Coherent e^+e^- production at very low transverse momentum at STAR

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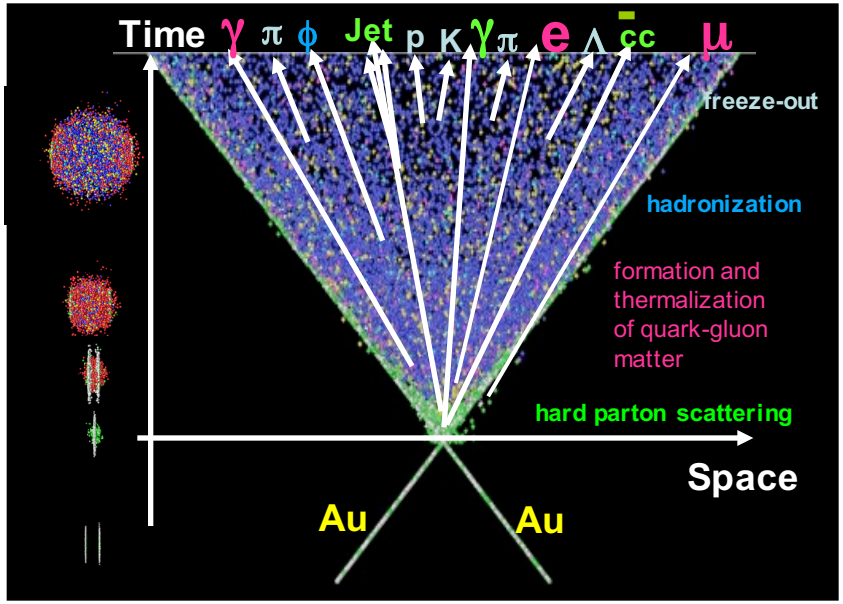
Outline

- ✓ Electromagnetic probes at STAR
- ✓ Very low p_T e^+e^- production
- ✓ e^+e^- production and iTPC upgrade
- ✓ Summary and outlook

Electromagnetic probes in heavy-ion collisions

Direct photon and e^+e^- pairs —— ideal electromagnetic probes

- ✓ suffer no strong interaction, traverse the medium with minimum interaction
- ✓ produced throughout all stages of the evolution of the system



Direct photon:

Higher p_T -> Earlier produced

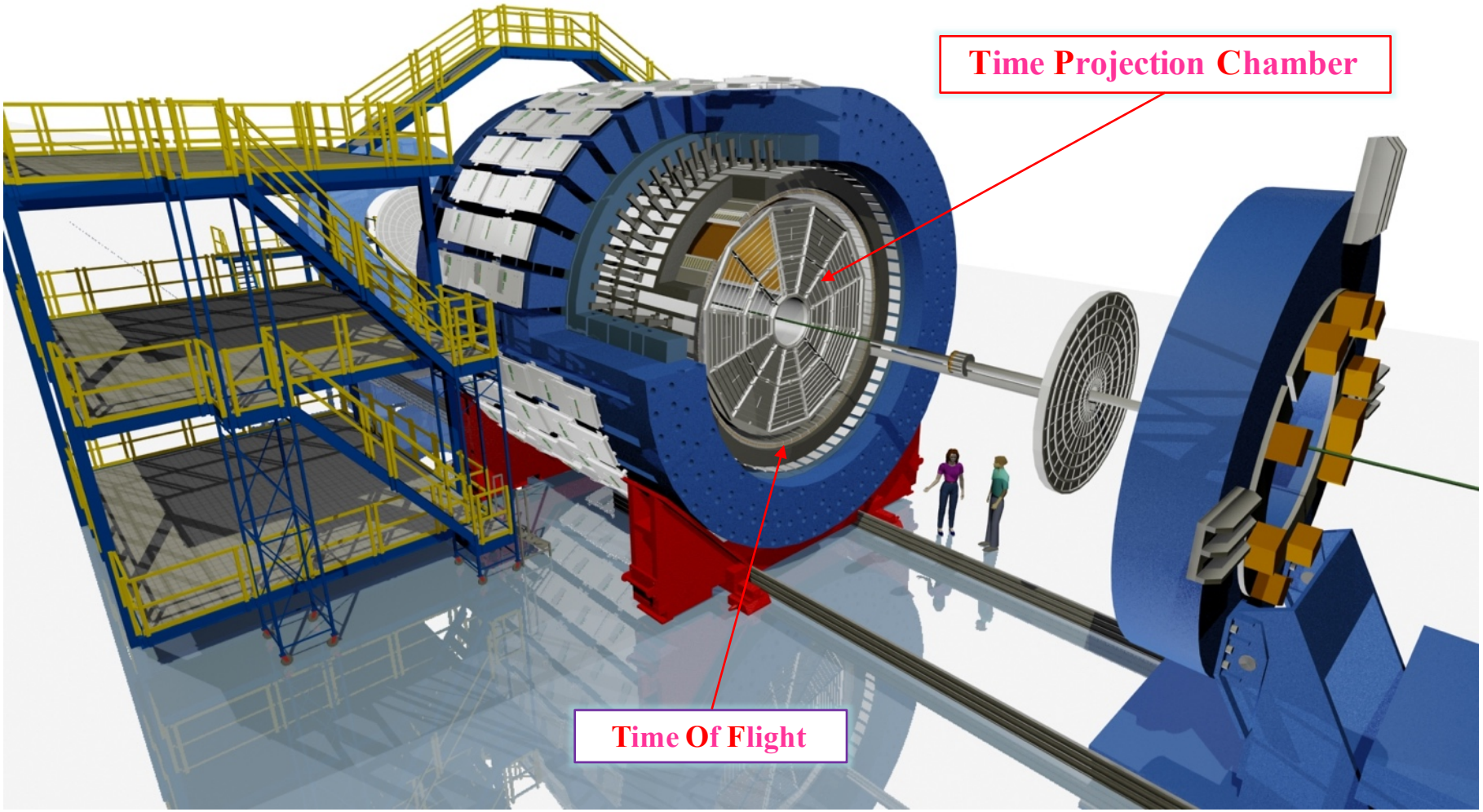
- ✓ high p_T : initial hard scattering
- ✓ low p_T : access QGP production

e^+e^- pairs:

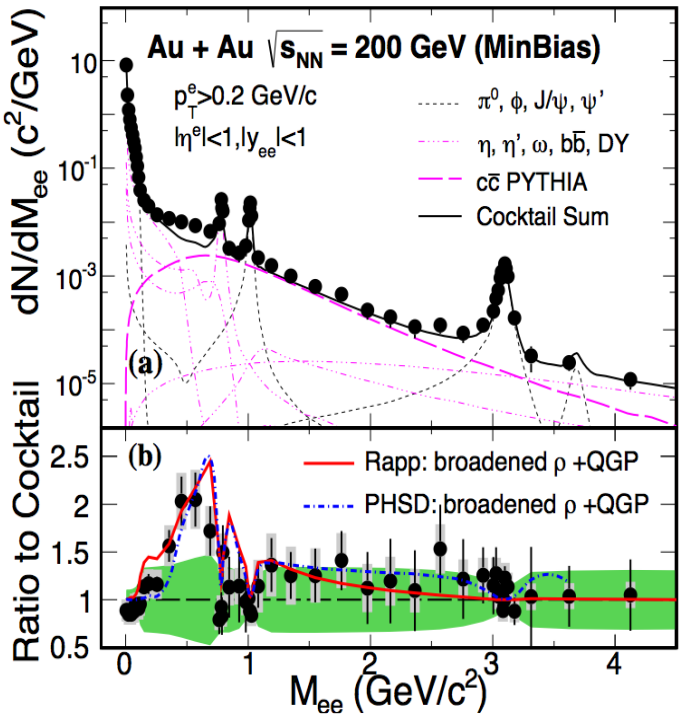
Higher M_{ee} -> Earlier produced

- ✓ Low Mass Region (<1.1 GeV/c^2): vector meson in-medium modification
- ✓ Intermediate Mass Region (1.1-3 GeV/c^2): thermal probe of QGP

STAR detectors

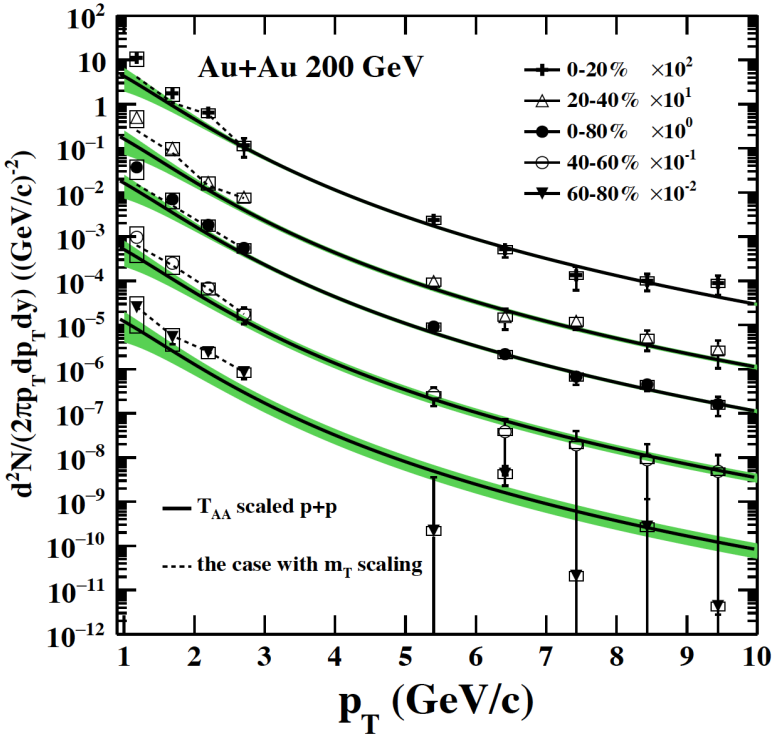


Electromagnetic probes at STAR



STAR, PRL 113 (2014) 22301

Direct photon invariant yield



STAR, PLB 770 (2017) 451-458

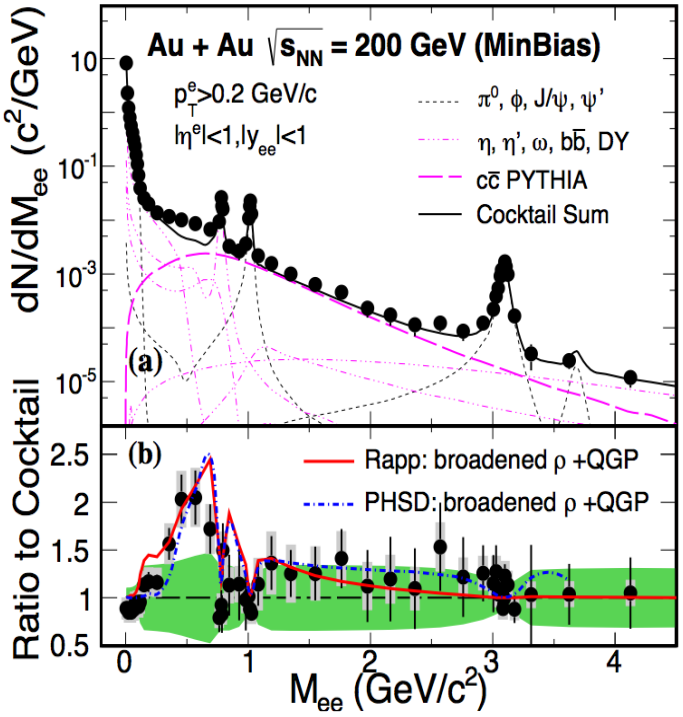
In ρ-like region, the enhancement factor is about 1.77

- ✓ No pair p_T selection
- ✓ No ρ contribution in hadronic cocktail simulation

Compared to pp reference, thermal photons can be observed

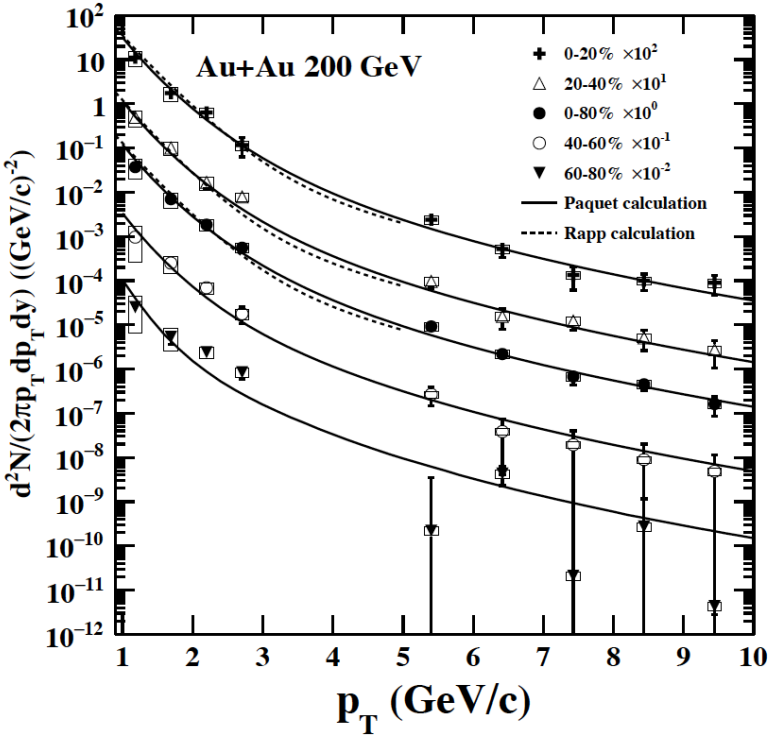
Green bends represent the systematic uncertainties for hadronic cocktail and pp reference, respectively.

Electromagnetic probes at STAR



STAR, PRL 113 (2014) 22301

Direct photon invariant yield



STAR, PLB 770 (2017) 451-458

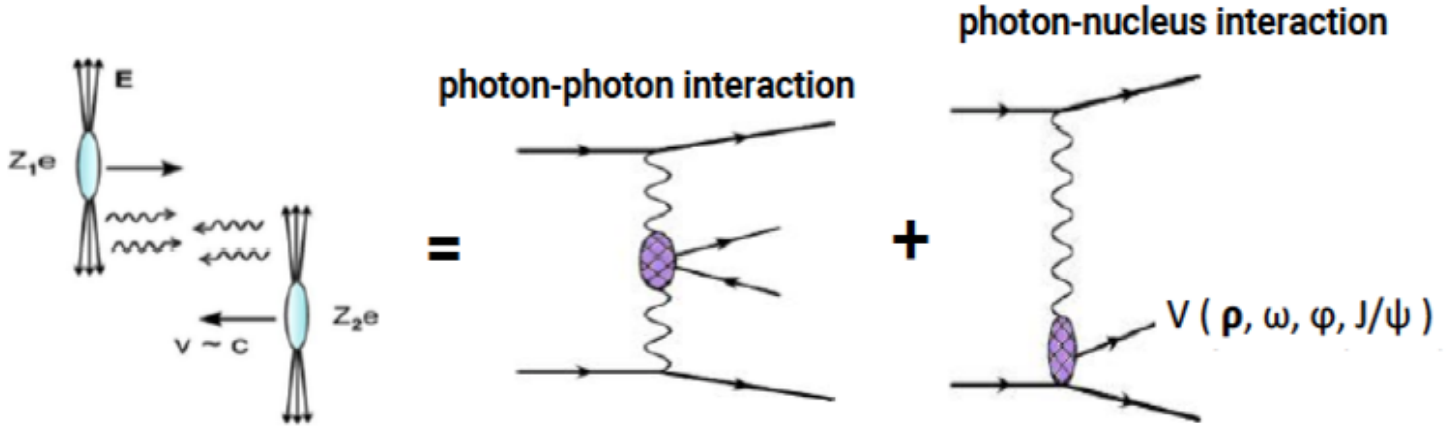
In ρ-like region, the enhancement factor is about 1.77

- ✓ No pair p_T selection
- ✓ No ρ contribution in hadronic cocktail simulation

Model predictions which include the contributions from thermal radiation and initial hard-processes are consistent with our yield within uncertainties except some bins in 60-80%

Photoproduction in UPC

Photoproduction in Ultra Peripheral Collisions (UPC)

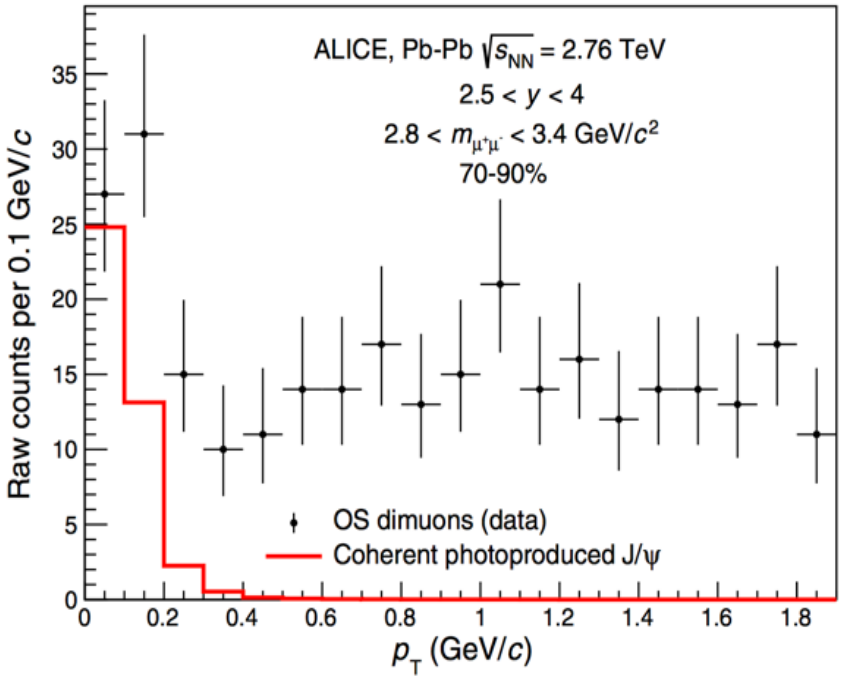


Coherent:

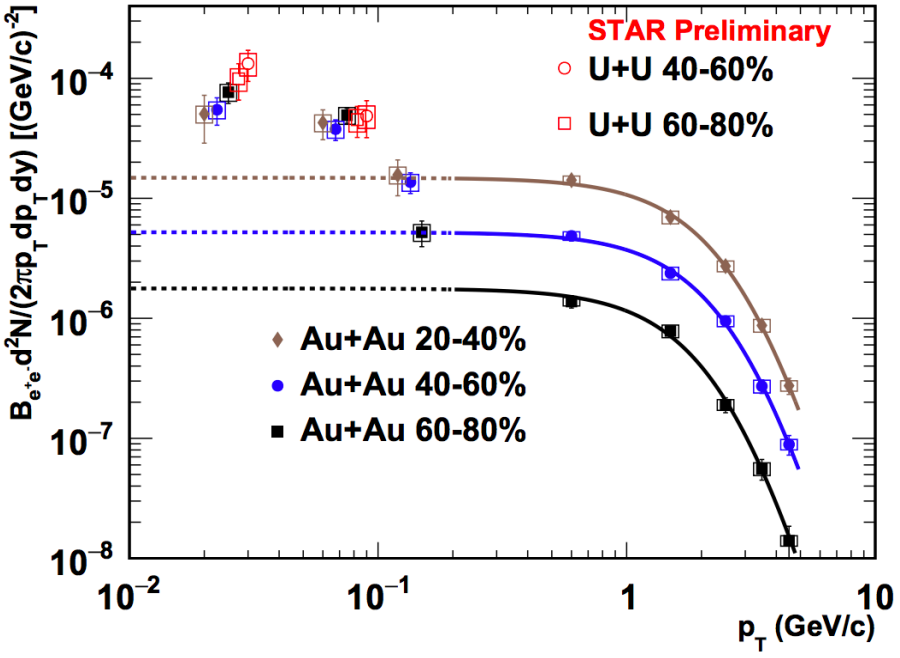
- ✓ Emitted photon/pomeron interacts with the nucleus as a whole
- ✓ Strong coupling results in large cross sections
- ✓ Photon wavelength $\lambda = h/p > R_A$
- ✓ $p_T < h/R_A \sim 30$ MeV/c for heavy ions

Coherent J/ψ production in non-UPC

- Recent results in ALICE and STAR



ALICE, PRL116(2016)222301



W. Zha, JPCS 779 (2017) no.1, 012039

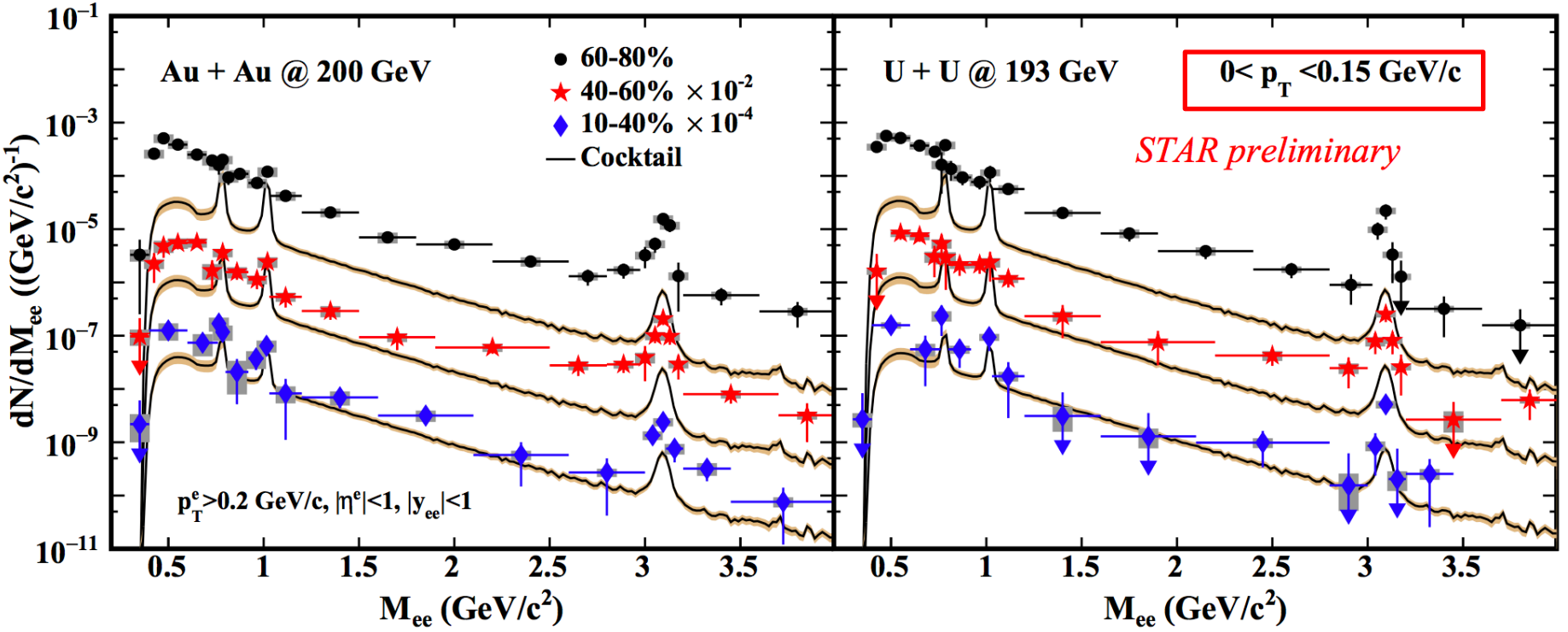
The solid curves are the fits from hadronic distribution region.

Both STAR and ALICE experiments observe J/ψ excess in dilepton channel in non-UPC collisions

—— Photon-nucleus interactions

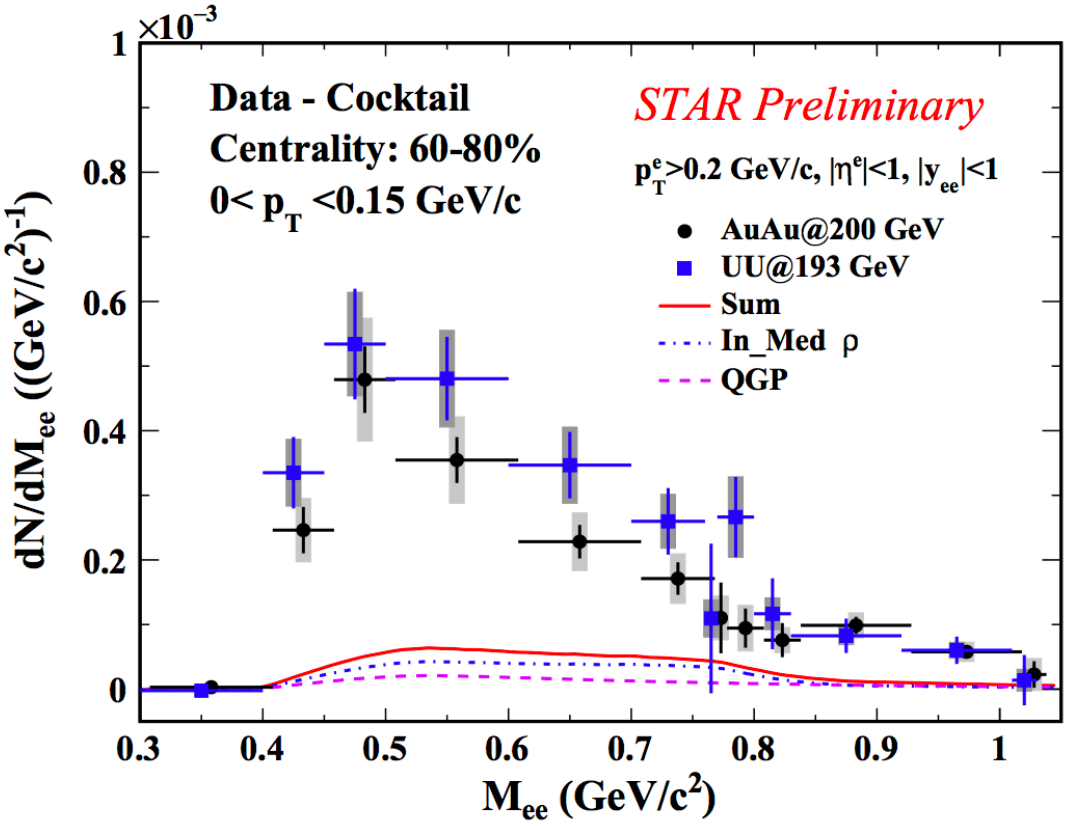
Can this excess be observed for e^+e^- itself over the whole M_{ee} range?

Low p_T e^+e^- in Au+Au and U+U at STAR



- ✓ Clear excess in non-central Au+Au and U+U collisions
- ✓ Excess observed over the whole mass range (<4 GeV/c^2)

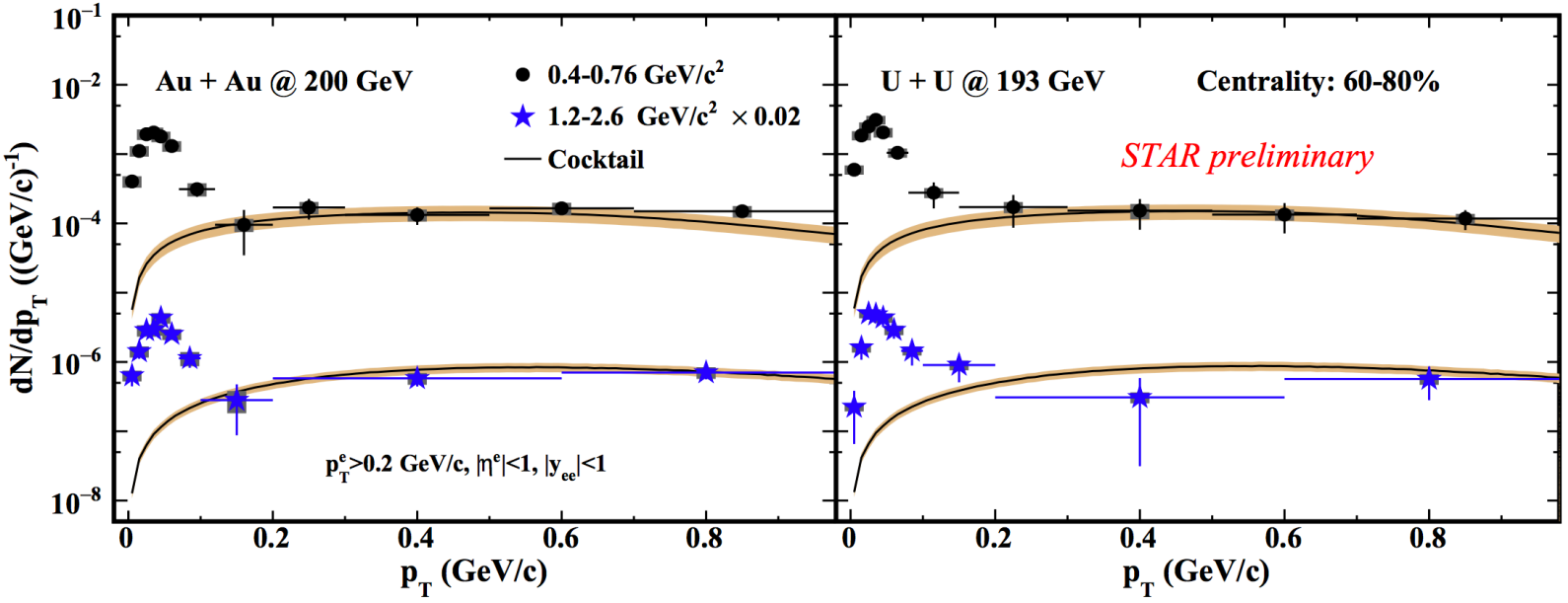
Excess yield compared to model calculation



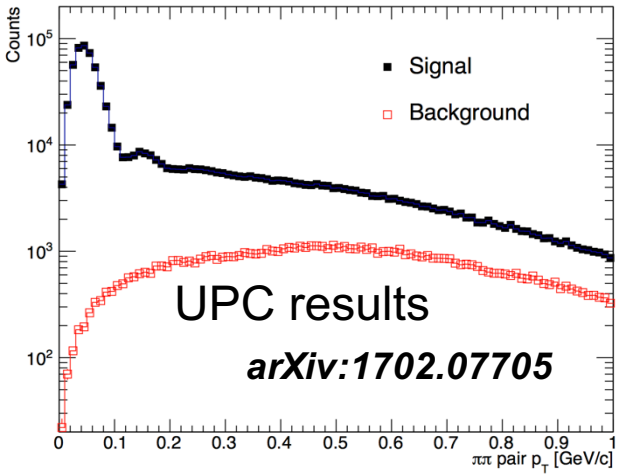
- ✓ Consistent between Au+Au and U+U
- ✓ Similar to what is observed for J/ψ
- ✓ Model calculation based on hadron decay modified by medium can not explain the excess

Can it be explained by coherent photoproduction?

dN/dp_T versus p_T

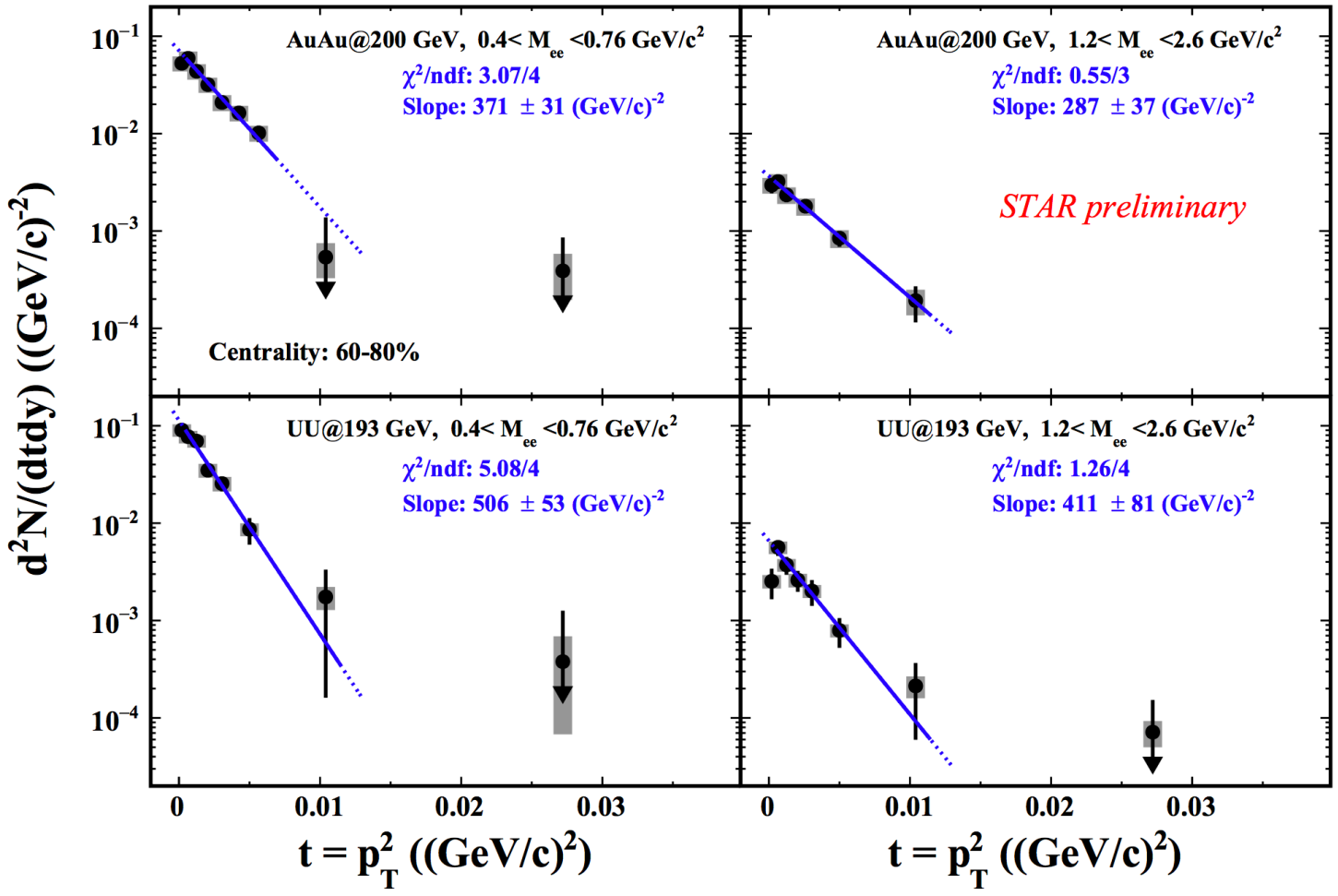


- ✓ Excess only observed at very low p_T
- ✓ Meets p_T requirement for coherent photoproduction
- ✓ The shape is similar to that in the UPC case

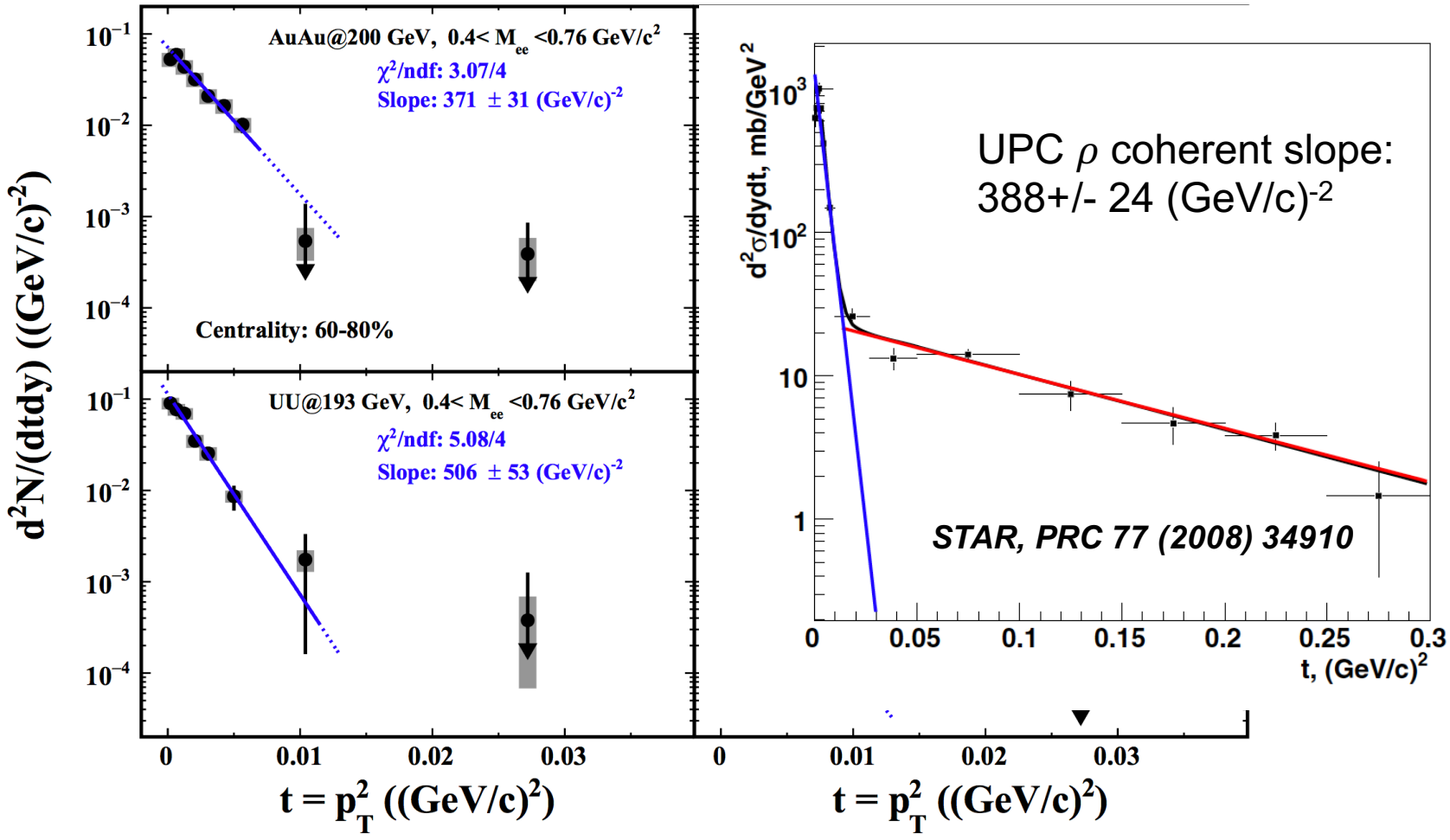


Challenge current understanding for coherent photoproduction

$d^2N/dtdy$

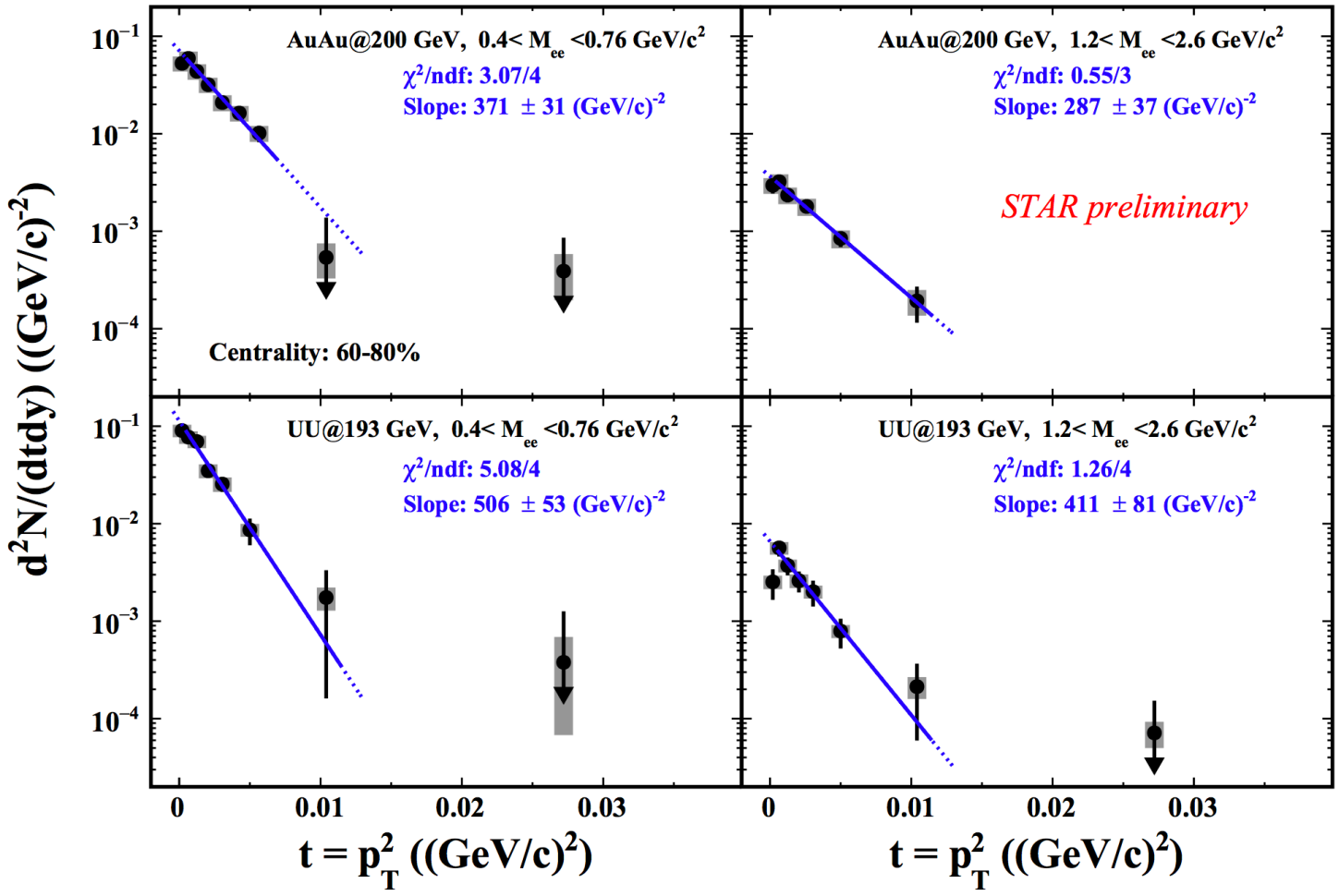

AuAu@200 GeV, 0.4< M_ee <0.76 GeV/c²
χ²/ndf: 3.07/4
Slope: 371 ± 31 (GeV/c)⁻²
Centrality: 60-80%
AuAu@200 GeV, 1.2< M_ee <2.6 GeV/c²
χ²/ndf: 0.55/3
Slope: 287 ± 37 (GeV/c)⁻²
STAR preliminary
UU@193 GeV, 0.4< M_ee <0.76 GeV/c²
χ²/ndf: 5.08/4
Slope: 506 ± 53 (GeV/c)⁻²
UU@193 GeV, 1.2< M_ee <2.6 GeV/c²
χ²/ndf: 1.26/4
Slope: 411 ± 81 (GeV/c)⁻²
d²N/(dtdy) ((GeV/c)⁻²)
t = p_T² ((GeV/c)²)
t = p_T² ((GeV/c)²)

$d^2N/dtdy$



The slope is similar to that in UPC coherent production.

$d^2N/dtdy$



- ✓ Consistent with coherent production scenario

  Large slope parameter => Large interaction size

  Slope in U+U is sharper than that in Au +Au

Discussion on these results

Do these e^+e^- pairs come from coherent photoproduction?

- ✓ The behaviors of measured observables are similar with those in UPC
- ✓ Need to measure the relation with EM field to confirm coherent photoproduction scenario
- ✓ Photon-photon interaction and photon-nucleon interaction contributions need to be distinguished
- ✓ No clear ρ signal, melted/broadened by medium or much smaller compared to photon-photon process? Or both? May be novel probes to the medium

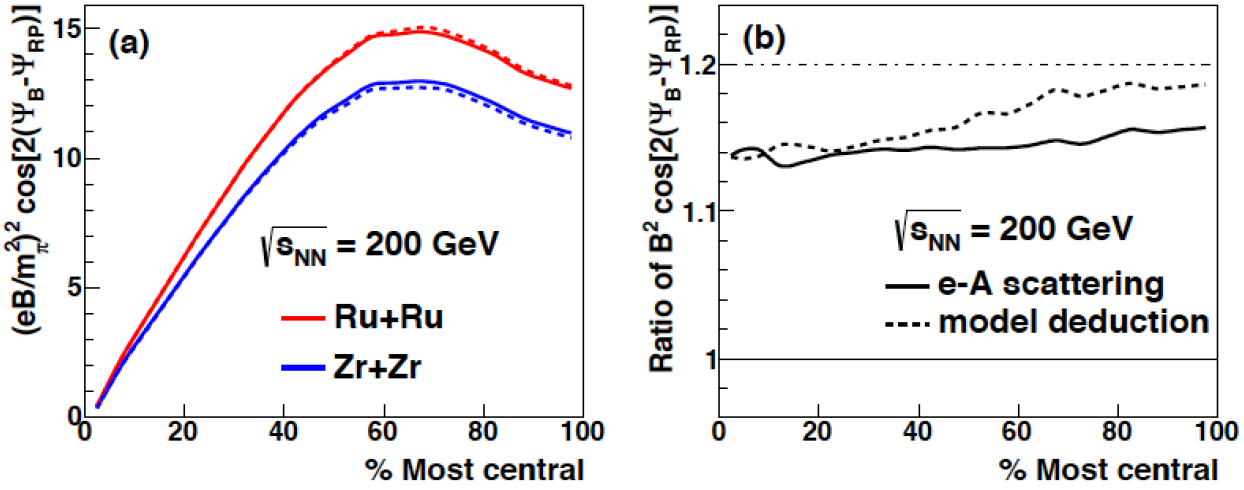
Can coherent photoproduction and hadron-hadron interaction be factorized?

Call for theoretical calculations!

Physics opportunities in isobaric collisions

- STAR plans to take $_{44}^{96}$Ru+$_{44}^{96}$Ru and $_{40}^{96}$Zr+$_{40}^{96}$Zr 200GeV data in 2018, 1.2 billion for each dataset
- Study the impact from systems with different EM fields
- Study the Z dependence -> $af(Z^2)+bf(Z^4)$?

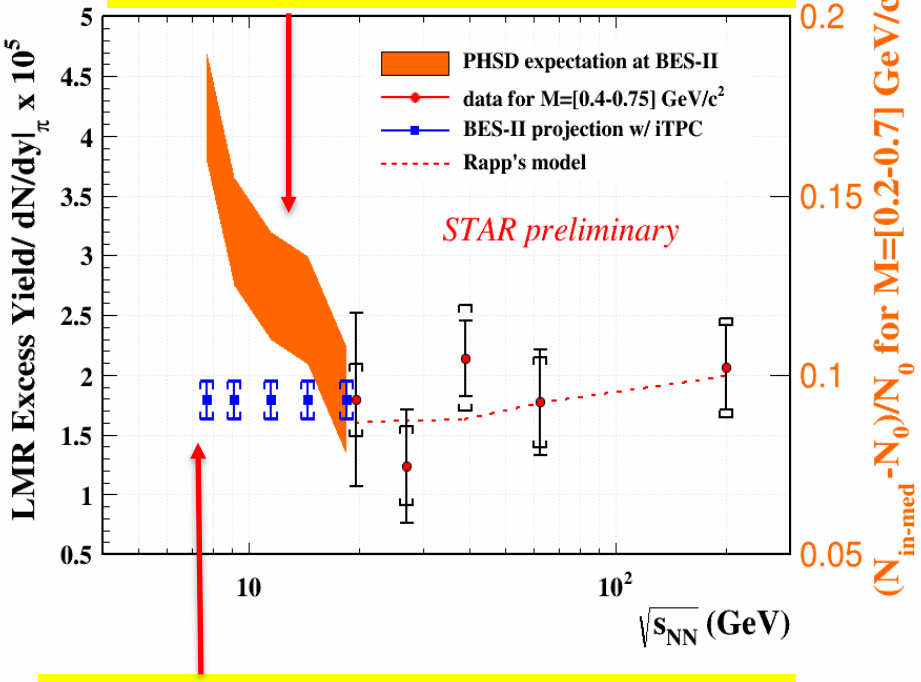
Predicted (e*B)^2 distribution in isobaric collisions



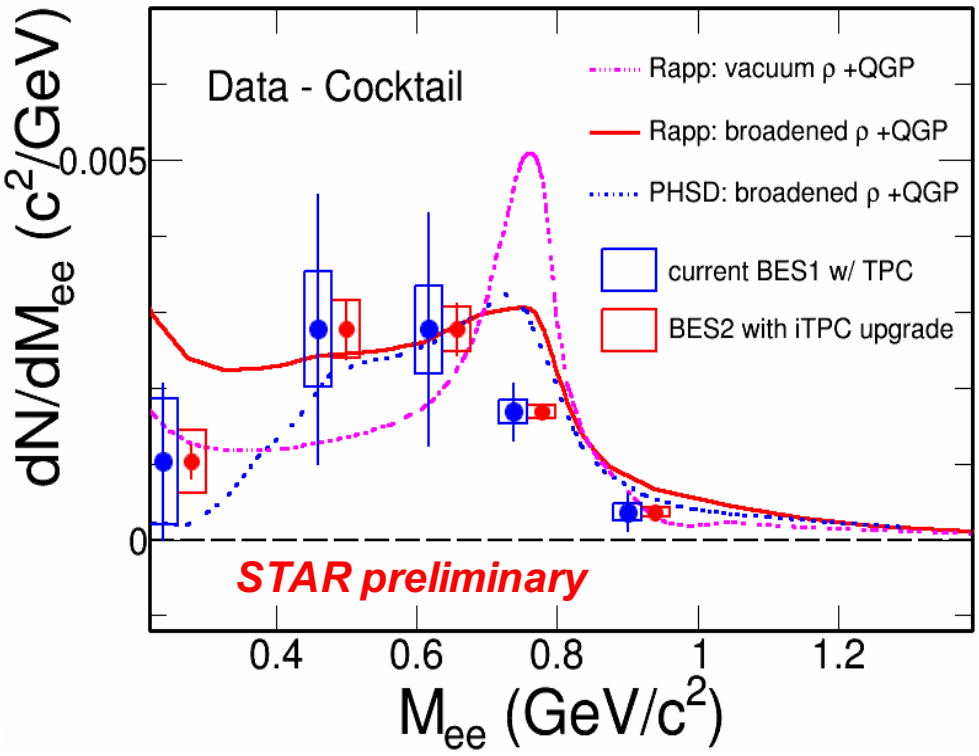
W. -T. Deng and X. -G. Huang, PRC 85 (2012) 044907

e^+e^- measurement with inner TPC upgrade

PHSD model expects "raising"



Uncertainty projection with iTPC



- ✓ Systematically study continuum from 7.7-19.6 GeV
- ✓ Distinguish model with different rho-meson broadening
- ✓ Study effect of total baryon density on LMR excess
- ✓ ~10 times more statistics, ~1/2 systematic uncertainties (improved dE/dx)

See Flemming's talk on Jun.14th at 11:55 am

Summary and outlook

- ✓ Observed significant excesses for e^+e^- at very low p_T in non-central heavy-ion collisions at top RHIC energies
- ✓ The production features seems to be consistent with coherent photoproduction scenario. Theoretical input is needed!
- ✓ Isobaric collisions proposed by STAR in 2018 will help to study this very low p_T production mechanism further
- ✓ Isobaric collisions will help to study the EM field impact on e^+e^- production

backup

inner TPC upgrade

iTPC upgrade

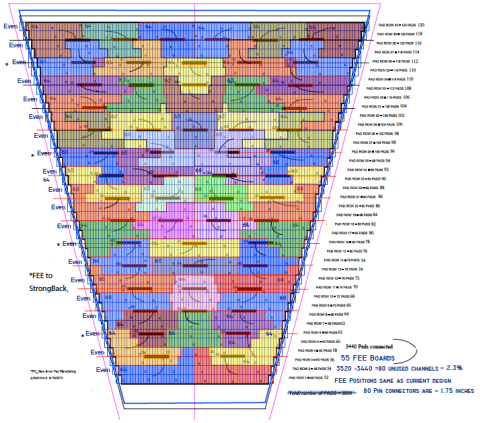
Continuous pad rows
Replace all inner TPC sectors

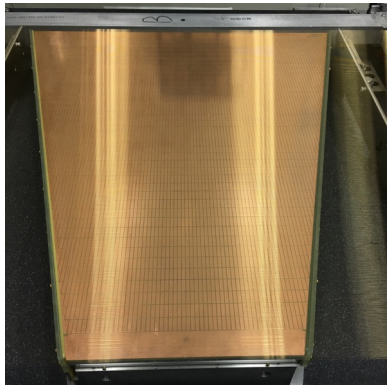
|η|<1 -> |η|<1.5

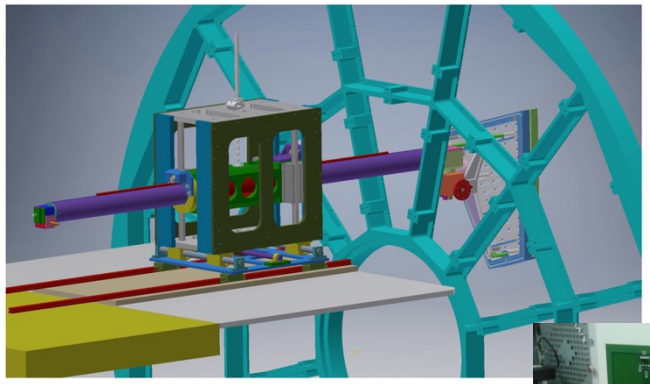
p_T >60 MeV/c

Better dE/dx resolution
Better momentum resolution

Fully operational in 2019

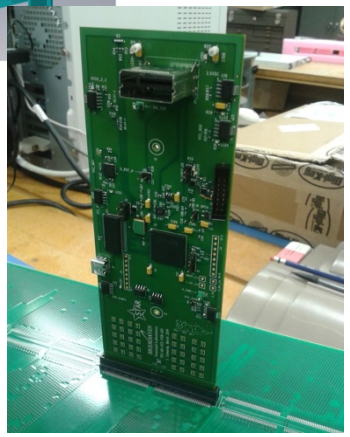






Replace all 24 inner sectors, with:

- ✓ Increase readout pad rows from 13 to 40
  -- *20% coverage -> ~100% coverage*
- ✓ Renew all three wire frames
  -- *Replace ageing wires, MWPC building in Shandong University*
- ✓ New electronics for inner sectors
  -- *Double # of readout channels per FEE, use ALICE SAMPA chip*
- ✓ New designed insertion tools
- ✓ New designed strongback



STAR Note 619