Recent γ/ϕ_3 measurement @ Belle II

师晓东
KEK, IPNS

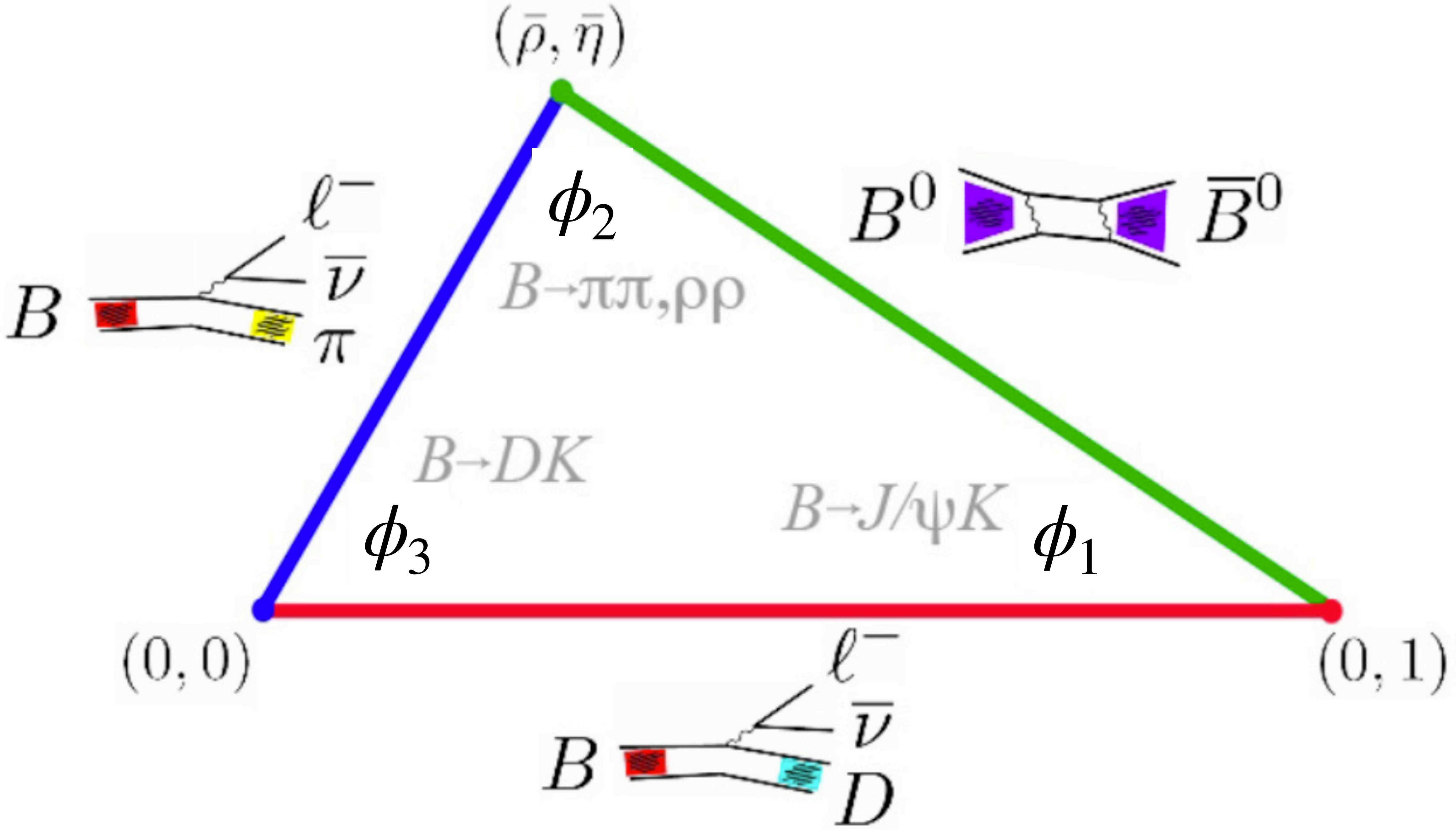
Includes JHEP 09 2023,146, JHEP 02 2022,063, arXiv:2308.05048, and one preliminary result.

2023.12.15-18
全国第二十届重味物理和CP破坏研讨会

CKM matrix and the unitary triangle

$$\begin{pmatrix} u \\ c \\ t \end{pmatrix} \leftarrow W^{\pm} \rightarrow \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \begin{pmatrix} d \\ s \\ b \end{pmatrix}$$

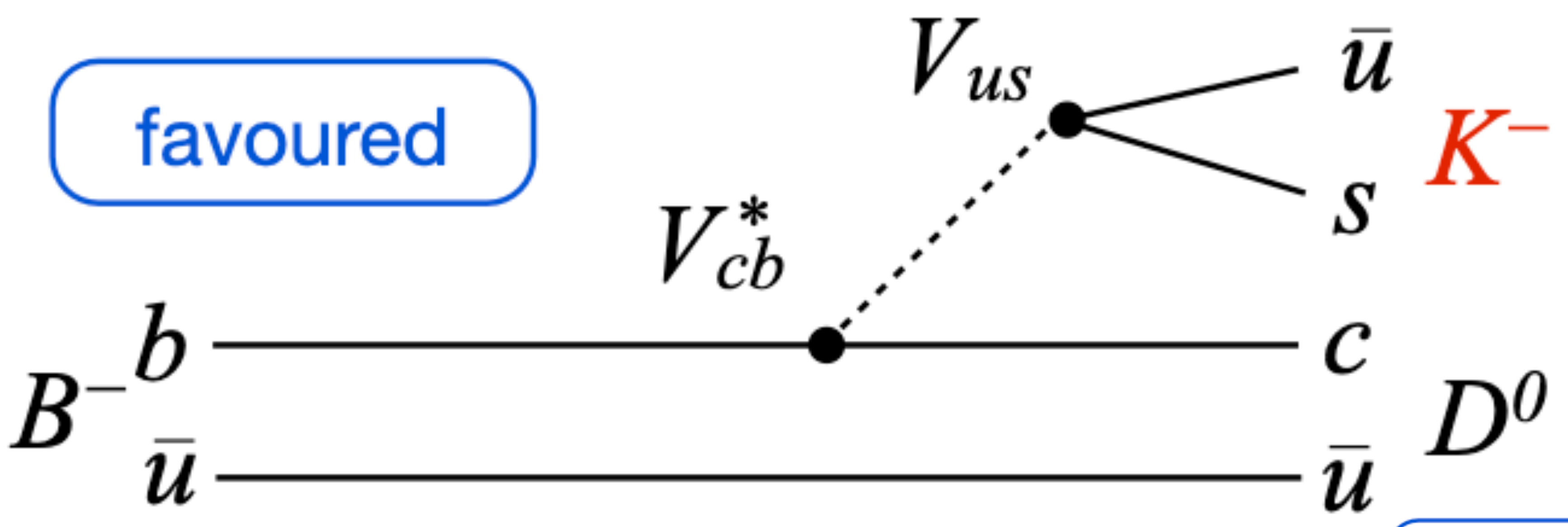
- CKM matrix connects *u*- and *d*-type quarks via weak force.
- In SM, CKM matrix is unitary: four free parameter, one of them is the complex phase, the **only one source** of CPV in quark sector in SM!

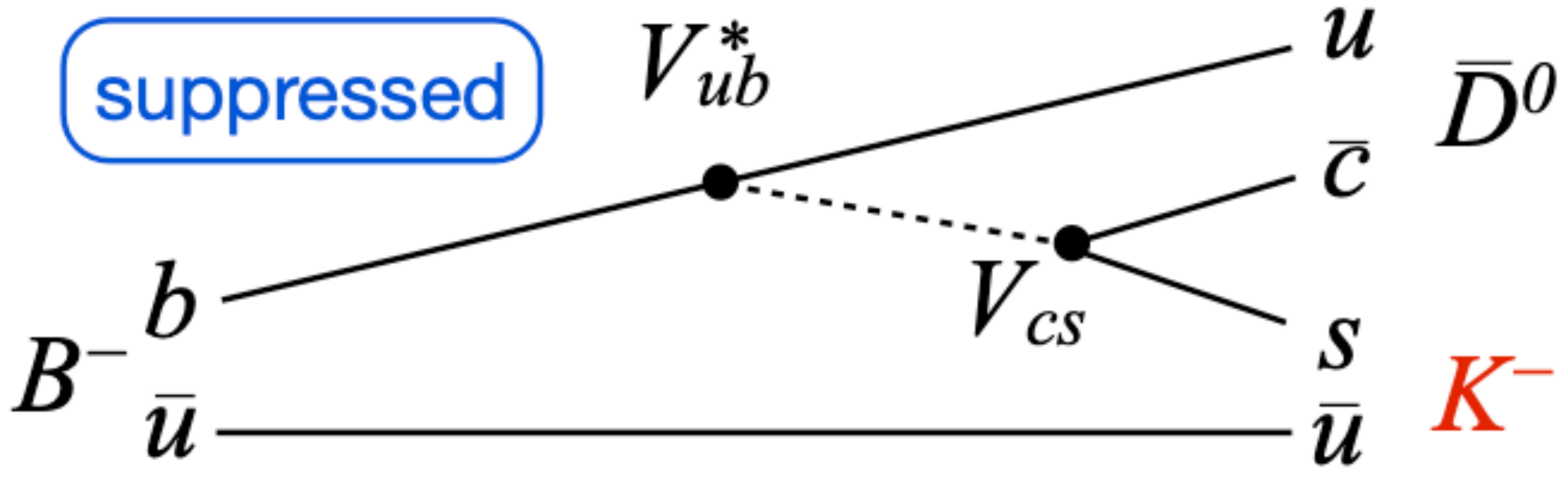


- $\phi_1 = \beta = \arg\left(-\frac{V_{cd}V_{cb}^*}{V_{td}V_{tb}^*}\right)$, $(22.2 \pm 0.7)^\circ$
- $\phi_2 = \alpha = \arg\left(-\frac{V_{td}V_{tb}^*}{V_{ud}V_{ub}^*}\right)$, $(85.2^{+4.8}_{-4.3})^\circ$
- $\phi_3 = \gamma = \arg\left(-\frac{V_{ud}V_{ub}^*}{V_{cd}V_{cb}^*}\right)$, $(66.2^{+3.4}_{-3.6})^\circ$

HFLAV

How to measure ϕ_3: interference in $B^- \to DK^-$





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

$\sim A\lambda^3$

relative amplitude:

$$\left|\frac{V_{cs} V_{ub}^*}{V_{us} V_{cb}^*}\right| f_{col} = r_B \approx 0.1$$

relative strong phase:

$$= \delta_B$$

weak phase difference:

$$\arg\left(\frac{V_{cs} V_{ub}^*}{V_{us} V_{cb}^*}\right) = \arg\left(-\frac{V_{ub}^*}{V_{cb}^*}\right) = \phi_3$$

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

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

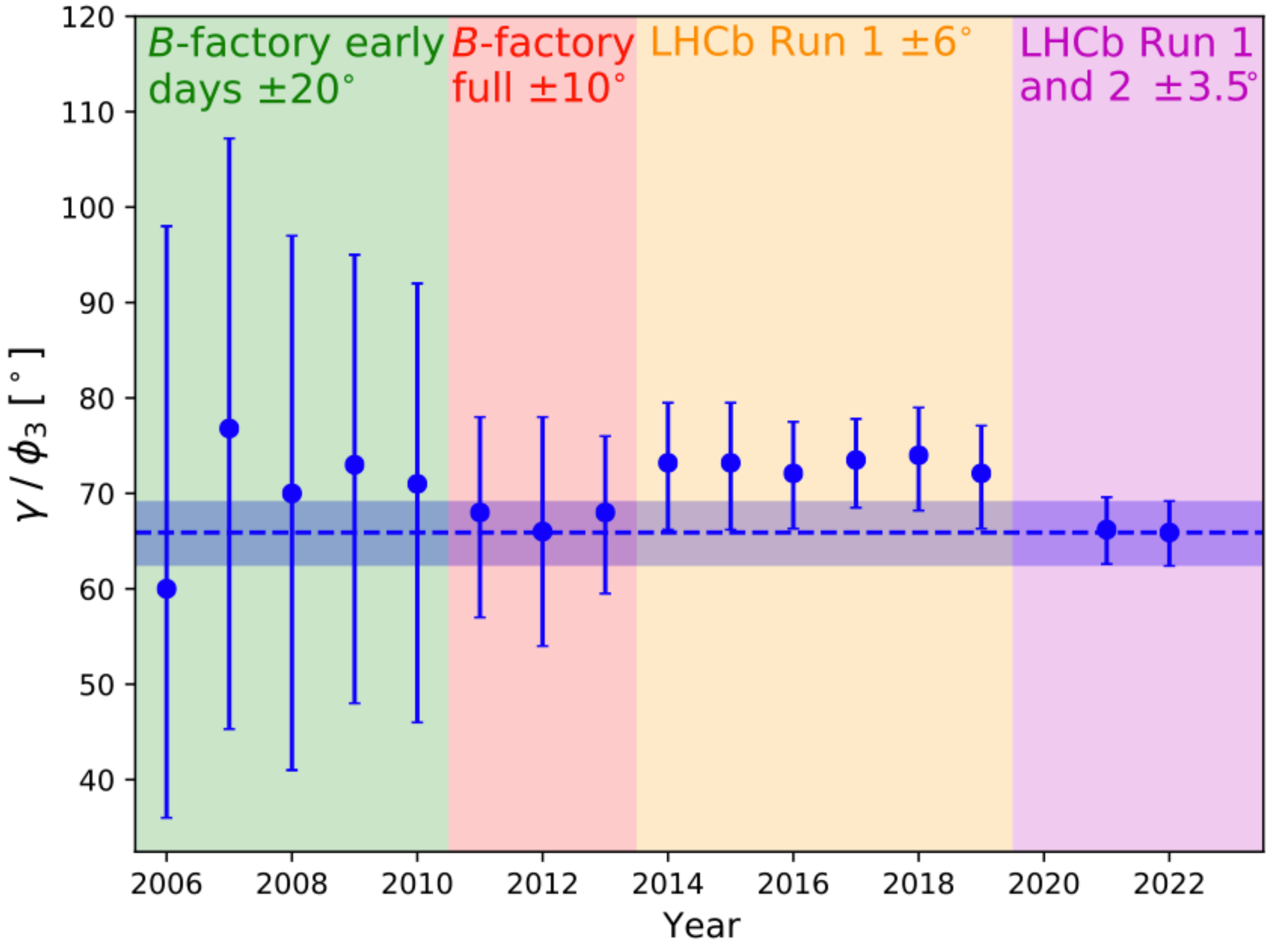
- Depends on the D decay final states, different methods:
  - **BPGGSZ**: self conjugated multi-body decays, e.g. $K_S^0\pi^+\pi^-, K_S^0\pi^+\pi^-\pi^0, \pi^+\pi^-\pi^+\pi^-$
  - **GLW**: CP eigenstates, e.g. $K_S^0\pi^0, K^+K^-$
  - **ADS**: CF and DCS decays, e.g. $K^-\pi^+, K^-\pi^+\pi^0, K^-\pi^+\pi^\pm\pi^\mp$
  - **GLS**: SCS decays, e.g. $K_S^0K^\mp\pi^\pm$

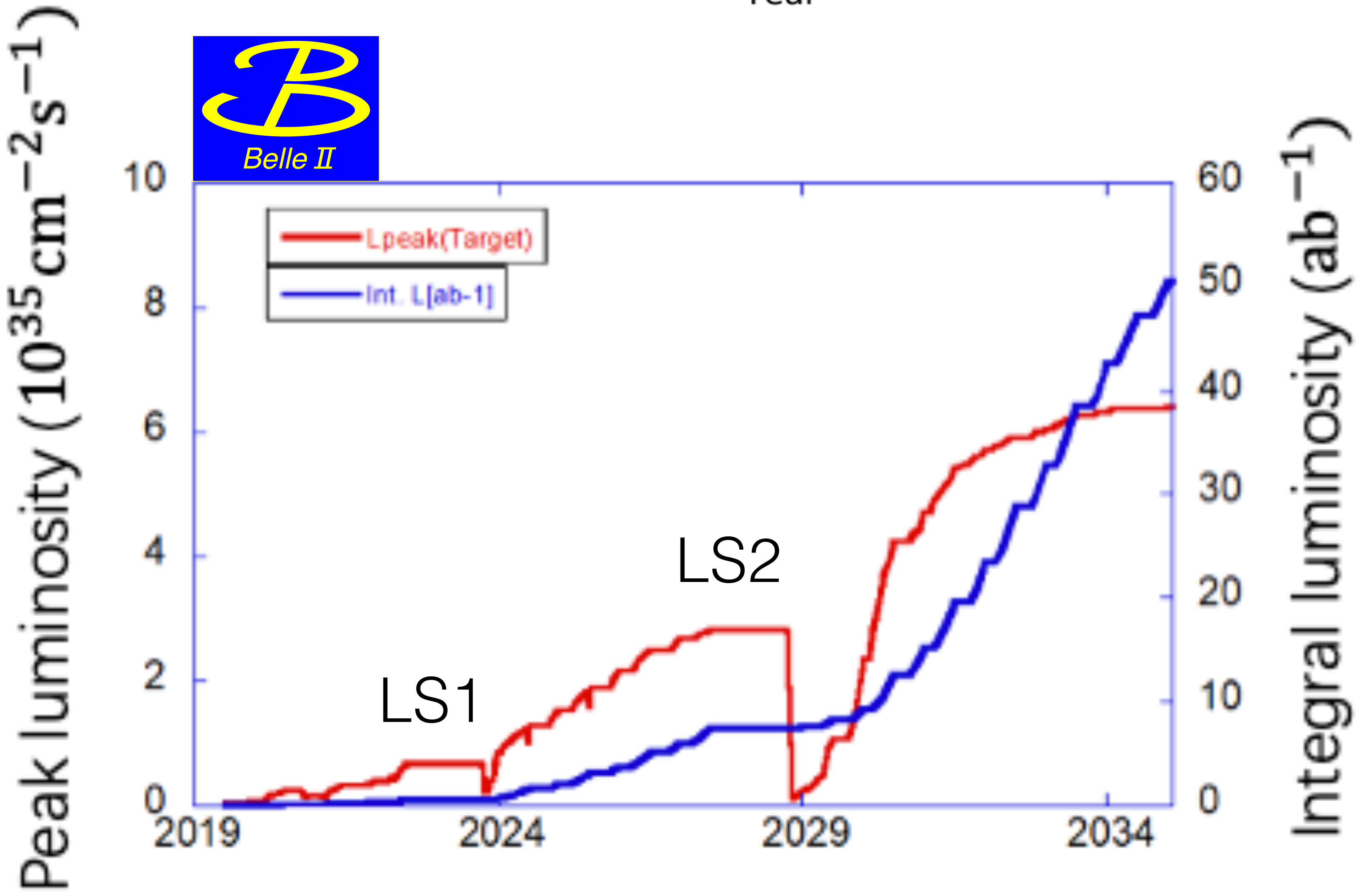
- Need inputs from charm experiments, e.g. strong-phase difference.
  - CLEO-c and BESIII provides **model-independent** external inputs.(**Significant contribution!**)

Prospect on ϕ_3

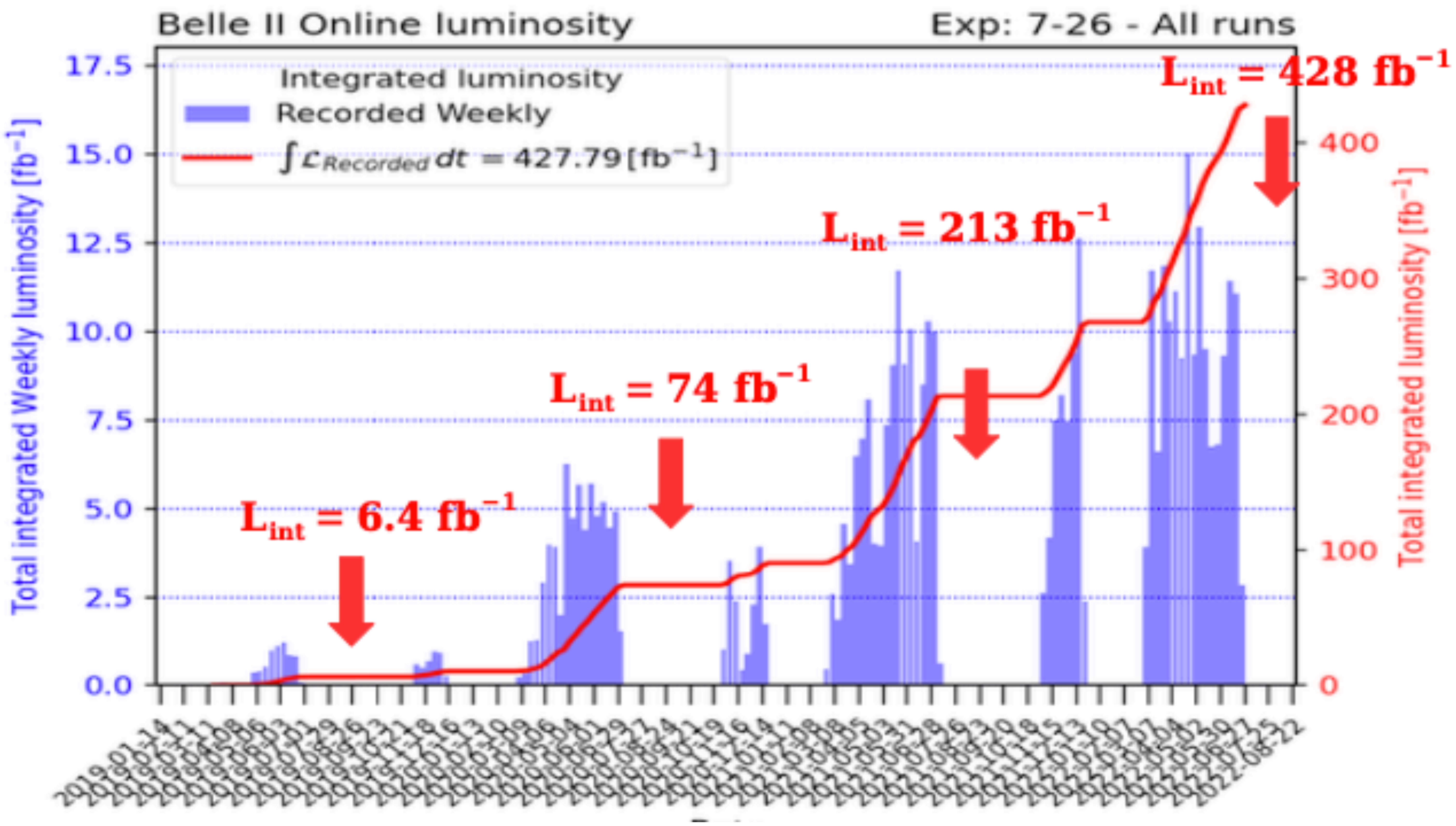
- Theoretically **clean**, non-tree SM contribute ~10^{-7} [arXiv:1308.5663]
- Current W.A.: $\phi_3 = (66.2^{+3.4}_{-3.6})^\circ$[HFLAV], **statistically uncertainty dominated**.
- More B data in the next decades
    - LHCb expect 1.5° by end of Run 3 (~ 22 fb^{-1}), $<1^\circ$ by end of Run 4 (~ 50 fb^{-1}), ~ 0.4° in Phase II upgrade (~ 300 fb^{-1}). [arXiv:1709.10308, CERN-LHCC-2017-003]
    - Belle II expect 1.5° with $50\ \mathrm{ab}^{-1}$ [2020 snowmass].

—> In the future (10 years?), ϕ_3 can be a "**candle**" of SM.





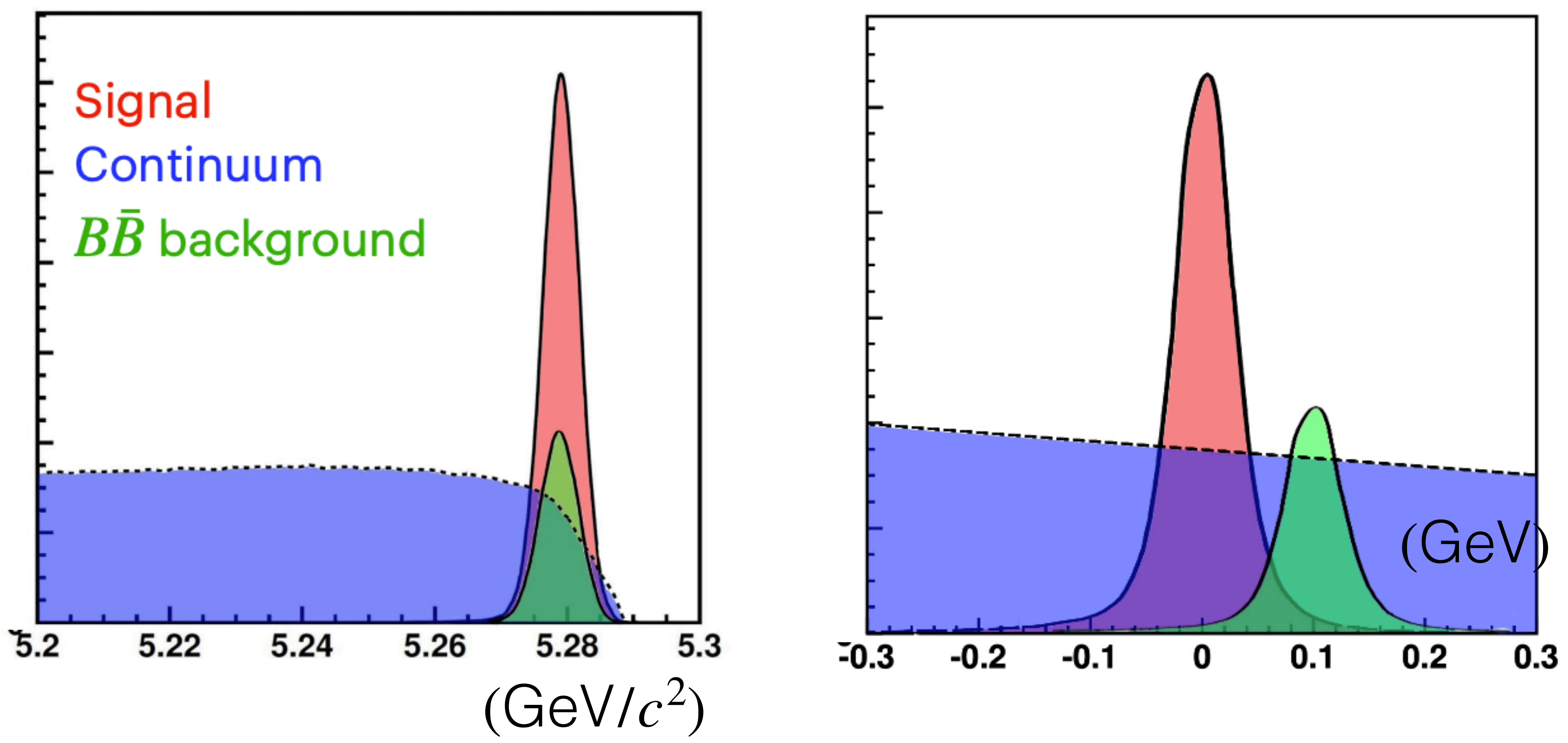
Belle II run I data sets (2019-2022)



- 362/fb at Y(4S) (goal: 50/ab)
- The results in this talk
  - **BPGGSZ** using 128/fb Belle II data
  - **GLW** using 189/fb Belle II data
  - **GLS** using 362/fb Belle II data sets [* and 711/fb Belle data sets for all three]
  - **Combination** of results from Belle and Belle II

Similar analysis flow

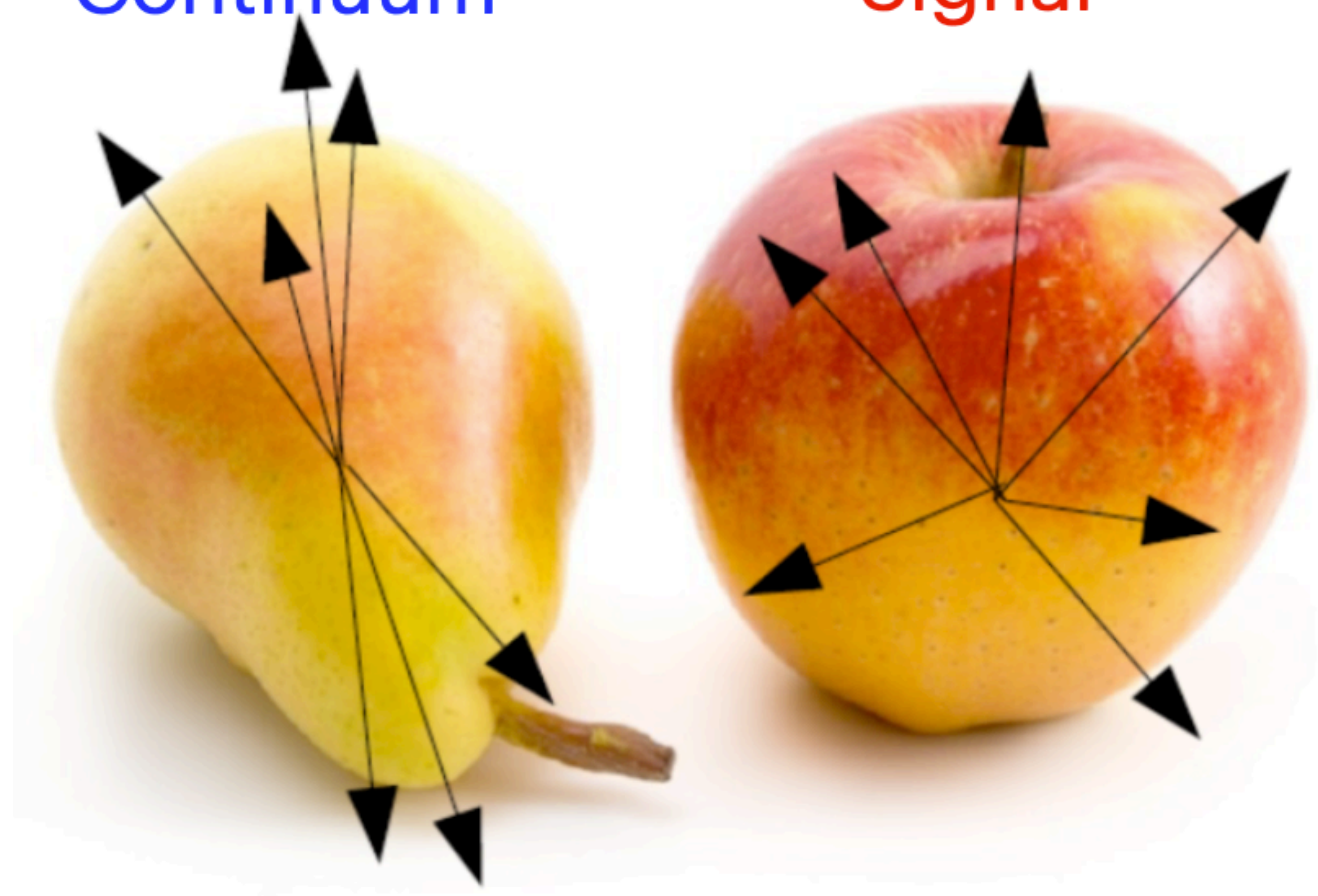
- e^+e^- collide at $\Upsilon(4S)$, just above $B\bar{B}$ threshold: low background and well-known knowledge of initial state



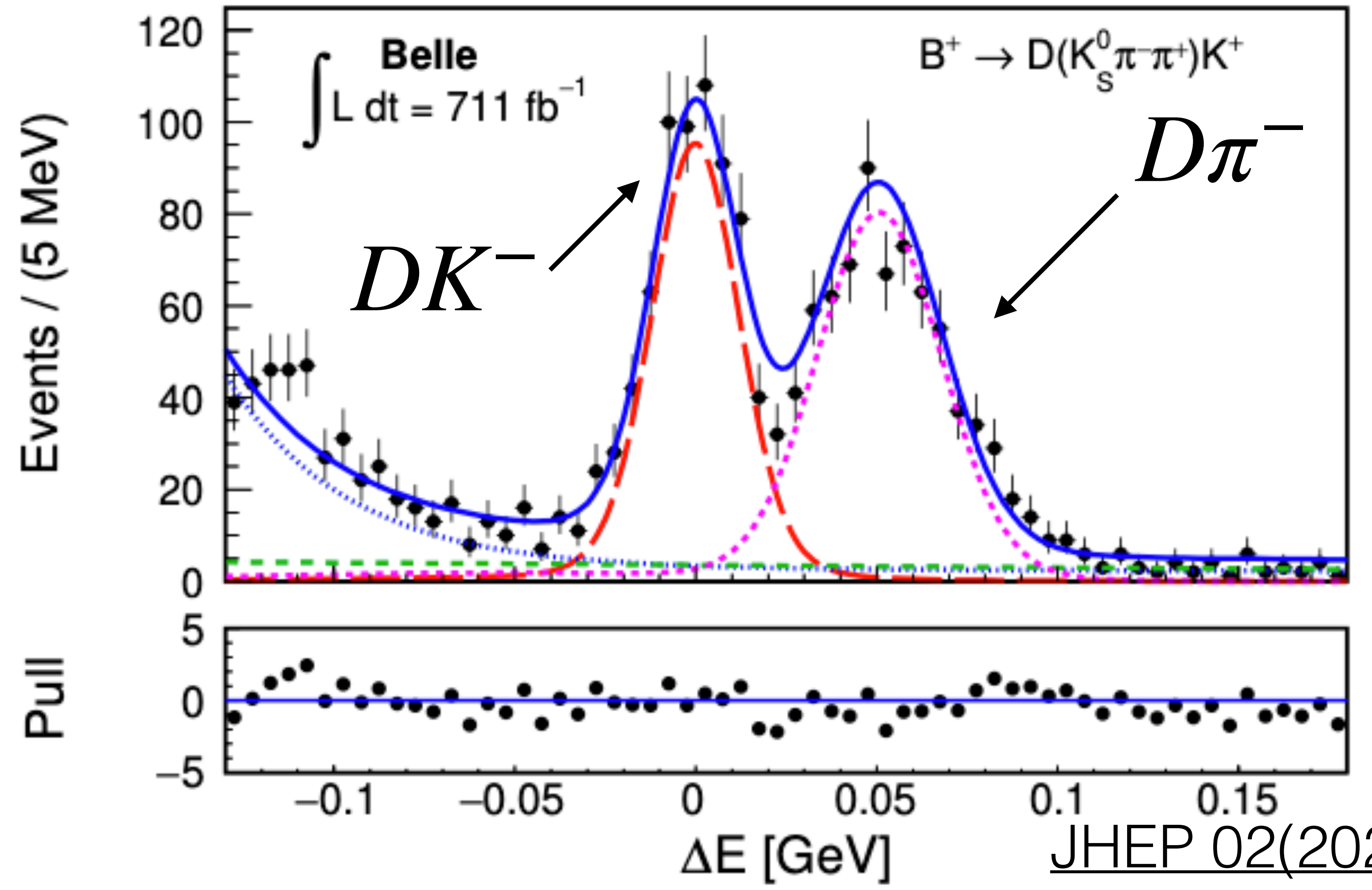
$M_{\rm bc} = \sqrt{s/4 - p_B^{*2}}$ $\Delta E = E_B^* - \sqrt{s}/2$

Collision energy

- Use **event shape** to identify continuum background (qqbar).



Extract signal on ΔE and BDT output.

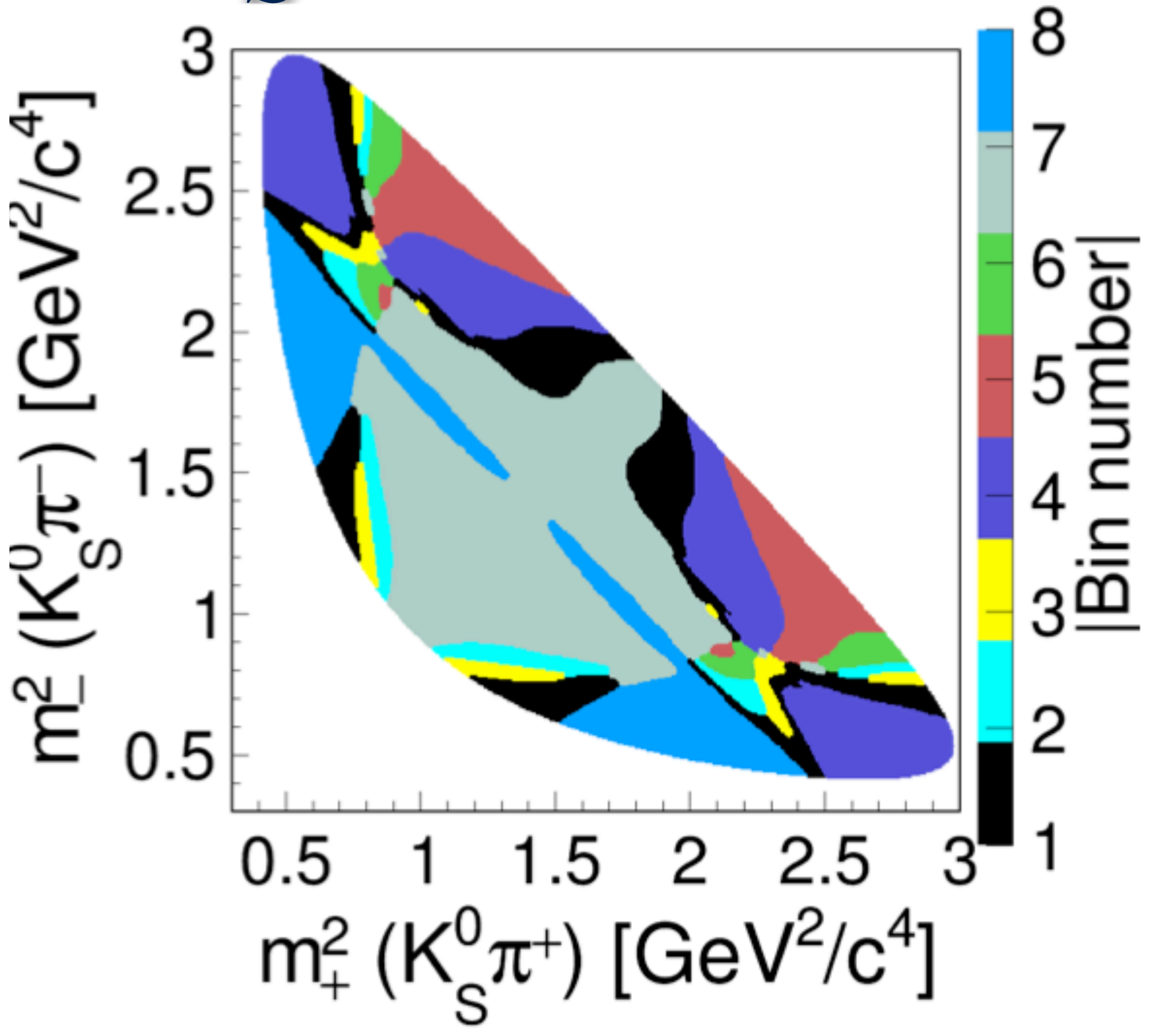


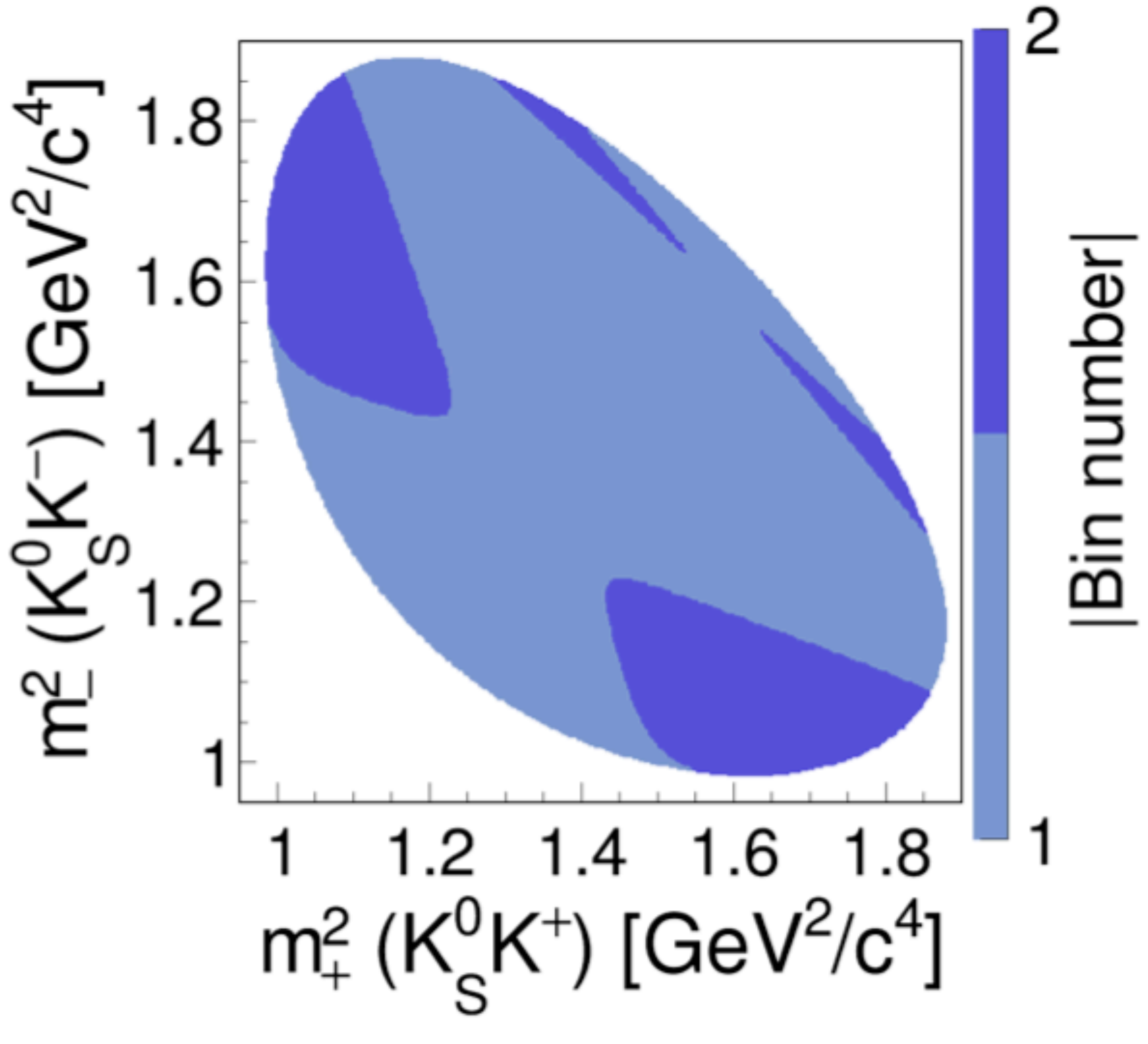
JHEP 02(2022)063

BPGGSZ results $B^+ \to Dh^+, D \to K_S^0 h^+ h^-, h = \pi, K$

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

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

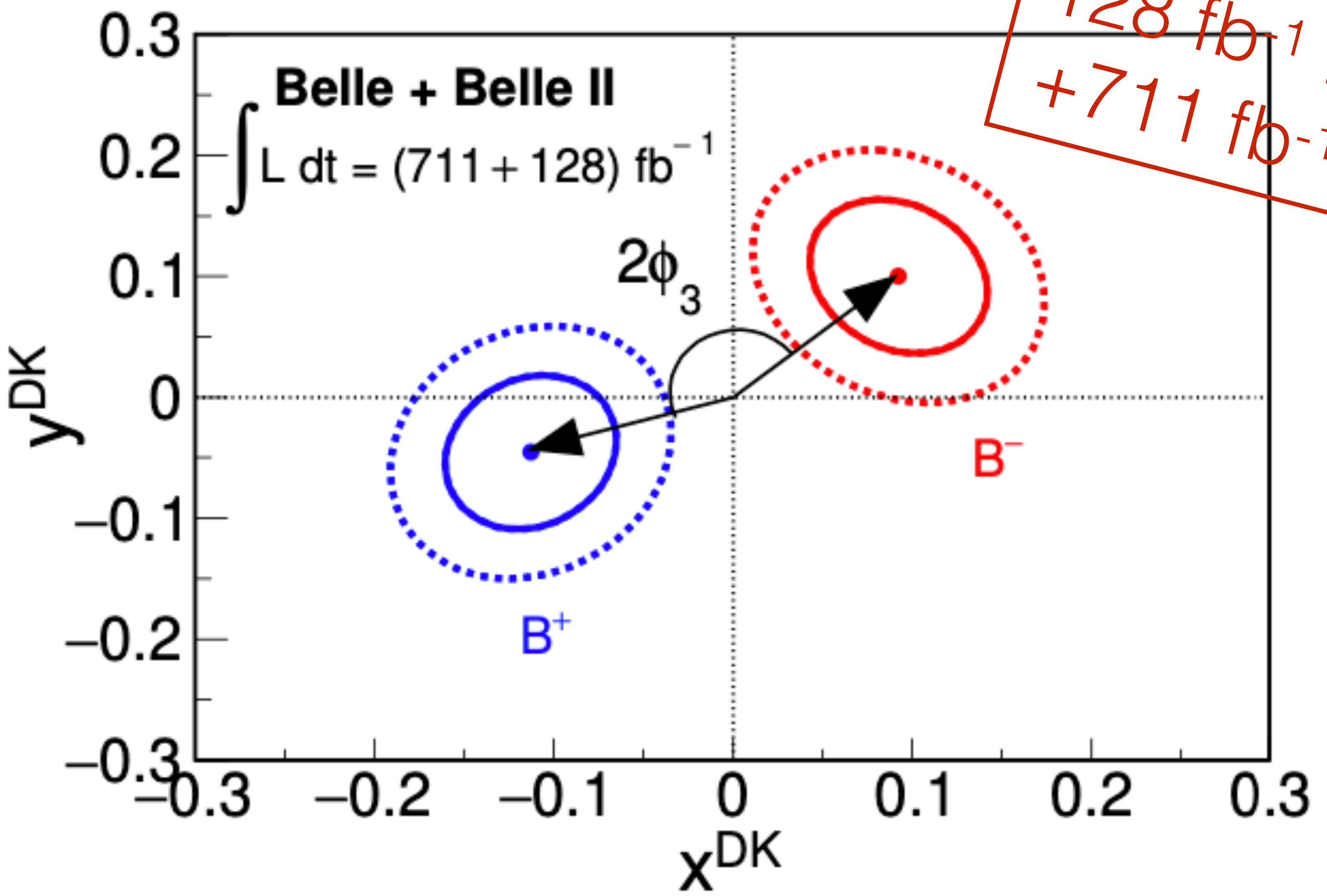




Binning scheme of $D \to K_S^0 \pi^+ \pi^-$

Binning scheme of $D \to K_S^0 K^+ K^-$

- Fit on yields in different bins, extract $x_\pm, y_\pm, F_i$.
- The c_i, s_i are cited from BESIII results [Phys.Rev.D 101 (2020) 11, 112002, Phys.Rev.D 102 (2020) 5, 052008]



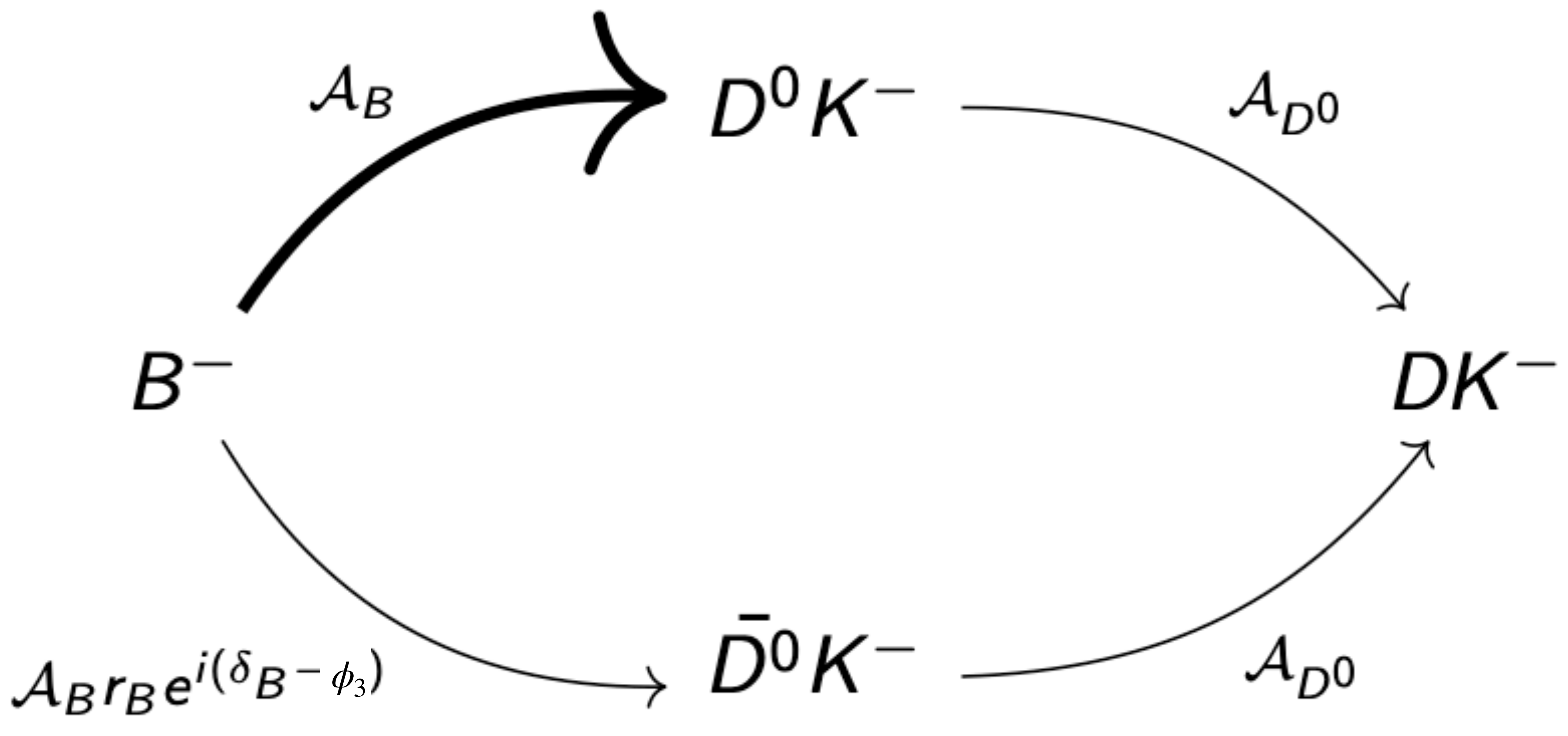
128 fb^{-1} Belle II
+711 fb^{-1} Belle

JHEP 02(2022)063

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

GLW results $B^+ \to DK^+, D \to K_S^0\pi^0, K^+K^-$

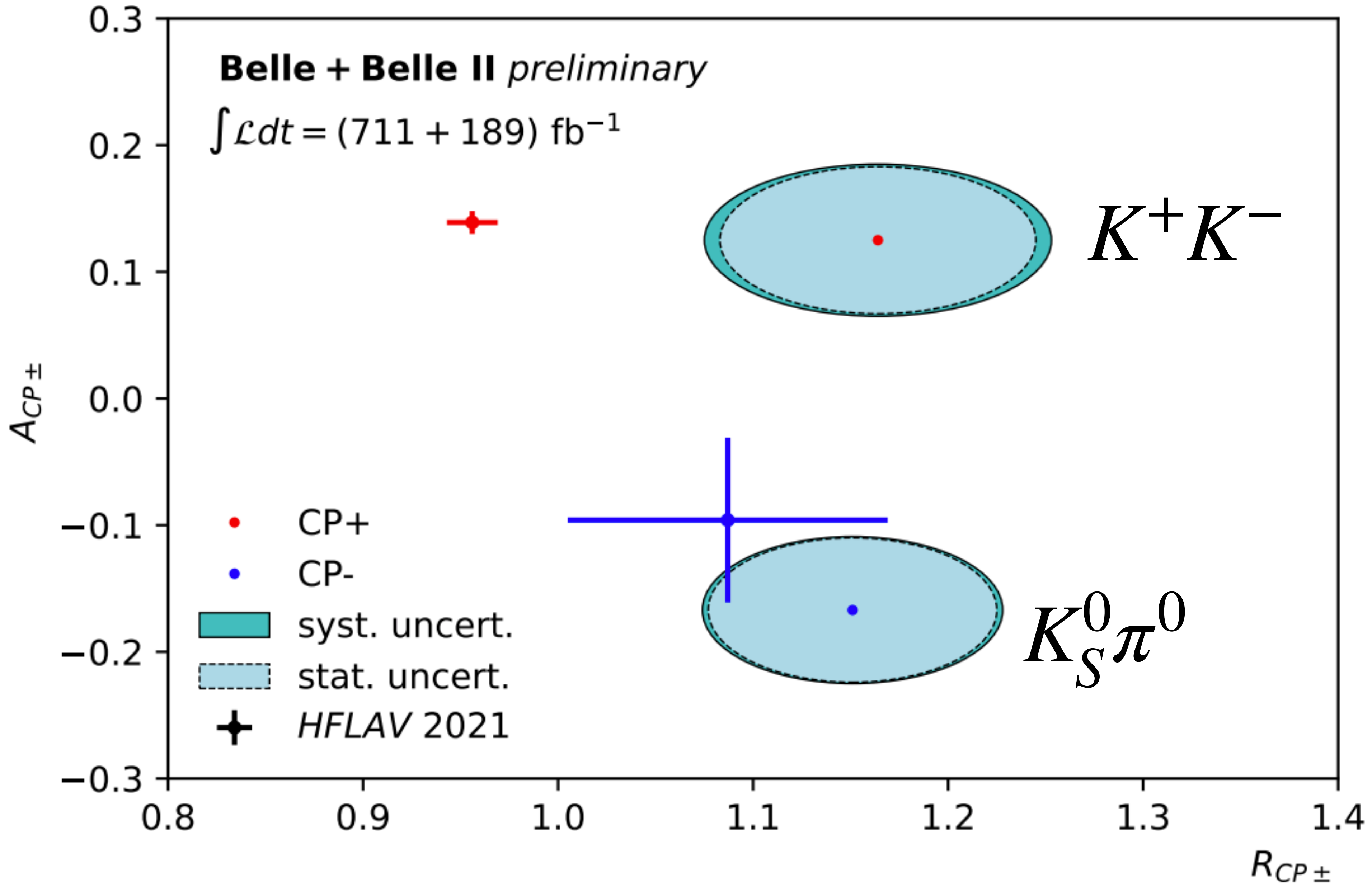
Preliminary

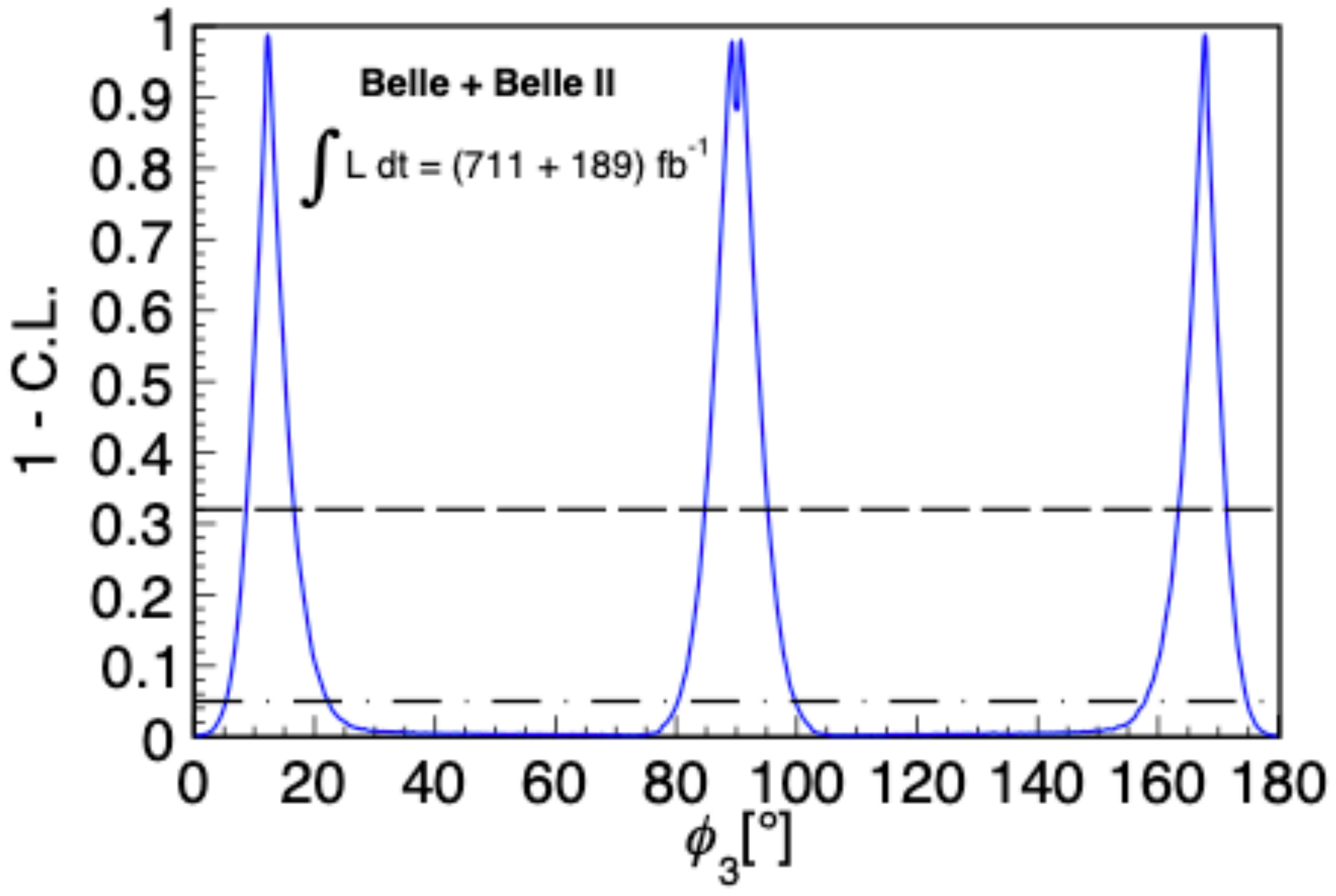


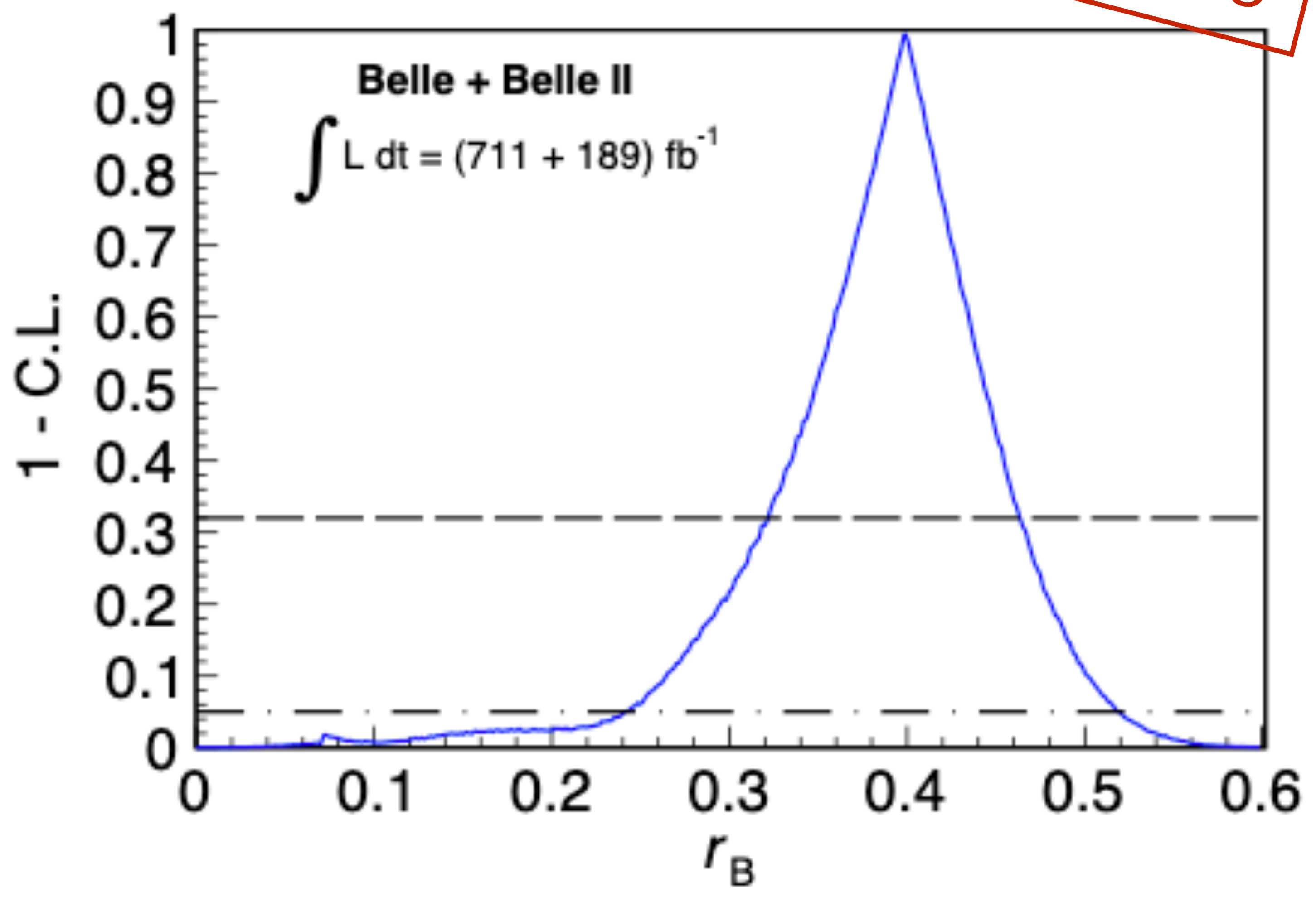
$$R_{CP\pm} = \frac{\mathcal{B}(B^- \to D_{CP\pm}K^-) + \mathcal{B}(B^+ \to D_{CP\pm}K^+)}{\mathcal{B}(B^- \to D^0K^-) + \mathcal{B}(B^+ \to \bar{D}^0K^+)},$$
$$= 1 + r_B^2 + 2\eta_{CP}r_B\cos(\delta_B)\cos(\phi_3),$$
$$A_{CP\pm} = \frac{\mathcal{B}(B^- \to D_{CP\pm}K^-) - \mathcal{B}(B^+ \to D_{CP\pm}K^+)}{\mathcal{B}(B^- \to D_{CP\pm}K^-) + \mathcal{B}(B^+ \to D_{CP\pm}K^+)},$$
$$= 2\eta_{CP}r_B\sin(\delta_B)\sin(\phi_3)/R_{CP\pm}.$$

arXiv:2308.05048, submitted to JHEP

189 fb^{-1} Belle II +711 fb^{-1} Belle







GLS results $B^+ \to Dh^+, D \to K_S^0 K^\mp \pi^\pm$

$B^\pm \to DK^\pm, D\pi^\pm$ with $D \to K_S^0 K^\pm \pi^\mp$: SS: same-sign, OS: opposite sign.

Two sets of results: in full D phase space and in the K*K region (expected large δ_D).

Observe 4 Acp and 3 BR ratios.

362 fb^{-1} Belle II
+711 fb^{-1} Belle

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

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

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

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

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

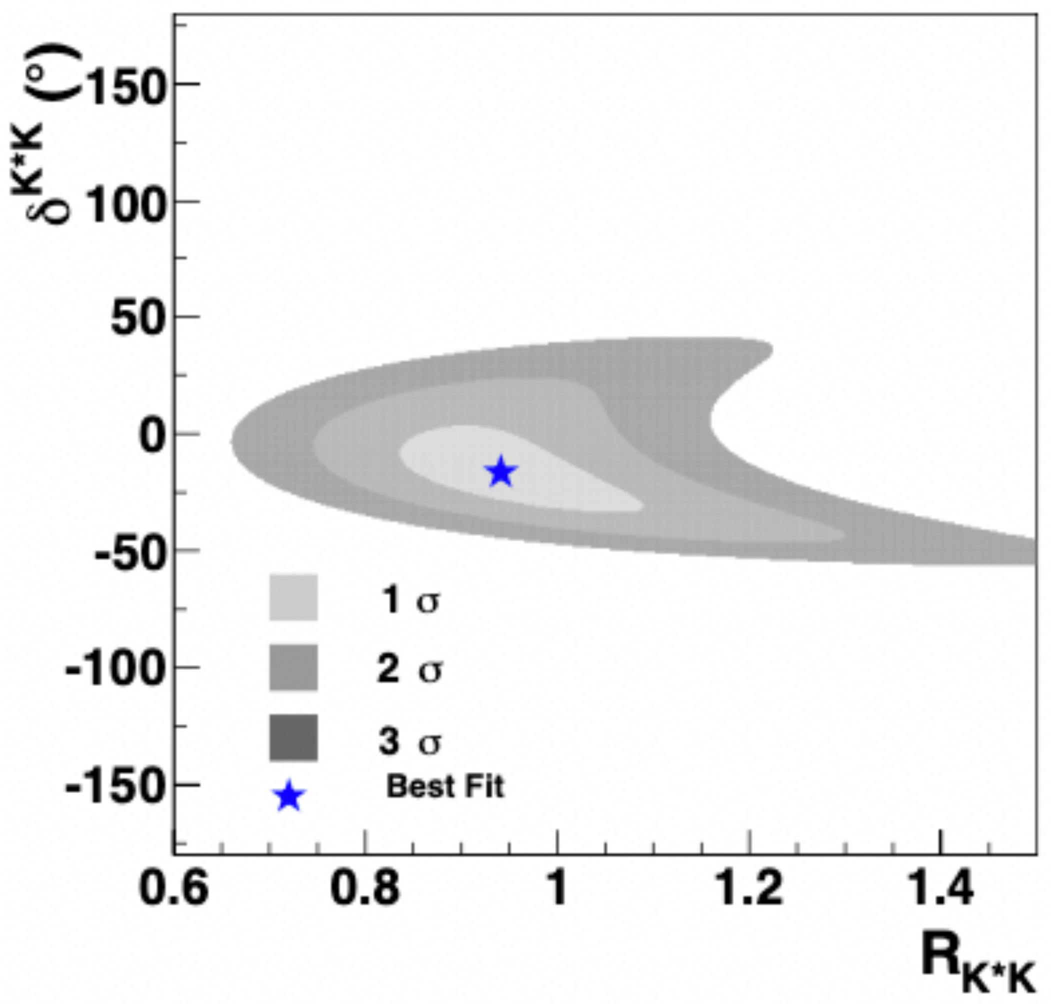
$$R_{OS}^{DK/D\pi} = R\frac{(r_B^{DK})^2 + r_D^2 + 2r_B^{DK} r_D \kappa_D \cos(\delta_B^{DK} + \delta_D)\cos\phi_3}{(r_B^{D\pi})^2 + r_D^2 + 2r_B^{D\pi} r_D \kappa_D \cos(\delta_B^{D\pi} + \delta_D)\cos\phi_3},$$

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

In K*K region:

$$A_{\rm SS}^{DK} = 0.055 \pm 0.119 \pm 0.020,$$
$$A_{\rm OS}^{DK} = 0.231 \pm 0.184 \pm 0.014,$$
$$A_{\rm SS}^{D\pi} = 0.046 \pm 0.029 \pm 0.016,$$
$$A_{\rm OS}^{D\pi} = 0.009 \pm 0.046 \pm 0.009,$$
$$R_{\rm SS}^{DK/D\pi} = 0.093 \pm 0.012 \pm 0.005,$$
$$R_{\rm OS}^{DK/D\pi} = 0.103 \pm 0.020 \pm 0.006,$$
$$R_{\rm SS/OS}^{D\pi} = 2.412 \pm 0.132 \pm 0.019,$$

JHEP 09 2023,146



- Model-independent result from CLEO-c.[arXiv:1203.3804]
- **Hope BESIII update this!**

Combination of ϕ_3 using results from Belle and Belle II

Preliminary

- Combine four different methods, 17 different final states.
- Tool: GammaCombo, a dedicated tool for combination by LHCb.

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

- $B^0 \to D^{(*)} h^{(*)}$ results are not used: negligible contribution and extra parameters introduced.

External inputs to ϕ_3 combination

Preliminary

- External inputs: mainly from CLEO and BESIII.
- Looking forward to more precise and valuable results from BESIII!

r_D: amplitude ratio

δ_D: strong-phase difference

$$R_D = r_D^2$$

κ_D: coherence factor

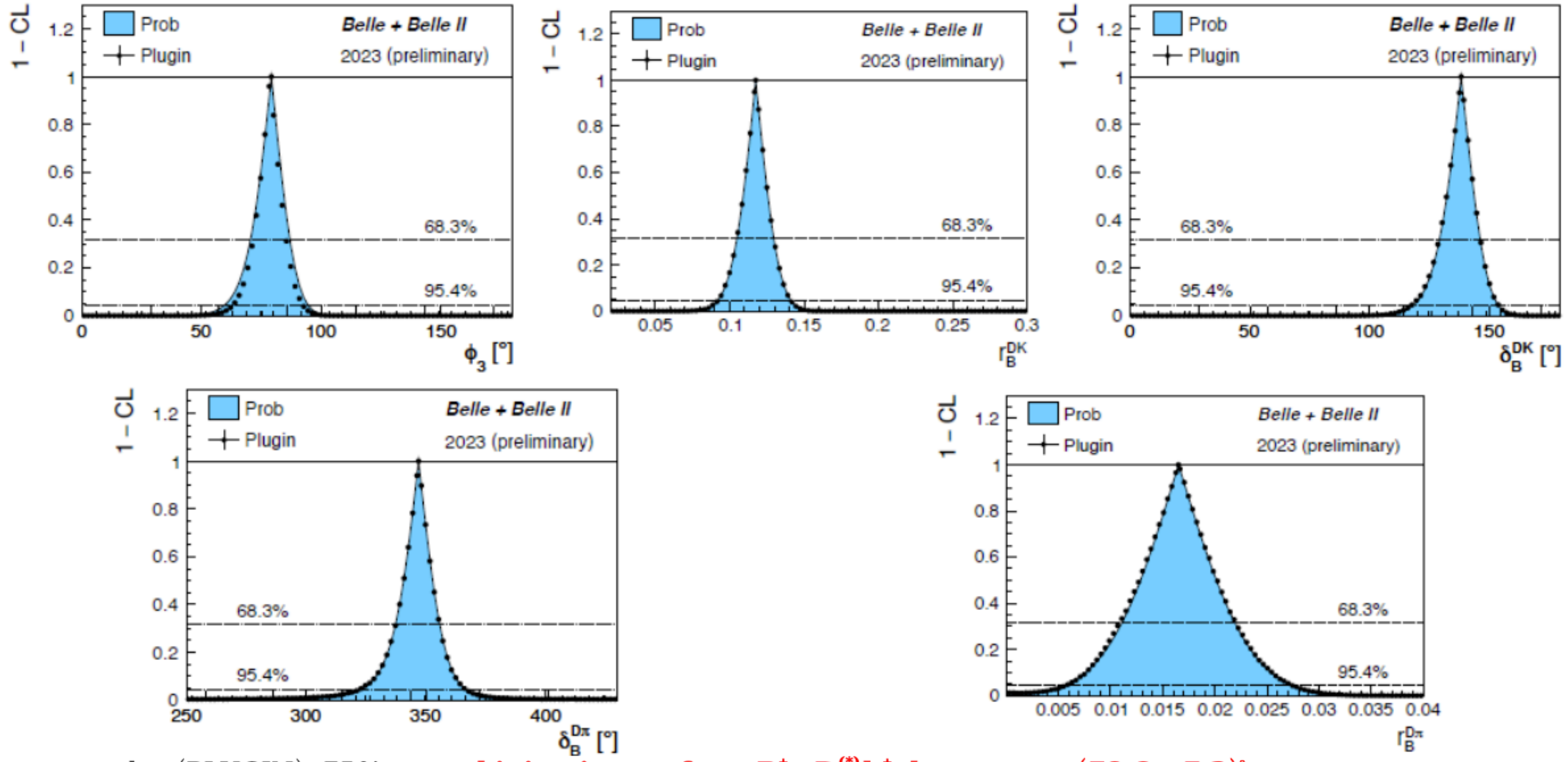
$$R_{GLS} = \frac{\mathscr{B}(D^0K^-)}{\mathscr{B}(D^0\pi^-)}$$

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		
	$\delta_D^{K\pi\pi^0}$	$(196 \pm 15)^\circ$		
$D \to K_S^0K^-\pi^+$	$(r_D^{K_S^0K\pi})^2$	0.356 ± 0.034	CLEO	[PRD 85, 092016 (2012)]
	$\kappa_D^{K_S^0K\pi}$	0.94 ± 0.12		
	$\delta_D^{K_S^0K\pi}$	$(-16.6 \pm 18.4)^\circ$		
	$(r_D^{K_S^0K\pi})^2$	0.370 ± 0.003	LHCb	[PRD 93, 052018 (2012)]
$B^+ \to Dh^+$	R_{GLS}	0.0789 ± 0.0027	PDG	

Results: 1D scans

- 60 input observables and 16 parameters.

Preliminary



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]

Discussion about ϕ_3 combination

Preliminary

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]

Comparing to W.A.: [HFLAV]

$\phi_3 = (65.9^{+3.3}_{-3.5})^\circ$

$r_B(DK^-) = (0.0994 \pm 0.0026)$

$\delta_B(DK^-) = (127.7^{+3.6}_{-3.9})^\circ$

$r_B(D\pi^-) = (0.0049 \pm 0.0006)$

$\delta_B(D\pi^-) = (294^{+9.7}_{-11})^\circ$

- Large ϕ_3, but consistent with w.a. in 2 σ

Discussion about ϕ_3 combination

Preliminary

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]

Comparing to W.A.: [HFLAV]

$\phi_3 = (65.9^{+3.3}_{-3.5})^\circ$

$r_B(DK^-) = (0.0994 \pm 0.0026)$

$\delta_B(DK^-) = (127.7^{+3.6}_{-3.9})^\circ$

$r_B(D\pi^-) = (0.0049 \pm 0.0006)$

$\delta_B(D\pi^-) = (294^{+9.7}_{-11})^\circ$

- Large ϕ_3, but consistent with w.a. in 2 σ
- Large r_B, so if future Belle II's data favor the small w.a. r_B, the ϕ_3's precision will be worse a bit.

Discussion about ϕ_3 combination

Preliminary

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]

Comparing to W.A.: [HFLAV]

$\phi_3 = (65.9^{+3.3}_{-3.5})^\circ$

$r_B(DK^-) = (0.0994 \pm 0.0026)$

$\delta_B(DK^-) = (127.7^{+3.6}_{-3.9})^\circ$

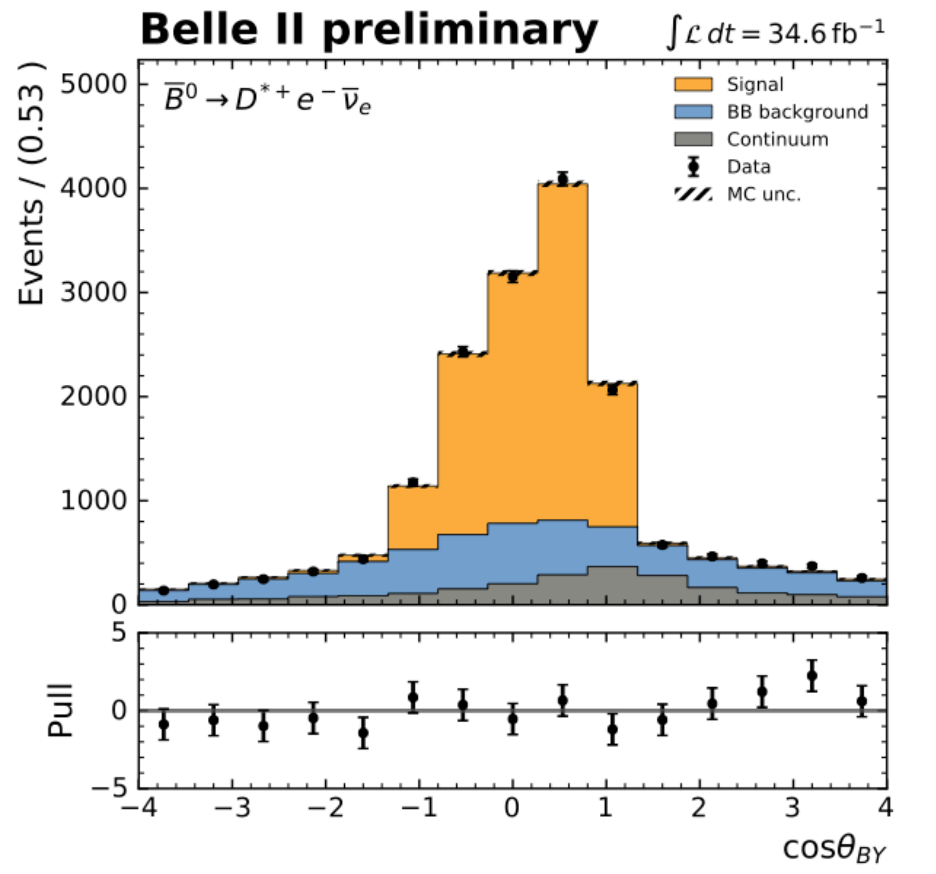
$r_B(D\pi^-) = (0.0049 \pm 0.0006)$

$\delta_B(D\pi^-) = (294^{+9.7}_{-11})^\circ$

- Large ϕ_3, but consistent with w.a. in 2 σ
- Large r_B, so if future Belle II's data favor the w.a. r_B, the ϕ_3's precision will be worse a bit with same data size.
- $(\delta_B(D\pi) + \delta_D) \sim 180^\circ$, $\cos(\delta_B(D\pi) + \delta_D)$'s uncertainty is much smaller than expected -> **unexpected precision** from ADS method. Not true anymore with w.a. $\delta_B(D\pi)$.

$$R_{ADS} = r_B^2 + r_D^2 + 2 r_B r_D \cos(\delta_B + \delta_D)\cos(\phi_3)$$

Determine hadronic parameter r_B^{DK} independently?



$$\cos\theta_{BY} = \frac{2E_B^* E_Y^* - M_B^2 - m_Y^2}{2p_B^* p_Y^*}$$

Now in all methods, we determine $r_B^{DK}, \delta_B^{DK}, \phi_3$ **simultaneously**.

The ϕ_3's precision highly depends on value of r_B^{DK}.

Can we determine r_B^{DK} solo? Will be an important extra constrain on ϕ_3!

Experimentally: N($B^+ \to D^0 K^+, D^0 \to K^- e^+ \nu_e$)/N($B^+ \to \bar{D}^0 K^+, \bar{D}^0 \to K^+ e^- \bar{\nu}_e$),

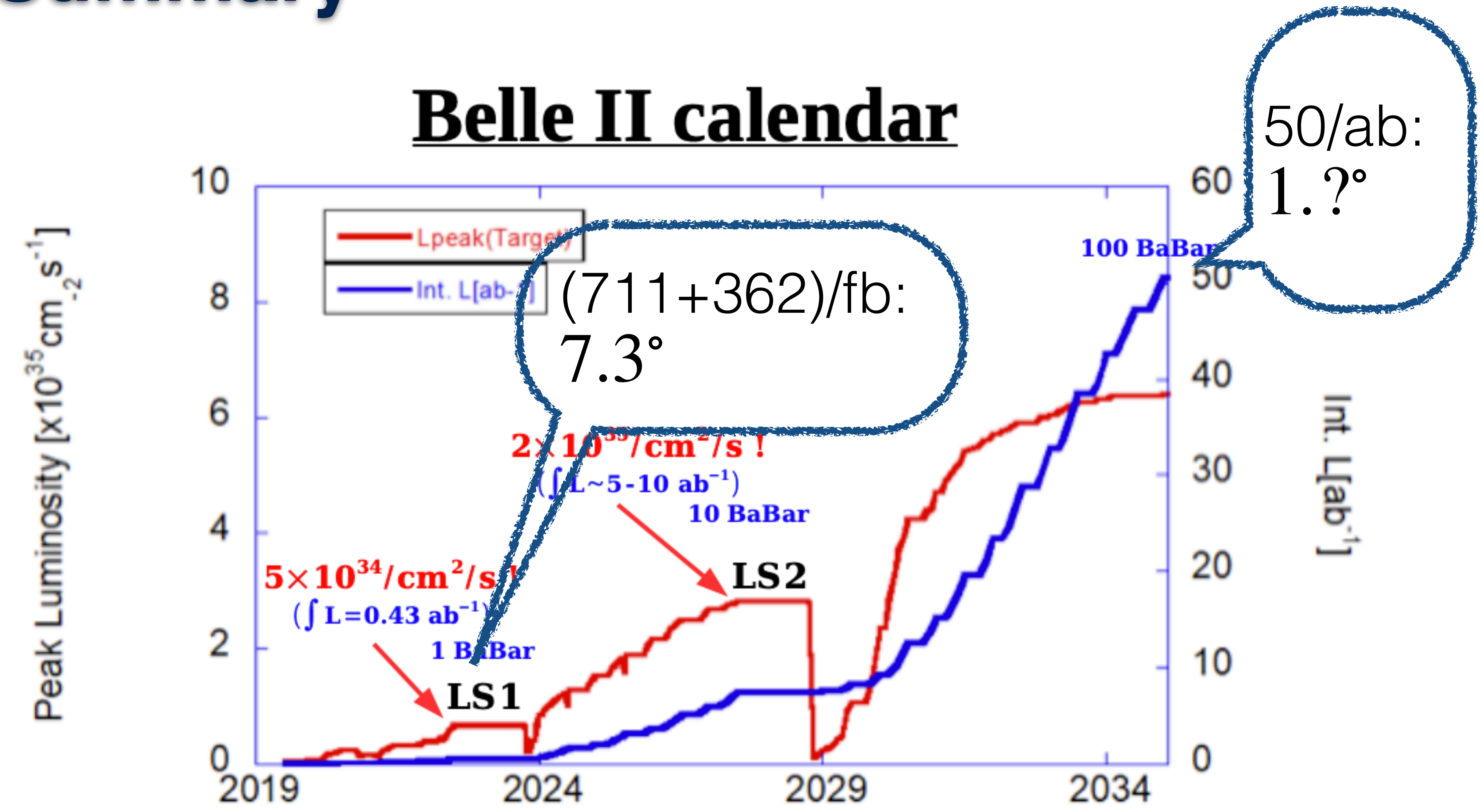
Rough estimation: for CF channel: N(raw)/1ab^{-1} ~ 6500

- If use hadronic tag (FEI): eff ~ 0.2%? N(CF) ~600 at 50 ab^{-1}
- Untag? Fit cosθ_{BY}, like semi-leptonic study. Maybe more difficult, due to small p(ν_e).

N(CF) ~60000 at 50 ab^{-1}, 4% precision? Won't be useful.

More idea? Or constrain from theory? We don't like model-dependent uncertainties…

Summary



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}

- BPGGSZ, GLW, GLS results using Belle + Belle II data.
- First ϕ_3 combination from Belle + Belle II : $(78.6 \pm 7.3)^\circ$.
- On the way to 1 degree (or less) uncertainty on ϕ_3.
- BESIII's **precise D results** will be highly appreciated. Will be helpful if BESIII also measure the Br($D^0 \to K^-\pi^+\pi^0$)/Br($D^0 \to K^-\pi^+$), dominant uncertainty in π^0 systematic uncertainty in Belle II.

Thank you!

Back-Up

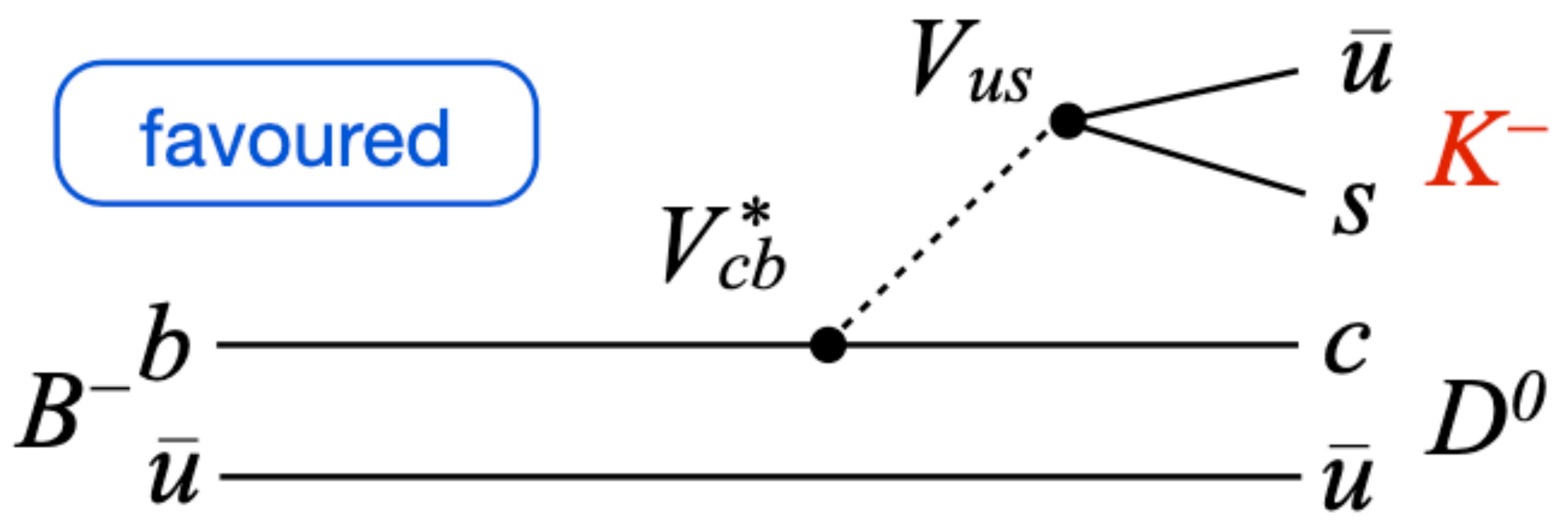
How to measure ϕ_3: interference in $B^- \to DK^-$

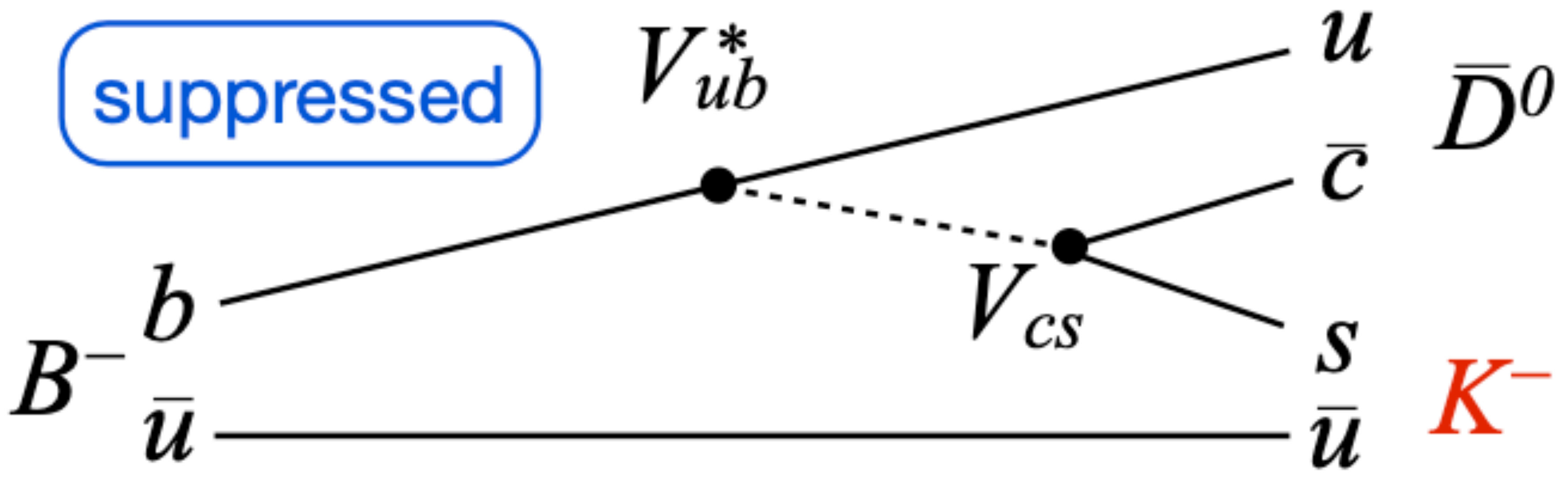
$$V_{CKM} = \begin{matrix} u \\ c \\ t \end{matrix} \overset{\begin{matrix} d & s & b \end{matrix}}{\begin{pmatrix} 1-\frac{1}{2}\lambda^2 & \lambda & A\lambda^3(\rho - i\eta + \frac{i}{2}\eta\lambda^2) \\ -\lambda & 1-\frac{1}{2}\lambda^2 - i\eta A^2\lambda^4 & A\lambda^2(1+i\eta\lambda^2) \\ A\lambda^3(1-\rho-i\eta) & -A\lambda^2 & 1 \end{pmatrix}} + \mathcal{O}(\lambda^6)\ (\sim 10^{-4})$$

Wolfenstein expansion in powers of the Cabibbo angle, λ, up to λ^5

$$\phi_3 = \arg\left(-\frac{V_{ud}V_{ub}^*}{V_{cd}V_{cb}^*}\right) = \arg\left(-\frac{V_{ub}^*}{V_{cb}^*}\right)$$

Zero phase in V_{ud}, V_{cd}





relative amplitude:

$$\left|\frac{V_{cs}V_{ub}^*}{V_{us}V_{cb}^*}\right| f_{col} = r_B \approx 0.1$$

relative strong phase:

$$= \delta_B$$

weak phase difference:

$$\arg\left(-\frac{V_{cs}\ V_{ub}^*}{V_{us}\ V_{cb}^*}\right) = \arg\left(-\frac{V_{ub}^*}{V_{cb}^*}\right) = \phi_3$$

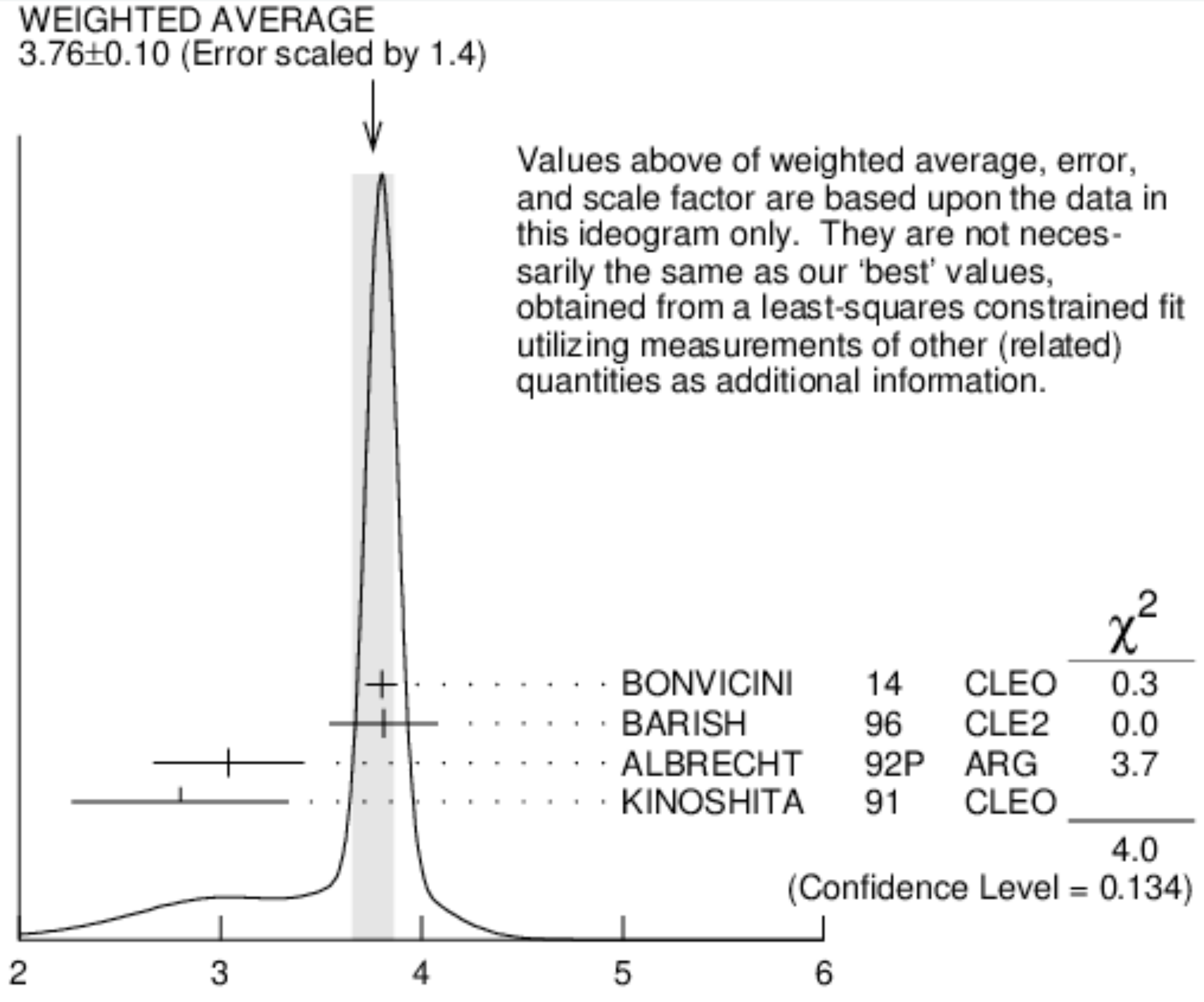
Almost zero phase in V_{us}, V_{cs}

$* r_B(D\pi^-) = (0.0049 \pm 0.0006)$

$\Gamma(D^0 \to K^-\pi^+\pi^0)/\Gamma(D^0 \to K^-\pi^+)$ Γ_{58}/Γ_{37}

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
3.65 ± 0.14	OUR FIT Error includes scale factor of 2.3.				
3.76 ± 0.10	OUR AVERAGE Error includes scale factor of 1.4. See the ideogram below.				
3.802 ±0.022 ±0.073		BONVICINI	2014	CLEO	All CLEO-c runs
3.81 ±0.07 ±0.26	10k	BARISH	1996	CLE2	$e^+e^- \approx \Upsilon(4S)$
3.04 ±0.16 ±0.34	931	[1] ALBRECHT	1992P	ARG	$e^+e^- \approx$ 10 GeV
2.8 ±0.14 ±0.52	1050	KINOSHITA	1991	CLEO	$e^+e^- \sim$ 10.7 GeV

[1] This value is calculated from numbers in Table 1 of ALBRECHT 1992P.



$\Gamma(D^0 \to K^-\pi^+\pi^0)/\Gamma(D^0 \to K^-\pi^+)$

Results: 2D scans

Preliminary