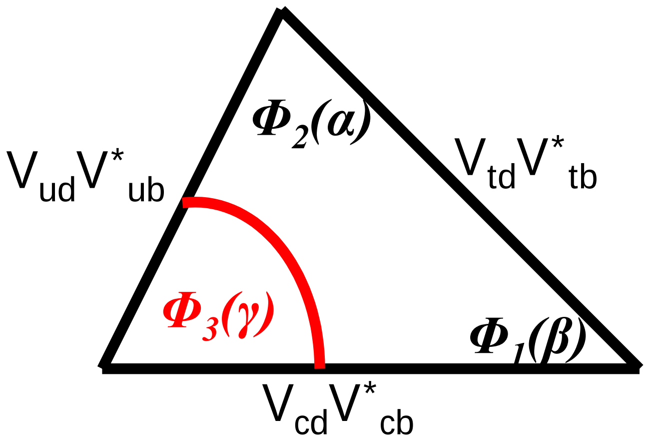
CPV in B $\to$ $D^{(*)} K^{(*)}$ (and B $\to$ D K π) in BaBar and Belle

Outline:

- CPV in B $\to$ $D^{(*)}X_s$
- theoretical ideas
- experimental issues
- experimental results
  - $B^{\cdot} \to D^{(*)0} K^{(*)\cdot}$
  - $B^0 \to D^{(*)0} K^{(*)0}$
- some other approaches
- summary

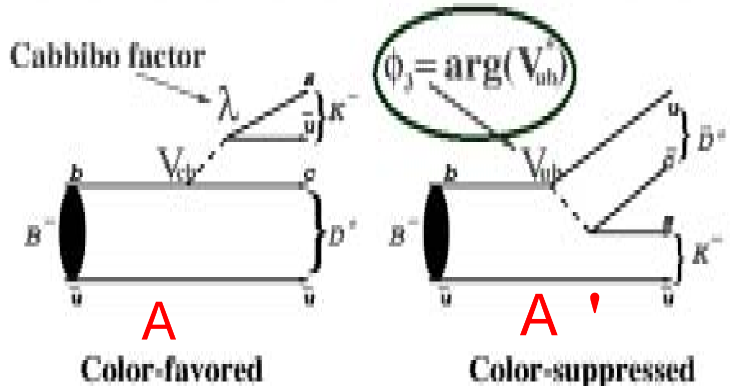
CPV in $B \to DX_s$



$\Phi_3(\gamma) \equiv \arg(-V_{ud}V^*_{ub} / V_{cd}V^*_{cb})$

CPV in interference between
$b \to c$ & $b \to u$

$B \to DX_s$ is a good place to look



interference between

$B \to D^{(*)0} K(X_s)$ • $B \to \overline{D}^{(*)0} K(X_s)$ → f

theoretically clean: only tree diagrams

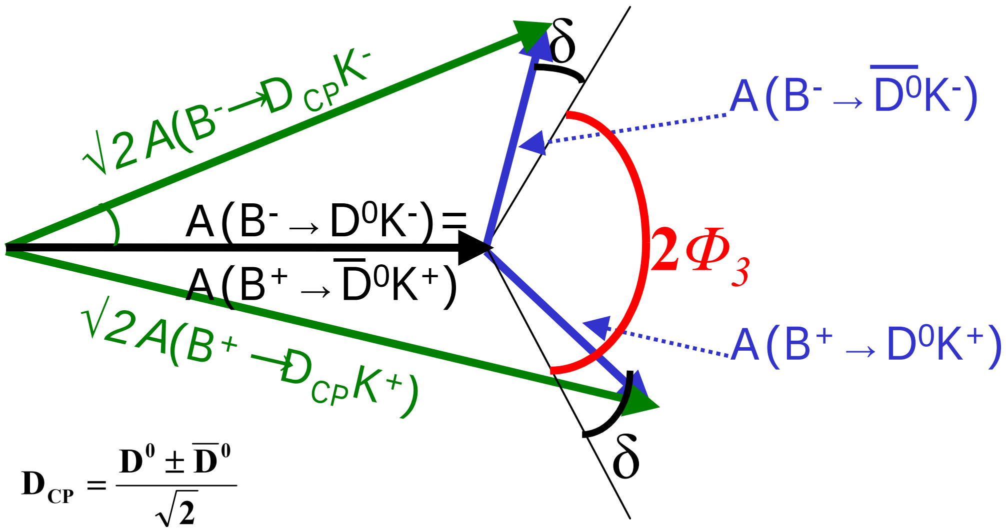
experimentally challenging:

sensitive to $r \equiv \frac{A'}{A}$

Ways to measure Φ_3 in $B \to DX_s$

$D \to f_{CP}$ (Gronau, London & Wyler method)

amplitude triangles



$$D_{CP} = \frac{D^0 \pm \overline{D}^0}{\sqrt{2}}$$

δ **-** relative strong phase

PROBLEMS:

- $r = A(B^- \to \overline{D}^0K^-)/A(B^- \to D^0K^-) \sim 0.1(0.2)$
- $A(B^- \to \overline{D}^0K^-)$ **difficult to measure directly**

extensions and modifications

various f

various X_s, (D)

many observables ...

statistics required:

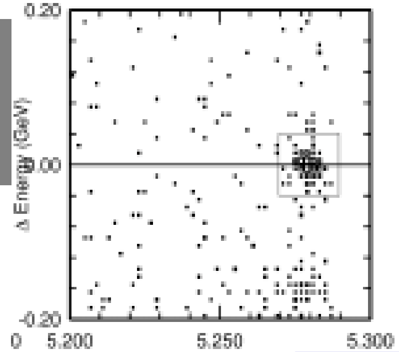
- **0.5 ab^{-1}**

Experimental issues

Use beam constraints to reconstruct B:

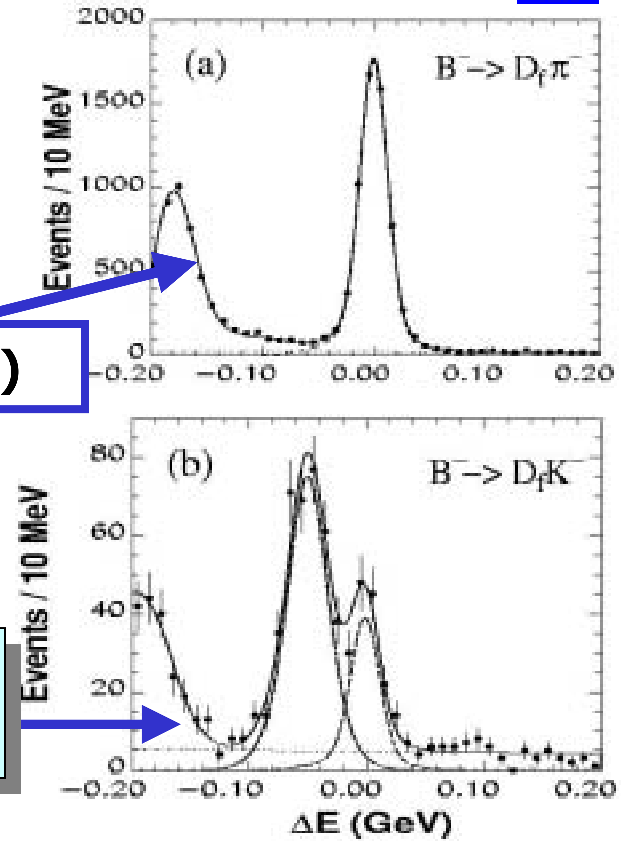
$$\Delta E = E^*_B - E^*_{beam}$$

$$M_{bc} = \sqrt{E^{*2}_{beam} - p^{*2}_B}$$



M_{bc}(GeV)

$\Delta E\ (B^- \to D^0 h^-)$



$\Delta E \approx$ **-49 MeV for DK$^-$**

$$R = \frac{B(B^- \to D K^-)}{B(B^- \to D \pi^-)} \cong \frac{f_K^2}{f_\pi^2} \tan^2 \Theta_C \approx 0.075$$

K/π separation

Babar : dE/dx in SVT & DCH, DIRC

Belle: dE/dx in CDC, TOF, ACC

≥2.5σ (K/π) separation up to 3.5 GeV

Apply tight K-ID cut:

Experimental issues

Continuum suppression:
multidimensional cuts exploiting event topology (Fox-Wolfram moments, thrust...)
angle of B-flight direction...

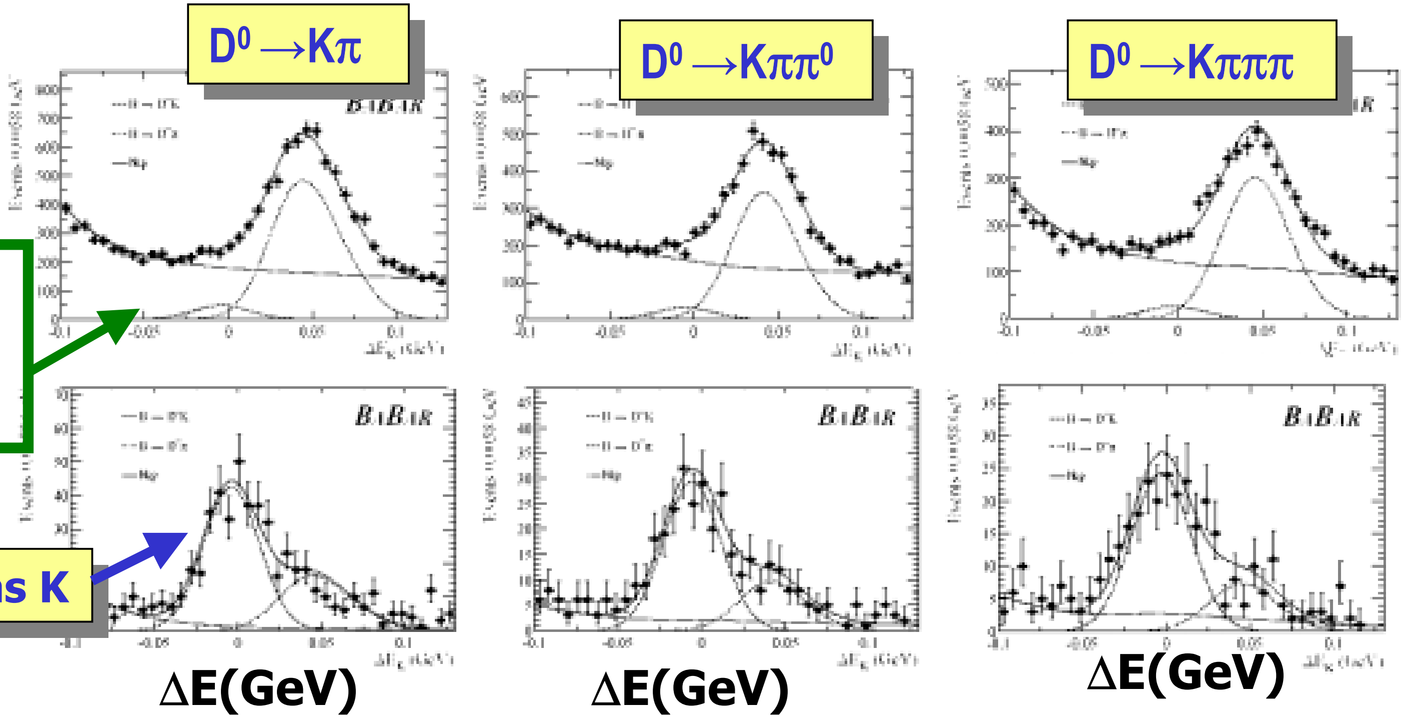
Background suppression from other B decays depends on specific final states:
veto for some B-decays, ...

Signal extraction:
Maximum likelihood fits with
signal shape from MC and data control samples,
background from side bands and off-resonance data (combinatorial), MC (B-decays)

56 fb^{-1}

Preliminary

$B^- \to D^0 h^-$ measurements



Signal extracted wit ML fit to the $\Delta E, M_{bc}$, PID(π/K)

h^- identified as K

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

$(7.7 \pm 0.9 \pm 0.6)\%$	Belle, PRL **87**,111801(2001)	10.4 fb^{-1}
$(8.31 \pm 0.35 \pm 0.2)\%$	Babar, hep-ex/0207087	56 fb^{-1}
$(9.9 \pm 1.3 \pm 0.7)\%$	CLEO, hep-ex/0302026	15.3 fb^{-1}

For other $B \to D(*)K^-$ modes see Belle, PRL **87**,111801(2001)

81.2 fb^{-1}

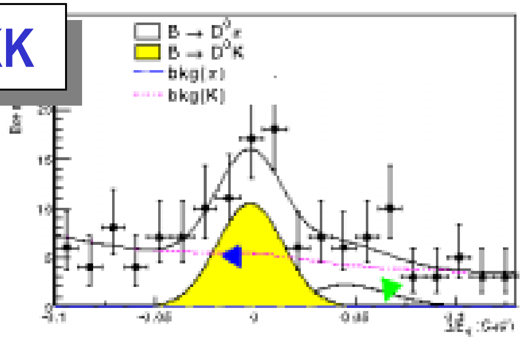
Preliminary

$B^- \to D_{CP} K^-$

$D_1 \equiv D_{CP=+}$ $D_2 \equiv D_{CP=-}$

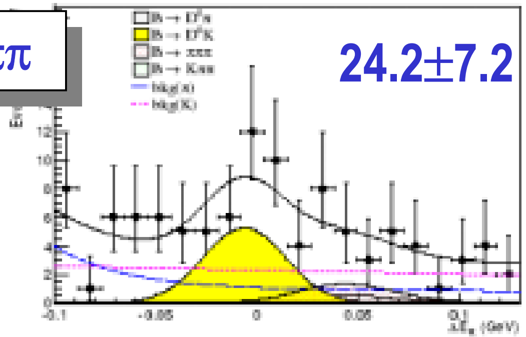
$B^\pm \to D_1 K^\pm$

$D_1 = KK$



$D_1 = \pi\pi$

24.2±7.2



ΔE(GeV)

Observables:

asymmetries

$$A_f \equiv \frac{B(B^- \to f) - B(B^+ \to \bar{f})}{B(B^- \to f) + B(B^+ \to \bar{f})}$$

branching ratios

$$R_{1,2} = R^{1,2} / R^{D0}$$

$$R^{1,2} \equiv B_{D_{1,2} K^-} / B_{D_{1,2} \pi^-}$$

$$R^{D0} \equiv B_{D^0 K^-} / B_{D^0 \pi^-}$$

$$B_f = \frac{\Gamma_{B \to f} + \Gamma_{\bar{B} \to \bar{f}}}{2\Gamma}$$

$$A_{1,2} = \frac{\pm 2r \sin\delta \sin\Phi_3}{1 + r^2 \pm 2r\cos\delta \cos\Phi_3}$$

$$R_{1,2} = 1 + r^2 \pm 2r\cos\delta \cos\Phi_3$$

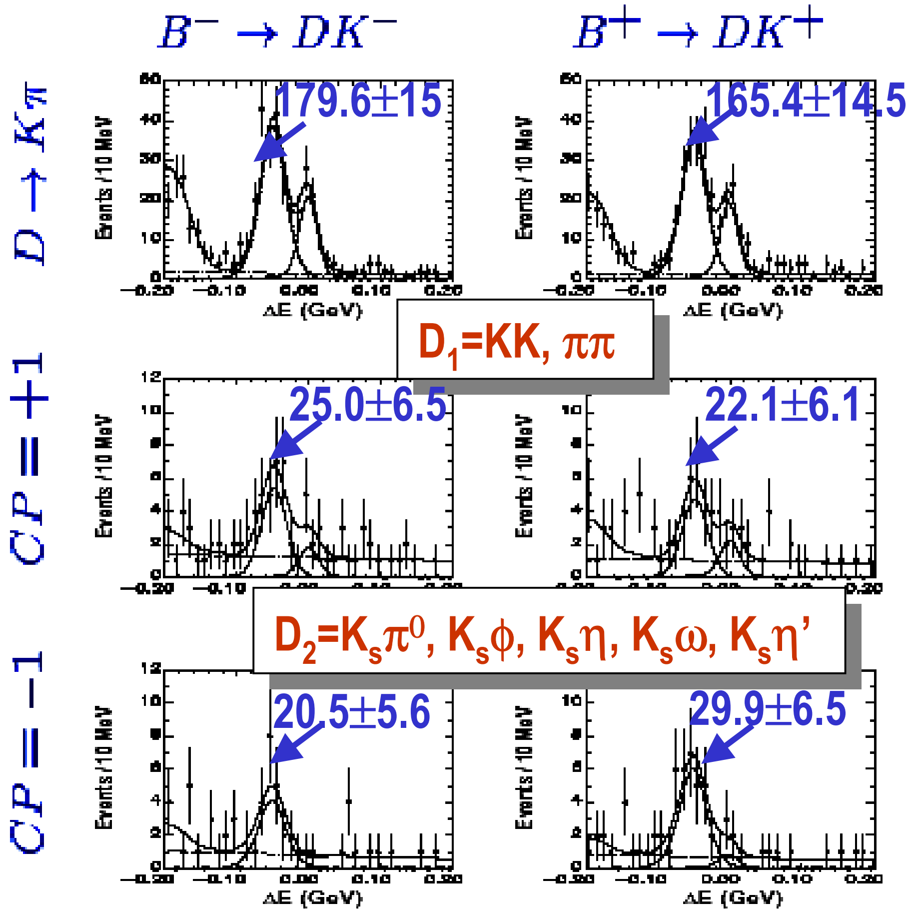
$$A_1 R_1 = -A_2 R_2$$

3 independent equations with 3 unknowns (Φ_3, r, δ)

A_1 = 0.17 ± 0.23(stat) ± 0.08(sys)

R_1 = 1.06 ± 0.26(stat) ± 0.17(sys)

$B^- \to D_{CP} K^-$



Signal yields extracted with a likelihood fit to the ΔE

A_1 = 0.06 ± 0.19(stat) ± 0.04(sys)

R_1 = 1.21 ± 0.25(stat) ± 0.14(sys)

A_2 = -0.19 ± 0.17(stat) ± 0.05(sys)

R_2 = 1.41 ± 0.27(stat) ± 0.15(sys)

$\sin^2(\Phi_3) \leq R_{1,2}$

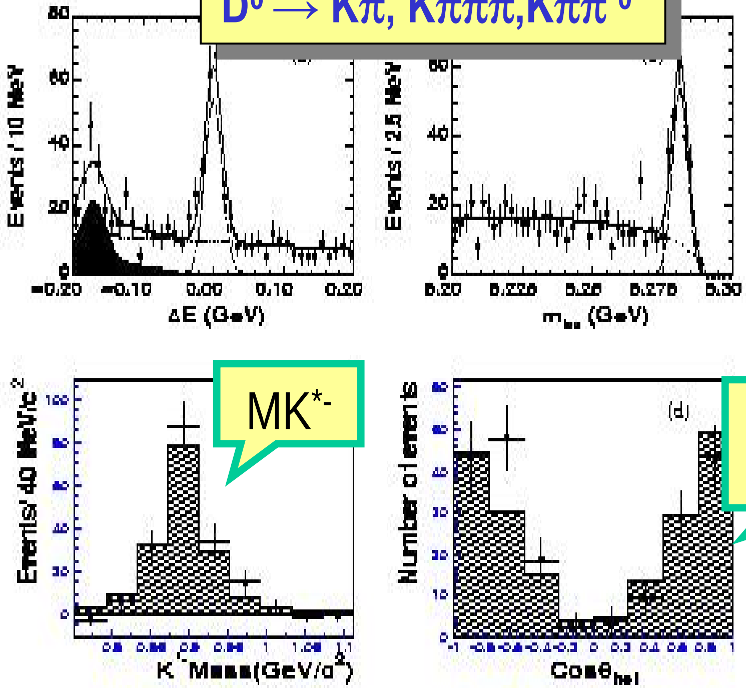
$r \geq 1/4\ |R_1 - R_2|$

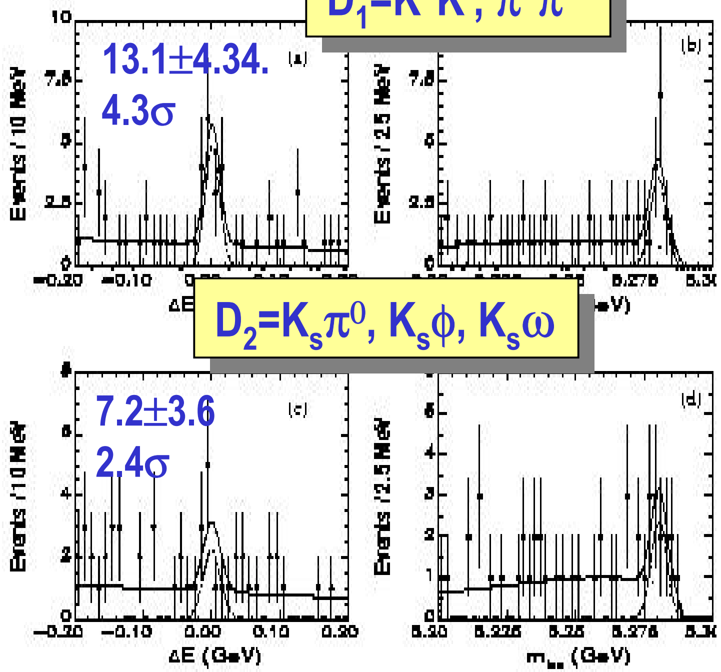
Similar analysis can be performed with K^{*-} replacing K^-

$B^- \to D_{CP} K^{*-}$

88 fb^{-1}

Preliminary





No indication for non-resonant $DK\pi$

$$B(B^- \to D^0 K^{*-}) = (5.2 \pm 0.5(stat) \pm 0.6(sys)) \times 10^{-4}$$

$(6.1 \pm 1.6(stat) \pm 1.7(sys)) \times 10^{-4}$ CLEO

A_1 = -0.02 ± 0.33(stat) ± 0.07(sys)

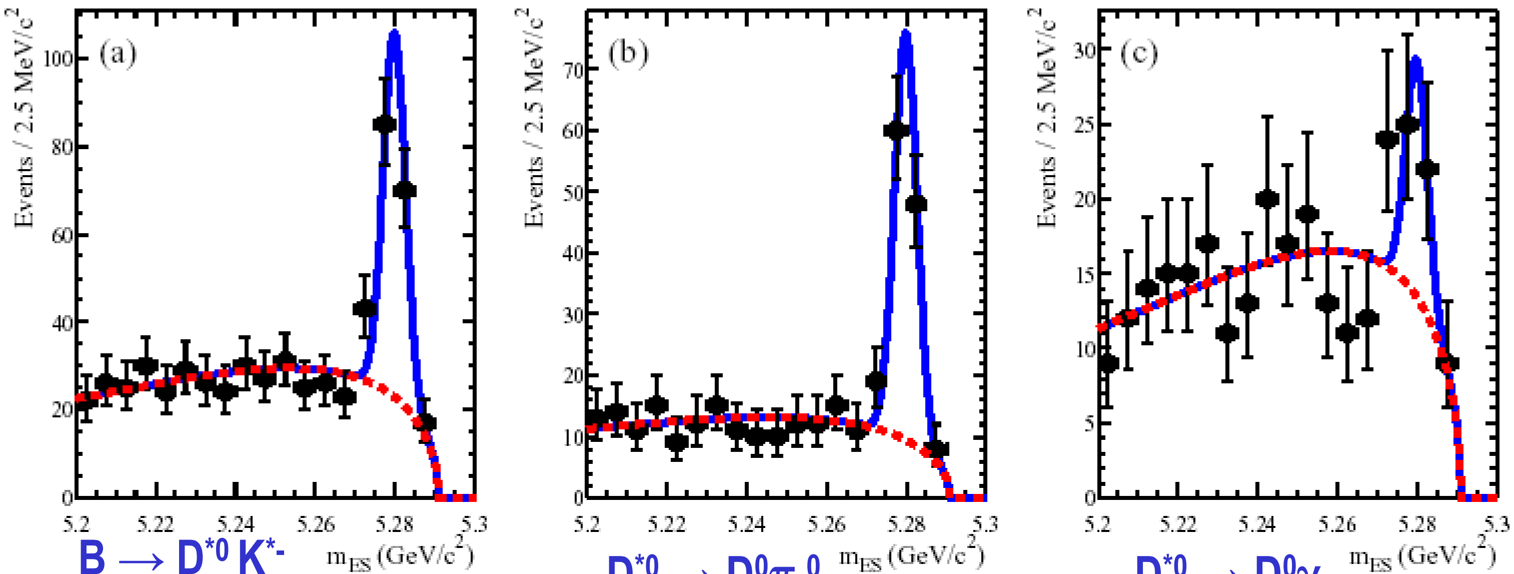
A_2 = 0.19 ± 0.50(stat) ± 0.04(sys)

B → V V can be also used,
angular analysis required,

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

81.2 fb^{-1}

Preliminary



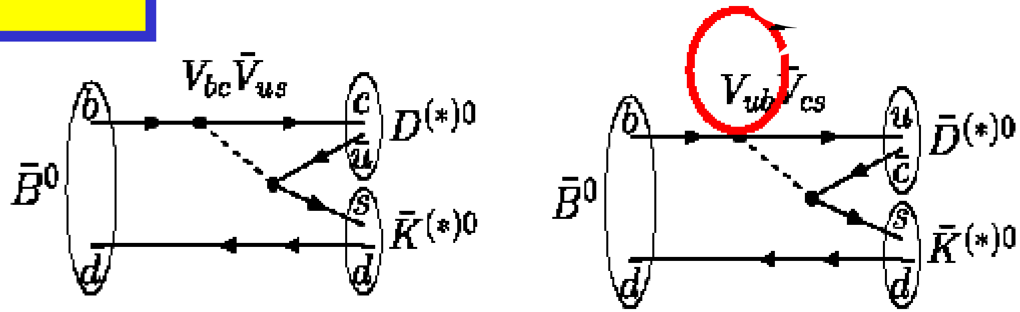
$B \to D^{*0} K^{*-}$ ALL

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

$D^{*0} \to D^0 \gamma$

$$\mathcal{B}(B^- \to D^{*0} K^{*-}) = \begin{array}{ll} (8.0 \pm 1.0(stat) \pm 1.2(sys)) \times 10^{-4} & \\ (7.7 \pm 2.2(stat) \pm 2.6(sys)) \times 10^{-4} & \text{CLEO} \end{array}$$

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



both amplitudes are color suppressed **r ~ 0.4**

isospin relations • extract Φ_3 and δ

$B^0 \to \overline{D}^0 K^{*0}$, $K^{*0} \to K^+\pi^-$ (kaon tags B^0 flavour)

rates and asymmetries $B^0 \to D_{1,2} K^{*0}$ • Φ_3

$B^0 \to \overline{D}^0 K^0_s$, $B^0 - \overline{B}^0$ mixing

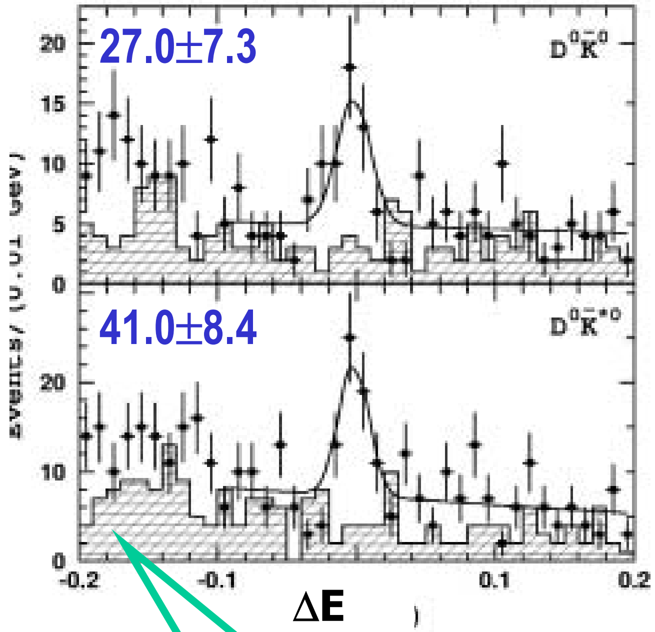
time dependent asymmetries

(B^0-decay vertex needed)

78 fb^{-1}

PRL **90**, 141802 (2003)

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



M(D^0) sidebands

$$\mathcal{B}(B^0 \to \overline{D}^0 K^{*0}) = (4.8 \pm 1.1(stat) \pm 0.5(sys)) \times 10^{-5}$$

$$\mathcal{B}(B^0 \to \overline{D}^0 K^0) = (5.0 \pm 1.3(stat) \pm 0.6(sys)) \times 10^{-5}$$

90% CL

$$\mathcal{B}(B^0 \to \overline{D}^{*0} K^0) < 6.6 \times 10^{-5}$$

$$\mathcal{B}(B^0 \to \overline{D}^{*0} K^{*0}) < 6.9 \times 10^{-5}$$

$$\mathcal{B}(B^0 \to D^0 K^{*0}) < 1.8 \times 10^{-5}$$

$$\mathcal{B}(B^0 \to D^{*0} K^{*0}) < 4.0 \times 10^{-5}$$

V_{ub}.

$$\frac{\mathcal{B}(B^0 \to \overline{D}^0 K^0)}{\mathcal{B}(B^0 \to D^- K^+)} = 0.25 \pm 0.10$$

$$\frac{\mathcal{B}(B^0 \to \overline{D}^0 K^{*0})}{\mathcal{B}(B^0 \to D^- K^{*+})} = 0.13 \pm 0.08$$

$$\frac{2\mathcal{B}(B^0 \to \overline{D}^0 \pi^0)}{\mathcal{B}(B^0 \to D^- \pi^+)} = 0.22 \pm 0.04$$

Summary of Br's, event yields, ...

PDG

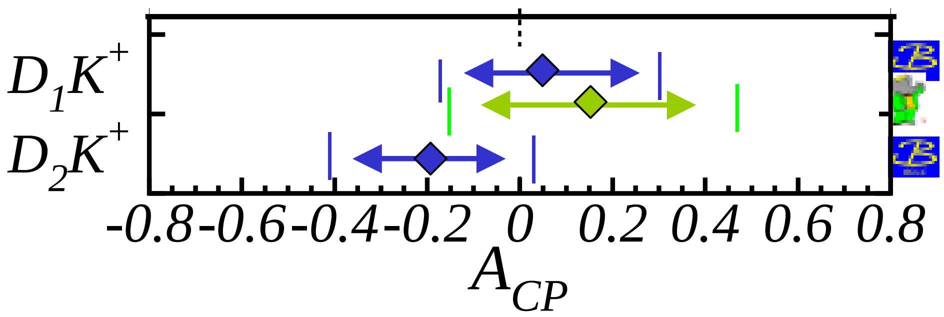
$\mathcal{B}(B^- \to D^0 K^-) = (3.7 \pm 0.6) \times 10^{-4}$ — **347±20 @ 78 fb^{-1} D → Kπ**; **360±20 @ 56 fb^{-1} D → Kπ**

$\mathcal{B}(B^- \to D^0 K^{*-}) = (5.2 \pm 0.5(stat) \pm 0.5(sys)) \times 10^{-4}$ — **70±10 @ 88 fb^{-1} D → Kπ**

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

$\mathcal{B}(B^0 \to \overline{D}{}^0 K^{*0}) = (4.8 \pm 1.1(stat) \pm 0.5(sys)) \times 10^{-5}$ — **10±4 @ 78 fb^{-1} D → Kπ**

$\mathcal{B}(B^0 \to \overline{D}{}^0 K^0) = (5.0 \pm 1.3(stat) \pm 0.6(sys)) \times 10^{-5}$ — **15±5 @ 78 fb^{-1} D → Kπ**



Some other approaches

- **Atwood,Dunietz, Soni (ADS):**

  use doubly Cabibbo-suppressed D decays

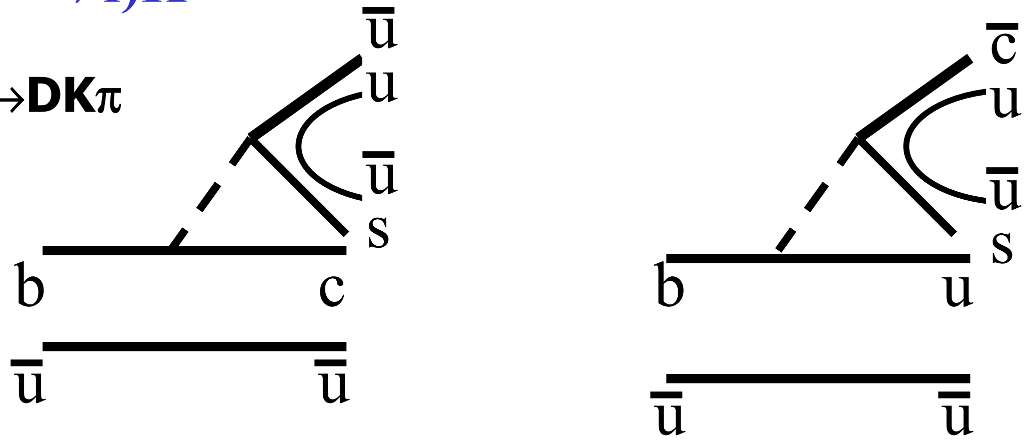
  $$B \xrightarrow{\text{allowed}} \overline{D}(\xrightarrow{\text{suppr.}} f)K$$

  $$B \xrightarrow{\text{suppr.}} D(\xrightarrow{\text{allowed}} f)K$$

  r ~ 1, Br ~ 10^{-7}

- **Dalitz plot analysis of B→DKπ**

Both amplitudes are color allowed



- **B→DK, Dalitz plot analysis of multibody D decays**

  (e.g. $D \to K_s \pi^+ \pi^-$)

- **................**

Summary and outlook

No direct CPV observed in $B \to D X_{s}$, no direct constraints on Φ_3 yet,

but there is a steady progress:

- **new relevant decay modes observed:**
  - $B^- \to D K^{(*)-}$ $D \to f_{CP}$, CP=+,-
  - $B^0 \to D K^{(*)0}$
  - other analyses in progress
- **accelerator performance**
  - KEKB: $L_{peak} > 10^{34} cm^{-2} s^{-1}$ PEP-II: $L_{peak} > 6 \times 10^{33} cm^{-2} s^{-1}$
  - Belle and BaBar aiming for ≈ 0.5 ab^{-1} in 2005

    some meaningful constraints on Φ_3 possible by that time
- new theoretical ideas
- precise measurements in D sector ....