Direct CPV at the LHCb upgrade
+ γ at LHCb now

Malcolm John, for the LHCb collaboration

CKM 2012 - Cincinnati, Ohio

30th September 2012

LHCb upgrade

- When: Installed in 2018/19 (LS2)
- Goal: 5 fb^{-1}/yr → 50 fb^{-1} in 10 years
    - Luminosity: 1×10^{33} cm^{-2} s^{-1} (assume 25 ns, 10^{34} is routine)
    - At 14 TeV, heavy flavour cross sections: ×2 current value
    - Final signal yields: at least 100 times 2011 sample (N_{2011})

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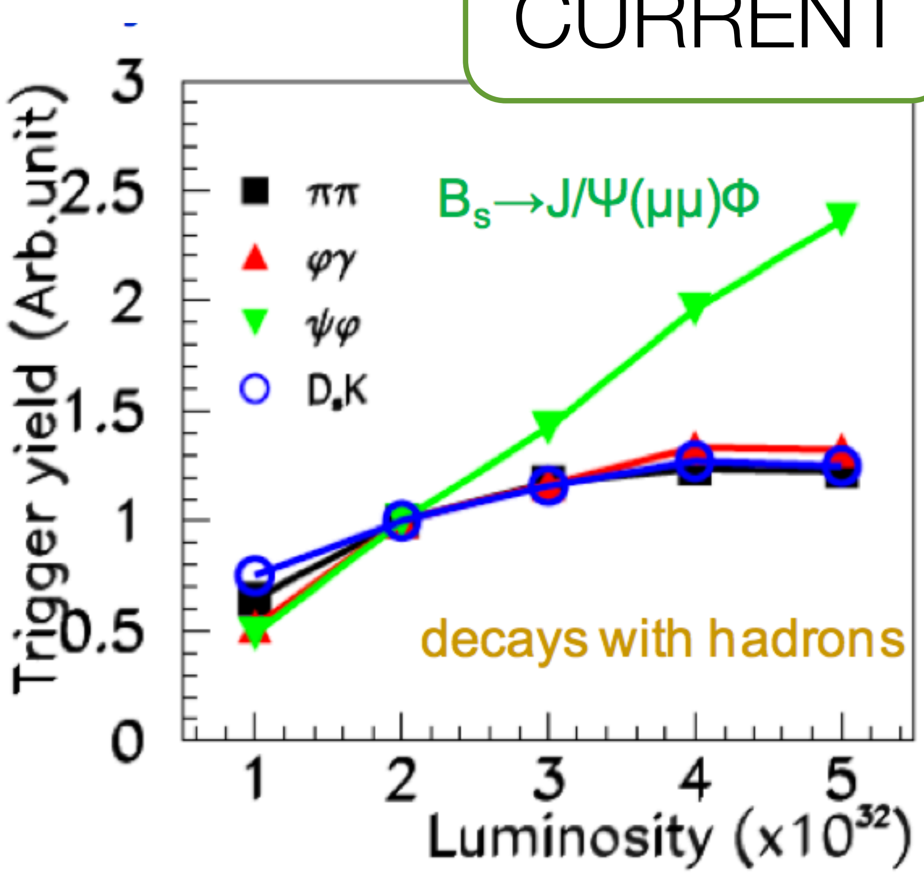
CURRENT



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  - Into [c++] HLT at 40 MHz and [partially] reconstruct all events
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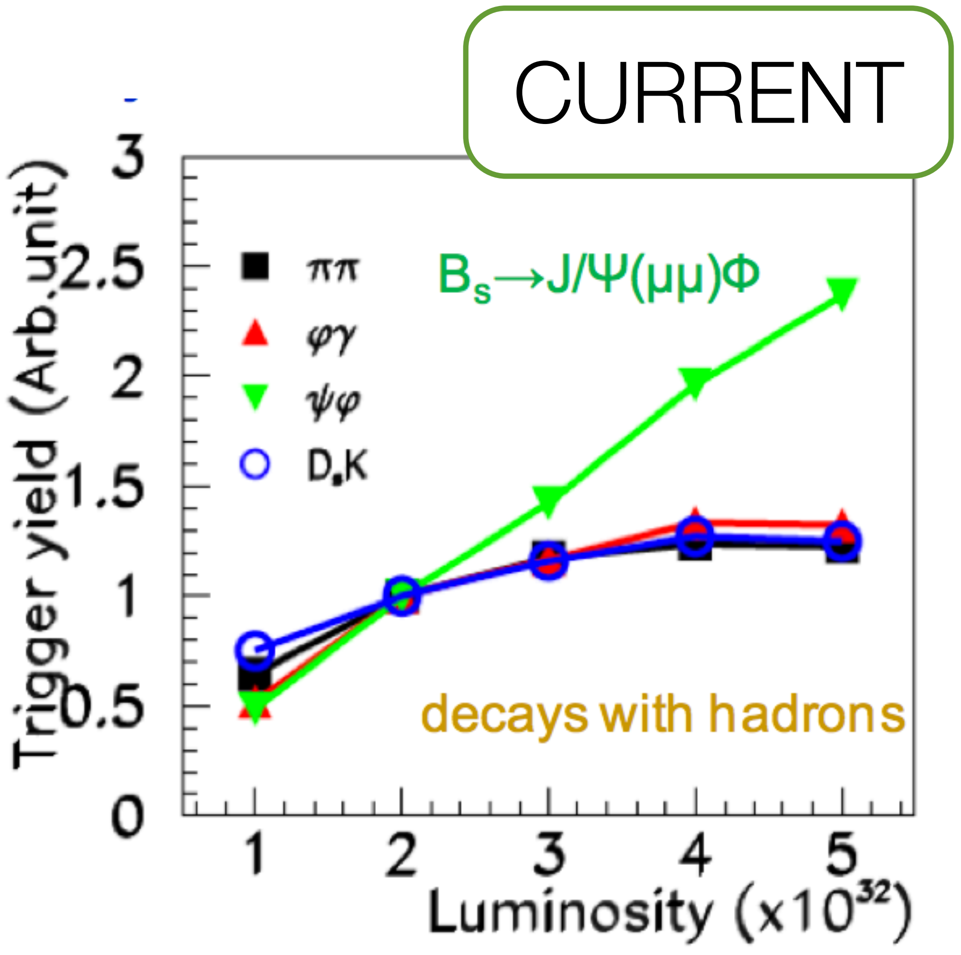

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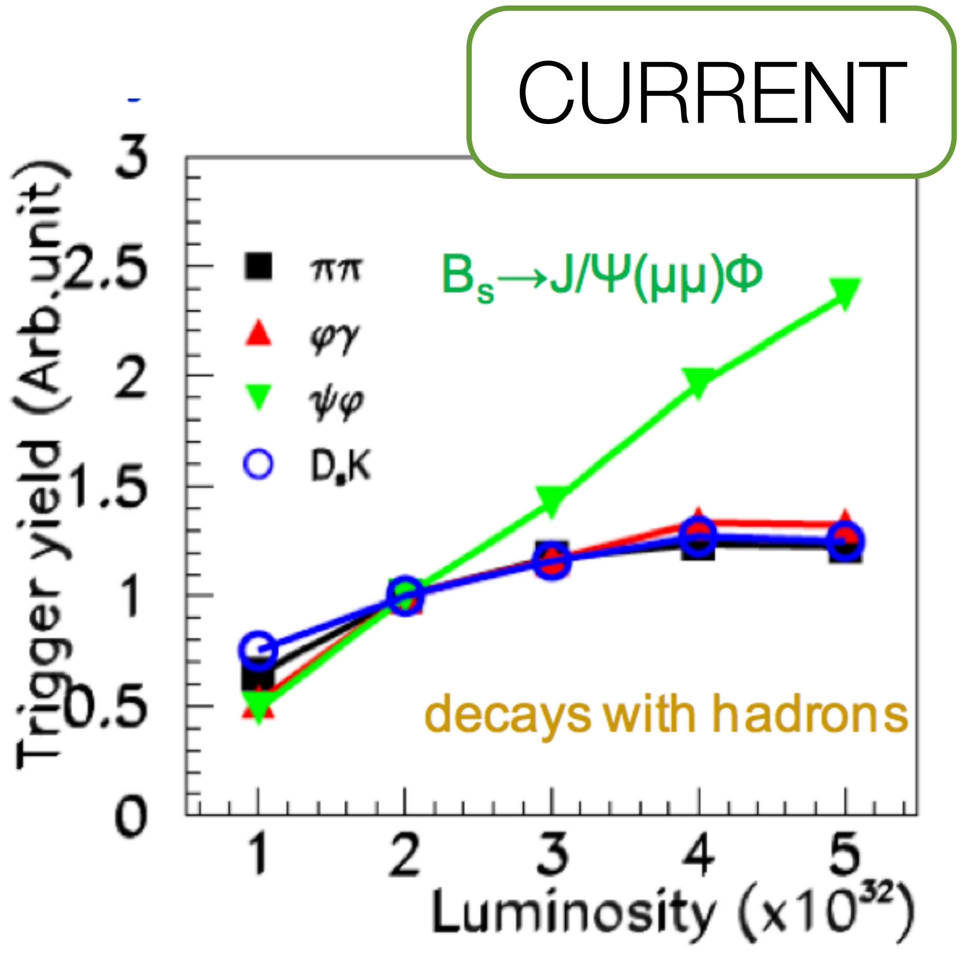
- Hope: Physics program greatly enhanced, especially in hadronic modes
  - For DCPV in fully reconstructed final states, there is little competition (Add a π^0 and maybe...)

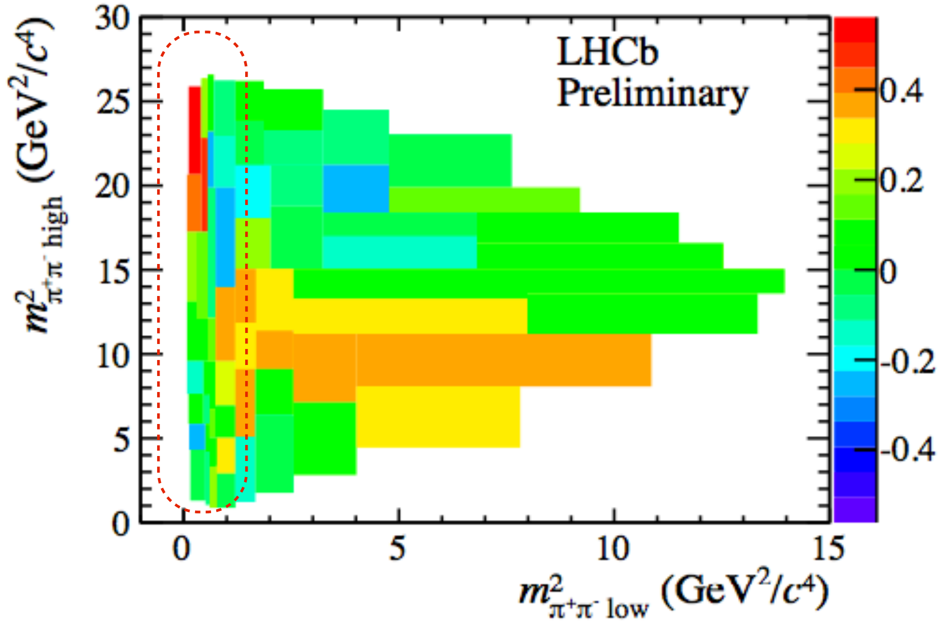


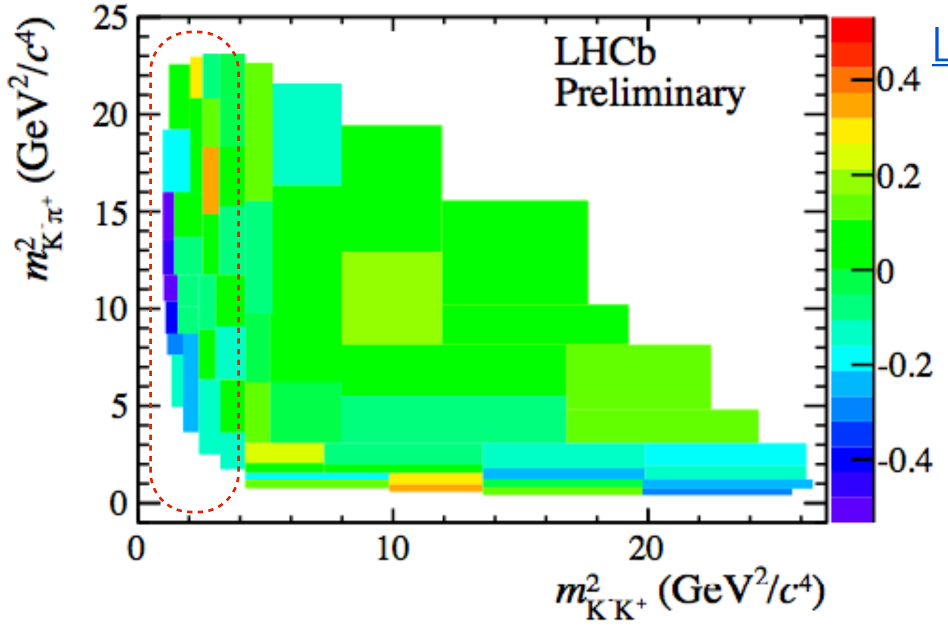
DCPV in charmless

Now		2030 stat. error	
$A_{CP}(B^0 \rightarrow K^+\pi^-) = (-8.8 \pm 1.1 \pm 0.8)\%$ NB: $0.35\ fb^{-1}$	➜	~0.1%	syst. dominated
$A_{CP}(B_s \rightarrow K^+\pi^-) = (+27 \pm 8 \pm 2)\%$ NB: $0.35\ fb^{-1}$	➜	~0.5%	stat. ≈ syst.
$A_{CP}(B^\pm \rightarrow K^+\pi^-\pi^\pm) = (3.4 \pm 0.9 \pm 0.4 \pm 0.7)\%$	➜	~0.1%	syst. dominated
$A_{CP}(B^\pm \rightarrow K^+K^-K^\pm) = (-4.6 \pm 0.9 \pm 0.5 \pm 0.7)\%$	➜	~0.1%	syst. dominated
$A_{CP}(B^\pm \rightarrow \pi^+\pi^-\pi^\pm) = (12.0 \pm 2.0 \pm 1.9 \pm 0.7)\%$	➜	~0.2%	syst. dominated
$A_{CP}(B^\pm \rightarrow K^+K^-\pi^\pm) = (-15.3 \pm 4.6 \pm 1.9 \pm 0.7)\%$	➜	~0.5%	stat. ≈ syst.

Common issue: normalisation from $A_{CP}(B^\pm \rightarrow J/\psi K^\pm)_{PDG}$

The three-body analyses are will be developed as full Dalitz analyses





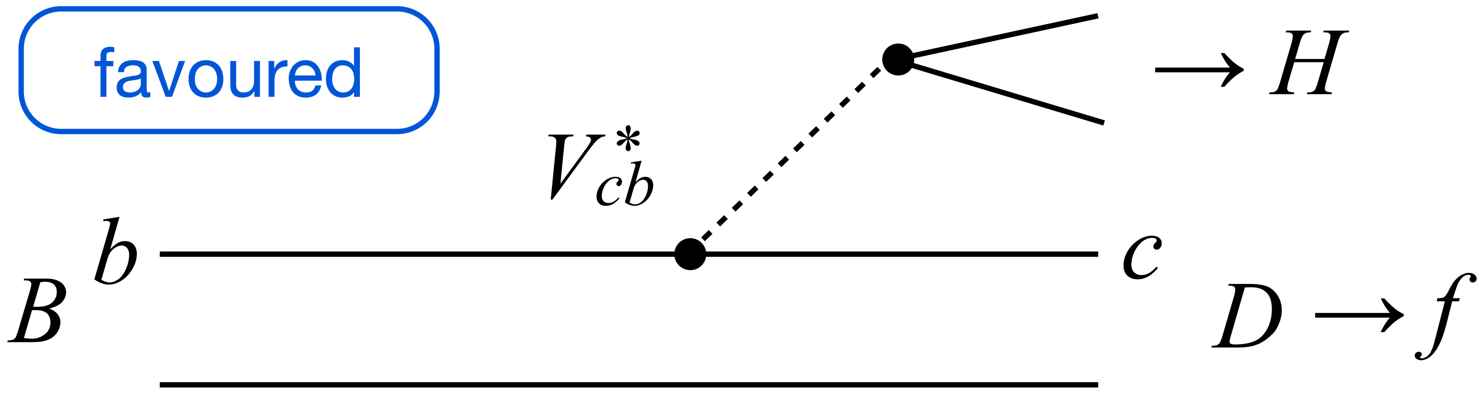
LHCb-CONF-2012-028

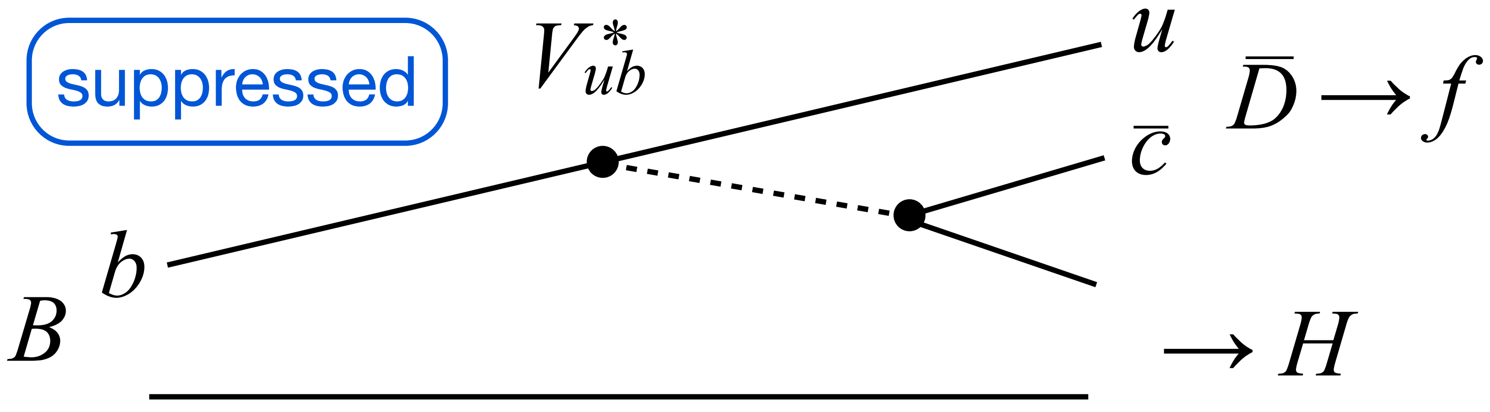
Common issues:
Dalitz models
PID calibration
and normalisation

- $A_{CP}(B^{\pm} \to \pi^+\pi^-\pi^{\pm}) = (62.2 \pm 7.5 \pm 3.2 \pm 0.7)\%$ ➤ ~0.8% syst. dominated
- $A_{CP}(B^{\pm} \to K^+K^-\pi^{\pm}) = (-67.1 \pm 6.7 \pm 2.8 \pm 0.7)\%$ ➤ ~0.7% syst. dominated

- Dalitz analyses of modes with K_S is in development and 4 body charmless will not be forgotten
  - 4-body Dalitz techniques developed for $D^0 \to hhhh$ at CLEOc can be extended

DCPV in open-charm B decays. Focussing on γ





	H	*D* mode	*B* decay
$B^\pm$	K	$K\pi$ / $K\pi\pi\pi$ / $K\pi\pi^0$	$B_u \to [\pi K(\pi\pi)]_D K$ (**ADS**)
	K	KK / $\pi\pi$ / $K_S\omega$	$B_u \to D_{CP} K$ (**GLW**)
	K	$K_S\pi\pi$ / K_SKK / $K_SK\pi$ / $KK\pi^0$ / $\pi\pi\pi^0$	$B_u \to$ [3-body]$_D$K (**GGSZ**)
	K	$\pi\pi\pi\pi$ / $K\pi\pi\pi$ / $KK\pi\pi$	$B_u \to [hhhh]_D K$ (**4-body Dalitz**)
	$K\pi\pi$	$K\pi$ / $K\pi\pi\pi$ / $K\pi\pi^0$	$B_u \to [\pi K(\pi\pi)]_D K$ (**ADS**)
	$K\pi\pi$	KK / $\pi\pi$	$B_u \to D_{CP} K$ (**GLW**)
	$K\pi\pi$	$K_S\pi\pi$ / K_SKK	$B_u \to$ [3-body]$_D$K (**GGSZ**)
B^0	K^* or $K\pi$	$K\pi$ / $K\pi\pi\pi$ / $K\pi\pi^0$	$B_d \to [\pi K(\pi\pi)]_D K$ (**ADS**)
	K^* or $K\pi$	KK / $\pi\pi$	$B_d \to D_{CP} K$ (**GLW**)
	K^* or $K\pi$	$K_S\pi\pi$ / K_SKK	$B_d \to$ [3-body]$_D$K (**GGSZ**)
	π	$K\pi\pi$ / $KK\pi$ / $\pi\pi\pi$	$B_d \to D\pi$ (**TD**)
B_s	KK	$K\pi$ / $K\pi\pi\pi$ / $K\pi\pi^0$ / KK / $\pi\pi$ / K_Shh	$B_s \to D\varphi$ (**TI**)
	K	$KK\pi$ / $K\pi\pi$ / $\pi\pi\pi$	$B_s \to D_sK$ (**TD**)
	$K\pi\pi$	$KK\pi$ / $K\pi\pi$ / $\pi\pi\pi$	$B_s \to D_sK\pi\pi$ (**TD**)
B_c	D	$K\pi$ / KK / $\pi\pi$	$B_c \to [hh]_D D$ (**ADS/GLW**)
$B^\pm$	$K_S\pi$	$K\pi$ / $K\pi\pi\pi$ / $K\pi\pi^0$ / KK / $\pi\pi$ / K_Shh	$B_u \to DK^*$ (**ADS/GLW/GGSZ**)
	π/K	$D^{*0} \to K\pi$ / $K\pi\pi\pi$ / KK / $\pi\pi$ / K_Shh	$B_u \to D^*h$ (**ADS/GLW/GGSZ**)
	π	$K\pi$ / $K\pi\pi\pi$ / $K\pi\pi^0$	$B_u \to [\pi K(\pi\pi)]_D K$ (**ADS**)
	π	KK / $\pi\pi$ / $K_S\omega$	$B_u \to D_{CP} K$ (**GLW**)
	π	$K_S\pi\pi$ / K_SKK / $K_SK\pi$ / $KK\pi^0$ / $\pi\pi\pi^0$	$B_u \to$ [3-body]$_D$K (**GGSZ**)
	π	$\pi\pi\pi\pi$ / $K\pi\pi\pi$ / $KK\pi\pi$	$B_u \to [hhhh]_D K$ (**4-body Dalitz**)

arxiv/1208.3355

Estimation of the precision on γ with 50 fb^{-1}

Decay mode	γ sensitivity
$B \to DK$ with $D \to hh'$, $D \to K\pi\pi\pi$	$1.3°$
$B \to DK$ with $D \to K_S^0\pi\pi$	$1.9°$
$B \to DK$ with $D \to 4\pi$	$1.7°$
$B^0 \to DK\pi$ with $D \to hh'$, $D \to K_S^0\pi\pi$	$1.5°$
$B \to DK\pi\pi$ with $D \to hh'$	$\sim 3°$
Time-dependent $B_s \to D_sK$	$2.0°$
Combined	$\sim 0.9°$

Many modes missing. Either:
1) reconstruction not developed or
2) their sensitivity not assessed

Notably Dπ...

Great! But systematics need to be under fantastic control:
1) Acceptance asymmetries - must have regular dipole polarity switches
2) Production and detection asymmetries - e.g. $A_{interaction}(\pi) = (0.08\pm0.24)\%$ arxiv/1205.0897.pdf
3) PID efficiencies - must retain large $D^* \to [K\pi]_D\pi$; $J/\psi \to \mu\mu, ee$; $\Lambda \to p\pi$ calibration samples

□γ measurement from the 2011 dataset

LHCb-CONF-2012-032

Modes ready to add in a combination

- Not ready means either:
  - Analysis has not finished (or even started...) or
  - has N(observables) ≦ N(additional parameters).
  - Systematics related to γ sensitivity incomplete.

	H	*D* mode	
$B^{\pm}$	**K**	**Kπ** / **Kπππ** / $K\pi\pi^0$	Sneha Malde, Sunday
	K	**KK** / **ππ** / $K_S\omega$	
	K	**$K_S\pi\pi$** / **K_SKK** / $K_SK\pi$ / $KK\pi^0$ / $\pi\pi\pi^0$	
	K	ππππ / Kπππ / KKππ	
	Kππ	Kπ / Kπππ / $K\pi\pi^0$	
	Kππ	KK / ππ	Mike Williams Monday
	Kππ	$K_S\pi\pi$ / K_SKK	
B^0	K* or Kπ	Kπ / Kπππ / $K\pi\pi^0$	
	K* or Kπ	KK / ππ	
	K* or Kπ	$K_S\pi\pi$ / K_SKK	
	π	Kππ / KKπ / πππ	
B_s	KK	Kπ / Kπππ / $K\pi\pi^0$ / KK / ππ / K_Shh	
	K	KKπ / Kππ / πππ	Steve Blusk Sunday
	Kππ	KKπ / Kππ / πππ	
B_c	D	Kπ / KK / ππ	
$B^{\pm}$	$K_S\pi$	Kπ / Kπππ / $K\pi\pi^0$ / KK / ππ / K_Shh	
	π/K	D^{*0}→Kπ / Kπππ / KK / ππ / K_Shh	
	π	**Kπ** / **Kπππ** / $K\pi\pi^0$	Sneha again
	π	**KK** / **ππ** / $K_S\omega$	
	π	$K_S\pi\pi$ / K_SKK / $K_SK\pi$ / $KK\pi^0$ / $\pi\pi\pi^0$	
	π	ππππ / Kπππ / KKππ	

Modes ready to add in a combination

"GGSZ" : arxiv/1209.5869

"K3π" : LHCb-CONF-2012-030

"ADS"
: Physics Letters B712, 203
"GLW"

- The parameters relating to the *D* decay are constrained by external information:
  - $D \rightarrow K^{\mp}\pi^{\pm}\pi^{\mp}\pi^{\pm}$ (including constraints from $D \rightarrow K^{\mp}\pi^{\pm}$)

"CLEOc" : Phys. Rev. D80, 031105

  - ΔA_{CP} = A(D→KK) - A(D→ππ)

"HFAG" : ΔACP = (-0.656±0.154)%

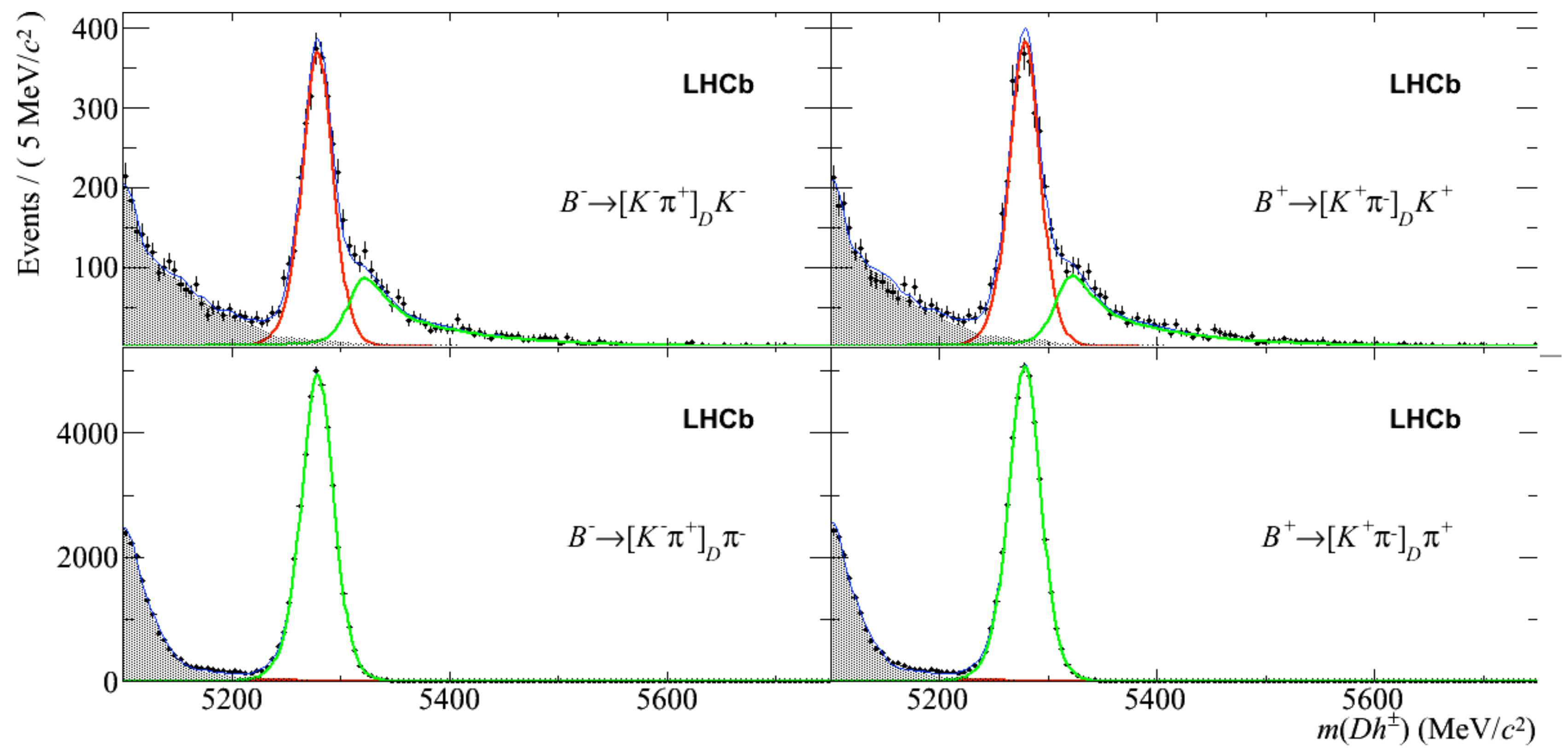
	H	*D* mode
$B^{\pm}$	**K**	**Kπ / Kπππ**
	K	**KK / ππ**
	K	**$K_S\pi\pi$ / K_SKK**
B^0		
B_s		
B_c		
$B^{\pm}$	**π**	**Kπ / Kπππ**
	π	**KK / ππ**

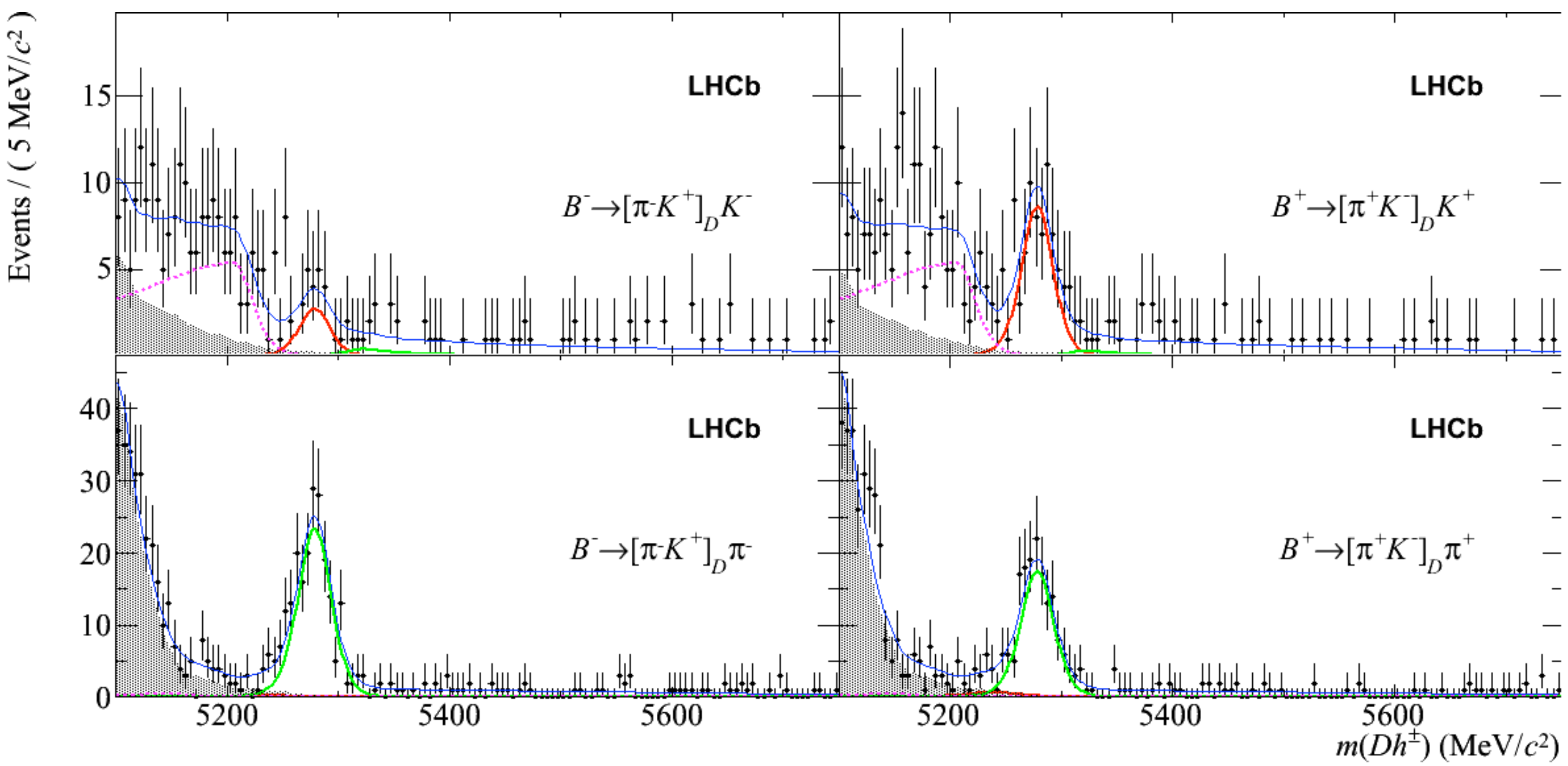
Parameters. gamma is not alone!

Analysis	N_{obs}	Parameters
$B^+ \to Dh^+$, $D \to hh$, GLW/ADS	14	γ, r_B, δ_B, r_B^π, δ_B^π, $R_{K/\pi}$, $r_{K\pi}$, $\delta_{K\pi}$, ΔA_{CP}
$B^+ \to DK^+$, $D \to K_S^0 h^+ h^-$, GGSZ	4	γ, r_B, δ_B
$B^+ \to Dh^+$, $D \to K\pi\pi\pi$, ADS	7	γ, r_B, δ_B, r_B^π, δ_B^π, $R_{K/\pi}$, $r_{K3\pi}$, $\delta_{K3\pi}$, $\kappa_{K3\pi}$
Cleo $D^0 \to K\pi$, $D^0 \to K\pi\pi\pi$	9	x_D, y_D, $\delta_{K\pi}$, $\delta_{K3\pi}$, $\kappa_{K3\pi}$, $r_{K\pi}$, $r_{K3\pi}$, $\mathcal{B}(K\pi)$, $\mathcal{B}(K\pi\pi\pi)$
ΔA_{CP}	1	ΔA_{CP}

e.g. one of the many relationships:

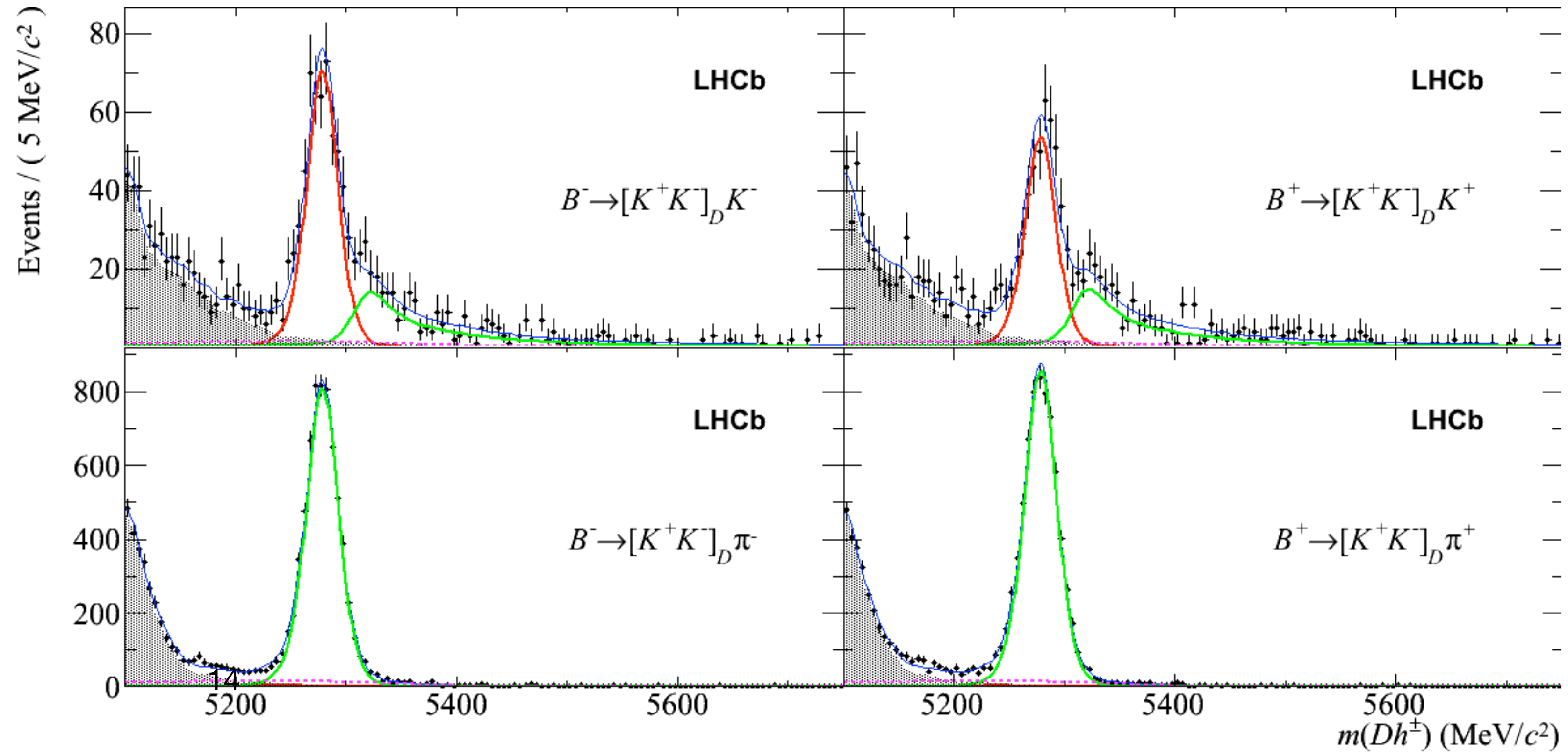
$$A_{ADS(K)} = \frac{2R^{K3\pi} r_{B(K)} r_D^{K3\pi} \sin(\delta_{B(K)} + \delta_D^{K3\pi}) \sin\gamma}{R_{ADS}}$$

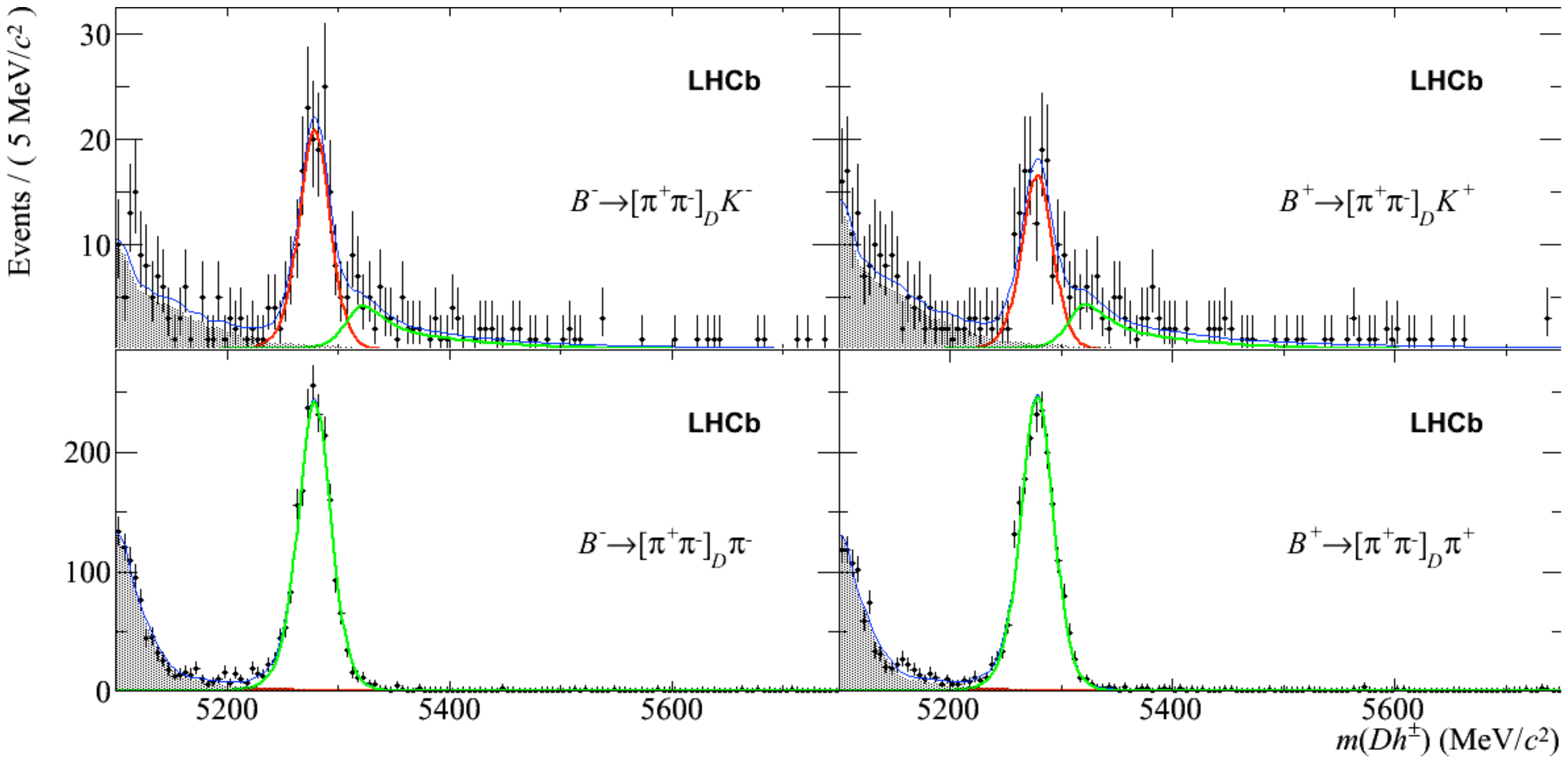


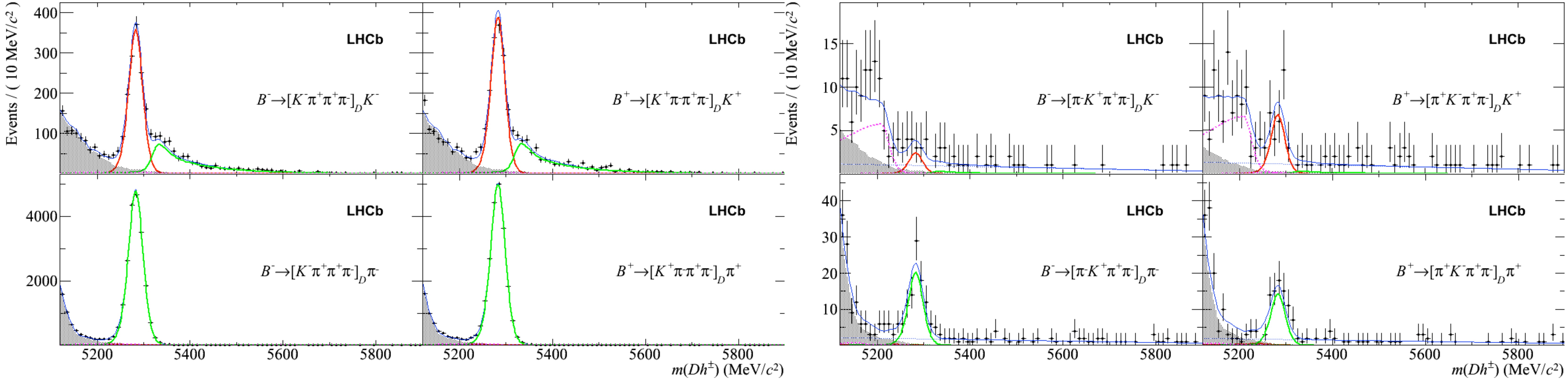


2-body ADS/GLW

: Physics Letters B712, 203



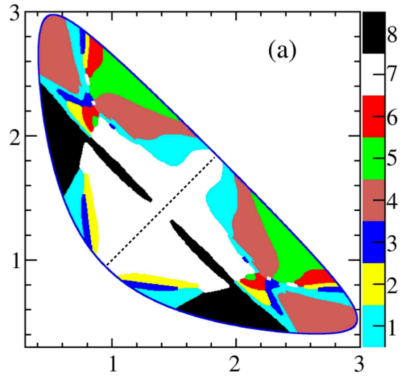




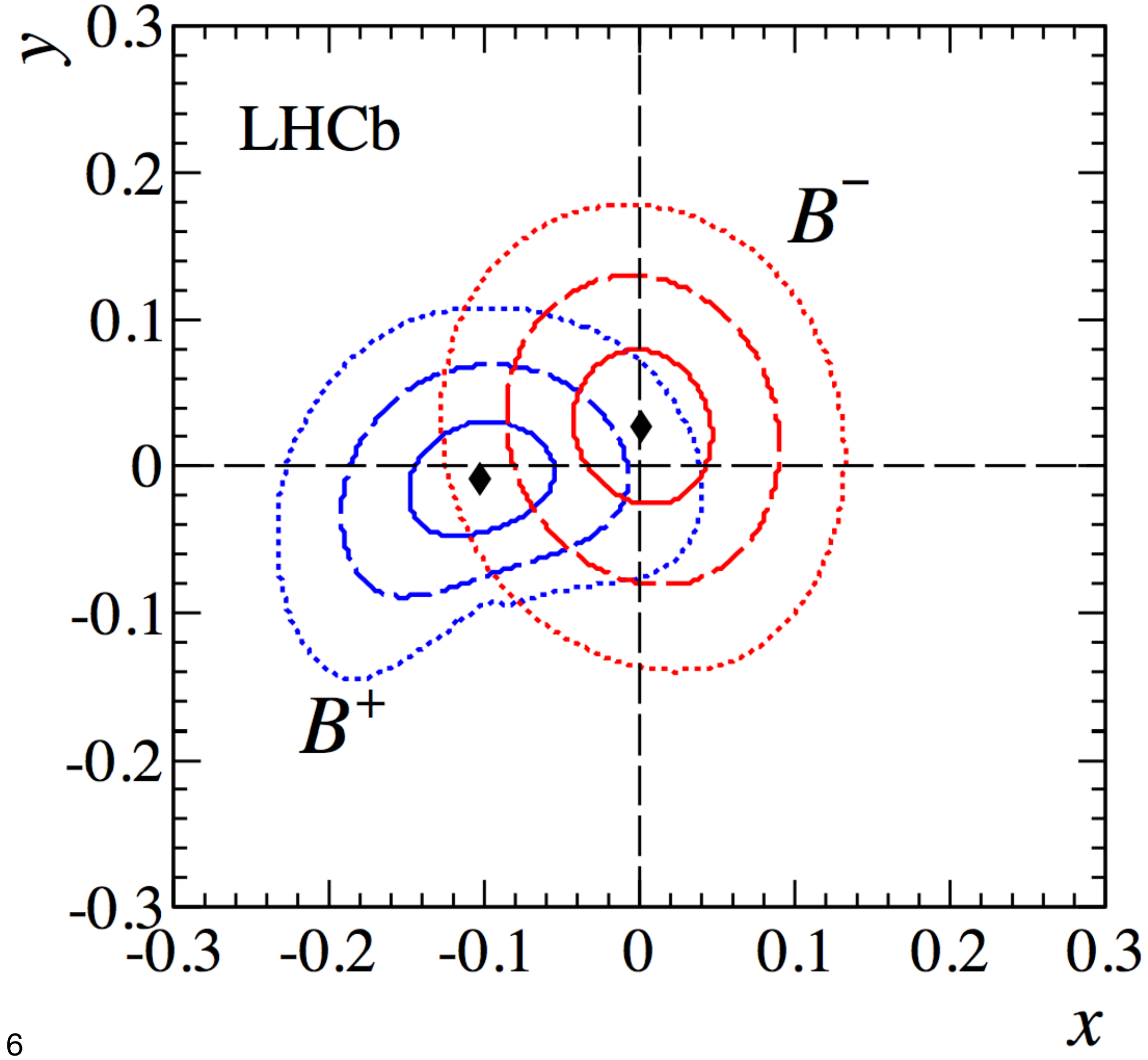
K3π : LHCb-CONF-2012-030

- Note, though these plots look similar to the 2-body the patterns of CP observables could, and should be different at the D-system parameters are different...
  - Orthogonal information; not “just stats”

Like elsewhere, the B→[K$_S$hh]$_D$K analysis battles the ambiguities



- Use the experimental likelihood
  - Dilute by systematics (with an assumption of uncorrelated Gaussian behaviour)



DK relations only

$$x^+ = r_{B(K)} \cos(\delta_{B(K)} + \gamma)$$
$$y^+ = r_{B(K)} \sin(\delta_{B(K)} + \gamma)$$
$$x^- = r_{B(K)} \cos(\delta_{B(K)} - \gamma)$$
$$y^- = r_{B(K)} \sin(\delta_{B(K)} - \gamma)$$

GGSZ : arxiv/1209.5869

Observables → parameters : ADS/GLW

“FAV”

$$R^{K\pi}_{K/\pi} = R_{cab}\frac{1 + r^2_{B(K)}r^{K\pi^2}_D + 2r_{B(K)}r^{K\pi}_D\cos(\delta_{B(K)} - \delta^{K\pi}_D)\cos\gamma}{1 + r^2_{B(\pi)}r^{K\pi^2}_D + 2r_{B(\pi)}r^{K\pi}_D\cos(\delta_{B(\pi)} - \delta^{K\pi}_D)\cos\gamma}$$

“GLW”

$$R^{KK}_{K/\pi} = R_{cab}\frac{1 + r^2_{B(K)} + 2r_{B(K)}\cos\delta_{B(K)}\cos\gamma}{1 + r^2_{B(\pi)} + 2r_{B(\pi)}\cos\delta_{B(\pi)}\cos\gamma}$$

$$R^{\pi\pi}_{K/\pi} = R^{KK}_{K/\pi}$$

“FAV”

$$A^{K\pi}_{\pi} = \frac{2r^2_{B(\pi)}\sin(\delta_{B(\pi)} - \delta^{K\pi}_D)\sin\gamma}{1 + r^2_{B(\pi)}r^{K\pi^2}_D + 2r_{B(\pi)}r^{K\pi}_D\cos(\delta_{B(\pi)} - \delta^{K\pi}_D)\cos\gamma}$$

$$A^{K\pi}_{K} = \frac{2r_{B(K)}r^{K\pi}_D\sin(\delta_{B(K)} - \delta^{K\pi}_D)\sin\gamma}{1 + r^2_{B(K)}r^{K\pi^2}_D + 2r_{B(K)}r^{K\pi}_D\cos(\delta_{B(K)} - \delta^{K\pi}_D)\cos\gamma}$$

“GLW”

$$A^{KK}_{\pi} = \frac{2r_{B(\pi)}\sin\delta_{B(\pi)}\sin\gamma}{1 + r^2_{B(\pi)} + 2r_{B(\pi)}\cos\delta_{B(\pi)}\cos\gamma} + A_{dir}(D \to KK)$$

$$A^{\pi\pi}_{\pi} = \frac{2r_{B(\pi)}\sin\delta_{B(\pi)}\sin\gamma}{1 + r^2_{B(\pi)} + 2r_{B(\pi)}\cos\delta_{B(\pi)}\cos\gamma} + A_{dir}(D \to \pi\pi)$$

$$A^{KK}_{K} = \frac{2r_{B(K)}\sin\delta_{B(K)}\sin\gamma}{1 + r^2_{B(K)} + 2r_{B(K)}\cos\delta_{B(K)}\cos\gamma} + A_{dir}(D \to KK)$$

$$A^{\pi\pi}_{K} = \frac{2r_{B(K)}\sin\delta_{B(K)}\sin\gamma}{1 + r^2_{B(K)} + 2r_{B(K)}\cos\delta_{B(K)}\cos\gamma} + A_{dir}(D \to \pi\pi)$$

“ADS”

$$R^{K\pi}_{\pi-} = \frac{r^2_{B(\pi)} + r^{K\pi^2}_D + 2r_{B(\pi)}r^{K\pi}_D\cos(\delta_{B(\pi)} + \delta^{K\pi}_D - \gamma)}{1 + r^2_{B(\pi)}r^{K\pi^2}_D + 2r_{B(\pi)}r^{K\pi}_D\cos(\delta_{B(\pi)} - \delta^{K\pi}_D - \gamma)}$$

$$R^{K\pi}_{\pi-} = \frac{r^2_{B(\pi)} + r^{K\pi^2}_D + 2r_{B(\pi)}r^{K\pi}_D\cos(\delta_{B(\pi)} + \delta^{K\pi}_D + \gamma)}{1 + r^2_{B(\pi)}r^{K\pi^2}_D + 2r_{B(\pi)}r^{K\pi}_D\cos(\delta_{B(\pi)} - \delta^{K\pi}_D + \gamma)}$$

$$R^{K\pi}_{K-} = \frac{r^2_{B(K)} + r^{K\pi^2}_D + 2r_{B(K)}r^{K\pi}_D\cos(\delta_{B(K)} + \delta^{K\pi}_D - \gamma)}{1 + r^2_{B(K)}r^{K\pi^2}_D + 2r_{B(K)}r^{K\pi}_D\cos(\delta_{B(\pi)} - \delta^{K\pi}_D - \gamma)}$$

$$R^{K\pi}_{K+} = \frac{r^2_{B(K)} + r^{K\pi^2}_D + 2r_{B(K)}r^{K\pi}_D\cos(\delta_{B(K)} + \delta^{K\pi}_D + \gamma)}{1 + r^2_{B(K)}r^{K\pi^2}_D + 2r_{B(K)}r^{K\pi}_D\cos(\delta_{B(\pi)} - \delta^{K\pi}_D + \gamma)}$$

DK-only relations

$$A_{FAV(K)} = \frac{2r_{B(K)}r^{K\pi}_D\sin(\delta_{B(K)} - \delta^{K\pi}_D)\sin\gamma}{1 + r^2_{B(K)}r^{K\pi^2}_D + 2r_{B(K)}r^{K\pi}_D\cos(\delta_{B(K)} - \delta^{K\pi}_D)\cos\gamma}$$

$$R_{CP(K)} = 1 + r^2_{B(K)} + 2r_{B(K)}\cos\delta_{B(K)}\cos\gamma$$

$$A_{CP(K)}(KK) = \frac{2r_{B(K)}\sin\delta_{B(K)}\sin\gamma}{R_{CP(K)}} + A_{dir}(D \to KK)$$

$$A_{CP(K)}(\pi\pi) = \frac{2r_{B(K)}\sin\delta_{B(K)}\sin\gamma}{R_{CP(K)}} + A_{dir}(D \to \pi\pi)$$

$$R_{ADS(K)} = \frac{r^2_{B(K)}r^{K\pi^2}_D + 2r_{B(K)}r^{K\pi}_D\cos(\delta_{B(K)} + \delta^{K\pi}_D)\cos\gamma}{1 + r^2_{B(K)}r^{K\pi^2}_D + 2r_{B(K)}r^{K\pi}_D\cos(\delta_{B(K)} - \delta^{K\pi}_D)\cos\gamma}$$

$$A_{ADS(K)} = \frac{2r_{B(K)}r^{K\pi}_D\sin(\delta_{B(K)} + \delta^{K\pi}_D)\sin\gamma}{R_{ADS(K)}}$$

- Use throughout:

$$\Delta(A_{CP}) = A_{CP}(D \to K^+K^-) - A_{CP}(D \to \pi^+\pi^-)$$

- And external information on r_D and δ_D (next slide)

Observables → parameters : K3π

- A rather similar set of equations is used
- Except that an new type of parameter, the coherence factor, $R^{K3\pi}$ is required

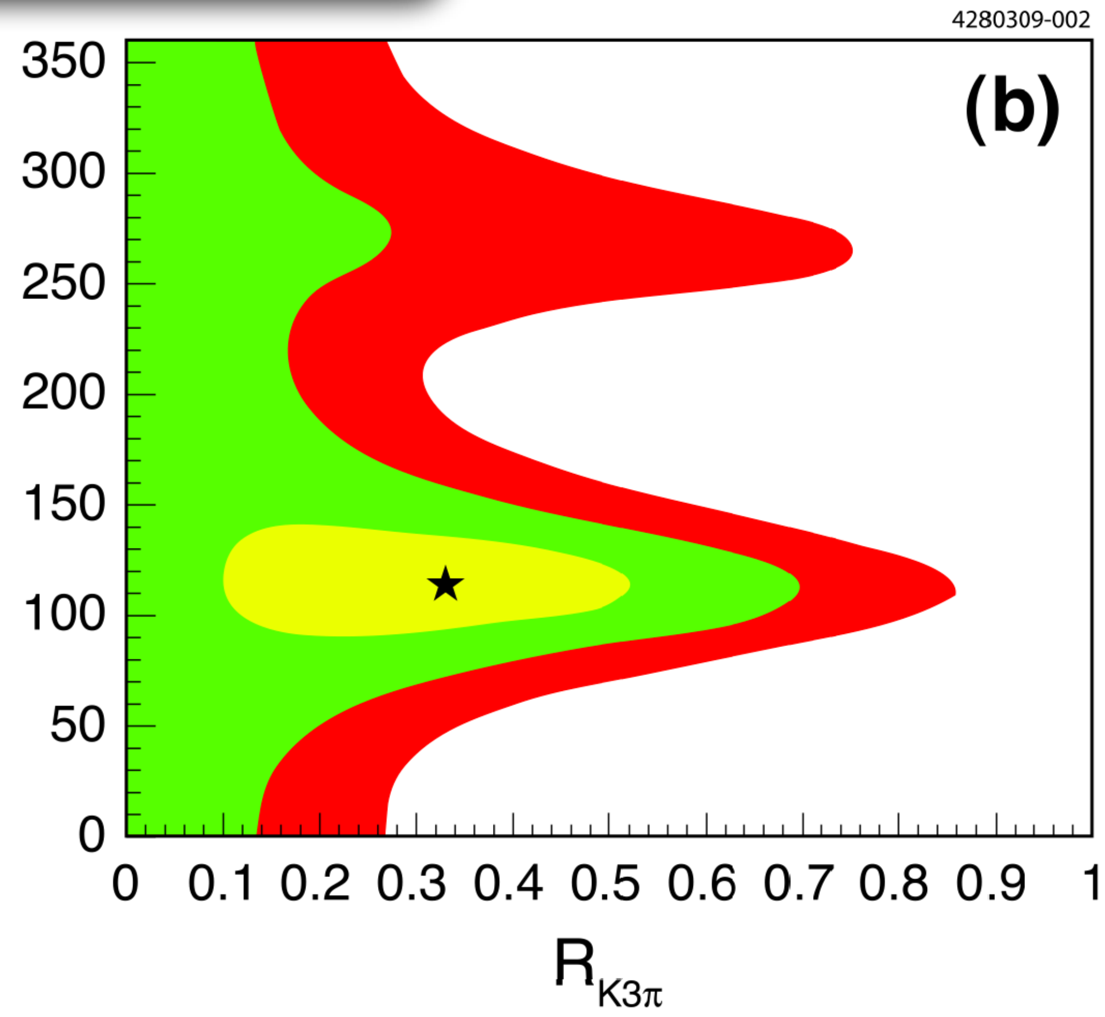
$$
\begin{aligned}
R^{K3\pi}_{DK/D\pi} &= R_{cab}\frac{1 + r^2_{B(K)} r^{K3\pi\,2}_D + 2R^{K3\pi} r_{B(K)} r^{K3\pi}_D \cos(\delta_{B(K)} - \delta^{K3\pi}_D)\cos\gamma}{1 + r^2_{B(\pi)} r^{K3\pi\,2}_D + 2R^{K3\pi} r_{B(\pi)} r^{K3\pi}_D \cos(\delta_{B(\pi)} - \delta^{K3\pi}_D)\cos\gamma} \\
A^{K3\pi}_{\pi} &= \frac{2R^{K3\pi} r^2_{B(\pi)} \sin(\delta_{B(\pi)} - \delta^{K3\pi}_D)\sin(\gamma)}{1 + r^2_{B(\pi)} r^{K3\pi\,2}_D + 2R^{K3\pi} r_{B(\pi)} r^{K3\pi}_D \cos(\delta_{B(\pi)} - \delta^{K3\pi}_D)\cos\gamma} \\
A^{K3\pi}_{K} &= \frac{2R^{K3\pi} r_{B(K)} r^{K3\pi}_D \sin(\delta_{B(K)} - \delta^{K3\pi}_D)\sin\gamma}{1 + r^2_{B(K)} r^{K3\pi\,2}_D + 2R^{K3\pi} r_{B(K)} r^{K3\pi}_D \cos(\delta_{B(K)} - \delta^{K3\pi}_D)\cos\gamma}
\end{aligned}
$$

“FAV”

$$
\begin{aligned}
R^{K3\pi}_{\pi-} &= \frac{r^2_{B(\pi)} + r^{K3\pi\,2}_D + 2R^{K3\pi} r_{B(\pi)} r^{K3\pi}_D \cos(\delta_{B(\pi)} + \delta^{K3\pi}_D - \gamma)}{1 + r^2_{B(\pi)} r^{K3\pi\,2}_D + 2R^{K3\pi} r_{B(\pi)} r^{K3\pi}_D \cos(\delta_{B(\pi)} - \delta^{K3\pi}_D - \gamma)} \\
R^{K3\pi}_{\pi+} &= \frac{r^2_{B(\pi)} + r^{K3\pi\,2}_D + 2R^{K3\pi} r_{B(\pi)} r^{K3\pi}_D \cos(\delta_{B(\pi)} + \delta^{K3\pi}_D + \gamma)}{1 + r^2_{B(\pi)} r^{K3\pi\,2}_D + 2R^{K3\pi} r_{B(\pi)} r^{K3\pi}_D \cos(\delta_{B(\pi)} - \delta^{K3\pi}_D + \gamma)} \\
R^{K3\pi}_{K-} &= \frac{r^2_{B(K)} + r^{K3\pi\,2}_D + 2R^{K3\pi} r_{B(K)} r^{K3\pi}_D \cos(\delta_{B(K)} + \delta^{K3\pi}_D - \gamma)}{1 + r^2_{B(K)} r^{K3\pi\,2}_D + 2R^{K3\pi} r_{B(K)} r^{K3\pi}_D \cos(\delta_{B(\pi)} - \delta^{K3\pi}_D - \gamma)} \\
R^{K3\pi}_{K+} &= \frac{r^2_{B(K)} + r^{K3\pi\,2}_D + 2R^{K3\pi} r_{B(K)} r^{K3\pi}_D \cos(\delta_{B(K)} + \delta^{K3\pi}_D + \gamma)}{1 + r^2_{B(K)} r^{K3\pi\,2}_D + 2R^{K3\pi} r_{B(K)} r^{K3\pi}_D \cos(\delta_{B(\pi)} - \delta^{K3\pi}_D + \gamma)}
\end{aligned}
$$

“ADS”

CLEO-c input



$$
\begin{aligned}
&D^0 \to F && A_F^2 \\
&D^0 \to \bar{F} && A_{\bar{F}}^2[1 - (y/r_D^F)\, R_F \cos\delta_D^F \\
& && +(x/r_D^F)\, R_F \sin\delta_D^F + (y^2 + x^2)/2(r_D^F)^2]
\end{aligned}
$$

Statistical treatment

- PDFs are formed from the contributing analysis results either from
    - the experimental likelihoods
    - the experimental result and its covariance matrix, i.e.:

$$f_i \propto \exp\left(-\chi^2\right) \propto \exp\left(-(\vec{A}_i(\vec{\alpha}_i) - \vec{A}_{i,\mathrm{obs}})^T V_i^{-1} (\vec{A}_i(\vec{\alpha}_i) - \vec{A}_{i,\mathrm{obs}})\right)$$

observables

$$\vec{A} = (x_-, y_-, x_+, y_+, A_{CP+}, R_{CP+}, R_+$$

parameters

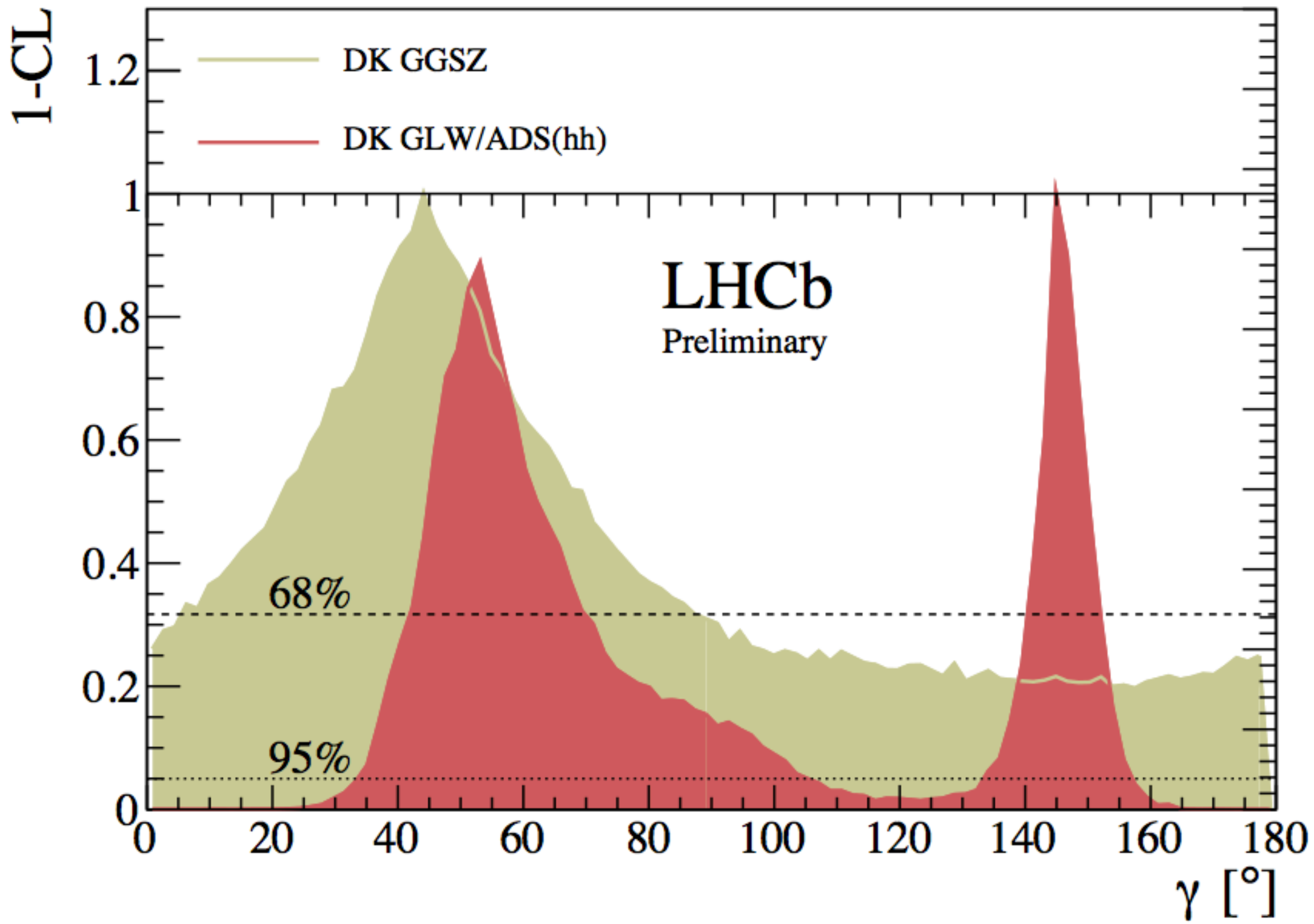
$$\vec{\alpha} = (\gamma, r_B, \delta_B, r_{K\pi}, \delta_{K\pi})^T$$

- The global best-fit is defined as that which maximises the likelihood

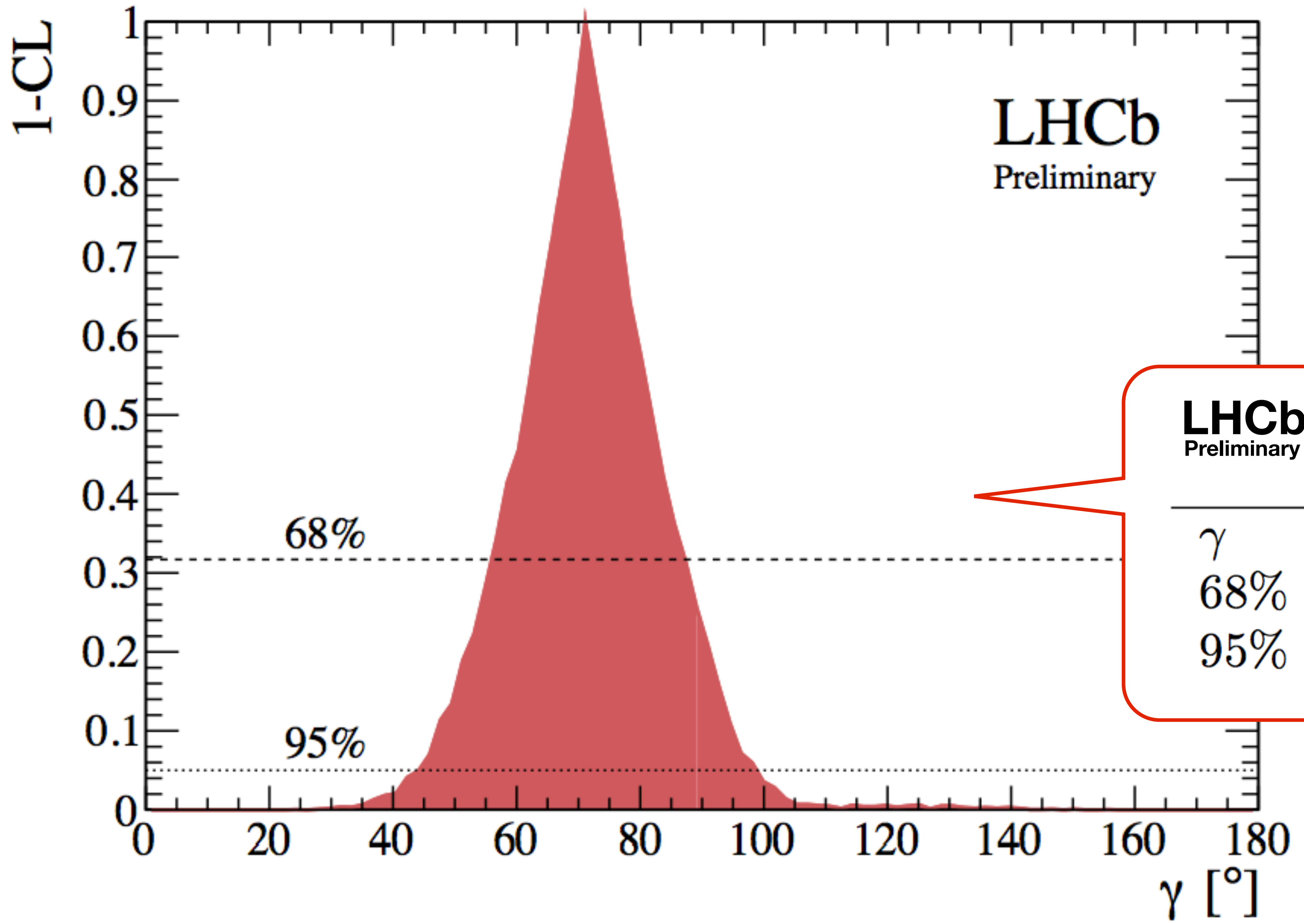
$$\mathcal{L}(\vec{\alpha}) = \prod_i f_i(\vec{A}_{i,\mathrm{obs}} | \vec{A}_i(\vec{\alpha}_i)) .$$

- Our confidence in in this best-fit is calculated by inspecting the change in χ^2 vs. a parameter of interest, = $\Delta\chi^2$
- The "probability" (well, 1-CL) is obtained with toy experiments generated at many values between [0–180]°
    - Ask: at a given value of γ, what proportion of toy-fits have $\Delta\chi^2$ larger than the real data has (at that given value)
    - To be explicit, this is the "**PLUGIN**" method. Coverage has been checked though studies are incomplete.

Using $B^- \to DK^-$ decays (2-body + GGSZ) + D-system (r_D,δ_D)



Using $B^- \to DK^-$ decays + D-system (from CLEOc)

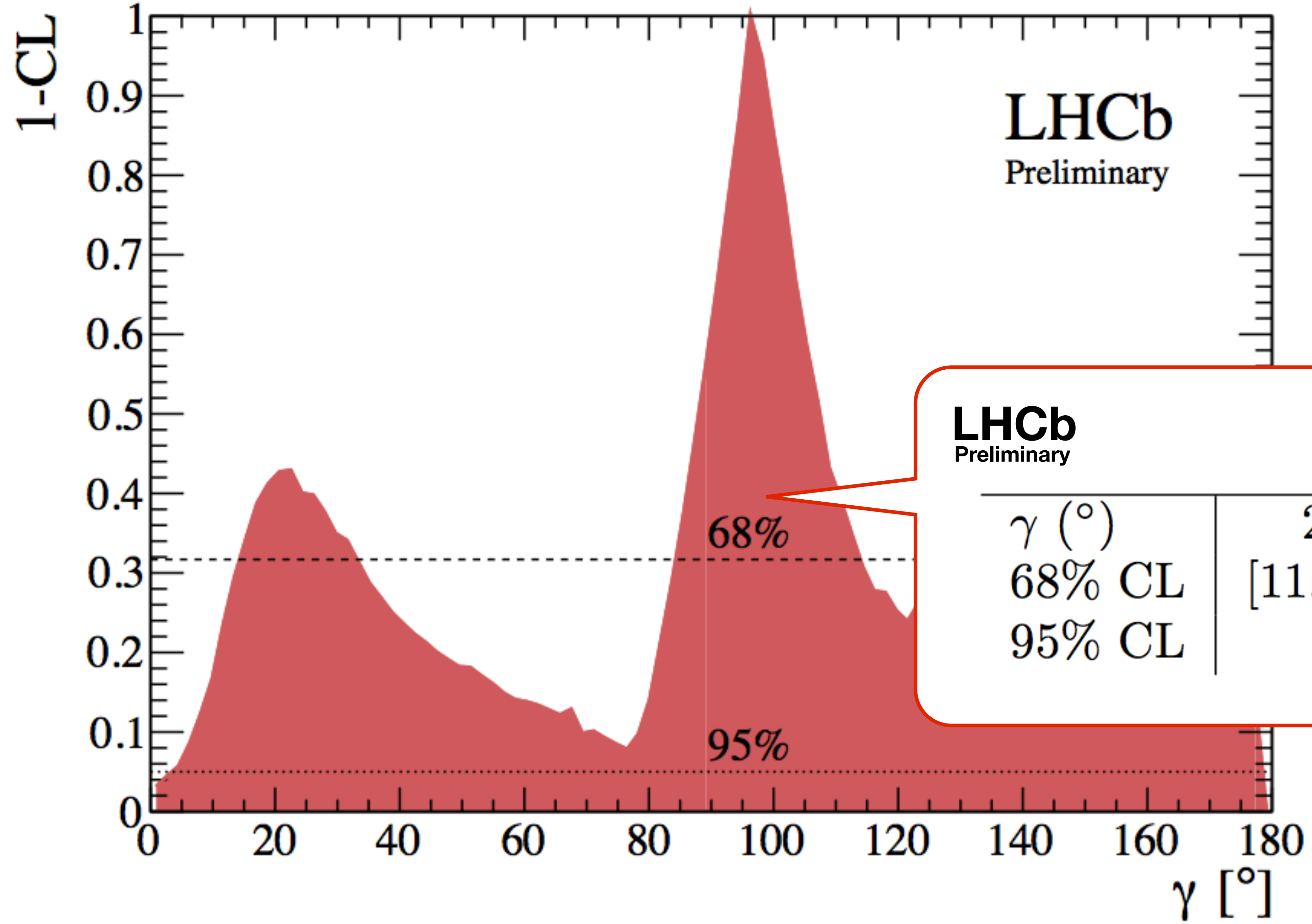


LHCb Preliminary — $B^\pm \to DK^\pm$

γ	$71.1°$	$^{+16.6}_{-15.7}$
68% CL	$[55.4,\ 87.7]°$	
95% CL	$[41.4, 101.3]°$	

Using $B^- \to D\pi^-$ decays + CLEOc

(result available from the “2-body ADS/GLW” + “K3π ADS” analyses)

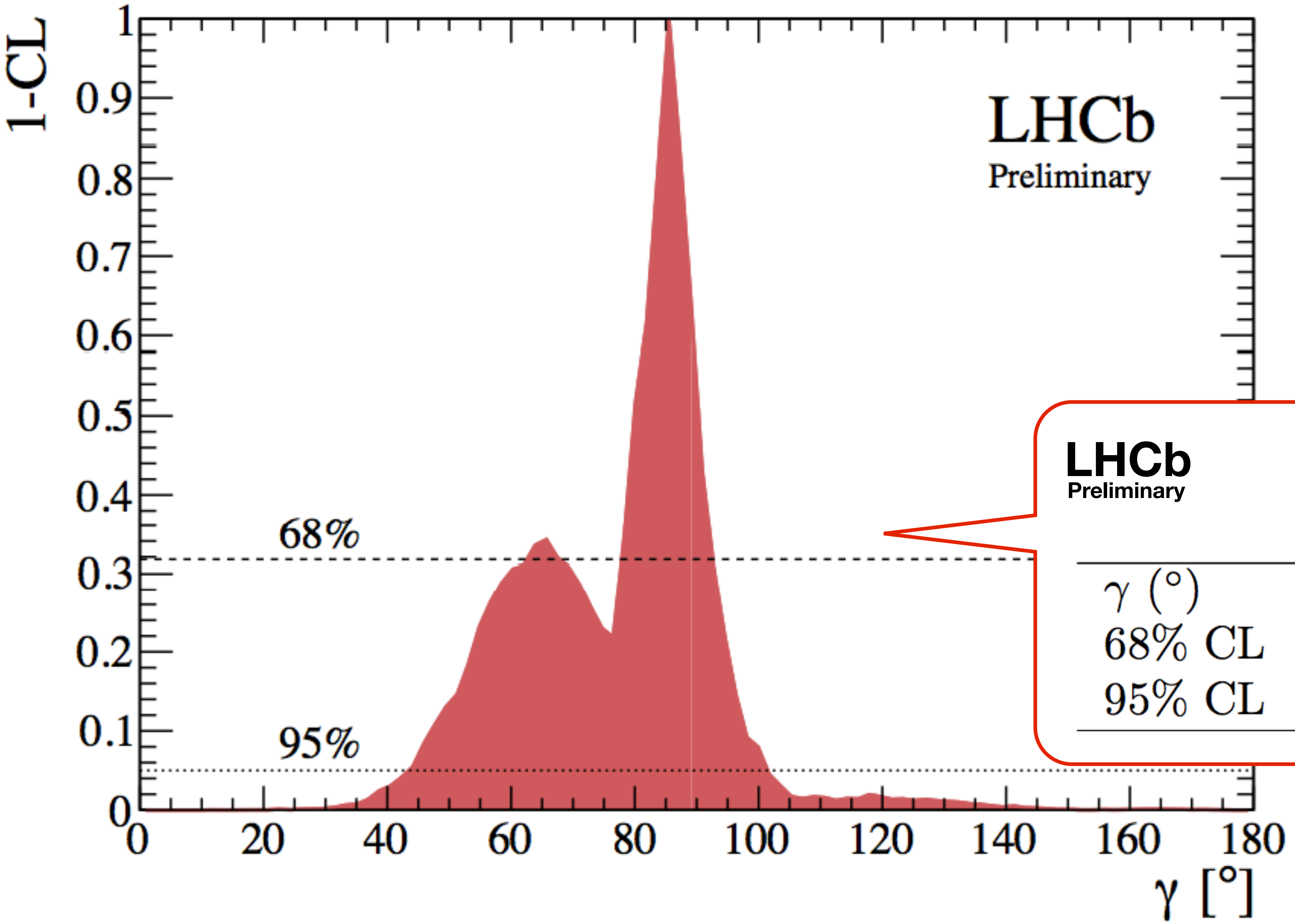


LHCb Preliminary

$B^\pm \to D\pi^\pm$

γ (°)	$20.25°$	$96.8°$
68% CL	$[11.7, 33.1]°$	$[85.5, 114.5]°$
95% CL	–	–

Using both $B^- \to DK^-$ and $B^- \to D\pi^-$ decays + CLEOc

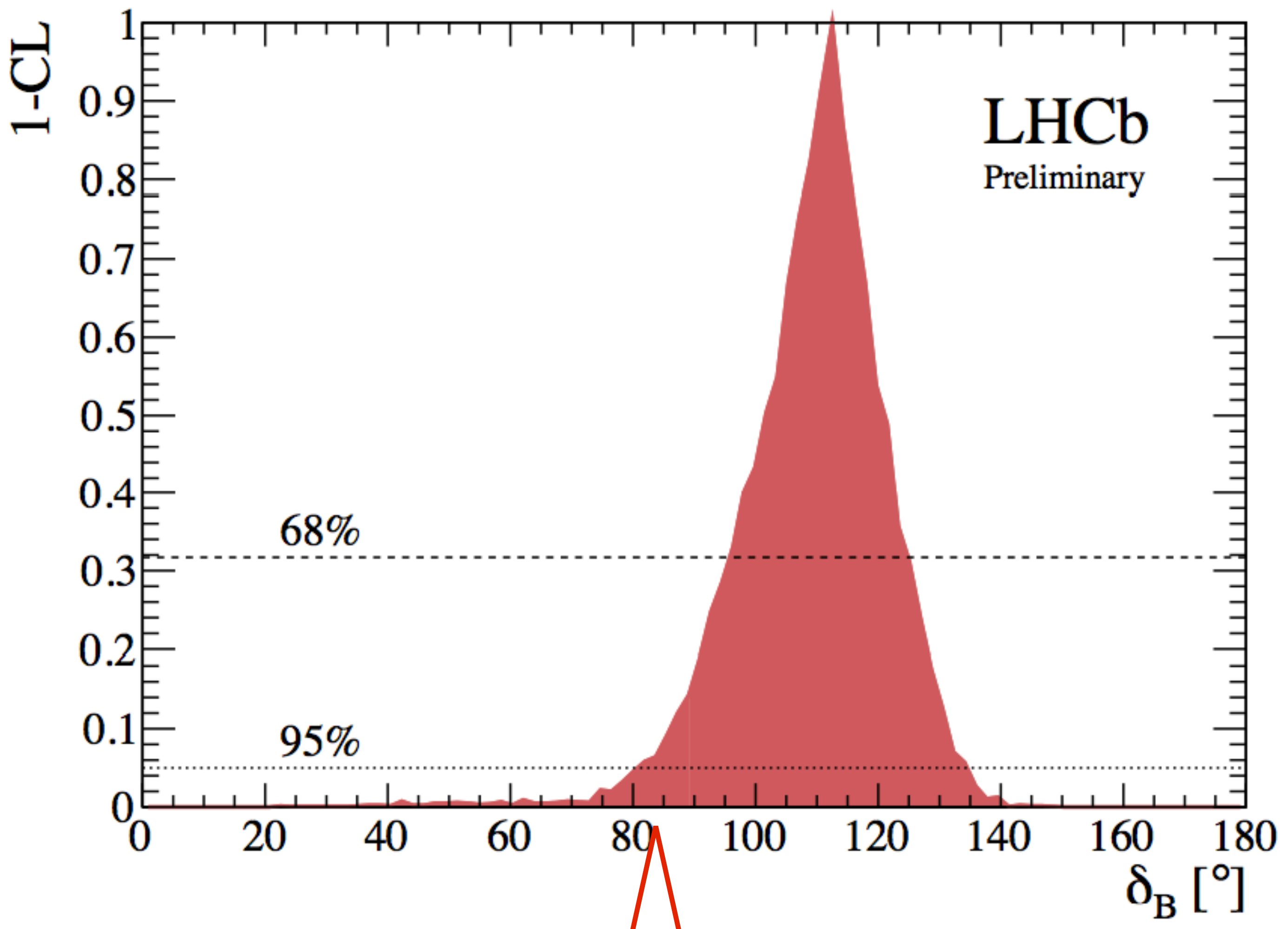


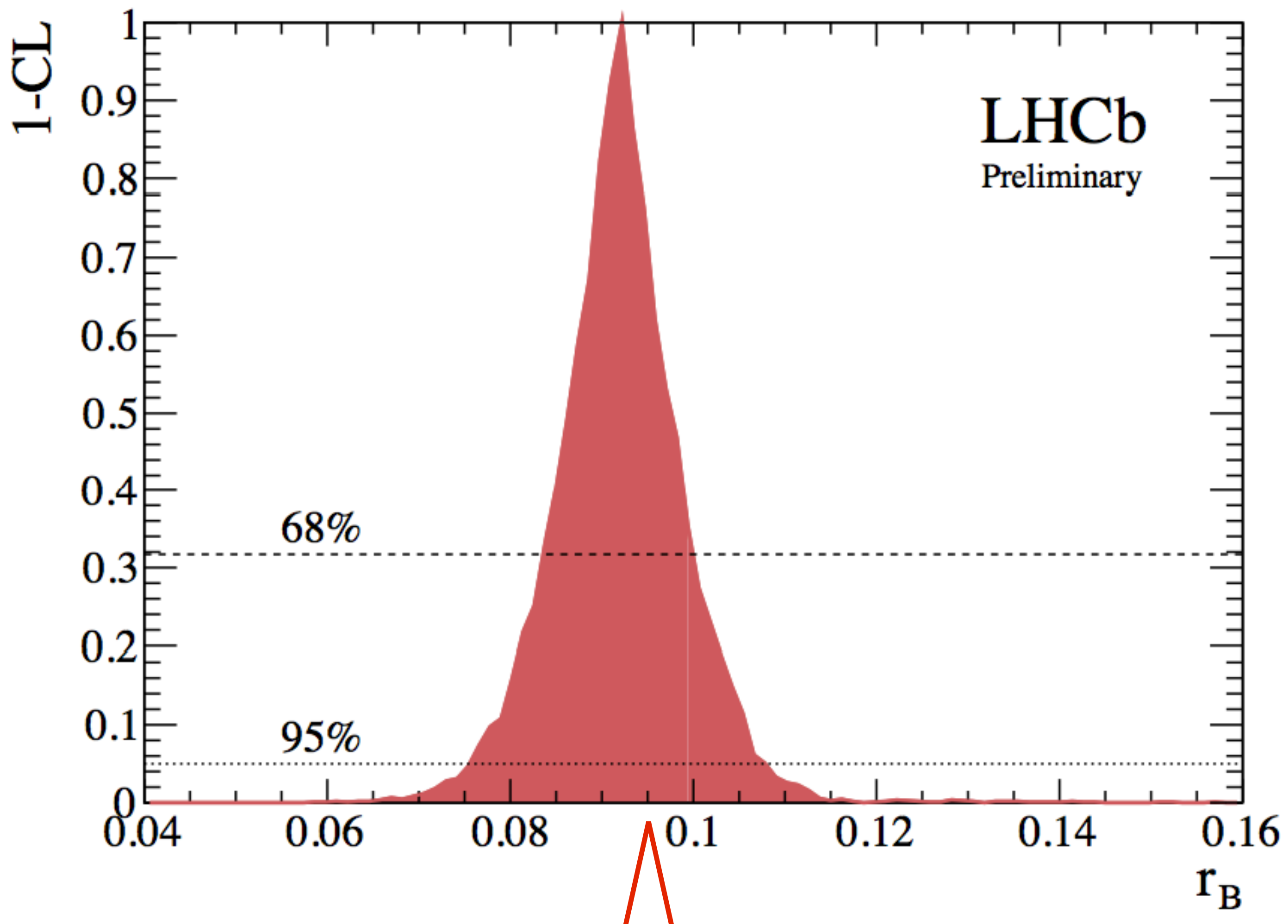
LHCb
Preliminary

$B^\pm \to DK^\pm$
$B^\pm \to D\pi^\pm$

γ (°)	63.7°	85.1
68% CL	[61.8, 67.8]	[77.9, 92.4]
95% CL		[43.8, 101.5]

$r_{B(K)}$ and $\delta_{B(K)}$





LHCb Preliminary

$^{+10.0°}_{-12.6°}$

$\delta_{B(K)}$ (°)	119.3°
68% CL	[106.7, 129.3]°
95% CL	[81.3, 138.3]°

LHCb Preliminary

$^{+0.008°}_{-0.009°}$

$r_{B(K)}$	0.095
68% CL	[0.086, 0.103]
95% CL	[0.078, 0.111]

Conclusion

- The study of direct *CP* violation has fantastic promise at the LHCb upgrade. Huge samples to fine tune Dalitz models and provide deep understanding of the penguin contributions in the search for non-CKM CPV
- The prospect of a precise (~1%) measurement of γ_{CKM} with tree-level processes alone is realistic
- 1st step: From the 2011 sample of $B^{\pm}\to DK^{\pm}$ decays, we find : $\gamma = 71.1^{\circ}\,^{+16.6}_{-15.7}$ $[41.4 - 101.3]_{95\%\ CL}$
- For $B^{\pm}\to DK^{\pm}$ + $B^{\pm}\to D\pi^{\pm}$ decays, an interesting maxima in the likelihood appears at 85.1°.
  - This solution is consistent with the input measurements. 95% CL : largely unchanged: $[43.8 - 101.5]_{95\%\ CL}$
  - And we note that it is only a 1 sigma effect...

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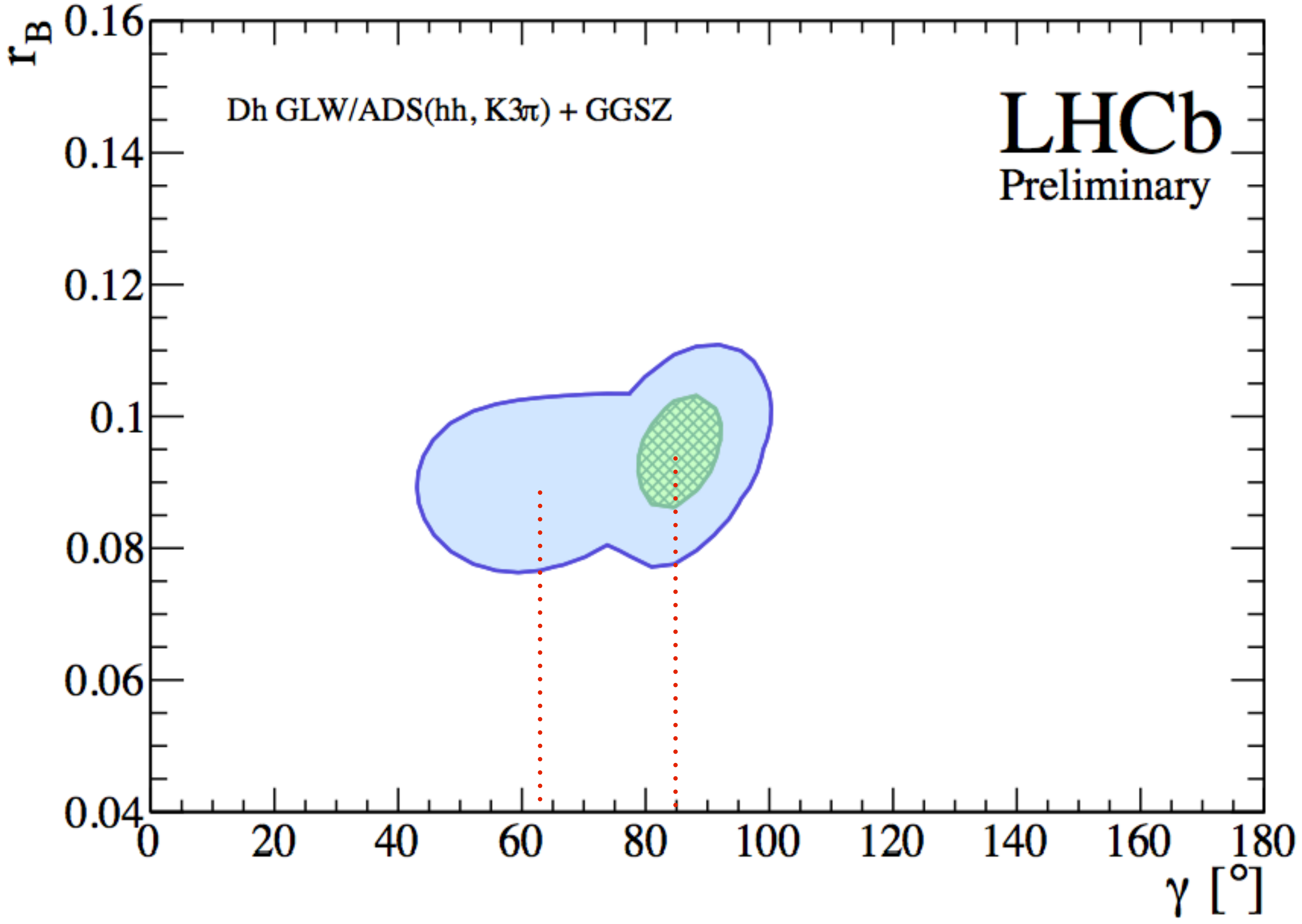
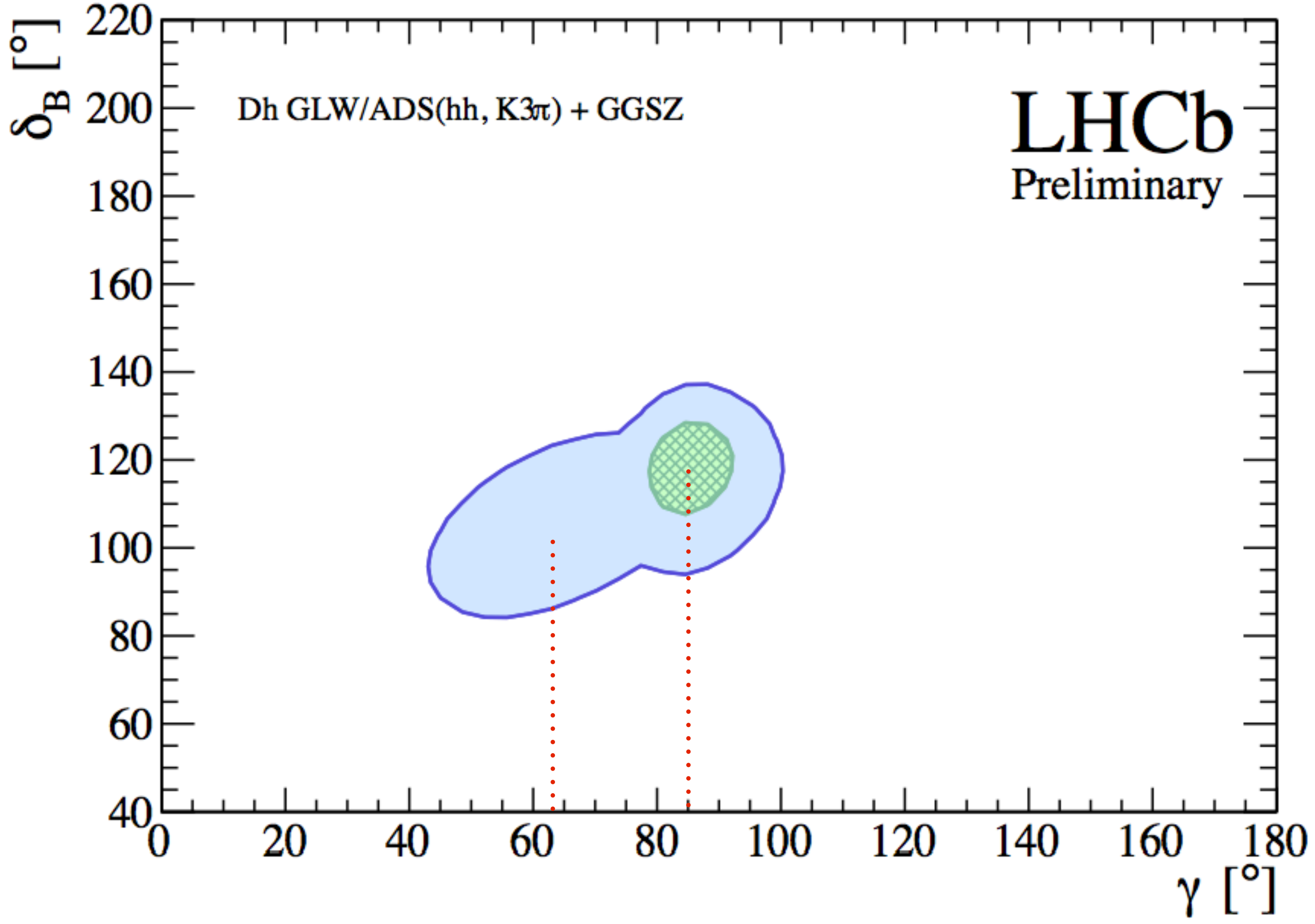
BACKUP

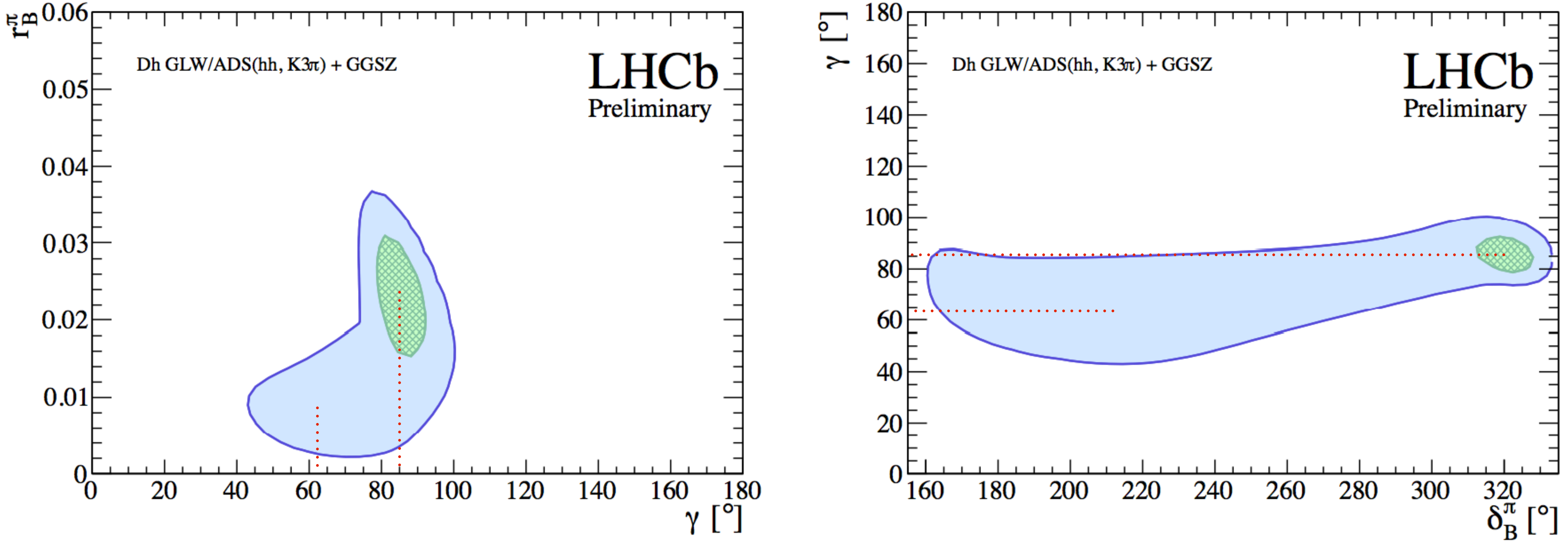
γ vs. $r_{B(K)}$ and $\delta_{B(K)}$





- Seems fine. About where you'd expect. DK system does not strongly differentiate between solutions

γ vs. $r_{B(\pi)}$ and $\delta_{B(\pi)}$



- The global minima is at a "surprisingly" high value of $r_{B(\pi)}$. One might expect $r_{B(\pi)} \simeq 0.005 - 0.010$

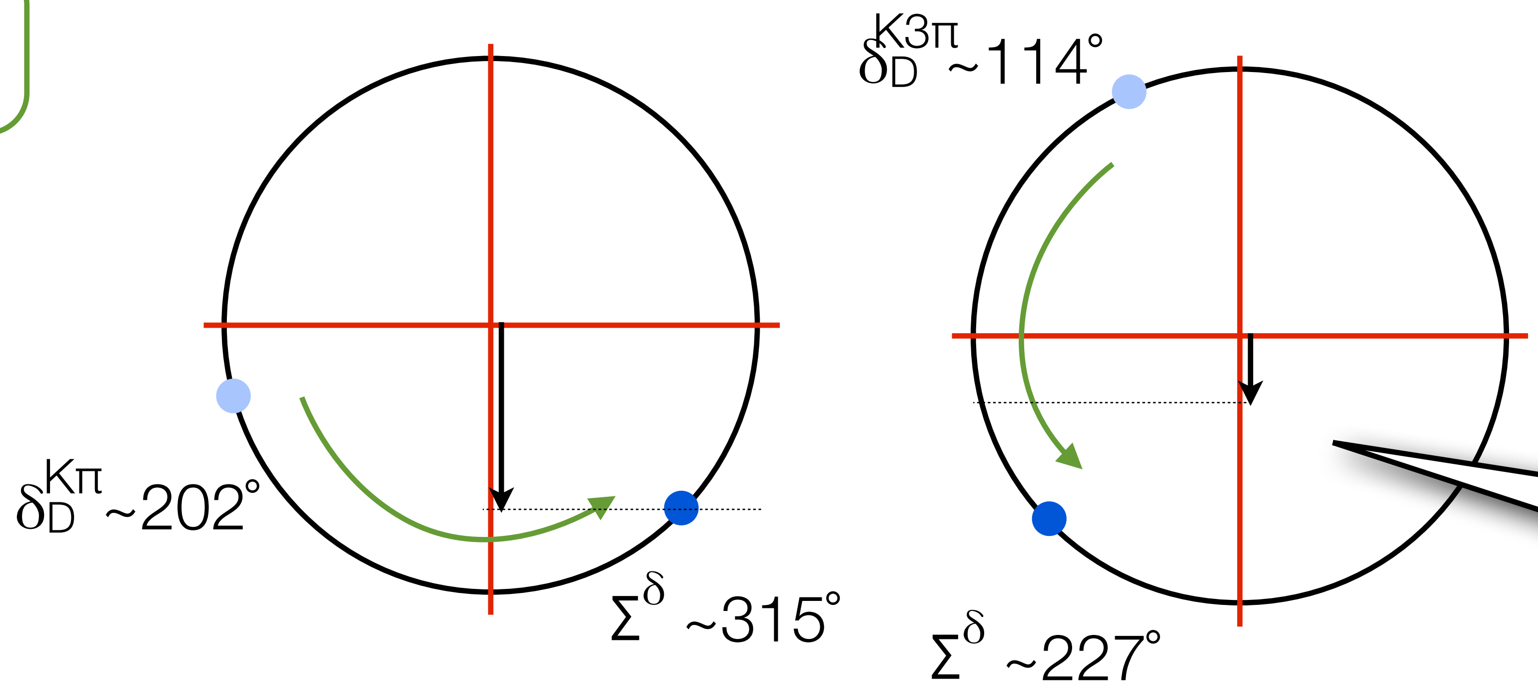
Is there any internal tension in our results?

$$A_{ADS(K)} = \frac{2R^{K3\pi} r_{B(K)} r_D^{K3\pi} \sin(\delta_{B(K)} + \delta_D^{K3\pi}) \sin\gamma}{R_{ADS}}$$

The only way to have an negative asymmetry is for the sum of strong phases to be ∈[180 - 360]°

- In B→DK, a consistent picture is seen with the strong phase around the 'usual' value.

δ_B^{DK}~113°

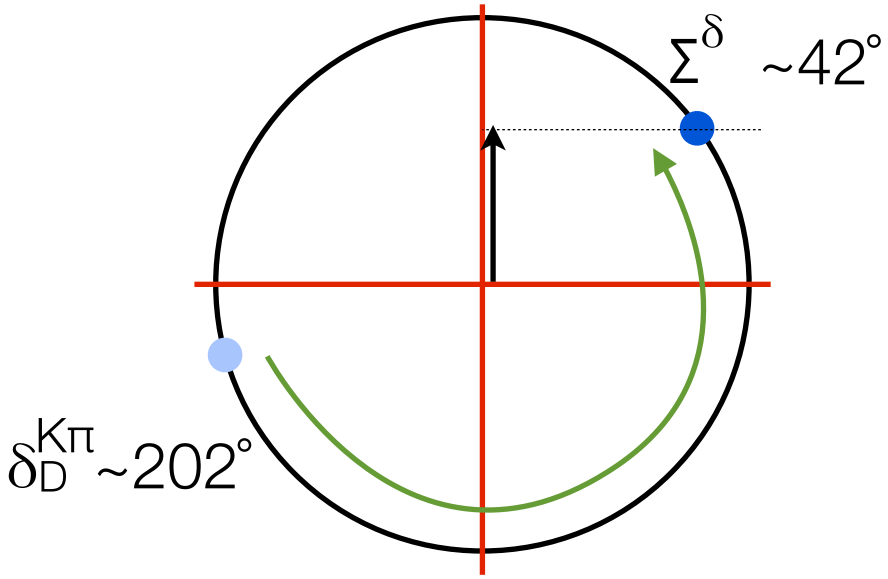


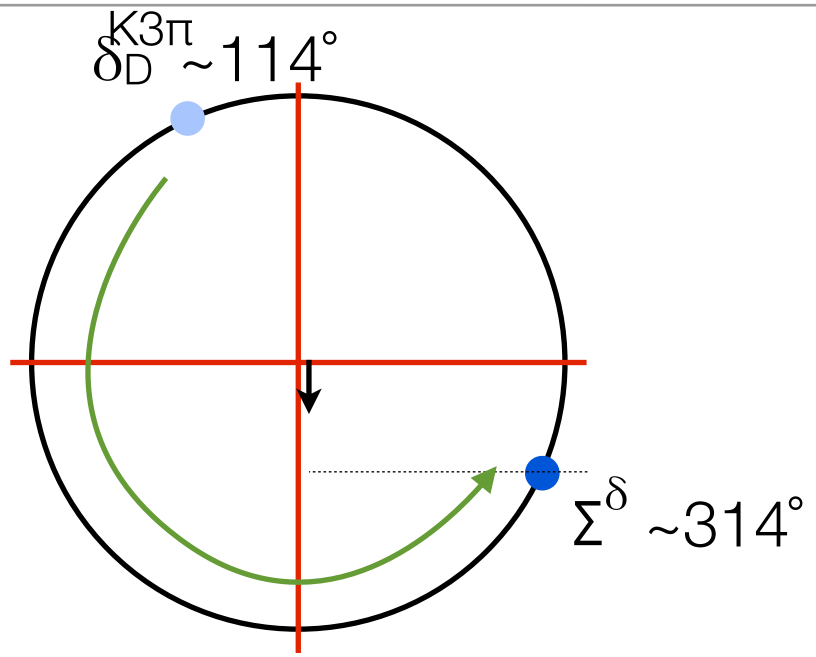
The small coherence factor in D→K3π dilutes the observed asymmetry (shortens the arrow)

In B→Dπ, we have two possible solutions

$\delta_B^{D\pi}$~210°

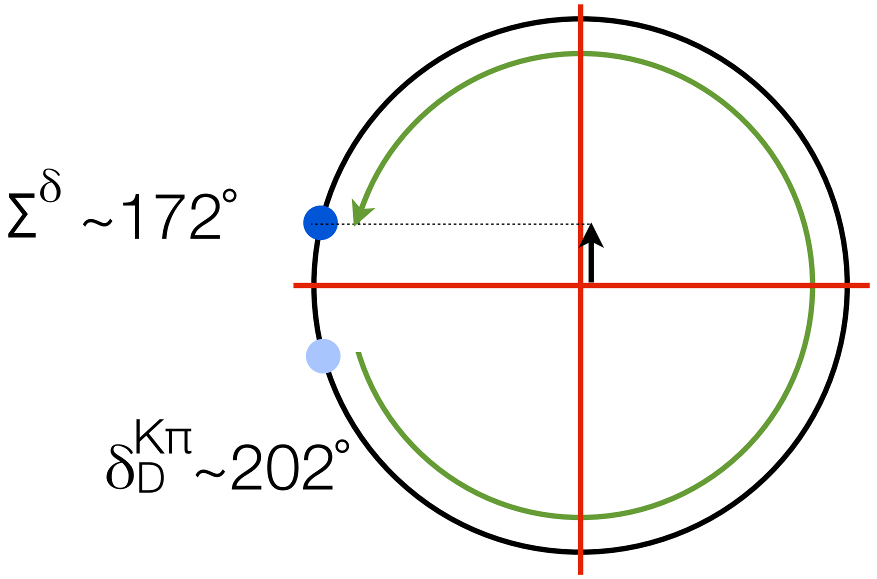
$A_{ADS(\pi)}(K\pi)$ = +big
$A_{ADS(\pi)}(K3\pi)$ = −small

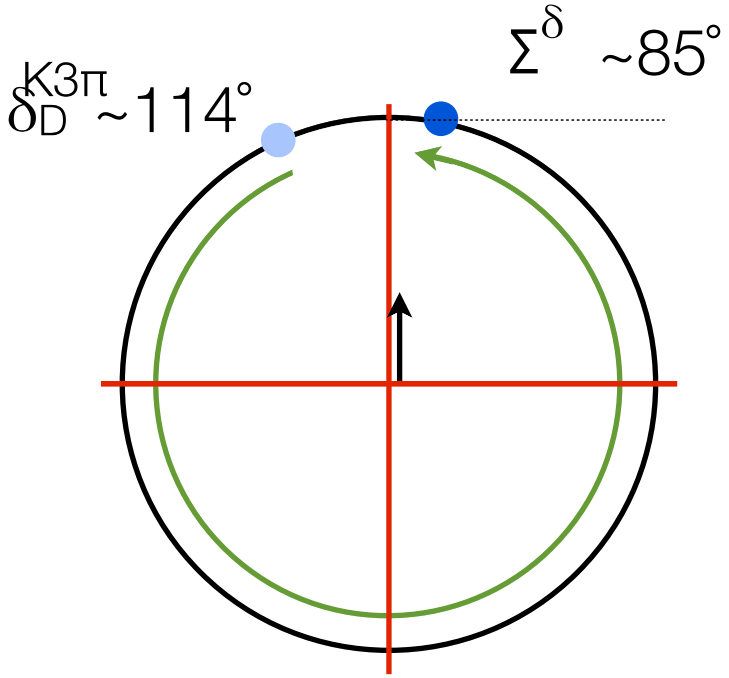




$\delta_B^{D\pi}$~320°

$A_{ADS(\pi)}(K\pi)$ = +small
$A_{ADS(\pi)}(K3\pi)$ = +small





So.. the surprise is that the asymmetry in $B^{\pm}\rightarrow[\pi^{\pm}K^{\mp}\pi\pi]_D\pi^{\pm}$ is in the same sense as the asymmetry in $B^{\pm}\rightarrow[\pi^{\pm}K^{\mp}]_D\pi^{\pm}$

$\delta_B^{D\pi}$~210°

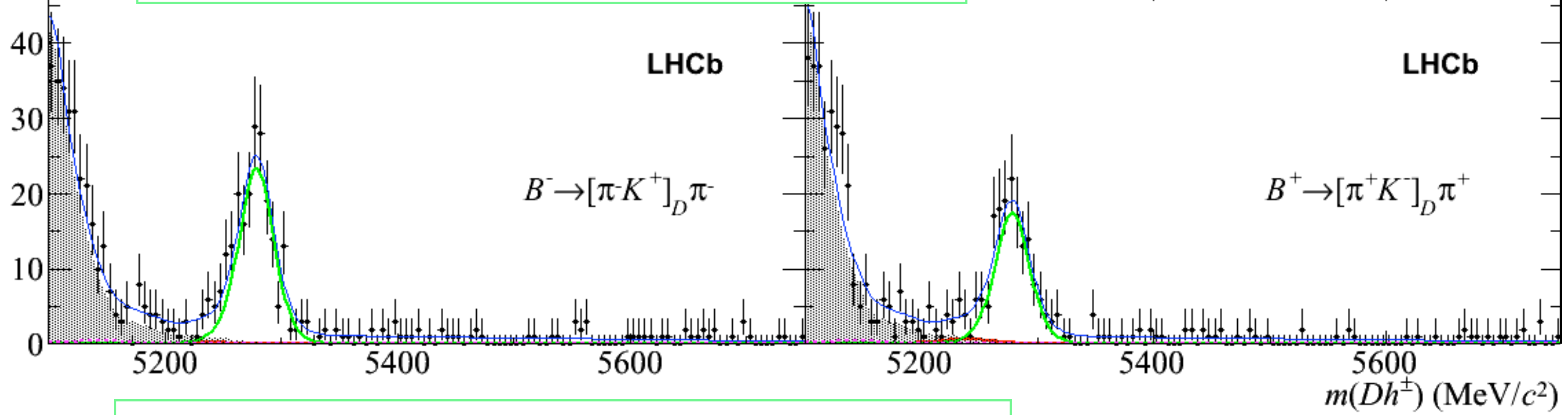
$A_{ADS(\pi)}(K\pi)$ = +big
$A_{ADS(\pi)}(K3\pi)$ = –small

preferred in combination

$\delta_B^{D\pi}$~320°

$A_{ADS(\pi)}(K\pi)$ = +small
$A_{ADS(\pi)}(K3\pi)$ = +small

$A_{ADS(\pi)}(K\pi)$ = (+14±6)%



$A_{ADS(\pi)}(K3\pi)$ = (+13±10)%