

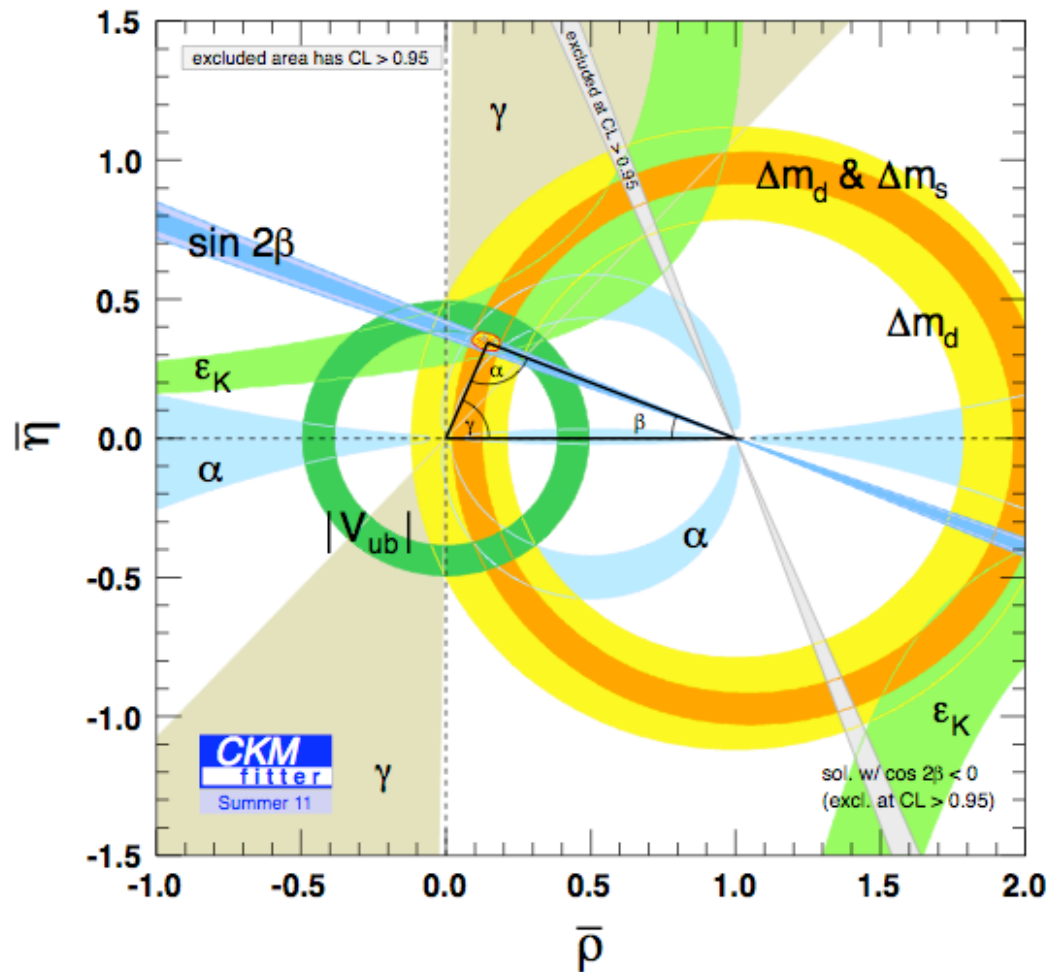
Towards a measurement of γ using $B \rightarrow DK$ decays

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on behalf of the LHCb Collaboration

Current experimental status



CKM matrix parameterises quark couplings

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

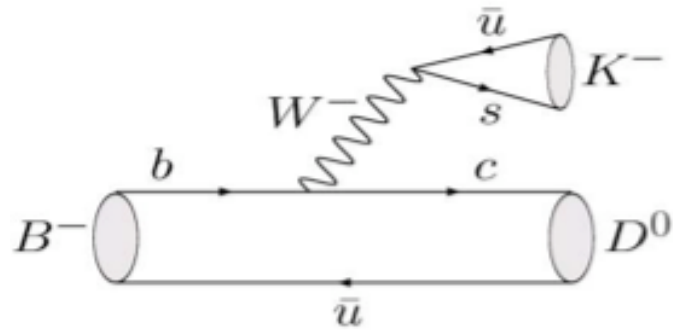
Does $\alpha + \beta + \gamma = 180^\circ$?

γ is the least well know angle

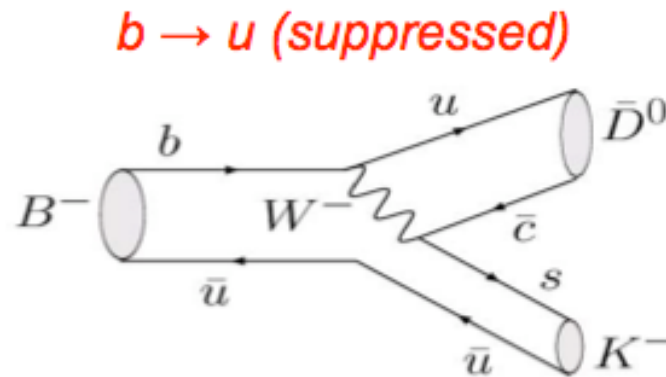
Precision measurement of γ can be achieved at LHCb

Goal: Measure γ in **tree** and loop decays

B → DK decays



$b \rightarrow c$ (favoured)

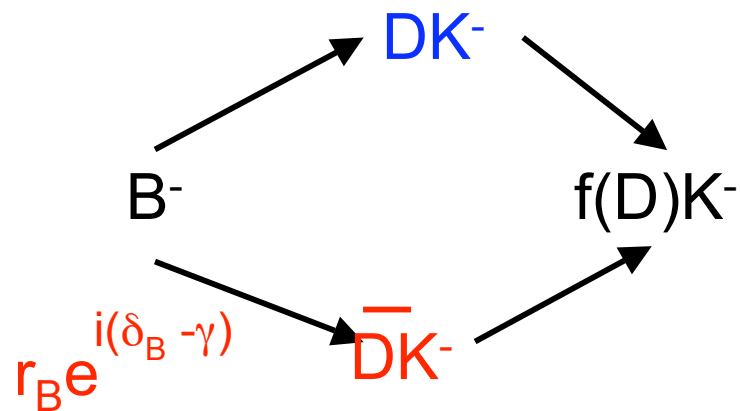


$b \rightarrow u$ (suppressed)

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

Sensitivity to γ from $b \rightarrow c$ and $b \rightarrow u$ interference

Require D^0 and \bar{D}^0 to decay to same final state



Today's talk: focus on two body decays of D^0

Simplest channel, high statistics, ideal for first results.

B → DK, D → CP eigenstates “GLW”

Both D^0 and \overline{D}^0 decay to CP eigenstates $KK, \pi\pi$ [CP even]

PLB 265 17 (1991)

$$\frac{\langle B^- \rightarrow \overline{D}^0 K^- \rangle}{\langle B^- \rightarrow D^0 K^- \rangle} = r_B e^{i(\delta_B - \gamma)}$$

CP odd states also possible e.g $K_S \pi^0$
Lower reconstruction efficiencies.

$r_B \sim 0.1$ Interference $\sim 10\%$

Construct observables of ratios of rates.

Partial cancellation of systematic uncertainties

CP modes

$$R_{CP+} = \frac{\langle \Gamma(B^\pm \rightarrow [\pi\pi]_D K^\pm), \Gamma(B^\pm \rightarrow [KK]_D K^\pm) \rangle}{\Gamma(B^\pm \rightarrow [K\pi]_D K^\pm)}$$

favoured mode

$$A_{CP+} = \frac{\Gamma(B^- \rightarrow D_{CP} K^-) - \Gamma(B^+ \rightarrow D_{CP} K^+)}{\Gamma(B^- \rightarrow D_{CP} K^-) + \Gamma(B^+ \rightarrow D_{CP} K^+)}$$

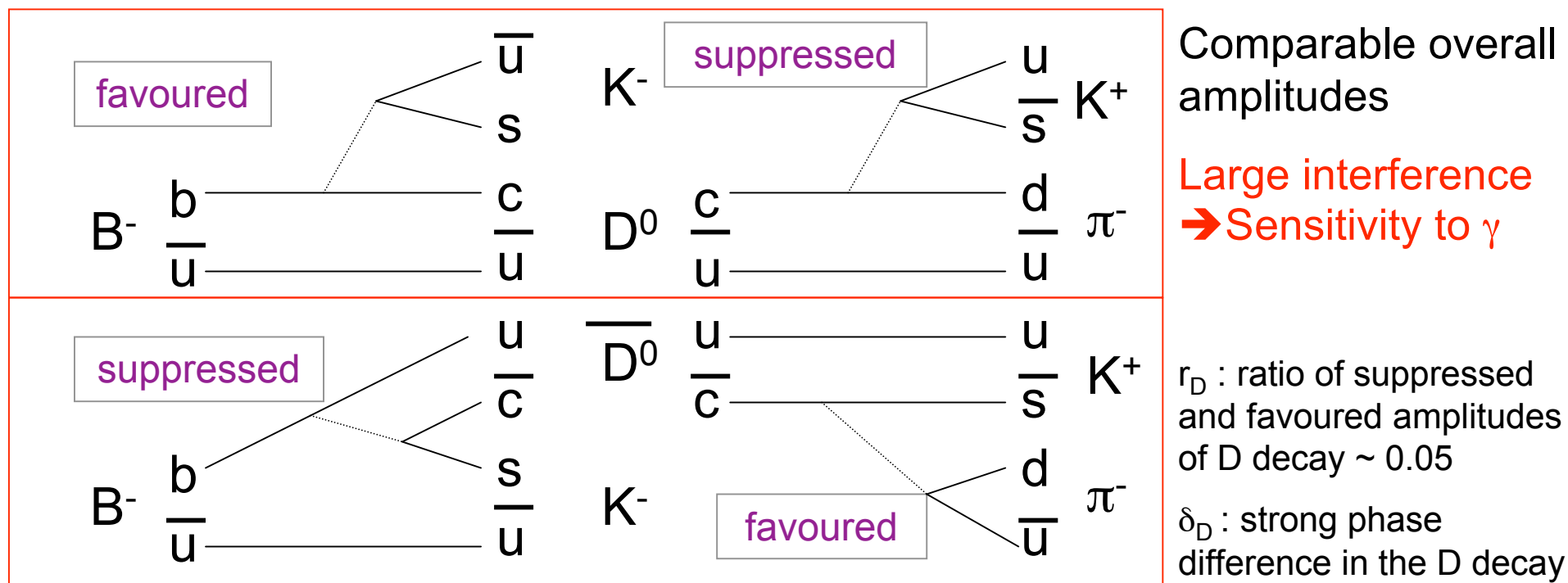
$$R_{CP+} = 1 + r_B^2 + 2r_B \cos \delta_B \cos \gamma$$

$$A_{CP+} = \frac{2r_B \sin \delta_B \sin \gamma}{1 + r_B^2 + 2r_B \cos \delta_B \cos \gamma}$$

$B^\pm \rightarrow DK^\pm, D \rightarrow K^\mp \pi^\pm$ “ADS”

Common final state $K\pi$ favoured & suppressed combination

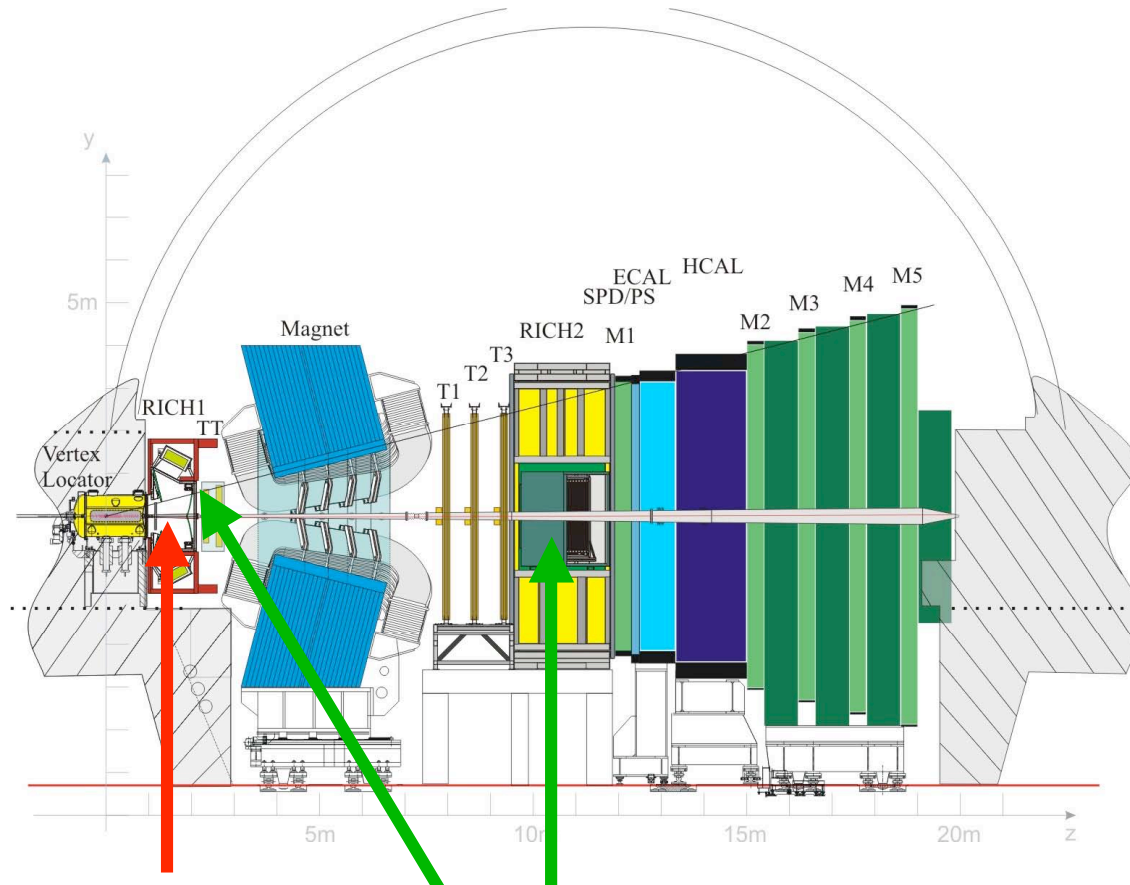
PRL 78(1997) 3257



$$R_{ADS} = \frac{\Gamma(B^\pm \rightarrow [\pi K]_D K^\pm)}{\Gamma(B^\pm \rightarrow [K\pi]_D K^\pm)}$$

$$R_{ADS} = \frac{r_B^2 + r_D^2 + 2r_B r_D \cos(\delta_B + \delta_D) \cos \gamma}{1 + r_B^2 r_D^2 + 2r_B r_D \cos(\delta_B - \delta_D) \cos \gamma}$$

LHCb Detector



Vertex Locator RICH Detectors

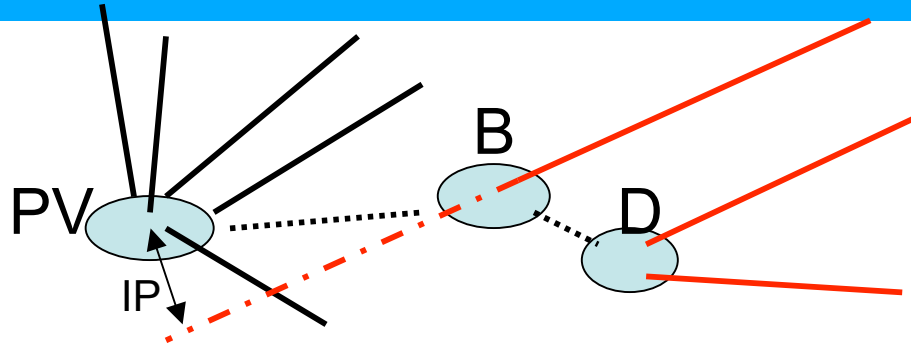
Vertex Locator

Find B and D
secondary vertices

RICH Detectors

Provide separation
between Kaons
and pions

Selection



Every mass hypothesis combination $B \rightarrow [hh]_D h$ is reconstructed. $h = K, \pi$

Analysis utilises full 2011 dataset 1 fb^{-1} .

Use TMVA BDT with 20 variables trained on MC and data sidebands from 2010 (35 pb^{-1} , [independent dataset](#))

Useful variables include:

- Transverse momenta
- Impact parameters
- Flight distances
- Vertex quality

Further selection applied to remove specific backgrounds

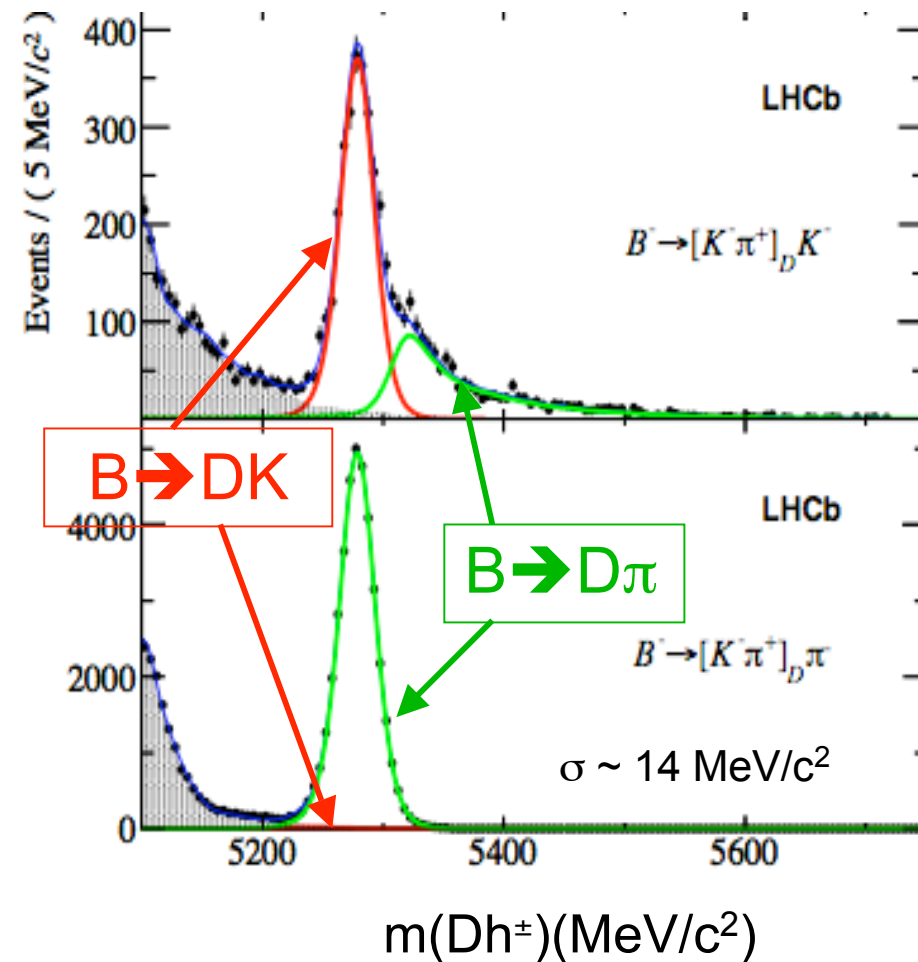
e.g Cut on D flight distance to remove charmless bkg like $B \rightarrow hhh$.

Vetos to remove other B decays.

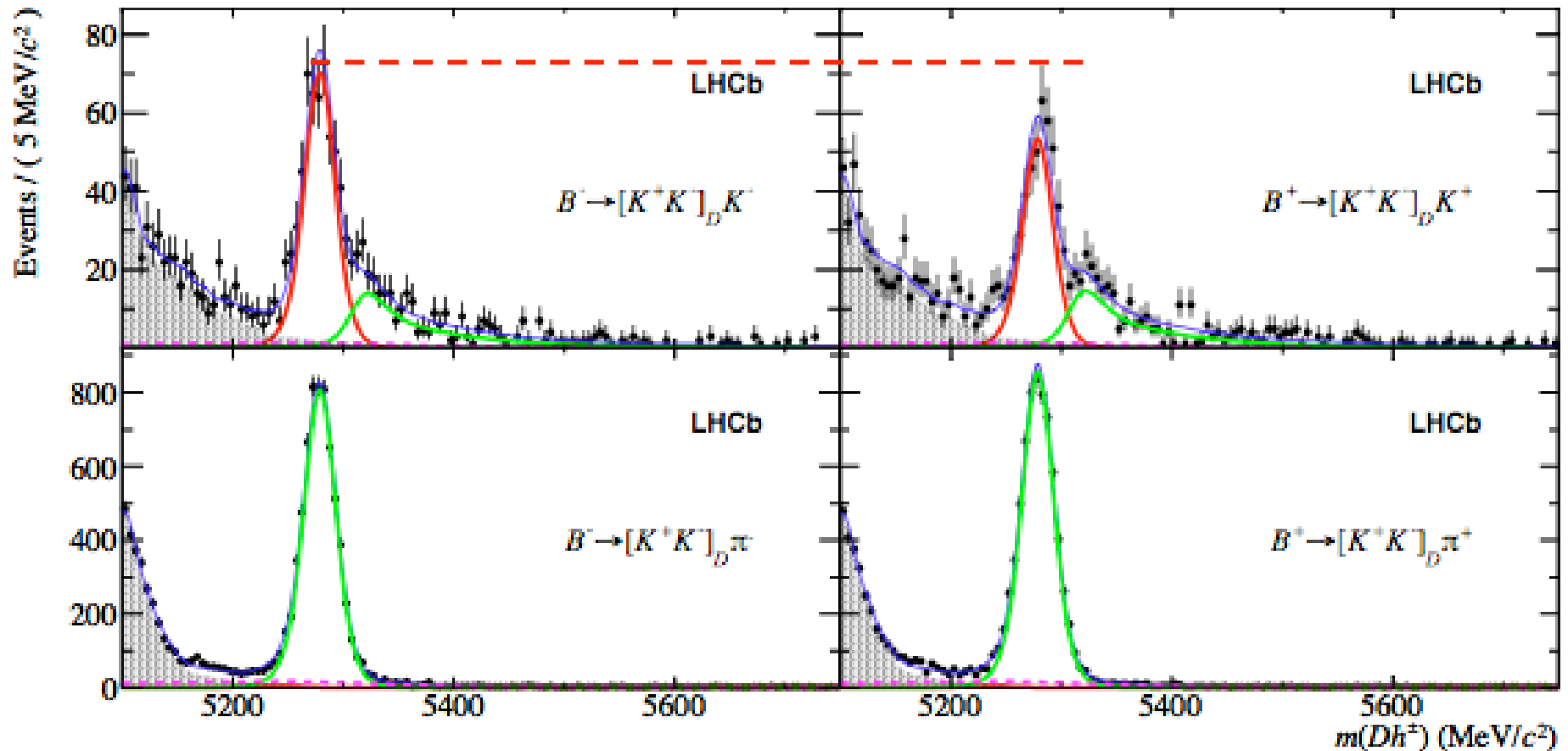
Mass parameterisation

arXiv:1203.3662

- Favoured decay modes dominate statistics and constrain the shapes
- Very low combinatoric levels.
- Partially reconstructed low mass background shapes determined from MC
- Particle identification information on h from B divides the data.
- mis-ID rates fix the yield of the mis-ID component relative to the yield in the opposite plot.



$B^\pm \rightarrow [KK]_D h^\pm$

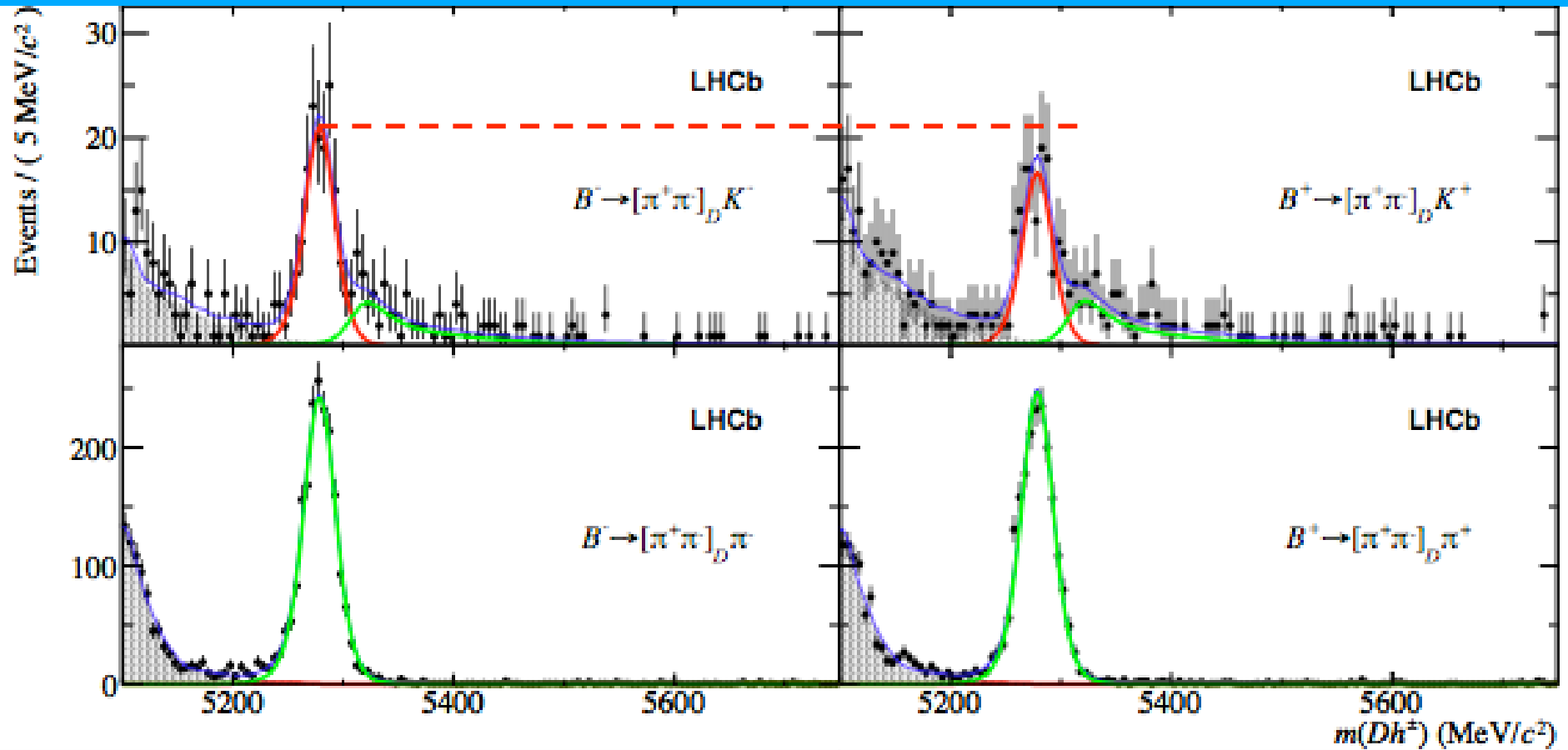


Clear asymmetry in $B \rightarrow DK$

None seen in $B \rightarrow D\pi$ ($r_B \sim \times 10$ smaller)

arXiv:1203.3662

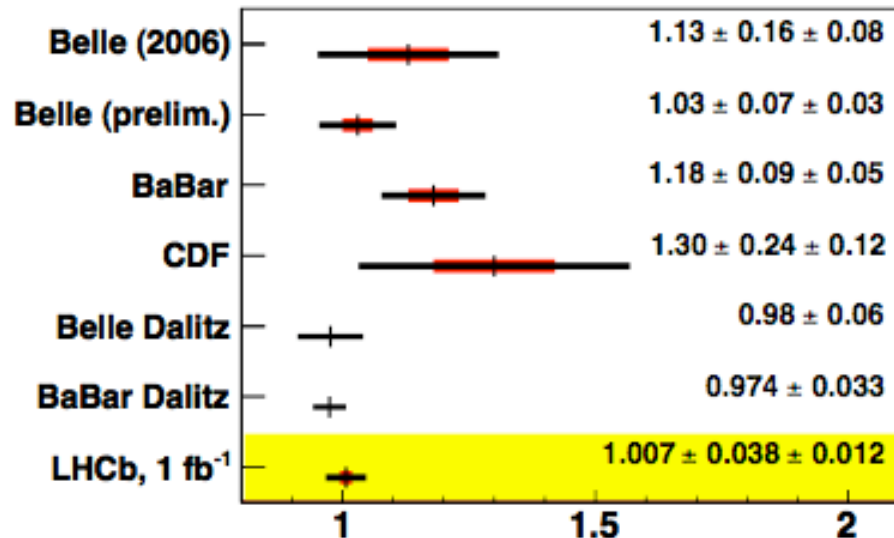
$$B^\pm \rightarrow [\pi\pi]_D h^\pm$$



Similar observations for $D \rightarrow \pi\pi$

arXiv:1203.3662

Results from the CP modes



$$R_{CP+} = 1 + r_B^2 + 2r_B \cos\delta_B \cos\gamma$$

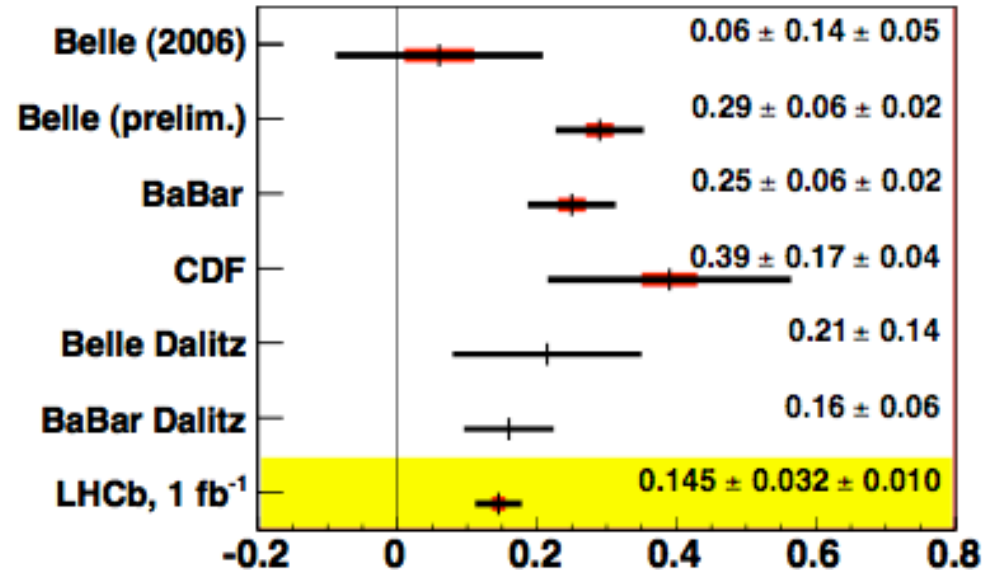
Small systematic uncertainties, dominated by:

Particle identification uncertainties for Ratios

Production/interaction/detection effects for Asymmetries

Evidence of non-zero A_{CP+} with 4.5σ significance

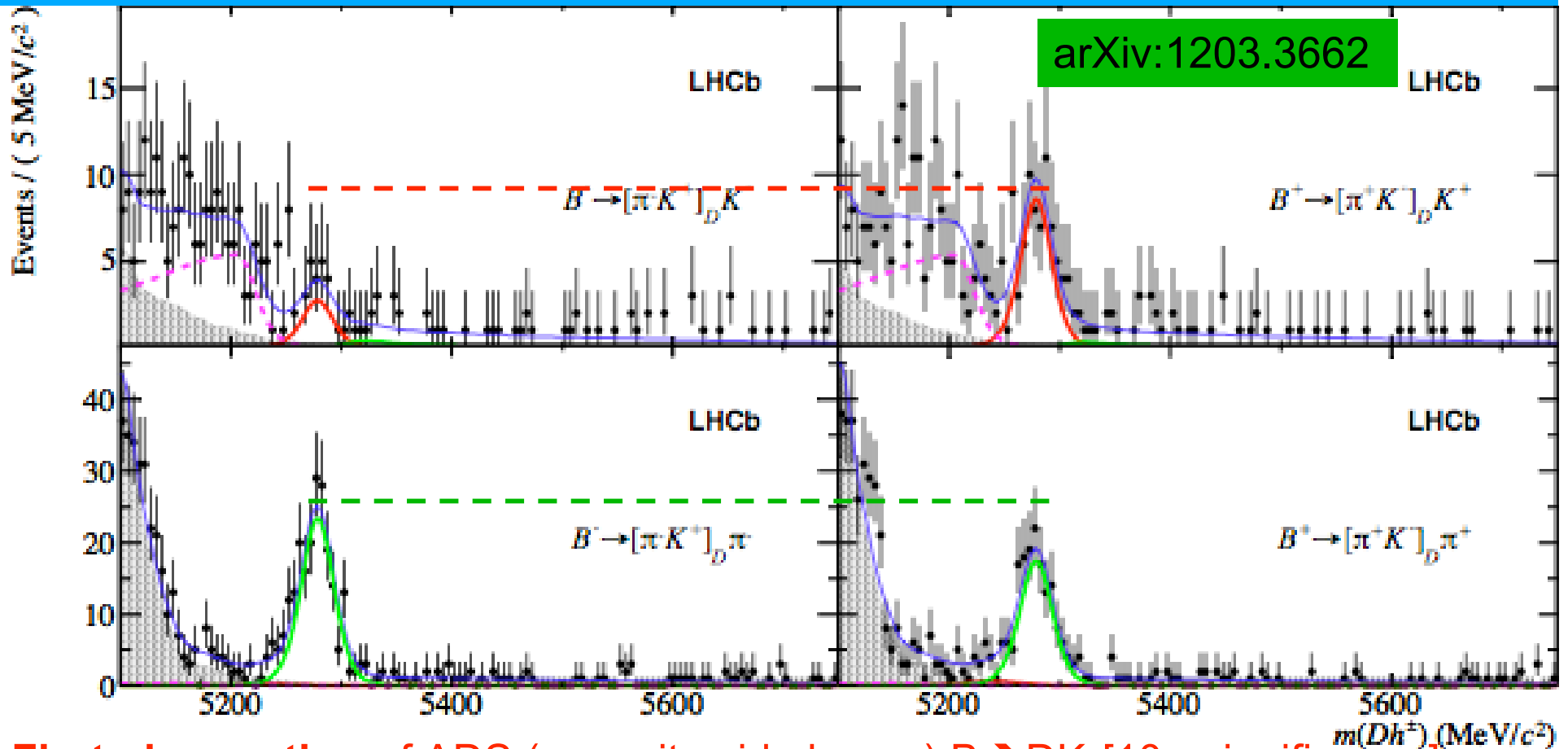
Asymmetries in $B \rightarrow D\pi$ consistent with 0



$$A_{CP+} = \frac{2r_B \sin\delta_B \sin\gamma}{1 + r_B^2 + 2r_B \cos\delta_B \cos\gamma}$$

arXiv:1203.3662

$B^\pm \rightarrow [\pi K]_D h^\pm$ (ADS modes)

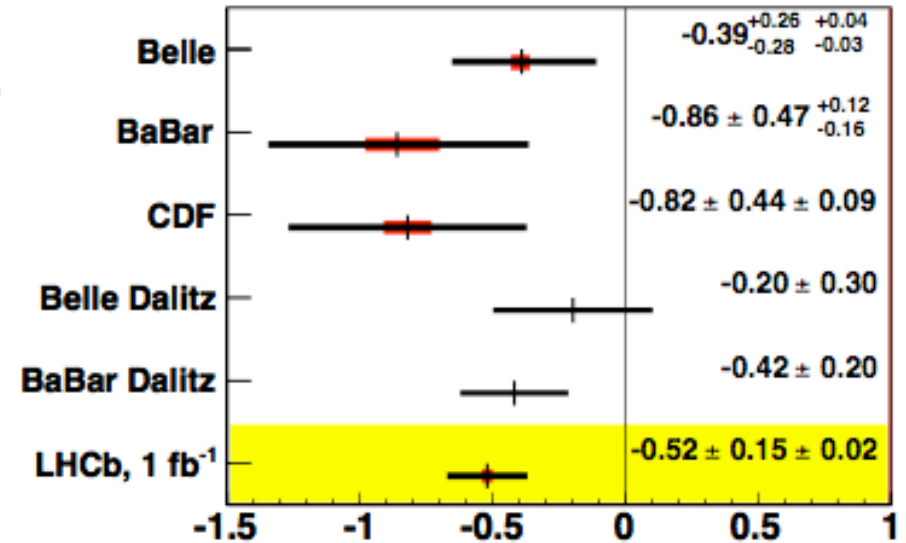
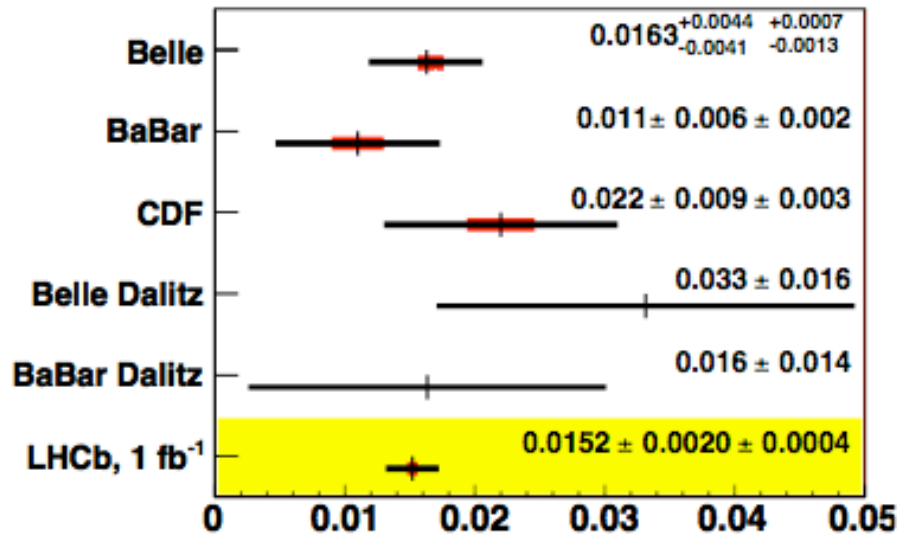


First observation of ADS (opposite side kaons) $B \rightarrow DK$ [10σ significance]

Hint of asymmetry in $B \rightarrow D\pi$

Partially reconstructed $B_S \rightarrow \bar{D}^0 K^- \pi^+$ contribution visible in this mode.

Results from the ADS modes



$$R_{ADS} = \frac{r_B^2 + r_D^2 + 2r_B r_D \cos(\delta_B + \delta_D) \cos \gamma}{1 + r_B^2 r_D^2 + 2r_B r_D \cos(\delta_B - \delta_D) \cos \gamma}$$

$$A_{ADS} = \frac{2r_B r_D \sin(\delta_B + \delta_D) \sin \gamma}{r_B^2 + r_D^2 + 2r_B r_D \cos(\delta_B + \delta_D) \cos \gamma}$$

Asymmetry in $B \rightarrow DK$ ADS 4.0σ

arXiv:1203.3662

Hint of asymmetry in $B \rightarrow D\pi$ ADS 2.4σ

Combining with CP modes, CP violation is observed in $B \rightarrow DK$ with a significance of 5.8σ

What about γ ?

Want to extract 3 parameters: r_B , δ_B & γ

Using only the results presented today \rightarrow Multiple, overlapping solutions.

These can be resolved by looking at more D decay modes

Today, saw results from

$B^- \rightarrow DK^-$, $D \rightarrow K^+\pi^-$, $D \rightarrow K^+K^-$, $D \rightarrow \pi^+\pi^-$

Later this year:

$B^- \rightarrow DK^-$, $D \rightarrow K_s \pi \pi$, $D \rightarrow K_s KK$ (mixed CP - "GGSZ"),

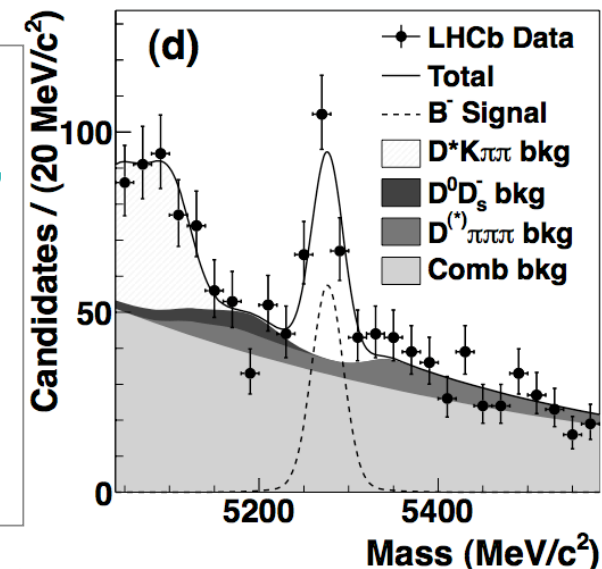
$D \rightarrow K\pi\pi$, $D \rightarrow K\pi\pi^0$

& Also

$B^0 \rightarrow DK^{*0}$, $D \rightarrow K^+\pi^-$, $D \rightarrow K^+K^-$, $D \rightarrow \pi^+\pi^-$

$B^- \rightarrow DK^-\pi\pi$, $D \rightarrow K^+K^-$, $D \rightarrow \pi^+\pi^-$

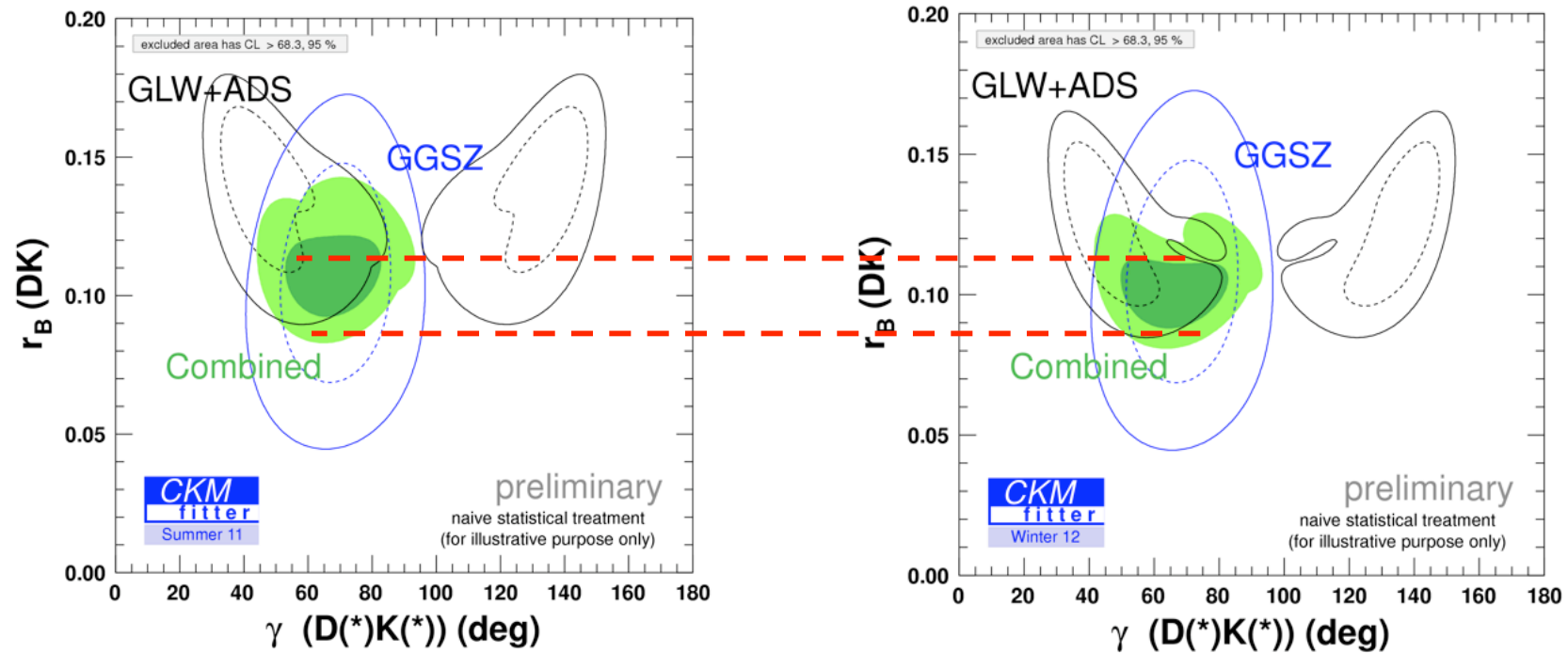
Favoured $B \rightarrow DK\pi\pi$ 35 pb^{-1}



All bring extra information for measurement of γ

arXiv:1201.4402

Impact of LHCb $B \rightarrow DK$ results



Combination of B factory data including GGSZ ($D \rightarrow K_s \pi \pi$) and today's results

Best fit value favours lower value of r_B .

Uncertainty on γ dependent on r_B ; Overall uncertainty on γ similar.

Summary & Outlook

- Observation of direct CP violation in $B \rightarrow DK$ decays
- Measurements shown today have dependence on γ
- Are an important contribution to a measurement of γ
- This is the first step. Other modes discussed targeted for this year.
- It will be a very exciting year
- More data \rightarrow Opens up new decay channels