10th International Conference on Hard and Electromagnetic Probes of High-Energy Nuclear Collisions

STAR Highlights at HP2020

Zaochen Ye (Rice University) for the STAR Collaboration

In part supported by U.S. DEPARTMENT OF ENERGY | Office of Science

RICE

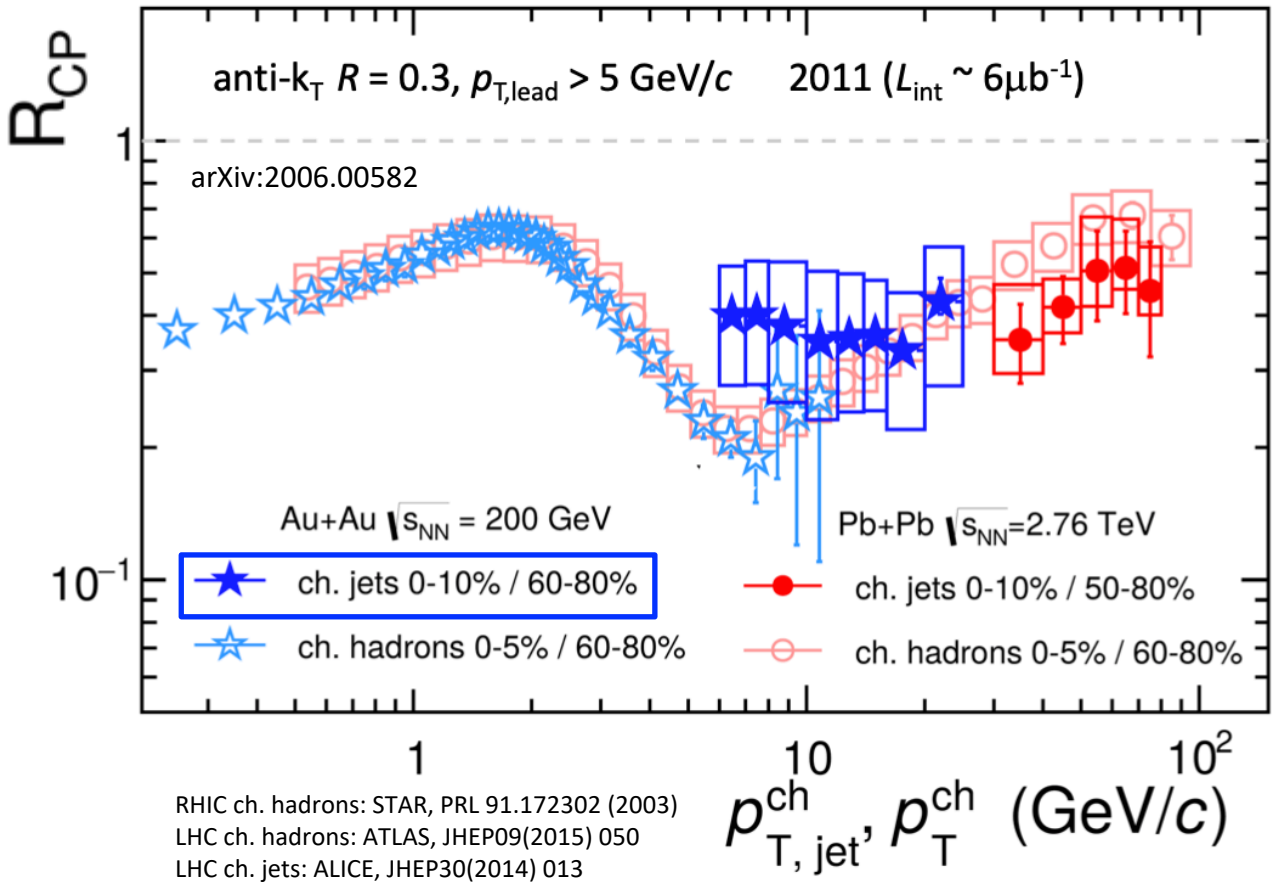
STAR Highlights at HP2020

- Jet
- Heavy Flavor
- Electroweak Probe
- Beyond BES-II

Selected results out of **15** Parallel Talks + **4** Posters

Jet Suppression: Inclusive Charged Jet

R. Licenik, 1 June, 12:20, A1



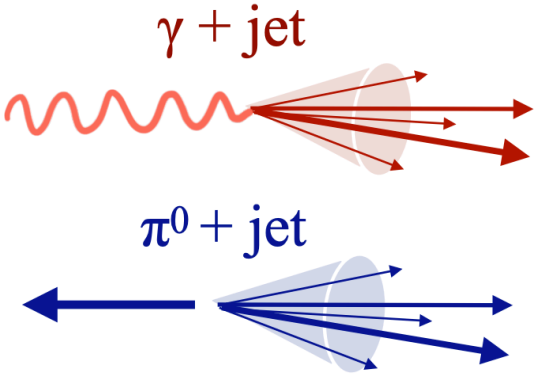
RHIC ch. hadrons: STAR, PRL 91.172302 (2003)
LHC ch. hadrons: ATLAS, JHEP09(2015) 050
LHC ch. jets: ALICE, JHEP30(2014) 013

First inclusive charged jet R_{CP} and R_{AA} at RHIC:

- Significant suppression in central collisions w.r.t peripheral collisions
- Suppression level is similar as inclusive hadrons (RHIC & LHC) and jets (LHC), with a possibly different p_T-dependence

Jet Suppression: γ^{dir}+jet and π^0+jet

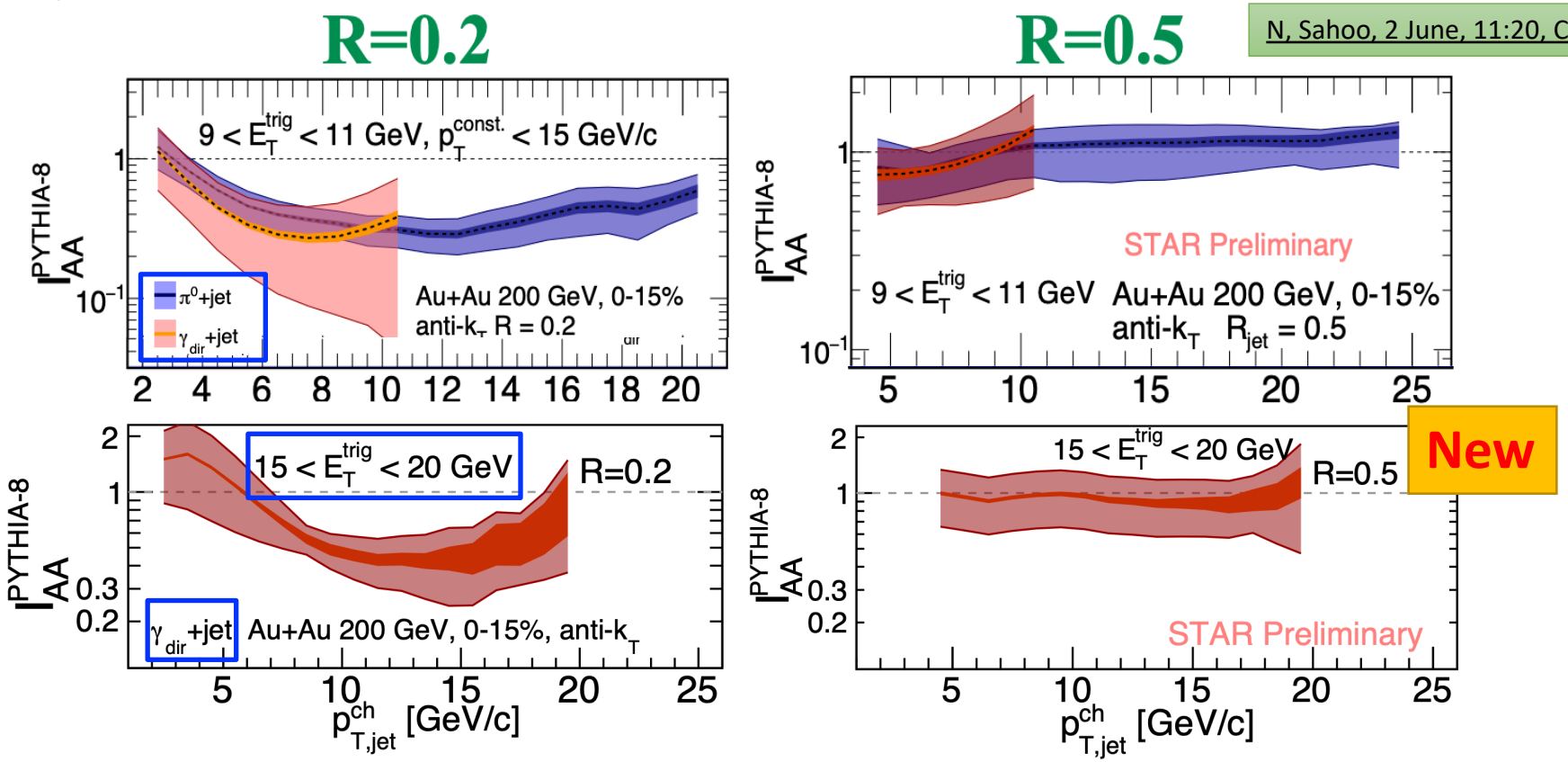
N, Sahoo, 2 June, 11:20, C1



Vary:

- quark vs. gluon of recoil jets
- <path length>

$$I_{AA}(p_{T,jet}^{ch}) = \frac{Y(p_{T,jet}^{ch})^{Au+Au}}{Y(p_{T,jet}^{ch})^{p+p}}$$



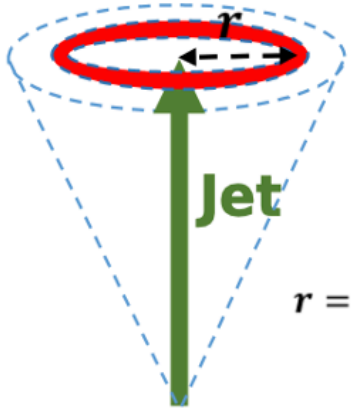
First γ^{dir}+jet and π^0+jet in Au+Au at RHIC:

- γ^{dir}+jet and π^0+jet show similar level of suppression, no significant trigger E_T dependence
- R dependence of suppression sensitive to reference used (PYTHIA 6 STAR tune vs. PYTHIA8); will be resolved with p+p measurements

Jet Shape in Au+Au

J. Mazer, 4 June, 13:50, H1

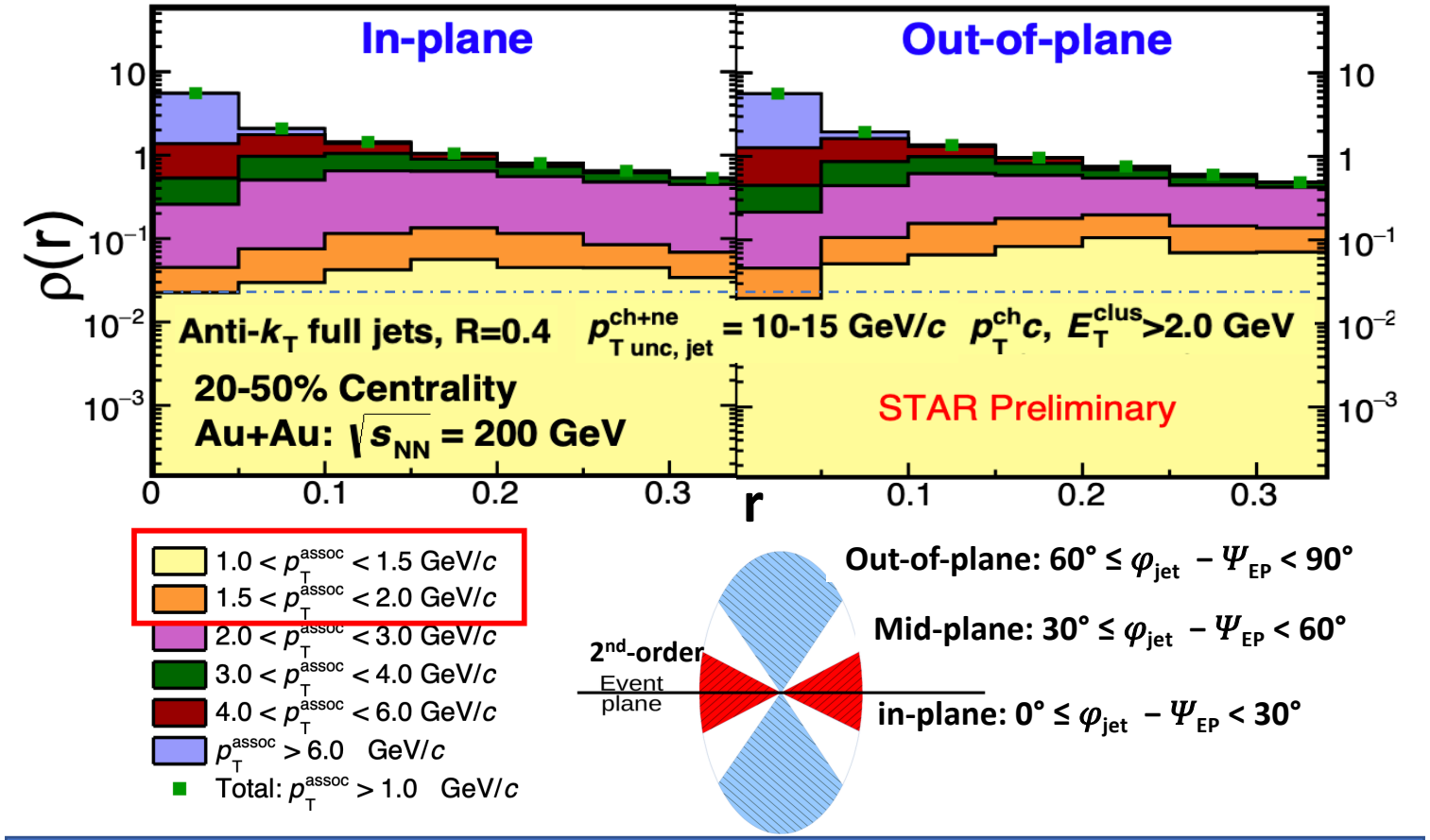
Jet Shapes



$$r = \sqrt{(\Delta\varphi)^2+(\Delta\eta)^2}$$

$$\rho(r) = \frac{1}{\delta r}\frac{1}{N_{\text{jet}}}\sum_{\text{jet}}\frac{\sum_{\text{track}\in(r-\delta r/2,r+\delta r/2)} p_{\text{T,track}}}{p_{\text{T,jet}}}$$

- Provides information about the radial distribution of momentum carried by the jet constituents (fragments)

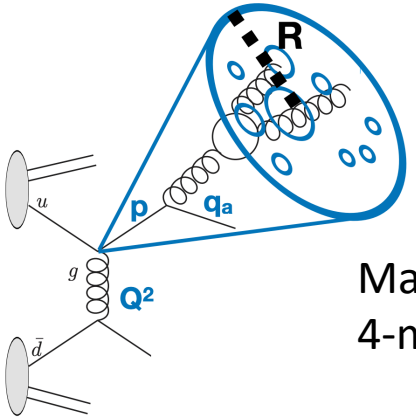


First full-jet (charged+neutral) shapes in Au+Au at RHIC:

- Low-p_T particles have larger yields, and are pushed toward larger r in the out-of-plane direction
  → Hint of path-length dependent jet quenching

Jet (groomed) Mass in p+p and p+Au

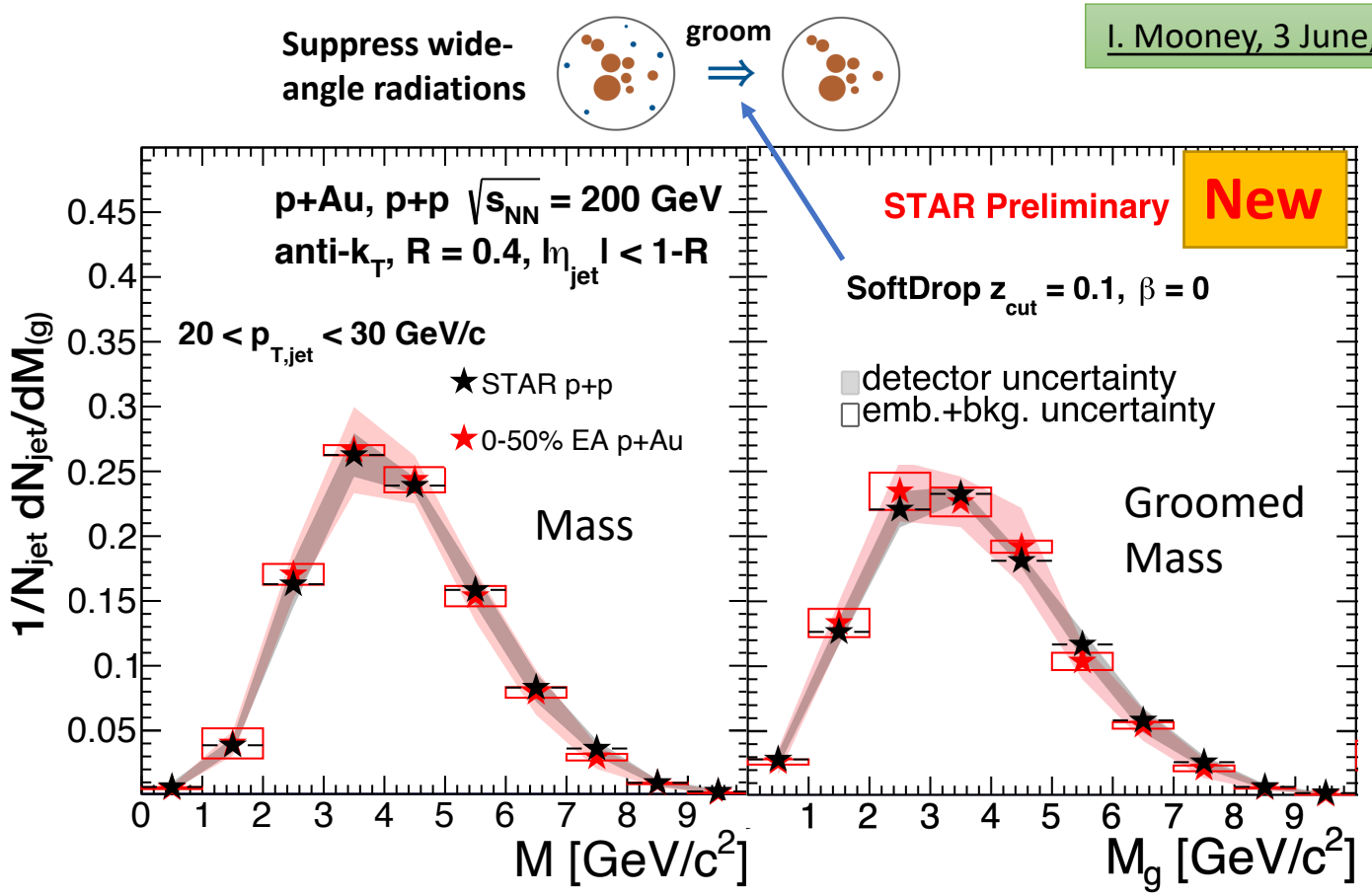
I. Mooney, 3 June, 11:50, E1



$$M_{\text{jet}} = \left| \sum_{i \in J} p_i \right| = \sqrt{E^2 - \mathbf{p}^2}$$

Magnitude of constituents 4-momentum sum within R

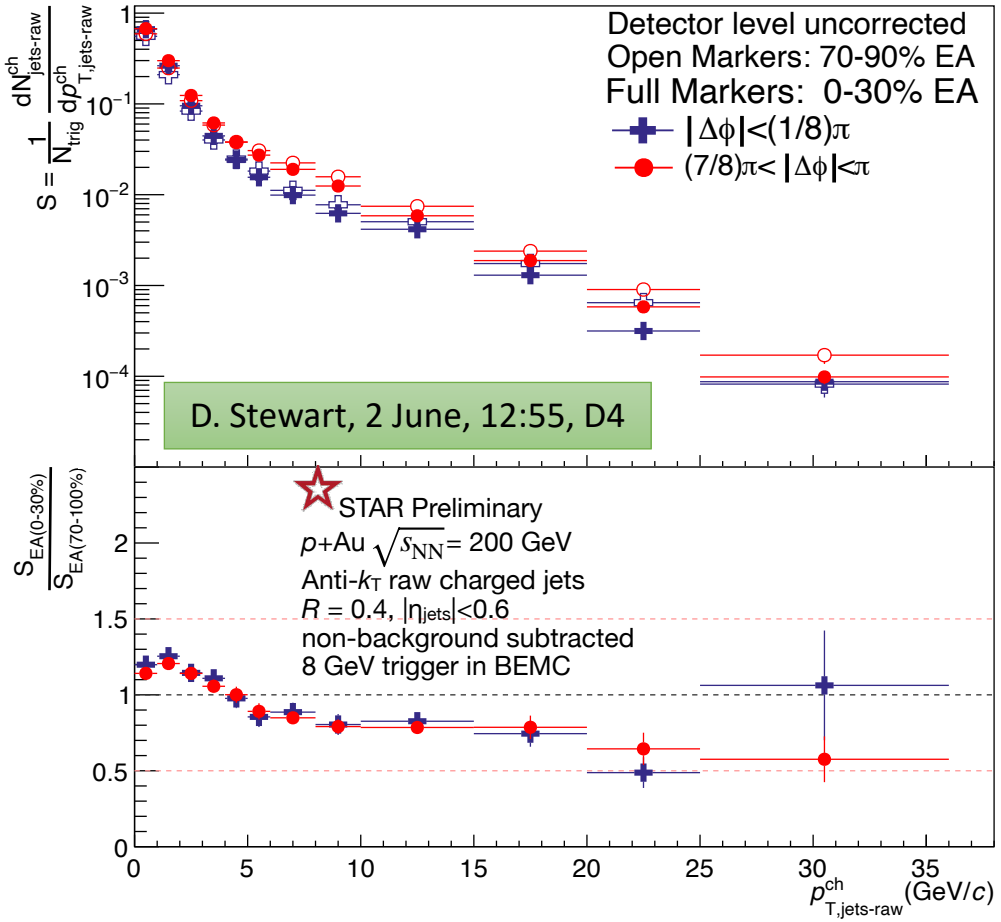
- Jet mass is sensitive to how parton loses energy in medium
- Jets with different masses resolve medium at different scales

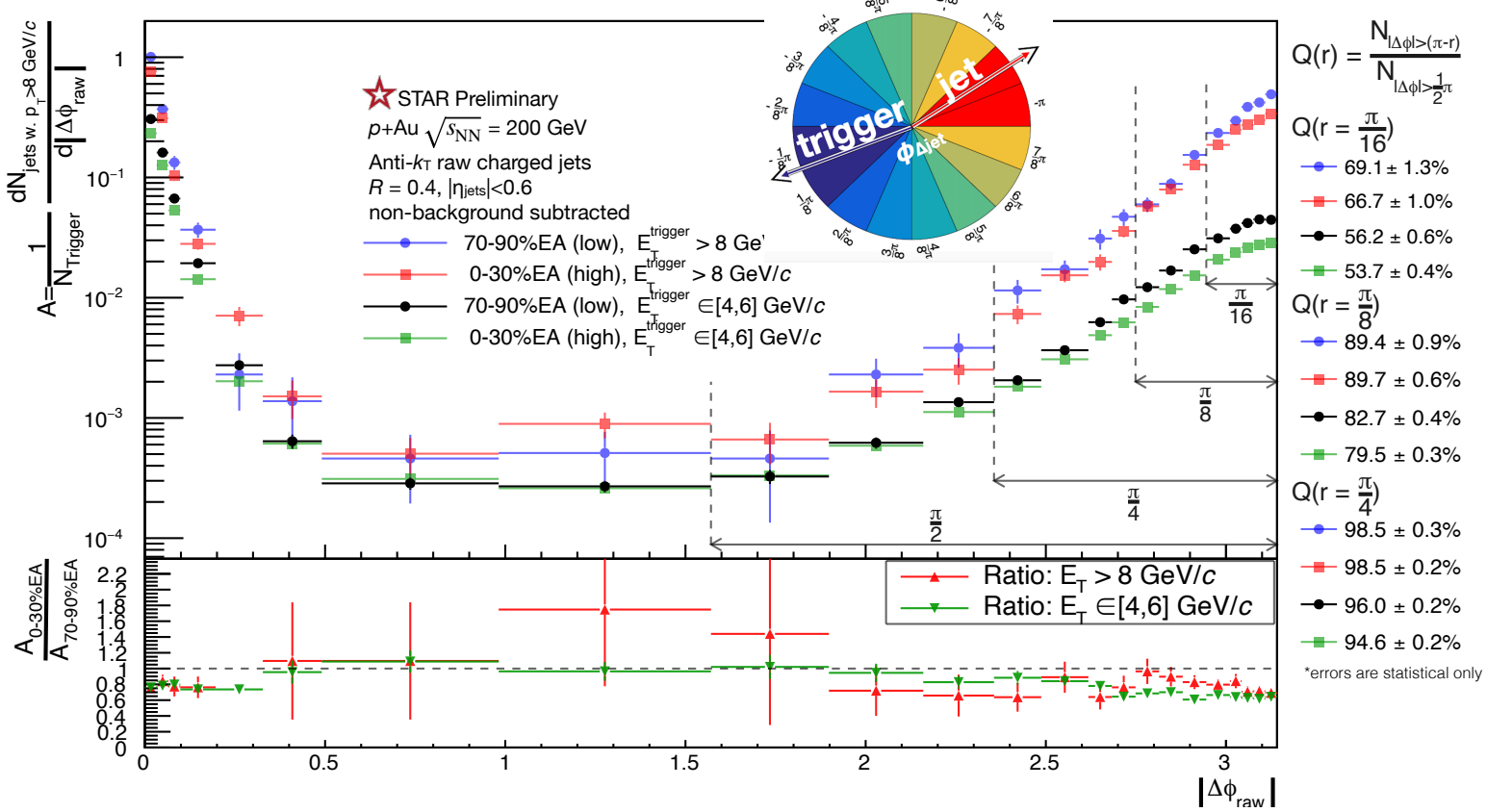


First inclusive jet (groomed) mass measurements in p+p and p+Au at RHIC:

- High event activity p+Au consistent with p+p, suggesting p+p-like fragmentation
- No significant modification on jet mass due to the CNM effects

Event Activity Dependent Jet Study in p+Au





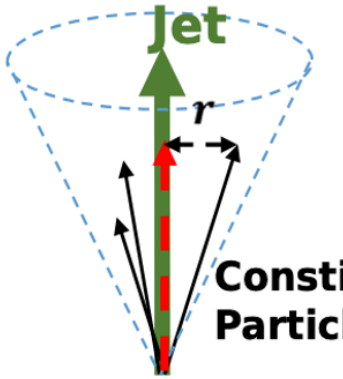
EA is defined with the BBC activity in the Au-going direction

- High-EA vs. low-EA: spectra clearly suppressed, but acoplanarity minimally modified
- Consistent with phase-space correlation; qualitatively reproduced by PYTHIA (details in Dave's talk)

Jet Fragmentation Function in Au+Au

J. Mazer, 4 June, 13:50, H1

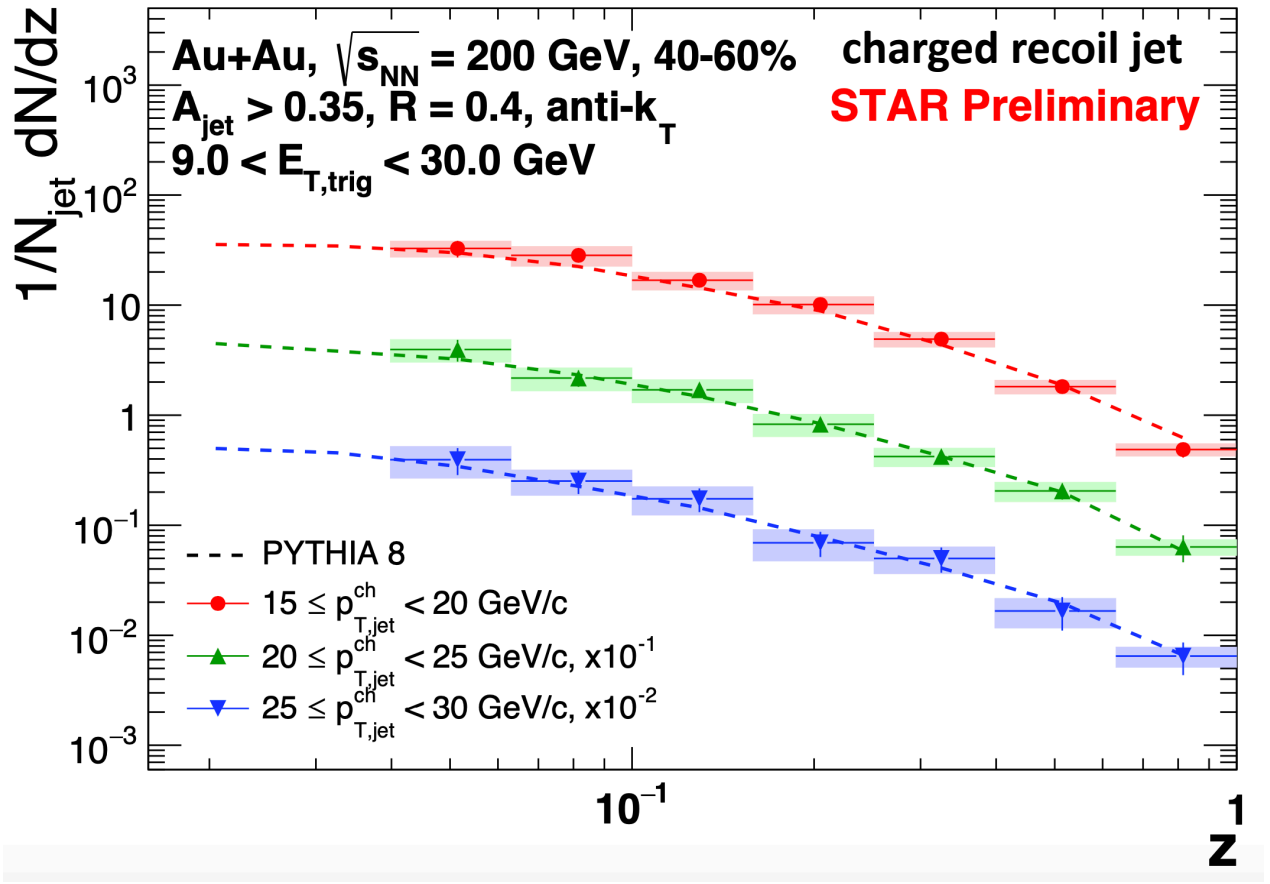
Jet Fragmentation Functions



$$z = \frac{p_{T,track}\cos(r)}{p_{T,jet}}$$

$$\text{Fragmentation Function} = \frac{1}{N_{jet}}\frac{dN}{dz}$$

- Provides information of the longitudinal momentum fraction of particles with respect to the jet



Semi-inclusive jet fragmentation functions in 15 <= $p_{T,jet}^{ch}$ < 30 GeV/c:

- Unfolded results (40-60%) are comparable to PYTHIA8 predictions

J/ψ Production in Jet in p+p

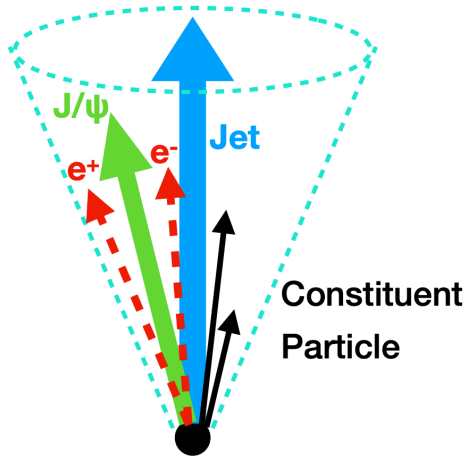
Q. Yang, 2 June, 12:55, D2

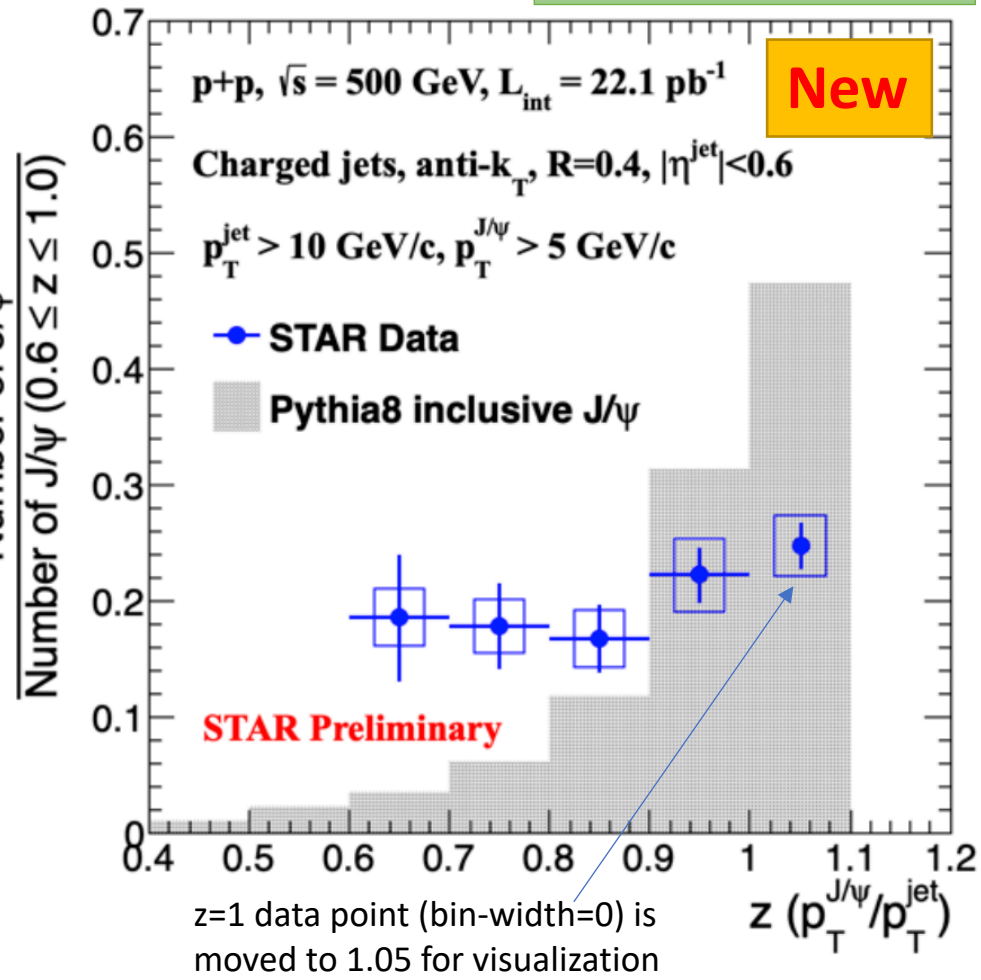
J/ψ as a probe of QGP, its production mechanism is still unclear

- The non-pQCD transition ($c\bar{c} \rightarrow J/\psi$) can be characterized through the universal NRQCD long-distance matrix elements (LDMEs)

- Calculations with different LMDEs could well describe the inclusive J/ψ p_T spectrum, but give significantly different predictions on J/ψ distribution inside jets

Zhong-Bo, Kang et.al, PRL 119, 032001(2017)





First J/ψ-jet fragmentation function at RHIC:

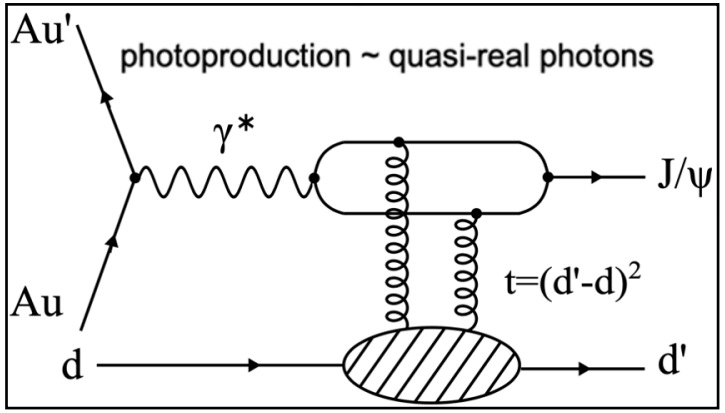
- Data indicate different trend and less isolated production than PYTHIA8

- **Welcome theoretical calculations for RHIC**

Photoproduction of J/ψ in d+Au UPC

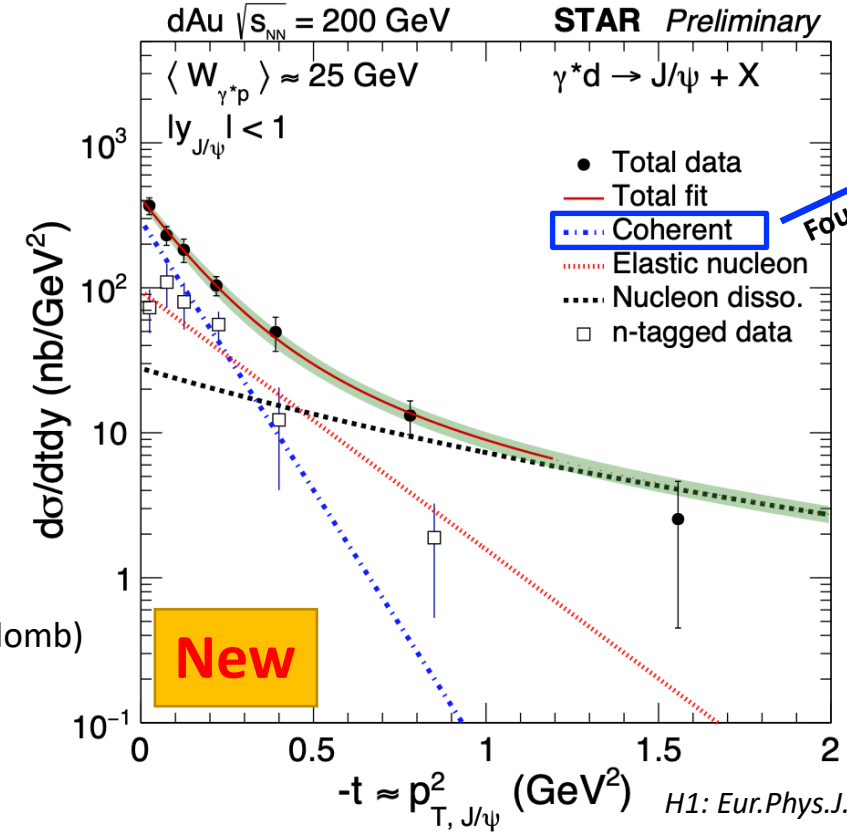
Z. Tu, 1 June, 11:20, A4

Photoproduction of J/ψ is a good tool to study the gluon density distributions inside nucleons and nucleus

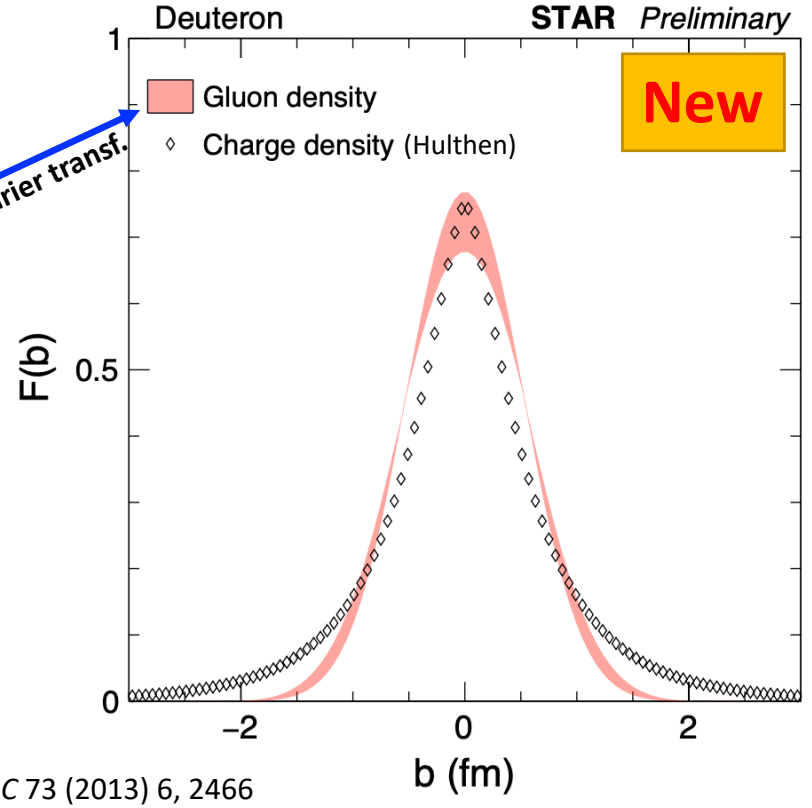


Au + d → J/ ψ + Au' + X

- X = d' (coherent) or d'→ p'+n' (coherent + coulomb)
- X = p'+n' (elastic nucleon)
- X = p'+X or n'+X (nucleon dissoc.)



Fourier transf.



H1: Eur.Phys.J.C 73 (2013) 6, 2466

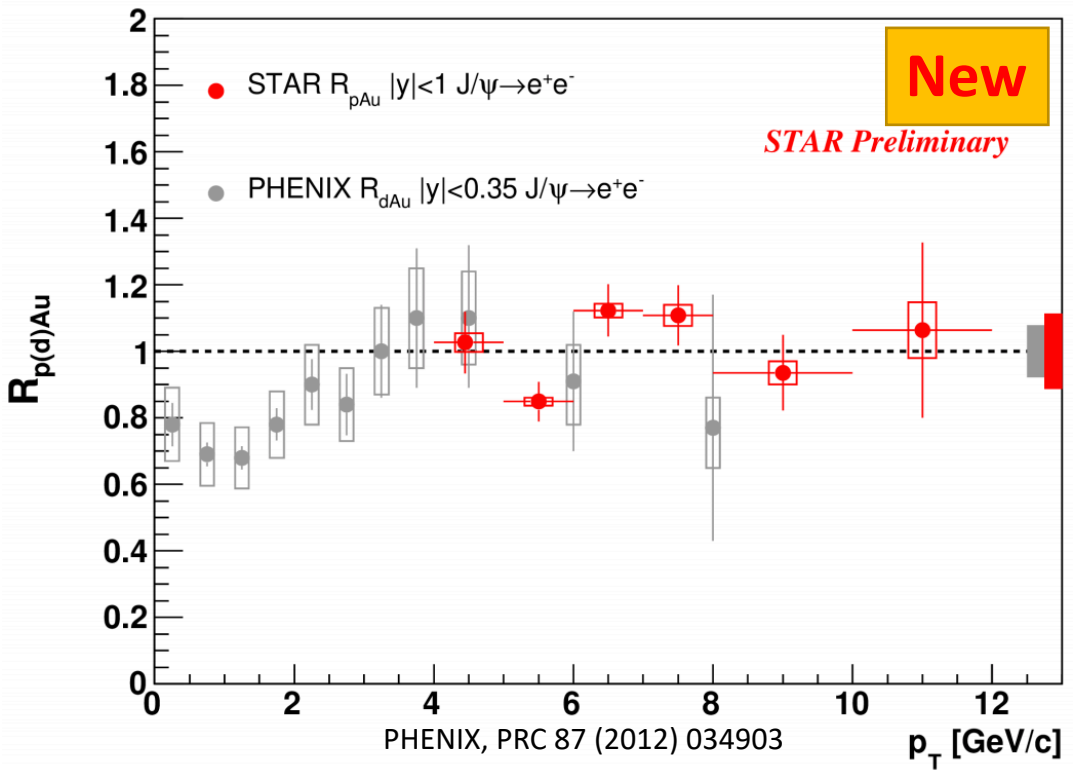
First coherent J/ψ photoproduction off deuteron:

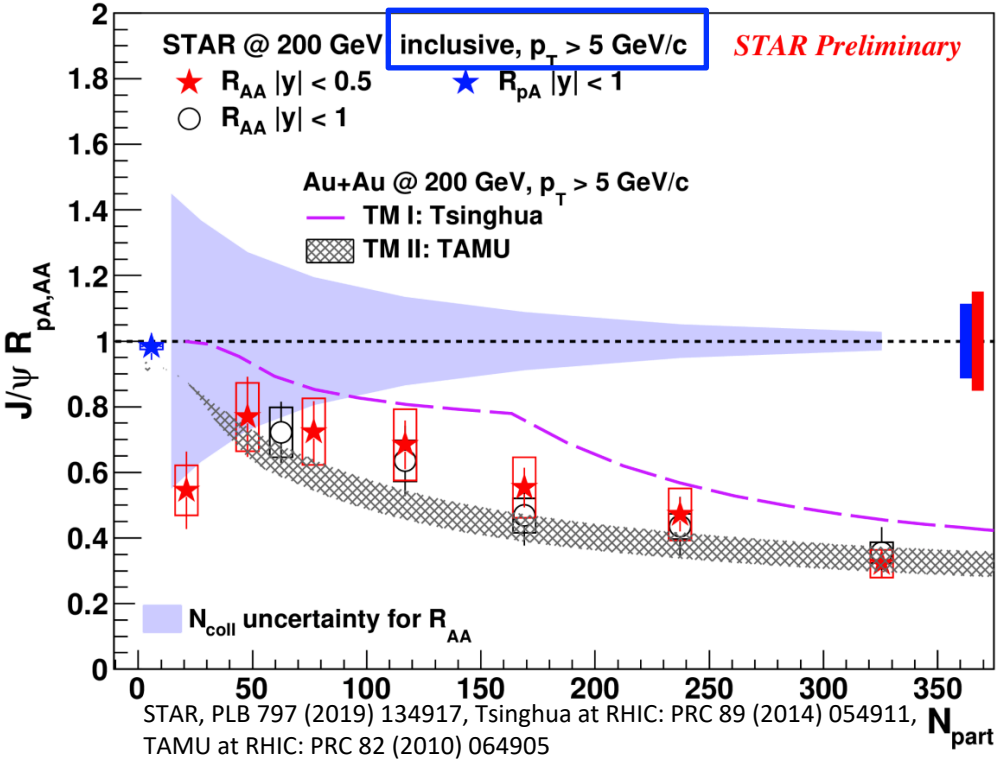
- Cross sections of different physics processes are extracted
- Hint: gluon distribution is different to the charge distribution

J/ψ Suppression in p+Au w.r.t. p+p

ZY Zhang, 1 June, 12:20, A3

CNM effects on J/ψ production are important to interpret J/ψ suppression in AA

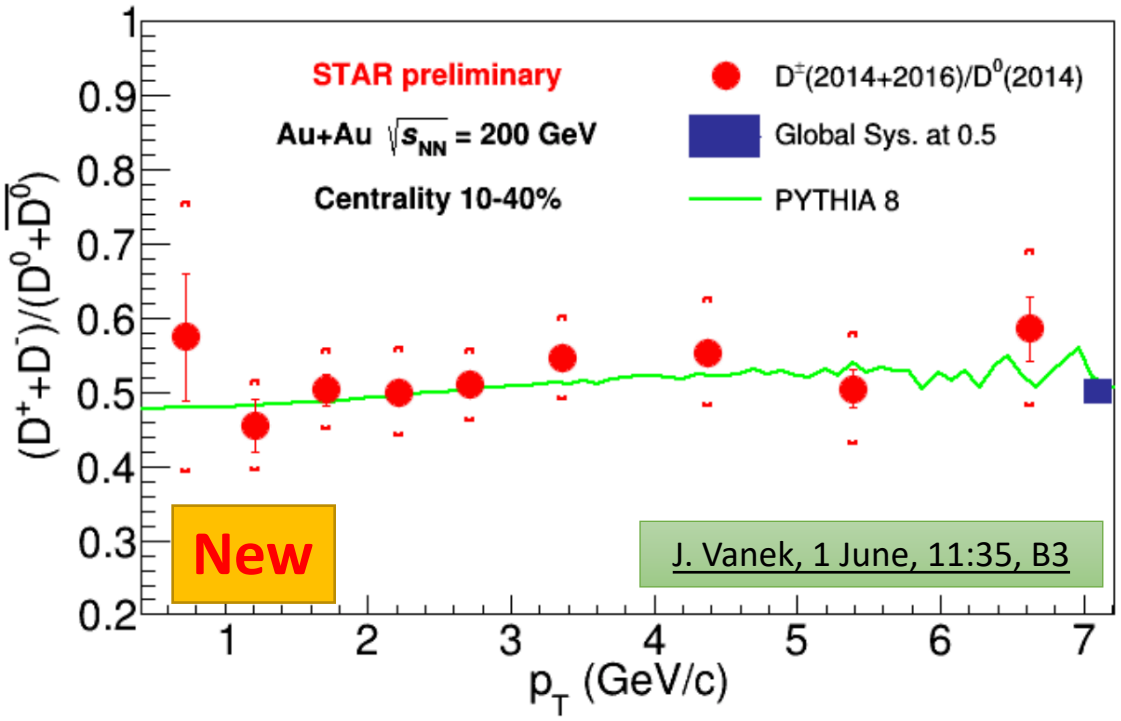




The new J/ψ R_{pA} measurements:

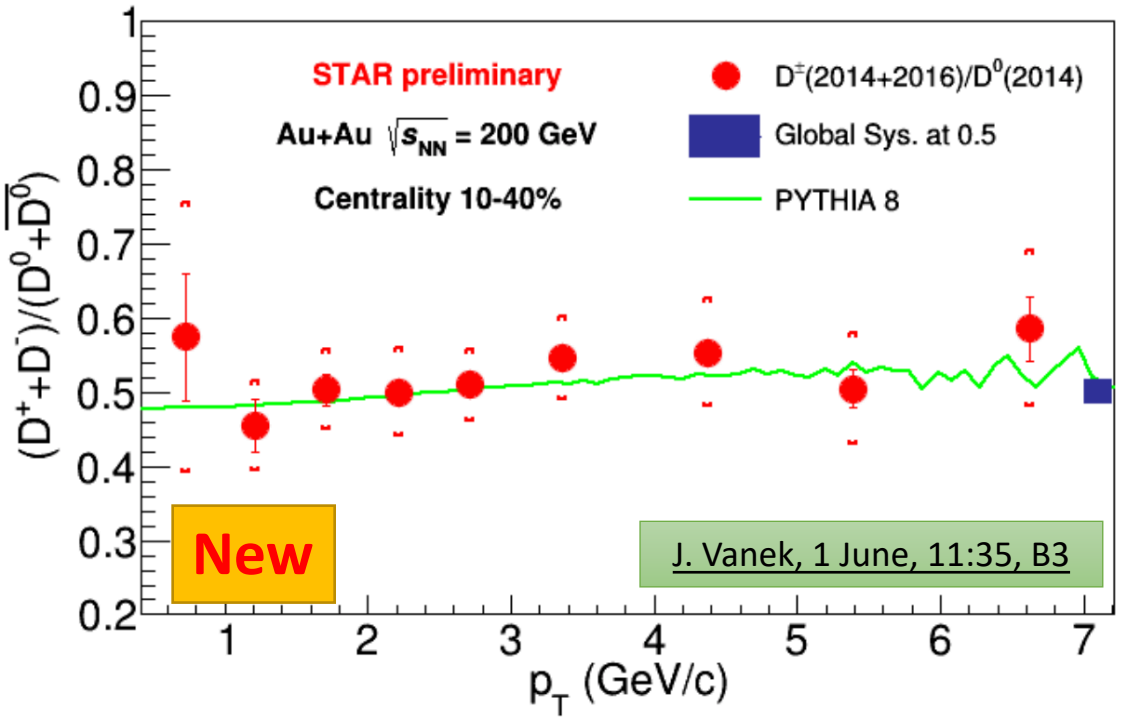
- Consistent with unity, suggesting no suppression at high p_T due to the CNM effects
- Suppression of high p_T J/ψ in Au+Au are dominantly due to the hot medium effect

$D^{\pm}$ and $D_s^{\pm}$ vs D^0 in Au+Au



- $D^{\pm}$ show similar level of suppression as D^0, as expected

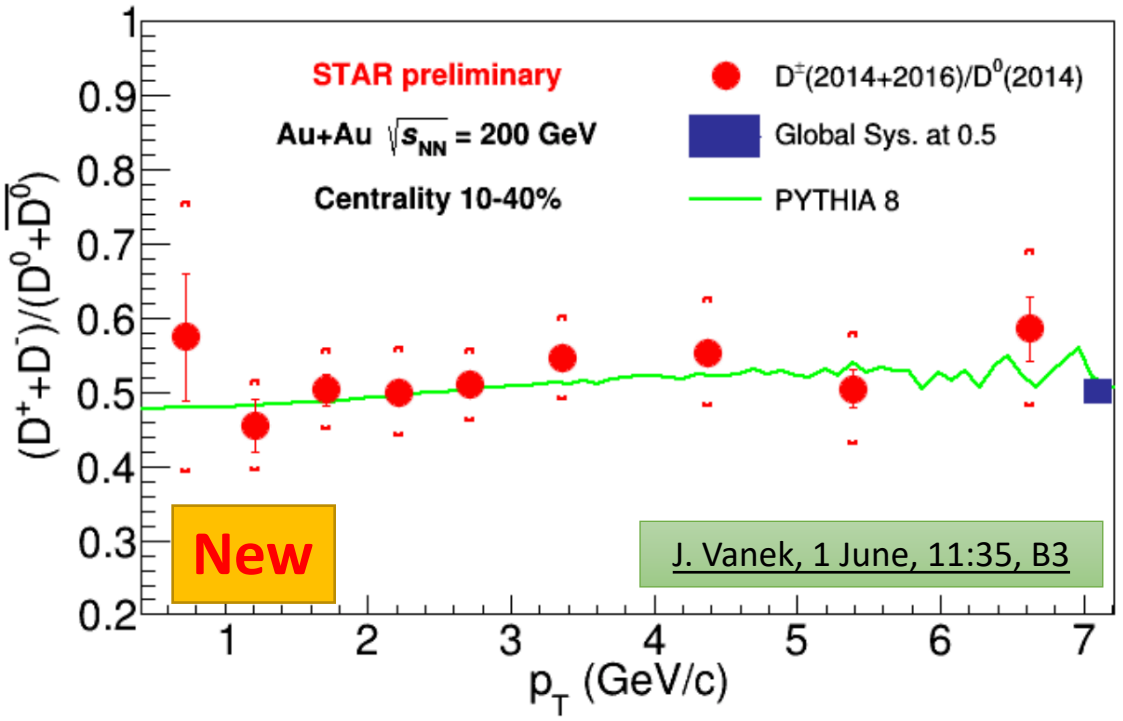
$D^{\pm}$ and $D_s^{\pm}$ vs D^0 in Au+Au

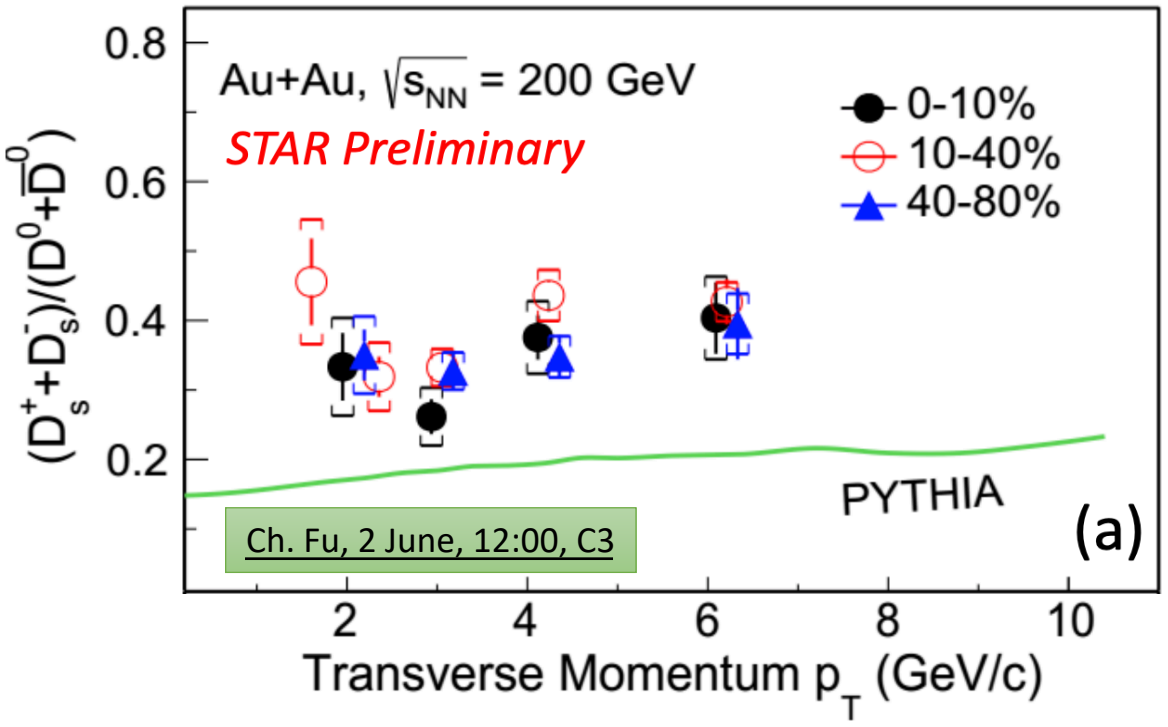


- Will the enhanced strangeness production observed in A-A collisions be reflected in D_s production ?

- $D^{\pm}$ show similar level of suppression as D^0, as expected

$D^{\pm}$ and $D_s^{\pm}$ vs D^0 in Au+Au

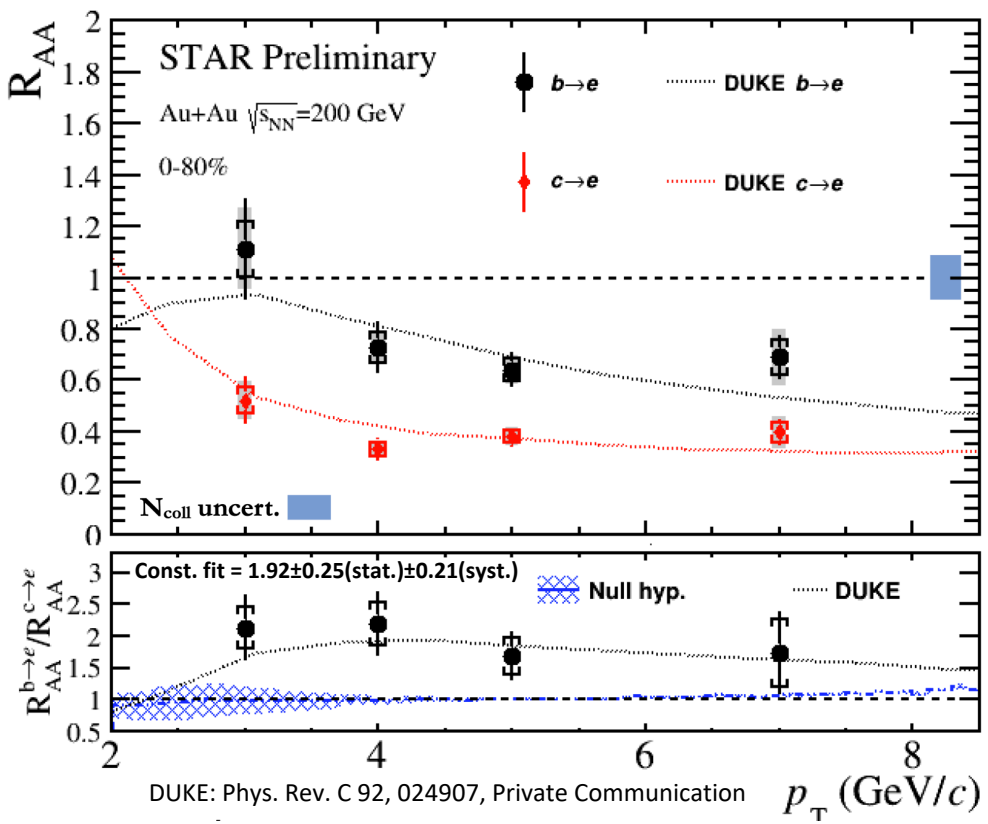




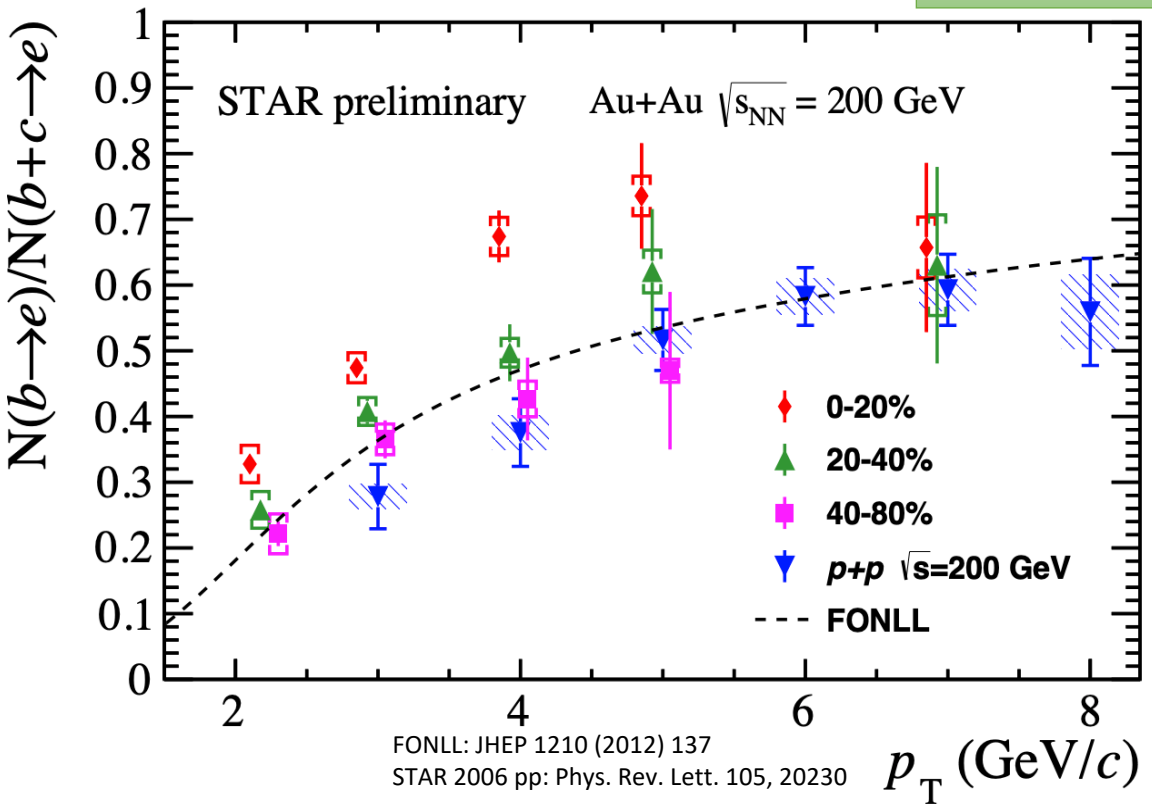
- $D^{\pm}$ show similar level of suppression as D^0, as expected
- $(D_s^+ + D_s^-)/(D^0 + \overline{D}^0)$: larger than the PYTHIA calculation (1.5~2 times), consistent with the expectation of coalescence hadronization of *c* with enhanced *s* quarks

$c \rightarrow e$ and $b \rightarrow e$ with Heavy Flavor Tracker

YJ Zhou, 4 June, 11:35, G3



DUKE: Phys. Rev. C 92, 024907, Private Communication



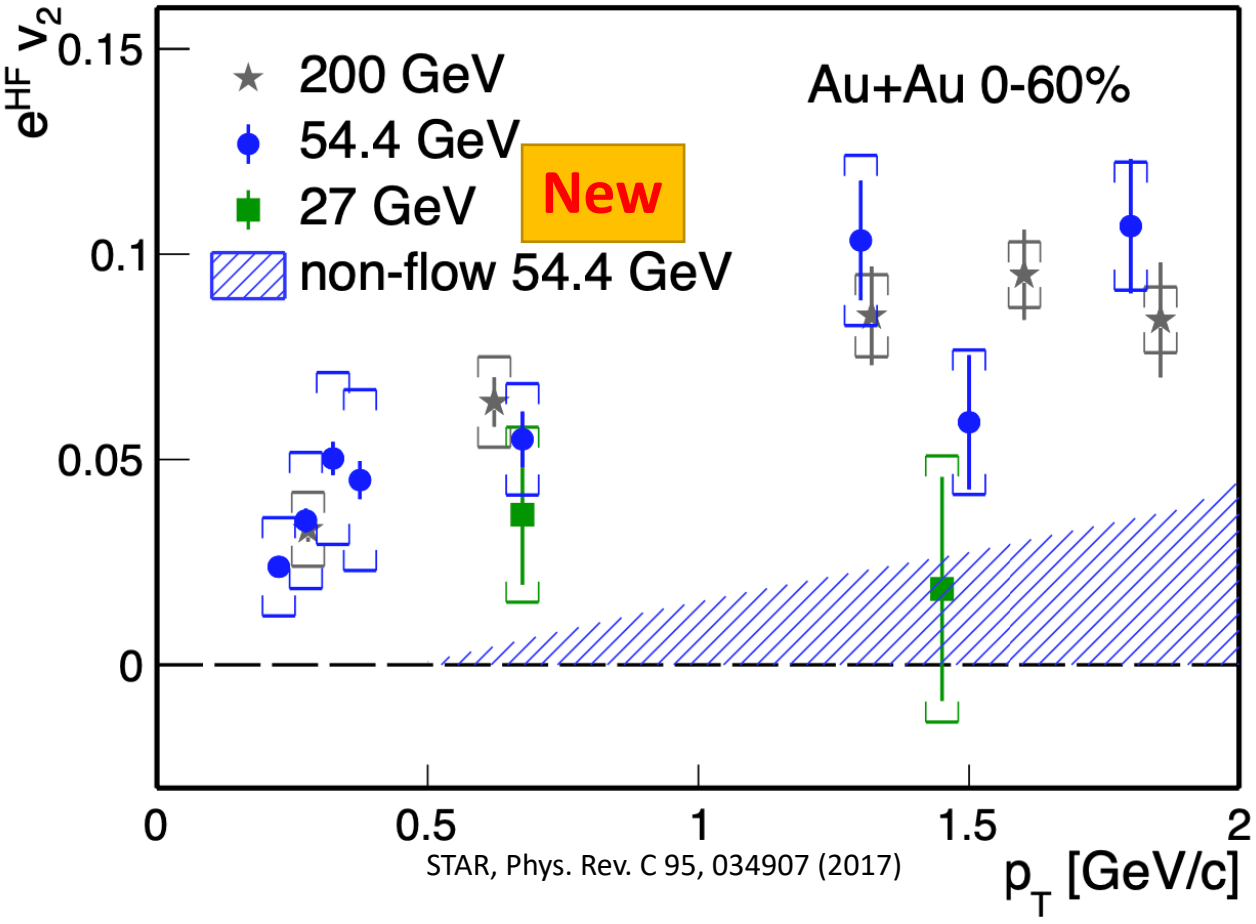
FONLL: JHEP 1210 (2012) 137
STAR 2006 pp: Phys. Rev. Lett. 105, 20230

- $R_{AA}(b \rightarrow e) > R_{AA}(c \rightarrow e)$ (>3σ): bottom is less suppressed than charm
- Bottom fraction significantly enhanced in central collisions, approach p+p data towards peripheral
- Consistent with $\Delta E(b) < \Delta E(c)$ in the QGP

HF (c+b)→ e v_2 at Lower Energies

YJ Ji, 4 June, 11:15, G3

Do heavy flavor quarks show similar collectivity at lower energies?



Large datasets ~10x BES-I allow measuring HF decayed electron v_2 at lower energies

- e^{HF} in 54.4 GeV: non-zero v_2, comparable to e^{HF} at 200 GeV as well as light hadrons at 54.4 GeV
  - Indication of strong charm-medium interactions at 54.4 GeV
- e^{HF} in 27 GeV: hint of a smaller v_2 than 54.4 and 200 GeV

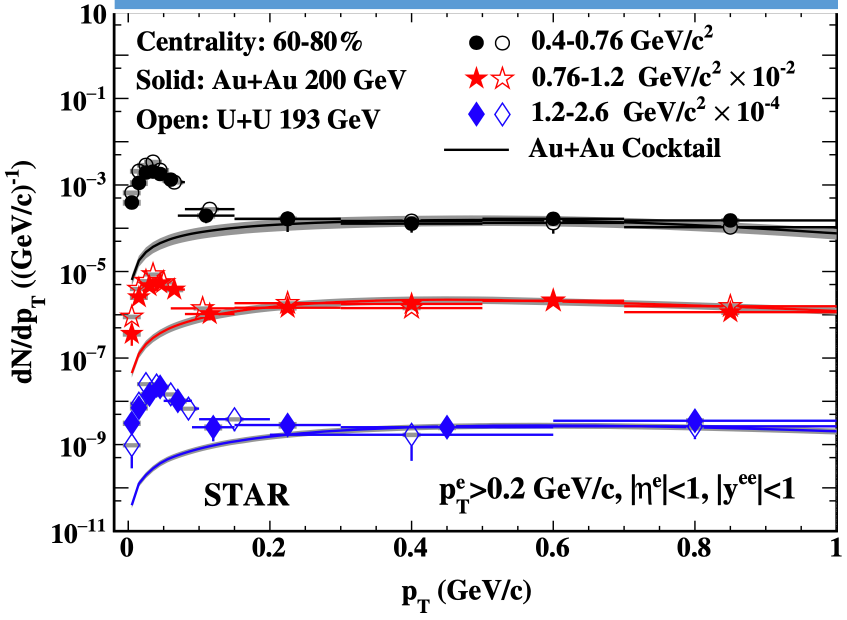
$\mu^+\mu^-$ pairs Enhancement in Peripheral Au+Au

Z. Liu, 2 June, 11:00, C2

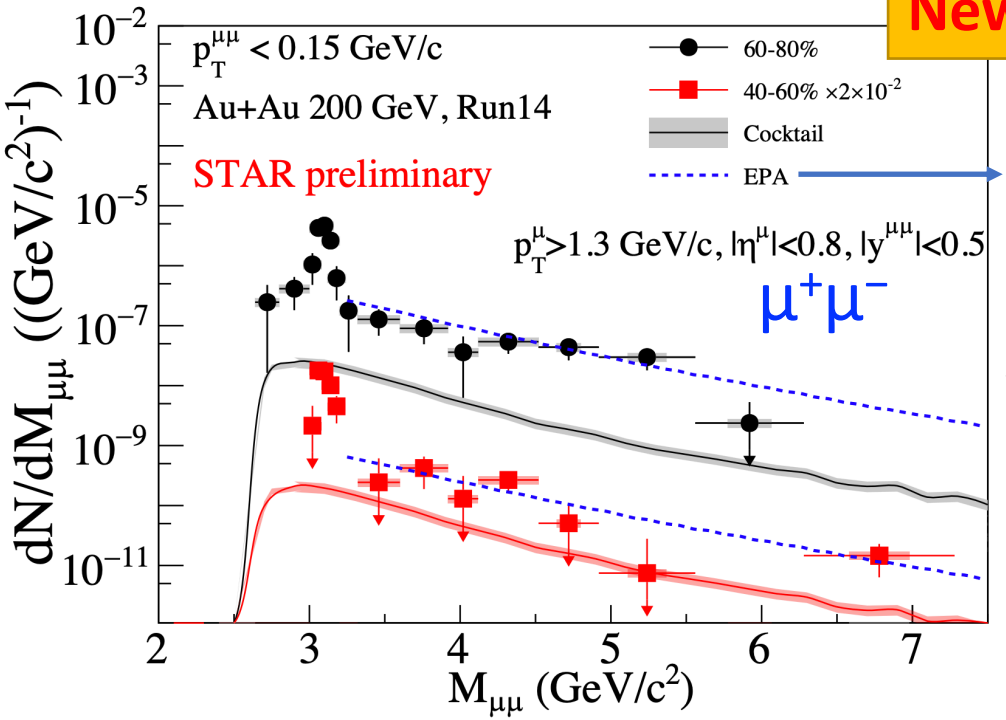
Significant enhancement of the very low-p_T J/ψ and low mass e^+e^- pairs observed in peripheral A+A collisions at STAR

STAR, Phys. Rev. Lett. 123 (2019)132302, STAR, Phys. Rev. Lett. 121 (2018) 132301

STAR published e^+e^- enhancement



New



Equivalent **P**hoton **A**pproximation
- Photon as real
- Weizsacker–Williams method to estimate photon flux

W.M. Zha et al., Phys. Lett. B 800 (2020) 135089

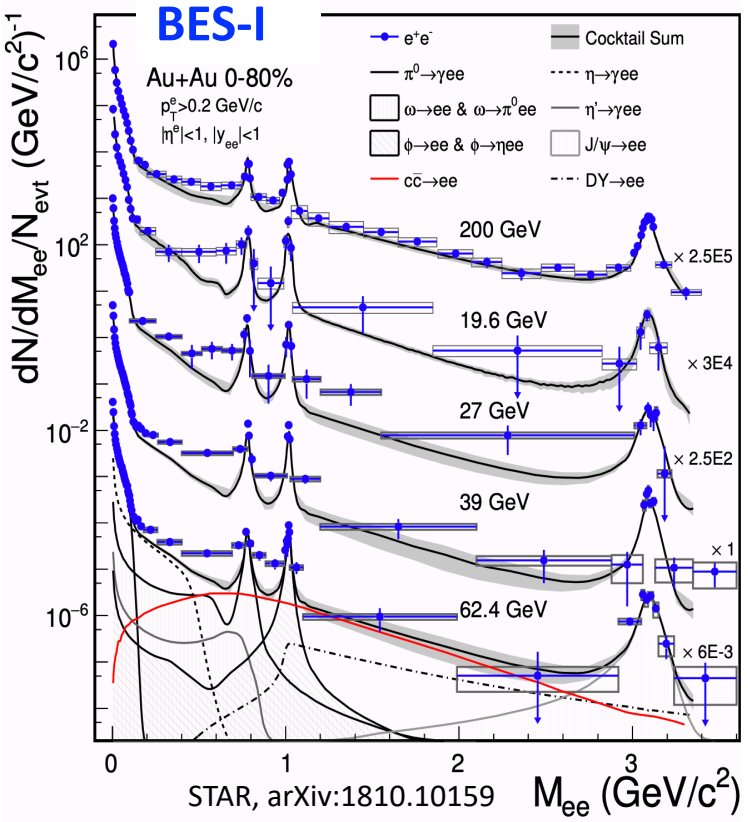
First dimuon enhancement from STAR:
- Similar as in previous dielectron measurements at M_{ee}<3.2 GeV/c^2, extend to the higher mass region
- Consistent with EPA model calculations

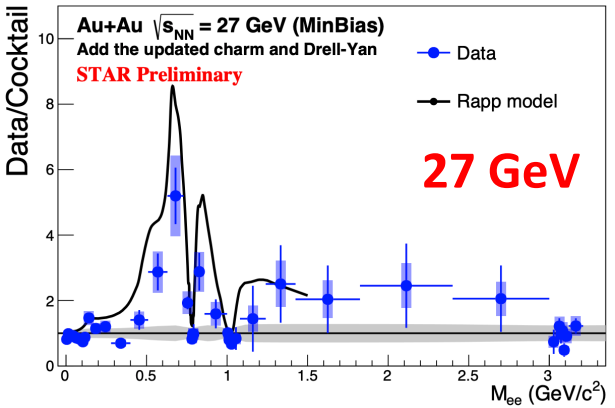
Dielectron Production in Au+Au

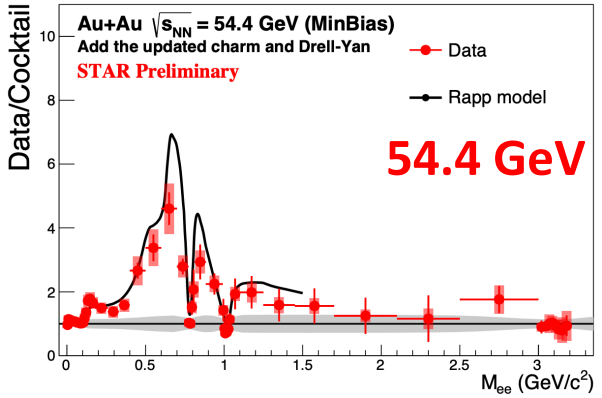
Excellent penetrating probe, created throughout evolution of medium

Z. Wang, 2 June, 11:40, C2

- LMR ($M_{ee} < M_{\phi}$): in-medium modifications linked to the chiral symmetry restoration
- IMR ($M_{\phi} < M_{ee} < M_{J/\psi}$): excess from thermal radiation → medium temperature







New 54.4 GeV and improved 27 GeV (~x10 BES-I):

- Consistent with published data with greatly improved data precision
- Hint of more enhancement at IMR in 27 GeV than 54 GeV → lower energy 7.7-19.6 GeV (BES-II) could further explore

STAR Beyond BES-II (2021+)

D. Brandenburg, 4 June, 11:55, G4

STAR

- The forward ($2.5 < \eta < 4$) upgrade includes **Trackers (**silicon microstrip tracker **& s**mall-strip **Thin Gap Chamber)** and **Calorimeters (ECAL & HCAL)** dedicated to study nuclear structure, QGP (details will be in Daniel's talk).

Forward-rapidity 2.5 < h < 4.0

A+A

Beam:
Full Energy AuAu

Physics Topics:
- Temperature dependence of viscosity through flow harmonics up to h~4
- Longitudinal decorrelation up to h~4
- Global Lambda Polarization → strong rapidity dependence predicted

p+p & p+A

Beam:
500 GeV: p+p
200 GeV: p+p and p+A

Physics Topics:
- TMD measurements at high x transversity → tensor charge
- Improve statistical precision for Sivers through DY
- $Dg(x,Q^2)$ at low x through Di-jets
- Gluon PDFs for nuclei
- ➢ R_{pA} for direct photons & DY
- Test of Saturation predictions through di-hadrons, g-Jets

Observables:
- Inclusive jets and di-jets
- Hadrons in jets
- Direct photons
- Drell-Yan *e+e-*
- Lambda's
- Mid-forward & forward-forward
- rapidity correlations

Requirements:
- Good *e*/*h* separation
- Hadrons, photons, π^0 identification

2021/22: 500 GeV polarized pp run

Additional pp, pA, and AA data taking in parallel to the sPHENIX campaign

Summary: Enjoy All STAR Talks and Posters !!!

Click for contributions

Initial State

234. **Dependence of jet and high-p_T charged particle production on event activity at high rapidity in sqrt(sNN) = 200 GeV p+Au collisions** — David Stewart, 2 June, 12:55, D4
315. **Photoproduction of J/psi -mesons off deuteron in d+Au Ultra-Peripheral Collisions using the STAR detector** — Zhoudunming Tu, 1 June, 11:20, A4

Jets and High Momentum Hadrons

235. **Jet substructure in p+p and p+Au collisions at sqrt(sNN) = 200 GeV at STAR** — Isaac Mooney, 3 June, 11:50, E1
236. **Evolution of jet shapes and fragmentation functions in Au+Au collisions at sqrt(sNN) = 200 GeV with the STAR experiment at RHIC** — Joel Mazer, 4 June, 13:50, H1
237. **Measurement of fully-reconstructed inclusive jet production in Au+Au collisions at sqrt(sNN) = 200 GeV by the STAR experiment** — Robert Licenik, 1 June, 11:20, A1
238. **γ+jet and π^0+jet Measurements in Au+Au Collisions at sqrt(sNN) = 200 GeV with the STAR Experiment** — Nihar Sahoo, 2 June, 11:20, C1
247. **Measuring the groomed shared momentum fraction (z_g) in Au+Au collisions at sqrt(sNN) = 200 GeV at STAR** — Daniel Nemes
248. **Measurement of semi-inclusive jet fragmentation functions in Au+Au collisions at sqrt(sNN) = 200 GeV in STAR** — Saehanseul Oh
249. **Jet and Di-jet Underlying Event in p+Au collisions at sqrt(sNN) = 200 GeV at STAR** — Veronica Verkest
253. **Transverse Momentum Imbalance for Jets Recoiling from Direct-photon and π^0 Triggers in Au+Au Collisions at sqrt(sNN) = 200 GeV** — Annika Ewigleben

Heavy Flavor and Quarkonia

223. **Elliptic flow of electrons from heavy-flavor decays in 54.4 and 27 GeV Au+Au collisions from the STAR experiment at RHIC** — Yuanjing Ji, 4 June, 11:15, G3
225. **Measurements of electron production from heavy flavor decays in p+p and Au+Au collisions at sqrt(sNN) = 200 GeV at STAR** — Yingjie Zhou, 4 June, 11:35, G3
227. **Measurement of $D^{\pm}$ meson production in Au+Au collisions at sqrt(sNN) = 200 GeV with the STAR experiment** — Jan Vanek, 1 June, 11:35, B3
229. **Production of $D_s^{\pm}$ mesons in Au+Au collisions at sqrt(sNN) = 200 GeV by STAR** — Chuan Fu, 2 June, 12:00, C3
232. **J/psi production in jets in p+p collisions at sqrt(s) = 500 GeV by STAR** — Qian Yang, 2 June, 12:55, D2
233. **Cold Nuclear Matter Effects on J/psi and Upsilon Productions at RHIC with the STAR Experiment** — Ziyue Zhang, 1 June, 12:20, A3

Electroweak Probes

240. **Measurements of dielectron production in Au+Au collisions at sqrt(sNN) = 27 and 54.4 GeV with the STAR experiment** — Zhen Wang, 2 June, 11:40, C2
245. **Low-p_T μ^+ μ^- pair production in Au+Au collisions at sqrt(sNN) = 200 GeV at STAR** — Zhen Liu, 2 June, 11:00, C2

New Experimental Developments

288. **The Forward Rapidity Upgrade for the STAR Detector** — D. Brandenburg, 4 June, 11:55, G4

The STAR Collaboration: https://drupal.star.bnl.gov/STAR/presentations/

THANK YOU

STAR is composed of 68 institutions from 14 countries and region, with a total of 722 collaborators

STAR Collaboration Acknowledgements

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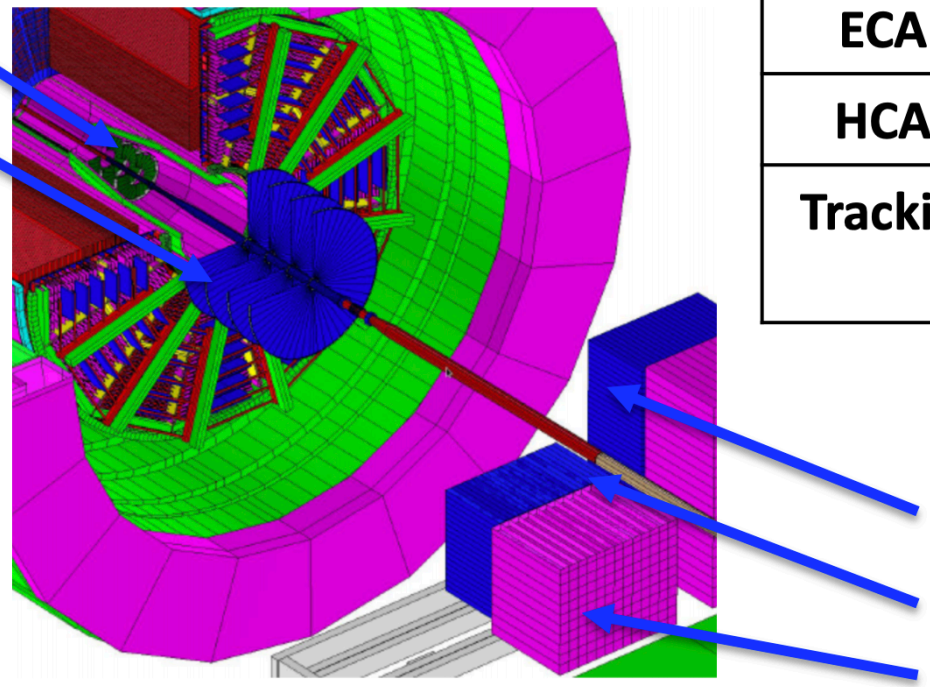
STAR official webpage: https://www.star.bnl.gov/

STAR Beyond BES-II

D. Brandenburg, 4 June, 11:55, G4

- **Detectors from BES-II upgrade (iTPC and EPD) will keep going**
- The forward ($2.5 < \eta < 4$) upgrade includes **Trackers** (silicon microstrip tracker **&** small-strip **Thin Gap Chamber)** and **Calorimeters (ECAL & HCAL)** dedicated to study nuclear structure, QGP.

Forward Tracker
- 3 silicon disks
- 4 sTGC layers



Detector	pp and pA	AA
ECAL	~10%/√E	~20%/√E
HCAL	~60%/√E	---
Tracking	Charge separation Photon suppression	$0.2 < p_T < 2$ GeV/c with 20 – 30% $1/p_T$

Preparing for data-taking from **2021+**

Forward Calorimeters
- Pre/post-shower: scintillator
- ECAL: PbSc towers (18 X_0)
- HCAL: FeSc plates (4.5 λ)