The CKM angle γ

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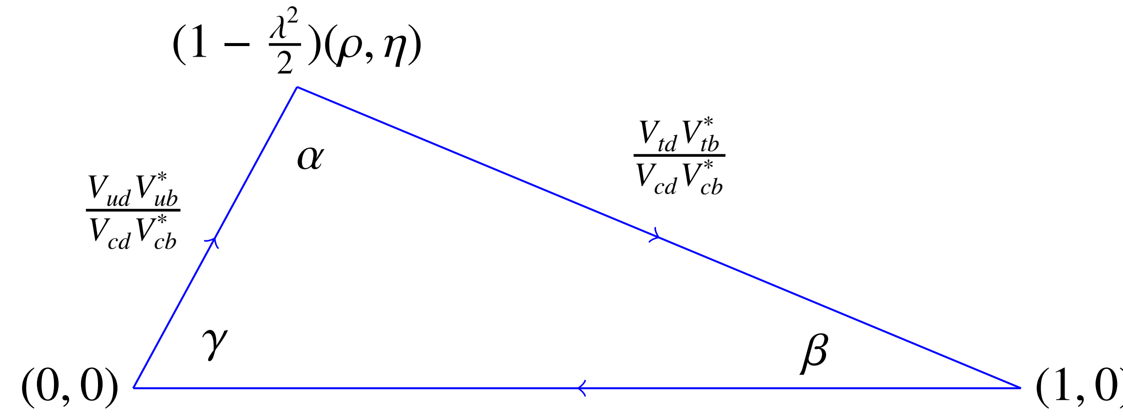
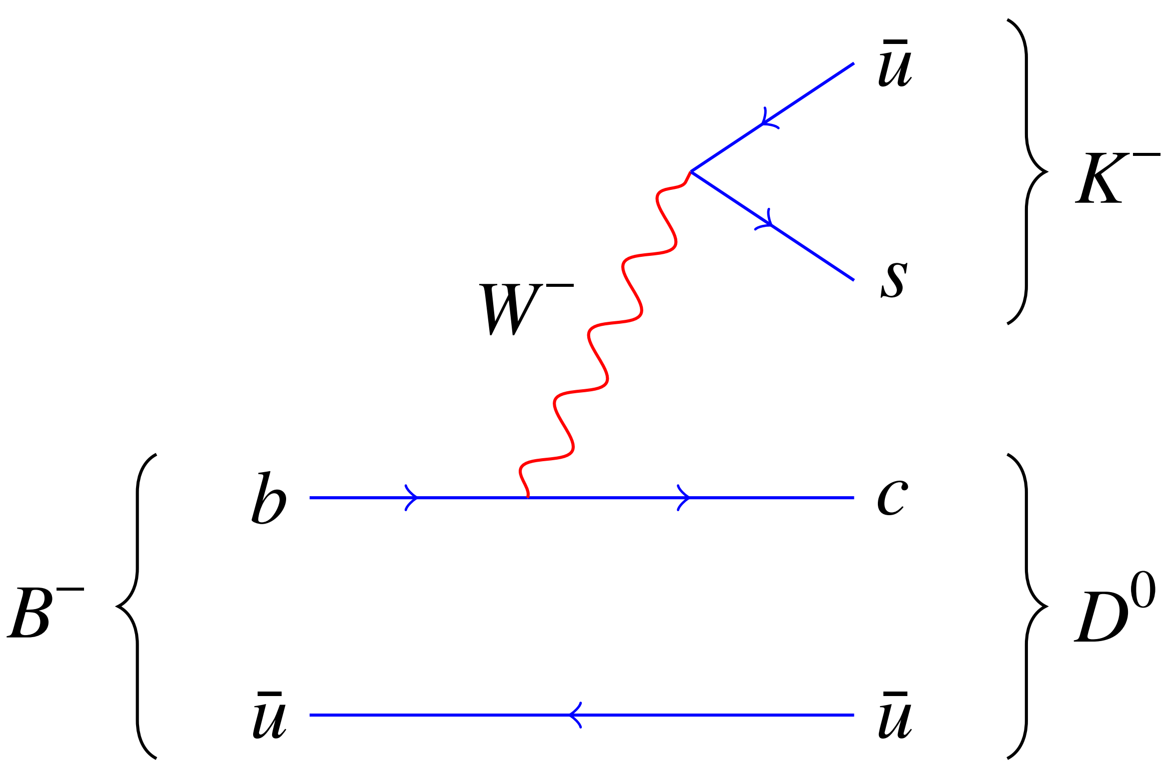
on behalf of the LHCb collaboration

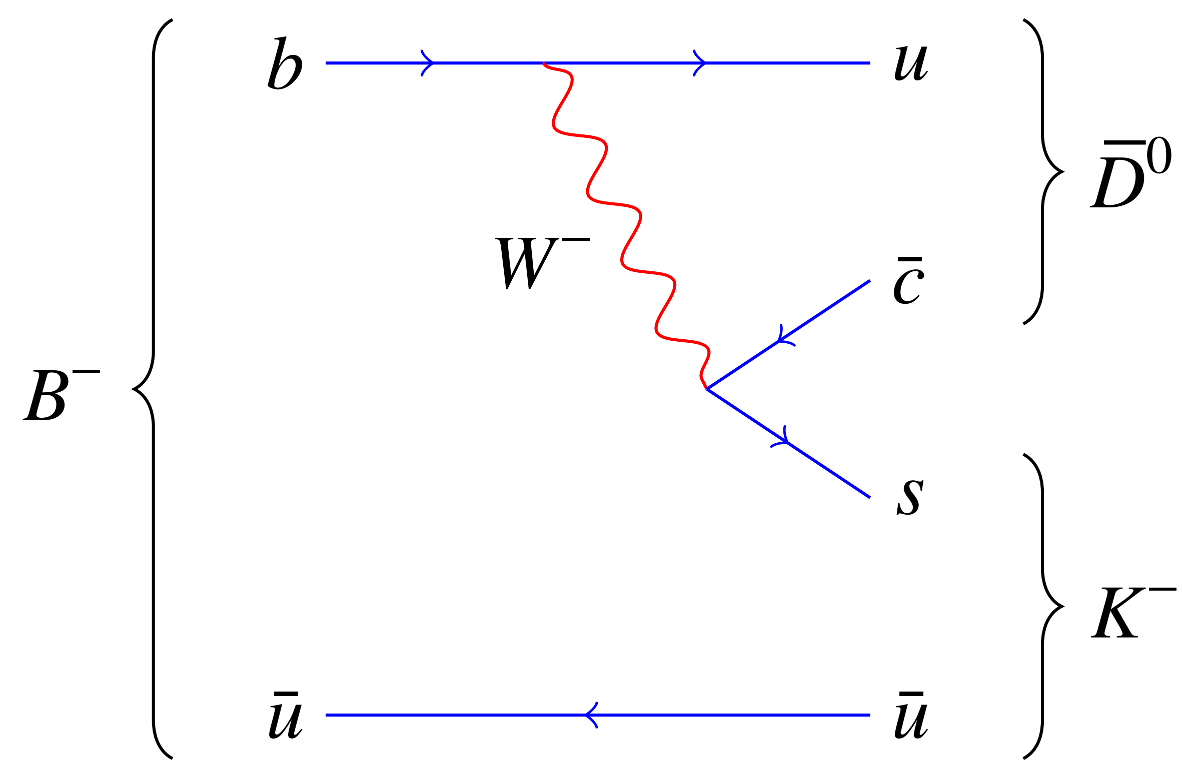
Rencontres de Moriond, 13th March 2016

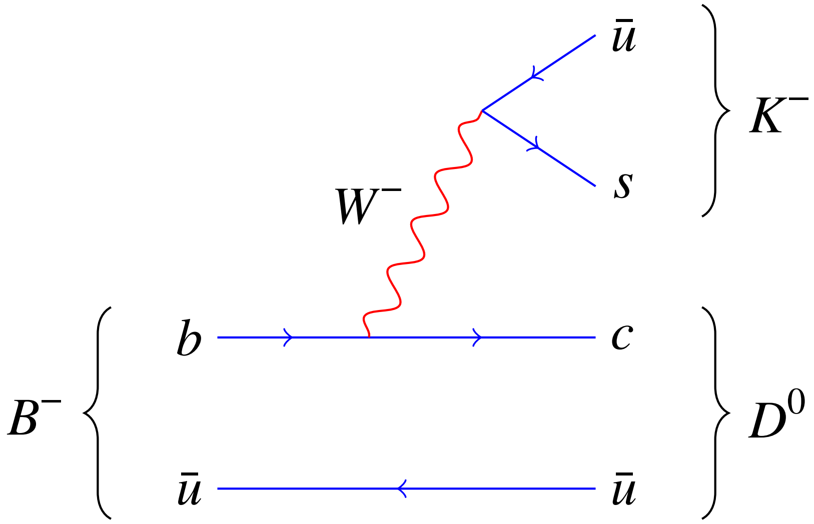
$$\gamma \equiv \arg\left(-\frac{V_{ud}V_{ub}^*}{V_{cd}V_{cb}^*}\right) \approx \arg\left(-\frac{V_{ub}^*}{V_{cb}^*}\right)$$

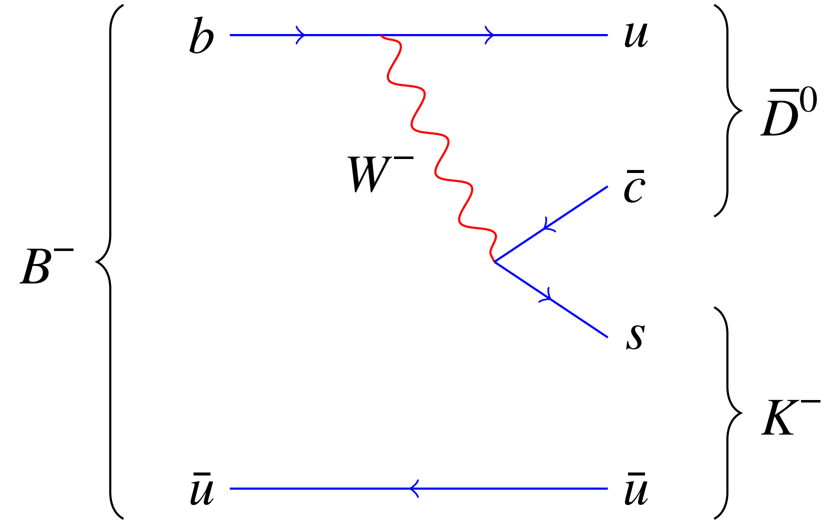


- Accessible in decays where $b \to u$ and $b \to c$ transitions interfere to give *CP* violation
- No dependence on coupling to top so γ can be determined from direct *CPV* in tree decays
- $B \to DX$ decays satisfy these criteria and a few are known to exhibit large *CP* violation. The most studied case is $B^- \to DK^-$ decays,









- The hadronic parameters are the amplitude ratio r_B and the CP-conserving phase δ_B,

$$\frac{A\left(B^- \to \bar{D}^0 K^-\right)}{A\left(B^- \to D^0 K^-\right)} = r_B\, e^{i(\delta_B - \gamma)}$$

- To unambiguously determine γ, measurements of partial width ratios and charge asymmetries are needed from many final states of the *D* meson. Analyses of different types of D decay require different techniques and are categorised as,

GLW: $D \to K^+K^-$, $\pi^+\pi^-$, $K_S\pi^0$

ADS: $D \to \pi^-K^+$

quasi-ADS $D \to \pi^-K^+\pi^+\pi^-$, $\pi^-K^+\pi^0$

quasi-GLW $D \to \pi^+\pi^-\pi^+\pi^-$, $K^+K^-\pi^0$, $\pi^+\pi^-\pi^0$

GGSZ $D \to K_S\pi^+\pi^-$, $K_SK^+K^-$

GLS $D \to K_SK^-\pi^+$, $K_S\pi^-K^+$

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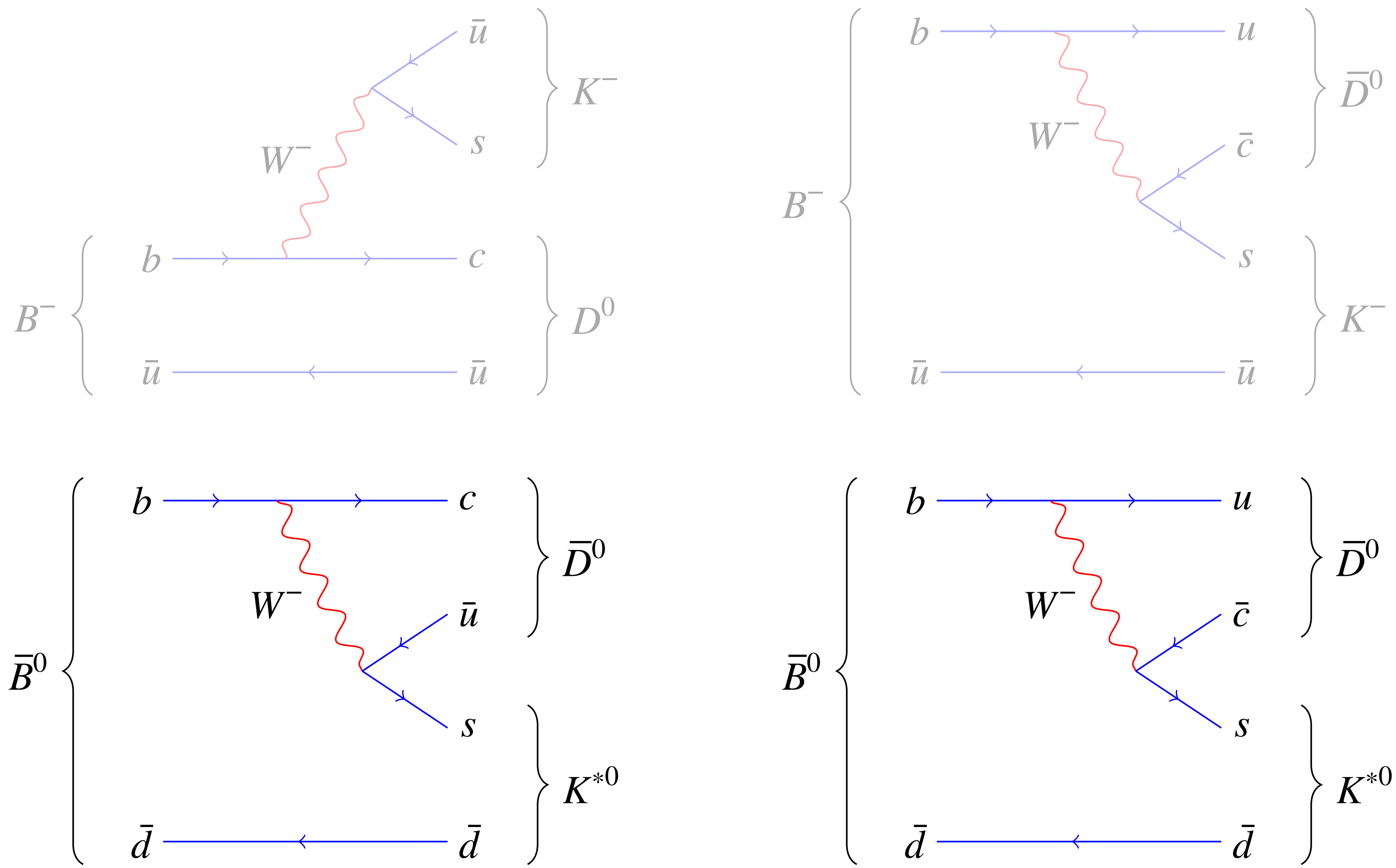

- The LHCb data sample size is such that some B^0 analysis becomes viable for measuring γ

Dalitz-GLW: $D \rightarrow K^+K^-$
$\pi^+\pi^-$
$K_S\pi^0$

ADS: $D \rightarrow \pi^-K^+$.

quasi-ADS
π

quasi-GLW
K
π

GGSZ $D \rightarrow K_S\pi^+\pi^-$.
$K_S K^+K^-$

GLS
K

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Four new papers are described today (final Run 1 analyses),

Constraints on the unitarity triangle angle γ from Dalitz plot analysis of $B^0 \to DK^+\pi^-$ decays	LHCb-PAPER-2015-059 arXiv:1602.03455	$B^0 \to [K^+K^-]K\pi$ $B^0 \to [\pi^+\pi^-]K\pi$
Measurement of CP observables in $B^\pm \to DK^\pm$ and $B^\pm \to D\pi^\pm$ with two- and four-body D decays	LHCb-PAPER-2016-003	$B^\pm \to [h^\pm h^\pm]h^\pm$ $B^\pm \to [K^+\pi^-\pi^+\pi^-]h^\pm$ $B^\pm \to [\pi^+\pi^-\pi^+\pi^-]h^\pm$
Model-independent measurement of the CKM angle γ using $B^0 \to DK^{*0}$, $D \to K^0_S\pi^+\pi^-$, $K^0_S K^+K^-$ decays	LHCb-PAPER-2016-006	$B^0 \to [K_S{}^0 h^+h^-]K^{*0}$
Measurement of the CKM angle γ using $B^0 \to DK^{*0}$ with $D \to K^0_S\pi^+\pi^-$ decays	LHCb-PAPER-2016-007	$B^0 \to [K_S{}^0\pi^+\pi^-]K^{*0}$

which add to five published papers,

A study of CP violation in $B^\pm \to DK^\pm$ and $B^\pm \to D\pi^\pm$ decays with $D \to K_S{}^0 K^\pm\pi^\mp$ final states
Phys. Lett. B733 (2014) 36 **arXiv:1402.2982** — $B^\pm \to [K_S{}^0 K^+\pi^-]h^\pm$

Measurement of CP asymmetry in $B_s{}^0 \to D_s{}^\mp K^\pm$ decays
JHEP 11 (2014) 060 **arXiv:1407.6127** — $B_s \to D_s K$

Measurement of CP violation parameters in $B^0 \to DK^{*0}$ decays
Phys. Rev. D90 (2014) 112002 **arXiv:1407.8136** — $B^0 \to [K^\pm\pi^\pm]K^{*0}$

Measurement of the CKM angle γ using $B^\pm \to DK^\pm$ with $D \to K_S{}^0\pi^+\pi^-$, $K_S{}^0 K^+K^-$ decays
JHEP 10 (2014) 097 **arXiv:1408.2748** — $B^\pm \to [K_S{}^0 h^+h^-]K^\pm$

A study of CP violation in $B^\mp \to Dh^\mp$ $(h=K,\pi)$ with the modes $D \to K^\mp\pi^\pm\pi^0$, $D \to \pi^+\pi^-\pi^0$ and $D \to K^+K^-\pi^0$
Phys. Rev. D91 (2015) 112014 **arXiv:1504.05442** — $B^\pm \to [h^\pm h^\pm \pi^0]h^\pm$

to be combined today in,

Measurement of the CKM angle γ from a combination of $B \to DK$ analyses — LHCb-CONF-2016-001

$B^{\pm}\rightarrow Dh^{\pm}$, $D\rightarrow$ 2-body

Many observables that have direct sensitivity to γ

$$\frac{\Gamma(B^- \to [K^+K^-]_D K^-) + \Gamma(B^+ \to [K^+K^-]_D K^+)}{\Gamma(B^- \to [K^-\pi^+]_D \pi^-) + \Gamma(B^+ \to [K^+\pi^-]_D \pi^+)} = R_{CP}$$

$$\frac{\Gamma(B^- \to [\pi^+\pi^-]_D K^-) + \Gamma(B^+ \to [\pi^+\pi^-]_D K^+)}{\Gamma(B^- \to [K^-\pi^+]_D \pi^-) + \Gamma(B^+ \to [K^+\pi^-]_D \pi^+)} = R_{CP}$$

$$\frac{\Gamma(B^- \to [K^-\pi^+]_D K^-) - \Gamma(B^+ \to [K^+\pi^-]_D K^+)}{\Gamma(B^- \to [K^-\pi^+]_D K^-) + \Gamma(B^+ \to [K^+\pi^-]_D K^+)} = A_K^{K\pi}$$

$$\frac{\Gamma(B^- \to [K^-K^+]_D K^-) - \Gamma(B^+ \to [K^+K^-]_D K^+)}{\Gamma(B^- \to [K^-K^+]_D K^-) + \Gamma(B^+ \to [K^+K^-]_D K^+)} = A_K^{KK}$$

$$\frac{\Gamma(B^- \to [\pi^-\pi^+]_D K^-) - \Gamma(B^+ \to [\pi^+\pi^-]_D K^+)}{\Gamma(B^- \to [\pi^-\pi^+]_D K^-) + \Gamma(B^+ \to [\pi^+\pi^-]_D K^+)} = A_K^{\pi\pi}$$

$$\frac{\Gamma(B^- \to [\pi^-K^+]_D K^-) + \Gamma(B^+ \to [\pi^+K^-]_D K^+)}{\Gamma(B^- \to [K^-\pi^+]_D K^-) + \Gamma(B^+ \to [K^+\pi^-]_D K^+)} = R_{ADS(K)}^{\pi K}$$

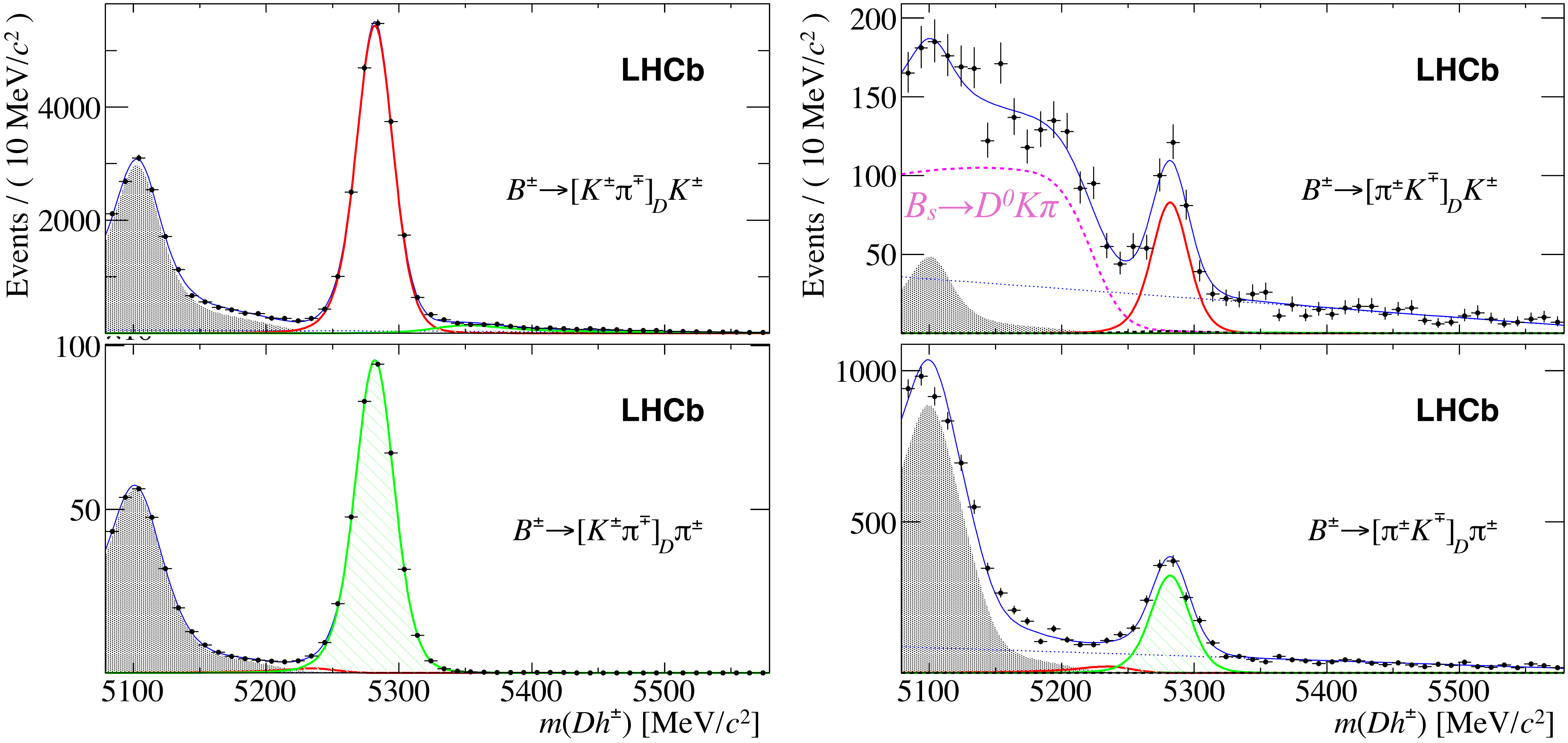
$$\frac{\Gamma(B^- \to [\pi^-K^+]_D K^-) - \Gamma(B^+ \to [\pi^+K^-]_D K^+)}{\Gamma(B^- \to [\pi^-K^+]_D K^-) + \Gamma(B^+ \to [\pi^+K^-]_D K^+)} = A_{ADS(K)}^{\pi K}$$

$$\Gamma\left(B^{\pm} \to [f]_D K^{\pm}\right) = r_D^2 + r_B^2 + 2\kappa_D r_D r_B \cos(\delta_B + \delta_D \pm \gamma)$$

ADS: $B^{\pm} \to Dh^{\pm}$, $D \to \pi^{+}K^{-}$

29 500 $B^{\pm} \to DK^{\pm}$, $D \to K^{+}\pi^{-}$

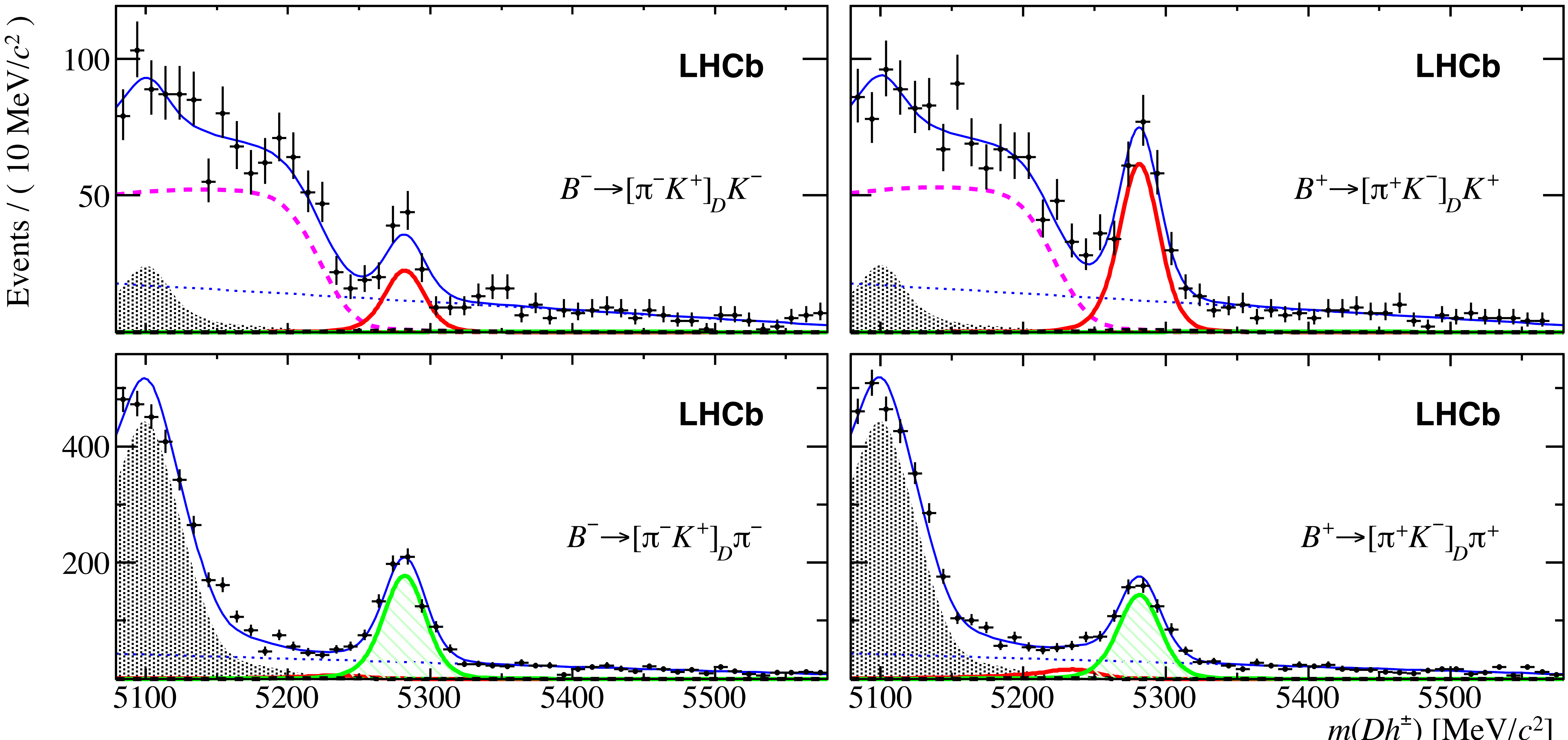
550 $B^{\pm} \to DK^{\pm}$, $D \to \pi^{+}K^{-}$



ADS: $B^{\pm} \to Dh^{\pm}$, $D \to \pi^{+}K^{-}$

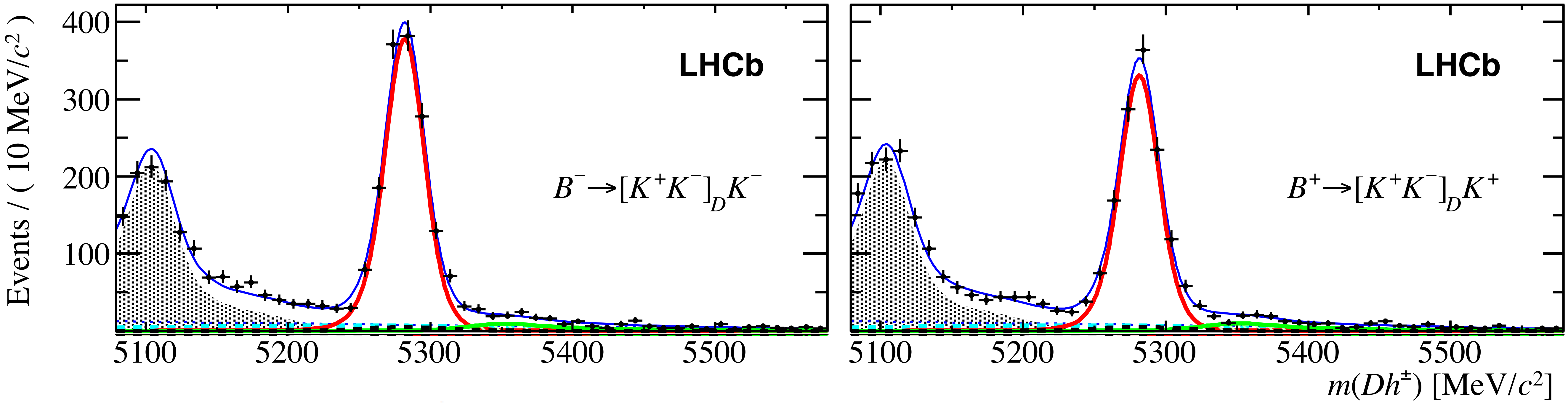
$$A^{\pi K}_{\mathrm{ADS}(K)} = -0.403 \quad \pm 0.056 \quad \pm 0.011$$

8σ



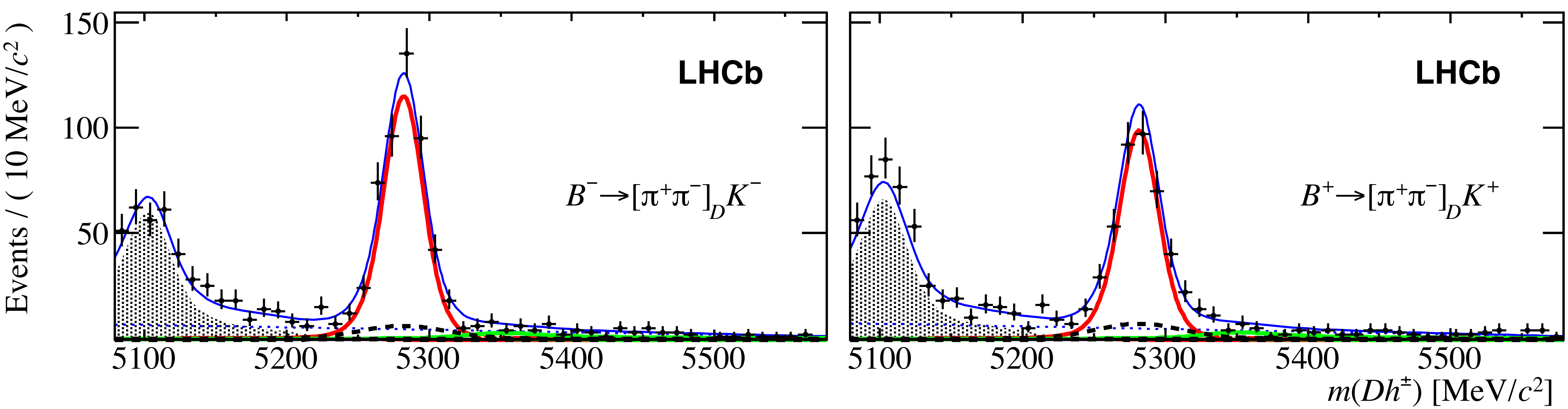
$$A^{\pi K}_{\mathrm{ADS}(\pi)} = 0.100 \quad \pm 0.031 \quad \pm 0.009$$

GLW: $B^{\pm} \to DK^{\pm}$, $D \to K^+K^-$, $\pi^+\pi^-$



$$A_K^{KK} = 0.087 \pm 0.020 \pm 0.008$$

$$A_K^{\pi\pi} = 0.128 \pm 0.037 \pm 0.012$$



$B^{\pm} \rightarrow Dh^{\pm}$, $D \rightarrow$ 4-body

Same observables as in the 2-body analysis and similarly sensitivity to γ

$$\frac{\Gamma(B^- \to [\pi^-\pi^+\pi\pi]_D K^-) + \Gamma(B^+ \to [\pi^+\pi^-\pi\pi]_D K^+)}{\Gamma(B^- \to [K^-\pi^+\pi\pi]_D \pi^-) + \Gamma(B^+ \to [K^+\pi^-\pi\pi]_D \pi^+)} = R_{CP}^{\pi\pi\pi\pi}$$

$$\frac{\Gamma(B^- \to [K^-\pi^+\pi\pi]_D K^-) - \Gamma(B^+ \to [K^+\pi^-\pi\pi]_D K^+)}{\Gamma(B^- \to [K^-\pi^+\pi\pi]_D K^-) + \Gamma(B^+ \to [K^+\pi^-\pi\pi]_D K^+)} = A_K^{K\pi\pi\pi}$$

$$\frac{\Gamma(B^- \to [\pi^-\pi^+\pi\pi]_D K^-) - \Gamma(B^+ \to [\pi^+\pi^-\pi\pi]_D K^+)}{\Gamma(B^- \to [\pi^-\pi^+\pi\pi]_D K^-) + \Gamma(B^+ \to [\pi^+\pi^-\pi\pi]_D K^+)} = A_K^{\pi\pi\pi\pi}$$

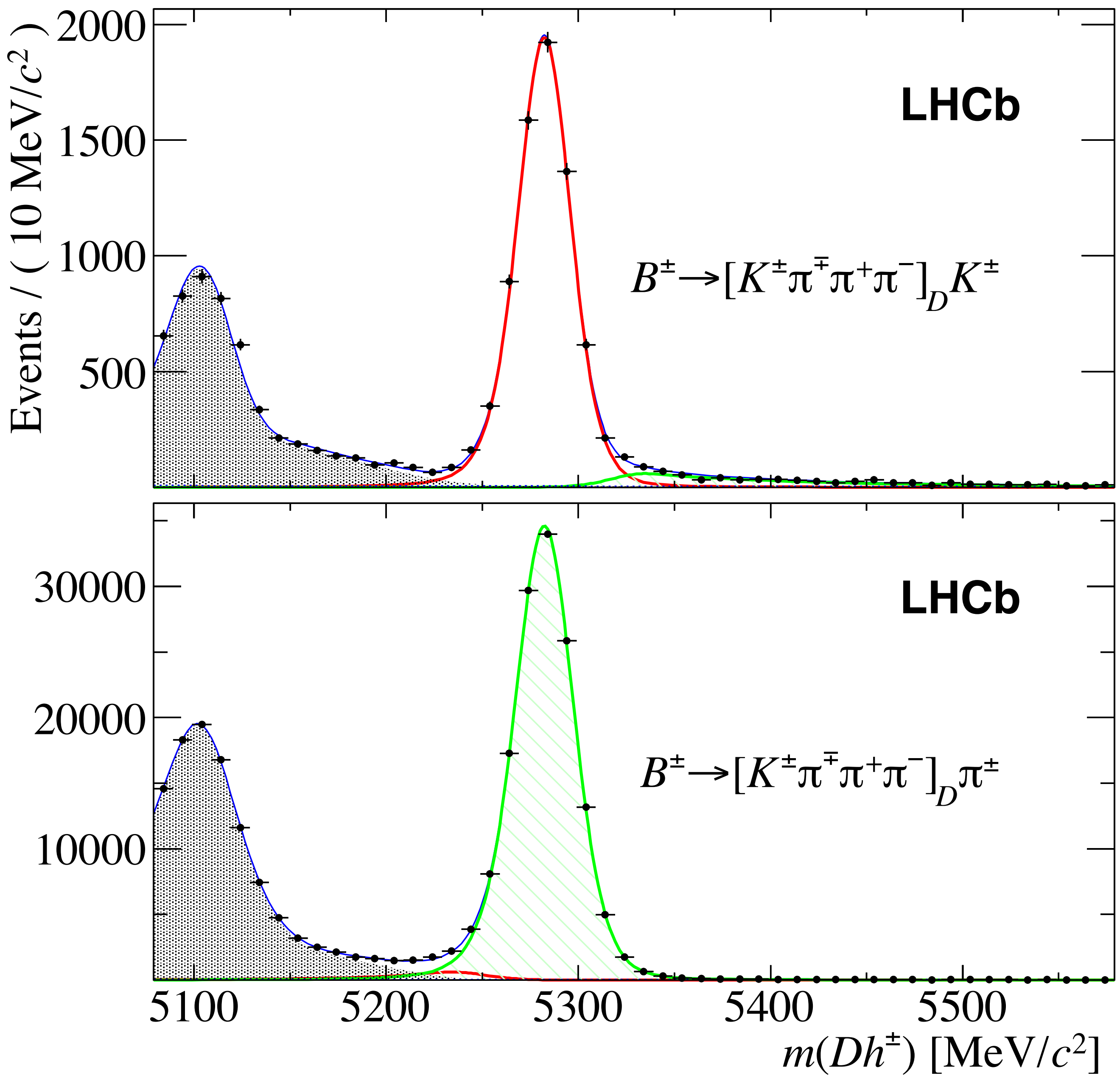
$$\frac{\Gamma(B^- \to [\pi^-K^+\pi\pi]_D K^-) + \Gamma(B^+ \to [\pi^+K^-\pi\pi]_D K^+)}{\Gamma(B^- \to [K^-\pi^+\pi\pi]_D K^-) + \Gamma(B^+ \to [K^+\pi^-\pi\pi]_D K^+)} = R_{ADS(K)}^{\pi K\pi\pi}$$

$$\frac{\Gamma(B^- \to [\pi^-K^+\pi\pi]_D K^-) - \Gamma(B^+ \to [\pi^+K^-\pi\pi]_D K^+)}{\Gamma(B^- \to [\pi^-K^+\pi\pi]_D K^-) + \Gamma(B^+ \to [\pi^+K^-\pi\pi]_D K^+)} = A_{ADS(K)}^{\pi K\pi\pi}$$

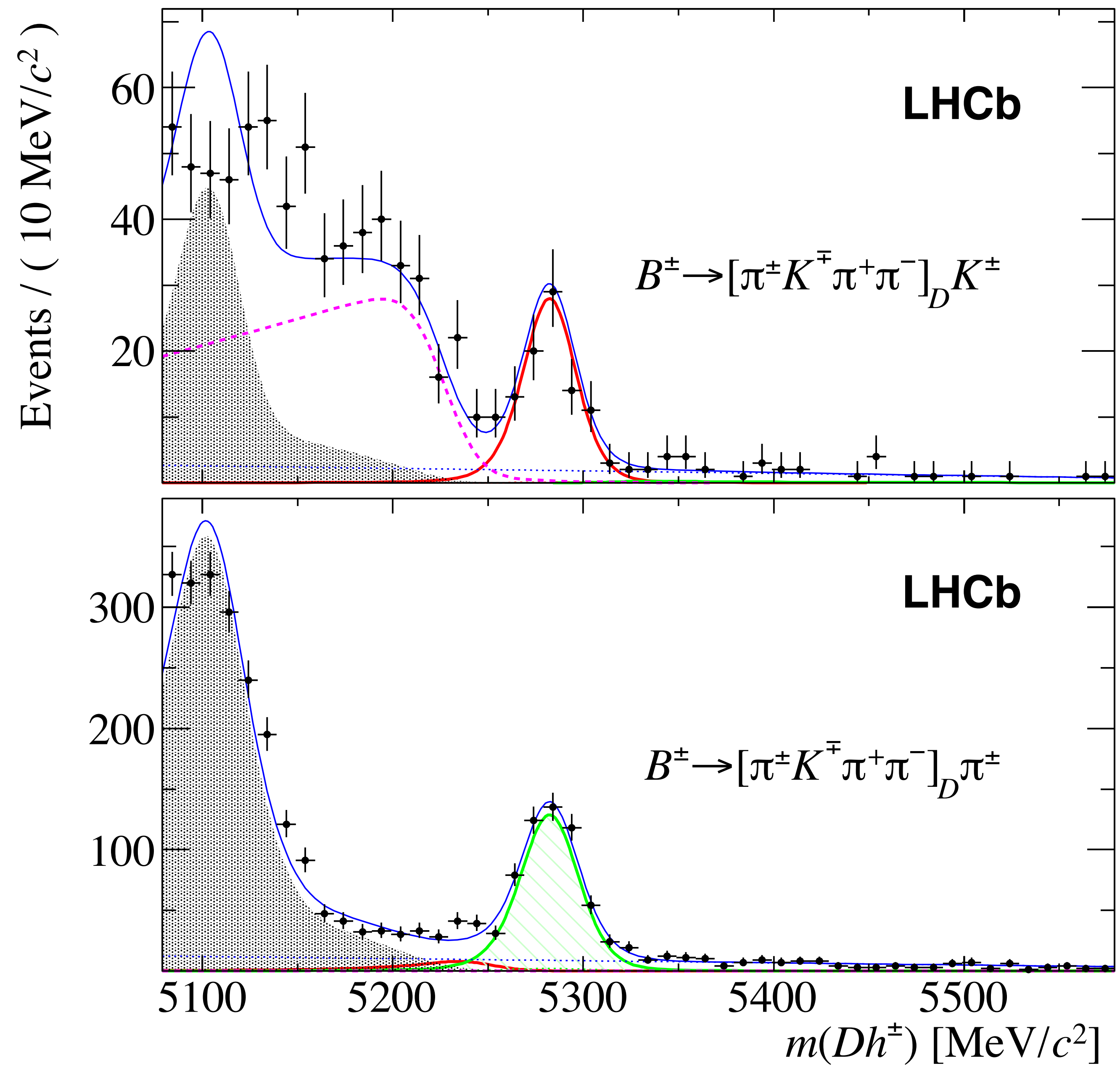
$$\Gamma\left(B^{\pm} \to [f]_D K^{\pm}\right) = r_D^2 + r_B^2 + 2\kappa_D r_D r_B \cos(\delta_B + \delta_D \pm \gamma)$$

qADS: $B^{\pm}\to Dh^{\pm}$, $D\to \pi^{+}K^{-}\pi^{+}\pi^{-}$

11 300 $B^{\pm}\to DK^{\pm}$, $D\to K^{+}\pi^{-}\pi^{+}\pi^{-}$

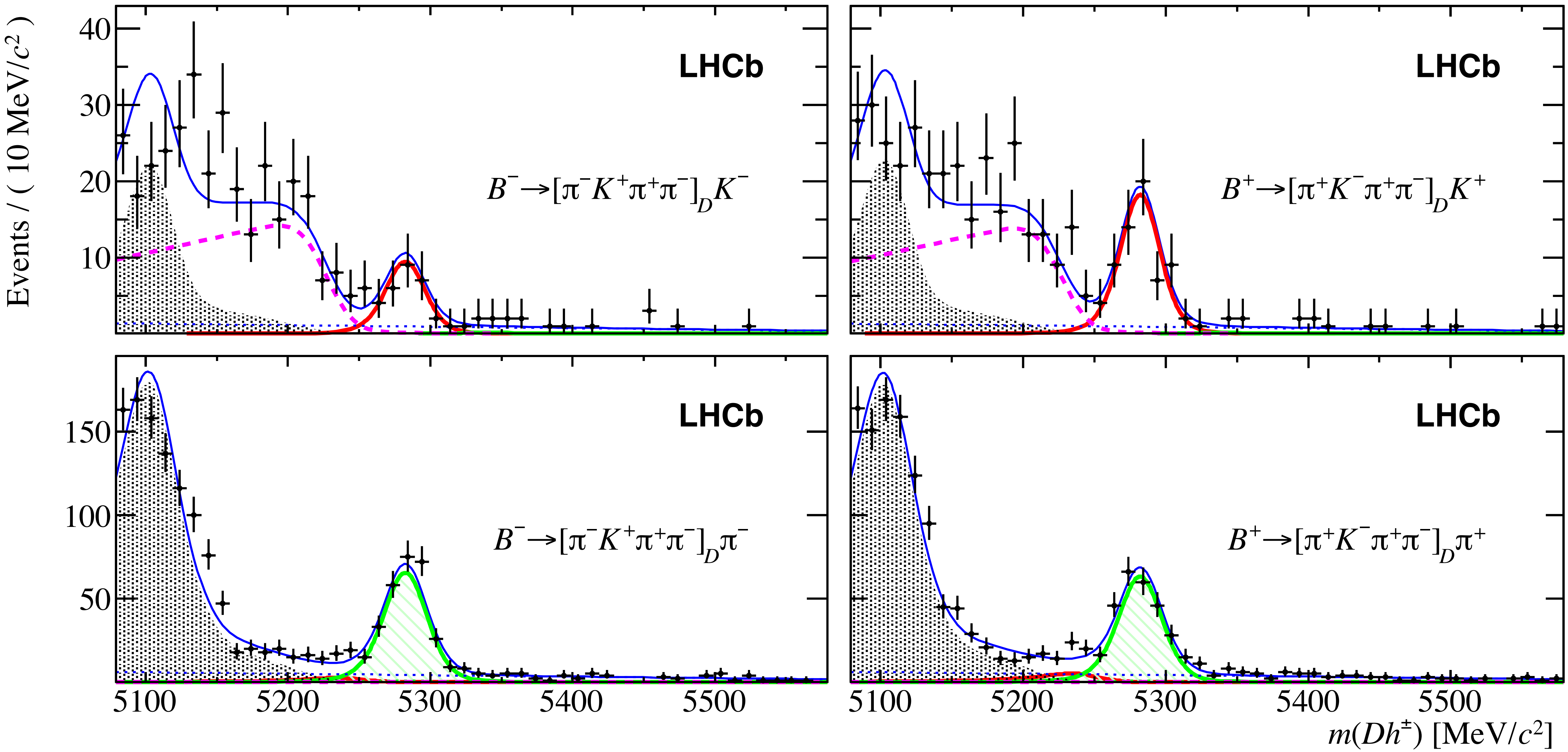


160 $B^{\pm}\to DK^{\pm}$, $D\to \pi^{+}K^{-}\pi^{+}\pi^{-}$



qADS: $B^{\pm}\to Dh^{\pm}$, $D\to \pi^+K^-\pi^+\pi^-$

$$A^{\pi K\pi\pi}_{\mathrm{ADS}(K)} = -0.313 \quad \pm 0.102 \quad \pm 0.038$$

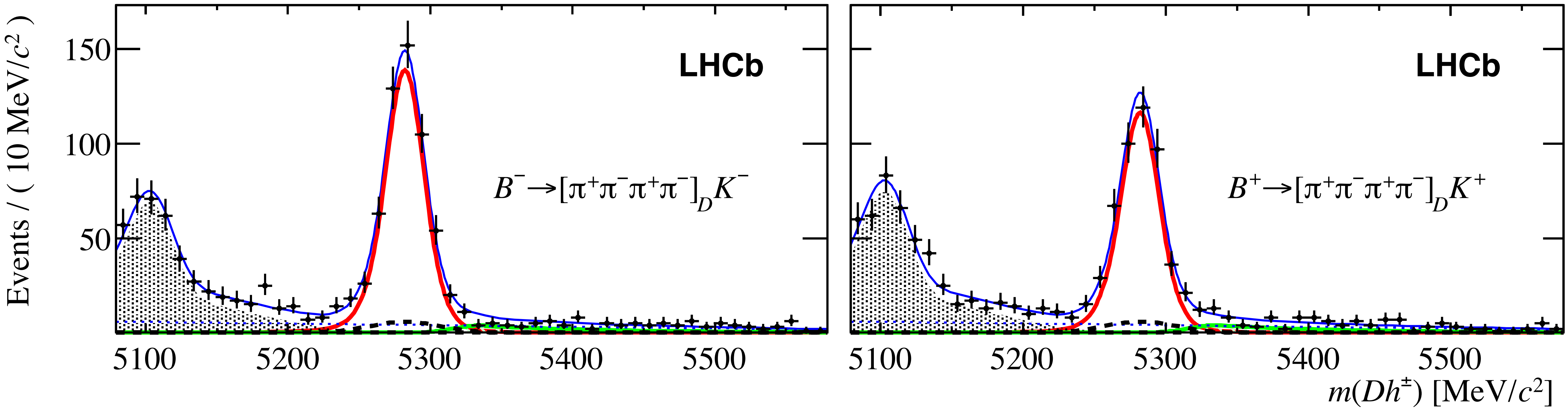


Expect a negative A_{ADS}, like the 2-body ADS mode, given knowledge of δ_D, arXiv:1602.07430

$$A^{\pi K}_{\mathrm{ADS}(K)} = -0.403 \quad \pm 0.056 \quad \pm 0.011$$

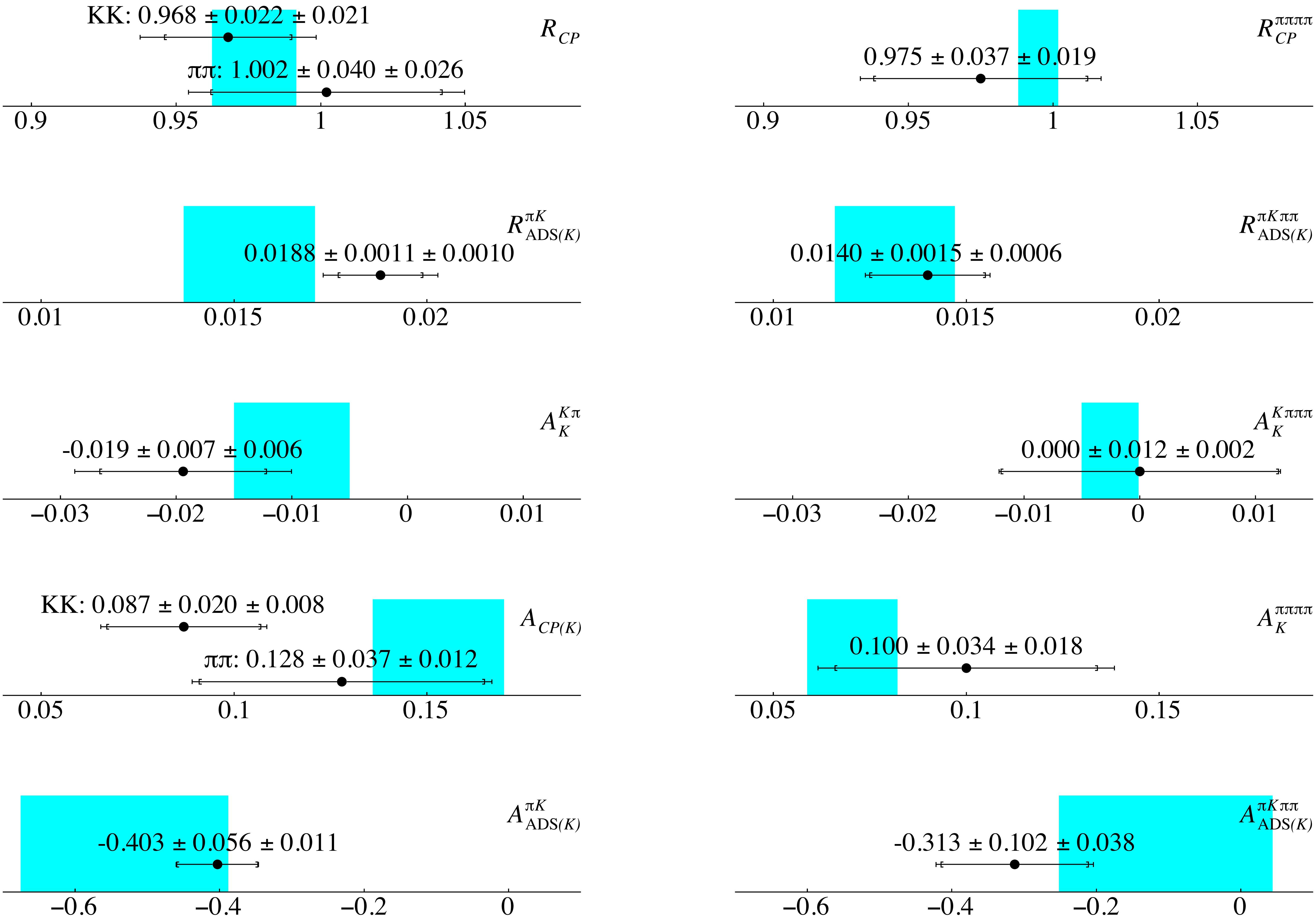
qGLW: $B^{\pm} \to Dh^{\pm}$, $D \to \pi^+\pi^-\pi^+\pi^-$ First analysis of this mode

$$A_K^{\pi\pi\pi\pi} = 0.100 \pm 0.034 \pm 0.018$$

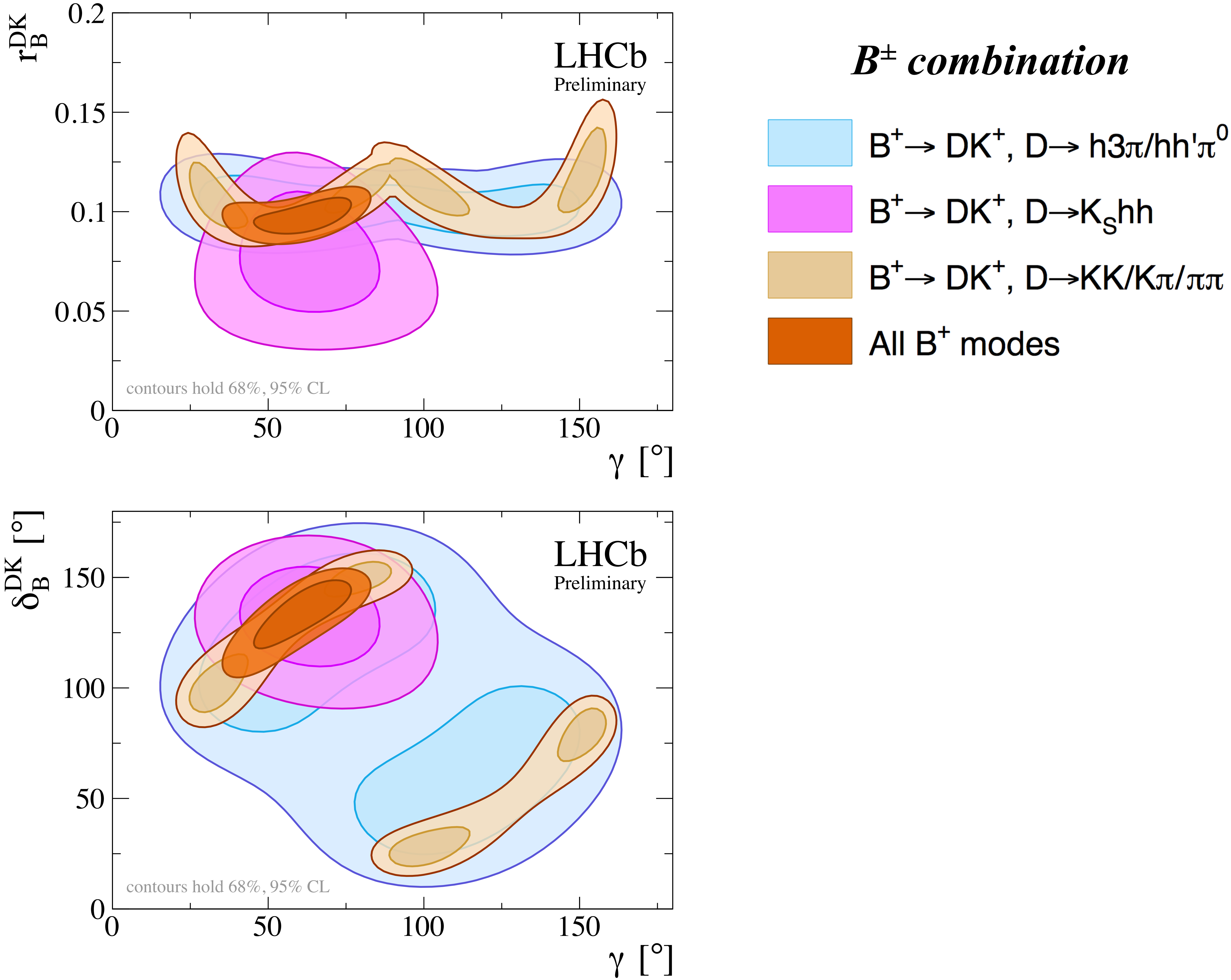


Compared to 2-body GLW modes; interference expected to be diluted by ~0.5 , arXiv:1504.05878

$$A_K^{KK} = 0.087 \pm 0.020 \pm 0.008$$
$$A_K^{\pi\pi} = 0.128 \pm 0.037 \pm 0.012$$



KK: 0.968 ± 0.022 ± 0.021
ππ: 1.002 ± 0.040 ± 0.026
R_{CP}
0.9
0.95
1
1.05
0.975 ± 0.037 ± 0.019
$R_{CP}^{\pi\pi\pi\pi}$
0.9
0.95
1
1.05
0.0188 ± 0.0011 ± 0.0010
$R_{\mathrm{ADS}(K)}^{\pi K}$
0.01
0.015
0.02
0.0140 ± 0.0015 ± 0.0006
$R_{\mathrm{ADS}(K)}^{\pi K\pi\pi}$
0.01
0.015
0.02
-0.019 ± 0.007 ± 0.006
$A_{K}^{K\pi}$
−0.03
−0.02
−0.01
0
0.01
0.000 ± 0.012 ± 0.002
$A_{K}^{K\pi\pi\pi}$
−0.03
−0.02
−0.01
0
0.01
KK: 0.087 ± 0.020 ± 0.008
ππ: 0.128 ± 0.037 ± 0.012
$A_{CP(K)}$
0.05
0.1
0.15
0.100 ± 0.034 ± 0.018
$A_{K}^{\pi\pi\pi\pi}$
0.05
0.1
0.15
-0.403 ± 0.056 ± 0.011
$A_{\mathrm{ADS}(K)}^{\pi K}$
−0.6
−0.4
−0.2
0
-0.313 ± 0.102 ± 0.038
$A_{\mathrm{ADS}(K)}^{\pi K\pi\pi}$
−0.6
−0.4
−0.2
0



B± combination
B+→ DK+, D→ h3π/hh'π0
B+→ DK+, D→KShh
B+→ DK+, D→KK/Kπ/ππ
All B+ modes
LHCb
Preliminary
contours hold 68%, 95% CL
rBDK
0.2
0.15
0.1
0.05
0
0
50
100
150
γ [°]
LHCb
Preliminary
contours hold 68%, 95% CL
δBDK [°]
150
100
50
0
0
50
100
150
γ [°]

$B^0 \to DK^{*0}$, $K_S^0 h^+ h^-$

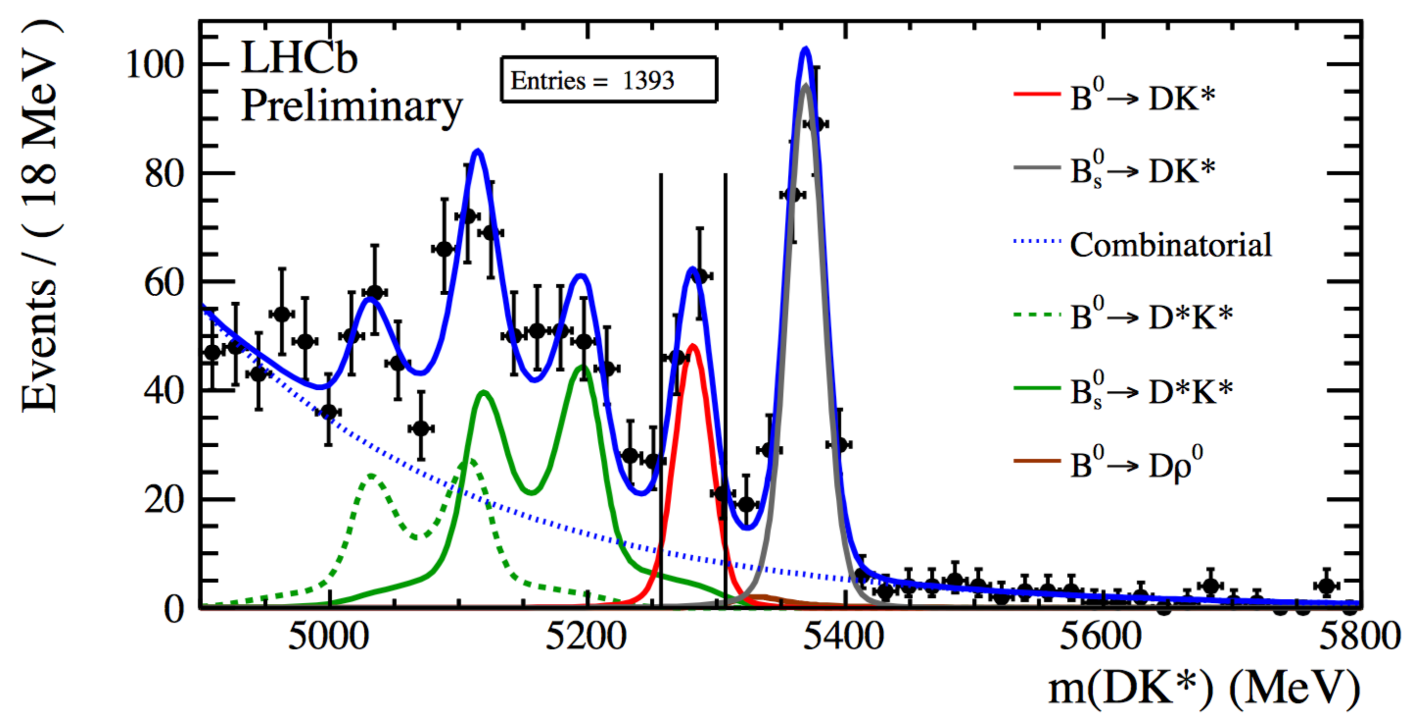
- Two methods attempted using the 3.0fb^{-1} data
  - Model-dependent (uses an amplitude model to fit the Dalitz distribution)
  - Model-independent (counts events in bin across the Dalitz plane)

- Both analyses extract a set of four “cartesian” observables

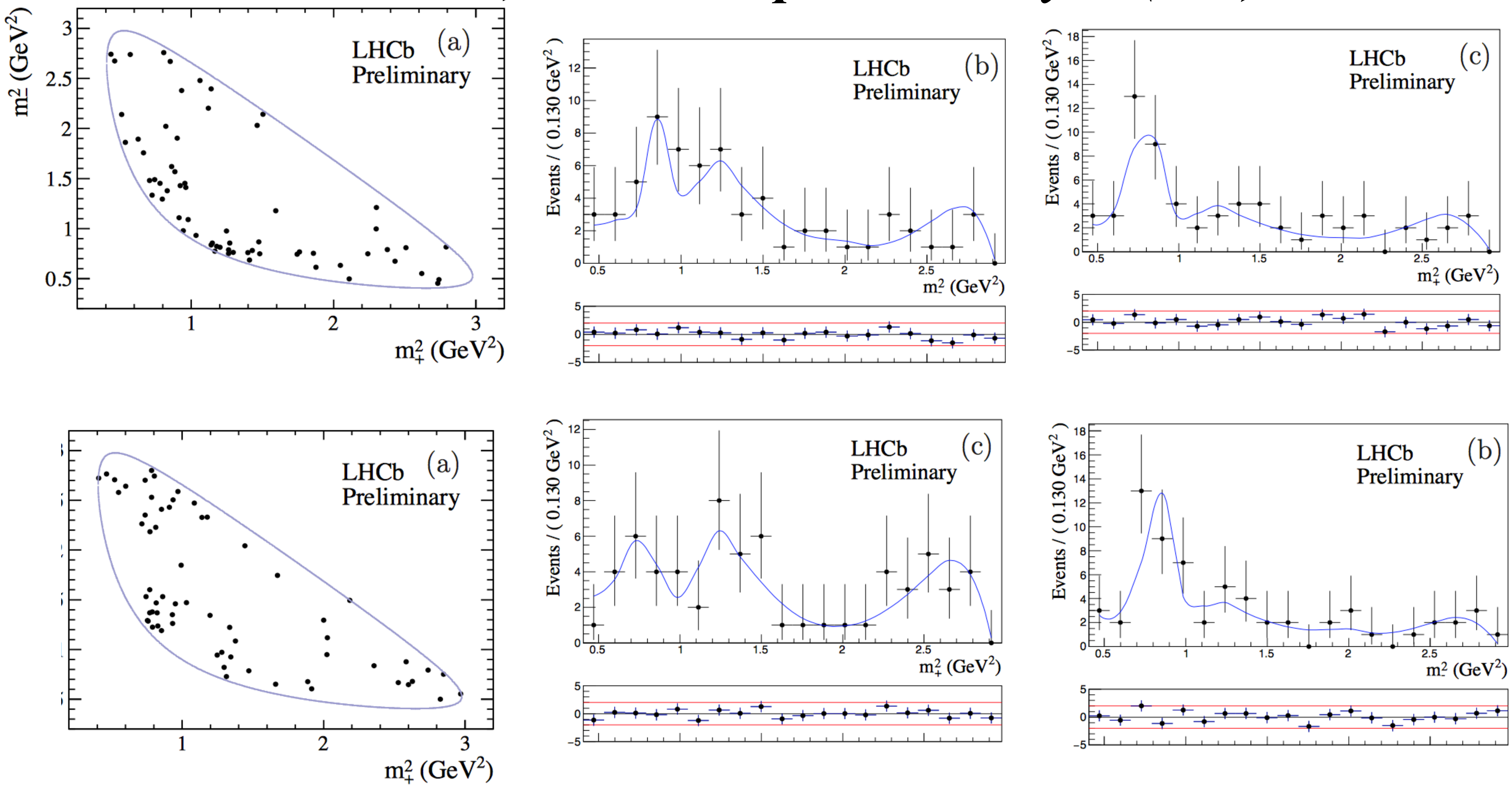
$$x_\pm = r_B \cos(\delta_B \pm \gamma)\,,$$
$$y_\pm = r_B \sin(\delta_B \pm \gamma)$$

or $z_\pm = r_{B^0}\, e^{i(\delta_{B^0} \pm \gamma)}$

- Model-dependent analysis (MD) starts by extracting the signal (red) from an invariant mass fit, then fitting an amplitude model to the Dalitz distribution



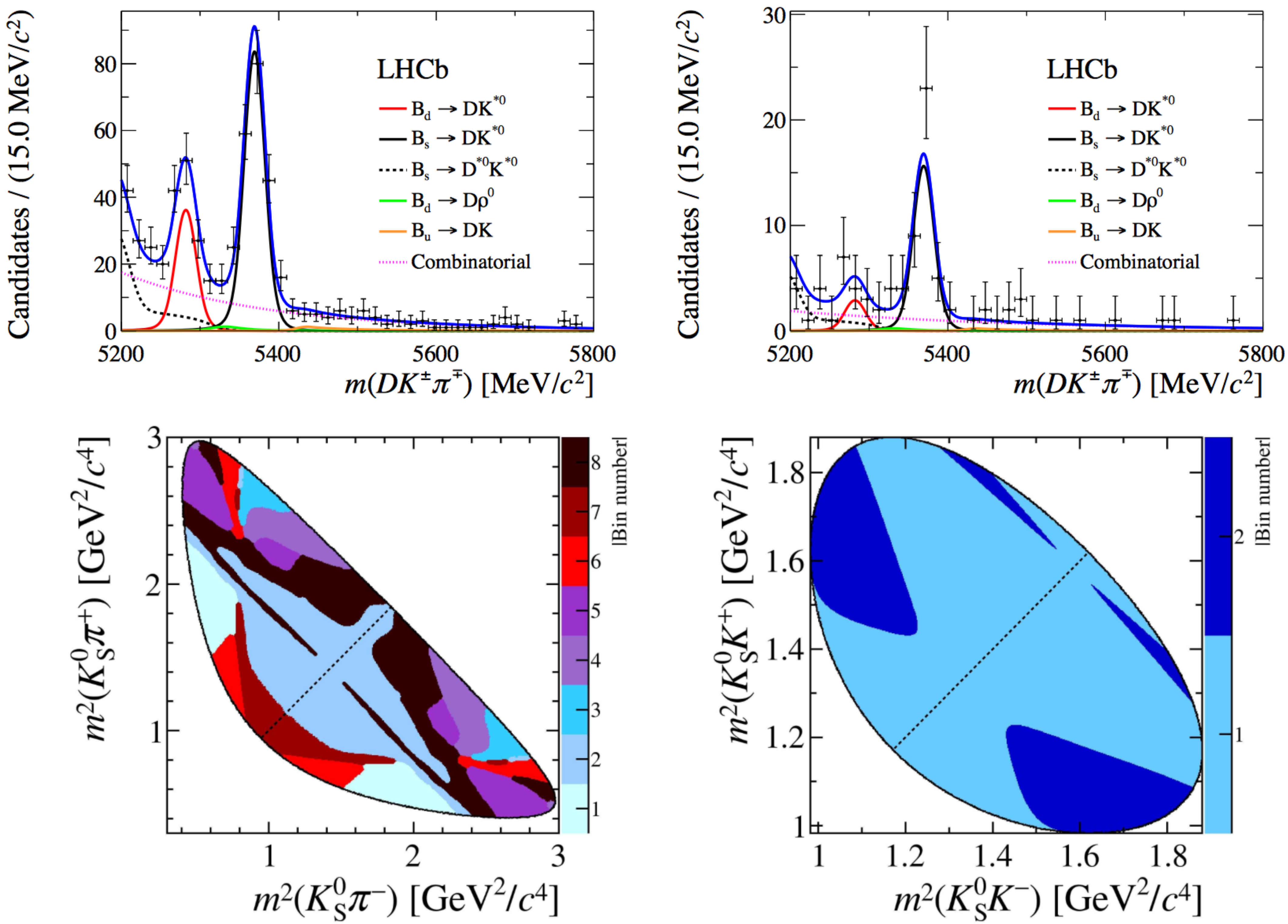
$B^0 \to DK^{*0}$, $K_S^0\pi^+\pi^-$ amplitude analysis (MD)



$$\mathcal{P}_{\bar{B}^0}(m_-^2, m_+^2) \propto \mathcal{P}(A_f, z_-, \kappa)$$
$$\mathcal{P}_{B^0}(m_-^2, m_+^2) \propto \mathcal{P}(\bar{A}_f, z_+, \kappa)$$

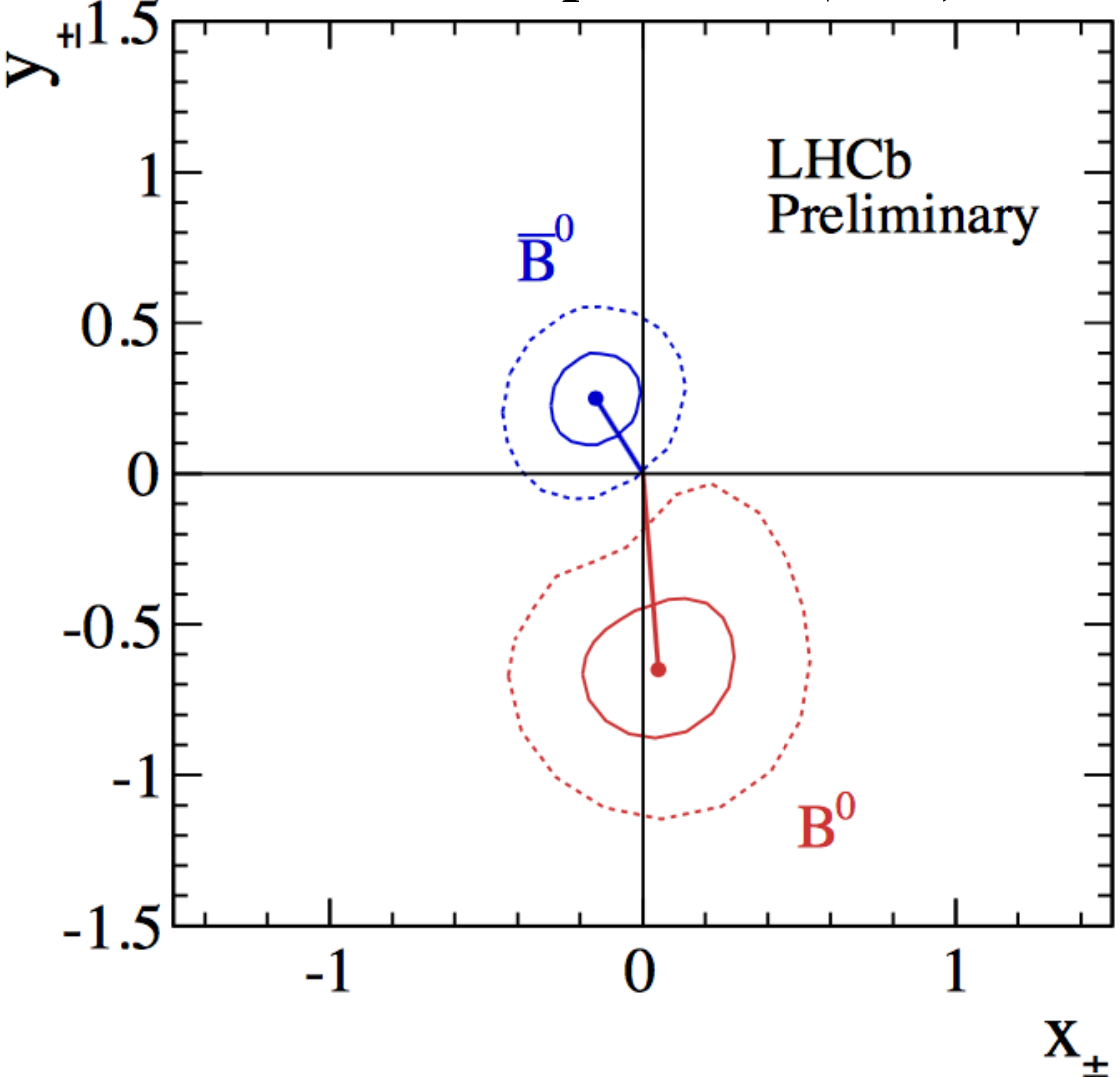
$$\mathcal{P}(A, z, \kappa) = \left|A\right|^2 + \left|z\right|^2 \left|\bar{A}\right|^2 + 2\kappa \mathcal{R}e\left[zA^\star \bar{A}\right],\ \ z_\pm = r_{B^0}\, e^{i(\delta_{B^0} \pm \gamma)}$$

$B^0 \to DK^{*0}$, $K_S{}^0\pi^+\pi^-$ and $K_S{}^0K^+K^-$ mass fits (MI)



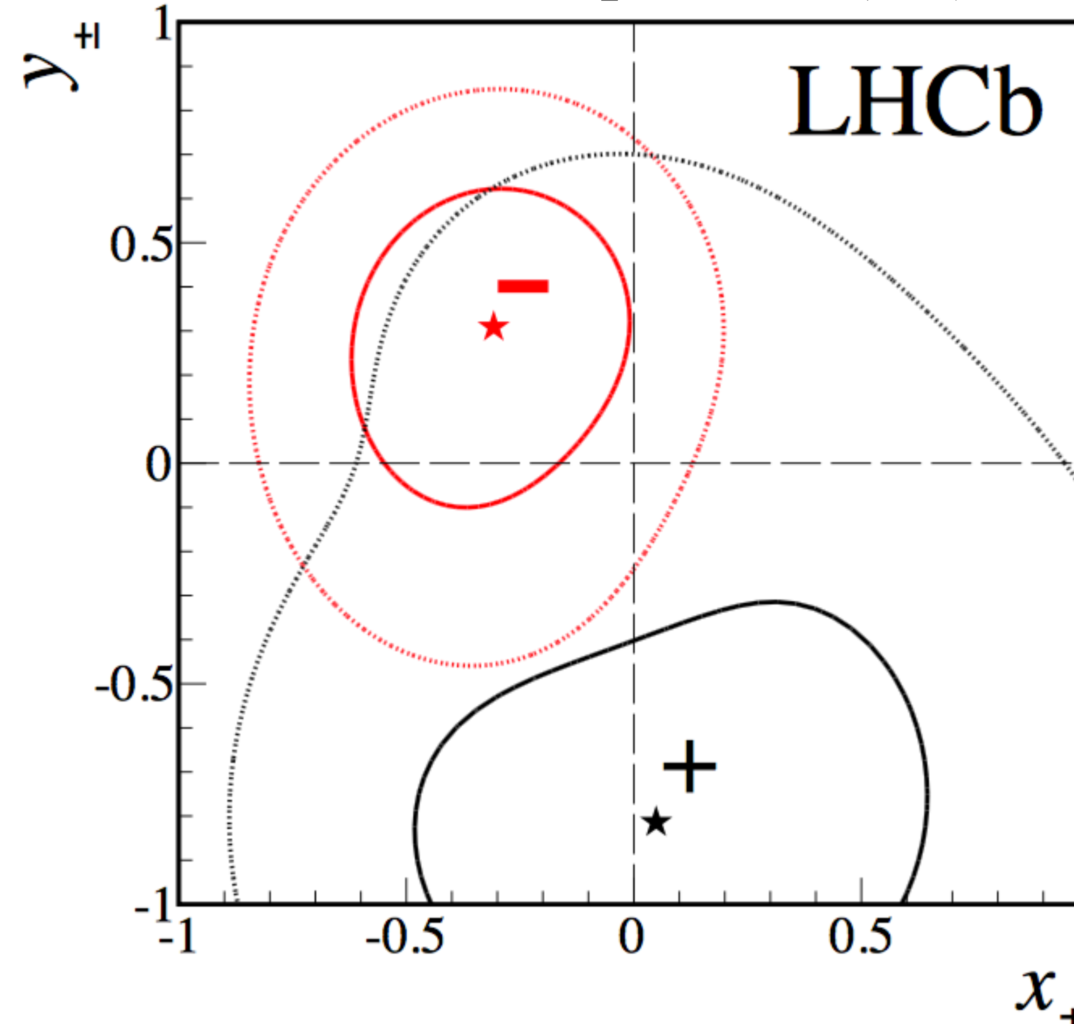
Cartesian coordinates result, note: different scale

model-dependent (MD)



$$x_+ = 0.05 \pm 0.24 \pm 0.04 \pm 0.01,$$
$$x_- = -0.15 \pm 0.14 \pm 0.03 \pm 0.01,$$
$$y_+ = -0.65\,^{+0.24}_{-0.23} \pm 0.08 \pm 0.01,$$
$$y_- = 0.25 \pm 0.15 \pm 0.06 \pm 0.01,$$

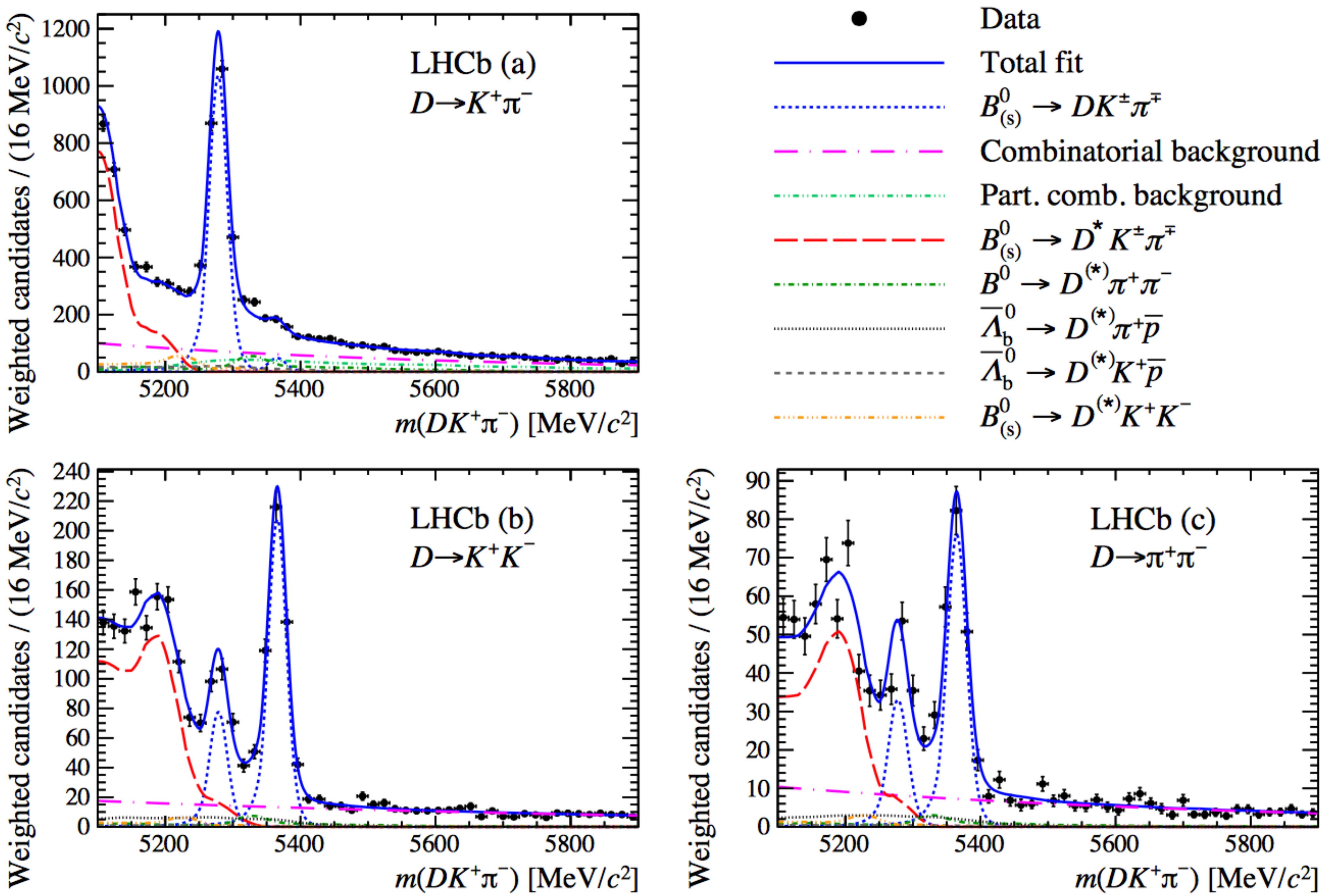
model-independent (MI)

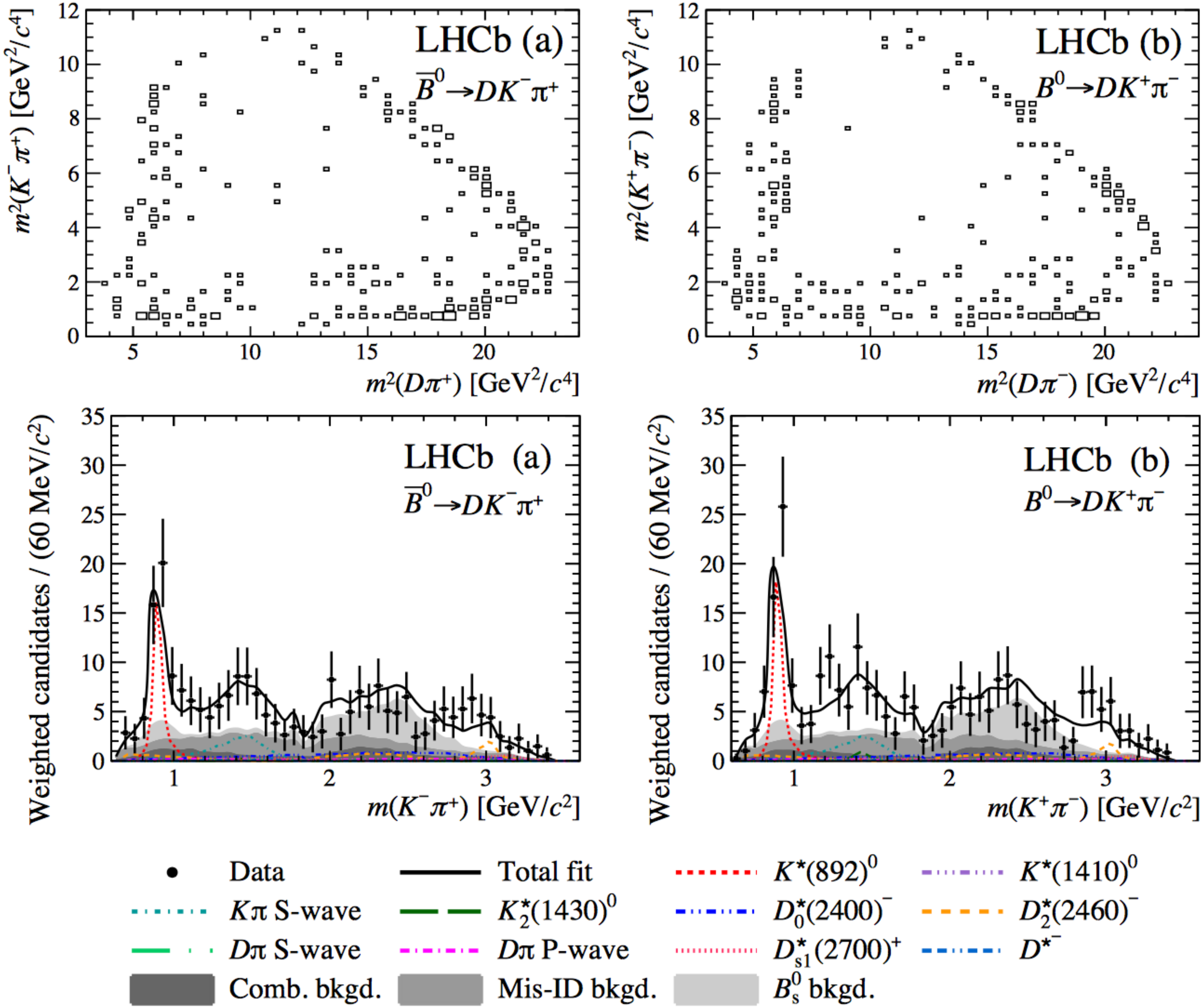


$$x_+ = 0.05 \pm 0.35 \pm 0.02,$$
$$x_- = -0.31 \pm 0.20 \pm 0.04,$$
$$y_+ = -0.81 \pm 0.28 \pm 0.06,$$
$$y_- = 0.31 \pm 0.21 \pm 0.05,$$

$B^0 \to D_{CP} K^+ \pi^-$, $D_{CP} \to K^+ K^-$ and $D_{CP} \to \pi^+ \pi^-$

First use of a B^0 amplitude analysis to target γ

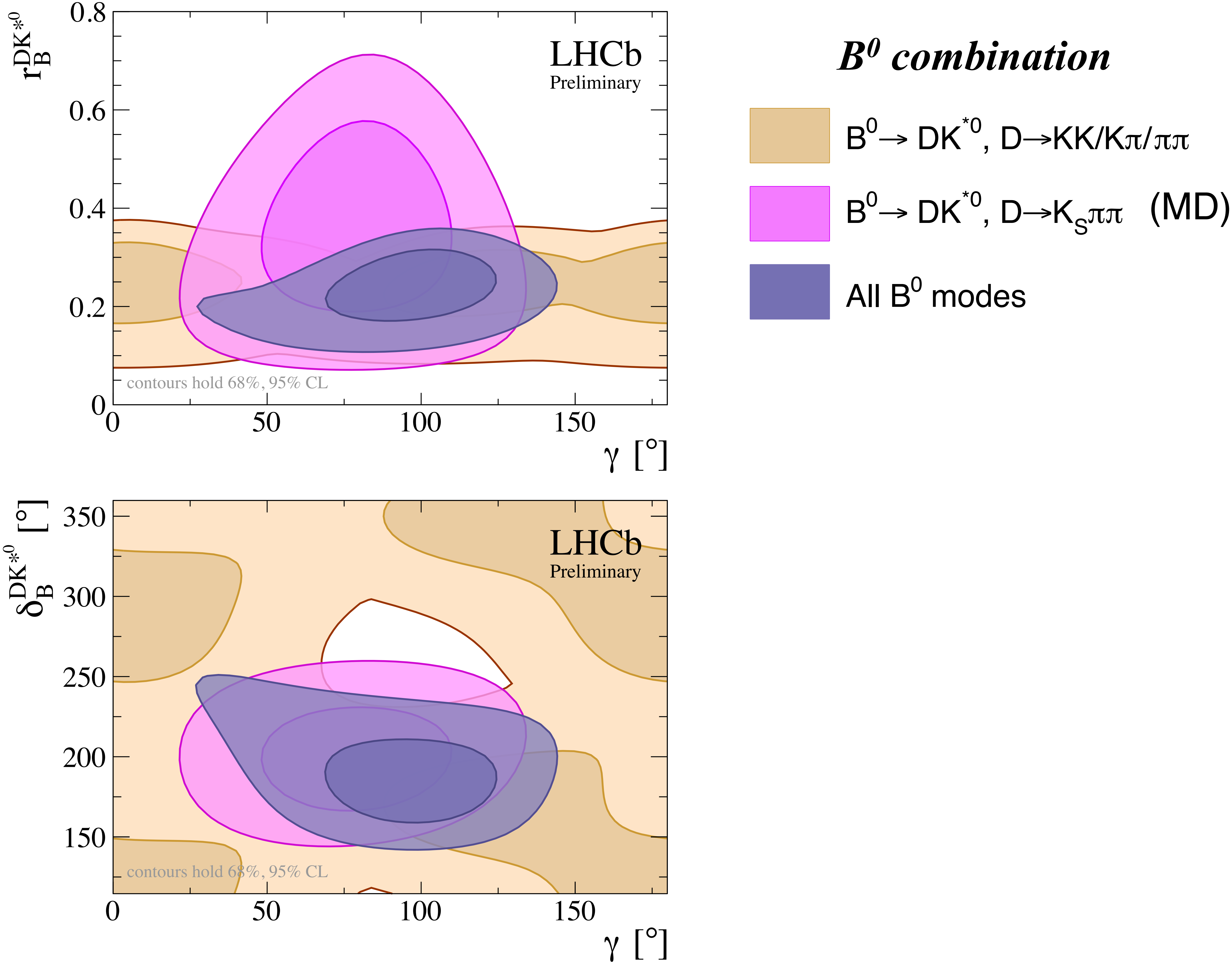


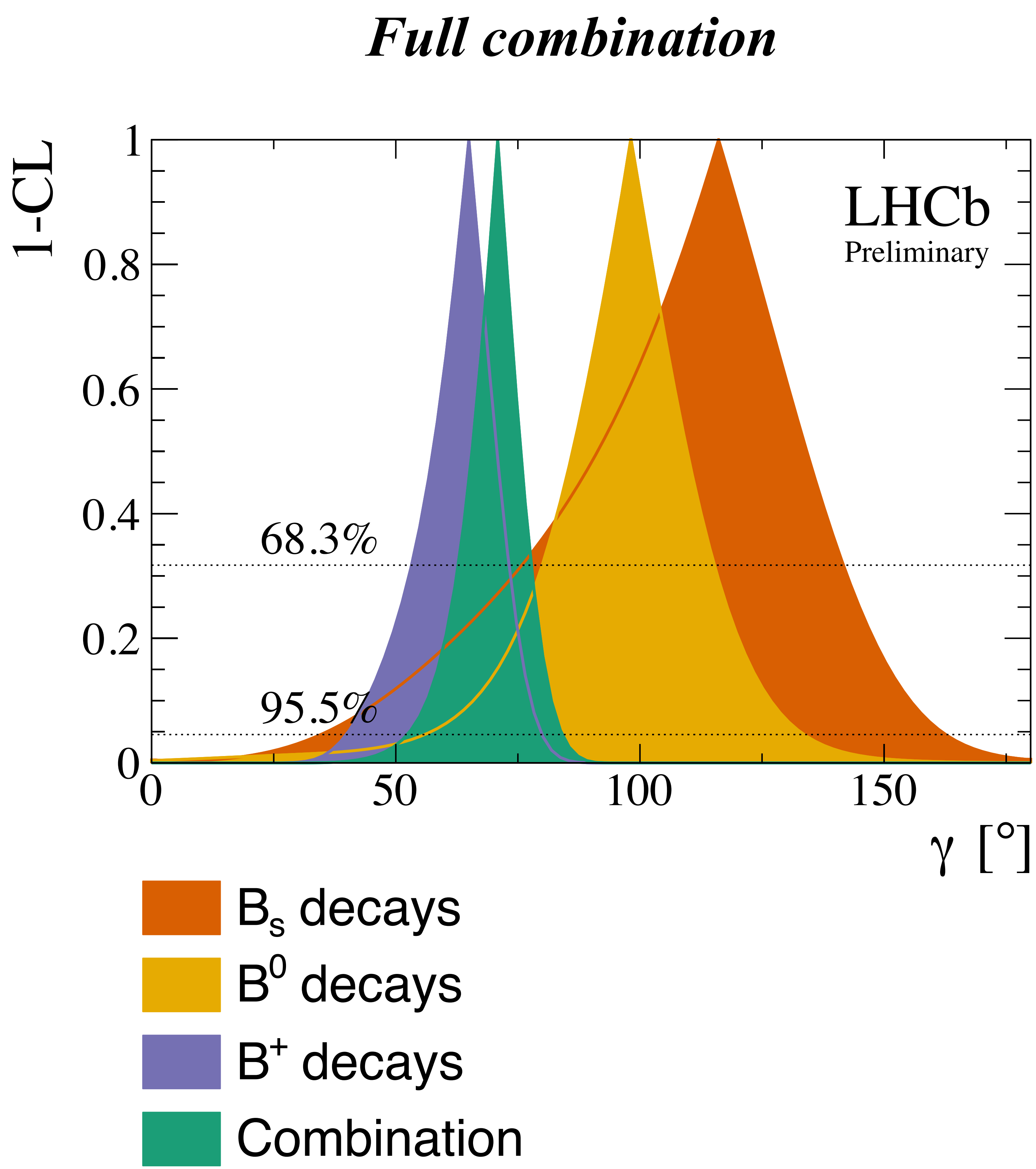


For the K^{*0} region:

$$x_+ = 0.04 \pm 0.16 \pm 0.11\,, \qquad y_+ = -0.47 \pm 0.28 \pm 0.22\,,$$
$$x_- = -0.02 \pm 0.13 \pm 0.14\,, \qquad y_- = -0.35 \pm 0.26 \pm 0.41\,,$$

B^0 combination





Quantity	Value
γ (°)	70.9
68% CL (°)	[62.4, 78.0]
95% CL (°)	[51.0, 85.0]
r_B^{DK}	0.1006
68% CL	[0.0946, 0.1065]
95% CL	[0.0890, 0.1120]
δ_B^{DK} (°)	141.1
68% CL (°)	[133.4, 147.2]
95% CL (°)	[122.0, 153.0]
$r_B^{DK^{*0}}$	0.217
68% CL	[0.169, 0.261]
95% CL	[0.115, 0.303]
$\delta_B^{DK^{*0}}$ (°)	189.0
68% CL (°)	[169.0, 213.0]
95% CL (°)	[149.0, 243.0]

Conclusion

- A world-leading measurement of γ is made from a combination of LHCb analysis, concluding with

$$\gamma = 70.9^{+7.1}_{-8.5}$$

which improved the previous LHCb-only conclusion by 2°

- Inline with B-factory conclusions from $B \to DK$,
  - BaBar: $\gamma = (70 \pm 18)^\circ$
  - Belle: $\gamma = (73^{+13}_{-15})^\circ$

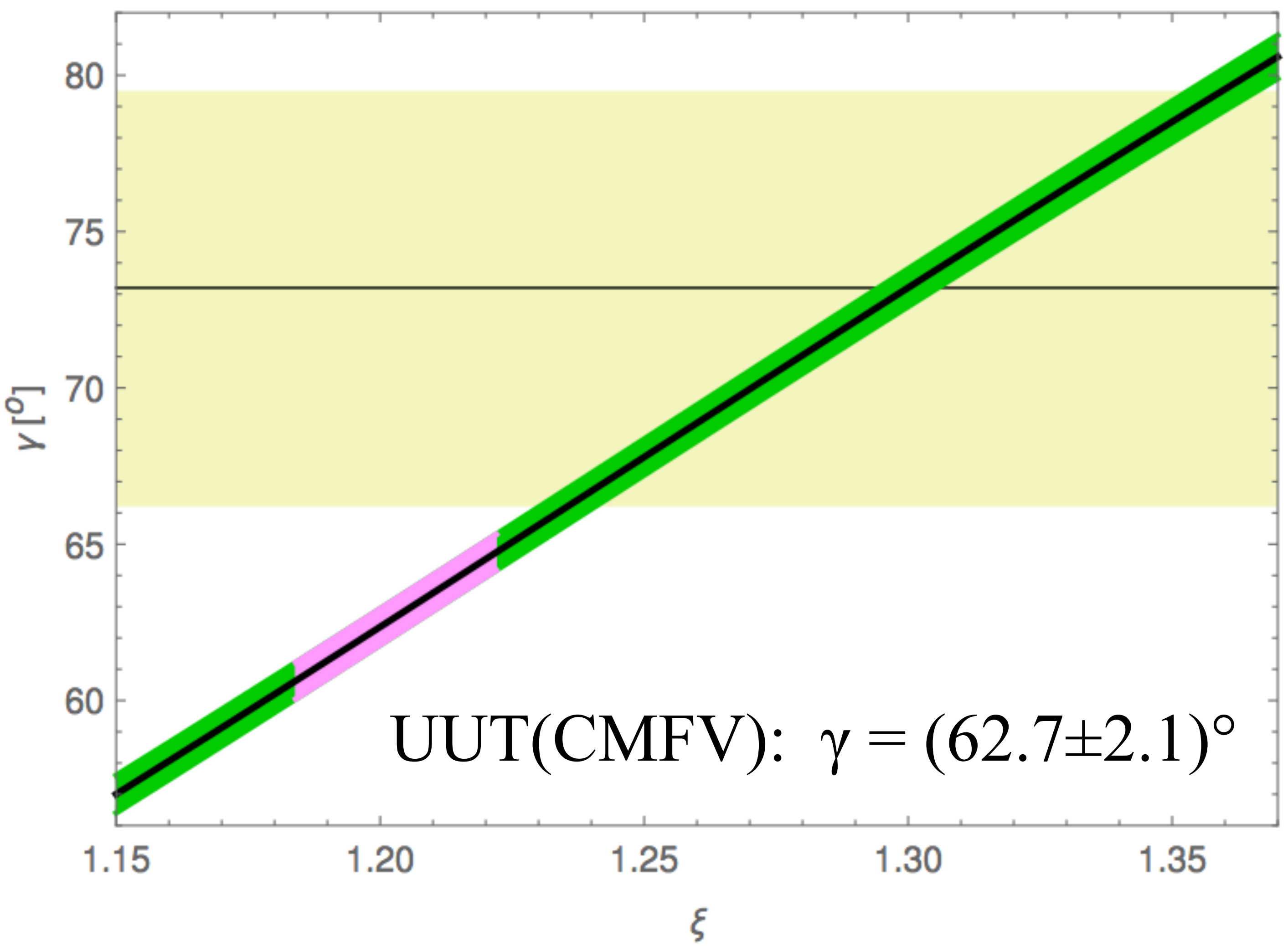
- But ~1σ above expectation (with Constrained Minimal Flavour Violation) for sin 2β=0.691±0.017 and new lattice determinations of hadronic matrix elements in B mixing (Fermilab-MILC `arXiv:1602.03560`)
  - UUT(CMFV): $\gamma = (62.7 \pm 2.1)^\circ$ (Blanke/Buras `arXiv:1602.0402`)

- Large collaborative effort in this area:
  - update to $B_s \to D_s K$ expected soon
  - new (for LHCb) $B \to D^{(*)} X^{(*)}$ modes are in development
  - on-going investigating of $B^\pm \to D\pi^\pm$ for γ

BACKUP

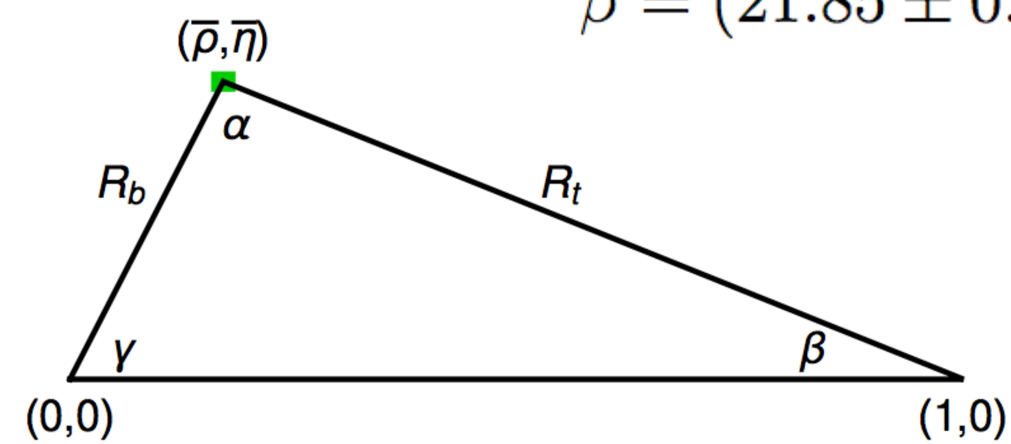
Universal Unitarity Triangle 2016 and the Tension Between $\Delta M_{s,d}$ and ε_K in CMFV Models

(Blanke/Buras `arXiv:1602.0402`)



$$\cot\gamma = \frac{1 - R_t\cos\beta}{R_t\sin\beta}$$

$$\beta = (21.85 \pm 0.67)^\circ$$

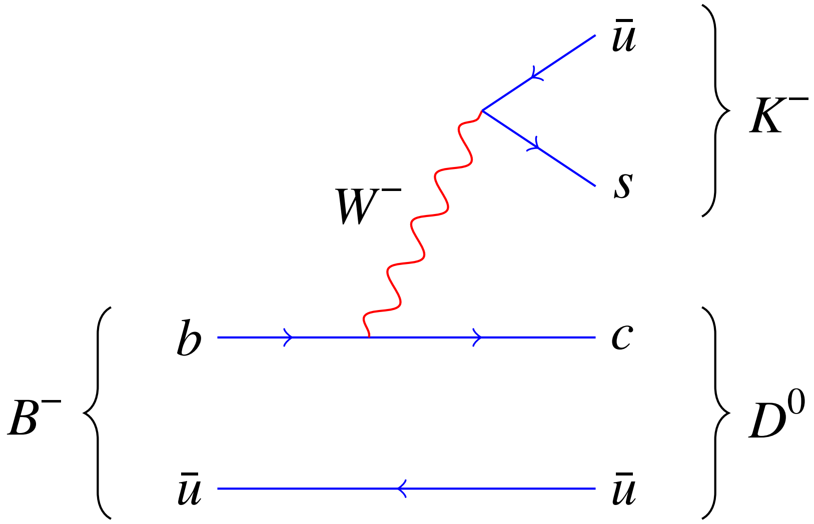


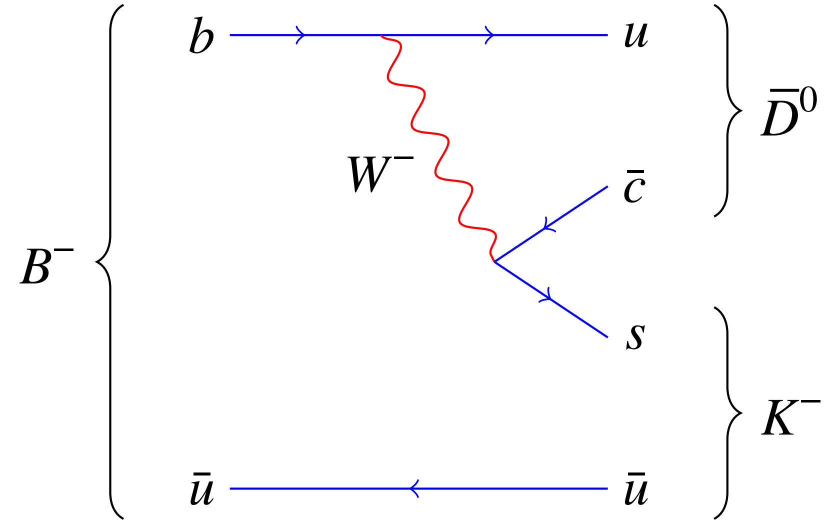
$$R_t = 0.741\,\xi = 0.893 \pm 0.013$$

$$\xi = \frac{F_{B_s}\sqrt{\hat{B}_{B_s}}}{F_{B_d}\sqrt{\hat{B}_{B_d}}} = 1.203 \pm 0.019$$

(Fermilab-MILC `arXiv:1602.03560`)

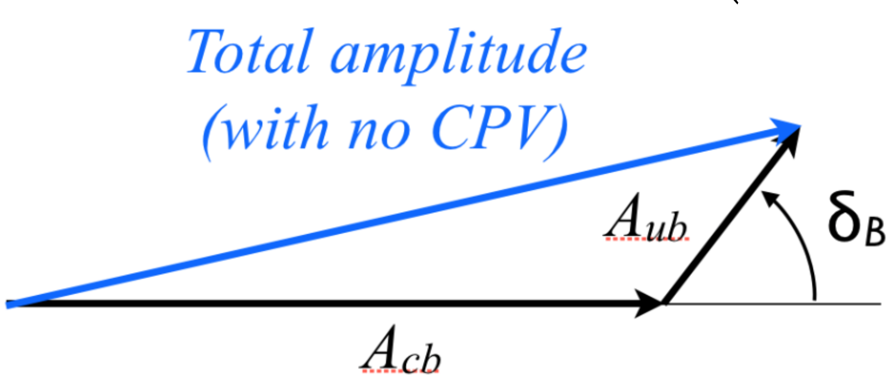
GLW $D \to K^+K^-$
$\pi^+\pi^-$.

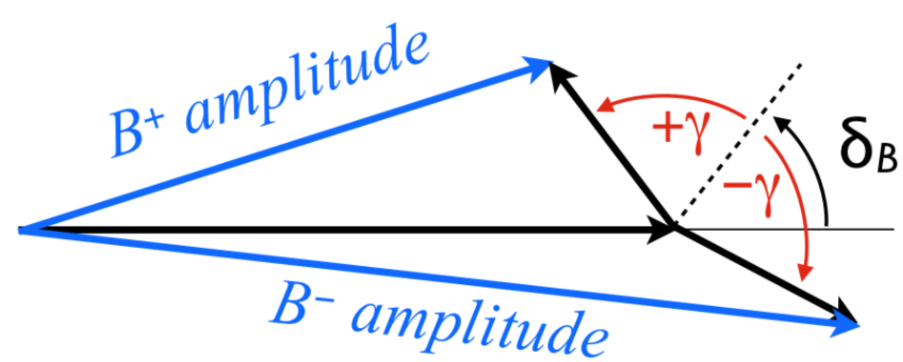




The ancillary "hadronic parameters" are the amplitude magnitude ratio and the CP-conserving part of the phase,

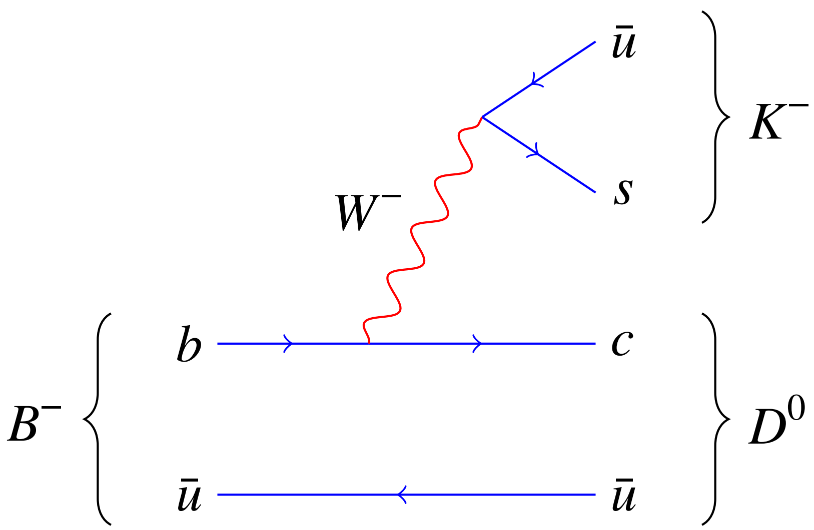
$$\frac{A\left(B^- \to \bar{D}^0 K^-\right)}{A\left(B^- \to D^0 K^-\right)} = r_B \, e^{i(\delta_B - \gamma)}$$

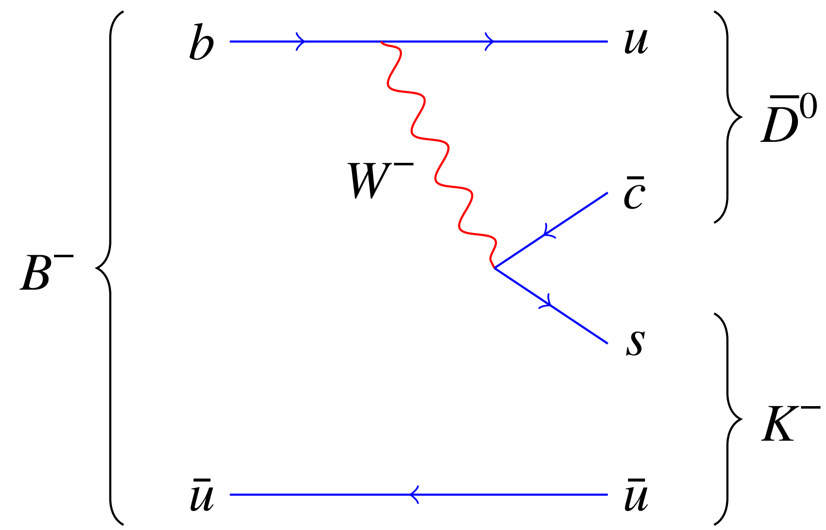




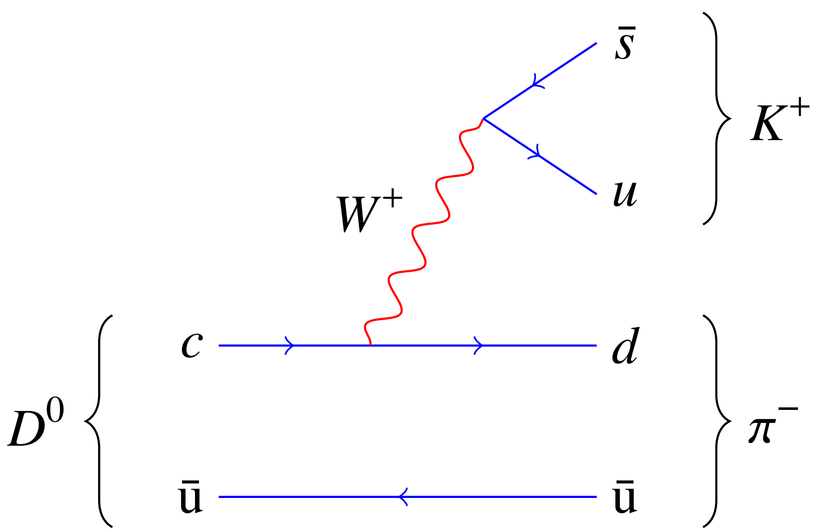
GLW analysis uses *CP* eigenstate *D* decays, equally accessible to the D^0 and $\bar{D}^0$

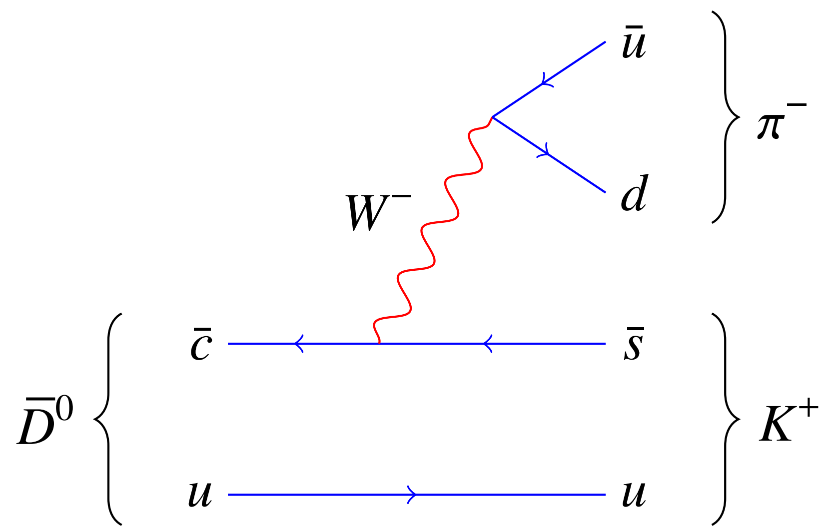
$$\Gamma\left(B^\pm \to [f]_D K^\pm\right) = \quad 1 \; + r_B^2 + \qquad 2 r_B \cos(\delta_B \qquad \pm \gamma)$$

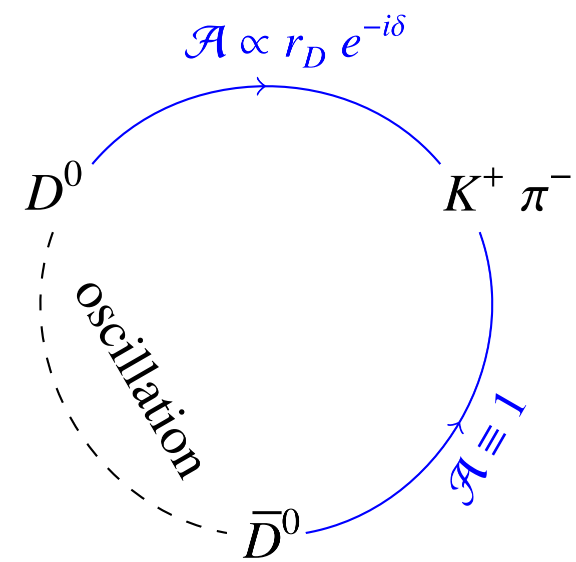




ADS $D \longrightarrow \pi^- K^+$.

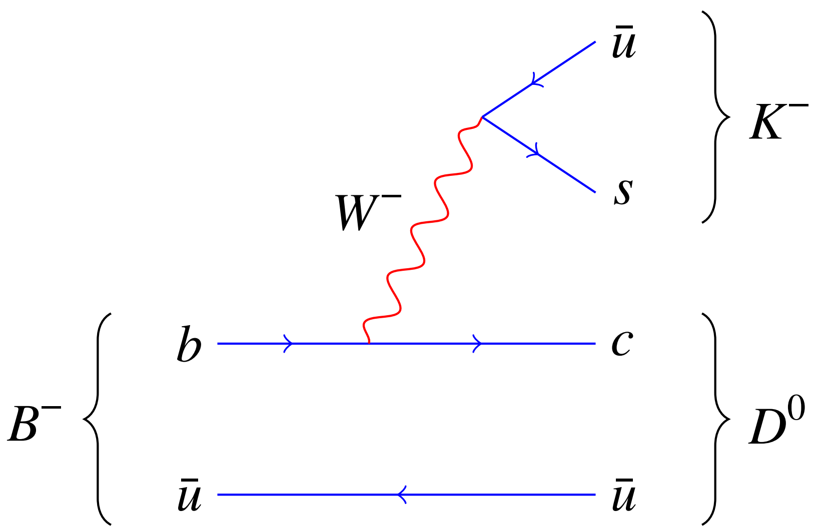


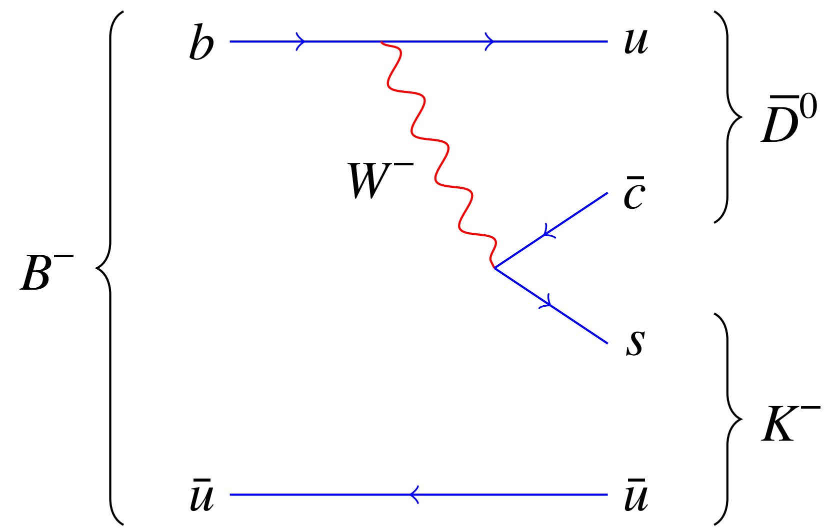




The rates equations can be generalised to non-*CP* eigenstate *D* decays. So-called ADS modes may have large asymmetry due to the interplay of suppressed and favoured B and D decays.

$$\Gamma\left(B^{\pm} \to [f]_D K^{\pm}\right) = r_D^2 + r_B^2 + 2 \quad r_D r_B \cos(\delta_B + \delta_D \pm \gamma)$$





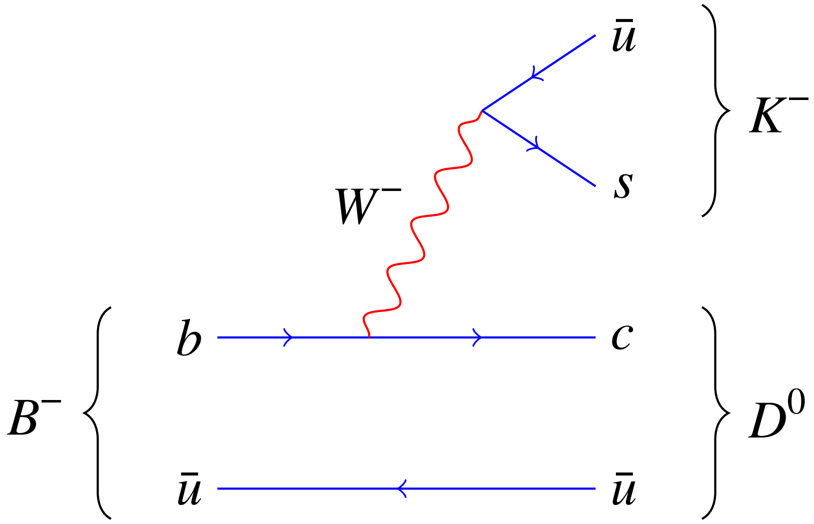
qGLW $D \to \pi^+\pi^-\pi^+\pi^-$
$K^+K^-\pi^0$
$\pi^+\pi^-\pi^0$

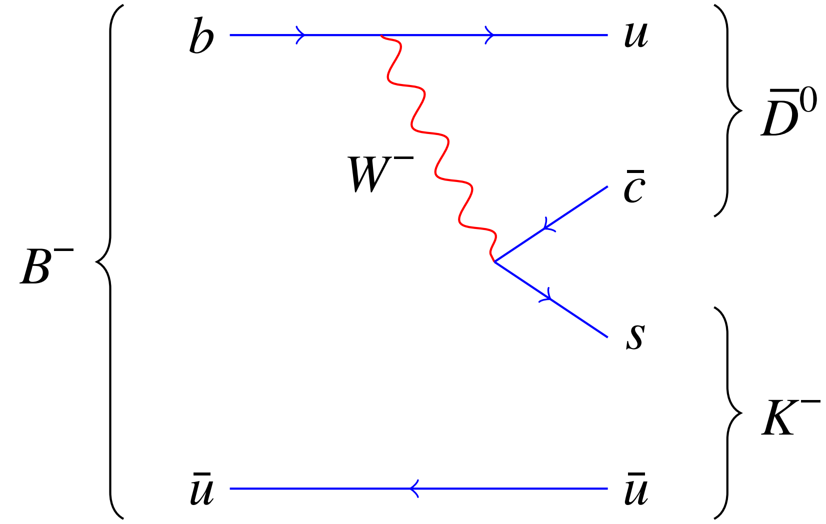
qADS $D \to \pi^-K^+\pi^+\pi^-$
$\pi^-K^+\pi^0$
$D \to K_S K^-\pi^+$
$K_S \pi^- K^+$

"quasi" ADS/GLW analysis are applicable for 3- or 4-body D decays and are effective if external measurements of the D-decay parameters are available

- for qADS analyses, $\kappa_D^f \, e^{i\delta_D^f} = \dfrac{\int A_f(\mathbf{x}) A_{\bar{f}}(\mathbf{x}) d\mathbf{x}}{A_f A_{\bar{f}}}$
- for qGLW analyses, $\kappa_D = (2F_+ - 1)$ where, $F_+^f \equiv \dfrac{\int_{\mathbf{x}\in\mathcal{D}} |\langle f(\mathbf{x})|D_{CP+}\rangle|^2 \, \mathrm{d}\mathbf{x}}{\int_{\mathbf{x}\in\mathcal{D}} |\langle f(\mathbf{x})|D_{CP+}\rangle|^2 + |\langle f(\mathbf{x})|D_{CP-}\rangle|^2 \, \mathrm{d}\mathbf{x}}$
- for classic ADS and GLW analyses, $\kappa_D = 1$

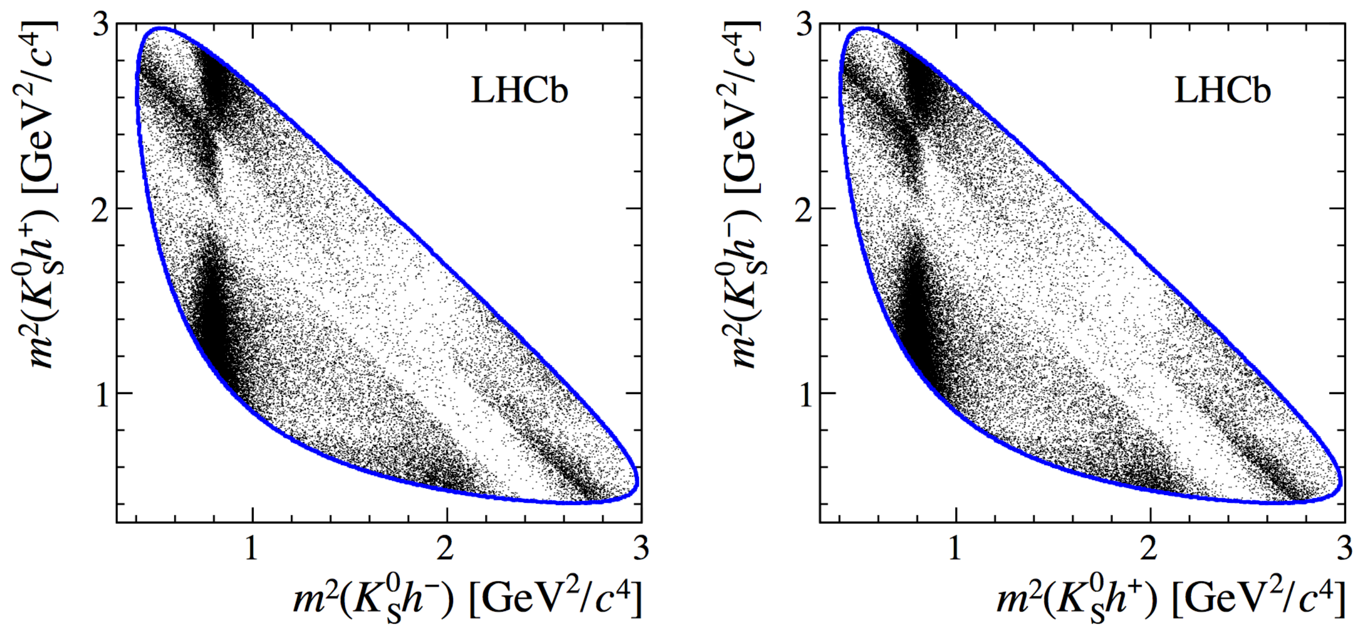
$$\Gamma\left(B^\pm \to [f]_D K^\pm\right) = r_D^2 + r_B^2 + 2\kappa_D r_D r_B \cos(\delta_B + \delta_D \pm \gamma)$$





GGSZ $D \to K_S \pi^+ \pi^-$,
$K_S K^+ K^-$

GGSZ analysis uses multi-body self-conjugate final states and looks for asymmetries in the D-decay Dalitz plot from b-quark decays vs. that from $\overline{b}$-quark decays

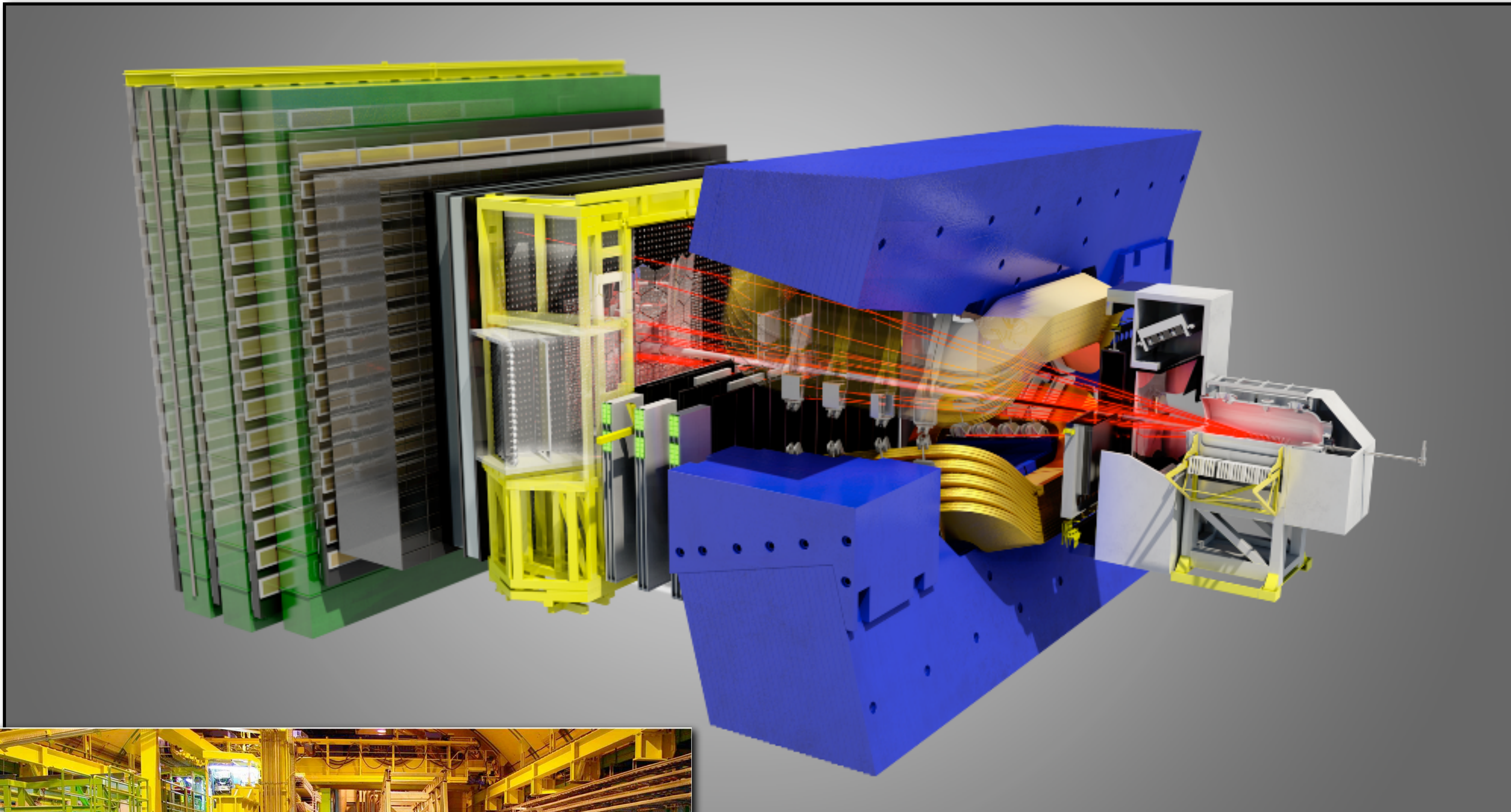


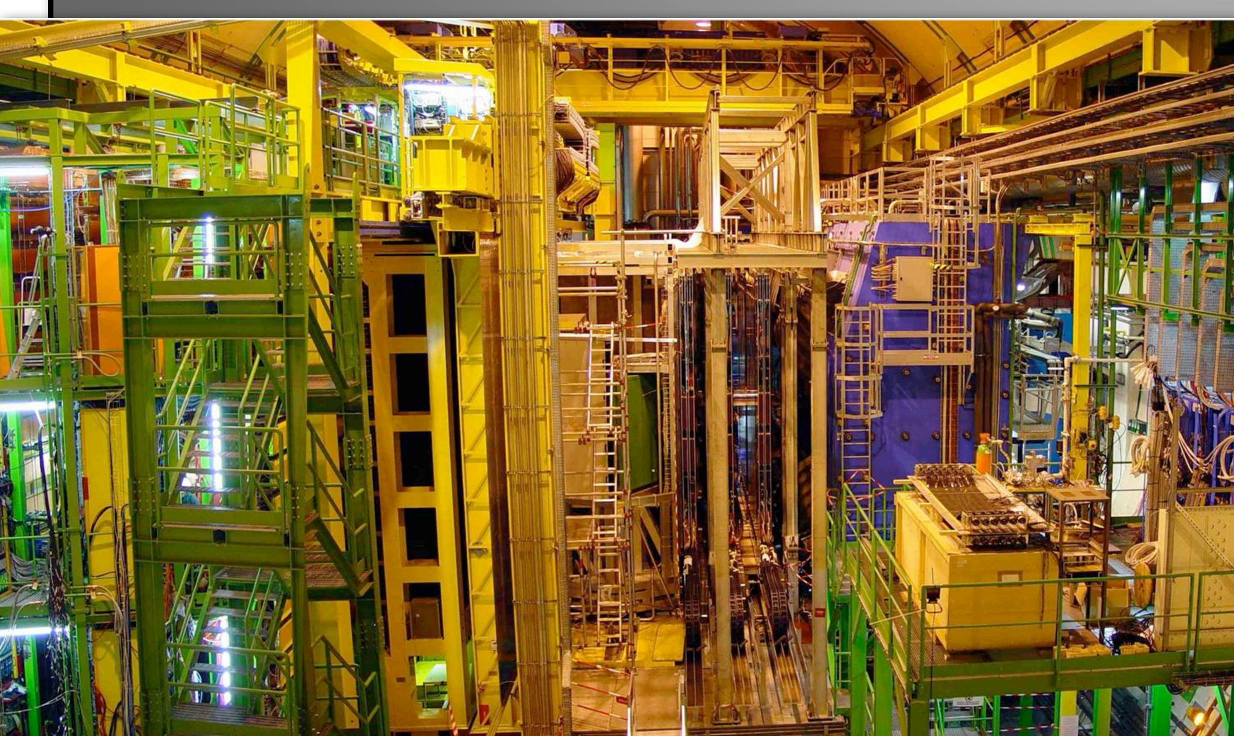
illustrative plots from flavour-tagged $D \to K_S \pi^+ \pi^-$ decays

$$x_\pm = r_B \cos(\delta_B \pm \gamma)\,,$$
$$y_\pm = r_B \sin(\delta_B \pm \gamma)$$

Common themes of $B \to DX$ analyses

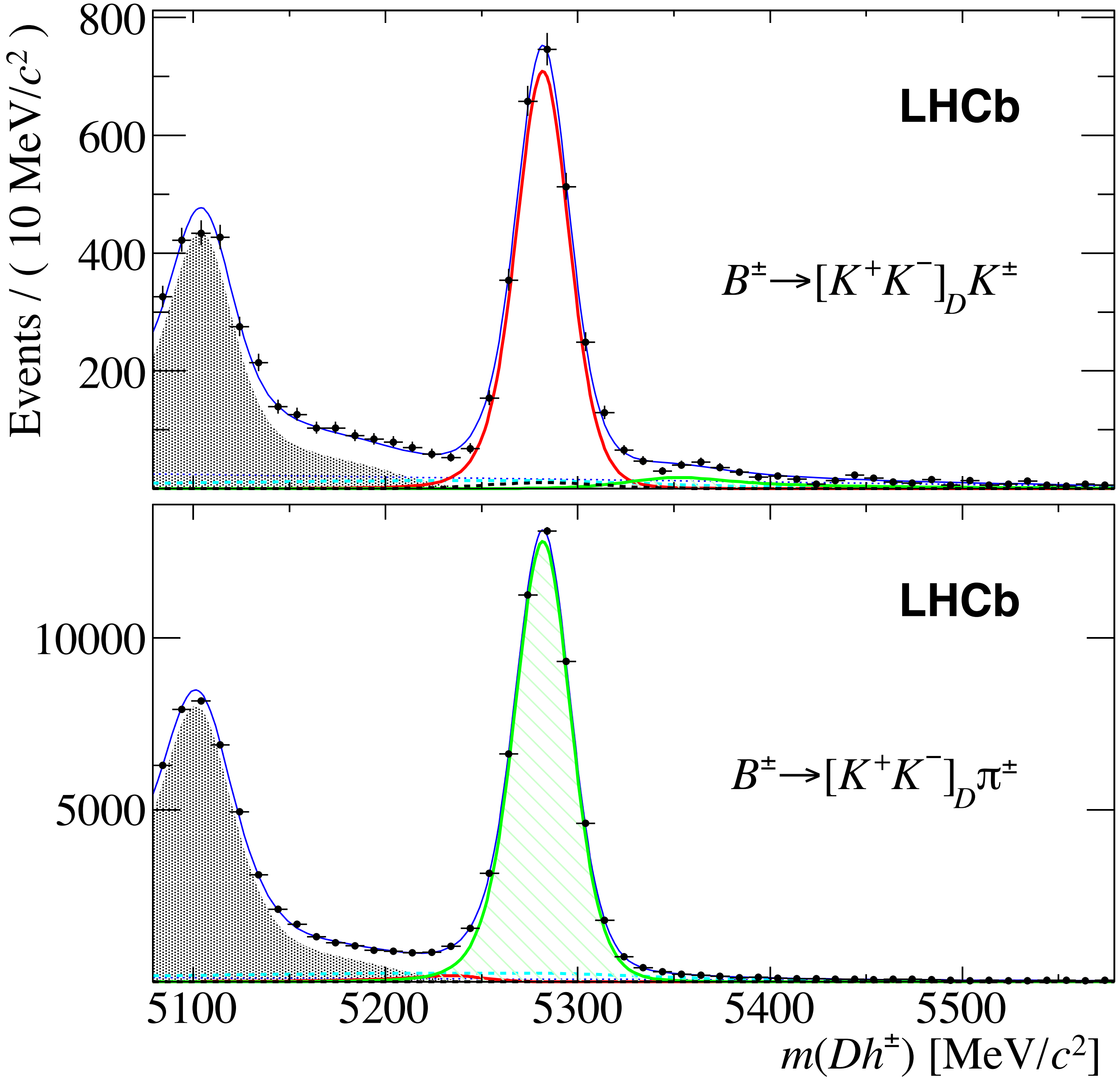
- Use multivariate background rejection algorithms to minimise combinatorial background
- The LHCb RICH system is extensively exploited to minimise backgrounds from other D-decays and crucially, to separate the kinematically similar $B \to DK$ and $B \to D\pi$ decays
- The LHCb vertex detector is vital for topologically distinguishing the B and D decay vertex. This is vital to control charmless physics backgrounds
- K_S^0 are reconstructed either in decays inside the vertex detector or further downstream leading to a significant boost in event yield
- Signals are measured using fits to invariant mass spectra
    - The high-precision momentum measurement from the tracking system, plus the use of decay-tree refits leads to a invariant mass resolution of B candidates of around 15 MeV/c^2



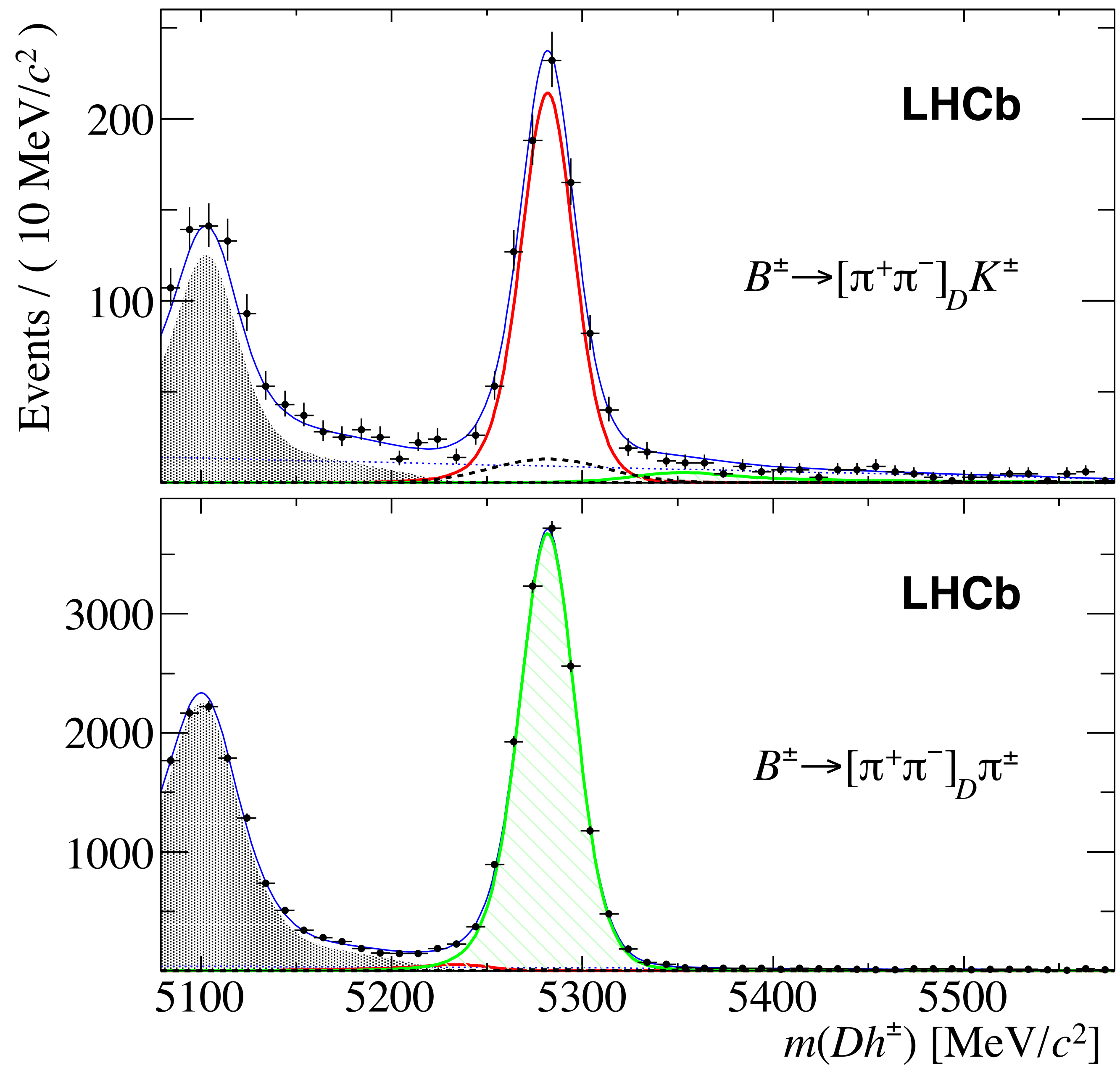


GLW: $B^{\pm} \to Dh^{\pm}$, $D \to K^+K^-$, $\pi^+\pi^-$

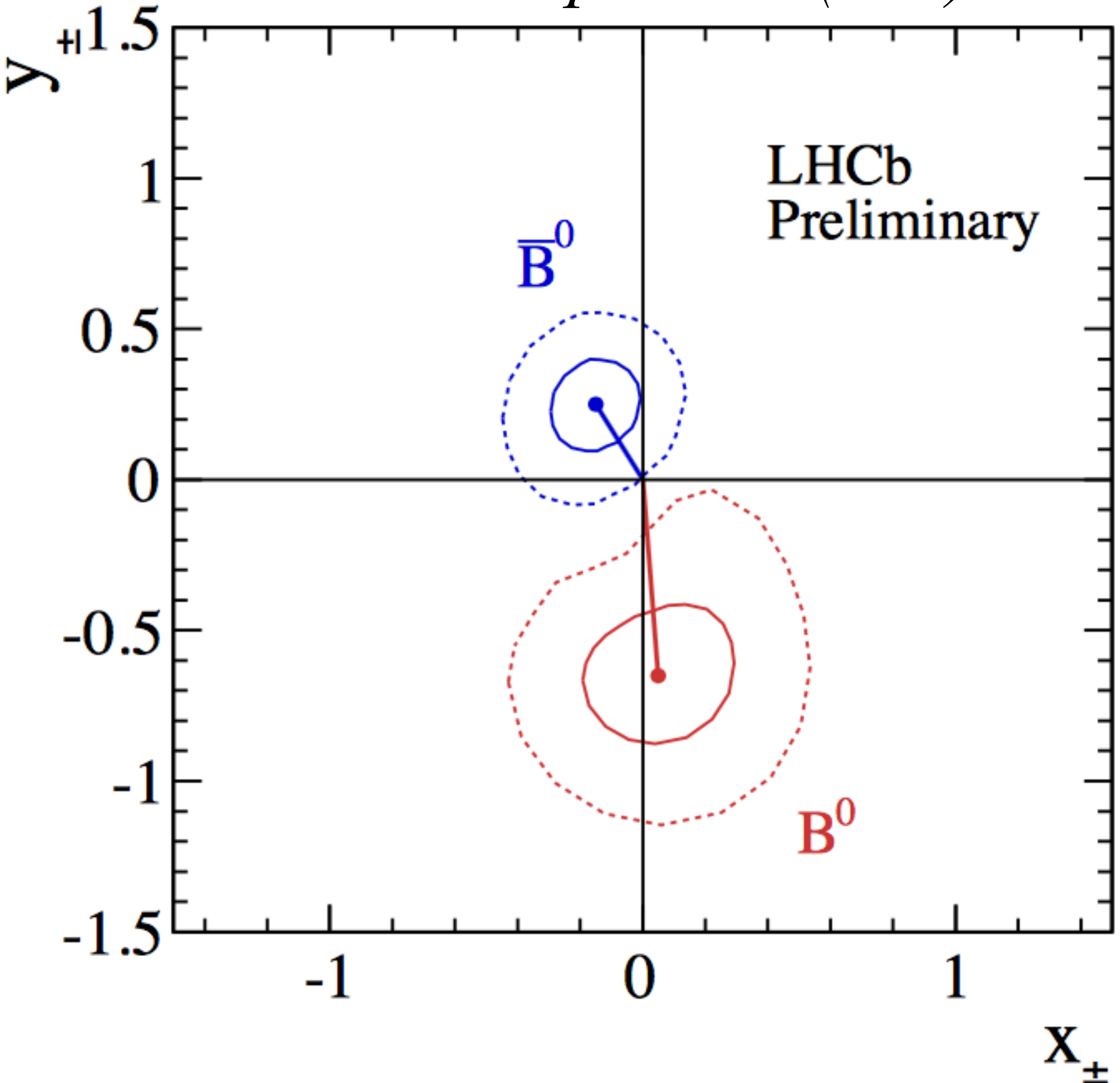
3800 $B^{\pm} \to DK^{\pm}$, $D \to K^+K^-$



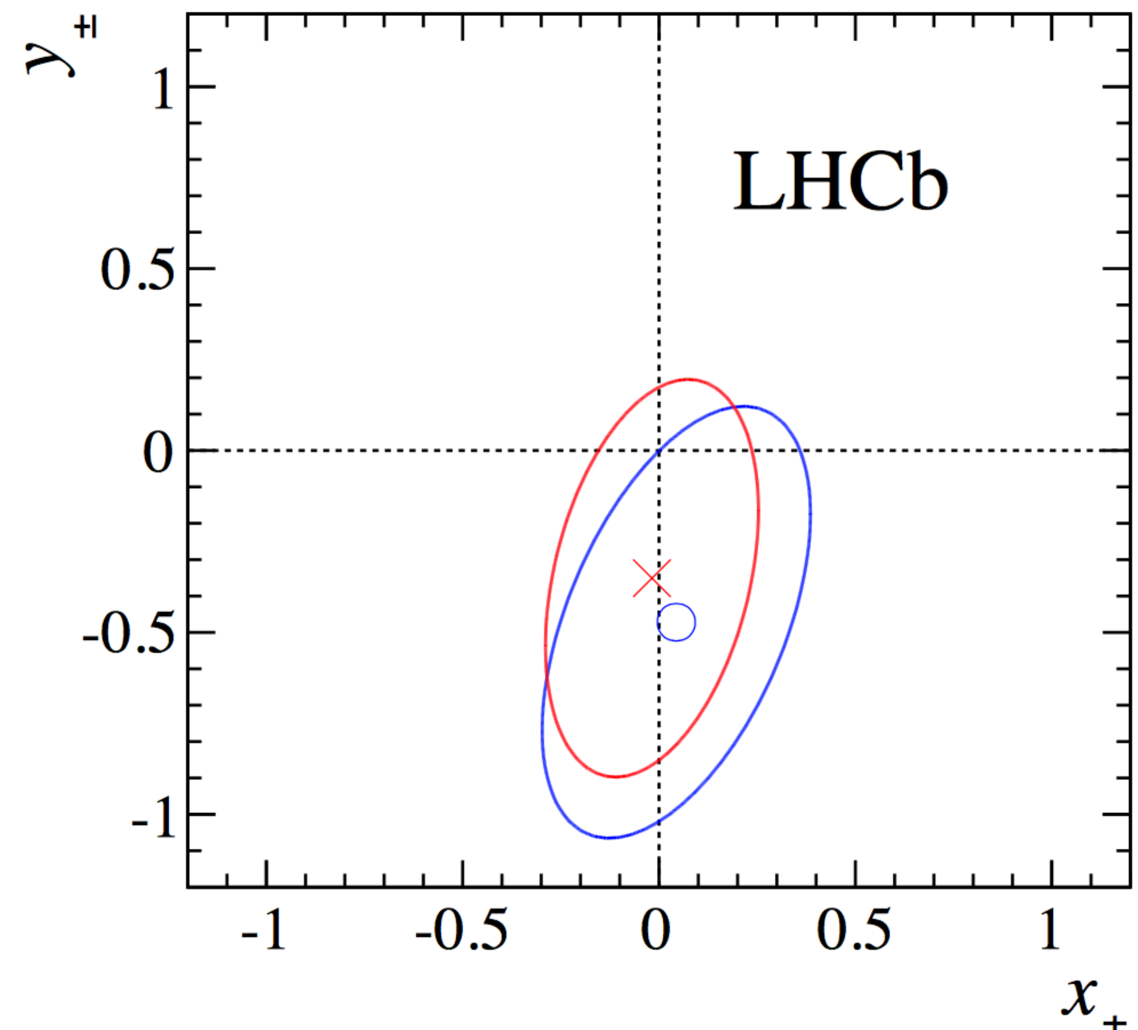
1160 $B^{\pm} \to DK^{\pm}$, $D \to \pi^+\pi^-$

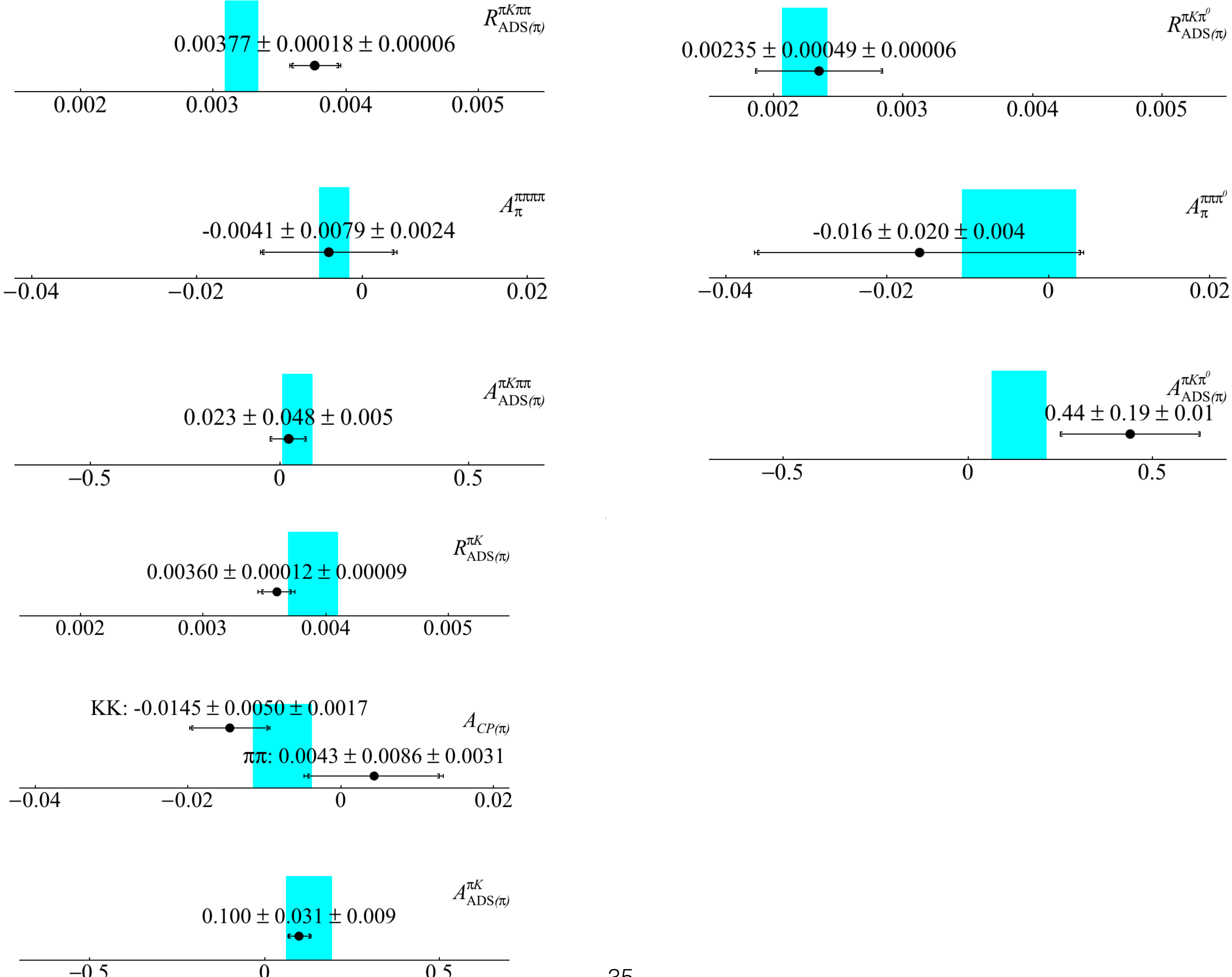


model-dependent (MD)



Dalitz-GLW





$R^{\pi K\pi\pi}_{ADS(\pi)}$
0.00377 ± 0.00018 ± 0.00006
0.002 0.003 0.004 0.005
$R^{\pi K\pi^0}_{ADS(\pi)}$
0.00235 ± 0.00049 ± 0.00006
0.002 0.003 0.004 0.005
$A^{\pi\pi\pi\pi}_{\pi}$
-0.0041 ± 0.0079 ± 0.0024
−0.04 −0.02 0 0.02
$A^{\pi\pi\pi^0}_{\pi}$
-0.016 ± 0.020 ± 0.004
−0.04 −0.02 0 0.02
$A^{\pi K\pi\pi}_{ADS(\pi)}$
0.023 ± 0.048 ± 0.005
−0.5 0 0.5
$A^{\pi K\pi^0}_{ADS(\pi)}$
0.44 ± 0.19 ± 0.01
−0.5 0 0.5
$R^{\pi K}_{ADS(\pi)}$
0.00360 ± 0.00012 ± 0.00009
0.002 0.003 0.004 0.005
$A_{CP(\pi)}$
KK: -0.0145 ± 0.0050 ± 0.0017
ππ: 0.0043 ± 0.0086 ± 0.0031
−0.04 −0.02 0 0.02
$A^{\pi K}_{ADS(\pi)}$
0.100 ± 0.031 ± 0.009
−0.5 0 0.5