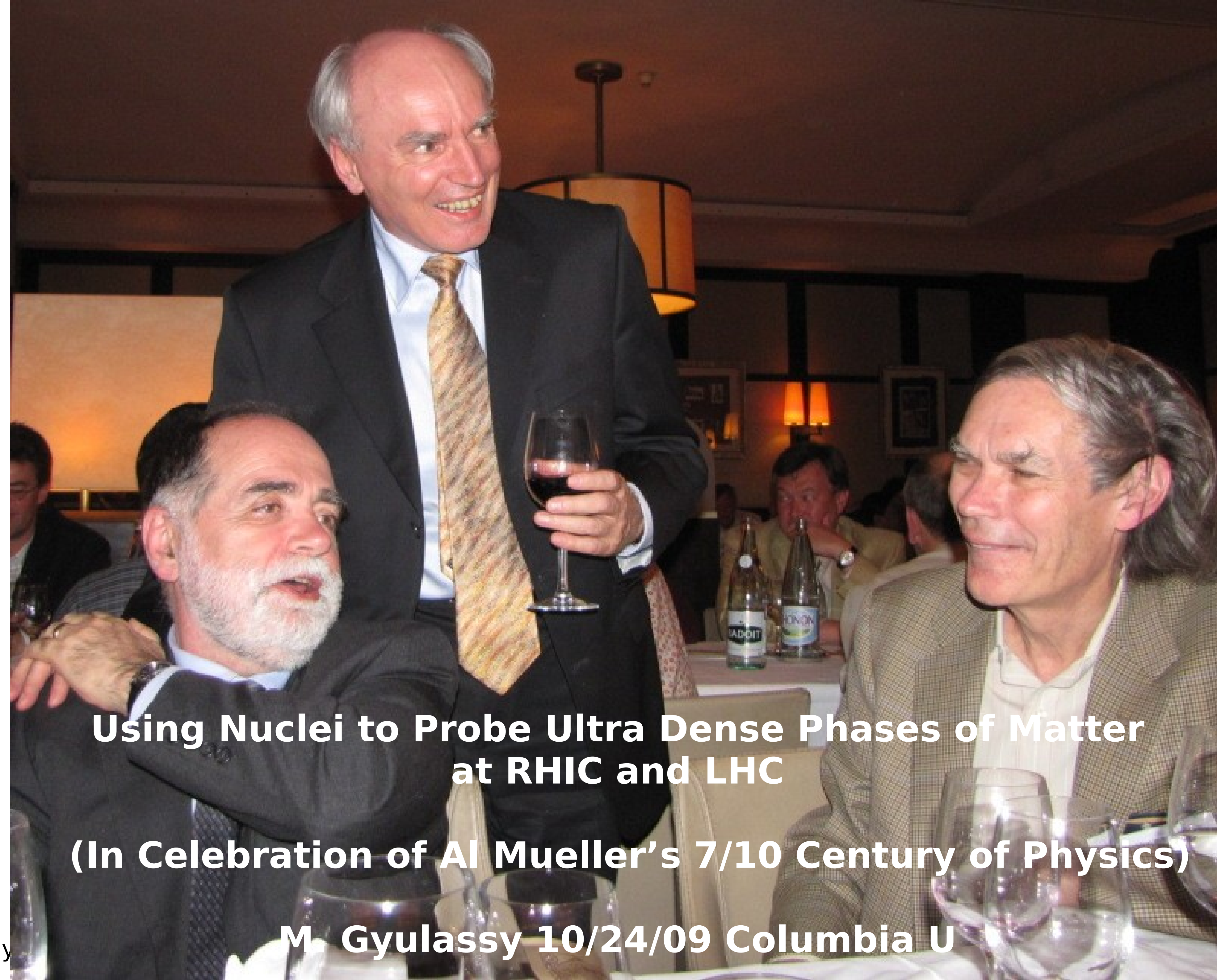


Using Nuclei to Probe Ultra Dense Phases of Matter at RHIC and LHC

(In Celebration of Al Mueller’s 7/10 Century of Physics)

M. Gyulassy 10/24/09 Columbia U

Revenge of the Septarians

Der sQGP űber ~~60~~ 70 Schwerionen Klub

60 et al | Al | Stan

Part 1: Recalling last century

when perturbative QCD ruled the world

(on the very long road to RHIC and sQGPs)

Part 2: The plot thickens and the ante goes up.

PHENIX kills the dead cone !

Part 3: Can pQCD be resurrected numerically at N~7-9 ?

Acceleration of Nitrogen Ions to 7.4 Gev in the Princeton Particle Accelerator

M. G. White [1], M. Isaila [1], K. Prelec [1], and H. L. Allen [1]

THE ACCELERATION OF HEAVY IONS TO VERY HIGH ENERGIES AND THEIR SCIENTIFIC SIGNIFICANCE

M. G. White
Princeton-Pennsylvania Accelerator

We now raise our sights to the region 300-1000 MeV/N and even higher. It is quite unclear what new phenomena will appear in addition to the obvious, and possibly unexciting, free nucleon-nucleon collisions with consequent meson production. The collision of two ions, say uranium at 1000 MeV/N will resemble in density and temperature the Primeval Fireball a few milliseconds after the moment of maximum density and temperature. This Micro-Fireball will last only about 10^{-24} seconds, but a lot can happen in that brief explosion. It should also be noted that a 1000 MeV nucleon is travelling much faster than the speed of sound in nuclear matter. Whether this will lead to some form of shock front, full of baryons and mesons, I do not know, but it would be interesting to have a close look. To the

TD set foundation of ideas of using relativistic A+A to probe dense matter in 1974

"Bev/nucleon collisions of heavy ions" at Bear Mountain, New York,

organizers:
Arthur Kerman, Leon Lederman, Mal Ruderman, Joe Weneser and **T.D. Lee**

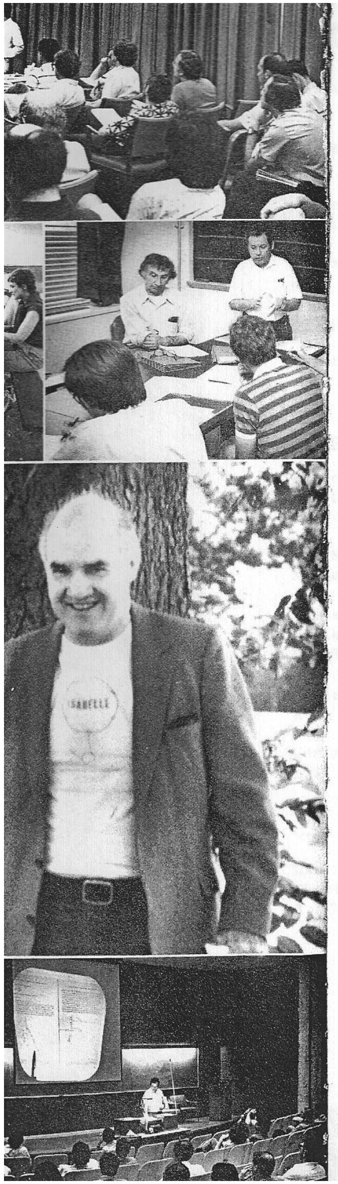
"The driving question at the meeting was, as Lee emphasized,
whether the vacuum is a medium whose properties one could change;

"we should investigate phenomena by distributing high energy or high nucleon density over a relatively large volume." (TD)

one could restore broken symmetries of the vacuum, then it might be
possible to create abnormal dense states of nuclear matter,
as Lee and Gian-Carlo Wick speculated."

Gordon Baym QM2001 talk

Al's first public A+A Nuk'em talk 1981



BNL 51443
UC-28
UC-34d
(Particle-Accelerators
and High-Voltage Machines;
Physics — Particles and Fields TIC-4

ISABELLE
PROCEEDINGS OF THE 1981 SUMMER WORKSHOP

JULY 20 — 31, 1981

VOLUME 2
PHYSICS

BROOKHAVEN NATIONAL LABORATORY
ASSOCIATED UNIVERSITIES, INC.

UNDER CONTRACT NO. DE-AC02-76CH00016 WITH THE

UNITED STATES DEPARTMENT OF ENERGY

Consider now the distribution of quarks and gluons of small x, technically the region $\ln \frac{1}{x} > \ln A^{1/3} + C$. The longitudinal spread of such partons is proportional to 1/px which is large compared to the valence quark spread in the x region under consideration. *Inelastic muon* scattering experiments tell us that there is some shadowing at these small values of x. In terms of $P^{\alpha}(x)$ this means that $P^{\alpha}(x)$ is somewhat smaller, perhaps by a factor of 2 or so at our $\underline{b} = 0$ values, than a *simple addition* of quark densities from the nucleons in the ion would indicate. Since the partons coming from different nucleons, at a given $\underline{b}$, overlap completely in coordinate space for small values of x we might expect that the parton density should saturate to a value independent of $A^{1/3}$ at large A. (This is equivalent to the statement that fixed Q^2 inelastic muon scattering should have a cross section proportional to $A^{2/3}$ for large enough A.) That is, in the absence of strong correlations between quanta far apart in rapidity one would expect a limiting density of partons as the source strength, the valence quarks, increases.

Then $\int G(x)dx \stackrel{\sim}{\sim} 3$ so that $\mathcal{E} \stackrel{\sim}{\sim} \frac{9}{8\pi} A^{1/3}$ GeV/fm^3. For $A^{1/3} = 6$ $\mathcal{E} = 2$ GeV/fm^3. This may be an overestimate as we have not taken shadowing effects properly into account. If such effects reduce the gluon density by a factor of 2 then our estimate of $\mathcal{E}$ will be too large by a factor of 2.

REFERENCES

1. R. Anishetty, P. Koehler and L. McLerran, Phys. Rev. D22, 2793 (1980).
2. L. McLerran, Talk at the 5th High Energy Heavy Ion Study, Lawrence Berkeley Laboratory.

Al’s 1981 Speculation for Pion Rapidity Distribution in high energy A+A at ISABELLE assuming maximal shadowing at small x

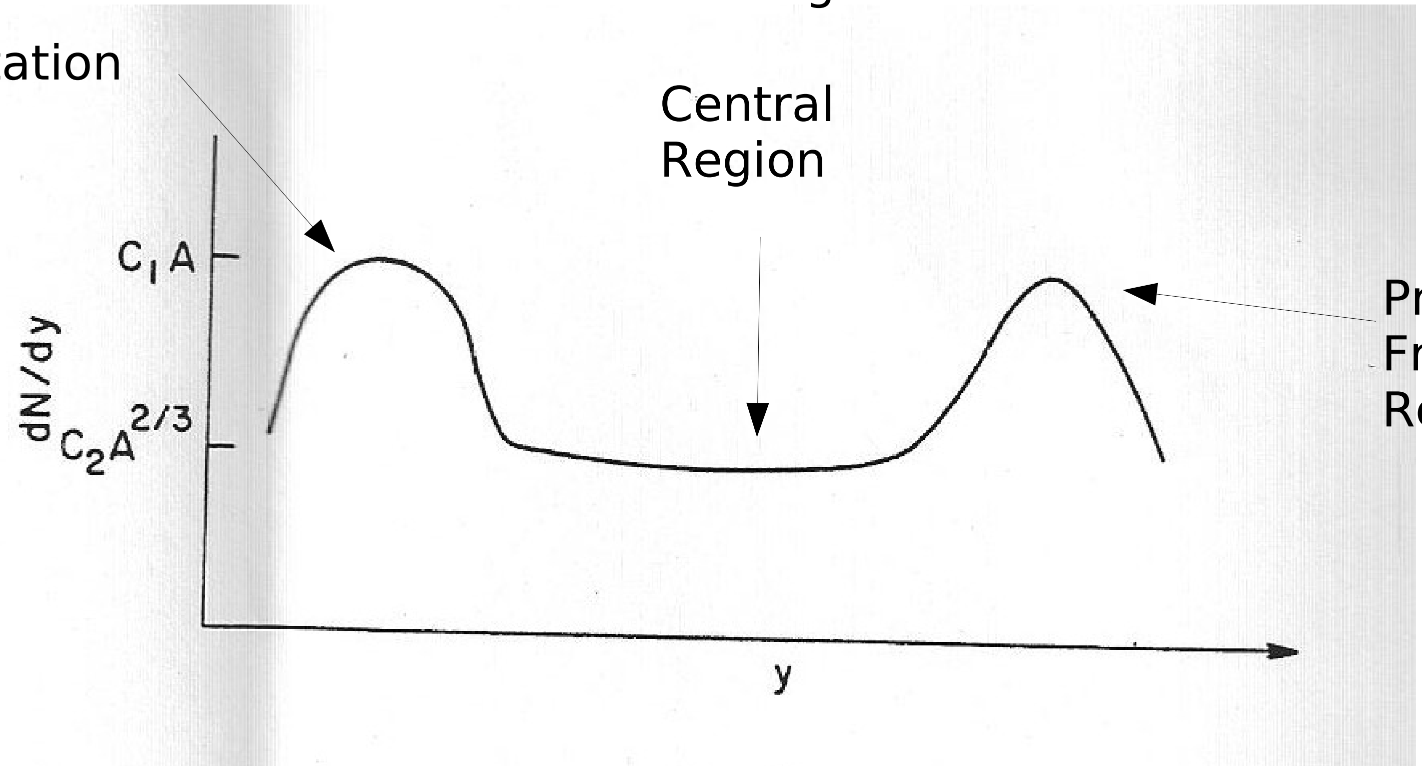


Fig. 2

If True it would have been a bummer for RHIC

Hadron Production in Nuclear Collisions—a New Parton-Model Approach

Stanley J. Brodsky
Stanford Linear Accelerator Center, Stanford University, Stanford, Califo

and

John F. Gunion
Department of Physics, University of California, Davis, California 95616

and

J. H. Kühn
Max-Planck-Institut für Physik und Astrophysik, München 40, Germany
(Received 5 May 1977)

2) **Nuclear Phenomena And The Short Distance Structure Of Hadrons.**
Stanley J. Brodsky H, (SLAC) . SLAC-PUB-2395, Sep 1979. 45pp.
Microfiche at Fermilab.
Invited talk given at 1st Workshop on Ultra-Relativistic Nuclear Collisions, Berkeley, Calif., May 21-24, 1979.

Longitudinal Flux Tubes Save the Day

The BGK Longitudinal Color Neutralization Model

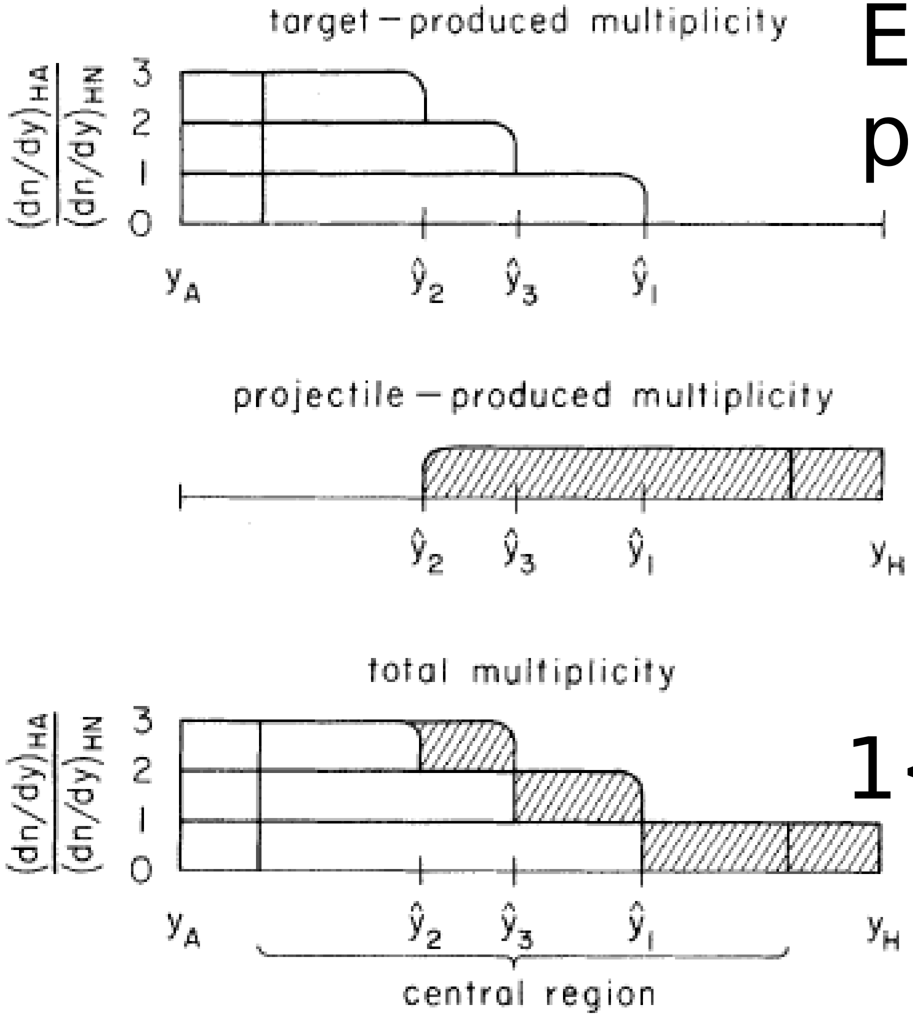


FIG. 1. Idealized multiplicity distribution for an H–A collision with $\bar{\nu} = 3$ inelastic excitations. The y_i are uniformly distributed in rapidity and can be produced in any sequence.

Explained Busza's pA "Triangle" rapidity

And Predicted 23 years before RHIC that

$$1 < \frac{dN(A+A)/dy}{dN(p+p)/dy} < 2$$

Extremely High Multiplicities in High-Energy Nucleus-Nucleus Collisions

T. H. Burnett, S. Dake, M. Fuki, J. C. Gregory, T. Hayashi, R. Holynski, J. Iwai, W. V. Jones, A. Jurak, J. J. Lord, O. Miyamura, H. Oda, T. Ogata, T. A. Parnell, T. Saito, T. Tabuki, Y. Takahashi,[a] T. Tominaga, B. Wilczynska, R. J. Wilkes, W. Wolter, and B. Wosiek

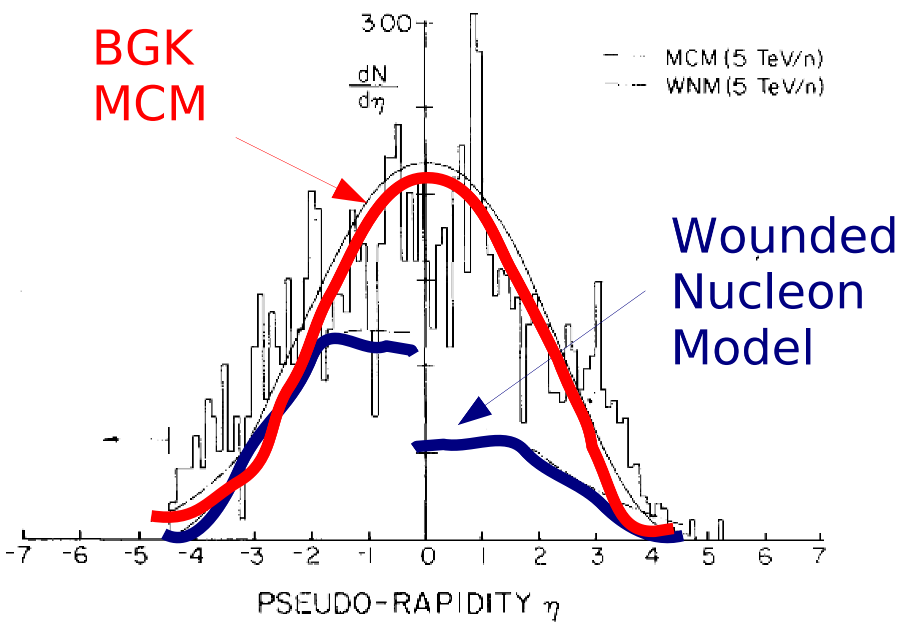


FIG. 1. The CMS pseudorapidity distribution of charged particles in the Si + AgBr event. Solid curve, multichain-model calculation; dashed curve, wounded-nucleon-model calculation; both for $\langle P_{T\pi}\rangle = 0.4$ GeV/c. The arrow indicates the unobserved region.

$Si^{28} + Ag^{107}$ 5 TeV/nucl

First experimental confirmation of

$$\frac{dN(A+A)/dy}{dN(p+p)/dy} \sim (1.5\text{- } 2.0)\ A$$

(and validity of Glauber AA Geometry)

[1] L. D. Landau, Izv. Akad. Nauk SSSR, Ser. Fiz. 17, 51 (1953).

[2] A. Bialas, M. Bleszynski, and W. Czyz, Nucl. Phys. B111, 461 (1976).

[3] K. Kinoshita, A. Minaka, and H. Sumiyoshi, Z. Phys. C 8, 205 (1981).

[4] S. A. Chin, Phys. Lett. 78B, 552 (1978).

[5] T. D. Lee, Columbia University Report No. CU-TP-170, 1981 (unpublished); E. V. Shuryak, Phys. Rep. 61, 71 (1980), and references therein; J. Engels,

Nuclear Physics B289 (1987) 847–860
North-Holland, Amsterdam

First professional pQCD estimate of RHIC initial conditions

THE EARLY STAGE OF ULTRA-RELATIVISTIC HEAVY ION COLLISIONS

J.P. BLAIZOT

SPhT-CEN Saclay, 91191 Gif-sur-Yvette Cedex, France

A.H. MUELLER*

Physics Department, Columbia University, New York, NY 10027, USA

Received 20 February 1987

We investigate the properties of the system of partons produced in the very beginning of ultra-relativistic heavy ion collisions. We propose simple criteria for characterizing the partons which get freed during the collision and which give the dominant contribution to the initial energy density. These partons are found to have an average transverse momentum which grows with the size of the colliding nuclei. Numerical estimates of their initial energy density are given.

the inclusive gluon "jet" cross section is:

$$x\frac{\mathrm{d}\sigma}{\mathrm{d}p_{\mathrm{T}}^2\,\mathrm{d}x}=2\int_0^1\frac{\mathrm{d}x_1}{x_1}x_1G_A(x_1,p_{\mathrm{T}}^2)xG_A(x,p_{\mathrm{T}}^2)\frac{\mathrm{d}\hat{\sigma}}{\mathrm{d}p_{\mathrm{T}}^2}\Theta(x_1xs-4p_{\mathrm{T}}^2), \quad (3.1)$$

where $G_A(x,p_{\mathrm{T}}^2)$ is the usual gluon density of the nucleus. We shall ignore possible correlation effects in the nucleus which could make x greater than 1. Also, in our estimates we shall take $G_A(x,p_{\mathrm{T}}^2)=AG(x,p_{\mathrm{T}}^2)$ with A the number of nucleons and $G(x,p_{\mathrm{T}}^2)$ the gluon number density of the nucleon. $\hat{\sigma}$ is the gluon-gluon cross section given by [6]:

choose p_{T} very small to increase σ. However, (3.8) ceases to be valid when p_{T}^2 is too small since gluon saturation effects become important. Perhaps it is worth reminding the reader of the physical idea behind gluon saturation [7] and why such effects are especially important in large ions.

When $xG_A(x,p_{\mathrm{T}}^2)\gtrsim p_{\mathrm{T}}^2R^2$ different gluons must begin to occupy the same spatial region. Since $xG_A(x,p_{\mathrm{T}}^2)\simeq AxG(x,p_{\mathrm{T}}^2)$ one sees that this dense configuration is enhanced in large nuclei with strong interactions expected between the quanta when $p_{\mathrm{T}}^2\sim\alpha A/R^2$. (The factor of α, to be derived below, reflects the fact that the overlapping gluons interact (recombine) with strength α.) Thus, the actual transition from a low density to a high density gluonic system occurs at $xG_A(x,p_{\mathrm{T}}^2)\gtrsim p_{\mathrm{T}}^2R^2/\alpha$.

[7] L.V. Gribov, E.M. Levin and M.G. Ryskin, Phys. Reports 100 (1983) 1

In order to get numerical estimates, let's take $A^{1/3} = 6$, $R = 1.2\,A^{1/3}$ fm, $xG = 3$ and $\alpha = \frac{1}{3}$, i.e. $\alpha C_A = 1$ (the value $xG = 3$ is reasonable, even traditional, but at this time it is not a well determined quantity, experimentally). Then eq. (3.15) gives $p_T \approx 0.94$ GeV, i.e. $\tau_0 \sim 0.2$ fm$/c$, and one finds:

$$\frac{dN}{dy} \approx 1300\,, \tag{4.3a}$$

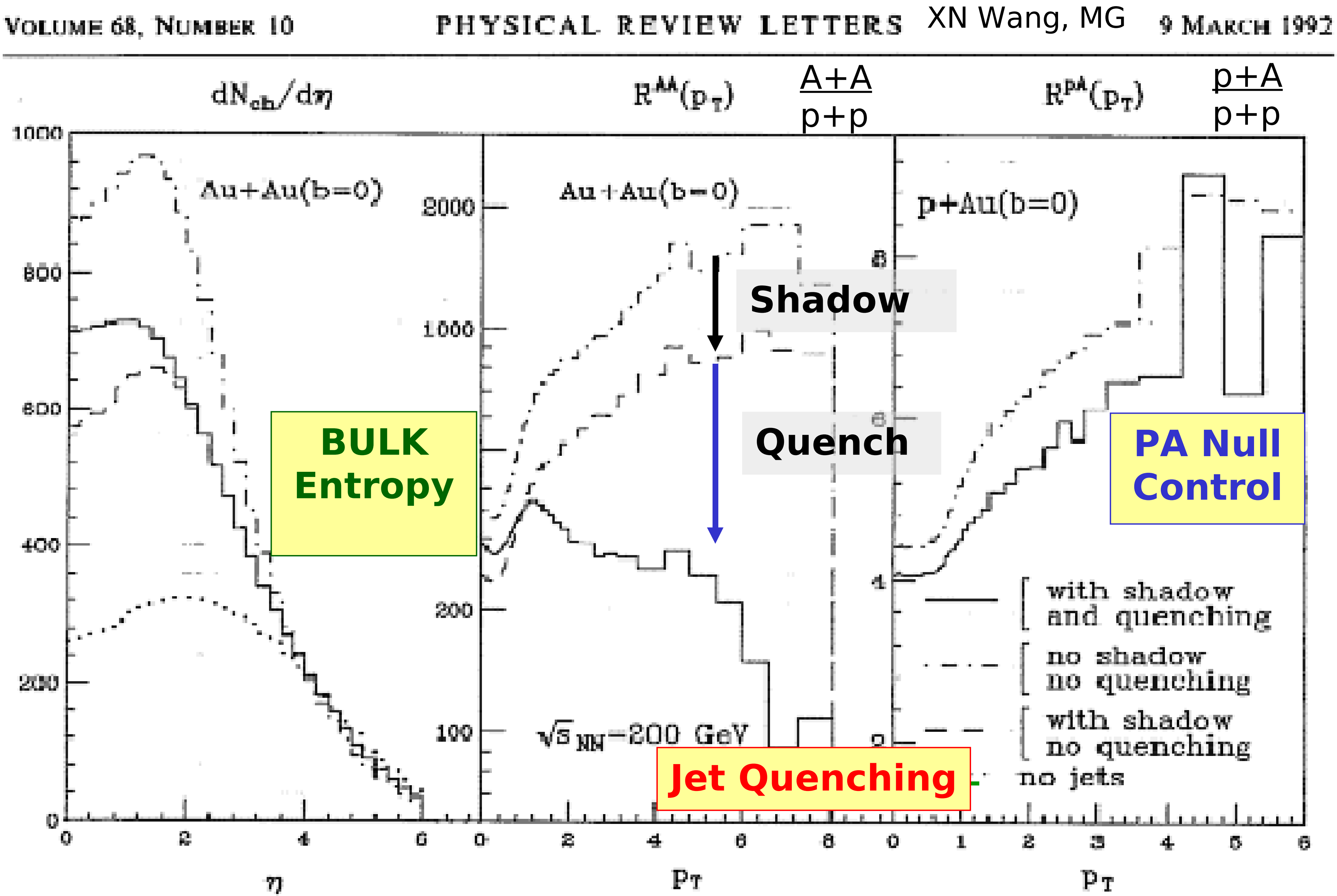
$$\frac{dE_T}{dy} \approx 1.2 \text{ TeV}\,, \tag{4.3b}$$

$$n \approx 37/\text{fm}^3\,, \tag{4.3c}$$

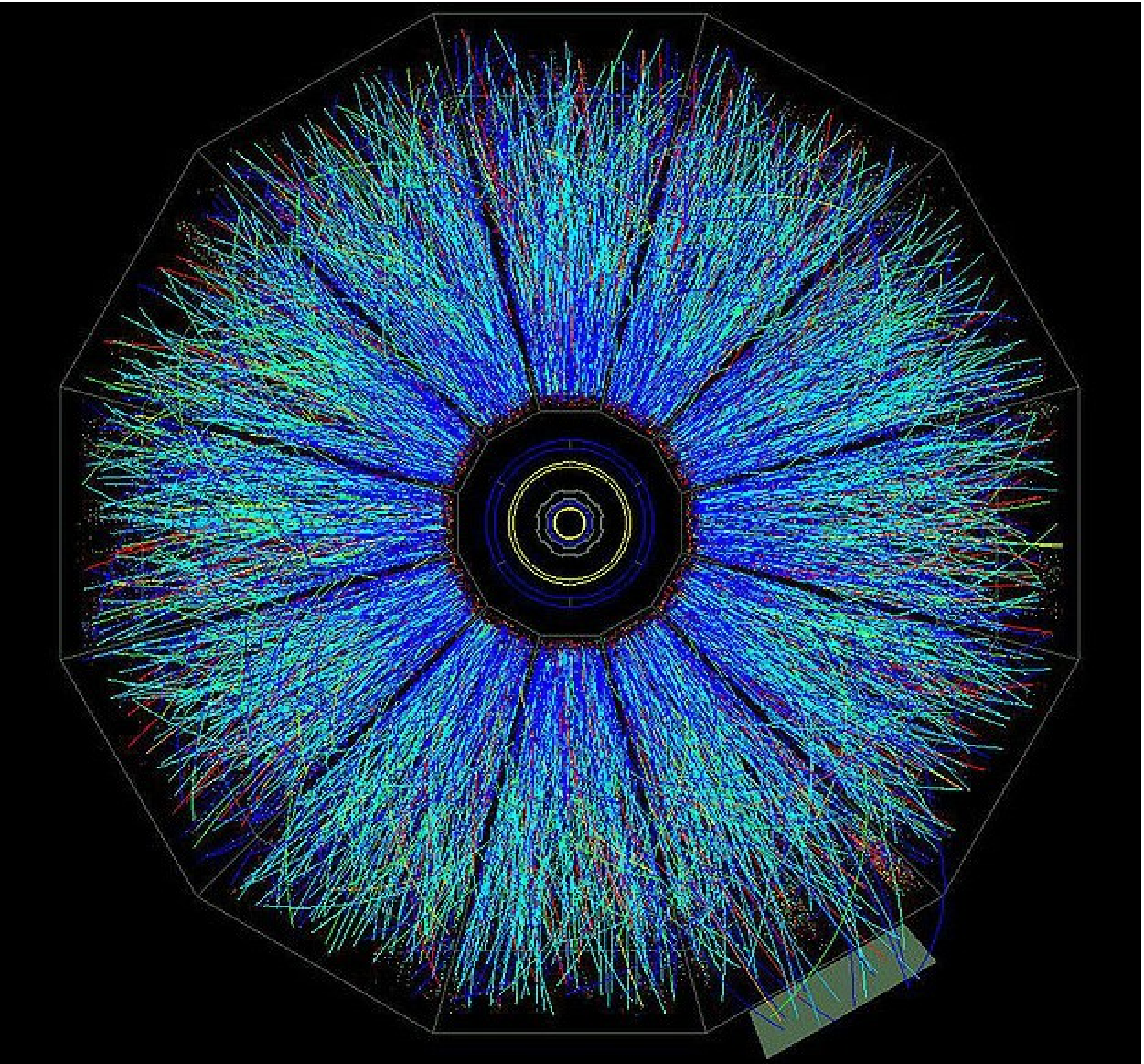
$$\varepsilon \approx 35 \text{ GeV}/\text{fm}^3\,. \tag{4.3d}$$

Our second estimate gives $p_T \approx 0.65$ GeV, eq. (3.25), and hence $\tau_0 \sim 0.3$ fm, $n \approx 25/\text{fm}^3$, and $\varepsilon \approx 17$ GeV$/\text{fm}^3$. These large numbers reflect the large value of the optimum p_T in large nuclei. They correspond for $A = 1$, that is for proton-proton or

again that this is meant to serve only as a rough estimate and not as a substitute to a decent treatment of the thermalization problem. In any case, energy densities such as those given above are sufficiently high that heavy ion collisions involve new and interesting aspects of QCD independently or not a true equilibrium is reached.



Our HIJING = multi minijets + strings Monte Carlo predictions for RHIC at 200 AGeV cm



First STAR TPC
event at RHIC

“Day 1” discovery

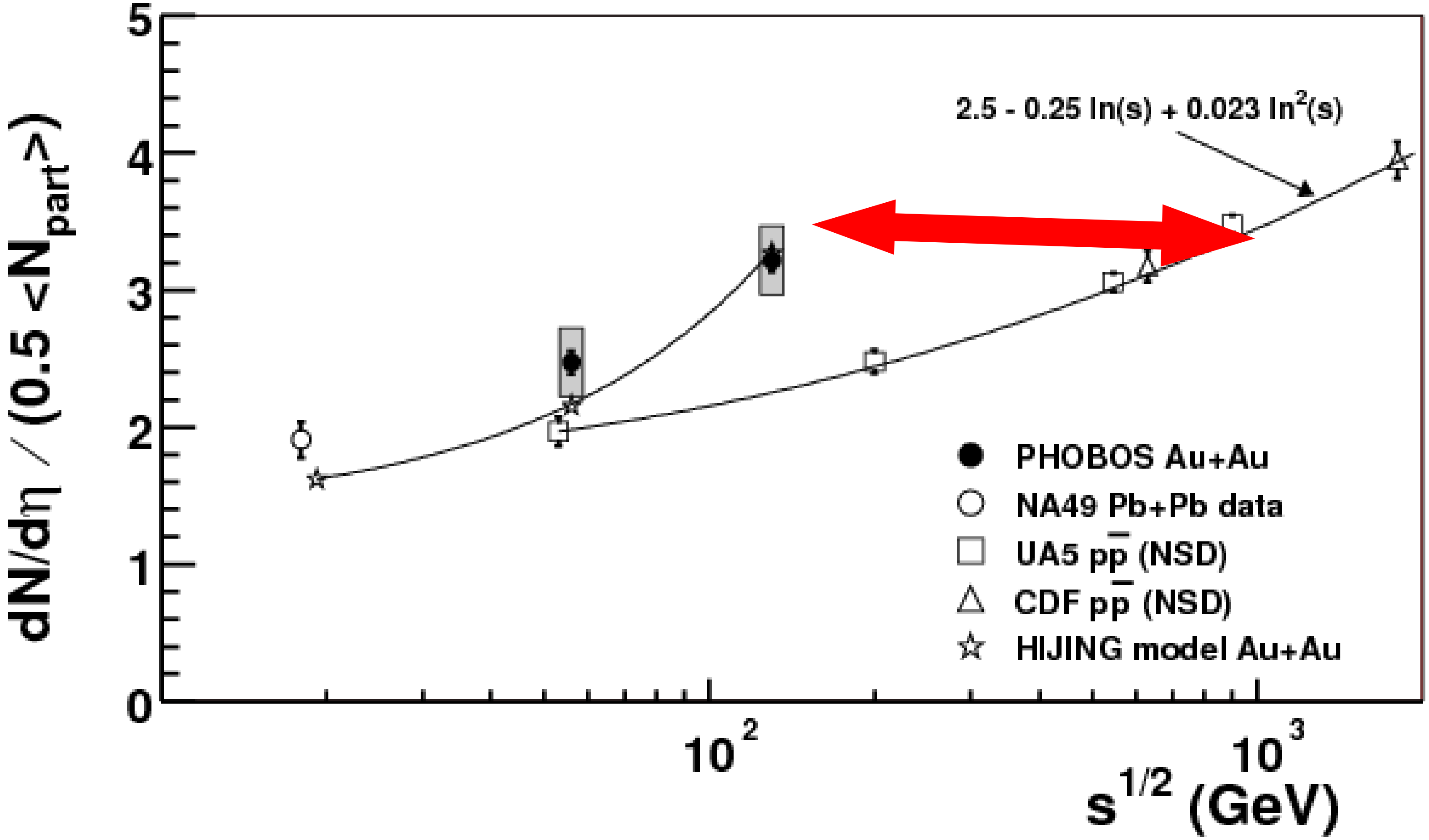
Elliptic Flow
in Au+Au
Collisions
at 130 GeV

Sep. 12, 2000
PRL86 (2001)
402

Charged-Particle Multiplicity near Midrapidity in Central Au + Au Collisions at $\sqrt{s_{NN}} = 56$ and 130 GeV

First Phobos
PRL 7/20/00

$A^{1/3}$ factor seen !
BGK or Minijets seen!



XN Wang, MG

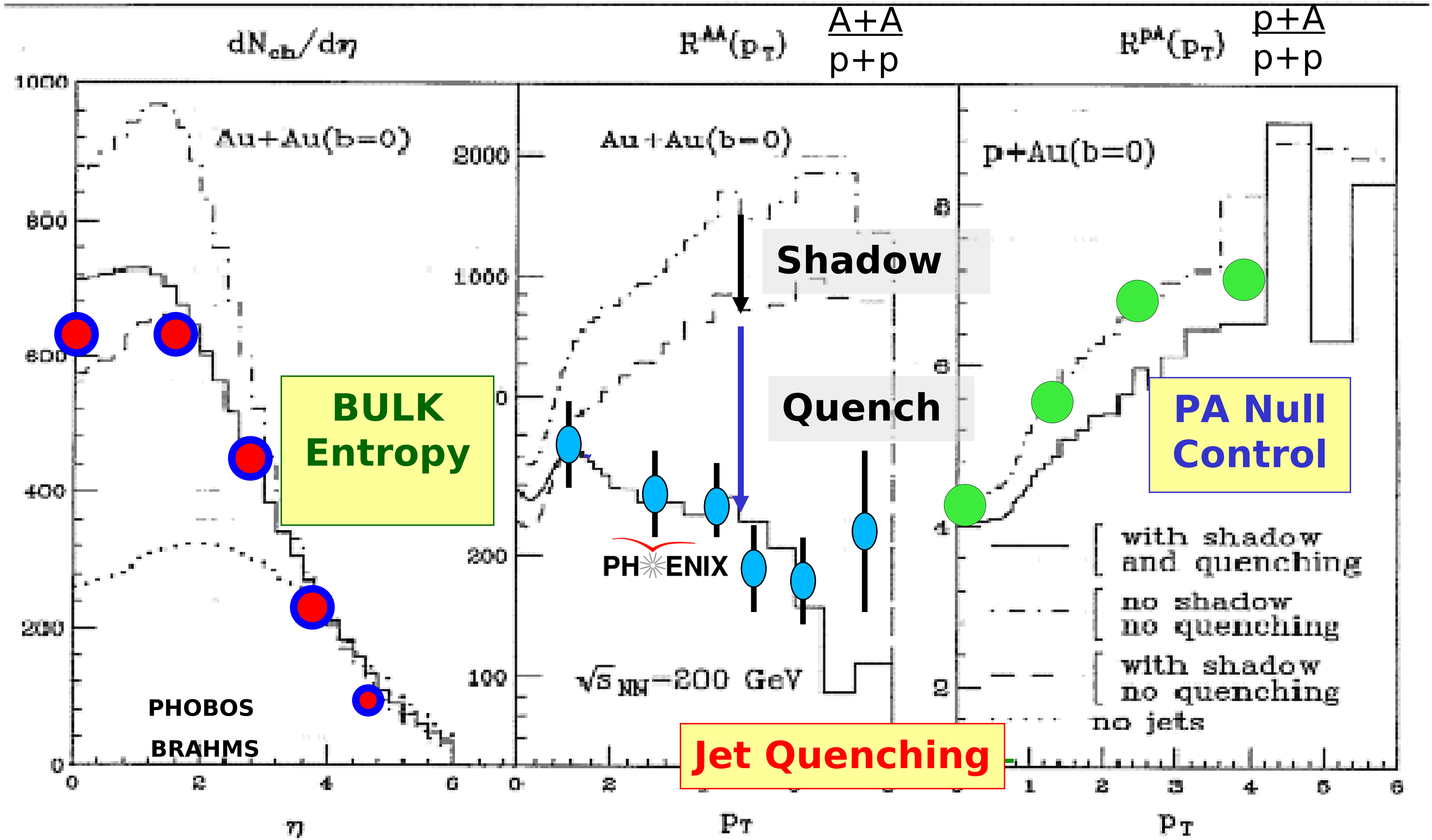


FIG. 1. Results of HIJING on the dependence of the inclusive charged-hadron spectra in central Au+Au and $p+$Au collisions on minijet production (dash-dotted line), gluon shadowing (dashed line), and jet quenching (solid line) assuming that gluon shadowing is identical to that of quarks and $dE/dl = 2$ GeV/fm with $\lambda_s = 1$ fm. $R^{AB}(p_T)$ is the ratio of the inclusive p_T spectrum of charged hadrons in $A+B$ collisions to that of $p+p$.

PHENIX data by 2003

PHENIX QGP birth day announcement (in disguise)

(Received 18 June 2003; published 15 August 2003)

VOLUME 91, NUMBER 7 PHYSICAL REVIEW LETTERS week ending 15 AUGUST 2003

Absence of Suppression in Particle Production at Large Transverse Momentum in $\sqrt{s_{NN}} = 200$ GeV d + Au Collisions

VOLUME 91, NUMBER 7 PHYSICAL RE

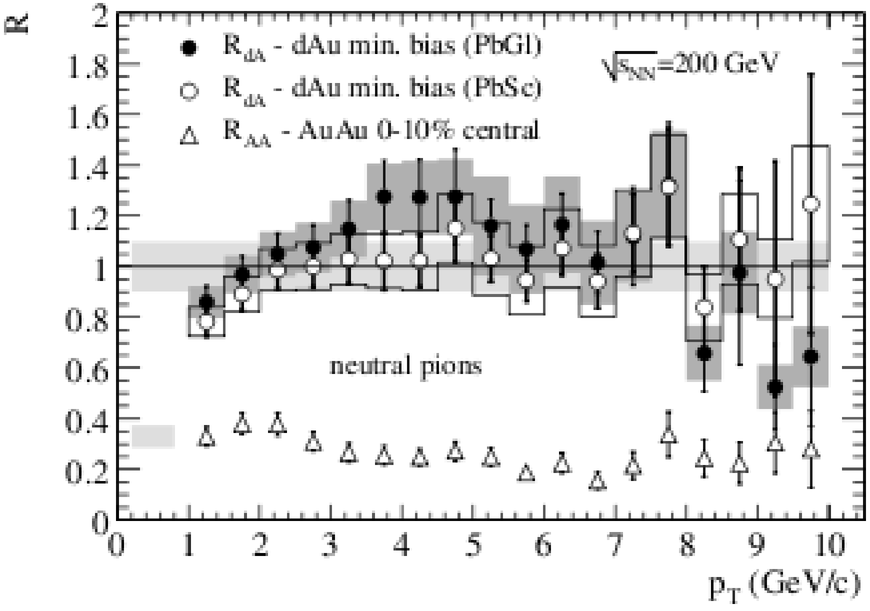


FIG. 2. Nuclear modification factor R_{dA} for π^0 in the PbGl

By 2004 first 275 RHIC publications

22 (4 PRL) from BRAMHS

92 (15 PRL) from PHENIX

34 (6 PRL) from PHOBOS

127 (21 PRL) from STAR

Plus SPS/CERN data base E<20 AGeV

(108: NA49/35, 69: NA50/38, 26: CERES/NA45,

79: WA98/80, 32: na57/wa97)

Conviced TD, L.McLerran, and me that two new forms of matter, sQGP and CGC, were discovered at RHIC. So we organized a RBRC Workshop to work out the details

Wit Busza acted as honest referee to keep the fighting as clean as possible.

Three Lines of Empirical Evidence in 2004 converged to QGP Discovery

QGP =P_{QCD} + pQCD + dA = v_2 + $(R+I)_{AA}$ + $(R+I)_{DA}$

- **Unique long wavelength collective properties**
  - **Elliptic flow ⇔ P_{QCD}**
- **Unique short wavelength dynamical properties**
  - **Jet Quenching ⇔ pQCD**
- **Conclusive Null Control with D+Au**

RHIC QGP = sQGP ≠ wQGP

Part II: The plot **thickens** and the ante goes up 9/24/04
PHENIX *kills* the dead cone
and pQCD jet quenching predictions of it

Extension of BDMSP formalism for energy loss:
R.Baier, Y.L.Dokshitzer, A.H.Mueller, S.Peigne and D.Schiff, NPB483,B484 1997

to Heavy quark jets

"Heavy quark colorimetry of QCD matter"
Y.Dokshitzer, D. Kharzeev PLB591 (2001)

Finite quark mass effects lead to an in-medium enhance- ment of the heavy–to–light D/π ratio at moderately large (5–10 GeV)

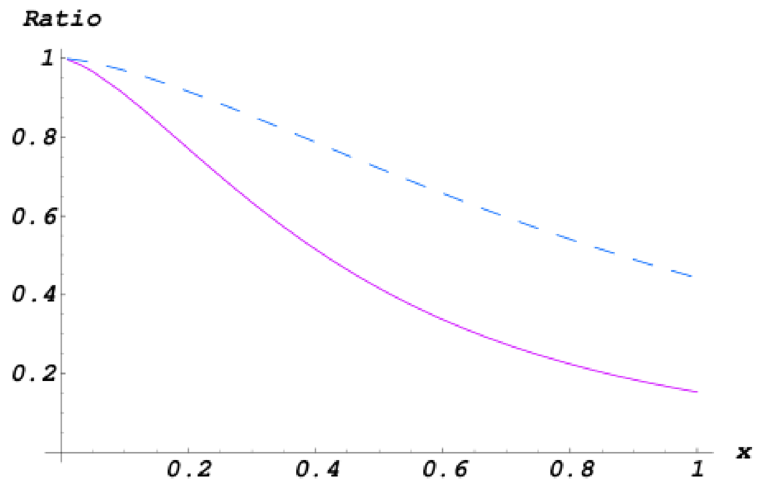


Figure 1: Ratio of gluon emission spectra off charm and light quarks for quark momenta $p_\perp = 10\,\mathrm{GeV}$ (solid line) and $p_\perp = 100\,\mathrm{GeV}$ (dashed); $x = \omega/p_\perp$.

DGLV Theory of Mass M Quark Jet radiation + thermal dispersion glue n-th order in opacity induced gluon radiation

$$x\frac{dN^{(n)}}{dx\,d^2\mathbf{k}} = \frac{C_R\alpha_s}{\pi^2}\frac{1}{n!}\int\prod_{i=1}^{n}\left(d^2\mathbf{q}_i\,\frac{L}{\lambda_g(i)}\left[\bar{v}_i^2(\mathbf{q}_i)-\delta^2(\mathbf{q}_i)\right]\right)$$

$$\times\left(-2\tilde{\mathbf{C}}_{(1,\ldots,n)}\sum_{m=1}^{n}\tilde{\mathbf{B}}_{(m+1,\ldots,n)(m,\ldots,n)}\right.$$

$\Delta z_k = z_k - z_{k-1} \sim L/(n+1)$

Formation Time
QCD LPM Effect

$$\left.\times\left[\cos\left(\sum_{k=2}^{m}\Omega_{(k,\ldots,n)}\Delta z_k\right)-\cos\left(\sum_{k=1}^{m}\Omega_{(k,\ldots,n)}\Delta z_k\right)\right]\right)$$

$$\omega_{(m,\ldots,n)} = \frac{(\mathbf{k}-\mathbf{q}_m-\cdots-\mathbf{q}_n)^2}{2xE} \rightarrow \Omega_{(m,\ldots,n)} \equiv \omega_{(m,\ldots,n)} + \frac{m_g^2+M^2x^2}{2xE}.$$

Current elements
“Dead Cone”

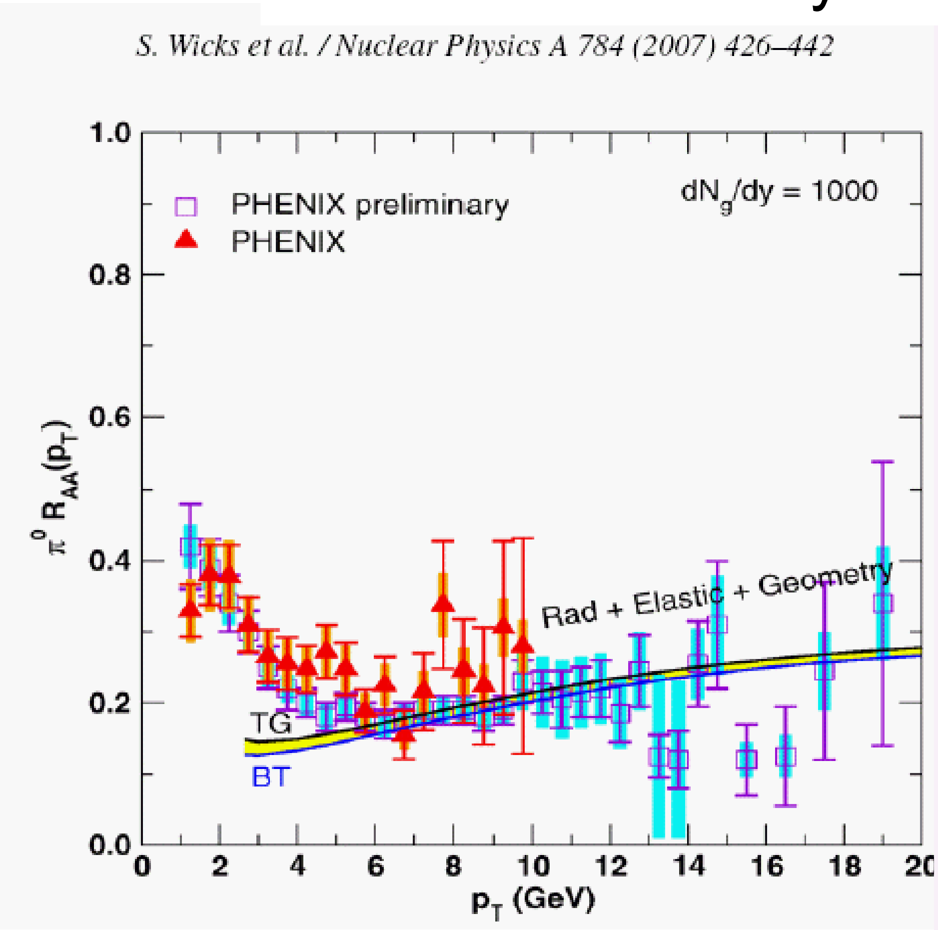
$$\tilde{\mathbf{H}} = \frac{\mathbf{k}}{\mathbf{k}^2+m_g^2+M^2x^2},$$

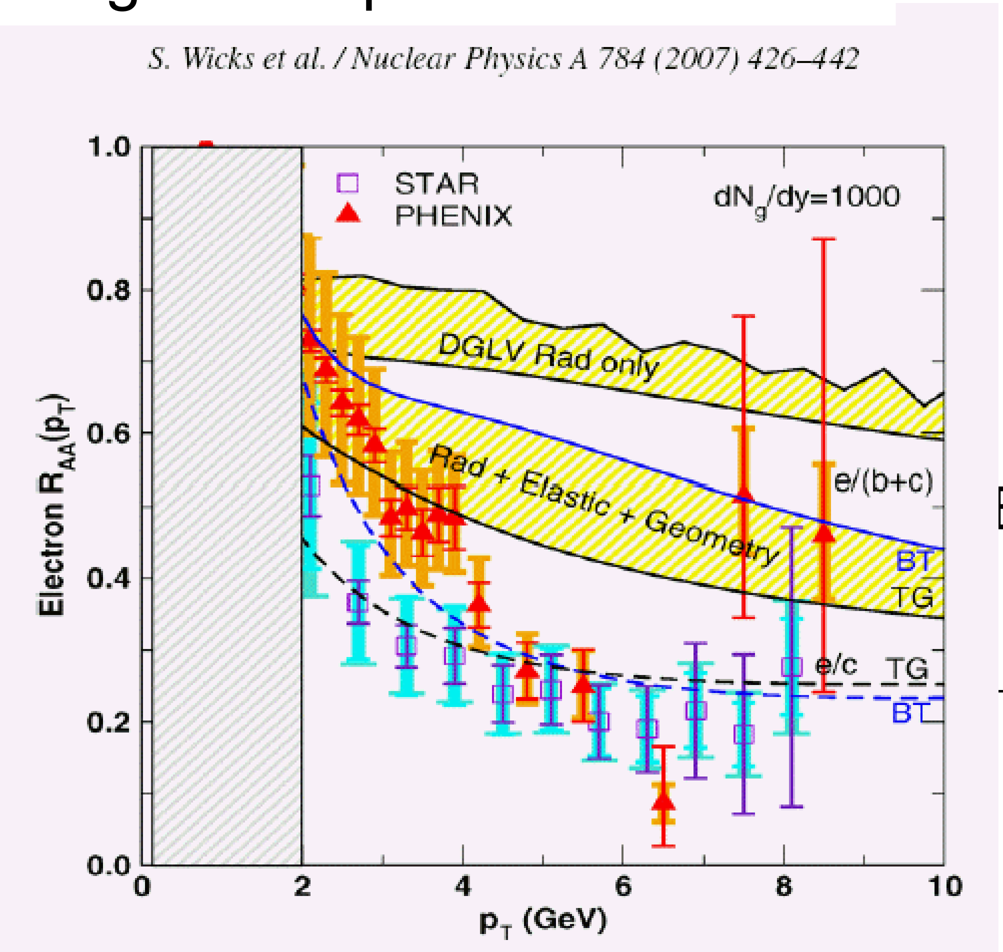
$$\tilde{\mathbf{C}}_{(i_1i_2,\ldots,i_m)} = \frac{(\mathbf{k}-\mathbf{q}_{i_1}-\mathbf{q}_{i_2}-\cdots-\mathbf{q}_{i_m})}{(\mathbf{k}-\mathbf{q}_{i_1}-\mathbf{q}_{i_2}-\cdots-\mathbf{q}_{i_m})^2+m_g^2+M^2x^2}$$

$$\tilde{\mathbf{B}}_i = \tilde{\mathbf{H}}-\tilde{\mathbf{C}}_i,$$

$$\tilde{\mathbf{B}}_{(i_1i_2,\ldots,i_m)(j_1j_2,\ldots,j_n)} = \tilde{\mathbf{C}}_{(i_1i_2,\ldots,j_m)}-\tilde{\mathbf{C}}_{(j_1j_2,\ldots,j_n)}.$$

The Bottom Quark jet quenching data stumped us all !
How can a heavy bowling ball stop in air ?





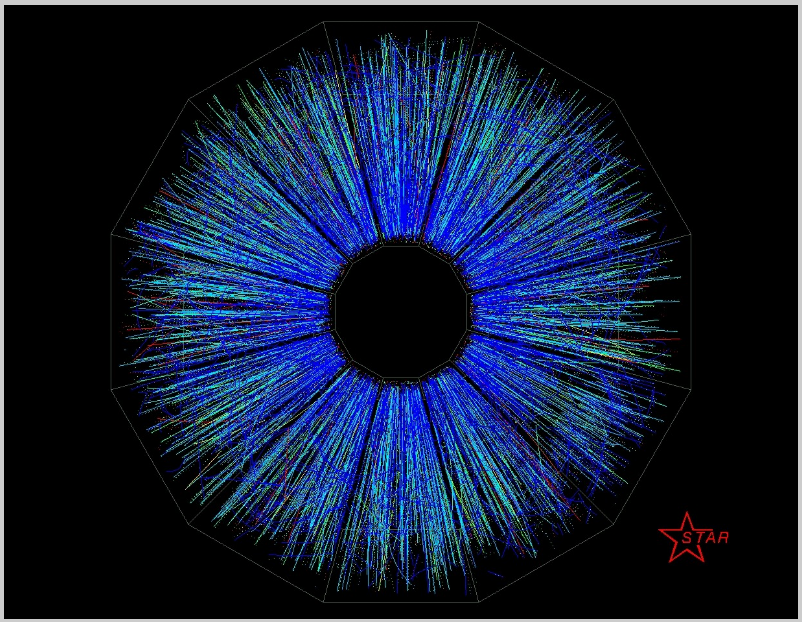
Both c+b

– c only

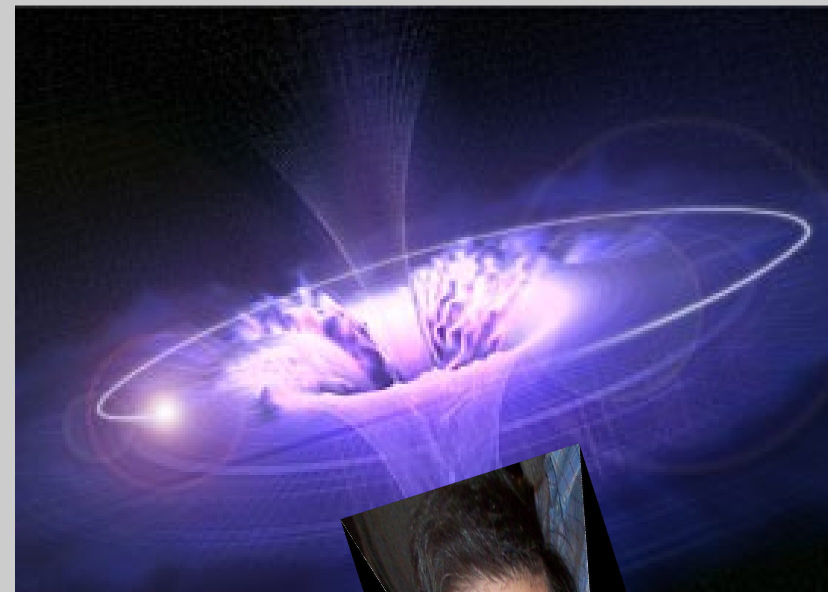
Electron data seems to falsify pQCD radiative loss theory
even after bells and whistles (elastic+geom fluc) added
Recent RHIC data closed the b/c loophole
observed b/c ~ 1 => pQCD HQ production OK but quenching is not

 Simon Wicks, William Horowitz, Magdalena Djordjevic, MG 2007

Should we abandon QCD and follow Ed and Dam into the 5D AdS Black Hole to describe Quark Gluon Plasmas at RHIC?



? =

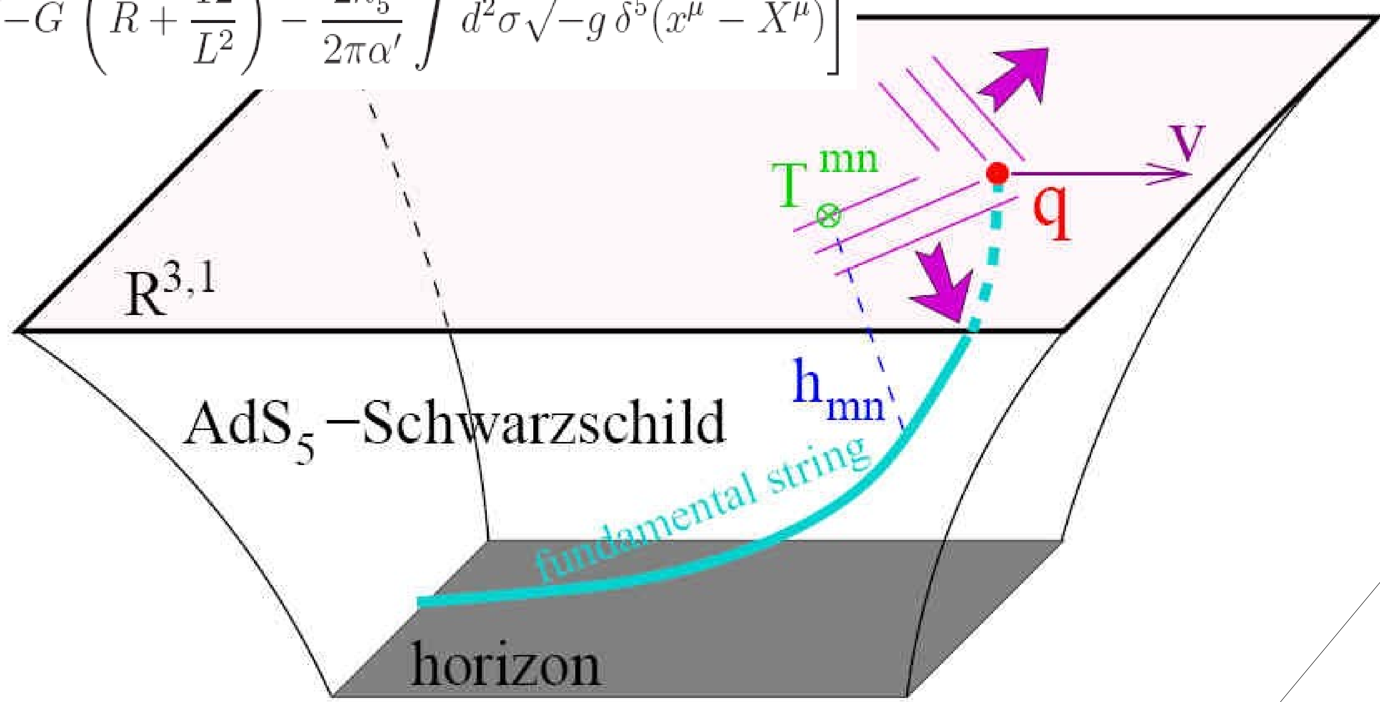


Ed may want to stop his clock, but we better Keep one foot on this side of the horizon.

3. Jet Quenching in AdS/CFT

Gubser et al
Herzog et al

$$S = \frac{1}{2\kappa_5^2}\int d^5x\left[\sqrt{-G}\left(R+\frac{12}{L^2}\right) - \frac{2\kappa_5^2}{2\pi\alpha'}\int d^2\sigma\sqrt{-g}\,\delta^5(x^\mu - X^\mu)\right]$$

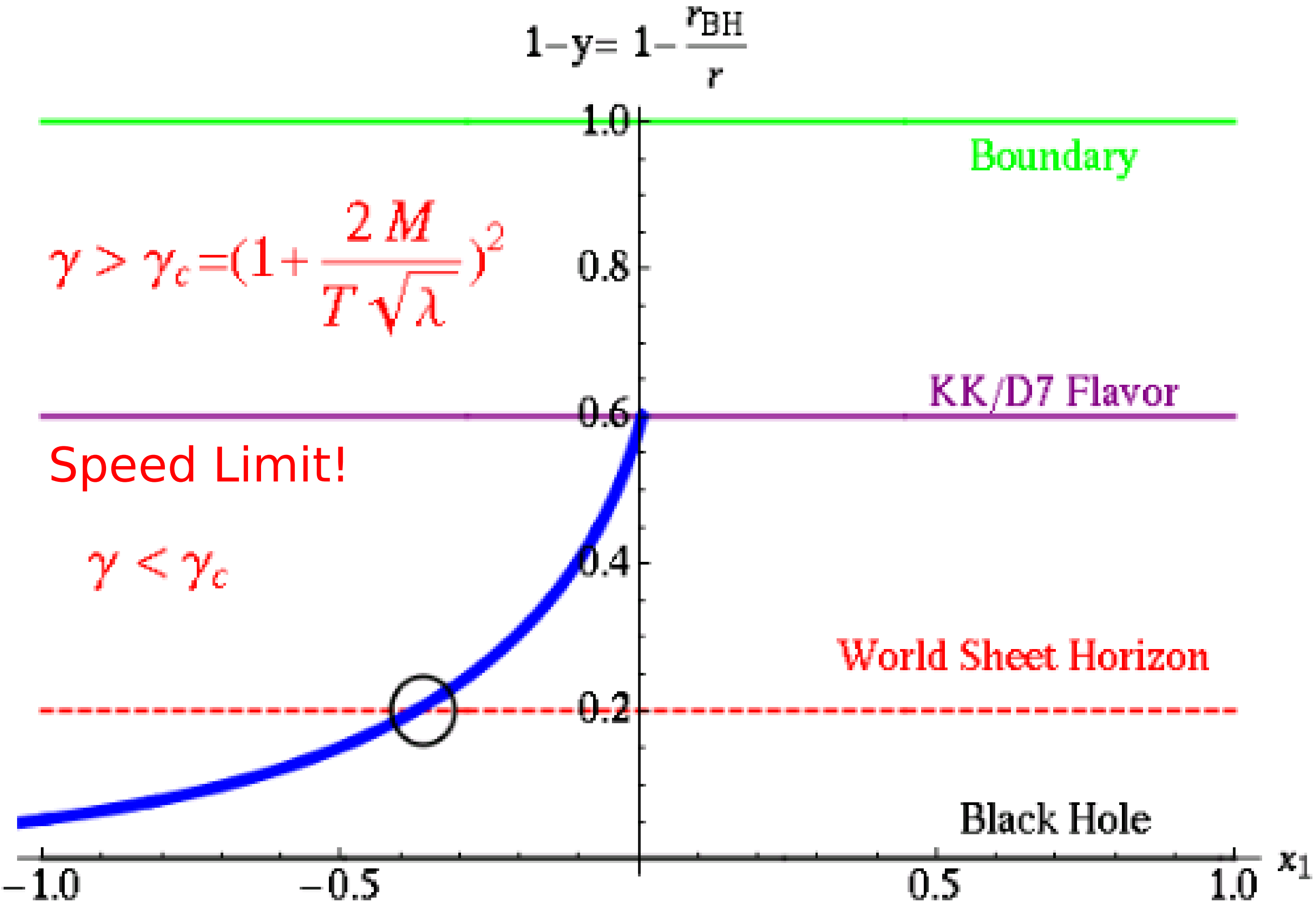


Very different from pQCD

$$\frac{dp_T}{dt} = -\mu_Q p_T = -\frac{\pi\sqrt{\lambda}(T^*)^2}{2M_Q}p_T, \qquad (1)$$

where T^* is the temperature of the SYM plasma as fixed by the Hawking temperature of the dual D3 black brane.

Even Al dived into the AdS Black Brane to save his Qsat



Karsh,Katz

Speed Induced Worlsheet Horizon at coordinate

$$1 - y_S = 1 - \sqrt{\sqrt{1 - v^2}} = 1 - \frac{1}{\sqrt{\gamma}}$$

Gubser et al 07

(**Saturation scale** $Q_s = \sqrt{\gamma}\,\pi T$)

A.Mueller et al

1) Stochastic trailing string and Langevin dynamics from AdS/CFT.
G.C. Giecold, E. Iancu, (Saclay, SPhT) , A.H. Mueller, (Columbia U.) . Mar 2009. 26pp.
Published in JHEP 0907:033,2009. e-Print: arXiv:0903.1840 [hep-th]

2) Deep inelastic and dipole scattering on finite length hot N=4 SYM matter.
A.H. Mueller, (Columbia U.) , A.I. Shoshi, (Bielefeld U.) , Bo-Wen Xiao, (LBL, Berkeley) . Dec 2008. 26pp.
Published in Nucl.Phys.A822:20-40,2009. e-Print: arXiv:0812.2897 [hep-th]

3) Jet evolution in the N=4 SYM plasma at strong coupling.
Y. Hatta, (Tsukuba U., GSPAS) , E. Iancu, (Saclay, SPhT) , A.H. Mueller, (Columbia U.) . Mar 2008. 37pp.
Published in JHEP 0805:037,2008. e-Print: arXiv:0803.2481 [hep-th]

4) Comparing energy loss and p-perpendicular - broadening in perturbative QCD with strong coupling N = 4 SYM theory. Fabio Dominguez, (Columbia U.) , C. Marquet, (Saclay, SPhT & Columbia U.) , A.H. Mueller, (Columbia U.) , Bin Wu, (Peking U. & Columbia U.) , Bo-Wen Xiao, (Columbia U.) . Mar 2008. 33pp.
Published in Nucl.Phys.A811:197-222,2008. e-Print: arXiv:0803.3234 [nucl-th]

5) Deep inelastic scattering at strong coupling from gauge/string duality: The Saturation line.
Y. Hatta, E. Iancu, (Saclay, SPhT) , A.H. Mueller, (Columbia U.) . Oct 2007. 40pp.
Published in JHEP 0801:026,2008. e-Print: arXiv:0710.2148 [hep-th]

6) Deep inelastic scattering off a N=4 SYM plasma at strong coupling.
Y. Hatta, E. Iancu, (Saclay, SPhT) , A.H. Mueller, (Columbia U.) . Oct 2007. 36pp.
Published in JHEP 0801:063,2008. e-Print: arXiv:0710.5297 [hep-th]

Al @70 and colleagues are now somewhere in the depths of the AdS Black Hole

Will they tunnel back to our illusionary MATRIX QCD like world?

Gubser, Klebanov, Tseytlin (98)
Gubser, PRD74 (06)
Buchel, Myers, Sinha, Paulos (08,09)

Kats, Petrov 07
Brigante 08
Maldacena Hoffman 08

The *Lure* of Black Holes Hard & Soft Phenomena @ RHIC

J. Noronha, M. Gyulassy, G. Torrieri, hep-ph: 0906.4099

The idea is to use both $R^2 \propto \lambda_{GB} \sim 1/N_c$ *and* $R^4 \propto \lambda^{-3/2}$ *pertubations* to R^1 (AdS_5)

(2) $$\frac{\eta}{s} = \frac{1}{4\pi}\left(1 - 4\lambda_{GB} + 15\frac{\zeta(3)}{\lambda^{3/2}}\right)$$

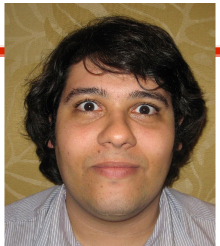
(1) $$\frac{s}{s_{SB}} = \frac{3}{4}\left(1 + \lambda_{GB} + \frac{15}{8}\frac{\zeta(3)}{\lambda^{3/2}}\right)$$

Heavy quark energy loss

(3) $$\frac{dp}{dt} = -\frac{\sqrt{\lambda}\pi T^2}{2M_Q}\left(1 + \frac{3}{2}\lambda_{GB} + \frac{15}{16}\frac{\zeta(3)}{\lambda^{3/2}}\right)$$

To compute

$$R^e_{AA} \times v_2$$



*** New result J. Noronha**

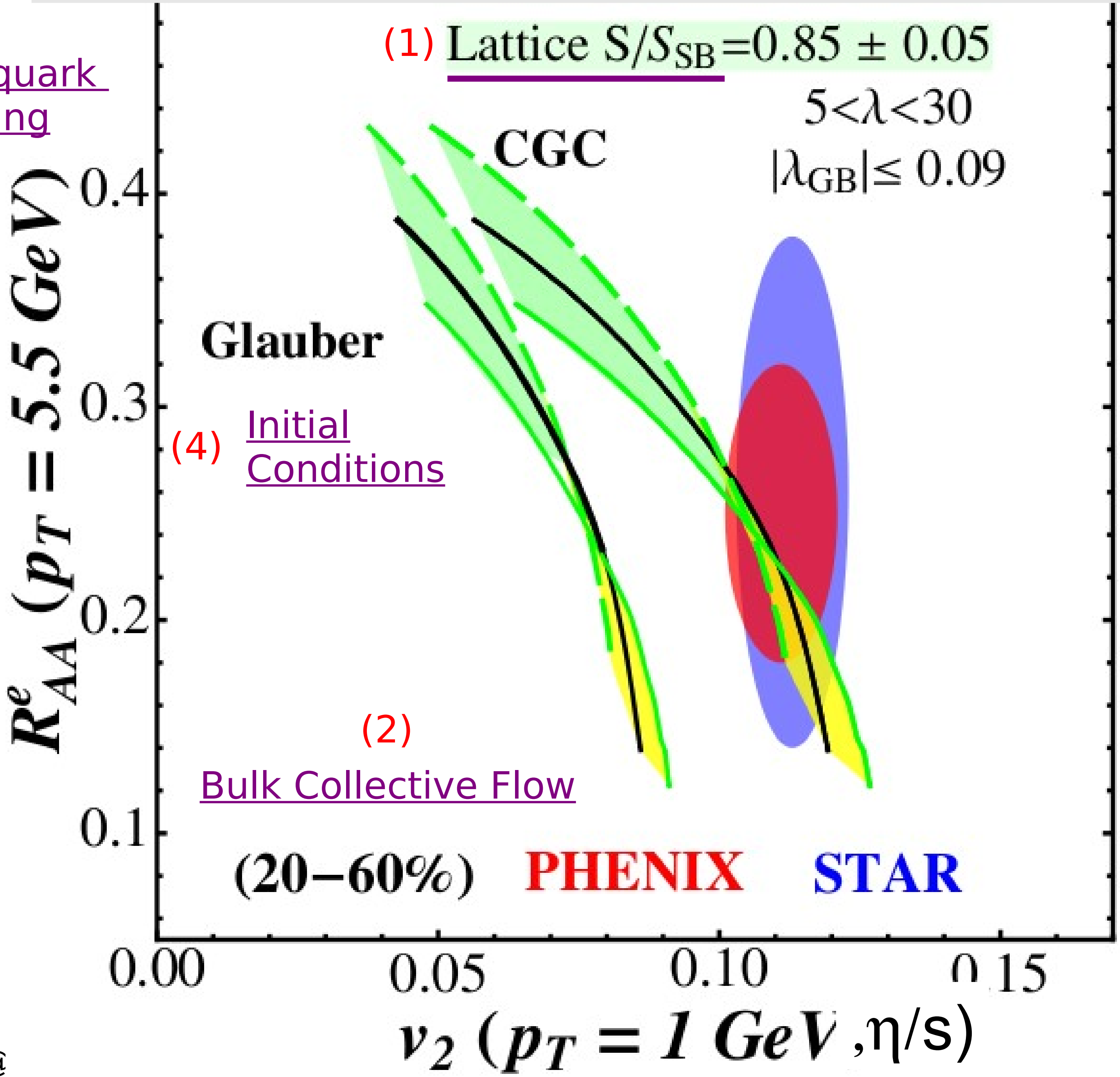
*Predicts *analytic* correlations between soft thermo, transport, *and* hard nonequilib dynamics for the first time !

5 Fold AA correlations! described by the sQGP ~ AdS BH paradigm

J. Noronha, MG, G. Torrieri, hep-ph: 0906.4099

(1) Lattice S/S_{SB}=0.85 ± 0.05

(3) Heavy quark Jet quenching



(4) Initial Conditions

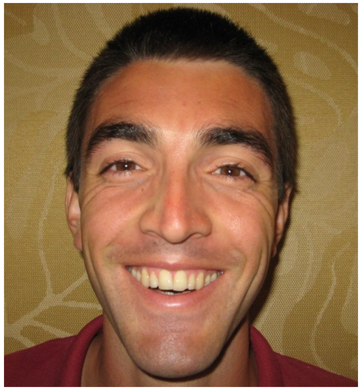
(2) Bulk Collective Flow

(5) Heavy quark Jet induced collective flow

The Future

Part 3: Can Radiative Energy Loss

at *intermediate* opacity $(L/\lambda)^{N\sim7}$ rescue pQCD?



Alessandro Buzzatti, Andrej Ficnar, MG, Simon Wicks,
(work in progress)

"DGLV-BFW-MC1.0: High Order DGLV Monte Carlo Radiative Energy Loss"

The only practical numerical tool to compute intermediate order up to N=10 is brute force Monte Carlo

Simon Wicks in 2008, Buzzatti, Ficnar 2009

1) Sample 2N vec(q_i) momentum kicks
   from given v(q_i) differential distribution

2) Sample N collision points from Glauber multiple scatt

3) Evaluate integrand n~ 10^7 times for each x, kT point

4) Wait a 3^N minutes until job done and plot answer

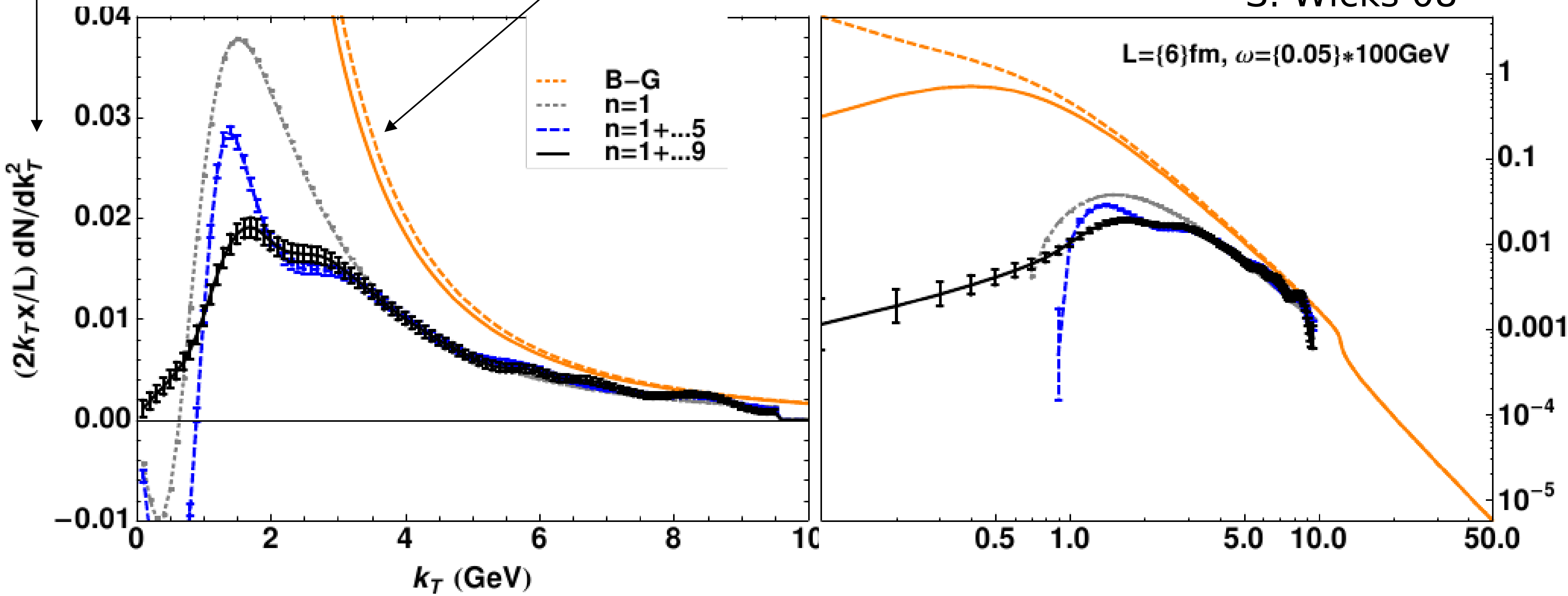
results for x=0.05, ω=5 GeV, Ejet=100 GeV, L/λ = 6

(x/L) dN/dxdk

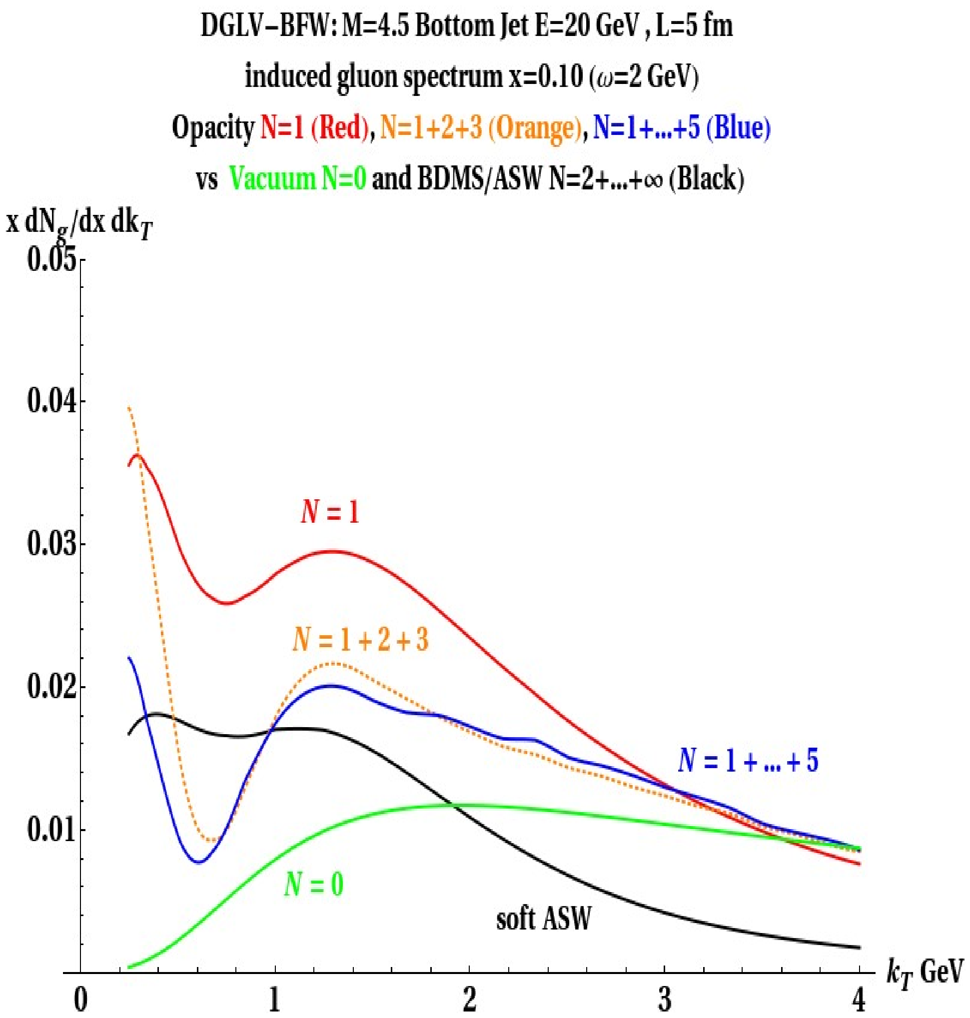
λ= 1fm, μ = 0.5 GeV

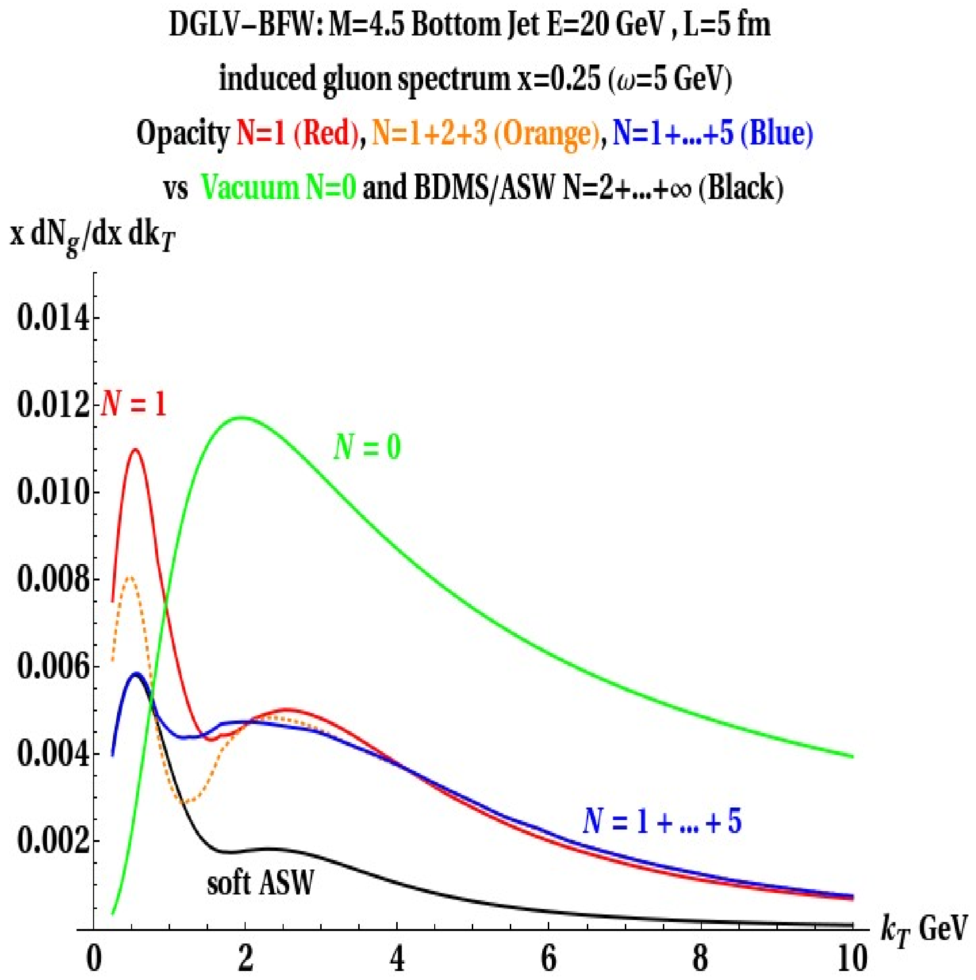
Bertsch-Gunion incoherent 'limit' * L/x

S. Wicks 08



First results with DGLV-BFW MC Heavy Quark Quenching





Compared to multi soft Armesto Salgado Wiedemann
finite kinematics extension of BDMSP and the vacuum dead cone

Happy Birthday, Al

Physics has never been so fun and full of opportunities

The LHC energy frontier is just about to open

May you enjoy the pleasures of its physics and discoveries

and keep guiding us on the right trails