Measurement of Relative Fragmentation Fractions of B Hadrons at CDF

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Recent B Physics Results from CDF

B_s mixing

Brashly alluring

B fragmentation fractions

Demure, but charming

Outline

- B fragmentation overview
- Semileptonic signal reconstruction
- Semileptonic sample composition
- Reconstruction efficiencies
- Fit for fragmentation fractions
- Fragmentation fraction results
- Outlook

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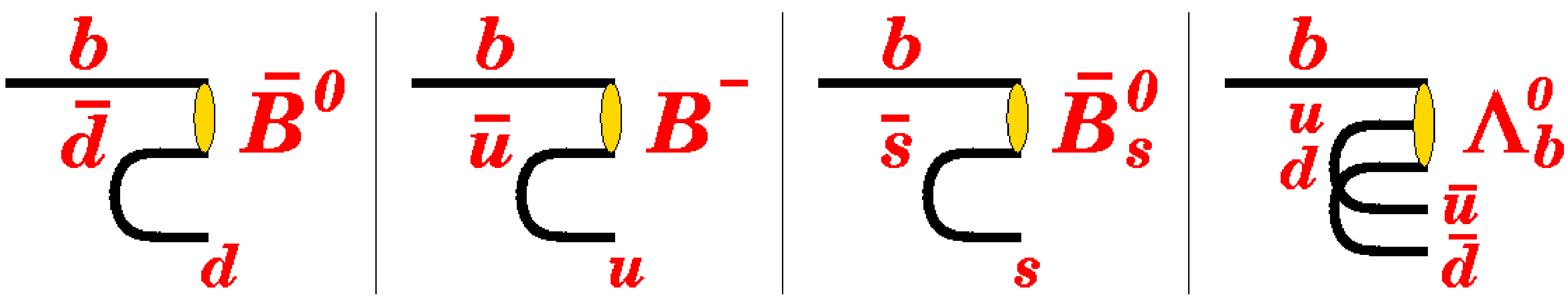
B Physics at Tevatron

- Reconstruct all flavors of B hadrons
  - B_d^0, B_u^+, B_s^0, B_c^+, Λ_b^0
  - Contrast to B factories, Υ(4S) [Υ(5S)]
    - B_d^0, B_u^+ [B_s^0]
- Large dataset of B hadrons
  - ~1 fb^{-1} data available for B measurements
    - Very large production cross-section makes Tevatron competitive w/B factories
  - Make exciting new measurements
    - B_s mixing (1 fb^{-1})
  - Refine older measurements
    - B fragmentation fractions (360 pb^{-1})

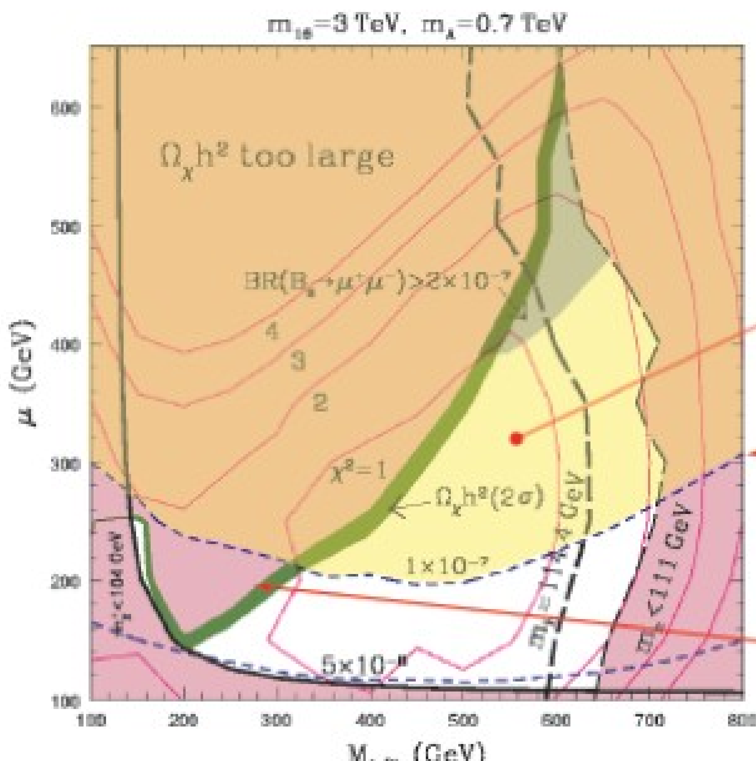
B Fragmentation

- Probability of b quark hadronizing with an anti-quark or a di-quark pair
  - $f_q \equiv \mathcal{B}(b \rightarrow B_q)$
- Many models for heavy flavor fragmentation
  - Petersen, Lund, …
- B fragmentation fractions inherently empirical quantity
  - Include B*, B** in fragmentation fractions



Why Fragmentation Fractions?

- Search for $B_s \to \mu^+\mu^-$
  - $\mathcal{B}(B_s \to \mu^+\mu^-) = f_u/f_s \times \mathcal{B}(B^+ \to J/\psi K^+) \times \ldots$
  - Improvement in limit @95% CL if
    - Reduce uncertainty on f_s/f_d
    - f_s/f_d at Tevatron is higher than world average…



e.g., Dermisek et al., hep-ph/0507233
dark matter and S0(10) with soft SUSY breaking,
other experimental constraints

Excluded at 95% CL! (CDF Limit)

Contour of equal $Br(B_s \to \mu^+\mu^-)$

Allowed by dark matter constraints

Fragmentation Fraction Status

- Measured many times before
  - LEP (ALEPH, DELPHI, OPAL)
    - f_u, f_d, f_s, $f_{b\text{-baryon}}$
    - e^+e^- collisions
    - $p_T(b) \sim 40$ GeV/c
    - $f_s/(f_u+f_d) = 0.109 \pm 0.026$

2004 PDG,
dominated by LEP

  - Tevatron
    - f_u/f_d, $f_s/(f_u+f_d)$, $f_{\Lambda b}/(f_u+f_d)$
    - $p\bar{p}$ collisions
    - $p_T(b) \sim 10\text{-}15$ GeV/c
    - CDF Run I: $f_s/(f_u+f_d) = 0.213 \pm 0.038$

Average between two CDF
Run I results

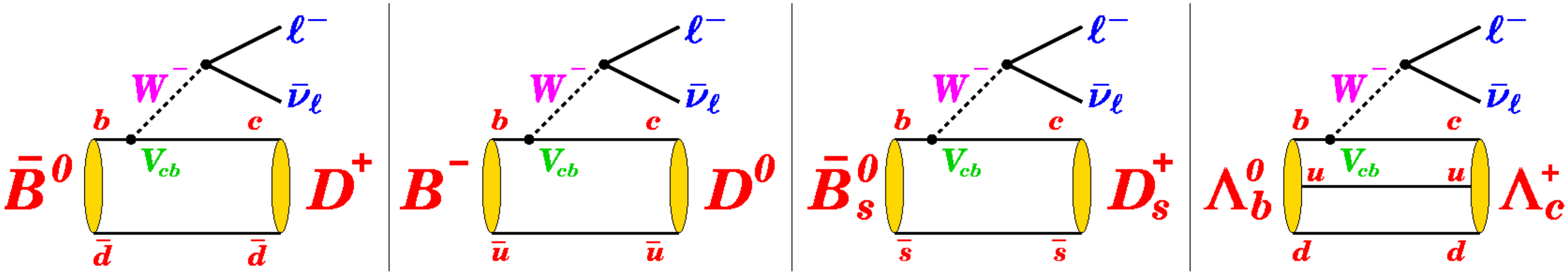
B Fragmentation Intrigue

- Other ~2.5 sigma discrepancies observed between LEP and CDF Run I
  - $\bar{\chi} = f_d\chi_d + f_s\chi_s$
    - 0.118 ± 0.005 average measured at LEP
    - 0.152 ± 0.013 measured at CDF Run I (110 pb-1)
  - The discrepancies could be due to
    - New physics present in $p\bar{p}$ collisions
    - **OR** f_s is simply higher at Tevatron
    - **OR** just fluctuations, etc…

Note: PDG 2004 calculates $f_s/(f_u+f_d) = 0.134 \pm 0.014$ when $\bar{\chi}$ constraints are included

B Frag. Fractions in Run II

- Use method similar to Run I measurement
  - Reconstruct five semileptonic B signals
    - $\ell^- D^+$, $\ell^- D^0$, $\ell^- D^{*+}(\to D^0\pi^+)$, $\ell^- D_s^+$, $\ell^- \Lambda_c^+$ (ℓ=e,μ)
  - Relate to parent B hadrons
    - $\overline{B}_d^0$, B_u^-, $\overline{B}_s^0$, Λ_b^0
    - Cross-talk from excited charm states makes life complicated!



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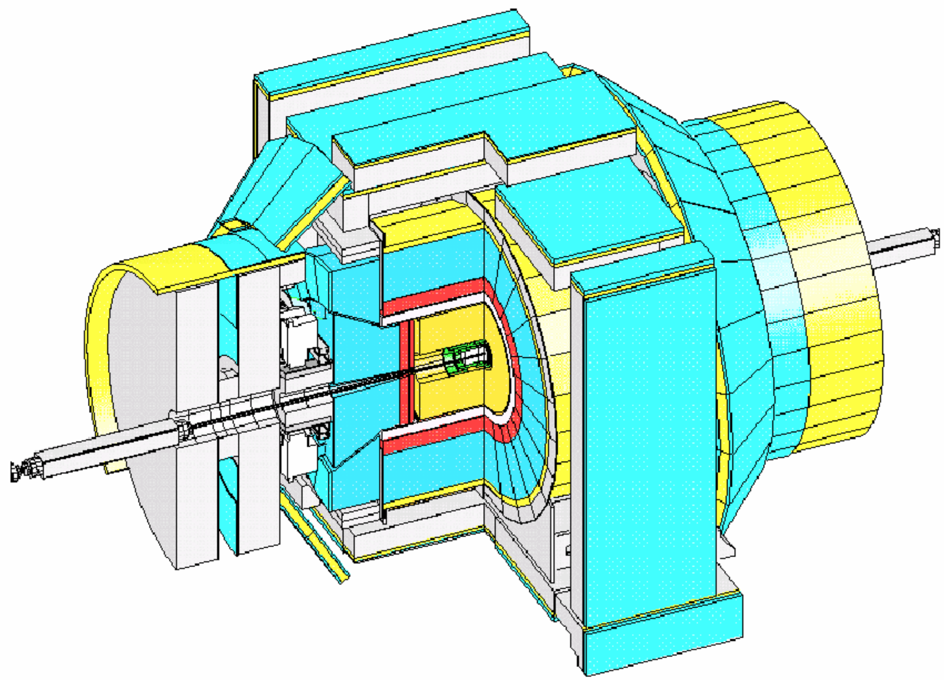
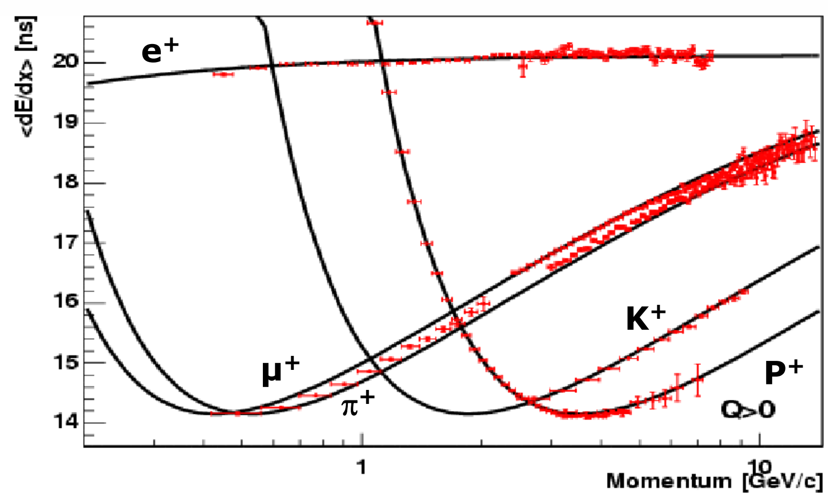
CDF Detector

- Tracking chamber
  - Eight layers of silicon
    - Precision detection of displaced tracks
  - Drift Chamber
    - dE/dx
- Lepton Identification
  - Electromagnetic Calorimeter
  - Hadronic Calorimeter
  - Muon chambers



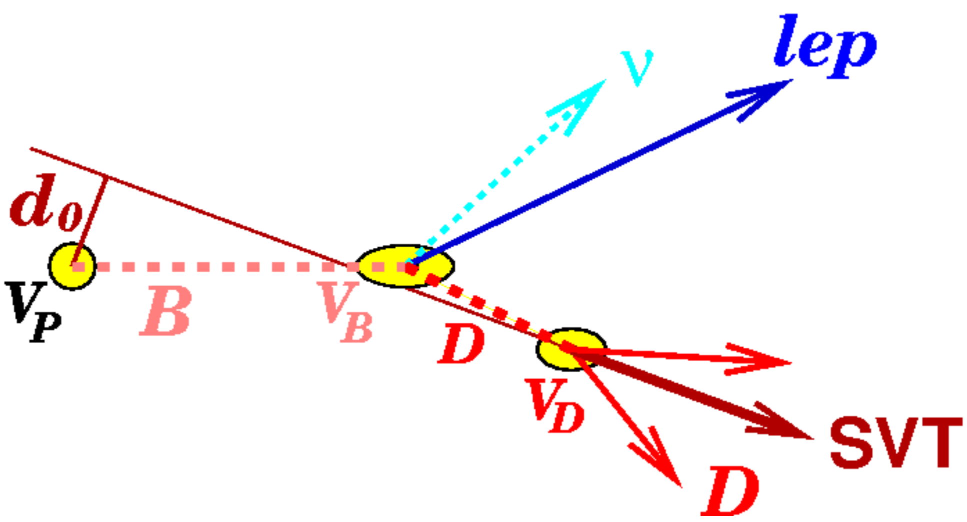


SVT

- Hardware trigger
- Can trigger on displaced tracks in Run II
  - Allows for accumulation of large sample of B events
  - Uses information from
    - Drift chamber (XFT)
    - Silicon detector

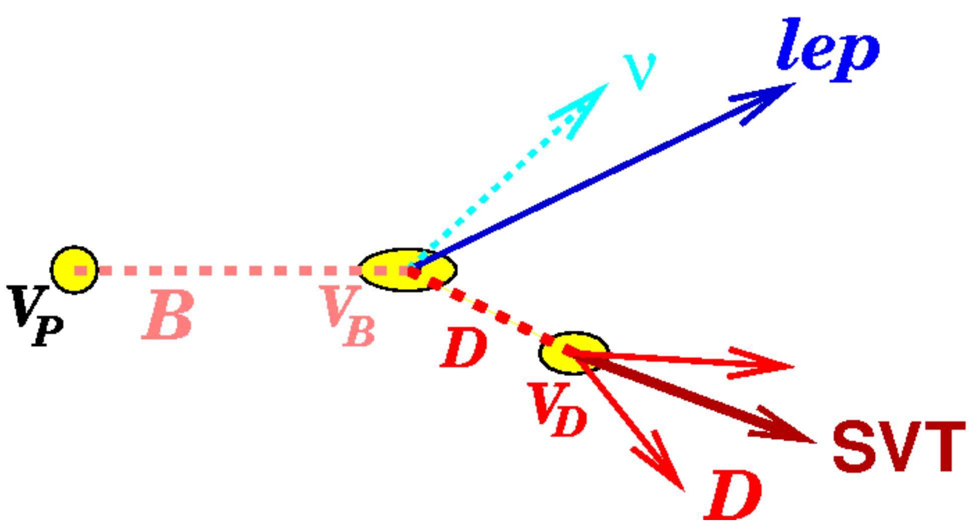
Semileptonic B Trigger

- New ℓ+SVT trigger in Run II
  - $p_T(\ell) > 4$ GeV/c
  - $p_T(\text{SVT}) > 2$ GeV/c
  - 120 μm $< d_0(\text{SVT}) <$ 1 mm
  - $m(\ell,\text{SVT}) < 5$ GeV/c^2
- Run I trigger
  - $p_T(\ell) > 8$ GeV/c



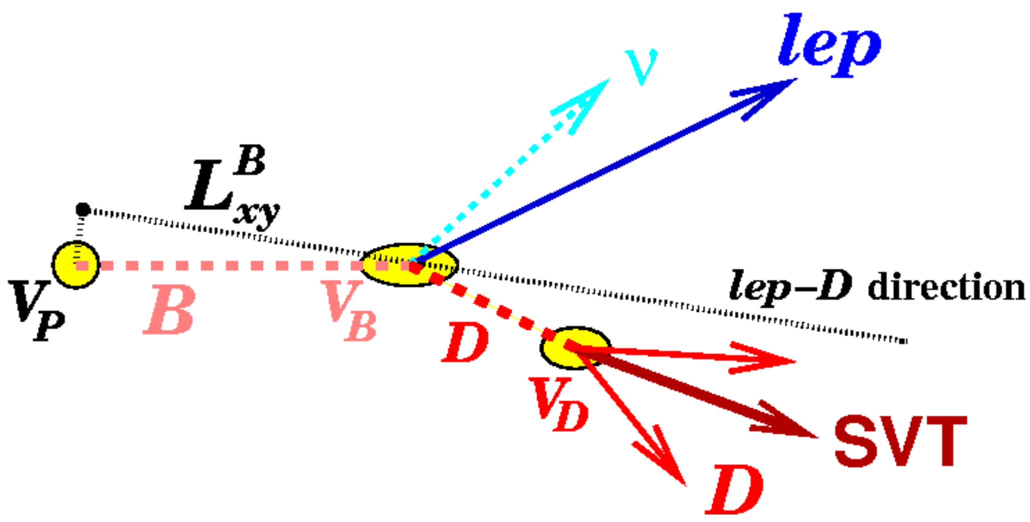
ℓ+Charm Reconstruction

- Reconstruct 5 charm signals
  - $D^+ \to K^-\pi^+\pi^+$
  - $D^0 \to K^-\pi^+$
  - $D^{*+} \to D^0\pi^+$
  - $D_s^+ \to \varphi\pi^+$, $\varphi \to K^-K^+$
  - $\Lambda_c^+ \to pK^-\pi^+$
  - Require one of charm tracks be SVT track
  - Require a trigger lepton in vicinity of charm hadron
- Vertex charm hadron with trigger lepton

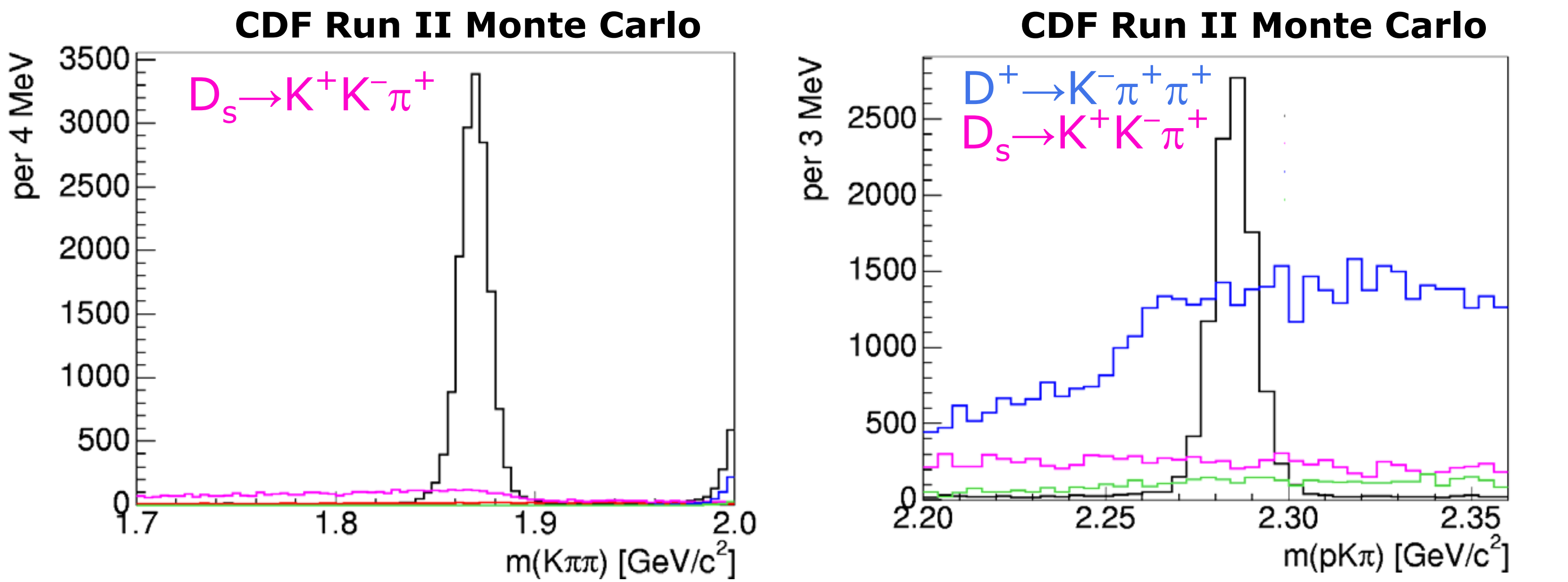


Signal Selection

- Cut on quantities which distinguish B decays
  - $ct^*(\ell D) = L_{xy}(P.V. \to \ell D) \cdot m(B)/p_T(\ell D) > 200\ \mu m$
    - Inconsistent with being prompt
  - $L_{xy}(P.V. \to D)$
  - p_T(tracks)
  - Probability of vertex fits to bottom and charm hadrons

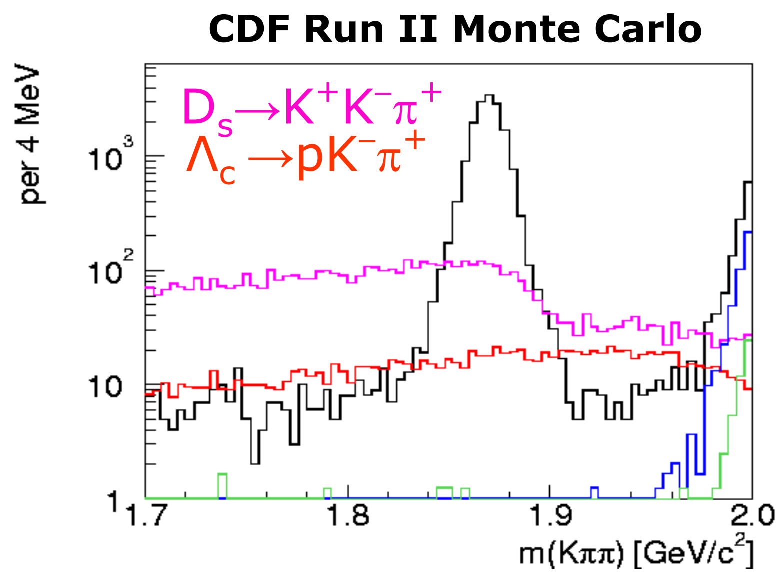


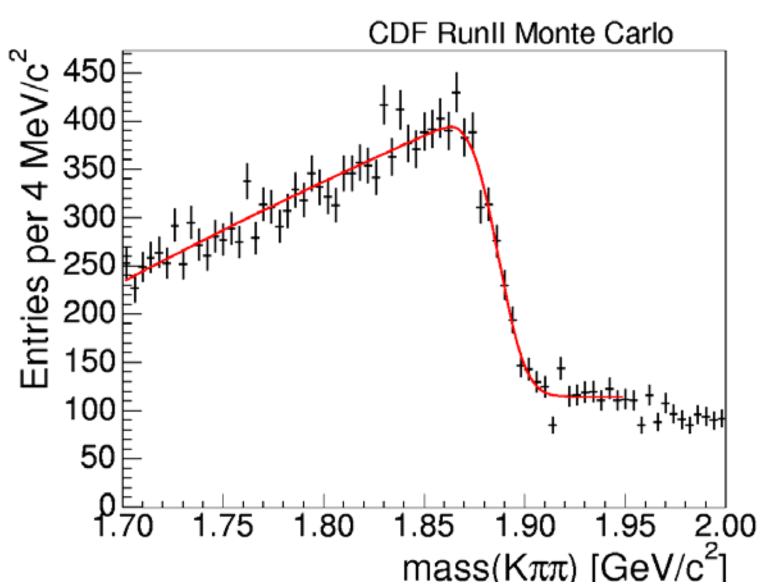
Reflection Backgrounds



- Combinatorial backgrounds present beneath all signals
- Significant reflection backgrounds present in two signals
  - D^+ signal contaminated by $D_s^+ \to K^+K^-\pi^+$
    - Include reflection in fit to signal
  - Λ_c^+ signal contaminated by $D^+ \to K^-\pi^+\pi^+$, $D_s^+ \to K^+K^-\pi^+$
    - Use dE/dx cut on proton in $\Lambda_c^+ \to pK^-\pi^+$

D_s^+ Reflection in D^+ Signal



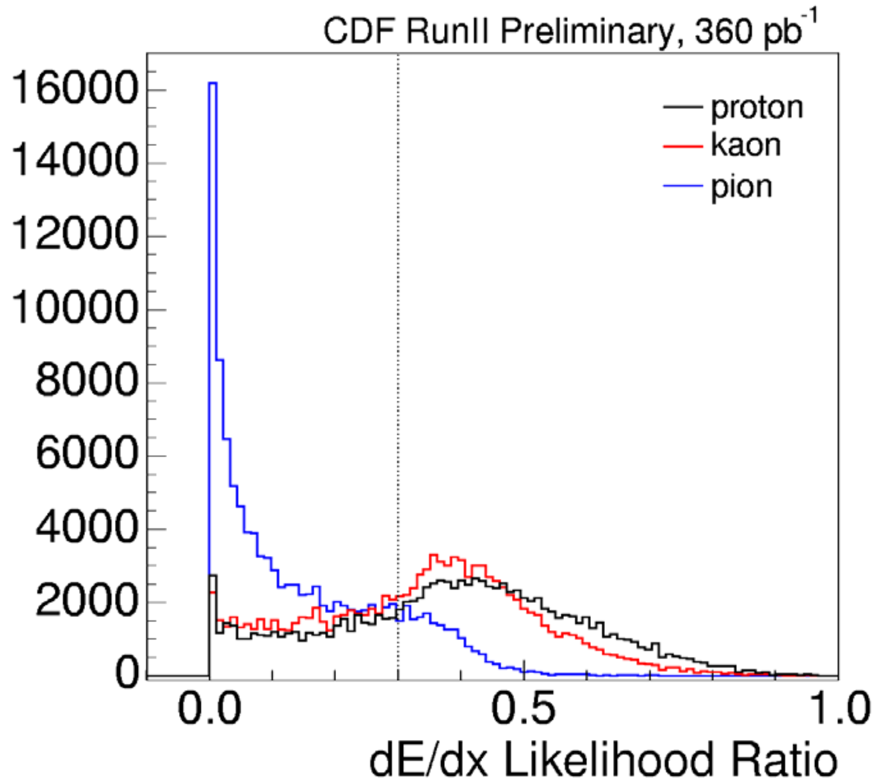


- Use MC to determine reflection shape
- Fit number of $D_s^+ \rightarrow \varphi\pi^+$ observed in data
- Scale efficiency of $D_s^+ \rightarrow \varphi\pi^+$ to generic $D_s^+ \rightarrow K^-K^+\pi^+$

$$R_{\phi\pi} = 0.246 \pm 0.016$$

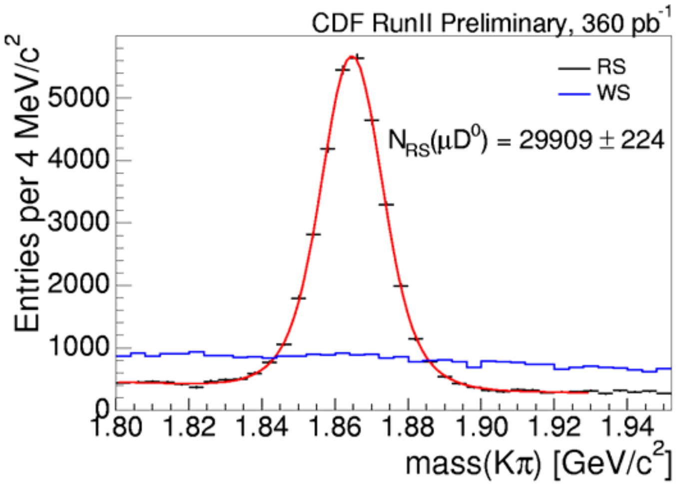
- Measure N_{D_s} = 13.4 ± 0.8 % relative to D^+ yield in $m \in [1.78, 1.95]$

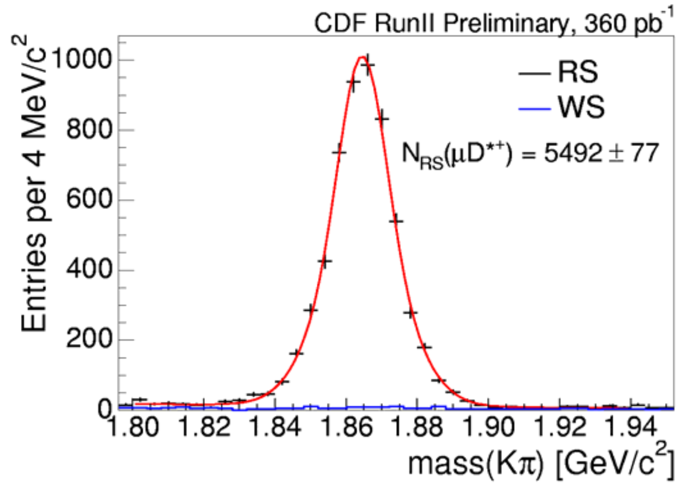
dE/dx Likelihood Cut

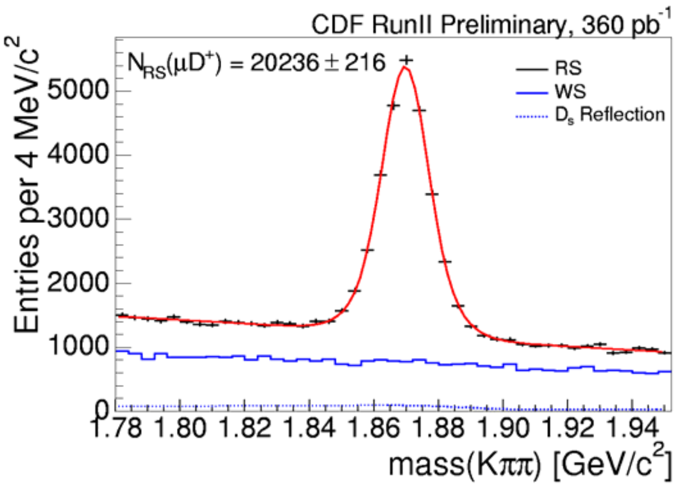


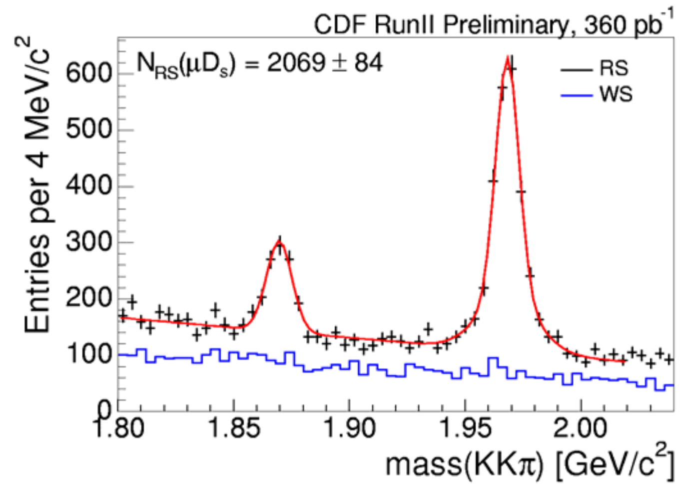
- $\mathcal{LR} \equiv \mathcal{L}(p)/[\mathcal{L}(p)+\mathcal{L}(K)+\mathcal{L}(\pi)+\mathcal{L}(e)+\mathcal{L}(\mu)]$
  - $\mathcal{L}(i)$ constructed from $Z=\mathrm{Log}[(dE/dx)_{meas}/(dE/dx)_{pred}]$

μ+Charm Meson Signals

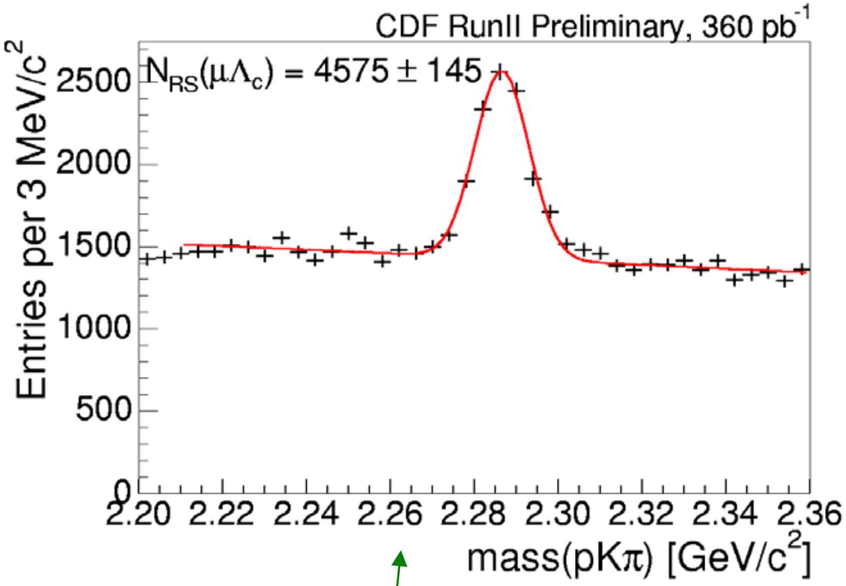


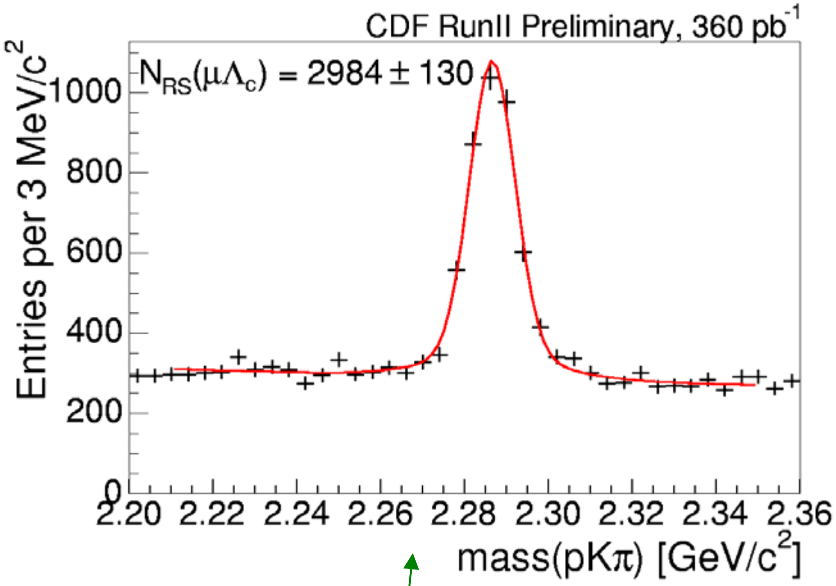






$\mu+\Lambda_c$ Signal





No dE/dx cut

With dE/dx cut on proton

Semileptonic B Yields

Signature	Yield
$\ell^- D^0$	46,848 ± 275
$\ell^- D^{*+}$	8,490 ± 95
$\ell^- D^+$	31,015 ± 262
$\ell^- D_s^+$	3,081 ± 95
$\ell^- \Lambda_c^+$	4,739 ± 168

360 pb^{-1}

- Run I yields used in fragmentation fraction measurement
  - $N(e^- D_s^+) = 59 \pm 10$
  - $N(e^- \Lambda_c^+) = 79 \pm 17$

More than 50 times the yield in Run II compared to Run I!

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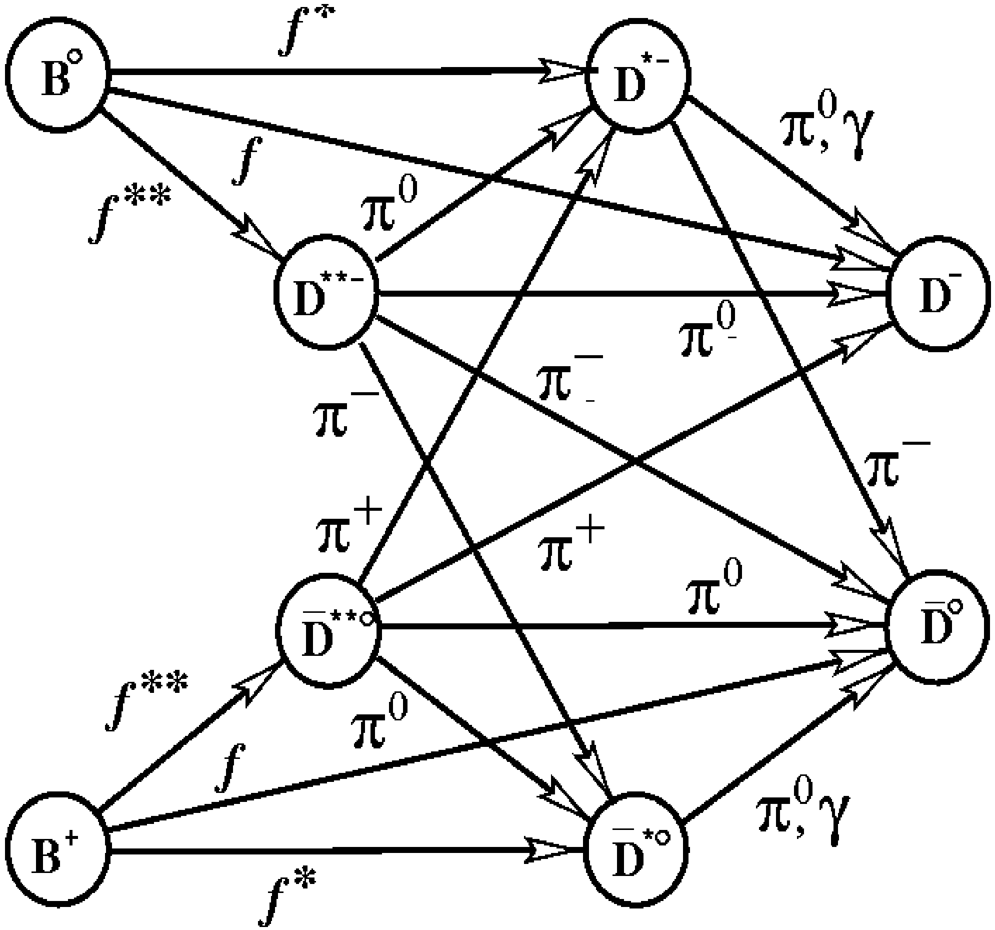
Sample Composition

- Need to disentangle parent B hadrons from lepton-charm signals
  - Missing neutrino prevents fully reconstructing decay at CDF
  - Allows excited charm states to contribute to reconstructed charm signals
- Cross-talk between signals
  - $\overline{B}^0$, B^-, $\overline{B}_s^0$ contribute to $\ell^- D^+$, $\ell^- D^0$, $\ell^- D^{*+}$, $\ell^- D_s^+$
  - Λ_b^0 contributes to $\ell^- \Lambda_c^+$
    - Meson $\leftrightarrow$ baryon cross talk small

Simple Sample Composition



- Simple parameterization of semileptonic B^0, B^+ decays into $\bar{D}^0$ and D^-

Full Sample Composition

$\bar{B}^0$	B^-	$\bar{B}_s^0$	Λ_b^0
$\ell\nu D^+$	$\ell\nu D^0$	$\ell\nu D_s^+$	$\ell\nu\Lambda_c^+$
$\ell\nu D^{*+}$	$\ell\nu D^{*0}$	$\ell\nu D_s^{*+}$	$\ell\nu\Lambda_c(2593)^+$
$\to D^0\pi^+$	$\to D^0\pi^0/\gamma$	$\to D_s^+\gamma$	$\to \Sigma_c(2455)^{++}\pi^-$
$D^+\pi^0/\gamma$			$\hookrightarrow \Lambda_c^+\pi^+$
			$\to \Sigma_c(2455)^0\pi^+$
$\ell\nu D_1^+$	$\ell\nu D_1^0$	$\ell\nu D_{s1}^+(2460)$	$\hookrightarrow \Lambda_c^+\pi^-$
$\to D^{*0}\pi^+$	$\to D^{*0}\pi^0$	$\to D_{s0}^{*+}\pi^0$	$\to \Sigma_c(2455)^+\pi^0$
$\hookrightarrow D^0\pi^0/\gamma$	$\hookrightarrow D^0\pi^0/\gamma$	$\hookrightarrow D_s^+\pi^0$	$\hookrightarrow \Lambda_c^+\pi^0$
$\to D^{*+}\pi^0$	$\to D^{*+}\pi^-$	$\to D_s^+\gamma$	$\to \Lambda_c^+\pi^+\pi^-$
$\hookrightarrow D^0\pi^+$	$\hookrightarrow D^0\pi^+$		$\to \Lambda_c^+\pi^0\pi^0$
$D^+\pi^0/\gamma$	$D^+\pi^0/\gamma$		$\to \Lambda_c^+\gamma$
$\ell\nu D_0^{*+}$	$\ell\nu D_0^{*0}$	$\ell\nu D_{s0}^{*+}(2317)$	$\ell\nu\Lambda_c(2625)^+$
$\to D^0\pi^+$	$\to D^0\pi^0$	$\to D_s^+\pi^0$	$\to \Lambda_c^+\pi^+\pi^-$
$D^+\pi^0$	$D^+\pi^-$		$\to \Lambda_c^+\pi^0\pi^0$
			$\to \Lambda_c^+\gamma$
$\ell\nu D_1^{'+}$	$\ell\nu D_1^{'0}$	$\ell\nu D_{s1}^{'+}(2535)$	
$\to D^{*0}\pi^+$	$\to D^{*0}\pi^0$	$\to D^{*+}K^0$	$\ell\nu\Sigma_c(2455)^{++}\pi^-)$
$\hookrightarrow D^0\pi^0/\gamma$	$\hookrightarrow D^0\pi^0/\gamma$	$\hookrightarrow D^0\pi^+$	$\to \Lambda_c^+\pi^+$
$\to D^{*+}\pi^0$	$\to D^{*+}\pi^-$	$D^+\pi^0/\gamma$	
$\hookrightarrow D^0\pi^+$	$\hookrightarrow D^0\pi^+$	$\to D^{*0}K^+$	$\ell\nu\Sigma_c(2455)^0\pi^+$
$D^+\pi^0/\gamma$	$D^+\pi^0/\gamma$	$\hookrightarrow D^0\pi^0/\gamma$	$\to \Lambda_c^+\pi^-$
$\ell\nu D_2^{*+}$	$\ell\nu D_2^{*0}$	$\ell\nu D_{s2}^{'+}(2573)$	$\ell\nu\Sigma_c(2455)^+\pi^0$
$\to D^{*0}\pi^+$	$\to D^{*0}\pi^0$	$\to D^{*+}K^0$	$\to \Lambda_c^+\pi^0$
$\hookrightarrow D^0\pi^0/\gamma$	$\hookrightarrow D^0\pi^0/\gamma$	$\hookrightarrow D^0\pi^+$	
$\to D^{*+}\pi^0$	$\to D^{*+}\pi^-$	$D^+\pi^0/\gamma$	$\ell\nu\Lambda_c^+ f_0$
$\hookrightarrow D^0\pi^+$	$\hookrightarrow D^0\pi^+$	$\to D^{*0}K^+$	
$D^+\pi^0/\gamma$	$D^+\pi^0/\gamma$	$\hookrightarrow D^0\pi^0/\gamma$	$\ell\nu\Lambda_c^+\pi^+\pi^-(\mathrm{NR})$
$\to D^0\pi^0$	$\to D^0\pi^0$	$\to D^+K^0$	
$\to D^+\pi^-$	$\to D^+\pi^-$	$\to D^0K^+$	$\ell\nu\Lambda_c^+\pi^0\pi^0(\mathrm{NR})$
$\ell\nu D^{*+}\pi^0(\mathrm{NR})$	$\ell\nu D^{*+}\pi^-(\mathrm{NR})$	$\ell\nu D_s^{*+}\pi^0(\mathrm{NR})$	
$\to D^0\pi^+$	$\to D^0\pi^+$	$\to D_s^+\gamma$	
$D^+\pi^0/\gamma$	$D^+\pi^0/\gamma$		
		$\ell\nu D_s^+\pi^0(\mathrm{NR})$	
$\ell\nu D^{*0}\pi^+(\mathrm{NR})$	$\ell\nu D^{*0}\pi^0(\mathrm{NR})$		
$\to D^0\pi^0/\gamma$	$\to D^0\pi^0/\gamma$		
$\ell\nu D^+\pi^0(\mathrm{NR})$	$\ell\nu D^+\pi^-(\mathrm{NR})$		
$\ell\nu D^0\pi^+(\mathrm{NR})$	$\ell\nu D^0\pi^0(\mathrm{NR})$		
$D^{(*)}\bar{D}^{(*)}K$	$D^{(*)}\bar{D}^{(*)}K$	$D^{(*)}\bar{D}^{(*)}K$	
$D^{(*)+}D^{(*)-}$			
$D_s^{(*)}D^{(*)}X$	$D_s^{(*)}D^{(*)}X$	$D_s^{(*)}D^{(*)}X$	$\tau^-\nu\Lambda_c^+$
		$D_s^{(*)}D_s^{(*)}X$	$\tau^-\nu\Lambda_c(2593)^+$
$\tau^-\nu D^{+(*),(**)}$	$\tau^-\nu D^{0(*),(**)}$	$\tau^-\nu D_s^{+(*),(**)}$	$\tau^-\nu\Lambda_c(2625)^+$

Consider all significant decays to semileptonic charm signals, including sequential semileptonic decays.

"Physics backgrounds"
e.g. $B^0 \to D^+(\to K^-\pi^+\pi^+)D^-(\to \ell^- X)$

Parameterization

- Simple example w/only ground state

$N(\ell^+ D^-)$

$$=N(B^0)\times\mathcal{B}(B^0\to\ell^+\nu D^-)\times\mathcal{B}(D^-\to K^+\pi^-\pi^-)$$
$$\times\varepsilon(B^0\to\ell^+\nu D^-, D^-\to K^+\pi^-\pi^-)$$

$$=N(b)\times f_d\times\tau(B^0)\times\Gamma(B^0\to\ell^+\nu D^-)\times\mathcal{B}(D^-\to K^+\pi^-\pi^-)$$
$$\times\varepsilon(B^0\to\ell^+\nu D^-, D^-\to K^+\pi^-\pi^-)$$

Number of b quarks

- Extend this to all mesons
  - Generalize notation
  - $N(\ell D_i)=\Sigma_{j=d,u,s}\, N(b)\times f_j\times\tau(B_j)\times\Sigma_k\Gamma_k\times\mathcal{B}_{ijk}(D_{jk}\to D_i)\times\varepsilon_{ijk}$
    - $D_i = D^-, D^0, D^{*-}$, and D_s
    - $\Gamma_k = \Gamma, \Gamma^*, \Gamma^{**}$

Branching Ratios

- Need model for semileptonic decays
  - $\Gamma(B\to \ell\nu D^{(*,**)}) = 1/\tau(B)\ \mathrm{x}\ \mathcal{B}(B\to \ell\nu D^{(*,**)})$
  - Use spectator model for meson decays
    - $\Gamma(B^0\to \ell\nu D^-) = \Gamma(B^+\to \ell\nu D^0) = \Gamma(B_s\to \ell\nu D_s) \equiv \Gamma$
    - $\Gamma(B^0\to \ell\nu D^{*-}) = \Gamma(B^+\to \ell\nu D^{*0}) = \Gamma(B_s\to \ell\nu D_s^{*}) \equiv \Gamma^*$
    - $\Gamma(B^0\to \ell\nu D^{**-}) = \Gamma(B^+\to \ell\nu D^{**0}) = \Gamma(B_s\to \ell\nu D_s^{**}) \equiv \Gamma^{**}$
  - Assume $\Gamma + \Gamma^* + \Gamma^{**} = \Gamma_{s\ell}(B\to \ell\nu X)$
- Use fixed sample composition for $\Lambda_b\to\ell\nu\Lambda_c X$
- Use PDG 2004 for known branching ratios
  - Use theoretical predictions and symmetry principles for unmeasured BR

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Acceptances and Efficiencies

- Need relative acceptances and efficiencies of individual ℓ+charm decays
  - Fit to relative fractions
- Use MC to determine acceptances
  - Detector geometry
  - Kinematic differences between lepton-charm signals
- Use data to determine remaining efficiencies which are different between charm channels

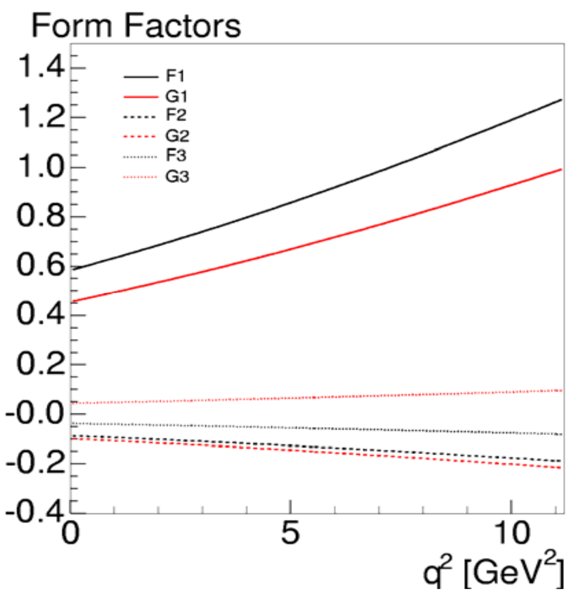
Monte Carlo

- Monte Carlo is good for most kinematic differences between lepton-charm signals
  - $ct(D)$, p_T(tracks), etc…
- Generate single B hadron directly
  - Decay with EvtGen package
  - Use input p_T spectrum measured from data
    - Inclusive $p_T(b \to J/\psi X)$ spectrum
  - Separate set of Monte Carlo generated for each decay in sample composition
  - Separate sets of Monte Carlo for e, μ
- Validate with inclusive Monte Carlo samples by comparing data and Monte Carlo
  - *e.g.* $B \to \ell \nu D X$

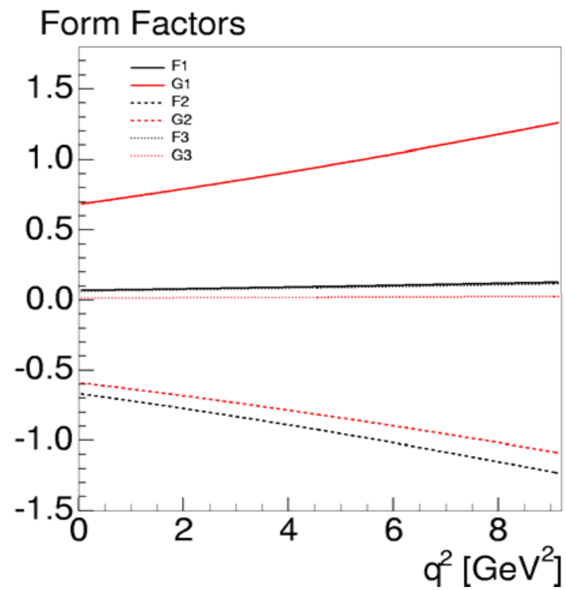
Baryon Decays

- Need to implement physical baryon decay model
- $T = (G_F/\sqrt{2})V_{Qq}\bar{u}_\ell\gamma_\mu(1-\gamma_5)v_\nu\langle\Lambda_q|J^\mu|\Lambda_Q\rangle$
- V-A current
  - $1/2^+ \rightarrow 1/2^+$ $(\Lambda_b^0 \rightarrow \Lambda_c^+)$
    - $\langle\Lambda_c^+|V^\mu|\Lambda_b^0\rangle = \bar{u}(p',s')[F_1(q^2)\gamma^\mu + F_2(q^2)p^\mu/m_{\Lambda b} + F_3(q^2)p'^\mu/m_{\Lambda c}]u(p,s)$
    - $\langle\Lambda_c^+|A^\mu|\Lambda_b^0\rangle = \bar{u}(p',s')[G_1(q^2)\gamma^\mu + G_2(q^2)p^\mu/m_{\Lambda b} + G_3(q^2)p'^\mu/m_{\Lambda c}]\gamma^5 u(p,s)$
  - $1/2^+ \rightarrow 3/2^-$ $(\Lambda_b^0 \rightarrow \Lambda_c^+(2625))$
    - $\langle\Lambda_c^+(2625)|V^\mu|\Lambda_b^0\rangle = \bar{u}_\alpha(p',s')[p^\alpha/m_{\Lambda b}(F_1\gamma^\mu + F_2 p^\mu/m_{\Lambda b} + F_3 p'^\mu/m_{\Lambda c}) + F_4 g^{\alpha\mu}]u(p,s)$
    - $\langle\Lambda_c^+(2625)|A^\mu|\Lambda_b^0\rangle = \bar{u}_\alpha(p',s')[p^\alpha/m_{\Lambda b}(G_1\gamma^\mu + G_2 p^\mu/m_{\Lambda b} + G_3 p'^\mu/m_{\Lambda c}) + G_4 g^{\alpha\mu}]\gamma^5 u(p,s)$
    - $u_\alpha(p',s') = u(p',s')\varepsilon_\alpha$
      - $u_\alpha(p',s')p'^\alpha = u(p',s')\varepsilon_\alpha p'^\alpha = 0$
      - $\varepsilon_\alpha(0,\underline{e}(M))$ in rest frame (of $\Lambda_c(2625)$)
        - $\underline{e}(\pm 1) = 1/\sqrt{2}(-/+1, -i, 0)$
        - $\underline{e}(0) = (0,0,1)$

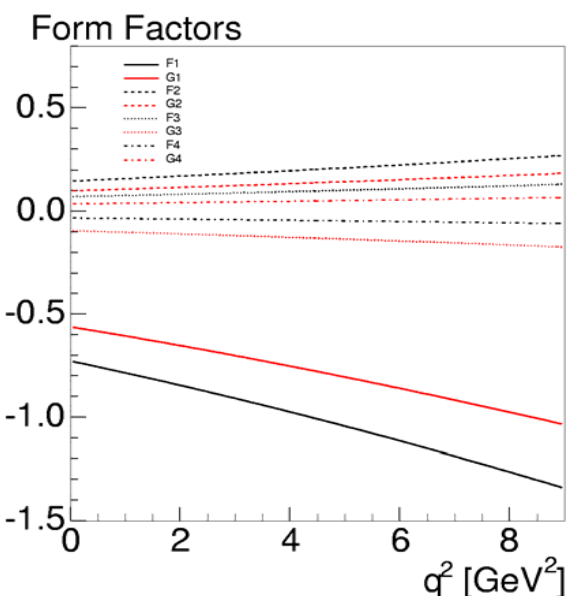
$\Lambda_b \to \Lambda_c$ Form Factors



Λ_c^+



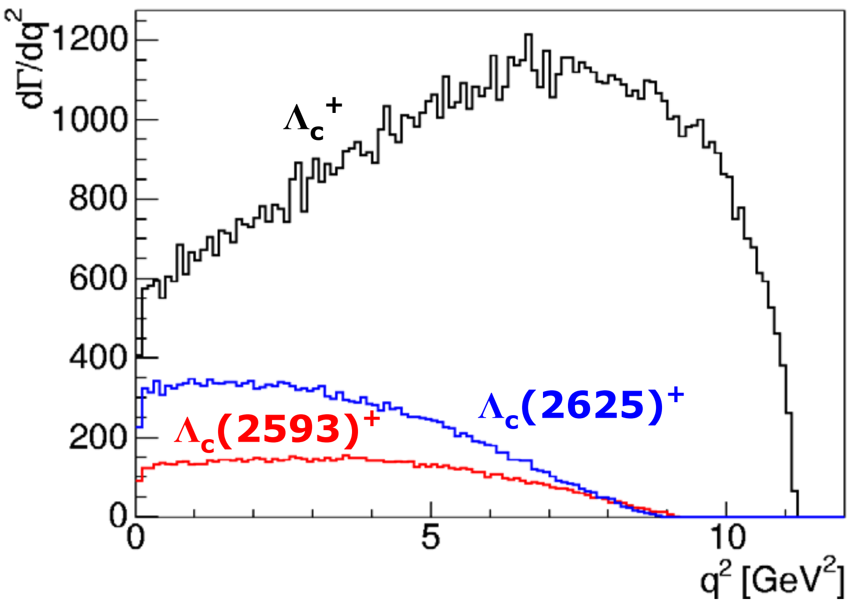
$\Lambda_c(2593)^+$



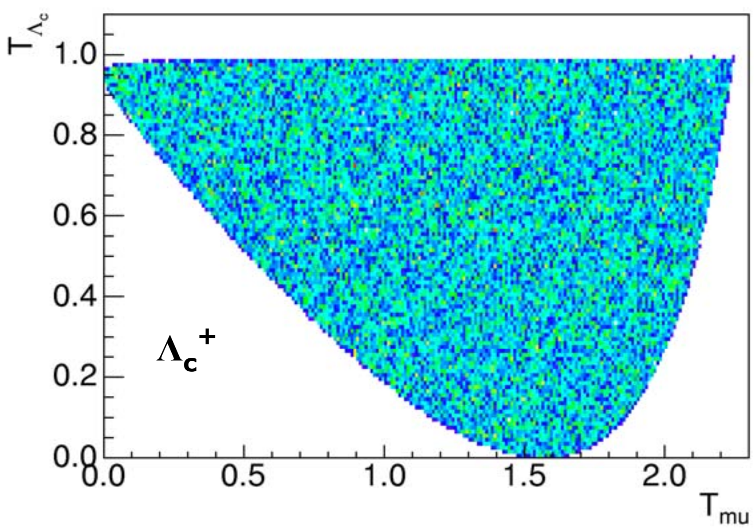
$\Lambda_c(2625)^+$

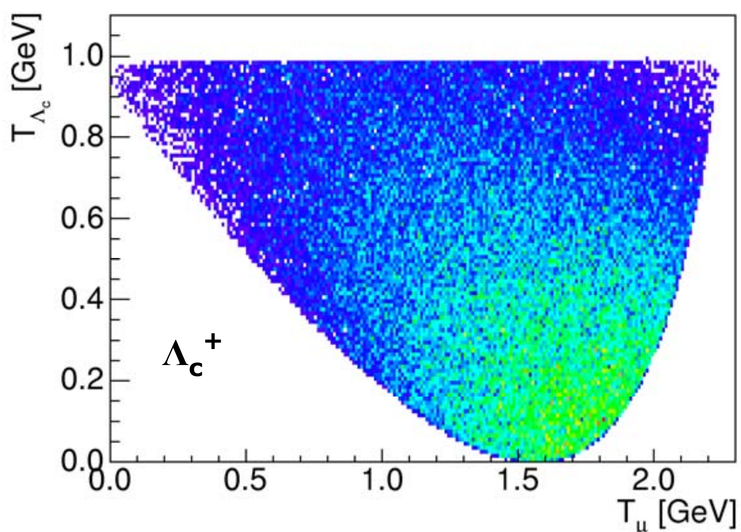
Form factor predictions from Pervin, Capstick, and Roberts et al. only made for $\ell\nu\Lambda_c^{(*,**)}$ final states

New Baryon Decay Model



- New baryon decay model implemented according to predictions by Pervin, Capstick, and Roberts
  - Constituent quark model
  - Phys. Rev. C72,035201 (2005)





Reconstruction Efficiencies

- Measure some efficiencies from data
  - Single track efficiency
    - $D^0 \to K^- \pi^+$ vs. $D^+ \to K^- \pi^+ \pi^+$
  - XFT trigger efficiencies for p, K, π
  - dE/dx efficiency for cut on proton
    - $\Lambda_c^+ \to p K^- \pi^+$
- Use to re-weight Monte Carlo for total efficiency

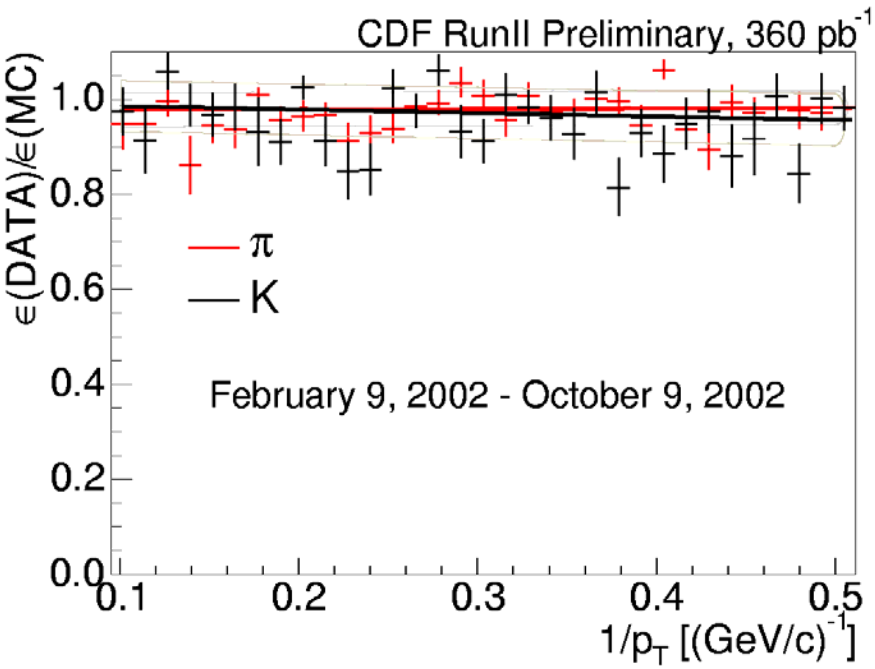
Single Track Efficiency

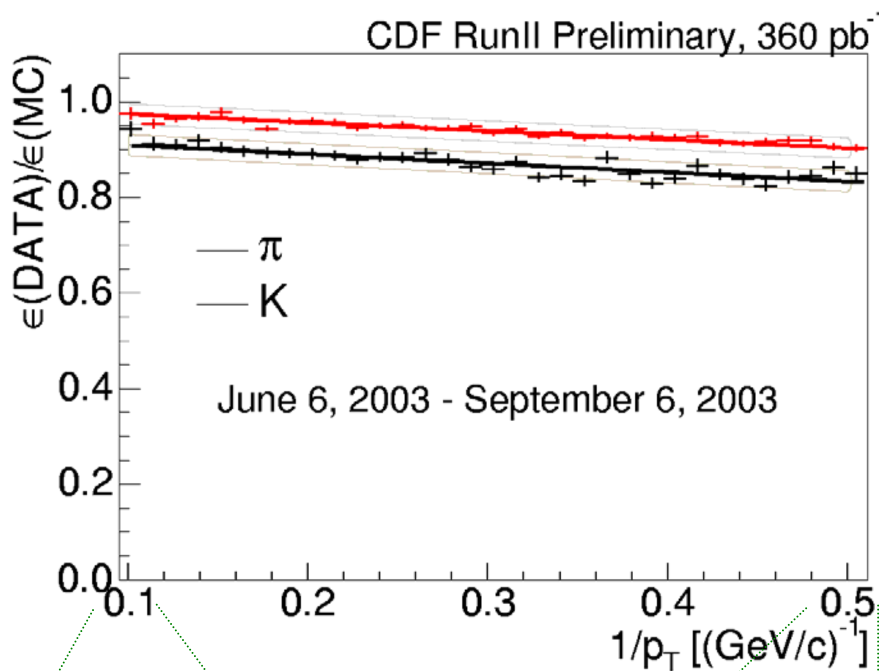
- Efficiency to add an additional track depends on environment in detector
  - Monte Carlo only generates B hadron
- Reconstruct $D^0 \rightarrow K^- \pi^+ \pi^- \pi^+$
  - Measure efficiency relative to $D^0 \rightarrow K^- \pi^+$ in data and Monte Carlo
  - Efficiency to add two additional tracks
- Measure
  - $\varepsilon_{trk} = 87.8\ ^{+2.1}_{-1.2}$ (stat.+sys.)%

XFT Efficiencies

- Differences in tracking p, K, π in drift chamber
  - Differences in efficiencies between reconstructed charm states
  - Only applies to SVT trigger track
  - Varying drift chamber performance not optimally described by Monte Carlo
  - Again measure from data
    - Re-weight Monte Carlo
    - Measure in separate run ranges

XFT Efficiencies



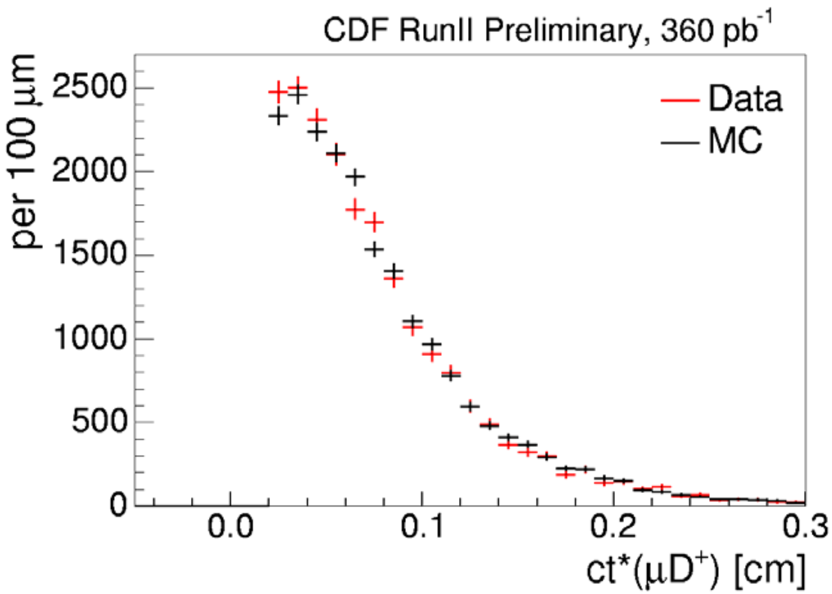


10 [GeV/c]

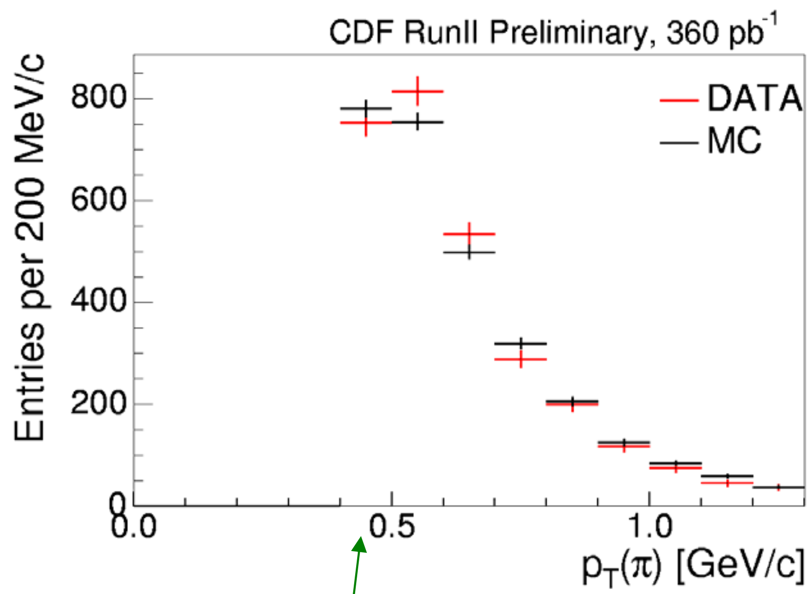
2 [GeV/c]

Comparison of Data and MC

χ^2**/NDF=24.3/27.0**

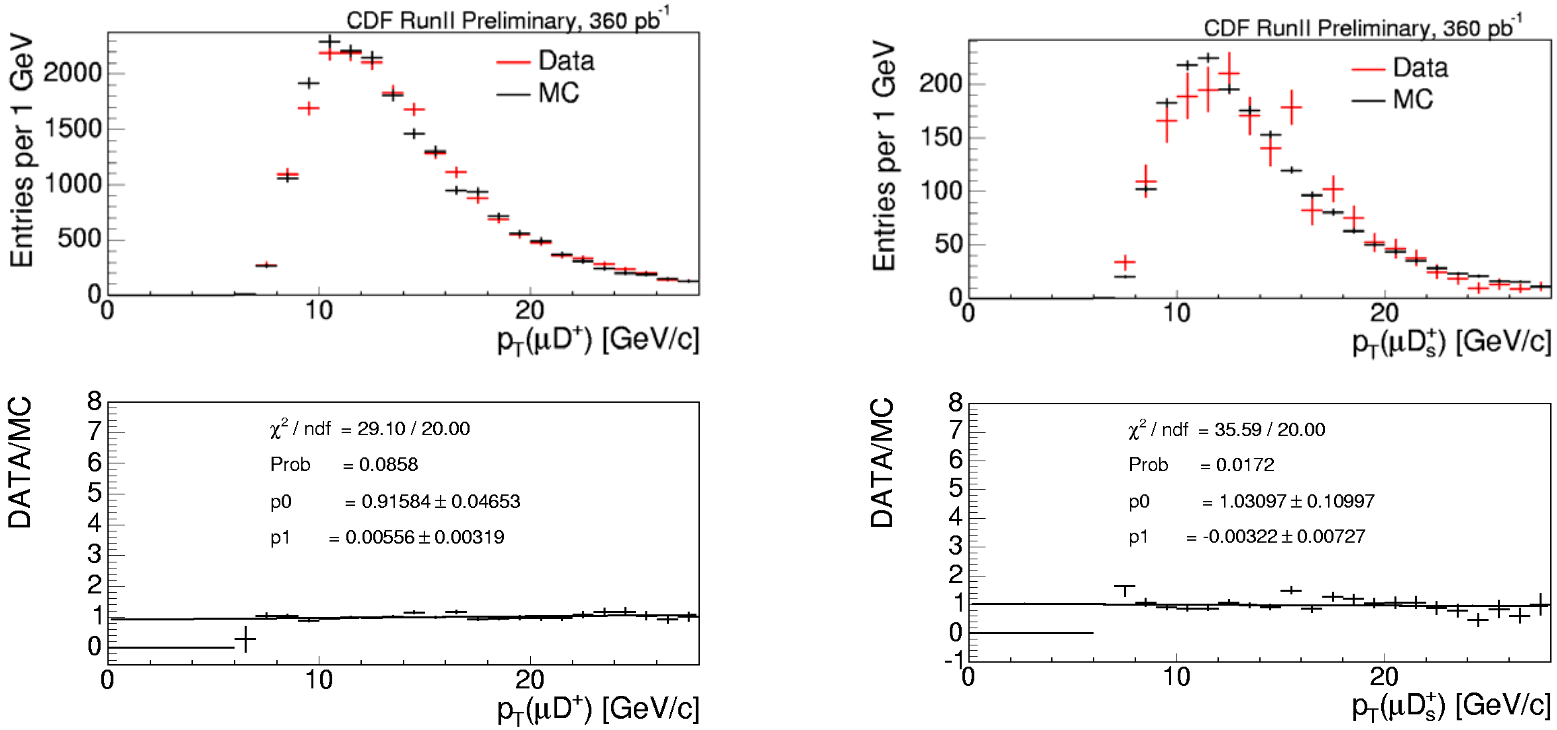


χ^2**/NDF=11.9/8.0**



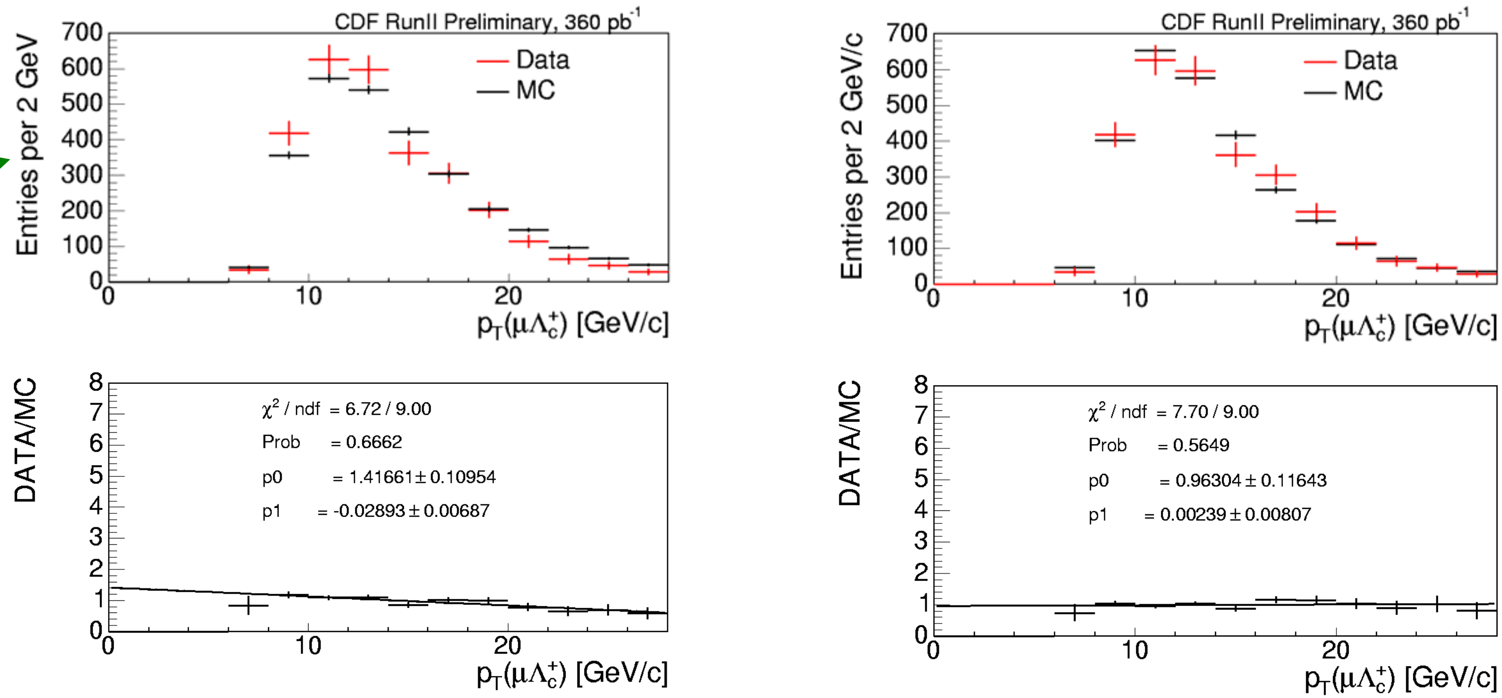
π^* from eD*

B Meson p_T Spectra



- Choice of p_T spectrum used is important for determination of efficiencies
- Use inclusive $p_T(b \to J/\psi X)$ spectrum measured in Run II for meson signals
  - Good agreement with data

Λ_b p_T Spectra



- Inclusive $p_T(b \to J/\psi X)$ spectrum does not describe the $\ell\Lambda_c$ data
  - Observe softer spectrum in data than the MC
- Tune the $\ell\Lambda_c$ Monte Carlo spectrum to match the $\ell\Lambda_c$ data

Outline

- B fragmentation overview
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General Idea of Fit

- Express each term of sample composition in terms of B^0
  - Fit for relative production

    $$N_{pred}(\ell D_i) = N(B^0)\ \Sigma_{j=d,u,s}\ f_j/f_d \times \tau(B_j) \times \Sigma_k \Gamma_k \times \mathcal{B}_{ijk}(D_{jk} \rightarrow D_i) \times \varepsilon_{ijk}$$

    $$N_{pred}(\ell \Lambda_c) = N(B^0) \times [f_{\Lambda_b}/(f_u+f_d)](1+f_u/f_d) \times [(\Sigma_k \mathcal{B}_k (\Lambda_b \rightarrow \ell \nu \Lambda_{c,k} \rightarrow \Lambda_c)) \times \varepsilon_k]$$

- χ^2 fit to 5 lepton charm channels
  - f_u/f_d, $f_s/(f_u+f_d)$, $f_{\Lambda_b}/(f_u+f_d)$
    - $f_s/f_d = [f_s/(f_u+f_d)] \times (1+f_u/f_d)$
  - $N(B^0)$
    - Parameter for fit, not physical number of B^0's

Implementation of Fit

- Fit looks like

$$\chi^2 = \Sigma_{i=1..5} (N_{pred}(\ell D_i) - N_{meas}(\ell D_i))^2/\sigma_{meas,i}^2$$
$$+ (\Gamma - \Gamma_{PDG})^2/\sigma_{\Gamma_{PDG}}^2$$
$$+ (\Gamma^* - \Gamma^*_{PDG})^2/\sigma_{\Gamma^*_{PDG}}^2$$
$$+ (\Gamma^{**} - \Gamma^{**}_{PDG})^2/\sigma_{\Gamma^{**}_{PDG}}^2$$

  - Gaussian constraints for Γ, Γ^*, Γ^{**}
  - Test with high statistics toy Monte Carlo

Fit Results

Fit Parameter	e+SVT	μ+SVT
f_u/f_d	1.044±0.028	1.062±0.024
$f_s/(f_u+f_d)$	0.162±0.008	0.158±0.006
$f_{\Lambda_b}/(f_u+f_d)$	0.292±0.020	0.275±0.015
Γ [ps^{-1}]	0.0157±0.0007	0.0154±0.0007
Γ^* [ps^{-1}]	0.0327±0.0014	0.0331±0.0013
Γ^{**} [ps^{-1}]	0.0145±0.0010	0.0146±0.0010
$N(\bar{B}^0)$ (10^9)	2.02±0.07	2.93±0.10

<u>2004 PDG</u>
w/o $\bar{\chi}$ constraint:
$f_s/(f_u+f_d) = 0.109 \pm 0.026$
$f_{\Lambda b}/(f_u+f_d) = 0.133 \pm 0.023$

with all constraints:
$f_s/(f_u+f_d) = 0.134 \pm 0.014$
$f_{\Lambda b}/(f_u+f_d) = 0.125 \pm 0.021$

$f_{\Lambda b}$ higher than previously measured!

- Statistical errors ONLY
- Fit e+SVT and μ+SVT separately
  - Cancel lepton ID efficiencies
  - Statistically independent samples
    - Results are consistent- very nice!
  - Results are consistent if f_u/f_d fixed to unity

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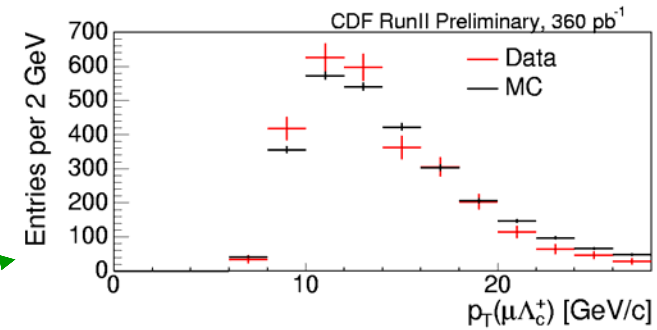
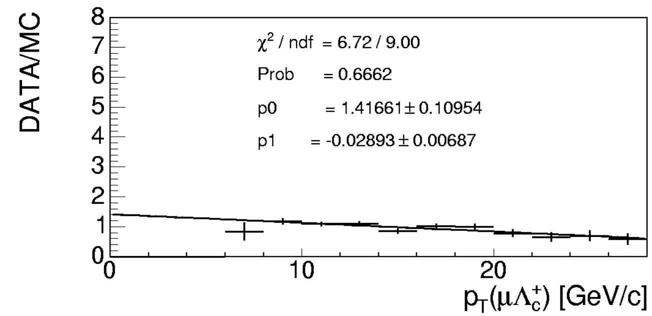
Systematic Uncertainties

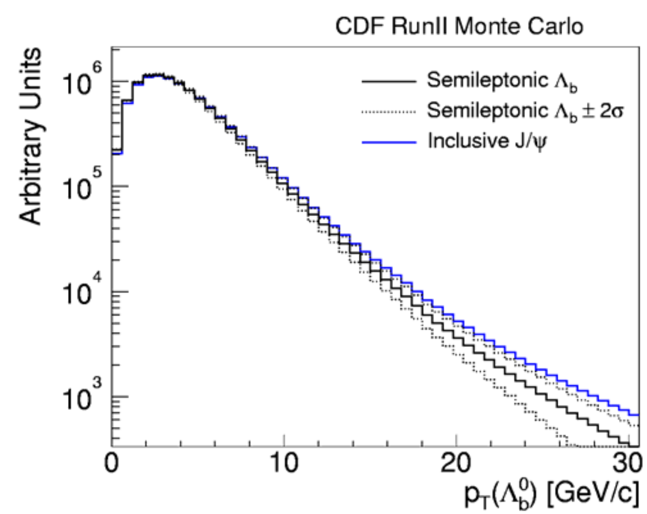
- Measurement is dominated by systematic uncertainties
  - Largest come from knowledge of branching ratios
    - Particularly ground state charm BRs!!!
  - Other source of systematic uncertainty arise from determination of efficiencies, counting yields, and false lepton backgrounds
    - Knowledge of the B_s^0 and Λ_b^0 p_T spectrum
    - Residual false lepton contamination

Λ_b p_T Spectrum Uncertainty

- Vary tuned $\ell\Lambda_c$ spectrum to match agree with inclusive J/ψ spectrum
  - Produces large uncertainty: ± 0.049
  - Estimate conservatively
    - True Λ_b^0 spectrum isn't known





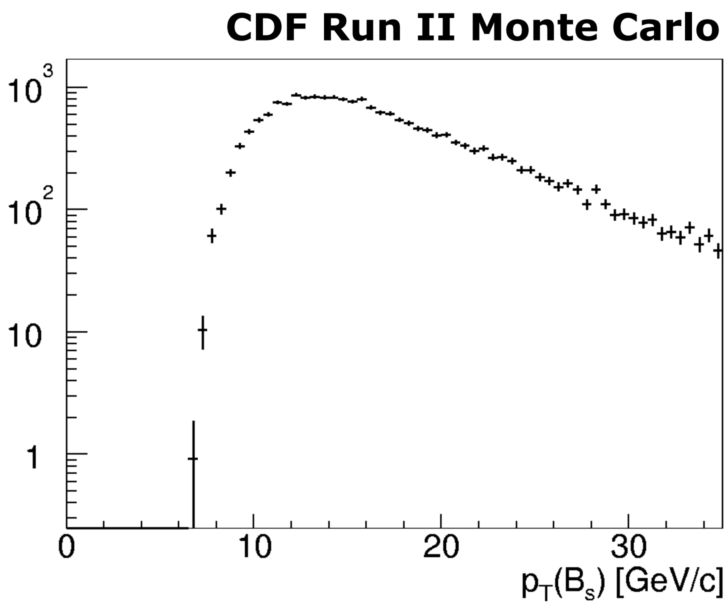


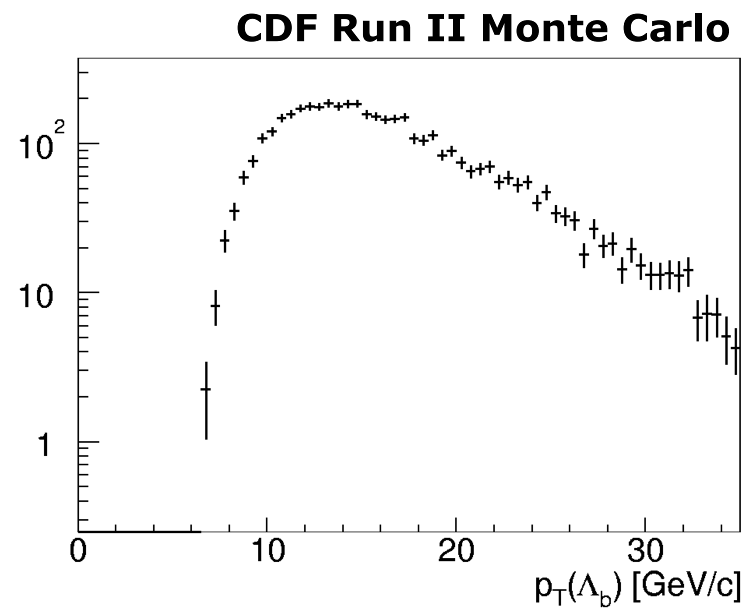
Systematic Uncertainties

Systematic	f_u/f_d	$f_s/(f_u+f_d)$	$f_{\Lambda_b}/(f_u+f_d)$
Fake Leptons	-0.039	-0.001	$+0.018$
Variation of cuts	± 0.011	± 0.0003	± 0.019
D_s reflection	$+0.001$	$+0.00002$	$+0.0001$
XFT eff.	± 0.003	± 0.0004	± 0.006
Single track	$^{+0.013}_{-0.014}$	± 0.002	± 0.002
Sample comp. lifetimes	$^{+0.018}_{-0.014}$	± 0.006	± 0.002
MC lifetimes	-	$^{+0.005}_{-0.001}$	$^{+0.0077}_{-0.0136}$
MC statistics	± 0.005	± 0.0007	± 0.0006
p_T spectra	-	± 0.008	± 0.049
dE/dx eff.	-	-	± 0.012
Λ_b^0 polarization	-	-	± 0.007
Total (eff)	$^{+0.025}_{-0.045}$	$^{+0.011}_{-0.010}$	$^{+0.058}_{-0.056}$
$\mathcal{BR}(\Lambda_b^0 \to \ell^- \nu \Lambda_c^+ X)$	-	-	$^{+0.076}_{-0.048}$
Λ_b^0 sample composition	-	-	± 0.045
$\mathcal{BR}(D^{**})$	± 0.010	± 0.004	± 0.011
"physics bkgs"	± 0.001	± 0.002	± 0.001
$\mathcal{BR}(D^+ \to K^-\pi^+\pi^+)$	± 0.054	± 0.003	± 0.010
$\mathcal{BR}(D^0 \to K^-\pi^+)$	± 0.020	± 0.003	± 0.003
$\mathcal{BR}(D_s^+ \to \phi\pi^+)$	± 0.0006	$^{+0.057}_{-0.034}$	± 0.001
$\mathcal{BR}(\Lambda_c^+ \to pK^-\pi^+)$	-	-	$^{+0.091}_{-0.053}$
Total ($\mathcal{BR}$)	± 0.058	$^{+0.057}_{-0.034}$	$^{+0.128}_{-0.086}$
Total	$^{+0.062}_{-0.074}$	$^{+0.058}_{-0.035}$	$^{+0.141}_{-0.103}$

+0.062 -0.074 +0.058 -0.035 +0.141 -0.103

p_T Threshold for Measurement





- Choose to quote p_T threshold for all fragmentation fractions
  - $p_T(B) > 7$ GeV/c determined from Monte Carlo

Final Results

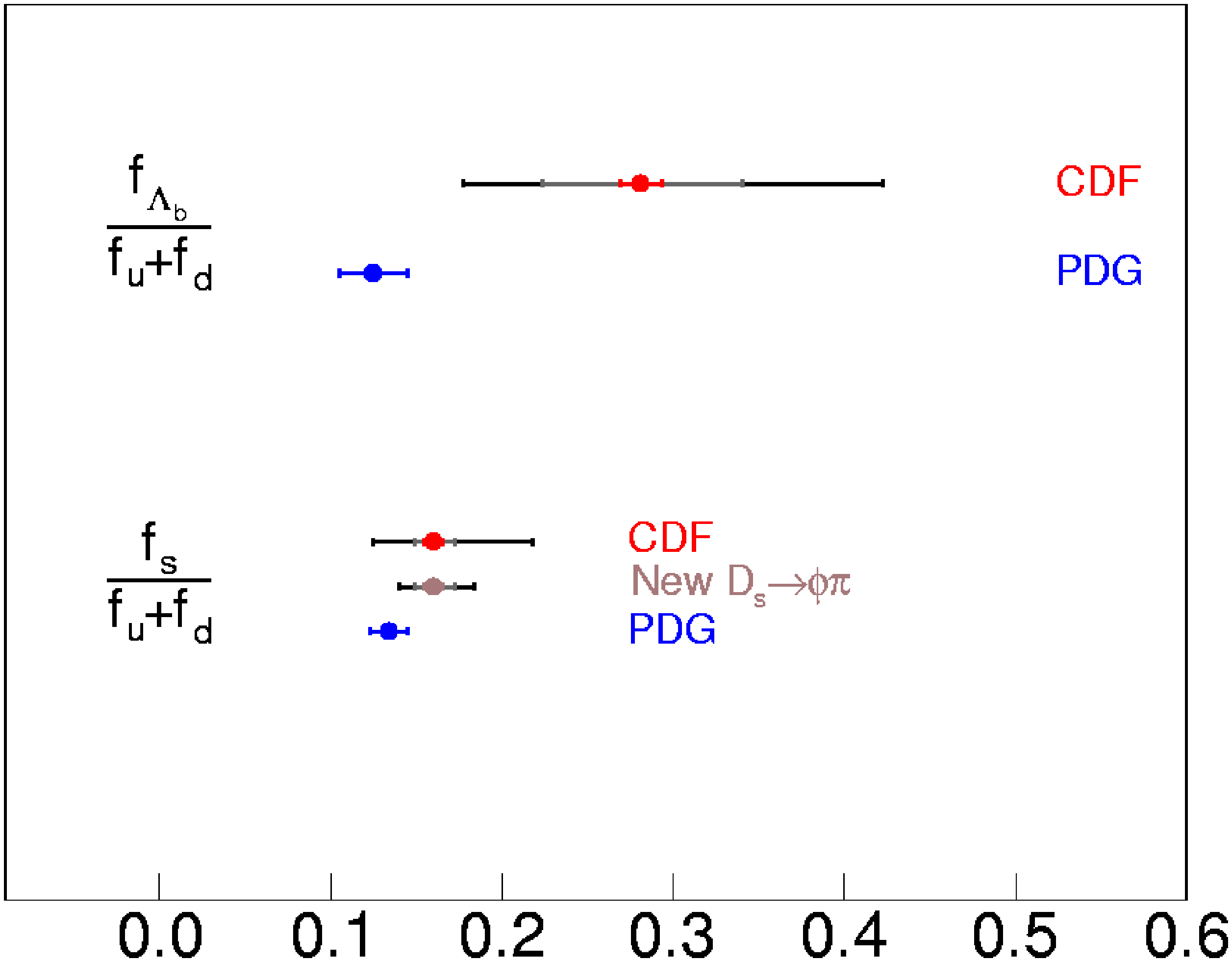
$$\frac{f_u}{f_d} = 1.054 \pm 0.018(stat)^{+0.025}_{-0.045}(sys) \pm 0.058(\mathcal{BR})$$

$$\frac{f_s}{f_u + f_d} = 0.160 \pm 0.005(stat)^{+0.011}_{-0.010}(sys)^{+0.057}_{-0.034}(\mathcal{BR})$$

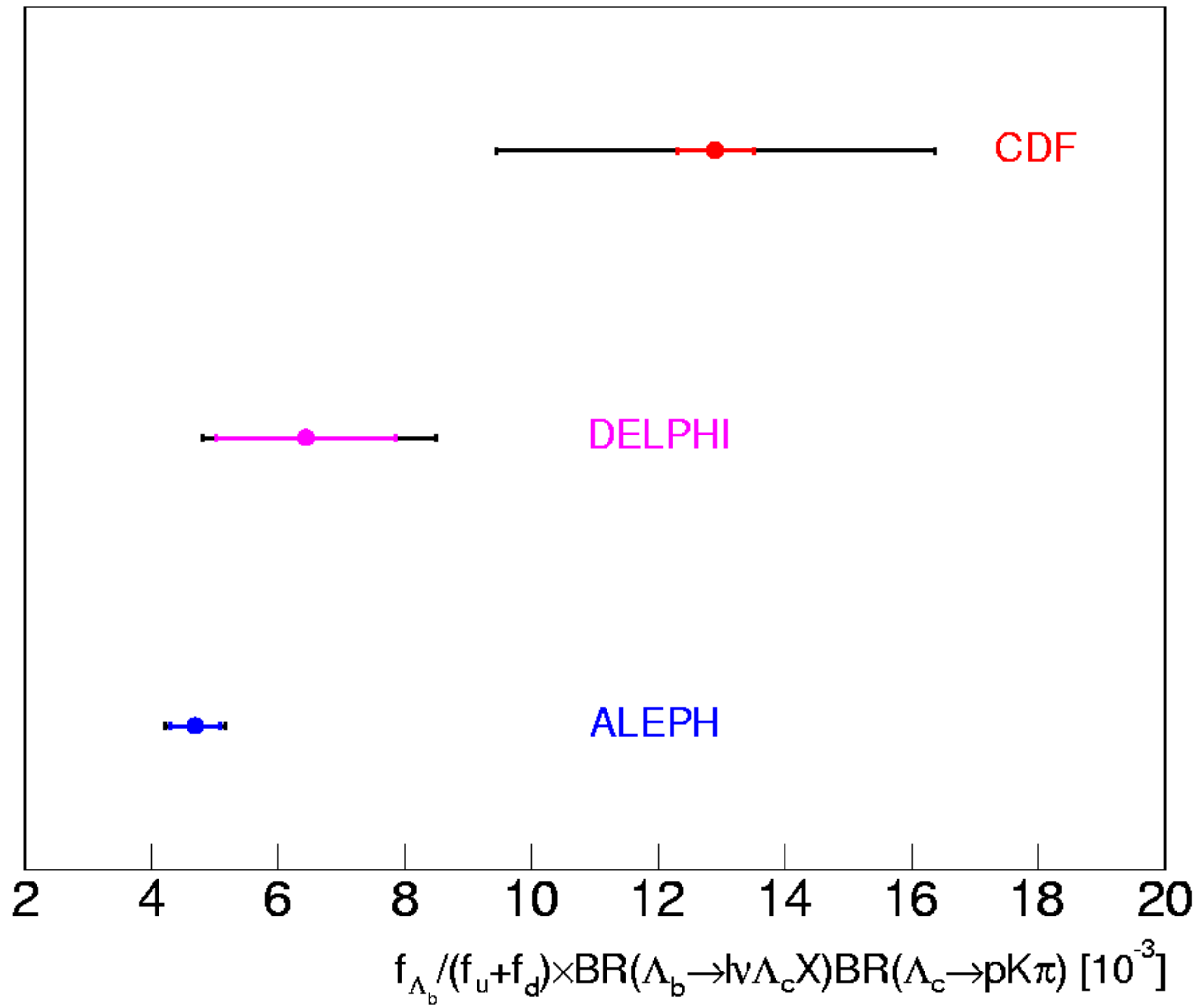
$$\frac{f_{\Lambda_b}}{f_u + f_d} = 0.281 \pm 0.012(stat)^{+0.058}_{-0.056}(sys)^{+0.128}_{-0.086}(\mathcal{BR}).$$

- Weighted average between e+SVT and μ+SVT samples
  - Statistical error is very small!
  - Error on $f_s/(f_u+f_d)$ is dominated by PDG 2004
    - $\mathcal{B}(D_s^+ \to \varphi\pi^+)$ = (3.6 ± 0.9)%
  - Sheldon Stone's estimate of CLEO-c measurement (FPCP06)
    - $\mathcal{B}(D_s^+ \to \varphi\pi^+)$ = (3.73 ± 0.42)%

Comparison with PDG



Comparisons with Other Results



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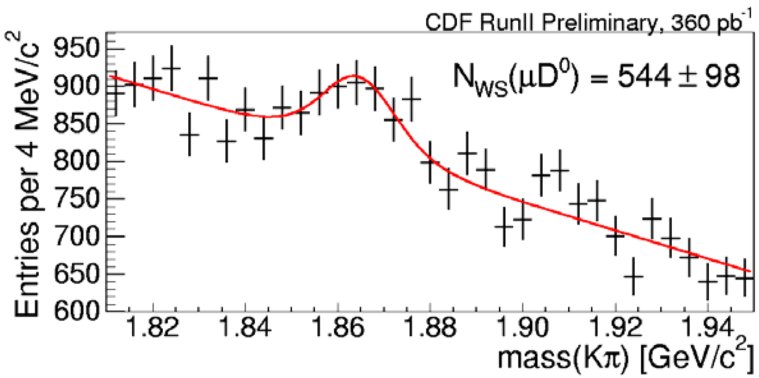
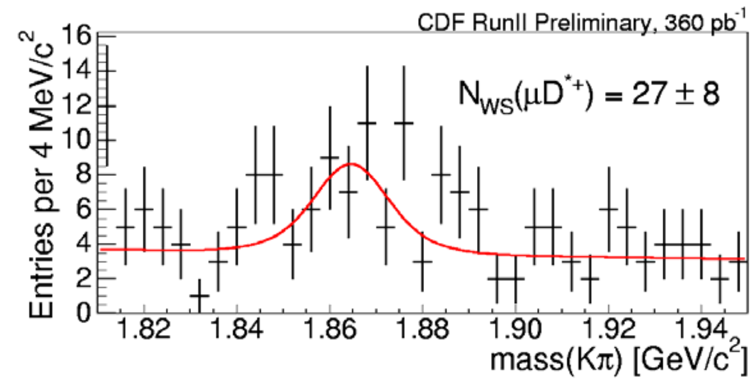
Prospects

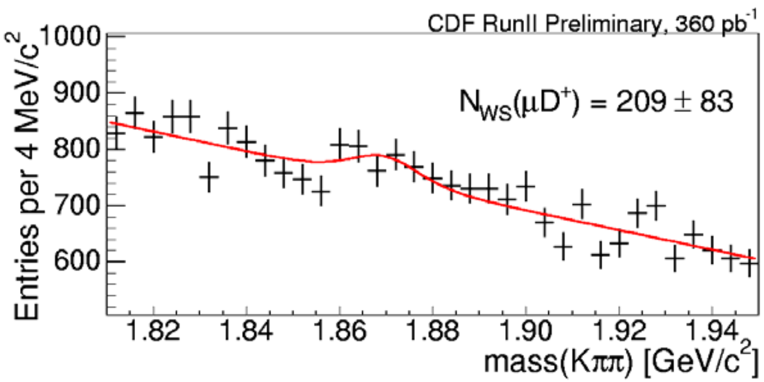
- New fragmentation fraction measurement at CDF will be improved with better measurement of charm branching ratios
- Measurements of B p_T spectra at CDF in fully reconstructed modes limit uncertainty on efficiencies
- Improved statistics are always helpful!!

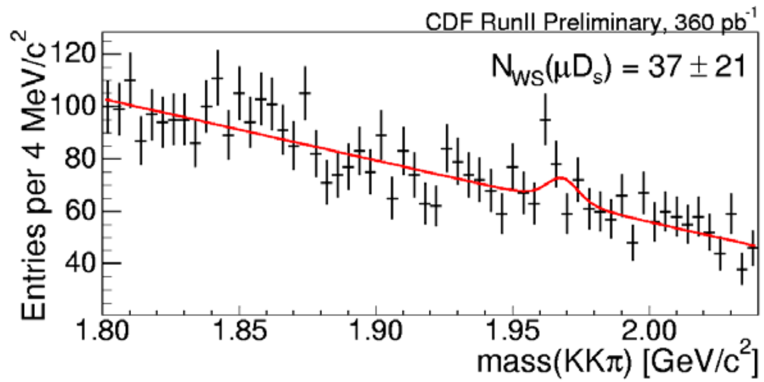
Backup Slides

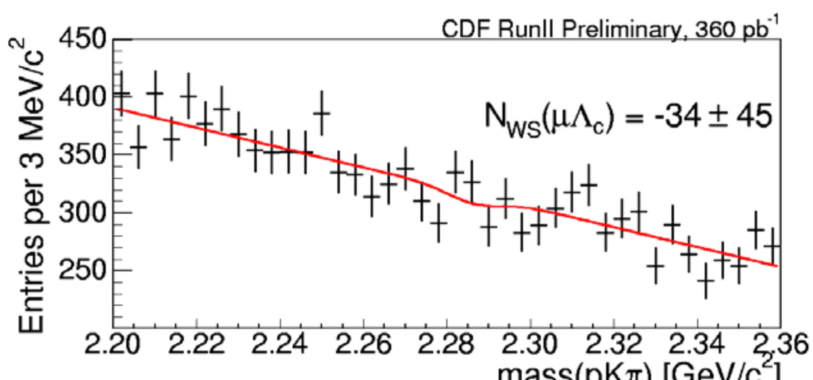
Wrong Sign Lepton-Charm











Fit Results with $f_u = f_d$

Fit Parameter	e+SVT	μ+SVT
f_u/f_d	1.0	1.0
$f_s/(f_u+f_d)$	0.163±0.008	0.158±0.006
$f_{\Lambda_b}/(f_u+f_d)$	0.294±0.020	0.277±0.015
Γ [ps^{-1}]	0.0156±0.0007	0.0153±0.0007
Γ^* [ps^{-1}]	0.0330±0.0014	0.0335±0.0013
Γ^{**} [ps^{-1}]	0.0144±0.0010	0.0143±0.0010
$N(\bar{B}^0)$ (10^9)	2.05±0.07	3.00±0.10

<u>2004 PDG</u>

w/o $\bar{\chi}$ constraint:

$f_s/(f_u+f_d) = 0.109 \pm 0.026$

$f_{\Lambda_b}/(f_u+f_d) = 0.133 \pm 0.023$

with all constraints:

$f_s/(f_u+f_d) = 0.134 \pm 0.014$

$f_{\Lambda_b}/(f_u+f_d) = 0.125 \pm 0.021$

- Statistical errors ONLY
- Fix $f_u/f_d = 1.0$
- Results are consistent with default result
  - Also very nice…

Relaxed Spectator Model

Fit Parameter	e+SVT	μ+SVT
f_u/f_d	1.006±0.006	1.029±0.006
$f_s/(f_u+f_d)$	0.159±0.010	0.155±0.009
$f_{\Lambda_b}/(f_u+f_d)$	0.297±0.020	0.279±0.014
Γ_{B^0} [ps^{-1}]	0.0158±0.0007	0.0156±0.0007
Γ_{B^+} [ps^{-1}]	0.0133±0.0009	0.0133±0.0008
Γ_{B_s} [ps^{-1}]	0.0134±0.0009	0.0134±0.0009
$\Gamma^*_{B^0}$ [ps^{-1}]	0.0328±0.0014	0.0333±0.0014
$\Gamma^*_{B^+}$ [ps^{-1}]	0.0370±0.0017	0.0368±0.0015
$\Gamma^*_{B_s}$ [ps^{-1}]	0.0371±0.0017	0.0372±0.0017
$\Gamma^{**}_{B^0}$ [ps^{-1}]	0.0142±0.0010	0.0142±0.0009
$\Gamma^{**}_{B^+}$ [ps^{-1}]	0.0144±0.0010	0.0145±0.0010
$\Gamma^{**}_{B_s}$ [ps^{-1}]	0.0141±0.0010	0.0141±0.0010
$N(\bar{B}^0)$ (10^9)	2.03±0.08	3.00±0.10

<u>2004 PDG</u>

w/o $\bar{\chi}$ constraint:

$f_s/(f_u+f_d) = 0.109 \pm 0.026$

$f_{\Lambda_b}/(f_u+f_d) = 0.133 \pm 0.023$

with all constraints:

$f_s/(f_u+f_d) = 0.134 \pm 0.014$

$f_{\Lambda_b}/(f_u+f_d) = 0.125 \pm 0.021$

- Allow spectator model constraints to differ between B species
  - Total $\Gamma + \Gamma^* + \Gamma^{**} = \Gamma_{s\ell}$ and $(\Gamma^{(*,**)} - \Gamma_{PDG}^{(*,**)})/\sigma_{\Gamma_{PDG}}$ constraints applied to each B meson separately

Fit Parameter Correlations

	f_u/f_d	$f_s/(f_u+f_d)$	$f_{\Lambda_b}/(f_u+f_d)$	Γ	Γ^*	Γ^{**}	$N(B^0)$
f_u/f_d		-0.021	-0.053	-0.011	-0.135	0.162	-0.249
$f_s/(f_u+f_d)$			0.077	-0.015	-0.058	0.150	-0.116
$f_{\Lambda_b}/(f_u+f_d)$				0.425	0.563	0.239	-0.575
Γ					0.657	-0.122	-0.674
Γ^*						0.134	-0.853
Γ^{**}							-0.436
$N(B^0)$							