Multiplicities and inclusive hadrons in saturation approach

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an extrapolation from NPA897('13)1, Albacete-Dumitru-HF-Nara

by mckt-1.30/1.31 (A. Dumitru, Y. Nara)
http://faculty.baruch.cuny.edu/naturalscience/physics/dumitru/CGC_IC.html

all new plots are ***very preliminary*** from pilot runs

contents

- Introduction
- First estimate in saturation model at FCC for
  - dNdy in AA & pA
  - pt spectrum and RpA in pA
  -
- Discussion

Gluons at small x

- Interactions initiated by small-x partons (gluons)
  - Bjorken-x in 2-->1

$$x_{1,2} = \frac{m_\perp}{\sqrt{s}} \; e^{\pm y}$$

for mT=1 GeV, y=0

sqrt(s)/TeV	0.2	2.7	5	8	39	63	100
x	0.005	3.7E-4	2E-4	1.25E-4	2.6E-5	1.6E-5	1E-5

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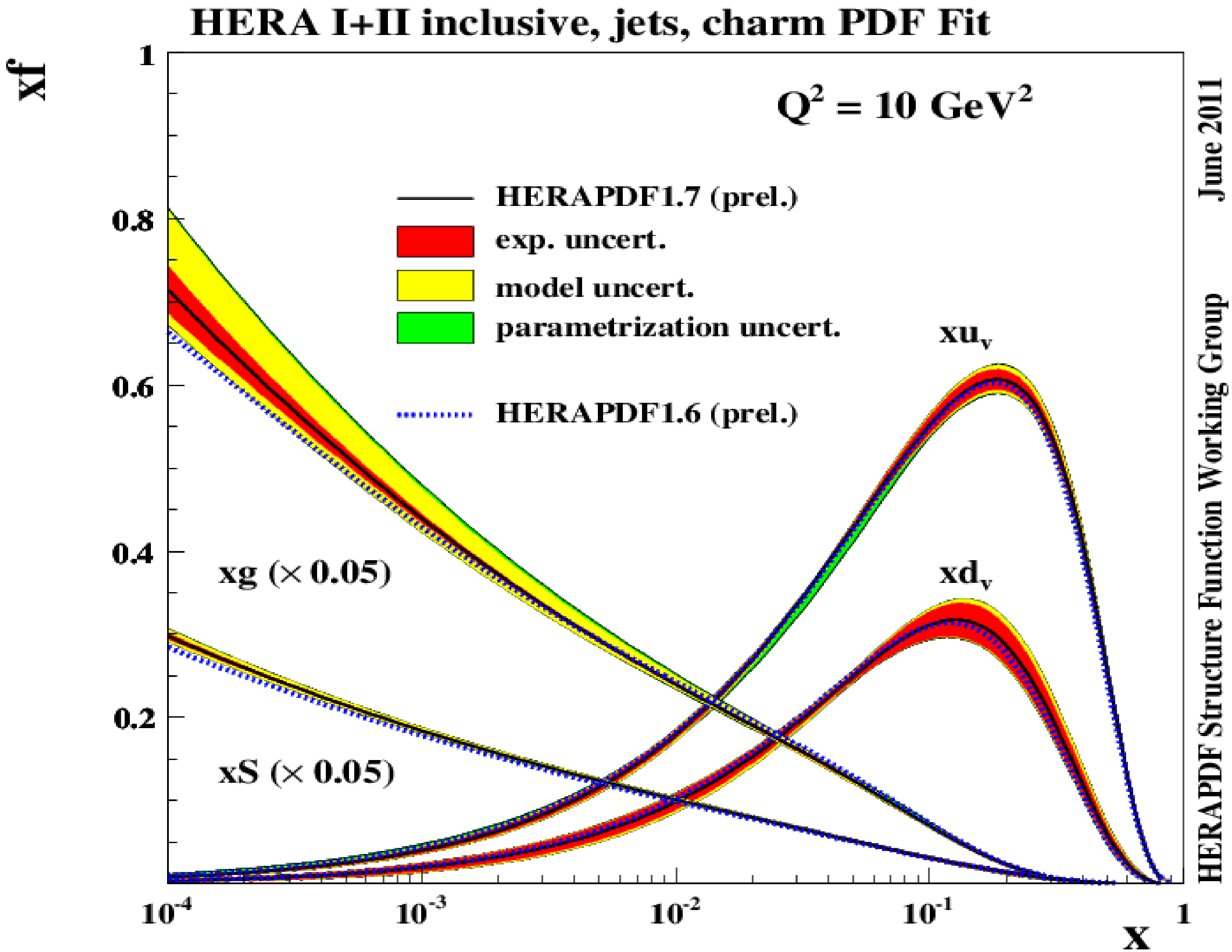
  - Bjorken-x in ...



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- Small-x gluons are dense and created coherently

The CGC picture

- One gluon is radiated by O(1) prob. $\sim \alpha_s \, dx/x \; d^2k/k^2$
- A daughter gluon emits a grand-daughter gluon, ...
- ...a bunch of gluons at small x (high energy)
- Nonlinearity (recomb) becomes important at

$$Q_s^2(x) \sim \alpha_s \cdot \frac{xG(x, Q_s^2)}{\pi R_h^2}$$

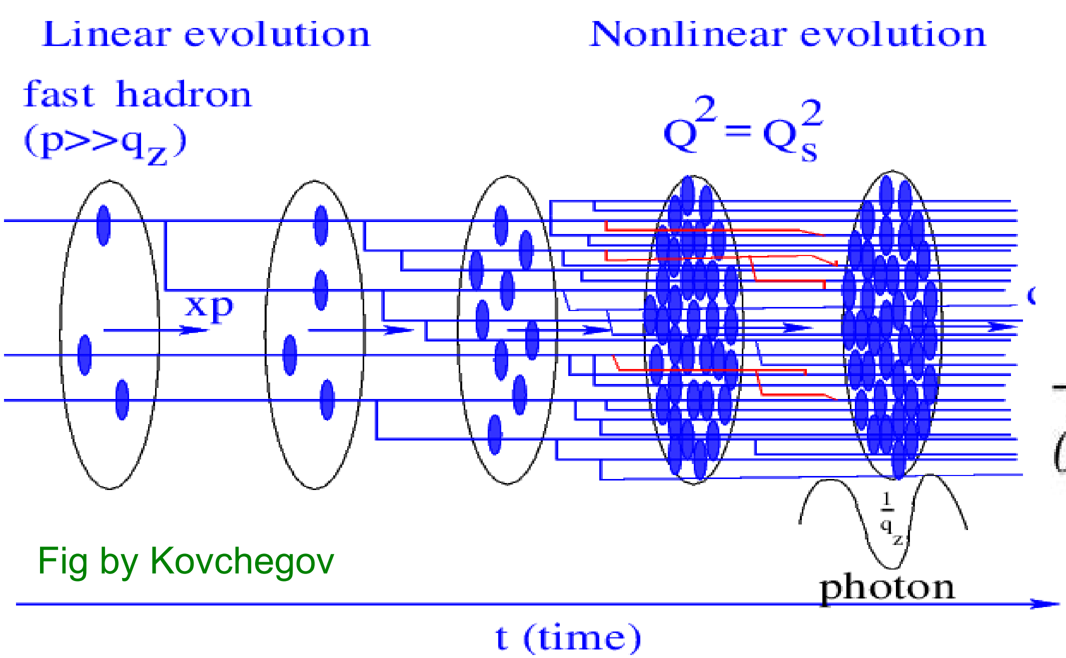

Fig by Kovchegov

Phase space density

$$\frac{dN}{d^2r\,d^2p} \sim \frac{xG(x, Q_s^2)}{\pi R_h^2 Q_s^2(x)} \sim \frac{1}{\alpha_s}$$

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- Small-x gluons are dense and created coherently
  -- described by rcBK x-evolution for uGD (or JIMWLK)

$$\frac{\partial \mathcal{N}_F(r,x)}{\partial \ln(x_0/x)} = \int d^2\underline{r}_1\, K^{\rm run}(\underline{r},\underline{r}_1,\underline{r}_2)\big[\mathcal{N}_F(r_1,x)+\mathcal{N}_F(r_2,x) - \mathcal{N}_F(r,x) - \mathcal{N}_F(r_1,x)\mathcal{N}_F(r_2,x)\big],$$

small-x gluon distribution

- AAMQS constrained UGD via available DIS data
- ADFN use a smooth cutoff for α_s

UGD set	$Q^2_{s0,\mathrm{proton}}$ (GeV^2)	γ	α_{fr}	C
MV	0.2	1	0.5	1
g1.119	0.168	1.119	1.0	2.47
g1.101	0.157	1.101	0.8	1

$$\mathcal{N}_F(r, x = x_0) = 1 - \exp\left[-\frac{(r^2 Q^2_{s0,\mathrm{proton}})^\gamma}{4} \ln\left(\frac{1}{\Lambda r} + e\right)\right]$$

$$\alpha_s(r^2) = \frac{4\pi}{\beta \ln(\frac{4C^2}{r^2\Lambda^2} + \mu)}$$

other IC is possible (Cf. Lappi et al.)

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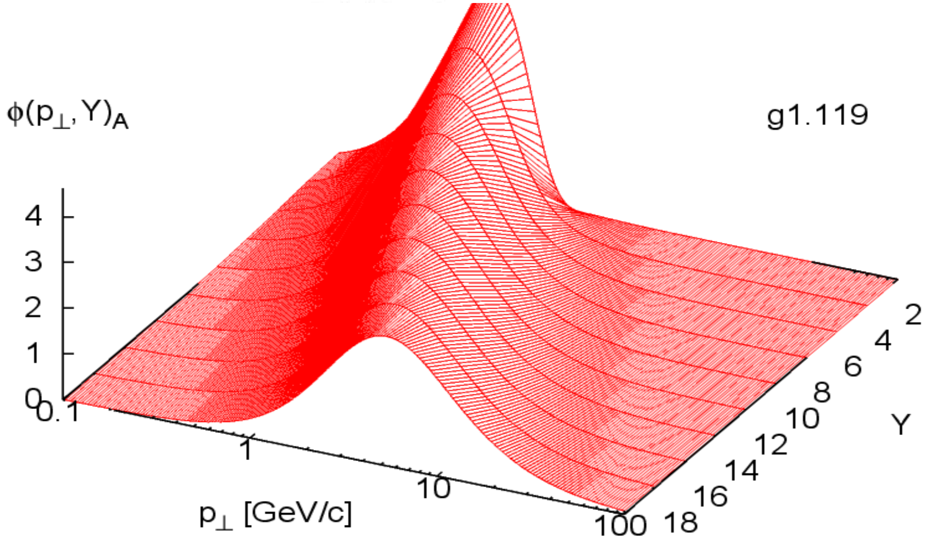
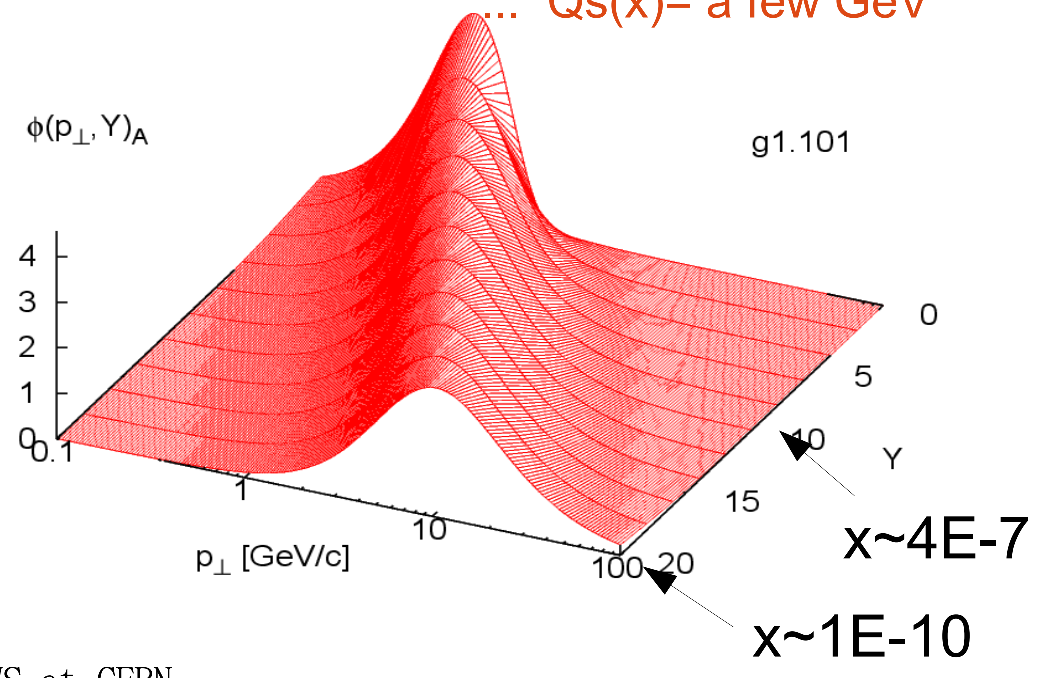
$$\varphi(k,x,\mathbf{R}) = \frac{C_F}{\alpha_s(k)(2\pi)^3}\int d^2\mathbf{r}\, e^{-i\mathbf{k}\cdot\mathbf{r}}\nabla^2_{\mathbf{r}}\mathcal{N}_A(r,x,\mathbf{R})$$





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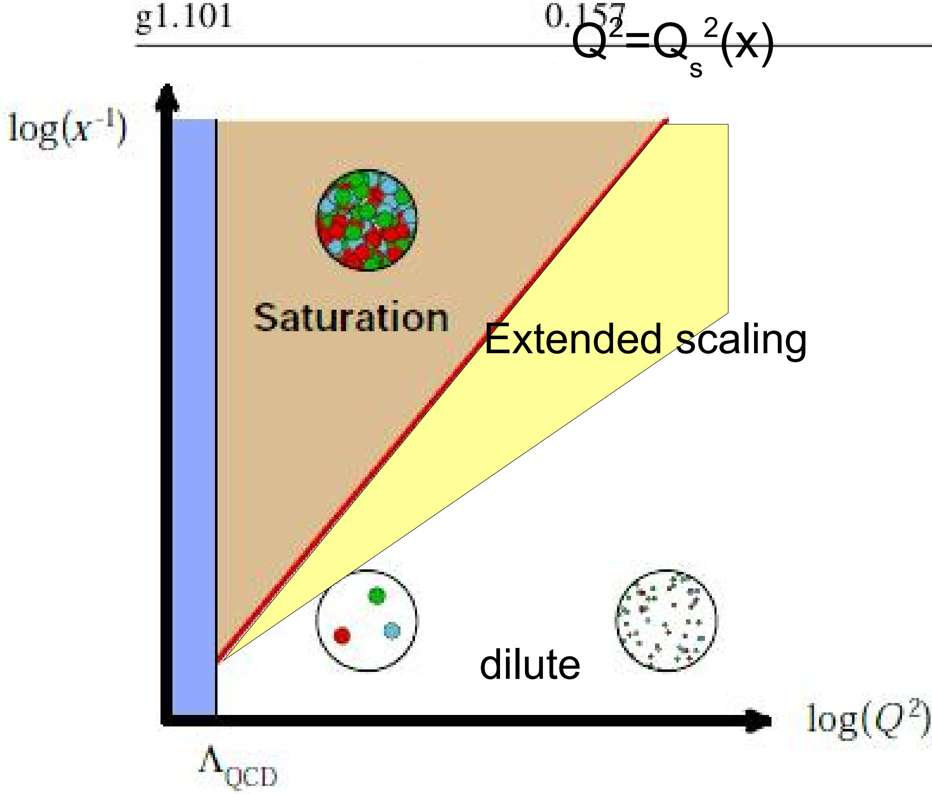

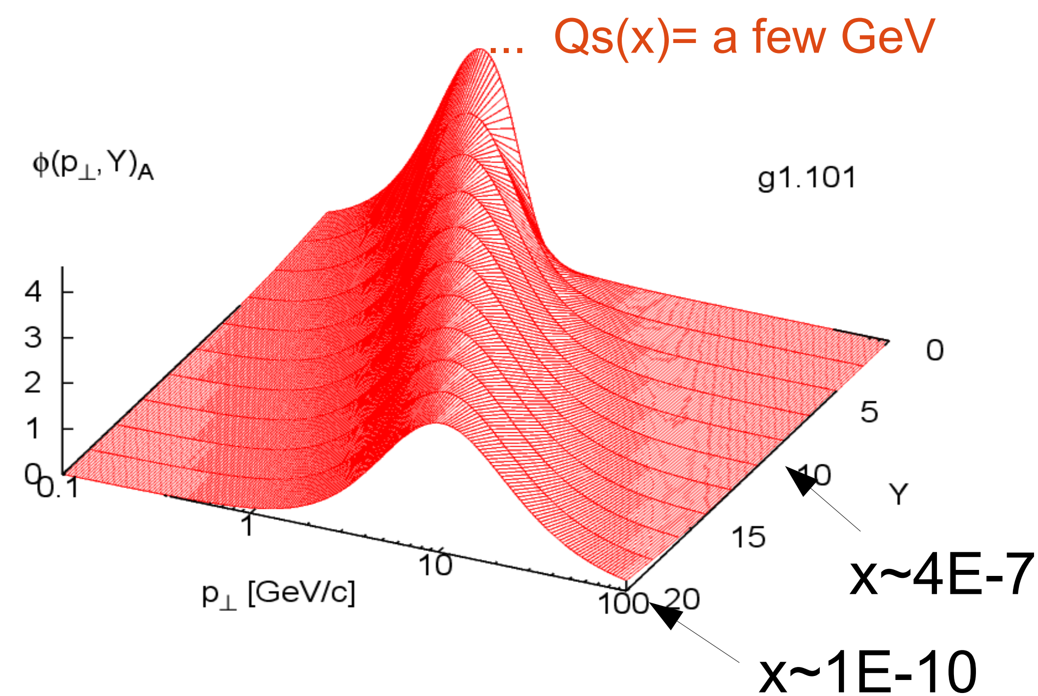

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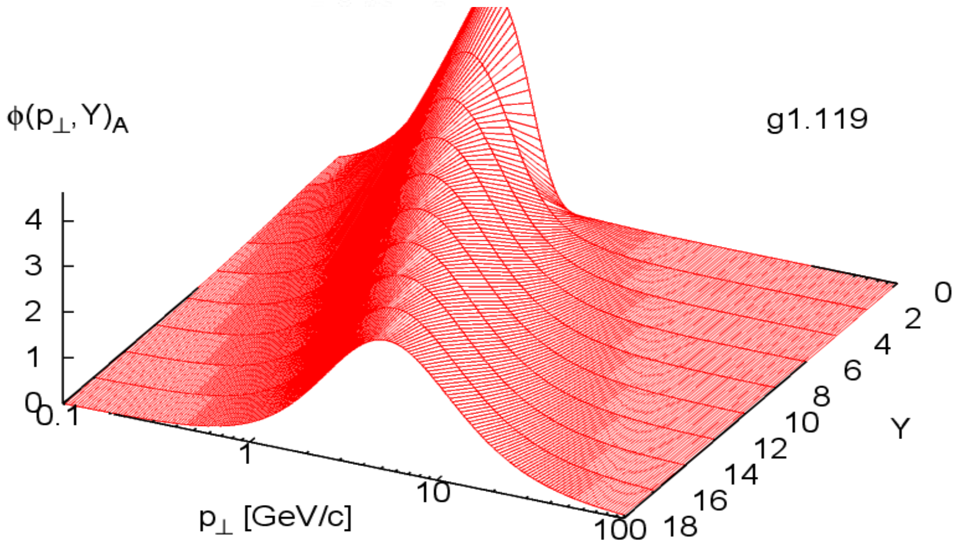
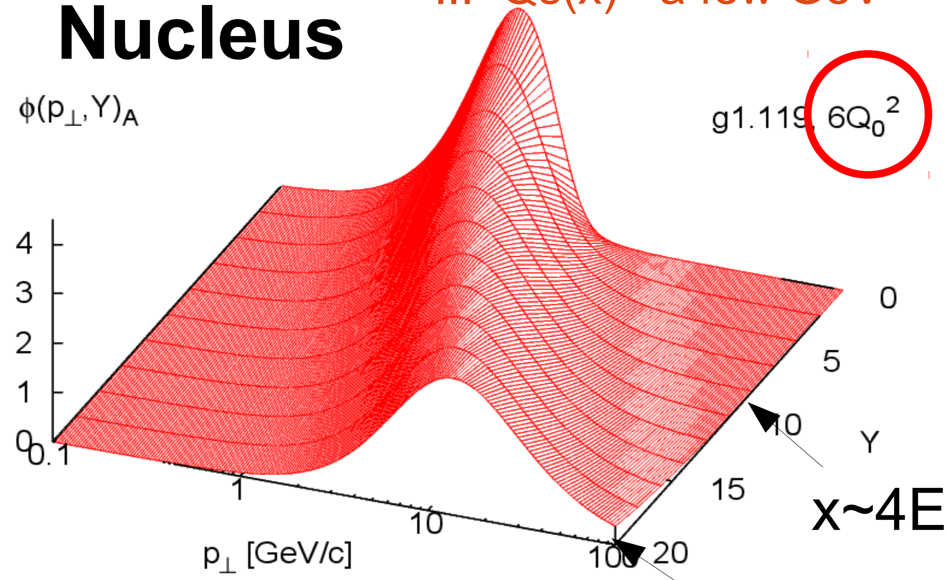


Nucleus

... Qs(x)= a few GeV



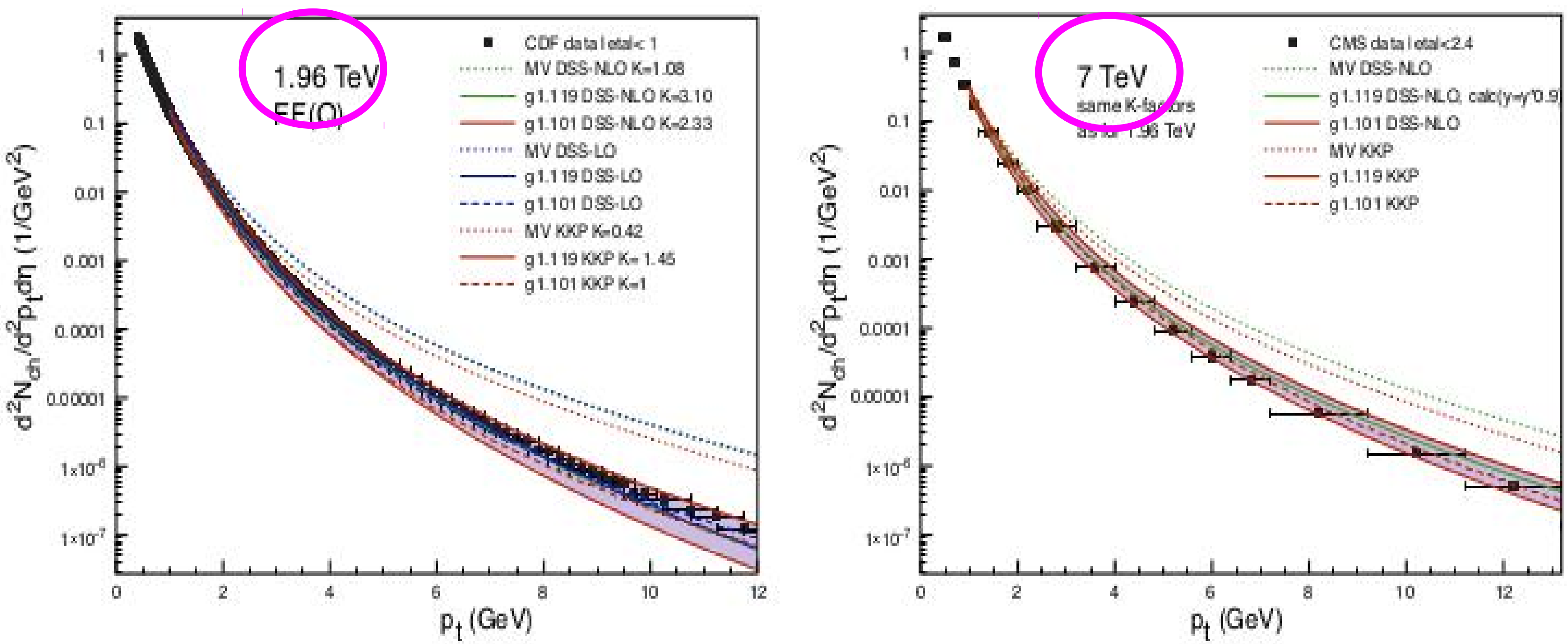
x~4E-7

x~1E-10

Particle production from CGC

- Here we use the kT factorized model

$$\frac{d\sigma^{A+B\to g}}{dy\,d^2p_t\,d^2R} = K^k\frac{2}{C_F}\frac{1}{p_t^2}\int^{p_t}\frac{d^2k_t}{4}$$
$$\times\int d^2b\,\alpha_s(Q)\varphi_P\left(\frac{|p_t+k_t|}{2},x_1;b\right)\varphi_T\left(\frac{|p_t-k_t|}{2},x_2;R-b\right)$$



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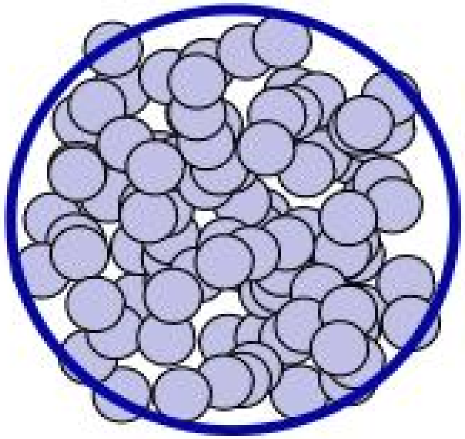
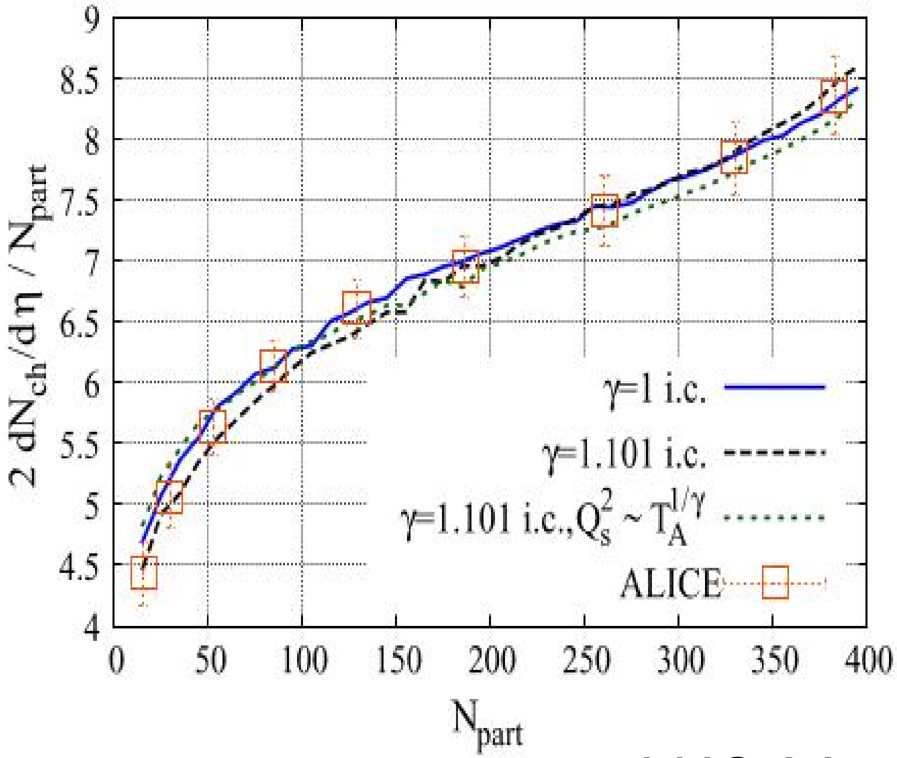
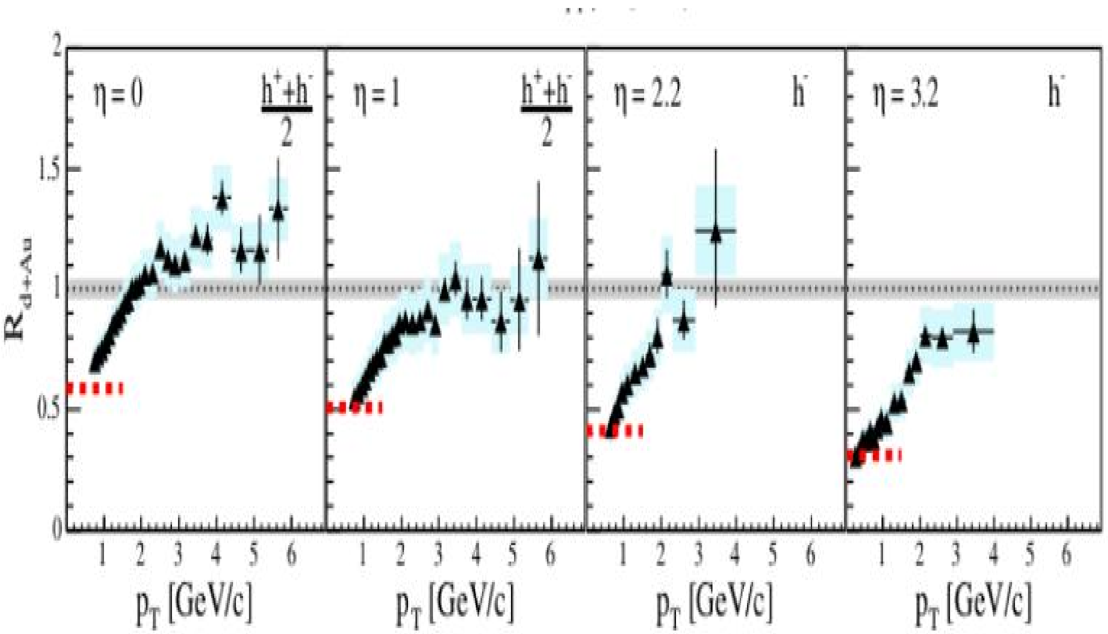
- For nuclear target,
  - Nucleons randomly distributed
  - Initial Q_{s0}^2 prop-to thickness



- CGC approach helps to understand some observables in nuclear collisions so far



LHC AA



RHIC dA

FCC – pp 100 TeV, pA 63 TeV, AA 39 TeV

- Even a 10 GeV particle comes from small x
  - e.g., x = 10 GeV / 100,000 GeV = 1E-4 !
  - x1 = 10 GeV / 100,000 GeV*exp[4] = 0.005 !
  - Saturation? but 10 GeV > Qs(x)
  - Extended scaling region?

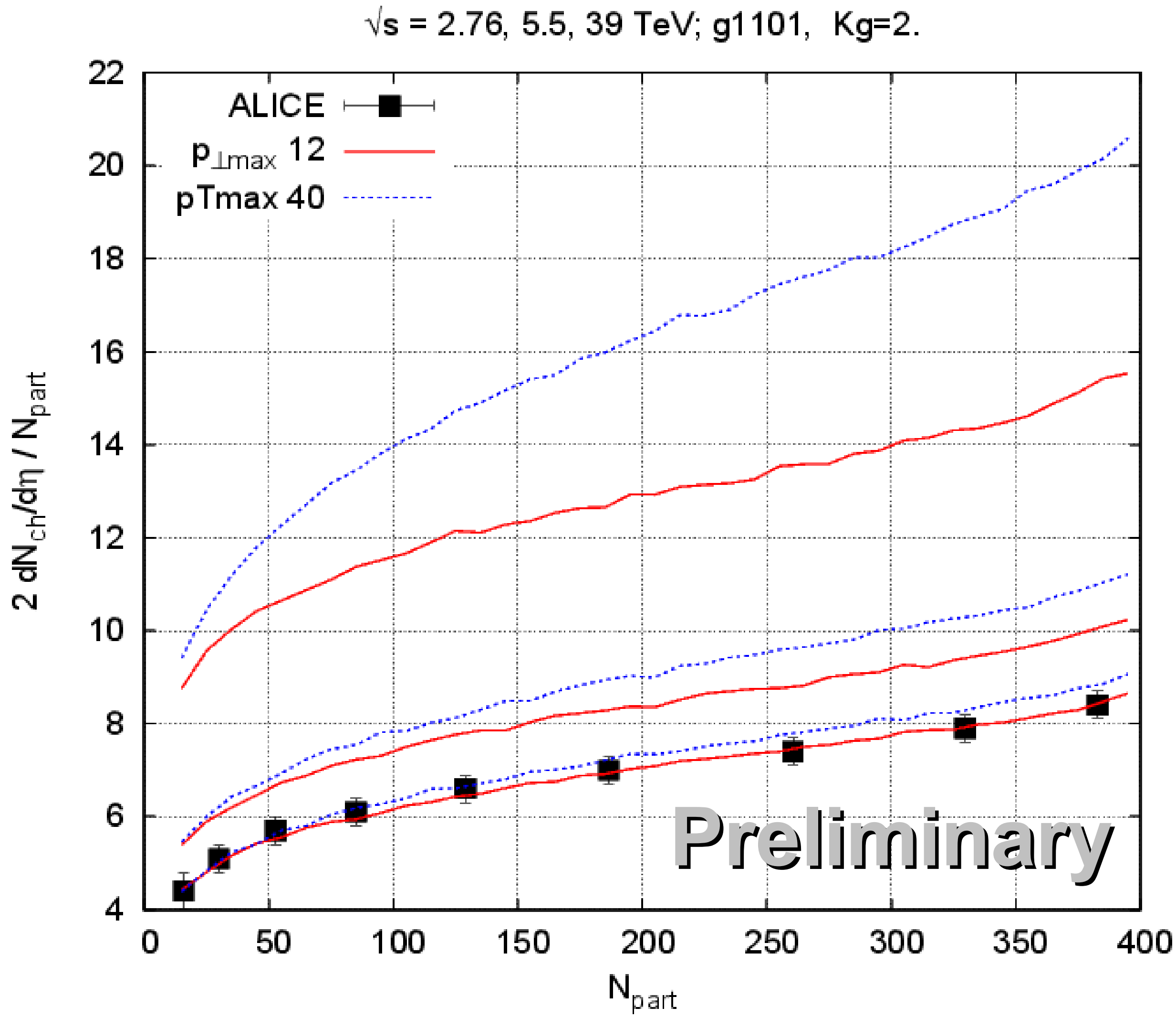
- Many particles also in larger pT region

Multiplicity vs Npart in AA

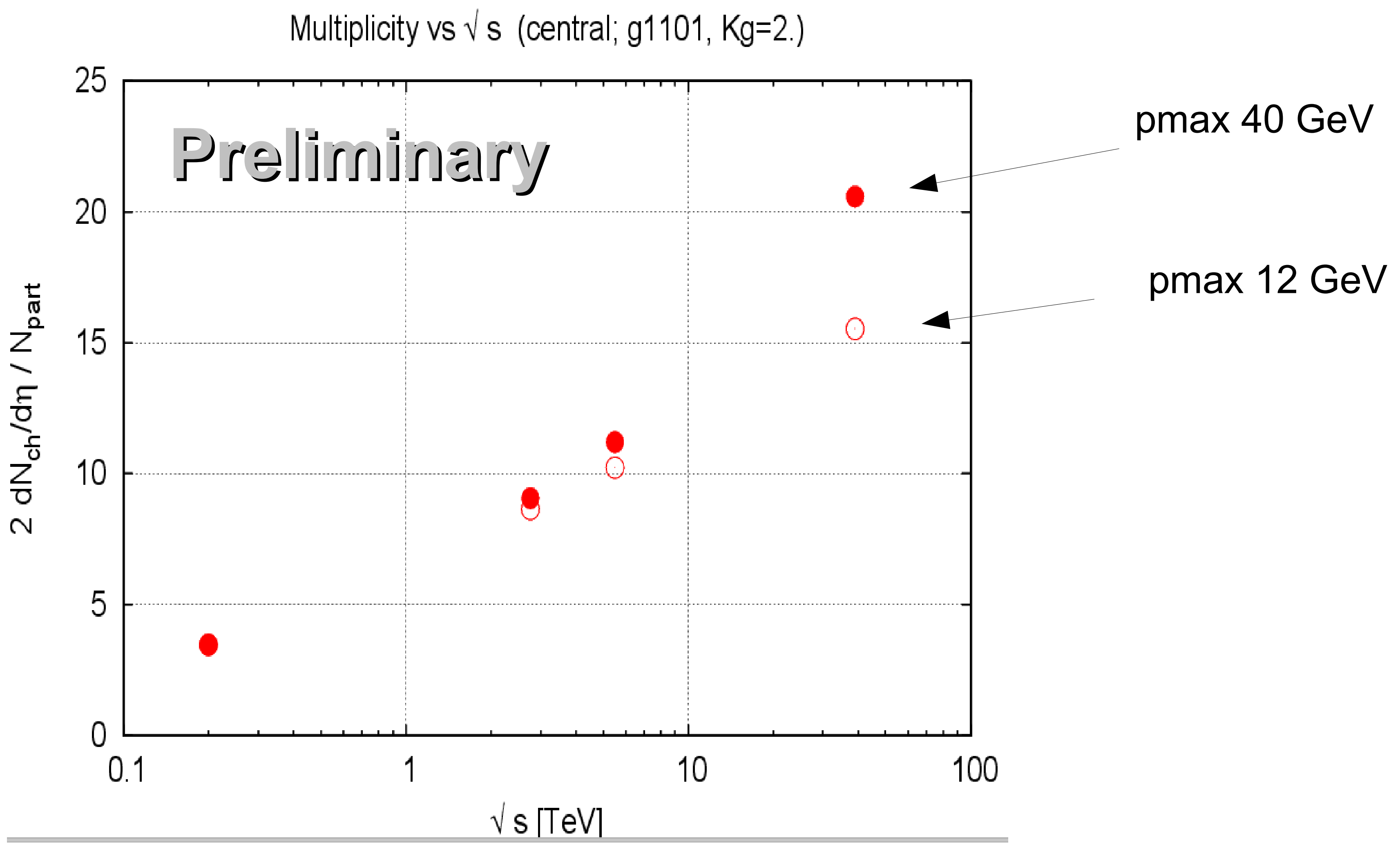
- Fits ALICE data
- Original model incl. gluons **pT<12 GeV/c**
- For a test of higher mom contrib, calculate from **12<pT<40 GeV/c**

  (here&next only)

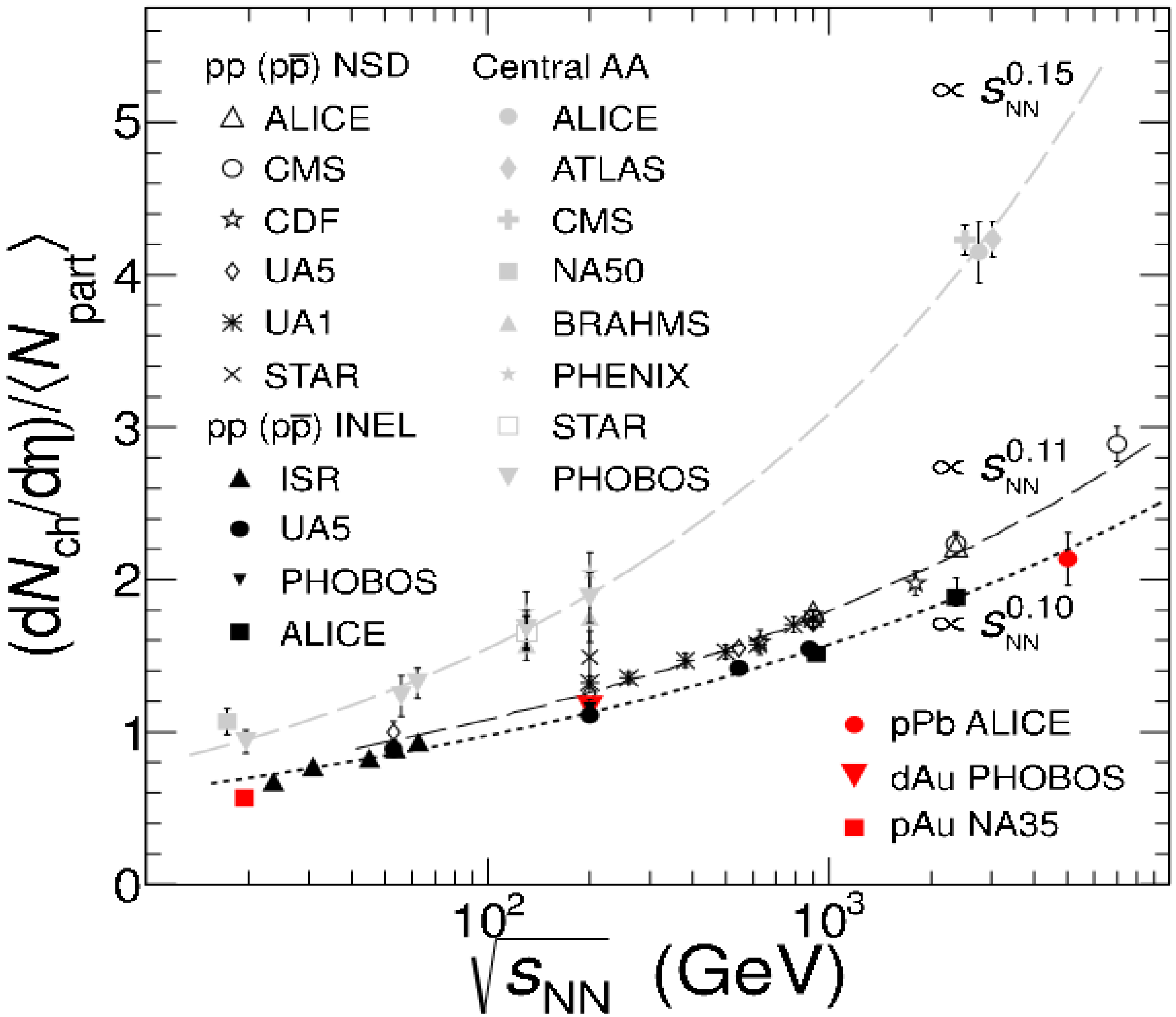
- x small, but pT>Qs may be important



Multiplicity vs sqrt(s) in AA

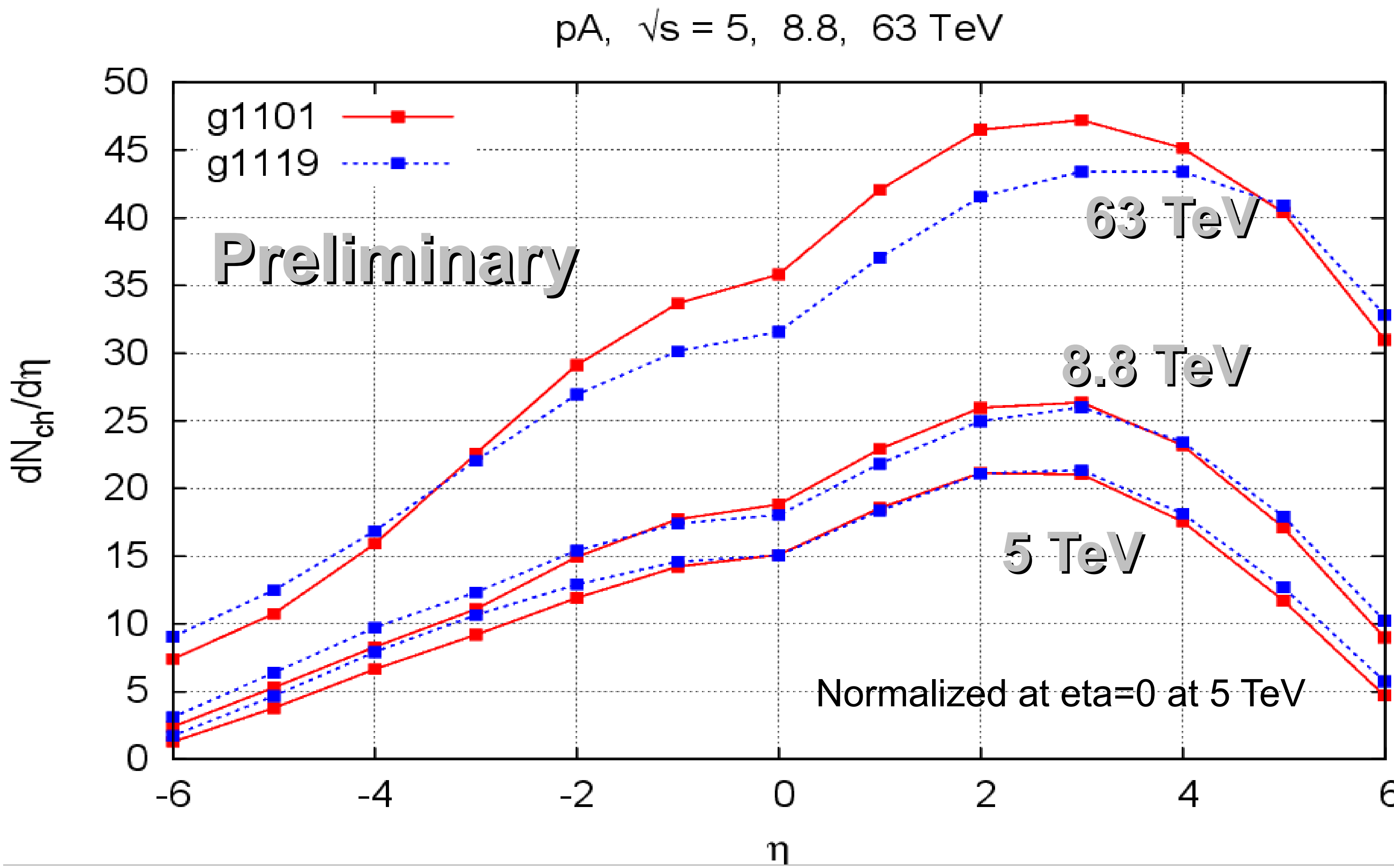


Multiplicity vs sqrt(s) in AA, pA

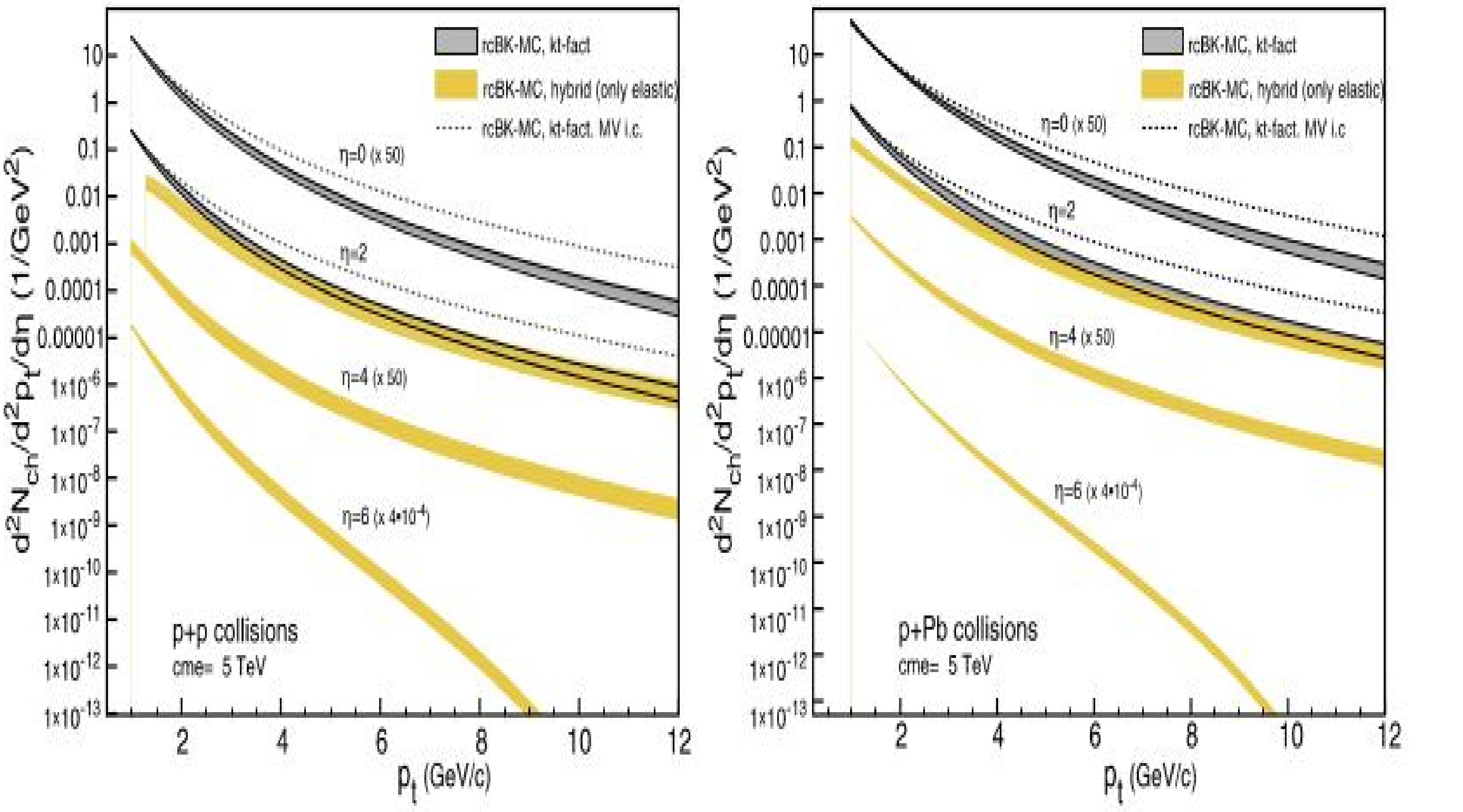


ALICE;1210.3615

Multiplicity vs rapidity in pA

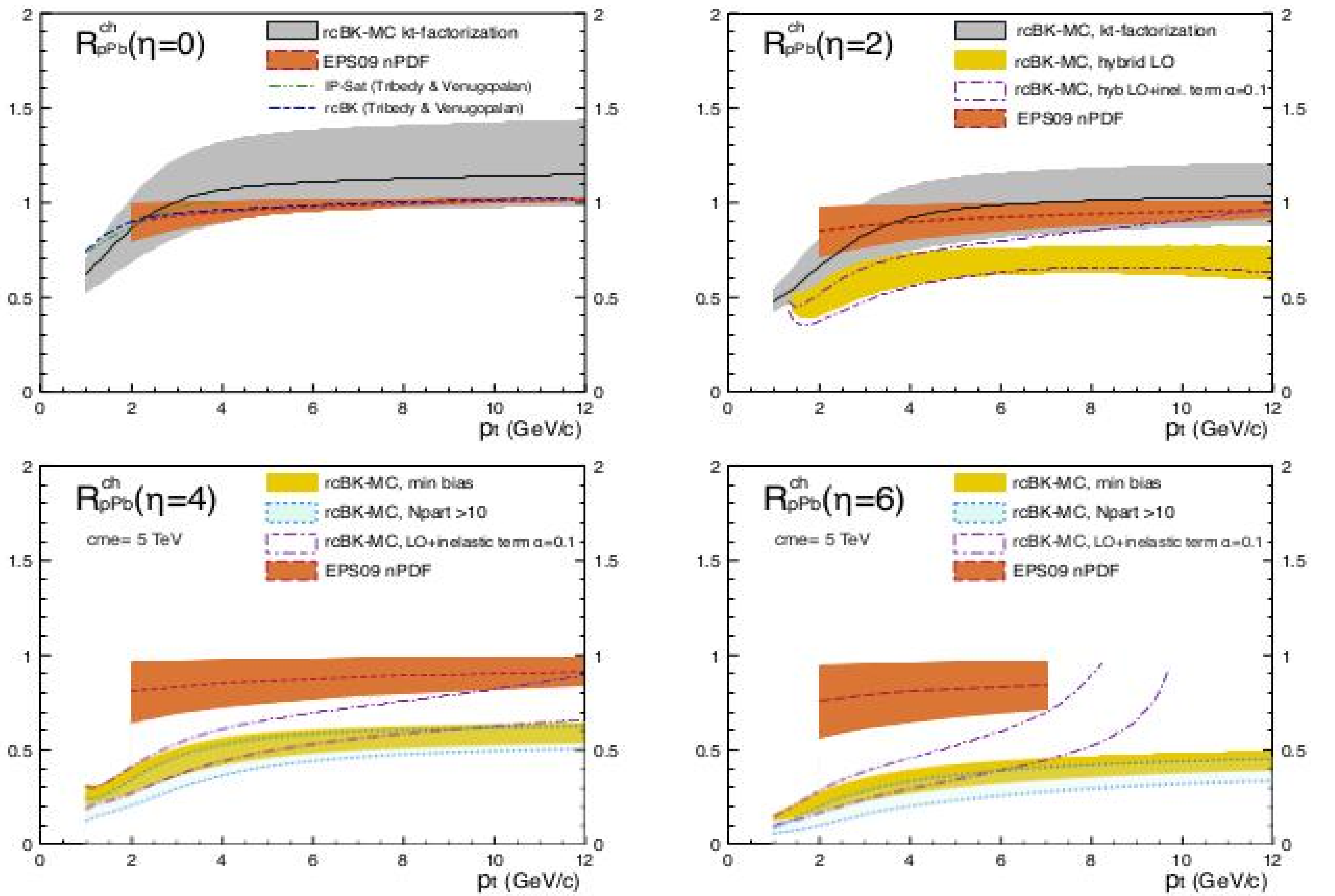


pT spectrum in pp and pA at 5 TeV



RpA at 5 TeV

$$R_{\mathrm{p+Pb}}(p_\perp) \equiv \frac{1}{\langle N_{\mathrm{coll}}\rangle} \frac{dN_{\mathrm{ch}}^{\mathrm{p+Pb}}/d\eta\, d^2p_\perp}{dN_{\mathrm{ch}}^{\mathrm{p+p}}/d\eta\, d^2p_\perp}$$



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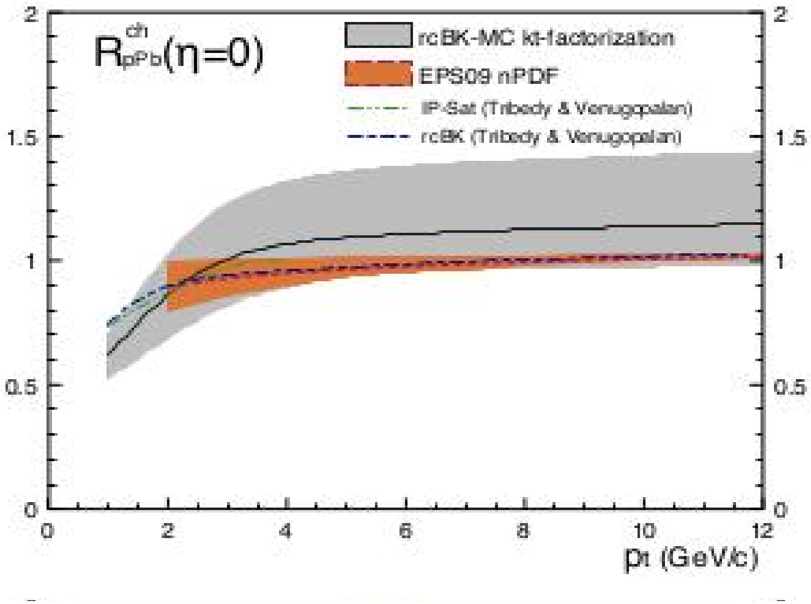
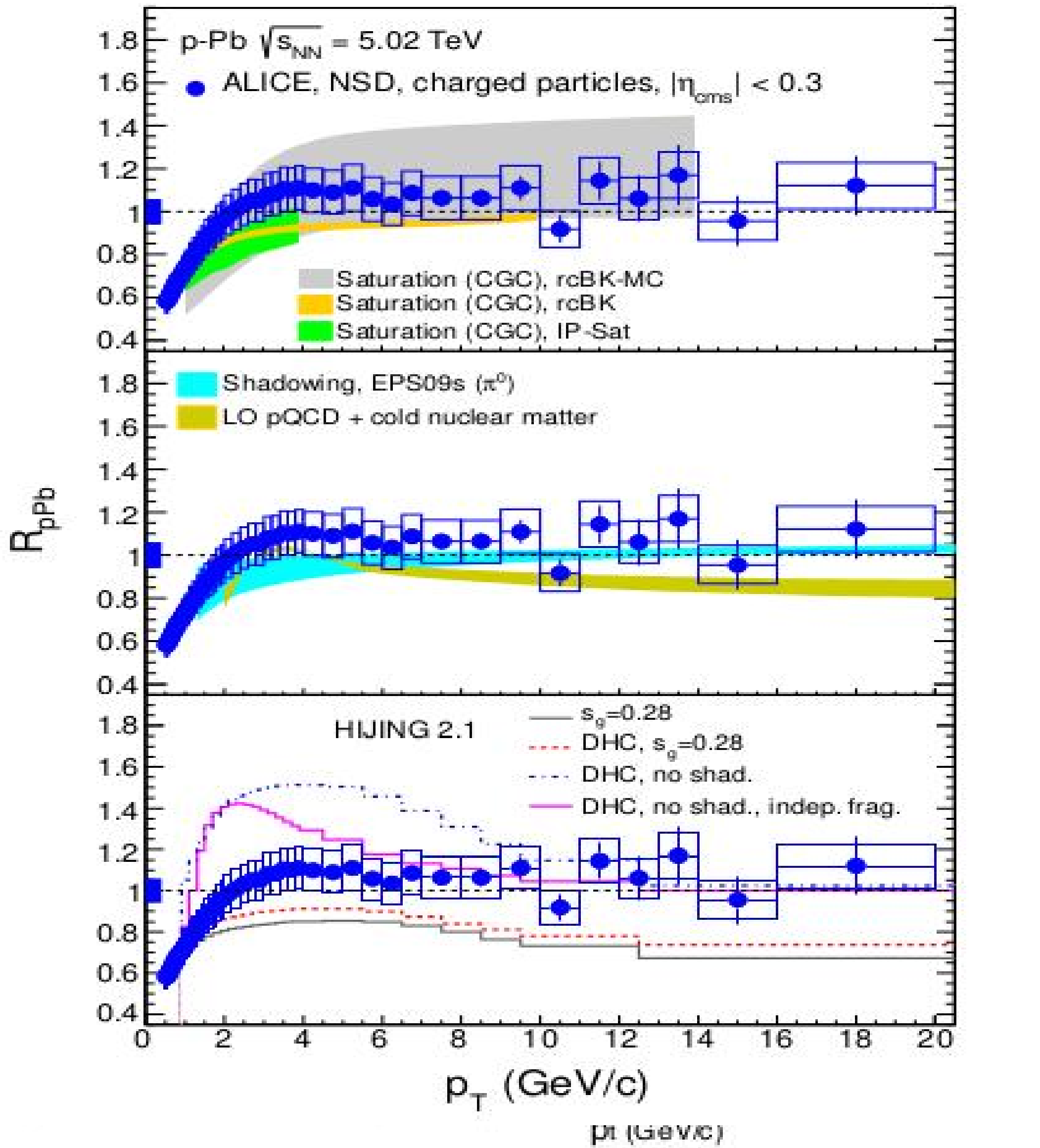
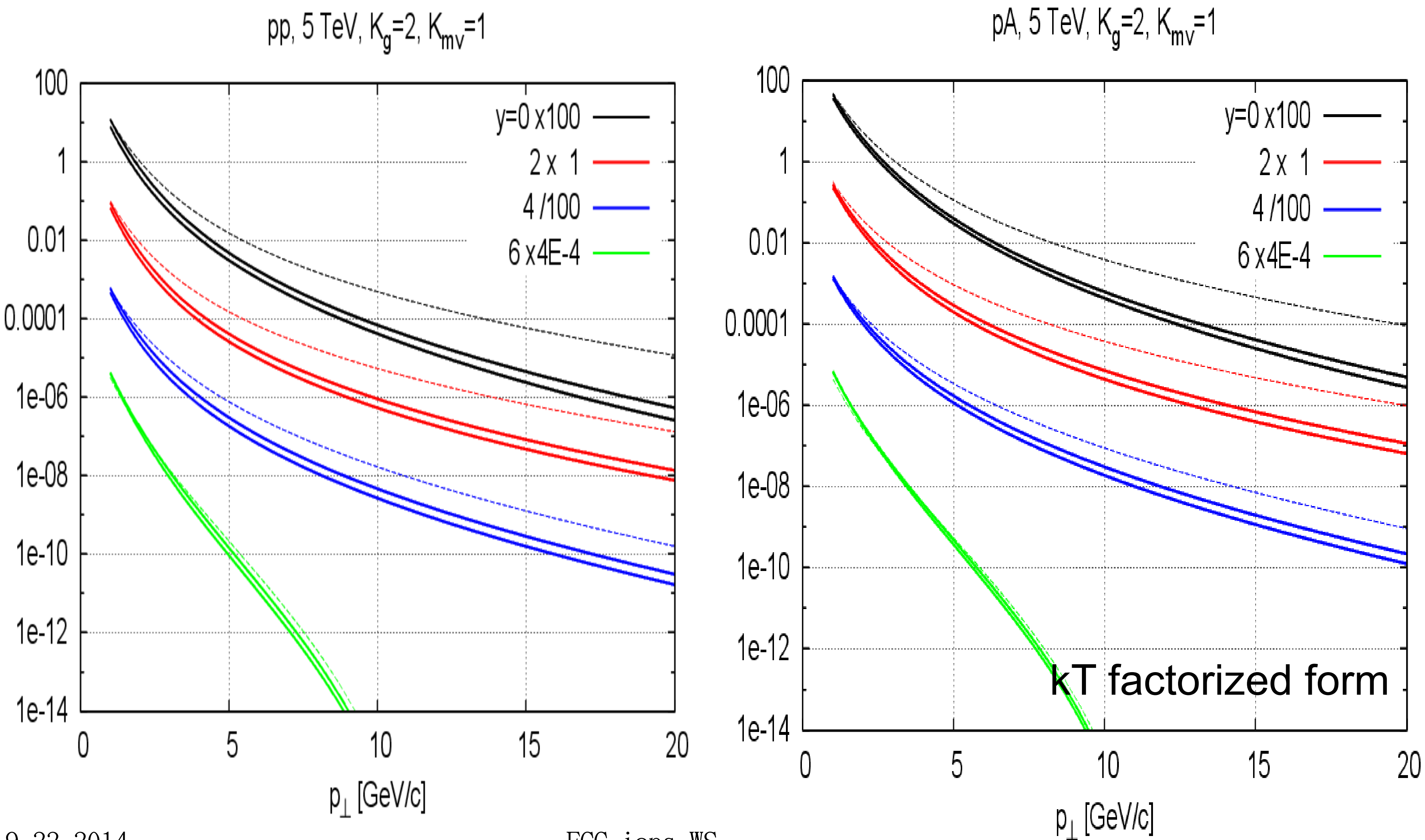


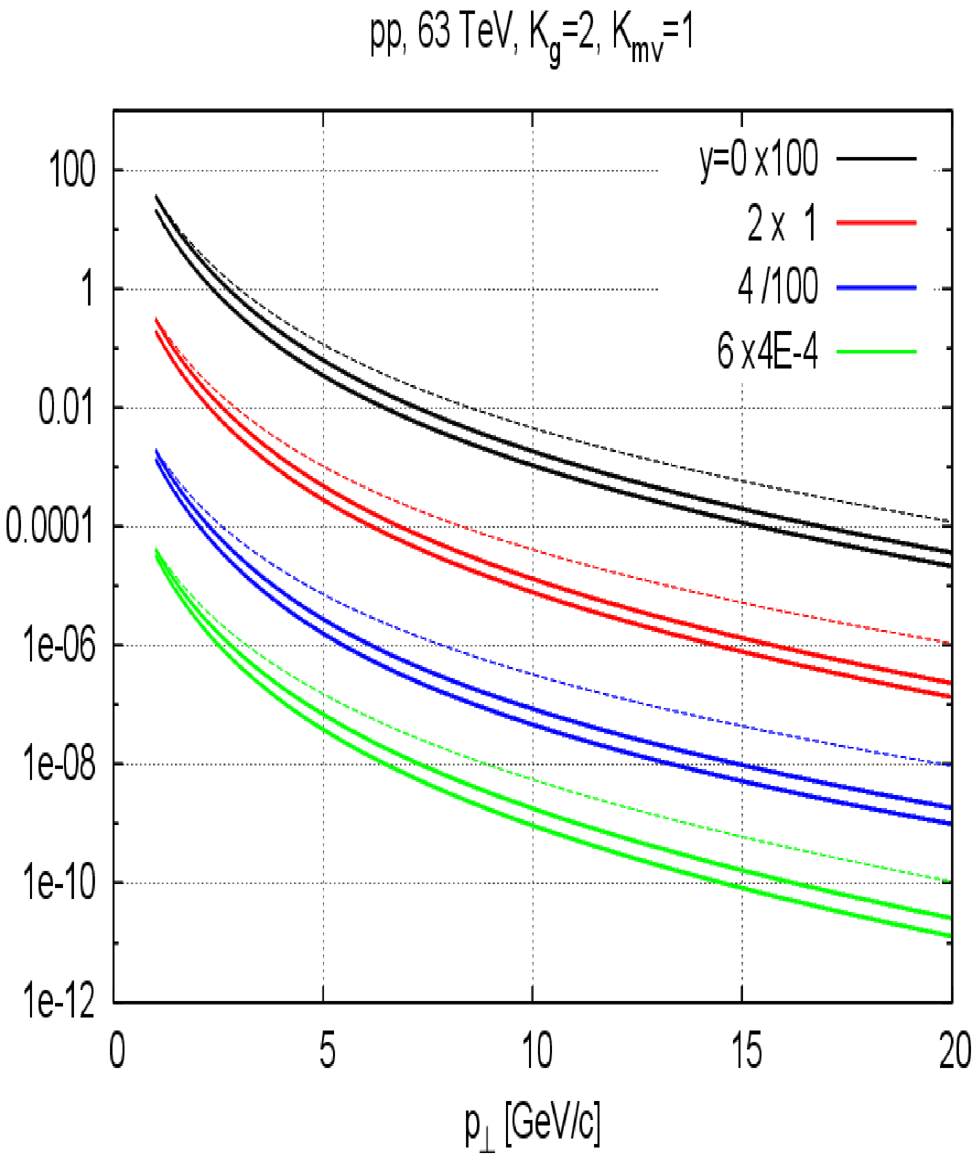


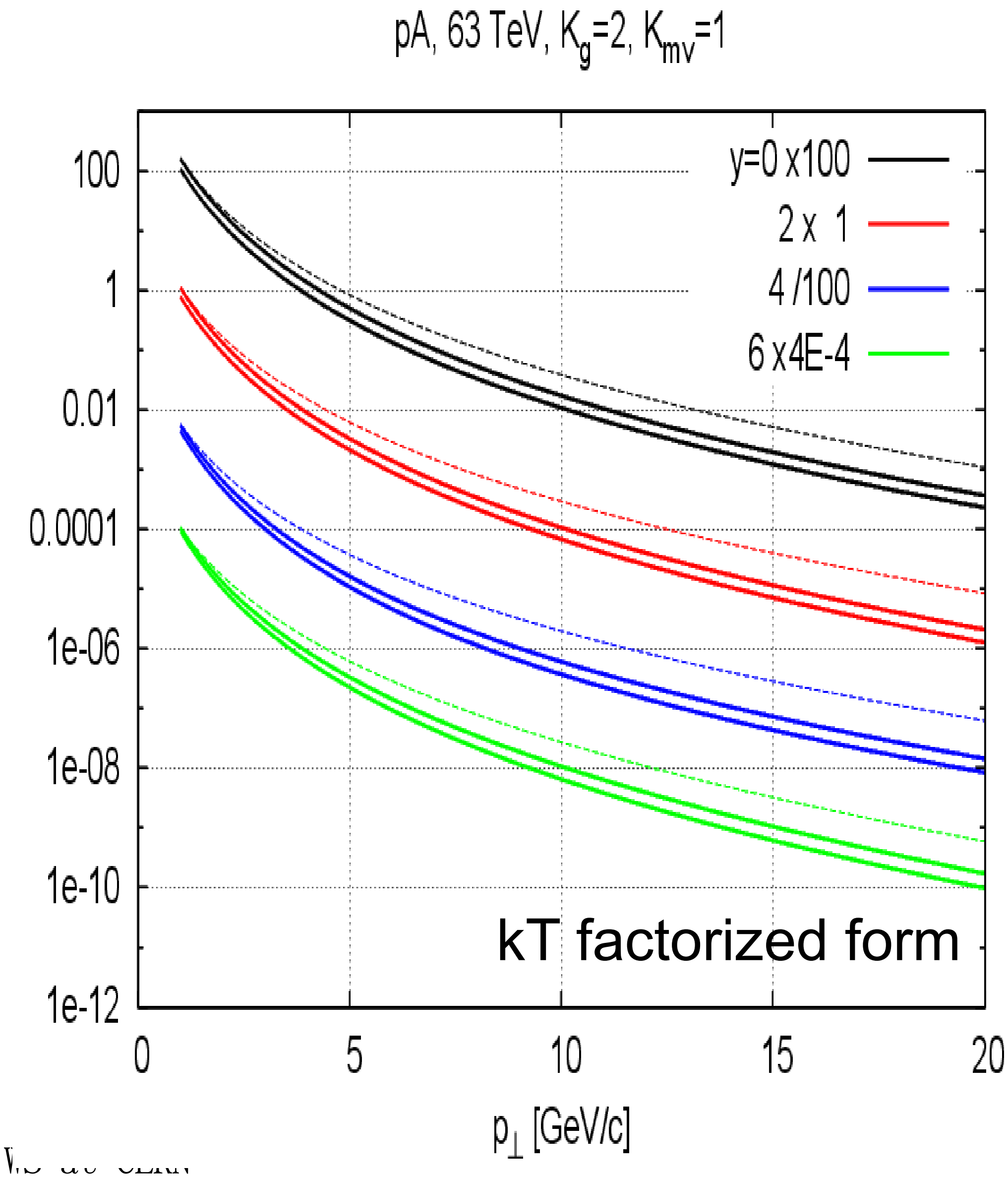
pT spectum at 5 TeV mv, g1119,g1101; DSS-NLO



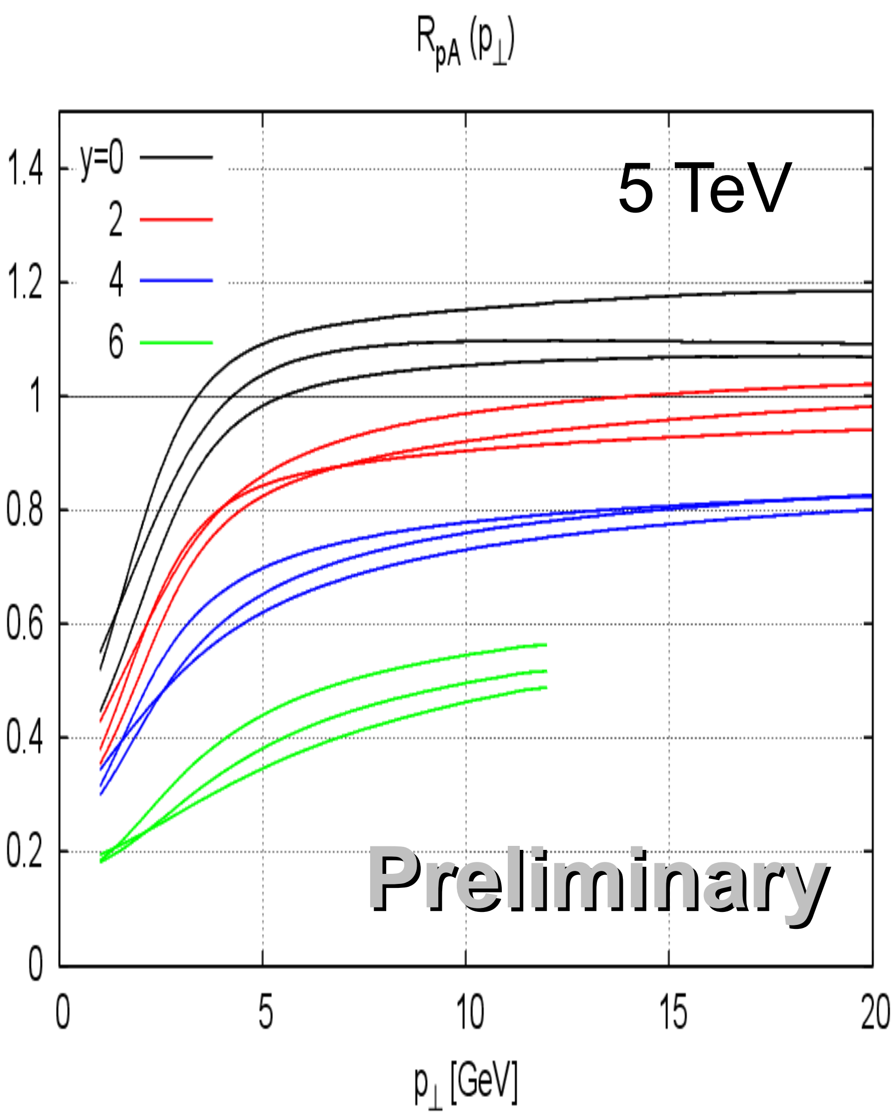
pT spectum at 63 TeV mv, g1119,g1101; DSS-NLO

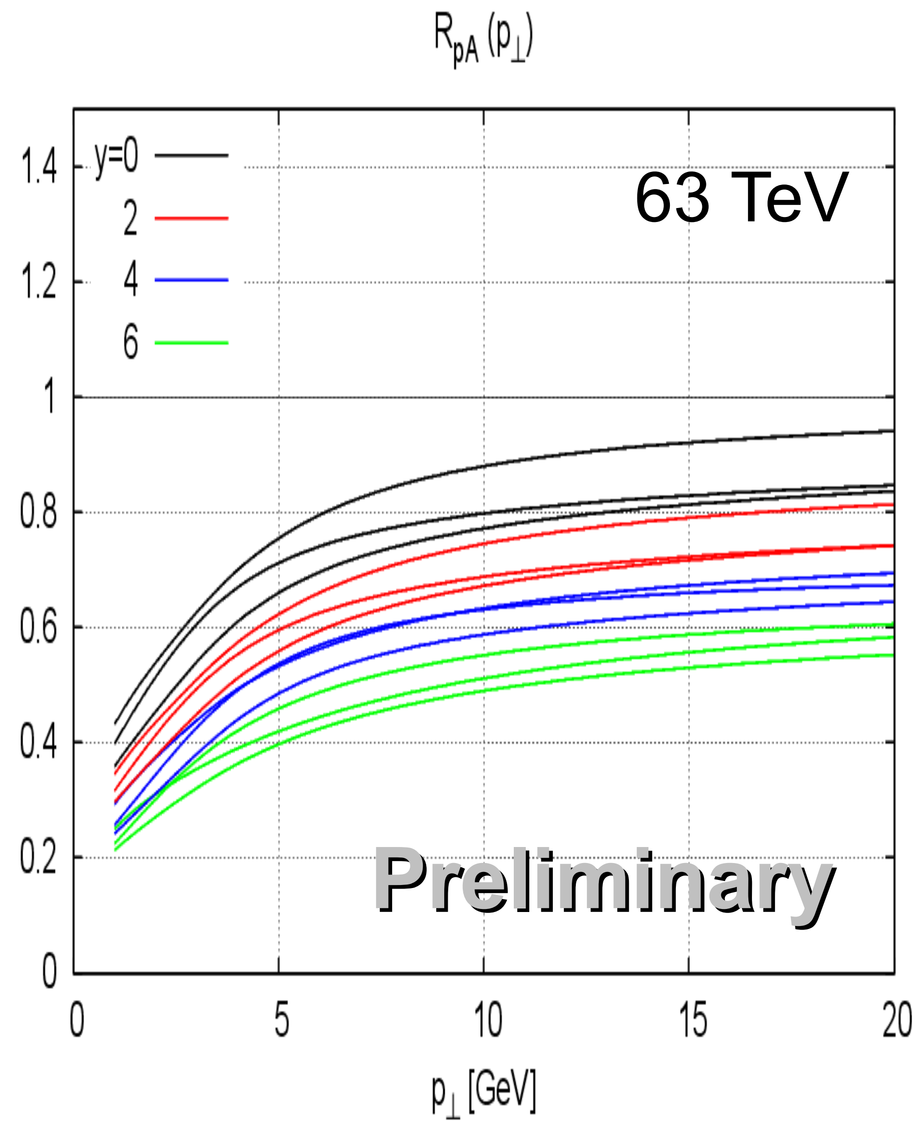
High mom tail of MV still visible





RpA at 5 and 63 TeV, mv, g1119,g1101; DSS-NLO





One more option -

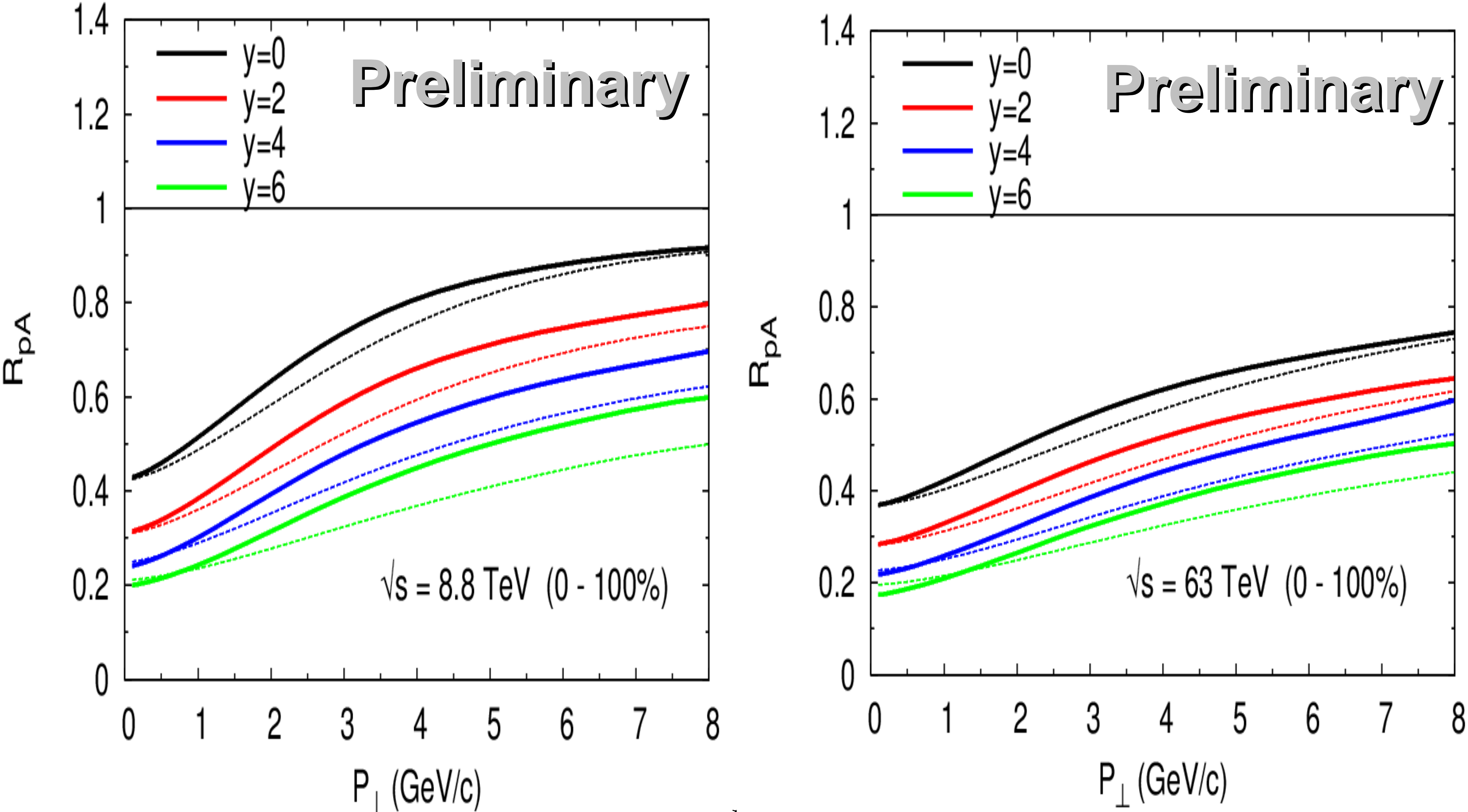
charm

$$\frac{d\sigma_{q\bar{q}}}{d^2\boldsymbol{p}_\perp\, d^2\boldsymbol{q}_\perp\, dy_p\, dy_q} = \frac{\alpha_s^2 N}{8\pi^4(N^2-1)} \frac{1}{(2\pi)^2} \int_{\boldsymbol{k}_{2\perp},\boldsymbol{k}_\perp} \frac{\Xi(\boldsymbol{k}_{1\perp},\boldsymbol{k}_{2\perp},\boldsymbol{k}_\perp)}{\boldsymbol{k}_{1\perp}^2 \boldsymbol{k}_{2\perp}^2} \phi_{A,y_2}^{q\bar{q},g}(\boldsymbol{k}_{2\perp},\boldsymbol{k}_\perp)\varphi_{p,y_1}(\boldsymbol{k}_{1\perp}),$$

Open charm

mv, g1118

direct only $Q_{s0A}^2 = 6\ Q_{s0}^2$



Discussion

- An estimate for dNdy & hadron spectrum at FCC energies in CGC approach
  - A big extrapolation from DIS to FCC with a simple model
  - Reasonable values are obtained
- At FCC, harder processes are also active
  - how to see/extract the very saturation effects?
  - more studies needed
- Observables more sensitive to saturation
  - two-particle correlations in pT and y
  - or ...