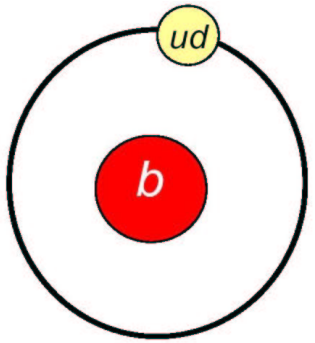
First Measurement of $\mathcal{B}(\Lambda_b^0 \to \Lambda_c^+ \mu^- \bar{\nu}) / \mathcal{B}(\Lambda_b^0 \to \Lambda_c^+ \pi^-)$ at CDF II

Petar Maksimovic for CDF

Why Λ_b?

- decay modes poorly known (only two BF's in PDG)
- in HQET: to LO in $1/m$, all b-hadrons behave the same
- Λ_b: heavy quark + (u,d) of spin=0,

  $\Longrightarrow$ sub-LO corrections are simpler than for B mesons



- Theoretical predictions:

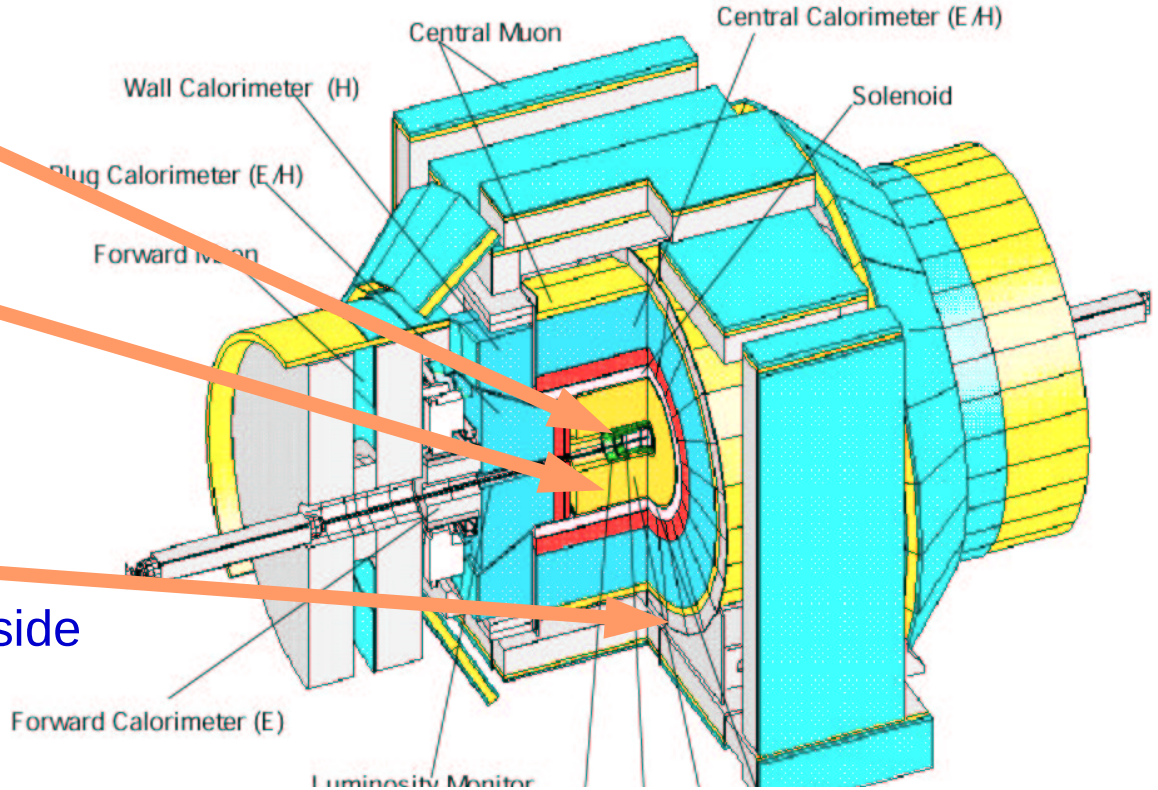
  Leibovich *et. al.*
  [Phys.Lett. B586, (2004) 377]

$$\mathcal{B}(\Lambda_b \to \Lambda_c^+ \mu^- \bar{\nu})^{theory} = 6.6\ \%$$

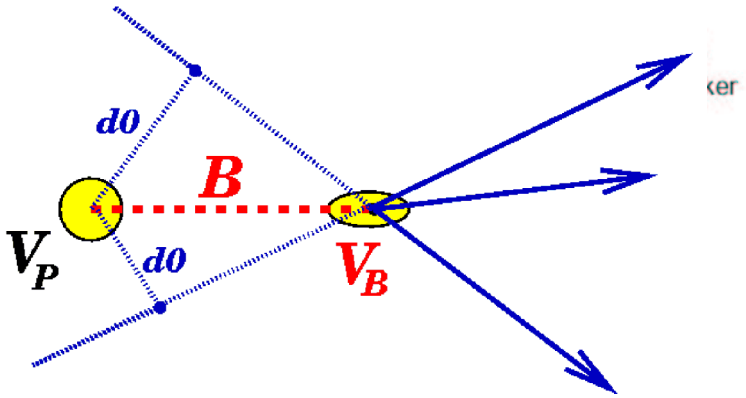
$$\mathcal{B}(\Lambda_b \to \Lambda_c^+ \pi^-)^{theory} = 0.45\%$$

CDF's Displaced TrackTriggers

- Silicon Tracker
  - 7-8 layers, $|\eta| < 2$
  - $\sigma_{vertex} \sim 30\ \mu m$
- Central Outer Tracker
  - 96 layers drift chamber
  - $|\eta|<1$
  - $\sigma_{P_T}/P_T \sim 0.15\%\ P_T$
- Muon chamber
  - 4 layers drift chamber outside calorimeter
  - $|\eta| < 0.6$



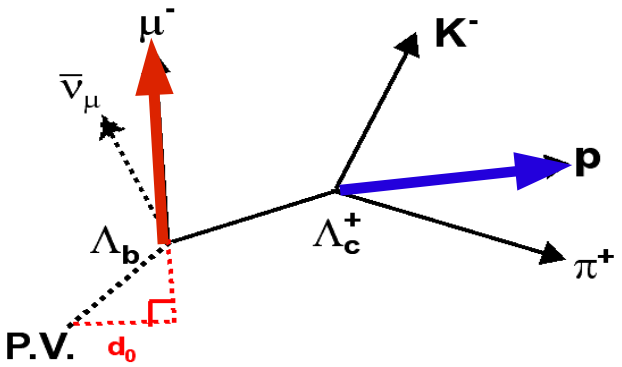
- **Two displaced-track trigger**
  - $p_T > 2$ GeV/c, $120\ \mu m \le d_0 \le 1$ mm, $L_{xy} > 200\ \mu m, \Sigma p_T > 5.5$ GeV/c
  - 150 M events analyzed for this measurement



Ratios of Braching Fractions

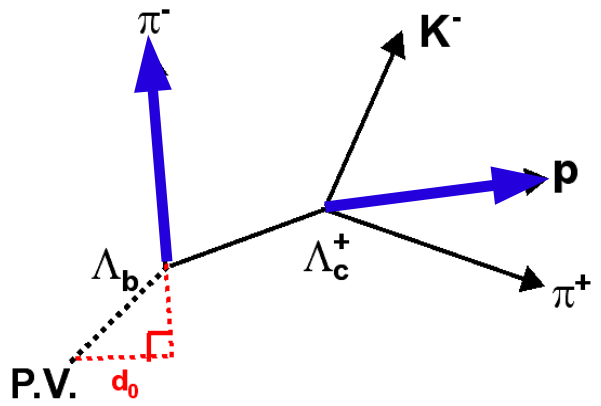
- Both decays on same trigger
- Most systematics cancel in ratio
- Check method on control samples:

$$\frac{\mathcal{B}(\overline{B}^0 \to D^+ \mu^- \overline{\nu})}{\mathcal{B}(\overline{B}^0 \to D^+ \pi^-)} \quad \text{and} \quad \frac{\mathcal{B}(\overline{B}^0 \to D^{*+} \mu^- \overline{\nu})}{\mathcal{B}(\overline{B}^0 \to D^{*+} \pi^-)}$$



$\Lambda_b \to \Lambda_c^+ \mu^- \bar{\nu}_\mu$
$\to pK^-\pi^+$

- Inclusive $\Lambda_c^+ \mu^- X$ reconstruction: must subtract all backgrounds

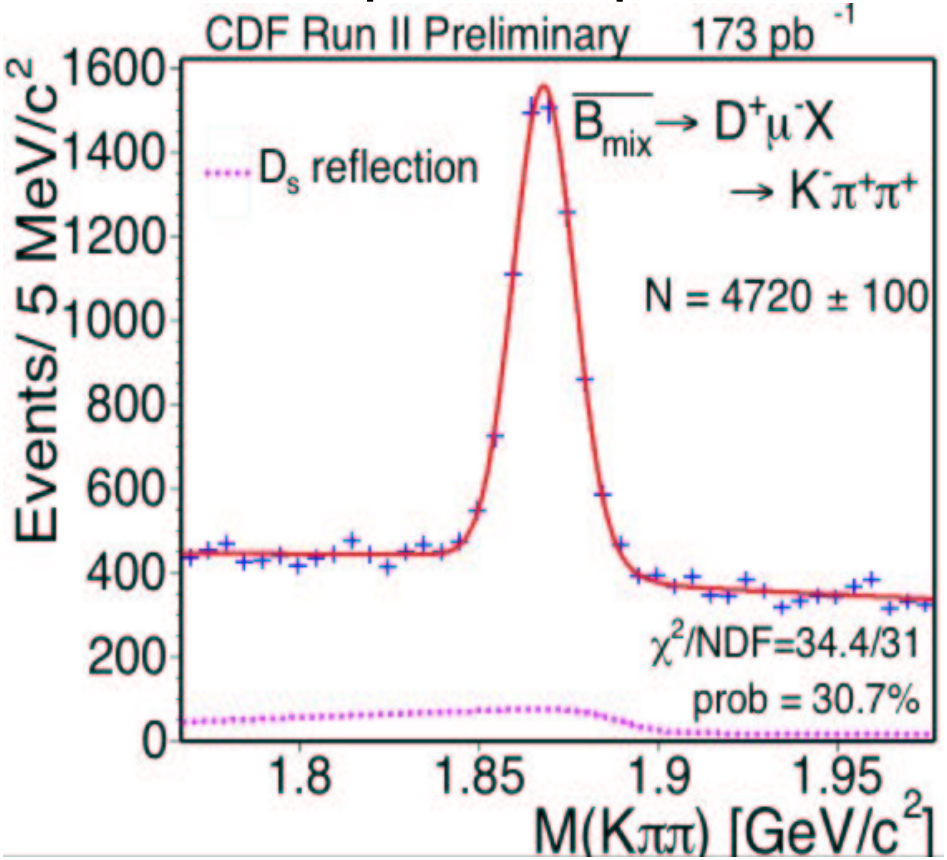


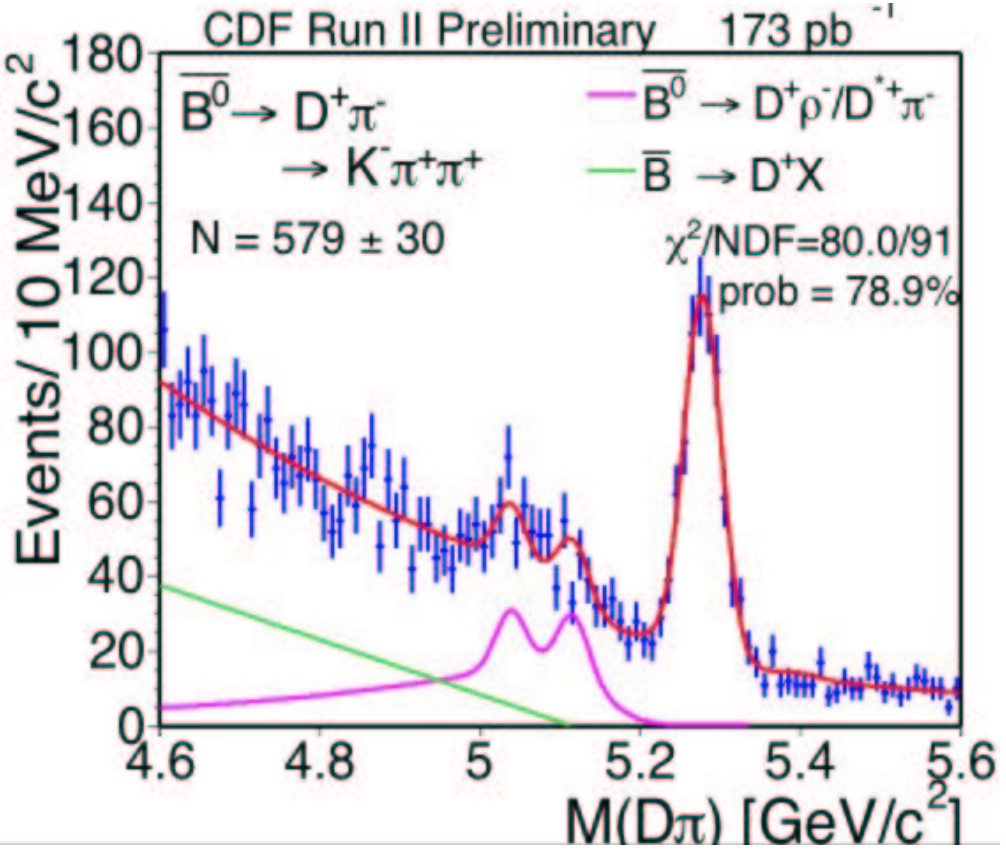
$\Lambda_b \to \Lambda_c^+ \pi^-$
$\to pK^-\pi^+$

$$\frac{\mathcal{B}(\Lambda_b \to \Lambda_c^+ \mu^- \overline{\nu})}{\mathcal{B}(\Lambda_b \to \Lambda_c^+ \pi^-)} = \frac{(N_{B_{\text{mix}} \to \Lambda_c \mu X} - N_{\text{bg}}) \times \varepsilon_{\Lambda_b \to \Lambda_c \pi}}{N_{\Lambda_b \to \Lambda_c \pi} \times \varepsilon_{\Lambda_b \to \Lambda_c \mu \overline{\nu}}}$$

Calibration samples: $B_{mix} \to D^+ \mu^- X$

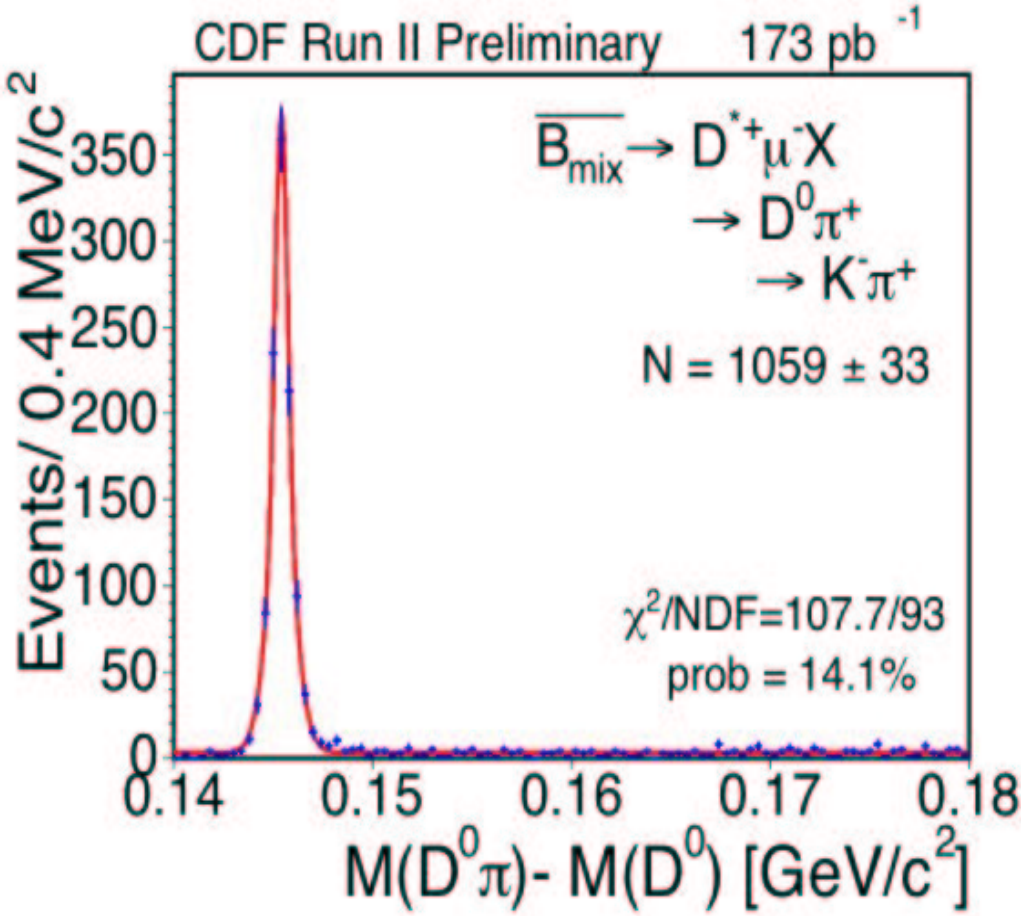
- Contributions from $\bar{B}^0 \to D^{*+} \mu^- X$, $D^{*+} \to \bar{D}^0 \pi^0$
- Also from B^+, via four D^{**} states
- Sample composition: MC and other measurements

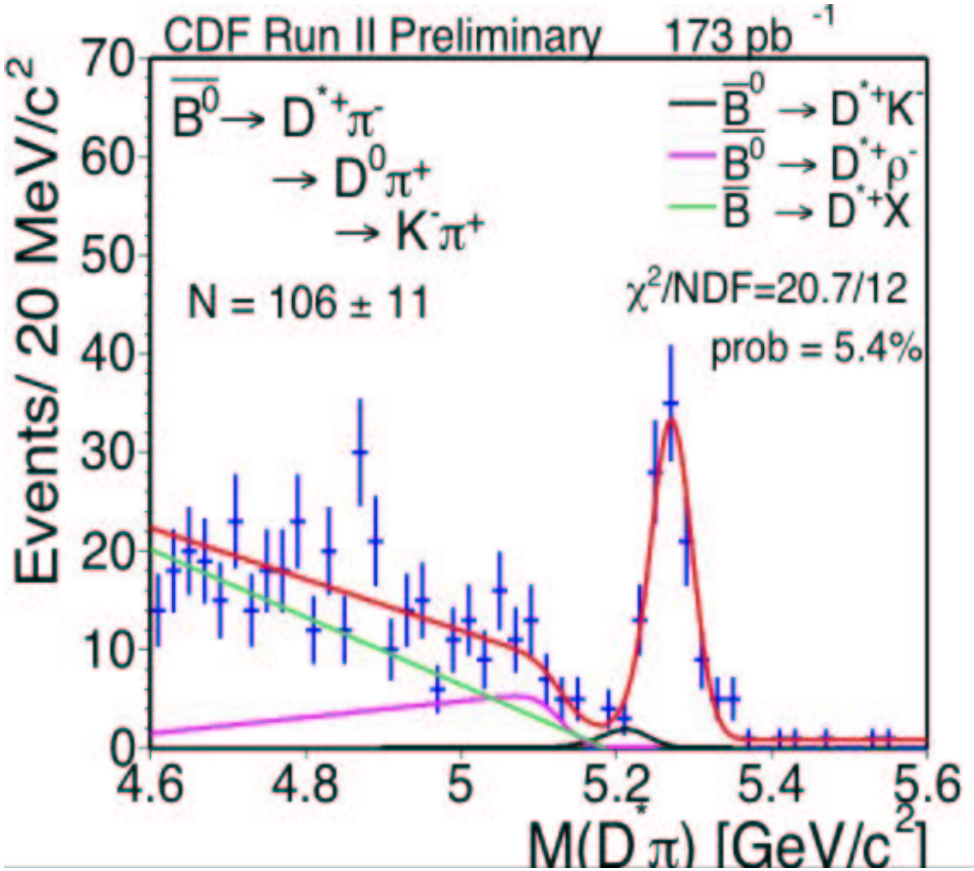




Calibration samples: $B_{mix} \to D^{*+}\mu^- X$

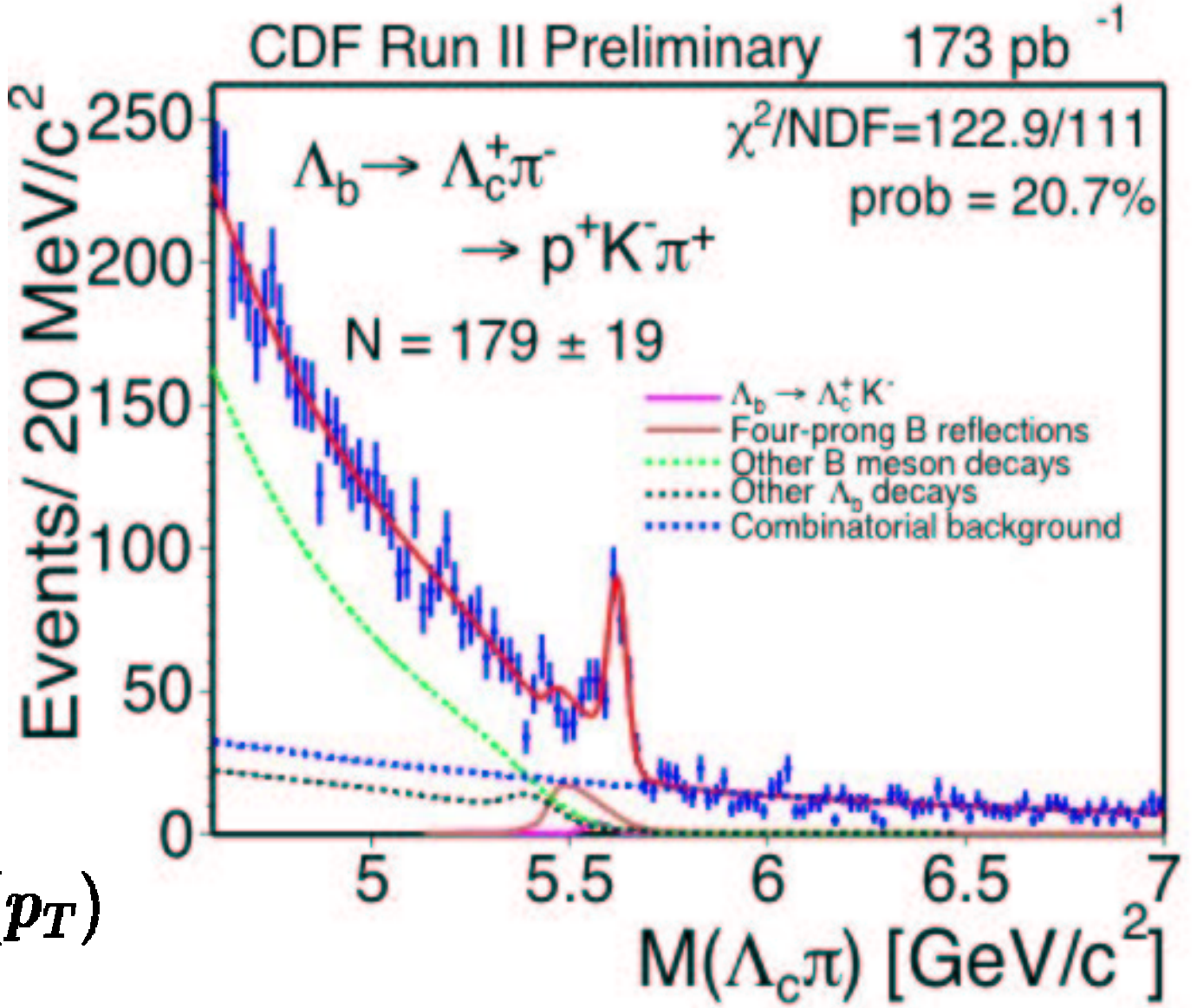
- Cleaner than $B_{mix} \to D^{+}\mu^- X$, but sample composition is still an issue





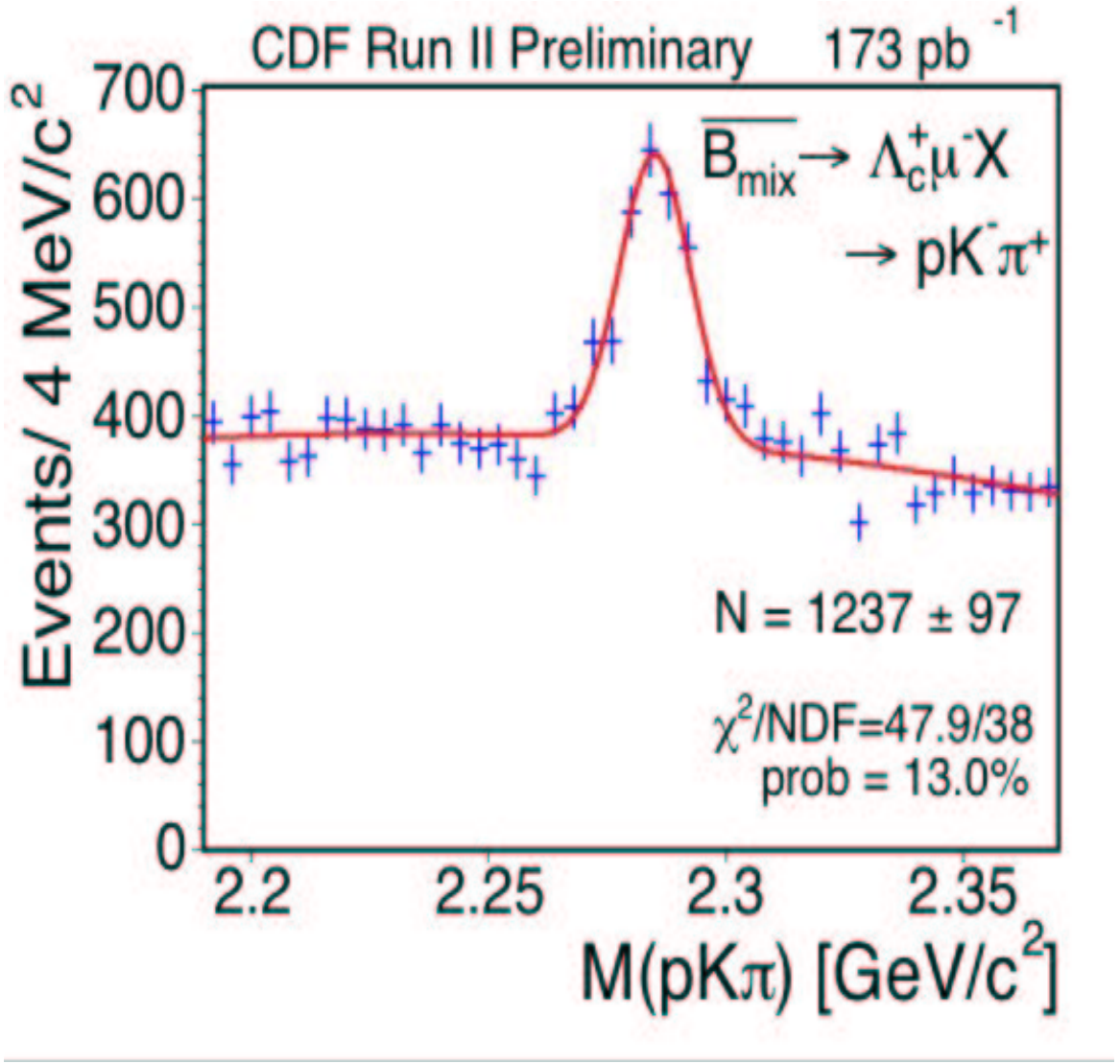
Fully reconstructed Λ_b

- 1st observation
- physics bkgs. from MC
- components floating separately in the fit
- this sample used to measure $\sigma_{\Lambda_b}(p_T)$



Semileptonic Λ_b

- Largest Λ_b sample collected so far
- Problem: are there contribution from unknown semileptonic decays of Λ_b?



Physics backgrounds: strategy

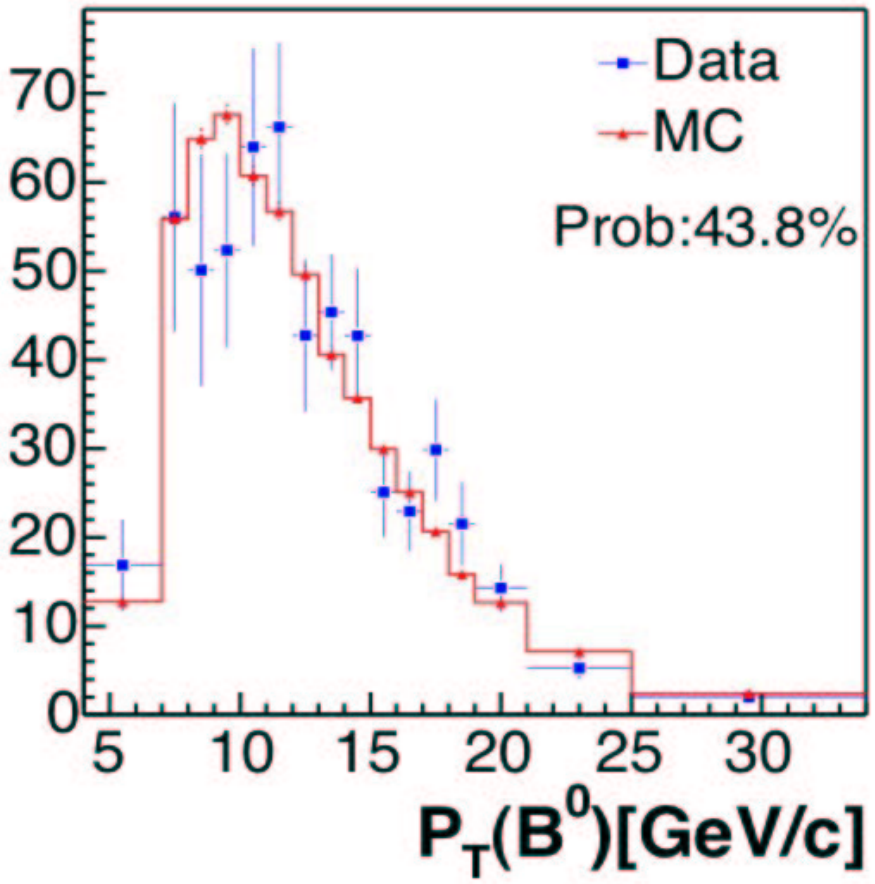
- **Need to make sure the data and MC match**
  - Part 1: Λ_b production spectrum, $\sigma_{\Lambda_b}(p_T)$

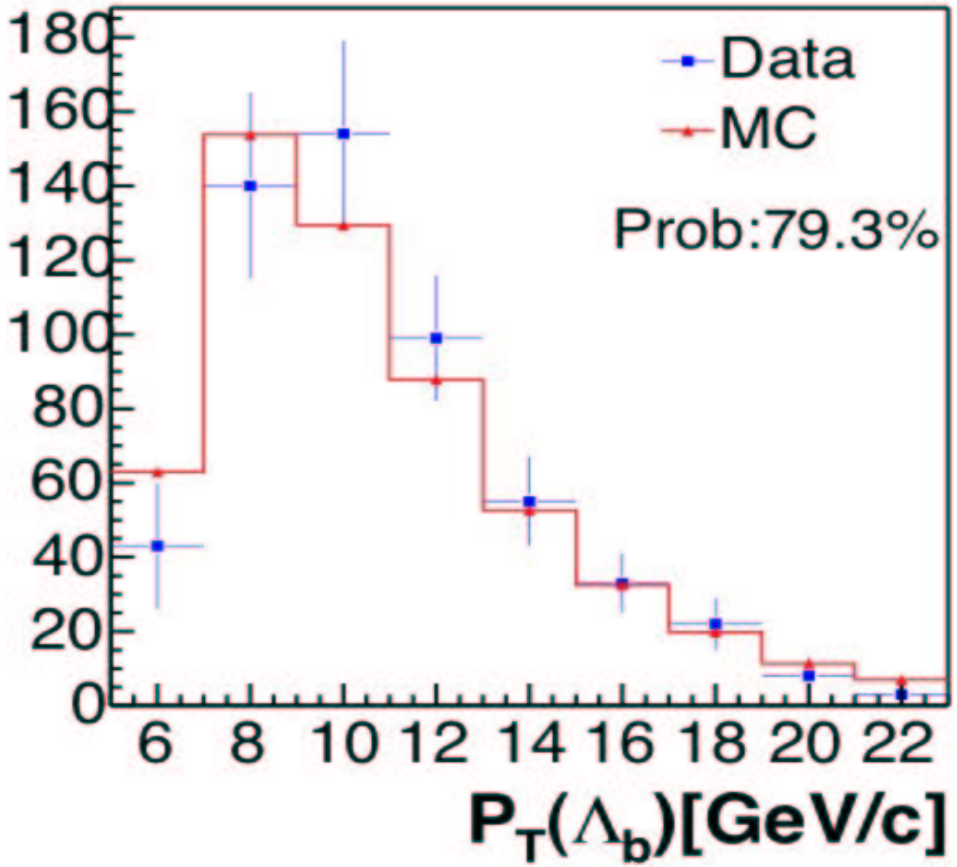
    $\Rightarrow$ to get efficiencies right
  - Part 2: distribution of $m(\mu, \Lambda_c)$

    $\Rightarrow$ to ensure that we have a good picture of all the backgrounds!
- Get $\sigma_{\Lambda_b}(p_T)$ from fully reconstructed Λ_b decays
- Explicitly reconstruct most dominant phys. bkgs.
- Estimate other phys. bkgs. from EvtGet
- Muon fakes, gluon spliltting: suppress by cuts

b-hadron production spectra

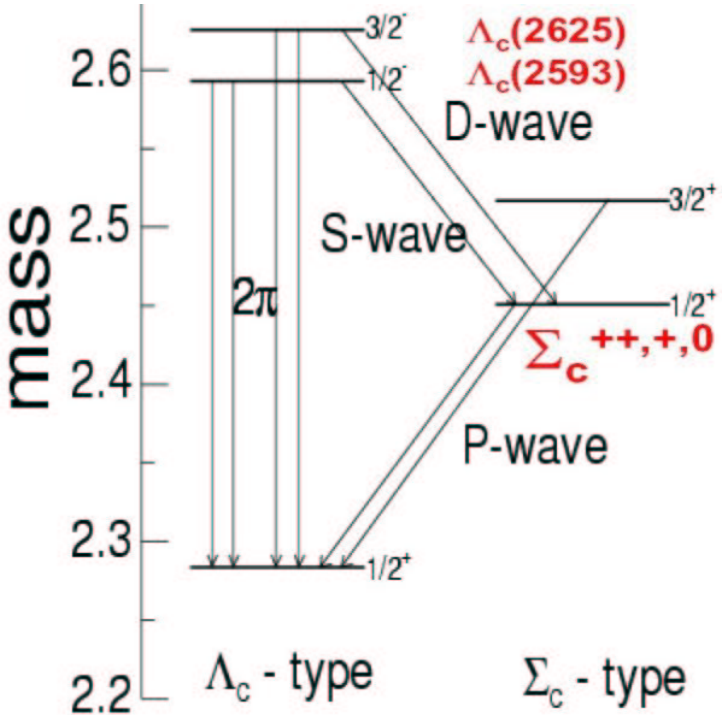
- $p_T(\bar{B}^0)$ spectrum is okay (also in $B_{mix} \to J/\psi X$)
- Use $\Lambda_b^0 \to \Lambda_c^+ \pi^-$ and $\Lambda_b^0 \to J/\psi \Lambda$ to measure $\sigma_{\Lambda_b}(p_T)$ then reweight spectrum in MC to match



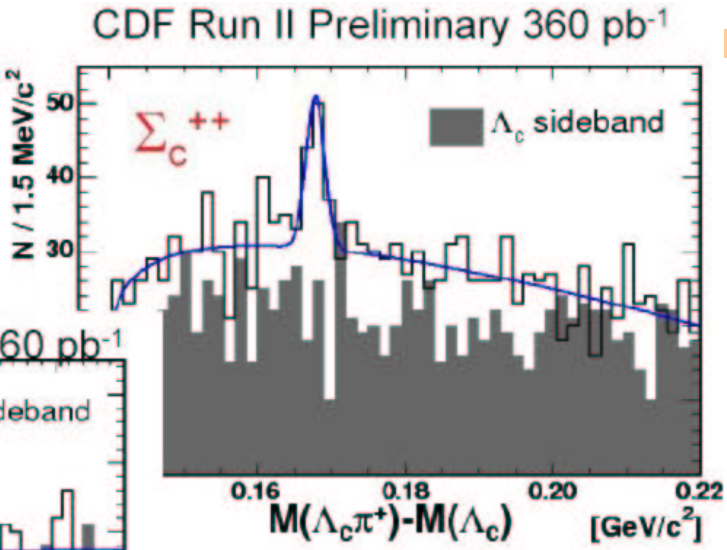


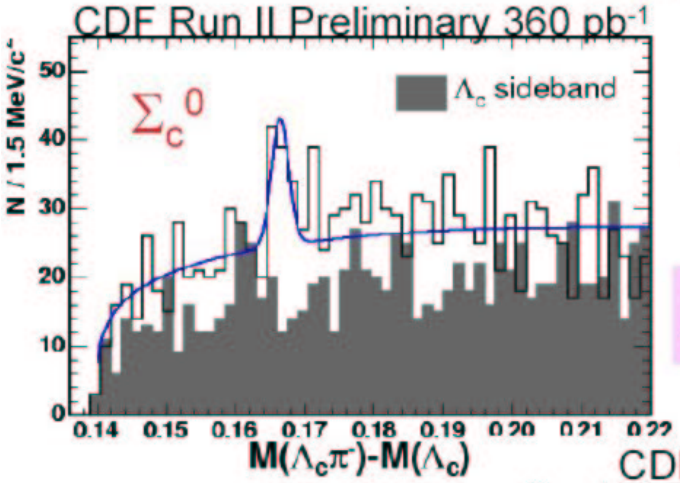
Reconstruct largest physics bkgs.

- Measure their contribution in our own data!



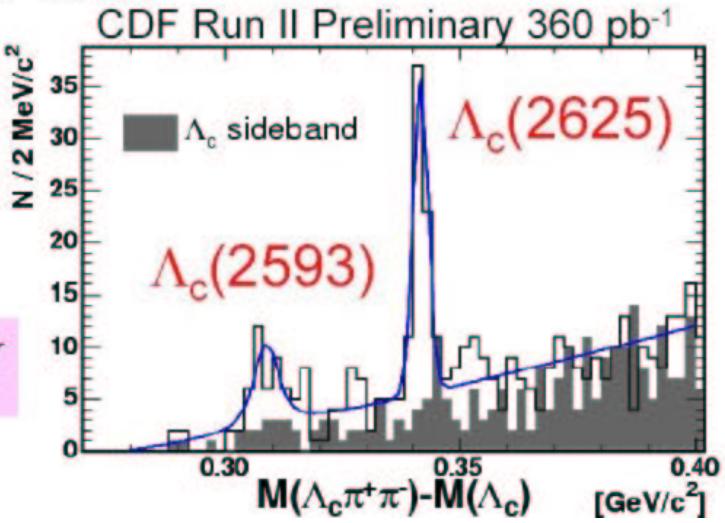
$\Lambda_b \to \Sigma_c^{++} \pi^- \mu^- X$





$\Lambda_b \to \Sigma_c^0 \pi^+ \mu^- X$

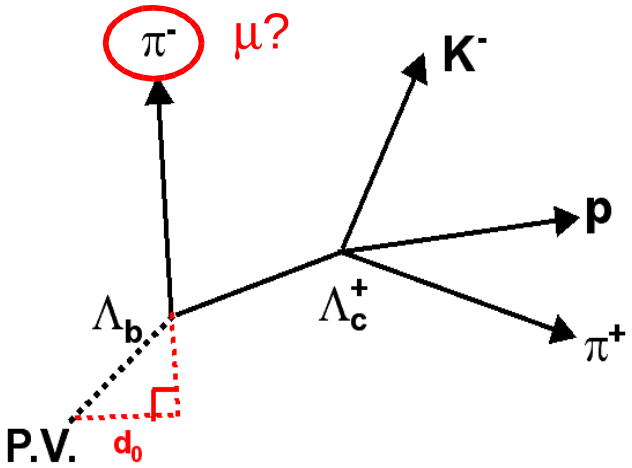
$\Lambda_b \to \Lambda_c^{*+} \mu^- X$



Muon fakes, gluon splitting

Muon fakes: ~ 5%

- π,*K*,*p* punch through calorimeter
- mostly from B decays
- use inclusive B MC sample
- suppressed by p_T, *d0* cuts

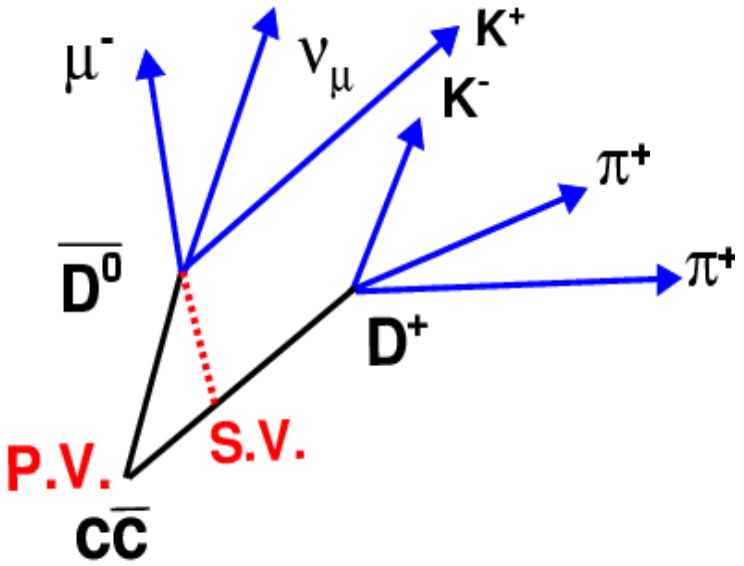


$\Lambda_b \rightarrow \Lambda_c^+ \pi^-$

$\rightarrow pK^-\pi^+$

QCD $c\bar{c}$, $b\bar{b}$: ~ 0.2%

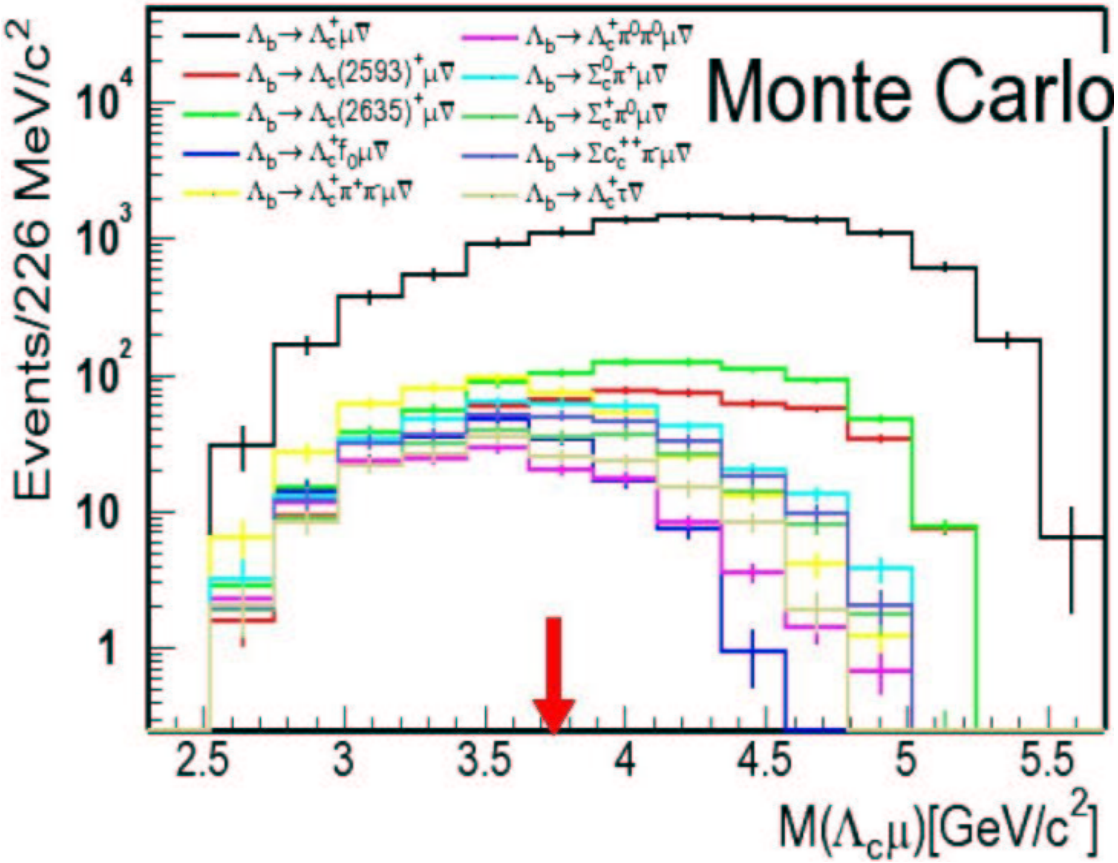
- charm,μ from different hadrons
- mostly from gluon splitting
- use Pythia
- suppressed by p_T, *ct* cuts

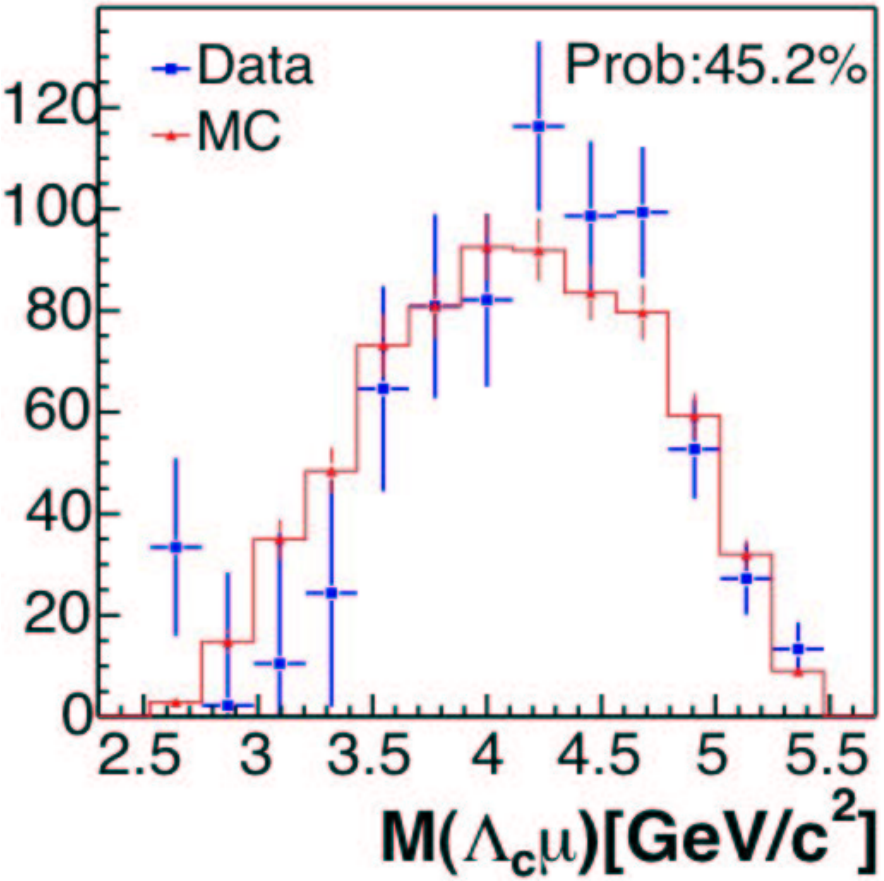


Compare $m(\mu, \Lambda_c)$ in MC and data

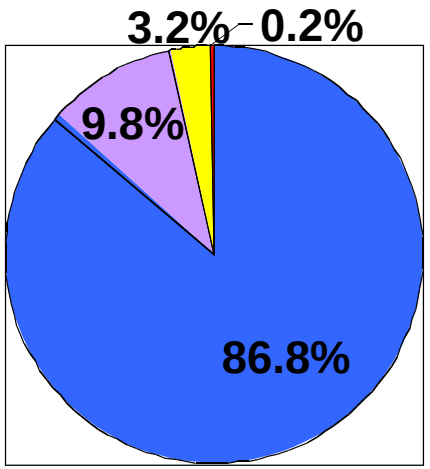
- data + educated guesses ==> EvtGen decay table
- cut at 3.75 GeV/c^2 to reduce phys. bkgs.

$\Rightarrow$ **MC/data agreement good** $\Leftrightarrow$ **no missed bkgs!**

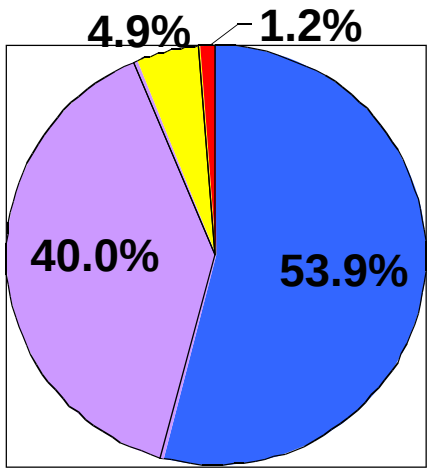




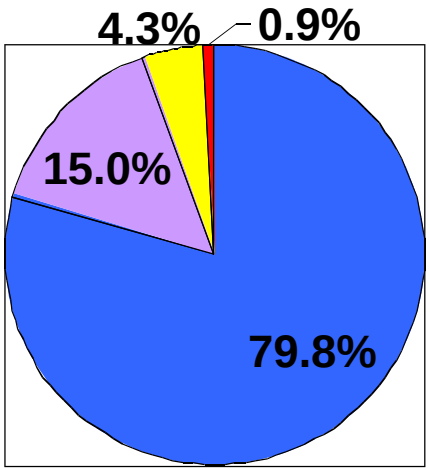
All backgrounds at a glance



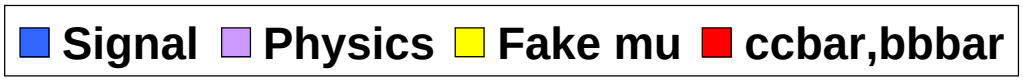
$\Lambda_b \to \Lambda_c^+ \mu^- X$



$B_{mix} \to D^{*+} \mu^- X$



$B_{mix} \to D^{+} \mu^- X$



- $\Lambda_b \to \Lambda_c^+ \mu^- X$ sample has the **least amount of bkg!**
- (in the long run, maybe a better place to measure Vcb?)

Ratios of branching fractions

Control samples:

$$\frac{\mathcal{B}(\bar{B}^0 \to D^+ \mu^- \bar{\nu})}{\mathcal{B}(\bar{B}^0 \to D^+ \pi^-)} = 9.8 \pm 1.0(\text{stat}) \pm 0.6(\text{syst}) \pm 0.8(\text{BR}) \pm 0.9(\text{UBR})$$

$$\frac{\mathcal{B}(\bar{B}^0 \to D^{*+} \mu^- \bar{\nu})}{\mathcal{B}(\bar{B}^0 \to D^{*+} \pi^-)} = 17.7 \pm 2.3(\text{stat}) \pm 0.6(\text{syst}) \pm 0.4(\text{BR}) \pm 1.1(\text{UBR})$$

- both comparable to respective world averages from 2004

Signal sample:

$$\frac{\mathcal{B}(\Lambda_b^0 \to \Lambda_c^+ \mu^- \bar{\nu})}{\mathcal{B}(\Lambda_b^0 \to \Lambda_c^+ \pi^-)} = 20.0 \pm 3.0(\text{stat}) \pm 1.2(\text{syst})^{+0.7}_{-2.1}(\text{BR}) \pm 0.5(\text{UBR})$$

- consistent with DELPHI, theory [Phys.Lett. B586, (2004) 377]

Bottom line

Physics:

- **First reconstruction of $\Lambda_b^0 \to \Lambda_c^+ \mu^- \bar{\nu}$ in hadronic environment** (yes, it can be done!)
- Dominant systematics $\mathcal{B}(\Lambda_b^0 \to \Lambda_c^+ \pi^-)$
- Low backgrounds $\Longrightarrow$ good for measuring Vcb

Technical:

- Λ_b production spectrum is different from B mesons! **(We have more Λ_b's than we thought!)**
- Rapidly adding to the Λ_b decay table

BACKUP SLIDES

Systematic errors

Physics background and hadronic signal branching fractions

MC modeling of efficiency and acceptance

	fractional uncertainty (%)		
	$\frac{\mathcal{B}(\Lambda_b \to \Lambda_c \pi)}{\mathcal{B}(\Lambda_b \to \Lambda_c \mu \nu)}$	$\frac{\mathcal{B}(\bar{B}^0 \to D^0 \pi)}{\mathcal{B}(\bar{B}^0 \to D^0 \mu \nu)}$	$\frac{\mathcal{B}(\bar{B}^0 \to D^{*0} \pi)}{\mathcal{B}(\bar{B}^0 \to D^{*0} \mu \nu)}$
Measured BR	**+3.5 -10.5**	**± 8.2**	**± 2.3**
Estimated BR	**± 2.5**	**± 9.2**	**± 6.2**
CDF Internal			
Mass fitting	± 3.2	± 4.1	< 0.1
Muon fake	± 0.9	± 0.7	± 0.4
Pt spectrum	+1.4-2.5	± 3.2	± 2.2
CDF material	± 1.1	± 1.7	± 1.3
ε scaling	± 0.4	± 0.5	± 0.4
$b\bar{b}, c\bar{c}$	± 0.2	± 2.2	± 1.3
$\Lambda_{b,c}$ polarizations	± 1.9	--	--
Λ_c Dalitz	± 0.4	--	--
Λ_b lifetime	± 1.1	--	--
Λ_b decay model	± 2.9	--	--
	± 6.0	**± 6.1**	**± 3.4**
Statistical	**± 15.0**	**± 10.2**	**± 13.0**