日本 2013

Recent sPHENIX / ePHENIX Meeting in Japan

RHIC Strategy Meeting in Detroit

デトロイト 2013

Jamie Nagle, University of Colorado

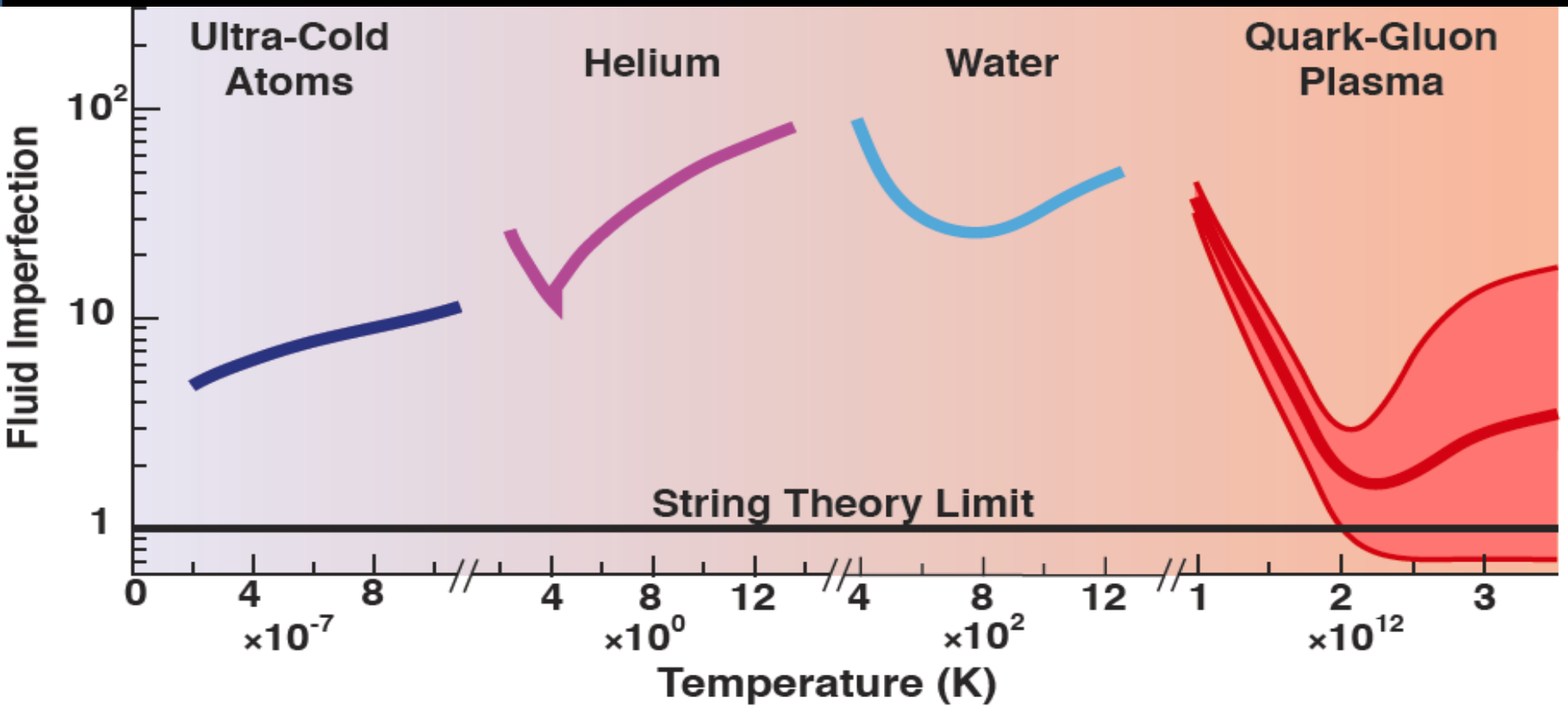
August 25, 2013

What does the future hold?

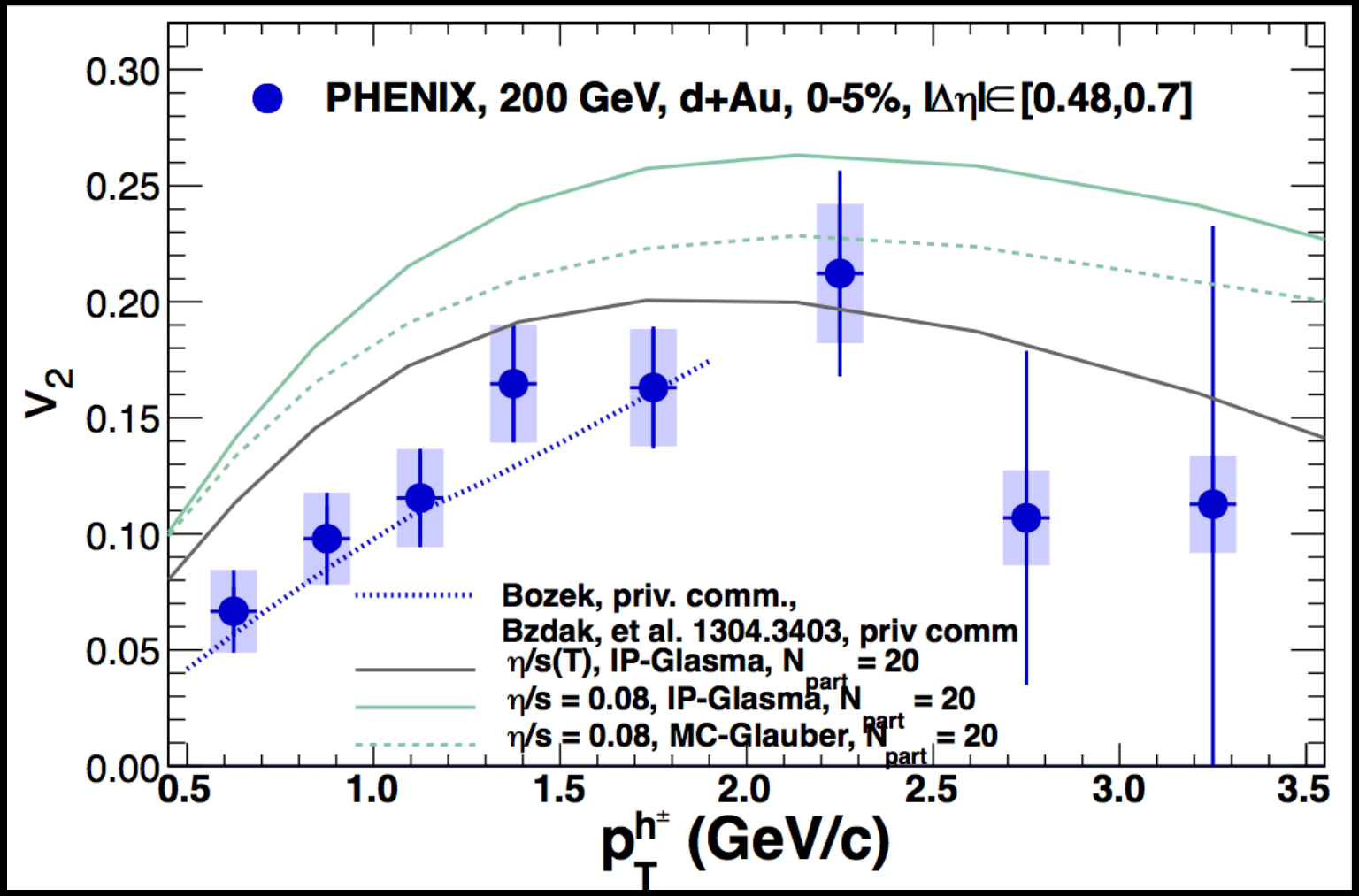
Maybe Berndt, Xin-Nian, and Dave know from their trip to China

sPHENIX is motivated by interest in dissecting how the quark-gluon plasma works and how its nature evolves with temperature

Is the QGP a perfect fluid with no quasi-particles at any scale?

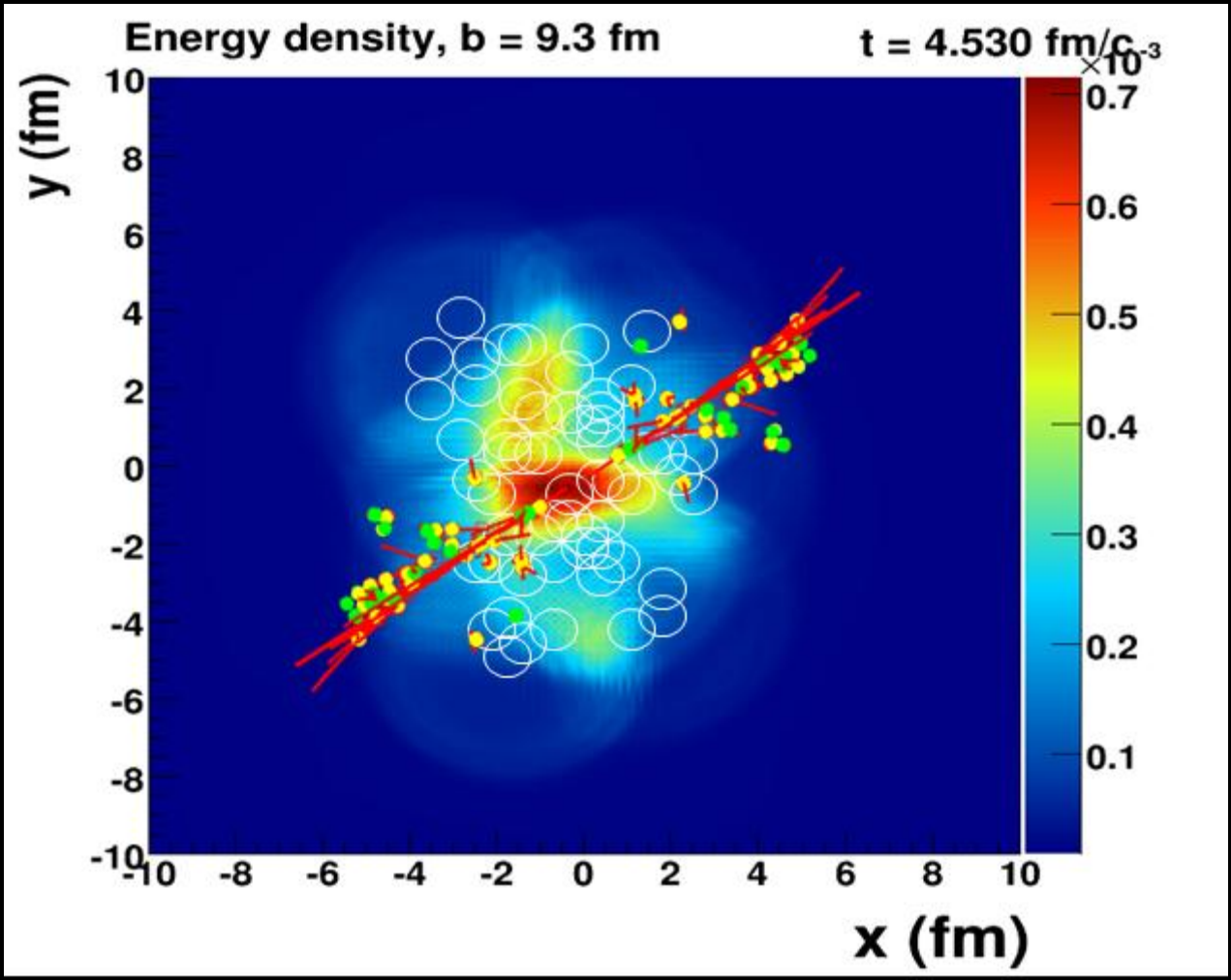


Can even d+Au/p+Pb produce a nearly inviscid fluid?



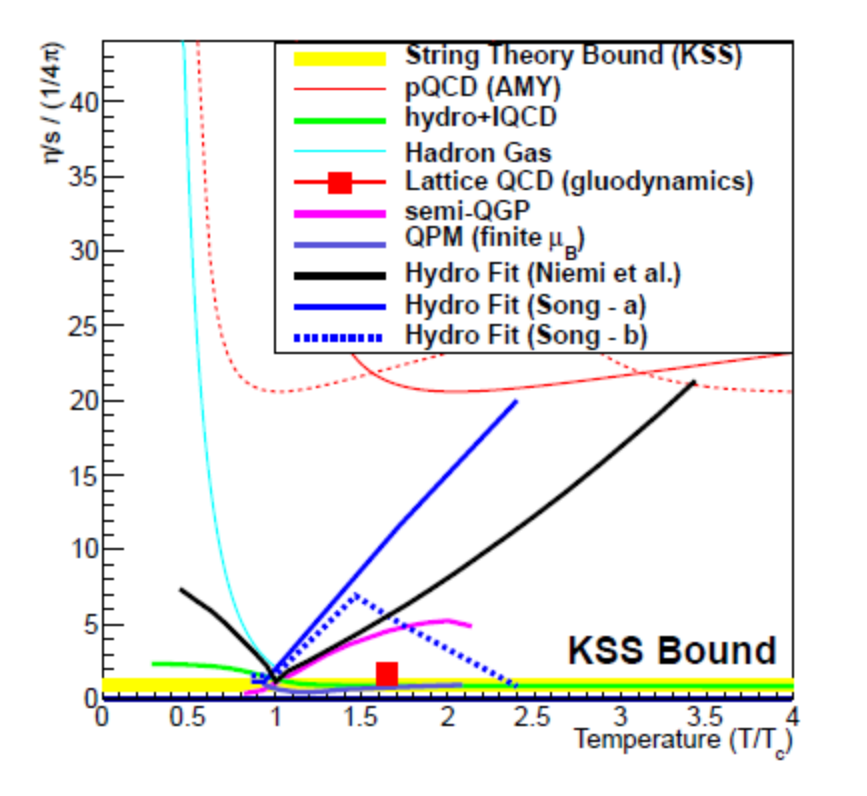
These developments in the past year underscore the need for measurements to address why and how perfect fluidity arises

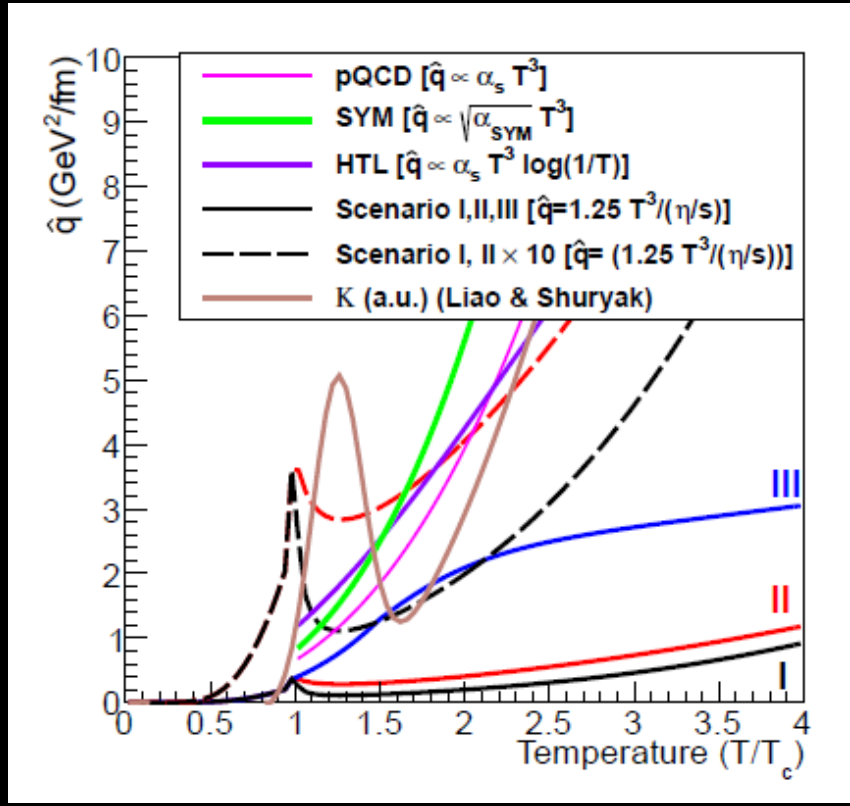
Probing the Medium



When does the strongly coupled bulk (*lower momentum IR*) transition to a weakly coupled probe (*higher momentum UV*)?

At what scale does bulk coupling relate to probe coupling?





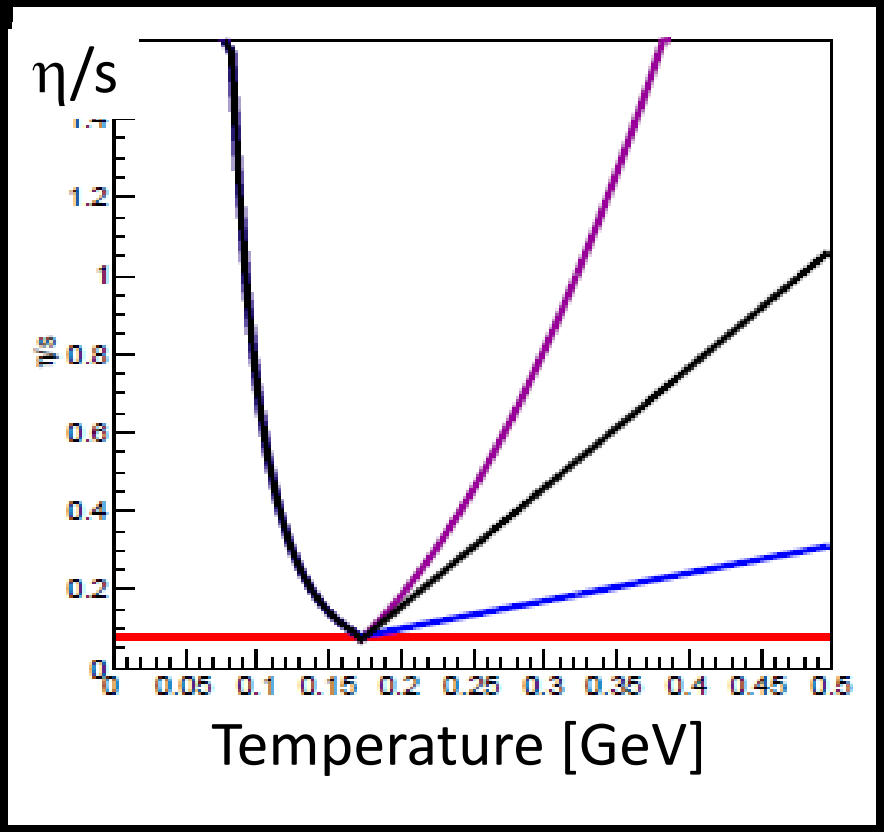
PRL 99, 192301 (2007) PHYSICAL REVIEW LETTERS week ending 9 NOVEMBER 2007

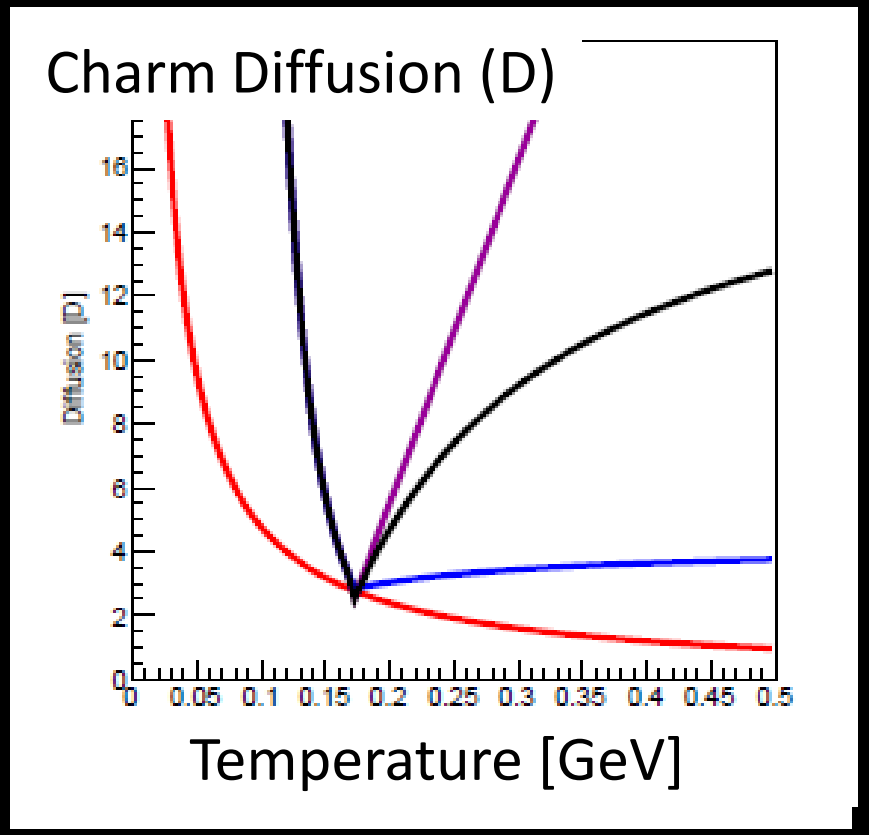
Small Shear Viscosity of a Quark-Gluon Plasma Implies Strong Jet Quenching

Abhijit Majumder,[1] Berndt Müller,[1] and Xin-Nian Wang[2]
[1]*Department of Physics, Duke University, Durham, North Carolina 27708, USA*
[2]*Nuclear Science Division, MS 70R0319, Lawrence Berkeley National Laboratory, Berkeley, California 94720, USA*
(Received 10 March 2007; revised manuscript received 13 June 2007; published 7 November 2007)

$$\hat{q} = \frac{1.25T^3}{\eta / s}$$

At what scale does bulk coupling relate to probe coupling?





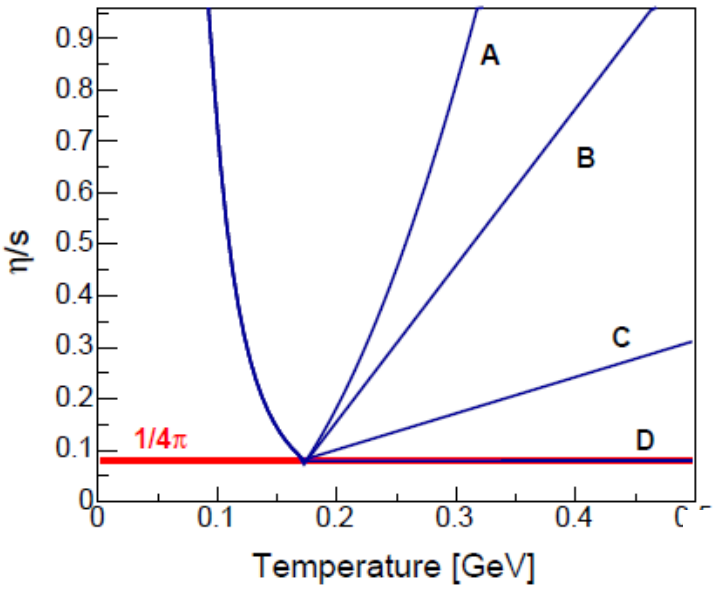
How Much do Heavy Quarks Thermalize in a Heavy Ion Collision?

Guy D. Moore

Derek Teaney

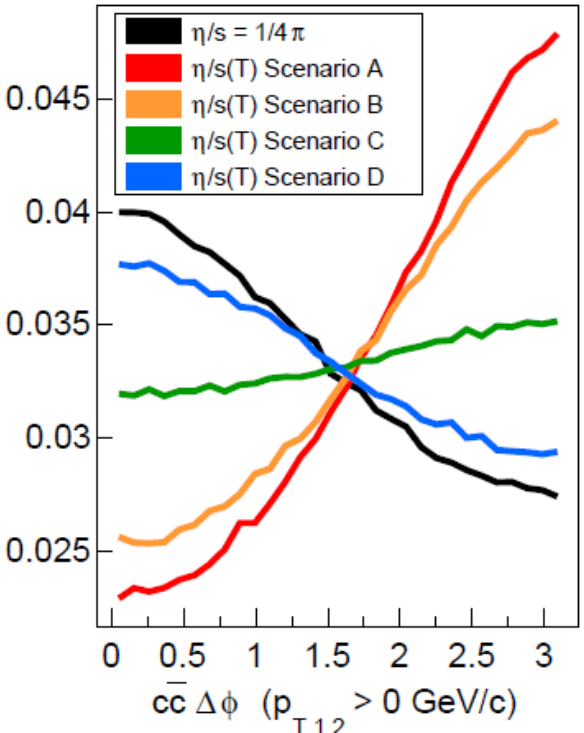
$$D = \frac{\eta}{s}\frac{6}{T}$$

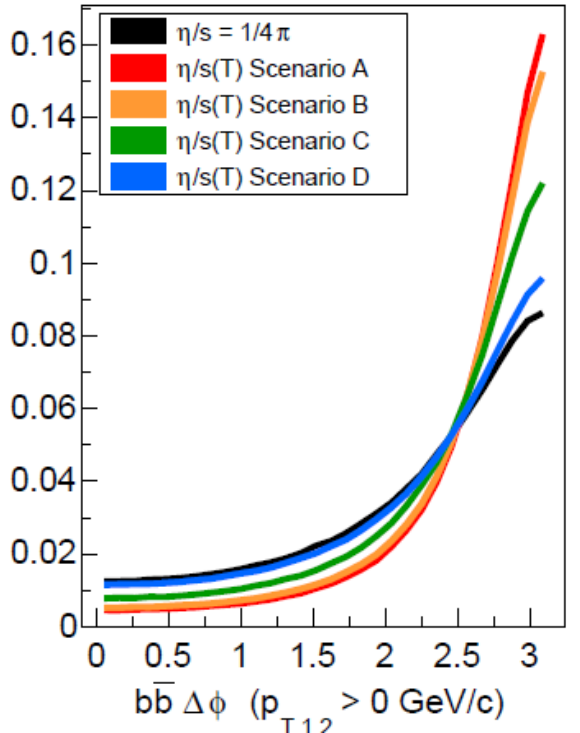
Charm and Beauty – sensitivity to early time!



Beauty R_{AA} sensitive to early time coupling!

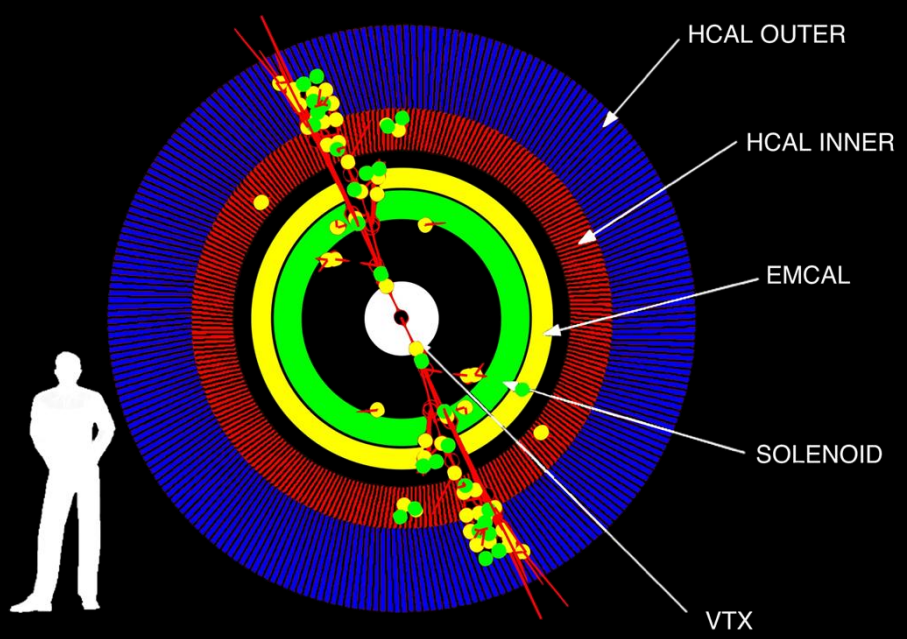
Charm-AntiCharm Correlations sensitive to early time coupling!

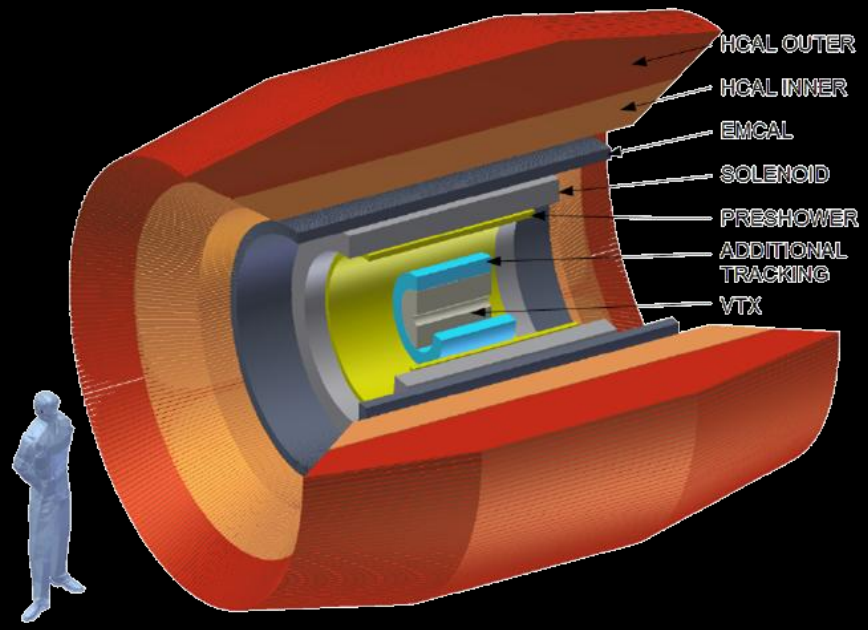




Major Upgrade to PHENIX Proposed

Taking advantage of significant technology advances (exciting synergies with LHC upgrades)





http://arxiv.org/abs/arXiv:1207.6378

External review of sPHENIX MIE, October 5–6, 2012

Committee members: Miklos Gyulassy (Columbia), Xin-Nian Wang (LBNL), Raju Venugopalan (BNL), John Harris (Yale), Jimmy Proudfoot (Argonne), Mike Harrison (BNL), Bolek Wyslouch (MIT)

The Committee ... "strongly endorses the science case for this program."

- emphasize broad physics program of sPHENIX

- emphasize uniqueness of the RHIC measurements

- more GEANT4 studies of full jet reconstruction

- test beam to validate EMCal/HCal design

- reduce technical risk on solenoid (biggest issue)

BaBar Solenoid

Excellent foundation for sPHENIX and ePHENIX:
inner radius 140 cm, length 385 cm, field 1.5 T

Reduces technical risk associated with acquiring new superconducting research magnets

STANDARD FORM 122
JUNE 1974
GENERAL SERVICES ADMINISTRATION
FPMR (41 CFR) 101-32.306
FPMR (41 CFR) 101-43.315

TRANSFER ORDER
EXCESS PERSONAL PROPERTY

1. ORDER NO.
SLAC 2013-07-18

2. DATE
July 18, 2013

3. TO: GENERAL SERVICES ADMINISTRATION*

4. ORDERING AGENCY (Full name and address)*
Brookhaven National Lab
Attention: John Haggerty; haggerty@bnl.gov
Upton, NY 11973-5000

5. HOLDING AGENCY (Name and address)*
SLAC National Accelerator Laboratory
2575 Sand Hill Road, MS 85A
Menlo Park, CA 94025

6. SHIP TO (Consignee and destination)*
Same as block 4

7. LOCATION OF PROPERTY
SLAC National Accelerator Laboratory
C/O Mike Racine
2575 Sand Hill Road, MS 53
Menlo Park, CA 94025
650 926-3543 racine@slac.stanford.edu

8. SHIPPING INSTRUCTIONS
BNL to arrange for shipping

9 ORDERING AGENCY APPROVAL

A. SIGNATURE [signature]

B. DATE 7-19-13

C. TITLE Property Manager

10. APPROPRIATION SYMBOL AND TITLE
transfer from DE-AC02-76SFO0515
transfer to DE-AC02-98CH10886

11. ALLOTMENT

12. GOVERNMENT B/L NO.

13. PROPERTY ORDERED

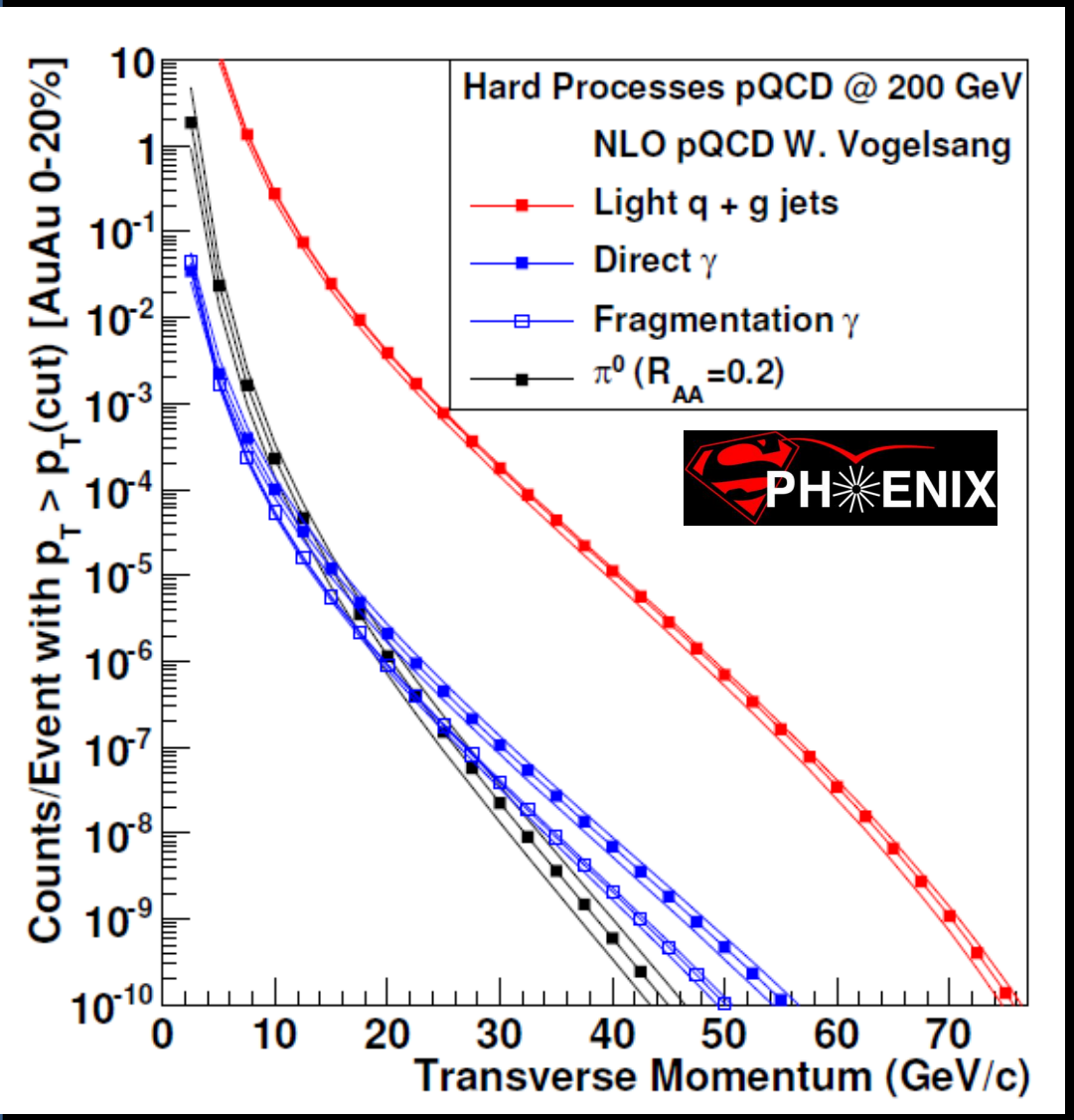
GSA AND HOLDING AGENCY NOS. (a)	ITEM NO. (b)	DESCRIPTION (Include noun name, FSC Group and Class, Condition Code and if available, National Stock Number) (c)	UNIT (d)	QUANTITY (e)	ACQUISITION COST UNIT (f)	ACQUISITION COST TOTAL (g)
	1	Administrative Transfer BaBar Solenoid and Components Date of Mfr: 1996 (See attached list)	ea	1	12,000,000.00	$ 12,000,000.00

Total Acquisition Cost $ 12,000,000.00

A broad physics program of the sQGP

- What are the inner workings of the sQGP?
- Are the key degrees of freedom quasi-particles? excitations? other?
- full jet probes and high statistics dijets
- where does jet energy lost go?
- direct photons
- photon-jet, photon-hadron, jet-hadron correlations
- high statistics upsilons, high statistics open heavy flavor

sPHENIX Rates: Jets, Dijets, γ-Jet



Sampling 50 billion Au+Au events in one year

(can record 20 billion without selective triggers)

10^7 jets > 20 GeV

10^6 jets > 30 GeV

80% are dijet events

10^4 direct γ > 20 GeV

A+B

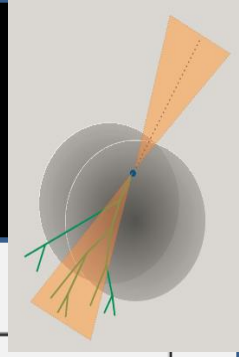
p+A (different nuclei)

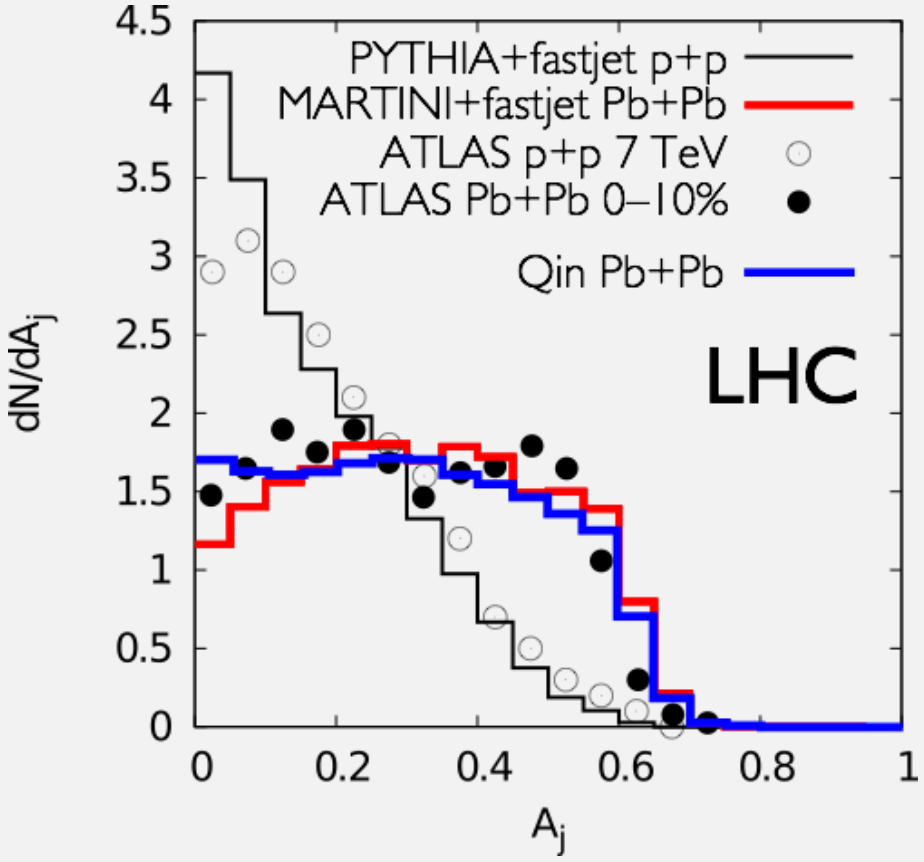
U+U

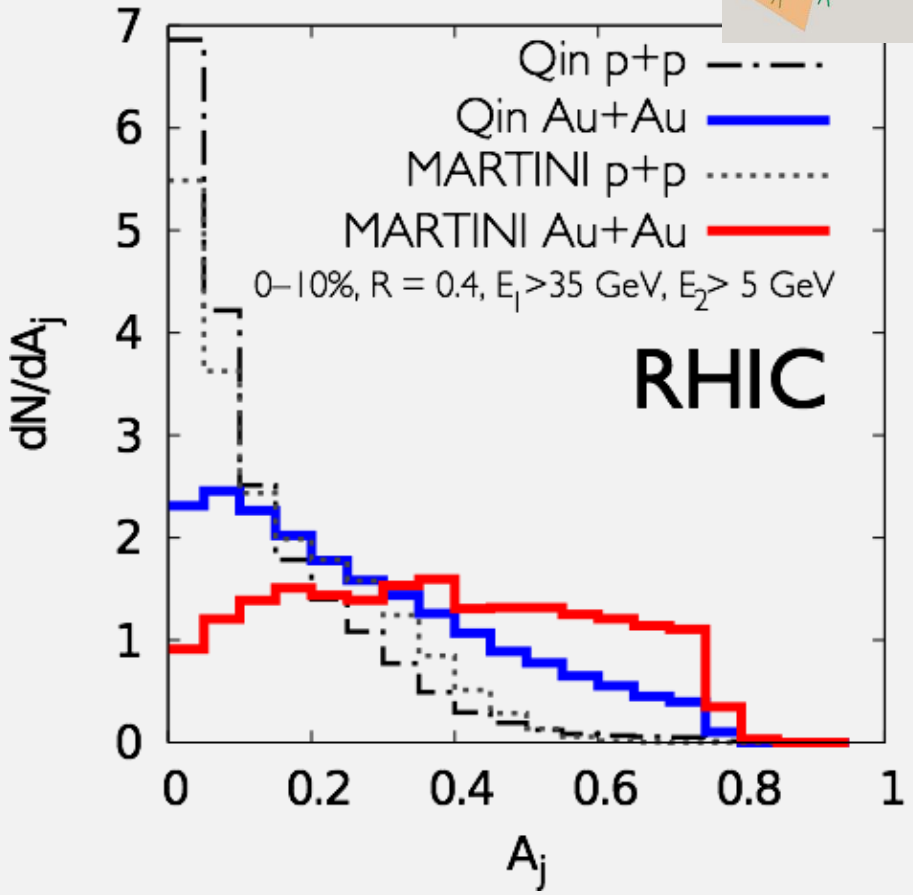
Differential measures

Jets Rates for Au+Au @ 100 GeV and Unique Flexibility of RHIC Enable Additional Lever Arm

RHIC Jet Discriminating Power

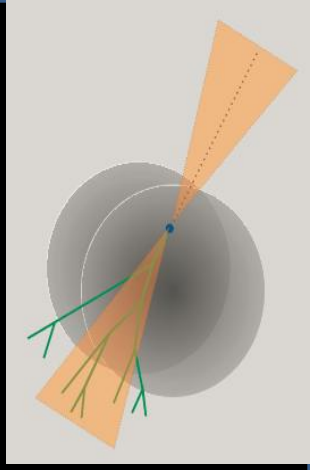






$$A_J = \frac{E_1 - E_2}{E_1 + E_2}$$

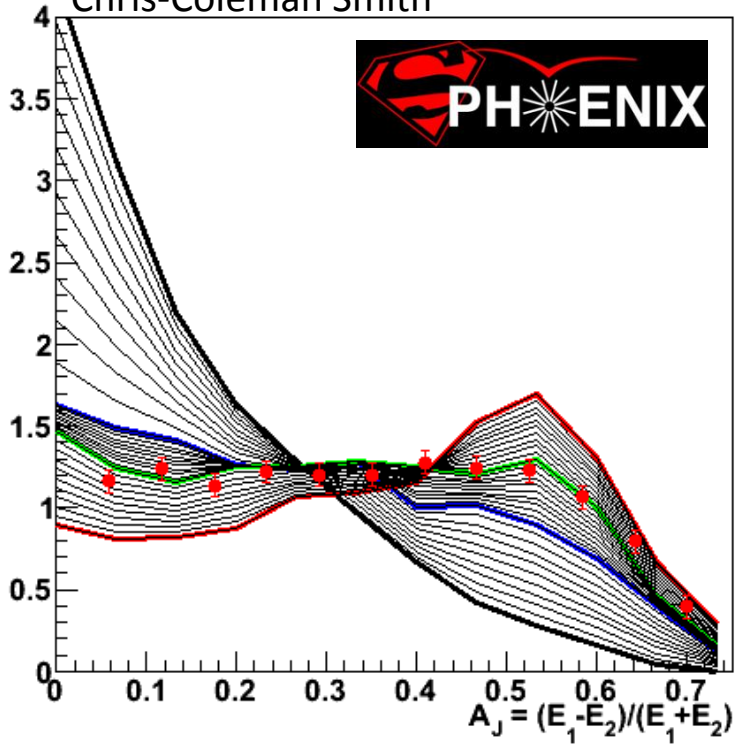
Comprehensive picture across *scales* and QGP *temperatures* spanned by RHIC and LHC needed

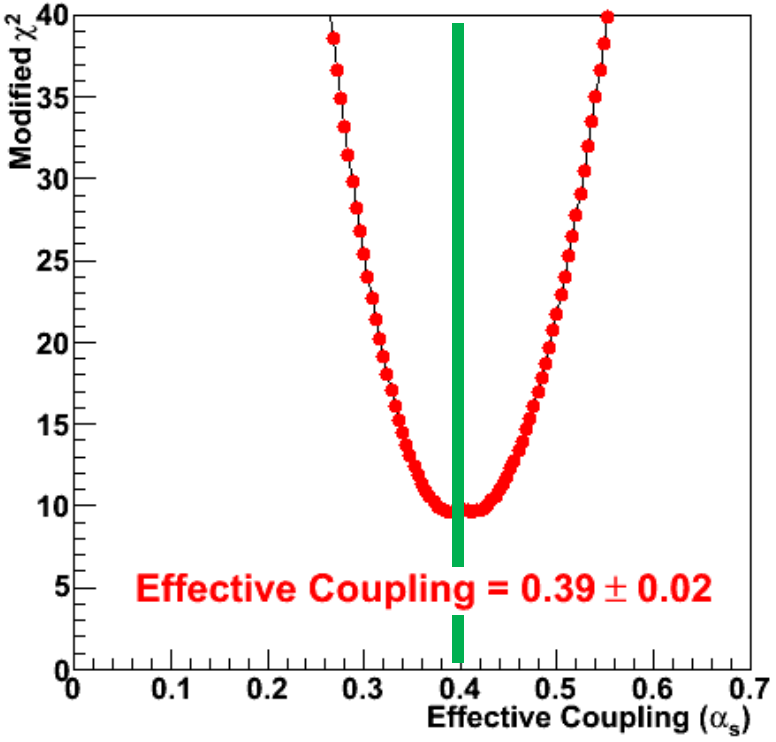


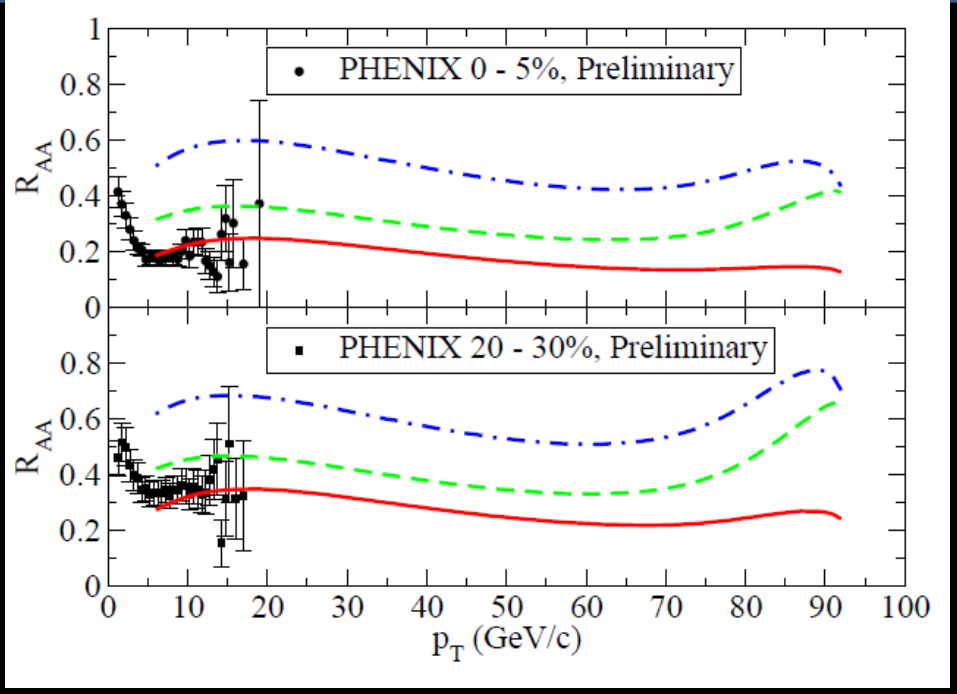
Lever Arm, Strongest Coupling Near T_c?
What is the Underlying Physics (not just η/s value)?

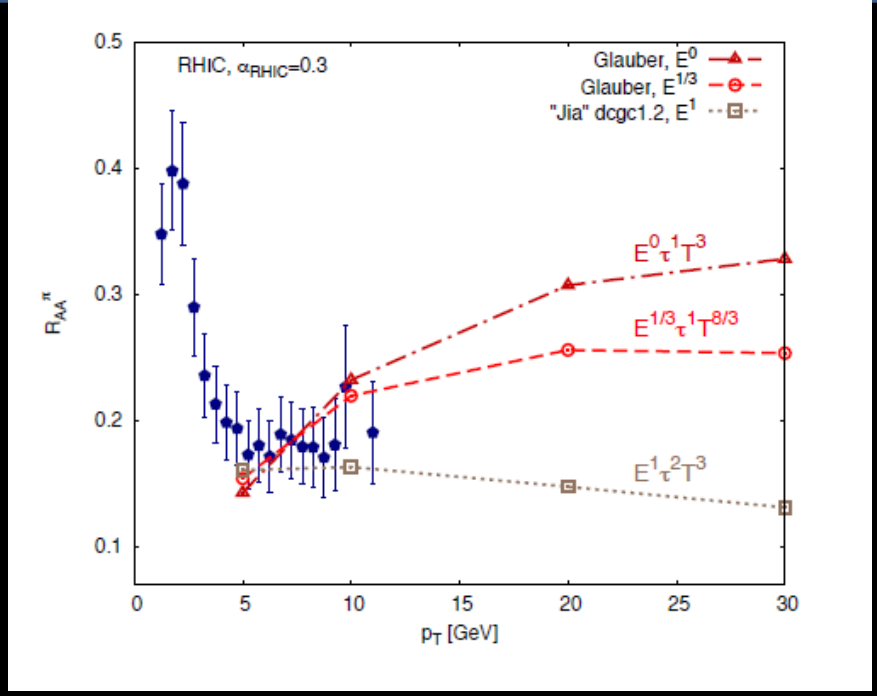
Example RHIC precision measurement

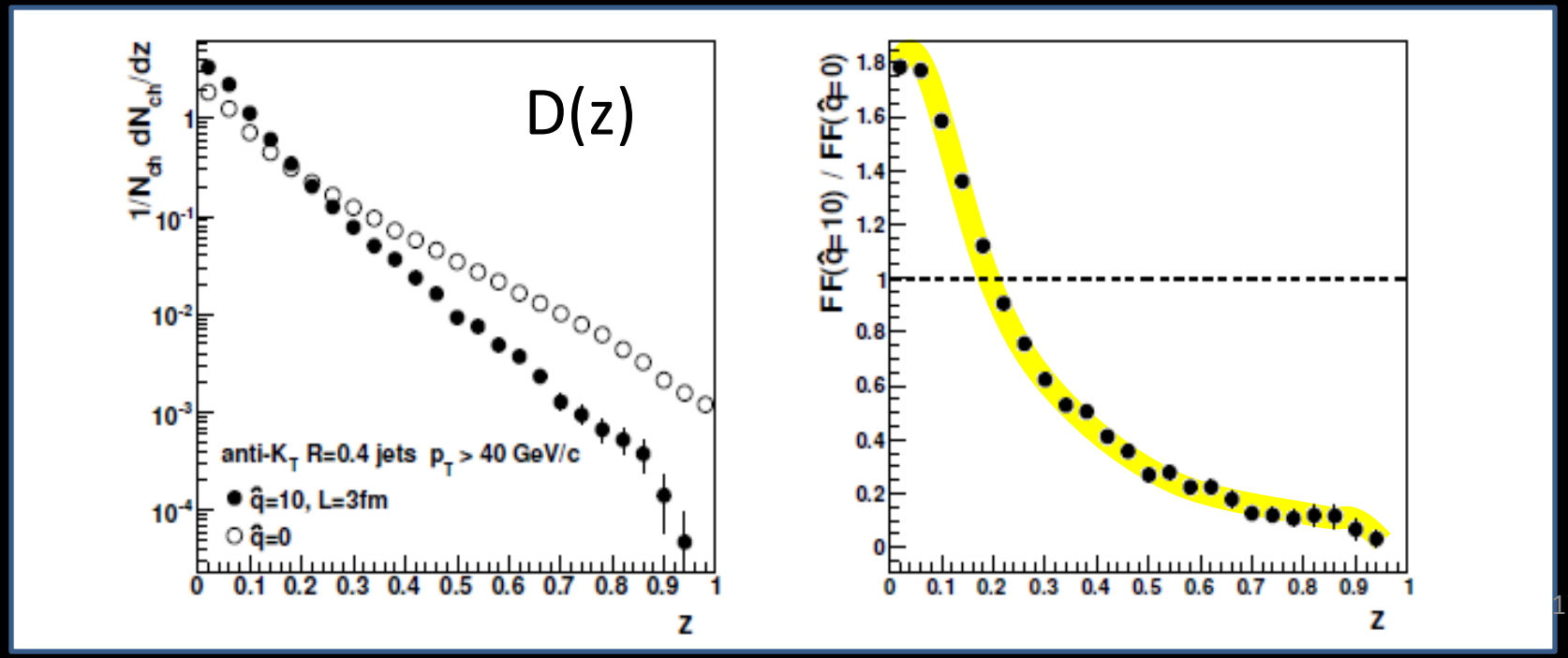
Chris-Coleman Smith

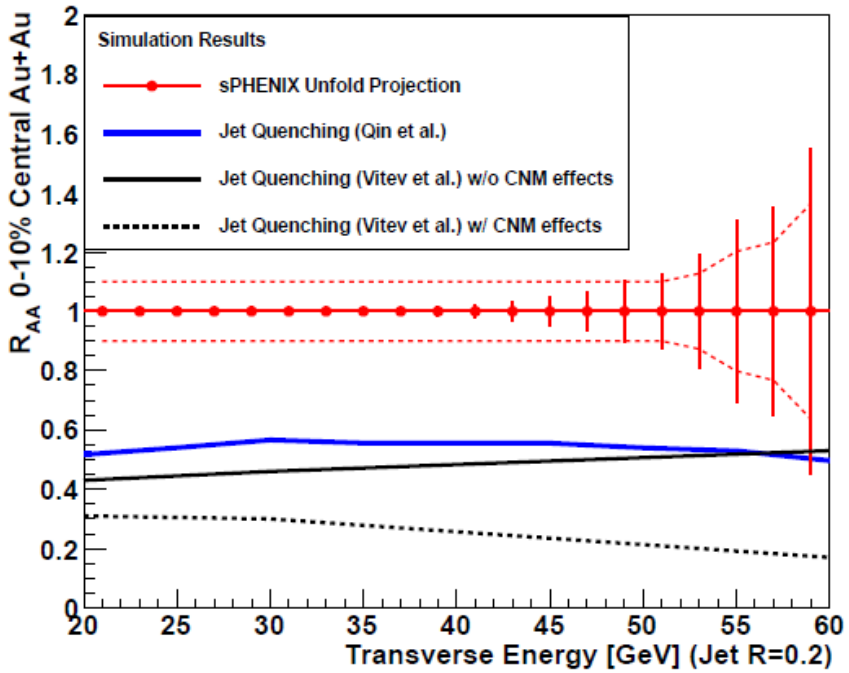





PHENIX 0 - 5%, Preliminary
PHENIX 20 - 30%, Preliminary
R_AA
p_T (GeV/c)


RHIC, α_RHIC=0.3
Glauber, E^0
Glauber, E^1/3
"Jia" dcgc1.2, E^1
E^0τ^1T^3
E^1/3τ^1T^8/3
E^1τ^2T^3
R_AA^π
p_T [GeV]


D(z)
1/N_ch dN_ch/dz
anti-K_T R=0.4 jets p_T > 40 GeV/c
q̂=10, L=3fm
q̂=0
z
FF(q̂=10) / FF(q̂=0)
z



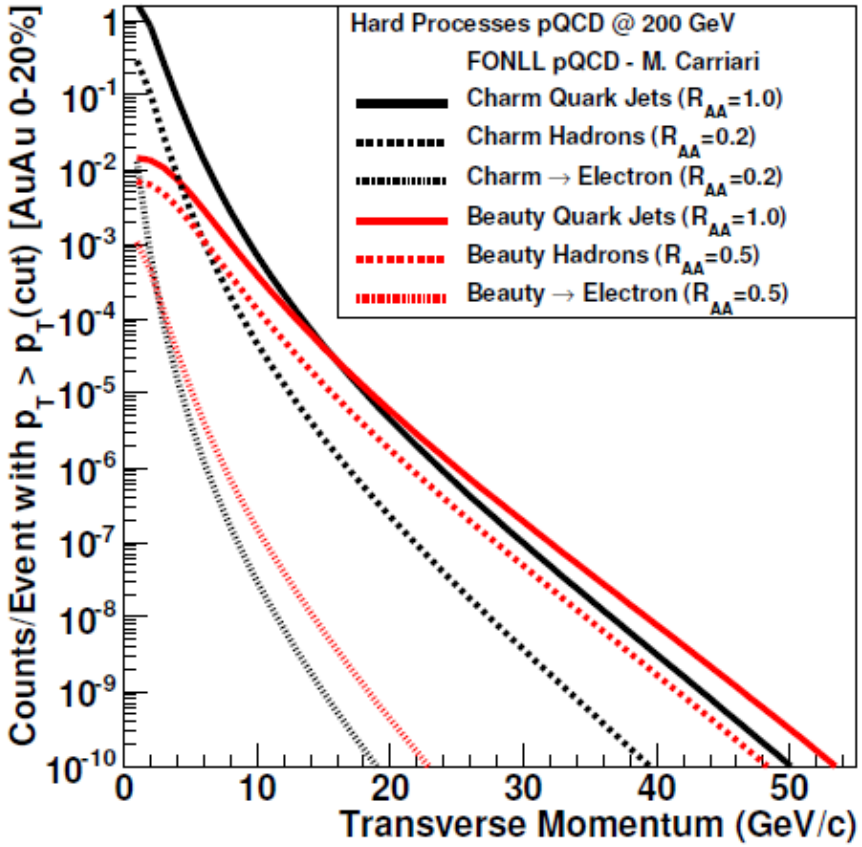
Jet R_{AA} high statistics…

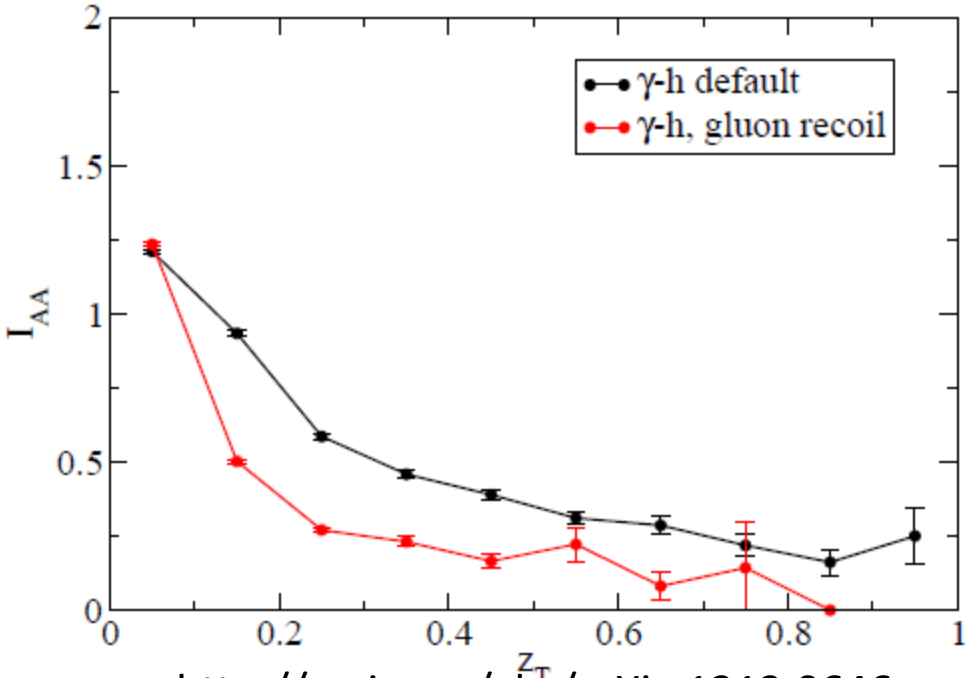
Good first measurements

Good heavy quark jet rates

However, difficulty in tag jet

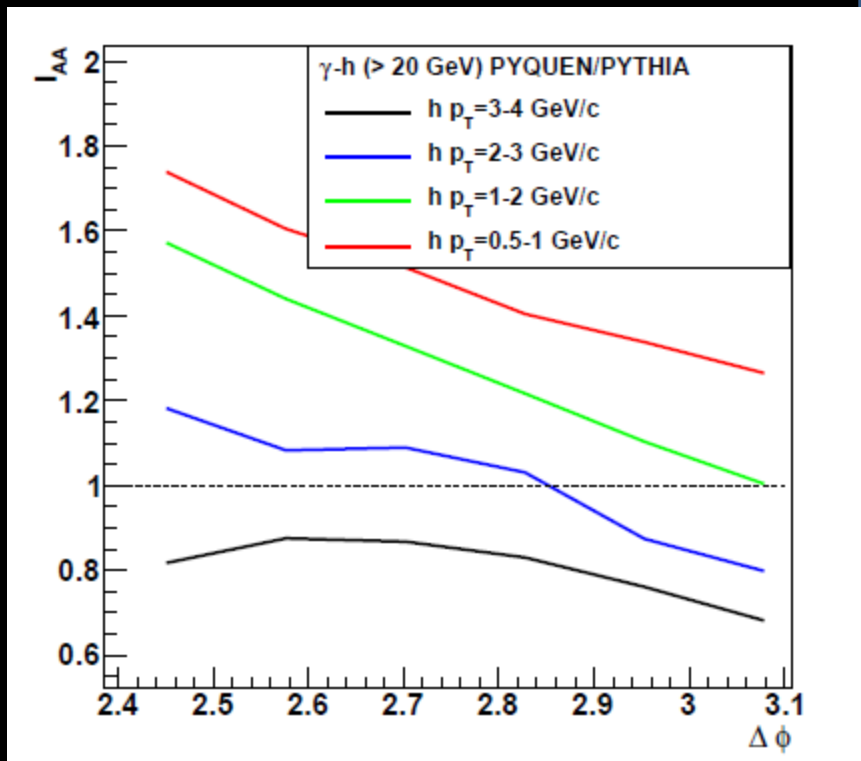
sPHENIX has great D meson acceptance and DCA tag, but loses S/B without Kaon ID.



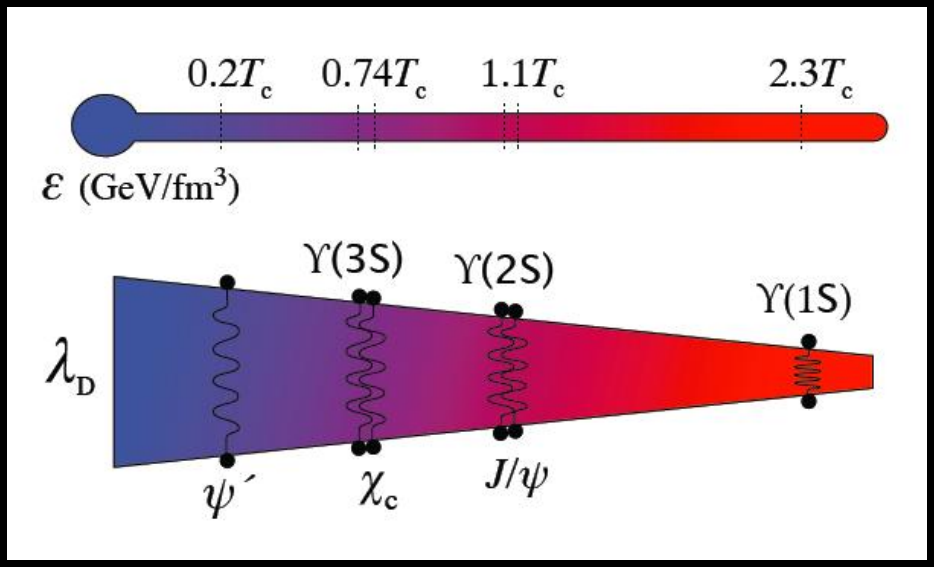


http://arxiv.org/abs/arXiv:1212.0646

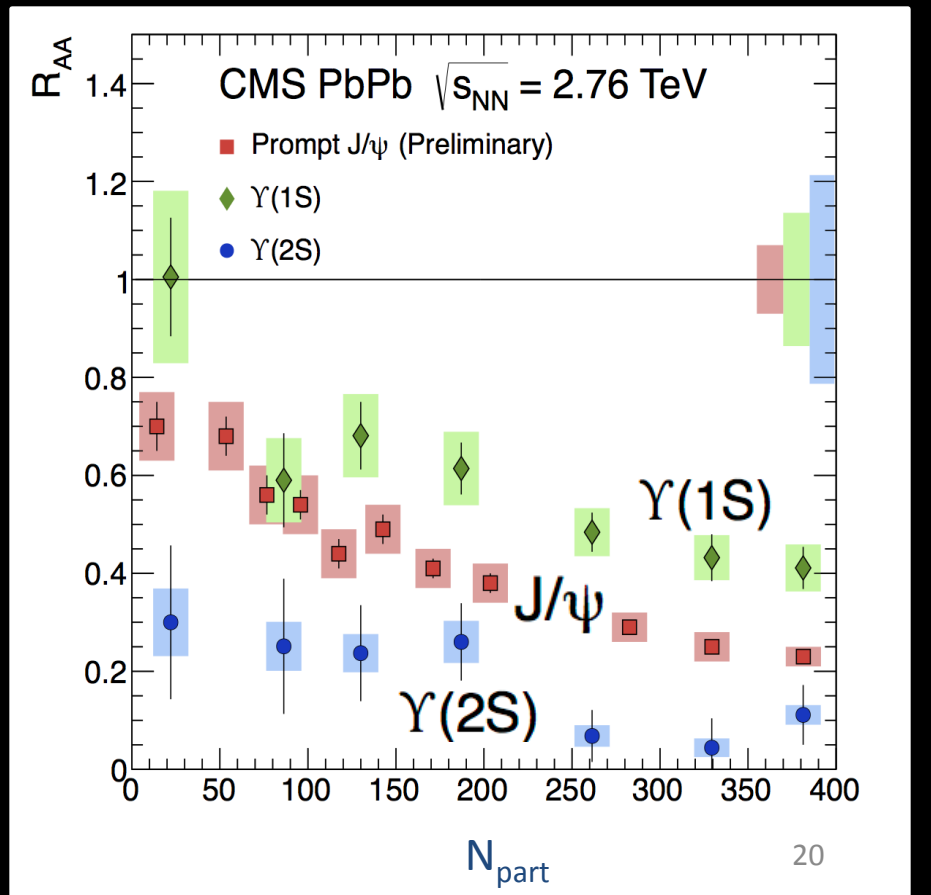
Can measure not only γ-h I_{AA}, but also angular dependence…



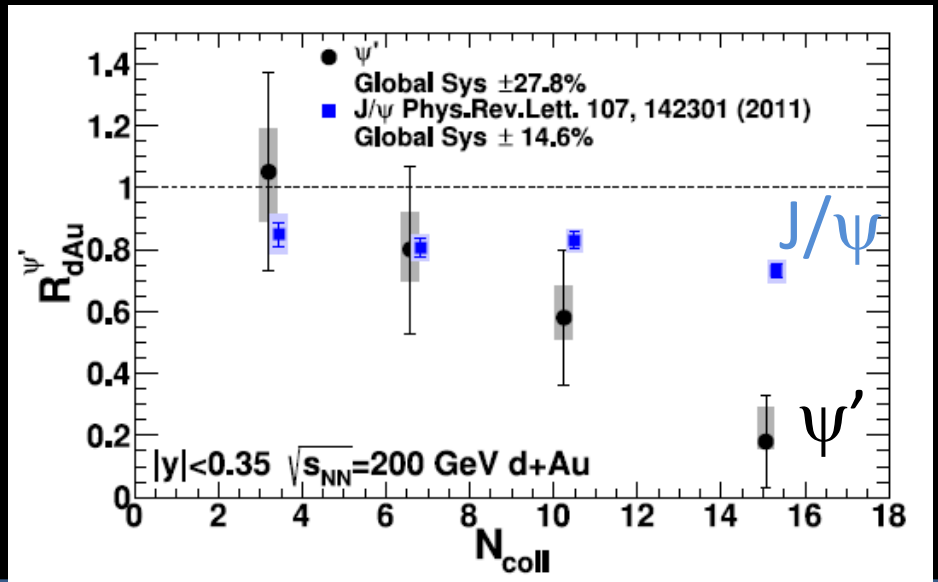
Quarkonia Thermometer



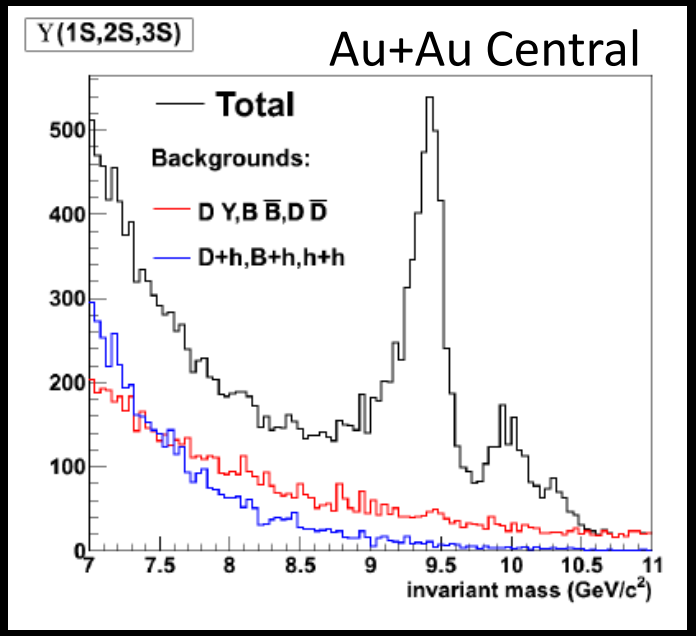
CMS data consistent with *melting* of Υ(2s,3s)

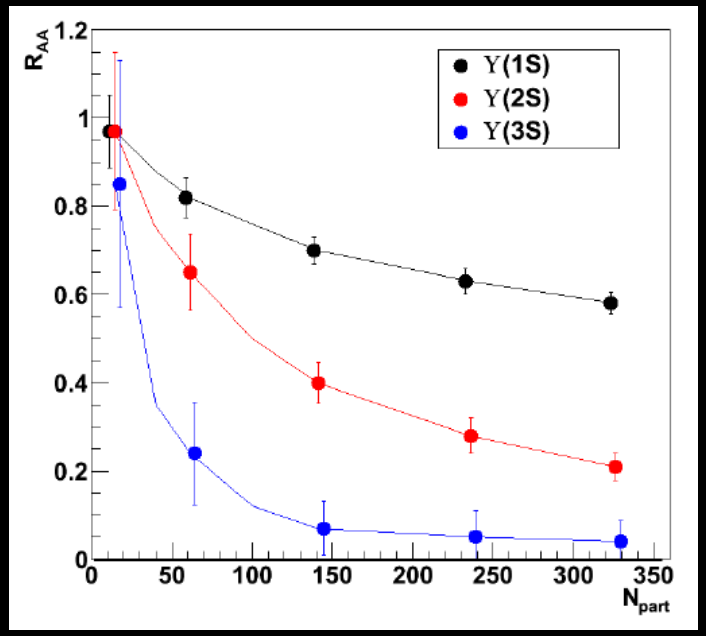


Controls: PHENIX d+Au



sPHENIX Upsilon Measurements





Extremely exciting LHC Upsilon results
Key to map out temperature dependence

sPHENIX will have similar statistics to LHC
and > 7x STAR MTD measurement

Needs additional tracking + preshower

There are arguments that fully reconstructed jets are not in the end the most sensitive to medium properties.

- Single hadrons
- Di-hadron correlations
- Photon-hadron correlations
- Multi-hadron correlations
- Hadron-flow correlations (v_2, v_3, v_4, v_5)
- Reco Jet spectrum
- Reco Jet-hadron correlations
- Reco-Jet – underlying event correlations (v_2, v_3, v_4, v_5)
- Quarkonia – underlying event correlations
- Quarkonia – Reco-Jet correlations
- ….

sPHENIX can do all that with 25 billion recorded events (no trigger bias) with very large acceptance. And in p+p, p+A too.

My g-2 Analogy

Years ago when g-2 was proposing a factor of 10 improvement with more running at BNL, the BNL PAC noted that the experiment would have uncertainties much smaller than those from theory.

Bill Marciano confidently stated that given the time to build and run the experiment, theory would be much lower.

Fermilab believed that to be the case!

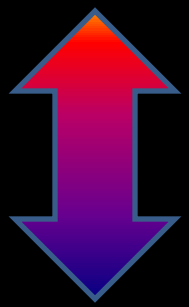
What is our theory projection?

Where do we really have a solid connection between theory and experiment?

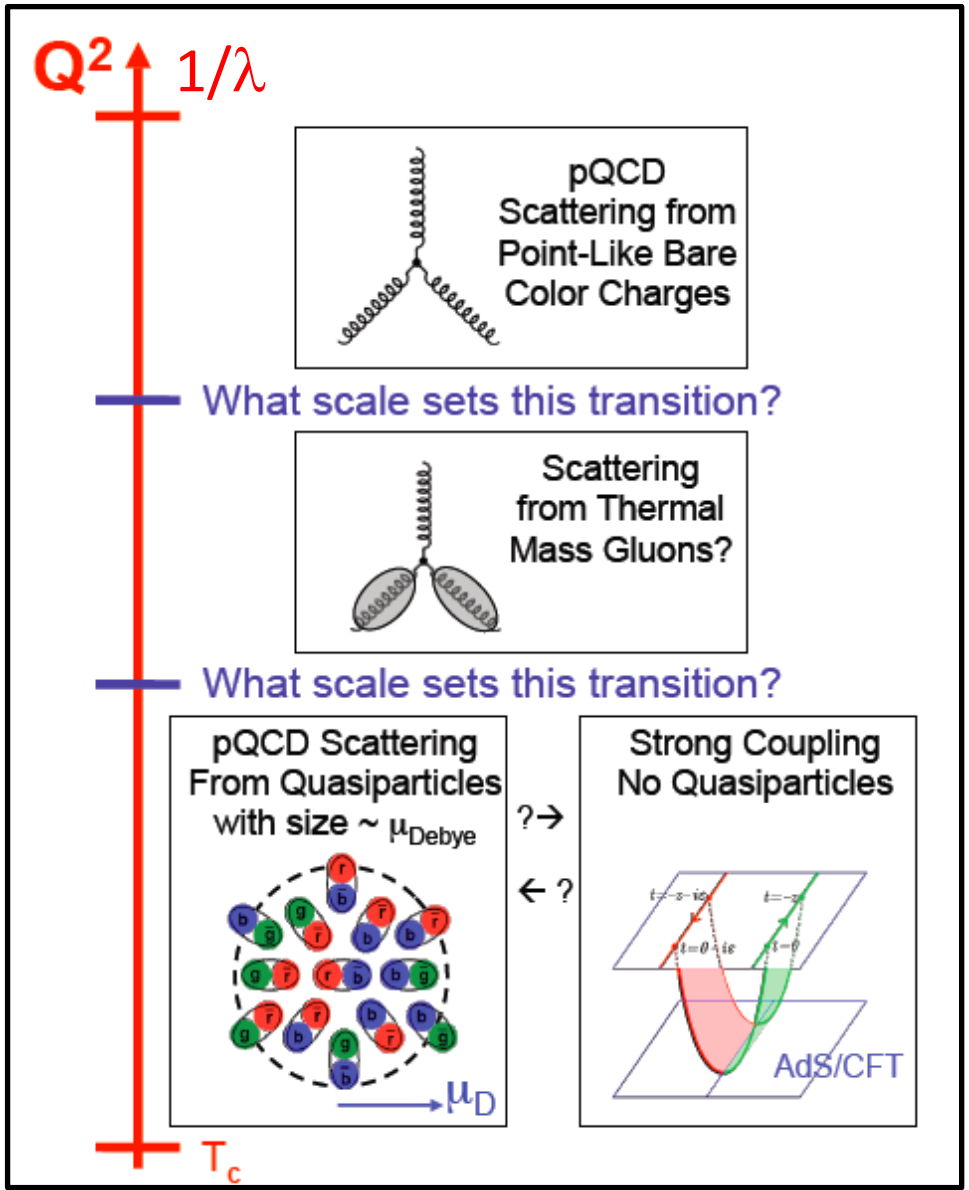
If things are not perturbatively describable, do we “jump into a black hole”?

As high energy quarks or quark-antiquark pairs traverse the QGP, what do they see?

Do the highest energy jets at LHC see point-like color charges?



Do the lowest energy jets at RHIC scatter from coherent fields or only excite sound waves?

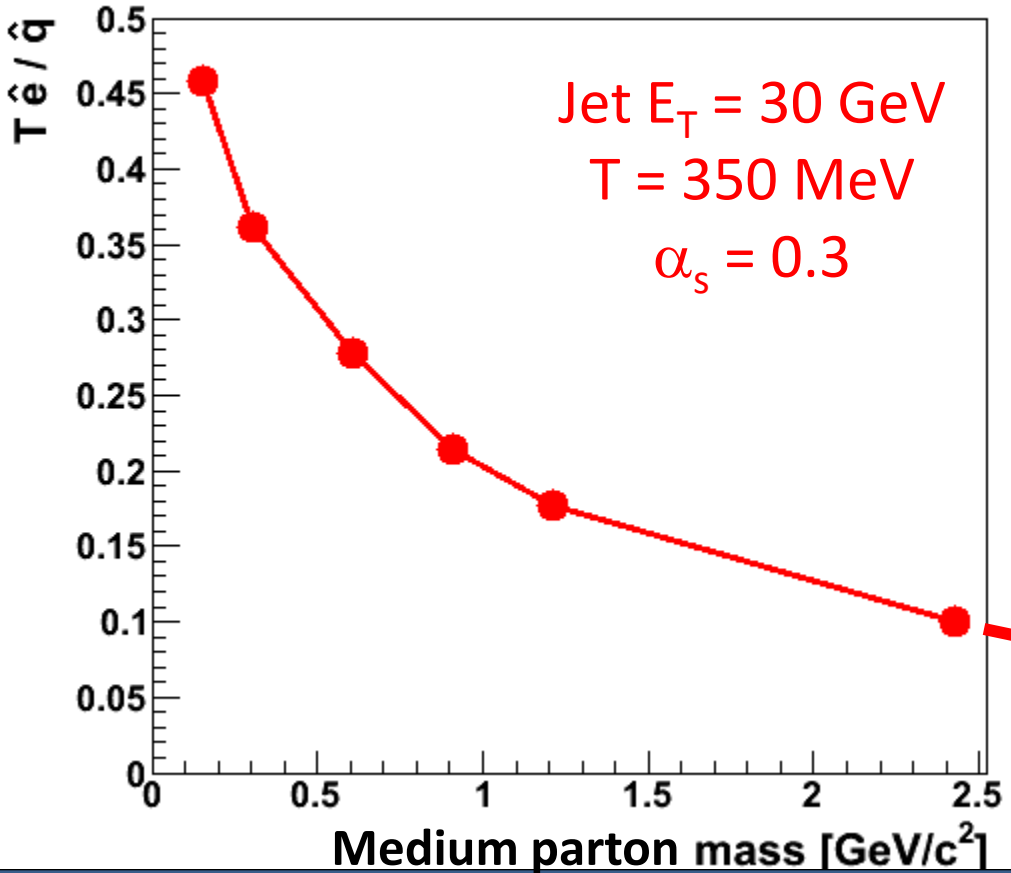


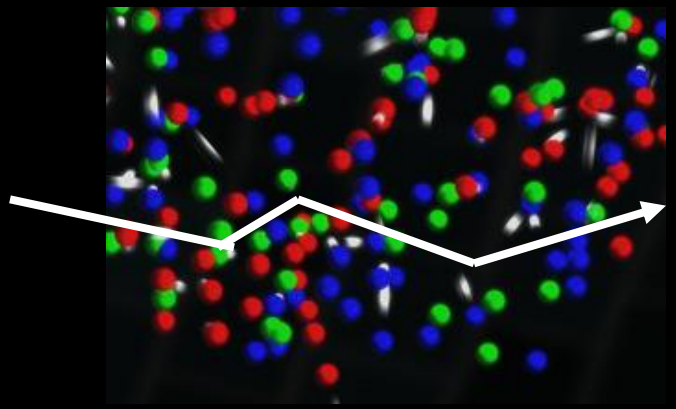
Constituent mass dependence of transport coefficients in a quark-gluon plasma

C. E. Coleman-Smith* and B. Müller
Department of Physics, Duke University, Durham, NC 27708-0305
(Dated: September 18, 2012)
http://arxiv.org/abs/arXiv:1209.3328

qhat → scattering of lead parton → radiation e-loss

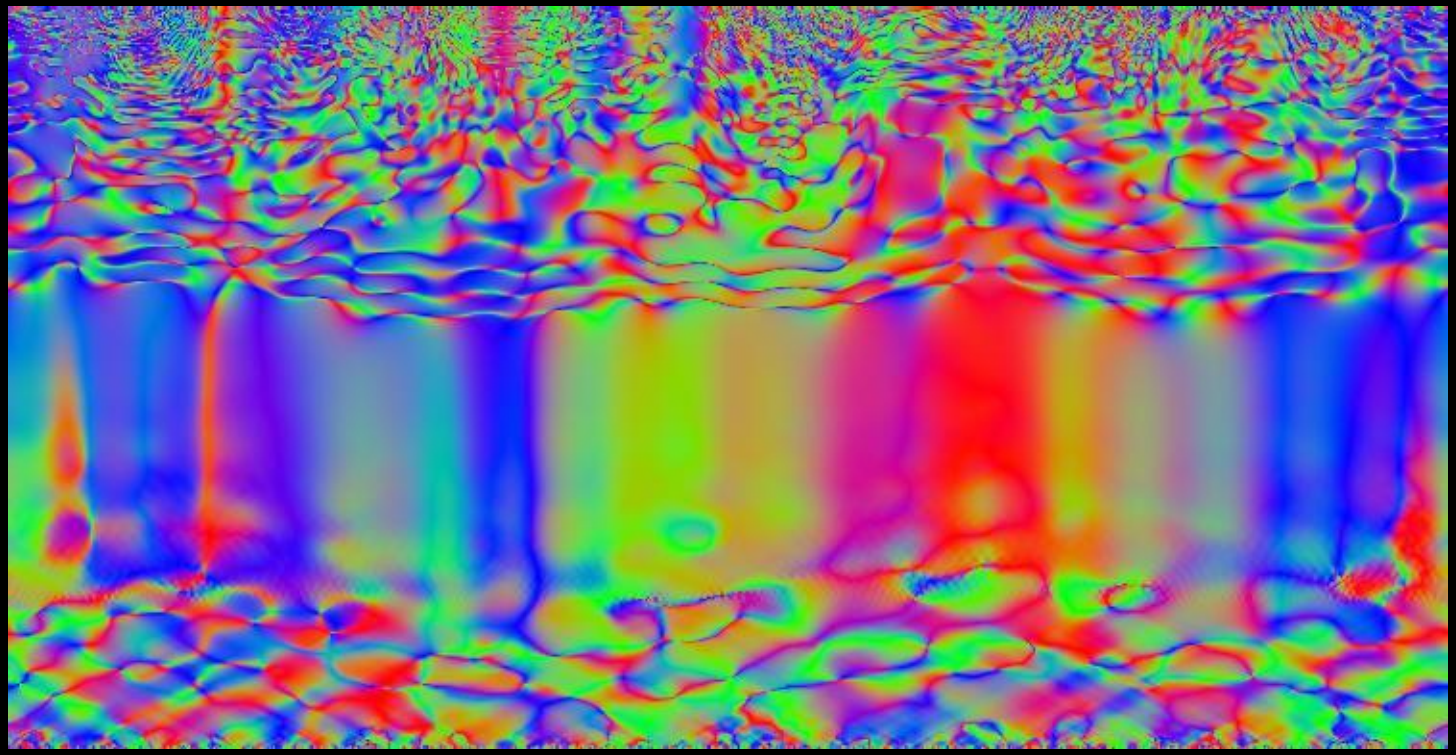
ehat → energy transferred to the QGP medium





Limit of infinitely massive scattering centers yields all radiative e-loss.

Is there experimental evidence for influence of strong Color E+M fields?



Is the perturbative qhat / ehat prescription appropriate at the earliest times?

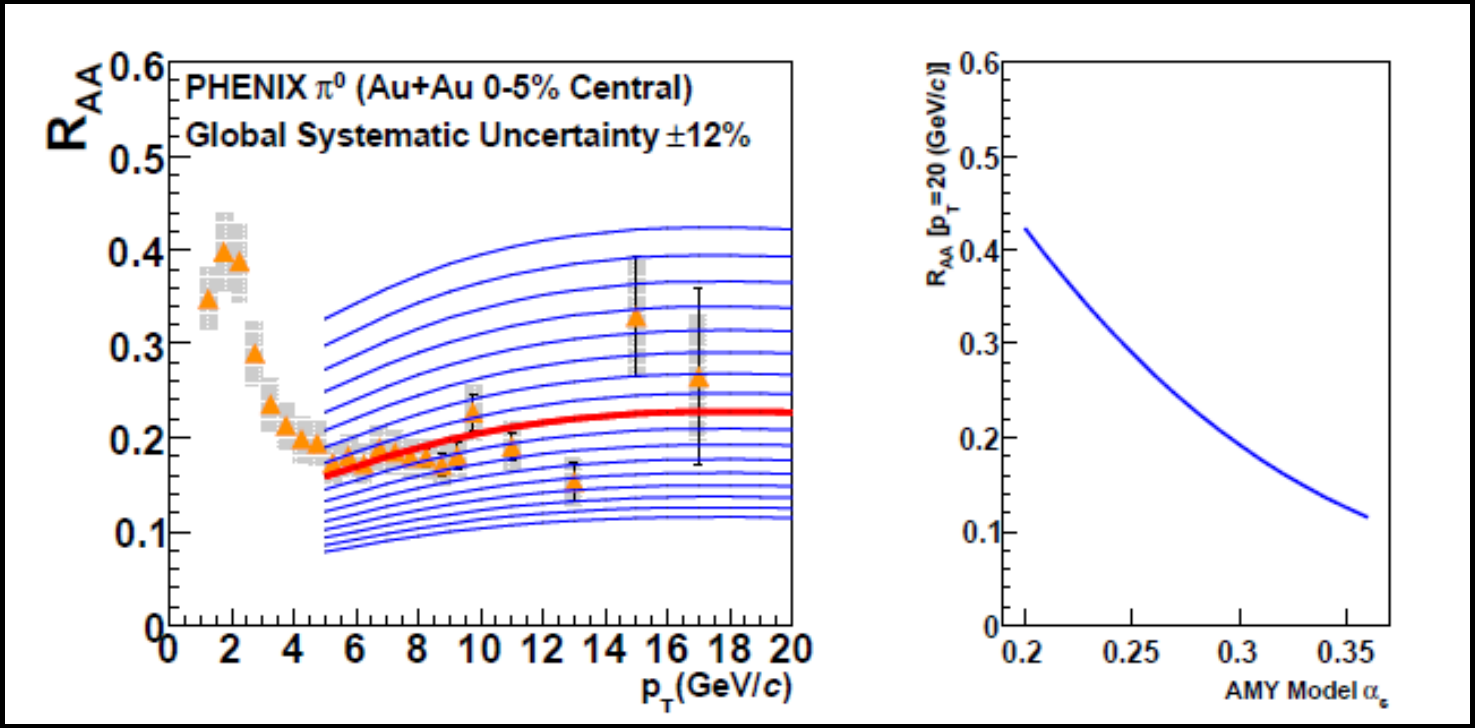
What is the influence of pre-equilibrium times?

How to connect these with experimental observables?

Qhat constraint… the past

Not the key observables, but pinning down the right picture

Very strong historical evidence for the power of energy reach of observables… (both up and down)

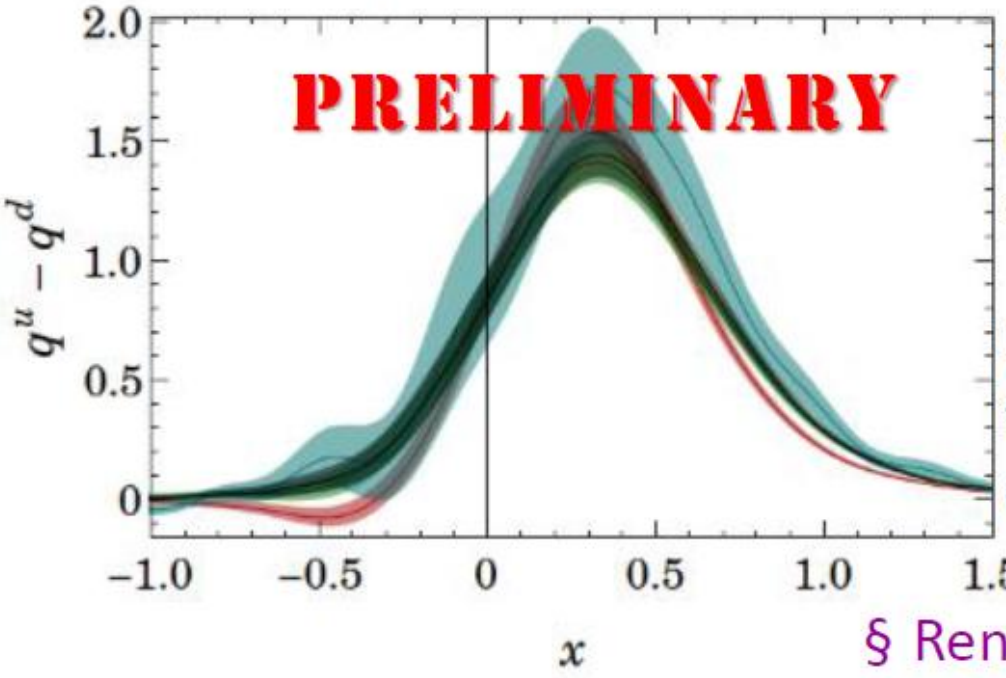


Lattice Revolution: Non-perturbative Connection

Quark Distribution

§ Exploratory study

- N_f= 2+1+1 clover/HISQ lattices
  $M_\pi \approx$ **310** MeV, $a \approx$ **0.12** fm ($L \approx$ 2.88 fm)
- Isovector only ("disconnected" contribution suppressed)



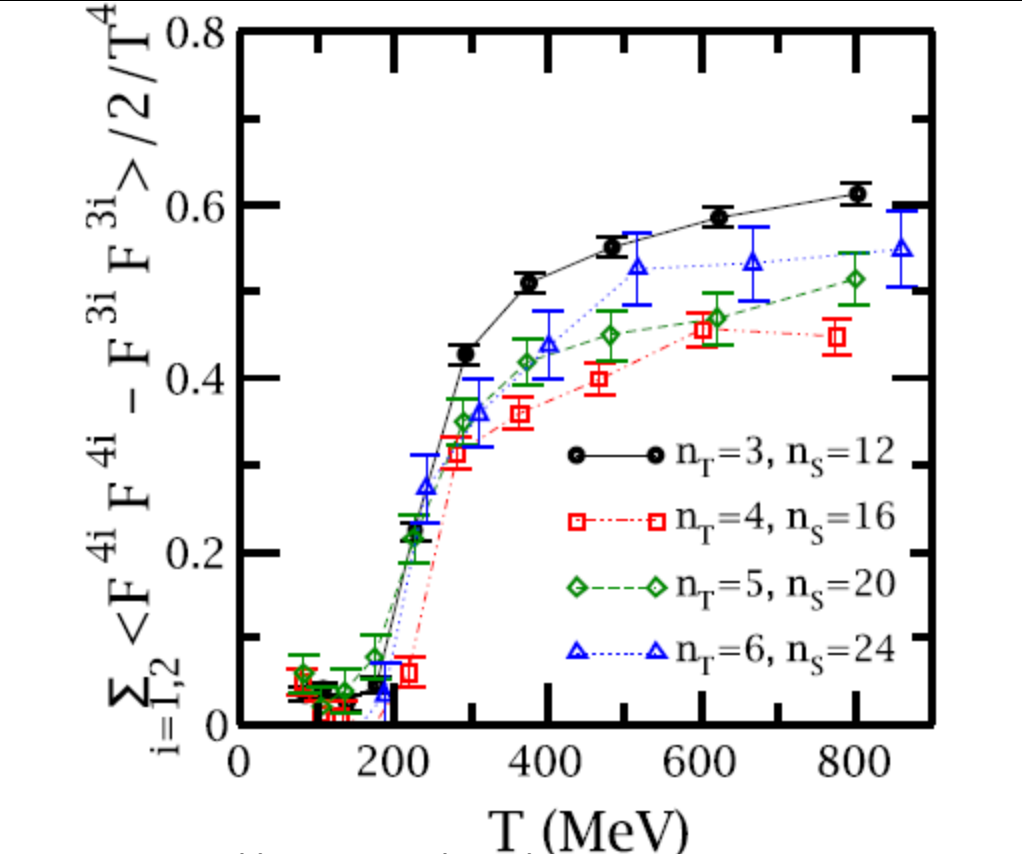
Corrected to $O(P_z^{-2})$
Gray band shows extrapolation of P_z^{-4} terms

No significant finite-momentum effect seen

§ Renormalization needed

Lattice Revolution: Non-perturbative Connection

→ Revolution in Jet Quenching Theory (?) ←

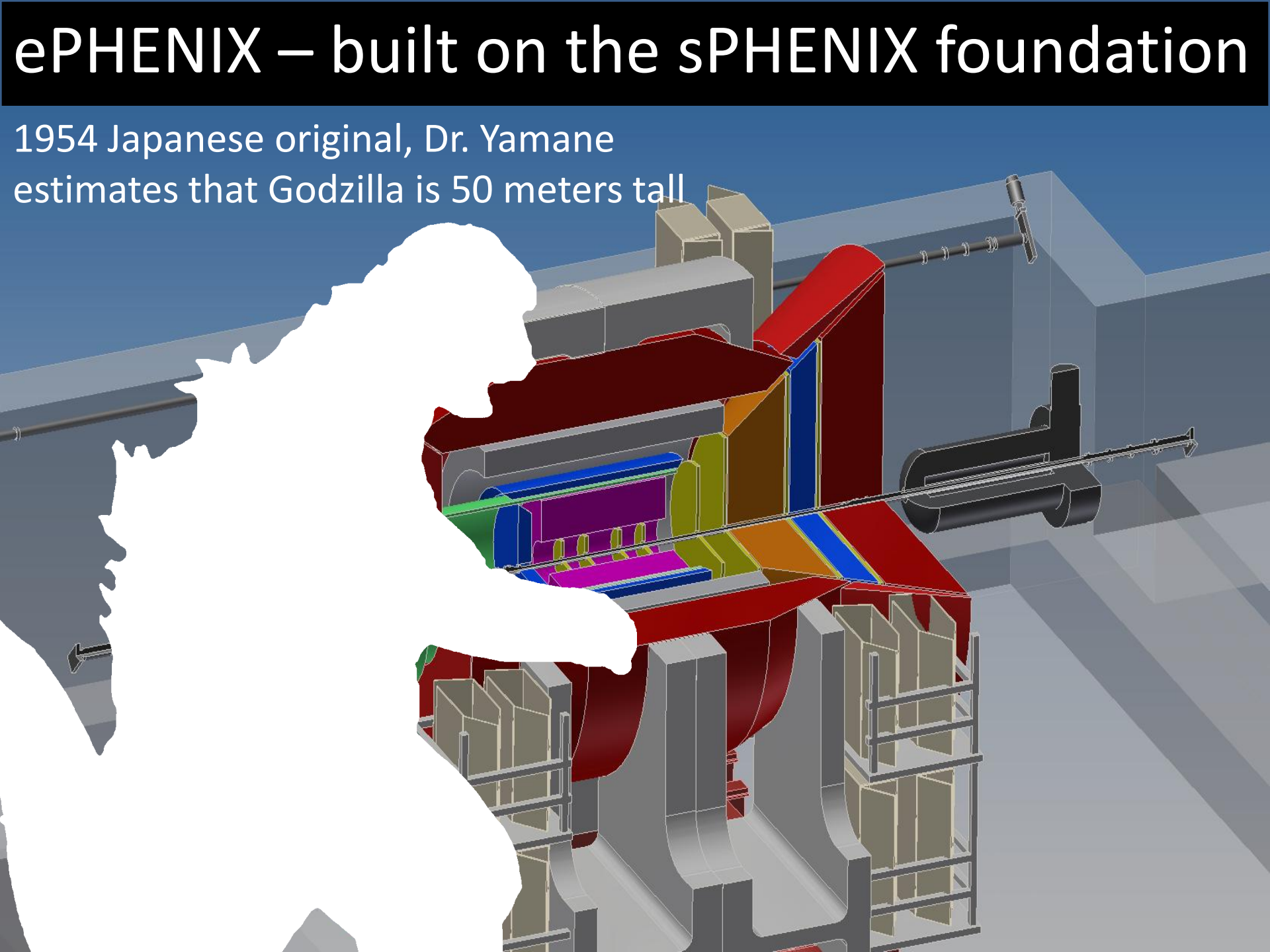


http://arxiv.org/abs/arXiv:1303.0318

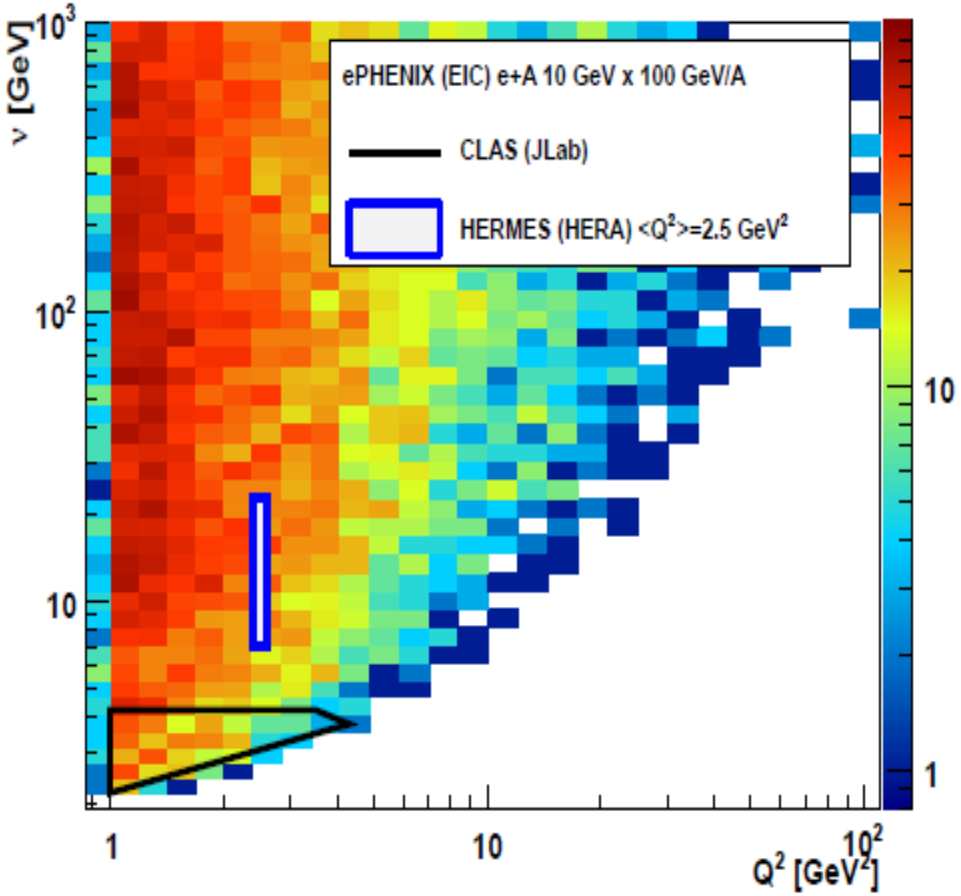
If they can calculate parton distribution functions and helicity distribution functions on the lattice in 10 years, what can be done for jet quenching observables?

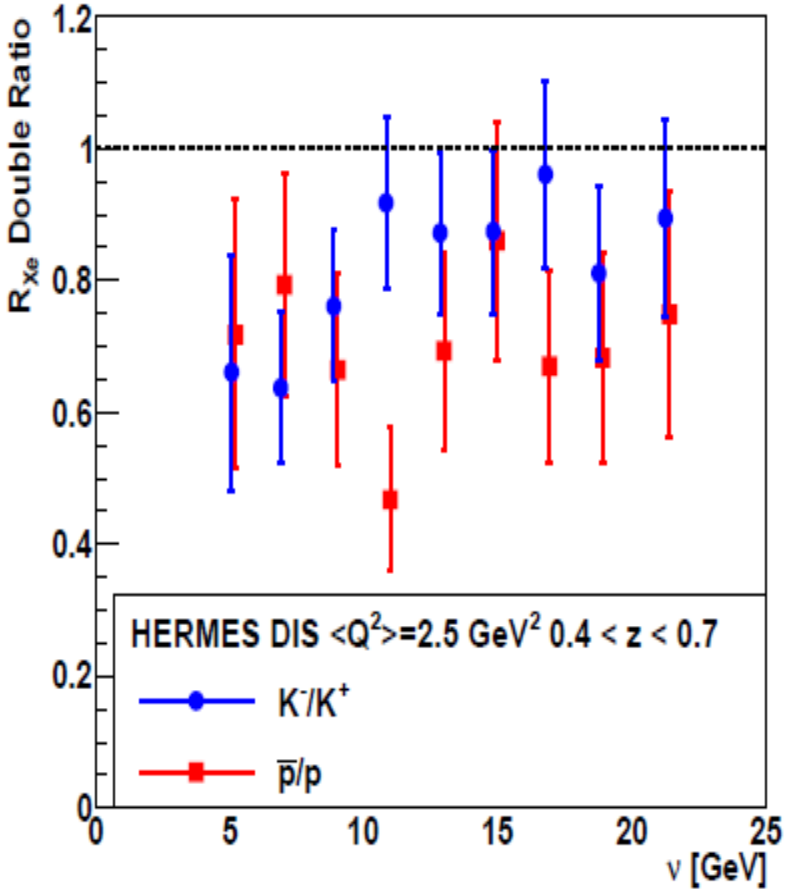
ePHENIX – built on the sPHENIX foundation

1954 Japanese original, Dr. Yamane estimates that Godzilla is 50 meters tall



ePHENIX DIS on heavy nuclei…. Large range in struck quark energy in nuclear rest frame and initial virtuality.

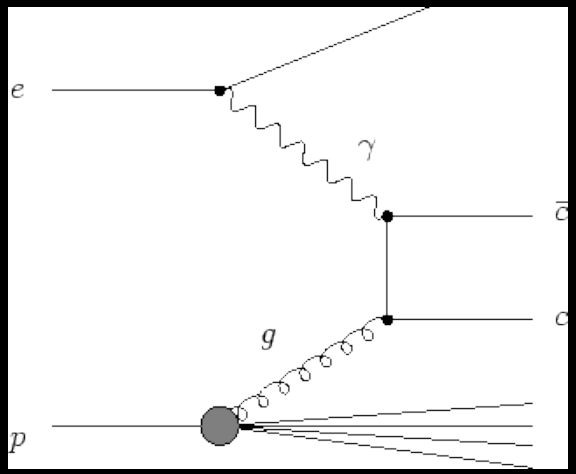


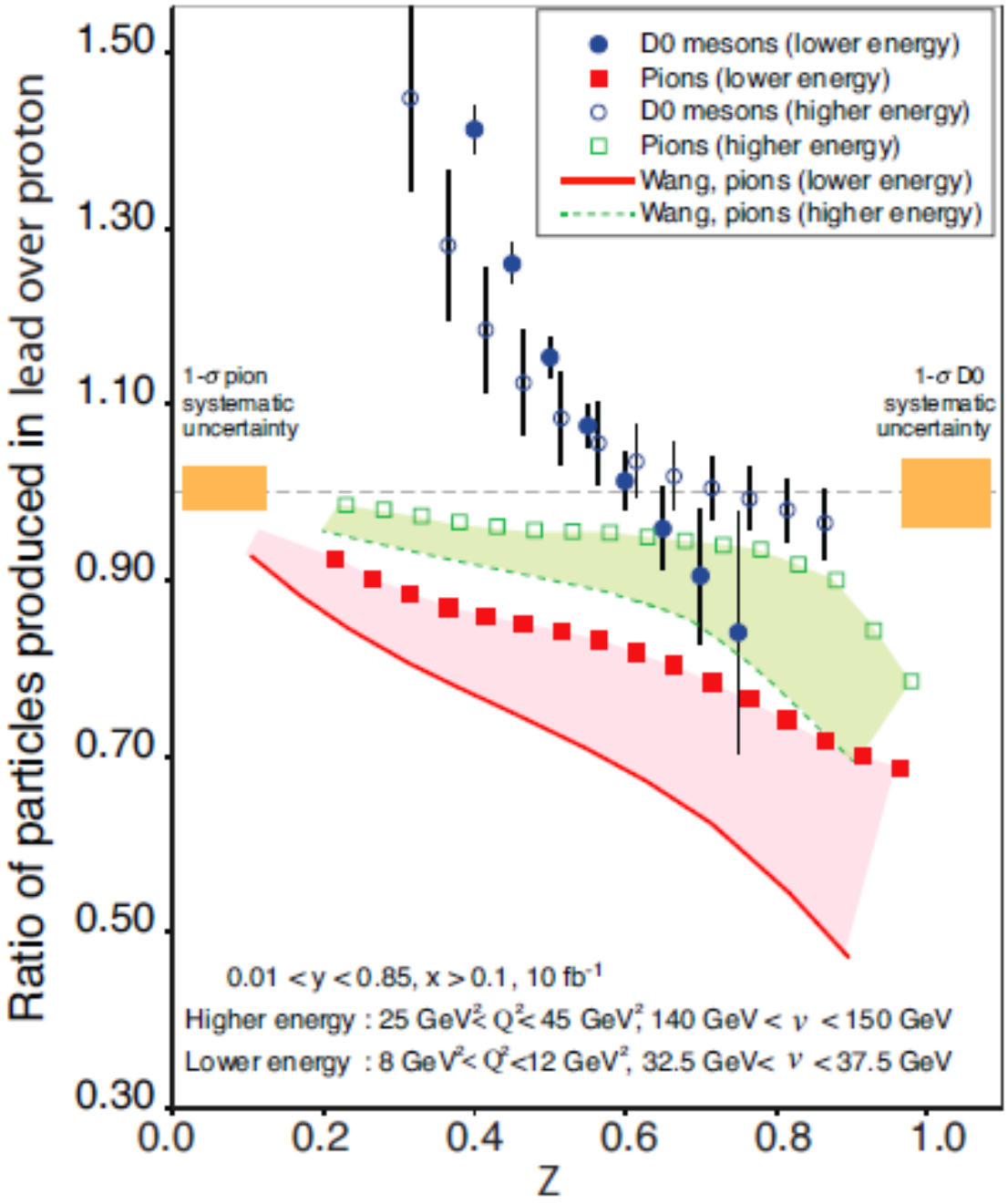


Good to see virtuality evolution plot and prediction

Calculation done as if scattering off intrinsic charm, so that scattered electron gives ν, denominator for z.

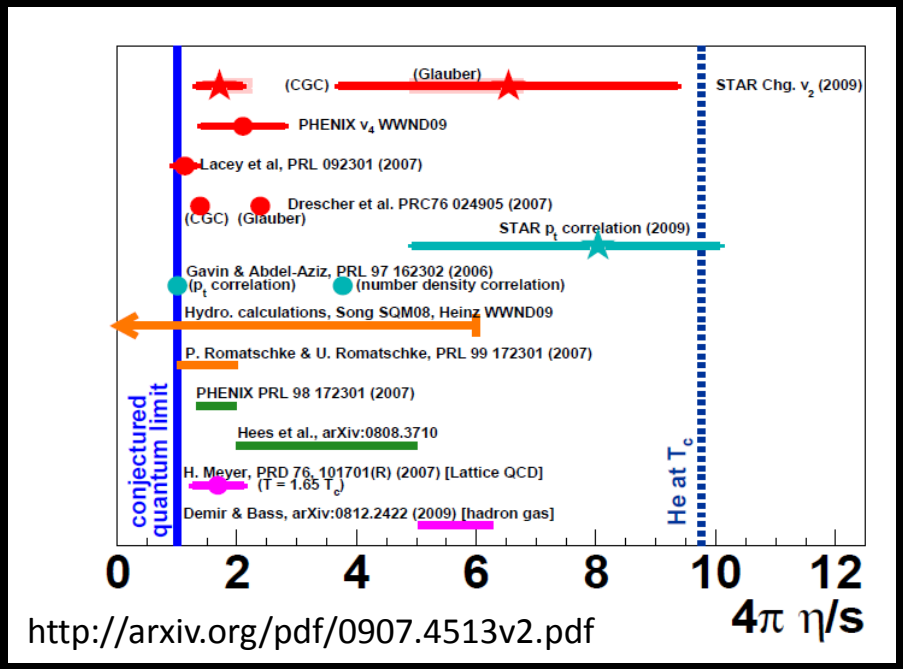
Broken with photon-gluon fusion. Is that still worth measuring?



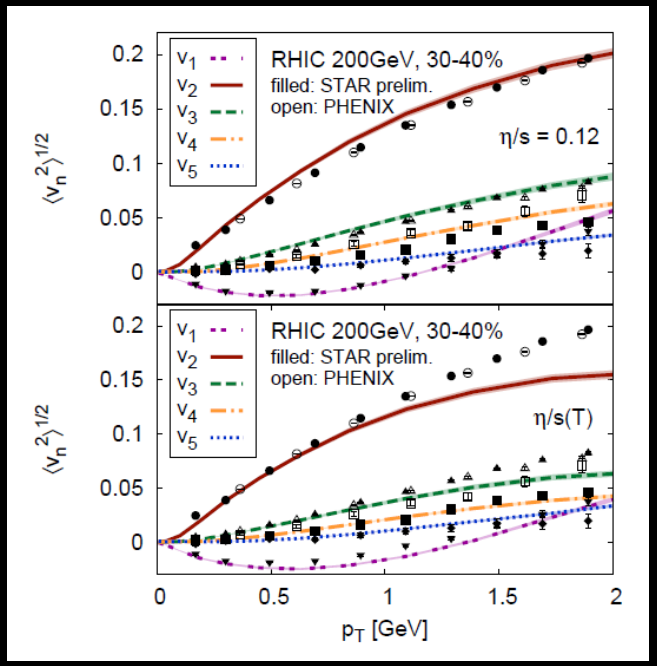


Two action items:

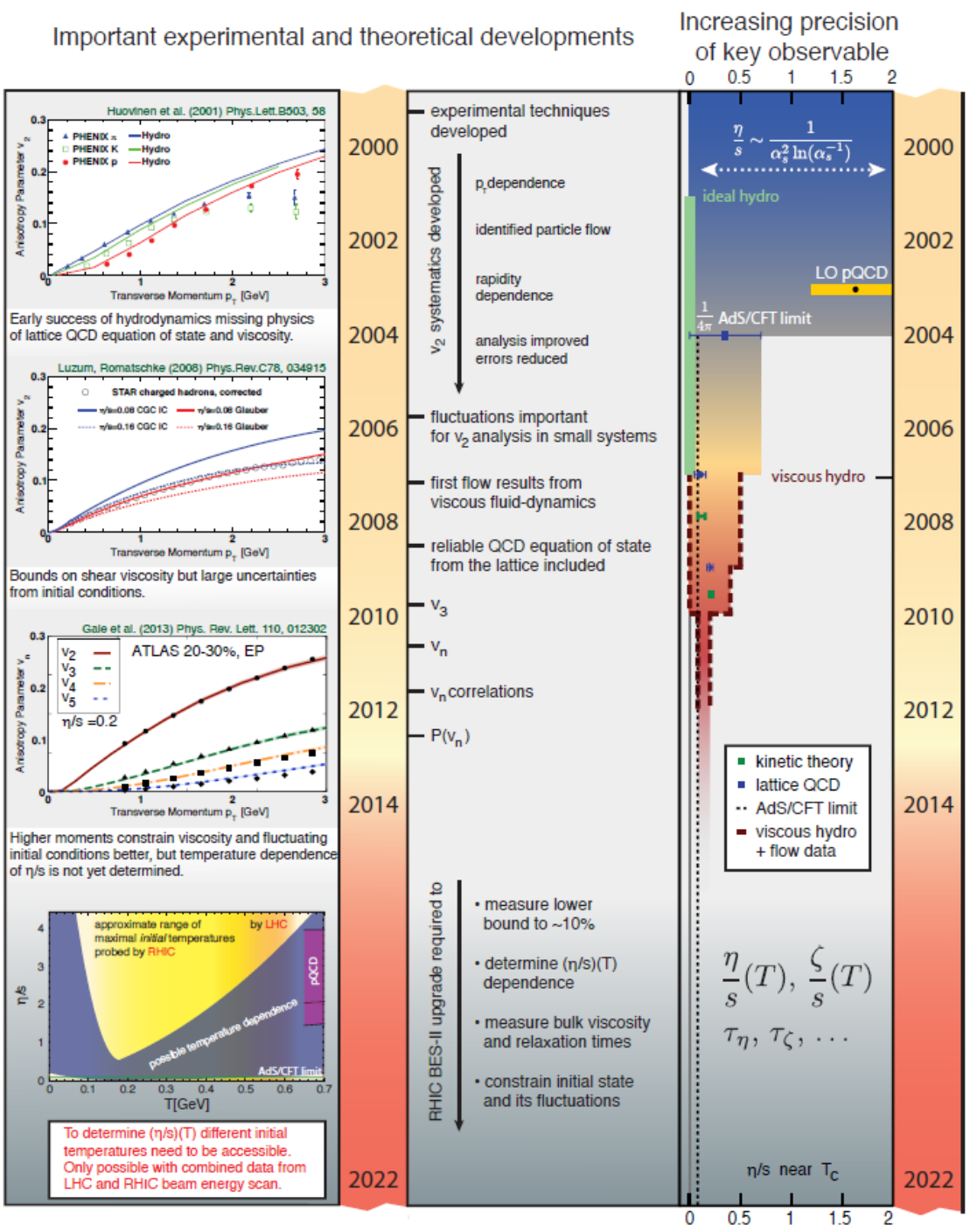
1. Write some text regarding analogy of theory on h/s (factor of 10 differences in 2009). Theory advances, higher moments, ruling out some pictures…



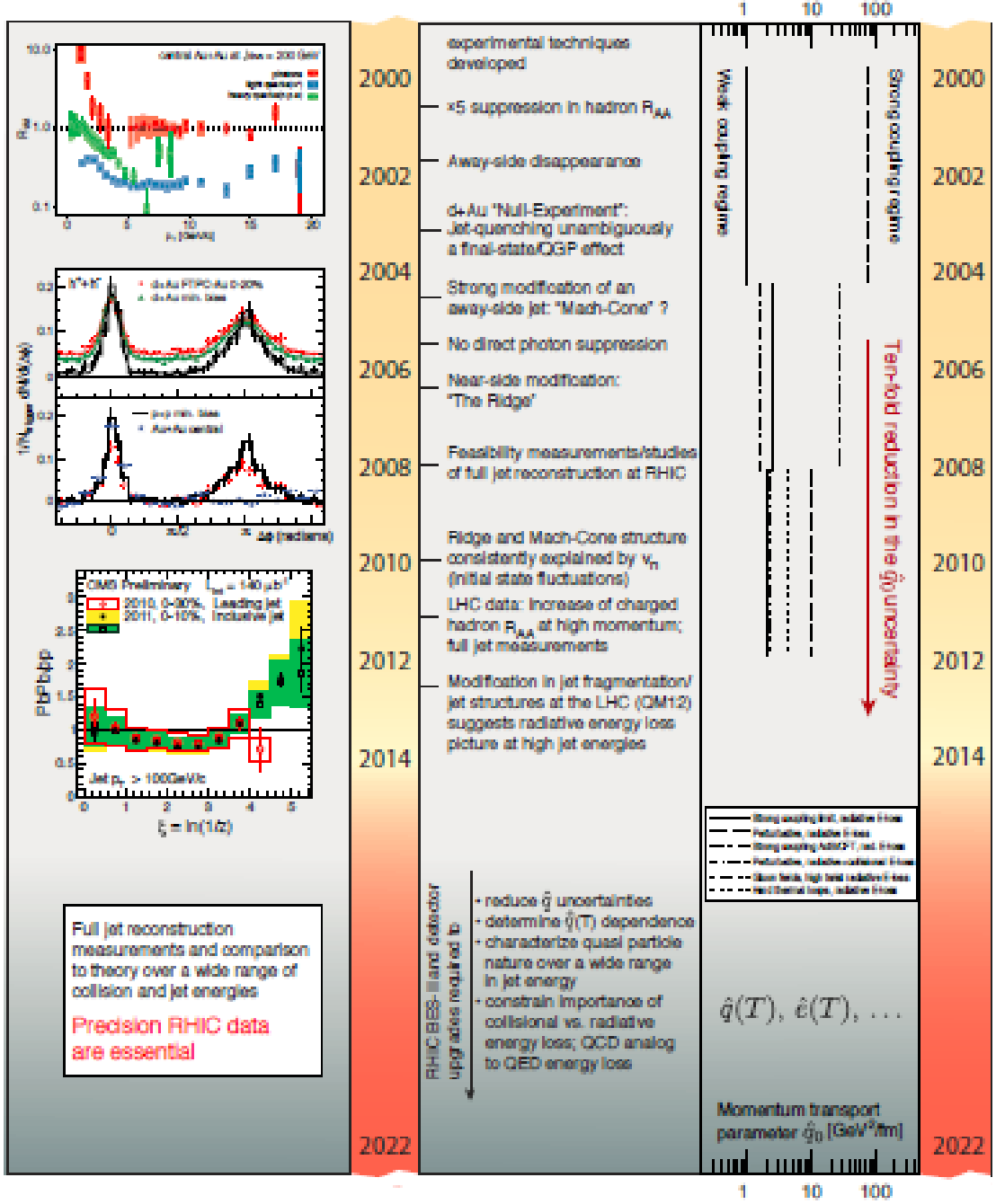
http://arxiv.org/pdf/0907.4513v2.pdf



Now η/s pinned down to < ±50%, thus indicating the tools exist to attack the temperature dependence and more



Reasonable Representation…



Perhaps a version of Xin-Nian's figure with a larger box from 5 years ago and today would be a good proximity…

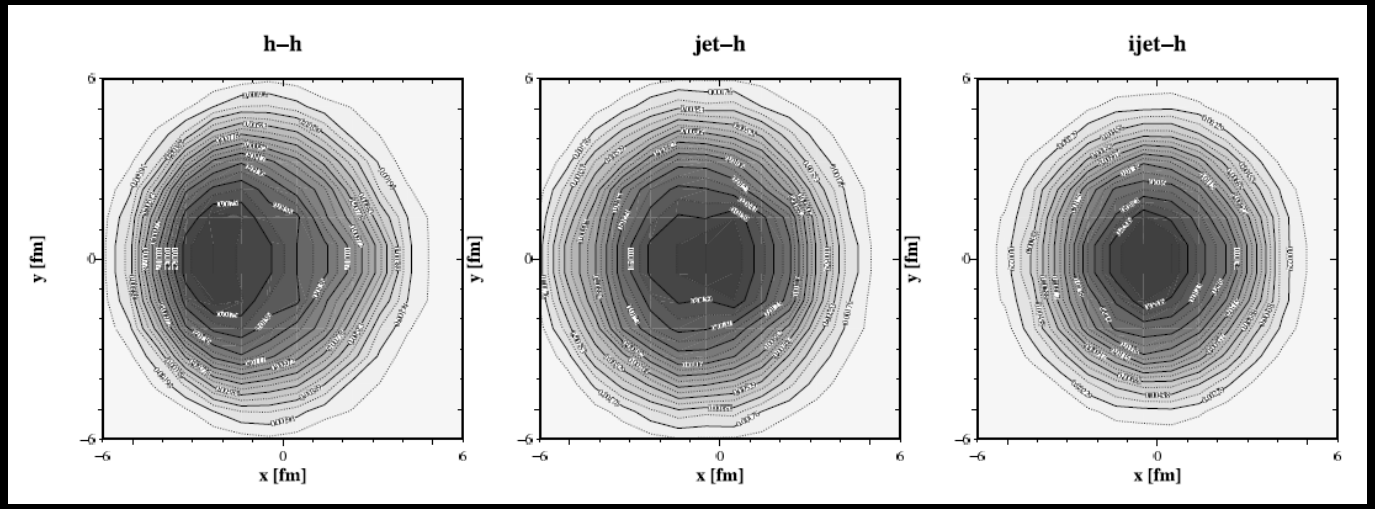
Then argue that progress for tools to go to the next step… Can we attach evolution, m_D, scattering from ?

2. Read Thorsten's paper and get his code…

Biased Showers — a common conceptual Framework for the Interpretation of High P_T Observables in Heavy-Ion Collisions

Thorsten Renk*
Department of Physics, P.O. Box 35, FI-40014 University of Jyväskylä, Finland and Helsinki Institute of Physics, P.O. Box 64, FI-00014 University of Helsinki, Finland

Try thinking through connecting sPHENIX capabilities / statistics with these different "bias is good" observables…



sPHENIX can dial the range between these extremes…
And sPHENIX has discovered color plots!

Summary

sPHENIX will have unprecedented
RHIC measurement capabilities

Very strong argument for key insights with
large collision energy span combined with LHC
(almost 100% parallel in previous examples)

How to gain fundamental new insights
from these hard probes?

How to translate that into precision constraints?

Open for discussion…

Extras…

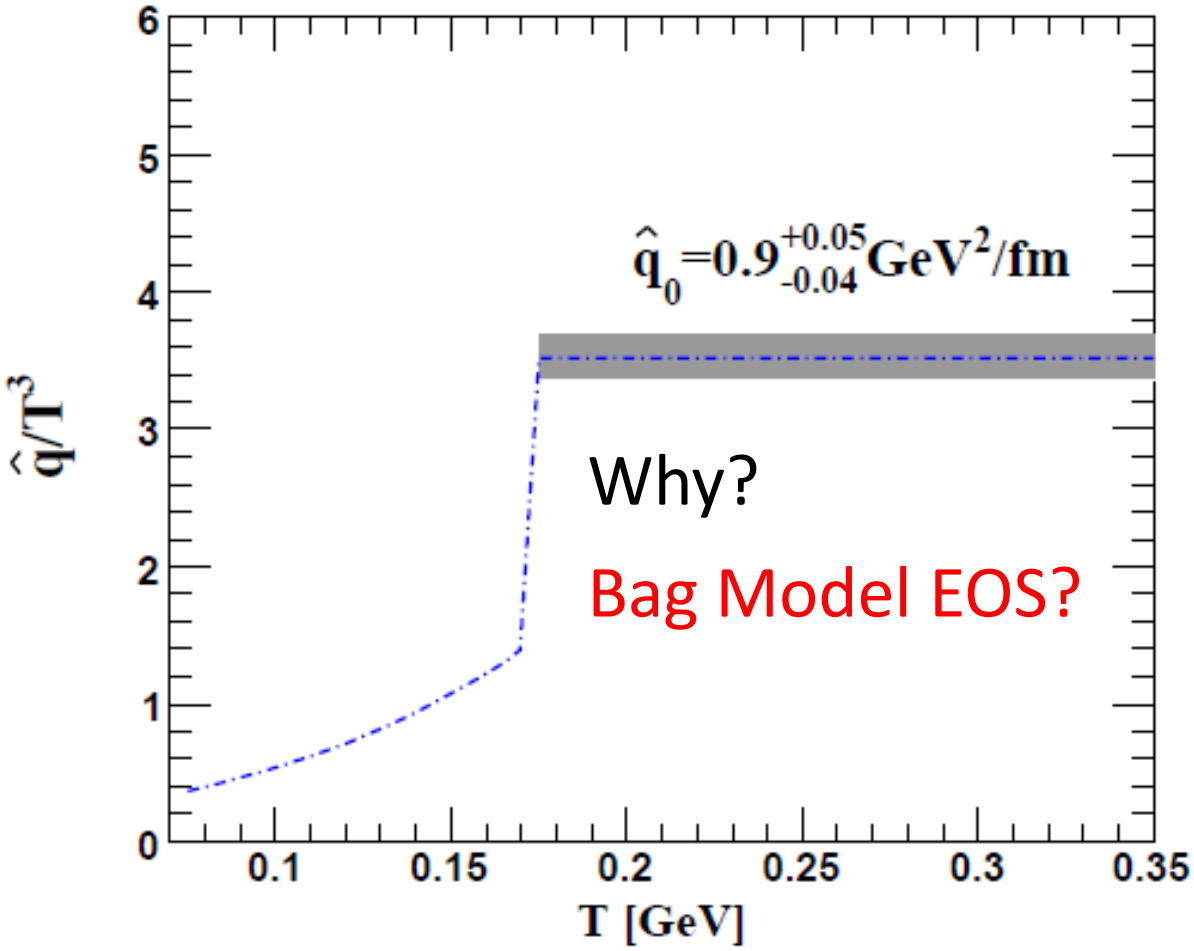
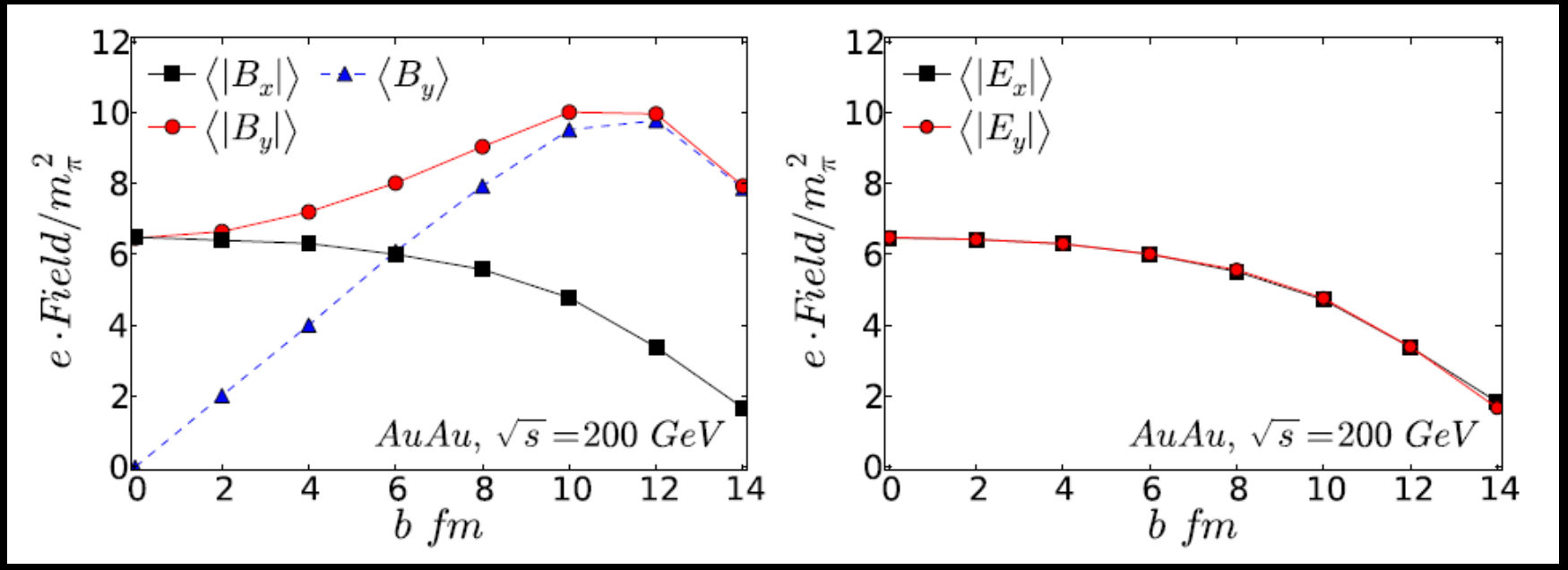
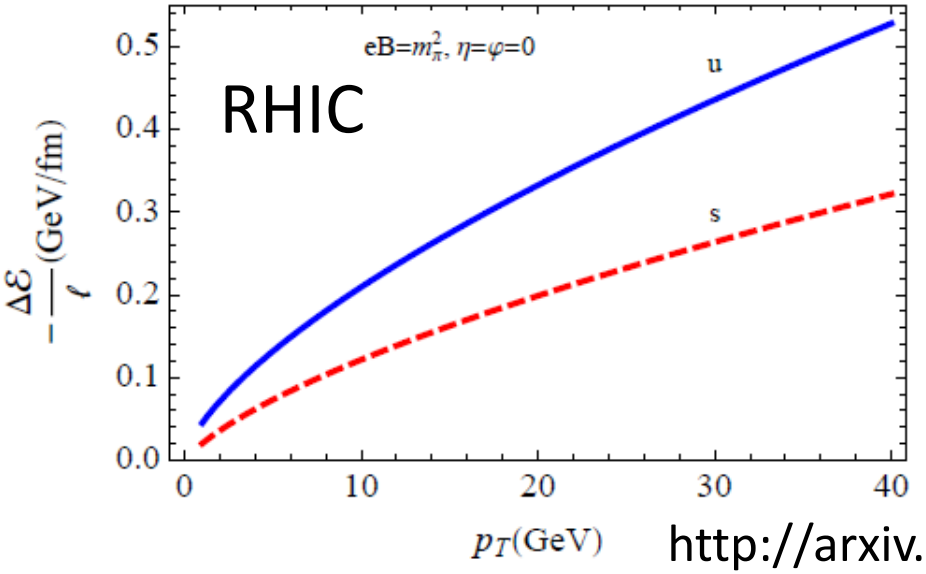


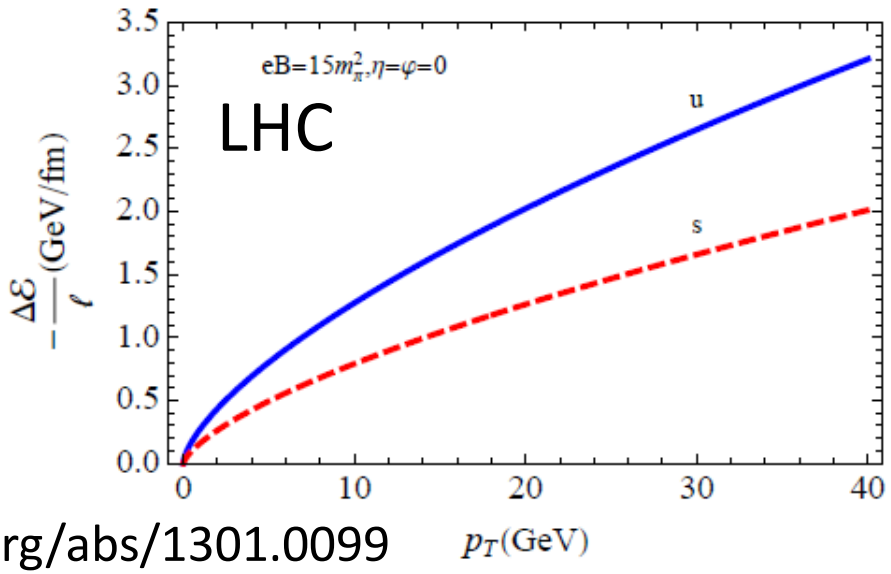
FIG. 3: The temperature dependence of $\hat{q}/T^3$.

http://arxiv.org/abs/arXiv:1002.1165

Is there experimental evidence for influence of strong E+M fields?







http://arxiv.org/abs/1301.0099