16th Central European Seminar on Particle Physics and Quantum Field Theory
November 24-25, 2022, Vienna, AUSTRIA

CKM unitary results from Belle and Belle II

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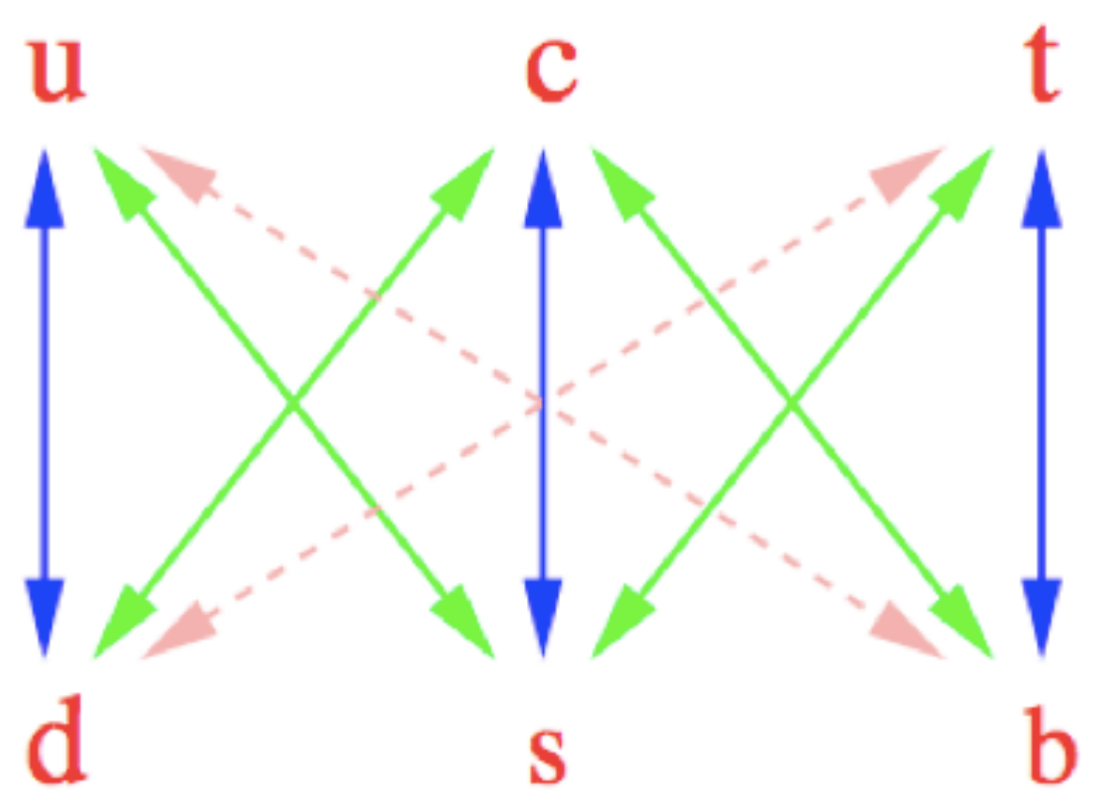
representing the Belle and Belle II collaborations

Cabibbo-Kobayashi-Maskawa quark mixing

$$\begin{pmatrix} d' \\ s' \\ b' \end{pmatrix} = \mathbf{V} \begin{pmatrix} d \\ s \\ b \end{pmatrix}$$

$$V_{\mathrm{CKM}} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix}$$

$$\mathbf{V}\,\mathbf{V}^\dagger = \mathbf{V}^\dagger\,\mathbf{V} = 1$$



- The physical quark states are a mixture of the flavour eigenstates described by the unitary Cabibbo-Kobayashi-Maskawa (CKM) matrix
- The CKM element magnitudes squared determine the rate of quark flavour transitions in charged current processes

$$-\mathcal{L}_{W^\pm} = \frac{g}{\sqrt{2}}\,\overline{u_{Li}}\,\gamma^\mu\,(V_{\mathrm{CKM}})_{ij}\,d_{Lj}\,W_\mu^+ + \mathrm{h.c.}$$

CP violation

Wolfenstein parametrization of V_{CKM}

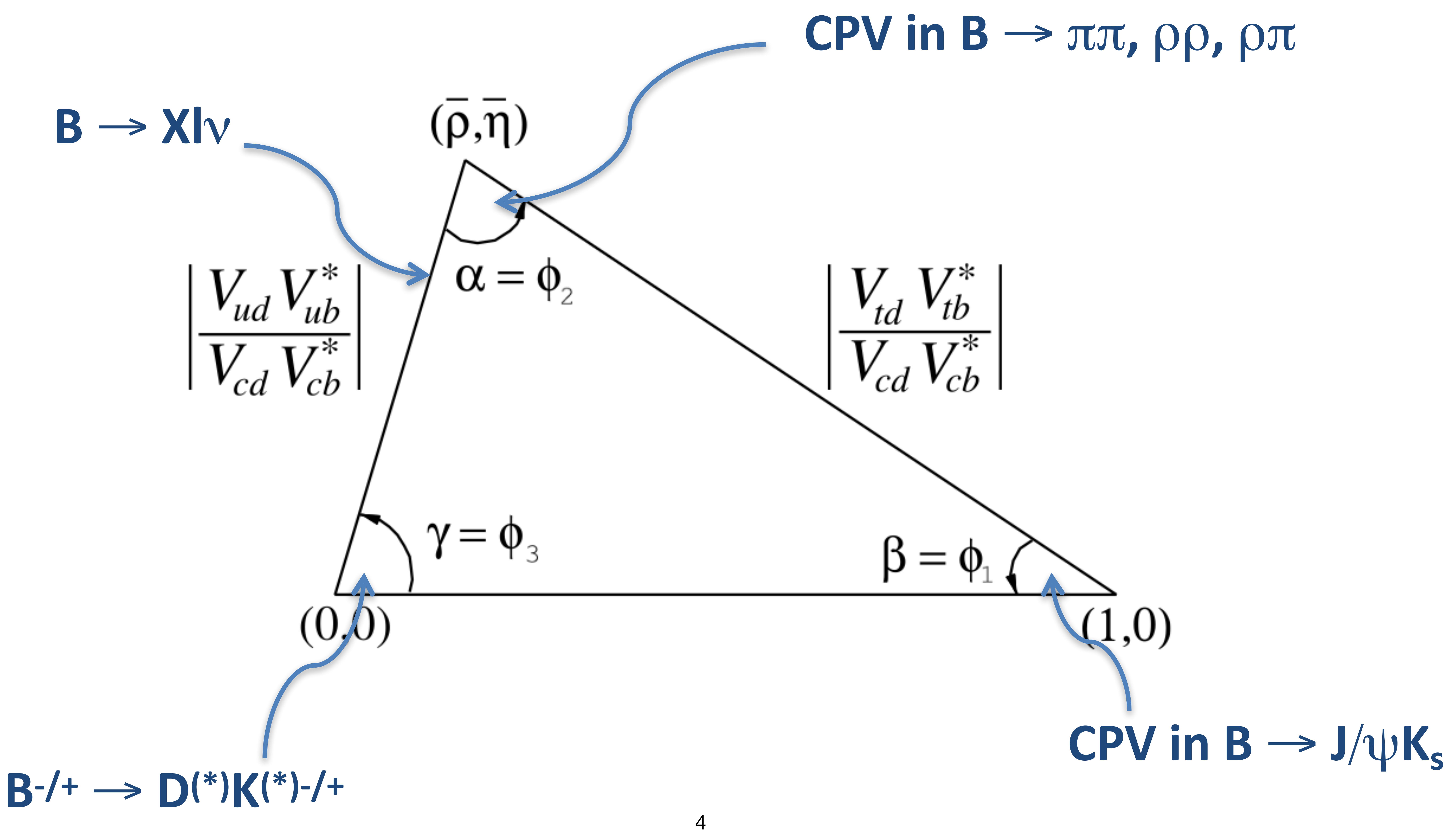
$$V_{\mathrm{CKM}} = \begin{pmatrix} 1-\lambda^2/2 & \lambda & A\lambda^3(\rho - i\eta) \\ -\lambda & 1-\lambda^2/2 & A\lambda^2 \\ A\lambda^3(1-\rho-i\eta) & -A\lambda^2 & 1 \end{pmatrix} + \mathcal{O}(\lambda^4)$$

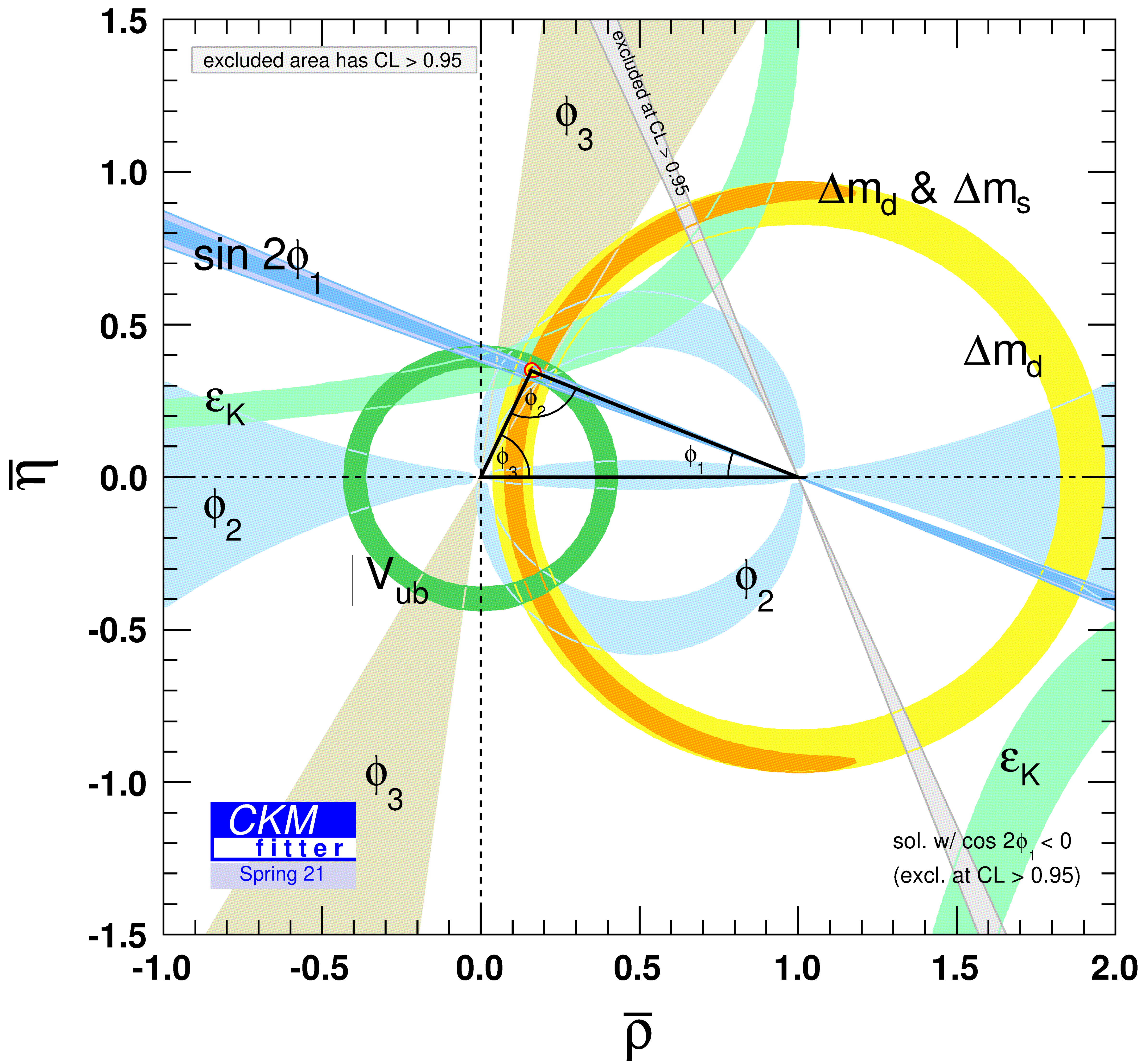
- However, V_{CKM} also contains a complex phase, responsible for all CP-violating phenomena in kaon and B meson decays observed so far → extremely constrained system)
- New physics would typically disturb the SM pattern of CPV

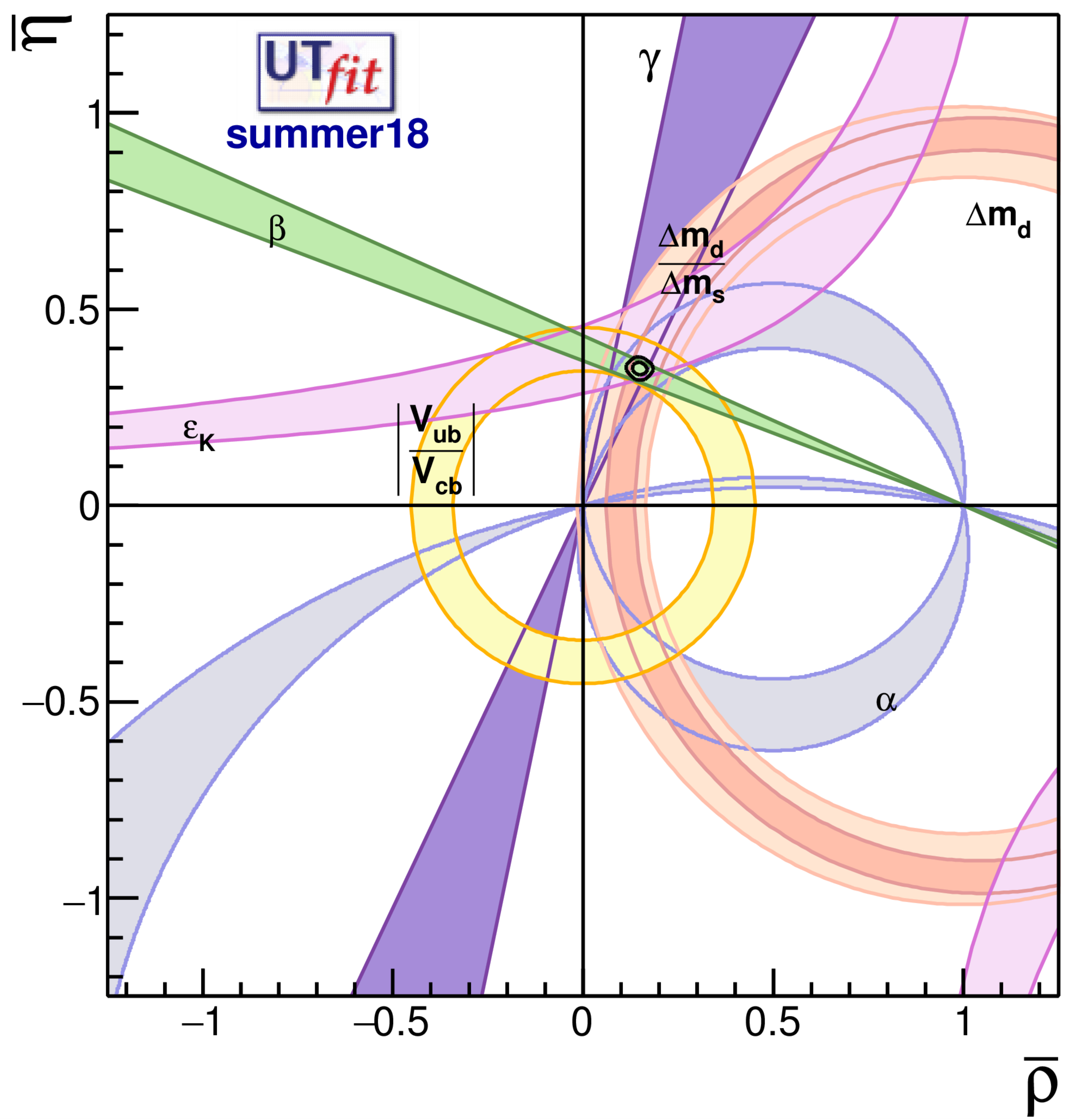
The CKM unitarity triangle

$$V_{ud}V_{ub}^* + V_{cd}V_{cb}^* + V_{td}V_{tb}^* = 0$$

…and how to probe it with B mesons

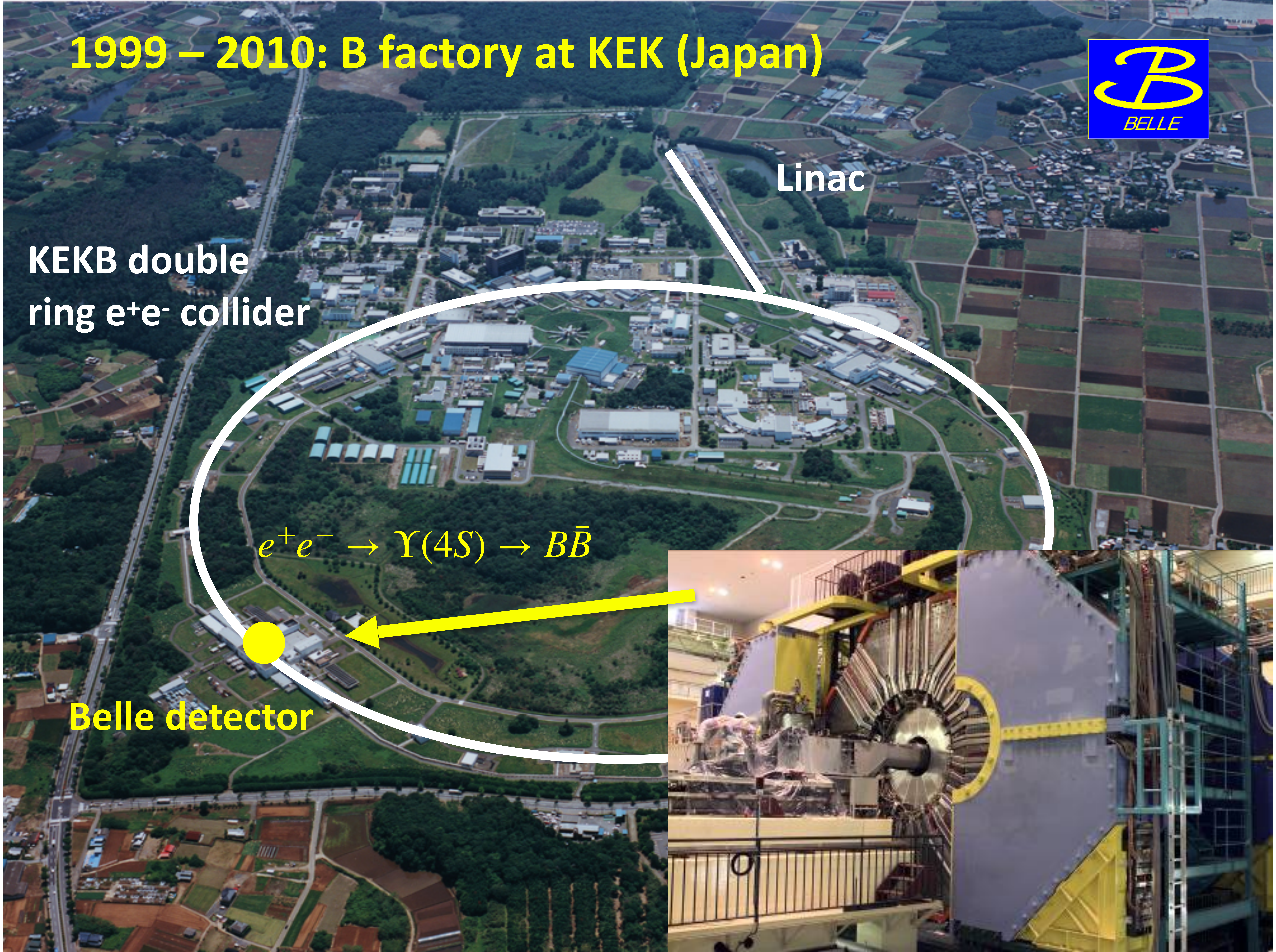



excluded area has CL > 0.95
excluded at CL > 0.95
ϕ_3
Δm_d & Δm_s
sin $2\phi_1$
Δm_d
ε_K
ϕ_2
ϕ_1
ϕ_3
V_{ub}
ϕ_2
ϕ_3
ε_K
CKM fitter
Spring 21
sol. w/ cos $2\phi_1$ < 0
(excl. at CL > 0.95)
$\bar{\eta}$
$\bar{\rho}$

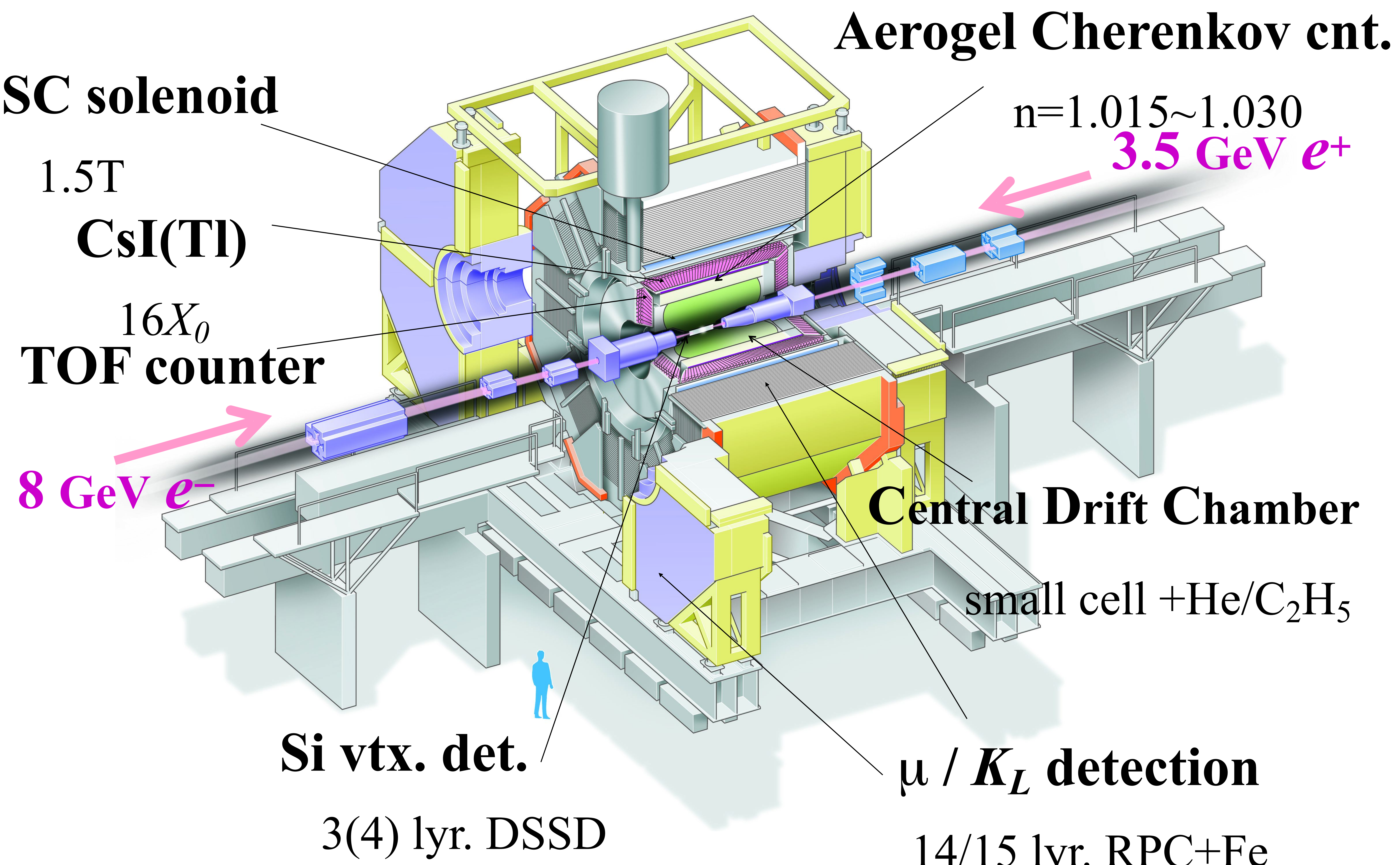

UTfit
summer18
γ
β
Δm_d
$\Delta m_d / \Delta m_s$
ε_K
$|V_{ub}/V_{cb}|$
α
$\bar{\eta}$
$\bar{\rho}$

The Belle and Belle II experiments

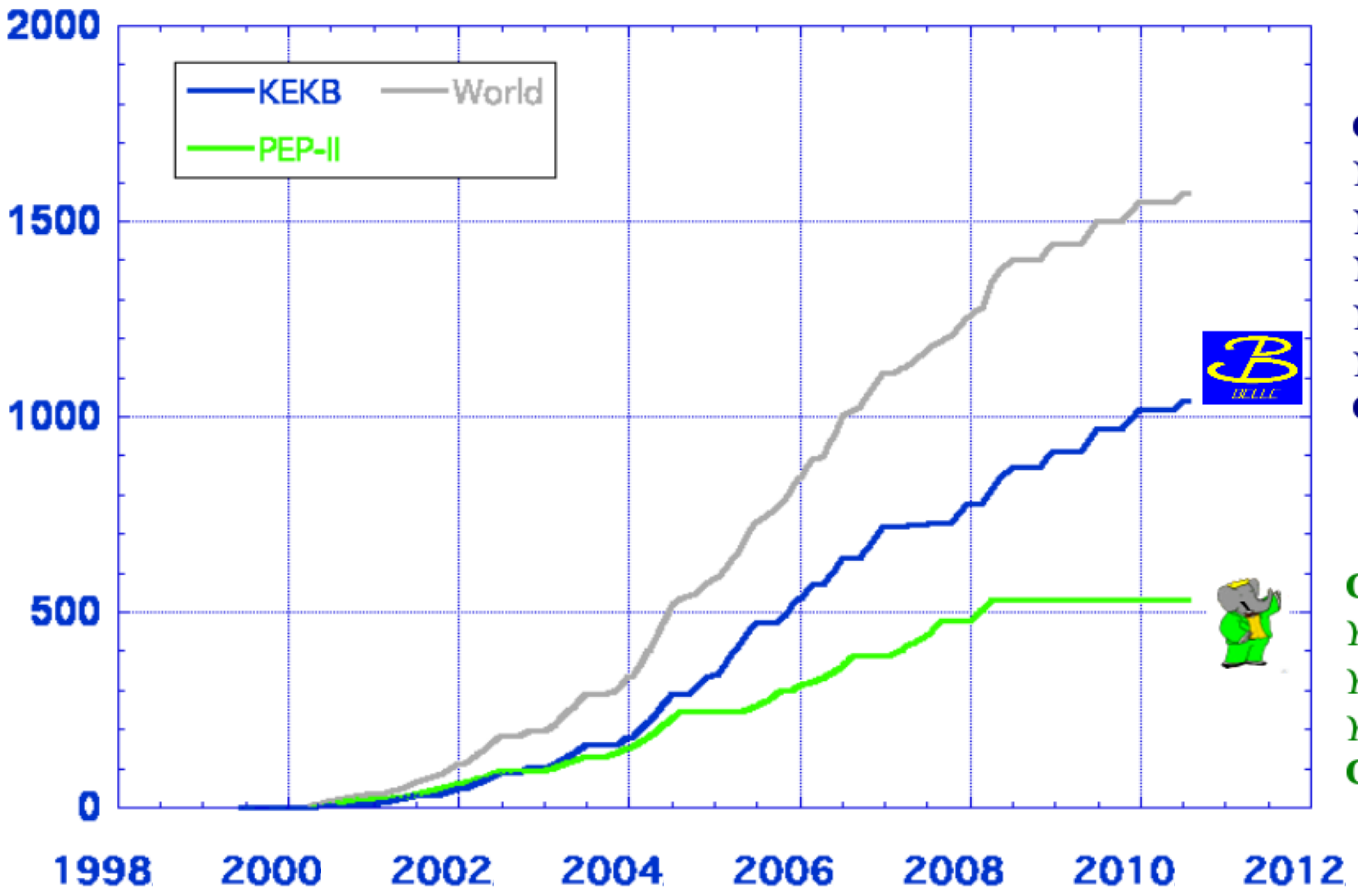
1999 – 2010: B factory at KEK (Japan)



The Belle detector



Comparison to the B factories (1999-2010)



$> 1\ ab^{-1}$
On resonance:
$\Upsilon(5S)$: 121 fb^{-1}
$\Upsilon(4S)$: 711 fb^{-1}
$\Upsilon(3S)$: 3 fb^{-1}
$\Upsilon(2S)$: 24 fb^{-1}
$\Upsilon(1S)$: 6 fb^{-1}
Off reson./scan:
$\sim 100\ fb^{-1}$

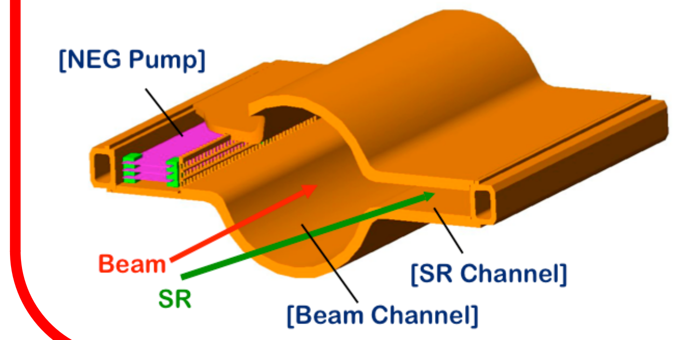
$\sim 550\ fb^{-1}$
On resonance:
$\Upsilon(4S)$: 433 fb^{-1}
$\Upsilon(3S)$: 30 fb^{-1}
$\Upsilon(2S)$: 14 fb^{-1}
Off resonance:
$\sim 54\ fb^{-1}$

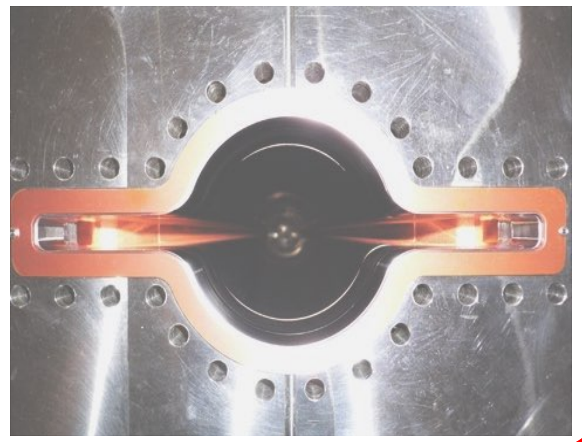
From KEKB to SuperKEKB

$$L = 8\times 10^{-35}\left[cm^{-2}s^{-1}\right] \propto \frac{I_{e\pm}\xi_{\pm y}}{\beta_y^*}.$$

Take advantage of existing items (KEKB tunnel, KEKB components)

New beam pipe& bellows
TiN-coated beam pipe with antechambers

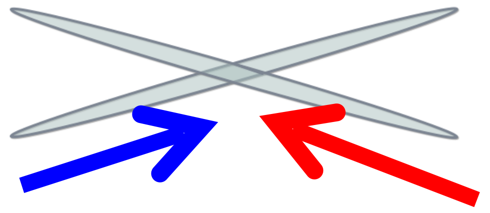


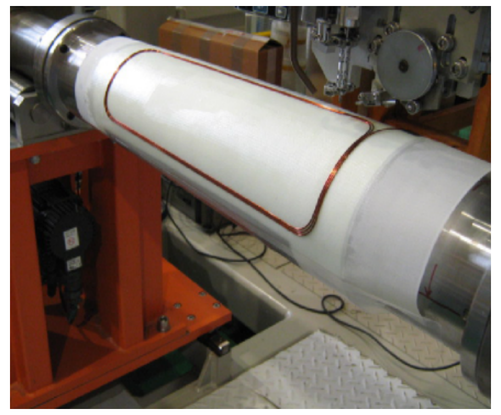


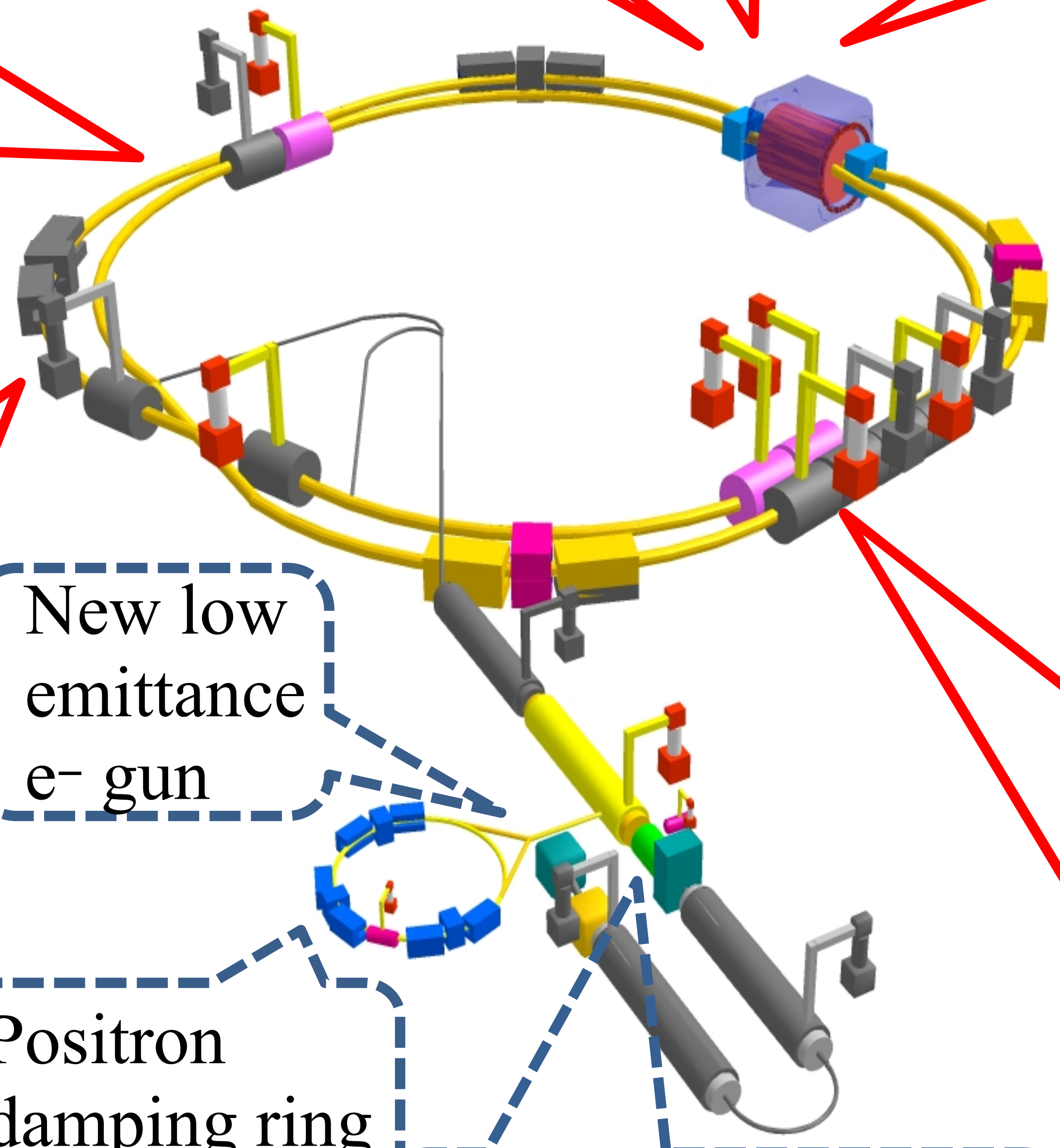
Build new beam line Tsukuba section

New design for Near-IR

New QCS magnet for Nano-beam scheme
New superconducting / permanent final focusing quads near the IP

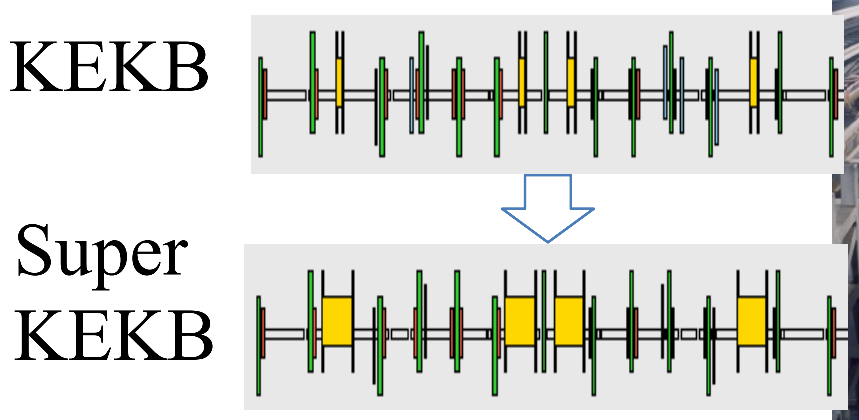


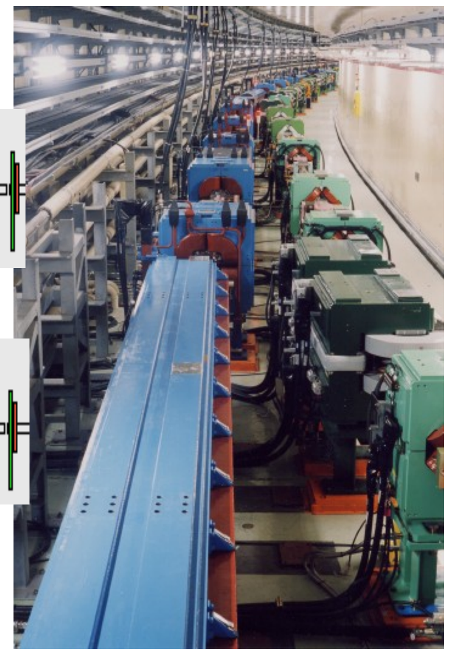




Add / modify RF systems for higher beam current

Main ring arc and straight section:
Redesign the lattices of both rings to reduce the emittance



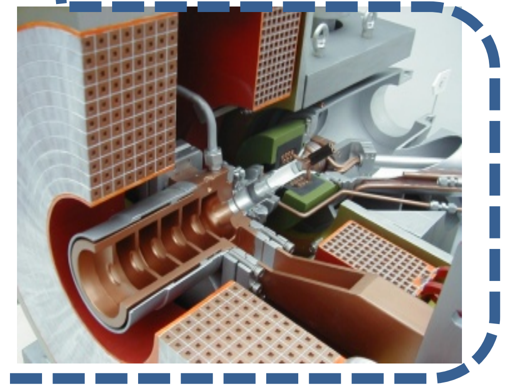


Main ring arc section:
LER: Replace all main dipoles
HER: Preserve the present cells

New low emittance e− gun

Positron damping ring

New e+ source



New and re-use wiggler magnets are mixed:

Oho section (LER&HER)

Nikko section (LER)

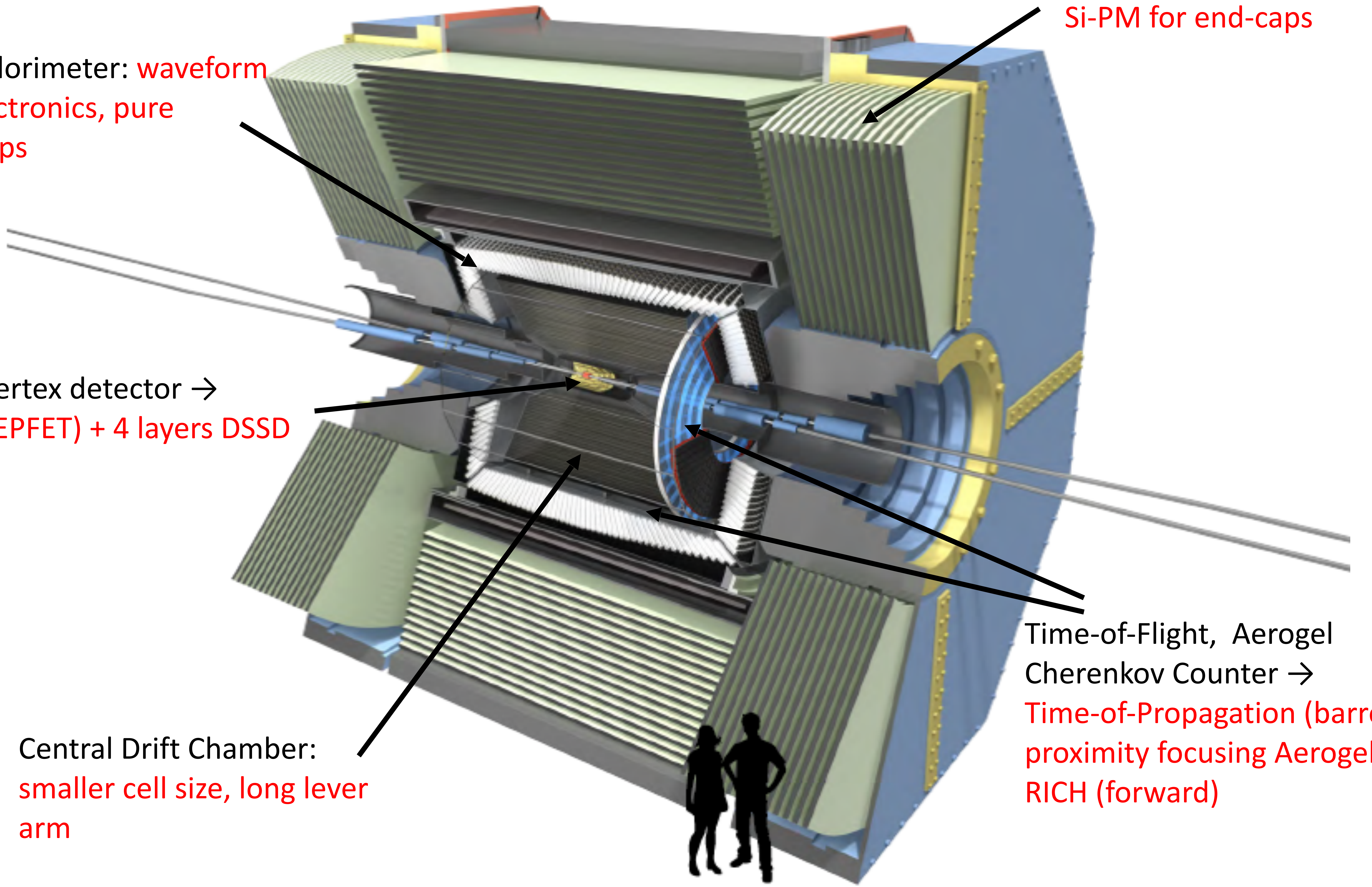
Super KEKB
uest for BSM

(Final parameters)

parameters		KEKB		SuperKEKB		units
		LER	HER	LER	HER	
Beam energy	E_b	3.5	8	4	7	GeV
Half crossing angle	ϕ	11		41.5		mrad
Horizontal emittance	ε_x	18	24	3.2	4.3-4.6	nm
Emittance ratio	κ	0.88	0.66	0.27	0.25	%
Beta functions at IP	β_x^*/β_y^*	1200/5.9		32/0.27	25/0.31	mm
Beam currents	I_b	1.64	1.19	3.60	2.60	A
beam-beam parameter	ξ_y	0.129	0.090	0.0886	0.0830	
Luminosity	L	2.1×10^{34}		8×10^{35}		$cm^{-2}s^{-1}$

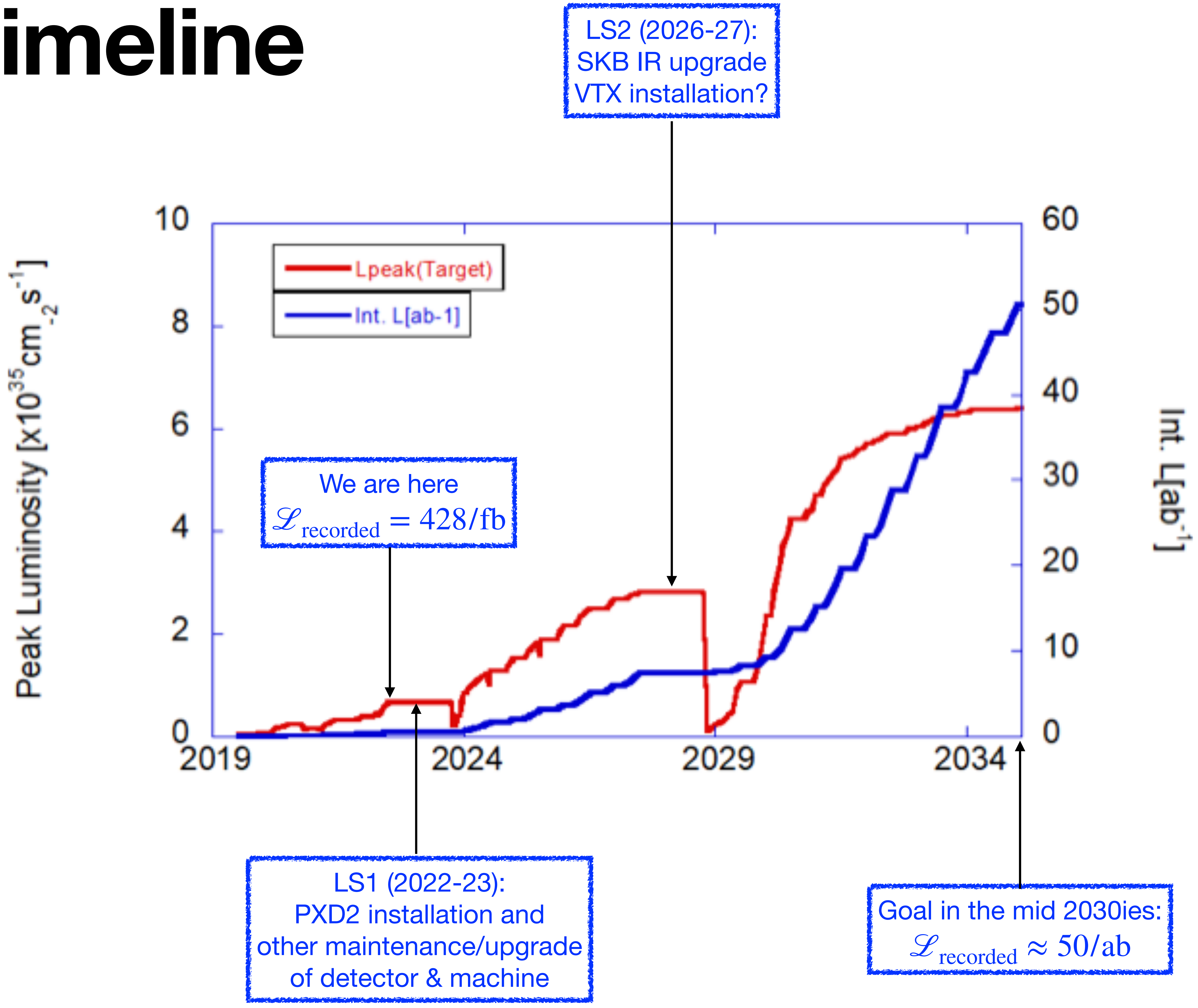
- **Small beam size & high current** to increase luminosity
- **Large crossing angle**
- **Change beam energies** to solve the problem of LER short lifetime

From Belle to Belle II



Belle II timeline

Luminosity

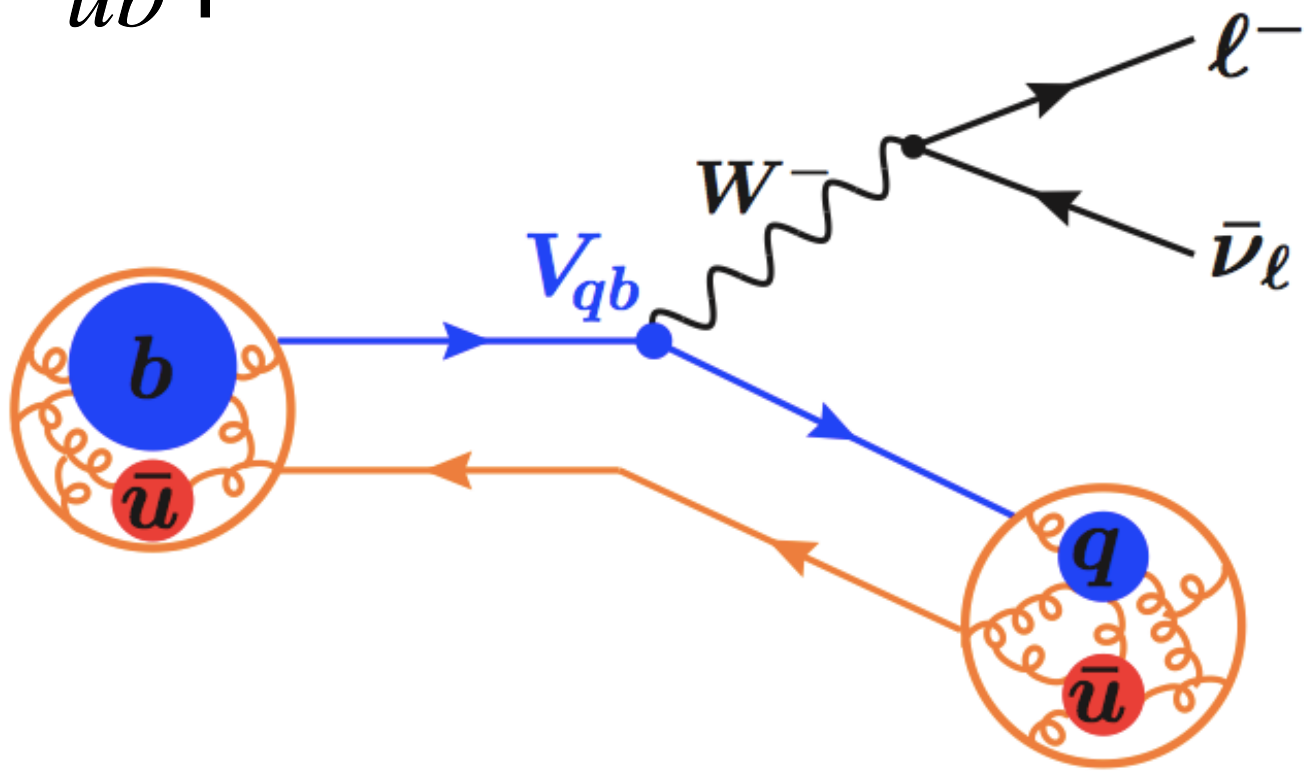


$|V_{cb}|$ and $|V_{ub}|$

Semileptonic B decays

Determination of the CKM elements $|V_{cb}|$ and $|V_{ub}|$

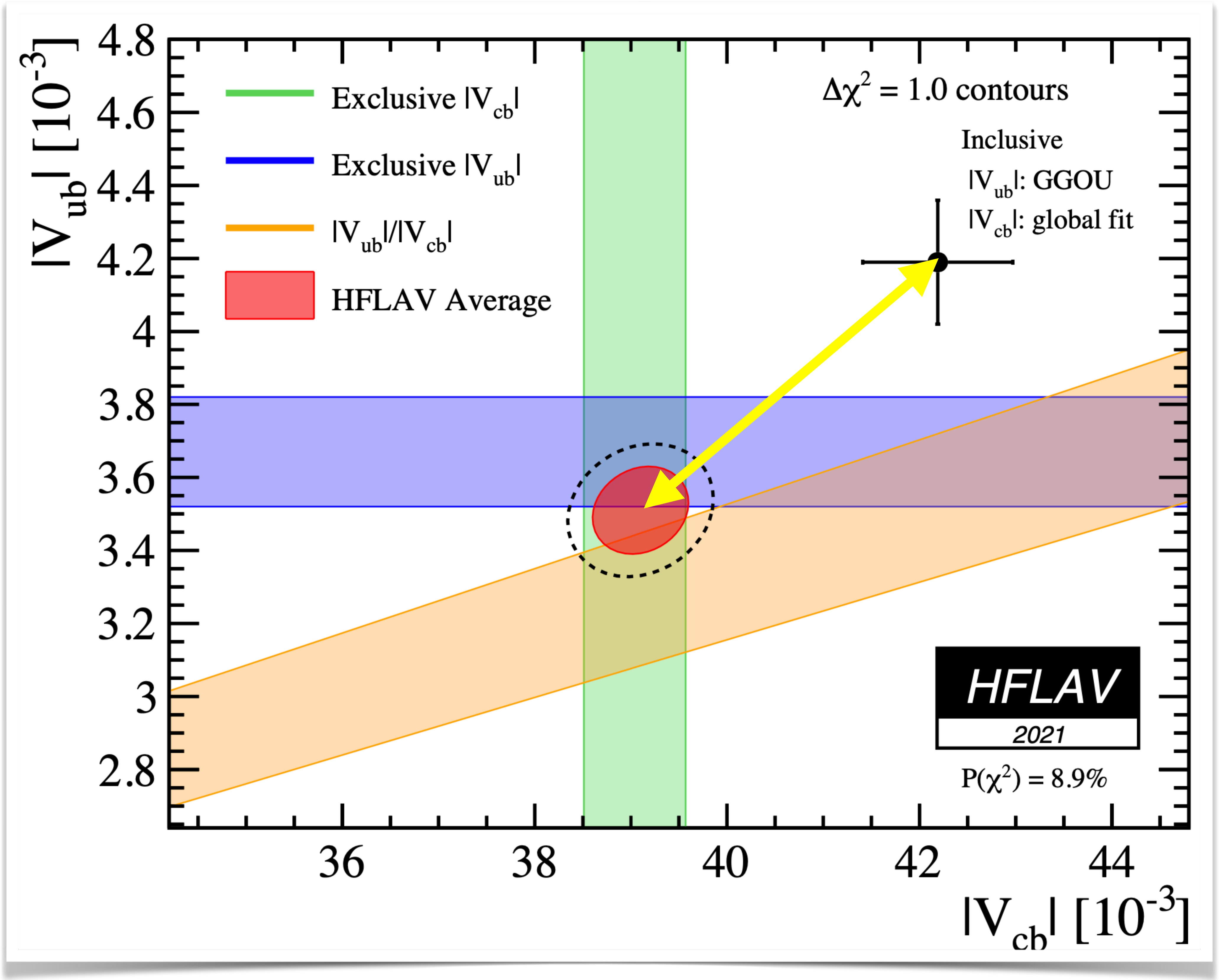
- SL B decays are studied to determine the CKM elements $|V_{cb}|$ and $|V_{ub}|$
  - $|V_{xb}|$ are limiting the global constraining power of UT fits
  - Important inputs in predictions of SM rates for ultrarare decays such as $B_s \to \mu\nu$ and $K \to \pi\nu\nu$
- The determinations can be
  - *Exclusive* — from a single final state
  - *Inclusive* — sensitive to all SL final states



$$d\Gamma \propto G_F^2 |V_{qb}|^2 \left| L_\mu \langle X | \bar{q}\gamma_\mu P_L b | B \rangle \right|^2$$

	Experiment	Theory
Exclusive $\lvert V_{cb}\rvert$	B → Dlν, D*lν (low backgrounds)	Lattice QCD, light cone sum rules
Inclusive $\lvert V_{cb}\rvert$	B → Xlν (higher background)	Operator product expansion

Inclusive vs. exclusive puzzle



~3σ difference between *inclusive* and *exclusive* $|V_{xb}|$

New results in this talk

Magnitude of V_{cb}

	$\lvert V_{cb} \rvert \times 10^3$		Reference	
Belle $B \to D^* \ell \nu$ tagged	40.30 ± 0.86 (CLN)	Preliminary	Moriond 2022	Exclusive
Belle II $B^0 \to D^{*-} \ell^+ \nu$ tagged	38.0 ± 2.8 (CLN)	Preliminary	Discrete 2022	
Belle II $B \to D \ell \nu$ untagged	38.53 ± 1.15 (BGL)	Preliminary	arXiv:2210.13143	
Belle q^2 moments in $B \to X_c \ell \nu$	41.69 ± 0.63		PRD 104, 112011 (2021) arXiv:2205.10274	Inclusive
Belle II q^2 moments in $B \to X_c \ell \nu$	41.69 ± 0.63	Preliminary	arXiv:2205.06372 arXiv:2205.10274	

New results in this talk

Magnitude of V_{ub}

	$\lvert V_{ub} \rvert \times 10^3$		Reference
Belle II $B \to \pi e \nu$ tagged	3.88 ± 0.45	Preliminary	arXiv:2206.08102
Belle II $B \to \pi \ell \nu$ untagged	3.54 ± 0.25	Preliminary	arXiv:2210.04224
Belle $B \to X_u \ell \nu$	4.10 ± 0.28		PRD 104, 012008 (2021)

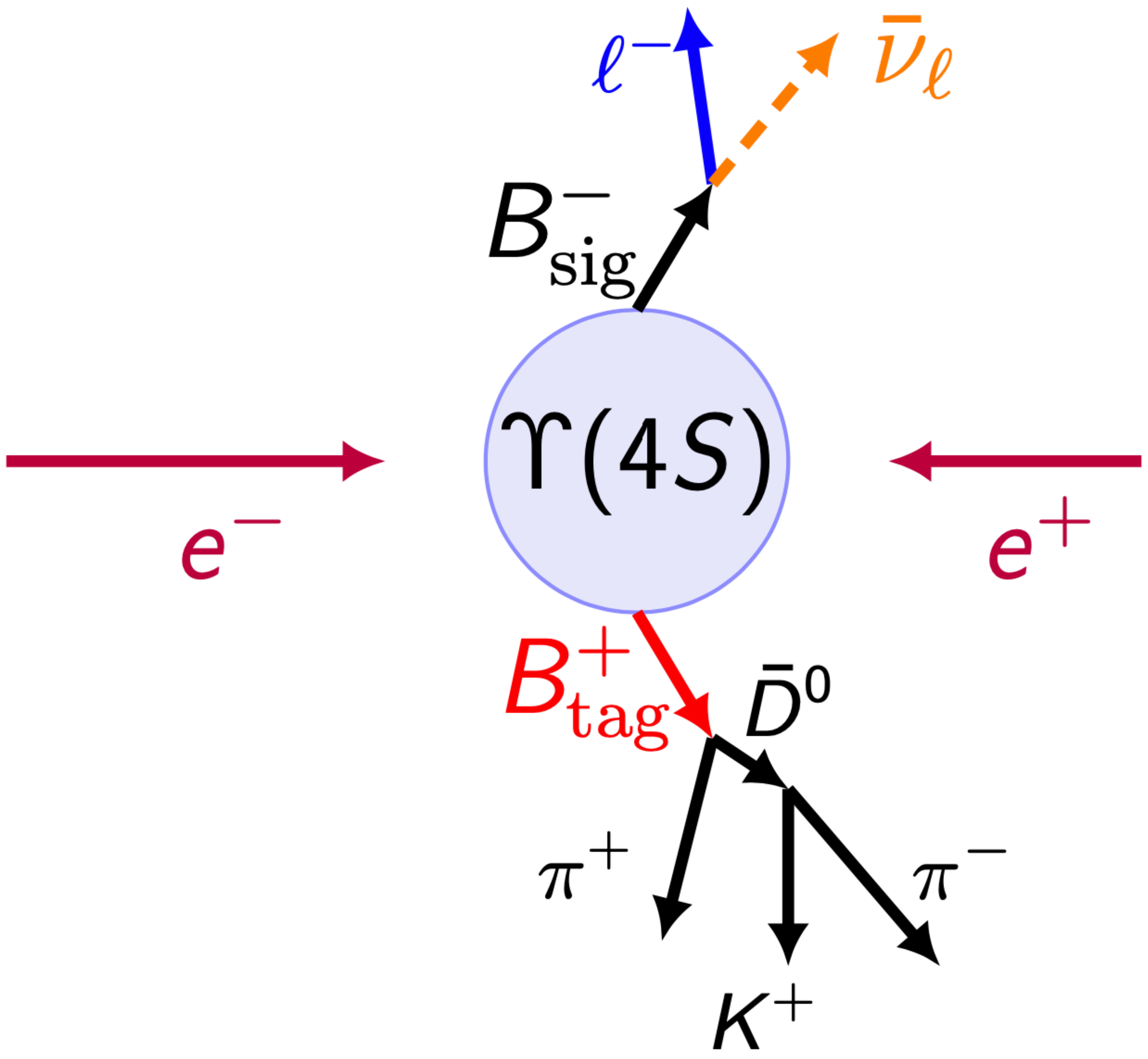
Exclusive

Inclusive

Untagged vs. Tagged

Untagged:
only B_{sig} is reconstructed

high signal yield (+)
high backgrounds (-)
poor neutrino reconstruction (-)

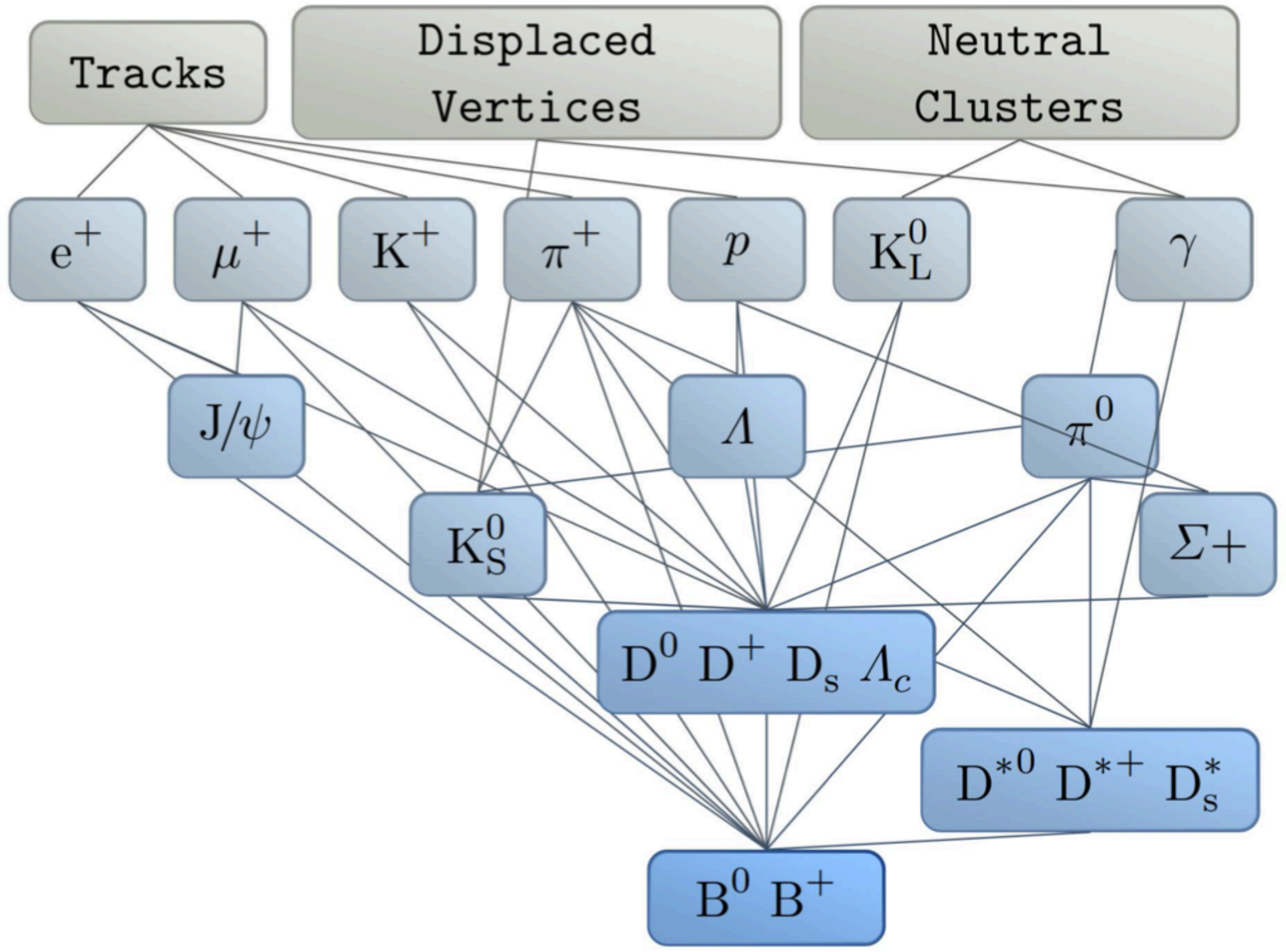


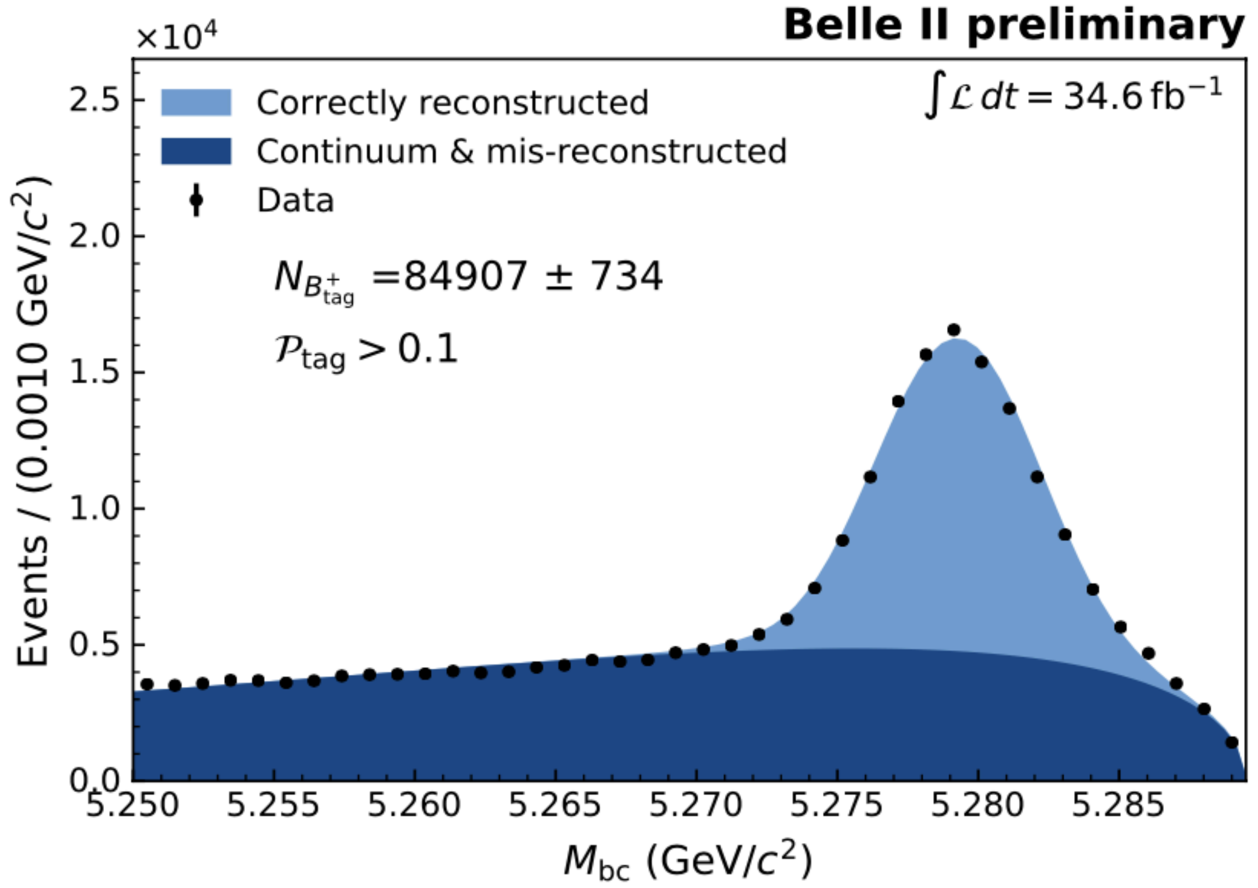
Tagged:
B_{sig} and B_{tag} are reconstructed

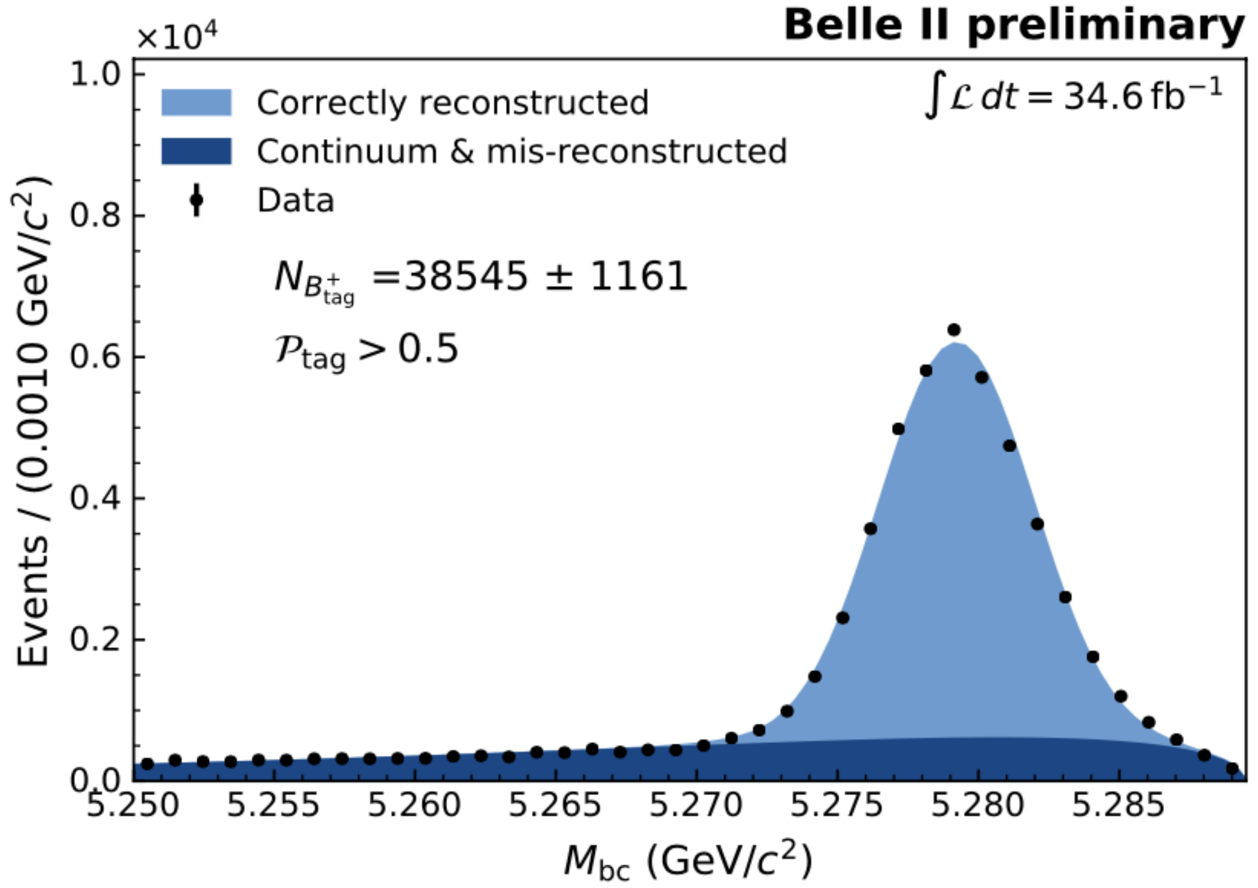
signal yield $O(10^3)$ lower (-)
low backgrounds (+)
good neutrino reconstruction (+)
tag calibration (-)

Hadronic tagging at Belle II

Comput Softw Big Sci (2019) 3: 6.







$$M_{bc} = \sqrt{E_{beam}^2/4 - (p_{B_{tag}}^{cm})^2} > 5.27\ \mathrm{GeV}/c^2$$

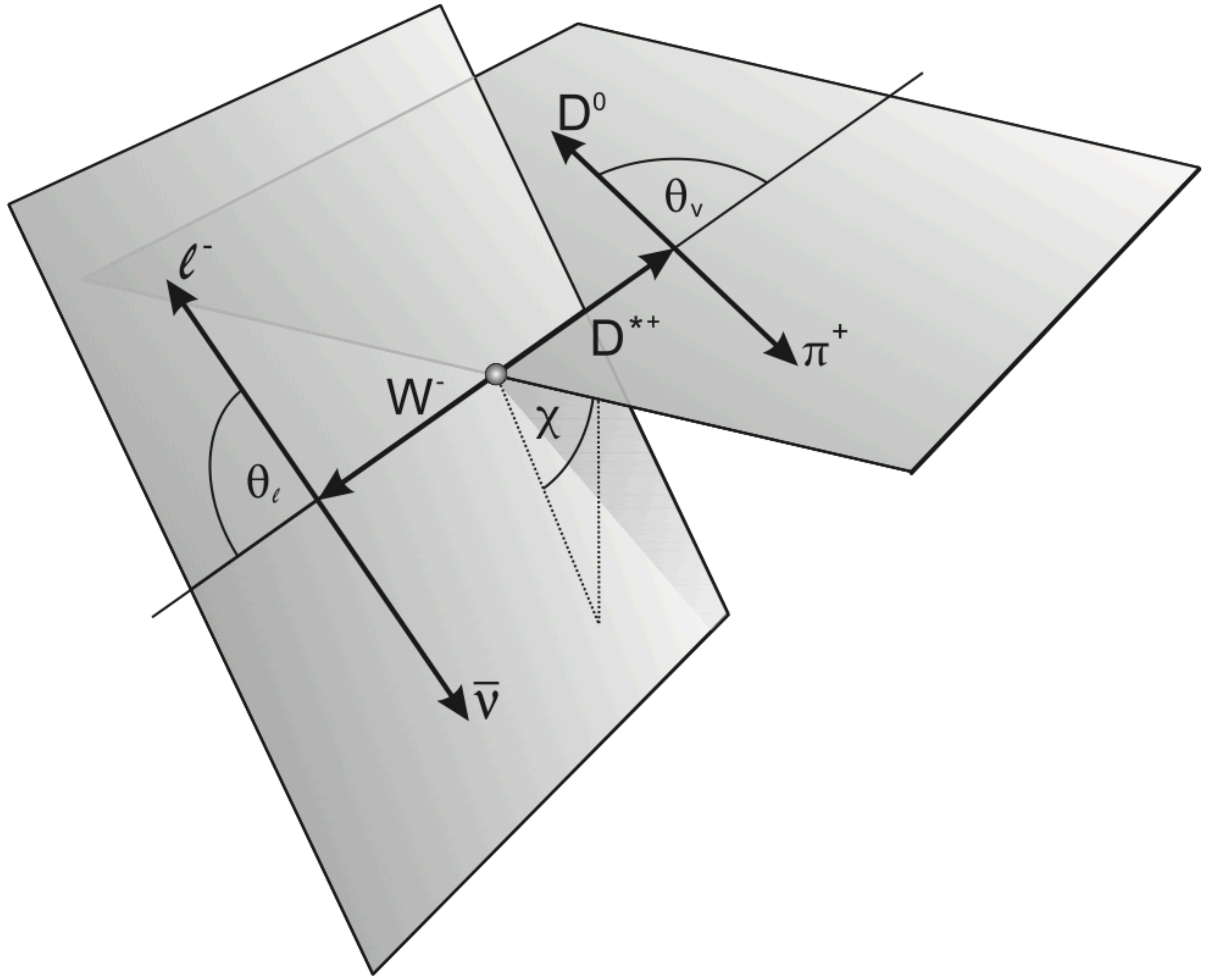
- The hadronic FEI employs over 200 boosted decision trees to reconstruct 10000 B decay chains
  - $\epsilon_{B^+} \approx 0.5\ \%$, $\epsilon_{B^0} \approx 0.3\ \%$ at low purity (about 50% increase with respect to the Belle tag)

$B \to D^* \ell \nu$

$$w = v_B \cdot v_{D^{(*)}}$$

$$\frac{d\Gamma(\overline{B} \to D^* \ell^- \overline{\nu}_\ell)}{dw} = \frac{G_F^2 m_{D^*}^3}{48\pi^3}(m_B - m_{D^*})^2 \chi(w) \eta_{EW}^2 \mathcal{F}^2(w) |V_{cb}|^2$$

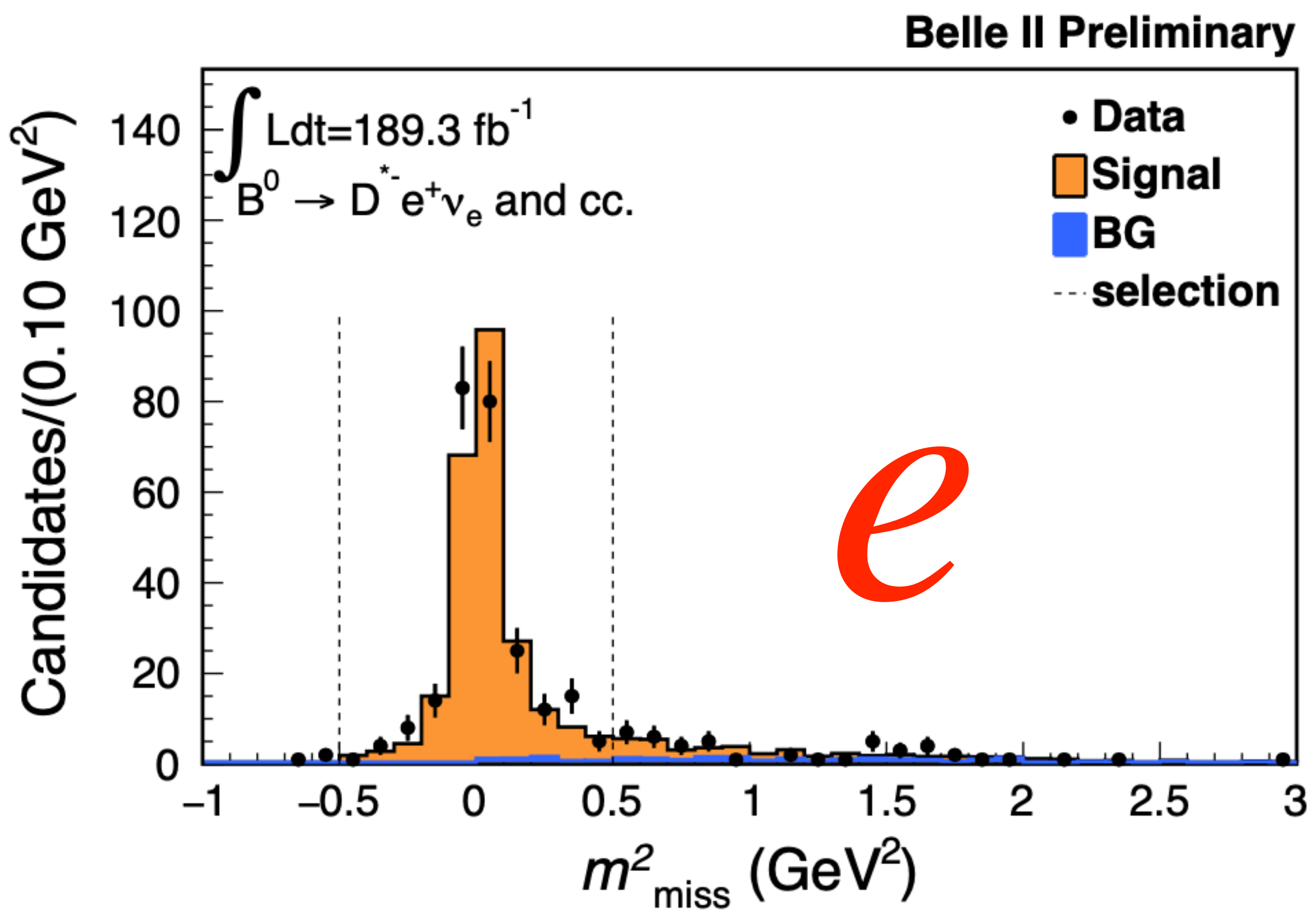
$$\chi(w)\mathcal{F}^2(w) = h_{A_1}^2(w)\sqrt{w^2-1}(w+1)^2 \left\{ 2\left[\frac{1-2wr+r^2}{(1-r)^2}\right]\left[1+R_1^2(w)\frac{w-1}{w+1}\right] + \left[1+(1-R_2(w))\frac{w-1}{1-r}\right]^2 \right\},$$

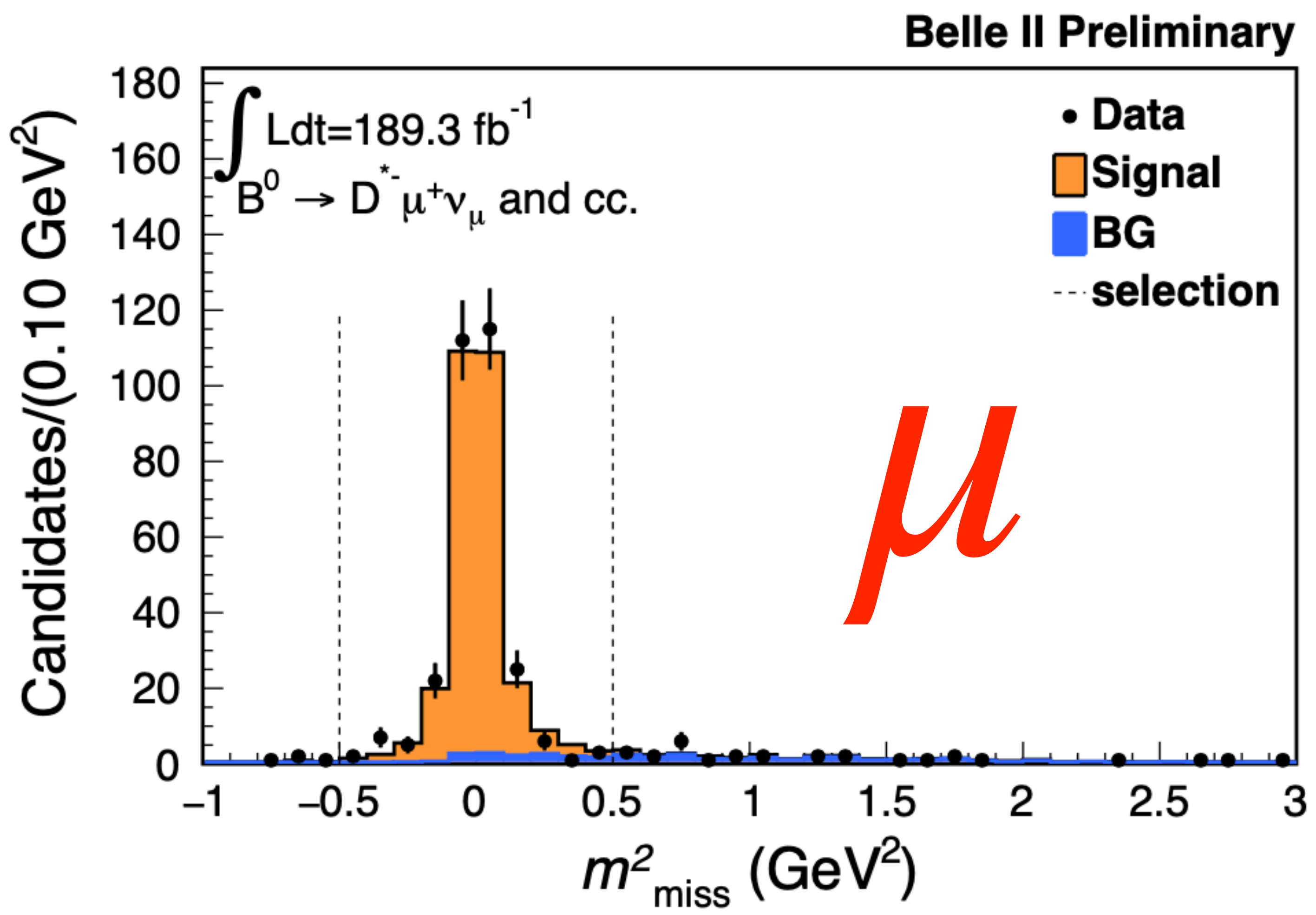


$B^0 \to D^{*-}\ell^+\nu$ tagged and $|V_{cb}|$ exclusive

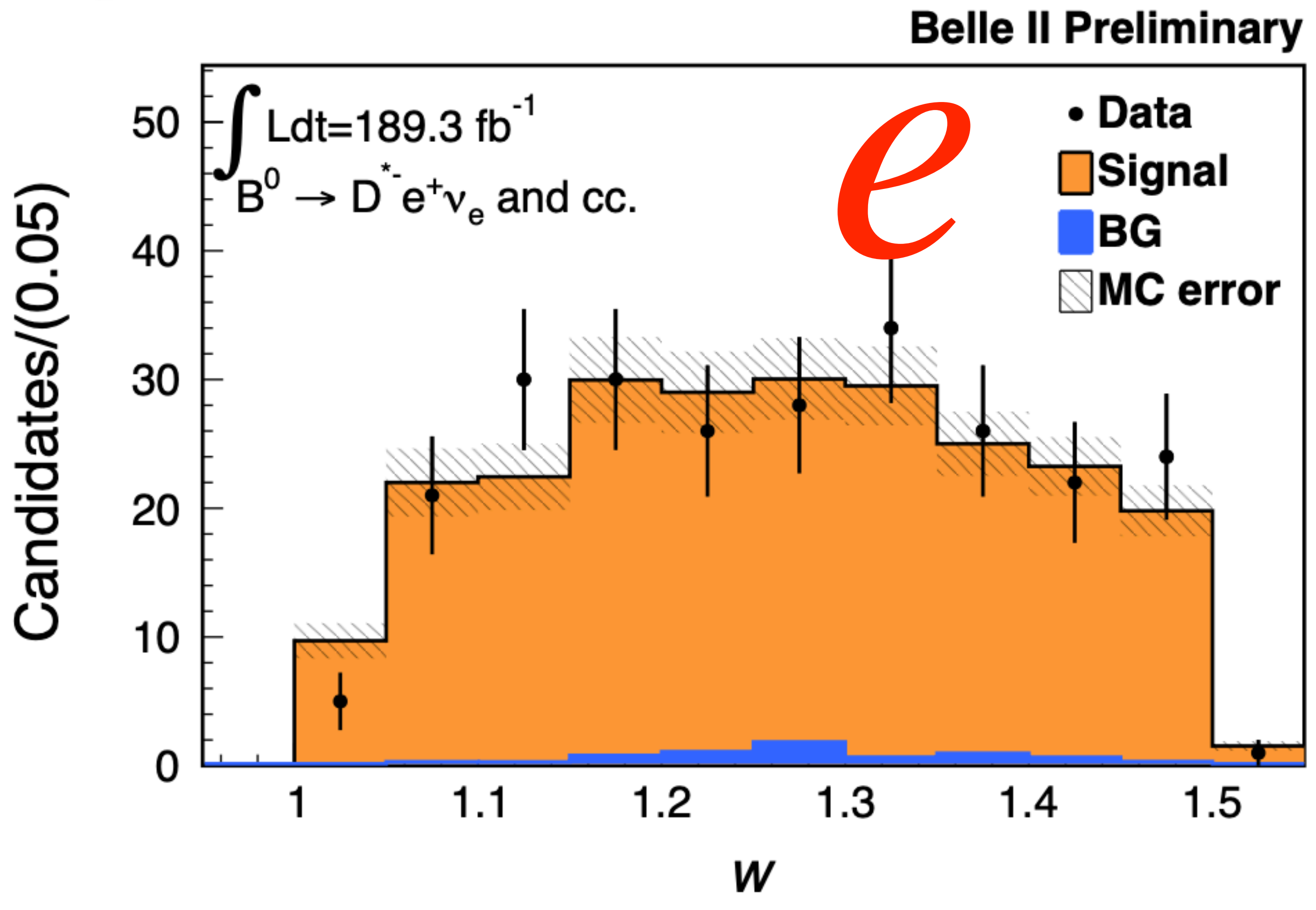
Winter 2022

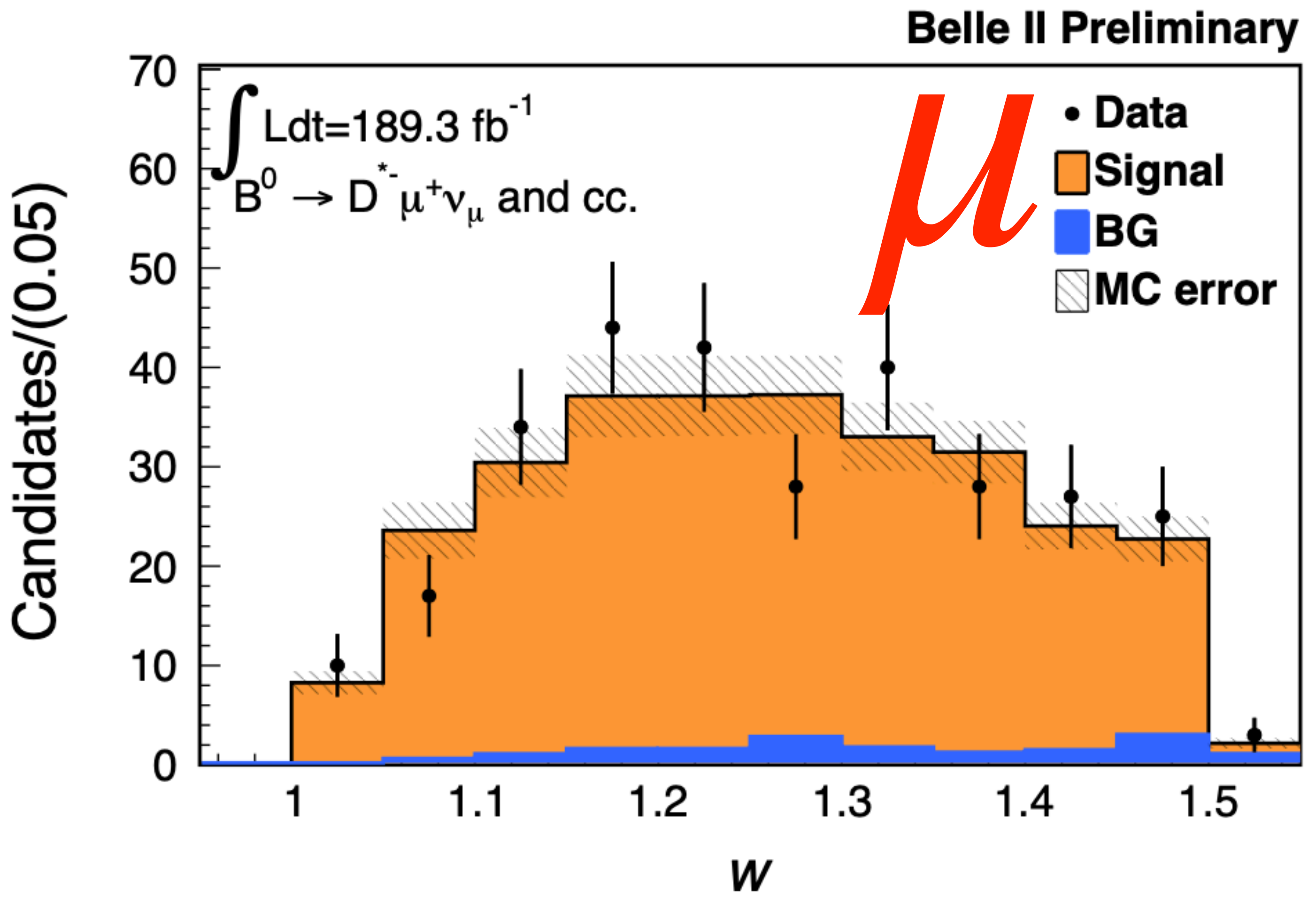
- 189.3/fb of hadronic tagged Belle II events
- Reconstruct $D^{*+} \to D^0(K^-\pi^+)\pi^+$ and identify ℓ (e or μ)
- Fit missing mass squared $m^2_{\text{miss}} = (p_{\Upsilon(4S)} - p_{B_{\text{tag}}} - p_{D^*} - p_\ell)^2$ in bins of $w = v_B \cdot v_{D^*}$ to extract w spectrum





$$\mathcal{B}\left(B^0 \to D^{*-}\ell^+\nu_\ell\right) = (5.27 \pm 0.22\,(\text{stat.}) \pm 0.38\,(\text{syst.}))\,\%$$





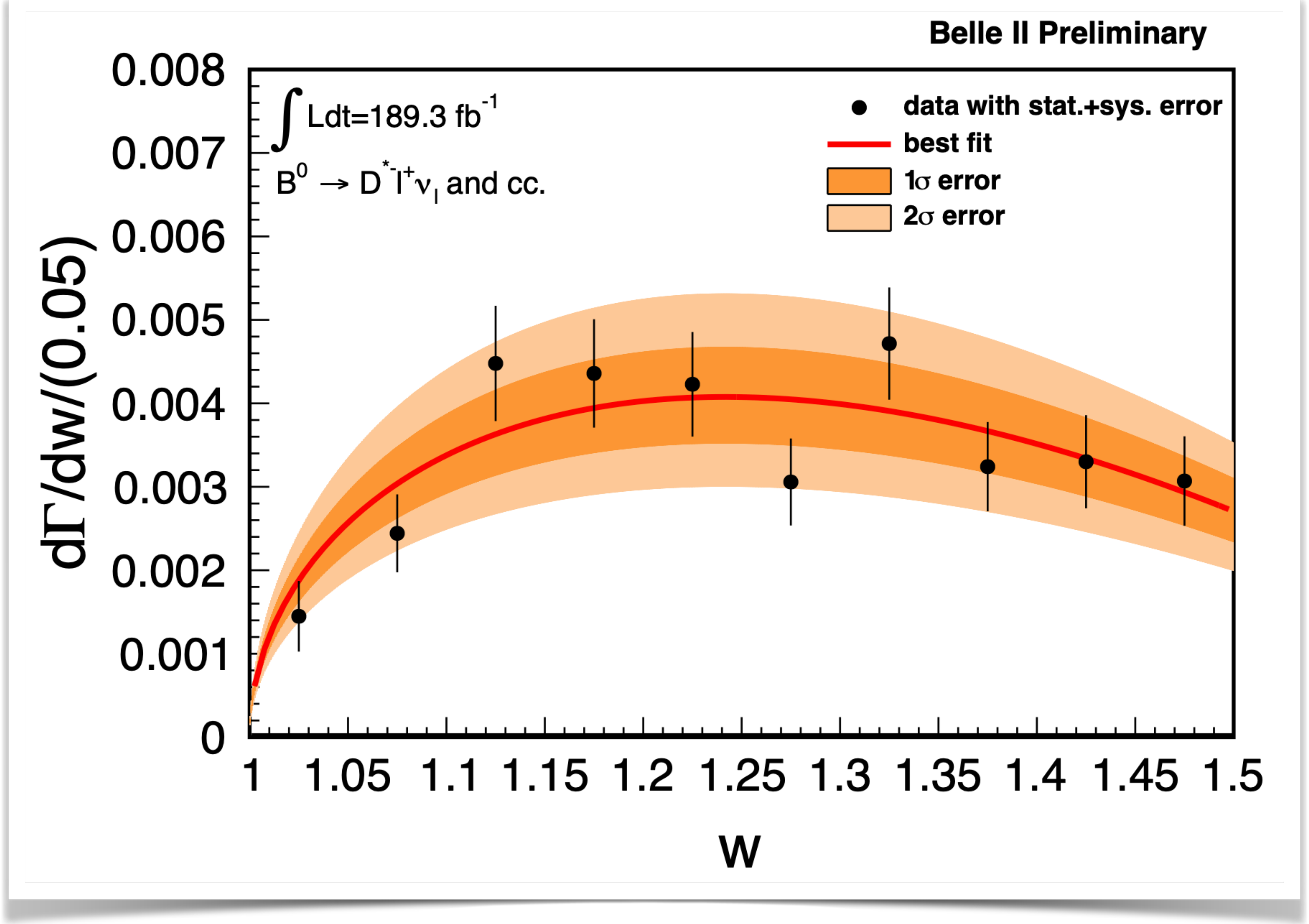
$B^0 \to D^{*-}\ell^+\nu$ tagged and $|V_{cb}|$

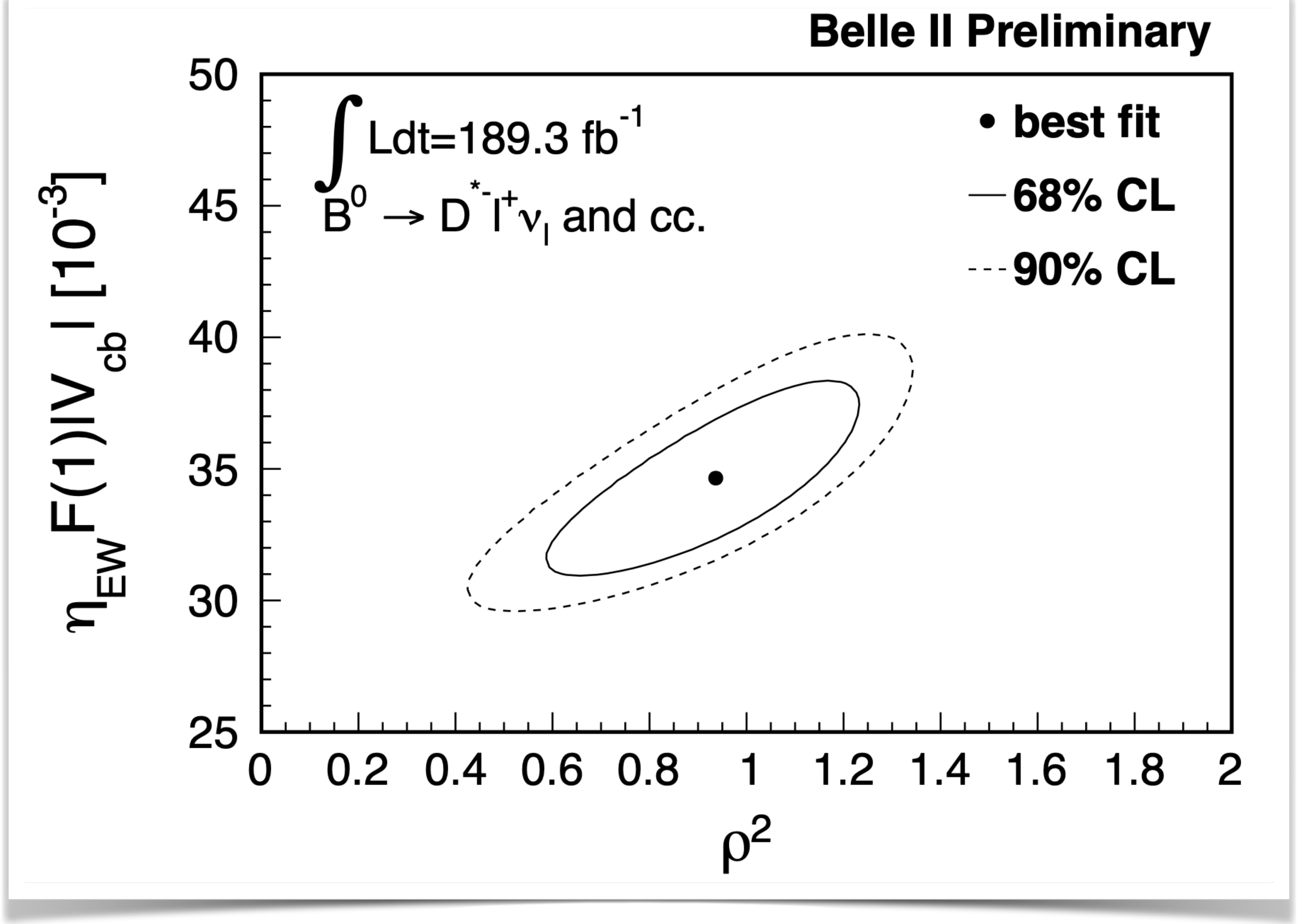
Winter 2022

In the CLN parameterisation [NPB530, 153 (1998)]
$\mathscr{F}(w)$ depends on $\mathscr{F}(1)$, ρ^2, $R_1(1)$ and $R_2(1)$

- Fit of the w spectrum

$$\frac{d\Gamma}{dw} = \frac{G_F^2 m_{D^*}^3}{48\pi^3}(m_B - m_{D^*})^2\sqrt{w^2-1}\,\chi(w)\mathcal{F}^2(w)|V_{cb}|^2$$



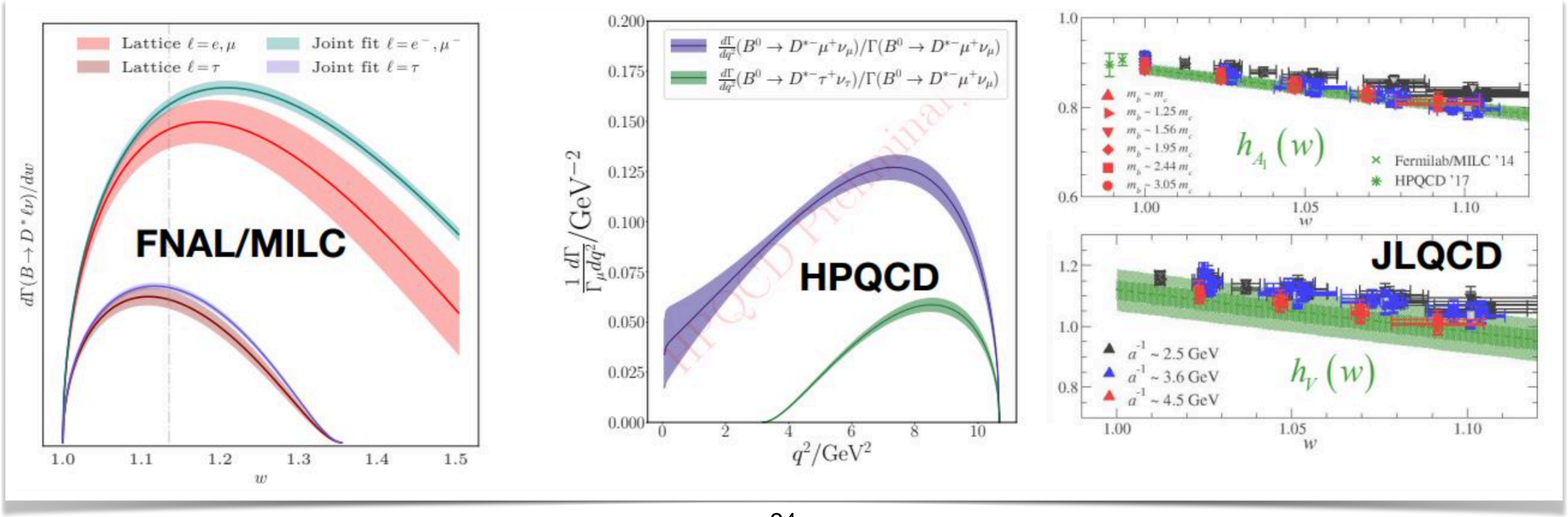


$$\eta_{\mathrm{EW}}\mathscr{F}(1)\,|V_{cb}| = (34.6 \pm 2.5)\cdot 10^{-3}$$
$$\rho^2 = 0.94 \pm 0.21$$

- Largest systematics: tag calibration, slow pion tracking

$B \to D^* \ell \nu$ lattice QCD input

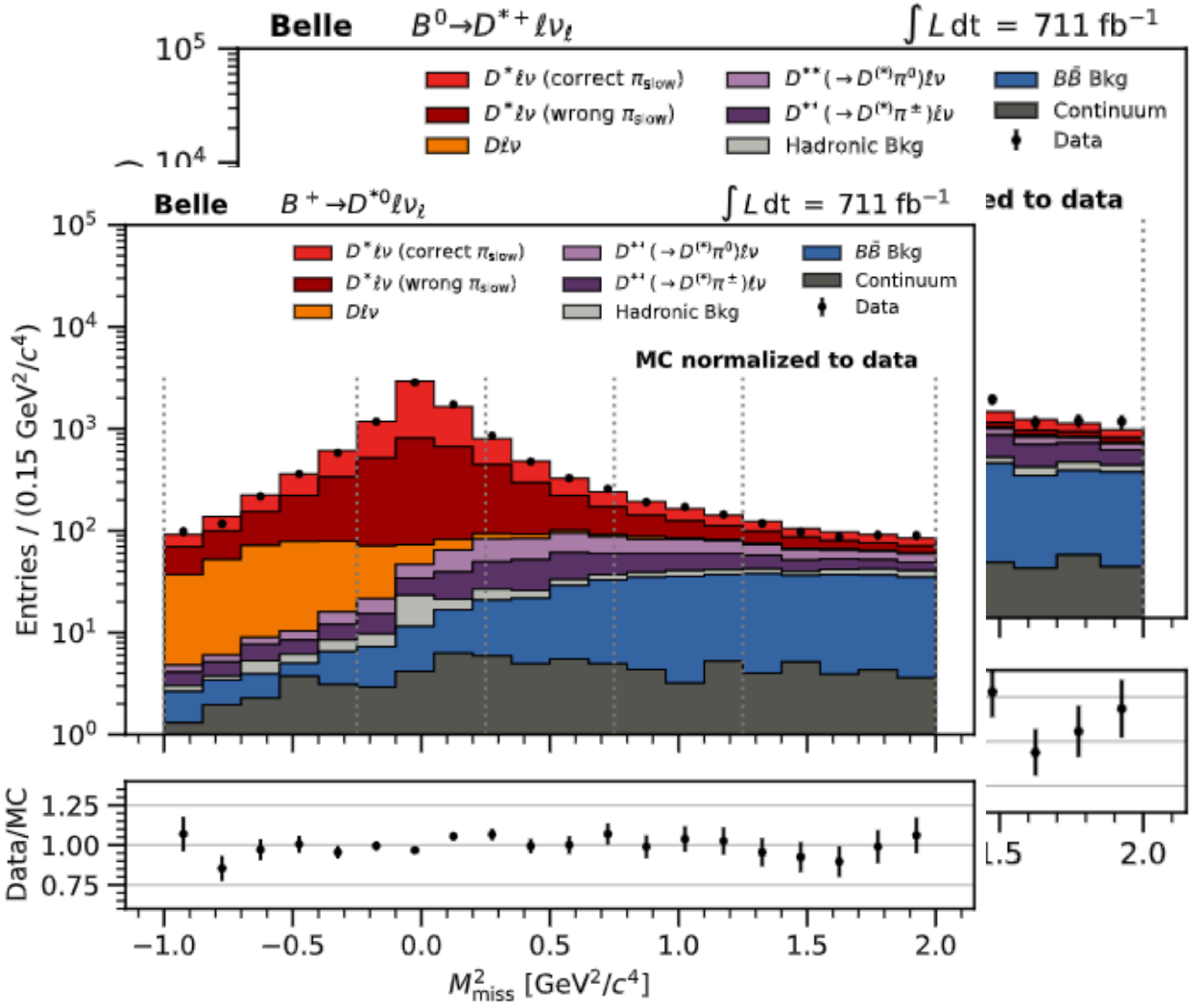
- FLAV 2021 average [arXiv:2111.09849]: $\eta_{\rm EW} \mathcal{F}(1) = 0.910 \pm 0.013$
- New lattice calculations beyond zero recoil ($w > 1$)
  - FNAL/MILC under review A. Bazarvov et al. [arXiv:2105.14019]
  - HPQCD & JLQCD in preparation



$B \to D^* \ell \nu$ tagged and $|V_{cb}|$ exclusive

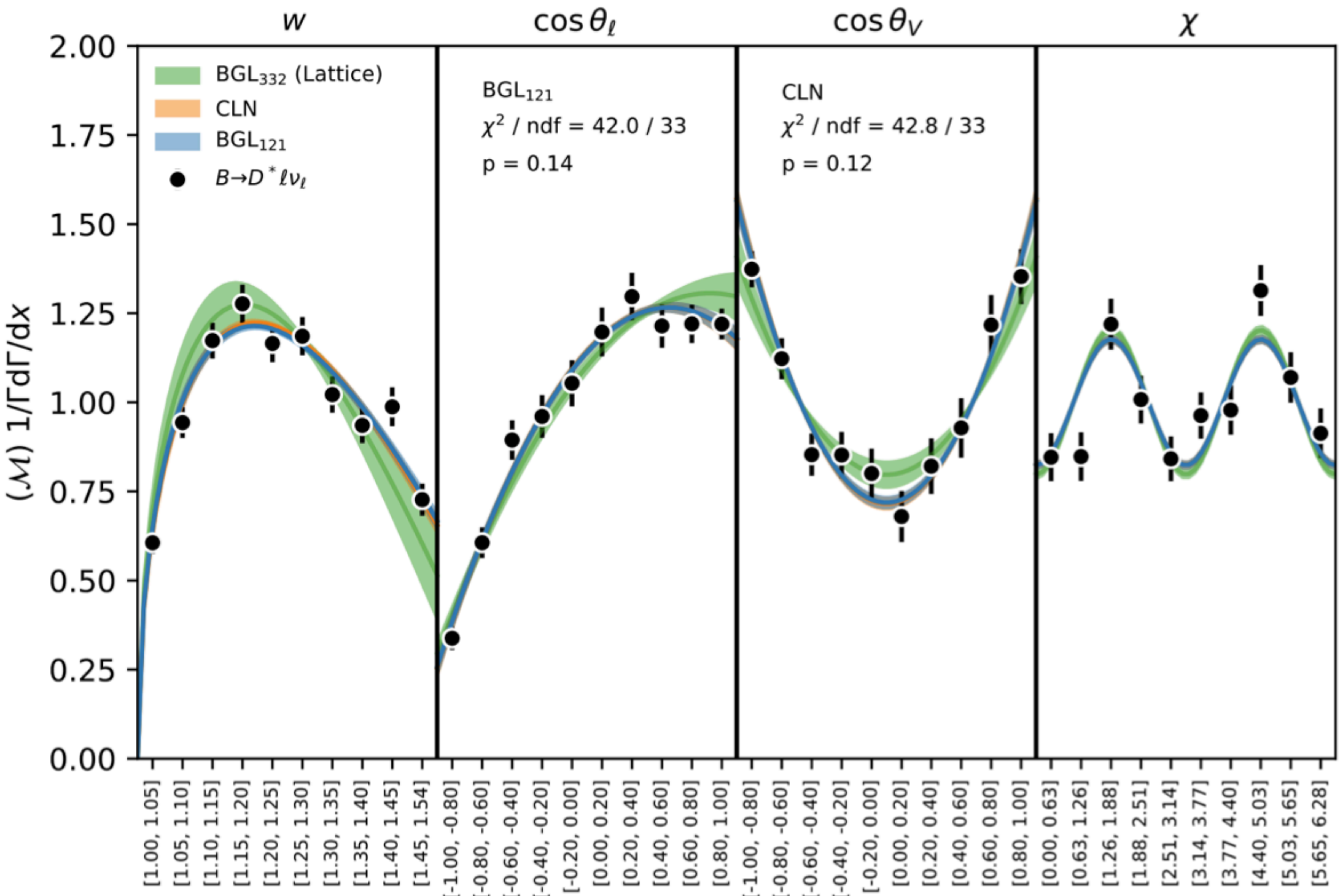
Preliminary

- Based on 711/fb, 4 samples ($B^0 e, B^0 \mu, B^+ e$ and $B^+ \mu$)
- Belle II hadronic tag is used
- Signal is extracted from the M^2_{miss} distribution in bins of the kinematic variables ($w, \cos\theta_l, \cos\theta_V, \chi$)



$B \to D^*\ell\nu$ tagged and $|V_{cb}|$ exclusive

Preliminary



Measured Shapes + External Branching Ratio Input

BGL(121)	Value	Correlation				
$a_0 \times 10^3$	24.93 ± 1.41	1.00	0.25	−0.21	0.26	−0.30
$b_0 \times 10^3$	13.11 ± 0.18	0.25	1.00	−0.01	−0.01	−0.62
$b_1 \times 10^3$	-11.93 ± 12.72	−0.21	−0.01	1.00	0.25	−0.48
$c_1 \times 10^3$	-0.87 ± 0.97	0.26	−0.01	0.25	1.00	−0.49
$\|V_{cb}\| \times 10^3$	40.77 ± 0.92	−0.30	−0.62	−0.48	−0.49	1.00

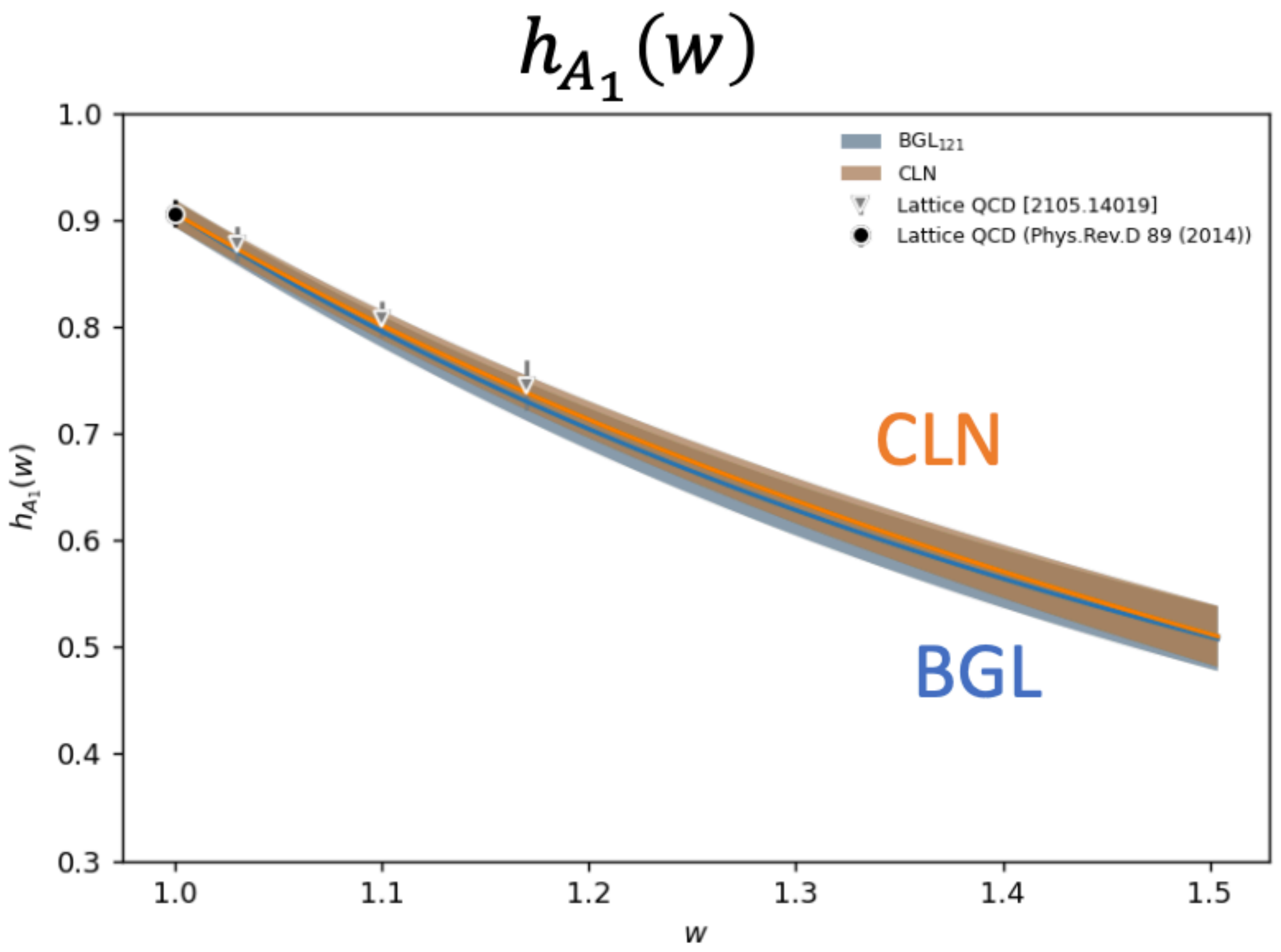
CLN	Value	Correlation			
ρ^2	1.25 ± 0.09	1.00	0.56	−0.89	0.38
$R_1(1)$	1.32 ± 0.08	0.56	1.00	−0.63	−0.03
$R_2(1)$	0.85 ± 0.07	−0.89	−0.63	1.00	−0.15
$\|V_{cb}\| \times 10^3$	40.30 ± 0.86	0.38	−0.03	−0.15	1.00

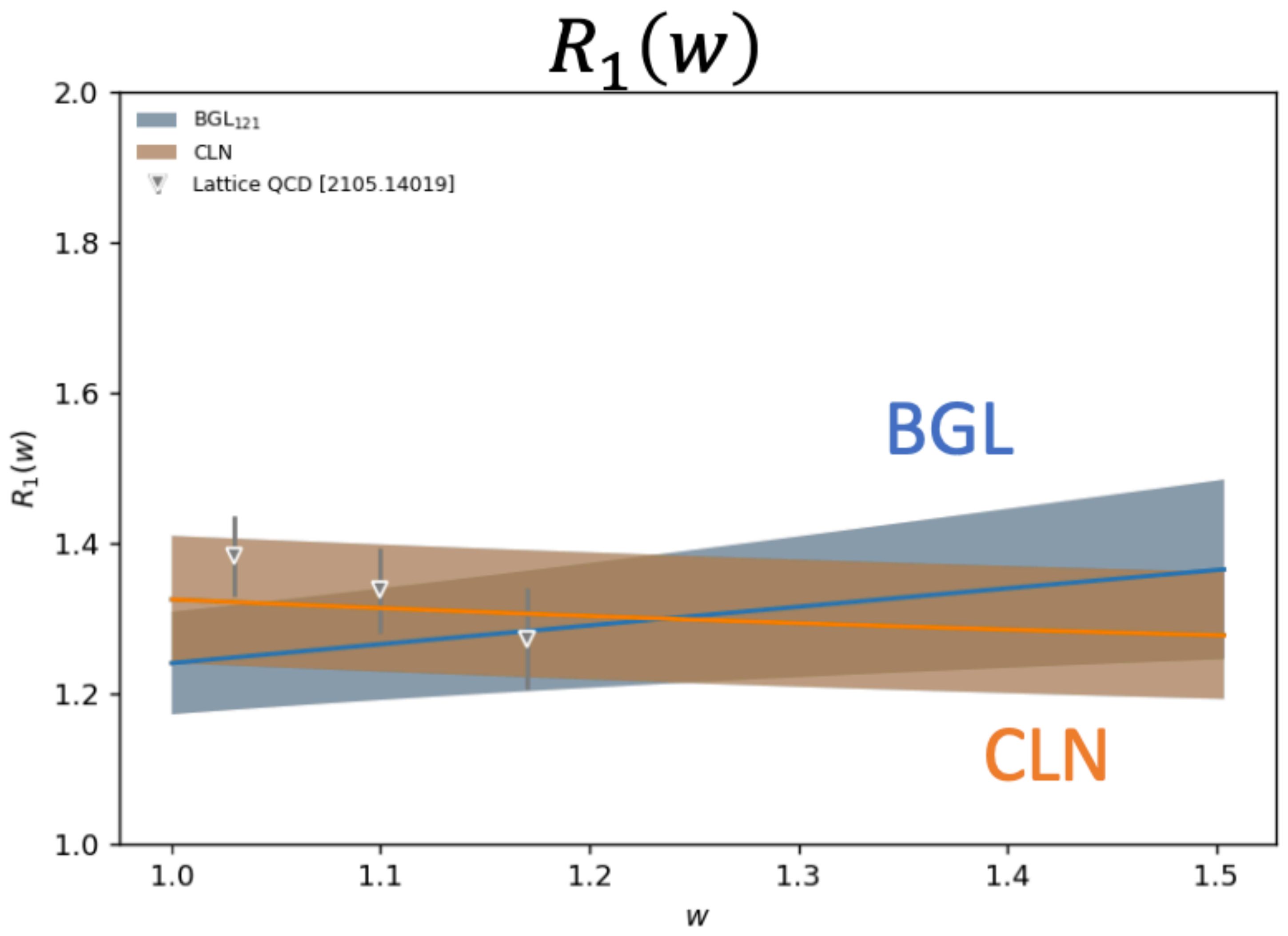
Based on the lattice input at zero-recoil:

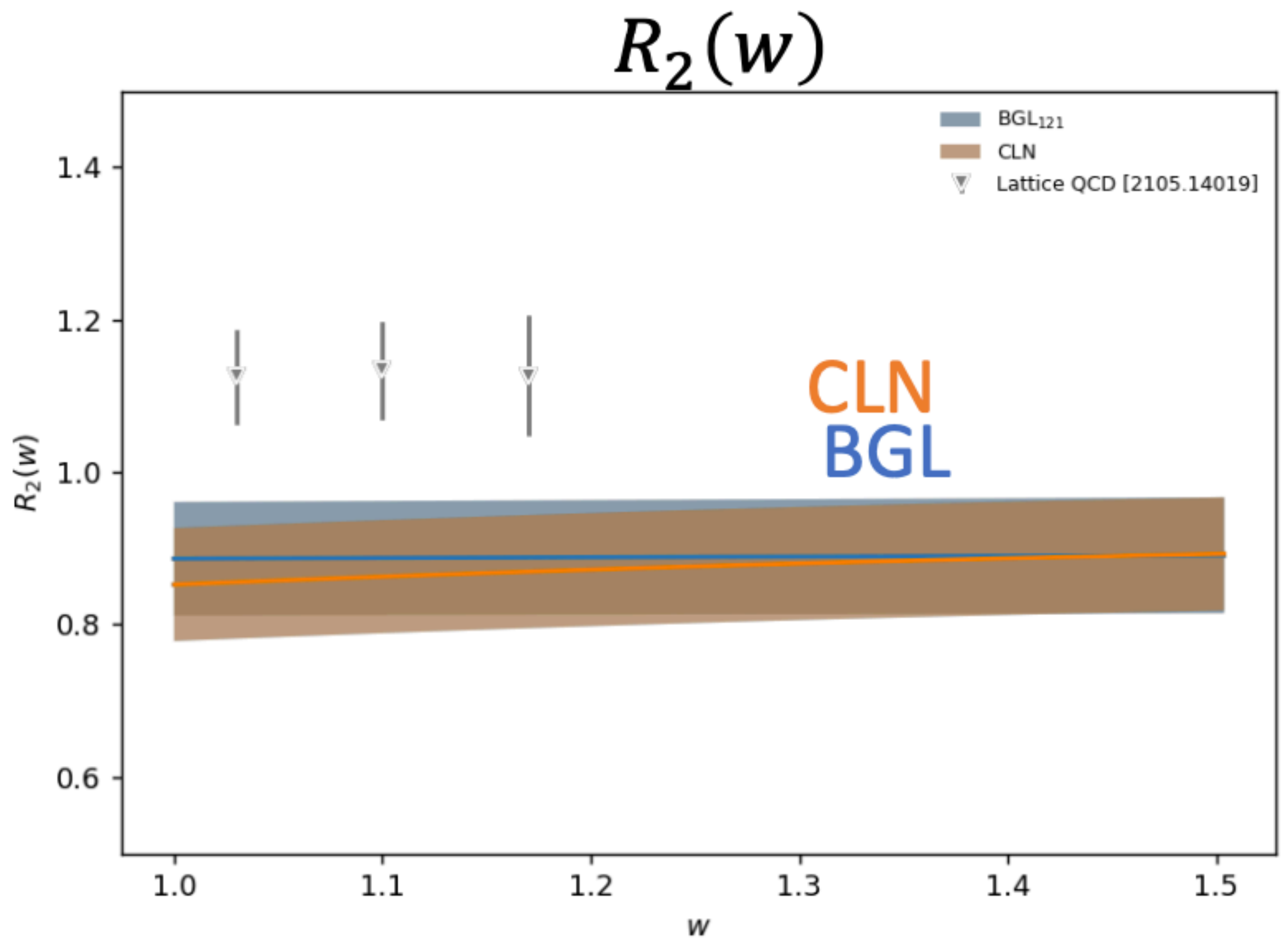
$$h_{A_1}(1) = 0.906 \pm 0.013$$

$B \to D^{*}\ell\nu$ tagged, comparison to non-zero recoil lattice

Preliminary





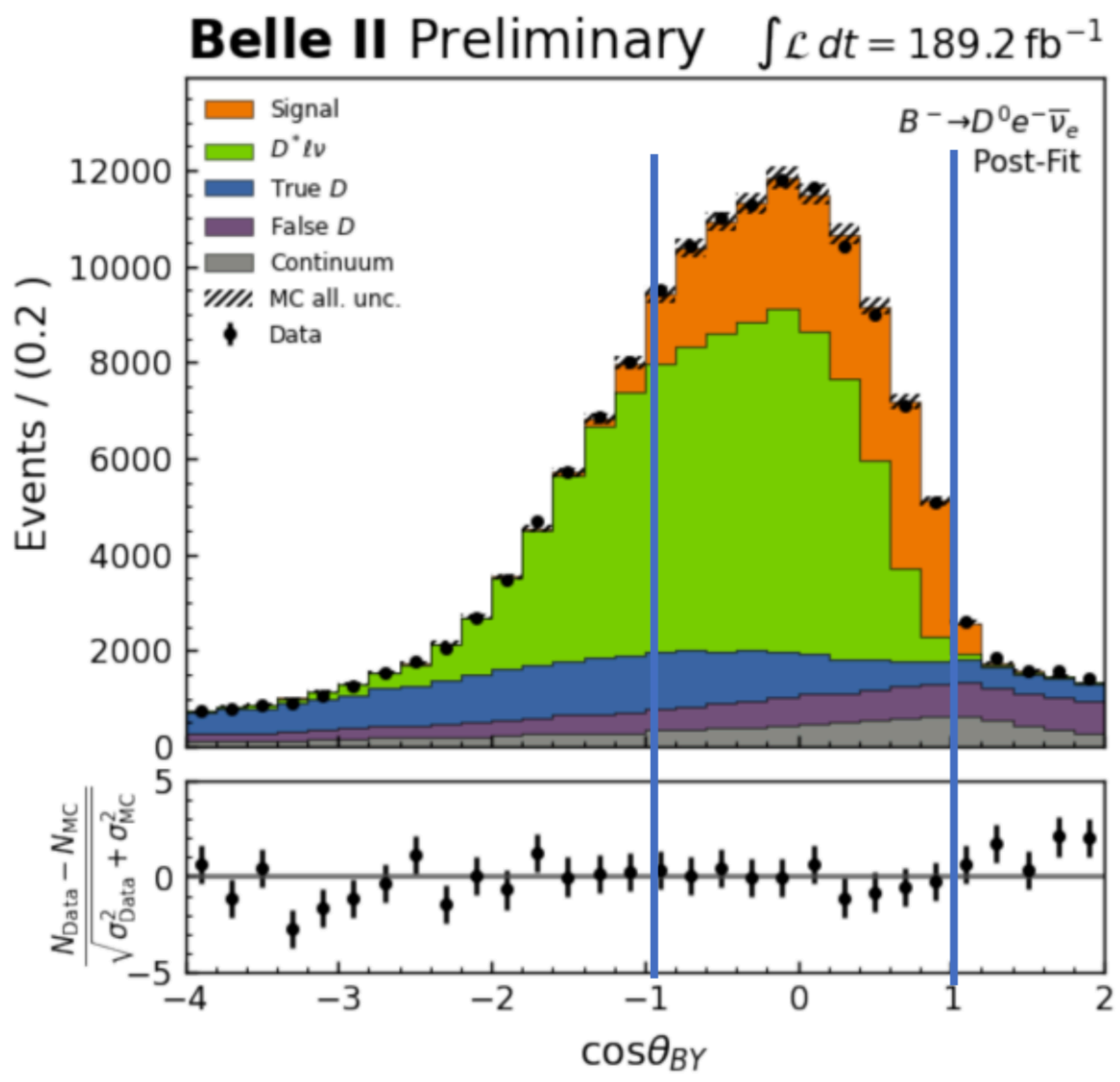


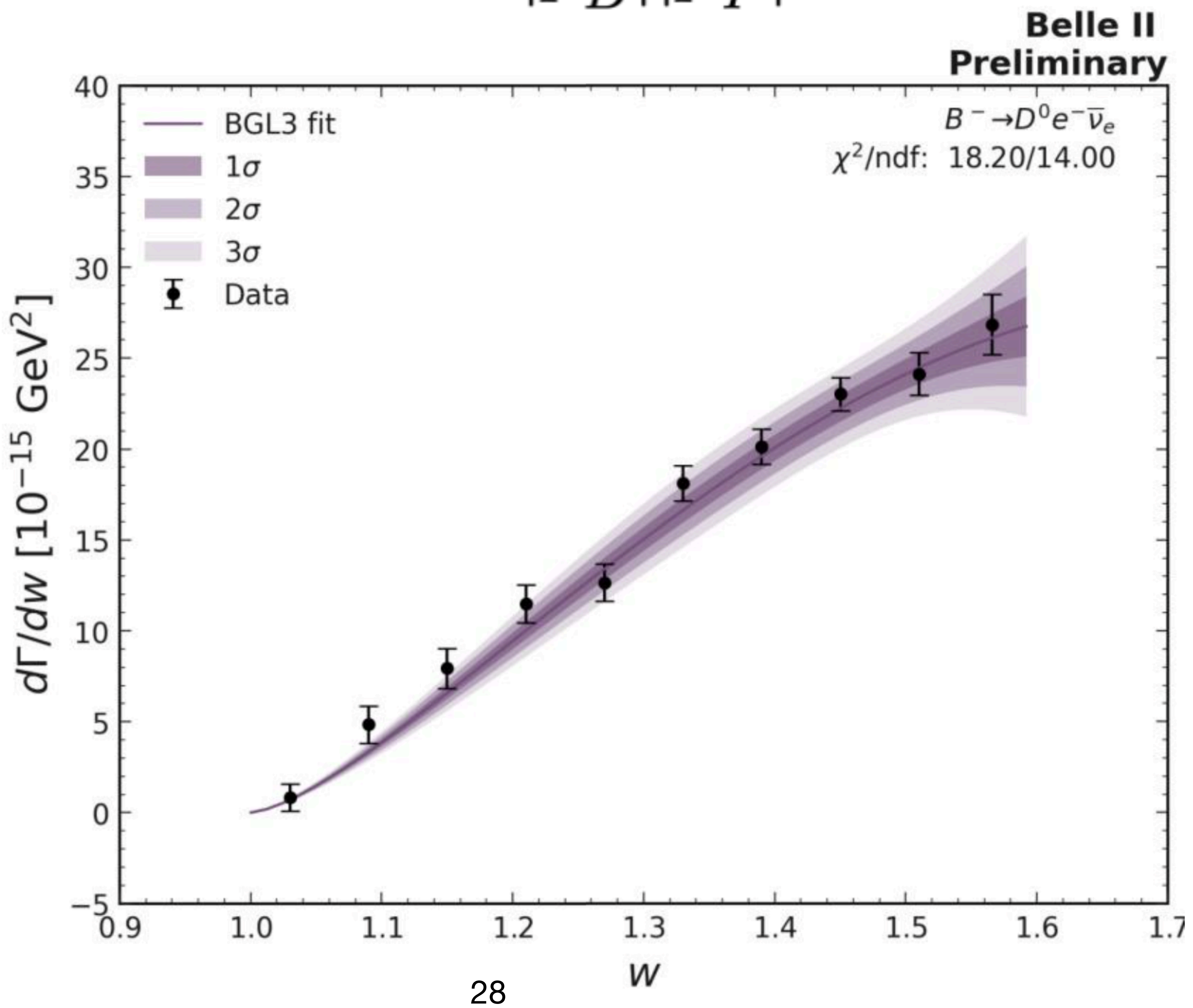
Here: beyond zero-recoil points overlayed (not in fit)

$B \to D\ell\nu$ untagged and $|V_{cb}|$ exclusive

arXiv:2210.13143

- 189.3/fb of Belle II data, four subsamples ($B^0 e, B^0\mu, B^+ e$ and $B^+\mu$)
- Signal extracted from $\cos\theta_{BY} = \dfrac{2\,E_B^* E_Y^* - m_B^2 - m_Y^2}{2|p_B^*||p_Y^*|}$





$\eta_{EW}|V_{cb}|_{BGL} =$

$(38.53 \pm 1.15) \times 10^{-3}$

$|V_{cb}|$ from inclusive decays

$B \to Xl\nu$

$$\Gamma = \frac{G_F^2 m_b^5}{192\pi^3}|V_{cb}|^2\left(1+\frac{c_5(\mu)\,\langle O_5\rangle(\mu)}{m_b^2}+\frac{c_6(\mu)\,\langle O_6\rangle(\mu)}{m_b^3}+\mathcal{O}(\frac{1}{m_b^4})\right)$$

- Based on the Operator Product Expansion (OPE)
- $<O_i>$: hadronic matrix elements (non-perturbative)
  c_i: coefficients (perturbative)
- Parton-hadron duality → the hadronic ME depend only on the initial state

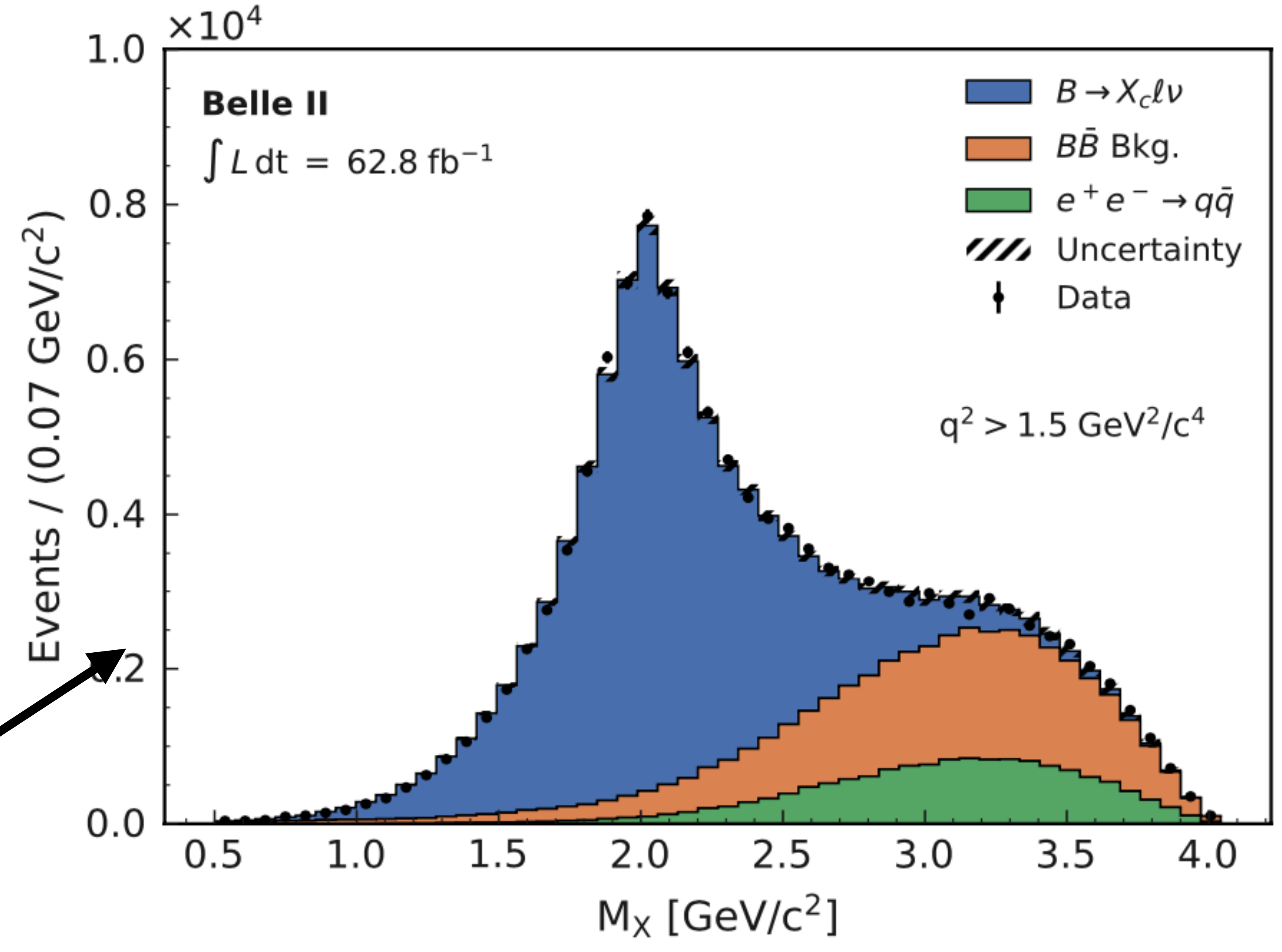
	Kinetic [JHEP 1109 (2011) 055]	1S [PRD70, 094017 (2004)]
O(1)	m_b, m_c	m_b
$O(1/m^2_b)$	μ^2_π, μ^2_G	λ_1, λ_2
$O(1/m^3_b)$	ρ^3_D, ρ^3_{LS}	ρ_1, $\tau_{1\text{-}3}$

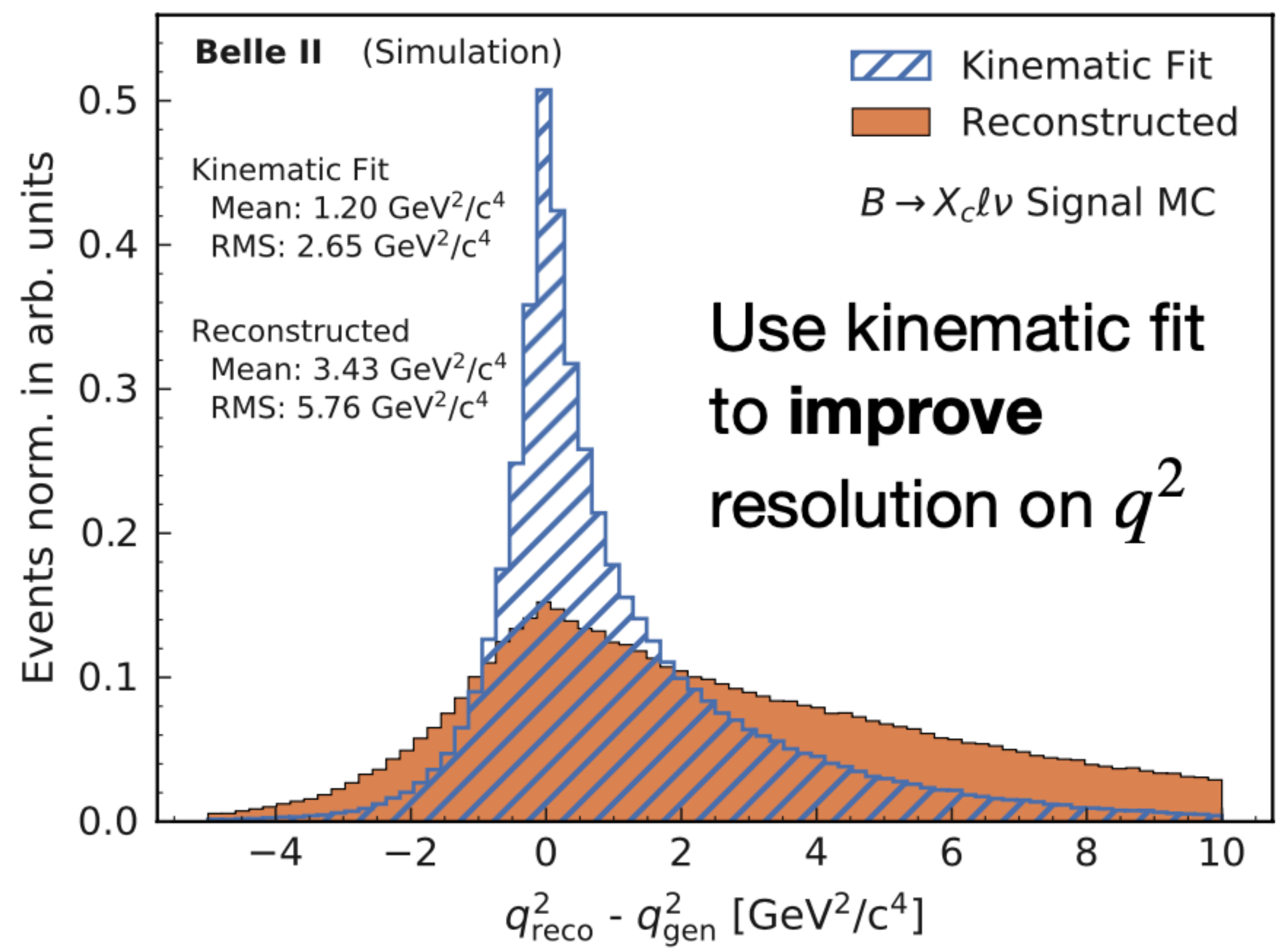
$q^2 = (p_\ell + p_\nu)^2$

q^2 moments in $B \to X_c \ell \nu$

arXiv:2205.06372, submitted to PRD

- Motivated by JHEP 02 (2019) 177 [arXiv:1812.07472]
- Semileptonic B decays are reconstructed in 62.8/fb of hadronic tagged Belle II events
- Signal weight w as a function of q^2 determined from fitting the hadronic mass M_X
- q^2 spectra are calculated as event-wise average
- Leading systematics: background, moment calibration

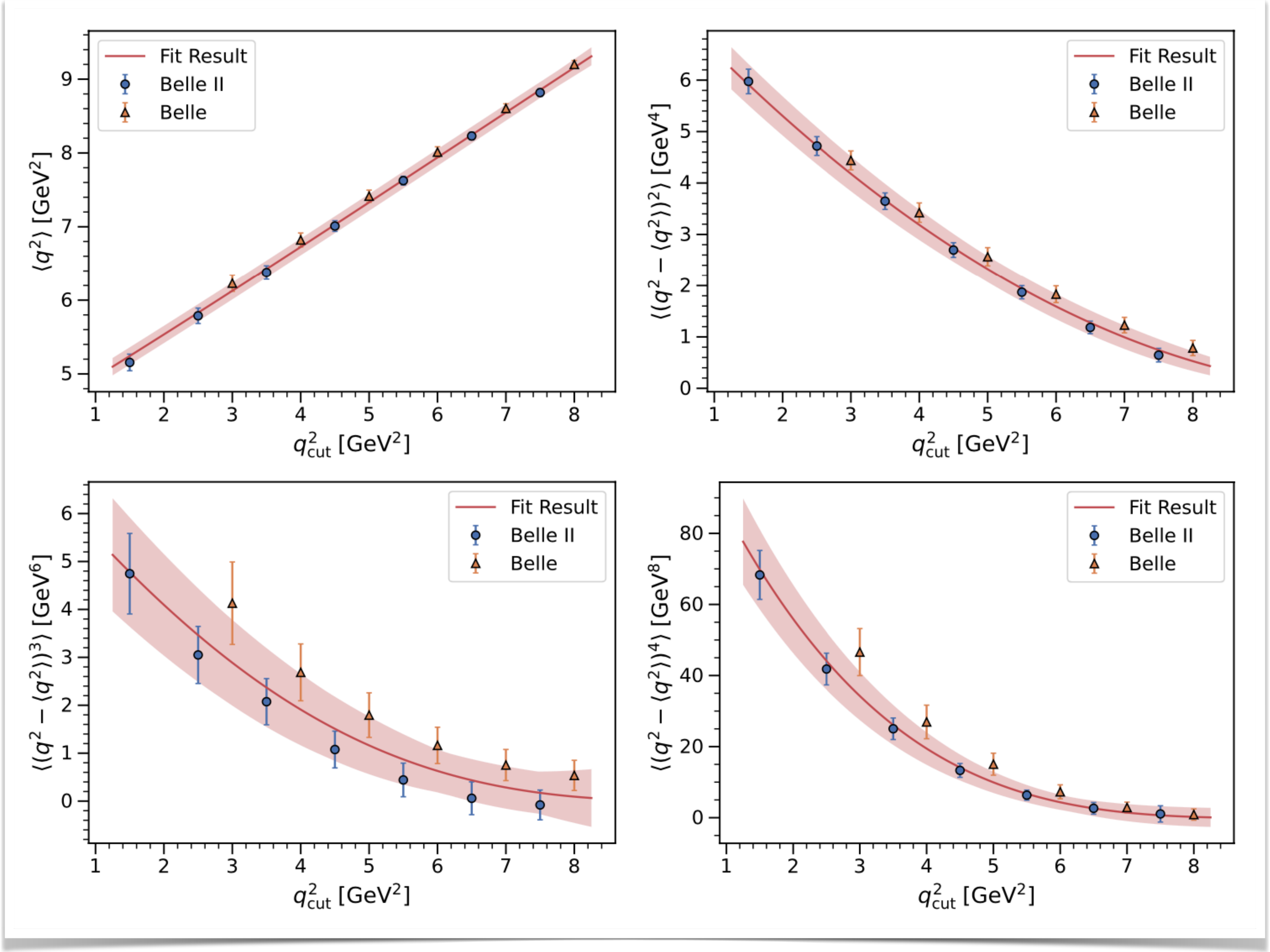




$$\langle q^{2m} \rangle = \frac{C_{\mathrm{cal}} \cdot C_{\mathrm{acc}}}{\sum_i^{\mathrm{events}} w(q_i^2)} \times \sum_i^{\mathrm{events}} w(q_i^2) \cdot q_{\mathrm{cal}\,i}^{2m}$$

q^2 moments in $B \to X_c \ell \nu$

arXiv:2205.06372, submitted to PRD



- Belle II q^2 moments compared to Belle q^2 moments PRD 104, 112011 (2021) [arXiv:2109.01685]
- And fit by Bernlochner et al. [arXiv:2205.10274]
- This fit gives $|V_{cb}| = (41.69 \pm 0.63) \cdot 10^{-3}$

$B \to \pi \ell \nu$

The golden mode for $|V_{ub}|$ exclusive

- Differential rate in terms of $q^2 = (p_\ell + p_\nu)^2$

$$\frac{d\Gamma(B^0 \to \pi^- \ell^+ \nu)}{dq^2} = \frac{G_F^2}{24\pi^3} |V_{ub}|^2 |p_\pi|^3 |f_+(q^2)|^2$$

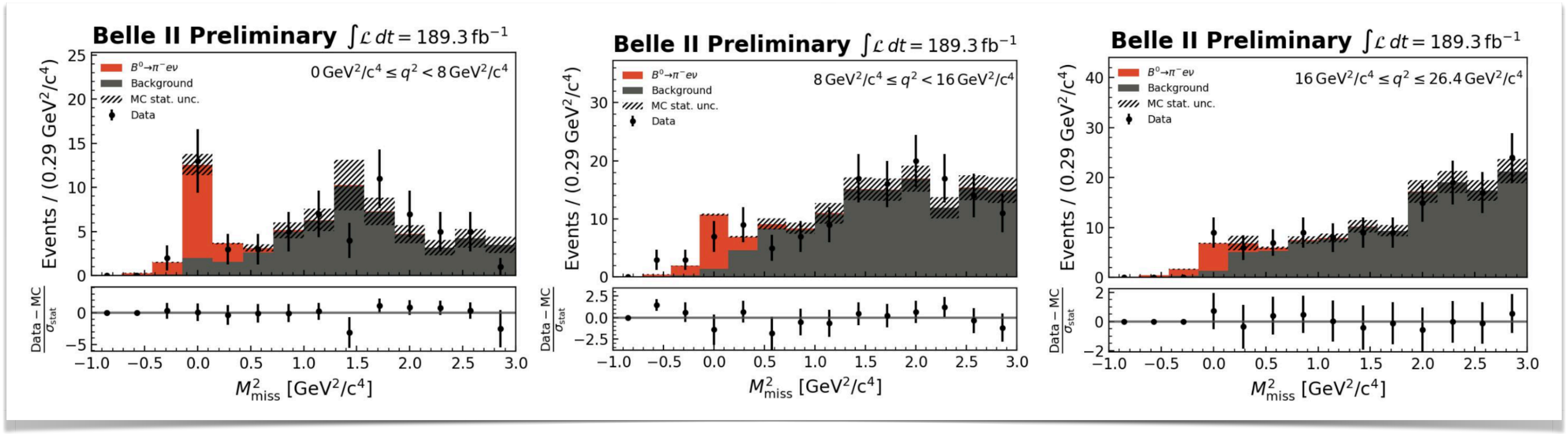
- BCL extraction of $|V_{ub}|$ [Phys.Rev.D79:013008,2009; Erratum-ibid.D82:099902,2010]
  - Measure the differential rate in bins of q^2
  - Theory calculates $f_+(q^2)$ at values of q^2
  - Combined fit to the BCL expansion to determine $|V_{ub}|$ and b_k (z is a map of q^2)

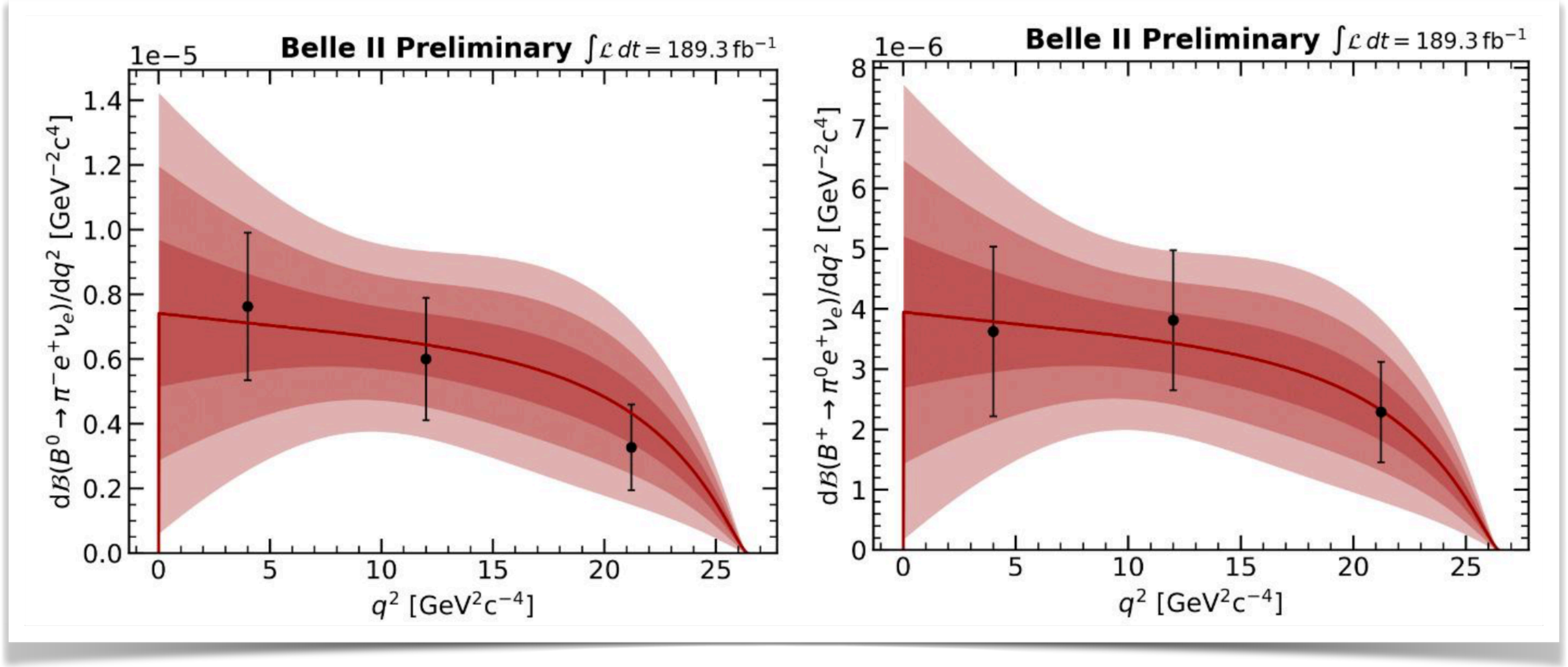
$$f_+(q^2) = \frac{1}{1 - q^2/m_{B*}^2} \sum_{k=0}^{K-1} b_k \left[z^k - (-1)^{k-K} \frac{k}{K} z^K \right]$$

$B \to \pi e \nu$ tagged and $|V_{ub}|$ exclusive

arXiv:2206.08102

- 189.3/fb of Belle II, tag side is reconstructed by hadronic tag

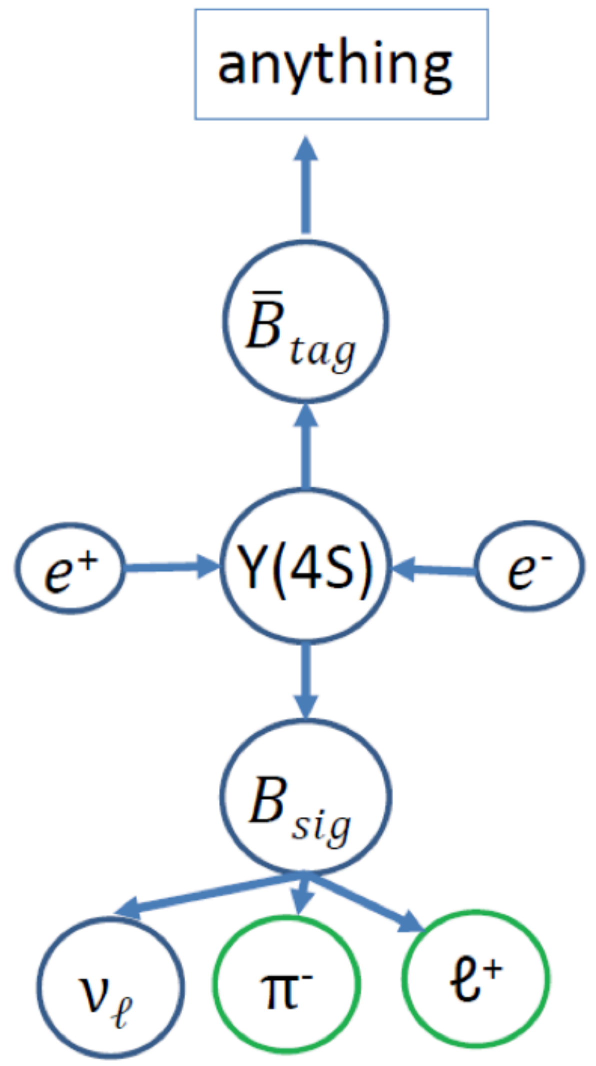




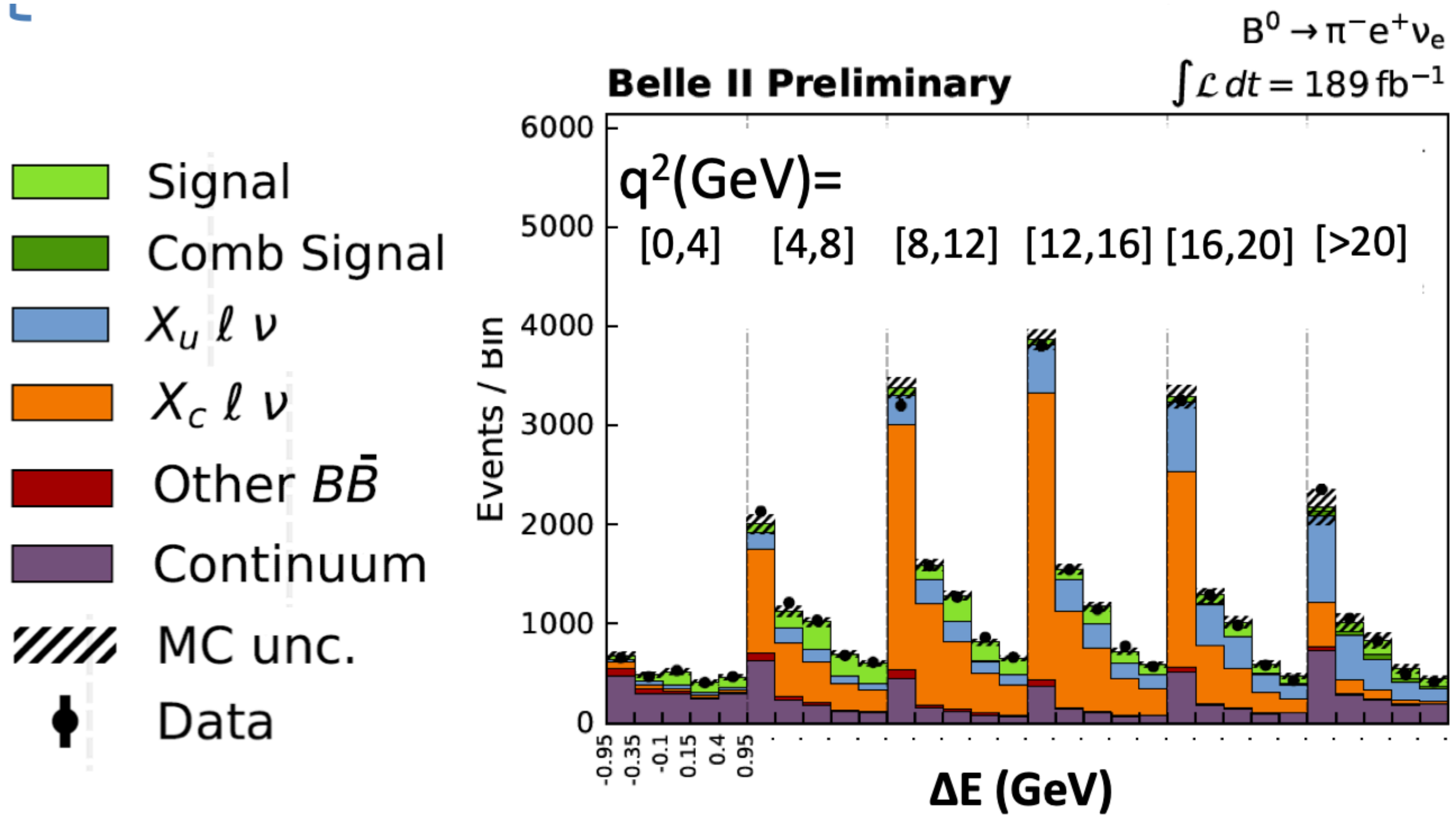
Decay mode	Fitted $|V_{\rm ub}|$
$B^0 \to \pi^- e^+ \nu_e$	$(3.71 \pm 0.55) \times 10^{-3}$
$B^+ \to \pi^0 e^+ \nu_e$	$(4.21 \pm 0.63) \times 10^{-3}$
Combined fit	$(3.88 \pm 0.45) \times 10^{-3}$

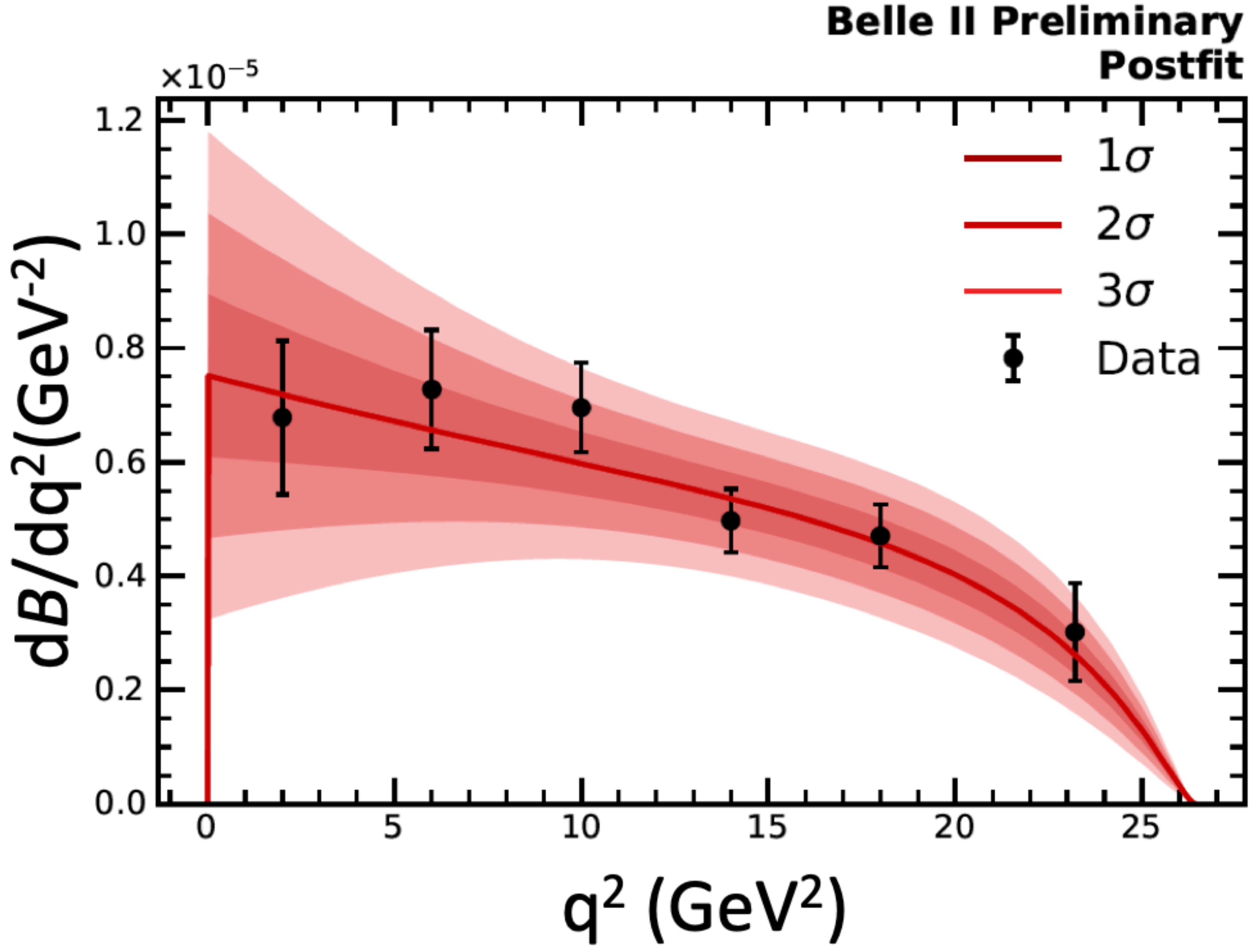
$B \to \pi \ell \nu$ untagged and $|V_{ub}|$ exclusive

arXiv:2210.04224



- 189.3/fb of Belle II data





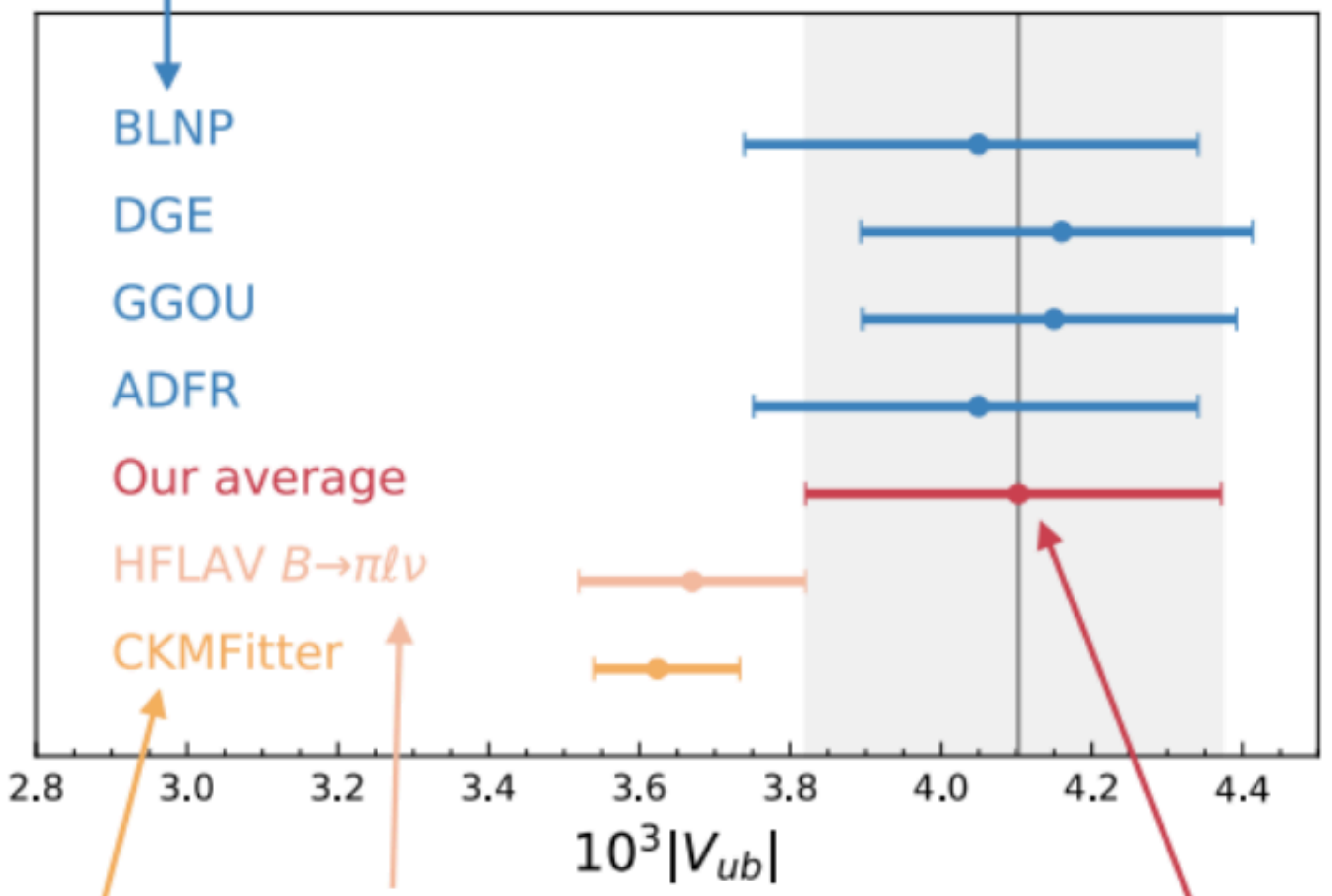
$$|V_{ub}|_{B^0 \to \pi^- \ell^+ \nu_\ell} = (3.54 \pm 0.12_{\text{stat}} \pm 0.15_{\text{sys}} \pm 0.16_{\text{theo}}) \times 10^{-3}$$

$B \to X_u \ell \nu$ and $|V_{ub}|$ inclusive

PRD 104, 012008 (2021), PRL 127, 261801 (2021)

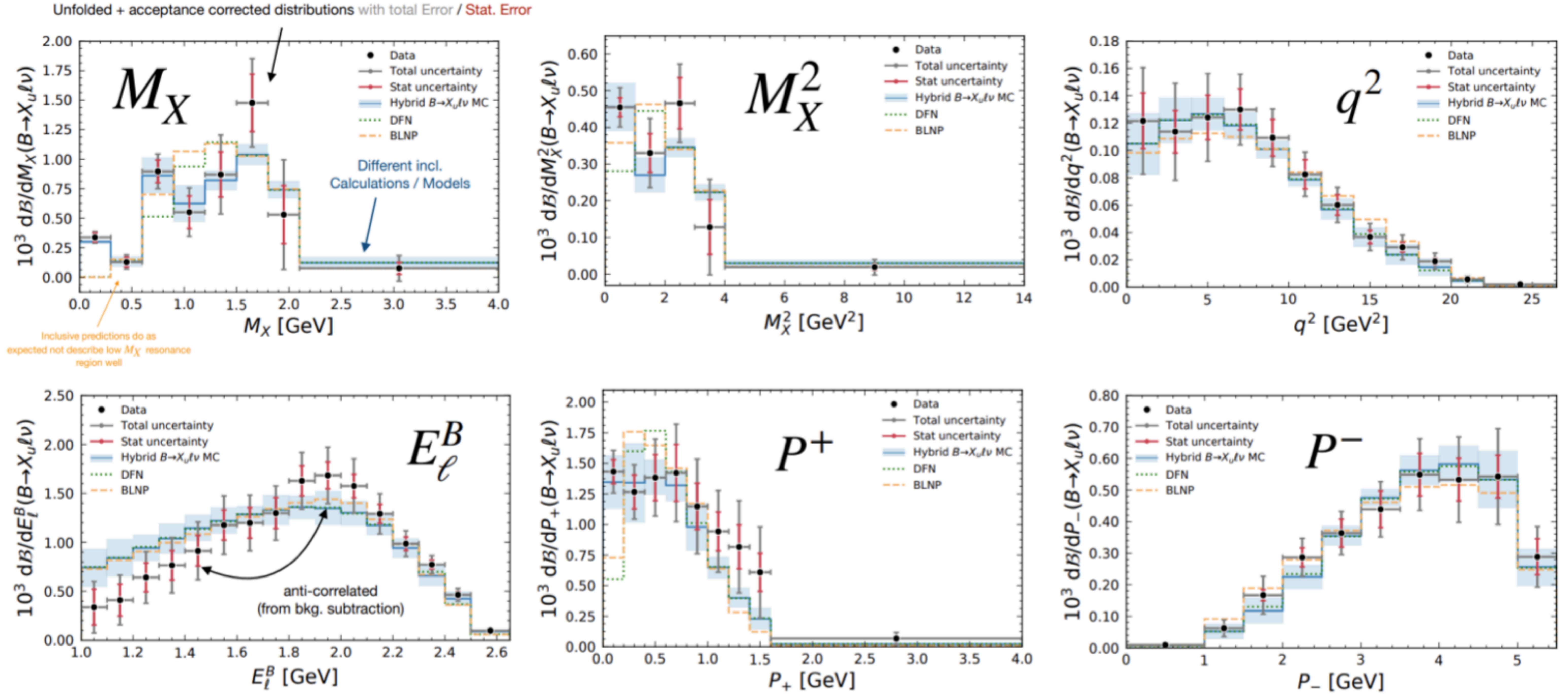
4 predictions of the partial rate

Result for most inclusive region with $E_\ell^B > 1\,\mathrm{GeV}$



Exclusive Average for $B \to \pi \ell \bar{\nu}_\ell$:
$|V_{ub}| = (3.67 \pm 0.09 \pm 0.12) \times 10^{-3}$

CKM Unitarity:
$|V_{ub}| = (3.62^{+0.11}_{-0.08}) \times 10^{-3}$



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

Can be used for future shape-function independent determination of Vub

NNVub

P. Gambino, K. Healey, C. Mondino, Phys. Rev. D 94, 014031 (2016), [arXiv:1604.07598]

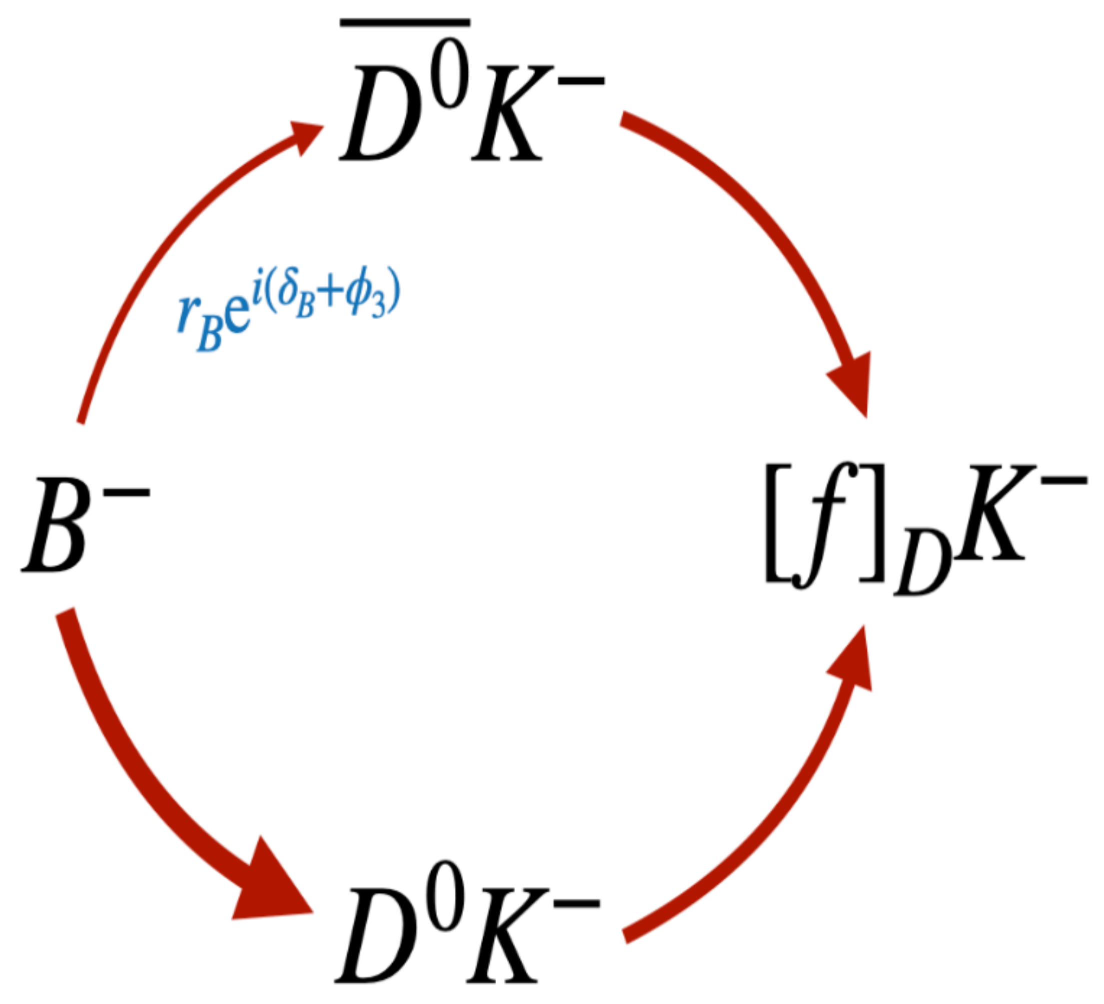
F. Bernlochner, H. Lacker, Z. Ligeti, I. Stewart, F. Tackmann, K. Tackmann Phys. Rev. Lett. 127, 102001 (2021) [arXiv:2007.04320]

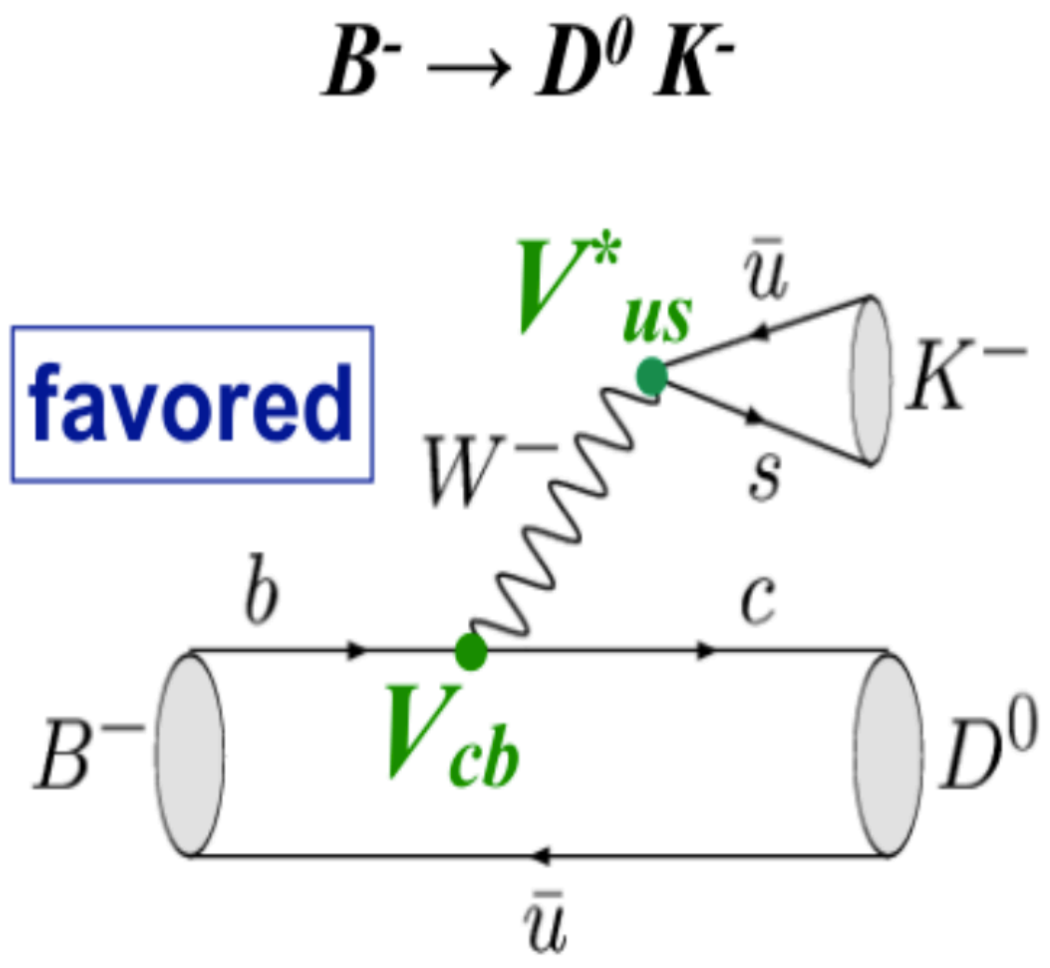
ϕ_3 / γ

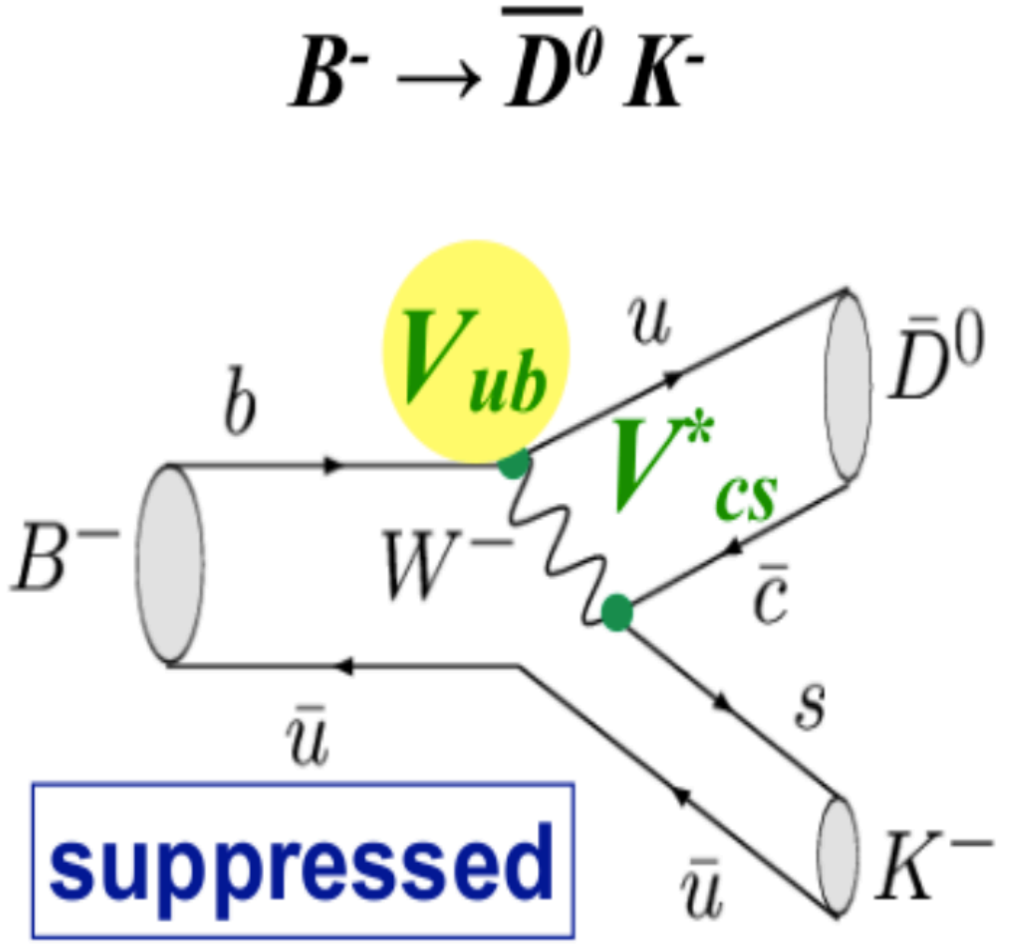
CKM angle ϕ_3/γ

BPGGSZ method (binned model-independent) Phys.Rev.D68, 054018

- ϕ_3/γ is the phase between $b \to u$ and $b \to c$ transitions
- The interference between these two diagrams gives access to the amplitude ratio, which contains ϕ_3/γ





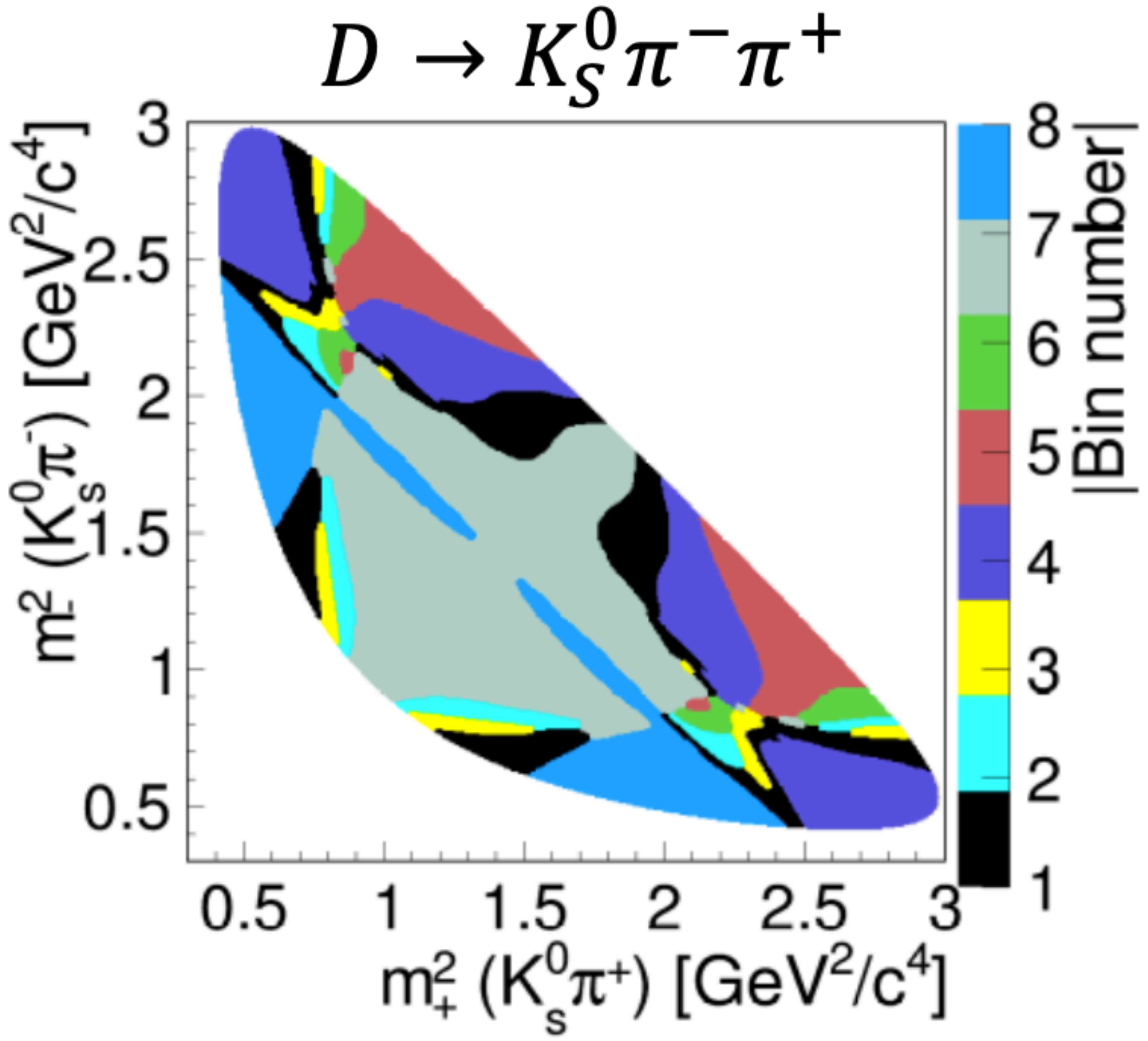


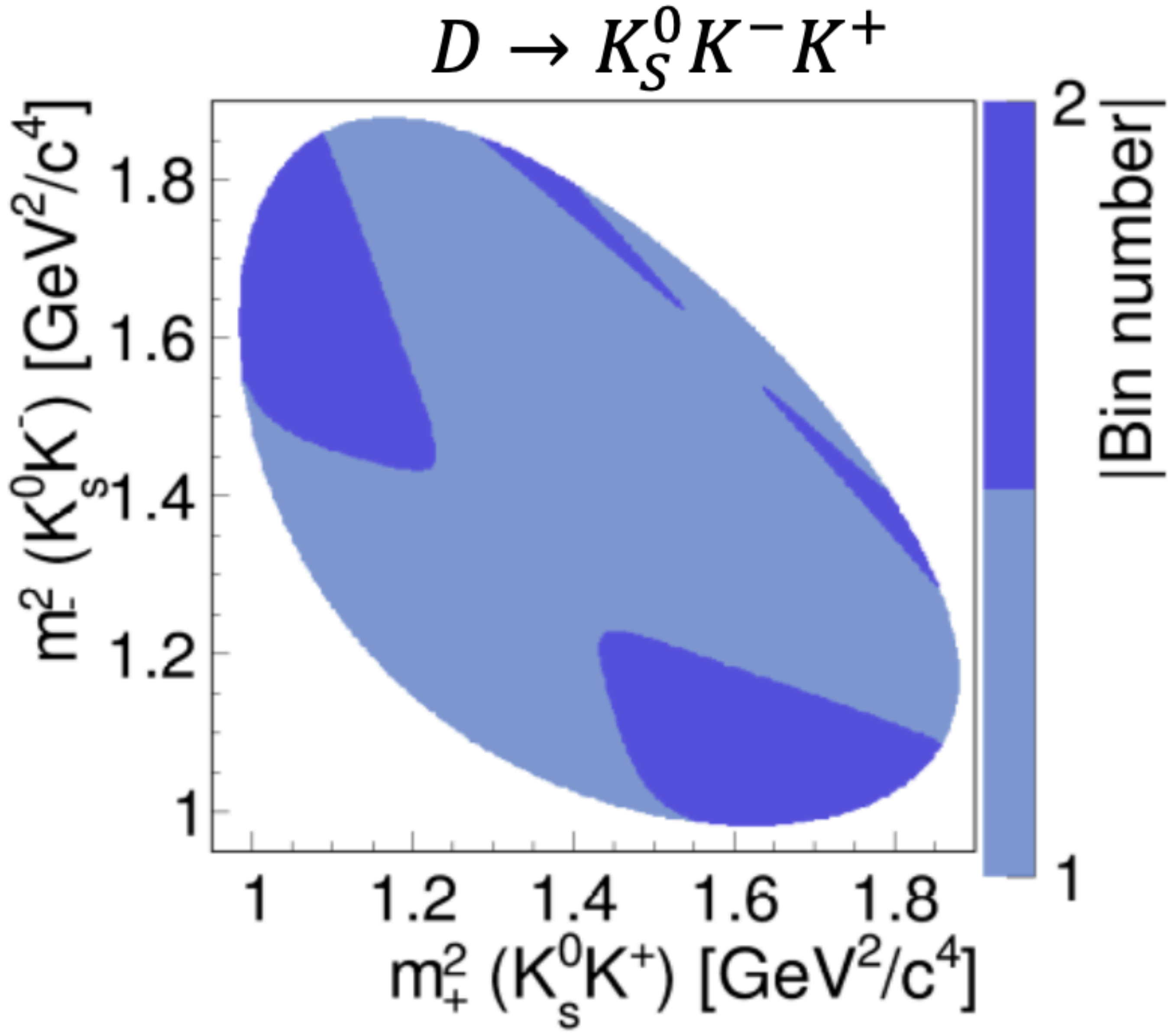
$$\frac{A^{\text{suppr.}}(B^- \to \overline{D}^0K^-)}{A^{\text{favor.}}(B^- \to D^0K^-)} = r_Be^{i(\delta_B+\phi_3)}$$

CKM angle ϕ_3/γ

BPGGSZ method (binned model-independent) Phys.Rev.D68, 054018

- To observe interference, we need to reconstruct D^0 in a self-conjugate mode
- To avoid model dependence, the strong phase difference between the D^0 and $\bar{D}^0$ decays is measured by CLEO/BES III





$$(x_\pm,\ y_\pm) = r_B\left(\cos(\gamma+\delta_B),\ \sin(\gamma+\delta_B)\right)$$

c_i, s_i: D^0-$\bar{D}^0$ strong phase differences (inputs from BES III/CLEO)

F_i: fraction of D decays to i-th bin

$$N_i^\pm = h_{B^\pm}\left[F_i + r_B^2\bar{F}_i + 2\sqrt{F_i\bar{F}_i}(c_i x_\pm + s_i y_\pm)\right]$$

Belle+Belle II measurement of $B \to DK$

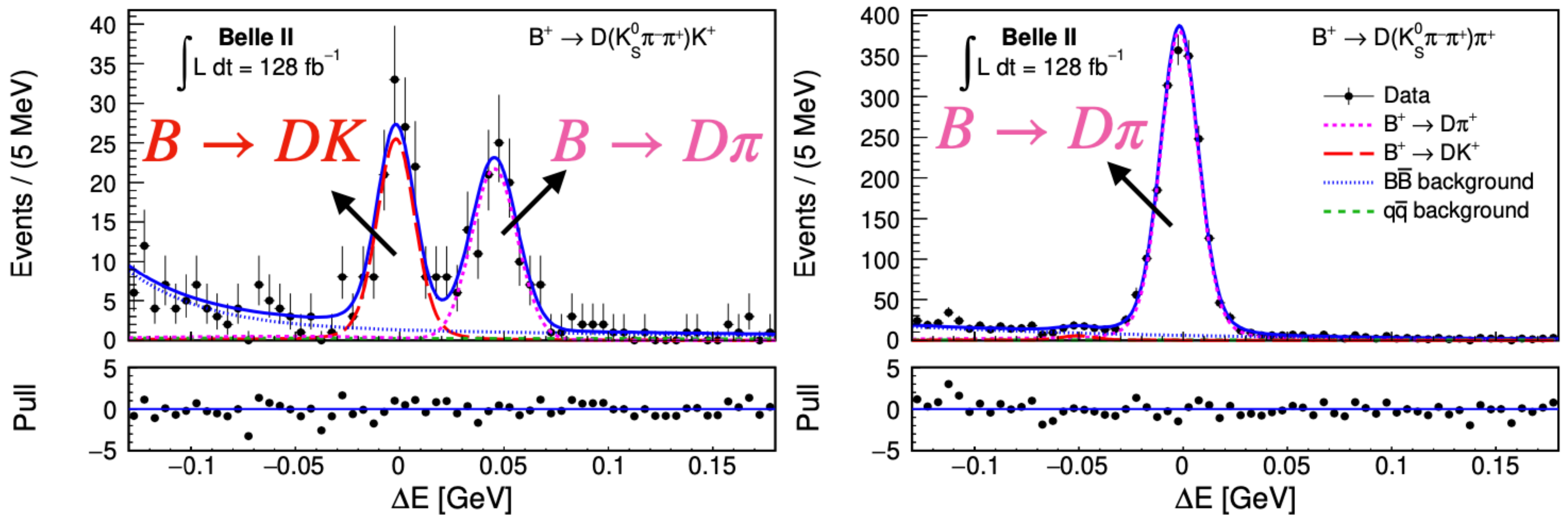
JHEP 02, 063 (2022), arXiv:2110.12125

- 711/fb of Belle and 128/fb of Belle II data
- Using both $D^0 \to K_S^0\pi^+\pi^-$ and $D^0 \to K_S^0K^+K^-$
- Yields extracted in simultaneous fit to $B \to DK$ and $B \to D\pi$ (misID rate determined from data)

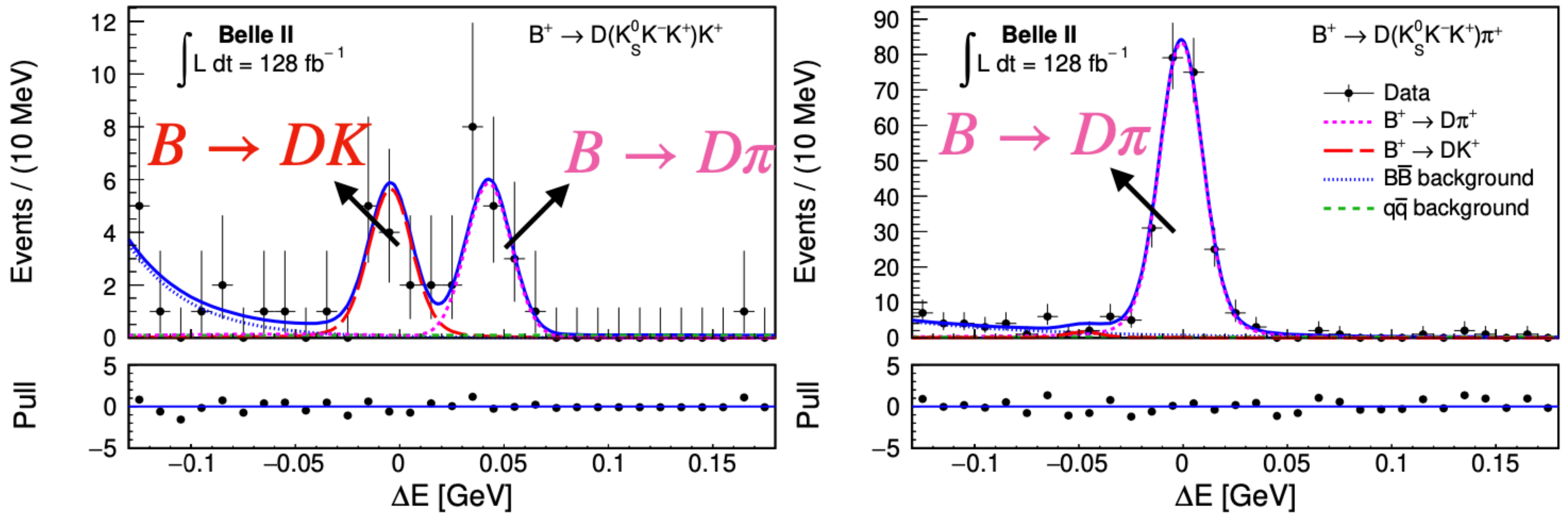
Signal yields:

Belle:	Belle II :
$K_S^0\pi\pi$: 1467 ± 53	$K_S^0\pi\pi$: 280 ± 21
K_S^0KK: 194 ± 17	K_S^0KK: 34 ± 7

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



$D^0 \to K_S^0K^+K^-$



Belle+Belle II measurement of $B \to DK$

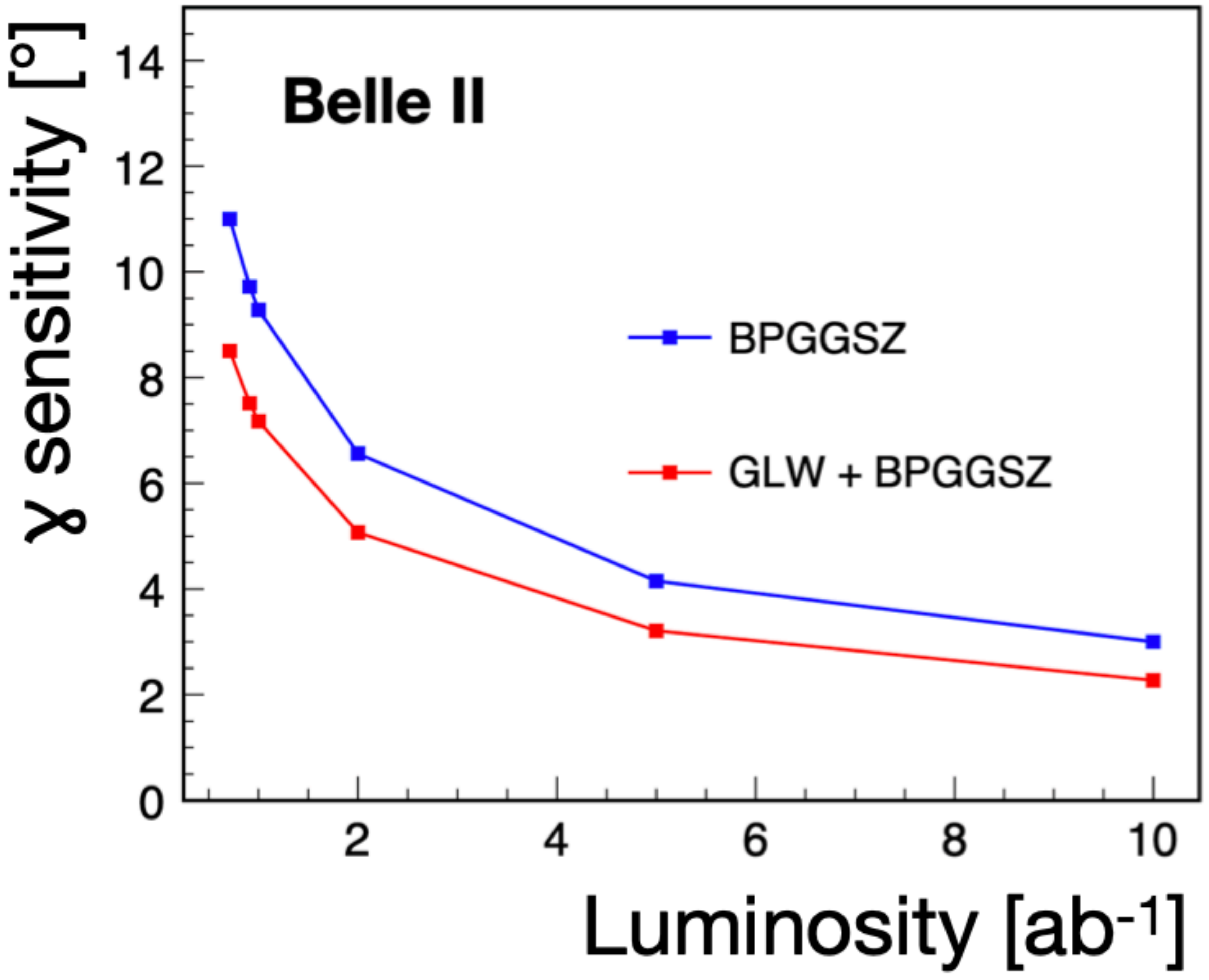
JHEP 02, 063 (2022), arXiv:2110.12125

- Simultaneous fit in Dalitz bins to extract CP observables $(x_\pm, y_\pm)$ which contain r_B, δ_B and ϕ_3/γ
- Extract F_i directly from data to reduce systematics
- Best result from B factories but still not competitive with LHCb (~3 degrees uncertainty)

$$\delta_B[^\circ] = 124.8 \pm 12.9\ (\text{stat})\ \pm 0.5\ (\text{syst})\ \pm 1.7\ (\text{ext})$$

$$r_B^{DK} = 0.129 \pm 0.024\ (\text{stat})\ \pm 0.001\ (\text{syst})\ \pm 0.002\ (\text{ext})$$

$$\gamma[^\circ] = 78.4 \pm 11.4\ (\text{stat})\ \pm 0.5\ (\text{syst})\ \pm 1.0\ (\text{ext})$$



Summary

- Current data of the B factories confirms 3-generation quark mixing and fits the CKM unitarity triangle extremely well
  - There is however an experimental anomaly in the CKM magnitudes $|V_{cb}|$ and $|V_{ub}|$ and the precision of the angle ϕ_3/γ is still largely limited by statistics
- Belle II is an upgrade programme for the Belle B factory which aims accumulating about 50 times more data
  - 428/fb have been recorded by Belle II by summer 2022
- Belle II has produced first results for $|V_{cb}|$ and $|V_{ub}|$ in 2022
  - Once these analyses are finalised, we will revisit the inclusive vs. exclusive situation
- ϕ_3/γ has been measured combining the Belle and Belle II data samples
  - We need an order of magnitude more data to be competitive with hadron collider experiments