Moriond QCD
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Charmed Meson, Onia Production/Polarisation at the Tevatron

(for CDF collaboration)

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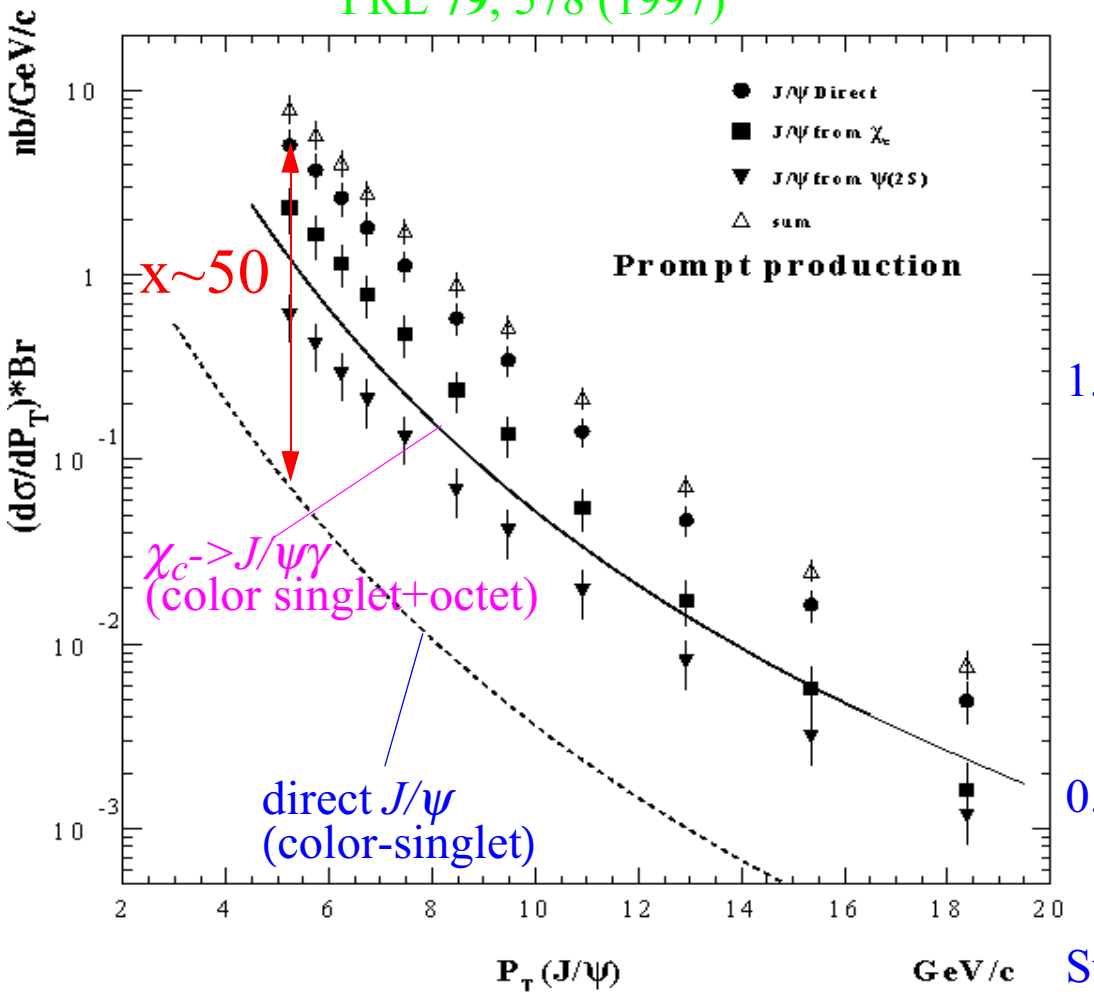
(this work has been done at the University of Chicago)

1. Physics Motivation
   (CDF anomaly for J/ψ production, b-quark production...)
2. What's new?
3. Charmed Meson (D^{*+}) Production cross section.
4. J/ψ, ψ(2S) production/polarization
5. Y(1S) production/polarization
6. Summary and Conclusion

1. Physics Motivation (CDF Anomaly)

J/ψ production

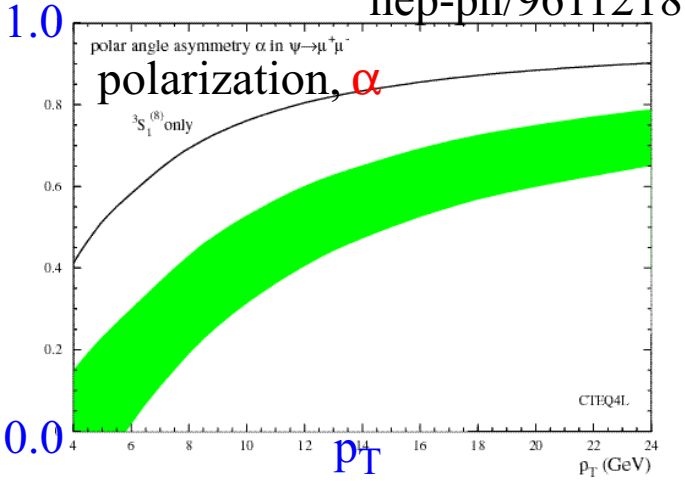
PRL **79**, 578 (1997)



Color Singlet Model off by a factor of **~50**

Color Octet Model (NRQCD) is proposed.

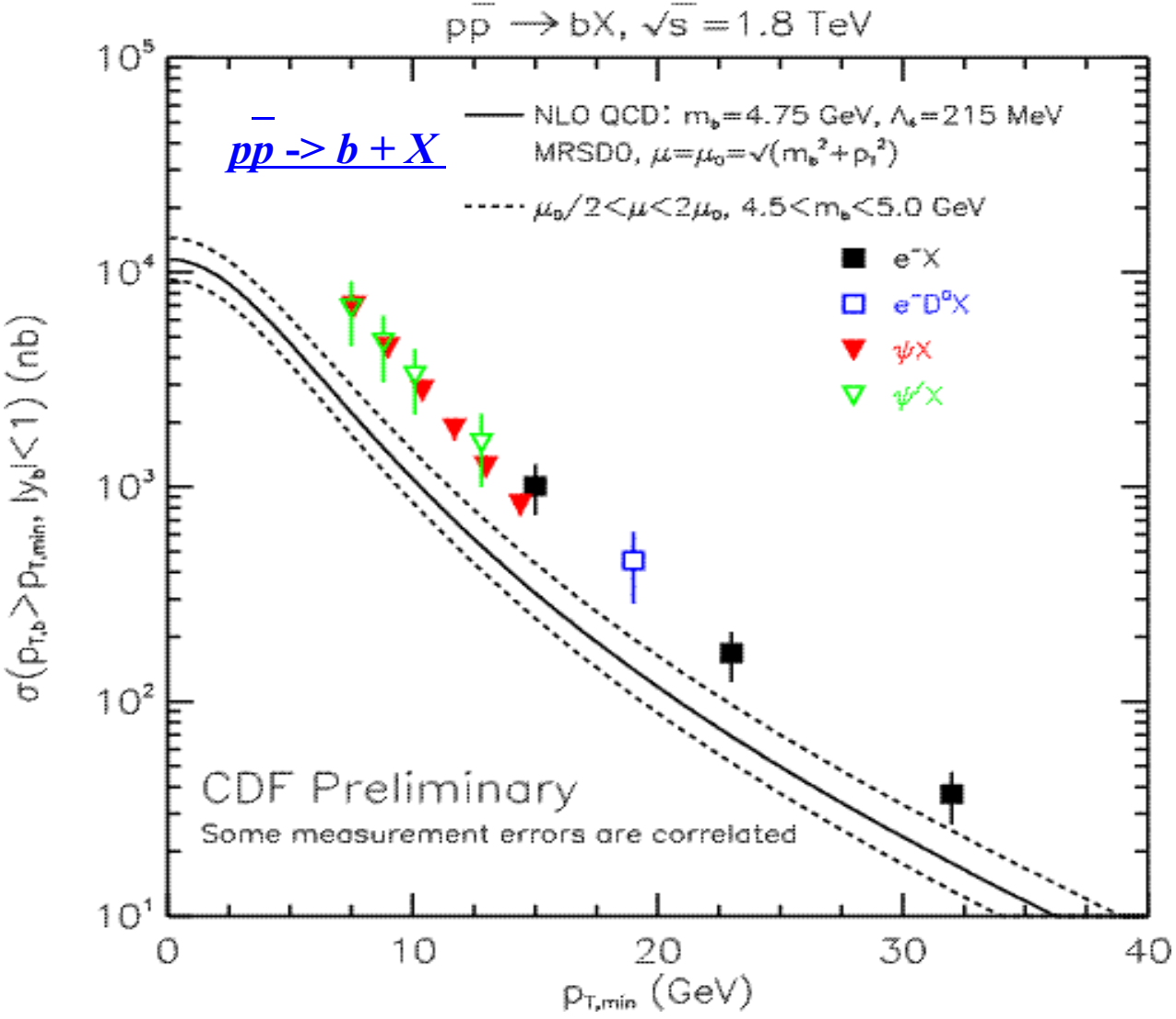
hep-ph/9611218



$g \rightarrow c\bar{c} \rightarrow J/\psi$

Study Υ(1S) production/polarization

Open Heavy quark production ($p\bar{p}$ -> $Q + X$)



***b* quark cross section**

DATA

~ **x 2-3** than a theory

How is charm?

NO measurement, so far

2. What's new?

1. First Measurement of $\sigma(p\bar{p} \rightarrow D(2010)^{*+} + X)$
   -> probe charm quark production

2. New Measurement of J/ψ production/**polarization**
   -> Is a measured cross section consistent with a theory?
   -> A theory predicts a large transverse polarization at high p_T.

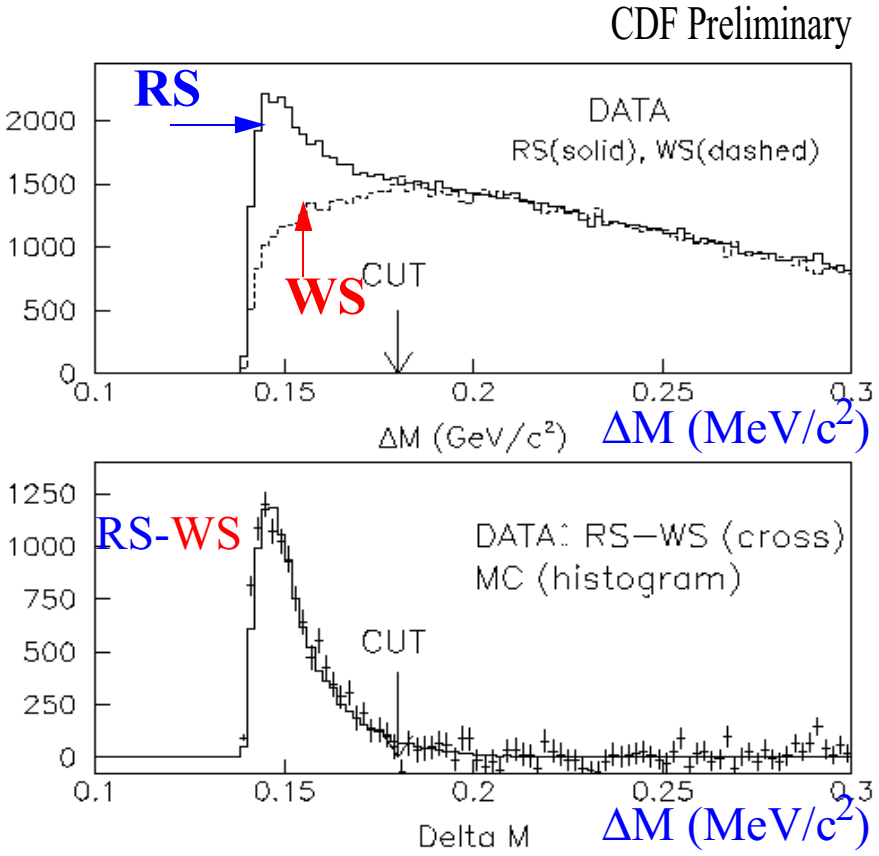
3. New Measurement of $\Upsilon(1S)$ production/**polarization**
   -> Is a measured cross section consistent with a theory?
   -> What is polarization?

3. Charmed Meson ($D^{*\pm}$) Production cross section (~86.5pb^{-1}).

$D^{*+} \rightarrow D^0\pi^+_s \rightarrow (K^-\mu^+ + X) + \pi^+_s$ (and the charge conjugation.)

Look for $\Delta M = M(\mu K\pi_s) - M(\mu K)$ [~ $M\pi$ + Q(=6MeV)]

signal of D^{*+}



Right Sign (RS): $\mu^+K^-\pi_s^+$

Wrong Sign (WS): $\mu^+K^-\pi_s^-$

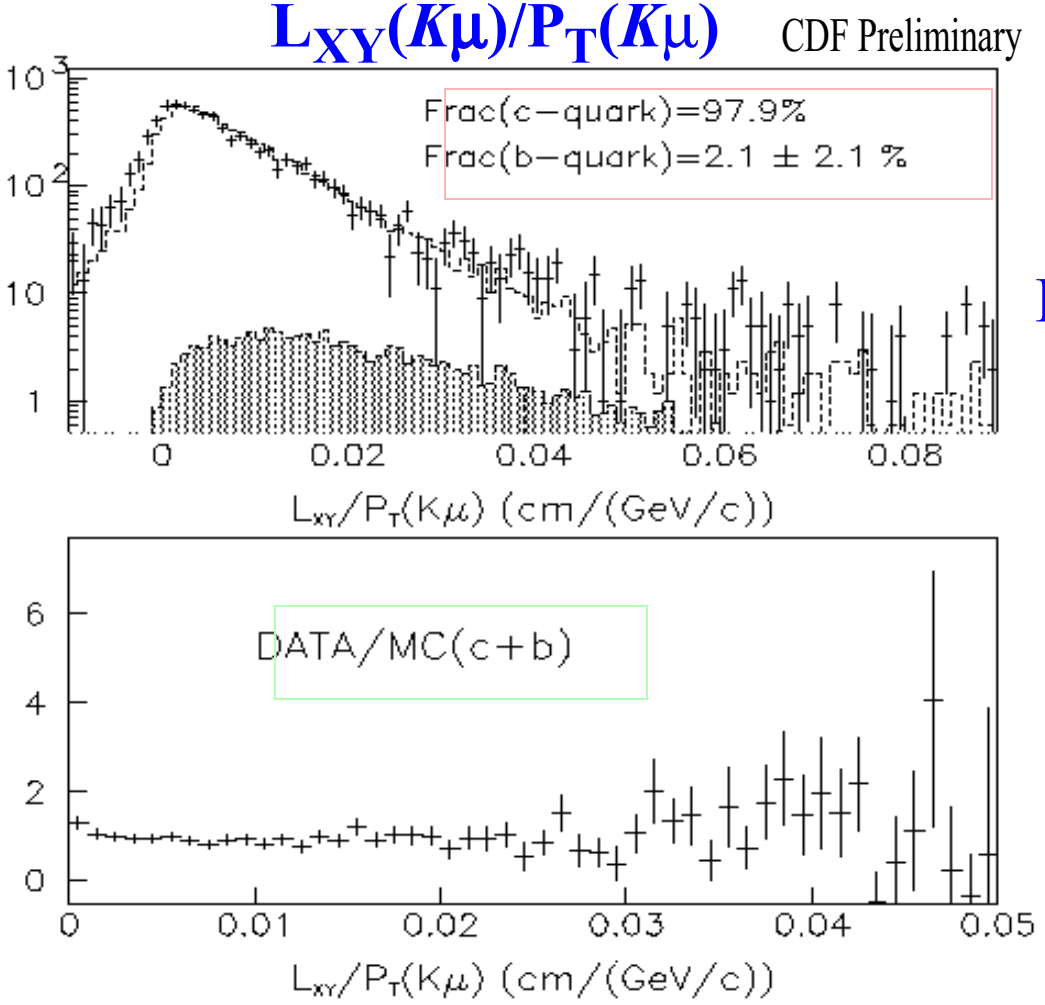
(RUN-IB)

$\mathbf{N(D^{*\pm})} = N(RS) - N(WS)$

$= 19{,}457 - 11{,}437$

$= \mathbf{8{,}020 \pm 176}$

$D^{*\pm}$ fraction: mostly charm quark contribution.

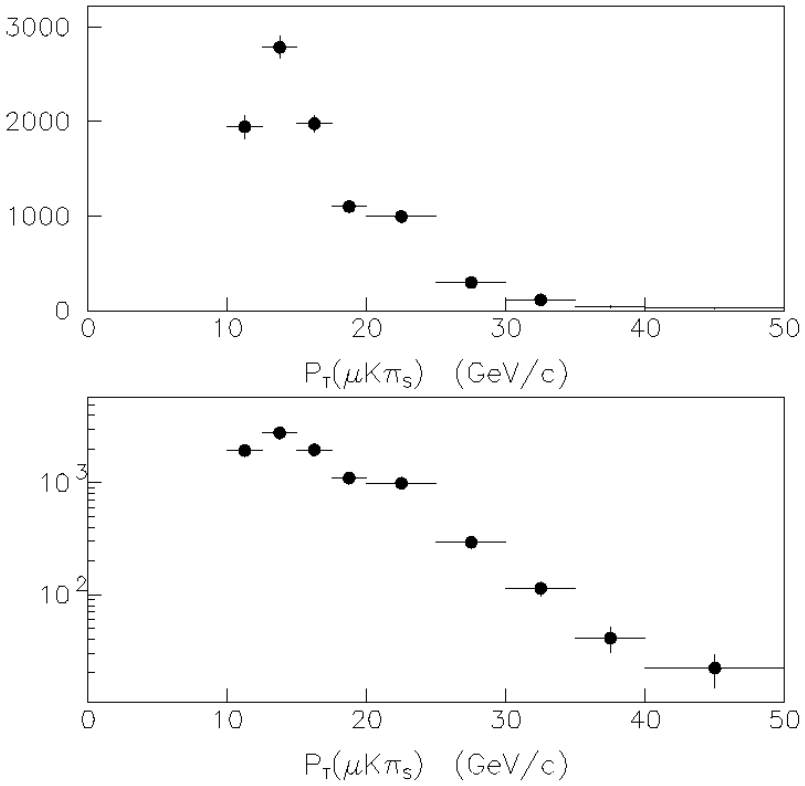


$L_{XY}(K\mu) = D^0$ decay point

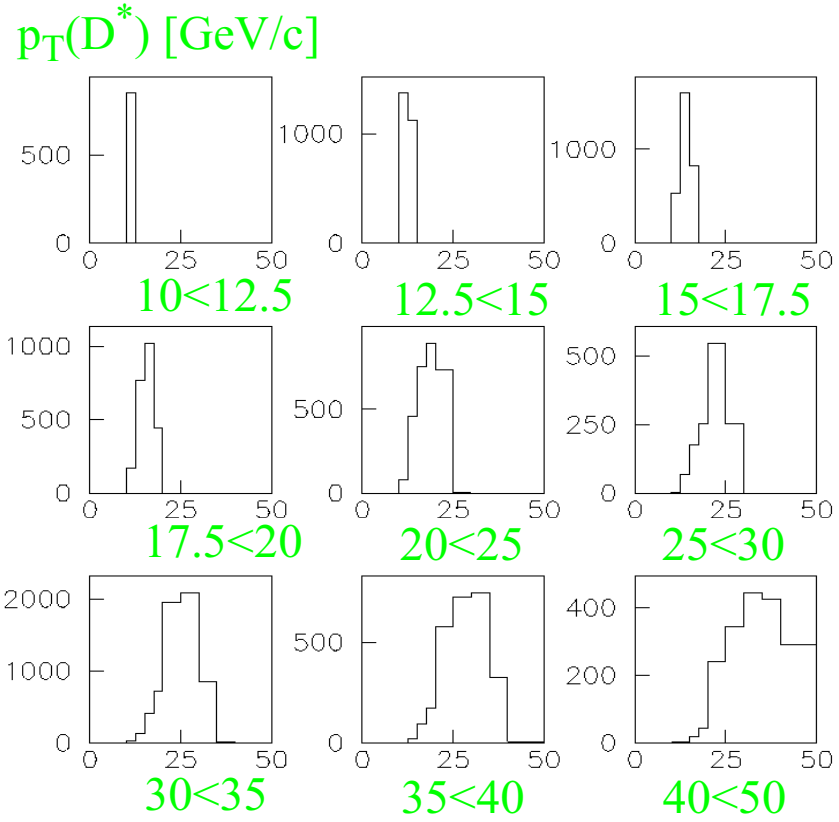
98% from charm-quark

Fit the $P_T(\mu K\pi_s)$ distribution with the MC templates, and measure the fraction of $D^{*\pm}$ signals with each P_T bin.

DATA



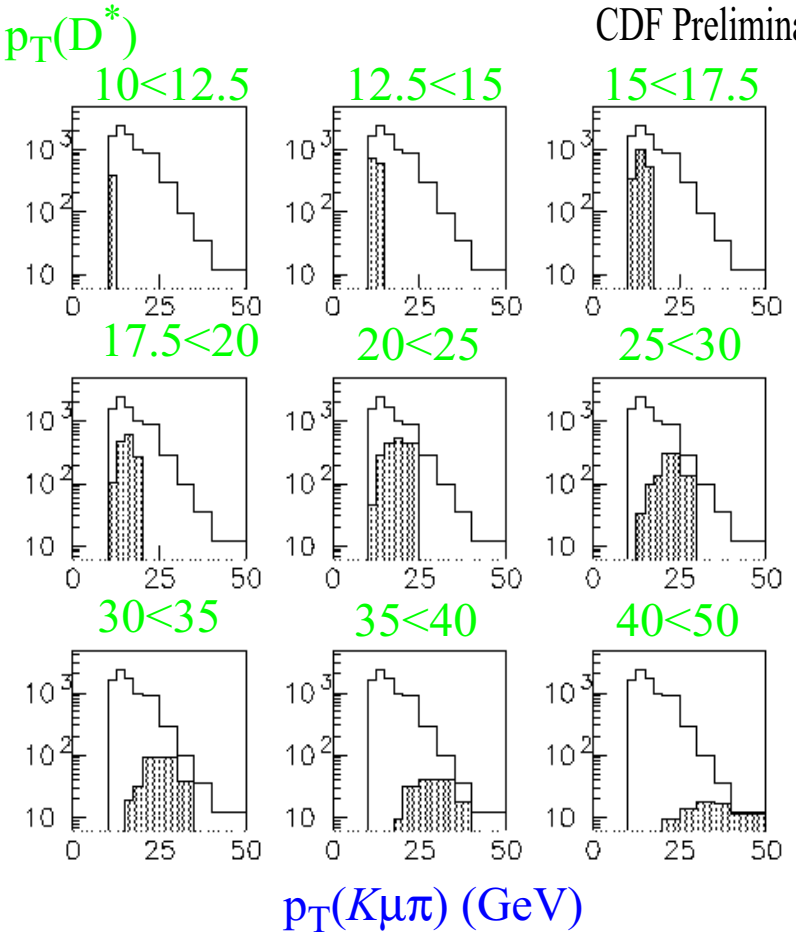
MC templates with each P_T bin



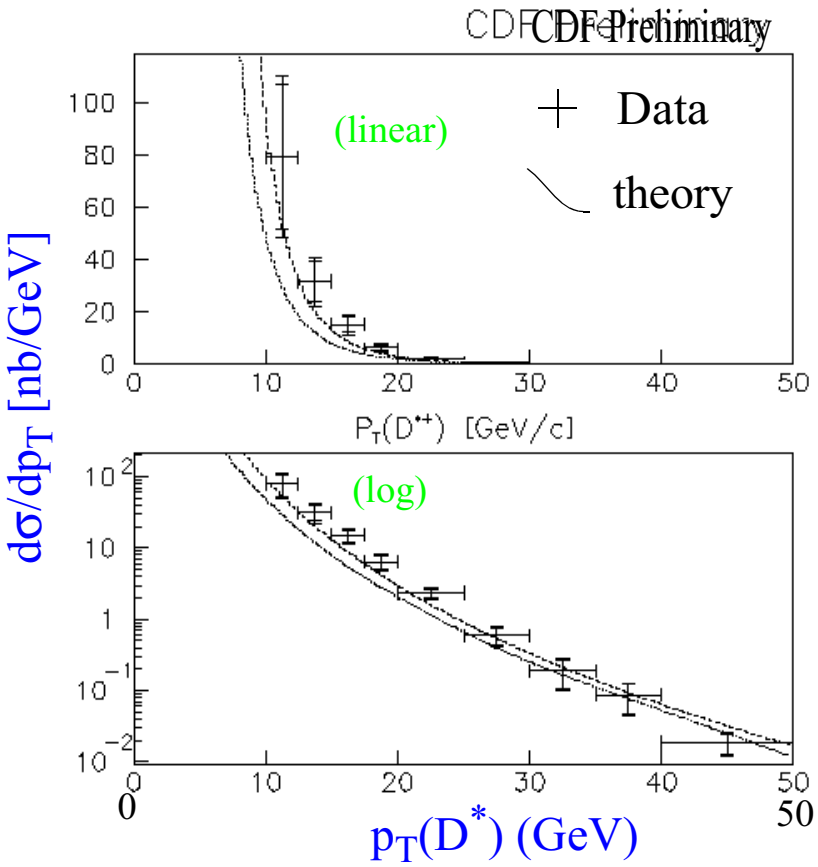
$$d\sigma(p\bar{p}\text{->}D^{*+}+X,\ P_T(i))/dP_T = F(i)\ x\ N(D^{*+})/2\ /\ Lum\ /\ (A*\varepsilon)\ /\ BR(D^{*+}\text{->}\mu+X)\ /\ P_T$$

$86.5pb^{-1}$ 0.045

FIT Result

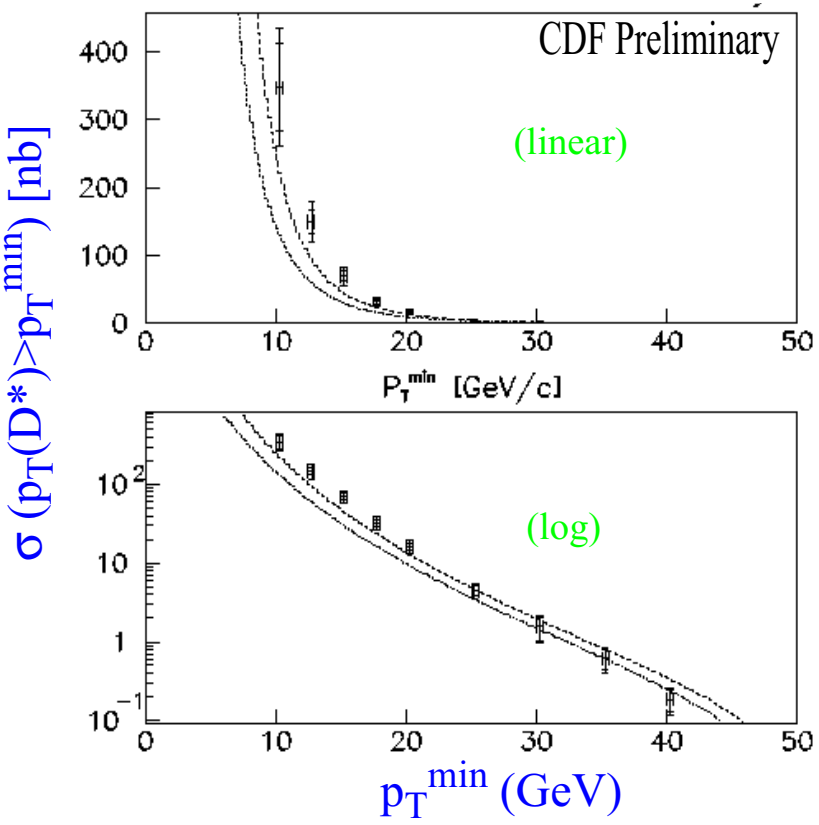


Differential Cross Section



Total Systematic Error: 16.8% (12.8% come from BR(D^0 -> μ + X))

$\sigma(P_T > P_T^{min}) = \Sigma\, d\sigma/dP_T * P_T$



CDF Preliminary

$P_T(D^{*\pm})$	$< P_T >$	$d\sigma/dP_T$ (nb/(GeV/c))	$\sigma(P_T > P_T^{min})$ (nb)
10.0 - 12.5	11.03	$79 \pm 28 \pm 13$	$347 \pm 65 \pm 58$
12.5 - 15.0	13.56	$31.6 \pm 7.5 \pm 5.3$	$149 \pm 18 \pm 25$
15.0 - 17.5	16.08	$15.2 \pm 2.8 \pm 2.6$	$70.0 \pm 6.8 \pm 11.8$
17.5 - 20.0	18.60	$6.4 \pm 1.3 \pm 1.1$	$32.1 \pm 3.1 \pm 5.4$
20.0 - 25.0	21.96	$2.3 \pm 0.3 \pm 0.4$	$16.2 \pm 1.5 \pm 2.7$
25.0 - 30.0	27.04	$0.59 \pm 0.15 \pm 0.10$	$4.5 \pm 0.7 \pm 0.8$
30.0 - 35.0	32.09	$0.19 \pm 0.08 \pm 0.03$	$1.6 \pm 0.5 \pm 0.3$
35.0 - 40.0	37.13	$0.086 \pm 0.038 \pm 0.014$	$0.61 \pm 0.18 \pm 0.10$
40.0 - 50.0	43.67	$0.019 \pm 0.006 \pm 0.003$	$0.19 \pm 0.06 \pm 0.03$

Higher Cross Section than a theoretical calculation, especially at lower P_T range.

4. J/ψ, $\psi(2S)$ production/polarization

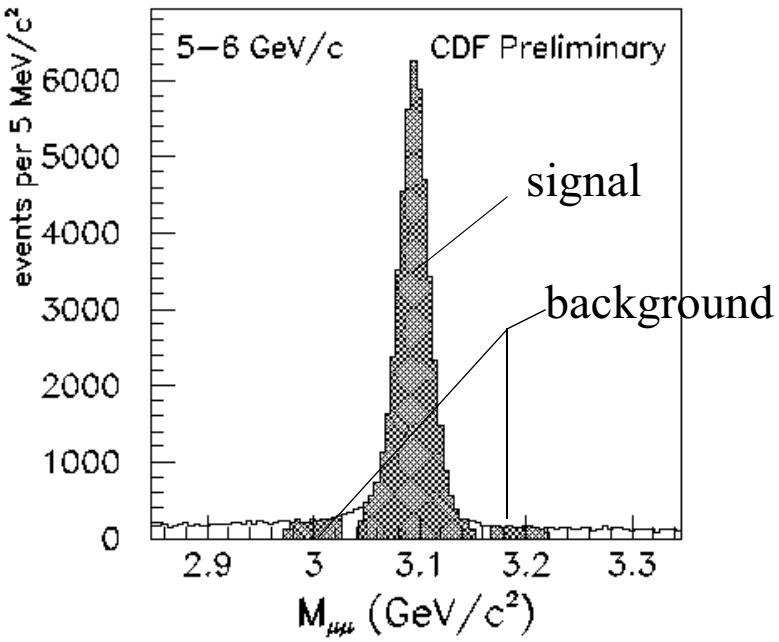
Color Singlet model failed to explain the J/ψ production at the Tevatron.

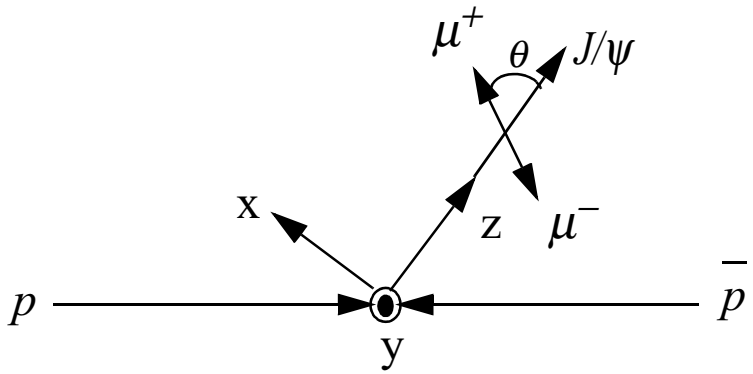
Color Octet (NRQCD) model is proposed.

Predict a large transverse polarization for J/ψ at high p_T.

Inclusive J/ψ prduction

interested in prompt J/ψ





$d\Gamma/d\cos\theta \propto 1 + \alpha^*\cos^2\theta$

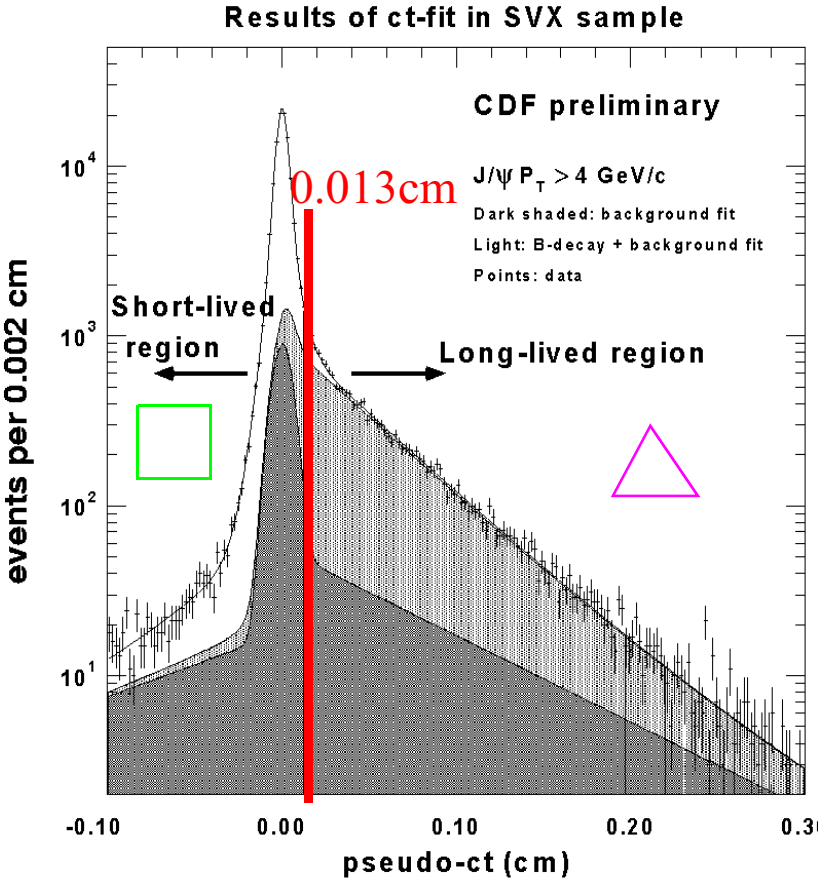
$\alpha = +1$: transverse polarization

$\alpha = -1$: longitudinal polarization

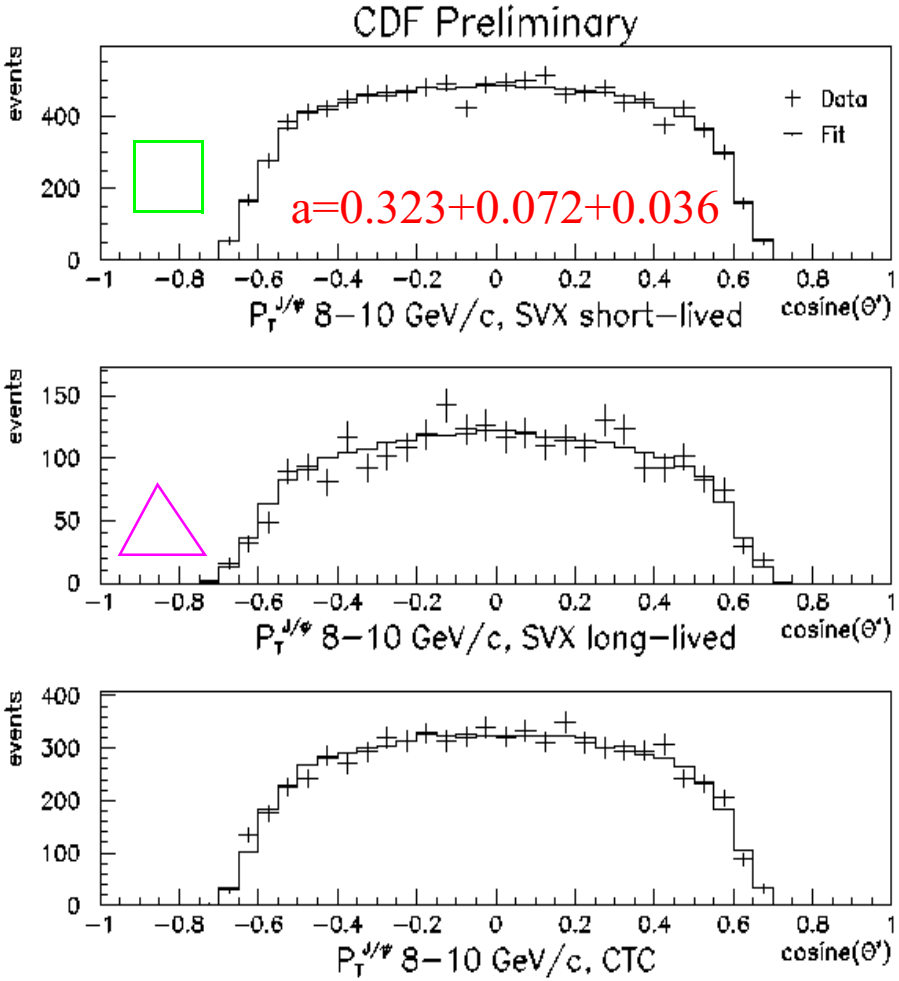
$\alpha = 0$: no polarization

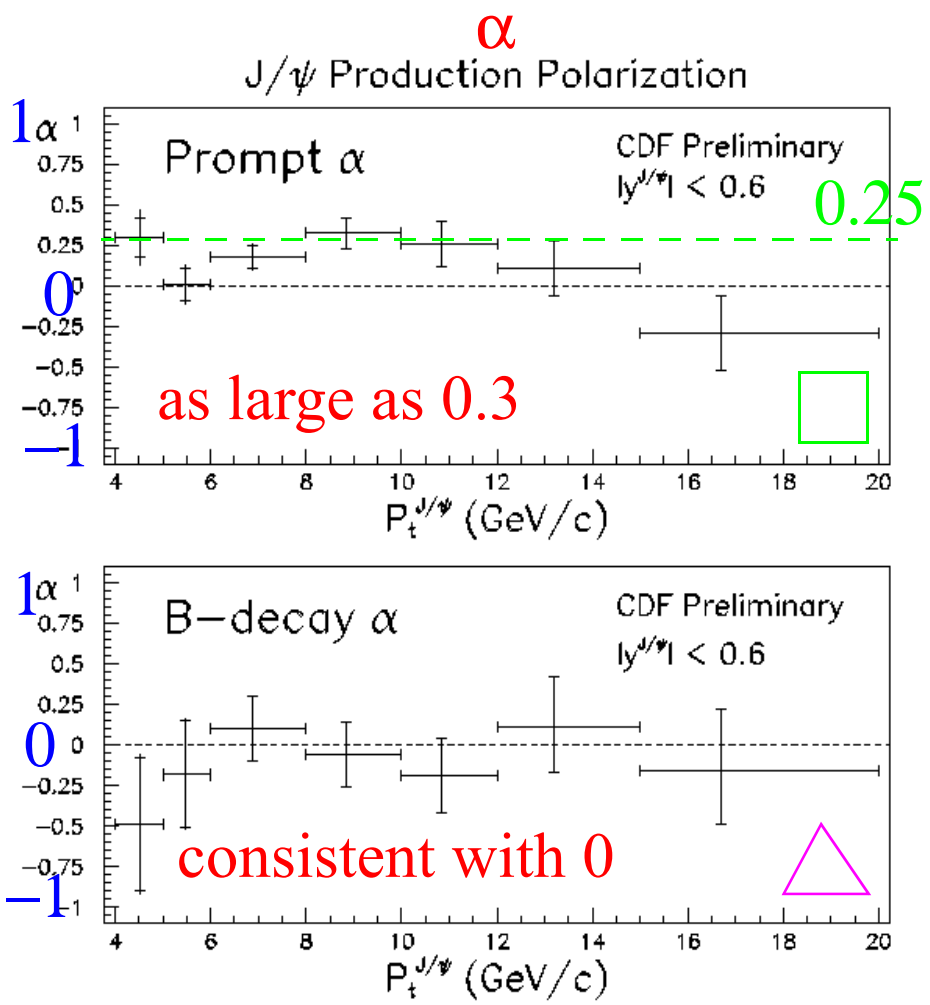
Inclusive J/ψ production

pseudo-cτ



cosθ





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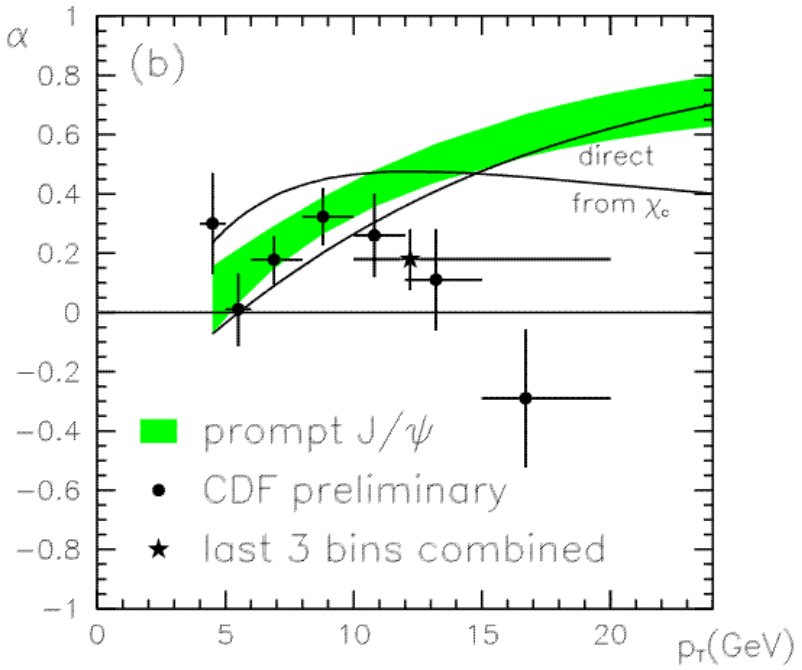
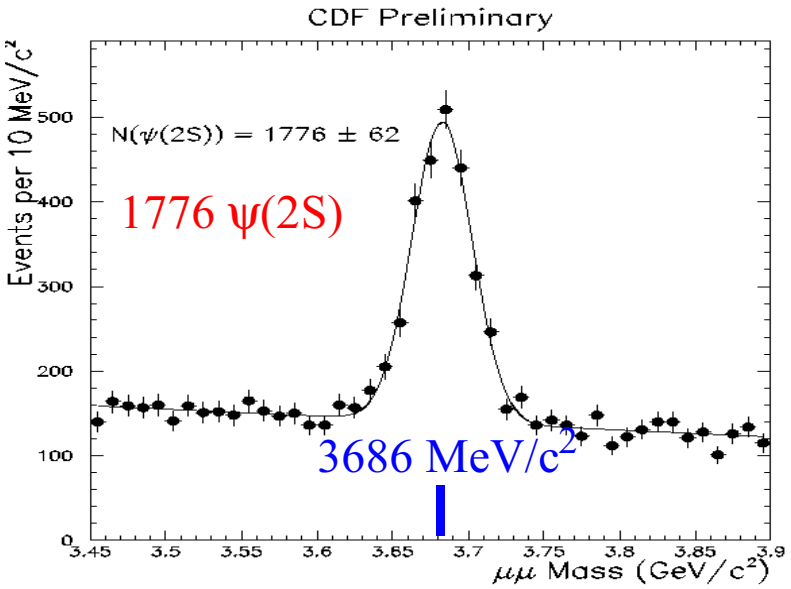
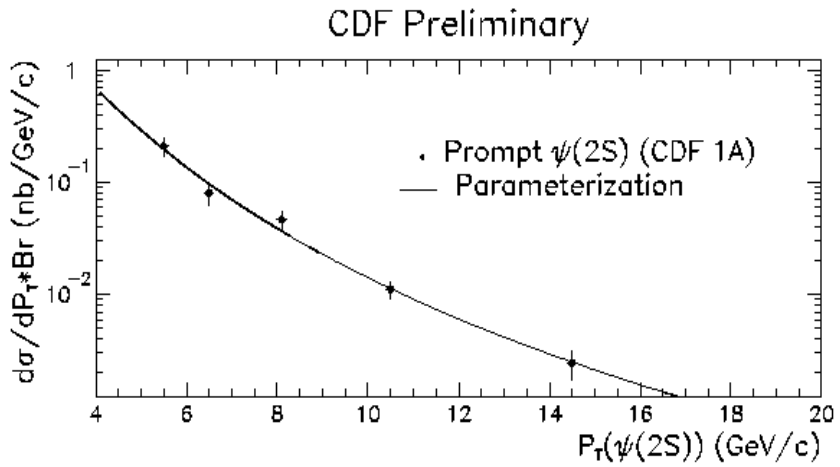


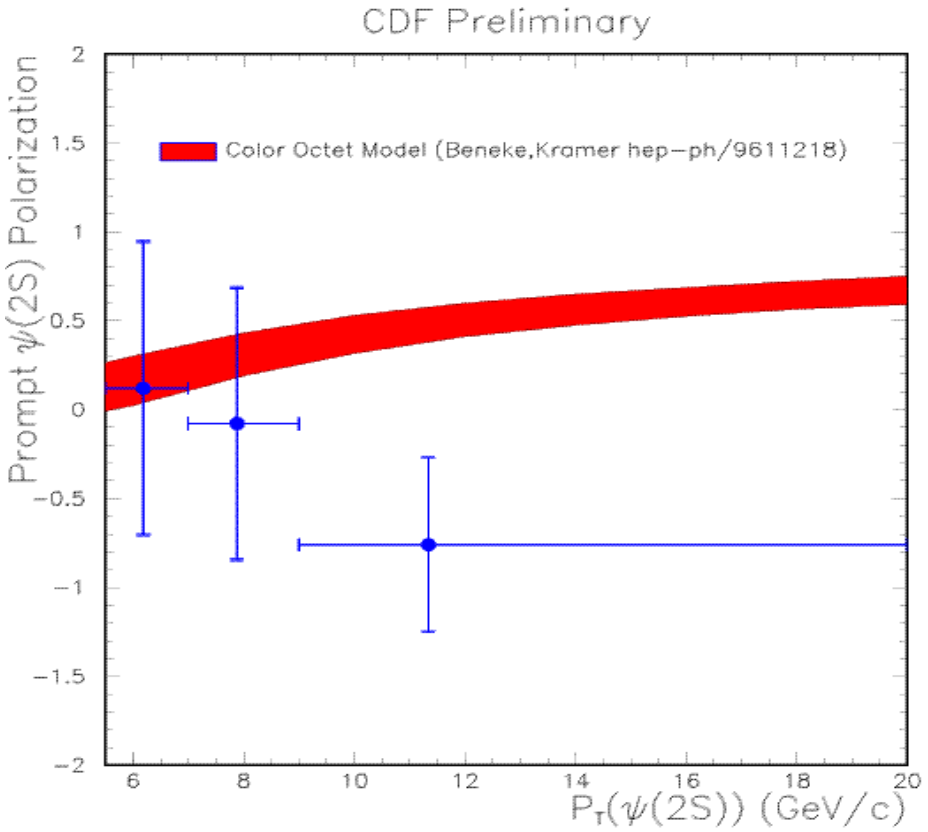
Zero polarization at high p_T in data.

inconsistent with a theory

ψ(2S) production/polarization

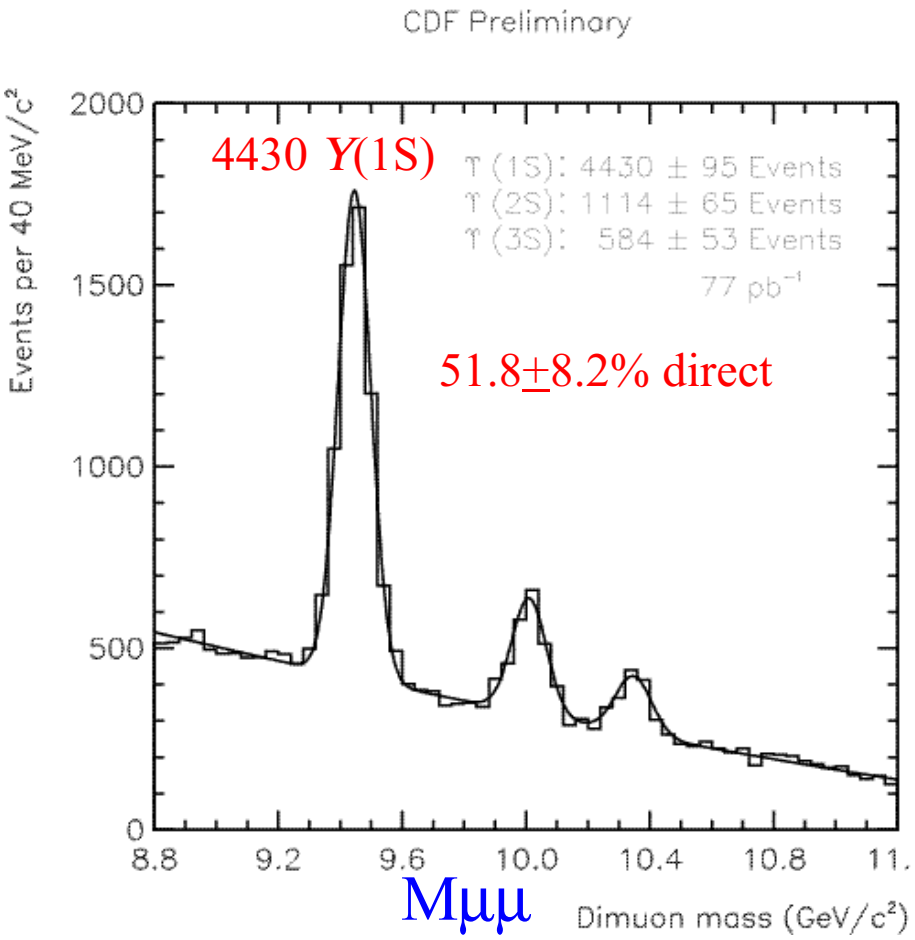


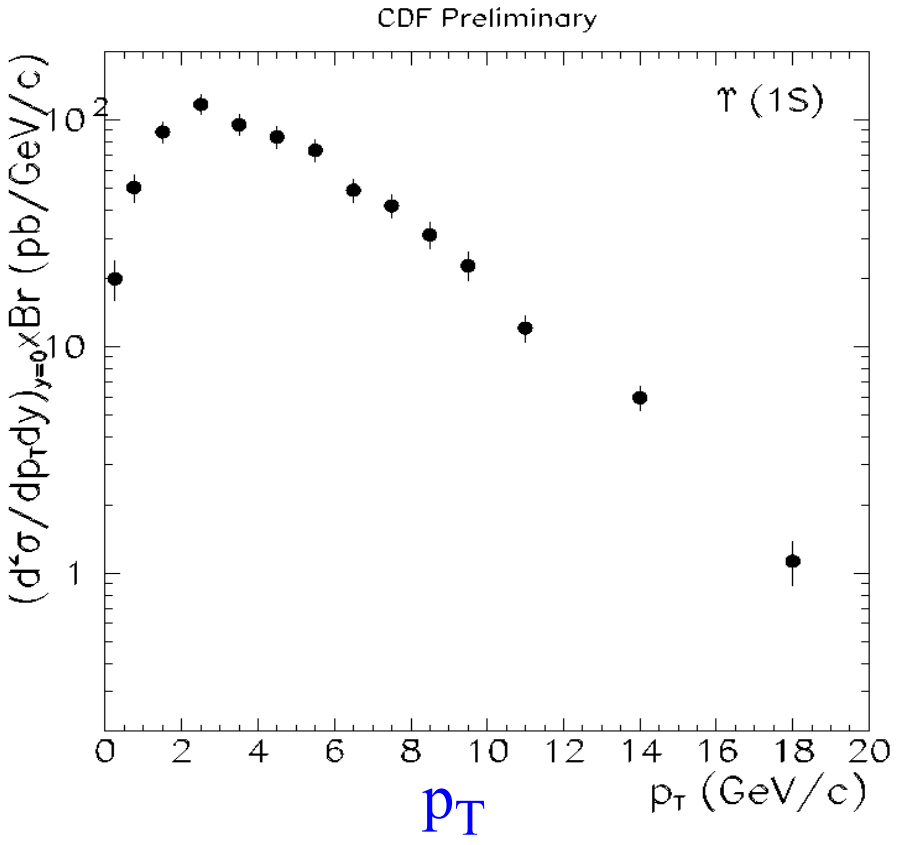


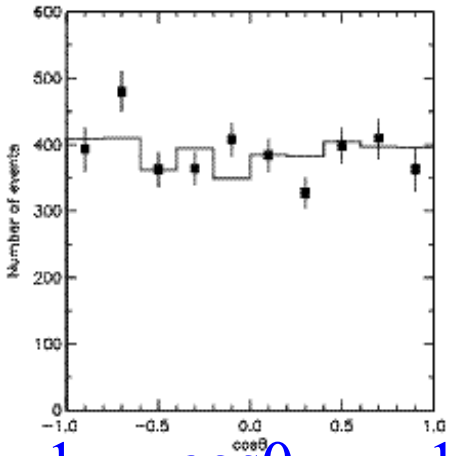


Polarization is consistent with 0.

5.Y (1S) production/polarization

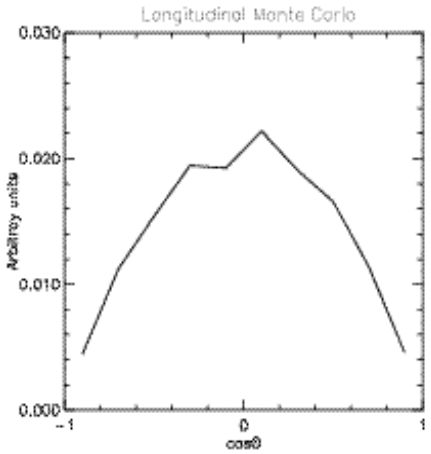






-1 cosθ 1

longitudinal



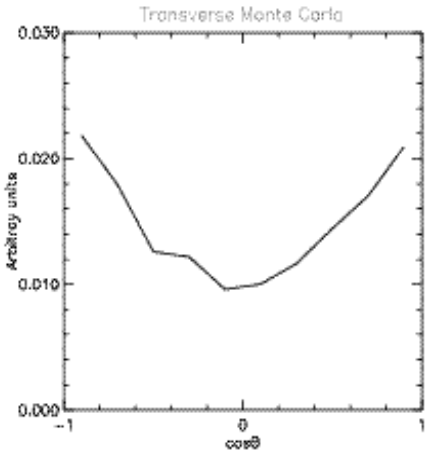
CDF Preliminary
Υ(1S) Polarization

$|y(\Upsilon)| < 0.4$
$2\ \mathrm{GeV}/c < p_T(\Upsilon) < 20\ \mathrm{GeV}/c$

$\Gamma_L/\Gamma = 0.37 \pm 0.04$

$\Gamma_L/\Gamma = 0.37 \pm 0.04$

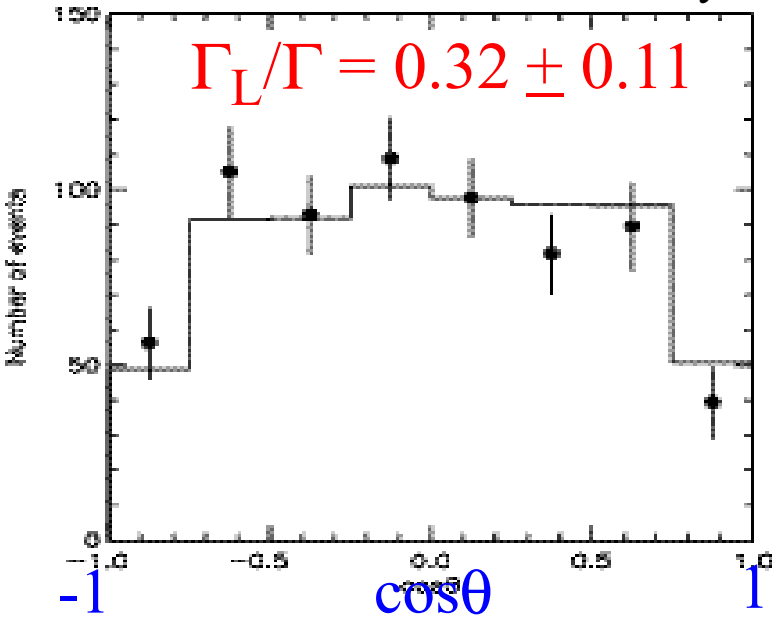
transverse



high p_T Υ(1S) [8<GeV/c^2<20]

CDF Preliminary

$\Gamma_L/\Gamma = 0.32 \pm 0.11$



-1 cosθ 1

Unpolarized production

6. Summary and Conclusion

- First measurement of D^{*+} production at an extensive p_T range.
  Higher cross section than a theory (especially at low p_T).
  $\sigma(p_T(D^*)>10\text{GeV}, |\eta|<1.0) = 347\pm65(\text{stat.})\pm58(\text{sys.})$ nb
  (from charm quark).
- New measurement of J/ψ polarization.
  Transverse polarization is as large as 0.3
  The polarization is consistent with zero at high p_T.
  Need more theoretical work???
  Update of $\psi(2S)$ production/polarization

- New measurement of $\Upsilon(1S)$ production/polarization.
  New cross section measurement.
  Unpolarized production.
  Need more theoretical work???