Shattering a

Color Glass Condensate

in heavy ion collisions

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Another perspective on shattering glass...

Outstanding Phenomenological Questions

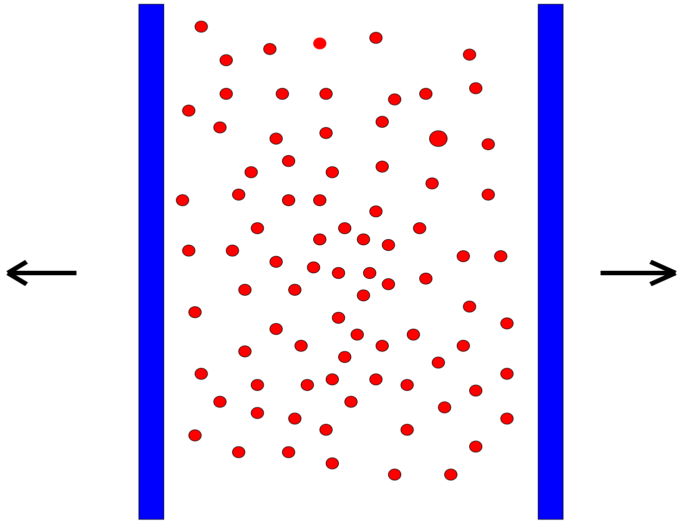
- *Is high energy density bulk quark gluon matter formed at RHIC ?*

- *Does this matter thermalize to form a Quark Gluon Plasma? What can we learn about the properties of the QGP ?*

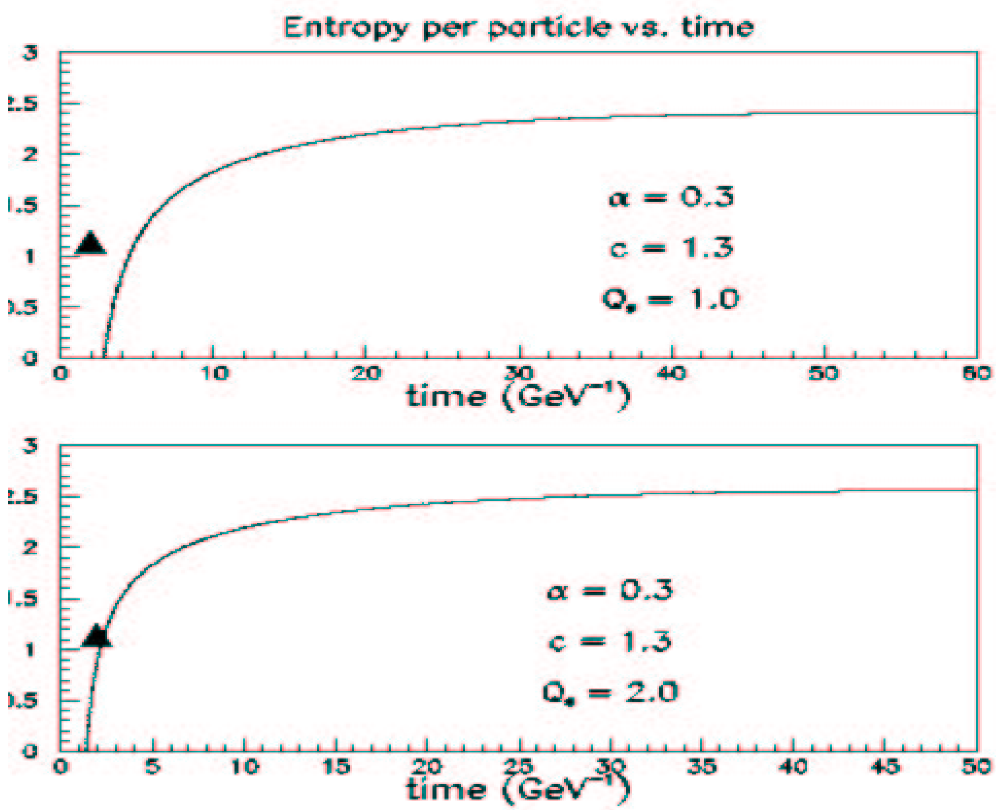
- *Can we learn about "universal" properties of hadronic wavefunctions at high energies? (Color Glass Condensate)*

Heavy–Ion Collisions–violent dynamical system...

Is Thermalization achieved ?

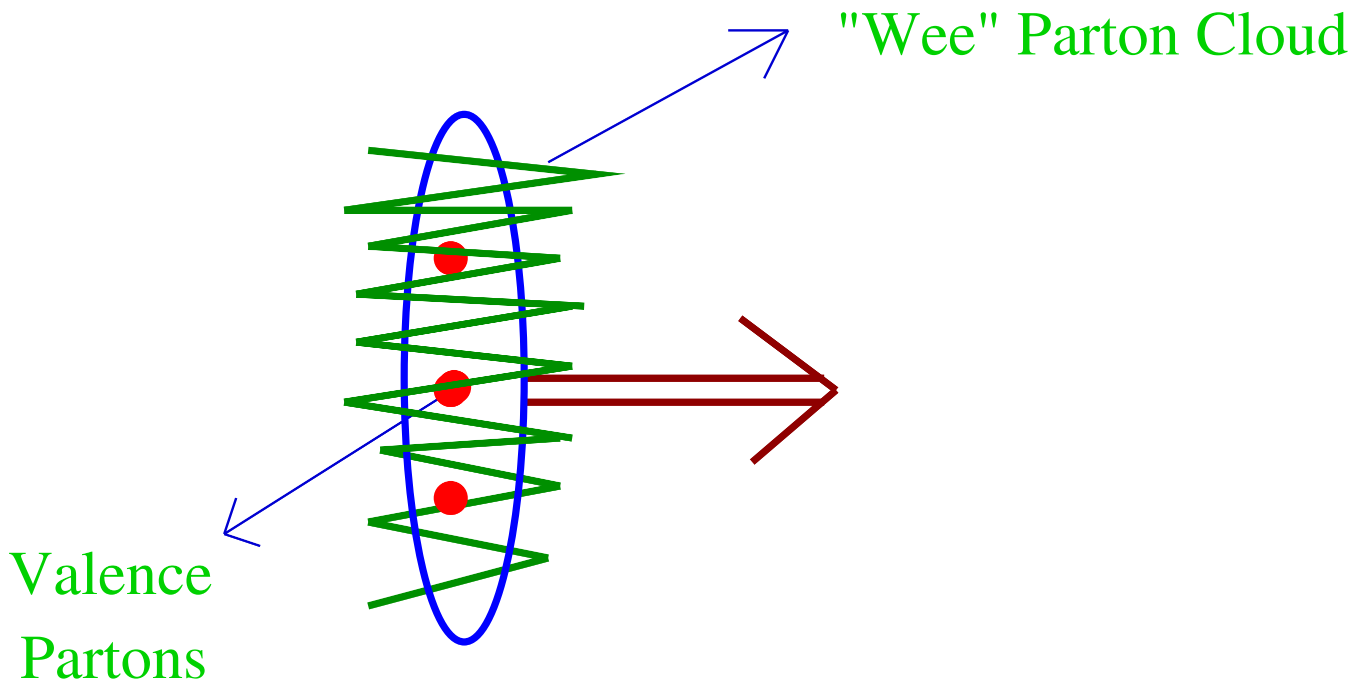


- Require ratio of rates: $\frac{\Gamma_{exp.}}{\Gamma_{coll.}} < 1$



- Thermalization very sensitive to initial conditions!

A Hadron at High Energies



$$|h> = |qqq> + |qqqg> + \cdots + |qqq \cdots gggq\bar{q}g>$$

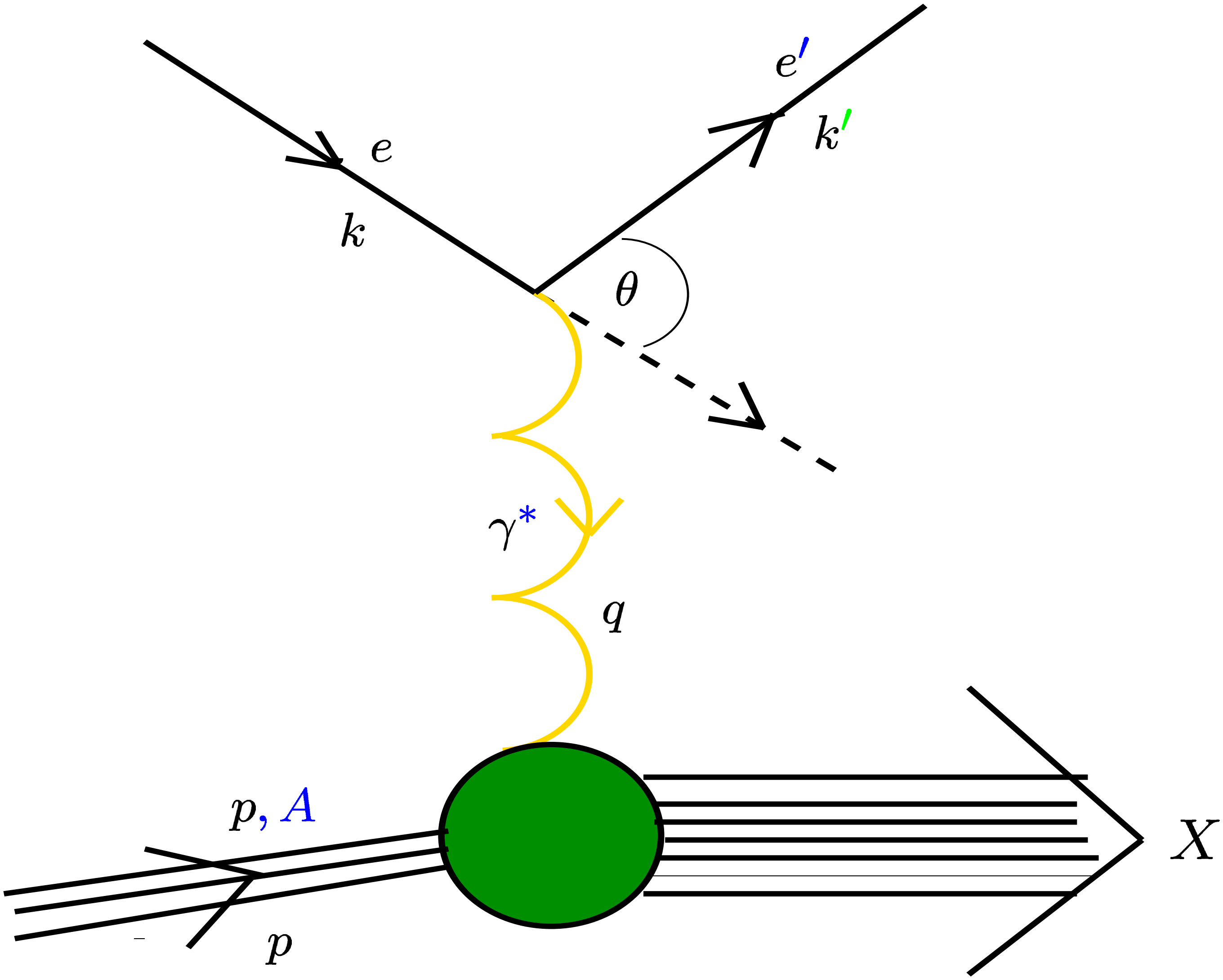
Each Wee Parton carries only a small fraction x= $k^+/P^+ << 1$

of momentum P^+ *of the hadron/nucleus*

- What is the behavior of Wee Partons in a High Energy Hadron ?

What does a Hadron look like at High Energies ?

The DIS Paradigm



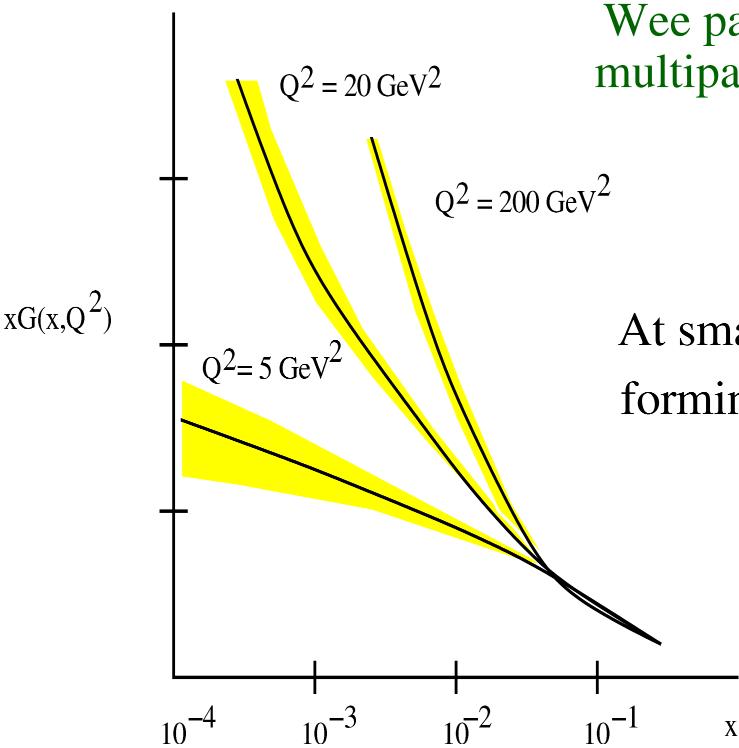
Kinematic Invariants:

$Q^2 = -q^2 > 0$; $x_{Bj} = \frac{Q^2}{2\,p\cdot q}$; $y = \frac{p\cdot q}{p\cdot k}$

$$x\,y = \frac{Q^2}{s}$$

$s = (p+k)^2$

Initial Conditions: Parton distributions in the nuclear wavefunction



Wee partons (x <<1) responsible for multiparticle−production at high energies

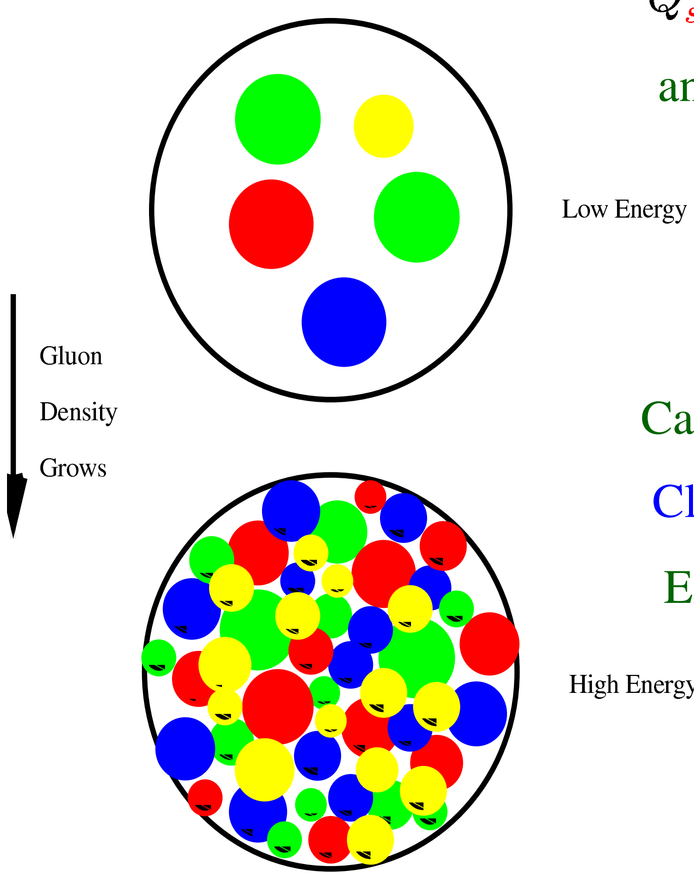
At small x, the gluon distribution saturates forming a Color Glass Condensate

Gluon density per unit area

$$Q_s^2 = \alpha_s N_c \frac{1}{\pi R^2} \frac{dN}{dy}$$

$Q_s^2 >> \Lambda_{QCD}^2$ for small x

and large nuclei



$$\alpha_s(Q_s^2) << 1$$

Can compute initial conditions in

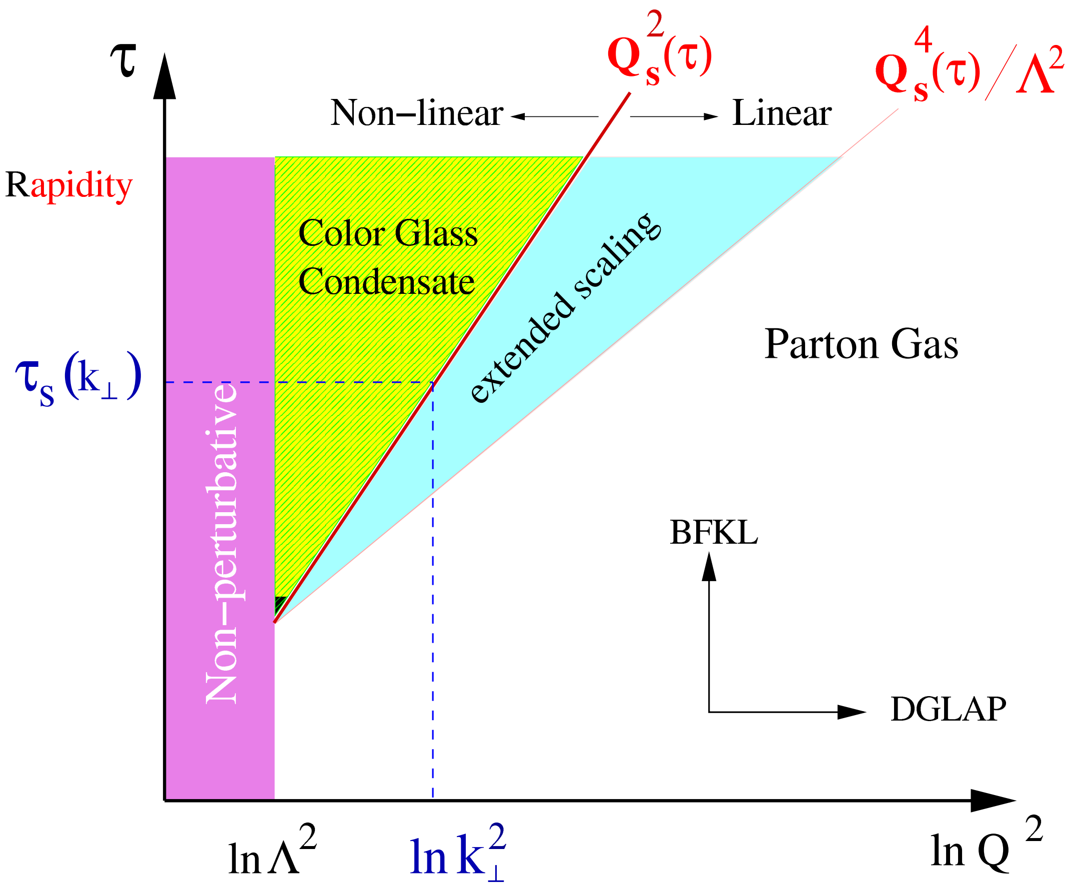
Classical $\left(f \sim \frac{1}{\alpha_S} > 1 \right)$

Effective Theory

Gribov, Levin, Ryskin
Mueller, Qiu
McLerran, Venugopalan
Jalilian−Marian,Kovner,Leonidov, Weigert ; Kovchegov

Iancu, Itakura, McLerran
Mueller, Triantafyllopolous

Phase Diagram of Hadron Wavefunction



- Usual pQCD evolution equations work very well at large x

  ⟶ problems at small x

- At small x, properties of partons described as a Color Glass Condensate

  ⟶ may be universal

- Geometrical scaling observed at HERA

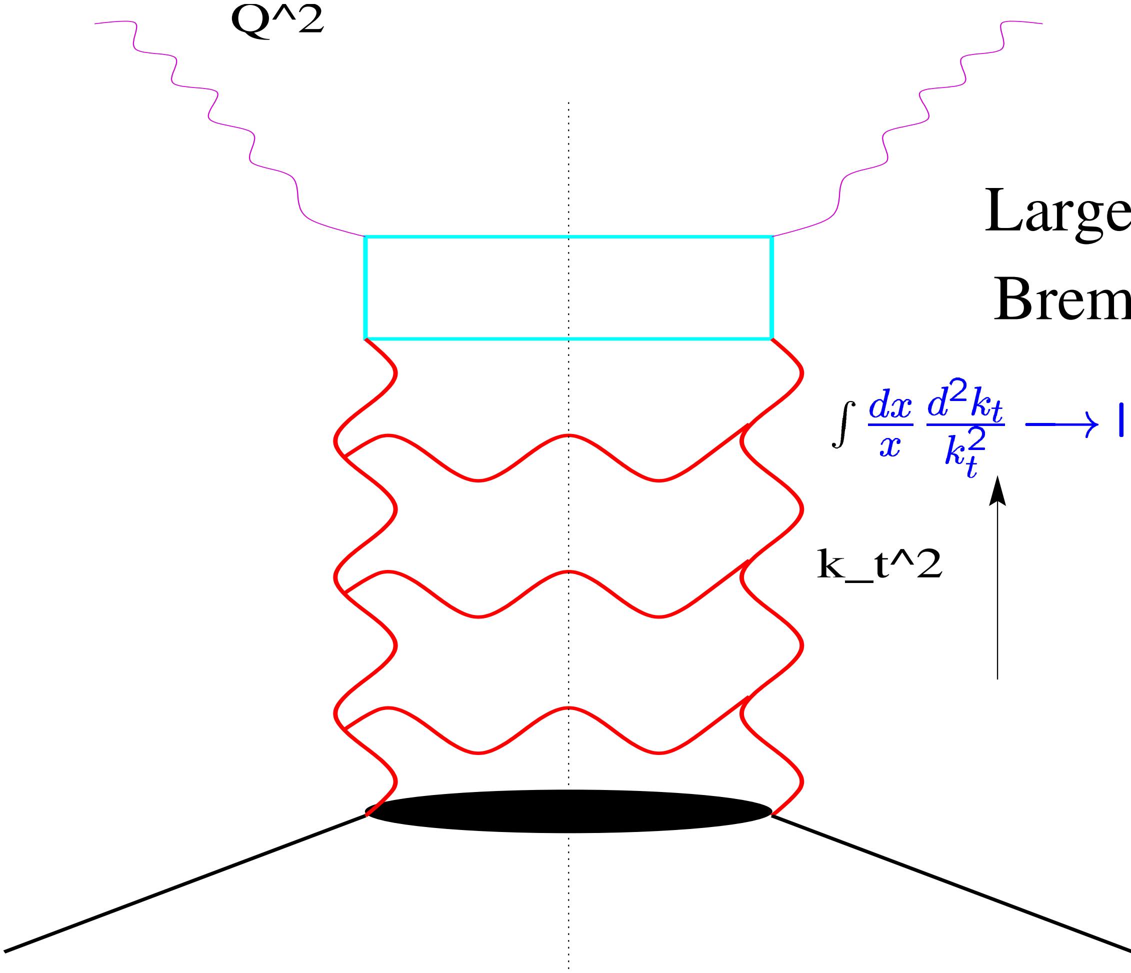
  ⟶ similar scaling in nuclei ?

Freund,Rummukainen,Schafer,Weigert

- QCD Evolution Equations at small x

a) The DGLAP (*Dokshitzer–Gribov–Lipatov–Altarelli–Parisi*) Equation

For x_Bj <<1, Gluon Bremsstrahlung is Largest Contribution in QCD Evolution: P_gg > P_qg > P_qq



Large Logs from Bremsstrahlung

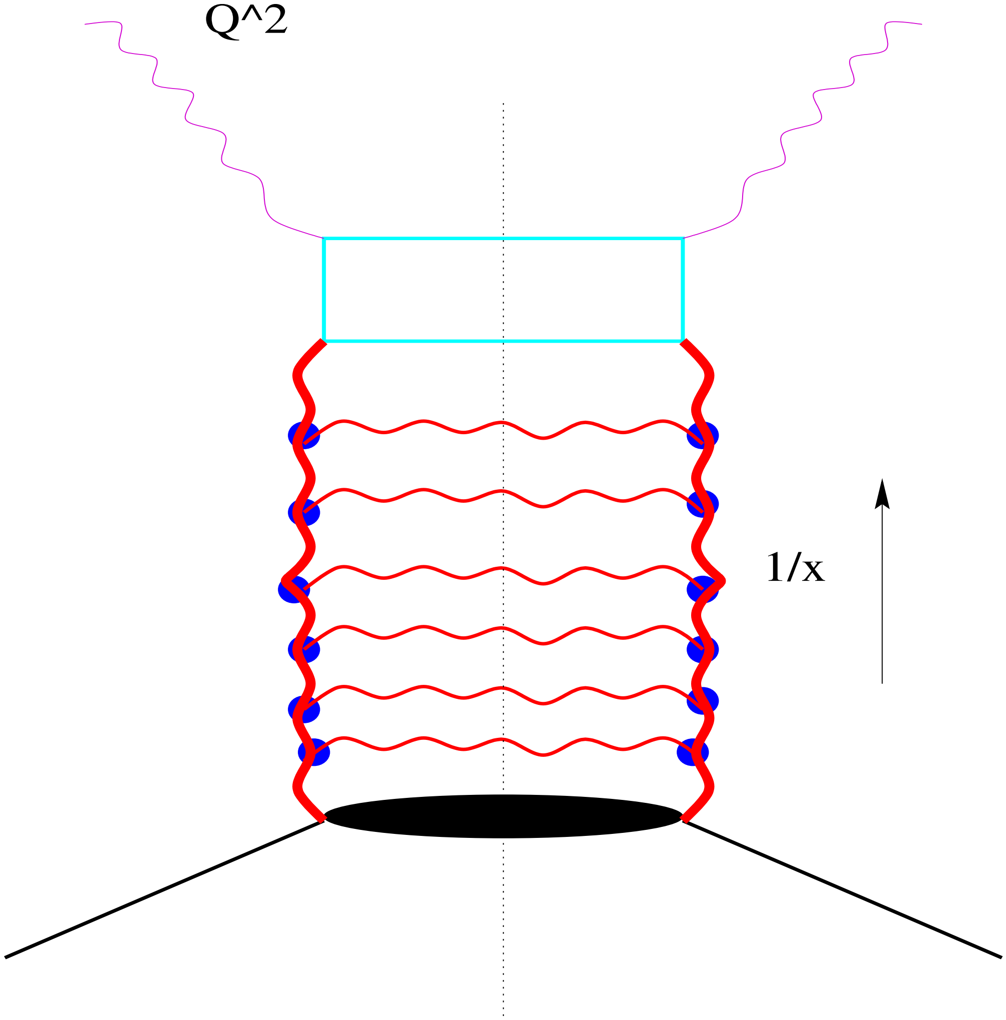
$$\int \frac{dx}{x} \frac{d^2k_t}{k_t^2} \longrightarrow \ln^m(1/x) \ln^n(Q^2)$$

- Re–sums $\alpha_s \ln(Q^2/\Lambda^2_{QCD})$ –Linear in Gluon Density

# of Gluons Grows Very Rapidly...

- QCD Evolution Equations at small x

b) The BFKL (*Balitsky−Fadin−Kuraev−Lipatov*) Equation



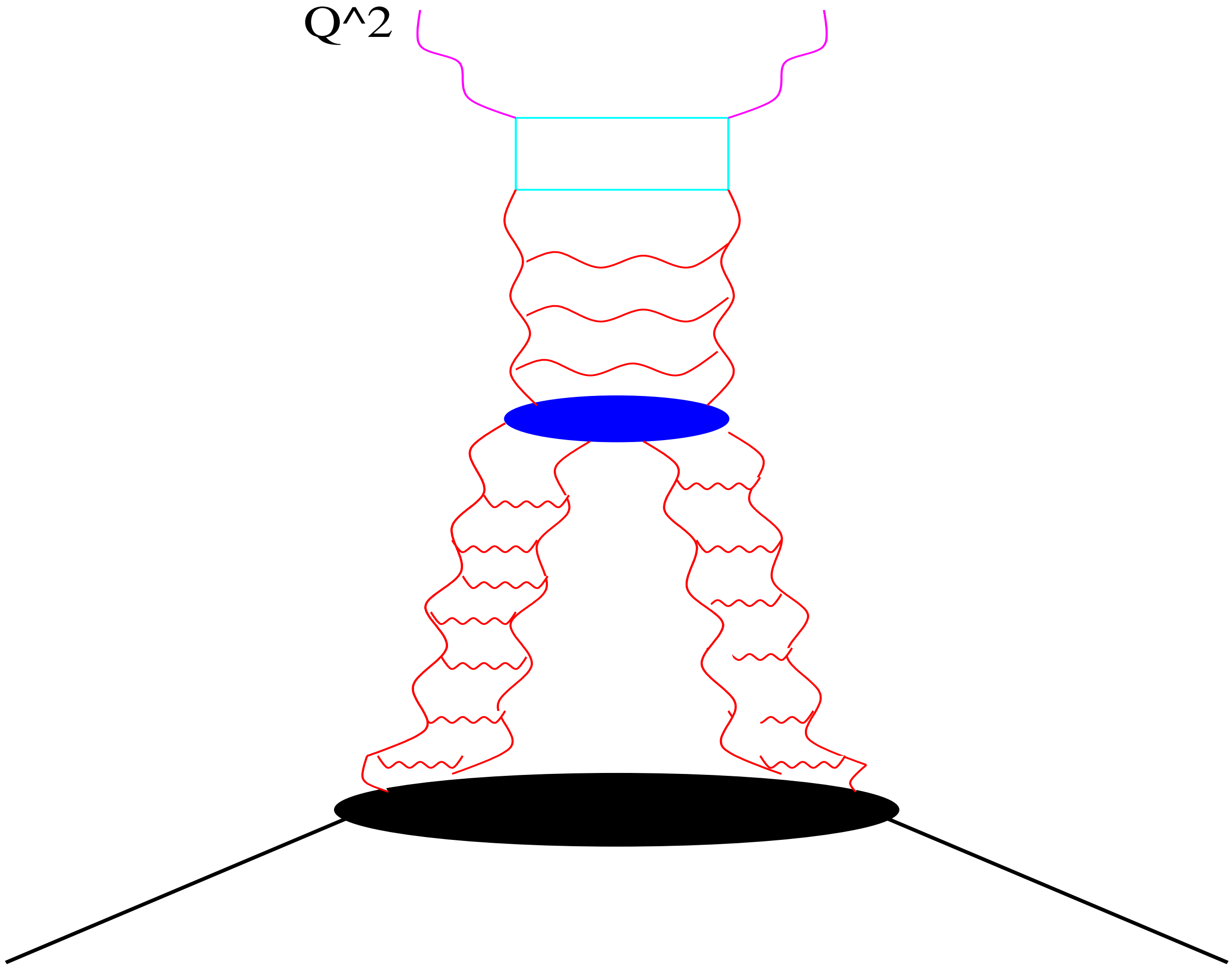
- Evolution in x, not Q^2
- Re−sums $\alpha_s \ln(1/x)$ −Linear in Gluon Density

# of Gluons Grows Even More Rapidly...

$$xG(x, Q^2) \propto \frac{1}{x^{\lambda}} \qquad \lambda = 0.5$$

Gribov,Levin,Ryskin
Mueller,Qiu

Gluon Recombination – Higher Twist Effects.

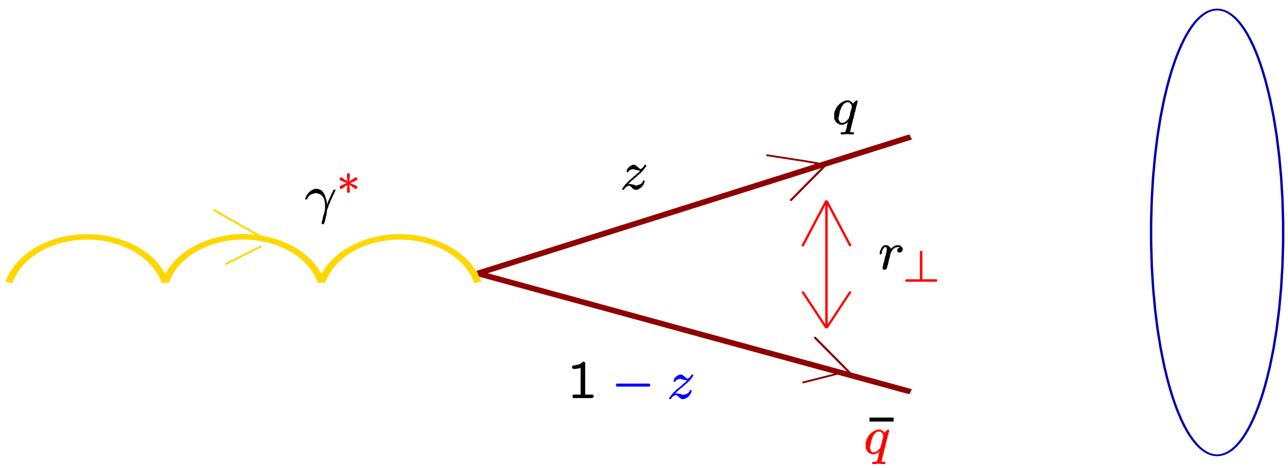


- Recombination Effects compete with DGLAP Bremsstrahlung effects when

$$\alpha_S xG(x, Q^2) \sim R^2 Q^2$$

- **Saturation of the Gluon Density**

Golec−Biernat & Wustoff's Model



$$\sigma_{T,L}^{\gamma^* p} = \int d^2 r_\perp \int dz \, |\psi_{T,L}(r_\perp, z, Q^2)|^2 \, \sigma_{q\bar{q}p}(r_\perp, x)$$

$$\sigma_{q\bar{q}p}(r_\perp, x) = \sigma_0 \left[1 - \exp\left(-r_\perp^2 Q_s^2(x)\right)\right]$$

with the saturation scale Q_s defined as

$$Q_s(x)^2 = Q_0^2 \, (x_0/x)^\lambda$$

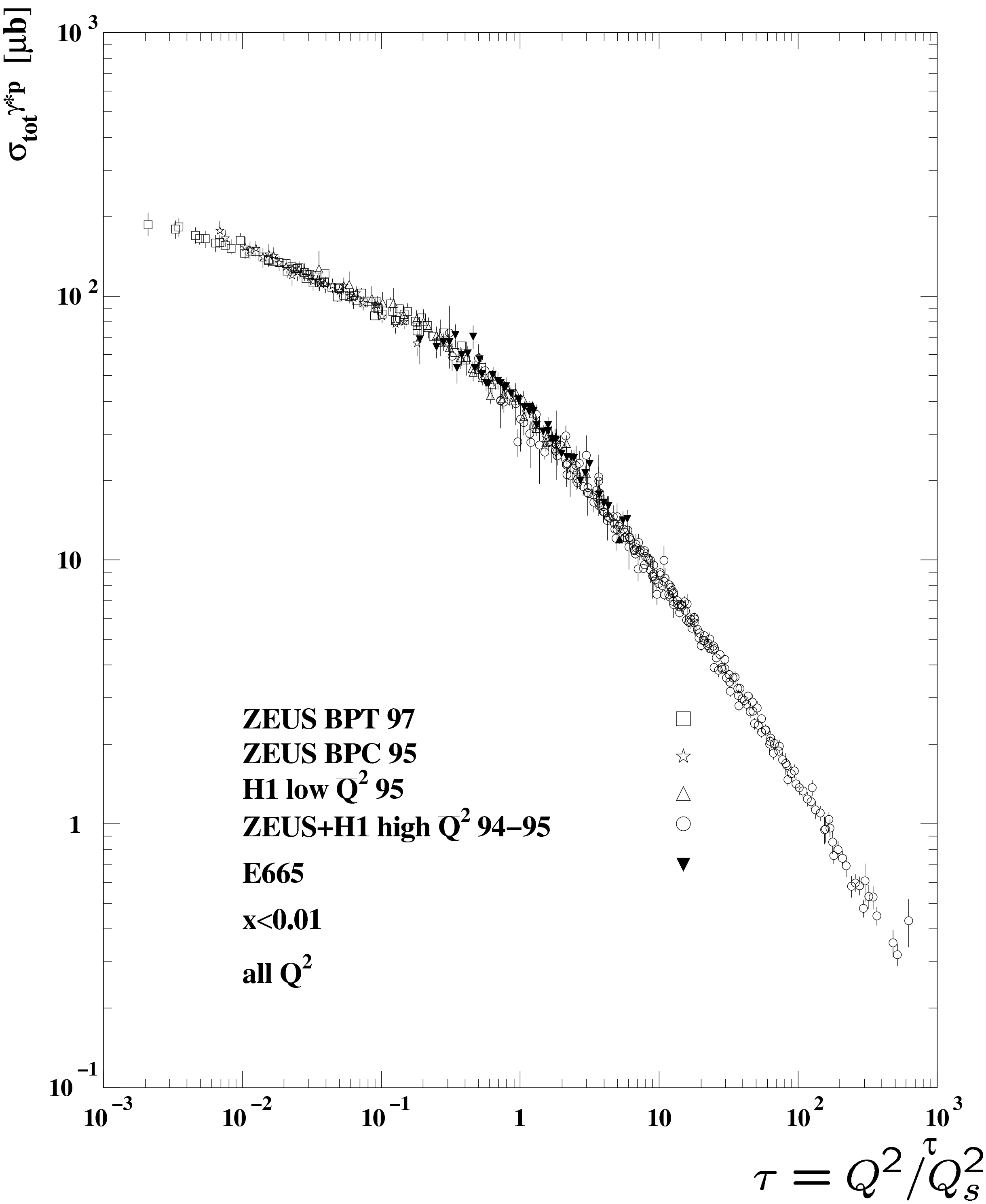
- Fit to HERA data for x < 0.01 ; all Q^2

  $Q_0 = 1$ GeV ; $\lambda = 0.3$; $x_0 = 3 \cdot 10^{-4}$; $\sigma_0 = 23$ mb

- Also, good fit to HERA diffractive data

Kowalski,Teaney

Geometrical Scaling at HERA

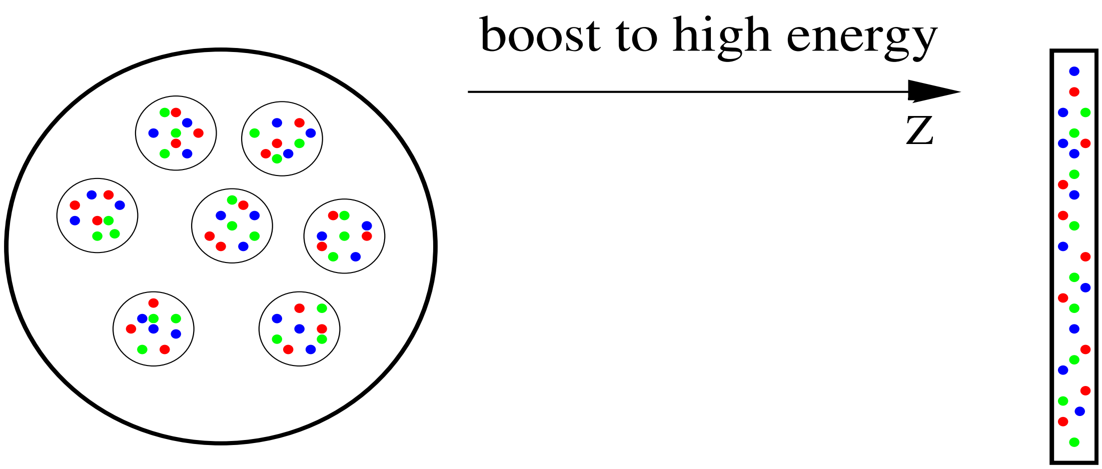


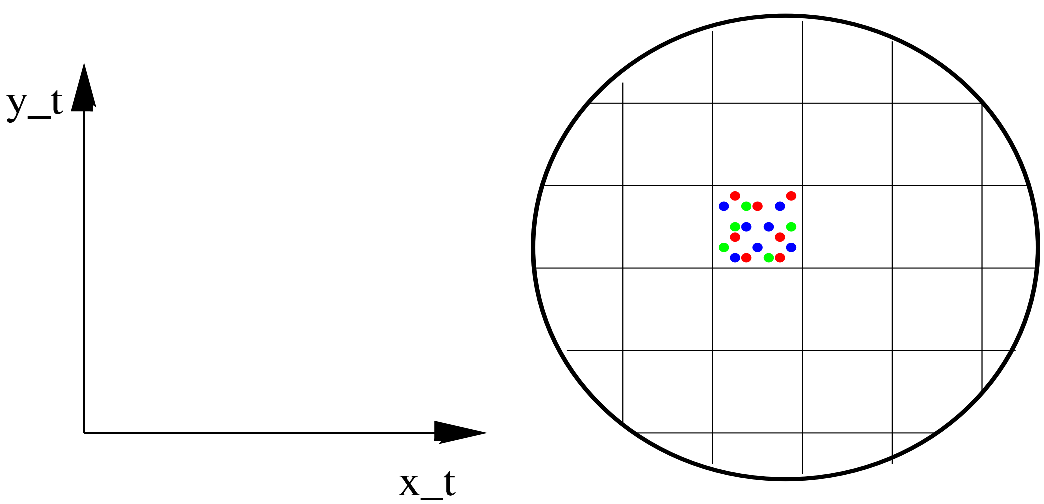
- *Scaling seen for all $x < 0.01$ and* $0.045 < Q^2 450 \mathrm{GeV}^2$

Effective Field Theory For Small x

- Consider, Large Nucleus in the Infinite Momentum Frame

McLerran & R.V





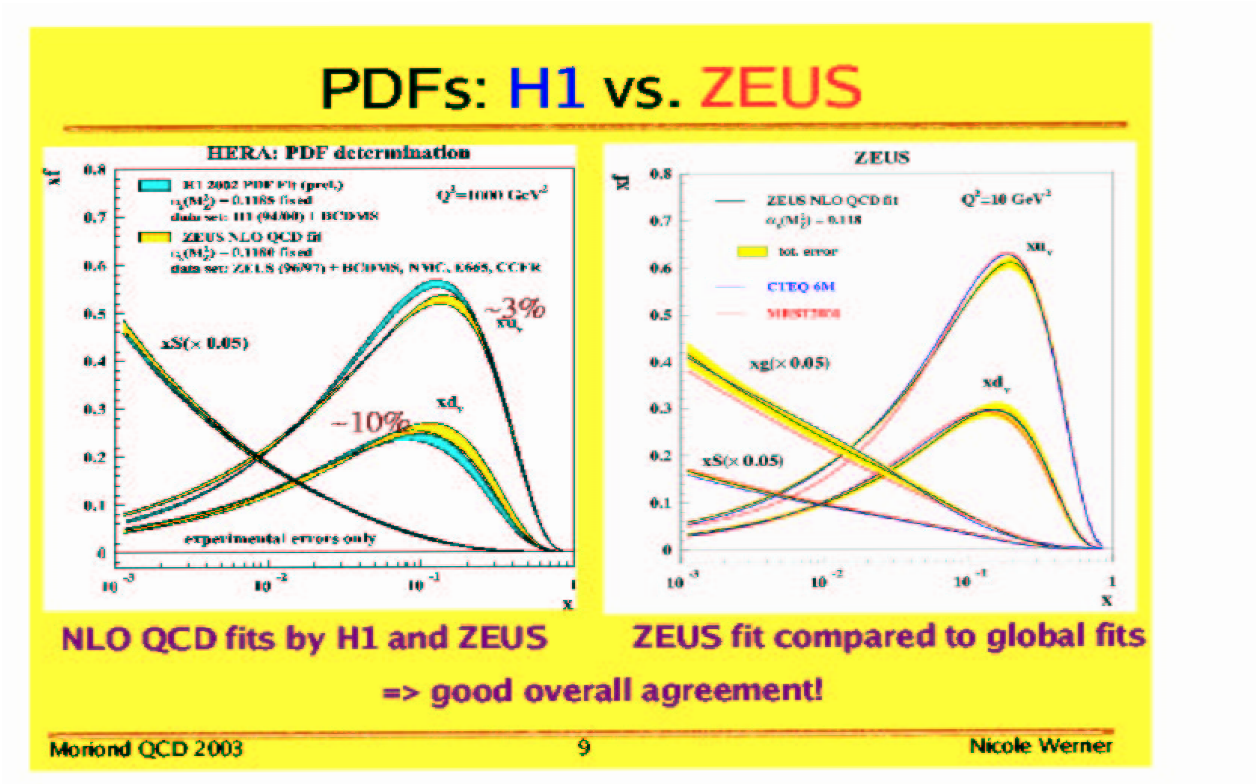
L^2 << 1 fm^2

- One large component of current–others suppressed by nuclear momentum: 1/P^+

$$J^{\mu,a} = \delta^{\mu +} \rho^a(x_t)\, \delta(x^-)$$

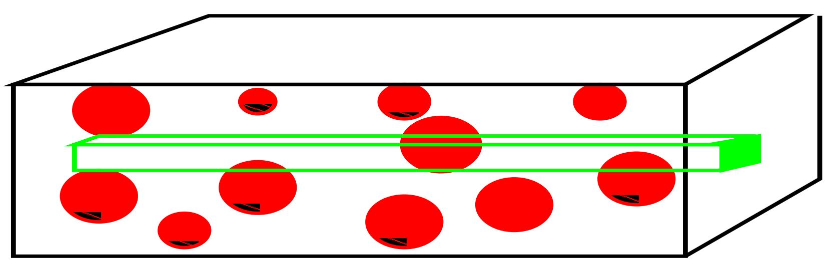
- *Wee Partons see a large density of valence color charges at small transverse resolutions*

- Born–Oppenheimer: *separation of large x & small x modes*



$$\tau_{\rm wee} \sim \frac{1}{k^-} = \frac{2k^+}{k_t^2} \equiv \frac{2xP^+}{k_t^2} << \tau_{\rm valence} \equiv \frac{2P^+}{k_t^2}$$

- Random Sources:



y_{max} y

$$\lambda_{\rm wee} \sim \frac{1}{k^+} \equiv \frac{1}{xP^+} >> \lambda_{\rm valence} \equiv \frac{R\, m_p}{P^+}$$

=> $x << A^{-1/3}\,;\ <\rho^a>= 0\,;<\rho^a\rho^b>=\mu_A^2\delta^{ab}$

$x << A^{-1/3}\,;\ <\rho^a>= 0\,;<\rho^a\rho^b>=\mu_A^2\,\delta^{ab}$

Effective action:

$$S = \frac{-1}{4}\int d^4x\, F_{\mu\nu}^2 + \frac{i}{N_c}\int d^2x_\perp dx^- \delta(x^-)\, \mathrm{Tr}\rho(x_\perp) W_{-\infty,\infty}[A^-] + i\int d^2x_\perp G[\rho(x_\perp)]$$

where $W_{-\infty,\infty}[A^-] = P\exp\left(ig\int dx^+ A^{-,a} T^a\right)$

For a large nucleus, $G[\rho(x_\perp)] = \frac{\rho^a\rho^a}{\Lambda_s^2}$ $\quad \Lambda_s^2 = g^4\mu_A^2$

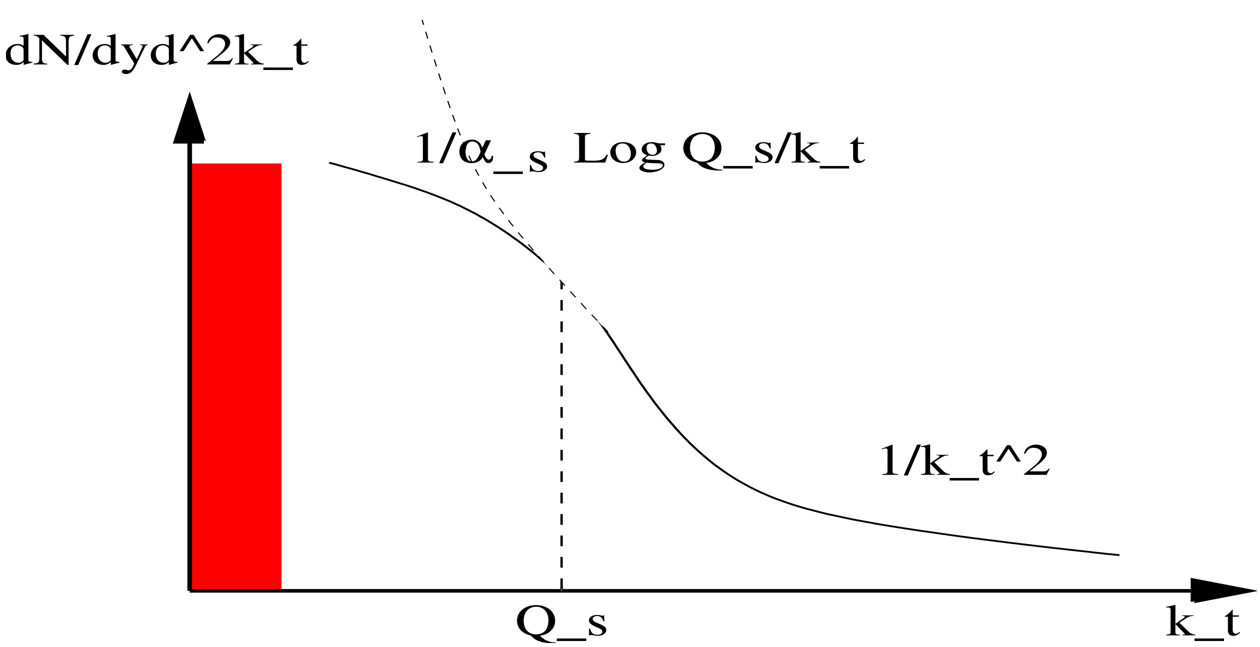
Classical field of a nucleus:

Solve Yang−Mills equations of motion $D_\mu F^{\mu\nu,a} = \rho^a(x_\perp)\,\delta(x^-)\,\delta^{\nu+}$

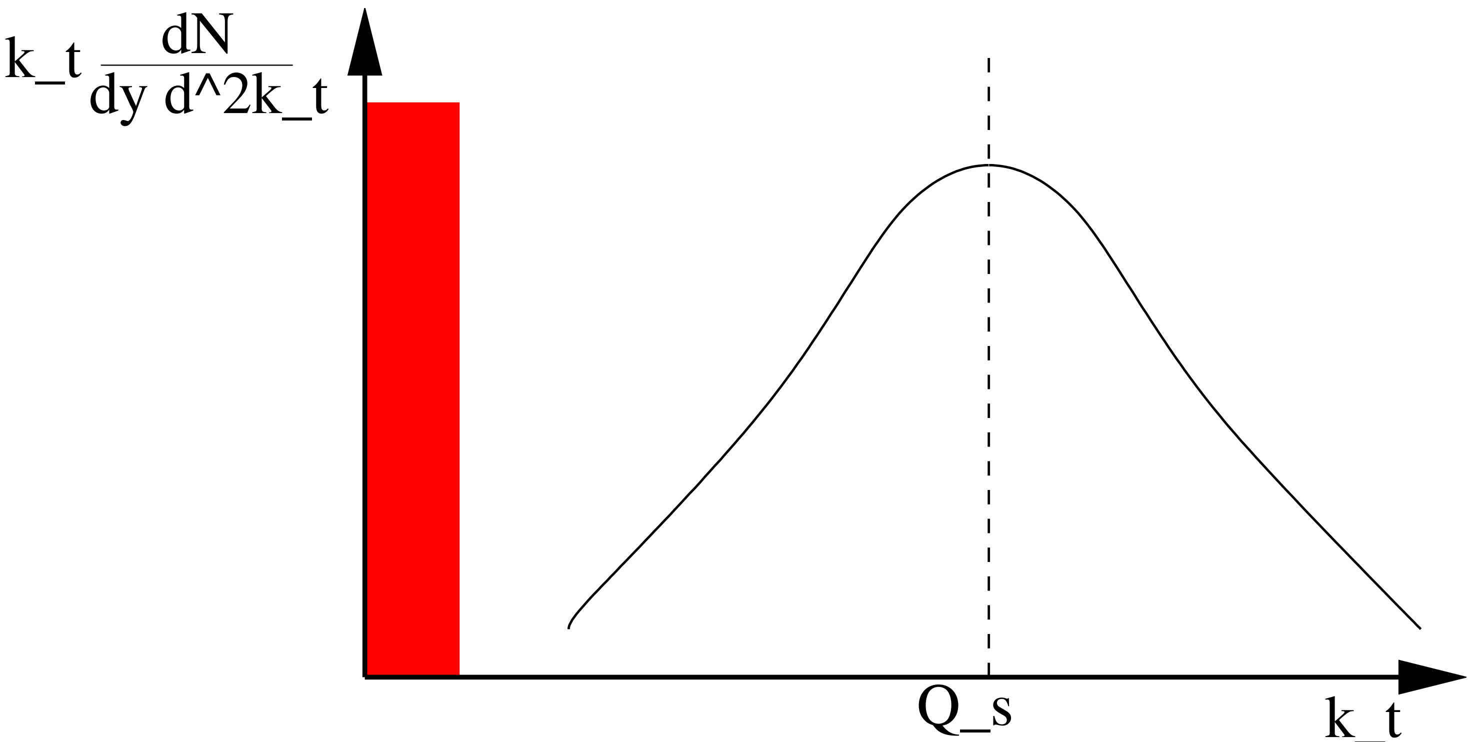
$A^{+,a} = A^{-,a} = 0\ ;\ F^{ij} = 0 \longrightarrow A^{i,a} = \theta(x^-)\frac{1}{ig} U\nabla^i U^\dagger$

$U = \exp\left(\frac{ig\rho}{\nabla^2}\right)$

Average over rho's to compute observables; e.g., gluon distribution <A A>



The Color Glass Condensate

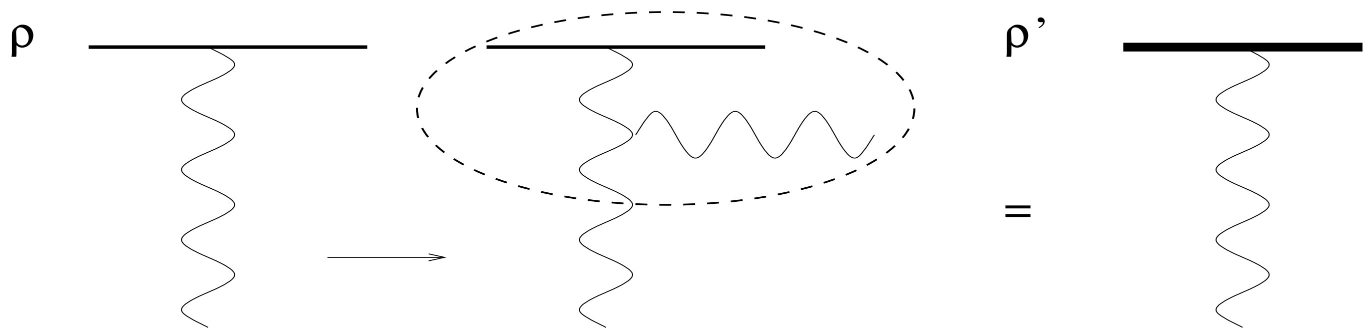


- *Typical momentum of gluons is Q_s*
- *Large occupation # ~* $1/\alpha_S$ *– form a condensate*
- *Gluons are colored*
- *Separation in time scales between hard & soft partons–similar to a glass*

Hadron/Nucleus at High Energies is a Color Glass Condensate !

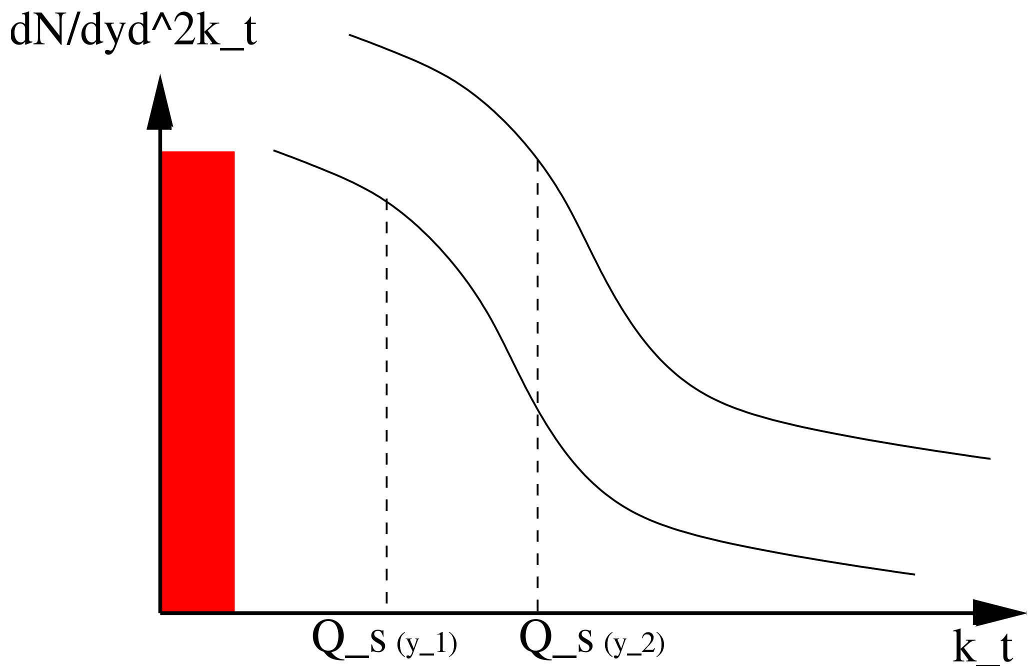
Quantum corrections to the Color Glass Condensate

- *Color charge grows due to inclusion of fields into hard source*



Jalilian−Marian,Iancu,McLerran,Weigert,Leonidov,Kovner

- *The saturation momentum grows*



- *Evolution described by a non−linear RG equation*

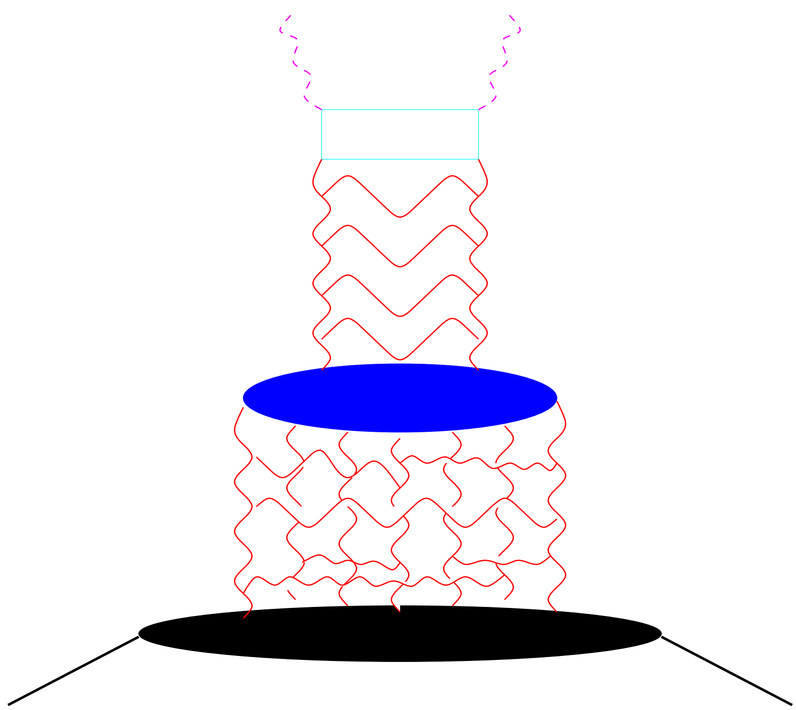
  −simplest version is the Balitsky−Kovchegov Eqn.

- *The statistical weight* $Z = \exp(-G[\rho])$ *satisfies the JIMWLK RG−equation,*

$$\frac{dZ}{d\ln(1/x)} = \frac{1}{2}\int_{x_\perp, y_\perp} \frac{\partial}{\partial \rho_y^a(x_\perp)} \chi_{ab}(x_\perp, y_\perp)[\rho] \frac{\partial}{\partial \rho_y^b(y_\perp)} Z$$

where, χ_{uv} *is a 2−point functional of* ρ

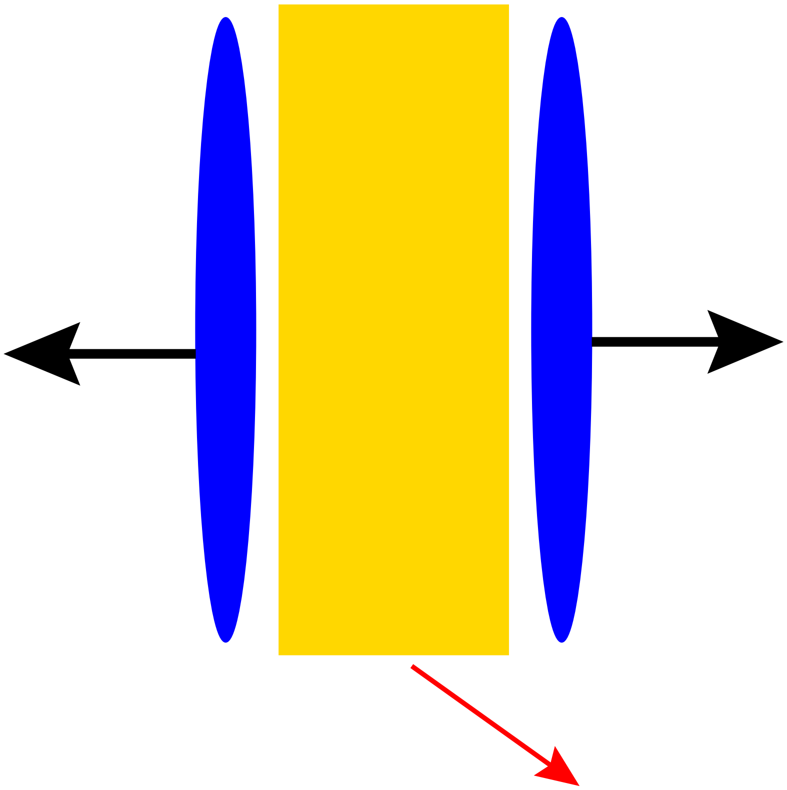
−the induced charge−charge correlator.



- *This Eqn. reduces to the Balitsky−Kovchegov Eqn. at* $N_c \to \infty$ *and* $\alpha_s^2 A^{1/3} \to \infty$

- *The JIMWLK Eqn. has been solved recently by Rummukainen & Weigert*

Real Time Gluodynamics of Nuclear Collisions



Kovner,McLerran,Weigert
Krasnitz,Nara,Venugopalan
Lappi

Classical Fields with occupation # $f = \frac{1}{\alpha_s}$

- Non–perturbative formulae for initial glue distributions

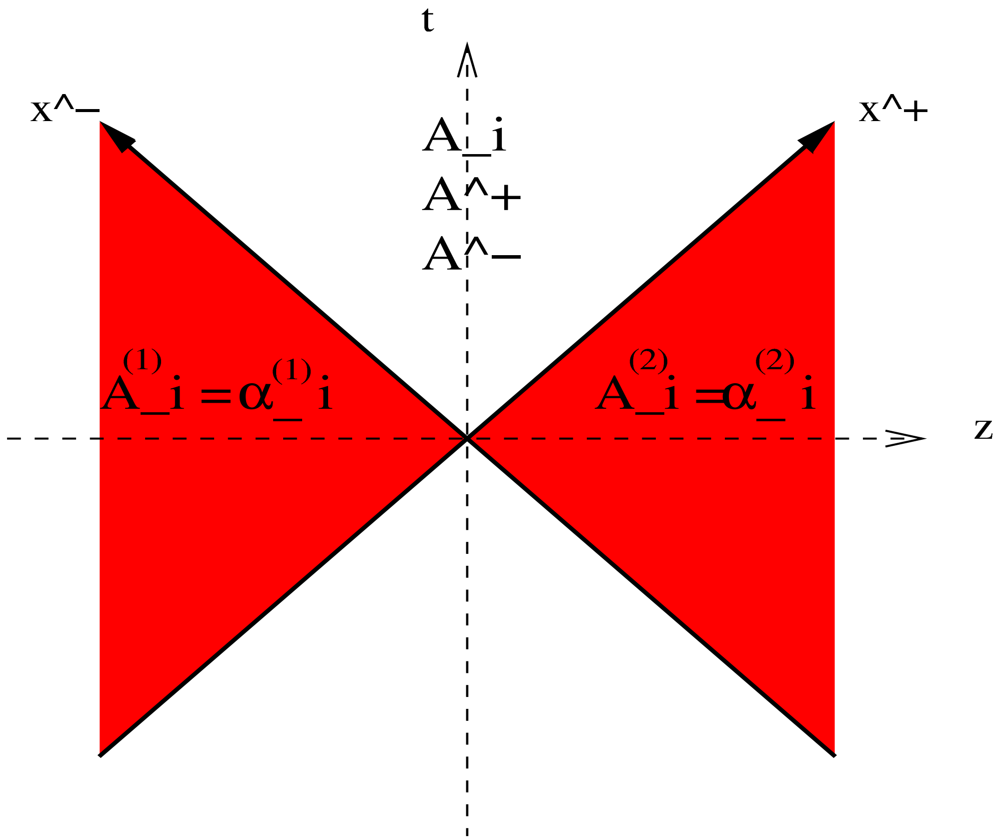
$$\frac{1}{\pi R^2}\frac{dE_T^{\text{glue}}}{d\eta} = \frac{0.25}{g^2} Q_s^3$$

$$\frac{1}{\pi R^2}\frac{dN^{\text{glue}}}{d\eta} = \frac{0.3}{g^2} Q_s^2$$

- Classical approach breaks down at late time when f << 1...

$\tau >> \frac{1}{Q_s}$ but $\tau << R$

The classical field of two nuclei



$$\mathcal{A}_i^a = A_i^{(1),a}\theta(x^-)\theta(-x^+) + A_i^{(2),a}\theta(-x^-)\theta(x^+)$$
$$+ \theta(x^-)\theta(x^+)A_i^a$$

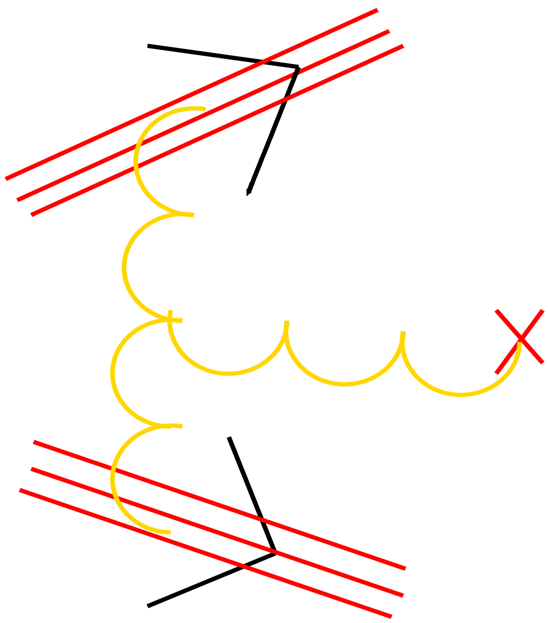
solves $D_\mu F^{\mu\nu,a} = \rho_1^a(x_\perp)\,\delta(x^-)\delta^{\nu+} + \rho_2^a(x_\perp)\,\delta(x^+)\delta^{\nu-}$

- *To compute distributions, average over all color charge configurations of the two (identical) nuclei*

$$\int [d\rho_1]\,[d\rho_2]\ \exp\left[-\int d^2x_\perp \left(\frac{\rho_1^a\rho_1^a+\rho_2^a\rho_2^a}{\Lambda_s^2}\right)\right]$$

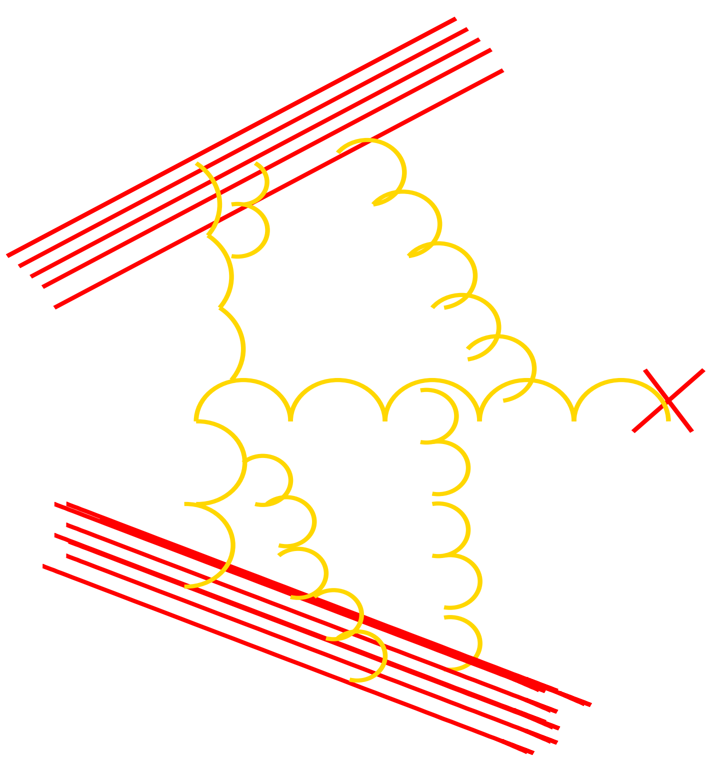
Kovner, McLerran, Weigert
Kovchegov, Rischke
Gyulassy, McLerran

- *To lowest order in* ρ



$$\propto \frac{\Lambda_s^2}{k_t^2}\frac{\Lambda_s^2}{k_t^2}\ln\left(\frac{k_t^2}{L^2}\right)$$

- *To all orders in* ρ



At present can only be computed numerically

Krasnitz,Nara,Venugopalan
Lappi

Lattice Formulation

- *Hamiltonian formalism better suited for numerical work. In the continuum,*

$$H = \frac{\tau}{2} \int d\eta \, d^2 r_\perp \left[p^\eta p^\eta + \frac{1}{\tau^2} p^r p^r + \frac{1}{\tau^2} F_{\eta r} F_{\eta r} + F_{xy} F_{xy} \right]$$

$$\eta = \ln(\frac{x^+}{x^-}) \quad \tau = \sqrt{2x^+ x^-}$$

- *For "perfect pancake" nuclei, only consider boost invariant configurations.*

$$\mathrm{A}_r(\tau, x_\perp, \eta) \equiv A_r(\tau, x_\perp) \;;\; A_\eta(\tau, x_{\perp\eta}) \equiv \Phi(\tau, x_\perp)$$

- *Per unit rapidity,*

$$H = \frac{\tau}{2} d^2 r_\perp \left[p^\eta p^\eta + \frac{1}{\tau^2} E_r E_r + \frac{1}{\tau^2} (D_r \Phi)(D_r \Phi) + F_{xy} F_{xy} \right]$$

- *Discretize on a 2−D lattice*

$$
\begin{aligned}
H_L &= \frac{1}{2\tau}\sum_{l} E_l E_l + \tau \sum_{\mathrm{pl}} \left(1 - \frac{1}{N_c}\mathcal{R}\mathrm{Tr}U_{\mathrm{pl}}\right) \\
&+ \frac{\tau}{2}\sum_{j} p_j p_j + \frac{1}{4\tau}\sum_{j,n} \mathrm{Tr}\left(\Phi_{\mathrm{j}} - \mathrm{U}_{\mathrm{j,n}}\Phi_{\mathrm{j+n}}\mathrm{U}^{\dagger}_{\mathrm{j,n}}\right)^2
\end{aligned}
$$

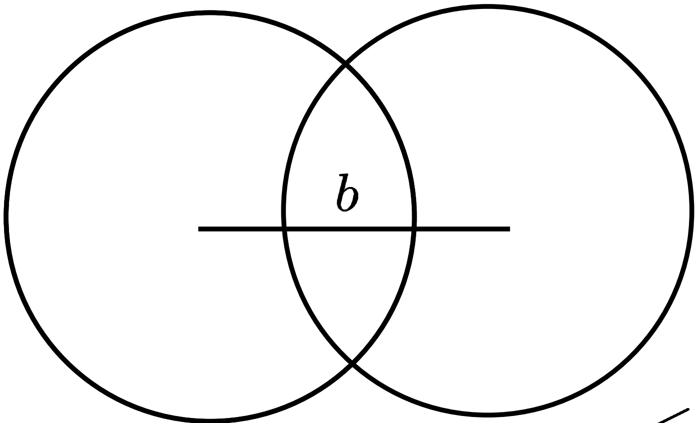
- *Solve numerically Hamilton's eqn. of motion for* $x^{\pm} > 0$

- *Initial conditions determined by matching eqns. of motion along the light cone*

- *Average over the different configurations of static color charges*

- *Impose periodic boundary conditions*

Refining Initial Conditions

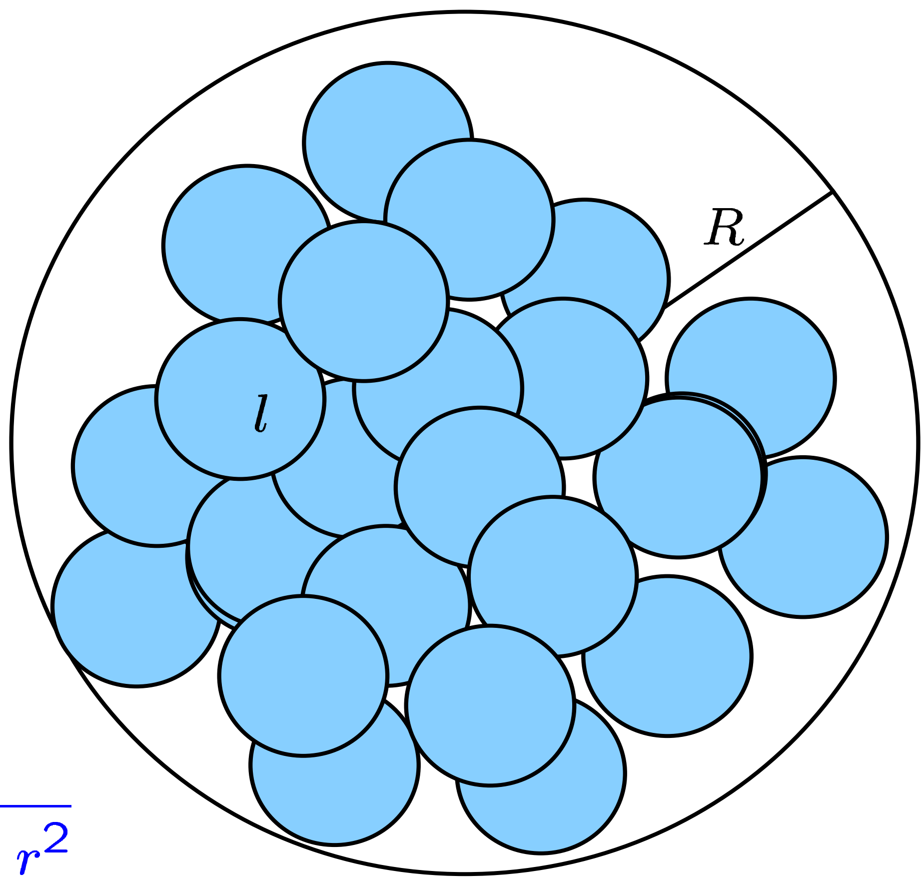


Color Neutrality:

Begin with

$$< \rho^a(\vec{r})\rho^b(\vec{r'}) >= \Lambda_n^2 \delta^{ab} \delta(\vec{r} - \vec{r'})$$

- Remove total color charge and color dipole moment by subtracting uniform distributions



$$\Lambda_s^2(r) = \frac{2}{l}\Lambda_n^2 \sqrt{R^2 - r^2}$$

- Nucleons uniformly distributed within a spherical nucleus

Relation to continuum physics:

Dimensional quantities in the classical lattice theory

- Λ_s
- R
- l *(the color neutrality scale)*
- a *(the lattice cutoff)*

- Ideal hierarchy of scales: $1/a >> \Lambda_s >> 1/l >> 1/R$

  In units of a, in the continuum limit, $\Lambda_s \to 0, R \to \infty$
  but $\Lambda_s R$ is constant

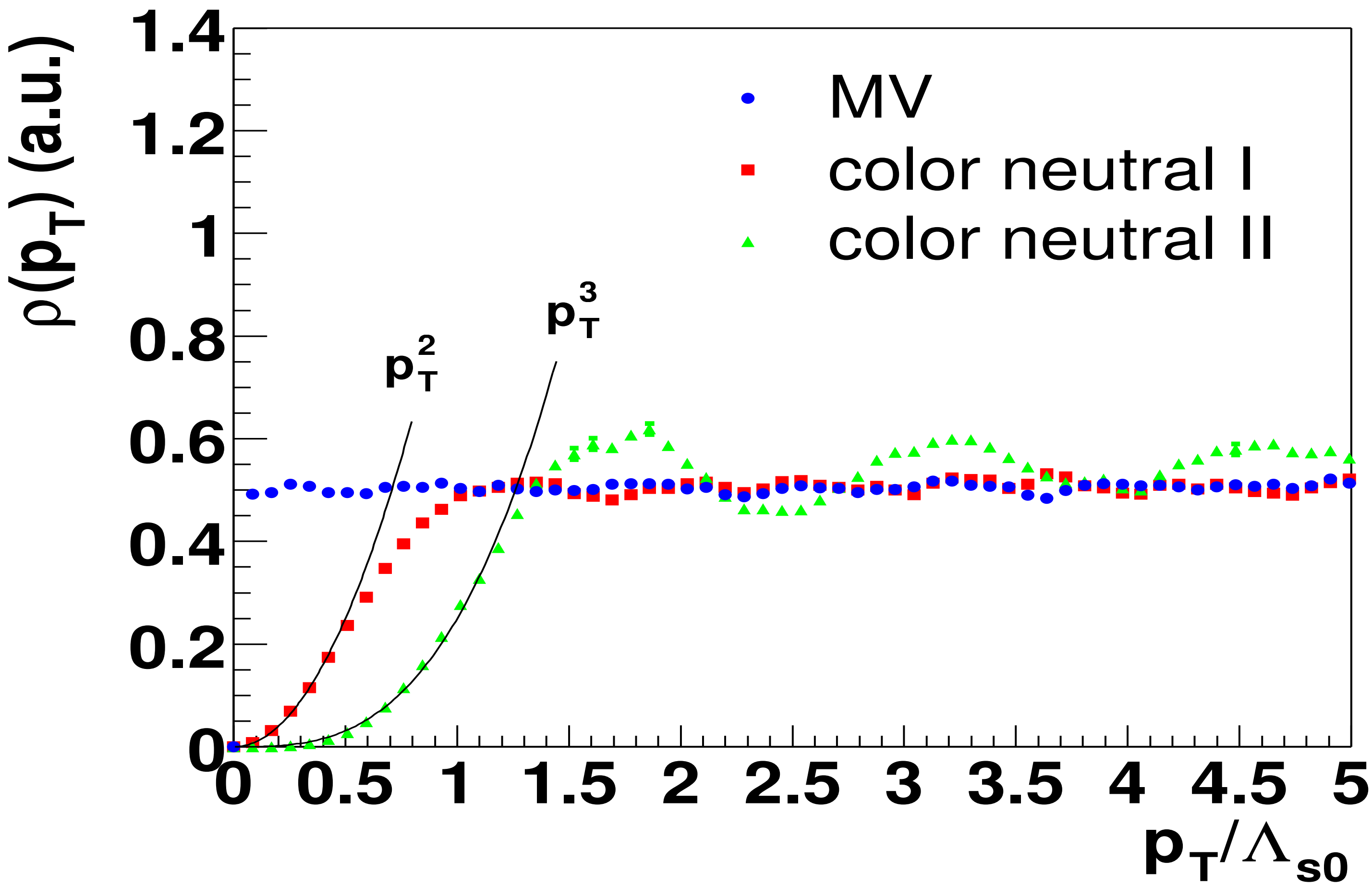
- For any well–defined observable P of dimension d,

$$P = (\Lambda_s)^d f_P(\Lambda_s R)$$

where f_P contains all the non–trivial physical info.

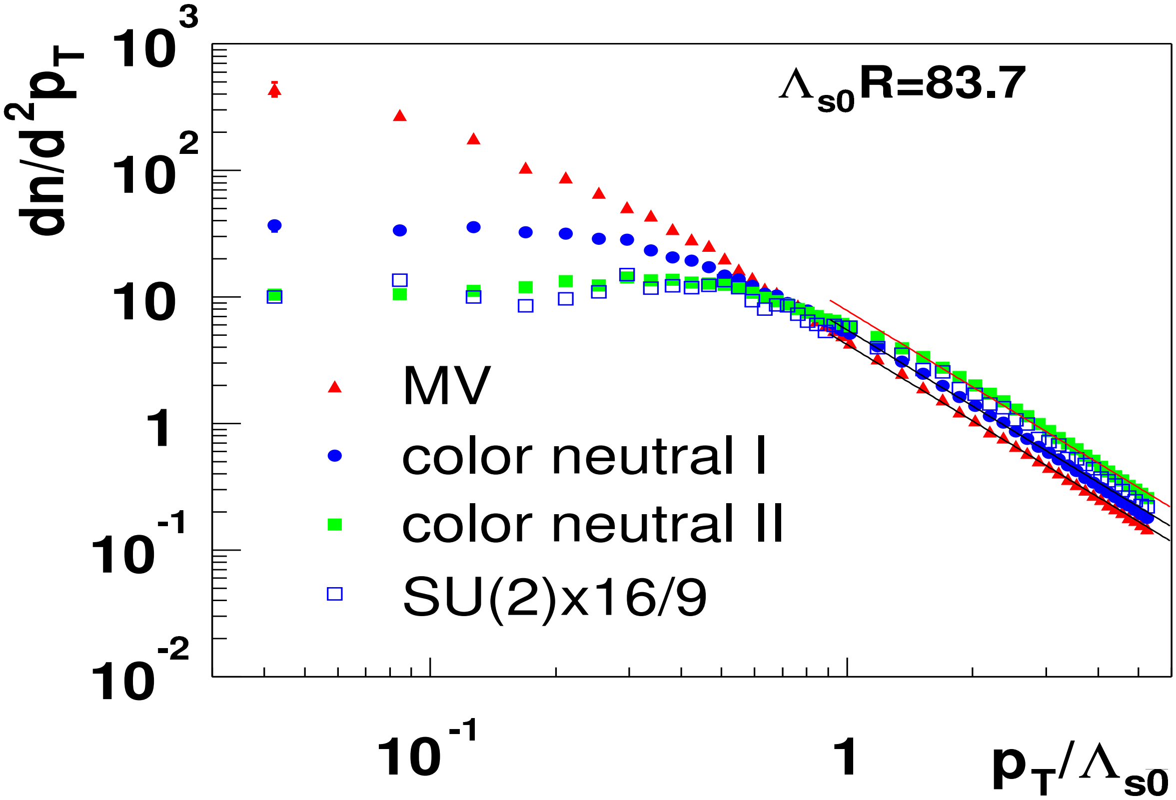
- **RHIC –** $\Lambda_s = 1.4\ GeV$ **LHC –** $\Lambda_s = 2.2\ GeV$

Color Charge Correlations in the Nucleus

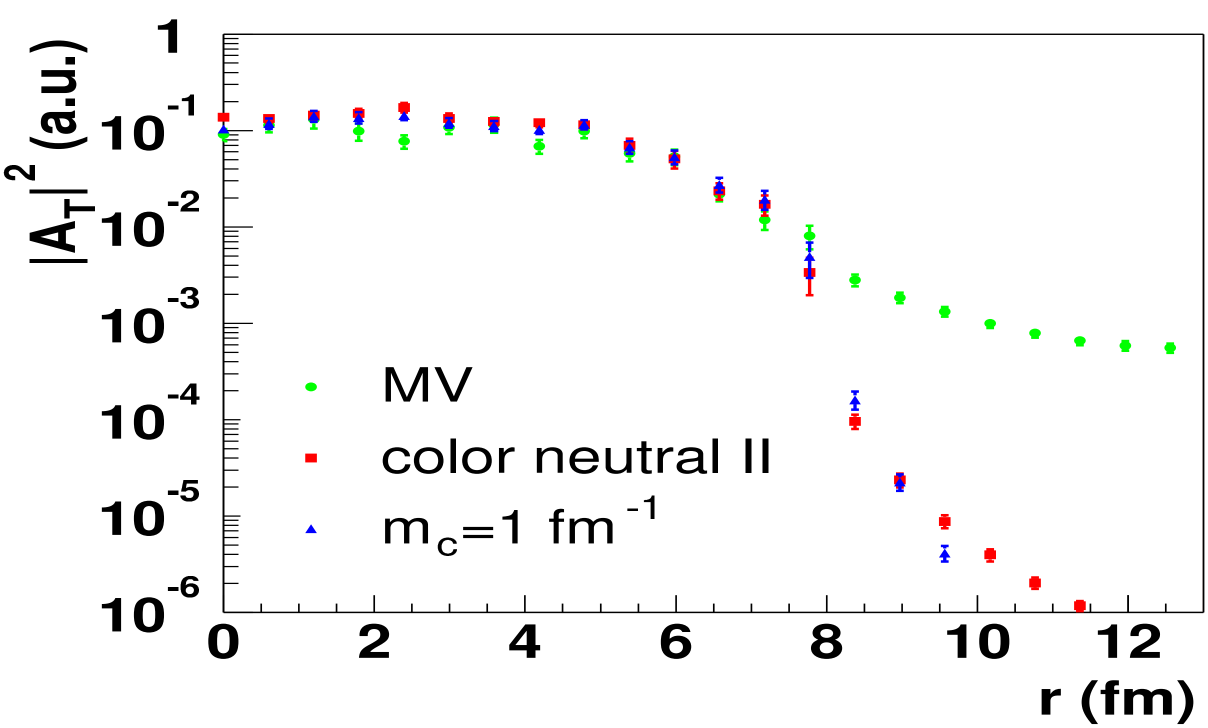


- *Local color neutrality suppresses color charge correlations at low momenta.*

Gluon Distribution for Large Nucleus



- *Local color neutrality gives suppression of the gluon distribution at low momentum*

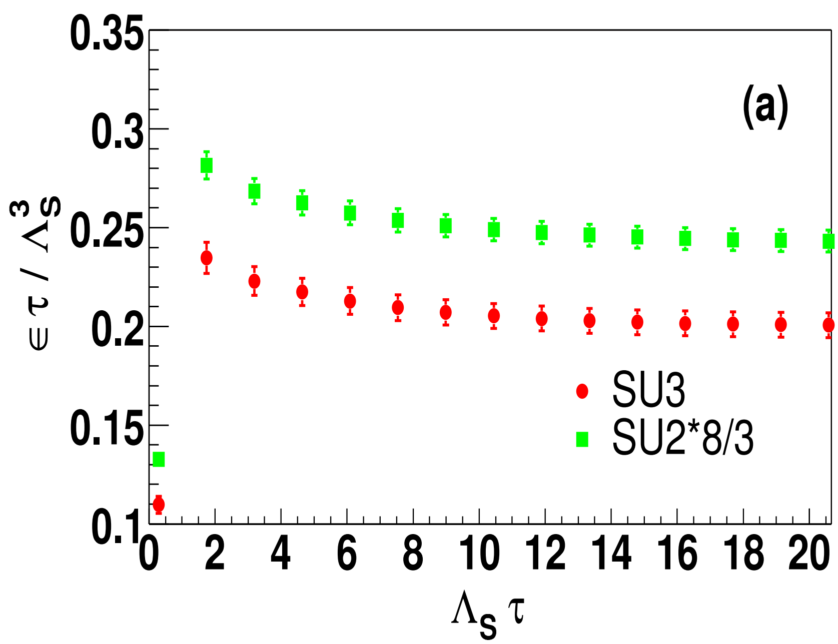


- *Local color neutrality suppresses the spread of gluon field outside the nucleus*

Results

Total energy of gluons

$$\frac{1}{\pi R^2}\frac{dE_\perp}{d\eta}|_{\eta=0} = \frac{f_E(\Lambda_s R)}{g^2}\Lambda_s^3$$



Proper time dependence:

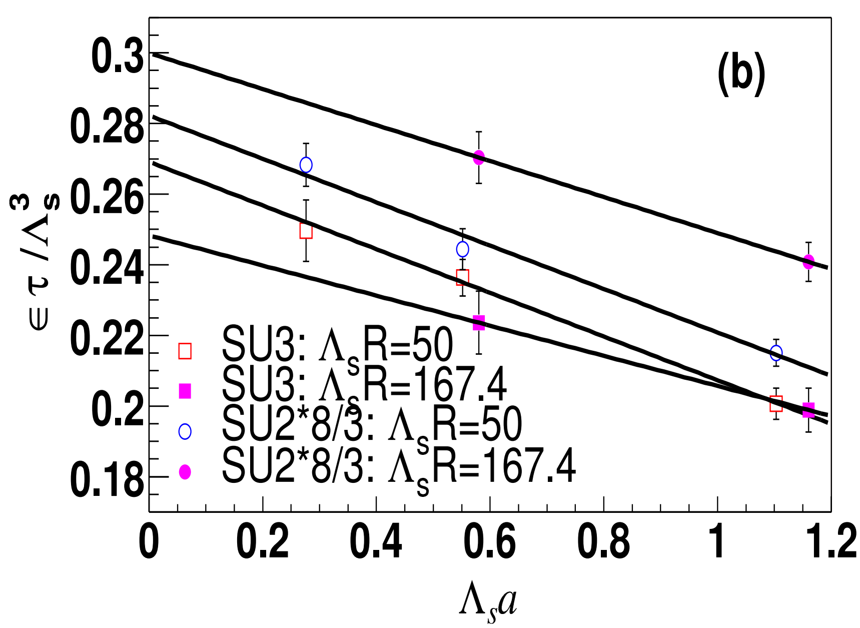
$$\varepsilon\tau = \alpha + \beta\exp(-\gamma\tau)$$

$dE_\perp/d\eta/\pi R^2 = \alpha$ is the energy density and

$$\tau_D = 1/\gamma/\Lambda_s$$

is the "formation time"

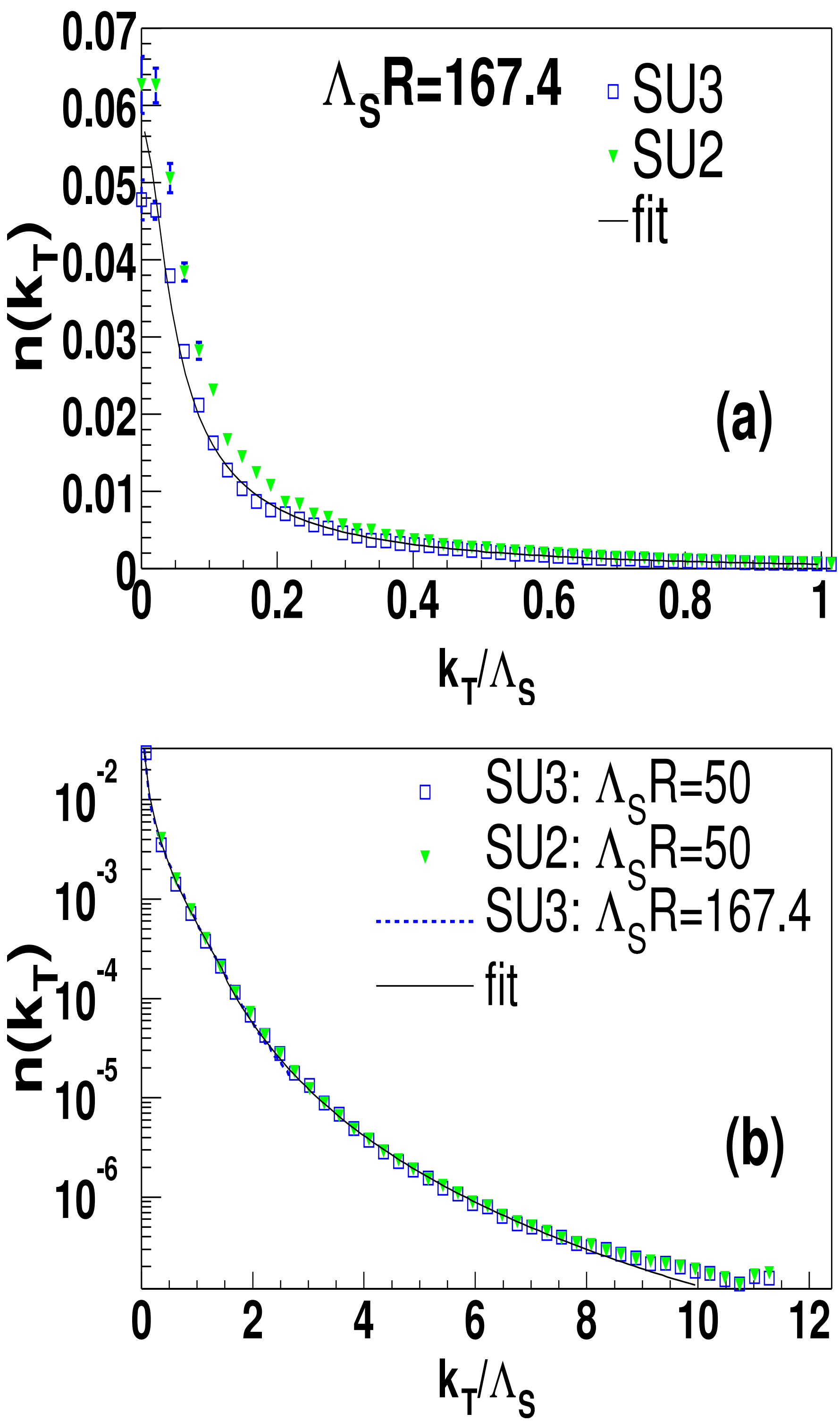
(~0.3 fm for RHIC and ~0.1 fm for LHC)



The energy density at τ_D *is then*

$$\varepsilon = \frac{0.08}{g^2}\Lambda_s^4$$

Transverse momentum distributions of gluons



$$n(k_\perp) = \tilde{f}_N/(N_c^2 - 1)$$

The SU(3) gluon distribution is fitted by the form

$$\frac{1}{\pi R^2}\frac{dN}{d\eta d^2k_\perp} = \frac{\tilde{f}_N}{g^2}$$

where

$$\tilde{f}_N = \frac{a_1}{\exp\left(\frac{\sqrt{k_\perp^2+m^2}}{T_{\rm eff}}\right) - 1}$$

for $k_\perp/\Lambda_s < 1.5$

and

$$\tilde{f}_N = a_2\,\Lambda_s^4\,\ln(4\pi k_\perp/\Lambda_s)\,k_\perp^{-4}$$

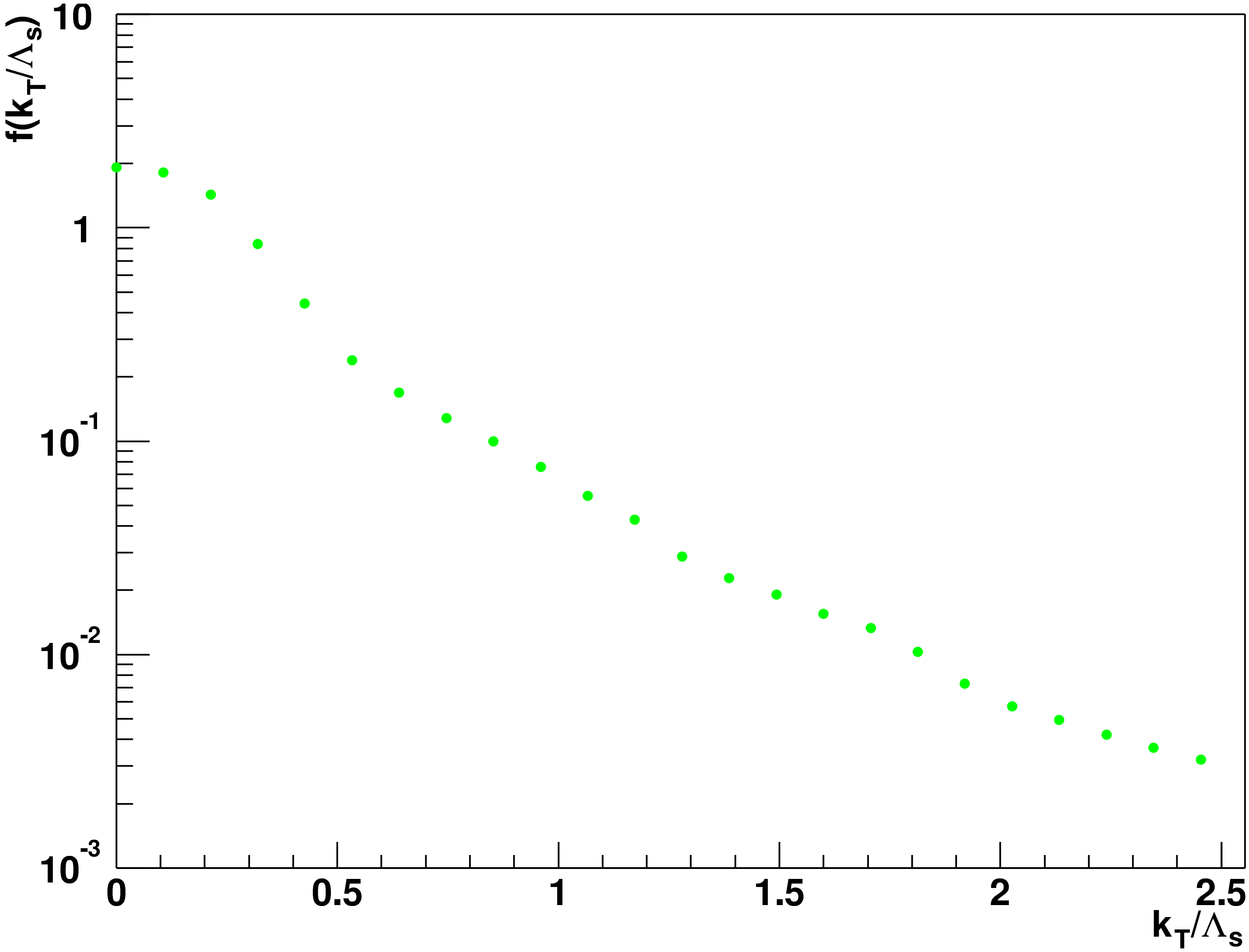
for $k_\perp/\Lambda_s > 1.5$

$$T_{\rm eff} = 0.47\Lambda_s$$

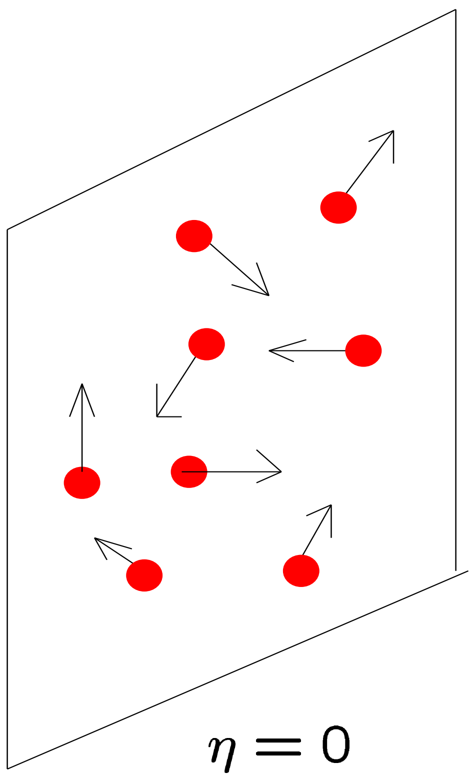
$a_1 = 0.137$; $a_2 = 0.009$; $m = 0.04\Lambda_s$

- *The transverse momentum dist. is infrared finite...*

Occupation # $f = \frac{(2\pi)^3}{2(N_c^2 - 1)} \frac{dN}{d^3x d^3p}$



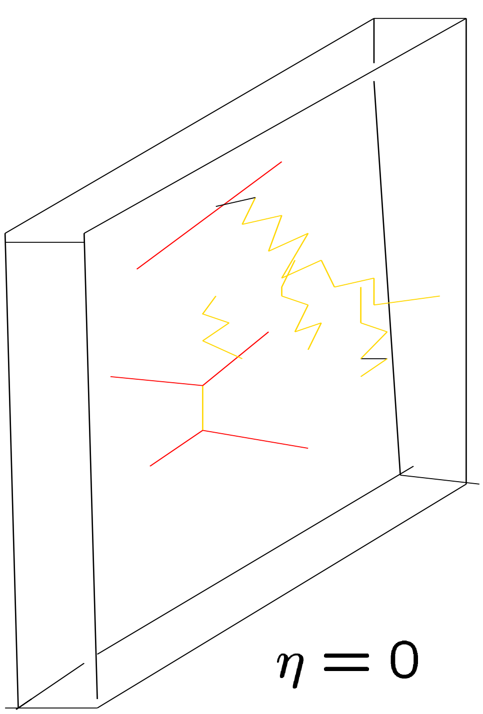
- *The CGC describes only the initial state−produced gluons may re−scatter and thermalize...*



$$\tau \sim 1/\Lambda_s$$

$$p_\perp \sim \Lambda_s$$

$$p_z \sim 0$$

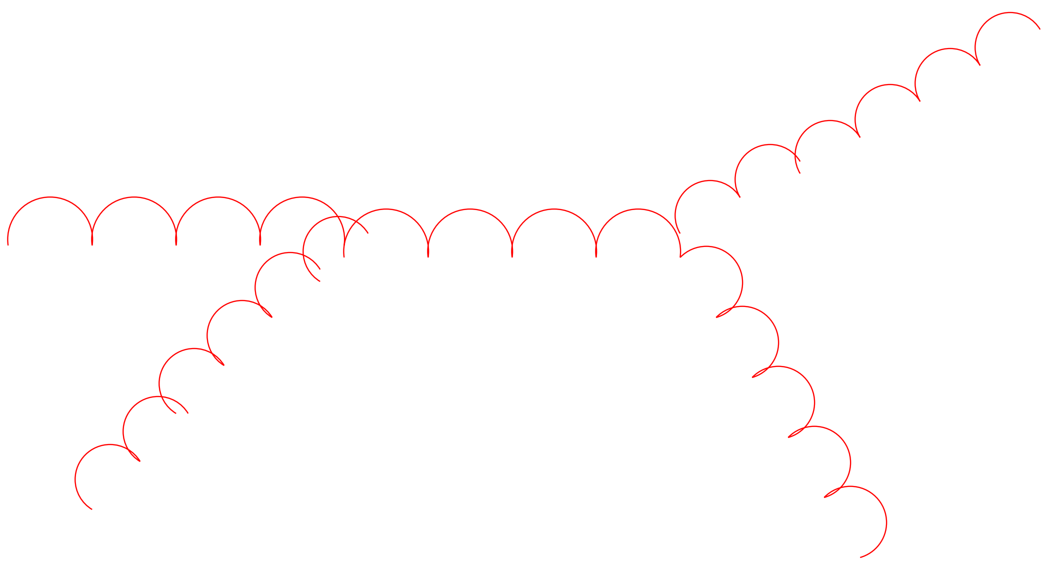


$$1/\Lambda_s << \tau << R$$

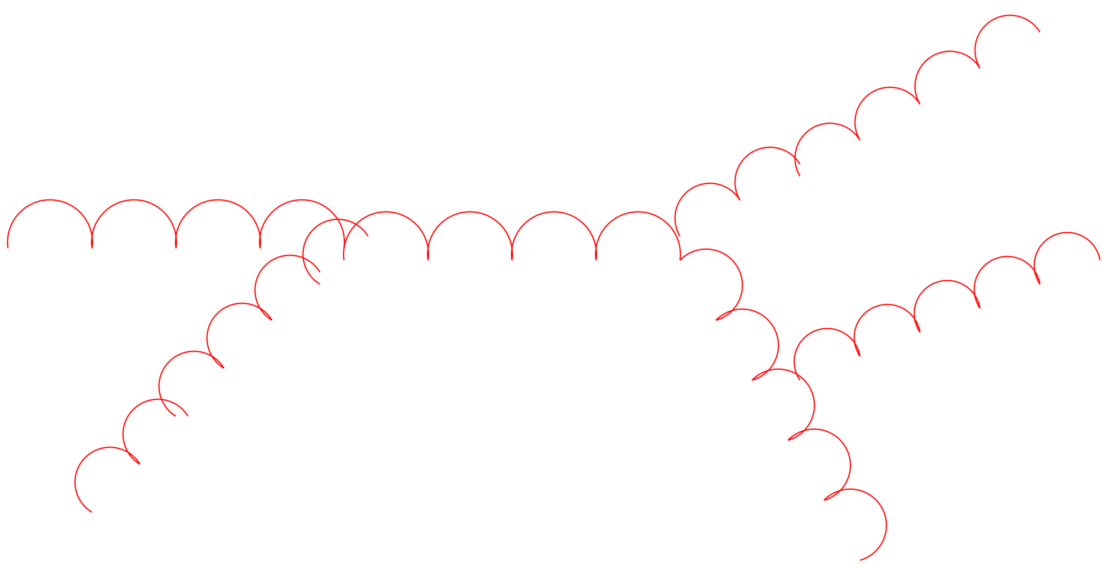
$$p_\perp \sim p_z \sim T$$

A. H. Mueller
Bjoraker , R.V

- *Small angle scattering drives the system only slowly towards equilibrium...*

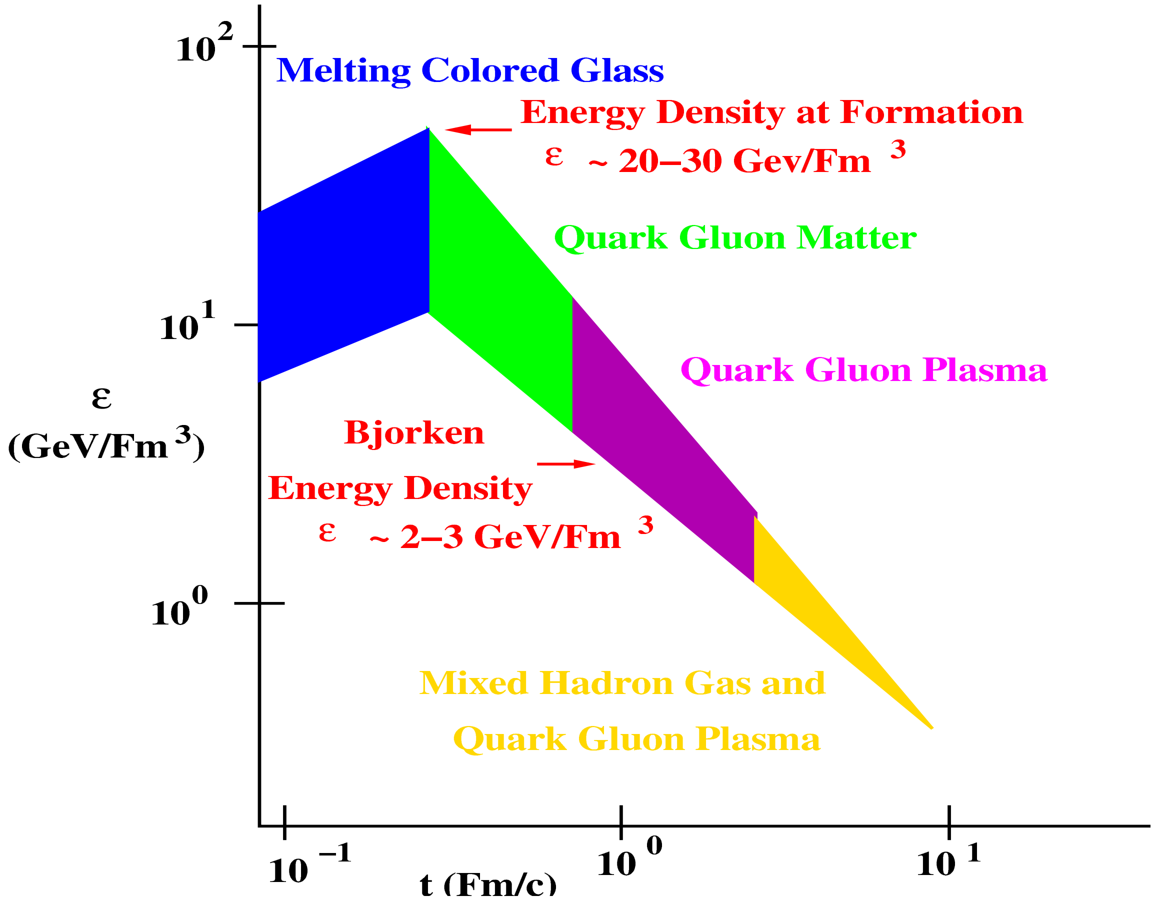


- *2 --> 3 processes may be more efficient...*



Baier, Mueller, Schiff, Son

From Classical fields towards Thermalized QGP...



- Monte–Carlo simulations problematic due to Quantum Mechanical Coherence...

- ‘‘Bottom–Up’’ Thermalization–can follow evolution from classical stage up to thermalization–requires $\alpha_s << 1$

  Baier,Mueller,Schiff,Son

- Two Strategies for Phenomenology:

  a) CGC + Hadronization –‘‘ignore" final state interactions

  b) Ideal Hydro+ Mini–Jets–‘‘ignore" initial state interactions

Tight Constrains on Final State Models from Classical Field results

and RHIC data

$$E_T^{\text{glue}} > E_T^{\text{hadrons}}$$

$$N^{\text{glue}} \leq N^{\text{hadrons}}$$

==> 1.3 GeV < Q_s < 2 GeV at RHIC energies

$$1.14\ \text{GeV} < \frac{E_T}{N}^{\text{glue}} < 1.76\ \text{GeV}$$

$$7.1\ \frac{\text{GeV}}{\text{fm}^3} < \epsilon^{\text{glue}} < 40\ \frac{\text{GeV}}{\text{fm}^3}$$

- E_t ~ 500 GeV ; N ~ 1000 at central rapidities in Au–Au at RHIC

- Golec–Biernat–Wusthoff Parametrization of HERA data extrapolated to RHIC gives Q_s ~ 1.4 GeV

RHIC Phenomenology: Current Status

- ## The CGC Scenario:

Kharzeev,Levin,Nardi

A) CGC + Parton−Hadron Duality :

- Explains Global Features−Energy, Rapidity, Centrality Dependence

  (also, see BMSS)

- Right p_T dependence at moderate p_T (~2−9 GeV)

  (via Geometrical Scaling)

  Kharzeev,McLerran,Levin

- Problems: v_2 !

  Krasnitz,Nara,Venugopalan

  −− Possible way out−''Non−Flow Correlations''

  Kovchegov, Tuchin

B) CGC + Hydro:

Baier,Mueller,Schiff,Son

−−Combines nice features of both approaches−phenomenology needs further study

Rapidity distribution of charged hadrons

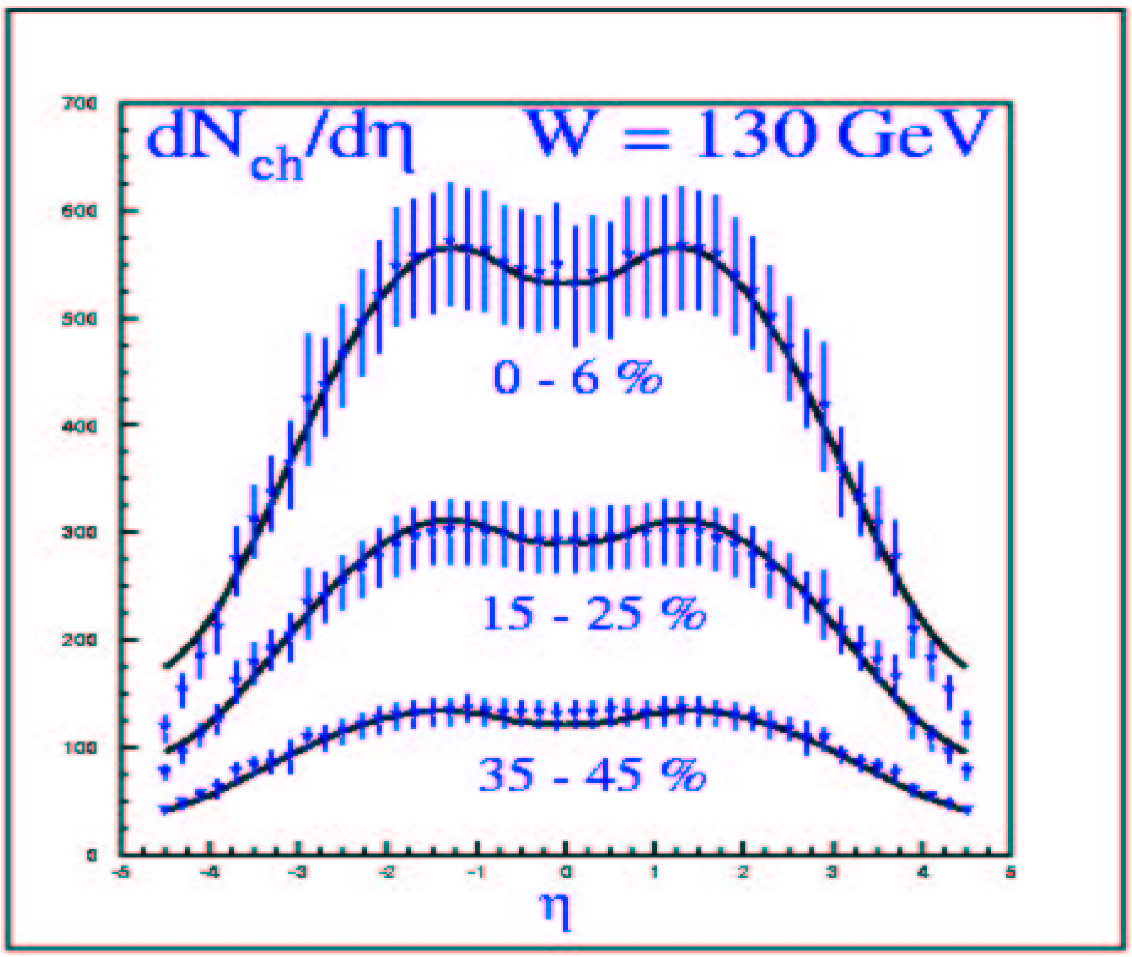
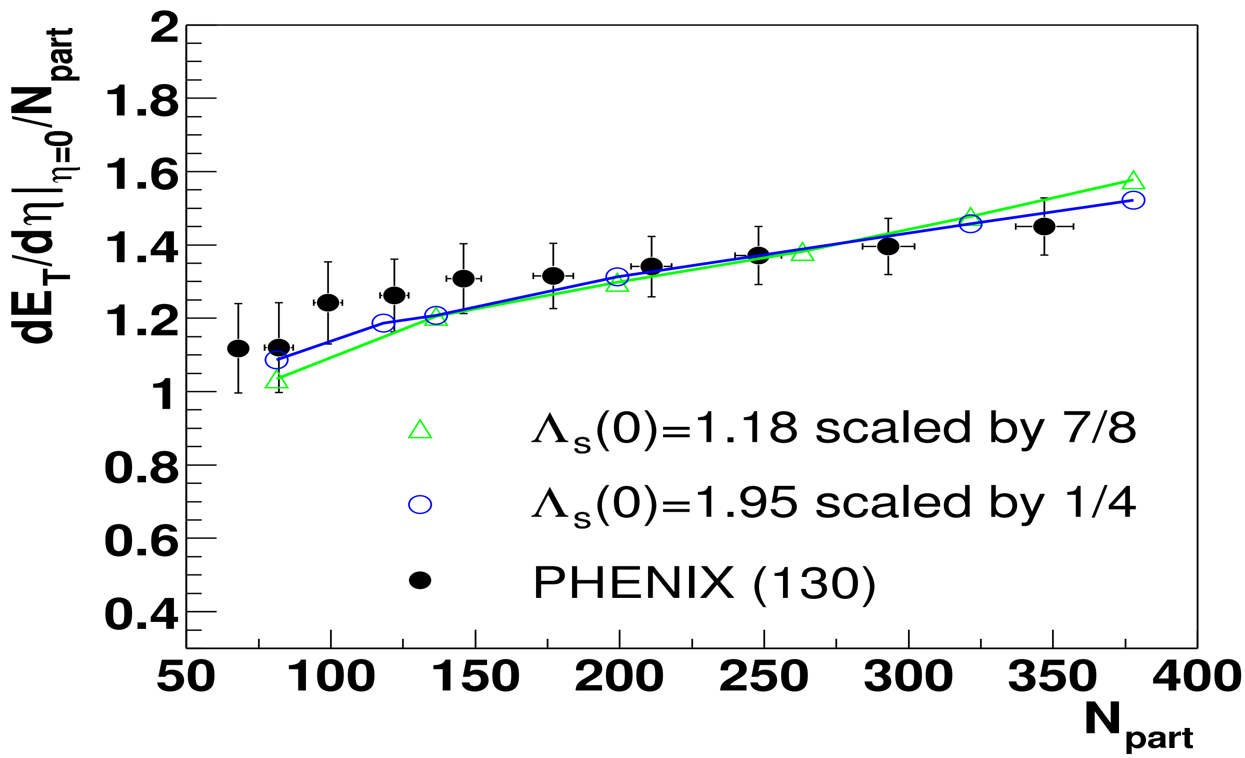


Figure 4: Pseudo–rapidity dependence of charged hadron production at different cuts on centrality in $Au - Au$ collisions at $\sqrt{s} = 130$ GeV; the data are from [25].

Krasnitz, Nara, R.V

Centrality dependence of $\eta = 0$ charged hadron data



- *Previously for $dN/d\eta$ by Kharzeev and Nardi*

Centrality dependence for different η

Kharzeev, Levin

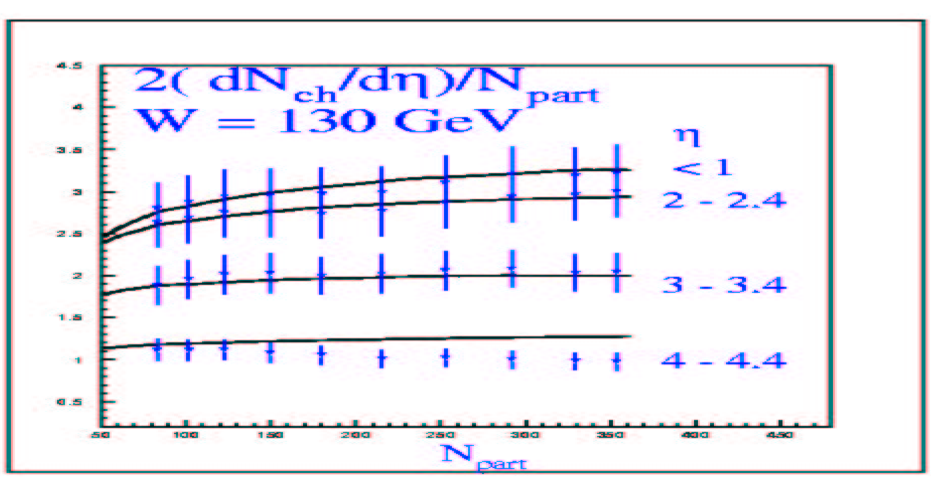
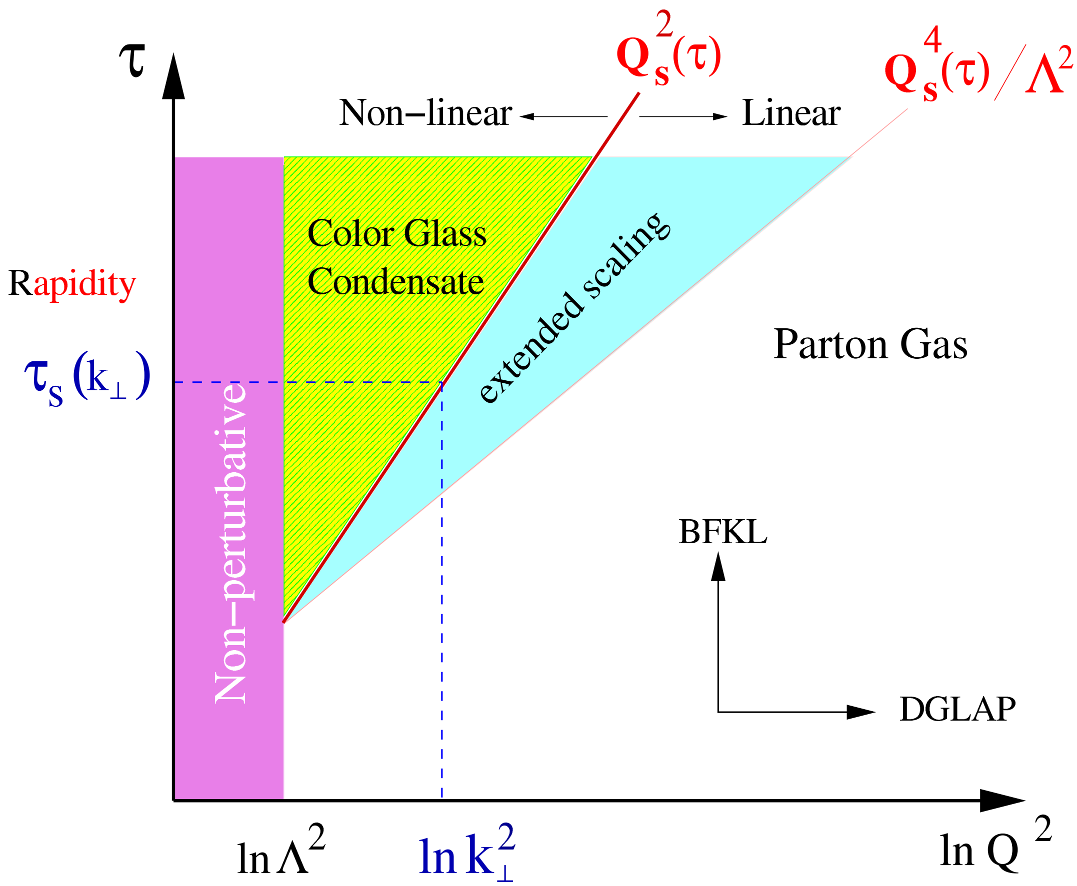


Figure 3: Centrality dependence of charged hadron production per participant at different pseudorapidity η intervals in $Au - Au$ collisions at $\sqrt{s} = 130$ GeV; the data are from [25].

9

Iancu, Itakura, McLerran
Mueller, Triantafyllopolous

Phase Diagram of Hadron Wavefunction



- ‘‘Color Glass Condensate" => Low p_t physics at RHIC

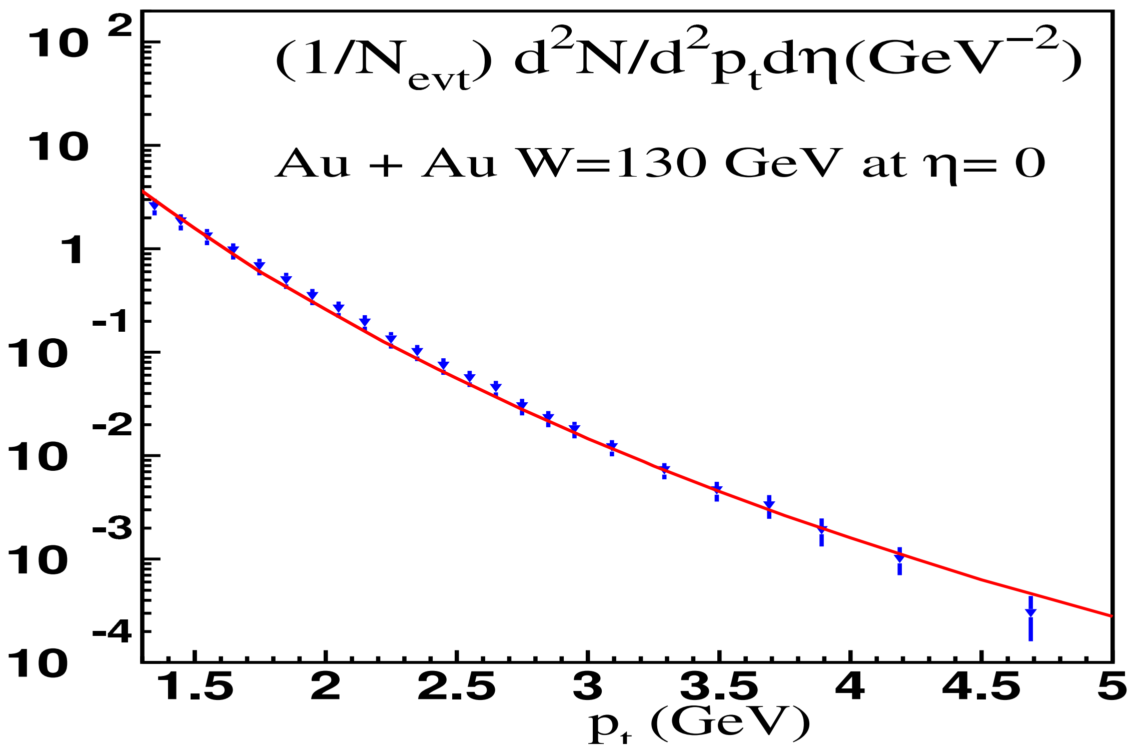
- ‘‘Extended Scaling" => Moderate p_t : $Q_s^2 << p_T << \frac{Q_s^2}{\Lambda_{QCD}^2}$

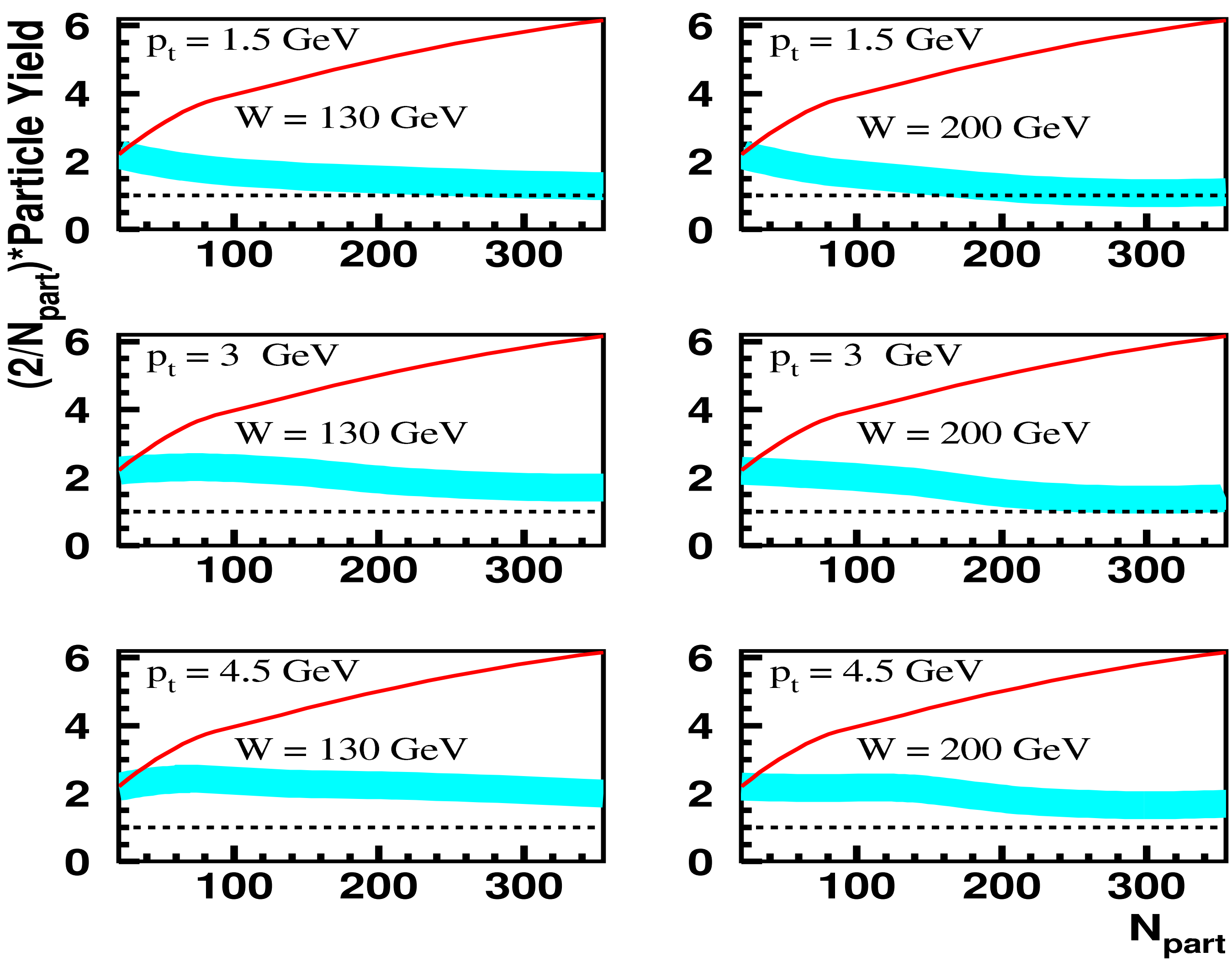
  (Kharzeev, Levin, McLerran)

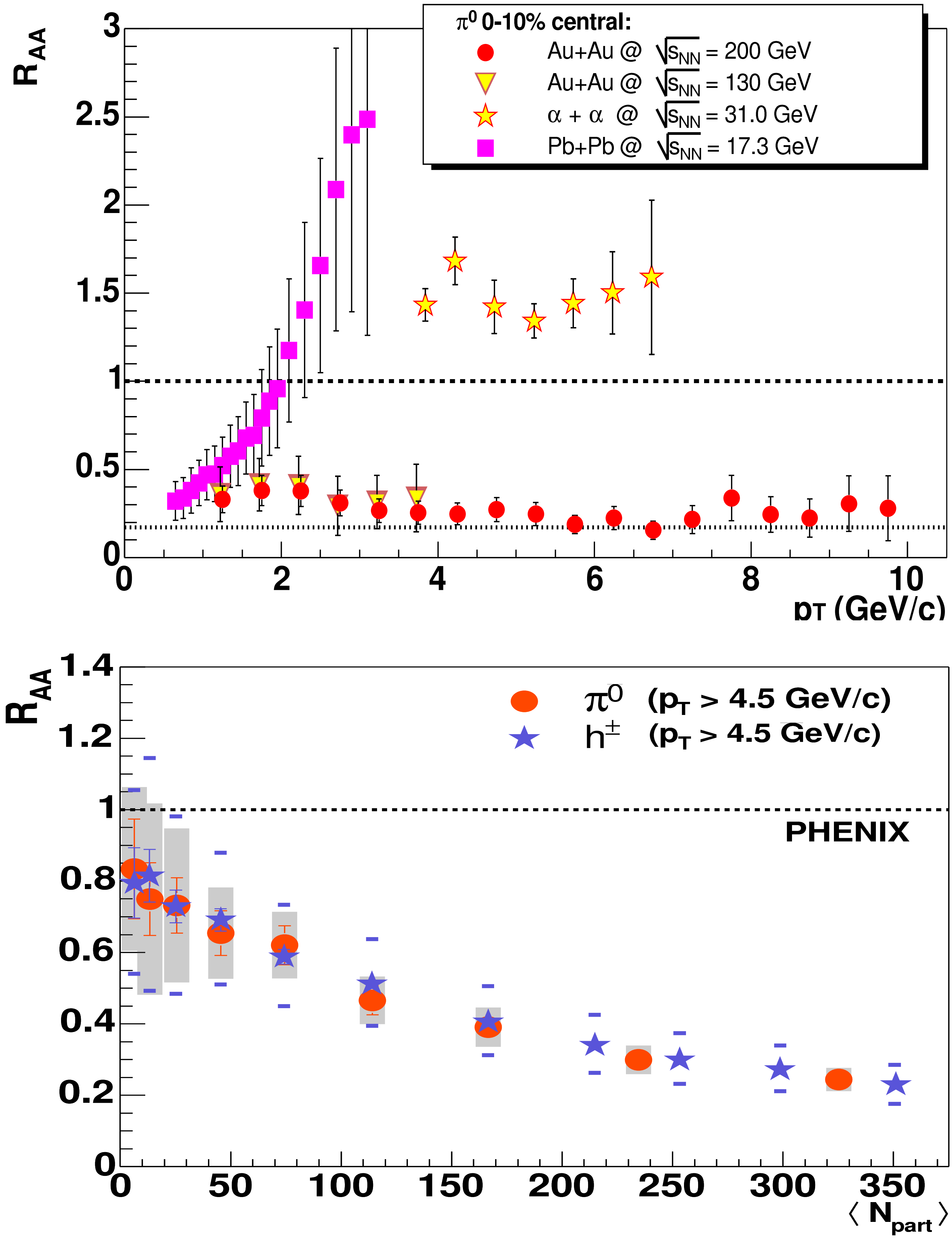
- ‘‘ Parton Gas" => Usual pert. QCD physics

Geometrical Scaling in Nuclear Collisions?

Kharzeev,Levin,McLerran

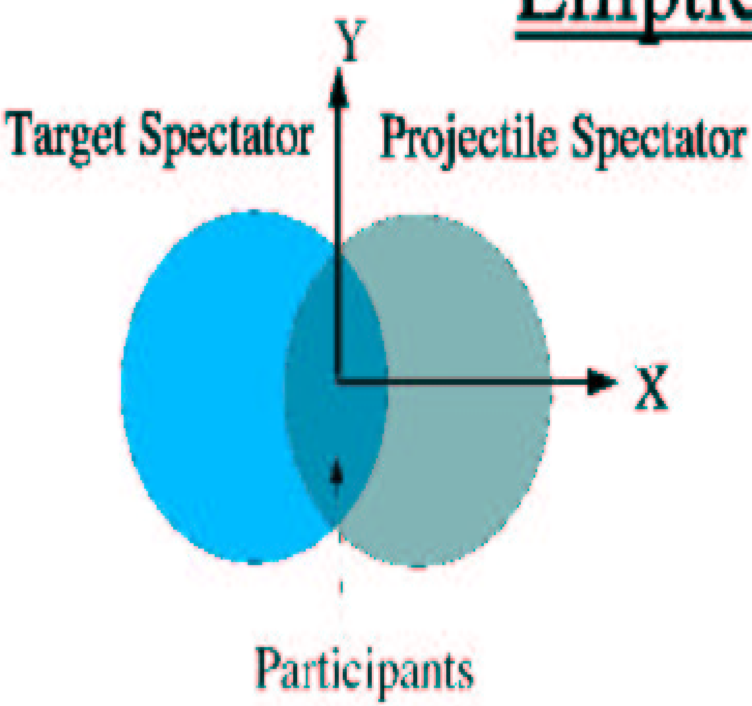




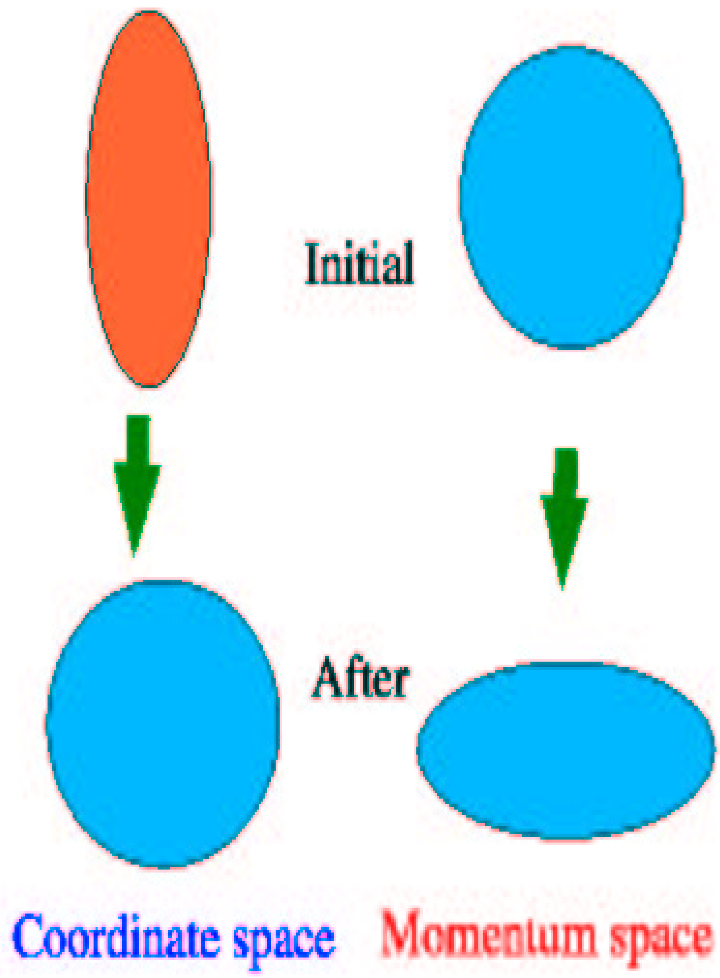


R_{AA}
π⁰ 0-10% central:
Au+Au @ √s_NN = 200 GeV
Au+Au @ √s_NN = 130 GeV
α + α @ √s_NN = 31.0 GeV
Pb+Pb @ √s_NN = 17.3 GeV
pT (GeV/c)
R_{AA}
π⁰ (p_T > 4.5 GeV/c)
h± (p_T > 4.5 GeV/c)
PHENIX
⟨ N_part ⟩

Elliptic flow

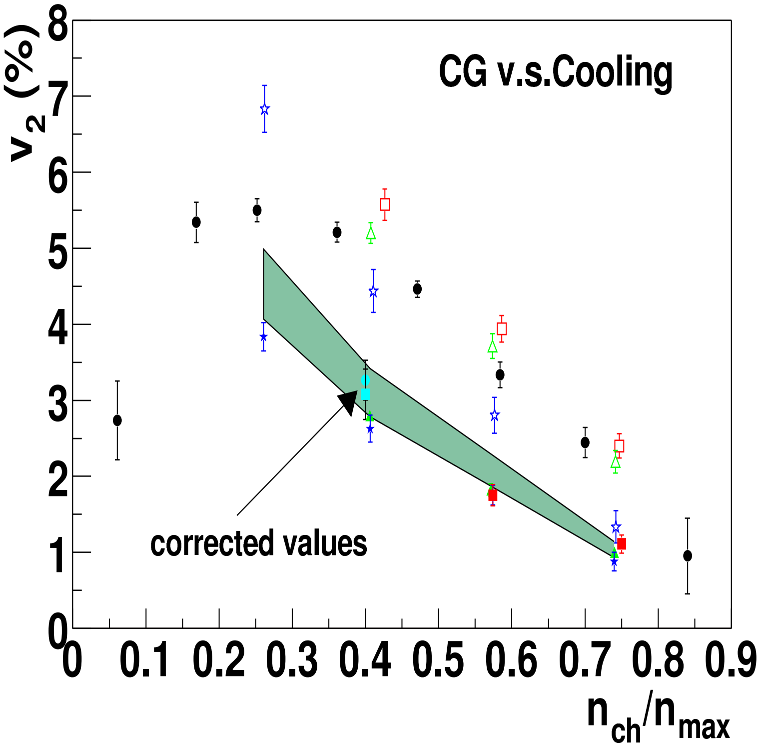


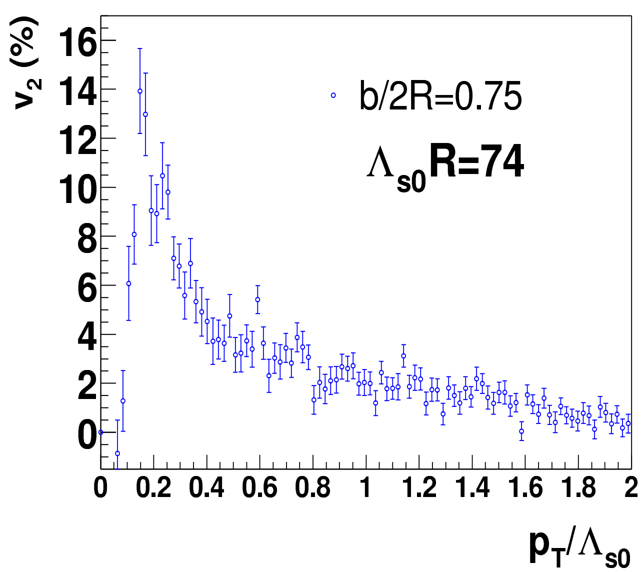
$$v_2 \equiv \langle \cos(2\phi) \rangle = \left\langle \frac{p_x^2 - p_y^2}{p_x^2 + p_y^2} \right\rangle$$



Idea : Interaction ⇨ convert space anisotropy to momentum anisotropy

The azimuthally anisotropic flow of Colored Glass

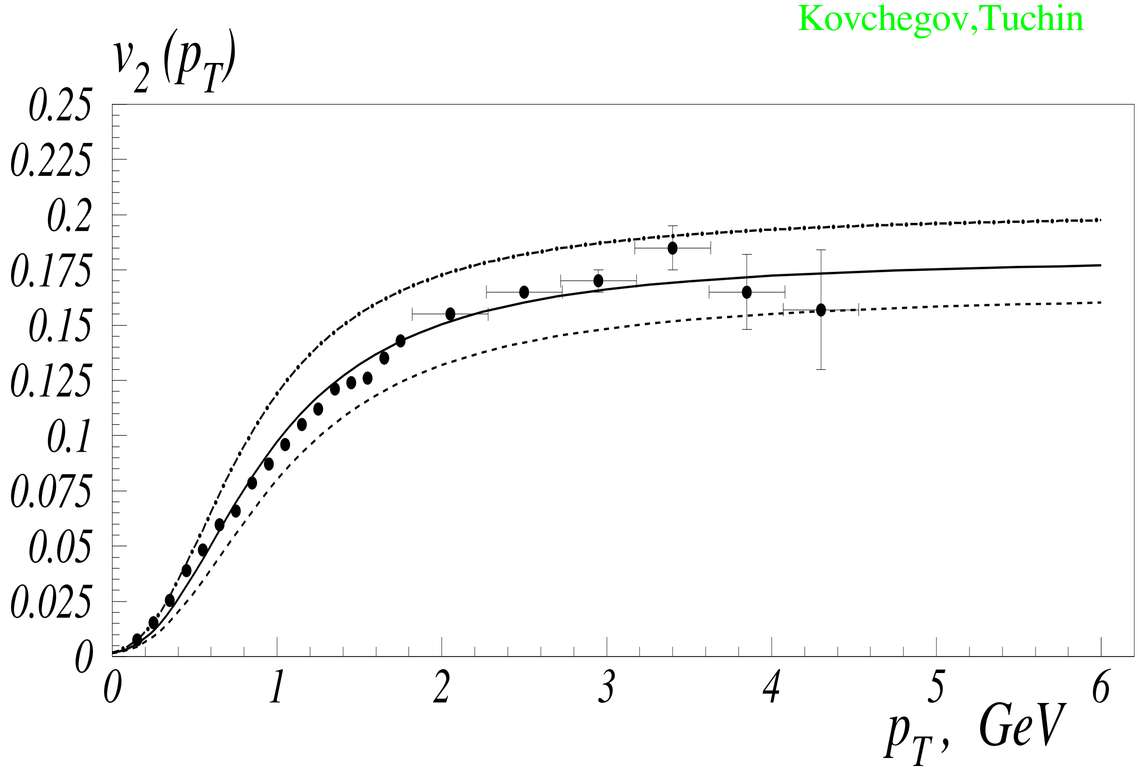




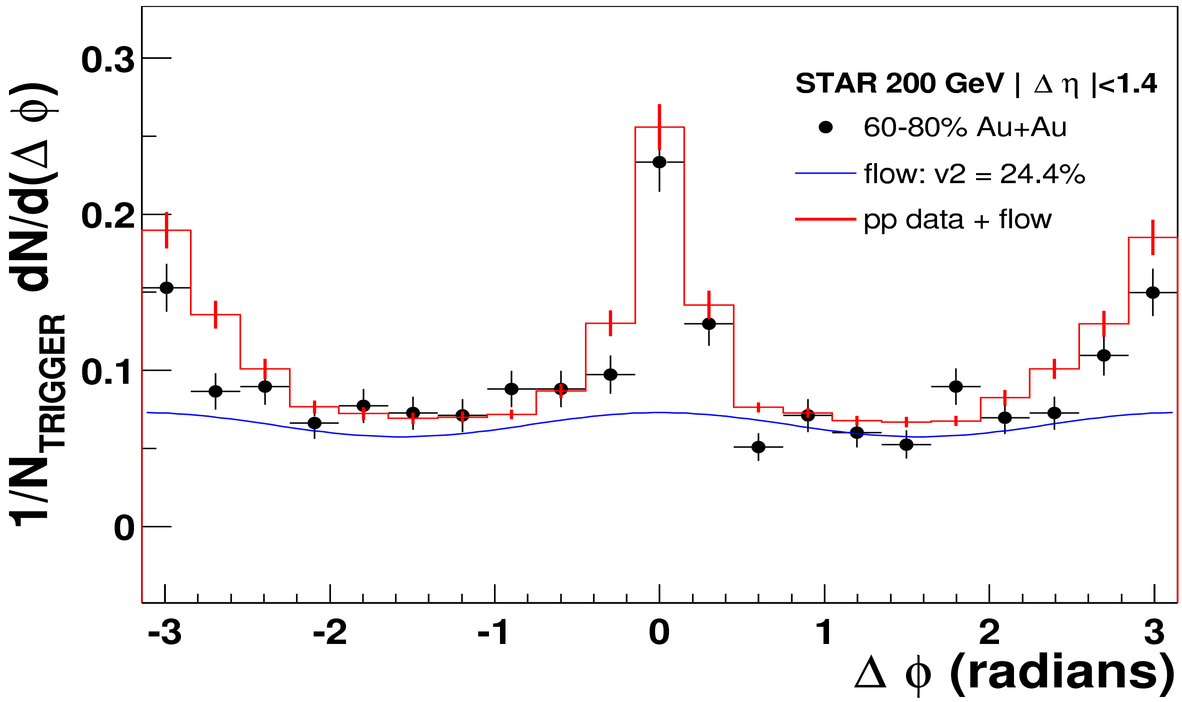
Krasnitz,Nara,Venugopalan

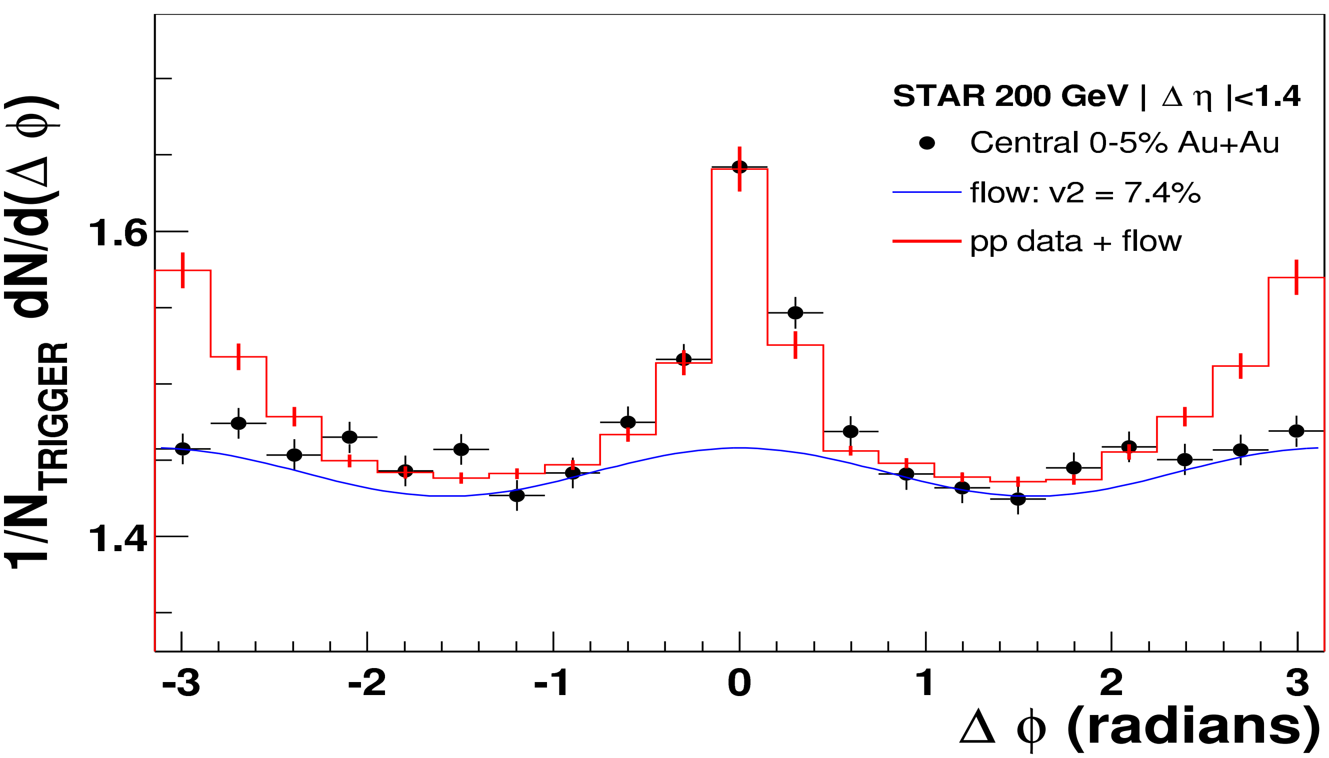
Non−flow Correlations?

Kovchegov,Tuchin



Azimuthal Correlations





- *Peripheral vs Central Correlations*
  - –expected in both CGC and jet quenching models

The Ideal Hydro + Energy Loss scenario

(A QGP scenario)

Braun−Munzinger,Stachel,Redlich,Xu,...

- Does very well with low p_t spectra/particle ratios

Teaney,Shuryak,Kolb<Houvinen,...

- Excellent description of v_2 for charged hadrons/flavor

  (requires very early thermalization times of 0.6 fm...)

- HB−T (Hanbury−Brown, Twiss) poses a puzzle−
  short−lived, opaque source?

Gyulassy,Vitev,Wang,Levai,...

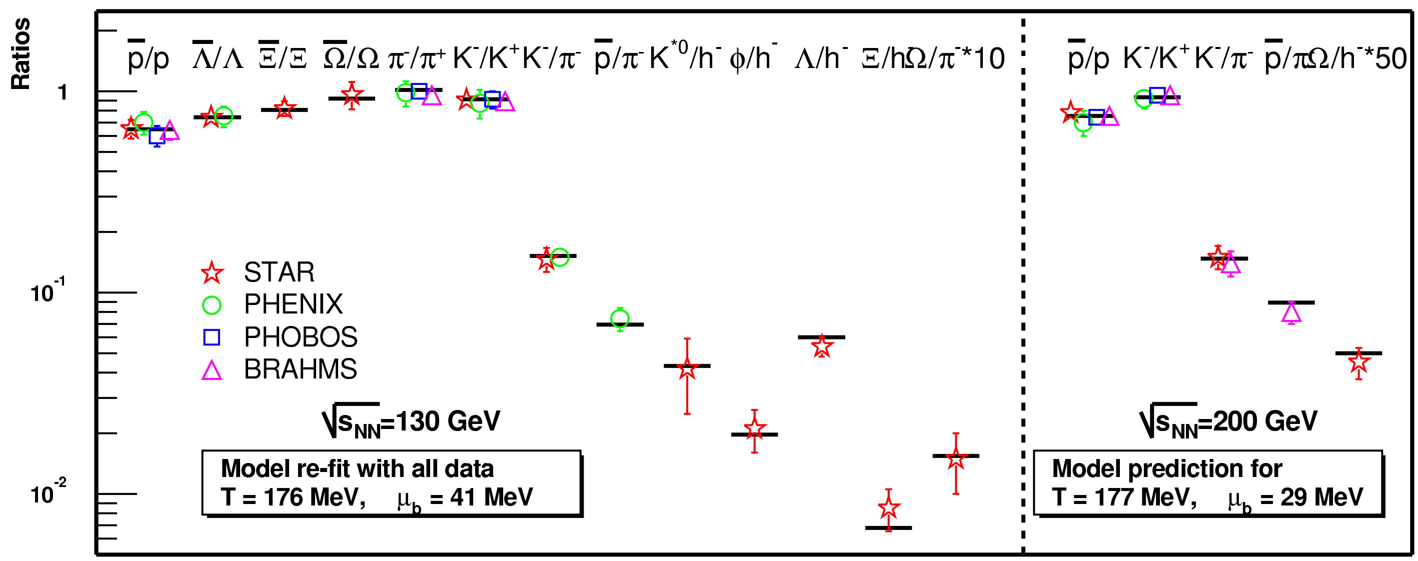
- Energy loss explains suppression of spectra
  p_t *qualitatively* −needs to be understood
  quantitatively.

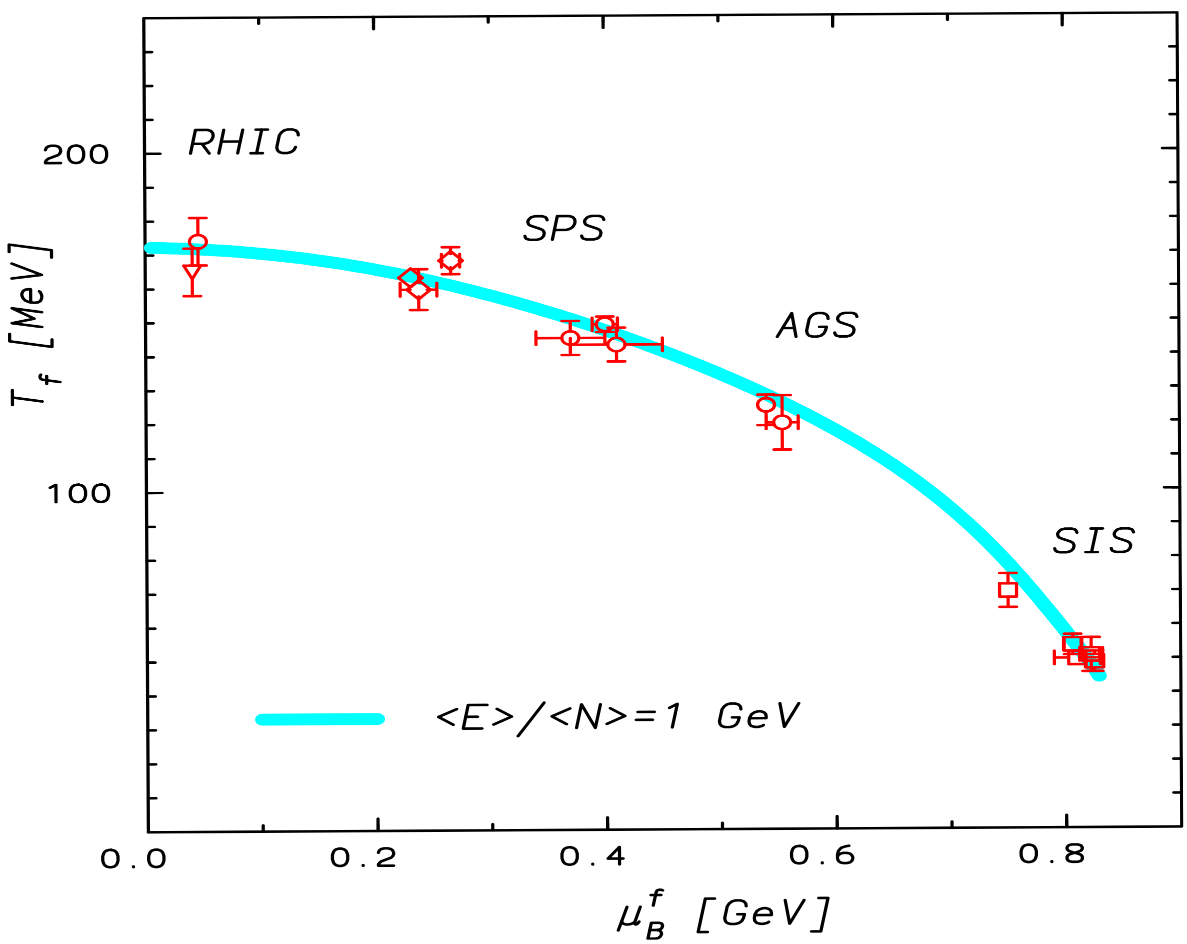
Fries et al., Molnar−Voloshin, Lin−Ko

- Independent fragmentation fails for baryons−recent
  work on fragmentation models...

Particle Ratios

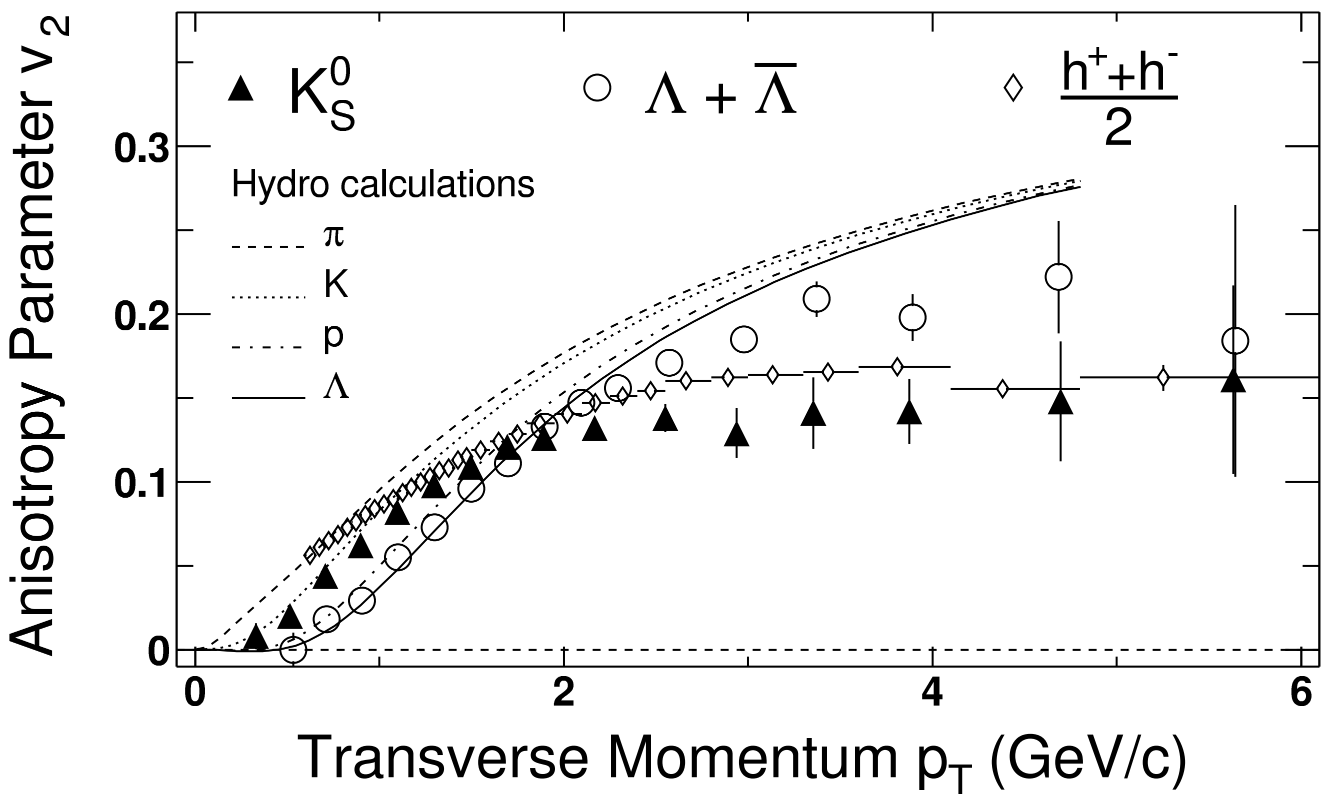
Braun–Munzinger, Redlich, Stachel





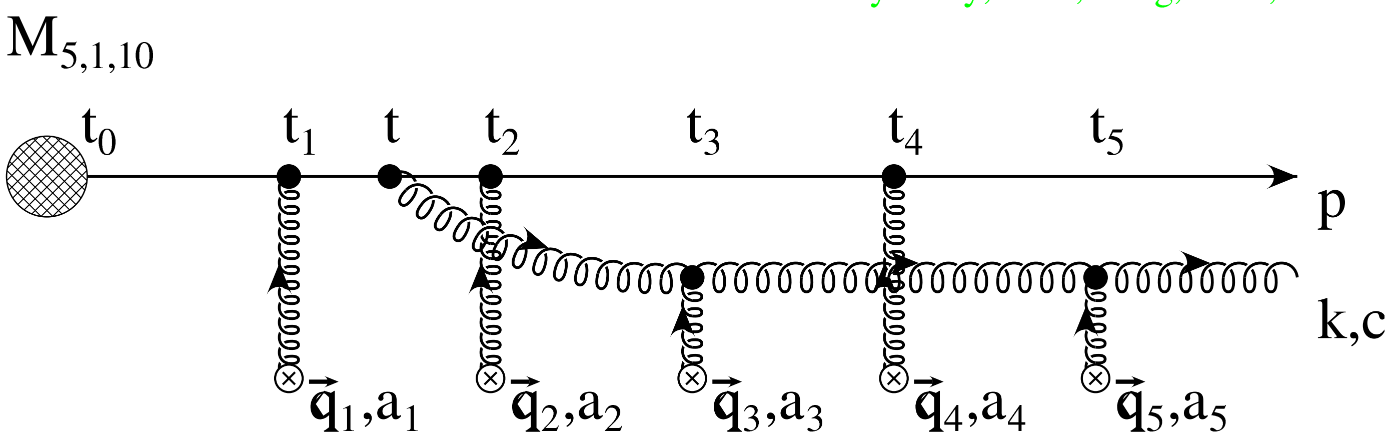
- Also works for pp and e^+ e^– collisions...

Collective behavior of v_2

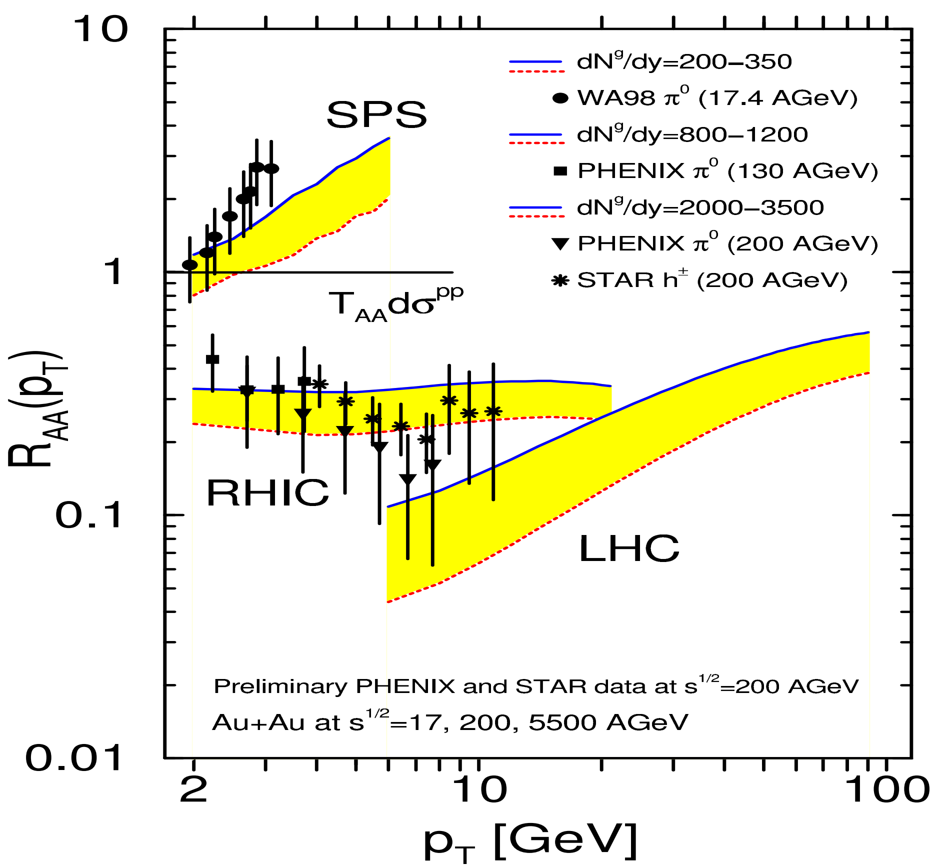


Final State Effects–Jet Quenching

Gyulassy,Vitev,Wang,Levai,...



- *Energy loss of Partons in hot matter responsible for suppression of particle spectrum?*



Open Conceptual Issues

In All Approaches!

D−Au Collisions

Kharzeev,Levin,McLerran

- *Quenching persists in KLN version of CGC*

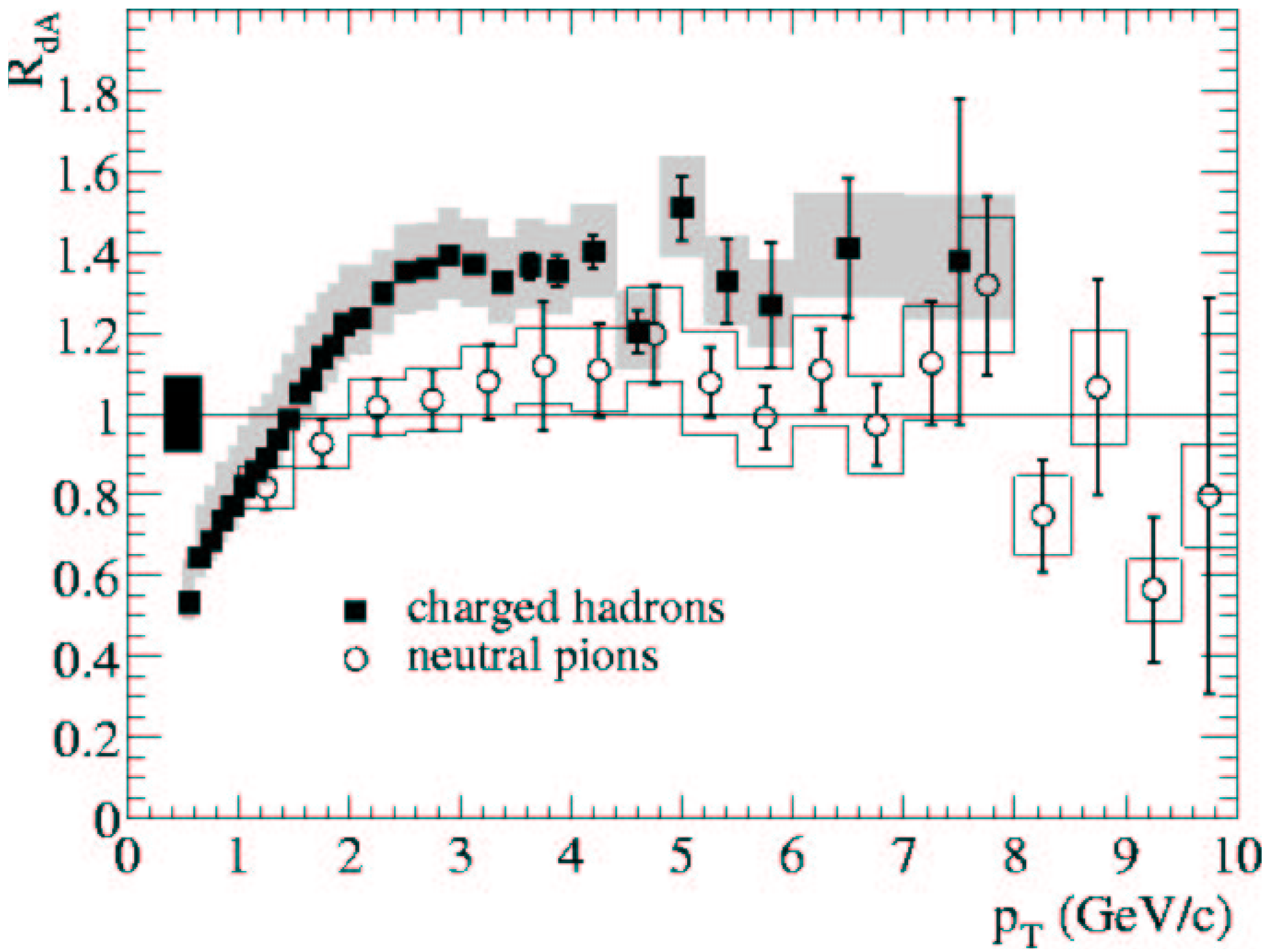
  −25−30% for most central collisions.

  (caveat: see work of Dumitru,Gelis,Jalilian−Marian)

Gyulassy,Vitev,Wang,...

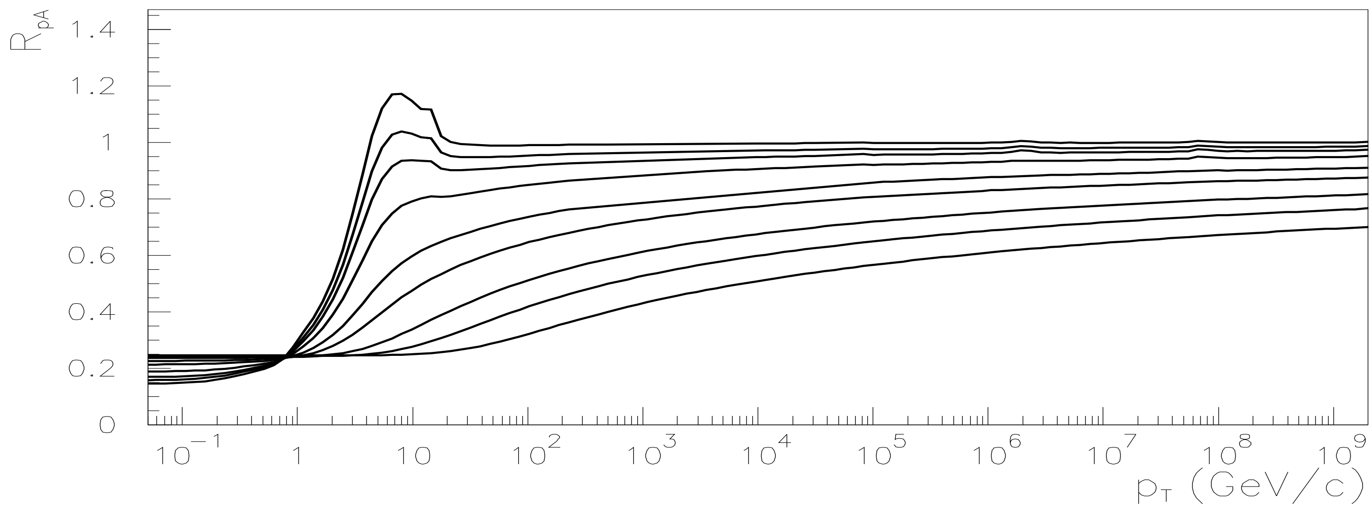
- *Cronin enhancement of lower energies persists in QGP+Energy Loss models.*

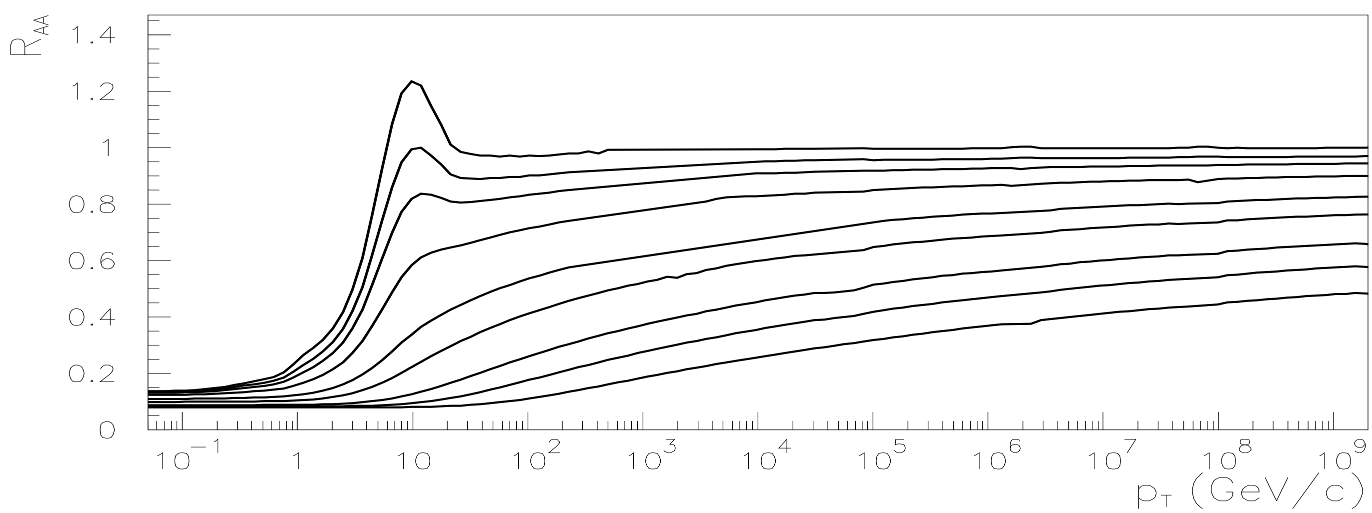
Recent Deuteron−Gold results from RHIC



- Very interesting recent results from BRAHMS at forward rapidities!! −−stay tuned...

Albacete,Armesto,Kovner,Salgado,Wiedemann





- *Non−linear Balitsky−Kovchegov evolution leads to rapid depletion of Cronin excess at forward rapidites...*

- *Very preliminary data from* **BRAHMS** *suggests that this depletion is seen...*

Recent D–Au results from RHIC suggest the following possible interpretation...

- Small x quantum evolution is not significant at y=0 (x ~ 10^{-2}). Classical simulations a la KNV phenomenological hydro models & high p_t suppression suggest strong partonic re–scattering essential to understand Au–Au results.

- CGC Quantum evolution may already be significant at y=3 (x ~ 10^{-3}) in Au nuclei. Azimuthal correlations in D–Au at y=3 may be decisive.

- LHC results may be qualitatively different from RHIC (LHC y~0 => x ~ 10^{-3})

Outlook:

- Data from RHIC and theoretical developments are evolving towards a rich and unexpected picture picture of heavy ion collisions...

- Look forward to exciting new results at this conference...