Probing QCD at High Energy:

predictions for single hadron production at LHC

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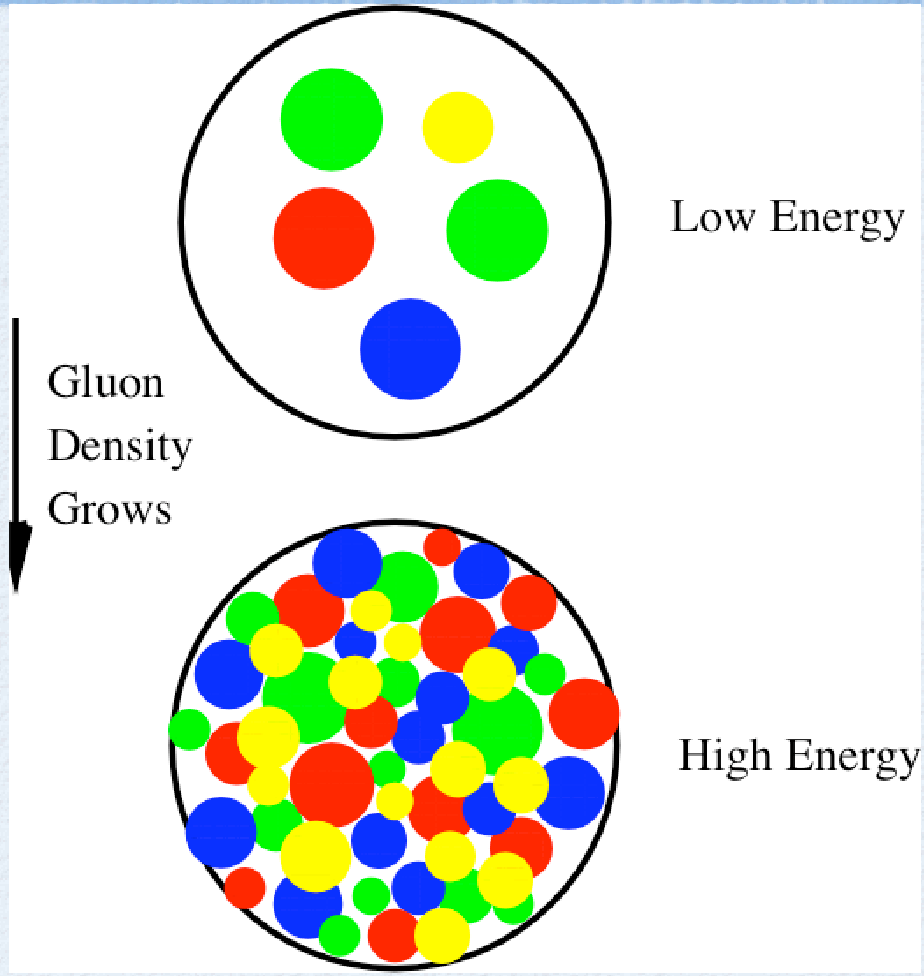
Last call for predictions, May 14th-June 8th, 2007, CERN

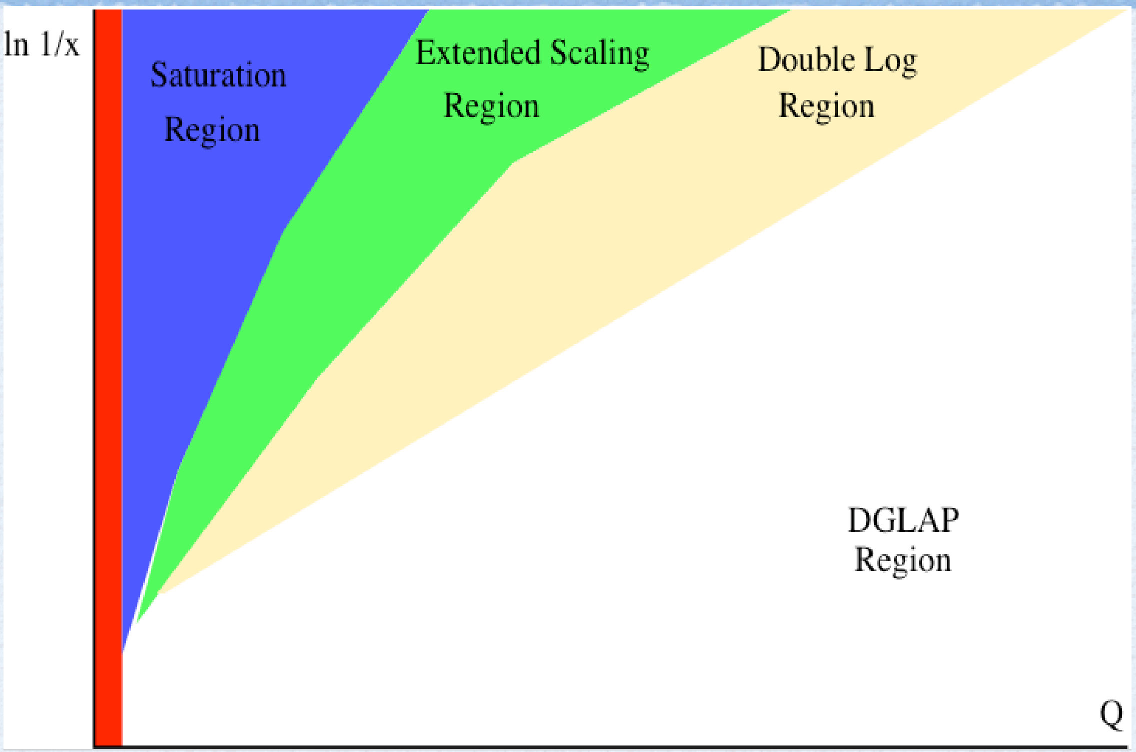
Resolving the Nucleus at High Energy

Radiated gluons have the same size ($1/Q^2$) - the number of partons increase due to the increased longitudinal phase space: **nucleus becomes a dense system of gluons**



QCD in the strong color field limit
novel universal properties of theory

A New Paradigm of QCD: CGC



Saturation: dense system of gluons (all twist)

Extended scaling: dilute system -anomalous dimension

Double Log: BFKL meets DGLAP

DGLAP: collinearly factorized pQCD

pA as a probe of high energy QCD

- Multiplicities (dominated by $p_t < Q_s$):

  energy, rapidity, centrality dependence

- **Single particle production: hadron,photon,dilepton**

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Averge P_t

CGC: qualitative expectations

Classical (multiple elastic scattering):

$p_t \gg Q_s$: enhancement (**Cronin effect**)

$R_{pA} = 1 + (Q_s^2/p_t^2) \log p_t^2/\Lambda^2 + \ldots$

$R_{pA}\,(p_t \sim Q_s) \sim \log A$

position and height of enhancement are increasing with centrality

Evolution in x:

can show analytically the peak disappears as energy/rapidity grows

and levels off at $R_{pA} \sim A^{-1/6} < 1$

These expectations are confirmed at RHIC

CGC vs. RHIC

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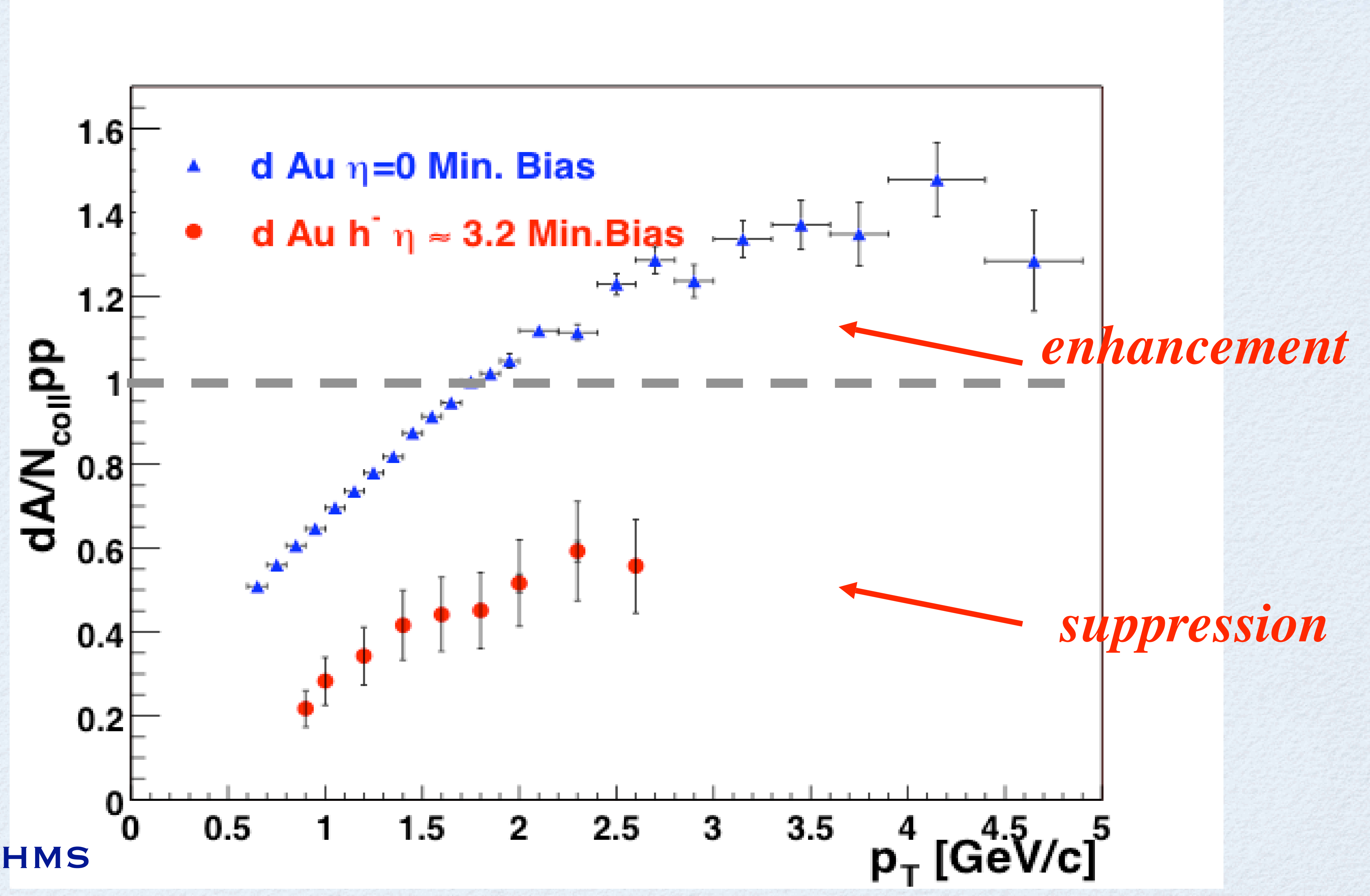


d Au η=0 Min. Bias
d Au h⁻ η ≈ 3.2 Min.Bias
dA/N_coll pp
p_T [GeV/c]
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
enhancement
suppression
BRAHMS

Single Hadron Production in pA

$$\frac{d\sigma^{pA\to hX}}{dY\, d^2P_t\, d^2b} = \frac{1}{(2\pi)^2}\int_{x_F}^{1} dx\, \frac{x}{x_F}$$

$$\left\{ f_{q/p}(x,Q^2)\; N_F[\frac{x}{x_F}P_t, b, y]\; D_{h/q}(\frac{x_F}{x}, Q^2) + f_{g/p}(x,Q^2)\; N_A[\frac{x}{x_F}P_t, b, y]\; D_{h/g}(\frac{x_F}{x}, Q^2) \right\}$$

N_F, N_A are dipoles in fundamental and adjoint representation and satisfy the JIMWLK evolution equation

Dumitru, Hayashigaki, Jalilian-Marian NPA765 (2006) 464
Baier, Mehtar-Tani, Schiff NPA764 (2006) 515

Models of Dipole Cross Section

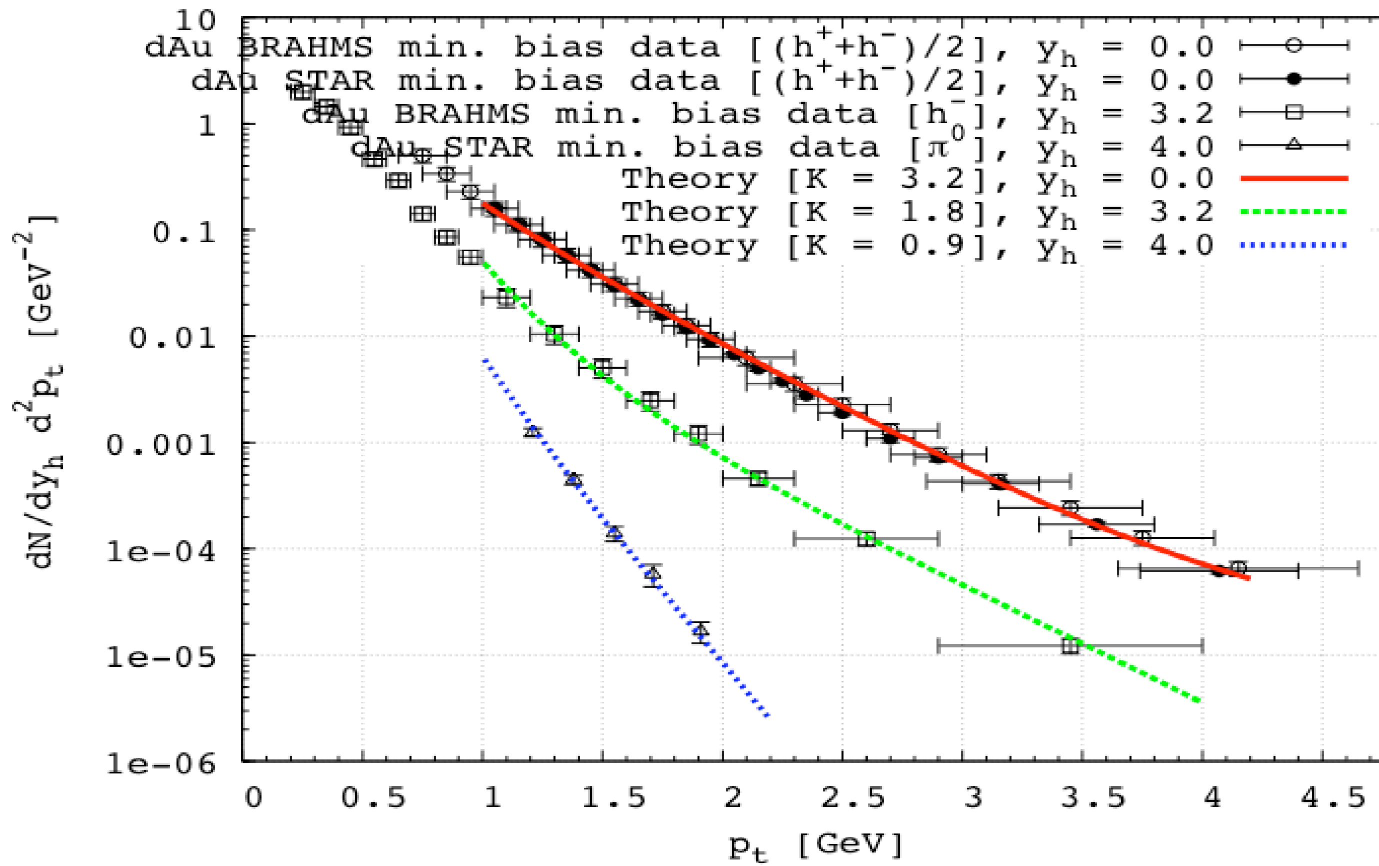
$$\mathcal{N}(r_t, Y) = 1 - e^{-\frac{1}{4}\left[\frac{C_F}{N_c} r_t^2 Q_s^2\right]^{\gamma(r_t, Y)}}$$

$$\gamma(r_t, Y) = \gamma_s + \Delta\gamma(r_t, Y)$$

$$\Delta\gamma = (1 - \gamma_s)\frac{\log(1/r_t^2 Q_s^2)}{\lambda Y + \log(1/r_t^2 Q_s^2) + d\sqrt{Y}}$$

Dumitru, Hayashigaki, Jalilian-Marian (DHJ), NPA 2006

Hadron production: rapidity and p_t dependence



What we see is a transition from DGLAP to BFKL to CGC kinematics

Dumitru, Hayashigaki, Jalilian-Marian, NPA 2006

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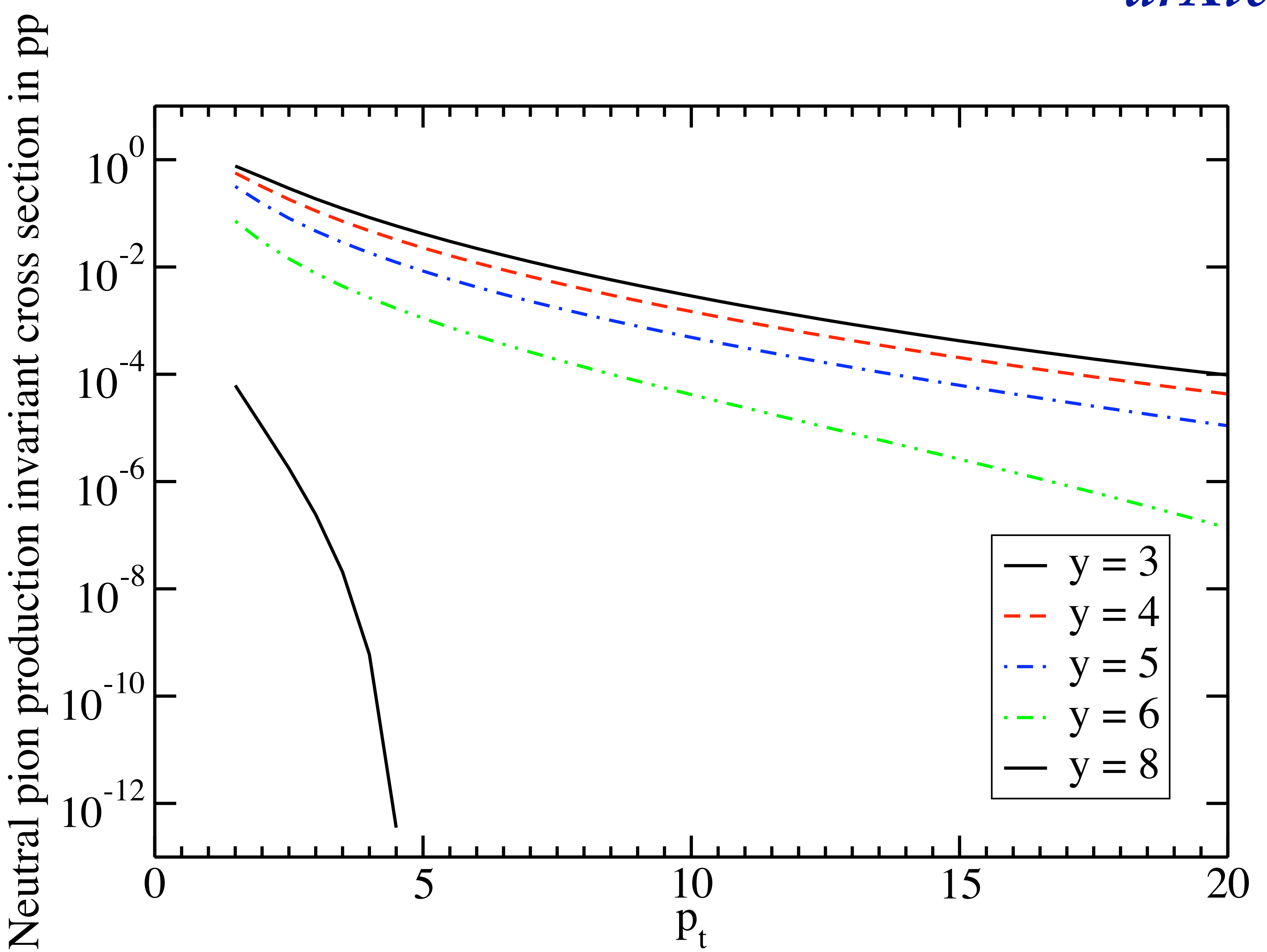
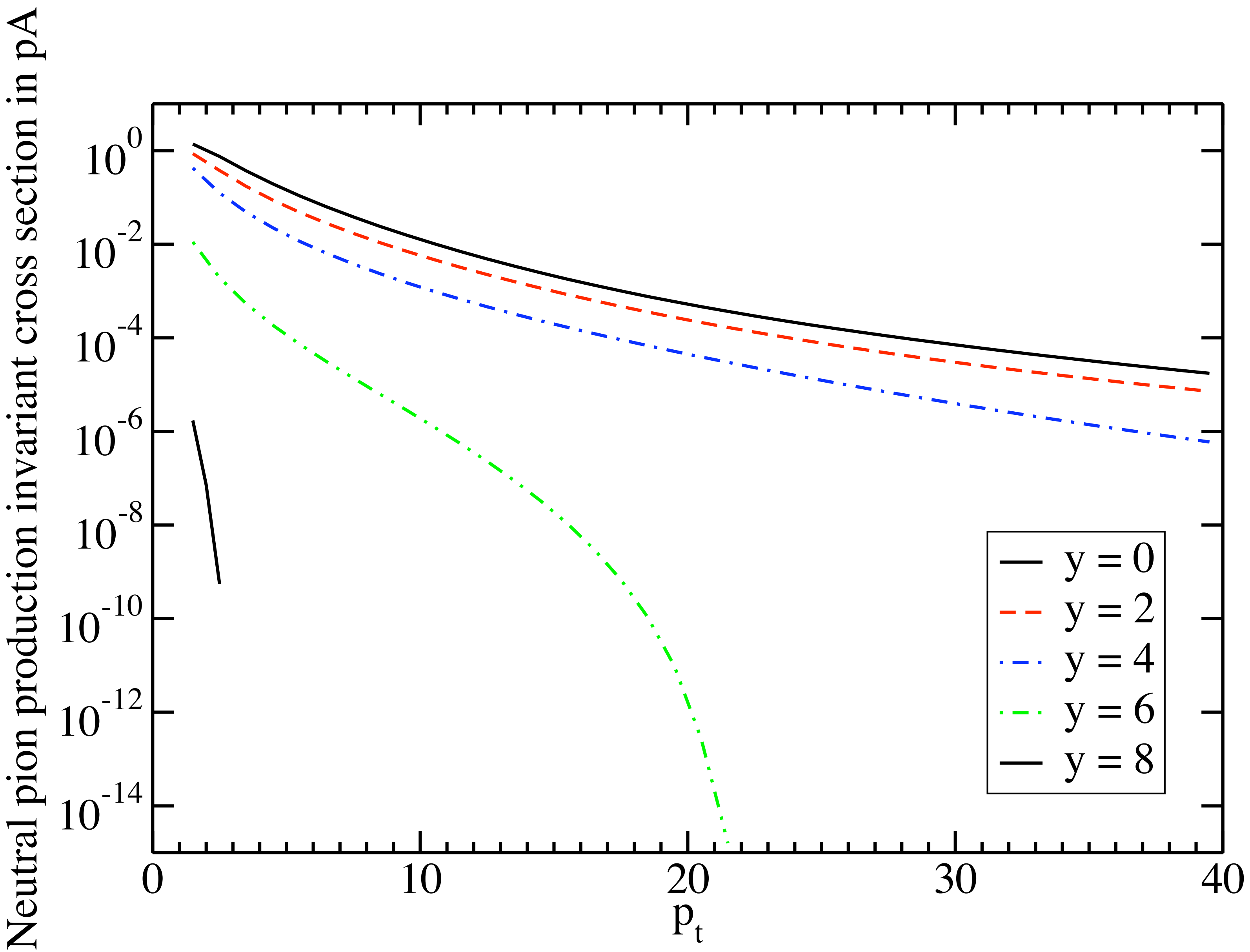
  - ***Overall normalization: need a constant K factor***
  - ***Different K factor at different rapidities***
- ***Average P_t***
  - ***Average p_t in total multiplicities***
    - ***Low pt: frag. functions?***
  - ☑ ***Average p_t with a cutoff*** $$< p_t > \equiv \frac{\int_{p_t^{min}} d^2p_t\, p_t\, \frac{d\sigma^{pA\to\pi^0(p_t,y_h)\,X}}{d^2p_t\, dy_h}}{\int_{p_t^{min}} d^2p_t\, \frac{d\sigma^{pA\to\pi^0(p_t,y_h)\,X}}{d^2p_t\, dy_h}}$$

Pion production in pp at LHC

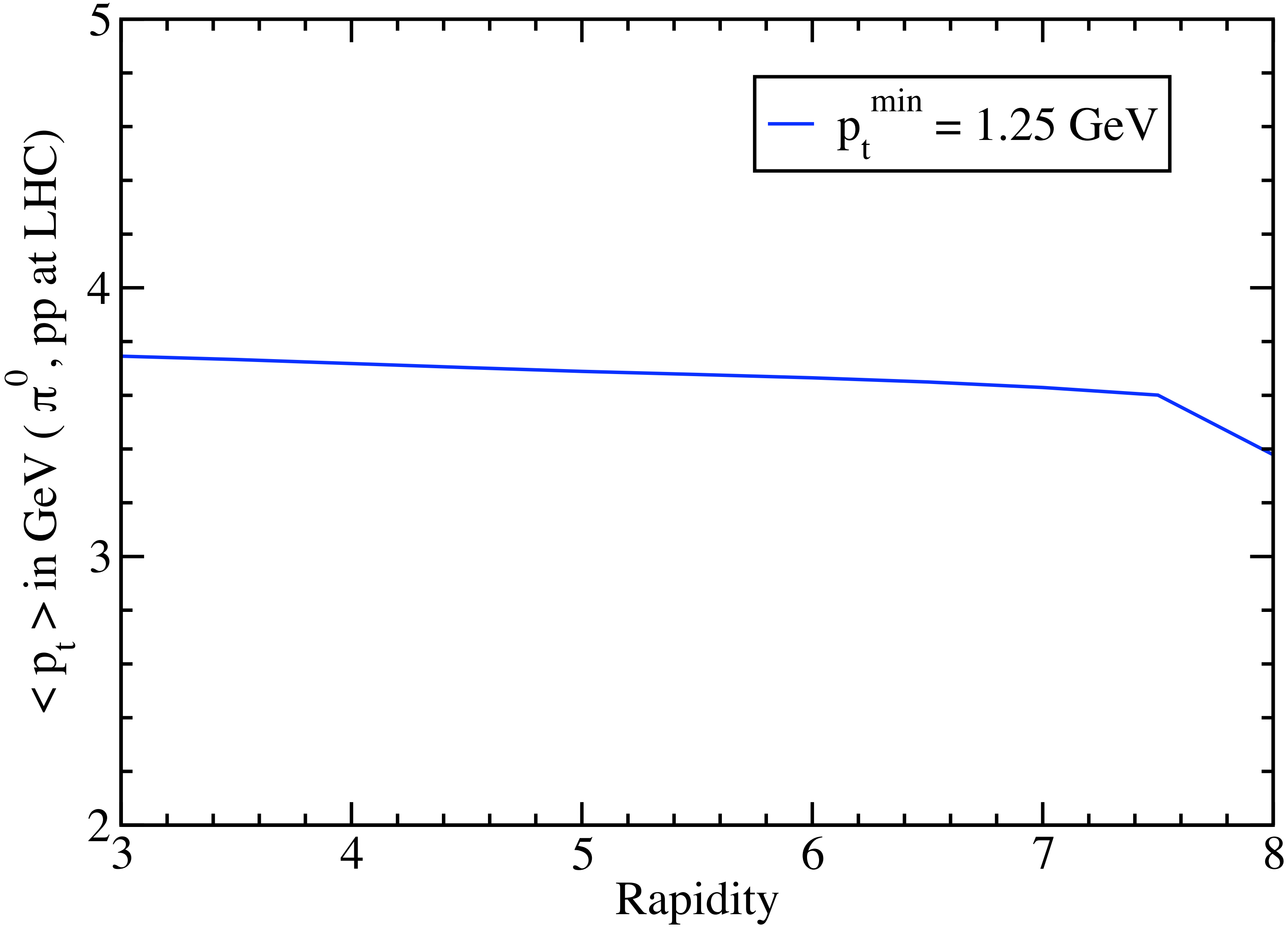
arXiv:0704.2628



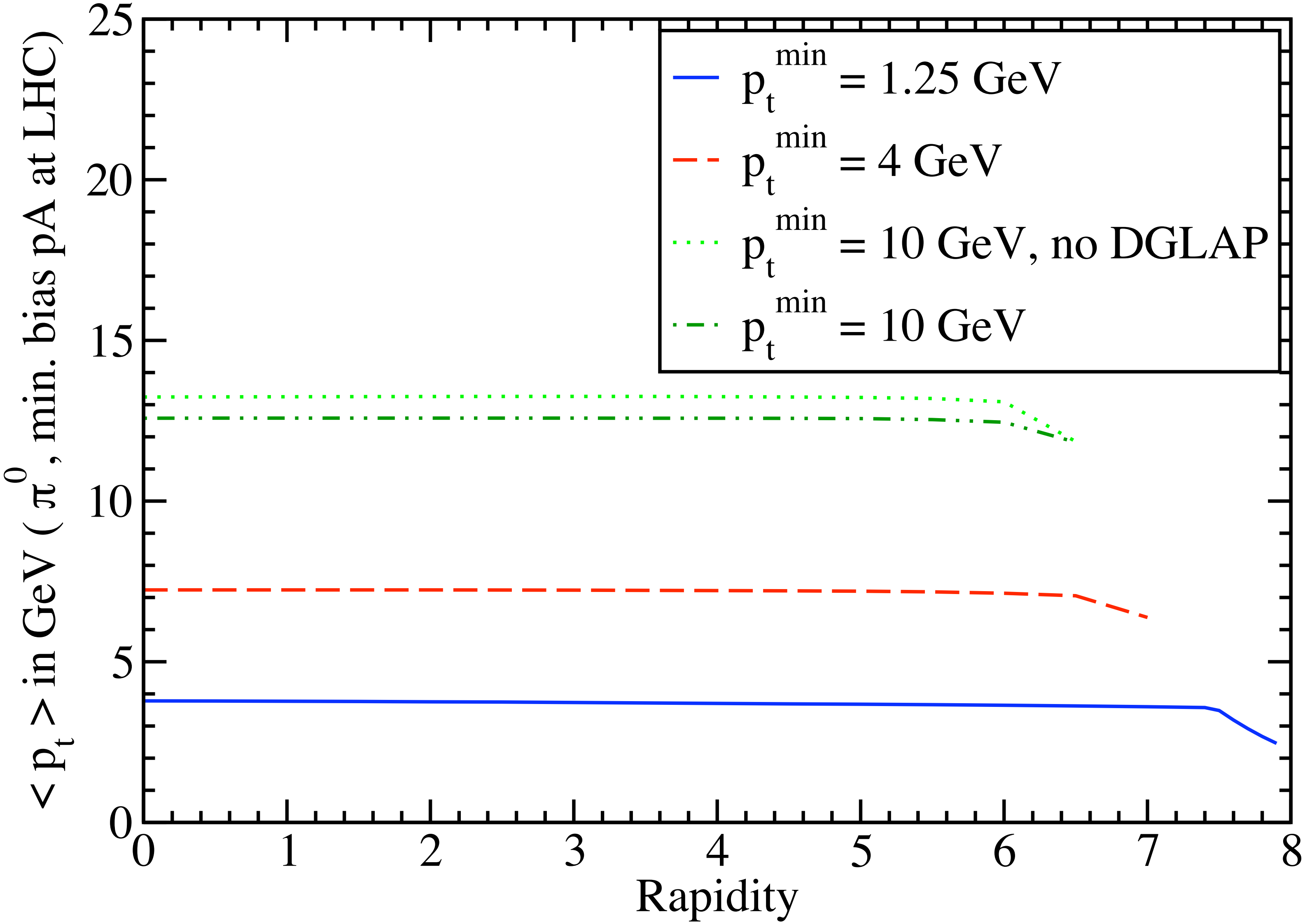
Pion production in pA at LHC



Pion average p_t in pp at LHC

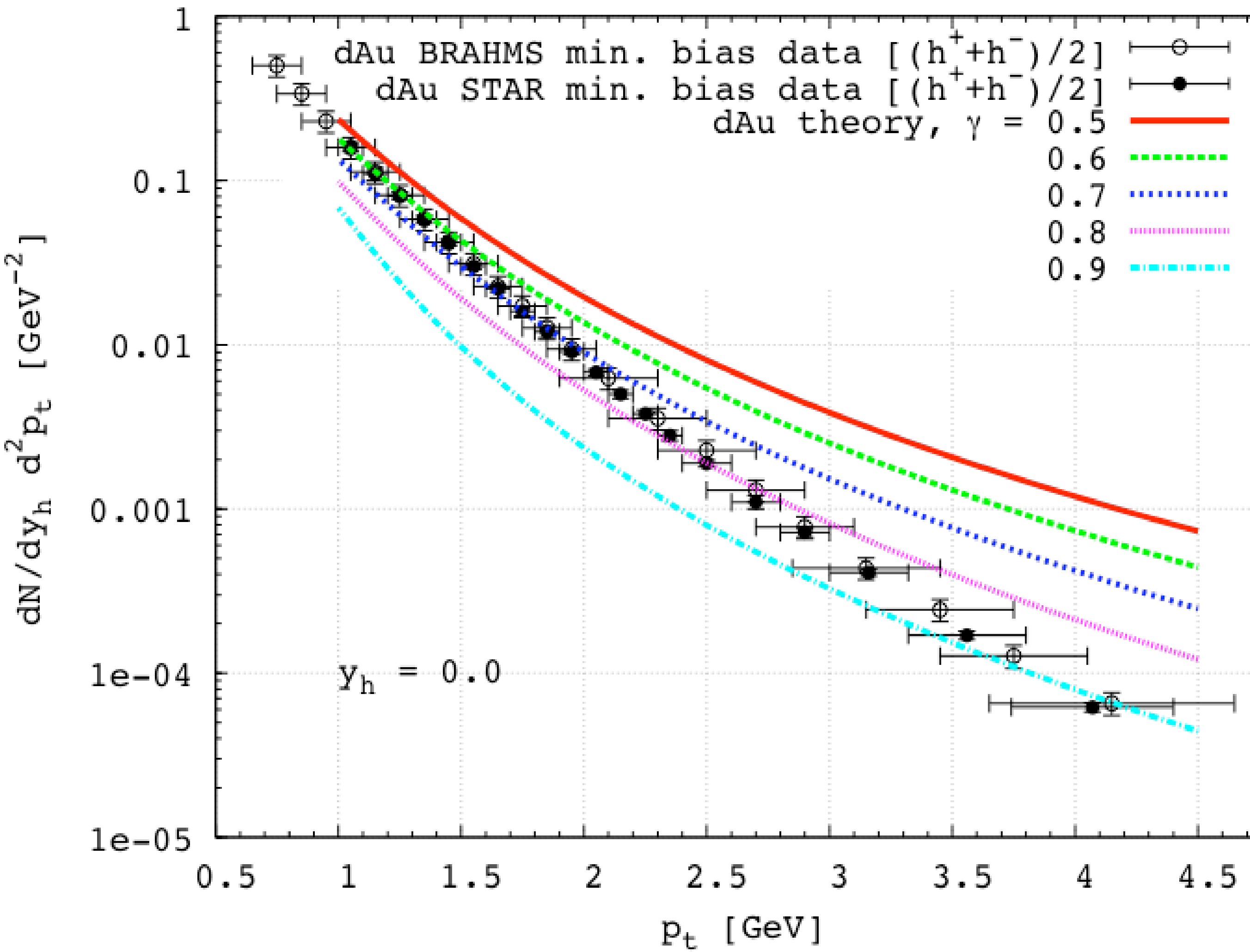


Pion average p_t in pA at LHC

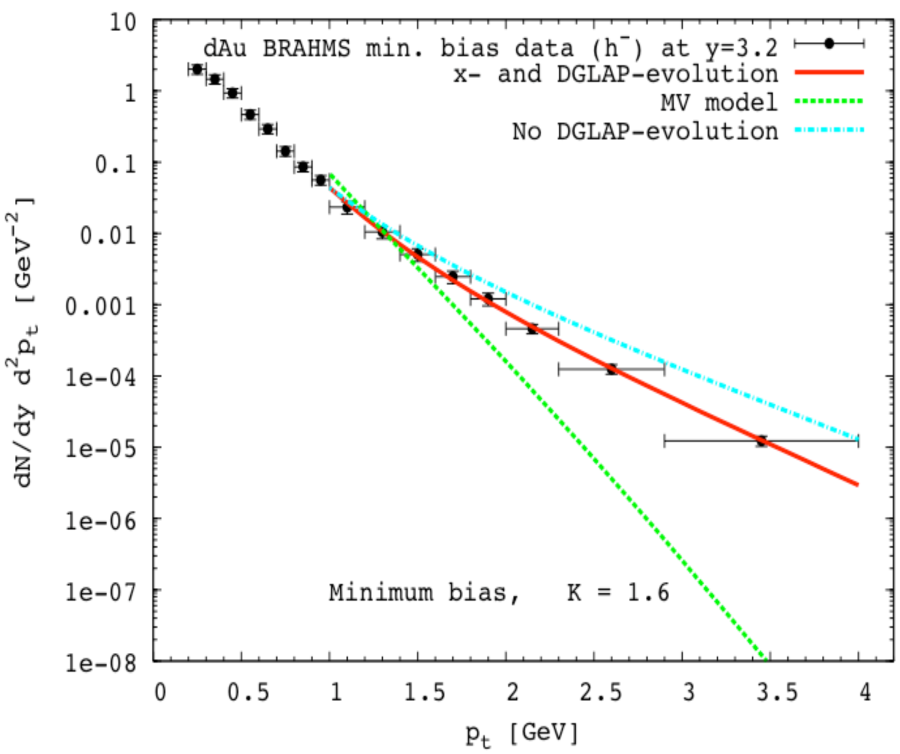


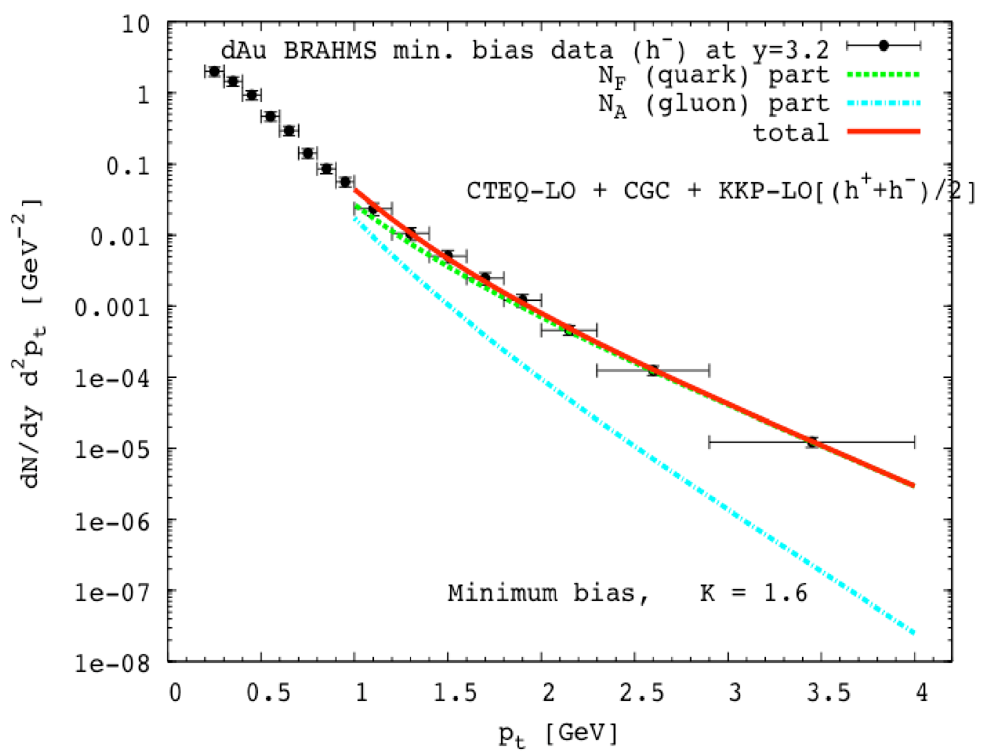
Looking forward to LHC

Mid rapidity: anomalous dimension



Hadron production in dA collisions at RHIC

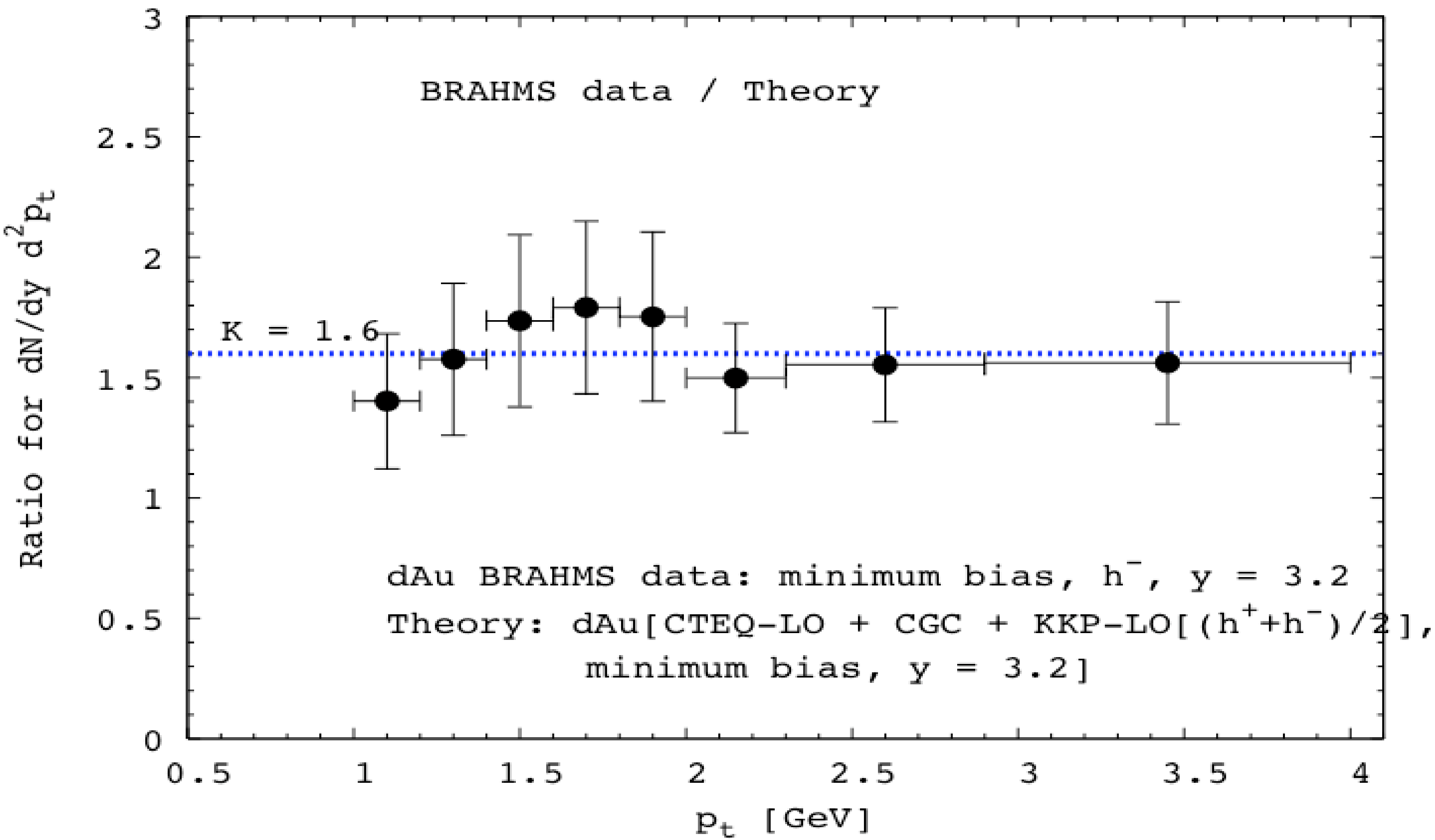




particle production at forward rapidity is dominated by quark scattering

both DGLAP and CGC are important

Application to dA at RHIC



BK= B-JIMWLK (mean field + large N_c)

A closed form equation

$$\partial_Y \langle T_{\mathbf{xy}} \rangle = \frac{\bar{\alpha}}{2\pi} \int d^2 z \, \frac{(\mathbf{x}-\mathbf{y})^2}{(\mathbf{x}-\mathbf{z})^2 (\mathbf{z}-\mathbf{y})^2} \left[\langle T_{\mathbf{xz}} \rangle + \langle T_{\mathbf{zy}} \rangle - \langle T_{\mathbf{xy}} \rangle - \langle T_{\mathbf{xz}} \rangle \langle T_{\mathbf{zy}} \rangle \right]$$

The simplest equation to include unitarity: T < 1

Exhibits extended (geometric) scaling

$$\mathbf{T(x, r_t) \rightarrow T[r_t Q_s(x)]}$$

for

$$\mathbf{Q_s < Q < \frac{Q_s^2}{\Lambda_{QCD}}}$$