$B \rightarrow DK$ measurements at CDF

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Outline

Motivation

- determination of γ from B^+ decays
- determination of γ from B_s^0 decays

CDF measurement of $\mathcal{B}(B^+ \to \overline{D}^0 K^+)/\mathcal{B}(B^+ \to \overline{D}^0 \pi^+)$

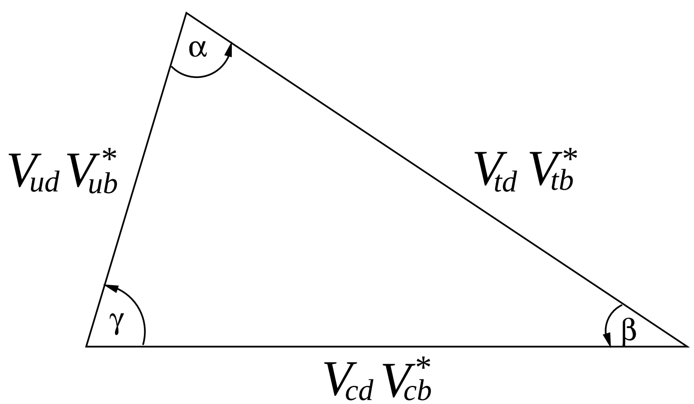
- sample
- fit method
- result

Projection

- $B^+ \to \overline{D}^0 K^+$
- $B^+ \to D^0_{CP} K^+$
- $B_s^0 \to D_s^{\mp} K^{\pm}$

Motivation: CKM angle γ

$$V = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} = \begin{pmatrix} 1-\frac{1}{2}\lambda^2 & \lambda & A\lambda^3(\rho - i\eta) \\ -\lambda & 1-\frac{1}{2}\lambda^2 & A\lambda^2 \\ A\lambda^3(1-\rho-i\eta) & -A\lambda^2 & 1 \end{pmatrix} + \mathcal{O}(\lambda^4)$$



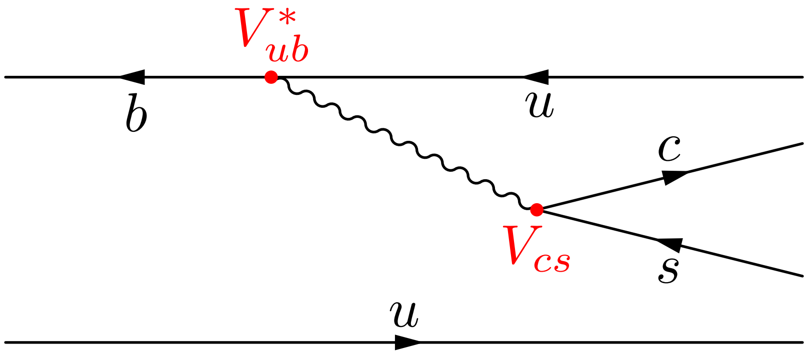
Unitarity: $V_{ud}V_{ub}^* + V_{cd}V_{cb}^* + V_{td}V_{tb}^* = 0$

$\gamma = \phi_3 = \arg(-V_{ud}V_{ub}^*/V_{cd}V_{cb}^*)$ is the weak phase associated with $b \to u$ transition

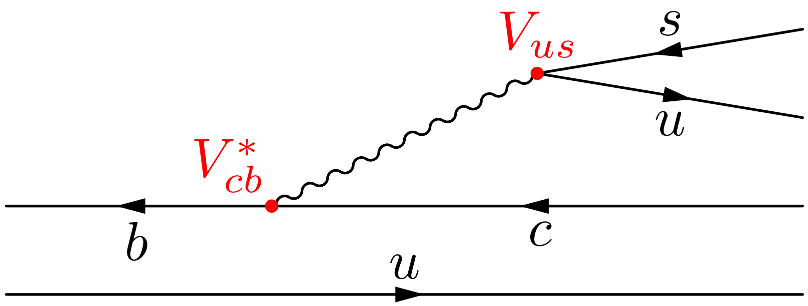
For observable effect, need interference:

- two diagrams with relative phase γ
- and with comparable amplitude

Determination of γ from B^+ decays



$B^+ \to D^0 K^+$



$B^+ \to \overline{D}^0 K^+$

$B^+ \to \overline{D}^0 K^+$ and $B^+ \to D^0 K^+$ have relative weak phase γ; decay width ratio ~ 10

Multiple methods for interference: GLW[1], ADS[2], Dalitz plot[3]

GLW uses $B^+ \to \overline{D}^0(\to f_{CP})K^+$, $B^+ \to D^0(\to f_{CP})K^+$

At CDF: f_{CP} is $D^0_{CP+} \to K^+K^-$, $D^0_{CP+} \to \pi^+\pi^-$

Advantage of B^+ measurement: no B-tagging, no time-dependence required

[1] M. Gronau and D. London., Phys. Lett. B **253**, 483 (1991); M. Gronau and D. Wyler, Phys. Lett. B **265**, 172 (1991).

[2] D. Atwood, I. Dunietz and A. Soni, Phys. Rev. D **63**, 036005 (2001) [arXiv:hep-ph/0008090].

[3] A. Giri, Y. Grossman, A. Soffer and J. Zupan, Phys. Rev. D **68**, 054018 (2003) [arXiv:hep-ph/0303187].

Determination of γ from B^+ decays

Need to measure:[4]

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

$$R_\pm = \frac{\mathcal{B}(B^- \to D^0_{CP\pm} K^-) + \mathcal{B}(B^+ \to D^0_{CP\pm} K^+)}{\mathcal{B}(B^- \to D^0_{CP\pm} \pi^-) + \mathcal{B}(B^+ \to D^0_{CP\pm} \pi^+)}$$

$$A_{CP\pm} = \frac{\mathcal{B}(B^- \to D^0_{CP\pm} K^-) - \mathcal{B}(B^+ \to D^0_{CP\pm} K^+)}{\mathcal{B}(B^- \to D^0_{CP\pm} K^-) + \mathcal{B}(B^+ \to D^0_{CP\pm} K^+)}$$

$$r = \frac{\mathcal{B}(B^+ \to D^0 K^+)}{\mathcal{B}(B^+ \to \overline{D}^0 K^+)} \approx 0.1$$

to extract γ, strong phase δ (and r):

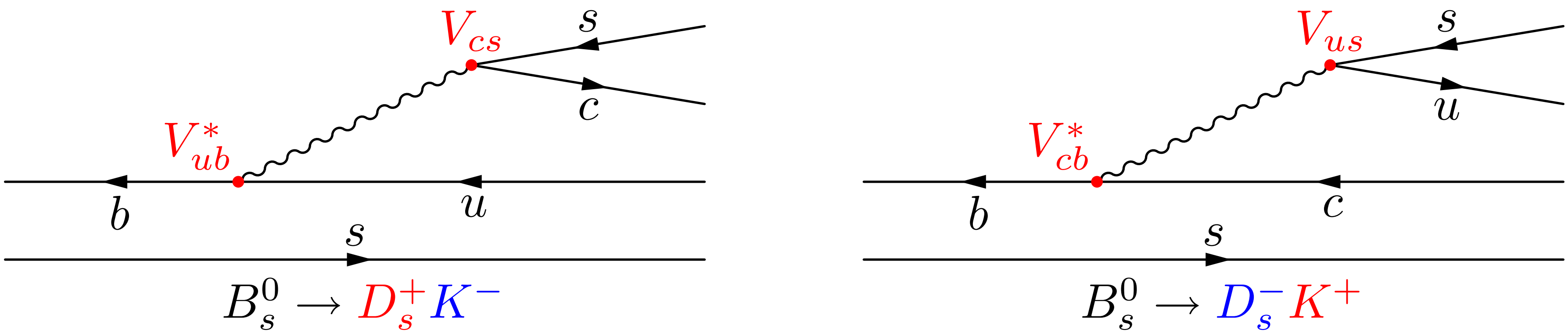
$$R_{CP\pm} = R_\pm / R = 1 + r^2 \pm 2r \cos\delta \cos\gamma$$

$$A_{CP+} R_{CP+} = -A_{CP-} R_{CP-} = 2r \sin\delta \sin\gamma$$

Measurement can be done with ratios of branching ratios

[4] M. Gronau, Phys. Rev. D **58**, 037301 (1998) [arXiv:hep-ph/9802315].

Determination of γ from B_s^0 decays



$B_s^0 \to D_s^- K^+$, $B_s^0 \to D_s^+ K^-$ have relative phase γ, comparable amplitude

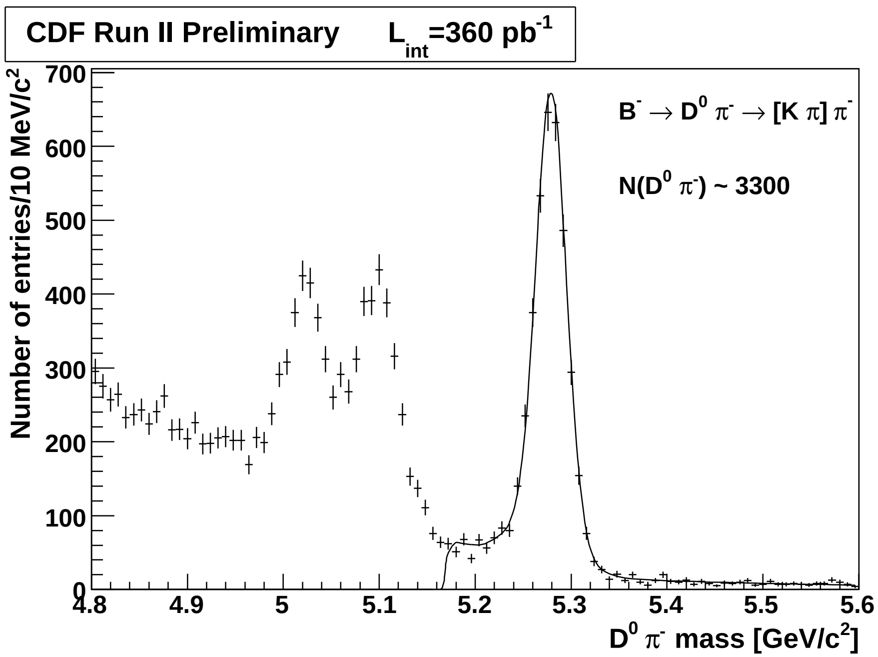
$B_s^0 \to D_s^- K^+$ interferes with $B_s^0 \overset{\text{(mixing)}}{\longrightarrow} \overline{B}_s^0 \to D_s^- K^+$

Time-dependent, flavor-tagged measurement[5]

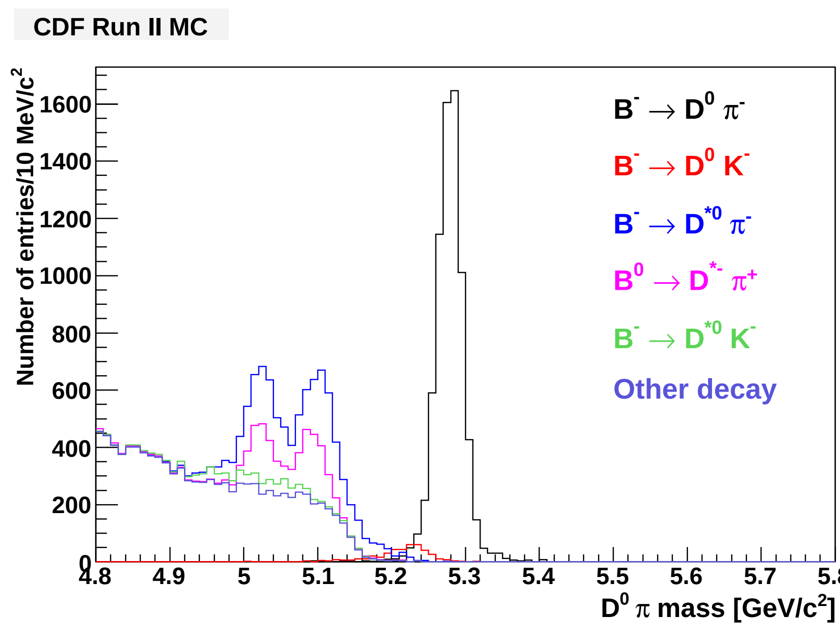
[5] R. Aleksan, I. Dunietz and B. Kayser, Z. Phys. C **54**, 653 (1992).

Measuring $\mathcal{B}(B^+ \to \overline{D}^0 K^+)/\mathcal{B}(B^+ \to \overline{D}^0 \pi^+)$

$R = \mathcal{B}(B^+ \to \overline{D}^0 K^+)/\mathcal{B}(B^+ \to \overline{D}^0 \pi^+)$ is first experimental step in GLW method: high-statistics mode compared to D^0_{CP} modes



$B^+ \to \overline{D}^0(K^+\pi^-)\pi^+$ (data after cuts)



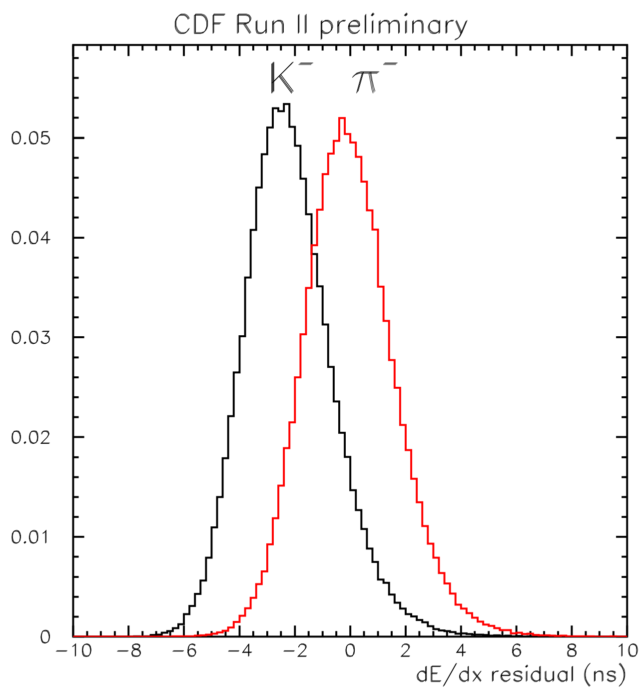
$B^+ \to \overline{D}^0(K^+\pi^-)\pi^+$ (MC)

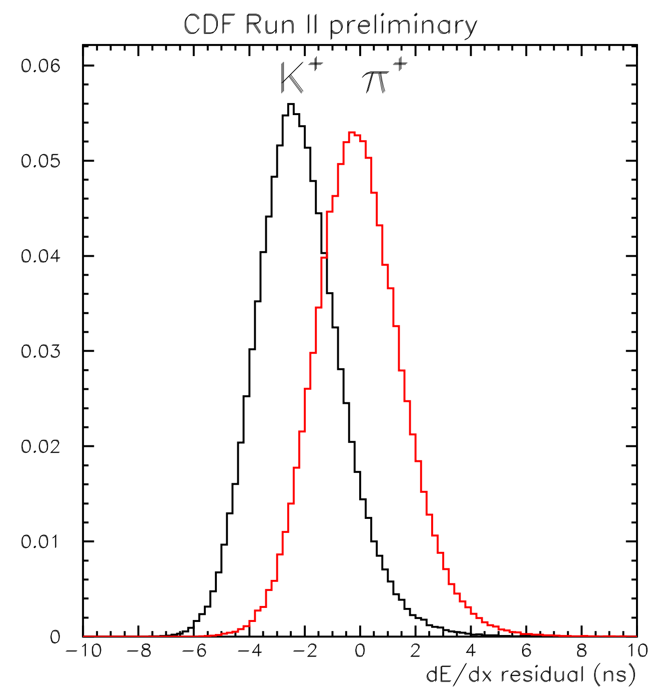
Strategy: use $D^0\pi$ mass and PID to separate $D^0\pi$, D^0K and backgrounds

Separating $D^0 K$ from $D^0 \pi$: dE/dx

Use dE/dx of track recoiling against D^0:

$$ID = \frac{dE/dx_{\text{meas}} - dE/dx_{\text{exp}}(\pi)}{dE/dx_{\text{exp}}(K) - dE/dx_{\text{exp}}(\pi)}$$



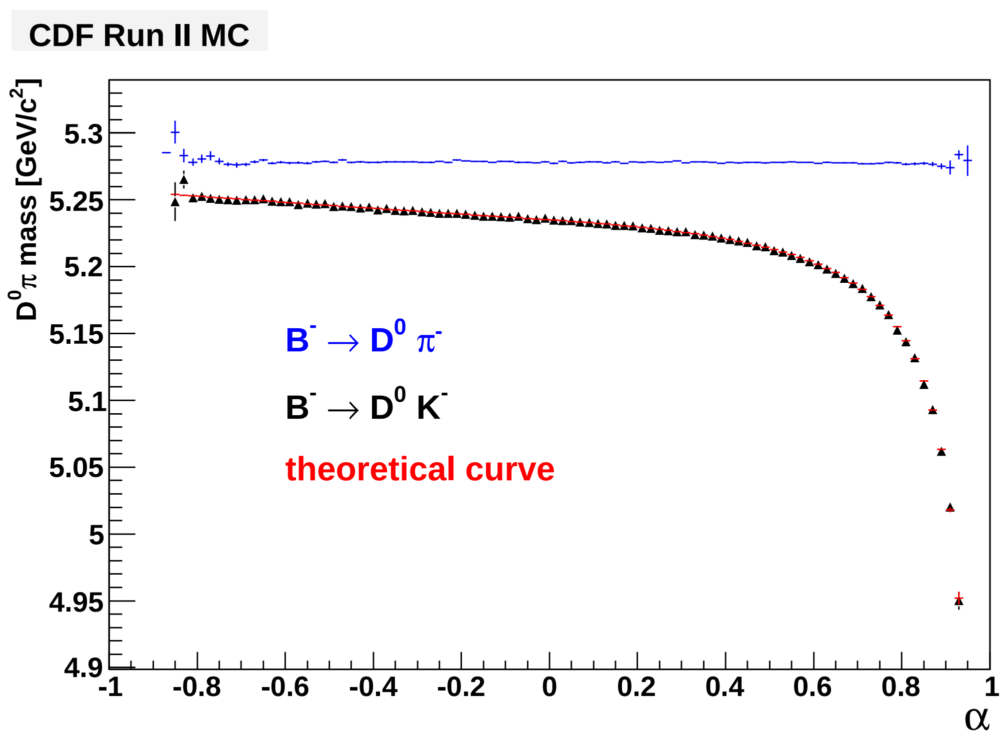


1.5σ separation from dE/dx between K and π

Separating D^0K from $D^0\pi$: Kinematics

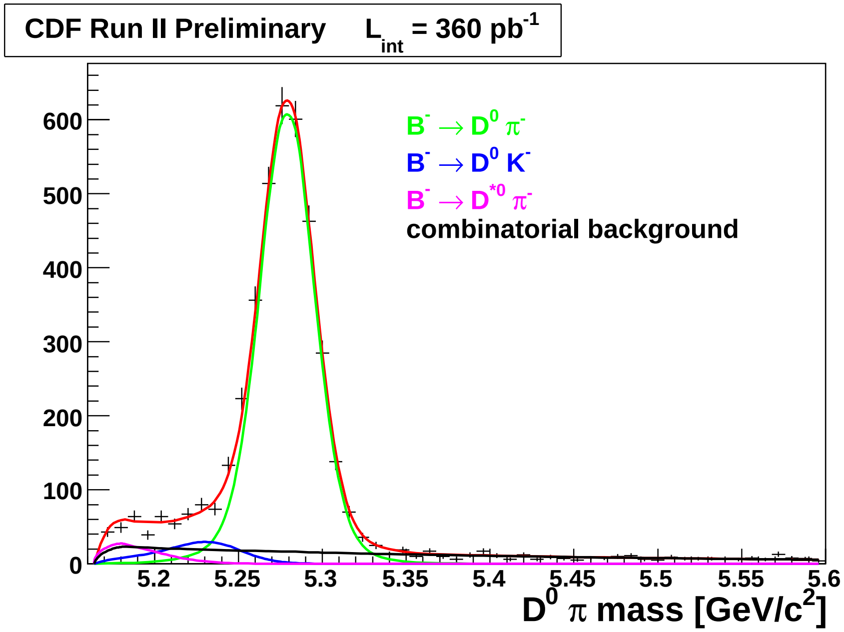
Reconstructed $(D^0\pi)$ mass depends on momentum imbalance:

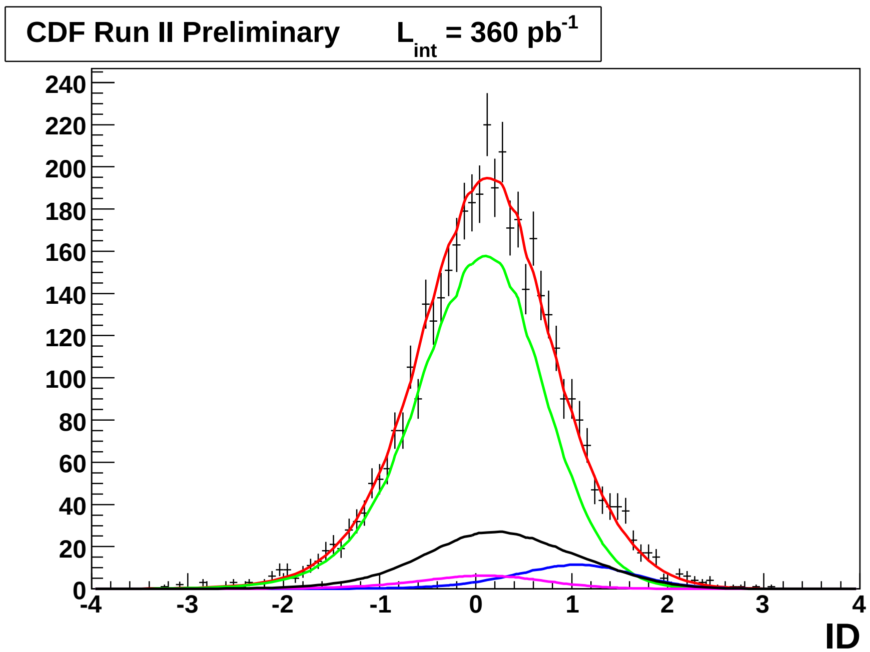
$$\alpha = \begin{cases} 1 - p_{\text{tr}}/p_{D^0} & \text{if } p_{\text{tr}} < p_{D^0} \\ -(1 - p_{D^0}/p_{\text{tr}}) & \text{if } p_{\text{tr}} \geq p_{D^0} \end{cases}$$

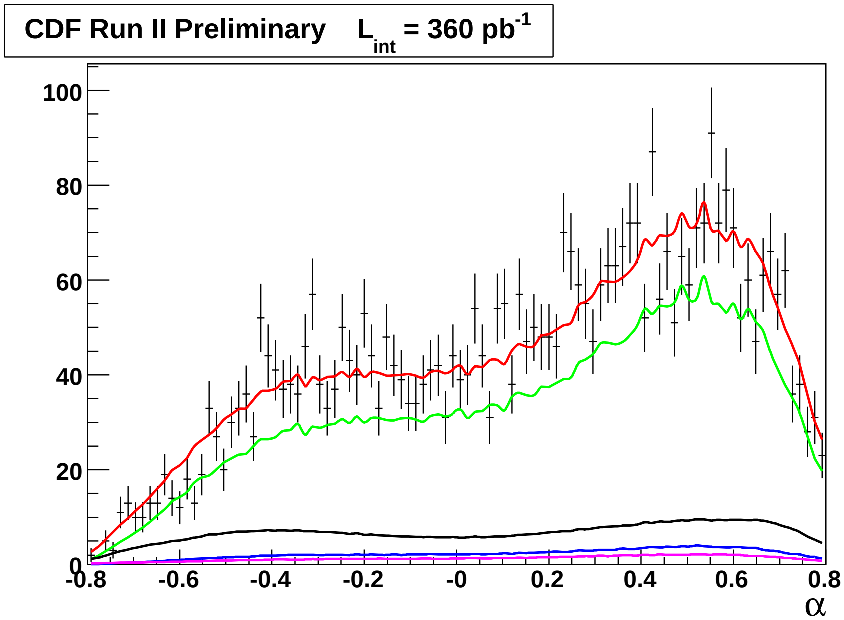


Fit

- unbinned maximum-likelihood fit
- fit in narrow range $[5.17, 5.6]$ GeV
- fit components: $D^0\pi$, D^0K, $D^{*0}\pi$, combinatorial background
- fit variables: $m(D^0\pi)$, α, dE/dx







Systematic errors

source	error
mass resolution tails	0.0006
B^+ mass	0.001
dE/dx	0.0015
combinatorial background model	0.001
alternate D^{*0} mass model	0.001
D^{*0} mass-model parameters left free	0.003
MC statistics + XFT efficiency	0.002
total	0.004

largest error: D^{*0} mass pdf

Result

CDF result on 360 pb^{-1} (~ 3300 $D^0\pi$ events):

$$R = \frac{\mathcal{B}(B^+ \to \overline{D}^0 K^+)}{\mathcal{B}(B^+ \to \overline{D}^0 \pi^+)} = (6.5 \pm 0.7(\text{stat}) \pm 0.4(\text{syst})) \times 10^{-2}$$

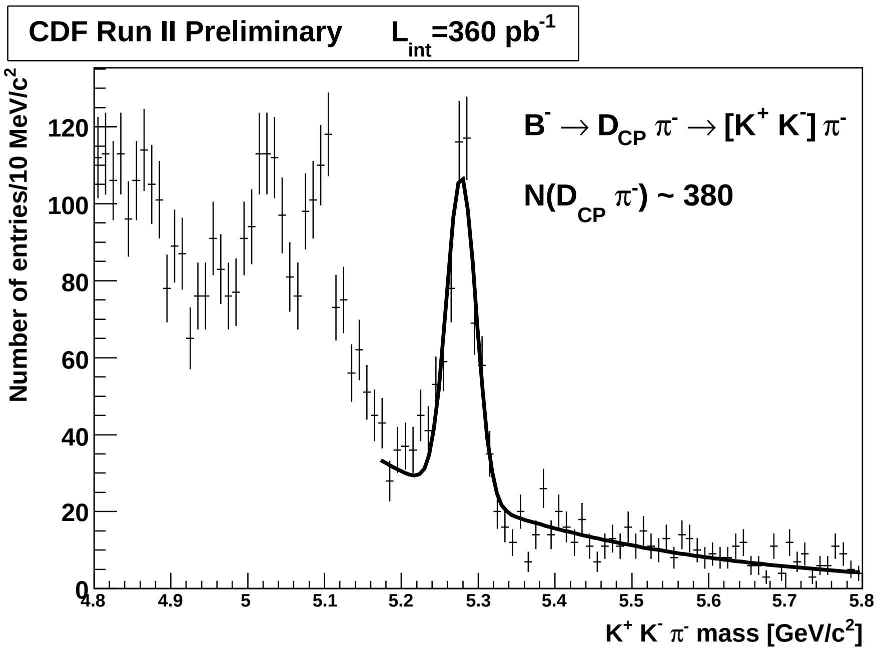
Also measured by BaBar[6], CLEO[7] and Belle:[8]

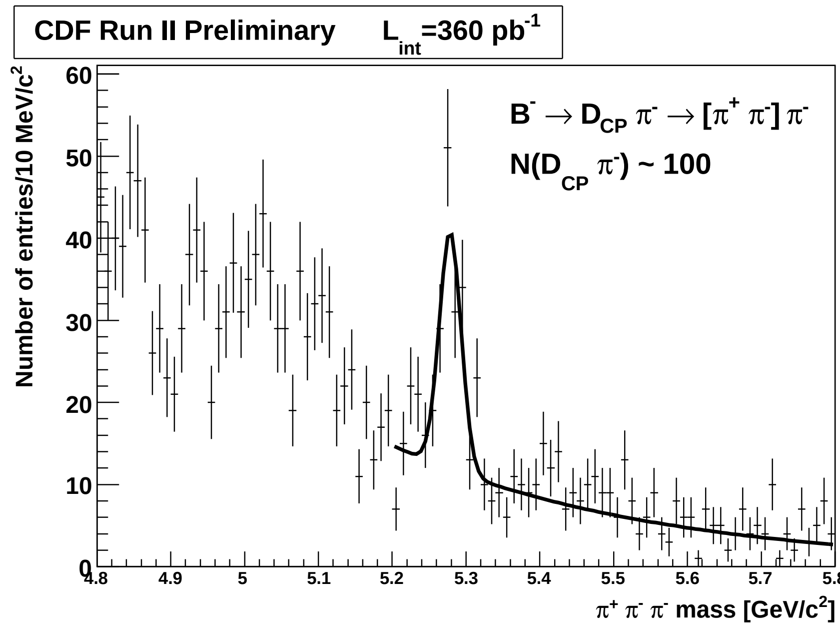
experiment	measurement (10^{-2})	$D^0\pi$ sample size	
BaBar	$8.31 \pm 0.35 \pm 0.20$	~ 10000	$\left(61.0 \times 10^6\ B\overline{B}\right)$
CLEO	$9.9^{+1.4+0.7}_{-1.2-0.6}$	~ 500	$\left(15.3\ \text{fb}^{-1}\right)$
Belle	$7.7 \pm 0.5 \pm 0.6$	~ 6000	$\left(85.4 \times 10^6\ B\overline{B}\right)$

[6] B. Aubert *et al.* [BABAR Collaboration], Phys. Rev. Lett. **92**, 202002 (2004) [arXiv:hep-ex/0311032].
[7] A. Bornheim *et al.* [CLEO Collaboration], Phys. Rev. D **68**, 052002 (2003) [arXiv:hep-ex/0302026].
[8] S. K. Swain *et al.* [Belle Collaboration], Phys. Rev. D **68**, 051101 (2003) [arXiv:hep-ex/0304032].

Outlook: $B^+ \to D^0_{CP} K^+$

Statistics in 360 pb^{-1}: $3300\ D^0\pi$, $500\ D^0_{CP+}\pi$

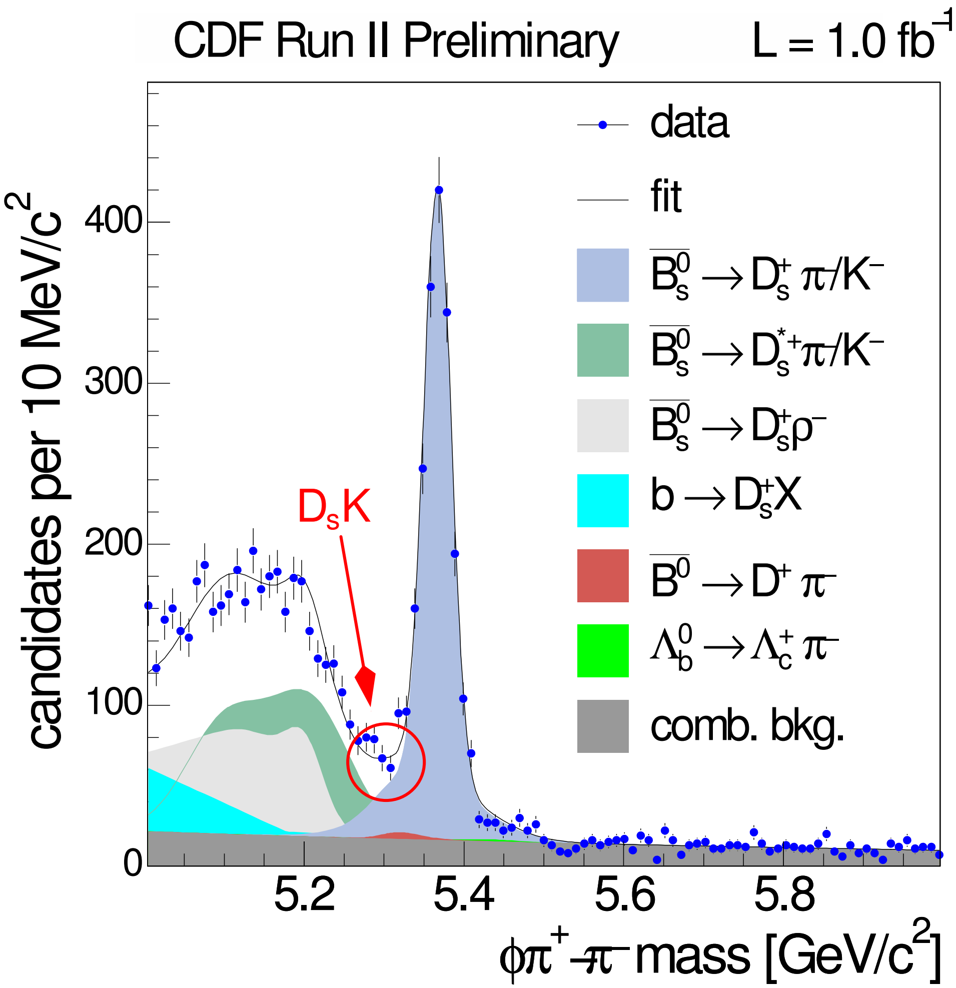




Analysis in progress on 1 fb^{-1}:

- $\times 3$ statistics
- template mass pdfs
- wider fit range
- improved BG model

Outlook: $\mathcal{B}(B_s^0 \to D_s K)/\mathcal{B}(B_s^0 \to D_s \pi)$



- $\mathcal{B}(B_s \to D_s K)/\mathcal{B}(B_s \to D_s \pi)$ measurement in progress
- first measurement of this ratio; potentially large interference
- this measurement will decide how much data is required for time-dependent, flavor-tagged $B_s^0 \to D_s^{\pm} K^{\mp}$ analysis

In summary

CDF has measured R in 360 pb^{-1}:

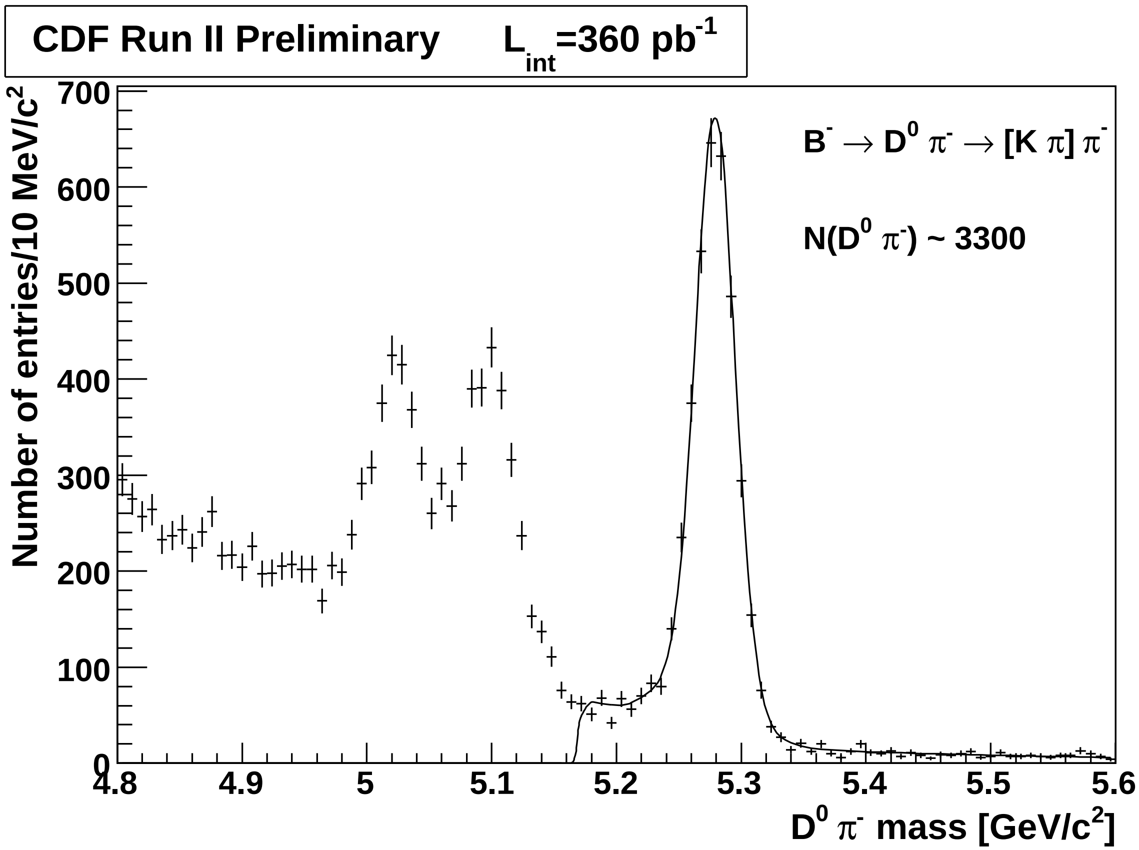
$$R = \frac{\mathcal{B}(B^+ \to \overline{D}^0 K^+)}{\mathcal{B}(B^+ \to \overline{D}^0 \pi^+)} = (6.5 \pm 0.7(\text{stat}) \pm 0.4(\text{syst})) \times 10^{-2}$$

Future steps in Cabibbo-suppressed program at CDF:

- R measurement in 1 fb^{-1} in progress
- A_{CP+} and R_{CP+} are next
- $\mathcal{B}(B_s \to D_s K)/\mathcal{B}(B_s \to D_s \pi)$ is also in the pipeline

Bonus slides

Sample selection



- $\chi^2_{\text{3D}}(B) < 15$
- iso > 0.5
- $L_{xy}(B)/\sigma_{L_{xy}}(B) > 8$
- $L_{xy}(B \to D) > 150$ µm
- $|d_0(B)| < 80$ µm
- $\Delta R < 2$
- $p_{\text{T}}(\pi_B) > 2.0$ GeV
- π_B is trigger track

Remove prompt physics and combinatorial background

Fit

fit in narrow range $[5.17, 5.6]$ GeV

fit components: $D^0\pi$, D^0K, $D^{*0}\pi$, combinatorial background

fit variables: m, α, p_{tot}, dE/dx

$$\log\mathcal{L} = \sum_i^{N_{\text{events}}} ((1-b)(f_\pi F_\pi(\boldsymbol{\theta}_i) + (1-f_\pi)F_K(\boldsymbol{\theta}_i)) + b\,(f_{D^*}B_{D^*}(\boldsymbol{\theta}_i) + (1-f_{D^*})B_{\text{comb}}(\boldsymbol{\theta}_i)), \qquad \boldsymbol{\theta} = (\alpha, p_{\text{tot}}, m_{D^0\pi}, ID)$$

$$F_j(\alpha, p_{\text{tot}}, m_{D^0\pi}, ID) = G(m_{D^0\pi} - M(\alpha, p_{\text{tot}}))P(\alpha, p_{\text{tot}})P(ID)$$

$$B_j(\alpha, p_{\text{tot}}, m_{D^0\pi}, ID) = B(m_{D^0\pi})P(\alpha, p_{\text{tot}})P(ID)$$

$P(\alpha, p_{\text{tot}})$ from MC for B-physics components, from high-sideband negative-L_{xy} B^+ for combinatorial