34th Rencontres de Blois

Particle Physics and Cosmology

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Recent Belle II Results on Hadronic *B* Decays

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on behalf of the Belle II collaboration

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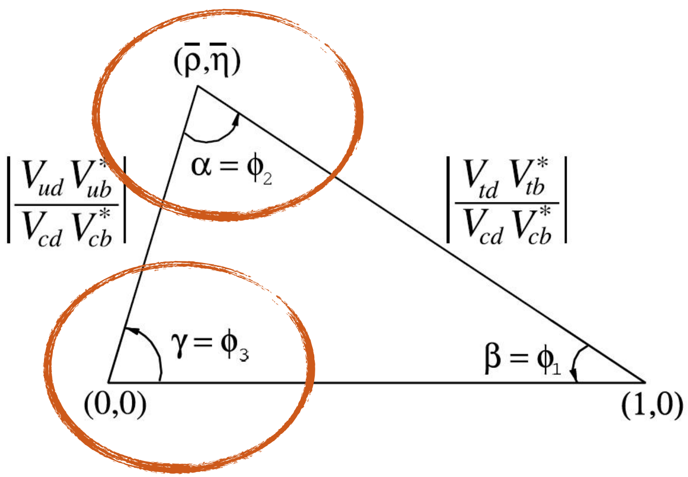
Outline and motivation

- Expanding our knowledge of the B hadronic sector: observation of new $B \to D^{(*)} K^- K_S^0$ decays.
- CKM matrix measurements for SM precision tests in favoured and suppressed B decays
  - Determination of CKM angle γ/ϕ_3

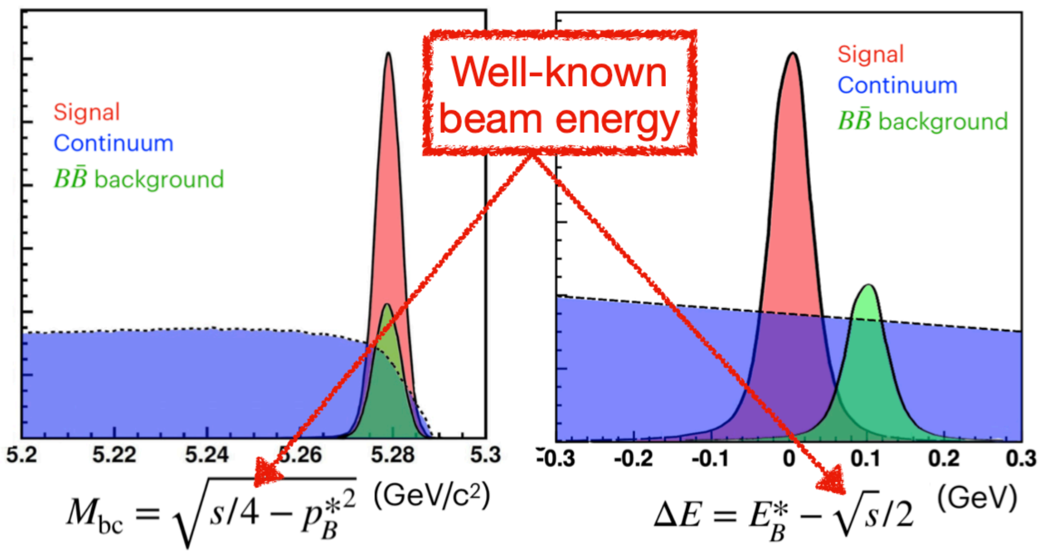
    SM gauge for CP violation
  - Toward CKM angle α/ϕ_2: $B \to \pi\pi,\ B \to \rho\rho$
  - $K\pi$ isospin sum rule

    Highly sensitive to NP, null test for SM

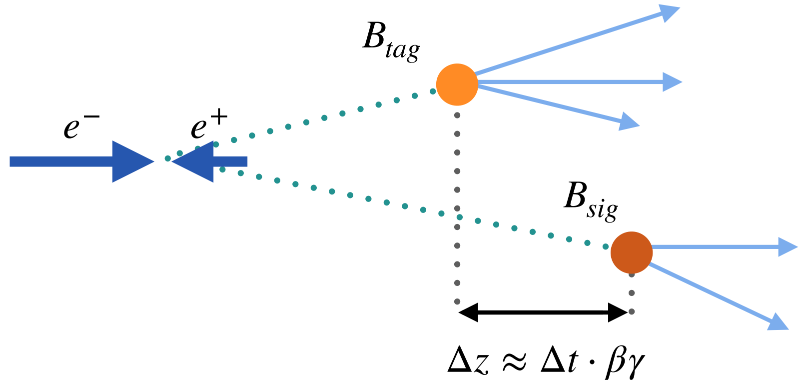


B factory basics

- Asymmetric-energy e^+e^- collisions at $\sqrt{s} = m(\Upsilon(4S)) = 10.58\ \text{GeV} \approx 2m_B$
  - Expected $M_{bc} \approx m_B$
  - Expected $\Delta E \approx 0$

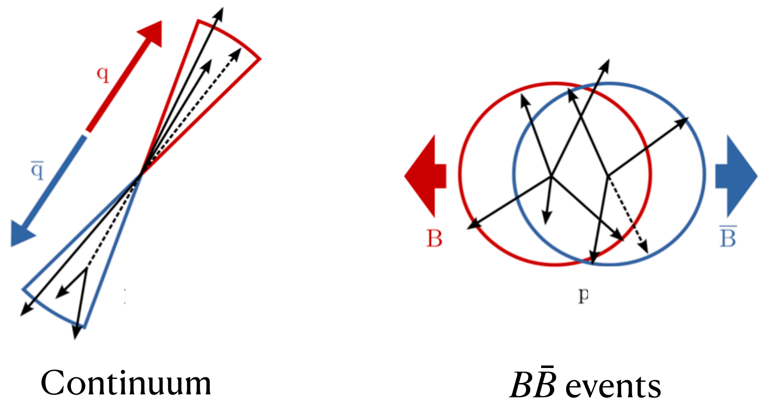


- Excellent vertexing ($\sigma \sim 15\ \mu$m) for decay-time dependent measurement of *CP* violation.
- Exploit coherent $B\bar{B}$ production for flavour tagging with 30% effective efficiency.



- Continuum background ($e^+e^- \to q\bar{q}$) suppression

  ⇒ MVA trained with topological variables



$B \to D^{(*)}K^-K^0_S$

New for Blois

362 fb^{-1}

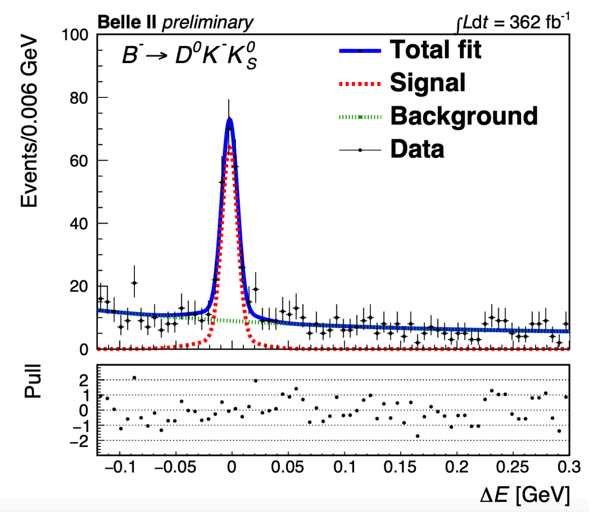
arXiv:2305.01321

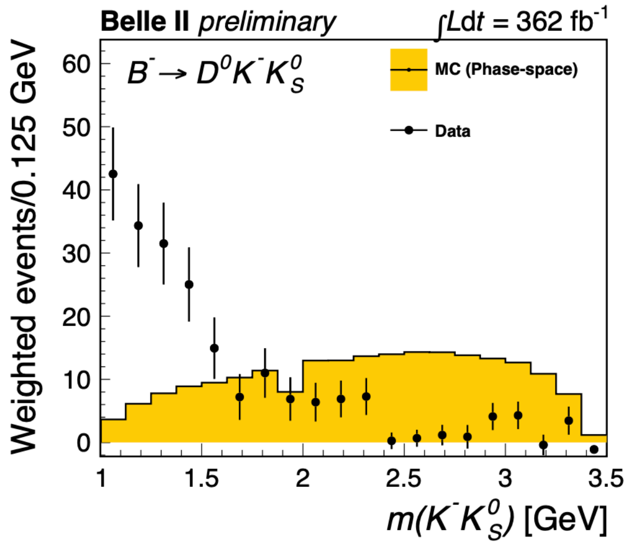
- $B \to D^{(*)}KK$ makes up a few % of B hadronic decay, but only a small fraction is known.
- First observation of 3 decays.

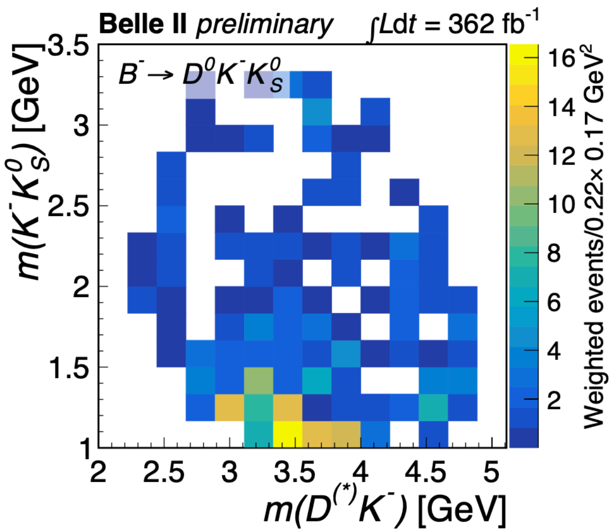
  Contribute to simulation and tagging techniques.

$$\mathscr{B}(B^- \to D^0K^-K^0_S) = (1.89 \pm 0.16 \pm 0.10) \times 10^{-4}$$
$$\mathscr{B}(\bar{B}^0 \to D^+K^-K^0_S) = (0.85 \pm 0.11 \pm 0.05) \times 10^{-4}$$
$$\mathscr{B}(B^- \to D^{*0}K^-K^0_S) = (1.57 \pm 0.27 \pm 0.12) \times 10^{-4}$$
$$\mathscr{B}(\bar{B}^0 \to D^{*+}K^-K^0_S) = (0.96 \pm 0.18 \pm 0.06) \times 10^{-4}$$

- Low mass structure observed in $m(K^-K^0_S)$.
- Structures observed from Dalitz distributions.



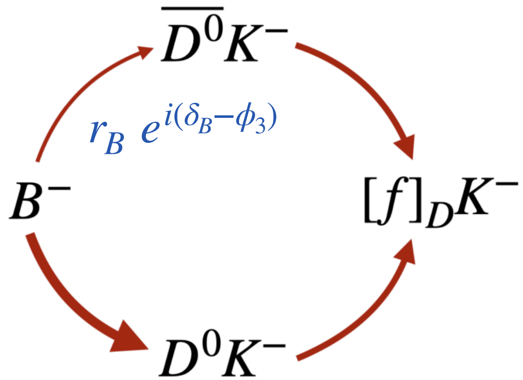




CKM angle γ/ϕ_3

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

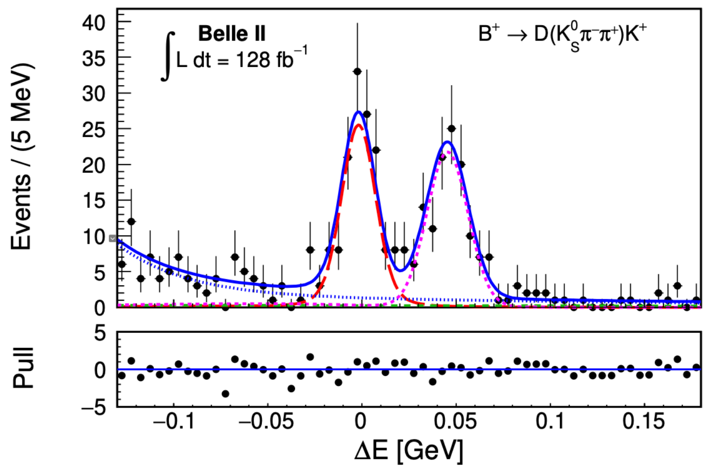
- Current world average: $\phi_3 = (\ 65.9^{+3.3}_{-3.5}\ )^\circ$, dominated by LHCb measurements.
- CPV in the interference $b \to c\bar{u}s$ and $b \to u\bar{c}s$
  - $\dfrac{A_{sup}(B^- \to \bar{D}K^-)}{A_{fav}(B^- \to DK^-)} = r_B\ e^{i(\delta_B - \phi_3)}$



- Approaches: different D decay final states
  - **Self-conjugate final states** $D \to K_S^0 h^+ h^-$

    Belle + Belle II: $\phi_3 = (78.4 \pm 11.4 \pm 0.5 \pm 1.0)^\circ$
  - **Cabibbo-suppressed decays** $D \to K_S^0 K^\pm \pi^\mp$
  - ***CP* eigenstates** $D \to K^+K^-, K_S^0\pi^0$

[JHEP02 2022, 063 (2022)]

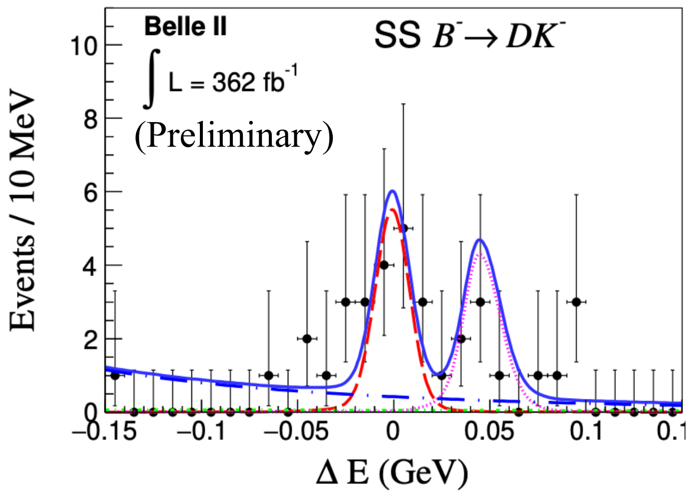


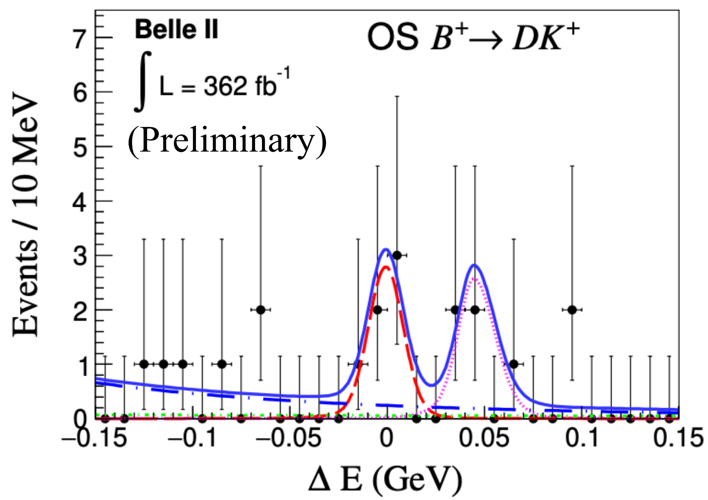
γ/ϕ_3 with Cabbibo-suppressed channels

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

New for Blois

- $B^\pm \to DK^\pm, D\pi^\pm$ $(D \to K^0_S K^\pm \pi^\mp)$ *SS*: same-sign, *OS*: opposite sign
- 2D fit $(\Delta E, C')$ of 8 categories: $(+,-) \times (SS, OS) \times (DK, D\pi)$ in the full D phase space and the interference-enhanced $D \to K^*K$ region. $m(K^0_S K) \sim m_{K^*(892)^\pm}$
- External input: D decay parameters from CLEO [Phys. Rev. D 94, 099905 (2016)].





K^* region

$$\mathcal{A}^{DK}_{SS} = 0.055 \pm 0.119 \pm 0.020$$
$$\mathcal{A}^{DK}_{OS} = 0.231 \pm 0.184 \pm 0.014$$
$$\mathcal{A}^{D\pi}_{SS} = 0.046 \pm 0.029 \pm 0.016$$
$$\mathcal{A}^{D\pi}_{OS} = 0.009 \pm 0.046 \pm 0.009$$
$$\mathcal{R}^{DK/D\pi}_{SS} = 0.093 \pm 0.012 \pm 0.005$$
$$\mathcal{R}^{DK/D\pi}_{OS} = 0.103 \pm 0.020 \pm 0.006$$
$$\mathcal{R}^{D\pi}_{SS/OS} = 2.412 \pm 0.132 \pm 0.019$$

- Results are consistent with LHCb, but not competitive.
- Contribute to constrain ϕ_3 in combination with measurements from other methods.

γ/ϕ_3 with CP eigenstates

New for Blois

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

- $B^\pm \to D_{CP\pm} K^\pm$
- CP eigenstates: K^+K^- (CP even), $K_S^0\pi^0$ (CP odd)

Accessible only at Belle II

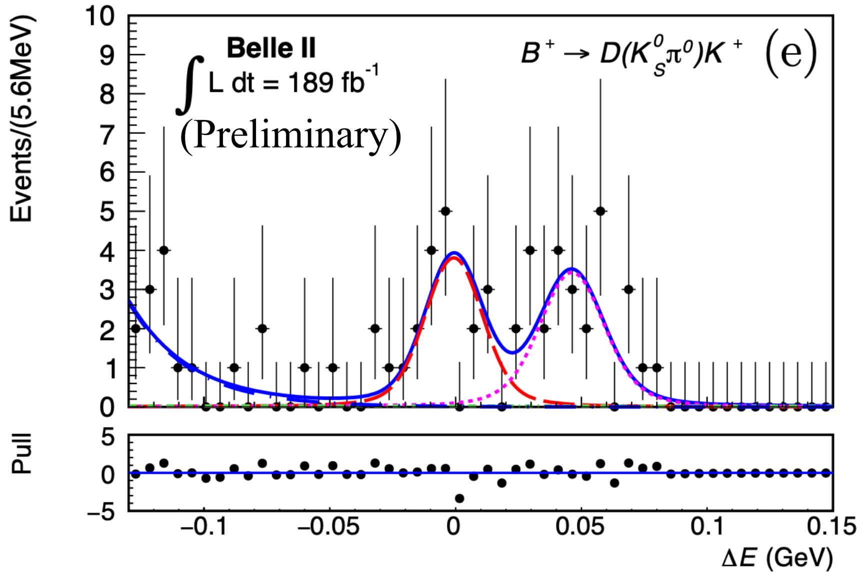
$$\mathcal{R}_{CP\pm} = 1 + r_B^2 \pm 2 r_B \cos\delta_B \cos\phi_3$$

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

- 2D fit ($\Delta E, C'$) of 6 categories: $(D\pi, DK) \times (K^+K^-, K_S^0\pi^0, K^+\pi^-)$

$$\mathcal{R}_{CP+} = 1.164 \pm 0.081 \pm 0.036$$
$$\mathcal{R}_{CP-} = 1.151 \pm 0.074 \pm 0.019$$
$$\mathcal{A}_{CP+} = (+12.5 \pm 5.8 \pm 1.4)\,\%$$
$$\mathcal{A}_{CP-} = (-16.7 \pm 5.7 \pm 0.6)\,\%$$

First evidence for difference in $\mathcal{A}_{CP\pm}$ in a direct measurement.



- Results are consistent with BarBar and LHCb, but not competitive.
- Contribute to constraining phi3 in combination with other measurements

Towards CKM angle α/ϕ_2

189 fb^{-1}

$$\phi_2 = \arg\left(-\frac{V_{td}V_{tb}^*}{V_{ud}V_{ub}^*}\right)$$

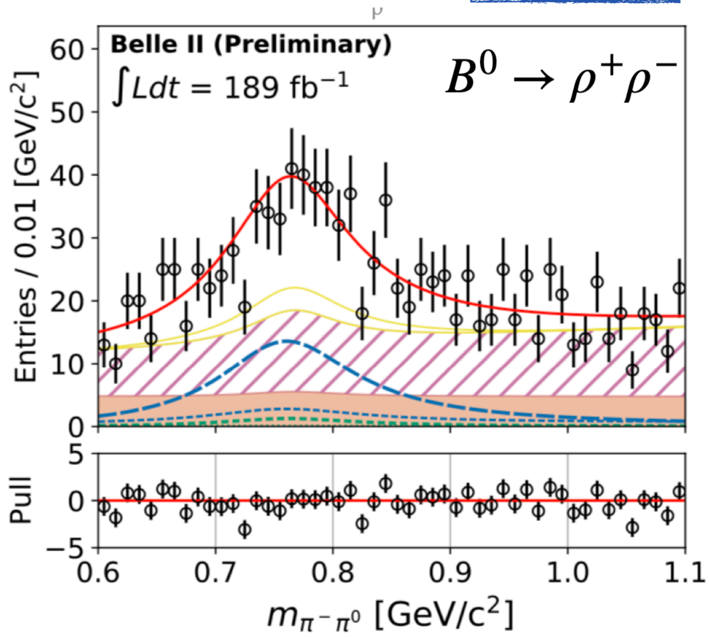
- Current world average: $\phi_2 = (\ 85.2^{+4.8}_{-4.3}\ )^\circ$

  Least precisely known angle starts limiting the global testing power of the CKM model.

- Combine information from BR and ACP measurement of
  - $B^0 \to \rho^+\rho^-$, $B^+ \to \rho^+\rho^0$, $B^0 \to \rho^0\rho^0$
  - $B^0 \to \pi^+\pi^-$, $B^+ \to \pi^+\pi^0$, $B^0 \to \pi^0\pi^0$

  to reduce impact of hadronic uncertainties exploiting isospin symmetry.

- Measurements of $B \to \rho\rho$ requires a complex angular analysis.
- Preliminary Belle II results on par with best performance from Belle/Babar.



$B^+ \to \rho^+\rho^0$ arXiv:2206.12362

$\mathcal{B} = (23.2^{+2.2}_{-2.1} \pm 2.7) \times 10^{-6}$

$f_L = 0.943^{+0.035}_{-0.033} \pm 0.027$

$\mathcal{A}_{CP} = -0.069 \pm 0.069 \pm 0.060$

$B^0 \to \rho^+\rho^-$ arXiv:2208.03554

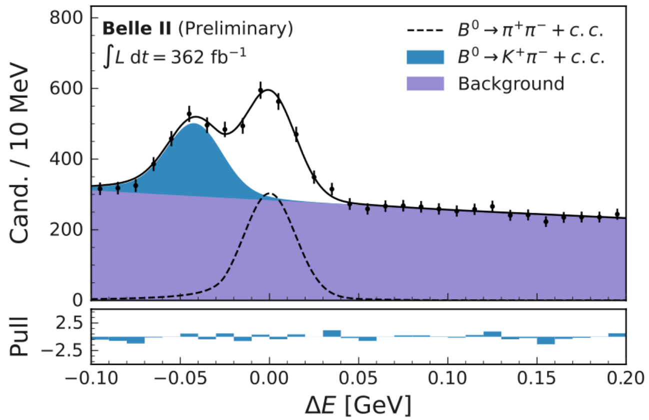
$\mathcal{B} = (26.7 \pm 2.8 \pm 2.8) \times 10^{-6}$

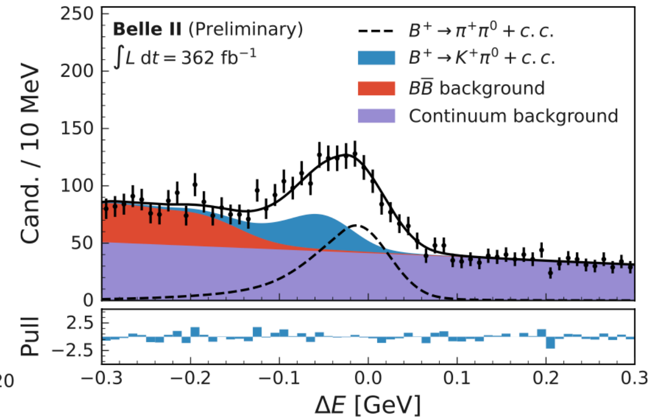
$f_L = 0.956 \pm 0.035 \pm 0.033$

Towards CKM angle α/ϕ_2

New for Blois

- $B^0 \to \pi^+\pi^-, B^+ \to \pi^+\pi^0$





$362\ \text{fb}^{-1}$

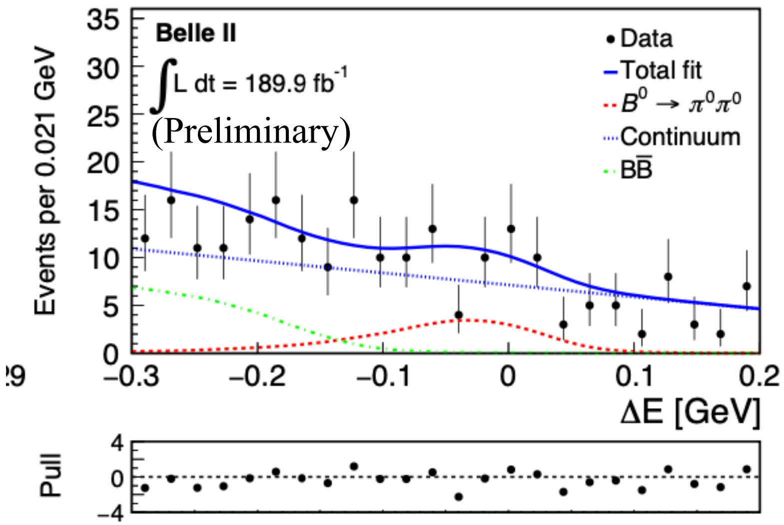
$$\mathscr{B}(\pi^+\pi^-) = (5.83 \pm 0.22 \pm 0.17) \times 10^{-6}$$
$$\mathscr{B}(\pi^+\pi^0) = (5.02 \pm 0.28 \pm 0.31) \times 10^{-6}$$
$$\mathscr{A}_{CP}(\pi^+\pi^0) = -0.082 \pm 0.54 \pm 0.008$$

arXiv:2303.08354

$189\ \text{fb}^{-1}$

- First measurement of $B^0 \to \pi^0\pi^0$ at Belle II.
  - Only photons in the final state.
  - CKM-suppressed and colour-suppressed.
  - Achieves Belle's precision using only 1/3 of data.

$$\mathscr{B}(\pi^0\pi^0) = (1.38 \pm 0.27 \pm 0.22) \times 10^{-6}$$
$$\mathscr{A}_{CP}(\pi^0\pi^0) = 0.14 \pm 0.46 \pm 0.07$$



Isospin sum rule

New for Blois

362 fb^{-1}

- Isospin sum rule

$$I_{K\pi} = \mathscr{A}_{K^+\pi^-} + \mathscr{A}_{K^0\pi^+} \cdot \frac{\mathscr{B}_{K^0\pi^+}}{\mathscr{B}_{K^+\pi^-}} \frac{\tau_{B^0}}{\tau_{B^+}} - 2\mathscr{A}_{K^+\pi^0} \cdot \frac{\mathscr{B}_{K^+\pi^0}}{\mathscr{B}_{K^+\pi^-}} \frac{\tau_{B^0}}{\tau_{B^+}} - 2\mathscr{A}_{K^0\pi^0} \cdot \frac{\mathscr{B}_{K^0\pi^0}}{\mathscr{B}_{K^+\pi^-}} \approx 0$$

  - Exactly zero in the limit of isospin symmetry and no EW penguins.
  - Theoretical precision: O(1%)
    experimental precision: O(10%), driven by $\mathscr{A}_{K^0\pi^0}$.

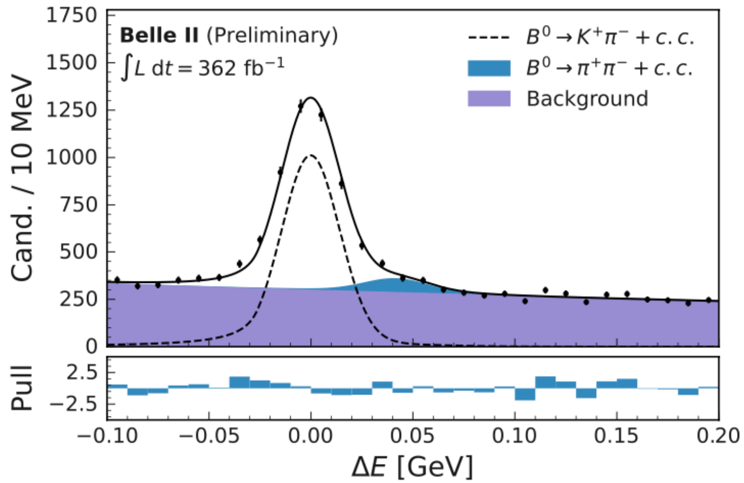
- All final states are measured: $B^0 \to K^+\pi^-,\ B^+ \to K_S^0\pi^+,\ B^+ \to K^+\pi^0,\ B^0 \to K_S^0\pi^0$

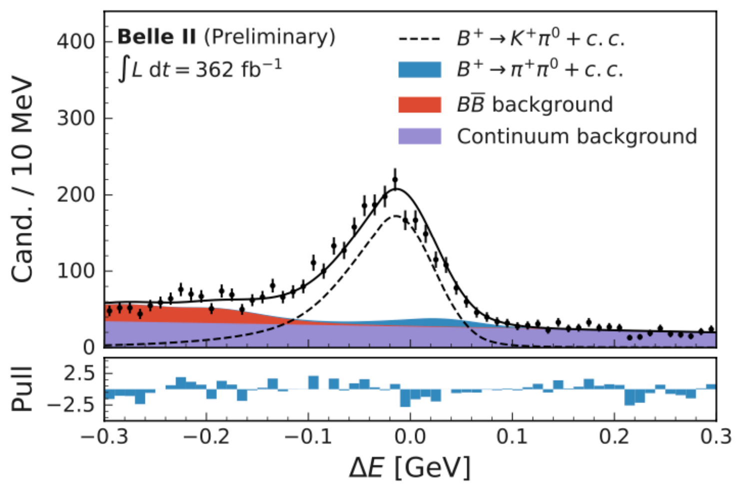
  Unique to Belle II

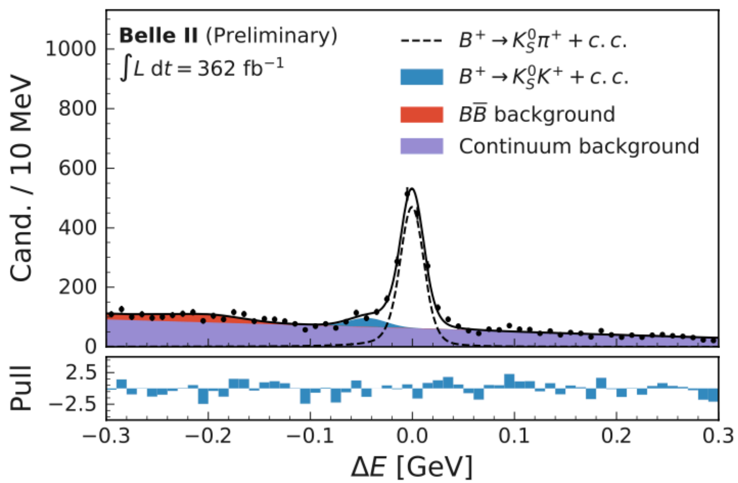
- Similar strategy for all modes:
  - Common selections for final-state particles.
  - Continuum suppression for each channel.
  - 2D fit (ΔE, C') for the branching fractions and **time-integrated** $\mathscr{A}_{CP}$.

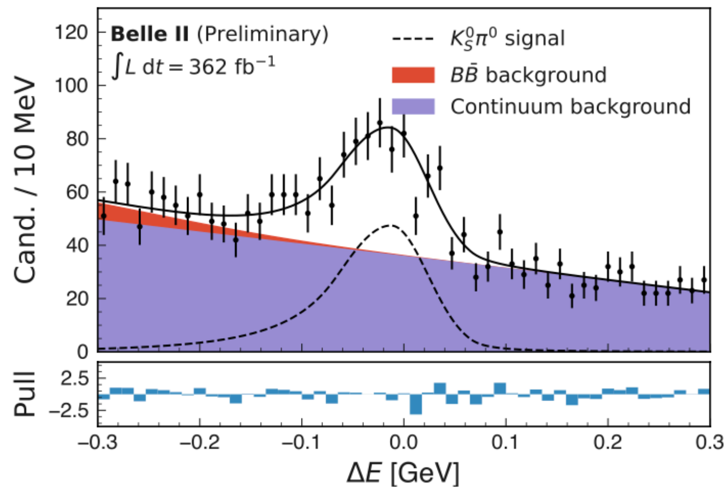
Isospin sum rule

ΔE fits









Isospin sum rule

Decay	Signal yield	$\mathcal{B}$ [10^{-6}]	$\mathcal{A}_{CP}$
$B^0 \to K^+\pi^-$	3868 ± 71	$20.67 \pm 0.37 \pm 0.62$	$-0.072 \pm 0.019 \pm 0.007$
$B^+ \to K^+\pi^0$	2070 ± 57	$14.21 \pm 0.38 \pm 0.85$	$0.013 \pm 0.027 \pm 0.005$
$B^+ \to K^0\pi^+$	1547 ± 45	$24.4 \pm 0.71 \pm 0.86$	$0.046 \pm 0.029 \pm 0.007$
$B^0 \to K^0\pi^0$	502 ± 32	$10.16 \pm 0.65 \pm 0.67$	$-0.06 \pm 0.15 \pm 0.05$
$B^0 \to K^0\pi^0$ (time-dependent analysis [11])	–	11.00 ± 0.67	$0.04 \pm 0.15 \pm 0.05$

- BR and A_{CP} results agree with world averages, competitive with world's best and BR systematically limited.

- $B^0 \to K_S^0\pi^0$ result is combined with **time-dependent analysis**, obtaining world's best:
  - More detail in the TDCPV talk by Jakub Kandra

  $$\mathcal{B}_{K^0\pi^0} = (10.50 \pm 0.65 \pm 0.69) \times 10^{-6}$$

  $$\mathcal{A}_{K^0\pi^0} = -0.01 \pm 0.12 \pm 0.05$$

- $I_{K\pi} = -0.03 \pm 0.13 \pm 0.05$ (world average: 0.13 ± 0.11)

  $\Rightarrow$ Competitive precision to world's best.

Summary

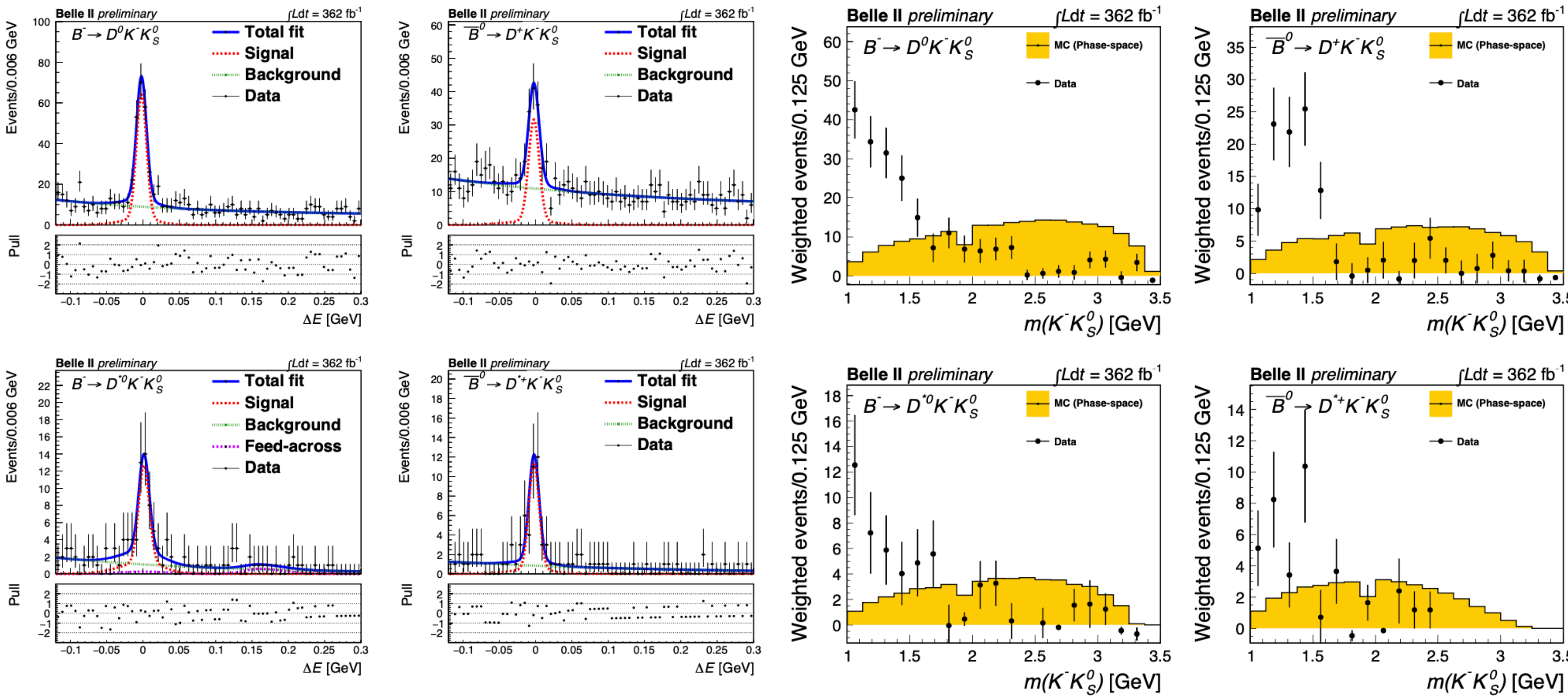
- First analyses using the full Belle II $\Upsilon(4S)$ sample (362 fb^{-1})
- 3 new decay channels observed in $B \to DKK$, with structures observed in $m(K^- K_S^0)$ and Dalitz distributions.
- Cabbibo-suppressed, CP eigenstates D final states contribute additional information to γ/ϕ_3.
- Belle II measurements of $B \to \pi\pi$ for α/ϕ_2.
- $B^0 \to K_S^0 \pi^0$ asymmetry achieves world's best precision, competitive $I_{K\pi}$ sensitivity.

Thank you
for your attention.

Backup

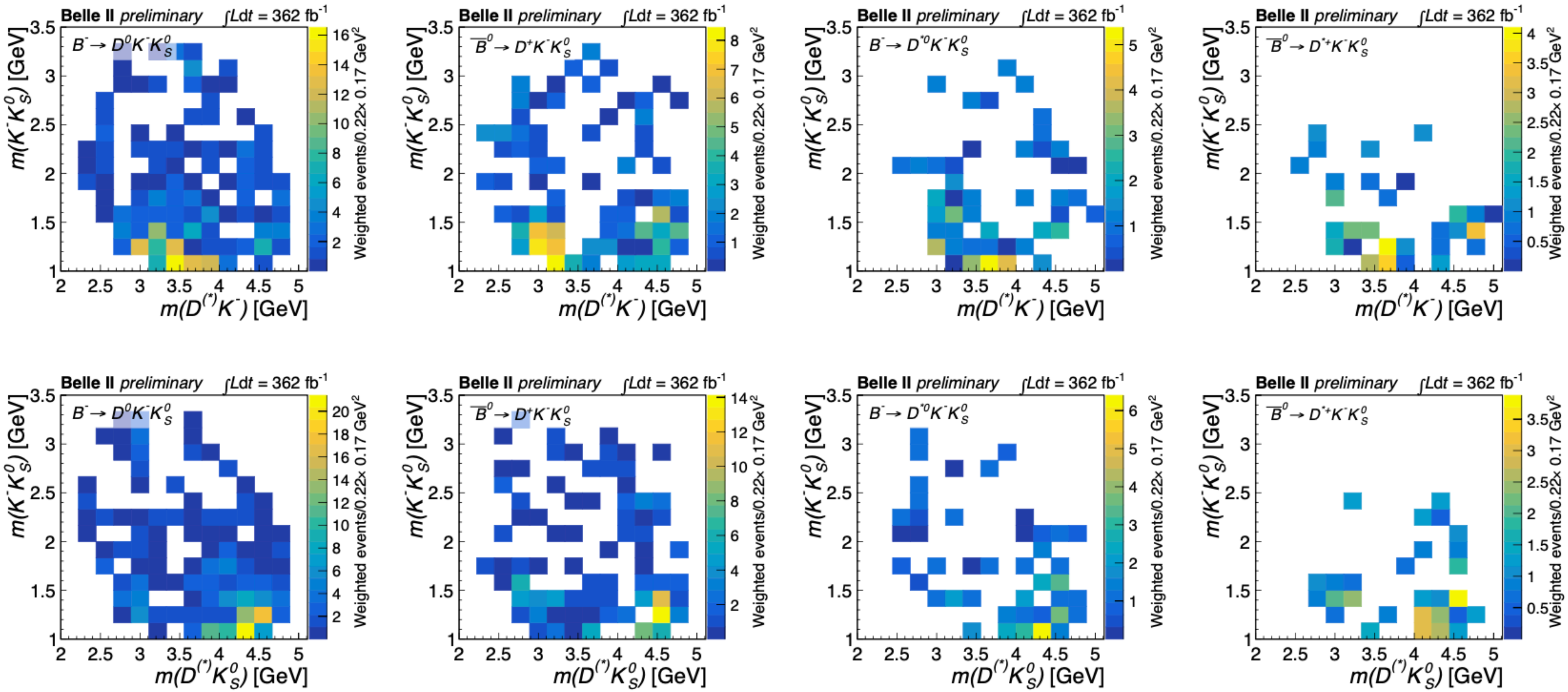
$B \to D^{(*)}K^{-}K_S^0$

ΔE fits and $m(K^{-}K_S^0)$



$B \to D^{(*)}K^-K_S^0$

Dalitz distributions



$B \to D^{(*)} K^- K_S^0$

Systematic uncertainties (relative)

Source	$B^- \to D^0 K^- K_S^0$	$\overline{B}^0 \to D^+ K^- K_S^0$	$B^- \to D^{*0} K^- K_S^0$	$\overline{B}^0 \to D^{*+} K^- K_S^0$
Eff. - MC sample size	0.6	0.9	1.0	0.8
Eff. - tracking	0.7	1.0	0.7	1.0
Eff. - π^+ from D^{*+}	-	-	-	2.7
Eff. - K_S^0	3.4	3.4	3.4	3.3
Eff. - PID	1.3	1.4	0.5	0.6
Eff. - π^0	-	-	5.1	-
Signal model	1.9	3.3	2.7	3.1
Bkg model	1.1	0.8	0.1	0.1
Self-cross-feed	-	-	2.7	-
D^{*0} peaking bkg	-	-	0.9	-
$N_{B\overline{B}}$, $f_{+-,00}$	2.7	2.8	2.7	2.8
Intermediate $\mathcal{B}$s	0.7	1.7	1.6	1.1
Total systematic	5.2	6.1	7.6	6.2
Statistical	8.3	13.5	17.1	19.0

γ/ϕ_3 with Cabbibo-suppressed channels

Physics meanings

- 2 $\mathcal{A}_{CP}$ for DK ($D\pi$):

$$\mathcal{A}_{SS}^{DK} \equiv \frac{N_{\bar{S}S}^{-} - N_{SS}^{+}}{N_{\bar{S}S}^{-} + N_{SS}^{+}}$$

$$\mathcal{A}_{OS}^{DK} \equiv \frac{N_{\bar{O}S}^{-} - N_{OS}^{+}}{N_{\bar{O}S}^{-} + N_{OS}^{+}}$$

Physics meanings →

$$\mathcal{A}_{SS}^{DK} = \frac{2r_B r_D \kappa \sin(\delta_B - \delta_D)\sin\phi_3}{1 + r_B^2 r_D^2 + 2r_B r_D \kappa cos(\delta_B - \delta_D)\cos\phi_3}$$

$$\mathcal{A}_{SS}^{DK} = \frac{2r_B r_D \kappa \sin(\delta_B + \delta_D)\sin\phi_3}{1 + r_B^2 + r_D^2 + 2r_B r_D \kappa cos(\delta_B + \delta_D)\cos\phi_3}$$

- 3 ratios:

$$\mathcal{R}_{SS}^{DK/D\pi} \equiv \frac{N_{\bar{S}S}^{-} + N_{SS}^{+}}{N_{\bar{S}S}^{\prime -} + N_{SS}^{\prime +}}$$

$$\mathcal{R}_{OS}^{DK/D\pi} \equiv \frac{N_{\bar{O}S}^{-} + N_{OS}^{+}}{N_{\bar{O}S}^{\prime -} + N_{OS}^{\prime +}}$$

$$\mathcal{R}_{SS/OS}^{D\pi} \equiv \frac{N_{\bar{S}S}^{\prime -} + N_{SS}^{\prime +}}{N_{\bar{O}S}^{\prime -} + N_{OS}^{\prime +}}$$

Physics meanings →

$$\mathcal{R}_{SS}^{DK/D\pi} = R\frac{1 + r_B^2 r_D^2 + 2r_B r_D \kappa \cos(\delta_B - \delta_D)\cos\phi_3}{1 + r_B^{\prime 2} r_D^2 + 2r_B^{\prime} r_D \kappa \cos(\delta_B^{\prime} - \delta_D)\cos\phi_3}$$

$$\mathcal{R}_{OS}^{DK/D\pi} = R\frac{r_B^2 + r_D^2 + 2r_B r_D \kappa \cos(\delta_B + \delta_D)\cos\phi_3}{r_B^{\prime 2} + r_D^2 + 2r_B^{\prime} r_D \kappa \cos(\delta_B^{\prime} + \delta_D)\cos\phi_3}$$

$$\mathcal{R}_{SS}^{DK/D\pi} = \frac{1 + r_B^{\prime 2} r_D^2 + 2r_B^{\prime} r_D \kappa \cos(\delta_B^{\prime} - \delta_D)\cos\phi_3}{r_B^{\prime 2} + r_D^2 + 2r_B^{\prime} r_D \kappa \cos(\delta_B^{\prime} + \delta_D)\cos\phi_3}$$

γ/ϕ_3

Results

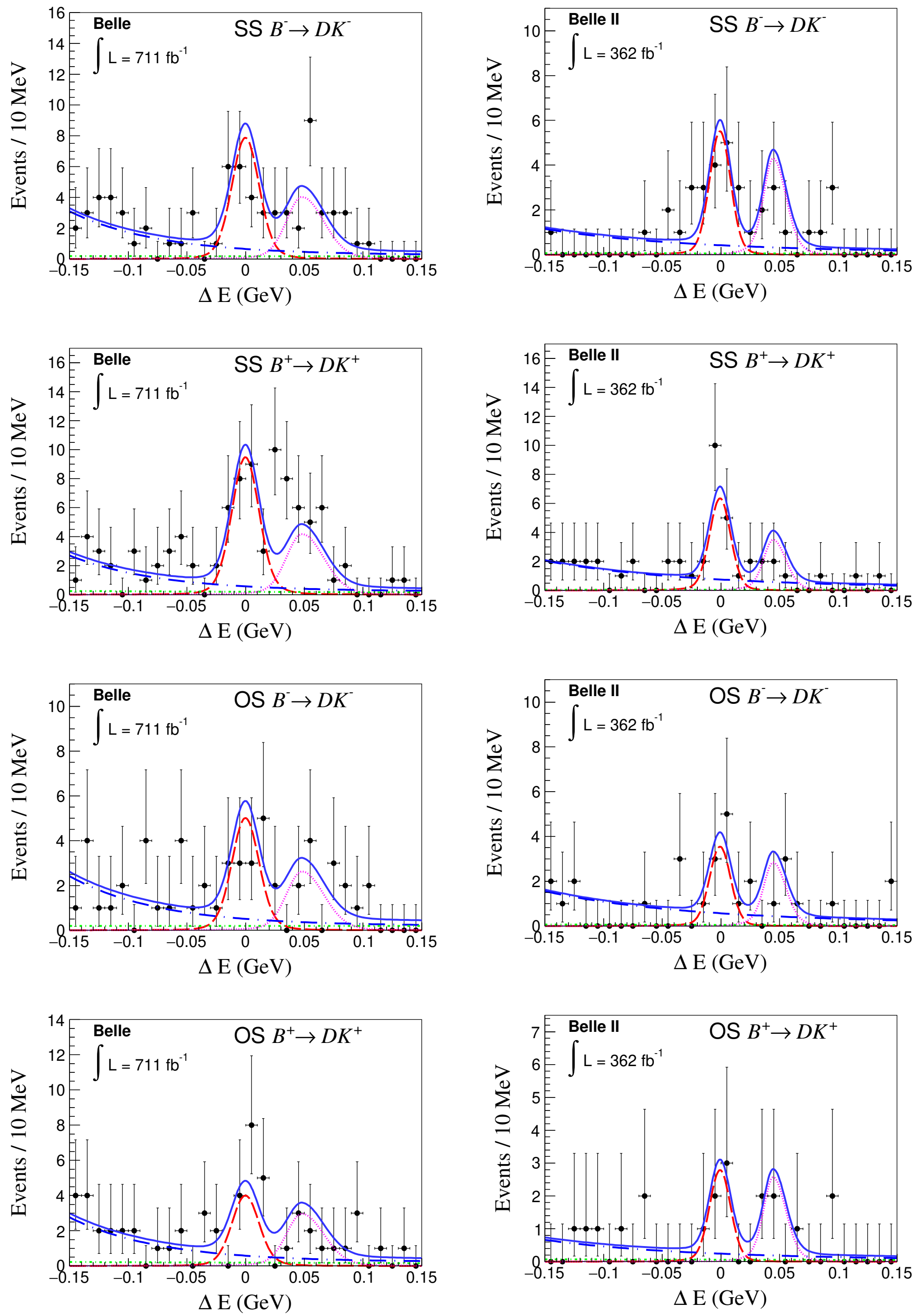
Full D phase space

$$\mathcal{A}_{SS}^{DK} = -0.089 \pm 0.091 \pm 0.011$$
$$\mathcal{A}_{OS}^{DK} = -0.109 \pm 0.133 \pm 0.013$$
$$\mathcal{A}_{SS}^{D\pi} = 0.018 \pm 0.026 \pm 0.011$$
$$\mathcal{A}_{OS}^{D\pi} = -0.028 \pm 0.031 \pm 0.009$$
$$\mathcal{R}_{SS}^{DK/D\pi} = 0.122 \pm 0.012 \pm 0.004$$
$$\mathcal{R}_{OS}^{DK/D\pi} = 0.093 \pm 0.013 \pm 0.002$$
$$\mathcal{R}_{SS/OS}^{D\pi} = 1.428 \pm 0.057 \pm 0.002$$

K^* region

$$\mathcal{A}_{SS}^{DK} = 0.055 \pm 0.119 \pm 0.020$$
$$\mathcal{A}_{OS}^{DK} = 0.231 \pm 0.184 \pm 0.014$$
$$\mathcal{A}_{SS}^{D\pi} = 0.046 \pm 0.029 \pm 0.016$$
$$\mathcal{A}_{OS}^{D\pi} = 0.009 \pm 0.046 \pm 0.009$$
$$\mathcal{R}_{SS}^{DK/D\pi} = 0.093 \pm 0.012 \pm 0.005$$
$$\mathcal{R}_{OS}^{DK/D\pi} = 0.103 \pm 0.020 \pm 0.006$$
$$\mathcal{R}_{SS/OS}^{D\pi} = 2.412 \pm 0.132 \pm 0.019$$

Full D phase space



γ/ϕ_3 with Cabbibo-suppressed channels

Systematic uncertainties

	$A_{\rm SS}^{DK}$	$A_{\rm OS}^{DK}$	$A_{\rm SS}^{D\pi}$	$A_{\rm OS}^{D\pi}$	$R_{\rm SS}^{DK/D\pi}$	$R_{\rm OS}^{DK/D\pi}$	$R_{\rm SS/OS}^{D\pi}$
			Full D phase space				
$\epsilon_{K^\pm}, \epsilon_{\pi^\pm}$	0.38	0.56	0.19	0.14	0.05	0.06	0.09
δ	—	0.03	—	—	0.04	0.03	0.02
Model	0.62	0.78	0.02	0.02	0.30	0.22	0.07
$\epsilon_{K_S^0 K^-\pi^+}/\epsilon_{K_S^0 K^+\pi^-}$	0.82	0.83	0.82	0.83	0.01	0.01	0.02
Total syst. unc.	1.1	1.3	0.9	0.9	0.4	0.3	0.2
Stat. unc.	9.1	13.3	2.6	3.1	1.2	1.3	5.7
			$K^*(892)^\pm$ region				
$\epsilon_{K^\pm}, \epsilon_{\pi^\pm}$	0.37	0.61	0.17	0.15	0.03	0.08	0.13
δ	0.02	0.02	0.01	0.01	0.03	0.04	0.04
Model	1.04	0.97	0.20	0.03	0.46	0.49	0.61
$\epsilon_{K_S^0 K^-\pi^+}/\epsilon_{K_S^0 K^+\pi^-}$	1.6	0.8	1.6	0.8	0.1	0.1	1.7
Total syst. unc.	2.0	1.4	1.6	0.9	0.5	0.6	1.9
Stat. unc.	11.9	18.4	2.9	4.6	1.2	2.0	13.2

γ/ϕ_3 with CP eigenstates

Physics meanings

$$\mathscr{A}_{CP\pm} = \frac{\Gamma(B^- \to D_{CP\pm}K^-) - \Gamma(B^+ \to D_{CP\pm}K^+)}{\Gamma(B^- \to D_{CP\pm}K^-) + \Gamma(B^+ \to D_{CP\pm}K^+)} = \pm \frac{r_B \sin\delta_B sin\phi_2}{1 + r_B^2 \pm 2r_B \cos delta_B \cos\phi_3},$$

$$\mathscr{R}_{CP\pm} = \frac{\mathscr{B}(B^- \to D_{CP\pm}K^-) + \mathscr{B}(B^+ \to D_{CP\pm}K^+)}{\mathscr{B}(B^- \to D_{flav}K^-) + \mathscr{B}(B^+ \to D_{flav}K^+)} \approx \frac{R_{CP\pm}}{R_{flav}}, \text{with}$$

$$R_X \equiv \frac{\mathscr{B}(B^- \to D_X K^-) + \mathscr{B}^+ \to D_X K^+)}{\mathscr{B}(B^- \to D_X \pi^-) + \mathscr{B}^+ \to D_X \pi^+)}.$$

$$\Rightarrow \begin{cases} \mathscr{R}_{CP\pm} = 1 + r_B^2 \pm 2\cos\delta_B \cos\phi_3 \\ \mathscr{A}_{CP\pm} = \pm 2r_B \sin\phi_3/\mathscr{R}_{CP\pm} \end{cases}, \text{ assuming } CP \text{ conservation in } B^\pm \to D\pi^\pm$$

- Channels:
  - Signal: $B \to D(\to KK, K_S^0\pi^0)K$
  - R_{flav} control channel: $B \to D(\to K\pi)K$
  - R_X control channel: $B \to D\pi$

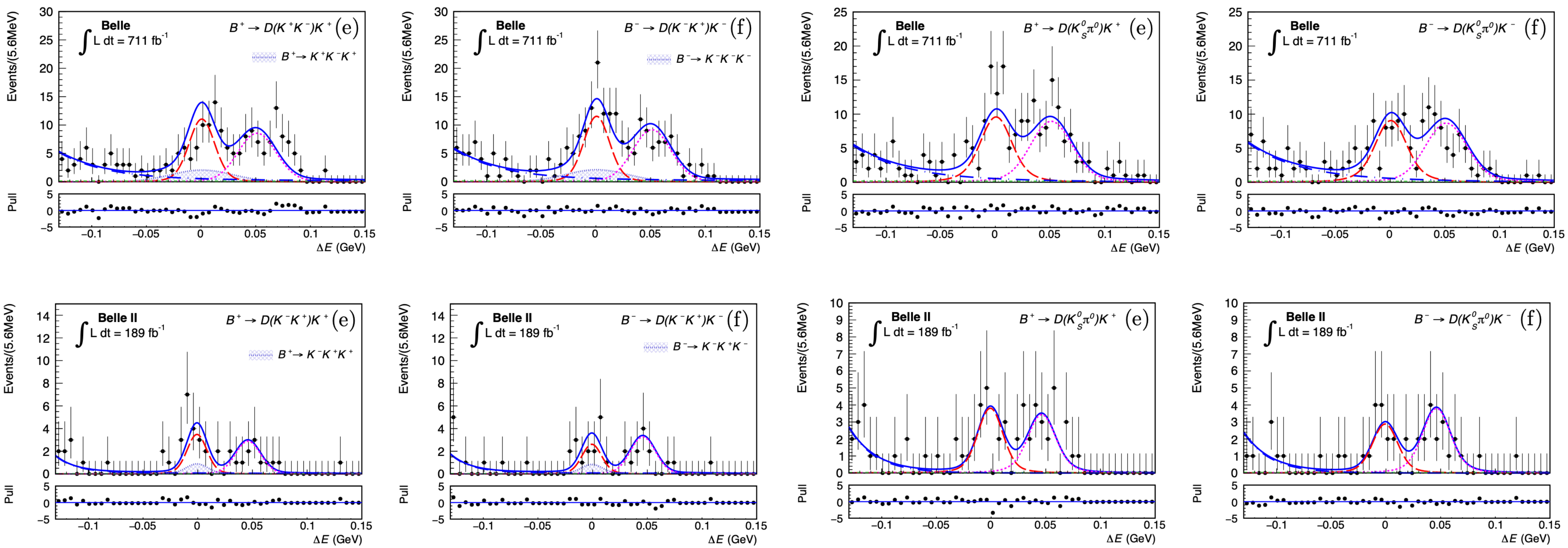
γ/ϕ_3 with CP eigenstates

Results

	68.3% CL	95.4% CL
ϕ_3 (°)	[8.5, 16.5]	[5.0, 22.0]
	[84.5, 95.5]	[80.0, 100.0]
	[163.3, 171.5]	[157.5, 175.0]
r_B	[0.321, 0.465]	[0.241, 0.522]

Yields

D_X mode		$N(B \to D_X K)$	$N(B \to D_X \pi)$
$D \to K^{\pm}\pi^{\mp}$	Belle	4238(94)	59 481(267)
	Belle II	1084(44)	14 229(126)
$D \to K^+K^-$	Belle	476(36)	5559(85)
	Belle II	107(15)	1336(40)
$D \to K_S^0\pi^0$	Belle	541(42)	6484(95)
	Belle II	145(16)	1763(46)



γ/ϕ_3 with CP eigenstates

Systematic uncertainties

	$\mathcal{R}_{CP+}$	$\mathcal{R}_{CP-}$	$\mathcal{A}_{CP+}$	$\mathcal{A}_{CP-}$
PDF parameters	0.012	0.014	0.002	0.002
PID parameters	0.009	0.010	0.003	0.005
peaking background yields	0.033	0.002	0.013	—
Efficiency ratio	0.001	0.001	<0.001	<0.001
commonality of ΔE modes	−0.005	−0.006	<0.001	<0.001
Total systematic uncertainty	0.036	0.019	0.014	0.006
Statistical uncertainty	0.081	0.074	0.058	0.057

Isospin sum rule

Systematic uncertainties

TABLE II. Summary of the relative systematic uncertainties (%) on the branching ratios.

Source	$B^0 \to K^+\pi^-$	$B^0 \to \pi^+\pi^-$	$B^+ \to K^+\pi^0$	$B^+ \to \pi^+\pi^0$	$B^+ \to K_S^0\pi^+$	$B^0 \to K_S^0\pi^0$
Tracking	0.5	0.5	0.2	0.2	0.7	0.5
$N_{B\bar{B}}$	1.5	1.5	1.5	1.5	1.5	1.5
$f^{+-/00}$	2.5	2.5	2.4	2.4	2.4	2.5
π^0 efficiency	-	-	5.0	5.0	-	5.0
K_S^0 efficiency	-	-	-	-	2.0	2.0
CS efficiency	0.2	0.2	0.7	0.7	0.5	1.7
PID correction	0.1	0.1	0.1	0.2	-	-
ΔE shift and scale	0.1	0.2	1.2	2.0	0.3	1.7
$K\pi$ signal model	0.1	0.2	0.1	<0.1	<0.1	0.1
$\pi\pi$ signal model	<0.1	0.1	<0.1	<0.1	-	-
$K\pi$ CF model	<0.1	0.1	<0.1	0.1	-	-
$\pi\pi$ CF model	0.1	0.2	<0.1	0.1	-	-
$K_S^0K^+$ model	-	-	-	-	0.1	-
$B\bar{B}$ model	-	-	0.3	0.5	<0.1	0.3
Multiple candidates	<0.1	<0.1	1.0	0.3	0.1	0.3
Total	3.0	3.0	6.0	6.2	3.6	6.6

TABLE III. Summary of the absolute systematic uncertainties on the *CP* asymmetries.

Source	$B^+ \to K^+\pi^-$	$B^+ \to K^+\pi^0$	$B^+ \to \pi^+\pi^0$	$B^+ \to K_S^0\pi^+$	$B^0 \to K_S^0\pi^0$
ΔE shift and scale	<0.001	0.001	0.002	0.001	0.003
$K_S^0K^+$ model	-	-	-	0.001	-
$B\bar{B}$ background asymmetry	-	-	-	-	0.046
$q\bar{q}$ background asymmetry	-	-	-	-	0.024
Fitting bias	-	-	0.007	0.006	-
Instrumental asymmetry	0.007	0.005	0.004	0.004	-
Total	0.007	0.005	0.008	0.007	0.052