Quarkonia with STAR at RHIC

Sonia Kabana (SUBATECH and University of Nantes, France) on behalf of the STAR collaboration

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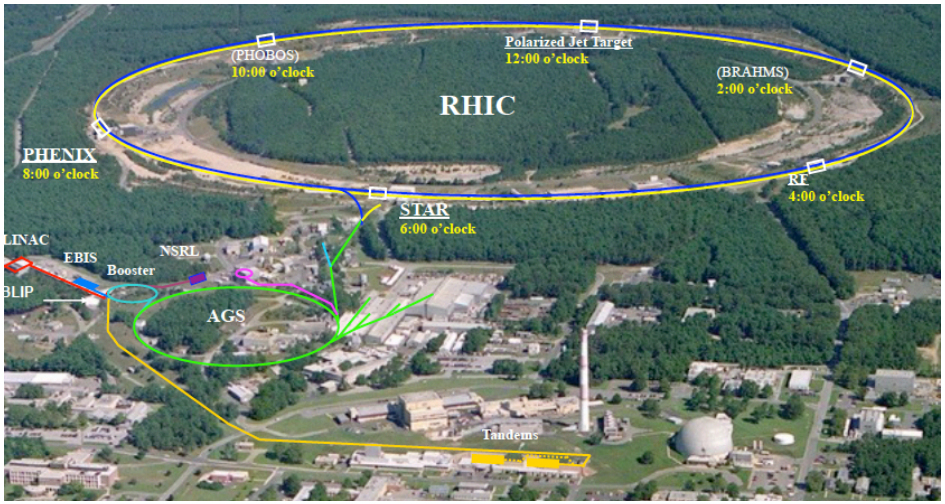


Outline

1- Introduction

2- STAR detector

3- J/Psi production

- p+p collisions
- Au+Au 200 GeV and U+U 193 GeV
- Energy dependence of J/Psi

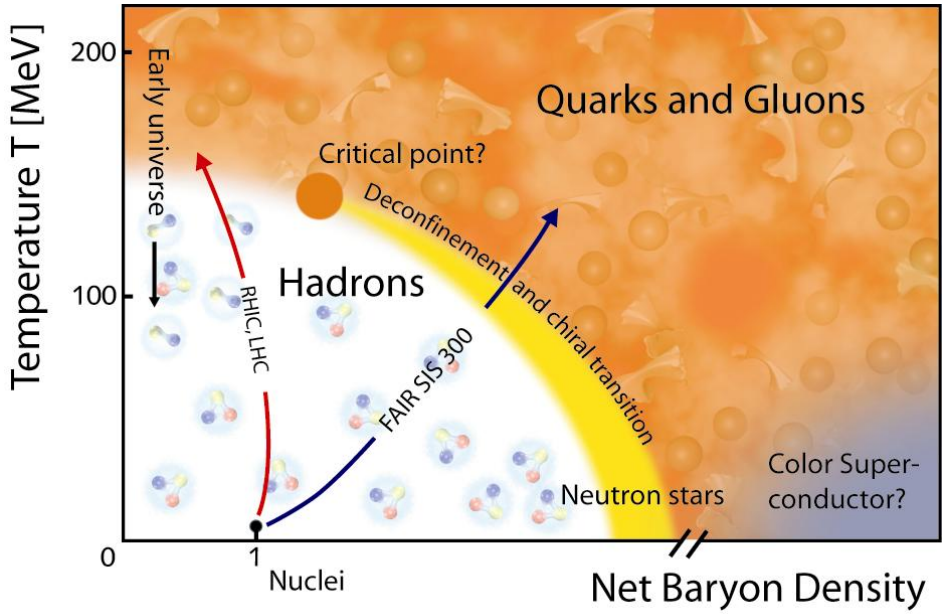
4- Upsilon production

- Au+Au 200 GeV and U+U 193 GeV

5- Conclusions

1- Introduction

The expected QCD phase diagram



Phases of QCD Matter

Areas of different net baryon densities and temperatures can be probed using different collision energies.

The order of the transition is expected to change with the net baryon density.

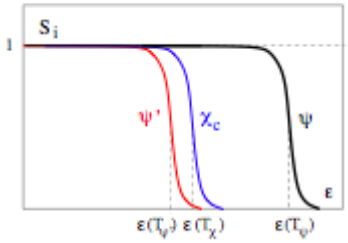
Heavy Ion Program of STAR: explore experimentally the QCD phase diagram (QCD phase transition, critical point, properties of the QGP).

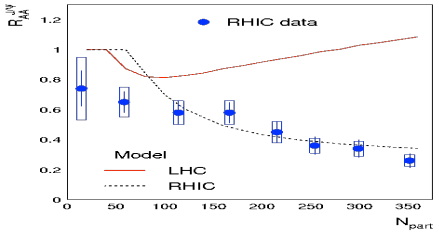
Quarkonia and Quark Gluon Plasma physics

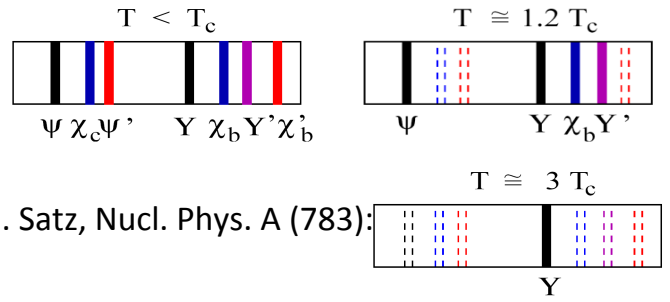
Quarkonia as QGP signature:

Quarkonia: Thermometer of QGP via their sequential suppression in heavy ion collisions due to color screening in QGP (Matsui, Satz, Nucl. Phys. A (783):249-260(2007))

Quarkonia enhancement as QGP signature due to recombination of c and cbar at hadronization time (A Andronic, P Braun Munzinger, J Stachel)







H. Satz, Nucl. Phys. A (783):

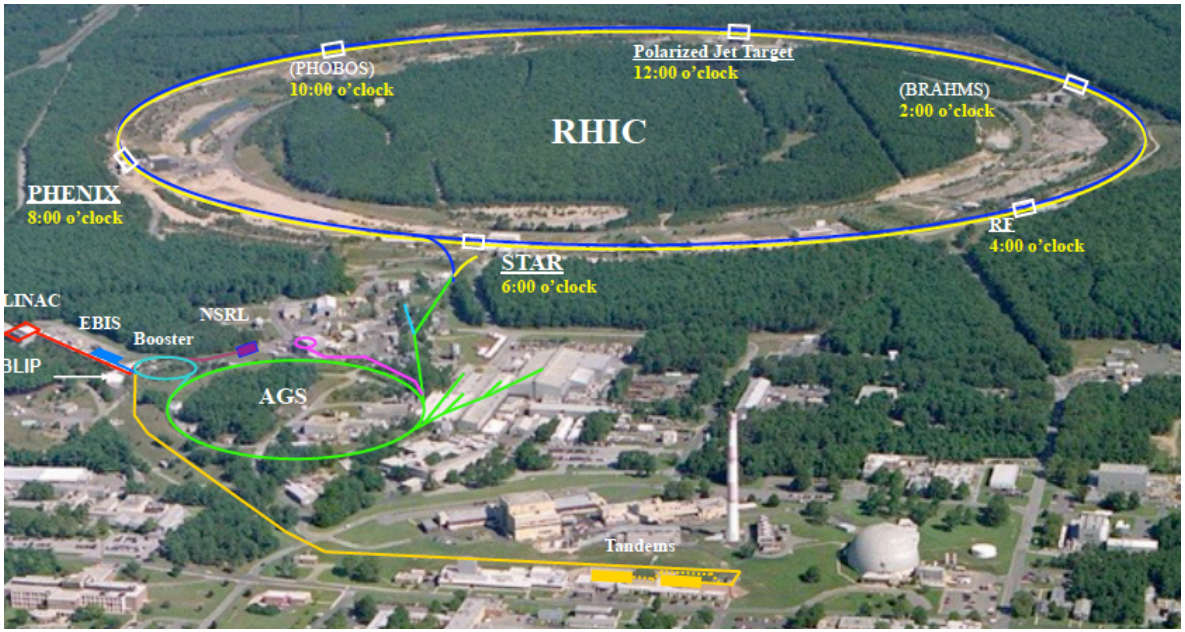
Other approaches e.g.: Quarkonia production mechanism with a double scattering correction etc; B. Kopeliovich et al (2015).

Many effects play a role, like dissociation in QGP, cold matter absorption, recombination/coalescence from c, cbar, feeding, eg B mesons carry 10-25% of charmonia yields (B->J/Psi from J/Psi-h correlation STAR measurement)

2- STAR detector

Relativistic Heavy Ion Collider

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



RHIC has been exploring nuclear matter at extreme conditions since 2000

4 experiments:
STAR PHENIX
BRAHMS PHOBOS

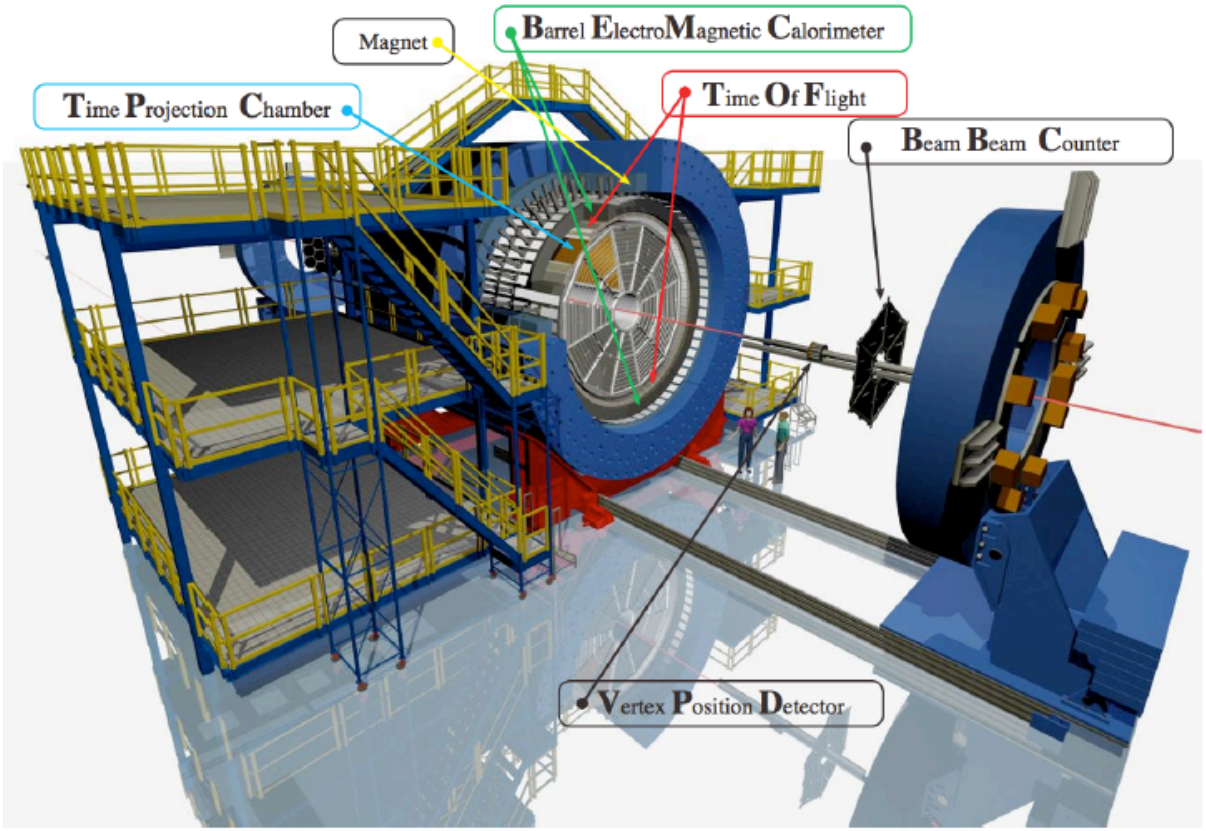
Colliding systems:

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

STAR detector



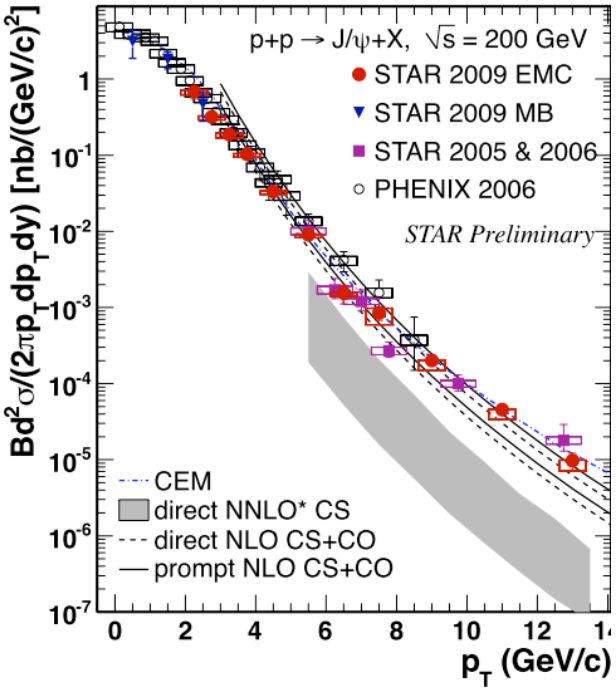
Particle identification mainly via
- de/dx in the TPC
- topological decay reconstruction in TPC for eg strange particles, D mesons
- TOF
- Barrel EMCal (used also as fast online trigger)

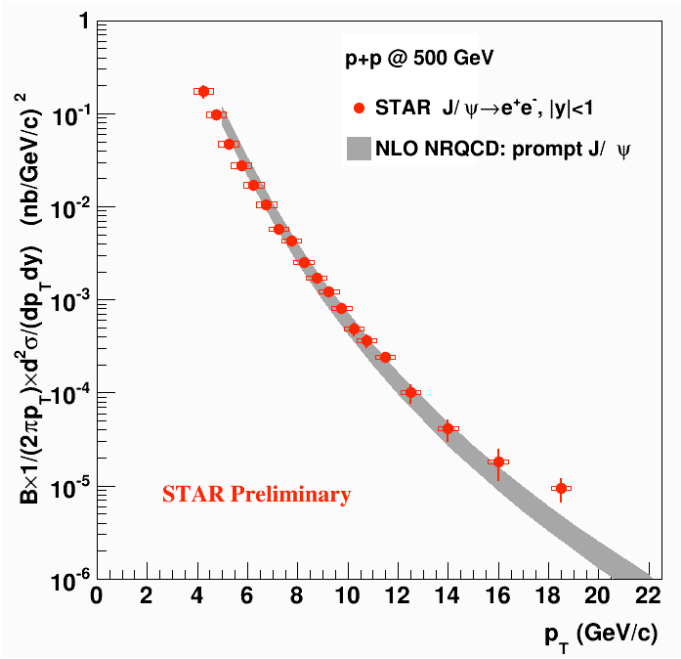
Some recent Upgrades: Muon Telescope Detector (MTD, 2013) and Heavy Flavor Tracker (HFT, 2014)

3- J/Psi production

J/Psi in p+p collisions

STAR: JPG38, 124107(2011), PRC80, 041902 (2009), PRC82, 012001 (2010)





NLO NRQCD: Phys.Rev.Lett. 106 (2011) 042002, Phys Rev. D84 (2011) 114001, JHEP 1505 (2015) 103

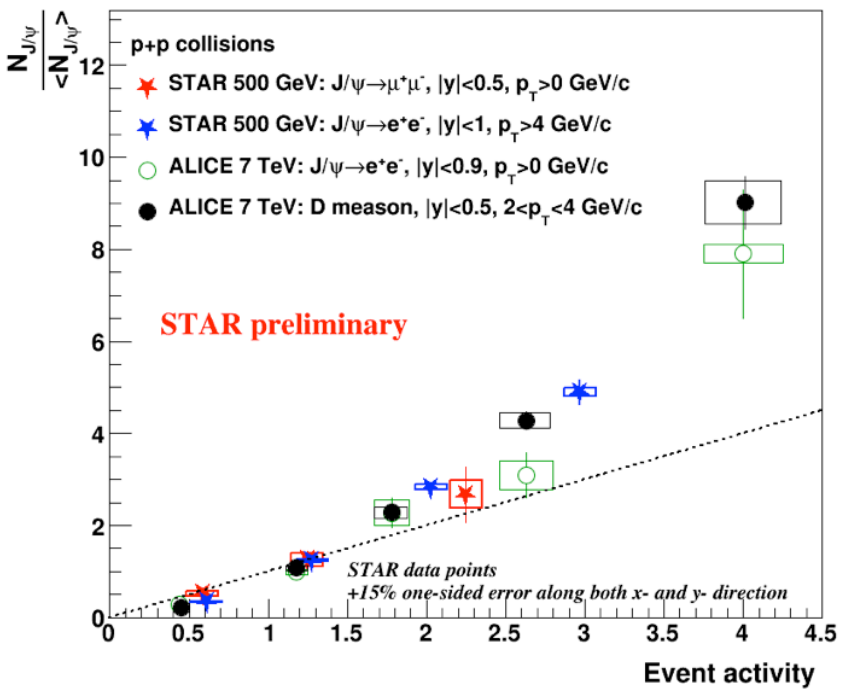
J/Psi in p+p collisions at 200 (left) and 500 GeV (right):

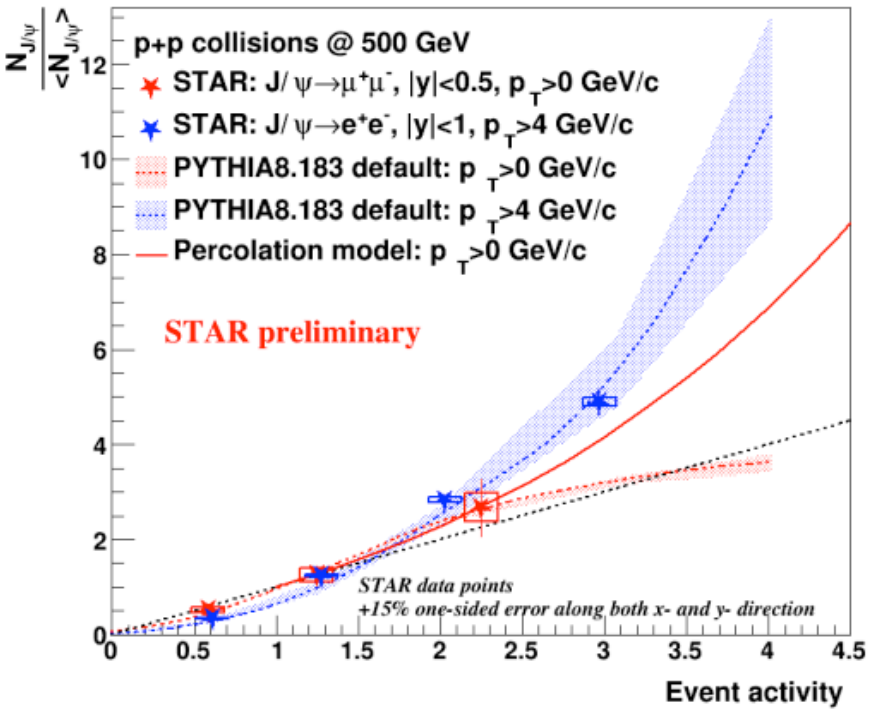
-p+p 200 GeV: NNLO* Color Singlet model direct J/Psi production misses data (high pT)

Prompt Color Evaporation Model (CEM) can reasonably describe the spectra

- pp 500 GeV : NLO NRQCD prompt production describes the data for pT> 4 GeV

J/Psi in pp collisions at 500 GeV vs event activity



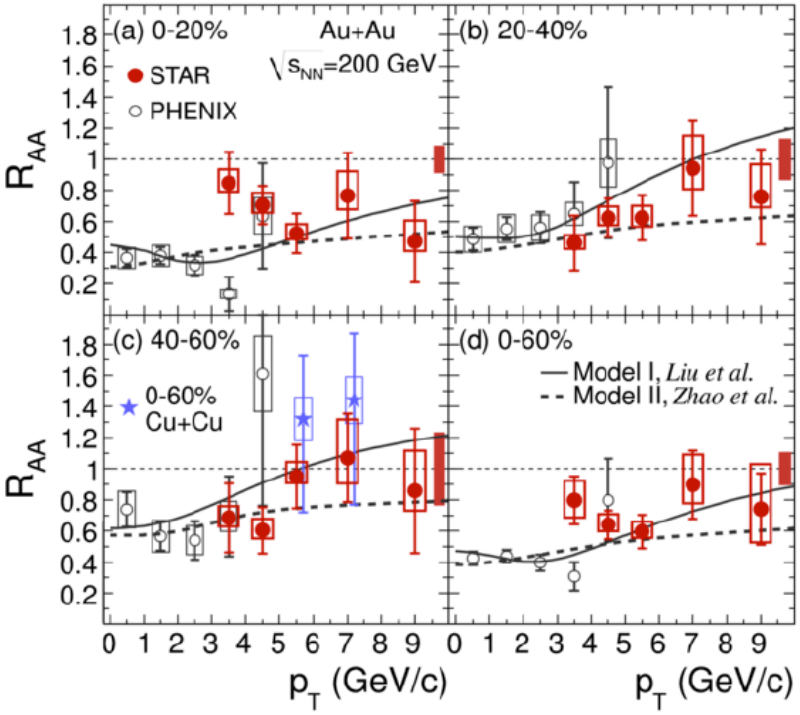


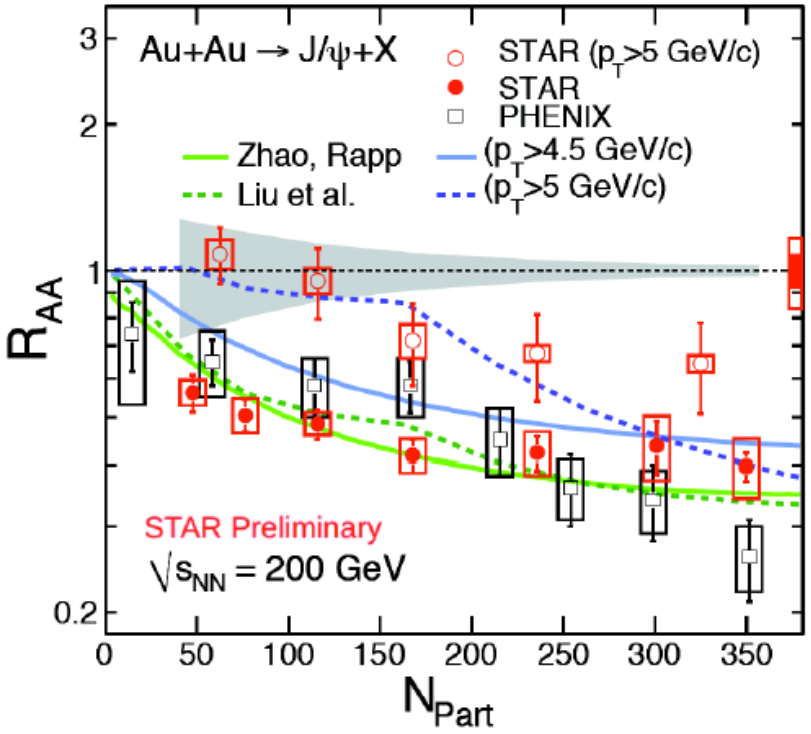
- J/psi increases more than linearly with the multiplicity (“event activity”) in p+p collisions at 500 GeV
-The rising seem to be faster for high pT at RHIC and LHC

Models shown:
Multiple parton-parton interactions - PYTHIA 8
String screening – percolation model, PRC 86 (2012) 034903

p_T dependence of J/Psi suppression in Au+Au, Cu+Cu 200 GeV

PLB 722 (2013) 55

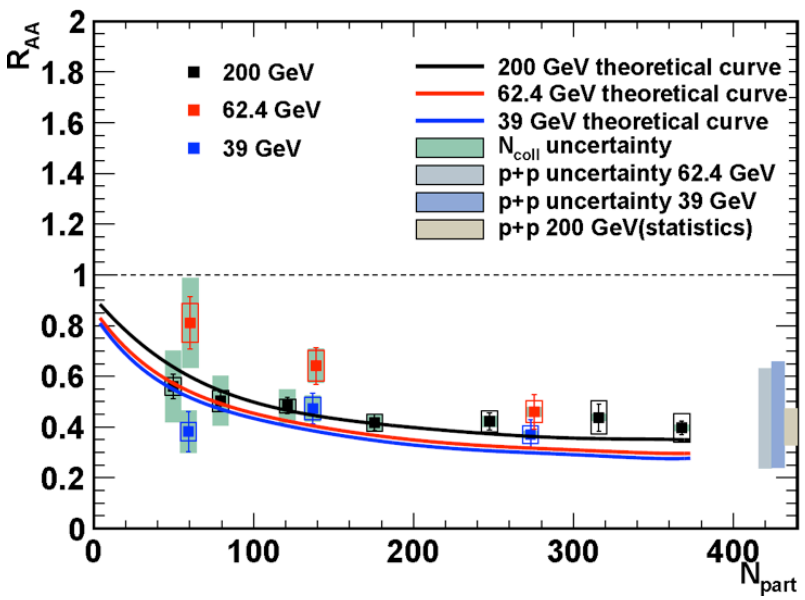


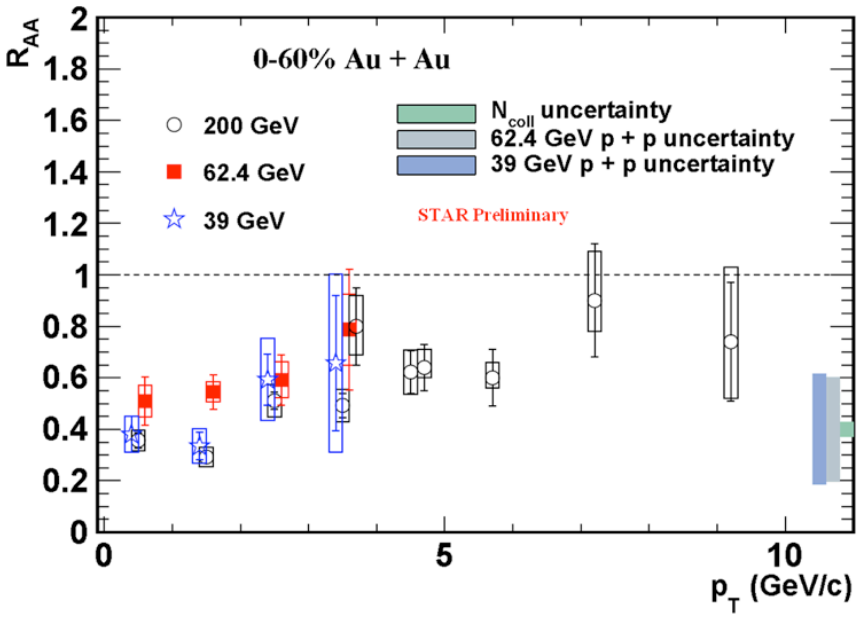


Liu et al, PLB 678 (2009) 72
Zhao et al, PRC 82 (2010) 064905

- J/Psi not suppressed at high p_T's in non-central collisions
- J/Psi suppressed at all p_T's for most central events
- R_{AA} of J/Psi is systematically larger for higher p_T. Low pT J/Psi is more suppressed.
  High pT region: less influenced by recombination and Cold Nuclear Matter effects
- Models with suppression of initial production and recombination describe the J/Psi data

J/Psi and Beam Energy Scan





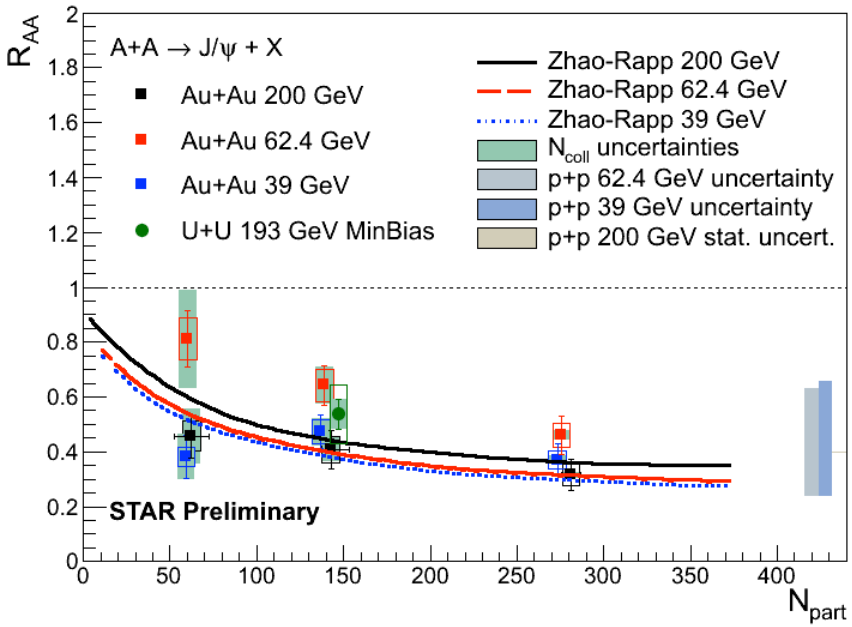
Note: the J/Psi in p+p collisions used for the R_{AA} calculation for 39 and 62.4 GeV comes from model calculation (Color Evaporation Model, Nelson, Vogt et al., PRC87, 014908 (2013))

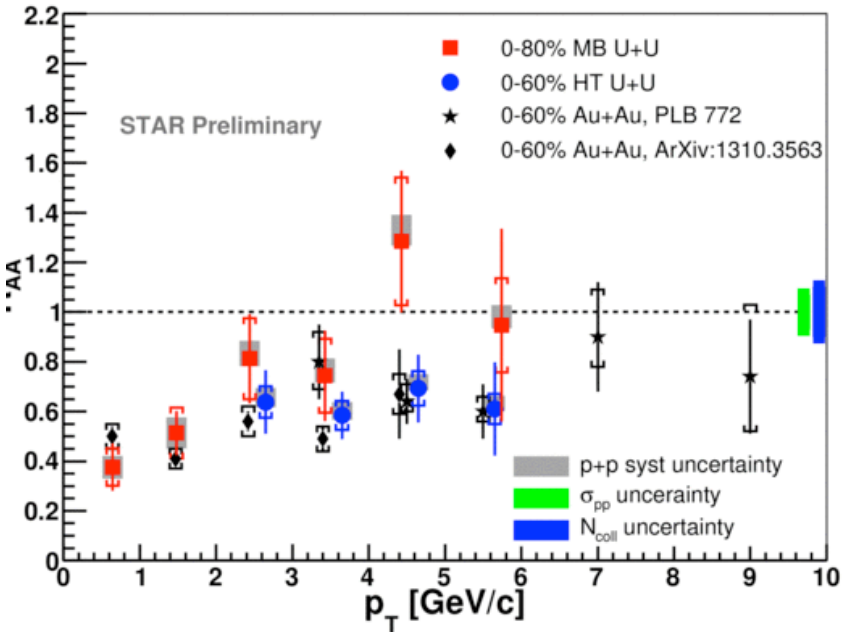
- RAA of J/Psi in Au+Au collisions is suppressed in similar way at 200, 62.4 and 39 GeV.

- Data agree with predictions from Theoretical R_{AA} curves: Zhao, Rapp PRC82, 064905 (2010)

- Almost **compensating interplay of melting and recombination**?

J/Psi in U+U 193 GeV



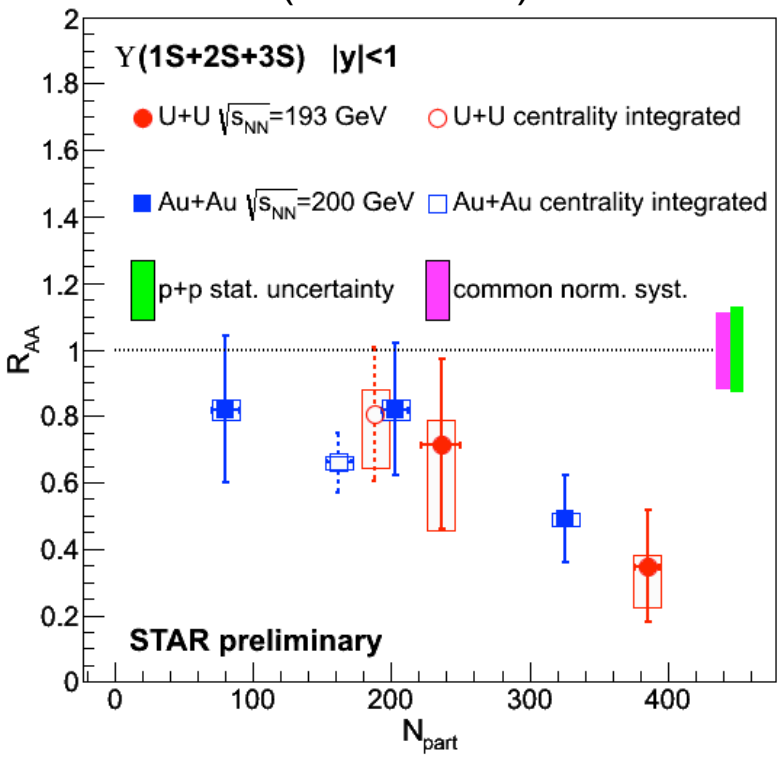


R_{AA} in U+U 193 GeV is consistent within errors with Au+Au 200 GeV

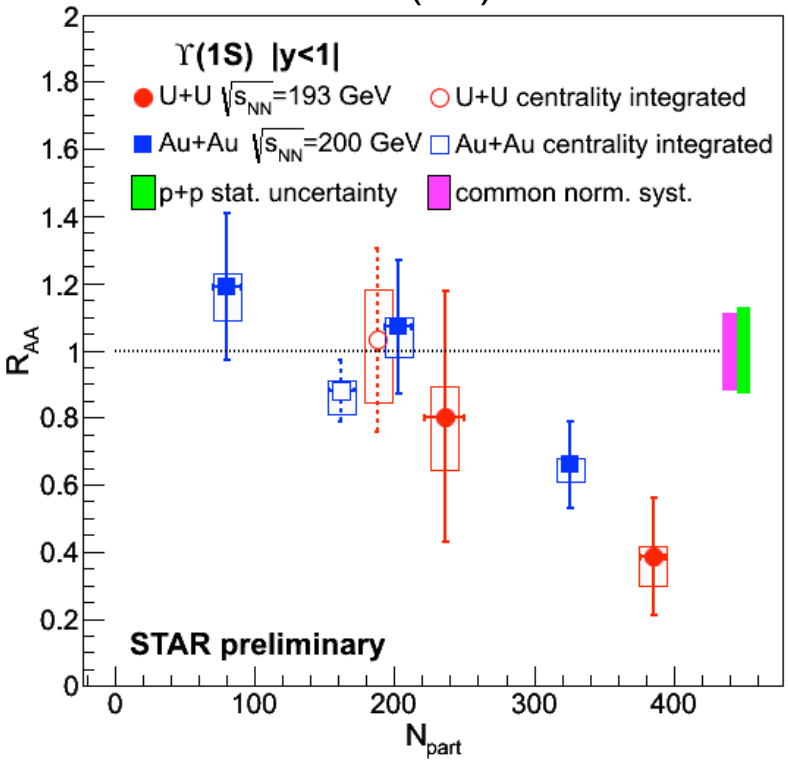
4- Upsilon production

Upsilon production in Au+Au and U+U collisions

Y(1S+2S+3S)

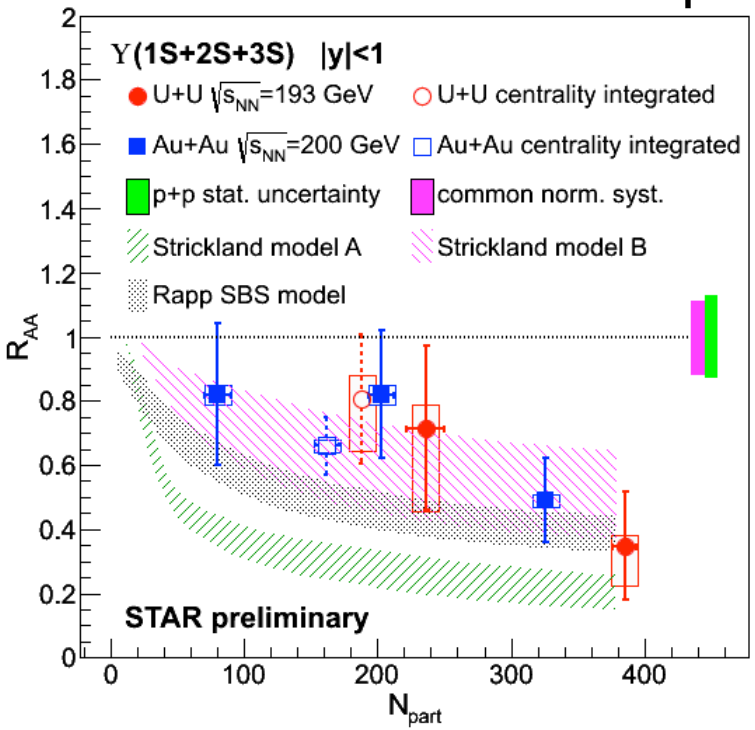


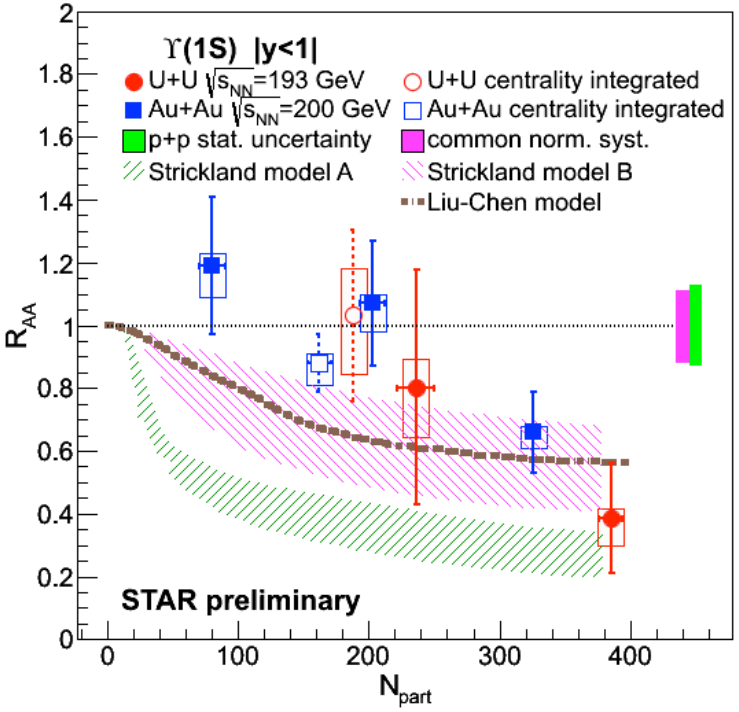
Y(1S)



Y(1S+2S+3S) and Y(1S):
R_{AA} not suppressed in peripheral A+A collisions
R_{AA} suppressed in central A+A collisions
Similar R_{AA} suppression pattern in central U+U and Au+Au collisions

Upsilon vs models





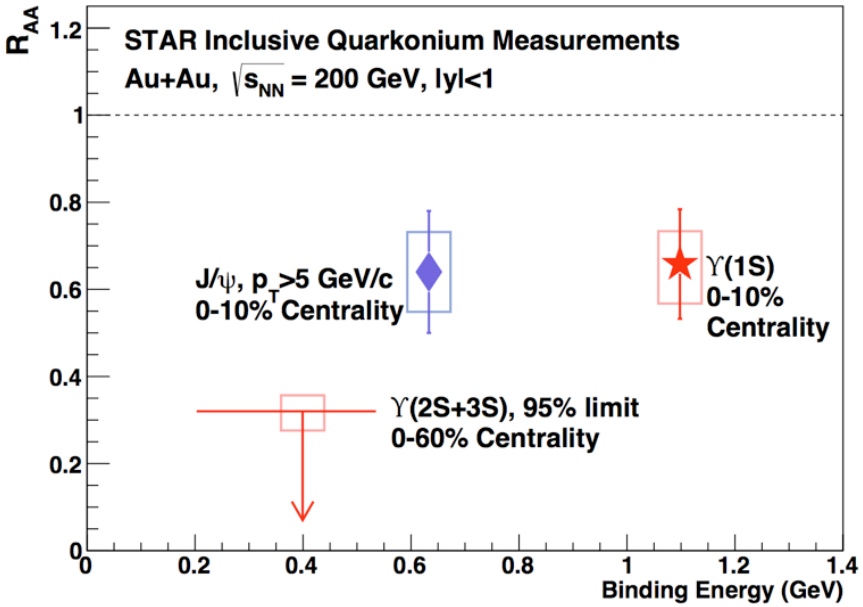
Model of Strickland, Bazov (Nucl. Phys. A 879, 25 (2012))
No Cold Nuclear Matter effects
T(initial)=428-443 MeV
Potential model A is based on heavy quark free energy (disfavored)
Potential model B is based on heavy quark internal energy

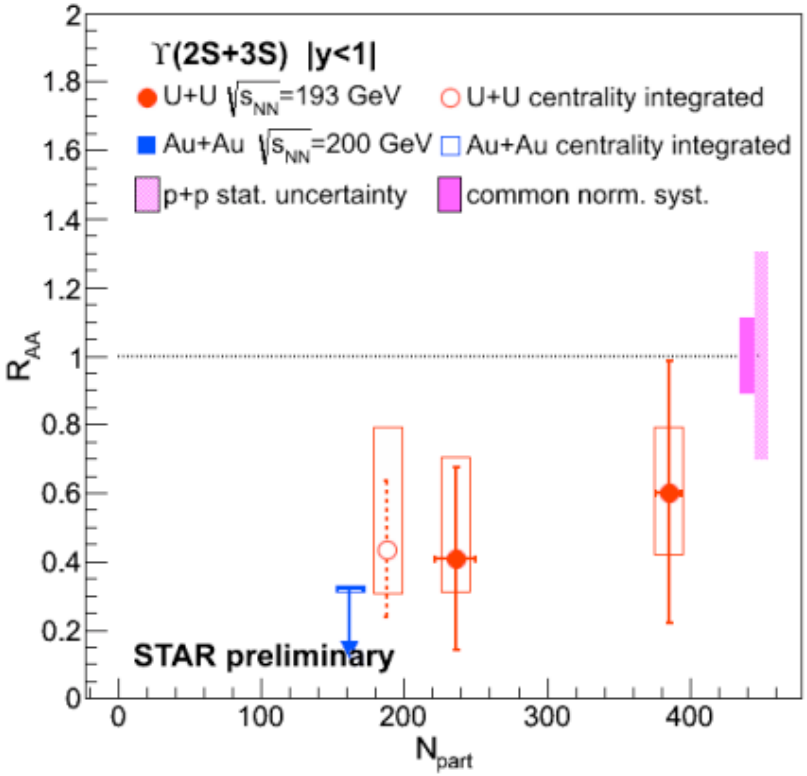
Model of Liu, Chen, Xu, Zhuang (Phys Lett B 697, 32 (2011)
Potential model, no Cold Nuclear Matter effects. T= 340 MeV

Model of Emerick, Zhaon, Rapp (Eur. Phys. J A48, 72 (2012))
Cold Nuclear Matter effects included

Y data in agreement with Y melting scenario

Quarkonia sequential suppression ?





- Au+Au 0-10%: Y(1S) similarly suppressed as J/Psi at high pT.
- Au+Au 0-60%: Y(2S+3S) consistent with complete melting/suppression (upper limits)
- U+U: centrality dependence pattern of Y(2S+3S) consistent with Au+Au Upper Limits

- J/Psi, Y(1S), Y(2S+3S) suppression pattern supports sequential melting.

Summary and outlook

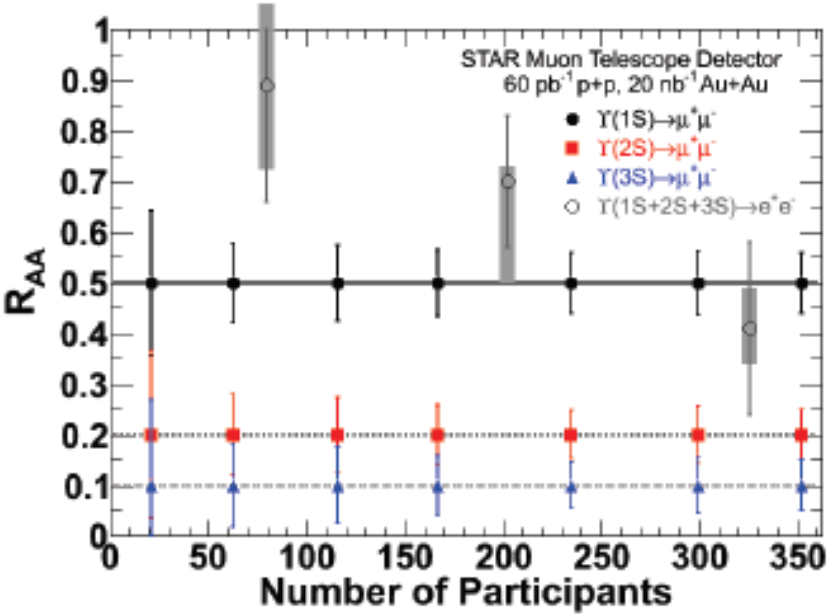
J/Psi pT spectra in p+p collisions described by pert. QCD models (NRQCD)
J/Psi increases faster than linearly with event multiplicity in p+p and the increase is faster for higher pT (pT>4 GeV)

J/Psi R_{AA} suppression is similar in Au+Au 200, 62.4, 39 GeV and U+U 193 GeV
-> interplay of melting and regeneration ?

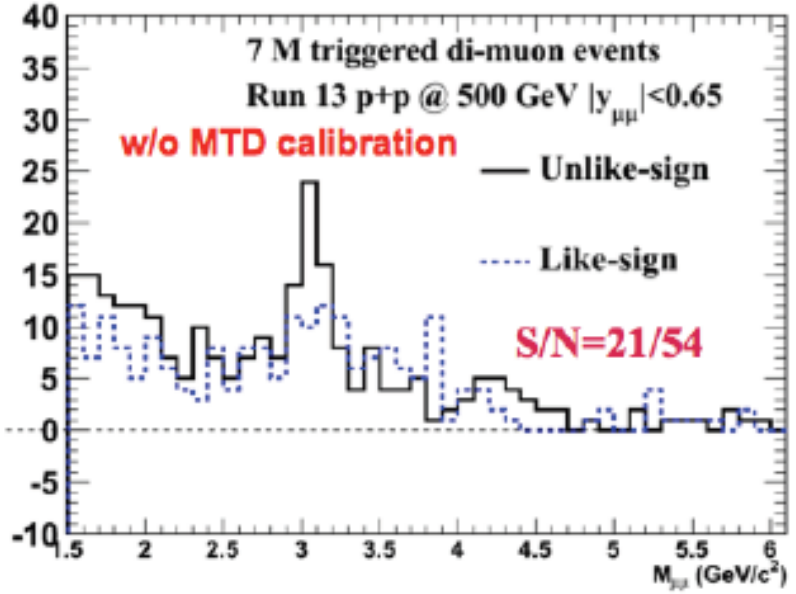
Suppression of Y states in central Au+Au 200 GeV and U+U 193 GeV
Suppression pattern similar
Y(1S) is suppressed similarly to the high pT J/Psi
Sequential quarkonia suppression : Y(2S+3S) more suppressed than Y(1)

Muon Telescope Detector

Simulation



STAR data, run 2013
First J/Psi peak with MTD



Expected errors of RAA from Muon Telescope Detector (simulation)

Q. Hao, STAR, SQM2013

Thank you very much for your attention