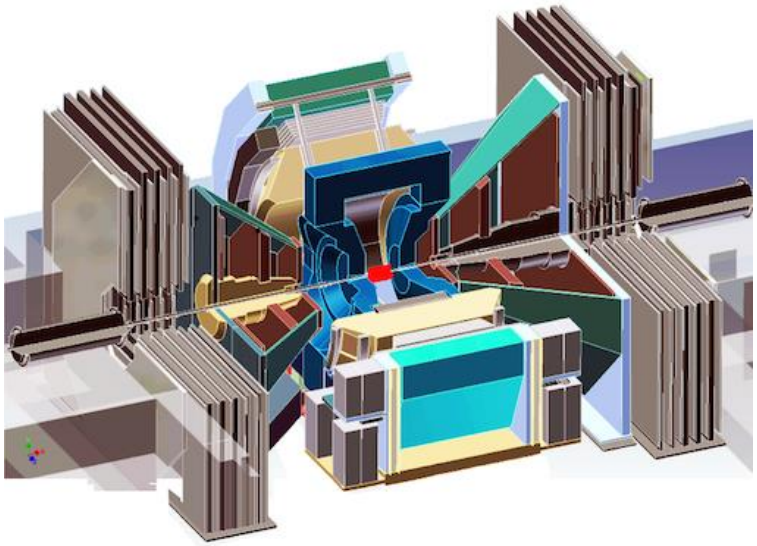
Recent PHENIX Results on High-p_T π^0 and η Production in Cu+Au and U+U Collisions

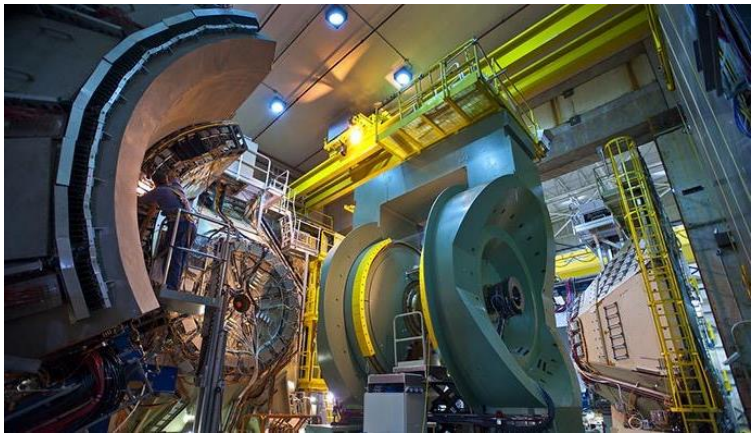
Murad Sarsour
Georgia State University
For the PHENIX Collaboration

U.S. DEPARTMENT OF ENERGY | Office of Science

Outline

- Introduction
- PHENIX detector
- Neutral pion and eta meson reconstruction
- Nuclear modification in Cu+Au
- Nuclear modification in U+U
- Summary





Motivation

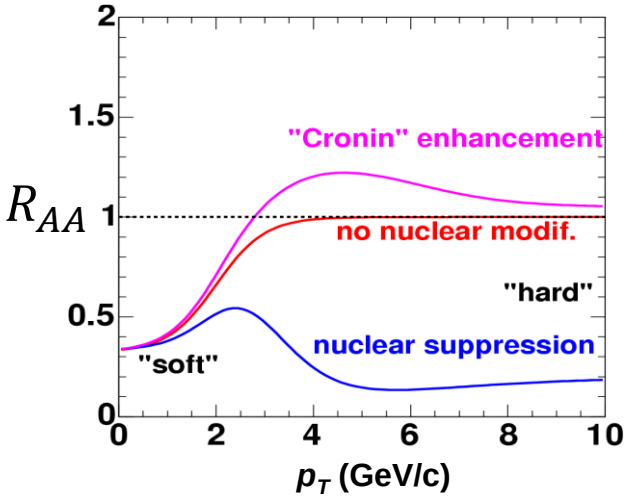
❑ Characterize the properties of the QGP

- ❑ dependence of parton energy loss on energy density and nuclei overlap geometry → better understanding of parton energy loss mechanisms

❖ Studied by measuring nuclear modification factors:

$$R_{AA}(p_T) = \frac{d^2N_{AA}/dydp_T}{\langle N_{coll}\rangle \times d^2N_{pp}/dydp_T}$$

where $d^2N_{AA}/dydp_T$ is the per-event yield of particle production in *A+A* collisions and $d^2N_{pp}/dydp_T$ is the per event yield of the same process in *p+p* collisions. Scaled by the number of nucleon-nucleon collisions in the *A+A* system, N_{coll}.



❖ **Leading hadrons** are used as proxy for jets:

- ➢ **π^0 meson**: abundantly produced → measurable at high p_T
- ➢ **η meson**: hidden strangeness → hadron suppression as a function of flavor and mass

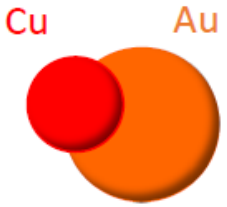
Motivation

❖ **Available A+A collisions at RHIC:**

A+A	Au+Au	Cu+Cu	Cu+Au	U+U
$\sqrt{s_{NN}}$ (GeV)	7.7, 9.2, 14.6, 19.2, 19.6, 27, 39, 62.4 ,130, 200	22.4, 62.4, 200	200	193

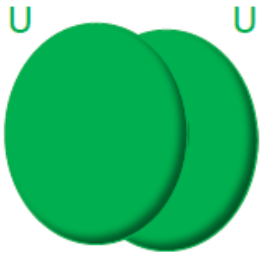
❑ Cu+Au:

- ➢ first asymmetric heavy-ion collision system
- ➢ different overlap geometry compared to symmetric systems



❑ U+U:

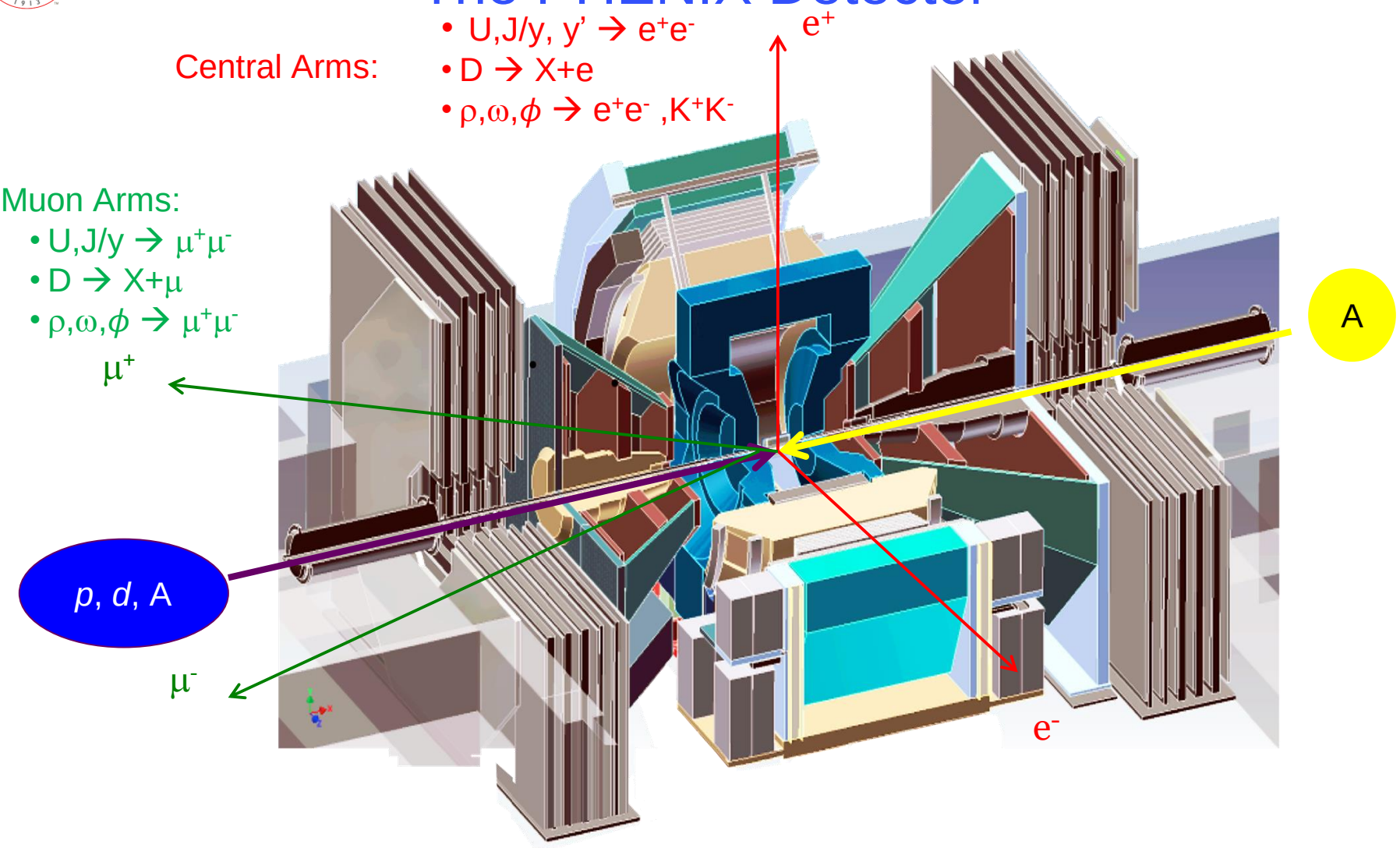
- ➢ the largest heavy ion collision system
- ➢ the largest energy density in central collisions



The PHENIX Detector

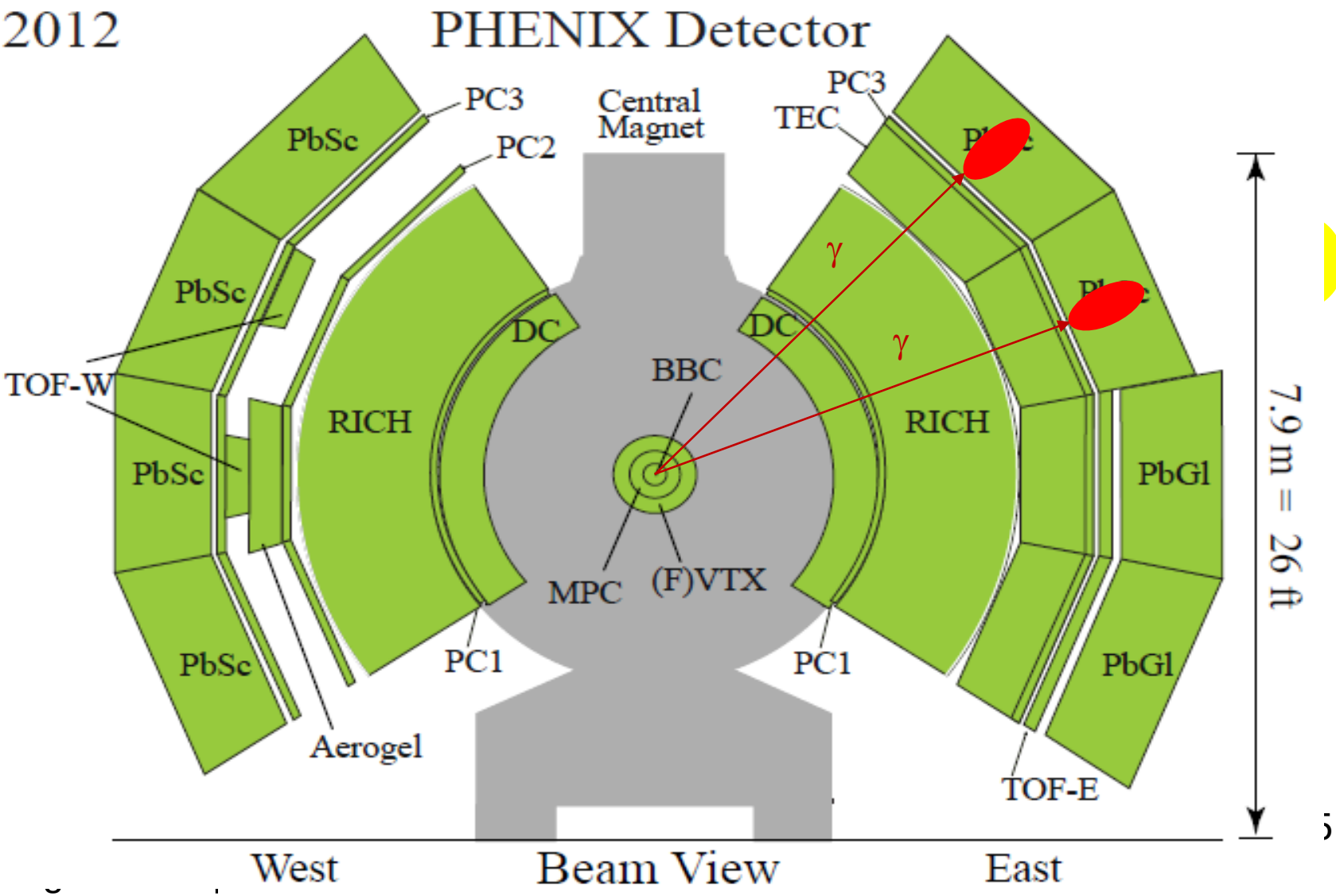
Central Arms:
- U,J/y, y' → e^+e^-
- D → X+e
- ρ,ω,ϕ → e^+e^- ,K^+K^-

Muon Arms:
- U,J/y → $\mu^+\mu^-$
- D → X+μ
- ρ,ω,ϕ → $\mu^+\mu^-$



PHENIX: optimized to measure leptons: rapidity coverage: 1.2<|y|<2.2 & |y|<0.35
- high rate capability with emphasis on mass resolution & particle ID
- first level e&μ triggers

The PHENIX Detector

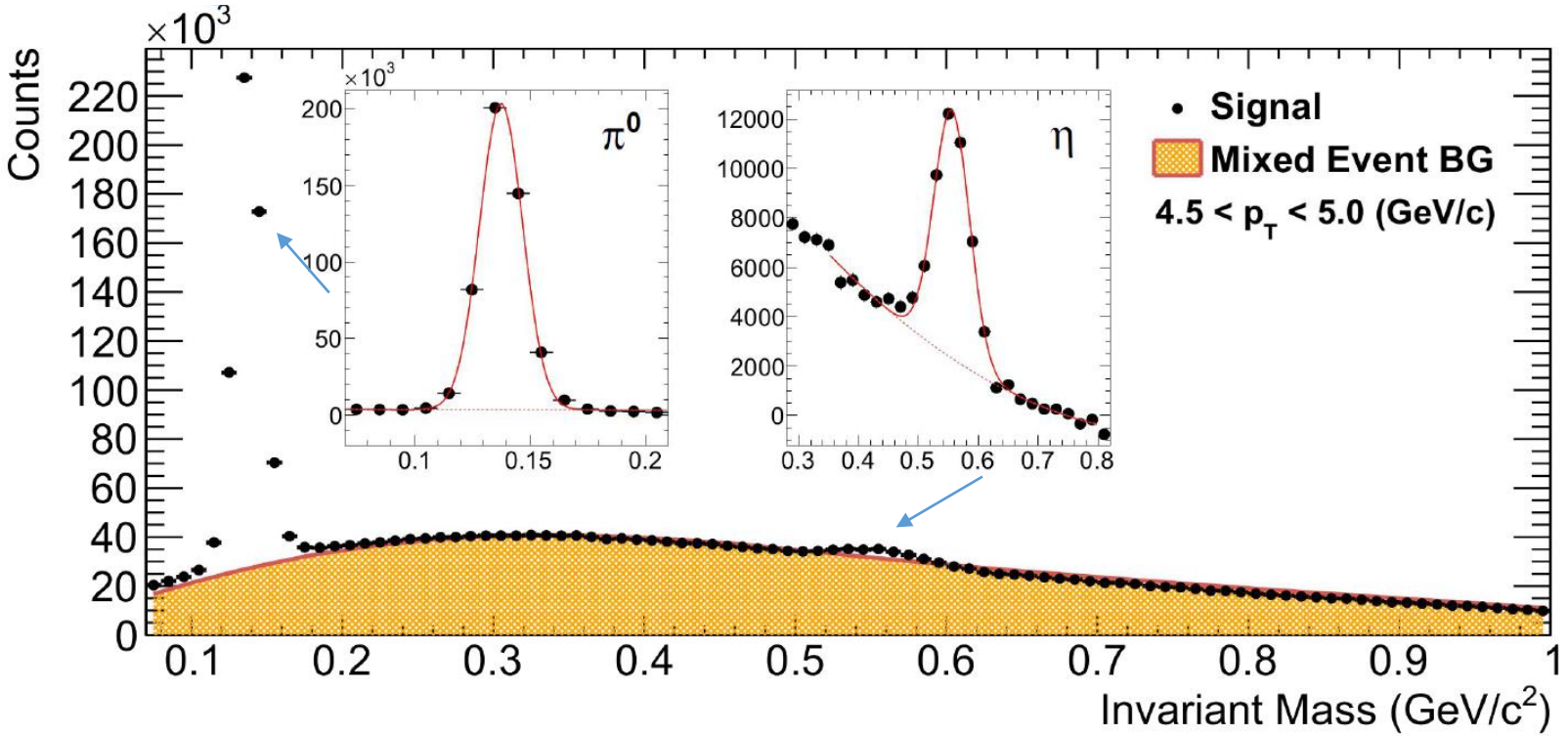


Muo
- U
- D
- p

F

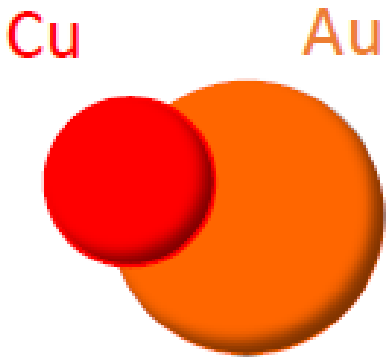
- ➢ first level e& **Acceptance: -0.35 < η < 0.35, Δφ – 2 x 90°**

π^0 & η Reconstruction in PHENIX



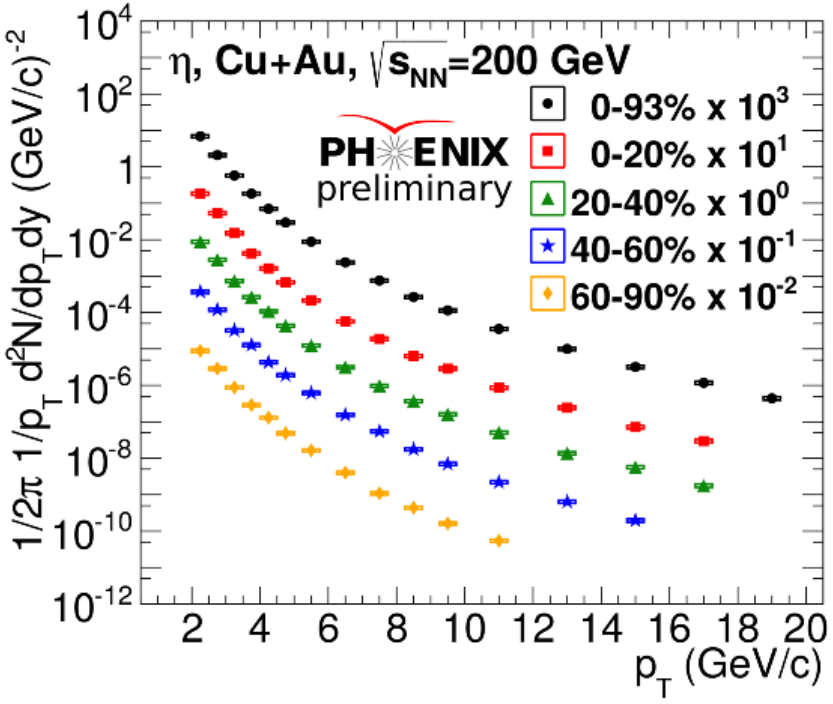
- π^0 and η are reconstructed by combining pairs of γ clusters in the EMCal
- Combinatorial BG is estimated using mixed-event technique and subtracted
- π^0 peak is better pronounced because of:
  - higher production rate and reconstruction efficiency
  - larger branching: BR($\pi^0 \rightarrow \gamma\,\gamma$) = 0.988, BR($\eta \rightarrow \gamma\,\gamma$) = 0.39
  - smaller width: $\sigma(\pi^0)$~10 MeV/c^2, $\sigma(\eta)$~30 MeV/c^2

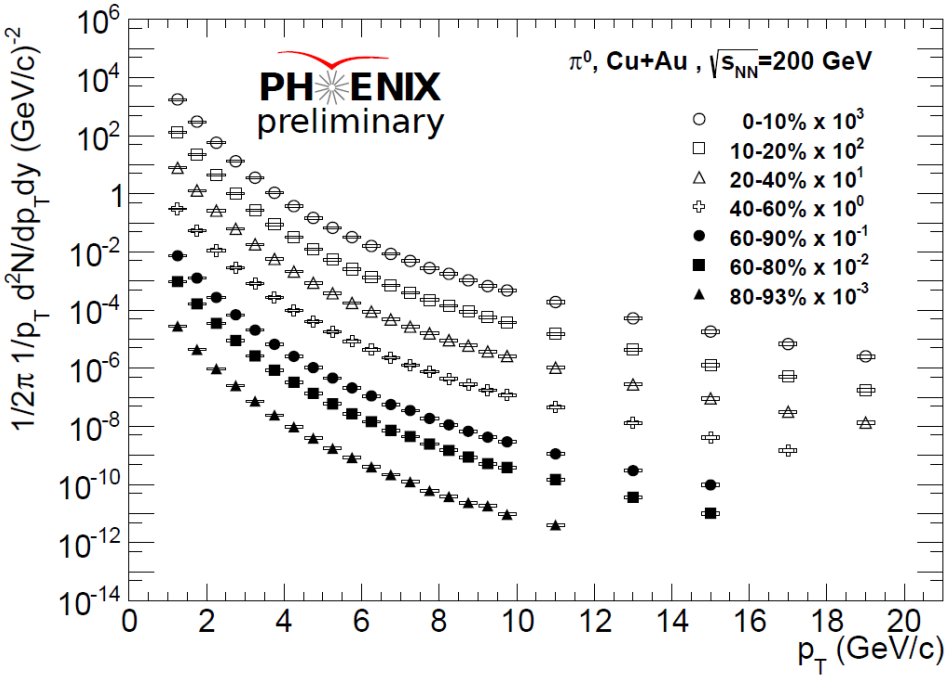
Cu+Au Collisions



- first asymmetric heavy-ion collision system
- different overlap geometry compared to symmetric systems

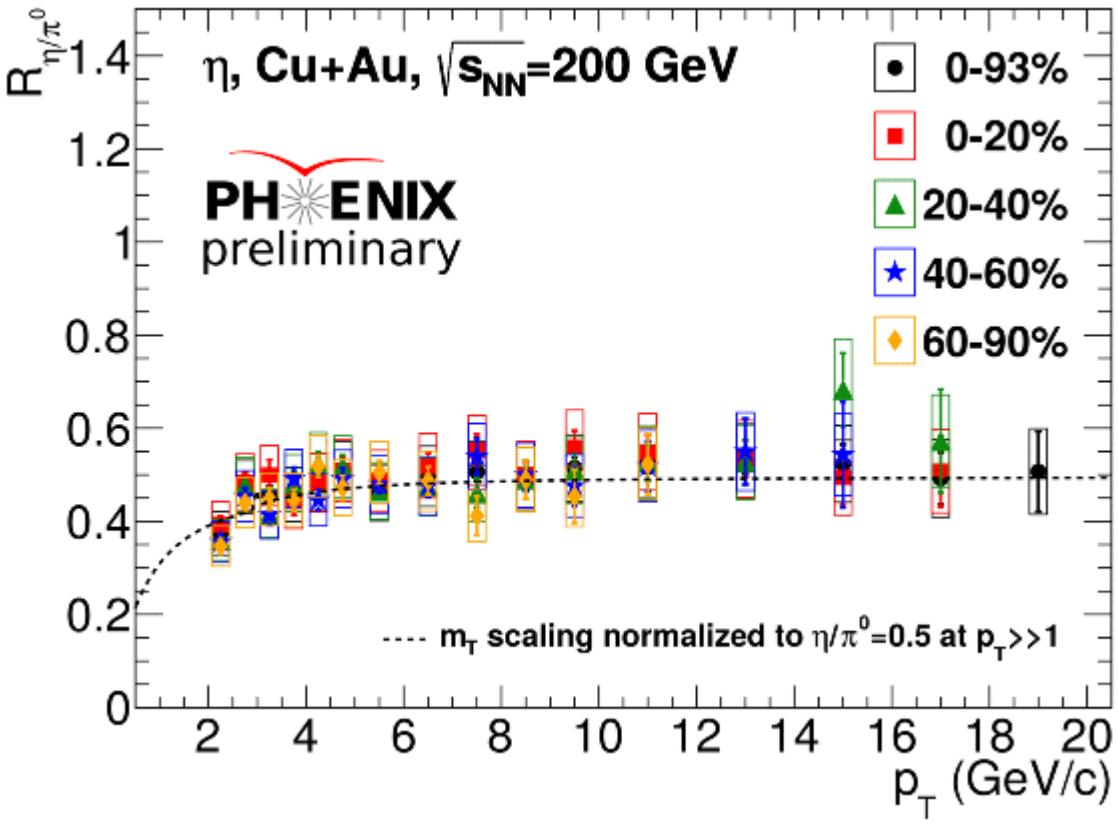
π^0 & η Spectra in Cu+Au





- Measured over a wide p_T range: up to 20 GeV/c in central collisions and semi-central collisions, and up to 16 GeV/c in peripheral

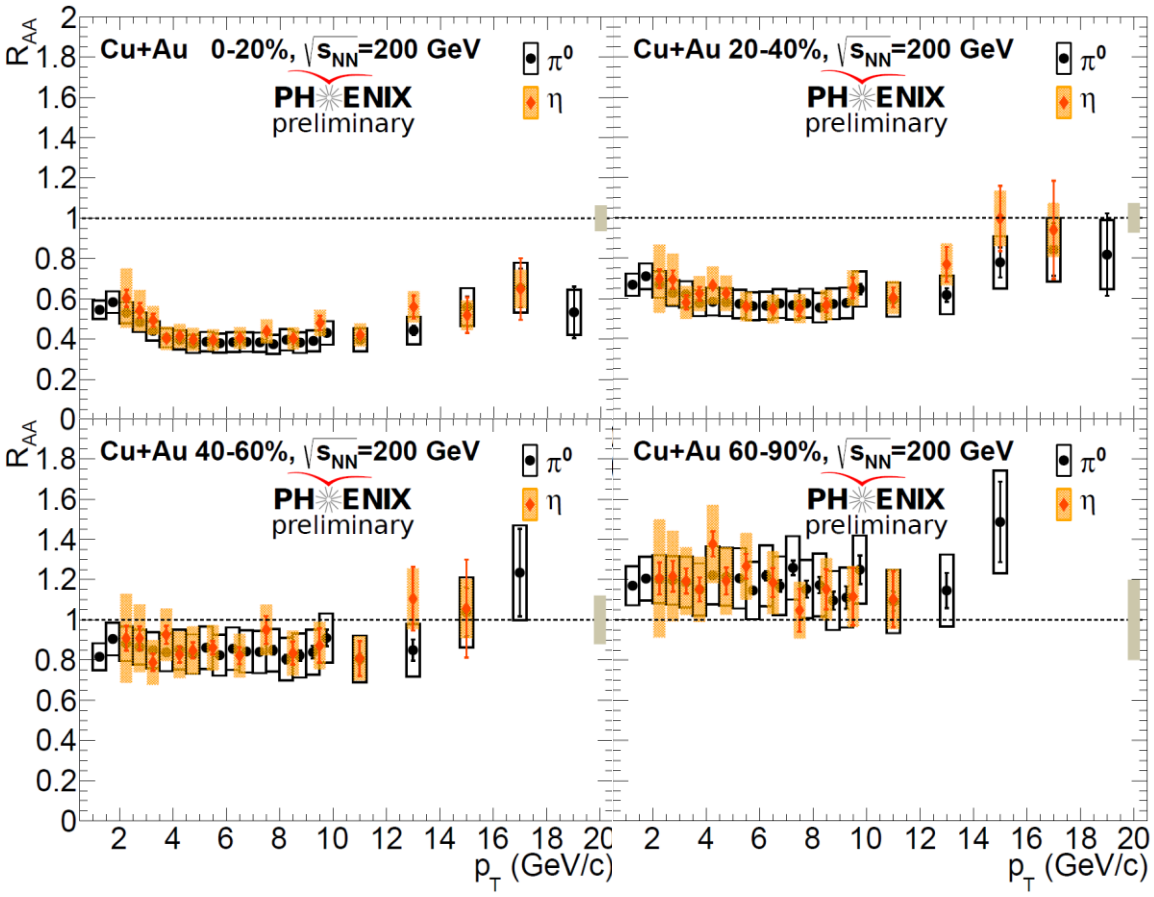
η/π^0 ratios in Cu+Au

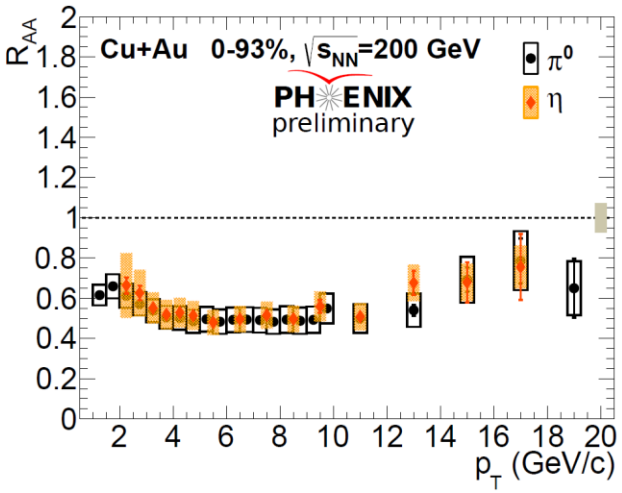


- η/π^0 is consistent with the m_T-scaling curve, normalized to 0.5 at high p_T
- η/π^0 is consistent with that measured in *p*+*p*, *p*+A and A+A collisions at different energies

PHENIX, Phys. Rev. C75, 024909 (2007)
CCRS, Phys. Lett. B 55, 232 (1975)

π^0 & η R_{AA} in Cu+Au: Centrality dependence

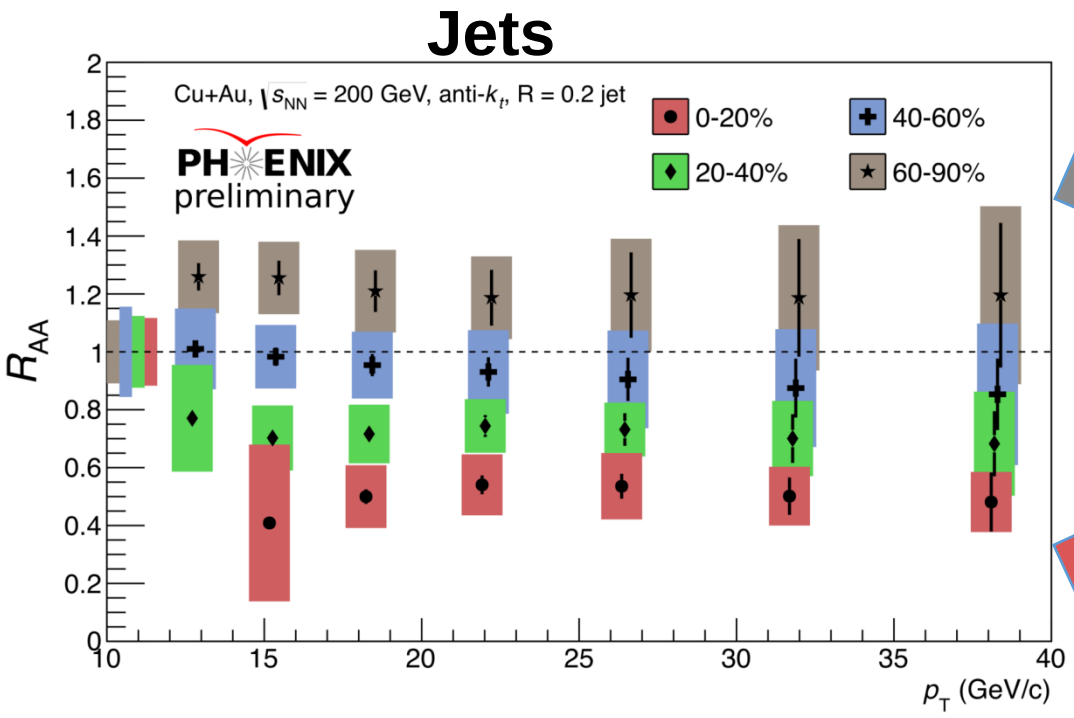


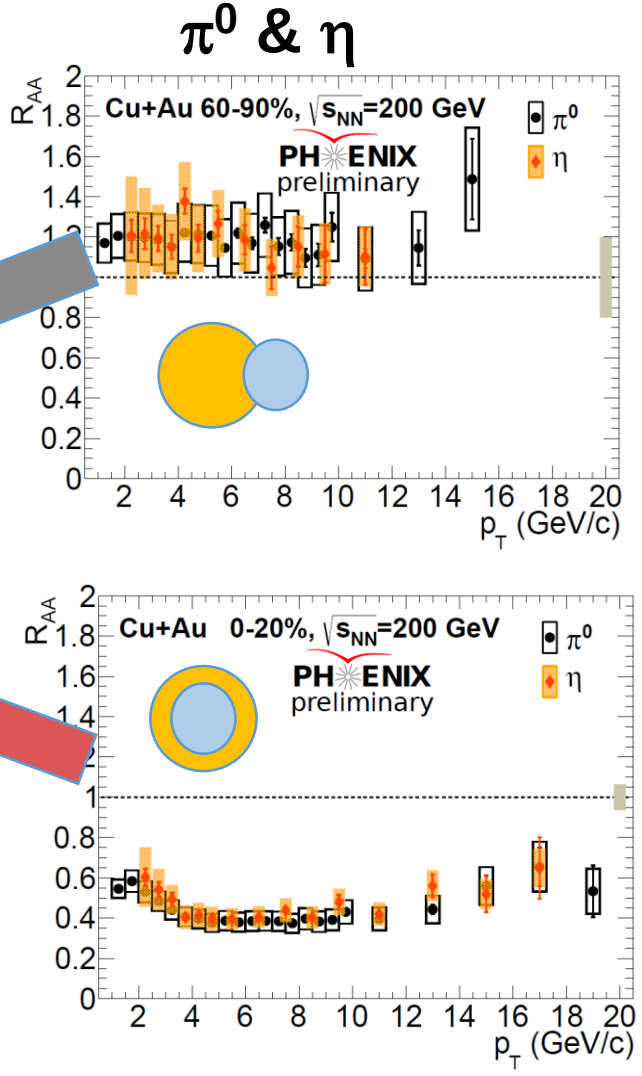


- In **central** and **semi central** Cu+Au collisions π^0 and η suppressed
- In **peripheral** Cu+Au collisions: a hint on π^0 and η enhancement

❖ π^0 and η results show a good agreement $\Rightarrow$ have similar fragmentation function modification by the medium in the accessed p_T range.

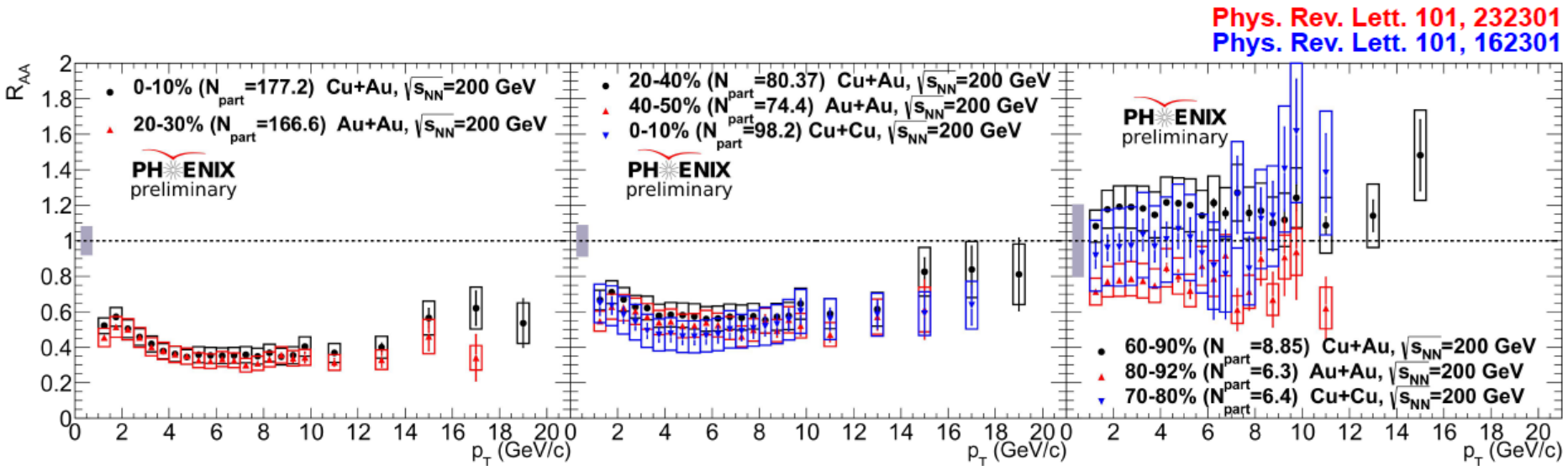
Comparison with Jets R_{AA} in Cu+Au





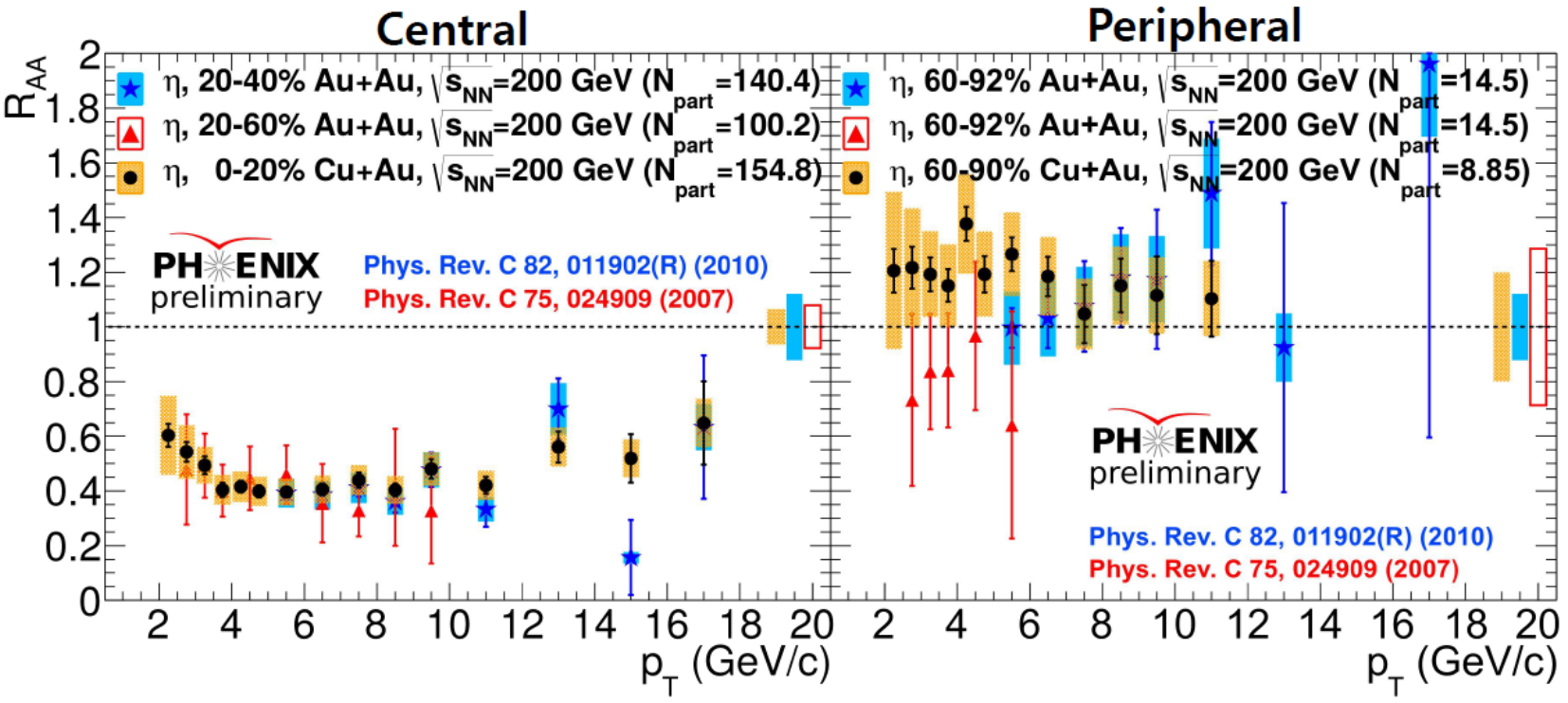
- π^0 & η and jets show similar centrality dependence of R_{AA}

Comparison of $\pi^0 R_{CuAu}$ with Other Systems



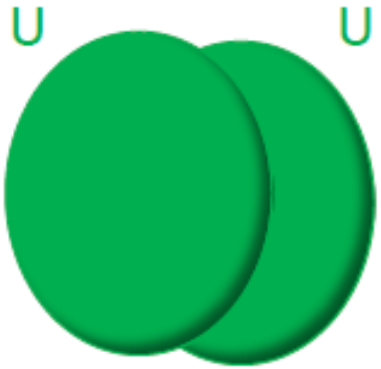
- In **central** and **semi-central Cu+Au** collisions π^0 yields show similar suppression as in **Cu+Cu** and **Au+Au** at similar N_{part}:
  - π^0 production depends on the size of the nuclear overlap, but not on it's shape
- In **peripheral Cu+Au** collisions π^0 yields show a hint on enhancement while in **Au+Au** – suppression, **Cu+Cu** is in between

Comparison of η R_{CuAu} with Au+Au



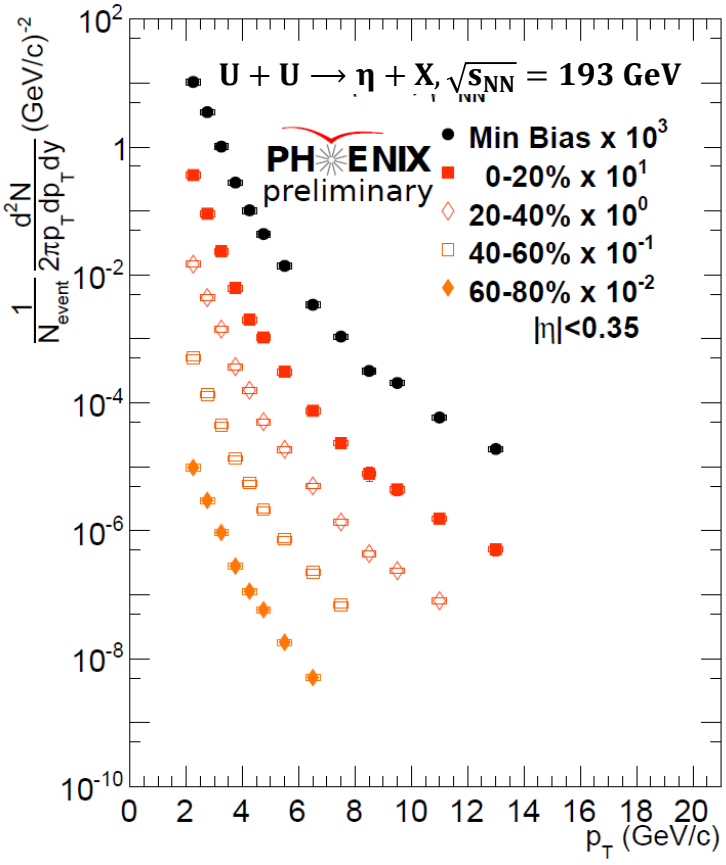
- At high p_T, production of η in **Cu+Au** is suppressed in the same way as in **Au+Au** at similar N_{part}

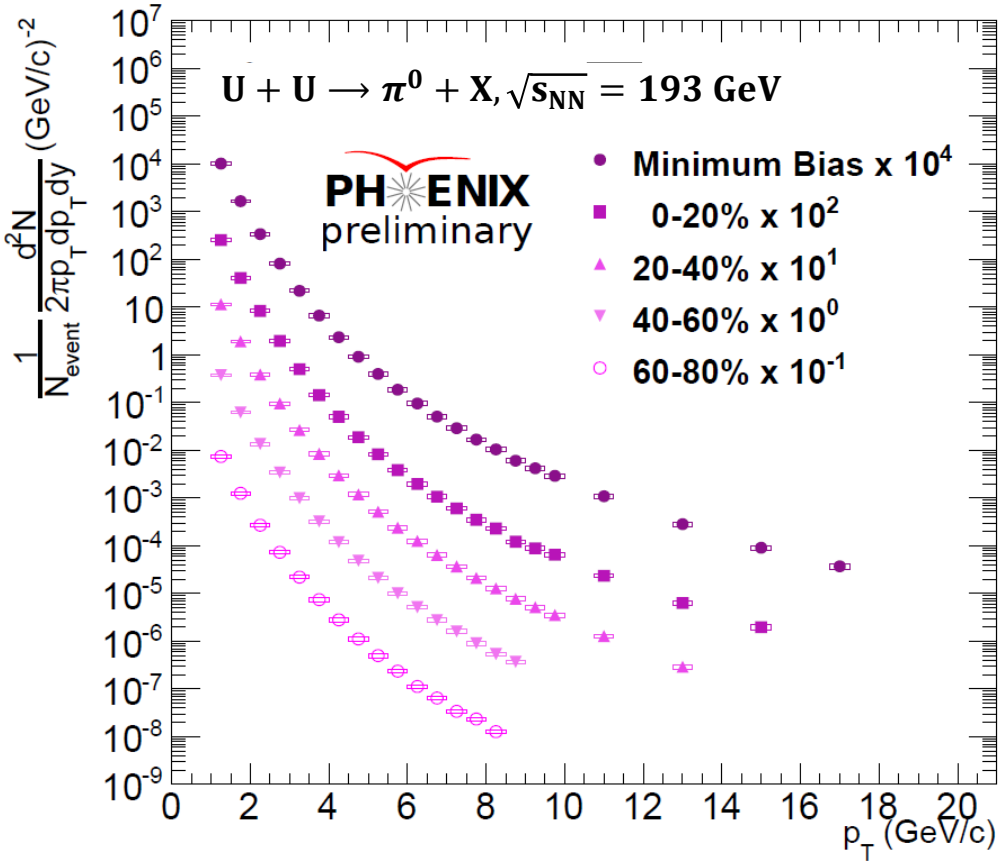
U+U Collisions



- The largest heavy ion collision system
- The largest energy density in central collisions

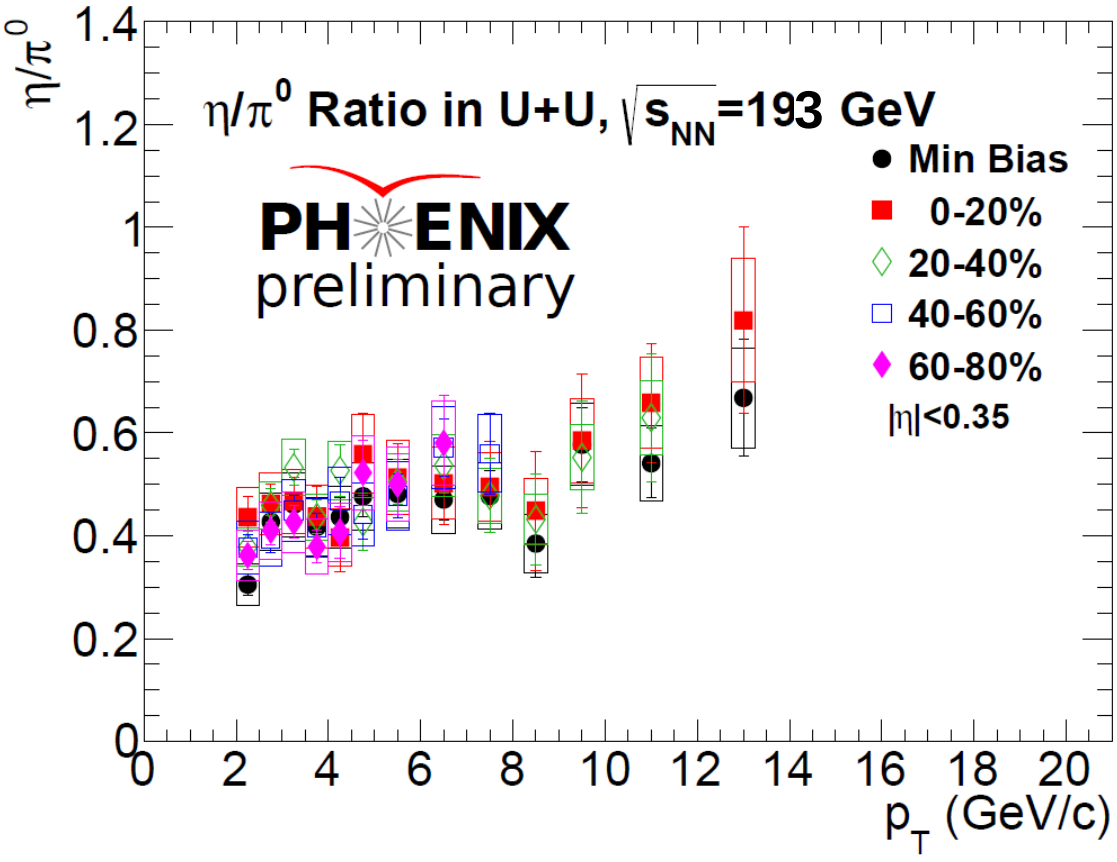
π^0 & η spectra in U+U





- Measured π^0 (η) over a wide p_T range: up to 15 (13) GeV/c in central collisions and semi-central collisions, and up to 9 (7) GeV/c in peripheral

η/π^0 ratios in U+U



- η/π^0 is consistent at different centralities and with that measured in other A+A collisions at different energies

U Nucleus Modification

- Deformed nucleus ⇒ use Wood-Saxon distribution of the U nucleus:

$$\rho = \frac{\rho_0}{1 + e^{([r-R']/a)}}$$

where *R'* depends on the polar angle θ:

$$R' = R\left[1 + \beta_2 Y_2^0(\theta) + \beta_4 Y_4^0(\theta)\right]$$

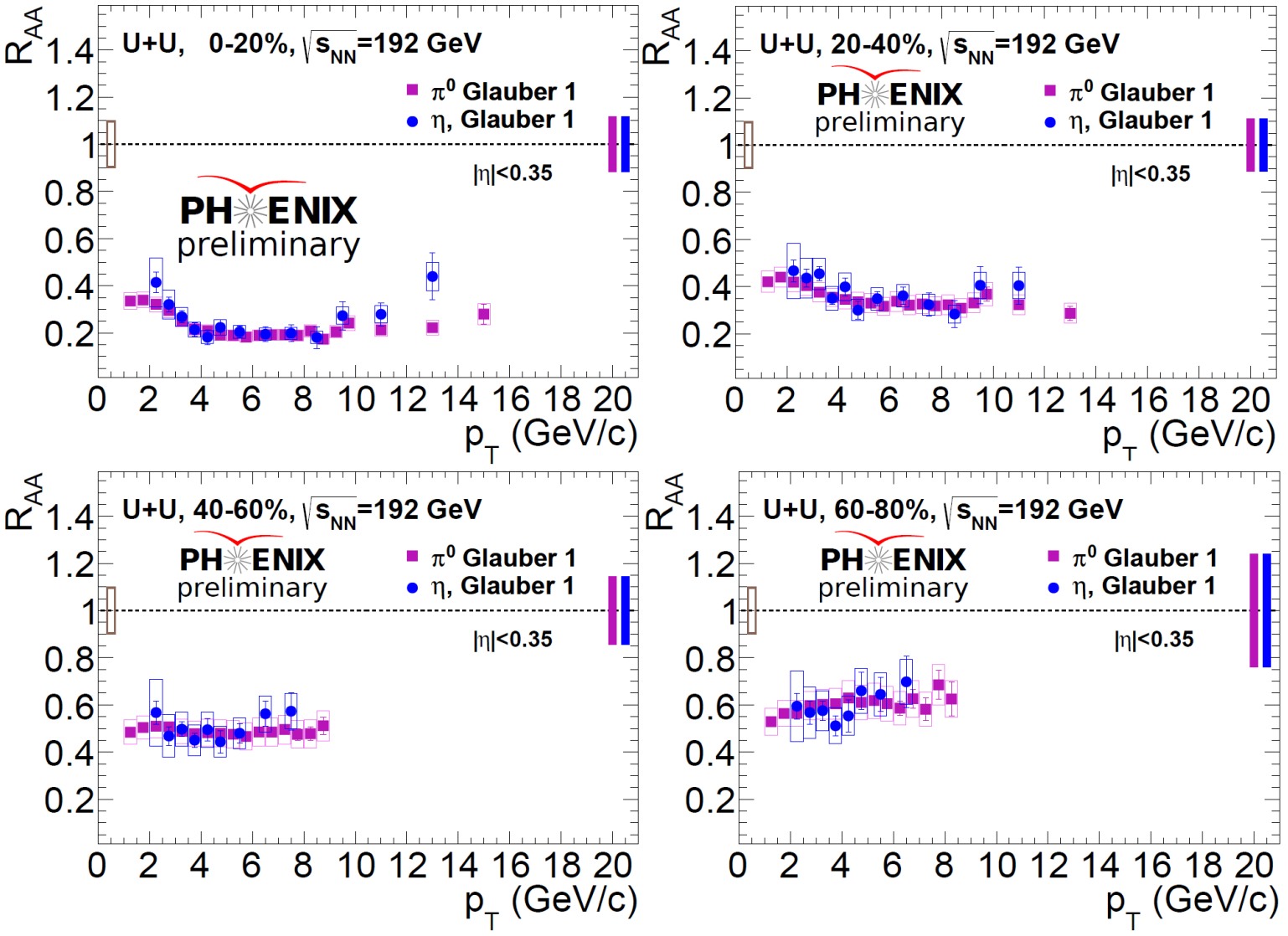
where Y^0 – Legendre polynomial.

- Two sets of Wood-Saxon parameters were used for the Glauber MC.

Parameter	Set1/Glauber1	Set2/Glauber2
$R\ (fm)$	6.81	6.86
$\alpha\ (fm)$	0.6	0.42
β_2	0.28	0.265
β_4	0.093	0
source	Phys. Lett. **B** 679, 440 (2009)	Phys. Lett. **B** 749, 215 (2015)

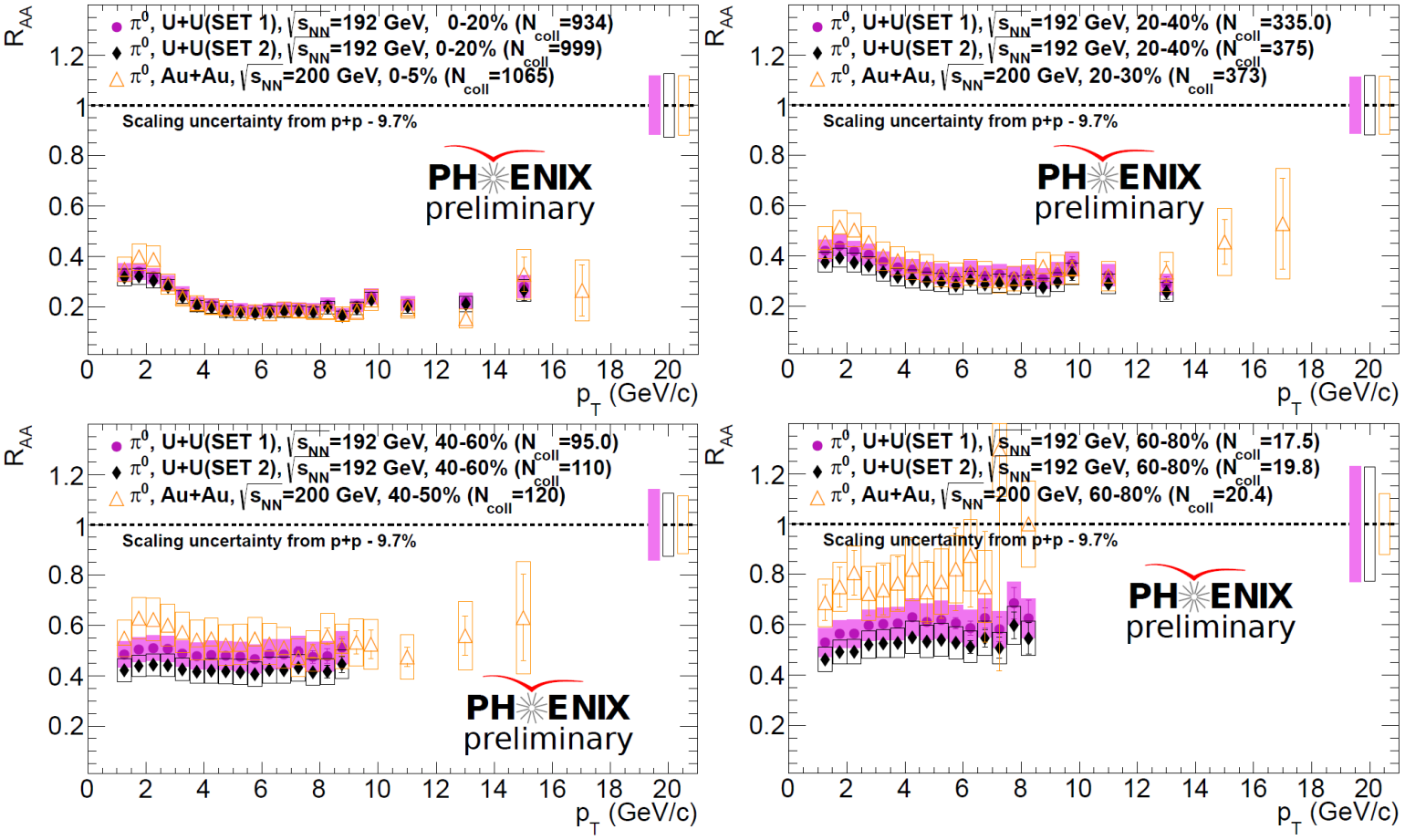
Deformation of the U ion

η & π^0 Nuclear Modification in U+U



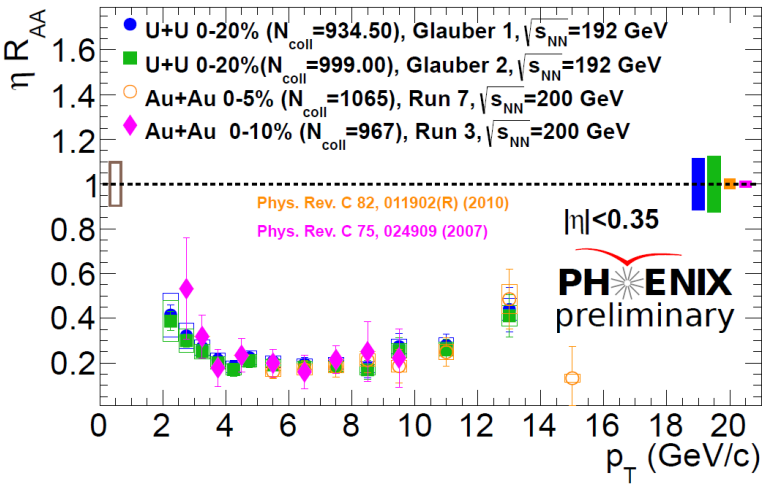
- η shows similar nuclear modification to that of π^0 over all centralities!

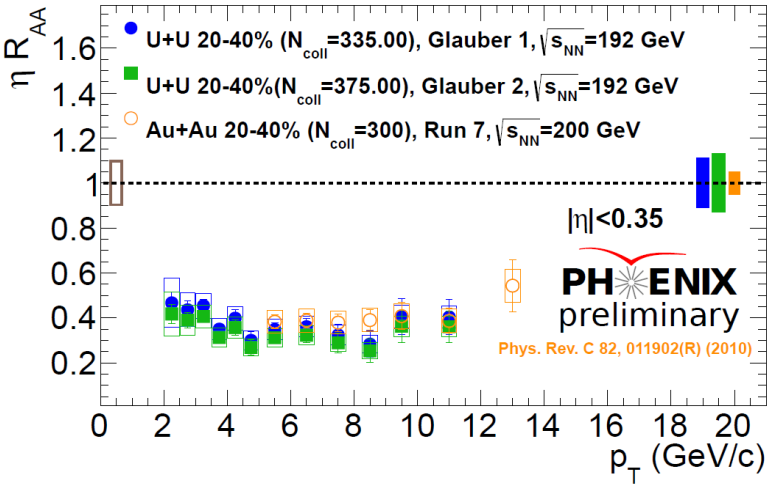
π^0 Nuclear Modification in U+U

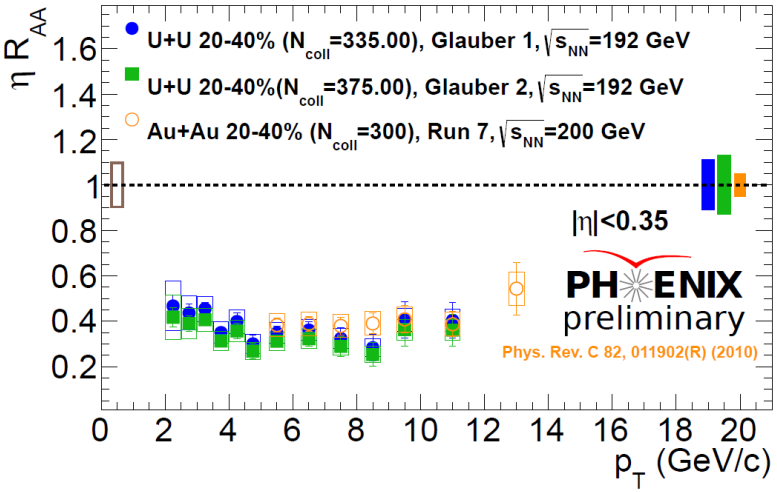


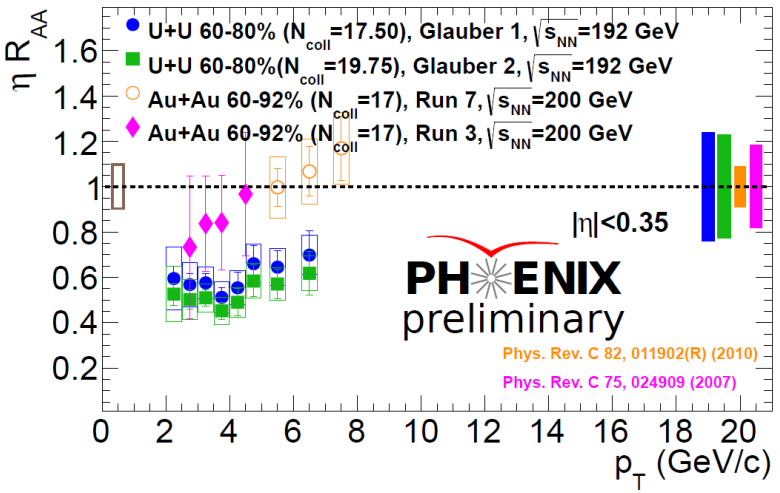
- At same N_{coll} values, the R_{AA} is consistent in most- to mid-central collisions
  - π^0 production depends on the size of the nuclear overlap, but not on it's density
- The most peripheral collision shows larger suppression in U+U collisions

η Nuclear Modification in U+U



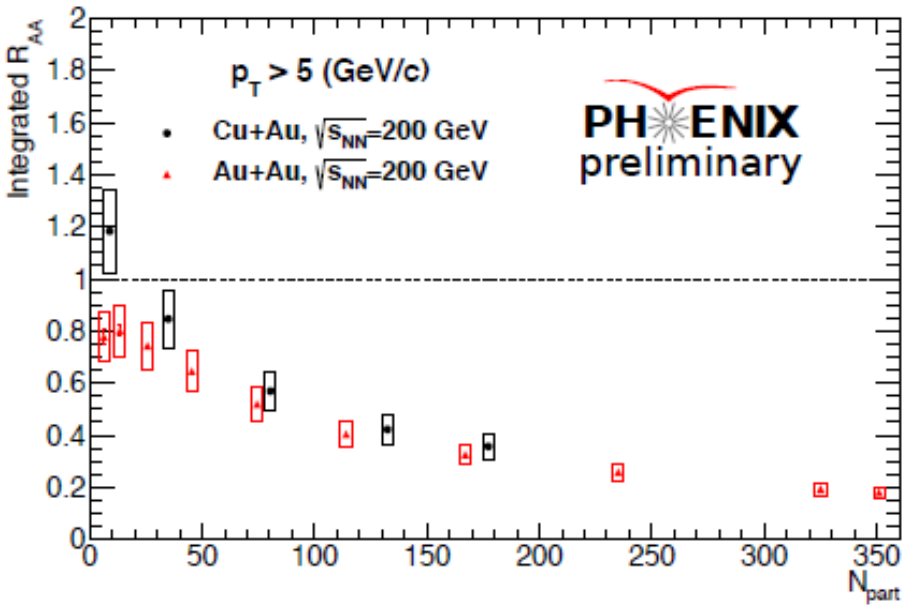


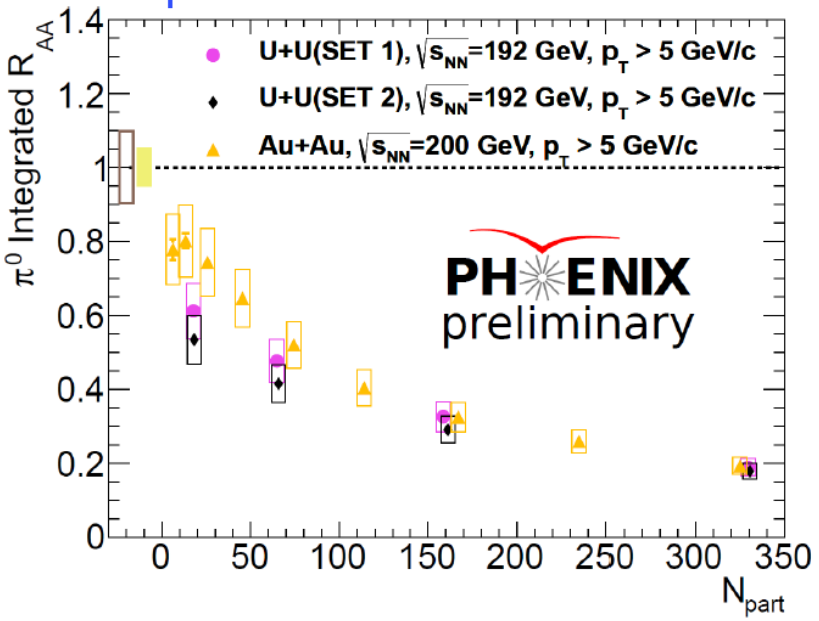


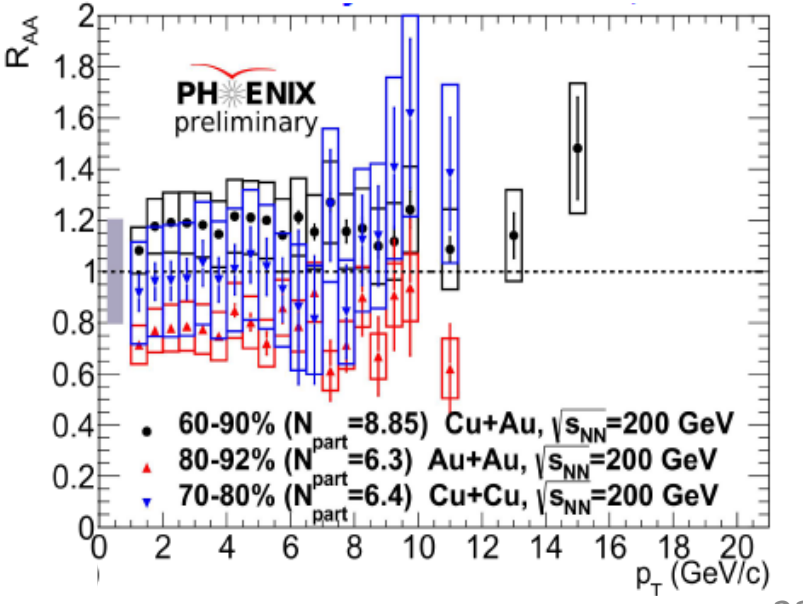


- At same N_{coll} values, the R_{AA} is consistent in most- to mid-central collisions
  - η production does not depend on it's density
- The most peripheral collision shows larger suppression in U+U collisions

Integrated R_{AA} vs N_{part}







R_{AB} comparison for Cu+Au, Cu+Cu, Au+Au and U+U shows that:

- At N_{part} >50, all systems consistent with each other.
- At N_{part} <50, (although consistent within uncertainties) there seems to be some ordering

Cu+Au > Cu+Cu > Au+Au > U+U

Summary

- PHENIX has measured p_T spectra and nuclear modification factors for π^0 and η in Cu+Au and U+U collisions at 200 and 193 GeV
- R_{AA} factors for π^0 and η are consistent within uncertainties at all momenta and centralities $\Rightarrow$ have similar fragmentation function modification by the medium in the accessed pT range.
- Very consistent with the previous jet measurements
- In **central** and **semi-central A+A** collisions: π^0 and η production depends on the size of the nuclear overlap but not on it's shape or density. However, there is a hint of dependence on both in most **peripheral**! Cu+Au > Cu+Cu > Au+Au > U+U?