HARD PROBES 2018

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POLYTECH
Peter the Great St.Petersburg Polytechnic University

PHENIX

# Scaling properties of high $p_T$ light hadrons from small to large systems by PHENIX

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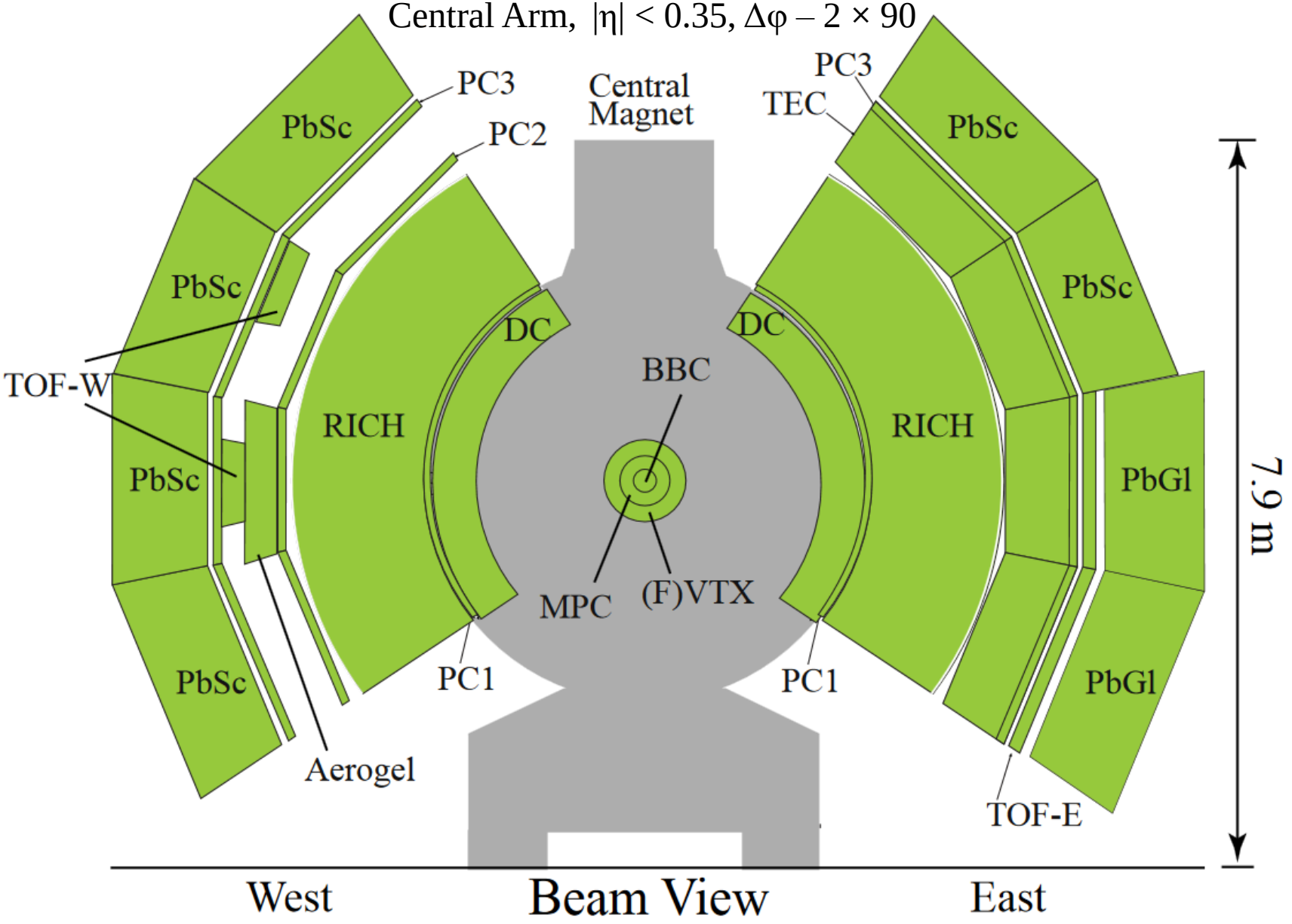
For PHENIX collaboration

# Motivation

- One of the major objectives in the field of high-energy nuclear physics is to quantify and characterize the properties of quark-gluon plasma (**QGP**);
- Hadron production in p+p, p+A, A+A collisions provides a look inside **QGP**;
- At high-$p_T$ hadron production is suppressed in central heavy ion collisions:
  - energy loss of hard scattered partons in hot and dense medium (**jet quenching**);
- In the intermediate $p_T$ range suppression was found to be species dependent:
  - "**baryon puzzle**" explained with recombination models;
- PHENIX measured light hadron production in a broad set of collisions:
  - **$\pi^0$, $\eta$, $K_s$, $\varphi$, $\omega$ in p+Au, d+Au, $^3$He+Au, Cu+Cu, Cu+Au, Au+Au, U+U**;
- Rich collection of results allows to study scaling properties of light hadron production from small to large systems:
  - parton energy loss in heavy ion collisions;
  - cold nuclear matter (**CNM**) effects in small systems.

# The PHENIX Detector

Central Arm, $|\eta| < 0.35$, $\Delta\varphi - 2 \times 90$



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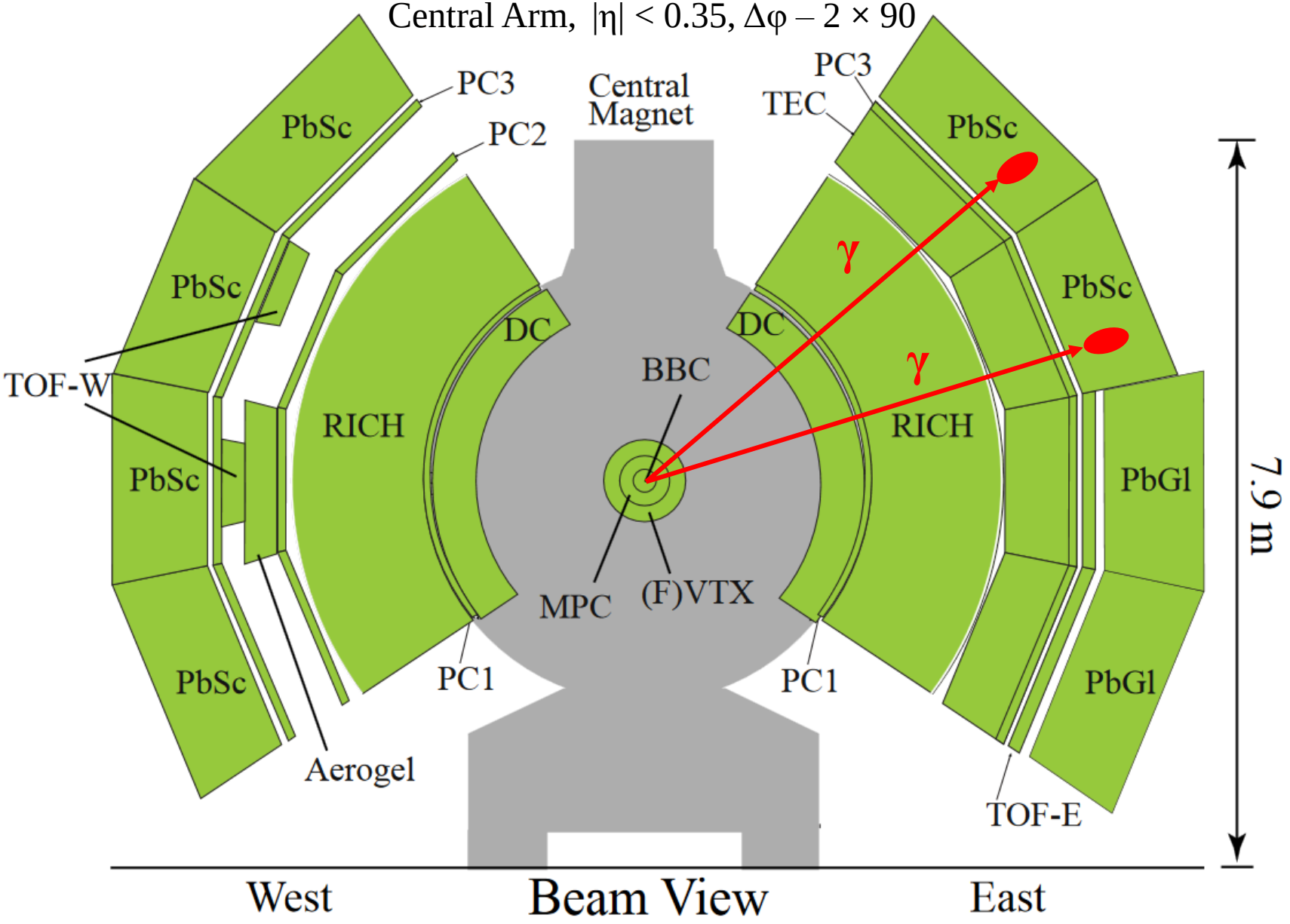

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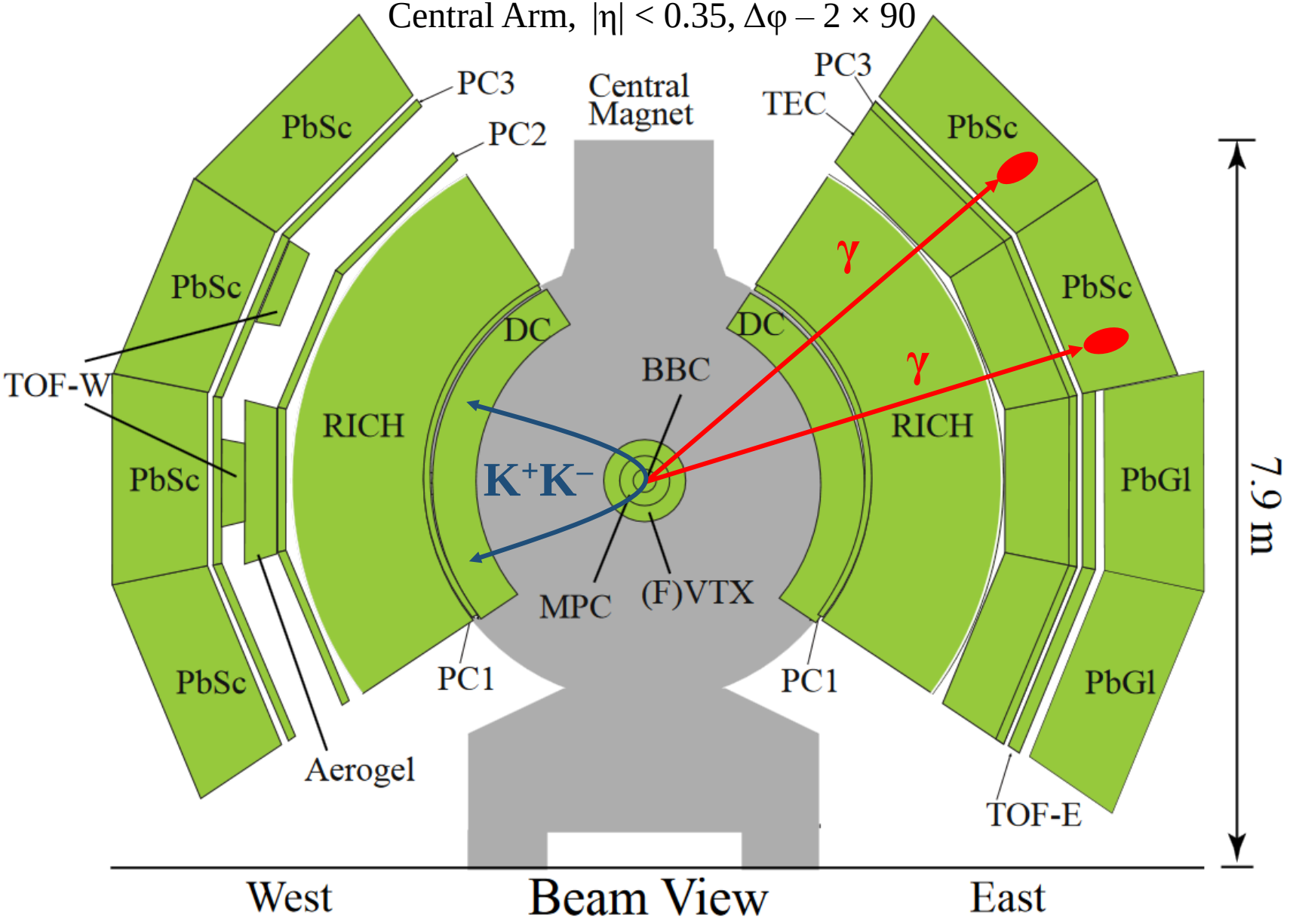
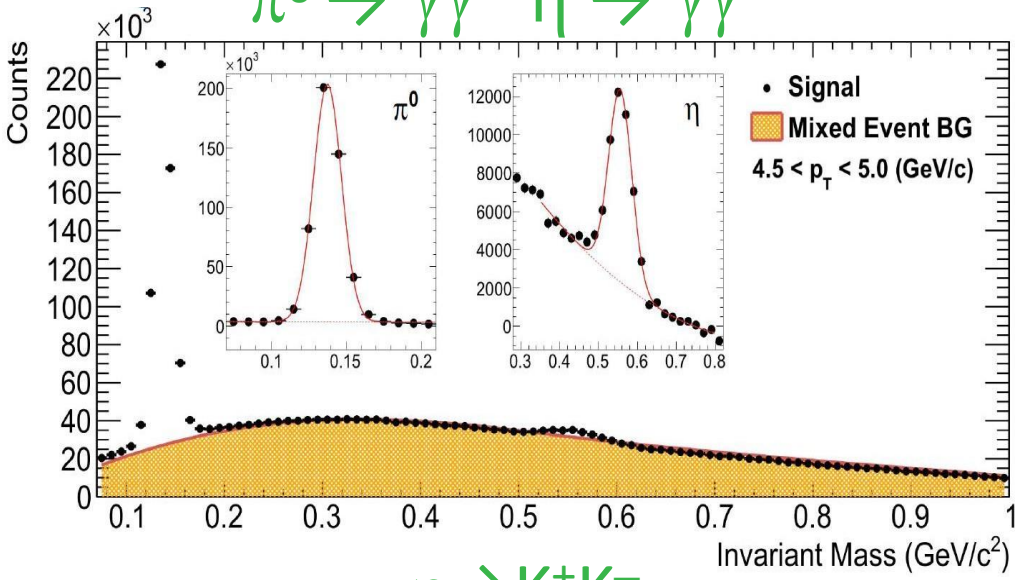
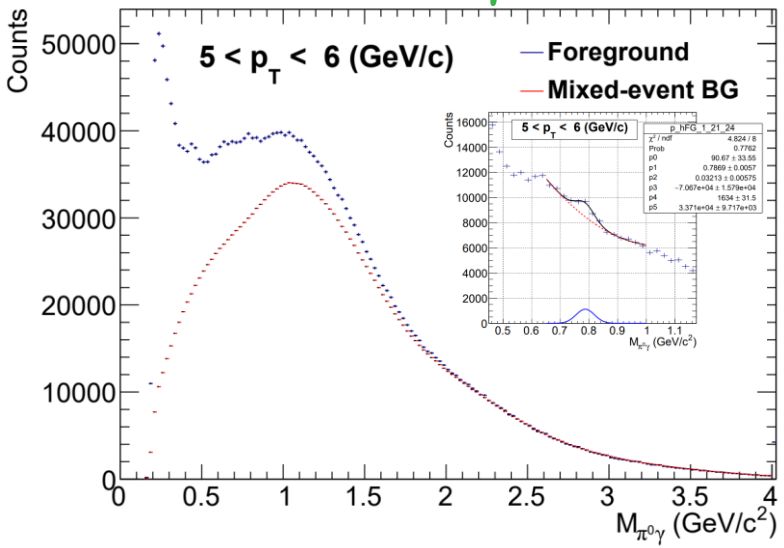


# $\pi^0, \eta, K_s, \varphi, \omega$ Reconstruction in PHENIX

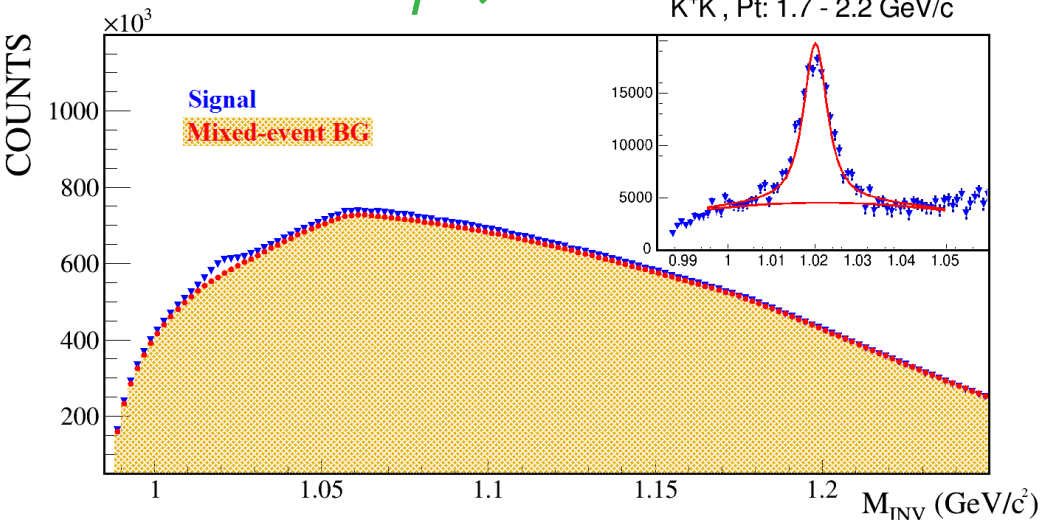
$\pi^0 \to \gamma\gamma$ $\eta \to \gamma\gamma$

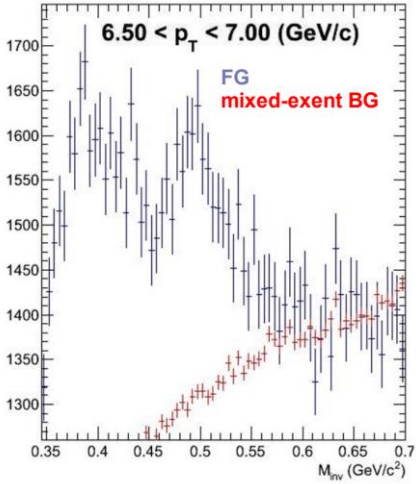



$\omega \to \gamma\pi^0$

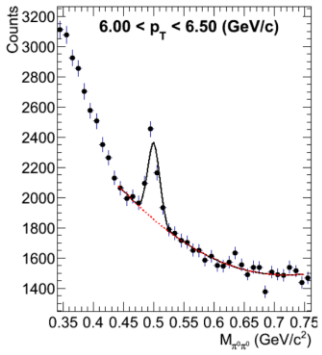



$\varphi \to K^+K^-$




$K_S \to \pi^0\pi^0$

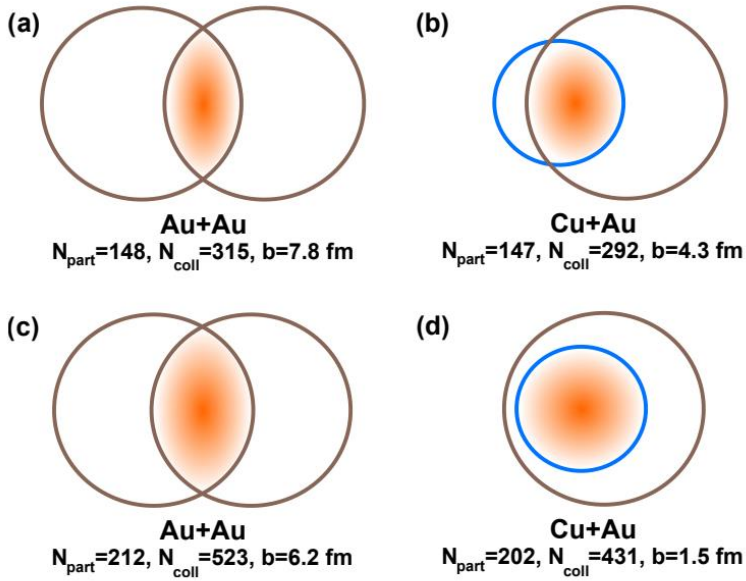


# Large systems: Cu+Au & U+U

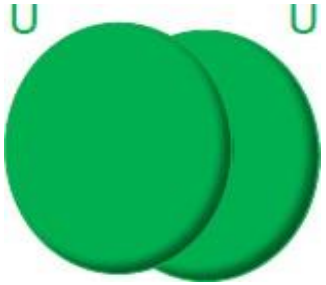
- Hadron production at PHENIX was successfully studied in symmetric systems;

- Cu+Au:
  - First asymmetric heavy-ion collision system available at PHENIX;
  - Collisions with unique initial geometrical configurations;

- U+U:
  - The largest heavy ion collision system;
  - The largest energy density in central collisions.

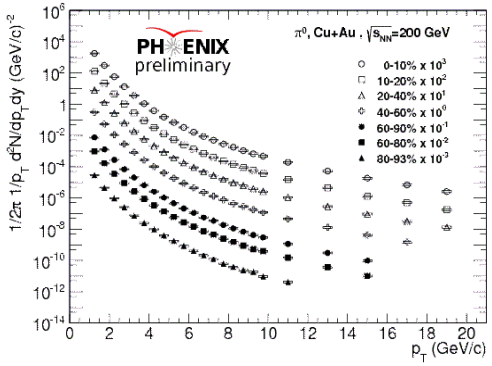


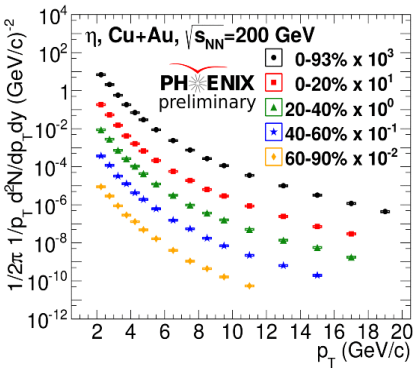

arXiv:1805.04389

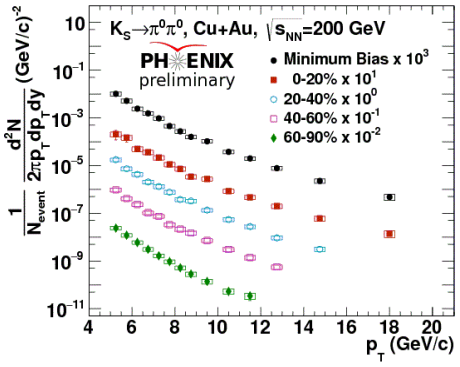


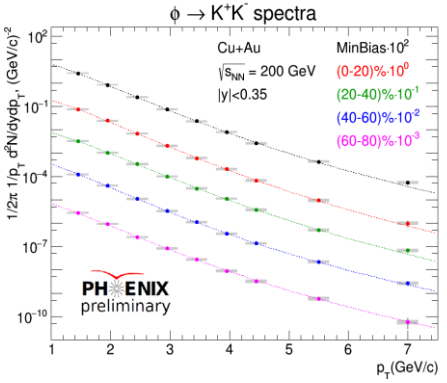
# $\pi^0, \eta, K_s, \varphi, \omega$ $p_T$-spectra in Cu+Au & U+U

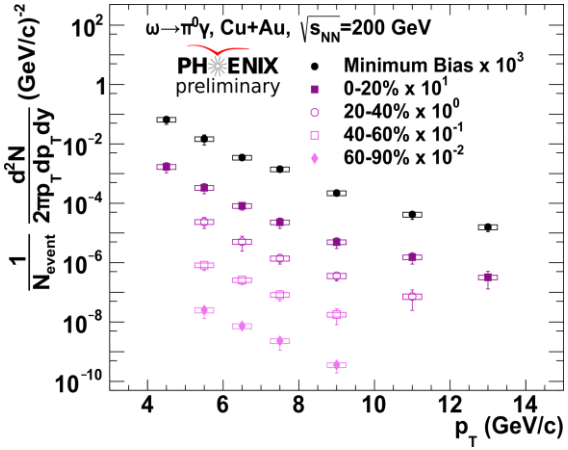
arXiv:1805.04389

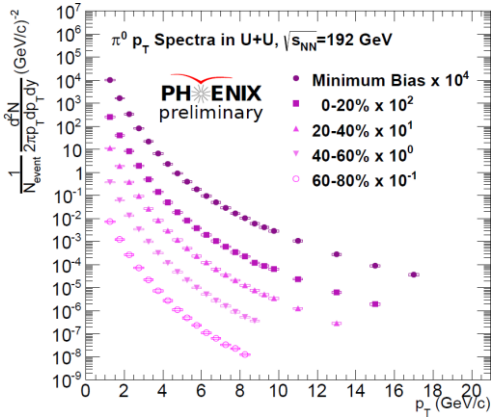


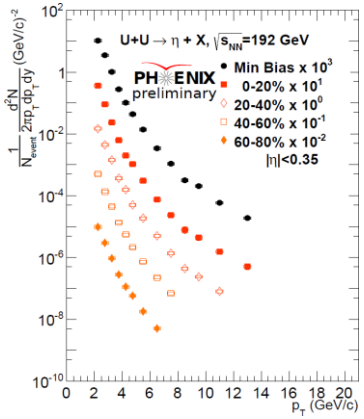



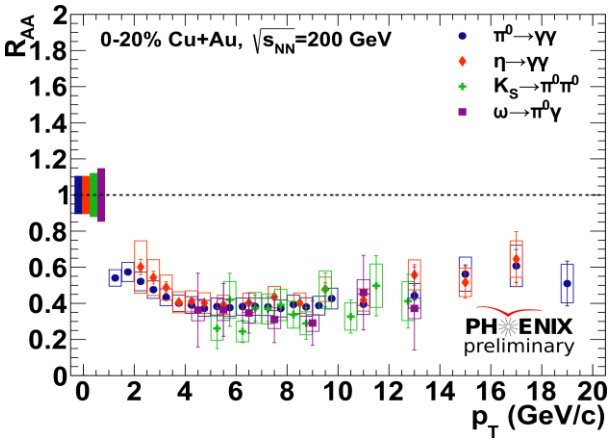



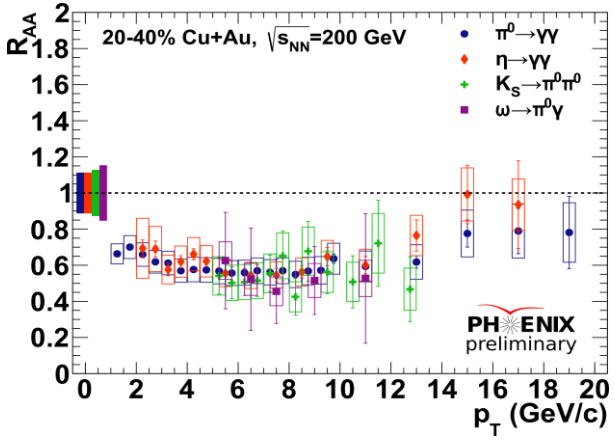



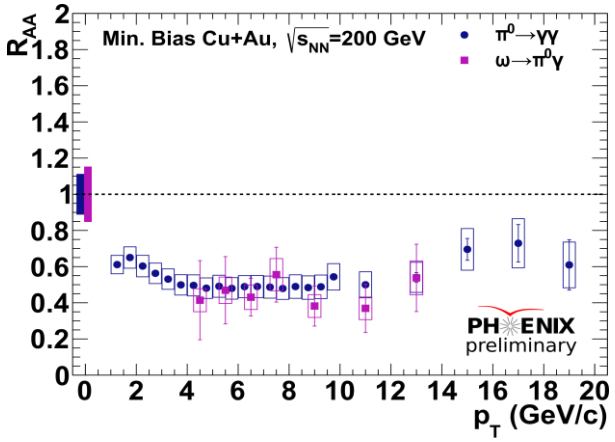



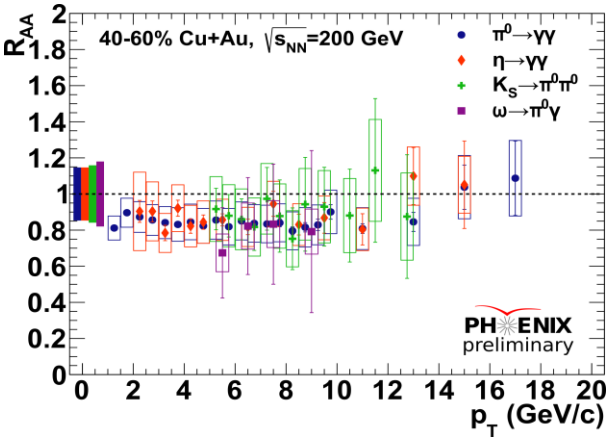



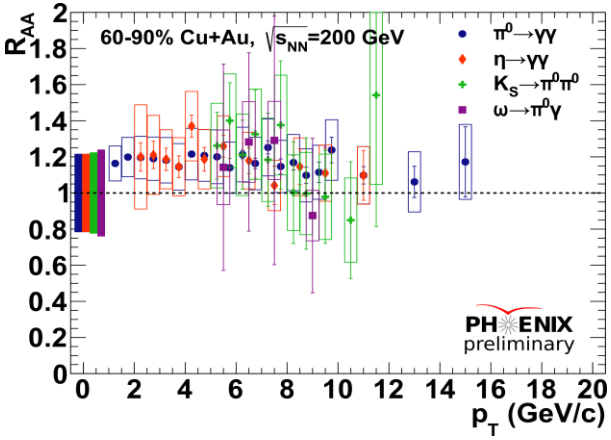
# $\pi^0, \eta, K_s, \omega$ $R_{CuAu}$ at $\sqrt{s_{NN}}$=200 GeV



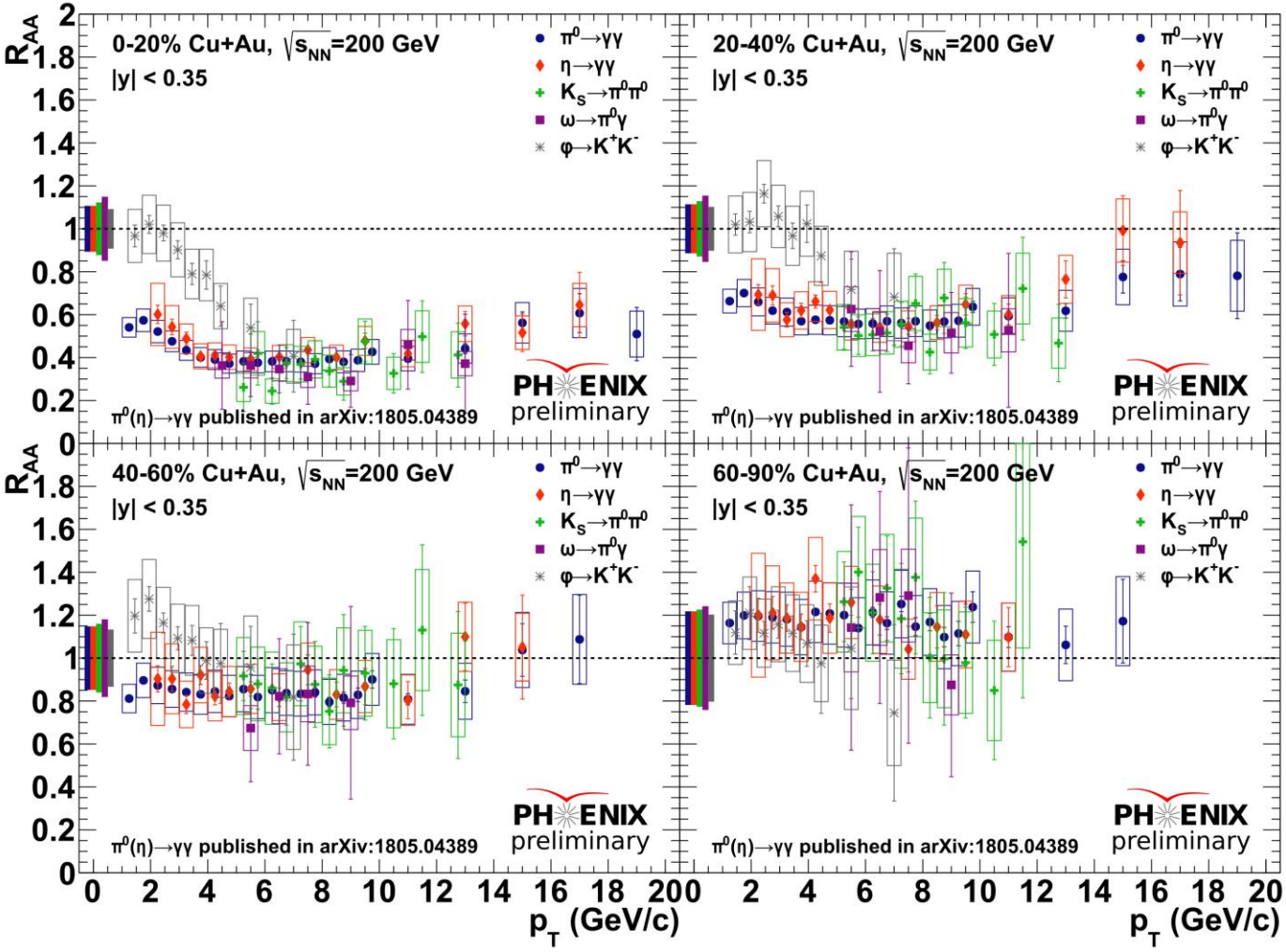




$$R_{AA}(p_T) = \frac{1}{N_{coll}} \frac{dN_{AA}}{dN_{pp}}$$

- $R_{AA} = 1$ – no medium effects
- $R_{AA} \neq 1$ – medium effects:
  - $R_{AA} < 1$ – suppression
  - $R_{AA} > 1$ – enhancement

- $\pi^0, \eta, K_s, \omega$ shows similar suppression values in Cu+Au collisions

# φ $R_{CuAu}$ at $\sqrt{s_{NN}}$=200 GeV



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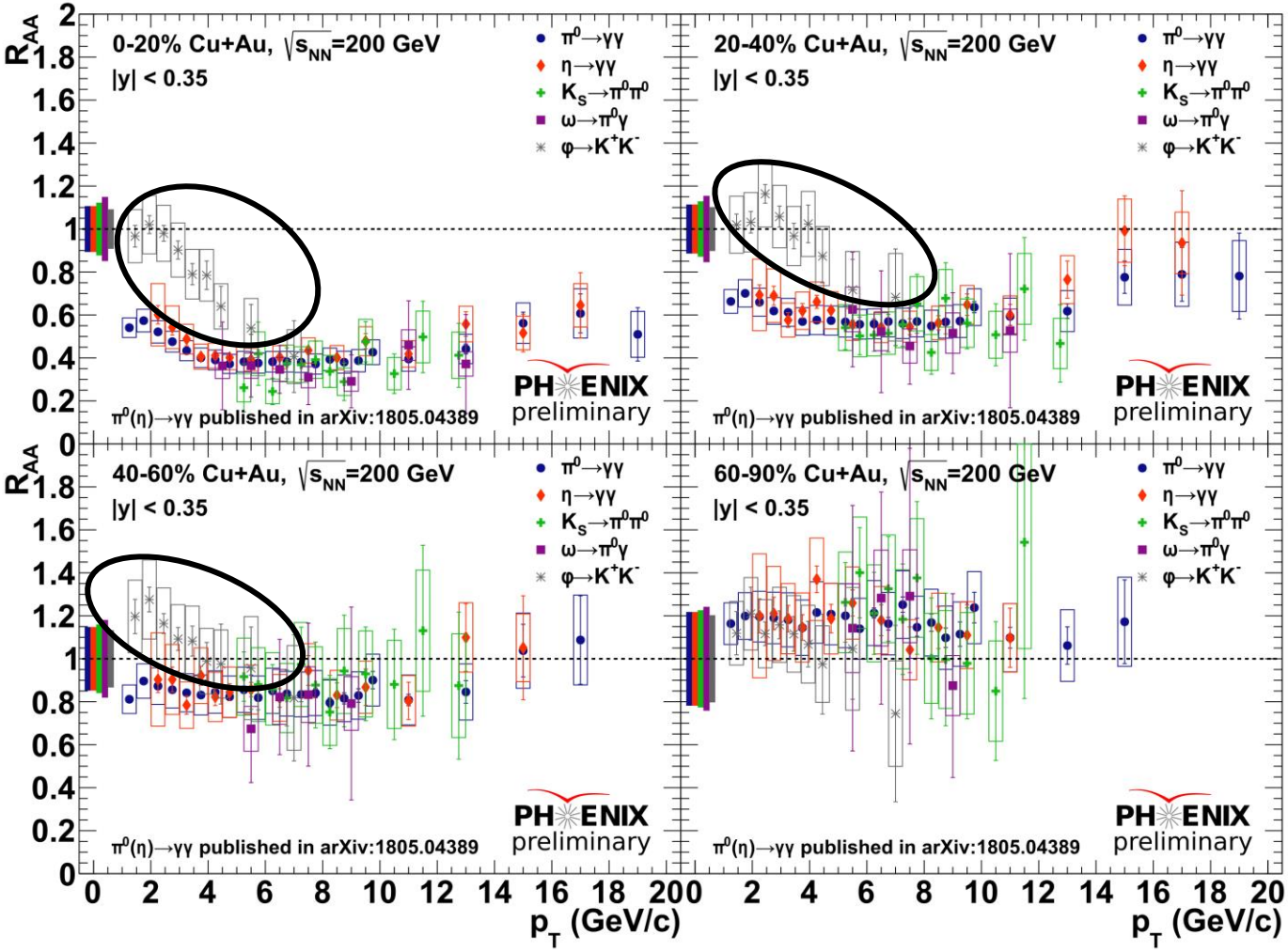
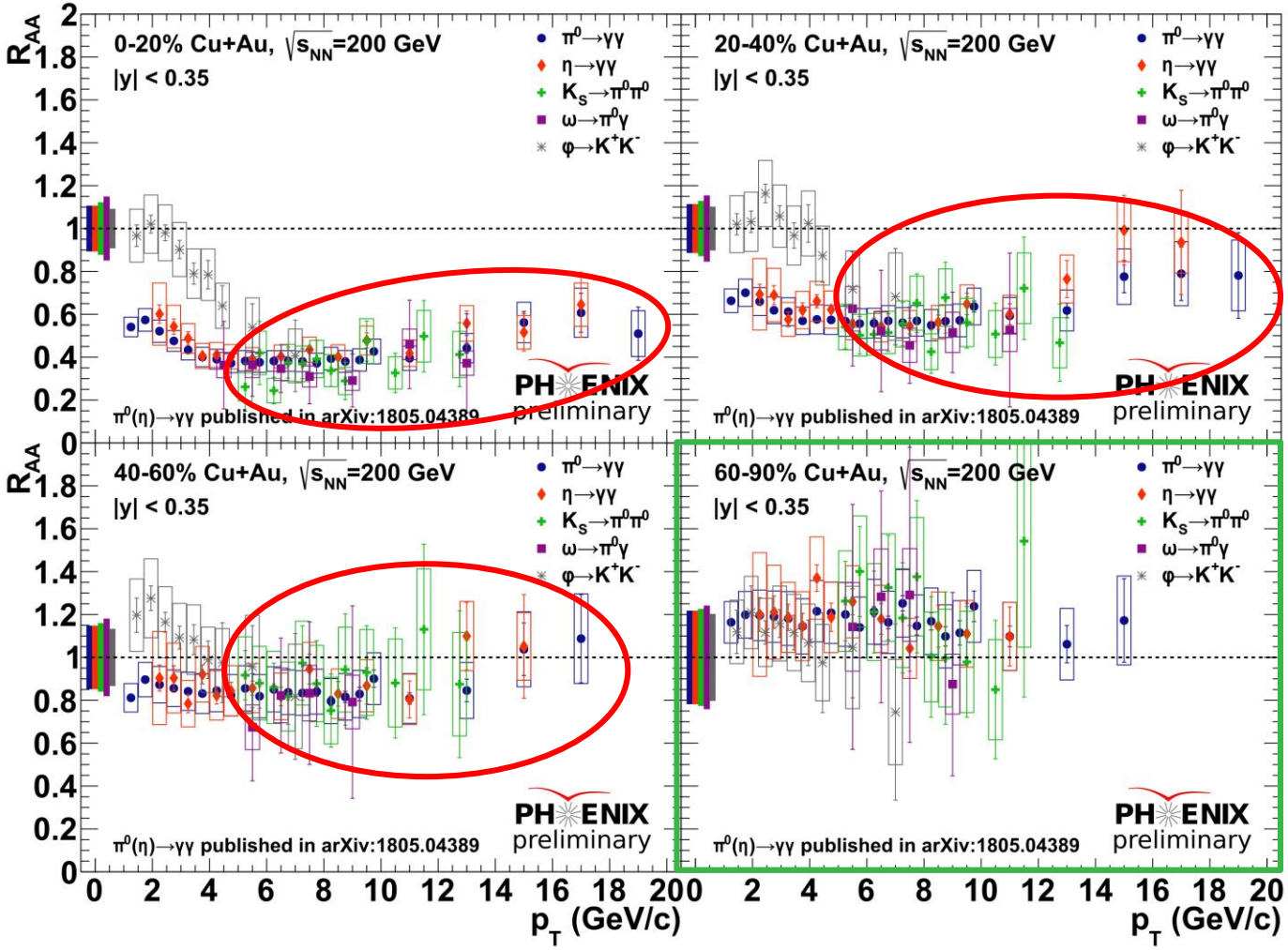



- For all centralities up to 40-60%, φ is less suppressed than $\pi^0$, η, $K_s$, ω in the intermediate $p_T$ range

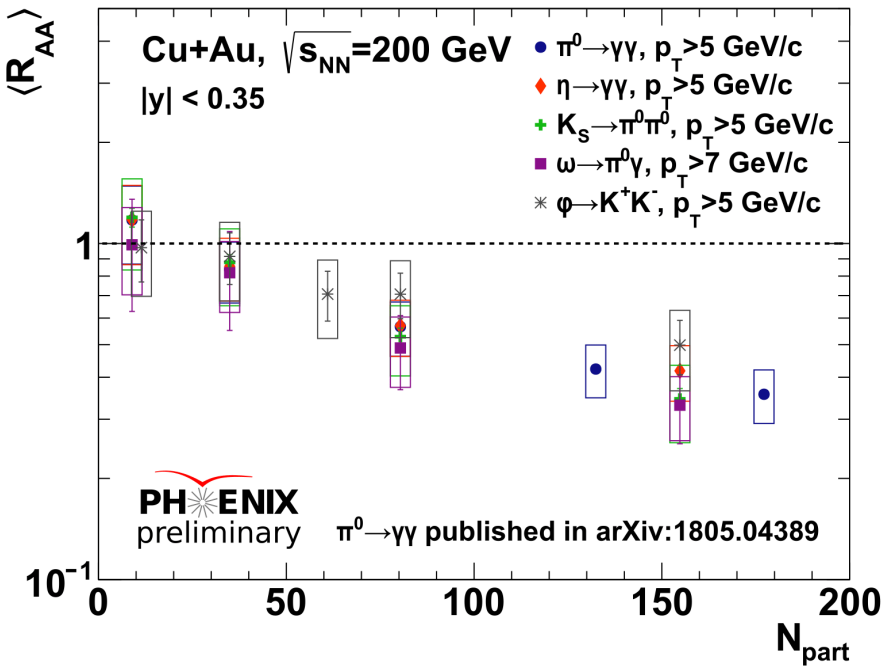
# φ $R_{CuAu}$ at $\sqrt{s_{NN}}$=200 GeV

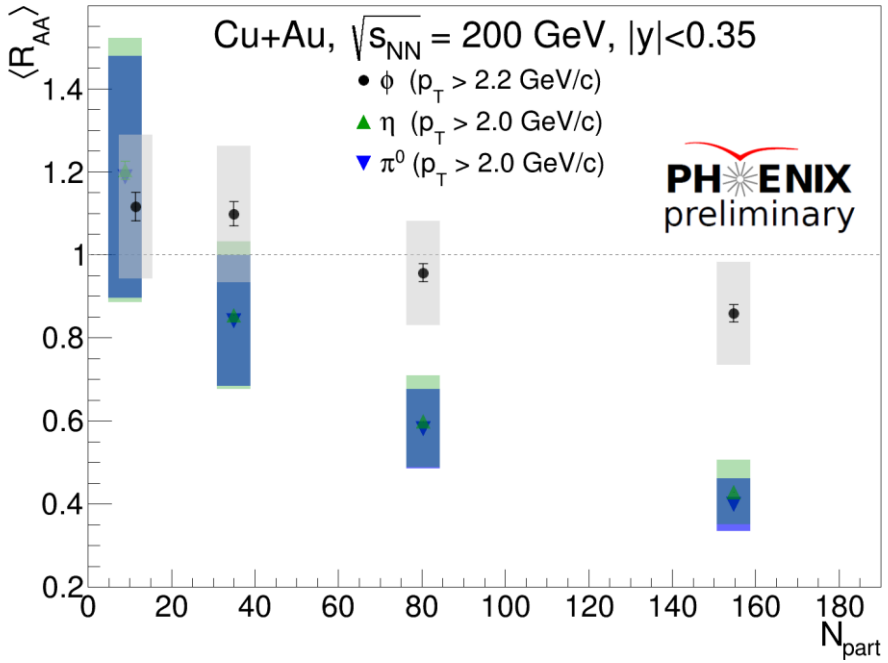



- $R_{CuAu}$ in peripheral collisions consistent with each

- **For all centralities up to 40-60%, φ is less suppressed than $\pi^0$, η, $K_s$, ω in the intermediate $p_T$ range**
- **At $p_T$>5 GeV/c, φ, $\pi^0$, η, $K_s$, ω show similar suppression values.**
- Same light meson behavior was observed in Cu+Cu and Au+Au collisions.

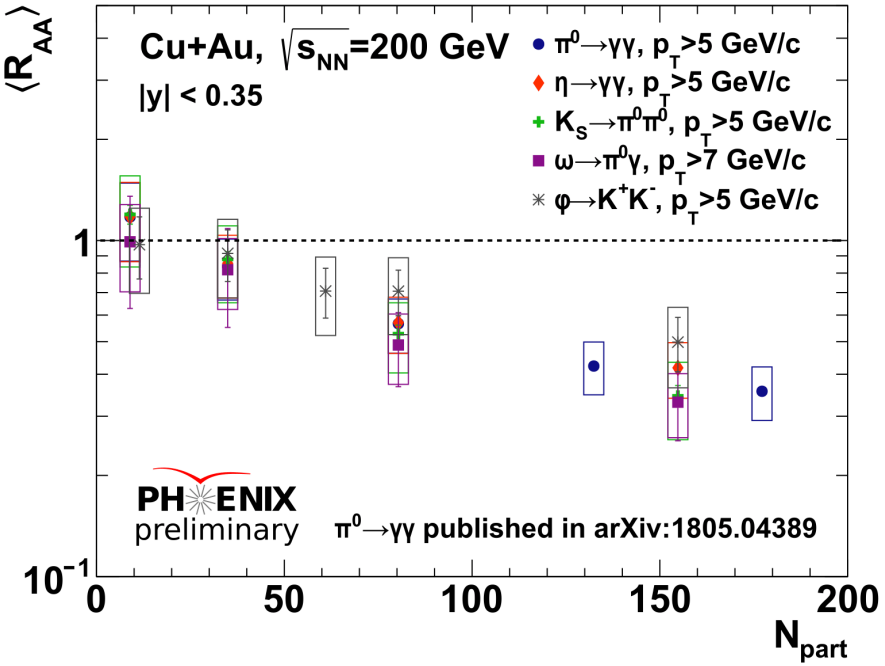
# Light mesons integrated $R_{CuAu}$ at $\sqrt{s_{NN}}$=200 GeV

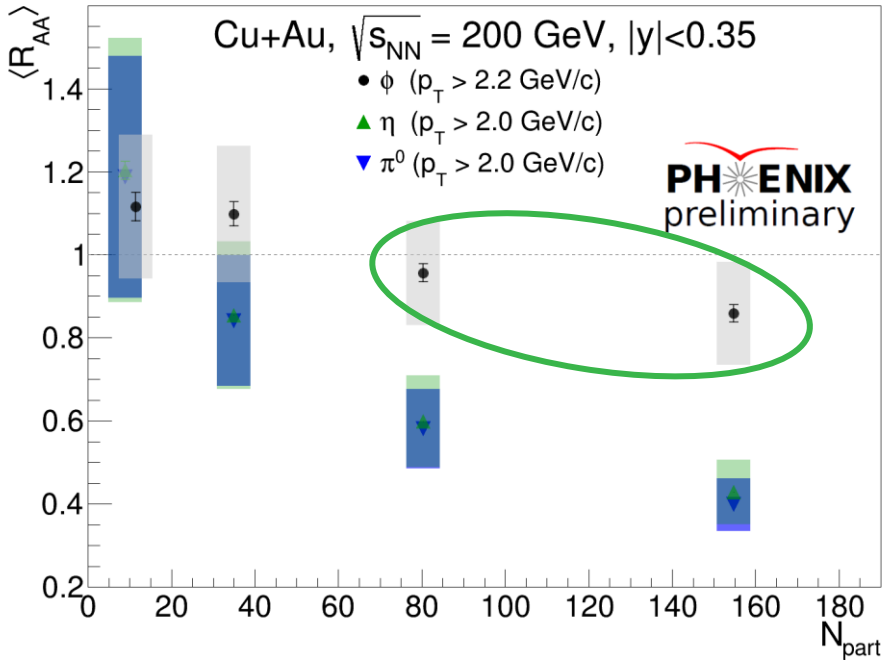



- Light mesons integrated $R_{AA}$ at $p_T$>5 GeV/c show approximately same suppression level.

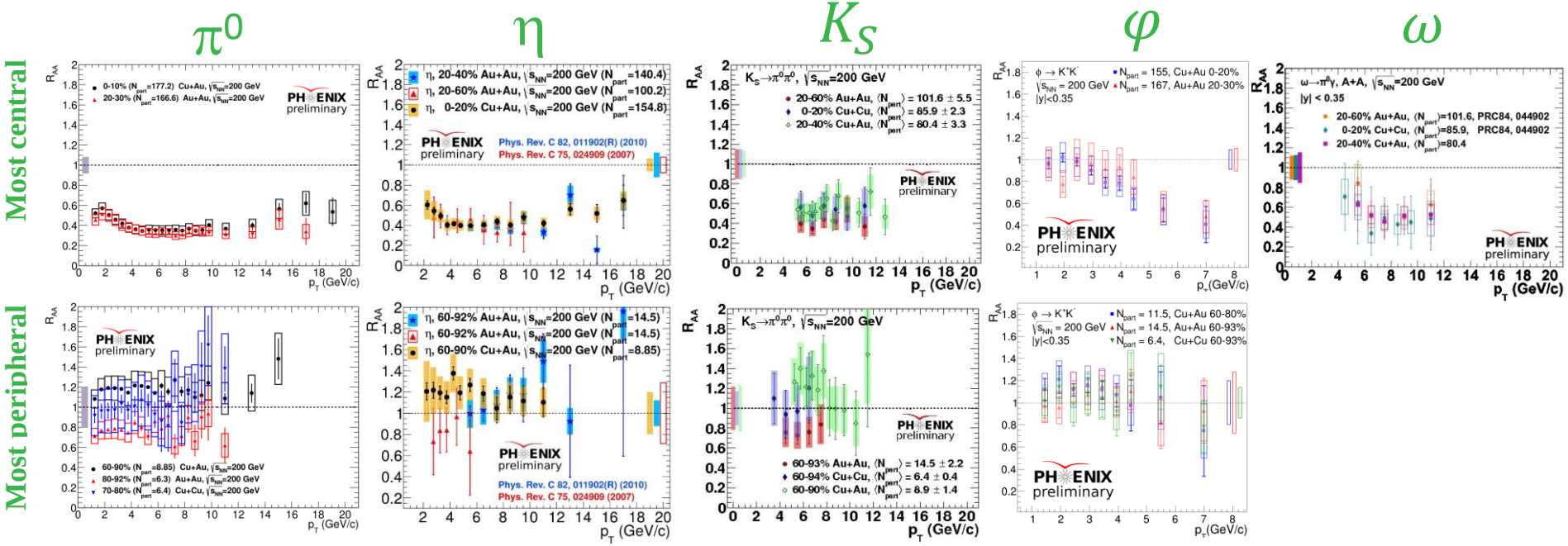
# Light mesons integrated $R_{CuAu}$ at $\sqrt{s_{NN}}$=200 GeV




- Light mesons integrated $R_{AA}$ at $p_T$>5 GeV/c show approximately same suppression level.
- **The φ integrated $R_{AA}$ at $p_T$>2 GeV/c show less suppression than $\pi^0$ & η;**

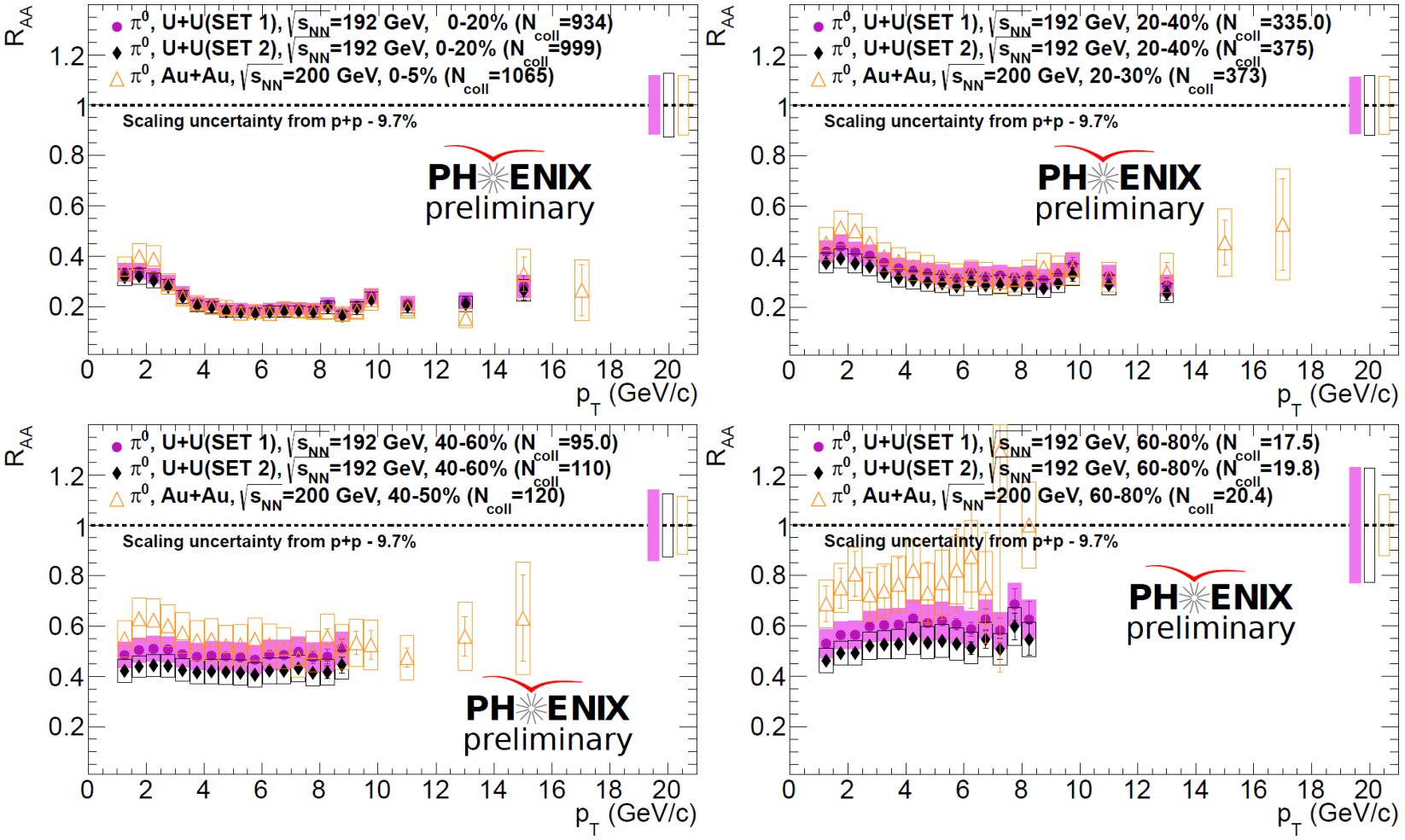
# Comparison of symmetric and asymmetric systems




arXiv:1805.04389

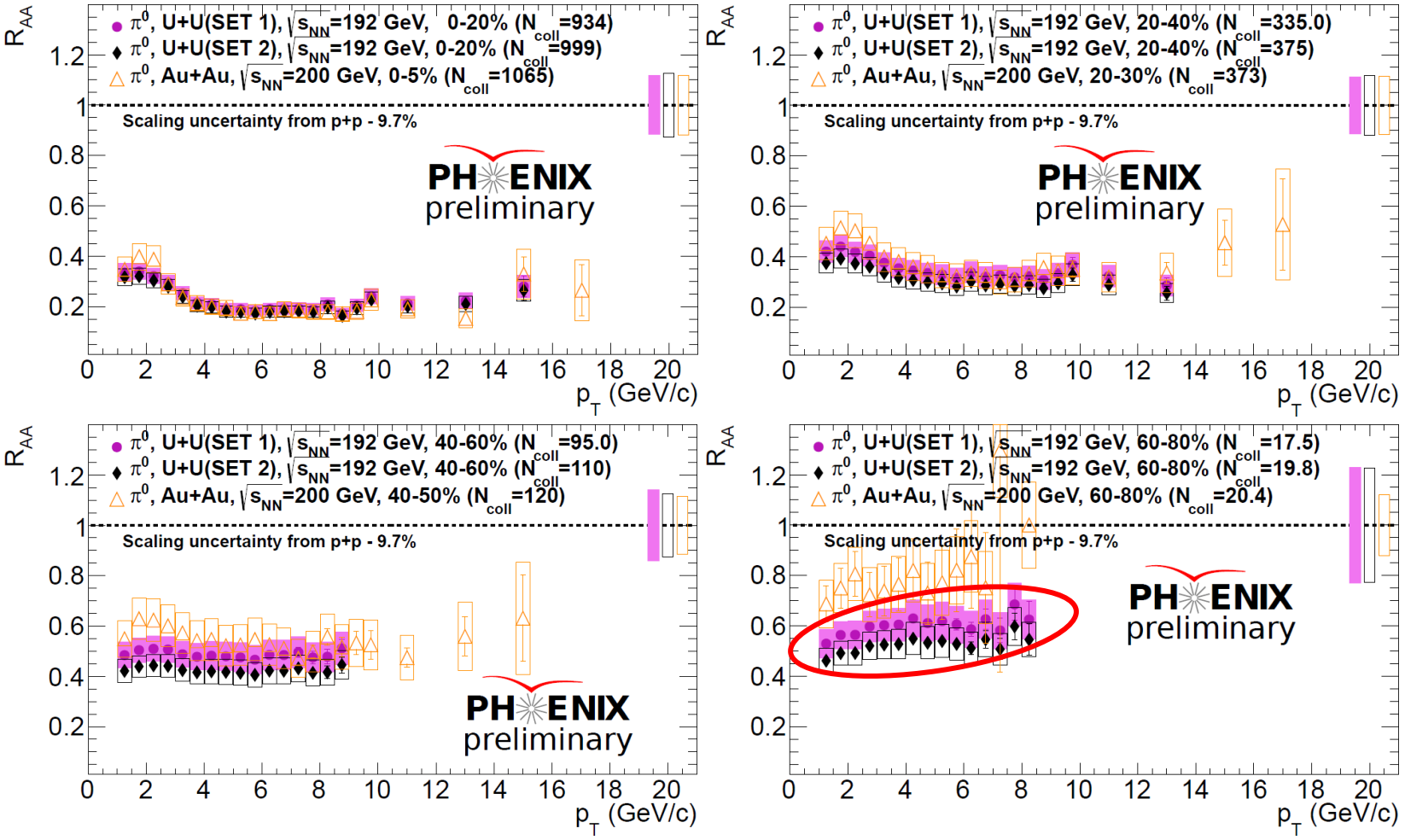
- Light mesons yields in Cu+Au show similar suppression as in Cu+Cu and Au+Au at similar $N_{part}$:
  - Production and suppression of the light mesons seems to scale with the average size of the nuclear overlap region, regardless of the details of its shape

# $\pi^0$ nuclear Modification in U+U



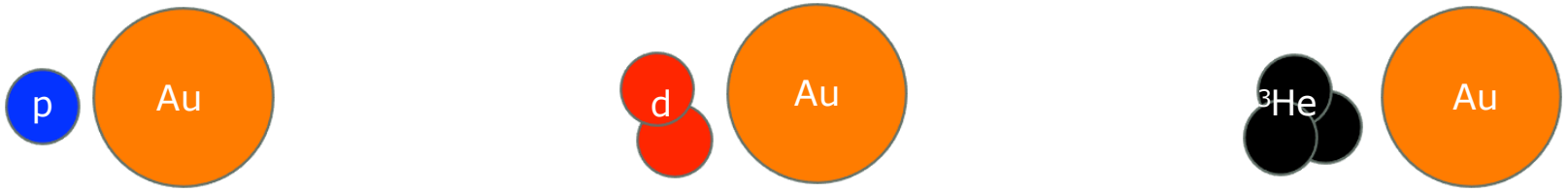

- At same $N_{coll}$ values, the $R_{AA}$ is consistent in most- to mid-central collisions
  - $\pi^0$ production depends on the size of the nuclear overlap, but not on it's density

# $\pi^0$ nuclear Modification in U+U



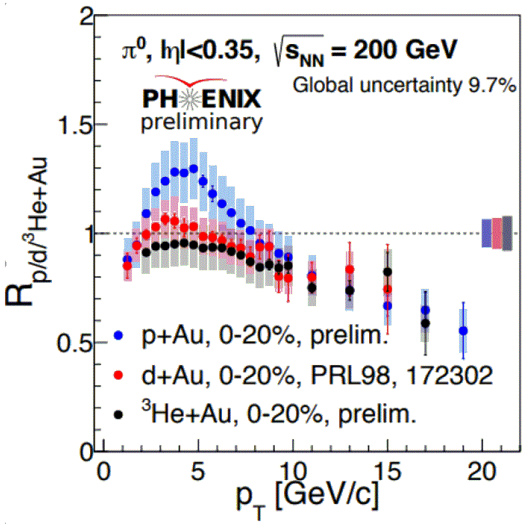

- At same $N_{coll}$ values, the $R_{AA}$ is consistent in most- to mid-central collisions
  - $\pi^0$ production depends on the size of the nuclear overlap, but not on it's density
- **The most peripheral collision shows larger suppression in U+U collisions**

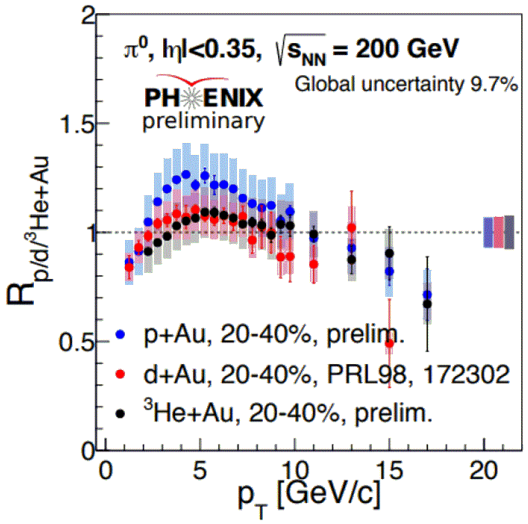
# Small systems: p+Au, d+Au, $^3$He+Au

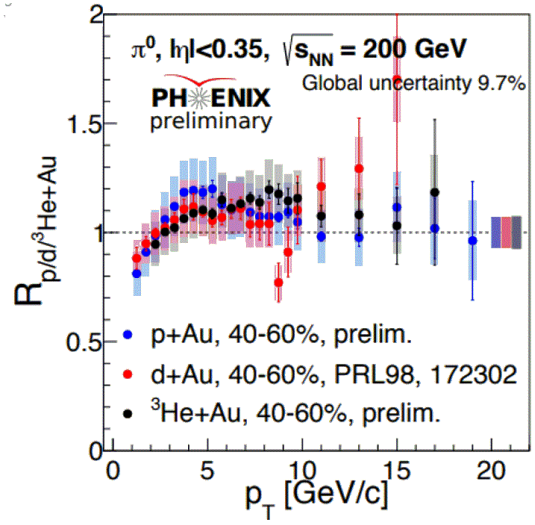


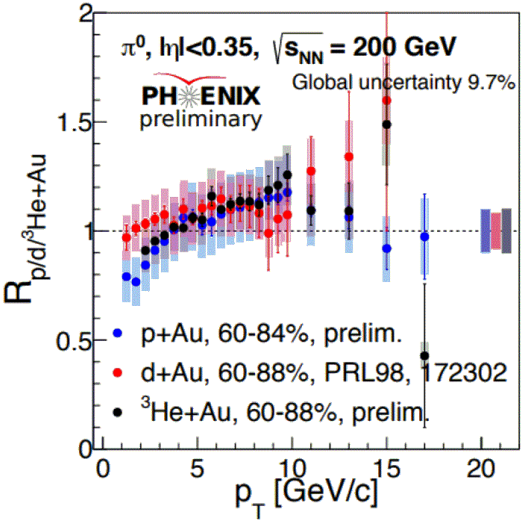

- Study of small systems collisions will help us to investigate:
  - Whether high-$p_T$ hadron suppression in large systems is due to final state effects or because of CNM effects;
  - CNM effects include:
    - multiple scattering of an incident proton in a target nucleus (Cronin effect);
    - initial-state energy loss;
    - $k_T$ broadening.

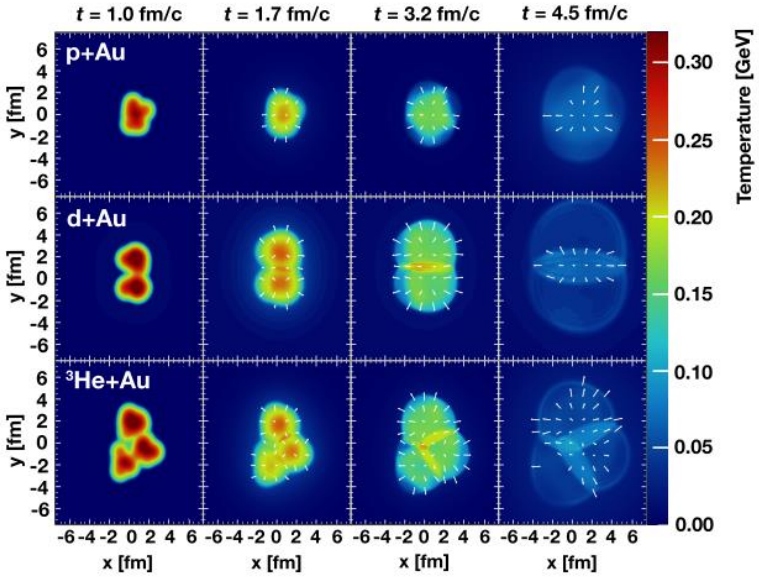
# $\pi^0$ $R_{AA}$ in p+Au, d+Au, $^3$He+Au



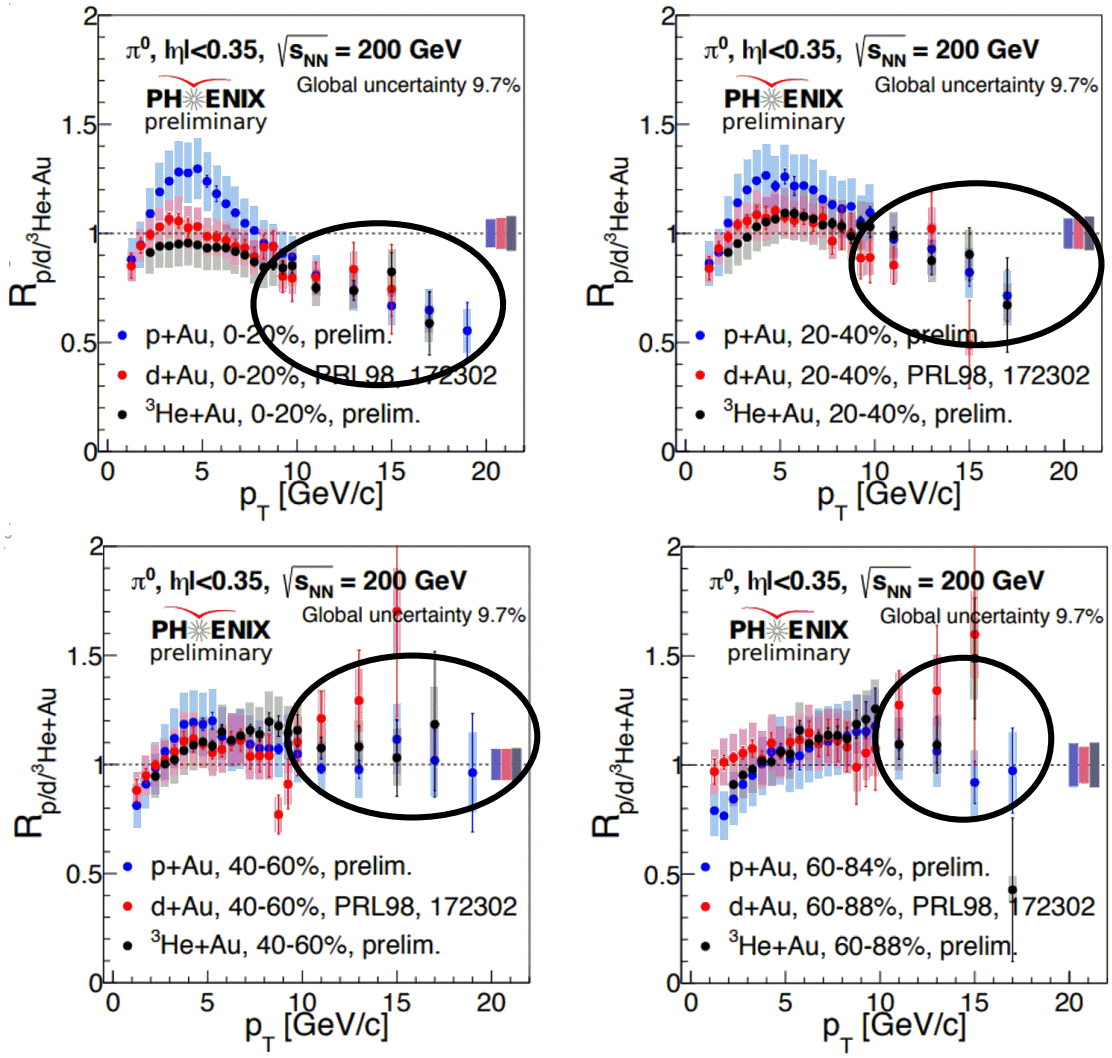



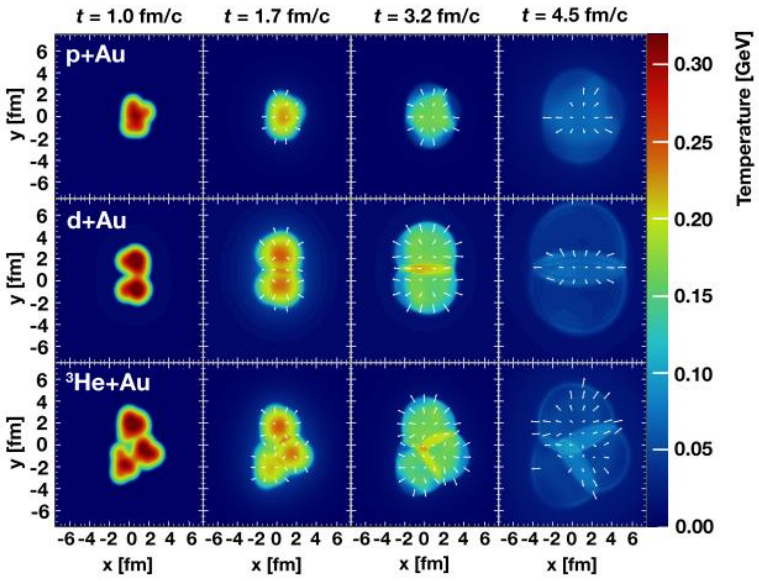



# $\pi^0$ $R_{AA}$ in p+Au, d+Au, $^3$He+Au




- **Small systems consistent with each other at high-$p_T$**



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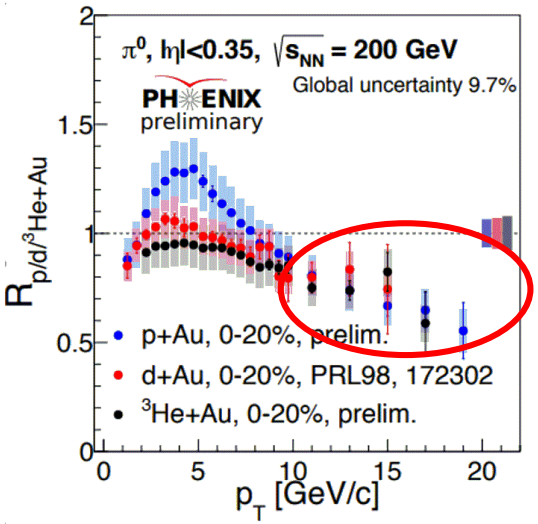
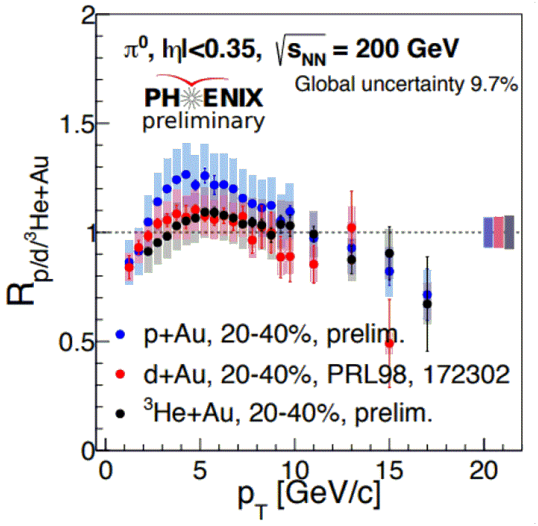
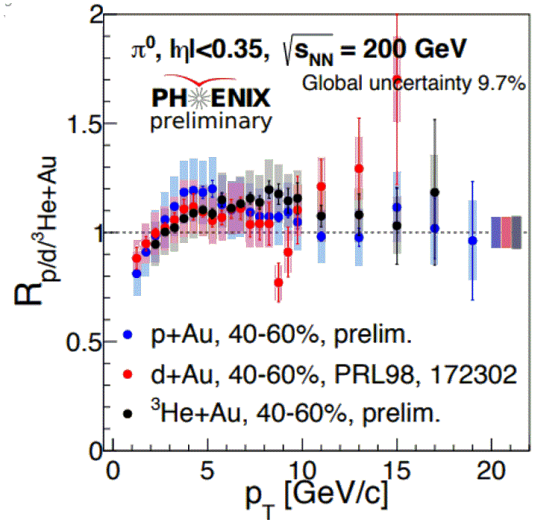
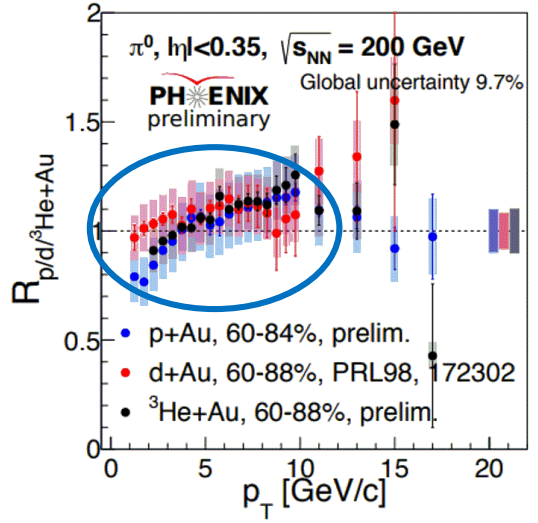
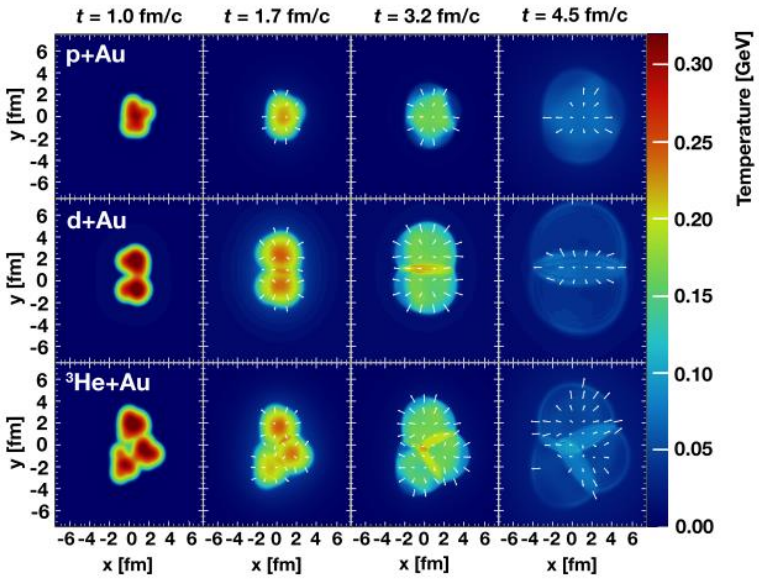


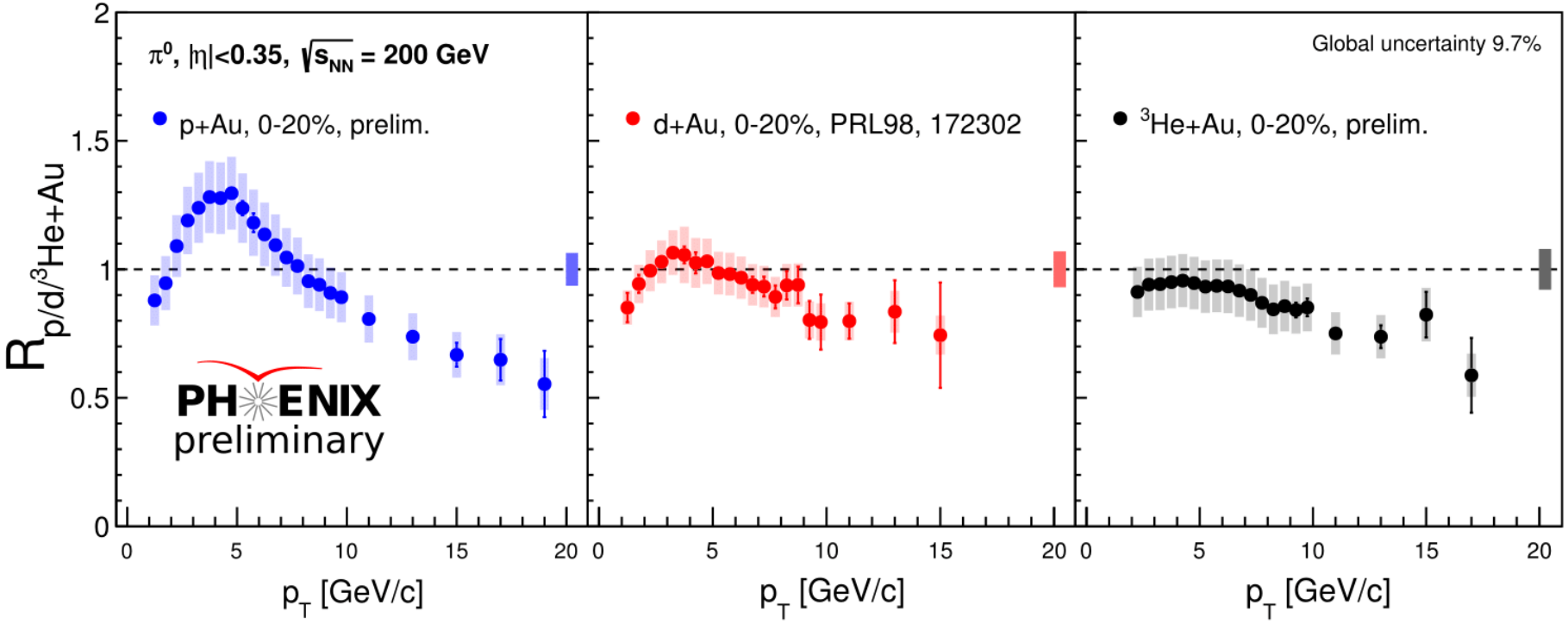




- **Small systems consistent with each other at high-$p_T$**
- **Hint of suppression at high $p_T$ in central collisions**
- **$\pi^0$ $R_{pAu} \approx R_{dAu} \approx R_{HeAu}$ in peripheral collisions**

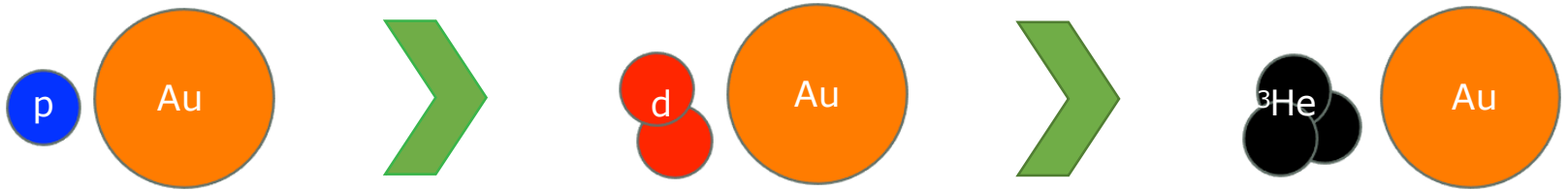


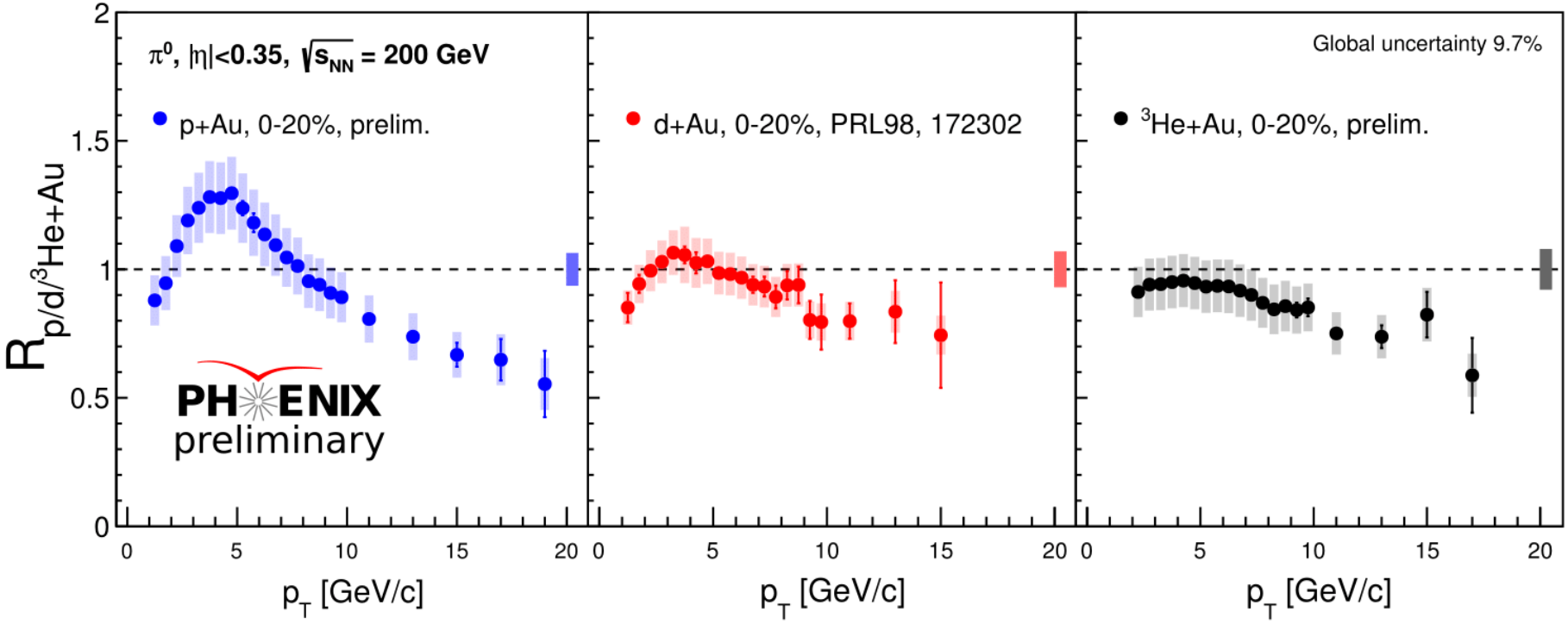
# $\pi^0$ $R_{AA}$ in p+Au, d+Au, $^3$He+Au




- In most central collisions in the intermediate $p_T$ range ordering is seen
  - Suppression at $p_T$ = 5 GeV/c indicates a system size dependence

# $\pi^0$ $R_{AA}$ in p+Au, d+Au, $^3$He+Au




- In most central collisions in the intermediate $p_T$ range ordering is seen
  - Enhancement indicates a system size dependence

# Summary

- **Large Systems:**
  - Light mesons $R_{AA}$ in large systems for similar $N_{part}$ values exhibit similar shape;
    - Production and suppression of the light meson seems to depend on nuclear overlap size, but not on its geometry and not on its density;
  - The φ-meson exhibits a different suppression pattern compared to lighter mesons;

- **Small systems:**
  - $\pi^0$ $R_{AA}$'s are consistent at high-$p_T$ in p/d/$^3$He+Au collisions in all centralities;
  - In most central collisions in the intermediate $p_T$ range there's an ordering of $R_{pAu}>R_{dAu}>R_{HeAu}$

# Summary

- **Large Systems:**
  - Light mesons $R_{AA}$ in large systems for similar $N_{part}$ values exhibit similar shape;
    - Production and suppression of the light meson seems to depend on nuclear overlap size, but not on its geometry and not on its density;
  - The φ-meson exhibits a different suppression pattern compared to lighter mesons;

- **Small systems:**
  - $\pi^0$ $R_{AA}$'s are consistent at high-$p_T$ in p/d/$^3$He+Au collisions in all centralities;
  - In most central collisions in the intermediate $p_T$ range there's an ordering of $R_{pAu}>R_{dAu}>R_{HeAu}$

**Thank you for your attention!**