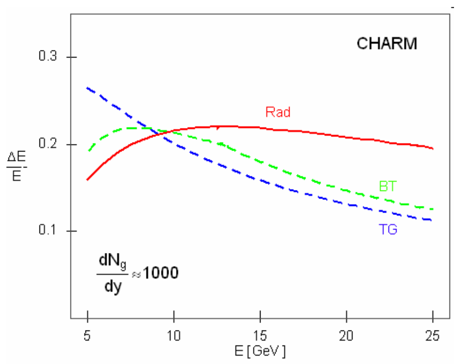
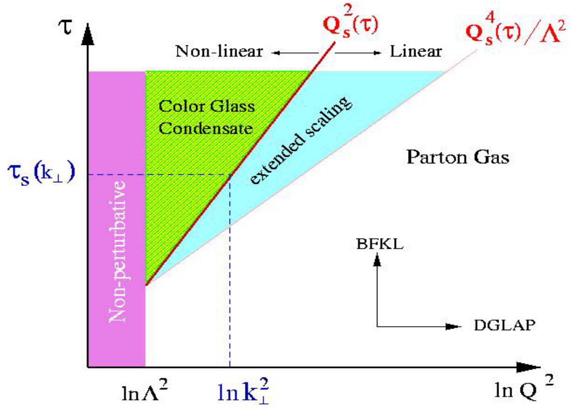
STAR Multi-Year Beam Use Request For

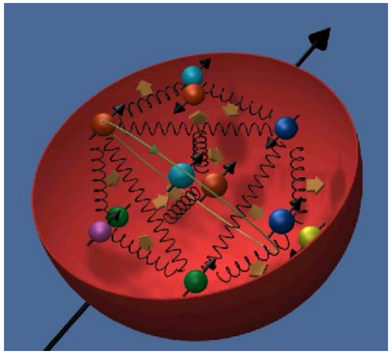
Run 7



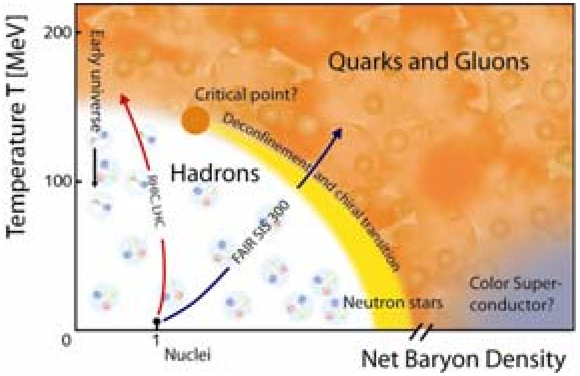
Run 7



Run 8



Run 9



Tim Hallman for the STAR Collaboration

Brookhaven National Laboratory

September 12, 2006

Philosophy Behind the STAR BUR

To allocate beam time to measurements that will provide qualitatively new insights into the properties of

- the nucleon
- the nucleus
- dense QCD matter

Specifically:

Run 7

- Definitive results on the saturation scale for the gluon distribution in relativistic heavy nuclei
- Decisive test of gluon saturation as the origin of particle suppression at forward pseudorapidity
- Qualitative advance in understanding the origin of the suppression of non-photonic electrons from D, B semi-leptonic decays

Run 8

- First significant measurement of the x dependence of gluon polarization in the proton, $\Delta G(x)$
- Qualitative advance in study of pp elastic scattering

Run 9

- Definitive search for the existence and location of the QCD Critical Point
- Precision tests of the properties of quark-gluon matter

The STAR 3 Year Beam Use Request

Run	Energy	System	Goal
7	$\sqrt{s_{NN}}$ = 200 GeV $\sqrt{s_{NN}}$ = 9 GeV $\sqrt{s_{NN}}$ = 200 GeV	Au + Au Au + Au d + Au	300 μb^{-1} sampled 60 Mevts usable (10 + 2 weeks) (1 + 1 weeks) (machine dev.) (10 + 3 weeks) 15 nb^{-1} sampled
8	$\sqrt{s}$ = 200 GeV $\sqrt{s}$ = 200 GeV $\sqrt{s}$ = 500 GeV	$p_{\rightarrow}$ $p_{\rightarrow}$ $p_{\rightarrow}$ $p_{\rightarrow}$ $p_{\rightarrow}$ $p_{\rightarrow}$	20 + 3 weeks 1 week pp2pp 2 weeks commissioning
9	Low $\sqrt{s_{NN}}$ $\sqrt{s_{NN}}$ = 200 GeV $\sqrt{s}$ = 200 GeV	Au + Au Au + Au $p_{\rightarrow}$ $p_{\rightarrow}$	12 + 2 weeks 3 weeks* 10+2 weeks

* Performance based, contingent on finishing QCD Critical Point Search

The philosophy: focus on qualitative, rather than only quantitative steps forward as the machine and detector capability improve to maximize the scientific impact and discovery potential in the next 3 years

Physics Driving Proposal for Run 7

Qualitative advance in our understanding of the suppression of non-photonic electrons from D, B semi-leptonic decays

Definitive results on the saturation scale for the gluon distribution in relativistic heavy nuclei

Decisive test of gluon saturation as the origin of particle suppression at forward pseudorapidity

Measurements at RHIC in Run 7 which address these questions can result in a sea change in our understanding of jet-quenching and the initial conditions in RHIC HI collisions

Enabling Developments

The Silicon Vertex Tracker shown to achieve design performance in Cu+Cu at 62 GeV

The STAR Forward Meson Spectrometer (FMS) will be in place by Run 7

No extraordinary assumptions about machine capability beyond what C-AD has projected or already achieved are necessary

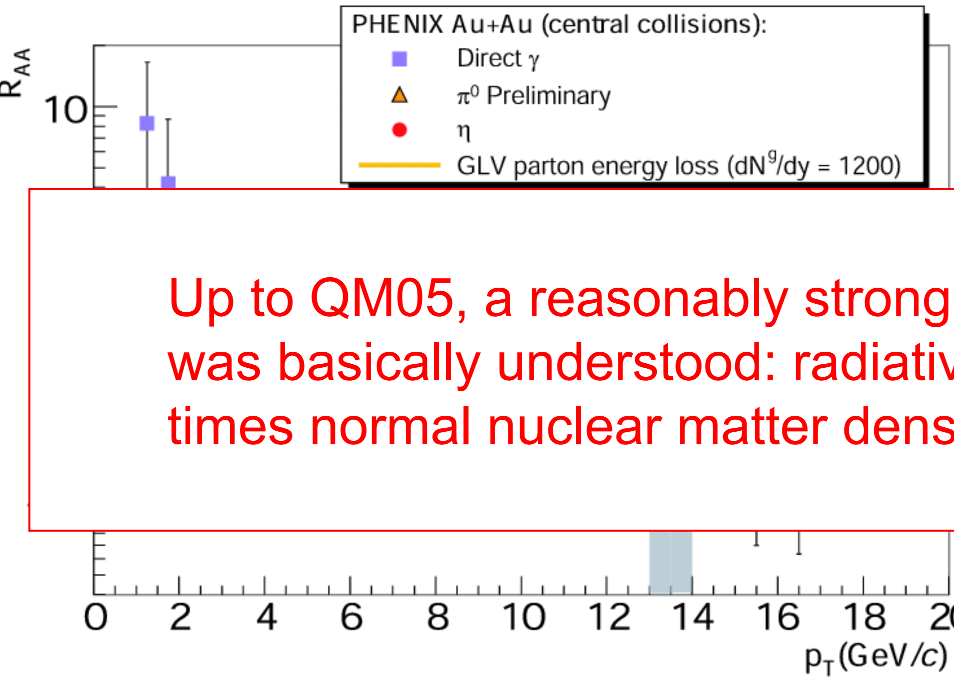
Status of Jet Quenching Story

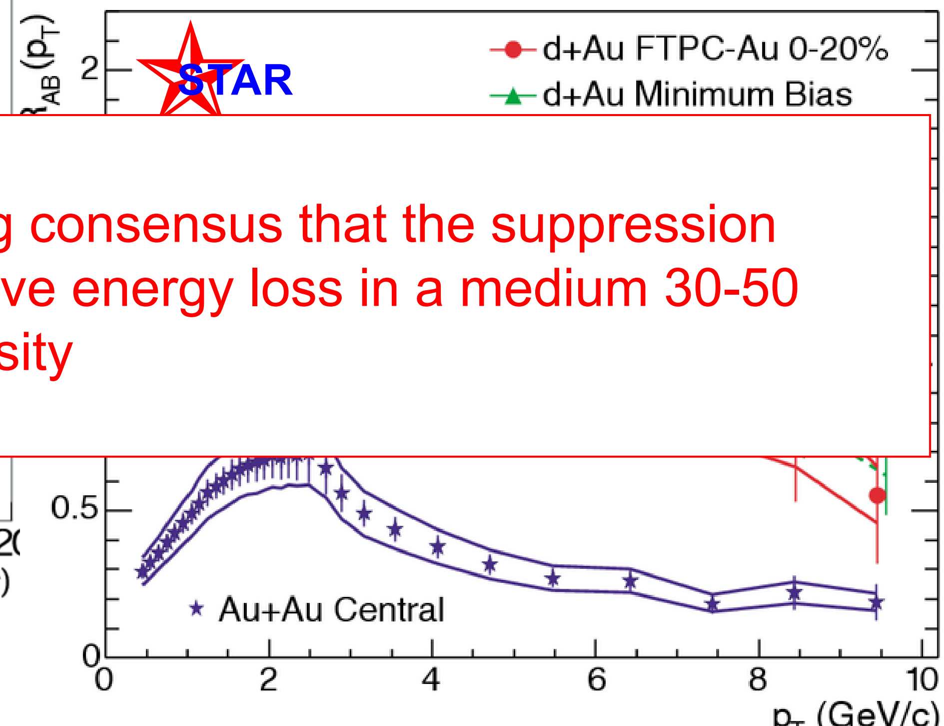
$$R_{AA}(p_T) = \frac{d^2N^{AA}/dp_T d\eta}{T_{AA} d^2\sigma^{NN}/dp_T d\eta}$$

← Nuclear Modification Factor

Binary collision scaling

Short summary: hadrons containing light quarks are suppressed; direct photons are not





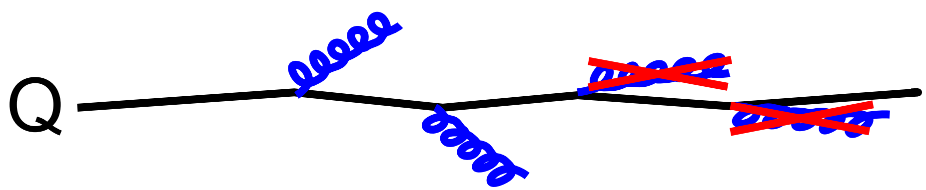
Up to QM05, a reasonably strong consensus that the suppression was basically understood: radiative energy loss in a medium 30-50 times normal nuclear matter density

$\sqrt{s_{NN}} = 200$

Status of Jet Quenching Story

Then these measurements were extended to the heavy quark sector (c, b) by studying suppression of electrons from their semi-leptonic decays

Heavy quark energy loss



Dokshitzer, Khoze, Troyan, JPG 17 (1991) 1602.
Dokshitzer and Kharzeev, PLB 519 (2001) 199.

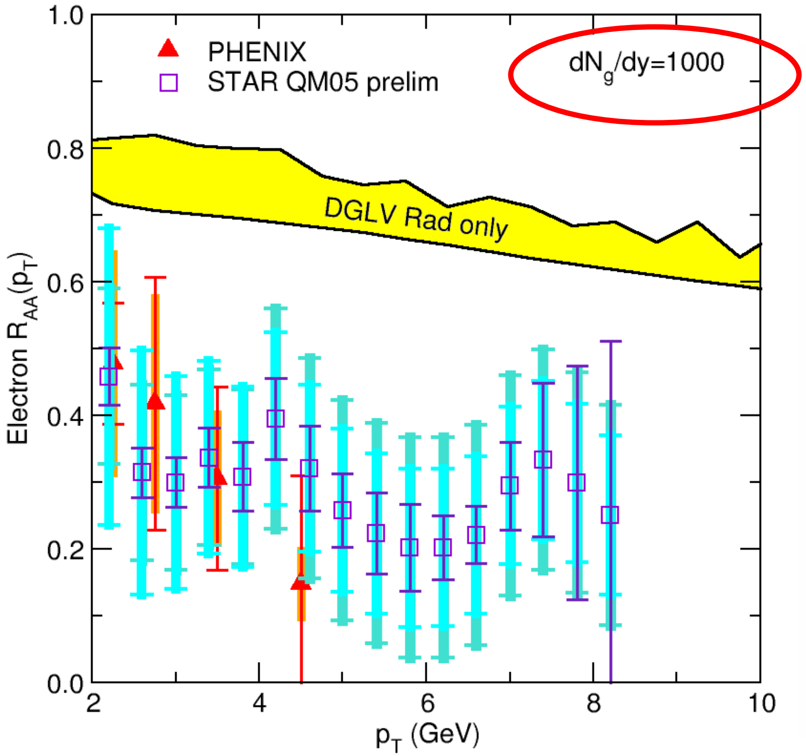
- In vacuum, gluon radiation suppressed at $\theta < m_Q/E_Q$

"Dead cone" also implies lower heavy quark energy loss in matter: (Dokshitzer-Kharzeev, 2001)

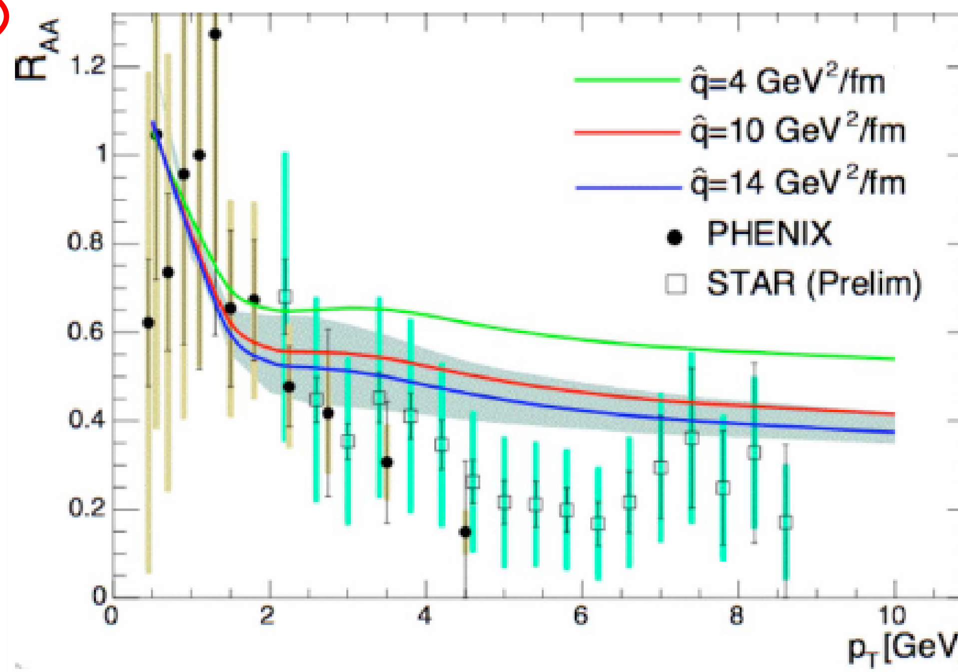
$$\omega \frac{dI}{d\omega}\bigg|_{HEAVY} = \frac{\omega \frac{dI}{d\omega}\Big|_{LIGHT}}{\left(1+\left(\frac{m_Q}{E_Q}\right)^2 \frac{1}{\theta^2}\right)^2}$$

Heavy flavor suppression via b,c $\rightarrow$ e+X

S.Wicks et al., nucl-th/0512076



Armesto et al., Phys.Lett.B637:362-366,2006



R_{AA}(non-photonic electrons) ~ 0.2 ~ $R_{AA}(\pi^0)$!!

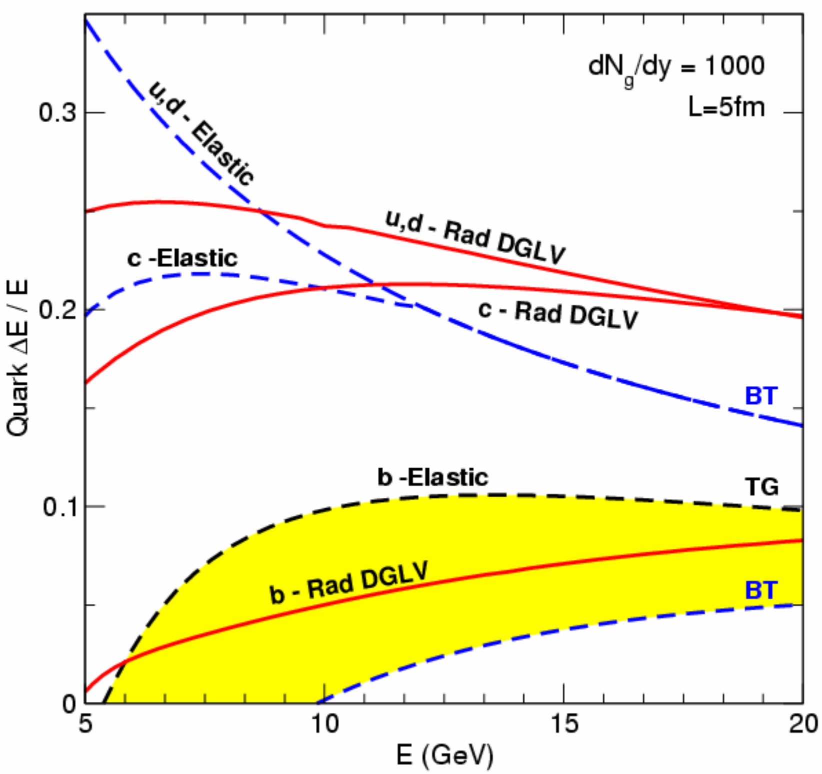
Gluon density/qhat constrained by light quark supression+entropy density (multiplicity)

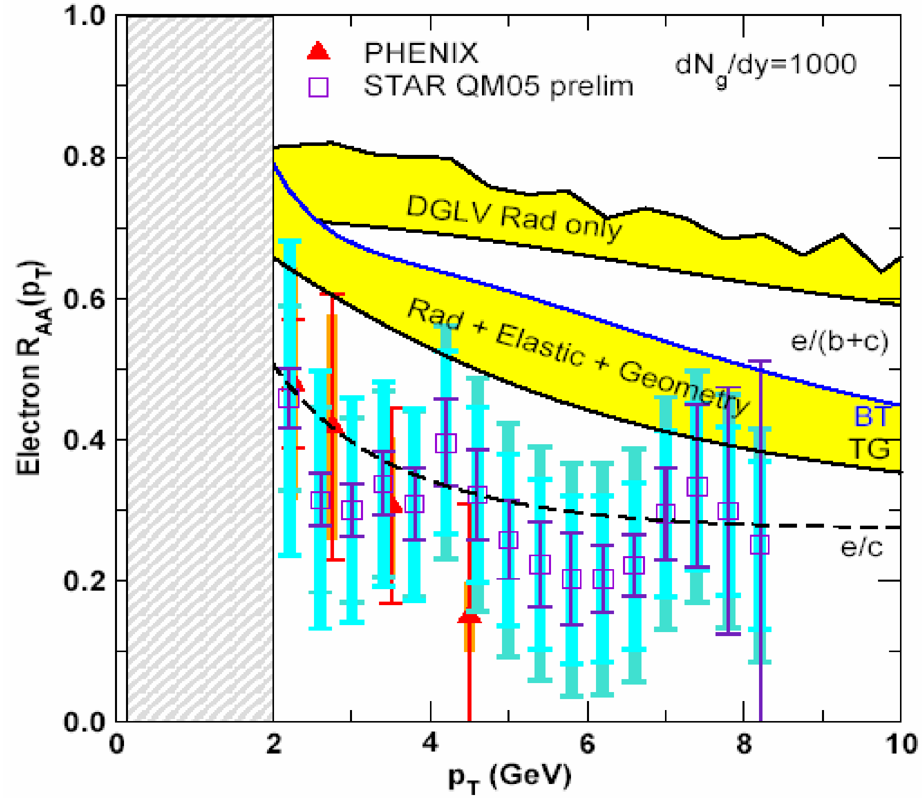
$\Rightarrow$ under-predicts electron suppression

$\Rightarrow$ charm vs beauty? elastic energy loss? …?

Elastic (collisional) energy loss revisited

S.Wicks et al., nucl-th/0512076





Elastic ΔE comparable to Radiative ΔE – not negligible

Elastic ΔE important even for light quarks

⇒ revisit energy density estimates?

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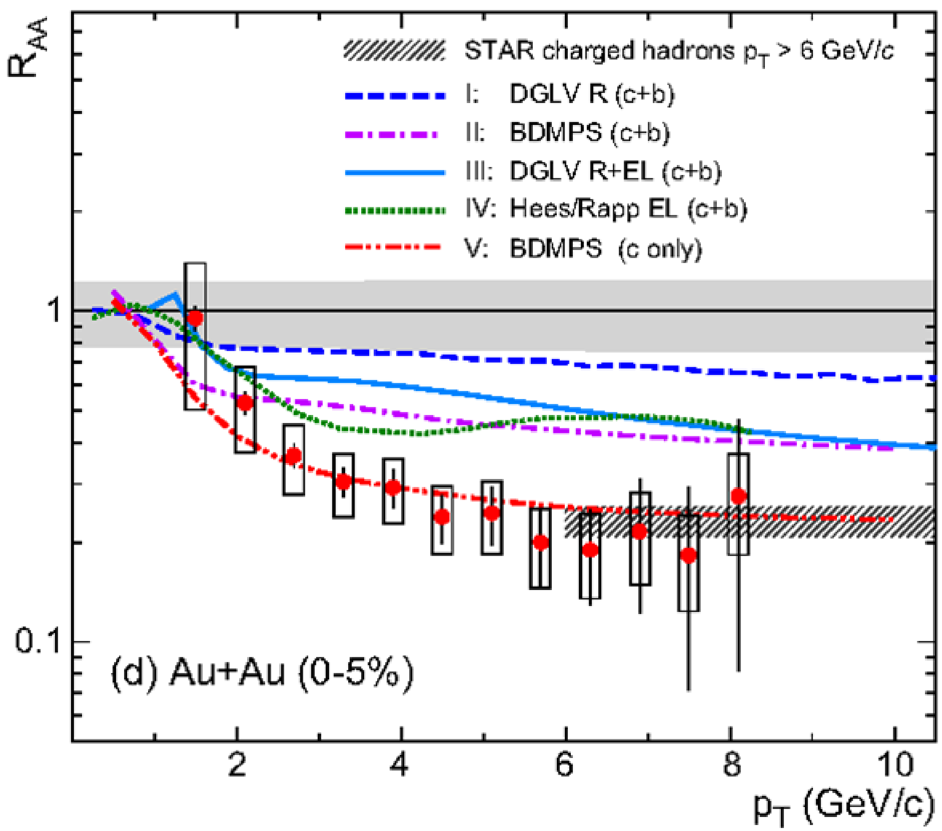
Status of Jet Quenching Story

One possibility: maybe all the non-photonic electrons are from charm decays?

Submitted to PRL, nucl-ex/0607012

BDMPS: N. Armesto et al, nucl-ex/0511257

DGLV: Wicks et al, nucl-ex/0512076



c+b, radiative only

c+b, collisional+radiative

c only, collisional+radiative

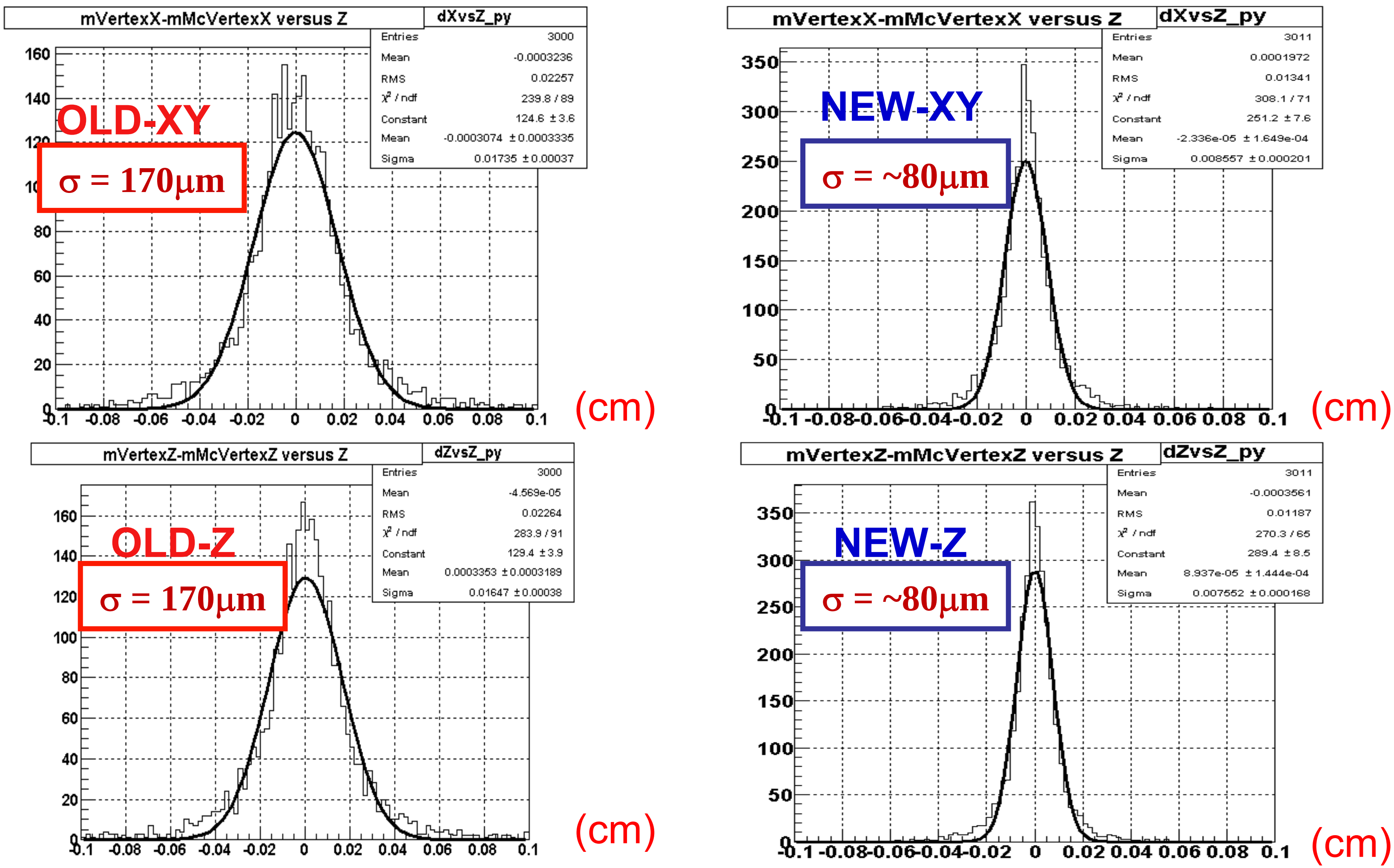
The short summary:

Resolution of non-photonic electron suppression puzzle needs

- experiment: explicit measurement of c vs b suppression
- theory: unified framework incorporating both elastic and radiative energy loss

A Recent Technical Accomplishment:

Progress optimizing event vertex resolution using SVT+SSD (Cu+Cu, 62 GeV)

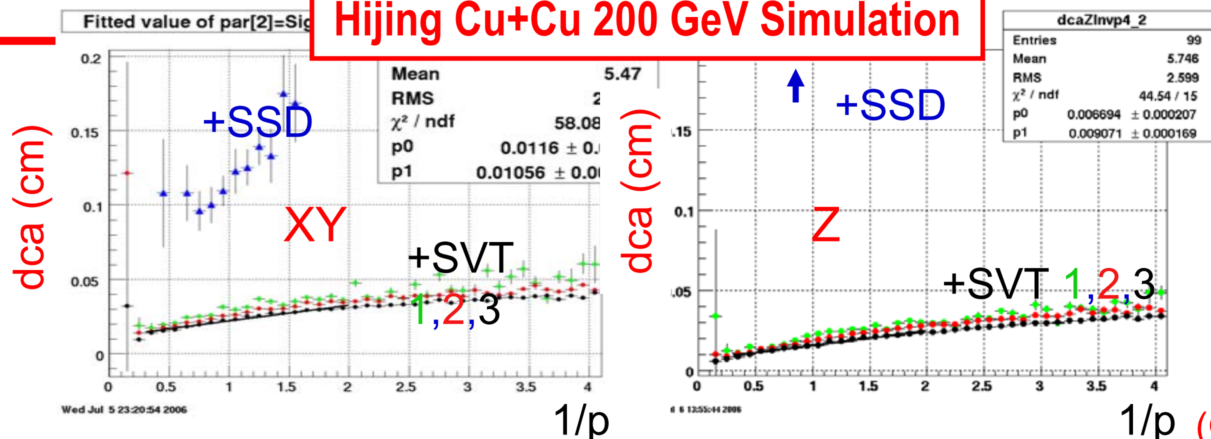


Factor of ~3 in event vertex resolution gained relative to previous SVT; ~7 relative to TPC

→ event vertex resolution not a limiting factor for μVertex-ing in STAR

Progress in optimizing DCA Resolution using SVT+SSD

Hijing Cu+Cu 200 GeV Simulation

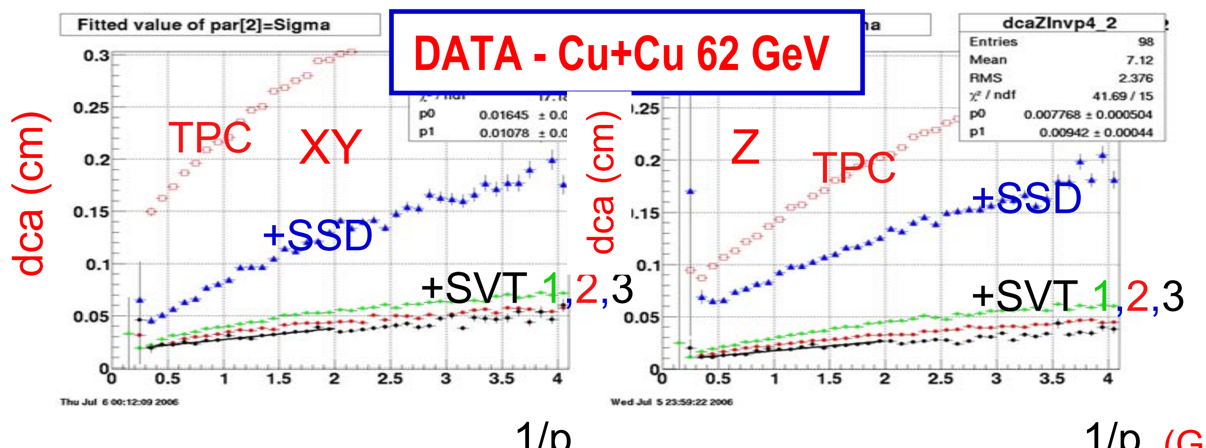


<u>IDEAL case scenario</u> (resolution includes vertex and hit resolutions)

At infinite momentum limit, dca resolution is ~120um in XY and 70um in Z

At 1 GeV/c it is 200um in XY and 150 in Z

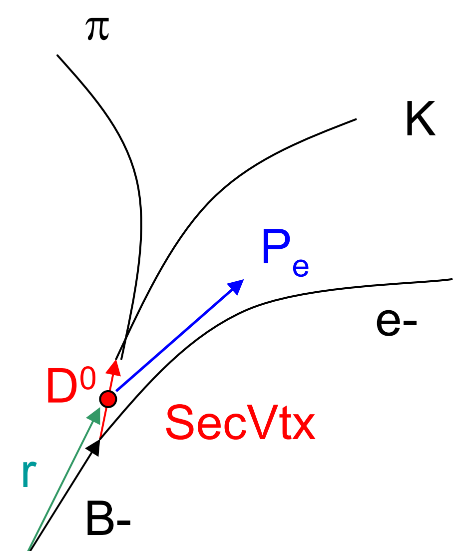
DATA - Cu+Cu 62 GeV



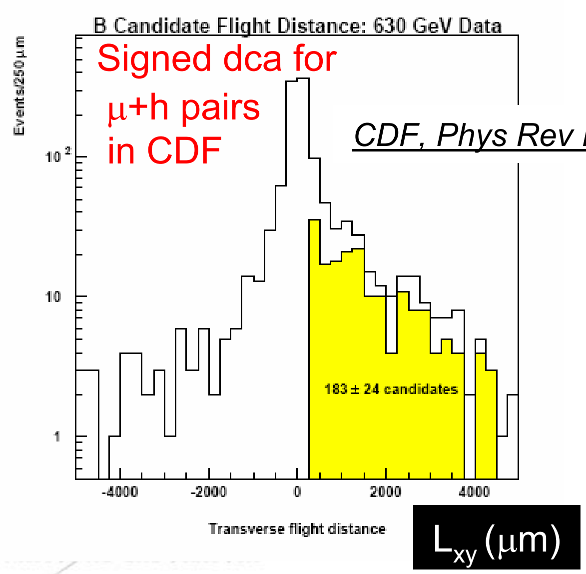
Conclusion: SVT now performing close to design
projected resolutions for Au+Au at $\sqrt{s_{NN}}$ = 200 GeV suggest
improved significance for D → kπ, comb subtraction possible

Displaced vertices using SVT

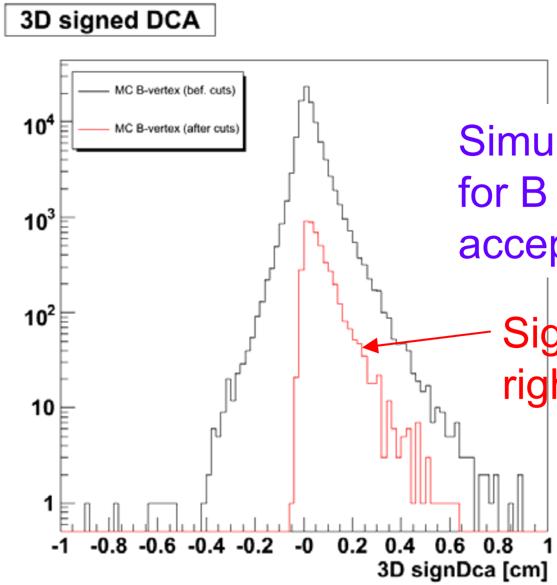
- Search for semi-leptonic B-decay
  - $B \Rightarrow e + D^0 \Rightarrow e + K^- + \pi^+$
- Create pairs of leptons and charged tracks which match the criteria for a secondary vertex:
  - $p_T > 1$ GeV/c, $R = \sqrt{\Delta\eta^2 + \Delta\phi^2}$
- Form signed DCA (sDCA) of lepton-hadron pairs as surrogate for B decay vertex



Quantity sDCA: $L_{(xy)z} = r \cdot p_e / |p_e|$



CDF, Phys Rev D 66 (2002)

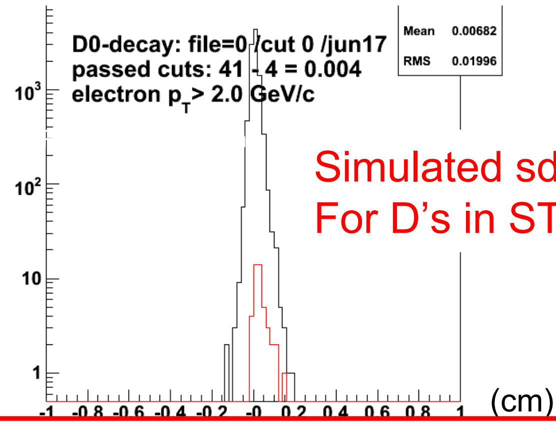


Simulated signed dca for B decays in STAR acceptance

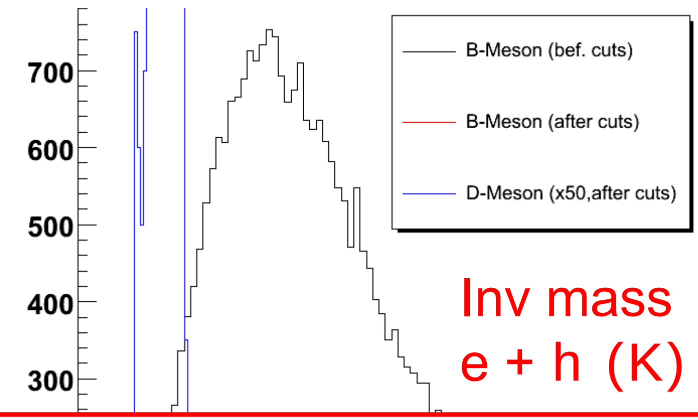
Signal from right – left subtraction

Disentangling B/C vertices

Semi-leptonic D^0 (~120μm)



D's and B's in the subtracted signal sample cleanly in the M_{inv} distribution



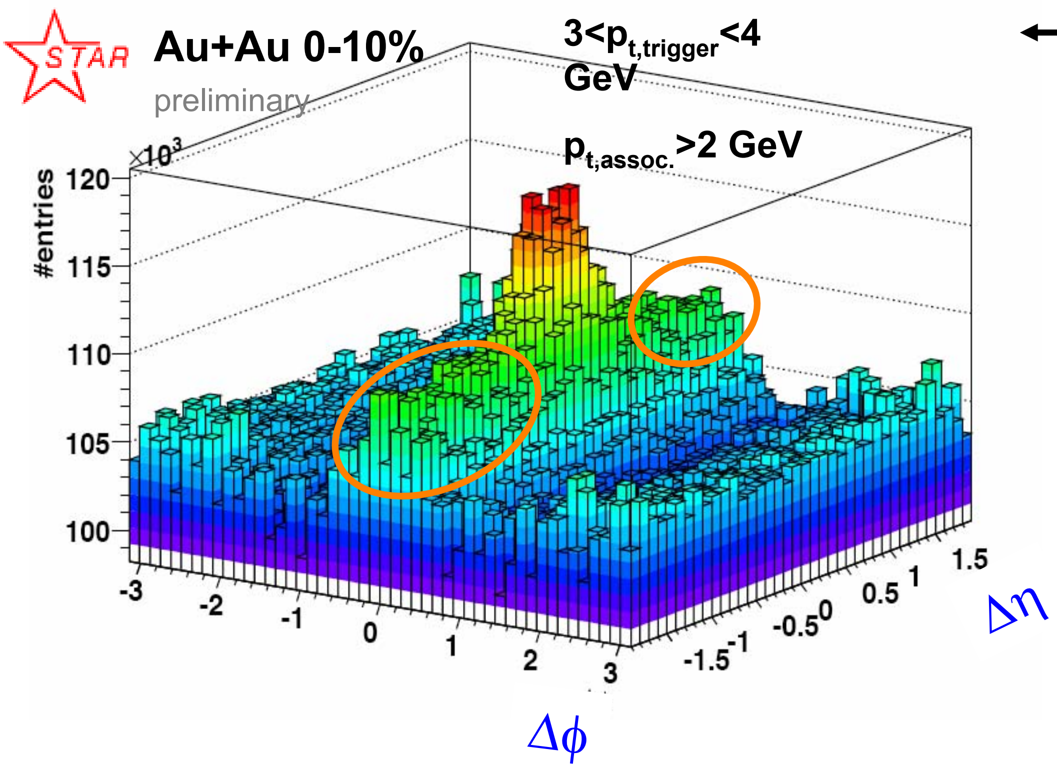
This study may give an initial result on relative D, B production

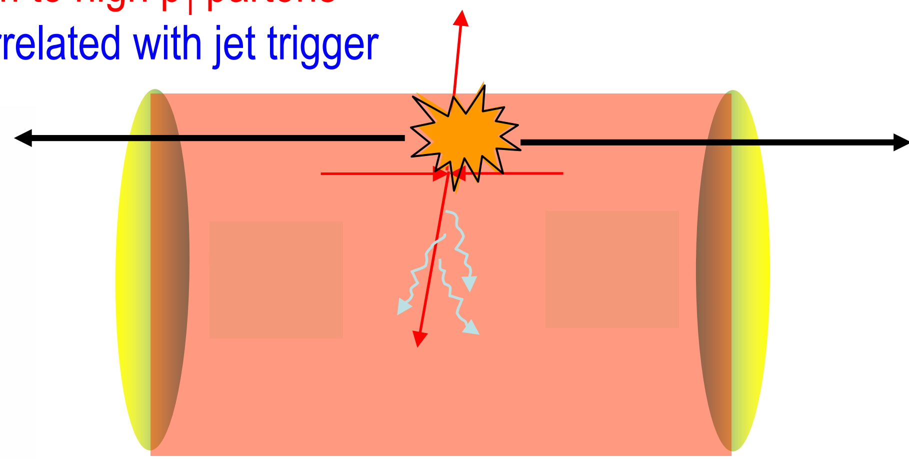
Ultimately event-by-event D, B reconstruction using STAR HFT+IST tracking upgrades required for precision yields and spectra

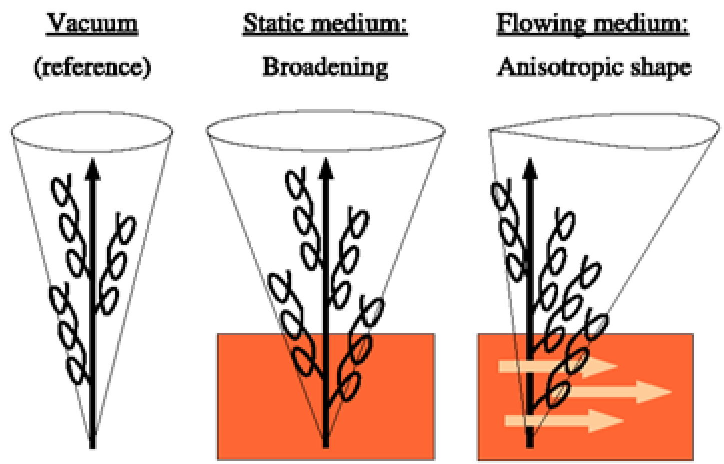
invariant mass cut

Another driving interest in Au+Au collisions

Further progress in testing the response of the medium to high p_T partons which penetrate it. One example: near-side “ridge” correlated with jet trigger



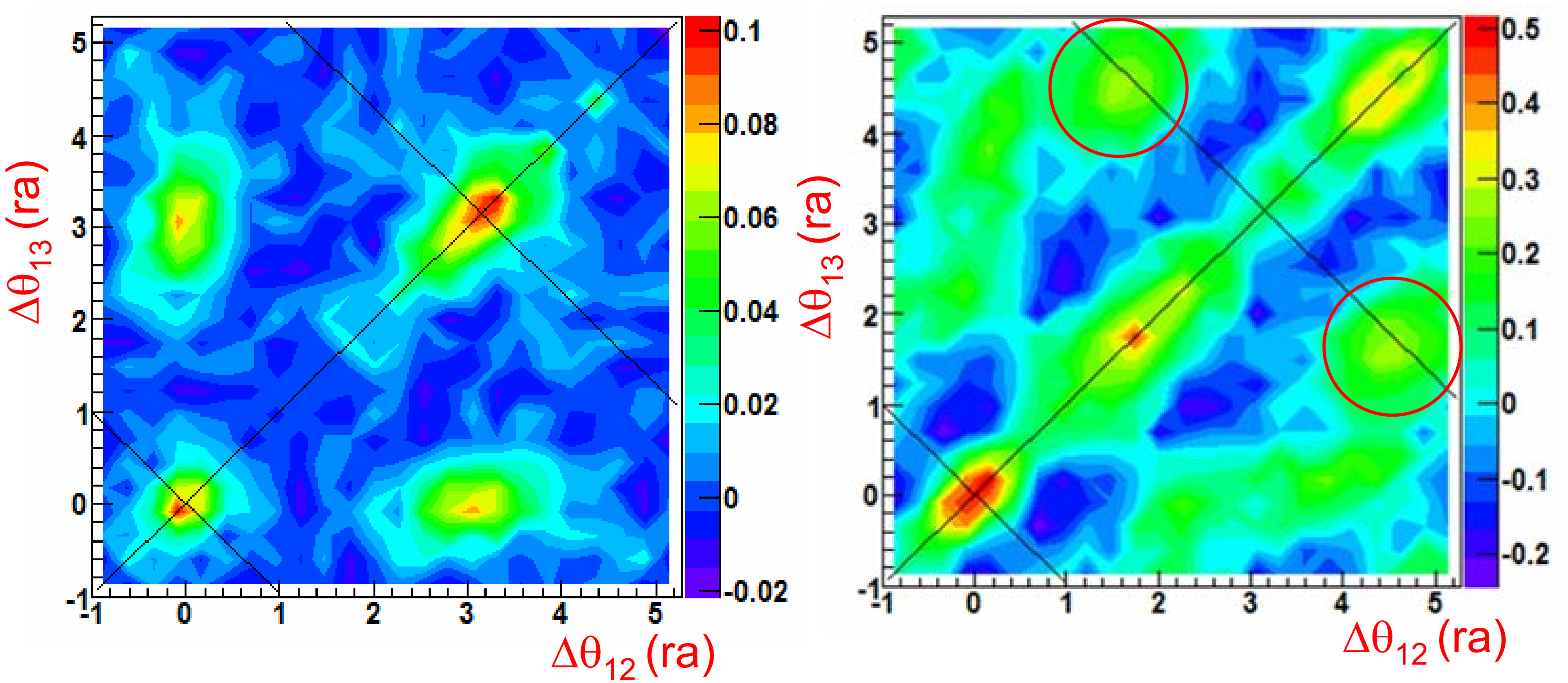




Armesto et al, nucl-ex/0405301

Induced radiation dragged by longitudinally expanding fluid?

Another intriguing conjecture

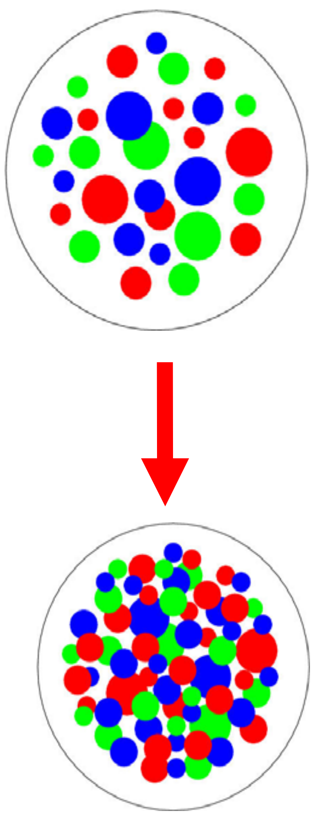


The use of triggered high pt photons from π^0 decay as a tag in Run 7 will increase the statistical power of this study by ~ order of magnitude

The science driving d+Au running

Definitive results on the saturation scale for the gluon distribution in relativistic heavy nuclei

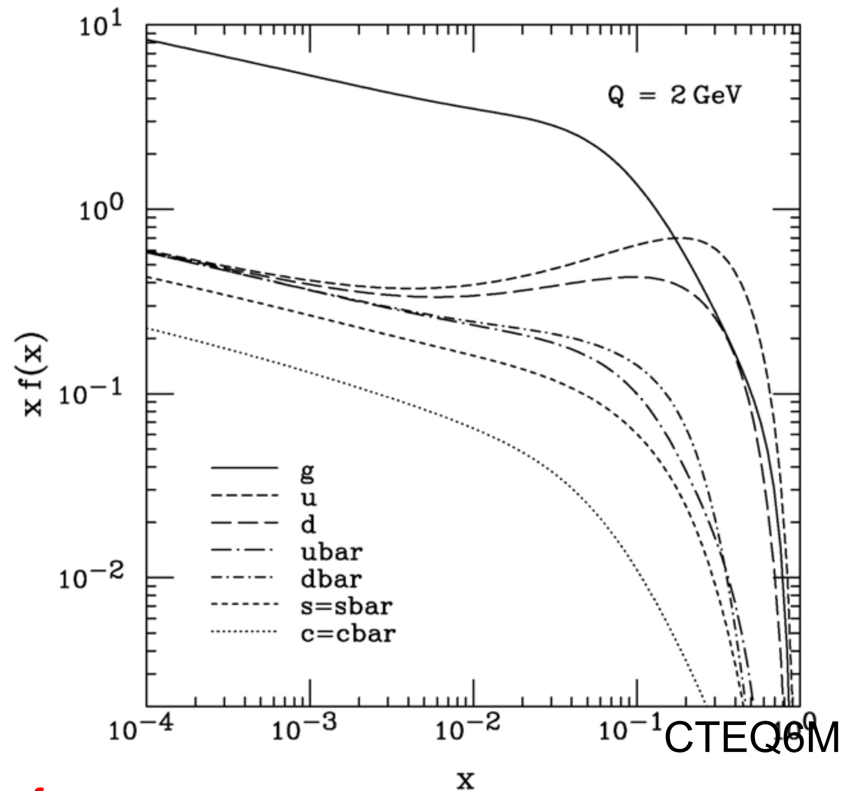
Decisive test of gluon saturation as the origin of particle suppression at forward pseudorapidity



Mid Rapidity

$$x \sim \frac{2\,p_T}{\sqrt{s}}\,e^{-y}$$

Forward Rapidity

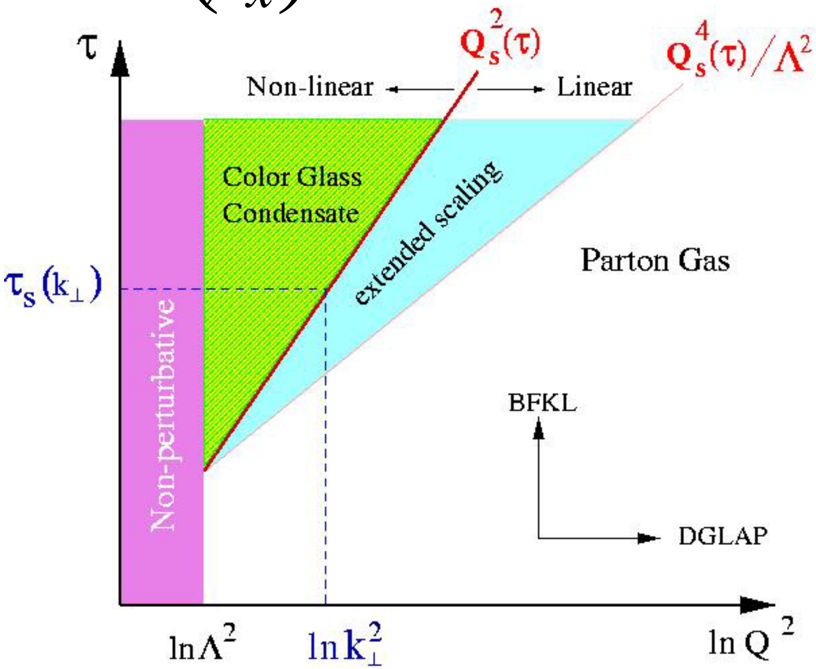


Gluon density can't grow forever.

Saturation must set in at forward rapidity when gluons start to overlap.

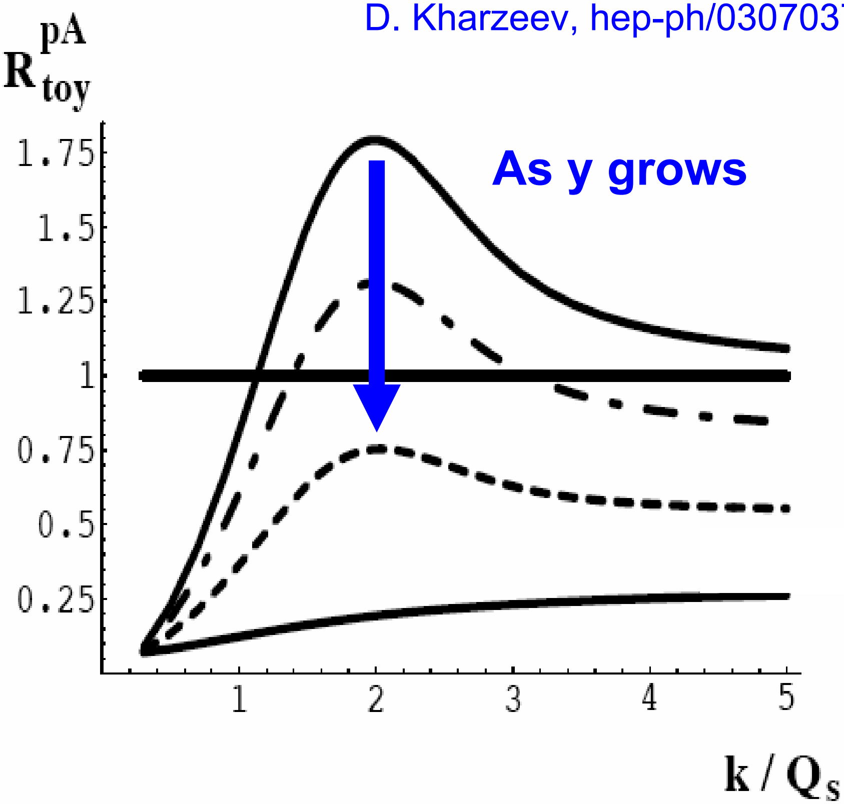
Expectations for a Color Glass Condensate

$\tau = \ln\left(1/x\right)$ τ related to rapidity of produced hadrons.



Iancu and Venugopalan, hep-ph/0303204

D. Kharzeev, hep-ph/0307037



Is there evidence for **gluon saturation at RHIC energies**?

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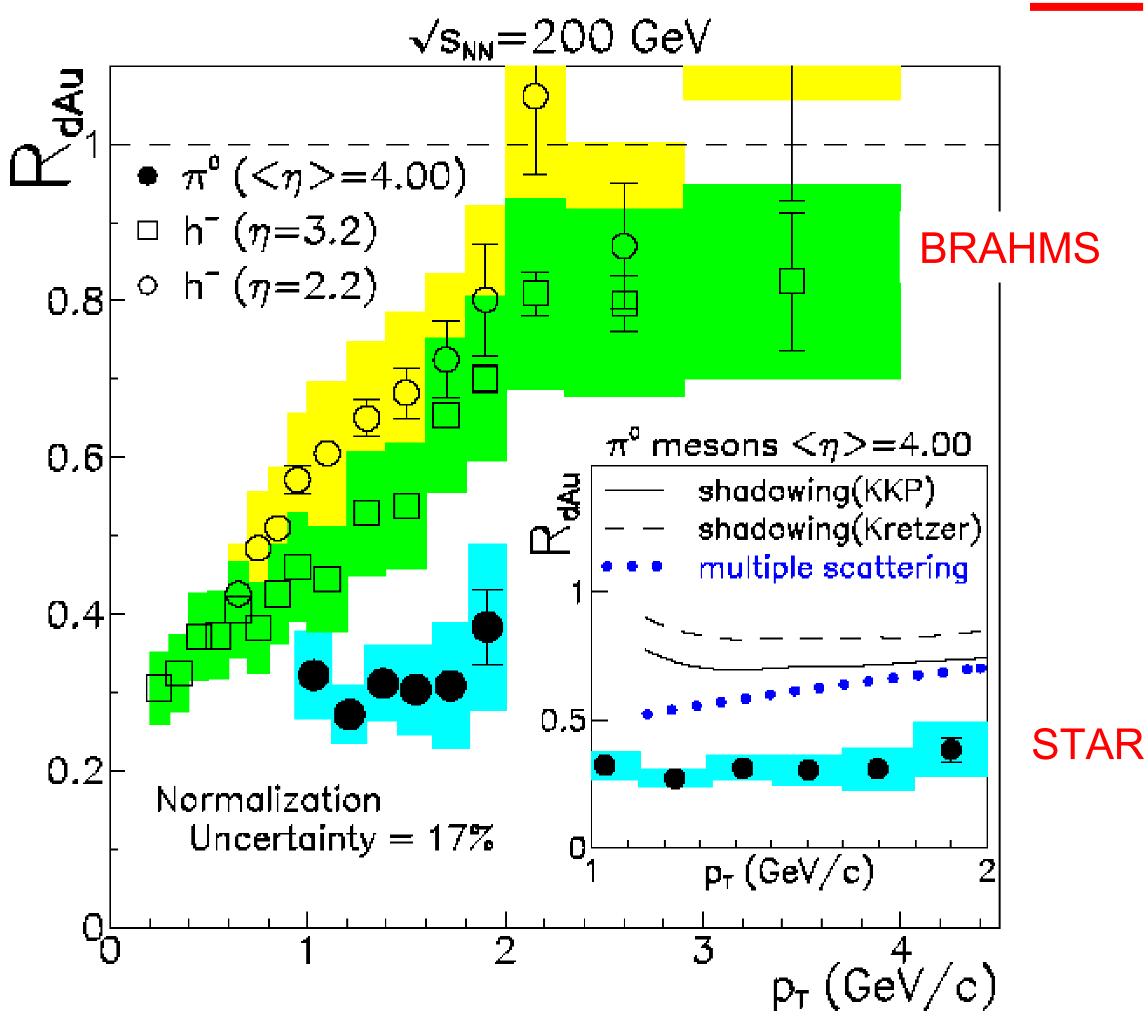
η dependence of R_{dAu} at RHIC

Accepted to PRL

nucl-ex/0602011

$$R_{dAu} = \frac{1}{2*197}\frac{\sigma_{dAu}}{\sigma_{pp}}$$



- Observe significant rapidity dependence, similar to expectations from the saturation framework.
- pQCD calculations significantly over predict R_{dAu}.

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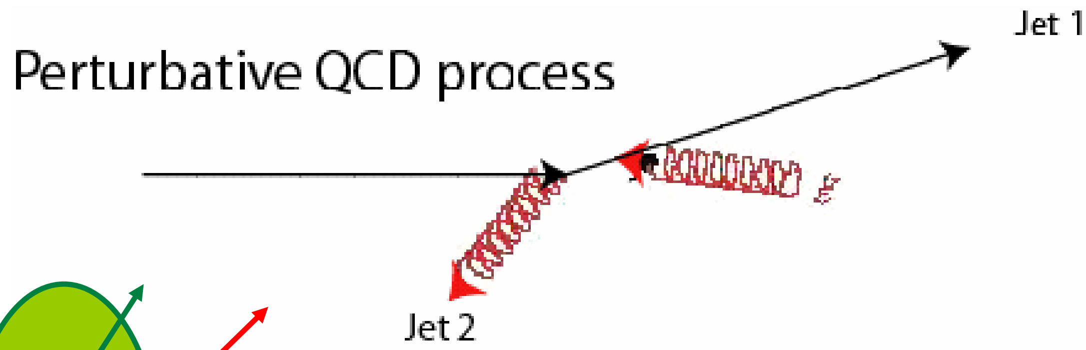
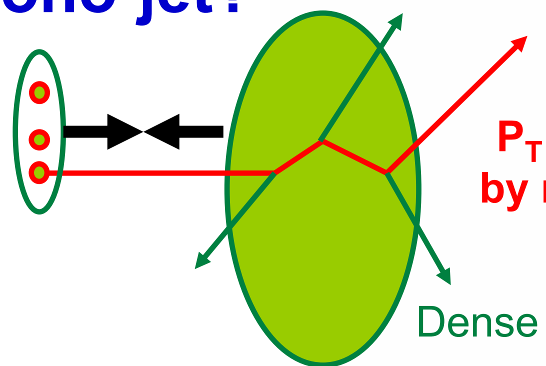
Correlations, a definitive test: the difference between p+p and d+Au

p+p: **Di-jet**

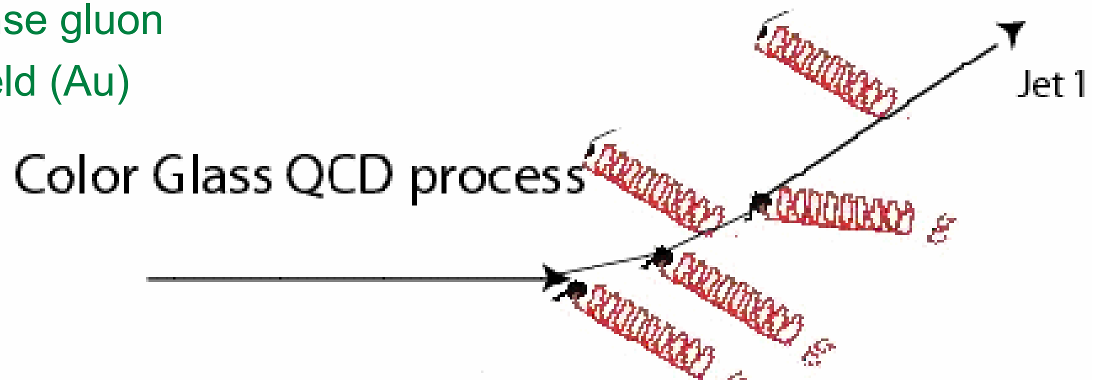


d+Au: **Mono-jet?**



P_T is balanced by many gluons

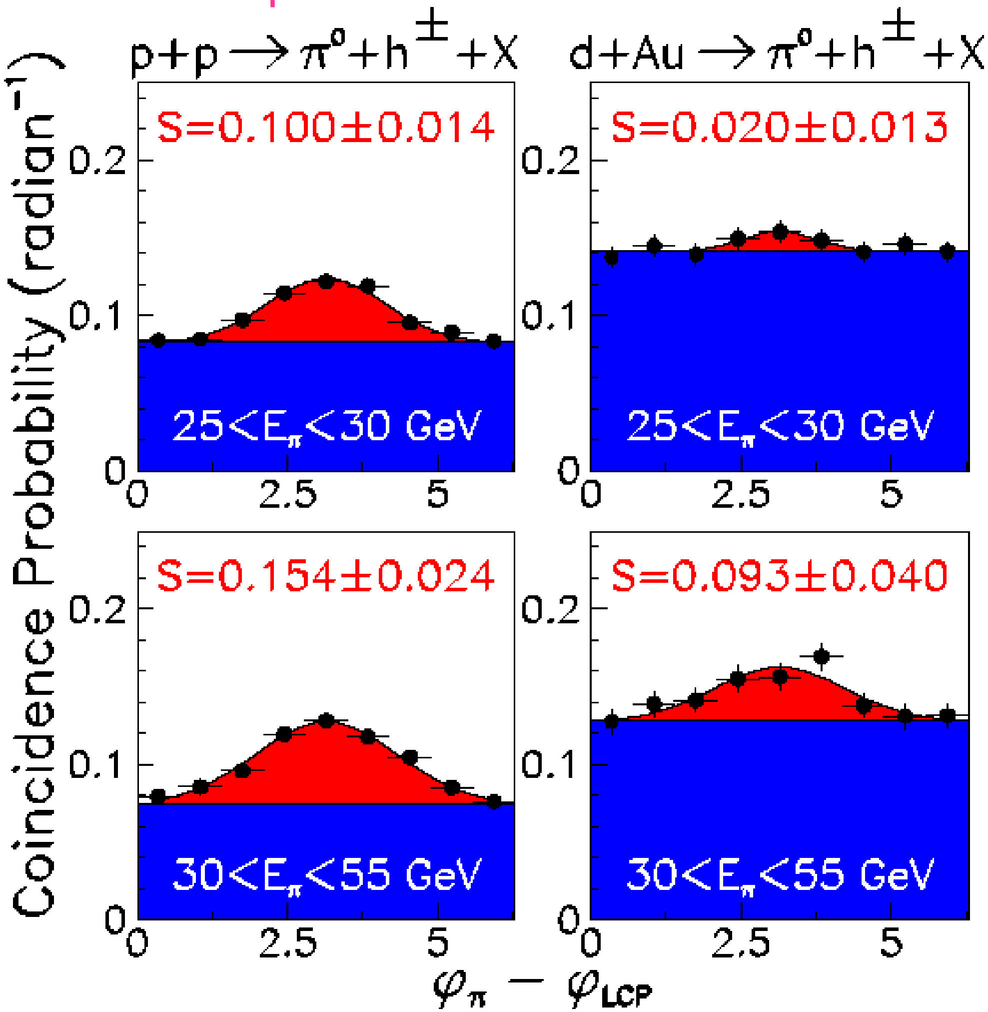
Kharzeev, Levin, McLerran gives physics picture (NPA748, 627)



Color glass condensate predicts that the back-to-back correlation from p+p should be suppressed

An initial glimpse: correlations in d+Au

Accepted to PRL   nucl-ex/0602011



<$p_{T,\pi}$> ~ 1.0 GeV/c

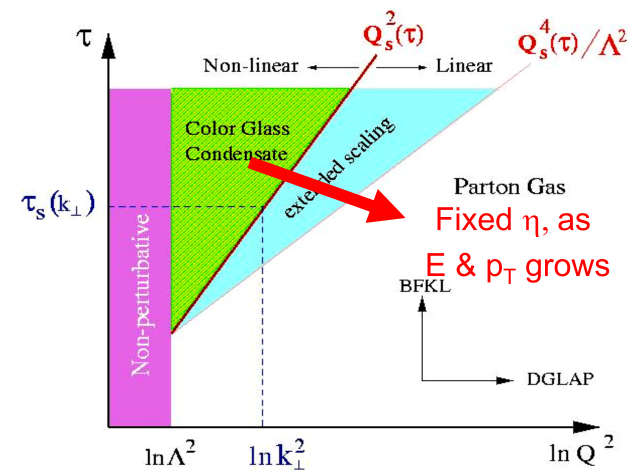
<$p_{T,\pi}$> ~ 1.3 GeV/c

π^0: |<η>| = 4.0

$h^{\pm}$: |η| < 0.75; p_T > 0.5 GeV/c

- are suppressed at small <x_F> and <$p_{T,\pi}$>

consistent with CGC picture



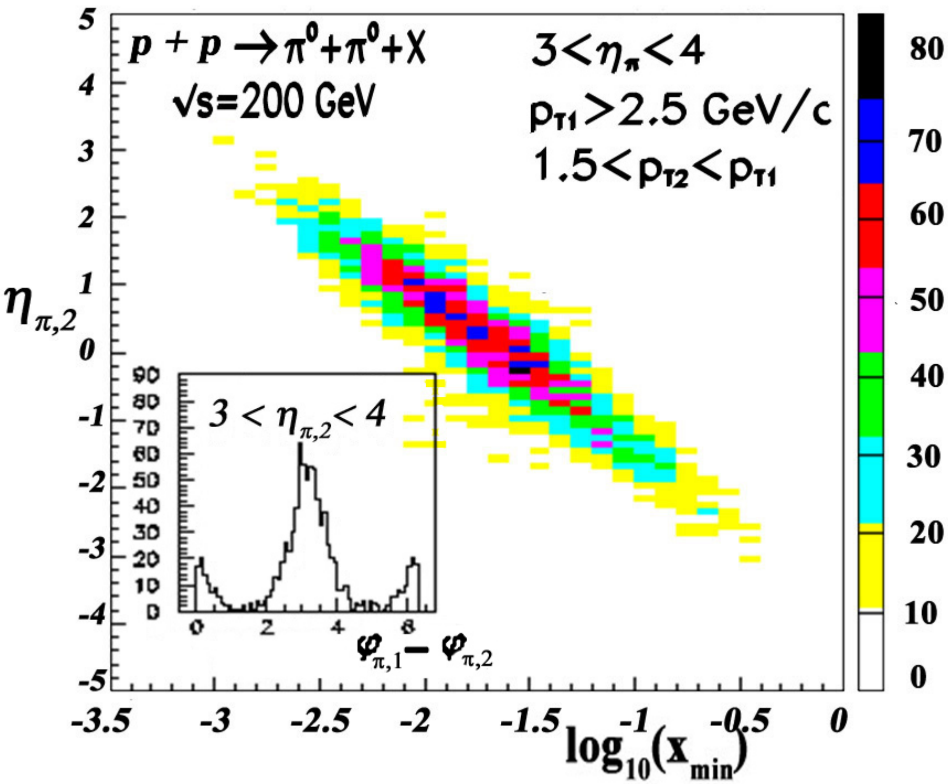
- are similar in d+Au and p+p at larger <x_F> and <$p_{T,\pi}$>

As expected by HIJING

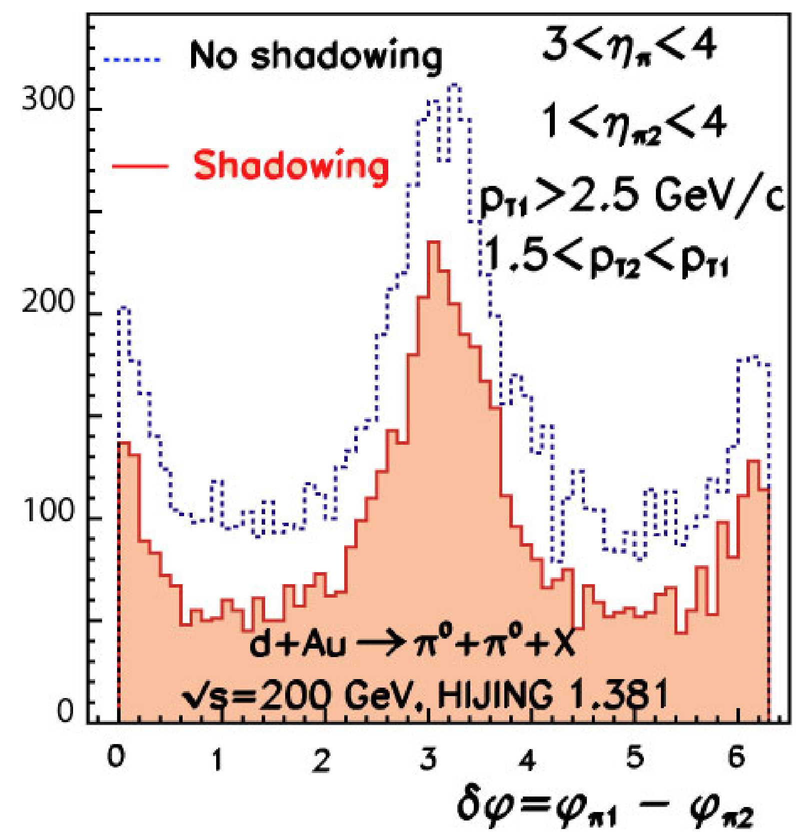
p+p and d+Au → $\pi^0+\pi^0+X$ correlations with forward π^0

STAR

p+p in PYTHIA



d+Au in HIJING hep-ex/0502040



Conventional shadowing will **change yield, but not coincidence structure**.

Coherent effects such as CGC evolution will **change the structure**.

Sensitive to x_g **~ 10^{-3} in pQCD** scenario; **few x 10^{-4} in CGC** scenario.

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World-wide interest in this science? QM06 abstracts…

CGC, Full 3-D Hydro, and Hadronic Cascade

Hyrano, Heinz, Kharzeev, Lacey, Nara

Jet Tomographic Tests of the CGC Initial State at RHIC and LHC

Adil, Gyulassy

Forward Nuclear Modification Form Factor in Au-Au and Cu-Cu Collisions at $\sqrt{s_{NN}}$ = 62.4 GeV

Larsen

Centrality Dependence of Charge Hadron Spectra pT at Forward Rapidities in Cu-Cu Collisions at $\sqrt{s_{NN}}$ = 200

Bekele

System Size and Rapidity Dependence of the Nuclear Modification Factor

Karabowicz

Does the Cronin Peak Disappear?

Barnaf, L'evaia, Papp, Fai, Cole

Are Jets Quenched in Cold Nuclei?

Vitev

Identified Particle Nuclear Modification Factors at Rapidity = 2-3.8 in Au-Au Collisions at s_{NN} = 200 GeV

Ristea

World-wide interest in this science? QM06 abstracts…

Nuclear-Induced Particle Suppression at Large XF at RHIC
Lee

Heavy Flavor Production in pA Collisions with the MV + BK Framework
Fujii, Gelis, Venugopalan

Multiplicity Fluctuations in Cu-Cu and Au-Au Collisions at RHIC
Wo'zniak

Are there Mono-jets in High Energy Proton-Nucleus Collisions
Borghini, Gelis

Energy Dependence of Nuclear Suppression in the Fragmentation Region
Tywoniuk, Arsene, Bravina, Kaidalov, Zabrodin

QQbar Production in pA Collisions at RHIC and the LHC
Albacete, Kovchegov, Tuchin

Identified Hadron Production in d+Au and p+p Collisions at RHIC
Yang

Probing small-x gluons and large-x quarks: jet-like correlations between forward and mid-rapidity in pp, d+Au, and Au-Au Collisions from STAR
Molnara

World-wide interest in this science? QM06 abstracts…

Nuclear Modification to parton Evolution and onset of parton saturation

Kang, Qiu

Early Time Evolution of High Energy Heavy Ion Collisions

Fries, Kapusta, Li

Multiplicity Fluctuations in Cu-Cu and Au-Au Collisions at RHIC

Wo’zniak

Probing partonic distribution functions in nucleons and nuclei with Forward Calorimeters in the PHENIX Experiment at RHIC

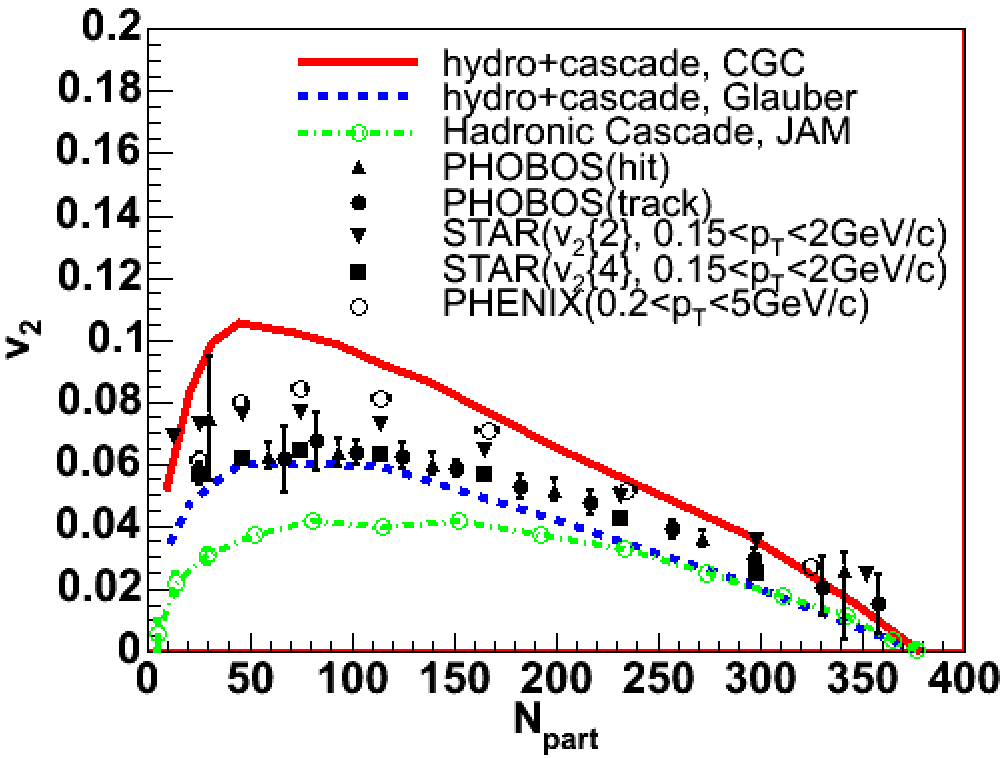
Kistenev

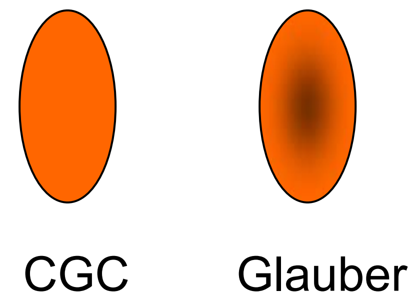
Low-x QCD with CMS at CERN-LHC

This is discovery physics of broad interest to the programs at RHIC and the LHC

Another urgent d+Au question: v_2 and the hydro limit--Glauber vs Color Glass Condensate

Hirano et al, PLB 636, 299





CGC: Treats the nucleus as a saturated gluon field

Effects initial eccentricity of the overlap zone

- Do we have Glauber matter distribution + perfect liquid, or Color Glass Condensate distribution + viscous matter?
- Understanding the initial state is **crucial to understand what we are seeing in the final state**

The short summary:

It is time to stop guessing. The proposed d+Au run will:

- Determine the saturation scale for the gluon distribution in heavy nuclei
- Provide a decisive test of gluon saturation as the origin of particle suppression at forward pseudorapidity
- Provide a crucial reference, far superior to p+p for the D, B meson studies in Au+Au

This research is compelling to:

Understand the initial state conditions for relativistic heavy nuclei at RHIC and confirm our understanding of multiplicities and rapidity dependence

Understand how thermalization appears to be established so quickly at RHIC

Understand whether we have really reached the hydro limit for v_2

Understand mid-rapidity particle production at the LHC in the future

Status of STAR Forward Meson Spectrometer upgrade

Some materials (Pb glass, tubes & bases) not available from IHEP on necessary time scale

Revised configuration under construction

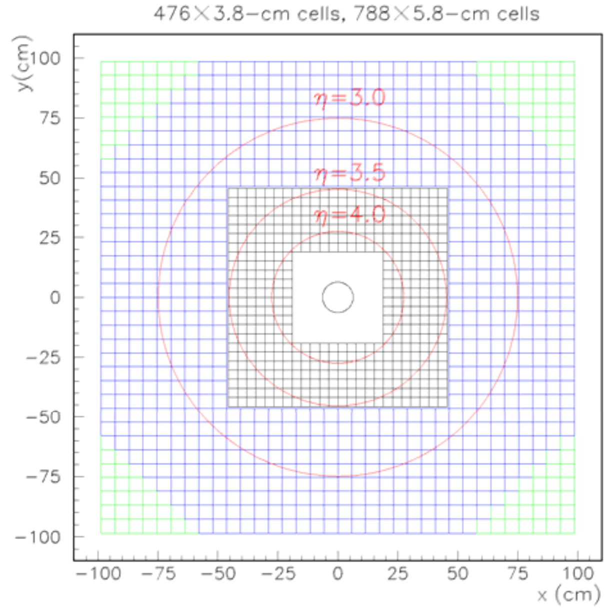
FDP++ array disassembled; movable trolley for new configuration in place

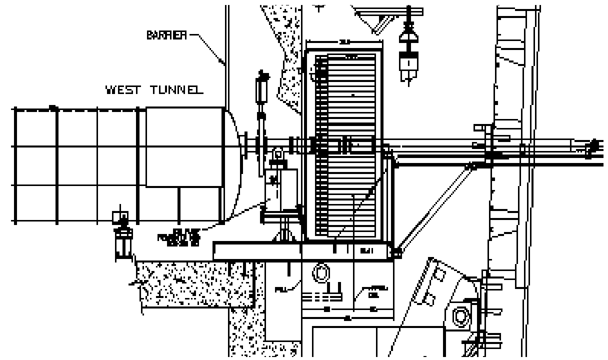
Materials procured; PMT base construction ongoing at Penn State

Sizeable student team (5 graduate, 7 undergraduate) "in harness"

Readout electronics being constructed at Space Science Lab

FMS expected to be ready for Run 7





- FMS increases areal coverage of forward EMC from 0.2 m^2 to 4 m^2
- Addition of FMS to STAR provides nearly continuous EMC from $-1<\eta<+4$

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The Physics Driving Run 8

- What is the helicity preference of gluons in the proton as a function of momentum fraction
- What is the role of orbital motion in the structure of the proton?
- What is the role of transversity in the proton?
- Seminal pp elastic scattering studies

Due to improvements in RHIC/STAR's capabilities, Run 6 data are already going to lead to a sea change in our understanding of the spin structure of the proton (Spin 2006)

By Run 8, STAR and RHIC will be ready to address a priority goal of the RHIC spin program: mapping the helicity preference of gluons as a function of momentum fraction x_{BJ}

This measurement will be optimized by an increase of 2-3 in luminosity, an increase in polarization from 60-70%, and the improved trigger effectiveness that will come from analyzing Run 6

Performance in Run 6

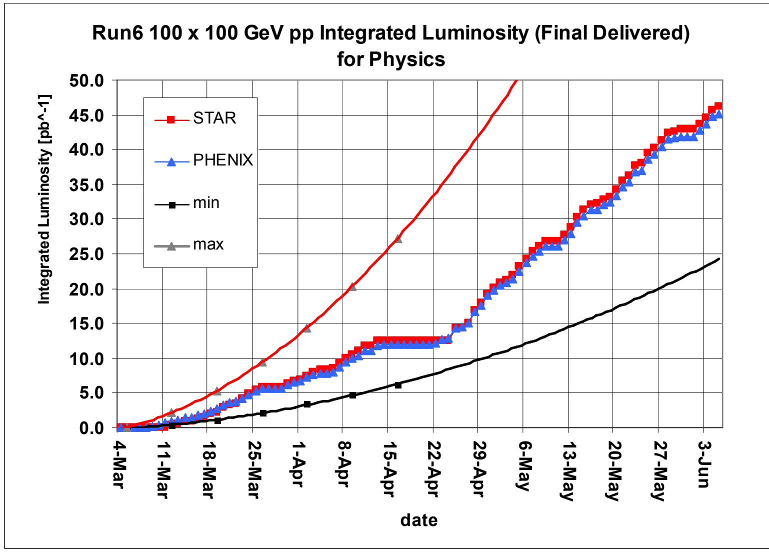


Figure 1: Integrated luminosity delivered to PHENIX and STAR during Run 6 as a function of time.

Year	Long. recorded luminosity [pb^{-1}]	Trans. recorded luminosity [pb^{-1}]	Beam polarization [%]
2002 (Run 2)	0.3	0.15	15
2003 (Run 3)	0.3	0.25	30
2004 (Run 4)	0.4	0	40-45
2005 (Run 5)	3.1	0.1	45-50
2006 (Run 6)	8.5	3.4/6.8	60

Table 2: Evolution of the recorded luminosity at STAR during longitudinal and transverse running modes at $\sqrt{s}$ = 200 GeV together with the average beam polarization from 2002 until 2006.

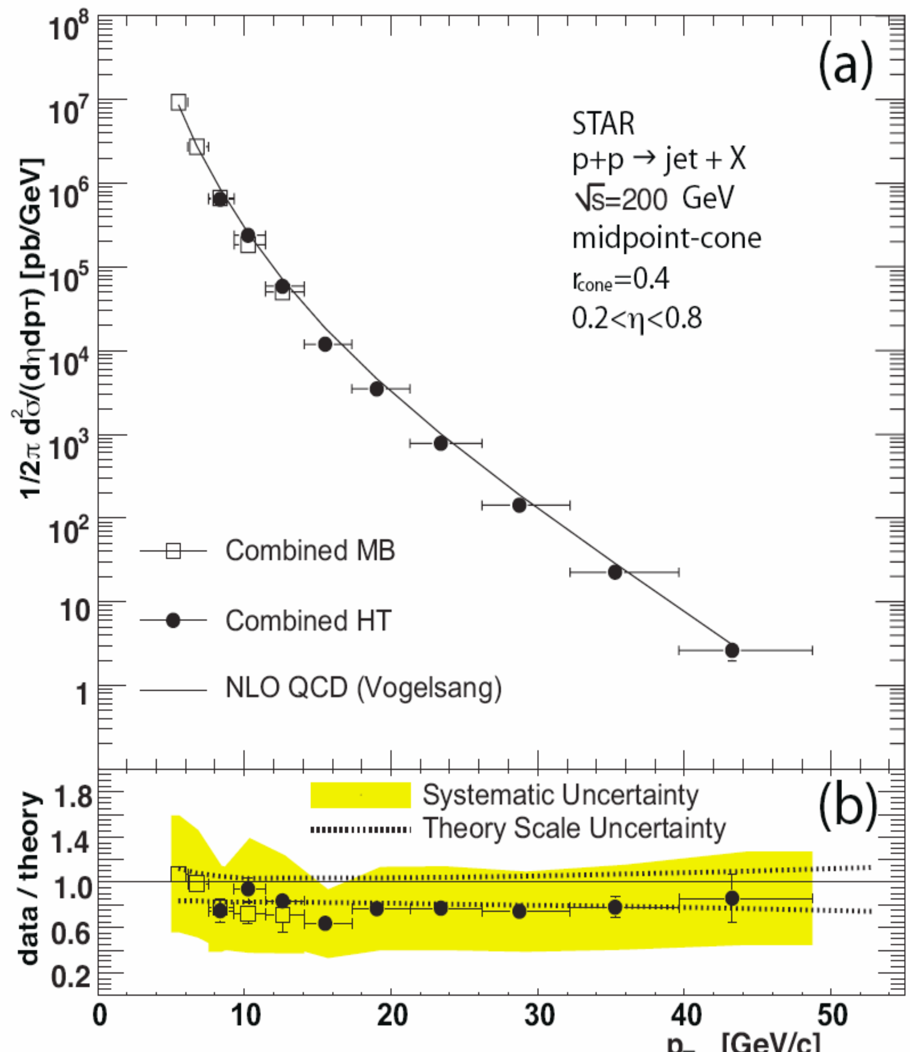
In Run 6, significant improvements in RHIC’s capability as a polarized proton-proton collider as well as in STAR detector acceptance, background suppression, and trigger capability resulted in a qualitative change in the quality, magnitude, and richness of the spin data acquired

STAR longitudinal spin program - Results

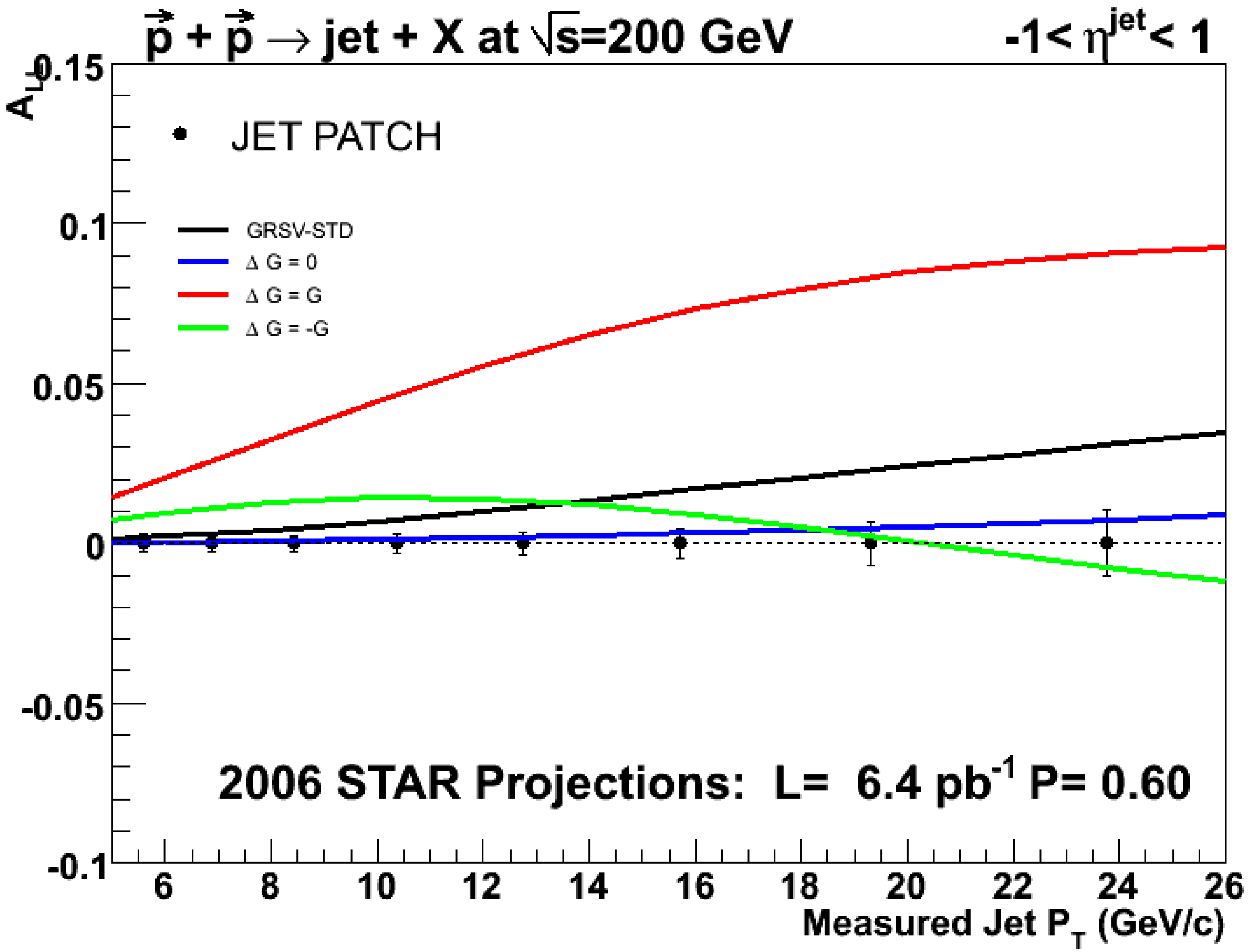
First inclusive jet cross section result at RHIC

- 2003+2004 p+p runs
  - Sampled luminosity: ~0.16 pb^{-1}
  - Good agreement between MB and HT data
  - Good agreement with NLO over 7 orders of magnitude
  - Agreement with NLO calculation within systematic uncertainty

Submitted to PRL, hep-ex/0608030



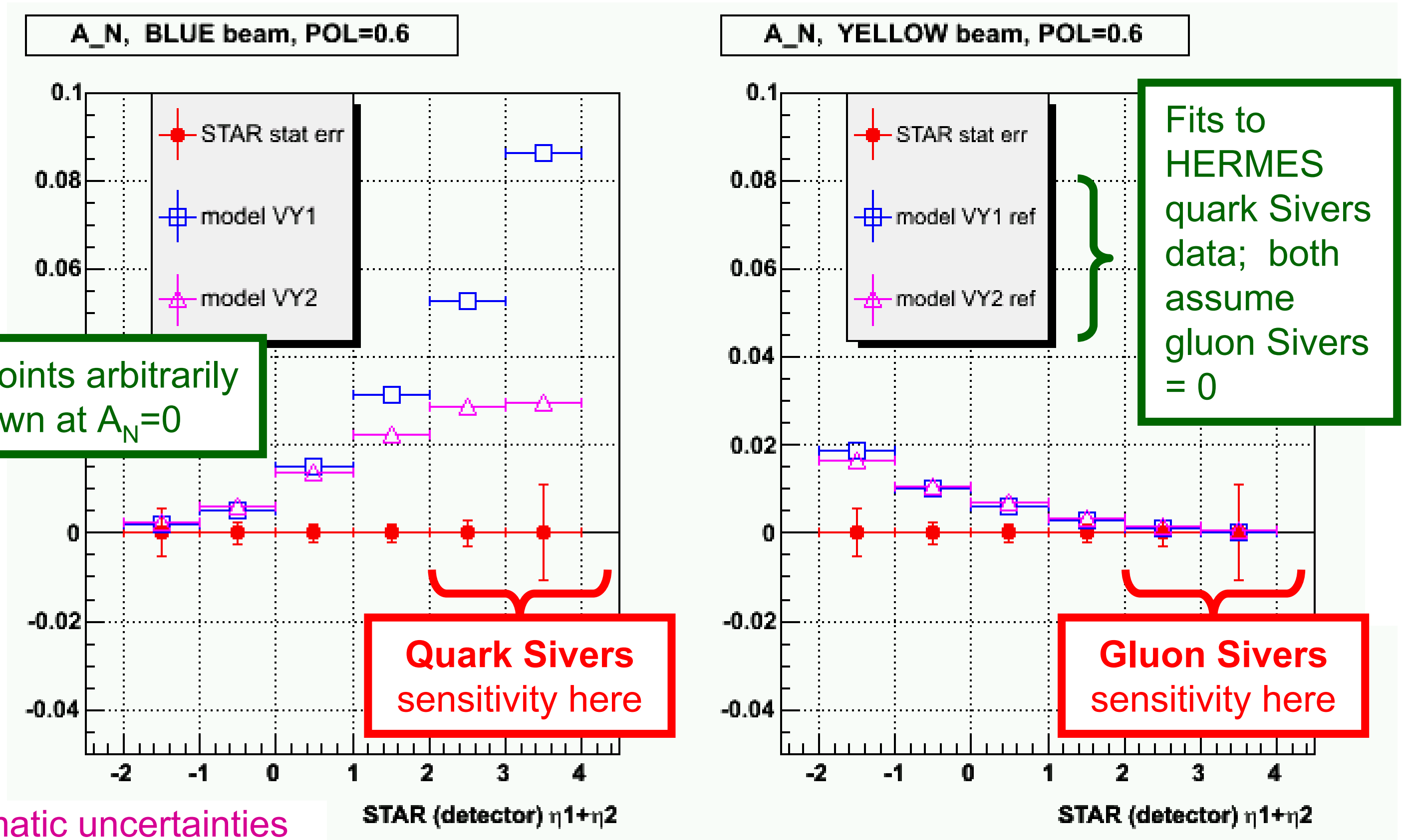
A_{LL} published (Run 3+4) and projected Run 5, Run 6 results on inclusive jet production in p+p collisions at √s =200GeV

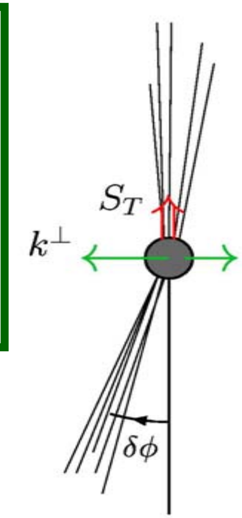


These results will place a world-class constraint on gluon polarization in the proton, ΔG

Run 6 sensitivity to Sivers effect with di-jets

(Preliminary results will be shown at SPIN'06)





Fits to HERMES quark Sivers data; both assume gluon Sivers = 0

Data points arbitrarily drawn at A_N=0

Quark Sivers sensitivity here

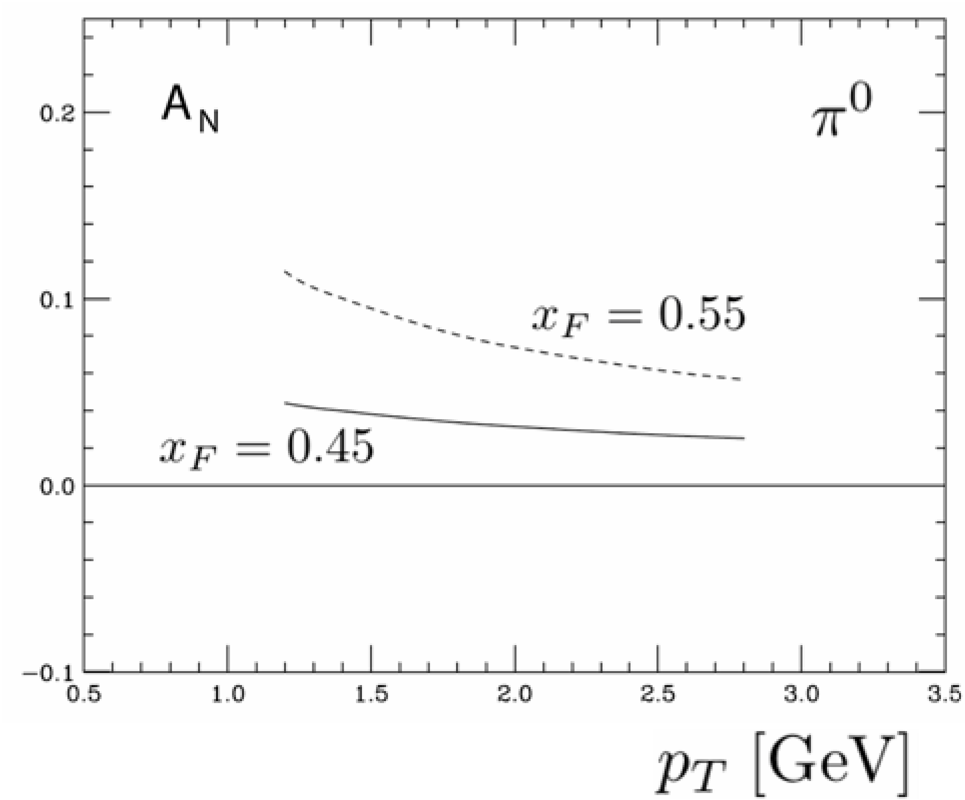
Gluon Sivers sensitivity here

Systematic uncertainties comparable to stat. errors shown.

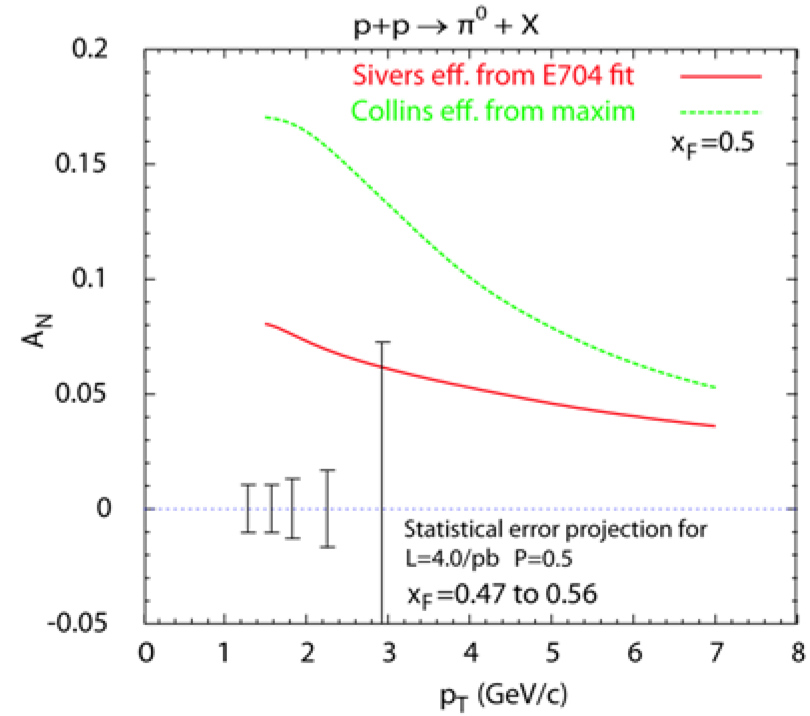
- Use di-jet opening angle to observe spin-dependent k_T (Sivers effect)
- Indicated regions have $x_B/x_Y > 7$; primarily blue beam quark + yellow beam gluon
- Simultaneous measurements of **both quark and gluon Sivers functions**, thanks to the large pseudo-rapidity coverage of *STAR*

Recent predictions for A_N in $pp \to \pi^0 + X$

W.Vogelsang
http://www.npl.uiuc.edu/~rseidl/workshops/TransverseSpin_RHICAGS06/Vogelsang.pdf



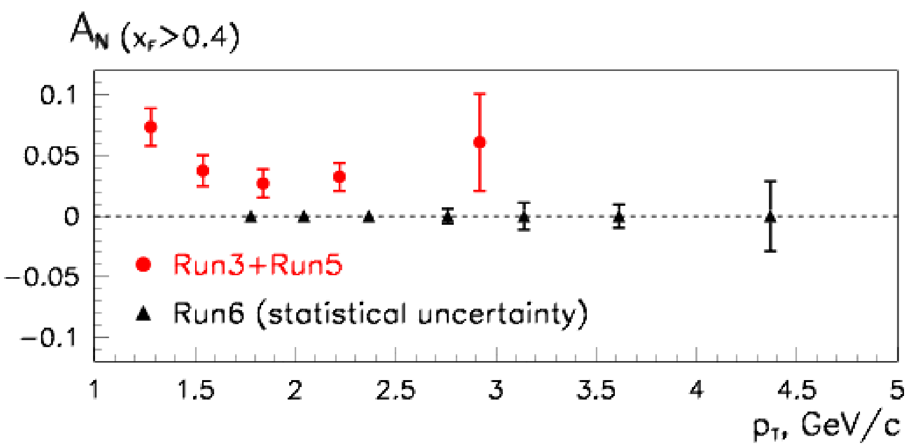
U.d'Alesio



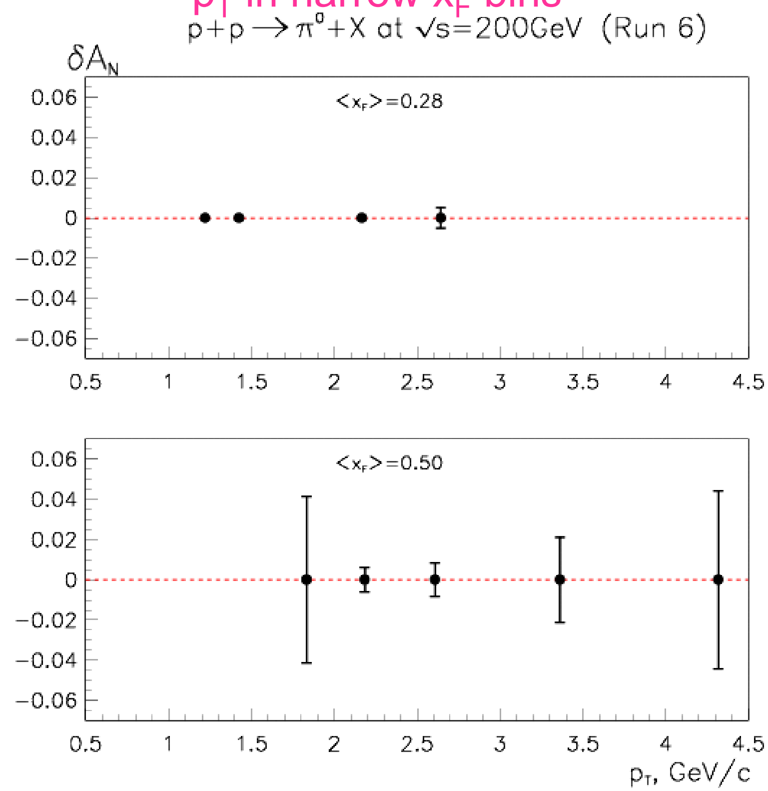
- Several models have been proposed – including Collins effect, Sivers effect, and twist-3 parton correlations.
- Can test the models by separating the x_F and p_T dependences

Sensitivity of initial Run 6 results

A_N vs. p_T for x_F > 0.4



Two examples of A_N vs. p_T in narrow x_F bins

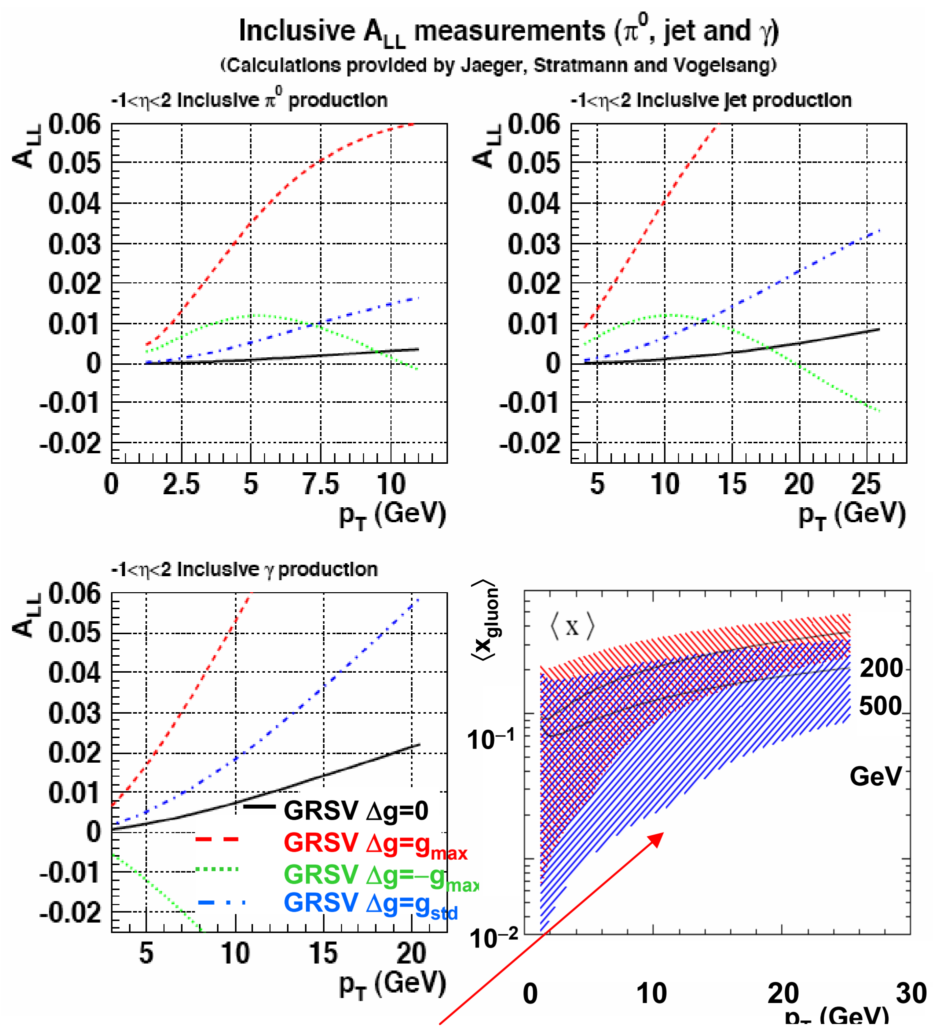


All Run 6 data points arbitrarily drawn at A_N=0

- Statistical precision of results to be shown at SPIN'06
- Systematic uncertainties small compared to statistical
- Coming soon: A_N for "jet-like" events with the FPD++
  - Clean distinction between Collins and Sivers effects

STAR

Why it is essential to map the x dependence of ΔG



NLO pQCD predictions for inclusive jet, π^0 and direct photon production. The upper two frames and the lower left frame show A_{LL} within the STAR calorimeter acceptance as a function of p_T under different assumptions for the underlying polarized gluon distribution.

The lower right frame shows the gluon x-ranges contributing to inclusive π^0 production in p+p collisions at $\sqrt{s}$ = 200 and 500 GeV, with solid curves indicating the mean contributing x-values, and the shaded bands indicating the rms spread of contributing x-values.

Inclusive measures which do not resolve the parton kinematics only weakly constrain the range of x_{gluon} which contributes to the observed asymmetry.

Makes interpretation sensitive to model assumptions about shape of *ΔG(x)*

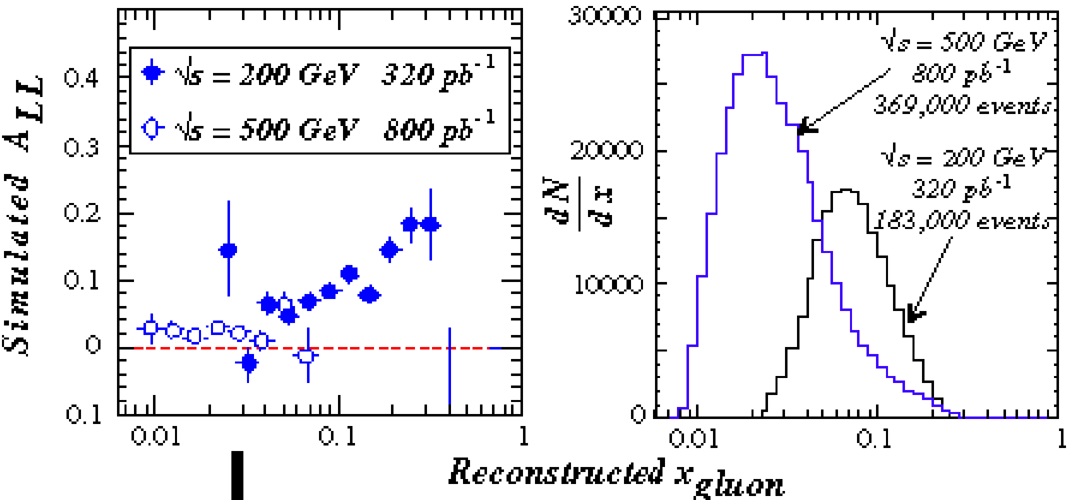
STAR Sensitivity to ΔG(x)

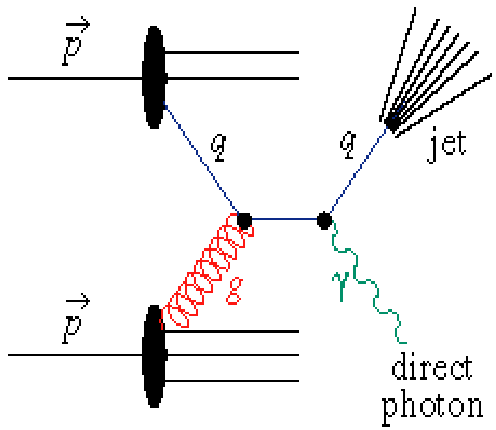
STAR

STAR's wide acceptance = Coincident detection of γ and away-side jet direction

→ Determination of initial-state partonic kinematics.

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





200 and 500GeV

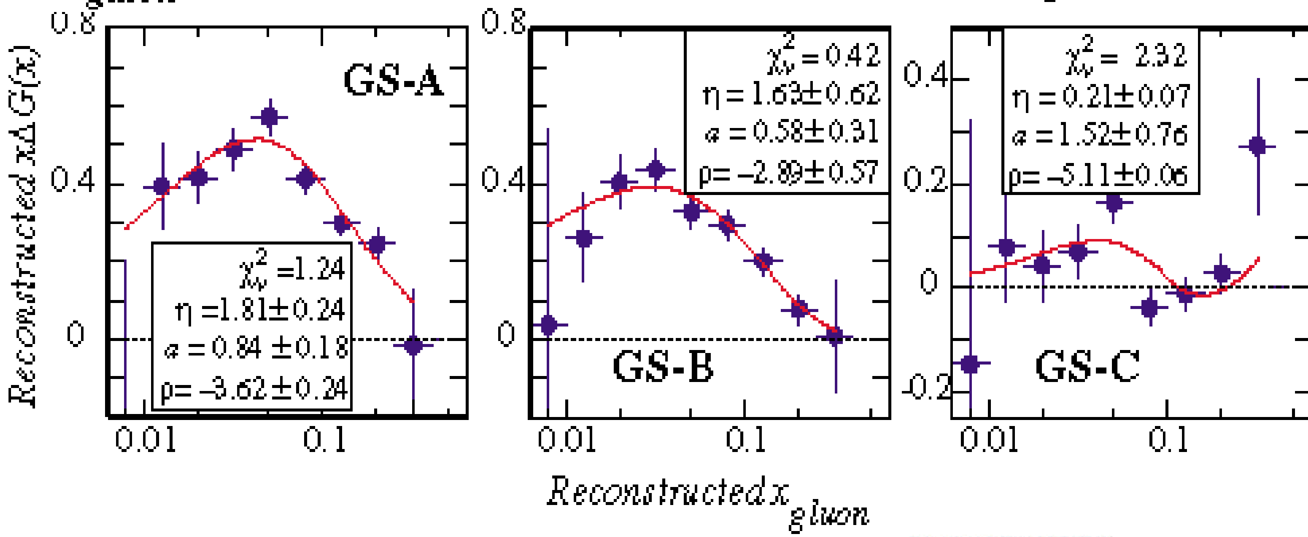
Going to forward rapidity

Better sensitivity

Wider x range

to determine integral

$$\Delta G\,(Q^2) = \int_0^1 \Delta G(x, Q^2)\, dx$$



U.S. DEPARTMENT OF ENERGY

Work to do before Run 8

Technical issues that can be quantitatively assessed for realistic detector performance in the analysis of 2006 data and related simulations:

(1) What levels of γ retention and $\pi 0$ rejection can be attained to optimize signal/background for photon-jet coincidences?

(2) How low in *pT* can direct photons be identified in the presence of a growing $\pi 0$ background?

(3) Does low-mass background seen to date in $\pi 0$ reconstructions in STAR constitute an additional background for direct photon analyses?

(4) Is an L2 coincidence trigger for γ-jet desirable, or will it enhance background more than signal?

(5) How efficiently, and with what bias in extracted four-momenta, can jets be reconstructed beyond the barrel EMC region, despite the services gap (η=0.98 – 1.08) and rapidly decreasing TPC tracking performance?

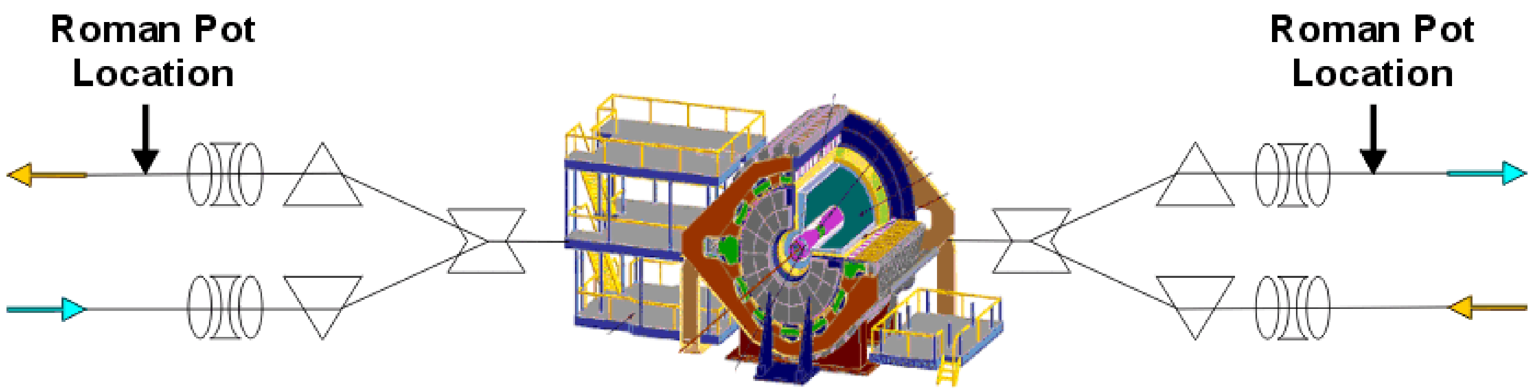
(6) What trigger biases on contributing partonic processes and *x*-ranges are imposed by the 2006 di-jet trigger?

(7) What bandwidth trade-off between di-jet and gamma+jet optimizes ability to constrain ΔG(x)?

One year from now, STAR will be better able to demonstrate the sensitivity to $\Delta G(x)$ attainable in given length runs at 200 GeV with an optimized trigger mix.

STAR strongly endorses continue work on polarization in the AGS behind RHIC stores

Seminal elastic scattering studies with polarized proton beams



The Roman pots of the pp2pp experiment in the STAR interaction region, with the arrows indicating proposed location. At each location one Roman Pot station is horizontal and one vertical.

The pp2pp Roman Pot detectors will be used to select processes in which the proton stays intact, and the exchange has quantum numbers of the vacuum,—i.e., the probability of measuring reactions where colorless gluonic matter dominates the exchange is enhanced.

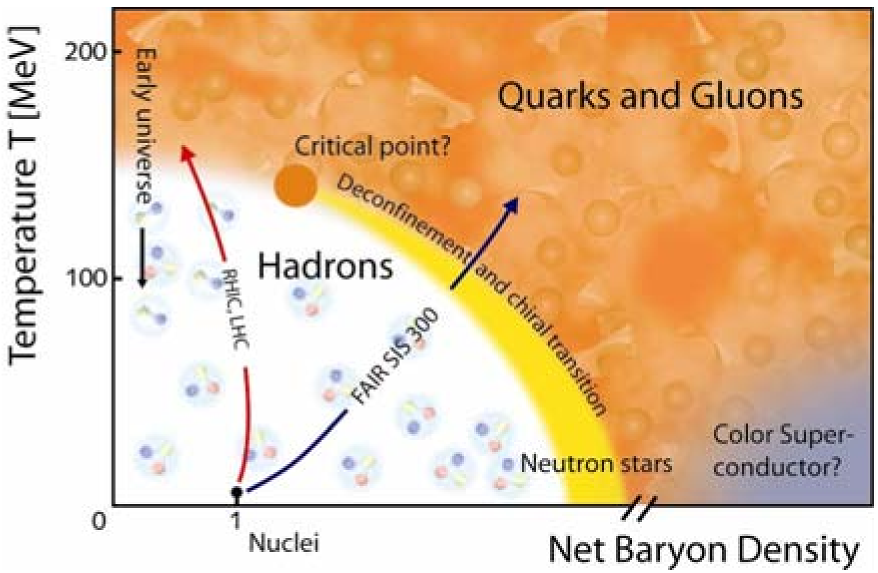
The use of polarized proton beams, unique at RHIC, will allow exploring unknown spin dependence of diffraction including both elastic and inelastic processes

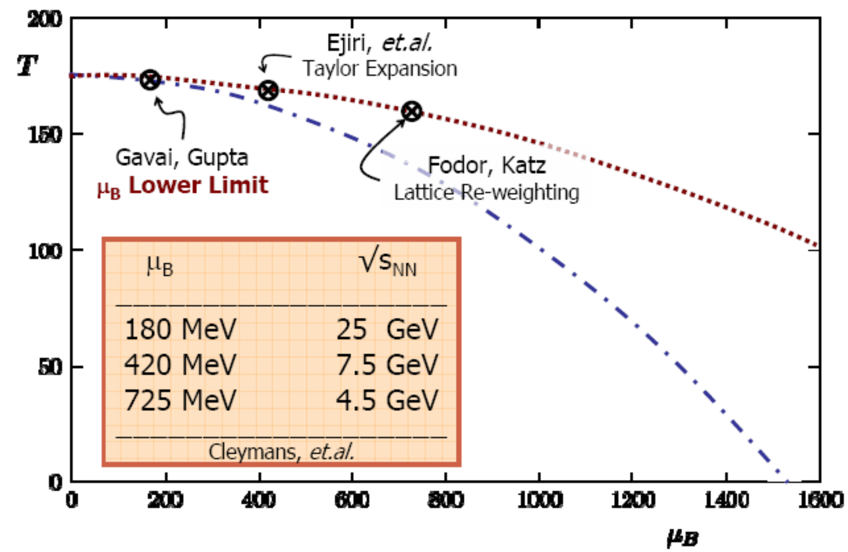
The Physics Driving Return to AuAu in Run 9

- Definitive results on the existence/location of the QCD Critical Point
- Completion of ΔG(x) map above $x_{BJ} \sim 0.03$
- First measurements of event-by-event charm and bottom
- What will PID'd correlations reveal?
- What will higher precision for short wavelength probes tell us?

The STAR DAQ upgrade, full TOF barrel and prototype heavy flavor tracker planned to be available in Run 9. These upgrades will provide a qualitative advance in STAR detector capability for heavy ion studies.

Does a QCD Critical Point Exist? If so, where?





Available results from LQCD suggest that at non-vanishing chemical potential, as the temperature of dense hadronic matter increases it should undergo a rapid transition from a hadron resonance gas to a quark-gluon plasma signaled by a sudden change in the equation of state. As the baryon chemical potential is increased, the fluctuations on the cross-over line increase dramatically suggesting the existence of a critical point in the phase diagram.

The location of the QCD Critical Point, if it exists, remains a matter for experiment

STAR Capabilities for QCD Critical Point Study

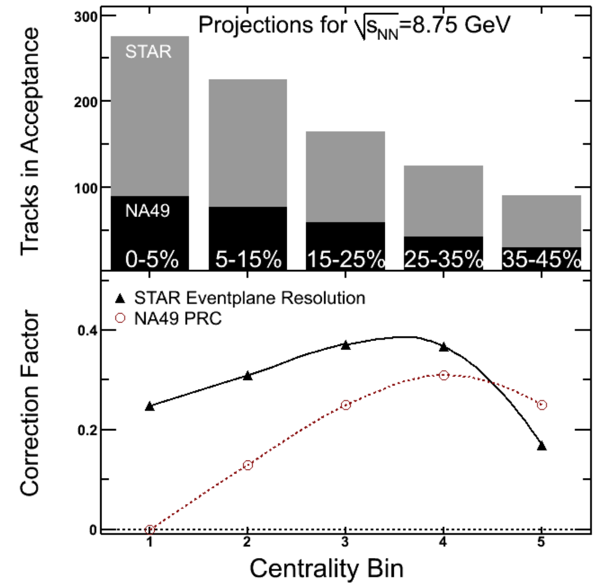
Because of its 2π acceptance and excellent PID (including TOF by Run 9) STAR is an ideal detector this study.

Triggering efficiently appears feasible

impact parameter	AuAu @ 5 GeV		AuAu @ 8.75 GeV	
	BBC Inner	BBC Outer	BBC Inner	BBC Outer
b<0	5	27	12	54
3<b<6	11	30	21	57
6<b<9	22	35	39	40

Particle hit multiplicities in the STAR Beam-Beam counters for low $\sqrt{s_{NN}}$ Au+Au running

Low luminosity and beam background will still present challenges



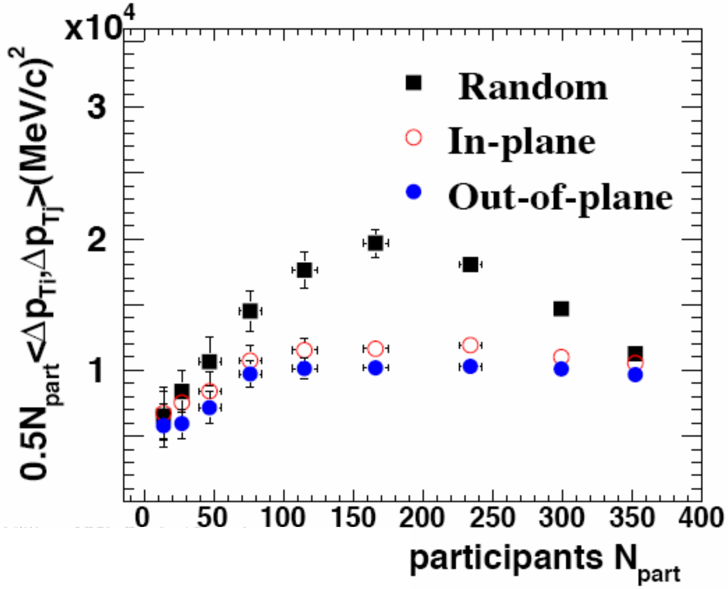
Simulation of the event plane resolution in STAR vs NA49 for comparable centrality bins ($\sqrt{s_{NN}}$ = 8.75 GeV Au+Au (Pb+Pb)).

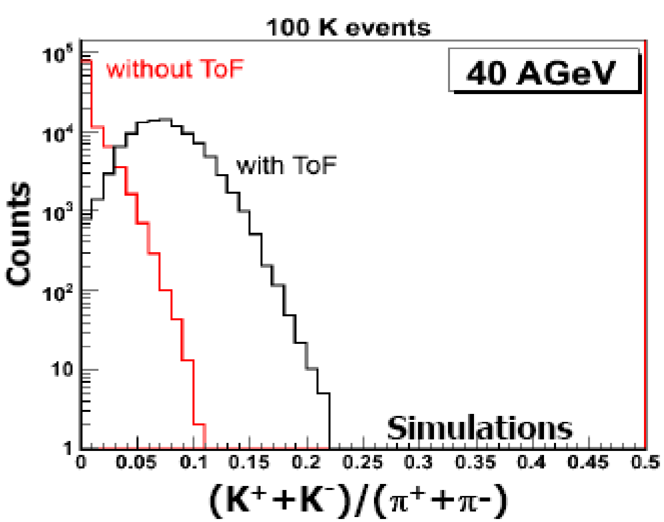
Large 2π acceptance important for these studies

Importance of acceptance and PID

Contribution of elliptic flow to the apparent magnitude of <ΔpTiΔpTj > fluctuations for particles within

- 45 degrees of the event plane (red),
- 45 degrees of the out-of-plane direction (blue),
- a detector with partial angular coverage when the event plane is unknown (black). (Fluctuations are overestimated because the event plane is fluctuating randomly in, out, and within the acceptance.)





Study, based on 100,000 simulated events of the statistical and systematic uncertainties with and without the PID capability of the STAR TOF

Full Barrel TOF is Crucial

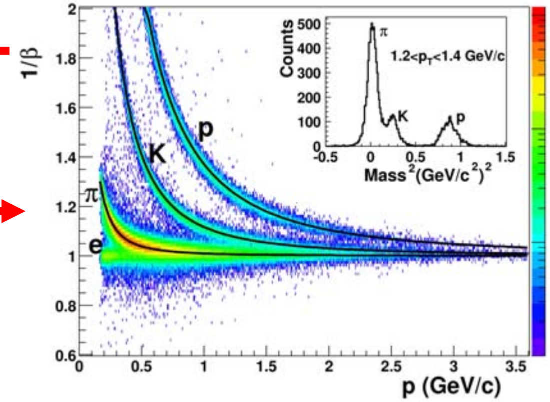
Misidentification of only 1% leading to a swapping of pions for kaons reduces the width of the observed k/pi fluctuation distribution by 10%. A misidentification of 2% leads to a reduction in width of 20%.

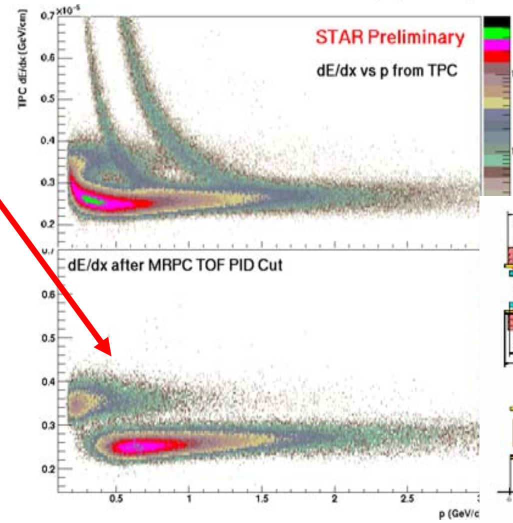
STAR TOF Barrel Status

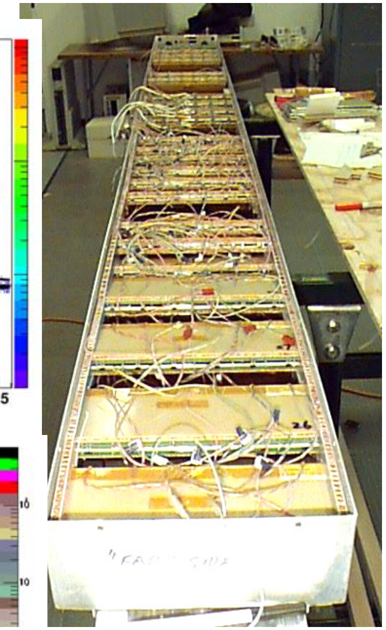
What TOF Provides:

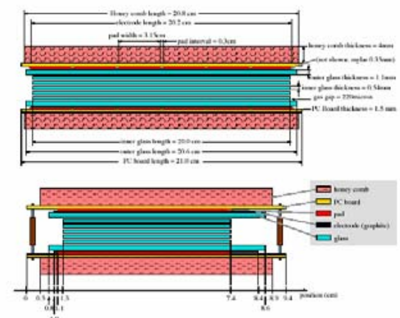
PID information for > 95% of kaons and protons in the STAR acceptance

clean e± ID down to 0.2 GeV/c





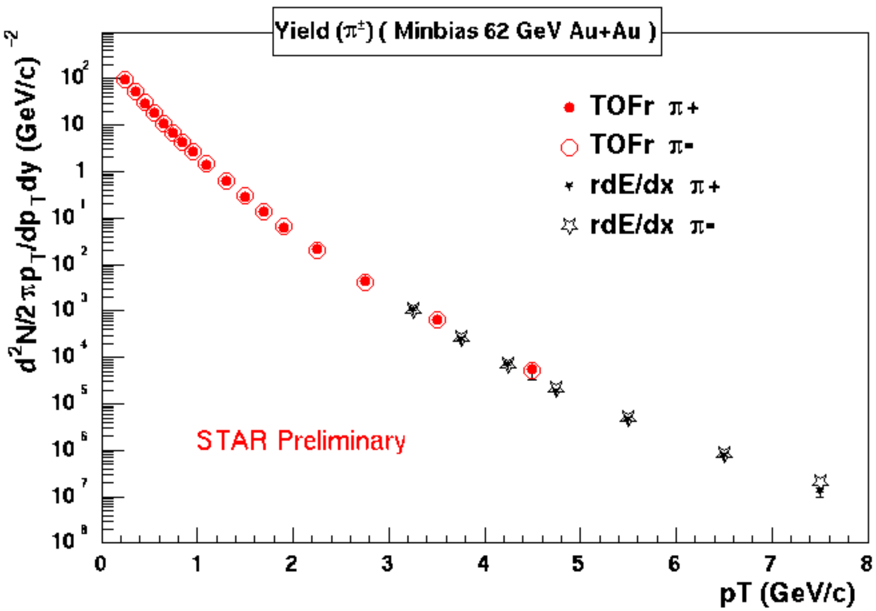


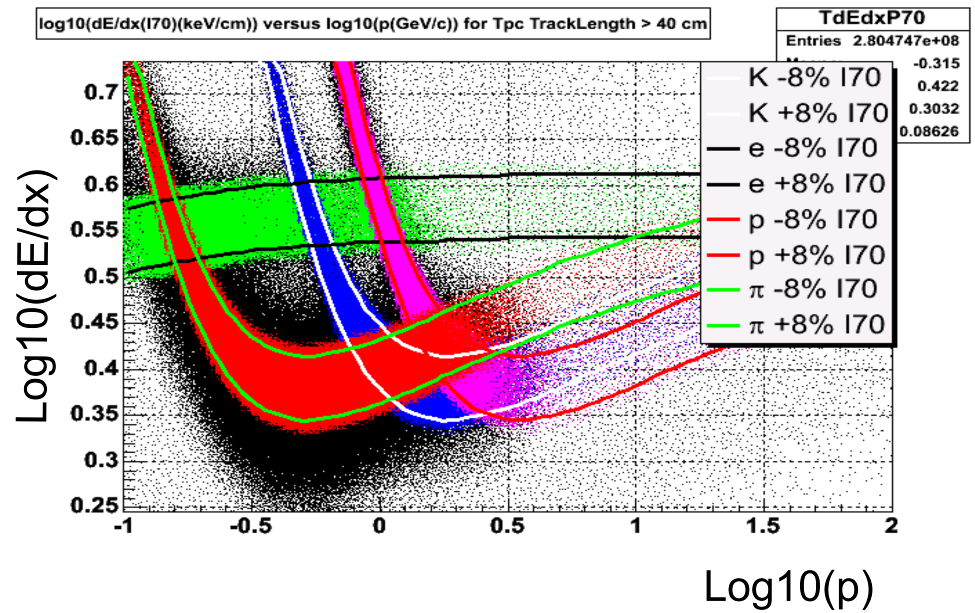


Status of Construction Project

- Construction project begun
- First 32 modules off Chinese production lines complete & ready for shipment to U.S.A.
- Mechanical elements (trays, stacking fixtures, etc.) on track
- Project cost and schedule within envelope of DOE construction project
- Significant implementation by Run 8, completion for Run 9
- Budget: $4.7M US, $2.3M in-kind from China

Extending STAR Particle ID





Methods paper submitted to NIM A, nucl-ex/0505026.

Results to 12 GeV in Au+Au

- TPC:
  - Pion: 0-~0.6GeV/c
  - Kaon: 0.2-~0.6GeV/c
  - Proton: 0.2-~1 GeV/c
- TOF:
  - Pion: 0.2-~1.6GeV/c
  - Kaon: 0.2-~1.6GeV/c
  - Proton: 0.2-~3 GeV/c
- TPC+TOF:
  - Pion: 0.-~10 GeV/c
  - Kaon: 0.2-~3GeV/c
  - Proton: 0.2-~? GeV/c

DAQ1000 – TPC Readout Upgrade

- Acquisition of very large data samples for precision and rare process studies: e.g., symmetry restoration /breaking, $\gamma\gamma$ HBT, …
- Triggered data sets benefit - dead time reduced to ~ 0
- Space for end cap tracker for W physics

Goal: Increase data rate for most detectors to ≥ 1kHz
Effectively zero dead time for rare probes

Make use of CERN developments for ALICE/LHC:

Cost *Estimate*: $1.8 M

PASA (preamp/shaper amp)
ALTRO (digitizer, digital filter, zero suppression, buffer)
SIU (RDO, optical data sender)
D-RORC (PCI receiver board)

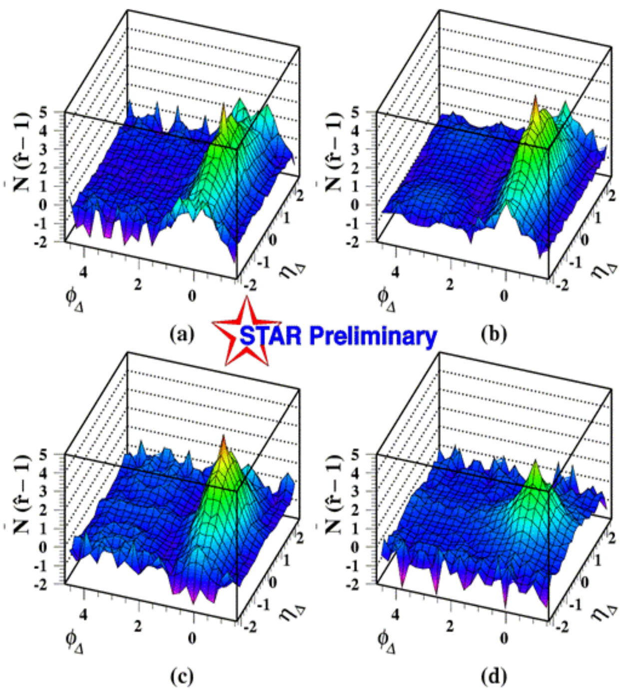
Status / Schedule:

After ~ 1 year delay due to contract difficulties, chip procurement appears in-hand
Prototyping effort ongoing through 2006
Nov. 2006 small prototype (one sector) operational in STAR
Full TPC readout in STAR complete for Run 9

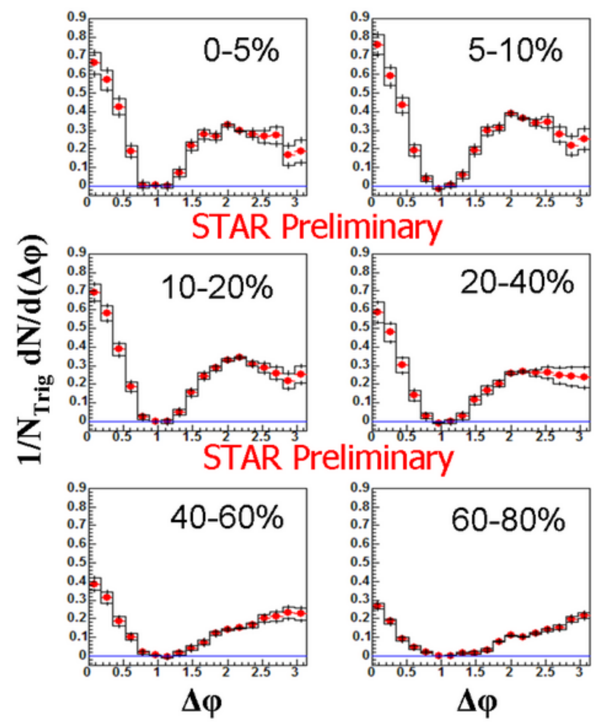
STAR

Upgraded Detector Capability in Run 9

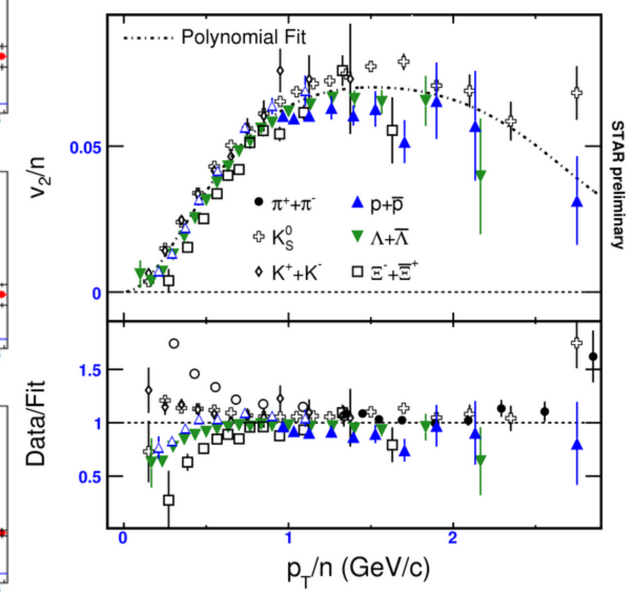
Two particle correlations at low p_T



Two (3) particle correlations at intermediate p_T



Constituent-quark-scaled v_2 at intermediate p_T



Further examples of the types of measurements which will make a major advance with the combination of upgraded PID capability and increased DAQ throughput in Run 9

Conclusions

- The STAR Collaboration strongly believes the proposed plan will provide for qualitative advances in our understanding of the nucleon, the nucleus, and dense QCD matter in a way that make maximal use of RHIC beams and STAR/RHIC capability as it develops
- STAR maintains this is an optimal plan for maximizing the scientific impact and discovery potential in the next 3 years
- **The relative order of d+Au and polarized p+p in the STAR plan is deliberate and considered. The order is very important. Doing them in reverse order will seriously compromise both:**
  - **$\vec{p}+\vec{p}$ material of SVT shadowing endcap creating conversions; lack of knowledge from analysis of Run 6 on how to optimize trigger mix**
  - **d+Au lack of crucial reference for D, B studies in Au+Au since SVT will be removed following Run 7. p+p in Run 7 would not provide a suitable reference.**

Increasing luminosity for **$\vec{p}+\vec{p}$** is clearly important, BUT it is not the only factor to optimize the physics impact of the polarized proton program

The STAR Collaboration: 47 Institutions, 12 countries, ~ 500 Scientists and Engineers

STAR

U.S. Labs:
Argonne, Lawrence Berkeley, and Brookhaven National Labs

U.S. Universities:
UC Berkeley, UC Davis, UCLA, Carnegie Mellon, Creighton, CCNY, Indiana, Kent State, MSU, Ohio State, Penn State, Purdue, Rice, Texas A&M, UT Austin, Washington, Wayne State, Valparaiso, Yale, MIT

Brazil:
Universidade de Sao Paolo

China:
IHEP - Beijing, IPP - Wuhan, USTC, Tsinghua, SINR, IMP Lanzhou

Croatia:
Zagreb University

Czech Republic:
Institute of Nuclear Physics

England:
University of Birmingham

France:
Institut de Recherches Subatomiques Strasbourg, SUBATECH – Nantes

India:
Bhubaneswar, Jammu, IIT-Mumbai, Panjab, Rajasthan, VECC

Netherlands:
NIKHEF

Poland:
Warsaw University of Technology

Russia:
MEPHI – Moscow, LPP/LHE JINR – Dubna, IHEP – Protvino

South Korea:
Pusan National University

Frankfurt, and MPI left due to retirements
Cal Tech and Bern left due to position changes

Interest by members of BRAHMS
New applications from members of pp2pp

BROOKHAVEN NATIONAL LABORATORY

Office of Science U.S. DEPARTMENT OF ENERGY

Status of STAR: a growing list of degree recipients

83 advanced degrees to students at 24 institutions awarded on STAR research

Max-Planck-Institut
2005 Frank Simon, PhD
2004 Joern Putschke, PhD
2003 Maierbeck Peter, Dipl.
2002 Markus Oldenburg, PhD
2000 Holm Huemmler, PhD
2000 Tobias Eggert, Dipl.
1998 Rainer Marstaller, Dipl.
1997 Michael Konrad, PhD
1997 Xaver Bittl, Dipl.

Michigan State University
2002 Marguerite Tonjes, PhD

Ohio State University
2004 Selemon Bekele, PhD
2004 M. Lopez-Noriega, PhD
2003 Randy Wells, PhD
2002 Robert Willson, PhD

Purdue University
2003 Timothy Herston, M.S.
2002 Alex Cardenas, PhD
2006 Levente Molnar, PhD

Rice University
2001 Martin DeMello, M.S.

USTC China
2005 Xin Dong, PhD
2004 Shengli Huang, PhD
2004 Lijuan Ruan, PhD

SUBATECH
2005 Magali Estienne, PhD
2004 Gael Renault, PhD
2003 Ludovic Gaudichet, PhD
2002 Javier Castillo, PhD
2000 Fabrice Retiere, PhD
2000 Walter Pinganaud, PhD

University of Texas - Austin
2004 Aya Ishihara, PhD
2004 Yiqun Wang, PhD
2003 Bum Choi, PhD
2002 Curtis Lansdell, PhD

Warsaw University of Technology
2004 Adam Kisiel, PhD
2004 Zbigniew Chajecki, M.S.

University of Washington
2002 Jeff Reid, PhD

Institute of Particle Physics
2005 Zhixu Liu, PhD
2002 Jinghua Fu, PhD

Yale University
2006 Sevil Salur, PhD
2004 Jon Gans, PhD
2003 Haibin Zhang, PhD
2003 Michael Miller, PhD
2002 Matthew Horsley, PhD
2001 Manuel Calderon, PhD

University of Bern
2005 Mark Heinz, PhD

University of Birmingham
2005 John Adams, PhD
2002 Matthew Lamont, PhD

UC – Los Angeles
2006 Jingguo Ma, PhD
2006 Johan Gonzalez, PhD
2006 Weijiang Dong, PhD
2005 Dylan Thein, PhD
2005 Jeff Wood, PhD
2005 Hai Jiang, PhD
2003 Yu Chen, PhD
2003 Paul Sorensen, PhD
2002 Hui Long, PhD
2001 Eugene Yamamoto, PhD

Carnegie Mellon University
2003 Christopher Kunz, PhD

Creighton University
2003 Steve Gronstal, M.S.
2003 Nil Warnasooriya, M.S.
2003 Sarah Parks, M.S.
1999 Jie Lin, M.S.
1998 Quinn Jones, M.S.
1996 John Meier, M.S.
1995 Jeffrey Gross, M.S.

Wayne State University
2005 Ying Guo, PhD
2005 Alexander Stolpovsky, PhD

Nucl. Physics Inst., Prague
2002 Petr Chaloupka, M.S.

UC - Davis
2002 Ian Johnson, PhD

University of Frankfurt
2006 Thorsten Kollegger, PhD
2003 Dominik Flierl, PhD
2003 Jens Berger, PhD
2003 Clemens Adler, PhD
2003 Christof Struck, PhD
1998 Jens Berger, Dipl.
1998 Clemens Adler, Dipl.

Reserches Sub. Strasbourg
2004 Julien Faivre, PhD
2002 Boris Hippolyte, PhD
2001 Christophe Suire, PhD

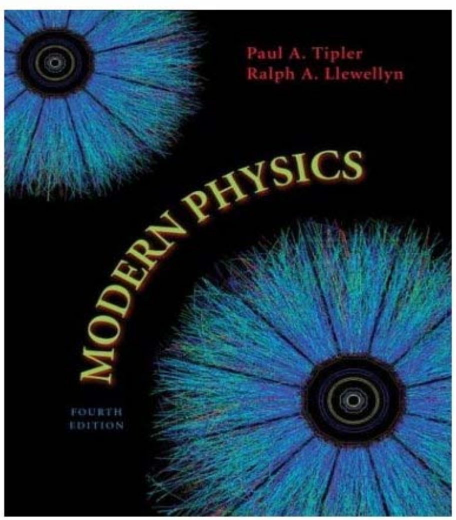
Kent State University
2005 Camelia Mironov, PhD
2005 Gang Wang, PhD
2003 Ben Norman, PhD
2002 Wensheng Deng, PhD
2002 Aihong Tang, PhD

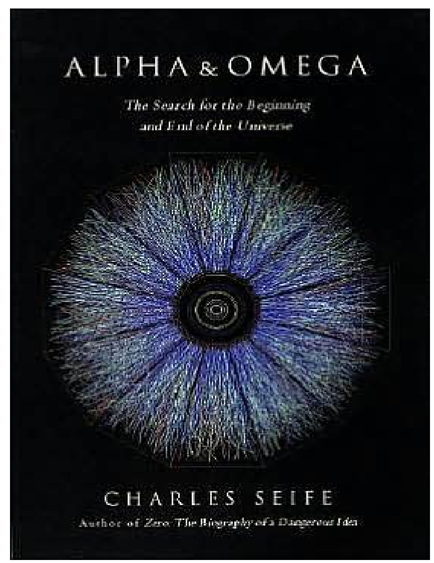
LBNL
2003 Vladimir Morozov, PhD

Blue = awarded since July 2005

Status of STAR: a growing publication record

- 34 Physical Review Letters
- 19 Physical Review C
- 9 Physics Letters B / J. Physics G / Nuclear Physics A /PRD
- 4,194 Citations
- 11 “Very well known” (topcite) Papers with >100, < 250 citations
- 3 “Famous” Papers with >250, < 500 citations





Visibility which is impacting the popular image of modern physics

Status of STAR scientific productivity

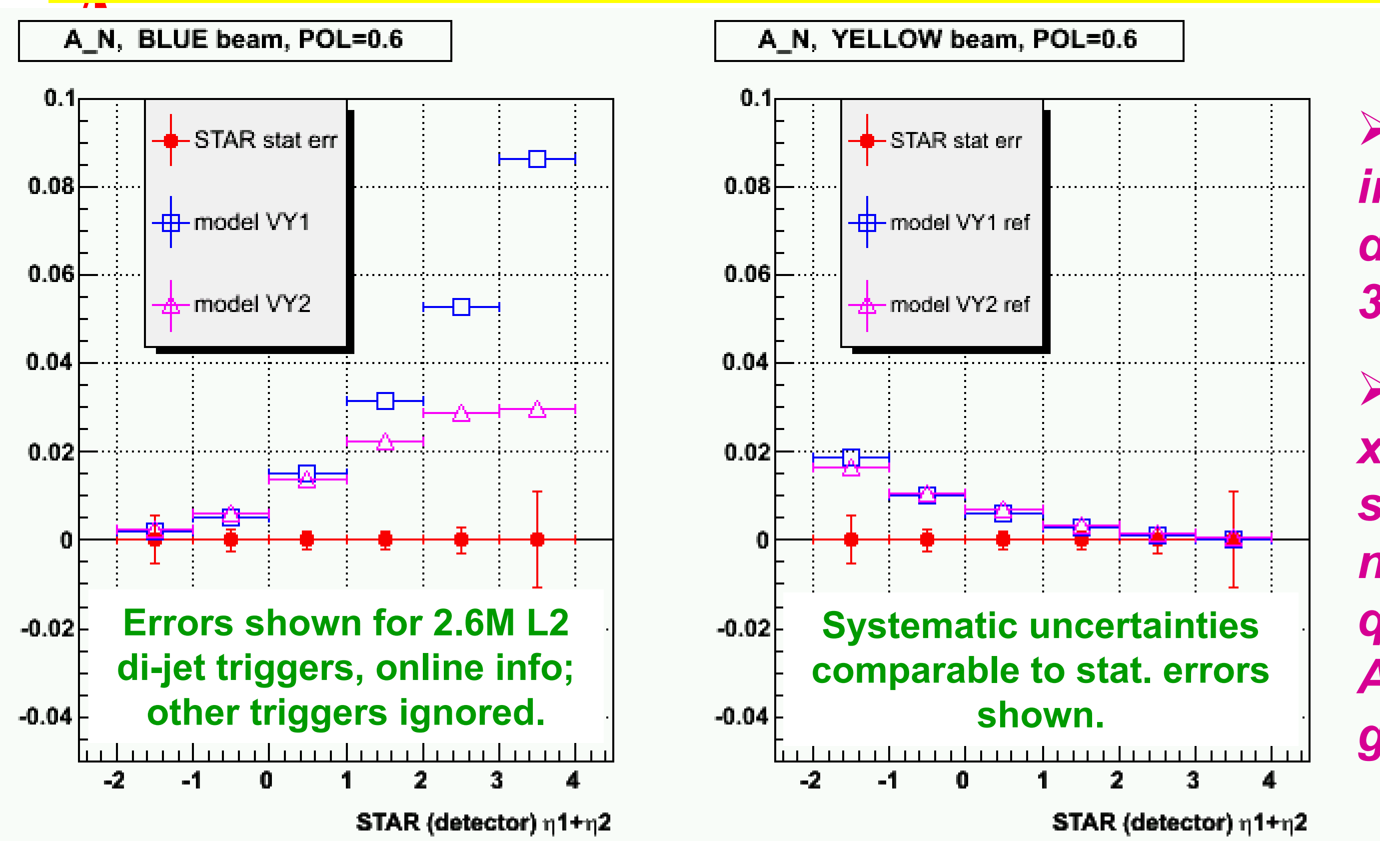
Abstracts Submitted to Spin06

- Longitudinal spin results (all based on Run 5 results):
  - Inclusive Jets A_{LL} (Relyea)
  - Inclusive π^0 A_{LL} and cross section at $-1 < \eta < 1$ (Simon)
  - Inclusive π^0 A_{LL} at $1 < \eta < 2$ (Webb)
  - Inclusive charged hadron A_{LL} (Kocoloski)
  - Longitudinal spin transfer in Λ production (Xu)

- Transverse spin results (both based on Run 6 results):
  - Mid-rapidity Sivers asymmetry for di-jets (Balewski)
  - A_N for forward π^0 and jet-like events (Nogach)

35 abstracts submitted to QM06; 21 accepted

Physics Reach of STAR 2006 pp Data: Sivers Effect



- *Measured SSA integrated over all di-jets with p_T^{EMC} > 3.5 GeV/c*
- *For $(\eta_1 + \eta_2) > 2$, $x_a / x_b > 7 \Rightarrow$ q-g scattering dominates, A_N^{blue} probes quark Sivers, A_N^{yellow} probes gluon Sivers.*

- *Model calcs by Vogelsang & Yuan integrate over STAR acceptance, $5 < p_T^{jet} < 10$ GeV/c, with quark Sivers functions fitted to HERMES data:*

$$VY\ I:\ u_T^{(1/2)}/u(x) = -0.81\,x(1-x);\quad d_T^{(1/2)}/u(x) = 1.86\,x(1-x)$$
$$VY\ II:\ u_T^{(1/2)}/u(x) = -0.75\,x(1-x);\quad d_T^{(1/2)}/d(x) = 2.76\,x(1-x)$$

Assume zero gluon Sivers fcn.

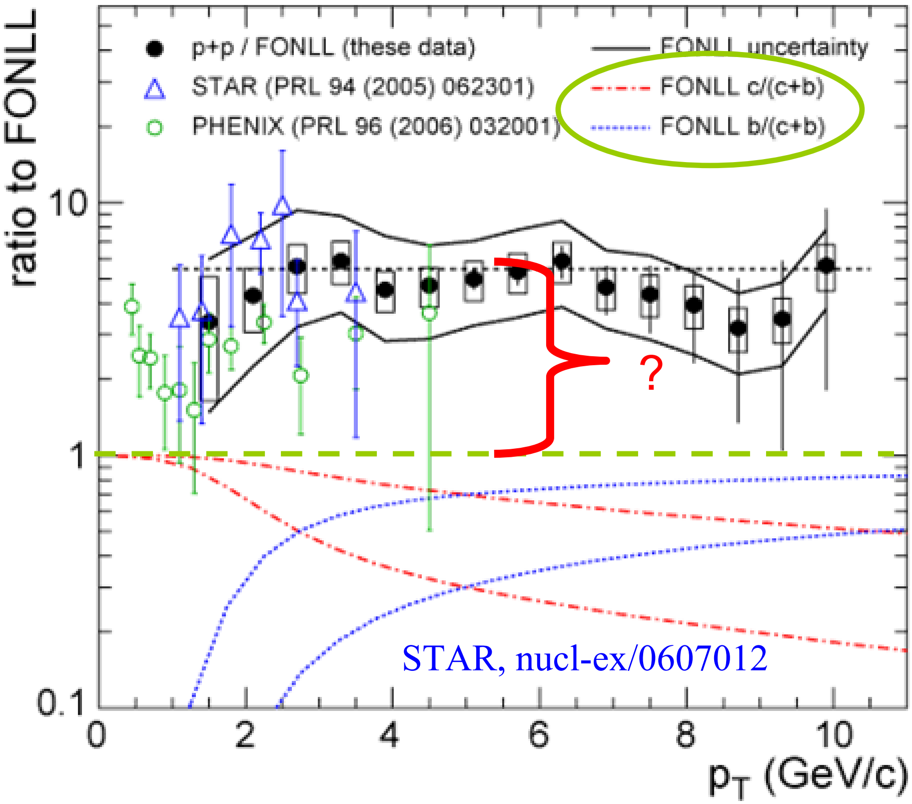
- *STAR 2006 data will provide sensitive test of quark Sivers function universality, plus first measurements sensitive to gluon Sivers fcn.*

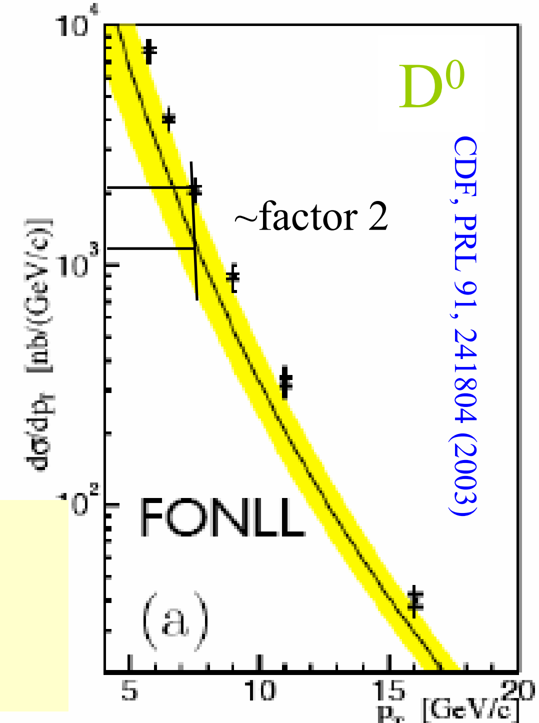
Upgrades planned to carry out the future STAR program

- A Barrel MRPC TOF — PID information for > 95% of kaons and protons in the STAR acceptance; clean $e^{\pm}$ ID down to 0.2 GeV/c extended scientific reach for key observables
- Heavy Flavor Tracker — Precise hit position close to the primary vtx $\rightarrow$ D's ,flavor- tagged jets
- A DAQ/ TPC FEE Upgrade — New architecture / FEE $\rightarrow$ > 1 khz of events available at L3; effective increase in utilization of luminosity by factor of 10
- Development of GEM tech. — Technology development for forward tracking upgrade
- Forward Tracking Upgrade — W charge sign identification
- Forward Calorimeter Upgrade: — Jet reconstruction at high pseudorapidity: CGC monojet search in d(p) + A; isolation of fragmentation effects in large pp $\rightarrow \pi^0$ production single-spin transverse asymmetries

Another thing to understand:
N. P. electrons in p+p at RHIC vs FONLL

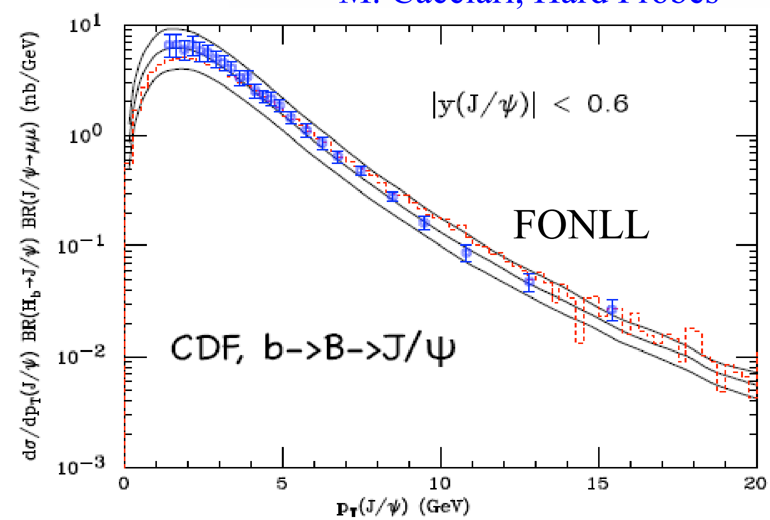
State of the art: Fixed-Order Next-to-Leading Log





M. Cacciari, Hard Probes

Tevatron charm and beauty vs FONLL: OK



- RHIC n.p. electrons: factor 3-5 excess(!)
- Large ambiguity in relative contribution of c→e/b→e
  - ⇒ need to resolve b and c explicitly

NB: Consistent data between multiple independent measurements; problem is comparison with theory

The STAR Detector