First measurement from Charmless B Decays at Belle II

Yun-Tsung Lai

On behalf of Belle II collaboration

Kavli IPMU

yun-tsung.lai@ipmu.jp

1

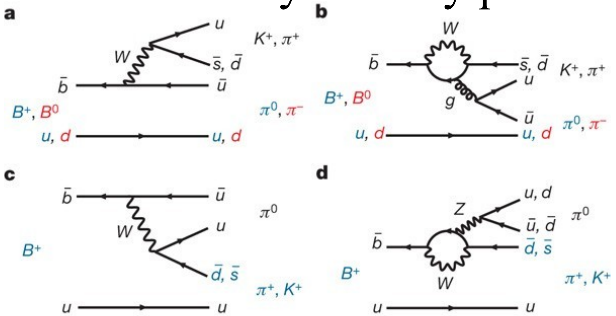
Beauty 2020

Sep. 22nd, 2020

Introduction

- Charmless B decays mainly process via:

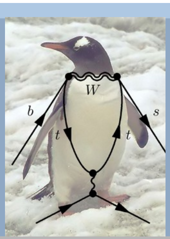
$b \to u$: Cabibbo-suppressed tree diagram.



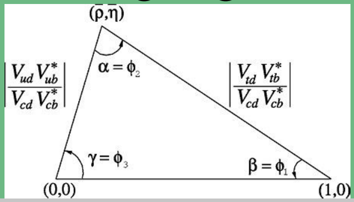
$b \to d,s$: Penguin diagram.

- A good topic to search for new physics in Belle II.

Non-SM contribution in the penguin loop.

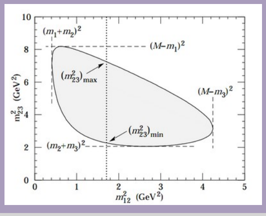


More precise quark-mixing angle α/φ_2 measurement by Belle II.



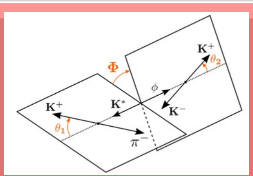
Interference between different amplitudes:

Localized CP violation in three-body decays.



$B \to K\pi$ puzzles: $\mathcal{B}$ and $\mathcal{A}_{CP}$ relations constrained by isospin sum rule.

Polarization "puzzles" in $B \to \varphi K^*$.



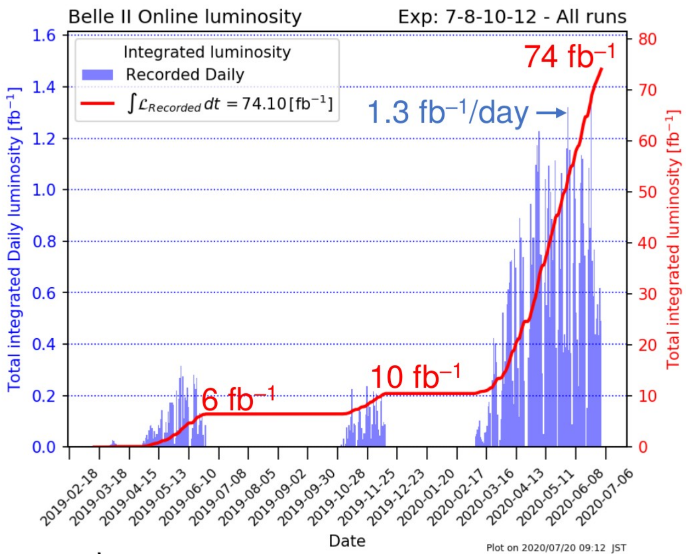
Time-dependent CP violation measurement of $B \to \varphi K^0$ v.s. $B \to J/\psi K^0$.

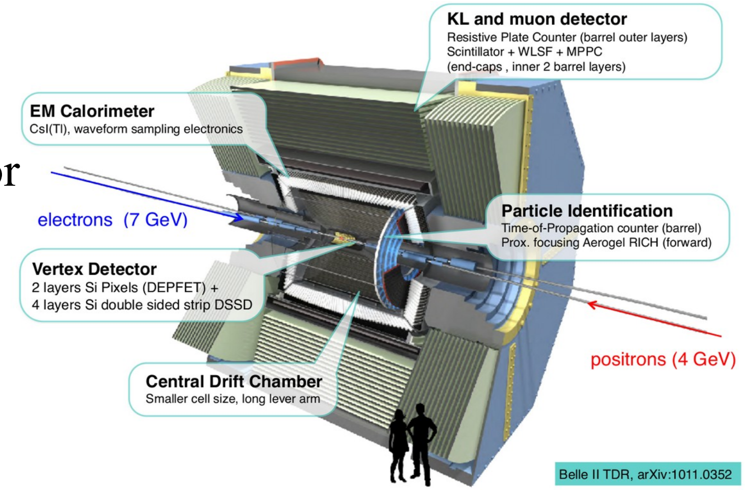
Decays into neutral particle (e.g. π^0, K_s): Complementary to LHCb.

Challenge: Small signals and final states hardly distinguishable from 10^5 times larger common backgrounds: PID and comtinuum suppression are critical.

Belle II experiment

- Belle II with SuperKEKB:
  - L_{int}: ~74 fb^{-1} in 2019~2020.
  - World record L_{peak}: 2.4 $x10^{-34}$ $cm^{-2}s^{-1}$ with lower beam currents than KEKB's.
- In this report:
  - A good-quality skimmed data sample of 34.6 fb^{-1} is used (~38M $B\bar{B}$ events).
  - Early stage work: Uses the rediscovery results to validate and optimize the detector performance, software and analysis techniques, etc.





12 decay modes

arXiv:2009.09452

* $B^0 \rightarrow K^+\pi^-$	$B^0 \rightarrow \pi^+\pi^-$
* $B^+ \rightarrow K^+\pi^0$	* $B^+ \rightarrow \pi^+\pi^0$
* $B^+ \rightarrow K^0\pi^+$	$B^0 \rightarrow K^0\pi^0$
* $B^+ \rightarrow K^+K^-K^+$	* $B^+ \rightarrow K^+\pi^-\pi^+$

arXiv:2008.03873

$B^+ \rightarrow \varphi K^+$

$B^0 \rightarrow \varphi K^0$

v $B^+ \rightarrow \varphi K^{*+}$

v $B^0 \rightarrow \varphi K^{*0}$

- Branching fraction.
- CP asymmetry(*): Flavor-specific final state.
- Polarization parameter(v): $B \rightarrow \varphi K^*$

Selection and reconstruction

Charged track:
- Vertex detector and Drift chamber..
- Full polar acceptance in drift chamber.
- Impact parameters: to reduce off-IP tracks from beam background.

PID:
- From TOP and ARICH detectors.
- Validation with $B^+ \to \overline{D}^0 \pi^+$.

$\pi^0 \to \gamma\gamma$:
- Photon energy > 20 MeV.
- Mass window selection.
- Exclude extreme helicity angle: to reduce background from collinear soft γ.
- Kinematic fit to constrain π^0 mass.
- Selection is optimized with $B^+ \to \overline{D}^0 \pi^+$.
- Validation with $B^0 \to D^{*-} \pi^+$.

Peaking bkg veto for 3-body modes:
- From charmonion and charmed intermidiate state.
- Veto on peaking structures' mass windows in 2-body invariant masses.

$K^0_S \to \pi^+ \pi^-$:
- 2 pions from a common vertex.
- Additional requirements on K^0_s momentum, flight distance, distance between trajectories of the two pions, angle between K^0_S and π direction.
- Validation with $B \to \varphi K^{(*)}$ modes.

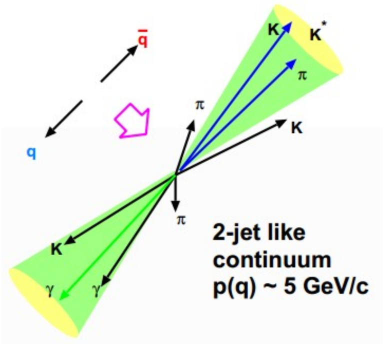
Selection and reconstruction (cont'd)

Continuum suppression: Challenge for this study.

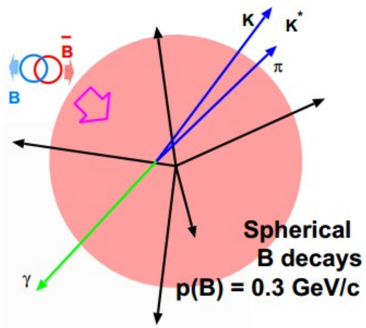
- Multivariate tool: Binary boosted decision-tree (BDT) to combine 30+ variables.

- Input variables to BDT:
  - Event topology.
  - Flavor tagging.
  - Vertex information.
  - Kinematic fit.

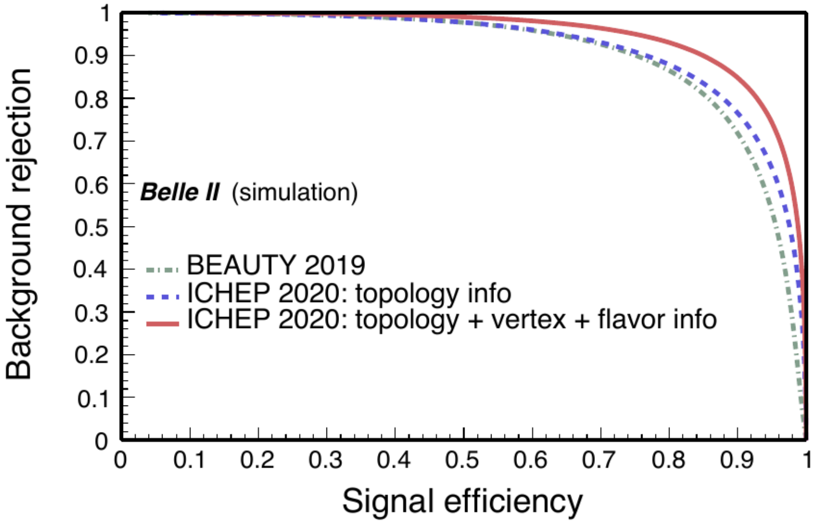
- The input variables are required to be not correlated with variables for fitting.
- Selections are optimized.
- Validation with $B^+ \to \overline{D}^0 \pi^+$.



$q\overline{q}$ event



$B\overline{B}$ decay



Signal extraction and physics observables

Signal extraction: Unbinned maximum likelihood fit

- Energy difference: $\Delta E \equiv E_B^* - \sqrt{s}/2$
- Beam-energy-constrained mass: $M_{\rm bc} \equiv \sqrt{s/(4c^4) - (p_B^*/c)^2}$
- Transformed continuum suppression multivariate discriminator: $C'_{\rm out}$
- Invariant mass / cosine of helicity angle
  - of φ : $m(K^+K^-)$ / $\cos\theta_{H,\phi}$
  - of K^*: $m(K\pi)$ / $\cos\theta_{H,K^*}$

Branching fraction

$$\mathcal{B} = \frac{N}{\varepsilon \times 2 \times N_{B\bar{B}}}$$

N: **Signal yield**

ε: **Signal reconstruction efficiency**

B^+B^-: 19.7M

$B^0\bar{B}^0$: 18.7M

CP asymmetry

For the flavor-specific modes

$$\mathcal{A} = \frac{N(b) - N(\bar{b})}{N(b) + N(\bar{b})} = \mathcal{A}_{CP} + \mathcal{A}_{\rm det}$$

$\mathcal{A}$: **Raw asymmetry**

$N(b)$, $N(\bar{b})$: **Yield of the two flavors' final state.**

$\mathcal{A}_{CP}$: **CP asymmetry**

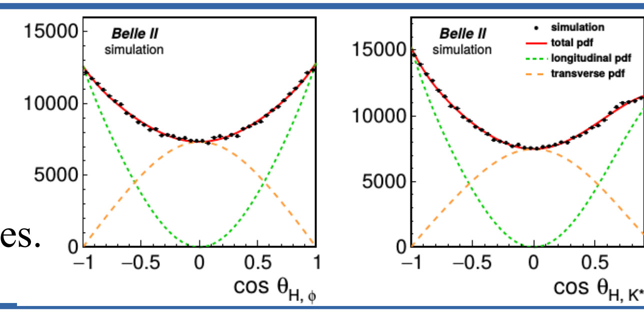
$\mathcal{A}_{\rm det}$: **Instrumental asymmetry**

f_L

For $B \to \varphi K^*$

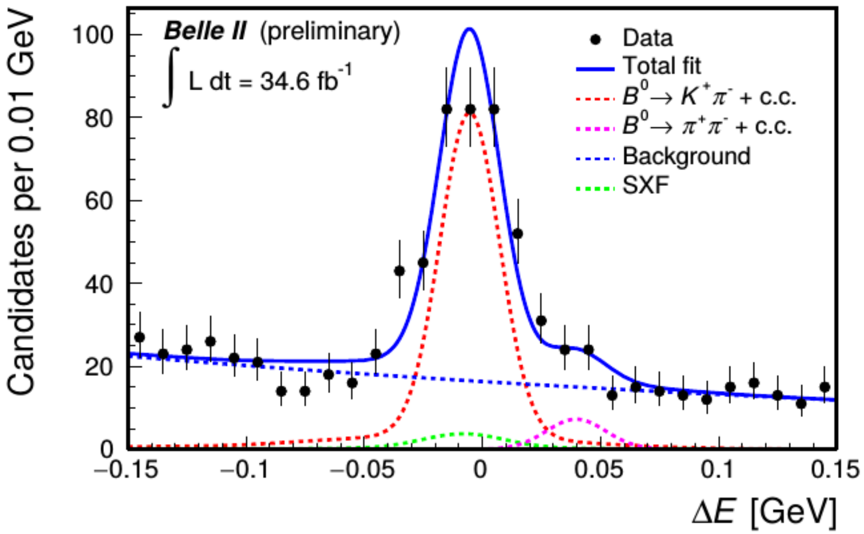
$$f_L = \frac{N_L/\varepsilon_L}{N_L/\varepsilon_L + N_T/\varepsilon_T}$$

Separation of signal yields: using the PDFs in helicity angles.



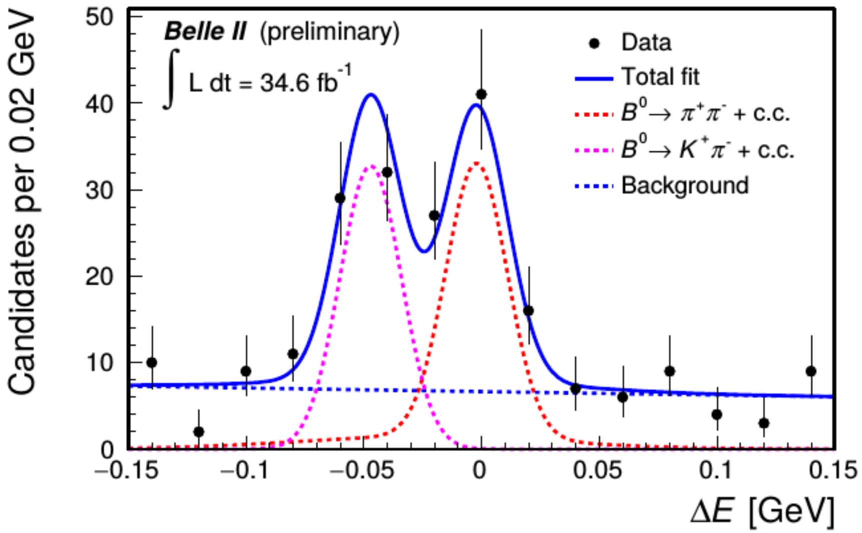
$B^0 \to K^+\pi^-$, $B^0 \to \pi^+\pi^-$: two-track final state

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



Signal Yield	289^{+22}_{-21}
Measured $\mathcal{B}$ (10^{-6})	$18.9 \pm 1.4(stat.) \pm 1.0(syst.)$
PDG (10^{-6})	19.6±0.5

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

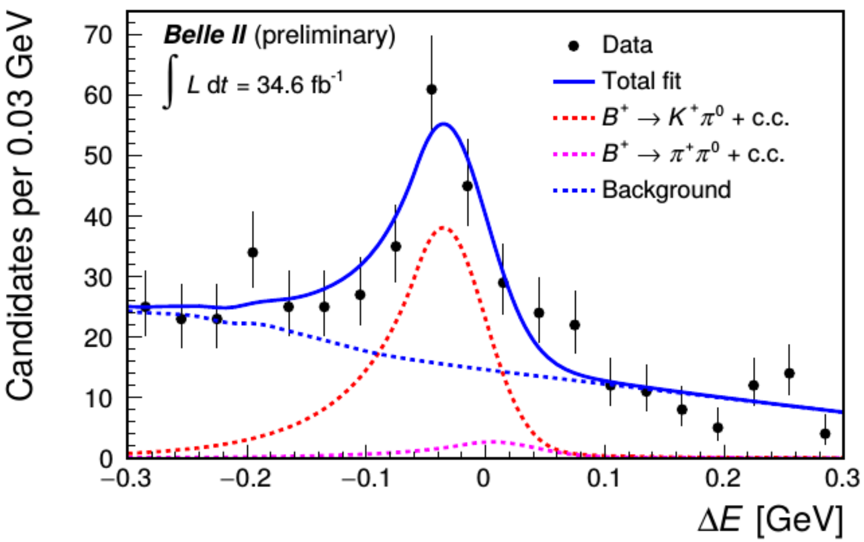


Signal Yield	62^{+11}_{-10}
Measured $\mathcal{B}$ (10^{-6})	$5.6^{+1.0}_{-0.9}(stat.) \pm 0.3(syst.)$
PDG (10^{-6})	5.12±0.19

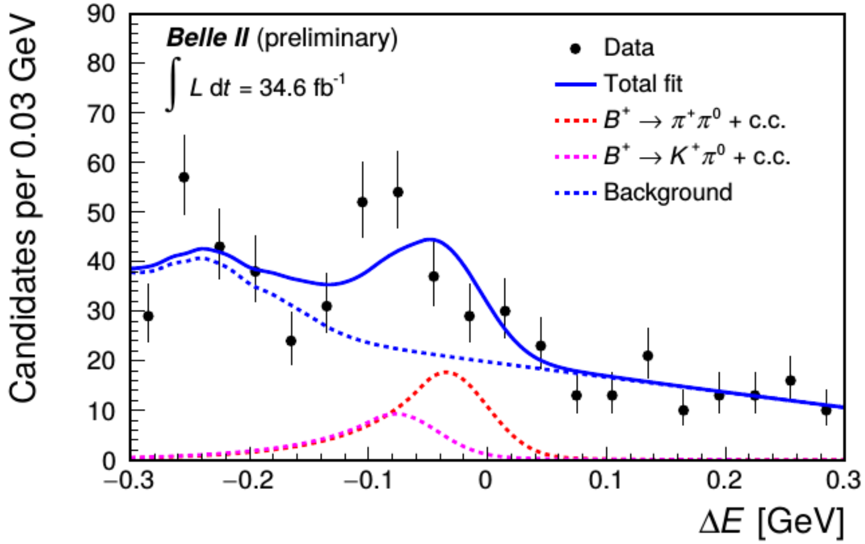
- 1D fit on difference between observed and expected B energy: $\Delta E \equiv E_B^* - \sqrt{s}/2$
- $B^0 \to K^+\pi^-$: relevant for isospin sum rule.
- $B^0 \to \pi^+\pi^-$: φ_2 determination.
- Physics validations on charged-particle reconstruction and PID.

$B^+ \to K^+\pi^0$, $B^+ \to \pi^+\pi^0$: 1 track and 1 π^0

$B^+ \to K^+\pi^0$



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



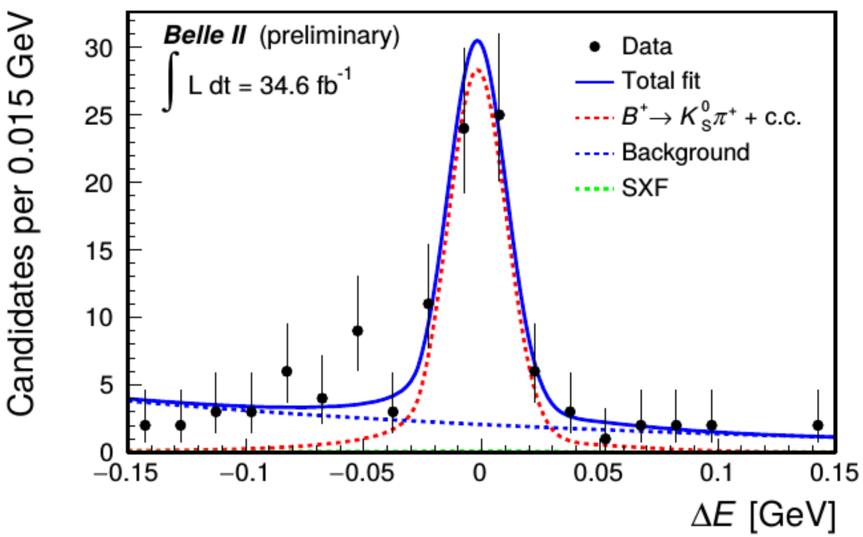
Signal Yield	144^{+25}_{-24}
Measured $\mathcal{B}$ (10^{-6})	$12.7^{+2.2}_{-2.1}(stat.) \pm 1.1(syst.)$
PDG (10^{-6})	12.9 ± 0.5

Signal Yield	68 ± 27
Measured $\mathcal{B}$ (10^{-6})	$5.7 \pm 2.3(stat.) \pm 0.5(syst.)$
PDG (10^{-6})	5.5 ± 0.4

- 1D fit on difference between observed and expected B energy: $\Delta E \equiv E_B^* - \sqrt{s}/2$
- $B^+ \to K^+\pi^0$: relevant for isospin sum rule.
- $B^+ \to \pi^+\pi^0$: φ_2 determination.
- Physics validation on π^0 reconstruction.

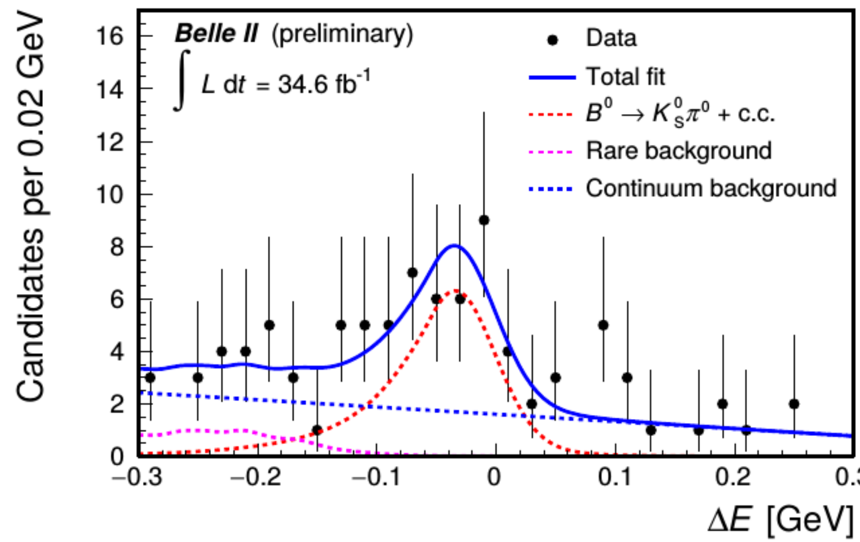
$B^+ \to K^0\pi^+$, $B^0 \to K^0\pi^0$: Final state with K^0_S

$B^+ \to K^0\pi^+$



Signal Yield	65^{+10}_{-9}
Measured $\mathcal{B}$ (10^{-6})	$21.8^{+3.3}_{-3.0}(stat.) \pm 2.9(syst.)$
PDG (10^{-6})	23.7 ± 0.8

$B^0 \to K^0\pi^0$

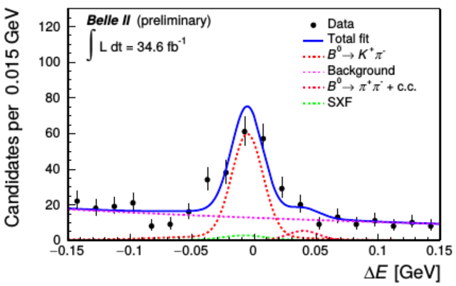


Signal Yield	35 ± 9
Measured $\mathcal{B}$ (10^{-6})	$10.9^{+2.9}_{-2.6}(stat.) \pm 1.6(syst.)$
PDG (10^{-6})	9.9 ± 0.5

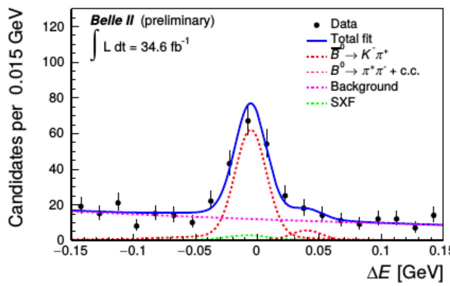
- 1D fit on difference between observed and expected B energy: $\Delta E \equiv E^*_B - \sqrt{s}/2$
- Relevant for isospin sum rule.
- Physics validation on K^0_S reconstruction scheme.

$\mathcal{A}_{CP}$ measurement for two-body decays

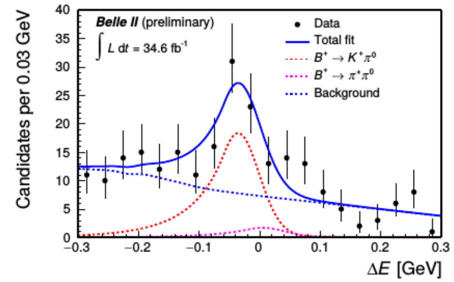
$B^0 \to K^+\pi^-$ 142^{+13}_{-13}



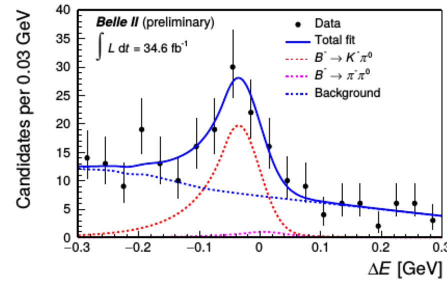
$\overline{B}^0 \to K^-\pi^+$ 147^{+13}_{-13}



$B^+ \to K^+\pi^0$ 69^{+14}_{-14}



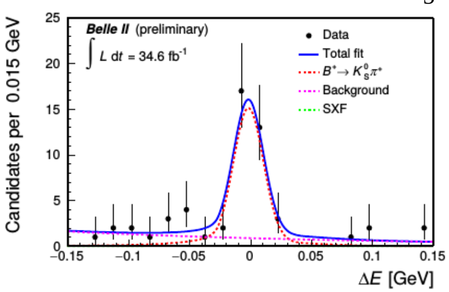
$B^- \to K^-\pi^0$ 75^{+15}_{-15}



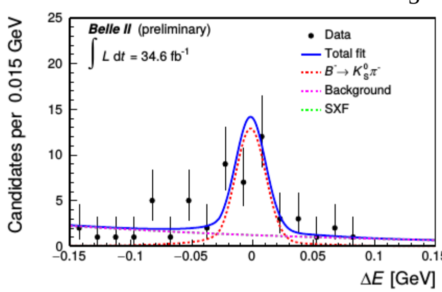
Measured $\mathcal{A}_{CP}$	$0.030 \pm 0.064(stat.) \pm 0.008(syst.)$
PDG	-0.083 ± 0.004

Measured $\mathcal{A}_{CP}$	$0.052^{+0.121}_{-0.119}(stat.) \pm 0.022(syst.)$
PDG	0.037 ± 0.021

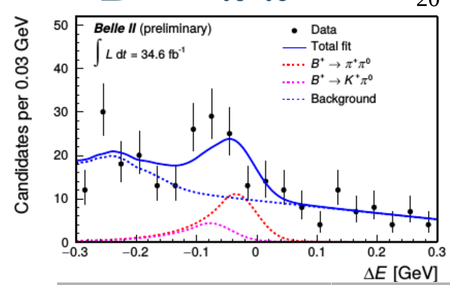
$B^+ \to K^0\pi^+$ 35^{+5}_{-5}



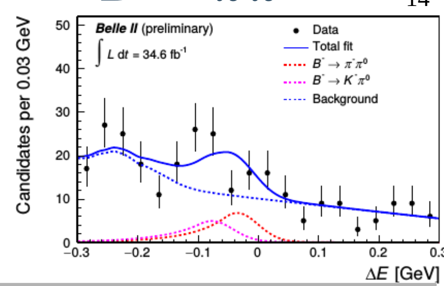
$B^- \to K^0\pi^-$ 30^{+4}_{-5}



$B^+ \to \pi^+\pi^0$ 43^{+19}_{-20}



$B^- \to \pi^-\pi^0$ 24^{+13}_{-14}



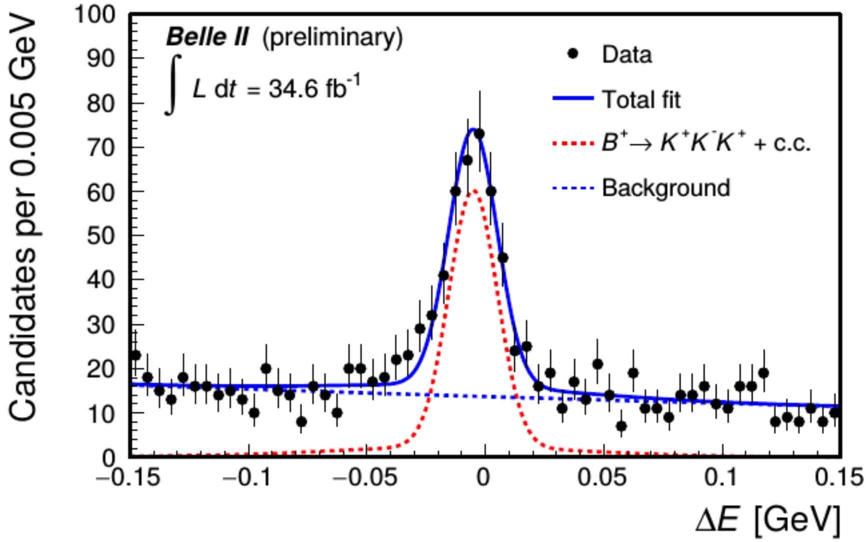
Measured $\mathcal{A}_{CP}$	$-0.072^{+0.109}_{-0.114}(stat.) \pm 0.024(syst.)$
PDG	-0.017 ± 0.016

Measured $\mathcal{A}_{CP}$	$-0.268^{+0.249}_{-0.322}(stat.) \pm 0.123(syst.)$
PDG	0.03 ± 0.04

- Fit to obtain yields of the 2 flavor's final states.
- Prompts a thorough data-driven study of charge-dependent reconstruction asymmetries: important for upcoming CP violation measurements.

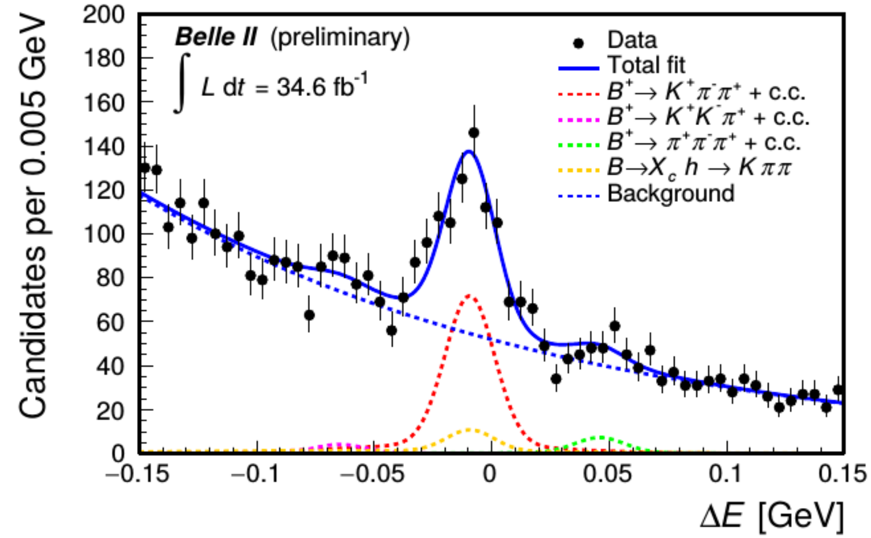
$B^+ \to K^+K^-K^+$, $B^+ \to K^+\pi^-\pi^+$: Three-body final state

$B^+ \to K^+K^-K^+$



Signal Yield	359 ± 25
Measured $\mathcal{B}$ (10^{-6})	**$32.0 \pm 2.2(stat.) \pm 1.4(syst.)$**
PDG (10^{-6})	34.0 ± 1.4

$B^+ \to K^+\pi^-\pi^+$

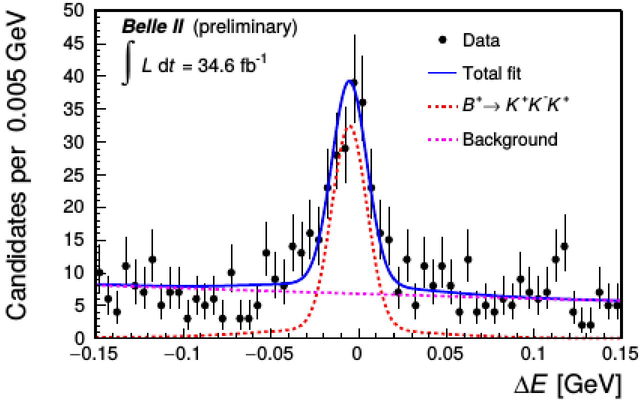


Signal Yield	449 ± 37
Measured $\mathcal{B}$ (10^{-6})	**$48.0 \pm 3.8(stat.) \pm 3.3(syst.)$**
PDG (10^{-6})	51.0 ± 2.9

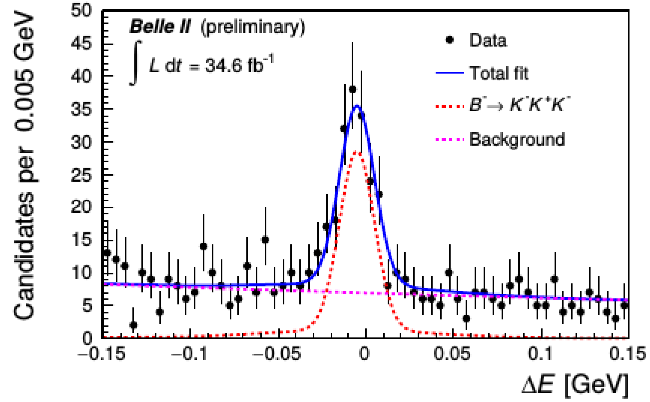
- 1D fit on difference between observed and expected B energy: $\Delta E \equiv E_B^* - \sqrt{s}/2$
- Prospect: analysis with Dalitz plot for resonance search and localized CP violation.
- Physics validation on simulation/treatment of complicated peaking backgrounds.

$\mathcal{A}_{CP}$ measurement for three-body decays

$B^+ \rightarrow K^+K^-K^+$ 191 ± 16



$B^- \rightarrow K^-K^+K^-$ 168 ± 16

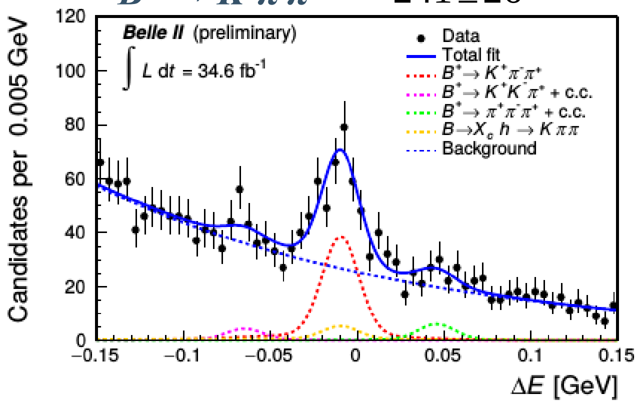


$B^+ \rightarrow K^+K^-K^+$

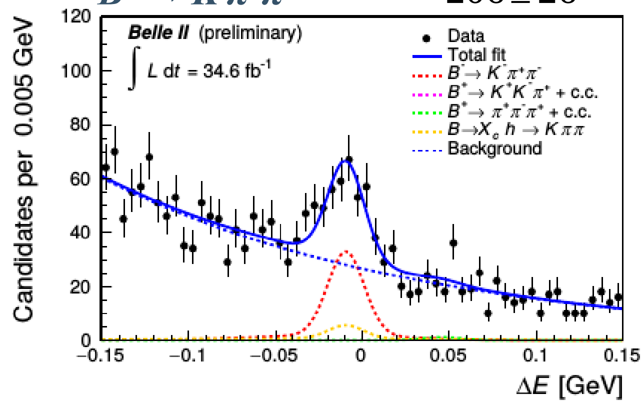
Measured $\mathcal{A}_{CP}$	$-0.049 \pm 0.063(stat.) \pm 0.022(syst.)$
PDG	-0.033 ± 0.008

- Prospect: localized asymmetry search with Dalitz plot.

$B^+ \rightarrow K^+\pi^-\pi^+$ 241 ± 26



$B^- \rightarrow K^-\pi^+\pi^-$ 206 ± 26

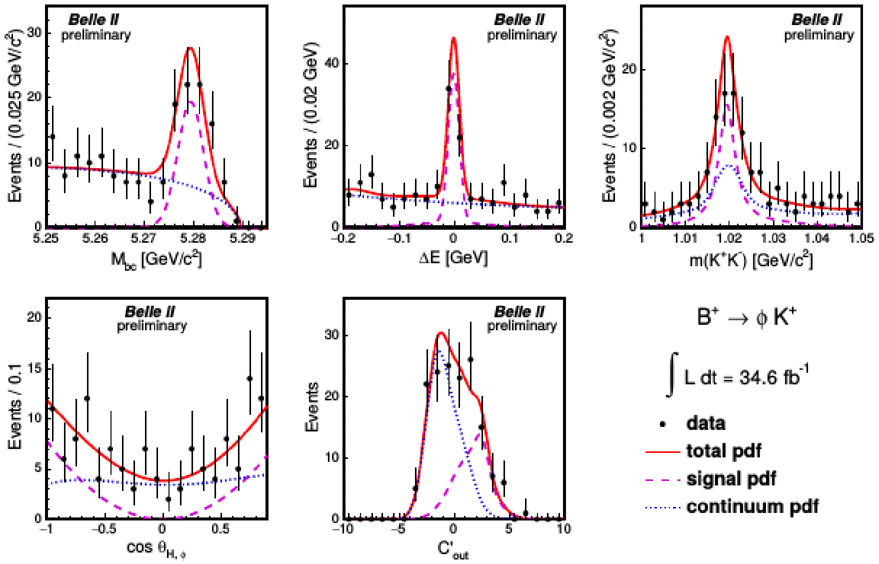


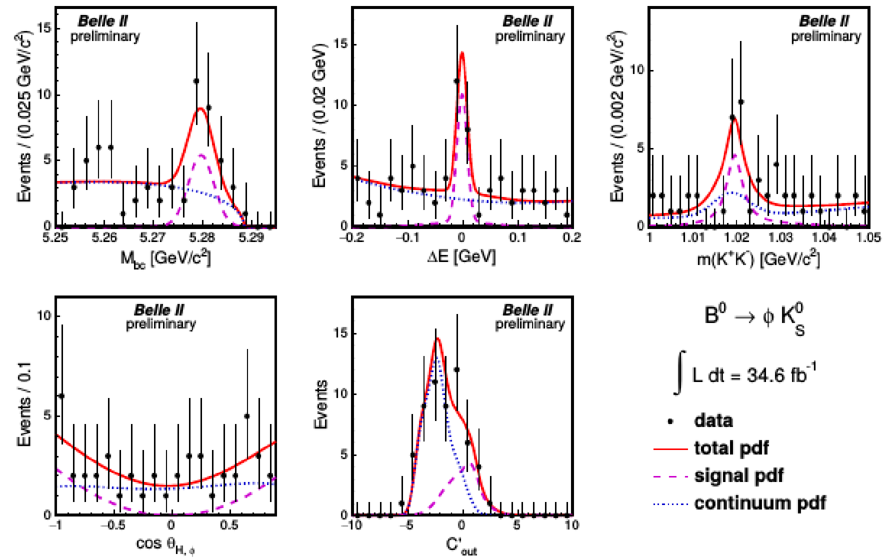
$B^+ \rightarrow K^+\pi^-\pi^+$

Measured $\mathcal{A}_{CP}$	$-0.063 \pm 0.081(stat.) \pm 0.023(syst.)$
PDG	0.027 ± 0.008

$B^+ \to \varphi K^+$, $B^0 \to \varphi K^0$: $B \to VP$

$B^+ \to \varphi K^+$ | $B^0 \to \varphi K^0$





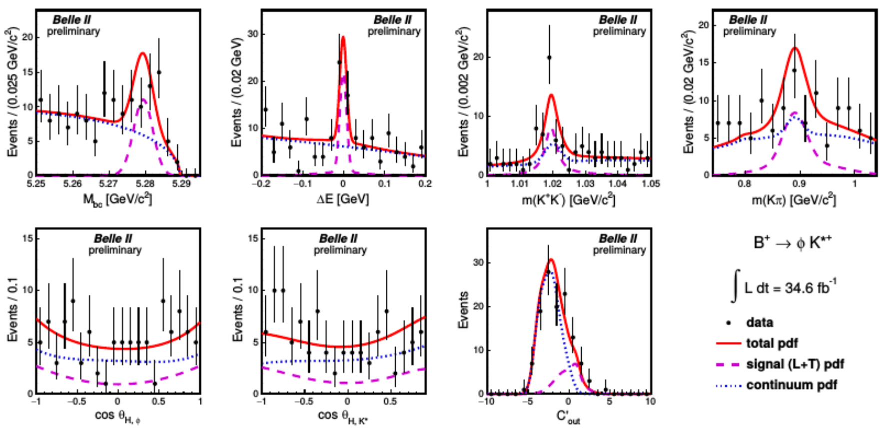
Signal Yield	55 ± 9
Measured $\mathcal{B}$ (10^{-6})	$6.7 \pm 1.1(stat.) \pm 0.5(syst.)$
PDG (10^{-6})	8.8 ± 0.7

Signal Yield	16 ± 5
Measured $\mathcal{B}$ (10^{-6})	$5.9 \pm 1.8(stat.) \pm 0.7(syst.)$
PDG (10^{-6})	7.3 ± 0.7

- 5D fit: ΔE / $M_{\rm bc}$ / $C'_{\rm out}$ / $m(K^+K^-)$ / $\cos\theta_{H,\phi}$
- Prospect: Time-dependent CP violation measurement for $B^0 \to \varphi K^0$.
  To compare with $B^0 \to J/\psi K^0$.

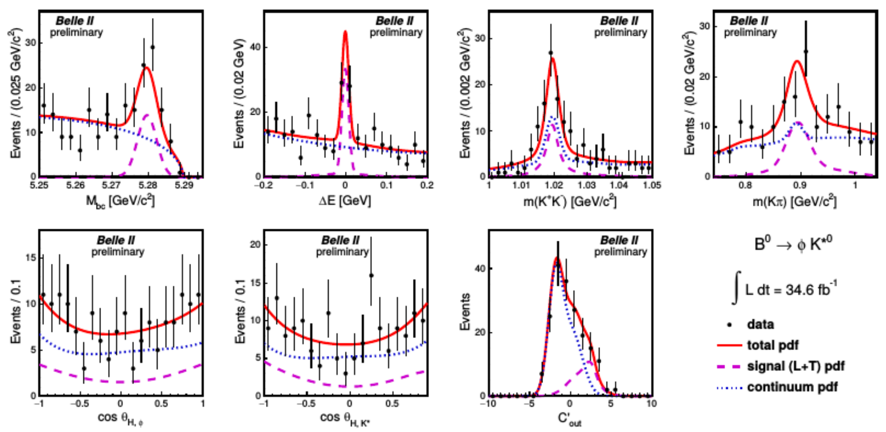
$B^+ \to \varphi K^{*+}$, $B^0 \to \varphi K^{*0}$: $B \to VV$

$B^+ \to \varphi K^{*+}$



Signal Yield	33 ± 8
Measured $\mathcal{B}\,(10^{-6})$	$21.7 \pm 4.6\,(stat.) \pm 1.9\,(syst.)$
PDG $\mathcal{B}\,(10^{-6})$	10 ± 2
Measured f_L	$0.58 \pm 0.23\,(stat.) \pm 0.02\,(syst.)$
PDG f_L	0.50 ± 0.05

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



Signal Yield	48 ± 10
Measured $\mathcal{B}\,(10^{-6})$	$11.0 \pm 2.1\,(stat.) \pm 1.1\,(syst.)$
PDG $\mathcal{B}\,(10^{-6})$	10.0 ± 0.5
Measured f_L	$0.57 \pm 0.20\,(stat.) \pm 0.04\,(syst.)$
PDG f_L	0.497 ± 0.17

- 7D fit: ΔE / $M_{\rm bc}$ / $C'_{\rm out}$ / $m(K^+K^-)$ / $\cos\theta_{H,\phi}$ / $m(K\pi)$ / $\cos\theta_{H,K^*}$
- f_L measurement: By separating the signal PDFs in the **two helicity angles**.

Summary

- Belle II performs the first measurement of the charmless *B* decays on the branching fractions, CP asymmetries, and longitudinal polarization fraction.

- With a data sample of 34.6 fb^{-1}, the rediscovery results are well consistent with present world average. Promising progress and good validation for the detector systems, analysis tools and schemes.

- As data collection is getting faster, Belle II will be ready for new physics hunting in coming years. Stay tuned for exciting results!

Backup

Systematic uncertainty

Tracking efficiency
- Data-MC difference in tracking.
- 0.91% per track.

K^0_S efficiency
- Linear decreasing with flight length.
- By $B \to \varphi K^{(*)}$ analysis.
- ~1% per cm. ~12% in total.

π^0 efficiency
- By $B^0 \to D^{*-}\pi^+$ control sample.
- 6.5%.

Continuum suppression & PID
- By $B^0 \to D^{*-}\pi^+$ control sample.
- 2~4%, depending on selection.

$N_{B\bar{B}}$
- Uncertainty on cross-section, L_{int}, and possible shift in the peak CM energy.
- 2.7%

Signal Modeling
- Varying the signal PDF in fit.
- Hit multiplicity in drift chamber.
- ~2%.

Background Modeling
- $q\bar{q}$, $B\bar{B}$, and peaking bkg.
- Varying shape, fit range, yield, and modeling in fit.
- 3% for $q\bar{q}$, and 0.3% for $B\bar{B}$ + peaking bkg.

$\mathcal{A}_{det}$
- Differences in interaction or reconstruction probabilities between opposite-charge hadrons.

For $B \to \varphi K^{(*)}$ modes:

Yields of backgrounds
- Varying each component by ±50%.
- < 1%.

Modeling on $C_{out'}$
- From MC v.s. from data sideband.
- 0.1% ~ 3.5%.

Acceptance function for the helicity angles
- Double or remove the acceptance function in fit.
- 0.7% ~ 1.4%.

Systematic uncertainty (cont'd)

TABLE V. Summary of the (fractional) systematic uncertainties of the branching-fraction measurements.

Source	$K^+\pi^-$	$K^+\pi^0$	$K^0\pi^+$	$K^0\pi^0$	$\pi^+\pi^-$	$\pi^+\pi^0$	$K^+K^-K^+$	$K^+\pi^-\pi^+$
Tracking	1.8%	0.9%	2.7%	1.8%	1.8%	0.9%	2.7%	2.7%
K_S^0 efficiency	-	-	12.5%	11.6%	-	-	-	-
π^0 efficiency	-	6.5%	-	6.5%	-	6.5%	-	-
PID and continuum-supp. eff.	1.1%	2.6%	0.9%	1.4%	1.3%	2.7%	2.3%	1.0%
$N_{B\bar{B}}$	2.7 %	2.7%	2.7%	2.7%	2.7%	2.7%	2.7%	2.7%
Signal model	1.1%	2.3%	$< 0.1\%$	$< 0.1\%$	4.5%	0.5%	0.6%	3.5%
Continuum bkg. model	4.2%	3.1%	1.5%	4.8%	$< 0.1\%$	3.6%	0.3%	4.6%
$B\overline{B}$ bkg. model	0.4%	$< 0.1\%$	-	-	1.6%	0.4%	-	0.2%
Total	5.5%	8.5%	13.2%	14.6%	5.9%	8.4%	4.5%	7.0%

TABLE VI. Summary of (absolute) systematic uncertainties in the $\mathcal{A}_{CP}$ measurements.

Source	$K^+\pi^-$	$K^+\pi^0$	$K^0\pi^+$	$\pi^+\pi^0$	$K^+K^-K^+$	$K^+\pi^-\pi^+$
Signal model	0.005	0.001	0.007	0.005	0.001	0.003
Pkg./$B\overline{B}$/s×f background model	0.005	-	0.006	0.120	-	0.004
Instrumental asymmetry corrections	0.003	0.022	0.022	0.022	0.022	0.022
Total	0.008	0.022	0.024	0.123	0.022	0.023

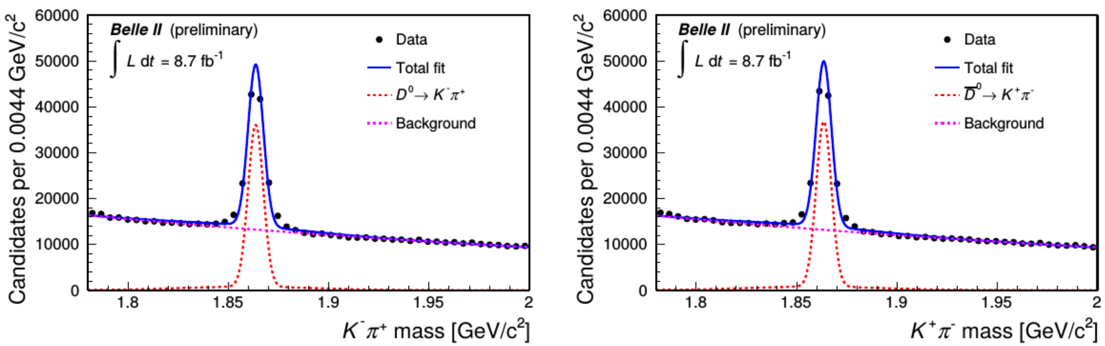
Systematic uncertainty (cont'd)

TABLE III. Summary of the systematic uncertainties, in per cent, affecting the signal yields. The uncertainties are categorized as multiplicative (M) or additive (A).

Source	$B^+ \to \phi K^+$	$B^+ \to \phi K^{*+}$	$B^0 \to \phi K_S^0$	$B^0 \to \phi K^{*0}$
Tracking efficiency (M)	2.7	4.6	3.6	3.6
K_S^0 reconstruction efficiency (M)	–	6.3	10.8	–
Kaon ID efficiency (M)	6.4	1.1	1.0	4.7
Number of $B\overline{B}$ events (M)	2.7	2.7	2.7	2.7
Modeling of $C_{\mathrm{out}'}$ (A)	1.3	1.2	1.0	5.9
$B\overline{B}$ background yield (A)	0.3	1.2	1.4	2.3
Nonresonant yield (A)	3.1	1.8	4.5	3.2
SXF fraction (A)	–	0.6	–	1.0
Total multiplicative	7.5	8.3	11.7	6.5
Total additive	3.4	2.5	4.8	7.1
Total	8.2	8.7	12.7	9.7

Instrumental effect on CP asymmetry measurement

- Due to differences in interaction or reconstruction probabilities between opposite-charge hadrons.
- It is measured by using $D^0 \to K^- \pi^+$ and $D^+ \to K^0_S \pi^+$ sample (with very small direct CP asymmetry):



$$\mathcal{A}_{\rm det}(K) = \mathcal{A}_{\rm det}(K\pi) - \mathcal{A}_{\rm det}(K^0_{\rm S}\pi) + \underline{\mathcal{A}(K^0_{\rm S})}$$

Obtained from LHCb

Instrumental asymmetry	Value
$\mathcal{A}_{\rm det}(K^+\pi^-)$	-0.010 ± 0.003
$\mathcal{A}_{\rm det}(K^0_{\rm S}\pi^+)$	-0.007 ± 0.022
$\mathcal{A}_{\rm det}(K^+)$	-0.015 ± 0.022
$\mathcal{A}_{\rm det}(\pi^+)$	-0.007 ± 0.022

Summary of measurements

$$\mathcal{B}(B^0 \to K^+\pi^-) = [18.9 \pm 1.4(\text{stat}) \pm 1.0(\text{syst})] \times 10^{-6},$$

$$\mathcal{B}(B^+ \to K^+\pi^0) = [12.7^{+2.2}_{-2.1}(\text{stat}) \pm 1.1(\text{syst})] \times 10^{-6},$$

$$\mathcal{B}(B^+ \to K^0\pi^+) = [21.8^{+3.3}_{-3.0}(\text{stat}) \pm 2.9(\text{syst})] \times 10^{-6},$$

$$\mathcal{B}(B^0 \to K^0\pi^0) = [10.9^{+2.9}_{-2.6}(\text{stat}) \pm 1.6(\text{syst})] \times 10^{-6},$$

$$\mathcal{B}(B^0 \to \pi^+\pi^-) = [5.6^{+1.0}_{-0.9}(\text{stat}) \pm 0.3(\text{syst})] \times 10^{-6},$$

$$\mathcal{B}(B^+ \to \pi^+\pi^0) = [5.7 \pm 2.3(\text{stat}) \pm 0.5(\text{syst})] \times 10^{-6},$$

$$\mathcal{B}(B^+ \to K^+K^-K^+) = [32.0 \pm 2.2(\text{stat.}) \pm 1.4(\text{syst})] \times 10^{-6},$$

$$\mathcal{B}(B^+ \to K^+\pi^-\pi^+) = [48.0 \pm 3.8(\text{stat}) \pm 3.3(\text{syst})] \times 10^{-6},$$

$$\mathcal{A}(B^0 \to K^+\pi^-) = 0.030^{+0.064}_{-0.064}(\text{stat}) \pm 0.008(\text{syst}),$$

$$\mathcal{A}(B^+ \to K^+\pi^0) = 0.052^{+0.121}_{-0.119}(\text{stat}) \pm 0.022(\text{syst}),$$

$$\mathcal{A}(B^+ \to K^0\pi^+) = -0.072^{+0.109}_{-0.114}(\text{stat}) \pm 0.024(\text{syst}),$$

$$\mathcal{A}(B^+ \to \pi^+\pi^0) = -0.268^{+0.249}_{-0.322}(\text{stat}) \pm 0.123(\text{syst}),$$

$$\mathcal{A}(B^+ \to K^+K^-K^+) = -0.049 \pm 0.063(\text{stat}) \pm 0.022(\text{syst}),$$

$$\mathcal{A}(B^+ \to K^+\pi^-\pi^+) = -0.063 \pm 0.081(\text{stat}) \pm 0.023(\text{syst}).$$

	This analysis
$\mathcal{B}(\times 10^{-6})$	
ϕK^+	$6.7 \pm 1.1 \pm 0.5$
ϕK^0	$5.9 \pm 1.8 \pm 0.7$
$I_{\phi K}$	$1.1 \pm 0.4 \pm 0.2$
ϕK^{*+}	$21.7 \pm 4.6 \pm 1.9$
ϕK^{*0}	$11.0 \pm 2.1 \pm 1.1$
$I_{\phi K^*}$	$2.0 \pm 0.6 \pm 0.3$
f_L	
ϕK^{*+}	$0.58 \pm 0.23 \pm 0.02$
ϕK^{*0}	$0.57 \pm 0.20 \pm 0.04$

$B \to K\pi$ puzzle

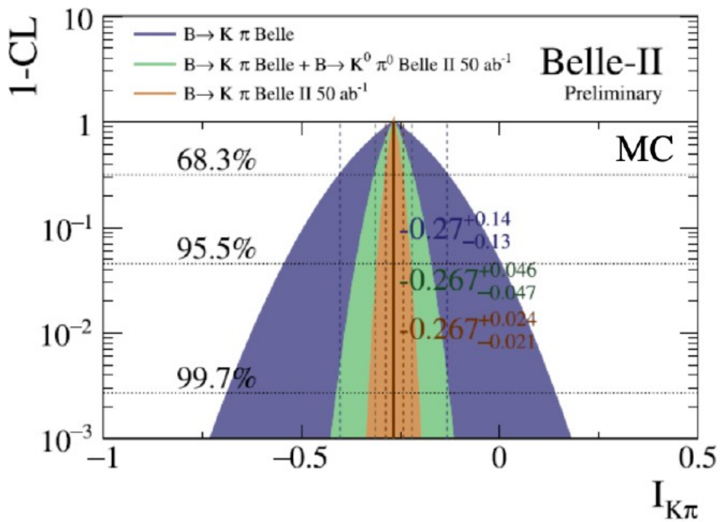
- The relations of branching fractions and CP asymmtries between different $B \to K\pi$ modes predicted by isospin sum rule.
  - Violation of the rules would be an indication to new physics.

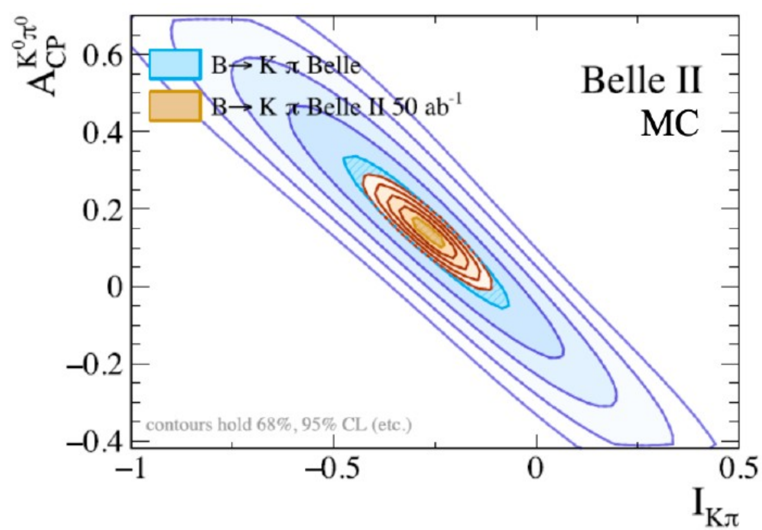
- Branching fraction: $R_c - R_n$ is expected to be 0.

$$R_c = 2\mathcal{B}(B^+ \to K^0\pi^+)/\mathcal{B}(B^+ \to K^+\pi^0)$$
$$R_n = \mathcal{B}(B^0 \to K^+\pi^-)/2\mathcal{B}(B^0 \to K^0\pi^0)$$

- CP asymmetry: $I_{K\pi}$ is expected to be 0.

$$I_{K\pi} = A_{CP}^{K^+\pi^-} + A_{CP}^{K^0\pi^+}\frac{Br(K^0\pi^+)}{Br(K^+\pi^-)}\frac{\tau_{B^0}}{\tau_{B^+}} - 2A_{CP}^{K^+\pi^0}\frac{Br(K^+\pi^0)}{Br(K^+\pi^-)}\frac{\tau_{B^0}}{\tau_{B^+}} - 2A_{CP}^{K^0\pi^0}\frac{Br(K^0\pi^0)}{Br(K^+\pi^-)}$$



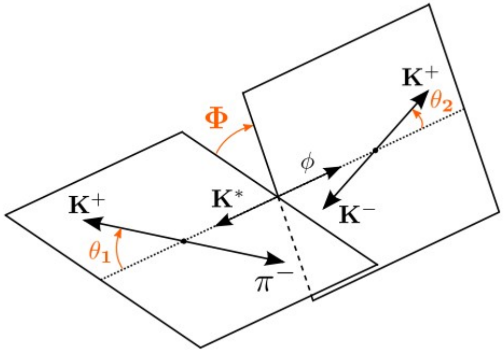


Polarization "puzzle"

- In the $B \to VV$ decay modes which are main via penguin process, measurement results show the transverse polarization has larger contribution than prediction ($f_L \sim 1$).

- This puzzle can be explained without considering new physics (e.g. large contributions from penguin annihilation or electroweak penguin diagrams).

- The experimental measurement is still improtant, since it could be very sensitive to effects produced by the non-uniform detector acceptance.



Peaking background veto for 3-body modes

Peaking backgrounds for $B^+ \to K^+K^-K^+$:

$$B^0 \to \overline{D}^0(\to K^+K^-)K^+,\ B^0 \to \eta_c(\to K^+K^-)K^+, \text{ and } B^0 \to \chi_{c1}(\to K^+K^-)K^+$$

Vetoed regions for $B^+ \to K^+K^-K^+$:

$1.84 < m(K^+K^-) < 1.88\ \mathrm{GeV/c^2}$, $2.94 < m(K^+K^-) < 3.05\ \mathrm{GeV/c^2}$, and $3.50 < m(K^+K^-) < 3.54\ \mathrm{GeV}/c^2$

Peaking backgrounds for $B^+ \to K^+\pi^-\pi^+$:

$B^+ \to \overline{D}^0(\to K^+\pi^-)\pi^+$, $B^+ \to \eta_c(\to \pi^+\pi^-)K^+$, $B^+ \to \chi_{c1}(\to \pi^+\pi^-)K^+$, and $B^+ \to \eta_c(2S)(\to \pi^+\pi^-)K^+$

π/μ mis-identification:

$$B^+ \to J/\psi(\to \mu^+\mu^-)K^+ \text{ and } B^+ \to \psi(2S)(\to \mu^+\mu^-)K^+$$

Vetoed regions for $B^+ \to K^+\pi^-\pi^+$:

$1.8 < m(K^+\pi^-) < 1.92\ \mathrm{GeV/c^2}$, $0.93 < m(\pi^+\pi^-) < 3.15\ \mathrm{GeV/c^2}$,
$3.45 < m(\pi^+\pi^-) < 3.525\ \mathrm{GeV/c^2}$, $62 < m(\pi^+\pi^-) < 3.665\ \mathrm{GeV/c^2}$,
$3.67 < m(\pi^+\pi^-) < 3.72\ \mathrm{GeV/c^2}$.

$$B^+ \to K^*(892)^0\pi^+ \text{ subcomponent}: 0.82 < m(K^+\pi^-) < 0.98\ \mathrm{GeV/c^2}$$