Recent B $\rightarrow$ hadron results from Belle II

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B → hadron WG at Belle II

Measure *B* decays without lepton

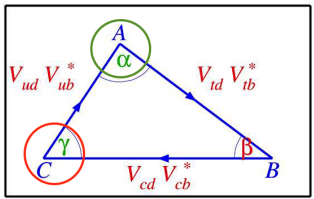
Two categories:

favored charmed $b \to c$ transitions

suppressed charmless $b \to u$ and $b \to d$ transitions

What can we do with them?

(Re-)measurements for better simulation



SM null tests

(Re-)measurements

Roughly 30% of B $\rightarrow$ hadron decays are still not measured.

Known decays often rely on 20+ year old measurements with small data sets.

- Poor knowledge of B $\rightarrow$ hadron decays leads to poor simulation
- Large data-simulation discrepancies, e.g. calibration factors for hadronic B^+ (B^0) tagging 0.65 ± 0.02 (0.83 ± 0.03) [2008.06096]
- Source of systematic uncertainty

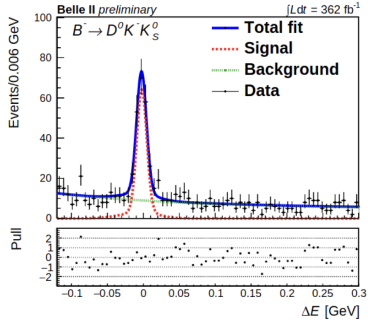
$\Rightarrow$ **Measure decays to improve simulation and enhance performance of our tools**

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

Total BF of $B \to D^{(*)}K^{(*)}K^{(*)}$ could be up to 6% (Pythia), only 0.3% measured

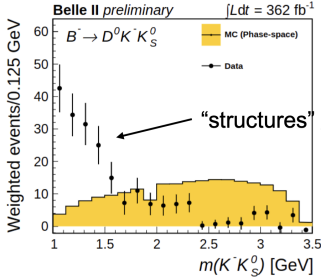
Currently not used in hadronic tagging, excellent candidates to improve tagging efficiency due to high purity

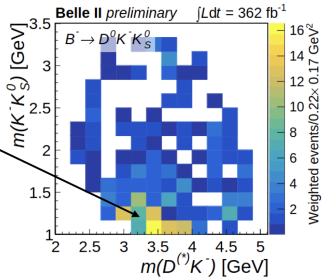
Fit $\Delta E = E^*_B - E^*_{\text{beam}}$ distribution and study background subtracted $m(KK^0_S)$ and Dalitz distributions [2305.01321]



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

3 first observations





Determination of CKM angle ϕ_3/γ

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phase between $b \to u$ and $b \to c$ transitions

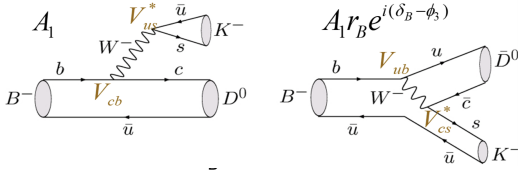
tree level only, negligible theory uncertainty

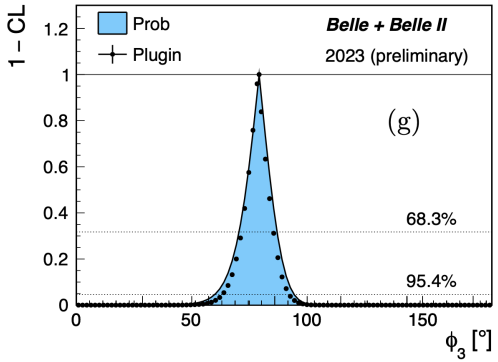
Several Belle + Belle II measurments:

- $D \to K^0_S hh$ [JHEP 02 (2022) 063]
- $D \to K^0_S K\pi$ [2306.02940]
- $D \to K^0_S \pi^0, KK$ [2308.05048]

New determination of γ using only Belle and Belle II measurments: $\gamma = (78.6 \pm 7.3)^\circ$

LHCb only: $\gamma = (63.8 \pm 3.6)^\circ$





Towards CKM angle ϕ_2/α

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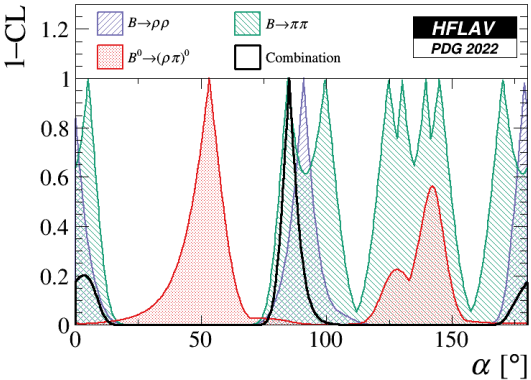
Least well known angle of CKM triangle

Accessible in tree level $B^0 \to \pi^+\pi^-$ transitions

Measured value shifted due to loop level contributions

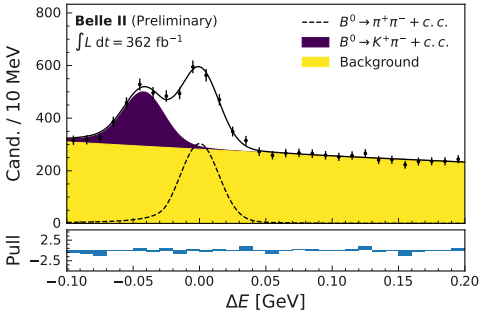
Remove shift using BF and ACP of $B^+ \to \pi^+\pi^0$ and $B^0 \to \pi^0\pi^0$

Opportunity for Belle II due to neutrals in final states.

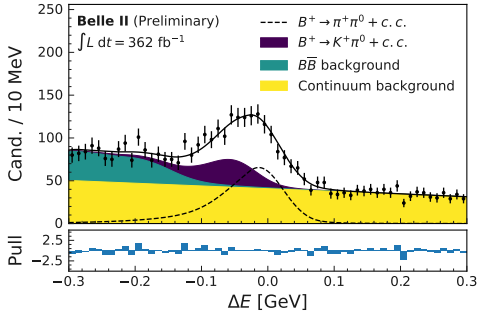


Similar for $B \to \rho\rho$ decays, better sensitivity due to smaller penguin pollution but experimentally more challenging

Towards CKM angle ϕ_2/α



$$\mathcal{B} = (5.83 \pm 0.33(\text{stat}) \pm 0.17(\text{syst})) \times 10^{-6}$$



$$\mathcal{A}^{CP} = 0.081 \pm 0.54(\text{stat}) \pm 0.008(\text{syst})$$
$$\mathcal{B} = (5.10 \pm 0.29(\text{stat}) \pm 0.32 \ (\text{syst})) \times 10^{-6}$$

World best result for BF of $B^0 \to \pi^+\pi^-$

SM Null Tests

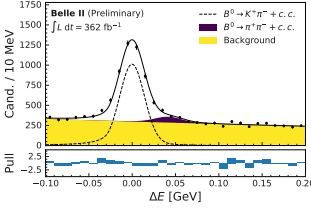
Isospin sum-rule

Combination of $B \to K\pi$ decays offers SM null test [Phys.Lett.B 627 (2005) 82-88]:

$$\mathcal{A}^{\mathrm{CP}}_{K^+\pi^-} + \mathcal{A}^{\mathrm{CP}}_{K^0\pi^+}\frac{\mathcal{B}_{K^0\pi^+}}{\mathcal{B}_{K^+\pi^-}}\frac{\tau_{B^0}}{\tau_{B^+}} - 2\mathcal{A}^{\mathrm{CP}}_{K^+\pi^0}\frac{\mathcal{B}_{K^+\pi^0}}{\mathcal{B}_{K^+\pi^-}}\frac{\tau_{B^0}}{\tau_{B^+}} - 2\mathcal{A}^{\mathrm{CP}}_{K^0\pi^0}\frac{\mathcal{B}_{K^0\pi^0}}{\mathcal{B}_{K^+\pi^-}} \approx 0$$

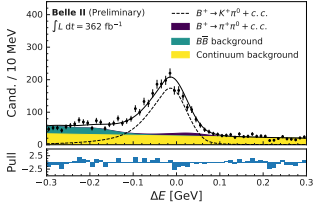
Theoretical precision: $\mathcal{O}(0.01)$, Experimental precision: $\mathcal{O}(0.1)$

Belle II is a unique place to measure all involved decays!



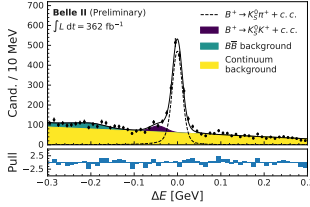
$\mathcal{A}^{\mathrm{CP}} = (-7.2 \pm 1.9\ \ (\mathrm{stat}) \pm 0.7(\mathrm{syst}))\%$

$\mathcal{B} = (20.67 \pm 0.37(\mathrm{stat}) \pm 0.6(\mathrm{syst})) \times 10^{-6}$



$\mathcal{A}^{\mathrm{CP}} = \ \ (1.3 \pm 2.7\ \ (\mathrm{stat}) \pm 0.5\ \ (\mathrm{syst}))\%$

$\mathcal{B} = (14.21 \pm 0.38(\mathrm{stat}) \pm 0.85(\mathrm{syst})) \times 10^{-6}$



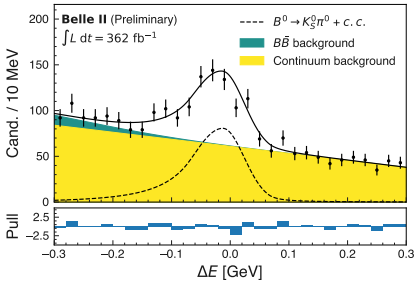
$\mathcal{A}^{\mathrm{CP}} = \ \ (4.6 \pm 2.9\ \ (\mathrm{stat}) \pm 0.7\ \ (\mathrm{syst}))\%$

$\mathcal{B} = (24.40 \pm 0.71(\mathrm{stat}) \pm 0.86(\mathrm{syst})) \times 10^{-6}$

Isospin sum-rule

Two analyses of $B^0 \to K^0_S \pi^0$ one time-dependent [PRL 131, 111803 (2023)] and one time-integrated. Both are combined to enhance sensitivity.

$$\mathcal{A}^{CP} = -0.01 \pm 0.12\,(\text{stat}) \pm 0.05\,(\text{syst})$$
$$\mathcal{B} = (10.50 \pm 0.62\,(\text{stat}) \pm 0.67\,(\text{syst})) \times 10^{-6}$$



Putting all together for the null test:

$$-0.03 \pm 0.13 \pm 0.05$$

Competitive with world average -0.13 ± 0.11

Summary

Ongoing studies of the B $\rightarrow$ hadron working group aim to:

- Improve our simulation
- Perform precision measurements of ϕ_2 and ϕ_3
- Conduct null tests of the SM