Branching Fractions (and Direct CPV) of Exclusive Hadronic B to Charm Decays

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Flavour Physics and CP Violation

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0 Symbol indicates a reference. Listed at the end

Contents of the review

- This talk attempts to summarize some recent results from the B-factories

Color Suppression ♠

- $B \rightarrow D^0\pi^0$
- $B \rightarrow D^0\omega^0$
- $B \rightarrow D^0\eta^0$

Working towards $2\beta+\gamma$

- $B \rightarrow D^*\pi$
- $B \rightarrow D_s\,\pi$
- $B \rightarrow D^0K^0$

Looking forward to γ ♣

- $B \rightarrow D^0K$
- $B \rightarrow D^0K^*$
- $B \rightarrow D^{*0}K^*$
- $B \rightarrow D^0_{(CP)}K$

♠ For further examples of experimental probes of $B \rightarrow D$ physics see:

"B to charmonium decays and open charm production" - Karim Trabelsi (FPCP, 5th June)

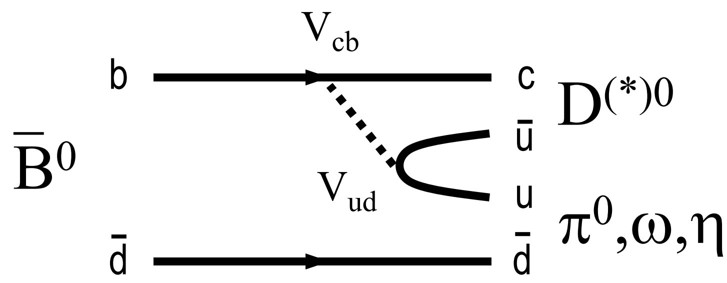
♣ For a full discussion on the extraction of γ/ϕ_3 see:

"*Reaching for gamma (present and future)*" - Andrey Golutvin (FPCP, 3rd June)

Observing colour-suppressed modes and learning that they are not as suppressed as previously thought

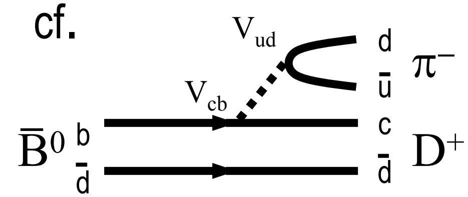
$$B^0 \longrightarrow D^{(*)0}\,\pi^0$$
$$B^0 \longrightarrow D^{(*)0}\,\omega$$
$$B^0 \longrightarrow D^{(*)0}\,\eta$$

Colour-suppressed B^0 Decays



$\mathcal{B}(\bar{B}^0 \rightarrow D^0\pi^0)$ = ...

cf.



$\mathcal{B} = (3.0 \pm 0.4) \times 10^{-3}$

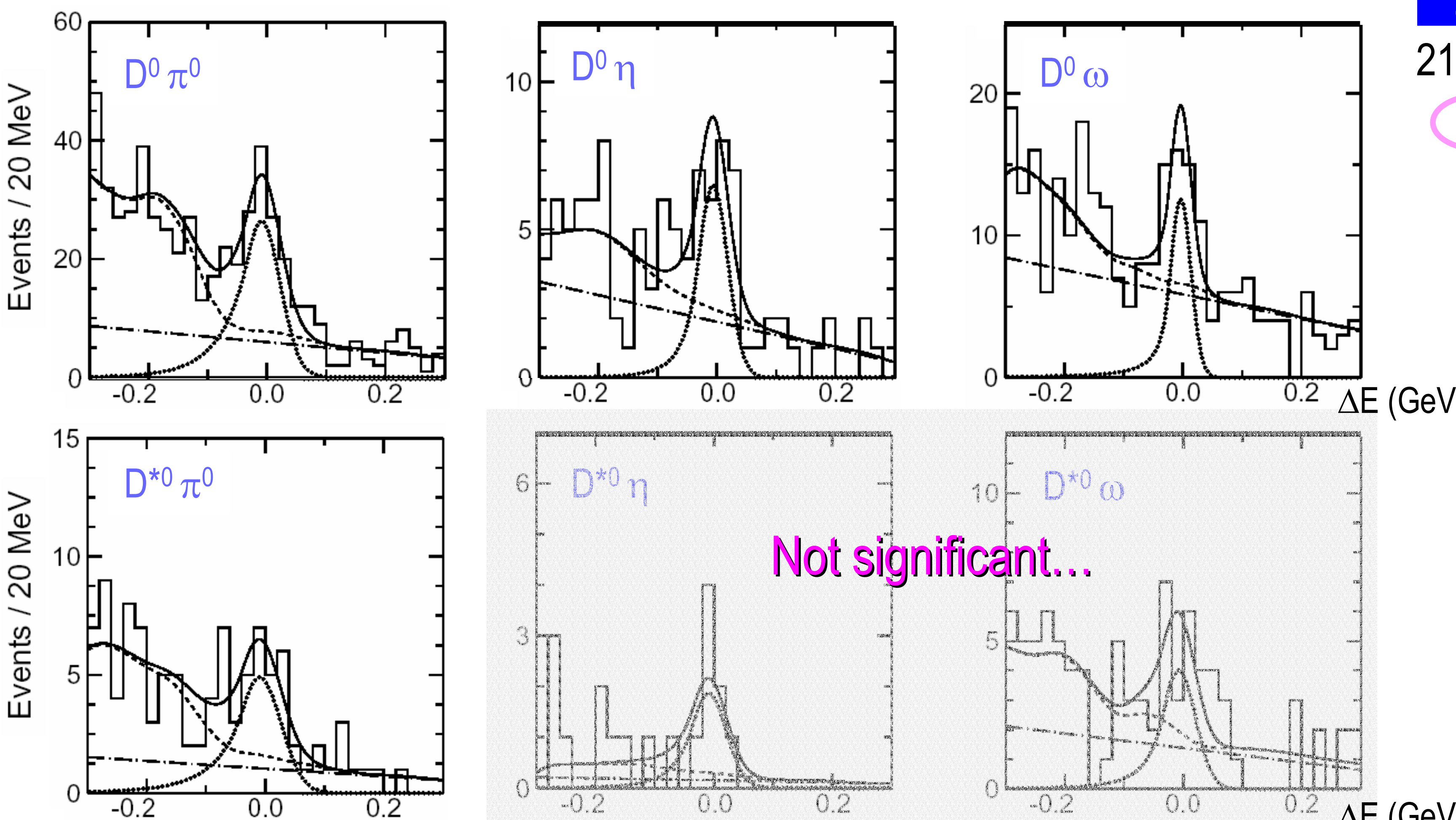
- Naively, we expect a factor of $(1/3)^2$ between the colour-suppressed and colour-favoured rates
- However, a detailed calculation predicates a suppression of approximately 1/50
  - Factorization models, for example Neubert & Stech (1997) [1] predict very low branching fractions for colour-suppressed decays, in the range $0.3\text{-}0.7\times10^{-4}$

Colour-suppressed B^0 Decays

- First Observation by BELLE (2001)
  - Yield extracted with a binned maximum likelihood in ΔE

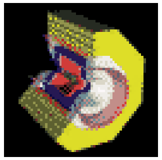
$21.3\ fb^{-1}$

2



Colour-suppressed B^0 Decays

- Followed in 2002 by CLEO with a confirmation of $D^0\pi^0$ and $D^{*0}\pi^0$
  - Signal extraction by extended likelihood fit over: m_{ES} , ΔE, a Fisher, $\cos\theta_{HEL}$

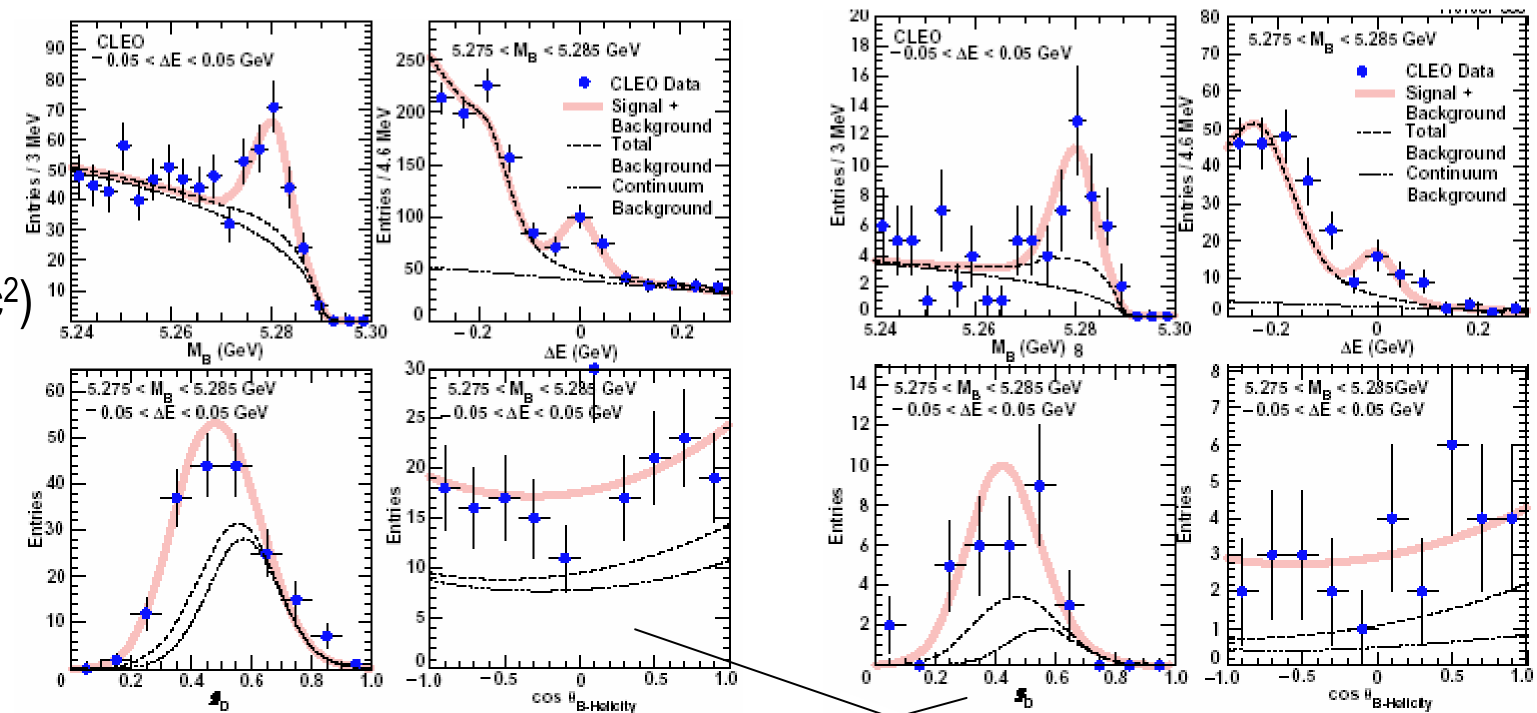


9.15 fb^{-1}

3

$D^0\pi^0$ $D^{*0}\pi^0$

m_{ES} (GeV/c^2)



ΔE (GeV)

Fisher = linear combination of several event shape variables

$\cos\theta_{HEL}$ = angle between D and B calcutated in the B rest frame

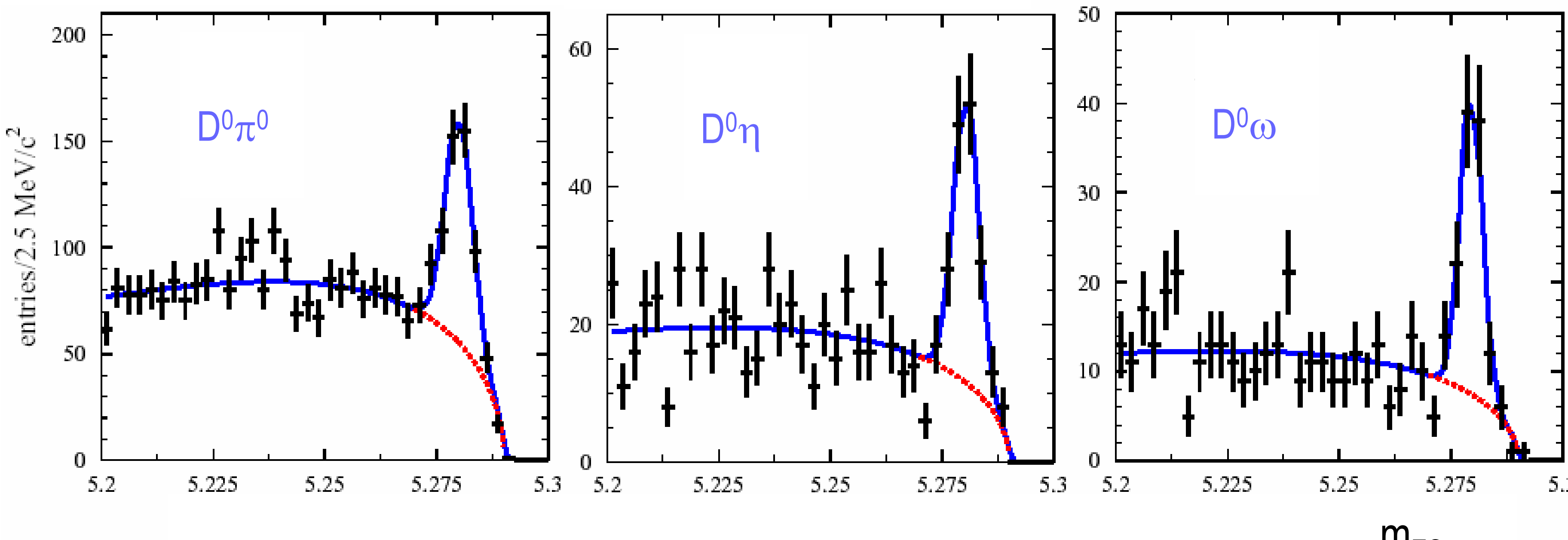
Colour-suppressed B^0 Decays

- Then Babar with the most accurate measurements on a large data set
  - Least-squares fit on the m_{ES} distribution for $B^0 \rightarrow D^0\pi^0$
  - Unbinned max. likelihood on the m_{ES} distribution for $B^0 \rightarrow D^0\omega$, $B^0 \rightarrow D^0\eta$

46.5 fb^{-1}

4

(Preliminary)



m_{ES} (GeV/c^2)

Colour-suppressed B^0 Decays

- Results are consistently approximately a factor 4 higher than predicted by factorization

Decay	Yield	Branching fraction (x 10^{-4})	Prediction (x 10^{-4})
$\overline{B}^0 \to D^0 \pi^0$	126 ± 20	$3.1 \pm 0.4 \pm 0.5$	0.7
	124 ± 15	$2.74 \pm^{0.36}_{0.32} \pm 0.55$	
	291 ± 31	$2.89 \pm 0.29 \pm 0.38$	
$\overline{B}^0 \to D^0 \eta$	22 ± 9	$1.4 \pm 0.5 \pm 0.3$	0.5
	101 ± 14	$2.41 \pm 0.39 \pm 0.32$	
$\overline{B}^0 \to D^0 \omega$	33 ± 11	$1.8 \pm 0.8 \pm 0.4$	0.7
	78 ± 12	$2.48 \pm 0.40 \pm 0.32$	
$\overline{B}^0 \to D^{*0} \pi^0$	26 ± 9	$2.7 \pm 0.8 \pm 0.6$	1.0
	29 ± 7	$2.20 \pm^{0.59}_{0.52} \pm 0.79$	
$\overline{B}^0 \to D^{*0} \eta$	8 ± 4	< 4.6	
$\overline{B}^0 \to D^{*0} \omega$	16 ± 9	< 7.9	

46.5 fb^{-1}
4
(Preliminary)

21.3 fb^{-1}
2

9.15 fb^{-1}
3

Working towards future $2\beta + \gamma$ analyses with rare B to charm processes

$B^0 \longrightarrow D_s^+ \pi^-$

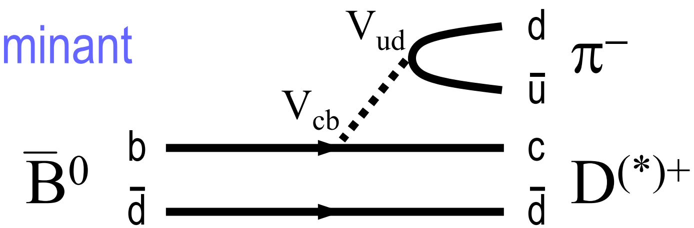
$B^0 \longrightarrow D_s^- K^+$

$B^0 \longrightarrow D^0 K^{(*)0}$

Motivation for $B^0 \to D_s^+\pi^-$

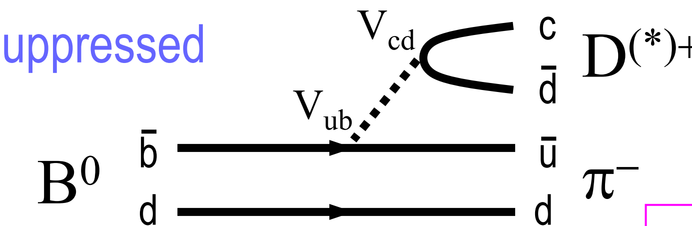
- Works towards a future measurement of $\sin(2\beta+\gamma)$. Both $D^{(*)-}\pi^+$ and $D^{(*)+}\pi^-$ are assessable from a B^0 or $\bar{B}^0$. One is cabbibo suppressed and dependant on V_{ub}

Dominant



$V_{cb}V_{ud} = A$

Suppressed



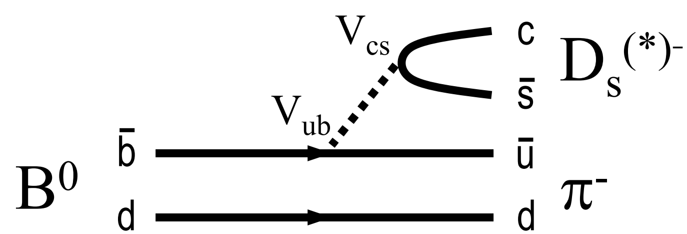
weak phase

$V_{ub}V_{cd}\, e^{i\delta} = \lambda^{(*)} A\, e^{i\gamma} e^{i\delta}$

- However, CP violating effect will be small

$$|\lambda^{(*)}| = \left|\frac{V_{ub}V_{cd}}{V_{cb}V_{ud}}\right| \approx 0.02$$

- And $|\lambda^{(*)}|$ cannot be extracted from data because each suppressed mode has a large background from the dominant



- BUT $B^0 \to D^{(*)+}\pi^-$ may be extracted from $\mathcal{B}(B^0 \to D_s^{(*)+}\pi^-)$ using SU(3) symmetry relations

$$\mathcal{B}(B^0 \to \overline{D}_S^{+} \pi^-) \approx \frac{\mathcal{B}(B^0 \to \overline{D}^{*+} \pi^-)}{\tan^2\theta_C}\left(f^2_{D_S} / f^2_{D^*}\right)\lambda^2$$ 5

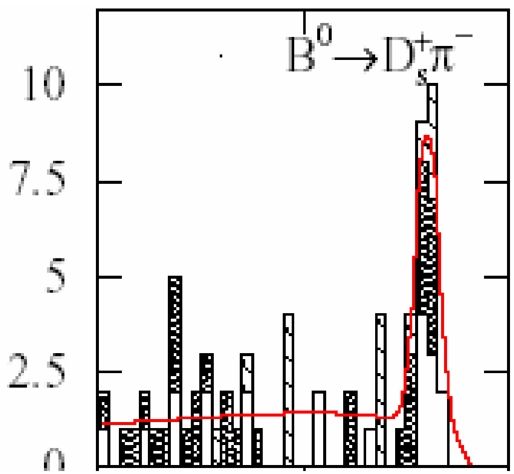
$B^0 \longrightarrow D_s^+\pi^-$

80.8 fb^{-1}

7

(Preliminary)

(Likelihood fit in m_{ES})



m_{ES} (GeV/c^2)

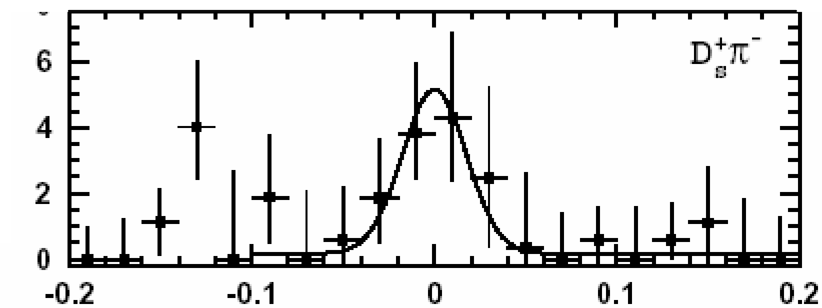
$D_S^+ \longrightarrow \phi\pi^+, K^*K^+, K_SK^+$

78.7 fb^{-1}

6

(Preliminary)

(Likelihood fit in ΔE and mass D_s)



ΔE (GeV)

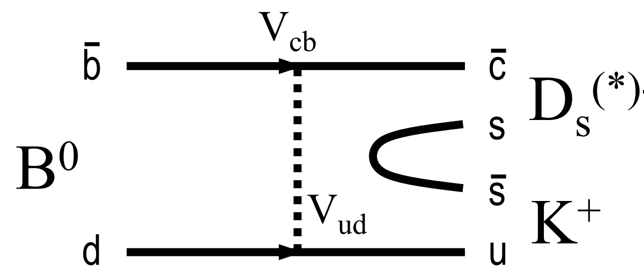
Branching fraction (x 10^{-5})

$B^0 \to D_S^+\pi^-$	Belle	2.4	± 1.0	± 0.7	3.6σ
	BaBar	3.2	± 0.9	± 1.0	3.3σ

- $\sin(2\beta+\gamma)$ analyses from $B^0 \longrightarrow D^{(*)-}\pi^+$ (+cc) are currently very statistics limited
  - However, expect first results [limits] soon followed but improvements as more modes are added ($B^0 \longrightarrow D^{(*)-}\rho^+$, $B^0 \longrightarrow D^{(*)-}a_1+$) and the datasets grow

$B^0 \longrightarrow D_s^- K^+$

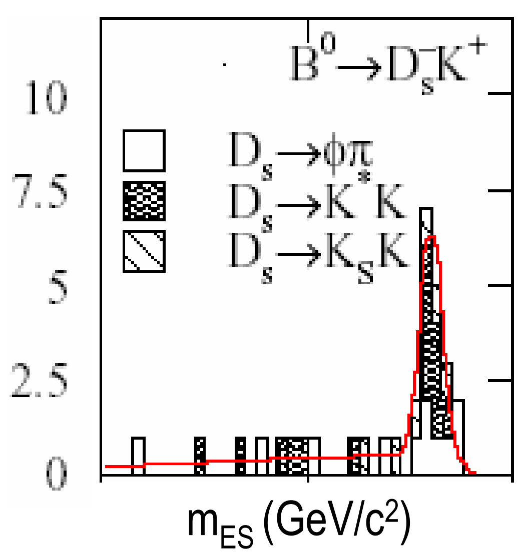
- A search for the kinematically similar $B^0 \longrightarrow D_s^{(*)-}K^+$ has also been performed
  - $B^0 \longrightarrow D_s^{(*)-}K^+$ can only proceed through W-exchange (or final state rescattering). Theory estimates the BR between 10^{-6}–10^{-4} 8

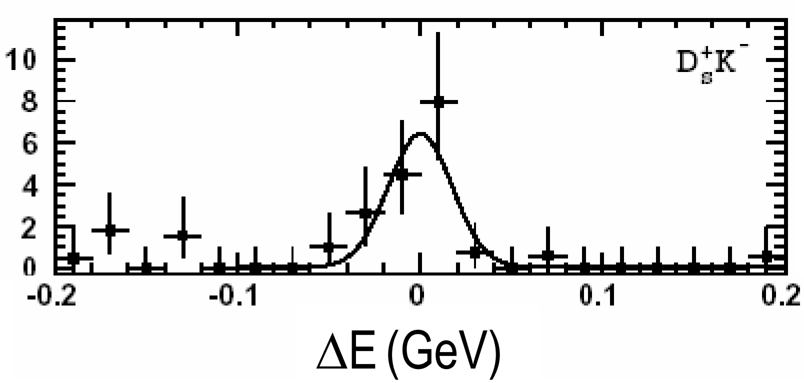


80.8 fb^{-1}

7

(Preliminary)





78.7 fb^{-1}

6

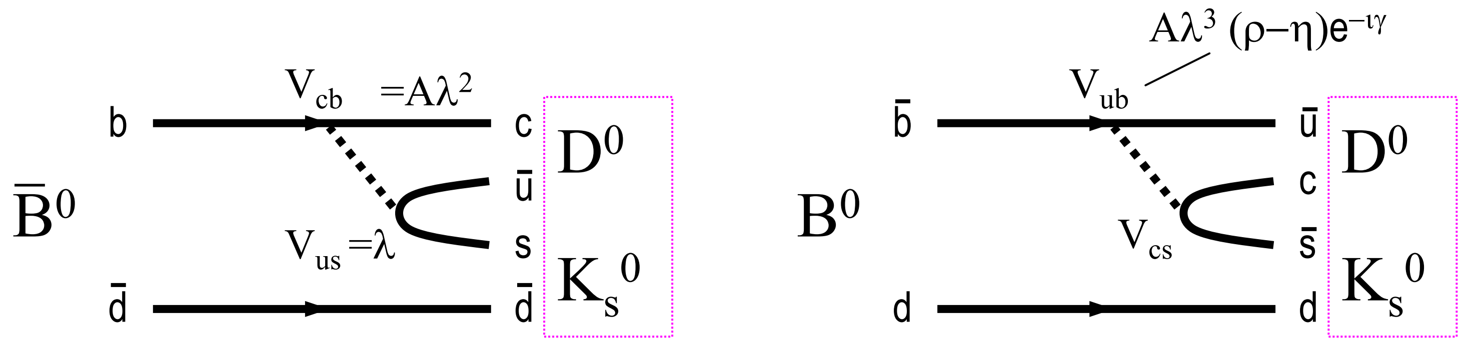
(Preliminary)

Branching fraction (x 10^{-5})

$B^0 \to D_S^+ K^-$

4.6	± 1.2	± 1.3	6.4σ
3.2	± 1.0	± 1.0	3.5σ

$B^0 \to D^0 K^0_s$, $B^0 \to D^0 K^{(*)0}$

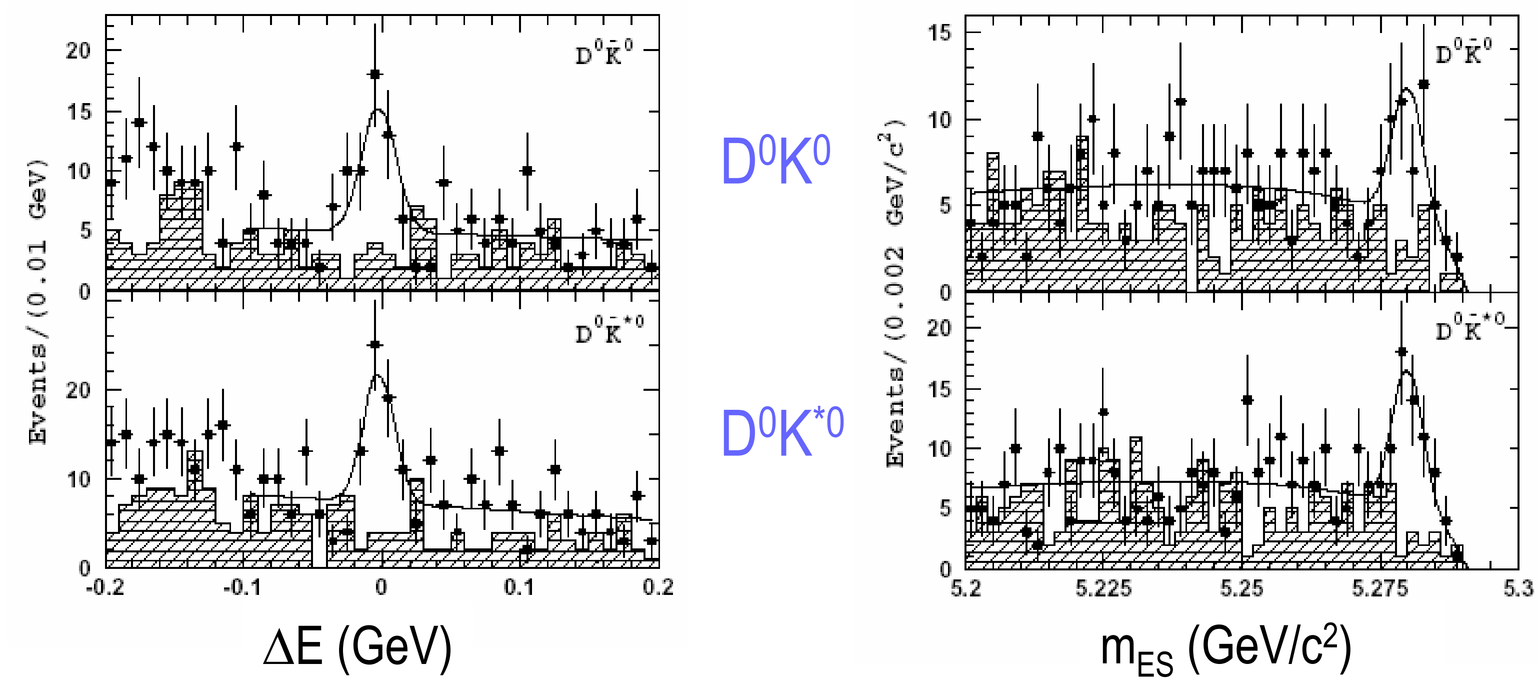


Interference between identical states

- Two color-suppressed amplitudes with relative phase $2\beta+\gamma$
  - Comparable amplitudes potentially give large CP asymmetry (~40%)
  - Potential for a future measurement of $2\beta+\gamma$ with a time-dependant analysis 9

- The low expected rate means a time-dependent analysis is statistically challenging
  - Analysis made more interesting in light of the higher rate seen in colour-suppressed $B^0 \to D^0\pi^0$ modes

$B^0 \rightarrow D^0K^0_s$, $B^0 \rightarrow D^0K^{(*)0}$



78 fb^{-1}

10

(Preliminary)

- Signal extracted with a likelihood fit to the ΔE

5.1σ

$\mathcal{B}(B^0 \rightarrow D^0K^0_s)$ = (5.0 ± 1.3 ± 0.6) x 10^{-5}

5.6σ

$\mathcal{B}(B^0 \rightarrow D^0K^{*0})$ = (4.8±1.1±0.5) x 10^{-5}

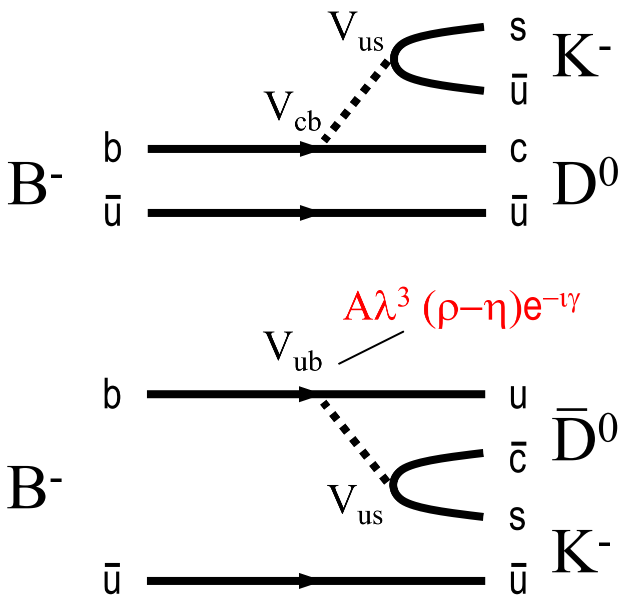
- Look forward to time-dependant analyses (sin(2β+γ)) in the near future

First steps towards future γ analyses with B to charm processes

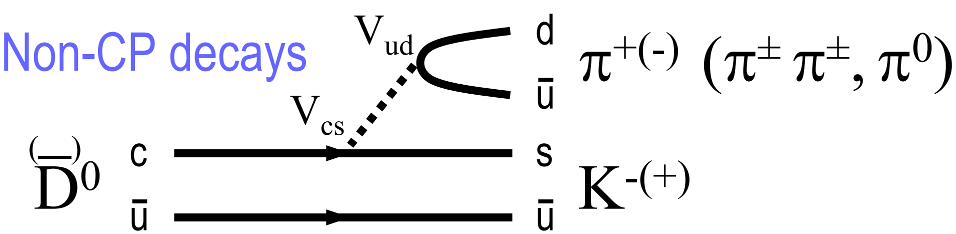
$$B^- \rightarrow D^{(*)0} K^{(*)-}$$
$$B^- \rightarrow D^0_{CP} K^-$$

$B^- \rightarrow D^0 K^-$

- Motivation: extract γ from interference of charged Bs decaying to common final states

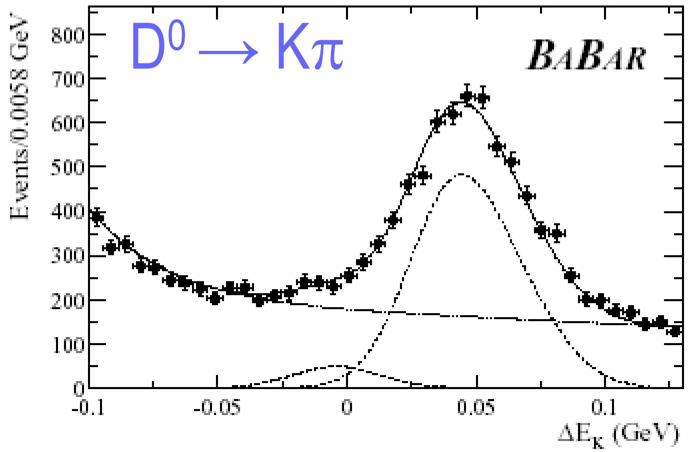


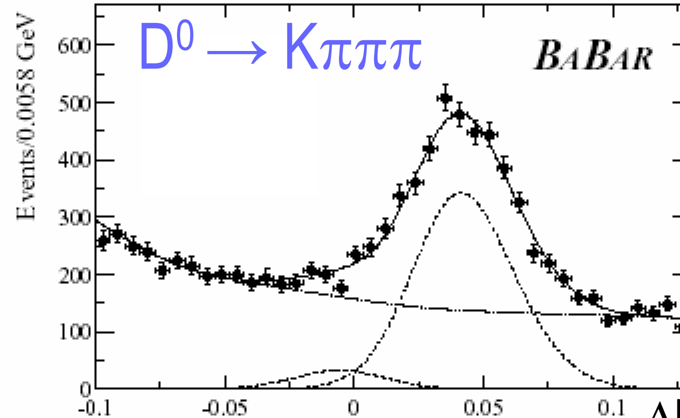
Non-CP decays



- Important first step towards the measurement of γ.
  - $b \rightarrow c\bar{u}s$ are important modes for a future, theoretically clean method for extracting γ.
  - Extraction is possible even when the D^0 decay is not a CP eigenstate. 11
  - However, this method uses interference of the colour-suppressed decay with the Cabibbo suppressed decay so it remains statistically very challenging… Perhaps $500ab^{-1}$

$B^- \to D^0 K^-$ $D^0 \to K\pi, K\pi\pi^0, K\pi\pi\pi$





ΔE (GeV)

75 fb^{-1}

12

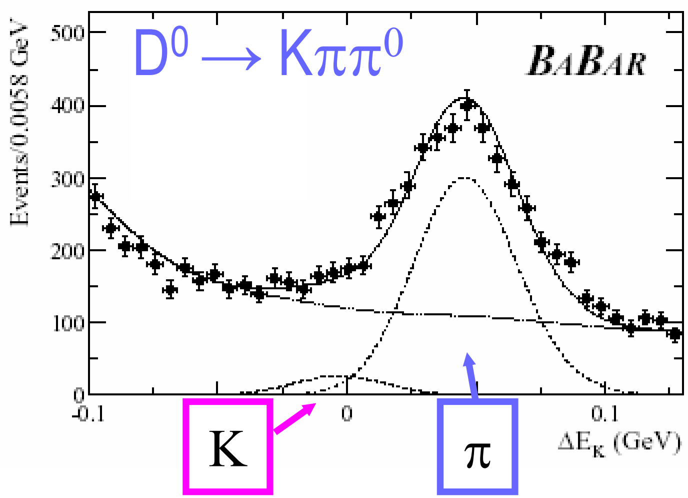
(Preliminary)

29 fb^{-1}

13

15.3 fb^{-1}

14



$$R = \frac{\mathcal{B}(B^\pm \to D^0 K^\pm)}{\mathcal{B}(B^\pm \to D^0 \pi^\pm)}$$

$R = (8.31 \pm 0.35 \pm 0.20)\%$

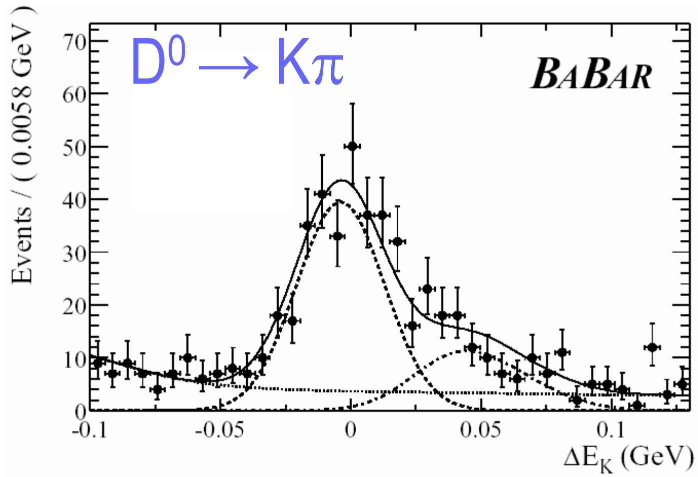
[weighted result over 3 modes]

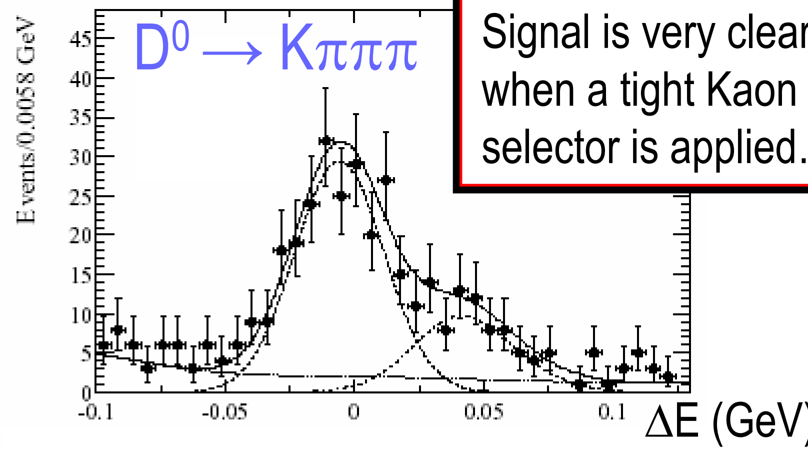
$R = (7.9 \pm 0.9 \quad \pm 0.6 \ )\%$

$R = (9.9 \pm 1.3 \quad \pm 0.7 \ )\%$

- Signal extracted with a likelihood fit to the ΔE, m_{ES}, $\theta_{Cherenkov}$ (π/K)
- So approx. BR(B- $\to$ D0 K-) = 4.3×10^{-4}

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



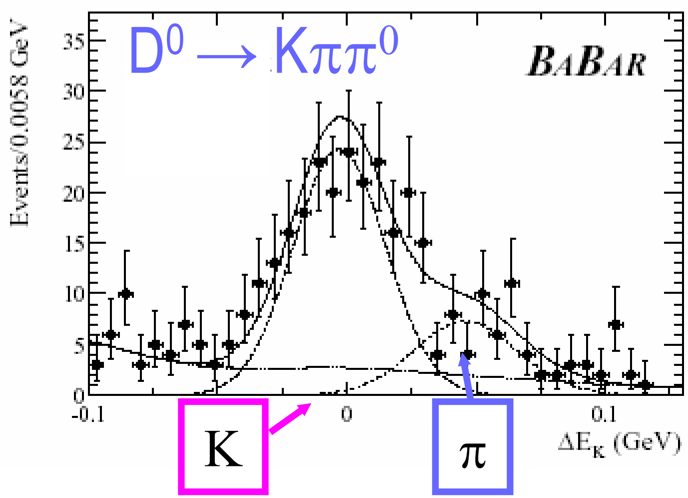


Signal is very clear when a tight Kaon PID selector is applied…

75 fb^{-1}

12

(Preliminary)



$$R = \frac{\mathcal{B}(B^{\pm}\rightarrow D^{0} K^{\pm})}{\mathcal{B}(B^{\pm}\rightarrow D^{0} \pi^{\pm})}$$

$R = (8.31 \pm 0.35 \pm 0.20)\%$

[weighted result over 3 modes]

BELLE

29 fb^{-1}

13

$R = (7.9 \pm 0.9 \pm 0.6)\%$

$R = (9.9 \pm 1.3 \pm 0.7)\%$

15.3 fb^{-1}

14

- So approx. BR(B- $\rightarrow$ D0 K-) = 4.3 x 10^{-4}

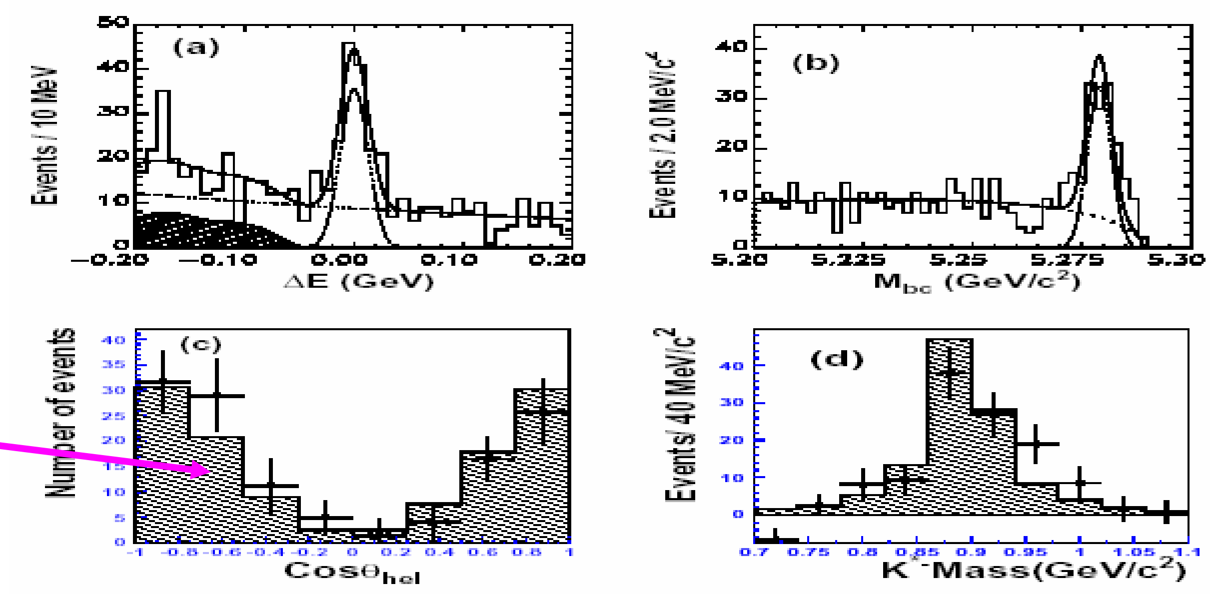
$B^- \rightarrow D^0 K^{*-}$ $D^0 \rightarrow K\pi, K\pi\pi^0, K\pi\pi\pi$

60.1 fb^{-1}

15

(Preliminary)

- The same physics can be targeted with excited K*- states replacing the K-



cos θ_{HEL} form from polarized pseudoscalar to pseudoscalar-vector decay

- Signal extracted with a likelihood fit to the ΔE

$$\mathcal{B}(B^- \rightarrow D^0 K^{*-}) = \quad (5.4 \pm 0.6(\text{stat}) \pm 0.8(\text{sys})) \times 10^{-4}$$

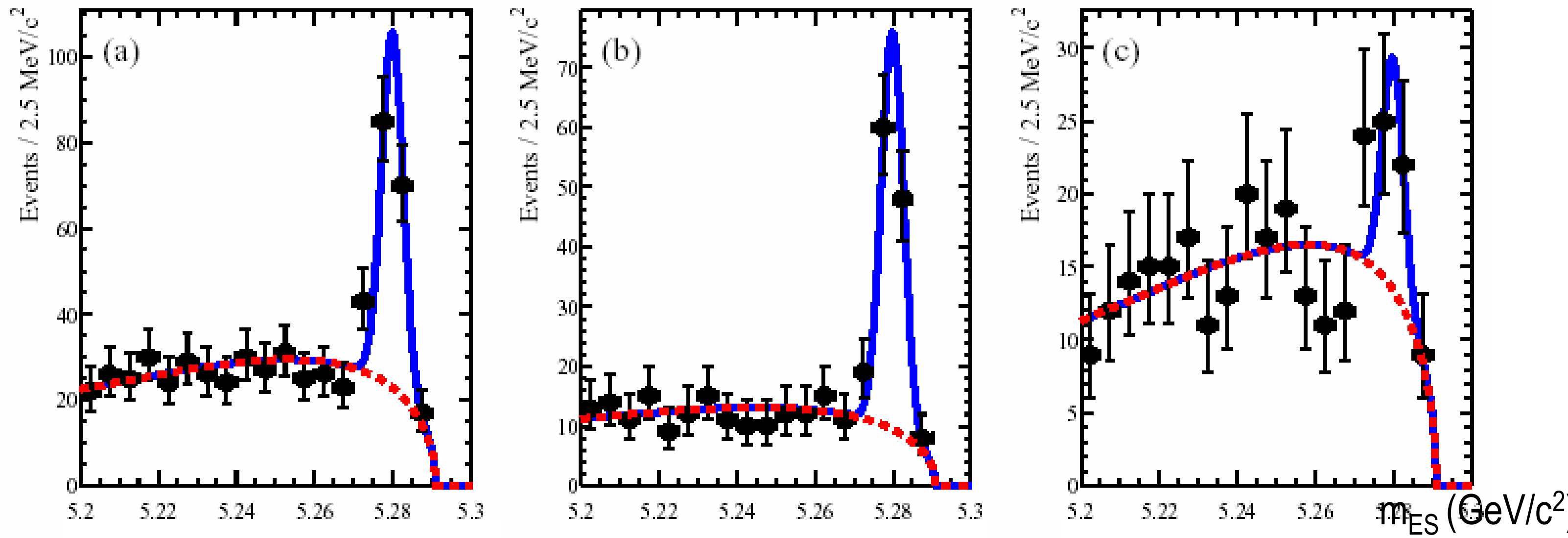
$B^- \to D^{*0} K^{*-}$ $D^0 \to K\pi, K\pi\pi^0, K\pi\pi\pi$

- For the same reason, observing and then using $B^- \to D^{*0}K^{*-}$ is also important.
  - Hot off the press from Babar

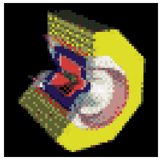
81.2 fb^{-1}

16

(Preliminary)



$B \to D^{*0} K^{*-}$	$B \to D^{*0} K^{*-}$	$B \to D^{*0} K^{*-}$
ALL	$D^{*0} \to D^0\pi^0$	$D^{*0} \to D^0\gamma$



$$\mathcal{B}(B^- \to D^{*0} K^{*-}) = \quad (8.0 \pm 1.0(\text{stat}) \pm 1.2(\text{sys})) \times 10^{-4}$$

9.13 fb^{-1}

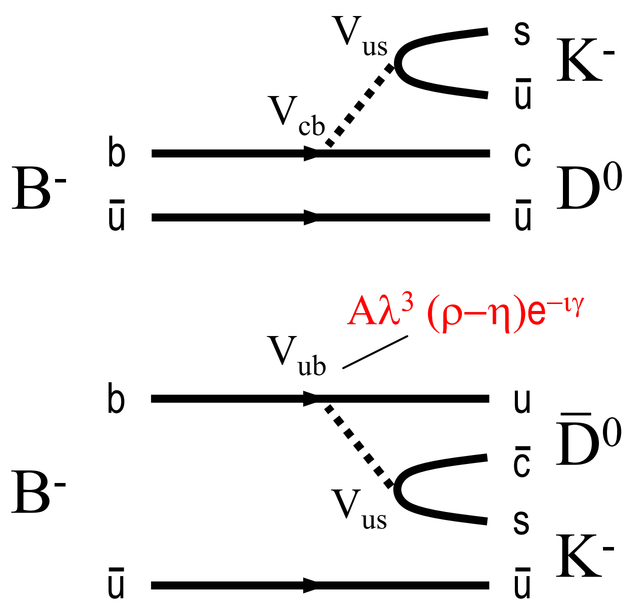
Compares well with CLEO (2001) result $(7.7 \pm 2.2(\text{stat}) \pm 2.6(\text{sys})) \times 10^{-4}$

17

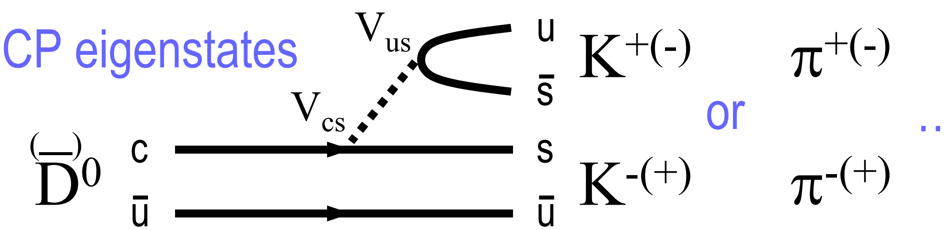
$B^- \to D^0 K^-$ $D^0 \to \{\text{CP-eigenstate}\}$

- We can also look for direct CP violation where the D^0 decays to CP eigenstates 18

CPV : $\mathcal{B}(B^- \to D_{CP}^0 K^-) \neq \mathcal{B}(B^+ \to D_{CP}^0 K^+)$



CP eigenstates



- Again, a statistically challenged analysis
  - Rate is suppressed (either by colour or cabbibo effects) for CP decays of the D^0 w.r.t. non-CP decays ($D \to K\pi$ …)
  - CP violation effect is expected to be small $\dfrac{\mathcal{B}(B^- \to D^0 K^-)}{\mathcal{B}(B^- \to \overline{D}^0 \pi^-)} \approx \left|\dfrac{a_2}{a_1}\right| \cdot \left|\dfrac{V_{ub}}{V_{cb}V^*_{us}}\right| \approx 10\%$
    - Assume $D\overline{D}$ mixing is negligible

colour suppression term

$B^- \longrightarrow D^0 K^-$ $D^0 \longrightarrow \{\text{CP-eigenstate}\}$

Results are presented for   CP = +1 : K^+K^-, $\pi^+\pi^-$ CP = -1 : $K_s\pi^0$, $K_s\phi$, $K_s\eta$, $K_s\omega$, $K_s\eta'$

78 fb^{-1}

13

(Preliminary)

$D \longrightarrow K\pi$

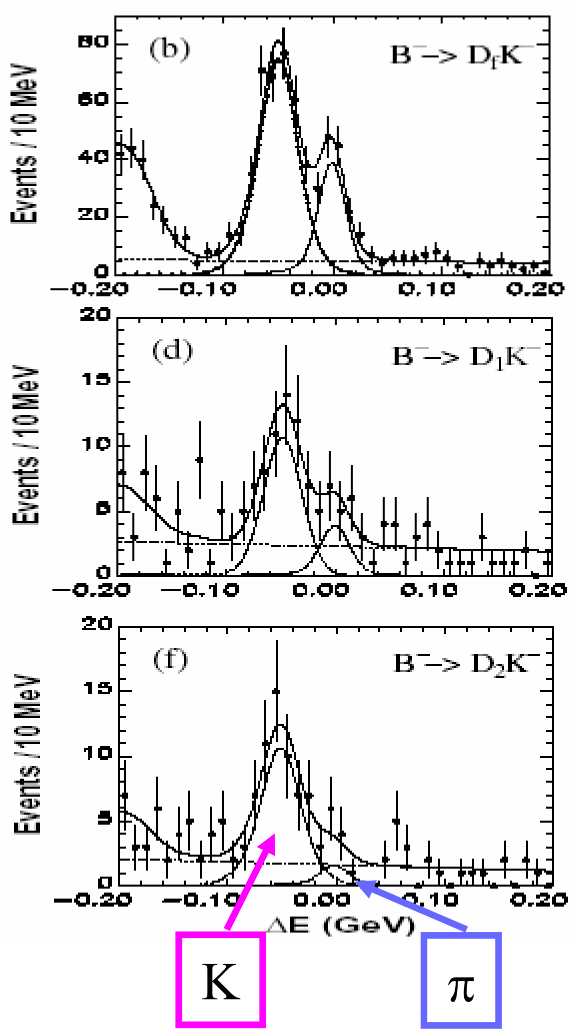
(or D_f)

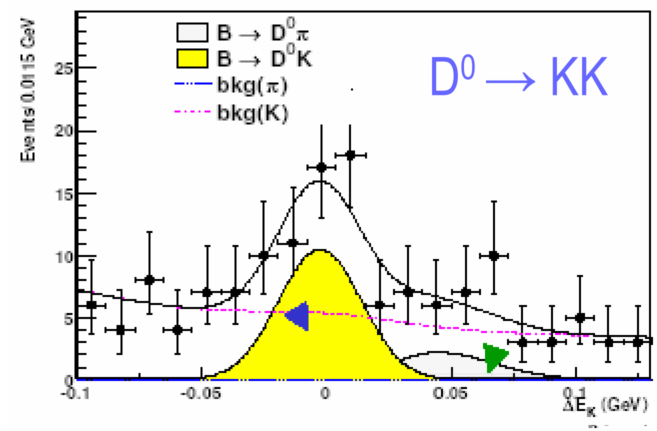
CP = +1

(or D_1)

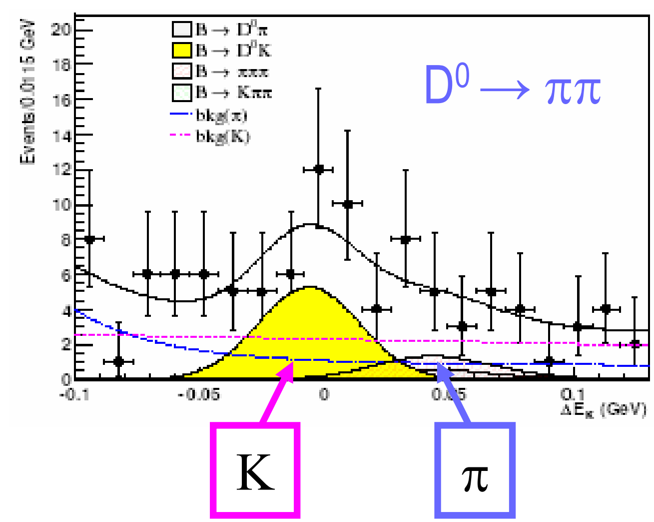
CP = -1

(or D_2)





ΔE



81.2 fb^{-1}

12

(Preliminary)

$B^- \longrightarrow D^0 K^-$ $D^0 \longrightarrow$ {CP-eigenstate}

- The asymmetry is expected to be small and, as yet, no CPV is seen

$$\mathcal{A}_{1,2} = \frac{\mathcal{B}(B^- \to D^0_{1,2}K^-) - \mathcal{B}(B^+ \to D^0_{1,2}K^+)}{\mathcal{B}(B^- \to D^0_{1,2}K^-) + \mathcal{B}(B^+ \to D^0_{1,2}K^+)} \qquad \mathcal{A}_{1,2} = \frac{2r\sin(\delta)\sin(\gamma)}{1 + r^2 + 2r\cos(\delta)\cos(\gamma)}$$

$$\mathcal{R}_{1,2} = \frac{\mathcal{B}(B^- \to D^0_{1,2}K^-) / \mathcal{B}(B^- \to D^0_{1,2}\pi^-)}{\mathcal{B}(B^- \to D^0_{D\to K\pi}K^-) / \mathcal{B}(B^- \to D^0_{D\to K\pi}\pi^-)} \qquad \mathcal{R}_{1,2} = 1 + r^2 + 2r\cos(\delta)\cos(\gamma)$$

81.2 fb^{-1}

12

(Preliminary)

$r = \dfrac{\Gamma(\text{colour sup.})}{\Gamma(\text{colour allow.})}$

δ = strong phase

γ = weak phase

1 internal relation

$$\mathcal{A}_1\mathcal{R}_1 = -\mathcal{A}_2\mathcal{R}_2$$

leaves 3 independent measurables for 3 unknowns (r, δ, γ) !

CP = +1

$\mathcal{A}_1$ = 0.06 ± 0.19(stat) ± 0.04(sys)

= 0.17 ± 0.23(stat) ± 0.08(sys)

$\mathcal{R}_1$ = 1.21 ± 0.25(stat) ± 0.14(sys)

= 1.06 ± 0.26(stat) ± 0.17(sys)

CP = -1

$\mathcal{A}_2$ = -0.19 ± 0.17(stat) ± 0.05(sys)

$\mathcal{R}_2$ = 1.41 ± 0.27(stat) ± 0.15(sys)

BELLE

78 fb^{-1}

13

(Preliminary)

Summary of the review

Color Suppression

- Colour-suppressed modes have been observed and confirmed by all the B-factory experiments
- Colour suppression in $B \to D^0 X^0$ decays is not as strong as previously expected
- Good news for statistically-limited analyses using colour-suppressed modes

Working towards $2\beta+\gamma$

- $>3\sigma$ evidence for $B \to D_s^* \pi$; a vital ingredient of $2\beta+\gamma$ analyses of $B \to D^{(*)} \pi$
- First observation of the annihilation process $B^- \to D_s^* K^-$
- First observation of $B^0 \to D^0 K^0$; beginning of a new $2\beta+\gamma$ analysis

Looking forward to γ

- A lot of effort is being targeted at $B \to D_{(CP)}^0 K$ decays. Several methods for extraction of γ
- The search direct CPV with exclusive hadronic B to charm decays is underway
- But we are definitely statistically limited so, as yet, no violation is seen

- Belle and Babar both currently approaching $150fb^{-1}$ and aiming for $500fb^{-1}$ in 2005,

Watch this space…..

References

Branching Fractions (and Direct CPV) of
Exclusive Hadronic B to Charm Decays

References of results included in this talk

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4 • Babar Collab., hep-ex/0207092
6 • Belle Collab., Belle-conf-0248
7 • Babar Collab., hep-ex/0211053
10 • Belle Collab., hep-ex/0212066
12 • Babar Collab., hep-ex/0207087
13 • Belle Collab., hep-ex/0304032
14 • CLEO Collab., hep-ex/0302026
15 • Belle Collab., Belle-conf-0236
16 • Babar Collab., PRL in draft
17 • CLEO Collab., Phys.Rev.Lett.**88** 1113002 (2002)

Other references (theory, phenomenology)

1 • M.Neubert & B.Stech, hep-ph/9705292, in "Heavy Flavors" ed. Buras & Lindner

5 • I.Dunietz, Phys.Lett. **B 427**, 179 (1998)

8 • Chun-Khiang Chua, Wei-Shu Hou Phys.Rev. **D 65**, 096007 (2002)
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M.Gronau & D.London, Phys.Lett. **B253** 483 (1991)

BACK-UP SLIDES

$$B^0 \text{ and } B^{\pm} \longrightarrow D^{(*)} D^{(*)} K$$

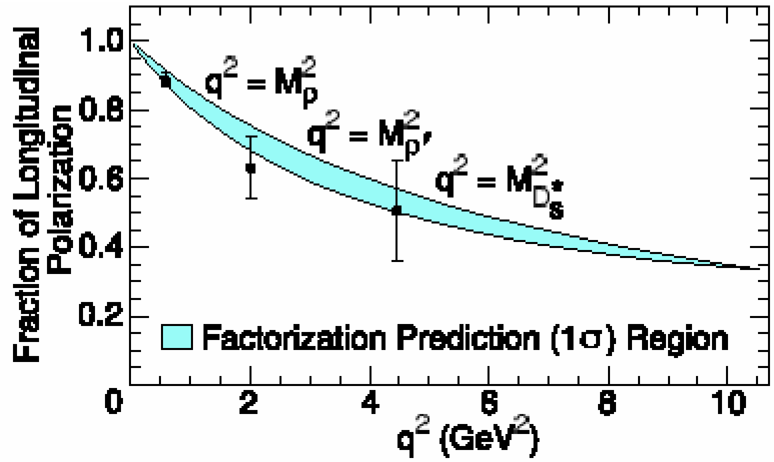
$$B^0 \longrightarrow D^{(*)} \pi\pi$$

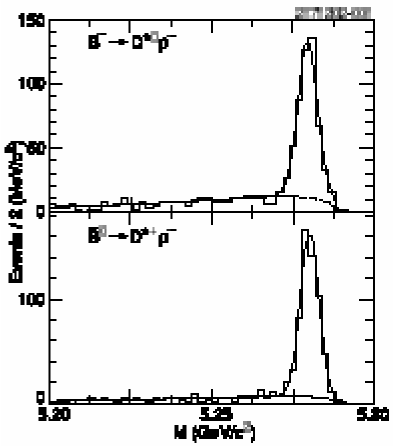
Testing factorization with polarization measurements in B to vector-vector decays

$$B^- \rightarrow D^{*0} \rho^-$$
$$B^- \rightarrow D^{*0} K^{*-}$$

Tests of factorization from $B \rightarrow D^{*}\rho^{-}$ and $B^{-} \rightarrow D^{*0} K^{*-}$

- Under the factorization hypothesis, B decays to vector mesons are analogous to semileptonic decays with a momentum transfer $q^2 = M^2_{\ell\nu}$



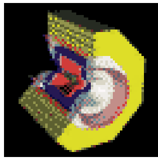


$B^{-} \rightarrow D^{*0} \rho^{-}$

$B^{0} \rightarrow D^{*+} \rho^{-}$

$B^{-} \rightarrow D^{*0} \rho^{-}$

$$\frac{\Gamma_L}{\Gamma} = 0.892 \pm 0.018 \pm 0.016$$



81.2 fb^{-1}

$B^{-} \rightarrow D^{*0} K^{*-}$

$$\frac{\Gamma_L}{\Gamma} = 0.86 \pm 0.06 \pm 0.03$$

(Preliminary)

$B^{0} \rightarrow D^{*+} \rho^{-}$

$$\frac{\Gamma_L}{\Gamma} = 0.885 \pm 0.016 \pm 0.012$$

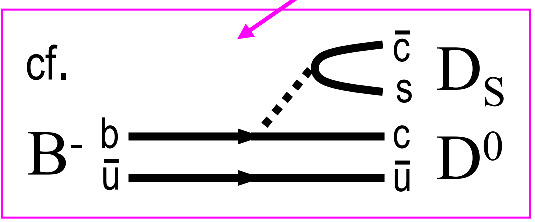
9.1 fb^{-1}

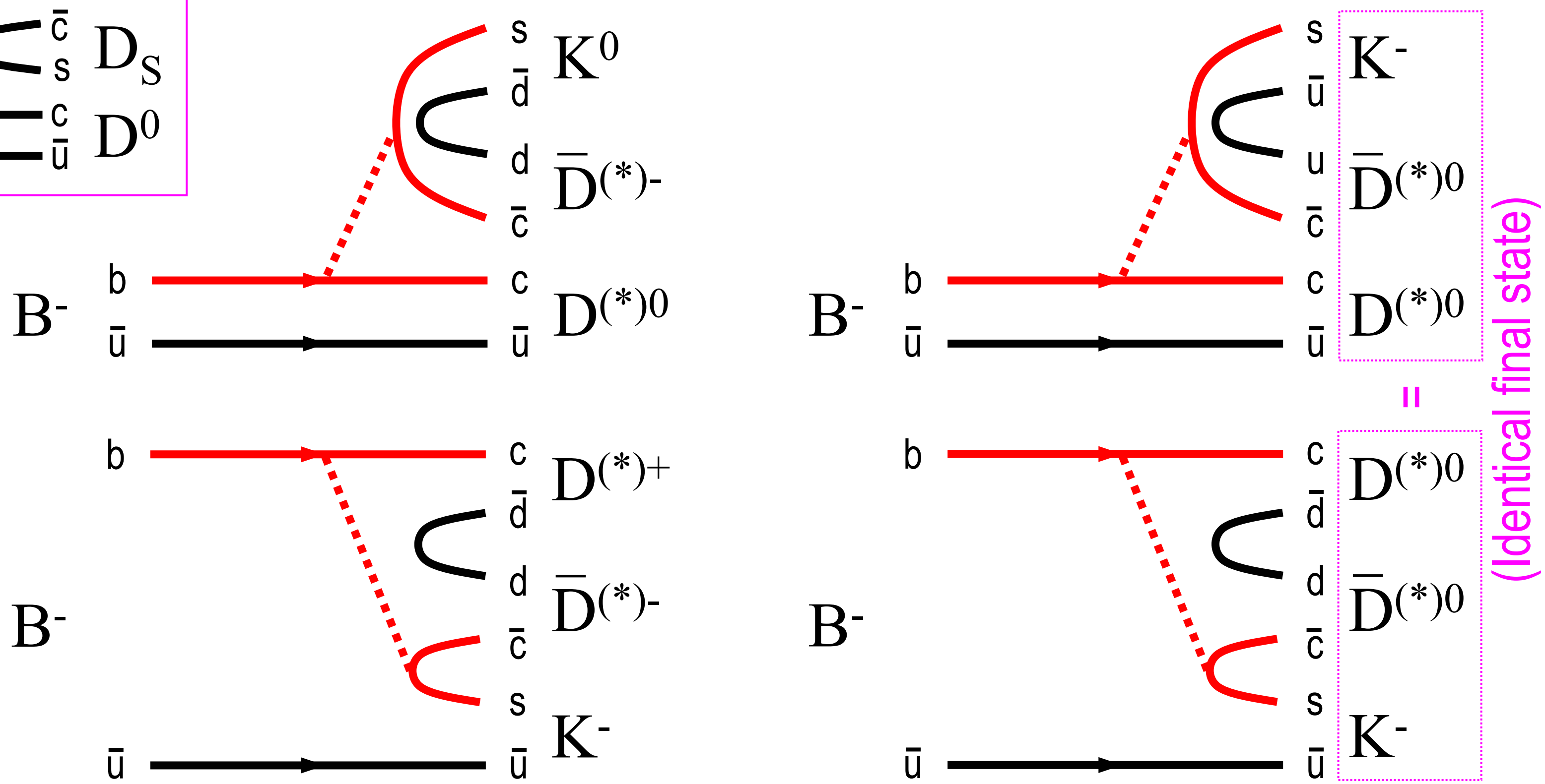
Resolving charm counting questions with the high statistics from the B-factories

$$B^0 \text{ and } B^{\pm} \longrightarrow D^{(*)}\, D^{(*)}\, K$$

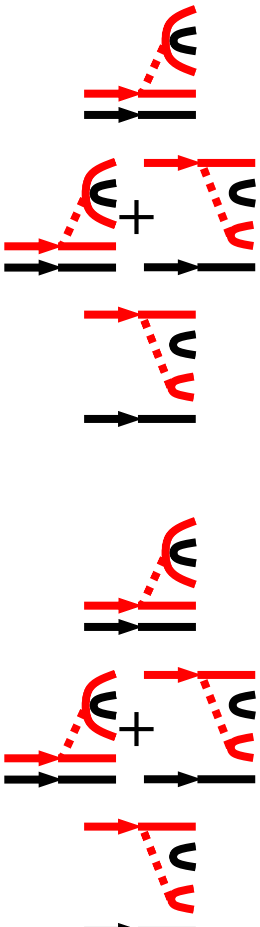
B^0 and $B^\pm \longrightarrow D^{(*)}\,D^{(*)}\,K$

- $\mathcal{B}(b \to c\bar{c}s)$ using $B \to D_sX$, $(cc)X$, Ξ_cX (~15%) is too low to agree with observed semi-leptonic rates (~10%) of B decays
- The observation of a significant rate for 3-body $B \to D^{(*)}\bar{D}^{(*)}K$ processes validates solutions this long-standing problem of charm content of B decays





B^0 and $B^\pm \longrightarrow D^{(*)} D^{(*)} K$



B decay mode	Branching fraction (10^{-3})	90% C.L. upper limit (10^{-3})
$B^0 \to D^- D^0 K^+$	$1.7 \pm 0.3 \pm 0.3$	
$B^0 \to D^- D^{*0} K^+$	$4.6 \pm 0.7 \pm 0.7$	
$B^0 \to D^{*-} D^0 K^+$	$3.1^{+0.4}_{-0.3} \pm 0.4$	
$B^0 \to D^{*-} D^{*0} K^+$	$11.8 \pm 1.0 \pm 1.7$	
$B^0 \to D^- D^+ K^0$	$0.8^{+0.6}_{-0.5} \pm 0.3$	< 1.7
$B^0 \to D^{*-} D^+ K^0$+CC	$6.5 \pm 1.2 \pm 1.0$	
$B^0 \to D^{*-} D^{*+} K^0$	$8.8^{+1.5}_{-1.4} \pm 1.3$	
$B^0 \to \overline{D}^0 D^0 K^0$	$0.8 \pm 0.4 \pm 0.2$	< 1.4
$B^0 \to \overline{D}^0 D^{*0} K^0$+CC	$1.7^{+1.4}_{-1.3} \pm 0.7$	< 3.7
$B^0 \to \overline{D}^{*0} D^{*0} K^0$	$3.3^{+2.1}_{-2.0} \pm 1.4$	< 6.6
$B^+ \to \overline{D}^0 D^+ K^0$	$1.8 \pm 0.7 \pm 0.4$	< 2.8
$B^+ \to \overline{D}^{*0} D^+ K^0$	$4.1^{+1.5}_{-1.4} \pm 0.8$	< 6.1
$B^+ \to \overline{D}^0 D^{*+} K^0$	$5.2^{+1.0}_{-0.9} \pm 0.7$	
$B^+ \to \overline{D}^{*0} D^{*+} K^0$	$7.8^{+2.3}_{-2.1} \pm 1.4$	
$B^+ \to \overline{D}^0 D^0 K^+$	$1.9 \pm 0.3 \pm 0.3$	
$B^+ \to \overline{D}^{*0} D^0 K^+$	$1.8^{+0.7}_{-0.6} \pm 0.4$	< 3.8
$B^+ \to \overline{D}^0 D^{*0} K^+$	$4.7 \pm 0.7 \pm 0.7$	
$B^+ \to \overline{D}^{*0} D^{*0} K^+$	$5.3^{+1.1}_{-1.0} \pm 1.2$	
$B^+ \to D^- D^+ K^+$	$0.0 \pm 0.3 \pm 0.1$	< 0.4
$B^+ \to D^- D^{*+} K^+$	$0.2 \pm 0.2 \pm 0.1$	< 0.7
$B^+ \to D^{*-} D^+ K^+$	$1.5 \pm 0.3 \pm 0.2$	
$B^+ \to D^{*-} D^{*+} K^+$	$0.9 \pm 0.4 \pm 0.2$	< 1.8

$$\mathcal{B}(B^0 \to D^{(*)} D^{(*)} K) = (4.3 \pm 0.3 \pm 0.6) \times 10^{-2}$$

$$\mathcal{B}(B^+ \to D^{(*)} D^{(*)} K) = (3.5 \pm 0.3 \pm 0.5) \times 10^{-2}$$

- A significant measurement has been made for all decay types
- The total BRs show that $B \to DDK$ contributes significantly to the $b \to c\bar{c}s$ rates
- The total $\mathcal{B}(b \to c\bar{c}s)$ is ~23% which is lower than ~30% predicted by theory

75.9 fb^{-1}

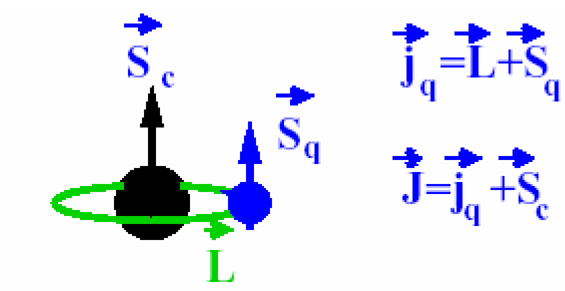
(Preliminary)

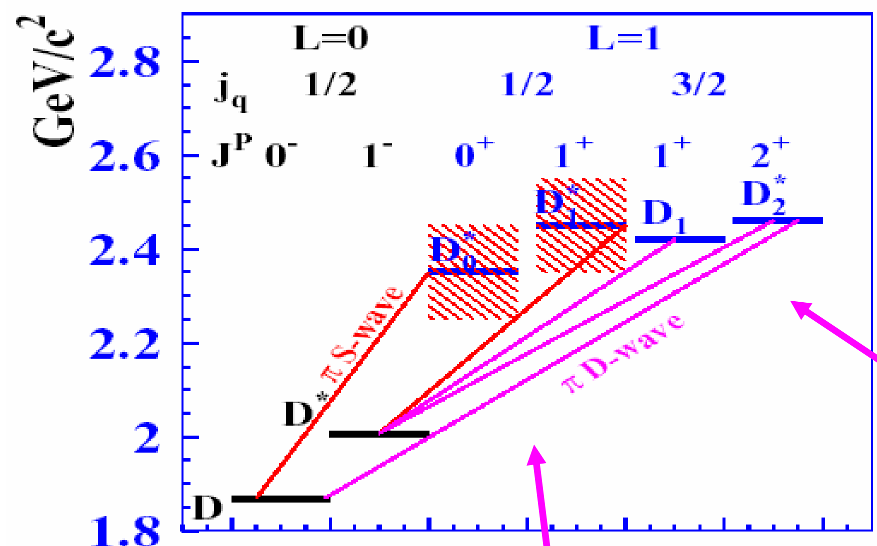
Exploring the resonant sub-structure of B-decays

$$B^- \longrightarrow D^{(*)-}\ \pi^+\pi^-$$
$$B^0 \longrightarrow D^{(*)+} K^- K^{(*)0}$$
$$B^- \longrightarrow D^{(*)0}\ K^+ K_s^{\ 0}$$

Resonance structure - $B^- \rightarrow D^{(*)+} \pi^- \pi^-$

- Study of charmed meson production in B decays provides an opportunity to test Heavy Quark Effective Theory (HQET)
  - In the heavy quark limit, the heavy quark spin s_c decouples from the other degrees of freedom, so that the total momentum of the light quark $j_q = L + s_q$ is a good quantum number

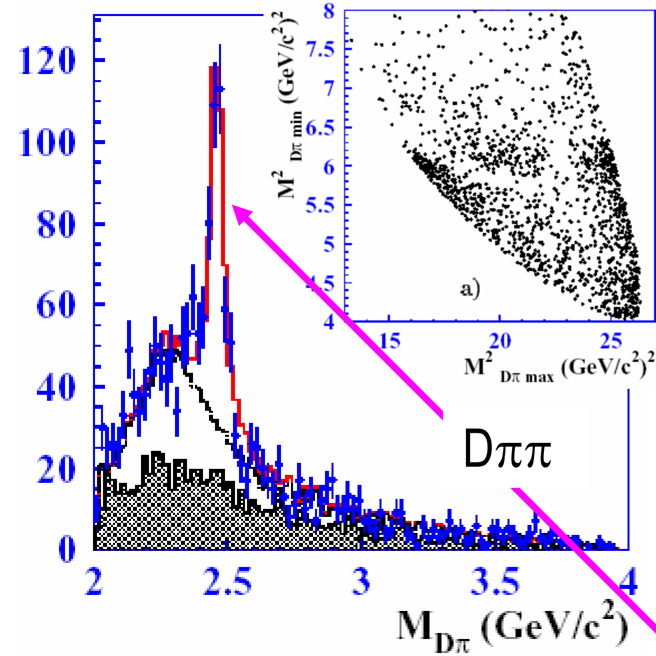


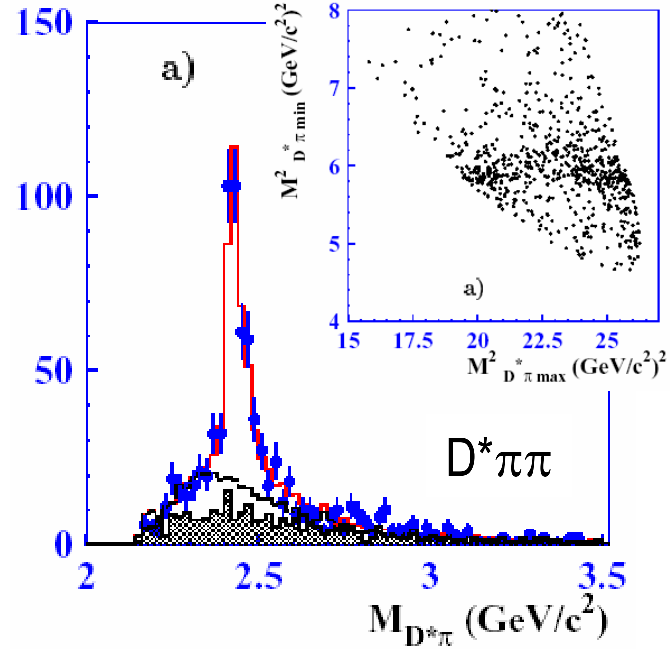


D_1 and D_2^* are narrow resonances observed by CLEO

D_0^* and D_1^* are broader

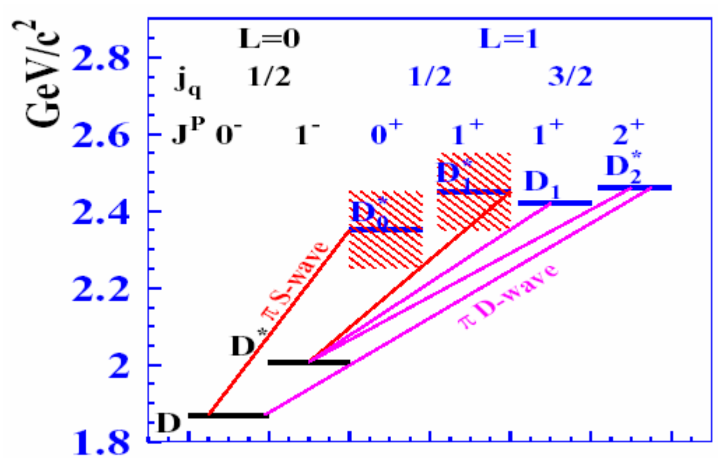
Resonance structure - $B^- \to D^{(*)+} \pi^- \pi^-$





60.4 fb^{-1}

(Preliminary)



$\mathcal{B}(B^- \to D_2^{*0}\pi^-) \times \mathcal{B}(D_2^{*0} \to D^-\pi^+)$ = (3.5±0.3±0.5) x 10^{-4}

$\mathcal{B}(B^- \to D_0^{*0}\pi^-) \times \mathcal{B}(D_0^{*0} \to D^-\pi^+)$ = (5.5±0.5±0.8) x 10^{-4}

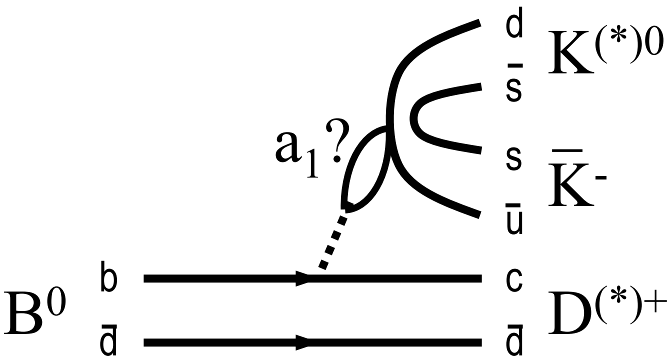
$\mathcal{B}(B^- \to D_1\pi^-) \times \mathcal{B}(D_1 \to D^{*-}\pi^+)$ = (6.2±0.5±1.1) x 10^{-4}

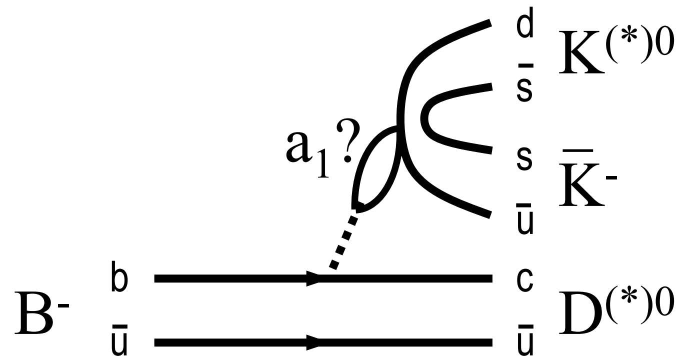
$\mathcal{B}(B^- \to D_2^{*0}\pi^-) \times \mathcal{B}(D_2^{*0} \to D^{*-}\pi^+)$ = (2.0±0.3±0.5) x 10^{-4}

$\mathcal{B}(B^- \to D_1^{*0}\pi^-) \times \mathcal{B}(D_1^{*0} \to D^{*-}\pi^+)$ = (4.1±0.5±0.8) x 10^{-4}

$B^0 \to D^{(*)+} K^- K^{(*)0}$, $B^\pm \to D^{(*)0} K^+ K_s^0$

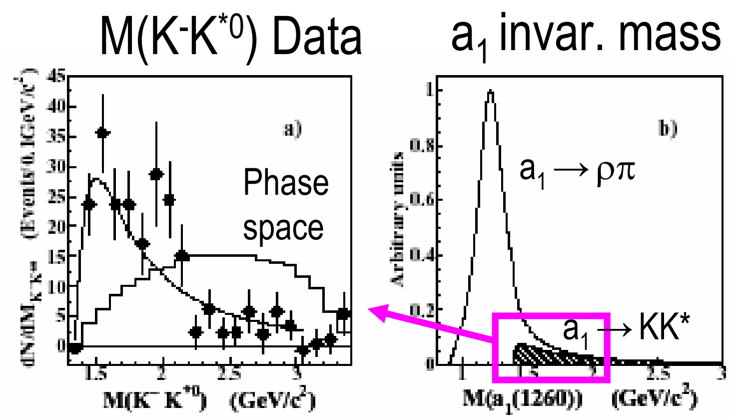
29.4 fb^{-1}





Decay modes	Br. fractions, upper limits (10^{-4})	Signif. σ
$B^- \to D^0 K^- K^{*0}$	$7.5 \pm 1.3 \pm 1.1$	8.0
$\bar{B}^0 \to D^+ K^- K^{*0}$	$8.8 \pm 1.1 \pm 1.5$	10.4
$B^- \to D^{*0} K^- K^{*0}$	$15.3 \pm 3.1 \pm 2.9$	6.7
$\bar{B}^0 \to D^{*+} K^- K^{*0}$	$12.9 \pm 2.2 \pm 2.5$	9.5
$B^- \to D^0 K^- K^0$	$5.5 \pm 1.4 \pm 0.8$	5.5

1st observation of all modes



"The observed behaviour can be interpreted as the production of an intermediate $a_1(1260)$ resonance that decays to $K^- K_s^0$."