Working Group IV

PRODUCTION, FRAGMENTATION, SPECTROSCOPY, ...

conveners: W. Trischuk, S. Menary, R. van Kooten, E. Laenen, K. Ellis, E. Braaten

Thursday PM QUARKONIUM PRODUCTION

Friday AM FRAGMENTATION

Friday PM B-HADRON PRODUCTION

Saturday AM SPECTROSCOPY

SPECTROSCOPY

Chao-Hsi Chang Production + Decay of B_c

$\sigma(gg \to B_c + b + \bar{c})$ 20 in α_s

lifetimes, exclusive decays

Rick van Kooten LEP Report on B Spectroscopy

B mesons: B^*, $\underbrace{B_1, B_2}_{\text{narrow } B^{**}}$, $\underbrace{B_{s1}, B^*_{s2}}_{\text{narrow } B_s^{**}}$, B'?

B baryons: Λ_b, Σ_b?, Ξ_b??

Prem Singh CDF Report on B_c

measurements of M, τ, $B \times \sigma$

Run II: 40 × data

Chris Quigg Double-Heavy Baryons

ccq, bcq, bbq

$\sigma(\Xi_{bc}) \sim 1$ nb

Friday PM

B-HADRON PRODUCTION

Giovanni Ridolfi (plenary talk)

B Production at the Tevatron

Kevin Davis

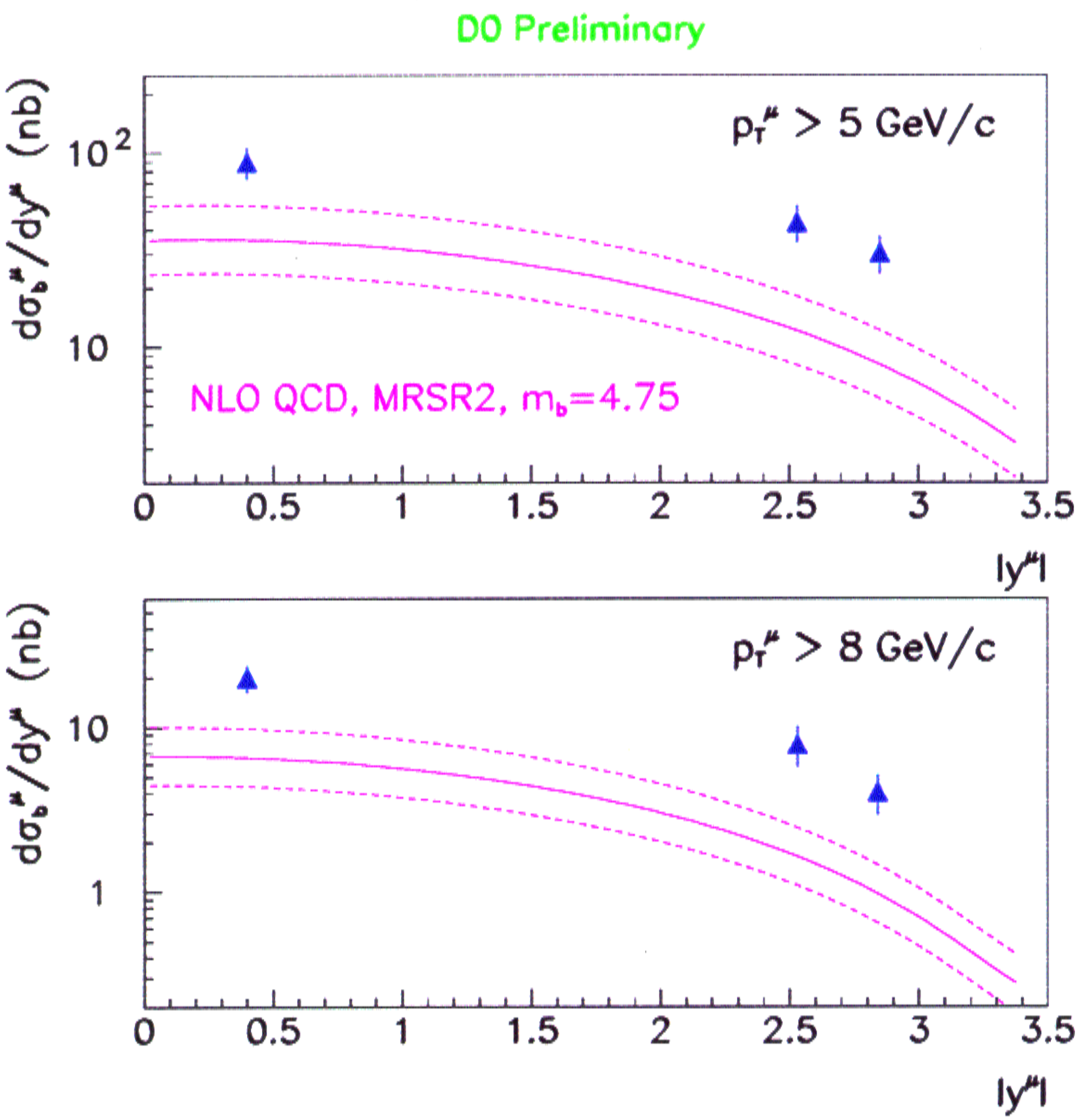
DØ Results

William Trischuk

CDF Results

Rapidity Dependence of *b*-Quark Production

By combining the forward muon cross section from *b* decays with that of a previous DØ measurement in the central rapidity range ($|y^\mu| < 0.8$) we study the rapidity dependence of *b*-quark production.



Friday AM FRAGMENTATION

Wendy Taylor

CDF measurements of fragmentation fractions

f_u	=	probability for	$b \to B_u$	$\approx$	0.41 ± 0.05
f_d	=	"	$b \to B_d$	$\approx$	0.34 ± 0.04
f_s	=	"	$b \to B_s$	$\approx$	0.16 ± 0.04
f_{baryon}	=	"	$b \to \Lambda_b$	$\approx$	0.09 ± 0.03
					1.00

Scott Menary

Peterson function $D(z) = \dfrac{1}{z\left[1 - \frac{1}{z} - \frac{\epsilon}{1-z}\right]^2}$

gives poor fit to fragmentation functions $D_{b \to B}(z)$

measured at SLD, LEP: $\dfrac{\chi^2}{d.o.f} \approx \dfrac{26}{16}$

Brian Harris

"beam drag effect" observed at HERA

$D_{c \to D^*}(z)$ increases at forward rapidity

$\Longrightarrow$ $D_{b \to B}(z)$ different at large rapidity?

Thursday AM QUARKONIUM PRODUCTION

Geoff Bodwin

Review of theory of $Q\bar{Q}$ production

Adam Leibovich

NRQCD analysis of Υ production

Andrei Mayorov

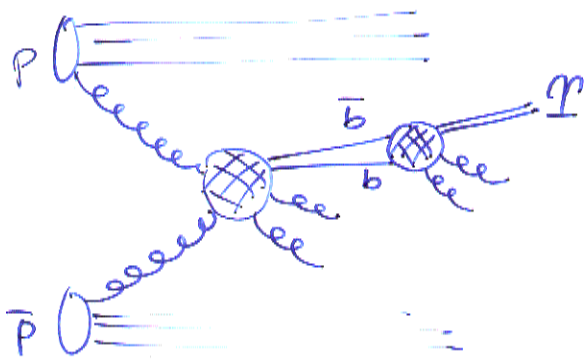
DØ results - dependence on rapidity

Greg Field

CDF results — production of $\Upsilon(1S)$, $\Upsilon(2S)$, $\Upsilon(3S)$
$\chi_b(1P)$, $\chi_b(2P)$
polarization of $\psi(2S)$
prompt J/ψ
$\Upsilon(1S)$

ONIUM PRODUCTION

$p\bar{p} \longrightarrow b\bar{b}$ + partons $\longrightarrow \Upsilon$ + hadrons



amplitude for $b\bar{b}$ to bind into Υ

depends on ... color of $b\bar{b}$ ($\underline{1}$ or $\underline{8}$)

spin ($s = 0$ or 1)

other partons

relative momentum q_{rel}

$\sigma(p\bar{p} \to \Upsilon + X)$

probes production of $b\bar{b}$

at small relative momentum

$|\vec{q}_{rel}| << m_b$ in $b\bar{b}$ rest frame

INCLUSIVE ONIUM PRODUCTION

Factorization Formula (Bodwin, Braaten, Lepage)

- standard factorization methods of perturbative QCD
- expansion in $v = q_{rel}/m_b$ ($v^2 \approx \frac{1}{10}$ for $b\bar{b}$)

$$d\sigma(p\bar{p} \to \Upsilon + X)$$

$$= \sum_n d\hat{\sigma}(p\bar{p} \longrightarrow (b\bar{b})_n + X) \; \langle \mathcal{O}_n^{\Upsilon} \rangle$$

parton cross sections $d\hat{\sigma}$

calculate using perturbative QCD + parton distributions

NRQCD matrix elements $\langle \mathcal{O}_n^{\Upsilon} \rangle$

nonperturbative, but universal

$\sum_n$ includes sum over

color	$\underline{1}$ or $\underline{8}$
spin	$S = 0$ or 1
orbital ang. mom	$L = S, P, D, \ldots$

most important matrix elements $\langle \mathcal{O}_{1 \text{ or } 8}({}^{2S+1}L_J) \rangle$

	color-singlet model	color-evaporation model	NRQCD
$\Upsilon(nS)$	$\mathcal{O}_1({}^3S_1)$	$\mathcal{O}_1({}^3S_1)$, $\mathcal{O}_1({}^1S_0)$ $\mathcal{O}_8({}^3S_1)$, $\mathcal{O}_8({}^1S_0)$	$\mathcal{O}_1({}^3S_1)$ $\mathcal{O}_8({}^3S_1)$, $\mathcal{O}_8({}^1S_0)$, $\mathcal{O}_8({}^3P_J)$
$\chi_{bJ}(nP)$	$\mathcal{O}_1({}^3P_J)$	$\mathcal{O}_1({}^3S_1)$, $\mathcal{O}_1({}^1S_0)$ $\mathcal{O}_8({}^3S_1)$, $\mathcal{O}_8({}^1S_0)$	$\mathcal{O}_1({}^3P_J)$ $\mathcal{O}_8({}^3S_1)$

bottomonium production at the Tevatron

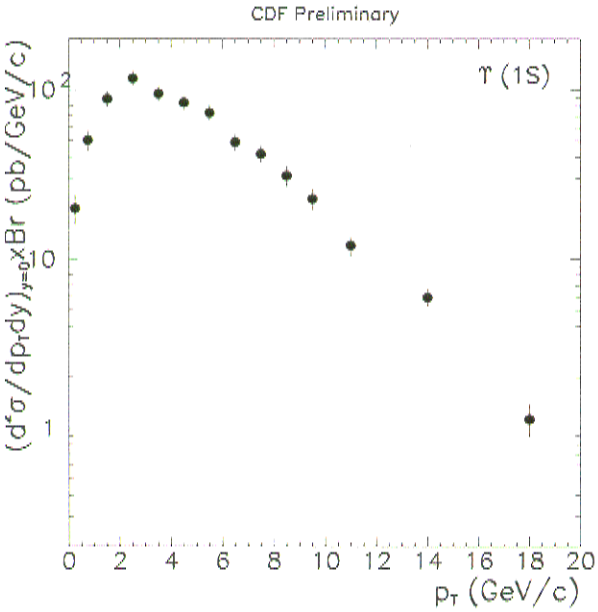
$\Upsilon(nS)$: 2 phenomenological parameters

$$\langle \mathcal{O}_8^{\Upsilon(nS)}({}^3S_1) \rangle, \quad \langle \mathcal{O}_8^{\Upsilon(nS)}({}^1S_0) \rangle + \frac{3}{m_b^2} \langle \mathcal{O}_8^{\Upsilon(nS)}({}^3P_0) \rangle$$

$\chi_{bJ}(nP)$, $J=0,1,2$: 1 phenomenological parameter

$$\langle \mathcal{O}_8^{\chi_{b0}(nP)}({}^3S_1) \rangle$$

$\Upsilon(1S)$, $\Upsilon(2S)$ and $\Upsilon(3S)$ production cross sections

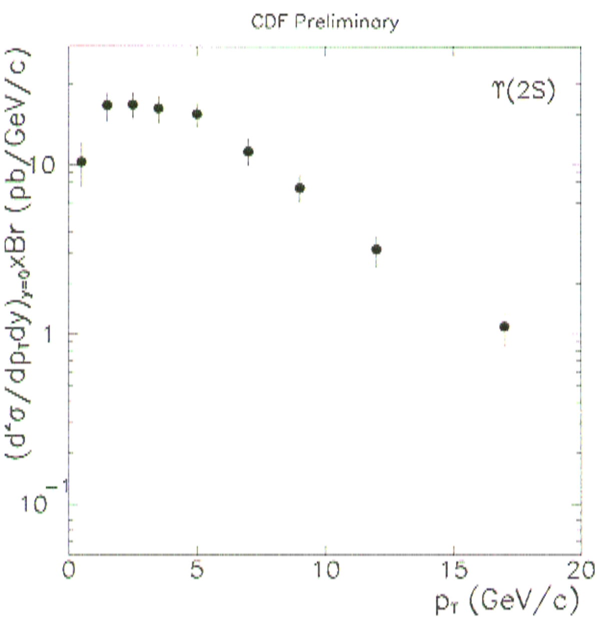


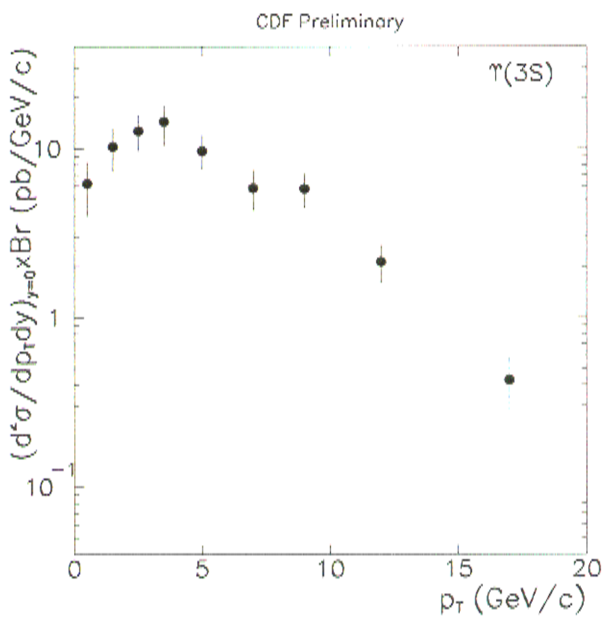
CDF Preliminary (77 pb^{-1})

$|y(\Upsilon)| < \mathbf{0.4}$
$\mathbf{0} < p_T(\Upsilon) < \mathbf{20}$ **Gev**$/c$
$\Upsilon \to \mu^+\mu-$

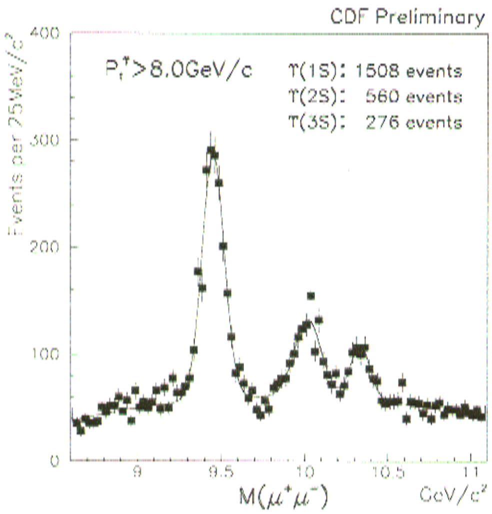
$d\sigma/dp_T$ **cross section shapes comparable for 1S, 2S, 3S**

www-cdf.fnal.gov/physics/ new/bottom/cdf5027/cdf5027.html





Fraction of $\Upsilon(1S)$ from prompt χ_b decays



$\chi_b(\mathbf{1P})$, $\chi_b(\mathbf{2P}) \to \Upsilon(\mathbf{1S})\gamma$

$\Upsilon(\mathbf{1S}) \to \mu^+\mu-$

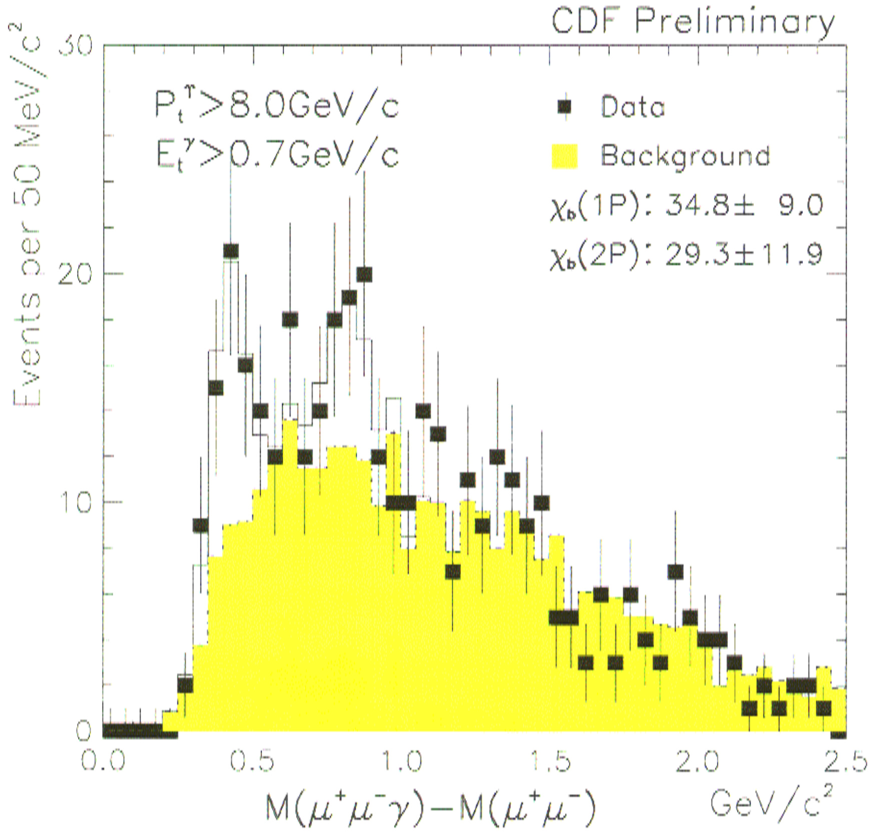
$p_T^\Upsilon > 8$ **GeV**$/c$, $E_T^\gamma > 0.7$ **GeV**$/c$

$F^\Upsilon_{\chi(1P)} = (26.7 \pm 6.9 \pm 4.3)\%$

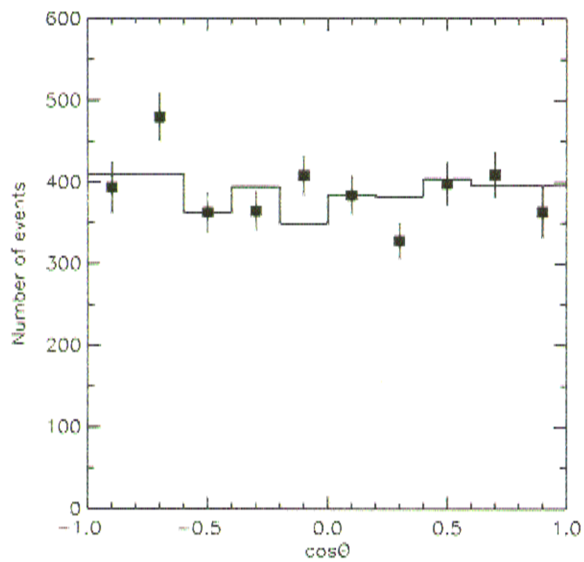
$F^\Upsilon_{\chi(2P)} = (10.8 \pm 4.4 \pm 1.3)\%$

$F(\mathbf{direct}) = (51.8 \pm 8.2)\%$

www-cdf.fnal.gov/physics/new/bottom/cdf4392/cdf4392.html



Polarization of $\Upsilon(1S)$ production

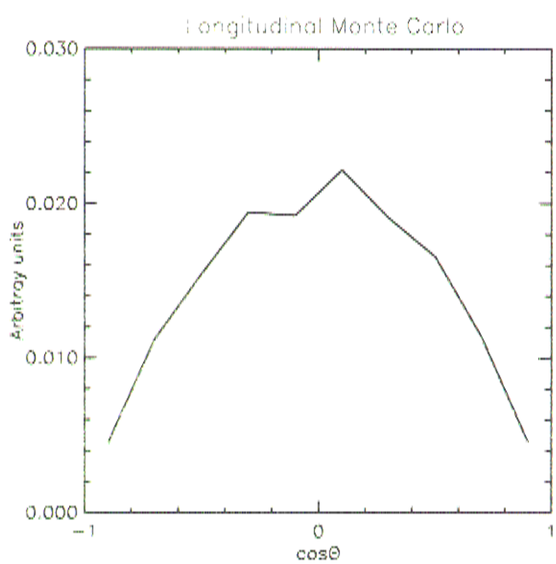


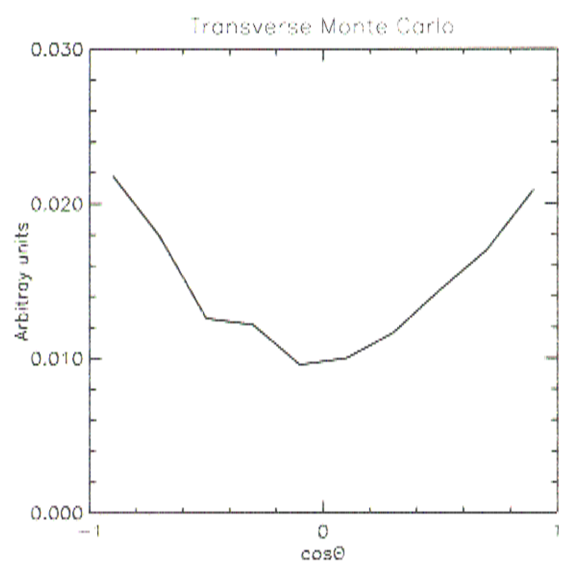
CDF Preliminary

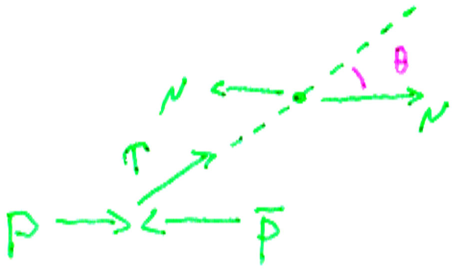
$\Upsilon \rightarrow \mu^+\mu-$
$|y(\Upsilon)| < \mathbf{0.4}$
$\mathbf{2}$ **Gev**$/c < p_T(\Upsilon) <$ **20 Gev**$/c$

Fit longitudinal and transversely polarized MC templates to data

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



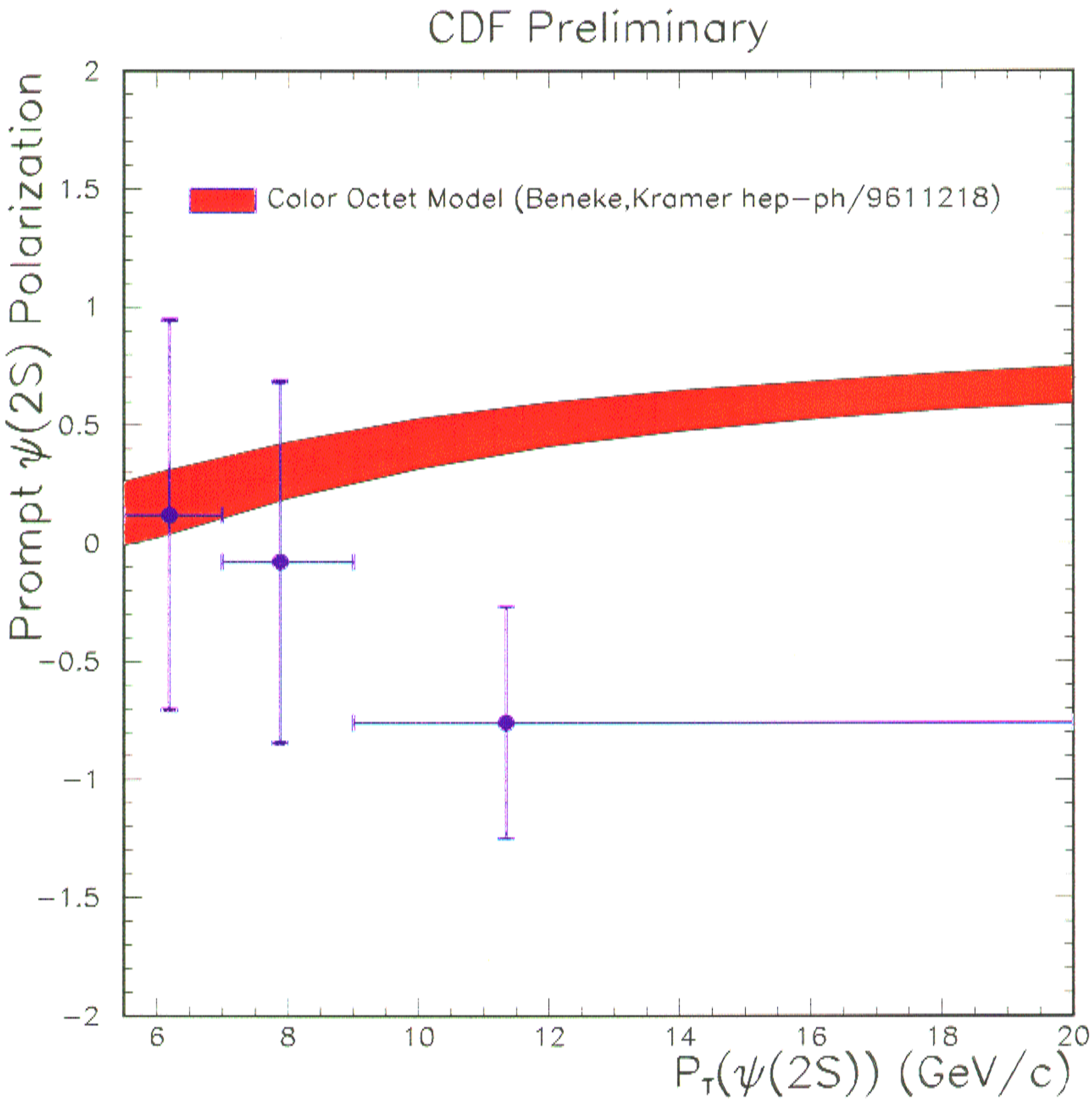




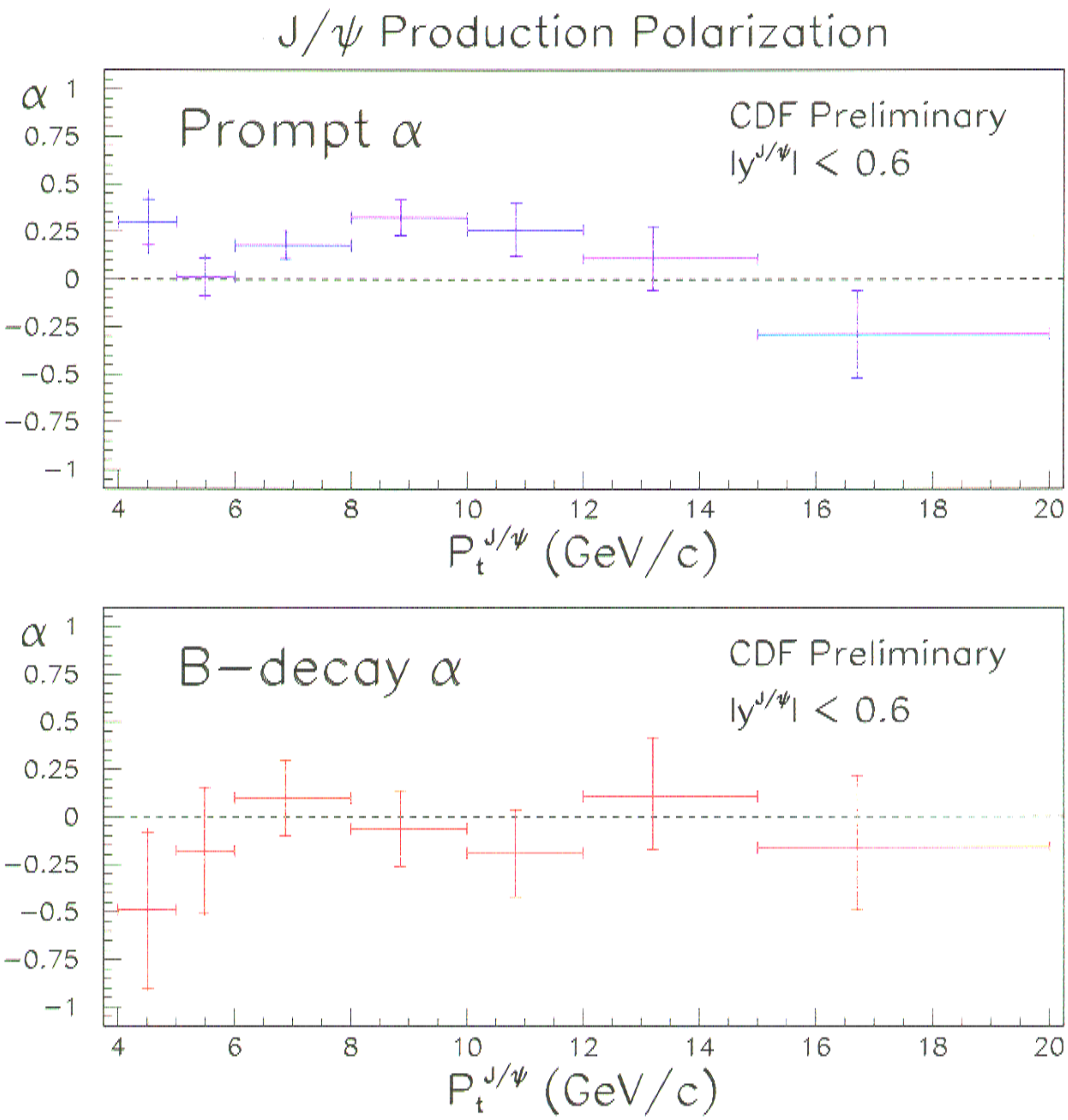
all theories predict this result!

Polarization of direct $\psi(2S)$ production:

α vs. $p_T(\psi(2S))$



Polarization of J/ψ production:
α vs. $p_T(J/\psi)$



Progress Meeting for ...

Nov. 8