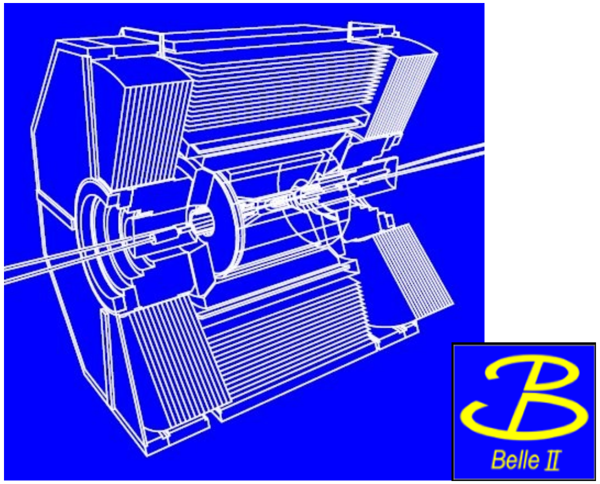
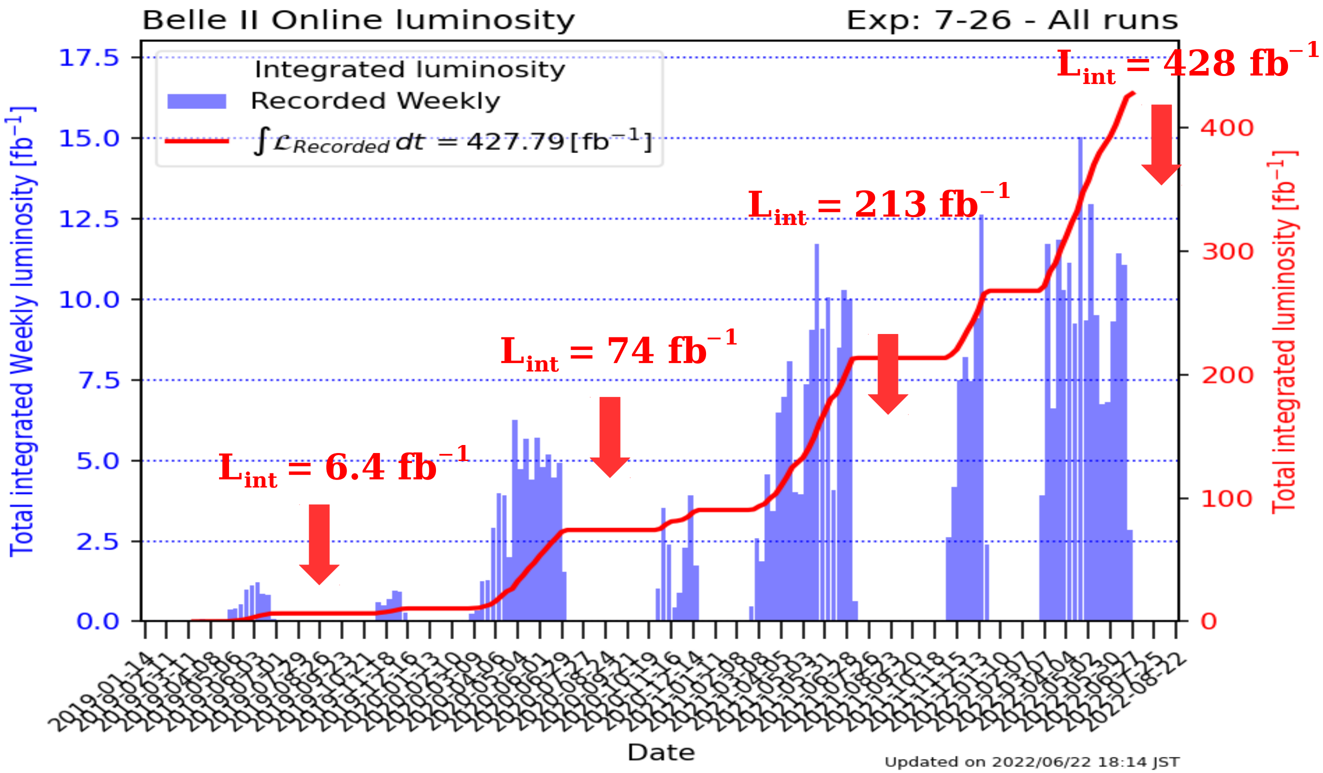
New results of the CKM angle γ/ϕ_3 at Belle/Belle II

K. Trabelsi (IJCLab)
karim.trabelsi@in2p3.fr

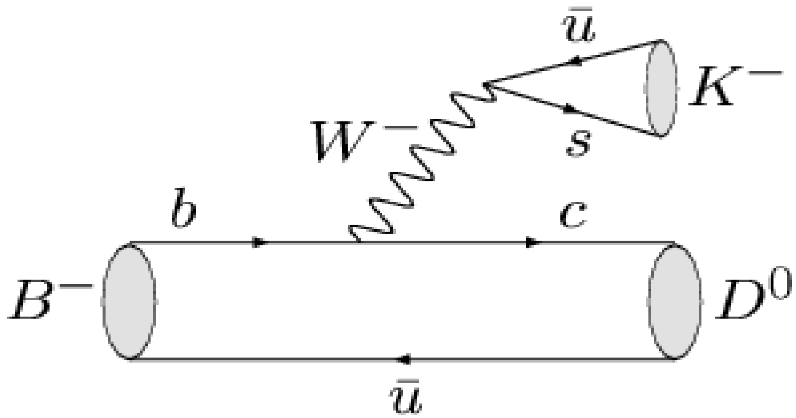




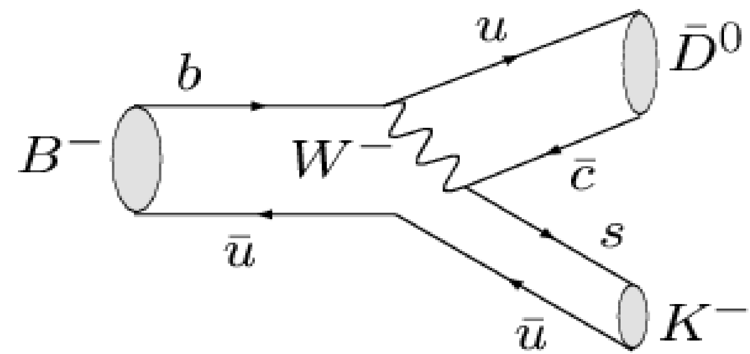
γ measurements from $B^{\pm} \to DK^{\pm}$

- Theoretically pristine $B \to DK$ approach

- Access γ via interference between $B^- \to D^0 K^-$ and $B^- \to \overline{D}^0 K^-$



color allowed
$B^- \to D^0 K^- \sim V_{cb} V^*_{us}$
$\sim \mathbf{A\lambda^3}$



color suppressed
$B^- \to \overline{D}^0 K^- \sim V_{ub} V^*_{cs}$
$\sim \mathbf{A\lambda^3(\rho + i\eta)}$

relative magnitude of suppressed amplitude is r_B

$$r_B = \frac{|A_{suppressed}|}{|A_{favoured}|} \sim \frac{|V_{ub} V^*_{cs}|}{|V_{cb} V^*_{us}|} \times [\text{color supp}] = 0.1\text{-}0.2$$

relative weak phase is γ, relative strong phase is δ_B

$\Rightarrow$ for $D\pi$: same dependence to γ, but different $r_B \sim 0.01$ $(V_{us} \to V_{ud}, V_{cs} \to V_{cd})$

γ measurements from $B^{\pm} \to DK^{\pm}$

- Theoretically pristine $B \to DK$ approach
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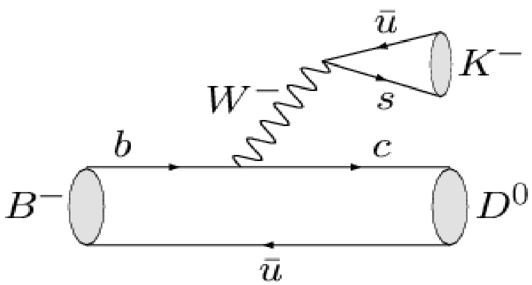
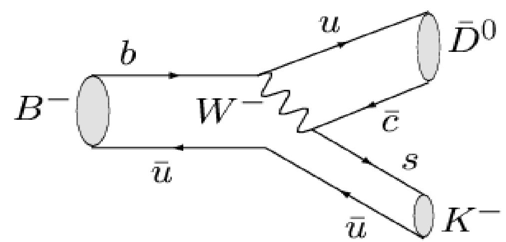


color allowed

$B^- \to D^0 K^- \sim V_{cb} V_{us}^*$

$\sim A\lambda^3$



color suppressed

$B^- \to \overline{D}^0 K^- \sim V_{ub} V_{cs}^*$

$\sim A\lambda^3(\rho + i\eta)$

relative weak phase is γ

relative strong phase is δ_B

$$r_B = \frac{|A_{suppressed}|}{|A_{favoured}|} \sim \frac{|V_{ub} V_{cs}^*|}{|V_{cb} V_{us}^*|} \times [\text{color supp}] = 0.1\text{-}0.2$$

$B^{\pm} \to D K^{\pm}$

$B^{\pm} \to D^* K^{\pm},\ D^* \to D\pi^0$

$B^{\pm} \to D^* K^{\pm},\ D^* \to D\gamma$

$B^{\pm} \to D K^{*\pm}$

$B^0 \to D K^{*0}$

$B^{\pm} \to D K\pi\pi$

$B \to \ldots$

$D \to K^+ K^-,\ \pi^+\pi^- \ldots$

$D \to K_S \pi^0,\ K_S \eta \ldots$

$D \to K K \pi^0,\ \pi\pi\pi^0 \ldots$

$D \to K_S \pi\pi, K_S K K$

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

$D \to \ldots$

γ measurements from $B^{\pm} \to DK^{\pm}$

- Reconstruct D in final states accessible to both D^0 and $\overline{D}^0$
  - $D = D_{CP}$, CP eigenstates as K^+K^-, $\pi^+\pi^-$, $K_S\pi^0$

    GLW method (Gronau-London-Wyler)
  - $D = D_{sup}$, Doubly-Cabbibo suppressed decays as $K\pi$

    ADS method (Atwood-Dunietz-Soni)
  - Three-body decays as $D \to K_S\pi^+\pi^-$, $K_SK^+K^-$

    BPGGSZ (Dalitz) method (Bondar-Poluektov-Giri-Grossman-Soffer-Zupan)

- Largest effects due to
  - charm mixing
  - charm CP violation

  } negligible

  Y.Grossman, A.Soffer, J.Zupan [PRD 72, 031501 (2005)]

- Different B decays (DK, D^*K, DK^*)
  - different hadronic factors (r_B, δ_B) for each

Belle II, a flavour-factory,

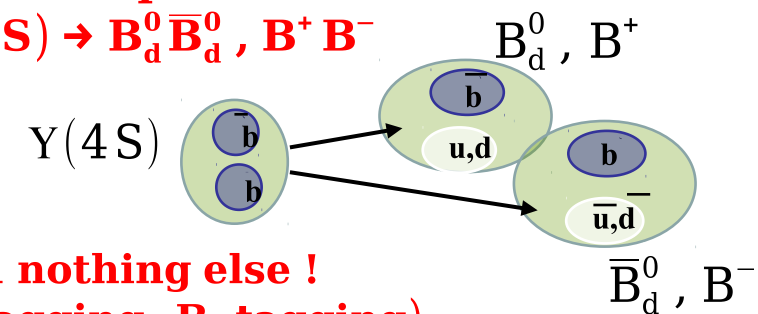
(Belle ~ 0.7 ab^{-1} at $\Upsilon(4S)$)

a rich physics program...

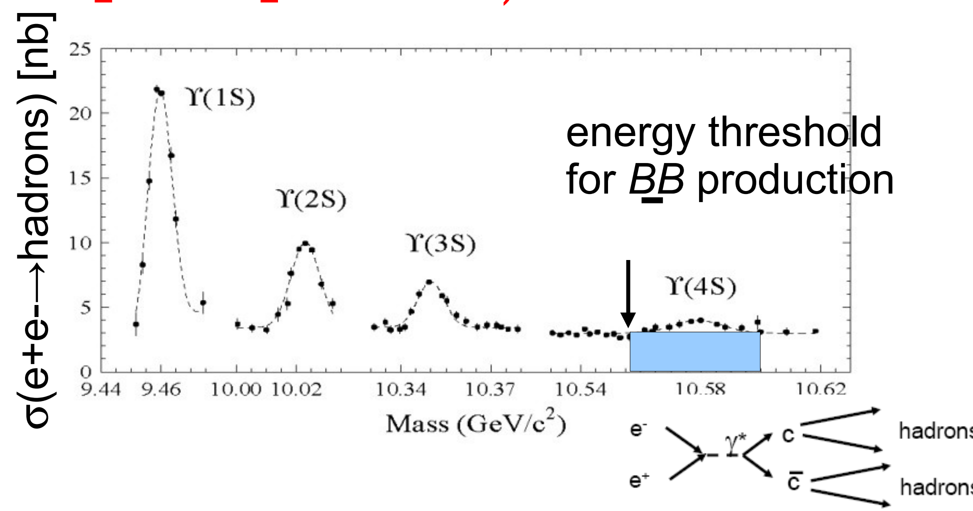
- We plan to ultimately collect many ab^{-1} of e^+e^- collisions at (or close to) the $\Upsilon(4S)$ resonance, so that we have:

– a (Super) B-factory ($\sim 1.1\times 10^9$ $B\overline{B}$ pairs per ab^{-1})

"on resonance" production
$e^+e^- \to \Upsilon(4S) \to B^0_d\overline{B}^0_d$, B^+B^-



- **2 B's and nothing else !**
  (flavour tagging, B-tagging)
- 2 B mesons are created simultaneously in a L=1 coherent state



For exclusive decays: high efficiency for K^0_S, π^0 reconstruction

– a (Super) charm factory ($\sim 1.3\times 10^9$ $c\bar{c}$ pairs per ab^{-1})
(but also charmonium, X, Y, Z, pentaquarks, tetraquarks, bottomonium...)
(scan data are also crucial here)

– a (Super) τ factory ($\sim 0.9\times 10^9$ $\tau^+\tau^-$ pairs per ab^{-1})

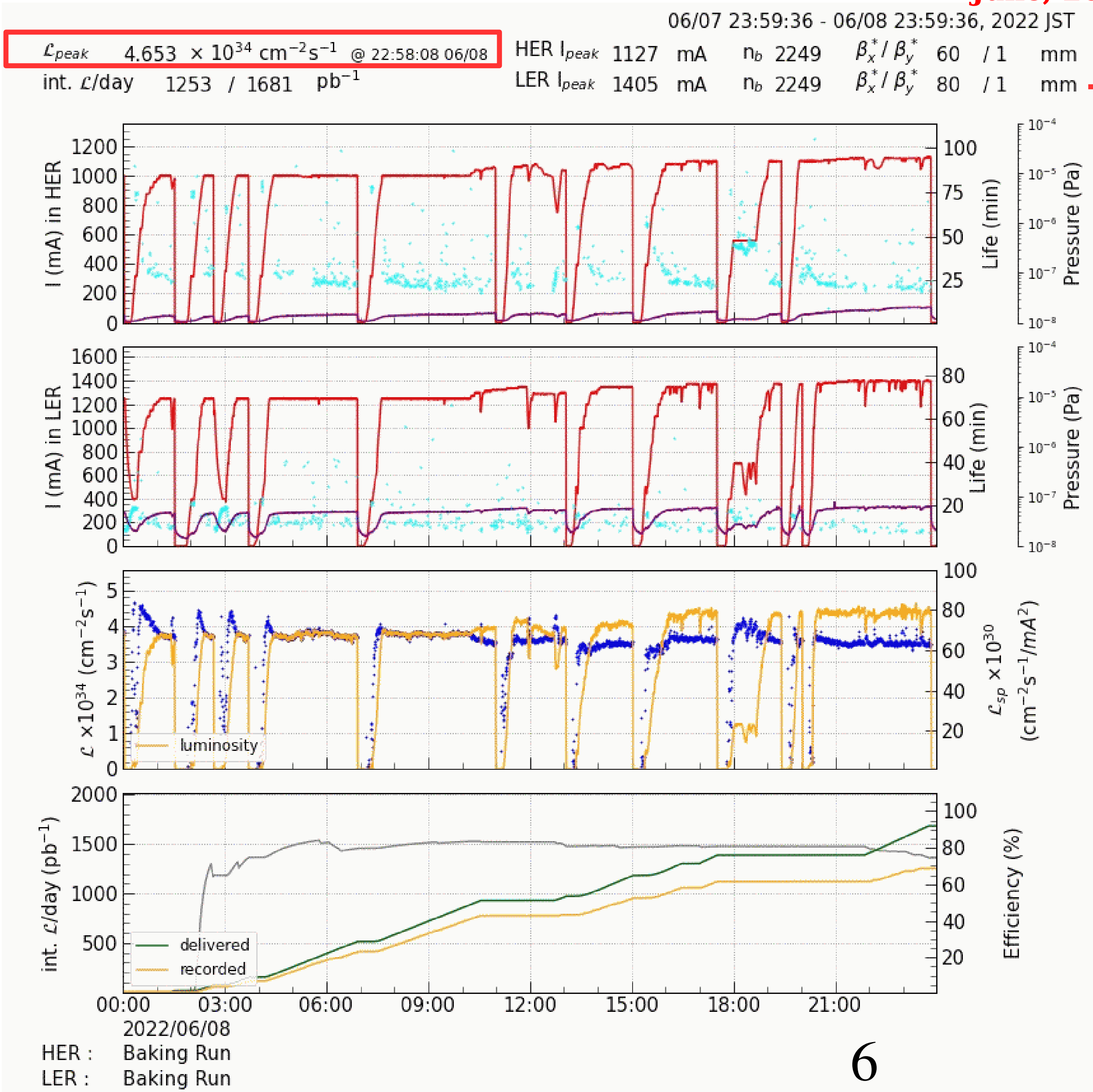
– exploit the clean e^+e^- environment to probe the existence of exotic hadrons, dark photons/Higgs, light Dark Matter particles, ALPs, LLPs ...

Belle II run I (2019 - 2022)

data taking from March 2019 to June 2022
→ despite difficult conditions since March 2020 (Covid, war in Ukraine, energy cost …)

luminosity: 4.7×10^{34}/cm^2/s ! > 2 fb^{-1} per day !

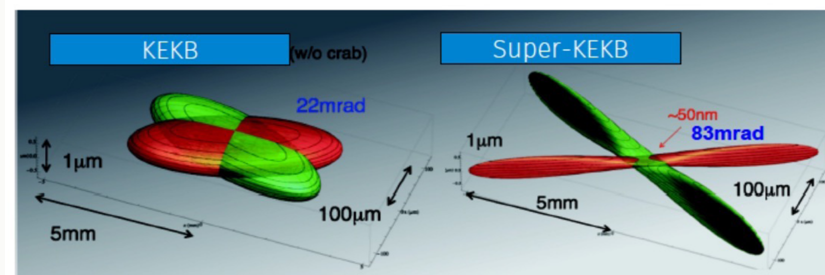
June, 2022



→ **$\beta_y^* = 1$ mm, $I_{LER/HER} = 1.4/1.1$ A**

record of KEKB/Belle
2×10^{34}/cm^2/s currents > 1 A

record of PEPII/BaBar
1×10^{34}/cm^2/s currents > 2 A

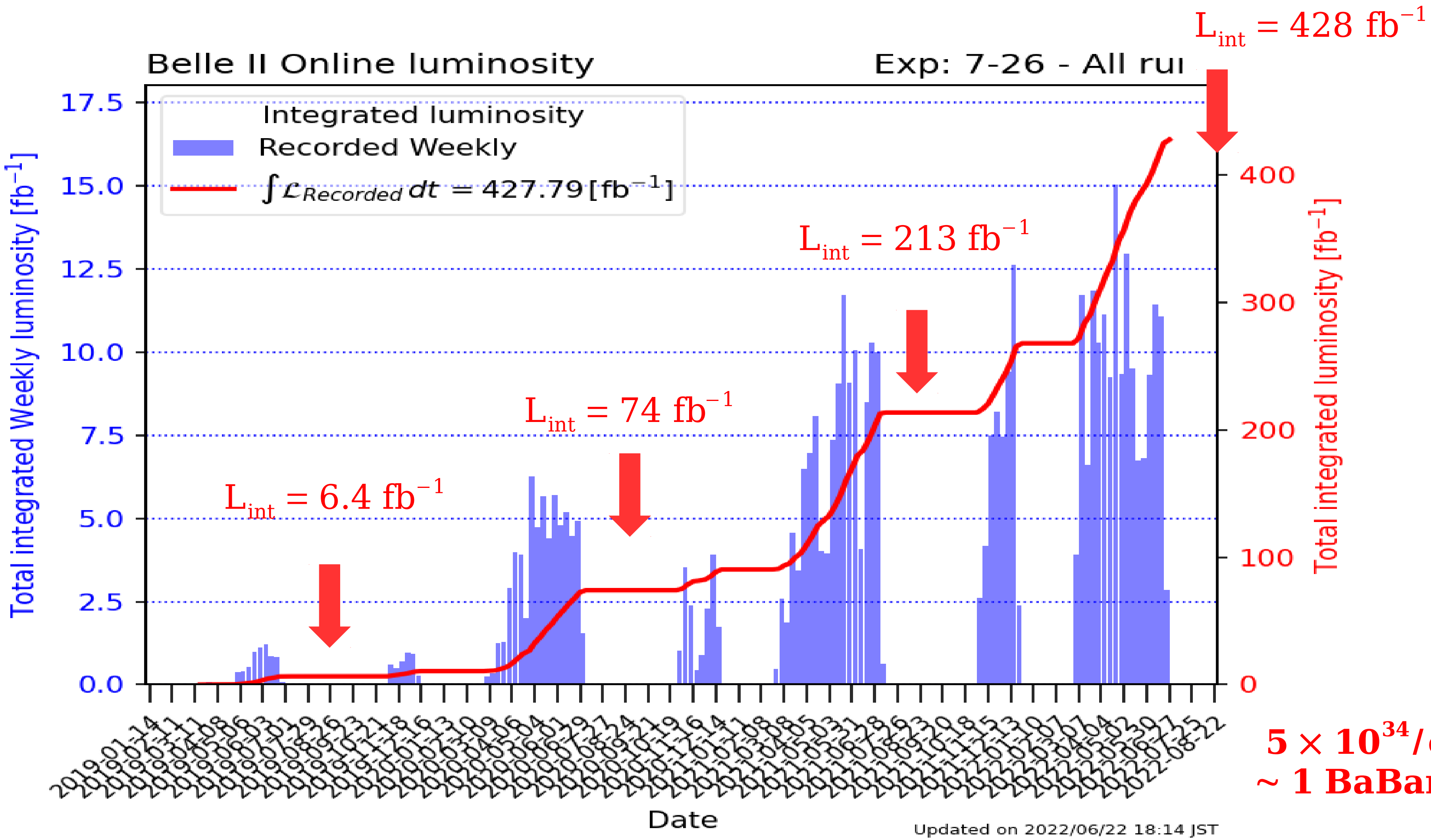


	E (GeV) LER/HER	β*$_y$ (mm) LER/HER	β*$_x$ (cm) LER/HER	φ (mrad)	I (A) LER/HER	L (cm^{-2}s^{-1})
KEKB	3.5/8.0	5.9/5.9	120/120	11	1.6/1.2	2.1 x 10^{34}
SuperKEKB	4.0/7.0	0.27/0.30	3.2/2.5	41.5	3.6/2.6	80 x 10^{34}

factor 20 factor 2-3

squeezing further β_y^* (→ 0.6 mm)
doubling (or more) the currents
⇒ L > 10^{35}/cm^2/s after LS1

Belle II run I (2019 - 2022)



$5 \times 10^{34}/\mathrm{cm}^2/\mathrm{s}$
~ 1 BaBar/year

⇒ **362 fb^{-1} at the Υ(4S) resonance (rest off resonance, and scan)**

⇒ **Belle II results presented here with 128 fb^{-1}, 189 fb^{-1}, 362 fb^{-1},**
always adding Belle data sample (BPGGSZ) (GLW) (GLS)

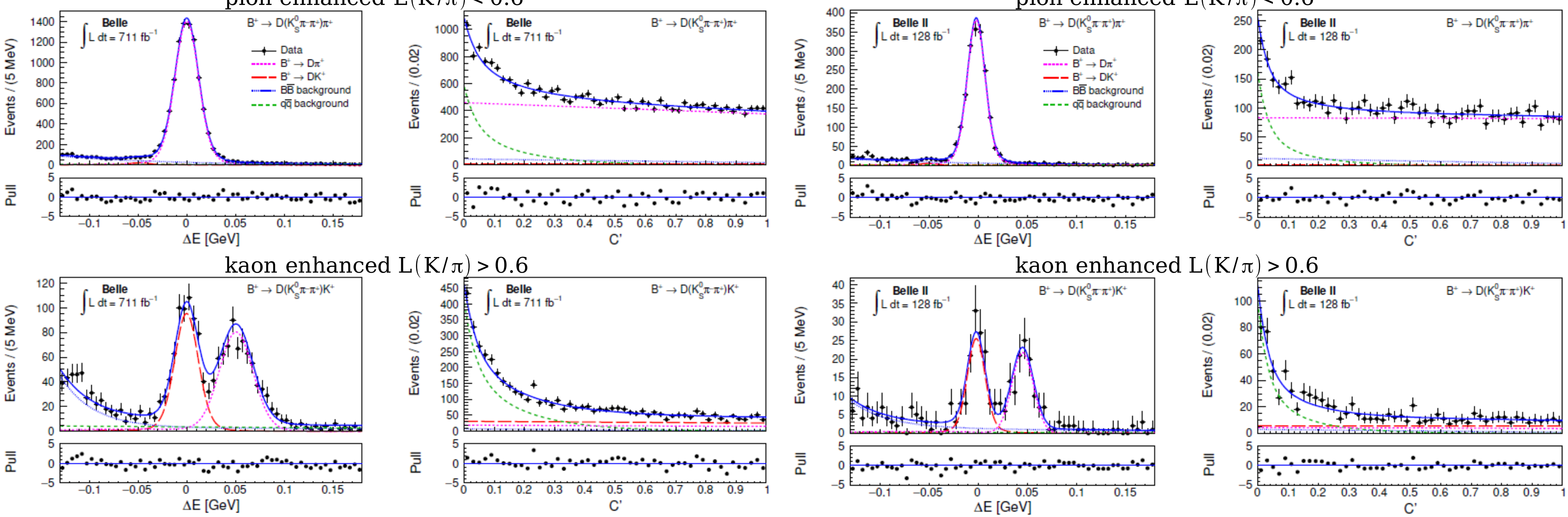
BPGGSZ study $B \to D(K_S^0 h^+ h^-) h^-$

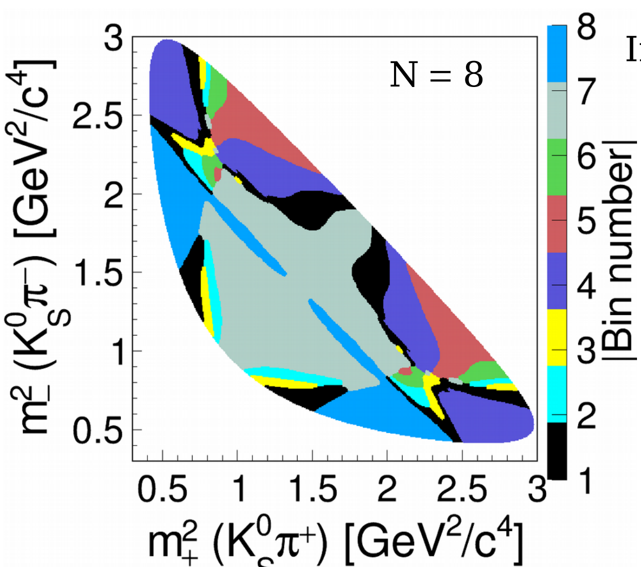
$h = \pi, K$

(Belle/Belle II collaboration)

[arXiv:2110.12125, JHEP 02 (2022) 63]

- Analysis with 711 fb^{-1} Belle data and 128 fb^{-1} Belle II data
- Unbinned 2D simultaneous fit of ΔE versus C' (shown below for $K_S^0\pi\pi$)





In the model-independent method, the D-decay Dalitz plot is divided into $2\times N$ bins

$$N_i^+ = h_{B^+}\left[F_{-i} + \left\{\left(x_+^{DK}\right)^2 + \left(y_+^{DK}\right)^2\right\} F_i + 2\sqrt{F_i F_{-i}}\left(x_+^{DK} c_i - y_+^{DK} s_i\right)\right]$$

$$N_{-i}^+ = h_{B^+}\left[F_i + \left\{\left(x_+^{DK}\right)^2 + \left(y_+^{DK}\right)^2\right\} F_{-i} + 2\sqrt{F_i F_{-i}}\left(x_+^{DK} c_i + y_+^{DK} s_i\right)\right]$$

$$N_i^- = h_{B^-}\left[F_i + \left\{\left(x_-^{DK}\right)^2 + \left(y_-^{DK}\right)^2\right\} F_{-i} + 2\sqrt{F_i F_{-i}}\left(x_-^{DK} c_i + y_-^{DK} s_i\right)\right]$$

$$N_{-i}^- = h_{B^-}\left[F_{-i} + \left\{\left(x_-^{DK}\right)^2 + \left(y_-^{DK}\right)^2\right\} F_i + 2\sqrt{F_i F_{-i}}\left(x_-^{DK} c_i - y_-^{DK} s_i\right)\right]$$

previous Belle analysis determined the values of F_i from a sample of $D^* \to D\pi$, simultaneously from a fit to $B \to Dh^\pm$ candidates

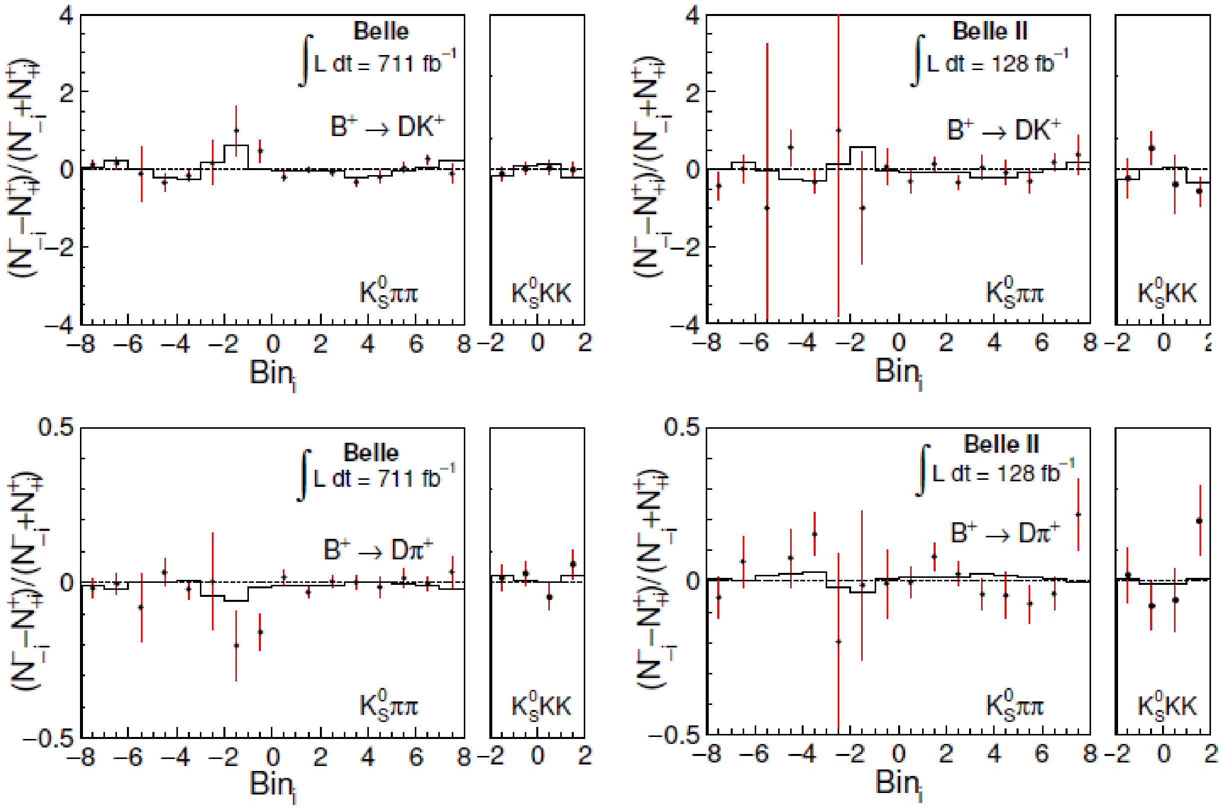
BPGGSZ study $B \to D(K^0_S h^+ h^-) h^-$

$h = \pi, K$

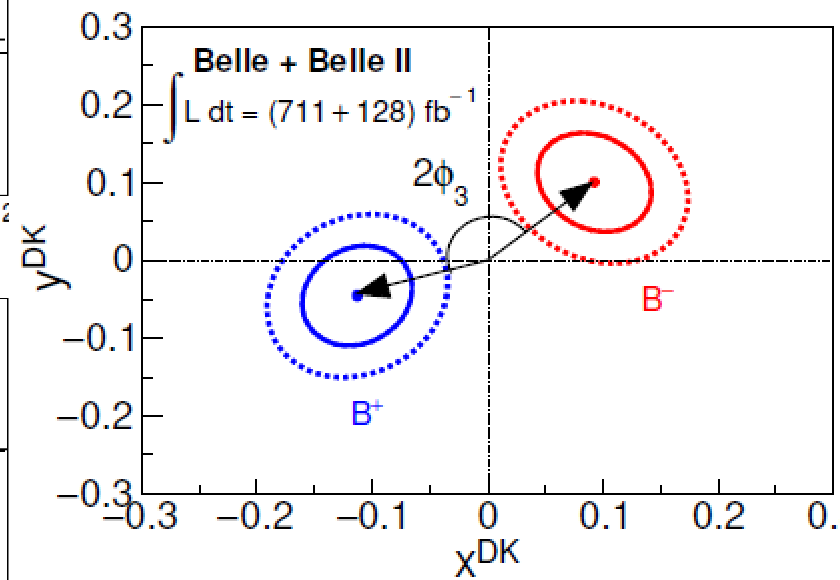
(Belle/Belle II collaborations)
[arXiv:2110.12125, JHEP 02 (2022) 63]

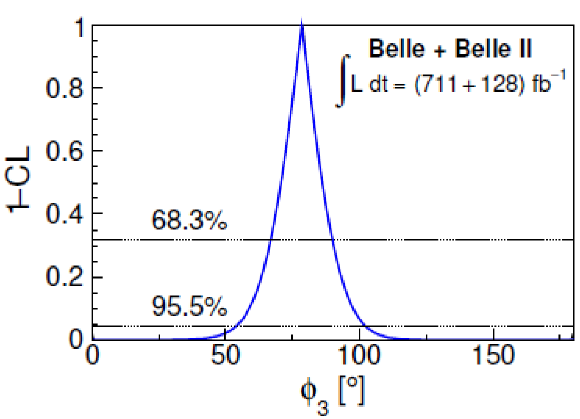
- Analysis with 711 fb^{-1} Belle data and 128 fb^{-1} Belle II data

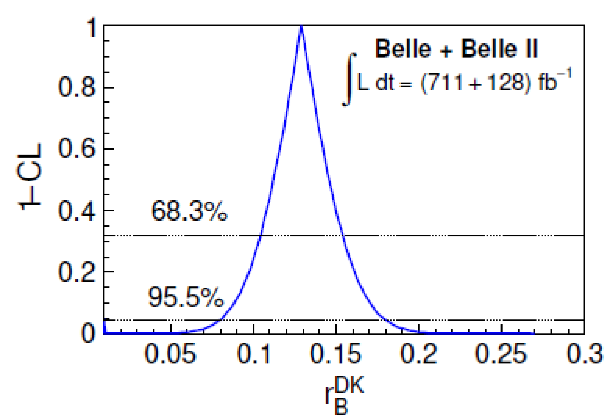
bin-by-bin asymmetries $(N_-^{-i} - N_+^{+i})/(N_-^{-i} + N_+^{+i})$ in each Dalitz plot bin i



$$x_\pm^{DK} = r_B^{DK} \cos(\delta_B^{DK} \pm \phi_3)$$
$$y_\pm^{DK} = r_B^{DK} \sin(\delta_B^{DK} \pm \phi_3)$$







$$\phi_3 = (78.4 \pm 11.4 \pm 0.5 \pm 1.0)^\circ,$$
$$r_B^{DK} = 0.129 \pm 0.024 \pm 0.001 \pm 0.002,$$
$$\delta_B^{DK} = (124.8 \pm 12.9 \pm 0.5 \pm 1.7)^\circ,$$
$$r_B^{D\pi} = 0.017 \pm 0.006 \pm 0.001 \pm 0.001,$$
$$\delta_B^{D\pi} = (341.0 \pm 17.0 \pm 1.2 \pm 2.6)^\circ.$$

$\sigma_{\phi_3} = 14^\circ$ **from earlier Belle measurement**

GLW study for $B \to D(KK)K$ and $D(K_S^0\pi^0)K$

arXiv:2308.05048
submitted to JHEP

CP-even, $D \to K^+K^-$, CP-odd, $D \to K_S^0\pi^0$

Fitting simultaneously the $B \to D\pi$ and DK samples, where $D \to K\pi$, $D \to KK$ and $K_S^0\pi^0$, Belle and Belle II samples

Observables (three branching -fraction ratios and six charge asymmetries):

$$R_{CP\pm} \equiv \frac{\mathcal{B}(B^- \to D_{CP\pm}K^-) + \mathcal{B}(B^+ \to D_{CP\pm}K^+)}{\mathcal{B}(B^- \to D_{CP\pm}\pi^-) + \mathcal{B}(B^+ \to D_{CP\pm}\pi^+)},$$

$$R_{\mathrm{flav}} \equiv \frac{\mathcal{B}(B^- \to D_{\mathrm{flav}}K^-) + \mathcal{B}(B^+ \to \overline{D}_{\mathrm{flav}}K^+)}{\mathcal{B}(B^- \to D_{\mathrm{flav}}\pi^-) + \mathcal{B}(B^+ \to \overline{D}_{\mathrm{flav}}\pi^+)}.$$

$$\mathcal{A}_{CP\pm} \equiv \frac{\mathcal{B}(B^- \to D_{CP\pm}K^-) - \mathcal{B}(B^+ \to D_{CP\pm}K^+)}{\mathcal{B}(B^- \to D_{CP\pm}K^-) + \mathcal{B}(B^+ \to D_{CP\pm}K^+)},$$

Yields of $B^\pm$ with the D decaying to X (CP+, CP−, flav) expressed as:

$$\begin{aligned}
Y_\pi(B^\pm \to D_X K^\pm) &= \tfrac{1}{2}[1 \mp \mathcal{A}(B \to D_X K)]\, N(B \to D_X\pi)\, R_X\, \delta\,(1-\varepsilon_\pm),\\
Y_K(B^\pm \to D_X K^\pm) &= \tfrac{1}{2}[1 \mp \mathcal{A}(B \to D_X K)]\, N(B \to D_X\pi)\, R_X\, \delta\, \varepsilon_\pm,\\
Y_\pi(B^\pm \to D_X \pi^\pm) &= \tfrac{1}{2}[1 \mp \mathcal{A}(B \to D_X \pi)]\, N(B \to D_X\pi)\, (1-\kappa_\pm),\\
Y_K(B^\pm \to D_X \pi^\pm) &= \tfrac{1}{2}[1 \mp \mathcal{A}(B \to D_X \pi)]\, N(B \to D_X\pi)\, \kappa_\pm,
\end{aligned}$$

ϵ is efficiency to identify a kaon (~ 80-85%), κ rate for misidentifying a pion (~ 7-8%)

$$\mathcal{R}_{CP\pm} \equiv \frac{\mathcal{B}(B^- \to D_{CP\pm}K^-) + \mathcal{B}(B^+ \to D_{CP\pm}K^+)}{(\mathcal{B}(B^- \to D_{\mathrm{flav}}K^-) + \mathcal{B}(B^+ \to \overline{D}_{\mathrm{flav}}K^+))/2} \approx \frac{R_{CP\pm}}{R_{\mathrm{flav}}},$$

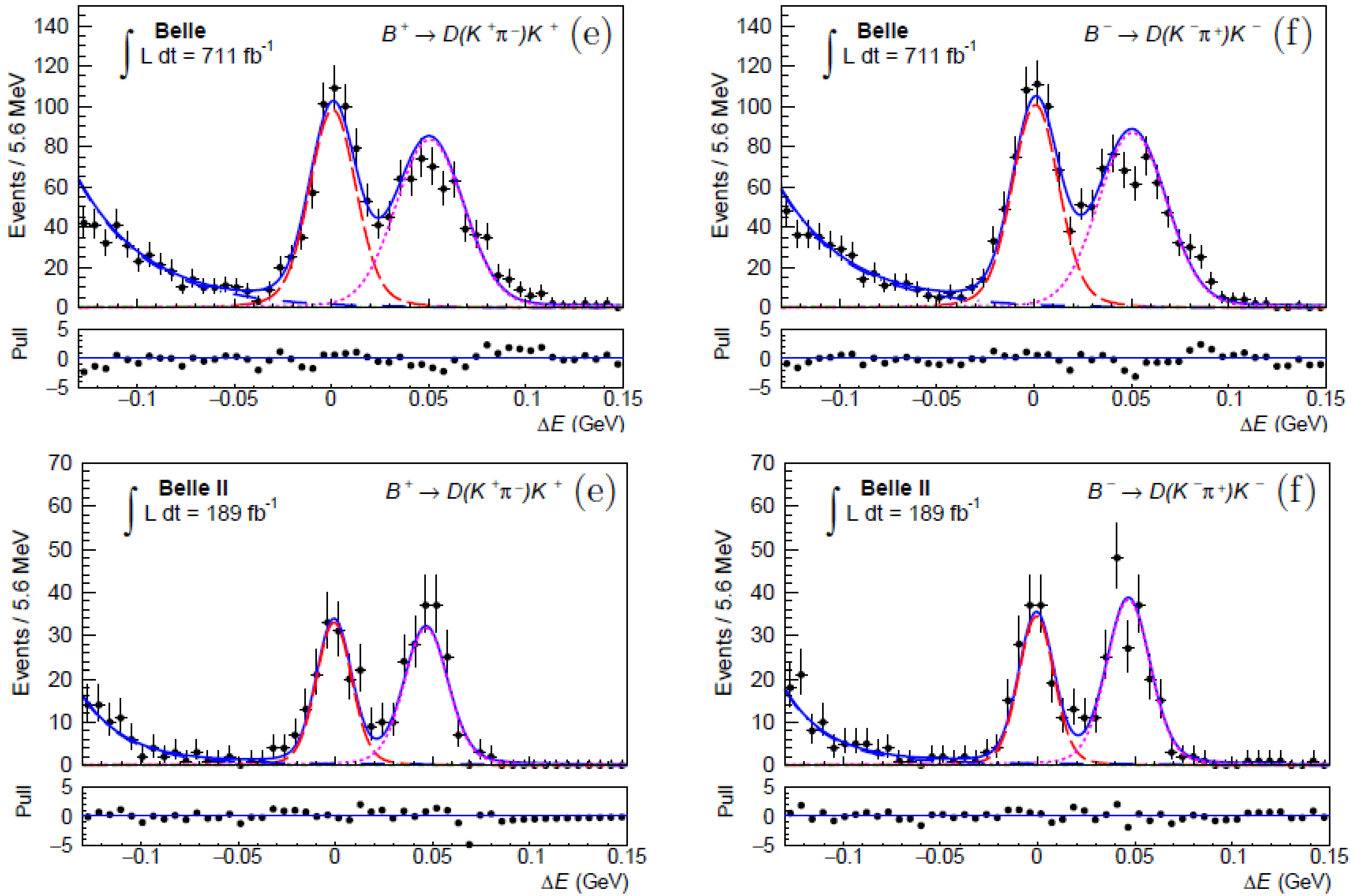
$$\begin{aligned}
\mathcal{R}_{CP\pm} &= 1 + r_B^2 \pm 2r_B \cos\delta_B \cos\phi_3,\\
\mathcal{A}_{CP\pm} &= \pm 2r_B \sin\delta_B \sin\phi_3 \,/\, \mathcal{R}_{CP\pm}.
\end{aligned}$$

GLW study for $B \to D(KK)K$ and $D(K_S^0\pi^0)K$

arXiv:2308.05048
submitted to JHEP

Using Belle (711 fb^{-1}) and Belle II (189 fb^{-1}), (previous measurement with Belle only 250 fb^{-1})

Fitting simultaneously the $B \to D\pi$ and DK samples, $D \to K\pi$ and...

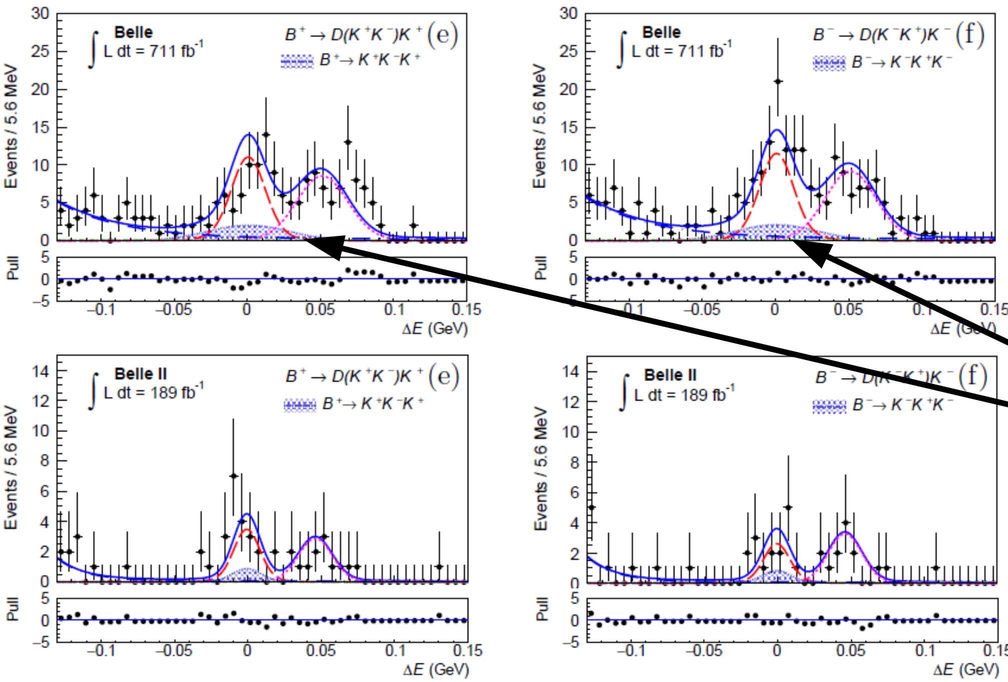


with asymmetry ~ 0 for $B \to D(K\pi)K$ modes

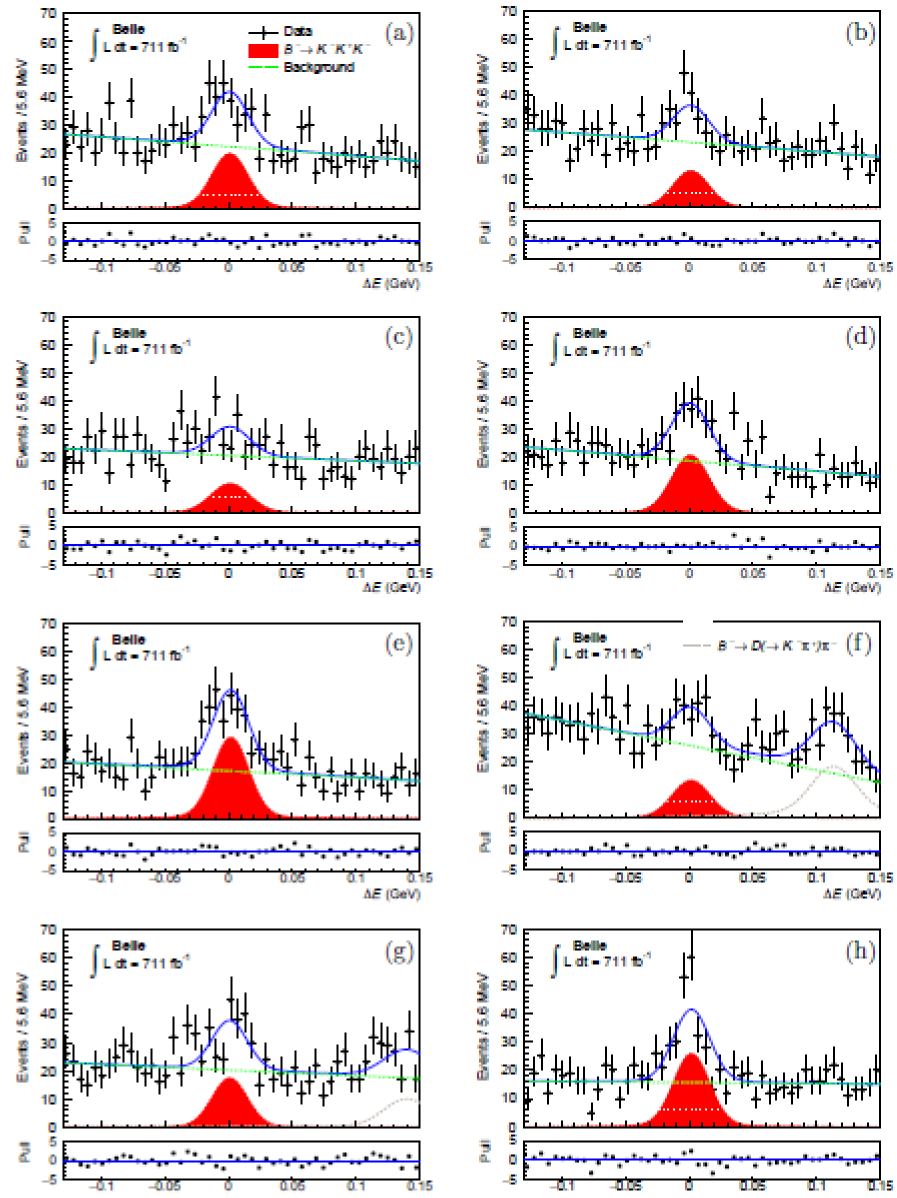
GLW study for B→D(KK)K and D($K_S^0\pi^0$)K

arXiv:2308.05048
submitted to JHEP

Fitting simultaneously the B→Dπ and DK samples, D→Kπ and…D→KK and …



charmless B→KKK contamination
estimated from D mass sidebands in data

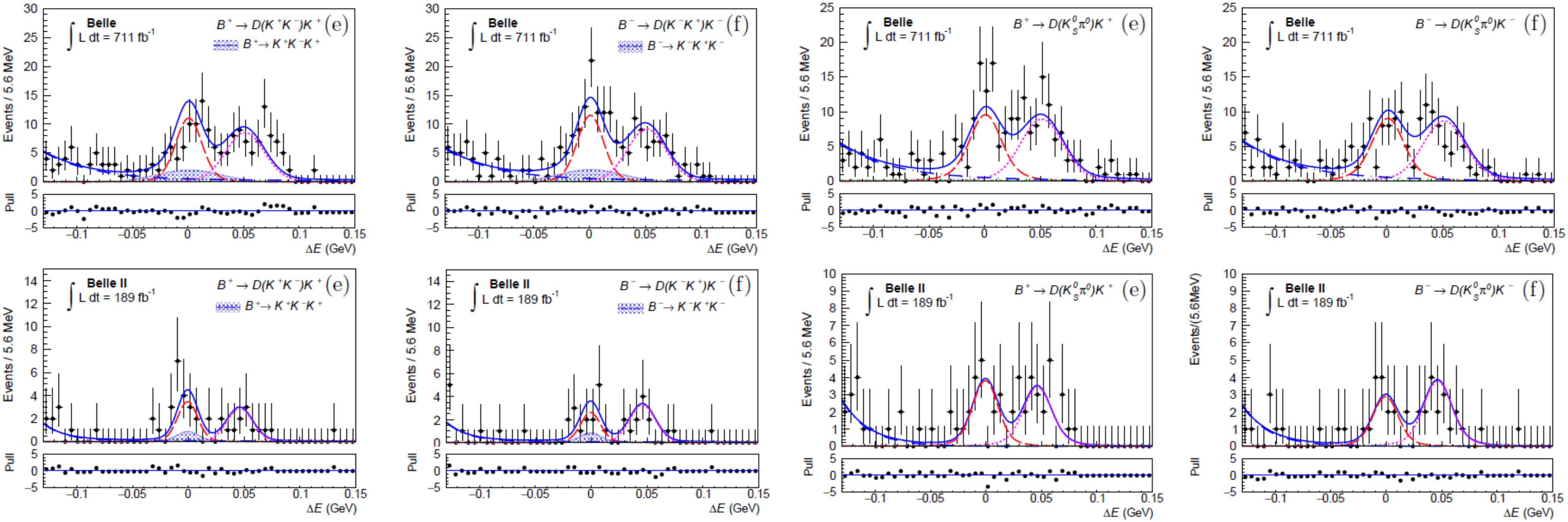


Analysis	Lower sidebands	Upper sidebands
Belle	[1.67,1.71][1.71,1.75]	[1.90,1.94][1.94,1.98]
	[1.75,1.79][1.79,1.83]	[1.98,2.02][2.02,2.06]
Belle II	[1.706,1.732][1.732,1.758]	[1.758,1.784][1.784,1.810]
	[1.920,1.946][1.946,1.972]	[1.972,1.998][1.998,2.024]

GLW study for $B \to D(KK)K$ and $D(K_S^0\pi^0)K$

arXiv:2308.05048
submitted to JHEP

Fitting simultaneously the $B \to D\pi$ and DK samples, $D \to K\pi$ and... $D \to KK$ and $K_S^0\pi^0$



$$\mathcal{R}_{CP\pm} = 1 + r_B^2 \pm 2r_B \cos\delta_B \cos\phi_3,$$

$$\mathcal{A}_{CP\pm} = \pm 2r_B \sin\delta_B \sin\phi_3 \,/\, \mathcal{R}_{CP\pm}.$$

In GLW, CP-odd state accessible only to B-factories

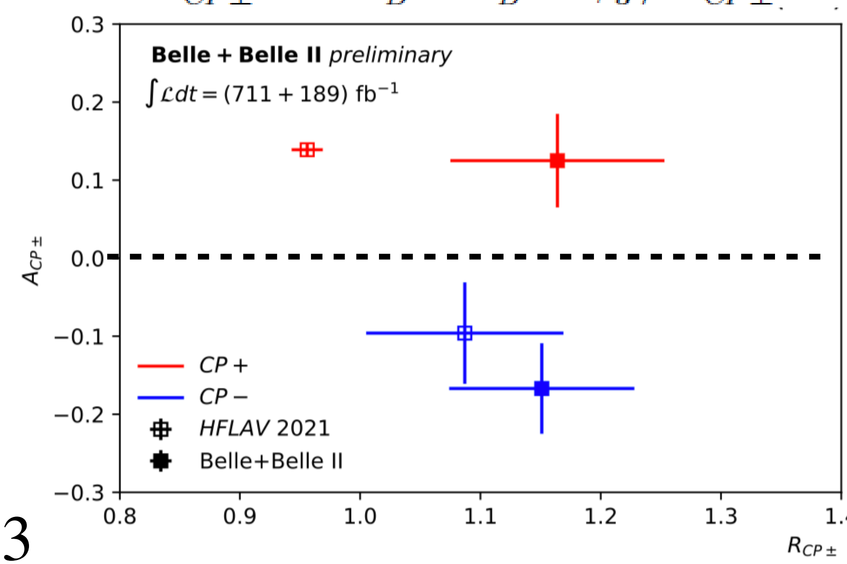
$$\mathcal{R}_{CP+} = 1.164 \pm 0.081 \pm 0.036,$$

$$\mathcal{R}_{CP-} = 1.151 \pm 0.074 \pm 0.019,$$

$$\mathcal{A}_{CP+} = (+12.5 \pm 5.8 \pm 1.4)\%,$$

$$\mathcal{A}_{CP-} = (-16.7 \pm 5.7 \pm 0.6)\%.$$

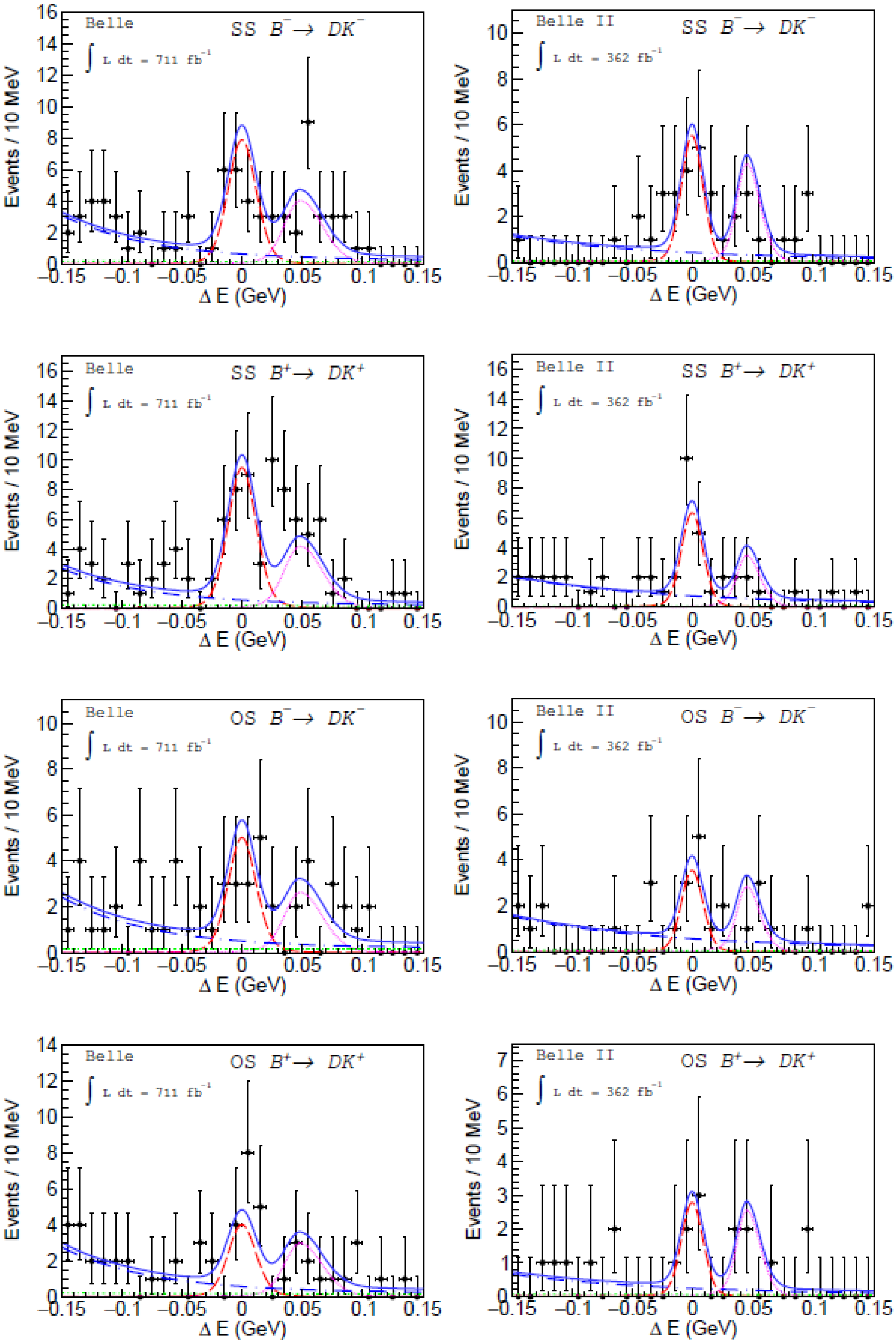
Direct evidence of opposite A_{CP} for even and odd states



GLS study for $B^{\pm} \to D(K_S^0 K^{\pm} \pi^{\mp}) K^{\pm}$

arXiv:2306.02940, accepted by JHEP

Using Belle $(711\ \mathrm{fb}^{-1})$ and Belle II $(362\ \mathrm{fb}^{-1})$



four asymmetries and three branching-fraction ratios

$$\mathcal{A}_m^{Dh} \equiv \frac{N_m^{Dh^-} - N_m^{Dh^+}}{N_m^{Dh^-} + N_m^{Dh^+}} \quad \text{with} \quad h = \pi, K,$$

$$\mathcal{R}_m^{DK/D\pi} \equiv \frac{N_m^{DK^-} + N_m^{DK^+}}{N_m^{D\pi^-} + N_m^{D\pi^+}}$$

$$\mathcal{R}_{\mathrm{SS/OS}}^{D\pi} \equiv \frac{N_{\mathrm{SS}}^{D\pi^-} + N_{\mathrm{SS}}^{D\pi^+}}{N_{\mathrm{OS}}^{D\pi^-} + N_{\mathrm{OS}}^{D\pi^+}}.$$

$$\begin{aligned}
A_{\mathrm{SS}}^{DK} &= -0.089 \pm 0.091 \pm 0.011, \\
A_{\mathrm{OS}}^{DK} &= 0.109 \pm 0.133 \pm 0.013, \\
A_{\mathrm{SS}}^{D\pi} &= 0.018 \pm 0.026 \pm 0.009, \\
A_{\mathrm{OS}}^{D\pi} &= -0.028 \pm 0.031 \pm 0.009, \\
R_{\mathrm{SS}}^{DK/D\pi} &= 0.122 \pm 0.012 \pm 0.004, \\
R_{\mathrm{OS}}^{DK/D\pi} &= 0.093 \pm 0.013 \pm 0.003, \\
R_{\mathrm{SS/OS}}^{D\pi} &= 1.428 \pm 0.057 \pm 0.002,
\end{aligned}$$

those results alone do not allow for an unambigious determination of ϕ_3, will be combined with other results

ϕ_3/γ determination with Belle/Belle II (preliminary)

inputs: four different methods, 17 different final states

B decay	D decay	Method	Data set (Belle + Belle II) [fb^{-1}]	
$B^+ \to Dh^+$	$D \to K_S^0 h^- h^+$	BPGGSZ	$711 + 128$	[JHEP 02 063 (2022)]
$B^+ \to Dh^+$	$D \to K_S^0 \pi^- \pi^+ \pi^0$	BPGGSZ	$711 + 0$	[JHEP 10 178 (2019)]
$B^+ \to Dh^+$	$D \to K_S^0 \pi^0, K^- K^+$	GLW	$711 + 189$	[arxiv:2308.05048]
$B^+ \to Dh^+$	$D \to K^+ \pi^-, K^+ \pi^- \pi^0$	ADS	$711 + 0$	[PRL 106 231803 (2011)]
$B^+ \to Dh^+$	$D \to K_S^0 K^- \pi^+$	GLS	$711 + 362$	[arxiv:2306.02940]
$B^+ \to D^* K^+$	$D \to K_S^0 \pi^- \pi^+$	BPGGSZ	$605 + 0$	[PRD 81 112002 (2010)]
$B^+ \to D^* K^+$	$D \to K_S^0 \pi^0, K_S^0 \phi, K_S^0 \omega,$ $K^- K^+, \pi^- \pi^+$	GLW	210+0	[PRD 73 051106 (2006)]

$B^0 \to D^{(*)} h^{(*)}$ decays are not included: minimal impact and introduce additional external parameters

Inputs on D decays dynamics: other experiments

(preliminary)

r_D: amplitude ratio

δ_D: strong-phase difference

$R_D = r_D^2$

κ_D: coherence factor

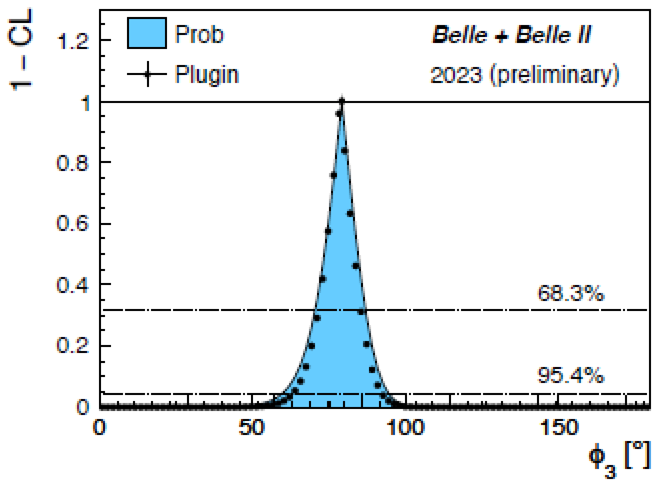
$$R_{GLS} = \frac{\mathcal{B}(D^0 K^-)}{\mathcal{B}(D^0 \pi^-)}$$

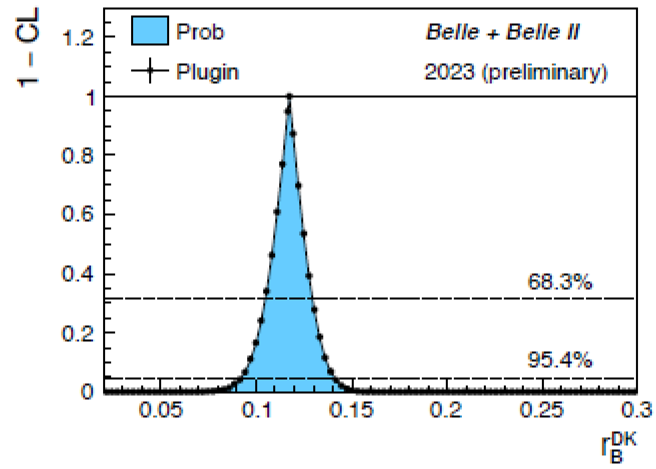
Decay	Observable	Value	Source	
$D \to K^+\pi^-$	$R_D^{K\pi}$	$(3.44 \pm 0.02) \times 10^{-3}$	HFLAV	[hflav.web.cern.ch]
	$\delta_D^{K\pi}$	$(191.7 \pm 3.7)^\circ$		
	$r_D^{K\pi}\cos(\delta_D^{K\pi})$	-0.0562 ± 0.0081	BESIII	[EPJC 82, 1009 (2022)]
	$r_D^{K\pi}\sin(\delta_D^{K\pi})$	-0.011 ± 0.012		
$D \to K^+\pi^-\pi^0$	$r_D^{K\pi\pi^0}$	0.0447 ± 0.0012	CLEO + LHCb	[PLB 765 (2017)]
	$\kappa_D^{K\pi\pi^0}$	0.81 ± 0.06		
	$\delta_D^{K\pi\pi^0}$	$(198 \pm 15)^\circ$		
	$r_D^{K\pi\pi^0}$	0.0440 ± 0.0011	BESIII	[JHEP 05, 164 (2021)]
	$\kappa_D^{K\pi\pi^0}$	0.78 ± 0.04		
	$\delta_D^{K\pi\pi^0}$	$(196 \pm 15)^\circ$		
$D \to K_S^0 K^- \pi^+$	$(r_D^{K_S^0 K\pi})^2$	0.356 ± 0.034	CLEO	[PRD 85, 092016 (2012)]
	$\kappa_D^{K_S^0 K\pi}$	0.94 ± 0.12		
	$\delta_D^{K_S^0 K\pi}$	$(-16.6 \pm 18.4)^\circ$		
	$(r_D^{K_S^0 K\pi})^2$	0.370 ± 0.003	LHCb	[PRD 93, 052018 (2012)]
$B^+ \to Dh^+$	$R_{\rm GLS}$	0.0789 ± 0.0027	PDG	

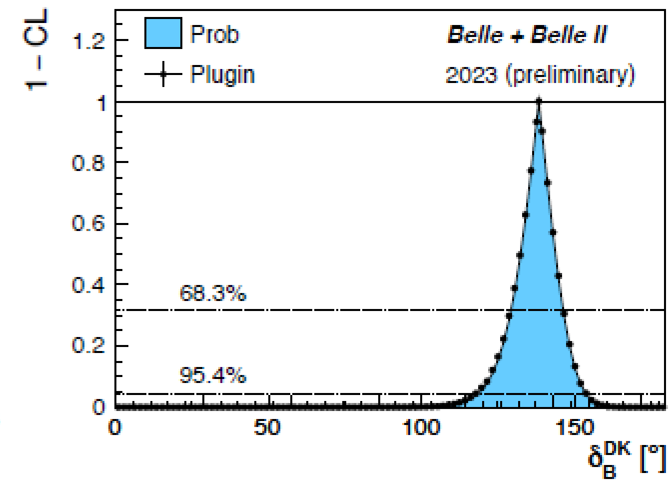
Results: 1D scans

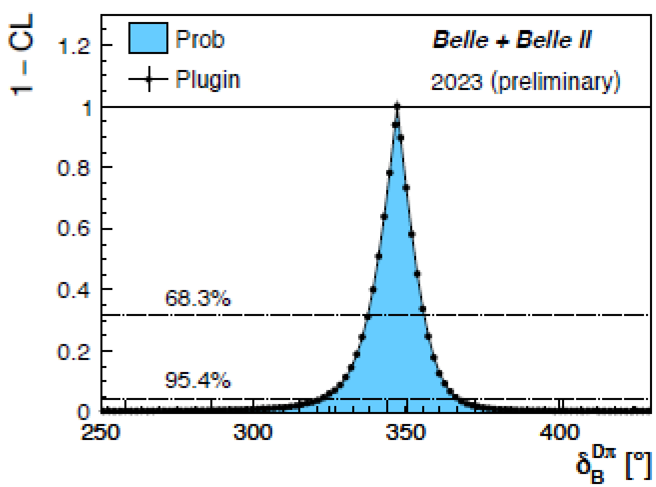
(preliminary)

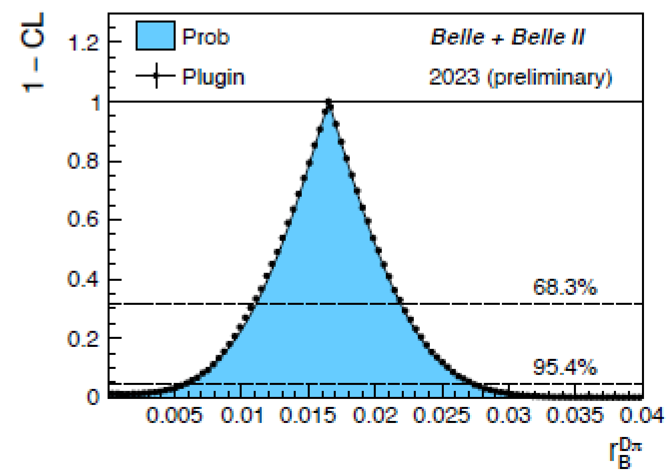
60 input observables and 16 auxiliary D-decay inputs











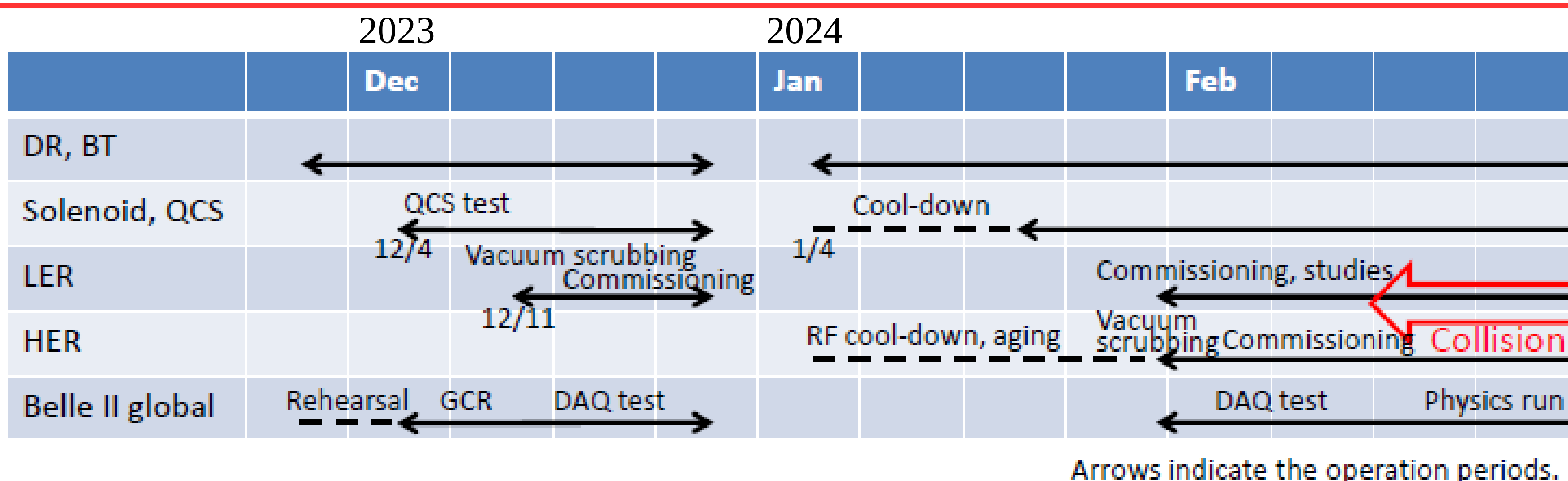
p-value (PLUGIN): 75%

combining inputs from $B^+ \to D^{(*)} h^+$ decays: $\phi_3 = (78.6 \pm 7.3)^\circ$

Parameters	$\phi_3(^\circ)$	r_B^{DK}	$\delta_B^{DK}(^\circ)$	$r_B^{D\pi}$	$\delta_B^{D\pi}(^\circ)$	$r_B^{D^*K}$	$\delta_B^{D^*K}(^\circ)$
PLUGIN method							
Best fit value	78.6	0.117	138.4	0.0165	347.0	0.234	341
68.3% interval	[71.4, 85.4]	[0.105, 0.130]	[129.1, 146.5]	[0.0109, 0.0220]	[337.4, 355.7]	[0.165, 0.303]	[327,355]
95.5% interval	[63, 92]	[0.092, 0.141]	[118, 154]	[0.006, 0.027]	[322, 366]	[0.10, 0.37]	[307, 369]

Summary

- Belle II has now on tape a sample equivalent to that of BaBar, half of Belle
- Allow to refine our tools, improve our analyses, understanding our detector
- **BPGGSZ, GLW, GLS results with Belle + Belle II are recently obtained**
- **first Belle + Belle II combination: $\phi_3 = (78.6 \pm 7.3)^\circ$, consistent with WA within 2σ** $(\phi_3 = (66.2^{+3.2}_{-3.6})^\circ)$
- Currently preparing the detector and the machine to ramp-up at full speed
- Will resume data-taking next Winter, on our way to the $10^{35}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$ world



- Target first day of MR beam operation: Dec 11 (driven by Belle II)

GLS relations

$$A_{SS}^{DK} = \frac{2r_B^{DK} r_D \kappa_D \sin(\delta_B^{DK} - \delta_D)\sin\phi_3}{1 + (r_B^{DK})^2 r_D^2 + 2r_B^{DK} r_D \kappa_D \cos(\delta_B^{DK} - \delta_D)\cos\phi_3},$$

$$A_{OS}^{DK} = \frac{2r_B^{DK} r_D \kappa_D \sin(\delta_B^{DK} + \delta_D)\sin\phi_3}{(r_B^{DK})^2 + r_D^2 + 2r_B^{DK} r_D \kappa_D \cos(\delta_B^{DK} + \delta_D)\cos\phi_3},$$

$$A_{SS}^{D\pi} = \frac{2r_B^{D\pi} r_D \kappa_D \sin(\delta_B^{D\pi} - \delta_D)\sin\phi_3}{1 + (r_B^{D\pi})^2 r_D^2 + 2r_B^{D\pi} r_D \kappa_D \cos(\delta_B^{D\pi} - \delta_D)\cos\phi_3},$$

$$A_{OS}^{D\pi} = \frac{2r_B^{D\pi} r_D \kappa_D \sin(\delta_B^{D\pi} + \delta_D)\sin\phi_3}{(r_B^{D\pi})^2 + r_D^2 + 2r_B^{D\pi} r_D \kappa_D \cos(\delta_B^{D\pi} + \delta_D)\cos\phi_3}.$$

$$R_{SS}^{DK/D\pi} = R\frac{1 + (r_B^{DK})^2 r_D^2 + 2r_B^{DK} r_D \kappa_D \cos(\delta_B^{DK} - \delta_D)\cos\phi_3}{1 + (r_B^{D\pi})^2 r_D^2 + 2r_B^{D\pi} r_D \kappa_D \cos(\delta_B^{D\pi} - \delta_D)\cos\phi_3},$$

$$R_{OS}^{DK/D\pi} = R\frac{(r_B^{DK})^2 + r_D^2 + 2r_B^{DK} r_D \kappa_D \cos(\delta_B^{DK} + \delta_D)\cos\phi_3}{(r_B^{D\pi})^2 + r_D^2 + 2r_B^{D\pi} r_D \kappa_D \cos(\delta_B^{D\pi} + \delta_D)\cos\phi_3},$$

$$R_{SS/OS}^{D\pi} = \frac{1 + (r_B^{D\pi})^2 r_D^2 + 2r_B^{D\pi} r_D \kappa_D \cos(\delta_B^{D\pi} - \delta_D)\cos\phi_3}{(r_B^{D\pi})^2 + r_D^2 + 2r_B^{D\pi} r_D \kappa_D \cos(\delta_B^{D\pi} + \delta_D)\cos\phi_3}.$$

few words on γ determination

- Toy study with WA values of the hadronic parameters: uncertainty on ϕ_3 is $12°$
- Repeat it and replace one parameter at a time with our fitted value:

Parameters	Precision on ϕ3 (⁰)
WA values	12
+ our fitted r_B^{DK}	10.5
+ our fitted δ_B^{DK}	10.0
+ our fitted $r_B^{D\pi}$	9.5
+ our fitted $\delta_B^{D\pi}$	8.1
+ our fitted ϕ_3	7.1

Some contribution from r_B^{DK} as well :
- Our r_B^{DK} is 1.5σ larger than WA
- Uncertainty on $\phi_3 \propto 1/r_B^{DK}$

Consistent with our nominal results

Parameters	Our value	WA	Difference (σ)
$\phi_3(°)$	$78.6^{+6.8}_{-7.0}$	$66.2^{+3.4}_{-3.6}$	1.6
$\delta_B^{DK}(°)$	$138.4^{+8.1}_{-9.3}$	$128.0^{+3.8}_{-4.0}$	1.1
r_B^{DK}	0.117 ± 0.012	0.0996 ± 0.0026	1.5
$\delta_B^{D\pi}(°)$	$347.0^{+8.7}_{-9.6}$	$294.0^{+9.7}_{-11.0}$	3.8
$r_B^{D\pi}$	0.016 ± 0.005	0.0049 ± 0.0005	2.2

$r_B^{D\pi}/r_B^{DK} \approx 1/20$

Our results: $\sim 1/7$

- p-value of the comparison: 0.07% (globally 4.25σ away)
- Results are 4σ away from WA

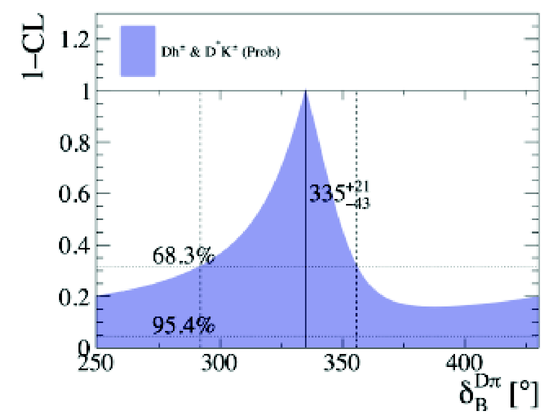
Impact from Dπ

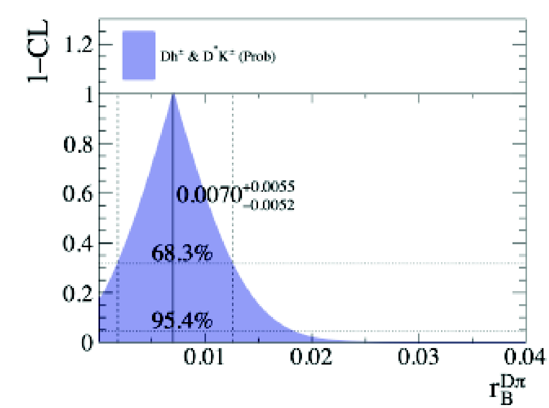
- Start with the most sensitive channel: $K_S^0 hh$ (BPGGSZ)
- Compare with LHCb values: 2σ away
- Perform a test: replace ξ-parameters with LHCb **central values (not the uncertainties)** and repeat the fit

Parameters	Belle(II) (10^{-2})	LHCb (10^{-2})	Difference (σ)
x_+^{DK}	-11.28 ± 3.15	-9.30 ± 0.98	0.60
y_+^{DK}	-4.55 ± 4.20	-1.25 ± 1.23	0.75
x_-^{DK}	9.24 ± 3.27	5.68 ± 0.96	1.05
y_-^{DK}	10.00 ± 4.20	6.55 ± 1.14	0.79
$x_\xi^{D\pi}$	-11.09 ± 4.75	-5.47 ± 1.99	1.10
$y_\xi^{D\pi}$	-7.90 ± 5.44	0.71 ± 2.33	1.46

Parameters	Our value	WA	Difference (σ)
$\phi_3(^\circ)$	79.1 ± 8.11	$66.2^{+3.4}_{-3.6}$	1.46
$\delta_B^{DK}(^\circ)$	136.4 ± 9.0	$128.0^{+3.8}_{-4.0}$	0.86
r_B^{DK}	0.116 ± 0.012	0.0996 ± 0.0026	1.34
$\delta_B^{D\pi}(^\circ)$	334.8^{+21}_{-43}	$294.0^{+9.7}_{-11.0}$	1.68
$r_B^{D\pi}$	0.007 ± 0.005	0.0049 ± 0.0005	0.42

- p-value of the comparison: 31% (1.2σ)
- Better agreement with WA





Impact from Dπ

- Expected value of $r_B^{D\pi} = 0.0053 \pm 0.0007$ [Phys. Rev. D 94, 054021 (2016)]
- Extra Gaussian constraint on $r_B^{D\pi}$ to its expected value → p-value for this fit is 63.4%

Parameters	Our value	WA	Difference (σ)
$\phi_3(^\circ)$	80.4 ± 7.8	$66.2^{+3.4}_{-3.6}$	1.66
$\delta_B^{DK}(^\circ)$	136.0 ± 7.9	$128.0^{+3.8}_{-4.0}$	0.91
r_B^{DK}	0.120 ± 0.012	0.0996 ± 0.0026	1.66
$\delta_B^{D\pi}(^\circ)$	342.6 ± 21	$294.0^{+9.7}_{-11.0}$	2.07
$r_B^{D\pi}$	0.0055 ± 0.0007	0.0049 ± 0.0005	0.70

Better agreement with WA

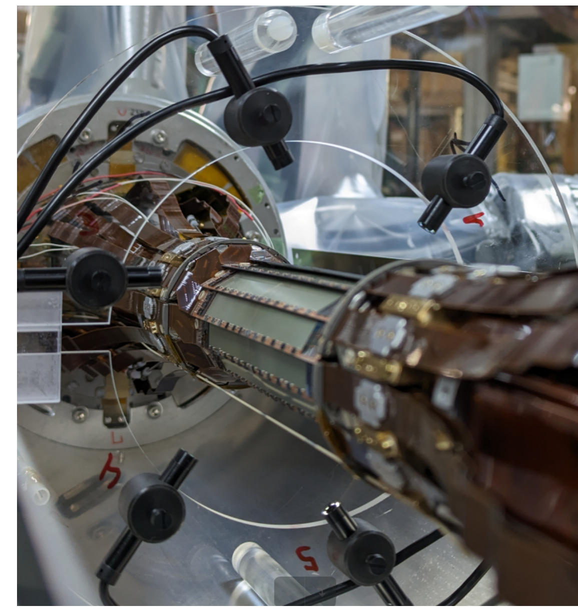
Long-shutdown (LS1) activity and plans

Belle II stopped taking data in Summer 2022 for a long shutdown

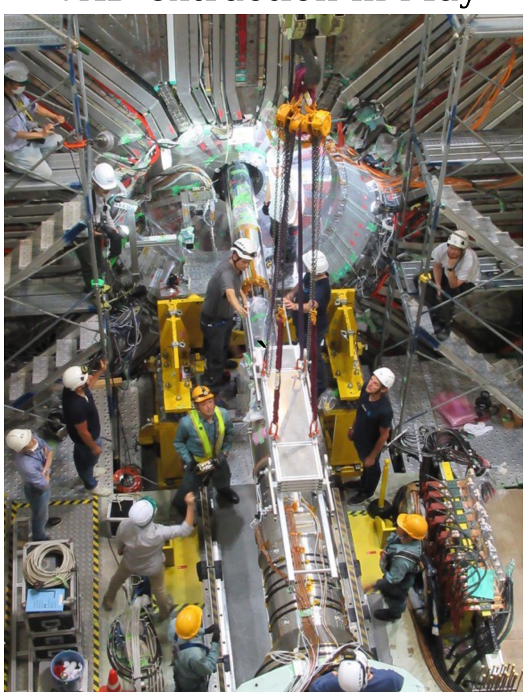
- accelerator improvements: injection, non-linear collimators, monitoring...
- additional shielding and increased resilience against beam bckg

- replacement of beam-pipe
- installation of 2-layered pixel vertex detector
- replacement of photomultipliers of the central PID detector (TOP)
- completed transition to new DAQ boards (PCIe40)
- work on other detectors as CDC, KLM...
- improved data-quality monitoring and alarm system

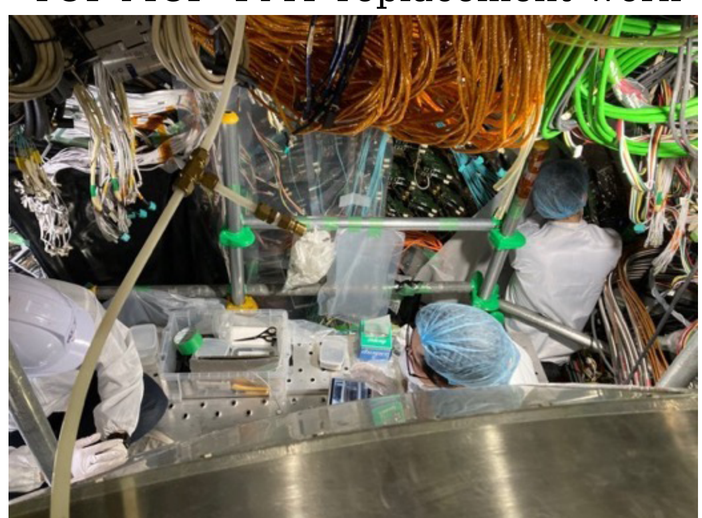
PXD2 at KEK since March



VXD extraction in May

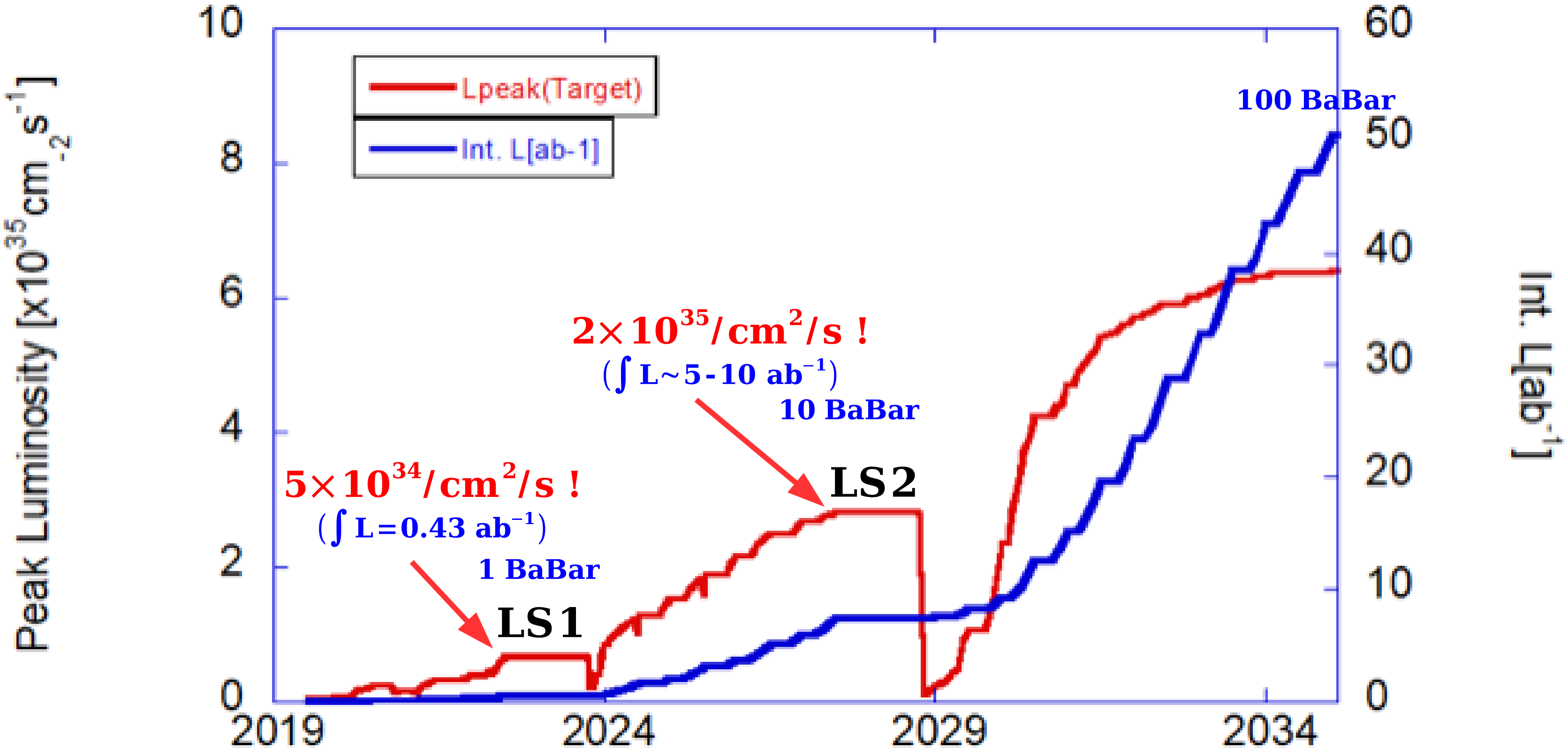


TOP MCP-PMT replacement work



CDC FE reinstallation work

Belle II calendar



run 1 (→ June 2022): integrated luminosity ~0.43 ab^{-1}, 4-5×10^{34}/cm^2/s
PXD complete (2 layers) to be installed during **LS1** (2022-2023)
(+beampipe + TOP PMTs)

run 2 (→ 2027): integrated luminosity 5-10 ab^{-1}, 2×10^{35}/cm^2/s

2027: collider upgrade (QCS+RF) → installation upgraded detector

run 3 (→ 2035): 50 ab^{-1}