Heavy Flavor Production and Cross Sections at the Tevatron

(Run II results only)

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For CDF and D0 Collaboration

Outline

- Tevatron and CDF/D0 upgrade
- Prompt charm meson production cross section
- Inclusive J/Ψ cross section
- b cross section
- b-jet cross section
- Conclusion

Tevatron Run **II**

The Tevatron is a proton-antiproton collider with 980 GeV/beam

1.80TeV in Run I

36 bunches p × 36 bunches $\bar{p}$

6×6 in Run I

396 ns bunch crossing time

3.5μs in Run I

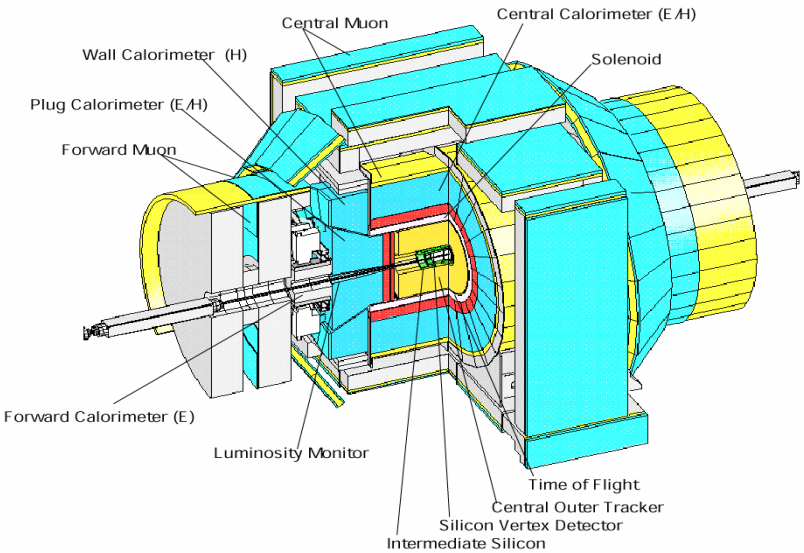
Tevatron Performance:

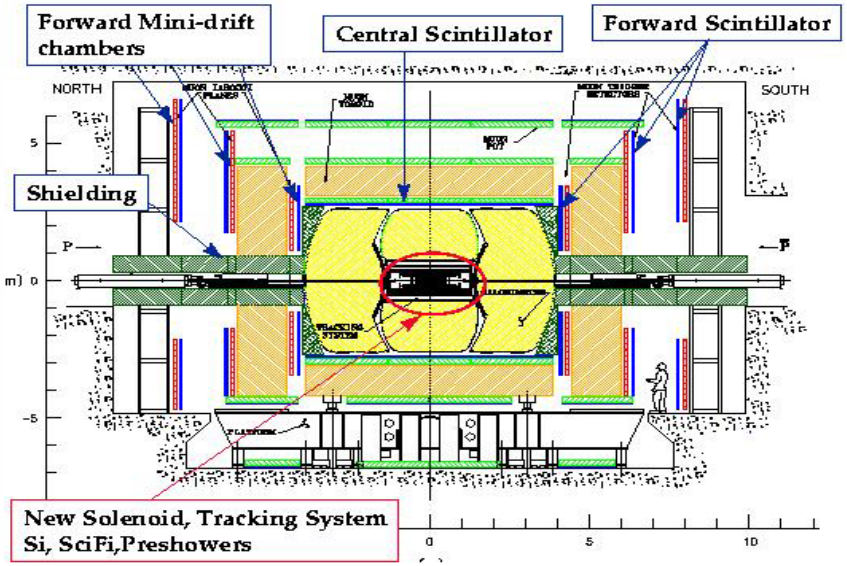
L~5.0 x 10^{31} $cm^{-2}s^{-1}$ 9 pb^{-1}/week

L_{int}~300 pb^{-1} delivered by Tevatron

Goal: L~10^{32} $cm^{-2}s^{-1}$

The upgraded detectors





- New silicon detector new drift chamber
- Upgraded calorimeter, μ
- Upgraded DAQ/trigger, esp. displaced-track trigger
- New TOF PID system

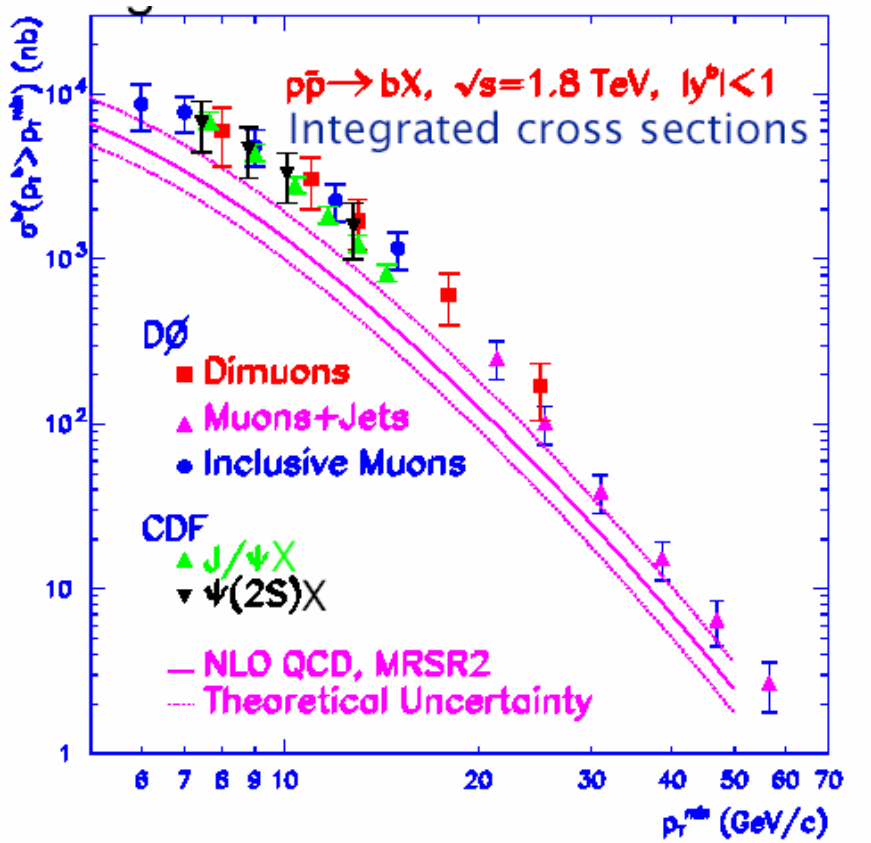
- New tracking: silicon and fibers in magnetic field
- Upgraded muon system
- Upgraded DAQ/trigger (displaced track soon)

Heavy Flavor Production X-Section

B cross section measured from Run I at Tevatron is consistently higher than NLO QCD

Theoretical development still ongoing.

Ex: fragmentation effect …….



Experimental Approaches:

More cross section measurement
- -- energy at 1.96TeV
- -- lower $p_T(B)$

Study $b\bar{b}$ correlation

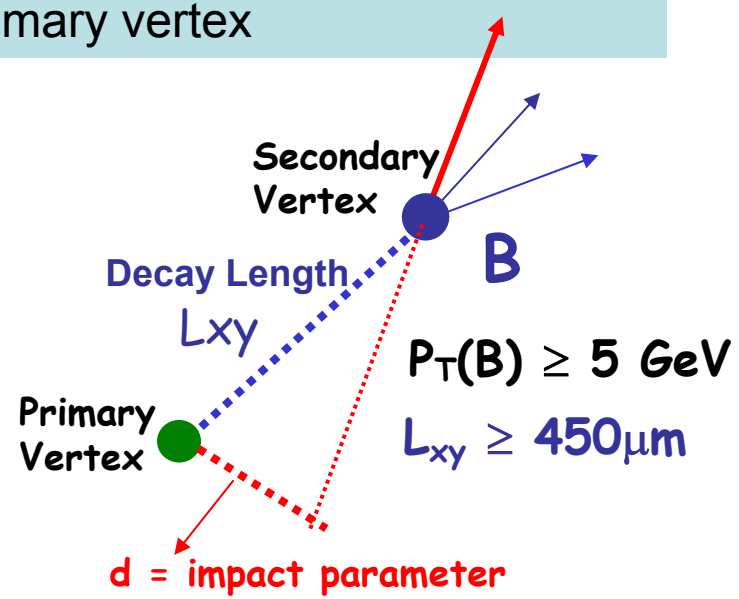
Measure charm production cross section

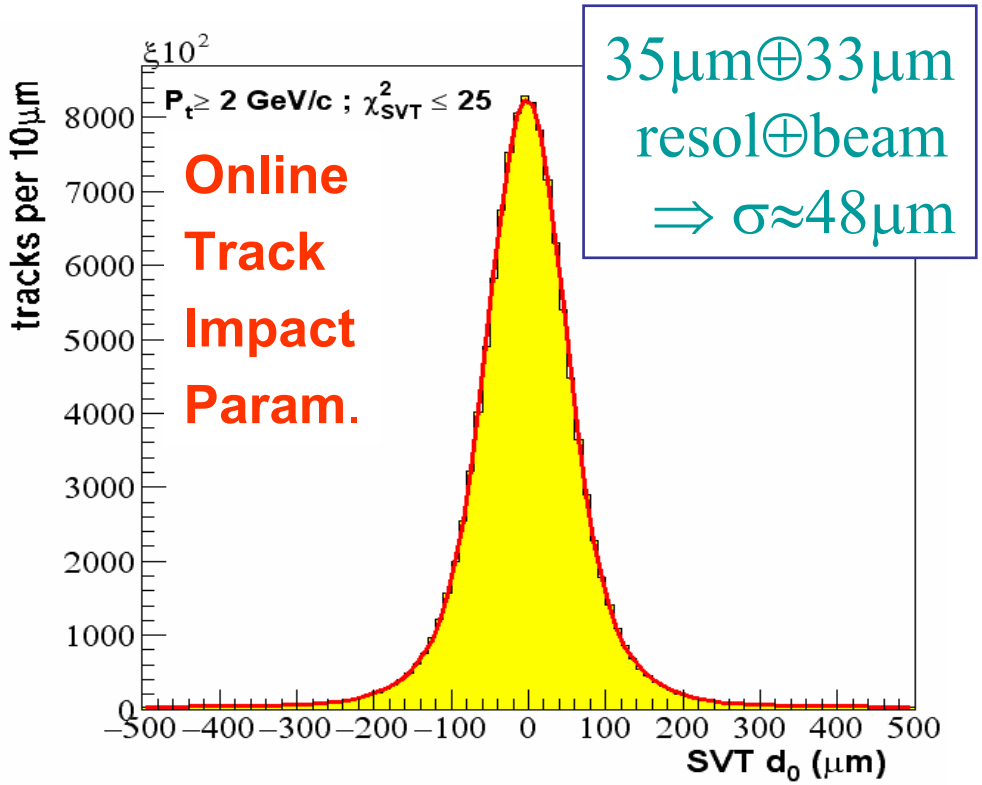
CDF Silicon Vertex Trigger (SVT)

Read out Silicon information and reconstruct tracks online at ~10's KHz

Using track impact parameter Information to make trigger decision

Tracks from B, D displaced from primary vertex





35μm⊕33μm resol⊕beam ⇒ σ≈48μm

Collect large amount and fully reconstructed B,D Hadrons:

Prompt Charm Meson X-Section

5.8±0.3pb^{-1}

Measure prompt charm meson production cross section

Data collected by SVT trigger from 2/2002-3/2002

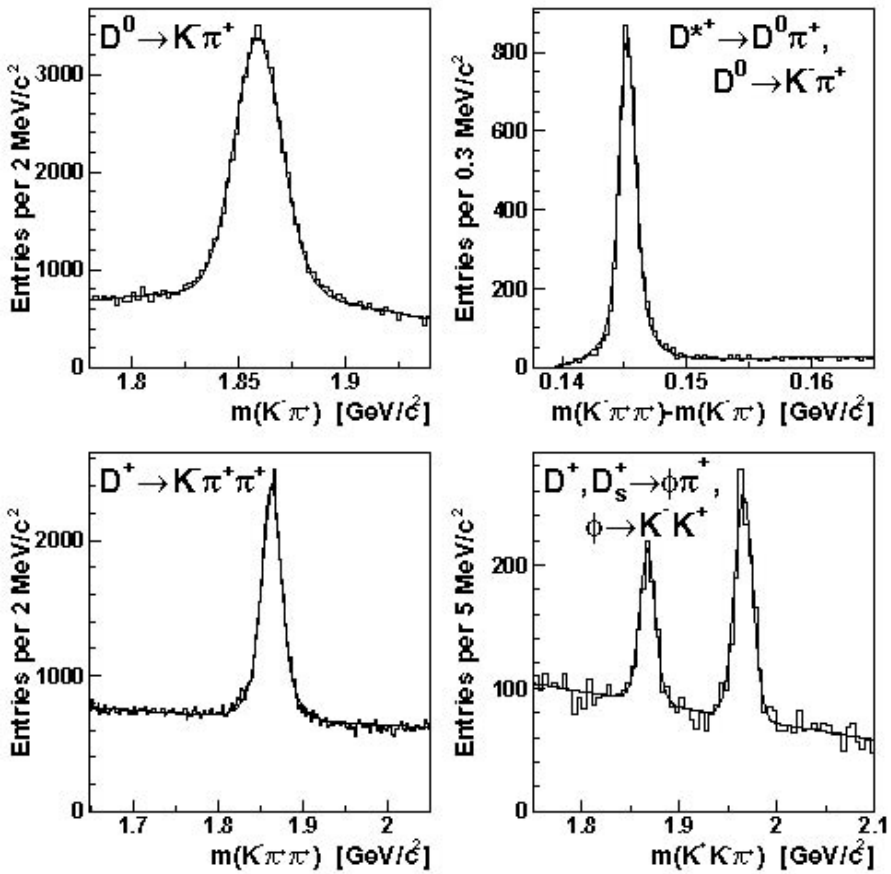
Large and clean signal
Measurement not limited by statistics

$D^0 \to K^-\pi^+$

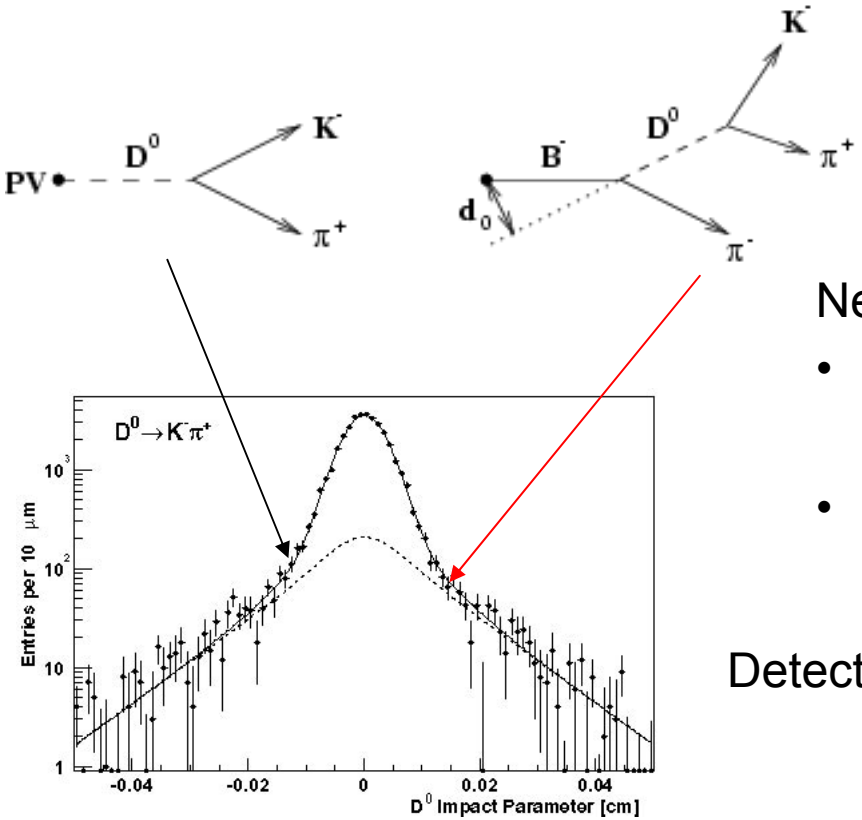
$D^{*+} \to D^0\pi_s^+$ with $D^0 \to K^-\pi^+$

$D^+ \to K^-\pi^+\pi^+$

$D_s^+ \to \phi\pi^+$ with $\phi \to K^+K^-$



Separate Prompt/Secondary Charm



Tail due to B→D

Separate prompt and secondary charm based on their **impact parameter distribution**.

Need to separate direct D and B→D decay

- Direct D point back to collision point
  I.P.=0
- Secondary D not point back to PV
  I.P.≠0

Detector I.P. resolution Measured from data

Direct Charm Meson Fraction:

D^0: f_D=86.5±0.4±3.5%

D^{*+}: f_D=88.1±1.1±3.9%

D^+: f_D=89.1±0.4±2.8%

D^+_s: f_D=77.3±4.0±3.4%

Most reconstructed charm mesons are direct

Prompt Charm Meson X-Sections

Determine trigger and reconstruction efficiency from data and MC

Measure charm meson p_T spectrum

Integral cross section: ($|Y| \leq 1$)

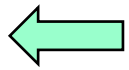
$$\sigma(D^0, p_T \geq 5.5\text{GeV}, |Y| \leq 1) = 13.3 \pm 0.2 \pm 1.5\,\mu b$$

$$\sigma(D^{*+}, p_T \geq 6\text{GeV}, |Y| \leq 1) = 5.2 \pm 0.1 \pm 0.8\,\mu b$$

$$\sigma(D^+, p_T \geq 6\text{GeV}, |Y| \leq 1) = 4.3 \pm 0.1 \pm 0.7\,\mu b$$

$$\sigma(D_s^+, p_T \geq 8\text{GeV}, |Y| \leq 1) = 0.75 \pm 0.05 \pm 0.22\,\mu b$$

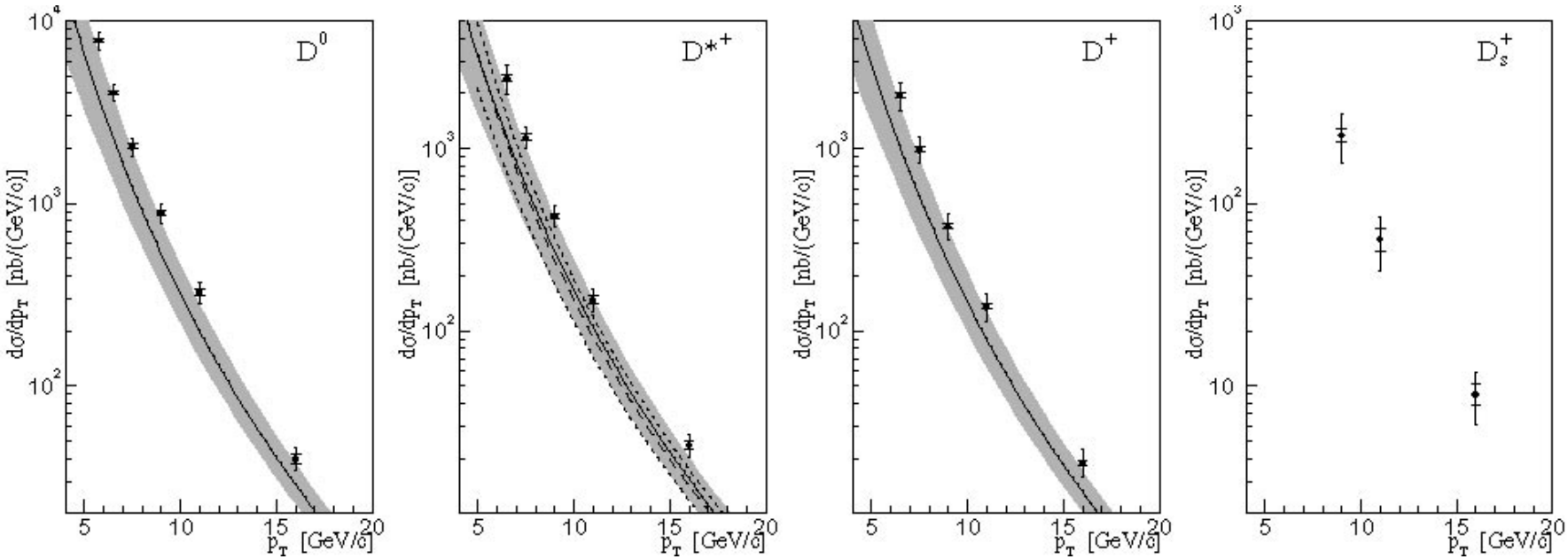
$$\sigma(B^+, p_T \geq 6\text{GeV}, |Y| \leq 1) = 3.6 \pm 0.6\,\mu b$$



CDF I

Prompt charm cross section result submitted to PRL hep-ex/0307080

Differential Charm Meson X-Section



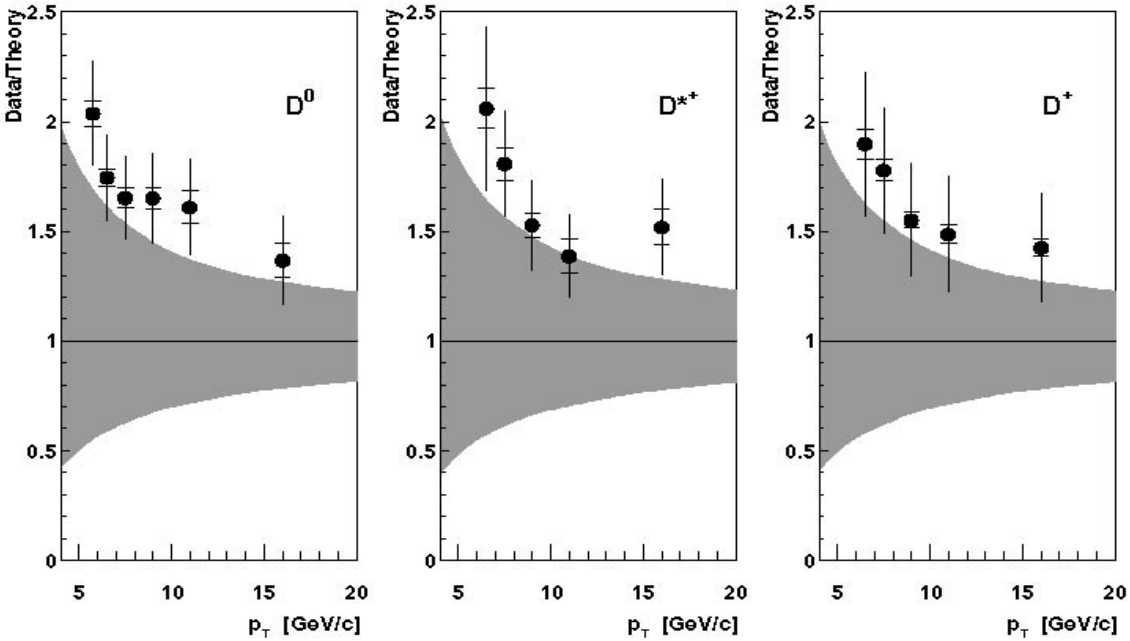
Calculation from M. Cacciari and P. Nason: Resummed perturbative QCD (FONLL) JHEP 0309,006 (2003)

CTEQ6M PDF
M_c=1.5GeV,
Fragmentation: ALEPH measurement
Renorm. and fact. Scale: $m_T=(m_c^2+p_T^2)^{1/2}$
Theory uncertainty: scale factor 0.5-2.0

D^{*+} also include calculation from B.A. Kniehl (private communication)

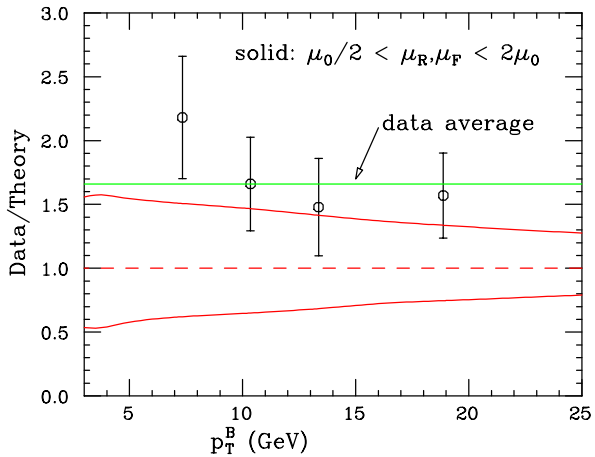
Comparison with Theory

Ratio of the measured to the predicted cross section



PRL89:122003,2002

$p\bar{p} \to B^+ X$ CDF I



Not incompatible with uncertainties

p_T shape consistent for D mesons

Measured cross section higher : similar to B

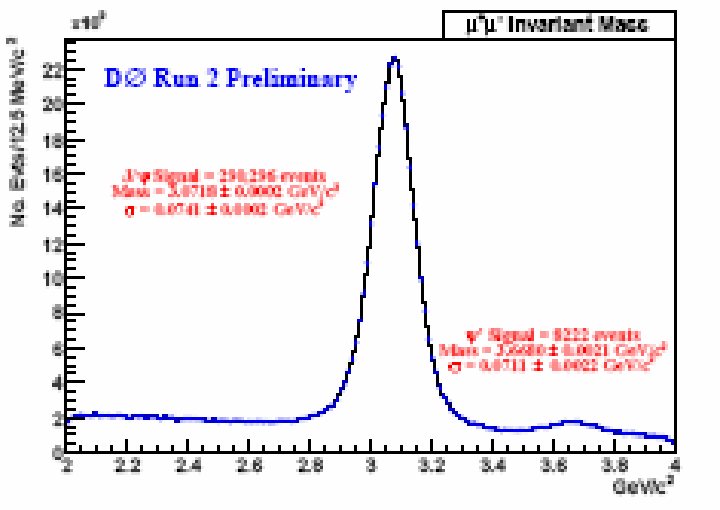
Inclusive J/Ψ Cross Section

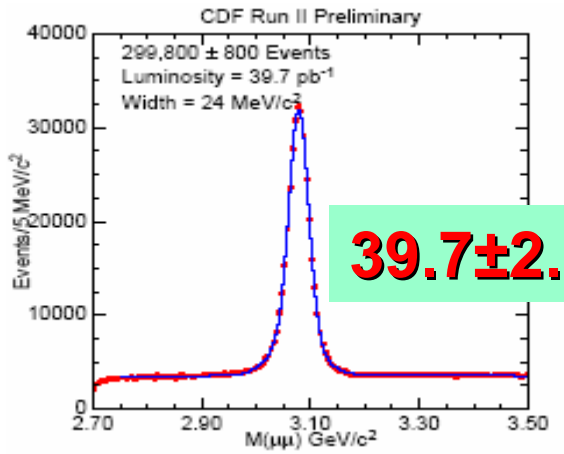
CDF: Lower p_T trigger threshold for μ: $p_T(\mu) \geq 1.5$GeV

J/Ψ acceptance down to $p_T=0$

D0: Larger y acceptance for μ

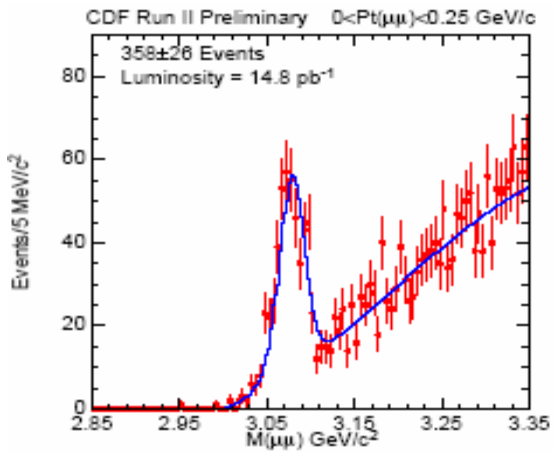
114 pb^{-1}





39.7±2.3 pb^{-1}

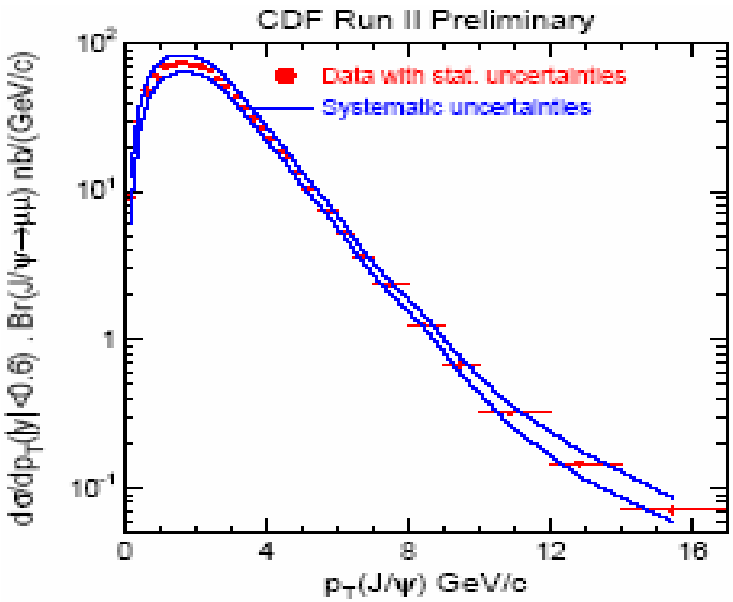
0 <p_T(J/Ψ)<0.25GeV



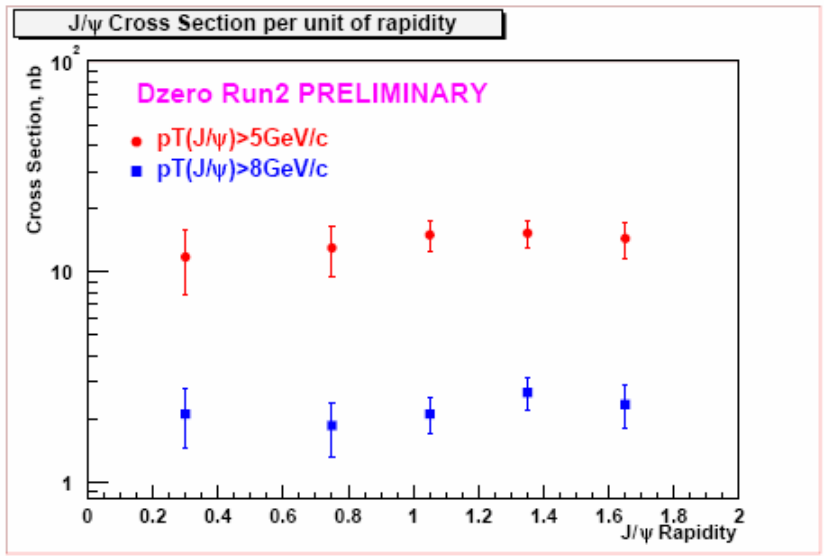
Inclusive J/Ψ Cross Section

$$\sigma(p\bar{p} \to J/\Psi X, |\, y(J/\Psi)\,| < 0.6) = 4.08 \pm 0.02(stat)^{+0.60}_{-0.48}(syst)\,\mu b$$

CDF: 39.7±2.3 pb^{-1}



D0: 4.74 pb^{-1}

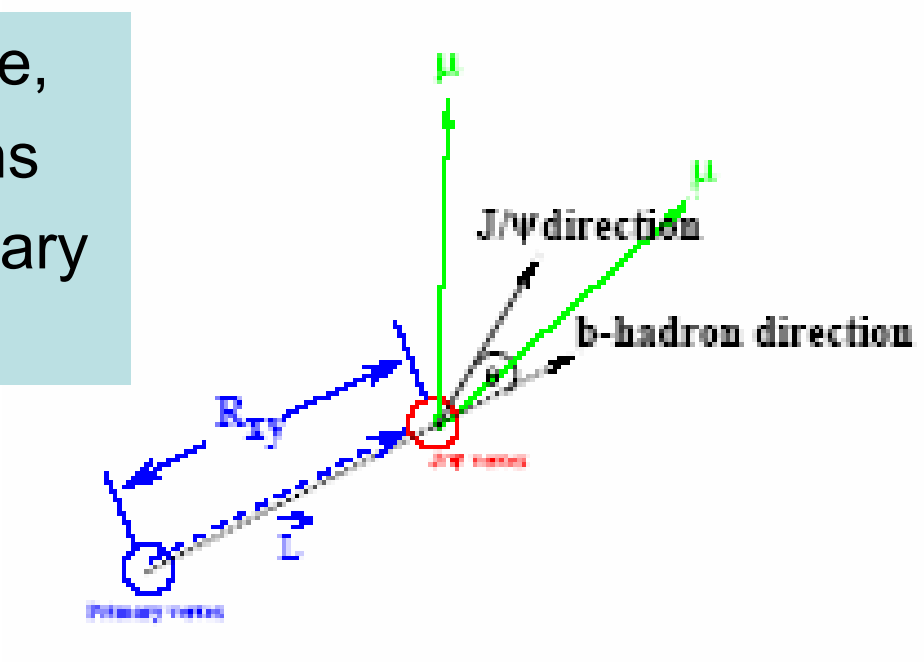


Extract Contribution from b $\rightarrow$ J/ΨX

The J/Ψ inclusive cross section includes contribution from

- Direct production of J/Ψ
- Decays from excited charmonium: $\Psi(2S) \rightarrow J/\Psi\pi^+\pi^-$, ……
- Decays of b-hadrons: B $\rightarrow$ J/ΨX, ……

b hadrons have long lifetime,
J/Ψ decayed from b hadrons
Will be displaced from primary vertex

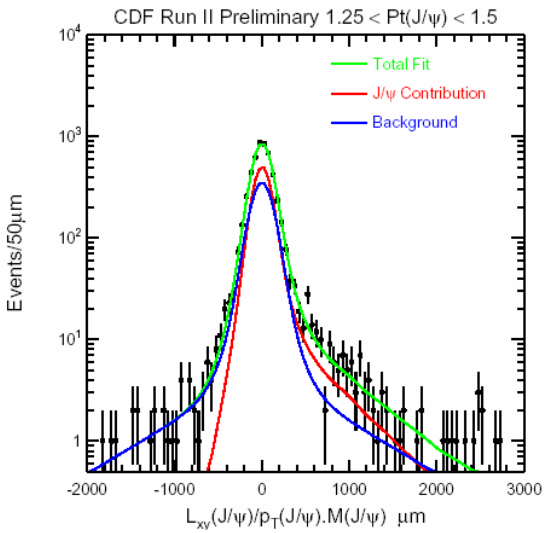


Extract Contribution from b → J/ΨX

A unbinned maximum likelihood fit to the flight path of the J/ Ψ in the r ϕ plane to extract the b fraction

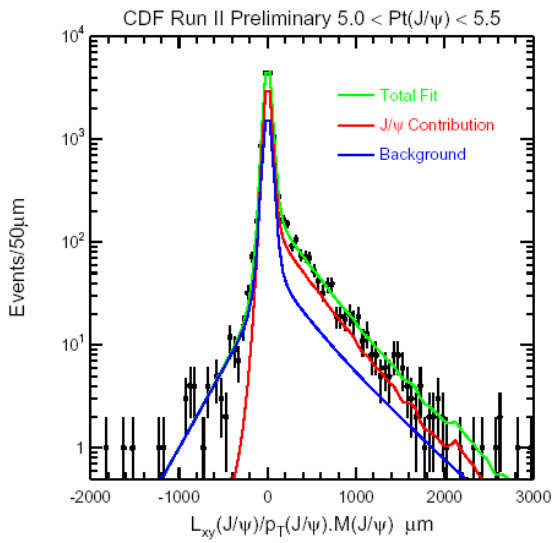
$1.25 < p_T < 1.5\text{GeV}$

$f_b = 0.097 \pm 0.010^{+0.012}_{-0.010}$



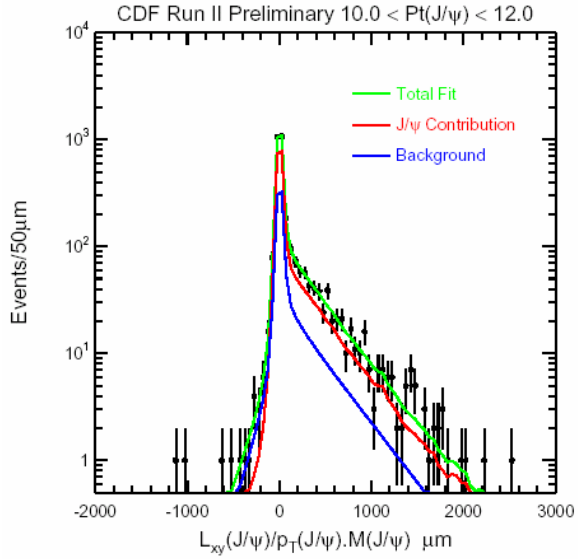
$5.0 < p_T < 5.5\text{GeV}$

$f_b = 0.143 \pm 0.005^{+0.006}_{-0.006}$



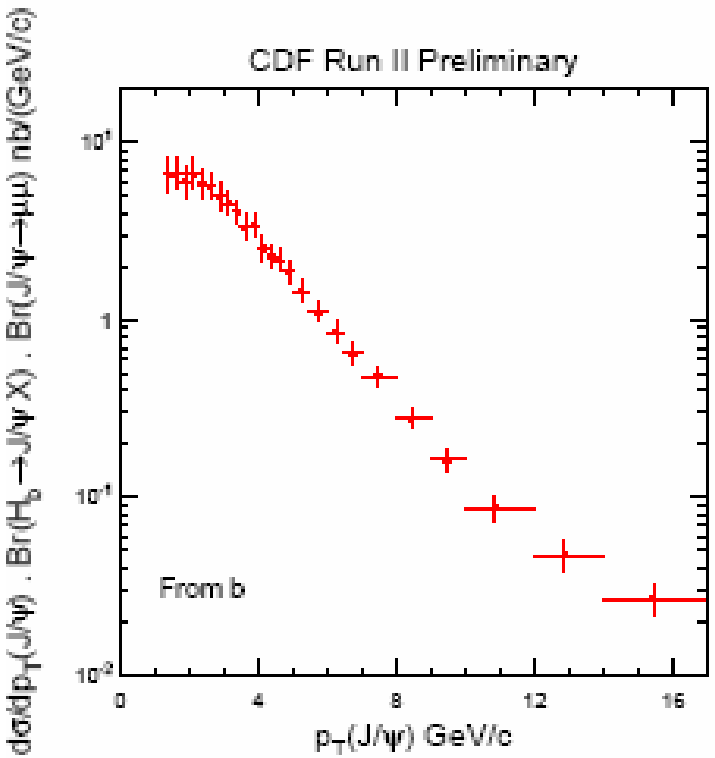
$10 < p_T < 12\text{GeV}$

$f_b = 0.279 \pm 0.012^{+0.008}_{-0.007}$



b Hadron Differential Cross Section

$$d\sigma(p\bar{p} \to H_b X, H_b \to J/\Psi X) \cdot Br(J/\Psi \to \mu\mu)/dp_T(J/\Psi)$$



H_b denote both b hadron and anti b hadron

$|Y(H_b)|<0.6$

But:

We can not extract b fraction when b hadron is at rest

We want total b hadron cross section

We want b cross section as a function of b hadron transverse momentum

b Hadron Differential X-Section

Bottom decays transfer about 1.7GeV p_T to the J/Ψ
We can probe b near p_T=0 if we can measure b fraction of J/Ψ with p_T below this value.

Assume a b-hadron p_T spectrum

↓

Unfold $p_T(H_b)$ from $p_T(J/\Psi)$ using MC

↓

b-hadron X-section $d\sigma/dp_T(H_b)$

↓

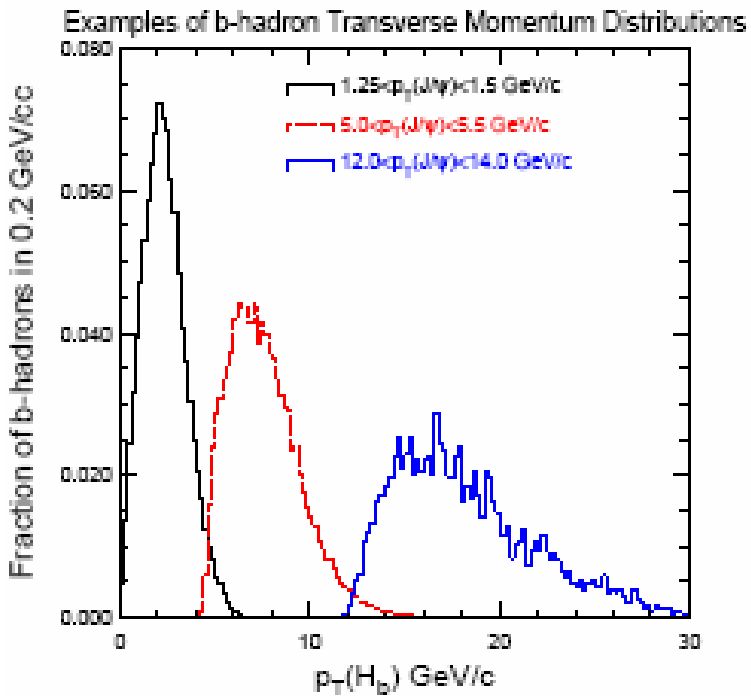
New b-hadron p_T spectrum

↓

Iterate to obtain the correct p_T spectrum

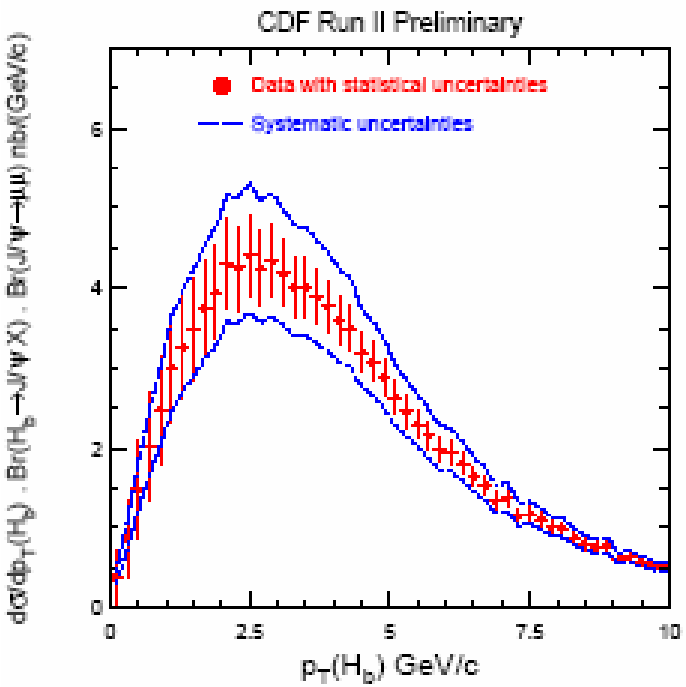
↓

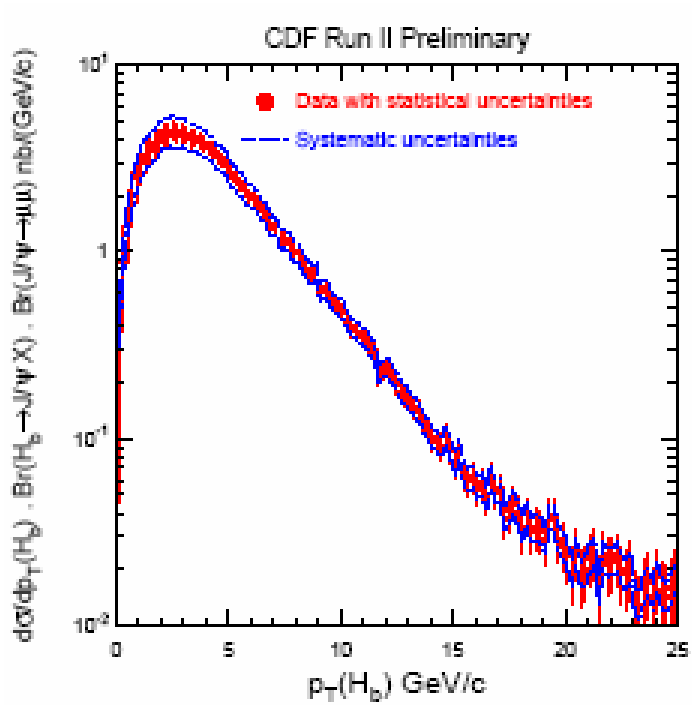
b-hadron differential and total X-section



b Hadron Differential X-Section

$$d\sigma(p\bar{p} \to H_b X, H_b \to J/\Psi X) \cdot Br(J/\Psi \to \mu\mu)/dp_T(H_b)$$





Total b Quark Production X-Section

$$d\sigma(p\bar{p} \to H_b X, |y| \le 0.6) \cdot Br(H_b \to J/\Psi X) \cdot Br(J/\Psi \to \mu\mu)$$
$$= 24.5 \pm 0.5(stat) \pm 4.7(syst)\text{nb}$$

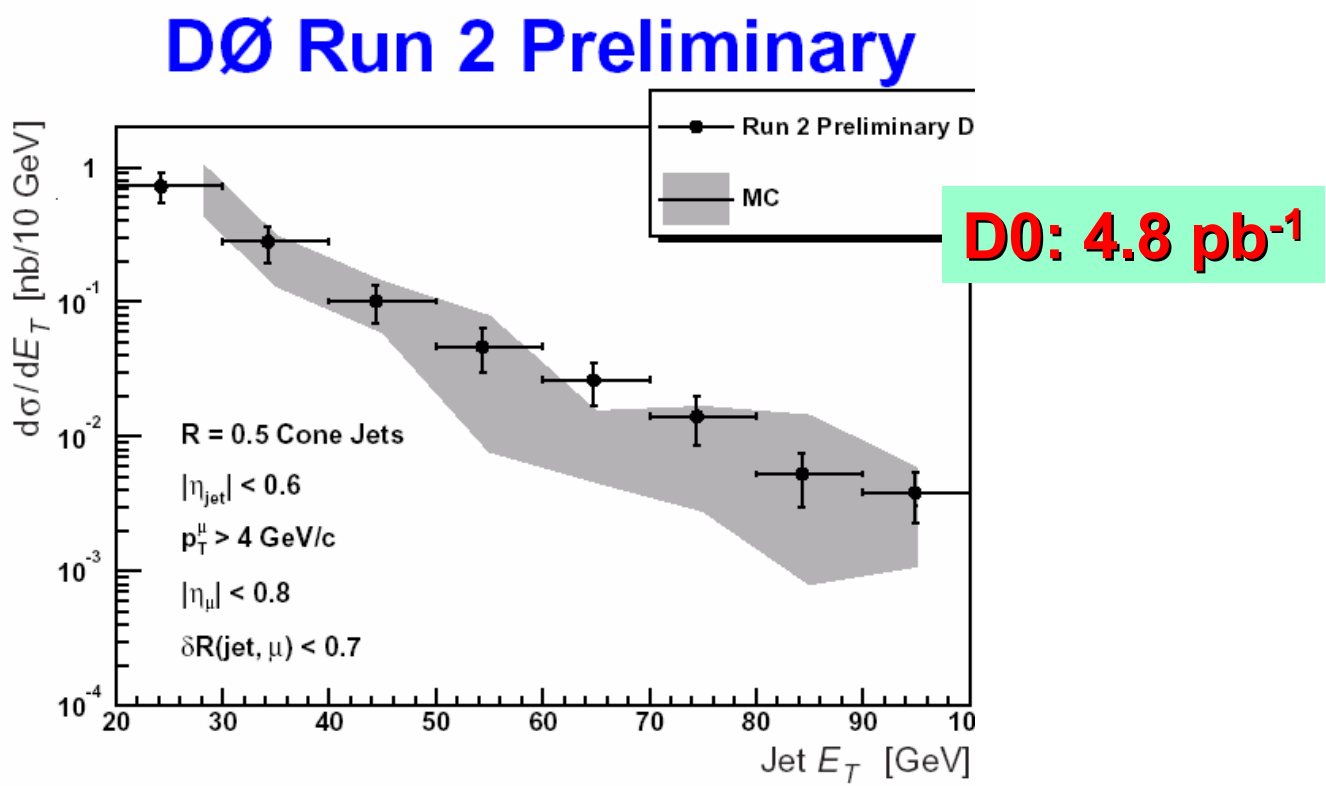
$$d\sigma(p\bar{p} \to \bar{b}X, |y| \le 0.6) = 18.0 \pm 0.4(stat) \pm 3.8(syst)\mu\text{b}$$

MC extract to high Y region

$$d\sigma(p\bar{p} \to \bar{b}X, |y| \le 1.0) = 29.4 \pm 0.6(stat) \pm 6.2(syst)\mu\text{b}$$

b-jet X-Section

μ + jet sample ⇒ Using μ p_T spectrum to fit the b and non b content as a function of jet E_T



Conclusion

- Large amount data collected by both CDF and D0 already surpass the run I statistics
- New Charm, Bottom cross section results
- Lots of analysis in progress:
  J/Ψ, Ψ(2S) cross section and polarization
  Upsilon cross section and polarization
  Updated b cross section ……
- Tevatron will contribute the knowledge of heavy flavor production
- Stay tuned