Statistical hadronization model predictions for charmed hadrons

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Abstract. We present predictions of the statistical hadronization model for charmed hadrons production in Pb+Pb collisions at LHC.

Remarks on production of open charm and charmonia

- charm quark mass >> Λ_{QCD} production described in QCD perturbation theory
- all calculations employ gluon fusion as starting point
- argument is energy independent until global energy conservation very close to threshold becomes important
- production of charm quark pairs takes place at timescale $1/m_c$
  $m_c = 1.5$ GeV --> $t_c = 0.13$ fm
- to build up wave function of mesons including those with open charm needs about t = 1fm --> charm production and charmed hadron formation are decoupled
- overall cross section is due to production of charm quark pairs
- time scale is much too short to dress the charm quarks
  essential to take current quarks

Method and inputs

Thermal model calculation (grand canonical) T, μ_B: $\rightarrow n_X^{th}$

$$N_{c\bar{c}}^{dir} = \frac{1}{2} g_c V (\sum_i n_{D_i}^{th} + n_{\Lambda_i}^{th}) + g_c^2 V (\sum_i n_{\psi_i}^{th} + n_{\chi_i}^{th})$$

$N_{c\bar{c}} << 1 \rightarrow$ Canonical: J.Cleymans, K.Redlich, E.Suhonen, Z. Phys. C51 (1991) 137

charm balance equation

$$N_{c\bar{c}}^{dir} = \frac{1}{2} g_c N_{oc}^{th} \frac{I_1(g_c N_{oc}^{th})}{I_0(g_c N_{oc}^{th})} + g_c^2 N_{c\bar{c}}^{th} \quad \rightarrow g_c$$

Outcome: $N_D = g_c V n_D^{th} I_1 / I_0 \quad N_{J/\psi} = g_c^2 V n_{J/\psi}^{th}$

Inputs: T, μ_B, $\quad V = N_{ch}^{exp} / n_{ch}^{th}$, $\quad N_{c\bar{c}}^{dir}$ (pQCD)

Charmonium regeneration models

- statistical hadronization model

  original proposal: pbm, J. Stachel, Phys. Lett. B490 (2000) 196

  assumptions:
  - all charm quarks are produced in hard collisions, N_c const. in QGP
  - all charmonia are dissolved in QGP or not produced before QGP
  - charmonium production takes place at the phase boundary with statistical weights

    $\rightarrow$ yield ~ N_c^2 -- quarkonium enhancement at high energies

    -- no feeding from higher charmonia
- charm quark coalescence model

  original proposal: R.L. Thews, M. Schroedter, J. Rafelski, Phys. Rev. C63 (2001) 054905

  assumptions:
  - all charm quarks are produced in hard collisions
  - all charmonia are produced in the QGP via charm quark recombination

    $\rightarrow$ yield ~ N_c^2 -- quarkonium enhancement at high energies

Many more papers on late generation

L. Grandchamp, R. Rapp, Phys. Lett. B523 (2001) 60
R. Rapp et al., PRL 92, 212301 (2004)
and refs. there
R. Thews et al, Eur. Phys. J C43, 97 (2005)
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M. I. Gorenstein et al., Phys. Lett. B509 (2001)277, ib. 524 (2002) 265
A.P. Kostyuk et al., Phys. Lett. B531 (2002) 195, Phys. Rev. C68 (2003) 041902
Yan, Zhuang, Xu, nucl-th/0608010
Bratkovskaya et al., PRC 69, 054903 (2004)
A. Andronic et al, Phys. Lett. B571 (2003) 36
A. Andronic et al, nucl-th/0611023, Nucl. Phys. A (in print)
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nucl-th/0701079, Phys. Lett. B (in print)
pbm, nucl-th/0701093 J. Phys. G (in print)

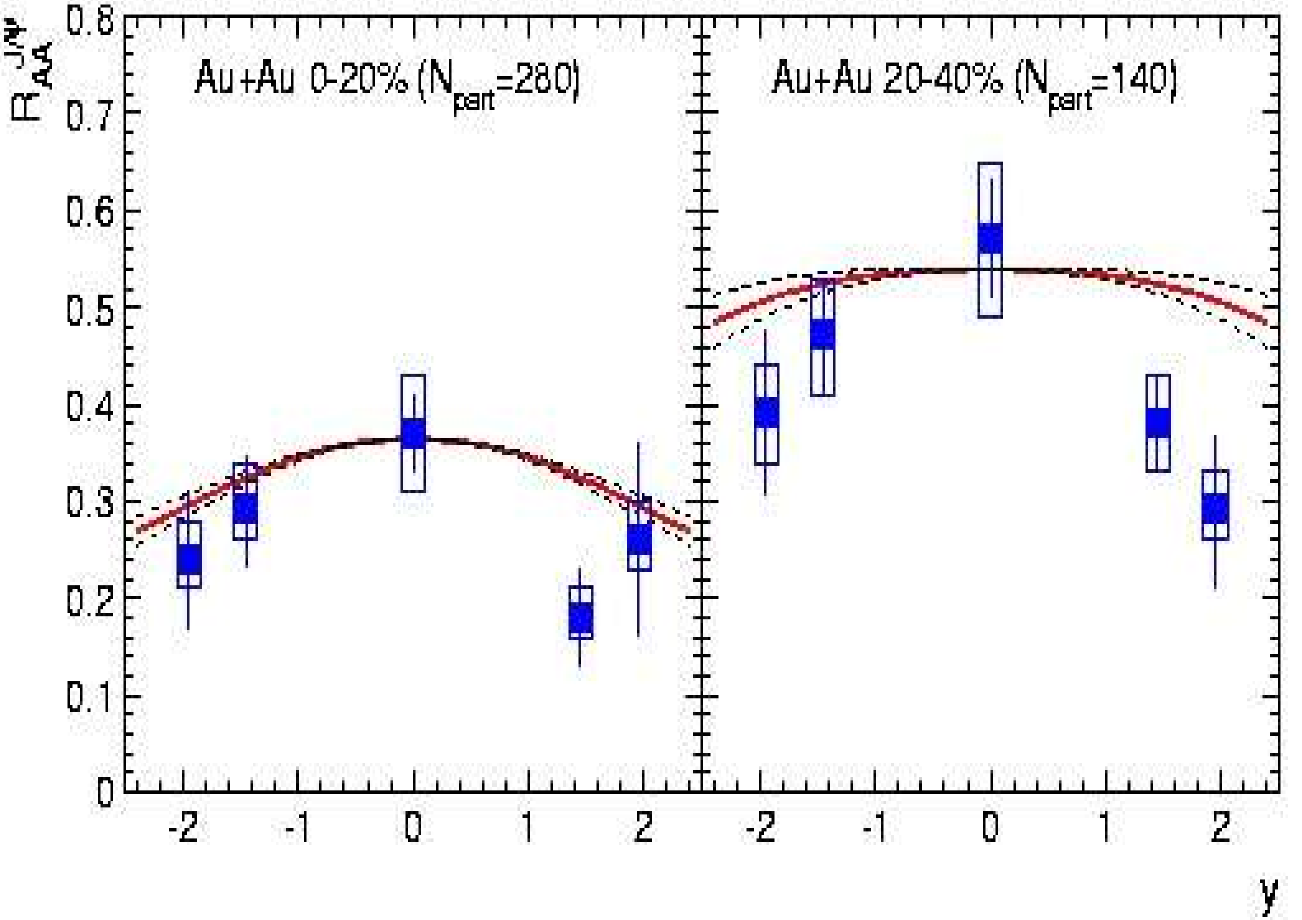
Ingredients for prediction of quarkonium and open charm cross sections

• open charm (open bottom) cross section in pp collisions

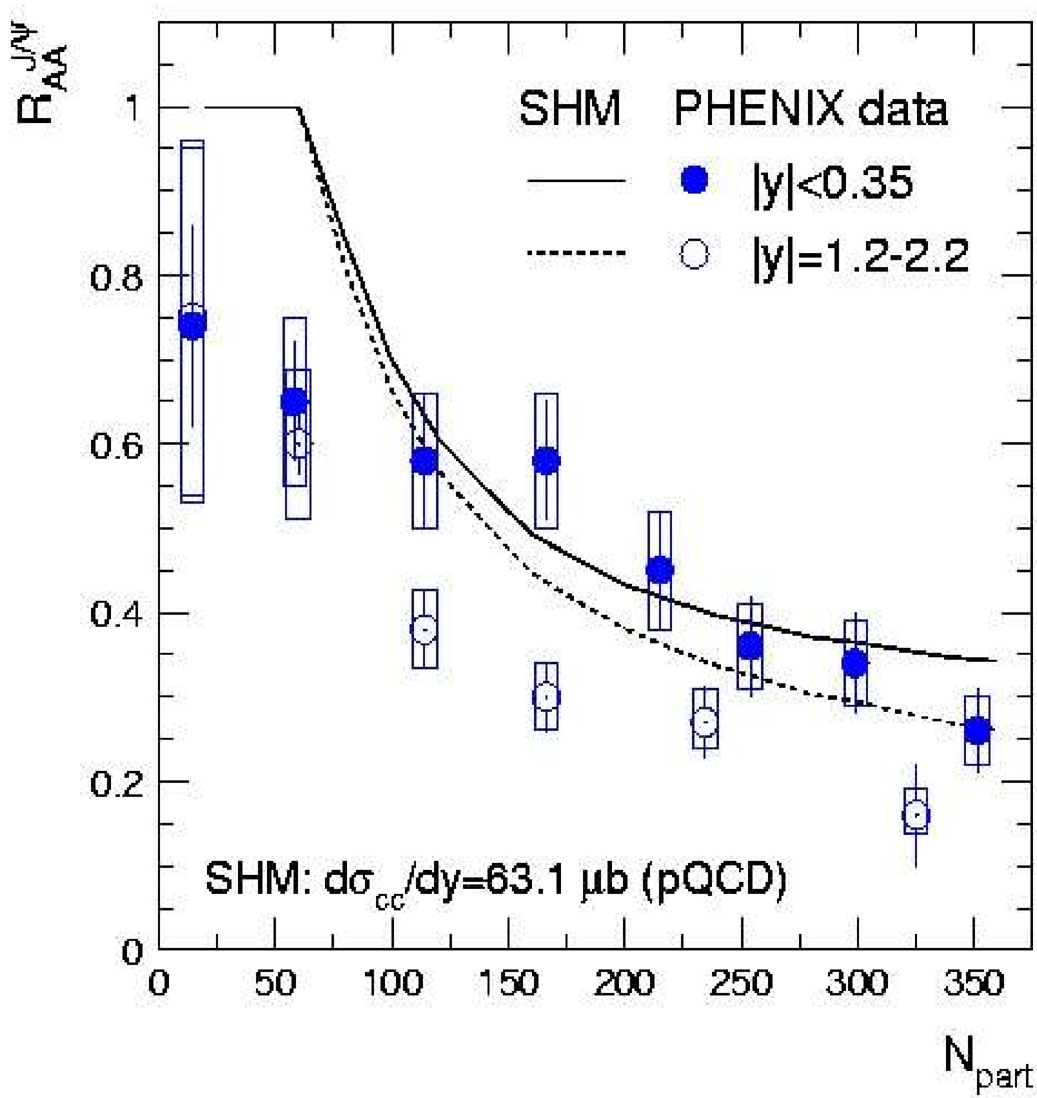
• quarkonium production cross section in pp collisions   (for corona part)

result: quarkonium and open charm cross sections as function of
energy, centrality, rapidity, and transverse momentum

Comparison of model predictions to RHIC data: rapidity dependence



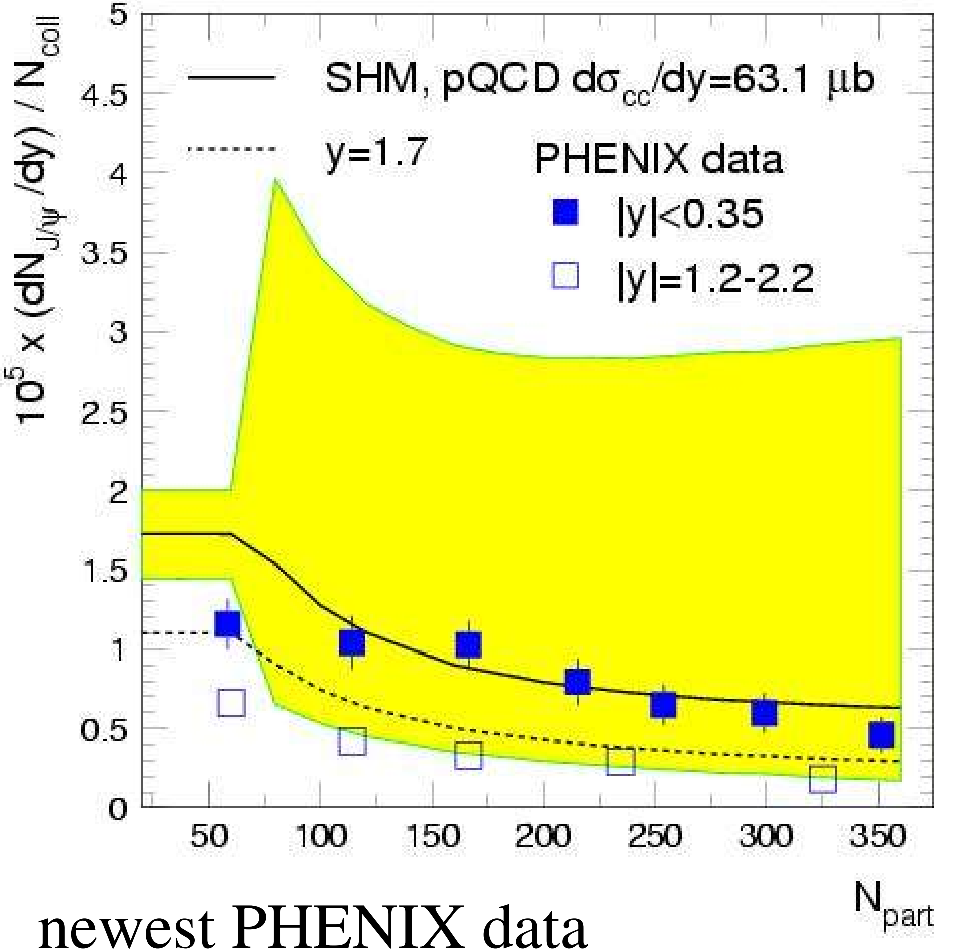
Centrality dependence of nuclear modification factor



Comparison of model predictions to RHIC data: centrality dependence

predictions for J/ψ production using NNLO pQCD results for open charm cross section by M. Cacciari, P. Nason, R. Vogt, Phys. Rev. Lett. 95 (2005) 122001, hep-ph/0502203

good agreement, no free parameters



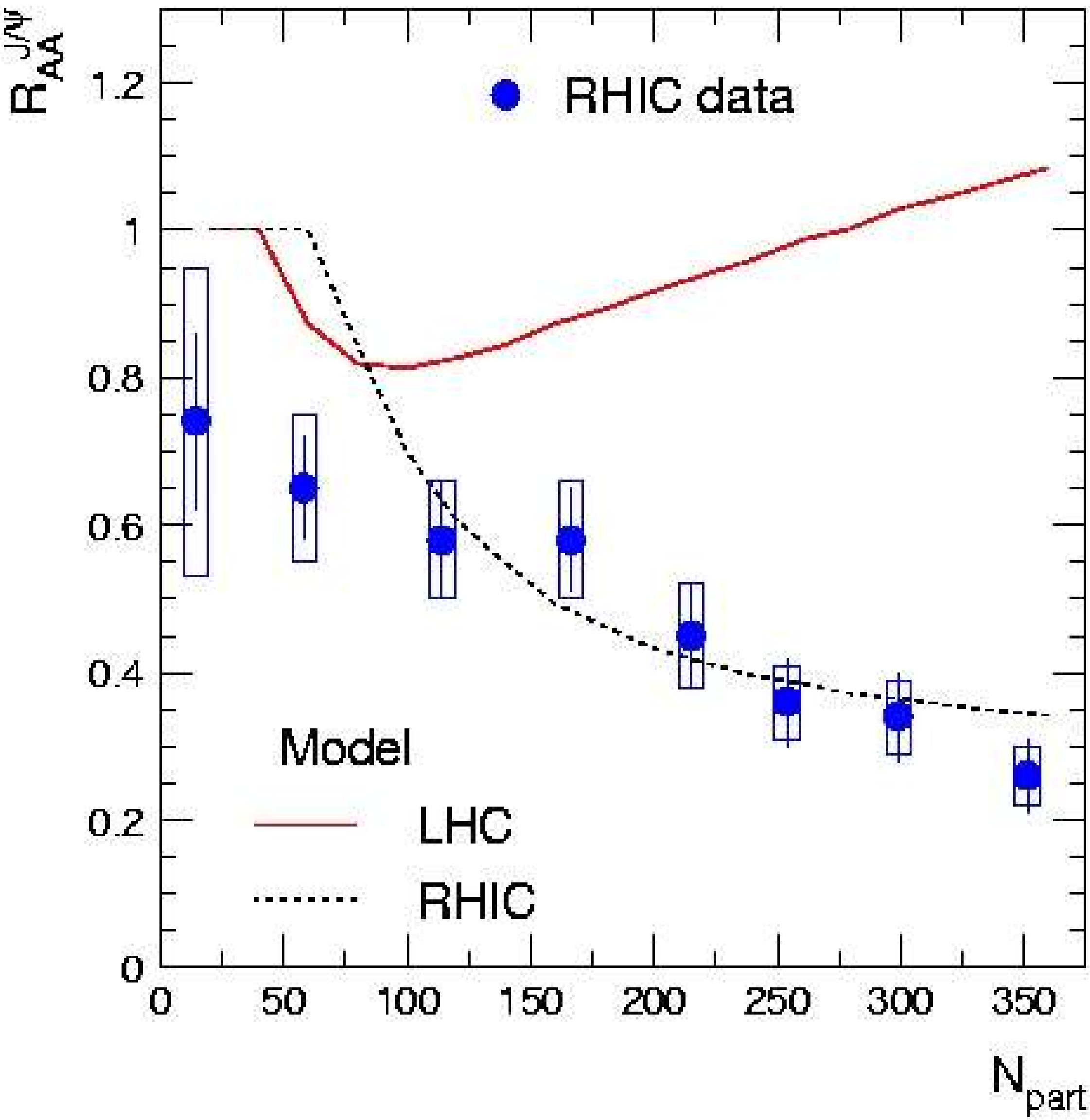
newest PHENIX data

Predictions for LHC energy

Summary of the parameters used

- characteristics at chemical freeze-out:
  (i) temperature T=161$\pm$4 MeV,
  (ii) baryochemical potential μ_b=0.8$^{+1.2}_{-0.6}$ MeV
  (iii) volume corresponding to one unit of rapidity V=6200 fm^3
- charm production cross section:
  $\mathrm{d}\sigma^{pp}_{c\bar{c}}/\mathrm{d}y = 0.64^{+0.64}_{-0.32}$ mb

Prediction for LHC energy: enhancement rather than suppression!



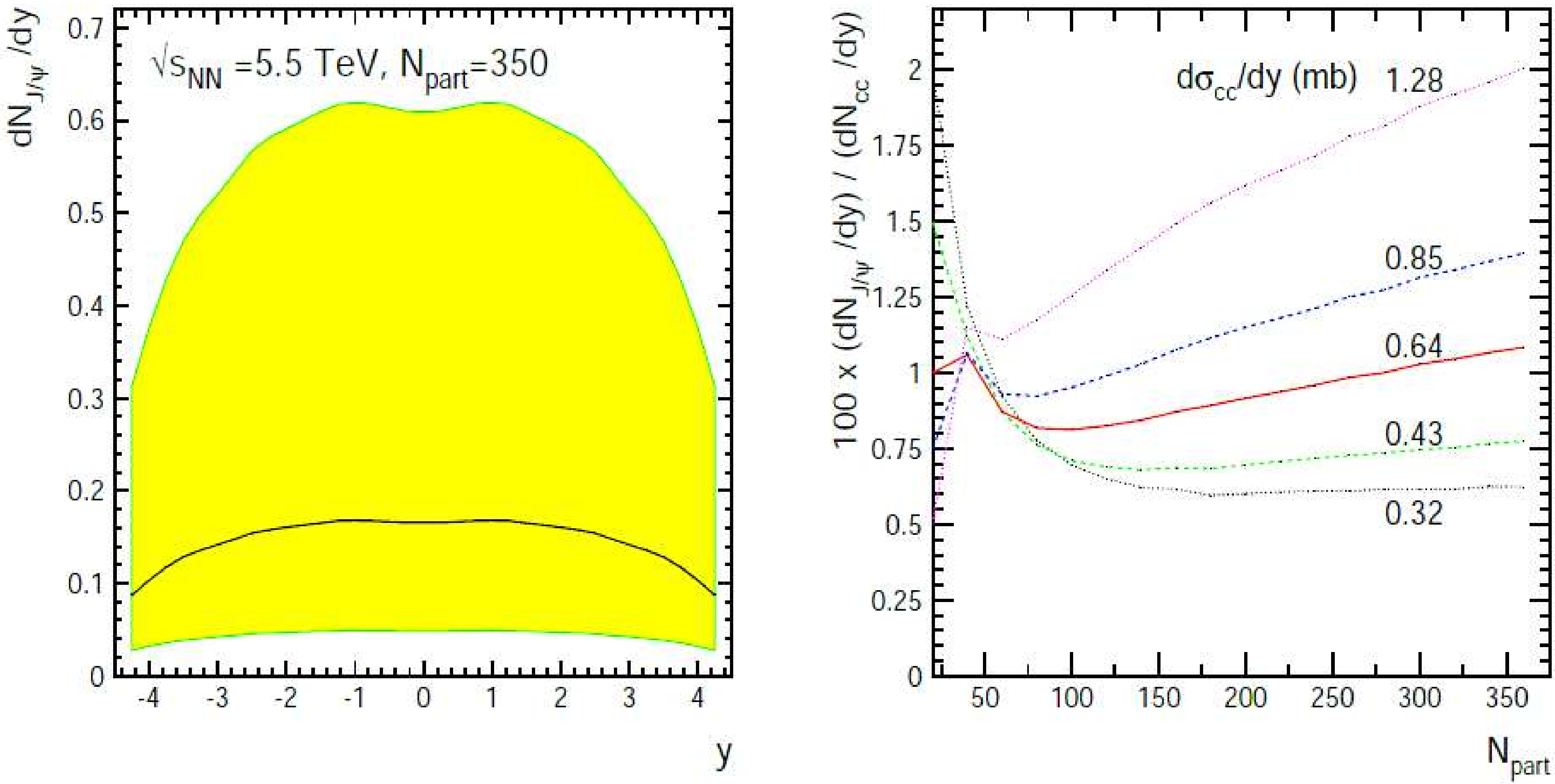


Figure 1. Predictions for J/ψ yield: rapidity distribution for central collisions (left panel) and centrality dependence of the yield relative to the charm production yield for different values of the charm cross section indicated on the curves (right panel).

Table 1. Predictions of the statistical hadronization model for charmed hadron ratios for Pb+Pb collisions at LHC. The numbers in parantheses represent the error in the last digit(s) due to the uncertainty of T.

D^-/D^+	$\bar{D}_0/D_0$	D^{*-}/D^{*+}	D_s^-/D_s^+	$\bar{\Lambda}_c/\Lambda_c$	D^+/D_0	D^{*+}/D_0
1.00(0)	1.01(0)	1.01(0)	1.00(1)	1.00(1)	0.425(18)	0.387(15)

D_s^+/D_0	Λ_c/D_0	ψ'/ψ	η_c/ψ	χ_{c1}/ψ	χ_{c2}/ψ
0.349(14)	0.163(16)	0.031(3)	0.617(14)	0.086(5)	0.110(8)

predictions for other charmed hadron ratios available upon request from the authors

Transverse momentum spectrum for charmonium in central Pb-Pb collisions