



Overview of STAR Results

Bingchu Huang (UIC)
For the STAR Collaboration



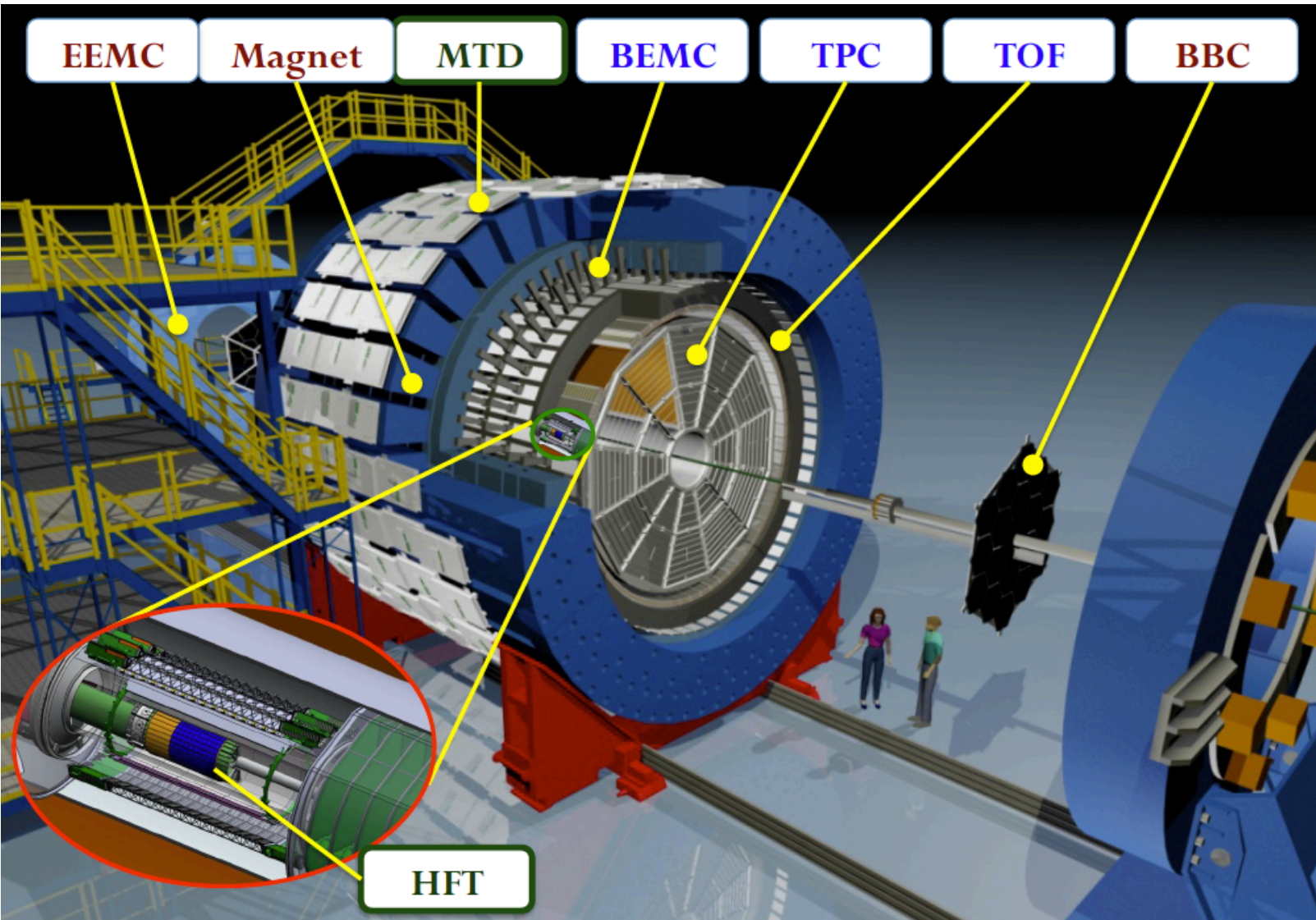


Outline

- STAR detectors.
- Hard probes in Heavy Ion Collisions.
 - Electro-magnetic probes:
 - e^+e^- and direct virtual photon production.
 - Heavy flavor measurements:
 - Photoproduced J/ψ R_{AA} .
 - Suppressions of J/ψ and Υ .
 - R_{AA} and elliptic flow v_2 of D mesons.
 - Jet observable:
 - Jet splitting function --- shared momentum fraction Z_g .
- Summary and Outlook



STAR detectors



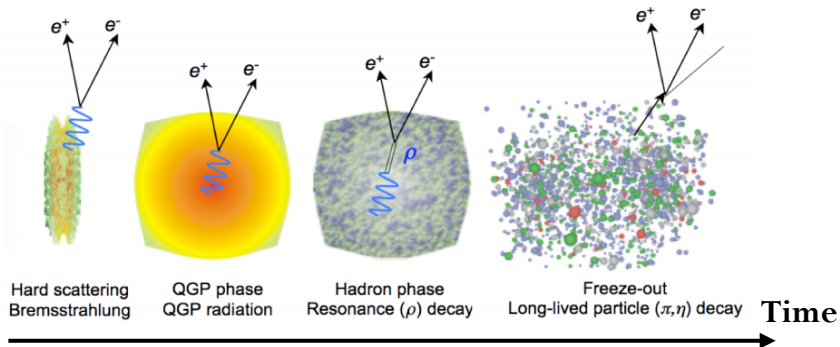
PID: e , μ , and hadrons.

HFT: track pointing resolution $\sim 50 \mu\text{m}$ at $p_T \sim 0.8 \text{ GeV}/c$.

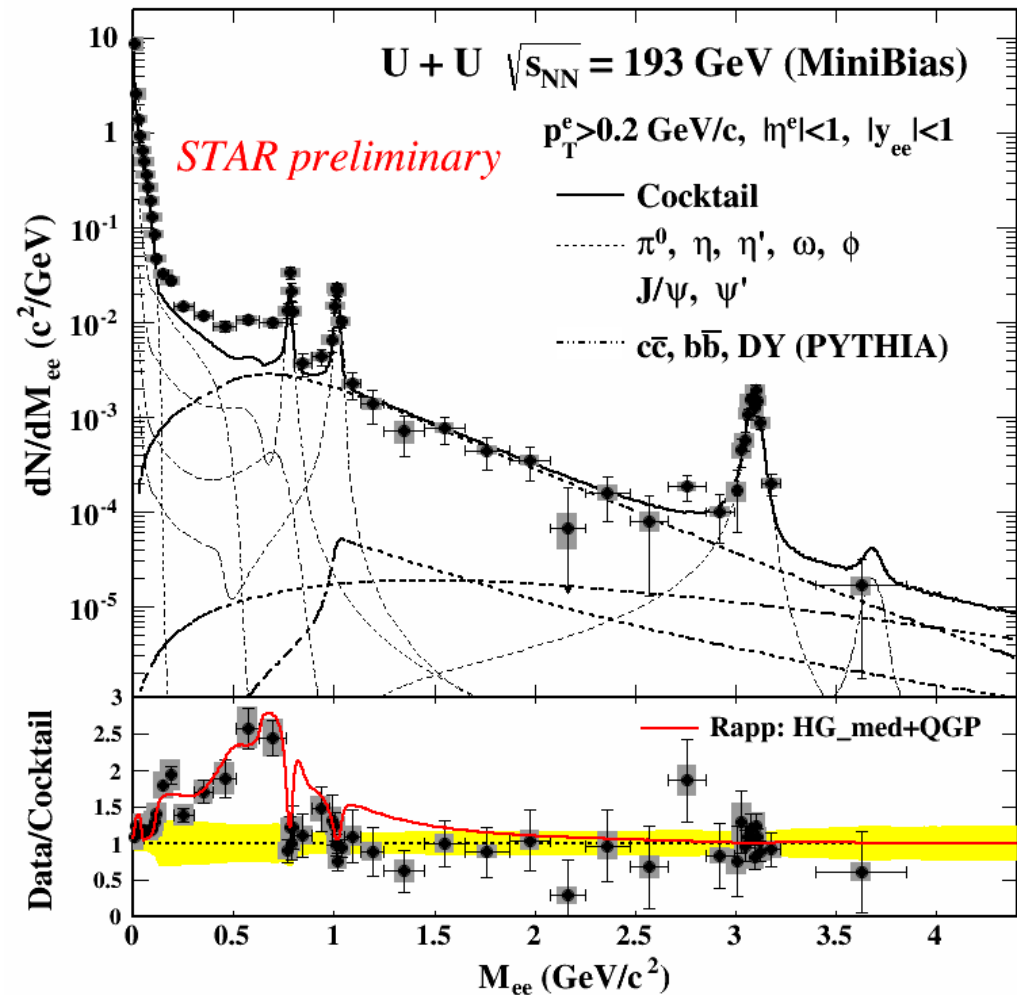


e^+e^- production in U+U

Joey Butterworth Sat 14:00
EM probes



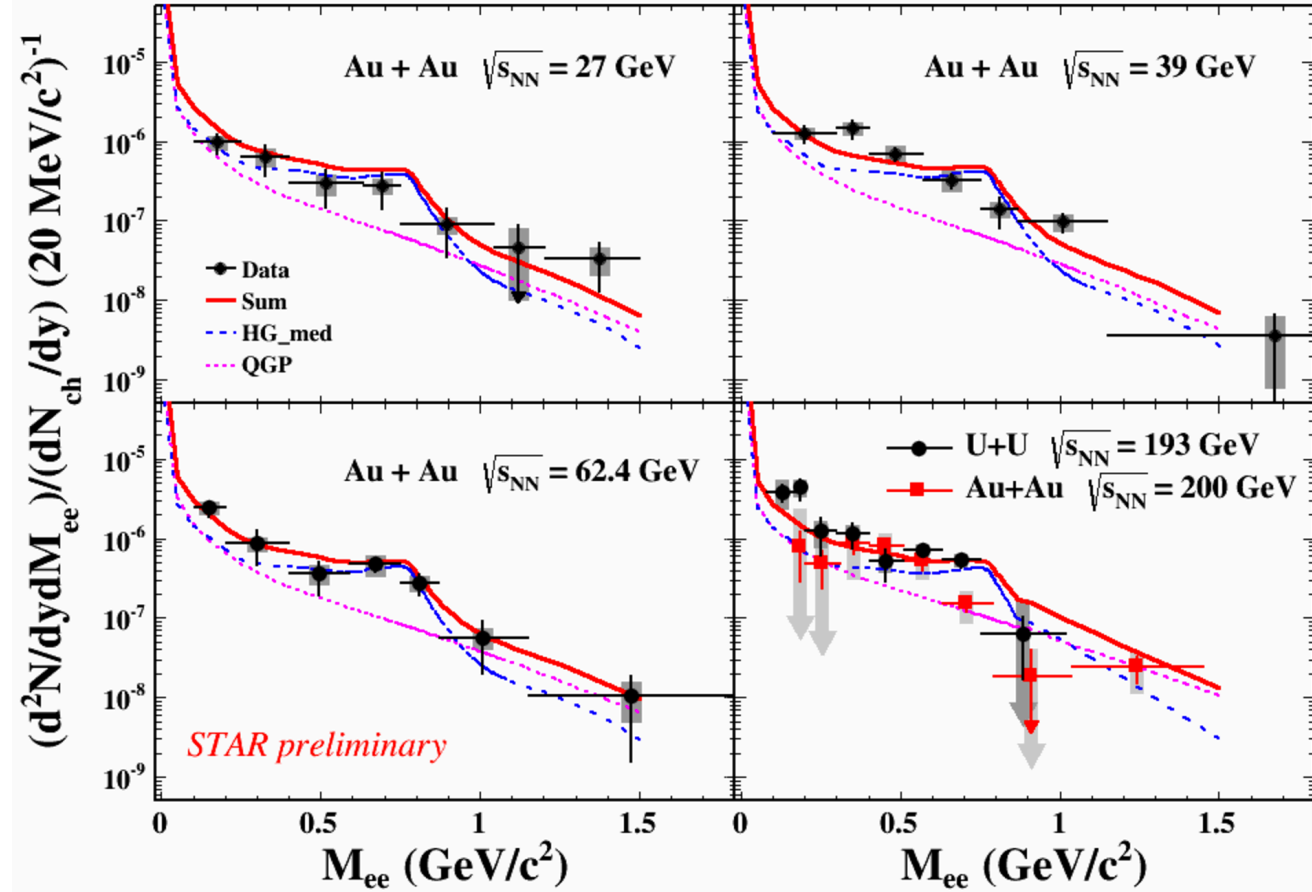
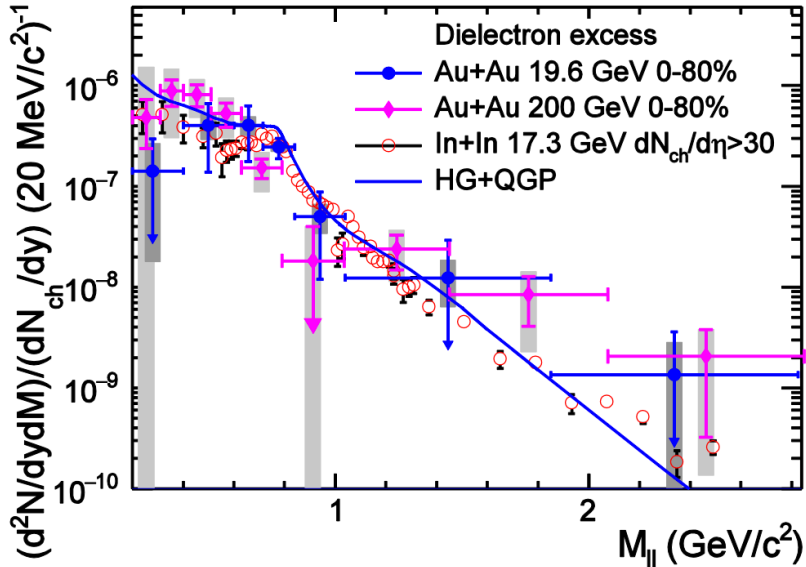
- Observed significant excess w.r.t hadronic sources at ρ -like mass region ($0.3-0.76 \text{ GeV}/c^2$).
- Enhancement is consistent with a broadened ρ spectral function of theory expectation. [R.Rapp, *Adv. High Energy phy.* 2013 (2013) 148253]



Within STAR acceptance.



Broadened ρ spectral function



- Acceptance-corrected excess mass spectra are well described by a model that incorporates a broadened ρ spectral function in various collision systems and energies.

Theory:

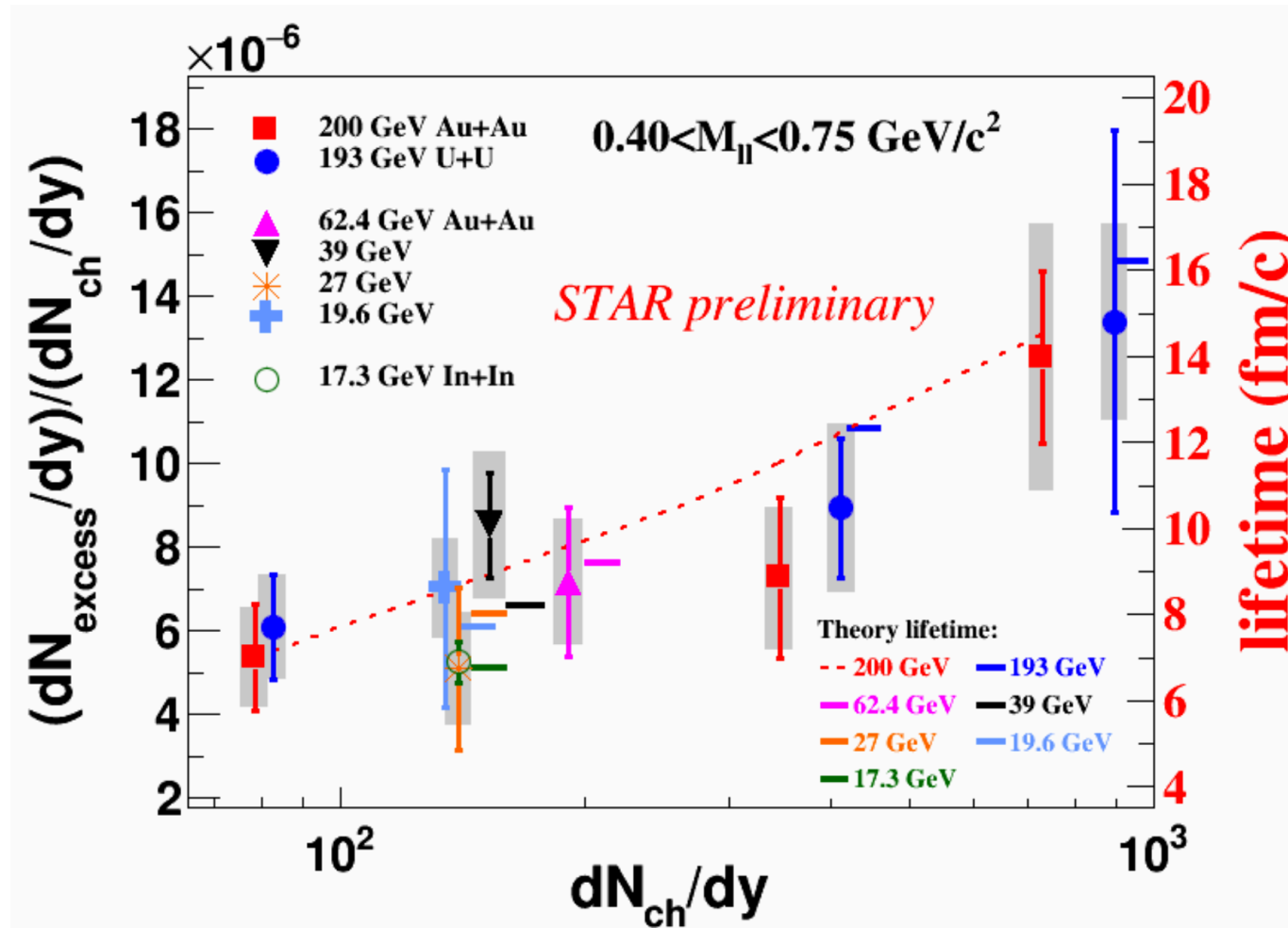
R. Rapp, PRC 63 (2001) 054907

Data Au+Au@200 GeV:

STAR, PLB 750 (2015) 64



Connection to fireball lifetime



- Integrated excess yield, normalized by dN_{ch}/dy , is proportional to lifetime of fireball from 17.3 – 200 GeV.

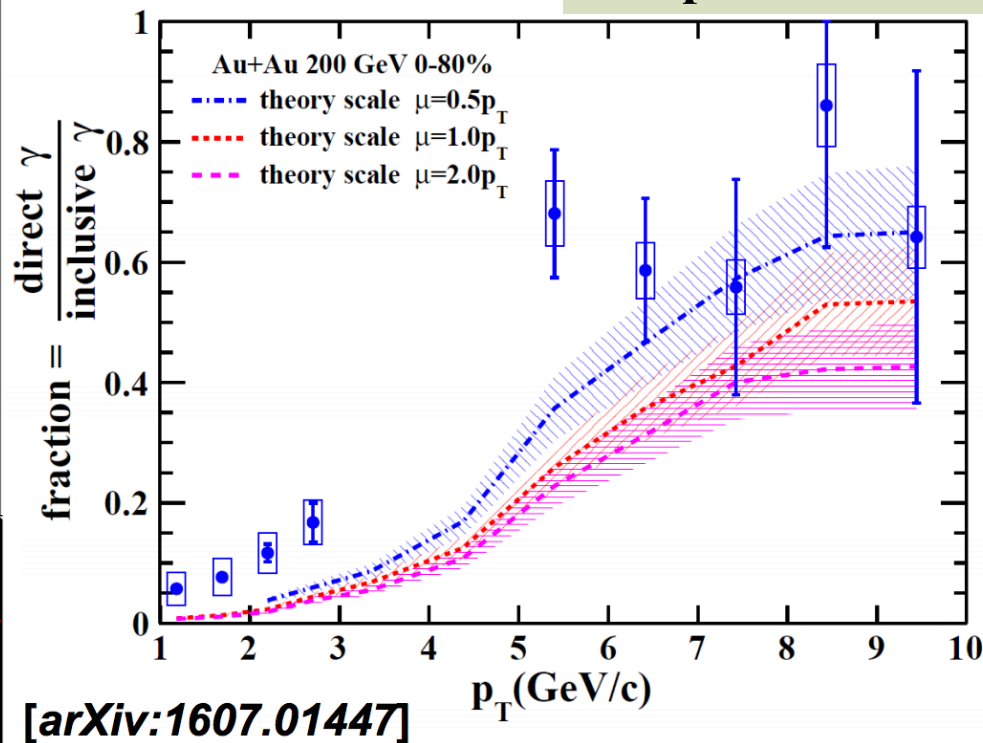
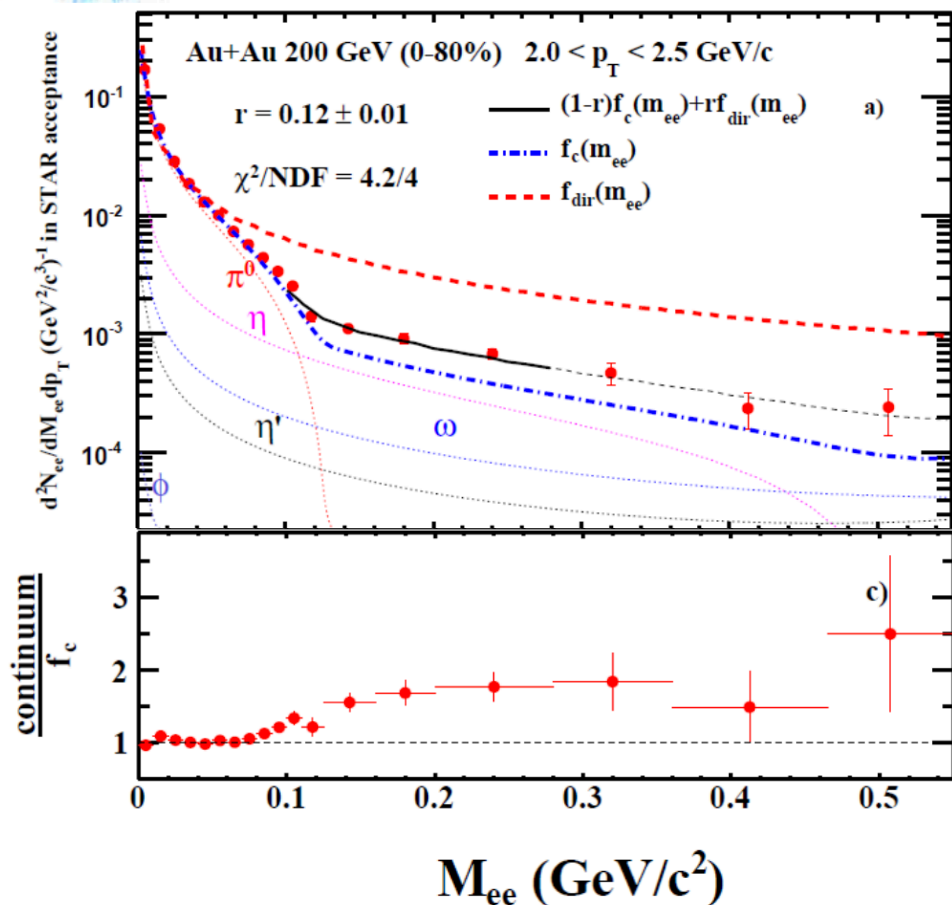
Given that total baryon density is nearly constant and emission rate is dominant in the near- T_c region.

R. Rapp, H. van Hees PLB 753 (2016) 586-590



Extract direct virtual photon yields

Chi Yang Sat 09:00
EM probes



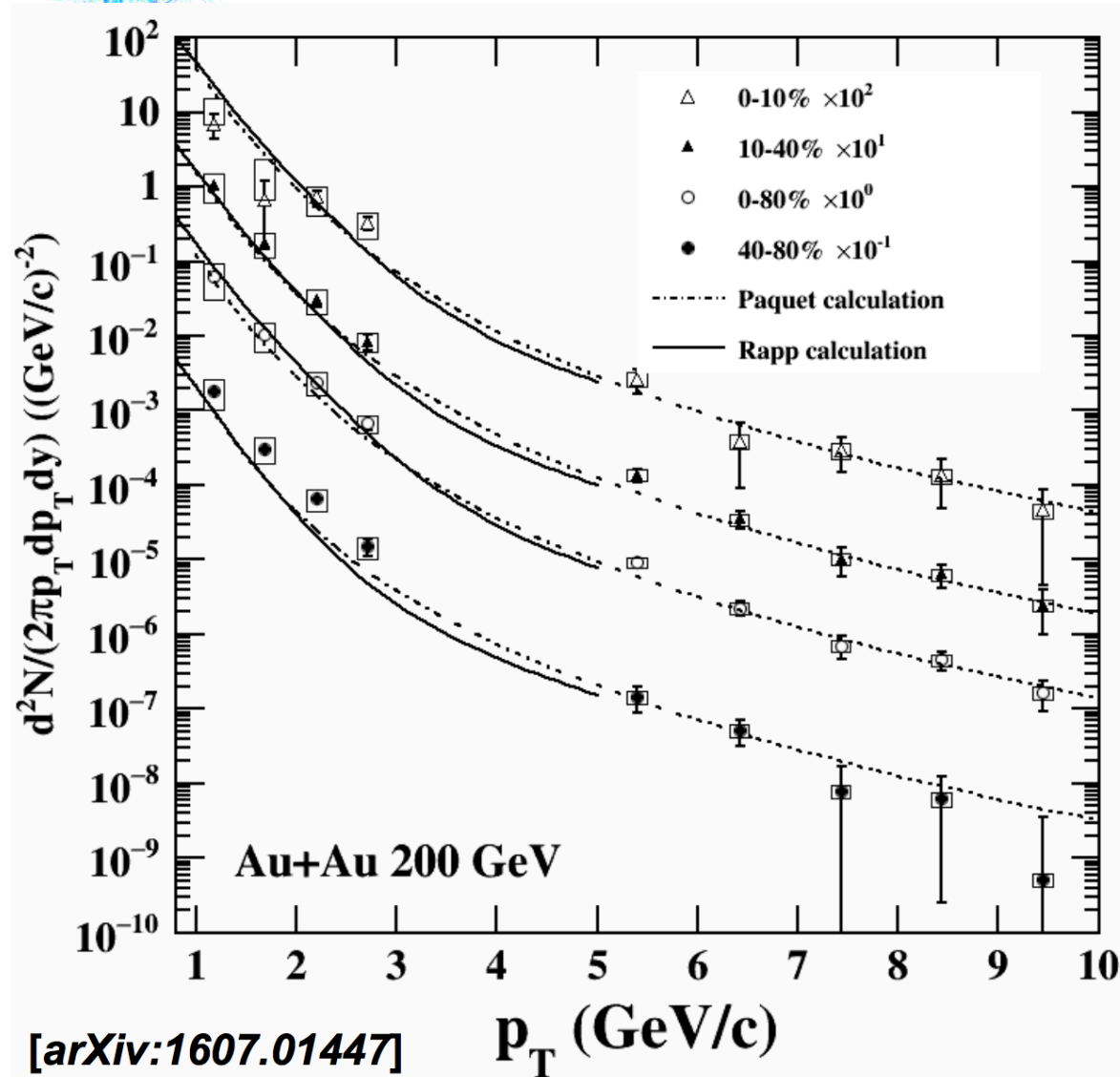
The curves represent NLO pQCD prediction: $\frac{T_{AA} d\sigma_{\gamma}^{\text{NLO}}(p_T)}{dN_{\gamma}^{\text{inclusive}}(p_T)}$

L. E. Gordon and W. Vogelsang, *Phys. Rev. D* 48, 3136 (1993).
 PHENIX Collaboration, *Phys.Rev.L* 98, 012002 (2007).
 PHENIX Collaboration, *Phys.Rev.L* 104,132301(2010).

Compared to $p+p$ reference, an excess is observed in low p_T



Direct virtual photon invariant yields



➤ $p_T > 6 \text{ GeV}/c$: dominated by initial hard-parton scattering.

Paquet: (2+1)D hydrodynamic evolution.
Rapp: Elliptic thermal fireball evolution.

➤ $p_T 1-3 \text{ GeV}/c$: dominated by thermal radiation from models.

➤ Data are consistent with both models for all the centralities except 40-80%.

H. van Hees, C. Gale, and R. Rapp [Phys. Rev. C 84, 054906 (2011)]

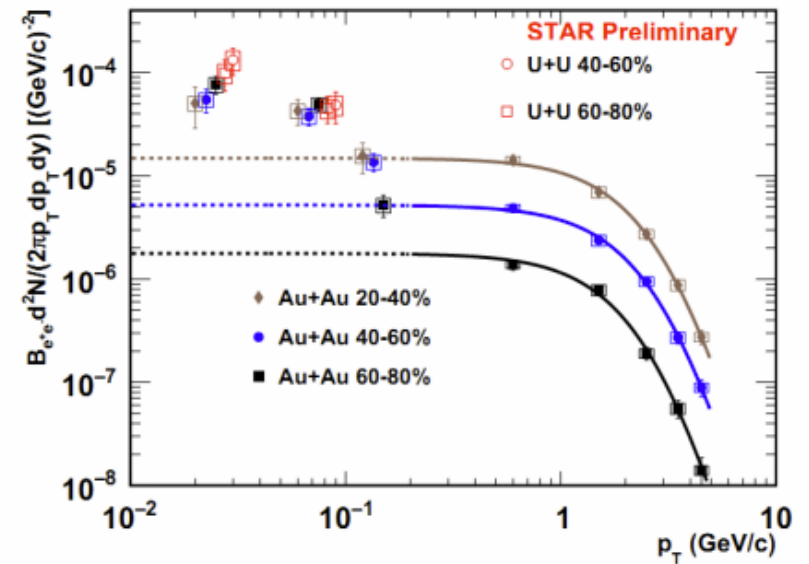
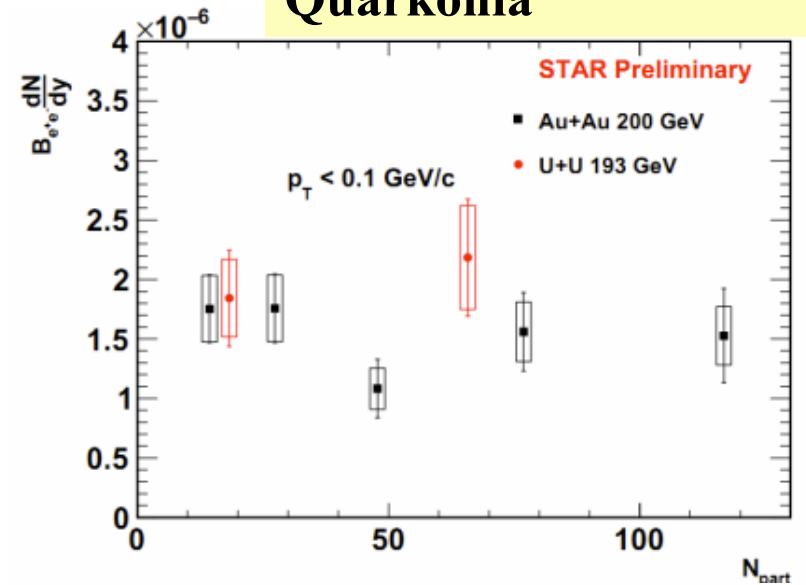
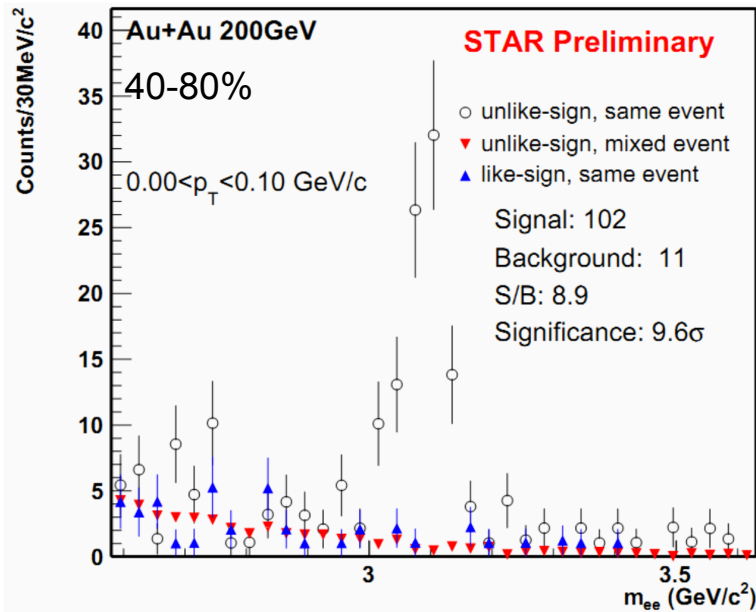
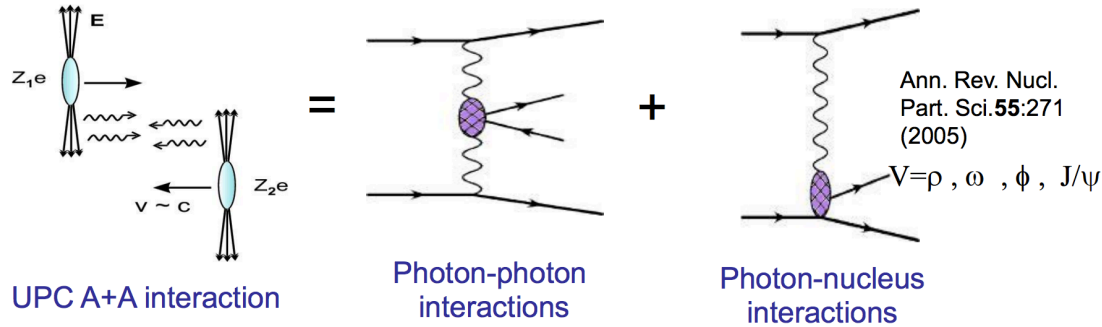
H. van Hees, M. He, and R. Rapp [Nucl. Phys. A 933, 256 (2015)]

J.-F. Paquet et al., [Phys. Rev. C 93, 044906 (2016)]



J/ψ at very low p_T

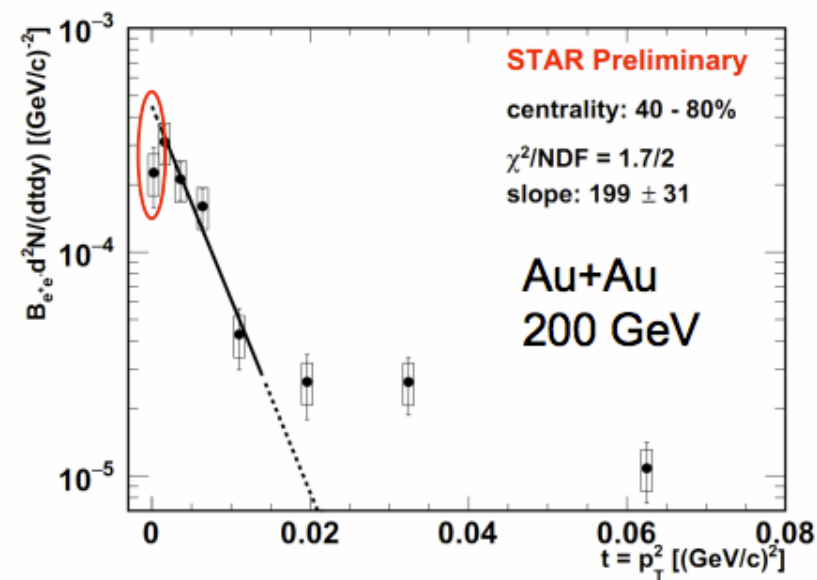
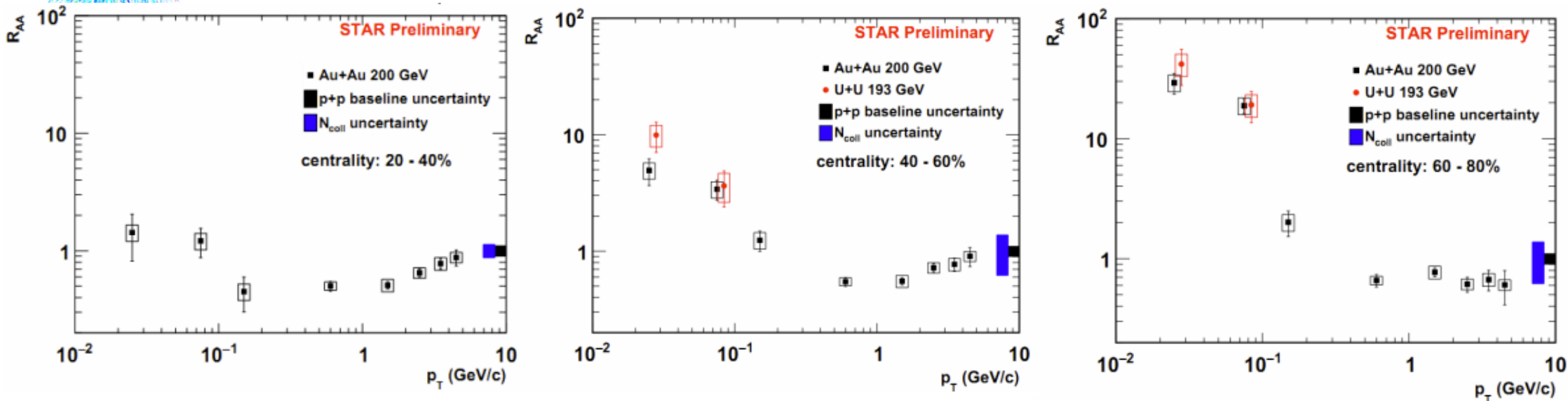
Wangmei Zha Sun 11:40
Quarkonia



- Significant J/ψ signals at very low p_T (<0.1 GeV/c) in 40-80%.
- No significant centrality dependence --- not from hadronic production.
- J/ψ yields in Au+Au and U+U are similar at p_T<0.1 GeV/c.



Nuclear modification factor R_{AA}



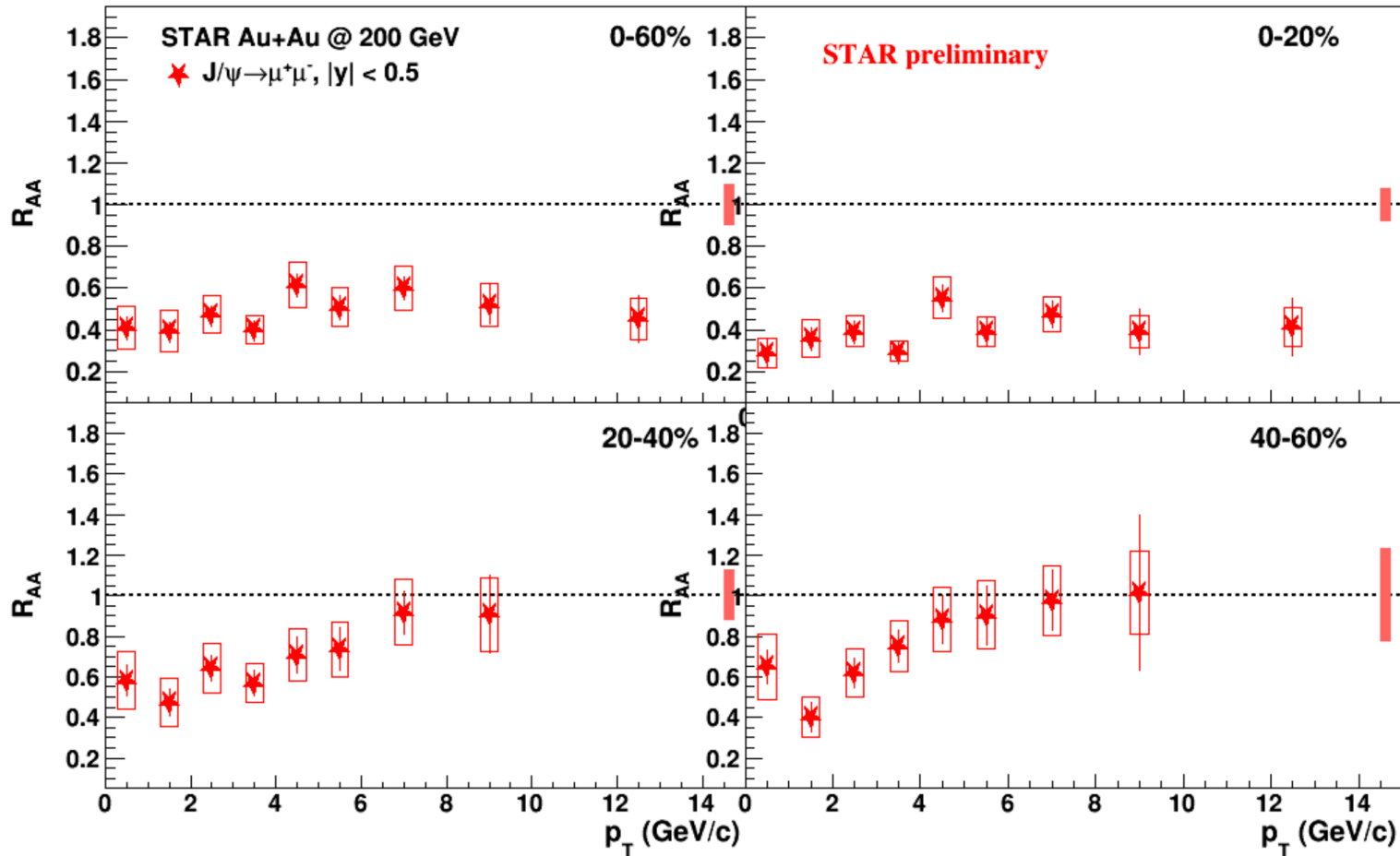
- R_{AA} drops from 20 to 1 as centrality changes from peripheral to semi-central.
- Slope from STARLight prediction in UPC is 196 (GeV/c)⁻², which reflects the size and shape of nucleus.
 - Fit w/o first data point: 199 ± 31 (GeV/c)⁻².

Possible new probe of QGP!

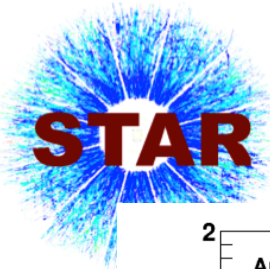


J/ψ R_{AA} from μμ channel

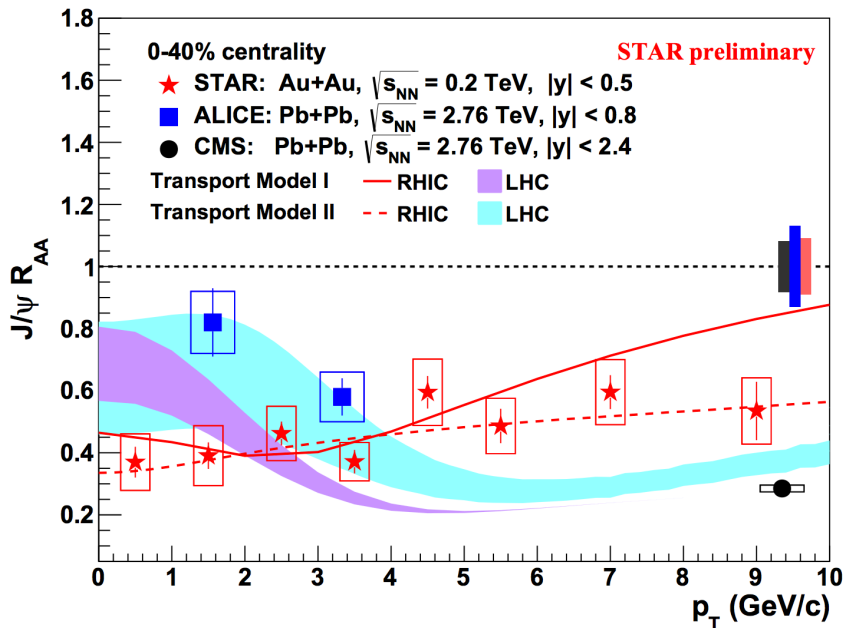
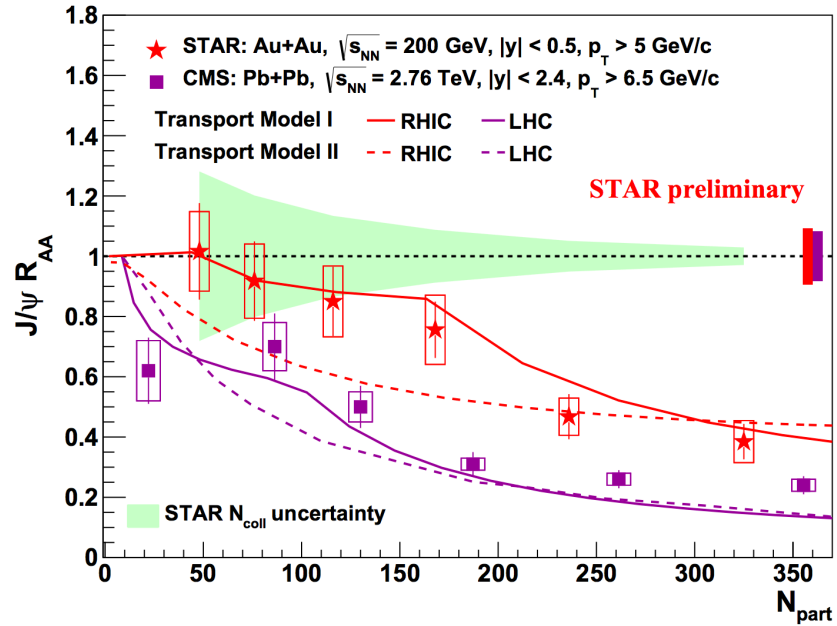
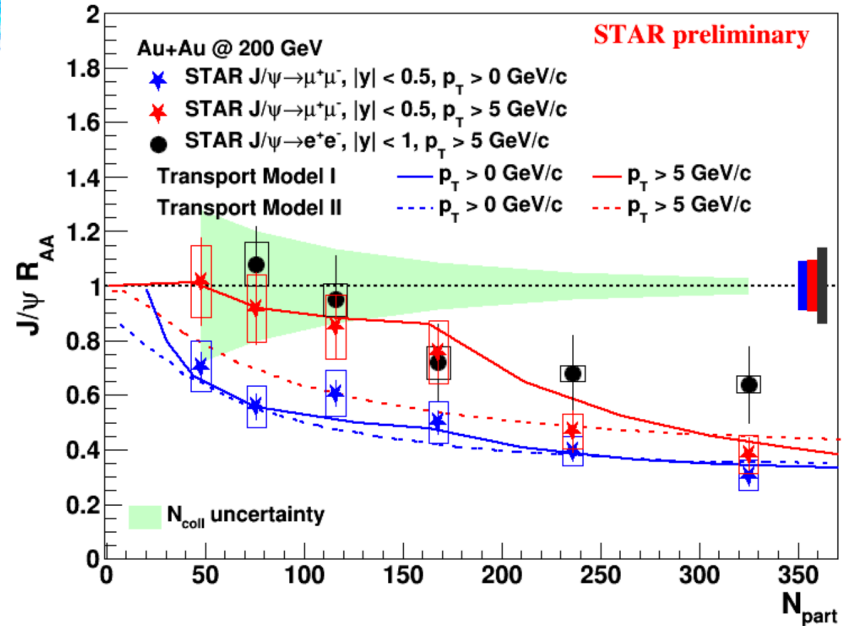
Yi Yang Sat 16:00
Quarkonia



➤ Results from MTD. J/ψ p_T coverage up to 14 GeV/c.



J/ψ R_{AA}



- Transport models with regeneration and dissociation are well consistent with data.
- Less regeneration and less dissociation at RHIC.

Data:

JHEP 05 (2016) 179 PRC 84 (2011) 054912

JHEP 05 (2012) 063 PLB 734 (2014) 314

Model:

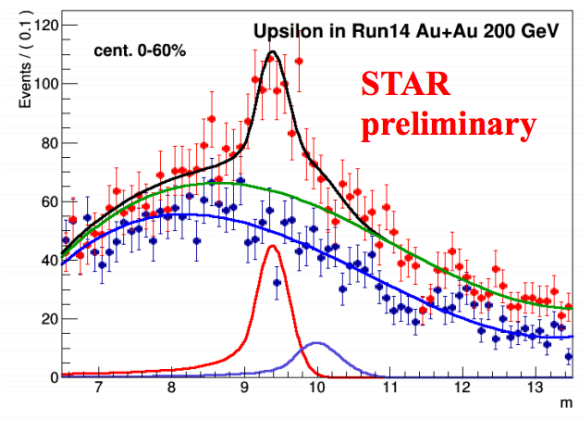
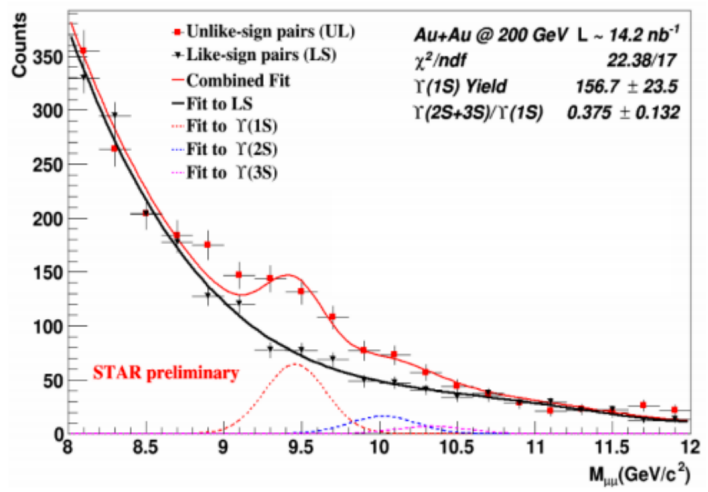
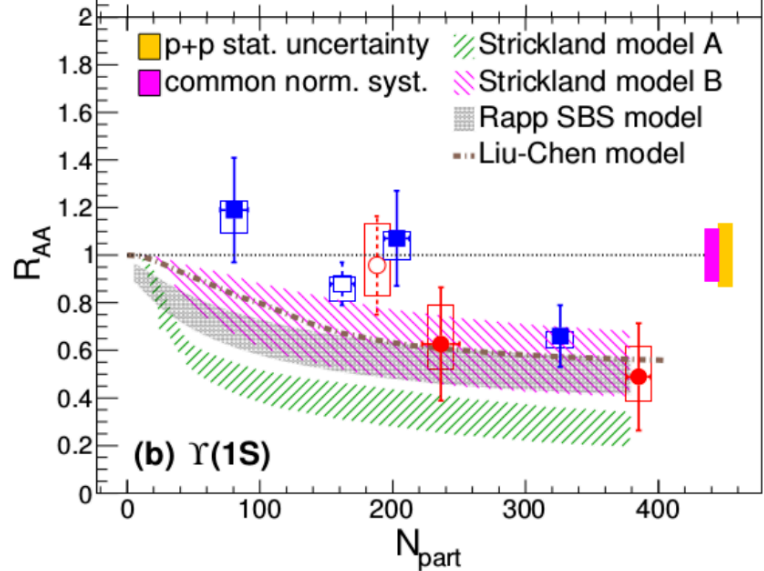
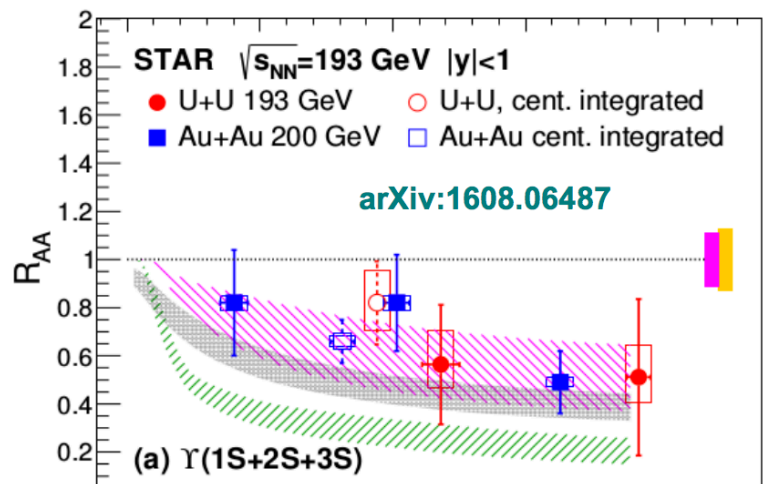
PLB 678 (2009) 72, PRC 89 (2014) 054911

PRC 82 (2010) 064905, NPA 859 (2011) 114



Υ suppression

Zaochen Ye Sun 08:50
Quarkonia



$428 < T < 443$ MeV

$T = 340$ MeV

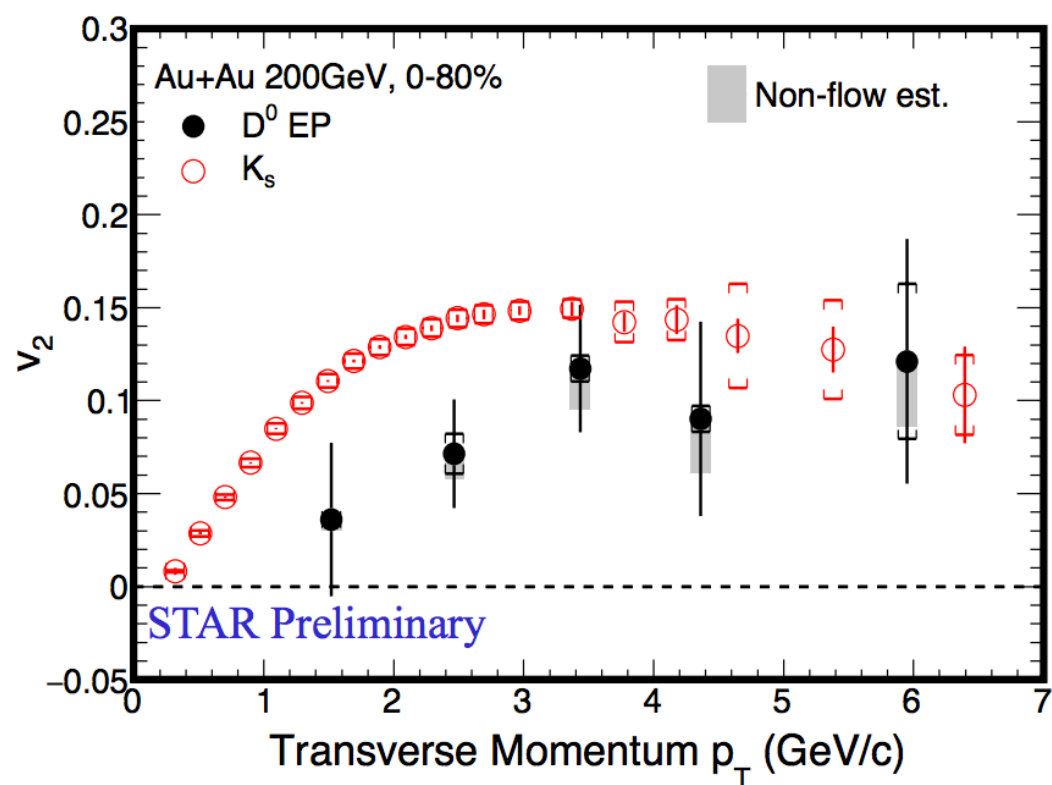
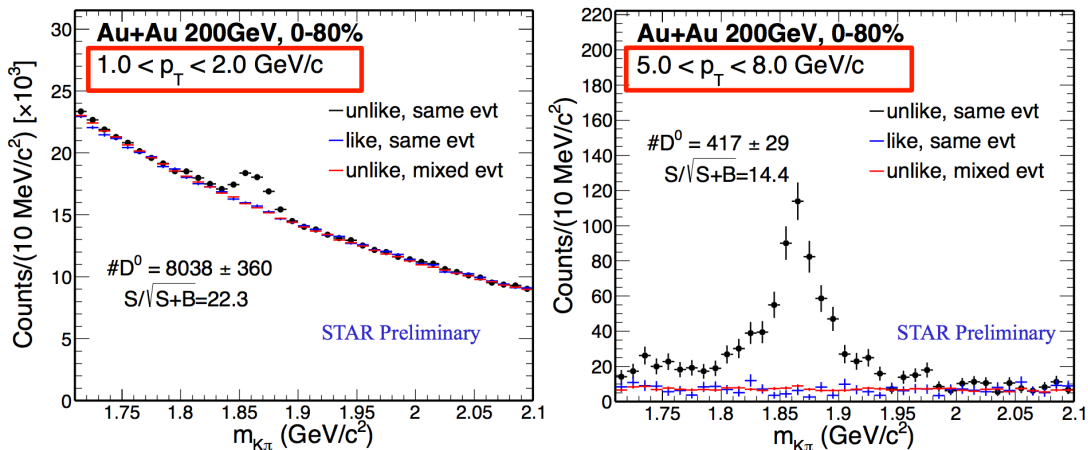
- Measurement in U+U extends the N_{part} coverage.
- Free-energy-based model tends to underpredict the R_{AA} .
- Internal-energy-based models agree with data.

- Measured difference Υ states via dimuon channel.
 - No bremsstrahlung tail.
- Expect to extract the ratio of (2S+3S)/1S from simultaneous fit to both dielectron and dimuon channel.
- A factor of 4 improvement of statistics is expected when combining Run11 and Run14.

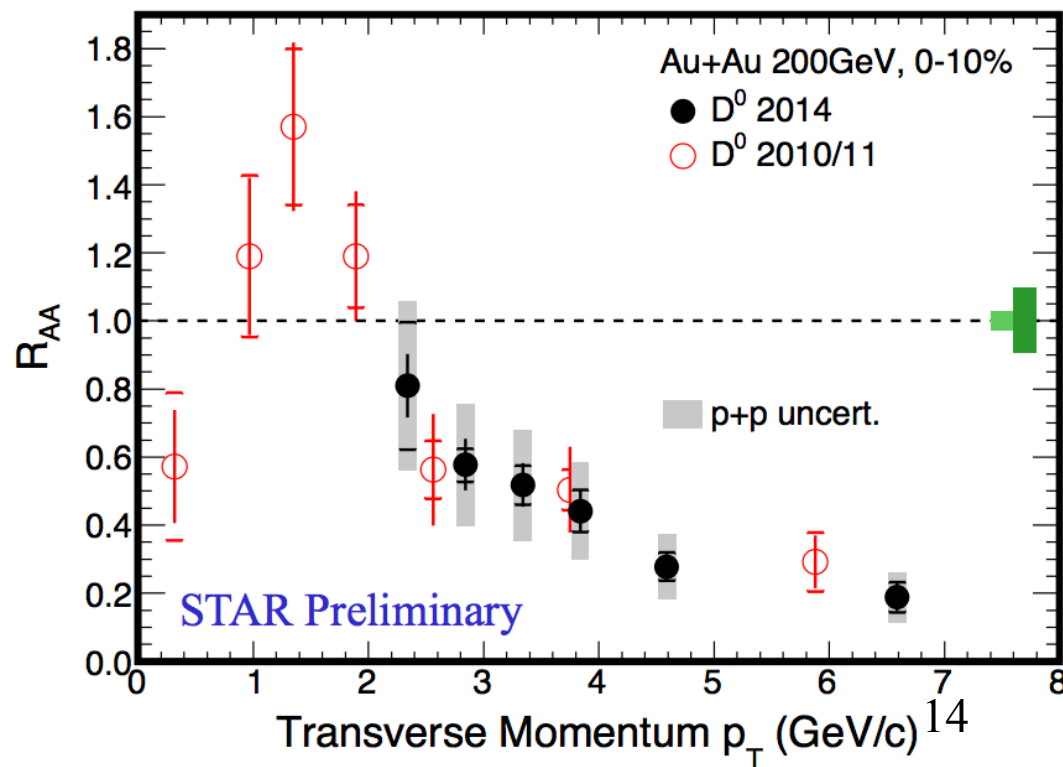


D⁰ R_{AA} and v₂

Guannan Xie Sat 08:30
HF



- First measurement of D⁰ R_{AA} using STAR HFT.
- D⁰ v₂ is finite and lower than that of light mesons for 1 < p_T < 4 GeV/c in 0-80%.
- Suppression is consistent with published result.



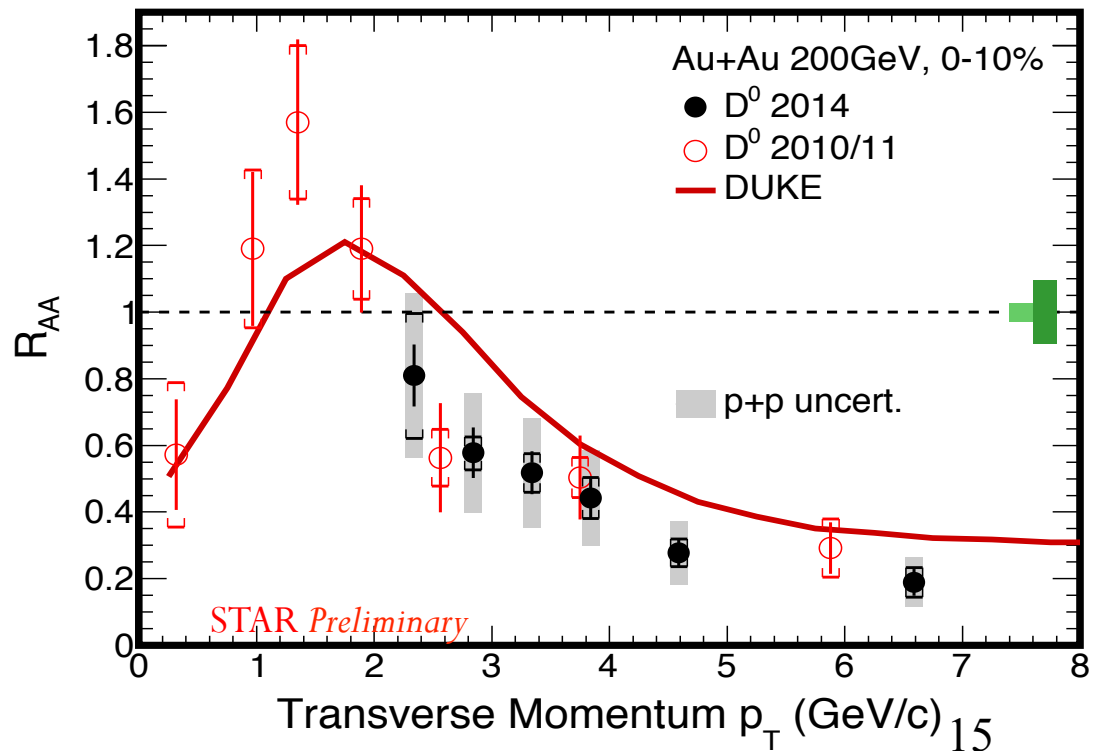
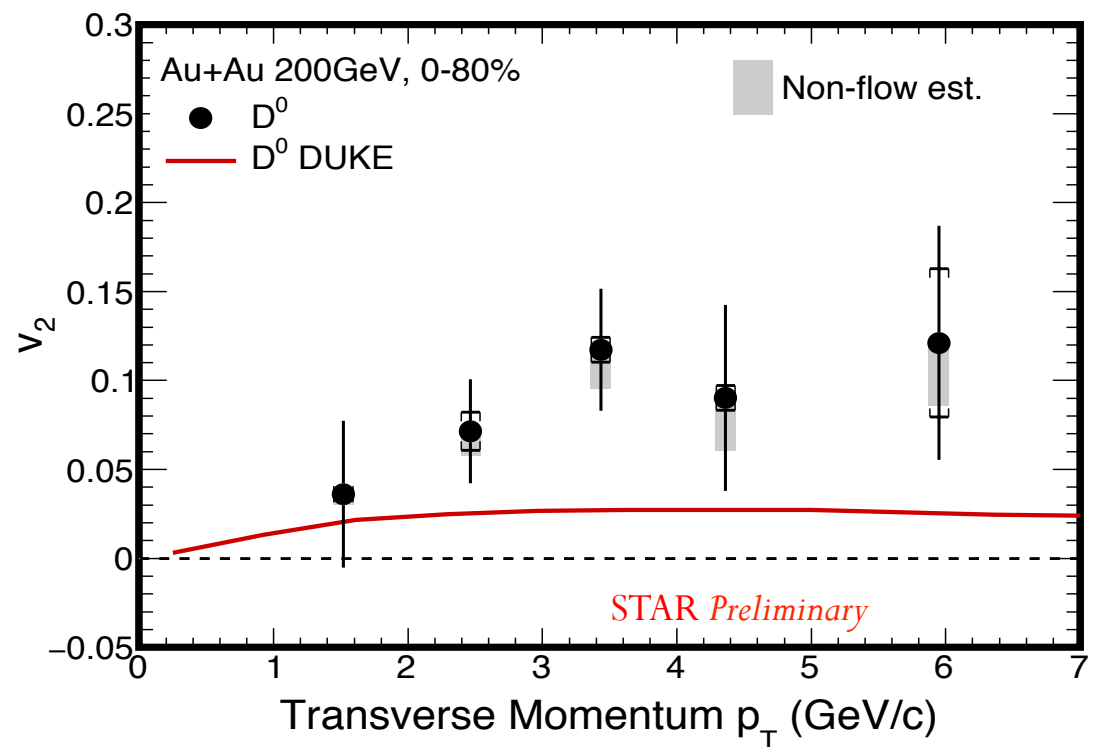


D^0 R_{AA} and v_2

DUKE:

- (2+1)-D viscous hydro + hybrid coalescence and fragmentation model
- Input value for diffusion coefficient $2\pi T \times D = 7$ fixed to fit LHC results
- Underestimate the magnitude of v_2 in experimental data

Theory: arXiv:1505.01413 & private comm.
STAR: PRL 113 (2014) 142301



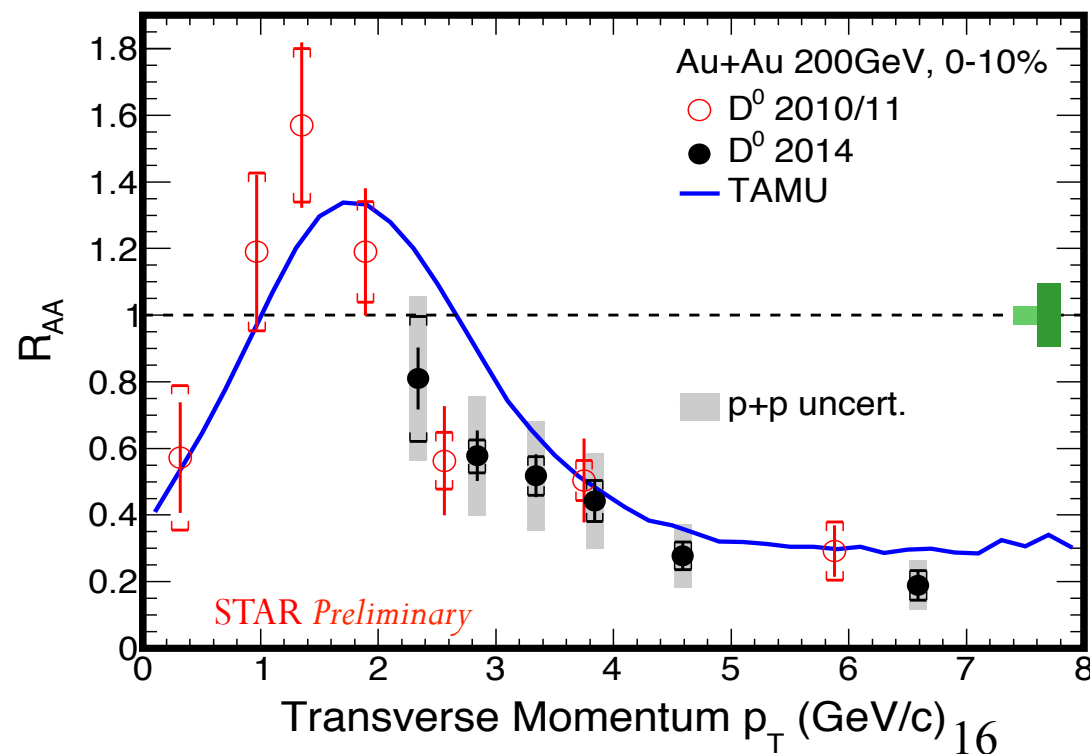
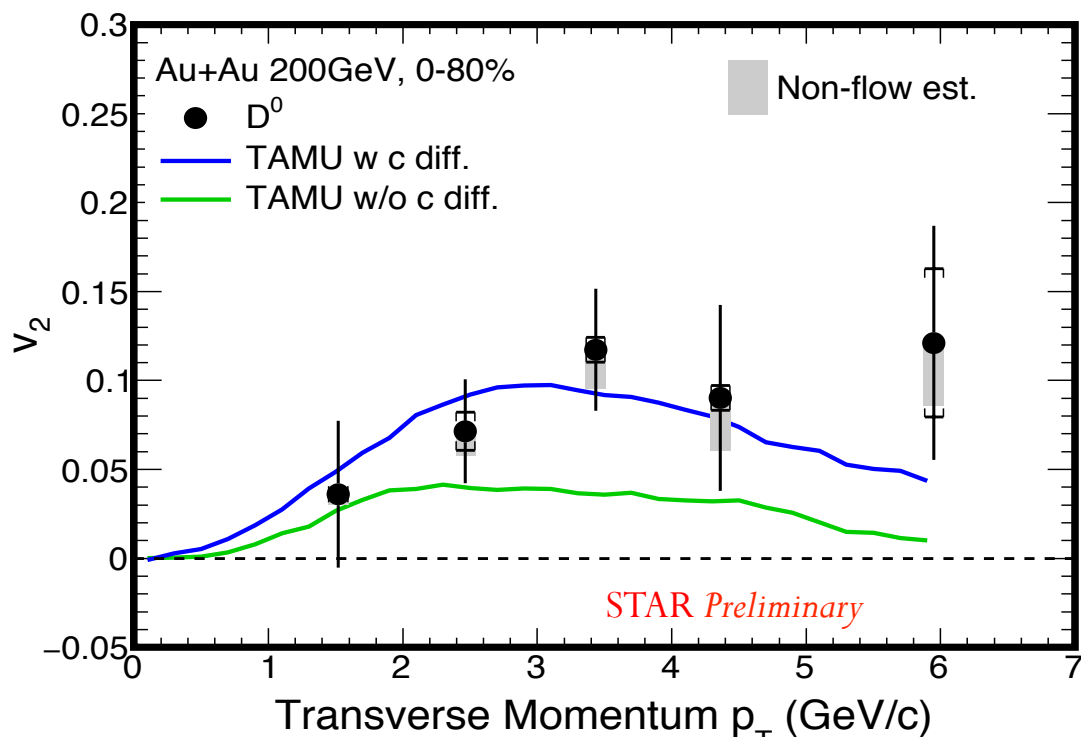


D^0 R_{AA} and v_2

TAMU:

- Full T-matrix treatment, non-perturbative model with internal energy potential
- Good agreement with D^0 meson v_2 , data favor model including c quark diffusion in the medium.
- Qualitatively describe R_{AA} .
- Diffusion coefficient extracted from calculation $2\pi T \times D = 3-11$

Theory: arXiv:1506.03981 (2015) & private comm.
STAR: PRL 113 (2014) 142301





D^0 R_{AA} and v_2

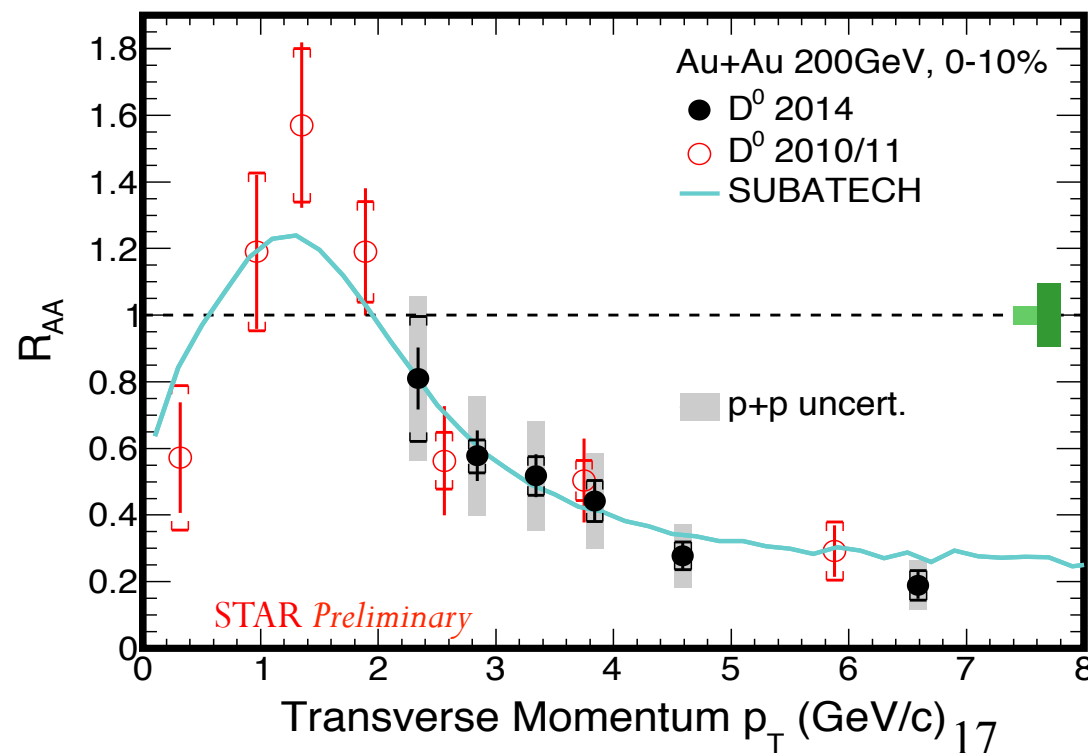
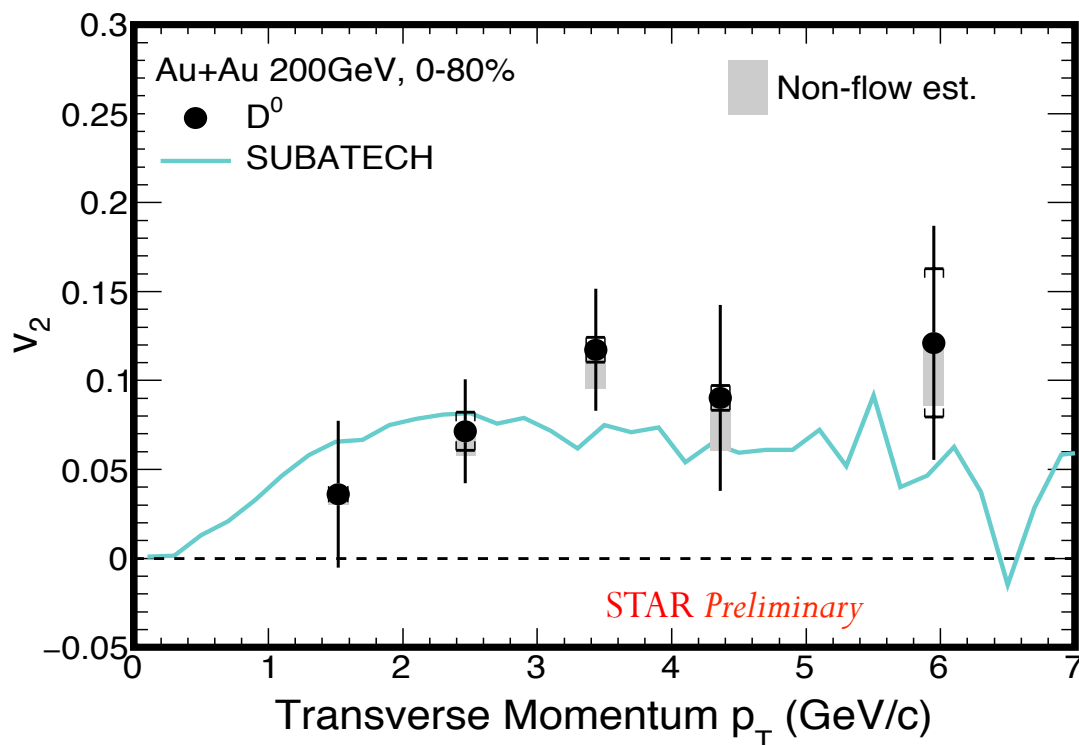
SUBATECH:

- MC@sHQ calculation with latest EPOS3 initial conditions
- Good agreement between model and experiment for both v_2 and R_{AA} in entire p_T range
- Diffusion coefficient extracted from calculations $2\pi T \times D \sim 2-4$

Theory: arXiv:1506.03981 (2015) & private comm.
STAR: PRL 113 (2014) 142301

Conclusion for D^0 R_{AA} and v_2 :

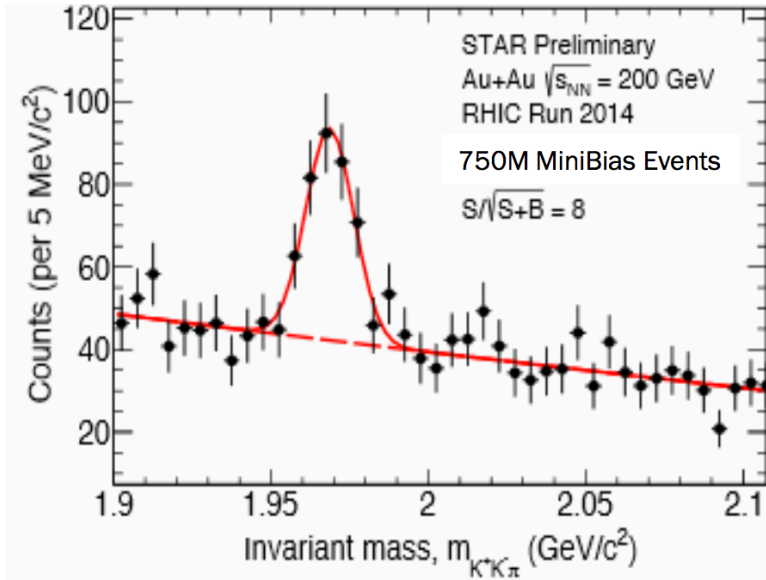
- Data favor model that charm quark flows.
- D^0 v_2 and R_{AA} can be simultaneously described by models with diffusion coefficient between 2-12, and differences between models need to be resolved.



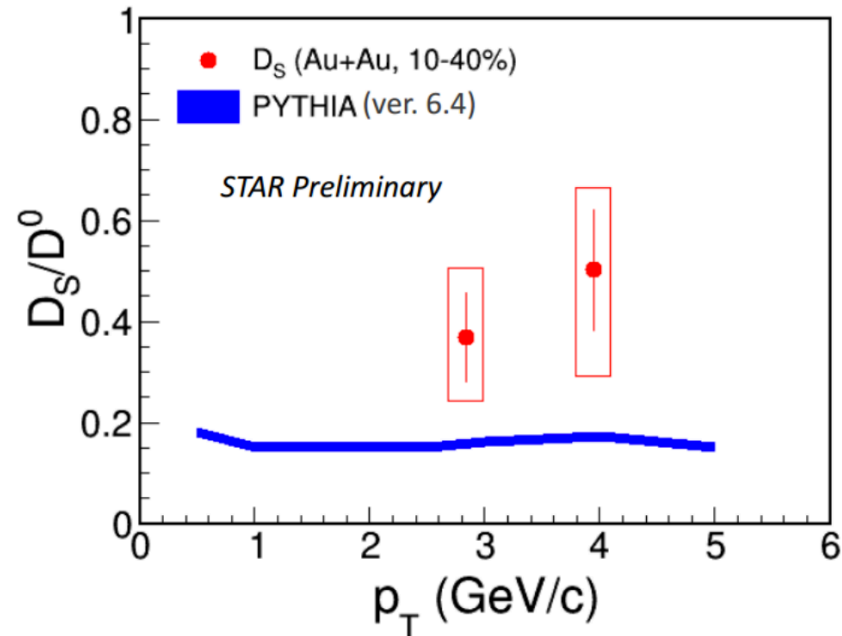
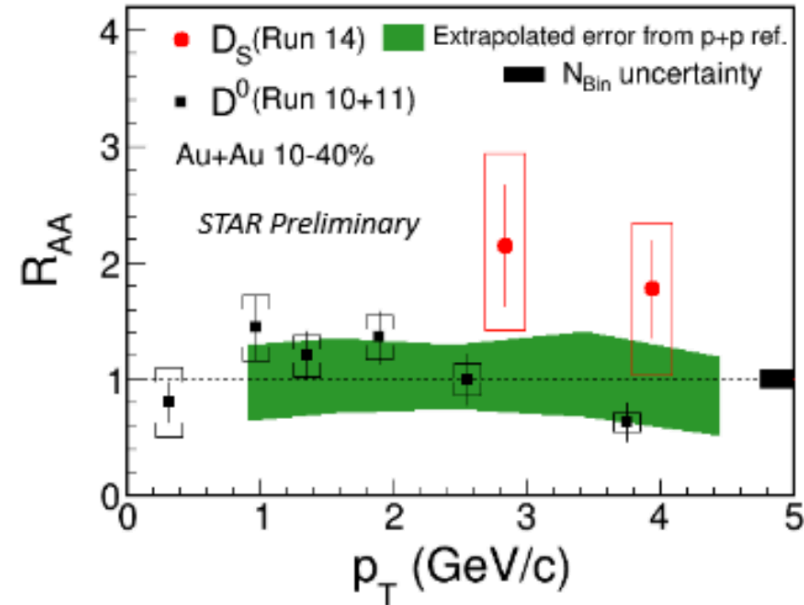


$D_s R_{AA}$ and elliptic flow v_2

Long Zhou Sat 08:30
HF

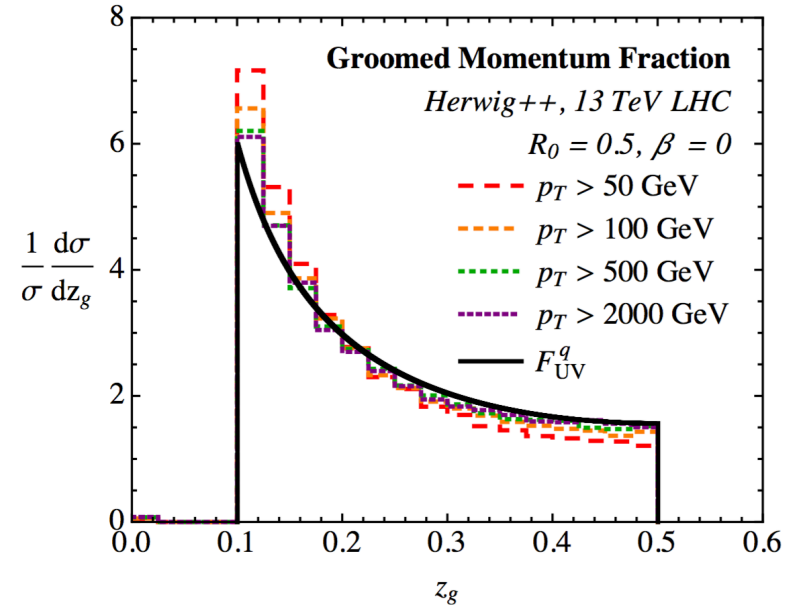
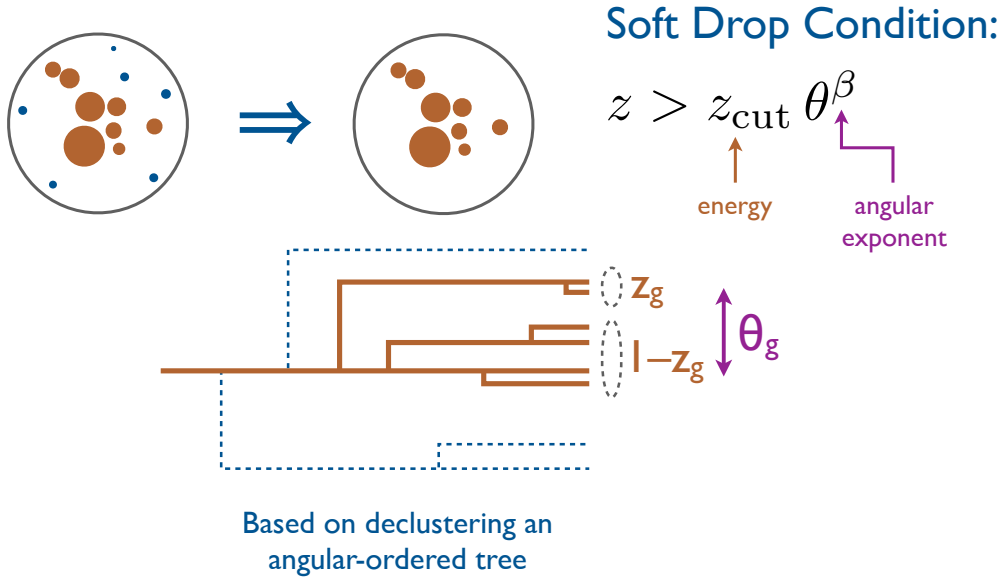


- $D_s R_{AA}$ may be higher than D^0 .
- Higher D_s/D^0 ratio wrt. PYTHIA?
- Will follow up with better precision measurements.





Jet splitting function



“Groomed Momentum Sharing”

$$z_g = \frac{\min(p_{T1}, p_{T2})}{p_{T1} + p_{T2}}$$

J. Thaler ALICE Jet Workshop, Yale

Larkoski et al.,
Phys. Rev. D 91, 111501 (2015)

For $\beta = 0, z_g > z_{\text{cut}}$:

$$\frac{d\sigma}{dz_g} \propto \overline{P}_i(z_g) + \mathcal{O}(\alpha_s^2)$$

- \sim independent of p_T (in UV limit)
- \sim independent of α_s

P_i : Altarelli-Parisi splitting functions (symmetrized)
 $q \rightarrow qg, g \rightarrow gg, g \rightarrow qg$ (Kernels in DGLAP)



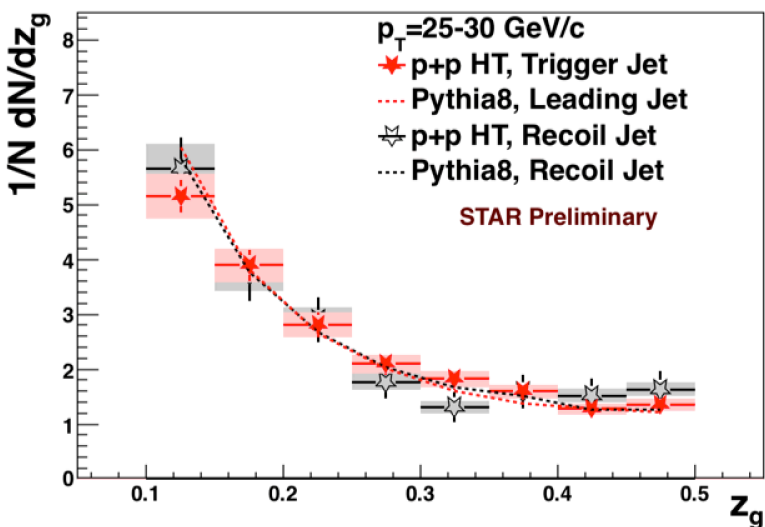
Z_g measurements in p+p and Au+Au

First measurement of z_g at RHIC

z_g for di-jets with “hard cores”.

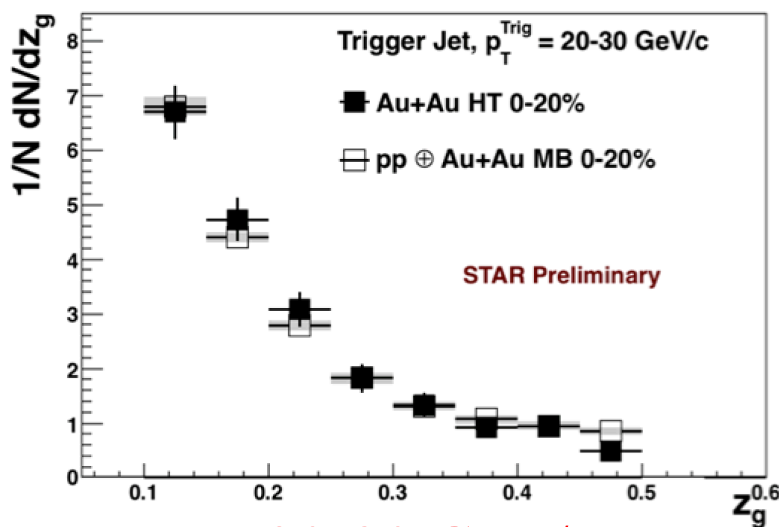
Kolja Kauder Sun 11:00
Jets

STAR



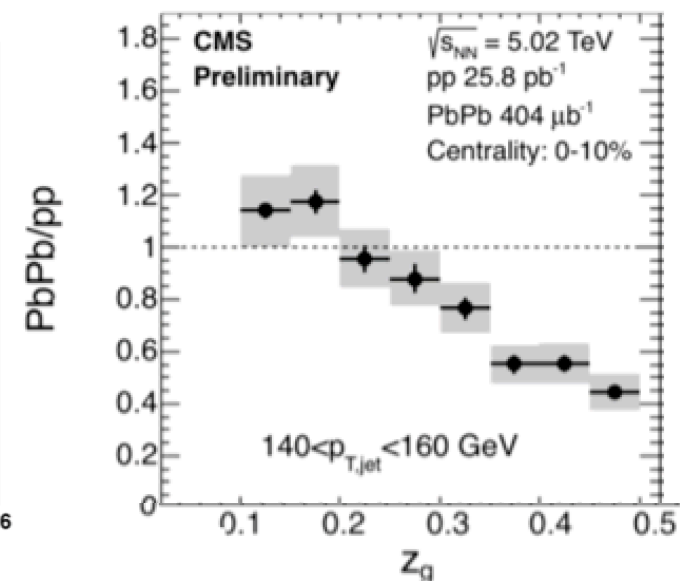
25-30 GeV/c

STAR



20-30 GeV/c

CMS



140-160 GeV/c

➤ p+p HT Run6
Results from trigger and recoil jets are consistent with PYTHIA.

➤ No significant modification of the splitting function found in Au+Au.

CMS observed significant modification in most central, but in quite different kinetic range.

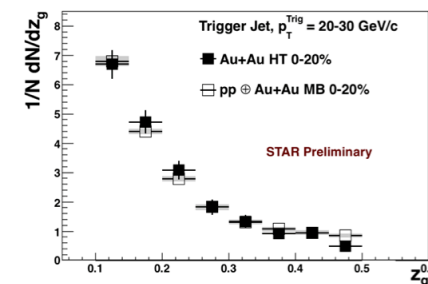
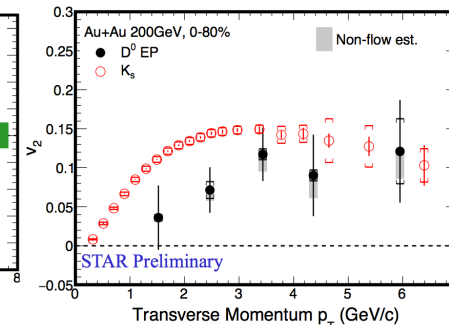
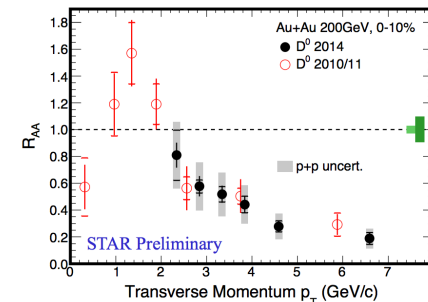
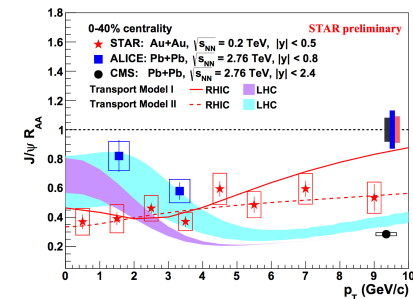
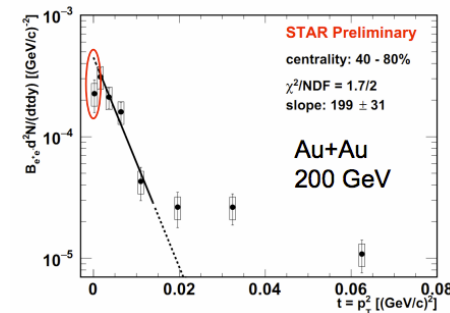
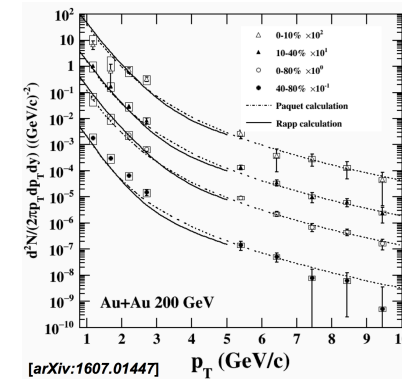
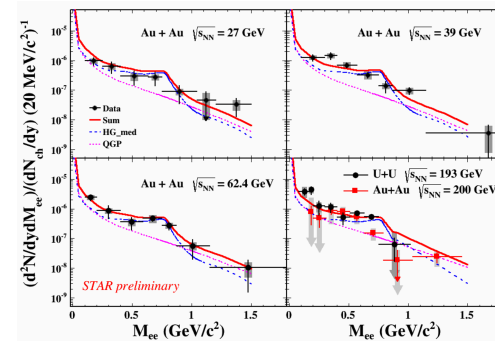
Constrains E-loss models, more theory input needed.



Summary

What we learned so far:

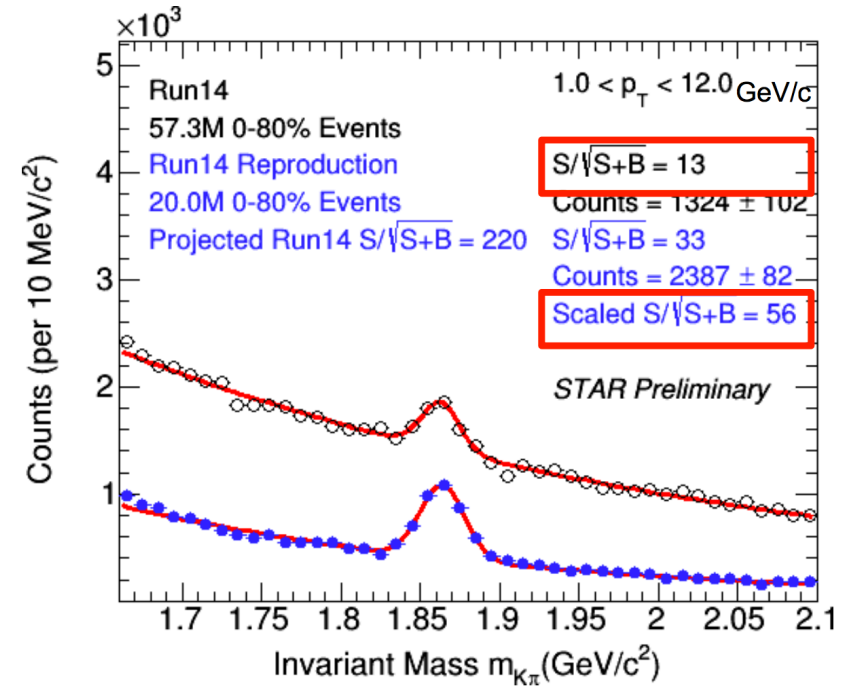
- Hot medium modifies ρ meson and emits radiation via lepton pairs.
- Photoproduced J/ψ is observed in the peripheral heavy ion collisions.
- Quarkonium appears suppression and regeneration effects in the medium.
- Charm quark has suppression and collective flow in the QGP.
- Jet splitting function has no significant modification for jet p_T 10-30 GeV/c at RHIC.





Outlook

- Y2014: with improved HFT efficiency after fixing a decoder issue, a factor of 2-4 improvement is expected in Au+Au.
- Y2015-2016: p+p, p+Au, and Au+Au at 200 GeV.



2014-2016	2019-2020
HF and Jet program.	BES-II, dilepton program.
sQGP properties with precision measurements.	High statistics data in low beam energies will be collected. QCD phase structure including chirality and disappearance of QGP signatures.



Parallel talks from STAR

EM probes:

Chi Yang,	Direct virtual photon production.	Sat 09:10
Joey Butterworth,	e^+e^- production in heavy ion collisions.	Sat 14:00

Heavy flavor probes:

Guannan Xie,	D^0 production and azimuthal anisotropy.	Sat 08:30
Long Zhou,	D_s production in Au+Au.	Sat 14:00
Long Ma,	D meson correlation in p+p.	Sat 15:20
Yi Yang,	J/ψ production in p+p and A+A.	Sat 16:00
Yaping Wang,	Electron from heavy flavor decays in p+p and Au+Au.	Sat 17:00
Zaochen Ye,	Υ production in Au+Au.	Sun 08:50
Wangmei Zha,	Excess of very low p_T J/ψ yield in A+A.	Sun 11:40

Jet probes:

Kun Jiang,	Away-side jet background subtraction.	Sun 09:30
Kolja Kauder,	Shared momentum fraction z_g of Jets in p+p and Au+Au.	Sun 11:00