Recent results on charmless B-decays at Belle

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(On behalf of the Belle Collaboration)

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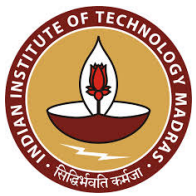


Outline of the talk

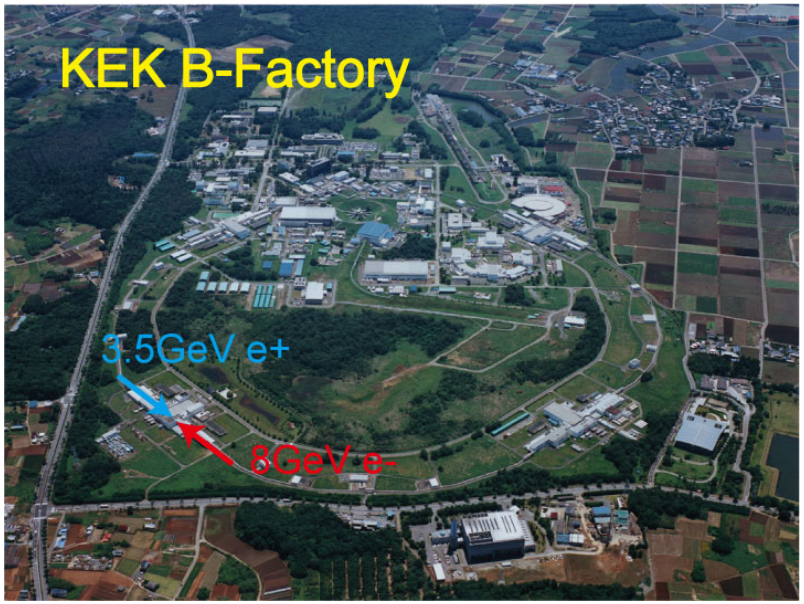
- Experimental overview
- Branching fraction and CP asymmetry in

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

$$\mathbf{B^0 \to \pi^0 \pi^0}$$

- Summary

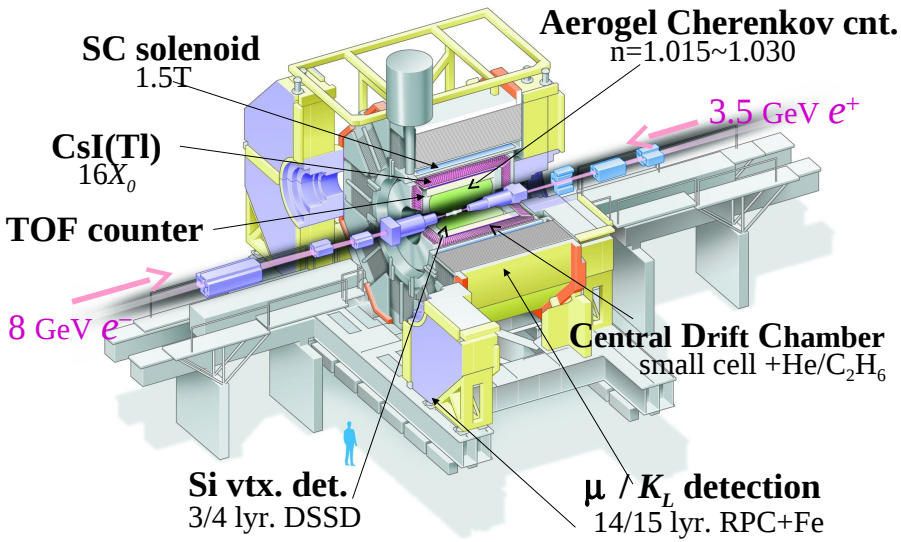
KEKB and Belle detector



- Asymmetric e^+e^- collider at the High Energy Accelerator Research Organization(KEK), Japan
- 8.0 GeV e^- collides to 3.5 GeV e^+ at the $\Upsilon(4S)$ resonance

- Collected about 772 $\times 10^6$ $B\bar{B}$ till 2010
- All results covered in this talk are based on the full Belle data set

Belle Detector



Charmless B decays

- Almost 99% of the **B** decays are $\mathbf{b} \to \mathbf{c}$ transitions
  Only 1%: charmless and rare ($\mathbf{b} \to \mathbf{u}, \mathbf{d}, \mathbf{s}$)

- Charmless **B** decays are sensitive to possible new physics contributions in the 'penguin' loops

- Interference between penguin and tree diagrams can lead to direct CP violation

- Relative weak phase of the two diagrams gives information about angles of the Unitarity Triangle (UT)

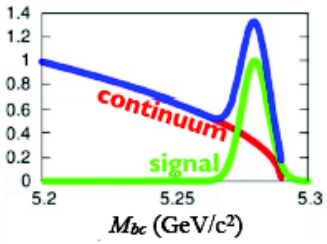
- An enhanced value of $\mathcal{B}$ and $\mathrm{A_{CP}}$ will be a hint to new physics

Analysis strategy

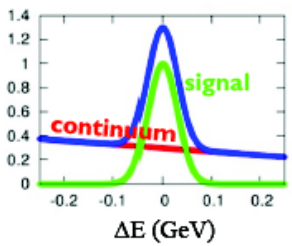
- Use kinematic variables ($\mathbf{\Delta E}$ and $\mathbf{M_{bc}}$) for the signal candidate selection

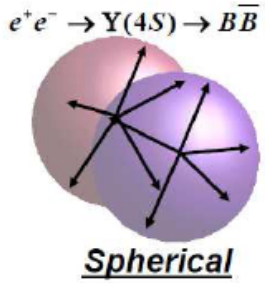
- Combine event topology variables in a Neural Network or a Fisher discriminant for the continuum ($e^+e^- \to q\bar{q}$) suppression

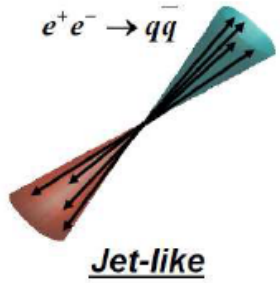
$$M_{bc} = \sqrt{E^{*2}_{BEAM} - \vec{p}^{\,*2}_{B}}$$



$$\Delta E = E^{*}_{B} - E^{*}_{BEAM}$$







$\mathbf{E^*_B}$ and $\mathbf{p^*_B}$ are energy and momentum of the **B** candidate while $\mathbf{E^*_{BEAM}}$ is the beam energy in the $\Upsilon(4S)$ center-of-mass frame

- Unbinned extended maximum likelihood fit to extract the signal yield

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

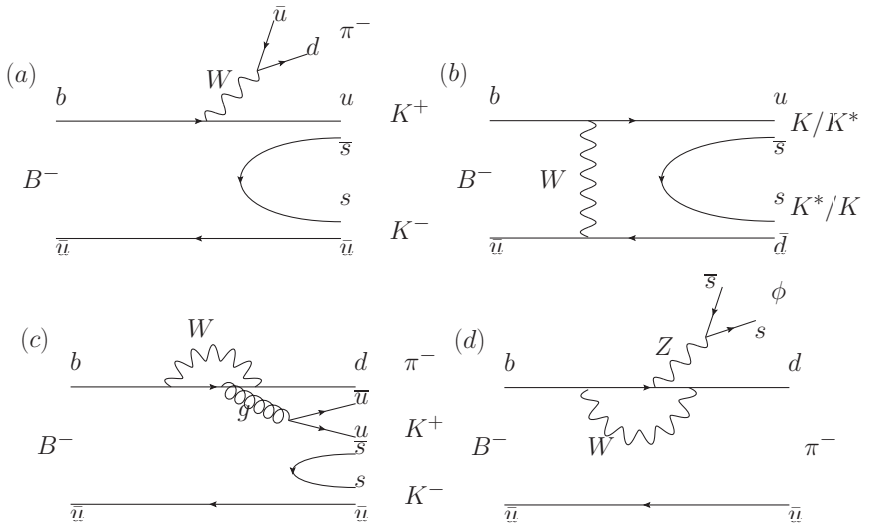
- Mainly proceeds via $b \to u$ tree and $b \to d$ penguin diagrams
- No intermediate state observed yet

Previous measurements:

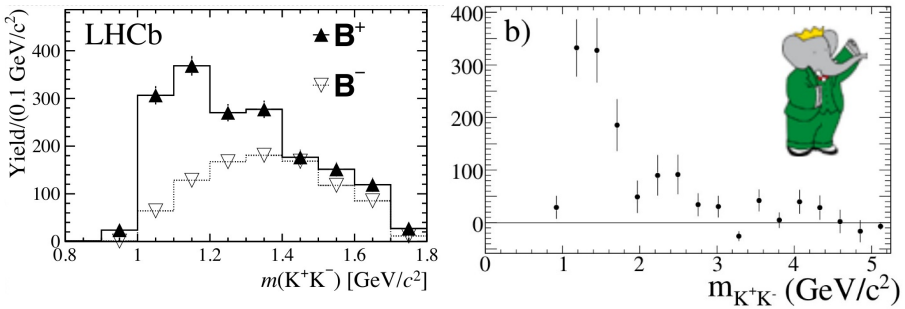
$\mathcal{B}(K^+K^-\pi^+) = (5.0 \pm 0.5 \pm 0.5) \times 10^{-6}$
$\mathcal{A}_{CP} = -0.123 \pm 0.017 \pm 0.012 \pm 0.007$

BaBar, PRL 99, 221801 (2007)

LHCb, PRD 90, 112004 (2014)



- Unidentified mass spectrum in low M_{KK} region, and a large local A_{CP} in the same region



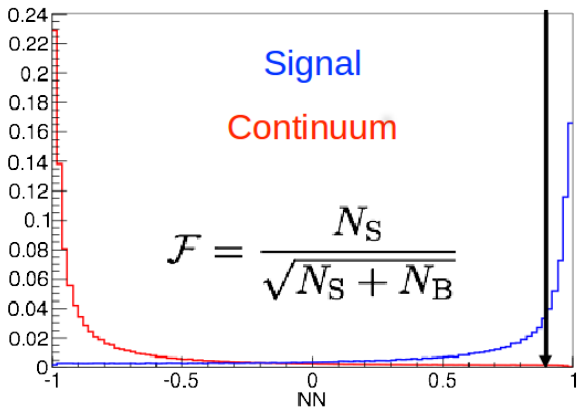
- Final-state interaction may be a contributing factor to CP violation

PLB 726, 337 (2013) PRD 89, 094013 (2014)

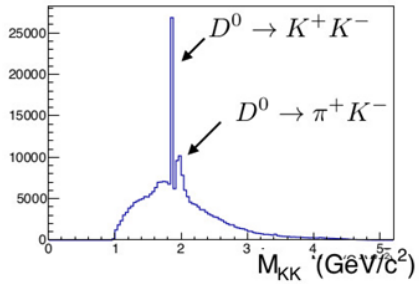
$B^+ \to K^+K^-\pi^+$: Backgrounds

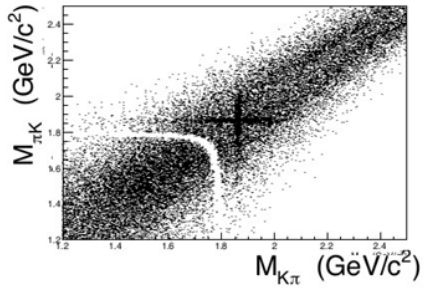
Continuum ($e^+e^- \to q\bar{q}$) process, generic ($b \to c$) and rare ($b \to u, d, s$) **B** decays

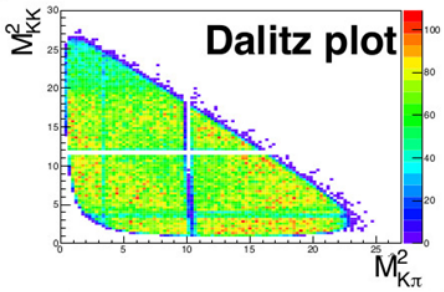
- A neural network is used to combine event shape variables
- Tight requirement on neural network output to reduce 99% of continuum events



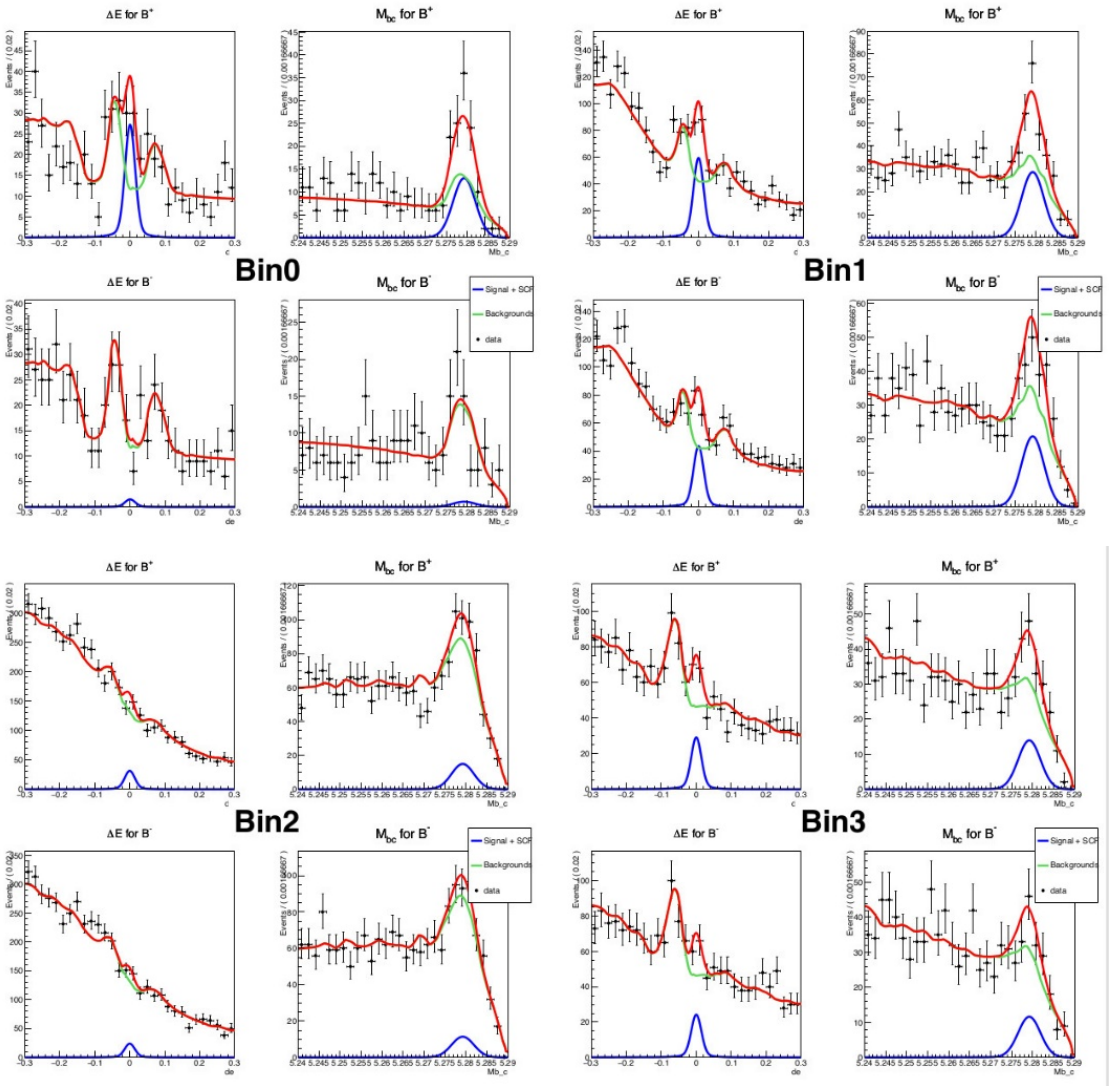
- Charm veto to reject $b \to c$ backgrounds after investigating the K^+K^- and $K^+\pi^-$ invariant-mass spectra

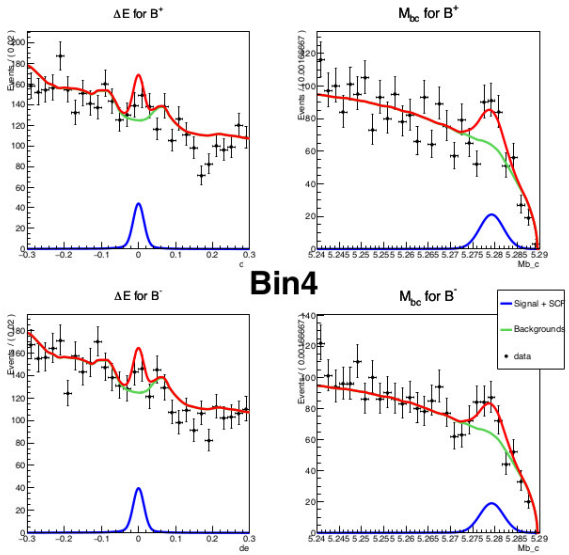






$B^+ \to K^+K^-\pi^+$: Fit results

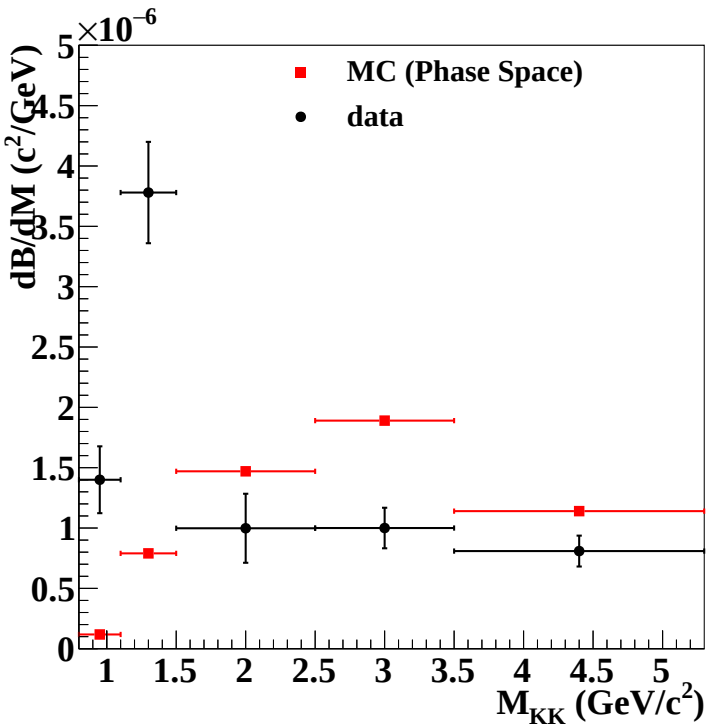


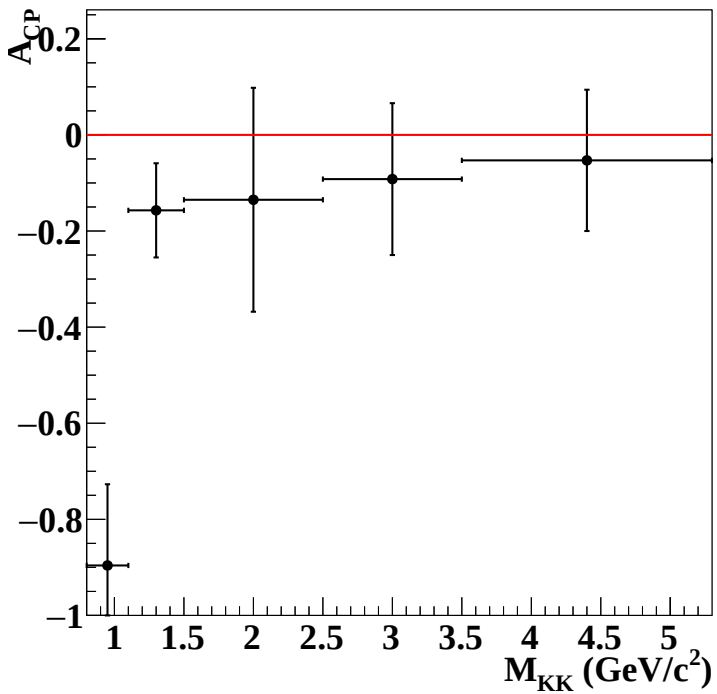


- Signal and A_{CP} are fitted in M_{KK} bins
- The overall results are obtained by integrating over the whole M_{KK} region
- We obtain $\mathrm{N_{sig}} = 715 \pm 48$

$B^+ \to K^+K^-\pi^+$: Fit results

- Observed an excess similar to LHCb and BaBar in $\mathrm{M_{KK}} < 1.5\ \mathrm{GeV/c^2}$
- Strong evidence for a large CP asymmetry of $-\mathbf{0.90 \pm 0.17 \pm 0.04}$ with $\mathbf{4.8}\sigma$ significance for $\mathrm{M_{KK}} < 1.1\ \mathrm{GeV/c^2}$





$B^+ \to K^+K^-\pi^+$: Fit results

- Overall $\mathcal{B}$ and $\mathcal{A}_{CP}$:

$$\boxed{\mathcal{B}(K^+K^-\pi^+) = (5.38 \pm 0.40 \pm 0.35) \times 10^{-6}}$$

$$\boxed{\mathcal{A}_{CP} = -0.182 \pm 0.071 \pm 0.016}$$

Table: Signal yield, efficiency, differential branching fraction, and $\mathcal{A}_{CP}$ for individual M_{KK} bins

$M_{\mathrm{K^+K^-}}\,(\mathrm{GeV/c^2})$	N_{sig}	Eff. (%)	$d\mathcal{B}/dM\ (\times 10^{-7})$	$\mathcal{A}_{CP}$
0.8-1.1	$59.8 \pm 11.4 \pm 2.6$	19.7	$14.0 \pm 2.7 \pm 0.8$	$-0.90 \pm 0.17 \pm 0.03$
1.1-1.5	$212.4 \pm 21.3 \pm 6.6$	19.3	$37.8 \pm 3.8 \pm 1.9$	$-0.16 \pm 0.10 \pm 0.01$
1.5-2.5	$113.5 \pm 26.7 \pm 18.0$	15.6	$10.0 \pm 2.3 \pm 1.6$	$-0.15 \pm 0.23 \pm 0.03$
2.5-3.5	$110.1 \pm 17.6 \pm 4.1$	15.1	$10.0 \pm 1.6 \pm 0.5$	$-0.09 \pm 0.16 \pm 0.01$
3.5-5.3	$172.6 \pm 25.7 \pm 6.87$	16.3	$8.1 \pm 1.2 \pm 0.5$	$-0.05 \pm 0.15 \pm 0.00$

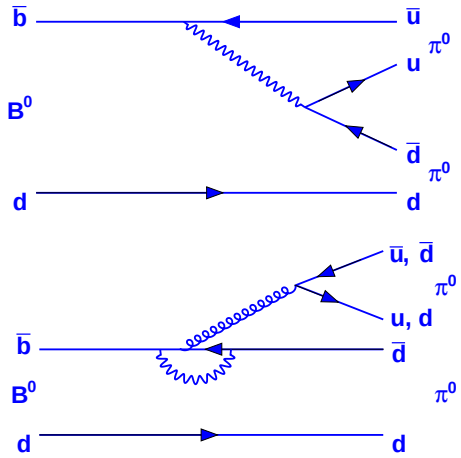
arXiv:1705.02640

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

- Proceeds via $b \to u$ tree and $b \to d$ penguin diagrams
- Time dependent measurements of $B \to \pi\pi$ are sensitive to the UT angle $\phi_2(\alpha)$
- Among the $B \to \pi\pi$ decays, $\mathcal{B}$ and A_{CP} for $B^0 \to \pi^0\pi^0$ are the least well determined

Theory:

- $\mathcal{B}(B^0 \to \pi^0\pi^0) < \mathcal{B}(B^0 \to \rho^0\rho^0)$
(Hsiang-nan Li and Satoshi Mishima. Phys.Rev.D73:114014,2006)
- Same diagrams and stronger coupling to ρ^0
- At most $\mathcal{B}(B^0 \to \pi^0\pi^0) < 1x10^{-6}$
(H.L. & SM Phys.Rev.D83:034023,2011)



Previous measurements:

- Belle $\mathcal{B} = (2.3 \pm 0.4 \pm 0.5) \times 10^{-6}$
PRL **94**, 181803(2005) $(275 \times 10^6\ B\bar{B})$
- Belle $\mathcal{B} = (1.12 \pm 0.3 \pm 0.1) \times 10^{-6}$
ICHEP 2006 $(535 \times 10^6\ B\bar{B})$
- BaBar $\mathcal{B} = (1.83 \pm 0.21 \pm 0.13) \times 10^{-6}$
PRD **87**, 052009(2013) $(467 \times 10^6\ B\bar{B})$
- PDG Average $\mathcal{B} = (1.62 \pm 0.31) \times 10^{-6}$

$B^0 \to \pi^0\pi^0$: Fit components

- 3D fit to ΔE, M_{bc} and T_c (continuum suppression variable) with four components:

1. Signal
2. Continuum
3. $B^+ \to \rho^+\pi^0$
4. Other rare charmless

- Simultaneous fit to 14 bins in the flavor tagging variable (**q.r**)

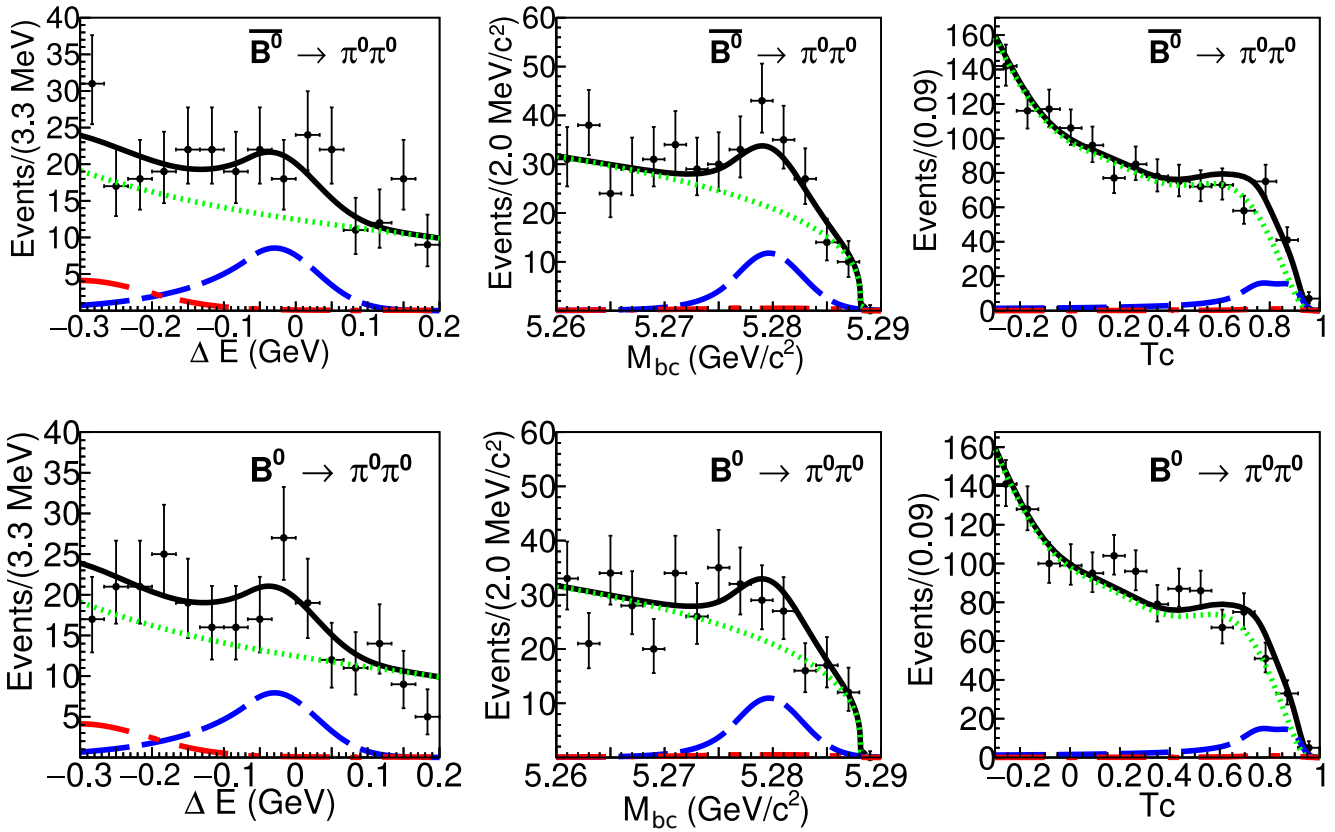
- T_c PDF obtained from analytic anzatz fit to signal MC and a data sideband for continuum

- ΔE and M_{bc} for signal obtained with analytic functions, accounting for correlation due to energy leakage in the calorimeter

$B^0 \to \pi^0\pi^0$: Fit results

$$\mathcal{B}(B^0 \to \pi^0\pi^0) = (1.31 \pm 0.19 \pm 0.18) \times 10^{-6}$$

$$\mathcal{A}_{CP} = +0.14 \pm 0.36 \pm 0.12$$



Black - All contributions Green - continuum backgrounds

Blue - signal Red - $B^+ \to \rho^+\pi^0$ and other rare backgrounds

$5.275\ \text{GeV} < \text{M}_{\text{bc}} < 5.285\ \text{GeV}$

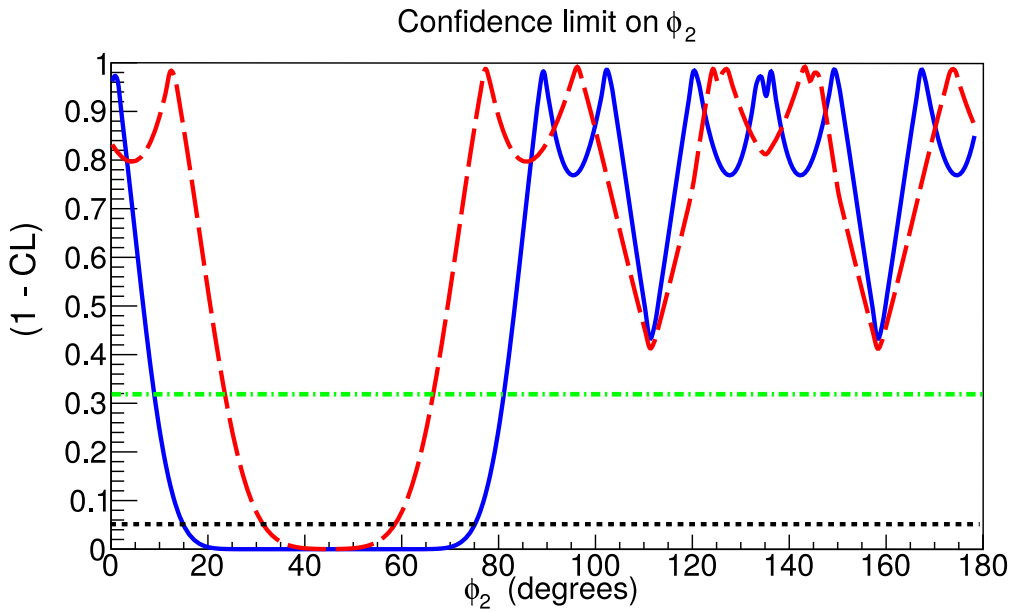
$-0.15\ \text{GeV} < \Delta\text{E} < 0.05\ \text{GeV}$, $T_c > 0.70$

$B^0 \to \pi^0\pi^0$: Constraint on the angle $\phi_2(\alpha)$

- $\mathcal{B}$ and $\mathcal{A}_{CP}$ results for $B^0 \to \pi^0\pi^0$ are combined with previous Belle results on $B^0 \to \pi^+\pi^-$ and $B^+ \to \pi^+\pi^0$ to constrain ϕ_2 employing isospin relations[1]

- Exclude $\boxed{15.5^\circ < \phi_2 < 75^\circ}$ at 95% confidence level

arXiv:1705.02083



previous constraint from Belle

including our new results

[1] Gronau & London, PRL 65, 3381 (1990)

Summary

$B^+ \to K^+K^-\pi^+$ Submitted for publication (arXiv:1705.02640)

$\mathcal{B}(K^+K^-\pi^\pm) = (5.38 \pm 0.40 \pm 0.35) \times 10^{-6}$

$\mathcal{A}_{CP} = -0.182 \pm 0.071 \pm 0.016$

Found strong evidence for a large CP asymmetry of $-\mathbf{0.90 \pm 0.17 \pm 0.03}$ with $\mathbf{4.8}\sigma$ significance for $\mathrm{M_{KK}} < 1.1\ \mathrm{GeV/c^2}$

$B^0 \to \pi^0\pi^0$ Submitted for publication (arXiv:1705.02083)

$\mathcal{B}(B^0 \to \pi^0\pi^0) = (1.31 \pm 0.19 \pm 0.18) \times 10^{-6}$

$\mathcal{A}_{CP} = +0.14 \pm 0.36 \pm 0.12$

Exclude the UT angle ϕ_2 from the range $\mathbf{15.5^\circ} < \phi_\mathbf{2} < \mathbf{75^\circ}$ at **95%** confidence level

Thank you