Colour reconnection and inclusive J/ψ hadroproduction

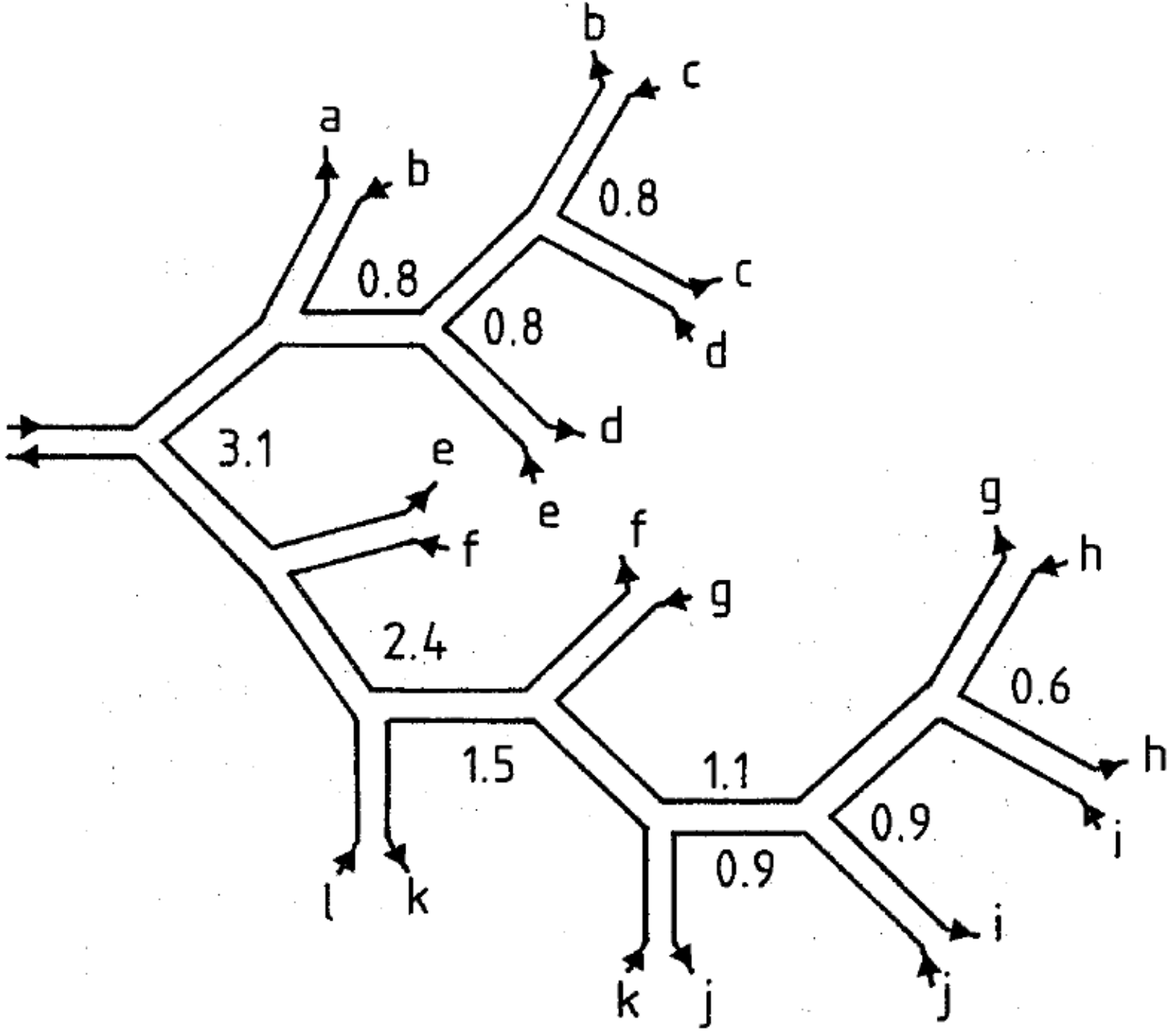
1. Colour reconnection

idea
measure (probability of reconnection)
MPI, main effects

2. Problem with J/ψ too small cross section

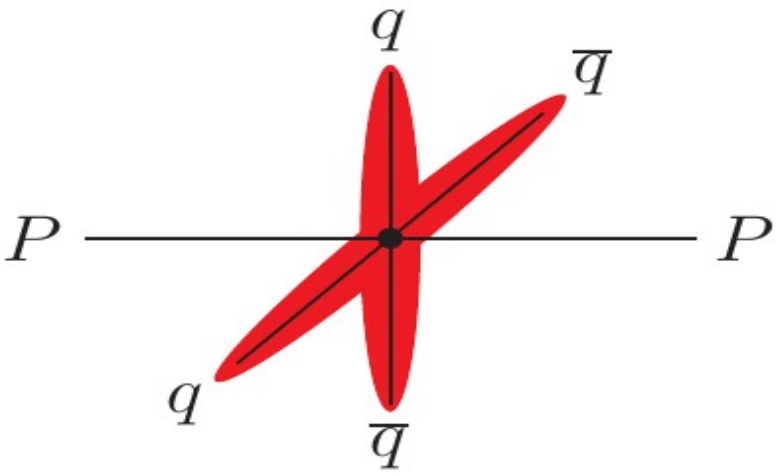
CSM, SCI, COM

3. J/psi from colour reconnection


a
b
b
c
0.8
c
0.8
0.8
d
d
3.1
e
e
f
f
g
2.4
g
h
0.6
h
1.5
1.1
0.9
i
0.9
i
l
k
k
j
j

1. Colour reconnection

Before colour reconnection

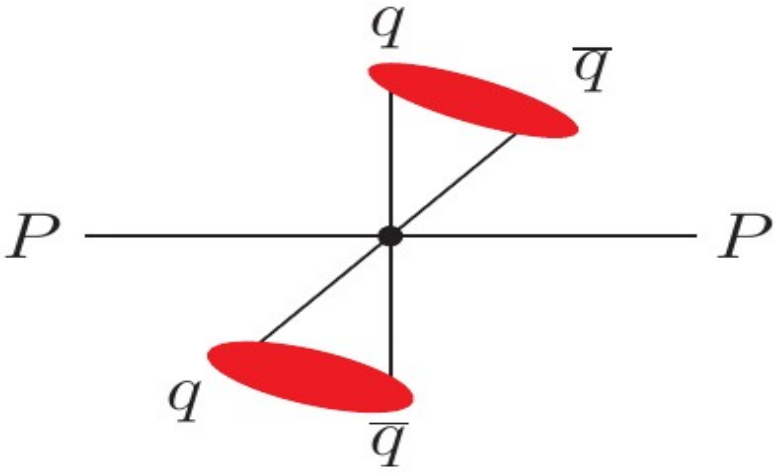


CR diminishes N

enlarges $< p_T >$

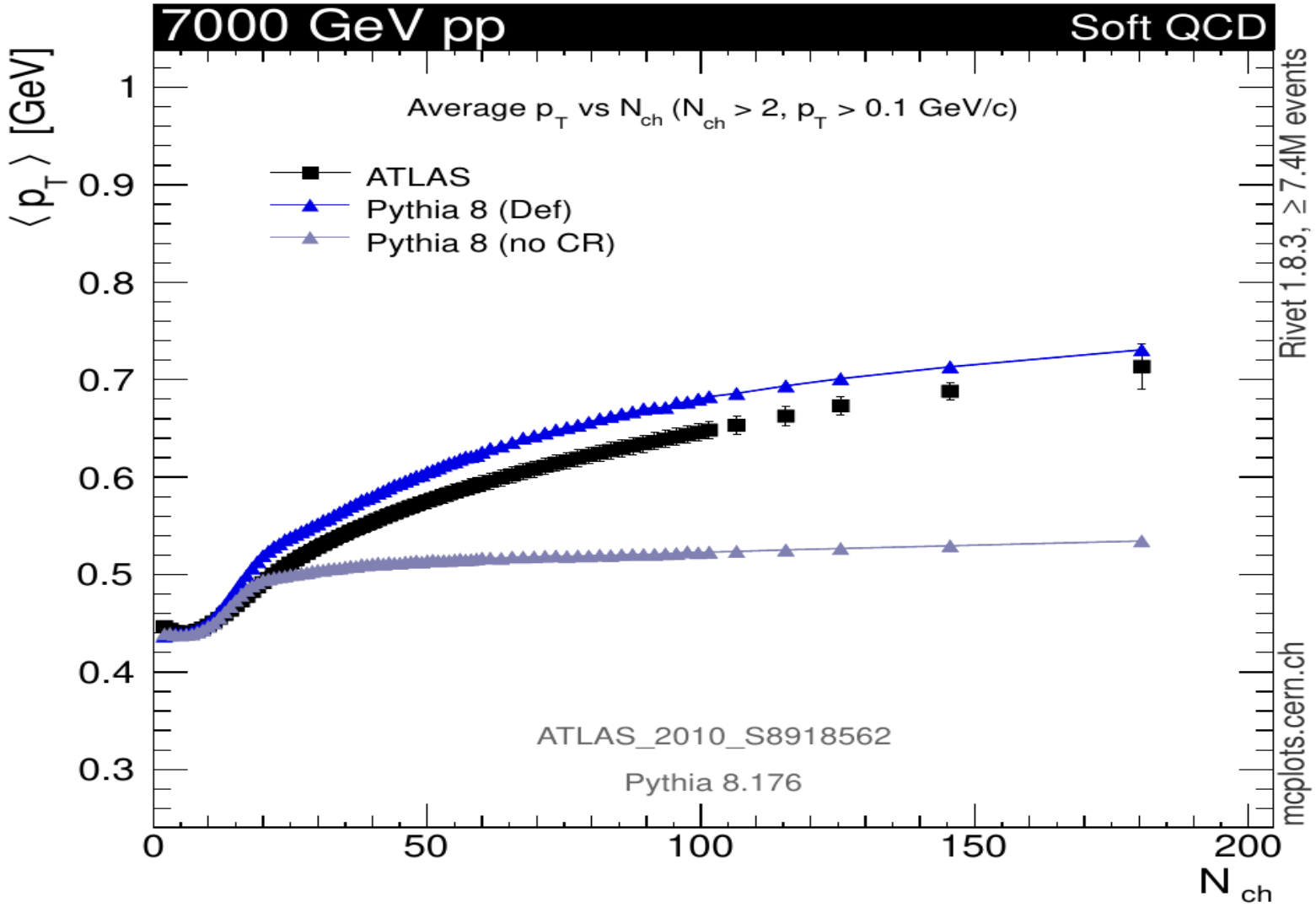
produces "collective flow"

After colour reconnection?



$1/N_c^2$ colour supression

Experimentally needed to explain the rise of $\langle p_\perp \rangle$ with multiplicity



Probabiluty of CR

$1/N_c^2$ colour supression

$$\lambda^{q\bar{q}} = \ln\left(1 + \frac{s_{q\bar{q}}}{2m_0^2}\right)$$

The λ measure can be interpreted as the potential energy of the string

$$P = N \cdot \textbf{colour factor} \cdot \exp(-\sum \lambda_i)$$

String Formation Beyond Leading Colour

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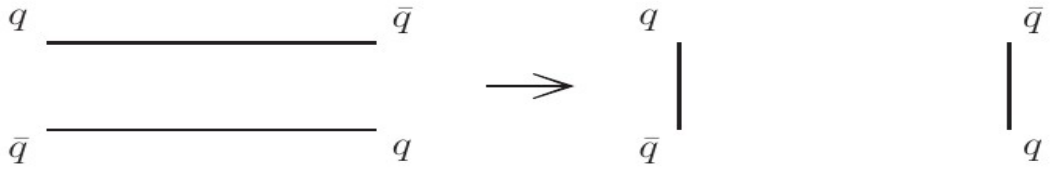
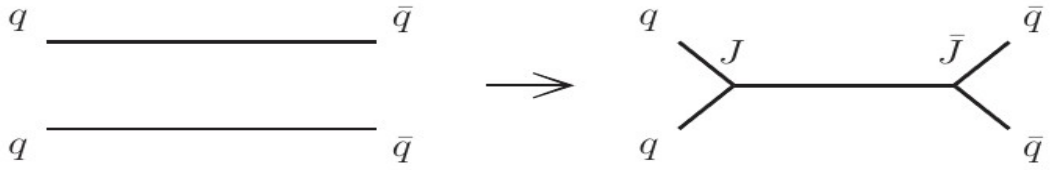
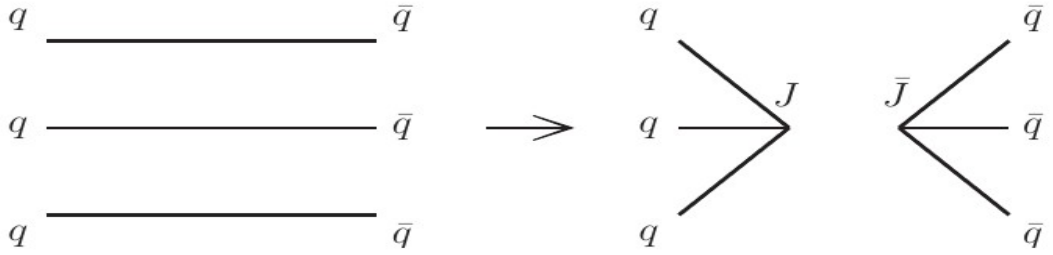
1505.01681



(a) Type I: ordinary dipole-style reconnection



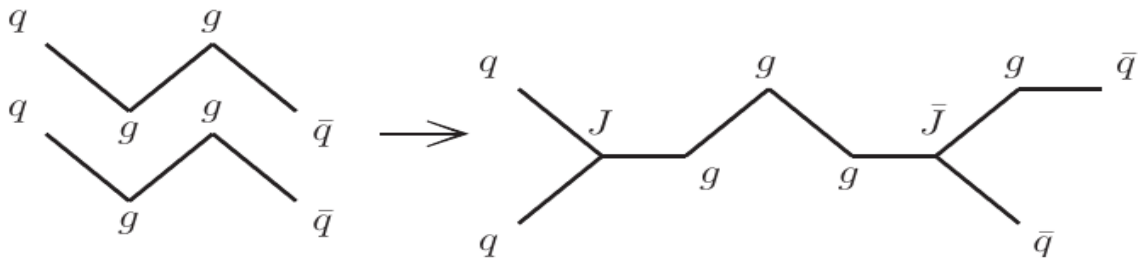
(b) Type II: junction-style reconnection



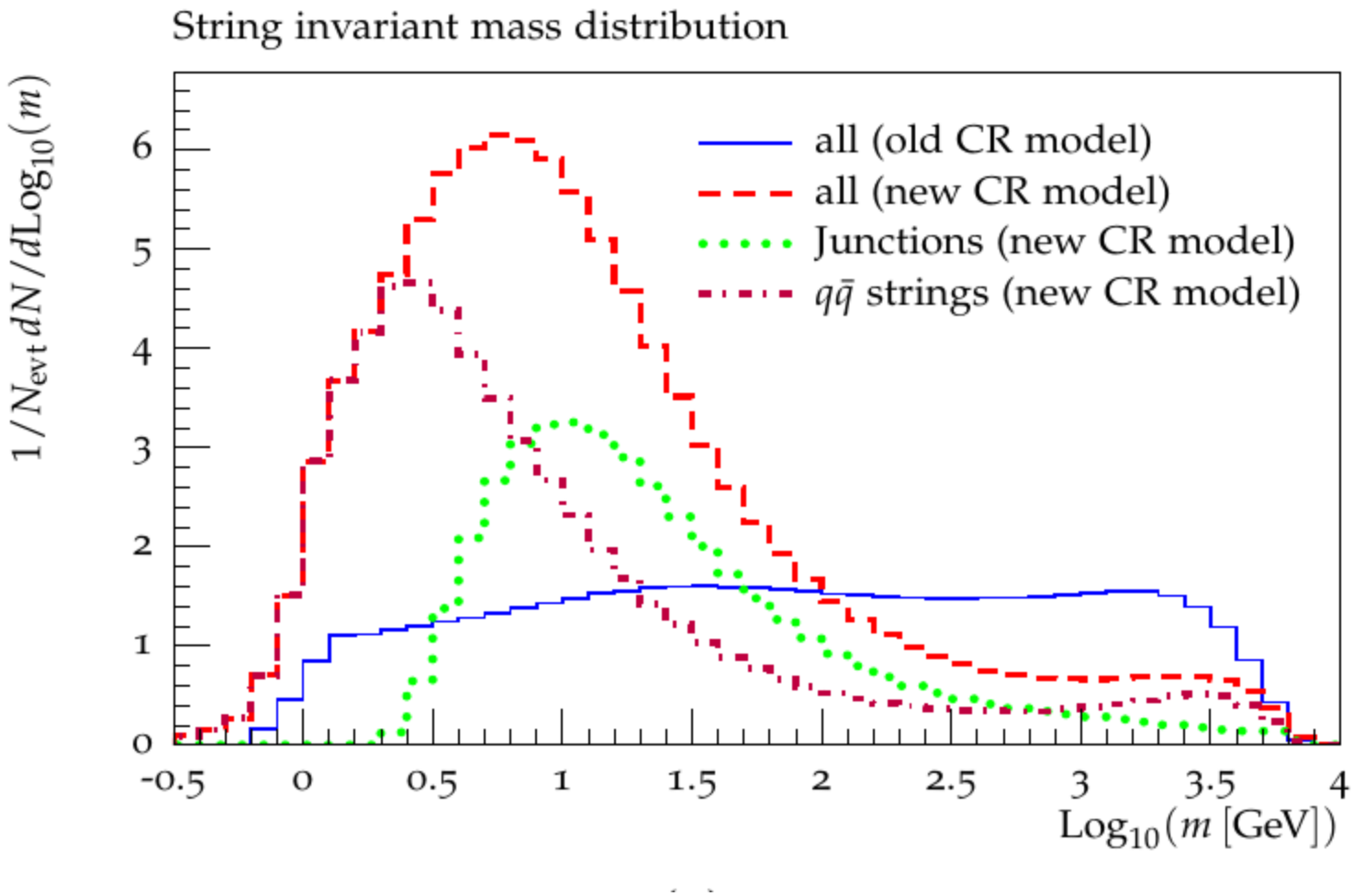
(c) Type III: baryon-style junction reconnection

$$\mathbf{3} \otimes \overline{\mathbf{3}} = \mathbf{8} \oplus \mathbf{1}$$

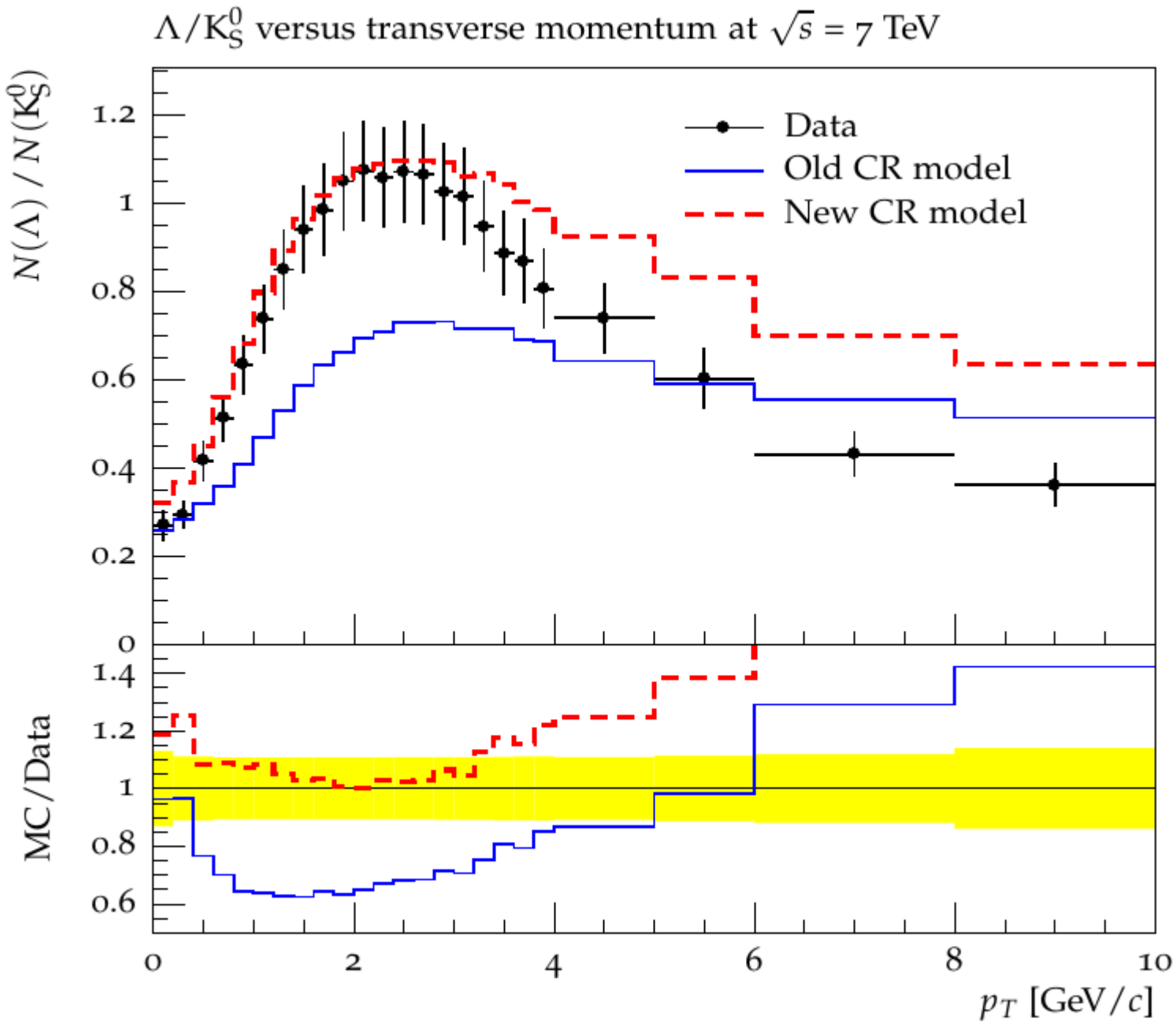
$$\mathbf{3} \otimes \mathbf{3} \otimes \mathbf{3} = \mathbf{10} \oplus \mathbf{8} \oplus \mathbf{8} \oplus \mathbf{1}$$



(d) Type IV: zipper-style junction reconnection


String invariant mass distribution
$1/N_{evt}\,dN/d\mathrm{Log}_{10}(m)$
all (old CR model)
all (new CR model)
Junctions (new CR model)
$q\bar{q}$ strings (new CR model)
0
1
2
3
4
5
6
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
$\mathrm{Log}_{10}(m\,[\mathrm{GeV}])$

Particle	New CR model ($N_{\text{par}}/N_{\text{events}}$)			Old CR model
	string	junction	all	$N_{\text{par}}/N_{\text{events}}$ (all)
π^+	$2.5 \cdot 10^1$	0	$2.5 \cdot 10^1$	$2.4 \cdot 10^1$
p	2.5	1.4	3.8	3.2
n	2.4	1.3	3.7	3.2
Δ^{++}	$6.1 \cdot 10^{-1}$	$4.5 \cdot 10^{-1}$	1.1	$8.9 \cdot 10^{-1}$
Δ^+	$6.0 \cdot 10^{-1}$	$4.0 \cdot 10^{-1}$	1.0	$8.6 \cdot 10^{-1}$
Δ^0	$5.5 \cdot 10^{-1}$	$4.0 \cdot 10^{-1}$	$9.4 \cdot 10^{-1}$	$7.9 \cdot 10^{-1}$
Δ^-	$4.7 \cdot 10^{-1}$	$4.4 \cdot 10^{-1}$	$9.1 \cdot 10^{-1}$	$7.1 \cdot 10^{-1}$
K^+	5.2	0	5.2	5.1
Λ	$4.7 \cdot 10^{-1}$	$3.9 \cdot 10^{-1}$	$8.6 \cdot 10^{-1}$	$6.5 \cdot 10^{-1}$
Σ^+	$3.4 \cdot 10^{-1}$	$4.2 \cdot 10^{-1}$	$7.6 \cdot 10^{-1}$	$5.1 \cdot 10^{-1}$
Σ^0	$3.5 \cdot 10^{-1}$	$4.5 \cdot 10^{-1}$	$7.9 \cdot 10^{-1}$	$5.1 \cdot 10^{-1}$
Σ^-	$3.2 \cdot 10^{-1}$	$4.2 \cdot 10^{-1}$	$7.4 \cdot 10^{-1}$	$4.9 \cdot 10^{-1}$
Σ^{*+}	$9.6 \cdot 10^{-2}$	$8.9 \cdot 10^{-2}$	$1.9 \cdot 10^{-1}$	$1.5 \cdot 10^{-1}$
Σ^{*0}	$9.2 \cdot 10^{-2}$	$7.7 \cdot 10^{-2}$	$1.7 \cdot 10^{-1}$	$1.4 \cdot 10^{-1}$
Σ^{*-}	$8.3 \cdot 10^{-2}$	$8.7 \cdot 10^{-2}$	$1.7 \cdot 10^{-1}$	$1.3 \cdot 10^{-1}$
Ξ^-	$6.9 \cdot 10^{-2}$	$1.1 \cdot 10^{-1}$	$1.8 \cdot 10^{-1}$	$1.1 \cdot 10^{-1}$
Ω^-	$2.0 \cdot 10^{-3}$	$1.3 \cdot 10^{-2}$	$1.5 \cdot 10^{-2}$	$3.9 \cdot 10^{-3}$
D^+	$5.3 \cdot 10^{-2}$	0	$5.3 \cdot 10^{-2}$	$6.5 \cdot 10^{-2}$
Λ_c^+	$4.0 \cdot 10^{-3}$	$7.9 \cdot 10^{-3}$	$1.2 \cdot 10^{-2}$	$6.6 \cdot 10^{-3}$
Σ_c^{++}	$2.7 \cdot 10^{-4}$	$1.3 \cdot 10^{-2}$	$1.3 \cdot 10^{-2}$	$5.4 \cdot 10^{-4}$
Σ_c^+	$2.5 \cdot 10^{-4}$	$1.5 \cdot 10^{-2}$	$1.5 \cdot 10^{-2}$	$5.2 \cdot 10^{-4}$
Σ_c^0	$2.5 \cdot 10^{-4}$	$1.3 \cdot 10^{-2}$	$1.3 \cdot 10^{-2}$	$5.1 \cdot 10^{-4}$
Σ_c^{*++}	$5.1 \cdot 10^{-4}$	$1.7 \cdot 10^{-3}$	$2.2 \cdot 10^{-3}$	$9.5 \cdot 10^{-4}$
Σ_c^{*+}	$4.9 \cdot 10^{-4}$	$1.9 \cdot 10^{-3}$	$2.4 \cdot 10^{-3}$	$9.4 \cdot 10^{-4}$


Λ/K^0_S versus transverse momentum at $\sqrt{s}$ = 7 TeV
$N(\Lambda)$ / $N(K^0_S)$
Data
Old CR model
New CR model
MC/Data
p_T [GeV/c]

CR is most effective in MPI events

enlarging the $< p_T >$, decreasing N_{ch}

producing some collective flow

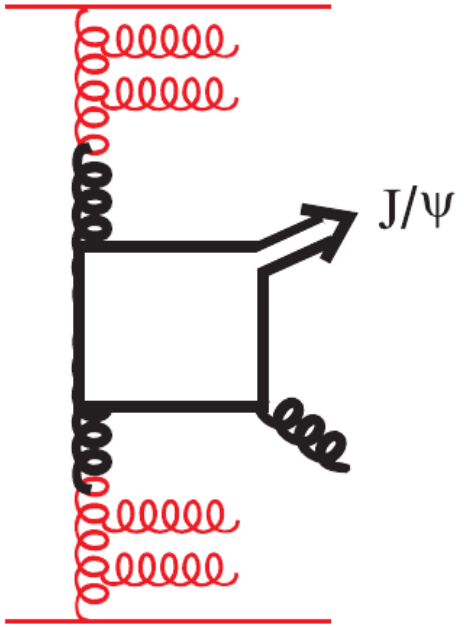
enlarges number of baryons

2. Problem with J/ψ

Most natural subprocess is CS$_{inglet}$M

$$gg \to c\bar{c} \to J/\psi + g$$

$\sigma^{theor} \sim 0.1\sigma^{exp}$



SCI and CO$_{ctet}$M, that is $(q\bar{q})_8 \to J/\psi$ without the α_s suppression

COM does not explain the p_T and N_{ch} dependence of J/ψ spectra

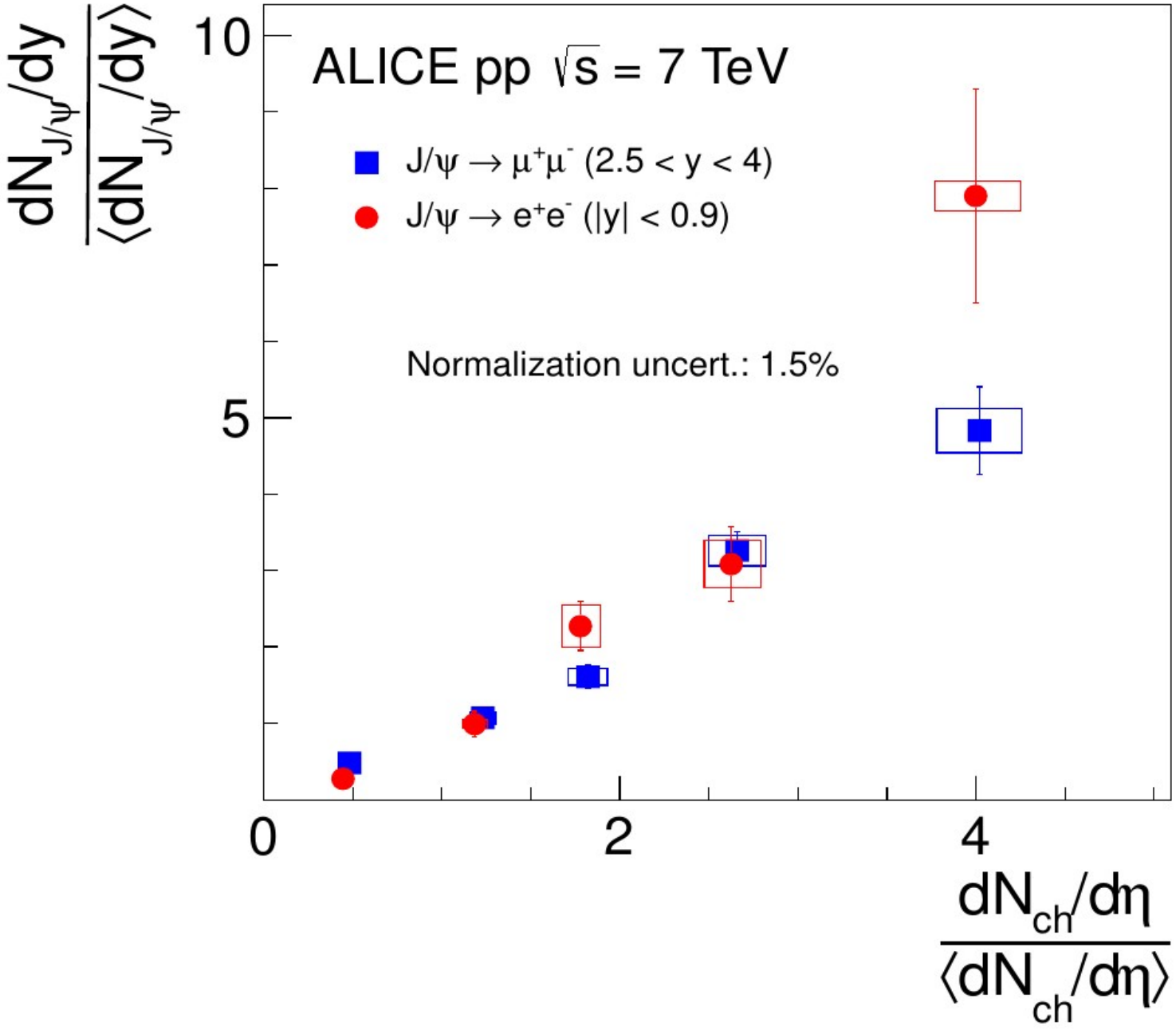


Fig. 3: J/ψ yield $\mathrm{d}N_{\mathrm{J}/\psi}/\mathrm{d}y$ as a function of the charged particle multiplicity densities at mid-rapidity $\mathrm{d}N_{\mathrm{ch}}/\mathrm{d}\eta$.

Color Reconnection Effects in J/ψ Hadroproduction

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2303.13128

PYTHIA MPI

colour singlet $c\bar{c}$ pair with $3 < M_{c\bar{c}} < 3.3\,GeV = J/\psi$

including c-quarks from parton shower

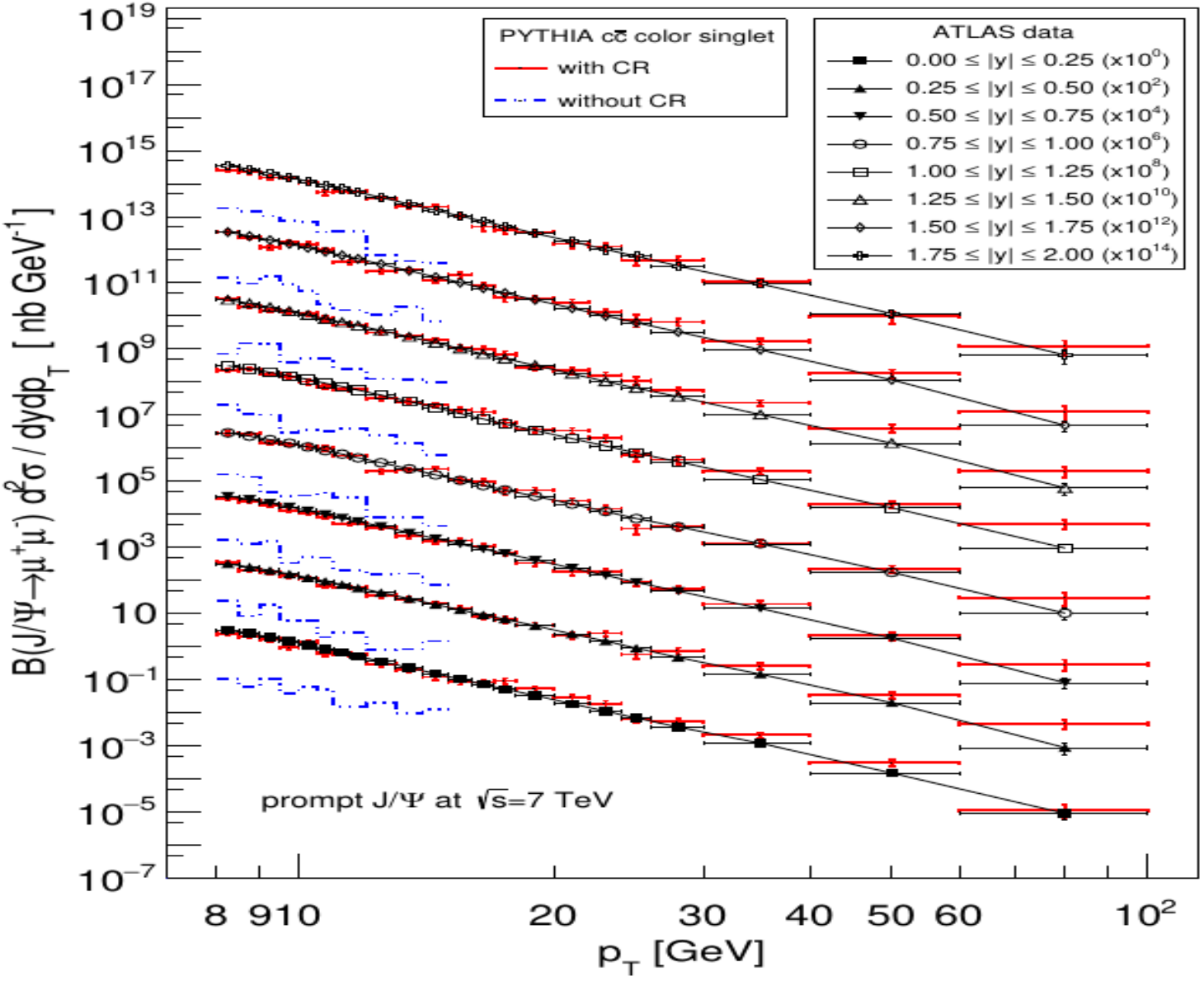

Figure 2: Transverse momentum spectra of J/ψ obtained from the PYTHIA generator, where the J/ψ state is constructed as the $c\bar{c}$ color singlet with invariant mass $3.0 < M < 3.3$ GeV, in comparison with the ATLAS data [59]. The dot-dashed histograms correspond to the scenario without the color reconnection model, which significantly underestimates the cross section (due to the low statistics, we show only the low p_T range).

THANK YOU