TESTING THE $k_\perp$-FACTORIZATION WITH P-WAVE QUARKONIA PRODUCTION

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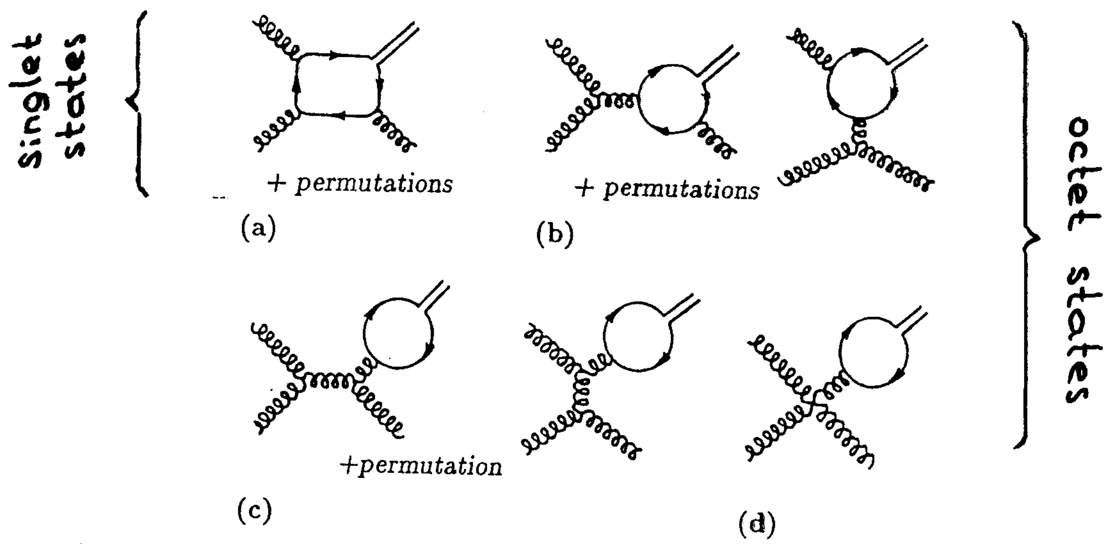


PRODUCTION MECHANISMS:

COLOUR-SINGLET (a), (b)

- perturbative creation of a $c\bar{c}$ pair with specified quantum numbers
- boundstate formation is determined by $|\Psi_P'(0)|^2 \sim v^5$

COLOUR-OCTET (a)-(d)

- perturbative creation of a $c\bar{c}$ pair in octet state
- subsequent emission of nonperturbative gluons

$^3S_1(8) \to {}^3P_{0,2}(1) \sim v^5$

$^3S_1(8) \to {}^3P_1(1) \sim v^7$ [Landau-Yang theorem]

EXTENSION TO SEMI-HARD APPROACH:

- introduction of noncollinear (= unintegrated) gluon distribution functions $\mathcal{F}(x, k_\perp^2, \mu^2)$
- modification of gluon spin density matrix

$\epsilon^\mu \epsilon^{\nu *} \sim k_\perp^\mu k_\perp^\nu / |k_\perp|^2$

(now longitudinal polarization appears)

PARTONIC SUBPROCESSES

	$Q\bar{Q}$ state	$^1S_0$	$^3S_1$	^3P_J
$2 \to 1$	$g+g \to$	$^1S_0[1]$, $^1S_0[8]$,	– $^3S_1[8]$,	$^3P_J[1]$ $^3P_J[8]$
	$\gamma+g \to$	– $^1S_0[8]$,	– –	– $^3P_J[8]$
	$\gamma+\gamma \to$	$^1S_0[1]$, –	– –	$^3P_J[1]$ –
$2 \to 2$	$g+g \to$	$^1S_0+g$, $^1S_0+g$, $^1S_0+\gamma$	$^3S_1+g$, $^3S_1+\gamma$, $^3S_1+g$, $^3S_1+\gamma$,	$^3P_J+g$ $^3P_J+g$, $^3P_J+\gamma$
	$\gamma+g \to$	$^1S_0+g$,	$^3S_1+g$, $^3S_1+g$, $^3S_1+\gamma$,	$^3P_J+g$
	$\gamma+\gamma \to$	– –	$^3S_1+\gamma$ $^3S_1+g$	– –

Effects of NLO matrix elements are present in the k_T gluon evolution, but only in part, not completely

PARAMETERS AND UNCERTAINTIES

$\mathcal{F}_g(x, k_\perp^2, \mu_F^2)$ Unintegrated gluon density

$\alpha_s(\mu_R^2)$ Renormalization scale $(\hat{s}/4,\ m_{\perp\psi}^2,\ k_\perp^2, \ldots)$

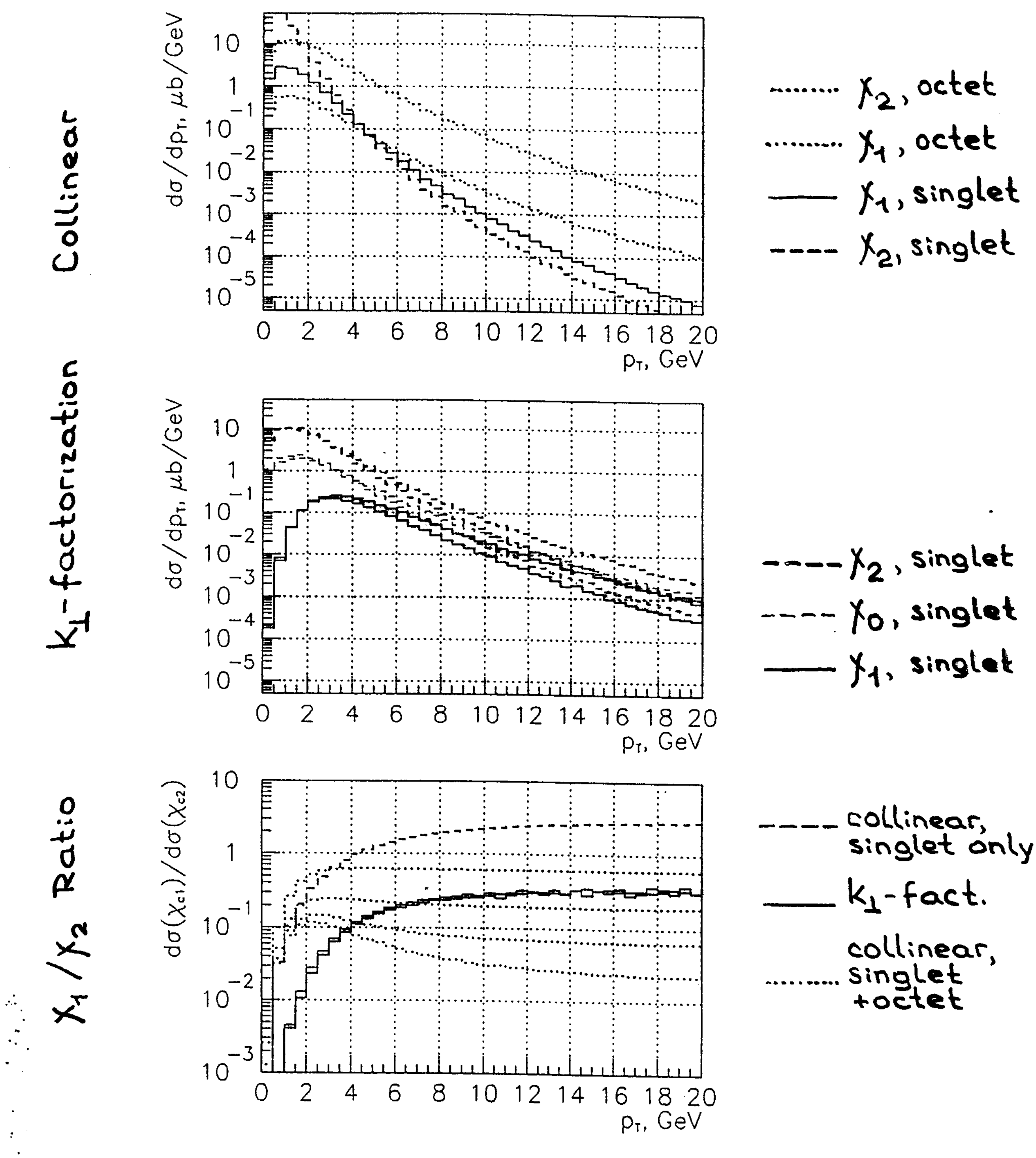
m_c Quark mass

Non-relativistic (colour-octet) matrix elements

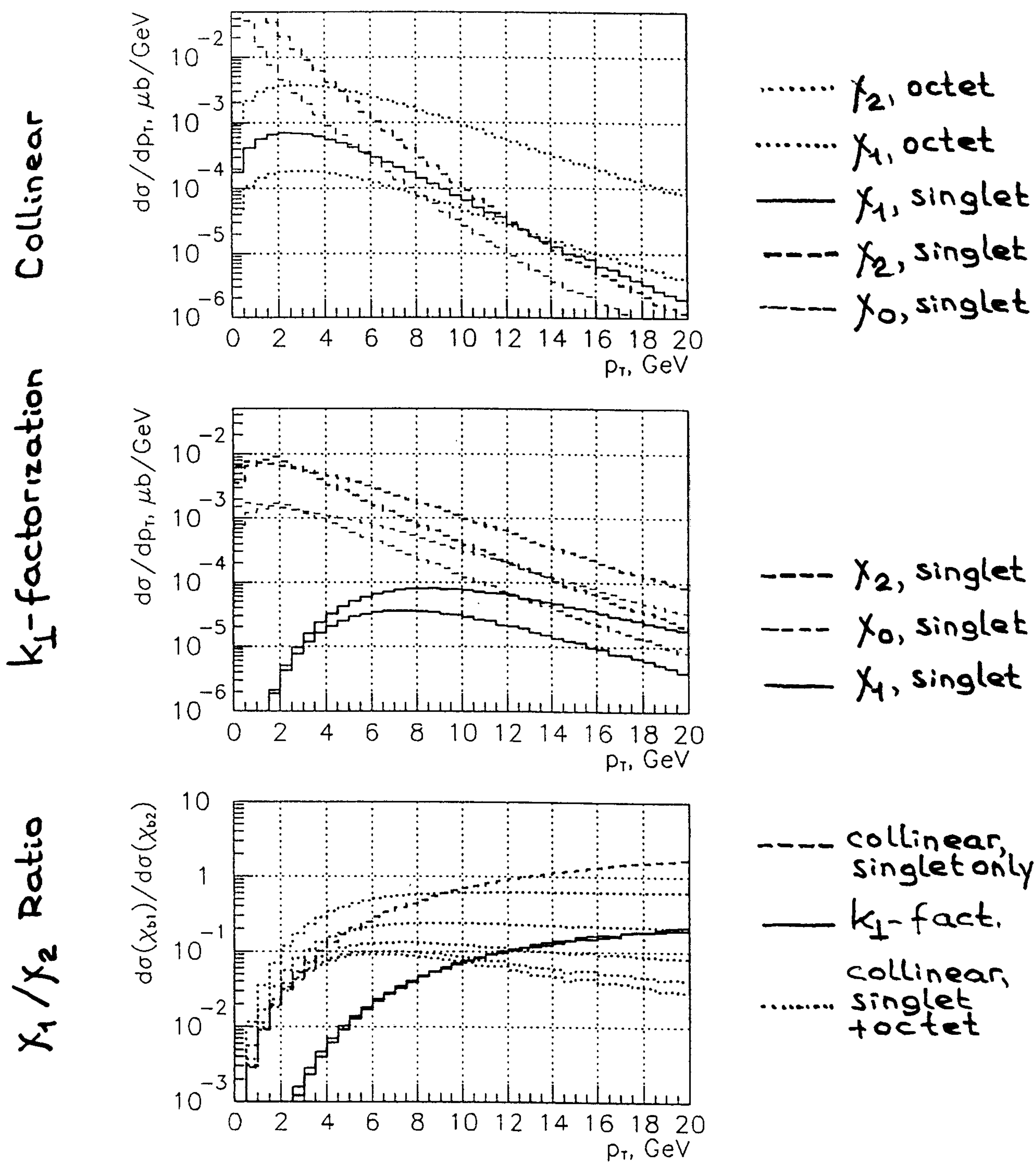
Inclusion/noninclusion of NLO pQCD

Regularization parameters

CHARMONIUM AT THE TEVATRON



BOTTOMONIUM AT THE TEVATRON



DISCUSSION / CONCLUSION

Two qualitative effects are found:

TRANSVERSE MOMENTUM SPECTRA AT $p_\perp \to 0$

In the collinear approach,

$d\sigma/dp_\perp$ is strongly peaking at $p_\perp \to 0$

In the $k_\perp$-factorization approach,

$d\sigma/dp_\perp$ remains finite or even decreasing

RATIO OF THE PRODUCTION RATES χ_1/χ_2

In the collinear approach,

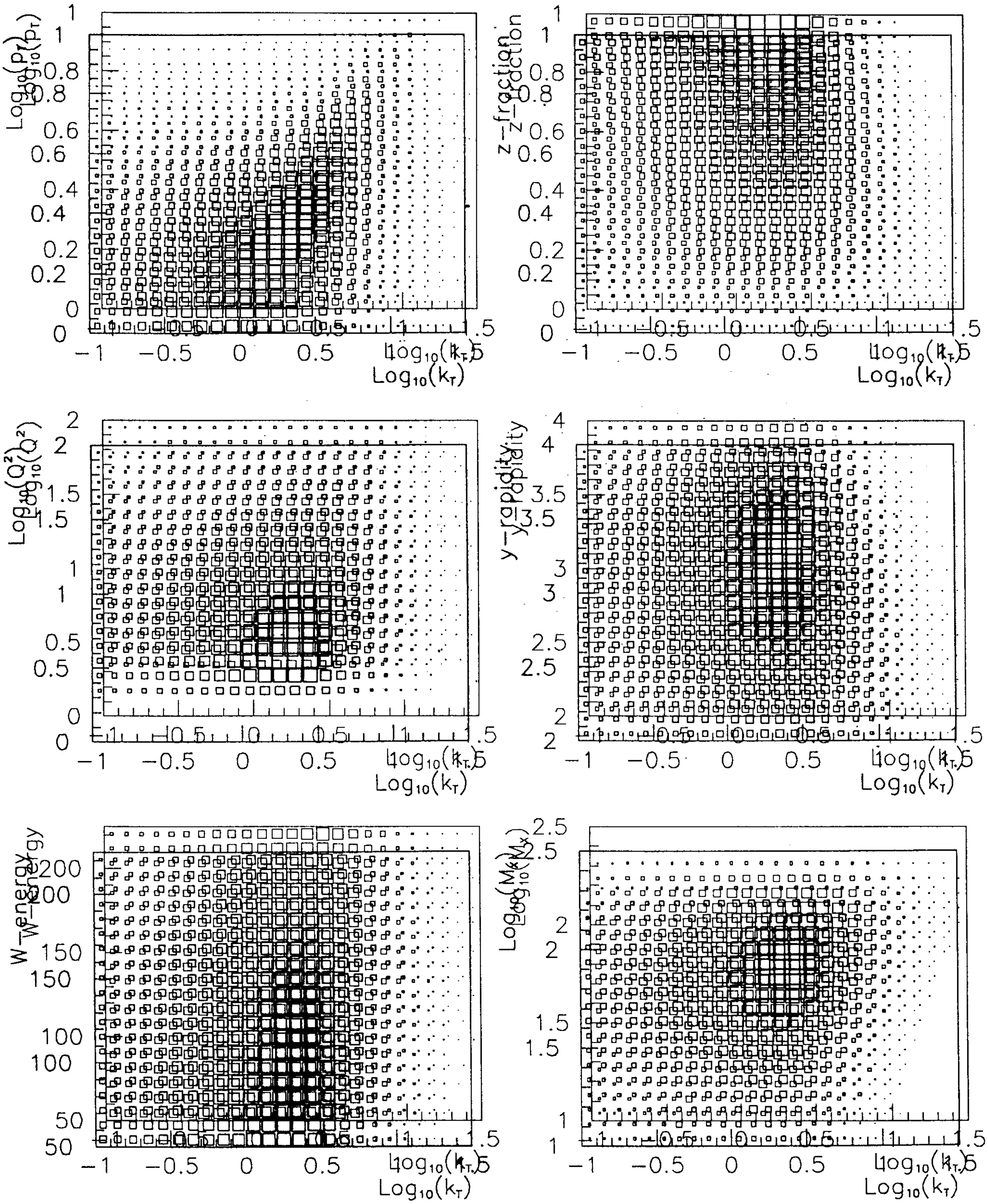
$d\sigma(\chi_1)/d\sigma(\chi_2)$ decreases with increasing $p_\perp$
because of the increasing role of colour-octet channel where gluon fragmentation to χ_1 is suppressed

In the $k_\perp$-factorization approach,

$d\sigma(\chi_1)/d\sigma(\chi_2)$ increases with increasing p_t
because of the increasing initial gluon off-shellness and its role in the Landau-Yang theorem

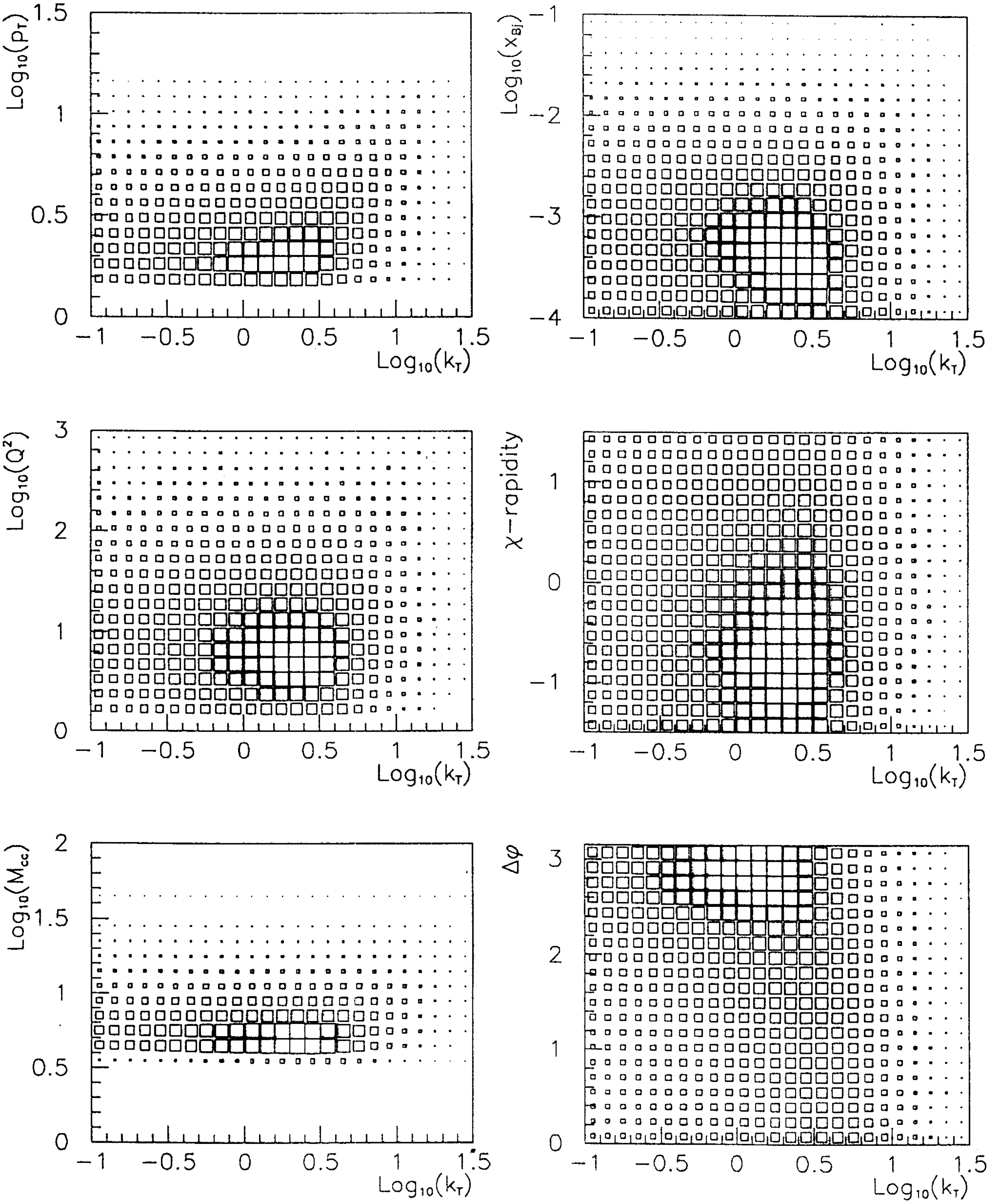
Alltogether, looks very promising

J/ψ AT HERA



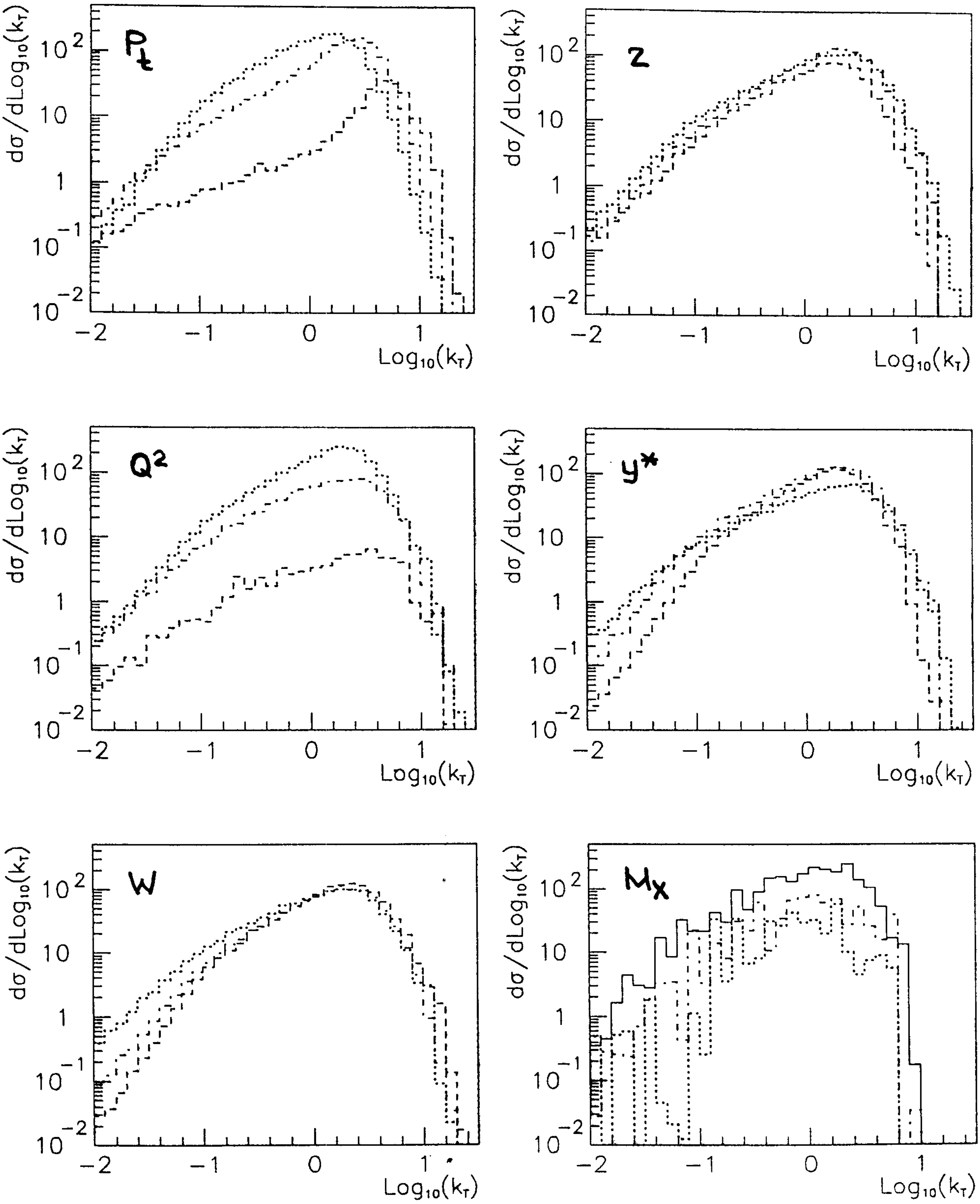
Log10(pT)
z–fraction
Log10(Q²)
y–rapidity
W–energy
Log10(Mx)
Log10(kT)

D^* AT HERA



J/ψ production H1 cuts	D^* production ZEUS cuts
transverse momentum p_t	transverse momentum p_t
$0 < p_t < 2$	$0 < p_t < 2$
$2 < p_t < 4$	$2 < p_t < 5$
$4 < p_t < \infty$	$5 < p_t < \infty$
momentum fraction z	momentum fraction x
$0. < z < 0.7$	$10^{-4} < x < 10^{-3}$
$0.7 < z < 0.9$	$10^{-3} < x < 10^{-2}$
$0.9 < z < 1.$	$10^{-2} < x < 10^{-1}$
photon virtuality Q^2	photon virtuality Q^2
$2 < Q^2 < 10$	$1 < Q^2 < 10$
$10 < Q^2 < 50$	$10 < Q^2 < 100$
$50 < Q^2 < \infty$	$100 < Q^2 < 1000$
rapidity in γp c.m.s. y^*	rapidity in lab. sys. η
$2.0 < y^* < 2.7$	$-1.5 < \eta < -0.5$
$2.7 < y^* < 3.3$	$-0.5 < \eta < 0.5$
$3.3 < y^* < 4.0$	$0.5 < \eta < 1.5$
γp invariant energy W	azim. angle diff. $\Delta\phi_{c\bar{c}}$
$50 < W < 100$	$0 < \Delta\phi_{c\bar{c}} < 1.0$
$100 < W < 150$	$1.0 < \Delta\phi_{c\bar{c}} < 2.7$
$150 < W < 225$	$2.7 < \Delta\phi_{c\bar{c}} < \pi$
hadronic mass M_X	invariant mass $M_{c\bar{c}}$
$0 < M_X < 6$	$0 < M_{c\bar{c}} < 6$
$6 < M_X < 10$	$6 < M_{c\bar{c}} < 10$
$10 < M_X < 20$	$10 < M_{c\bar{c}} < 20$
$20 < M_X < \infty$	$20 < M_{c\bar{c}} < \infty$

J/ψ PRODUCTION AT HERA



D* PRODUCTION AT HERA