New results in B decays

THE UNIVERSITY OF WARWICK

European Research Council

Mark Whitehead – for the LHCb collaboration

LHCb experiment

Why always χ ?

- The least well measured angle of the unitarity triangle \blacksquare
	- CKM fitter FPCP 2013: $(68.0^{+8.0}_{-8.5})^{\circ}$ CKM fitter FPCP 2013: (68.0 $^{+8.5}_{-8.5}$)
- UT fit Post EPS 2013: (70.1 ± 7.1) ^o $\frac{1}{2}$ **F** fit Post El *tb PCP 2013: (68.0*
EPS 2013: (70.1 ± 7
EHCb is to improve *l*_c*d*</sub>)
V^cd
- CKM fitter FPCP 2013: (68.0 $\frac{8.5}{8.5}$)°
• UT fit Post EPS 2013: (70.1 ± 7.1)°
• Key goal of LHCb is to improve this situation
	- A probe for new physics?
- Tree processes theoretically very clean $\begin{array}{ccc} \bullet & \bullet & \bullet \end{array}$
	-
	- Focus so far has been on $B^{\pm} \rightarrow DK^{\pm}$ decays
		- Interference of b→c and b→u transitions

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

decay modes used to measure in section 1.5. Mark Whitehead – LHCP 2014, NYC 3. The section 1.6. Section 1

B[±]→DK[±] decays

• The angle γ is the weak phase between b \rightarrow c and b \rightarrow u transitions » and the weak phase between diagram diagrams the second terms of the common terms of the common common common te angio più ano *wo* The angle y is the weak phase between b→c and b→u transitions T iligie γ is the weak phase between b \rightarrow c and b \rightarrow u transition.

• Interference occurs when D^0 and D^0 decay to the same final state the various parameters that are labelled $\frac{1}{24}$. It is clear from the figure that the fig Least accurate constraint on the plane construction on the plane construction of the plane complete state The drigit \int_0^∞ relative modify phase, $\frac{1}{2}$, $\frac{1}{2}$, $\frac{1}{2}$, $\frac{1}{2}$, $\frac{1}{2}$, $\frac{1}{2}$, $\frac{1}{2}$ • Interference occurs when D^0 and $\overline{D}{}^0$ decay to the same final state to as colour suppressed.

Example 10 Methods to measure y and methods apply to different decay to different decay to different decay to $\mathcal{G}_\mathcal{A}$, and the contract of $\mathcal{G}_\mathcal{A}$, and $\mathcal{G}_\mathcal{A}$, \mathcal{G}_\mathcal . Different methods apply to different methods apply to different decay topologies: topologies: topologies: to
The contract of the contract o **Example 10 Decay 10** n measure v $\mathcal{A}^{\text{max}}_{\text{max}}$ 2 » The angle gamma can be measured by looking at GLW and ADS BDK decays as K+K− or mathematic latternatively, or mathematic decays to non CP-eigenstates, one consider decays to non C \mathbb{Z} as a proposed by Atwood, Dunietz and Soni \mathbb{Z} α thode to moneuro vely can also consider decays to non α such as K[±]π[∓], as proposed by Atwood, Dunietz and Soni [ADS97]. The interference \blacksquare is the \blacksquare and \blacksquare \blacksquare

ments' $8,$ making them technically robust. The original suggestion, proposed by Gronau, proposed by Gronau, σ

2rB sin δ^B sin γ

 $\overline{}$

ments' $8,$ making them technically robust. The original suggestion, proposed by Gronau, proposed by Gronau, σ

ADS/GLW ³

- GGSZ ! Fits to distribution of events in the D → K⁰ **GUSZ**
- 3 body self conjugate decays $x_+ = r_B \cos(\delta_B + \gamma)$
 $y_+ = r_B \sin(\delta_B + \gamma)$ **BELL CONSECTED TO A COLLUGATE (**

order of magnitude of rB

 \cdot Eg: D→ K_{S} ππ $\mathrm{F}^{\prime}\mathrm{F}^{\prime}\mathrm{F}^{\prime}=\mathrm{F}^{\prime}\mathrm{F}^{\prime}\mathrm{F}^{\prime}$, where $\mathrm{F}^{\prime}\mathrm{F}^{\prime}\mathrm{F}^{\prime}$, where $\mathrm{F}^{\prime}\mathrm{F}^{\prime}\mathrm{F}^{\prime}$, where $\mathrm{F}^{\prime}\mathrm{F}^{\prime}$, where $\mathrm{F}^{\prime}\mathrm{F}^{\prime}$, where $\mathrm{F}^{\prime}\mathrm{F}^{\prime}$, where $\mathrm{$ $\text{kg: } D \rightarrow K_S \pi \pi$ \overline{y} Ly. $D \rightarrow N_S$ into \cdot Eg: D \rightarrow K $_{\rm S}$ ππ F_{G} : $D \sqrt{K + \pi n}$ \cdot bg: D \rightarrow K $_{\rm S}$ TTT

$$
-DK\n\begin{array}{rcl}\n\mathbf{D}K^- & & & A_{\mathcal{CP}+} & = & \frac{2r_B \sin \delta_B \sin \gamma}{R_{\mathcal{CP}+}} \\
r_B e^{i(\delta_B - \gamma)} & (\mathbf{K}^+ \mathbf{K}^-)_D \mathbf{K}^- & & & R_{\mathcal{CP}+} \\
\hline\n\end{array}
$$

RADS Phys. Lett. B 253 (1991) 483, Phys. Lett. B 265 (1991) 172

RCP+1
RCP+1
RCP+1

$$
\mathbf{B} = \begin{matrix} \mathbf{D}\mathbf{K}^{-} & r_{D}e^{i\delta_{D}} & A_{\text{ADS}}^{K} & = & \frac{2r_{B}r_{D}\sin(\delta_{B} + \delta_{D})\sin\gamma}{R_{\text{ADS}}} \\ \mathbf{B}^{-} & r_{B}e^{i(\delta_{B}-\gamma)} & (\mathbf{K}^{+}\pi^{-})_{D}\mathbf{K}^{-} & R_{\text{ADS}}^{K} & = & r_{B}^{2} + r_{D}^{2} + 2r_{B}r_{D}\cos(\delta_{B} + \delta_{D})\cos\gamma \end{matrix}
$$

Phys. Rev. Lett. 78 (1997) 3257, Phys. Rev. D 63 (2001) 03600 ا
Rev $Rev. D 63$ $(200$ 3257, Phys. Rev. D 63 (2001) 036005 Phys. Rev. Lett. 78 (1997) 3257, Phys. Rev. D 63 (2001) 036005

5Z
\nbody self conjugate decays
\n
$$
x_+ = r_B \cos(\delta_B + \gamma)
$$
\n
$$
y_+ = r_B \sin(\delta_B + \gamma)
$$

D¯ ⁰

the relative phase difference labelled as $\mathcal{L}_{\mathcal{A}}$. The amplitude ratio is the amplitude ratio is then given by

Phys. Rev. D 68 (2003) 054018

∴⇔ Rev. D 68 (2003) 054018 While each analysis measures different parameters, each contains contains complementary contains contains compl
This experimentary complementary complementary contains complementary complementary complementary complementar While each analysis measures different parameters, each contains measures different parameters, each contains complementary \sim 10 \pm 0.000 $\$ T is non-cegienstate \mathbb{R}^n may arise from either a C arise from either a C

referred to as the ADS method.

While each analysis measures of $\frac{1}{2}$ and $\frac{1}{2$ information on <mark>Ma</mark> 5/6/2014 Mark Whitehead – LHCP 2014, NYC
5 decay or a double \mathcal{O} or a double \mathcal{O} or as illustrated in \mathcal{O} decay, as illustrated in \mathcal{O} decay or a double \mathcal{O} or a double \mathcal{O} or as illustrated in \mathcal{O} decay, as illustrated in \mathcal{O} Since, as mentioned above, the value of r^B is small, the GLW method suffers from

the relative phase difference labelled as $\mathcal{L}_{\mathcal{A}}$. The amplitude ratio is the amplitude ratio is then given by

u¯

 \overline{a}

Phys. Lett. B 733C (2014) 36

- Recent result from B→DK studies
	- ADS-like analysis using a singly Cabibbo-supressed decay
	- Split the decay modes by the charge of the charged K_D and B mesons
	- Same sign (SS) and opposite sign (OS)
- Take input from CLEO measurements
	- Coherence factor (κ) and the average strong phase difference (δ)
	- Both measured over the full Dalitz plot and a K^{*}(892)[±] region.
- Full $3fb^{-1}$ 2011+2012 data sample used

Same sign B[±]→D(K_SKπ)h[±] 0 5200 5400 5600 5800 \subset) 2 *c* $\overline{\mathcal{L}}$ [→] *[K ⁺ B* (a) 5200 5400 5600 5800 5.20 5.0 5.0 5.0 $\overline{\mathsf{L}}$ T statistical yields and their statistical uncertainties derived from the fit to the T

Entries / (15 MeV/

5/6/2014 Entries / (15 MeV/

) 2

|
|-
|

5/6/2014 Mark Whitehead – LHCP 2014, NYC 7 *Mark Whitehead – LHCP 2014, NYC* Entries / (15 MeV/ **12 March 12 Ministread 2018 2019** ■ 5/6/2014 Mark Whitehead – LHCP 2014, NYC 7 7

[−] *KD*

) 2

100
100
100 100

portion of the Dalitz plot is around 75 %, whereas for *D*⁰ ! *K*⁰

at the 2 level. The correlations between *R*SS/OS ratio and the ratios *RDK/D*⇡, SS and

[−] ^π*⁺ K 0* ^S [→] *[K* [−] *^B* (g)

⁺ ^π *^D*

]+ ^π − *K 0* ^S [→] *[K ⁺ ^B* (f)

] −
− π
− π

) 2

^S*m*(*[K*

⁺ K

Entries / (15 MeV/

) 2

^S*K*⁺⇡ the fraction is

SS candidates

[−] ^π *^D*

+ KD

[−] ^π*⁺ K 0* ^S [→] *[K* [−] *^B* (h)

] −
− π
− π

⁺ K

− *K*

*]+*π

^S *m*(*[K*

^S *m*(*[K*

]+ ^π − *K 0* ^S [→] *[K ⁺ ^B* (e)

O pposite sign B[±]→D(K_SKπ)h[±] $\bigcap_{n=1}^{\infty}$]2) [MeV/*c ⁺*π *^D]* − π *⁺ K 0* ^S *m*(*[K* $+$. $\bigcap / \bigcup \bigcup \{ \cdot, \cdot \}$ − *K 0* ^S *m*(*[K* $1/7$ 0 U *p D* U *D*_{U} *D*_{U} *D*_{U} *D*_{U} *D*_{V </sup> *D*_{V} *D*_{V </sup> *D*_{V} *D*_{V}}} \blacksquare Thomasita s 5200 5400 5600 5800 0 5200 5400 5600 5800 \Box Opposite sign B[±]→D(**|** \rightarrow **P**P∪ ^S *m*(*[K* 5200 5400 5600 5800 − *K 0* ^S *m*(*[K* 600 500 500 500 500 *+ KD]+* ^π − *K 0* S [→] *[K ⁺ B* (e)) 2 *c* →D(KgKII)IIT Ω_{max} Ω_{max} is statistical uncertainties derived from the fit to the fit to the fit to the Ω_{max} [→] *[K* [−] *B* (c) plot region, and in the region of phase space around the *K*SNIII± region of phase space around the *K*

Entries / (15 MeV/

]2) [MeV/*^c + KD*

) 2

*]+*π − *K*

^S *m*(*[K*

Sum, incl. combinatorics

]

[−] π*⁺ K*

^S *m*(*[K*

Phys. Lett. B 733C (2014) 36 OS candidates]2) [MeV/*c ⁺*π *^D* **Sum, incl. combinatorics**

]2) [MeV/*c ⁺*π *^D*

*]+*π − *K*

Signal

^S *m*(*[K*

 $\frac{3}{2014}$ Entries / (15 MeV/

B[±] ! *DK[±]* and (b, d, f, h) *B[±]* ! *D*⇡*[±]* candidates in the full data sample. The fits are shown

0

) 2

OS candidates

OS candidates

0

Entries / (15 MeV/

Entries / (15 MeV/

5/6/2014 Mark Whitehead – LHCP 2014, NYC 8 Entries / (15 MeV/ 5/6/2014 Mark Whitehead – LHCP 2014, NYC 8

RDK/D⇡, OS are 16 % (13 %) and +16 % (+16 %), respectively, for the fit to the whole

0

0

] −
− π
− π

⁺ K

− *K*

*]+*π

^S *m*(*[K*

^S *m*(*[K*

around 44 % [12]. This accounts for the higher value of *R*SS/OS in the restricted region.

B[±] ! *DK[±]* and (b, d, f, h) *B[±]* ! *D*⇡*[±]* candidates in the full data sample. The fits are shown

$\begin{CD} \mathsf{B}^\pm{\rightarrow}\mathsf{D}(\mathsf{K}_\mathsf{S}\mathsf{K}\boldsymbol{\pi})\mathsf{h}^\pm \end{CD}$ Dalitz plot (*K*⇤(892)*[±]* region). The correlation between the *RDK/D*⇡, SS and *RDK/D*⇡, OS

• 7 observables calculated from the 8 yields quality plot regions of the values • *I* observables calculated from the o yields T Table 4: Absolute values of systematic uncertainties, in the restricted values of T in sula

RDK/D⇡, OS are 16 % (13 %) and +16 % (+16 %), respectively, for the fit to the whole

• 3 yield ratios and 4 asymmetries $\frac{1}{\sqrt{3}}$ \bullet 3 yield ratios and 4 asymmetries \bullet ... \bullet ... \bullet ... \bullet 10

- Higher sensitivity in the K^* region $\frac{6}{5}$ $1₂$
	- As expected from larger coherence factor <u>1a</u>
- Good future prospects Ω single statematic single systematic uncertainty is the knowledge of the ecoe Correction factor that multiplies the *RSS* observable. The sources is the sources of the sources: $\mathbf S$

for the 1 contour.

Phys. Lett. B 733C (2014) 36
 Phys. Lett. B 733C (2014) 36

RDK/D⇡, SS 0.01 0.25 0.02 0.25

5/6/2014 Mark Whitehead – LHCP 2014, NYC 9 and (b) the fit inside the *K*⇤ region (b). The contours are the usual *n* profile likelihood contours, Figure 4: Scans of the ² probabilities over the *r^B* parameter space for (a) the whole Dalitz fit where 2 with α with α with α with α (light blue), and 3 (light blue), and 3 (light blue). The 2 contour defined by

° γ

K* region and in a bound on K^* region

B^{\pm} → $D(K_{\rm S}$ ππ)h $^{\pm}$

LHCb-PAPER-2014-017

reconstructed

- Model dependent GGSZ amplitude analysis
	- Use Babar model for the fit to the D decay
	- 1fb-1 data sample
- Fit B mass to extract signal and backgrounds yields

Partiallyreconstructed

- Define signal region as \pm 50MeV/ c^2 Table 1: Fitted signal and background yields in the signal invariant mass region (*|B* mass after
	- **•** Downstream and Long refer to track types used to make the K_S T_{S} T_{S} T_{S} and T_{S} mass T_{S} mass T_{S} mass T_{S} mass T_{S} mass after T_{S}

)

1000

⁰ Downstream K

5/6/2014 **Mark Whitehead – LHCP 2014, NYC** 2014 **10** 1400 ± Dm ± Brand + Br $\overline{}$ Fit component *B[±]* ! *D*⇡*[±]*

)

500

⁰ Long K

B^{\pm} \rightarrow D(K_S $\pi\pi$)h^{\pm}

- Dalitz plot fit
	- K*(892) dominates
	- Split B+ and B-
	- **Backgrounds**
	- **Efficiency**
- Cartesian parameters
	- D⁰ mixing negligible

 $x_{-} = +0.027 \pm 0.044 \pm 0.010 \pm 0.001$ $y_{-} = +0.013 \pm 0.048 \pm 0.008 \pm 0.003$ $x_{+} = -0.084 \pm 0.045 \pm 0.009 \pm 0.003$ $y_{+} = -0.032 \pm 0.048 \pm 0.009 \pm 0.007$

Preliminary

 $\mathsf{B}\text{-}\mathsf{only}, \mathsf{m}\text{-} = \mathsf{m}(\mathsf{K}\text{-}\mathsf{m}\text{-})$ \pm 0.040 \pm 0.000 \pm 0.000
B- only, m₊ = m(K_S π ₊)

³¹⁰ decay phase space and could therefore appear in particularly sensitive regions. To estimate

403 where the first uncertainty in each case is statistical, the second systematic and the third extertainty in the first uncertainty in each case is statistical, the systematic and the third sy

ergy (11)

S/6/2014 **Mark Whitehead – LHCP 2014, NYC** 1997 11 11 $\mathcal{A}(\mathcal{A})$ these results are used to place constraints on the magnitude of the interfering of the inter

residual distributions.

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$B^{\pm}{\rightarrow}D(K_S\pi\pi)h^{\pm}$ ³⁷⁷ There is a two-fold ambiguity in the solution for , *r^B* and *B*; choosing the solution

²⁶² in Fig. 3.

• Convert the Cartesian parameters \cdot \cdot . Convert the Cartesia $\gamma = (84^{+49}_{-42})^{\circ}$ Preliminary

³⁷⁵ The results for the *CP* violation observables (*x±, y±*) are used to place constraints on the

- Includes all uncertainties
- Choose solution < 180o

 276 ± 276 These include variations of the fixed parameters of the signal and cross-feed functions, feed functions, for the signal and cross-feed functions, $\frac{1}{2}$

0.14

5/6/2014 **12 12 in the signal in the signal yield in the invariant mass region around the signal peak; the invariant mass region around the signal peak; the invariant mass region around the signal peak; they are the sign** 275 not consider as sources of systematic uncertainty on the Cartesian parameters. 1 Figure 8: Projections of the residual confidence level regions onto the (*, B*) and (*, rB*) p l sources with all sources of uncertainty taken into account \mathcal{L}

0.8

- Aim to measure the mass and lifetime of Ξ_b
	- Lifetime expected to be equal to that of Λ_{b} (Leading order HQE)
	- Large sample of ~3800 decays available from 3fb-1 data set
	- $\Lambda_b \rightarrow \Lambda_c \pi$ provides the ideal control channel, kinematics are ~identical
	- Decays of $Λ_c$ and Ξ_c to the same final state of pKπ

arXiv:1405.7223

 Γ 99 enable improved precision on lifetimes of other $\Xi_b^0 \!\!\rightarrow\!\Xi_c^0 \! \Pi^-$ because further tests of other tests of $\Xi_b^0 \!\!\rightarrow\!\Xi_c^0 \! \Pi^ \frac{M}{\sqrt{2}}$ the HQE. We also make the most precise measurements of the mass di $\frac{M}{\sqrt{2}}$ 179 enable improved precision on lifetimes of other precision on lifetimes of other provide further tests of o
In the contract provide further tests of other provide further tests of other provide further tests of other p \mathcal{L} , we also make the most precise measurements of the most precise measurements of the mass di \mathcal{L} in Fig. 1. Peaking backgrounds from charmless final states are investigated using the *X^c* ¹⁰³ **c** → 714 and 3775 ± 714 and 3775 ± 714 and 3775 ± 714 ± 725 ± 72 0 2 4 6 8 ¹¹⁷ value of about 0.93, except for the 0*.*0 0*.*5 ps bin, which has a value of about 0.7. This lower value is expected due to the di $=\frac{1}{6} \rightarrow \pm \frac{1}{6} \pi$ **c**) $\mathbf{r} = \mathbf{r} \cdot \mathbf{r}$ $\equiv_b \rightarrow \equiv_c \pi$ $\equiv_b^0 \rightarrow \equiv_c^+ \pi^-$

• Float the mass difference in the fit to data *b* maximum arximum **can be a set to the data** *b* \overline{AB} **c** \overline{AB} *b* \overline{AB} **c** Γ 100 to the second difference in the fit to dete • Fluat the mass unierence in the in to data
 $\frac{1}{2}$

^b ¹¹⁶), as obtained from simulated decays. This ratio is consistent with a constant

 $M(\varXi_b^0) - M(\varLambda_b^0) = 172.44 \pm 0.39\,\text{(stat)} \pm 0.17\,\text{(syst)}\,\text{MeV}/c^2$ $M(\Xi_b^0) = 5791.80 \pm 0.39\,(\text{stat}) \pm 0.17\,(\text{syst}) \pm 0.26\,(A_b^0)\,\text{MeV}/c^2$ $M(\Xi_b^0) - M(\Lambda_b^0) = 172.44 \pm 0.39 \text{ (stat)} \pm 0.17 \text{ (syst)} \text{ MeV}/c^2$ $\sigma(\omega_b)$ = M (M_b) = 112.44 \pm 0.09 (Stat) \pm 0.11 (SySt) NEV/C $M(\Xi_b^0) = 5791.80 \pm 0.39 \, \text{(stat)} \pm 0.17 \, \text{(syst)} \pm 0.26 \, (A_b^0) \, \text{MeV}/c^2$ $M(\Xi_b^{\circ})-M(\Lambda_b^{\circ})=172.44\pm 0.39\,({\rm stat})\pm 0.17\,({\rm syst})\,{\rm MeV}/c^2$

- Measure lifetime from yield ratio as a function of decay time
- Fit with the function $e^{\beta t}$ where $\beta=1/\tau_{A_b^0}-1/\tau_{\varXi_b^0}$
	-

ciency for the water $\mathcal{L}_{\mathcal{A}}$

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c is decays. The mass diaerence is decays.
The mass diagnosis

5/6/2014 Mark Whitehead – LHCP 2014, NYC الي المساحد ال
المساحد المساحد المسا α final function is shown. The uncertainties and uncertainties are statistical function is shown. The uncertainties are statistical function is shown. The uncertainties are statistical functions are statistical functio

 $\overline{}$ mode is due to the larger model in the daughters in the daughter $\overline{}$

173 for the 7 TeV and 8 TeV and 8 TeV and 8 TeV and 8 TeV and are statistically compatible with the 7 TeV and
173 for the 7 TeV and are statistically compatible with the 1990 for the 1990 for the 1990 for the 1990 for th ¹⁷⁵ *pp* collision data set is used to make the first measurement of 173 for the 7 TeV and 8 TeV and 8 TeV and 8 TeV and 8 TeV and are statistically compatible with the 7 TeV and
The 7 TeV and are statistically compatible with a statistically compatible with the 7 TeV and 8 TeV and 9 TeV ¹⁷⁵ *pp* collision data set is used to make the first measurement of Signal & back. model 0.06 0.05 0.1 0.5 *X* \sim **C** \sim **C** Trigger 1.3 (1991). The state of the state o
Trigger 1.3 (1991). The state of the state *X^c* mass range 0.3 Total 0.17 0.10 1.0 1.9) Λ $\overline{}$ $\overline{}$ 0.04 LHCb $\equiv_b^0 \rightarrow \equiv_c^+ \pi^-$

Ξ

(MeV*/c*²) (MeV*/c*²) (%) (%)

arXiv:1405.7223

• World first lifetime measurement **b** 176 metative and absolute and absolute the relative area in the relative and absolute $\frac{1}{2}$ \overline{a} Momentum scale 0.06 0.06 orld first lifetime measurement

Ξ

• Two world best mass measurements

 $M(\Xi_b^0) = 5791.80 \pm 0.39 \, (\text{stat}) \pm 0.17 \, (\text{syst}) \pm 0.26 \, (\varLambda_b^0) \, \text{MeV}/c^2$ $M(\varXi_c^+)=2467.97\pm 0.14\, {\rm (stat)}\pm 0.10\, {\rm (syst)}\pm 0.14\, (\varLambda_c^+)\, {\rm MeV}/c^2$ R_c^+) = 2467.97 \pm 0.14 (The large sample of ⌅⁰ *^b* ! ⌅⁺ *^c* ⇡ decays is exploited to measure the ⌅⁺ ¹³⁶ *^c* mass. Sig-

and the USA of the USA ¹⁸³ are consistent with, and about five times more precise than the value recently obtained 188 at least three times more precise three times more precise than other measurements \mathcal{Z} remove the 20 MeV*/c*² ¹³⁹ restriction on the *X^c* mass. The sum of two CB functions is used to 140 describes the signal and and an exponential shape describes the background. The signal shape describes the

nal *X^b* candidates within 50 MeV*/c*² ¹³⁷ of their respective peak values are selected, and a

Summary

- Latest updates from $B^{\pm} \rightarrow DK^{\pm}$ y studies
	- Using a new D decay mode, $D\rightarrow K_S K\pi$
	- First model dependent GGSZ results
- Much more still to come on y
	- Update all 1fb-1 analyses to the full 3fb-1 data sample
	- Other B decays e.g. $B^0 \rightarrow DKT$ and $B^0 \rightarrow DK^*$, $B_s \rightarrow D_sK$ and $B^{\pm} \rightarrow DK^{\pm}TT$
- Progress on b-Baryon decays
	- Precise lifetime and mass measurements of the E_b
- Stay tuned for all of our new results in this sector

Detector

Luminosity

Example 10 Methods to measure y and methods apply to different decay to different decay to different decay to $\mathcal{G}_\mathcal{A}$, and the contract of $\mathcal{G}_\mathcal{A}$, and $\mathcal{G}_\mathcal{A}$, \mathcal{G}_\mathcal . Different methods apply to different methods apply to different decay topologies: topologies: topologies: to
The contract of the contract o **Example 10 Decay 10** n measure v $\mathcal{A}^{\text{max}}_{\text{max}}$ 2

2rB sin δ^B sin γ

 $\overline{}$

- GLW
	- CP eigenstate D decays
	- Eg: D→KK, D→ππ \mathcal{P} and \mathcal{P} and states, equation-specific final states, eq. D \mathcal{P} and D \mathcal{P}

\n- GLW
\n- CP eigenstate D decays
\n- Eq: D→KK, D→TTT
\n- $$
R_{CP+} = \frac{2r_B \sin \delta_B \sin \gamma}{R_{CP+}}
$$
\n- $$
R_{CP+} = 1 + r_B^2 + 2r_B \cos \delta_B \cos \gamma
$$
\n

253 (1991) 483, Phys. Lett. B و Phys. Lett. B 265 (1991) 172
المسلم المسلم العلمية والمسلم المسلم الم RADS 2rB rD sin(δ^B + δ^D) sin γ Phys. Lett. B 253 (1991) 483, Phys. Lett. B 265 (1991) 172

RCP+1
RCP+1
RCP+1

- ADS
	- Quasi flavour specific decays $A_{ADS} = \frac{B}{\sqrt{2\pi}}$ Δ and Δ
- \cdot Eg: D \rightarrow Κπ, D \rightarrow Κπππ

$$
ABS
$$

\n• Quasi flavour specific decays
\n• Eg: D→Kπ, D→Kπππ
\n• Eg: D→Kπ, D→Kπππ
\n• A_{AS} = $r_B^2 + r_D^2 + 2r_Br_D \cos(\delta_B + \delta_D) \cos \gamma$

Phys. Rev. Lett. 78 (1997) 3257, Phys. Rev. D 63 (2001) 03600 ا
Rev $Rev. D 63$ $(200$ Phys. Rev. Lett. 78 (1997) 3257, Phys. Rev. D 63 (2001) 036005 . "General Self Chromogen S Phys. Rev. Lett. 78 (1997) 3257, Phys. Rev. D 63 (2001) 036005

- GGSZ \cdot GGSZ
	- 3 body self conjugate decays $v_{\pm} = r_B \sin(\delta_B + \gamma)$
	- Eg: D \rightarrow K_Sππ $\mathrm{F}^{\prime}\mathrm{F}^{\prime}\mathrm{F}^{\prime}=\mathrm{F}^{\prime}\mathrm{F}^{\prime}\mathrm{F}^{\prime}$, where $\mathrm{F}^{\prime}\mathrm{F}^{\prime}\mathrm{F}^{\prime}$, where $\mathrm{F}^{\prime}\mathrm{F}^{\prime}\mathrm{F}^{\prime}$, where $\mathrm{F}^{\prime}\mathrm{F}^{\prime}$, where $\mathrm{F}^{\prime}\mathrm{F}^{\prime}$, where $\mathrm{F}^{\prime}\mathrm{F}^{\prime}$, where $\mathrm{$ $\text{kg: } D \rightarrow K_S \pi \pi$

$$
\begin{array}{ll}\n\text{dy self conjugate decays} & x_+ = r_B \cos(\delta_B + \gamma) \\
y_+ = r_B \sin(\delta_B + \gamma)\n\end{array}
$$

 $\frac{1}{2}$ Phys. Rev. D 68 (2003) 054018 While each analysis measures different parameters, each contains contains complementary contains contains compl
This experimentary complementary complementary contains complementary complementary complementary complementar While each analysis measures different parameters, each contains measures different parameters, each contains complementary \sim 10 \pm 0.000 $\$

While each analysis measures of $\frac{1}{2}$ and $\frac{1}{2$ information on <mark>Ma</mark> 5/6/2014 Mark Whitehead – LHCP 2014, NYC

1fb-1 ɣ combination 10^{-1}

0 20 40 60 80 100 120 140 160 180

- Combination includes the following results \sqrt{V}
- 2 body GLW/ADS (D→KK, Kπ, ππ) Phys. Lett. B 712 (2012) 203
4 books: ADS (D + Kense)
- 4 body $ADS (D \rightarrow K\pi\pi\pi)$ Phys. Lett. B 723 (2013) 44 \mathbf{r} \cdot 4 body ADS (D→Kπππ) Phys. Lett. B 723 (2013) 44
 \cdot *Decay in Fitting*
- $GGSZ (D \rightarrow K_S \pi \pi, K_S KK)$ Phys. Lett. B 718 (2012) 43
	- Information on the strong phase from CLEO $\frac{\text{Phys. Rev. D 80}}{\text{Phys. Rev. D 80}}$ -3 10 2 *a*₂ *a*₂ *a*₁ *a*

- a Additionally:
- D⁰ mixing, CPV in charm decays 10^{-1} ϵ 95.59

 $\gamma = (72.0^{+14.7}_{-15.6})^{\circ}$ at 68% CL

• B→Dπ decays also used .

DK± and *D*⇡*±* combination. The reported numbers correspond to the best-fit values and the

Phys. Rev. D 80 (2009) 031105 Phys. Rev. D 80 (2009) 032002 0 0.01 0.02 0.03 0.04 0.05 0.06

Phys. Lett. B 726 (2013) 151

180 200 220 240 260 280 300 320 340 360

confidence intervals are set

1fb⁻¹ y combination + 2fb⁻¹ GGSZ reduced significantly, especially at confidence levels over 95*.*5%, resulting in much more Gaussian behaviour. The interval for *r^K* **B** complication **1** zip out

• Update to include 2012 GGSZ result LHCb-CONF-2013-004 constraints from the new 3 fb1 GGSZ measurement alone, and compare them to those compare them to those compare
The new 3 fb1 GGSZ measurement alone, and compare them to those compare them to those compare them to those co

• B→DK only here

from 1 fb¹ of 2011 data alone [4]. For the phases and *^K*

- Green is the old $B \rightarrow DK$ curve 0.14 \rightarrow DK curve
- Purple shows the updated interval 10^{-1} $\begin{bmatrix} 10^{-1} & 94 \\ 1 & 96 \end{bmatrix}$

 $\gamma = (67 \pm 12)^{\circ}$ at 68% CL

0 20 $-$ 20 $-$ 20 $-$ 20 $-$ 20 $-$ 20 $-$ 20 $-$ 20 $-$ 20 $-$ 20 $-$ All quoted values are modulo 180. **Preliminary**

^B the confidence intervals are

measurements of the *^B[±]*! *DK[±]* decay using 1 fb¹ of data (green, filled area), taken from

LHCb-CONF-2013-006

5/6/2014 **Mark Whitehead – LHCP 2014, NYC** Figure 4: Profile likelihood contours, separately for the *B[±]*! *DK[±]* GGSZ analysis (blue, partly-dashed contours) using 3 fb¹ of data, and the *^B[±]*! *DK[±]* part of the GLW/ADS

GLW/ADS (orange) parts of the *DK±* only combination. The contours are the usual *n* profile

curve represents the ^B [→] DK[±] events, the light (green) curve is ^B [→] ^Dπ[±]. The shaded contribution are partially reconstructed events and the total PDF includes the total PDF includes the component.

candidates are reconstructed assigning this track the kaon mass. The remaining events are placed in the

 $F = \frac{1}{\sqrt{2}}$ and $\frac{1}{\sqrt{2}}$ an for a full description.

2 body ADS

)

favoured, B00
favoured, B00
favoured, B00

600

 $s = \frac{1}{2}$

 $F = 1.1$ $Mark$ Mh itahaad $= 1$ HCP 2014 NNC Fig. 1 for a full description. The dashed line here represents the partially reconstructed, but Cabibbo **LHCb**

 $s \rightarrow \infty$, decays where the pions are lost. The pions are lost. The pions are lost. The pollution from α

4 body ADS

and 5/6/2014 and 5/6/2014 Mark Whitehead - LHCP 2014, NYC by charge the caption of F for a full description of F and F and F are represents the dashed line F

^s ! *DK*⇡+, and charge-conjugated, decays

partially reconstructed, but Cabibbo favoured, *B*⁰

1fb-1 MI GGSZ Sum, incld. combinatorics ^π*^D)* [−] ^π*⁺* ^π⁰ ^S [→] *(K* [±] *B* ⁰ Long *K*^S

^D ! *^K*⁰ ^S*K*+*K*, shown with both *K*⁰

background components, are superimposed.

0

5/6/2014 Mark Whitehead – LHCP 2014, NYC Figure 3: Invariant mass distributions of (a) *B[±]* ! *DK[±]* and (b) *B[±]* ! *D*⇡*[±]* candidates, with $S = \frac{1}{2}$ categories component and signal a Γ 2014, is the lowest ecoes regions where Γ

the pions has low momentum \mathcal{L}_max

0

2fb-1 MI GGSZ Purely combinatorial candidates are parameterised by a first-order polynomial. In the ^S types because there Table 1: Yields of each signal and background category in the signal region. The category

7

B[±] ! *DK[±]* bin as well as the eciency corrected *Kⁱ* parameters.

The log likelihood for *D*⇡*[±]* candidates is determined by summing the log likelihoods

identification eciencies.

5/6/2014 Mark Whitehead – LHCP 2014, NYC ously performed to the *B[±]* ! *DK[±]* candidates in each Dalitz plot bin and the *x[±]* and *y[±]* parameters are determined. In conjunction with this we fit the *B[±]* ! *D*⇡*[±]* candidates;

1fb-1 MD GGSZ 2 [MeV/c mB

background in the second second second in the second second second second second second second second second s

^S ⇡+⇡)⇡*[±] long* candidates. The fit results, including signal and background

^B[±] ! *^D*(! *^K*⁰

Candidates / (10 MeV/c

40

5/6/2014 Mark Whitehead – LHCP 2014, NYC ³²⁴ the uncertainty arising from this, the *CP* fit to data is repeated with the eciency

1fb-1 MD GGSZ

5/6/2014 Mark Whitehead – LHCP 2014, NYC and assumed to be distributed to background candidates are assumed to according to the phase space of the *D* \sim \sim \sim that the total combinatoric background yield, obtained from the *B[±]* invariant mass fit, is

of 1*.*2% [25] introduced for the signal and background components where the bachelor is

the *D* decay model changed to the sum of a phase-space distribution and a *K*⇤(892)*[±]*

in Table 1. Corresponding variations in the random *Dh* background yield are made, so

In the *B[±]* invariant mass fit, a component PDF for partially-reconstructed