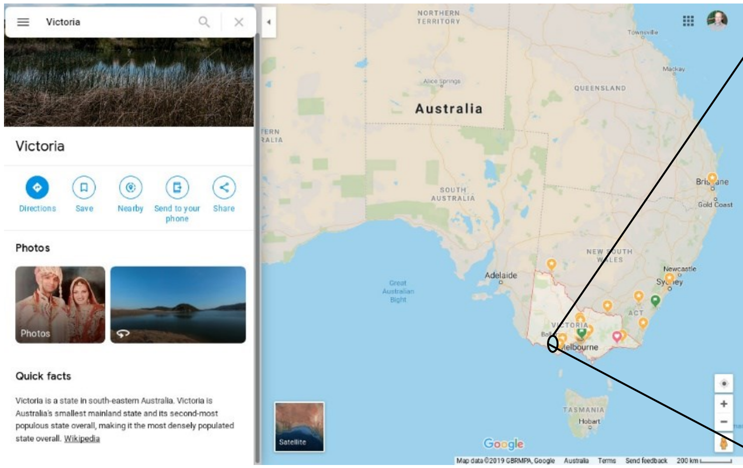
Recent measurements of MultiBody B-decays and time-integrated CPV

(www.tourismvictoria.com)

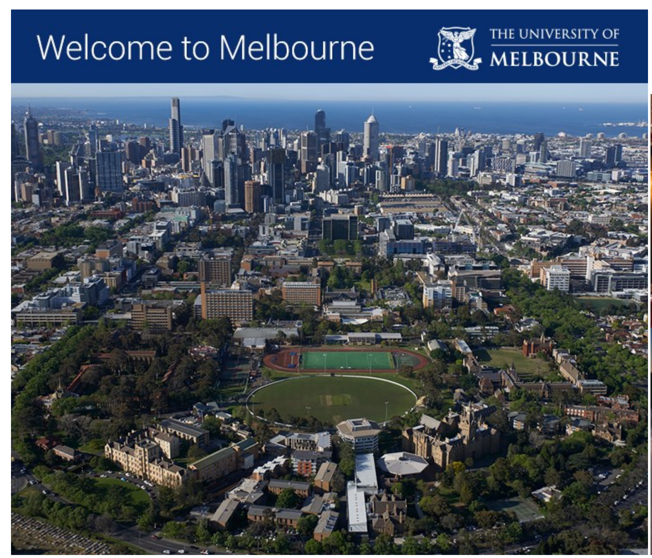
Martin Sevior, University of Melbourne
On behalf of Belle

A little aside…

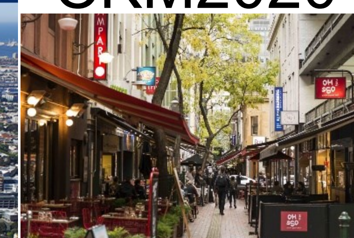


Beacon Hill Park

Younger me



CKM2020



Outline

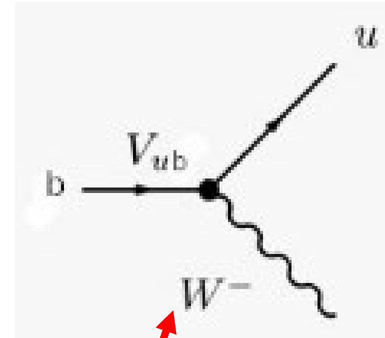
- Belle: $B^{\pm} \to K^{+}K^{-}\pi^{\pm}$, Branching Fraction,$(\mathcal{B})$, A_{CP} PRD 96, 031101(R)
- Belle: $B^{0} \to K^{+}K_{s}\pi^{-}$, Branching Fraction,$(\mathcal{B})$, A arXiv:1904.06835
- Belle: $B^{\pm} \to K_{s}K_{s}h^{\pm}$, Branching Fraction,$(\mathcal{B})$, A_{CP} PRD 99, 031102(R)
- Belle: $B^{0} \to p\bar{p}\pi^{0}$, Branching Fraction arXiv:1904.05713
- LHCb: $\overline{B^{0}} \to K_{s}\pi^{+}\pi^{-}$, Amplitude analysis, A_{CP} PRL 120, 261801
- LHCb: $B_{s} \to K_{s}K^{\pm}\pi^{\mp}$, Amplitude analysis arXiv:1902.07955
- LHCb: $B^{\pm} \to K^{+}K^{-}\pi^{\pm}$, Amplitude analysis, A_{CP}

(http://moriond.in2p3.fr/2019/EW/slides/5_Thursday/1_morning/5_Bertholet_TimeIndepCPV.pdf)

- LHCb: $B^{\pm} \to \pi^{+}\pi^{-}\pi^{\pm}$, Amplitude analysis, A_{CP} (FPCP, Tuesday, May 8, 17:00)

Charmless B-Decays

$$\begin{pmatrix} d' \\ s' \\ b' \end{pmatrix} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \begin{pmatrix} d \\ s \\ b \end{pmatrix}$$

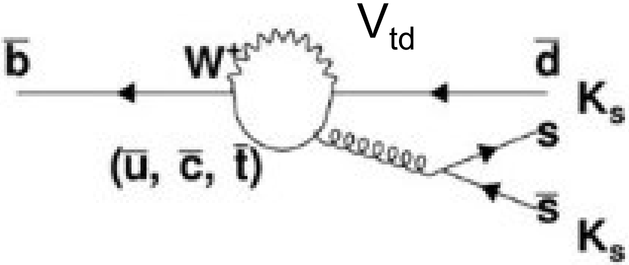


Tree decays

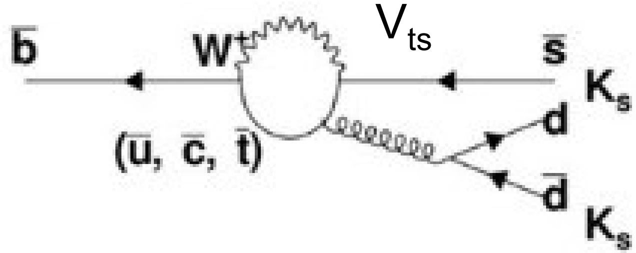
$$V_{CKM} \approx \begin{pmatrix} 1-\frac{\lambda^2}{2} & \lambda & A\lambda^3(\rho - i\eta) \\ -\lambda & 1-\frac{1}{2}\lambda^2 & A\lambda^2 \\ A\lambda^3(1-\rho-i\eta) & -A\lambda^2 & 1 \end{pmatrix}$$

Penguin decays

V_{td}

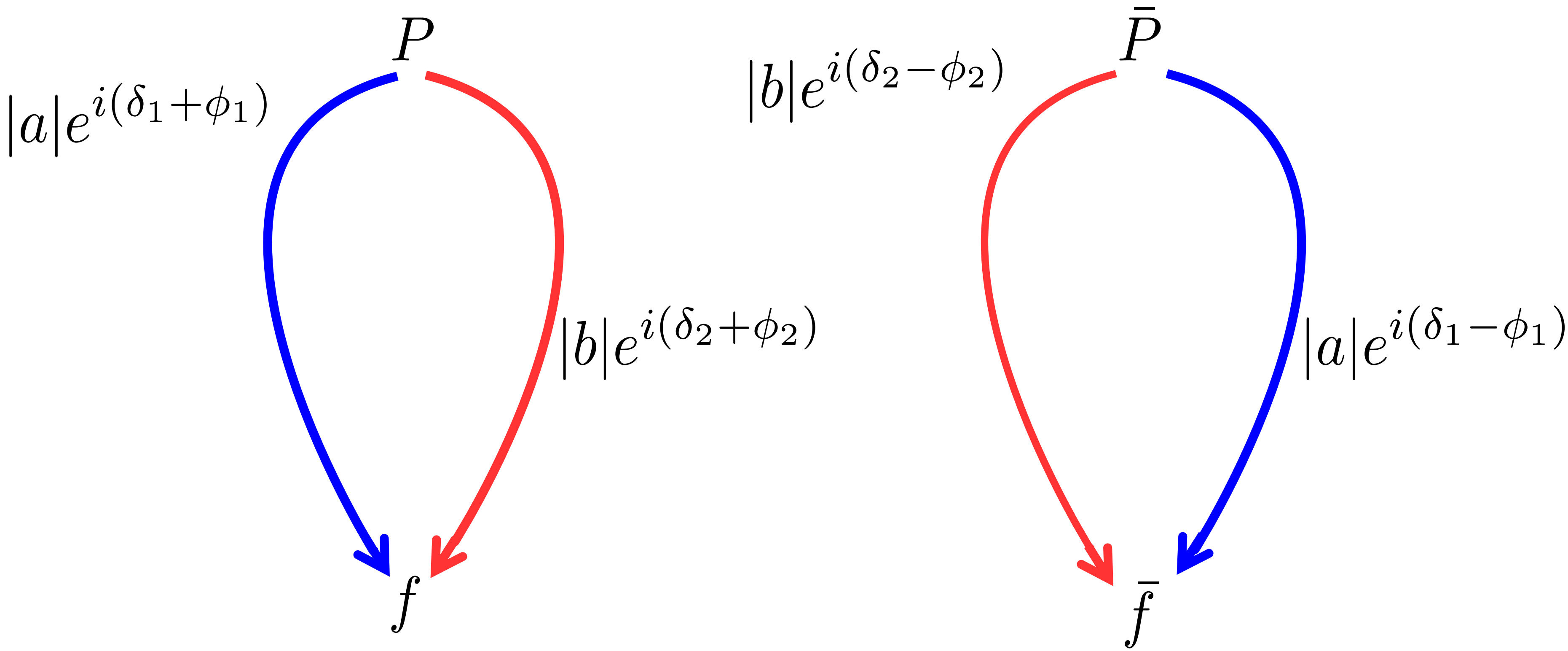


V_{ts}



Direct CP-violation

$$\Gamma(P \to f) \neq \Gamma(\bar{P} \to \bar{f})$$

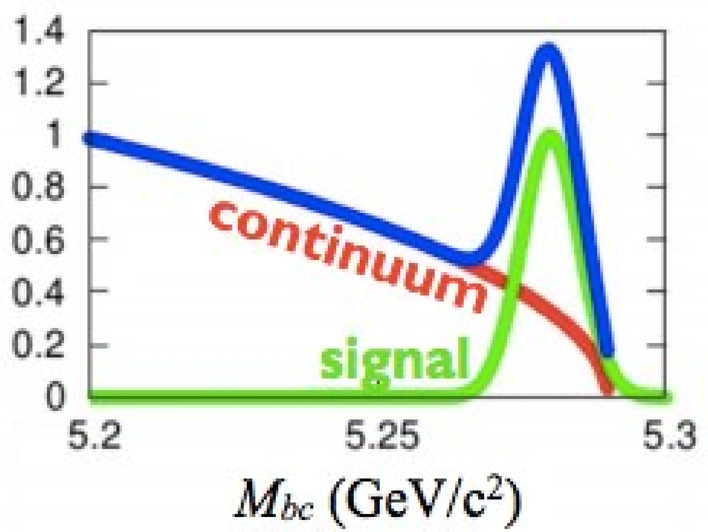


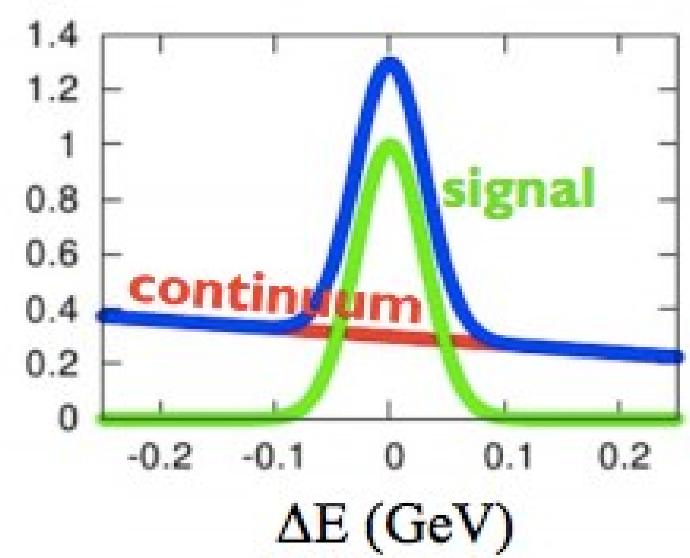
$$|A_f|^2 = |a|^2 + |b|^2 + 2|a||b|\cos(\Delta\delta + \Delta\Phi) \qquad |\bar{A}_f|^2 = |a|^2 + |b|^2 + 2|a||b|\cos(\Delta\delta - \Delta\Phi)$$

Kinematic Variables in B-Factory measurements

$$M_{bc} = \sqrt{E_{beam}^{*2} - P_B^{*2}}$$

$$\Delta E = E_B^* - E_{beam}^*$$



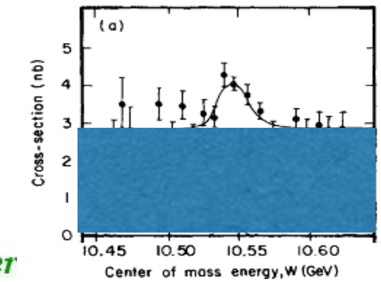


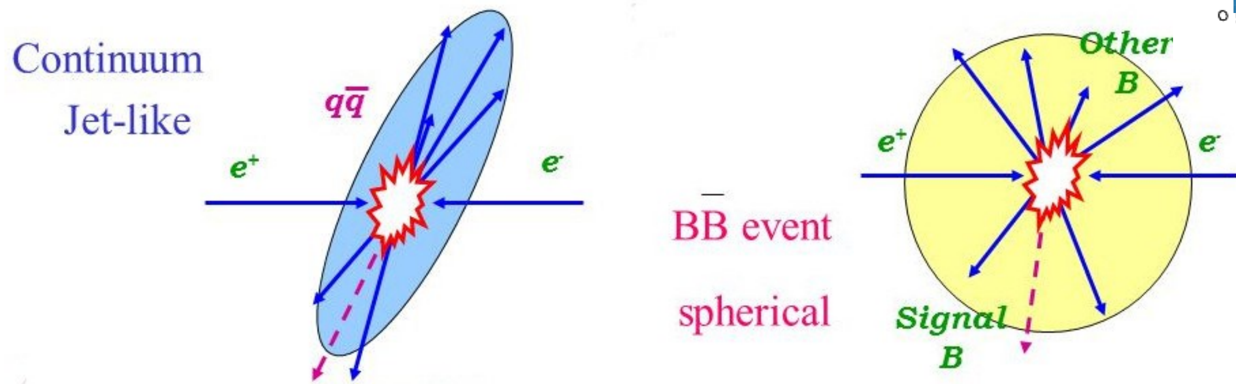
M_{bc} peaks at B mass for fully reconstructed signal

ΔE peaks at zero for fully reconstructed signal

Continuum Background

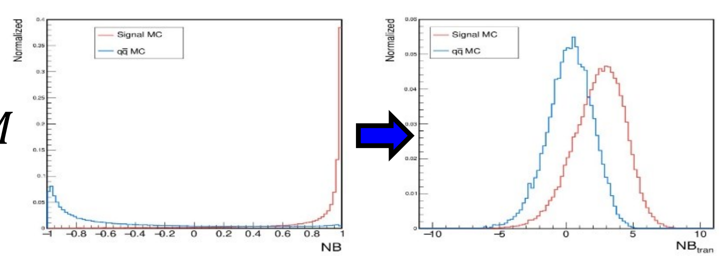
- Continuum background($e^+e^- \to q\bar{q}(u,d,s,c)$):
  - Dominant background
  - Event topology differs from BB decays





  - Combined variables describing the event topology in an artificial neural network.
  - Either tight cut to optimise FoM = $\frac{N_S}{\sqrt{N_S+N_B}}$
  - Make a loose cut to keep ~90% of signal and fit $\log(\frac{M_{max}-M}{M-M_{cut}})$

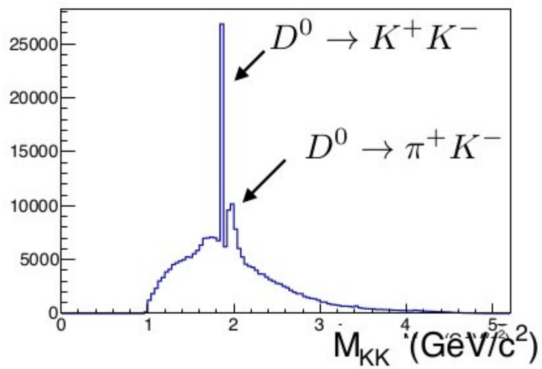
M

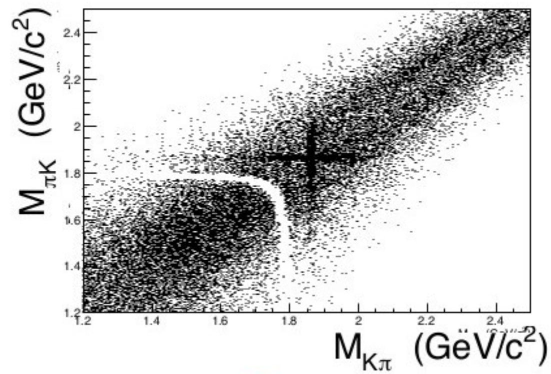


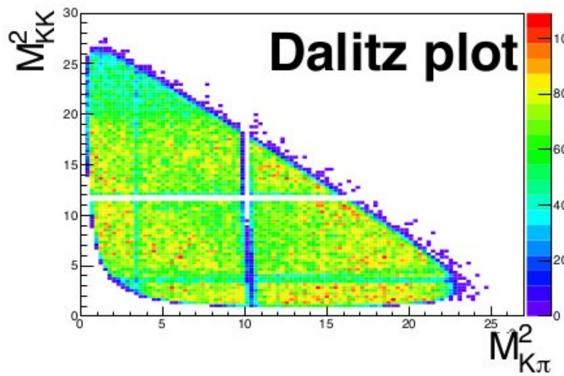
$$\log(\frac{M_{max}-M}{M-M_{cut}})$$

Charm Veto

Charm mesons and resonances are a copious source of h^+h^- $h \in \{p, K, \pi, \mu, e\}$
Cause peaking background directly or via incorrect PID
Apply a charm veto around charmed meson masses





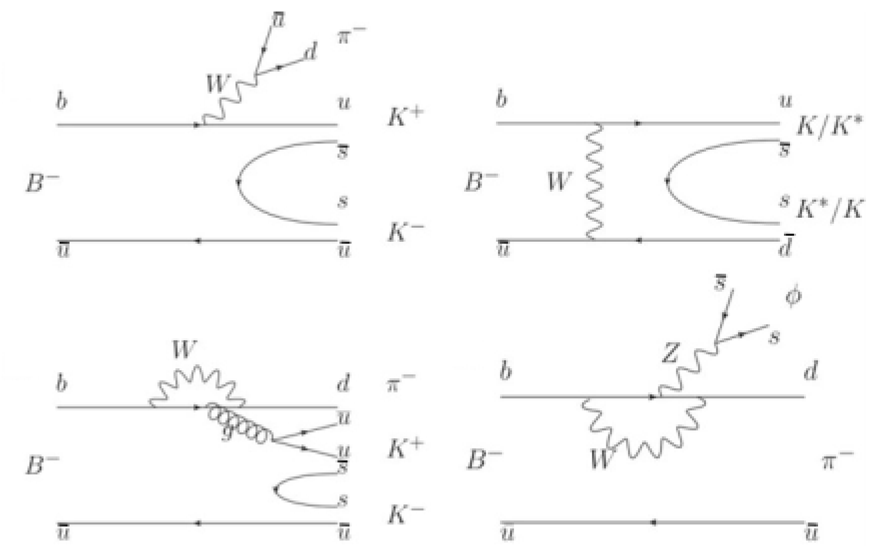


All Belle results are from the full dataset of 711 fb^{-1}

Belle: A_{CP} for $B^{\pm} \rightarrow K^{+}K^{-}\pi^{\pm}$

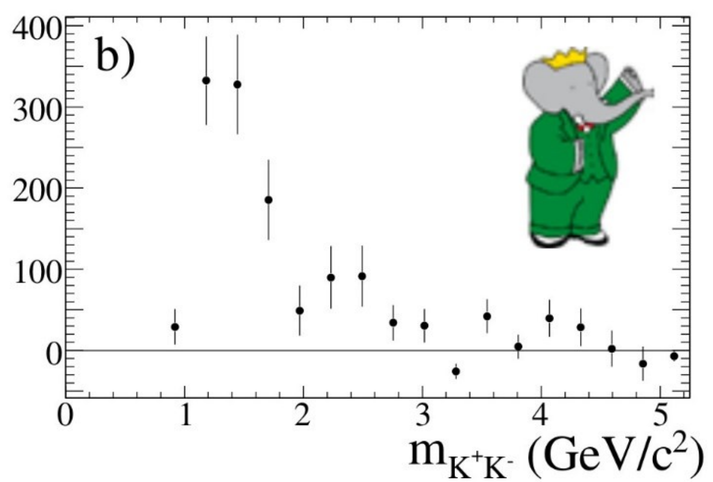
C.-L.Hsu et al. Phys. Rev. D96, 031101(R) (2017)

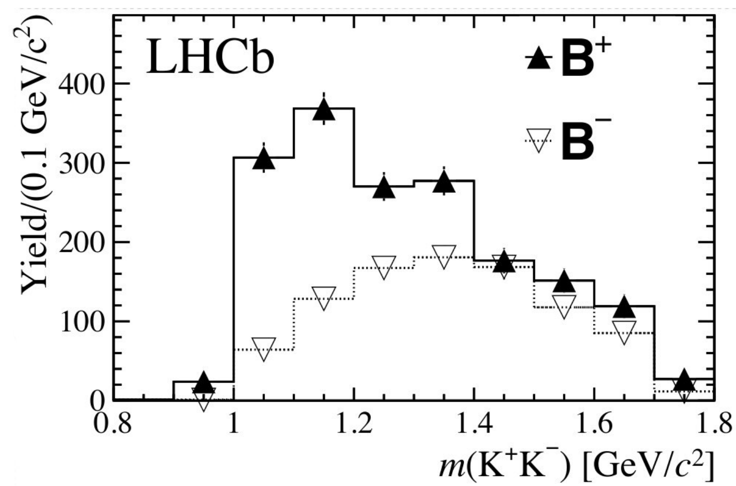
Cabibbo and color suppressed tree
And Penguin diagrams



Br($B^{\pm} \rightarrow K^{-}K^{+}\pi^{\pm}$) = $(5.0 \pm 0.5 \pm 0.5) \times 10^{-6}$
PRL 99, 221801 (2007) BaBar

A_{CP} = -0.123 ± 0.017 ± 0.012 ± 0.007
PRD 90, 112004 (2014) LHCb

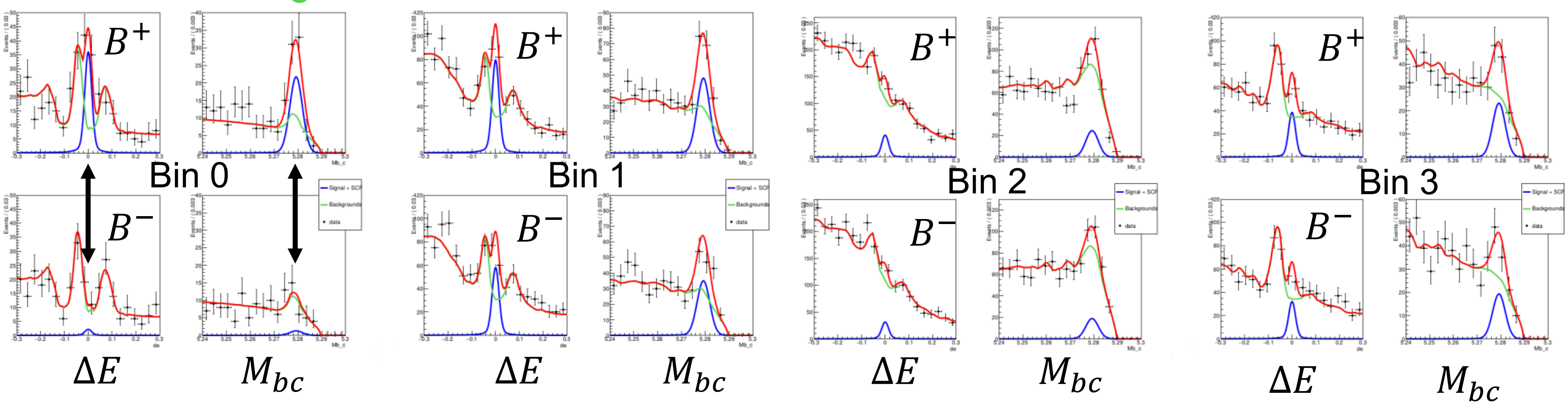


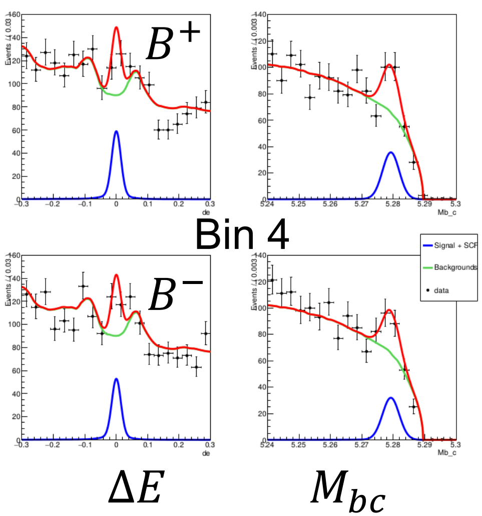


Belle: Fit for $B^{\pm} \to K^{+}K^{-}\pi^{\pm}$ in M_{KK} Bins

Signal — Sum — Backgrounds — • Data

Cut on Continuum-suppression, 2D fit to M_{BC} and ΔE



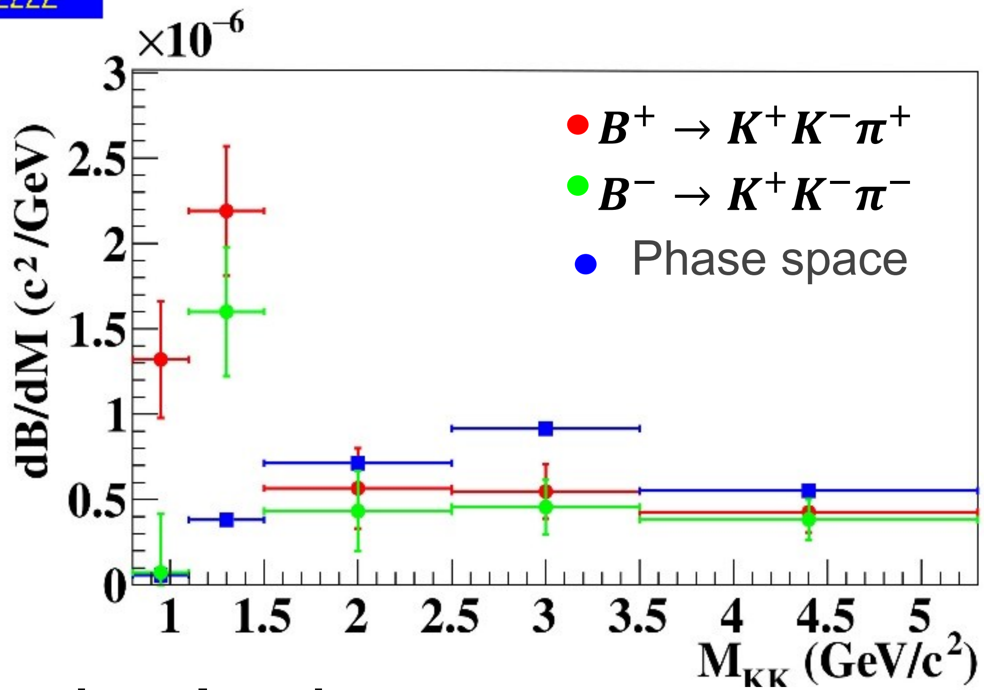


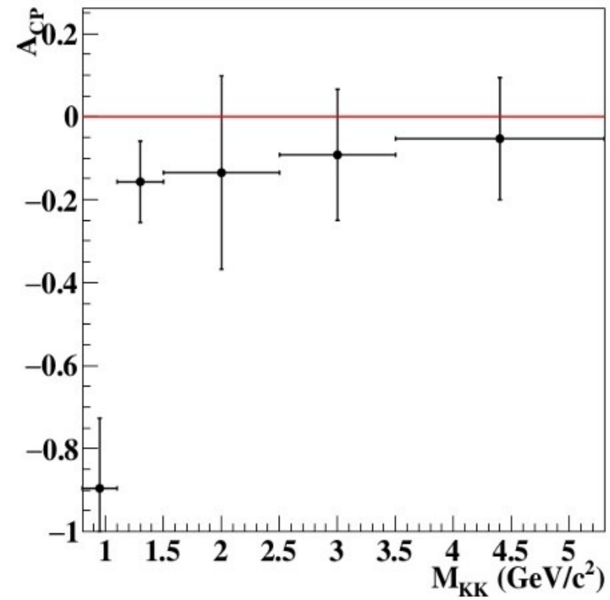
$M_{K^+K^-}$ (GeV/c^2)	$N_{\rm sig}$	Eff. (%)	$d\mathcal{B}/dM$ $(\times 10^{-7})$	$\mathcal{A}_{CP}$
0.8-1.1	$59.8 \pm 11.4 \pm 2.6$	19.7	$14.0 \pm 2.7 \pm 0.8$	$-0.90 \pm 0.17 \pm 0.04$
1.1-1.5	$212.4 \pm 21.3 \pm 6.7$	19.3	$37.8 \pm 3.8 \pm 1.9$	$-0.16 \pm 0.10 \pm 0.01$
1.5-2.5	$113.5 \pm 26.7 \pm 18.6$	15.6	$10.0 \pm 2.3 \pm 1.7$	$-0.15 \pm 0.23 \pm 0.03$
2.5-3.5	$110.1 \pm 17.6 \pm 4.9$	15.1	$10.0 \pm 1.6 \pm 0.6$	$-0.09 \pm 0.16 \pm 0.01$
3.5-5.3	$172.6 \pm 25.7 \pm 7.4$	16.3	$8.1 \pm 1.2 \pm 0.5$	$-0.05 \pm 0.15 \pm 0.01$

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

Total $\mathcal{B}$ = (5.38 ± 0.40 ± 0.35) × 10^{-6}
A_{CP} = −0.170 ± 0.073 ± 0.017

C.-L.Hsu et al. Phys. Rev. D96, 031101(R) (2017)





$$|A|^2 = A_1^2 + A_2^2 + 2A_1A_2\cos(\Delta\delta + \Delta\phi)$$

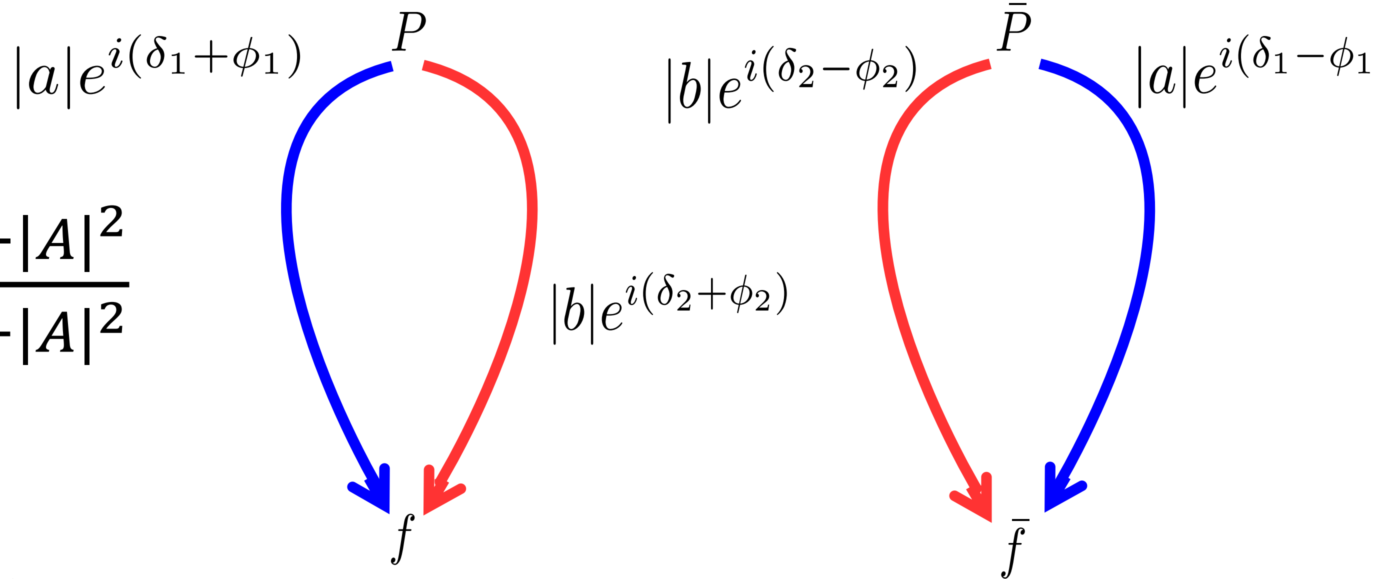
$$|\bar{A}|^2 = A_1^2 + A_2^2 + 2A_1A_2\cos(\Delta\delta - \Delta\phi)$$

Unusual dynamics showing a large enhancement and very large direct CP-violation
A_{CP} = -0.9 $\pm 0.17 \pm 0.03$ at M_{KK} < 1.1 GeV (4.8 σ)
Hard to make a model do both.

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

Recall

$$A_{CP} = \frac{|\overline{A}|^2 - |A|^2}{|\overline{A}|^2 + |A|^2}$$



$$|A_f|^2 = |a|^2 + |b|^2 + 2|a||b|\cos(\Delta\delta + \Delta\Phi)$$

$$|\bar{A}_f|^2 = |a|^2 + |b|^2 + 2|a||b|\cos(\Delta\delta - \Delta\Phi)$$

Need an order of magnitude increase in EW Tree diagram
And an order of magnitude increase in Penguin diagram
both in 0.99 GeV < M_{KK} < 1.1 GeV

Major role for $K\overline{K} \leftrightarrow \pi\bar{\pi}$ rescattering?
LHCb Moriond (http://moriond.in2p3.fr/2019/EW/slides/5_Thursday/1_morning/5_Bertholet_TimeIndepCPV.pdf)

Belle: $B^0 \to K^+ K_s \pi^-$, Branching Fraction, $(\mathcal{B})$, A

Y.S. Lai et al. arXiv:1904.06835

- Suppressed in Standard Model.

- The $B^0 \to K^+ K_s \pi^-$ decay mainly proceeds via $b \to d$ penguin process and hence sensitive to new physics in the loops

- Previous measurement by BaBar $BR = (6.4 \pm 1.0 \pm 0.6) \times 10^{-6}$ (PRD.82.031101)

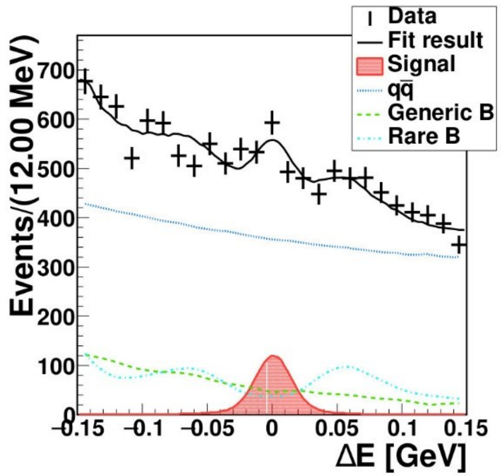
- Appears to be some structure at low $M_{K^-\pi^+}$ region and asymmetric helicity angle distribution at low $M_{K^-K_s}$ region but limited statistics (~200) makes a detailed study difficult

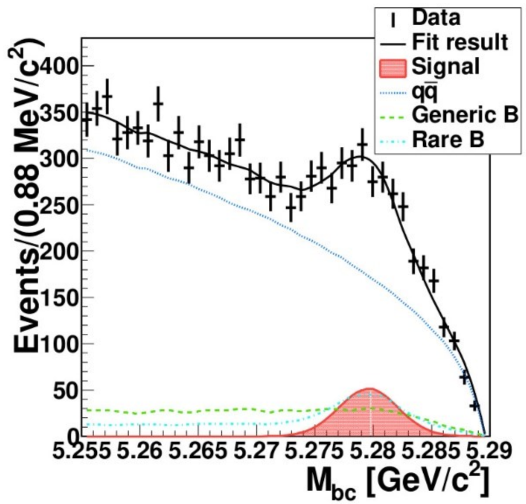
The similar process $\mathrm{B}^{\pm} \to \mathrm{K}^+\mathrm{K}^-\pi^{\pm}$ found a large direct CP asymmetry at $M_{KK} < 1.1$GeV

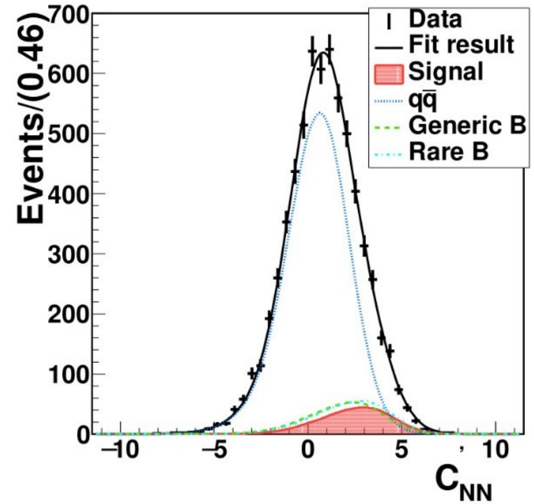
Belle: $B^0 \rightarrow K^+ K_s \pi^-$ fitted yields

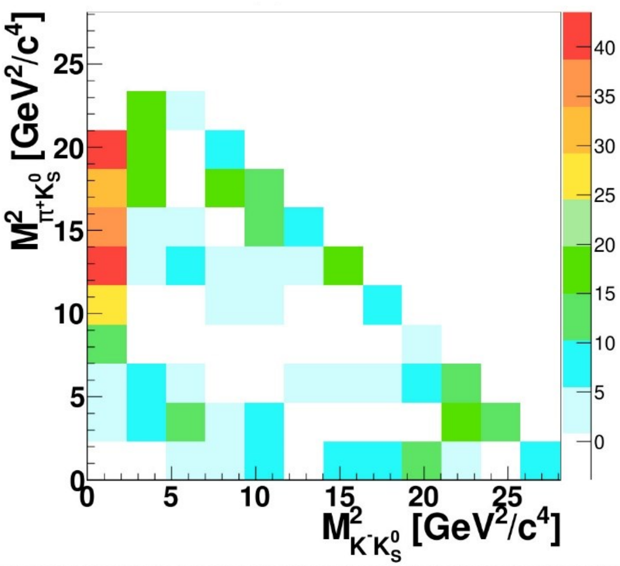
Make a unbinned maximum likelihood 3-D fit on $M_{BC}, \Delta E$ and log-transformed NB

Projection plots





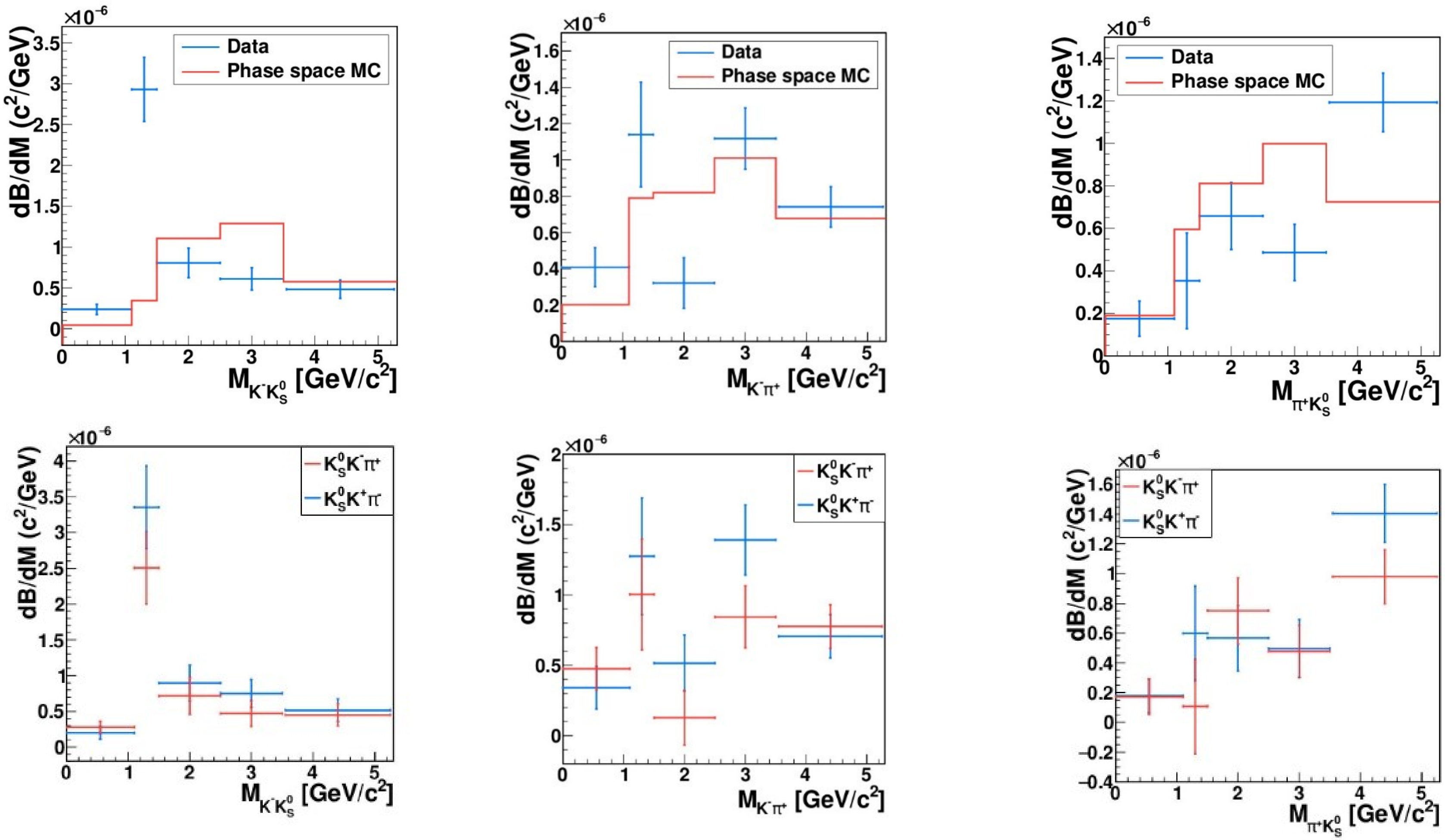




Use *sPlot* technique NIM **A 555**, 356 (2005) to extract background subtracted Dalitz distribution

$B^0 \to K^+ K_s \pi^-$ Differential decay rates and Asymmetry

Differential decay rates and Asymmetry plots



Belle: $B^0 \rightarrow K^+ K_s \pi^-$, Branching Fraction,$(\mathcal{B}), A$

$$A = \frac{N(K^+ K_s \pi^-) \; - N(K^- K_s \pi^+)}{N(K^+ K_s \pi^-) + N(K^- K_s \pi^+)}$$

Total Yield = 490$\pm$46 events

BR = (3.60 ± 0.33 ± 0.15) × 10 $^{-6}$

(Most precise measurement)

$A =$ (−8.5 ± 8.9 ± 0.2)%

Threshold enhancement seen near $1.2 \; GeV c^{-2}$ in $M_{K^- K_s}$ and a hint of a peak at $4.2 \; GeV c^{-2}$ in $M_{\pi^- K_s}$

Full tables of differential BR are given in Y.S. Lai et al. arXiv:1904.06835

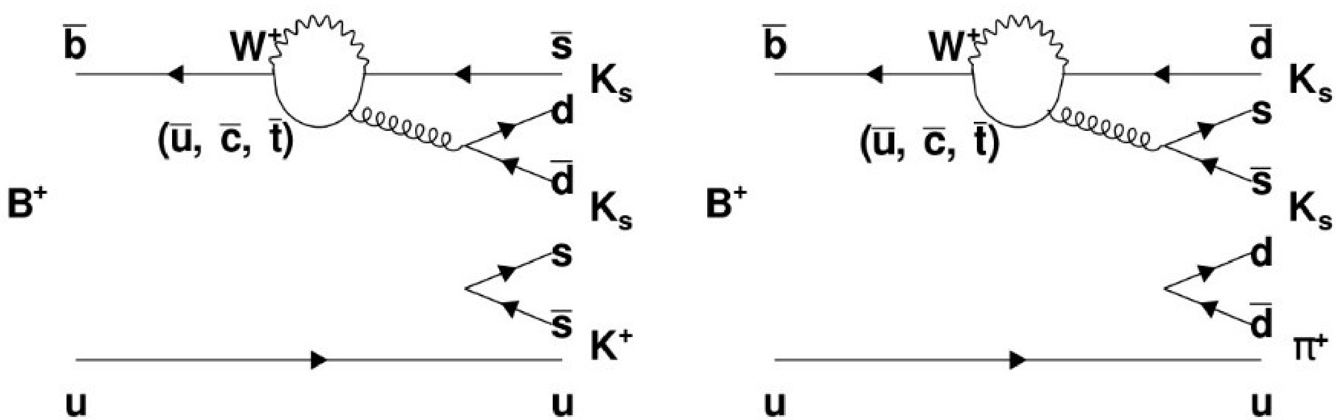
Belle: $B^{\pm} \rightarrow K_s K_s h^{\pm}$, Branching Fraction, $(\mathcal{B}), A_{CP}$

B. Kaliyar et al. PRD 99, 031102(R) (2019) arXiv:1812.10221

$B^{\pm} \rightarrow K_s K_s K^{\pm}$ and $B^{\pm} \rightarrow K_s K_s \pi^{\pm}$

No contribution from V_{ub}

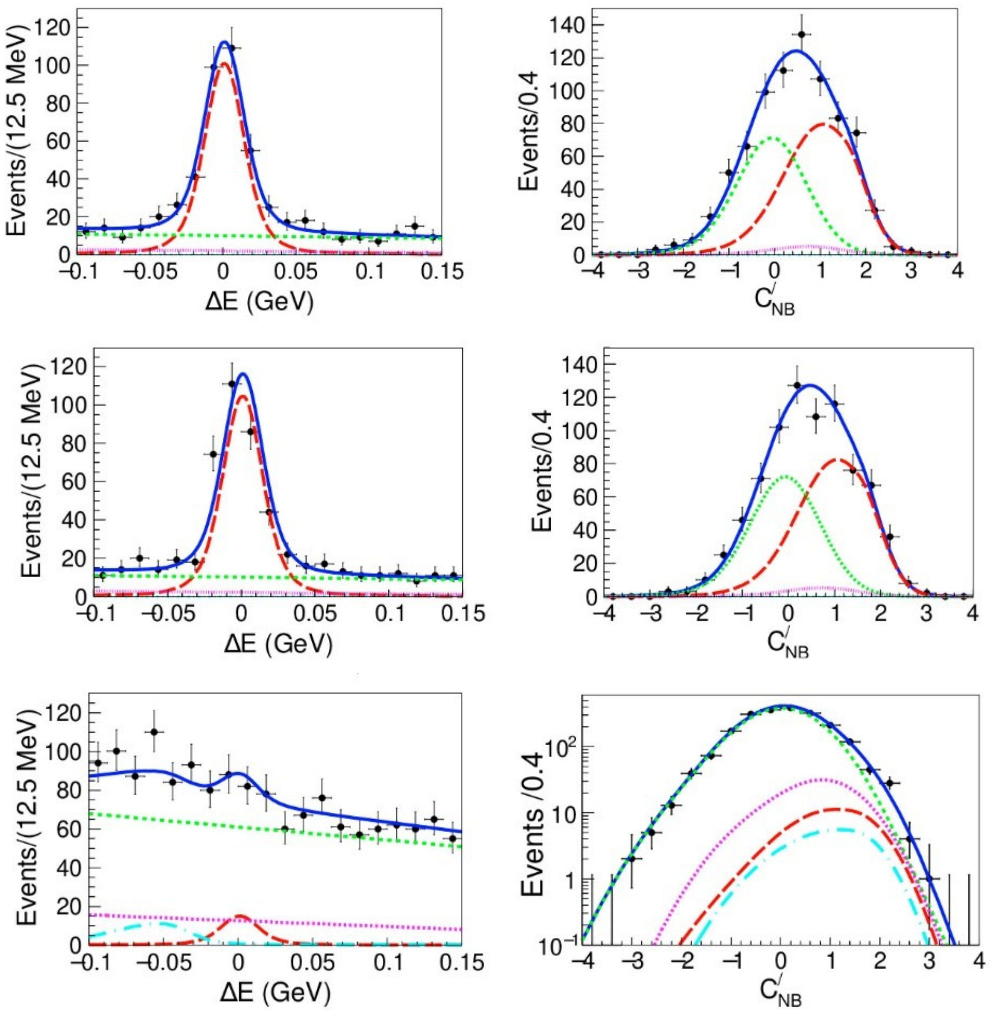
Proceeds only through penguin loops and hence sensitive to New Physics



Belle: $B^{\pm} \to K_s K_s h^{\pm}$ Fits

THE UNIVERSITY OF MELBOURNE

2-D fit to ΔE and log-transformed NB to $B^{\pm} \to K_s K_s K^{\pm}$ and $B^{\pm} \to K_s K_s \pi^{\pm}$ with cross feeds



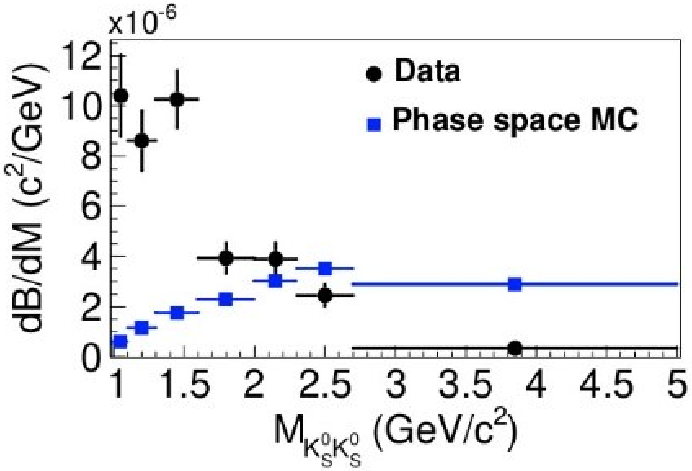
$B^{+} \to K_s K_s K^{+}$

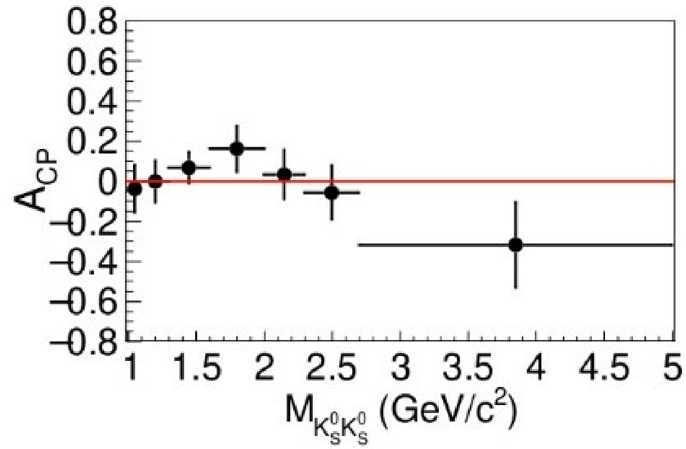
$B^{-} \to K_s K_s K^{-}$

$B^{\pm} \to K_s K_s \pi^{\pm}$

Belle: $B^{\pm} \rightarrow K_s K_s h^{\pm}$ Br, A_{CP}

Differential BR and A_{CP} for $B^{\pm} \rightarrow K_s K_s K^{\pm}$





$Br(B^{\pm} \rightarrow K_s K_s K^{\pm}) = (10.42 \pm 0.43 \pm 0.22) \times 10^{-6}$

$A_{cp}(B^{\pm} \rightarrow K_s K_s K^{\pm}) = (+1.6 \pm 3.9 \pm 0.9)\%$

$Br(B^{\pm} \rightarrow K_s K_s \pi^{\pm}) = (6.5 \pm 2.6 \pm 0.4) \times 10^{-7}$

(2.5 σ significance)

90% Confidence $Br(B^{\pm} \rightarrow K_s K_s \pi^{\pm}) < 8.7 \times 10^{-7}$

Substantial threshold enhancement over phase-space in $M_{K_s K_s}$(again)

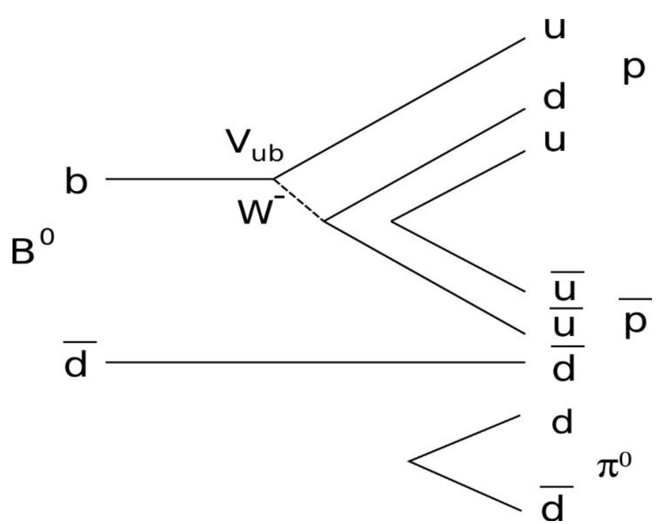
B. Kaliyar et al. PRD 99, 031102(R) (2019) arXiv:1812.10221

BELLE

Belle: $B^0 \to p\bar{p}\pi^0$, Branching Fraction

B. Pal et al. arXiv:1904.05713, To be published in PRD

- Charmless baryonic B-decays also proceed via V_{ub} and FCNC Penguin processes
- May exhibit DCPV and potentially sensitive to NP
- Hierarchy observed:
- 2 Body < 3 Body < 4 Body
- Observed threshold enhancement of baryonic particles



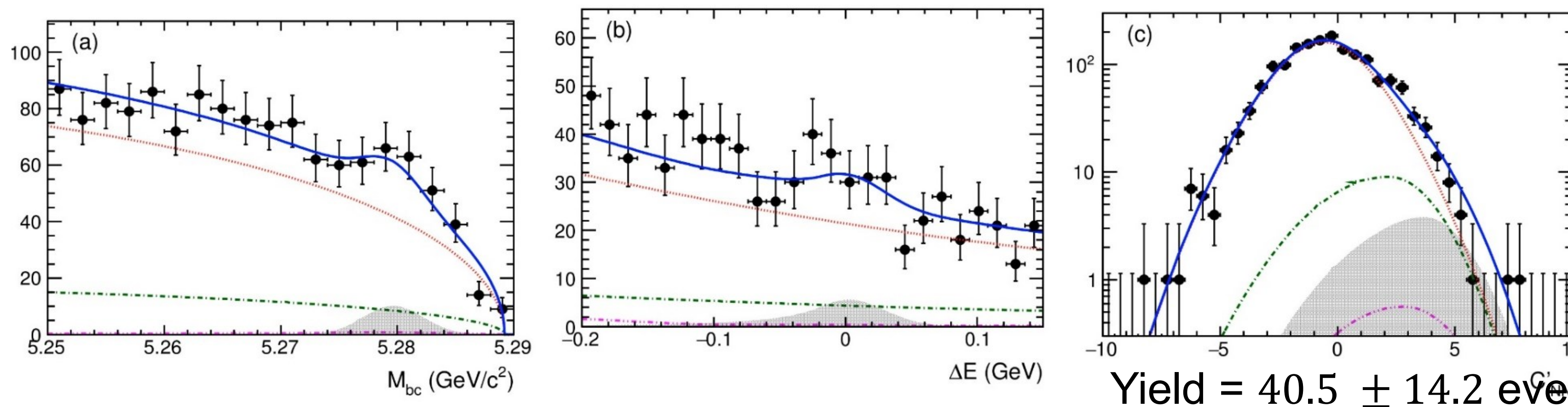
- The process $B^0 \to p\bar{p}\pi^0$ has not yet been observed

Belle: $B^0 \to p\bar{p}\pi^0$, Branching Fraction

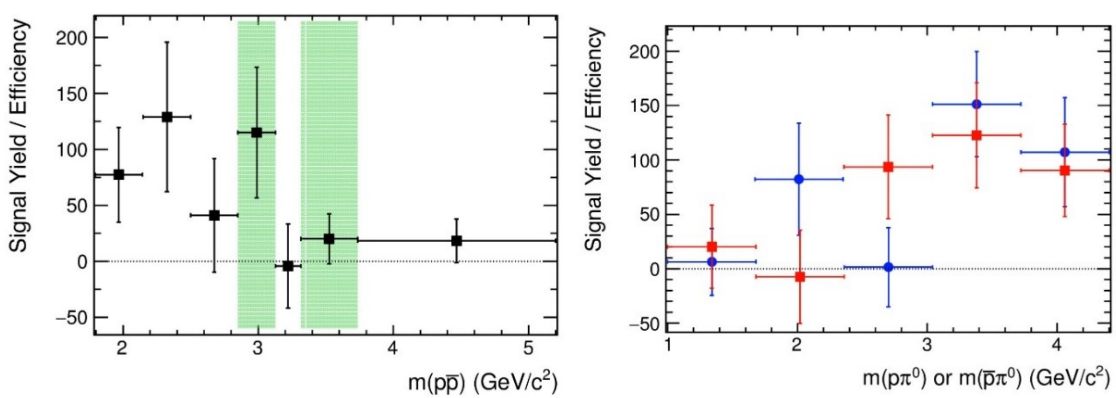
THE UNIVERSITY OF MELBOURNE

Correct for π^0 energy loss in ECL using: $\vec{P_B} = \vec{P}_p + \vec{P}_{\bar{p}} + \frac{\vec{P}_{\pi^0}}{|\vec{P}_{\pi^0}|}\sqrt{(E_{Beam} - E_p - E_{\bar{p}})^2 - m_{\pi^0}^2}$

Projection plots of 3D fit to data



Yield = 40.5 ± 14.2 events



$BR = (5.0 \pm 1.8 \pm 0.6) \times 10^{-7}$

3.1σ significance

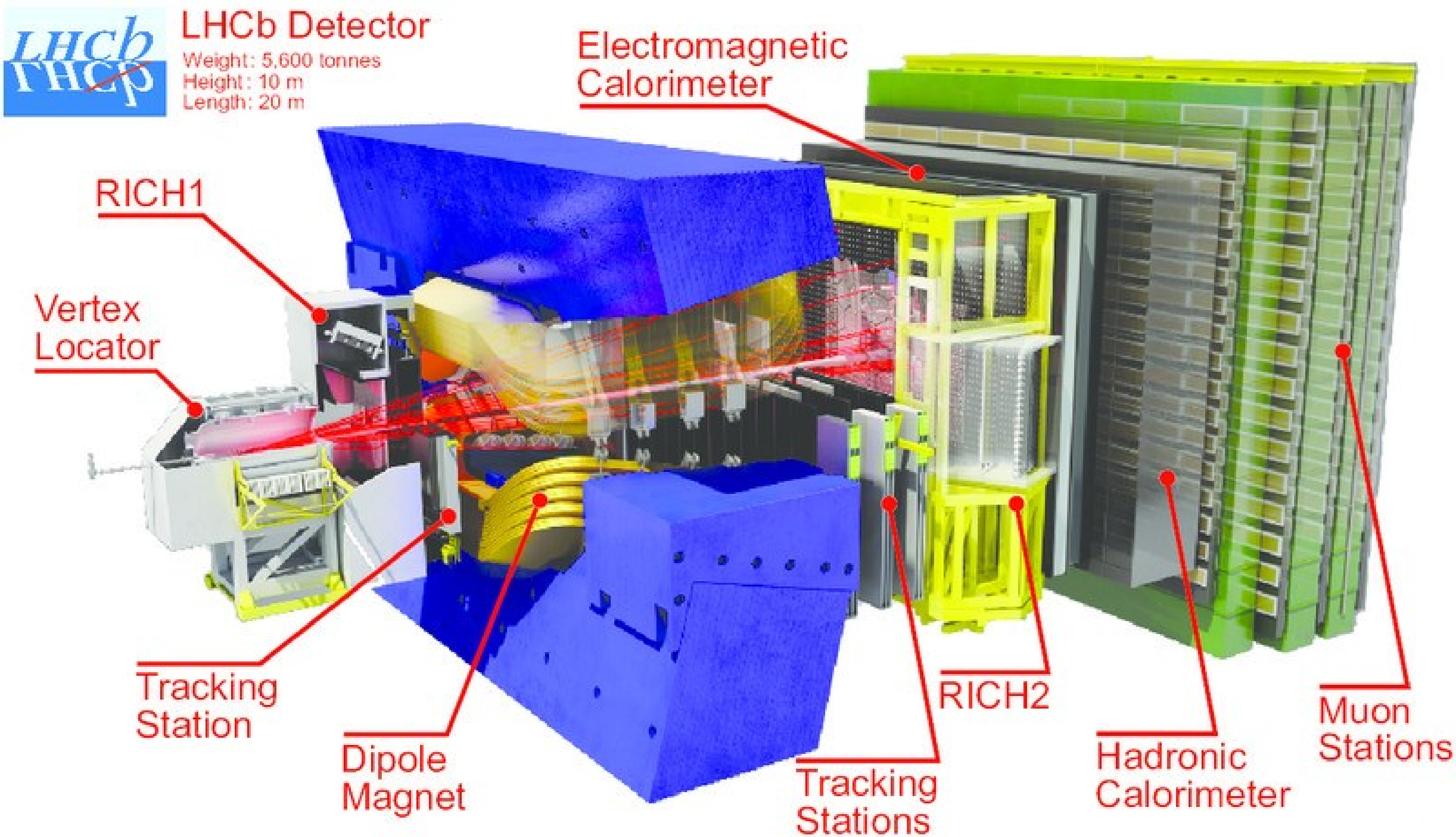
First Evidence for this decay

BELLE

sPlot NIM **A 555,** 356 (2005) used to extract distributions as function of $m_{p\bar{p}}$

B. Pal et al. arXiv:1904.05713, To be published in PRD

LHCb: Dalitz Plot (DP) Amplitude analyses

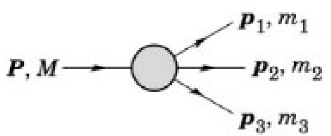


New results from run 1, (2011 and 2012, 3 fb^{-1})

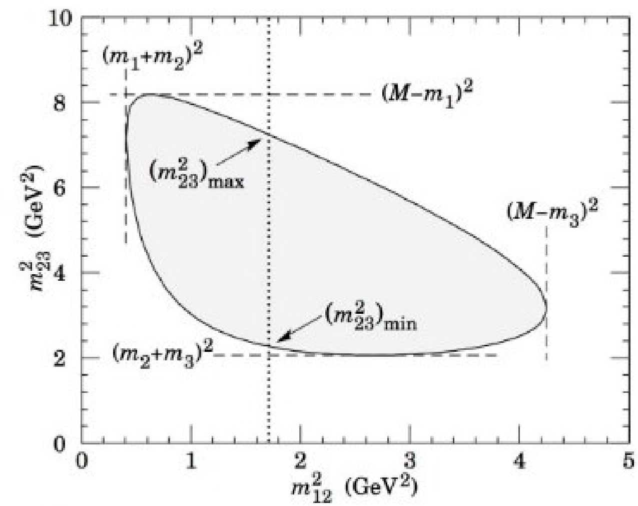
LHCb: Dalitz Plot (DP) Amplitude analyses

Emilie Bertholet
http://moriond.in2p3.fr/2019/EW/slides/5_Thursday/1_morning/5_Bertholet_TimeIndepCPV.pdf

- Information about the resonant structure.
- Direct access to phases.
- Branching ratios, direct and indirect (local) CP asymmetries.



$$d\Gamma = \frac{1}{(2\pi^3)}\frac{1}{32M^2}|\overline{A}|^2 dm_{12}^2 dm_{23}^2$$



Experimental parametrisation of the DP: Isobar Model

Quasi-two body approach.

The total amplitude of the decay is described as a coherent sum of partial amplitudes:

$$A(m_{12}^2, m_{23}^2) = \sum_{j=1}^{nRes} c_j F_j(m_{12}^2, m_{23}^2)$$

Isobar parameters
weak + strong interaction
⇒ sensitive to CPV

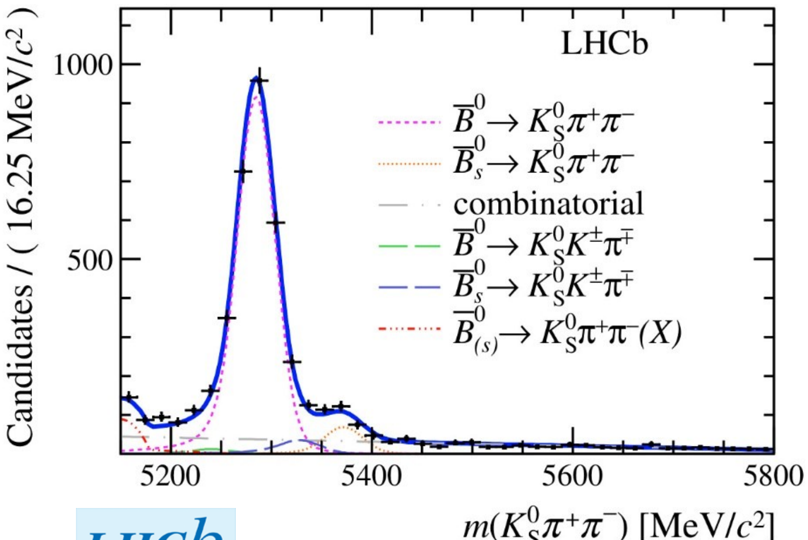
Lineshape
strong dynamics
⇒ no CPV

LHCb: $\overline{B^0} \to K_s\pi^+\pi^-$ and $\overline{B^0} \to K^{*-}\pi^+$, Amplitude analysis and A_{CP}

Phys. Rev. Lett. 120, 261801 (2018)

- The origin of the difference between neutral and charged modes for $\mathrm{B} \to K\pi$ for A_{CP} remains: (“K-π puzzle”)
- New, more precise measurements of $\Phi_3(\gamma)$ increase the SM tension for $B \to K^0\pi^0$ A_{CP} and S_{CP} to 2.2σ (PLB 785 (2018) 525)
- Recent theoretical work (Eur. Phys. J., C75(7), 340 (2015), J. Phys., G43(10), 105004 (2016)) shows that the $\overline{B^0} \to K^{*-}\pi^+$ modes can help understand the K-π puzzle
- An amplitude analysis of the 3-body $\overline{B^0} \to K_s\pi^+\pi^-$ decay can fully isolate the $\overline{B^0} \to K^{*-}\pi^+$ process.

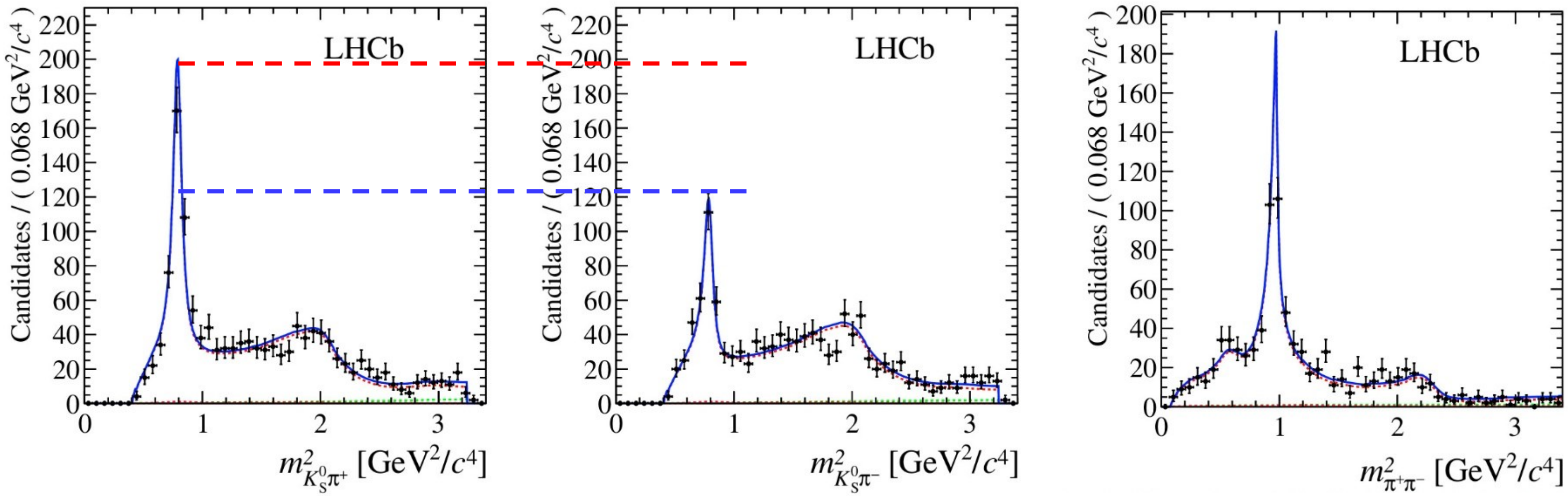
LHCb: $\overline{B^0} \to K_s\pi^+\pi^-$ and $\overline{B^0} \to K^{*-}\pi^+$, Amplitude analysis and A_{CP}



Build an Amplitude Analysis
Including the resonances shown

Resonance	Parameters	Lineshape	Value references
$K^*(892)^-$	$m_0 = 891.66 \pm 0.26$ $\Gamma_0 = 50.8 \pm 0.9$	RBW	[27]
$(K\pi)^-_0$	$\mathcal{R}e(\lambda_0) = 0.204 \pm 0.103$ $\mathcal{I}m(\lambda_0) = 0$ $\mathcal{R}e(\lambda_1) = 1$ $\mathcal{I}m(\lambda_1) = 0$	EFKLLM [28]	[28]
$K^*_2(1430)^-$	$m_0 = 1425.6 \pm 1.5$ $\Gamma_0 = 98.5 \pm 2.7$	RBW	[27]
$K^*(1680)^-$	$m_0 = 1717 \pm 27$ $\Gamma_0 = 332 \pm 110$	Flatté [29]	[27]
$f_0(500)$	$m_0 = 513 \pm 32$ $\Gamma_0 = 335 \pm 67$	RBW	[30]
$\rho(770)^0$	$m_0 = 775.26 \pm 0.25$ $\Gamma_0 = 149.8 \pm 0.8$	GS [31]	[27]
$f_0(980)$	$m_0 = 965 \pm 10$ $g_\pi = 0.165 \pm 0.025$ GeV $g_K = 0.695 \pm 0.119$ GeV	Flatté	[32]
$f_0(1500)$	$m_0 = 1505 \pm 6$ $\Gamma_0 = 109 \pm 7$	RBW	[27]
χ_{c0}	$m_0 = 3414.75 \pm 0.31$ $\Gamma_0 = 10.5 \pm 0.6$	RBW	[27]
Nonresonant (NR)		Phase space	

LHCb: $\overline{B^0} \to K_s\pi^+\pi^-$and $\overline{B^0} \to K^{*-}\pi^+$, Amplitude analysis and A_{CP}



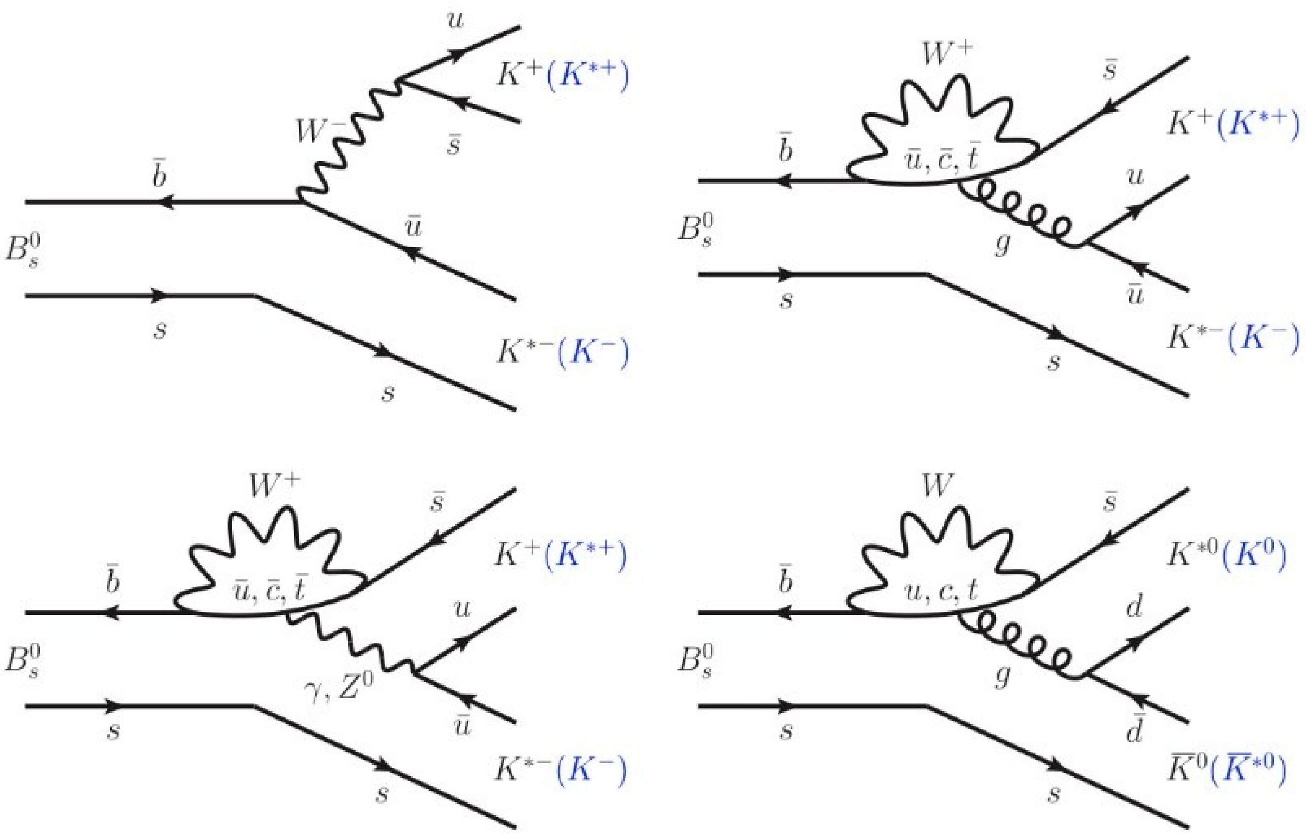
$\mathcal{A}_{CP}(K^*(892)^-\pi^+)$	$= -0.308 \pm 0.060 \pm 0.011 \pm 0.012$
$\mathcal{A}_{CP}((K\pi)_0^-\pi^+)$	$= -0.032 \pm 0.047 \pm 0.016 \pm 0.027$
$\mathcal{A}_{CP}(K_2^*(1430)^-\pi^+)$	$= -0.29 \pm 0.22 \pm 0.09 \pm 0.03$
$\mathcal{A}_{CP}(K^*(1680)^-\pi^+)$	$= -0.07 \pm 0.13 \pm 0.02 \pm 0.03$
$\mathcal{A}_{CP}(f_0(980)K^0_S)$	$= 0.28 \pm 0.27 \pm 0.05 \pm 0.14$

$A_{CP}\left(\overline{B^0} \to K^{*-}\pi^+\right) = -0.308 \pm 0.060 \pm 0.011 \pm 0.012$ > 6σ significance

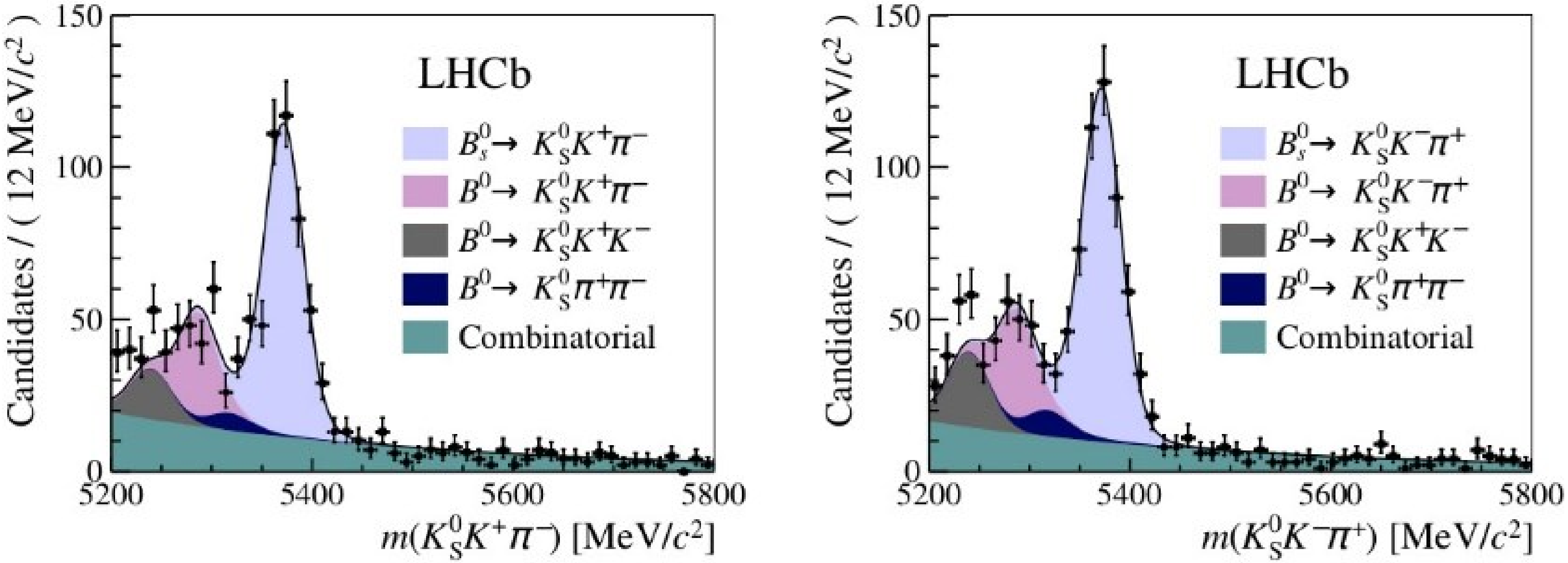
Phys. Rev. Lett. 120, 261801 (2018)

LHCb: $B_s \to K_s K^{\pm}\pi^{\mp}$, Amplitude analysis

Interesting admixture of Tree and FCNC Penguin Amplitude
Sensitive to NP arXiv:1902.07955



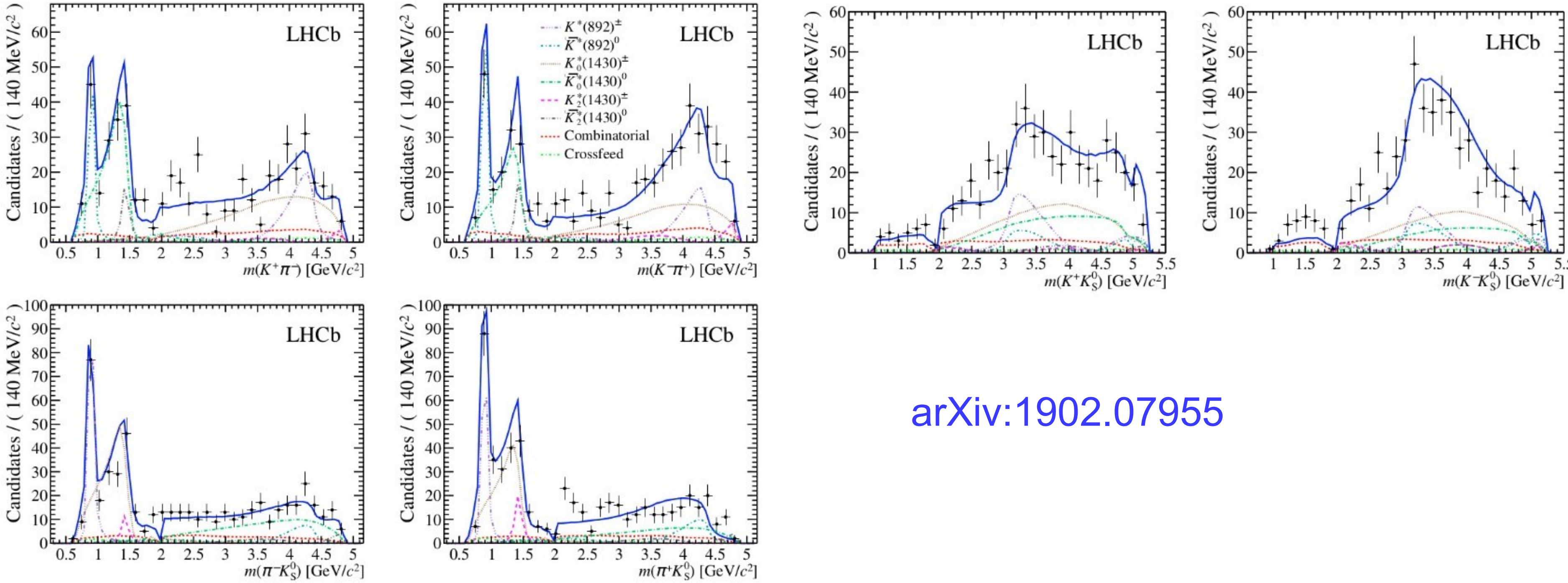
LHCb: $B_s \to K_s K^{\pm}\pi^{\mp}$, Amplitude analysis



Build an Amplitude Analysis
Including the resonances shown

$K_S^0 K^+\pi^-$		$K_S^0 K^-\pi^+$	
Resonance	Fit fraction (%)	Resonance	Fit fraction (%)
$K^*(892)^-$	15.6 ± 1.5	$K^*(892)^+$	13.4 ± 2.0
$K_0^*(1430)^-$	30.2 ± 2.6	$K_0^*(1430)^+$	28.5 ± 3.6
$K_2^*(1430)^-$	2.9 ± 1.3	$K_2^*(1430)^+$	5.8 ± 1.9
$K^*(892)^0$	13.2 ± 2.4	$\overline{K}^*(892)^0$	19.2 ± 2.3
$K_0^*(1430)^0$	33.9 ± 2.9	$\overline{K}_0^*(1430)^0$	27.0 ± 4.1
$K_2^*(1430)^0$	5.9 ± 4.0	$\overline{K}_2^*(1430)^0$	7.7 ± 2.8

LHCb: $B_s \to K_S K^{\pm} \pi^{\mp}$, Amplitude analysis



arXiv:1902.07955

$$\mathcal{B}\left(B_s^0 \to K^*(892)^{\pm} K^{\mp}\right) = (18.6 \pm 1.2 \pm 0.8 \pm \;\; 4.0 \pm 2.0) \times 10^{-6}$$

$$\mathcal{B}\left(B_s^0 \to K_0^*(1430)^{\pm} K^{\mp}\right) = (31.3 \pm 2.3 \pm 0.7 \pm 25.1 \pm 3.3) \times 10^{-6}$$

$$\mathcal{B}\left(B_s^0 \to K_2^*(1430)^{\pm} K^{\mp}\right) = (10.3 \pm 2.5 \pm 1.1 \pm 16.3 \pm 1.1) \times 10^{-6}$$

$$\mathcal{B}\left(B_s^0 \to \overset{(-)}{K}{}^*(892)^0 \overset{(-)}{K}{}^0\right) = (19.8 \pm 2.8 \pm 1.2 \pm \;\; 4.4 \pm 2.1) \times 10^{-6}$$

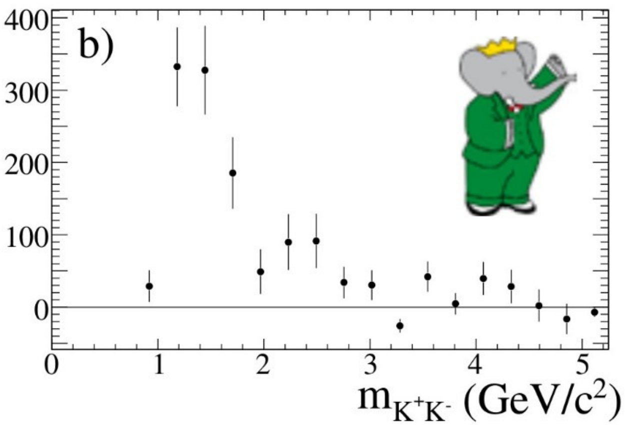
$$\mathcal{B}\left(B_s^0 \to \overset{(-)}{K}{}_0^*(1430)^0 \overset{(-)}{K}{}^0\right) = (33.0 \pm 2.5 \pm 0.9 \pm \;\; 9.1 \pm 3.5) \times 10^{-6}$$

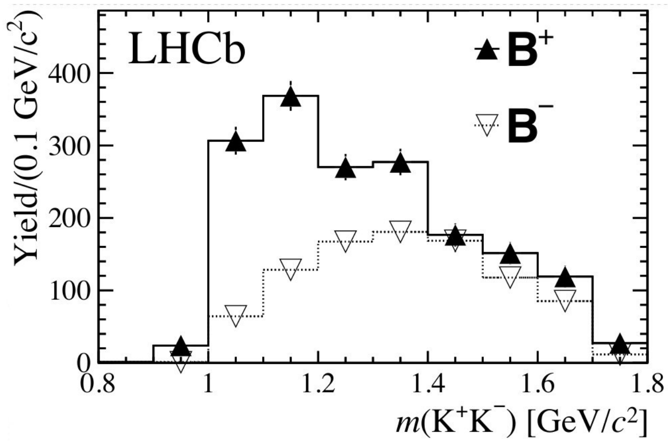
$$\mathcal{B}\left(B_s^0 \to \overset{(-)}{K}{}_2^*(1430)^0 \overset{(-)}{K}{}^0\right) = (16.8 \pm 4.5 \pm 1.7 \pm 21.2 \pm 1.8) \times 10^{-6}$$

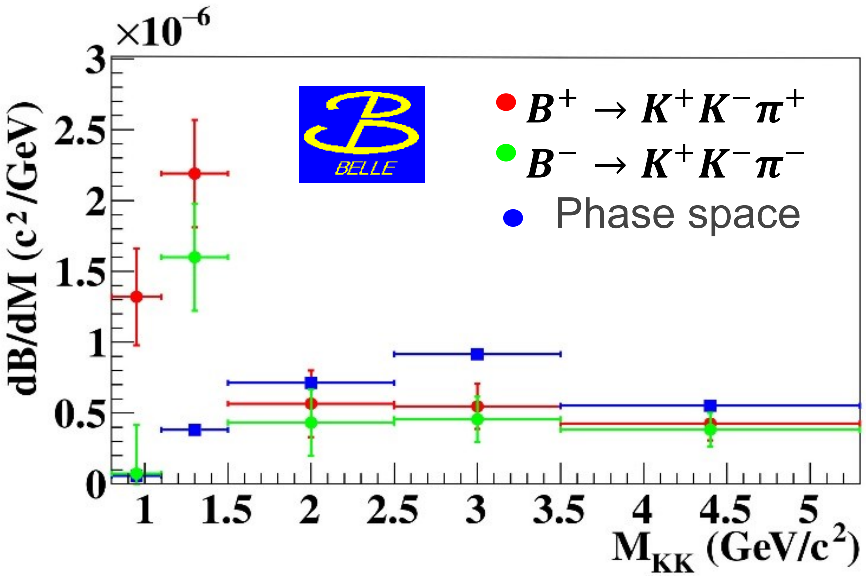
LHCb: $B^{\pm} \to K^+K^-\pi^{\pm}$, Amplitude analysis, A_{CP}

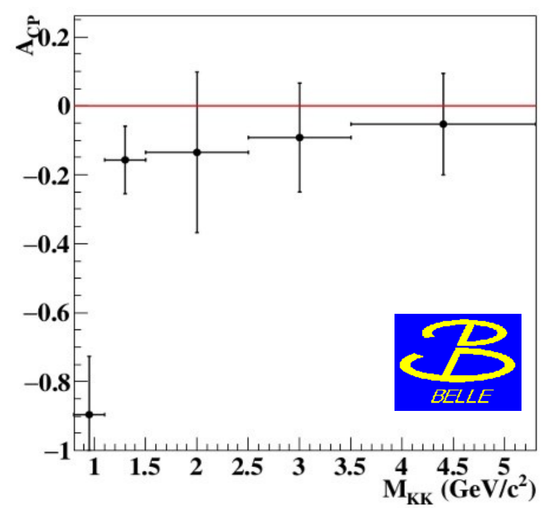
Interesting reaction dynamics leading to very large Direct CPV

New analysis with full Dalitz analysis









LHCb: $B^{\pm} \to K^{+}K^{-}\pi^{\pm}$, Amplitude analysis, A_{CP}

Emilie Bertholet

http://moriond.in2p3.fr/2019/EW/slides/5_Thursday/1_morning/5_Bertholet_TimeIndepCPV.pdf

LHCb-PAPER-2018-051

	Contribution	Fit Fraction(%)	A_{CP}(%)
(πK)	$K^*(892)^0$	$7.5 \pm 0.6 \pm 0.5$	$12.3 \pm 8.7 \pm 4.5$
(πK)	$K_0^{*0}(1430)$	$4.5 \pm 0.7 \pm 1.2$	$10.4 \pm 14.9 \pm 8.8$
(πK)	Polar Form Factor	$32.3 \pm 1.5 \pm 4.1$	$-10.7 \pm 5.3 \pm 3.5$
(KK)	$\rho(1450)$	$30.7 \pm 1.2 \pm 0.9$	$-10.9 \pm 4.4 \pm 2.4$
(KK)	$f_2(1270)$	$7.5 \pm 0.8 \pm 0.7$	$26.7 \pm 10.2 \pm 4.8$
(KK)	*rescattering*	$16.4 \pm 0.8 \pm 1.0$	$-66.4 \pm 3.8 \pm 1.9$
(KK)	$\phi(1020)$	$0.3 \pm 0.1 \pm 0.09$	$9.8 \pm 43.6 \pm 26.6$

Phenomenological description of the partonic interaction that produces the final state. Phys. Rev. D 92, 054010 (2015)

Accounts for the $\pi\pi \leftrightarrow KK$ re-scattering (1.0 GeV < m_{KK} < 1.5 GeV)
Phys.Rev. D71 (2005) 074016

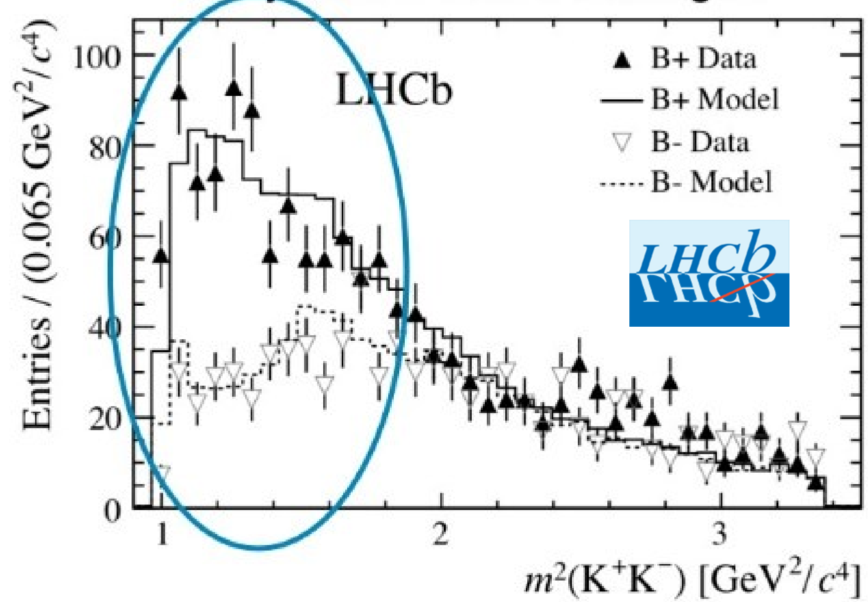
- Dominant contribution from the non-resonant component.
- Small contribution from $\Phi(1020)$.
- Strong destructive interferences.
- Large ACP in the re-scattering region.

Observables

$$A_{CP,i} = \frac{|\bar{c}_i|^2 - |c_i|^2}{|\bar{c}_i|^2 + |c_i|^2}$$

$$FF_i = \frac{\iint \left(|c_i F_i|^2 + |\bar{c}_i \bar{F}_i|^2 \right) dm^2_{\pi^\pm K^\mp} dm^2_{K^+K^-}}{\iint \left(|A|^2 + |\bar{A}|^2 \right) dm^2_{\pi^\pm K^\mp} dm^2_{K^+K^-}}$$

Projection in the low m^2_{KK} region



Conclusions

Summary

- Many interesting results from MultiBody Charmless decays and Direct CP violation
- $B^{\pm} \to K^{+}K^{-}\pi^{\pm}$ shows a large enhancement in $M_{K^{+}K^{-}}$ and very large Direct CP violation
- New LHCb results show$B^{\pm} \to K^{+}K^{-}\pi^{\pm}$ results could be the effects of $K\overline{K} \leftrightarrow \pi\overline{\pi}$ rescattering
- Threshold enhancements observed in all M_{KK} final states
- Amplitude Dalitz Plot analyses from LHCb show qualitative more information including quasi two-body measurements

Outlook

- New results expected from ongoing LHCb and Belle analyses
- New data from LHCb and Belle II
- Competitive and complimentary interplay between LHCb and Belle II

THE UNIVERSITY OF MELBOURNE

Thank you!