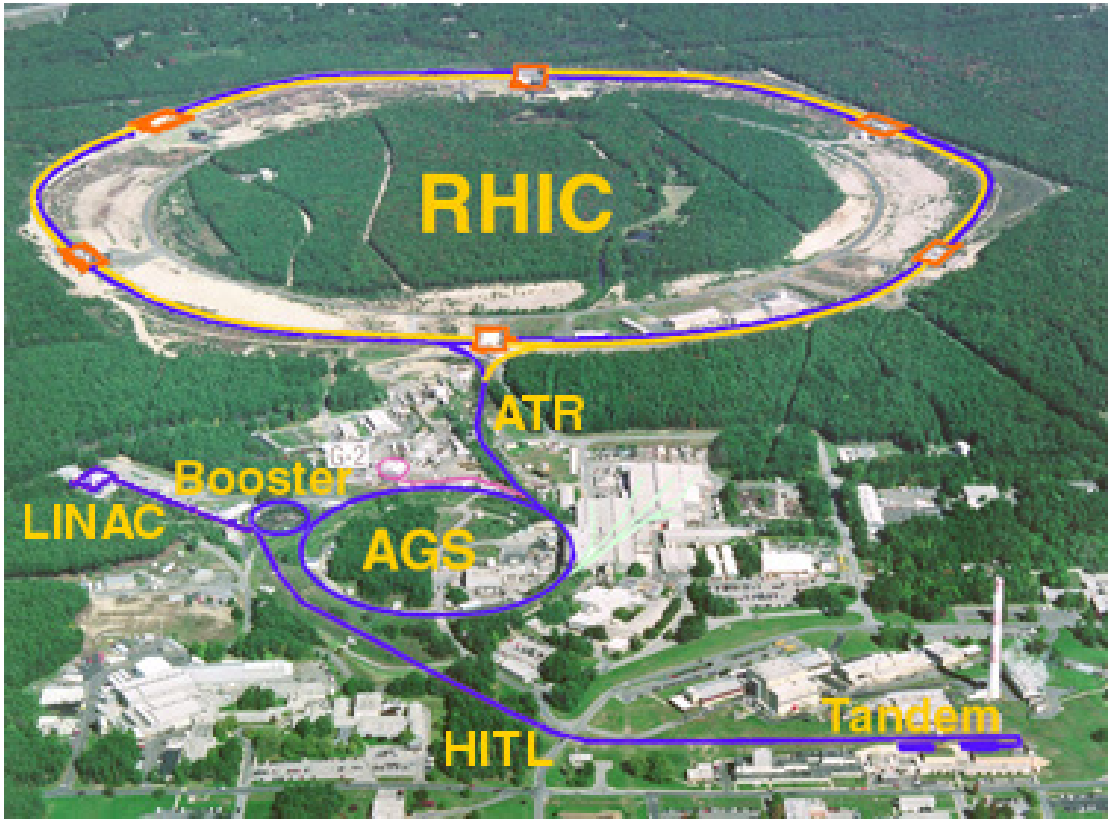
Recent Highlights at RHIC

T. Ludlam

NSAC Meeting

March 3, 2006



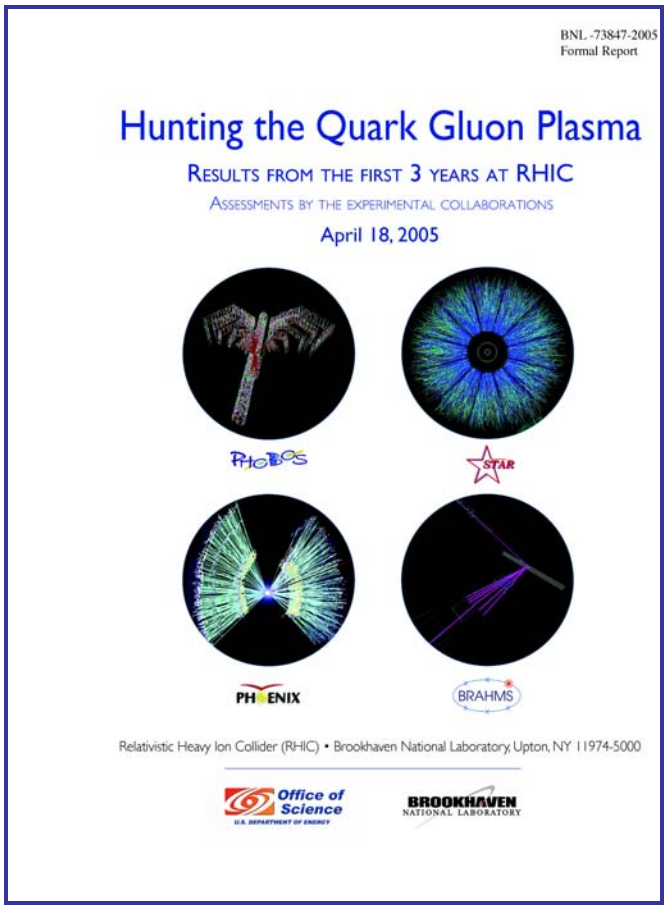
Office of Science
U.S. DEPARTMENT OF ENERGY

BROOKHAVEN NATIONAL LABORATORY

Brookhaven Science Associates
U.S. Department of Energy

Heavy Ion Collisions at RHIC

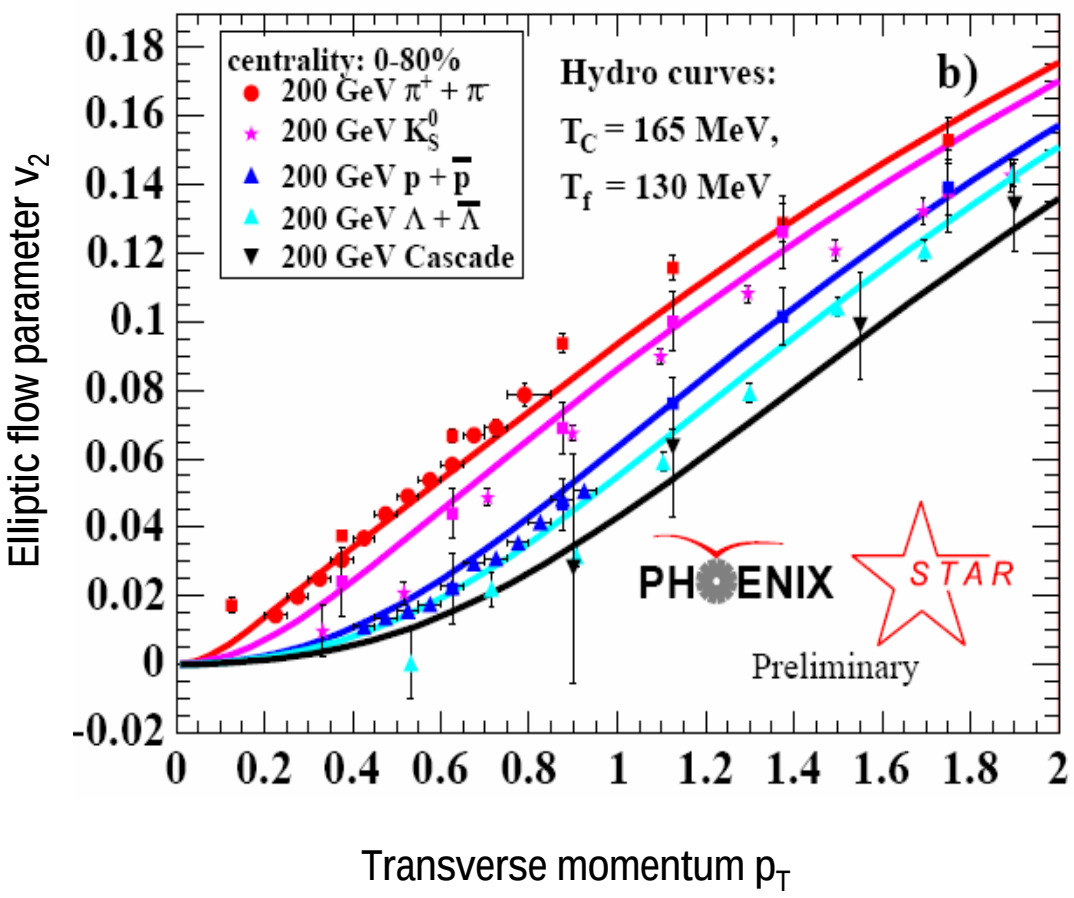
“White Papers” from the four experiments summarizing the first 3 years



- Evidence for the creation of a new state of thermalized matter.
- Highest energy density matter accessible in the Laboratory
- It’s density and enormous interaction cross section not consistent with hadronic degrees of freedom
- Medium exhibits collective expansion with extraordinarily small viscosity-to-entropy ratio

AIP number one physics story of 2005…

The White Papers, Joint publication: Nuclear Physics A, August, 2005



Press Event:
Tampa APS Meeting, April 2005

A new view of high-temperature matter:
"Ideal" Hydrodynamics

- Near-zero viscosity
- Very quick thermalization

"Perfect Liquid"

Strongly-coupled QGP = "sQGP"

New Results from RHIC 2004/2005 runs

Probing a partonic state of dense matter…

How dense?

- 20 GeV π^0 stopped in nuclear volume: $\varepsilon > 15$ GeV/fm^3
- Heavy quarks are quenched: problem for radiative energy loss
- J/Ψ suppression measured: Melting? Regeneration?

How strongly coupled?

- Charm quarks flow!

How hot?

- First measurements of direct (thermal?) photons

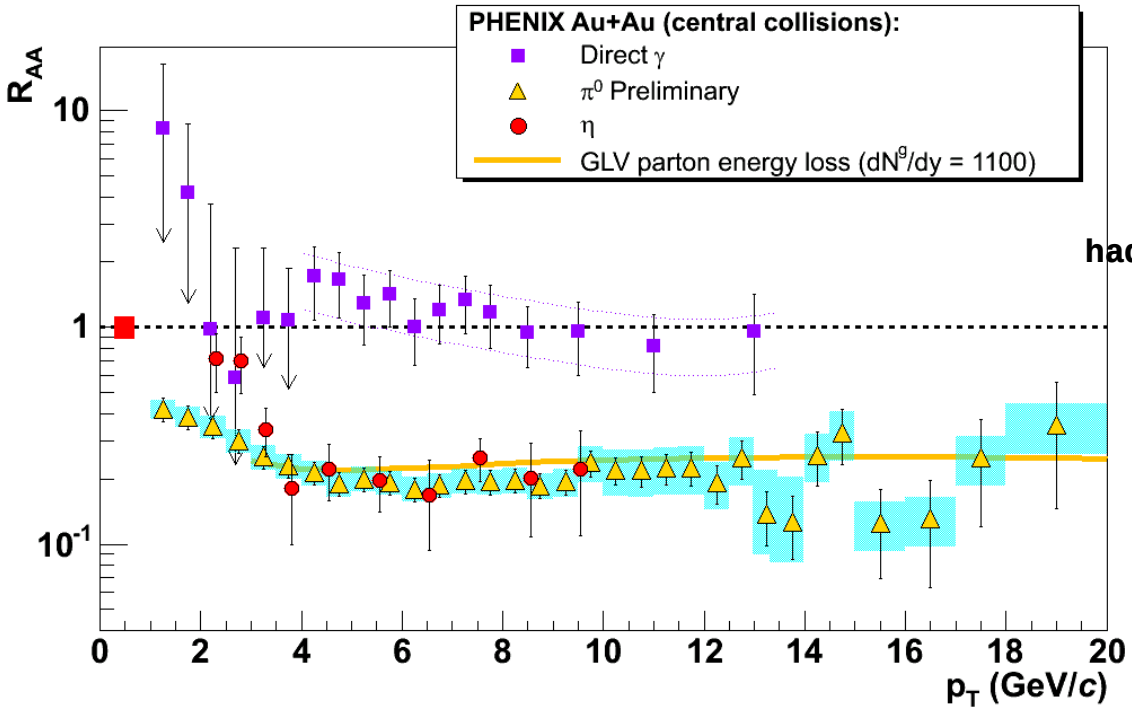
How can we see inside?

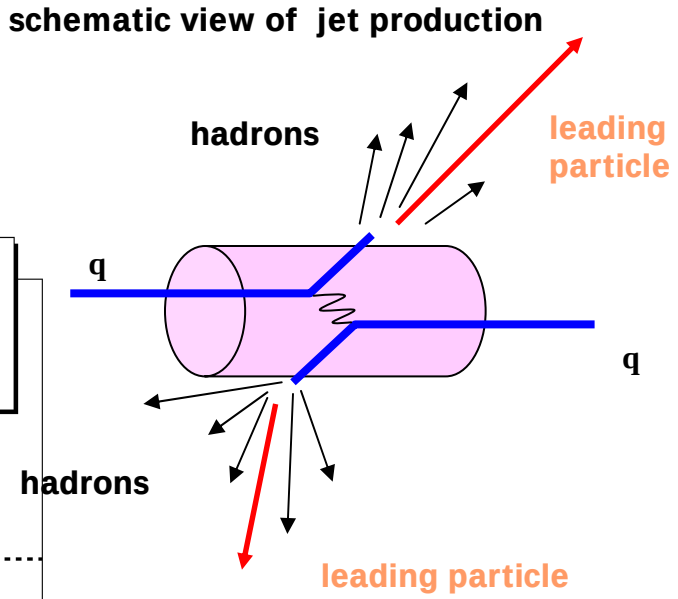
- "punch through" of quenched jets shows effects of medium
- di-jet tomography emerging as a powerful tool

R_{AA} = scaled prod. Rate: (Au-Au/p-p)

"opaque" strongly interacting medium: 20 GeV π^0 stopped

Direct photons not suppressed

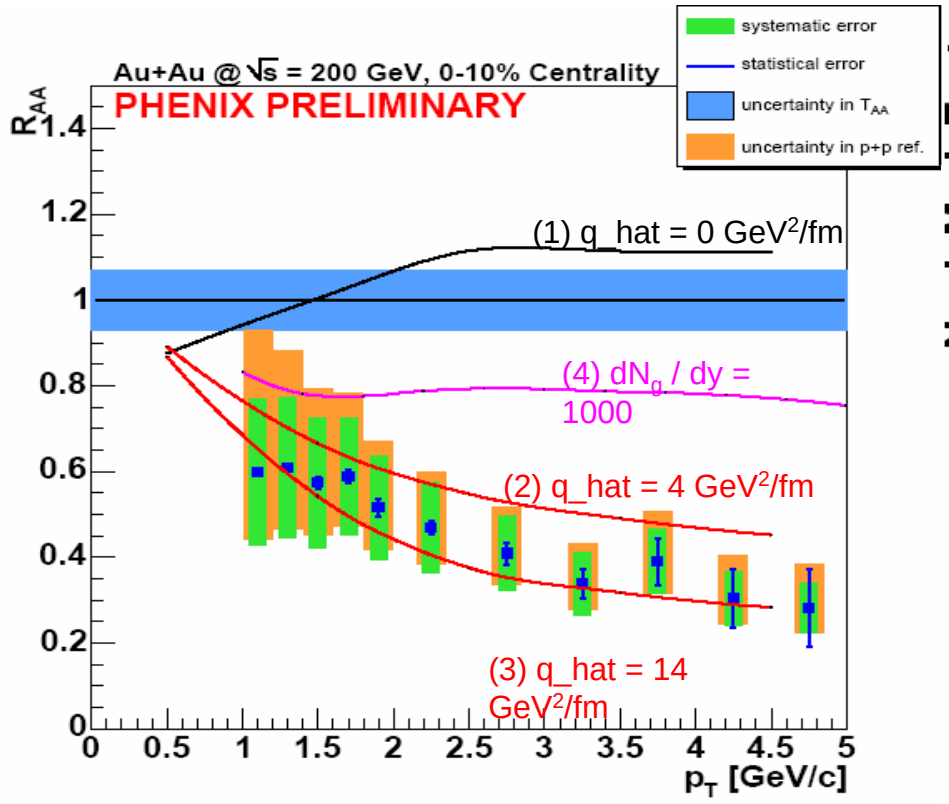




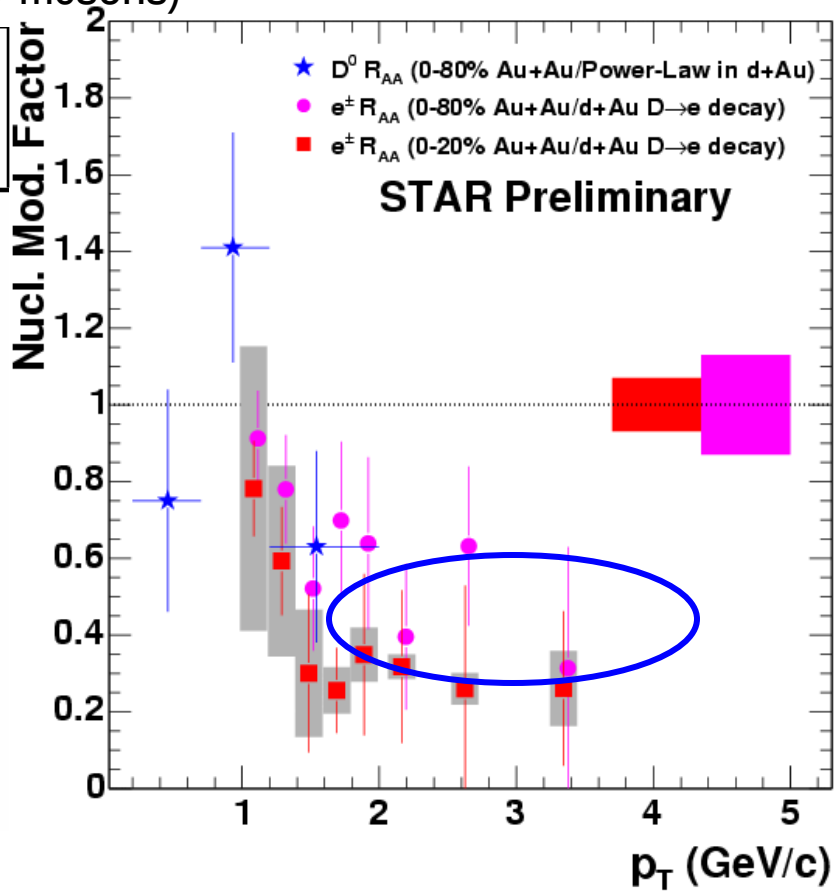
Charm is quenched in Au-Au collisions!

Heavy quarks suffer a large energy loss: A serious problem for the "standard" scenario of energy loss by gluon radiation.

R_{AA} for non-photonic electrons (decays from D-mesons)



PHENIX, Quark Matter'05

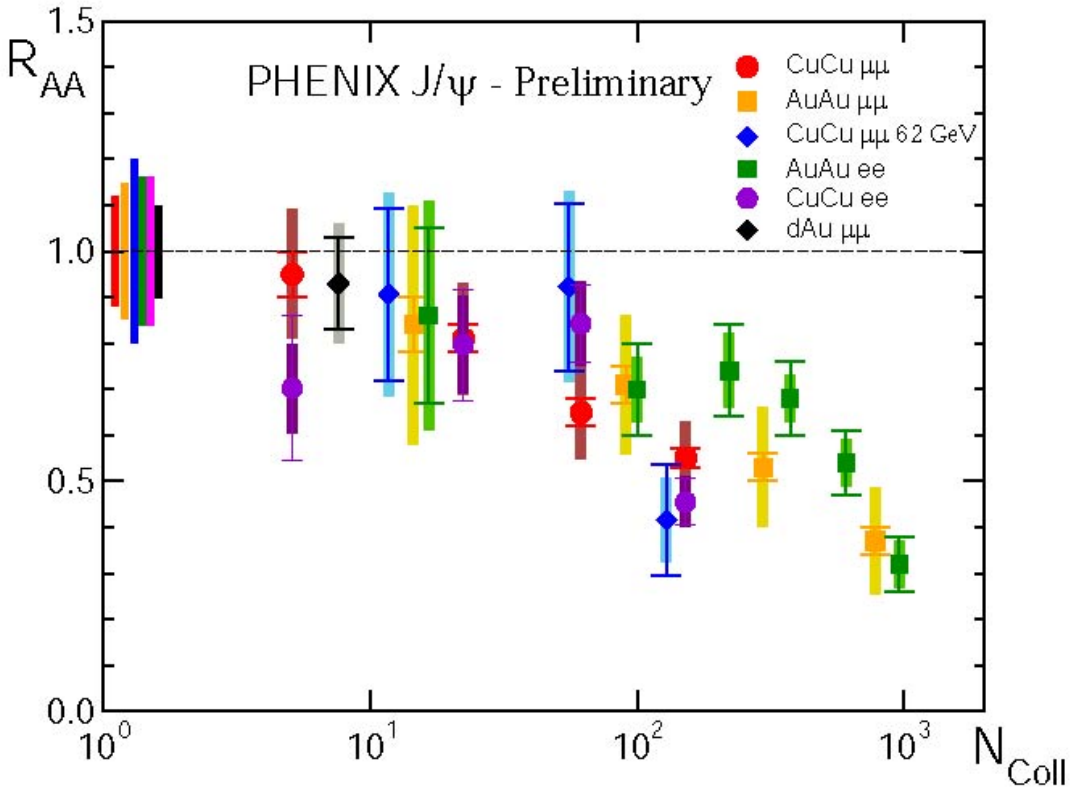


STAR, Quark Matter'05

J/Ψ suppression at RHIC

A long-proposed "signature" for a deconfined partonic state

- deconfinement → screening
  → no heavy quark bound states in a QGP



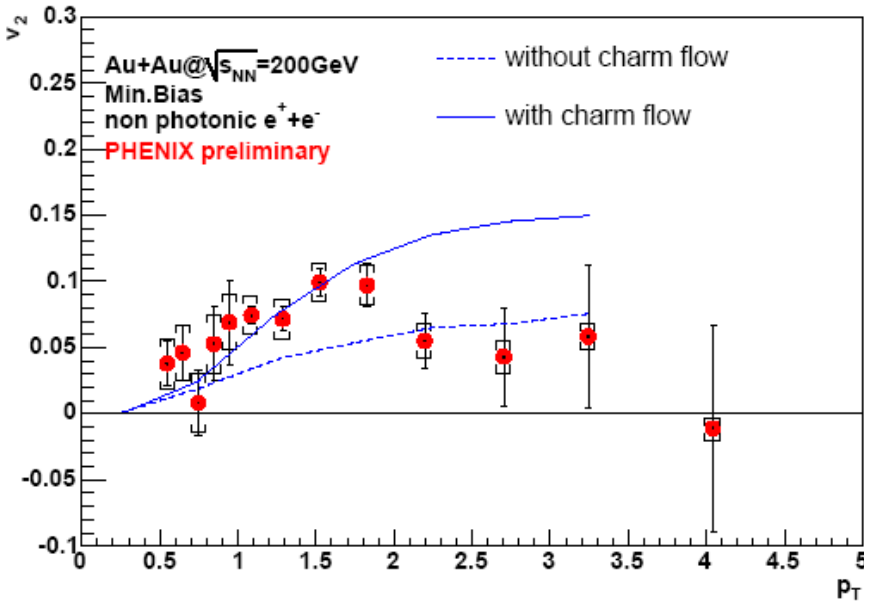
J/Ψ is suppressed beyond the cold nuclear matter effect (d-Au result).

Preliminary data are consistent with predictions for melting + regeneration at RHIC energy density

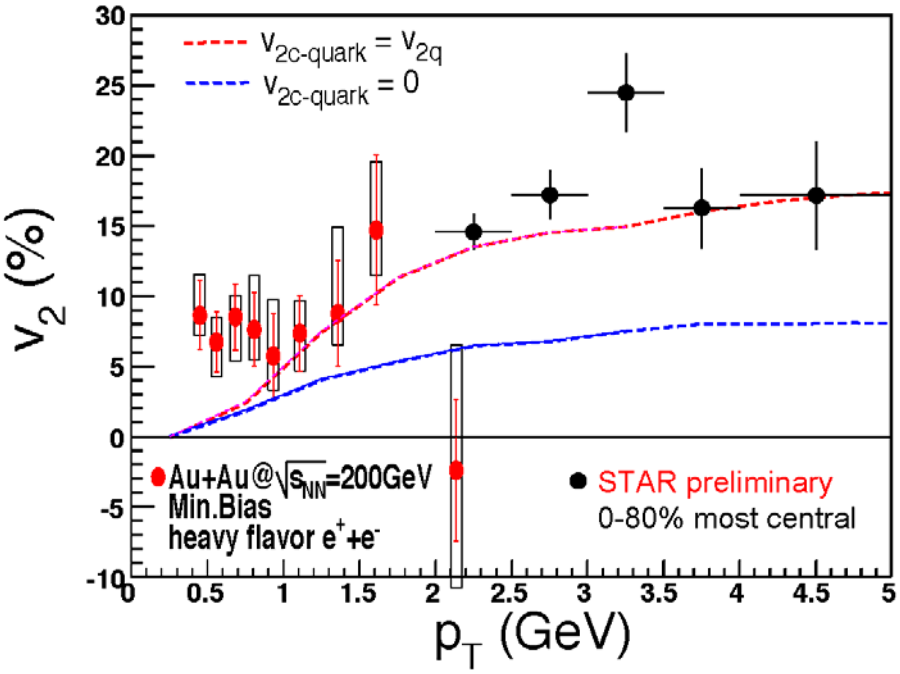
"Same as SPS"?

Charm Flows in Au-Au collisions!

PHENIX



STAR

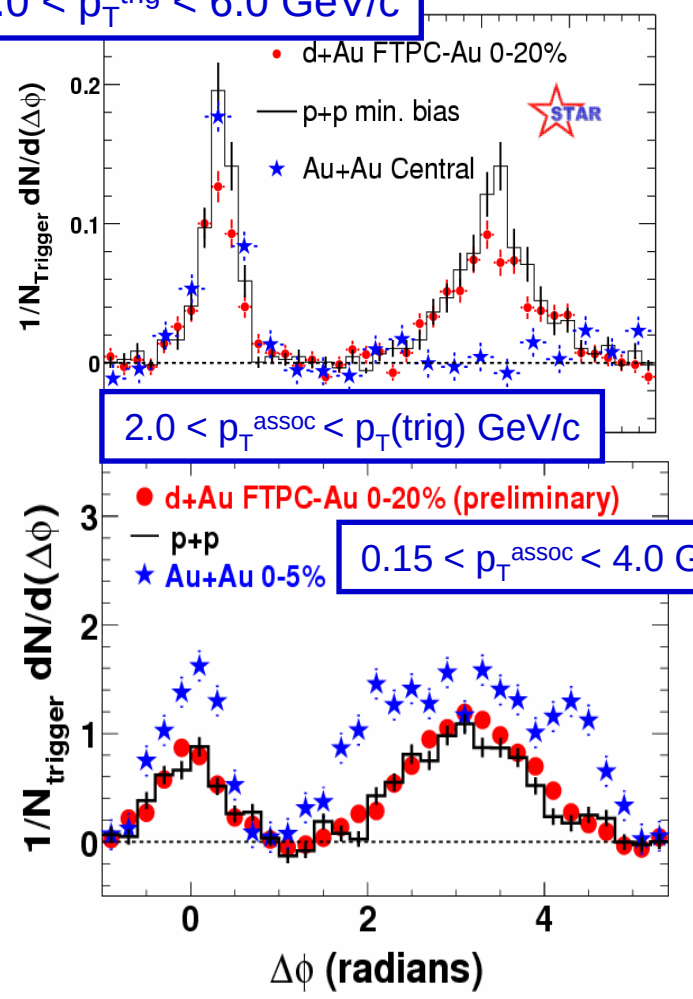


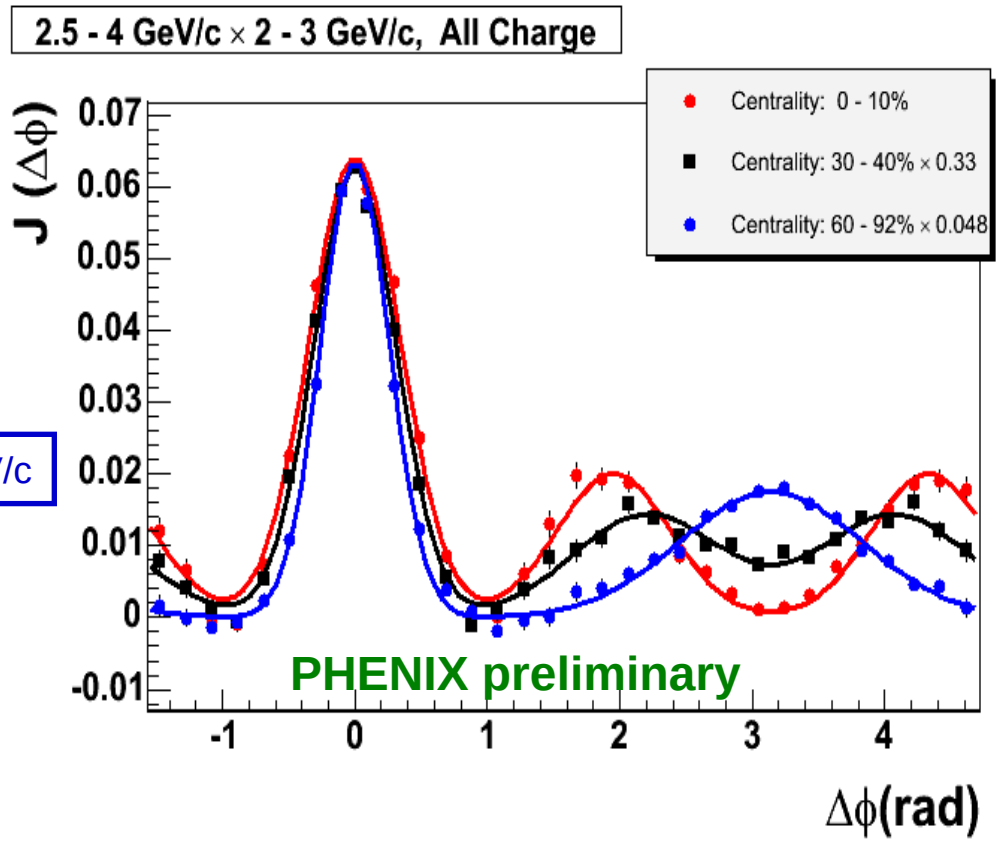
Indicates high parton density and strong coupling in the collectively expanding medium

Not a weakly-coupled gas

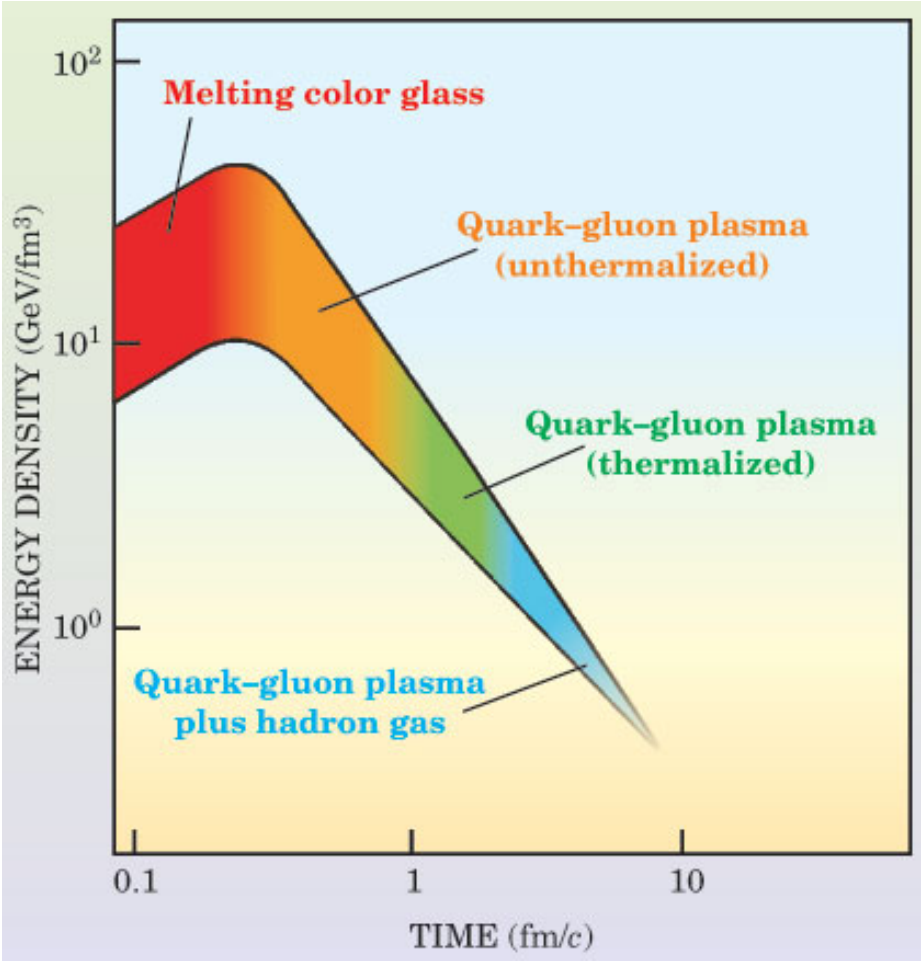
The Medium Modifies Quenched Jets

$4.0 < p_T^{trig} < 6.0$ GeV/c





The Emerging Picture

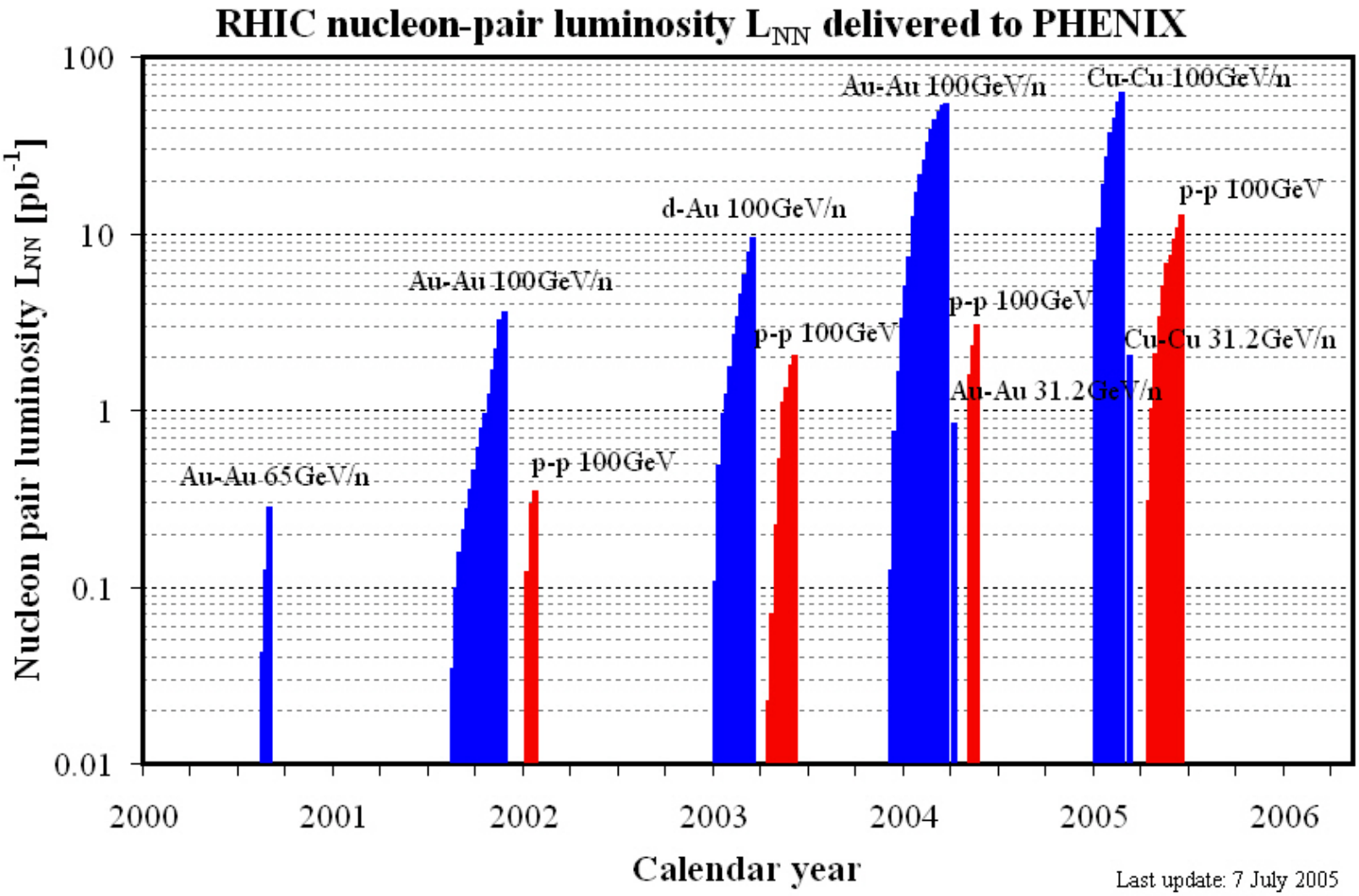


We are developing powerful tools -- experimental and theoretical -- to explore this new landscape.

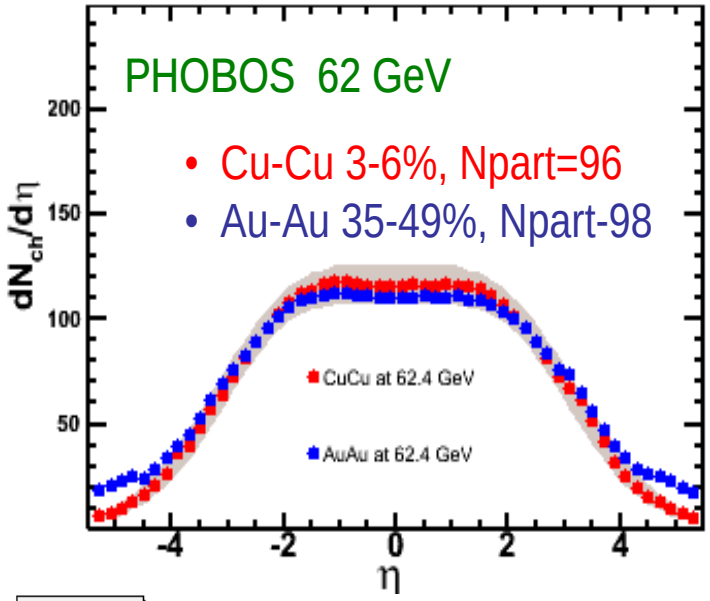
Most involve rare processes – Hence the need for improved luminosity, and upgraded detectors.

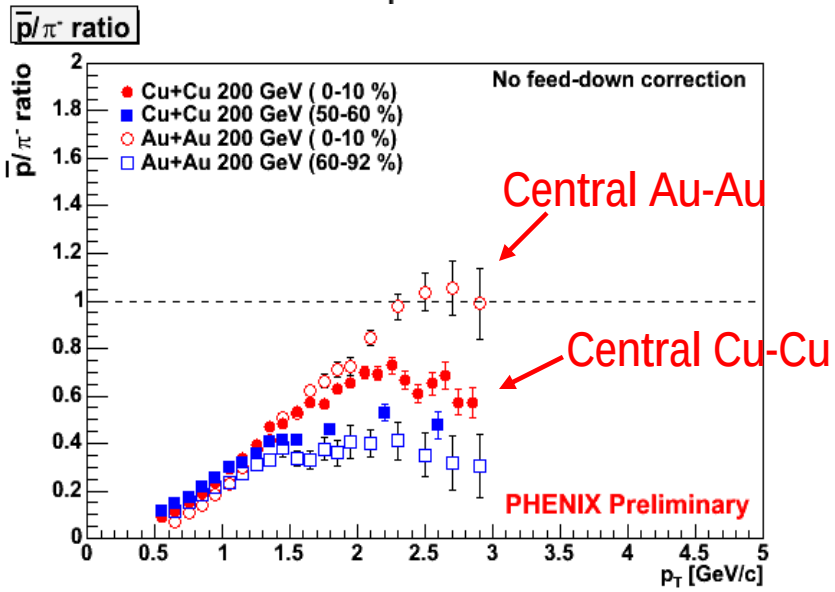
Why is thermalization so fast?

RHIC Delivered Luminosity

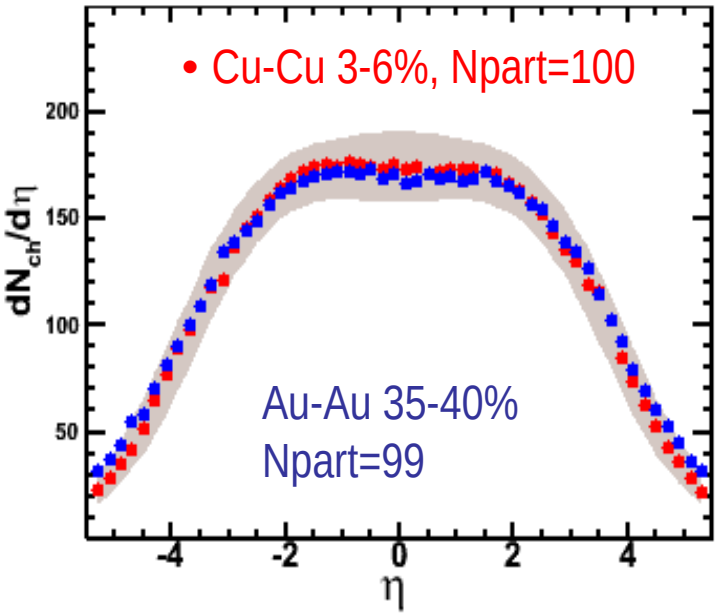


2005 Cu-Cu Run: Tight control over systematics





PHOBOS 100 GeV



Crisp studies of baryon/meson enhancement at intermediate values of p_T (PHENIX)

RHIC Spin

Run 5 (2005)p – p:

- 9.5 weeks physics at 100 + 100 GeV
- 12 pb^{-1}; 50% polarization
- First test of polarized collisions at 205 + 205 GeV

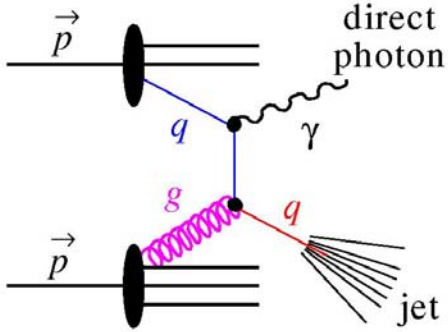
Run 6 (2006) dedicated spin run

- 20 week physics run of polarized proton collisions
- setup in progress; physics to start next week
- Made possible by $13M contribution from Renaissance Technology Corp.

Gluon polarization measurement: ΔG

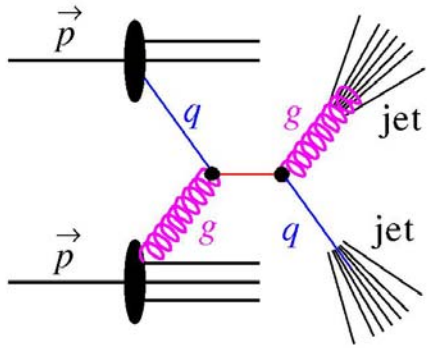
p p ⟶ π + X
Jet(s) + X
γ + jet + X

Double-spin asymmetry A_{LL} directly sensitive to gluon contribution



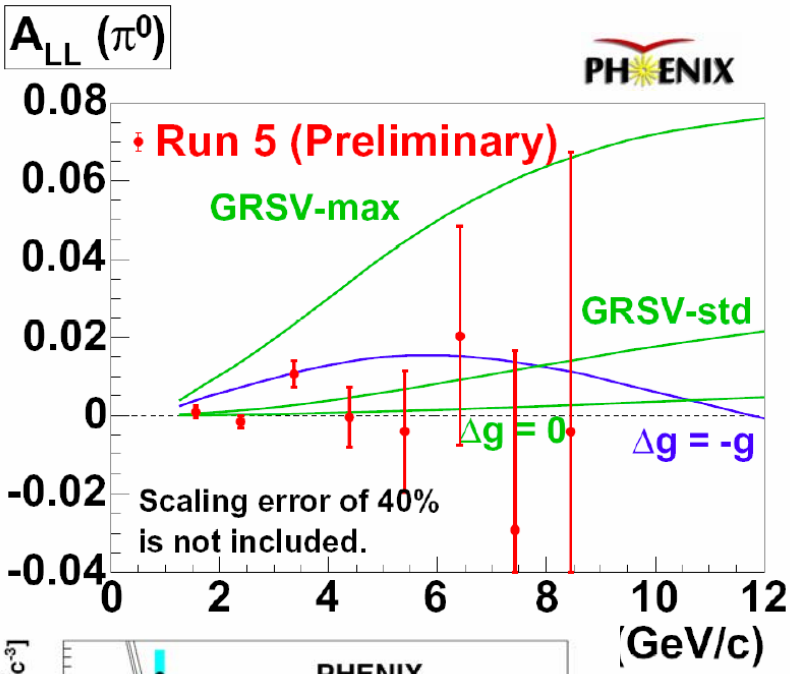
Quark - Gluon Compton Scattering

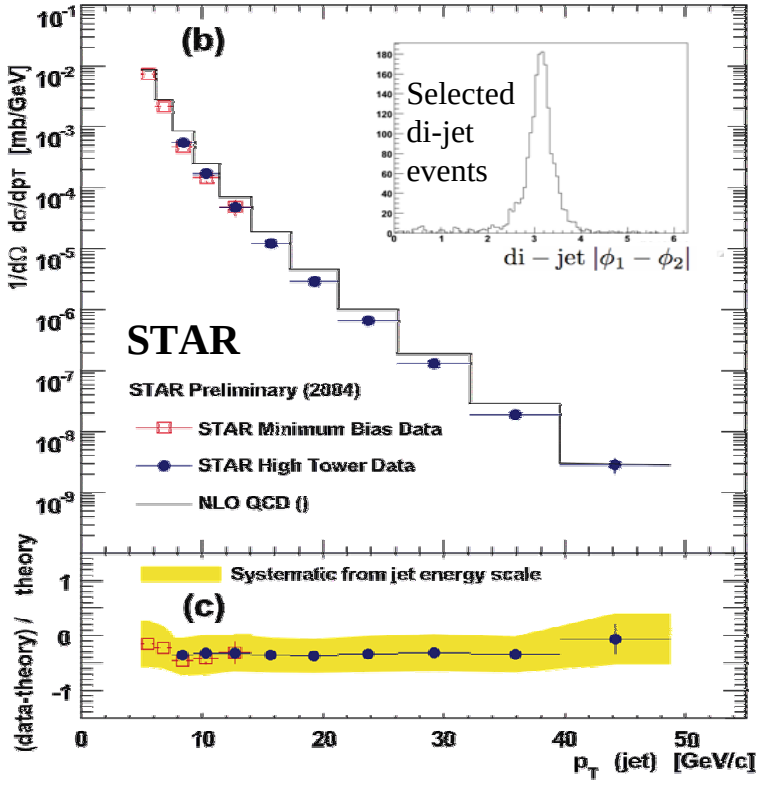
$\vec{p} + \vec{p} \rightarrow \gamma\,(+\,jet) + X$



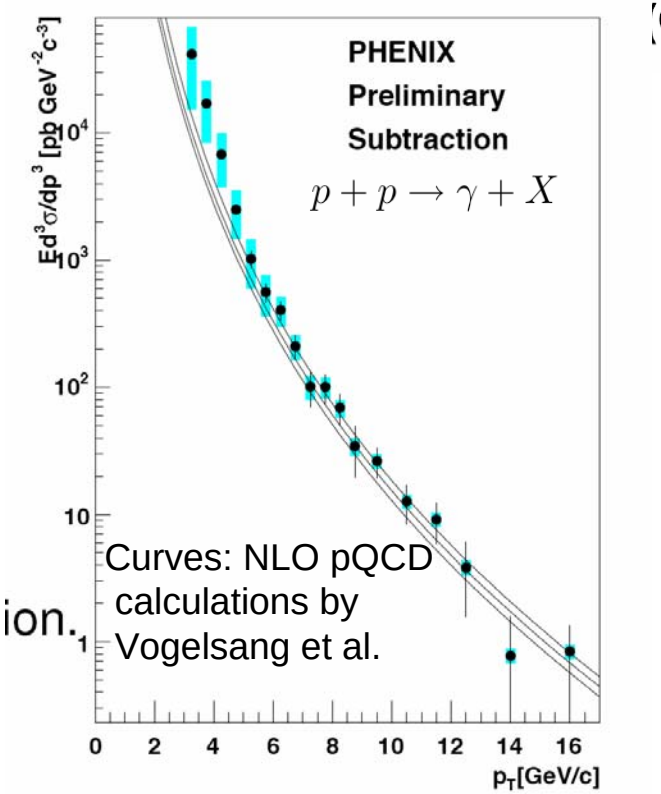
Quark - Gluon (also Gluon - Gluon) Elastic Scattering

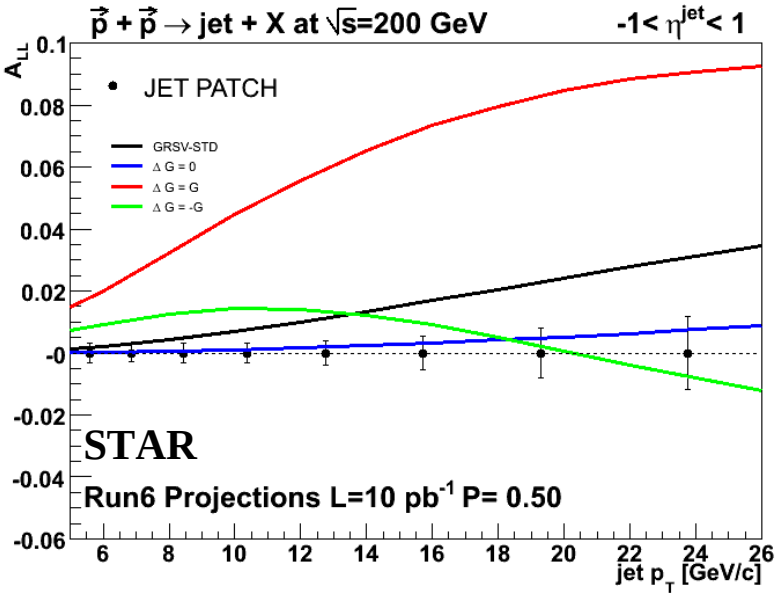
$\vec{p} + \vec{p} \rightarrow di\text{-}jets + X$





RHIC SPIN
A_{LL}

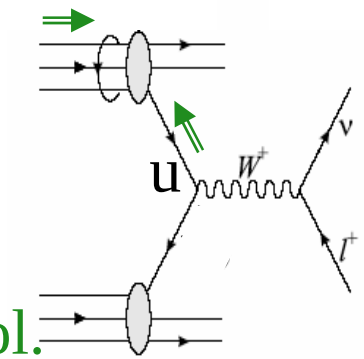


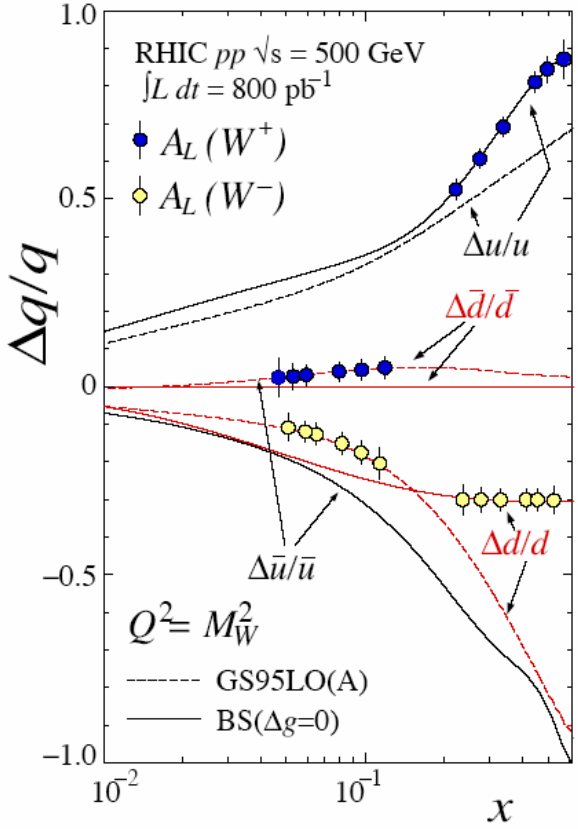


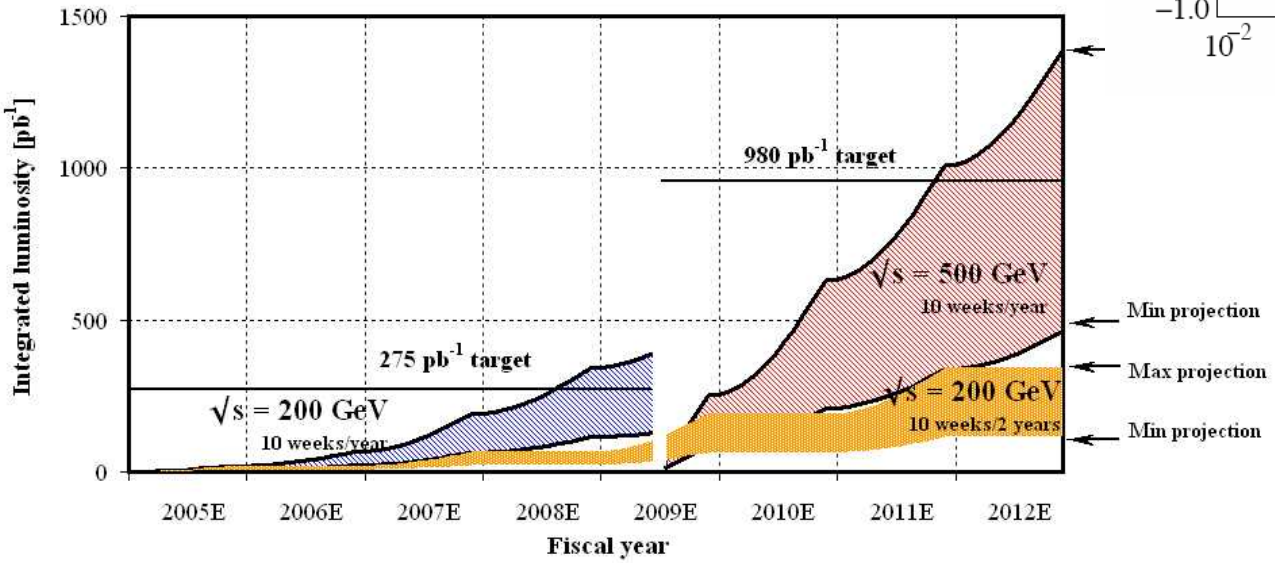
The RHIC Spin Research Plan

- Complete ΔG measurements
- Transverse Spin measurements

At 500 Gev: Parity violating W production



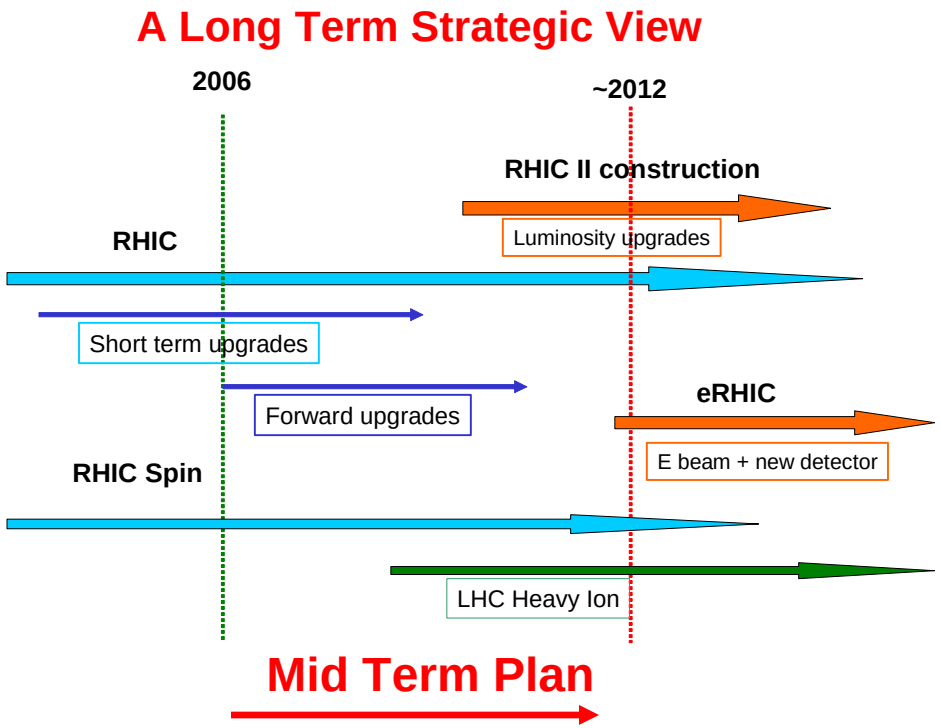


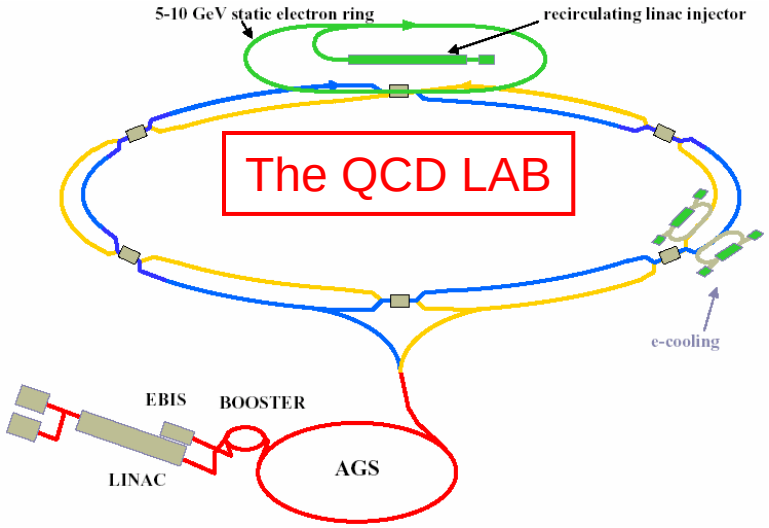


Data collection goals from the RHIC Spin Plan, And Collider projections.

RHIC Science Outlook

- QCD at high temperature and density: QGP … sQGP
- QCD at high energy and low x: Physics of strong color fields
- QCD and the structure of hadrons: What is the origin of nucleon spin?





The Mid-Term Strategy: 2006 - 2011

Phased implementation of key upgrades for PHENIX and STAR detectors

Study the new form of matter with resolving power afforded by hard probes

Annual data runs during this period will exploit these upgrades for critical advances in the Heavy Ion and Spin physics programs—
Along with continued improvements in machine performance

With the help of funding and collaborative resources outside of DOE, this strategy is realized with a sequence of MIE detector upgrade projects over ~6 years.

→ **Two large detectors well equipped for RHIC II physics**

→ **RHIC II luminosity upgrade *(electron-cooling of ion beams)* proceeds along technically-driven schedule**

Major Physics Measurements

Required Upgrades

Heavy Ion:

e-pair mass spectrum
- "Hadron Blind" Dalitz pair rejection — PM: 2010

Open charm measurements in AA
- Precision vertex detection

Charmonium Spectroscopy — PM: 2010
- High luminosity; precision vertex, particle ID

Jet Tomography
- High luminosity; increased acceptance; particle ID

Gluon shadowing; low-x in d-Au
- particle detection at forward rapidity — PM: 2012

Spin:

Complete initial $\Delta G/G$ measurement
- No upgrades needed — PM: 2008

Transverse spin measurement
- Forward particle measurement

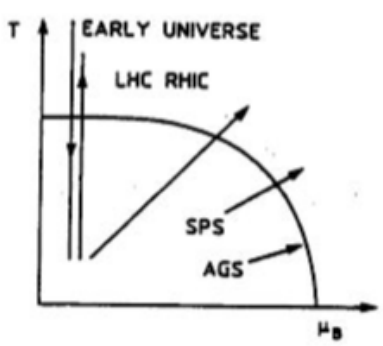
W measurements at 500 GeV — PM: 2013
- Forward tracking/triggering in PHENIX and STAR

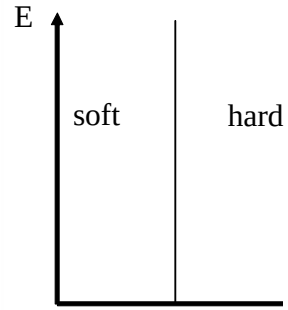
***DOE performance milestones set by NSAC**

What are the phases of QCD matter?

QCD diagrams, late XX century

What is the wave function of the proton?



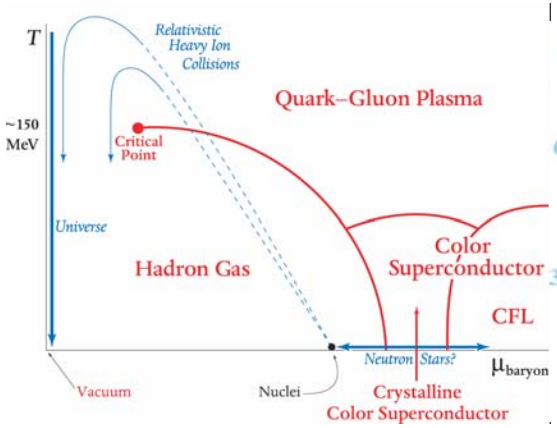


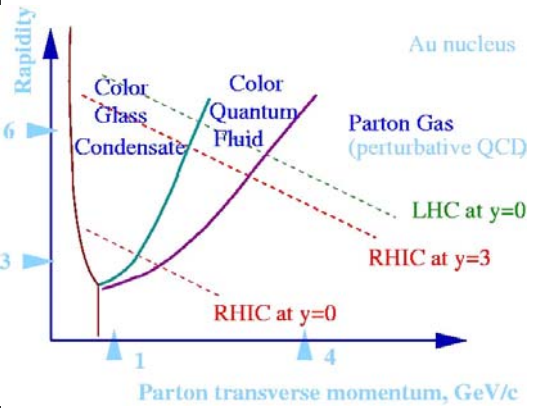
What is the wave function of a heavy nucleus?

What is the nature of non-equilibrium processes in a fundamental theory?

QCD diagrams, early XXI century

Fundamental Questions for the coming decades





RHIC…RHIC II…LHC HI… eRHIC