Beauty production cross section measurements at $E_{cm} = 1.96$ TeV

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On behalf of the D0 & CDF collaboration

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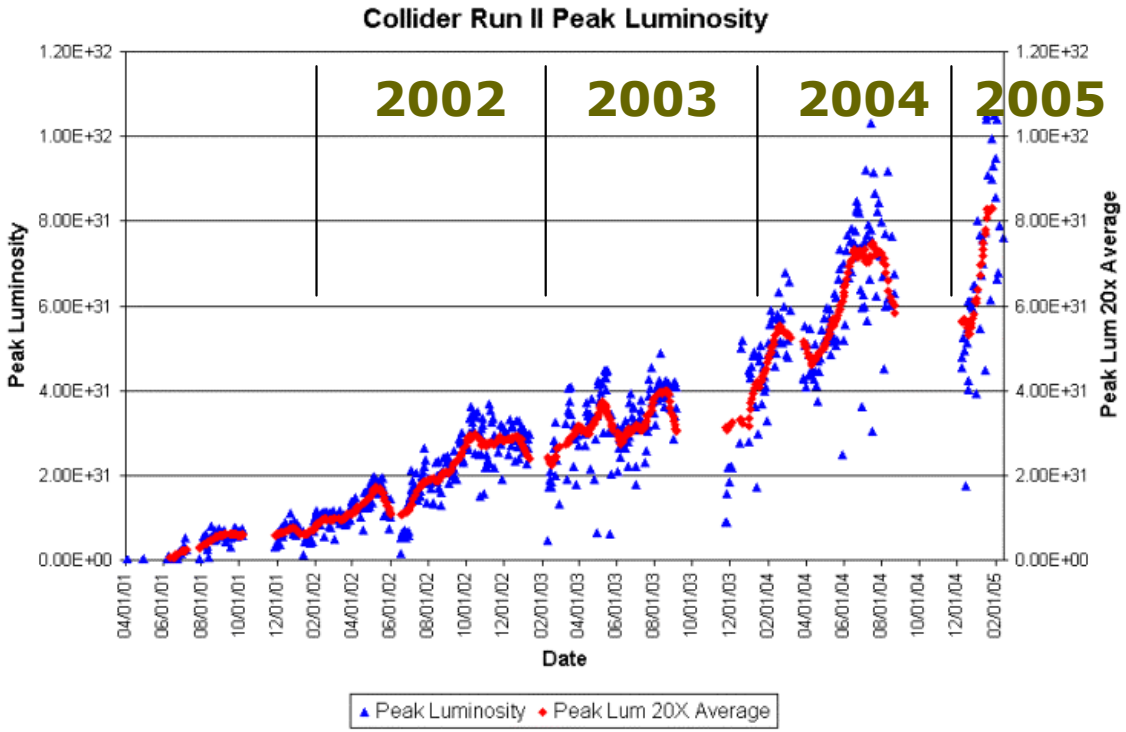
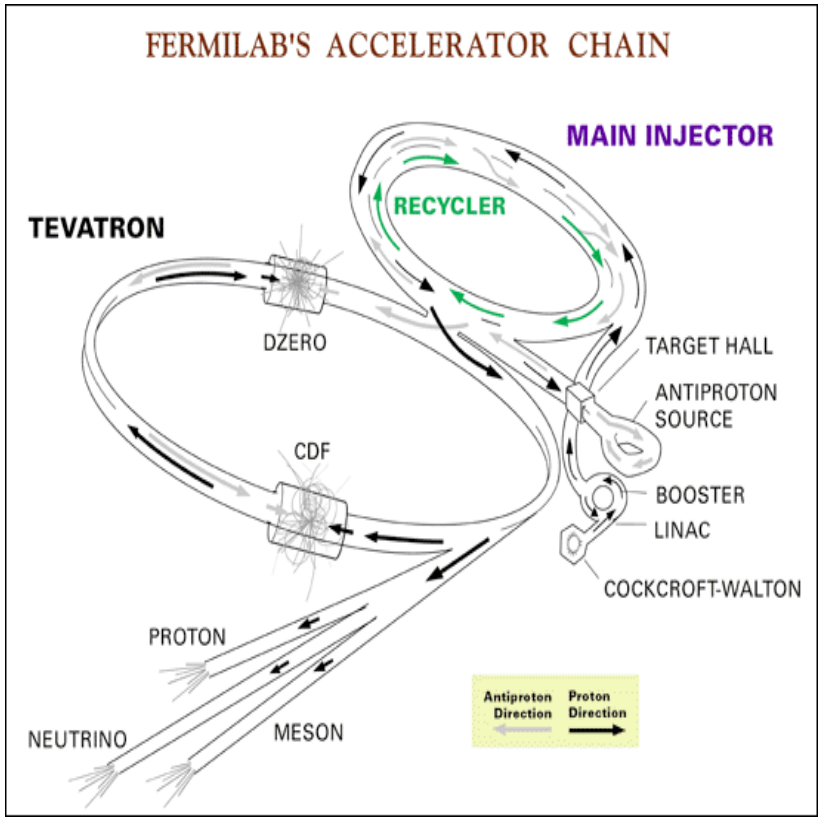
Outline

- The Tevatron, CDF and D0 experiments
- Theory of beauty production
- Run II results on beauty production:
  - b-hadron cross section with J/ψ
  - High p_T b-jet cross section
  - Bottomonium production
- Summary & Conclusions

The Tevatron in RunII

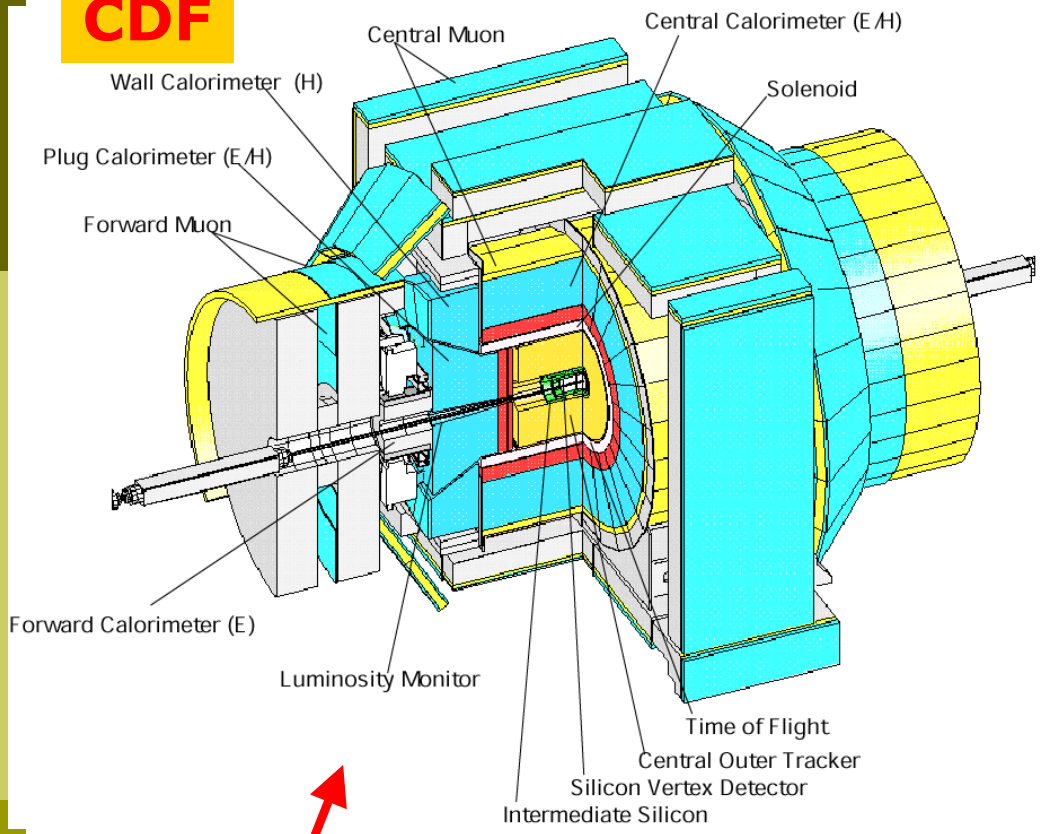
- Peak luminosity in 2005 above 10^{32} cm^{-2} s^{-1}
- CDF and D0 collected > 500 pb^{-1} on tape
- Analyses shown here use 40-300 pb^{-1}





CDF and D0 in RunII

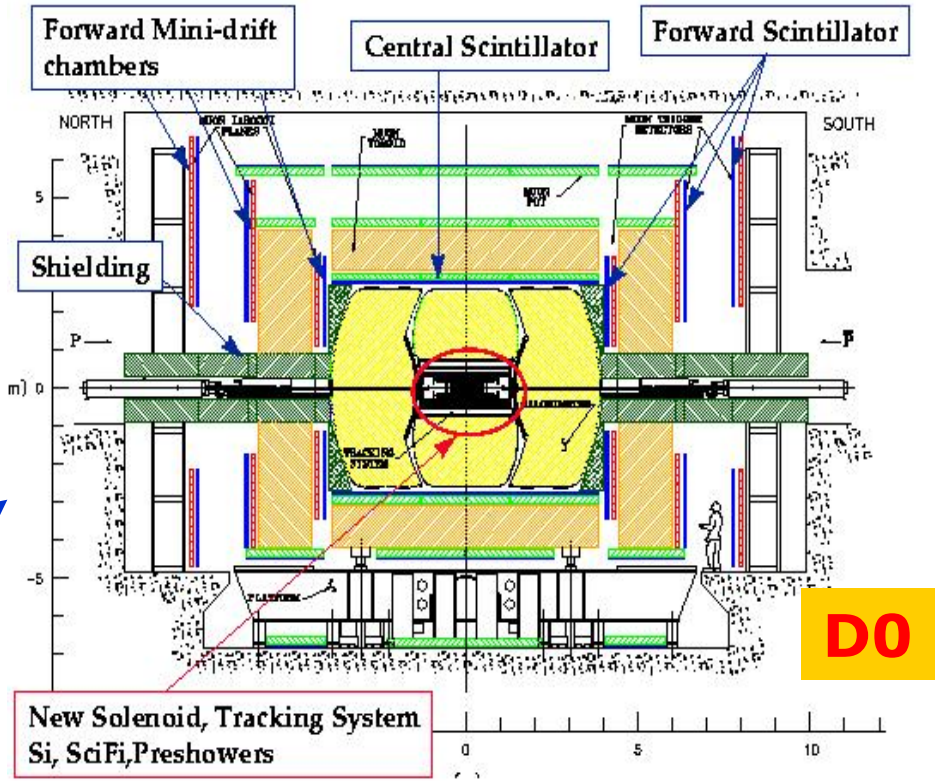
CDF



L2 trigger on displaced vertices
Excellent tracking resolution

Both detectors

- Silicon microvertex tracker
- solenoid
- High rate trigger/DAQ
- Calorimeters and muons



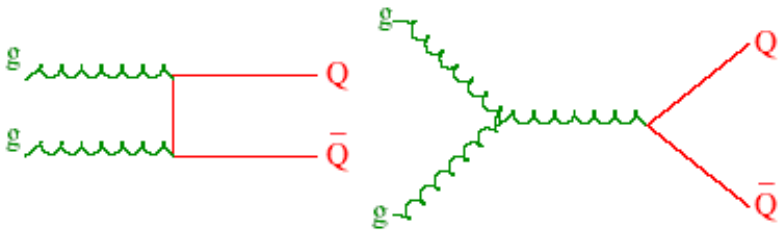
D0

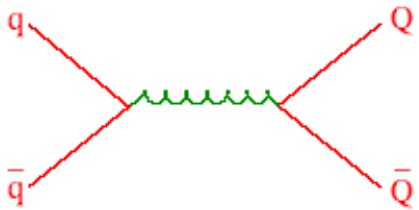
Excellent muon ID and acceptance
Excellent tracking acceptance $|\eta| < 2\text{-}3$

Beauty production

- To understand and probe perturbative QCD
- at E_{cm}=1.96 TeV $\sigma(b\bar{b})$ ~ 50 μb → few kHz event rate

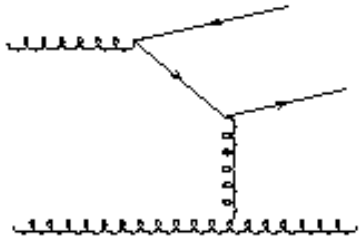
Leading Order



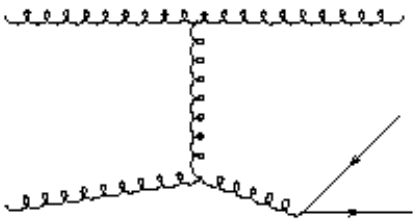


Flavor creation

Next to Leading Order



Flavor excitation



Gluon splitting

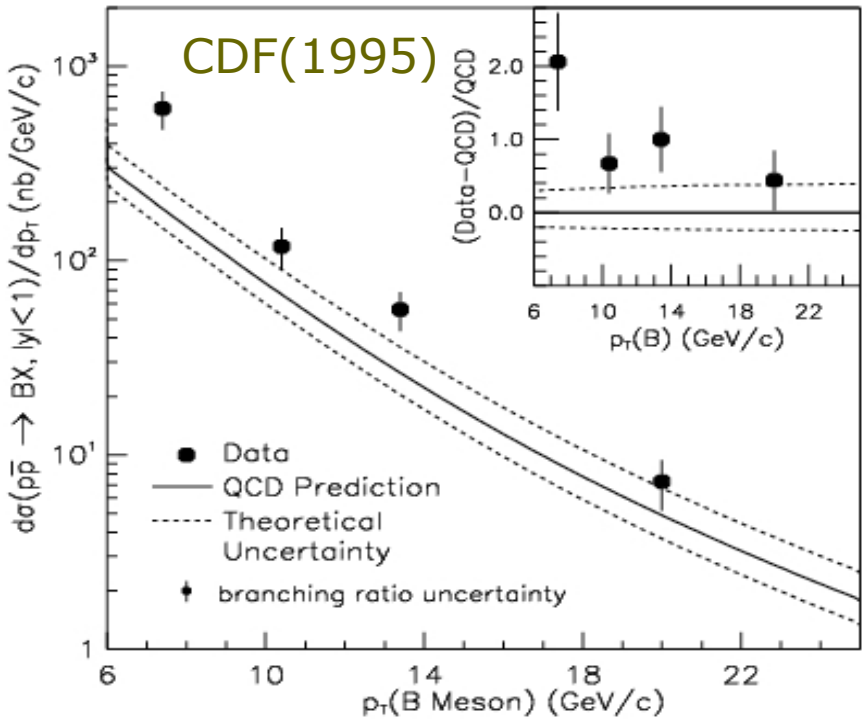
Full calculations have been done up to NLO and beyond ….

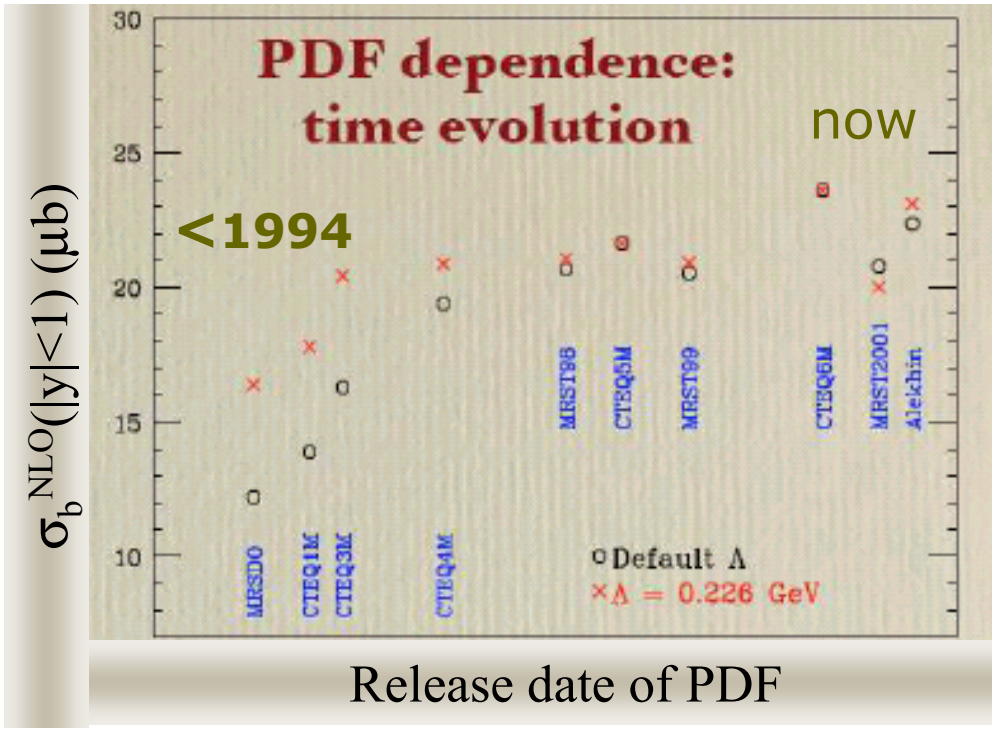
Many developments in the theoretical approach in the past years

Recent developments

- Beyond NLO: resummation of $\log(p_T/m)$ terms → FONLL
- Substantial change in fragmentation function extraction (from LEP data)
- new PDF functions

… the past





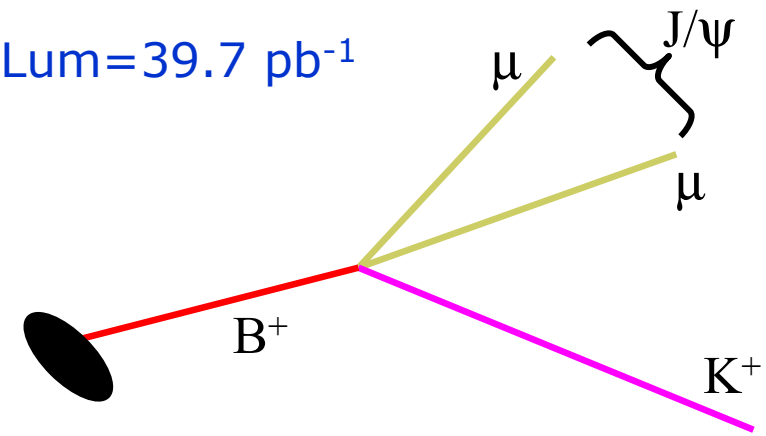
- Good data/theory agreement also due to improved treatment of experimental inputs (use b-jets and b-hadrons rather than b-quark)

… the present →

B hadron production using J/ψ (CDF)

Subm. to PRD, FERMILAB-PUB-04-440-E

Lum=39.7 pb^{-1}



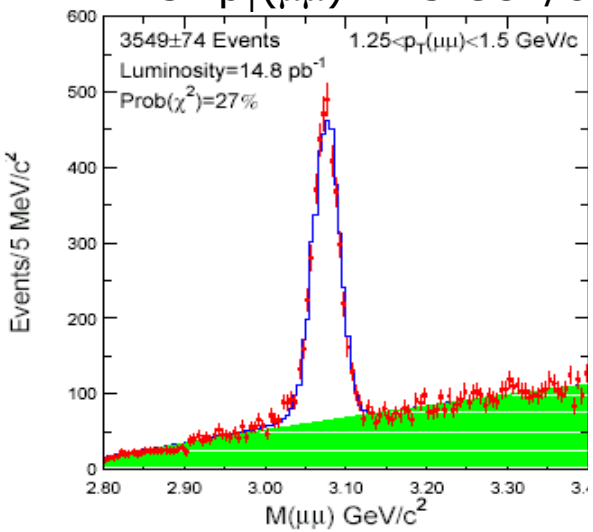
Exclusive decays of B-Hadrons used to measure the b production cross section

- Find J/ψ inclusive cross section
- Extract fraction of J/ψ from decay of long-lived b-hadrons
- Find b-hadrons cross section for p_T(B) down to 0 considering |y(J/ψ)|<0.6

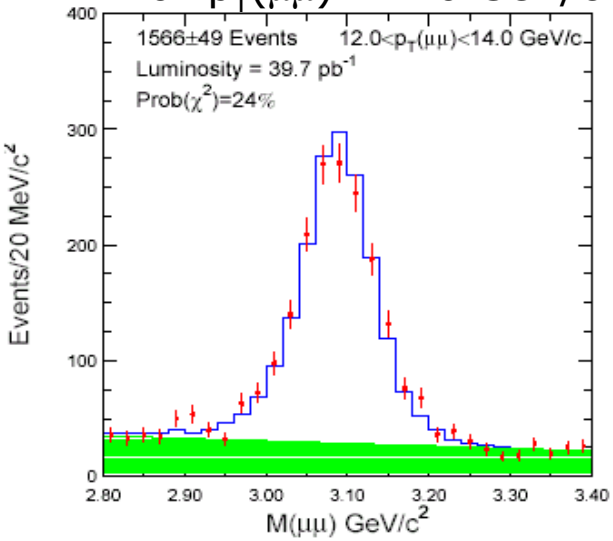
...Counting J/ψ (p_T= 0 to 20 GeV/c)

- muon trigger: ε=0.986±0.010 for $p^{\mu}{}_T$>1.5 GeV/c (|y|<0.6)
- use detector simulation to model the shape as expected for J/ψ signal
- Mass resolution ~ 14-15 MeV

1.25<p_T(μμ)<1.5 GeV/c



12.0<p_T(μμ)<14.0 GeV/c

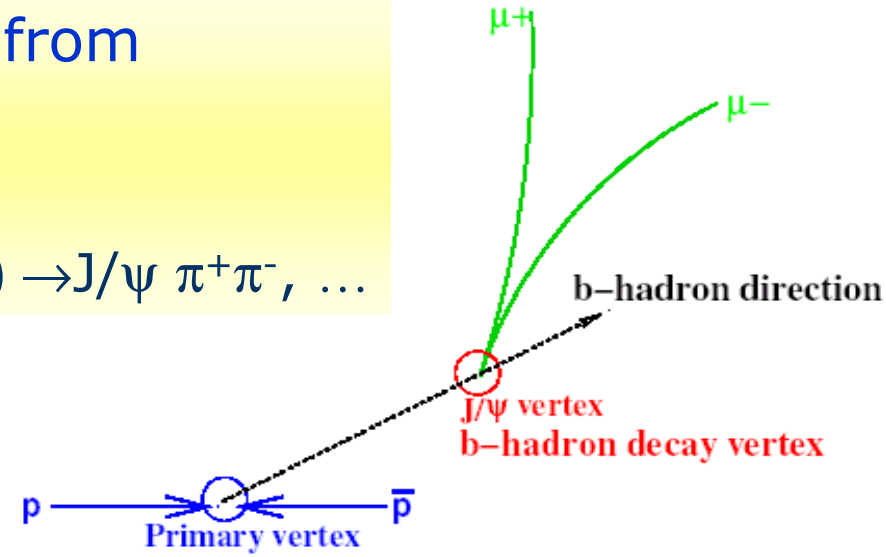


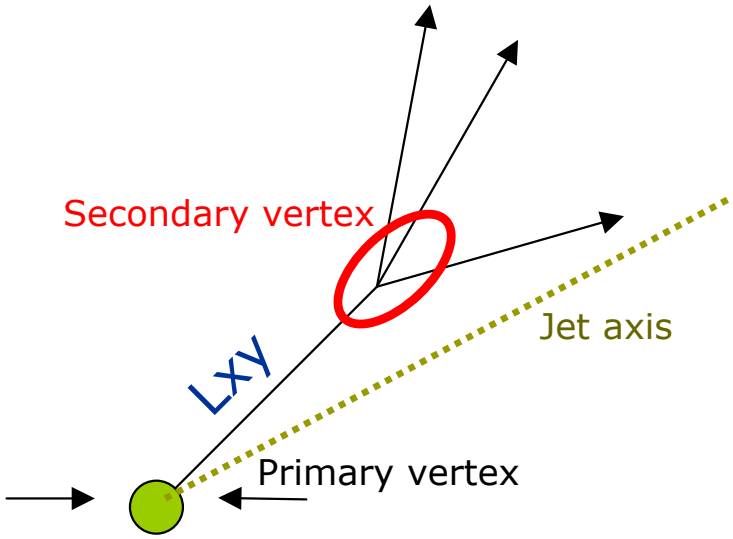
Tagging b …

J/ψ inclusive cross-section contribution from

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

→ J/ψ from B → J/ψ X will be displaced





In general b-tagging procedures take advantage of the long life-time of B hadrons → cτ ~ 450 μm

- use L_{xy}, distance primary-secondary vertex in r-ϕ space to define sec.vtx quality
- If considering jets, selection also on L_{xy} direction with respect to jet axis

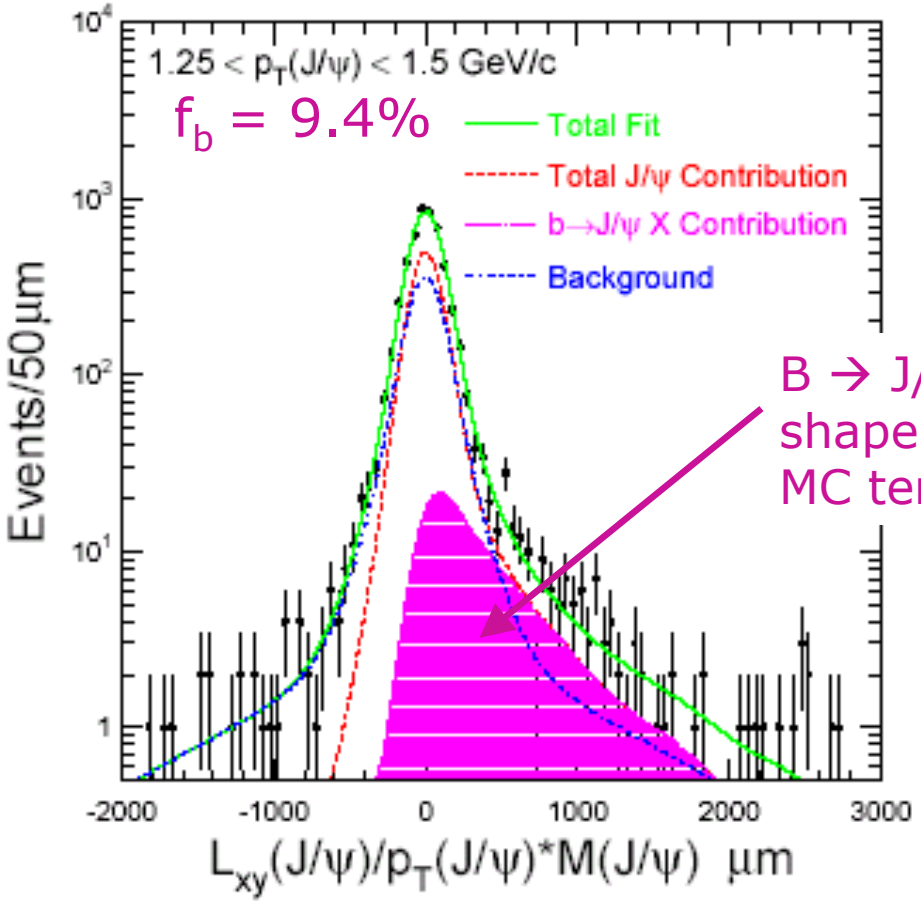
Extract b fraction

To reduce dependence on J/ψ p_T bin:

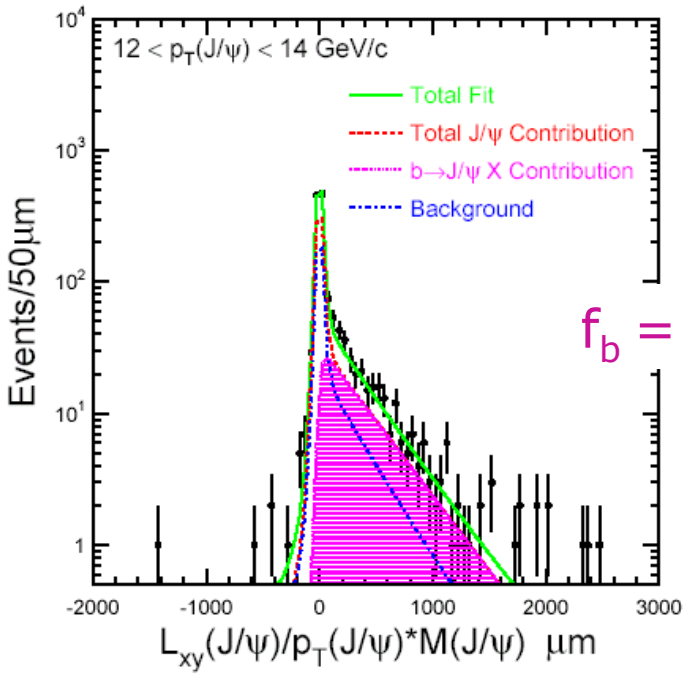
$x = L_{xy}(J/\psi) \bullet M(J/\psi) / p_T(J/\psi)$

= flight path of J/ψ in r-ϕ plane

Maximum likelihood fit to extract b fraction as function of $p_T(J/\psi)$



B → J/ψ X shape from MC templates



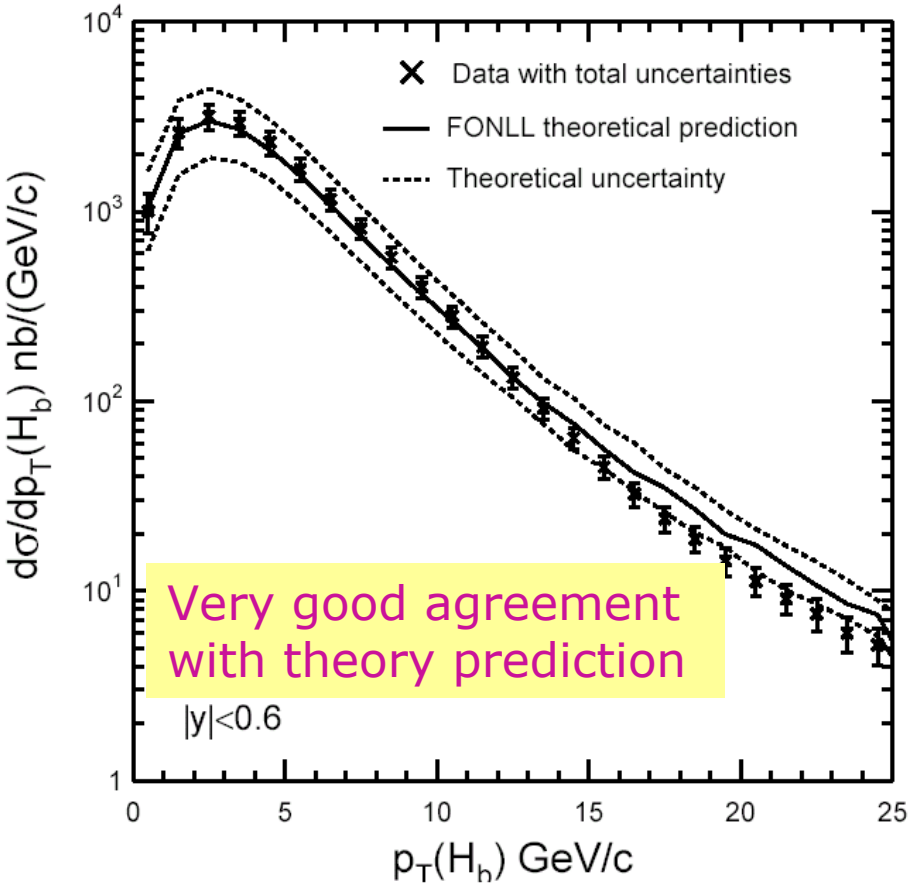
$f_b = 33.7\%$

B hadron production cross section

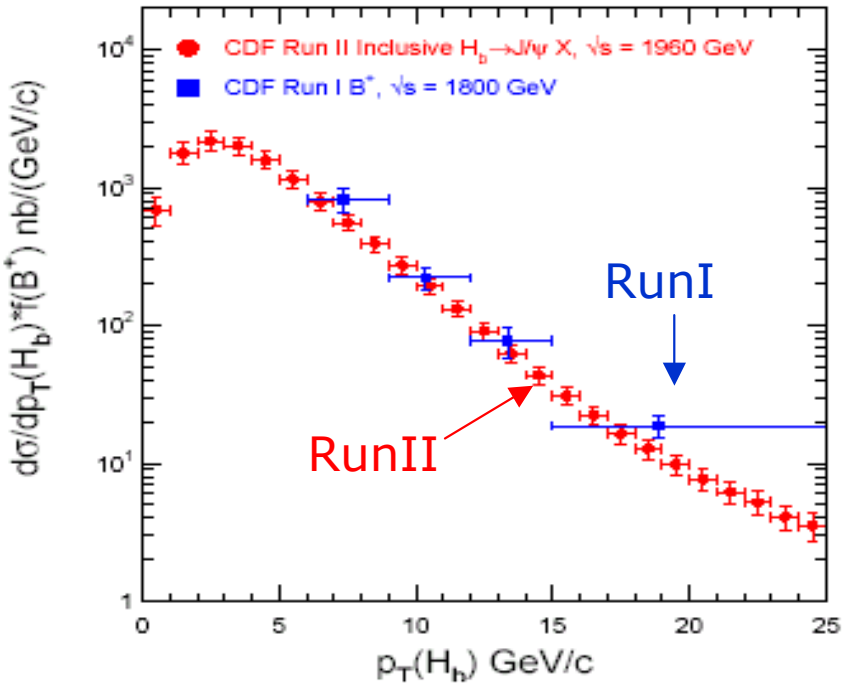
Total inclusive single b-hadron (H_b) cross section

$$\sigma(p\bar{p} \to H_b X, |y| < 0.6) = 17.6 \pm 0.4(stat)^{+2.5}_{-2.3}(syst)\ \mu\mathrm{b}$$

considering $Br(H_b \to J/\psi X)$ = 1.16±0.10% and $Br(J/\psi \to \mu\mu)$ = 5.88±0.10%



comparison with RunI data
$|y(H_b)| < 1$, σ(RunII) multiplied by B^+ fragmentation=0.4
(E_{cm} rescaled)



High P_T b-jet cross section (CDF)

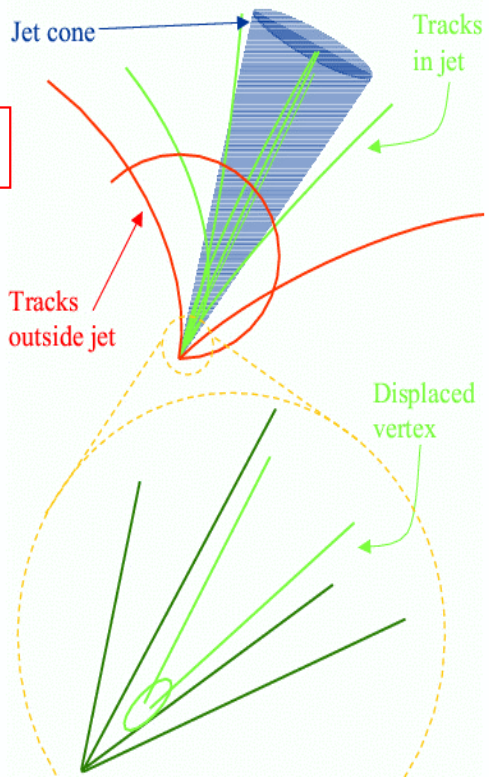
b-jets include most of quark fragmentation remnants

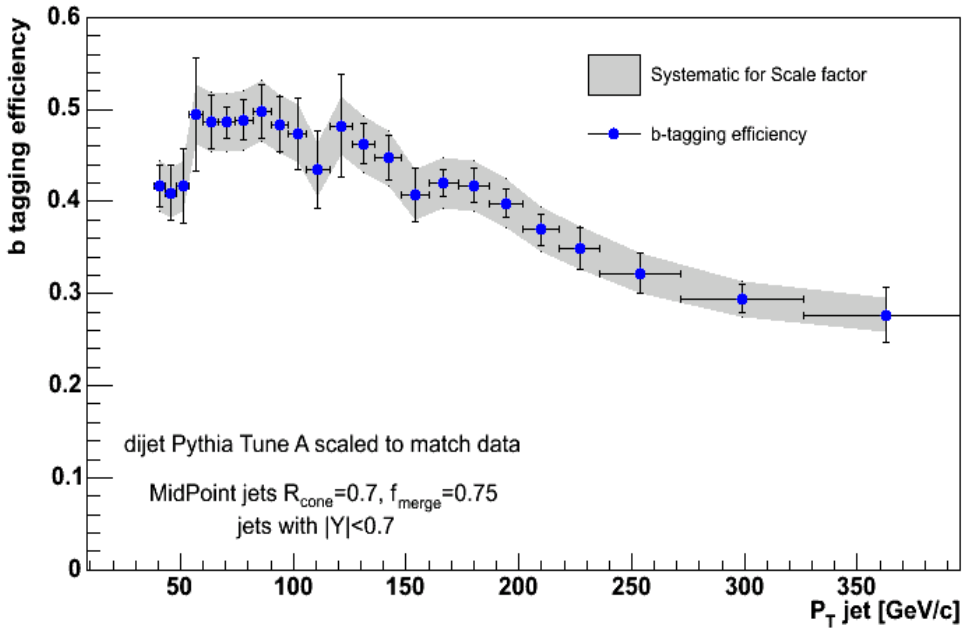
→ *small dependence on fragmentation*

- MidPoint algorithm for jet reconstruction
- kinematics: jet P_T and rapidity (y)
- jet R_{cone} = 0.7, $|y_{jet}|<0.7$
- P_T range 30-360 GeV/c → 38-400 GeV/c

(Energy scale corrected for detector effects)

Lum ~ 300 pb^{-1}

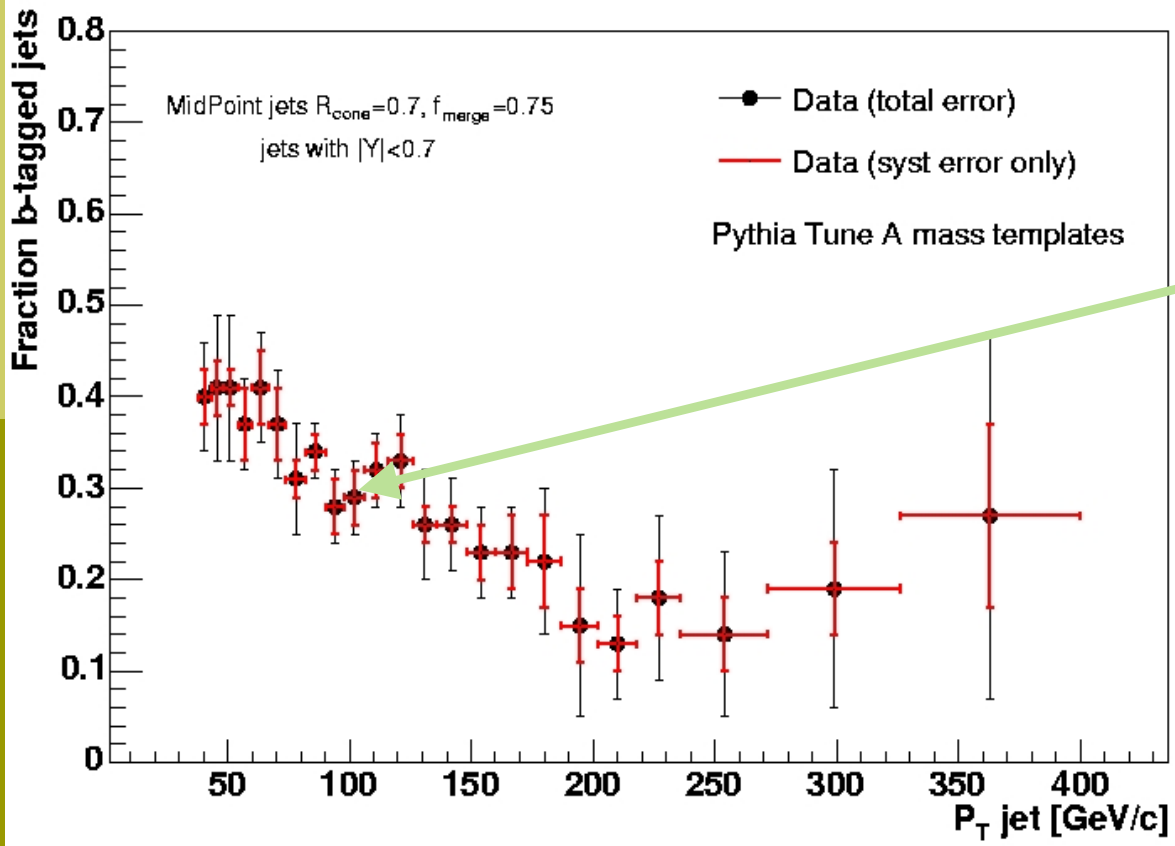


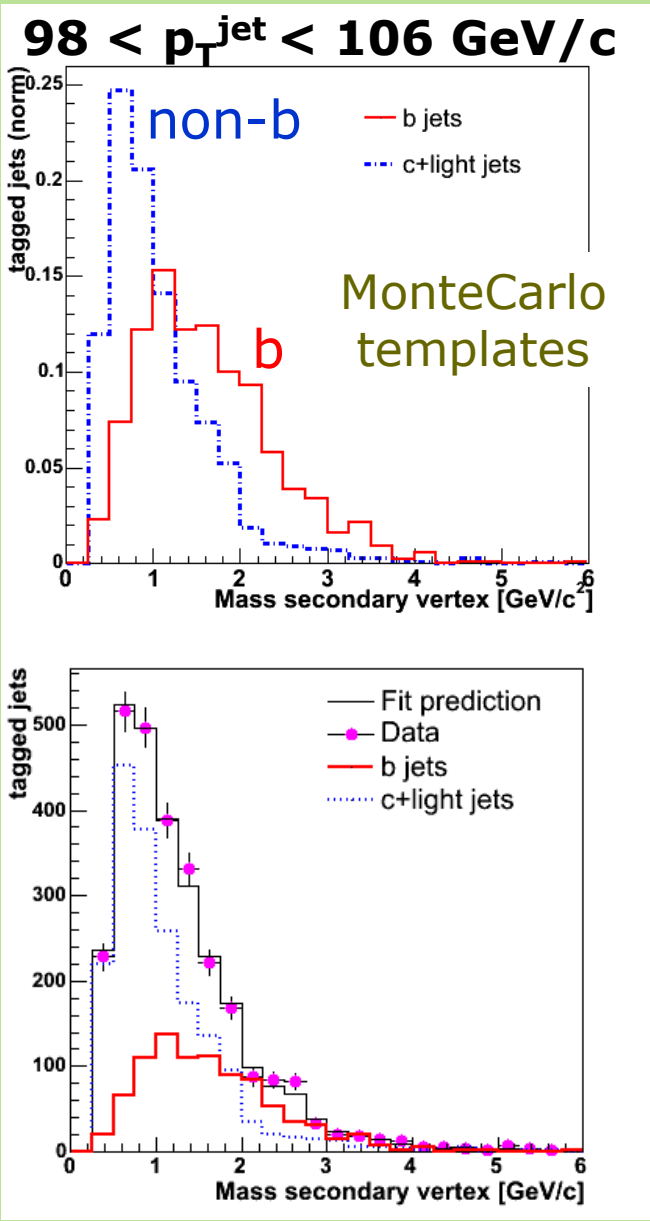


- Use displaced tracks inside jet to reconstruct the secondary vertex (b-tagging)

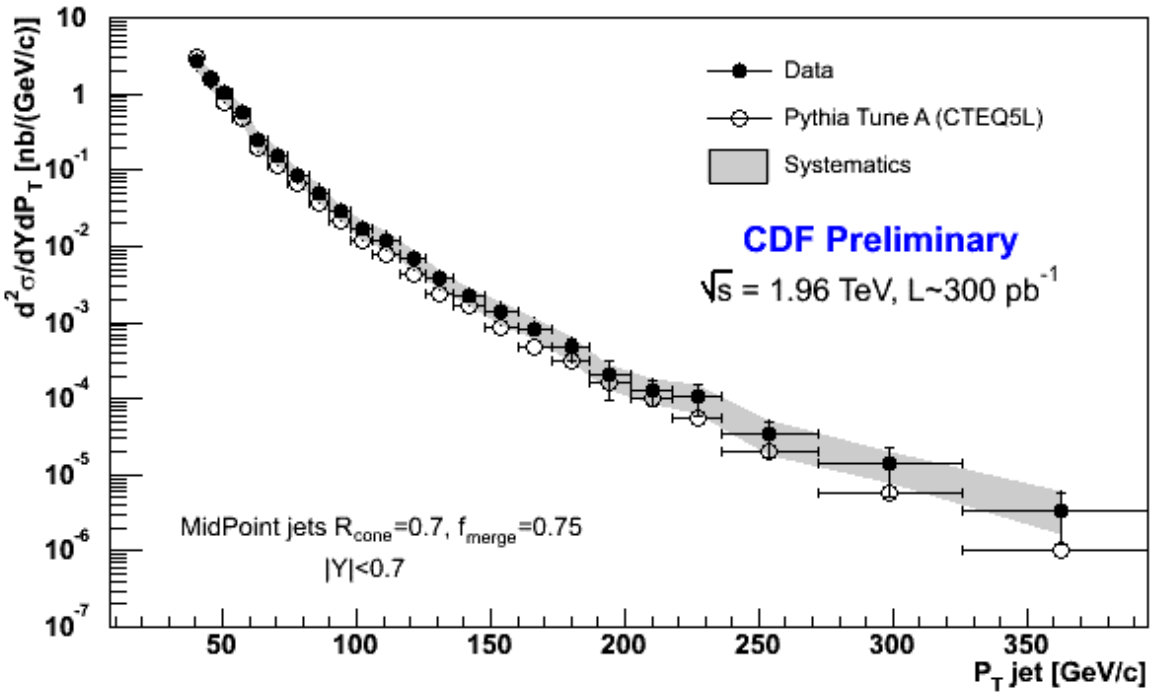
b-jet cross section: b-fraction tagged jets

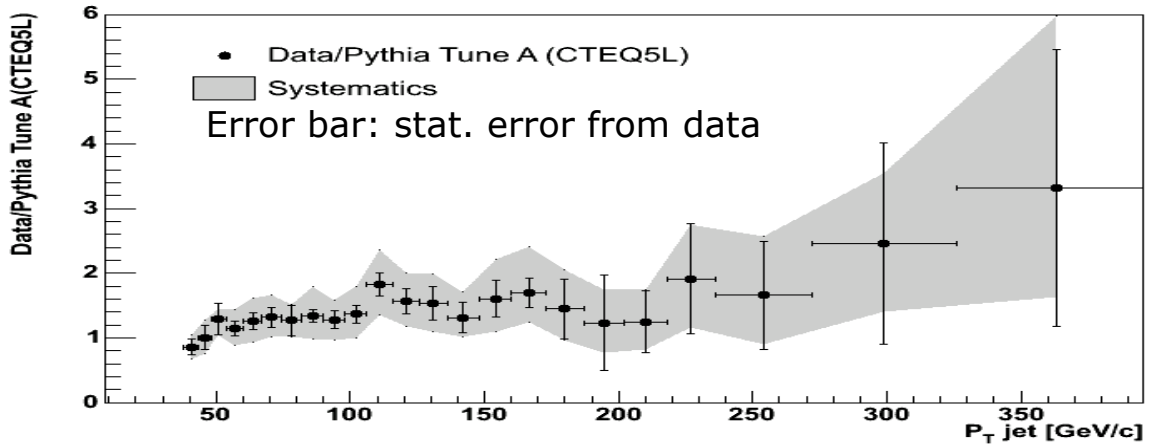
Extract fraction of b-tagged jets from data using shape of mass of secondary vertex as discriminating quantity
→ bin-by-bin as a function of jet p_T





b-jet cross section: results





b-jet cross section as function of jet p_T (Range 38-400 GeV/c)

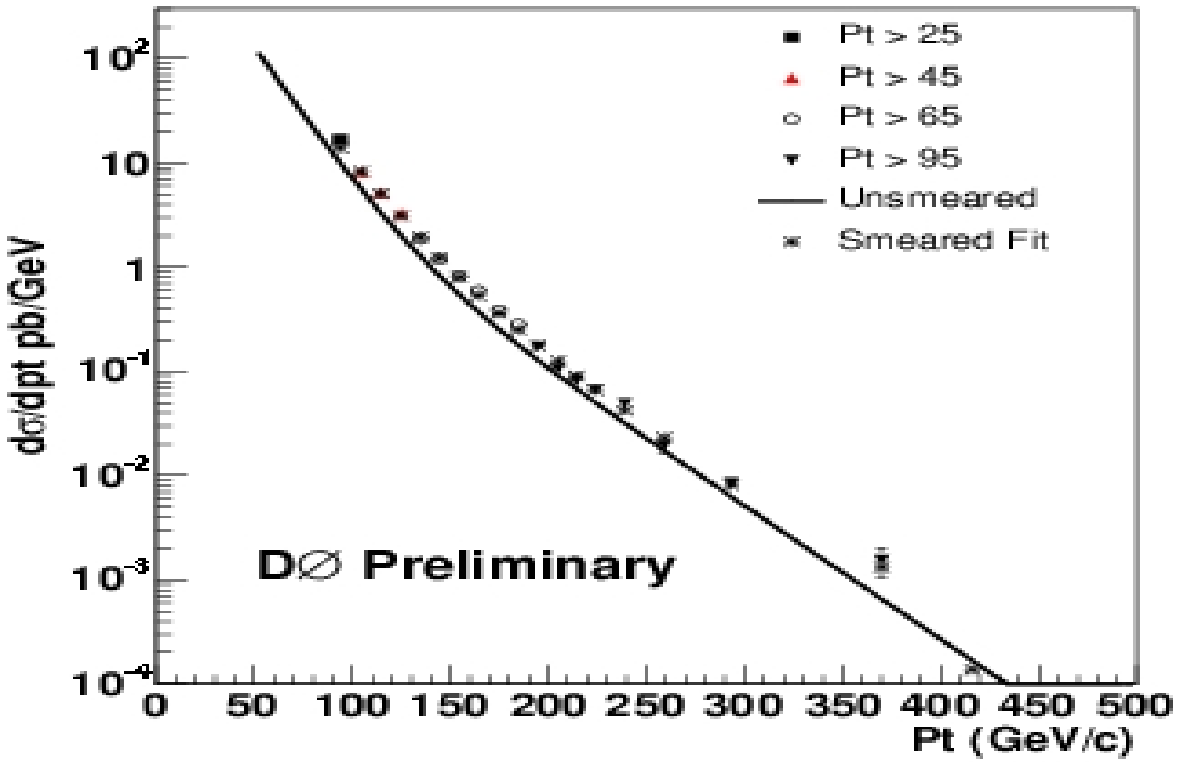
Systematic Error	low P_T	high P_T
Luminosity	6%	6%
Absolute Energy Scale	15-20%	40%
Jet energy resolution	6%	6%
B-tagging efficiency	10%	15%
B-tagged jets fraction	10-15%	40%
Unfolding	8%	8%

No comparison with NLO yet

Data/Pythia Tune A ~ 1.4
in agreement
with expectations

High P_T b-jet cross section (D0)

- Measurement performed also in RunI for $E_{T\ bjet}$ of 30-100 GeV using muon jets
- Preliminary results for μ-tagged jets



- Lum ~ 300 pb^{-1}
- $\Delta R(\mu\text{-jet}) < 0.5$
- $|y_{jet}|<0.5$
- $50<p_T^{jet}<400$ GeV/c

extraction of the b-jet cross section expected soon

Upsilon production (D0)

Subm. to PRD, FERMILAB-PUB-05/020-E

Quarkonium production is a window on boundary region between perturbative and non-perturbative QCD.

Bottomonium states production

- ✓ Prompt
- ✓ $\chi_b \rightarrow \Upsilon(1S)\gamma$

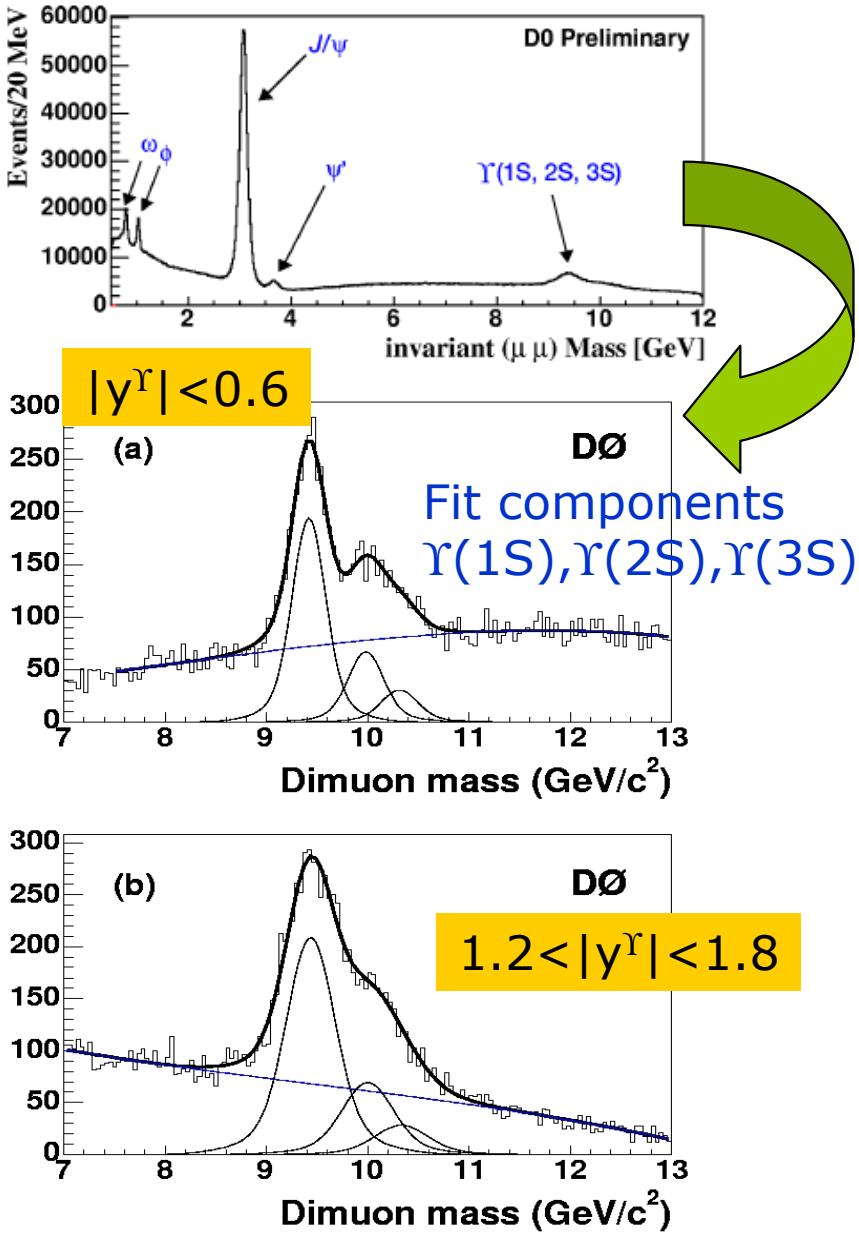
Here: production of $\Upsilon(1S)$ state

$\Upsilon(1S) \rightarrow \mu^+\mu^-$

Lum=159 pb^{-1} (dimuon trigger, ε>99% if p_T^{μ}>5 GeV/c)

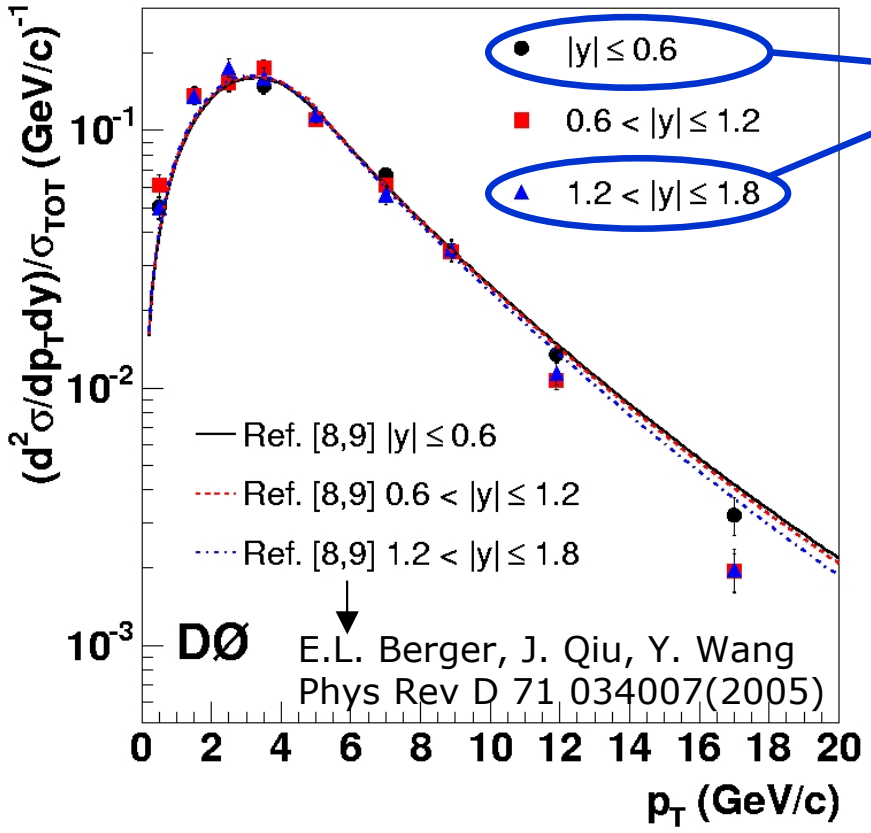
- Function of Υ p_T
- 3 rapidity range
  - 0.<$|y^{\Upsilon}|$<0.6
  - 0.6<$|y^{\Upsilon}|$<1.2
  - 1.2<$|y^{\Upsilon}|$<1.8

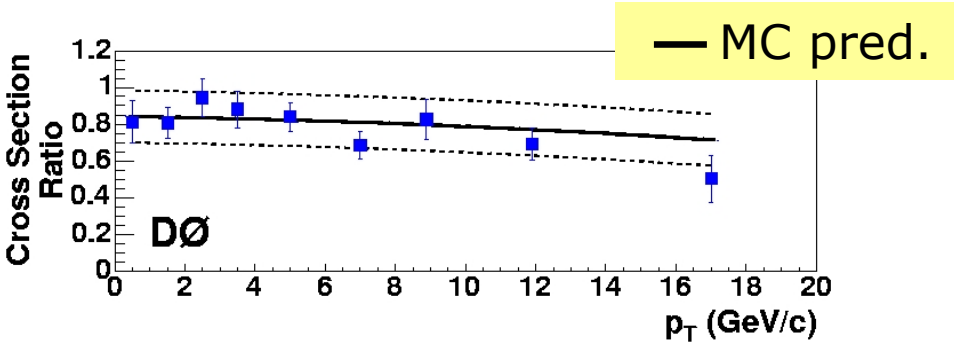
$p^{\Upsilon}_T \in [4,6]$ GeV/c



Upsilon production: results

ϒ(1S) cross section extracted

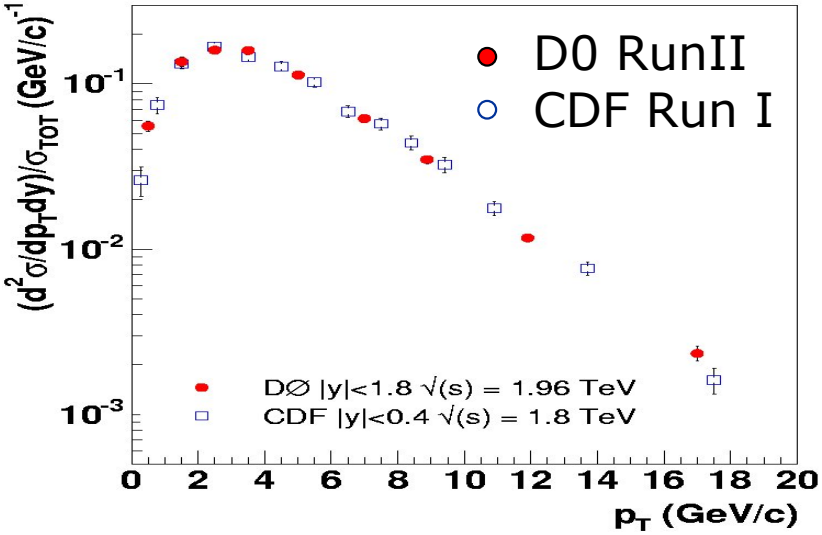




$d\sigma/dy*Br(\Upsilon \rightarrow \mu\mu)=$

732±19(stat)±73(syst)±48(lum) pb

[CDF RunI: 680±15(stat)±18(syst)±26(lum)
Factor 1.11 between 1.96 and 1.8 TeV Ecm]



- ✓ Assume ϒ(1S) production unpolarized
- ✓ small effect due to rapidity range
- ✓ good agreement with theory prediction

Summary and Conclusion

- Studies of beauty production are precision tests of NLO pQCD
- New RunII measurements reported:
  - Central b-hadron cross section extracted from J/ψ production → very good agreement with recent theoretical prediction.
  - New b-jets analyses considerably extend range in p_T of cross section: for CDF, NLO (and beyond) comparison expected soon, LO comparison as expected.
  - Improved measurement for Bottomonium production in a wider rapidity range: in agreement with earlier results and with theoretical expectation.
- Many further improvements are expected…:
  - Extraction of b-jet cross section from μ-tagged jets (D0)
  - $b\bar{b}$ cross section and correlations studies