Charm Physics at the Tevatron

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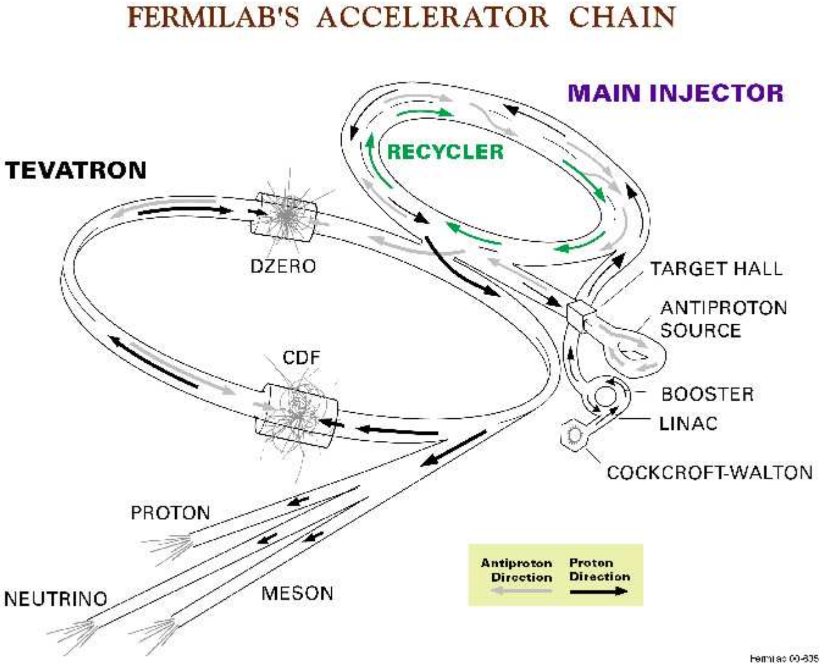
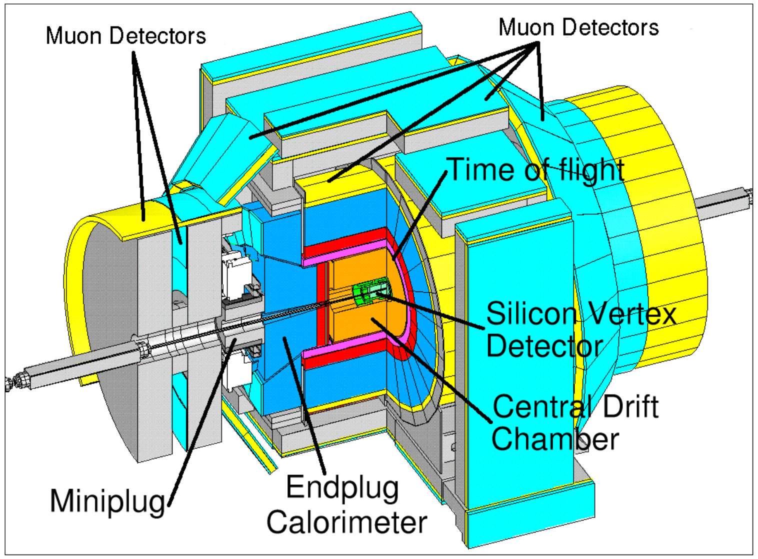
XXVIIIth Rencontres de Moriond
March 23rd-29th 2003

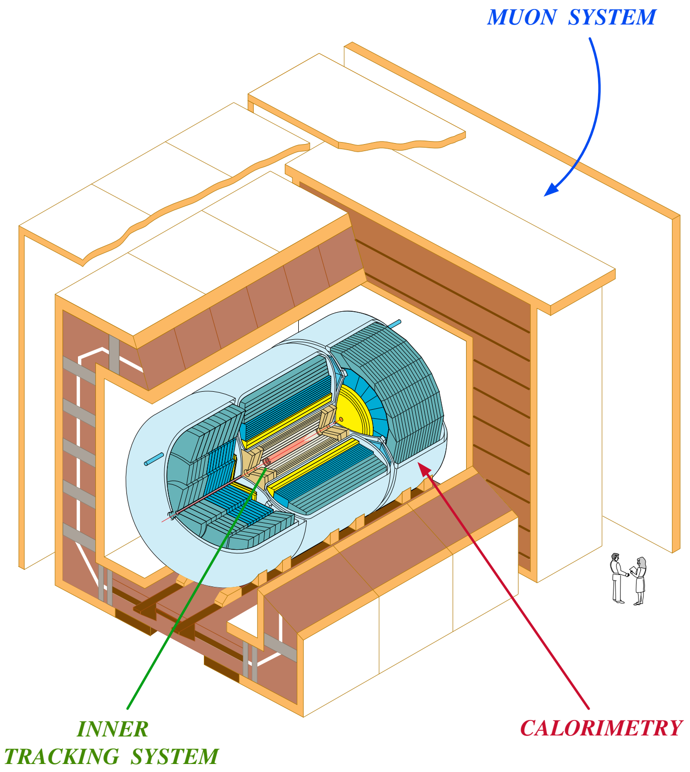
Tevatron Accelerator



- $p\bar{p}$ collider at $\sqrt{s} = 1.96\mathrm{TeV}$
- 2 general purpose detectors: CDF and D$\emptyset$
- current record luminosity $4.2 \times 10^{31}\mathrm{cm}^{-2}\mathrm{s}^{-1}$
- 180 pb^{-1} delivered
- recorded: CDF: 130 pb^{-1} D$\emptyset$: 100 pb^{-1}

CDF and DØ Detectors

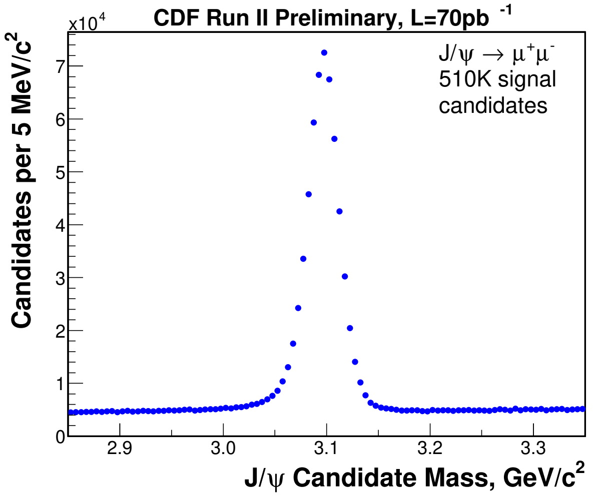


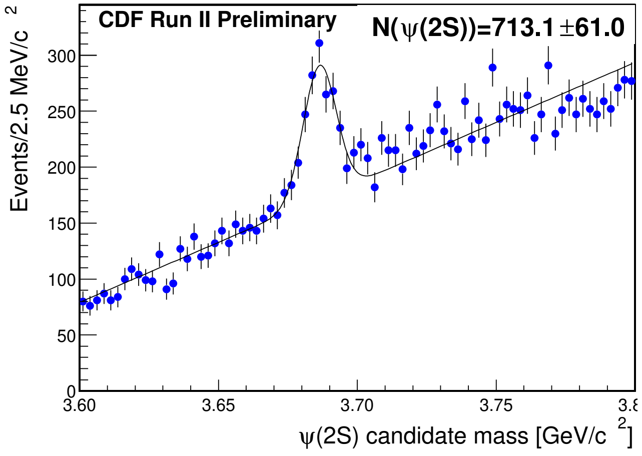


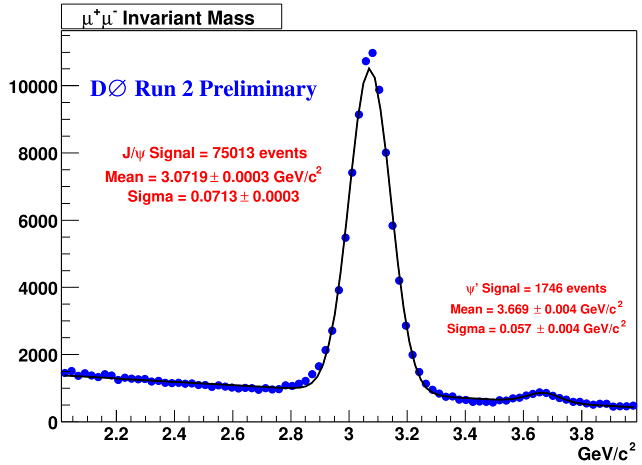
Detector Upgrades:

- CDF: Trigger, muon system, TOF
- DØ : new tracking system, muon system

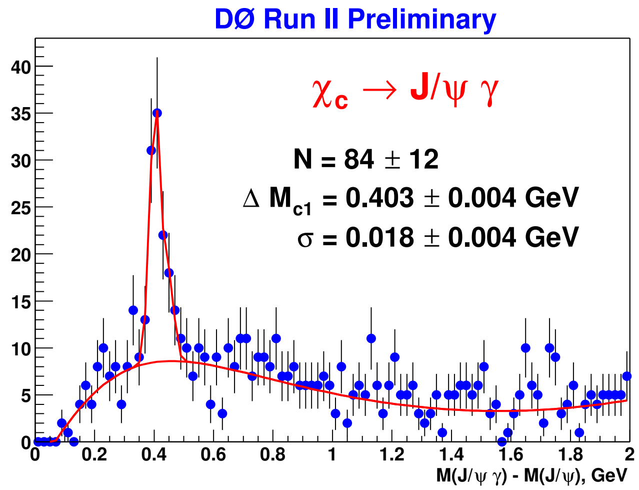
Conventional $p\bar{p}$ charm physics



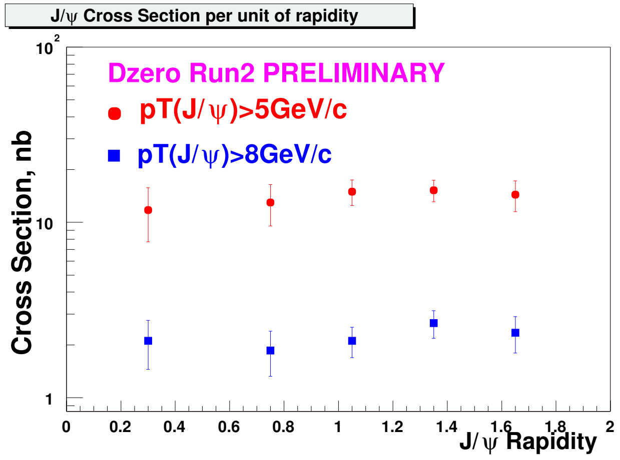


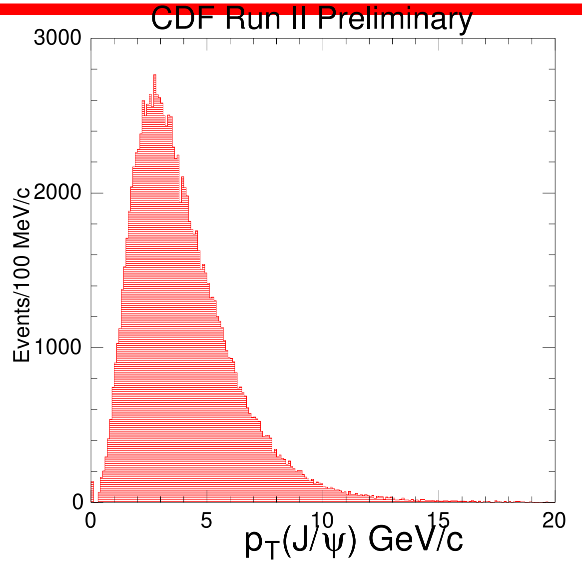


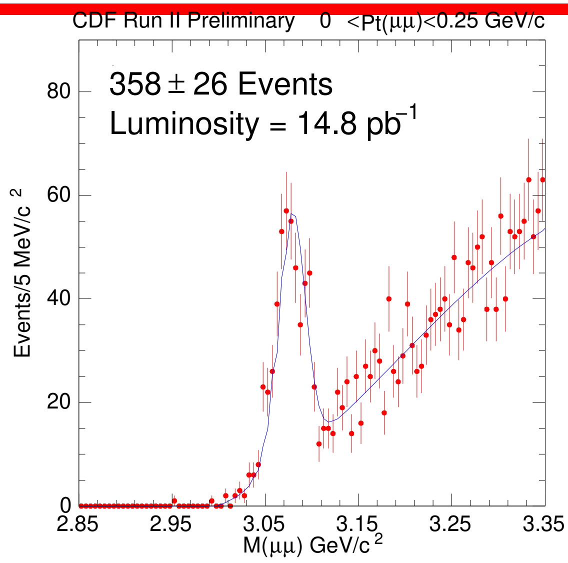
- $\Longrightarrow$ rely on lepton triggers
- CDF: 510k $J/\psi \to \mu\mu$, D$\emptyset$: 75k
- feeddown from excited states: $\chi_c \to J/\psi\gamma$, $\psi(2s) \to J/\psi\pi\pi$



J/ψ cross section



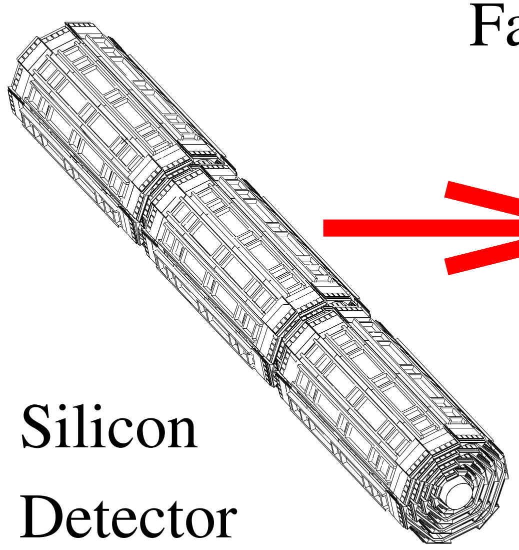




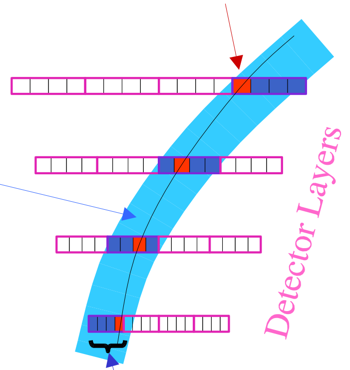
- measure $\frac{d\sigma_{J/\psi}}{dp_T d\eta}$
- DØ: extended η coverage
- new at CDF: $p_T(\mu) \geq 1.5\mathrm{GeV} \Longrightarrow \mathrm{p_T}(\mathrm{J}/\psi) \geq 0$
- final results to come soon

CDF's Secondary Vertex Trigger

Fast parallel Pattern Reco

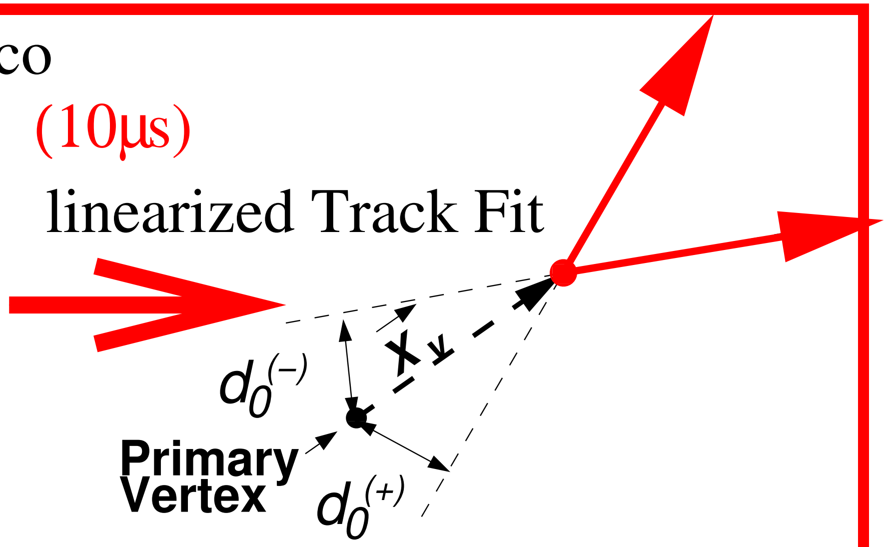


Silicon Detector



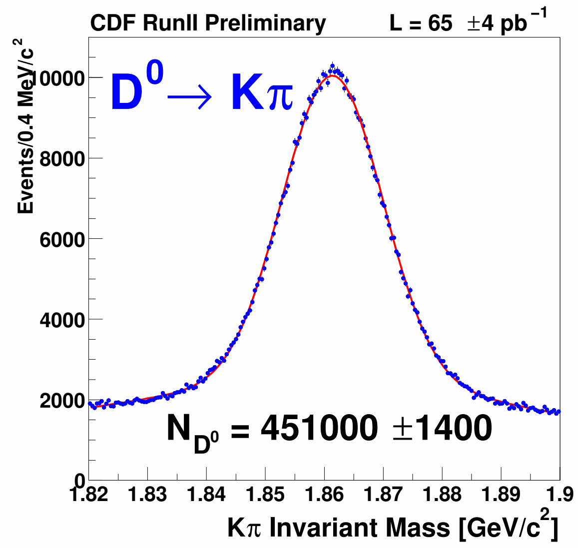
(10μs)

linearized Track Fit



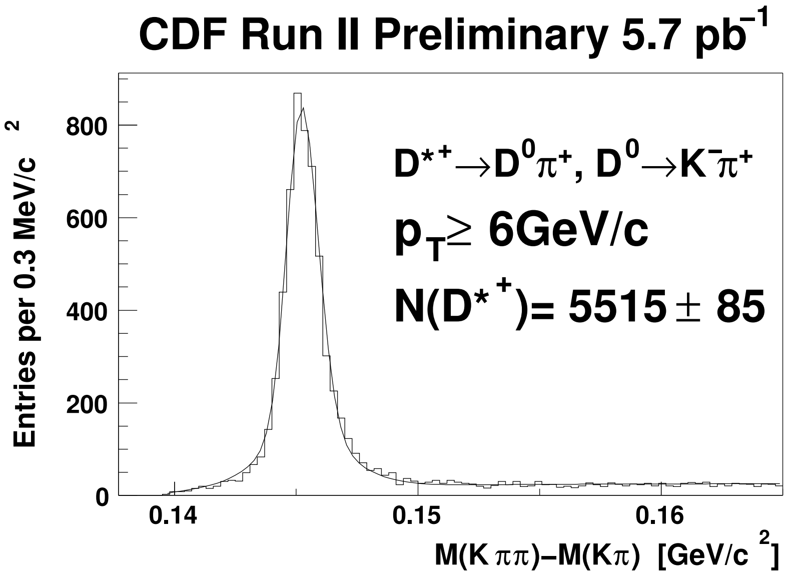
trigger on displaced Tracks!

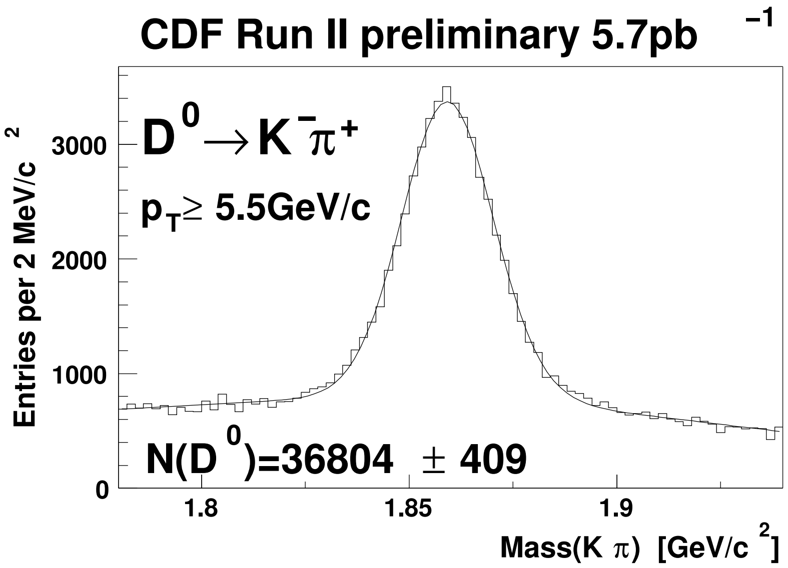
- $p\bar{p}$ large cross section (mb), but very small S/B
- trigger on displaced Tracks
- unexpected huge charm sample $\Longrightarrow$

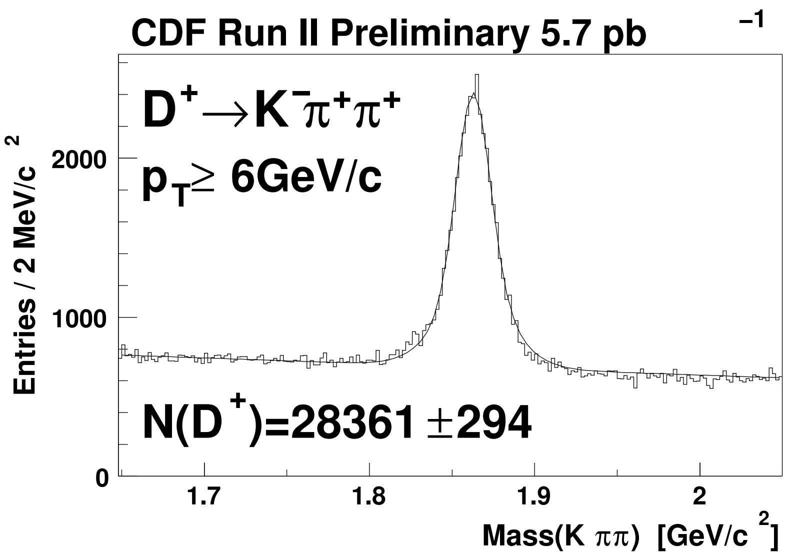


Charm cross section

- reconstruct $D^0, D^\pm, D_s^\pm, D^{*\pm}$
- estimate efficiencies
- measure $\frac{d\sigma}{dp_T}$
- separate secondary charm

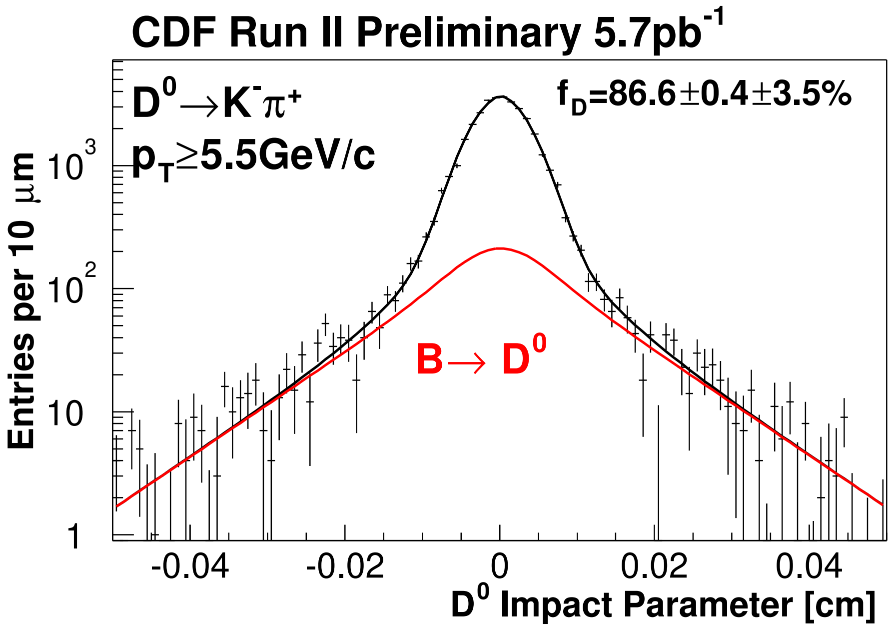




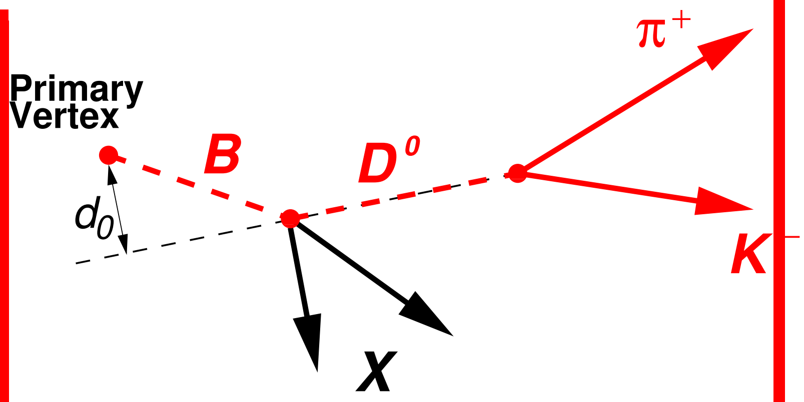


Separation of secondary charm

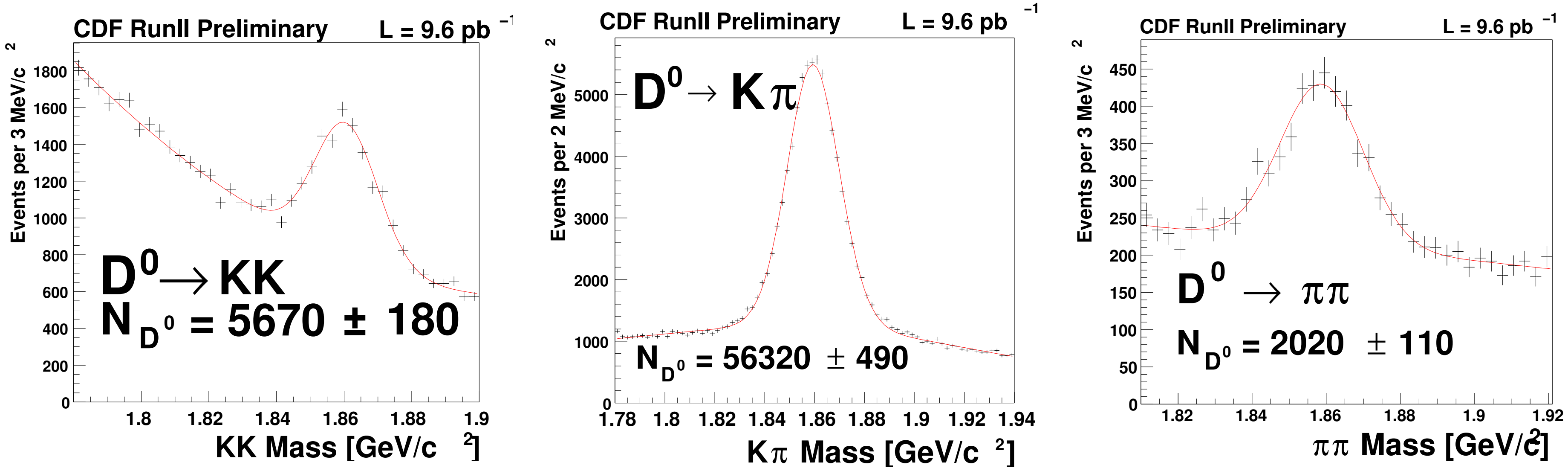
- use D-meson impact parameter d0
- secondary charm from B-decays has large d0
- fraction f_p of prompt mesons



$$f_p(D^0) \quad = \quad 86.6 \pm 0.4 \pm 3.5\%$$
$$f_p(D^{*+}) \quad = \quad 88.1 \pm 1.1 \pm 3.9\%$$
$$f_p(D^+) \quad = \quad 89.1 \pm 0.4 \pm 2.8\%$$
$$f_p(D_s^+) \quad = \quad 77.3 \pm 3.8 \pm 2.1\%$$



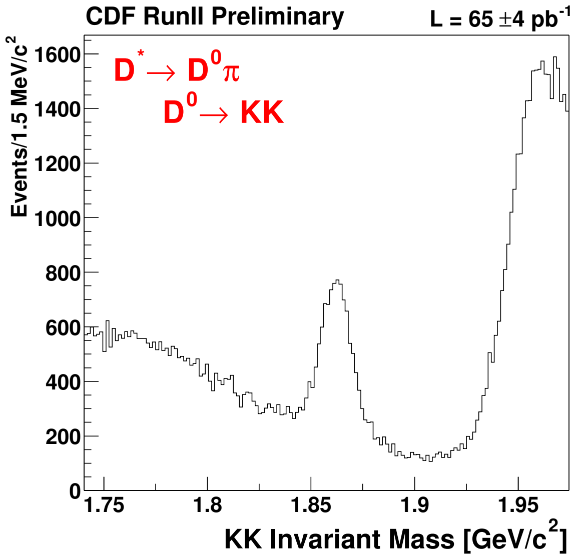
Cabbibo suppressed branching ratios

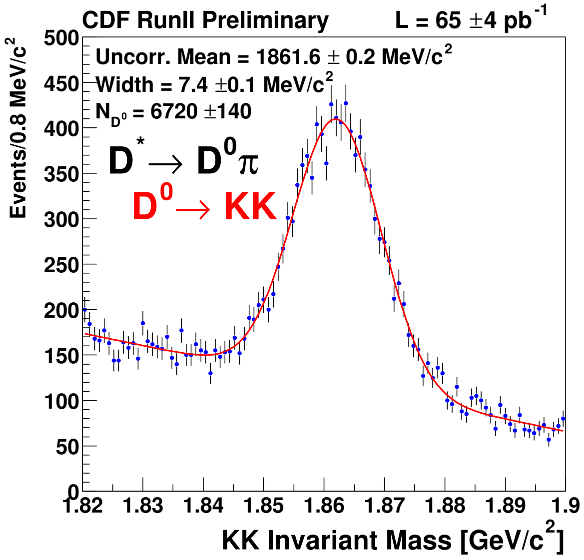


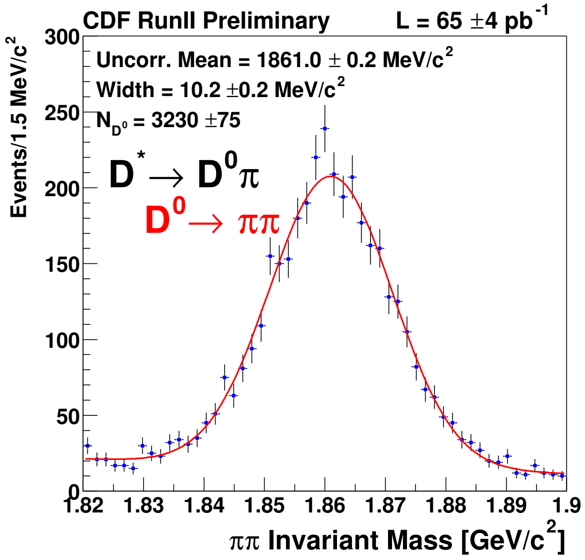
$$\frac{\Gamma(D^0 \to K^+K^-)}{\Gamma(D^0 \to K^-\pi^+)} = (11.17 \pm 0.48_{(stat)} \pm 0.98_{(syst)})\%$$

$$\frac{\Gamma(D^0 \to \pi^+\pi^-)}{\Gamma(D^0 \to K^-\pi^+)} = (3.37 \pm 0.20_{(stat)} \pm 0.16_{(syst)})\%$$

Cabbibo suppressed branching ratios

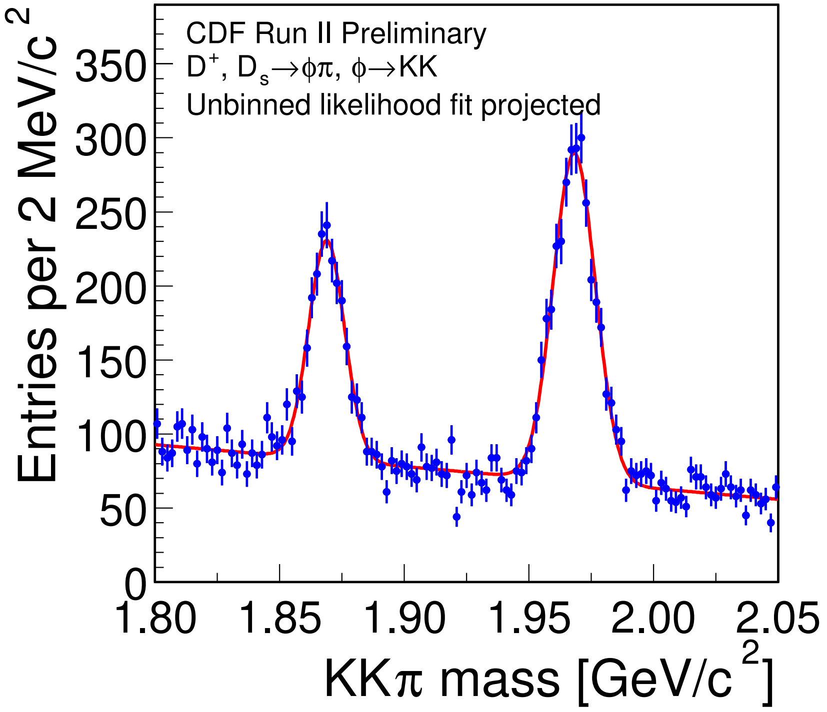


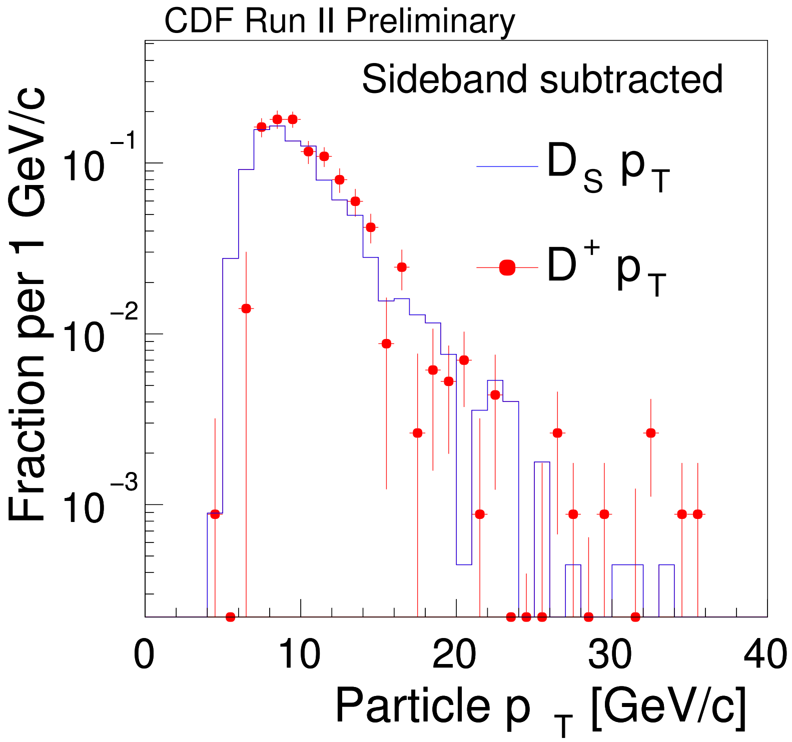




- clean separation of modes
- Outlook: larger data sample allows $D^* \to D^0\pi$ trick
- $\Longrightarrow$ reduced background
- updated measurement in preparation

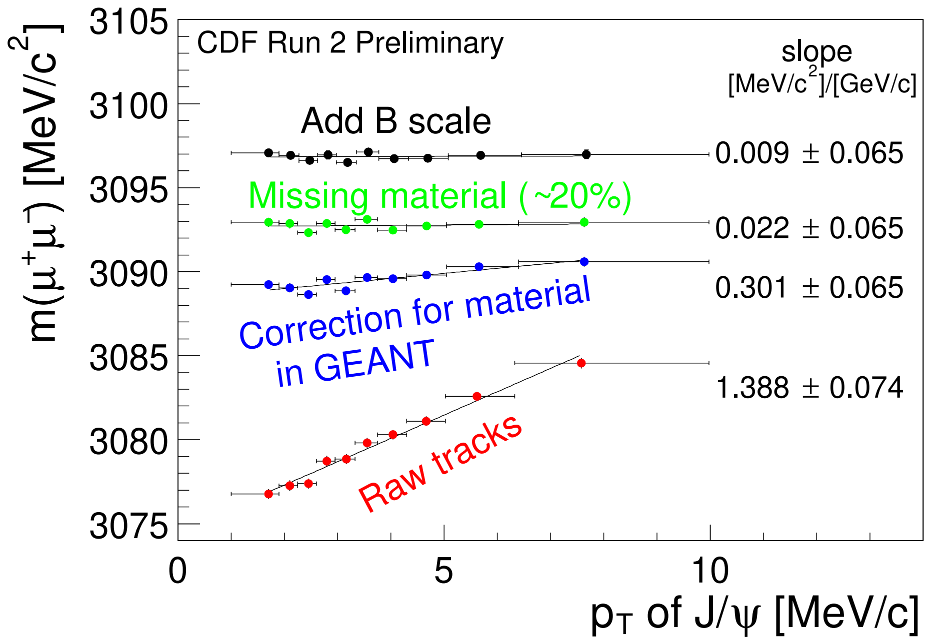
$m_{D_s^+} - m_{D^+}$ Mass Difference

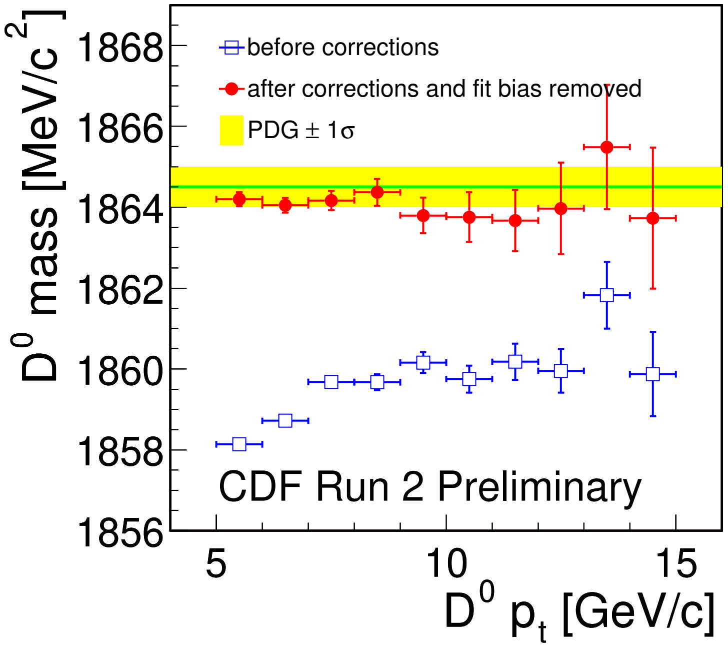




- use identical decay mode $D^{\pm}_{(s)} \to \phi\pi^{\pm}$
- similar kinematics
- $\Longrightarrow$ many systematics cancel
- relies on calibrated momentum scale

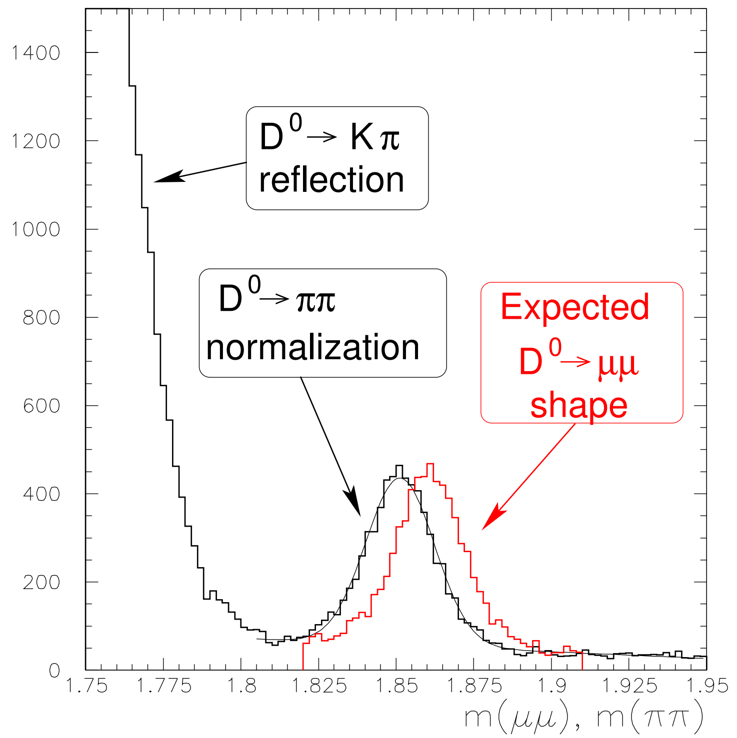
$\mathbf{m_{D_s^+} - m_{D^+}}$ Mass Difference

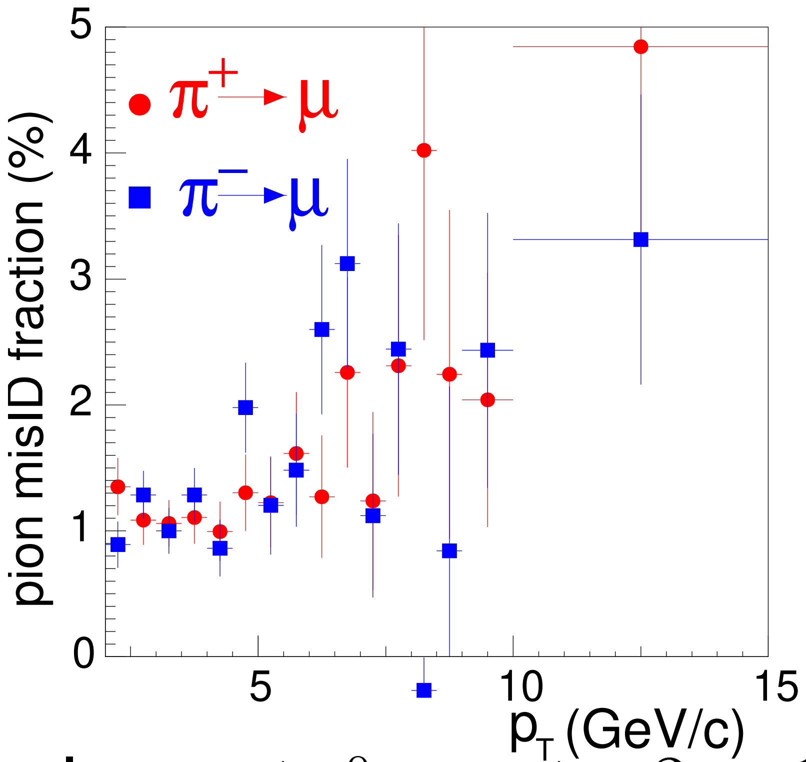




- calibrate E-loss and B-field using J/ψ
- $m_{D_s^+}\text{-}m_{D^+} = 99.41 \pm 0.38_{(stat)} \pm 0.21_{(syst)}\ \frac{\text{MeV}}{c^2}$
- largest systematic: background fit model
- Result submitted to PRD (first CDF RUN II paper!)

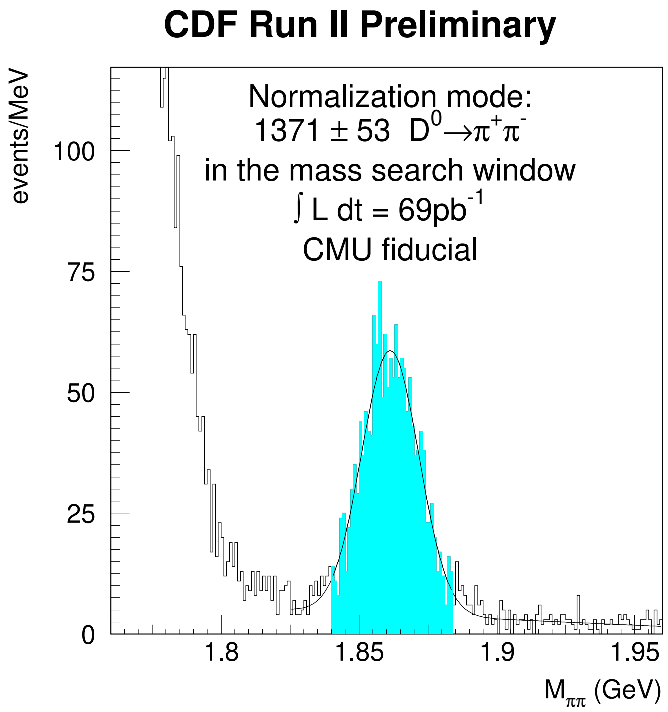
Search for rare decay $D^0 \to \mu^+\mu^-$

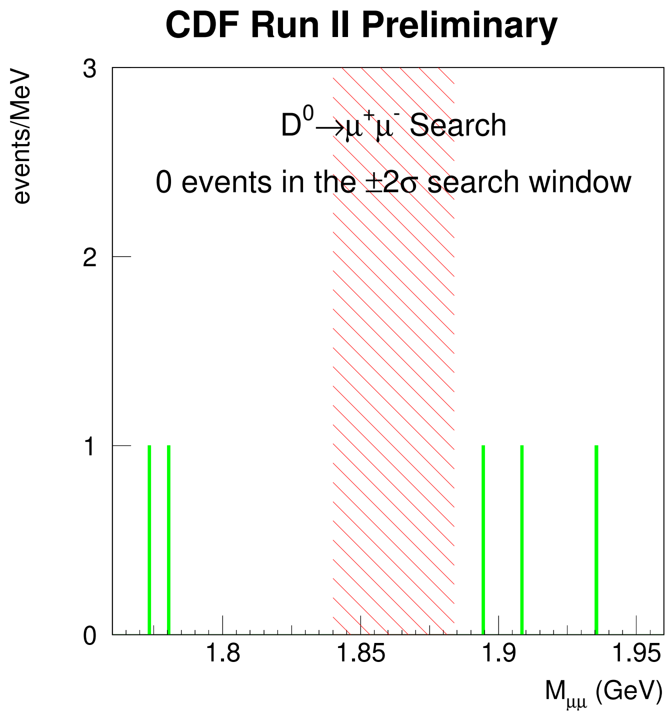




- standard model expectation: $\mathcal{B}(D^0 \to \mu\mu) = 3 \times 10^{-13}$
- enhanced in R violating SUSY: $\mathcal{B}(D^0 \to \mu\mu) = 3 \times 10^{-6}$
- use $D^{*\pm} \to D^0\pi^\pm$ trick to reduce Background
- normalize to $D^0 \to \pi^+\pi^-$
- background: muon fake rates from $D^0 \to \pi^\pm K^\mp$

Search for rare decay $D^0 \to \mu^+\mu^-$

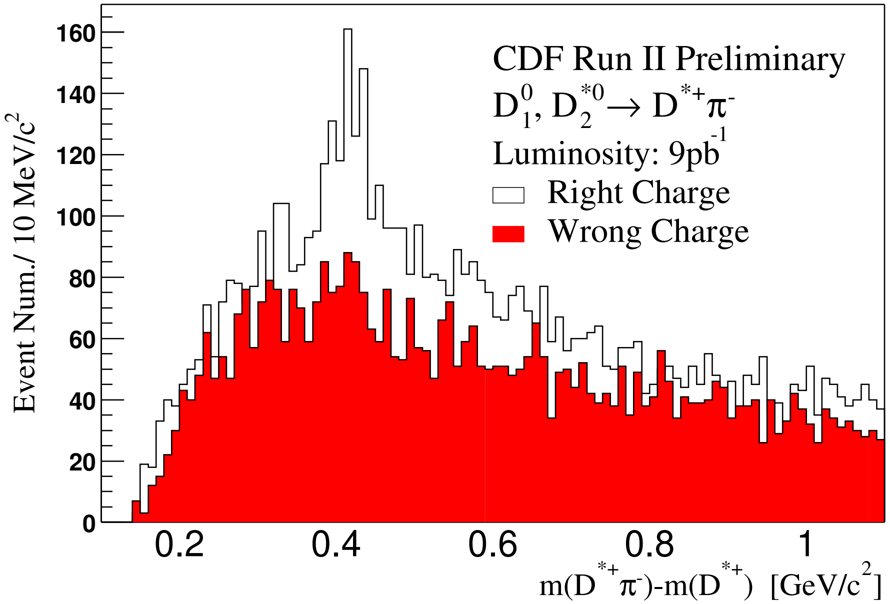


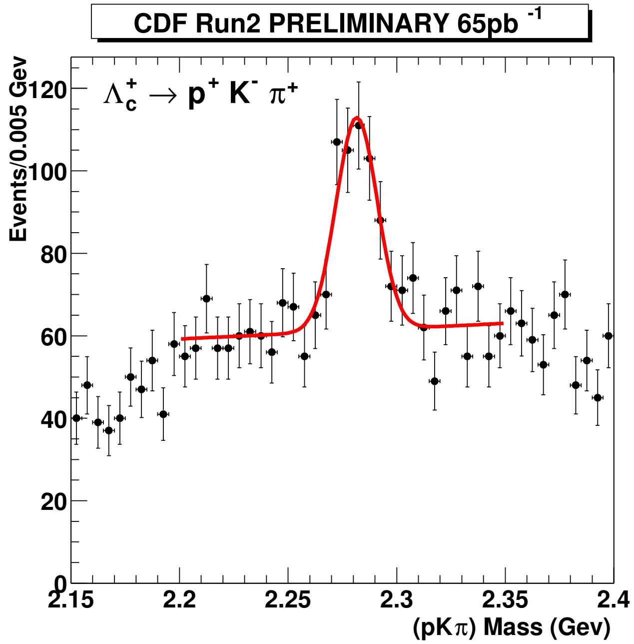


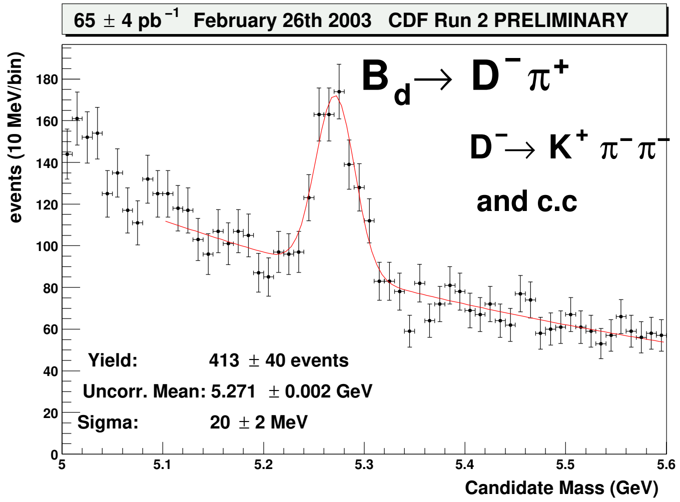
- No signal events observed, 1.8 ± 0.7 background expected
- $\frac{\mathcal{B}(D^0 \to \mu^+\mu^-)}{\mathcal{B}(D^0 \to \pi^+\pi^-)} = \frac{N_{CL}^{upper}(D^0 \to \mu^+\mu^-)}{N(D^0 \to \pi^+\pi^-)} \times \frac{\epsilon(D^0 \to \pi^+\pi^-)}{\epsilon(D^0 \to \mu^+\mu^-)}$
- $\mathcal{B}(D^0 \to \mu^+\mu^-) \leq 2.4 \times 10^{-6}$ at 90% CL (world best limit)

  previous: $\mathcal{B}(D^0 \to \mu^+\mu^-) \leq 4.1 \times 10^{-6}$ at 90% CL

Many more interesting topics ...







- more topics to be explored
- higher excited D states (D^{**}), charmed baryons
- our charm attracts beauty $\Longrightarrow$ (see Laurents talk)

Summary and Conclusion

- Secondary Vertex Trigger opened new opportunities
- $\mathcal{O}(10^7)$ $D^0 \to K^-\pi^+$ expected in $2\mathrm{fb}^{-1}$
- first competitive results:

  $\mathbf{m_{D_s^+}} - \mathbf{m_{D^+}} = 99.41 \pm 0.38_{(stat)} \pm 0.21_{(syst)}\ \frac{\mathrm{MeV}}{c^2}$,

  $\mathcal{B}(D^0 \to \mu^+\mu^-) \leq 2.4 \times 10^{-6}$ at 90% CL,

  $\frac{\Gamma(D^0 \to \pi^+\pi^-)}{\Gamma(D^0 \to K^-\pi^+)} = (3.37 \pm 0.20_{(stat)} \pm 0.16_{(syst)})\%$

  $\frac{\Gamma(D^0 \to K^+K^-)}{\Gamma(D^0 \to K^-\pi^+)} = (11.17 \pm 0.48_{(stat)} \pm 0.98_{(syst)})\%$
- results to come:

  cross sections, branching ratios, rare decays, life times, polarization, CP violation, excited states
- $\Longrightarrow$ Tevatron is turning into a charm factory