# Flavor Physics & CP Violation 2017

Overview of UT angle $\gamma/\phi_3$ Measurements

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on behalf of the LHCb collaboration

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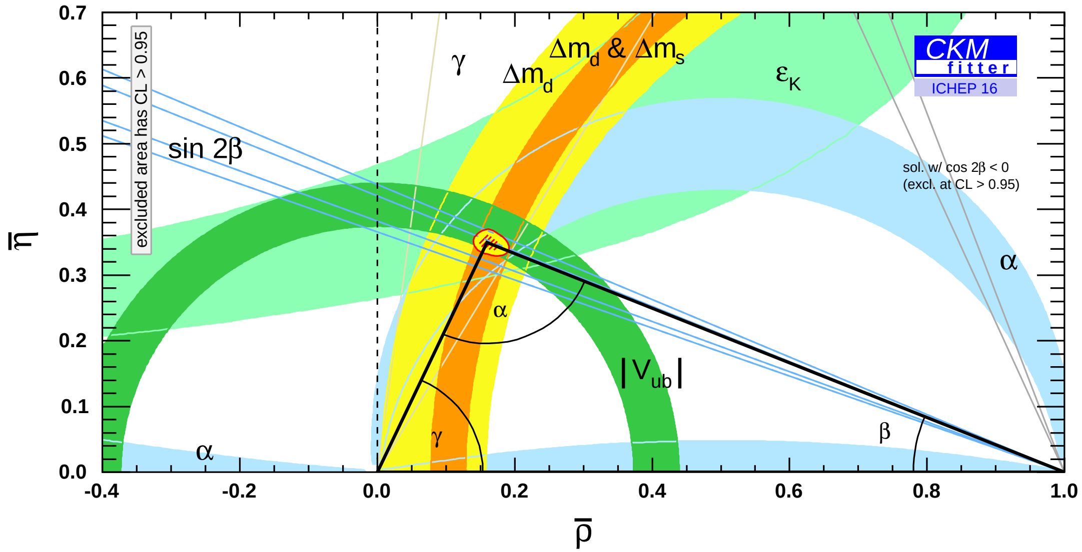
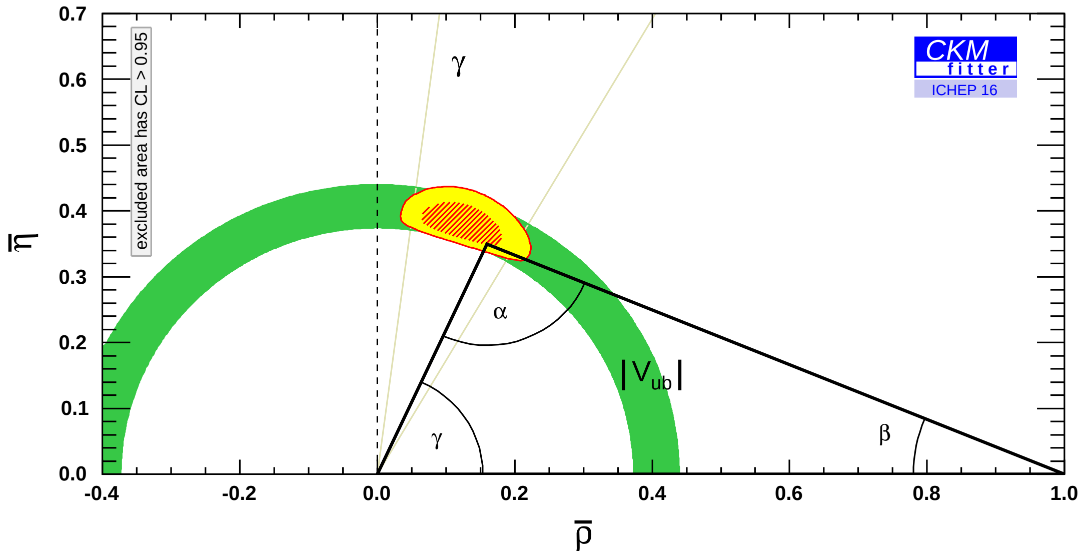
# Current Status of $\gamma/\phi_3$




$\gamma$ is the phase of $V_{ub}^*$

Indirect predictions from CKM paradigm

$$\gamma = 65.33^{+0.96}_{-2.54}$$




Direct measurement not quite as precise

$$\gamma = 72.1^{+5.4}_{-5.8}$$

New Physics manifests as discrepancy

# $\gamma$ from $B$ Decays

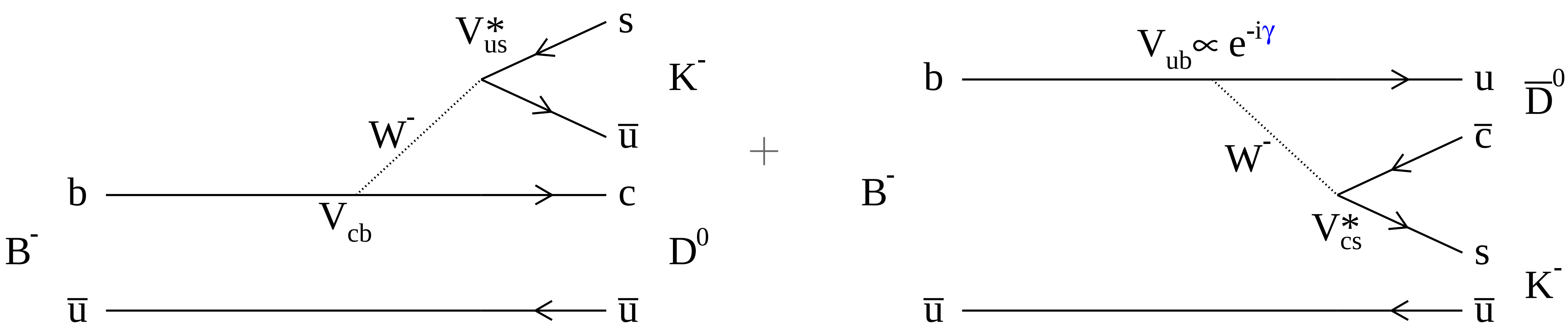
Theoretically cleanest Standard Model measurement of $\gamma$ from $B \to DK$ decays

$|\delta\gamma|/\gamma \lesssim \mathcal{O}(10^{-7})$ from electroweak corrections: J. Brod and J. Zupan, JHEP **1401** (2014) 051

When $D^0$ and $\bar{D}^0$ decay to the same final state

Interference between the dominant $b \to c\bar{u}s$ with the corresponding DCS $b \to u\bar{c}s$

$$A_{B^-} \propto A_{D^0} \quad + \quad r_B e^{i\delta_B} e^{-i\gamma} A_{\bar{D}^0}$$

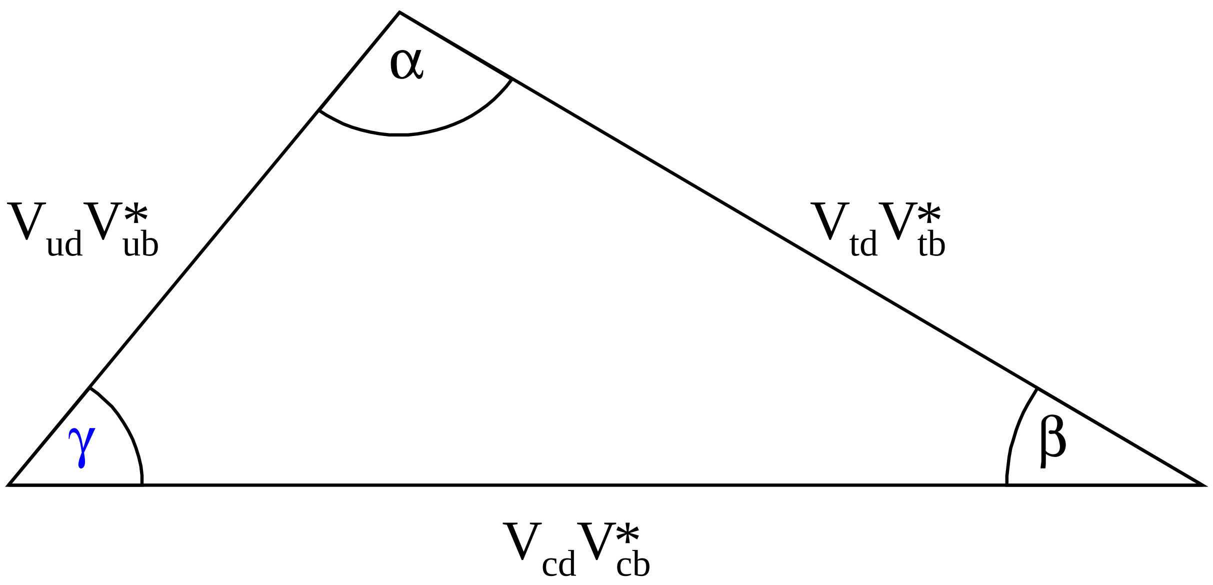



$r_B$: Ratio of colour-suppressed to colour-favoured diagrams, $\delta_B$: strong phase difference

Weak phase $2\gamma$ simply the phase difference between $A_{B^+}$ and $A_{B^-}$

# Outline

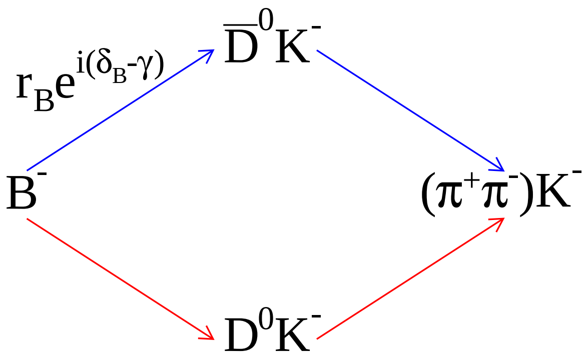
1. GLW
2. ADS
3. GGSZ
4. Time-dependent
5. Combination



# GLW Method

Gronau, London and Wyler: PLB **253**, 483 (1991); PLB **265**, 172 (1991)

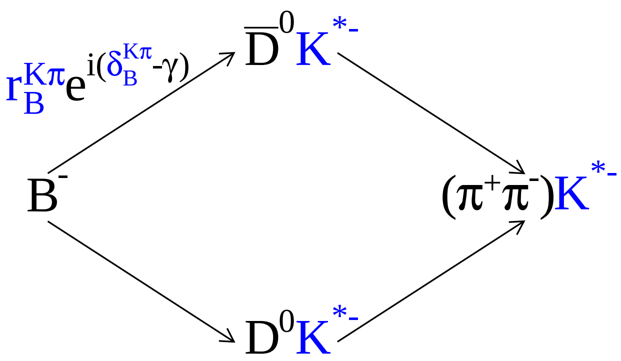
$D^0$ and $\bar{D}^0$ decays to $CP$ eigenstates




Various extensions to the GLW idea

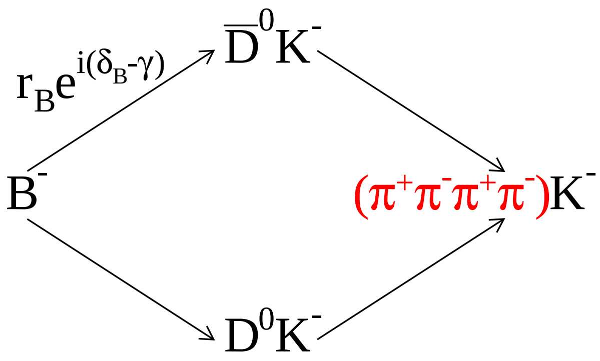
Excited kaons

Hadronic parameters averaged over phase space




Multibody $D$ decays

Dilution from $CP$-content admixture



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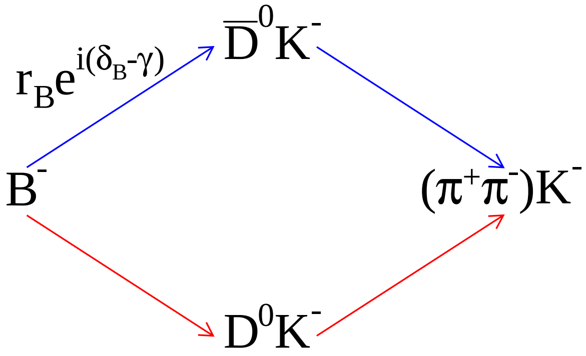
$D^0$ and $\bar{D}^0$ decays to $CP$ eigenstates




Various extensions to the GLW idea

Excited kaons

$\kappa$: Coherence factor from non-$K^*$ interference

Multibody $D$ decays

$F^+$: Fractional $CP$-even content

Observables relative to dominant $D \to K\pi$ decay

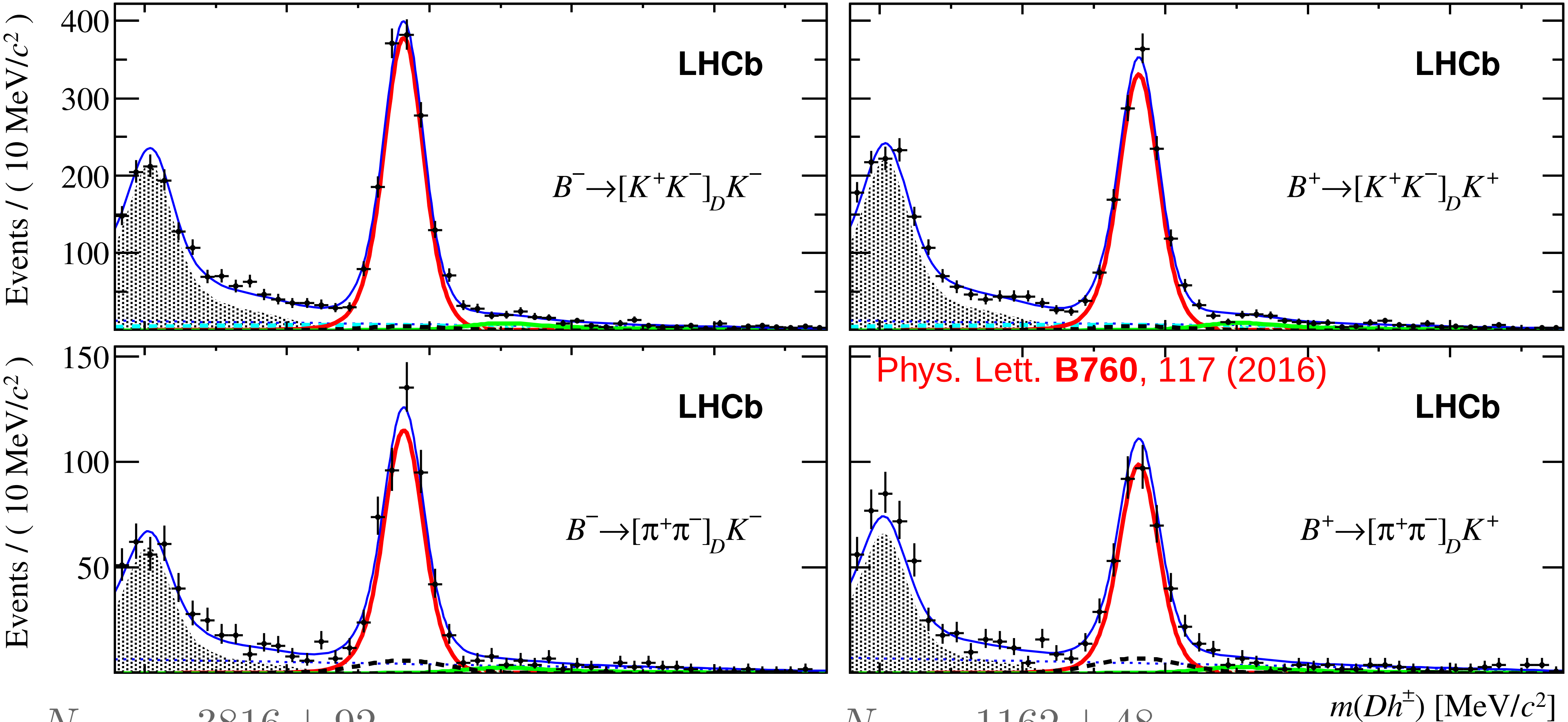
$$\mathcal{R}_{CP} = \frac{\Gamma(B^- \to D_{CP}K^{(*)-}) + \Gamma(B^+ \to D_{CP}K^{(*)+})}{\Gamma(B^- \to D[K^-\pi^+]K^{(*)-}) + \Gamma(B^+ \to D[K^+\pi^-]K^{(*)+})} = 1 + (r_B^{K\pi})^2 + 2r_B^{K\pi}\kappa(2F^+ - 1)\cos\delta_B^{K\pi}\cos\gamma$$

$$\mathcal{A}_{CP} = \frac{\Gamma(B^- \to D_{CP}K^{(*)-}) - \Gamma(B^+ \to D_{CP}K^{(*)+})}{\Gamma(B^- \to D_{CP}K^{(*)-}) + \Gamma(B^+ \to D_{CP}K^{(*)+})} = \frac{2r_B^{K\pi}\kappa(2F^+ - 1)\sin\delta_B^{K\pi}\sin\gamma}{R_{CP}}$$

# GLW Results

$B^- \to D[K^+K^-, \pi^+\pi^-]K^-$

2011+2012: $3$ fb$^{-1}$

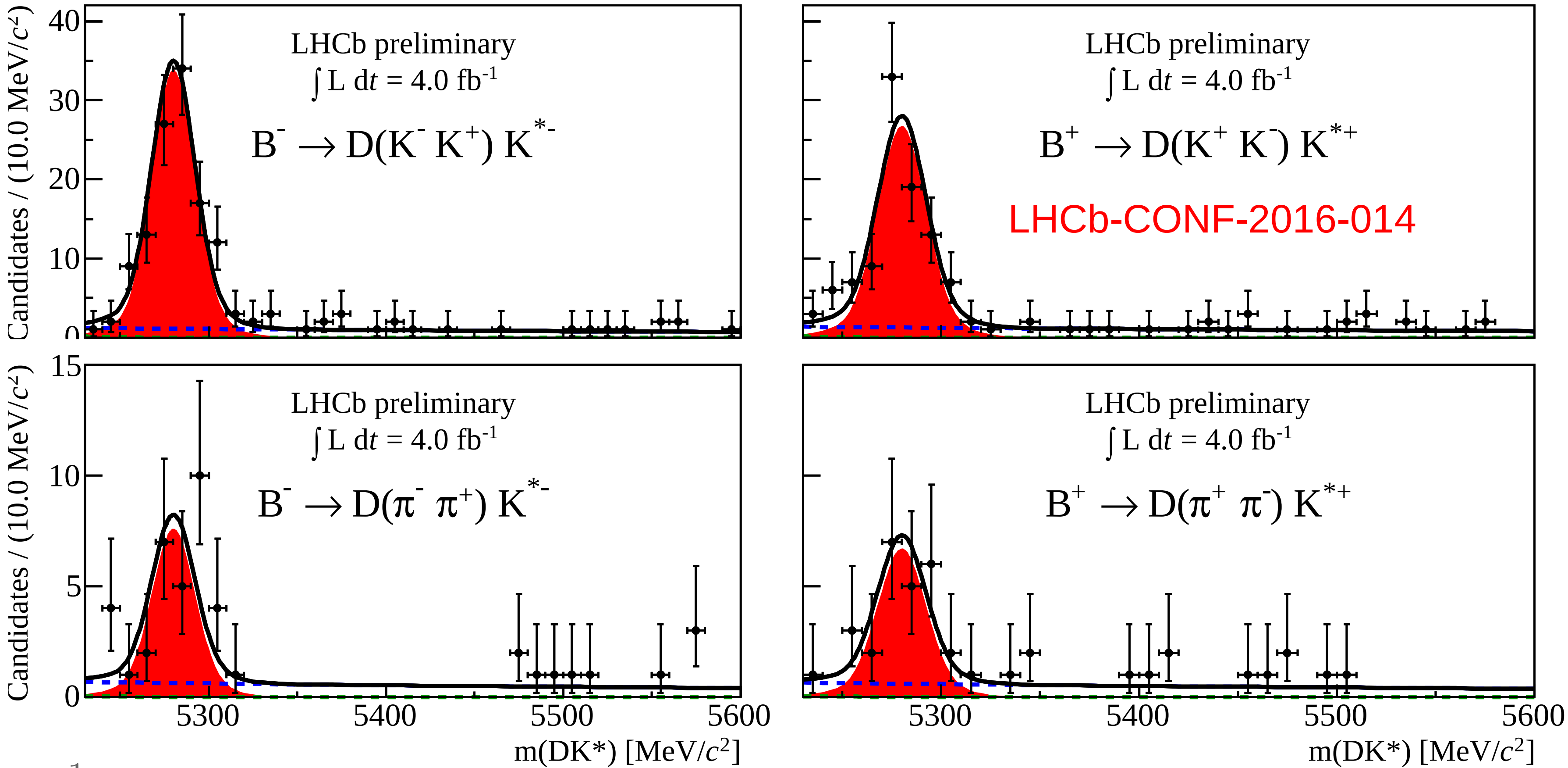



$N_{KK} = 3816 \pm 92$ $\quad$ $N_{\pi\pi} = 1162 \pm 48$

$\mathcal{A}_{KK} = +0.087 \pm 0.020 \pm 0.008$ $(4.0\sigma)$ $\quad$ $\mathcal{A}_{\pi\pi} = +0.128 \pm 0.037 \pm 0.012$ $(3.3\sigma)$

# quasi-GLW Results

New results for $B^- \to DK^{*-}$ Run 1+2015+2016: $4$ fb$^{-1}$

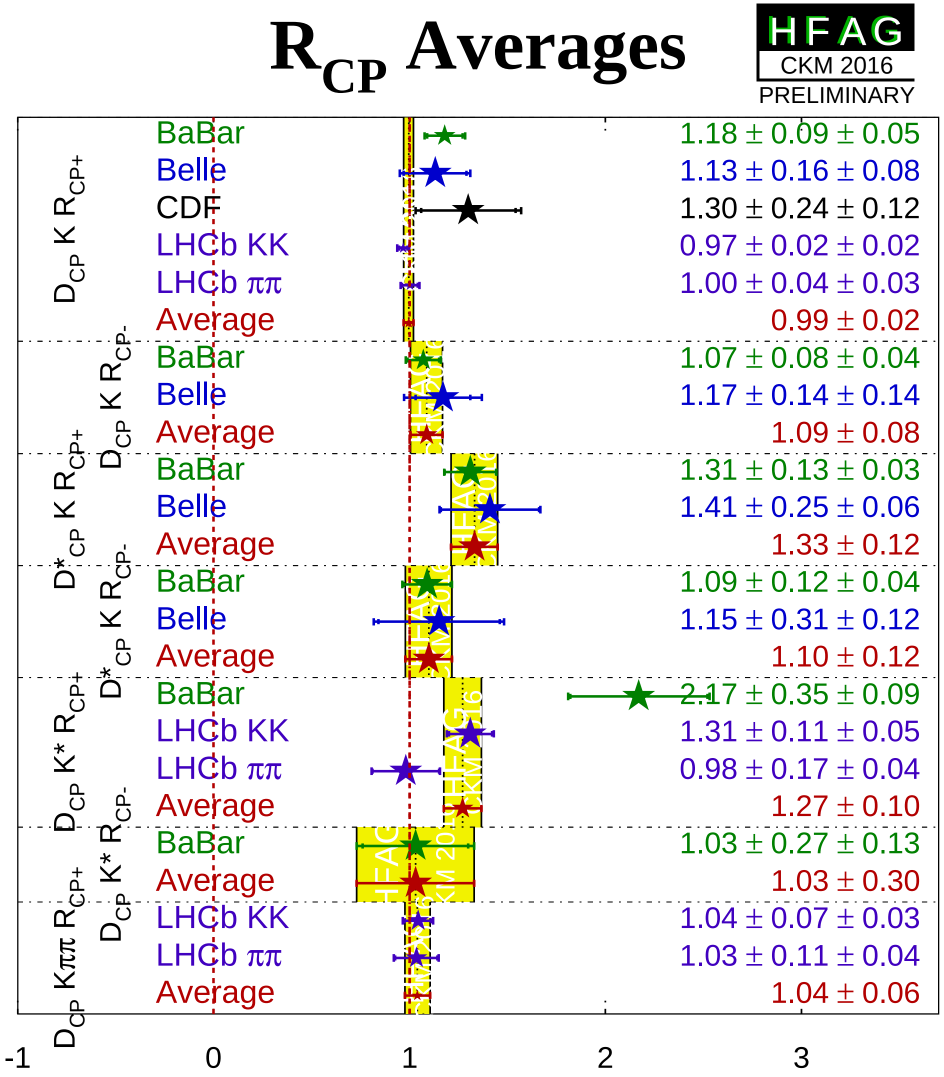



$1$ fb$^{-1}$ of Run II data worth about as much as Run 1 dataset

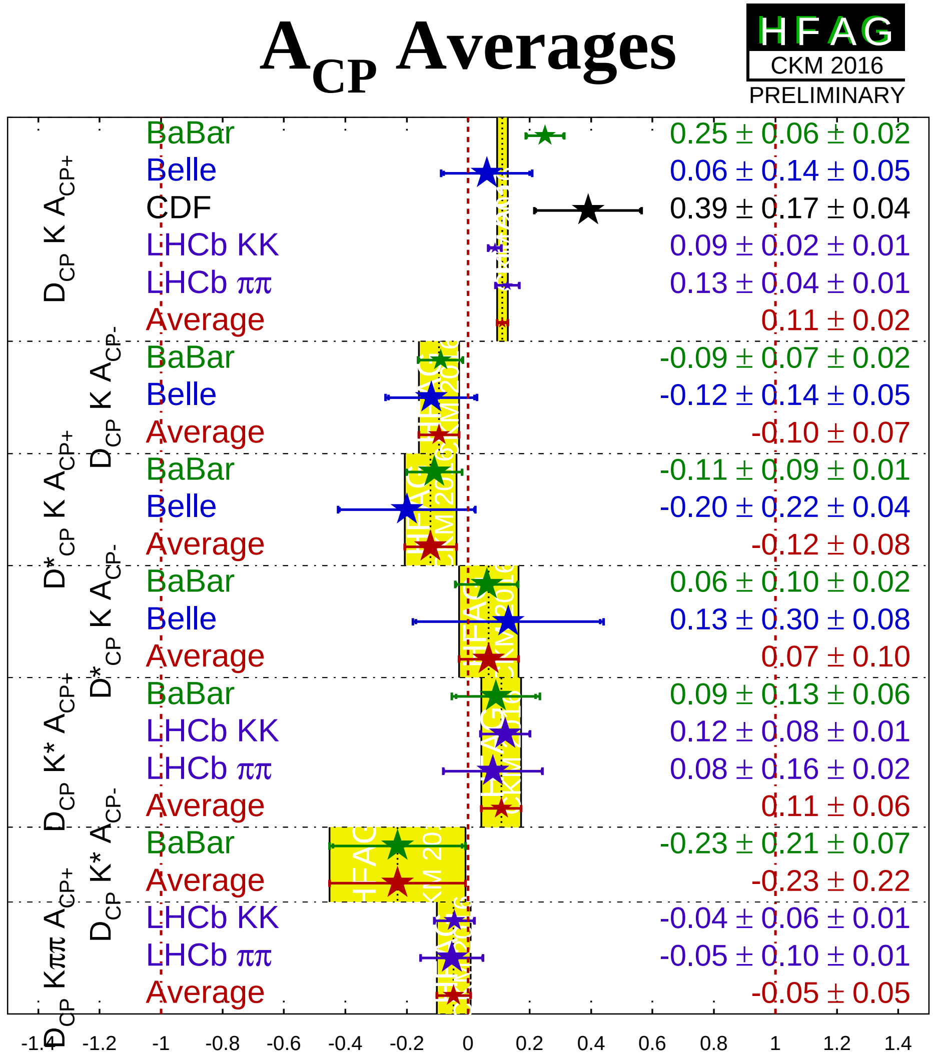
$N_{KK} = 194 \pm 16$ $N_{\pi\pi} = 49 \pm 8$

$\mathcal{A}_{KK} = +0.12 \pm 0.08 \pm 0.01$ $\mathcal{A}_{\pi\pi} = +0.08 \pm 0.16 \pm 0.02$

# GLW Average



$R_{CP}$ Averages
HFAG
CKM 2016
PRELIMINARY
$D_{CP}$ K $R_{CP+}$
BaBar 1.18 ± 0.09 ± 0.05
Belle 1.13 ± 0.16 ± 0.08
CDF 1.30 ± 0.24 ± 0.12
LHCb KK 0.97 ± 0.02 ± 0.02
LHCb ππ 1.00 ± 0.04 ± 0.03
Average 0.99 ± 0.02
$D_{CP}$ K $R_{CP-}$
BaBar 1.07 ± 0.08 ± 0.04
Belle 1.17 ± 0.14 ± 0.14
Average 1.09 ± 0.08
$D^*_{CP}$ K $R_{CP+}$
BaBar 1.31 ± 0.13 ± 0.03
Belle 1.41 ± 0.25 ± 0.06
Average 1.33 ± 0.12
$D^*_{CP}$ K $R_{CP-}$
BaBar 1.09 ± 0.12 ± 0.04
Belle 1.15 ± 0.31 ± 0.12
Average 1.10 ± 0.12
$D_{CP}$ K* $R_{CP+}$
BaBar 2.17 ± 0.35 ± 0.09
LHCb KK 1.31 ± 0.11 ± 0.05
LHCb ππ 0.98 ± 0.17 ± 0.04
Average 1.27 ± 0.10
$D_{CP}$ K* $R_{CP-}$
BaBar 1.03 ± 0.27 ± 0.13
Average 1.03 ± 0.30
$D_{CP}$ Kππ $R_{CP+}$
LHCb KK 1.04 ± 0.07 ± 0.03
LHCb ππ 1.03 ± 0.11 ± 0.04
Average 1.04 ± 0.06
-1
0
1
2
3

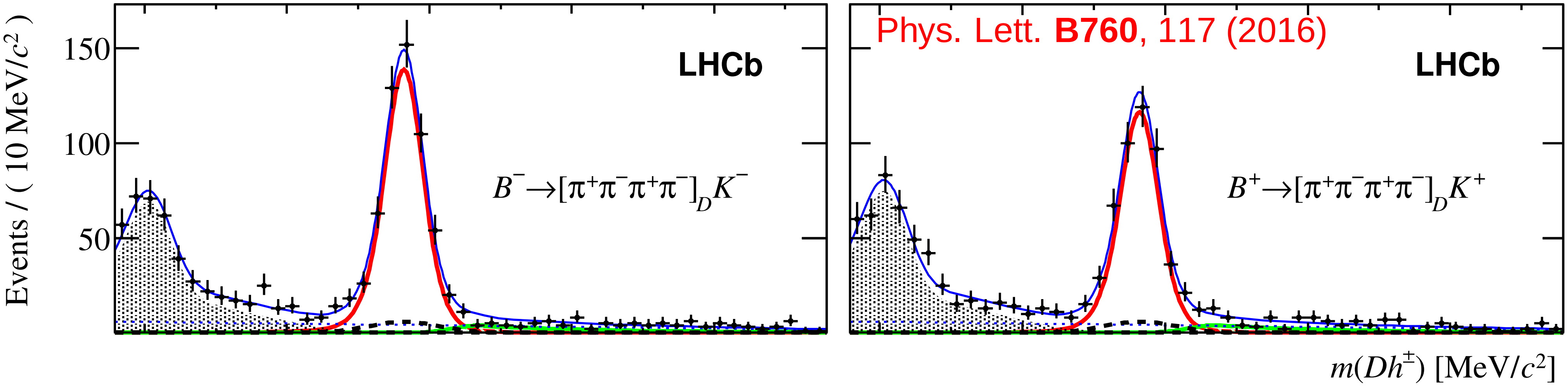



$A_{CP}$ Averages
HFAG
CKM 2016
PRELIMINARY
$D_{CP}$ K $A_{CP+}$
BaBar 0.25 ± 0.06 ± 0.02
Belle 0.06 ± 0.14 ± 0.05
CDF 0.39 ± 0.17 ± 0.04
LHCb KK 0.09 ± 0.02 ± 0.01
LHCb ππ 0.13 ± 0.04 ± 0.01
Average 0.11 ± 0.02
$D_{CP}$ K $A_{CP-}$
BaBar -0.09 ± 0.07 ± 0.02
Belle -0.12 ± 0.14 ± 0.05
Average -0.10 ± 0.07
$D^*_{CP}$ K $A_{CP+}$
BaBar -0.11 ± 0.09 ± 0.01
Belle -0.20 ± 0.22 ± 0.04
Average -0.12 ± 0.08
$D^*_{CP}$ K $A_{CP-}$
BaBar 0.06 ± 0.10 ± 0.02
Belle 0.13 ± 0.30 ± 0.08
Average 0.07 ± 0.10
$D_{CP}$ K* $A_{CP+}$
BaBar 0.09 ± 0.13 ± 0.06
LHCb KK 0.12 ± 0.08 ± 0.01
LHCb ππ 0.08 ± 0.16 ± 0.02
Average 0.11 ± 0.06
$D_{CP}$ K* $A_{CP-}$
BaBar -0.23 ± 0.21 ± 0.07
Average -0.23 ± 0.22
$D_{CP}$ Kππ $A_{CP+}$
LHCb KK -0.04 ± 0.06 ± 0.01
LHCb ππ -0.05 ± 0.10 ± 0.01
Average -0.05 ± 0.05
-1.4
-1.2
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1
1.2
1.4

# quasi-GLW Results

$B^- \to D[\pi^+\pi^-\pi^+\pi^\pm]K^-$

2011+2012: $3$ fb$^{-1}$




$N_{4\pi} = 1497 \pm 60$

$\mathcal{A}_{4\pi} = +0.100 \pm 0.034 \pm 0.018 \; (2.6\sigma)$

Recall $\gamma$ sensitivity diluted by $CP$ admixture of final state

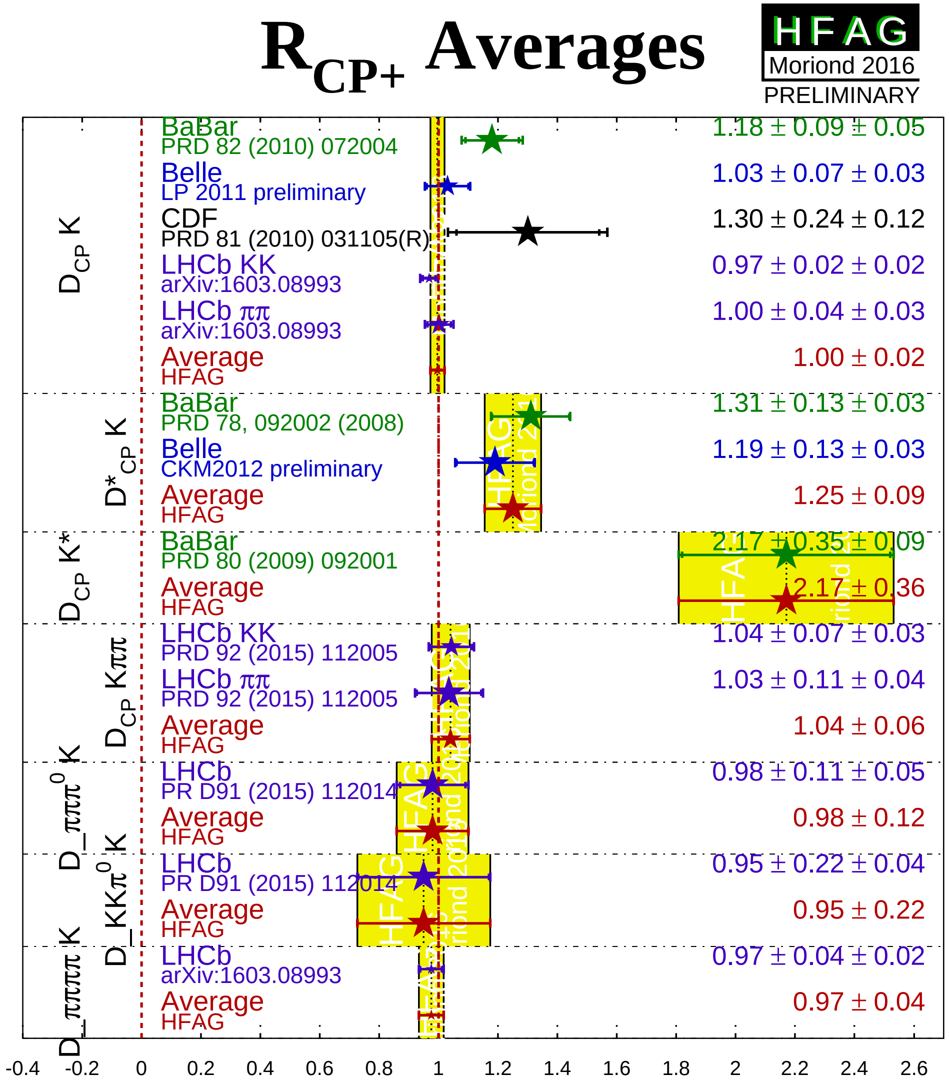
Fraction of $CP$-even content determined with $CP$-tagged CLEO-c data

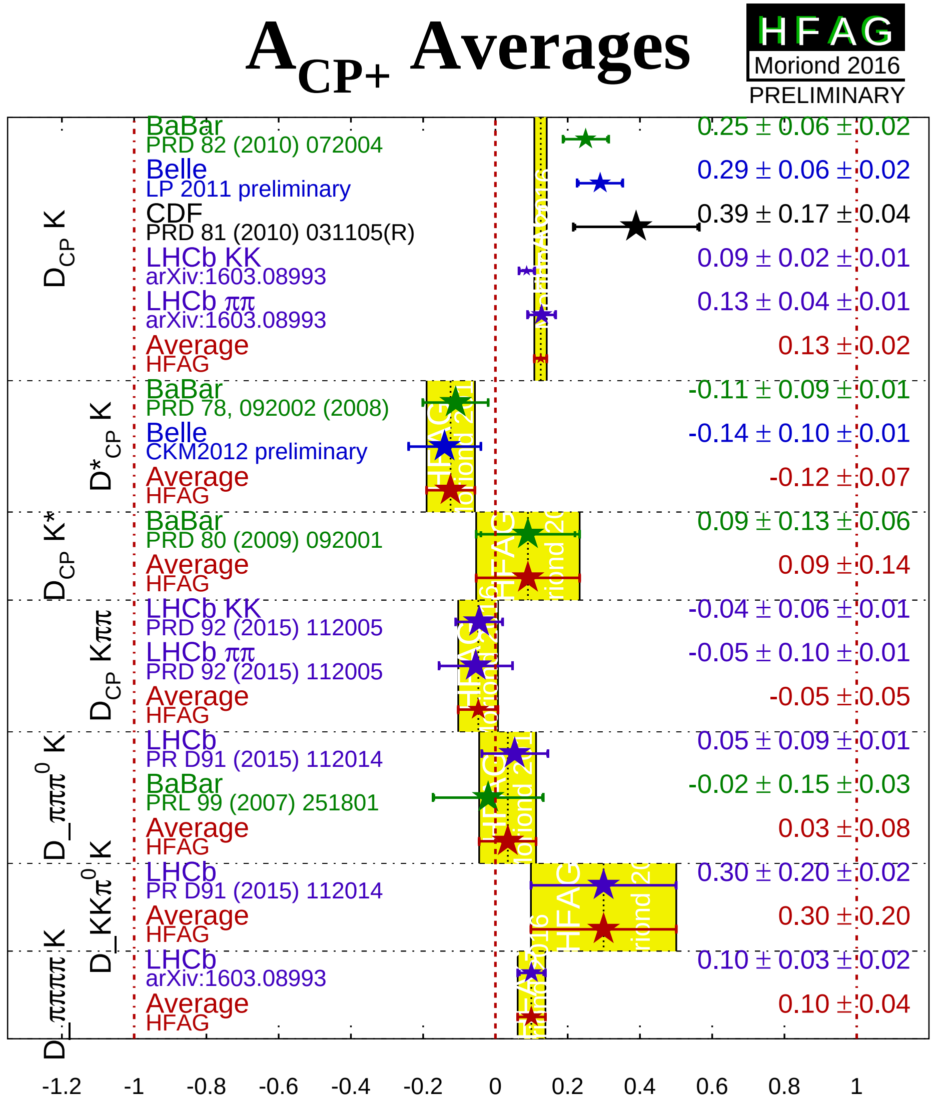
Phys. Lett. **B747**, 9 (2015)

$F_{4\pi}^{+} = 0.737 \pm 0.028$

Corresponds to a dilution $\sim 50\%$

# quasi-GLW Average



# GLW-Dalitz Method

Various extensions to the GLW idea

Amplitude Analysis of $B$ decays, *eg*. $B^0 \to DK^+\pi^-$

Dominant $D \to K\pi$ decay

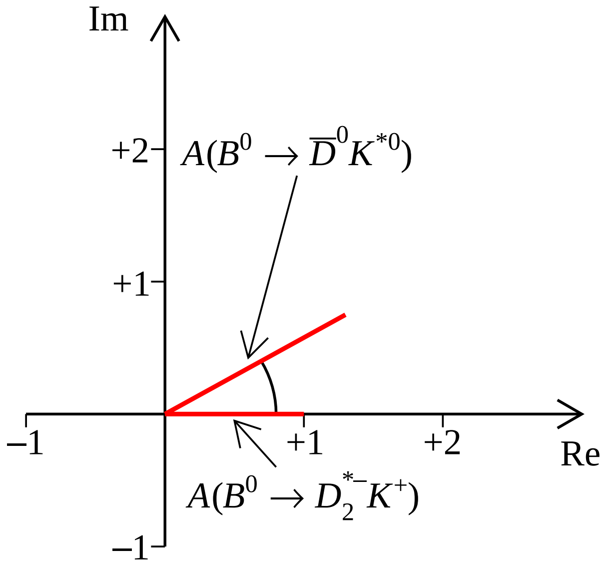
Negligible $V_{ub}$ contribution

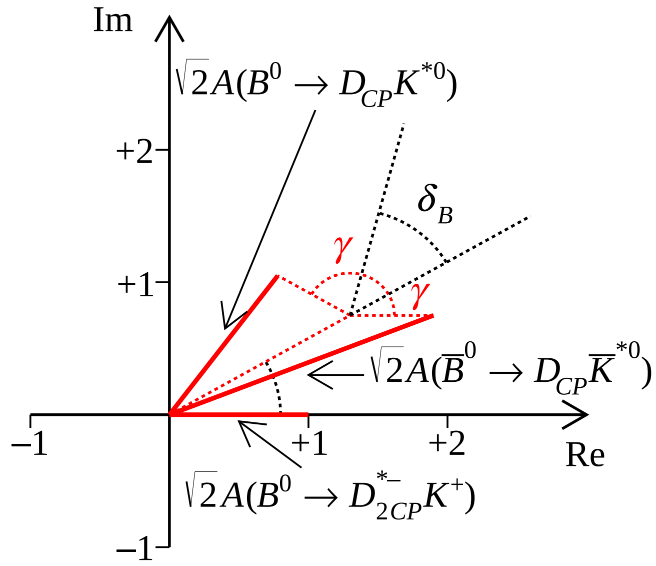
Determine relative amplitude

$D_{CP}$ decays, $b \to c$ also colour-suppressed

Slow pion from $D_2^{*-}$ tags the $D_{CP}$ flavour

Subtracts $CP$-conserving $V_{cb}$ component

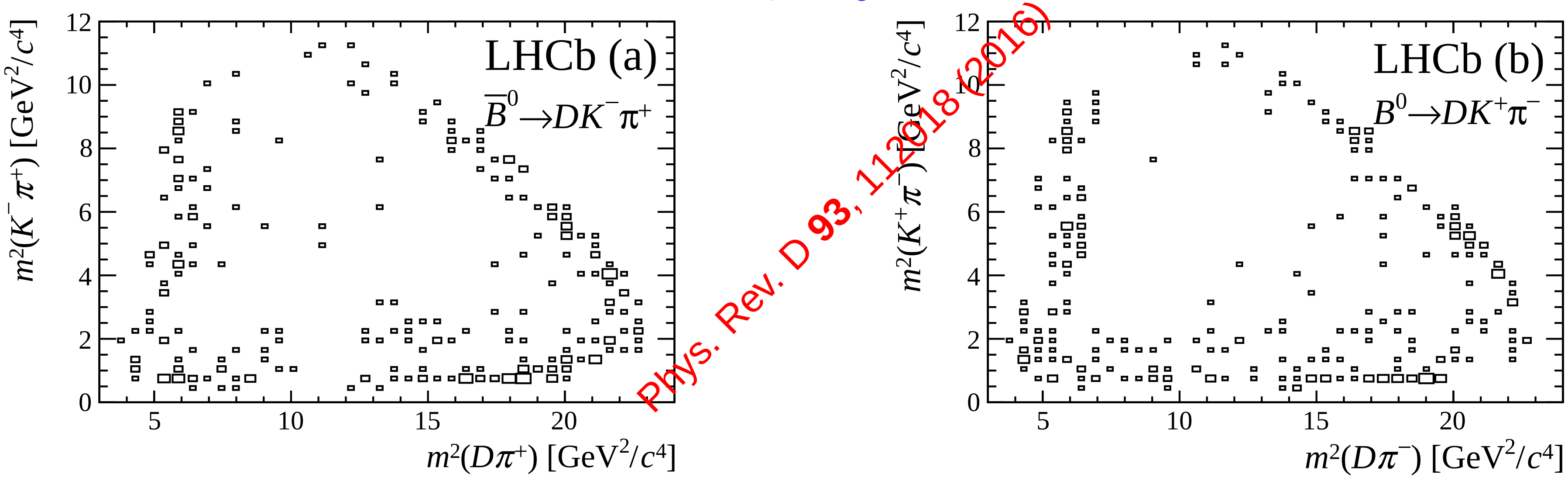



Measure $r_B$, $\delta_B$ and $\gamma$ directly, solution degeneracy reduced from $8 \to 2$

# GLW-Dalitz Results

2011+2012: $3\ \text{fb}^{-1}$




Interference in $D_2^{*-} - K^{*0}$ ovelapping region gives sensitivity to $\gamma$

$N_{KK} = 339 \pm 22$, $N_{\pi\pi} = 168 \pm 19$ in the $B^0$ signal region

Amplitude analysis with Isobar approach, $A(m^2_{D\pi}, m^2_{K\pi}) \equiv \sum_i a_i F_i(m^2_{D\pi}, m^2_{K\pi})$

$a_i$ is the relative coupling of various resonances $F_i$

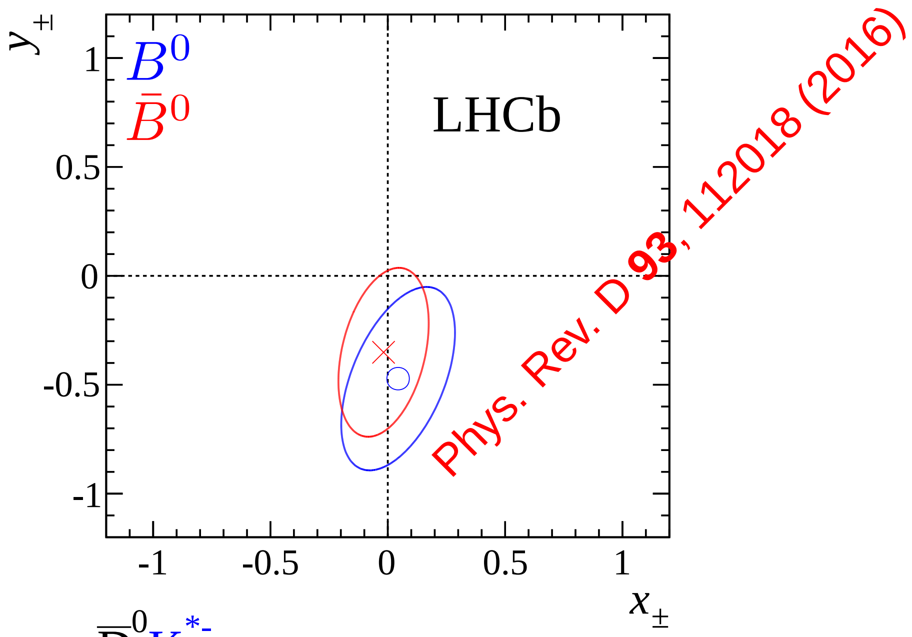
For $D \to KK, \pi\pi$ samples with a resonance in $B^0 \to DK^+\pi^-$

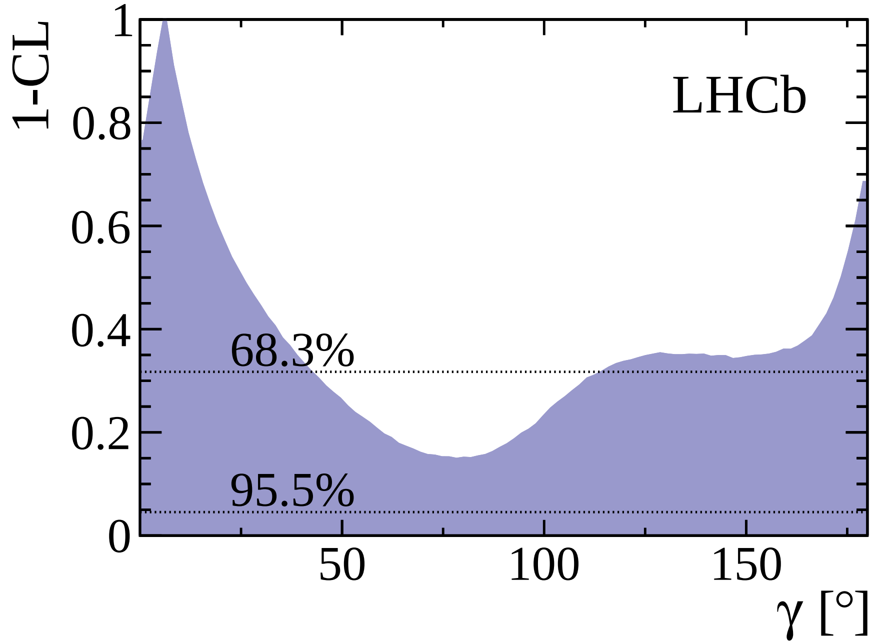
$a_i \to a_i(1 + x_i^{\pm} + iy_i^{\pm})$ where $+(-)$ corresponds to $B^0(\bar{B}^0)$

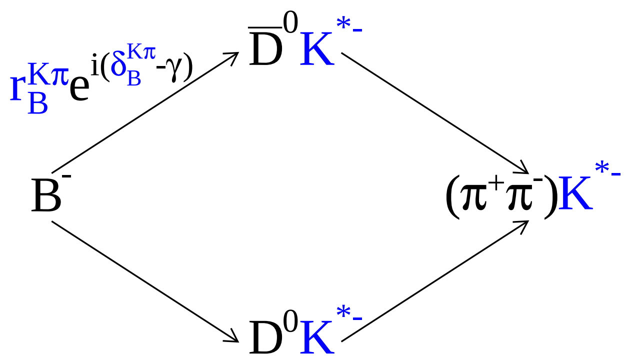
# GLW-Dalitz Results

Cartesian coordinates for $K\pi$ resonance $i$, related to $\gamma$

$$x_i^\pm = r_B^i \cos(\delta_B^i \pm \gamma), \qquad y_i^\pm = r_B^i \sin(\delta_B^i \pm \gamma)$$




Recall quasi-GLW method with excited kaons

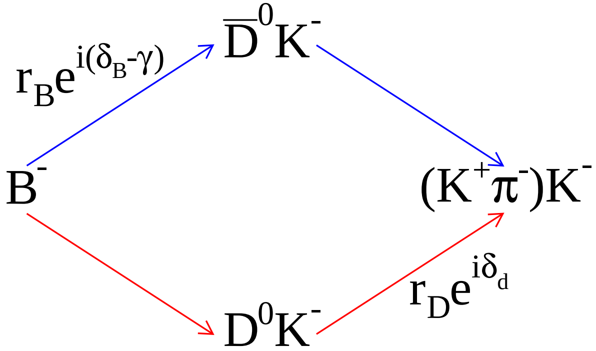
$$\mathcal{A}_{CP} = \frac{2 r_B^{K\pi} \kappa (2F^+ - 1) \sin\delta_B^{K\pi} \sin\gamma}{R_{CP}}$$

Calculate $\kappa$ from $B^0 \to DK^+\pi^-$ amplitude model for any $K^*$ selection

# ADS Method

Atwood, Dunietz and Soni; PRL **78**, 3257 (1997)

Matching colour-suppressed $B$ decay with Cabbibo-favoured $D$ decay and *vice versa*



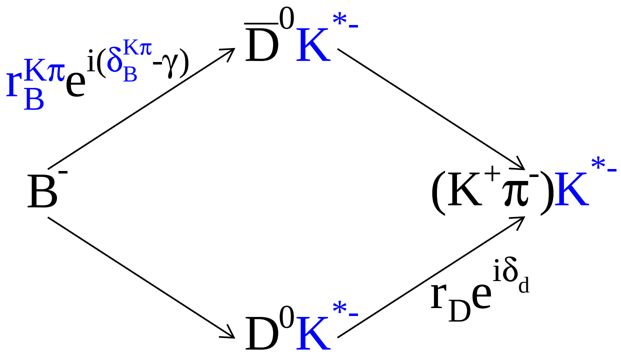

Enhancing observed asymmetries at a cost of additional $D$ hadronic parameters

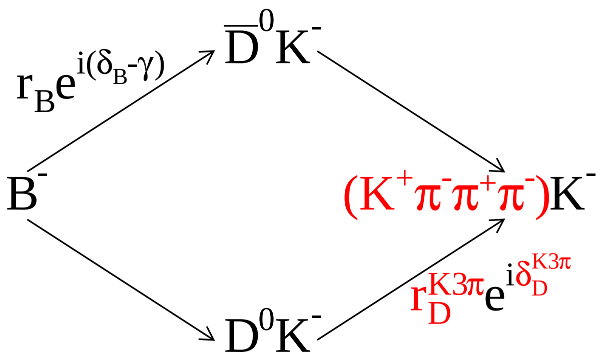
Excited kaons

Hadronic parameters averaged over phase space

Multibody $D$ decays

Average hadronic $D$ decay parameters



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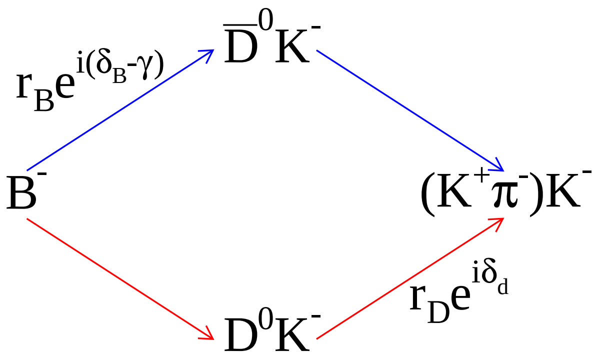
Matching colour-suppressed $B$ decay with Cabbibo-favoured $D$ decay and *vice versa*




Enhancing observed asymmetries at a cost of additional $D$ hadronic parameters

Excited kaons

$\kappa$: Coherence factor from non-$K^*$ interference

Multibody $D$ decays

Input from $D$ Dalitz analyses

Ratios of supressed to favoured modes give better statistically behaved observables

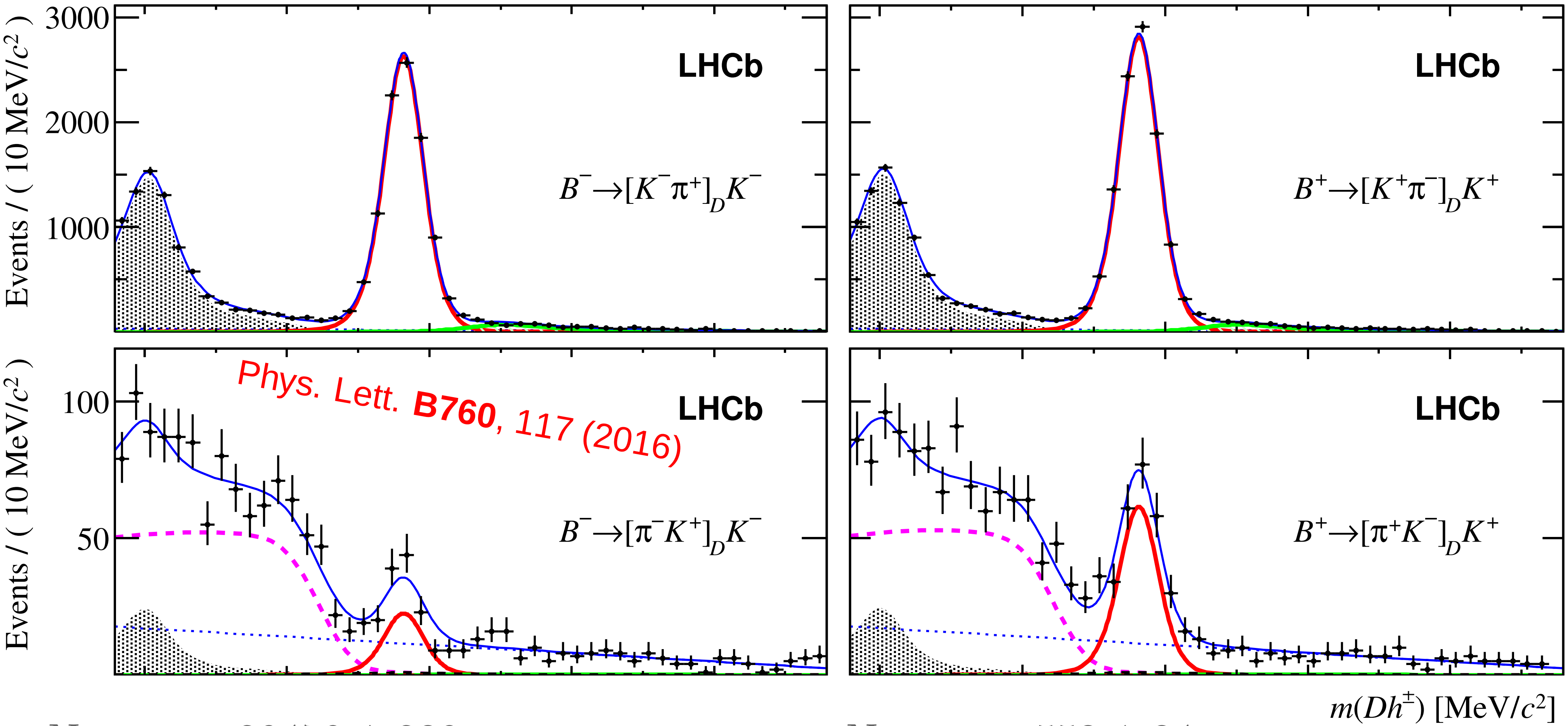
$$\mathcal{R}_{\mp} = \frac{\Gamma(B^{\mp} \to D_{\rm sup} K^{(*)-})}{\Gamma(B^{\mp} \to D_{\rm fav} K^{(*)-})} = \frac{(r_B^{K\pi})^2 + (r_D^{K3\pi})^2 + 2 r_B^{K\pi} \kappa_B r_D^{K3\pi} \kappa_D \cos(\delta_B^{K\pi} + \delta_D^{K3\pi} \mp \gamma)}{1 + (r_B^{K\pi} r_D^{K3\pi})^2 + 2 r_B^{K\pi} \kappa_B r_D^{K3\pi} \kappa_D \cos(\delta_B^{K\pi} - \delta_D^{K3\pi} \mp \gamma)}$$

$$\mathcal{R}_{\rm ADS} = \frac{R_- + R_+}{2}, \qquad \mathcal{A}_{\rm ADS} = \frac{R_- + R_+}{R_- + R_+},$$

# ADS Results

$B^- \to D[K^+K^-, \pi^+\pi^-]K^-$

2011+2012: $3$ fb$^{-1}$




$N_{K^\pm\pi^\mp} = 29470 \pm 230$

$N_{\pi^\pm K^\mp} = 553 \pm 34$

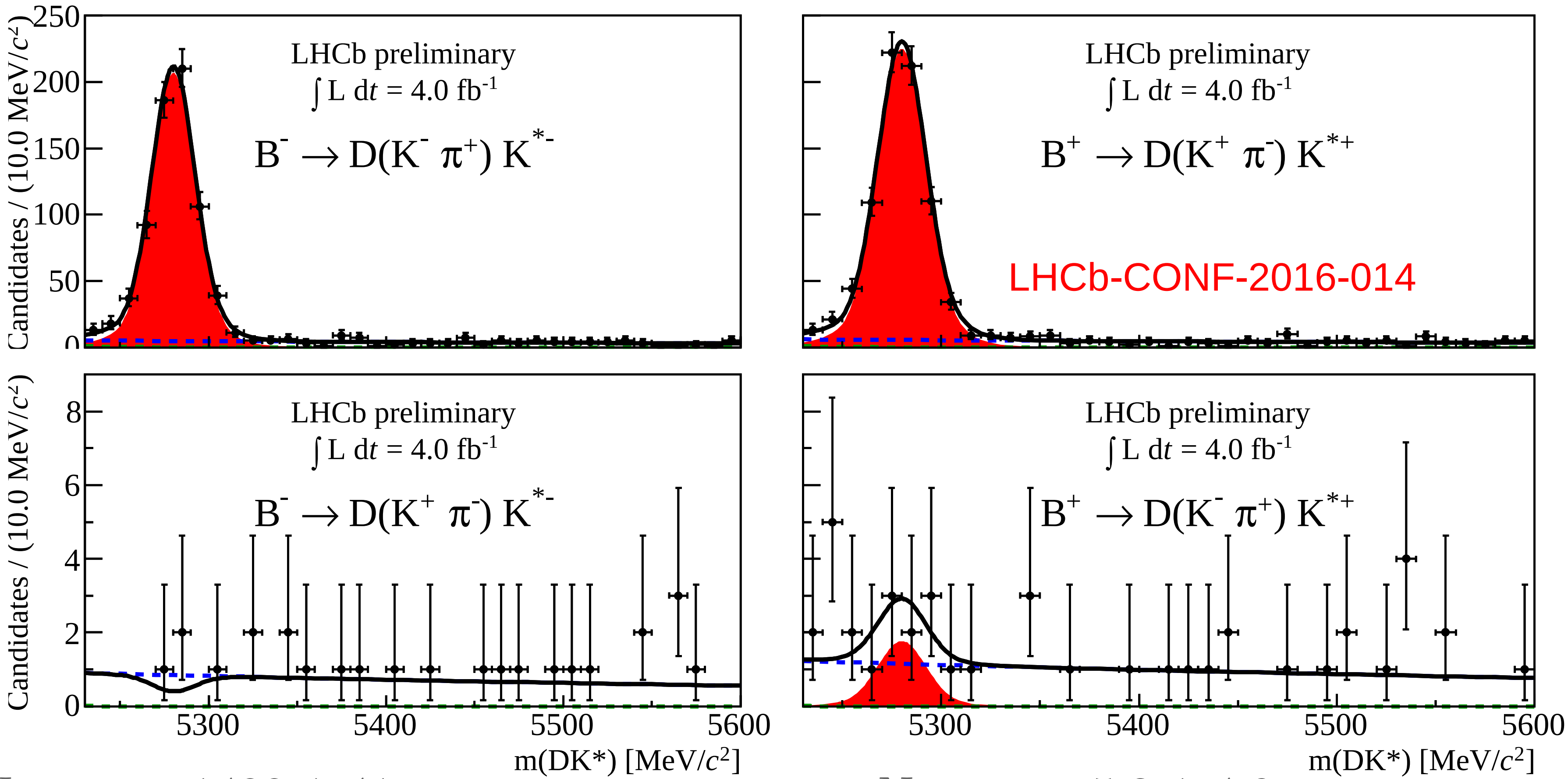
$\mathcal{R}^{\pi K}_{\rm ADS} = 0.0188 \pm 0.0011 \pm 0.0010$

$\mathcal{A}^{\pi K}_{\rm ADS} = -0.403 \pm 0.056 \pm 0.011\ (7.0\sigma)$

# quasi-ADS Results

New results for $B^- \to DK^{*-}$

Run 1+2015+2016: $4$ fb$^{-1}$




$N_{K^\pm\pi^\mp} = 1400 \pm 41$

$N_{\pi^\pm K^\mp} = 5.2 \pm 4.9$

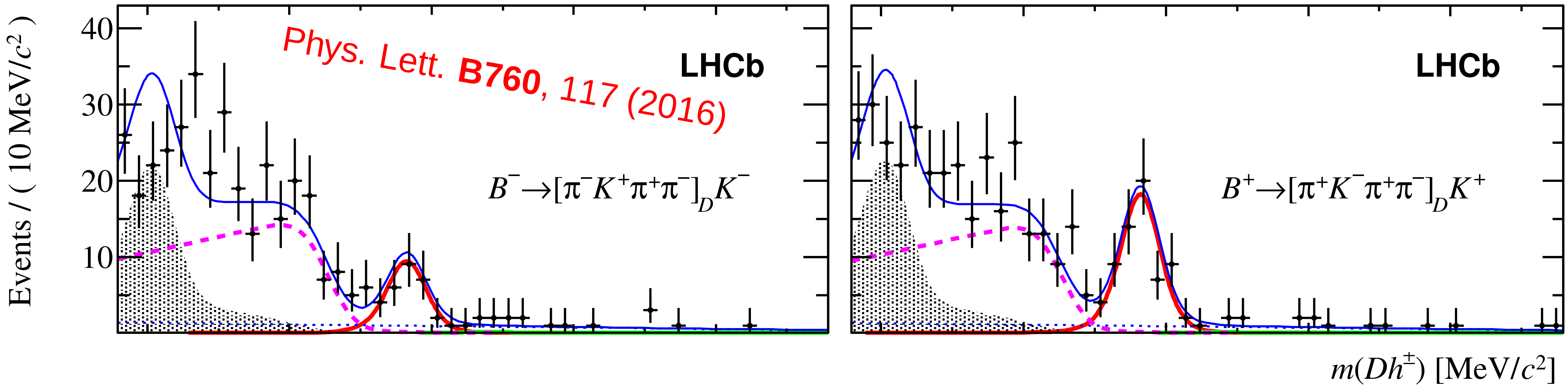
$\mathcal{R}_+^{\pi K} = +0.009 \pm 0.007 \pm 0.002$

$\mathcal{R}_-^{\pi K} = -0.003 \pm 0.004 \pm 0.002$

# quasi-ADS Results

$B^- \to D[K^\pm \pi^\mp \pi^\pi \pi^\mp]K^-$

2011+2012: $3$ fb$^{-1}$




$N_{K^\pm \pi^\mp \pi^\pi \pi^\mp} = 11330 \pm 140$ $\qquad$ $N_{\pi^\pm K^\mp \pi^\pi \pi^\mp} = 159 \pm 17$

$\mathcal{R}_{\mathrm{ADS}}^{\pi K \pi\pi} = 0.0140 \pm 0.0015 \pm 0.0006$ $\qquad$ $\mathcal{A}_{\mathrm{ADS}}^{\pi K \pi\pi} = -0.313 \pm 0.102 \pm 0.038\ (2.9\sigma)$

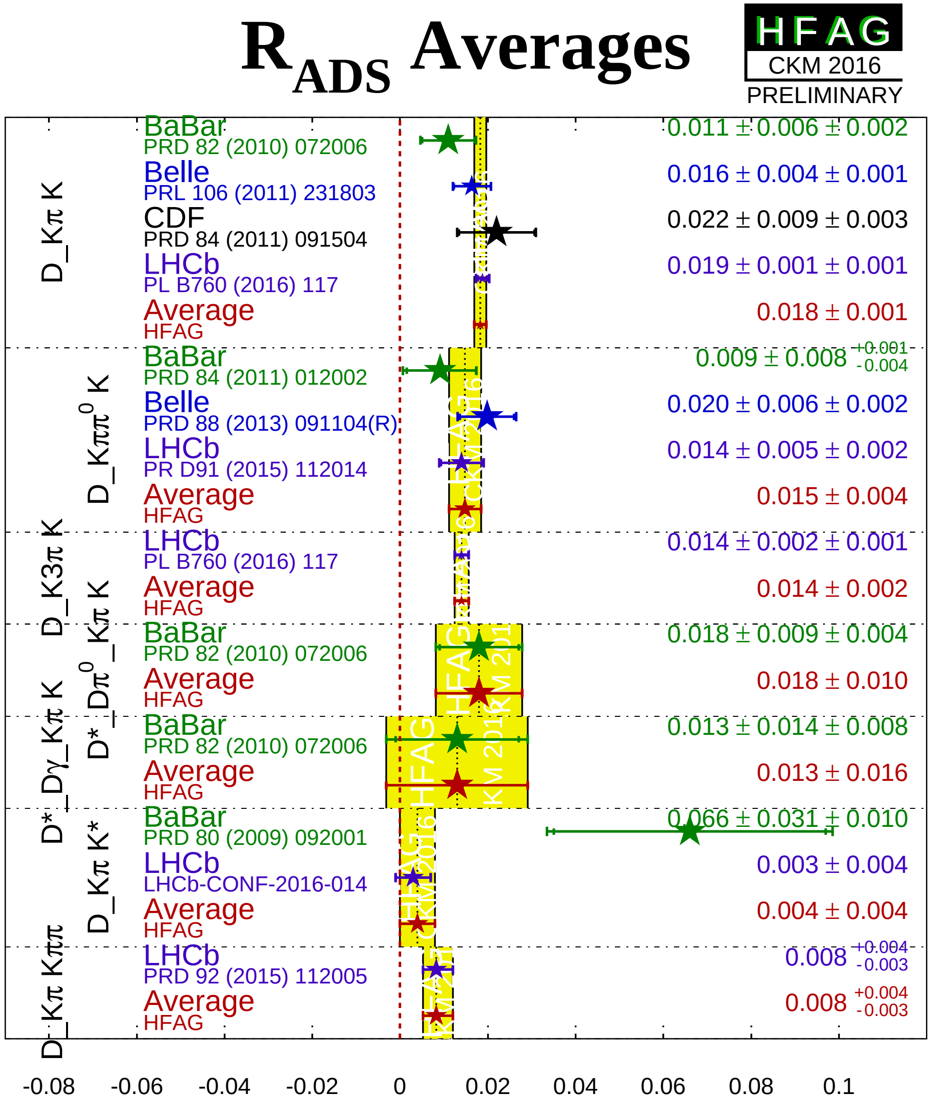
Recall $\gamma$ sensitivity depends on amount of interference in the final state

Coherence factor and average strong phase from CLEO-c data and LHCb $D^0$ mixing analysis

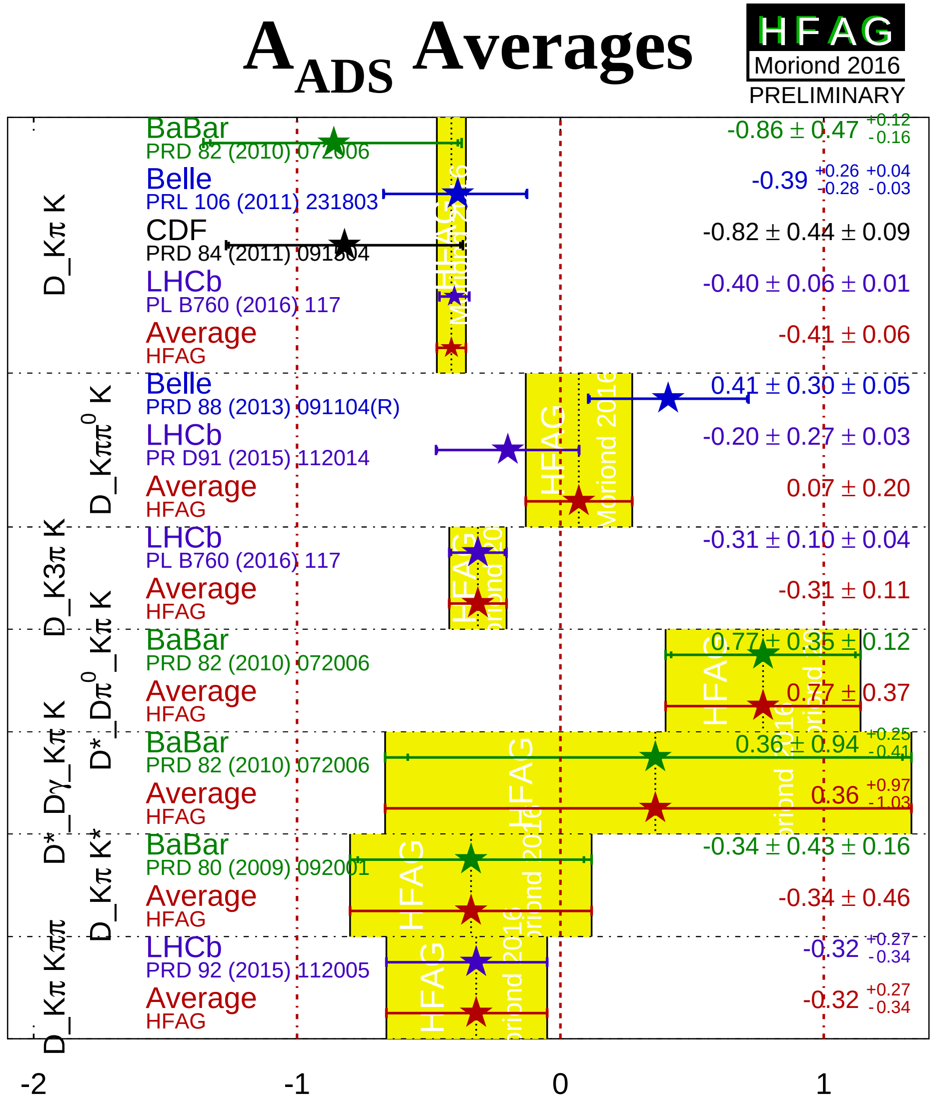
Phys. Lett. **B757**, 520 (2016)

$\kappa_D^{K3\pi} = 0.43^{+0.17}_{-0.13}, \qquad \delta_D^{K3\pi} = (128^{+28}_{-17})^\circ$

# ADS Average



R_ADS Averages
HFAG
CKM 2016
PRELIMINARY
D_Kπ K
BaBar PRD 82 (2010) 072006 0.011 ± 0.006 ± 0.002
Belle PRL 106 (2011) 231803 0.016 ± 0.004 ± 0.001
CDF PRD 84 (2011) 091504 0.022 ± 0.009 ± 0.003
LHCb PL B760 (2016) 117 0.019 ± 0.001 ± 0.001
Average HFAG 0.018 ± 0.001
D_Kππ0 K
BaBar PRD 84 (2011) 012002 0.009 ± 0.008 +0.001 -0.004
Belle PRD 88 (2013) 091104(R) 0.020 ± 0.006 ± 0.002
LHCb PR D91 (2015) 112014 0.014 ± 0.005 ± 0.002
Average HFAG 0.015 ± 0.004
D_K3π K
LHCb PL B760 (2016) 117 0.014 ± 0.002 ± 0.001
Average HFAG 0.014 ± 0.002
D*_Dπ0_Kπ K
BaBar PRD 82 (2010) 072006 0.018 ± 0.009 ± 0.004
Average HFAG 0.018 ± 0.010
D*_Dγ_Kπ K
BaBar PRD 82 (2010) 072006 0.013 ± 0.014 ± 0.008
Average HFAG 0.013 ± 0.016
D_Kπ K*
BaBar PRD 80 (2009) 092001 0.066 ± 0.031 ± 0.010
LHCb LHCb-CONF-2016-014 0.003 ± 0.004
Average HFAG 0.004 ± 0.004
D_Kπ Kππ
LHCb PRD 92 (2015) 112005 0.008 +0.004 -0.003
Average HFAG 0.008 +0.004 -0.003
-0.08 -0.06 -0.04 -0.02 0 0.02 0.04 0.06 0.08 0.1

A_ADS Averages
HFAG
Moriond 2016
PRELIMINARY
D_Kπ K
BaBar PRD 82 (2010) 072006 -0.86 ± 0.47 +0.12 -0.16
Belle PRL 106 (2011) 231803 -0.39 +0.26 -0.28 +0.04 -0.03
CDF PRD 84 (2011) 091504 -0.82 ± 0.44 ± 0.09
LHCb PL B760 (2016) 117 -0.40 ± 0.06 ± 0.01
Average HFAG -0.41 ± 0.06
D_Kππ0 K
Belle PRD 88 (2013) 091104(R) 0.41 ± 0.30 ± 0.05
LHCb PR D91 (2015) 112014 -0.20 ± 0.27 ± 0.03
Average HFAG 0.07 ± 0.20
D_K3π K
LHCb PL B760 (2016) 117 -0.31 ± 0.10 ± 0.04
Average HFAG -0.31 ± 0.11
D*_Dπ0_Kπ K
BaBar PRD 82 (2010) 072006 0.77 ± 0.35 ± 0.12
Average HFAG 0.77 ± 0.37
D*_Dγ_Kπ K
BaBar PRD 82 (2010) 072006 0.36 ± 0.94 +0.25 -0.41
Average HFAG 0.36 +0.97 -1.03
D_Kπ K*
BaBar PRD 80 (2009) 092001 -0.34 ± 0.43 ± 0.16
Average HFAG -0.34 ± 0.46
D_Kπ Kππ
LHCb PRD 92 (2015) 112005 -0.32 +0.27 -0.34
Average HFAG -0.32 +0.27 -0.34
-2 -1 0 1

# GGSZ Method

Giri, Grossman, Soffer, Zupan and the Belle Collaboration

A. Bondar, Proceedings of BINP Special Meeting on Dalitz Analysis, 24-26 Sep. 2002, unpublished

Phys. Rev. D **68**, 054018 (2003)

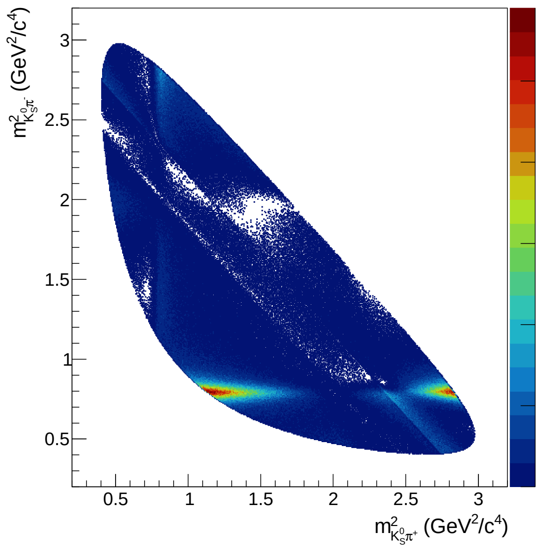
Multibody $D^0$ and $\bar{D}^0$ decays to self-conjugate final states

eg. $D^0 \to K_S^0\pi^+\pi^-$ and $\bar{D}^0 \to K_S^0\pi^+\pi^-$

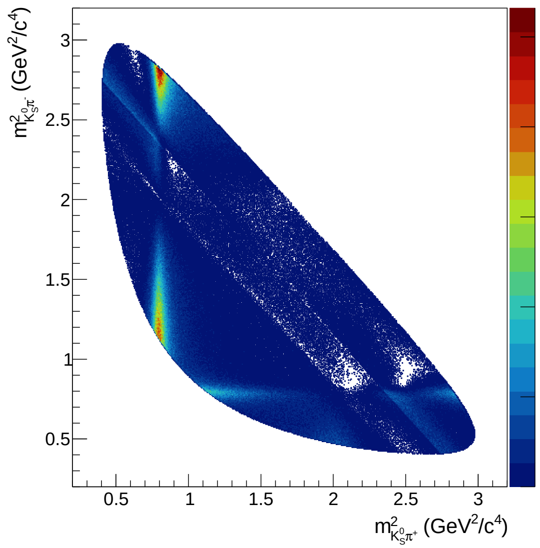
Provides enough degrees of determine hadronic parameters and $\gamma$ at amplitude-level

$$|A(B^- \to DK^-)|^2 = | \quad A_D^0 \quad + r_B e^{i(\delta_B-\gamma)} \quad A_{\bar{D}^0} \quad |^2$$

$$\Bigg| \quad \text{[plot 1]} \quad + r_B e^{i(\delta_B-\gamma)} \quad \text{[plot 2]} \quad \Bigg|^2$$

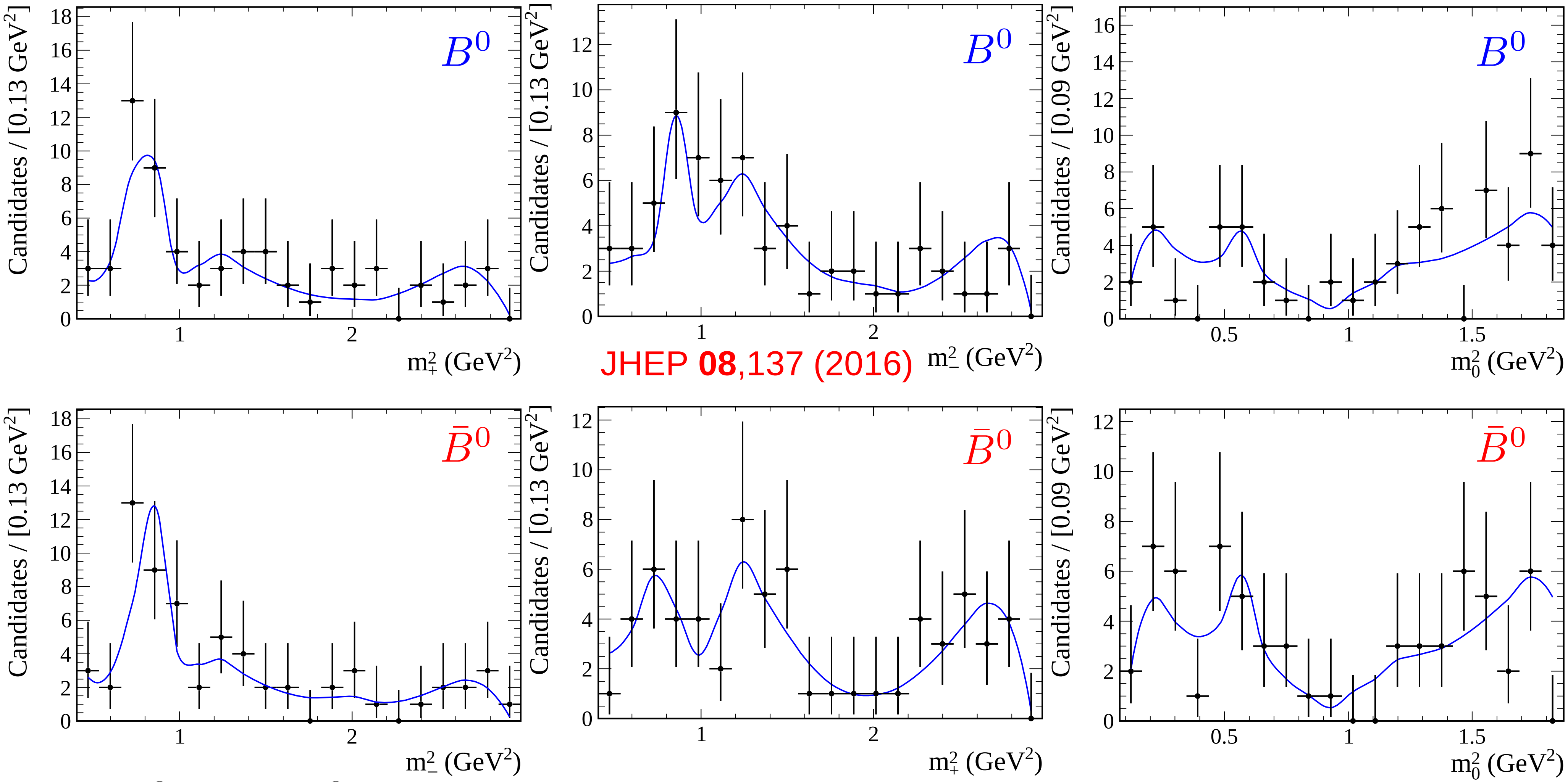



$+ r_B e^{i(\delta_B-\gamma)}$



# quasi-GGSZ Results

Model-dependent $B^0 \to D[K_S^0\pi^+\pi^-]K^{*0}$ with $3$ fb$^{-1}$ at LHCb




JHEP **08**,137 (2016)

$N(B^0 \to DK^{*0}) = 90 \pm 11$

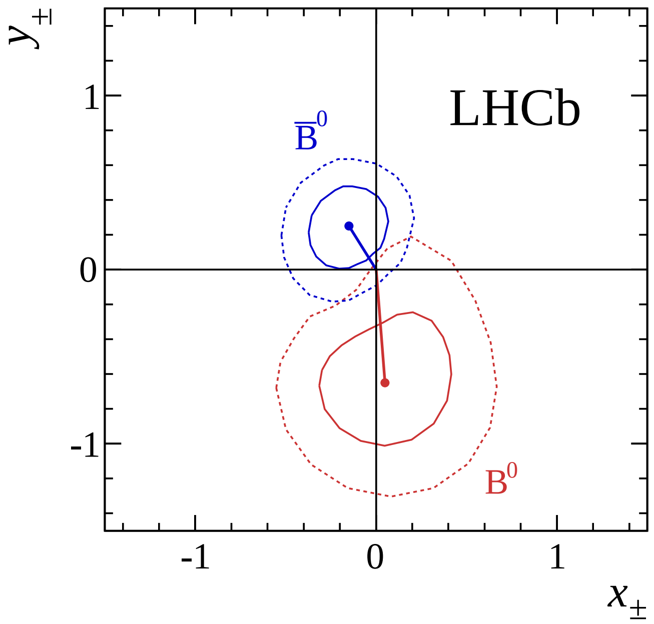
# quasi-GGSZ Results

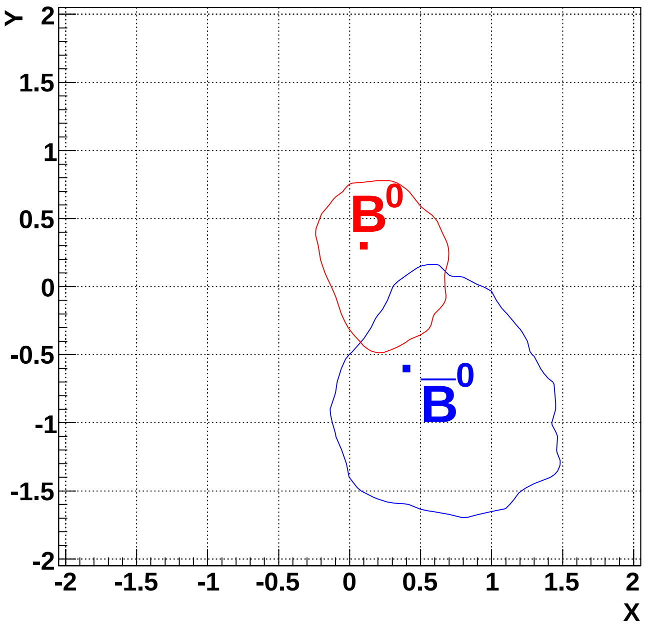
Take into account reduced sensitivity to $\gamma$ from non-$K^*$ interference

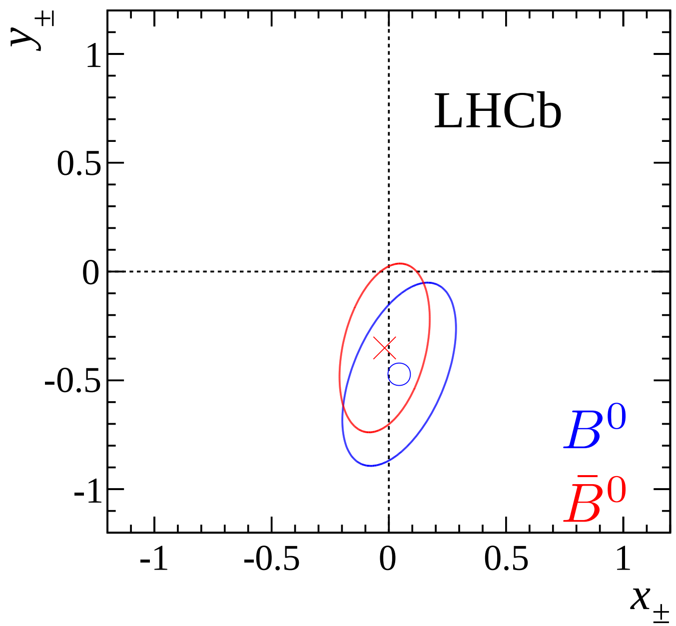
GLW-Dalitz: $\kappa = 0.958^{+0.005+0.002}_{-0.010-0.045}$, Phys. Rev. D **93**, 112018 (2016)

$$|A(B^- \to DK^-)|^2 = |A_{D^0}|^2 + r_B^2 |A_{\bar{D}^0}|^2 + 2 r_B \kappa \Re[e^{i(\delta_B - \gamma)} A^*_{D^0} A_{\bar{D}^0}]$$

| LHCb Model-dependent | Belle Model-independent | LHCb GLW-Dalitz |
|---|---|---|
| JHEP **08**,137 (2016) | PTEP **2016**, 043C01 (2016) | $B^0 \to D_{CP} K^+ \pi^-$ |



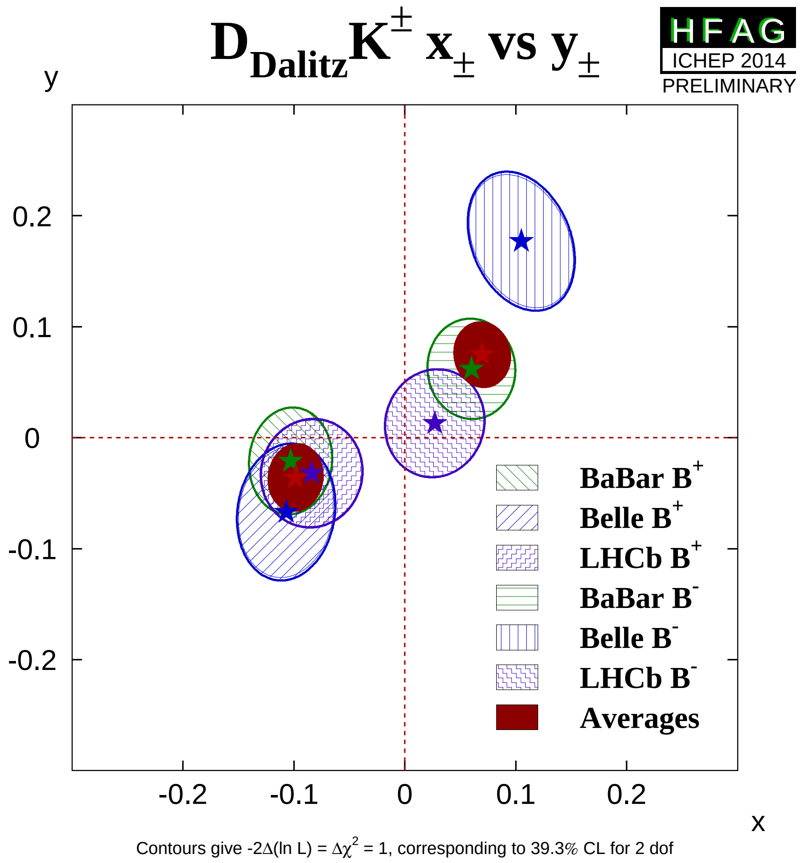




Comparable precisions

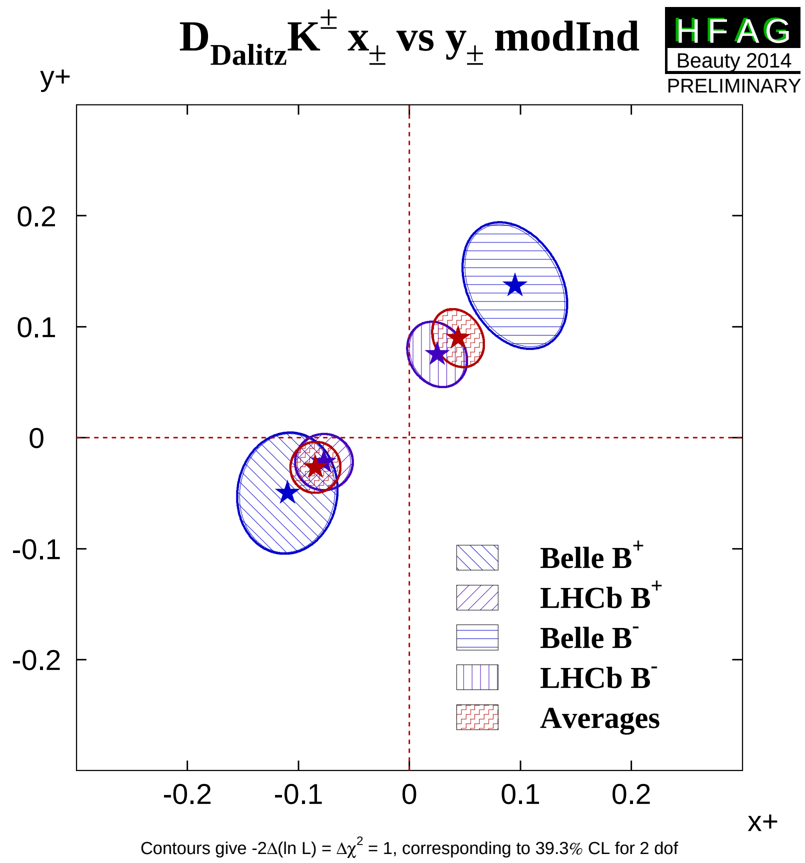
# GGSZ Average

$B^- \to D[K^0_S\pi^+\pi^-, K^0_S K^+ K^-]K^-$ dominates the GGSZ average

Model-dependent




Model-independent

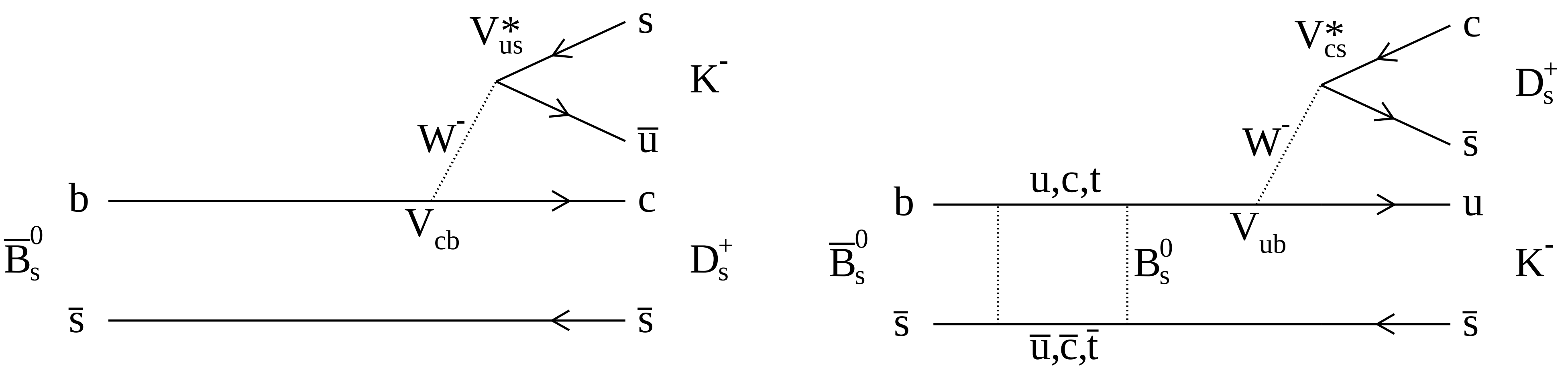



LHCb model-dependent results only based on $1$ fb$^{-1}$

# Time-dependent Method

Same order in $\lambda$, no colour-suppression, $\tau_{B_s^0} \gg \Delta m_s$

Comparable amplitudes gives excellent sensitivity to $\gamma$



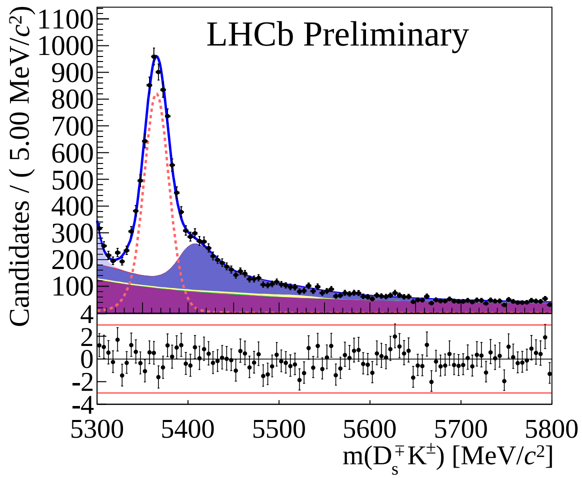

$$\frac{\Gamma(B_s^0(t) \to D_s^- K^+) - \Gamma(\bar{B}_s^0(t) \to D_s^- K^+)}{\Gamma(B_s^0(t) \to D_s^- K^+) + \Gamma(\bar{B}_s^0(t) \to D_s^- K^+)} = \frac{-\mathcal{C}_{D_s K} \cos \Delta m_s t + \mathcal{S}_{D_s^- K^+} \sin \Delta m_s t}{\cosh \Delta\Gamma_s t/2 + \mathcal{A}^{\Delta\Gamma}_{D_s^- K^+} \sinh \Gamma_s t/2}$$

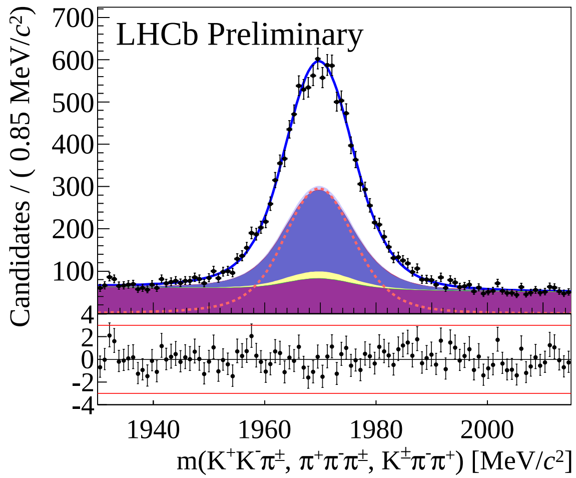
Assuming no other contributing amplitudes, $\mathcal{C}_{D_s K} = 1 - r_B^2 / 1 + r_B^2$

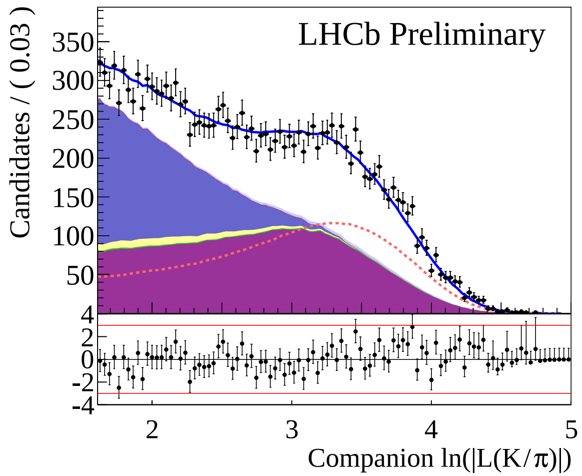
$$\mathcal{S}_{D_s^- K^+ (D_s^+ K^-)} = \frac{(-)2 r_B \sin[\delta_B - (+)(\gamma - 2\beta_s)]}{1 + r_B^2}, \quad \mathcal{A}^{\Delta\Gamma}_{D_s^- K^+ (D_s^+ K^-)} = \frac{2 r_B \cos[\delta_B - (+)(\gamma - 2\beta_s)]}{1 + r_B^2}$$

# Time-dependent Results

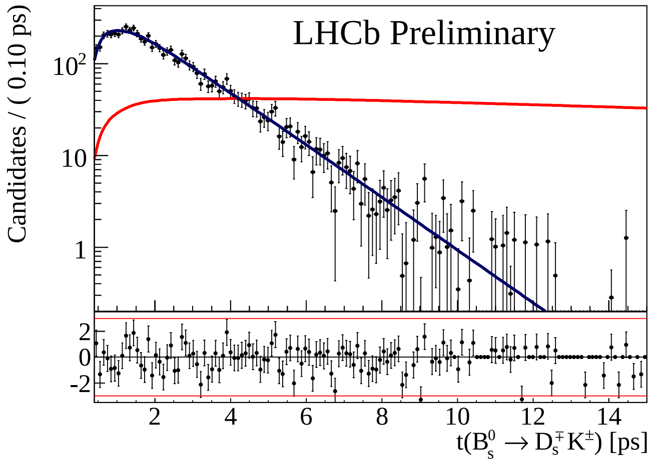
New results for $\bar{B}_s^0 \to D_s^- K^+$ with $3$ fb$^{-1}$ at LHCb, LHCb-CONF-2016-015




$sWeighted$ fit to time-distribution, overall tagging power $\sim (4.98 \pm 0.26)\%$




Red curve: Efficiency function

$$\mathcal{C}_{D_s K} = +0.735 \pm 0.143 \pm 0.048$$

$$\mathcal{S}_{D_s^- K^+} = -0.518 \pm 0.202 \pm 0.073$$

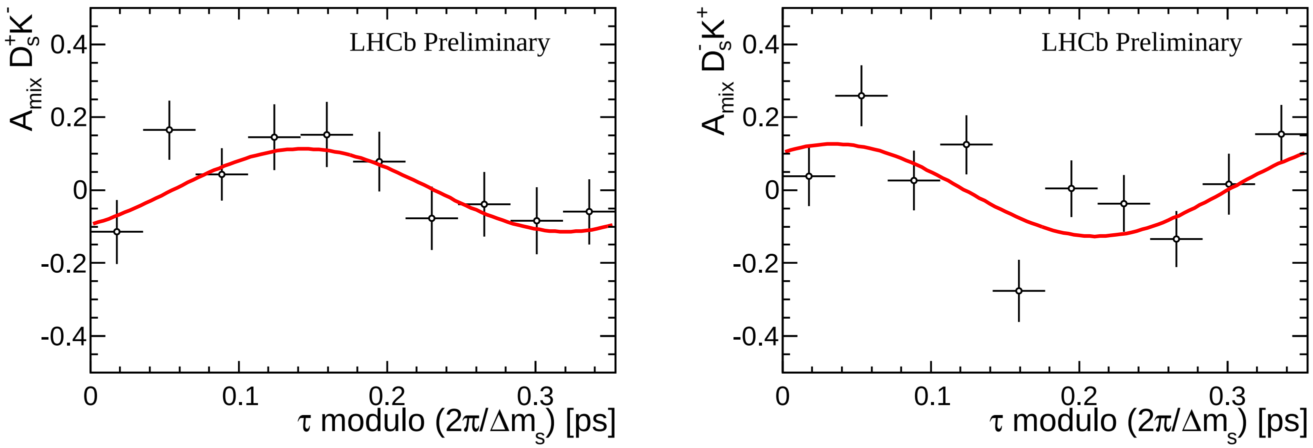
$$\mathcal{S}_{D_s^+ K^-} = -0.496 \pm 0.197 \pm 0.071$$

$$\mathcal{A}^{\Delta\Gamma}_{D_s^- K^+} = +0.395 \pm 0.277 \pm 0.122$$

$$\mathcal{A}^{\Delta\Gamma}_{D_s^+ K^-} = +0.314 \pm 0.274 \pm 0.107$$

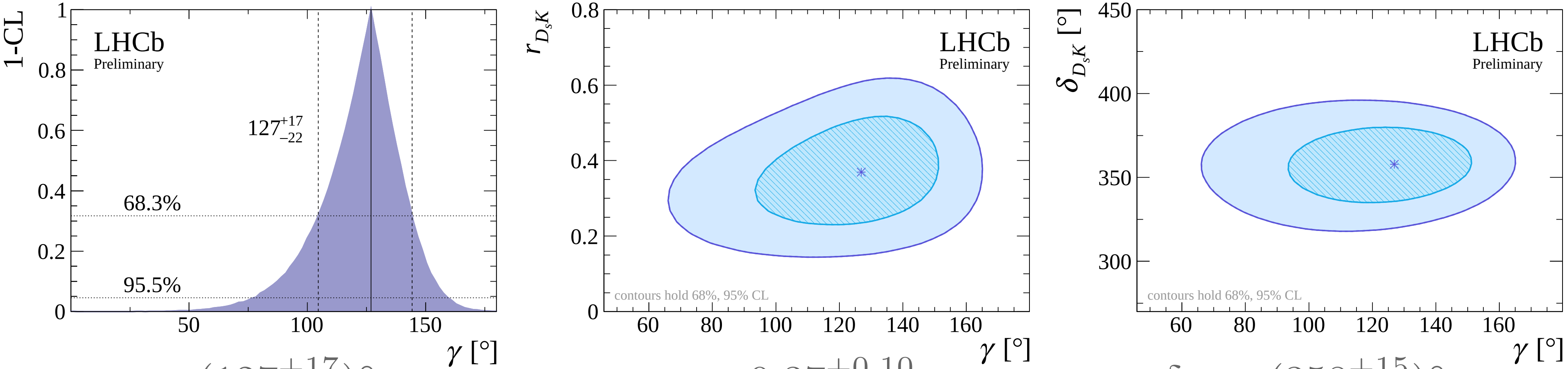
# Time-dependent Results

New results for $\bar{B}_s^0 \to D_s^- K^+$ with $3$ fb$^{-1}$ at LHCb, LHCb-CONF-2016-015




Clear $B_s^0$-$\bar{B}_s^0$ oscillations

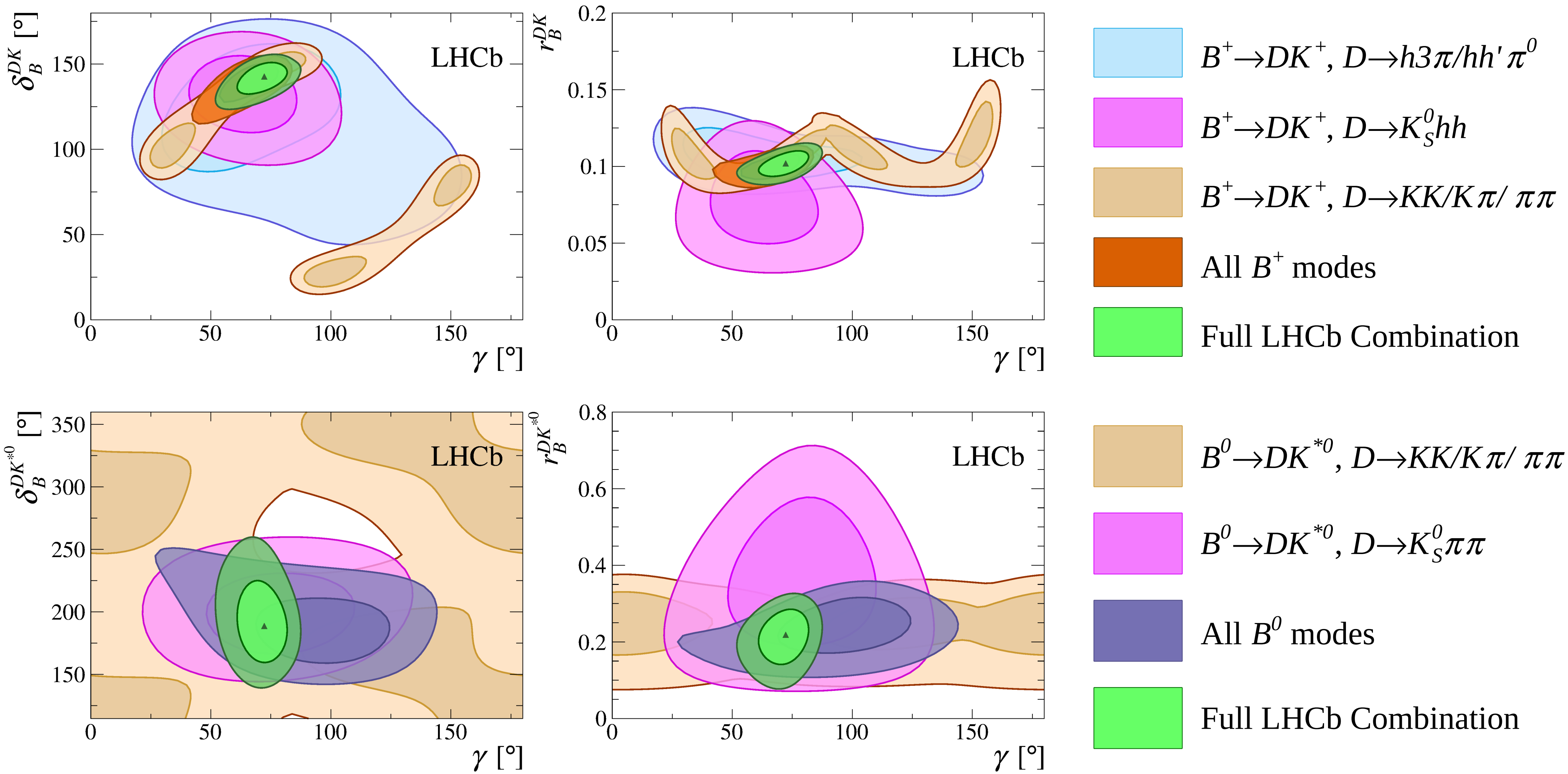
Constrain $-2\beta_s = \phi_s = (-0.01 \pm 0.038)$ rad, Phys. Rev. Lett. **114** 041801 (2015)




$\gamma = (127^{+17}_{-22})^\circ$ $r_B = 0.37^{+0.10}_{-0.09}$ $\delta_B = (358^{+15}_{-16})^\circ$

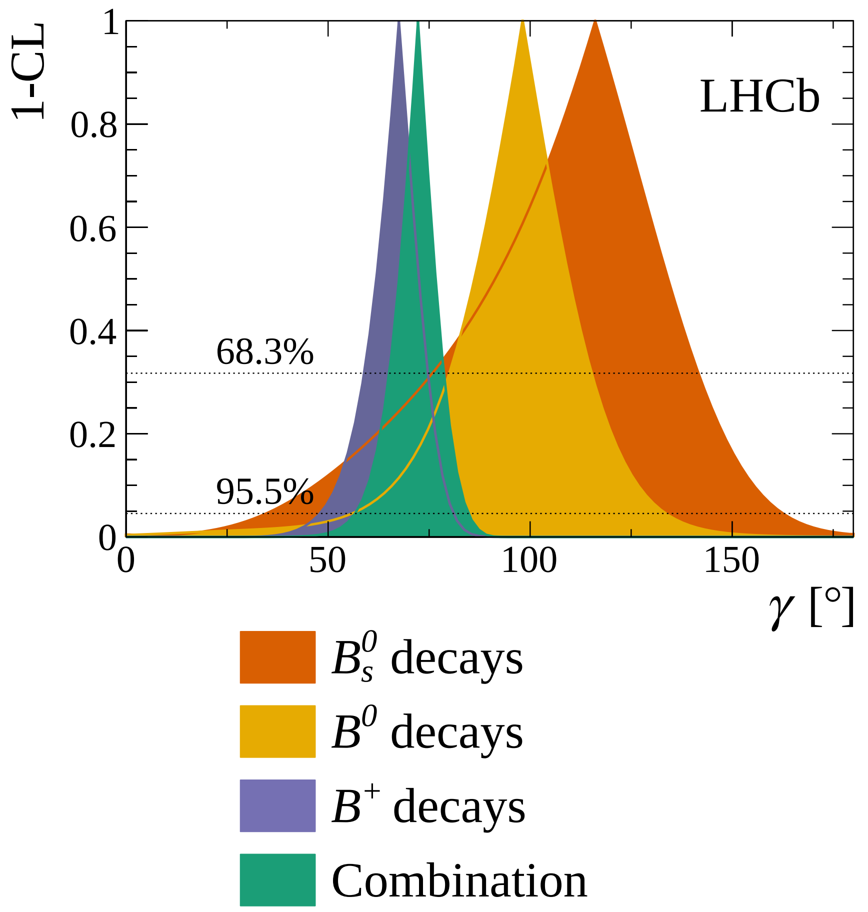
# LHCb $\gamma$ Combination

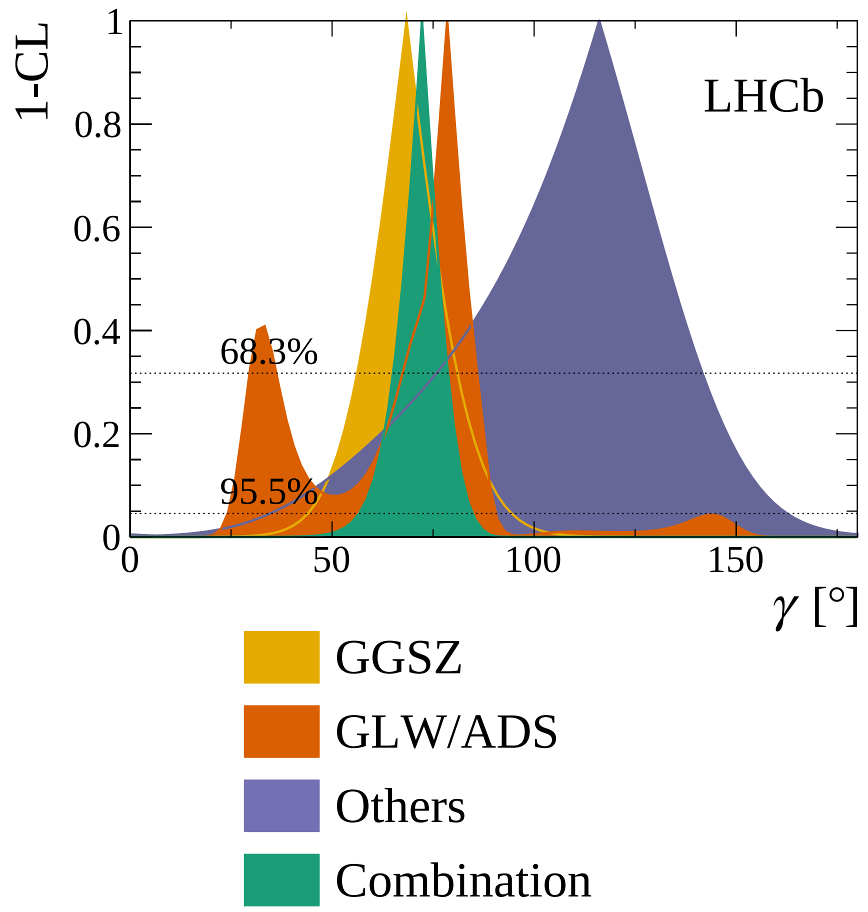
Good agreement between Frequentist and Bayesian approach, JHEP 12 (2016) 087



# LHCb $\gamma$ Combination

New results with quasi-GLW/ADS $B^- \to DK^{*-}$, time-dependent $\bar{B}_s^0 \to D_s^- K^+$ not included




$$\gamma = (72.2^{+6.8}_{-7.3})^\circ$$

# Summary

BaBar: $\gamma = (70 \pm 18)^\circ$

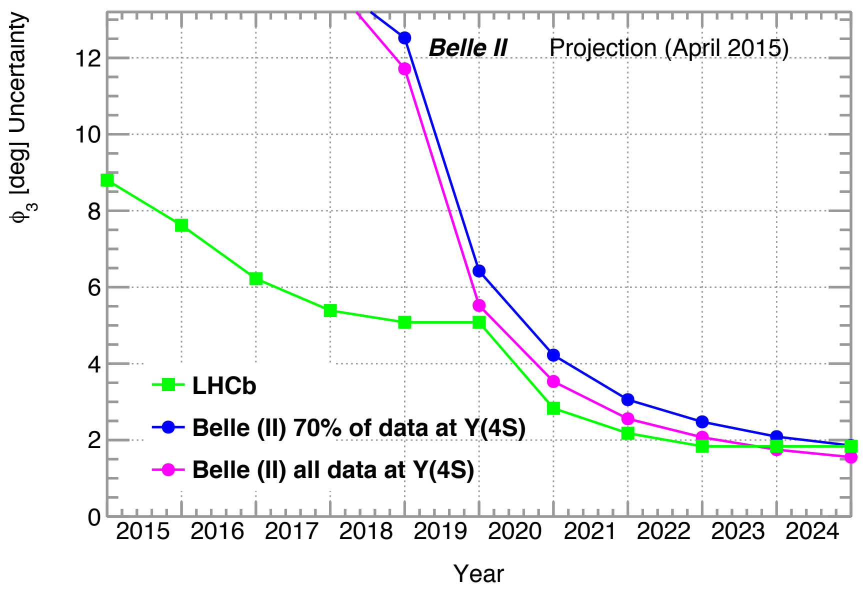
Belle: $\phi_3 = (73^{+13}_{-15})^\circ$

LHCb: $\gamma = (72.2^{+6.8}_{-7.3})^\circ$

New results

quasi-GLW/ADS $B^- \to DK^{*-}$ including Run II data up to 2016

Time-dependent $\bar{B}^0_s \to D^-_s K^+$ updated with full Run I dataset




BelleII expected to start recording data in 2018

Will quickly become competitive with LHCb

Expected uncertainty $\delta\phi_3 \sim 1.5^\circ$ with $50$ ab$^{-1}$

LHCb will have a similar precision on the same timescale