Selected highlights from RHIC

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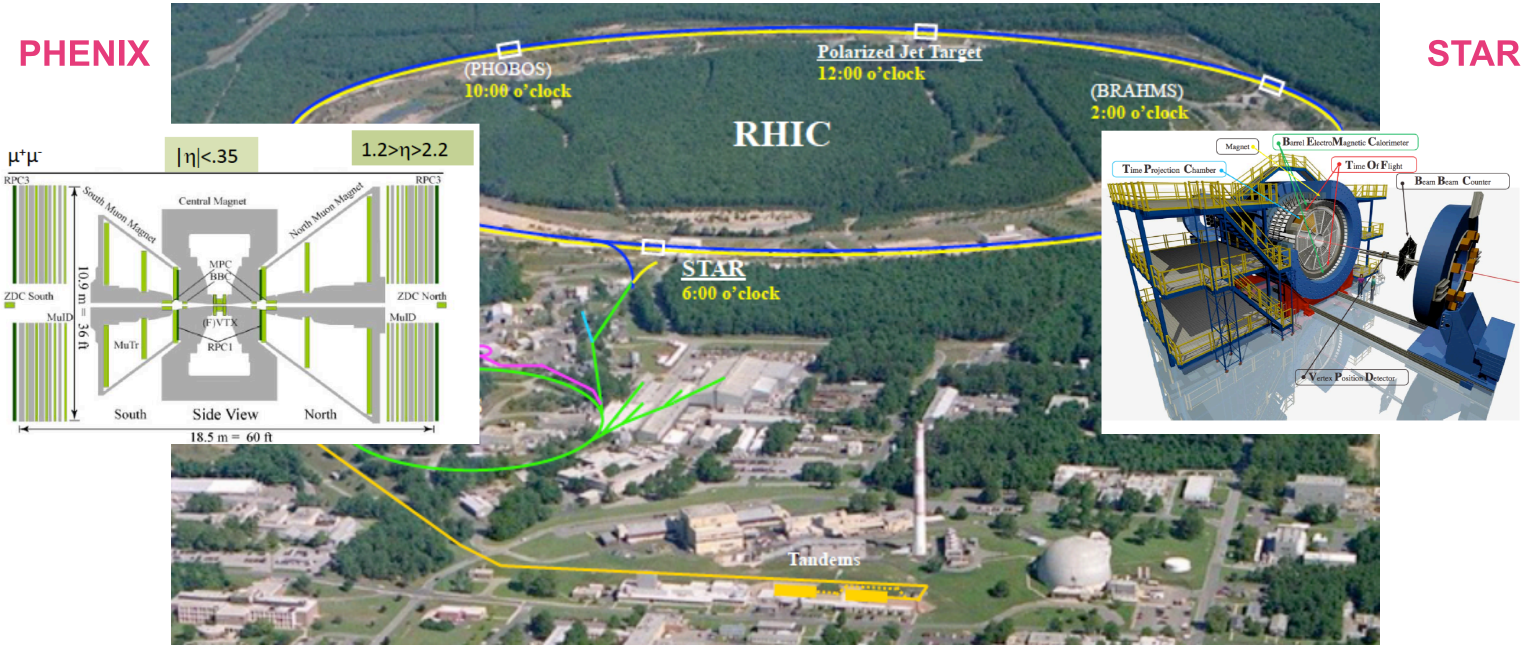
SUBATECH and University of Nantes, France

QGP-France workshop

Etretat, France, 15-18 September 2014

PHENIX

STAR



Outline

I Introduction

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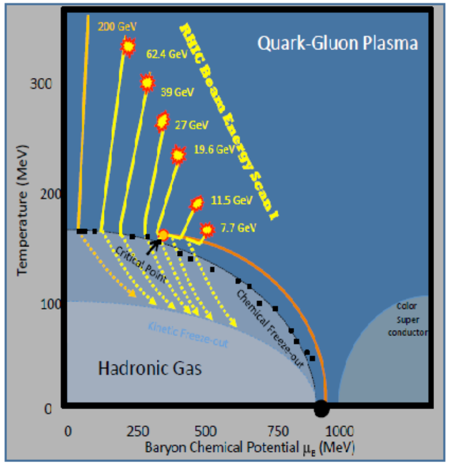
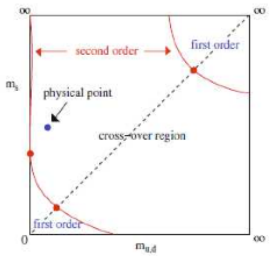
The QCD phase transition

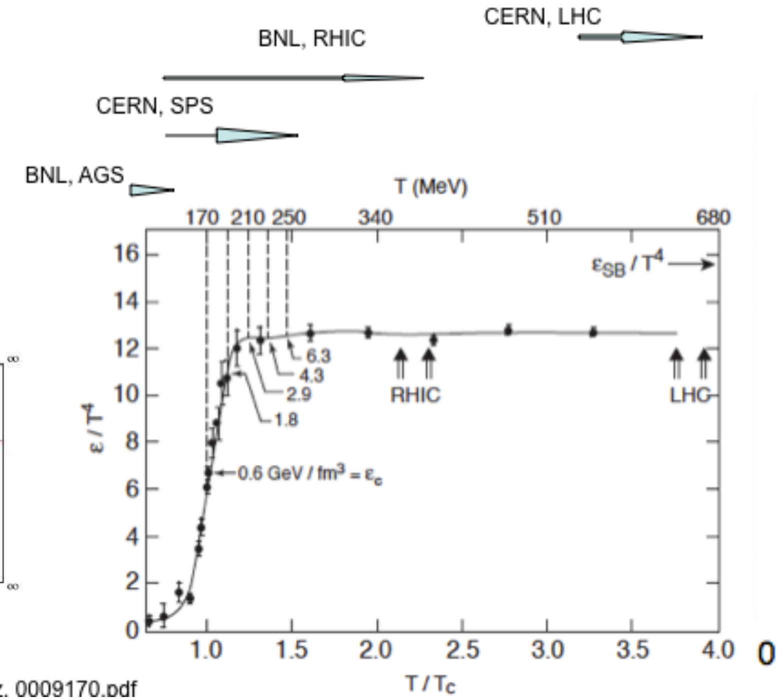
QCD on the lattice predicts a cross over from hadronic to partonic matter at zero net baryon density with critical temperature Tc~154+-9 MeV (2014), critical energy density ~0.6 GeV/fm^3

(Nuclear Density: rho=0.15 GeV/fm^3
Density inside Nucleon: rho=0.5 GeV/fm^3)



Zero net baryon density





U. Heinz. 0009170.pdf

Beam Energy Scan at RHIC:

*** Search for onset of QGP signatures**

*** Search for signals of the phase boundary**

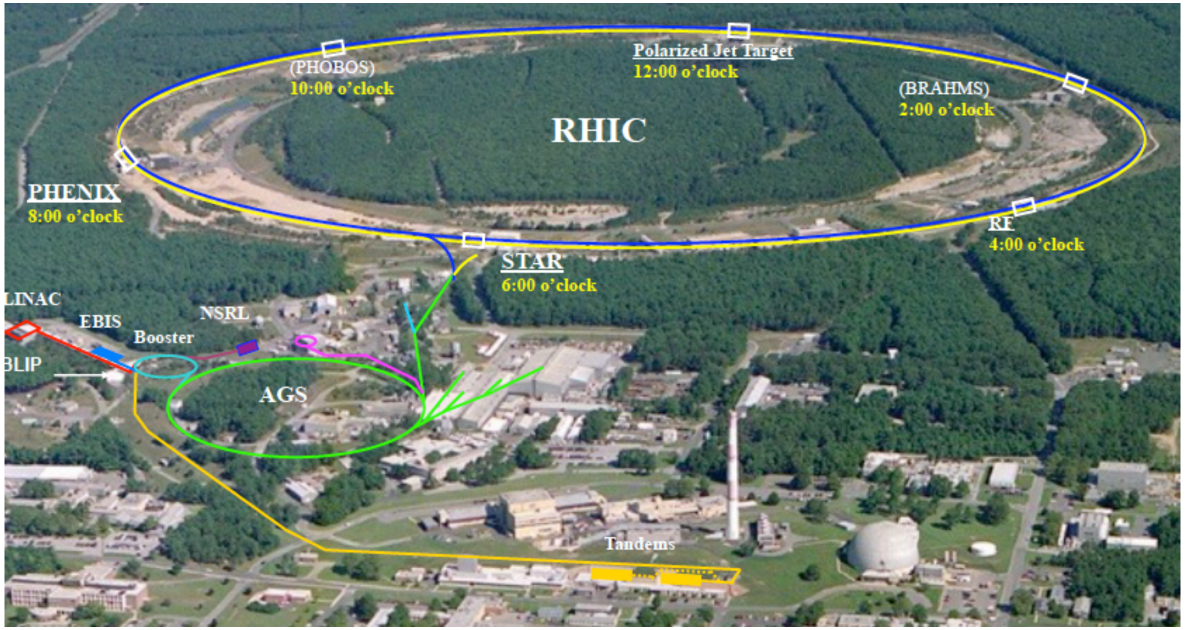
*** Search for the QCD critical point**

A cross over is expected for the physical point (for the physical u,d,s masses).

II Detectors and RHIC

Relativistic Heavy Ion Collider

at the Brookhaven Lab, Long Island, New York, USA



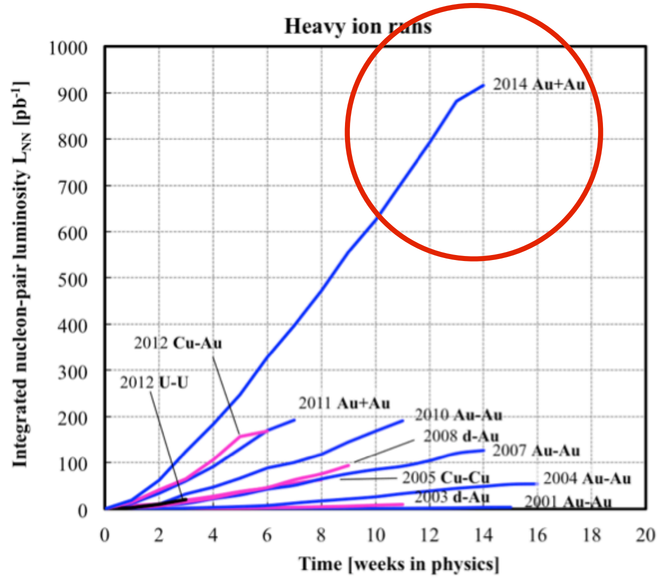
RHIC has been exploring nuclear matter at extreme conditions over the last decade 2000-2011

4 experiments:
STAR PHENIX
BRAHMS PHOBOS

Colliding systems:
p+p, d+Au, Cu+Cu, Au+Au
Cu+Au, U+U
Energies A+A :
$\sqrt{s_{NN}}$ = 62, 130, 200 GeV
and low energy scan
7.7, 11.5, 19.6, 22.4, 27, 39 GeV

RHIC news

Run 14: A+A with new longitudinal stochastic cooling pick-ups and kickers -> large enhancement in luminosity



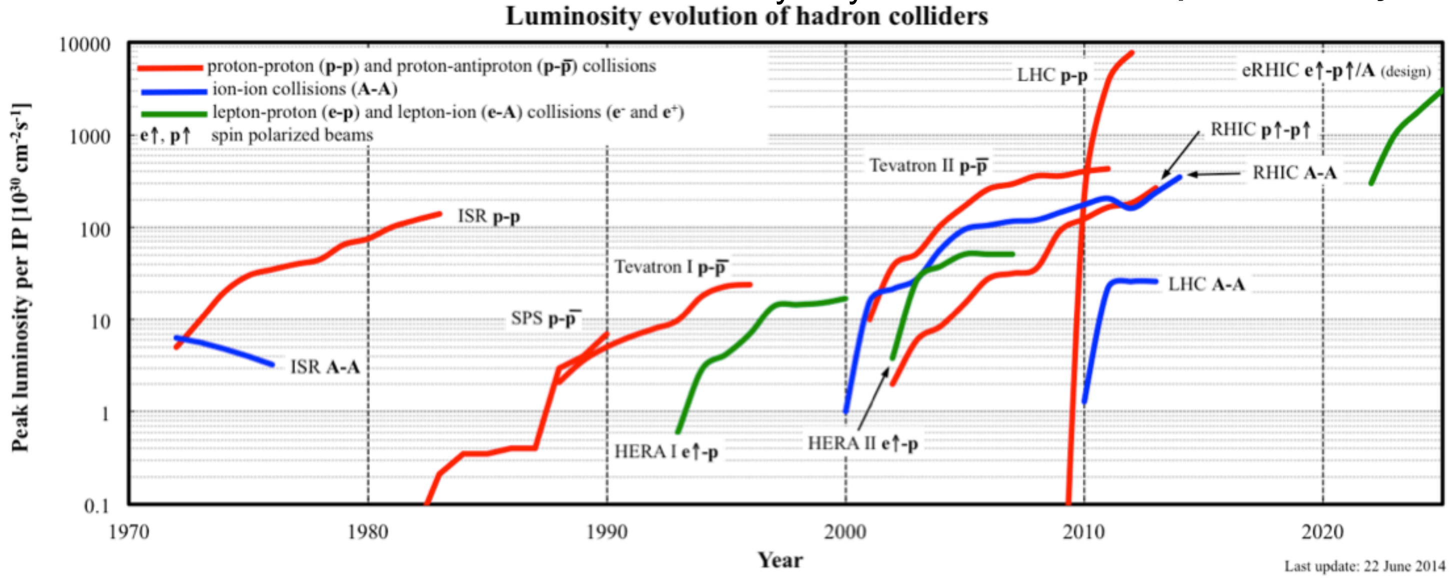
Nucleon pair luminosity L_{NN} for A+A

Data taking:

*** ^3He + Au, 103.9 GeV/nucleon +100 GeV/nucleon**
*** Au +Au, 100 GeV+100 GeV (~ 13 weeks)**
*** Au + Au, 7.3 GeV/nucleon +7.3 GeV/nucleon**

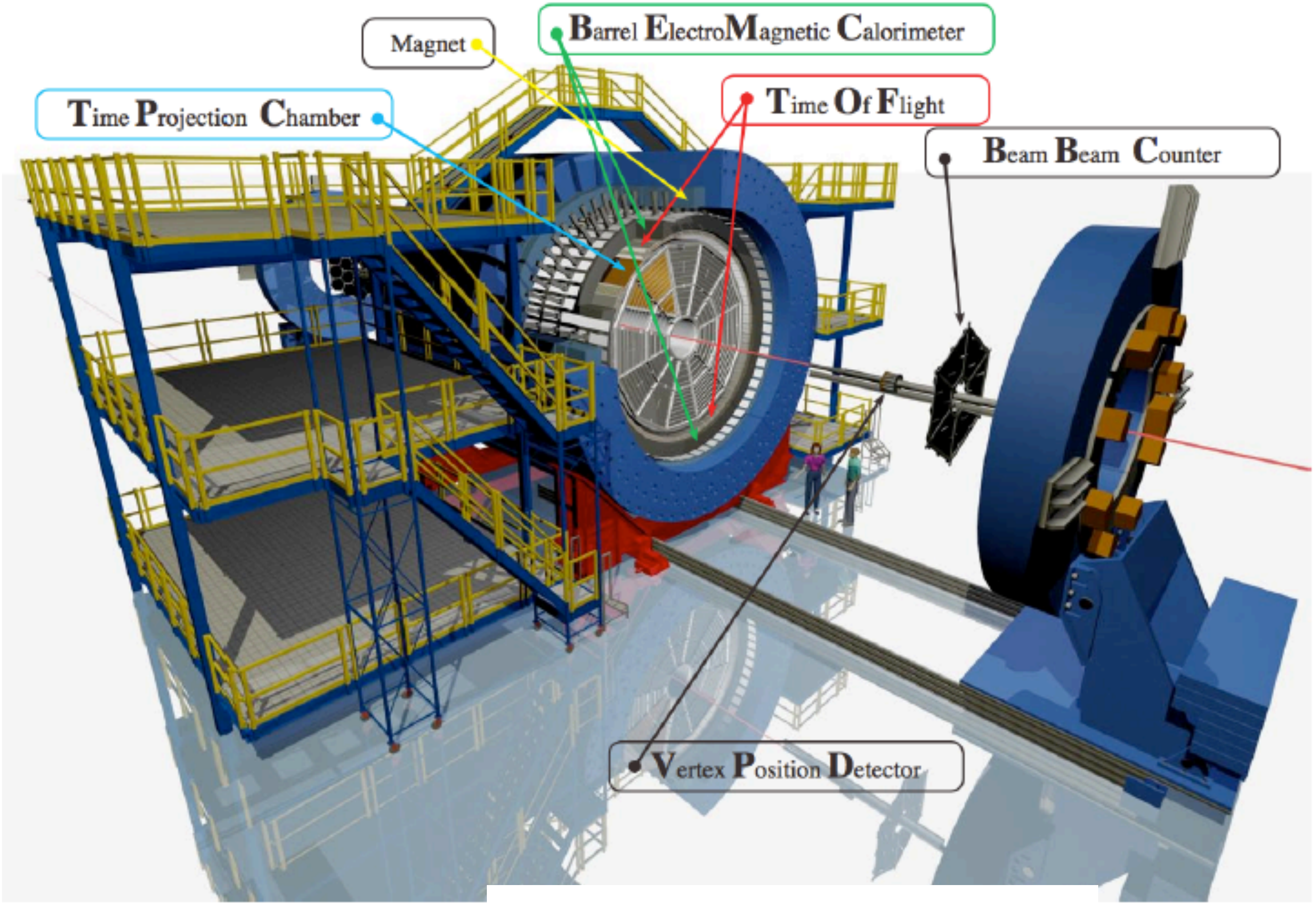
Total delivered integrated luminosity for Au+Au 100+100 GeV/nucleon:
STAR: 21.5 nb-1 (4.5xrun-11)
PHENIX: 23.6 nb-1 (4.7xrun-11)

Peak luminosity vs year



Note: For ion collisions the nucleon-pair luminosity is shown. The nucleon-pair luminosity is defined as $L_{NN} = A_1 A_2 L$, where L is the luminosity, and A_1 and A_2 are the number of nucleons of the ions in the two beam respectively. The highest energies for the machines are: ISR 31 GeV, SPS 315 GeV, Tevatron 980 GeV, HERA 920 GeV (p) 27.5 GeV (e), RHIC 255 GeV, LHC 4.0 TeV.

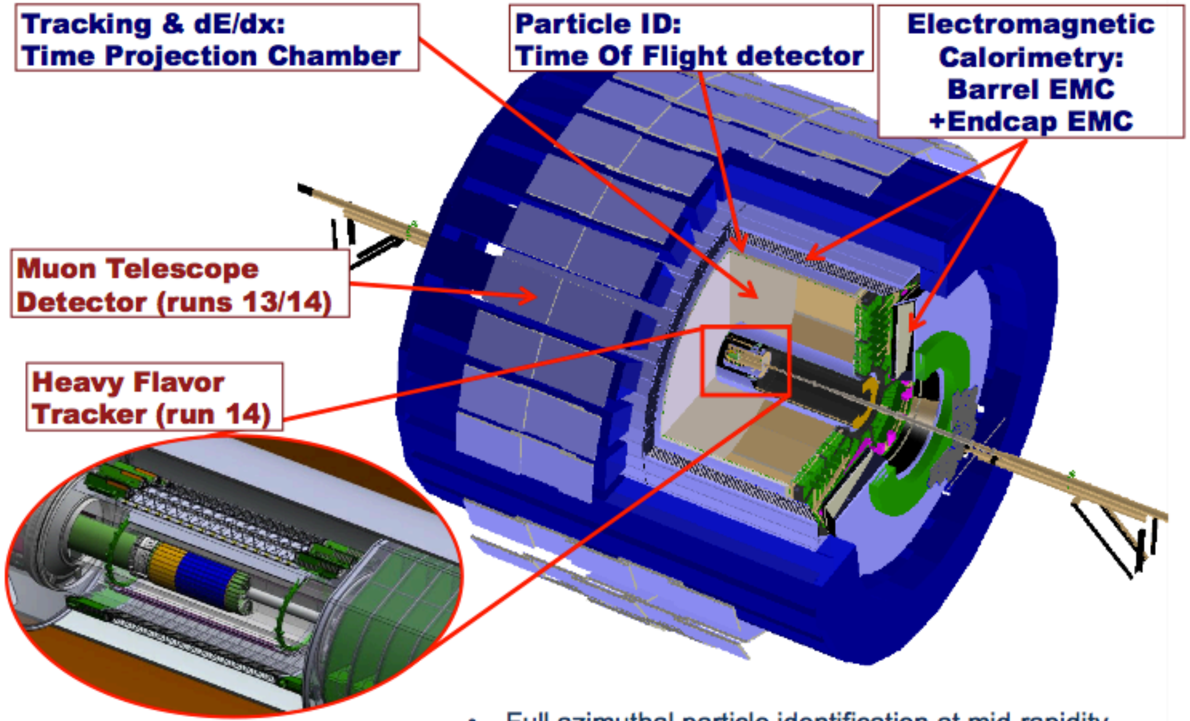
STAR: Solenoidal Tracker At RHIC



Particle identification mainly via
- de/dx in the TPC
- topological decay reconstruction in TPC for strange particles and D mesons
- TOF
- Barrel EMCal (used also as fast online trigger)

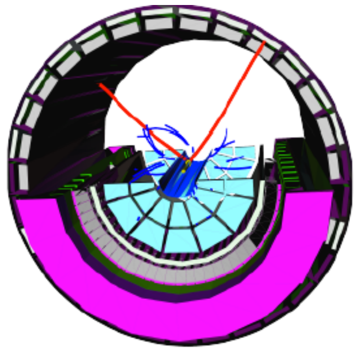
$$-1 < \eta < 1, 0 < \phi < 2\pi$$

News from STAR detector



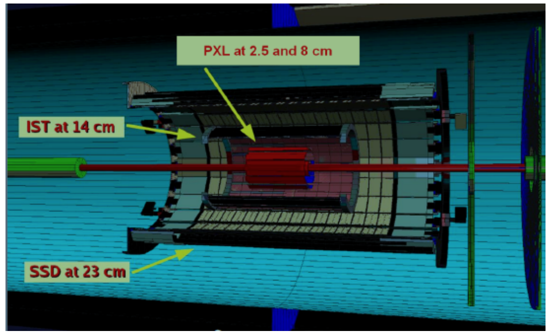
- Full azimuthal particle identification at mid-rapidity

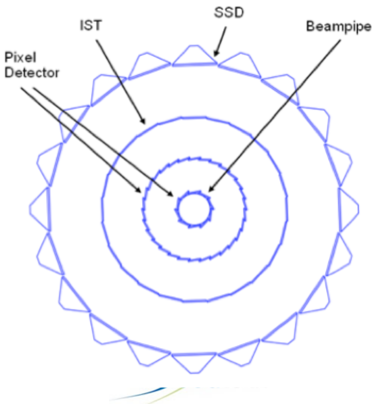
MTD



J/Psi event in p+p 500 GeV

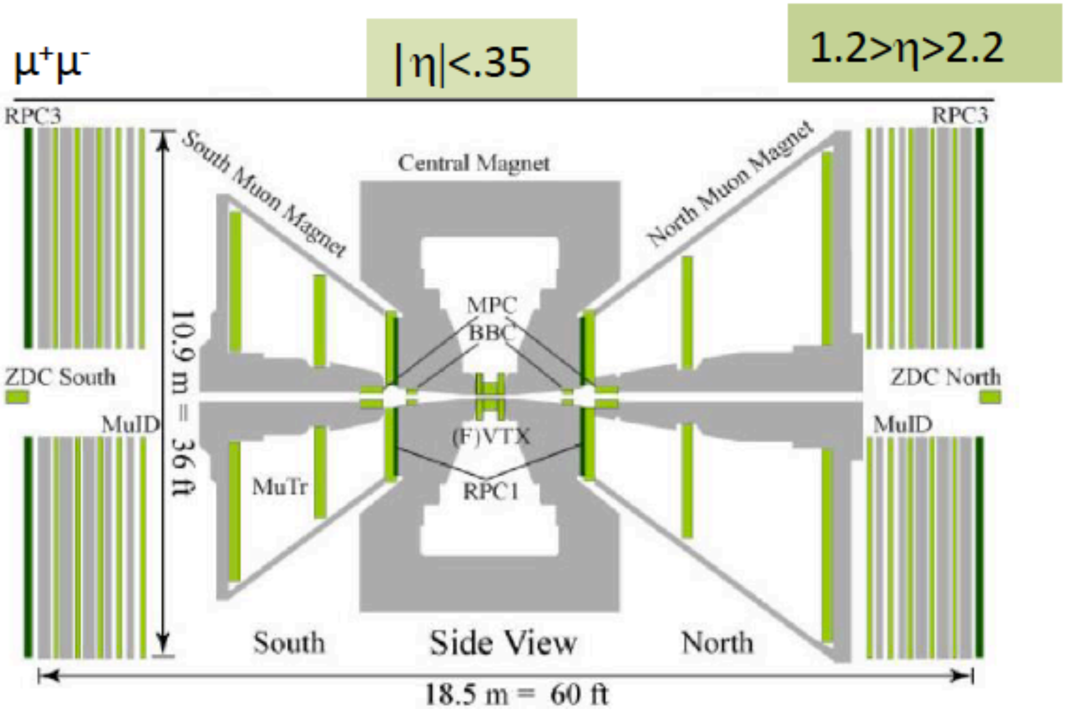
HFT

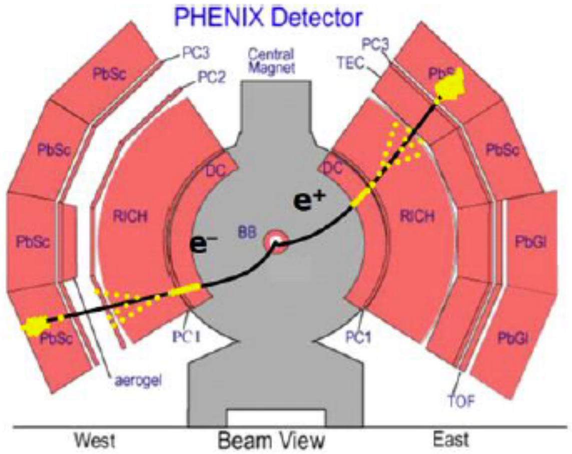




New detectors in STAR:
- Heavy Flavor Tracker run 14 (focus: open heavy flavor) and
- Muon Telescope Detector (focus: quarkonia), run 13/14.

PHENIX





- Energy in calorimeter
- Electron ID in RICH |eta|<3.5
- Drift chamber: tracking
- Myons at |eta| (1.2,2.2)
- Central Vertex Detector and Forward Vertex Detector

PHENIX in 2014

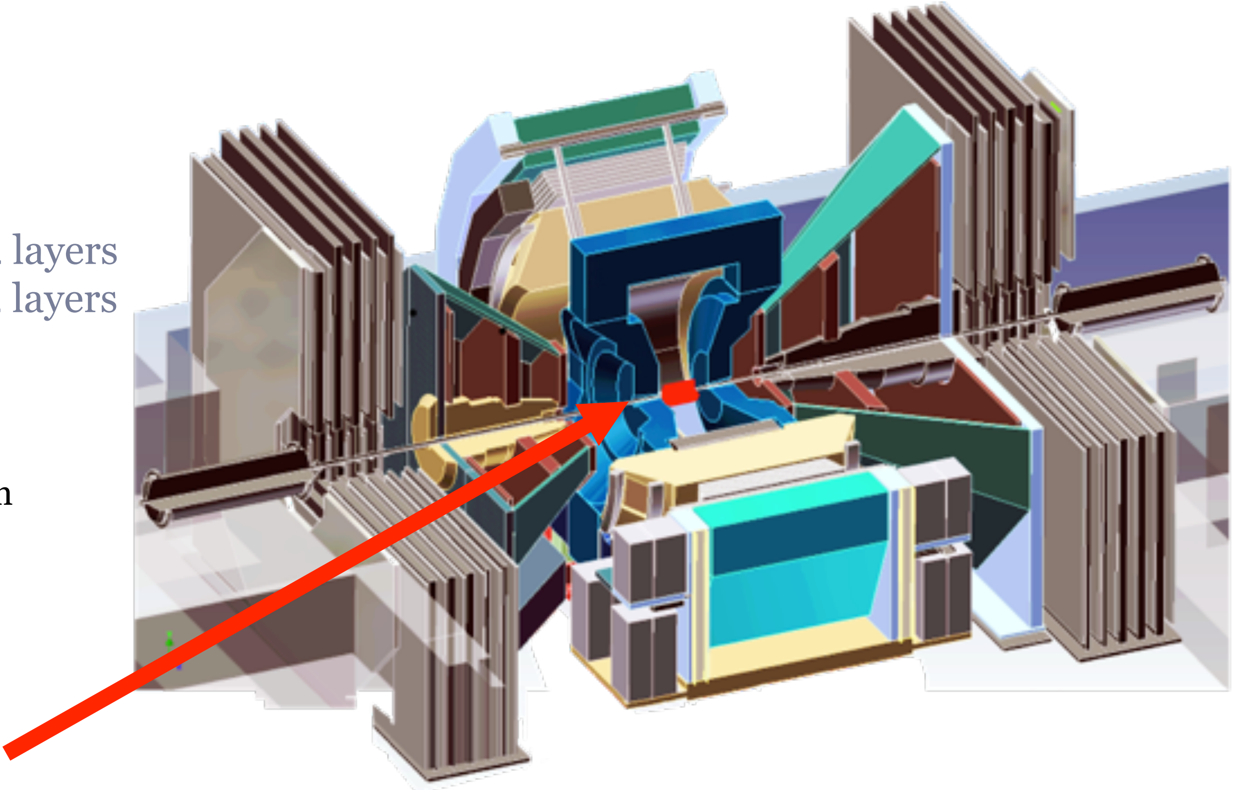
VTX detector

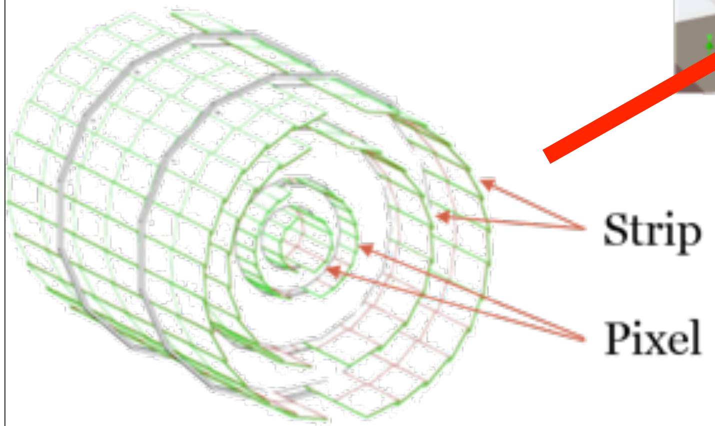
Barrel region

- $|\eta|<1.2$, almost 2π in ϕ
- Pixel sensors at inner 2 layers
- Strip sensors at outer 2 layers

Forward region

- $1.2<|\eta|<2.7$, 2π in ϕ
- 4 layers of mini strips
  - (50x 2000 to 11000μm

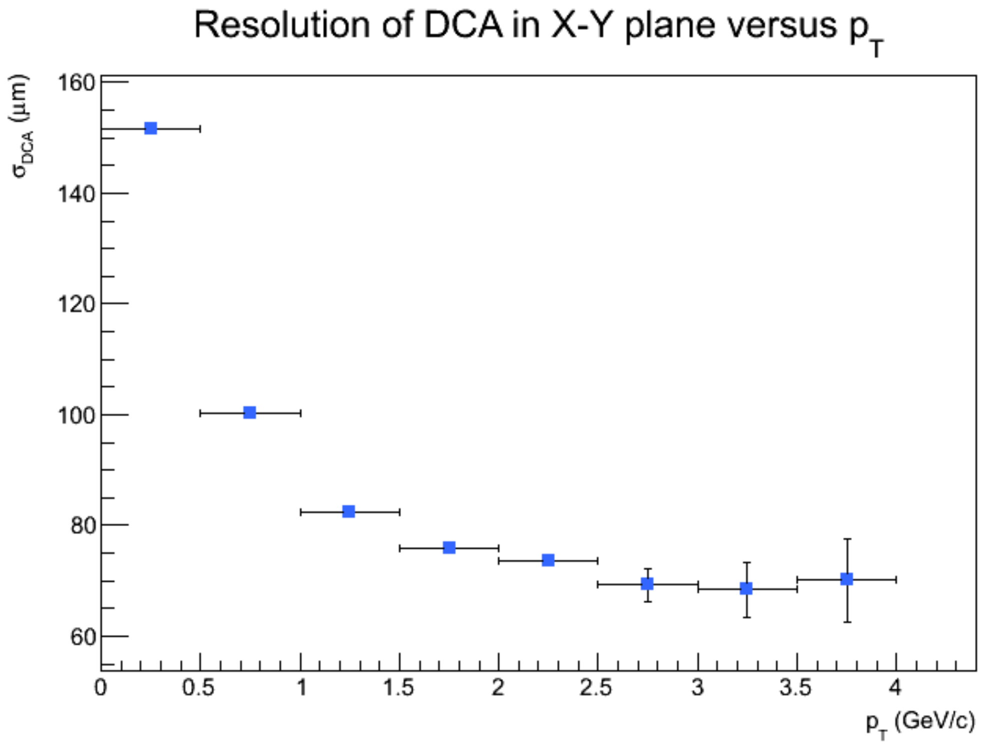




K. Dehmelt, PHENIX, AGS/RHIC user's meeting 2014

Detectors

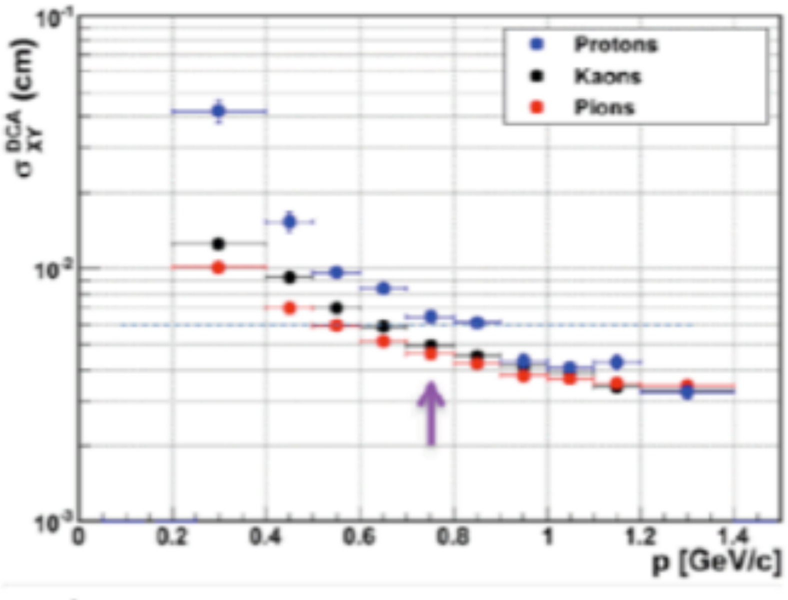
PHENIX F/VTX detectors operating well



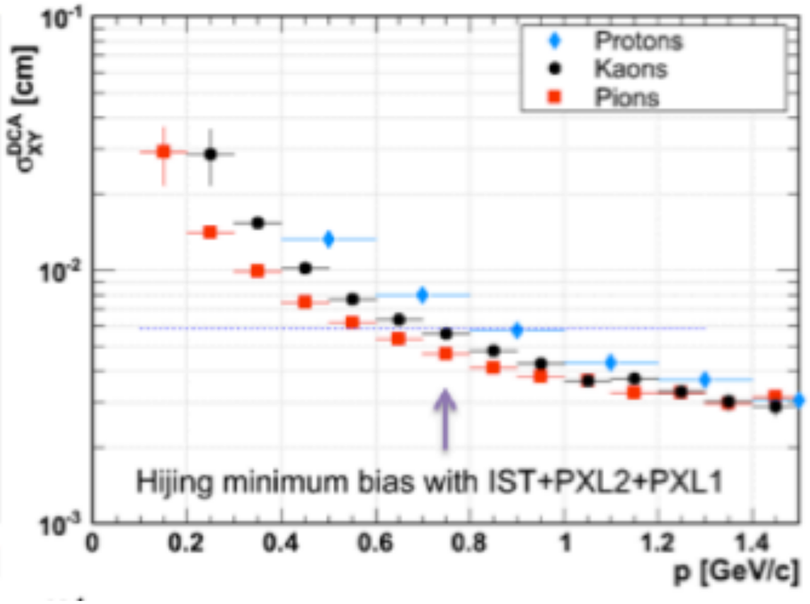
PHENIX: DCA(XY) ~ 70 microns at high pT

STAR HFT

Measured

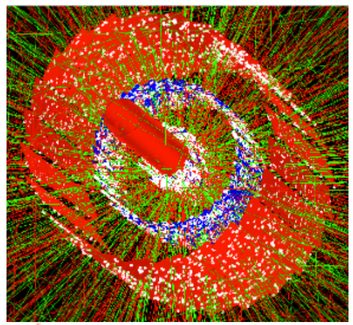


Simulated



Achieved goal: <60 µm for kaon with p_T= 750 MeV/c

Au+Au event STAR HFT

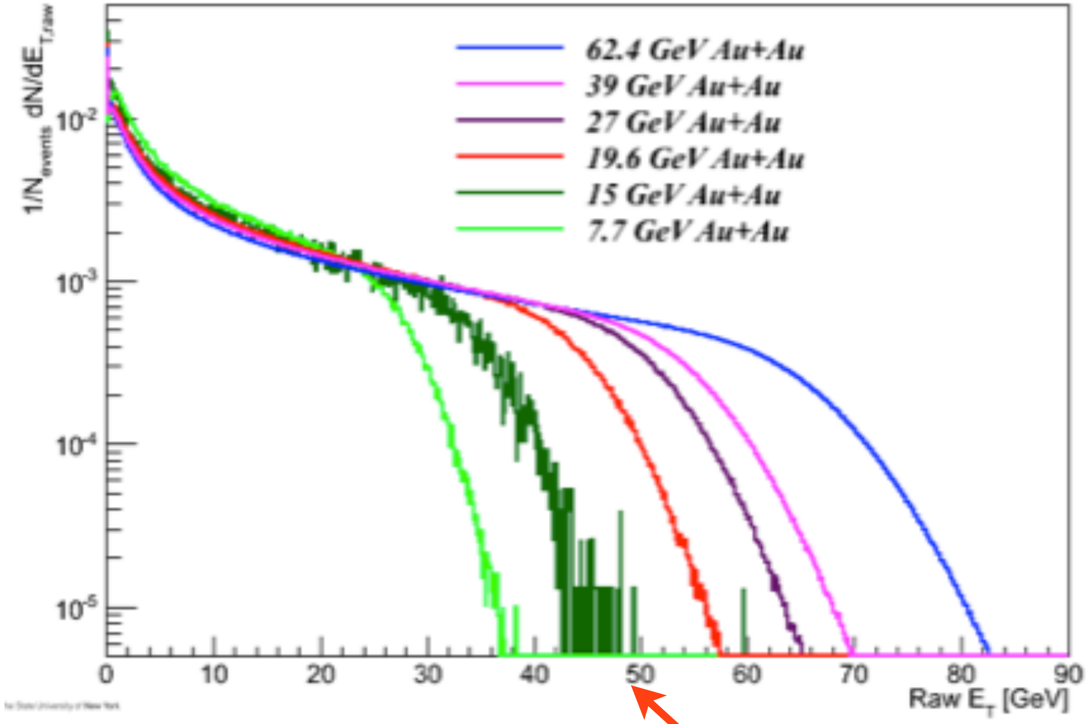


DCA(XY) ~ 30 microns at high pT

State-of-art Monolithic Active Pixel Sensors (MAPS) technology is used in STAR for the first time in a collider experiment.

PHENIX

K. Dehmelt, PHENIX, AGS/RHIC user's meeting 2014



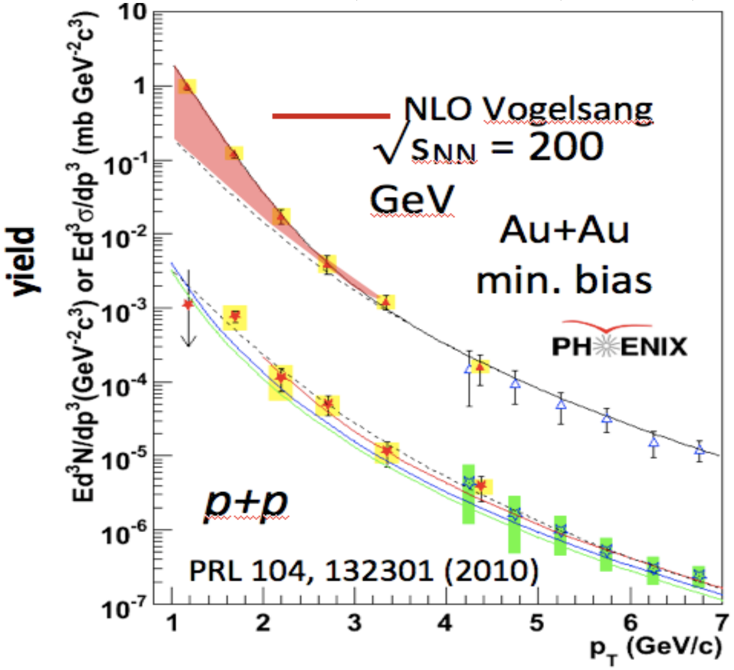
New ET distribution for new 2014 RHIC data at Au+Au 15 GeV

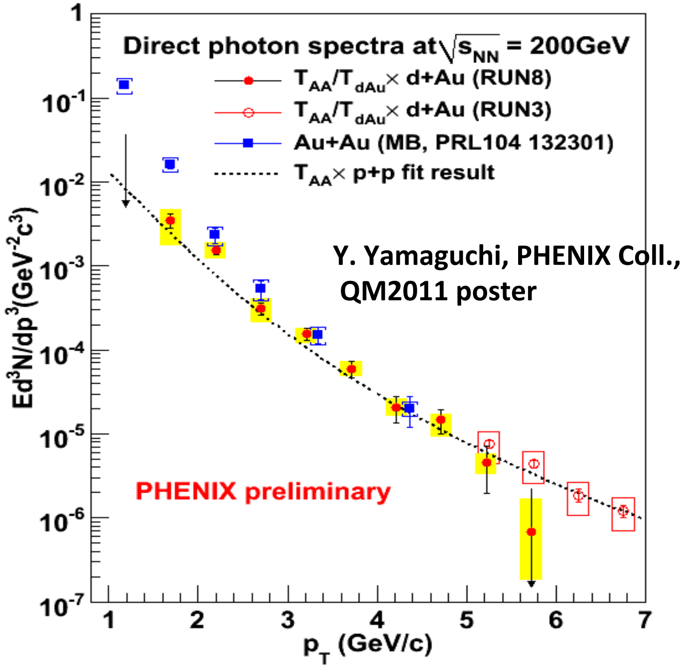
(only part of the statistics is used here)

III Selected physics results
1. Direct photons

Previous PHENIX results: Direct photon excess in min bias Au+Au at 200 GeV

Stefan Bathe, PHENIX Coll., QM2011, arXiv





PHENIX, PRL104 (2010) 132301, Finite collective flow : PL109 (2012) 122302, 1105.4126

Direct thermal photons firmly established for the first time !

Direct photons in p+p described by NLO

Direct photon excess in min. bias Au+Au at 200 GeV over p+p at 200 GeV below pT ~2.5 GeV

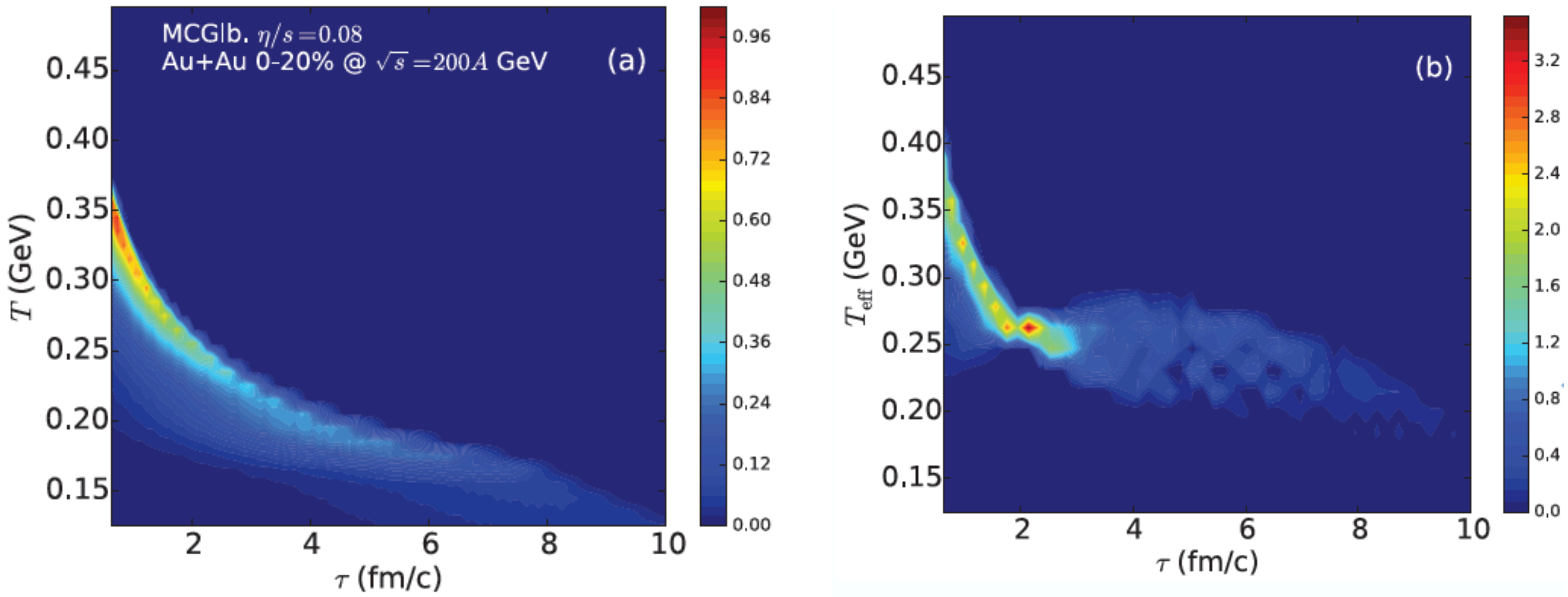
Exponential spectrum in Au+Au - consistent with thermal below pT ~2.5 GeV with inverse slope 220 ± 20 MeV --> T(init) from hydrodynamic models : 300-600 MeV, depending on thermalization time

Critical d+Au check : No exponential excess in d+Au

Puzzle: High T suggests early emission, large v2 suggest late emission (with low T)

Selected recent theory results on direct photons RHIC

C. Gale et al, 1308.2440



The 3rd dimension in these plots is cross section of photons

$$\frac{dN^{\gamma} / dydTd\tau}{dN^{\gamma} / dy}$$

Selected recent theoretical findings on direct photons

range of photon emission	fraction of total photon yield	
	AuAu@RHIC 0-20% centr.	PbPb@LHC 0-40% centr.
$T = 120\text{-}165$ MeV	17%	15%
$T = 165\text{-}250$ MeV	62%	53%
$T > 250$ MeV	21%	32%
$\tau = 0.6 - 2.0\,\mathrm{fm}/c$	28.5%	26%
$\tau > 2.0\,\mathrm{fm}/c$	71.5%	74%

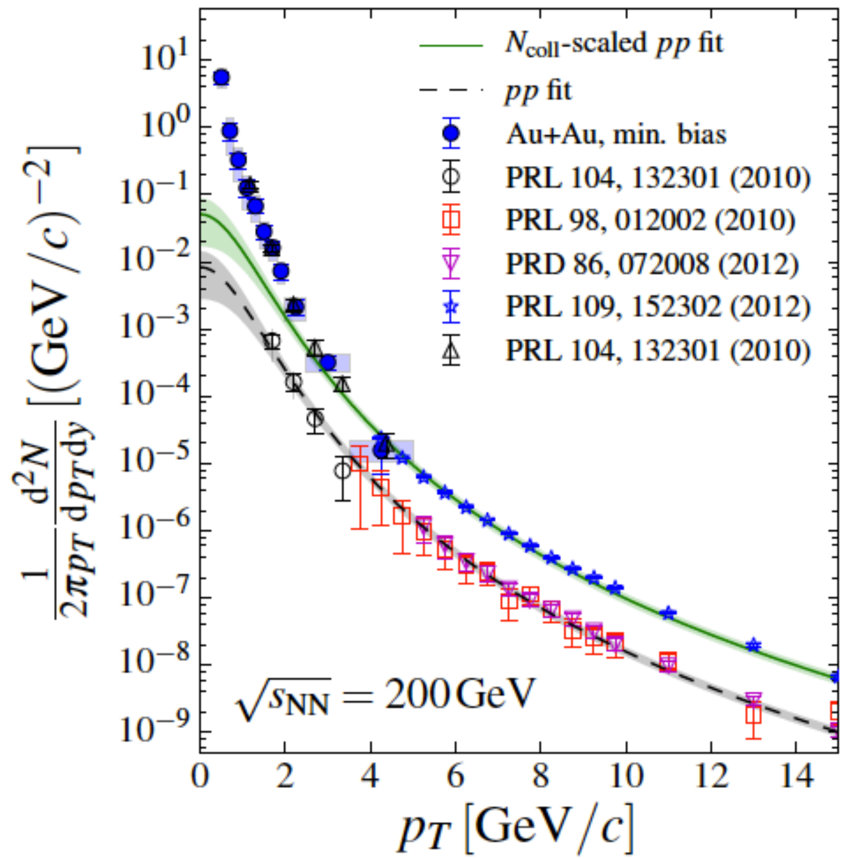
*** Most photons at RHIC and LHC are emitted from time near Tc**
*** Their effective temperature is enhanced by strong radial flow (effective temperature of hadrons decaying into photons are above Tc due to mass dependence of radial flow).**
*** However a very high temperature early initial collision stage is required to generate this radial flow**

Model conclusions:
*** Photons can be used as a thermometer**
*** T>Tc is reached**
*** Dynamic model needed to extract the details**

Also
*** More detailed data important to constraint the models !**

New data from PHENIX on direct photons

PHENIX 1405.3940



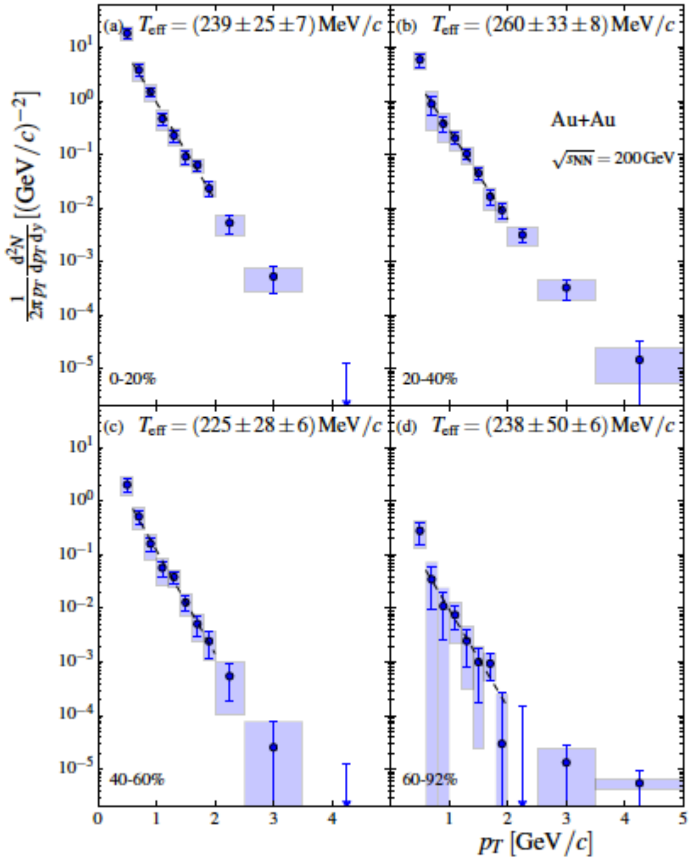
* New analysis extracts direct photons pT distributions and centrality dependence using external conversion to e+e- pairs in the detector material of real photons.

* New method very important check, constraining models even more.

* Agreement with old results

* Extended pT range, centrality study, precision

Direct photons PHENIX

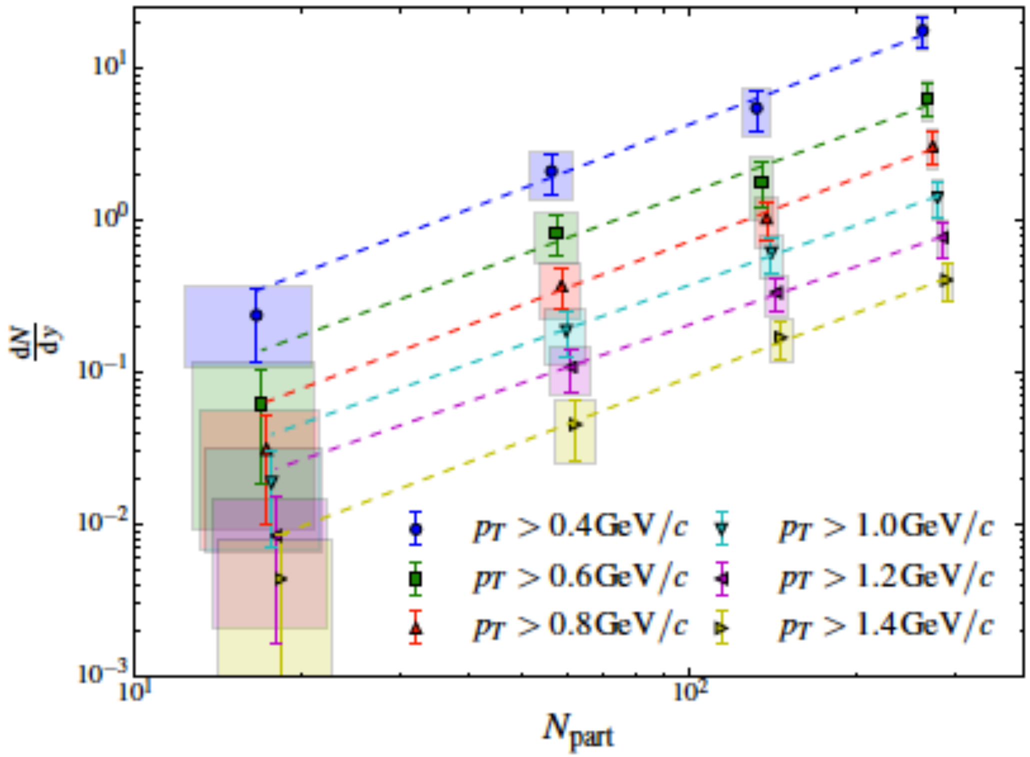


T (0-20%) = 239 ± 25 ± 7 MeV
T (20-40%) = 260 ± 33 ± 8 MeV
T (40-60%) = 225 ± 28 ± 6 MeV
T (60-92%) = 238 ± 50 ± 6 MeV

* **Exponential slopes are centrality independent within errors.**

* Direct photons in Au+Au after subtraction of p+p N(coll) scaled green bands (shown in the left plot), in centrality bins with an exponential fit Y~exp(-pT/T).

Direct photons dN/dy is Npart dependend



Integrated direct photon yields scale as

Yield = A N_{part}^{α}

α = 1.48 ± 0.08 (stat) ± 0.04 (sys)

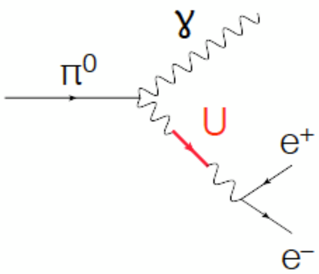
X. He, PHENIX, QM2014

-Also new data on v2 and first data on v3 of direct photons (not shown here)

-Strong new constraints on hydrodynamic time evolution and modeling of radiation emission

Dark Photon search PHENIX

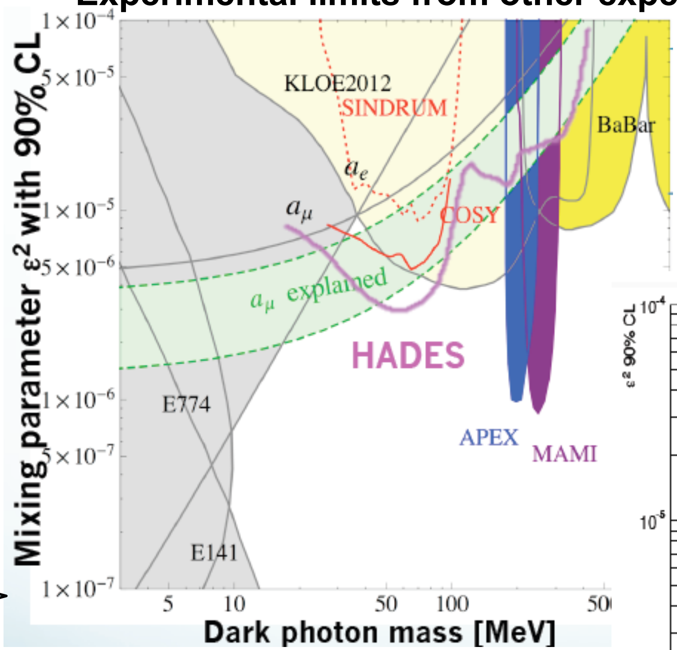
Dark photon: expected to have very weak coupling, low mass (eg MeV range).
Could explain the BNL muon g-2 experiment discrepancy from Standard Model of 3.6 sigma.



Possible contribution of dark photon U to the pi0-> e+e-gamma decay

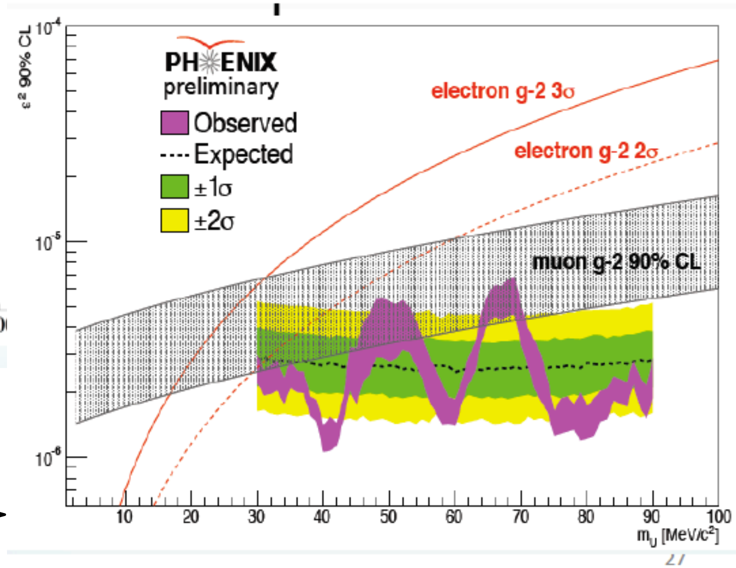
J. Hill, PHENIX, ICNFP2014

Experimental limits from other experiments



g-2 explainable band still survives 30-50 MeV

PHENIX:Search for U in e+e- invariant mass spectra

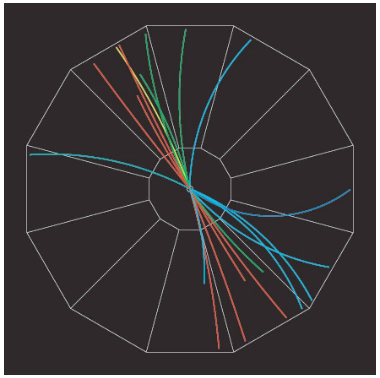


PHENIX set upper limits to the dark photon excluding 30-45 MeV region

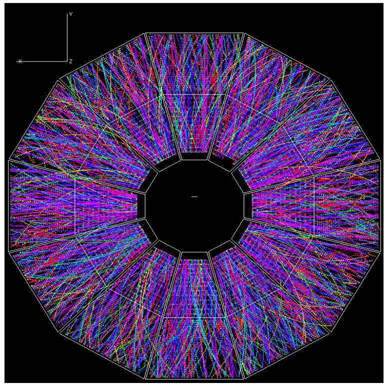
2. Open Heavy flavor

Jet quenching and heavy flavour

p+p Collision



Au+Au Collision

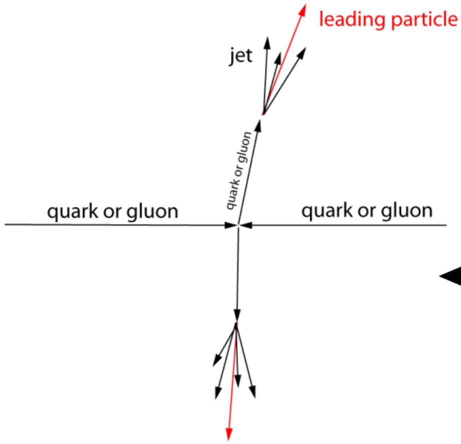


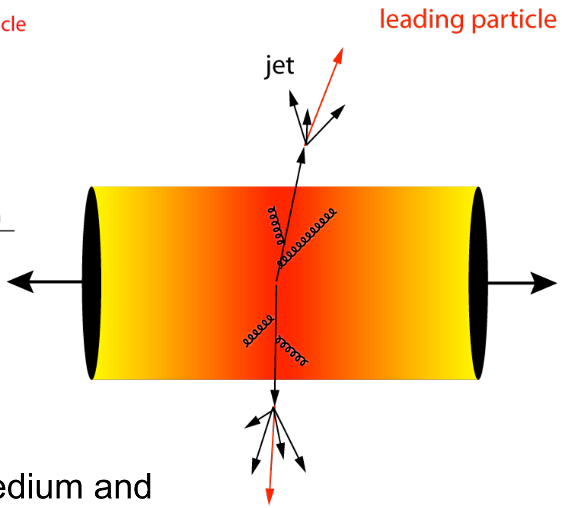
We compare A+A to expectations from p+p, using the “nuclear modification factor” R_{AA} defined as:

$$R_{AA}(p_T) = \frac{Yield(A+A)}{Yield(p+p) \times \langle N_{coll} \rangle}$$

N coll : Average number of NN collisions in AA collision

Suppression of jets in AuAu: $R_{AA} < 1$

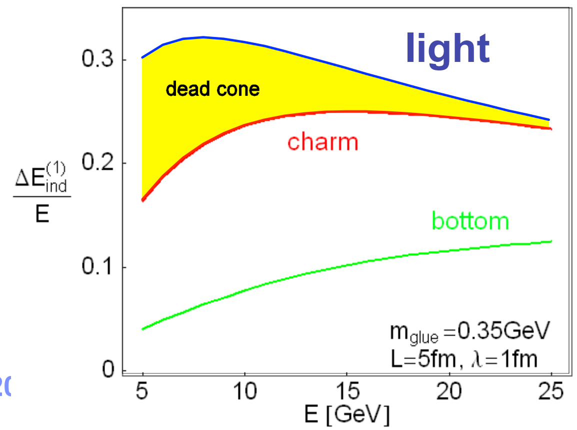




Partons interact with the medium and loose energy through eg gluon radiation

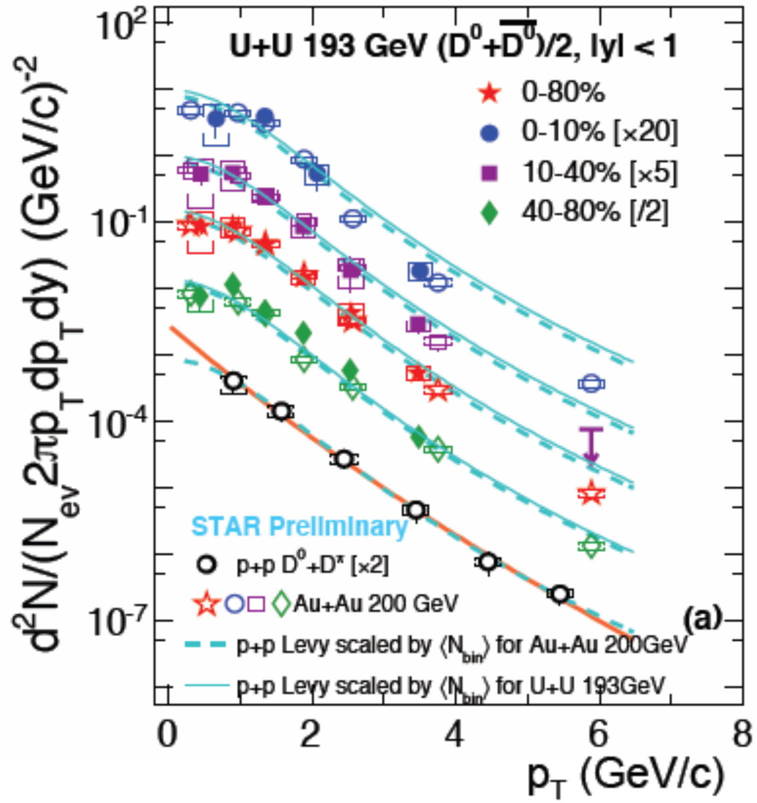
Quarks are expected to exhibit different radiative energy loss depending on their mass (**D.Kharzeev et al. Phys Letter B. 519:1999**)

M.Djordjevic PRL 94 (2004)



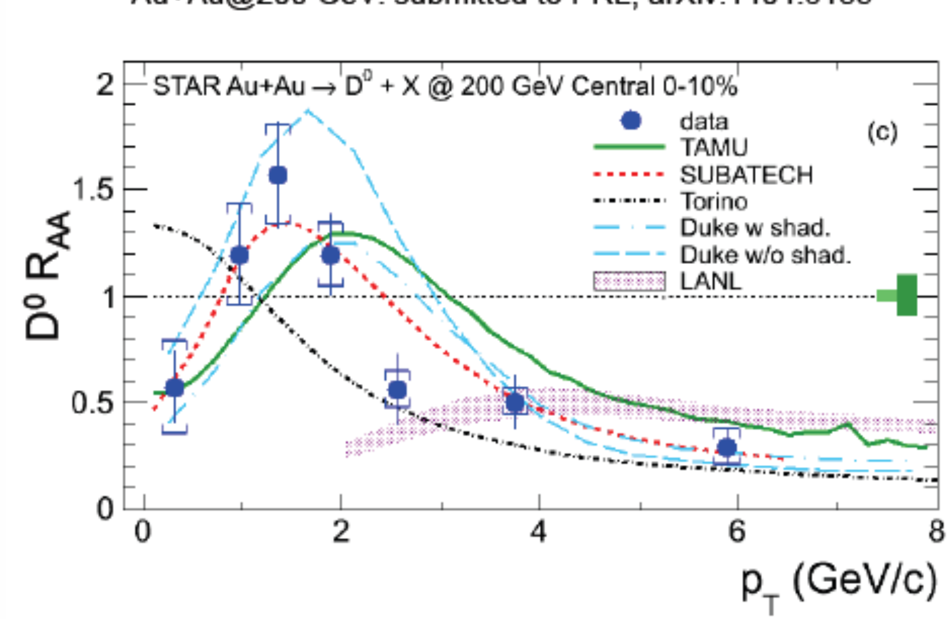
R_{AA} of D_0 in Au+Au 200 GeV

S. Shi, STAR, ICNFP2014



New results on D in U+U

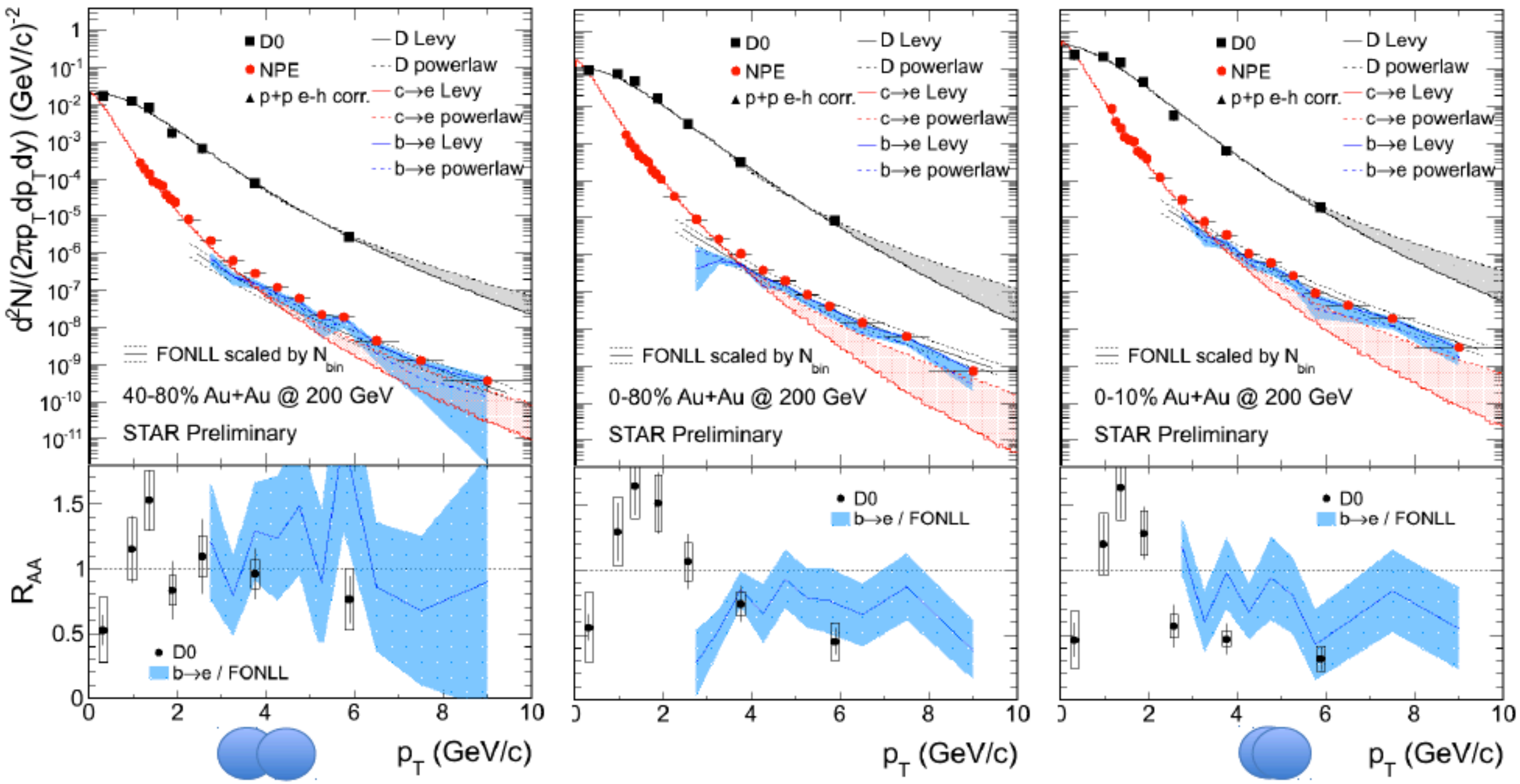
Au+Au@200 GeV: submitted to PRL, arXiv:1404.6185



R_{AA} of D_0 at high p_T:

- suppressed for central events
- suppression at high p_T similar to pions
- Enhancement at pT~0.7-2 GeV is described by models with charm quark coalescence with light quarks
- unsuppressed for peripheral events (not shown here)

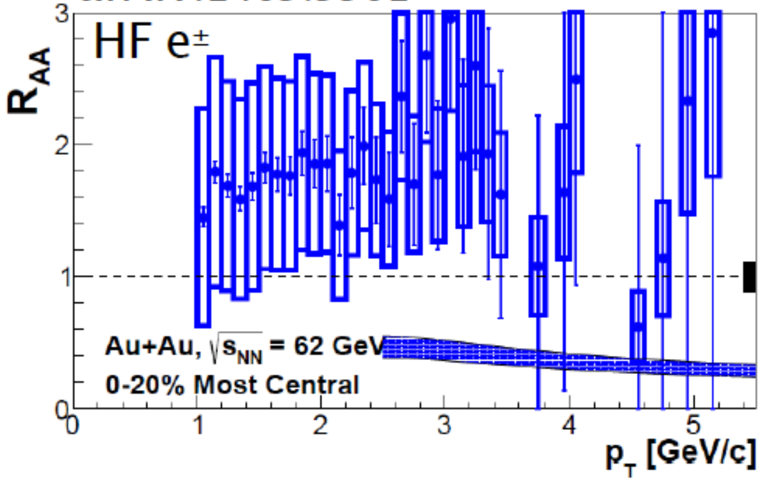
Is B less suppressed than charm ?

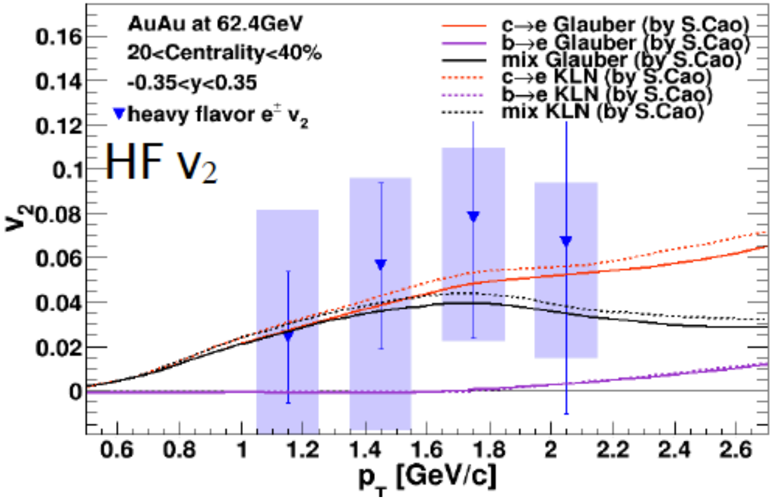


* Hint of possible less suppression of B as compared to D in some cases
* New STAR Heavy Flavor Tracker needed
* New result from PHENIX coming soon

PHENIX: Open heavy flavor RAA enhancement in Au+Au at 62 GeV

arXiv:1405.3301





PHENIX, QM2014

*** RAA of HF electrons in Au+Au 200 GeV 0-20% centrality, is enhanced above 1**

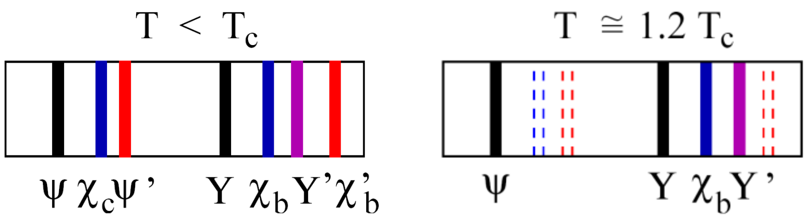
-> Different than Au+Au at 200 GeV

*** Flow of heavy quarks in Au+Au at 62 GeV measured**

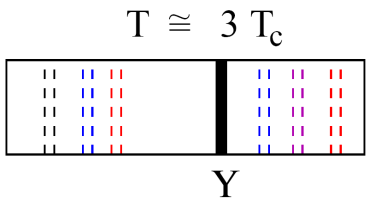
-> PHENIX proposes future high statistics running of p+p and Au+Au at 62 GeV to explore that further

3. Quarkonia

Quarkonia

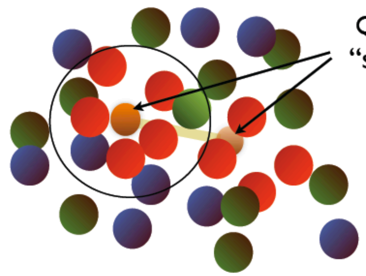


H. Satz, Nucl. Phys. A (783): 249-260(2007)



Matsui-Satz: screening the potential

Screening in a deconfined medium: effective charge of Q and Q̄ reduced



Q and Q̄ cannot "see" each other

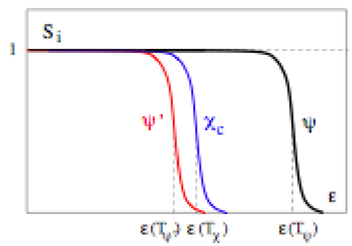
$r_D < r_{Q\bar{Q}}$

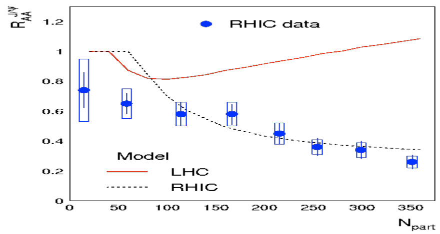
Assume: medium effects described with a T-dependent potential

$$-\frac{\alpha_{eff}}{r} e^{-r/r_D(T)}$$

A. Mocsy

state	J/ψ(1S)	χ_c(1P)	ψ'(2S)	Υ(1S)	$\chi_b(1P)$	Υ(2S)	$\chi_b(2P)$	Υ(3S)
T_d/T_c	2.10	1.16	1.12	> 4.0	1.76	1.60	1.19	1.17



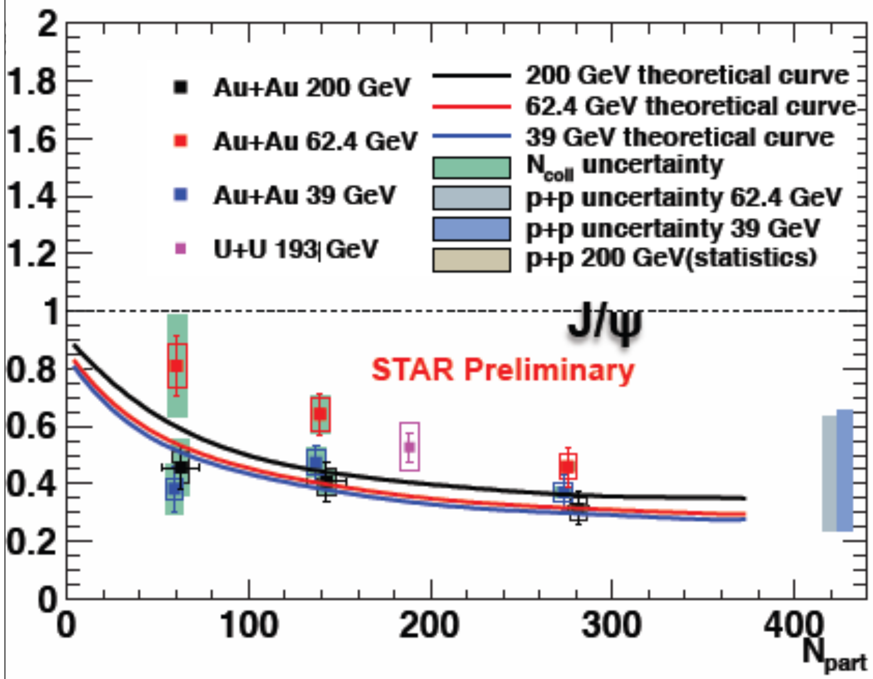


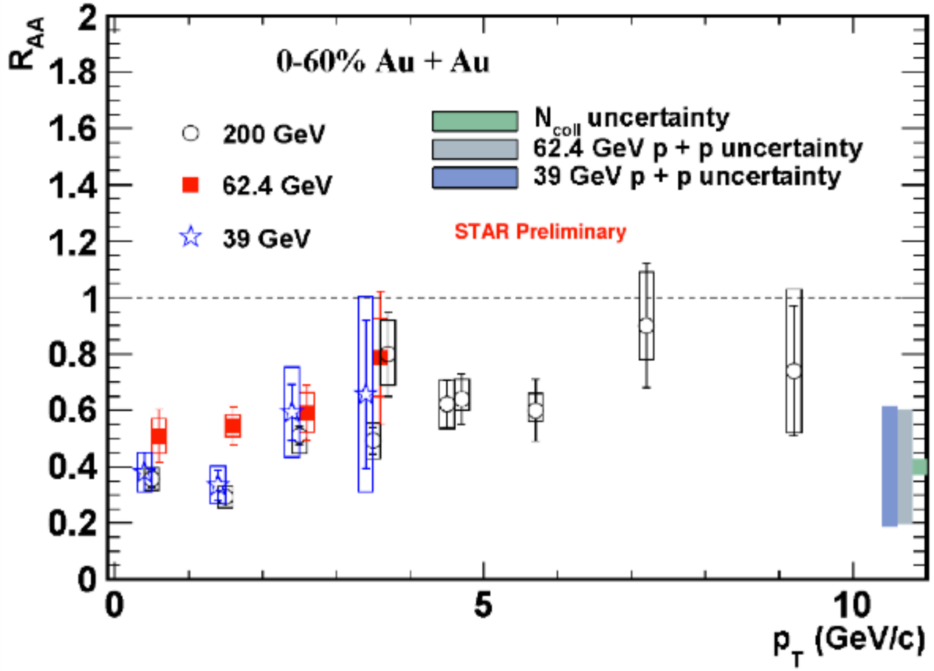
Quarkonia: Thermometer of QGP via their suppression pattern

Many effects play a role like dissociation in QGP, cold matter absorbtion, recombination/coalescence from c, cbar, feeding

At which energy J/Psi suppression in A+A turns off? How compares U+U to A+A?

B. Trzeciak, STAR, ICNFP2014





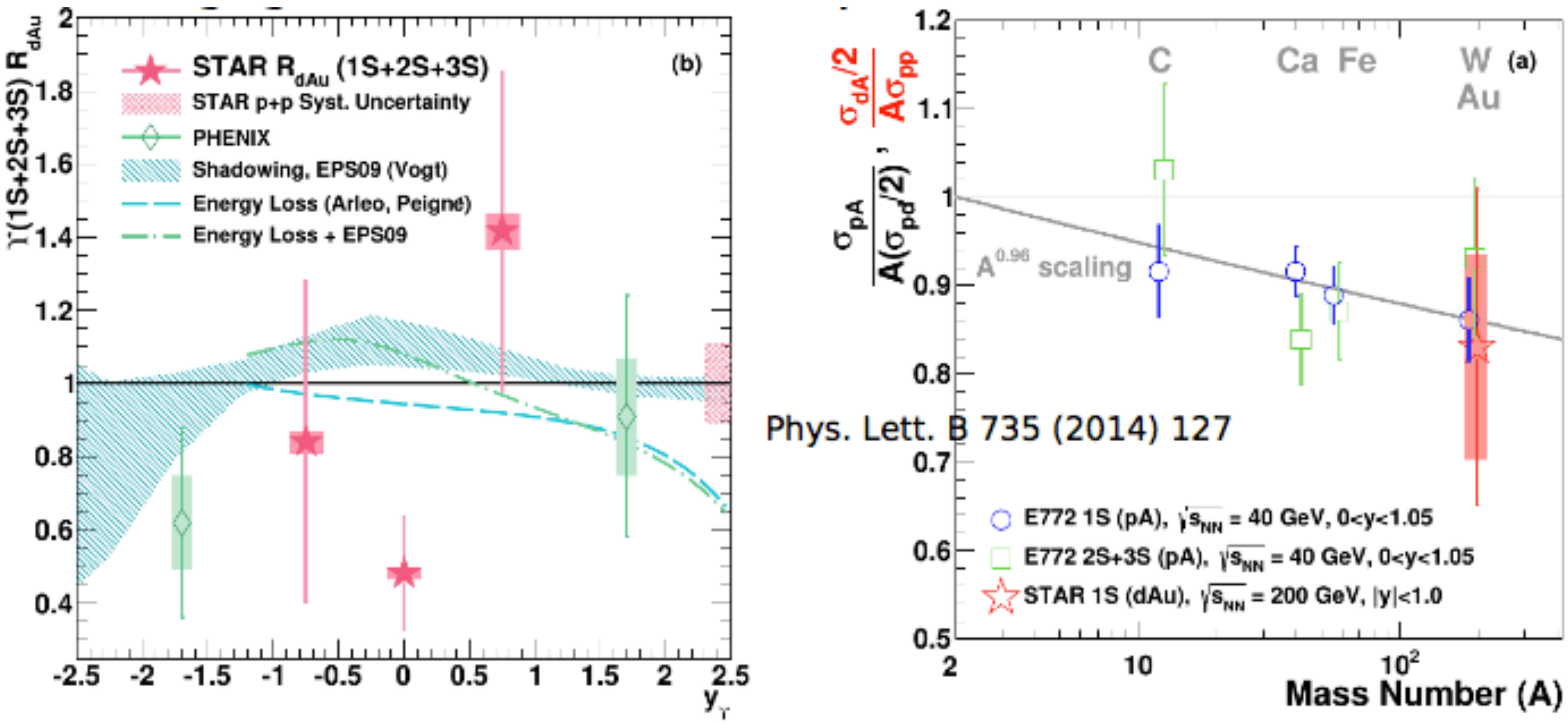
More suppression with larger collision centrality (left)

New U+U point agrees with Au+Au

Color Evaporation Model (CEM) estimate for p+p reference used for 39, 62 GeV

R_{AA} of J/Psi is suppressed in similar way at 39, 62 and 200 GeV (weak beam energy dependence)

STAR: Upsilon in d+Au (2014)



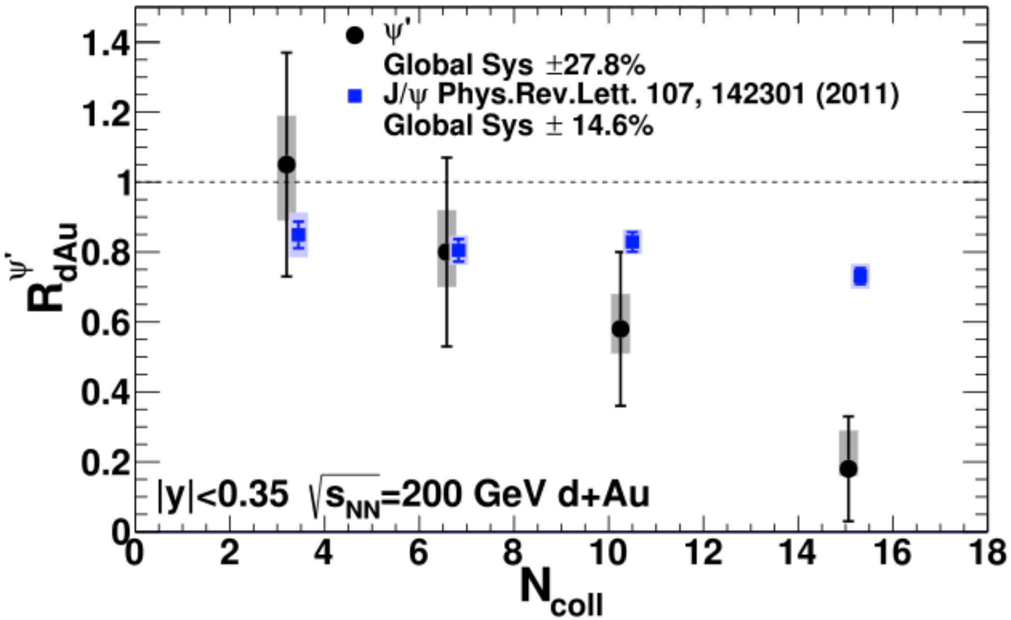
Phys. Lett. B 735 (2014) 127

- Agreement with models exept midrapidity -> suppression in addition to shadowing and initial state parton energy loss

- Similar suppression seen in E772

PHENIX data in left plot from dAu 1211.4017

Phenix quarkonia in d+Au



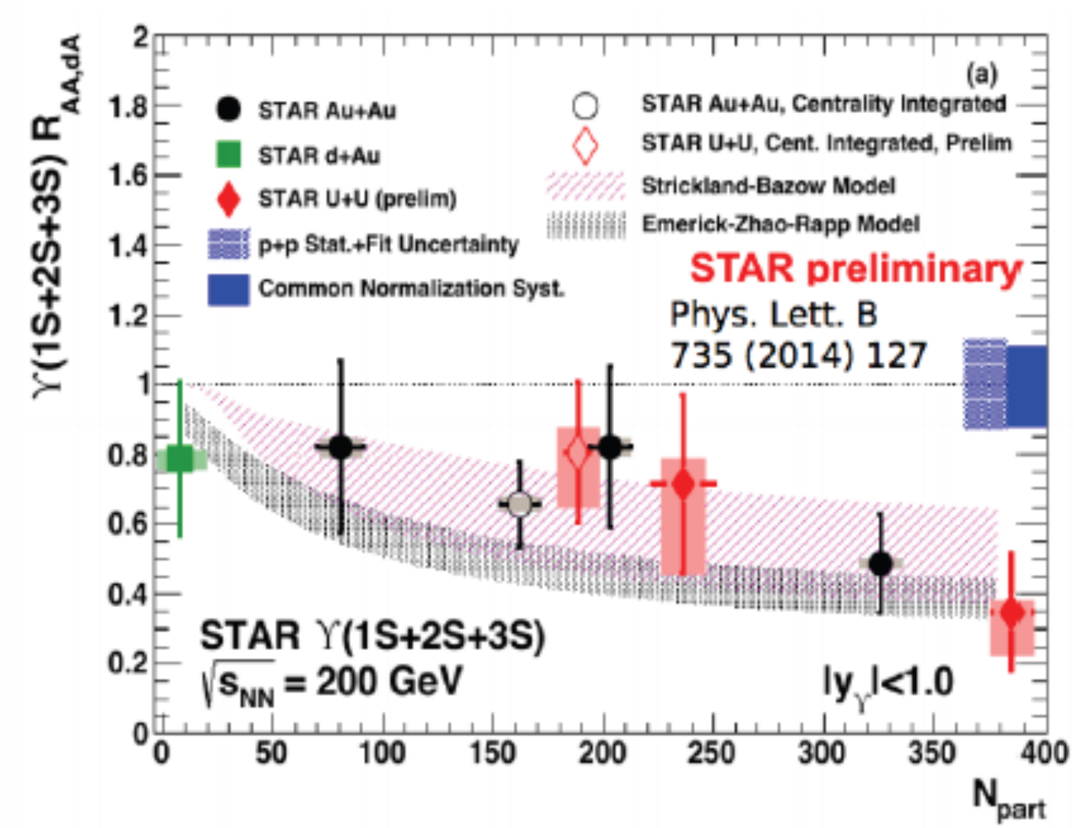
PHENIX arXiv:1305.5516

D. Jouan et al, SQM2013

Psi' more suppressed than the Psi in d+Au

Upsilon in STAR (2014)

B. Treciak, STAR, ICNFP2014



Strickland-Bazow Model (arXiv:1112.2761):

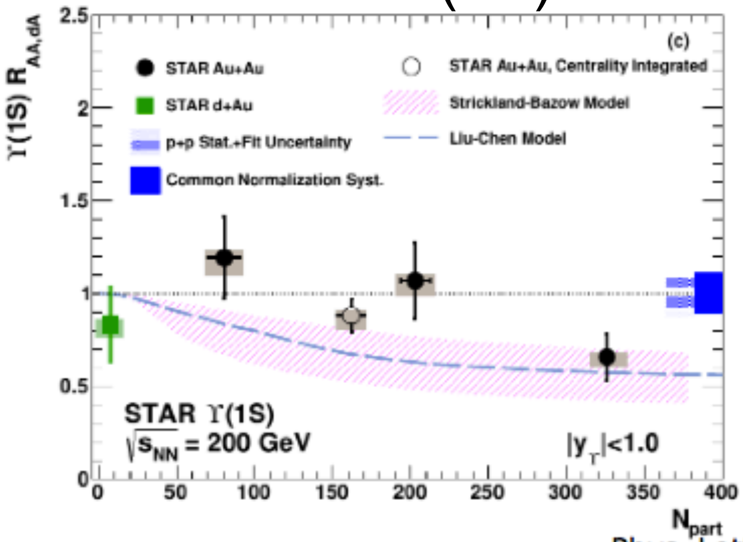
Assumes T_0= 428-442 MeV and 1/4π < η/S < 3/4π

Emerick-Zhao-Rapp Model (Eur. Phys. J A48, 72 (2012)): Cold Nuclear Matter effects included

- Similar trend in U+U and Au+Au
- Data agree with models that include presence of QGP

Upsilon in STAR

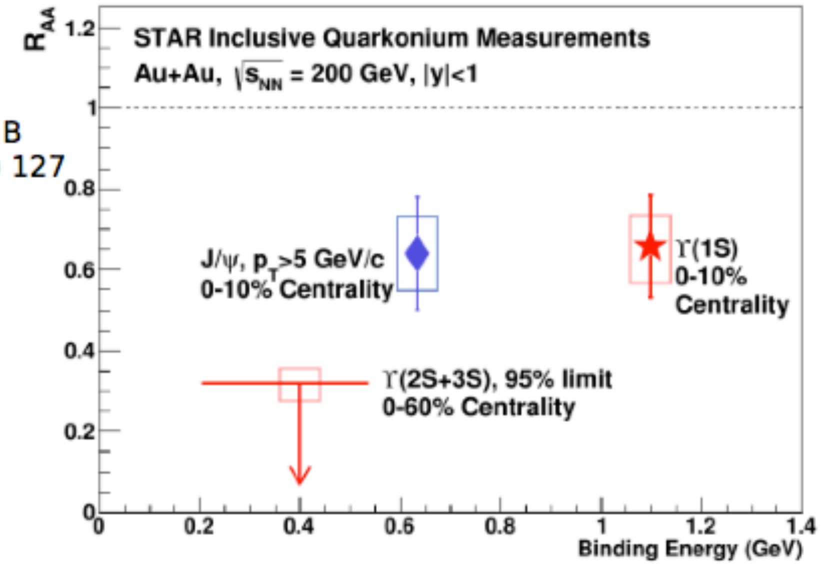
RAA Y(1S)



Phys. Lett. B 735 (2014) 127

- ✓ Suppression of ϒ(1S) in central collisions consistent with model predictions
- *Liu et al. Model (arXiv:1009.2585)* – suppression mostly due to dissociation of the excited states

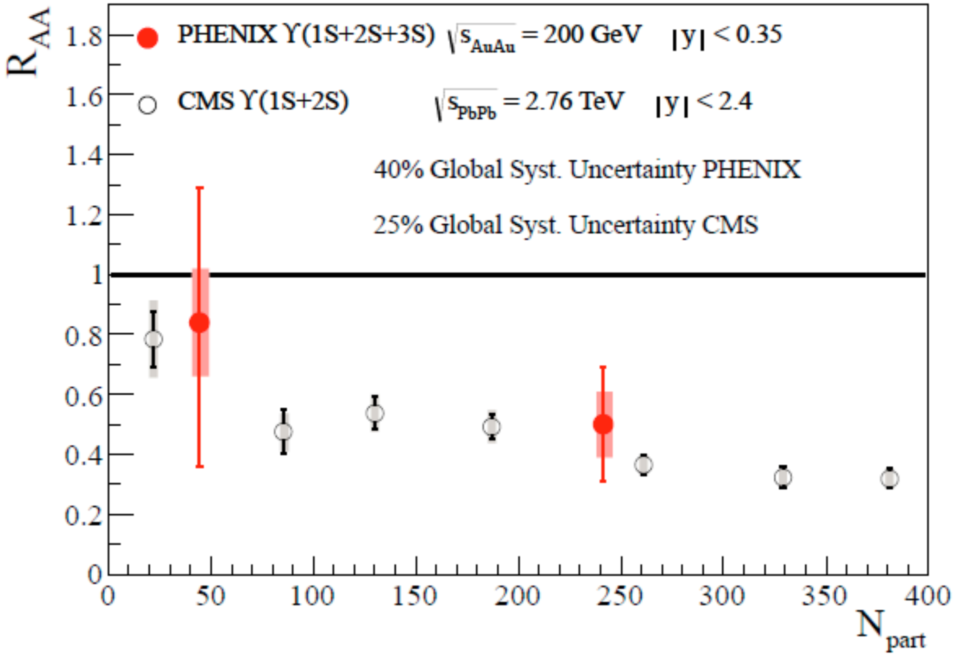
- ✓ Indication of complete ϒ(2S+3S) suppression



B Trzeciak , STAR, ICNFP2014

PHENIX: Upsilon in Au+Au

PHENIX 1404.2246

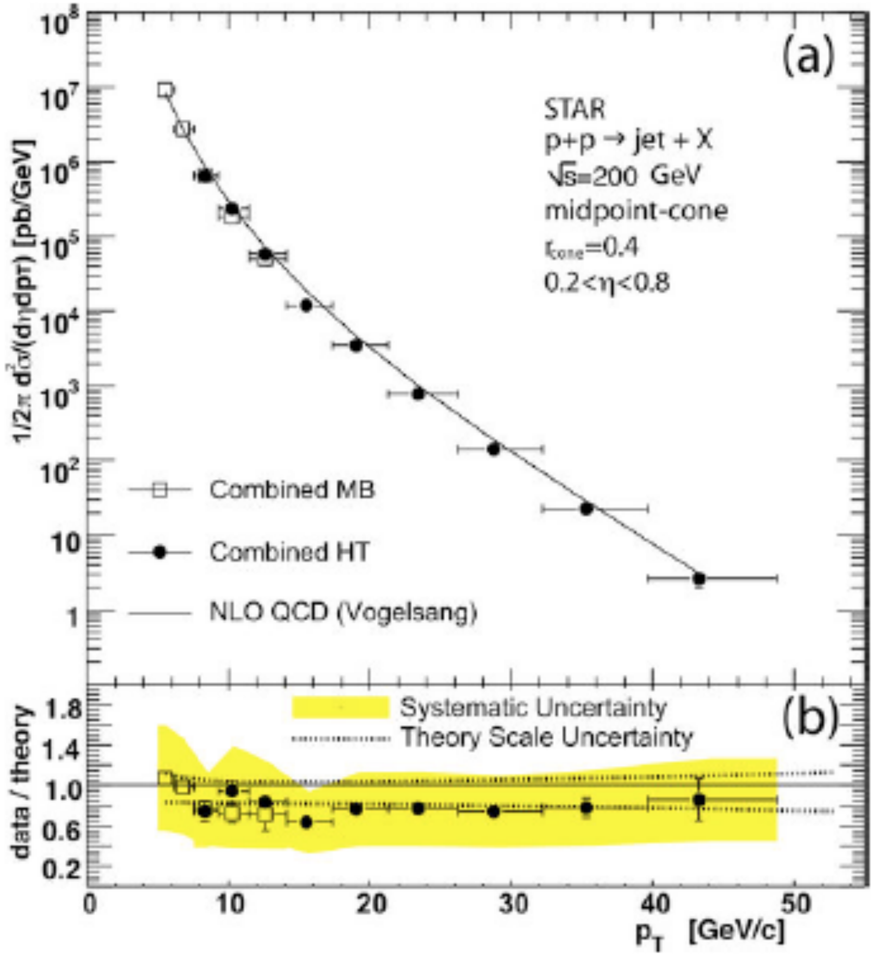


PHENIX, QM2014

- **Suppression of Upsilons Y(1S+2S+3S) observed in Au+Au at 200 GeV**
- **Consistent with disappearance of Y(2S) and Y(3S)**
- **Suppression similar to Pb+Pb LHC within uncertainties**

4. Jet quenching

Jet cross section in p+p 200 GeV

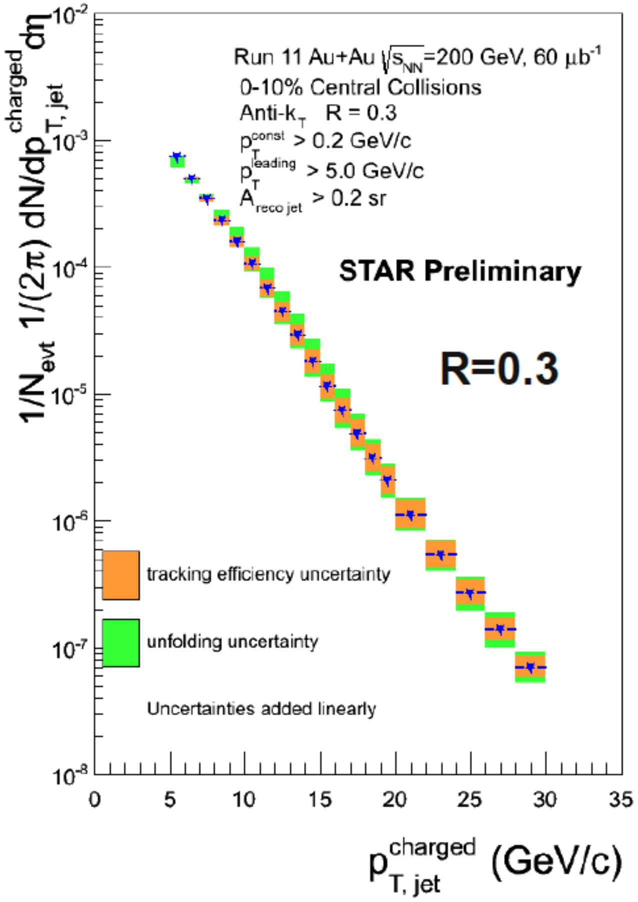


STAR, Phys. Rev. Lett. 97, 252001 (2006), hep-ex/0608030.

The jet cross section in p+p 200 GeV is described by NLO pQCD over seven orders of magnitude

STAR inclusive jets

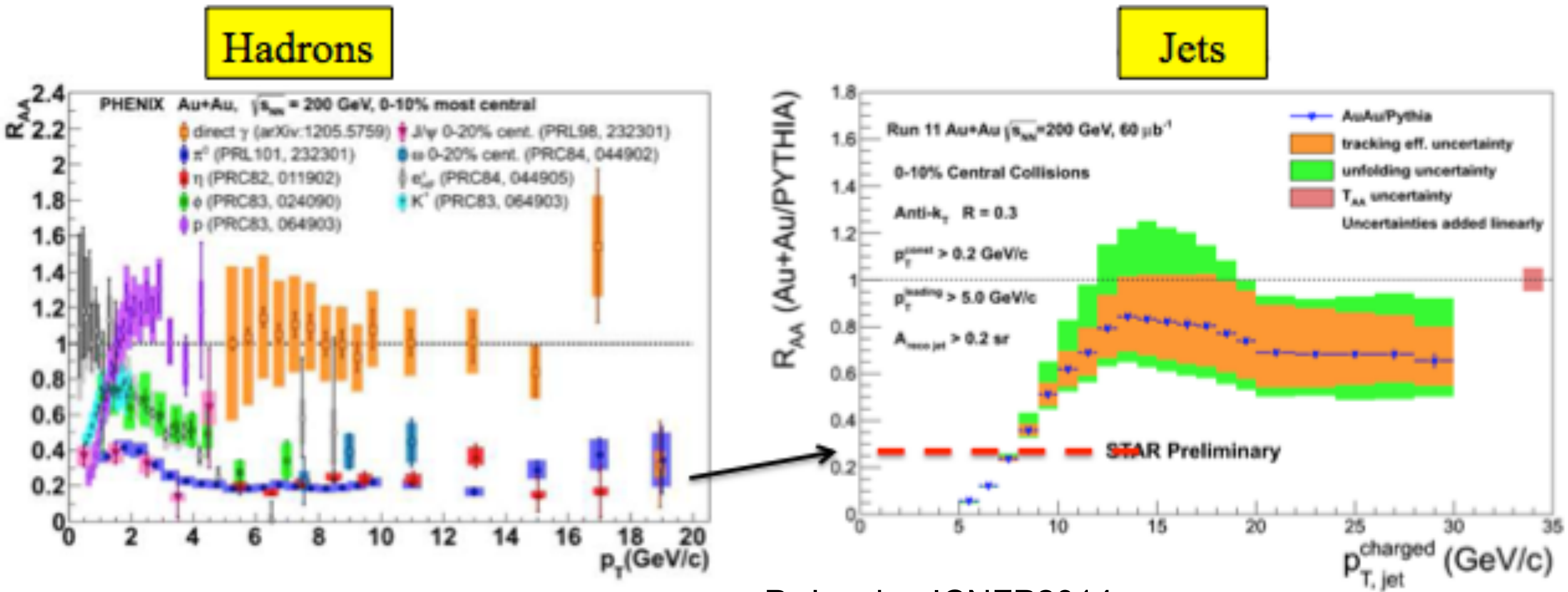
J. Rusnak, Hard probes 2013



Require hard leading hadron in jet to suppress background

pT(thresh)=5 GeV

Hadron vs jet suppression

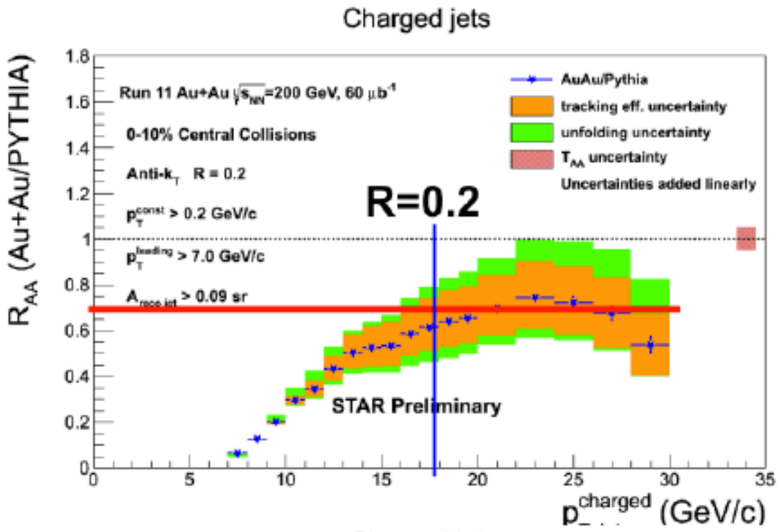


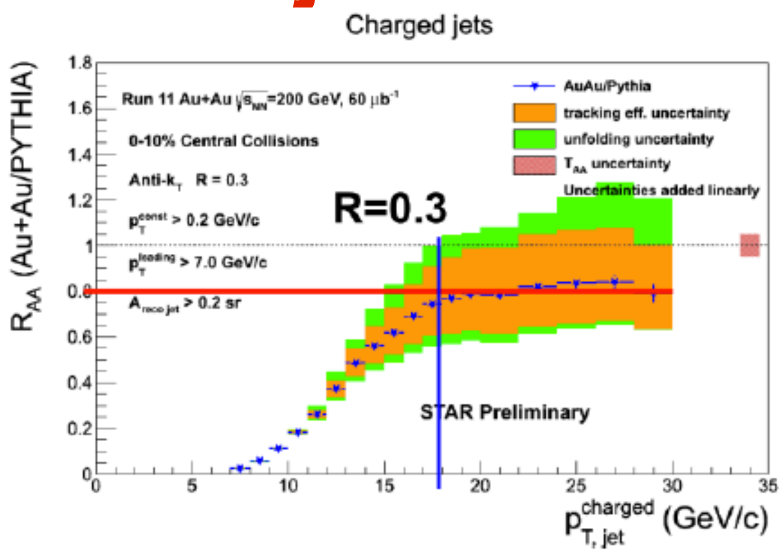
P. Jacobs, ICNFP2014

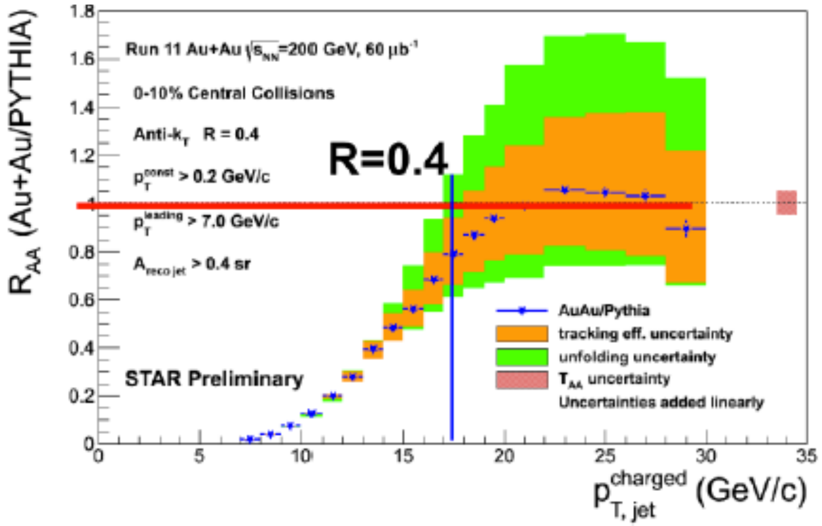
Jets are less suppressed than hadrons at RHIC, while in LHC they are suppressed the same.
Less out of cone radiation at RHIC?

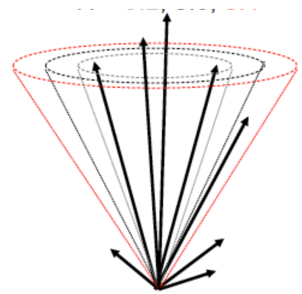
STAR: Effect of changing the R for inclusive RAA of jets

QM2014, Y.J. Lee







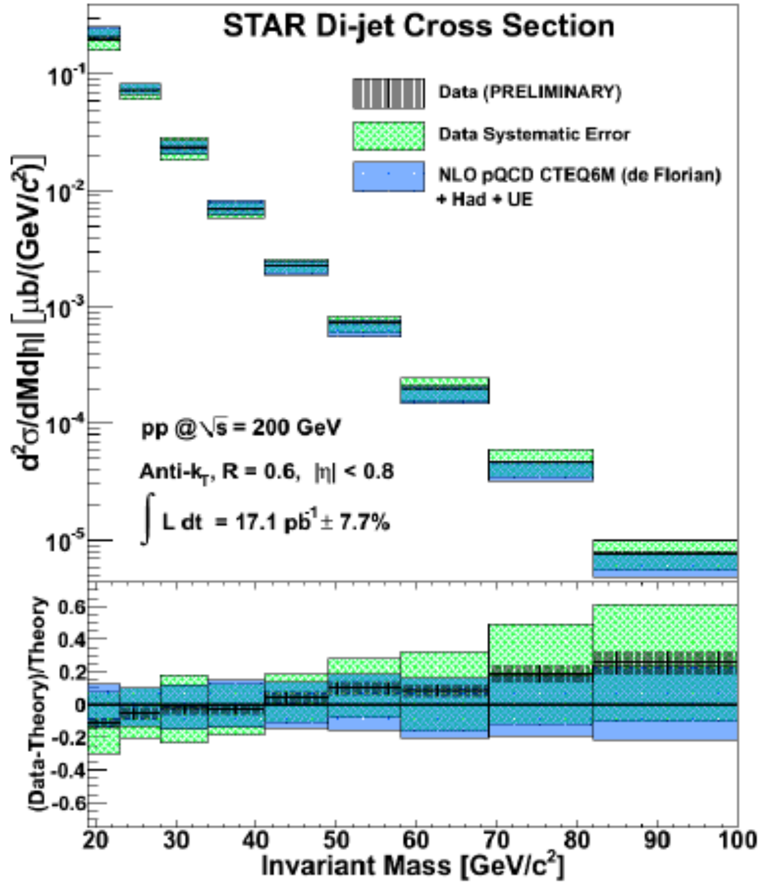


STAR observes a change of RAA(Au+Au/Pythia) with R from 0.2 to 0.4, in Au+Au 200 GeV 0-10%
RAA enhances to ~1 for R=0.4

While ATLAS Jet RCP (R=0.3) / RAA (R=0.2) ~ 1.0 ±0.2

Dijets

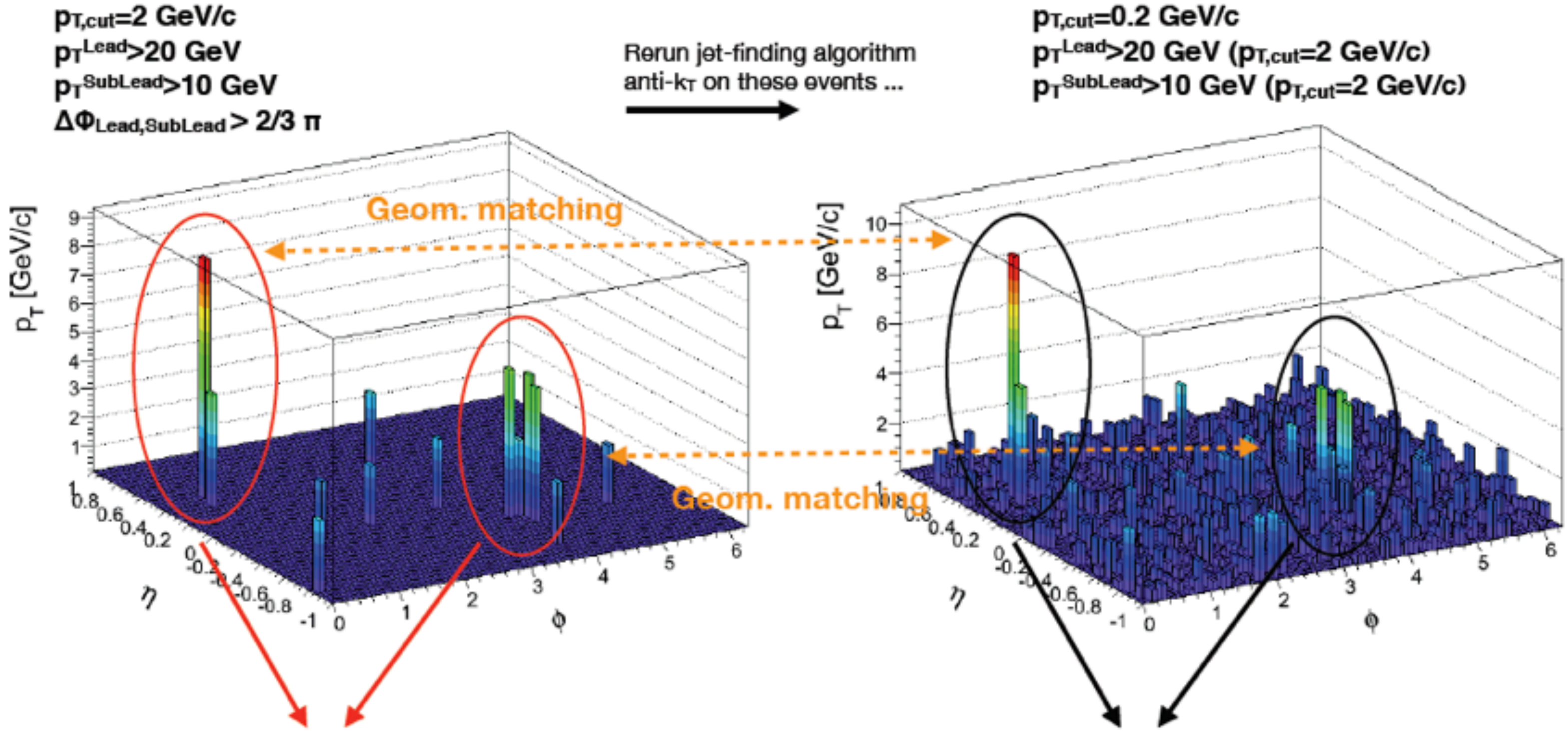
STAR dijet cross section



PhD Thesis B. Page, STAR

Preliminary dijet cross section in p+p 200 GeV is in agreement with NLO pQCD estimate within errors

Dijet imbalance in STAR: A_J



Calculate A_j with constituent $p_{T,cut}$>2 GeV/c

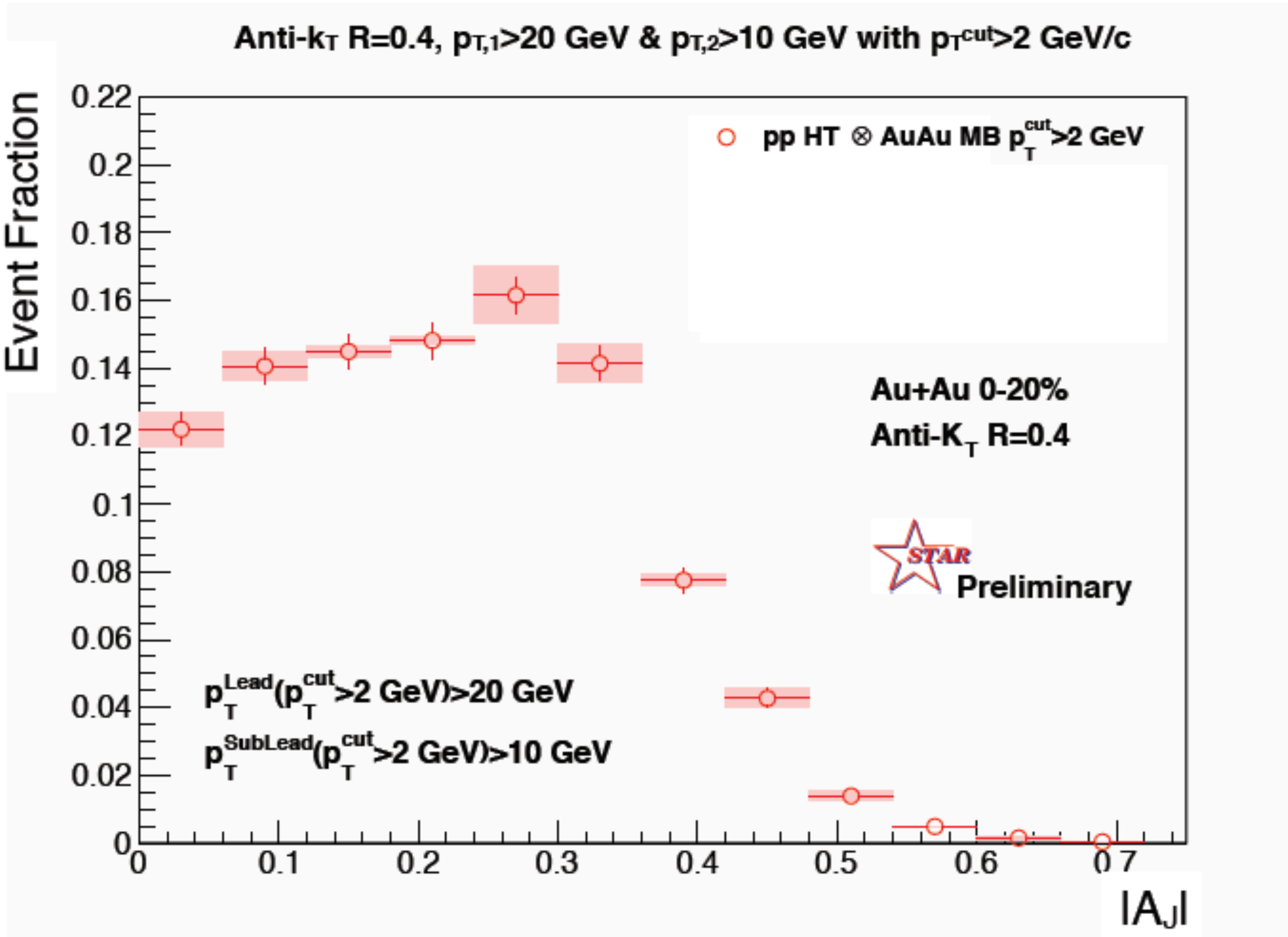
$$A_J = \frac{p_{T,1} - p_{T,2}}{p_{T,1} + p_{T,2}} \qquad p_T = p_T^{rec} - \rho \times A$$

Calculate "matched" $|A_j|$ with constituent $p_{T,cut}$>0.2 GeV/c.

J. Putschke, STAR, QM14

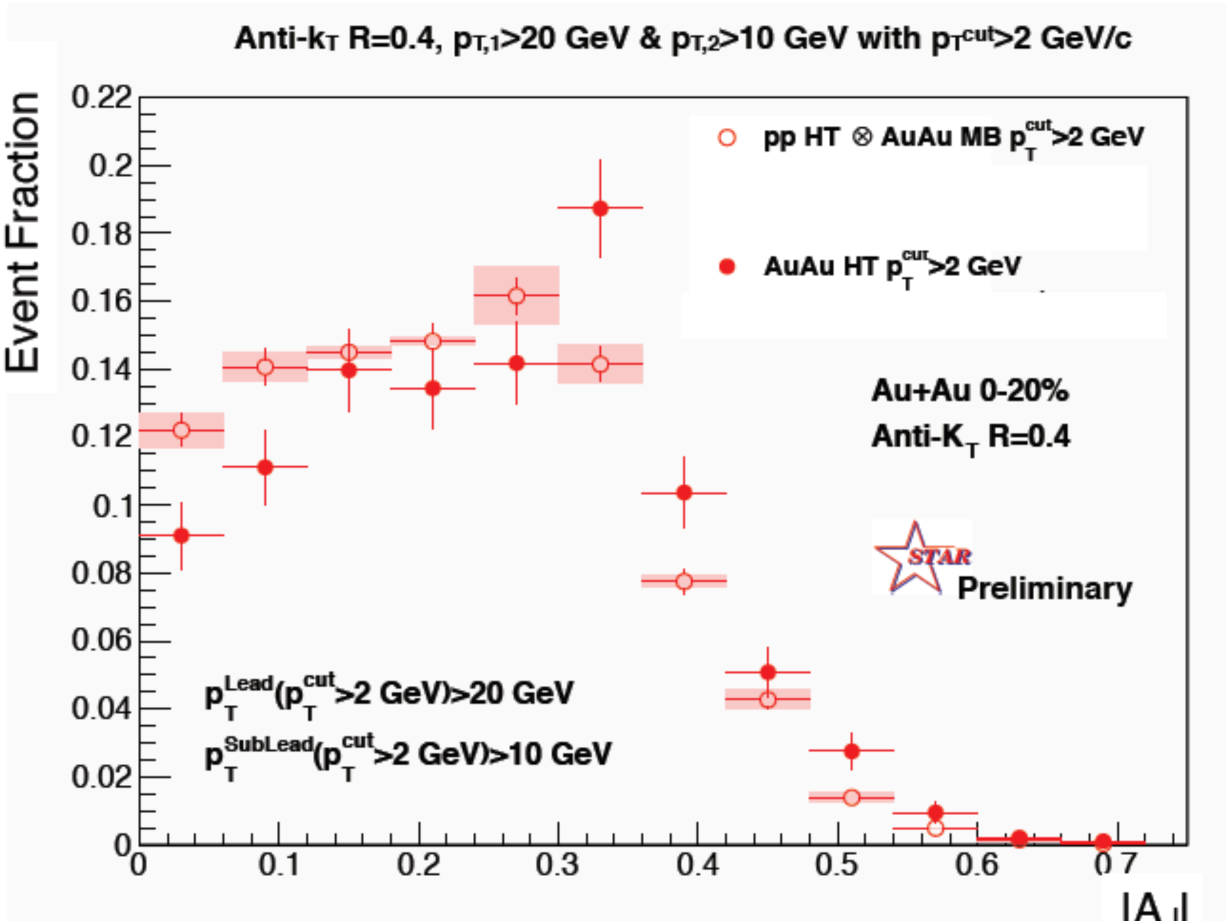
STAR, Dijet imbalance Au+Au 0-20% R=0.4

Sys. Uncertainties:
- tracking eff. 6%
- tower energy scale 2%



J. Putschke, STAR, QM14

STAR, Dijet imbalance Au+Au 0-20% R=0.4



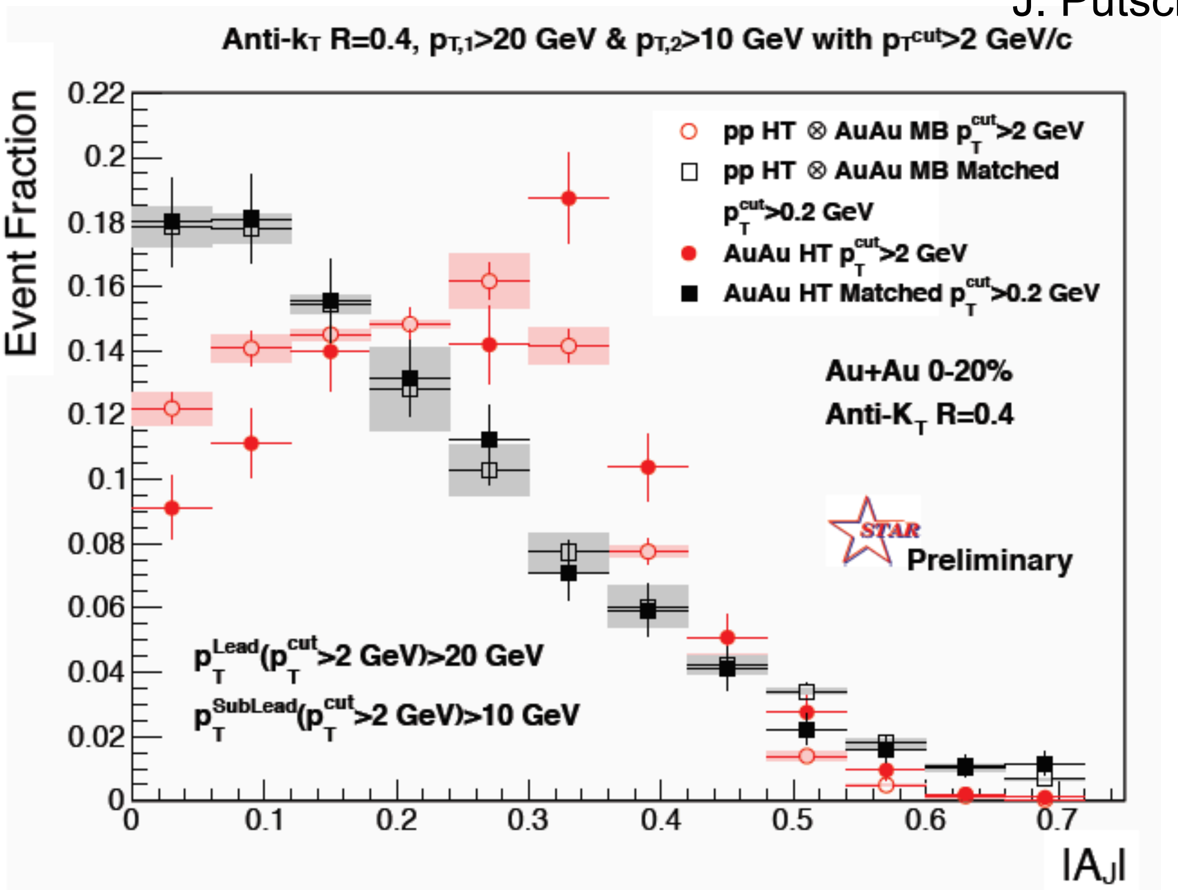
Sys. Uncertainties:
- tracking eff. 6%
- tower energy scale 2%

Au+Au di-jets more imbalanced than p+p for p_T^{cut}>2 GeV/c

J. Putschke, STAR, QM14

STAR, Dijet imbalance Au+Au 0-20% R=0.4

J. Putschke, STAR, QM14

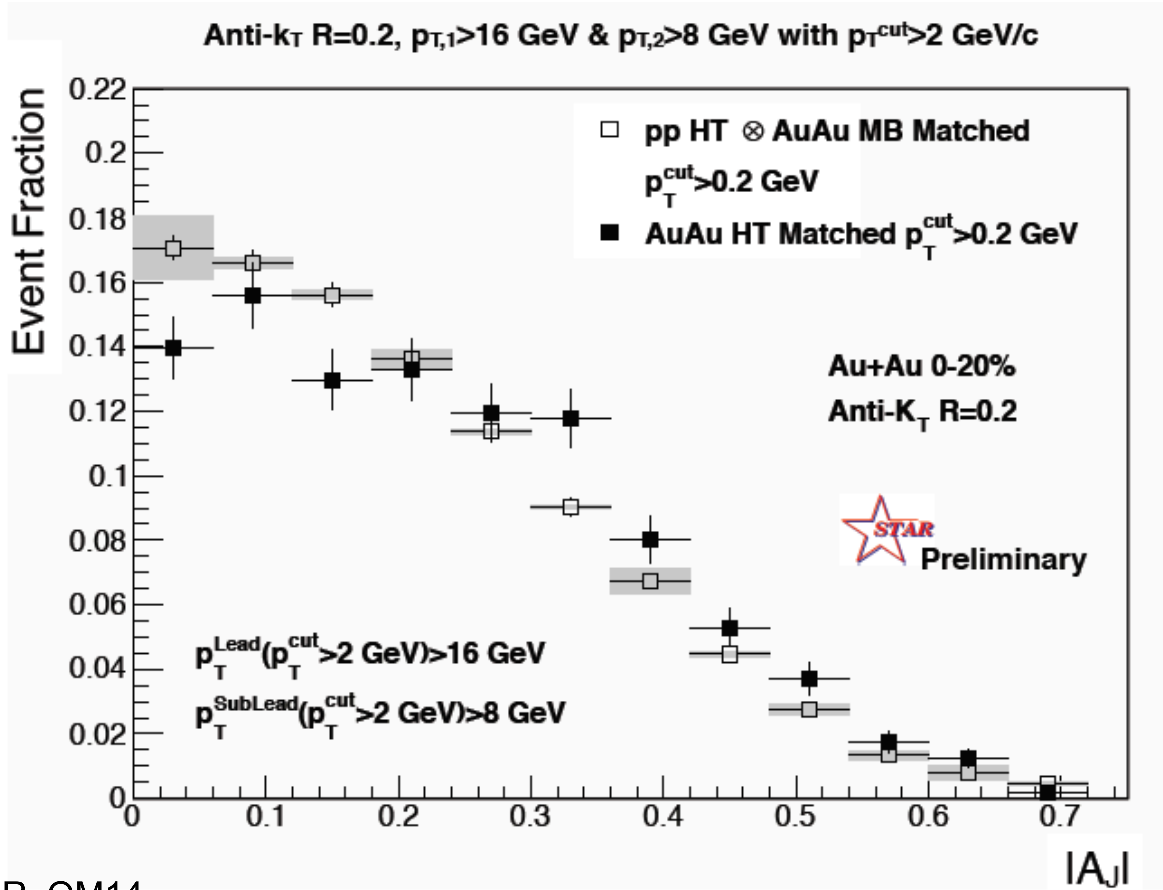


Sys. Uncertainties:
- tracking eff. 6%
- tower energy scale 2%

Au+Au di-jets more imbalanced than p+p for p_T^{cut}>2 GeV/c

Au+Au A_J ~ p+p A_J for matched di-jets (R=0.4)

Dijet imbalance with R=0.2, matched

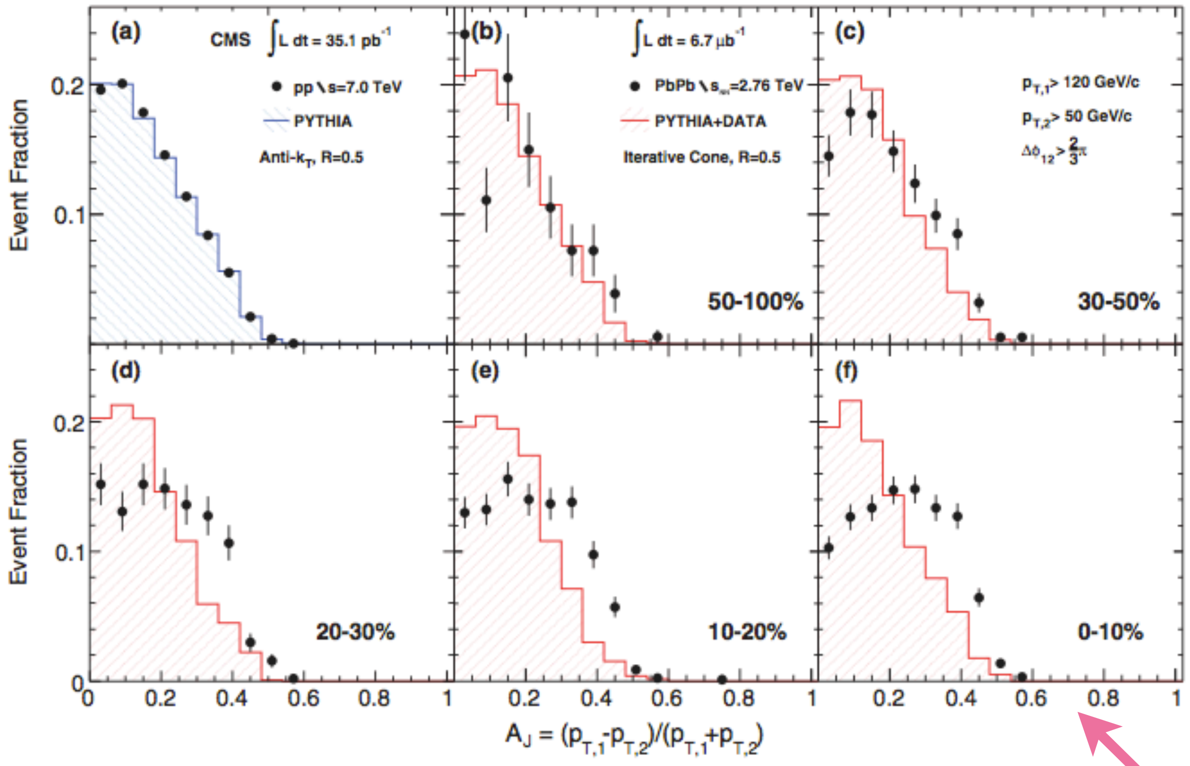


Sys. Uncertainties:
- tracking eff. 6%
- tower energy scale 2%

J. Putschke, STAR, QM14

Matched Au+Au $A_J \neq$ p+p A_J for R=0.2
→ (recoil) Jet broadening in 0.2 – 0.4

Comparison to LHC: Jet quenching via dijet imbalance



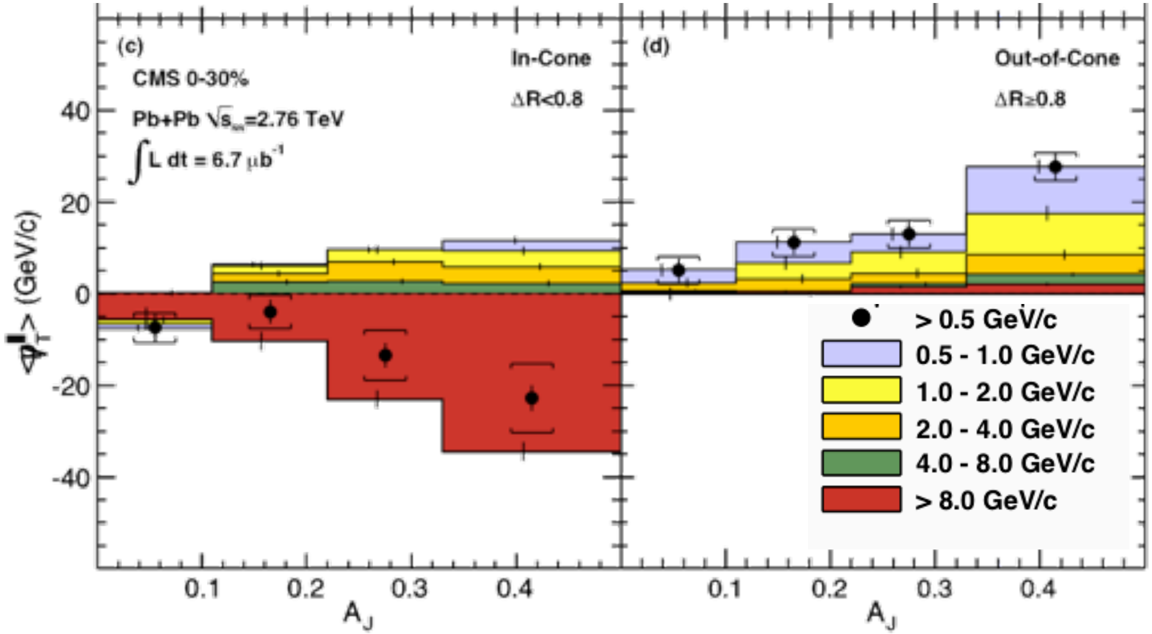
Observation of highly unbalanced dijet events in central PbPb collisions -> evidence for energy loss in medium or "jet quenching"

Where did the lost energy go?

CMS result from 2011: Look at track-jet correlations

-> RHIC and LHC differ: **in LHC lost energy is moved from large to small PT and from small to large angles namely outside the leading and subleading jets cones.**

CMS, PRC 84 (2011) 024906



Color decoherence can lead to large angle emission

N. Armesto et al, 1207.0984
K. Tywokiuk et al 1401.8293

Colored bands show contribution to pT for five pT ranges

Dijet balance (or imbalance) characterization:

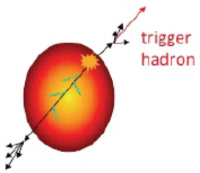
$$A = (p_{T1} - p_{T2}) / (p_{T1} + p_{T2})$$

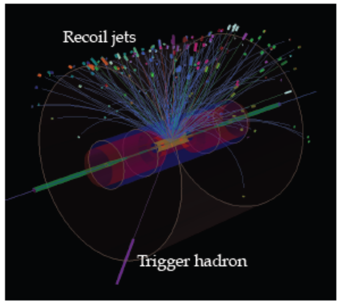
Recoil jets SameEvent-MixedEvent (SE-ME) pT(trig)> 9 GeV

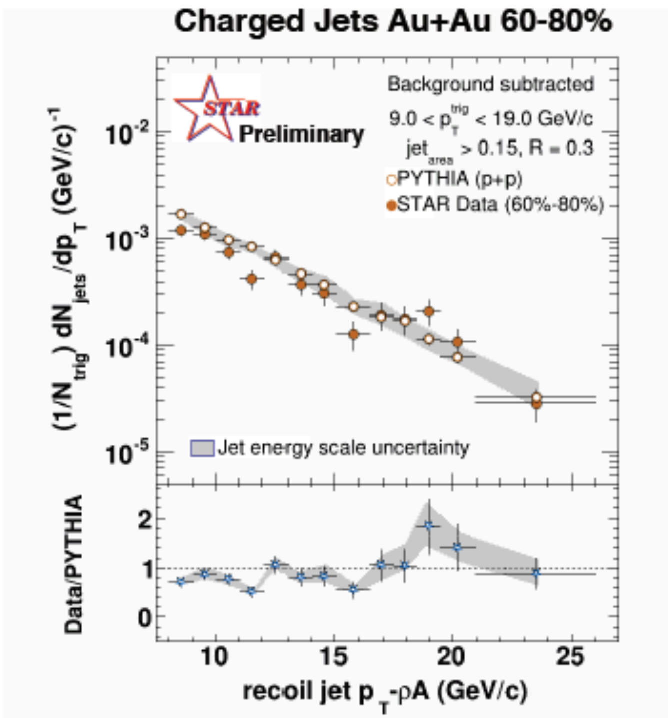
Au+Au background subtracted distributions (SE-ME):

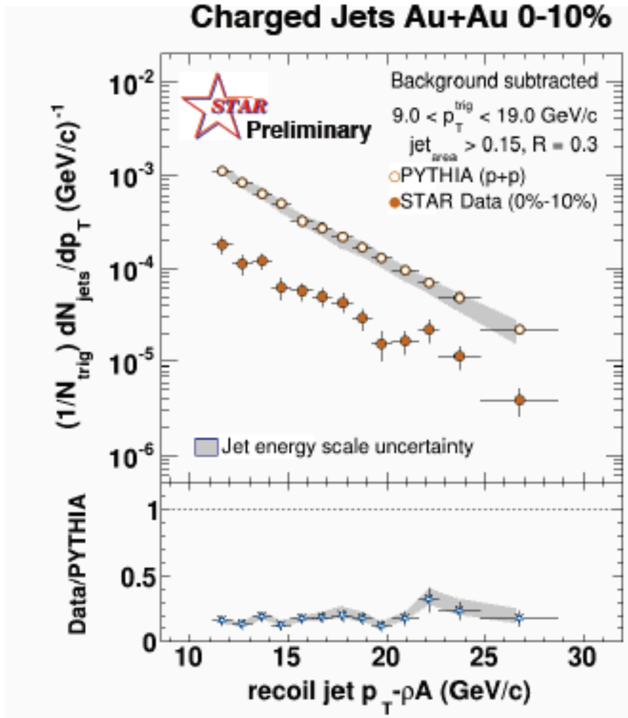
- *Ultimately:* Correct to particle level via unfolding of bkgd fluctuations and detector effects
- *Currently:* Compare to PYTHIA p+p distribution “smeared” by these effects

Dominant sys uncertainty: Tracking eff. → Jet energy scale (JES) uncertainty ~7%





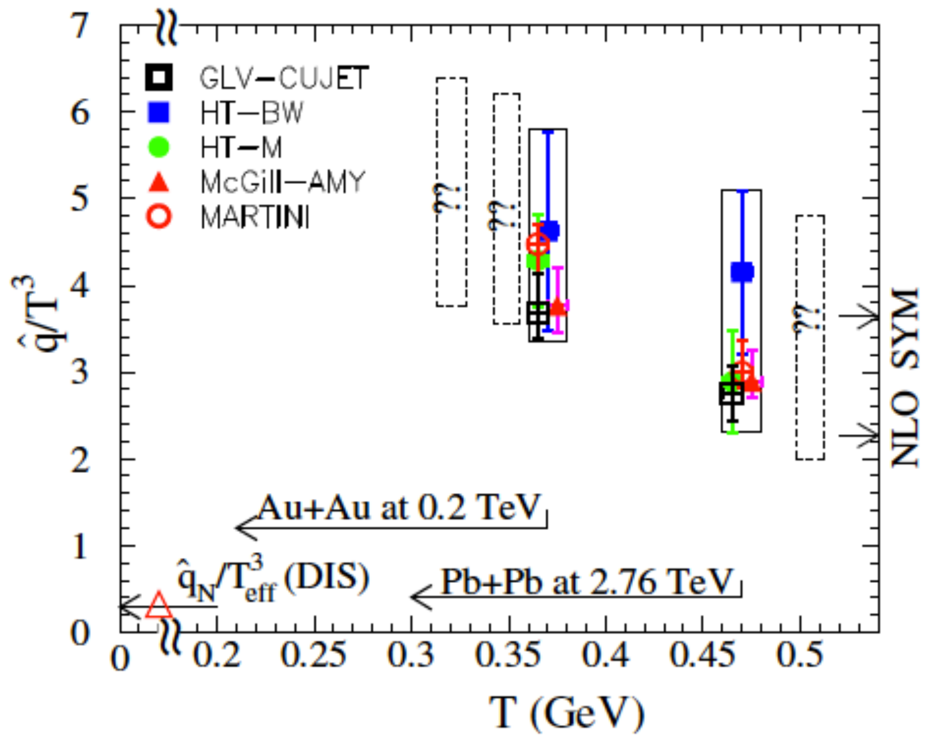




Peripheral Au+Au: Good agreement between data and PYTHIA

Central Au+Au: Strong suppression (relative to PYTHIA)

Scaled jet transport parameter q-hut/T^3



K. Burke et al, JET collaboration, 1312.5003

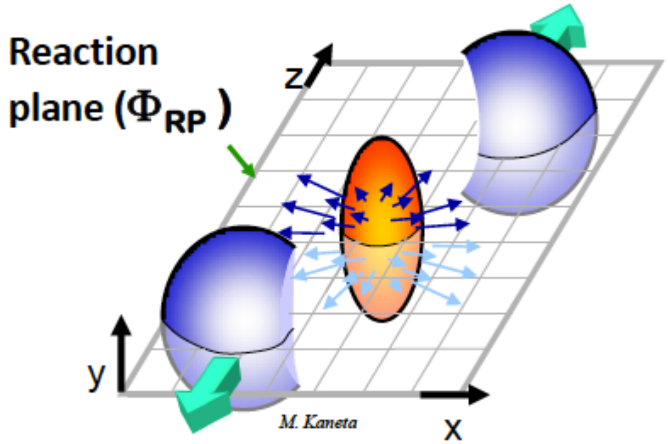
Dashed boxes show expected values for sqrt(s)=0.063, 0.130 and 5.5 TeV

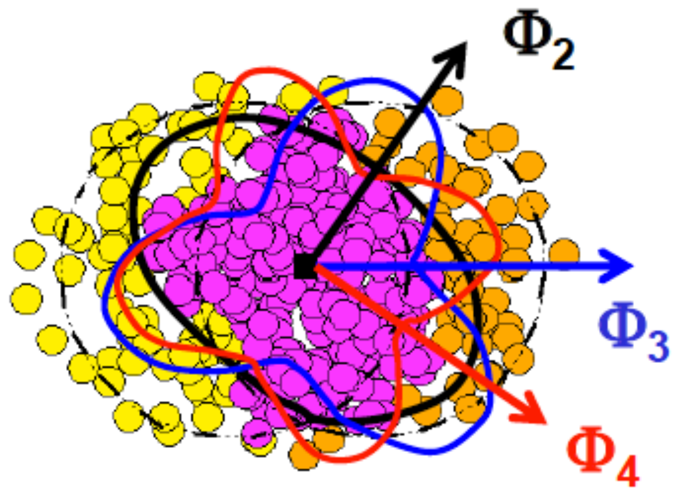
Results from JET collaboration agree with results from AdS/CFT correspondance shown here with the arrows named NLO SYM

$$\hat{q} \approx \begin{cases} 1.2 \pm 0.3 \\ 1.9 \pm 0.7 \end{cases} \mathrm{GeV}^2/\mathrm{fm} \ \text{at} \ \begin{matrix} \mathrm{T{=}370\ MeV} \\ \mathrm{T{=}470\ MeV} \end{matrix}$$

5. Collectivity and d+Au

Flow coefficients v_n, n=1,2,3..





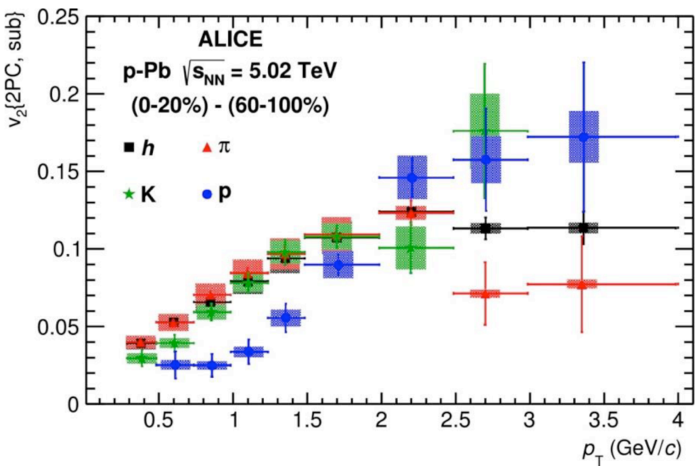
* Spatial anisotropy of interaction region -> momentum anisotropy

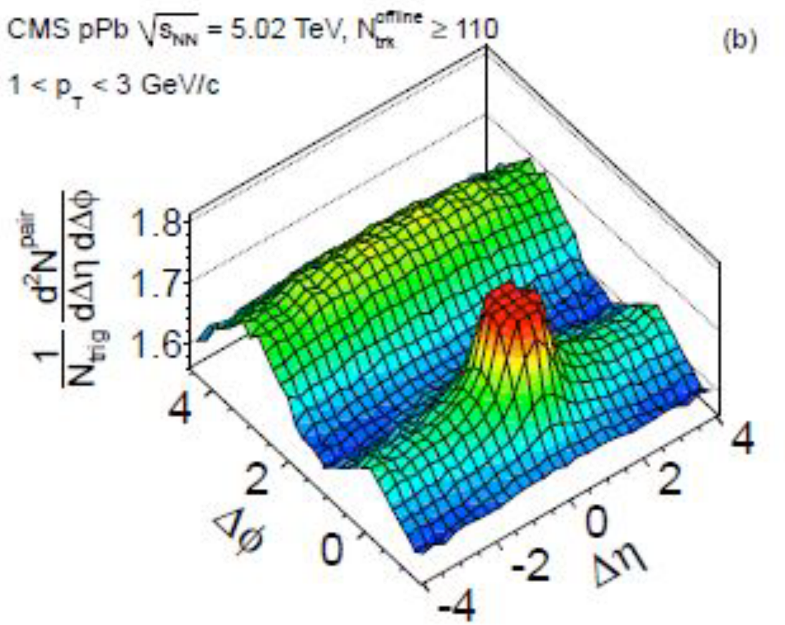
* Measured as coefficients v_n of the Fourier series (v1 - directed flow, v2 - elliptic flow, ...)

$$\frac{dN}{d\phi} \propto 1 + 2\sum_{n=1}^{\infty} v_n \cos[n(\phi - \Phi_n)]$$

$$v_n = \langle \cos[n(\phi - \Phi_n)] \rangle$$

Collectivity in small systems





ALICE: Physics Letters B 726 (2013)
ATLAS: Phys. Rev. Lett. 110(2013)
CMS: Phys. Lett. B 7198(2013

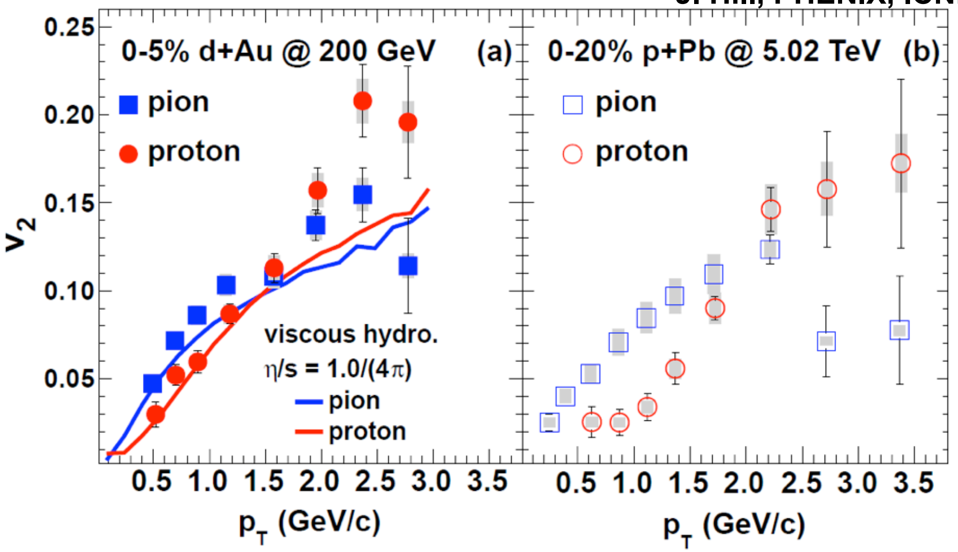
J. Hill, PHENIX, ICNFP2014

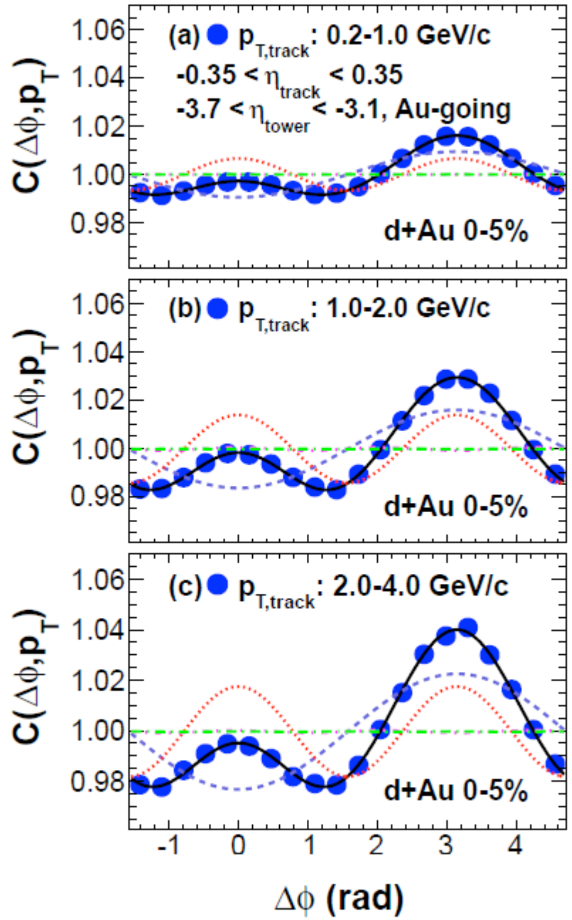
Flow and long range correlations ("ridge") observed in p+Pb at 5.05 TeV at the LHC

What about d+Au at RHIC?

v2 and "ridge" observed in d+Au at RHIC

J. Hill, PHENIX, ICNFP2014



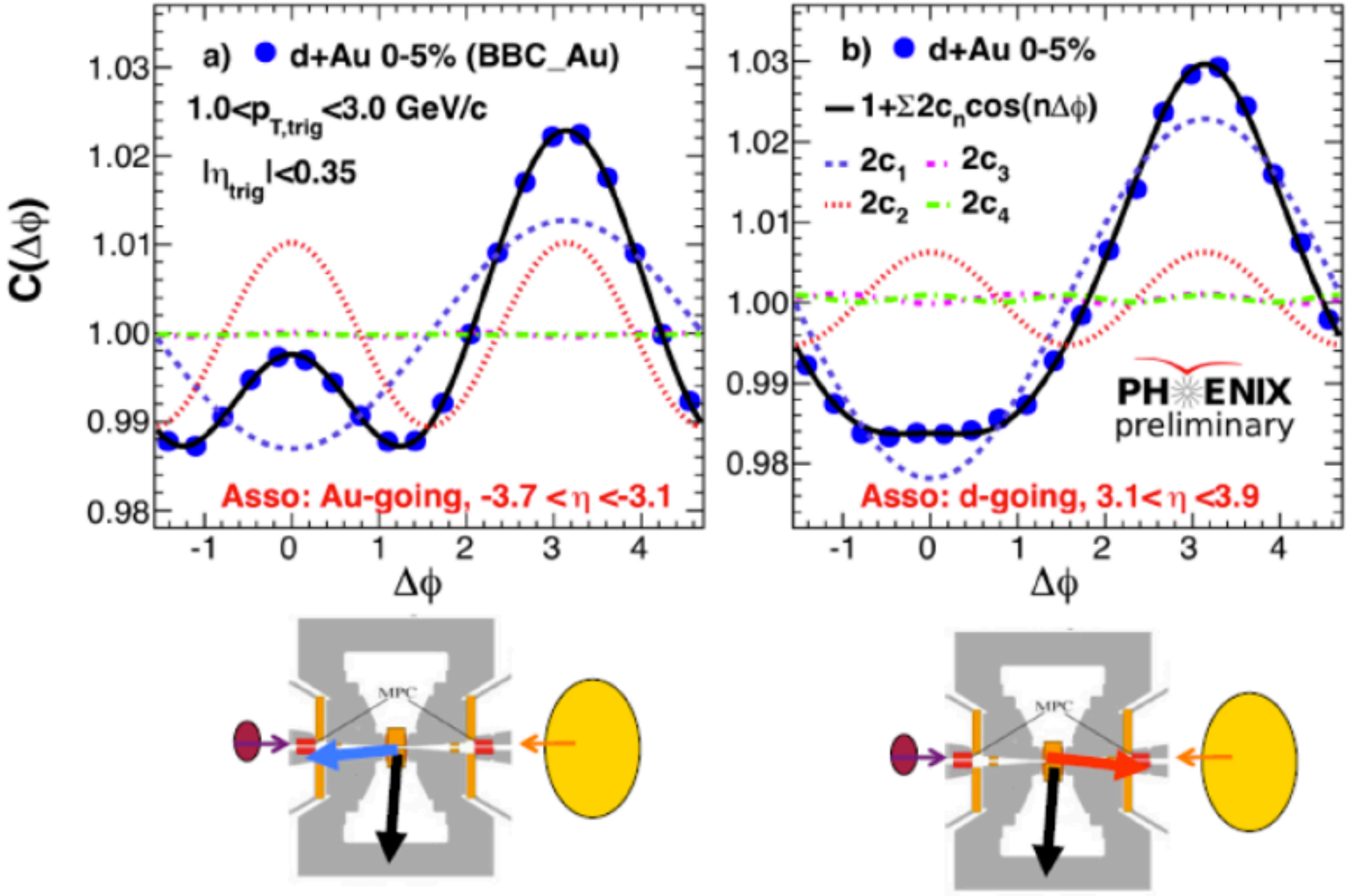


* Mass splitting observed in d+Au and p+Pb
* Viscous hydrodynamics describes d+Au below pT~ 2 GeV

"Ridge" search:

* Use one track in central arm and one in the forward calorimeter
* d+Au shows a near side peak (ridge) in 0-5% events and Au-going side.
* The ridge is increasing with centrality (not shown here)

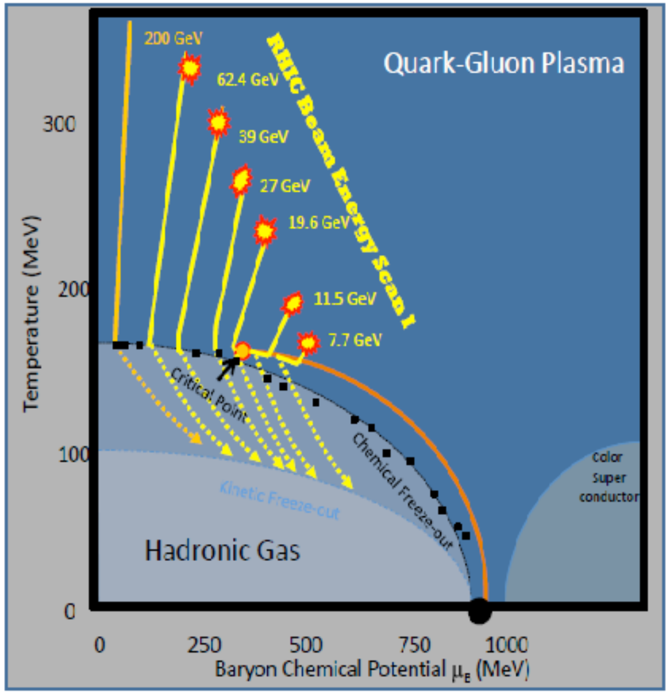
Compare d-going and Au-going sides

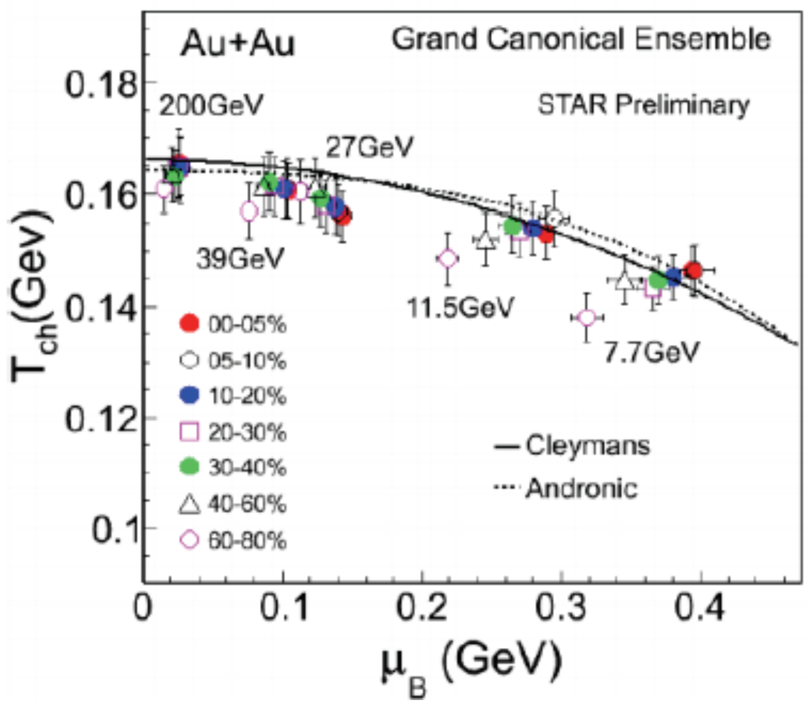


Ridge appears only in Au-going side.

6. Beam energy scan

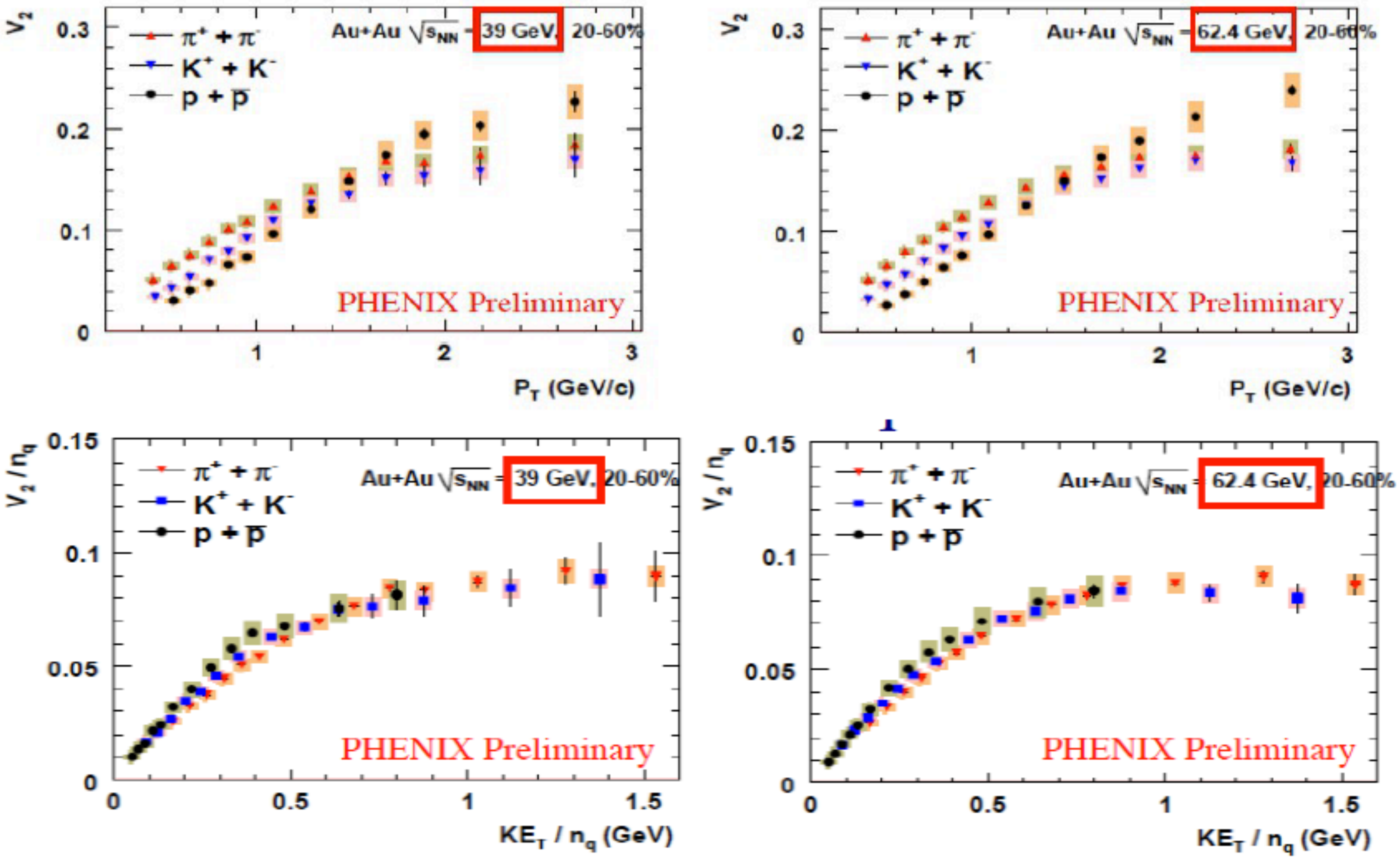
Chemical freeze out temperature vs baryochemical potential





Model used for particle ratio fits: THERMUS by J Cleymans et al

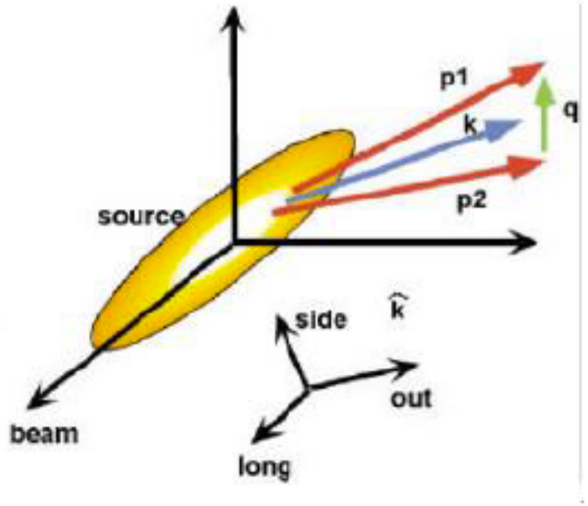
PHENIX v2 of identified particles in BES

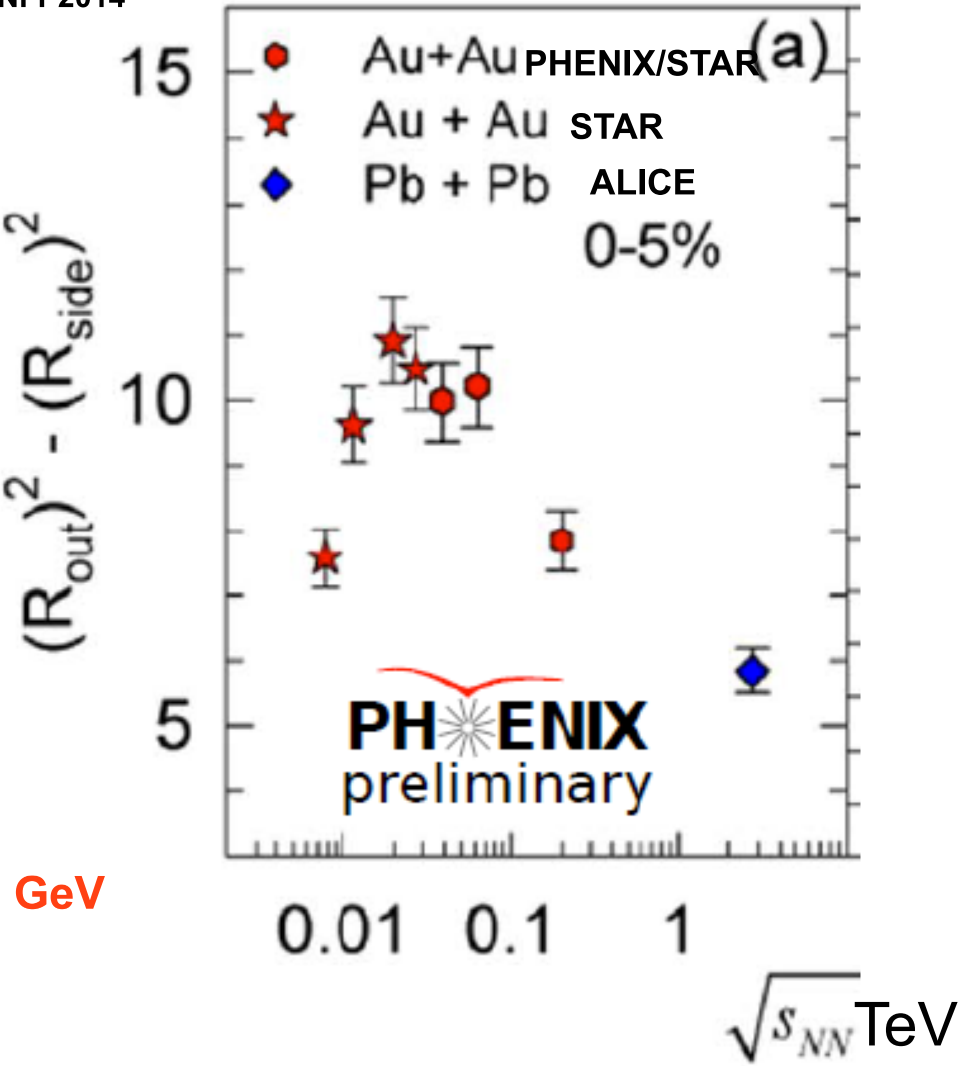


$$KE_T = M_T - M_0 = \sqrt{(M_0^2 + P_T^2)} - M_0$$

Beam energy dependence PHENIX/STAR: HBT

J. Hill, PHENIX, ICNFP2014



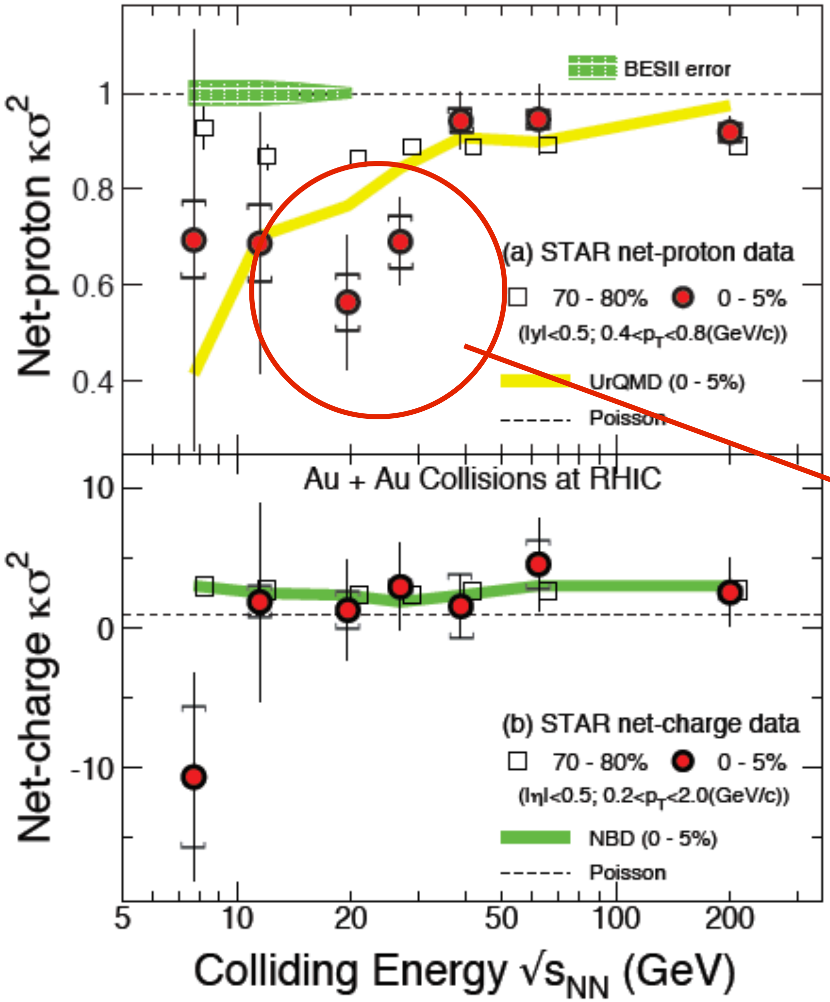


* (Rout)^2 - (Rside)^2 is a proxy for emission duration

* It has a maximum around sqrt(s)=30 GeV

High moments net-protons STAR

S. Shi, STAR, ICNFP 2014



Sensitive to critical point (ξ correlation length):

$$\langle(\delta N)^2\rangle \approx \xi^2, \langle(\delta N)^3\rangle \approx \xi^{4.5}, \langle(\delta N)^4\rangle \approx \xi^7$$

$$S\sigma \approx \frac{\chi_B^3}{\chi_B^2}, \kappa\sigma^2 \approx \frac{\chi_B^4}{\chi_B^2}$$

Non-monotonic behavior would be indicative of existence of CP

Net-proton results:

- Deviations below Poisson for $\kappa\sigma^2$ at all energies. Relatively larger deviation at $\sqrt{s_{NN}}$~20GeV

STAR: **PRL112**, 32302(2014)

Net-charge results:

- No non-monotonic behavior
- More affected by resonance decays

STAR: arXiv: 1402.1558

Higher statistics needed for collisions at $\sqrt{s_{NN}}$ < 20 GeV

IV Conclusions and outlook

IV Conclusions and perspectives

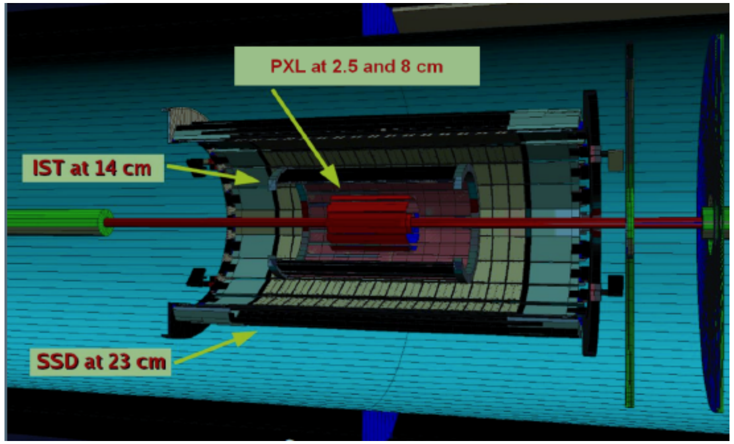
- Many exciting STAR and PHENIX new results are coming up and constrain the models, allowing together with the LHC data, the study of the energy dependence of QGP signatures and of the underlying physics.

- In run 15 RHIC plans to take p+p, p+Au and p+Al data.

Exciting prospects for in depth further studies of heavy ion physics at RHIC !

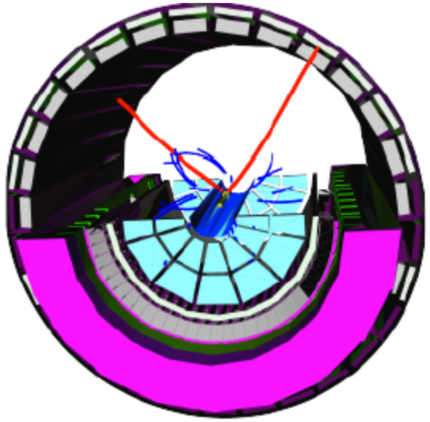
STAR outlook

Heavy Flavor Tracker



Expectations for 2014 run with HFT

Muon Telescope Detector



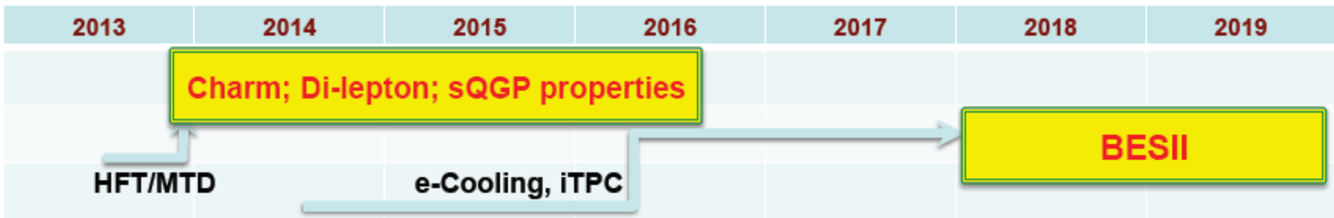
J/Psi event in p+p 500 GeV

* Both HFT and MTD have been fully installed and took data in 2014 (MTD was already 63% installed in 2013 and took data in 2013).

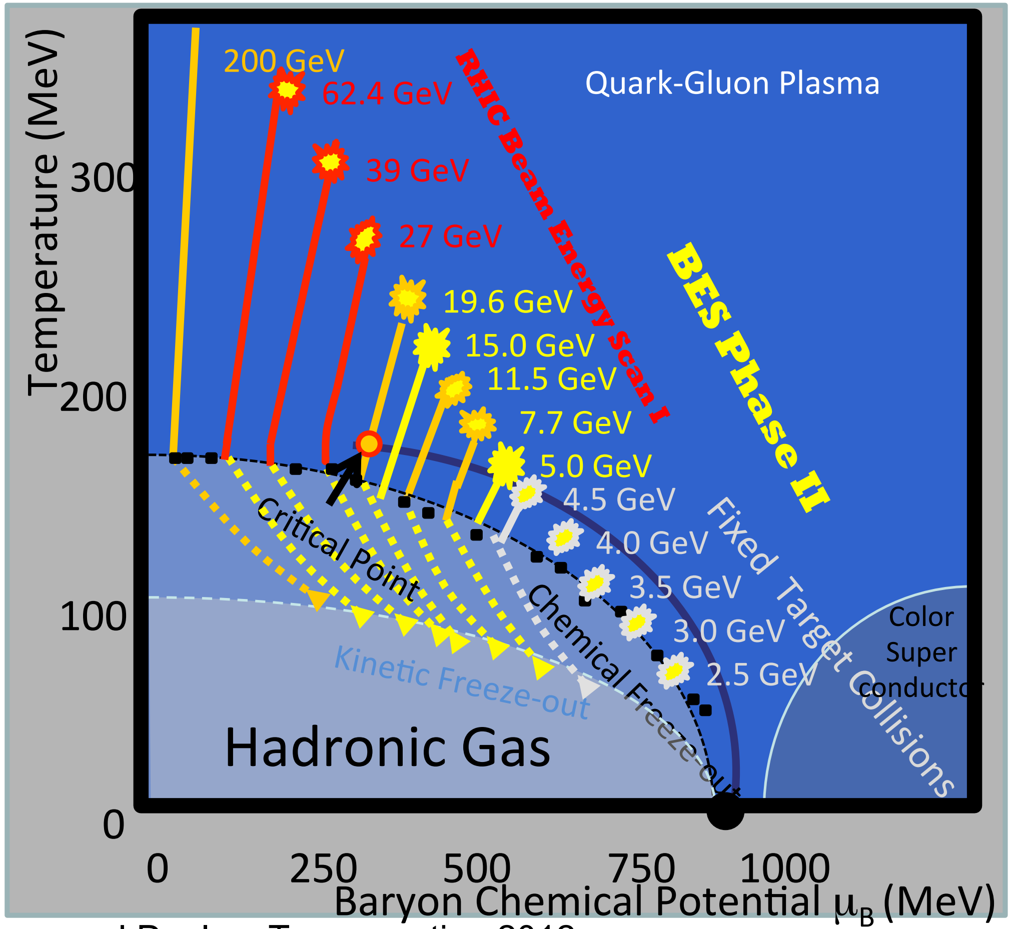
* Outlook: Heavy flavor program with new upgrades: new results from analysis of run 14 data with full HFT and MTD for Au+Au 200 GeV collisions. Also Au+Au 15 GeV and ^3He+Au.

BES II : <= sqrt(s)=20 GeV

S. Shi, ICNFP2014



Phase II of Beam Energy Scan at RHIC (2018-)



J Dunlop, Town meeting 2012

The power of RHIC:

Scan the region below √s=20 GeV

Supplemented by fixed target program in STAR to reach lower √s down to √s ~ 3 GeV

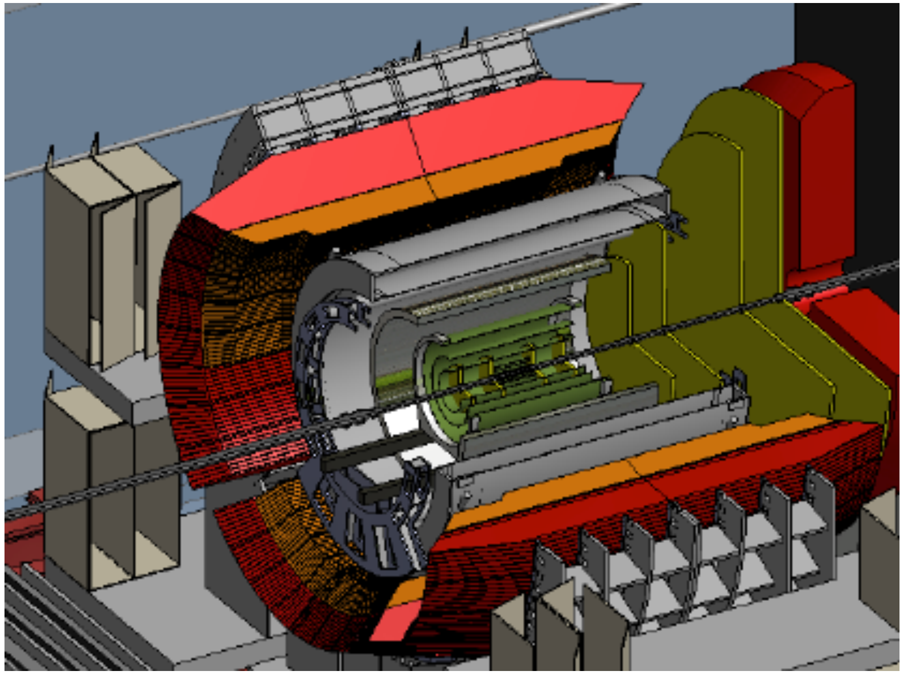
STAR BES II with up to 10 times more luminosity and detector upgrades (+iTPC) will be able to study with precision a large region of the QCD phase diagram

PHENIX outlook

-Wait for new results from VTX detector on c/b
-New results on Au+Au 200 GeV (and 15 GeV and ^3He+Au) from run 14

- sPHENIX moving forward (hadronic and electromagnetci calorimetry)

- Acquired 1.5 Tesla magnet of BaBar



Excitement about Electron-Ion Collider

PHENIX, QM2014

BaBar magnet and sPHENIX calorimetry are excellent foundation for an EIC Detector !
arXiv:1402.1209

Thank you very much for your attention