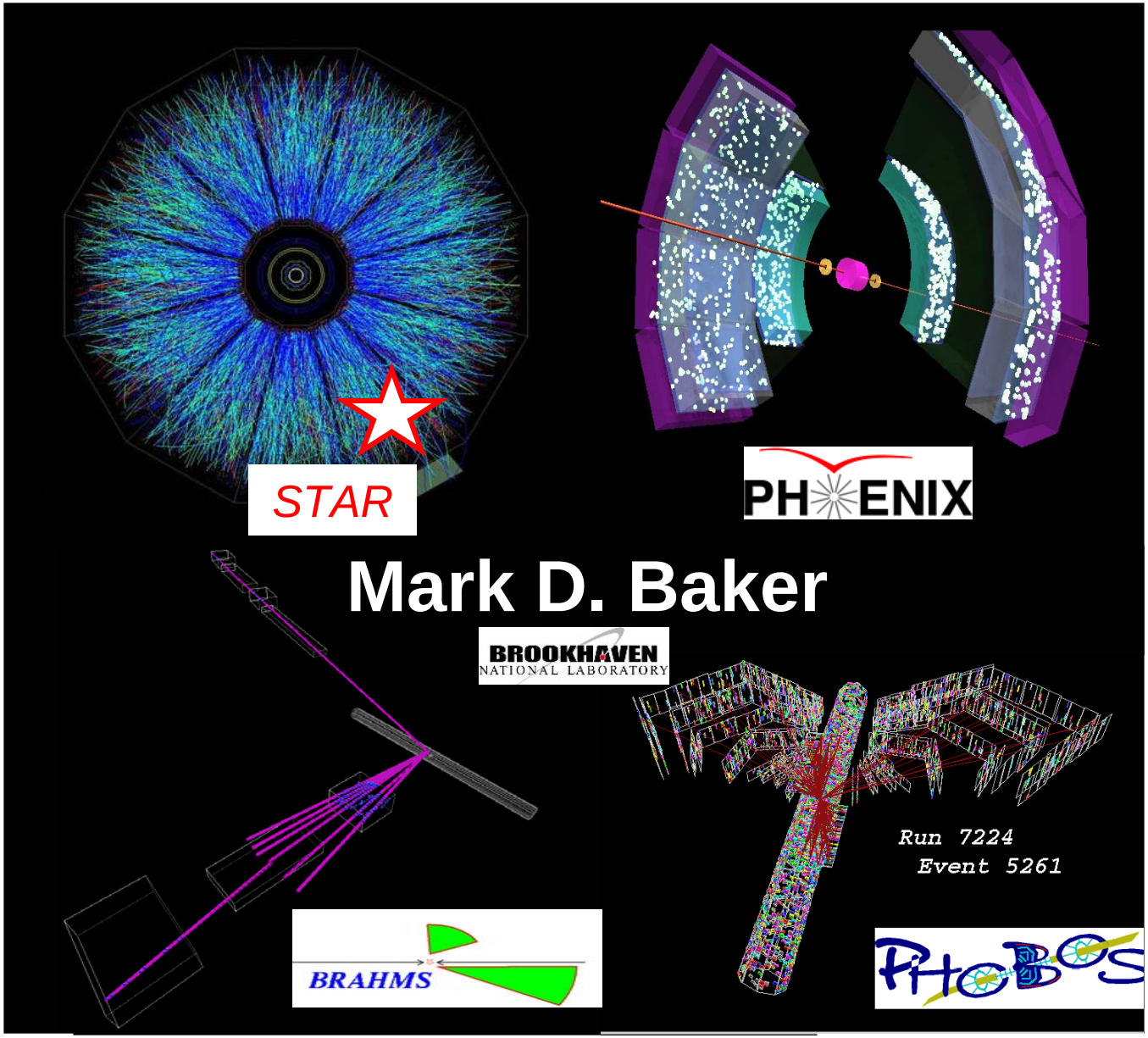
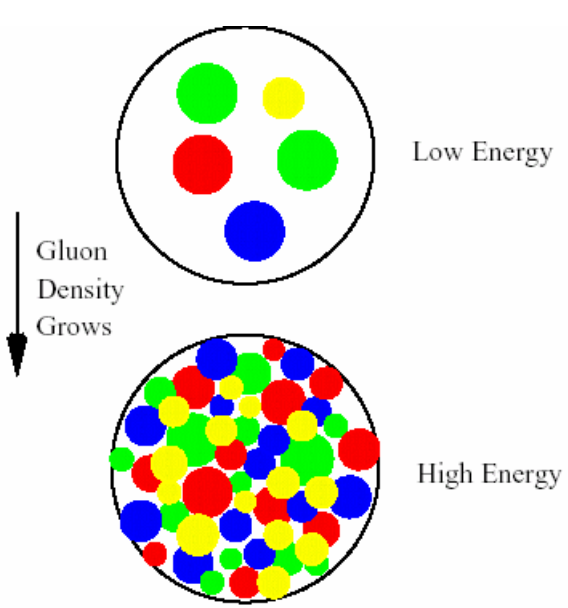
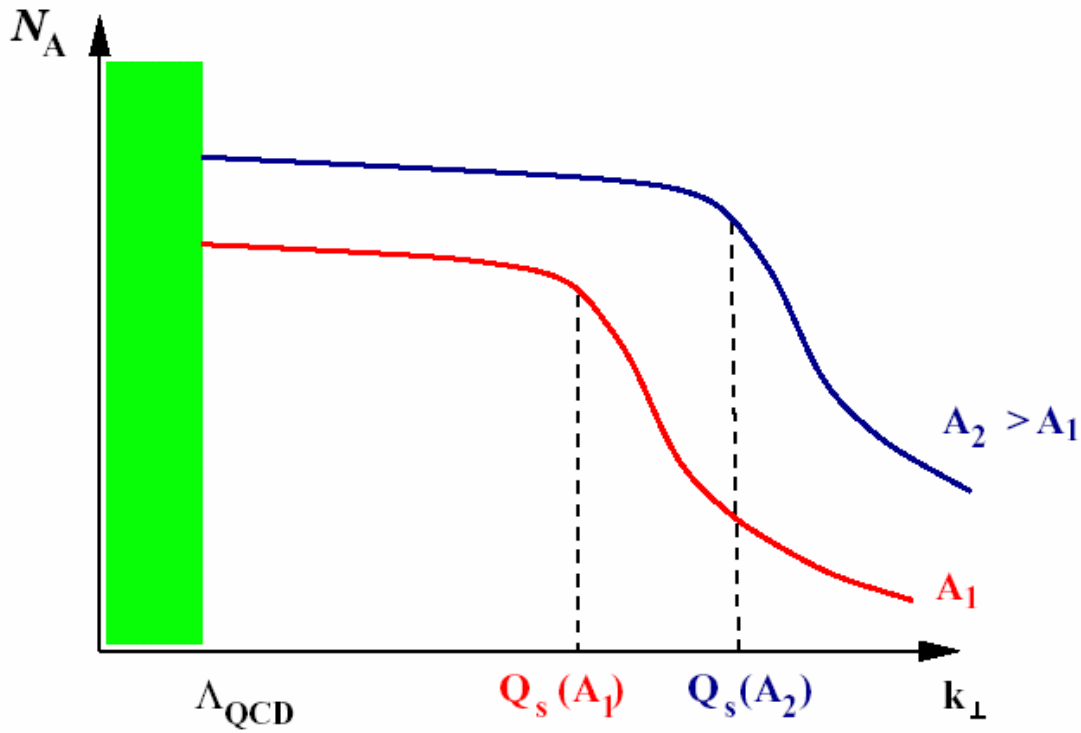
CGC: Lessons for eA from RHIC



Parton saturation (& CGC)

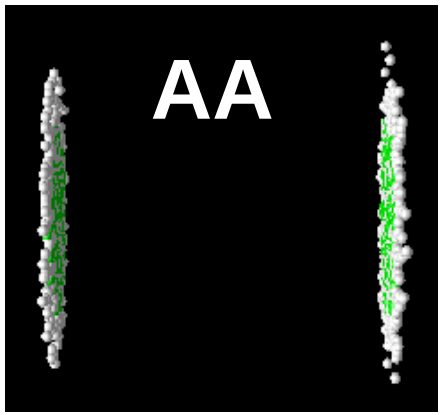
- **Parton density cannot grow indefinitely.**
- **Recombination (gg→g, qg→q) kicks in at low x.**

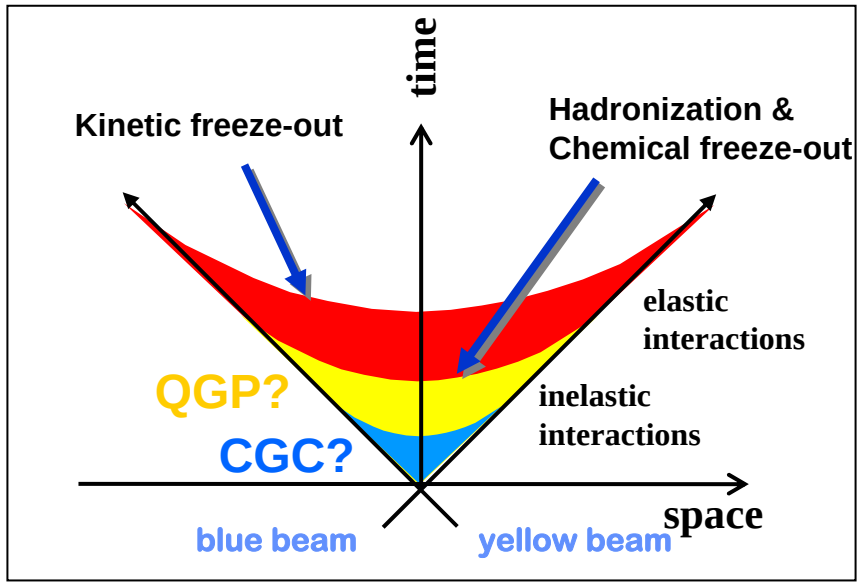


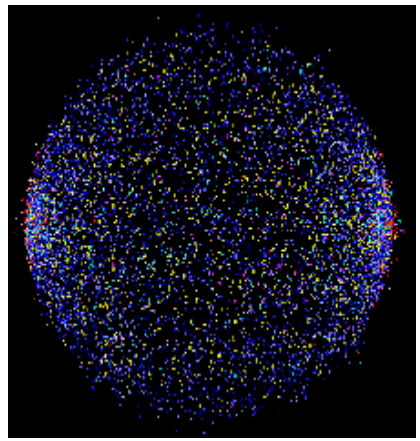


See e.g. Iancu, Venugopalan hep-ph/0303204 for a recent review
History: GLR, Mueller-Qiu, M-V, BK, JIMWLK & many more...

Accessing saturation at RHIC







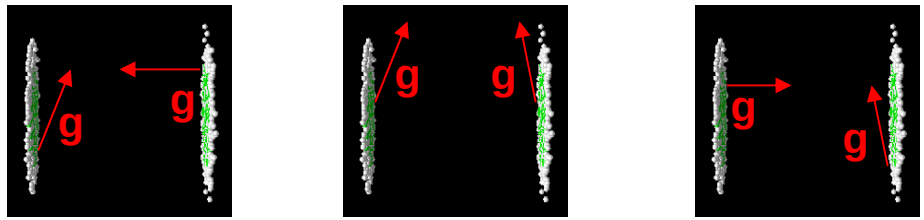
Nuclei (CGC)→ partonic system → frozen out hadrons

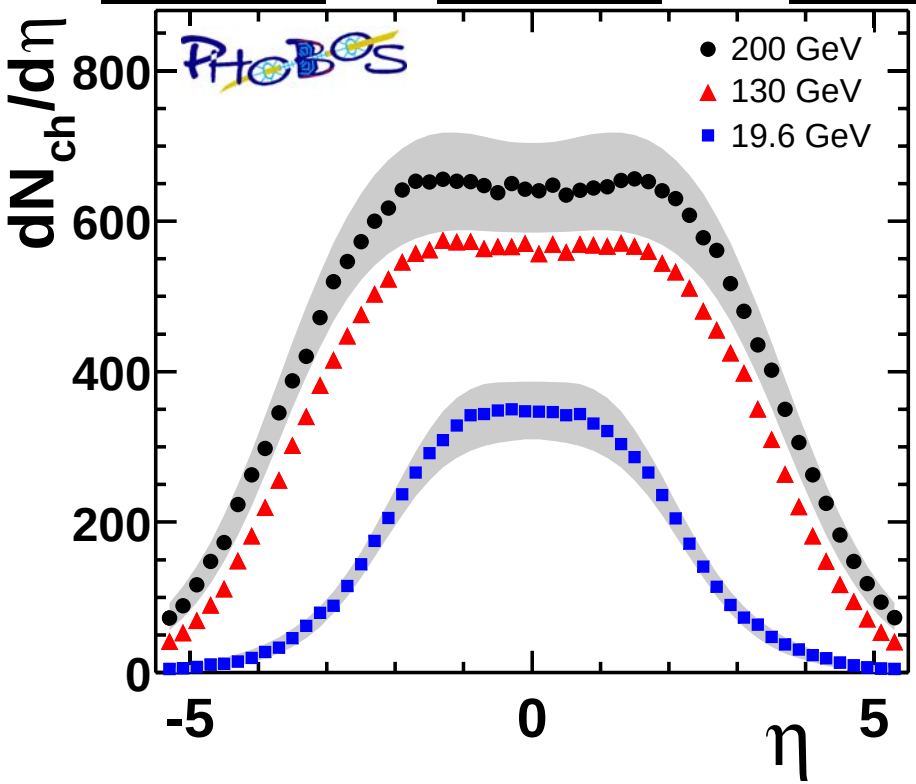
Theory

Modeling ansatz: “final state” effects are essentially trivial.

Let’s see what happens...

Pseudorapidity density





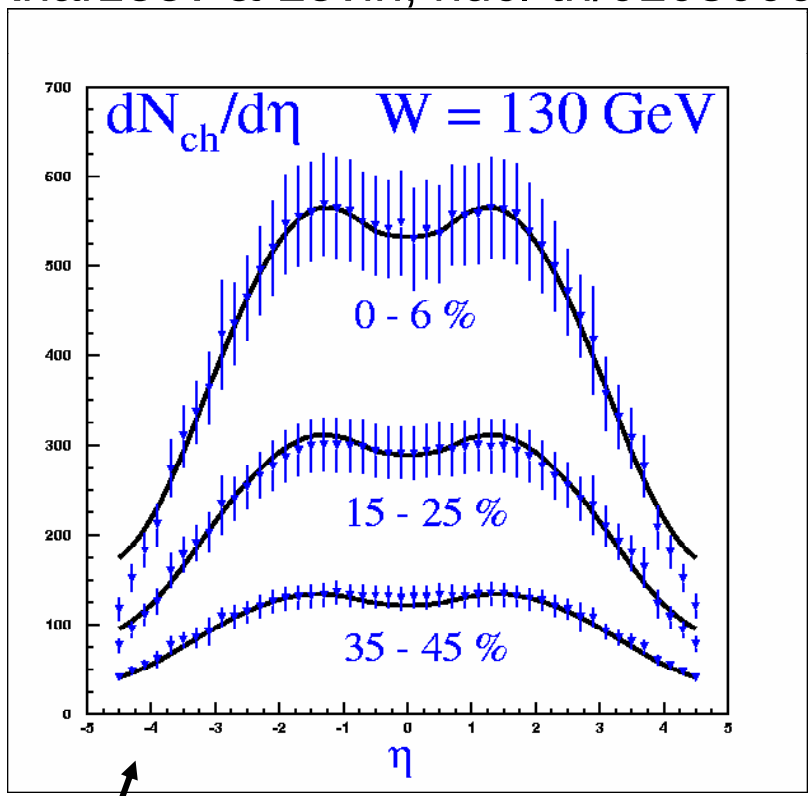
$$\eta \equiv \tanh^{-1} \hat{\beta}_z \approx \tanh^{-1} \beta_z$$

Parton Saturation "predicts" AA

$$\frac{dN}{d\eta} \cong \underbrace{cN_{part}\left(\sqrt{s}\right)^{\lambda} f(\lambda|y|, Q_s)}$$

# of gluons

Kharzeev & Levin, nucl-th/0108006



PHOBOS PRL 87 (2001)

λ fixed by HERA data:

$xG(x) \sim x^{-\lambda}$ & $\tau \sim Q^2 x^{\lambda}$

Describes dN/dη shape!

Fit PHOBOS data at 130 GeV to set c, Q_s

Saturation Works at 200 GeV

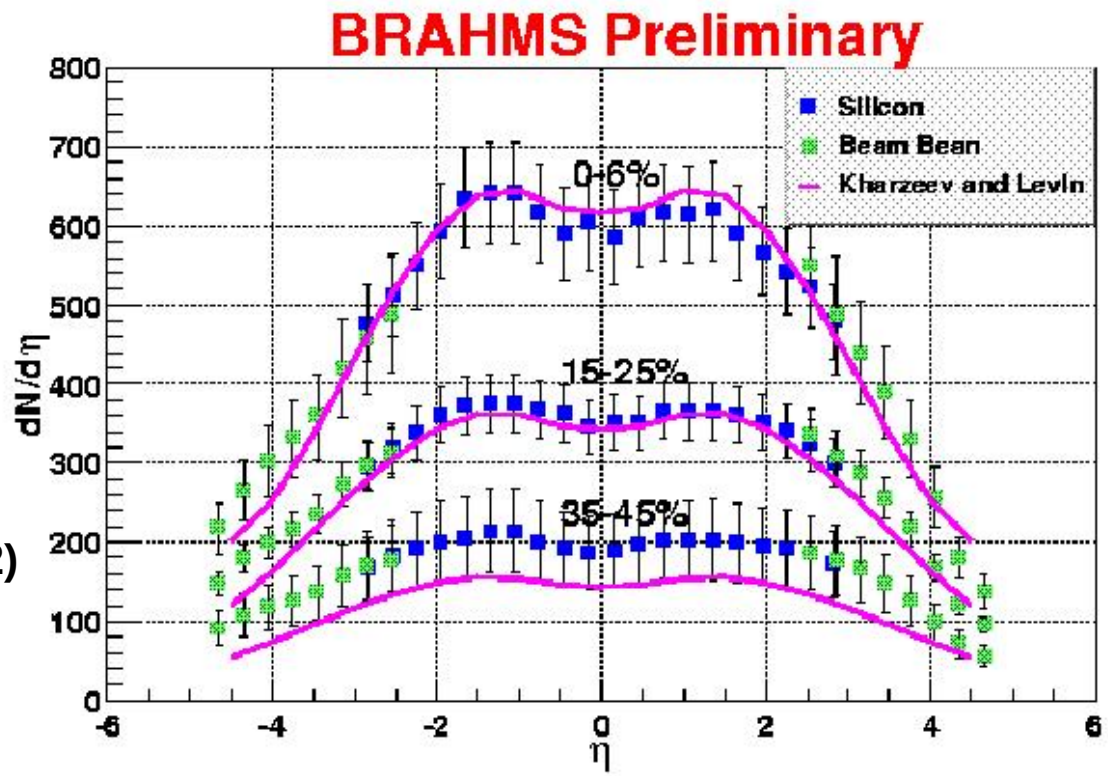
L. McLerran, DNP 2001

BRAHMS

nucl-ex/0112001

See now:

Phys. Rev. Lett. 88, 202301(2002)



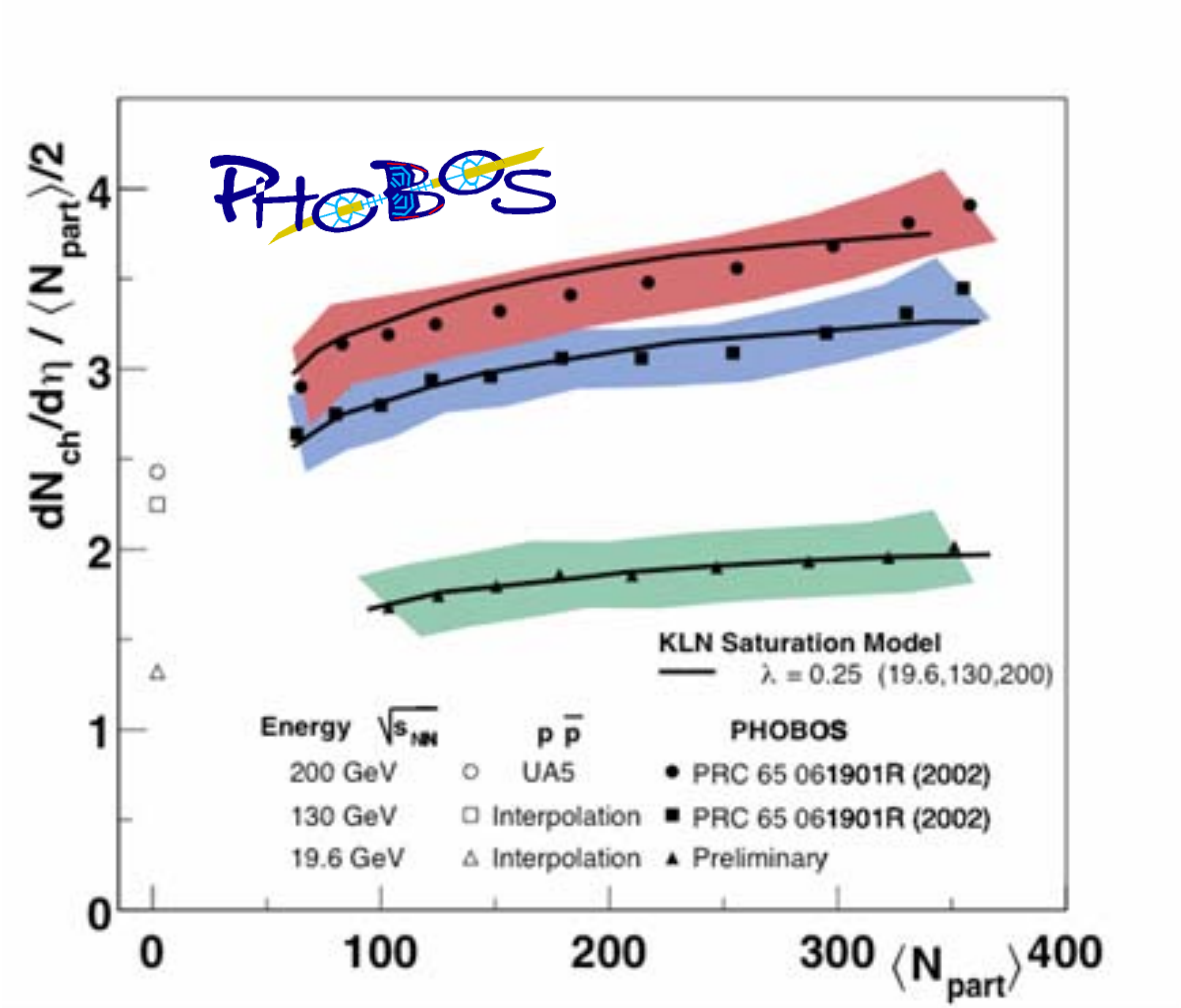
η

λ fixed by HERA data:

$xG(x) \sim x^{-\lambda}$ & $\tau \sim Q^2 x^{\lambda}$

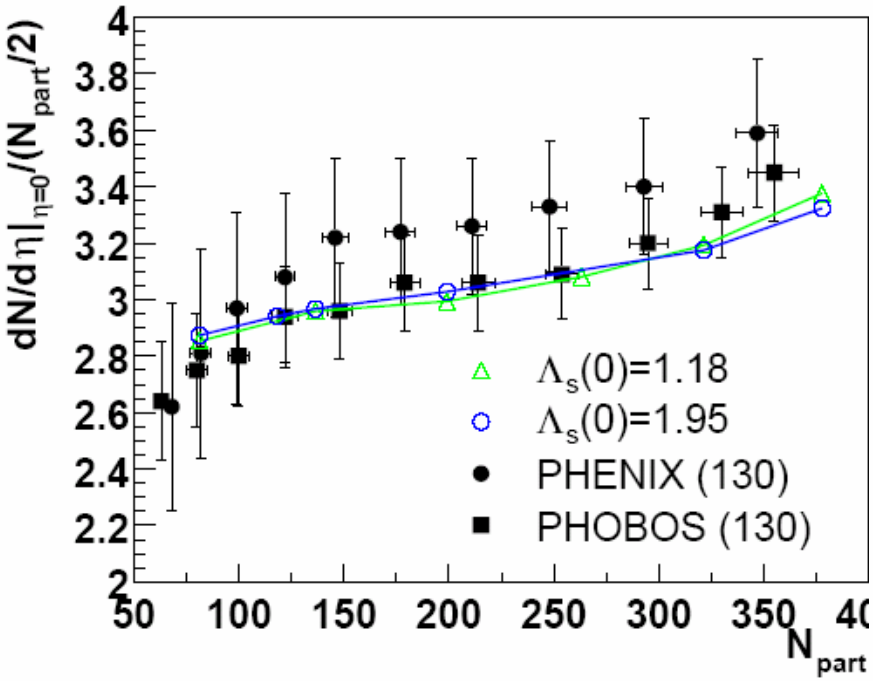
Describes dN/dη energy evolution!

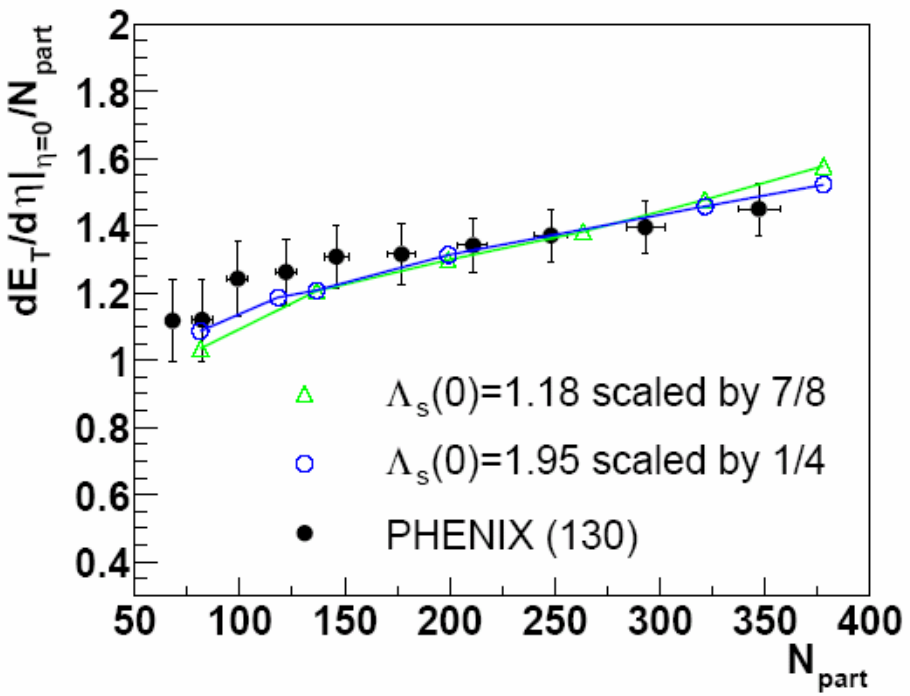
Color Glass Condensate at RHIC



- Energy and N_{part} evolution work over a broad range.

More CGC at RHIC

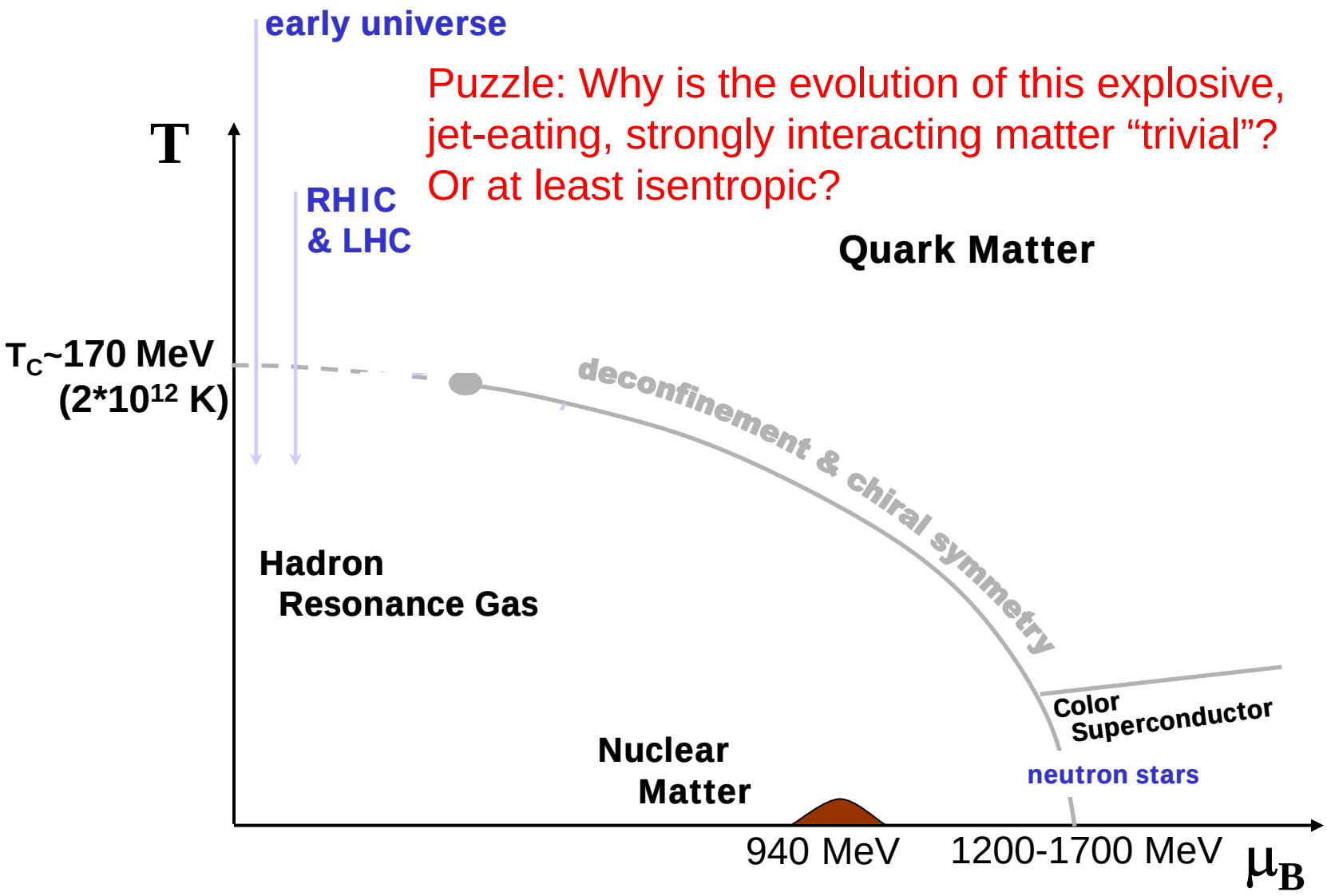




Iancu, Venugopalan hep-ph/0303204

Not just Kharzeev!

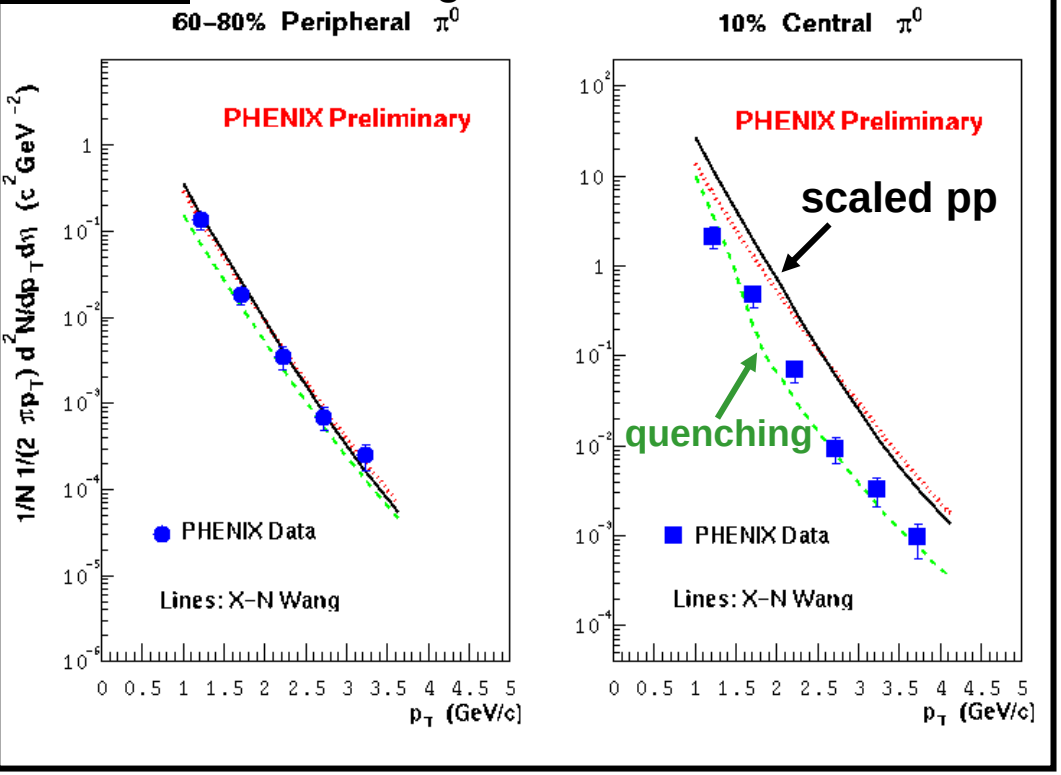
The QCD Phase Diagram



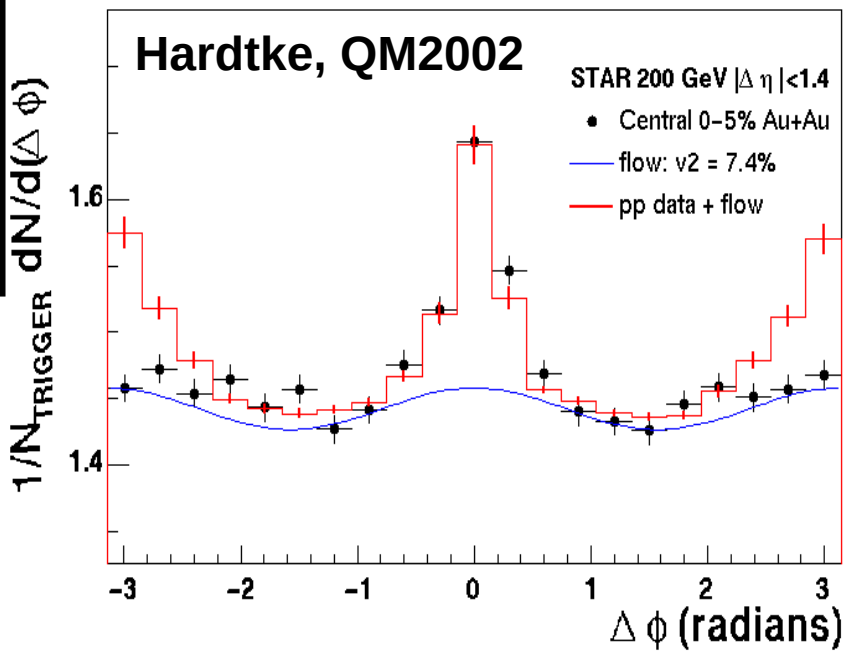
Interlude: Jet Quenching

PHENIX

Breaking news at EIC 3/2002



See PRL 90 (2003) 082302



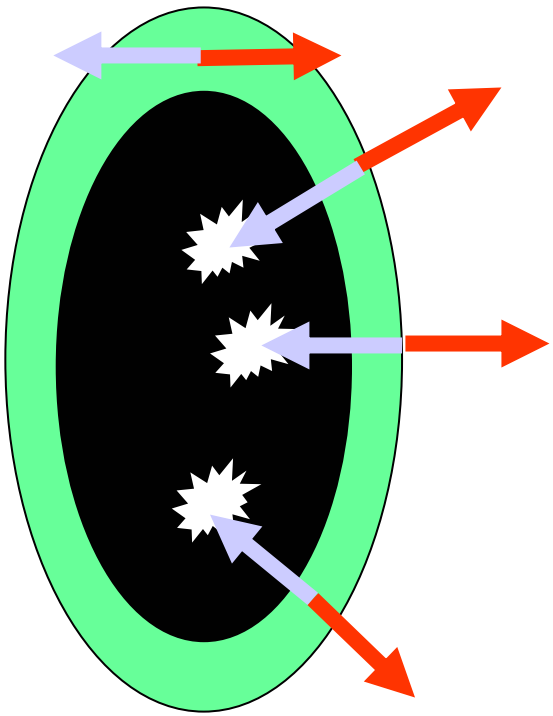
See now

- PRL 88 (2002) 022301
- arXiv:nucl-ex/0207009
- PRL 91 (2003) 072301
- arXiv:nucl-ex/0308006

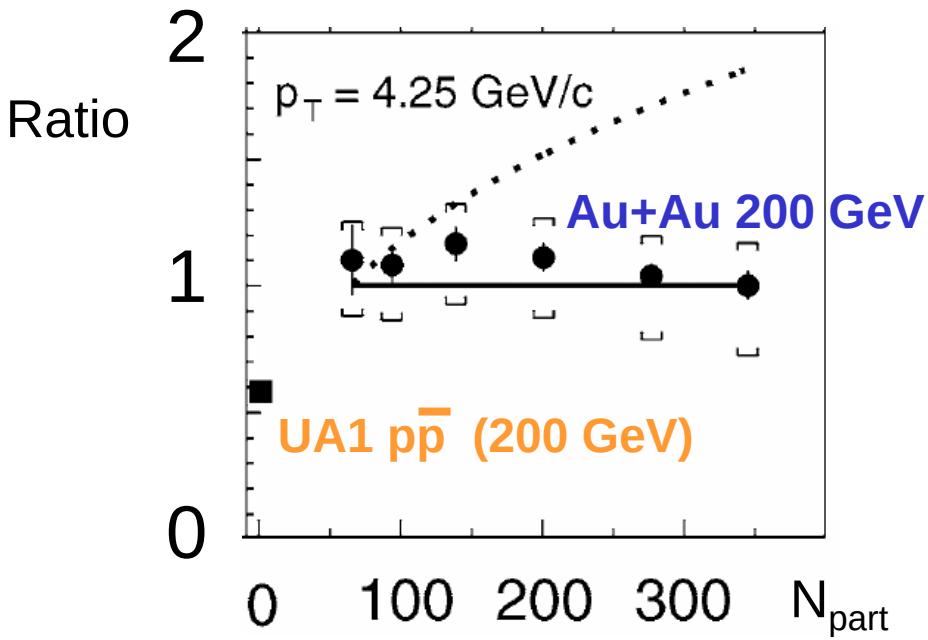
N_{part} scaling: MAXIMAL jet quenching?

$$N_{coll} * \Sigma / V \sim N_{part}^{4/3} / L \sim N_{part}$$

Only jets produced on the surface survive!



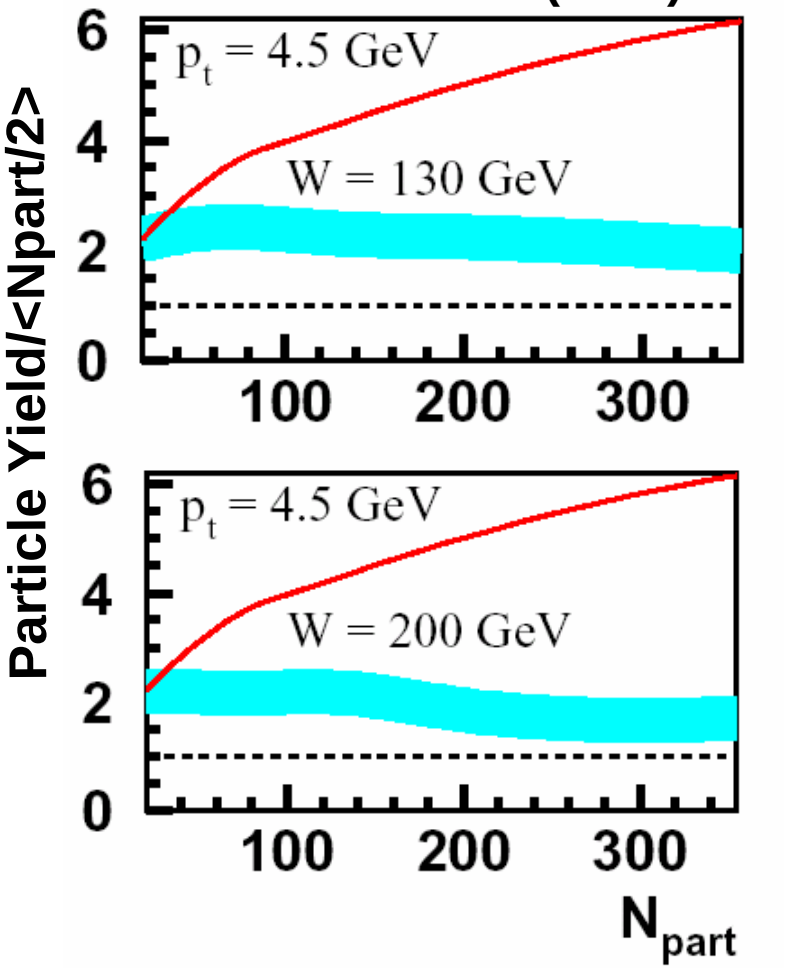
PHOBOS, PLB 578 (2004) 297



Normalize by $N_{part}/2$.
Divide by the value at $N_{part}=65$

Parton Saturation: another explanation?

KLM: PLB 561 (2003) 93

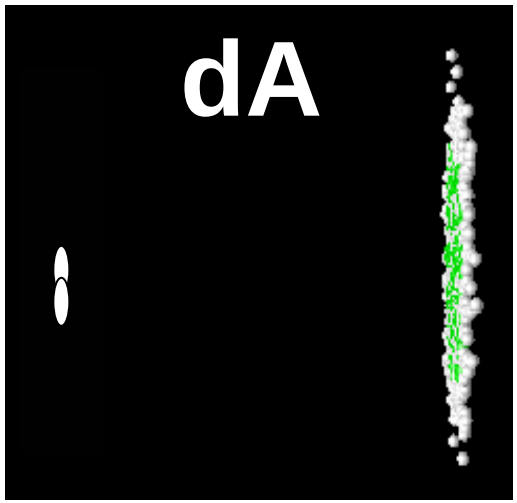


Requires strong saturation (large Q_s)

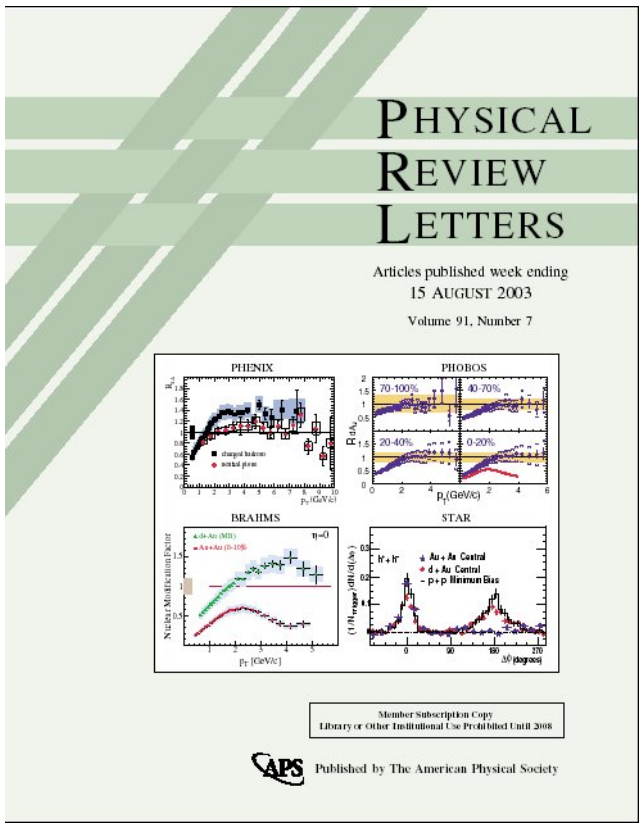
Nice summary from Jamal Jalilian-Marian (QM04)

- R_{AA} < 1: initial state?
  - BFKL anomalous dim.: $1/Q^2$ ---> $(1/Q^2)^{0.6}$
  - Approximate N_{part} scaling
- 2 ---> 1 processes
  - (reduced back to back correlations)

Accessing saturation at RHIC. (2)



IF saturation is strong enough to cause initial state “jet quenching”
THEN it should show up as suppression in central dAu (R_{dAu} ~ 70%)



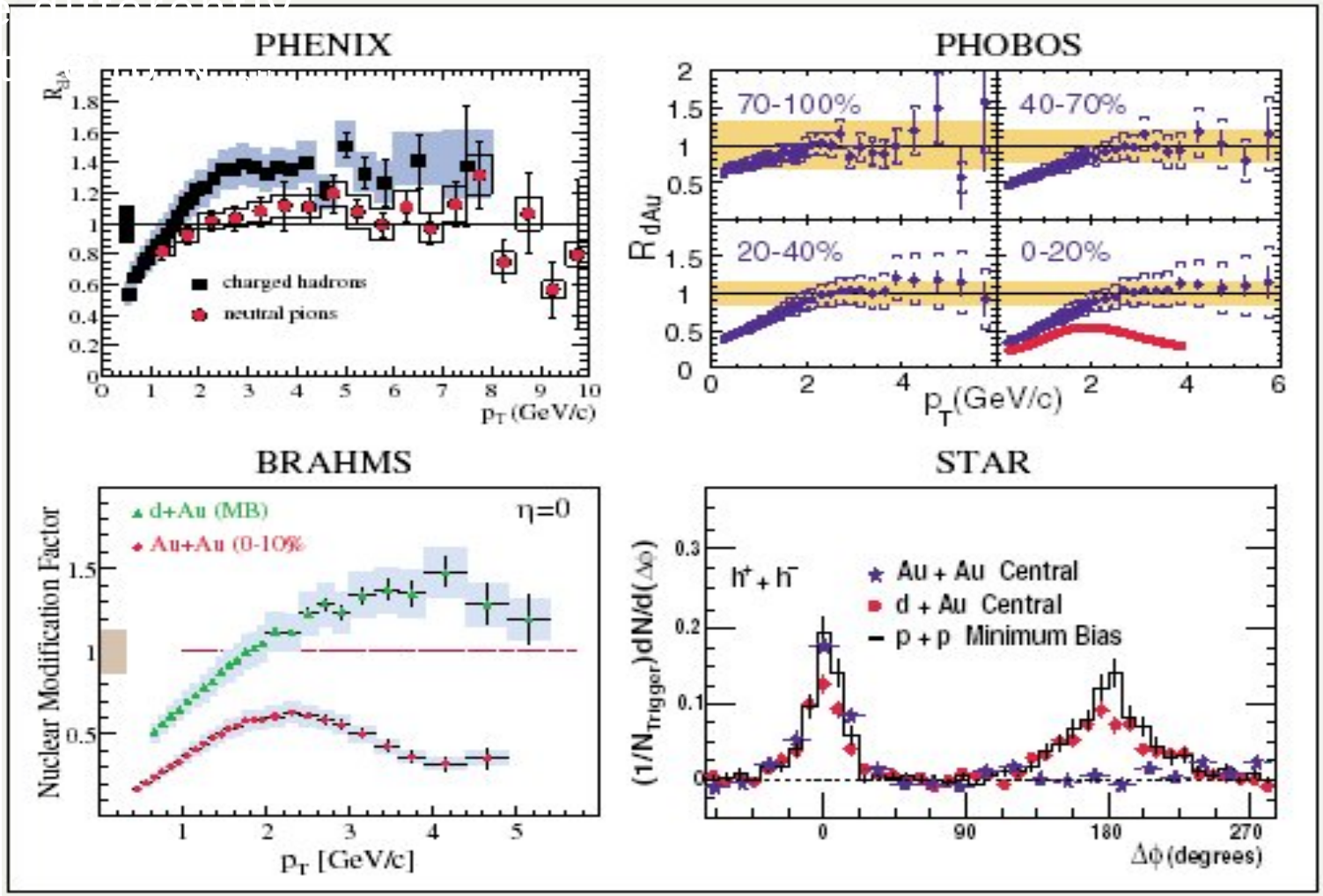
NO!
The saturation theory overreached

For AuAu:

- Midrapidity jet-quenching is a “final state effect”.
- The matter produced is very dense and strongly interacting.

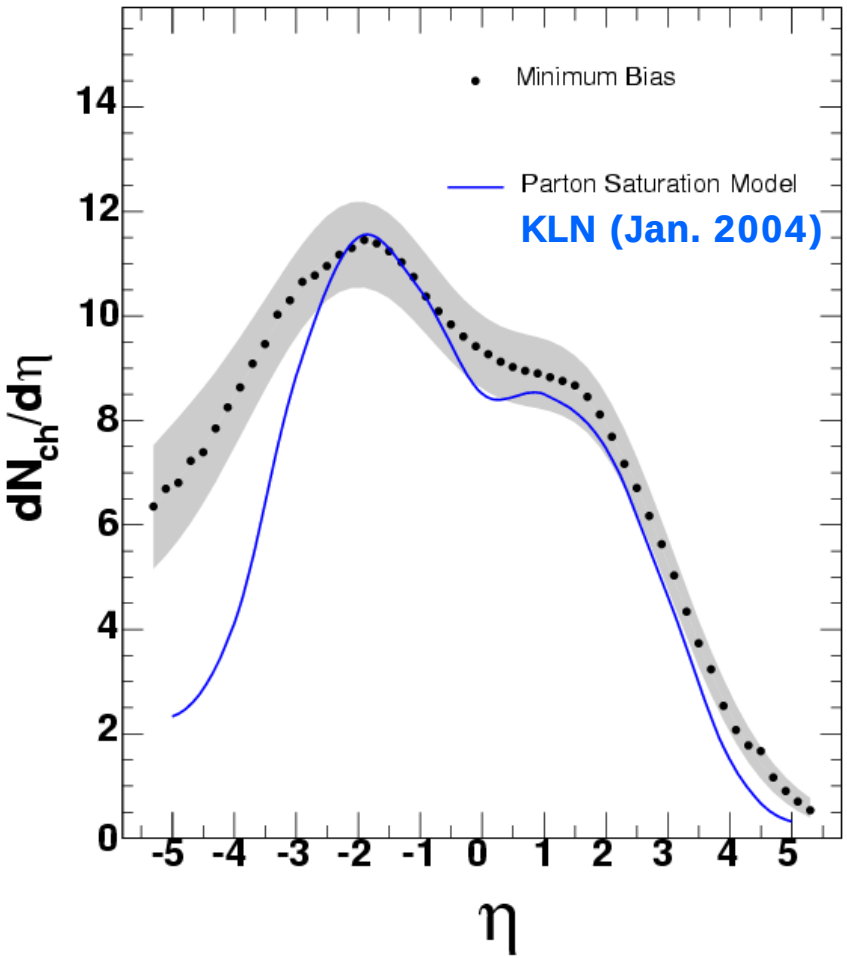
Results from dAu near mid-rapidity

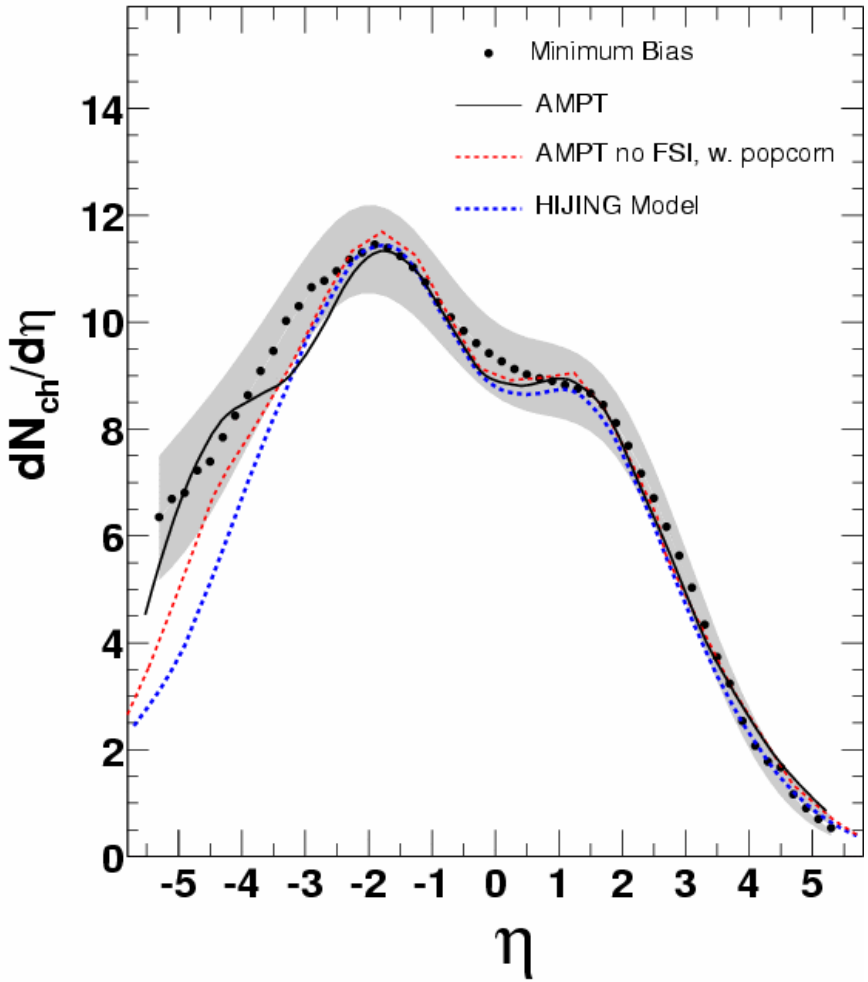
PRL91, (2003), 072302-5



Saturation in dA continued

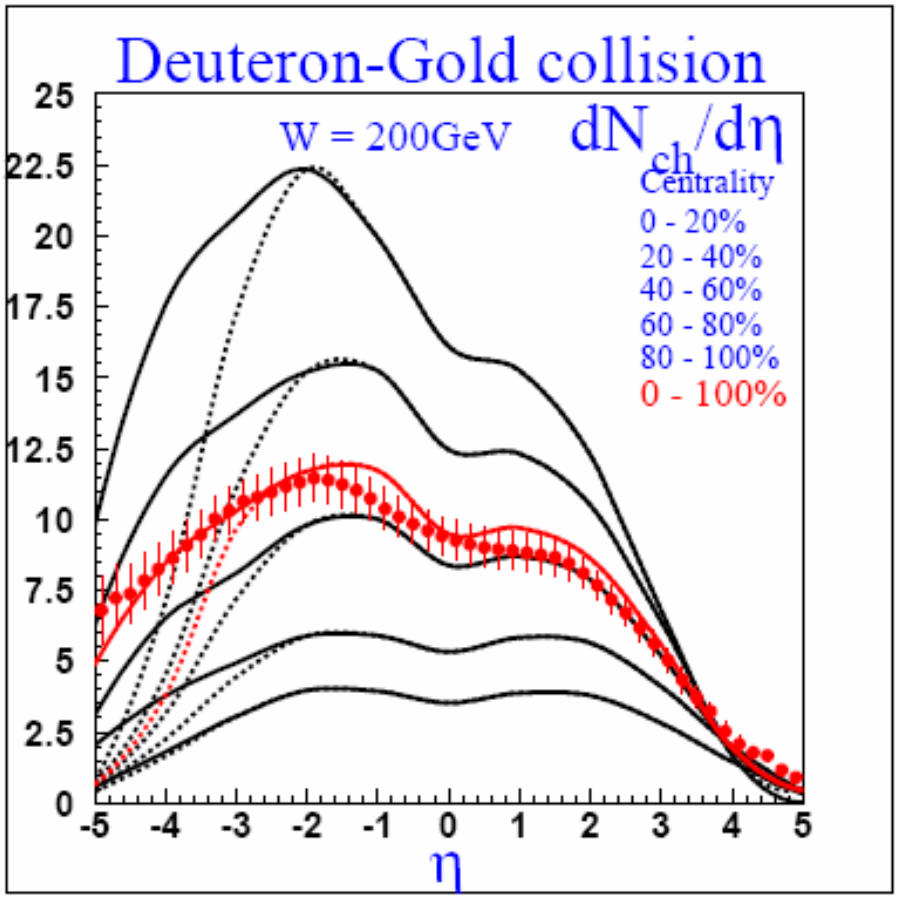
PHOBOS, nucl-ex/0311009, submitted to PRL

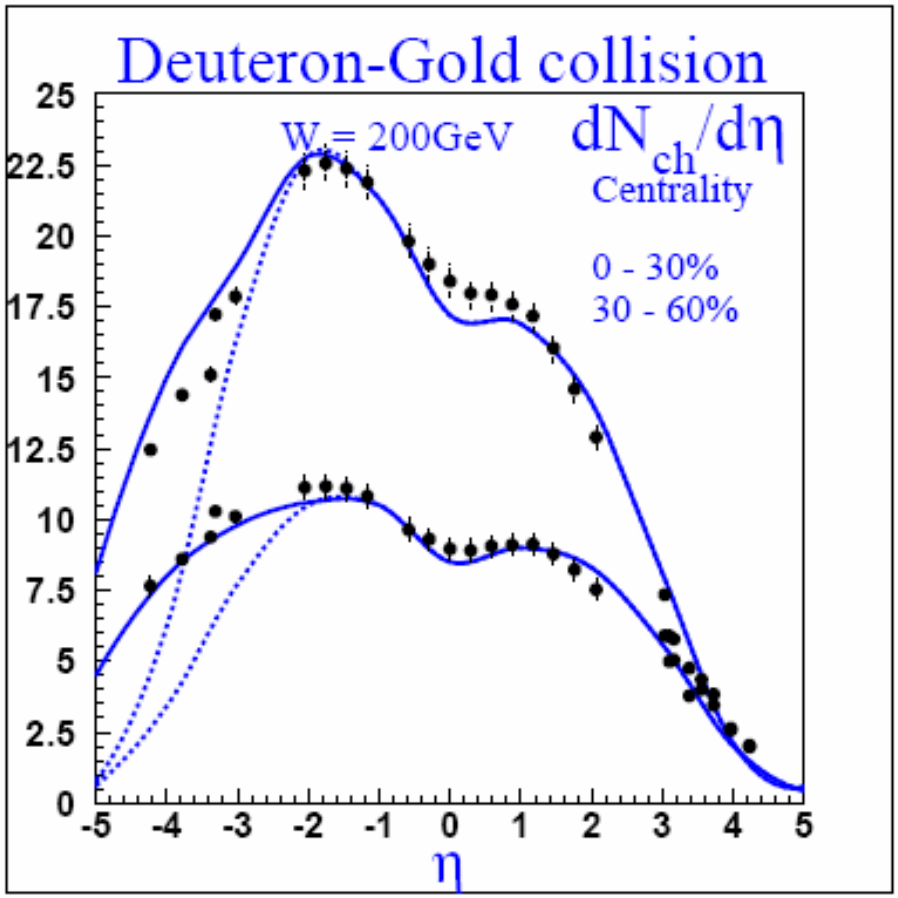




Claim: saturation ~OK for soft particles

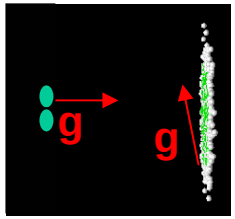
Latest KLN result

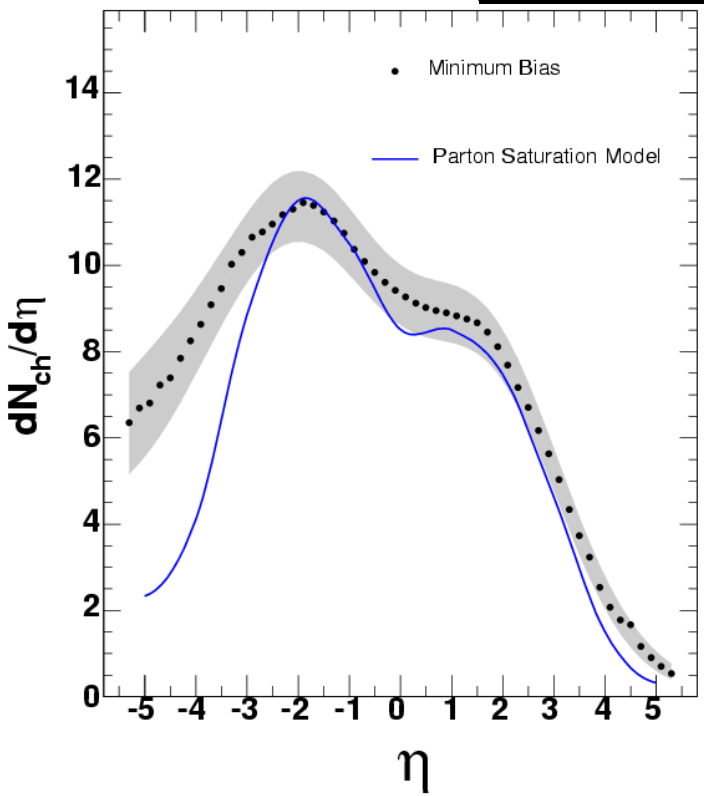


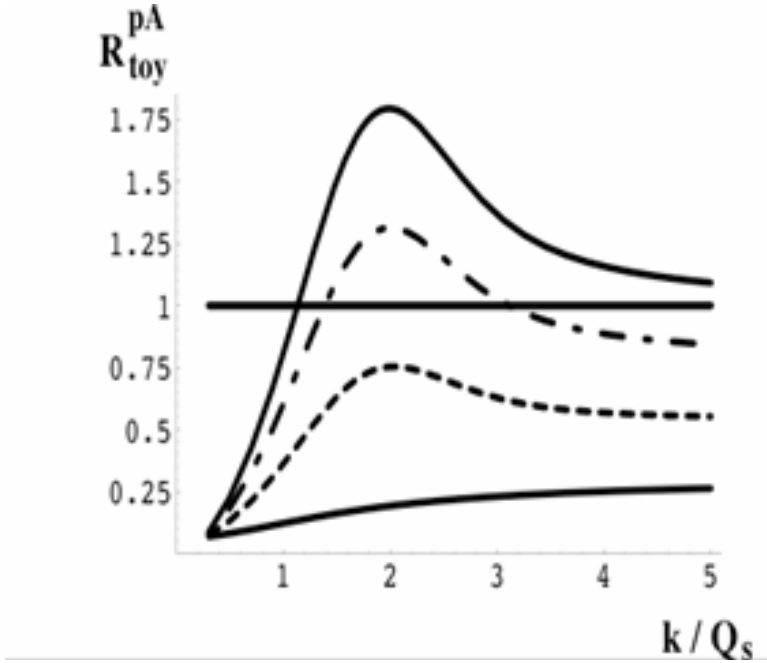


March 8, 2004 arXiv:hep-ph/0212316 v4

Next idea: Go forward!





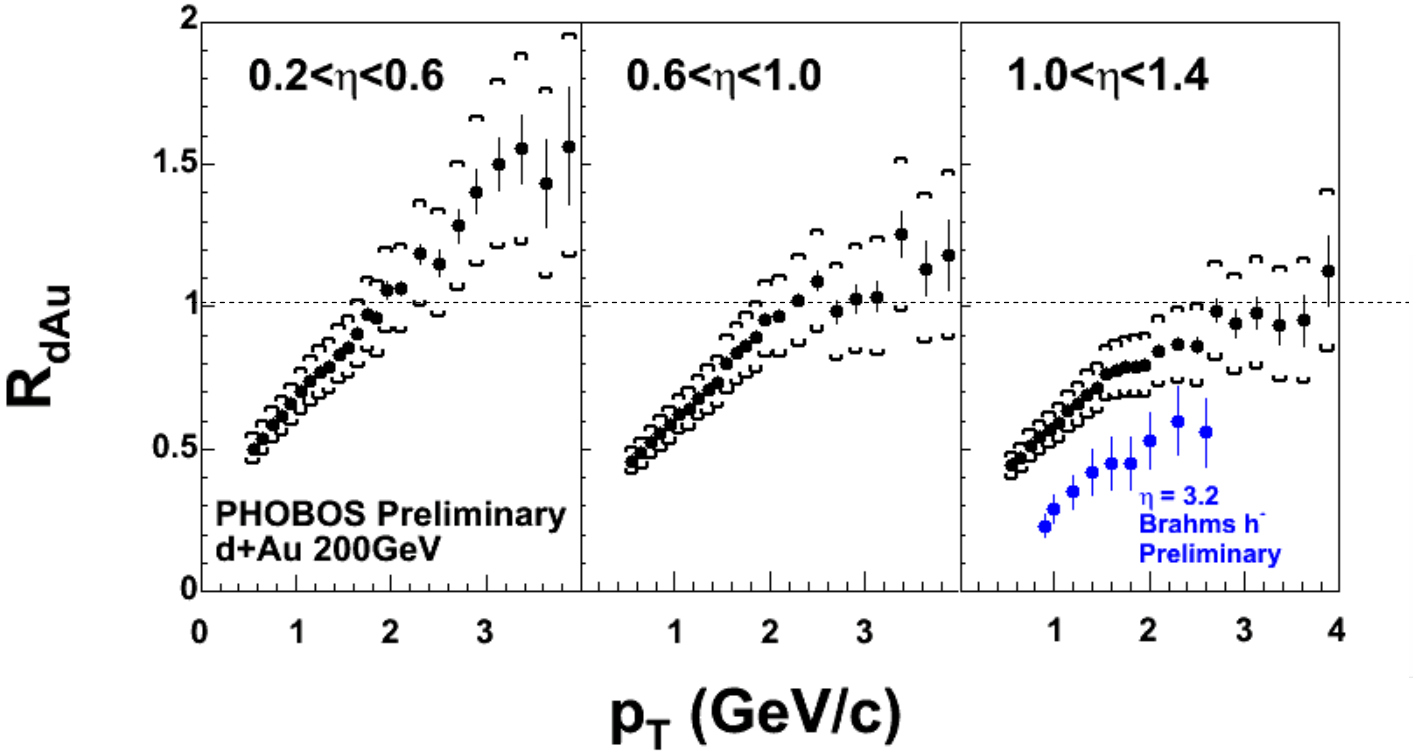


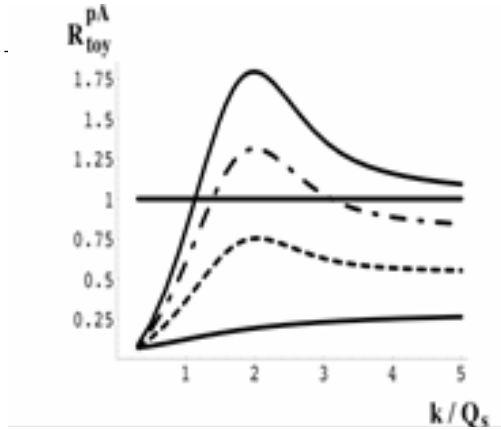
Note: PHOBOS $R_{dA}(\eta=1)$ < RHIC $R_{dA}(\eta=0)$!

Spectra in d+Au for η>0

Brahms DNP - submitted to PRL

G. Veres QM04 (PHOBOS)

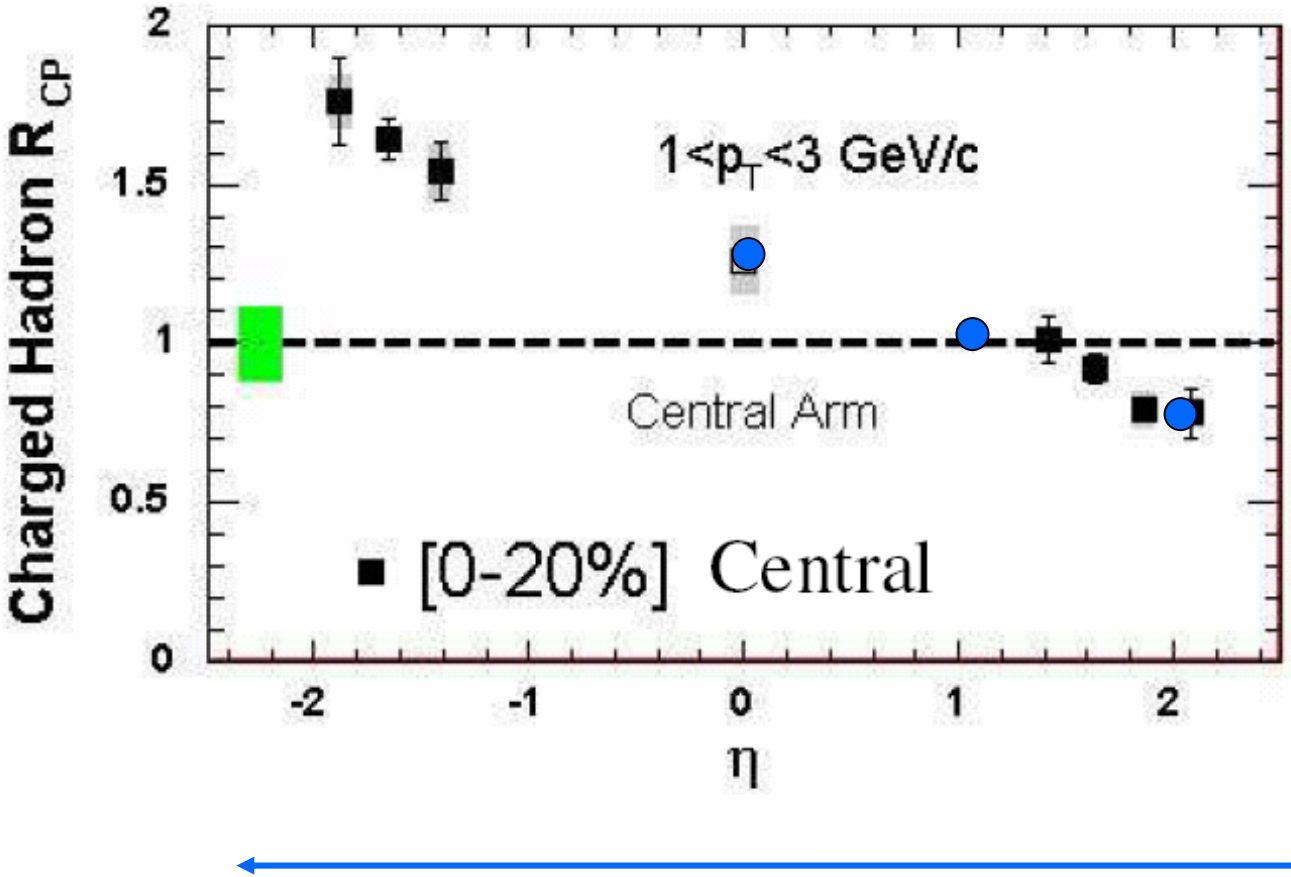




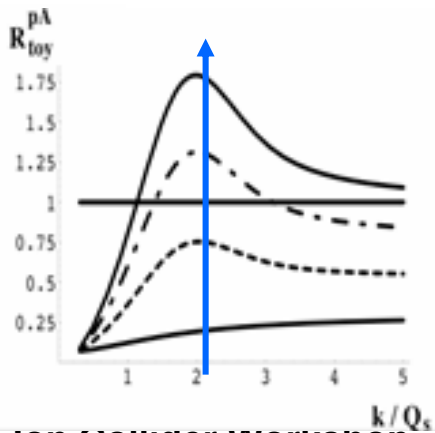
This could be the CGC**!**

CAVEAT:
Shape not perfect

What about backwards rapidity?



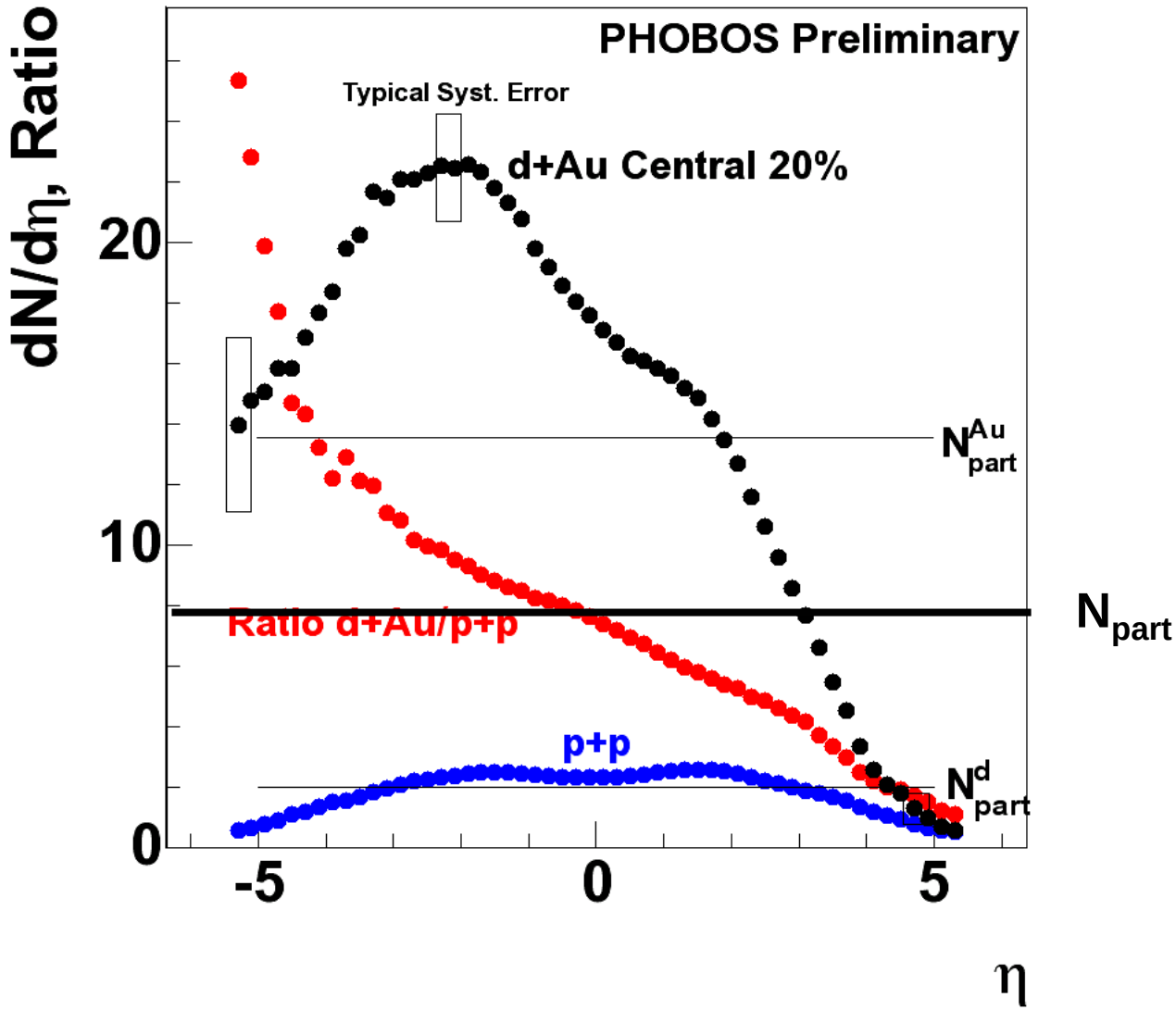
Phenix
Brahms



Not exactly in violation of theory,
but shouldn't really be in saturation region

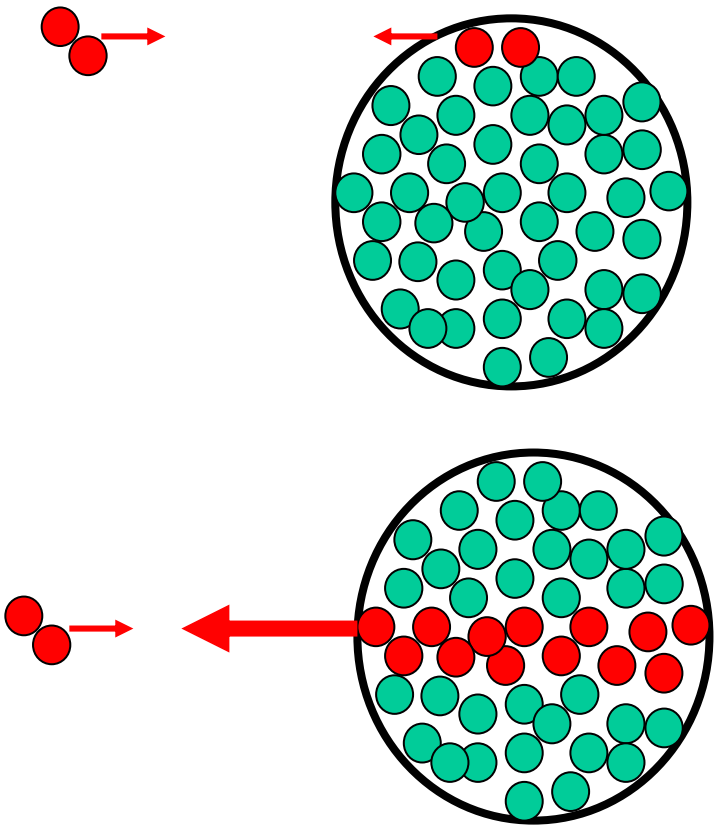
Soft particle enhancement/suppression pattern

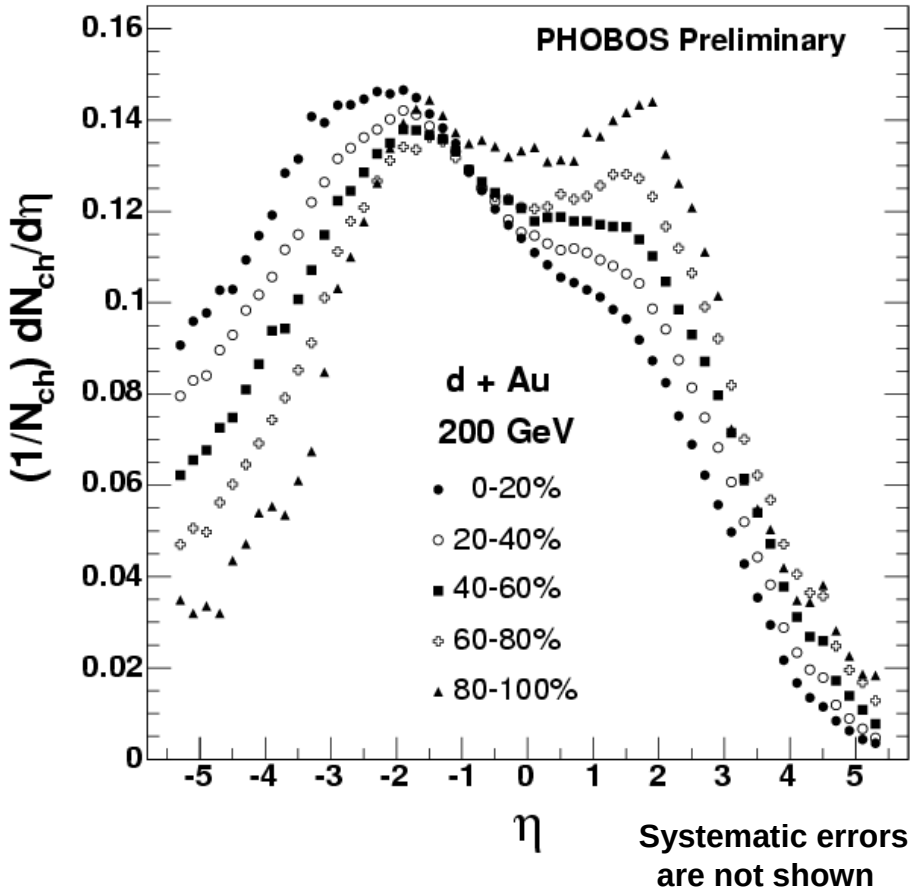
Miklos Gyulassy QM2004 - courtesy of Nouicer, Steinberg



Where is midrapidity?

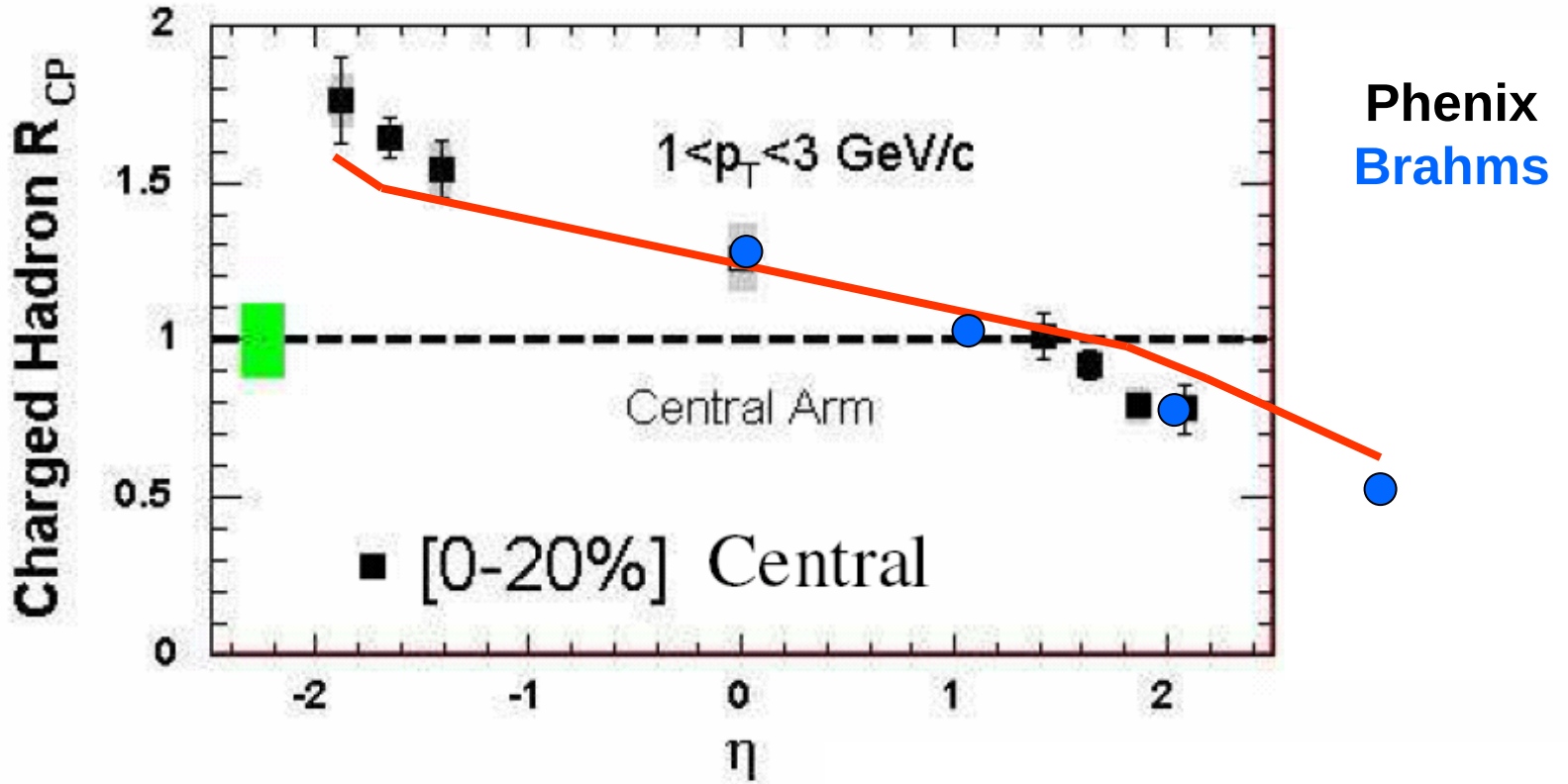
Soft particles see full participant zone





Hard, rare partonic collisions should just see NN frame

“Hard” & “soft” particles behave similarly



— **Phobos dN/dη dA/pp scaled by 1.4 /(N_{part}/2)**

“high pT” suppression (& enhancement) in dAu may interact with the bulk participant system or may lose rapidity through multiparticle collisions.

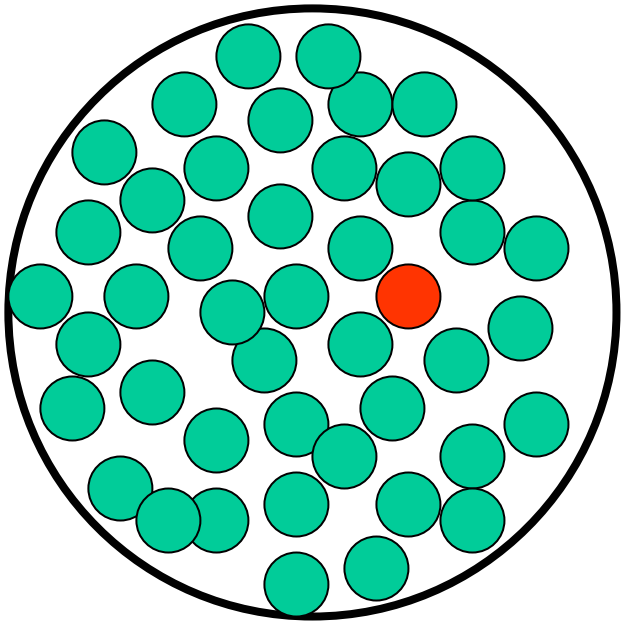
Summary

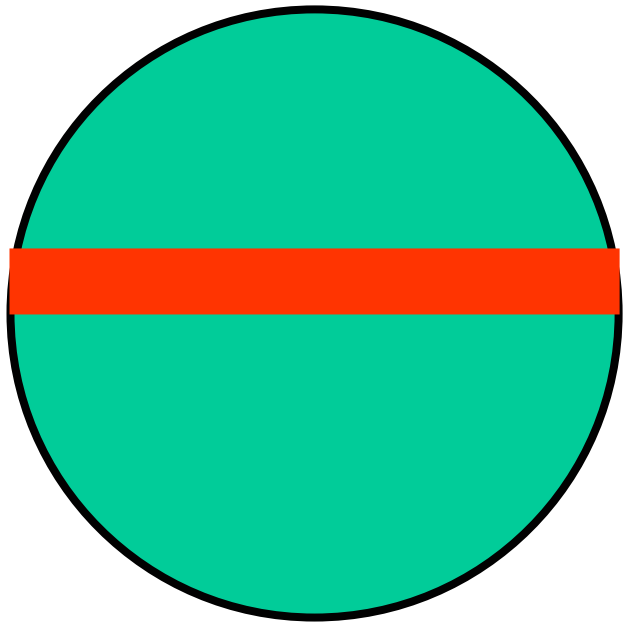
- Heavy ion results do lend support to the ideas of parton saturation (CGC).
  - dN/dη systematics for AA
  - dN/dη for dA (~)
  - "High" p_T suppression in forward dA
- Puzzles
  - How can a theory about initial state gluons describe hadrons that have been through so much?
  - Is it an accident that the $R_{\mathbf{dA}}(\eta)$ enhancement/suppresion pattern is the same for "hard" and "soft" particles?
- eA data will (eventually) be valuable.

Extras

Comparing AuAu to pp

A





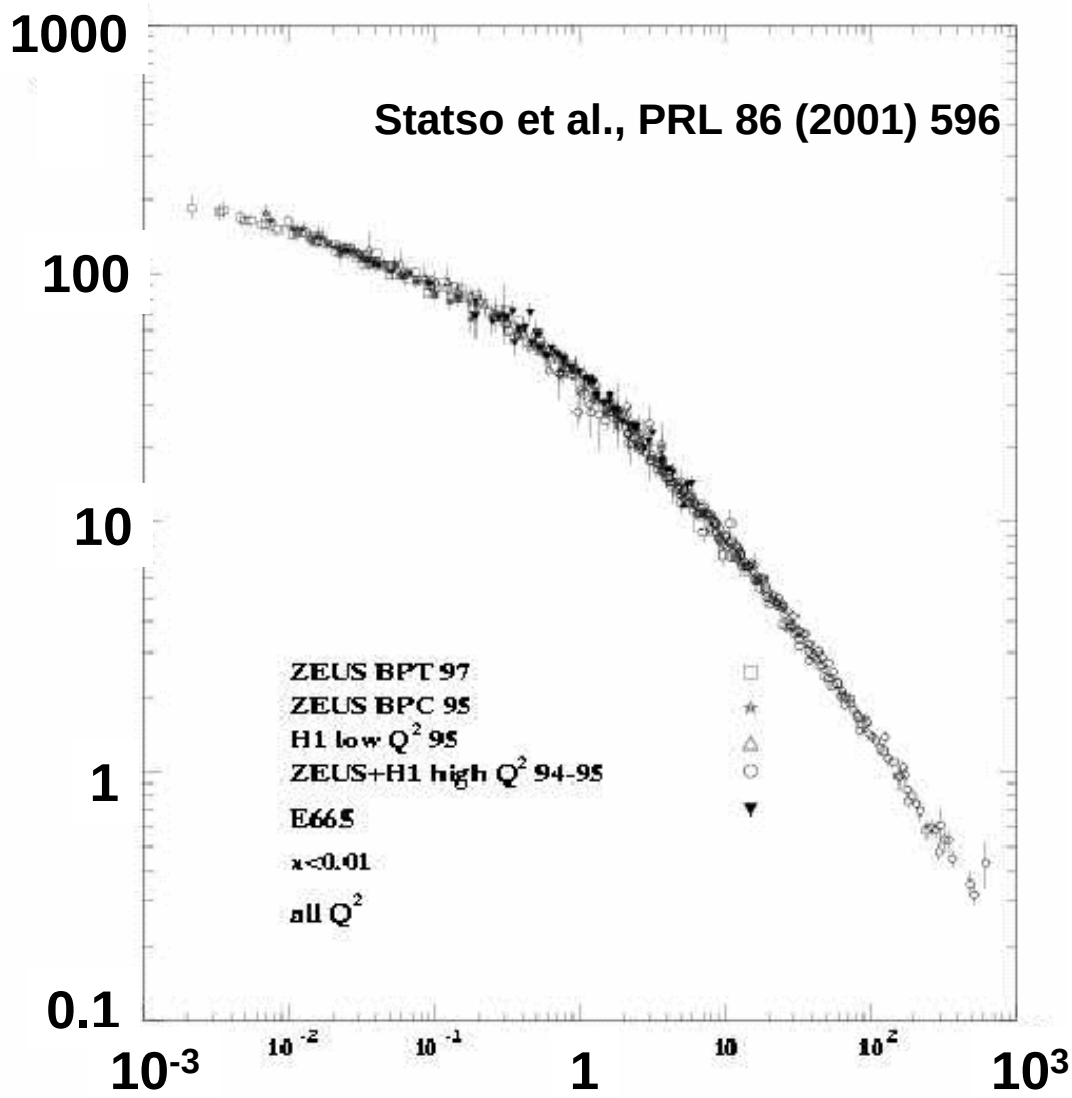
$L \sim A^{1/3}$

# of NN collisions $\sim A^{4/3}$ (formally Glauber $T_{AA}(b)$)

# of participating nucleons: 2A

“Tau scaling” in DIS

$\sigma_{tot}\,\gamma^*p$ (μb)



Fit λ=0.25

$\tau \propto Q^2 x^{\lambda}$