

Low p_T e^+e^- pair production in heavy-ion collisions

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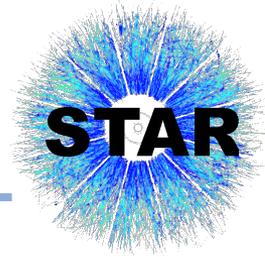
RHIC & AGS Annual Users' Meeting

June 20 – 23, 2017



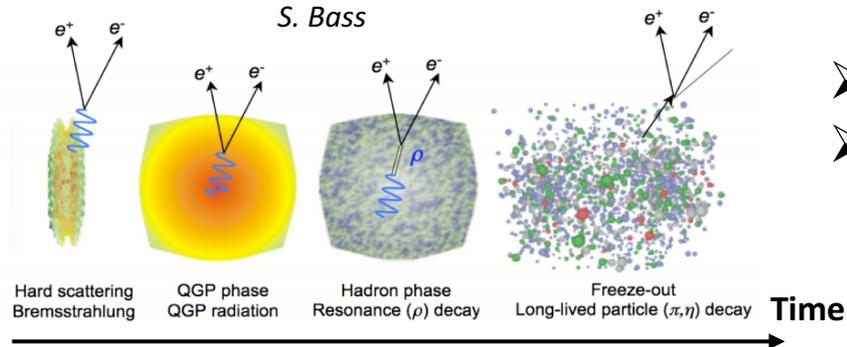
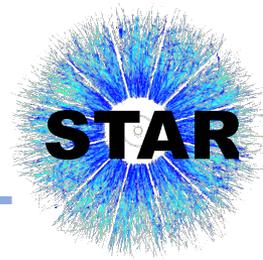
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Outline

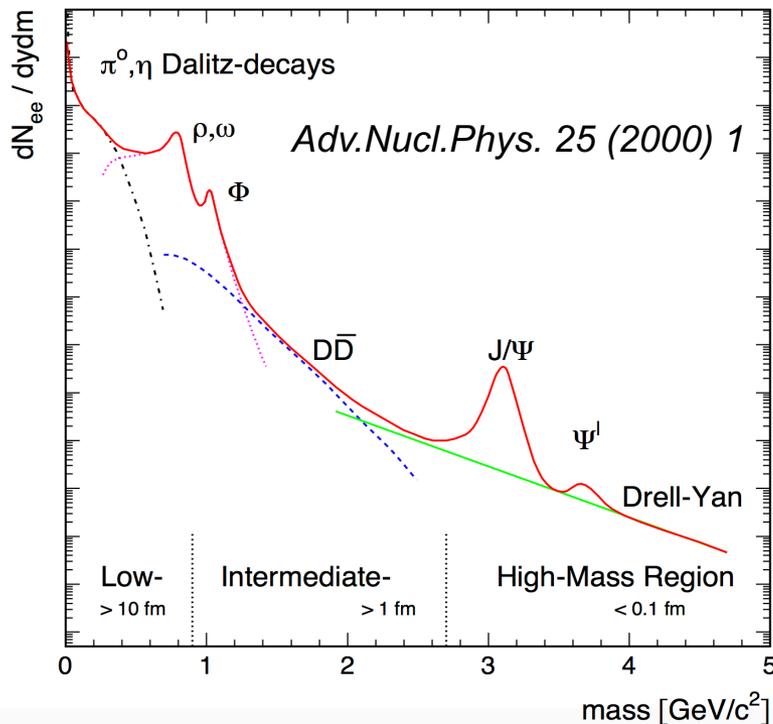


- Motivation
- STAR experiment
- Electron Identification
- Low p_T e^+e^- pair results in AuAu@200 GeV and UU@ 193 GeV collisions
 - Centrality dependence of low p_T e^+e^- pair invariant mass spectra
 - p_T spectra of mass differentials in 60-80% central collisions
 - p_T^2 distribution of STAR acceptance corrected excess spectra in 60-80% central collisions
- What can we do in isobaric collisions ($^{96}_{44}\text{Ru}$ vs. $^{96}_{40}\text{Zr}$)?
- Summary

Dilepton - penetrating probe of hot medium



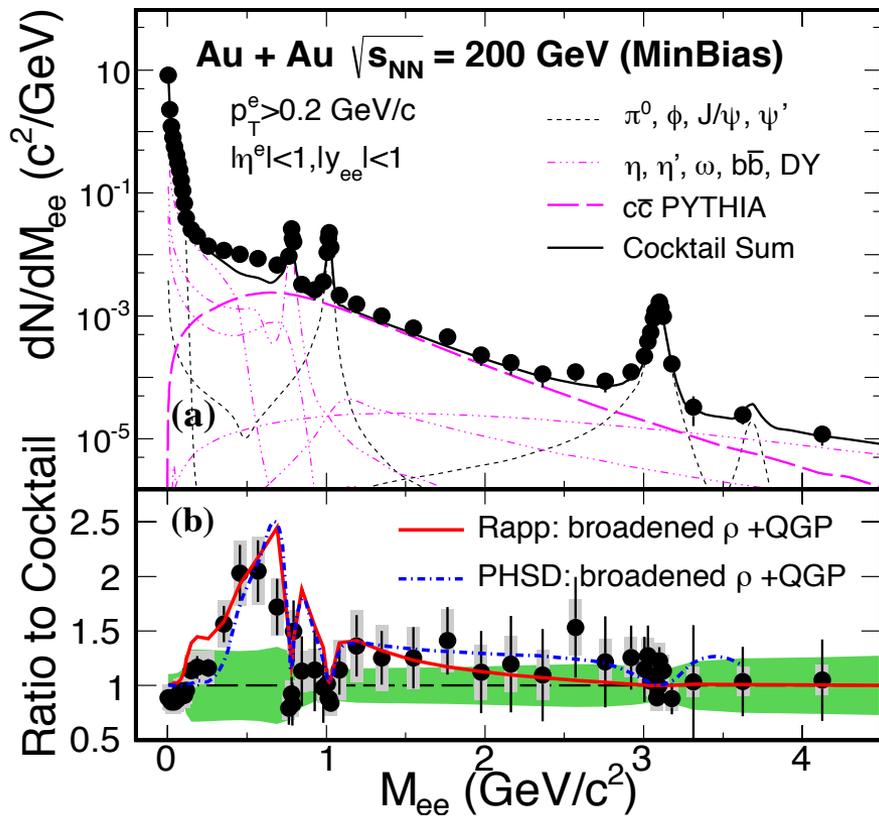
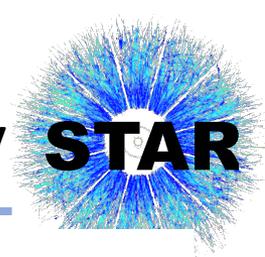
- Do not suffer strong interactions
- Bring direct information of the medium created in heavy ion collisions



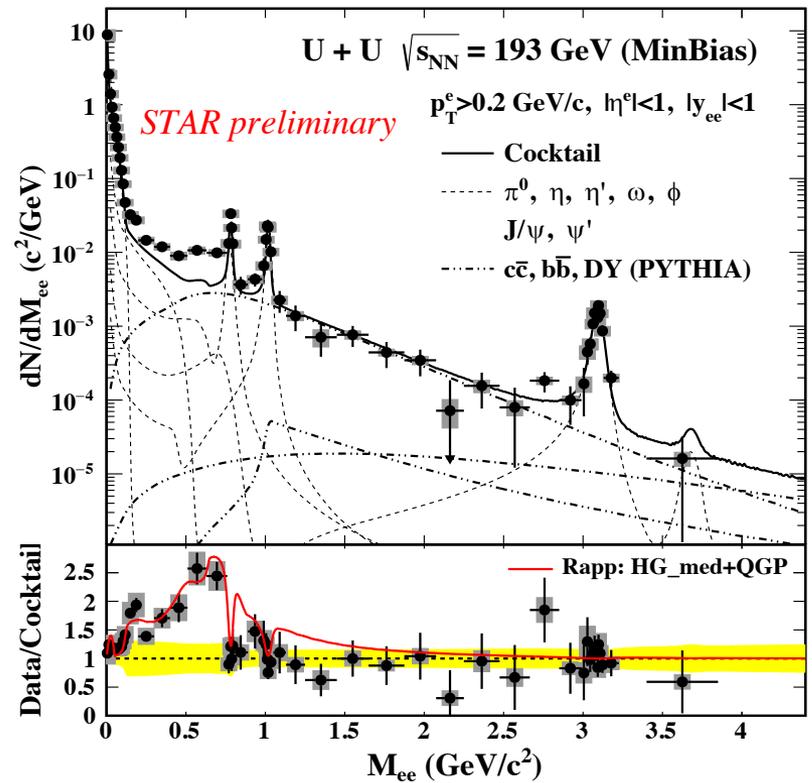
Different physics of interest

- **Low Mass Region (LMR)**
 - In-medium modifications of vector meson
- **Intermediate Mass Region (IMR)**
 - QGP thermal radiation
 - Semi-leptonic decays of correlated charm
- **High Mass Region (HMR)**
 - Drell-Yan process
 - Heavy quarkonia

p_T integrated invariant mass spectra in AuAu@200GeV and UU@193 GeV



PRL 113, 022301 (2014)



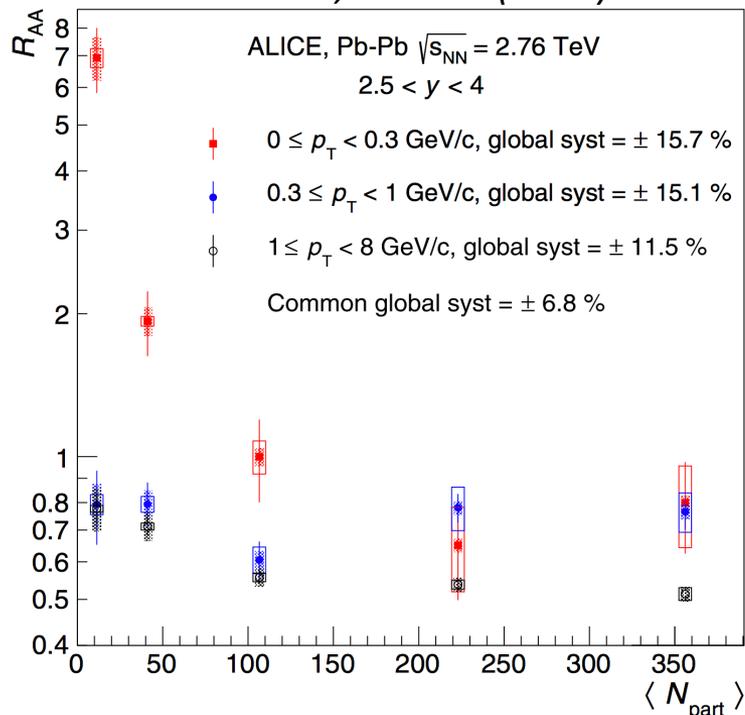
Nucl. Phys. A 956, 429 (2016)

- Consistent with theoretical calculation based on broadened ρ spectral function

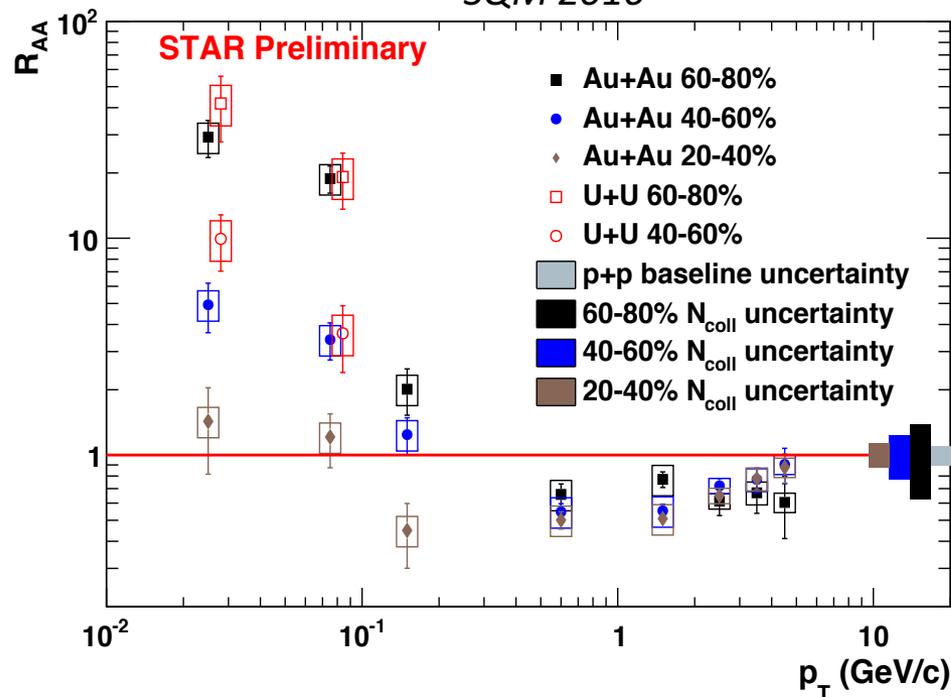
Low p_T J/ψ enhancement in peripheral heavy-ion collisions



PRL 116, 222301 (2016)

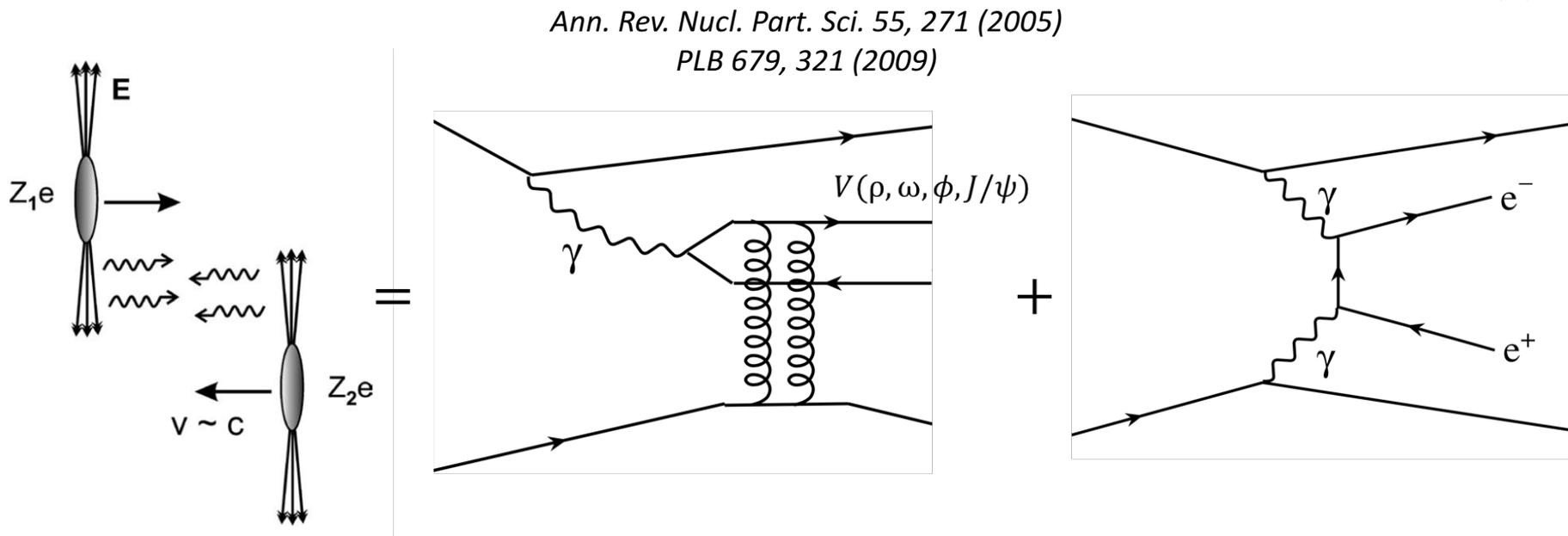
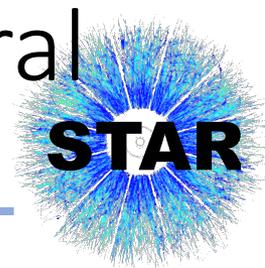


SQM 2016



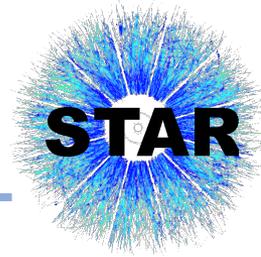
- Significant enhancement at low p_T in peripheral collisions
 - Can not be explained by hadronic production accompanied with the cold and hot medium effects
 - **Linked to coherent photoproduction ?**
- Measure e^+e^- pair production in a wider invariant mass region at low p_T to understand the production mechanism

Photon interactions in Ultra-Peripheral Collisions



- Photon – photon interaction $\propto Z^4$
- Photon – nucleus interaction $\propto Z^2$
 - Coherent: photon interacts with the whole nucleus
 - Incoherent: photon interacts with nucleon or parton individually

Features of photon interactions in UPC

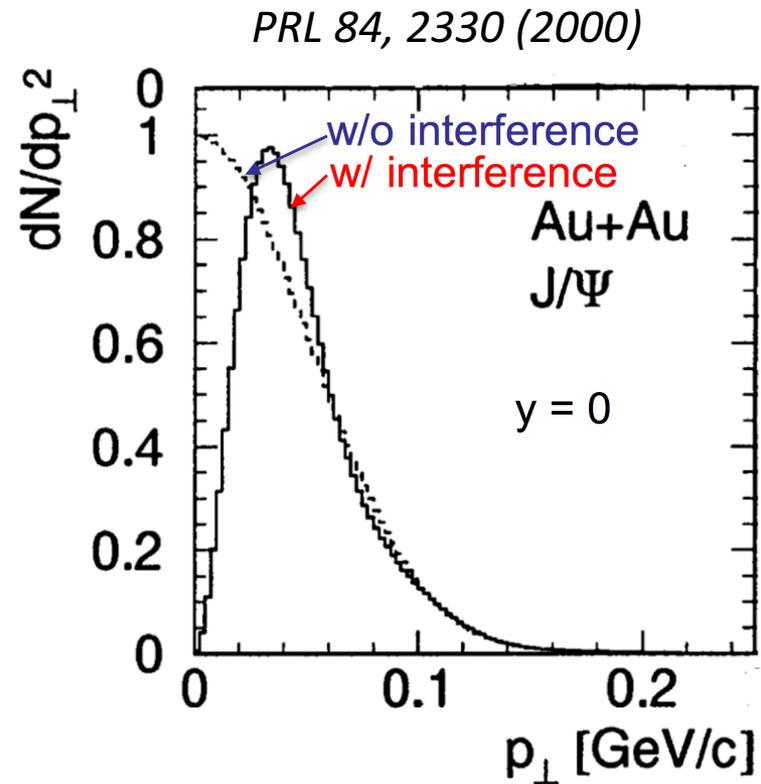


➤ Coherent photon – nucleus interaction

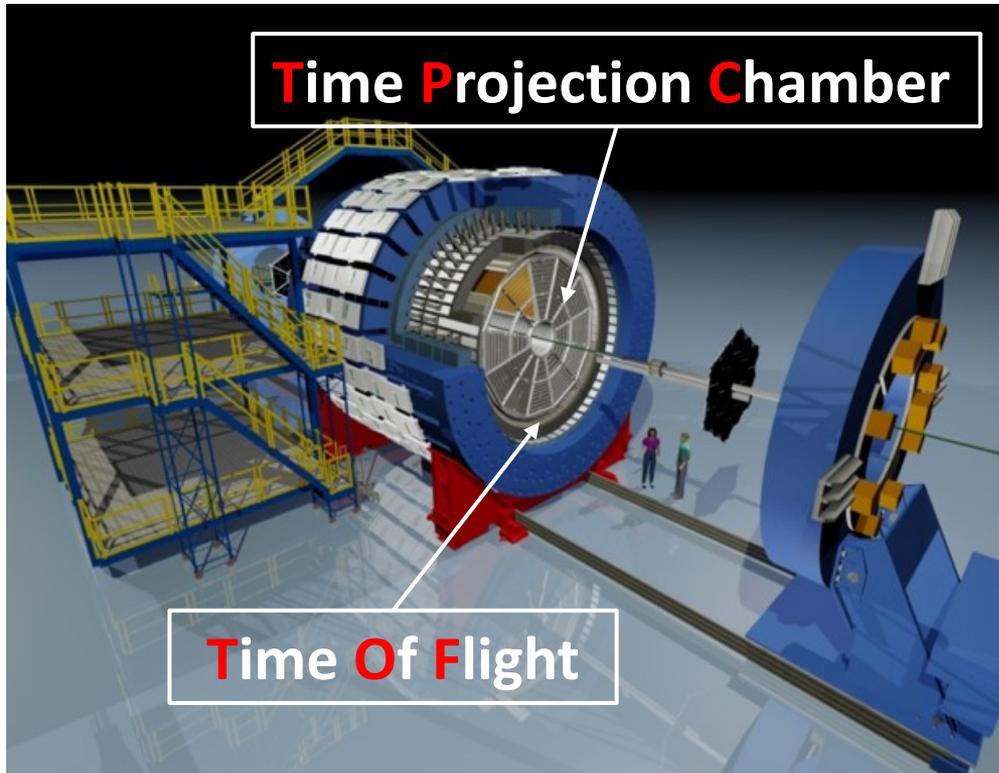
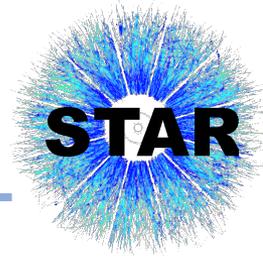
- Both nucleus remain intact
- Vector meson is restricted to low p_T
- Interference structure
 - ✓ Emitter and target are indistinguishable
 - ✓ Vector meson with negative parity, thus opposite sign in amplitude
 - ✓ destructive interference in $p_T \ll 1/b$

➤ Photon – photon interaction

- Continuum
- Pair p_T is even lower than photo-produced vector mesons



STAR detector



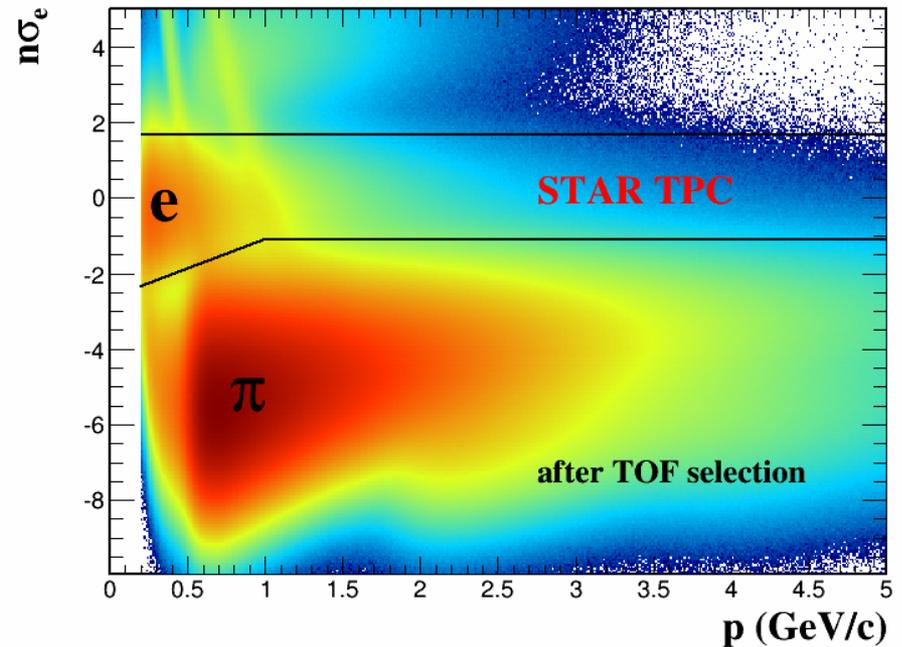
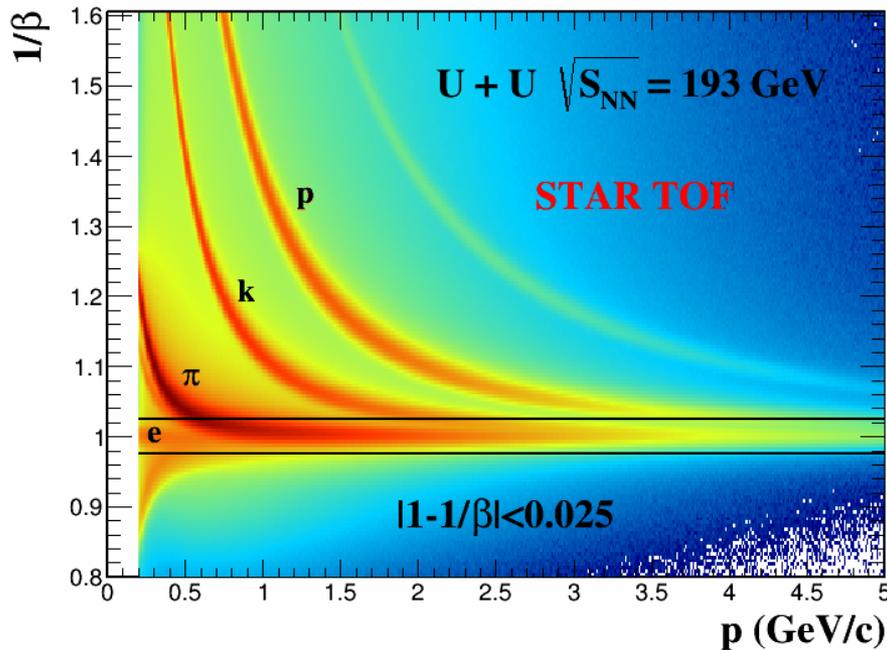
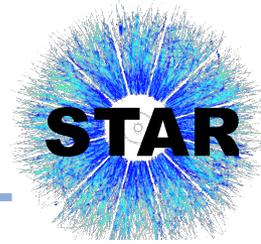
➤ Time Projection Chamber

- $|\eta| < 1, 0 < \phi < 2\pi$
- Main detector: tracking, momenta, and energy loss

➤ Time Of Flight

- $|\eta| < 0.9, 0 < \phi < 2\pi$
- Rejects slow hadrons, enables clean electron identification at $p < 3 \text{ GeV}/c$

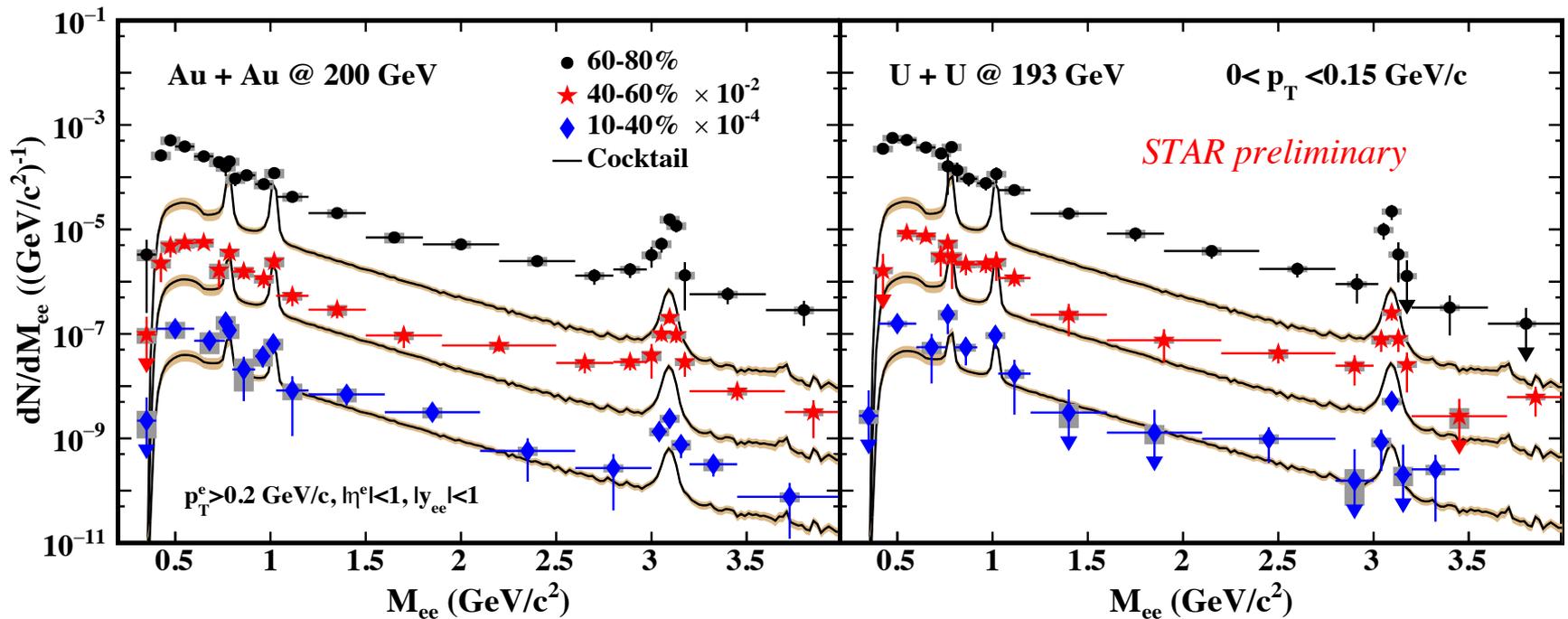
Electron identification



➤ Clean electron identification with a combination of TPC and TOF

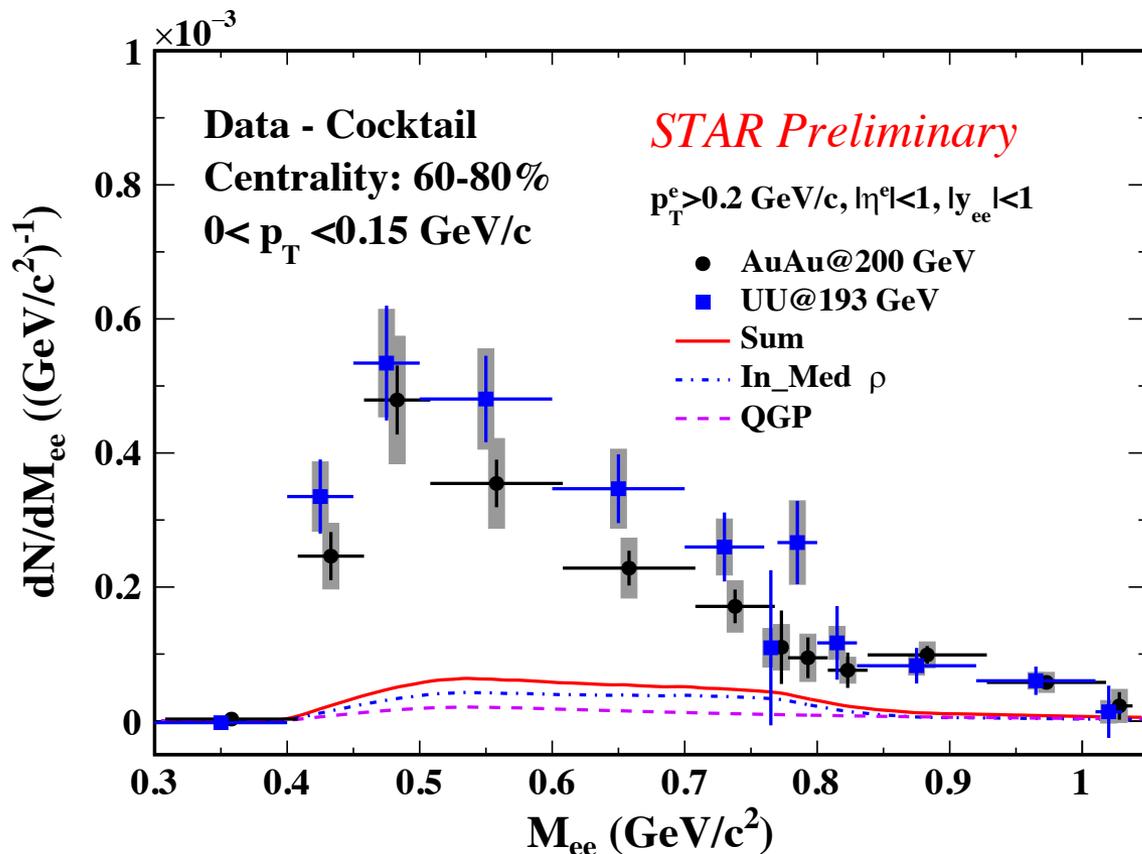
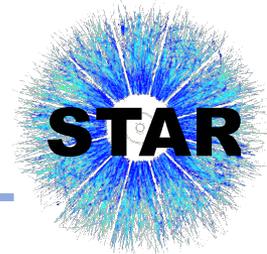
$$n\sigma_e = \frac{1}{R} \log \frac{(dE/dx)_{\text{measured}}}{(dE/dx)_{\text{electron}}}$$

Centrality dependence of e^+e^- pair invariant mass spectra in $p_T < 0.15$ GeV/c



- Significant enhancement in 60-80% central Au + Au and U + U collisions
- Enhancement decreases from peripheral to central collisions

Enhancement spectra in $p_T < 0.15$ GeV/c



➤ No vector meson peak is observed

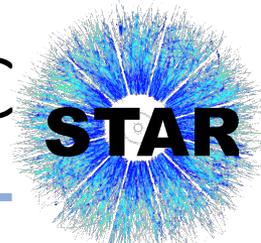
➤ Can not be explained by broadened ρ model calculation

➤ Need additional source(s) to account for the significant enhancement

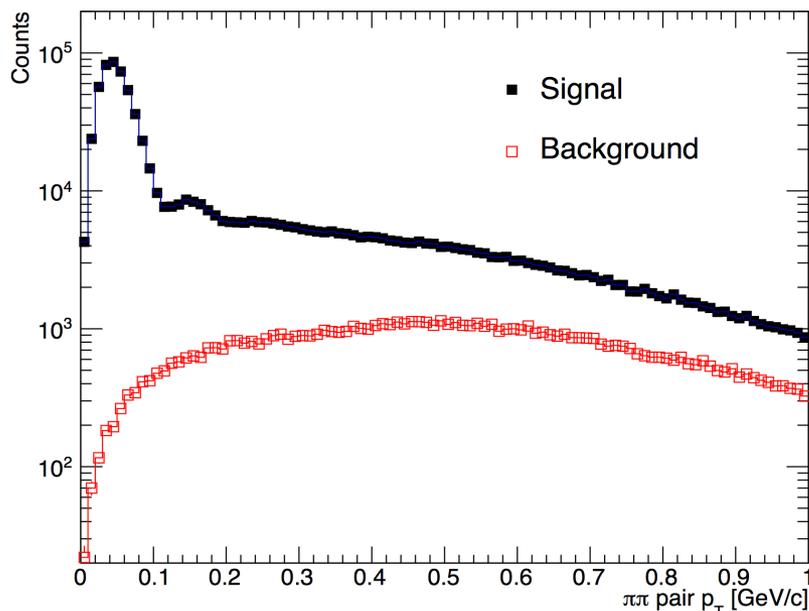
➤ Possible sources – photon interactions

- Photon – photon interaction
- Coherent photon – nucleus interaction

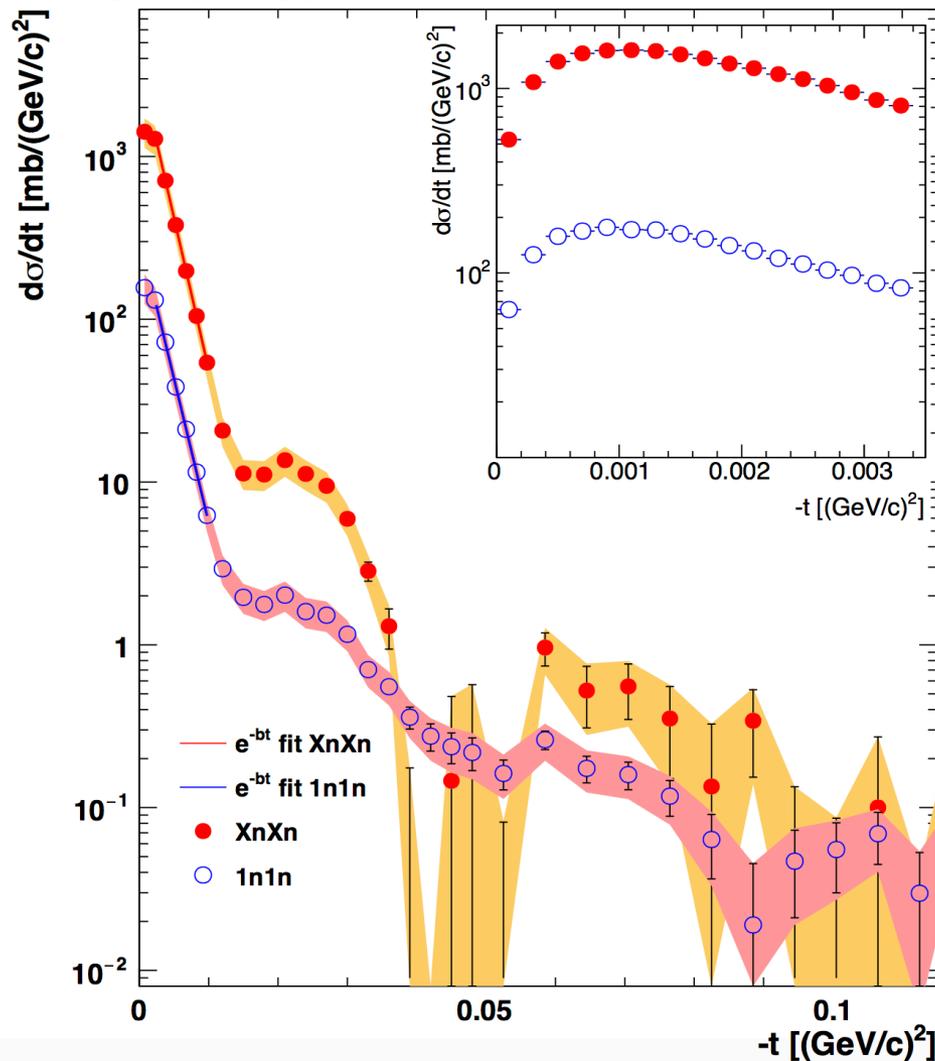
Coherent photoproduction results in UPC



arxiv: 1702.07705

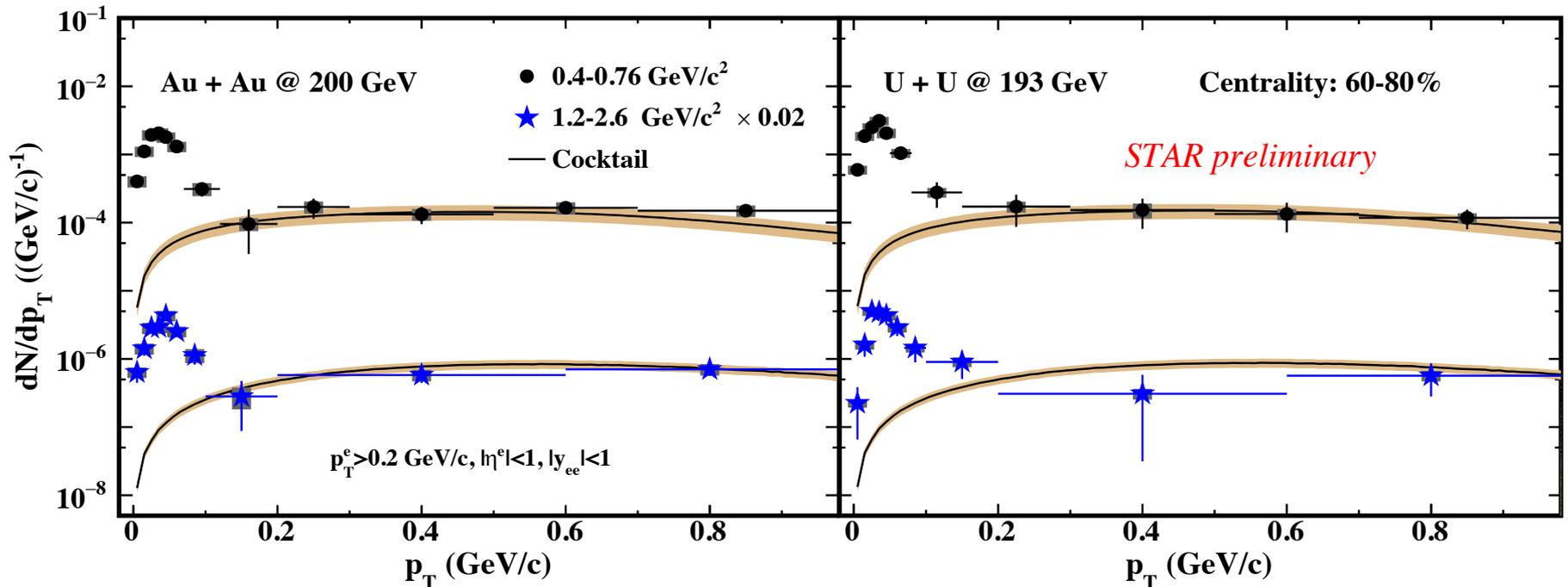
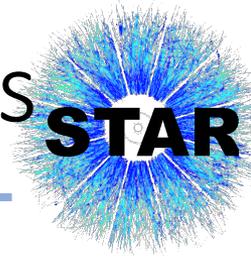


- Coherently produced $\pi^+\pi^-$ pairs locate in $p_T < 0.1$ GeV/c
- Large t ($-t \approx p_T^2$) slope – reflect target size
 - 426.4 ± 1.8 (GeV/c) $^{-2}$ for XnXn
 - 407.8 ± 3.2 (GeV/c) $^{-2}$ for 1n1n
- Destructive interference structure in very low p_T^2



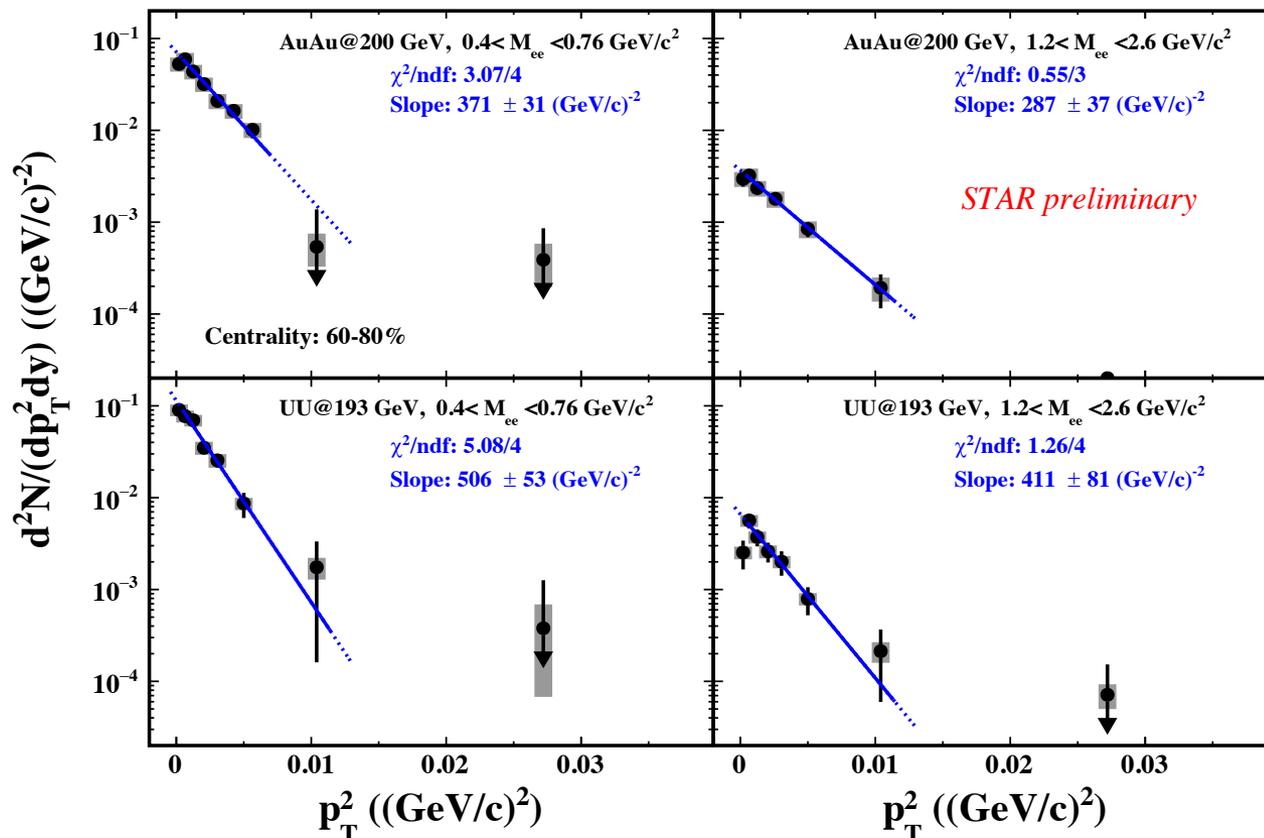
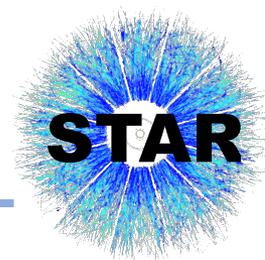
06/20/2017

p_T spectra in 60-80% central collisions



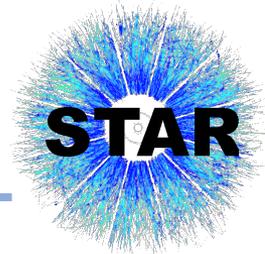
- Excesses entirely happen in $p_T < \sim 0.15$ GeV/c
- Data is consistent with hadronic expectation when $p_T > \sim 0.15$ GeV/c
- Similar p_T structure with coherent photoproduction in UPC

p_T^2 distributions in 60-80% central collisions



- STAR acceptance corrected – pure decay kinematics
- Similar slope values with that in UPC
- Slope in U+U is sharper than that in Au + Au

Isobaric collisions

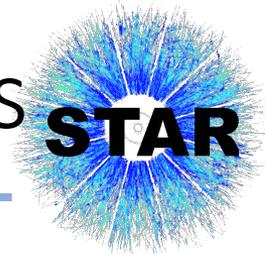


- ${}^{96}_{44}\text{Ru}$ vs. ${}^{96}_{40}\text{Zr}$ - charge different by 10%, everything else almost the same
- To keep hadronic contribution similar

Quantities	U+U	Ru+Ru	Zr+Zr
Centrality (% most central)	60 – 80	47 – 75	47 – 75
Multiplicity ($ \eta < 0.5$)	12 – 52	12 – 52	12 – 52
N_{part}	21 ± 1	21 ± 1	21 ± 1
B^2 (fm^{-1})	30.8 ± 0.1	30.1 ± 0.1	26.2 ± 0.1
B^4 (fm^{-1})	1984 ± 4	2121 ± 4	1672 ± 4

STAR BUR of Run18: SN0670

Projection of run18 isobaric collisions

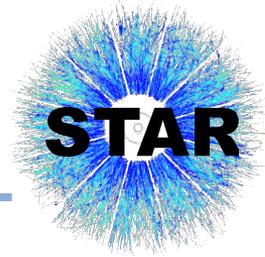


- 1.2 B good events for each particle species
 - A factor of 4.5 more than UU@193 GeV statistics
- Two-photon $\propto B^4$, photon-nucleus $\propto B^2$
- 0.4 – 0.76 GeV/c² in $p_T < 0.15$ GeV/c projection

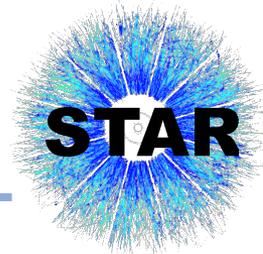
Physics process	data/cocktail 47 – 75% Ru+Ru	data/cocktail 47 – 75% Zr+Zr	Difference between Ru+Ru and Zr+Zr
Photonuclear	16.1 ± 0.4	14.3 ± 0.4	1.8 ± 0.6 (3.0σ)
Two-photon	17.4 ± 0.4	14.2 ± 0.4	3.2 ± 0.6 (5.3σ)

STAR BUR of Run18: SN0670

Summary



- A significant enhancement with respect to hadronic cocktail is observed at low p_T
 - Excess spectra has no peak structure and can not be explained by QGP radiation and broadening of vector meson in-medium
 - Strong centrality dependence of enhancement factor
 - Entirely happens in $p_T < 0.15$ GeV/c
 - Have similar slope with coherently photoproduced ρ^0 in UPC
- Isobaric collisions can help distinguish photon-photon and photon-nucleus processes



Backup

