Branching Ratios from B^0_s and Λ^0_b

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Outline:

- Motivation
- Branching Ratios at CDF
- Results from:
  - $B^0{}_S \rightarrow D^-{}_S \pi^+$
  - $\Lambda^0{}_b \rightarrow \Lambda^+{}_c \pi^-$
  - $B \rightarrow h^+ h^-$
- Conclusions

CDF plans a rich program of B-Physics:

- Precision study of the $B^0{}_S$:
  - BR's, mass and lifetime
  - Plan to observe or rule out SM $B^0{}_S$ mixing
  - Measure $\Delta\Gamma_{B_S}$
  - Measure γ
- The world's largest $\Lambda^0{}_b$ sample:
  - BR's, mass and lifetime
  - CP Violation searches
- This program just beginning…

What we know: $B^0{}_s$

PDG 2002:

New results for:

$$B^0{}_s \to D^-{}_s \pi^+$$

$$B^0{}_s \to K^+ K^-$$

	B^0_s DECAY MODES		Fraction (Γ_i/Γ)	Confidence level	p (MeV/c)
	D_s^- anything		(94 ± 30) %		–
	$D_s^- \ell^+ \nu_\ell$ anything	[iii]	(7.9 ± 2.4) %		–
NEW !	$D_s^- \pi^+$		< 13 %		2321
	$D_s^{(*)+} D_s^{(*)-}$		$(23 {}^{+21}_{-13})$ %		–
	$J/\psi(1S)\phi$		$(9.3 \pm 3.3) \times 10^{-4}$		1590
	$J/\psi(1S)\pi^0$		$< 1.2 \times 10^{-3}$	90%	1788
	$J/\psi(1S)\eta$		$< 3.8 \times 10^{-3}$	90%	1735
	$\psi(2S)\phi$		seen		1122
	$\pi^+\pi^-$		$< 1.7 \times 10^{-4}$	90%	2681
	$\pi^0\pi^0$		$< 2.1 \times 10^{-4}$	90%	2681
	$\eta\pi^0$		$< 1.0 \times 10^{-3}$	90%	2655
	$\eta\eta$		$< 1.5 \times 10^{-3}$	90%	2628
	$\rho^0\rho^0$		$< 3.20 \times 10^{-4}$	90%	–
	$\phi\rho^0$		$< 6.17 \times 10^{-4}$	90%	–
	$\phi\phi$		$< 1.183 \times 10^{-3}$	90%	–
	$\pi^+ K^-$		$< 2.1 \times 10^{-4}$	90%	2660
NEW !	$K^+ K^-$		$< 5.9 \times 10^{-5}$	90%	2639
	$\overline{K}^*(892)^0 \rho^0$		$< 7.67 \times 10^{-4}$	90%	–
	$\overline{K}^*(892)^0 K^*(892)^0$		$< 1.681 \times 10^{-3}$	90%	–
	$\phi K^*(892)^0$		$< 1.013 \times 10^{-3}$	90%	–
	$p\overline{p}$		$< 5.9 \times 10^{-5}$	90%	2515
	$\gamma\gamma$		$< 1.48 \times 10^{-4}$	90%	2685
	$\phi\gamma$		$< 7 \times 10^{-4}$	90%	2588
	Lepton Family number (LF) violating modes or $\Delta B = 1$ weak neutral current ($B1$) modes				
	$\mu^+\mu^-$	$B1$	$< 2.0 \times 10^{-6}$	90%	2682
	e^+e^-	$B1$	$< 5.4 \times 10^{-5}$	90%	2864
	$e^\pm\mu^\mp$	LF [ff]	$< 6.1 \times 10^{-6}$	90%	2864
	$\phi\nu\overline{\nu}$	$B1$	$< 5.4 \times 10^{-3}$	90%	–

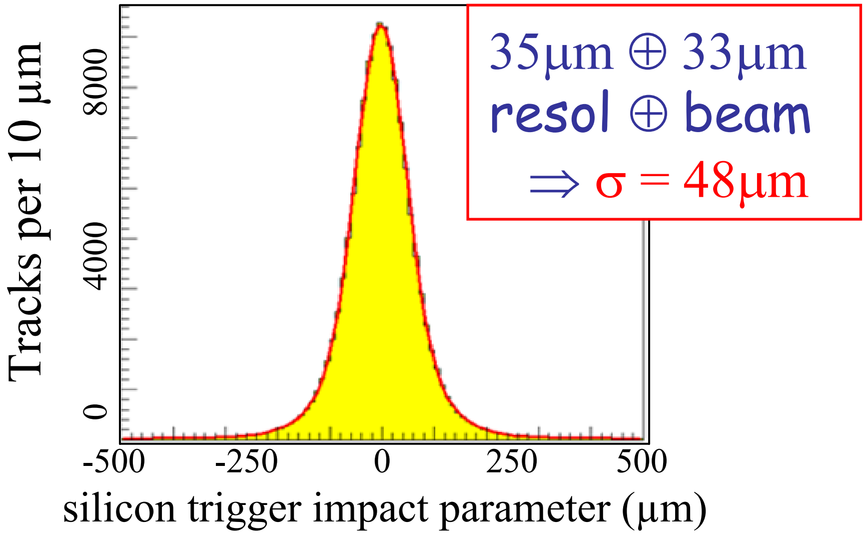
What we know: Λ^0_b

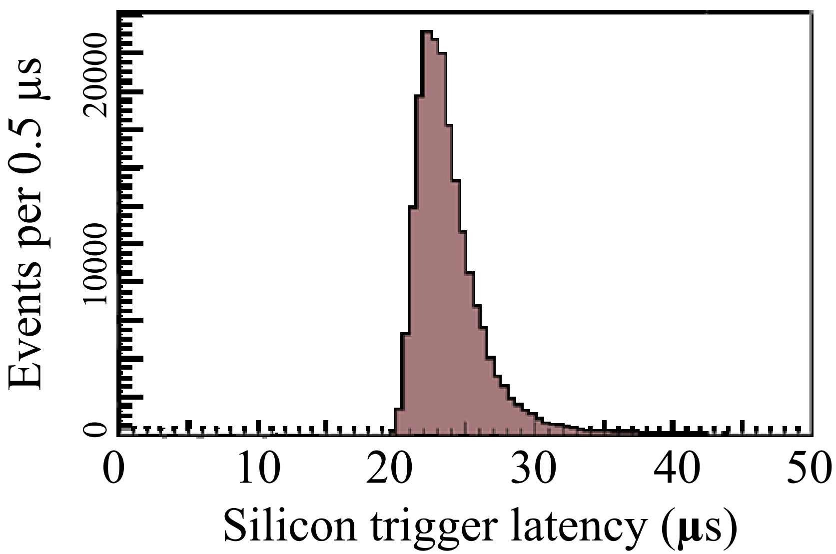
PDG 2002:

Λ^0_b DECAY MODES		Fraction (Γ_i/Γ)	Confidence level	p (MeV/c)
$J/\psi(1S)\Lambda$		$(4.7\pm2.8)\times10^{-4}$		1744
NEW ! $\Lambda_c^+\pi^-$		seen		2345
$\Lambda_c^+ a_1(1260)^-$		seen		2156
$\Lambda_c^+\ell^-\overline{\nu}_\ell$ anything	[s]	(7.7 ± 1.8) %		–
$p\pi^-$		$< 5.0 \times10^{-5}$	90%	2732
pK^-		$< 5.0 \times10^{-5}$	90%	2711

Nearly New results for: $\Lambda^0_b \rightarrow \Lambda^+_c \pi^-$

Hadronic Level 2 Trigger:





- Interaction rate $\sim 2.5\,MHz$
- Reduced to $\tilde{\sim} 300\,Hz$ on Level 2 output.
- Critical component : SVT impact parameter cuts.
- 2 Tracks with $IP > 120\,\mu m$

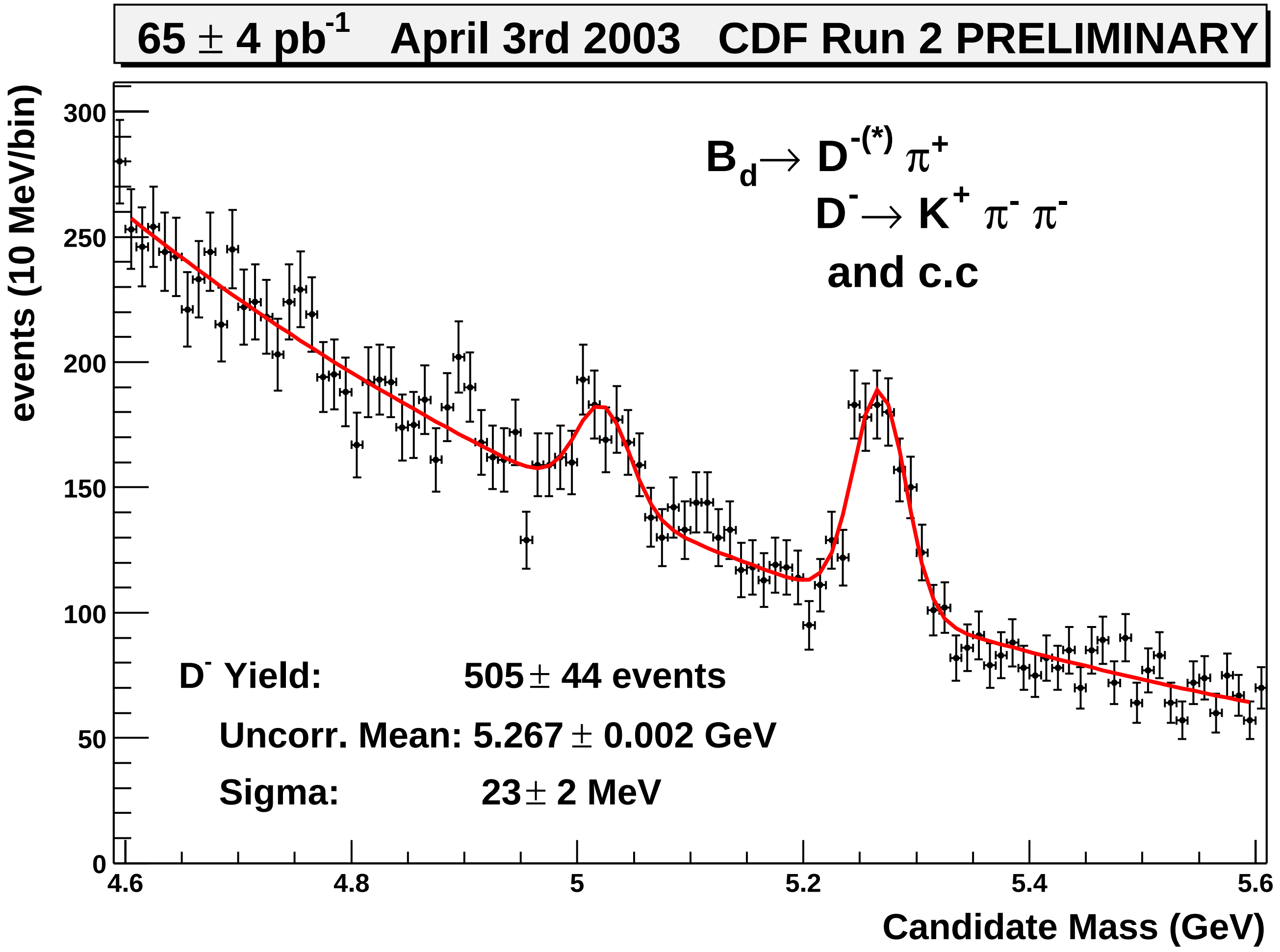
Branching Ratios at CDF:

- Compare search mode to kinematically similar mode, eg:

$$\frac{\sigma_b \times f_{baryon} \times BR(\Lambda^0{}_b \to \Lambda^+{}_c \pi^-)}{\sigma_b \times f_d \times BR(B^0{}_d \to D^+ \pi^-)} = \frac{\varepsilon_{B^0{}_d} \times N_{\Lambda^0{}_b} \times BR(D^- \to K^- \pi^+ \pi^+)}{\varepsilon_{\Lambda^0{}_b} \times N_{B^0{}_d} \times BR(\Lambda^+{}_c \to p K^- \pi^+)}$$

- Cancellation:
  - σ_b
  - Systematics in Trigger and Reconstruction Efficiency.
- Production fractions (f):
  - LEP/CDF Combined.
  - Aim to measure at CDF.
- Daughter BR's :
  - Rely on existing measurements.
  - Future : CLEO-C
- Plan to normalise to same channel Semileptonic

Normalisation mode: $B^0_d \to D^{\mp}\pi^{\pm}$



- Same mode for:
  - $B^0_s \to D^{\mp}_s \pi^{\pm}$
  - $\Lambda^0_b \to \Lambda^+_c \pi^-$

- Similar cuts to signal

- D^* also visible.

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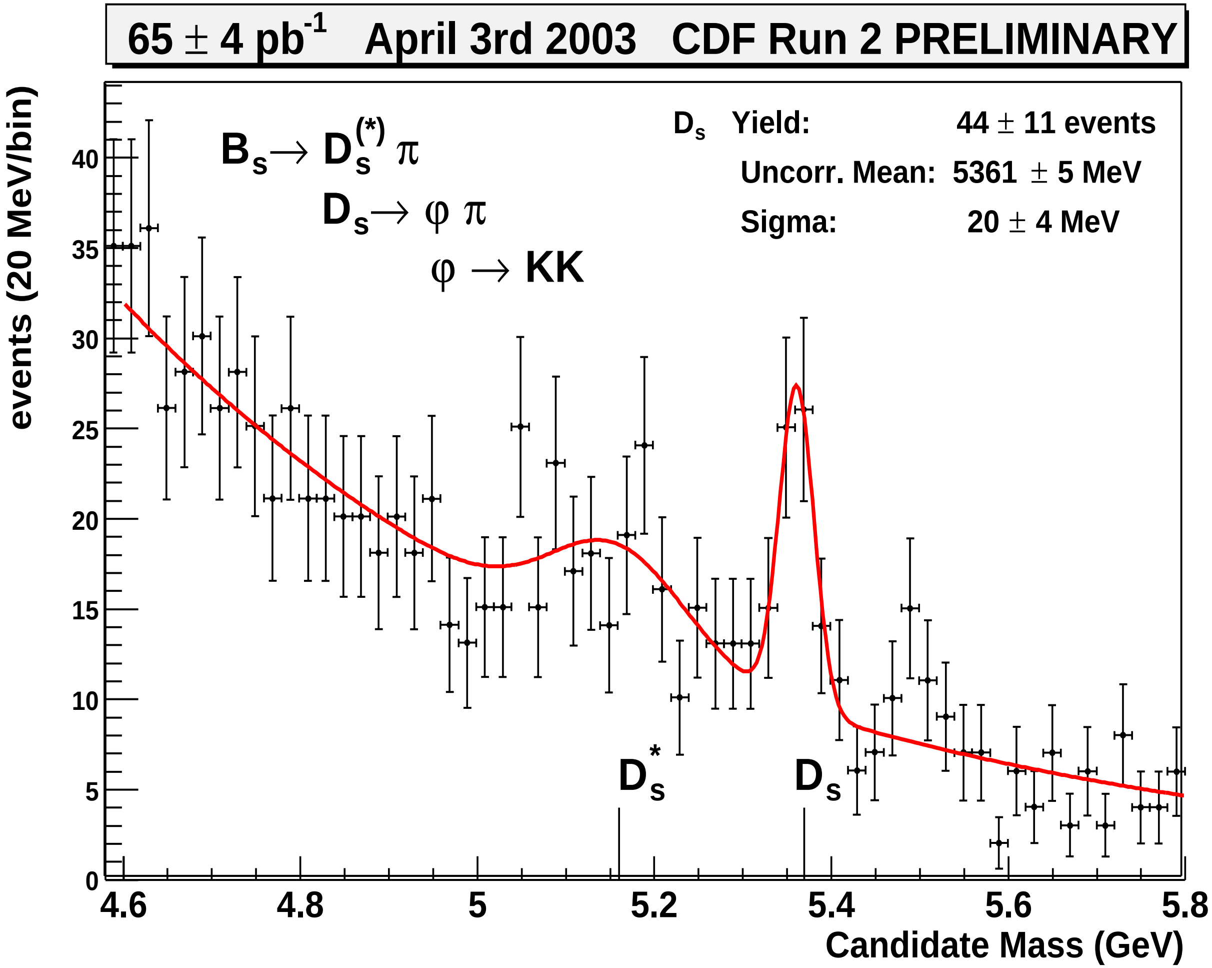
Reconstructing: $B^0_S \to D^{\mp}_S \pi^{\pm}$

First Observation!



Important Cuts:

- 2 Tracks required to be Trigger Tracks.
- $\left(1.013 < m_{K^+K^-} < 1.028\, GeV\right)$
- D_s mass constrained to PDG value
- $p_t\left(D_s\right) > 4\, GeV$
- $p_t\left(B_s\right) > 4\, GeV$
- 2D-Dist$\left(\text{Prim} \to D_s\right) > 400\, \mu m$
- 2D-Flight-Dist$\left(B_s\right) > 100\, \mu m$
- Impact-Par$\left(B_s\right) < 100\, \mu m$

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Systematics:

Particle	$\sigma\left(\frac{N_{B_s}}{N_{B_d}}\right)$
B_s	± 0.008
B_d	± 0.008

$\leftarrow$ Uncertainty in $\frac{N_{B_s}}{N_{B_d}}$ due to fit.

Source	$\sigma\left(\varepsilon_{B_s} / \varepsilon_{B_d}\right)$
XFT 1-miss	$+0.001$
Min b quark p_t	$-0.08 \quad ---$
B lifetimes	$-0.02 \quad +0.04$
D lifetimes	$0.00 \quad +0.04$
Total	$-0.08 \quad +0.06$

$\leftarrow$ Uncertainty in $\frac{\varepsilon_{B_s}}{\varepsilon_{B_d}}$ (Due to MC)

BR Total Syst: ± 0.07

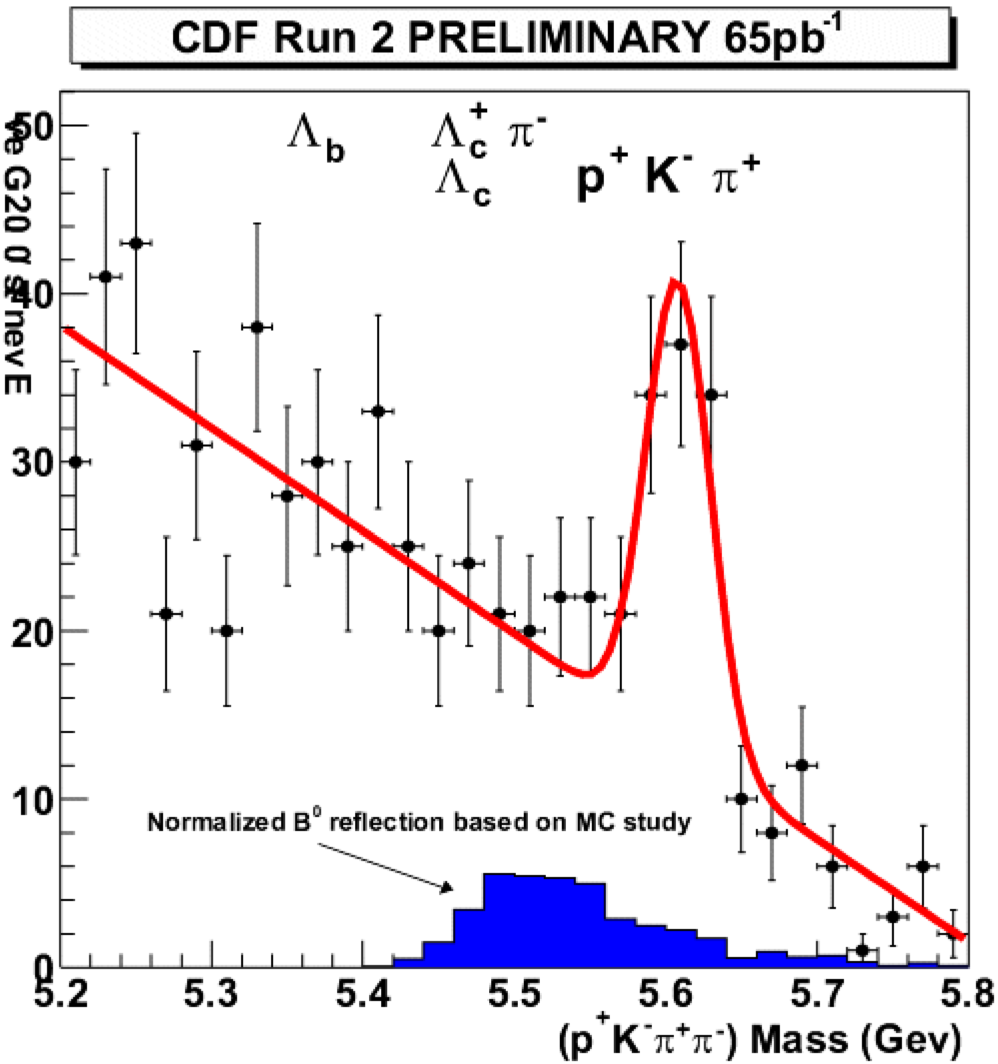
Results:

$$\frac{f_s \times BR(B_s \to D_s \pi)}{f_d \times BR(B_d \to D\ \pi)} = 0.44 \pm 0.11(stat) \pm 0.11(BR) \pm 0.07(syst)$$

From PDG: $\frac{f_s}{f_d} = 0.273 \pm 0.034$:

$$\frac{BR(B_s \to D_s \pi)}{BR(B_d \to D\ \pi)} = 1.61 \pm 0.40(stat) \pm 0.40(BR) \pm 0.26(syst) \pm 0.20 \left(PDG \frac{f_s}{f_d} \right)$$

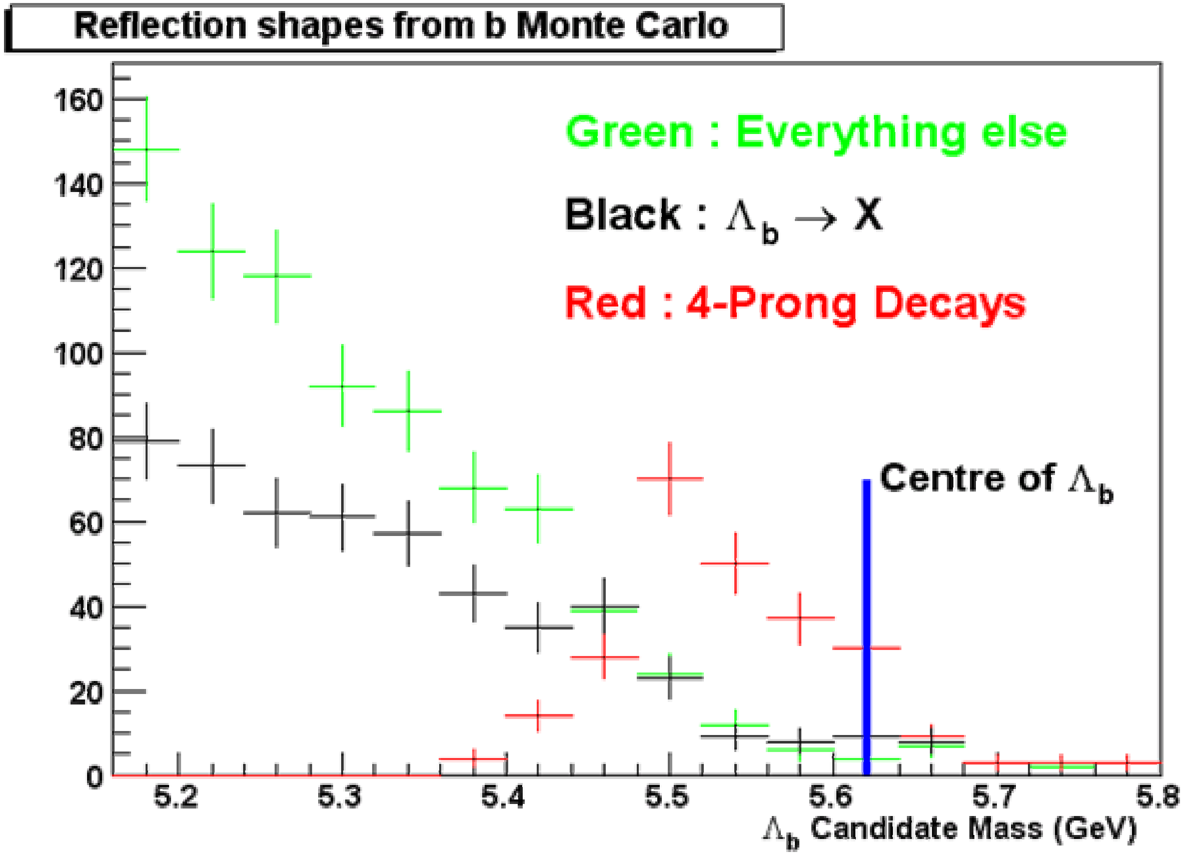
Reconstructing $\Lambda^0_b \to \Lambda^+_c \pi^-$



Important cuts:

- Confirm Trigger
- $p_t(P) > 2\,GeV$
- $p_t(\pi \text{ from } \Lambda^0_b) > 2\,GeV$
- $p_t(\Lambda^0_b) > 7.5\,GeV$
- $p_t(\Lambda^\pm_c) > 4.5\,GeV$
- $ct(\Lambda^0_b) > 225\,\mu m$
- $ct(\Lambda_c \text{ from } \Lambda^0_b) > -65\,\mu m$
- Impact-Par$(\Lambda^0_b) < 100\,\mu m$
- $(2.265 < m(\Lambda_c) < 2.303\,GeV)$

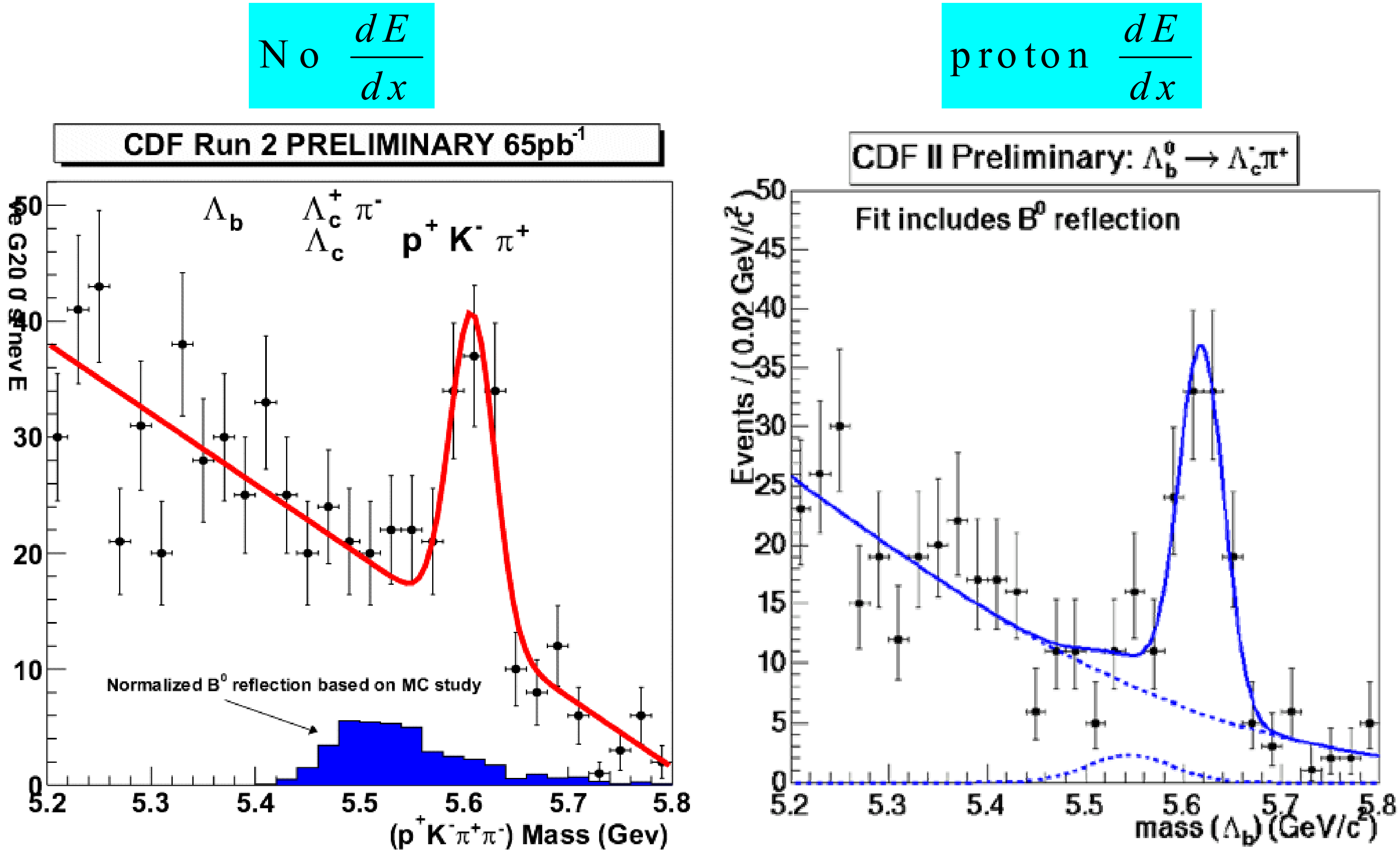
b Reflections:



- 3 Types of reflection:
  - 4-Prong Decays
    (eg $B^0_d \rightarrow D^{\mp} \pi^{\pm}$)
  - Other Λ^0_b decays
  - Everything else.

- Normalise Reflection shape to measured $B^0_d \rightarrow D^{\mp} \pi^{\pm}$ yield.

Effect of dE/dX:



Expected Systematics:

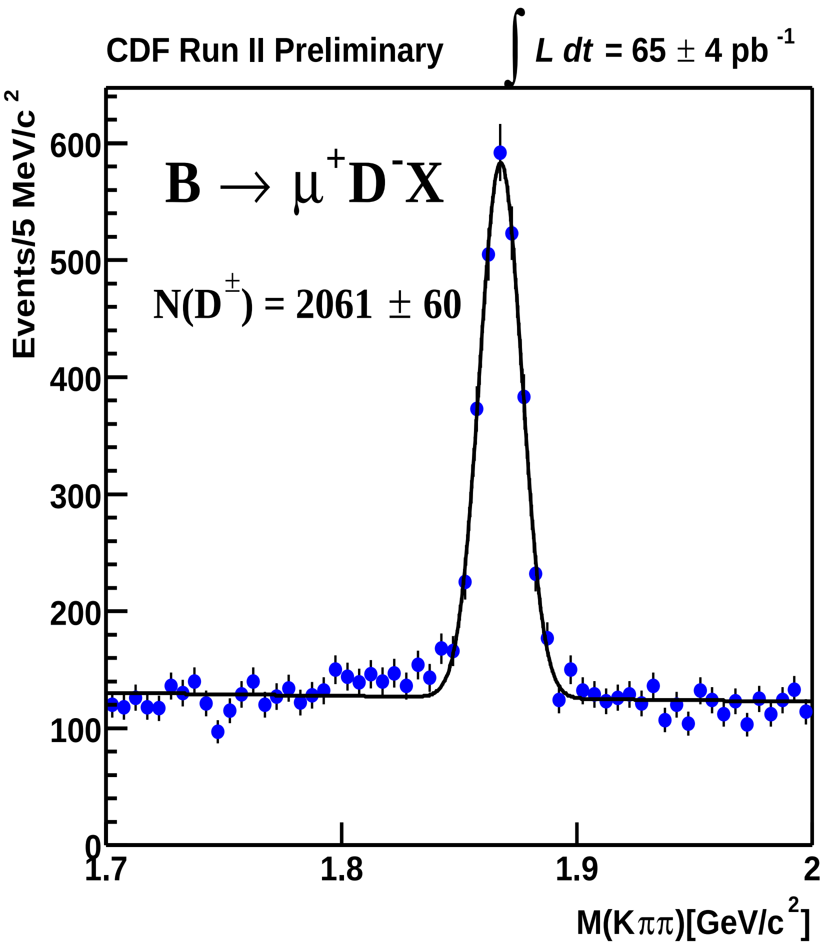
Source	Size (%)
B lifetime	negligible
Λ^0_b lifetime	$+4 \quad -5$
Λ_c Dalitz structure	± 1
b p_t spectrum	$+1$
Λ^0_b, Λ_c polarisation	± 2
XFT 1 miss	$+3$
Phi efficiency	$+3$
Total	$+6 \quad -5$

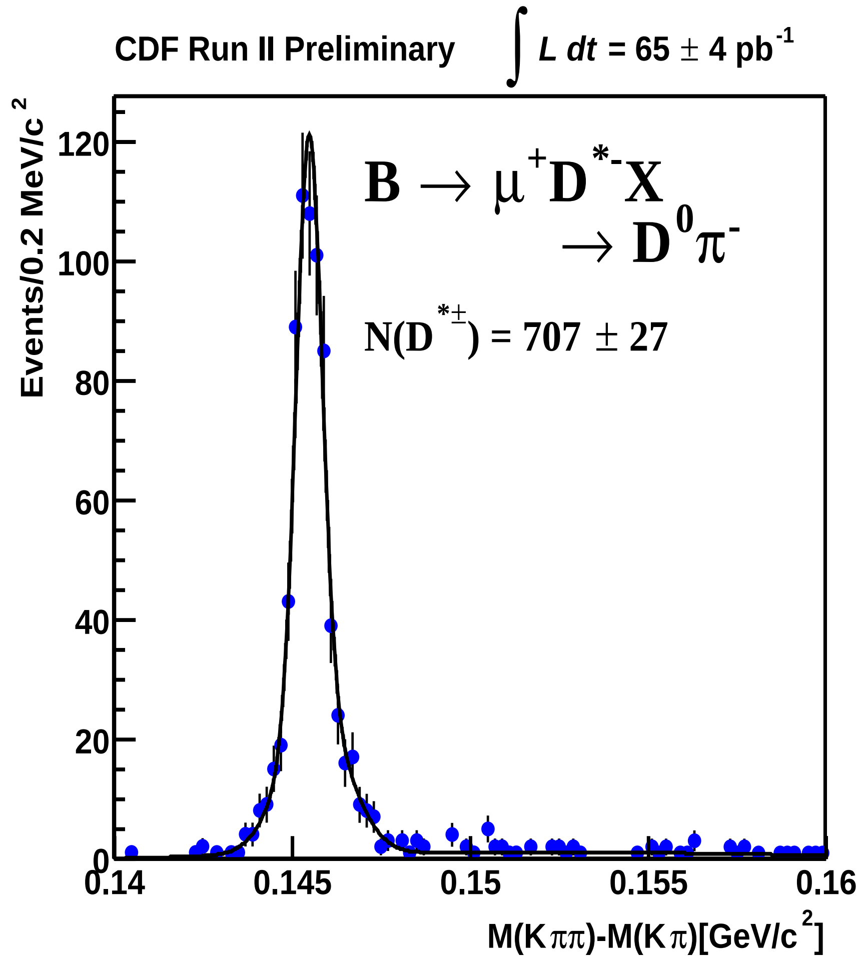
Current Status:

- Finalising reflection model
- $\dfrac{f_{baryon} \times BR(\Lambda^0{}_b \to \Lambda^+{}_c \pi^-)}{f_d \times BR(B^0{}_d \to D^+ \pi^-)}$ measurement for EPS
- Systematic uncertainty dominated by:

$$\sigma\left(BR(\Lambda^+{}_c \to pK^- \pi^+)\right) \sim 25\%$$

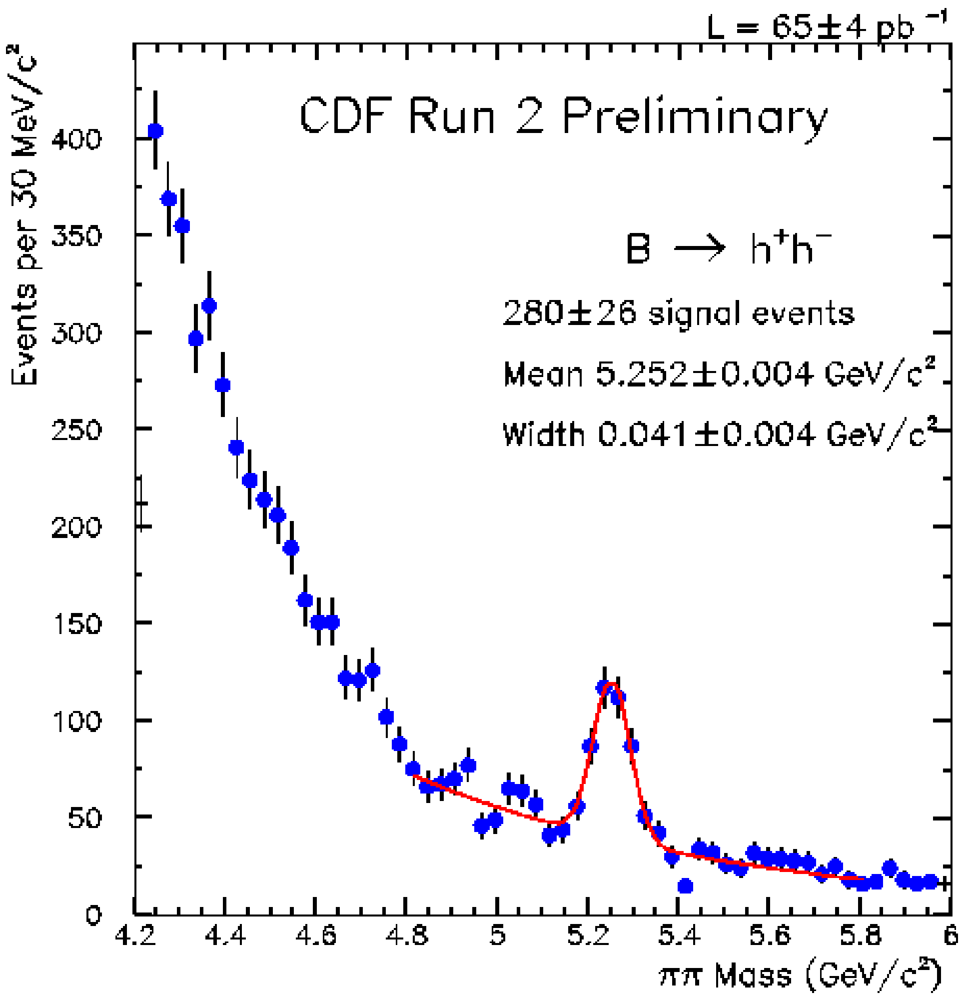
Prospects for improving normalisation:





Note : Hadronic Trigger Path

Reconstructing $B \to h^+ h^-$

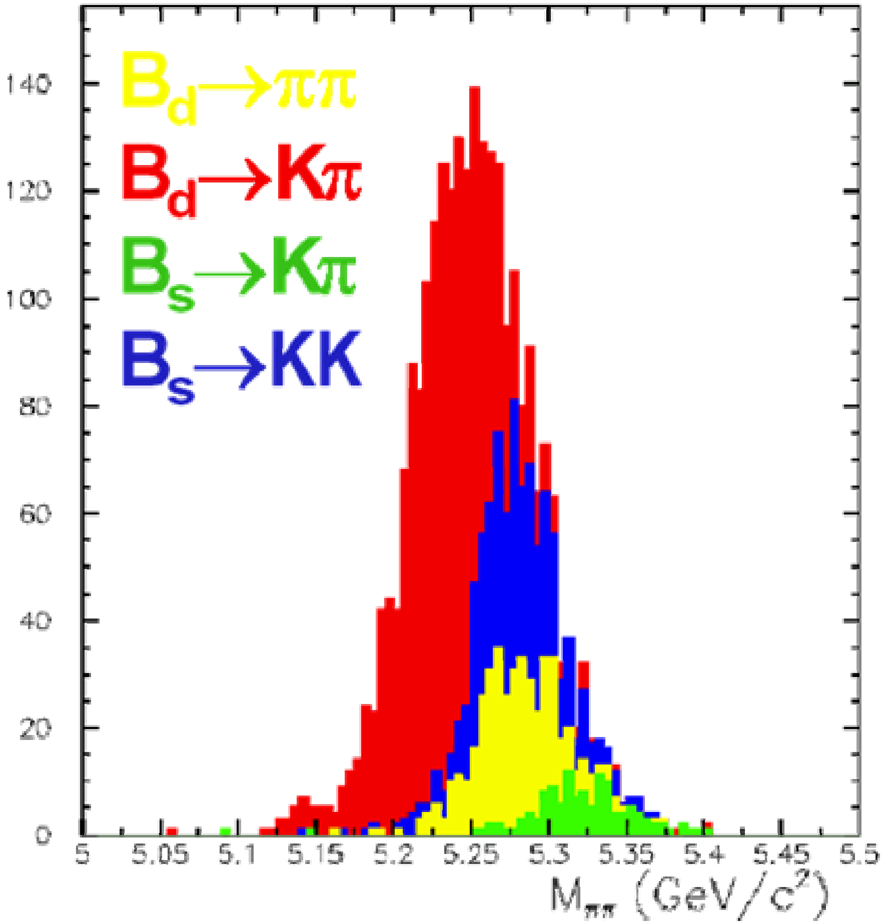


- $h^+ h^-$ required to be trigger tracks.
- Optimise offline Cuts on MC signal, data sideband:
  - $p_{t1} + p_{t2} > 5.5\ GeV$
  - $\left(|IP_1|, |IP_2|\right) > 150\ \mu m$
  - $\text{2D-Flight-Dist}\left(B\right) > 300\ \mu m$
  - $|IP_B| < 80\ \mu m$

- Isolation:
  - Defined in a cone about the B axis: $I = \dfrac{\sum_{B-daughters} p_t}{\sum_{All\ Tracks} p_t}$
  - Efficiency from data $\left(B^{\pm} \to J/\psi\ K^{\pm}\right)$

Different signal contributions:

Monte Carlo:



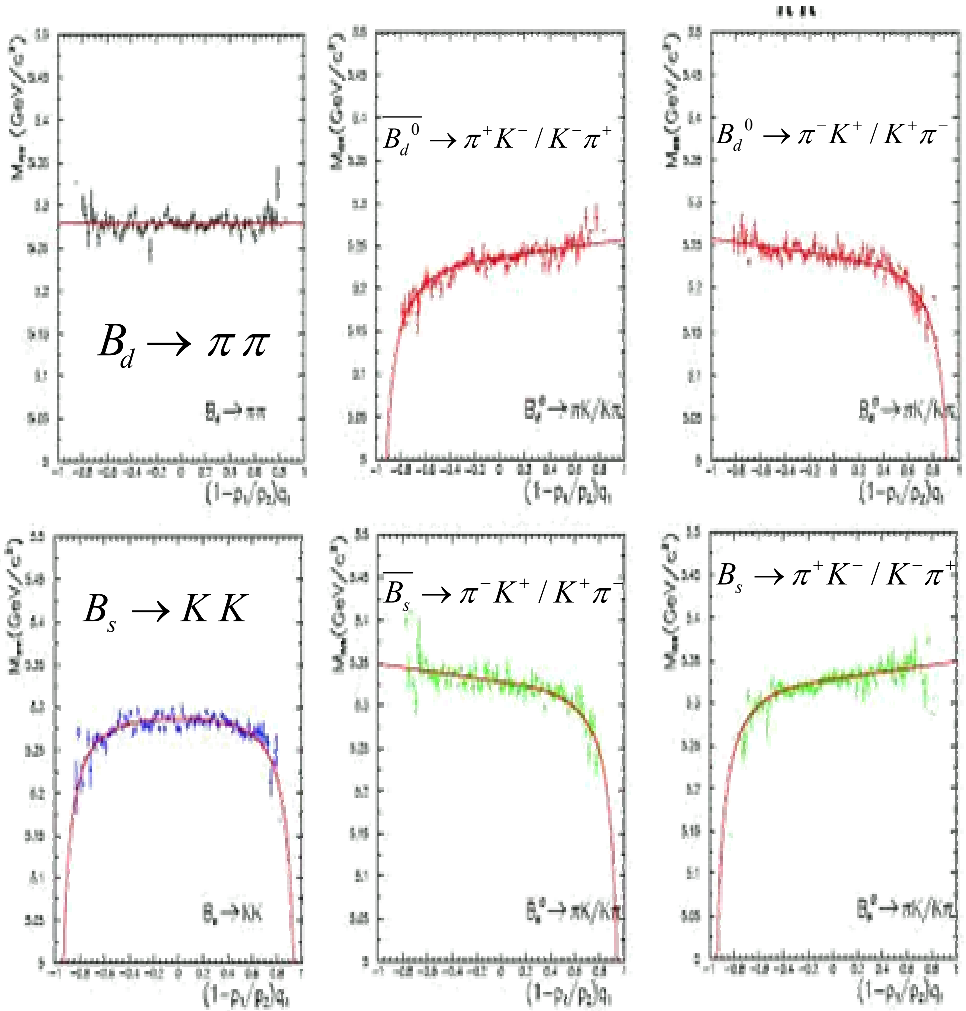
- Total width due to several different contributions.
- $B_d \to \pi\pi,\ B_s \to K\,K$ on top of each other $\Rightarrow$ PID essential
- Disentangle using:

Kinematic Separation { Invt Mass; Relative momentum

- PID$\left(\frac{dE}{dx}\right)$ ← Most Important

Kinematic separation:

Monte Carlo:



- Choose 2 variables:

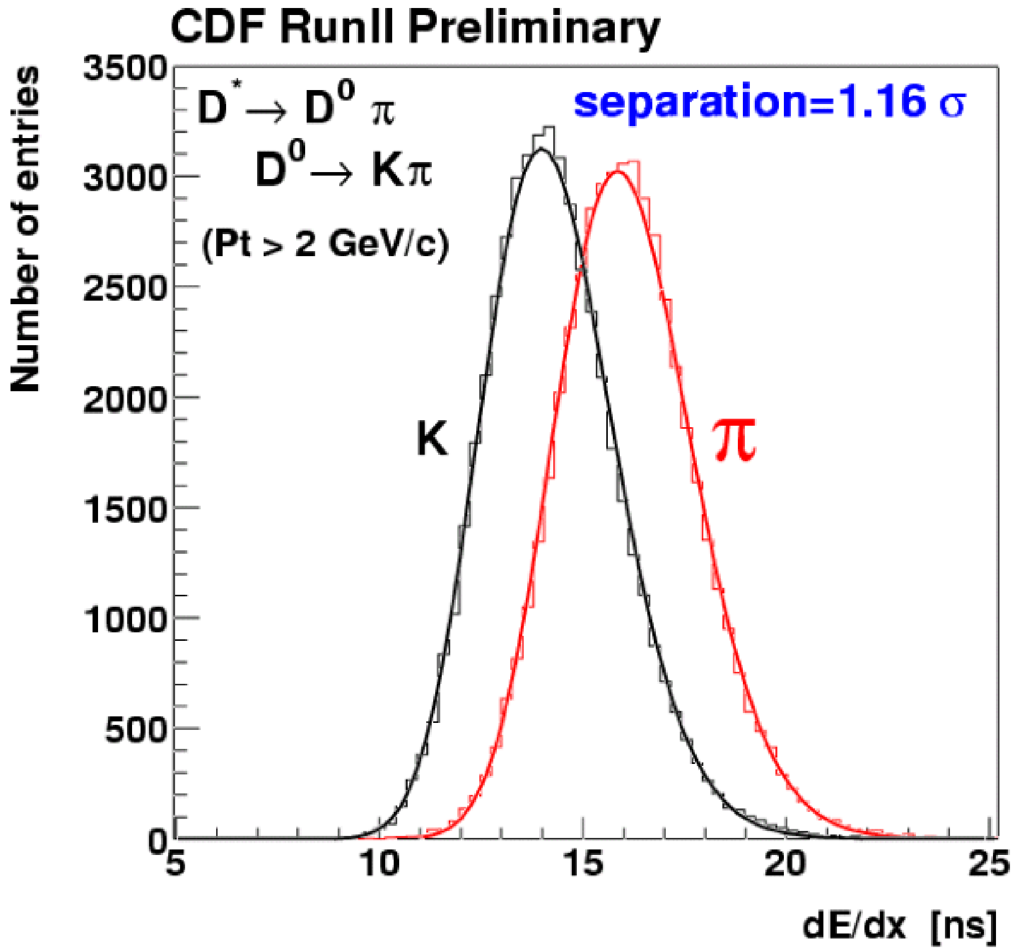
  - $M_{\pi\pi}$
  - $\alpha = \left(1 - \frac{p_1}{p_2}\right) q_1$

where: $p_1 < p_2$

- Signal Likelihood:

$$F = \frac{1}{\sqrt{2\pi\sigma}} \exp\left[-\frac{1}{2}\left(\frac{M_{\pi\pi} - M(\alpha)}{\sigma}\right)^2\right] P(\alpha)$$

Particle ID : dE / dx



- $\frac{dE}{dx}$ calibrated on D^* sample

- Bachelor π charge identifies D^0 daughters.

$$F_i = \frac{1}{\sigma^i \sqrt{2\pi}} \exp\left[-\frac{1}{2} \left(\frac{M_{\pi\pi} - M^i{}_{\alpha}}{\sigma^i} \right)^2 \right] P\left(\alpha^j\right) \; G_{\mu 1, \sigma j}\left(\left(ID1\right)^j\right) \; G_{\mu 1, \sigma j}\left(\left(ID2\right)^j\right)$$

Systematics:

	$\frac{B_d \to \pi\pi}{B_d \to K\pi}$	$A_{CP}^{dir}(\pi K)$
BCK Shape	+0.019 -0.015	+0.002 -0.009
$M(B_d)$	+0.004 -0.004	+0.0003 -0.0003
$M(B_s)$	+0.005 -0.006	+0.002 -0.003
$\sigma(M)$	+0.004 -0.009	+0.006 -0.005
MC stat	+0.002 -0.002	+0.007 -0.007
* dE/dx	+0.05 -0.05	+0.01 -0.01

* new calibration will reduce systematic

Current Results:

$$\frac{BR(B^0_d \to \pi\pi)}{BR(B^0_d \to K\pi)} = 0.26 \pm 0.11(stat) \pm 0.055(syst)$$

$$A^{dir}_{CP}(\pi K) = 0.02 \pm 0.15(\text{stat}) \pm 0.17(\text{syst})$$

PDG 2002:

$$\frac{BR(B^0_d \to \pi\pi)}{BR(B^0_d \to K\pi)} = 0.29^{+0.13\ +0.01}_{-0.12\ -0.02}$$

Yields:

$B^0_d \to \pi\pi$	148 ± 17(stat)
$B^0_d \to K\pi$	39 ± 14(stat)
$B^0_s \to KK$	90 ± 17(stat)
$B^0_s \to K\pi$	3 ± 11(stat)

Conclusions:

- CDF has robust signals in:
  - $\Lambda^0{}_b \rightarrow \Lambda^+{}_c \pi^-$
  - $B^0{}_S \rightarrow D^{\mp}{}_S \pi^{\pm}$
  - $B_s \rightarrow K K$
- First measurement of $B^0{}_S \rightarrow D^{\mp}{}_S \pi^{\pm}$ relative BR
- First observation of $B_s \rightarrow K K$
  - Measurement of $\frac{BR(B^0{}_d \rightarrow \pi\pi)}{BR(B^0{}_d \rightarrow K\pi)}$ validates extraction procedure
- Expect $B_s \rightarrow K K$ and $\Lambda^0{}_b \rightarrow \Lambda^+{}_c \pi^-$ for EPS
- First steps toward an exciting programme in $B^0{}_S$ physics and $\Lambda^0{}_b$ physics (mixing and CPV) .