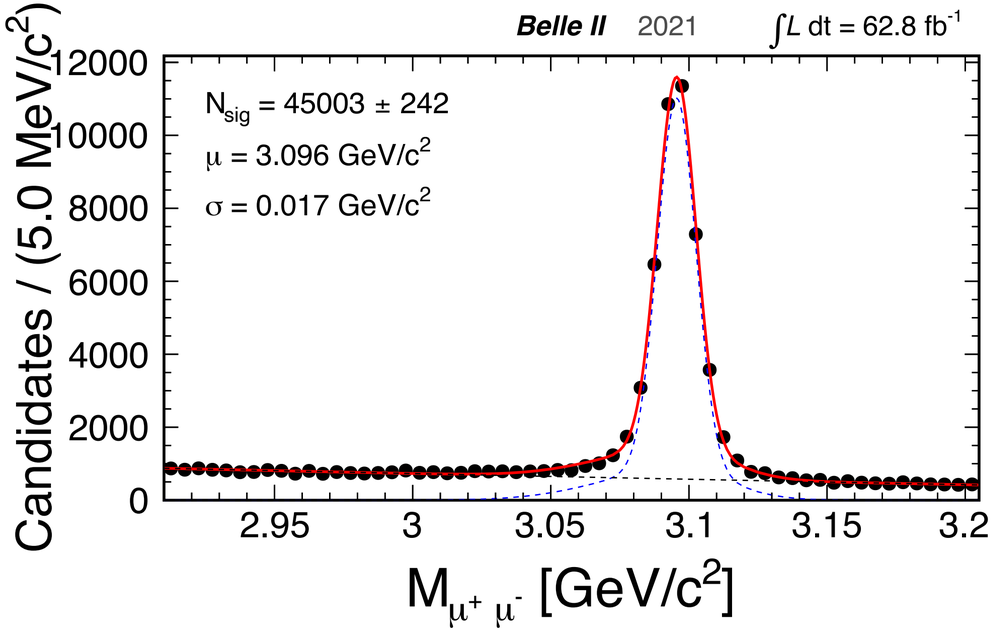
e: FSR, bremsstrahlung in material (less material in tracking volume than LHC detectors). Corrected at track level and/or calorimeter level.

material, averaged over ϕ



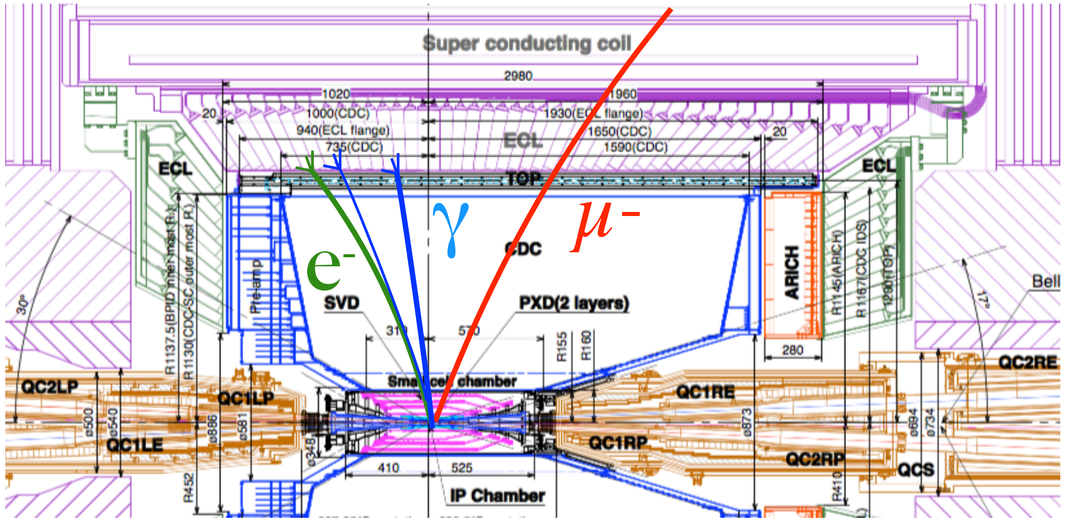
BELLE2-NOTE-PL-2020-027



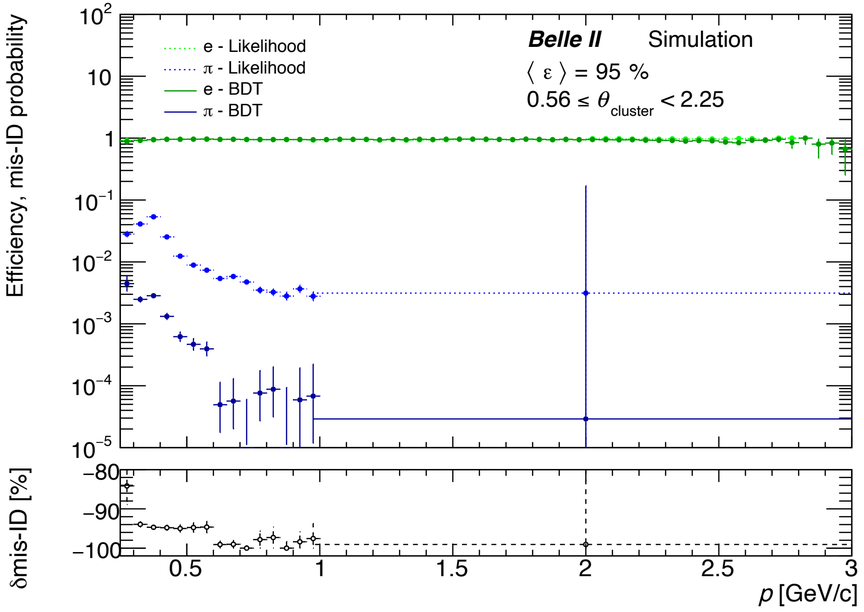


Lepton identification

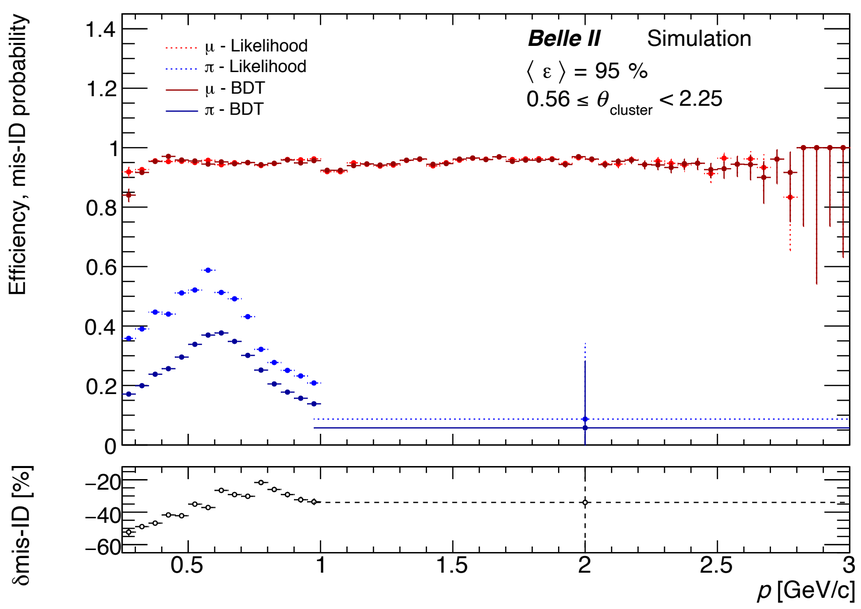
- Electrons strongly rely on ECL shower shapes, E/p, dE/dx (CDC).
- Muons rely on KLM (above ~700 MeV/c), and ECL (lower momenta).
- The τ problem: B→ τ→l have <p>~500 MeV/c.
  - Use of ML methods for e & μ ID in use, optimised for low p (big improvements with ECL shower shape BDT).



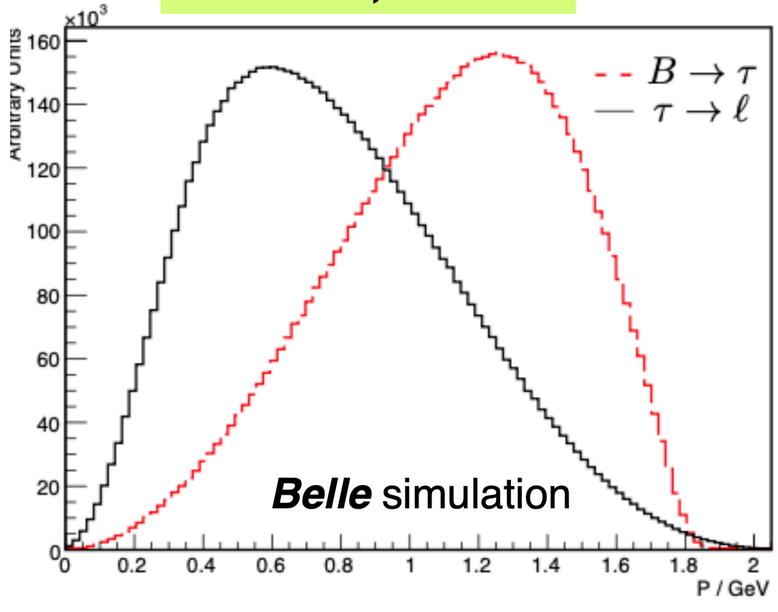
Electron ID



Muon ID



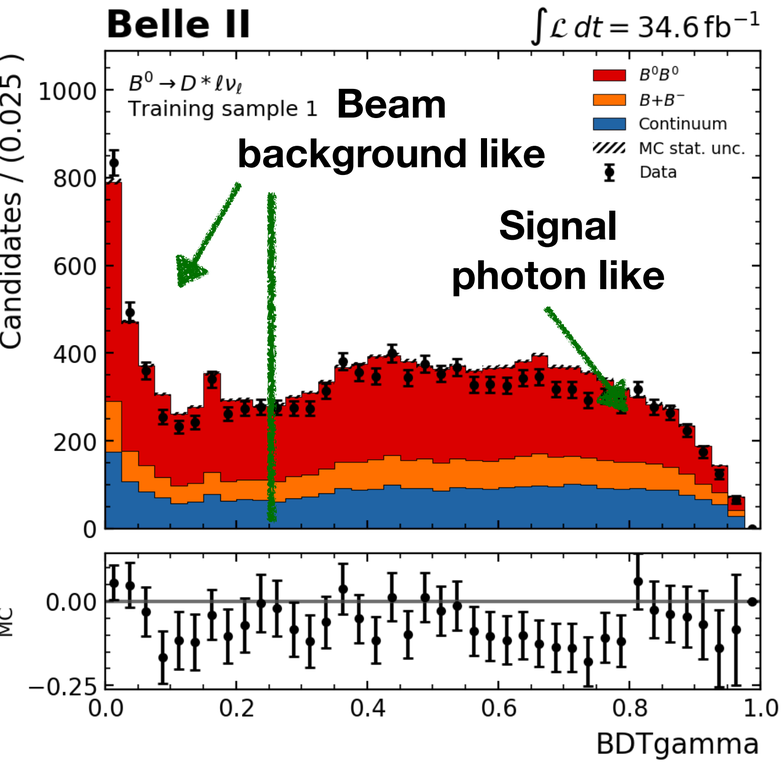
B→ τ→l decay kinematics



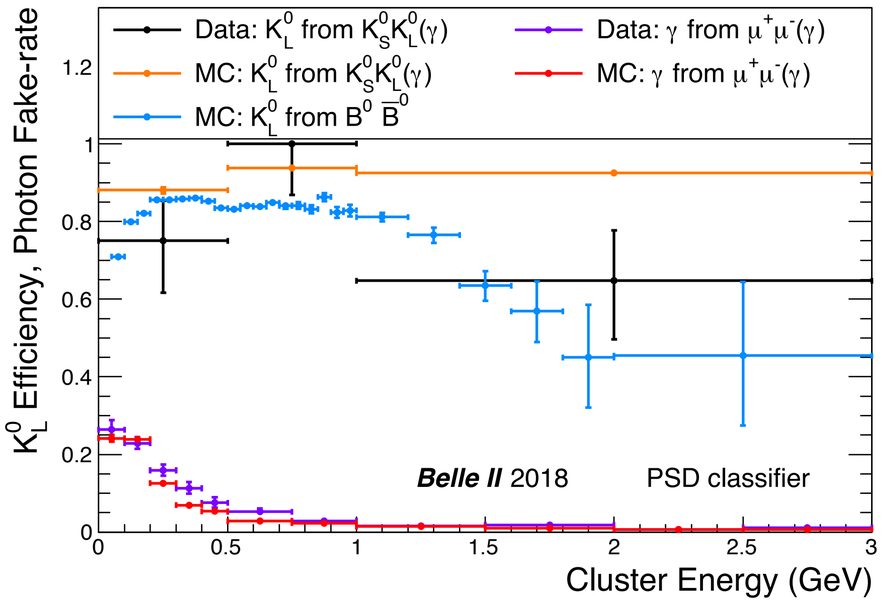
Neutrals and vetos

- Fundamentals of missing energy B decay studies at Belle II.
  - Calorimeter extra energy (ECL cluster based BDT to separate signal from beam background and split offs).
  - K_L - veto (ECL- pulse shape discrimination, KLM).
  - Track counting based veto (absolutely crucial).

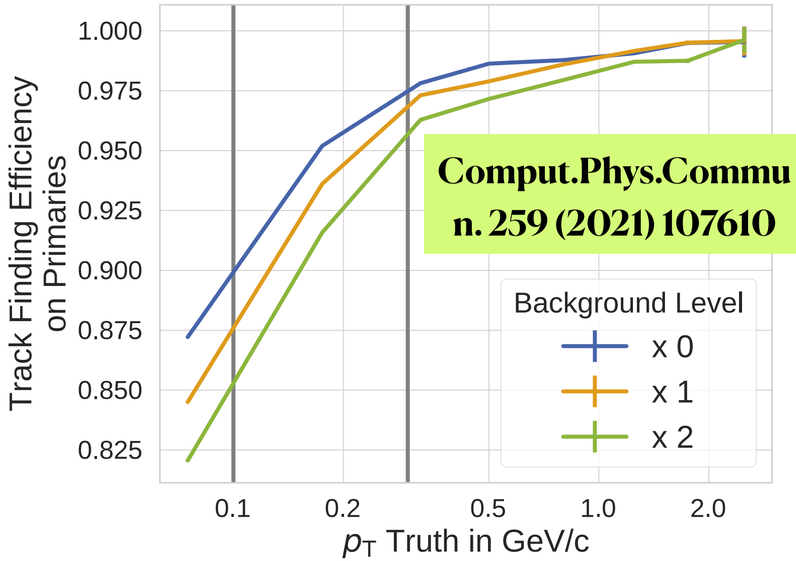
Extra energy - cluster variable BDT



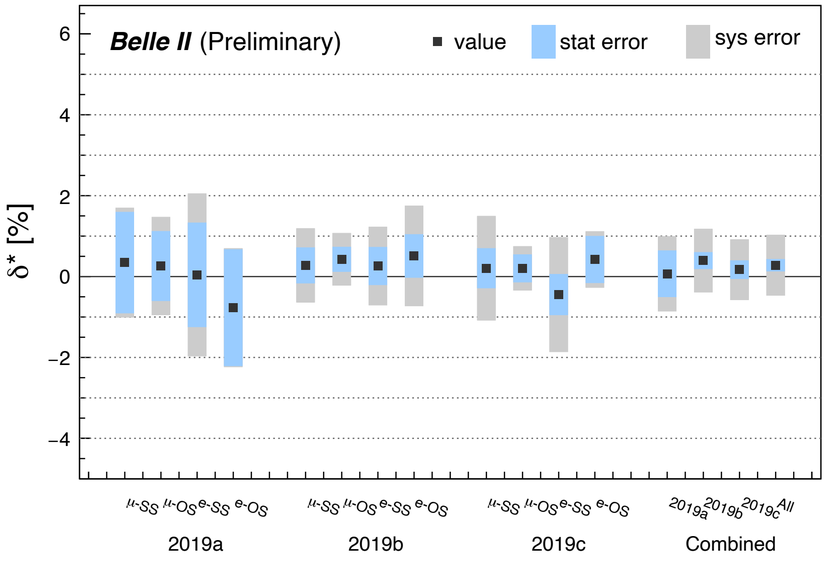
ECL PSD K_L/γ -ID (New to Belle II)
NIM A 982 (2020) 164562



Belle II Track Counting



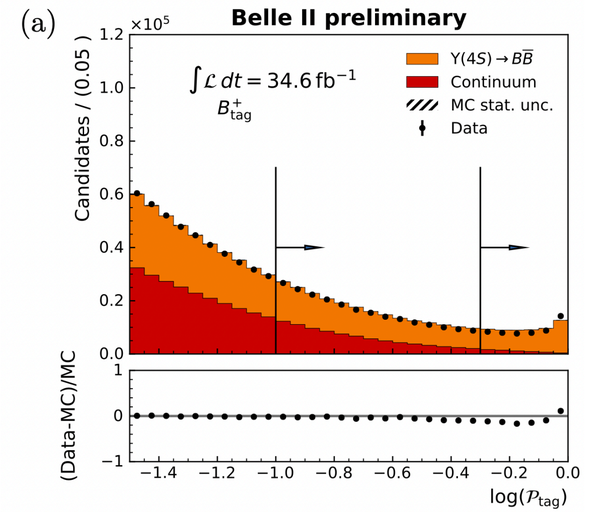
Comput.Phys.Commun. 259 (2021) 107610

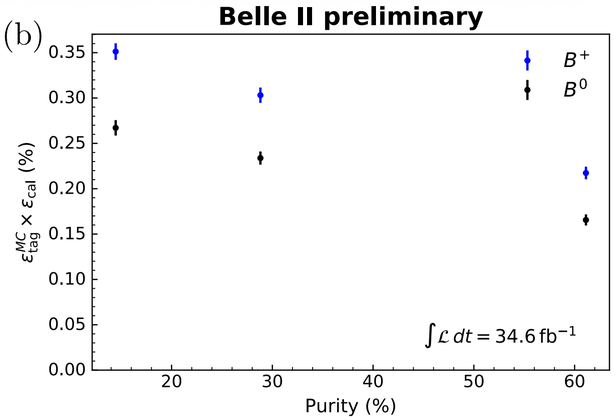


δ^* = Calibrated Data-MC discrepancy for tracking efficiency

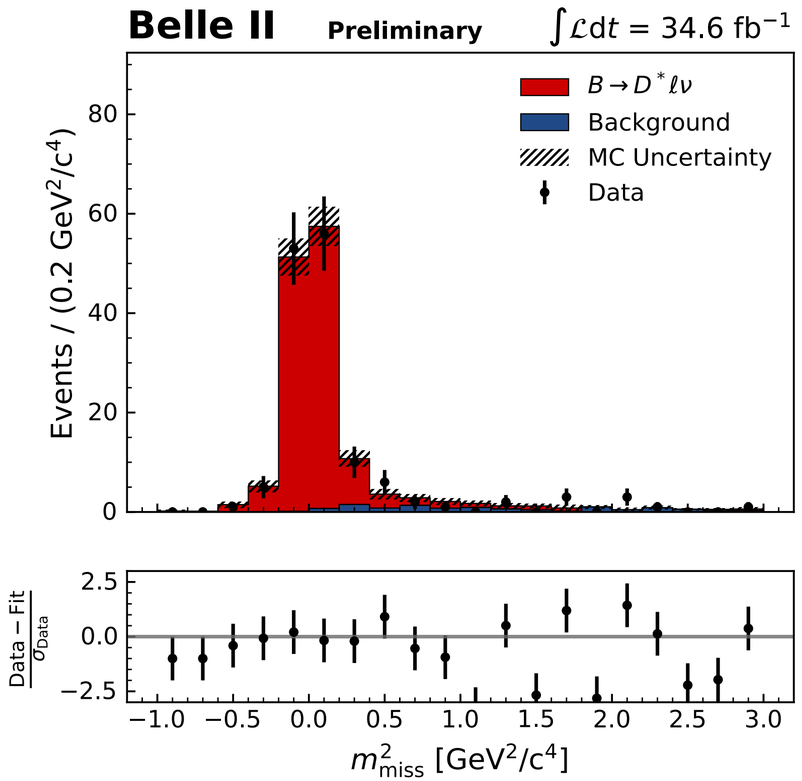
B_{tag} reconstruction

Hadronic FEI results with Belle II
BELLE2-CONF-PH-2020-019

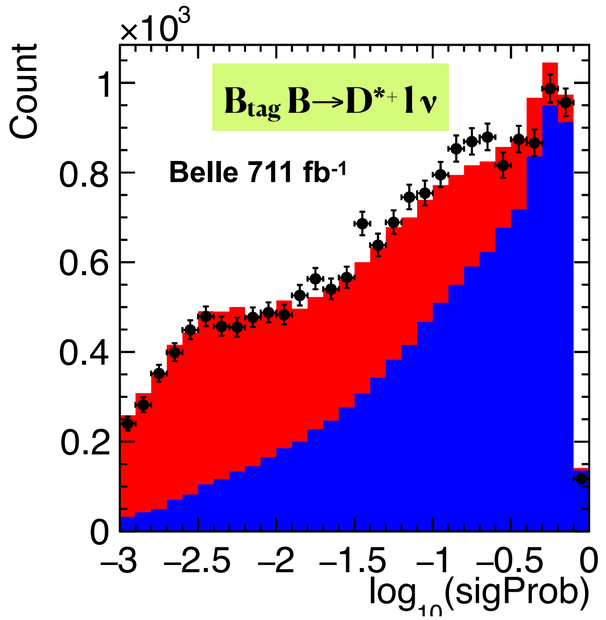


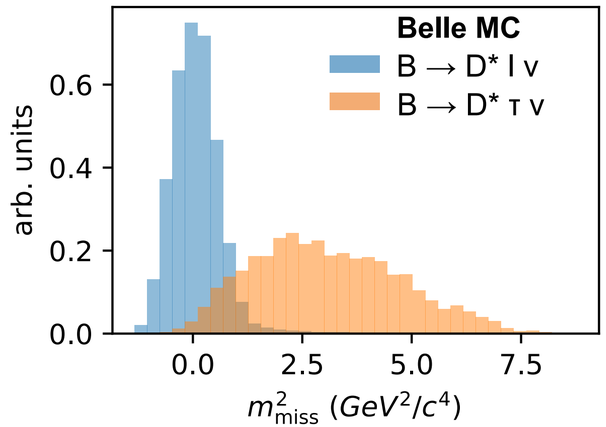


M^2_{miss} resolution with B→D* l ν
BELLE2-CONF-PH-2020-009



Semileptonic FEI with Belle
G. Caria PhD thesis

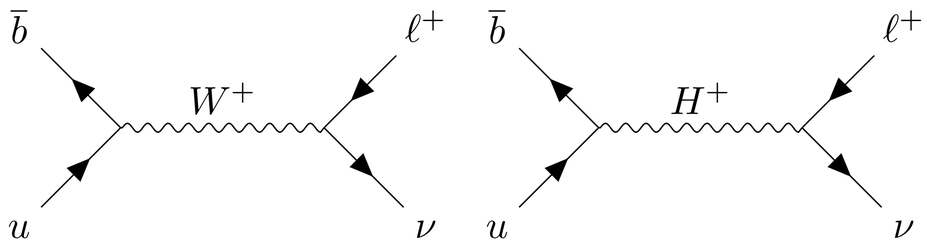




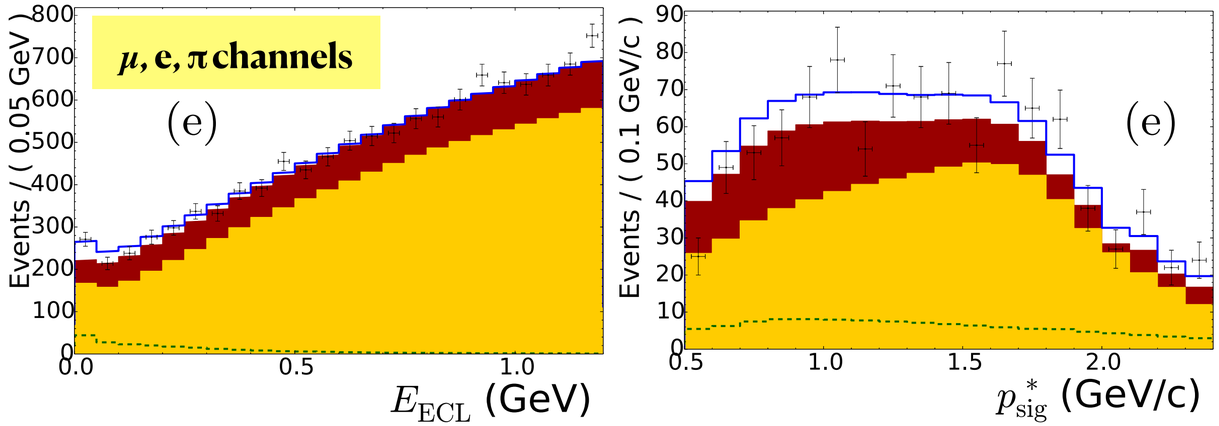
- >1 M hadronic B-tags, >5 M semileptonic B-tags in 200 fb^{-1} sample.
- Recent improvements (new channels, PID, vertex fitting).

Tree Decays

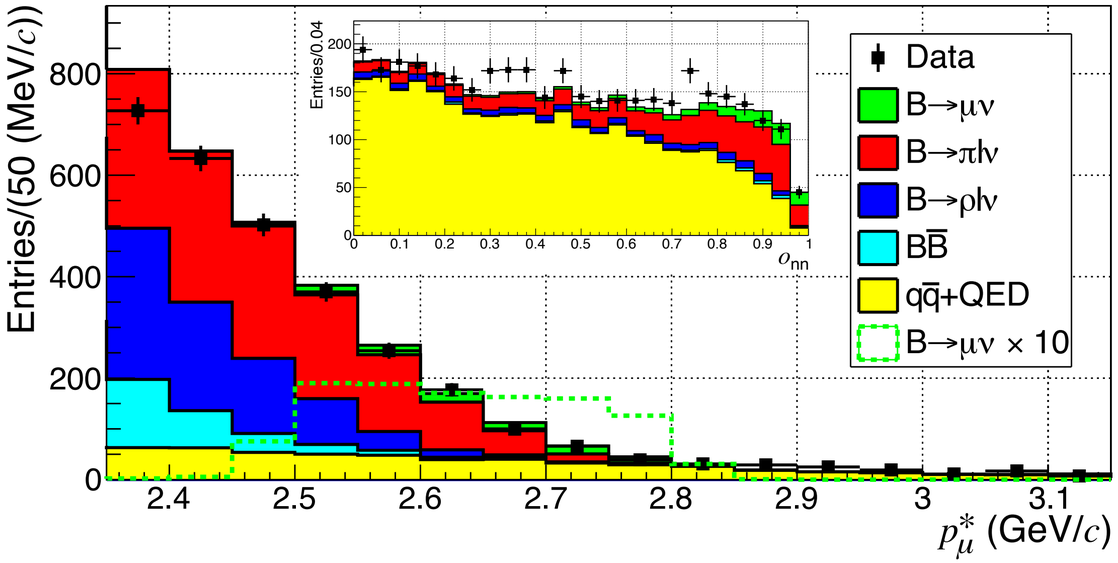
B→ τ ν and μ ν



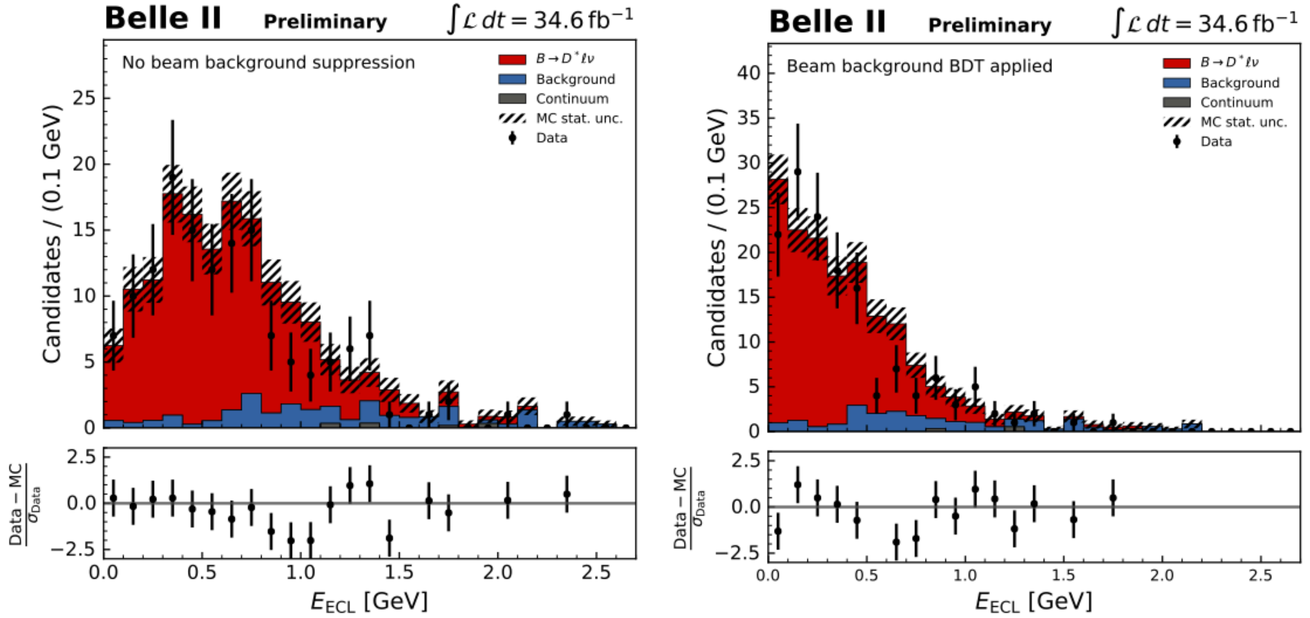
Belle, PRD 92, 051102 (2015) SL tagged B→ τ ν



Belle, Phys. Rev. Lett. 121, 031801 (2018) untagged B→ μ ν



Belle II, B→D* l ν, arXiv: 2008.10299
BDT ECL neutral energy classifier (left before, right after)

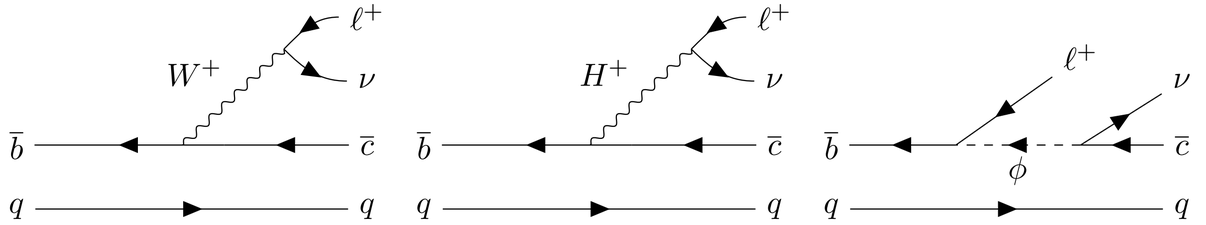


Observables	Belle	Belle II	
		5 ab^{-1}	50 ab^{-1}
$\mathcal{B}(B \to \tau\nu)$ $[10^{-6}]$	$91 \cdot (1 \pm 24\%)$	9%	4%
$\mathcal{B}(B \to \mu\nu)$ $[10^{-6}]$	< 1.7	20%	7%

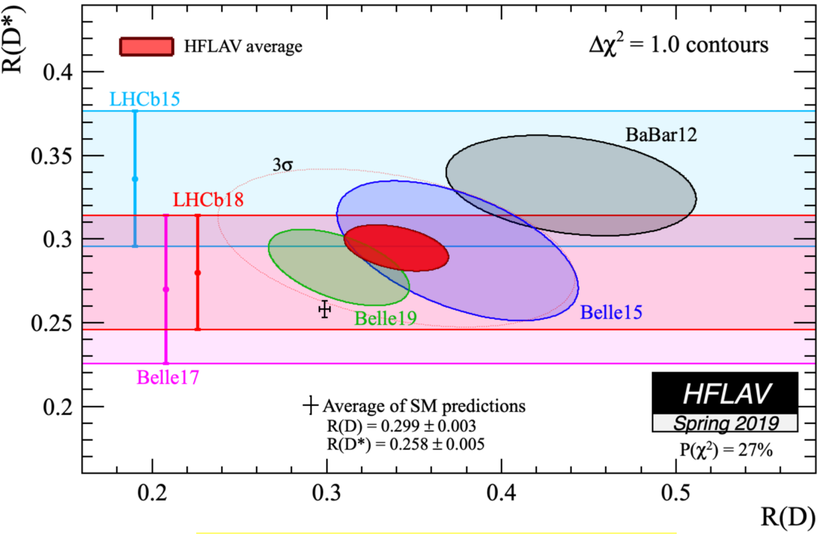
- **Leptonic** decays will *soon* reach <10% precision on $|V_{ub}|$.

$B \to D^{(*)} \tau \nu$

- Belle II needs to improve R(D) - also more sensitive to $H^{\pm}$-like scalar.
- Beyond R(D) and R(D*) - kinematics, polarisation and other observables.

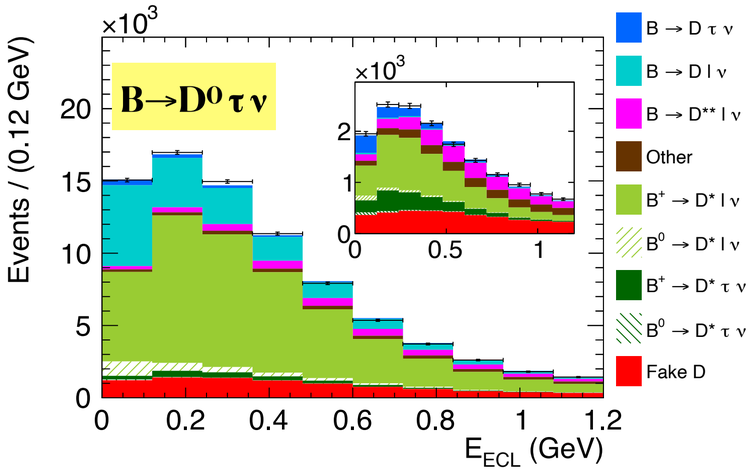


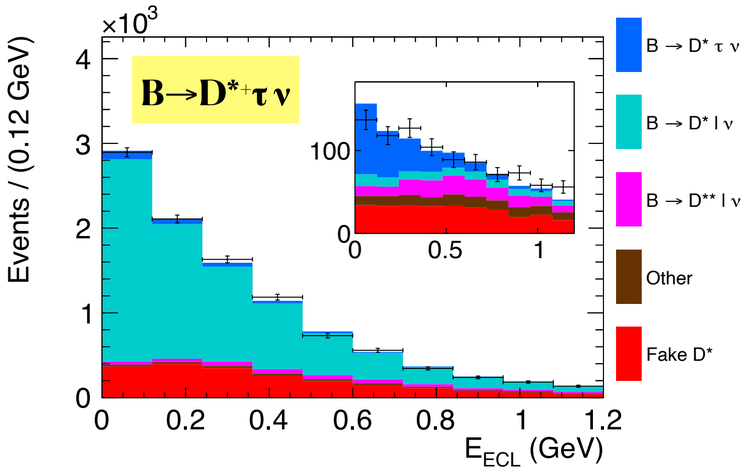
	$5\ \mathrm{ab}^{-1}$	$50\ \mathrm{ab}^{-1}$
R_D	$(\pm 6.0 \pm 3.9)\%$	$(\pm 2.0 \pm 2.5)\%$
R_{D^*}	$(\pm 3.0 \pm 2.5)\%$	$(\pm 1.0 \pm 2.0)\%$
$P_\tau(D^*)$	$\pm 0.18 \pm 0.08$	$\pm 0.06 \pm 0.04$



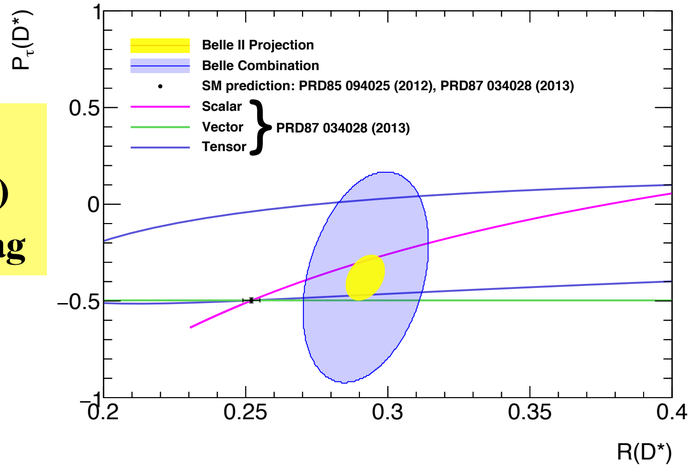
Belle PRL 124, 161803 (2020)
R(D), R(D*) SL tag

$$\mathcal{R}(D) = 0.307 \pm 0.037 \pm 0.016 \quad (13\%)$$
$$\mathcal{R}(D^*) = 0.283 \pm 0.018 \pm 0.014 \quad (8\%)$$

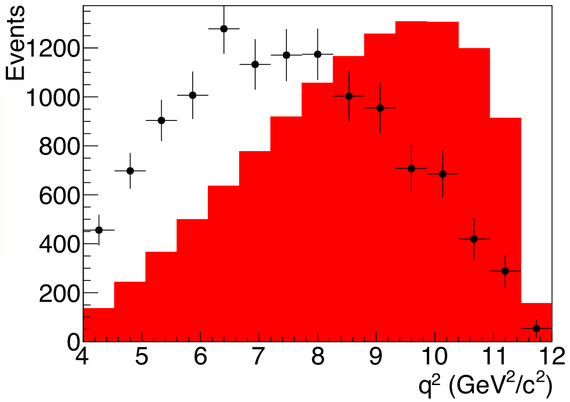




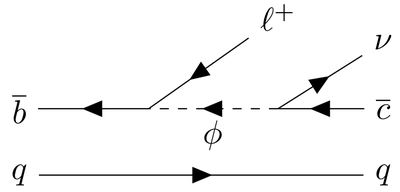
Belle PRD97, 012004 (2018)
R(D*), P_L Had tag



Belle II 50 ab-1, SM (data) vs 2HDM (Hist)

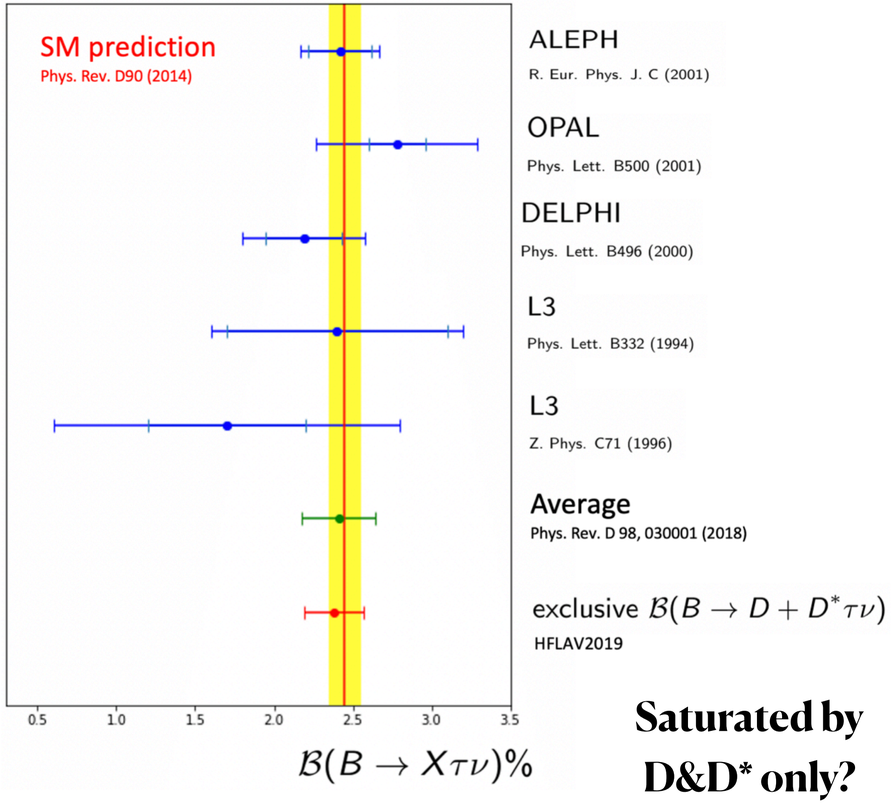


Future studies: $B \to X_c \tau \nu$ inclusive, $B \to \pi/\varrho \tau \nu$



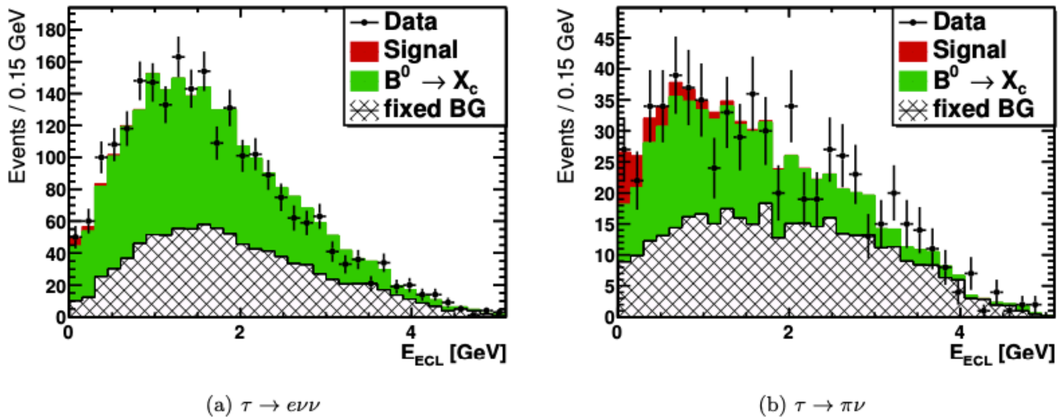
- Inclusive B→ Xτν (with FEI hadronic tag) — only ever measured by LEP.
- Charmless (Belle B→π τ ν had tag.) is highly stats limited and can be seen with Belle II.

Inclusive - Exclusive $B \to X \tau \nu$ tension

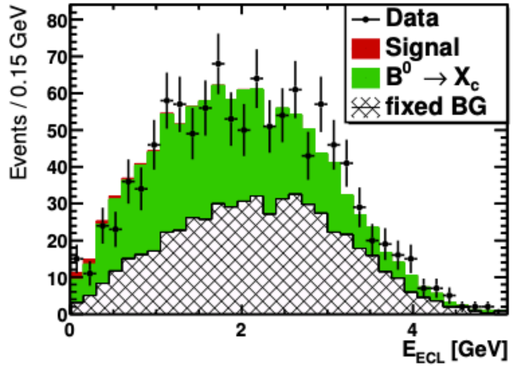


Saturated by D&D* only?

Belle Phys. Rev. D 93, 032007 (2016)
Br($B \to \pi \tau \nu$)<2.8 x 10^{-4} 95% CL



(a) $\tau \to e\nu\nu$ (b) $\tau \to \pi\nu$



(c) $\tau \to \rho\nu$

Belle II projection

$$R_\pi^{5\,\mathrm{ab}^{-1}} = 0.64 \pm 0.23$$

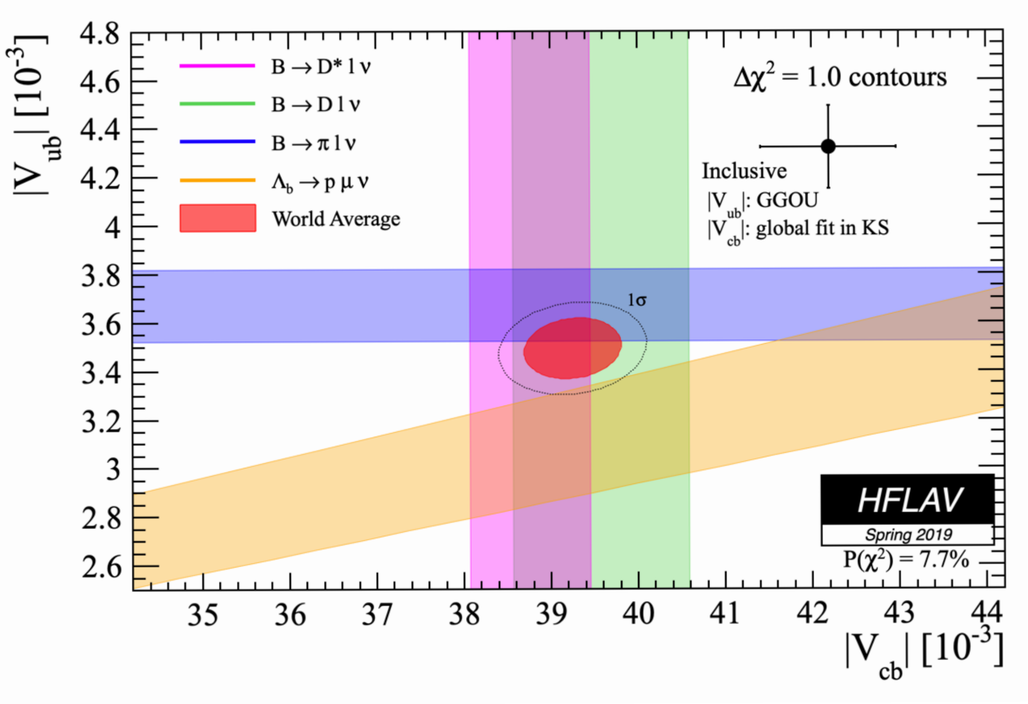
$$R_\pi^{50\,\mathrm{ab}^{-1}} = 0.64 \pm 0.09$$

$B \to X_{c,u}\, l\, \nu$, $B \to D^* l \nu$

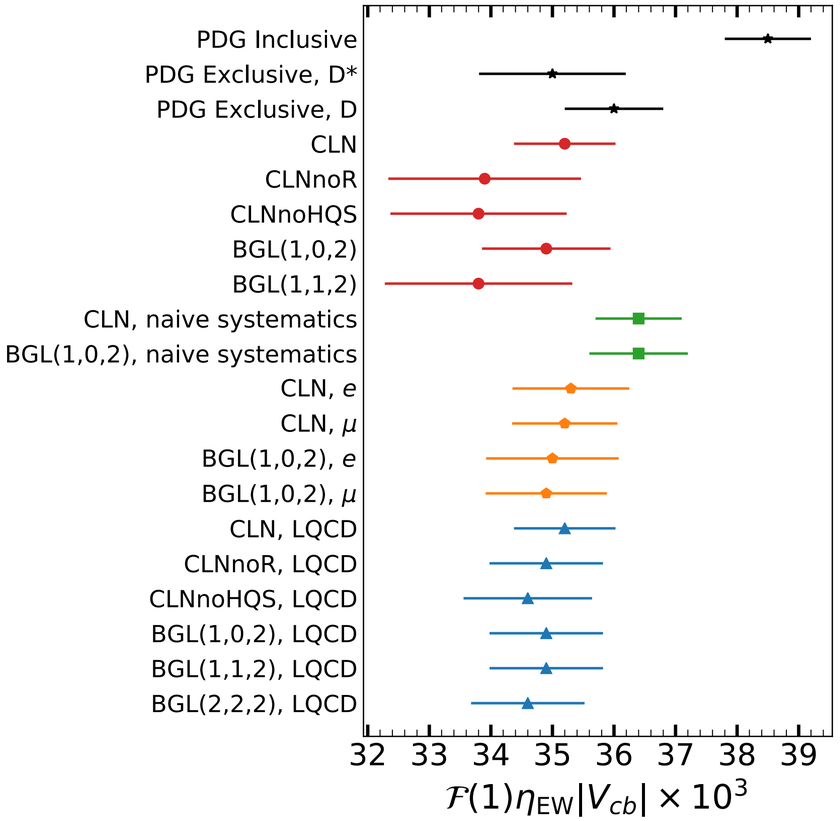
- V_{xb} inclusive-exclusive puzzle persists.
  - V_{ub}: recent inclusive Belle result reduces tension.
  - V_{cb}: Non-zero recoil LQCD inputs coming from Fermilab/MILC & JLQCD (Fermilab/MILC 2105.14019 [hep-lat]).

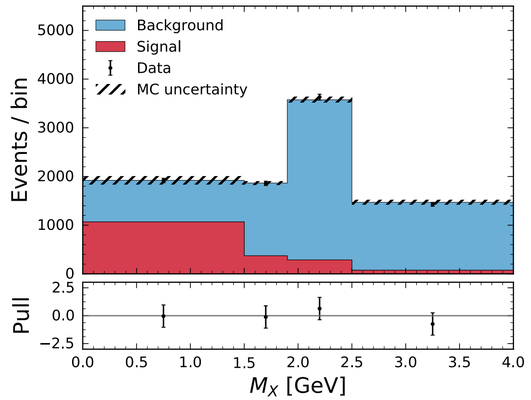
Belle arXiv:2102.00020
$|V_{ub}|$ inclusive

$$|V_{ub}| = (4.10 \pm 0.09 \pm 0.22 \pm 0.15) \times 10^{-3}$$



D. Ferlewicz, PU, E. Waheed
PRD 103, 073005 (2021) Belle
+ non-zero recoil JLQCD





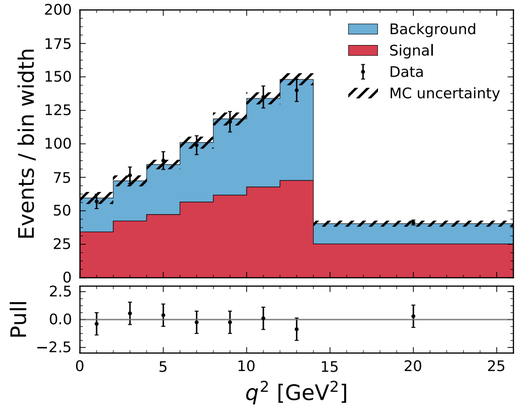


FIG. 9. The post-fit projection of M_X of the two-dimensional fit to $M_X : q^2$ on M_X and the q^2 distribution in the range of $M_X \in [0, 1.5]$ GeV are shown. The resulting yields are corrected to correspond to a partial branching fraction with $E_\ell^B > 1$ GeV. The remaining q^2 distributions are given in Figure 22 (Appendix D).

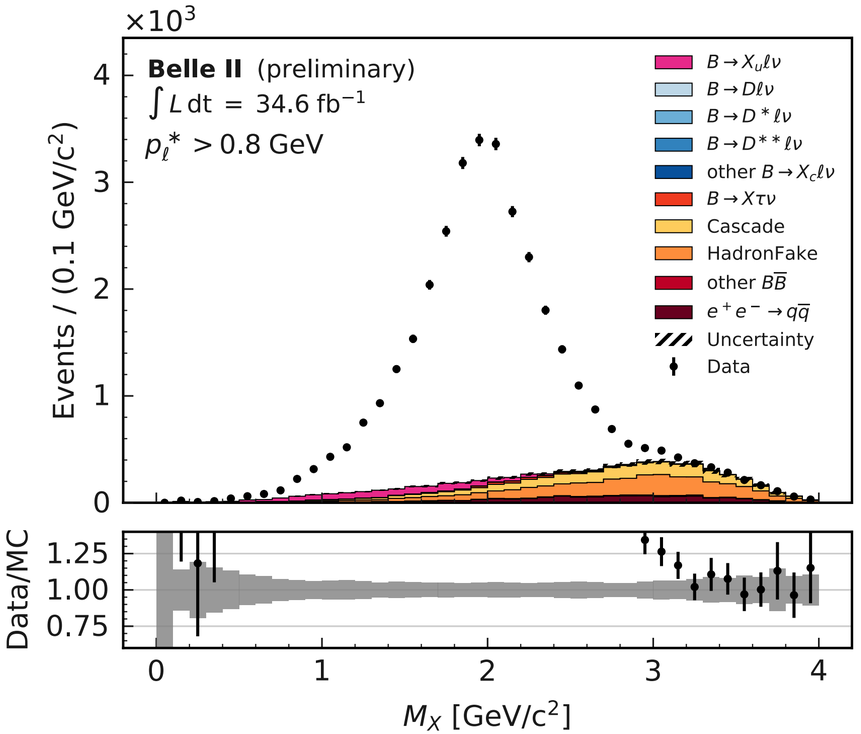
Future studies

Belle II arXiv: 2008.10299, B→D* l ν tagged
Belle II arXiv: 2008.07198, B→D* l ν untagged

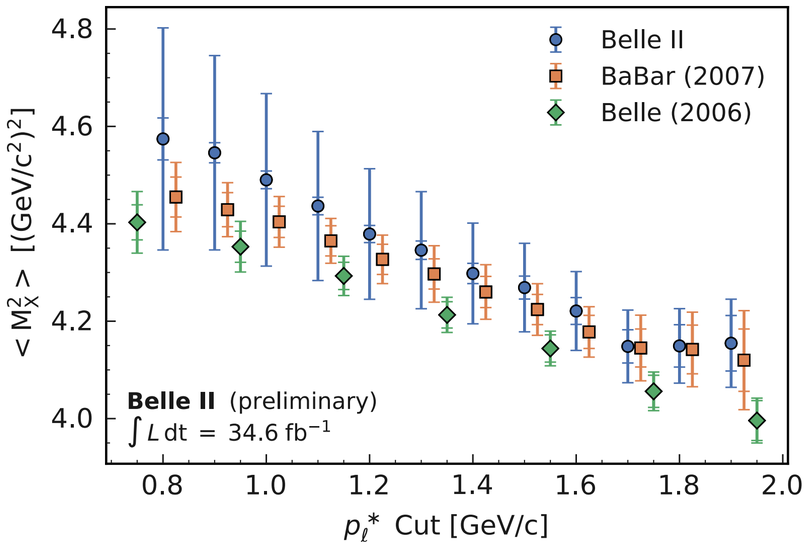
- V_{cb}: New Belle II results (inclusive Belle used only 140 fb^{-1}). Exclusive needs more data at **low *w*** (better **slow pion efficiency at Belle II**).

- V_{ub}: inclusive and exclusive are experimentally statistics limited.

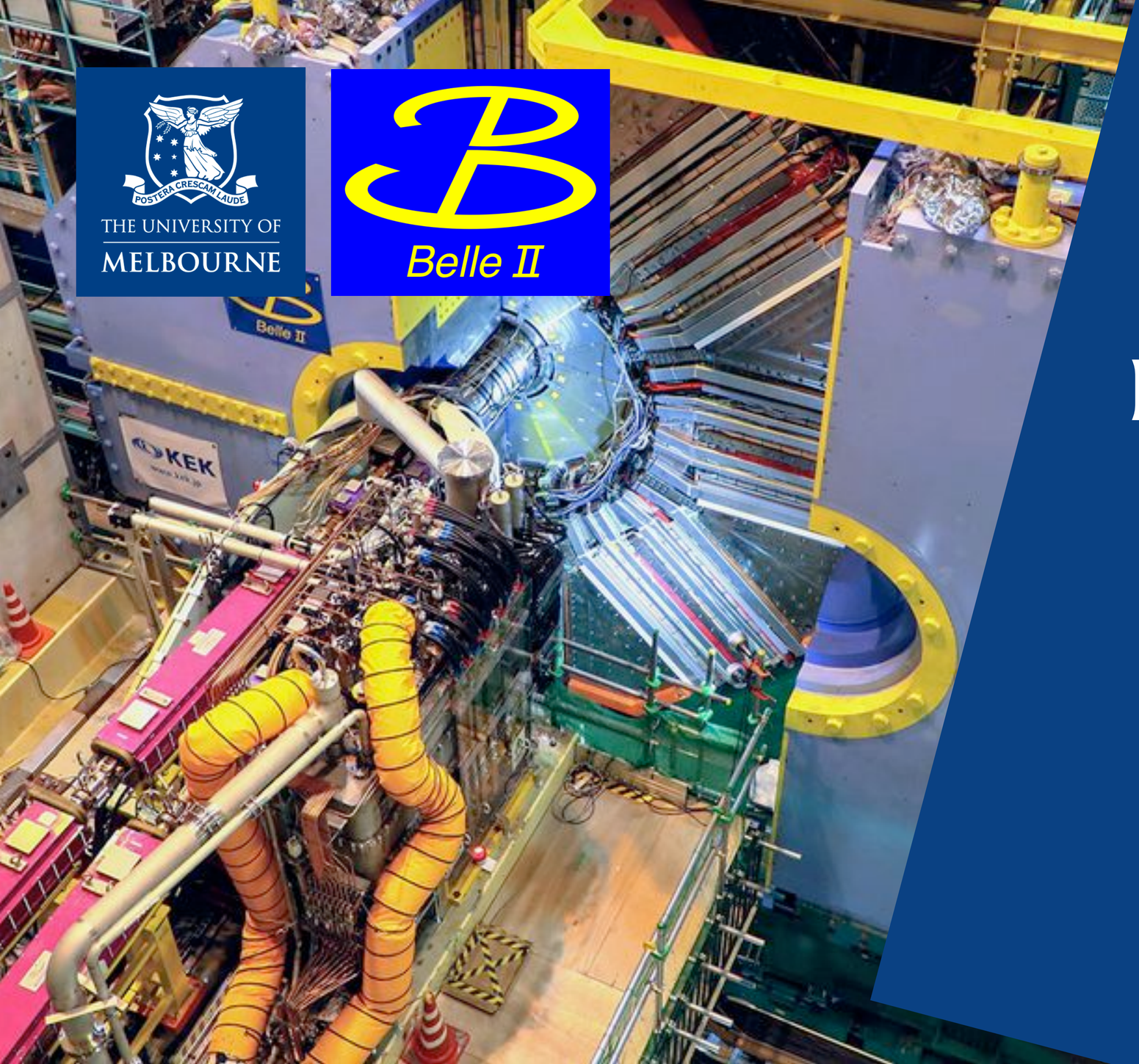
- New physics:
  - **LFUV with light leptons** (improved lepton identification systematics at Belle II).



Belle II arXiv: 2009.04493, B→X l ν M_X moments



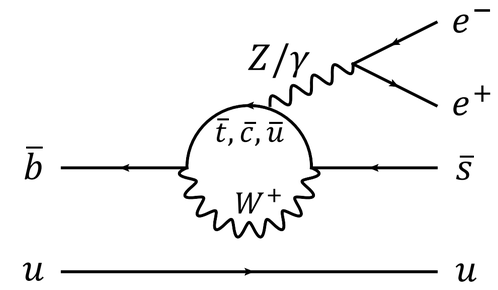
Observables	Belle	Belle II	
		5 ab^{-1}	50 ab^{-1}
$\|V_{cb}\|$ incl.	$42.2 \cdot 10^{-3} \cdot (1 \pm 1.8\%)$	1.2%	–
$\|V_{cb}\|$ excl.	$39.0 \cdot 10^{-3} \cdot (1 \pm 3.0\%_{\text{ex.}} \pm 1.4\%_{\text{th.}})$	1.8%	1.4%
$\|V_{ub}\|$ incl.	$4.47 \cdot 10^{-3} \cdot (1 \pm 6.0\%_{\text{ex.}} \pm 2.5\%_{\text{th.}})$	3.4%	3.0%
$\|V_{ub}\|$ excl. (WA)	$3.65 \cdot 10^{-3} \cdot (1 \pm 2.5\%_{\text{ex.}} \pm 3.0\%_{\text{th.}})$	2.4%	1.2%



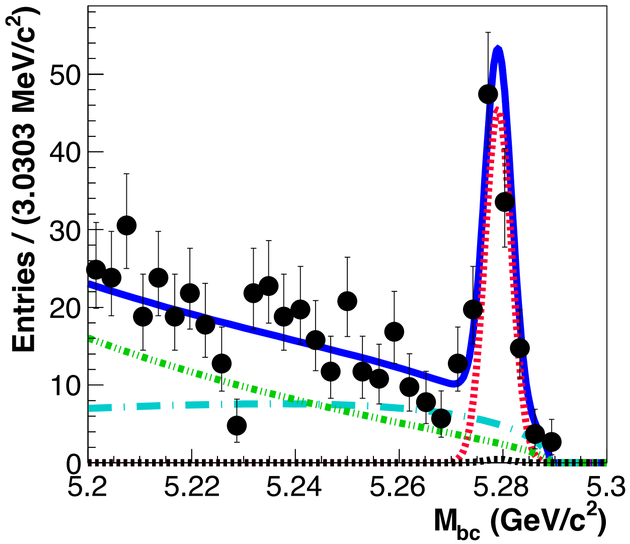
Loop Decays

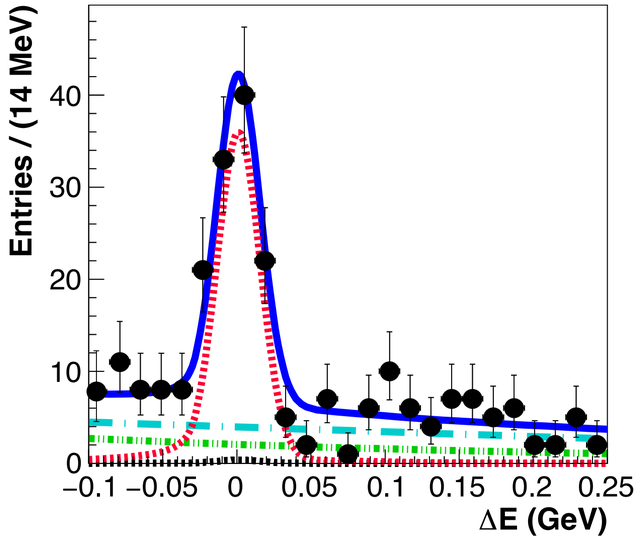
B→K(*)±/0 l+l-

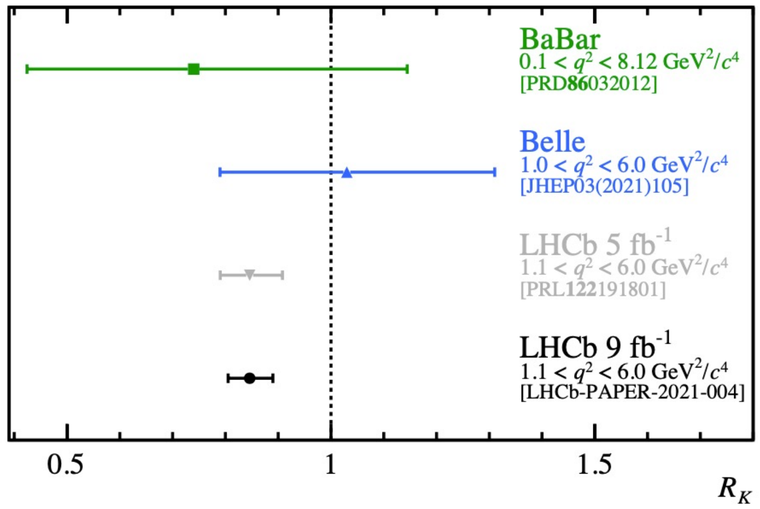
- Long term focus on electron channels (LFUV, angular analyses) & inclusive channels.
  - q^2 (electron) resolution ~ 50 MeV$^2/c^2$ near J/ψ, background constrained with M_{bc}.



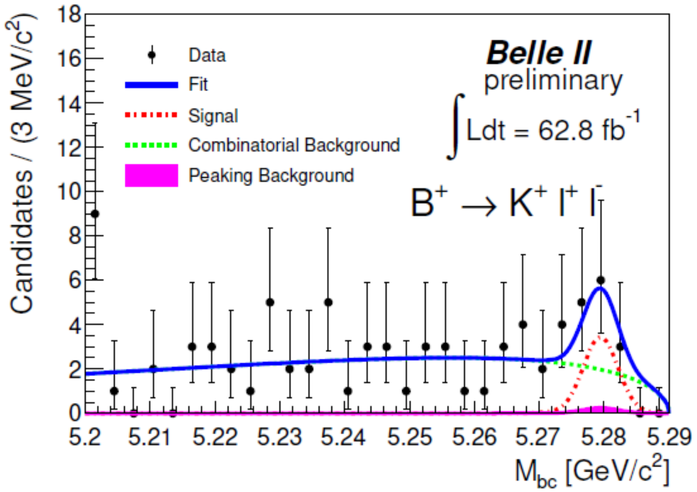
Belle JHEP 2103, 105 (2021) B→K⁺ e⁺ e⁻
Belle Phys. Rev. Lett. 126, 161801 (2021)







Belle II B→K⁺ l⁺ l⁻

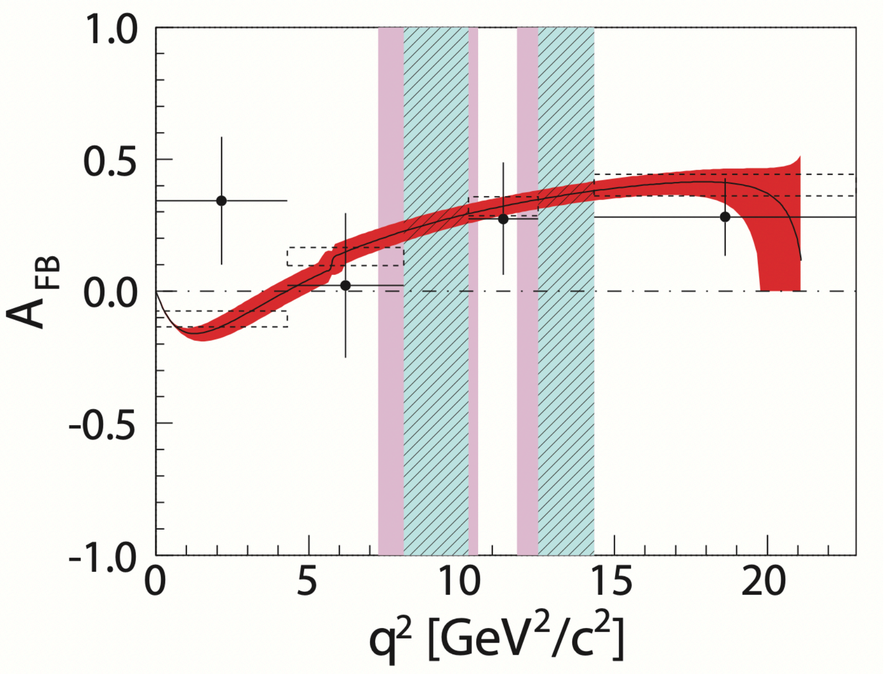


Observables	Belle 0.71 ab^{-1}	Belle II 5 ab^{-1}	Belle II 50 ab^{-1}
R_K ($[1.0, 6.0]$ GeV^2)	28%	11%	3.6%
R_K (> 14.4 GeV^2)	30%	12%	3.6%
R_{K^*} ($[1.0, 6.0]$ GeV^2)	26%	10%	3.2%
R_{K^*} (> 14.4 GeV^2)	24%	9.2%	2.8%
R_{X_s} ($[1.0, 6.0]$ GeV^2)	32%	12%	4.0%
R_{X_s} (> 14.4 GeV^2)	28%	11%	3.4%

$B \to X_s l^+ l^-$

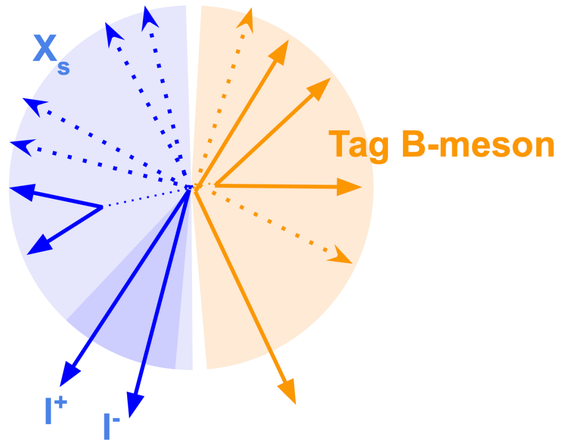
Belle Σ Exclusive: Phys. Rev. D 93, 032008 (2016)

$\bar{B}^0$ decays		B^- decays	
	(K^0_S)	K^-	
$K^-\pi^+$	$(K^0_S\pi^0)$	$K^-\pi^0$	$K^0_S\pi^-$
$K^-\pi^+\pi^0$	$(K^0_S\pi^-\pi^+)$	$K^-\pi^+\pi^-$	$K^0_S\pi^-\pi^0$
$K^-\pi^+\pi^-\pi^+$	$(K^0_S\pi^-\pi^+\pi^0)$	$K^-\pi^+\pi^-\pi^0$	$K^0_S\pi^-\pi^+\pi^-$
$(K^-\pi^+\pi^-\pi^+\pi^0)$	$(K^0_S\pi^-\pi^+\pi^-\pi^+)$	$(K^-\pi^+\pi^-\pi^+\pi^-)$	$(K^0_S\pi^-\pi^+\pi^-\pi^0)$



Tagged Dilepton Inclusive

- Novel Belle II studies based on tagging to inclusively reconstruct the X system (in progress).

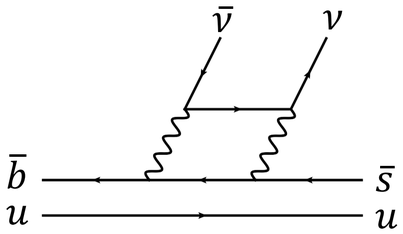


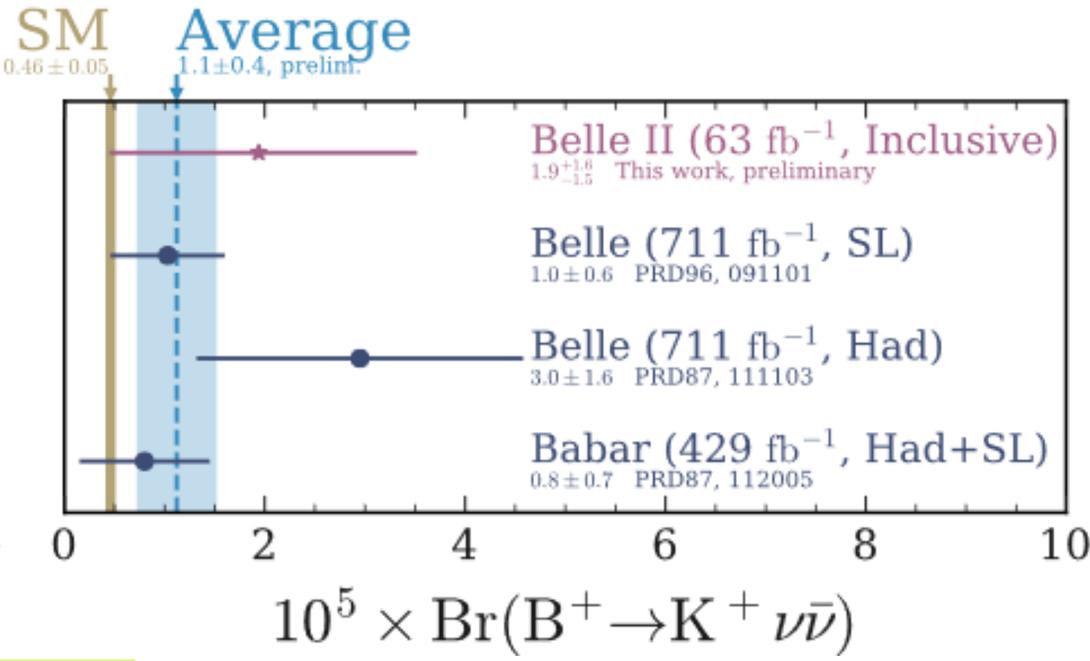
Σ Exclusive projections

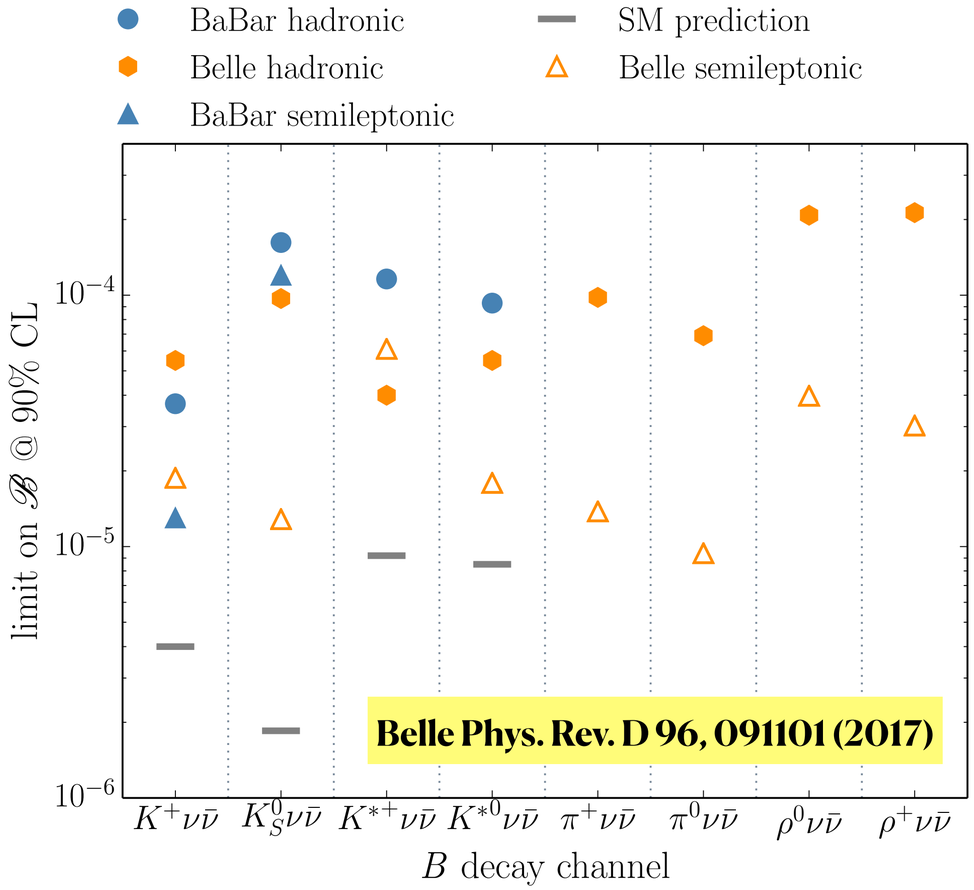
	Belle $0.71\ \text{ab}^{-1}$	Belle II $5\ \text{ab}^{-1}$	Belle II $50\ \text{ab}^{-1}$
$\text{Br}(B \to X_s\ell^+\ell^-)$ $([1.0, 3.5]\,\text{GeV}^2)$	29%	13%	6.6%
$\text{Br}(B \to X_s\ell^+\ell^-)$ $([3.5, 6.0]\,\text{GeV}^2)$	24%	11%	6.4%
$\text{Br}(B \to X_s\ell^+\ell^-)$ $(>14.4\,\text{GeV}^2)$	23%	10%	4.7%
$A_{\text{CP}}(B \to X_s\ell^+\ell^-)$ $([1.0, 3.5]\,\text{GeV}^2)$	26%	9.7%	3.1%
$A_{\text{CP}}(B \to X_s\ell^+\ell^-)$ $([3.5, 6.0]\,\text{GeV}^2)$	21%	7.9%	2.6%
$A_{\text{CP}}(B \to X_s\ell^+\ell^-)$ $(>14.4\,\text{GeV}^2)$	21%	8.1%	2.6%
$A_{\text{FB}}(B \to X_s\ell^+\ell^-)$ $([1.0, 3.5]\,\text{GeV}^2)$	26%	9.7%	3.1%
$A_{\text{FB}}(B \to X_s\ell^+\ell^-)$ $([3.5, 6.0]\,\text{GeV}^2)$	21%	7.9%	2.6%
$A_{\text{FB}}(B \to X_s\ell^+\ell^-)$ $(>14.4\,\text{GeV}^2)$	19%	7.3%	2.4%
$\Delta_{\text{CP}}(A_{\text{FB}})$ $([1.0, 3.5]\,\text{GeV}^2)$	52%	19%	6.1%
$\Delta_{\text{CP}}(A_{\text{FB}})$ $([3.5, 6.0]\,\text{GeV}^2)$	42%	16%	5.2%
$\Delta_{\text{CP}}(A_{\text{FB}})$ $(>14.4\,\text{GeV}^2)$	38%	15%	4.8%

B→K/K*/π/ϱ ν ν

- SM B→K(*) νν studies: Now 3 methods demonstrated.
  - SL tag, Hadronic tag, **Inclusive tag**. (Statistically ~independent).
  - Note: large efficiency improvements with FEI over previous iterations of B-full reconstruction.

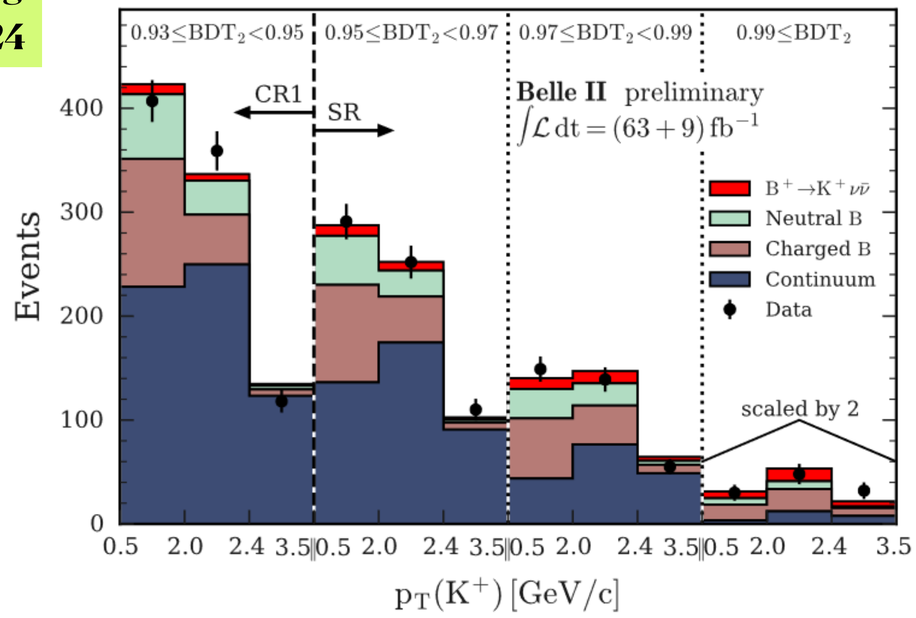






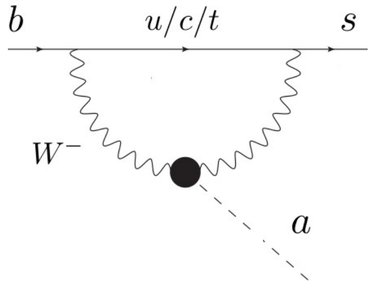
Belle Phys. Rev. D 96, 091101 (2017)

Belle II Novel inclusive tag method arXiv:2104.12624



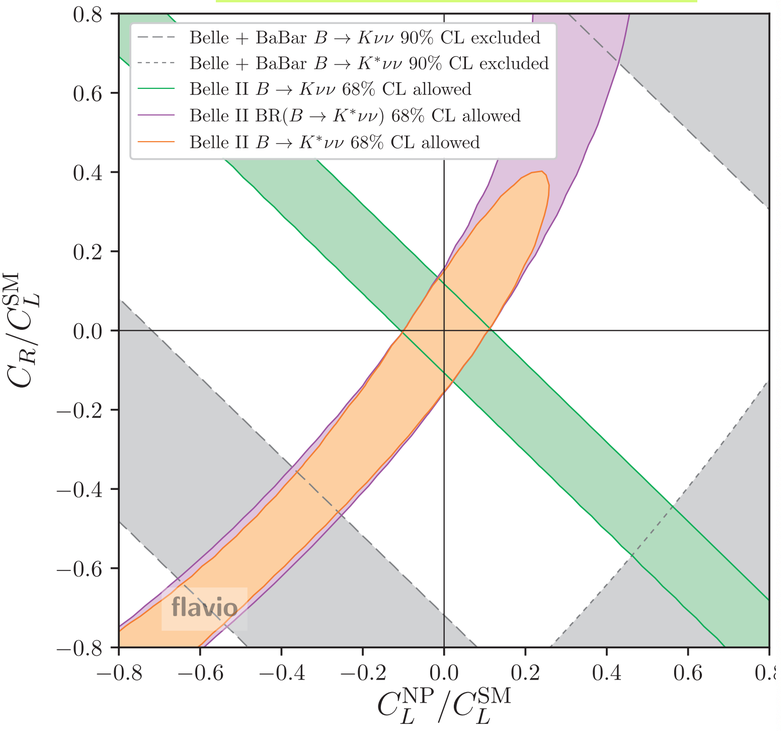
B→ K/K*/π/ϱ … + invisible or long-lived

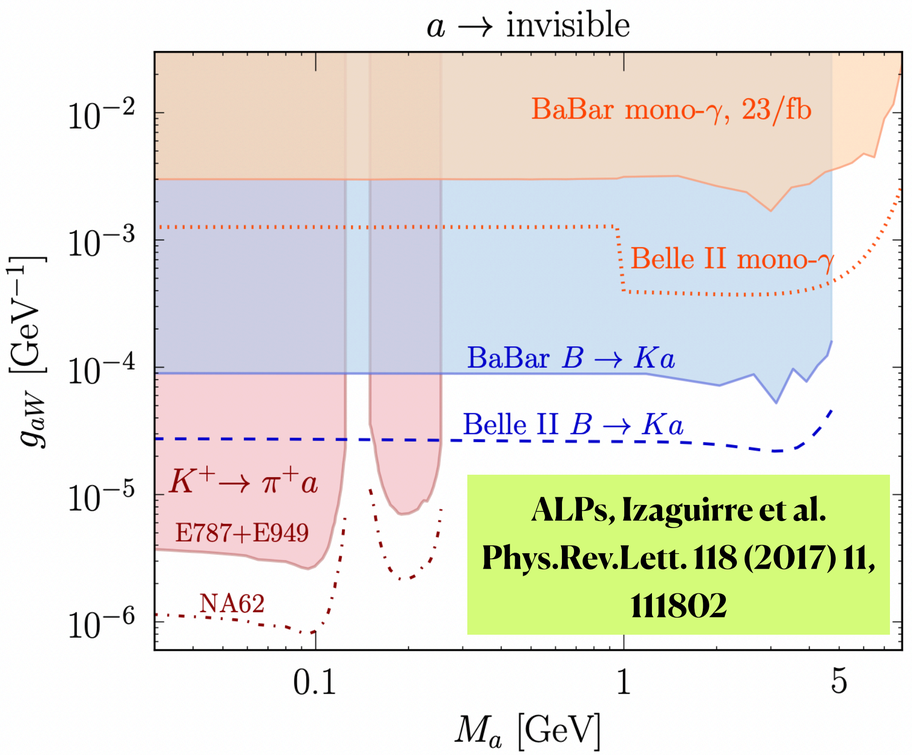
- B→K(*)νν studies: We may have significant signal of SM with 2-5 ab-1.
- B→X + ALPs, Dark Photons, **Higgs like scalars**. B→ X + (invisible, γγ, l+l-, h+h- etc.).



Observables	Belle 0.71 ab^{-1} (0.12 ab^{-1})	Belle II 5 ab^{-1}	Belle II 50 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%
$F_\mathrm{L}(B^0 \to K^{*0}\nu\bar{\nu})$	—	—	0.079
$F_\mathrm{L}(B^+ \to K^{*+}\nu\bar{\nu})$	—	—	0.077
$\mathrm{Br}(B^0 \to \nu\bar{\nu}) \times 10^6$	< 14	< 5.0	< 1.5
$\mathrm{Br}(B_s \to \nu\bar{\nu}) \times 10^5$	< 9.7	< 1.1	—

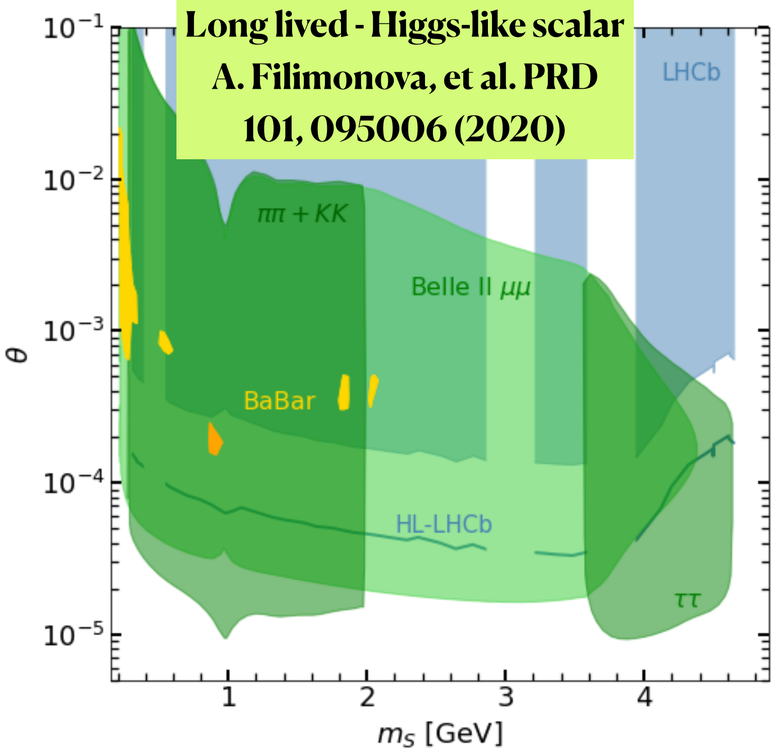
PTEP 2019 (2019) 12, 123C01





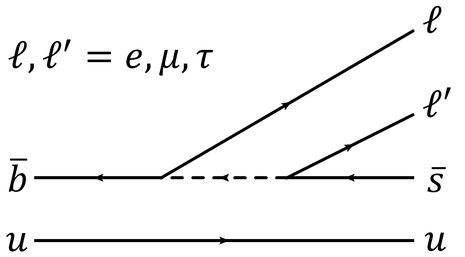
ALPs, Izaguirre et al. Phys.Rev.Lett. 118 (2017) 11, 111802

Long lived - Higgs-like scalar A. Filimonova, et al. PRD 101, 095006 (2020)



$B \to X_{s,d} \tau l$, $B \to X_{s,d} \tau \tau$

- LFV channels, use tagging to infer recoil mass near m_τ.
- LF conserving channels with τ probably out of reach of SM, but good for NP sensitivity.
- Results from Belle (II) on the way (none yet).



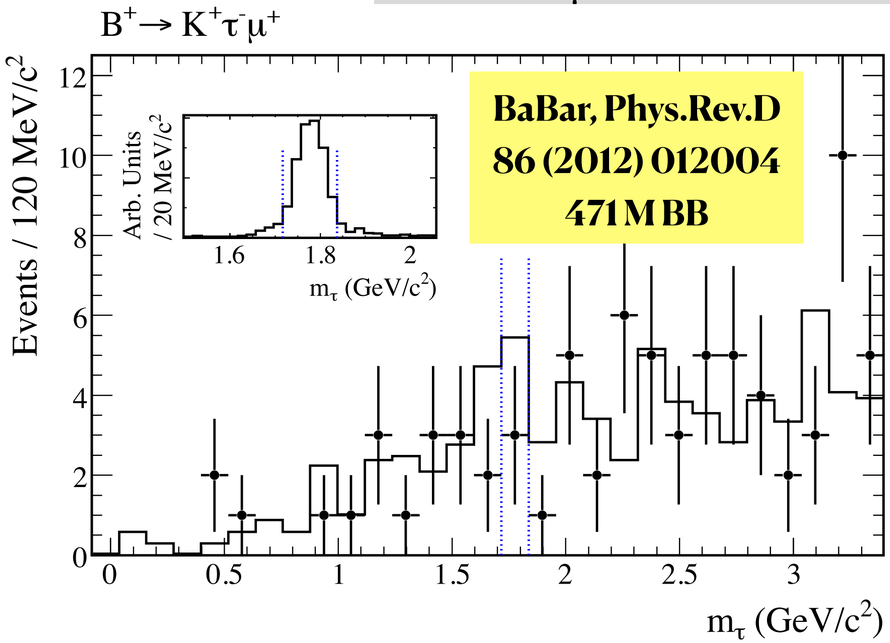
SM prediction

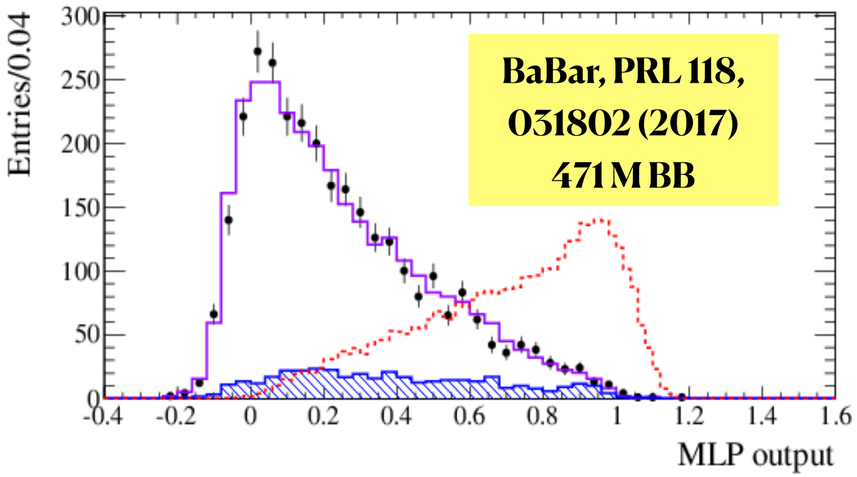
$$\mathrm{Br}(B^+ \to K^{*+}\tau^+\tau^-)_{\mathrm{SM}} = (0.99 \pm 0.12) \cdot 10^{-7},$$

$$\mathrm{Br}(B^0 \to K^{*0}\tau^+\tau^-)_{\mathrm{SM}} = (0.91 \pm 0.11) \cdot 10^{-7},$$

Current status of searches τ LFV

$B^+ \to K^+\tau\mu$	$<4.8\times10^{-5}$ (BaBar)
$B^+ \to K^+\tau e$	$<3.0\times10^{-5}$ (BaBar)
$B^+ \to K^+\tau^+\mu^-$	$<3.9\times10^{-5}$ (LHCb)

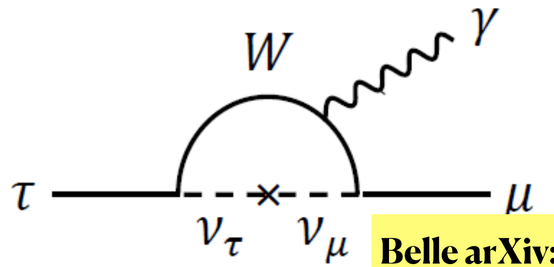




Observables	Belle 0.71 ab^{-1} (0.12 ab^{-1})	Belle II 5 ab^{-1}	Belle II 50 ab^{-1}
$\mathrm{Br}(B^+ \to K^+\tau^+\tau^-) \cdot 10^5$	< 32	< 6.5	< 2.0
$\mathrm{Br}(B^0 \to \tau^+\tau^-) \cdot 10^5$	< 140	< 30	< 9.6
$\mathrm{Br}(B_s^0 \to \tau^+\tau^-) \cdot 10^4$	< 70	< 8.1	—
$\mathrm{Br}(B^+ \to K^+\tau^\pm e^\mp) \cdot 10^6$	—	—	< 2.1
$\mathrm{Br}(B^+ \to K^+\tau^\pm \mu^\mp) \cdot 10^6$	—	—	< 3.3
$\mathrm{Br}(B^0 \to \tau^\pm e^\mp) \cdot 10^6$	—	—	< 1.6
$\mathrm{Br}(B^0 \to \tau^\pm \mu^\mp) \cdot 10^6$	—	—	< 1.3

τ LFUV & LFV

- New phenomena coupling to τs can be probed directly via ee→ττ.
- Good near term prospects for exotic searches, e.g. τ→l α (invisible), and τ decay LFUV (need to push Lepton ID systematics).

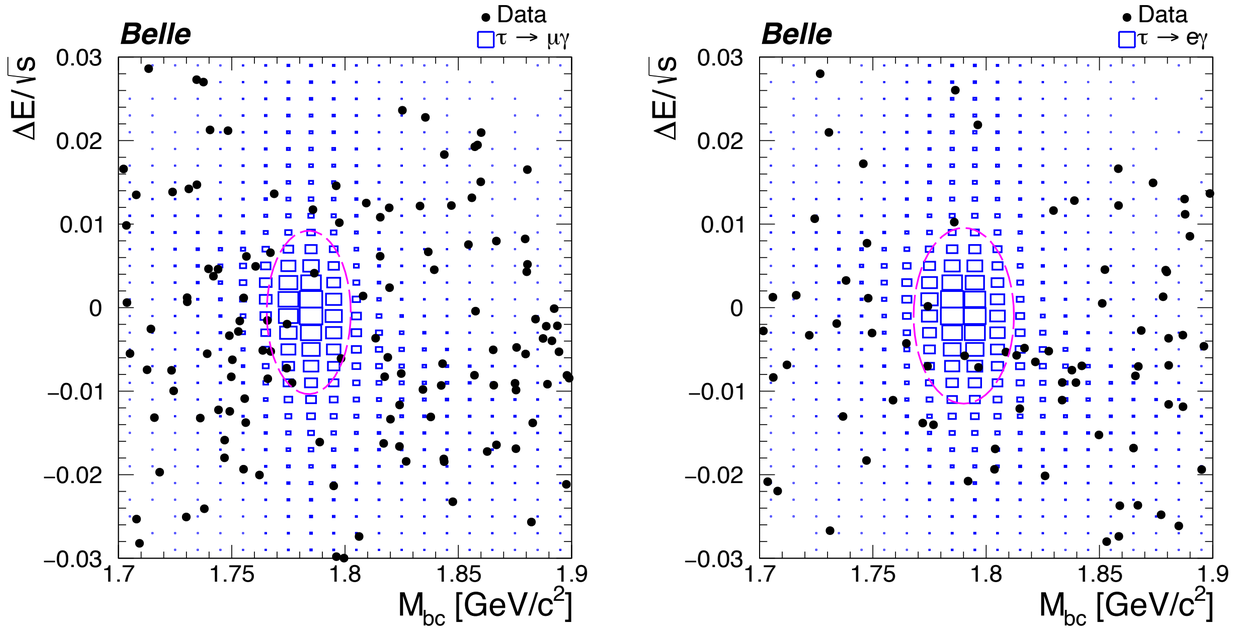


Belle arXiv:2103.12994

$$\mathcal{B}(\tau^\pm \to \mu^\pm\gamma) < \frac{\tilde{s}_{90}}{2\epsilon N_{\tau\tau}} = 4.2 \times 10^{-8},$$

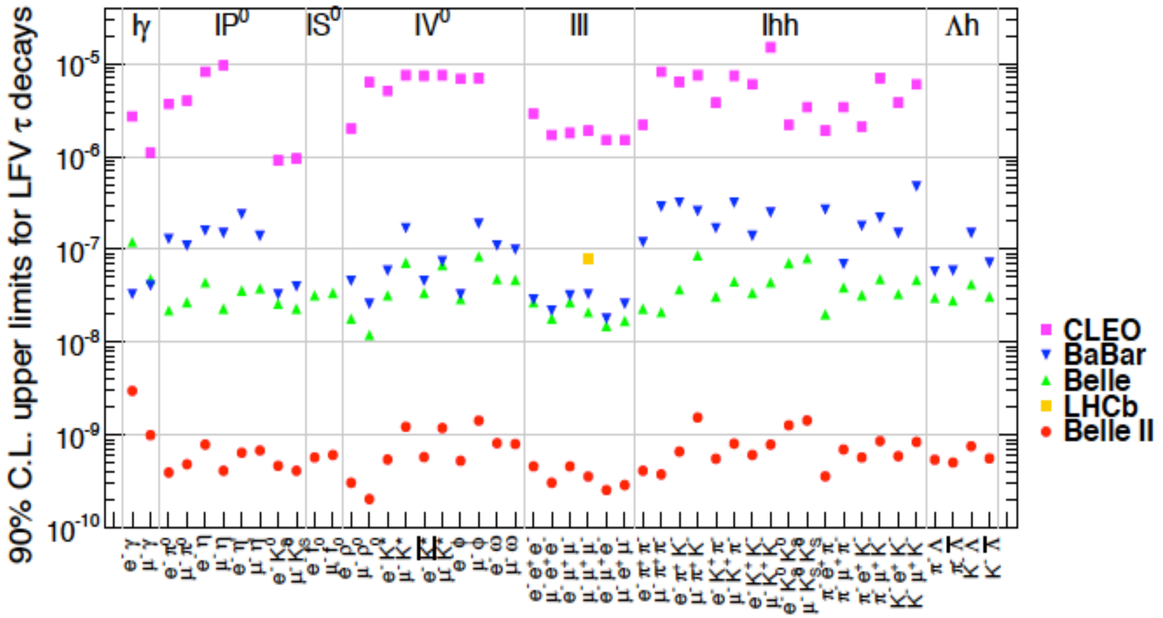
$$\mathcal{B}(\tau^\pm \to e^\pm\gamma) < \frac{\tilde{s}_{90}}{2\epsilon N_{\tau\tau}} = 5.6 \times 10^{-8},$$

Belle arXiv:2103.12994



(a) $\tau^\pm \to \mu^\pm\gamma$ (b) $\tau^\pm \to e^\pm\gamma$

PTEP 2019 (2019) 12, 123C01

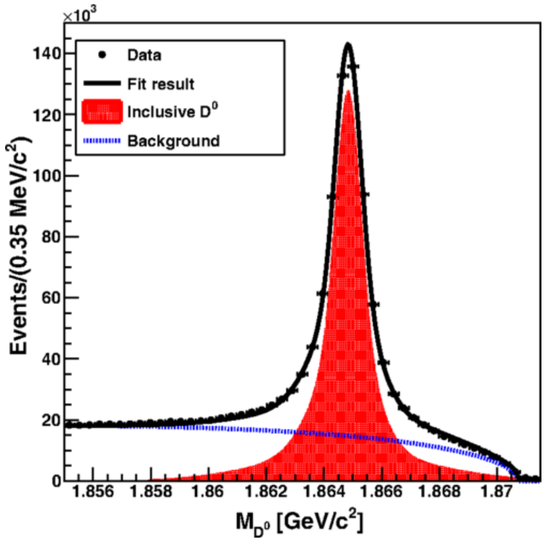


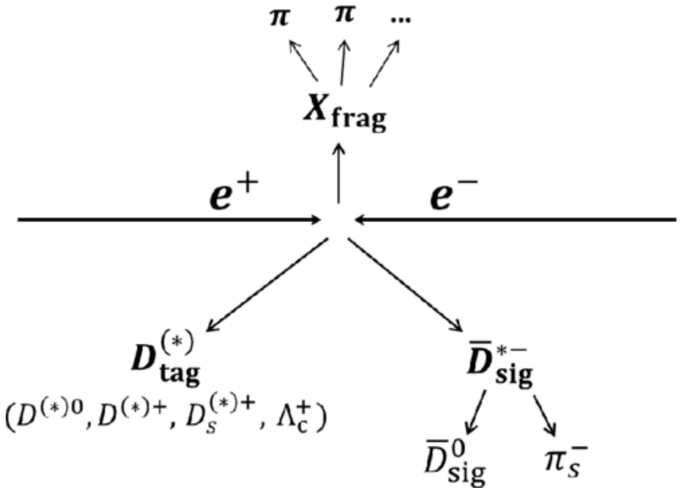
Charm: SL, Forbidden

- Belle II expects to have a program of leptonic & semileptonic measurements $D_s \to l\nu$ or $D \to \nu\nu$ using tag methods.

- Many charm forbidden or suppressed modes: most competitive with di-electron (recent updates by BaBar).

Belle Phys. Rev. D 95, 011102(R) (2017)



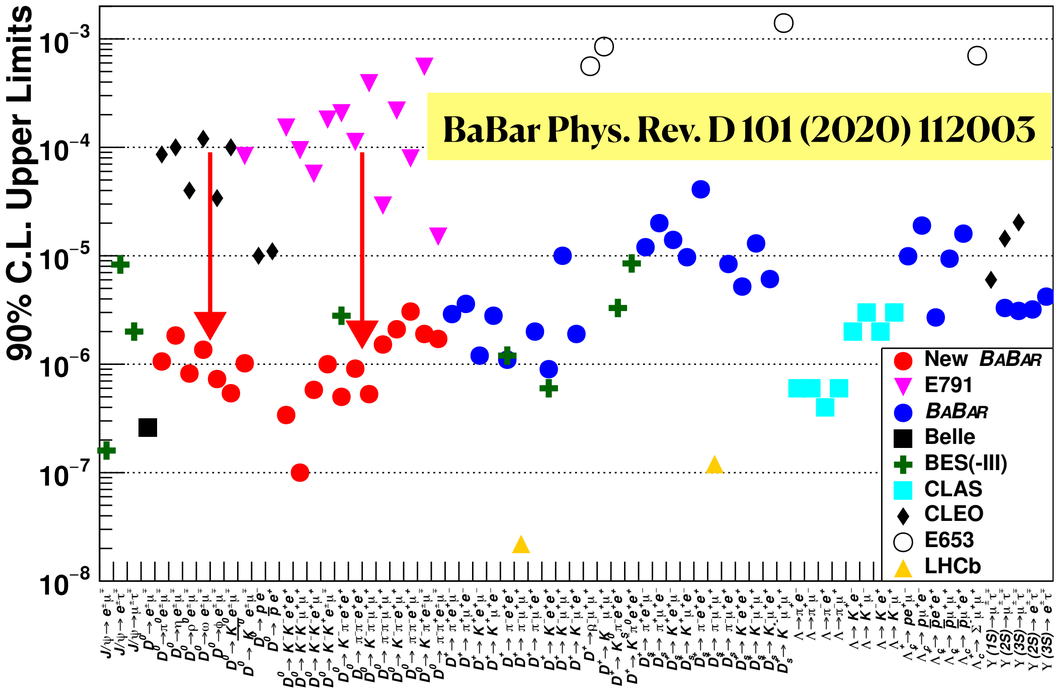


Stat limited up to 50 ab^{-1}

Most competitive on D_s

Channel	Observable	Belle/BaBar Measurement		Scaled	
		$\mathcal{L}$ [ab^{-1}]	Value	5 ab^{-1}	50 ab^{-1}
Leptonic Decays					
$D_s^+ \to \ell^+\nu$	μ^+ events	0.913	492 ± 26	2.7k	27k
	τ^+ events		2217 ± 83	12.1k	121k
	f_{D_s}		2.5%	1.1%	0.34%
$D^+ \to \ell^+\nu$	μ^+ events	-	-	125	1250
	f_D	-	-	6.4%	2.0%

BaBar Phys. Rev. D 101 (2020) 112003



Roadmap

2019: 10 fb^{-1}

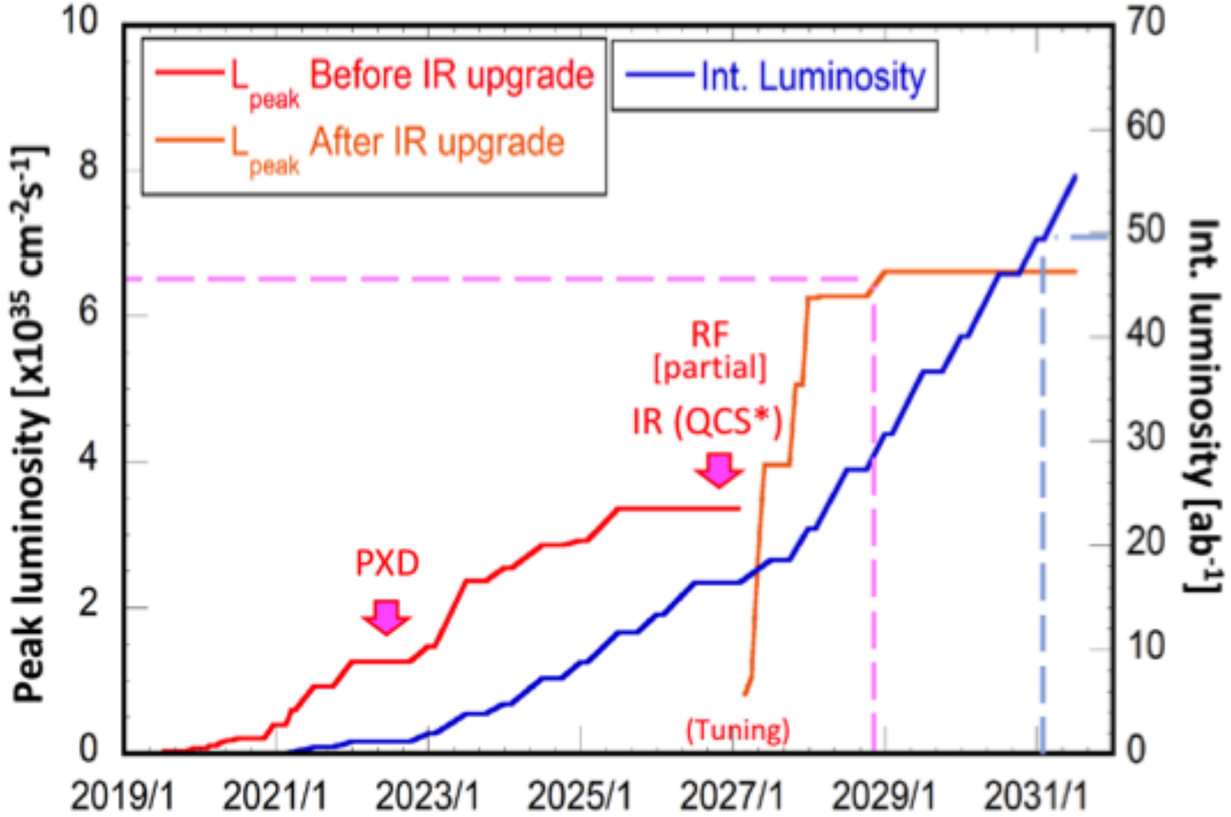
2020: ~100 fb^{-1}

2021: ~300-400 fb^{-1} (December, **Babar 500 fb^{-1}**)

2022: ~*O*(1) ab^{-1} (**Belle**). Long shutdown for PXD upgrade, 1→2 full layers.

2024/2025 5 ab^{-1} B2TiP Milestone
PTEP 2019 (2019) 12, 123C01

2026 Possible second shutdown for high luminosity upgrades (SuperKEKB and Belle II)



Four steps: *Intermediate luminosity* (1-2 x 10^{35} /cm^2/sec, 5ab^{-1});
High Luminosity (6.5 x 10^{35}/cm^2/sec, 50 ab^{-1}) with a detector upgrade
Polarization Upgrade, Advanced R&D
Ultra high luminosity (4 x 10^{36}/cm^2/sec, 250 ab^{-1}), R&D Project

Belle II - LHCb Comparison

Belle II
Higher sensitivity to decays with photons and neutrinos (e.g. B→Kνν, μν), inclusive decays, time dependent CPV in B_d, τ physics.

LHCb
Higher production rates for ultra rare B, D, & K decays, access to all b-hadron flavours (e.g. Λ_b), high boost for fast B_s oscillations.

Overlap in various key areas to verify discoveries.

Upgrades
Most key channels will be stats. limited (not theory or syst.).
LHCb scheduled major upgrades during LS3 and LS4.
Belle II formulating an upgrade program.

	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	13°	5.4°	4.7°	1.5°	1.5°	0.4°	0.4°
	α/φ_2	4°	–	2	0.6°	–	0.3°	–
✸	$\lvert V_{ub}\rvert$ (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							
	ΔA_{CP}(KK-ππ)	–	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)

○ Possible in similar channels, lower precision
– Not competitive.

Summary

- **210 fb^{-1} collected** (most of it during Covid19 travel restrictions)
  - Selected highlights with up to 63 fb^{-1} of 2020 data shown (major updates for EPS-HEP).

- The **flavour physics (publication) program has started.**
  - **Semileptonic and leptonic channels are a major focus.**
  - **Looking for both** high energy/mass scale NP and low mass “feeble” interactions.

- **Performance generally better than Belle** on lepton ID, neutral/extra calorimeter energy, K_L-ID, tracking at low momenta and *B* full-reconstruction (etc.).
  - Owing to better detector performance (VXD), use of more detector information (ECL waveform sampling), and better ML methods in particle reconstruction.
  - Excellent prospects for studies of missing particle channels.