Nuclear Theory at BNL

Goal: First Principles Understanding of Strong Interactions

How are strongly interacting particles made from fundamental constituents?

How do the fundamental interactions in QCD produce quark confinement and mass?

What is the behaviour of strongly interacting matter in bulk?
Nuclear Matter $\rightarrow$ Quark Gluon Plasma

All of these issues are intertwined!

Efforts in:
Nuclear Theory Group
Riken-BNL Center
High Energy Physics Group

Nuclear Theory at BNL

Current Interests:

Quark-Gluon Plasma:
New form of matter
Confinement and mass generation.
Equation of state

Color-Glass Condensate:
New form of matter
Universal matter determine high energy limit
Origin of quark and gluon distributions.

Structure of Strongly Interacting Particles:
Origin of spin
Distribution functions and weak coupling
QCD tests

Lattice Gauge Theory:
Masses and matrix elements of hadrons
Properties of QGP and hadronic matter
Extraction of mixing angles and tests of standard model

Nuclear Structure and Hypernuclei
Nature of Hyperon Interactions

Nuclear Theory at BNL
Strength of Effort:

Nuclear Theory:
6 Senior Staff supported by DOE
2 Senior Staff 1/2 by RIKEN-BNL
1 Senior Staff supported by SCIDAC
3 Postdocs by DOE Nuclear Theory
(1/2 Humboldt, 1/2 Riken)
1 Postdoc on Scidac

RIKEN-BNL Center:
8 RIKEN Fellows (1/2 time at lab)
6 Postdocs on Lattice Gauge Theory
3 Postdocs on QGP and CGC.
1/2 Postdoc on Spin

High Energy Theory:
1 Senior Staff on QGP
2 Senior Staff on Lattice Gauge Theory
1 Senior Staff on Spin

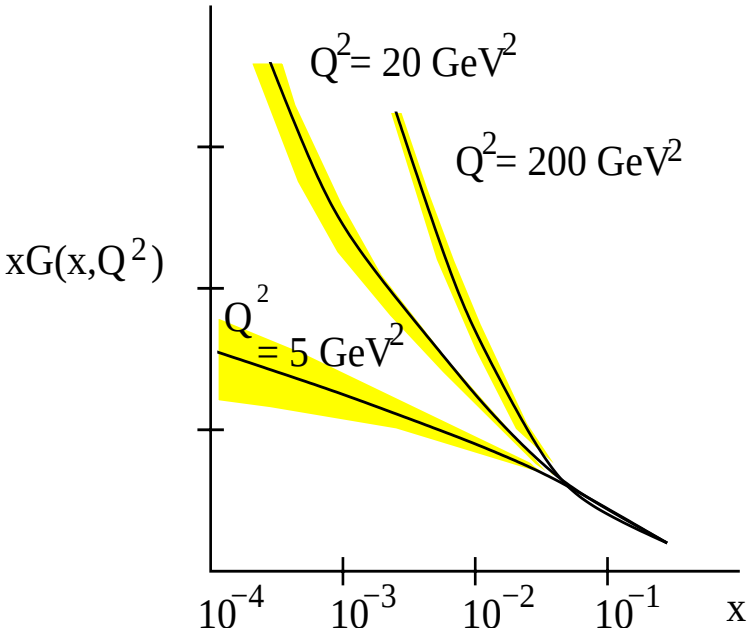
Publications and Citations

Name:	After 1992	After 1997	After 2001
Baltz	21 (405)	11 (245)	6 (29)
Jung	———	22 (54)	6 (20)
Kahana	27 (353)	15 (94)	6 (20)
Kharzeev	88 (1849)	50 (843)	23 (270)
Petreczky	———	34 (346)	20 (185)
Millener	11 (102)	6 (15)	4 (3)
McLerran	61 (2884)	41 (964)	23 (497)
Venugopalan	57 (1962)	35 (619)	14 (148)
Vogelsang	76 (2313)	48 (1014)	14 (325)

SPIRES underweights nuc. structure!

Nuclear Theory at BNL:

Color Glass Condensate:

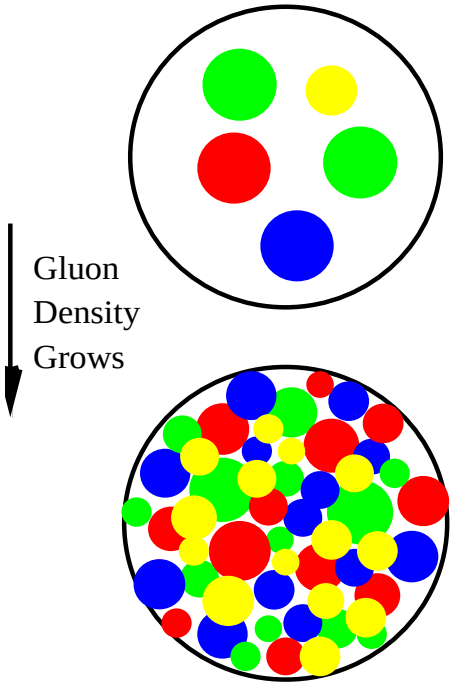


HERA data:
Gluon density grows

New form of matter:

Color:
Colored glue

Glass:
Lorentz time dilation
of sources of wee glue

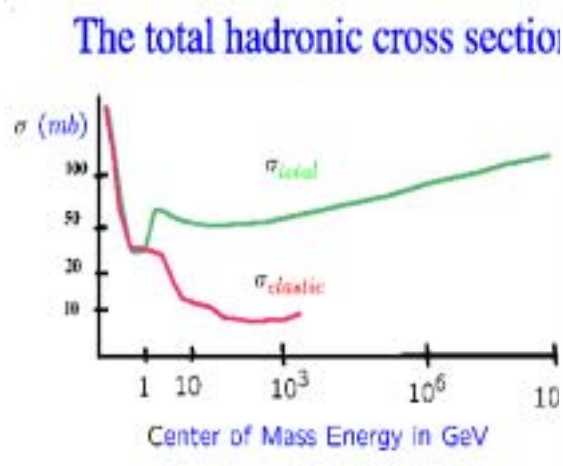


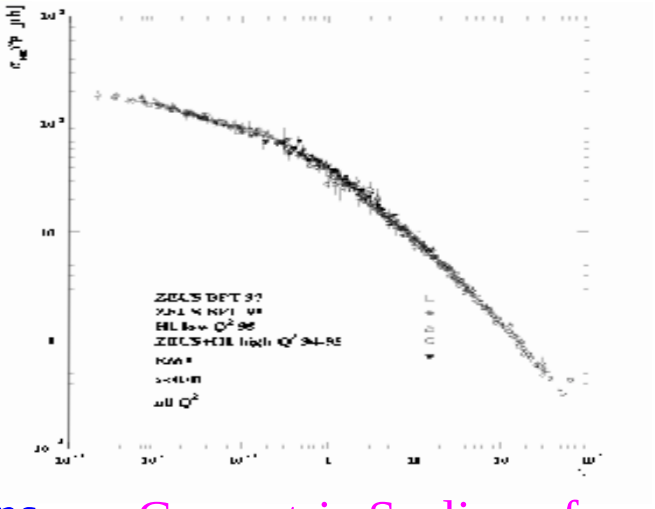
Condensate:
Density is as
high as possible
$\rho \sim 1/\alpha_s$

A new scale appears:
$Q^2_{sat} \sim density/area$

Weakly coupled but strongly interacting matter!

Nuclear Theory at BNL
Color Glass Condensate





High Energy Cross Sections Computed

Geometric Scaling of DIS Explained

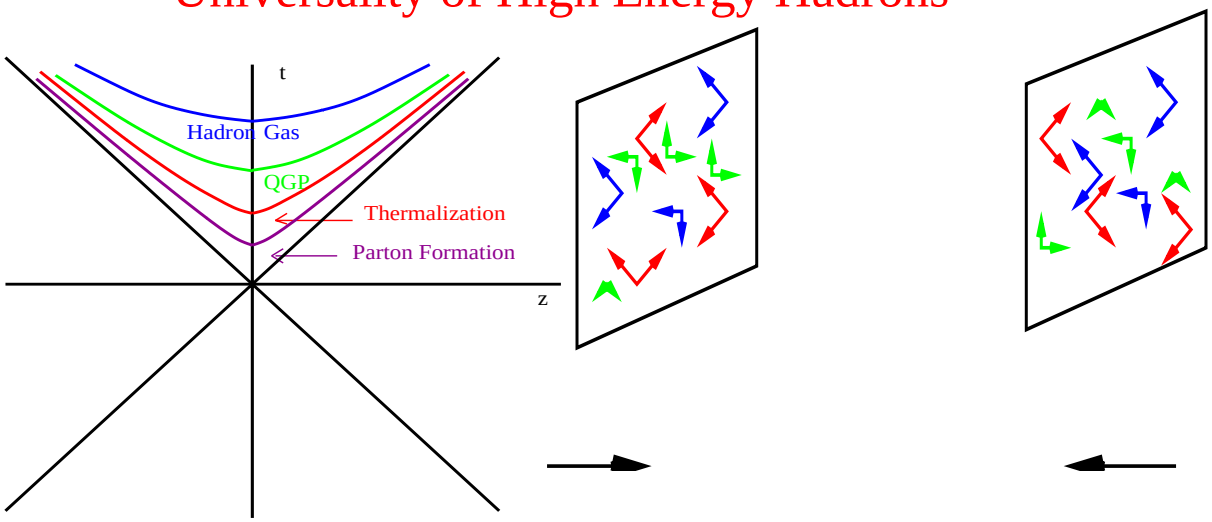
Energy and A dependence of Saturation Momentum Computed (HERA Small x Problem Understood)

Nuclear Shadowing Computable and Understood

$E \sim 10^{19} eV,\ \sigma_\nu \sim 10^{-1} - 10^{-2} mb$

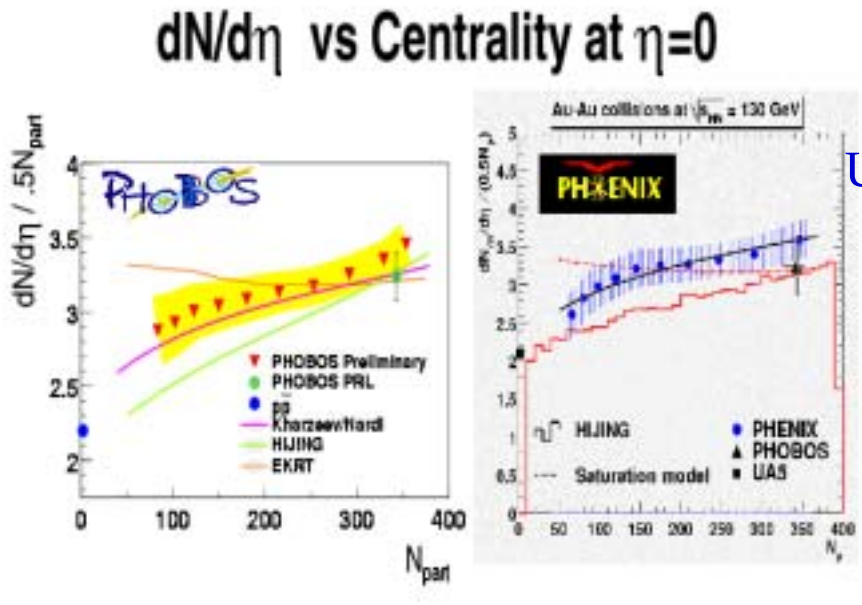
Neutrino astronomy?

Universality of High Energy Hadrons

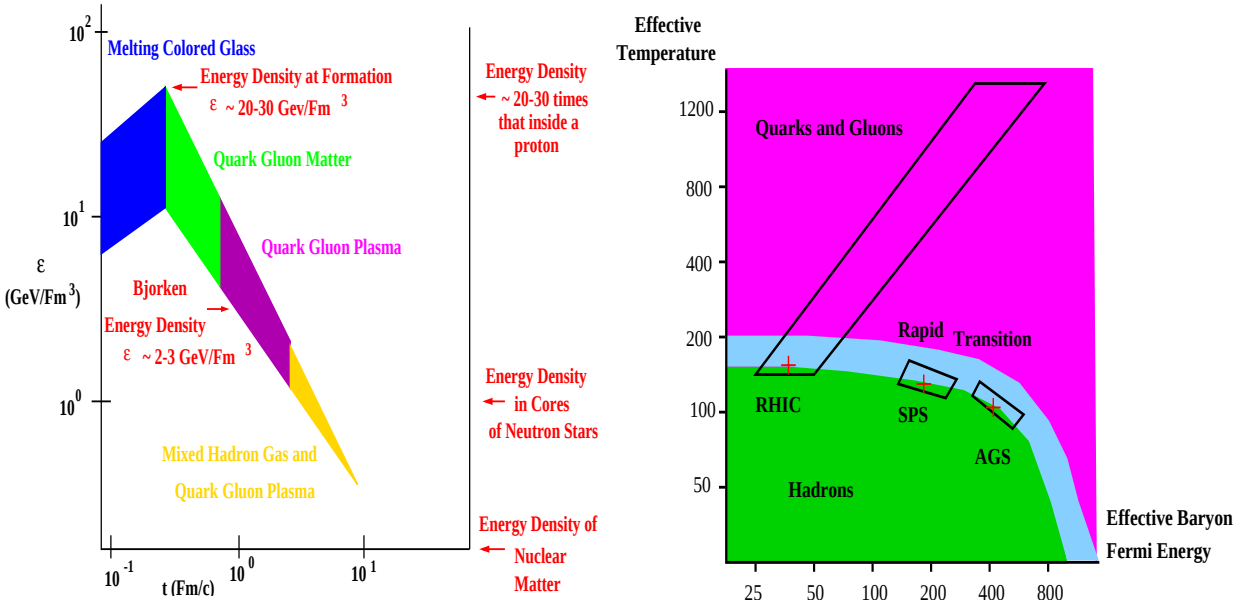


Initial Conditions for Ultra−relativistic Heavy Ion Collisions Understood

Nuclear Theory at BNL
Quark−Gluon Plasma

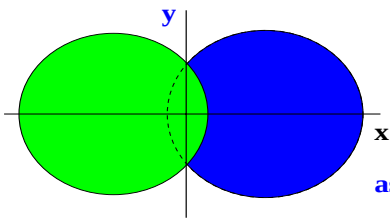


Understanding of Multiplicities and Rapidity Densities

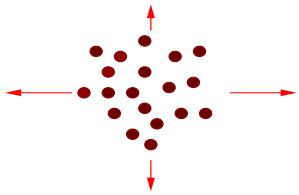


Understanding of Energy Densities
Time and Energy Scales

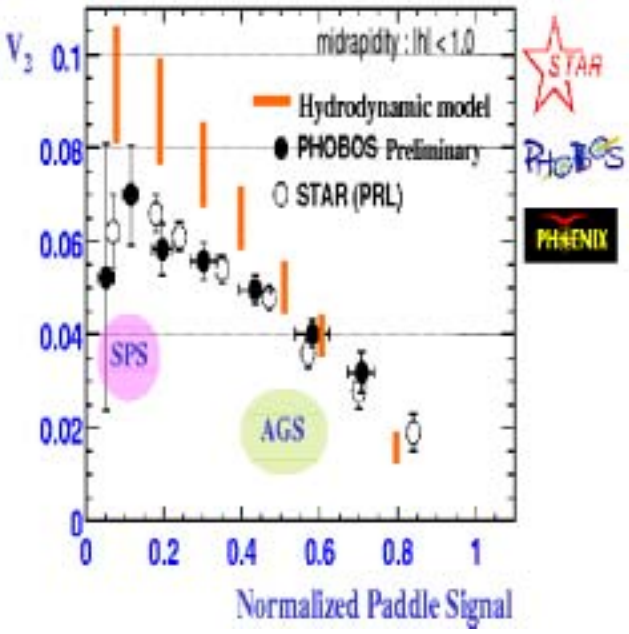
Nuclear Theory at BNL
Quarks and Gluons are Degrees of Freedom but
Is it Thermal?

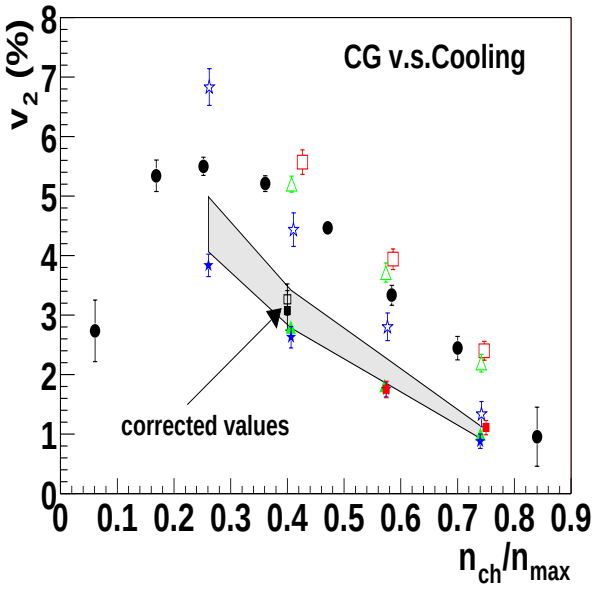


In region of overlap asymmetry of spatial distribution -> asymmetry of momentum distribution



$v_2 = \langle \cos(2\phi) \rangle$ $\tan(\phi) = P_y/p_x$



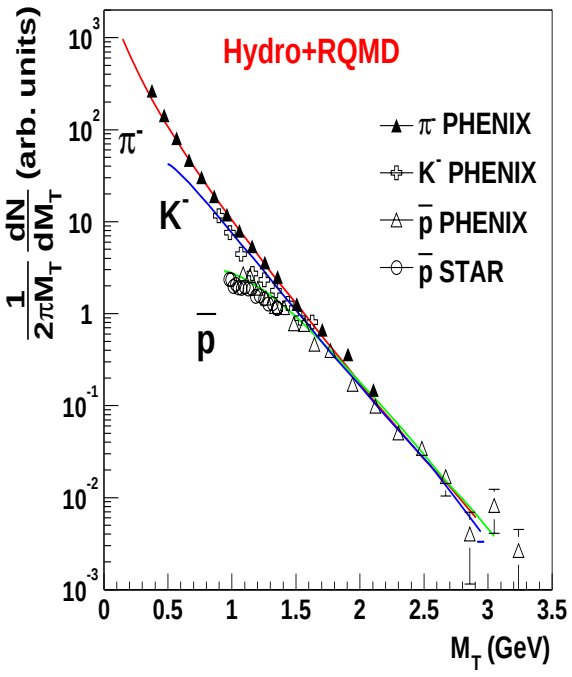


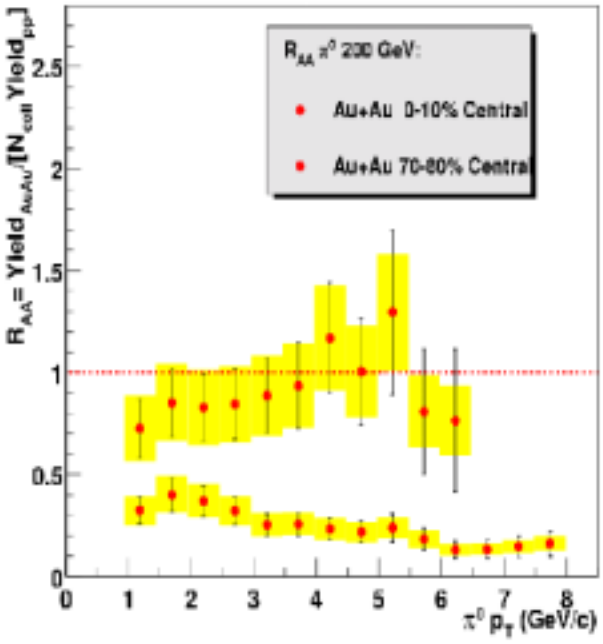
Whatever is the orgin of flow, it must have strong interactions at early times. From flow analysis of pp data, it is a collective effect for p < 2 GeV

Nuclear Theory at BNL

Is it Thermal?

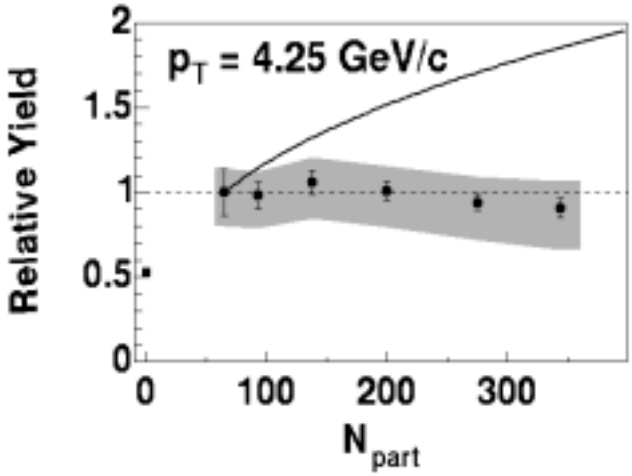
Color Glass Require High E/N to explain multiplicity.
Need a lot of cooling to get experimental E/N





Hydrodynamical models describe p < 2 GeV

Jets are suppressed at large pT



Npart dependence looks more hadronic than jetty

CGC or QGP?

Nuclear Theory at BNL
Flavor Structure of Hadrons

Nb/S: A Measure of Initial Conditions

In RHIC, Nb is large. Is it due to:

String junctions?

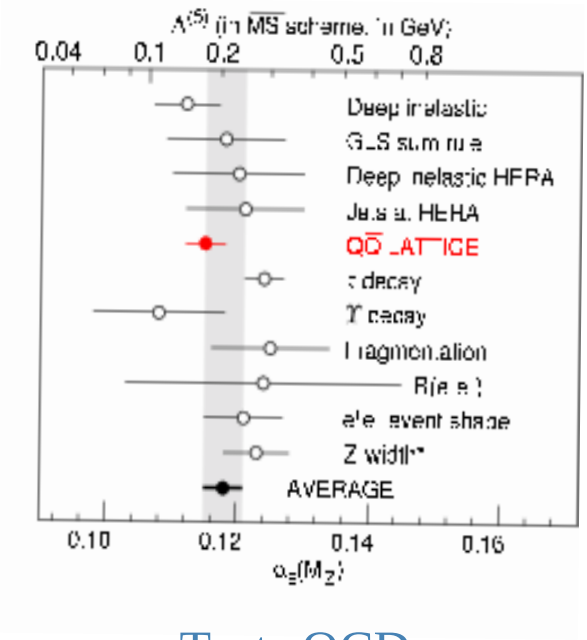
Small x evolution:
$1/x^{\sqrt{\alpha_s}}$.
Computable due to saturation.

Is this related to the
jet enhancement of baryons?

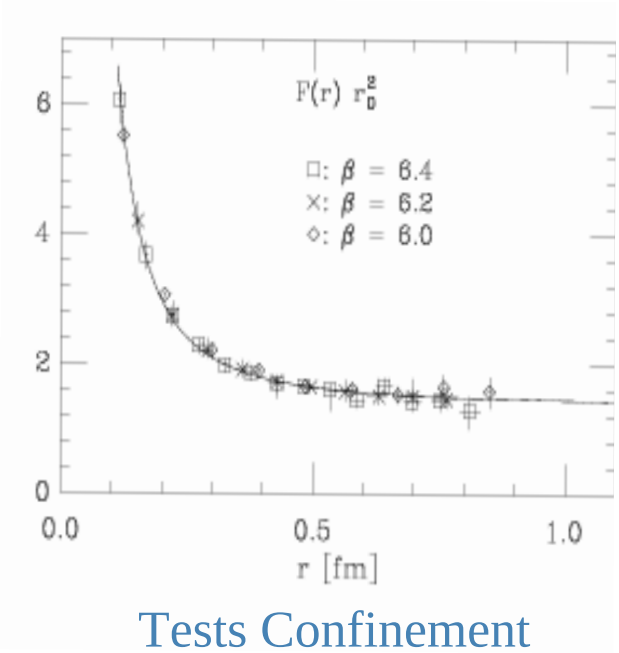
Spin structure functions:
Similar to evolution of baryon number, except:
Gluons can carry spin.

Do we understand spin evolution?

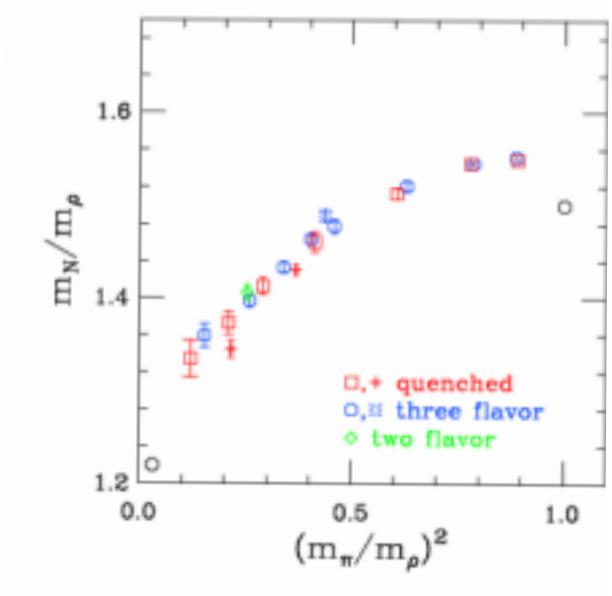
Nuclear Theory at BNL
Lattice Gauge Theory



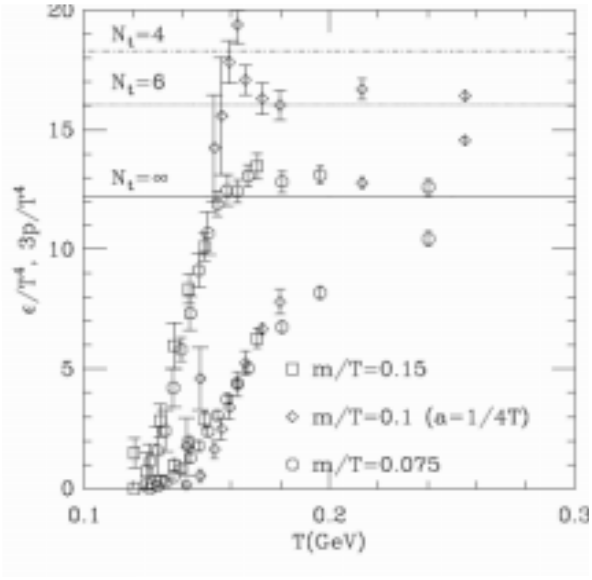
Tests QCD



Tests Confinement



Computes Masses

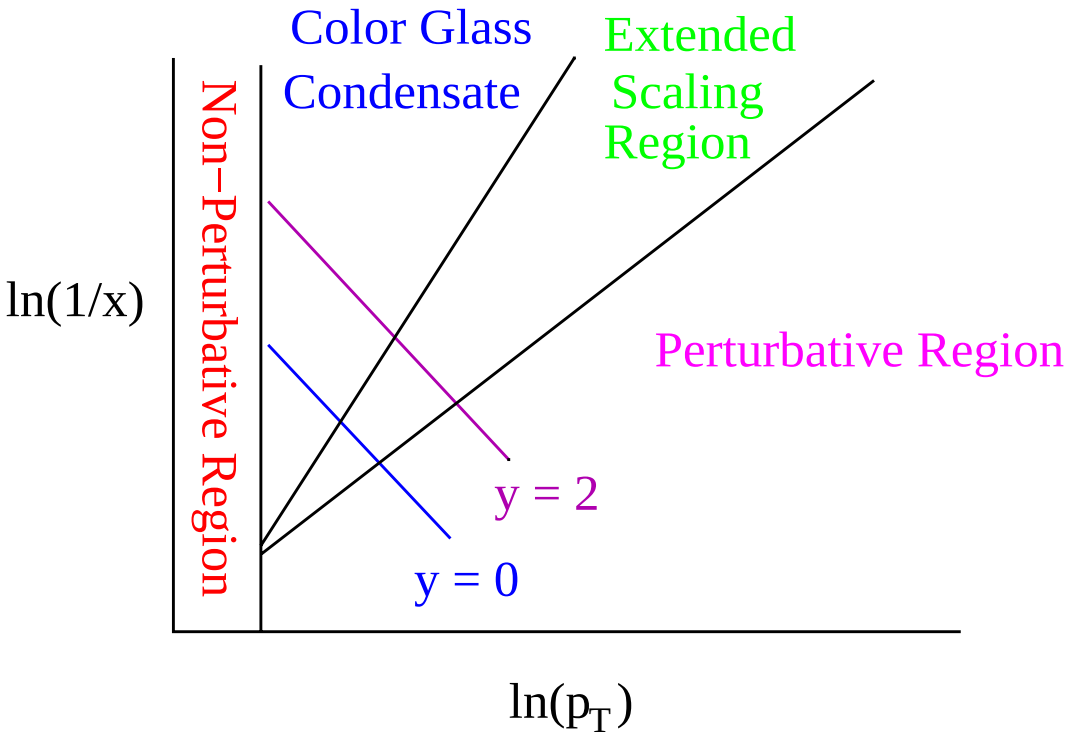


Computes Finite T QCD

QCDOC Project Promises 10+ TFlops
allowing great progress for realistic computations
with realistic quark masses

Where did the Color Glass Go?

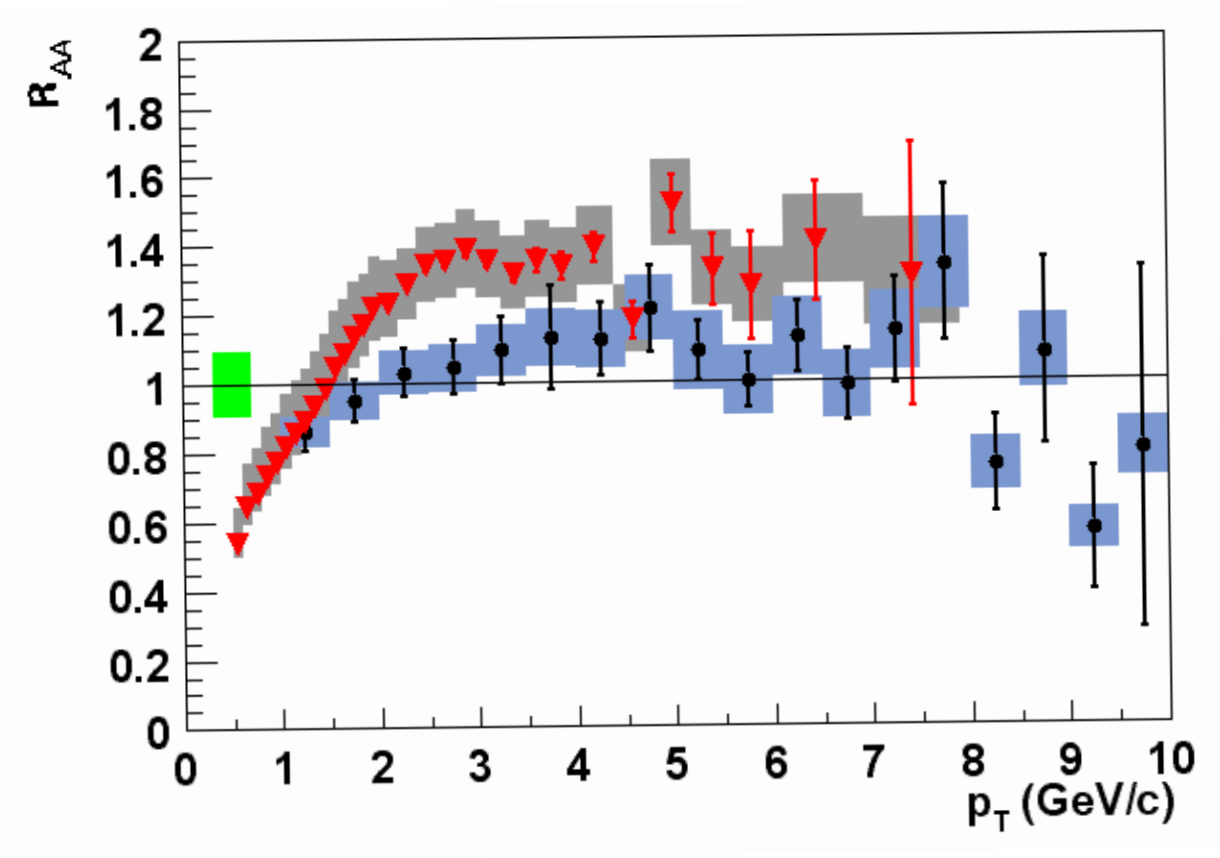
The multiplicity arises from physics
at the saturation scale $Q_{sat} \sim 1 - 2\ GeV$
which is $x \sim 10^{-2}$.
HERA shows saturation physics begins
at x $\sim 10^{-2}$



RHIC Kinematics:
$ln(p_T) = y_{CM} + y - ln(1/x)$
where p_T is the transverse momentum
of the jet, and x is that of the
nuclear parton constituent which
generated the jet.

Where are We Going?

Our group is sceptical of "party line" interpretation of dA data.



The charged data between Phenix and Phobos similar, but differ from π^0. Due to protons?

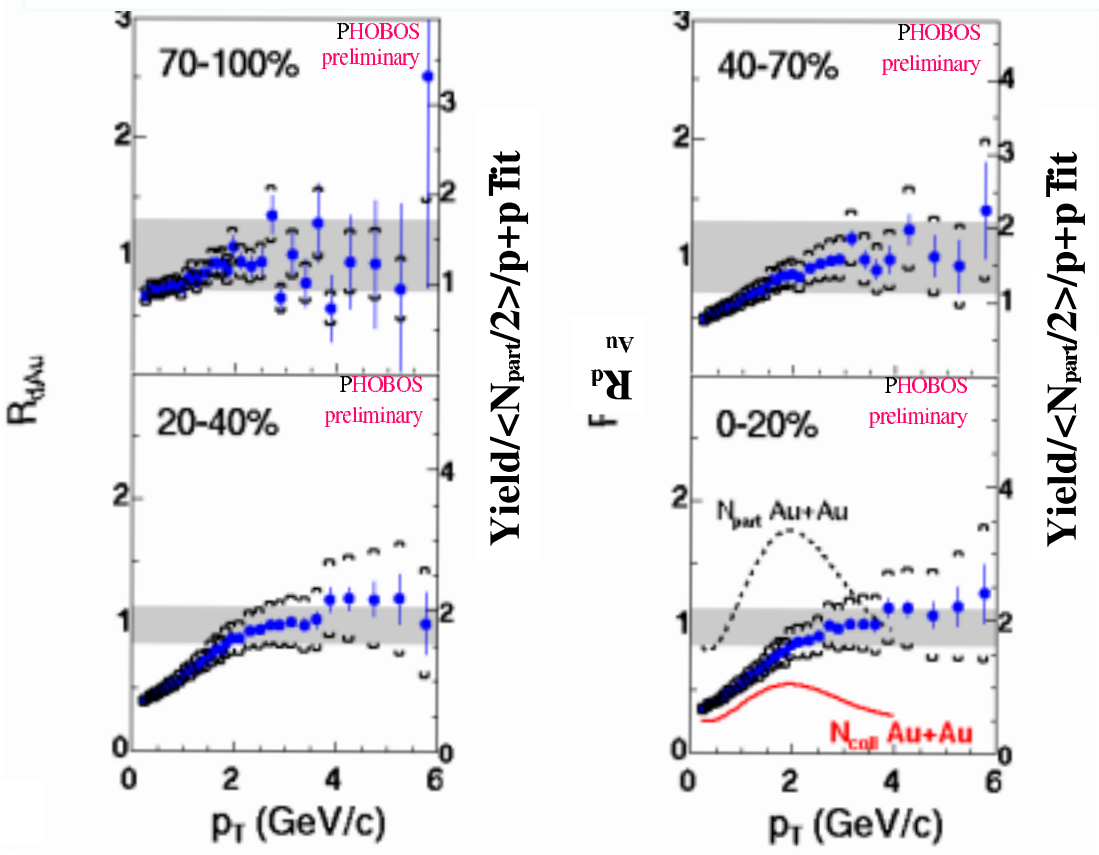
Discard the charged, then π^0 is consistent with 1 up to small effects

Predicted suppression in minimum bias is only 10 %

Perhaps some suppression at hign pT?

Where are we going?

Phenix dA Data



Lack of centrality dependence.

But what happens to protons?

Why is normalization different from Phenix and Star?

What happnes beyond the Cronin region of $4-5\ GeV$?

Where are We Going?

Most compelling evidence for jet quenching is dissappearence of forward backward correlation in central AA.

Can the forward peak in AA be due to a broadened distribution of soft hadrons?

Why does width of forward peak not depend upon centrality?

These are all scientific questions. They will be answered by various measurements.

Intend to have a number of RIKEN-BNL Center workshops on these and other topics over next year