Workshop on B physics at the Tevatron
September 23, 1999

CDF Results on Quarkonium Production

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New, old, and future quarkonia results from CDF

- Overview of results from Run IA
- The phenomenological response
- Results from Run IB
  - Updated Υ cross sections
  - Fraction of Υ(1S) from χ_b decays
  - Prodution polarization of Υ(1S)
  - Prodution polarization of prompt J/ψ
  - Prodution polarization of direct ψ(2S)
- Further possible results from Run I
- Measurements needed to be made in Run II

Compendium of Run 1A Results

J/ψ and $\psi(2S)$ Production (PRL 79, 572 (1997))

- inclusive J/ψ and $\psi(2S)$ production cross sections
- $B \to J/\psi X$ and $B \to \psi(2S)X$ cross sections
- prompt J/ψ and $\psi(2S)$ production cross sections

J/ψ from χ_c Decays (PRL 79, 578 (1997))

- fraction of J/ψ from χ_c decays
- direct J/ψ production cross section

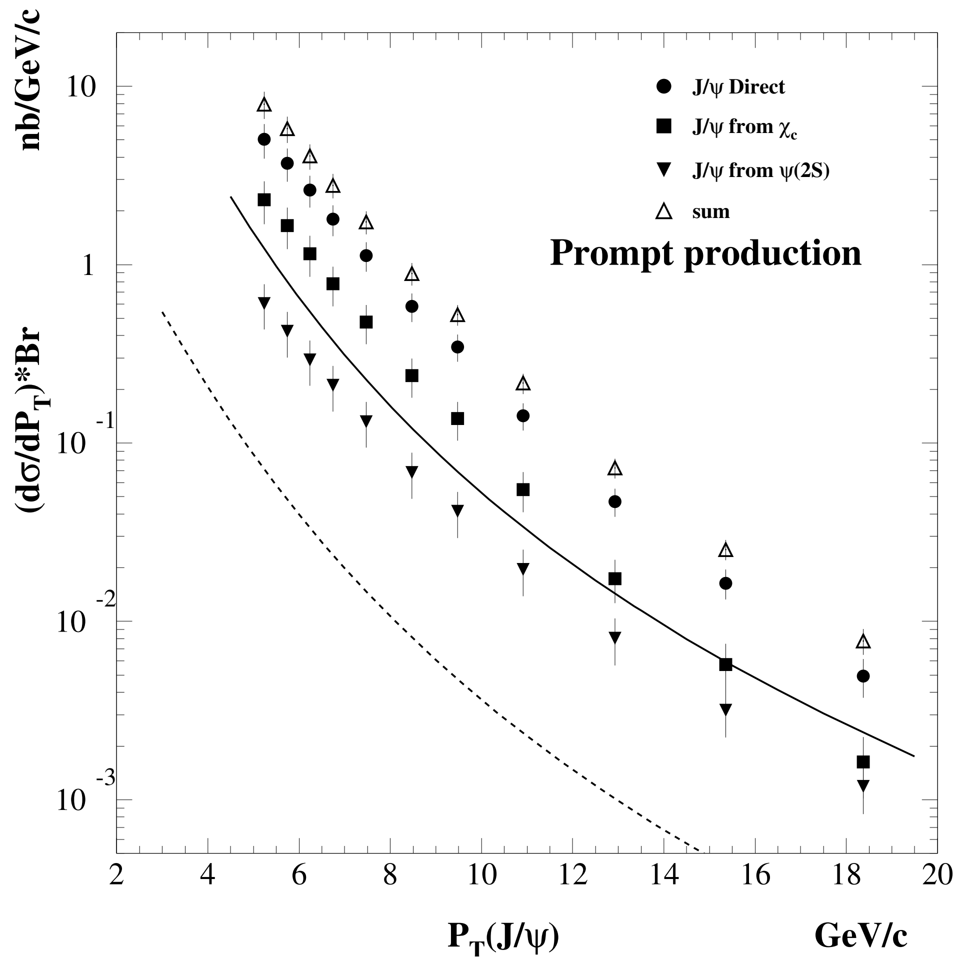
Υ Production (PRL 75, 4358 (1995))

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

Measurement of ratio of production of χ_{c1} to χ_{c2} (www-cdf.fnal.gov/physics/new/bottom /cdf3121/cdf3121.html)

Direct J/ψ Production Cross Section

Run 1A data: PRL 79, 578 (1997)
Color Singlet Model off by a factor of ~ 50
The Other CDF Anomaly



The Phenomenological Response

Color Singlet Model is not sufficient. Introducution of various color octet mechanisms of quarkonium production.

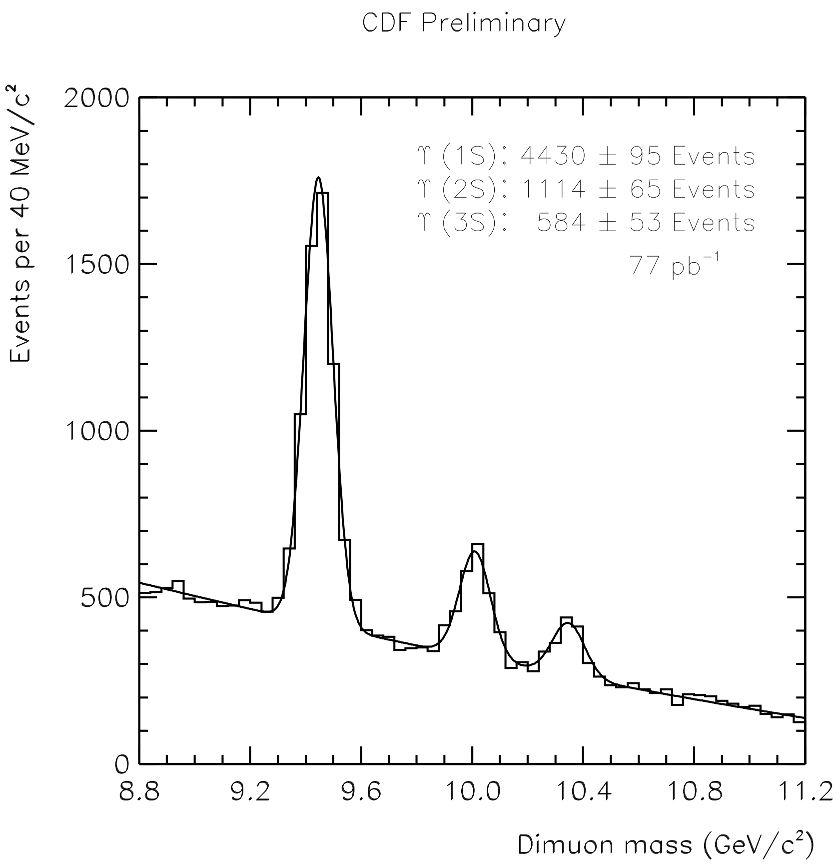
- Color Octet Model
- Color Evaporation Model
- Hard Rescattering
- Other ?

All these models seem to fit the data. Which is correct? What is needed? More measurements!

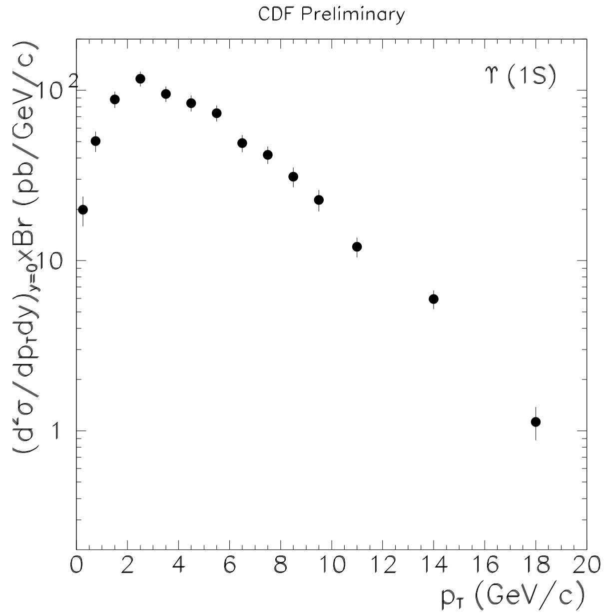
- Polarization of J/ψ and ψ(2S) production $\surd$
- More Υ production measurements $\surd$
- h_c and η_c production cross sections
- Look for associated jets in direct production; measure $z_{jet} = p_T(\Psi)/p_T(jet)$
- Other ?

Υ Production Measurements

- $\Upsilon(1S)$, $\Upsilon(2S)$, $\Upsilon(3S)$ production cross sections
- Fraction of $\Upsilon(1S)$ from direct production and χ_b decays
- Polarization of the $\Upsilon(1S)$



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

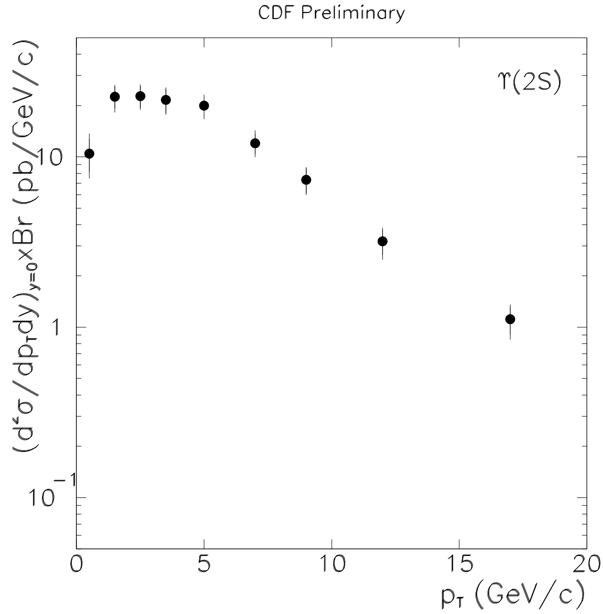


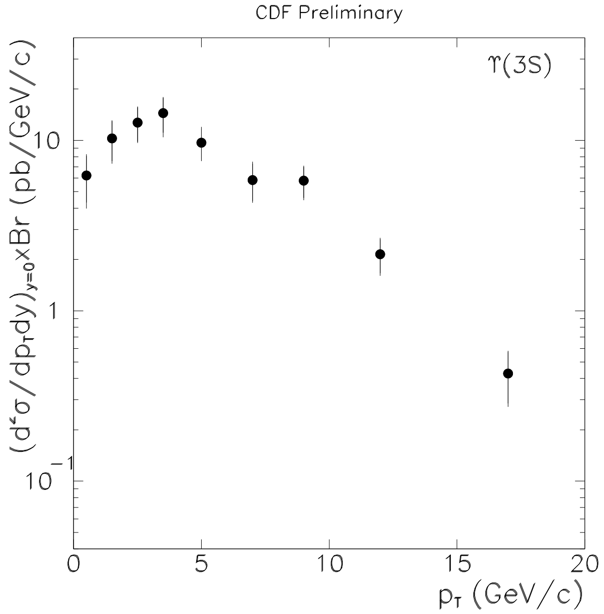
CDF Preliminary (77 pb^{-1})

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

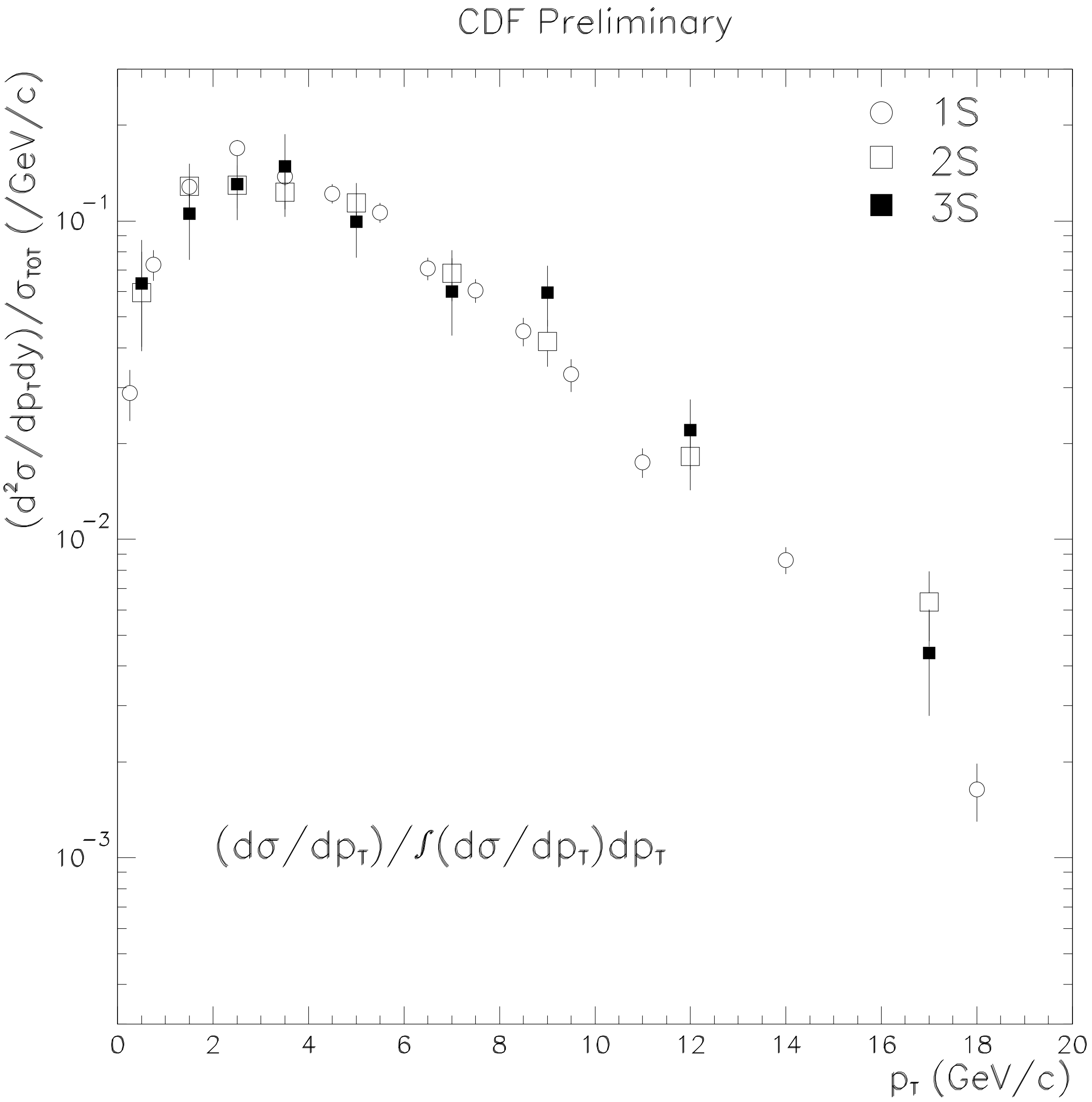
$d\sigma/dp_T$ **cross section shapes comparable for 1S, 2S, 3S**

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

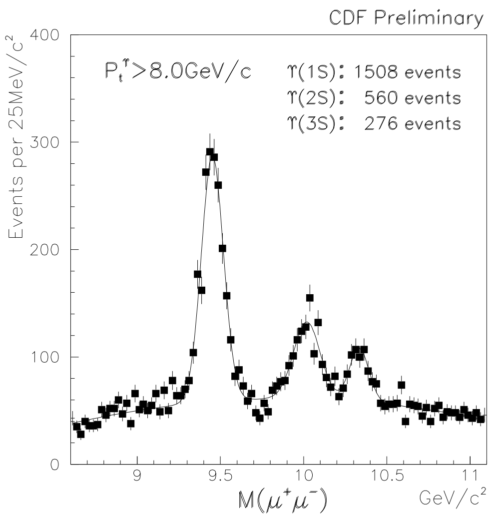




Comparison of Υ production cross section shapes



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

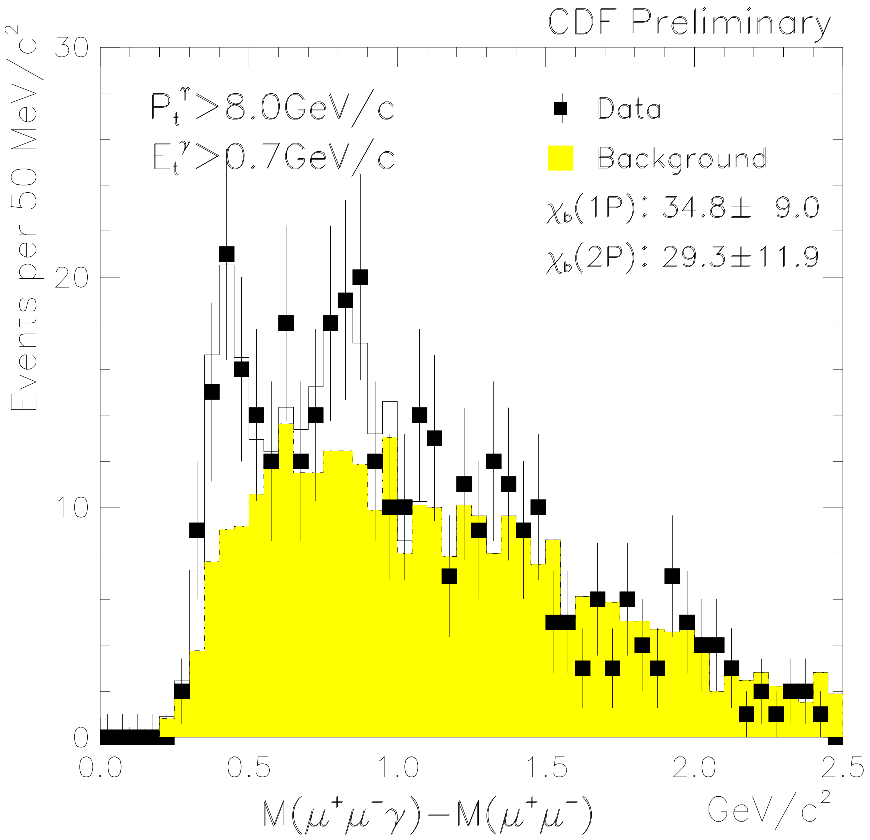


$\chi_b(\mathbf{1P}),\ \chi_b(\mathbf{2P}) \rightarrow \Upsilon(\mathbf{1S})\gamma$
$\Upsilon(\mathbf{1S}) \rightarrow \mu^+\mu-$
$p_T^\Upsilon > 8$ $\mathbf{GeV}/c$, $E_T^\gamma > 0.7$ $\mathbf{GeV}/c$

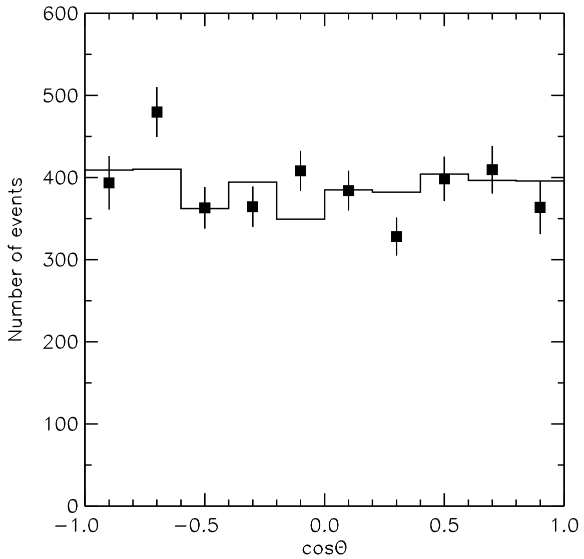
$F^\Upsilon_{\chi(1P)} = (26.7 \pm 6.9 \pm 4.3)\%$
$F^\Upsilon_{\chi(2P)} = (10.8 \pm 4.4 \pm 1.3)\%$

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

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



Polarization of $\Upsilon(1S)$ production

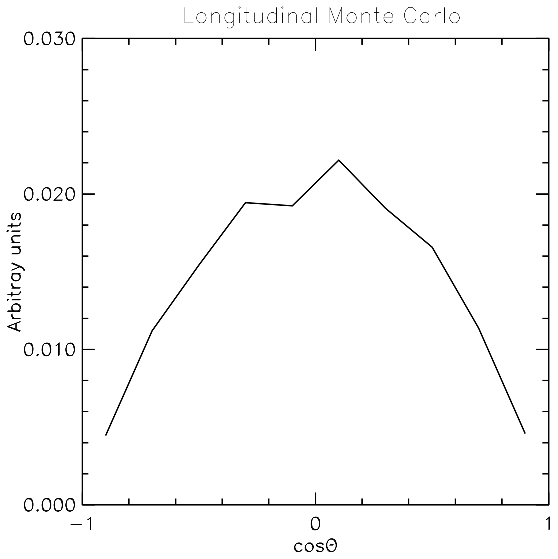


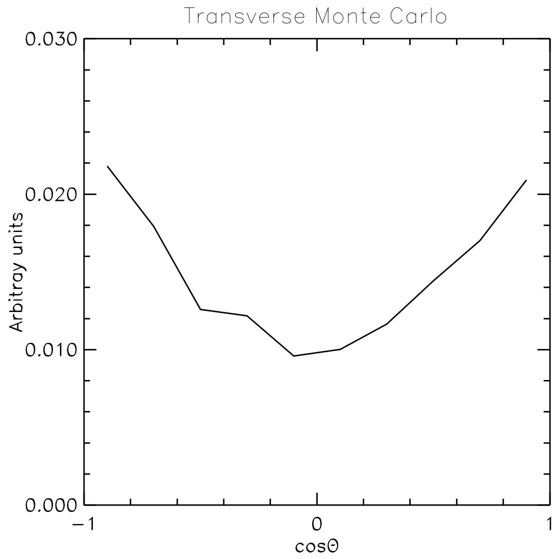
CDF Preliminary

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

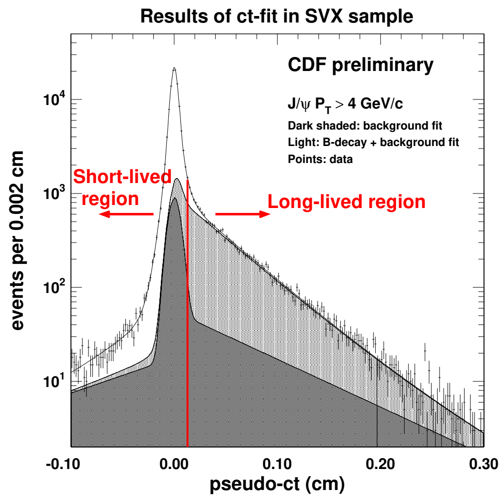
Fit longitudinal and transversely polarized MC templates to data

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





Polarization of prompt J/ψ production

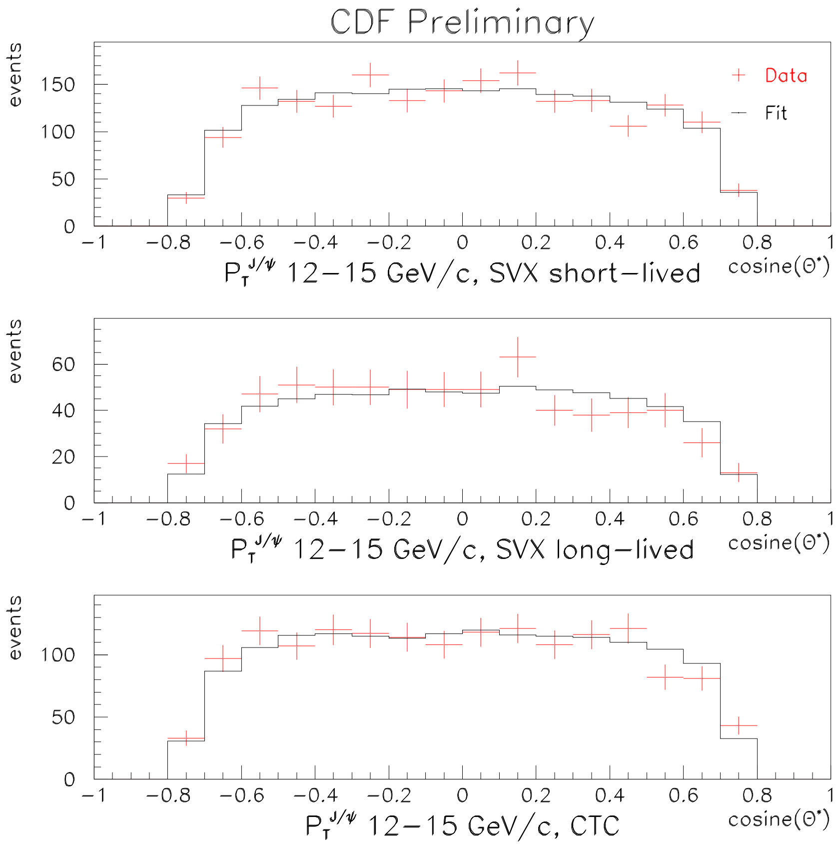


CDF Preliminary (110 pb^{-1})

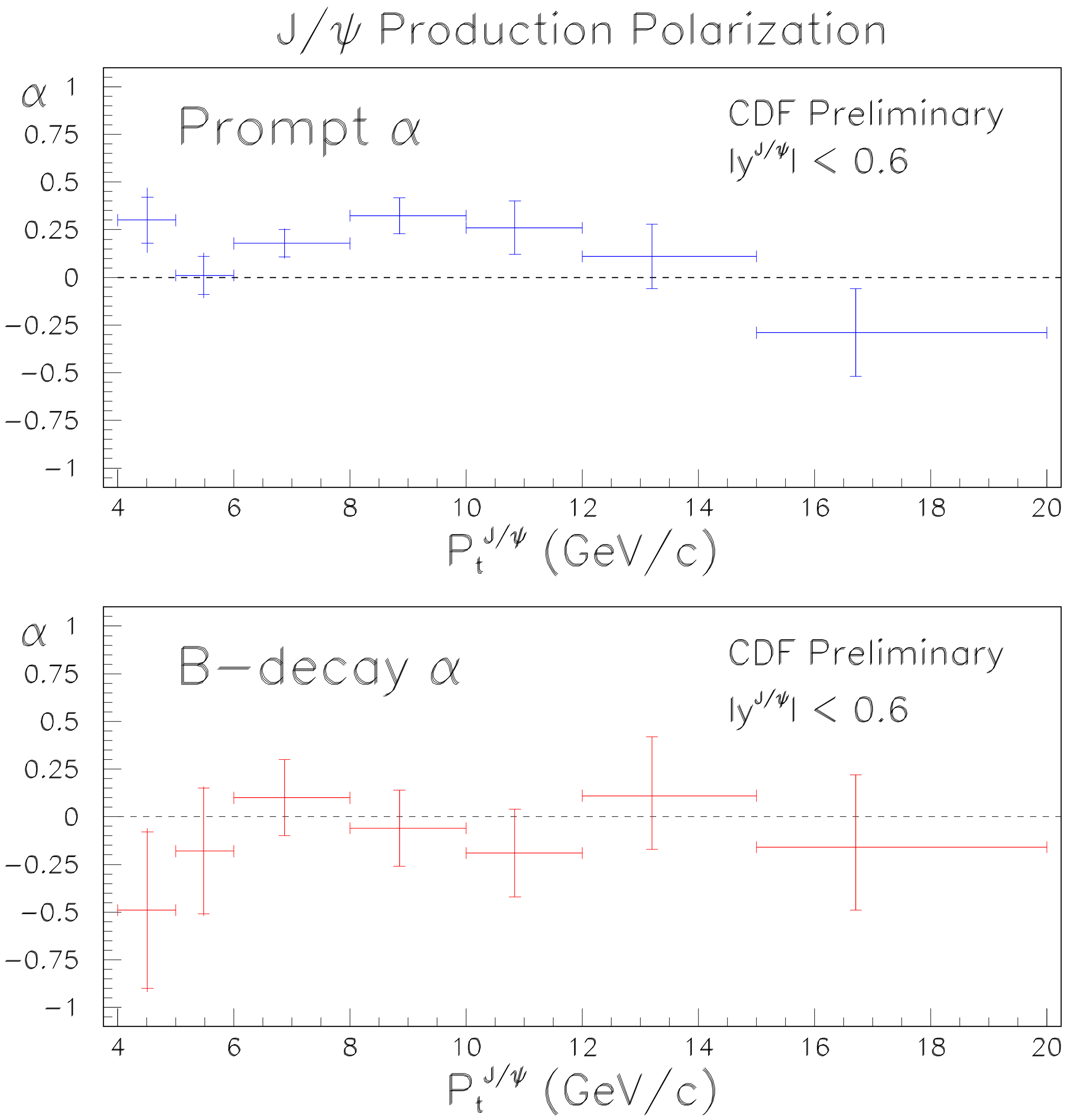
$J/\psi \to \mu^+\mu^-$
$p_T(J/\psi) > 4$ **GeV**$/c$
Prompt: $ct < 0.013$ **cm**
χ^2 **fit of** $1 + \alpha\cos^2\theta$ **to data**

Result: α **vs.** $p_T(J/\psi)$

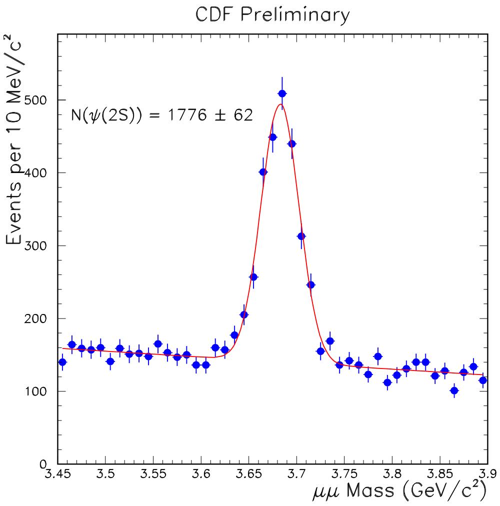
www-cdf.fnal.gov/physics/new/bottom/cdf5029/cdf5029.html



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



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

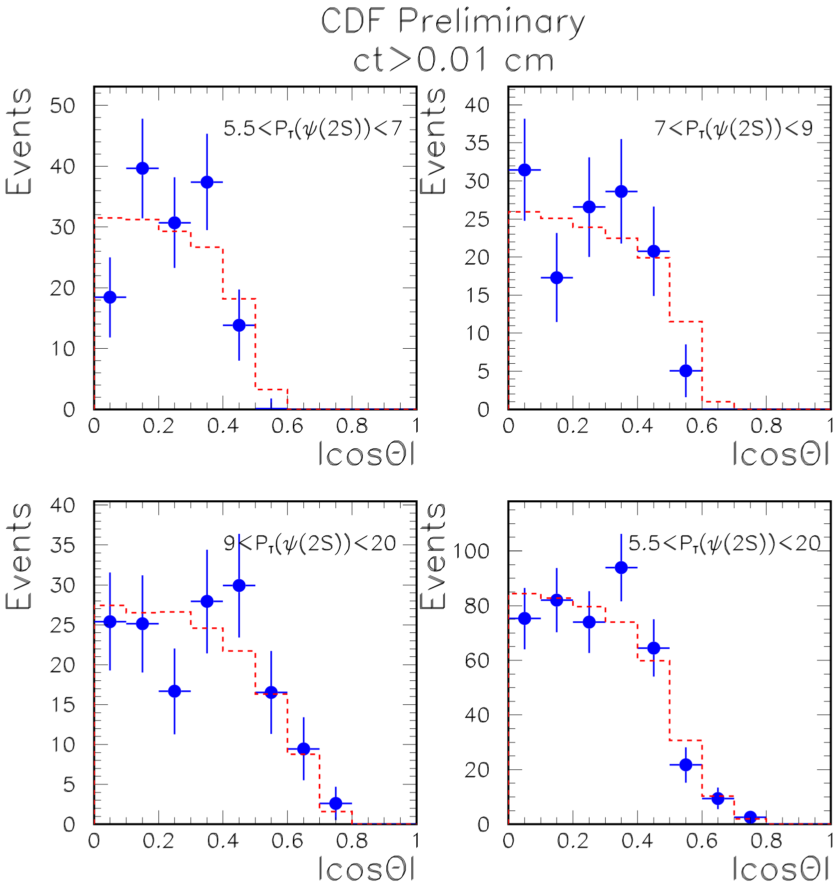


CDF Preliminary (110 pb^{-1})

$\psi(\mathbf{2S}) \to \mu^+\mu^-$
$p_T(\psi(\mathbf{2S})) > 5.5$ **GeV**$/c$
Prompt (direct): $ct < 0.01$ **cm**
χ^2 **fit of** $1 + \alpha\cos^2\theta$ **to data**

Result: α **vs.** $p_T(\psi(\mathbf{2S}))$
Compare to COM prediction

www-cdf.fnal.gov/physics/ new/bottom/cdf4876/cdf4876.html



Polarization of direct $\psi(2S)$ production: α vs. $p_T(\psi(2S))$