



# *Charm and Beauty Production at Fermilab*



**Thorsten Kuhl**

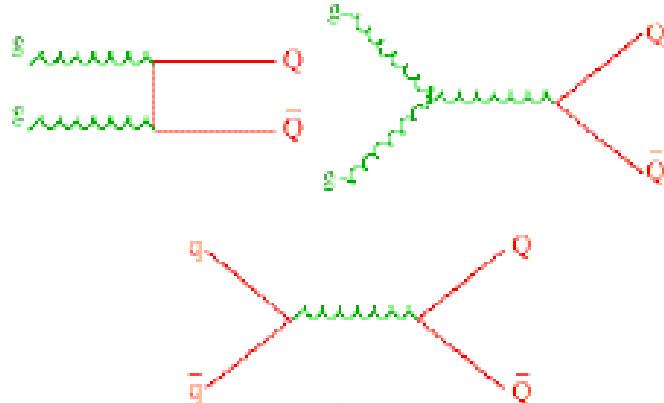
**La Thuile QCD 2007**

- Motivation
- Tevatron & DØ detector
- Results
  - Open Flavors
  - Quarkonium
- Conclusion and outlook

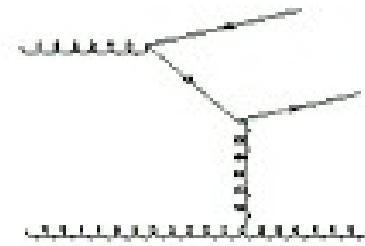


- Heavy flavor Production:  $m_Q > L_{QCD} \rightarrow$  should be well predictable
- Calculation in FONLL are available

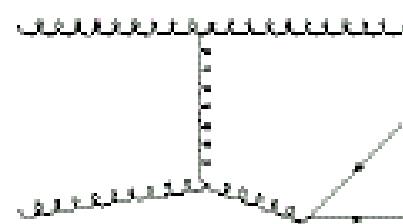
Leading Order:  
Flavor production



Next-to-leading Order  
Flavor excitation



Gluon splitting

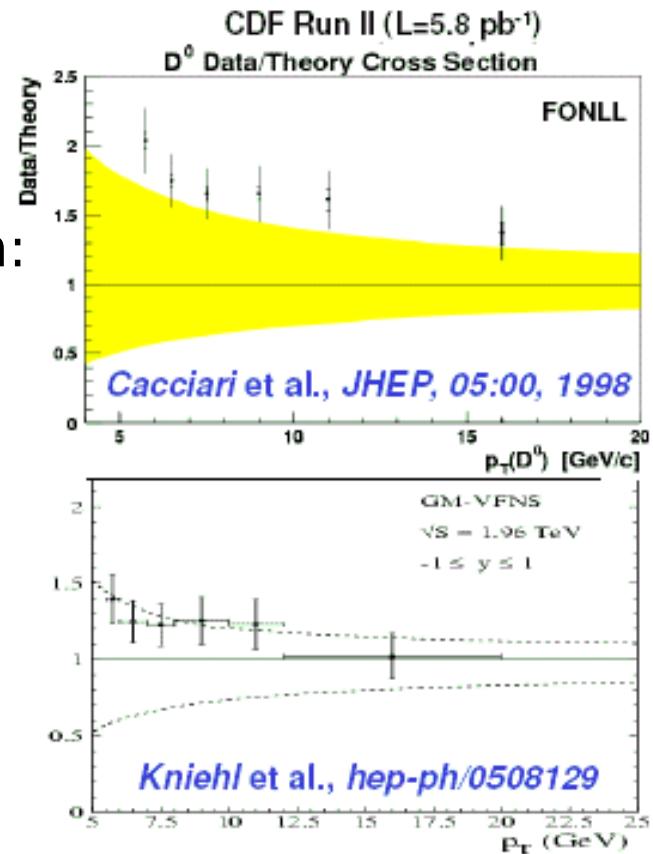
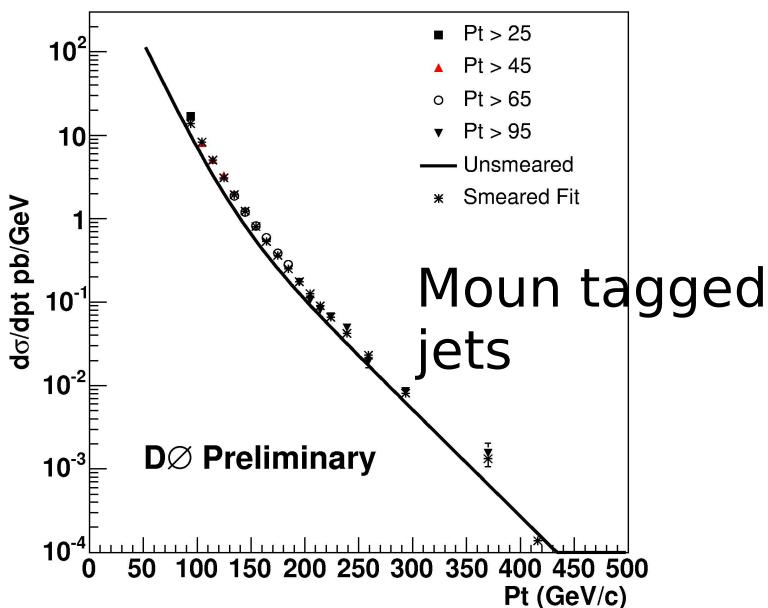




# Ccharm and Beauty production

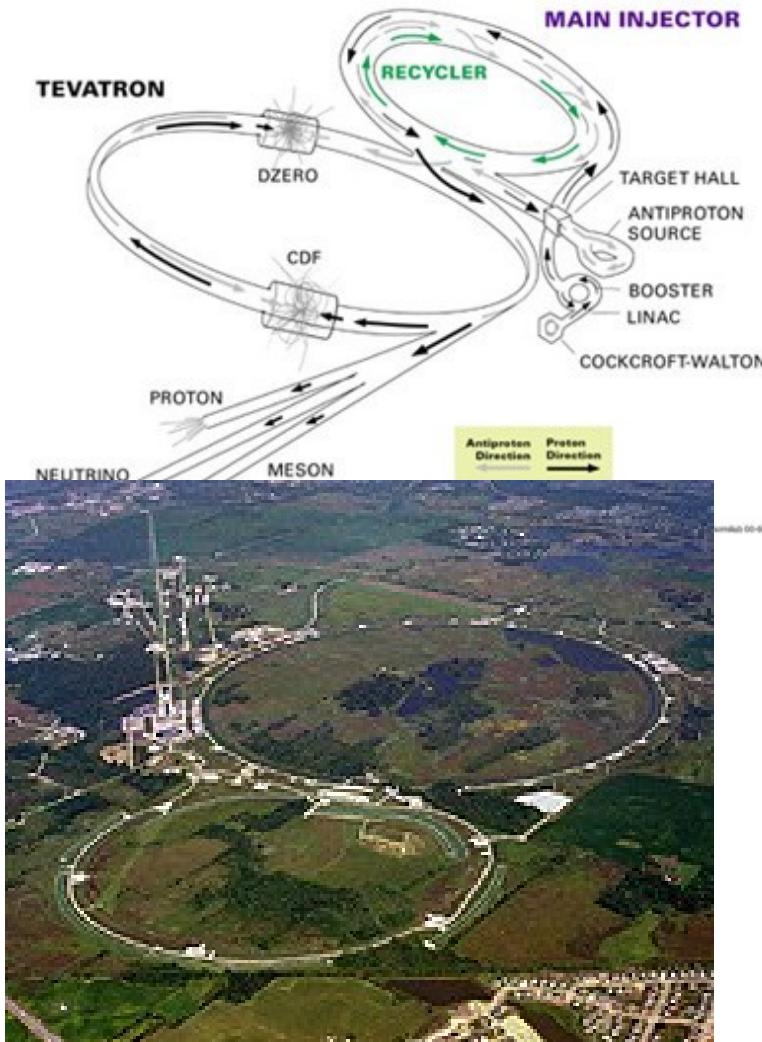


- Theory improves but still measured cross sections higher
- A Lot of measurements systematic limited
- Talk concentrate on production mechanism: charm-charm correlation; J/ $\Psi$  polarisation





# Tevatron

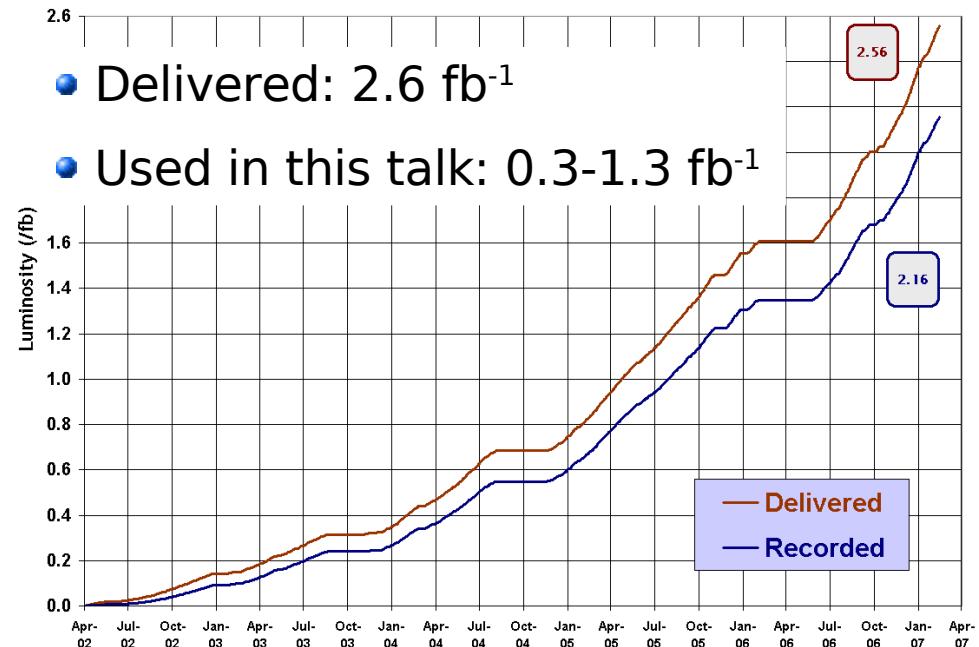


- pp collisions @  $\sqrt{s} = 1.96 \text{ TeV}$
- Bunch spacing: 396 ns
- Inst. luminosity: max.  $230 \cdot 10^{30} \text{ cm}^{-2}\text{s}^{-1}$

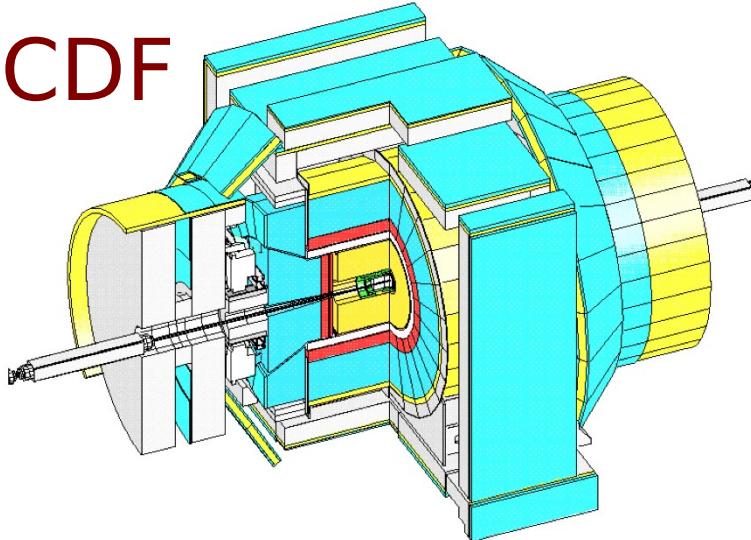


Run II Integrated Luminosity

19 April 2002 - 4 March 2007

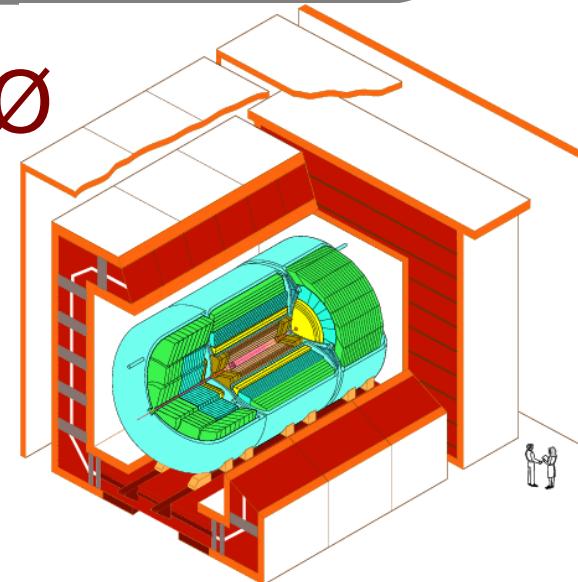


CDF



- Excellent mass resolution + particle ID
- Displaced vertex trigger: fast track trigger at Level 1 add SVT at Level 2
- Hadronic and semileptonic modes

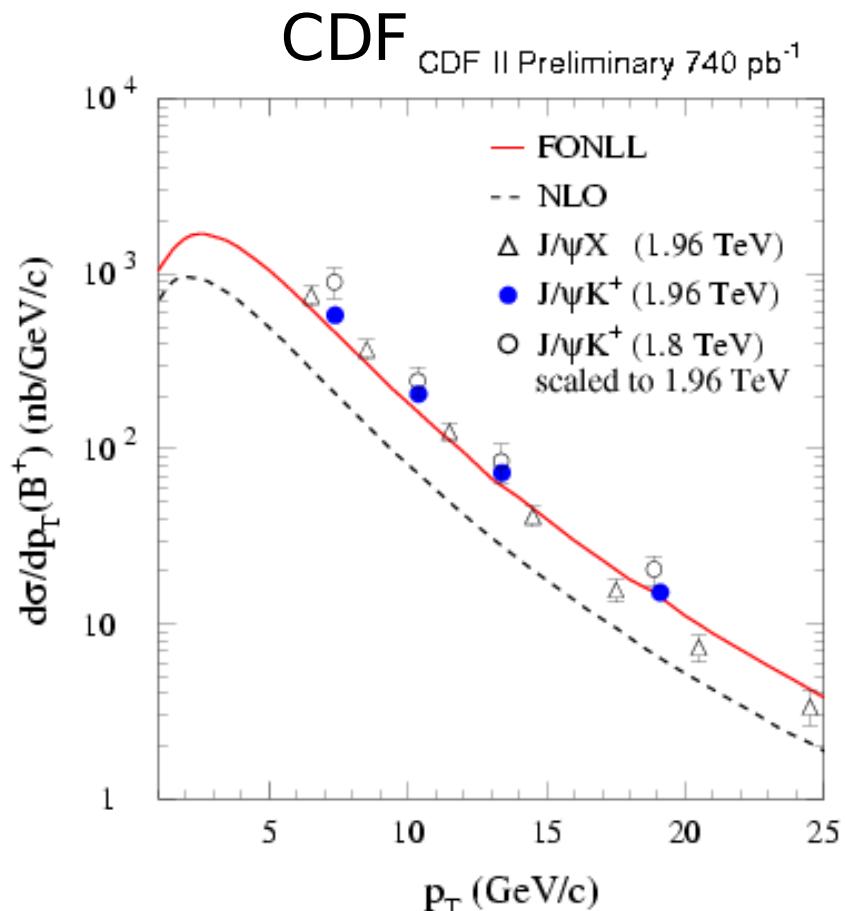
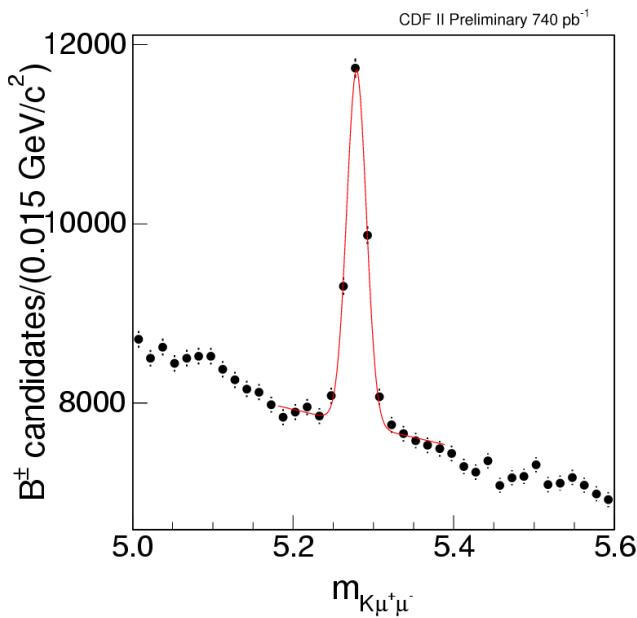
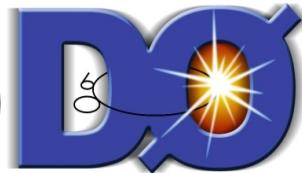
DØ



- Good Muon coverage ( $|h| < 2$ ) and forward tracking → high rapidities, high yields
- Di-Muons and semileptonic modes



# $B^+$ Production



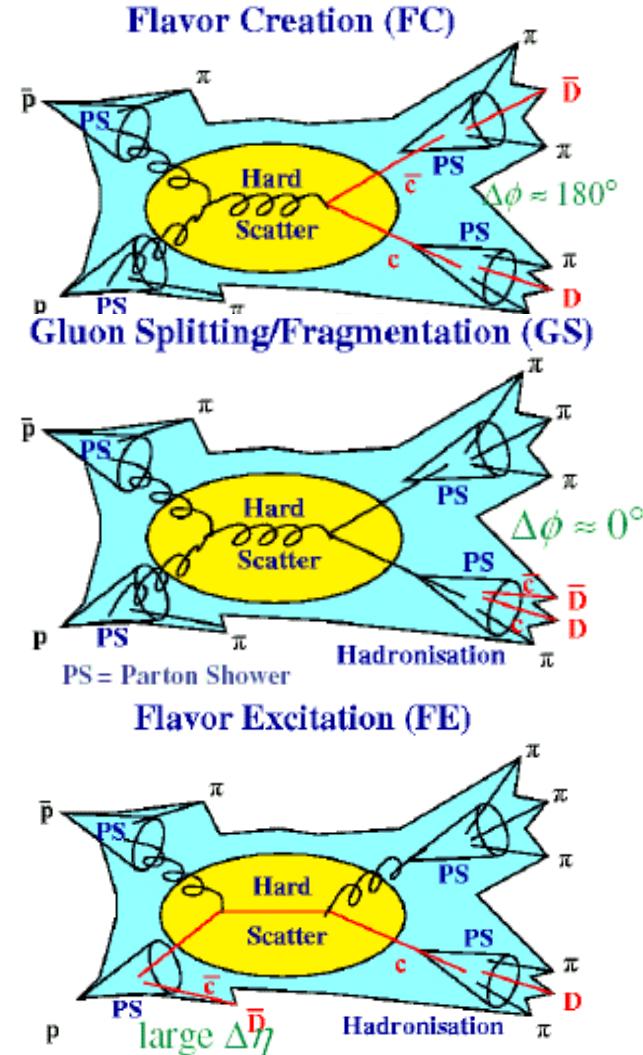
- New result with  $740 \text{ pb}^{-1}$  data
- $8197 \pm 239$  candidates
- data still higher than FONLL



# Charm-charm Correlation

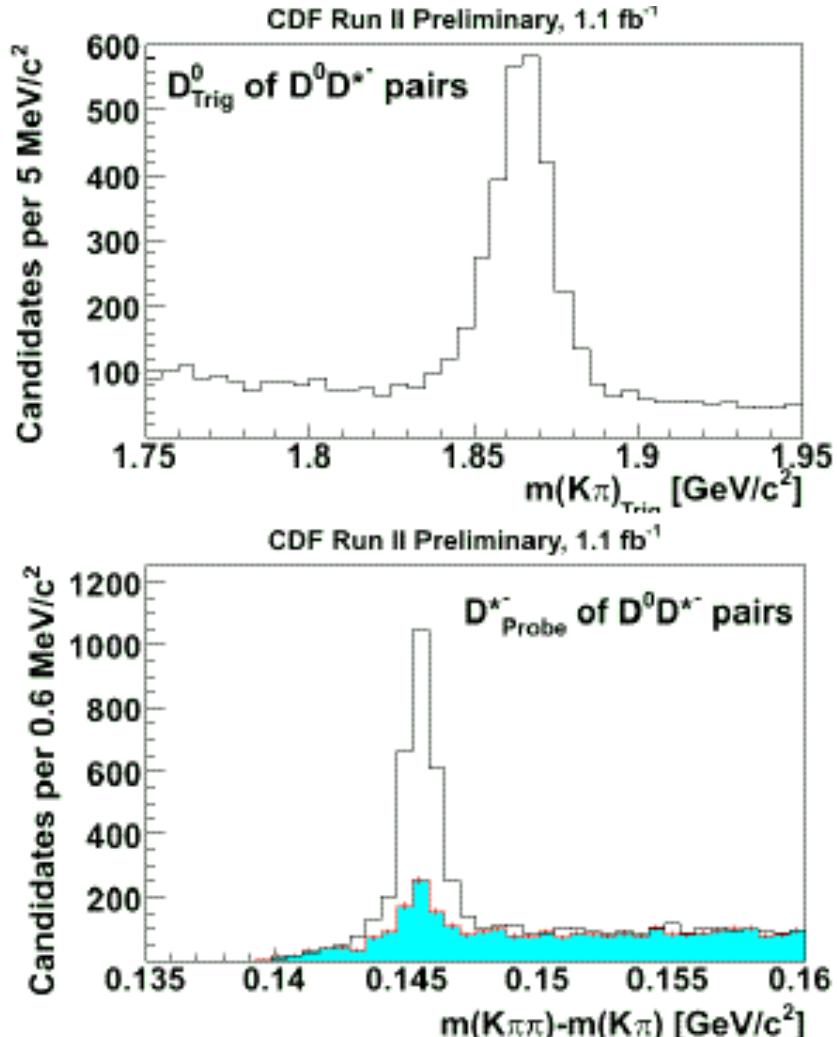
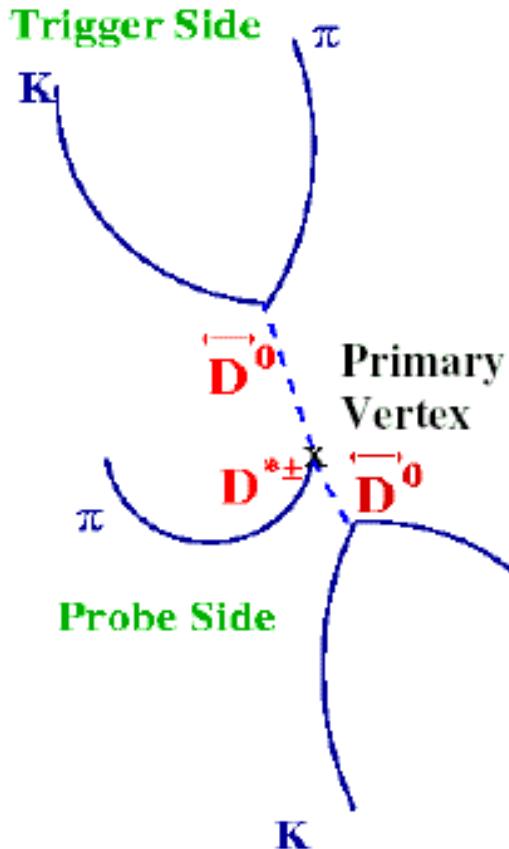


- Study of fully reconstructed charm Mesons
- Angular correlation: access to the underlying production process:
  - Flavor creation: large angle in  $\phi$
  - Gluon splitting: close together
  - Flavor excitation: large angle in  $\eta$
- Experimental approach:
  - Select triggered charm meson
  - Look for second charm meson (Probe)





# Charm Pair Production Correlation



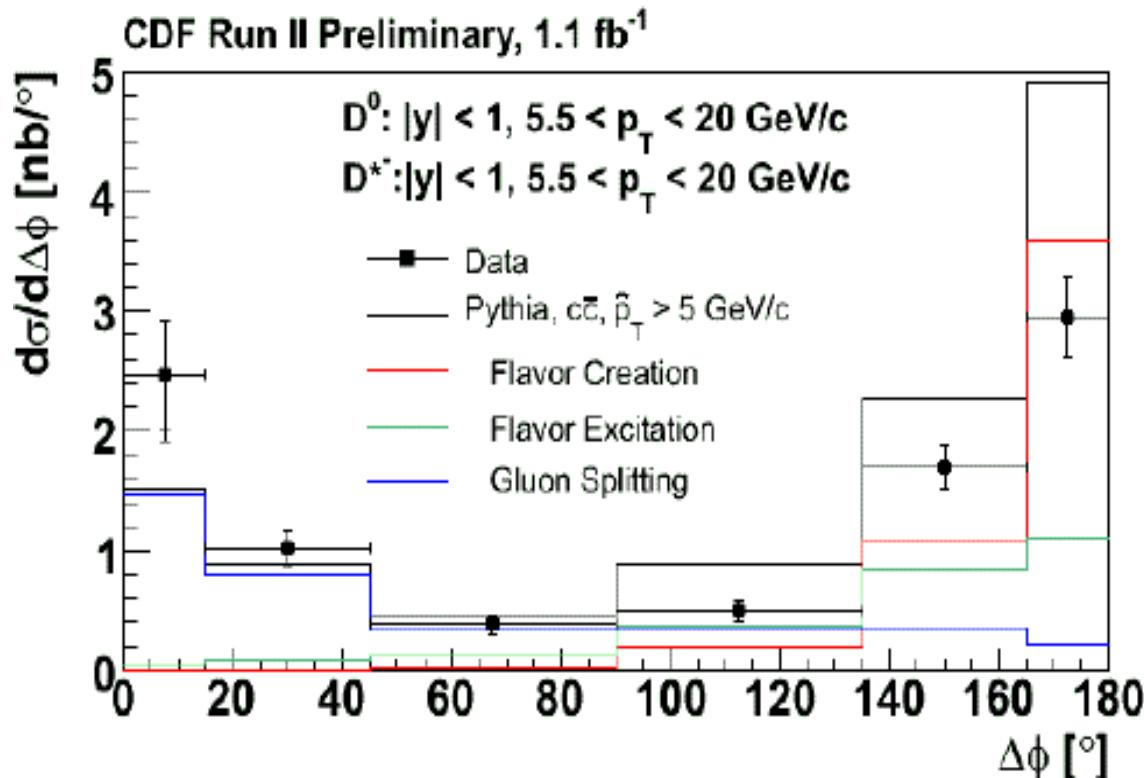
- Background subtraction using sidebands in the 2-dim  $mKp$ -  
 $mKpp$ -plane

20.03.2007

# CDF Run II Preliminary, 1.1 fb<sup>-1</sup>

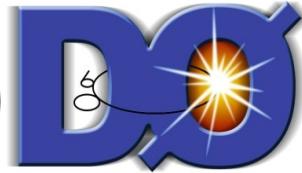
## Charm Pair Production: Theory and Results

- 1.1fb<sup>-1</sup> analysis
- More Flavor creation/less gluon splitting in the Monte Carlo than in data
- Error: stat  $\oplus$  syst ( $f_{bb} \sim 15\%$ , Fraction from bb)

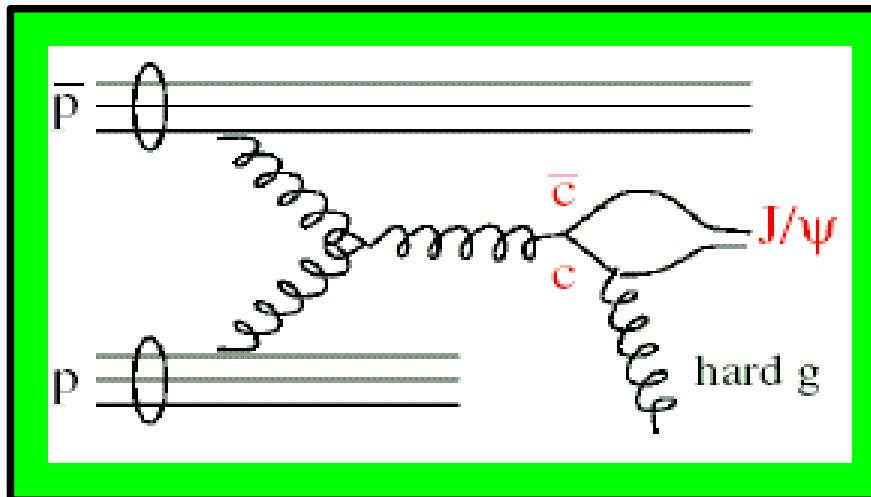




# Quarkonium

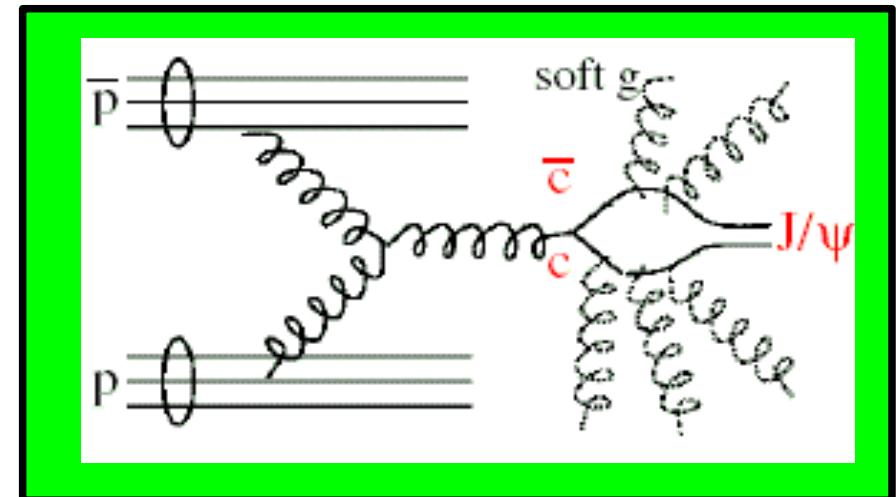


- Color singlet model:



- $J/\Psi$  + hard gluon (color)
- cross section factor 10-50 too low
- wrong  $p_T$  spectrum

- Color octet model:



- soft gluon radiation
- predicts correct  $p_T$  spectrum and adjustable to experimental cross section
- predicts transverse polarisation

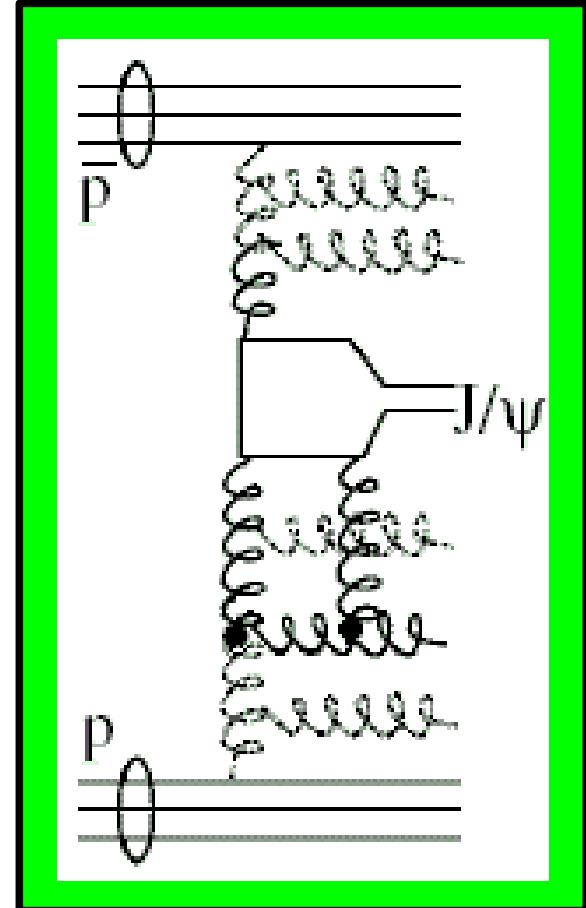


# Quarkonium



- New pomeronic ID:

- fusion state of color octet state with gluon
- predicted cross section and  $p_T$ -spectra match data
- expect longitudinal polarization of prompt  $J/\Psi$  increasing with  $p_T$

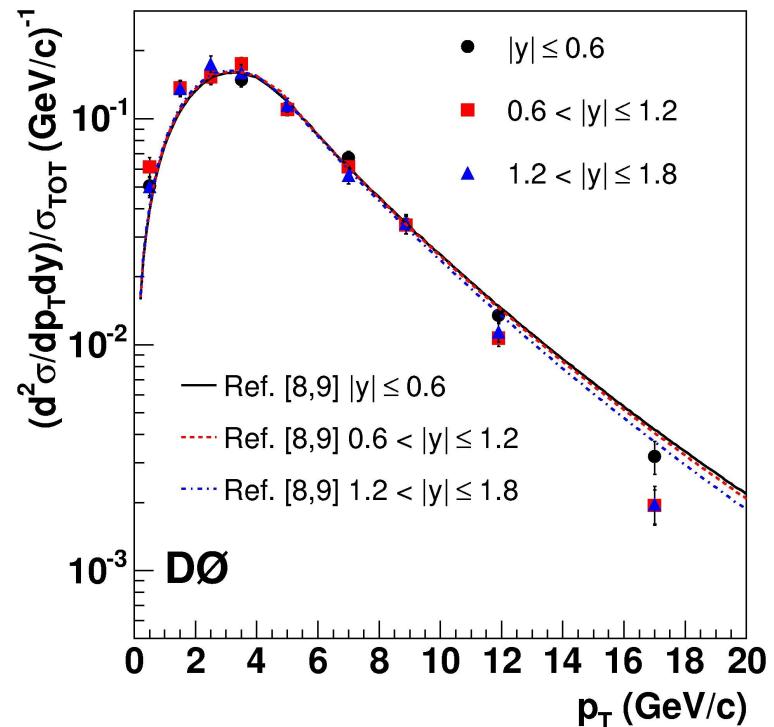
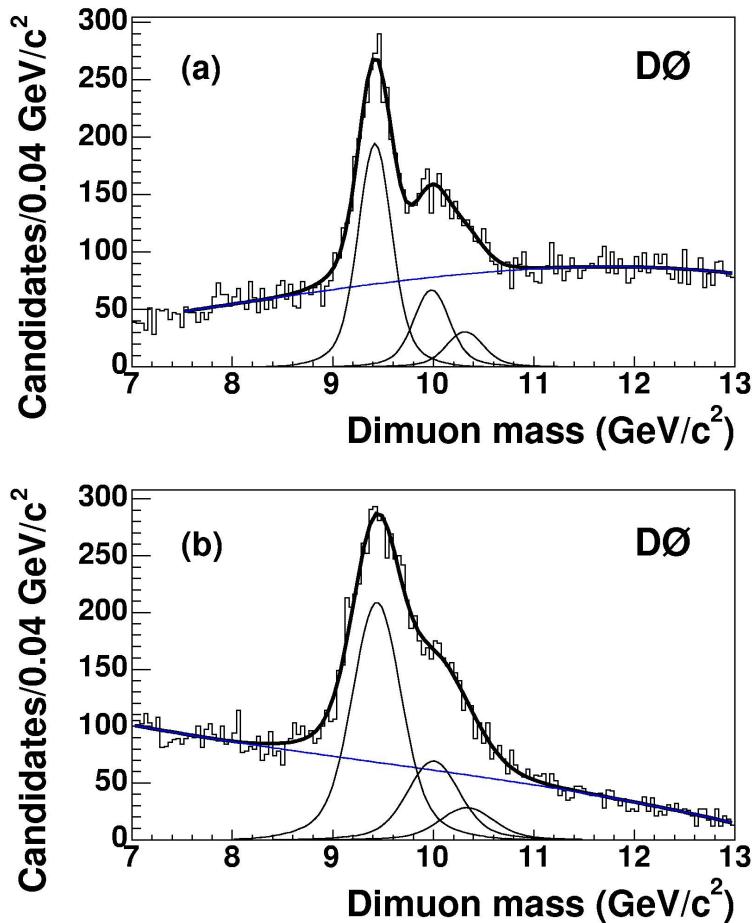




# Bottomium



$\Upsilon(1S), \Upsilon(2S), \Upsilon(3S)$



$$\sigma = 732 \pm 19(\text{stat}) \pm 73(\text{sys}) \pm 4(\text{lumi}) \text{ barn}$$



# Bottomium



Updated sample with 1.3fb-1

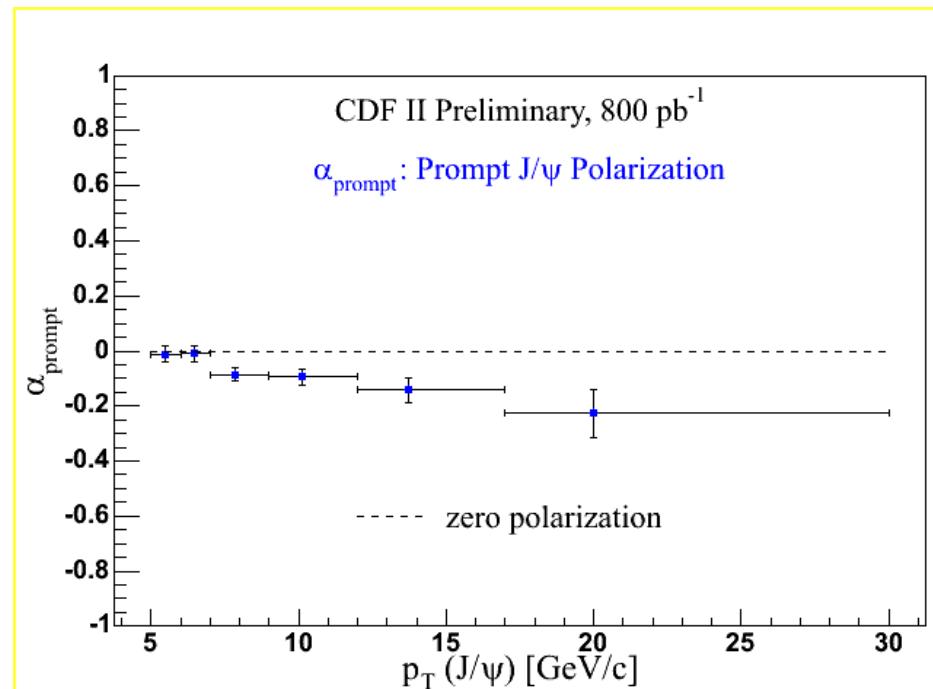
Preliminary, analysis in progress  
Polarization measurement in  
preparation



# Charmonium

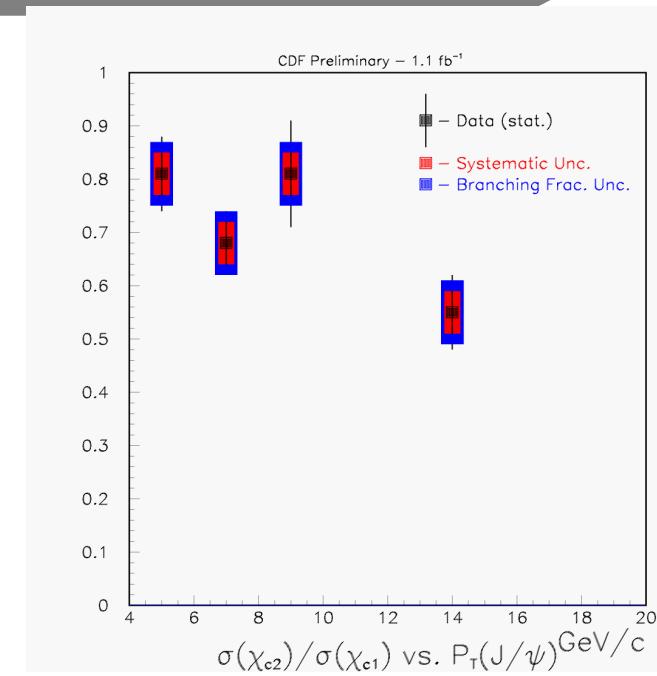
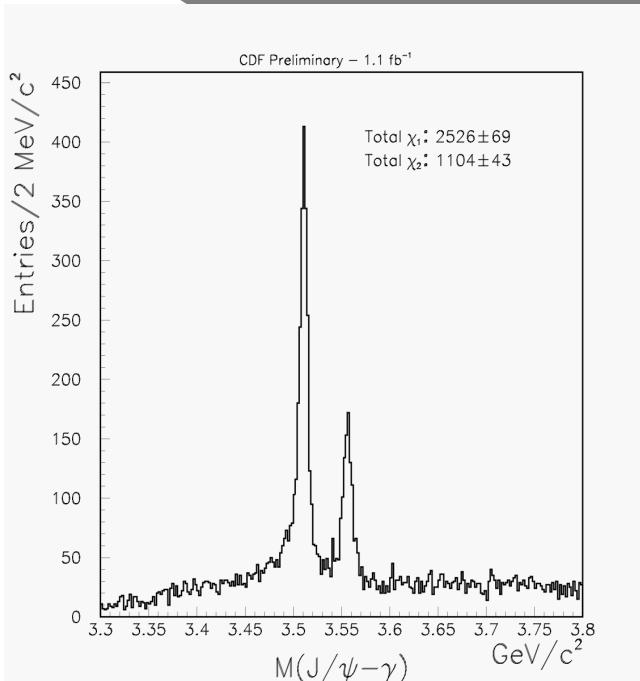


- Measurement of  $J/\Psi$  polarisation ( $800\text{pb}^{-1}$ )
- huge event sample (800000 events)
- Measurement of polarisation of  $J/\Psi$  from B-decay consistent with BaBar ( $\alpha_B = -0.066 \pm 0.05$ )
- longitudinal polarisation increasing with  $p_T$  like predicted from pQCD





# $\sigma(\chi_{c2})/\sigma(\chi_{c1})$ Measurement



- New 1.1fb<sup>-1</sup> Result: (about 3600 candidates)
  - prompt production:  
 $\sigma(\chi_{c2})/\sigma(\chi_{c1}) = 0.70 \pm 0.04(\text{stat.}) \pm 0.04(\text{sys.}) \pm 0.06(\text{B.F.})$
  - B decay production:  
 $\sigma(\chi_{c2})/\sigma(\chi_{c1}) = 0.25 \pm 0.07(\text{stat.}) \pm 0.01(\text{sys.}) \pm 0.02(\text{B.F.})$



# Summary



- Heavy flavor production is important topic at Tevatron
- Theory improves but still does not match data perfectly
- improved statistics allow detailed studies of production measurements:
  - Charm-charm production correlation: access to the production mechanism
  - Cross section and polarisation of Quarkonium production is described by pQCD
- Not covered:
  - b-Jet ( --> new double tagged result will be presented in talk about jet physics)
  - b+photons (dedicated talk this session)
- Future ( $6\text{-}8 \text{ fb}^{-1}$ ) allows more precise (factor 2) look into the details of heavy quark production