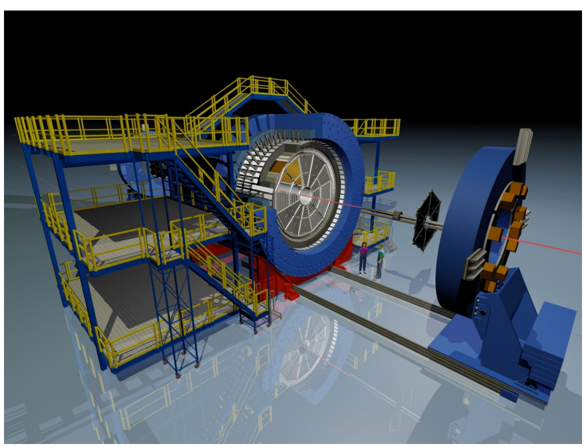
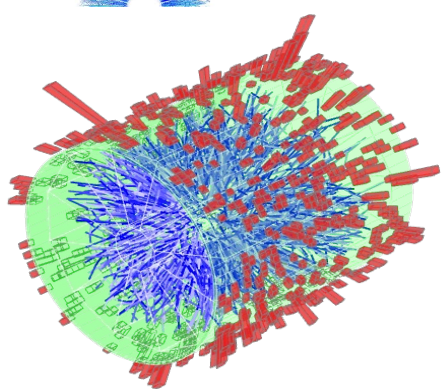
Xin-Nian's role in

^ The discovery of jet quenching by STAR

Peter Jacobs

Lawrence Berkeley National Laboratory





Home

SN0499 : STAR Conceptual design report

Updated on Mon, 2009-07-13 13:57. Originally created by jeromel on 2009-07-13 13:57.

Author(s) : The STAR collaboration

Date : Jun. 1, 1992

Abstract : The Solenoidal Tracker At RHIC (STAR) will search for signatures of quarkgluon plasma (QGP) formation and investigate the behavior of strongly interacting matter at high energy density. The emphasis will be the correlation of many observables on an event-by-event basis. In the absence of definitive signatures for the QGP, it is imperative that such correlations be used to identify special events and possible signatures. This requires a flexible detection system that can simultaneously measure many experimental observables. This document will present the conceptual design and detector concept of the STAR experiment.

Keywords : STAR detector design conceptual report

Category : Technical

Type : public

Attachment	Size
StarCDR.pdf	10.43 MB

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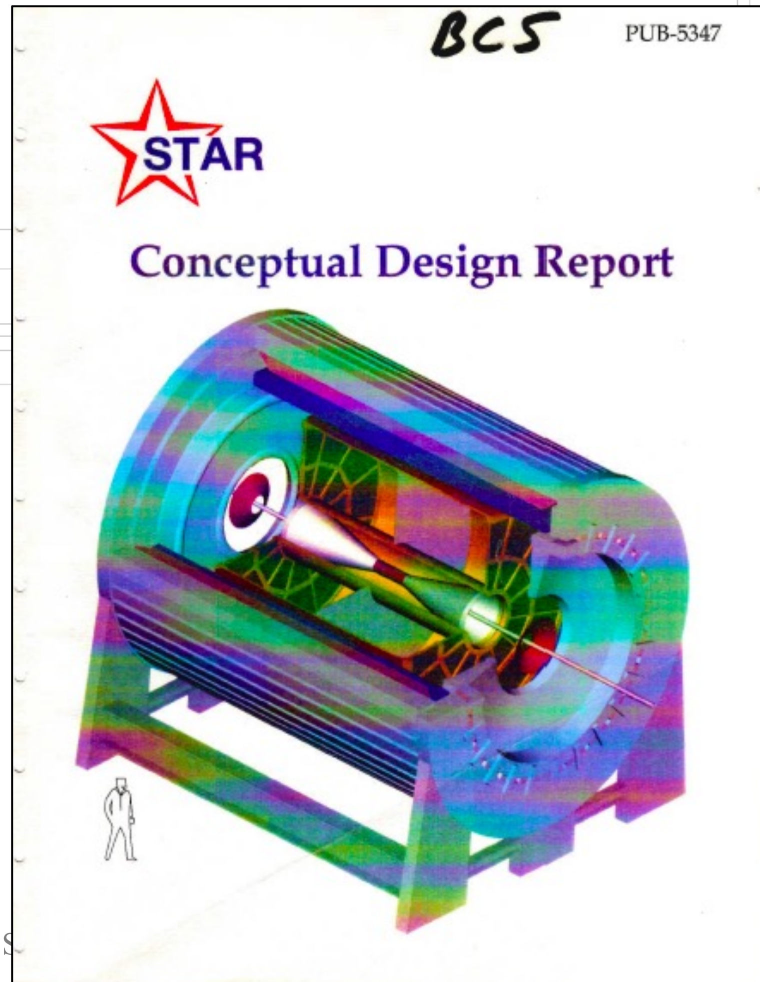

Spokesperson: J.W. Harris
Deputy Spokespersons: T. Hallman, E.D. Platner

Technical Director: J. Marx

3.B. Parton Physics

The goal of studying products of hard QCD processes produced in relativistic heavy ion collisions is to use the propagation of quarks and gluons as a probe of nuclear matter, hot hadronic matter and quark matter. Since the hard scattering processes occur at the very earliest stage of the collision ($t < 1$ fm/c), their production rates are dependent only upon the incoming state. Given the quark and gluon structure functions of the colliding nuclei, the rates of hard parton scattering are directly calculable in QCD. RHIC will be the first accelerator to provide nuclear collisions at energies where rates of detectable partonic debris (jets, high-p_t particles and direct photons) from hard partonic scattering permit accurate measurements. Various calculations have predicted that the propagation of quarks and gluons through matter depends strongly upon properties of the medium,[34,35,36,37,38] and that a measurement of the yield of hard scattered partons as a function of transverse energy may be sensitive to the state of the surrounding matter. For example, it has been suggested that there will be observable changes in the energy loss of propagating partons as the energy density of the medium increases, particularly if the medium passes through a phase transition to the QGP.[39] Energy loss in the medium results in jet quenching (i.e. a reduction of the jet yield at a given p_t) which has been observed in deep inelastic lepton scattering from nuclear targets. Jet quenching is expected to lead to significant effects in the spectra of single high p_t particles, di-hadrons and jets in AA collisions at RHIC.[40]

34 J.D. Bjorken, Fermilab Report 82/59/59-THY (1982).
35 D. Appel, Phys. Rev. D33 (1986) 717.
36 J.P. Blaizot and L.D. McLerran, Phys. Rev. D34 (1986) 2739.
37 M. Rammersdorfer and U. Heinz, Phys. Rev. D41 (1990) 306.
38 M. Gyulassy and M. Pluemmer, Phys. Lett. B243 (1990) 432.
39 M. Gyulassy et al, Lawrence Berkeley Laboratory Report LBL-31002, to be published in Proc. of 4th Conference on the Intersections between Particle and Nuclear Physics, Tuscon, Arizona, 1991.
40 X.N. Wang and M. Gyulassy, Phys. Rev. Lett. 68 (1992) 1480.
41 R. Baier and J.F. Owens in "QCD Hard Partonic Processes", B. Cox ed., Plenum Press, New York and London (1987); J. Appel et al, Phys. Lett. B176, 239 (1982); E.L. Berger and J. Qiu, Proceedings of the Polarized Collider Workshop, AIP Proceedings 223, Collins et al editors (1991).

Reconstruction of the parton scattering kinematics is limited by acceptance and detector resolution effects, and by the superposition of particles from other, incoherent processes which occur during the collision. This latter problem is especially serious in high multiplicity AA collisions, where the jet can be entirely obscured. The technique of jet reconstruction to extract parton information in AA collisions is being investigated with the STAR detector configuration. High p_t particle measurements can be used to extract parton information in pp, pA and AA collisions in STAR.

The distribution of final state particles is represented by the fragmentation function. A few percent of jets fragment into a limited number of hard particles carrying most of the jet momentum. Observing only hard particles above some p_t cut (e.g., $p_t > 2$

GeV) may solve the background problem for high multiplicity. However, in order to study parton dynamics in this way the fragmentation functions must be known. These functions are currently being studied by many groups and should be well known by the time RHIC experiments begin. However, these may change for fragmentation in the presence of a QGP or hadronic matter. Means of determining the fragmentation function for nuclear collisions are currently being investigated.

3.B.1. Jets

Hard parton-parton collisions will occur within the first fm/c of the start of the nucleus-nucleus collision.[44,45] Hence, the partons in a single hard scattering (dijet or γ-jet) whose products are observed at midrapidity must traverse distances of several fm through high density matter in a nucleus-nucleus collision. The energy loss of these propagating quarks and gluons is predicted[46,47] to be sensitive to the medium and may be a direct method of observing the excitation of the medium, i.e., the QGP.

[42] See the RHIC Spin Collaboration Letter of Intent (1990).
[43] European Muon Collaboration, J. Asham et al, Phys. Lett. 206B (1988) 364 ; M.J. Alguard et al, Phys. Rev. Lett. 37 (1976) 1258; G. Baum et al. *ibid*. 51 (1983) 1153.
[44] E.V. Shuryak in Proceedings of the Workshop on Experiments and Detectors for RHIC, Brookhaven National Laboratory, Upton, New York, 2-7 July 1990 to appear as a BNL report.
[45] T. Matsui in Proceedings of the Workshop on Experiments and Detectors for RHIC, Brookhaven National Laboratory, Upton, New York, 2-7 July 1990 to appear as a BNL report.
[46] M. Gyulassy and M. Pluemmer, Phys. Lett. B243 (1990) 432.
[47] X.N. Wang and M. Gyulassy in Proceedings of the Workshop on Experiments and Detectors for RHIC, Brookhaven National Laboratory, Upton, New York, 2-7 July 1990 to appear as a BNL report.

VOLUME 68, NUMBER 10 PHYSICAL REVIEW LETTERS 9 MARCH 1992

Gluon Shadowing and Jet Quenching in $A+A$ Collisions at $\sqrt{s}=200A$ GeV

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(Received 20 December 1991)

The sensitivity of moderate $p_T \lesssim 8$ GeV/c singles inclusive spectra in nuclear collisions to gluon shadowing and jet quenching is estimated using the HIJING Monte Carlo model. We show how the systematic study of the nuclear dependence of those spectra in $p+A$ can be used to determine the magnitude of gluon shadowing and how the enhanced suppression in $A+A$ would provide information on the energy loss mechanisms in dense partonic matter.

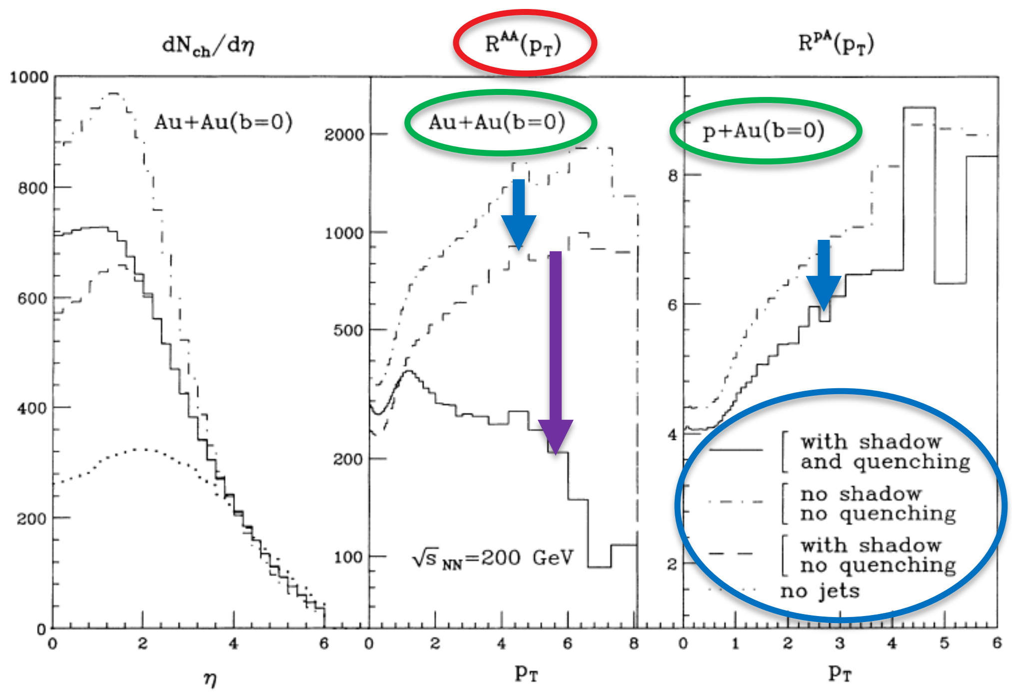


FIG. 1. Results of HIJING on the dependence of the inclusive charged-hadron spectra in central Au+Au and $p+$Au collisions on minijet production (dash-dotted line), gluon shadowing (dashed line), and jet quenching (solid line) assuming that gluon shadowing is identical to that of quarks and $dE/dl=2$ 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 $p+p$.

Defines R_{AA}

Proposes p+A to calibrate non-quenching effects

Shadowing effects are modest

Quenching effects are much larger than shadowing – predict factor 5!

How we described this in the STAR CDR:

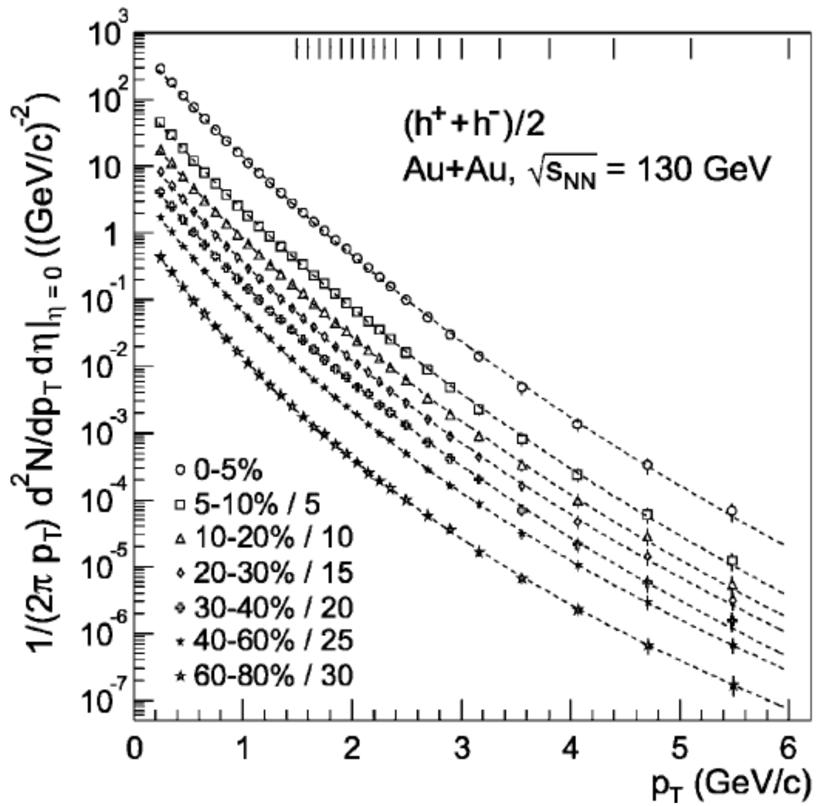
Wang and Gyulassy have developed a model to simulate nucleus-nucleus collisions at RHIC using the Pythia model[49] for pp interactions as a basis and including the nucleus-nucleus geometry. Partons are propagated through matter in the collision and their energy loss is calculated depending upon the type of matter traversed (nuclear, hadronic or QGP). Results from these simulations exhibit a strong attenuation

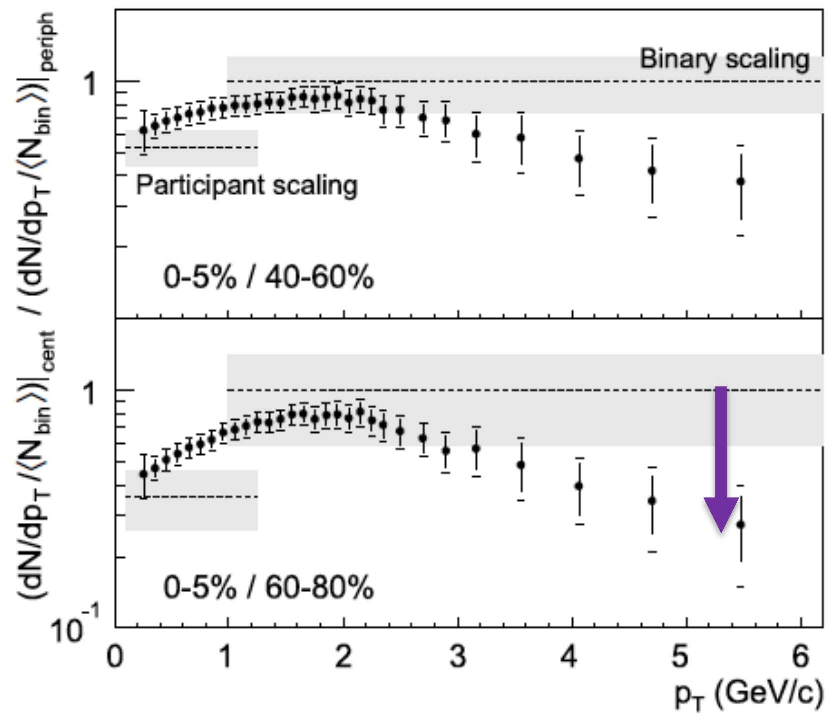
Inclusive p_t distributions of hadrons at $p_t > 3$ GeV/c will also be influenced by jets and mini-jets. It should be emphasized that the single particle cross sections fall off more rapidly as a function of p_t than the jet cross sections.[55] However, Wang and Gyulassy[56] have shown that the inclusive single particle yield is very sensitive to the state of the matter through which the parent scattered partons propagate. Fig. 3-5 shows the charged particle pseudorapidity distribution and the ratio of charged particle yields for Au-Au and p-Au collisions compared to p-p collisions as a function of p_t, under various assumptions about the nuclear structure functions (shadowing) and energy loss of the scattered partons (quenching). From the middle panel of Fig. 3-5 it is seen that the introduction of quenching (on top of shadowing) leads to a reduction in yield above p_t~4 GeV/c of a factor 5, which will be easily measurable at STAR.

Fast-forward 10 years….

VOLUME 89, NUMBER 20 PHYSICAL REVIEW LETTERS 11 NOVEMBER 2002

Centrality Dependence of High-p_T Hadron Suppression in Au + Au Collisions at $\sqrt{s_{NN}} = 130$ GeV



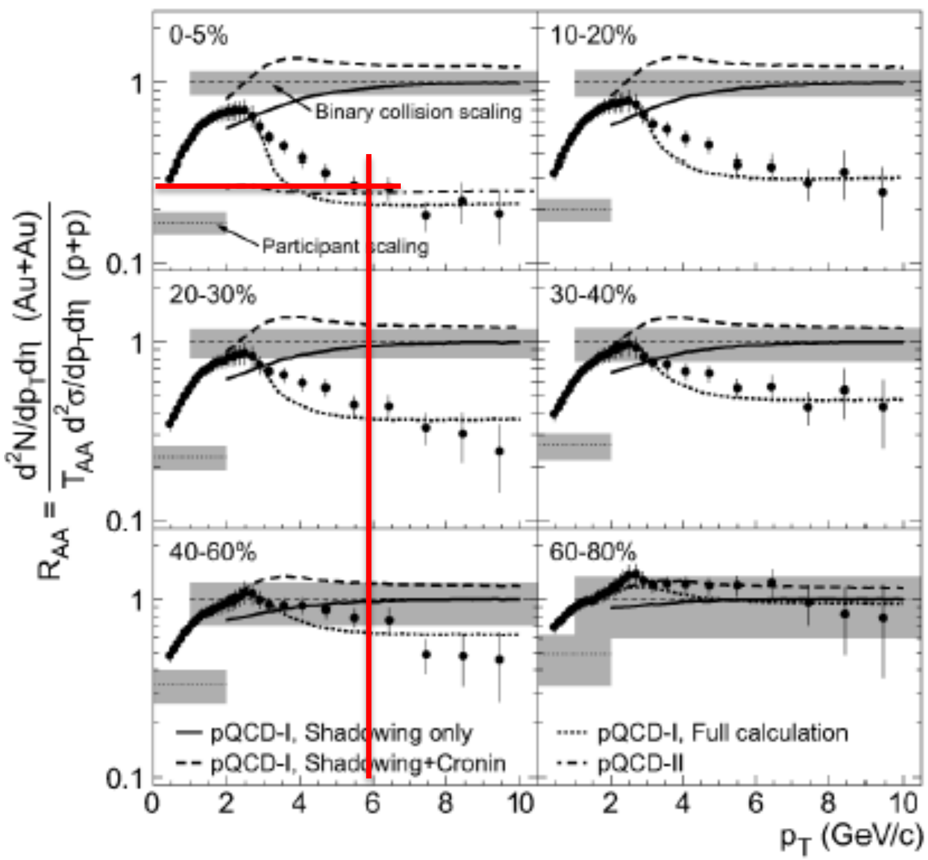


Factor ~5 suppression!

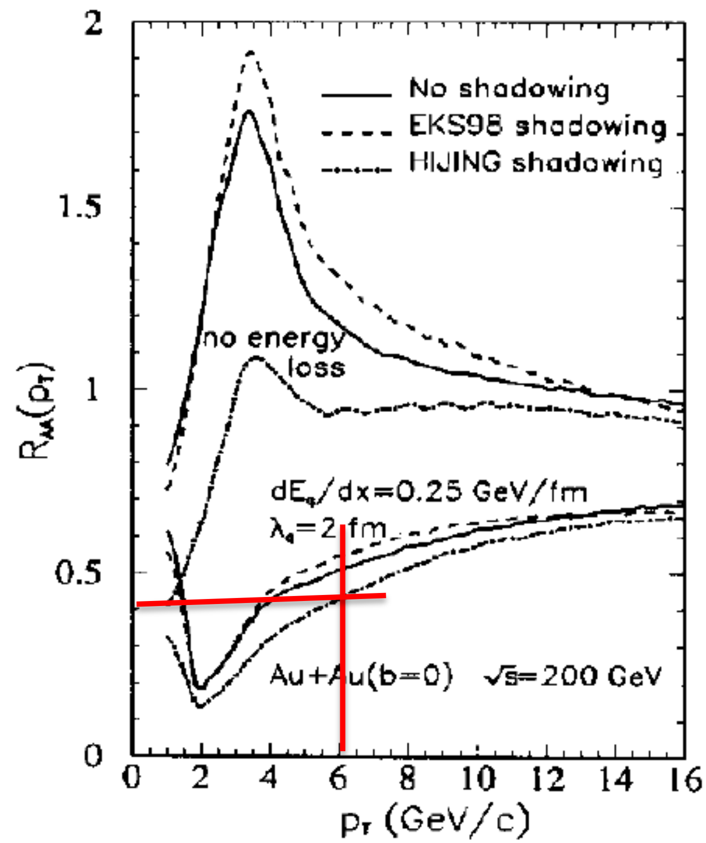
VOLUME 91, NUMBER 17 PHYSICAL REVIEW LETTERS week ending 24 OCTOBER 2003

Transverse-Momentum and Collision-Energy Dependence of High-p_T Hadron Suppression in Au + Au Collisions at Ultrarelativistic Energies

$\sqrt{s_{NN}}$=200 GeV;
R_{AA} with measured pp reference



XNW,
Last Call for RHIC Predictions,
Nucl Phys A661 (1999) 205c



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HIJING: A Monte Carlo model for multiple jet production in p p, p A and A A collisions

Xin-Nian Wang (LBL, Berkeley), Miklos Gyulassy (LBL, Berkeley)

Jul, 1991

55 pages
Published in: *Phys.Rev.D* 44 (1991) 3501-3516
DOI: 10.1103/PhysRevD.44.3501
Report number: LBL-31036
View in: OSTI Information Bridge Server, ADS Abstract Service

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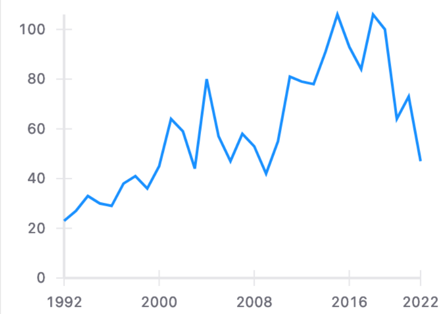


Feedback

Abstract: (APS)
Combining perturbative-QCD inspired models for multiple jet production with low pT multistring phenomenology, we develop a Monte Carlo event generator hijing to study jet and multiparticle production in high energy pp, pA, and AA collisions. The model includes multiple minijet production, nuclear shadowing of parton distribution functions, and a schematic mechanism of jet interactions in dense matter. Glauber geometry for multiple collisions is used to calculate pA and AA collisions. The phenomenological parameters are adjusted to reproduce essential features of pp multiparticle production data for a wide energy range (s=5–2000 GeV). Illustrative tests of the model on p+A and light-ion B+A data at s=20 GeV/nucleon and predictions for Au+Au at energies of the BNL Relativistic Heavy Ion Collider (s=200 GeV/nucleon) are given.

Published 31 years ago:

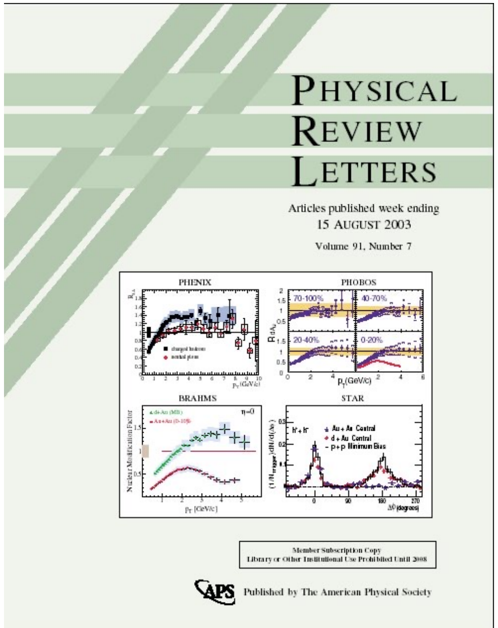
- > 1800 citations
- no indication that citation rate is slowing down

The only competition in our field:

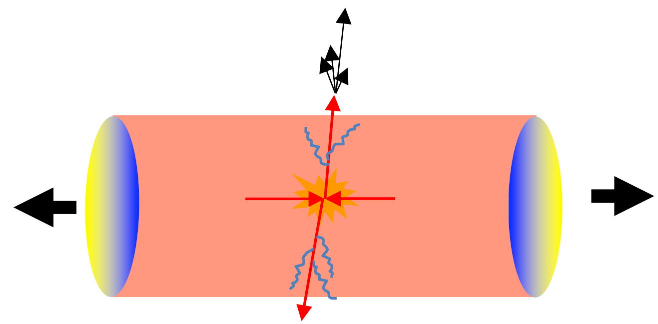
- Bjorken hydrodynamics
- Matsui+Satz quarkonium dissociation

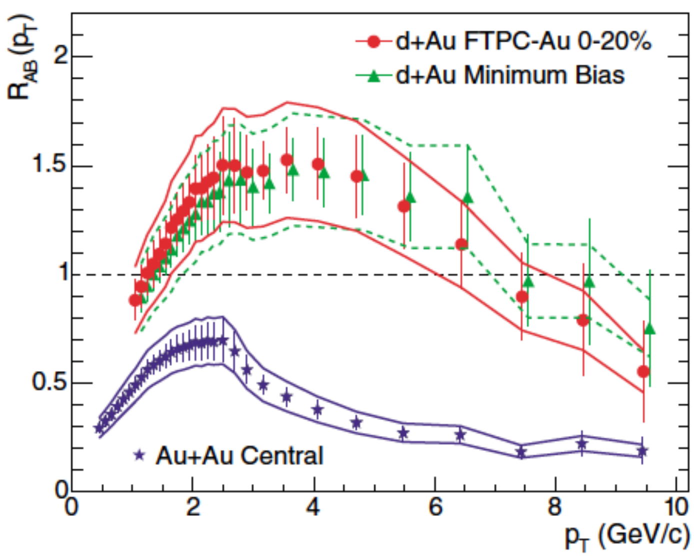
} Good company!

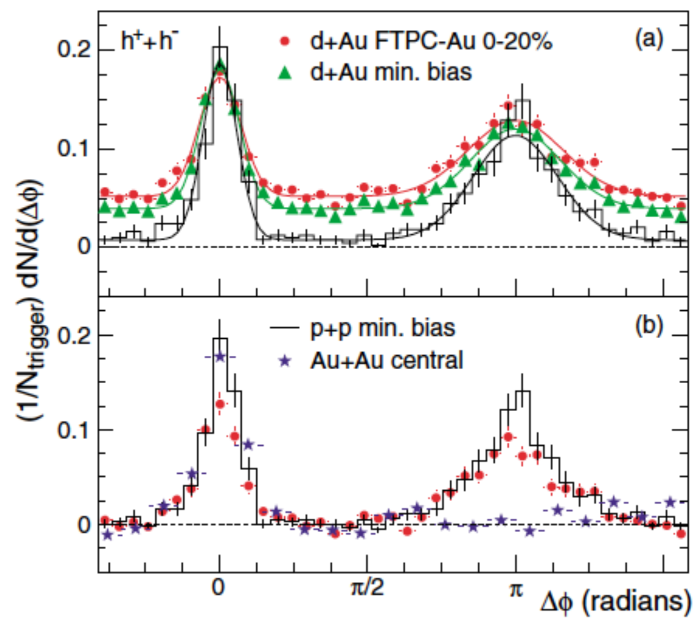
d+Au run ’03: discovery of jet quenching



Xin-Nian and Miklos ’92: proposed p+A for data-driven calibration of non-quenching effects

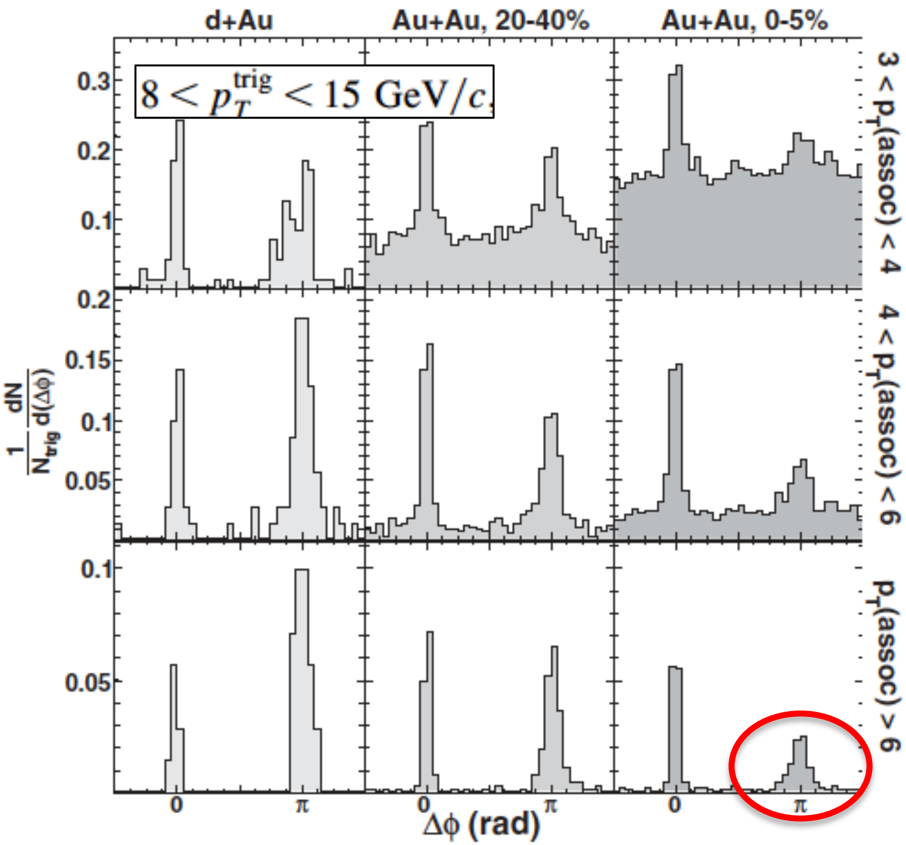


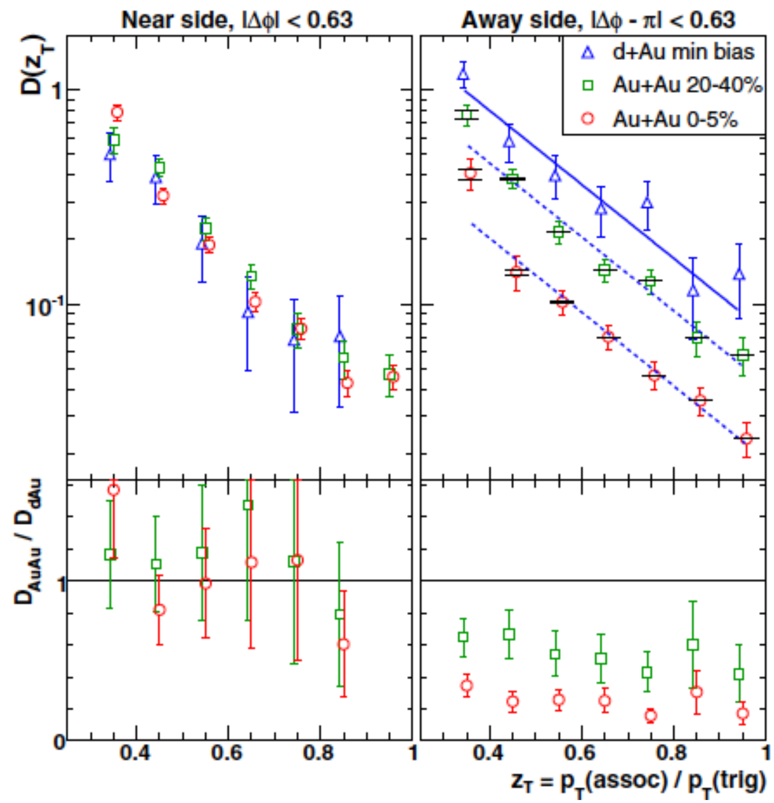




PRL **97**, 162301 (2006)   PHYSICAL REVIEW LETTERS   week ending 20 OCTOBER 2006

Direct Observation of Dijets in Central Au + Au Collisions at $\sqrt{s_{NN}} = 200$ GeV





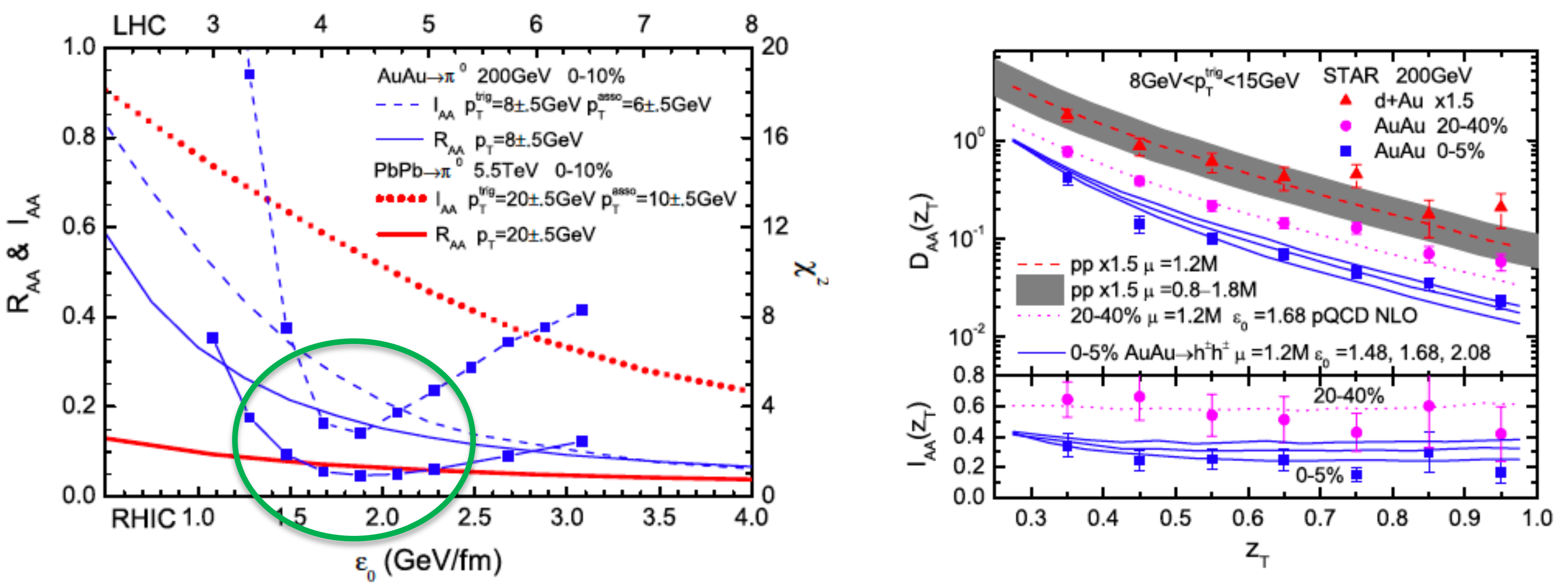
First positive observation of suppressed recoil yield due to quenching

PRL **98,** 212301 (2007) PHYSICAL REVIEW LETTERS week ending 25 MAY 2007

Dihadron Tomography of High-Energy Nuclear Collisions in Next-to-Leading Order Perturbative QCD

Hanzhong Zhang,[1] Joseph F. Owens,[2] Enke Wang,[1] and Xin-Nian Wang[3]

initial gluon density than the single hadron spectra that are more dominated by surface emission. A simultaneous χ^2 fit to both the single and dihadron spectra can be achieved within a range of the energy loss parameter $\epsilon_0 = 1.6$–2.1 GeV/fm. Because of the flattening of the initial jet production spectra at $\sqrt{s} = 5.5$ TeV, high p_T dihadrons are found to be more robust as probes of the dense medium.



First indication that coincidence measurements provide independent – and possibly more sensitive – probes of quenching than inclusive observables

VOLUME 77, NUMBER 2 PHYSICAL REVIEW LETTERS 8 JULY 1996

Jet Quenching in the Direction Opposite to a Tagged Photon in High-Energy Heavy-Ion Collisions

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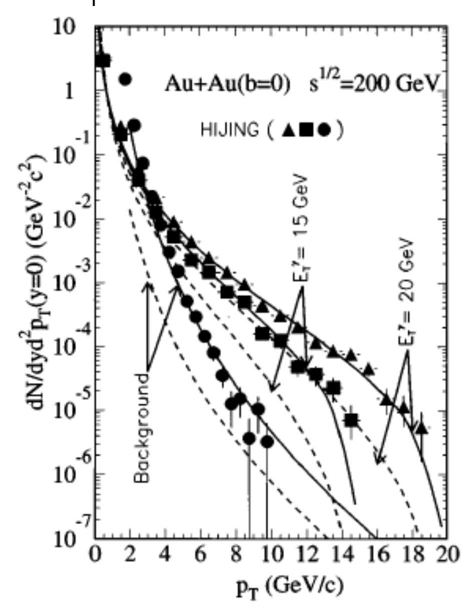
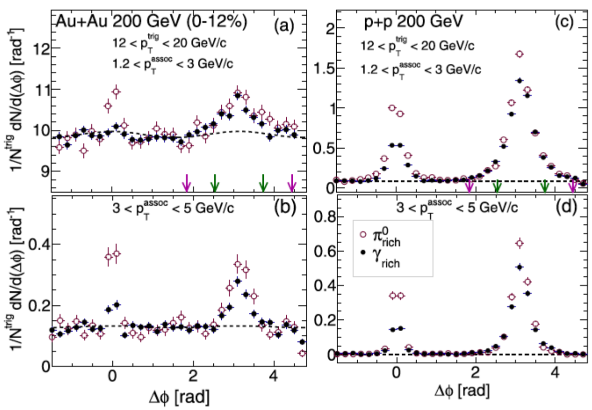
(Received 5 March 1996; revised manuscript received 3 May 1996)

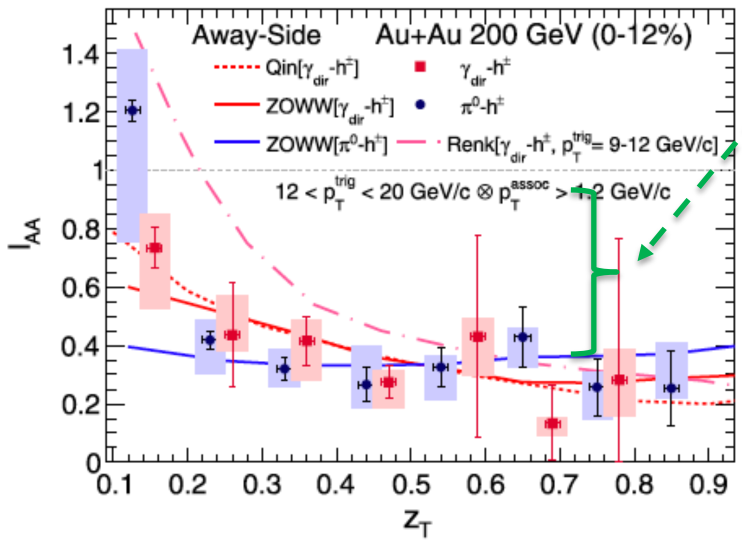
We point out that events associated with large E_T direct photons in high-energy heavy-ion collisions can be used to study jet energy loss in dense matter. In such events, the p_T spectrum of charged hadrons from jet fragmentation in the direction opposite to the tagged photon is estimated to be well above the background which can be reliably subtracted at moderately large p_T. We demonstrate that comparison between the extracted fragmentation function in AA and pp collisions can be used to determine the jet energy loss and the interaction mean free path in the dense matter produced in high-energy heavy-ion collisions. [S0031-9007(96)00635-7]

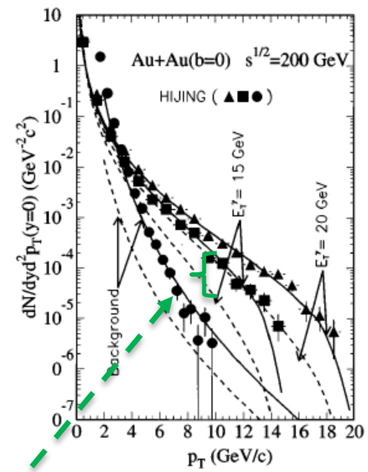


Jet-like correlations with direct-photon and neutral-pion triggers at $\sqrt{s_{NN}} = 200$ GeV

STAR Collaboration







PHYSICAL REVIEW C VOLUME 55, NUMBER 6 JUNE 1997

Medium-induced parton energy loss in γ+jet events of high-energy heavy-ion collisions

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(Received 9 January 1997)

VI. k_T BROADENING AND JET PROFILE

In our discussions so far, we have assumed that the jet profile in the opposite direction of the tagged photon remains the same in AA as in pp collisions, since we used the same acceptance factor $C(\Delta y, \Delta\phi)$. Such an acceptance factor is determined by the effective jet profile in the opposite direction of the tagged photon. One can imagine that there should be two sources of corrections. One is due to the initial- and final-state multiple parton scatterings with the colliding nucleons. As we have discussed, such multiple scatterings can cause the broadening of the jet E_T smearing. They shall also increase the acoplanarity of the jet with respect to the tagged photon. One can study this effect directly via the effective jet profile in $pA \to \gamma + \text{jet} + X$ processes as in dijet events [19]. Let us assume that such increased acoplanarity can be measured and corrected. The second correction to the effective jet profile comes from multiple scatterings suffered by the leading parton while it propagates inside the dense medium. These multiple scatterings induce radiative energy loss and in the meantime also cause the k_T broadening of the final parton with respect to its original transverse direction,

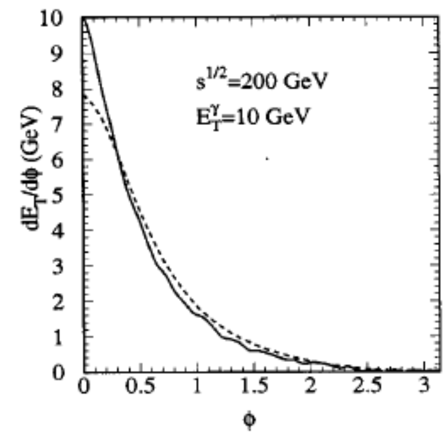
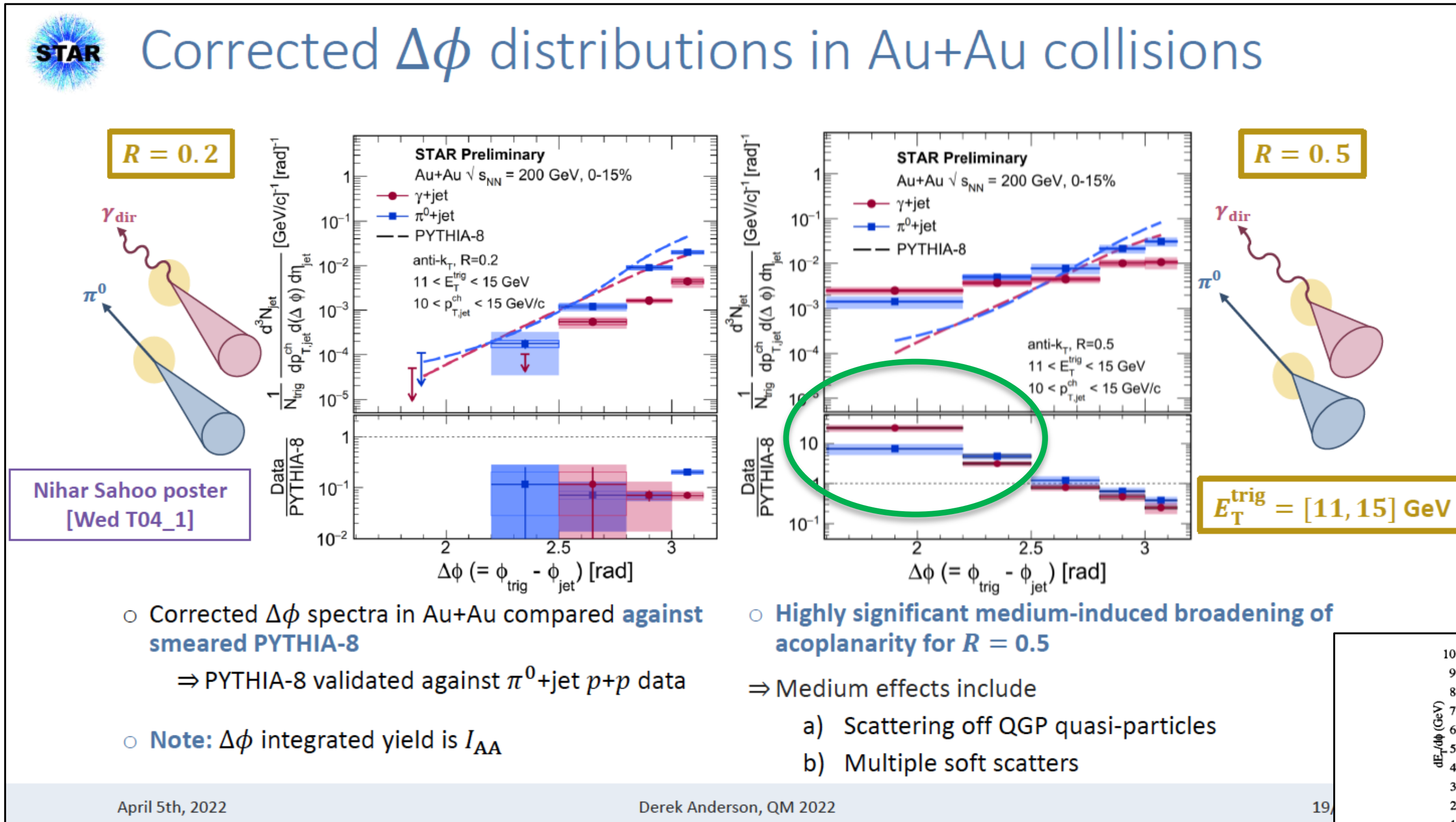


FIG. 11. Jet profile $dE_T/d\phi$ (within $|y|<0.5$) with respect to the opposite direction of the tagged photon. The solid line is the original profile in pp collisions from HIJING simulations, while the dashed line is the modified profile function with $\Delta k_T^2 = 4$ GeV$^2/c^2$.

Quark Matter '22 (!)



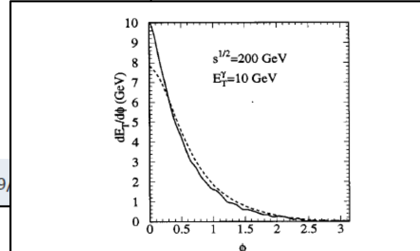


FIG. 11. Jet profile $dE_T/d\phi$ (within $|y|<0.5$) with respect to the opposite direction of the tagged photon. The solid line is the original profile in pp collisions from HIJING simulations, while the dashed line is the modified profile function with $\Delta k_T^2=4$ GeV$^2/c^2$.

Many of the key tools that we use to study jet quenching were invented by Xin-Nian and collaborators:

- R_{AA}
- p/d+A as data-driven calibration of non-quenching effects
- Importance of coincidence channels
- γ+h, γ+jet

This is only a partial list.

We aren’t ancient history…yet…

Looking forward to many more years of wonderful collaboration!