HADRON 2017(25 - 29 September, 2017, Salamanca, Spain)

RECENT MEASUREMENTS OF BRANCHING FRACTIONS AND CP ASYMMETRIES OF

CHARMLESS HADRONIC B MESON DECAYS AT BELLE

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on behalf of Belle Collaboration
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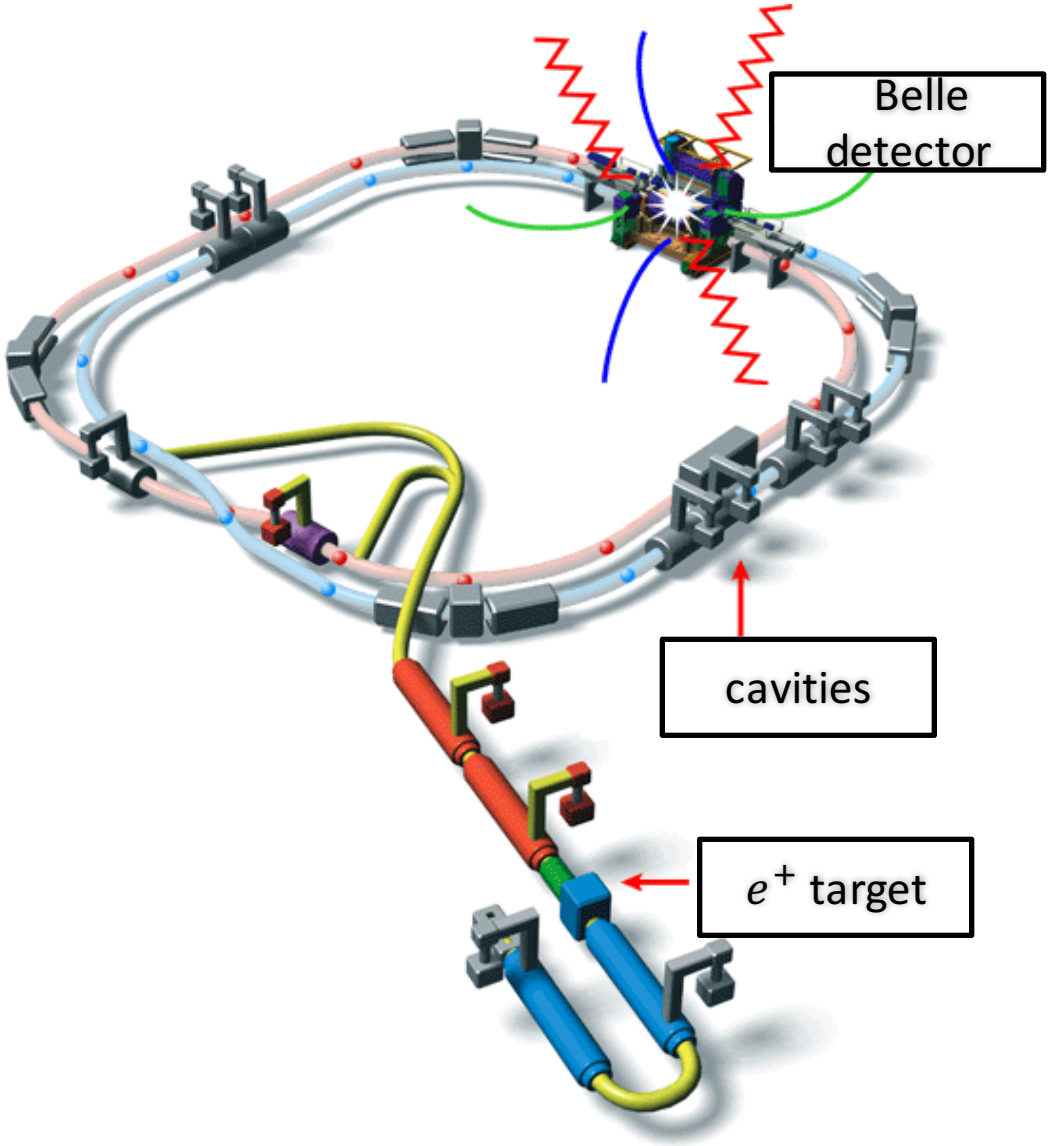
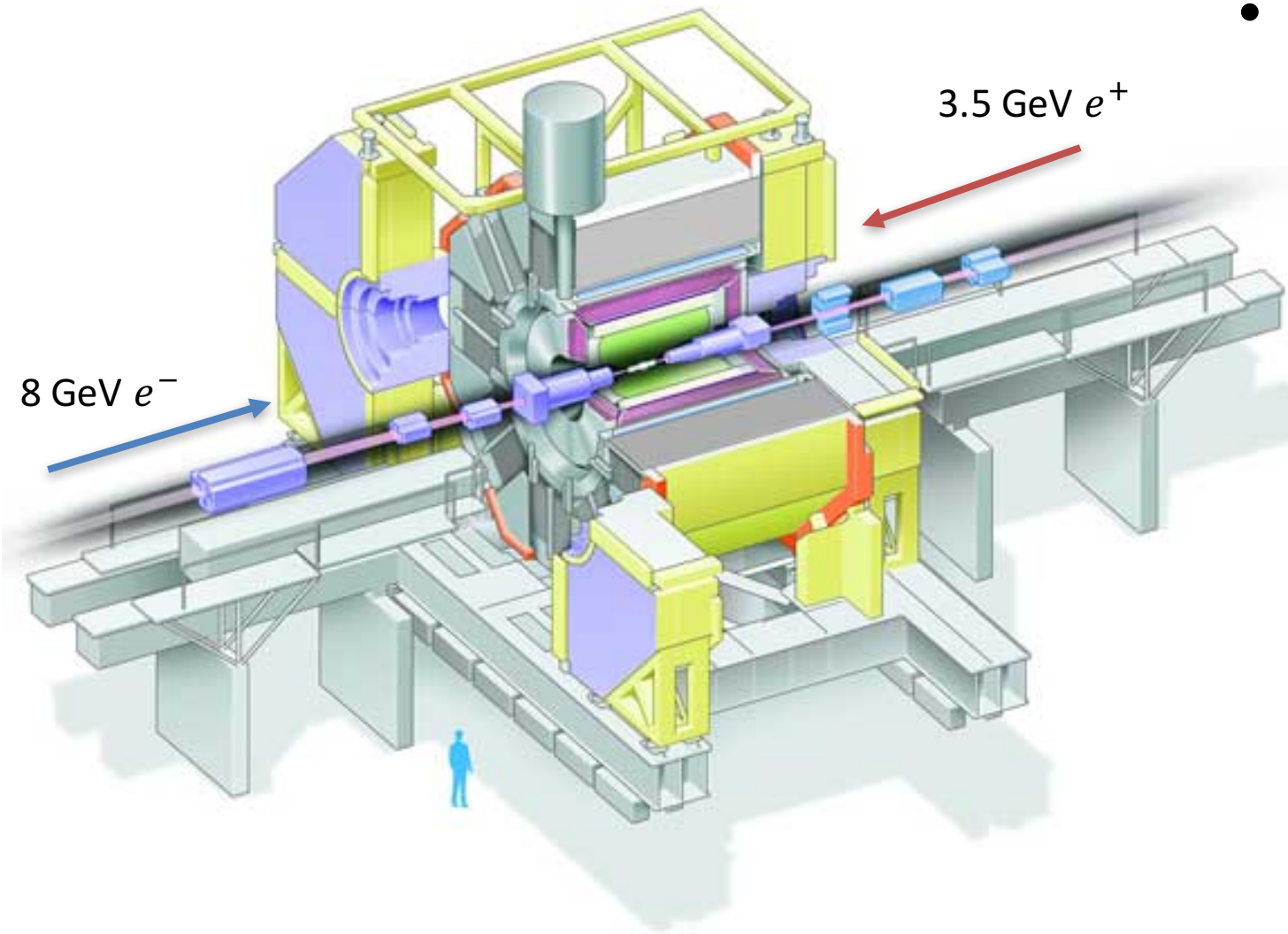
KEKB collider



- KEKB Lepton collider: 8 GeV e^- and 3.5 GeV e^+
- Located: KEK, Tsukuba, Japan

Belle detector



- Data sample: 752×10^6 $\boldsymbol{B\bar{B}}$ pairs @ $\Upsilon(4S)$ resonance, Belle detector, KEKB e^+e^- collider

Belle detector can be used to do the Event reconstruction, Vertexing, Particle Identification, …

Topic1

Ref: PRD 96, 032007 (2017)

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

Measurement of branching fraction and CP asymmetry

Improved constraint on ϕ_2

Topic2

Ref: PRD 96, 031101(R) (2017)

$$B^{\pm} \to K^+K^-\pi^{\pm}$$

Measurement of branching fraction and direct CP asymmetry

(Both published 31 August 2017)

Skip,
Still under
internal review

$$B^{\pm} \to K_S^0 \, K_S^0 h^{\pm}, h = K, \pi$$

Measurement of branching fraction and CP asymmetry

Skip,
Still under
internal review

$$B^{\pm} \to \pi^+ \pi^- \pi^{\pm}$$

Measurement of branching fraction and direct CP asymmetry

(Both not published yet)

Ref: PRD 96, 032007 (2017)

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

Measurement of branching fraction and CP asymmetry

Improved constraint on ϕ_2

Event selections:

$$\pi^0 \to \gamma\gamma$$

Photons must have energy greater than 50 (100) MeV in the barrel (endcap) region of ECL detector.

$115\ MeV/c^2 < m_{\gamma\gamma} < 152\ MeV/c^2$, $\pm 2.6\ \sigma$ around the nominal π^0 mass

Two kinematic variables are used to distinguish signal from background:

$$M_{bc} \equiv \sqrt{E_{beam}^2 - |\overrightarrow{p_B}|^2 c^2}$$

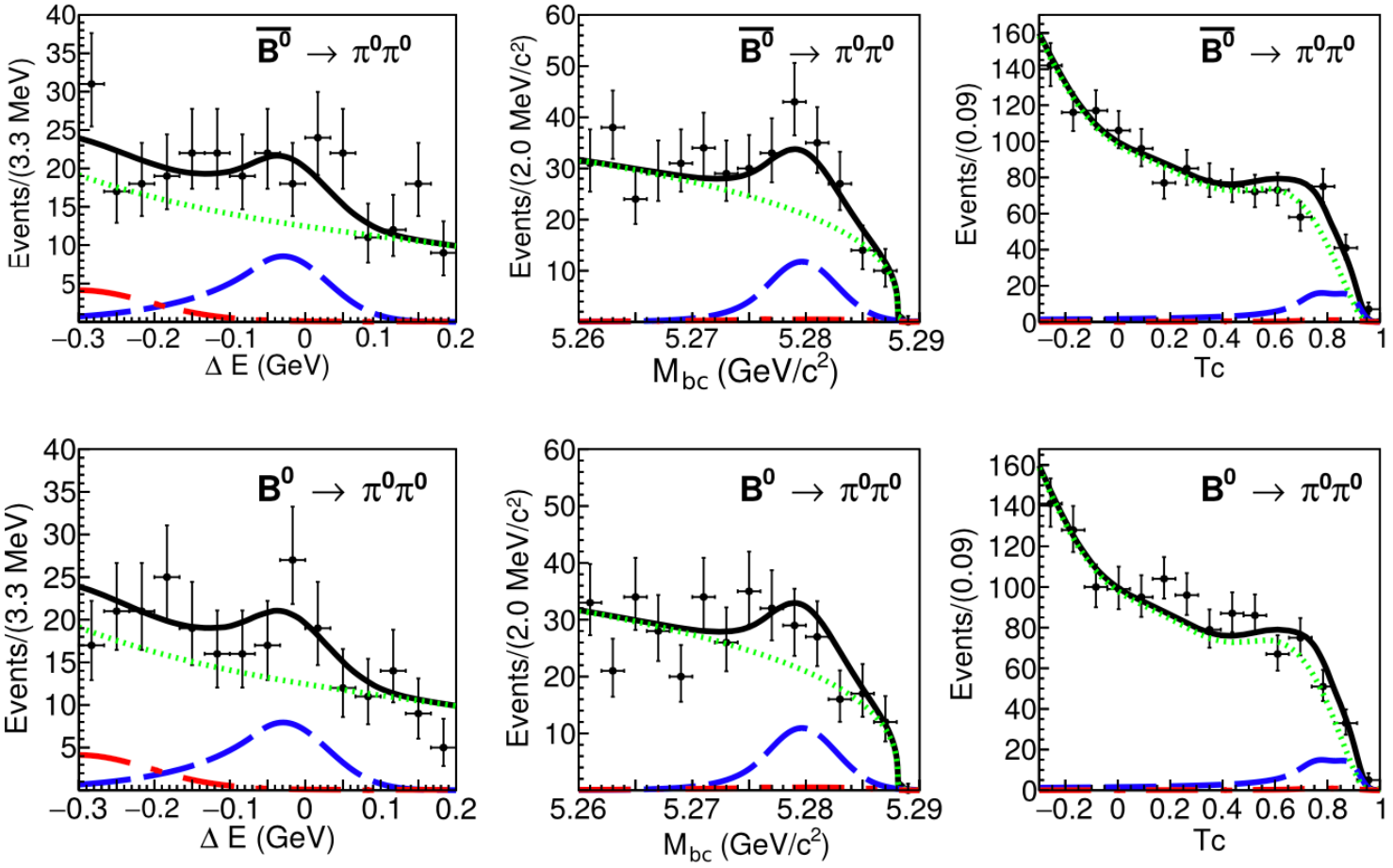
$$\Delta E \equiv E_B - E_{beam}$$

$M_{bc} > 5.26\ GeV/c^2$, $-0.3\ GeV < \Delta E <$ 0.2 GeV

Fisher discriminant (T_c) with value in the range (-1, +1), the values near -1(+1) denotes events having strong continuum (B-decay) characteristics.

Ref: PRD 96, 032007 (2017)

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



Data are points with error bars, fit results: solid black curves.

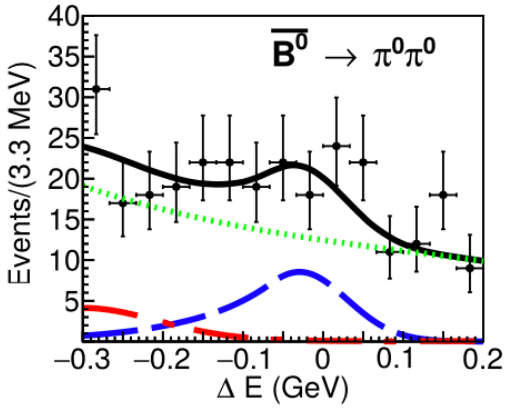
Signal: dashed blue
continuum $q\bar{q}$: dotted green
combined $\rho\pi$ and other rare B decays : dash-dotted red

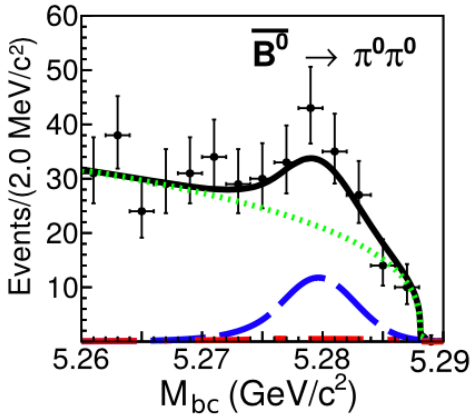
$$Br(B^0 \to \pi^0\pi^0) = [1.31 \pm 0.19(stat) \pm 0.19(syst)]\times 10^{-6} \qquad 6.4\sigma$$

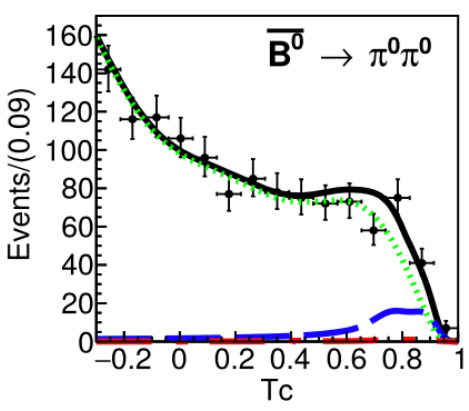
Signal region: $-0.15\ GeV < \Delta E < 0.05$ GeV, $5.275\ GeV/c^2 < M_{bc} < 5.285\ GeV/c^2$, $T_c > 0.7$

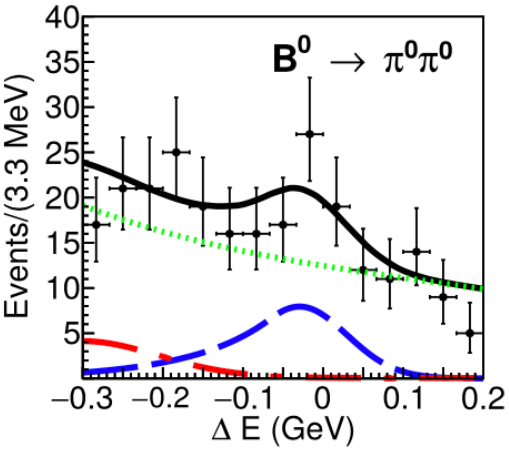
Ref: PRD 96, 032007 (2017)

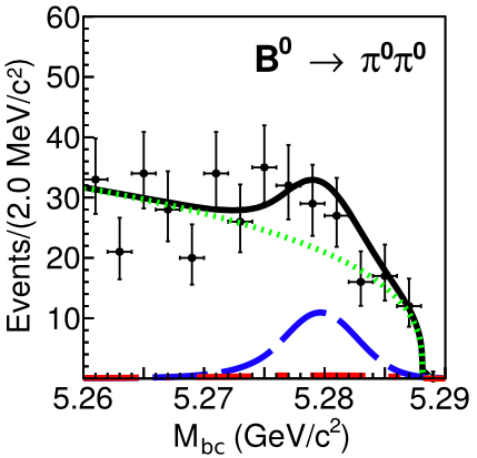
$B^0 \to \pi^0\pi^0$

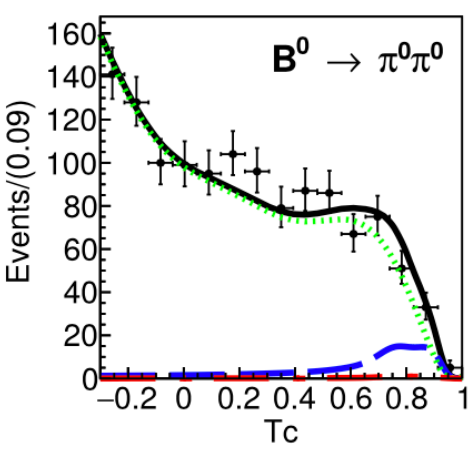












b tagged: b-flavor charge: q and purity for flavor charge r. The signal yield and A_{CP} are extracted via an **unbinned extended maximum likelihood fit** to four categories of events described by probability density functions.

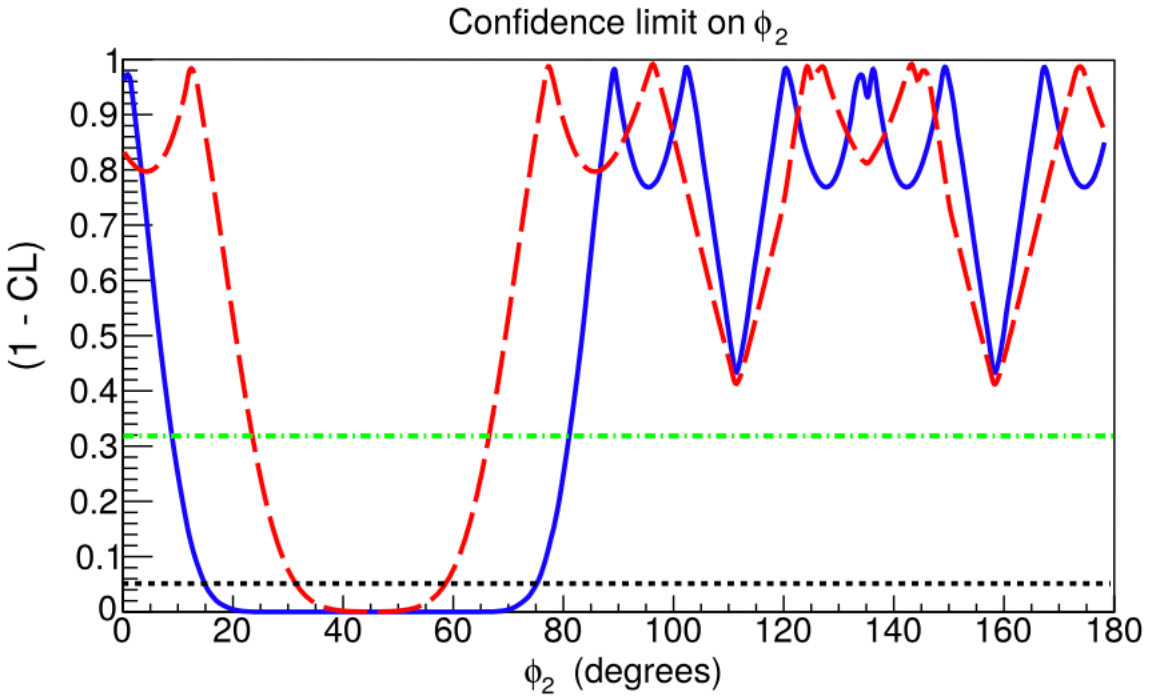
$$A_{CP} = \frac{\Gamma\left(\overline{B^0} \to \pi^0\pi^0\right) - \Gamma(B^0 \to \pi^0\pi^0)}{\Gamma\left(\overline{B^0} \to \pi^0\pi^0\right) + \Gamma(B^0 \to \pi^0\pi^0)}$$

$$A_{CP} = +0.14 \pm 0.36(stat) \pm 0.10(syst)$$

Where Γ is the partial decay width for the corresponding decay.

Ref: PRD 96, 032007 (2017)

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



Dashed red curve shows the previous constraint from Belle data*[1]

Solid blue curve includes our new results.

Green dot-dashed line @68% confidence level

$9.5^\circ < \phi_2 < 81.6^\circ$

Combine results with Belle's earlier measurements of $B^0 \to \pi^+\pi^-$ and $B^\pm \to \pi^\pm\pi^0$ to exclude the CP-violating parameter ϕ_2 from the range $15.5^\circ < \phi_2 < 75.0^\circ$ at 95% confidence level

Black dashed line @95% confidence level

$15.5^\circ < \phi_2 < 75.0^\circ$

*[1] J. Dalseno et al. (Belle Collaboration), Phys. Rev. D 88, 092003 (2013).

Ref: PRD 96, 032007 (2017)

Summary: $B^0 \to \pi^0\pi^0$

$$Br(B^0 \to \pi^0\pi^0) = [1.31 \pm 0.19(stat) \pm 0.19(syst)]\times 10^{-6}$$

$$A_{CP} = +0.14 \pm 0.36(stat) \pm 0.10(syst)$$

Combine results with Belle's earlier measurements of $B^0 \to \pi^+\pi^-$ and $B^\pm \to \pi^\pm\pi^0$ to exclude the CP-violating parameter ϕ_2 from the range $15.5^\circ < \phi_2 < 75.0^\circ$ at 95% confidence level

Ref: PRD 96, 031101(R) (2017)

$B^{\pm} \to K^{+}K^{-}\pi^{\pm}$

Event selections:

A $K-\pi$ likelihood ratio is used:

$$R_{K/\pi} = \mathcal{L}_K/(\mathcal{L}_K + \mathcal{L}_\pi)$$

$R_{K/\pi}$ > 0.6 are kaons

$R_{K/\pi}$ < 0.4 are pions

Two kinematic variables are used to distinguish signal from background:

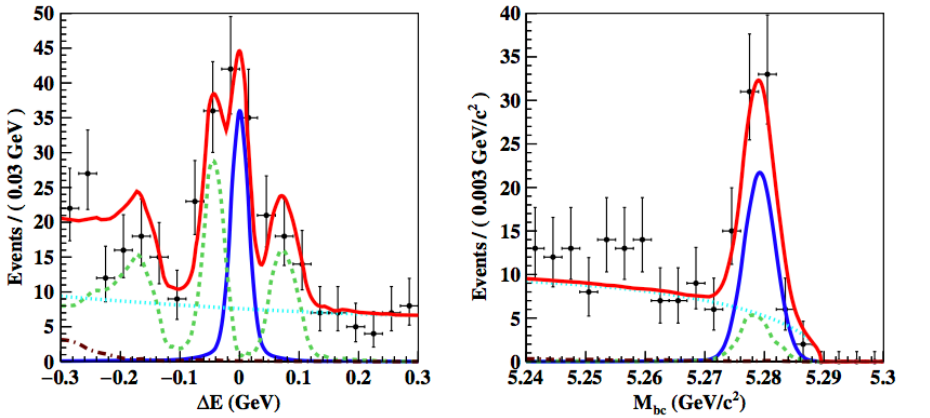
$$M_{bc} \equiv \sqrt{E_{beam}^2 - |\overrightarrow{p_B}|^2 c^2}$$

$$\Delta E \equiv E_B - E_{beam}$$

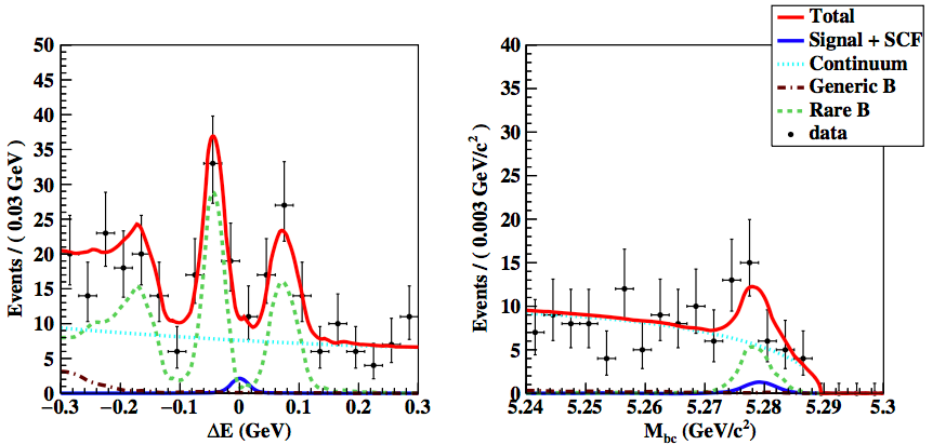
$M_{bc} > 5.24\ GeV/c^2$, $-0.3\ GeV < \Delta E <$ 0.3 GeV

Ref: PRD 96, 031101(R) (2017)

$B^{\pm} \to K^{+}K^{-}\pi^{\pm}$



(a) $B^{+} \to K^{+}K^{-}\pi^{+}$



(b) $B^{-} \to K^{-}K^{+}\pi^{-}$

Data are points with error bars, fit results: solid red curves.

Signal (&SCF): solid blue lines

continuum $q\bar{q}$: cyan dotted lines

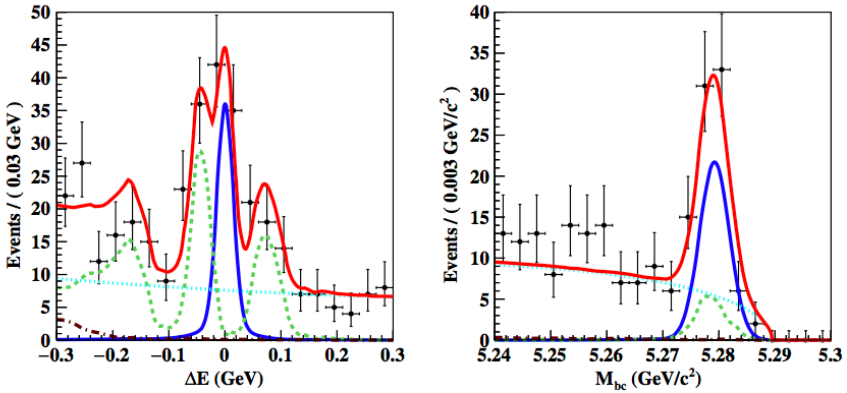
Generic B decays: brown dash-dotted lines

other rare B decays : green dashed lines

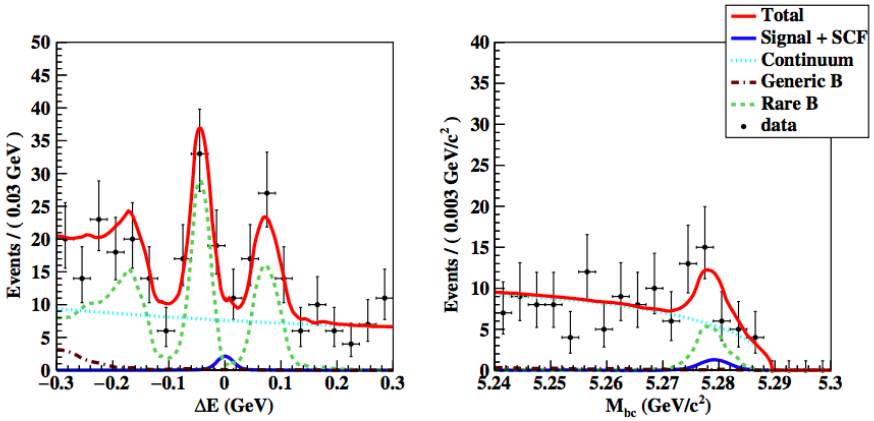
$$Br = \frac{N_{sig}}{\epsilon \times C_{PID} \times N_{B\bar{B}}}$$

Ref: PRD 96, 031101(R) (2017)

$B^{\pm} \to K^{+}K^{-}\pi^{\pm}$



(a) $B^{+} \to K^{+}K^{-}\pi^{+}$



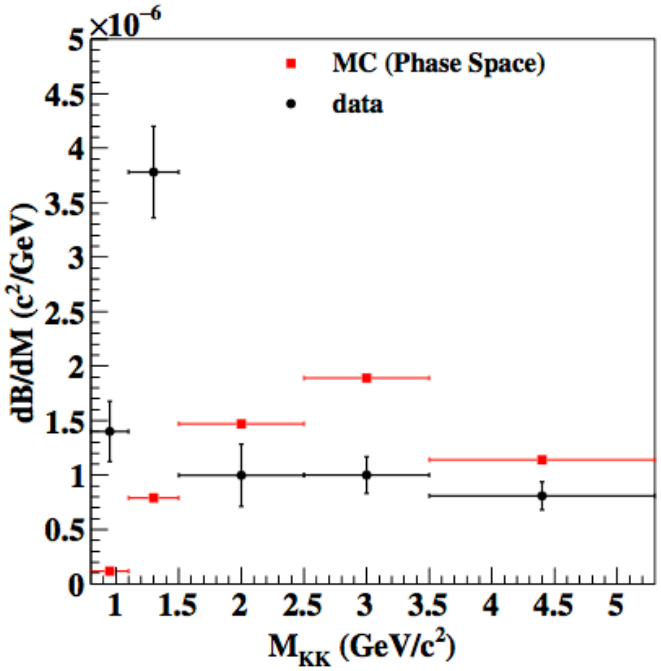
(b) $B^{-} \to K^{-}K^{+}\pi^{-}$

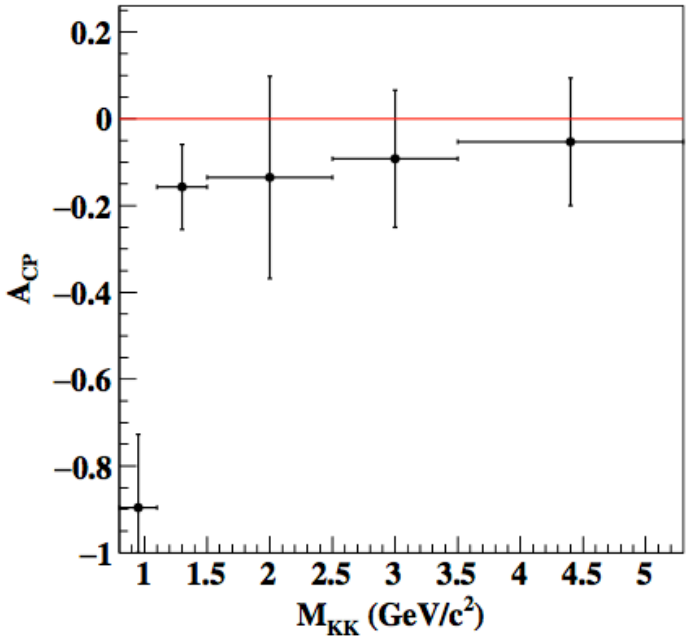
$$A_{CP} = \frac{N(B^{-} \to K^{-}K^{+}\pi^{-}) - N(B^{+} \to K^{+}K^{-}\pi^{+})}{N(B^{-} \to K^{-}K^{+}\pi^{-}) + N(B^{+} \to K^{+}K^{-}\pi^{+})}$$

Where N denotes the yield obtained for the corresponding mode

Ref: PRD 96, 031101(R) (2017)

$B^{\pm} \to K^{+}K^{-}\pi^{\pm}$





Differential branching fraction (left) and measured A_{CP} (right) as a function of $M_{K^+K^-}$.
Red squares with error bars: expected signal distribution in a three-body phase space MC.

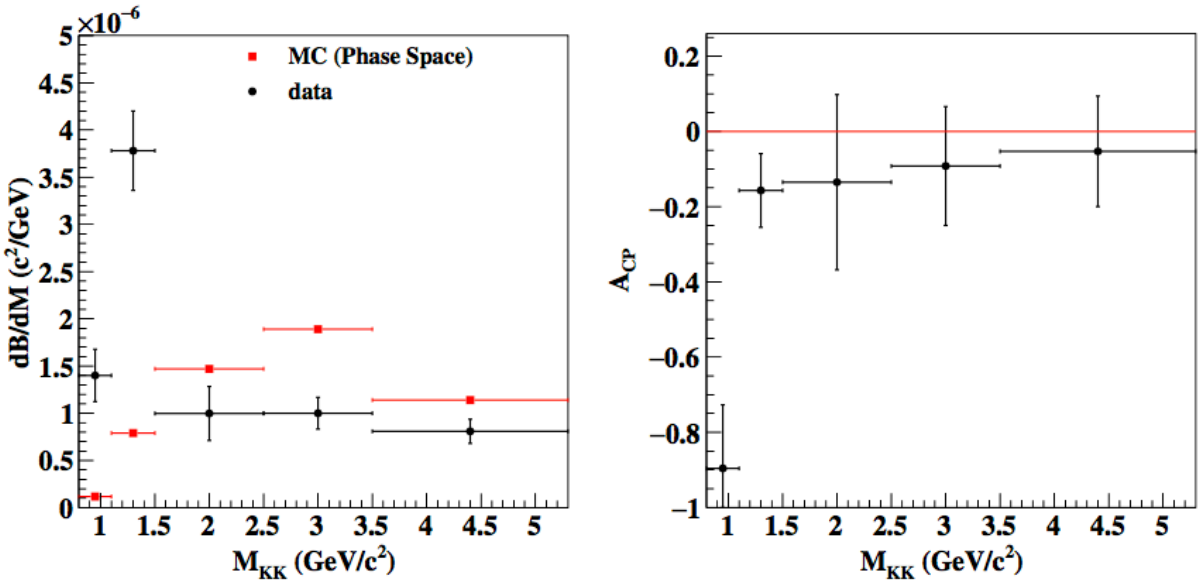
A large A_{CP} are seen in $M_{K^+K^-}$< 1.5 GeV/c^2.

Confirming the observations by BABAR and LHCb.

$A_{CP} = -0.90 \pm 0.17 \pm 0.03$ with 4.8σ significance for $M_{K^+K^-} < 1.1$ GeV/c^2

Ref: PRD 96, 031101(R) (2017)

$B^{\pm} \to K^{+}K^{-}\pi^{\pm}$



$$Br(B^{\pm} \to K^{+}K^{-}\pi^{\pm}) = [5.38 \pm 0.40(stat) \pm 0.35(syst)]\times 10^{-6}$$

We integrate the differential branching fractions over the entire mass range to obtain the inclusive branching fraction.

The weighted average A_{CP} over the entire $M_{K^+K^-}$ region is

$$A_{CP} = -0.170 \pm 0.073 \pm 0.017$$

Ref: PRD 96, 031101(R) (2017)

$B^{\pm} \to K^{+}K^{-}\pi^{\pm}$

- To understand **the origin of the low-mass dynamics**, a full Dalitz analysis from experiments with a **sizeable** data set, such as LHCb and Belle II, will be needed in the future.

Ref: PRD 96, 031101(R) (2017)

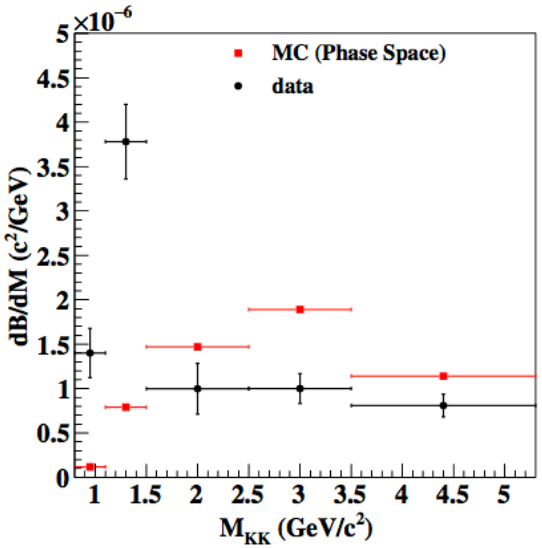
Summary: $B^{\pm} \to K^{+}K^{-}\pi^{\pm}$

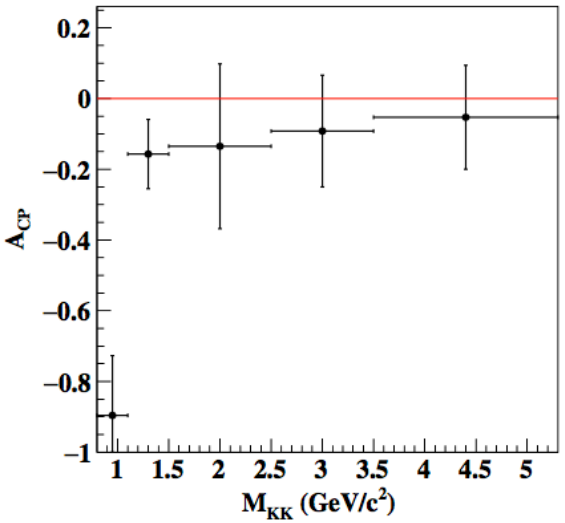
$$Br(B^{\pm} \to K^{+}K^{-}\pi^{\pm}) = [5.38 \pm 0.40(stat) \pm 0.35(syst)]\times 10^{-6}$$

$$A_{CP} = -0.170 \pm 0.073 \pm 0.017$$

$A_{CP} = -0.90 \pm 0.17 \pm 0.03$ with 4.8σ significance for $M_{K^+K^-} < 1.1$ GeV/c^2

the origin of the low-mass dynamics should be checked in the future.





Summary

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

$$Br(B^0 \to \pi^0\pi^0) = [1.31 \pm 0.19(stat) \pm 0.19(syst)]\times 10^{-6}$$

$$A_{CP} = \frac{\Gamma(\overline{B^0} \to \pi^0\pi^0) - \Gamma(B^0 \to \pi^0\pi^0)}{\Gamma(\overline{B^0} \to \pi^0\pi^0) + \Gamma(B^0 \to \pi^0\pi^0)}$$

$$A_{CP} = +0.14 \pm 0.36(stat) \pm 0.10(syst)$$

Combine results with Belle's earlier measurements of $B^0 \to \pi^+\pi^-$ and $B^\pm \to \pi^\pm\pi^0$ to exclude the CP-violating parameter ϕ_2 from the range $15.5^\circ < \phi_2 < 75.0^\circ$ at 95% confidence level

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

$$Br(B^\pm \to K^+K^-\pi^\pm) = [5.38 \pm 0.40(stat) \pm 0.35(syst)]\times 10^{-6}$$

$$A_{CP} = \frac{N(B^- \to K^-K^+\pi^-) - N(B^+ \to K^+K^-\pi^+)}{N(B^- \to K^-K^+\pi^-) + N(B^+ \to K^+K^-\pi^+)}$$

$$A_{CP} = -0.170 \pm 0.073 \pm 0.017$$

$A_{CP} = -0.90 \pm 0.17 \pm 0.03$ with 4.8σ significance for $M_{K^+K^-} < 1.1$ GeV/c^2

the origin of the low-mass dynamics should be checked in the future.