CHARGED HADRON PRODUCTION IN Cu+Au COLLISIONS

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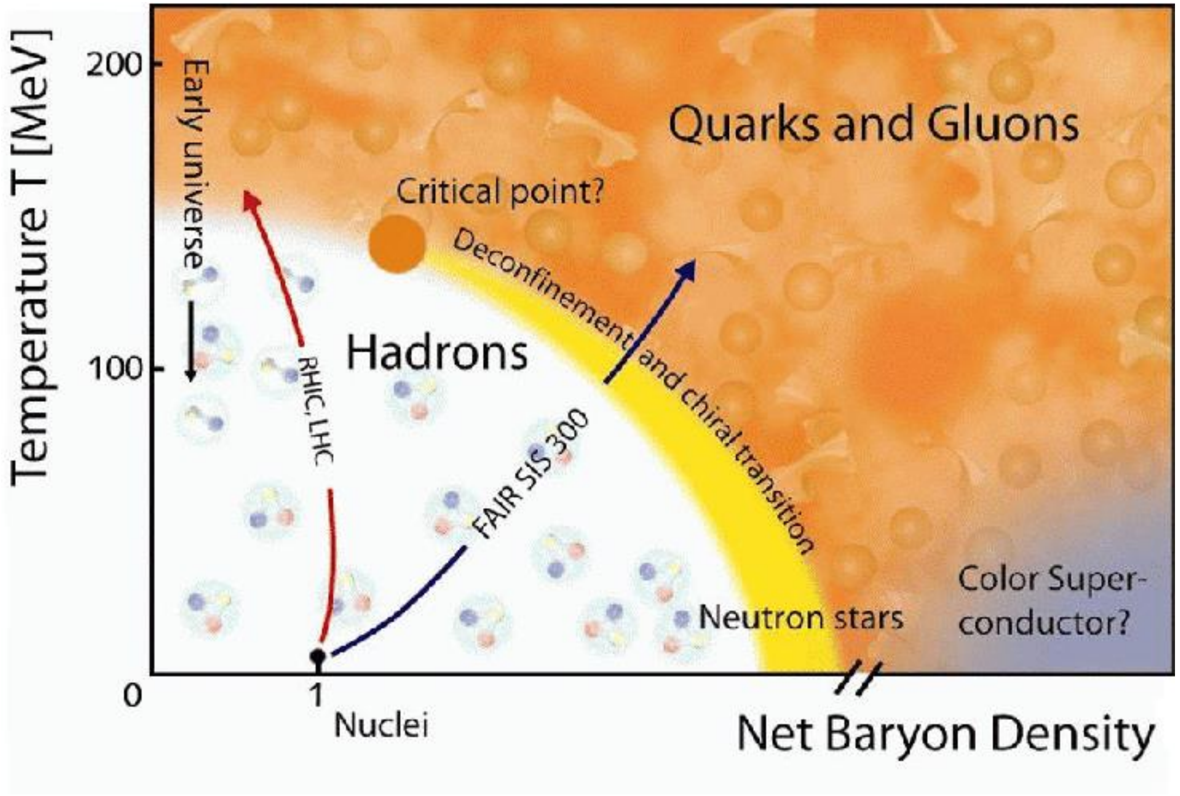
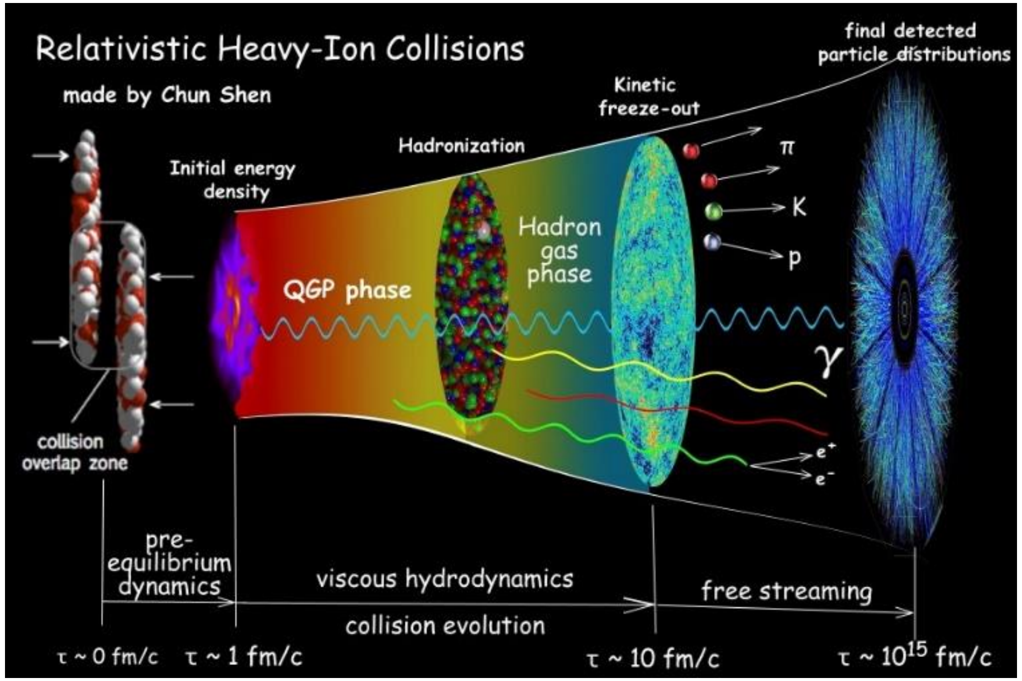
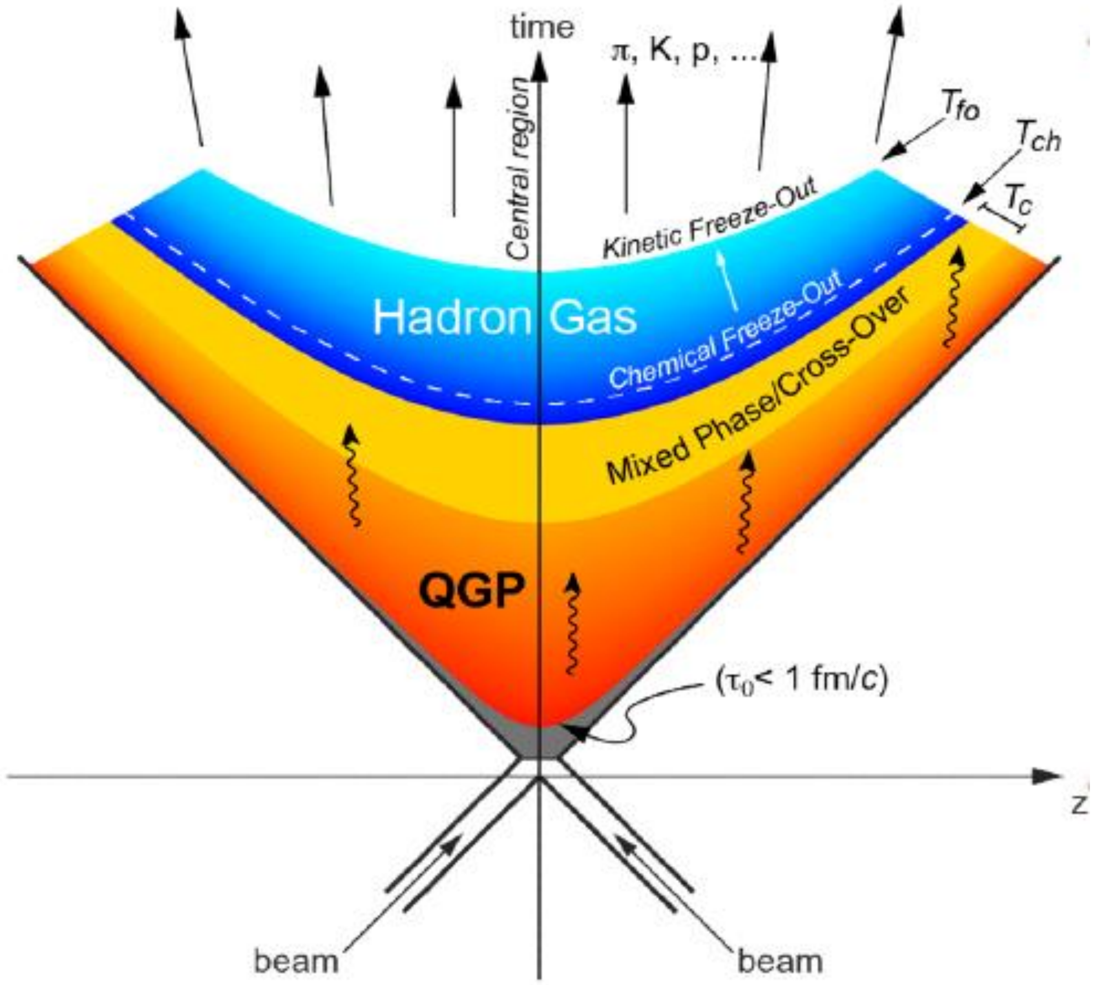
Quark-Gluon Plasma

QGP – is a state of matter which exists at extremely high temperature and/or density. This state is thought to consist of asymptotically free strong-interacting quarks and gluons, which are ordinarily confined inside atomic nuclei or other hadrons.





Heavy-ion collision evolution



Hadronization of the QGP medium at the Chemical freezeout temperature

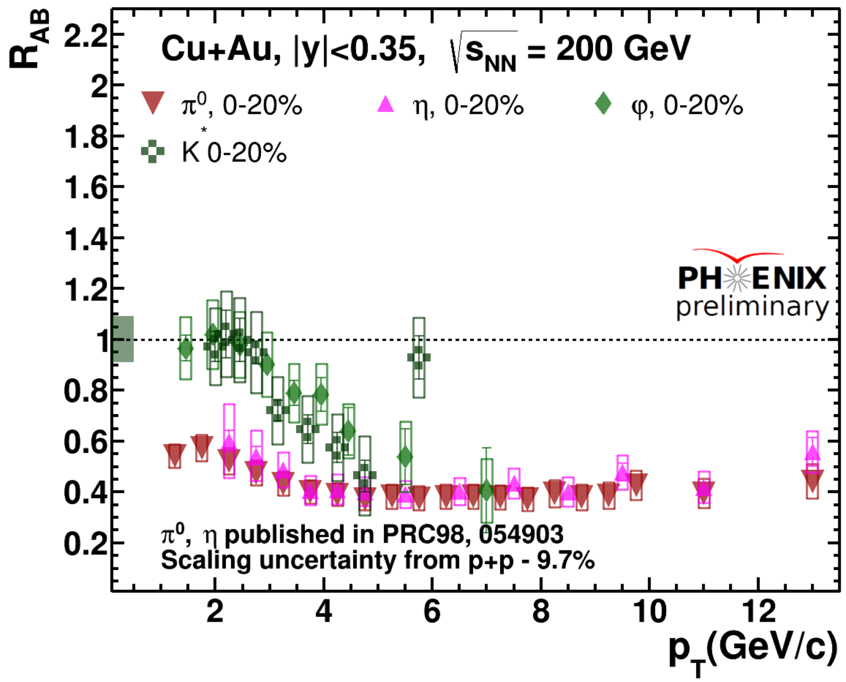
- Transition from a deconfined medium composed of quarks, antiquarks and gluons to color-neutral hadronic matter
- The partonic degrees of freedom of the deconfined phase convert into hadrons, in which partons are confined

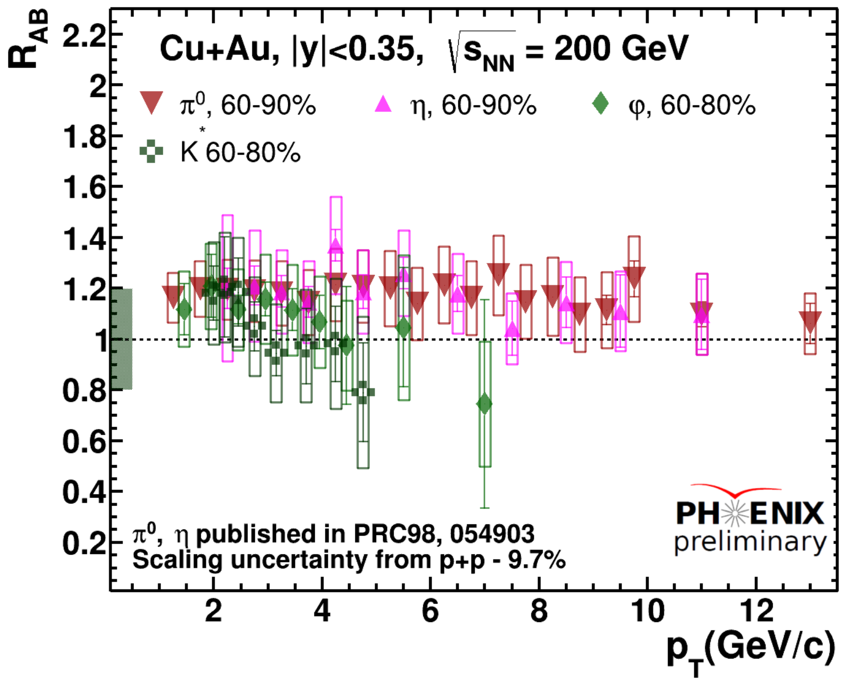
No first-principle description of hadron formation

- Non-perturbative problem, not calculable with QCD

Motivation (1/3)

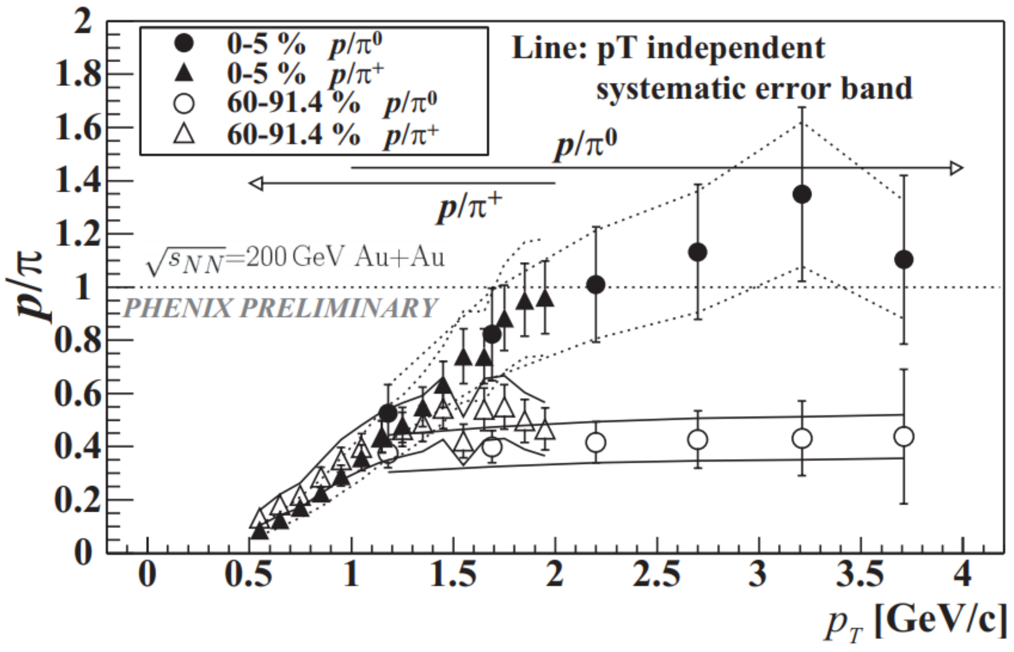
✓ Measurments of light meson (φ, K*, π, η, Ks, ω) production.
Study the QGP properties depending on the number and flavor of quarks.



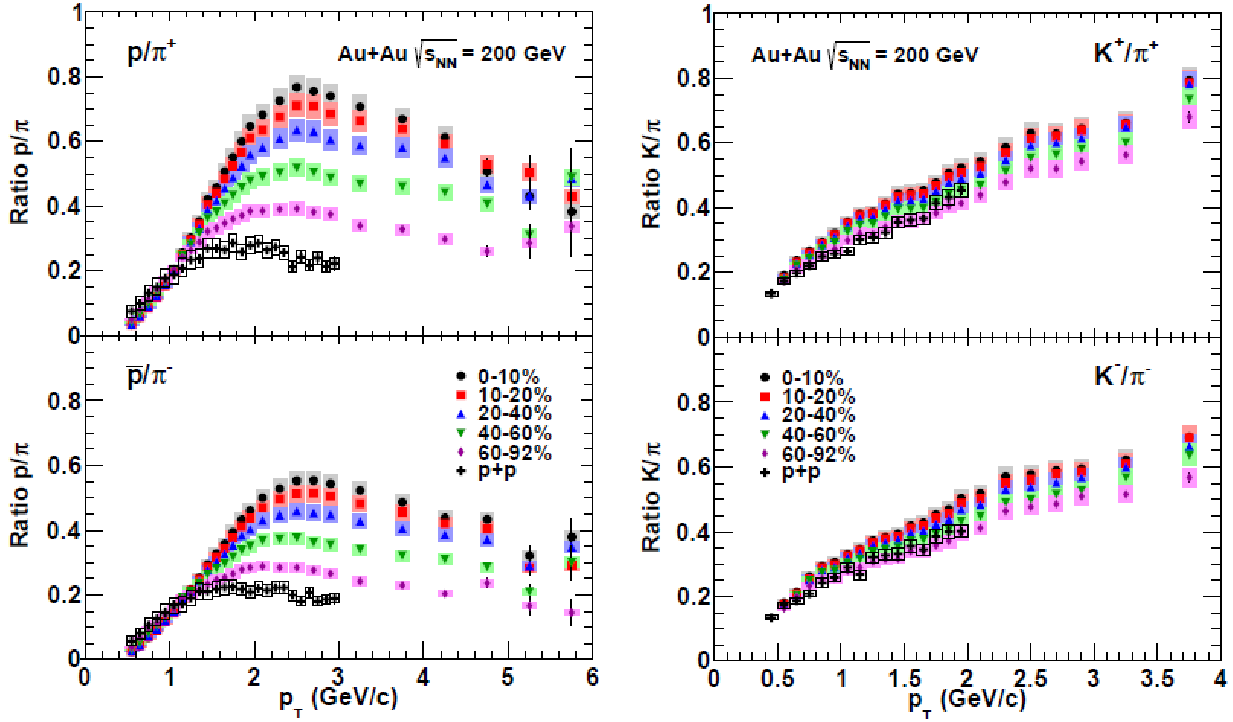


Motivation (2/3)

✓ Baryon Puzzle - Anomalous large ratio of protons (3 quarks) to π-mesons (2 quarks) yields in Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV discovered by PHENIX



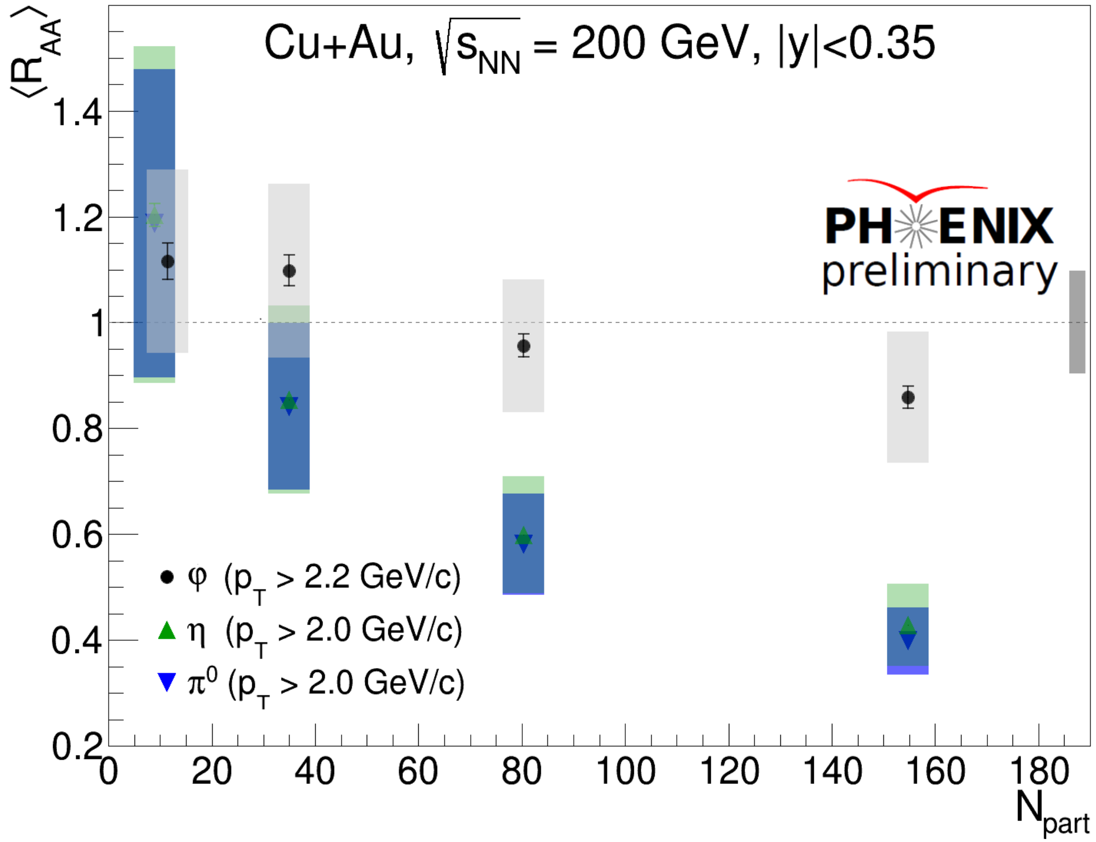
Chujo T et al., Nucl.Phys. A715 (2003) 151-160



Adare A et al., Physical Review C 88:024906

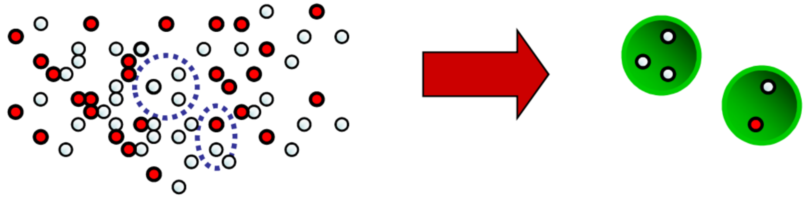
Motivation (3/3)

Baryon puzzle in asymmetric Cu+Au system?

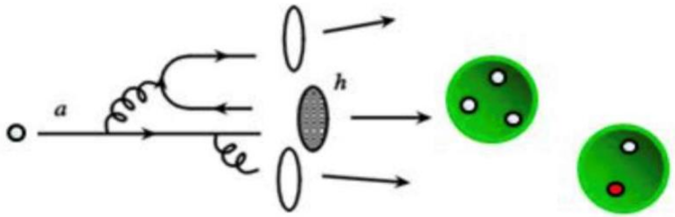


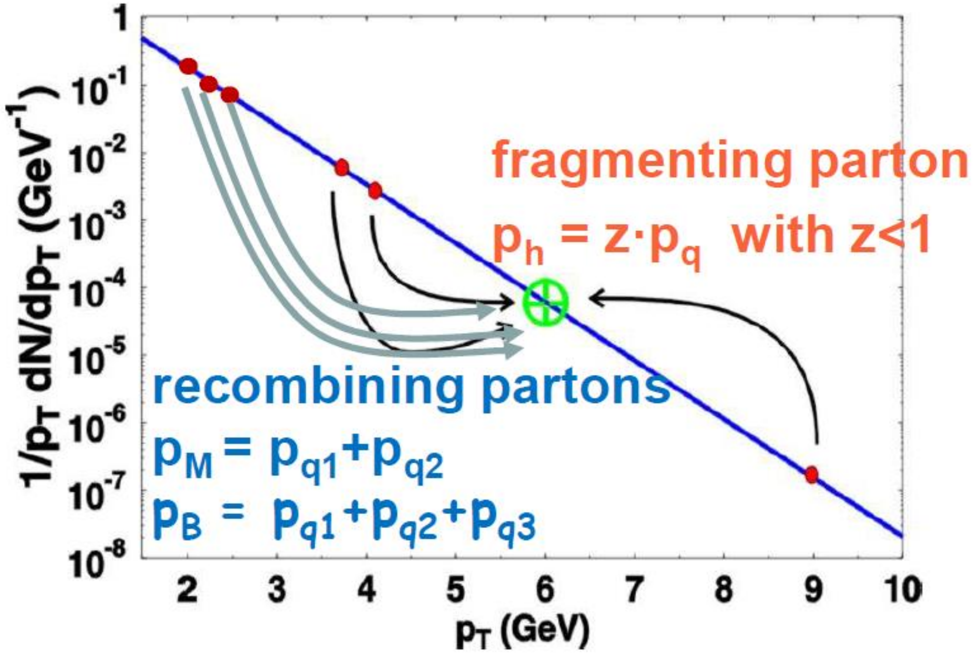
Hadronization

Recombination



Fragmentation





Phase space at the hadronization is filled with partons

- Single parton description may not be valid anymore
- No need to create $\bar{q}q$ pairs via splitting/string breaking
- Partons that are “close” to each other in phase space (position and momentum) can simply recombine into hadrons

Recombination vs. fragmentation:

- Competing mechanisms
- Recombination naturally enhances baryon/meson ratios at intermediate p_T

Greco et al., PRL 90 (2003) 202302
Fries et al., PRL 90 (2003) 202303
Hwa, Yang, PRC 67 (2003) 034902

(Pioneering High Energy Nuclear Interaction eXperiment)

Detectors in the central spectrometer arms ($|\eta| < 0.35$)

Charged Particle Tracking & Momentum measurements:

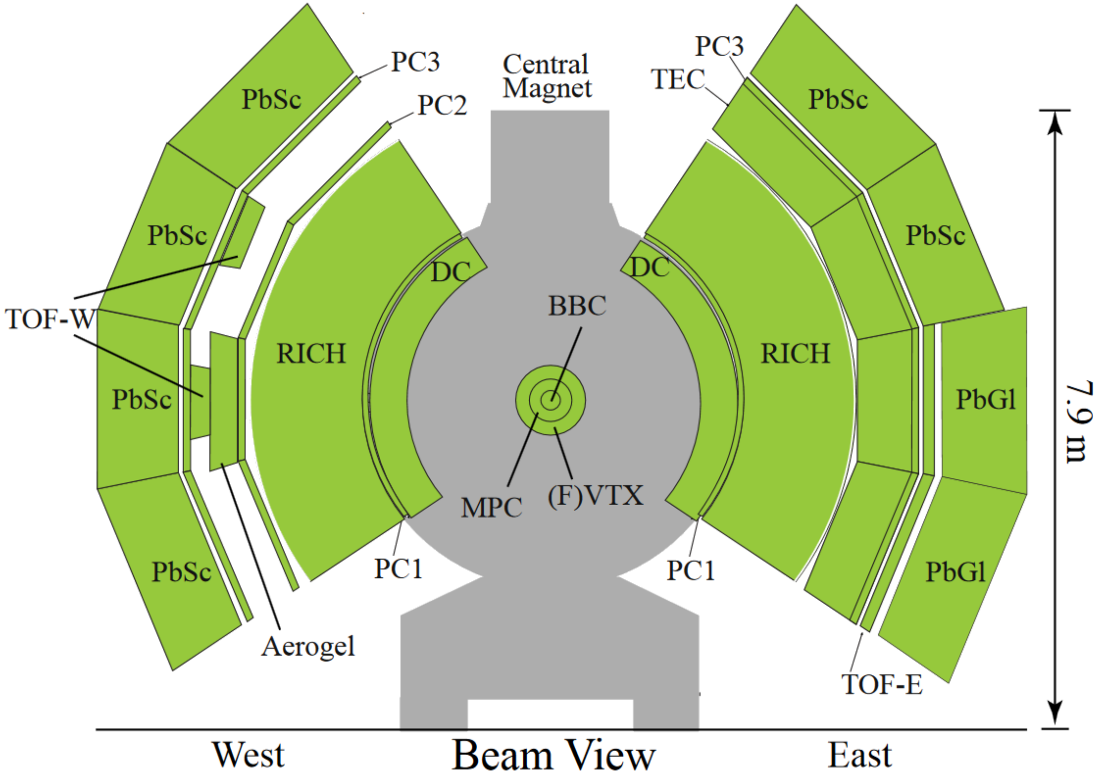
- Drift-Chambers (DC)

Identification of charged hadrons:

- Tine-of-Flight (TOF) with start signal from the Beam-Counters (BBC)

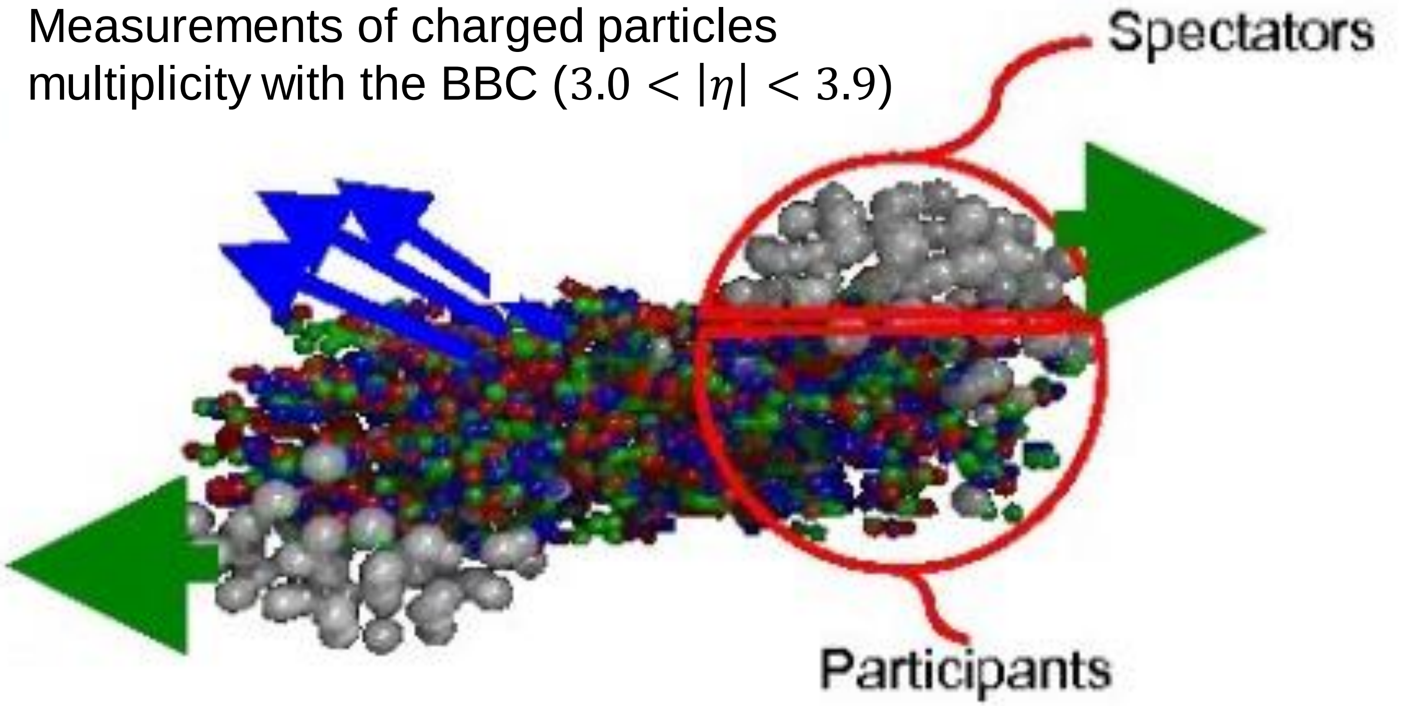
Centrality identification:

- BBC detectors (beam-beam counters)



Centrality

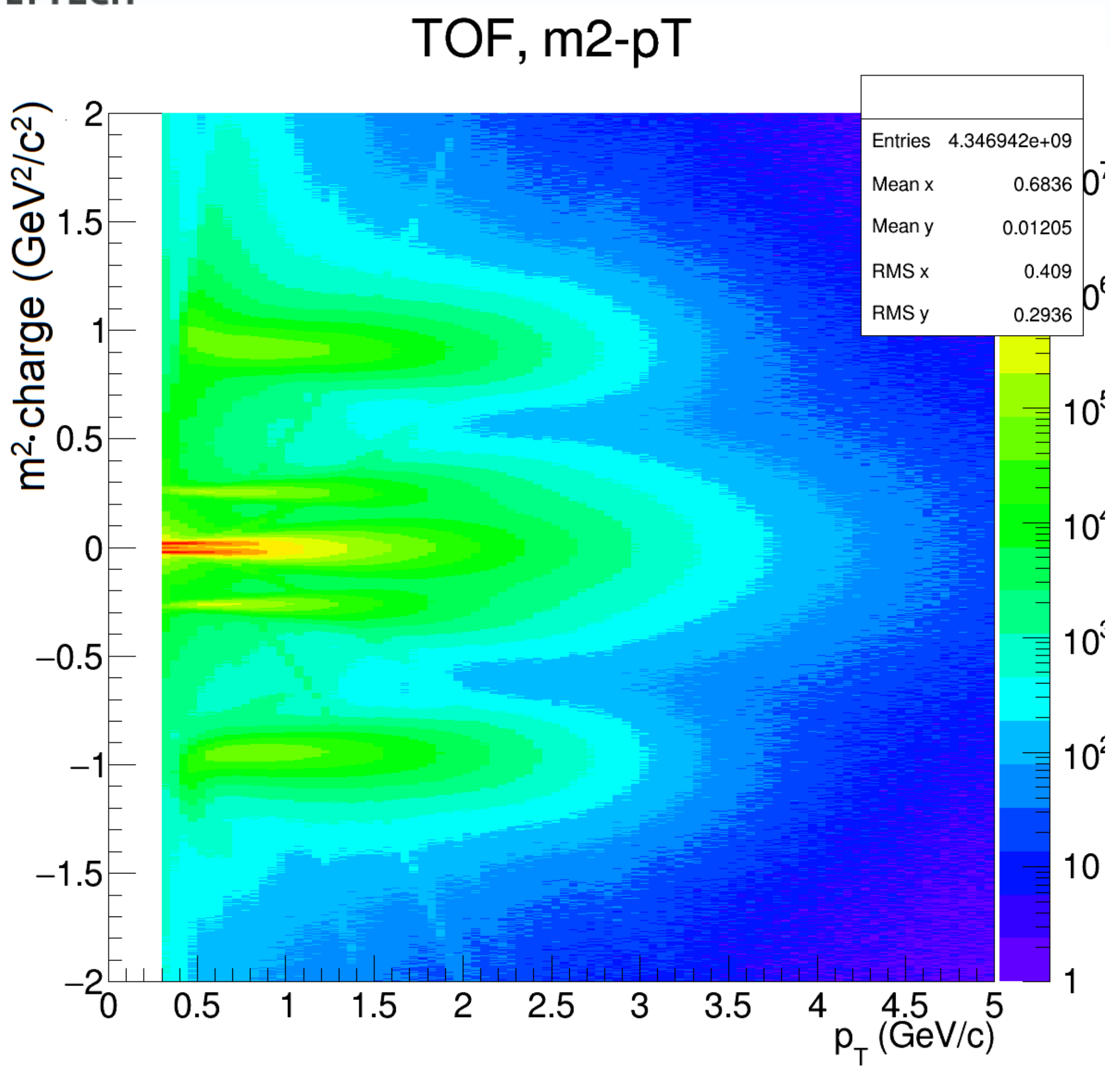
Measurements of charged particles multiplicity with the BBC ($3.0 < |\eta| < 3.9$)

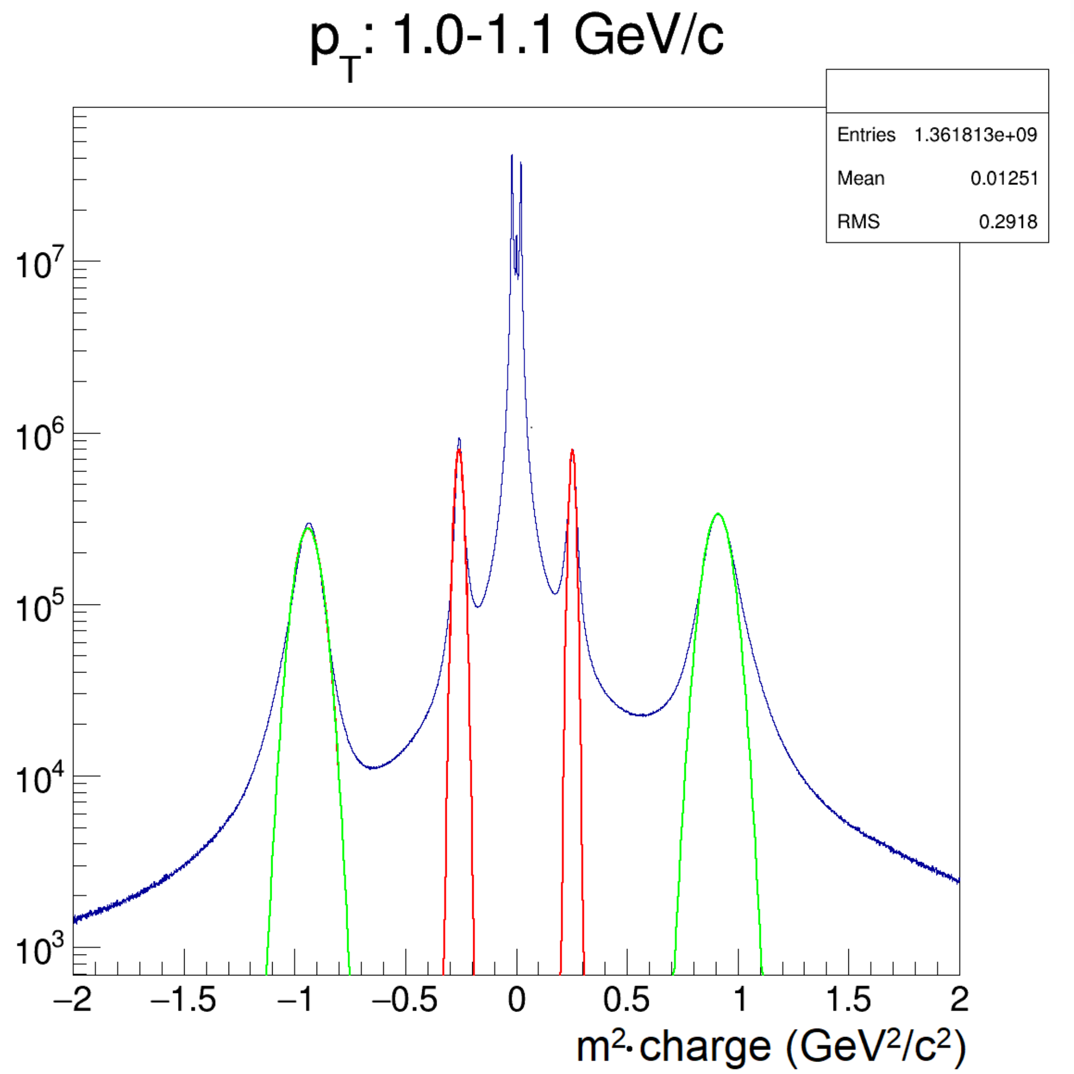


- Centrality characterized by
  N_{part}: Number of nucleons which suffered at least one inelastic nucleon-nucleon collision
  N_{coll}: Number of inelastic nucleon-nucleon collisions

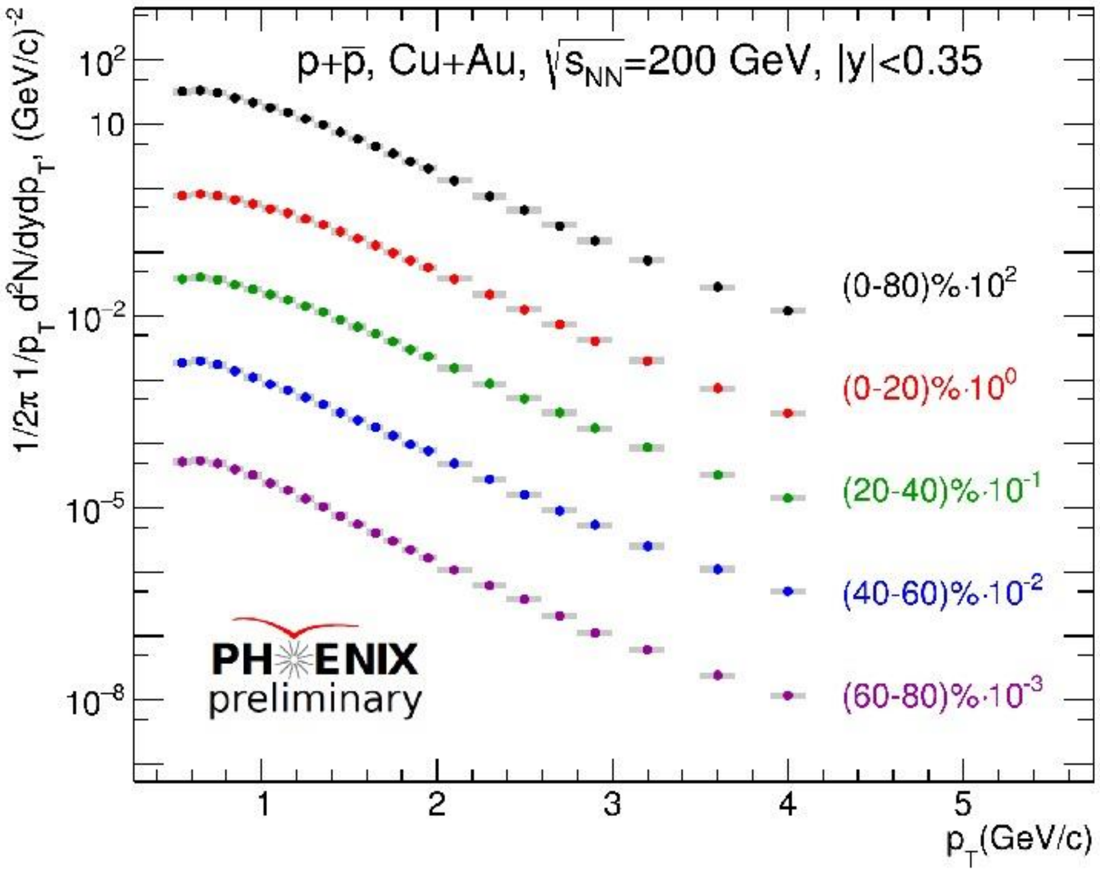
- N_{part} and N_{coll} from Glauber calculations

Particle identification





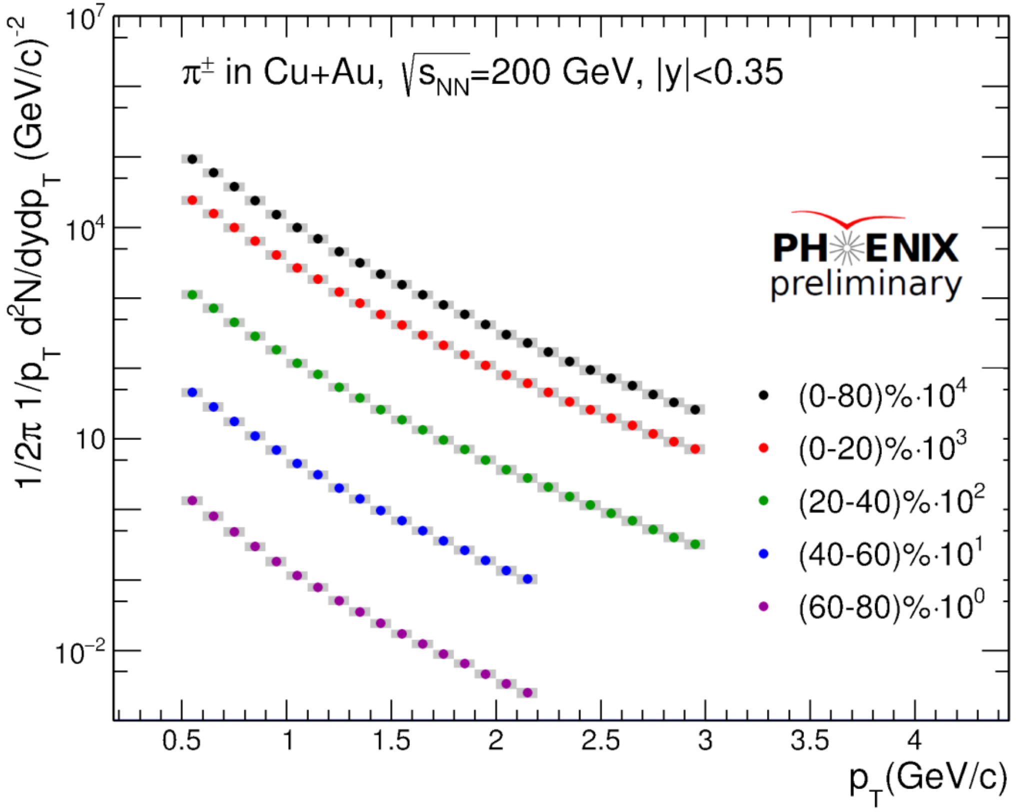
Invariant p_T spectra of $(p+\bar{p})/2$ in Cu+Au, $\sqrt{s_{NN}} = 200$ GeV

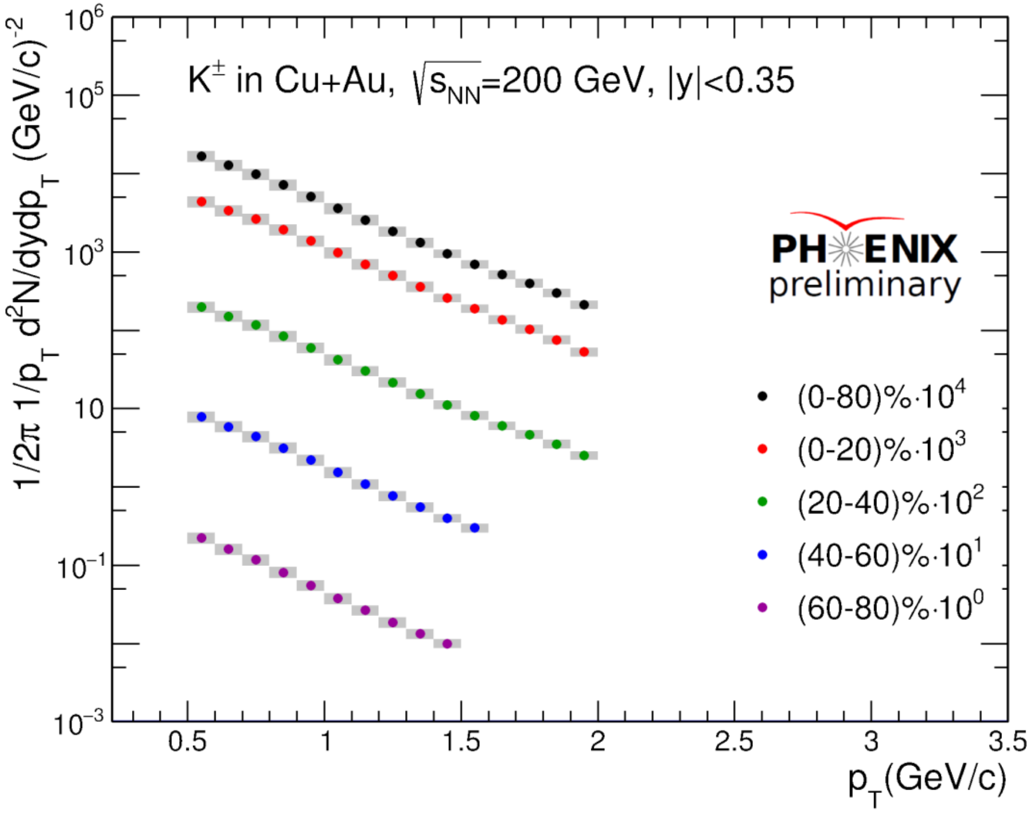


$$\frac{1}{2\pi p_T}\frac{d^2N}{dp_T dy} = \frac{N_p}{2\pi p_T N_{evt}\varepsilon_{rec}\Delta p_T \Delta y}$$

- N_{evt} is the number of events in a given centrality and p_T
- ε_{rec} is the efficiency of the protons identification
- N_p is the protons raw yield measured in the given centrality and p_T

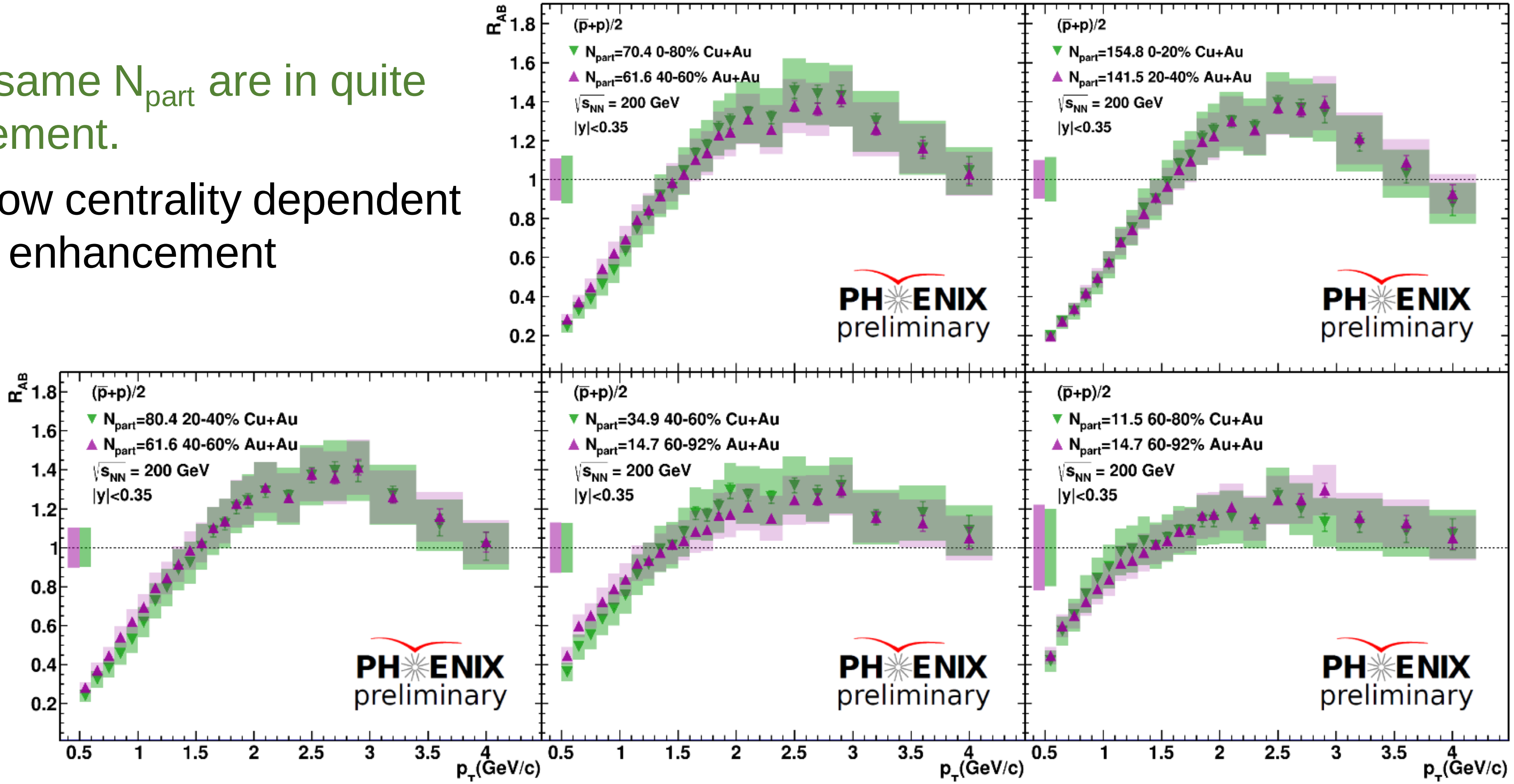
Invariant p_T spectra of $\pi^{\pm}$ and $K^{\pm}$ in Cu+Au, $\sqrt{s_{NN}} = 200$ GeV





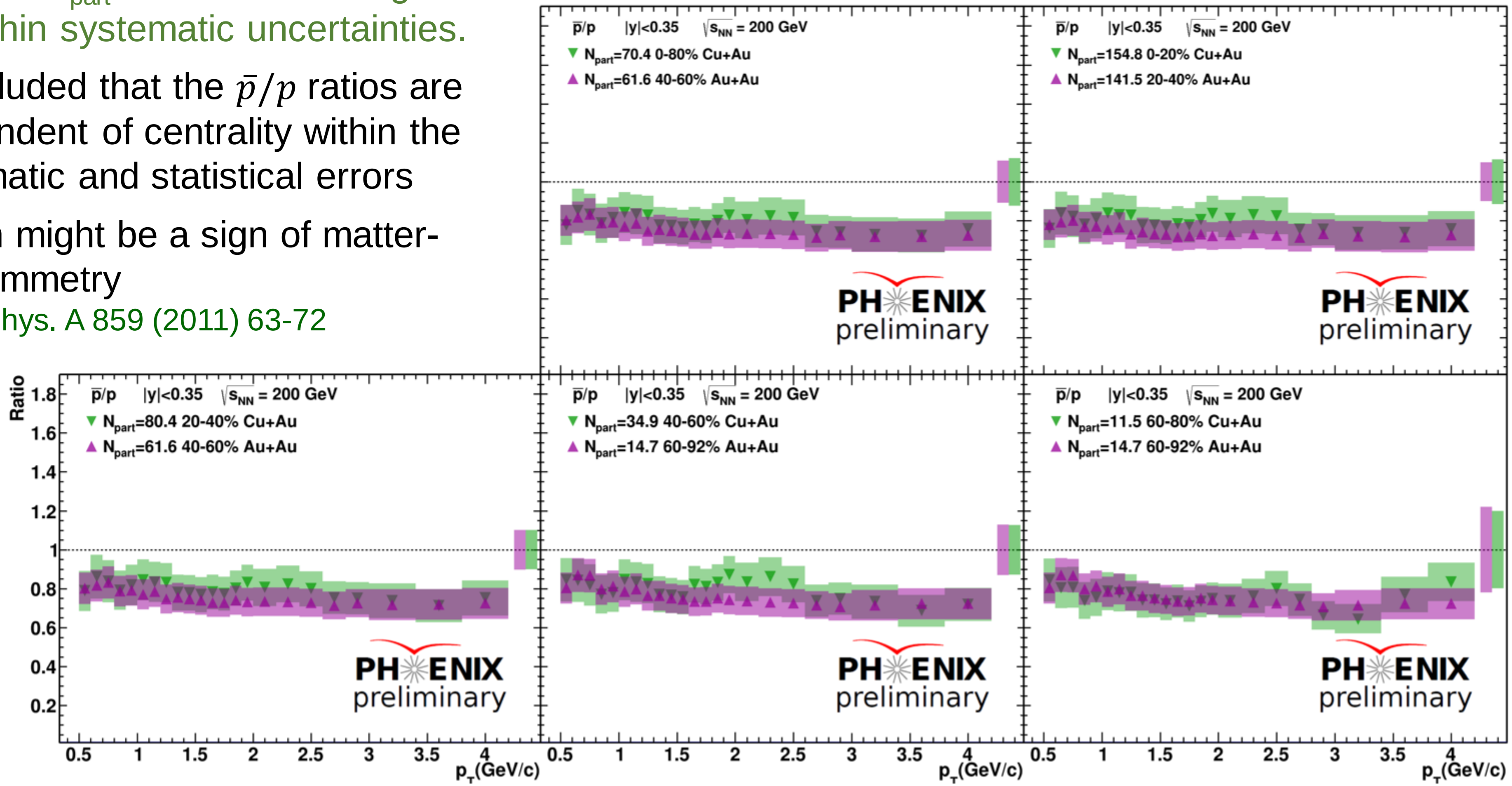
R_{AB} of $(p+\bar{p})/2$ in Cu+Au, $\sqrt{s_{NN}} = 200$ GeV

- Results at same N_{part} are in quite good agreement.
- Protons show centrality dependent Cronin-like enhancement

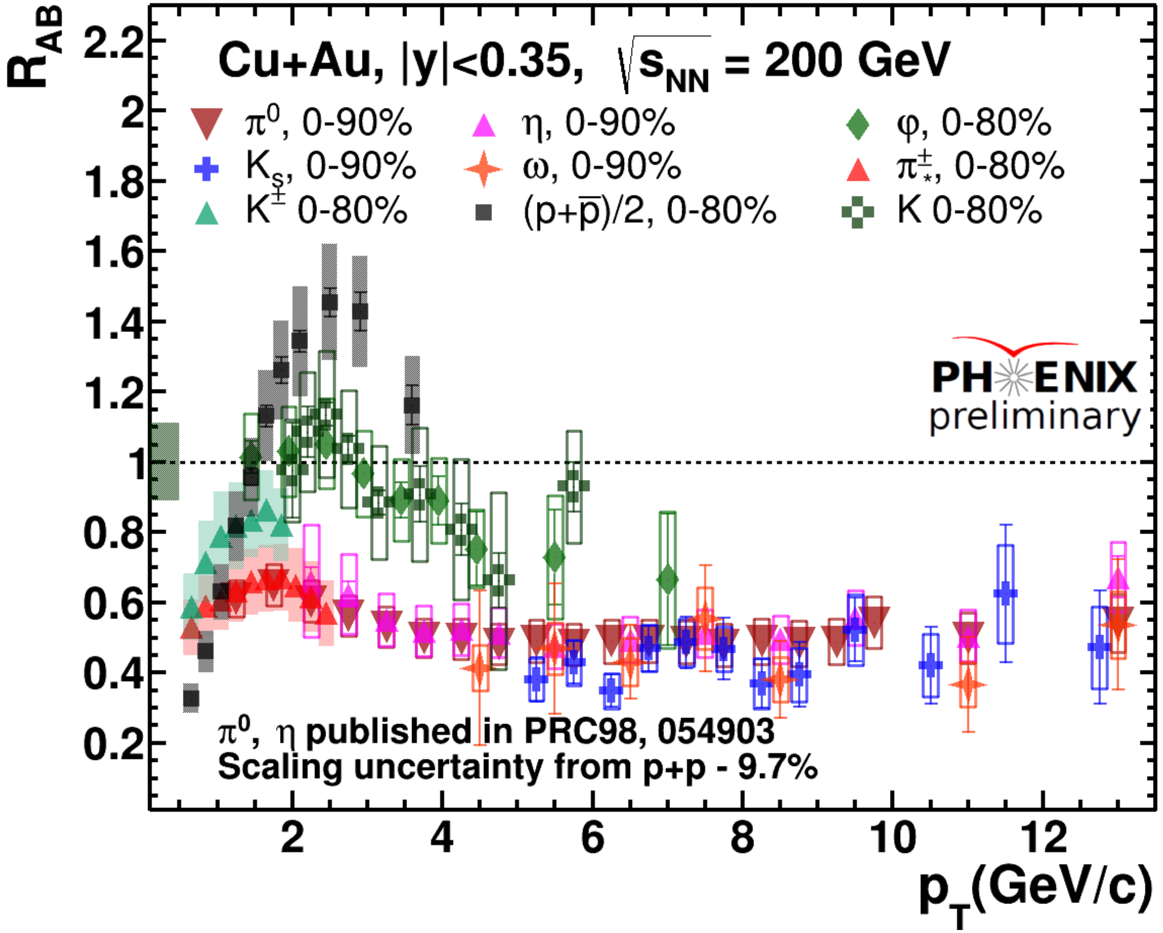


$\bar{p}/p$ ratio in Cu+Au, $\sqrt{s_{NN}}$ = 200 GeV

- Results at same N_{part} seem to be in a good agreement within systematic uncertainties.
- It can be concluded that the $\bar{p}/p$ ratios are almost independent of centrality within the current systematic and statistical errors
- $\bar{p}/p < 1$, which might be a sign of matter-antimatter asymmetry
  Tawfik A., Nucl. Phys. A 859 (2011) 63-72



Light hadron R_{AB} in Cu+Au, $\sqrt{s_{NN}}$ = 200 GeV



Observed patterns might indicate:

- Baryon Puzzle

  $R_{AB}^{\varphi} < R_{AB}^{p}$, $m_{\varphi} \approx m_p$

  This strongly suggests a baryon vs. meson dynamic, as opposed to a simple mass dependence
- $R_{AB}^{K^*} \approx R_{AB}^{K}$
- $R_{AB}^{\pi^0} \approx R_{AB}^{\pi^\pm} \approx R_{AB}^{\eta}$
- Strangeness enhancement
- Jet quenching

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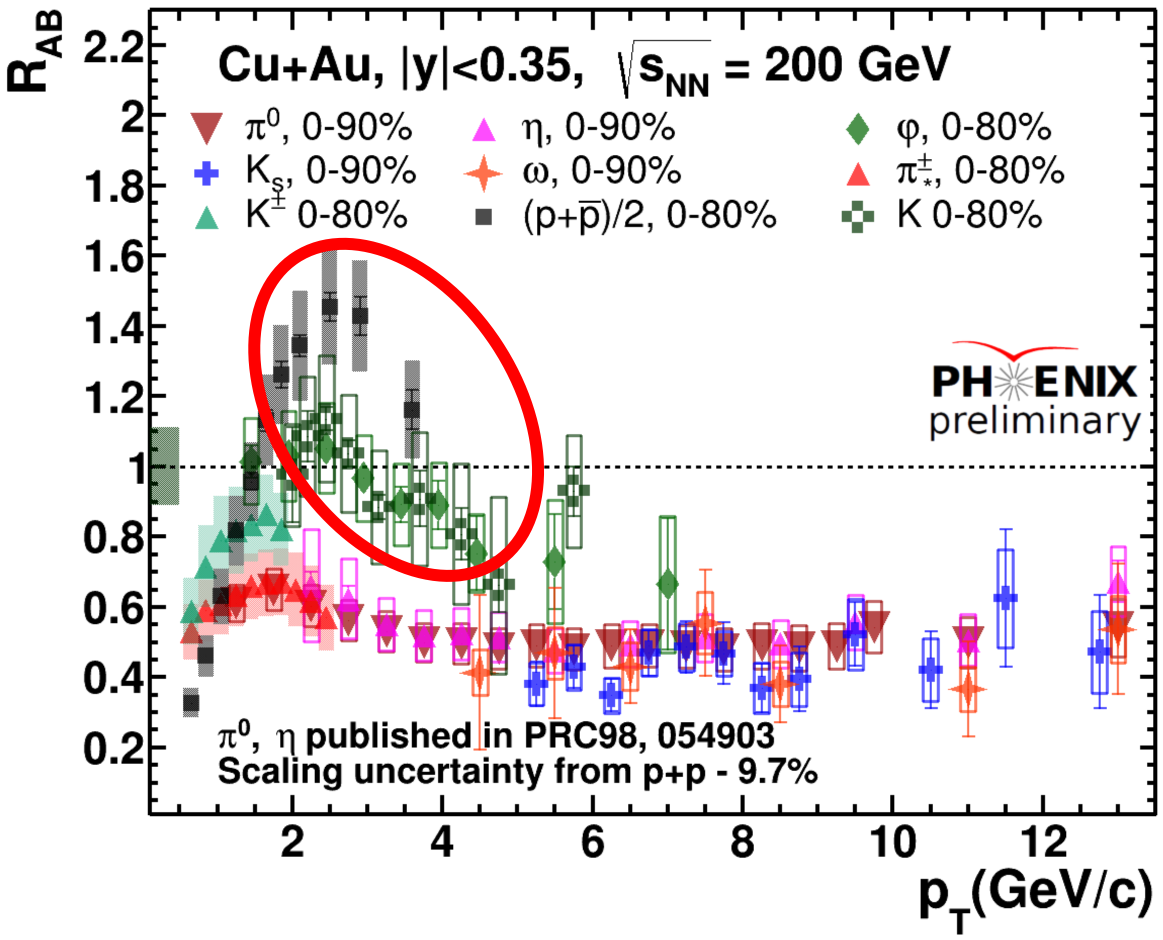

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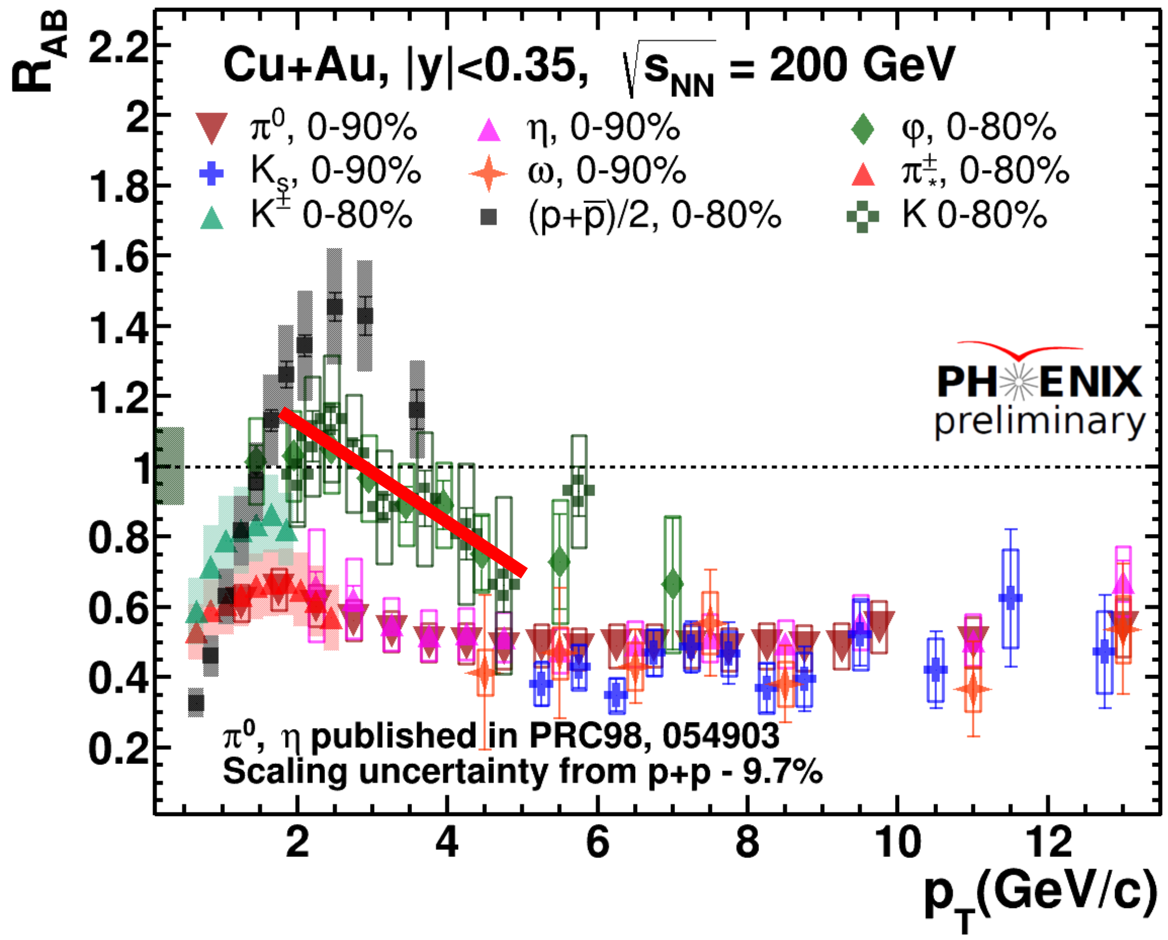

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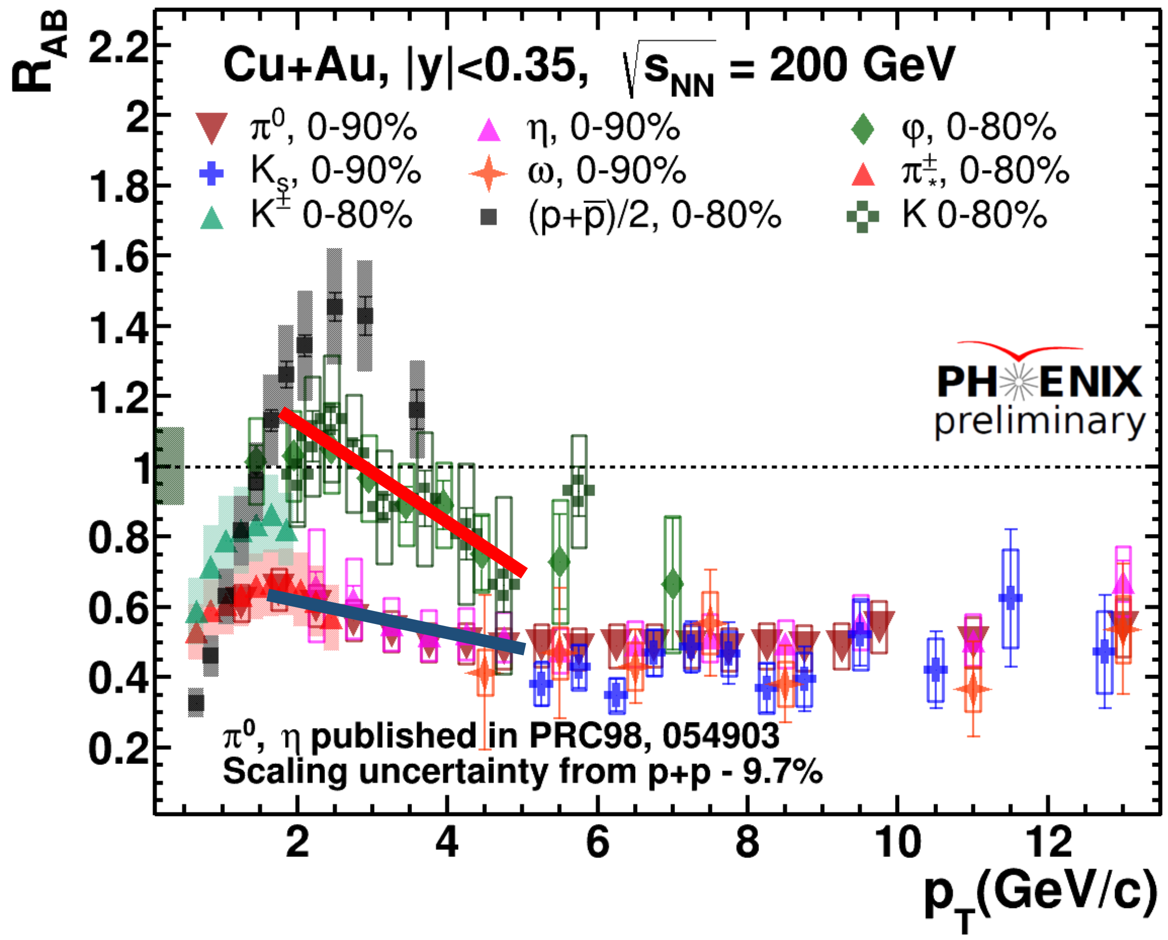

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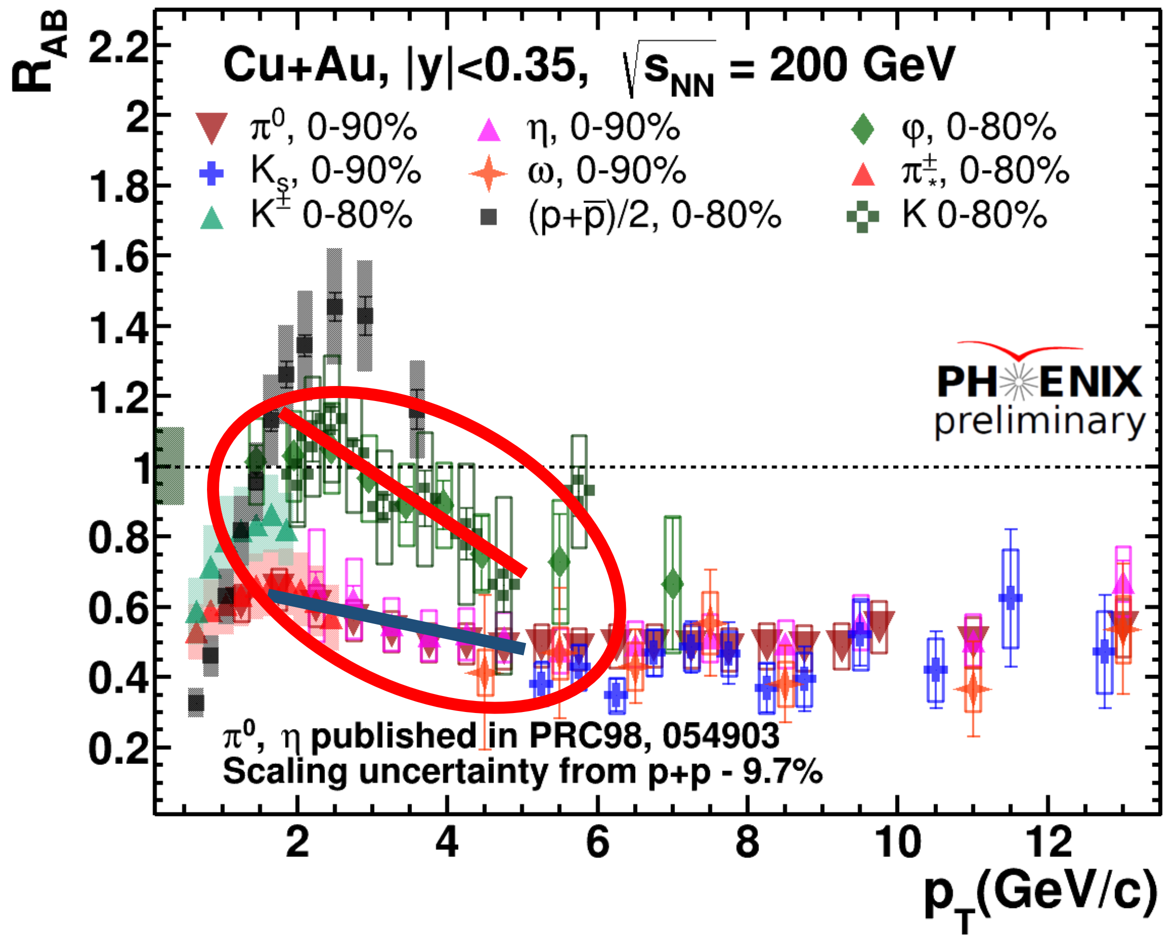

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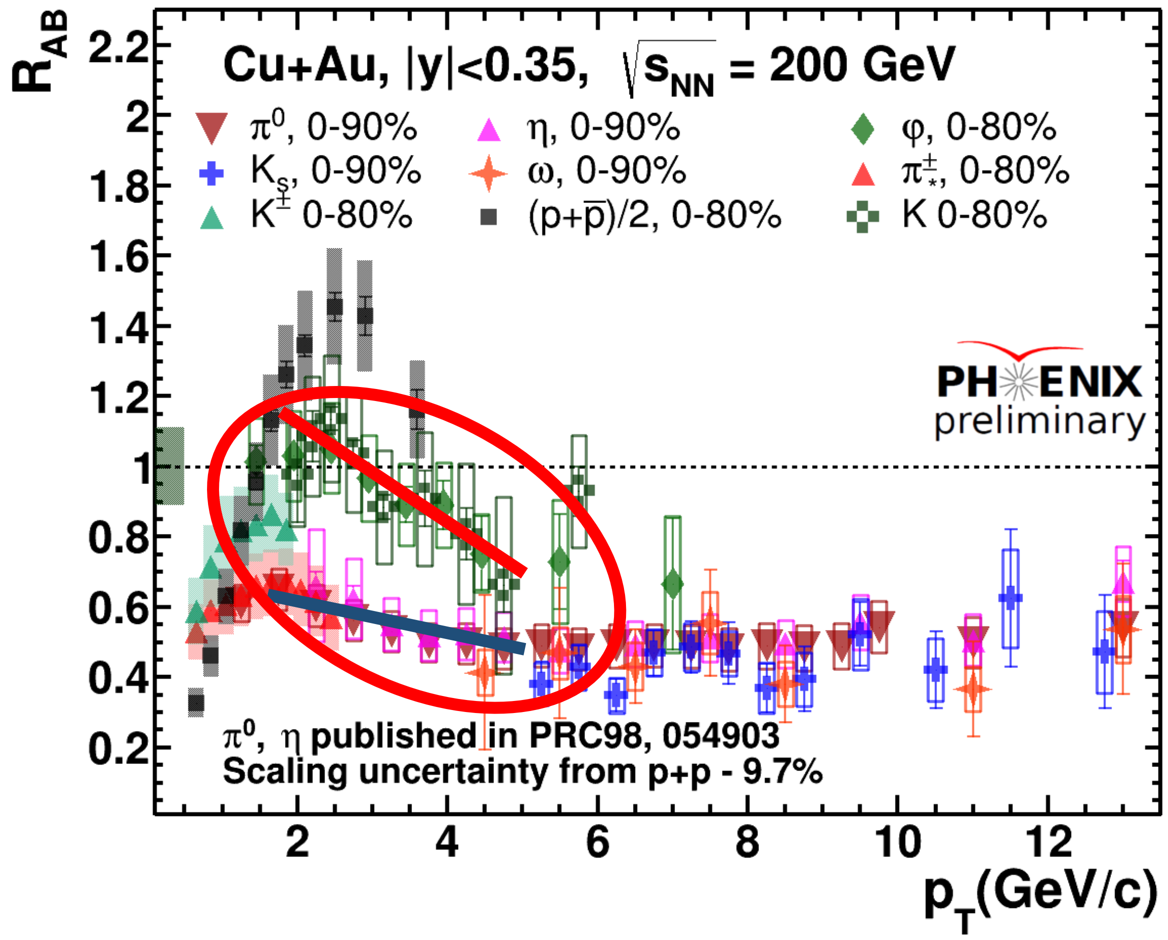

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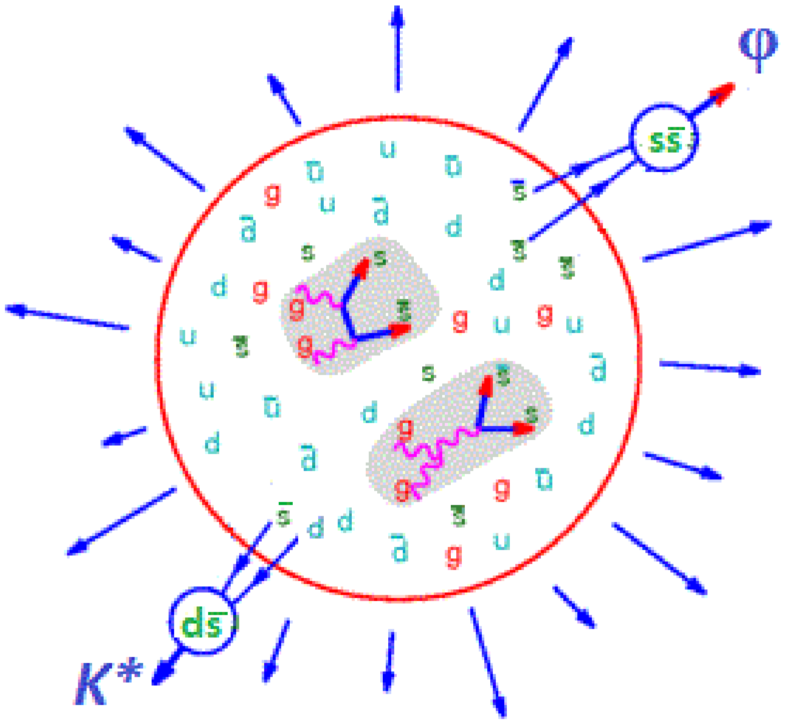

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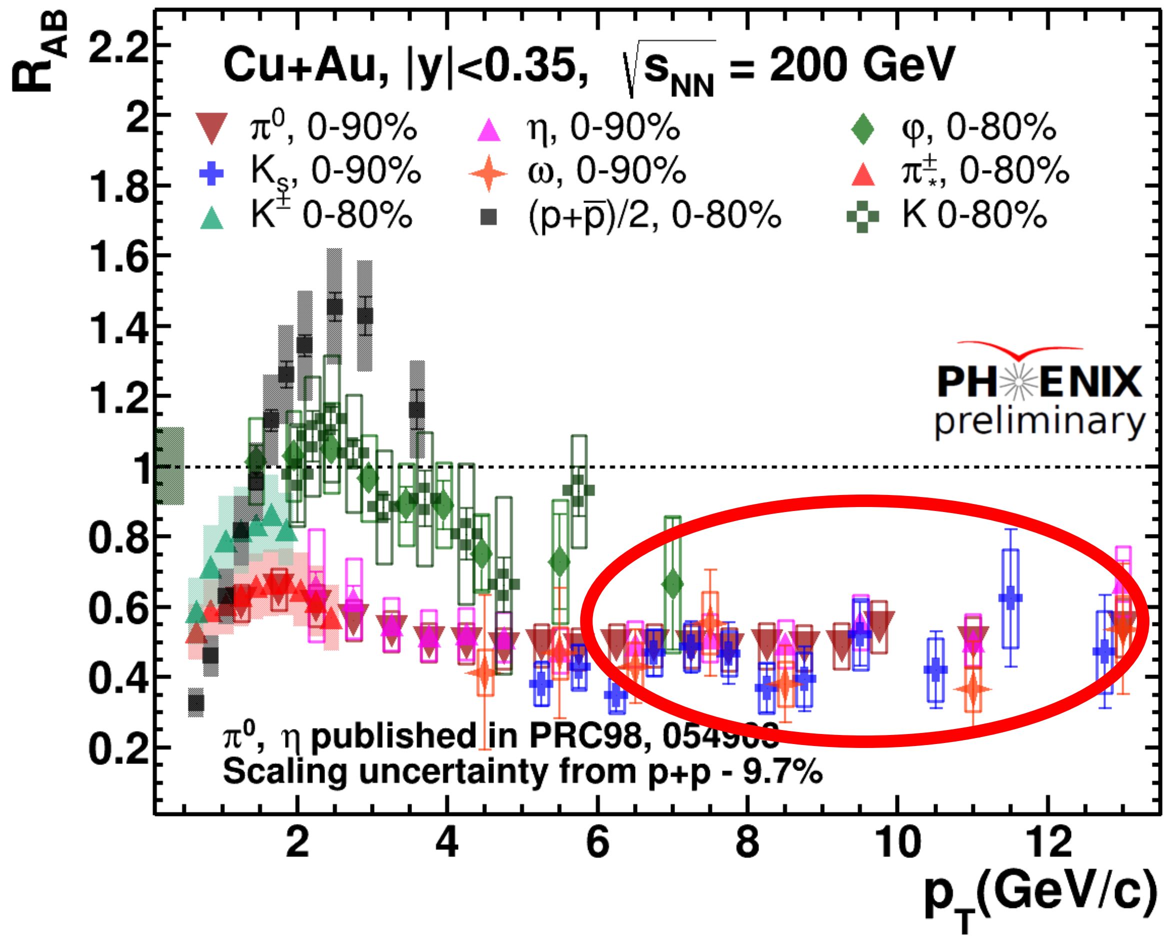

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- $R^{\pi^0}_{AB} \approx R^{\pi^{\pm}}_{AB} \approx R^{\eta}_{AB} \approx R^{\omega}_{AB}$
- Strangeness enhancement
- Jet quenching

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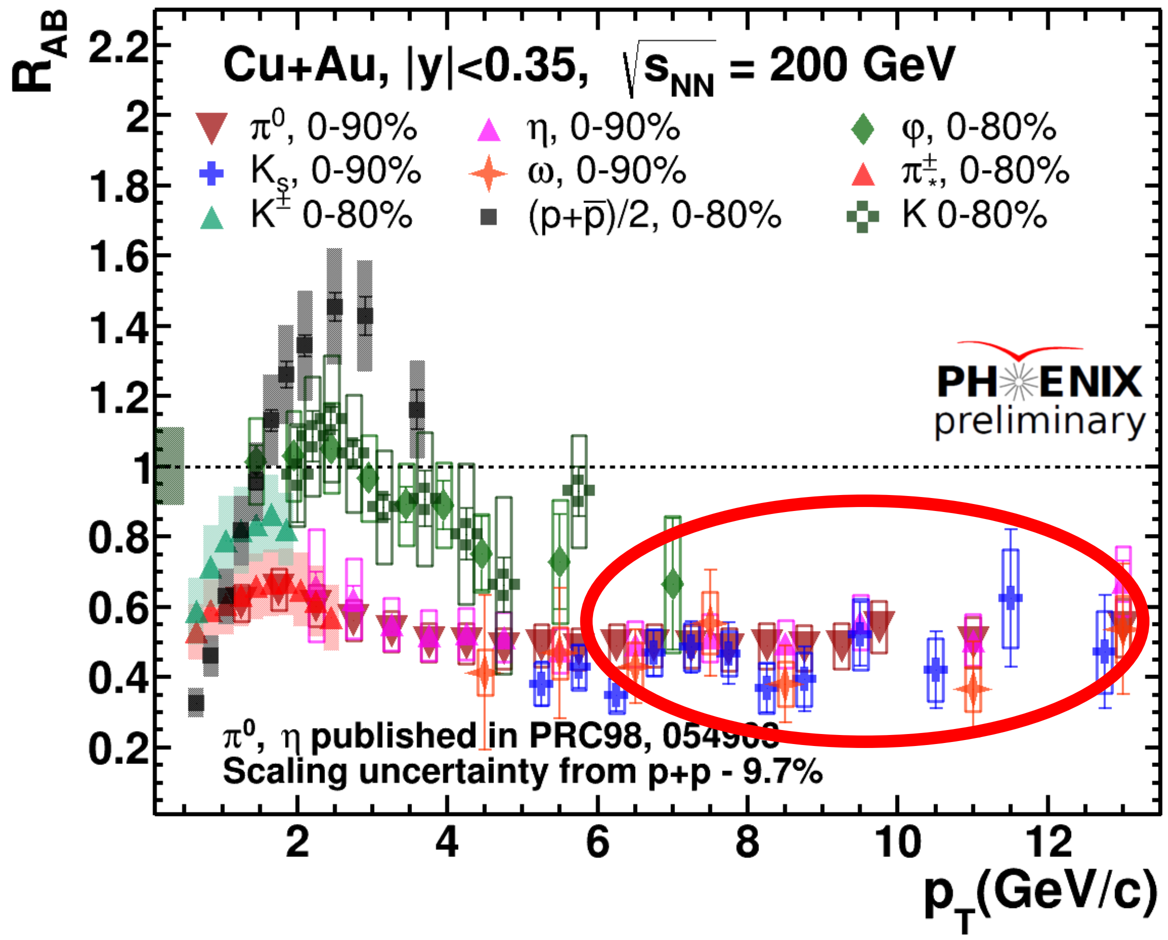
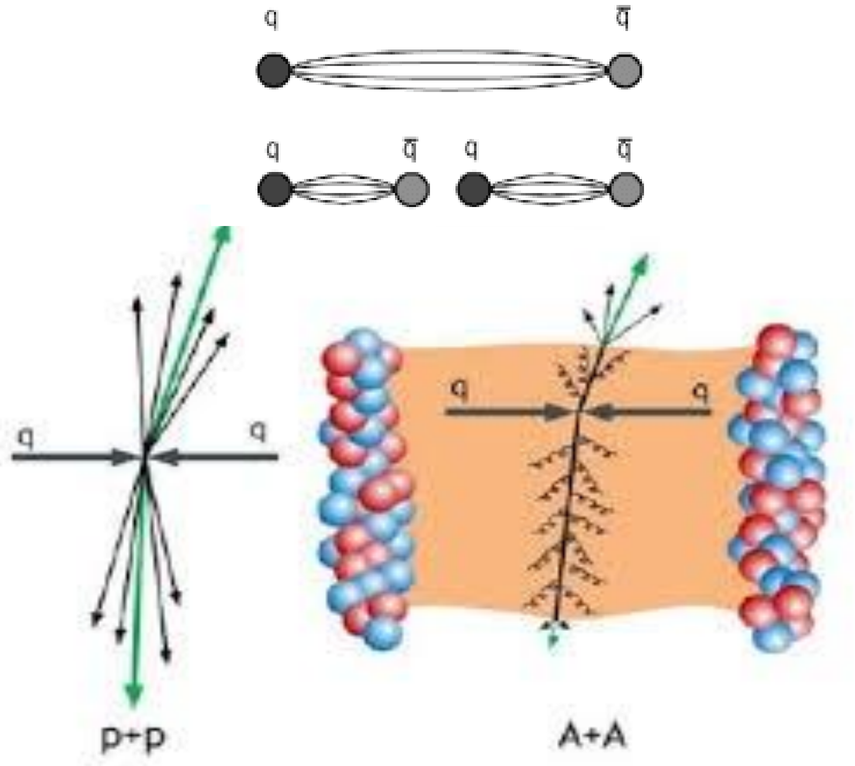


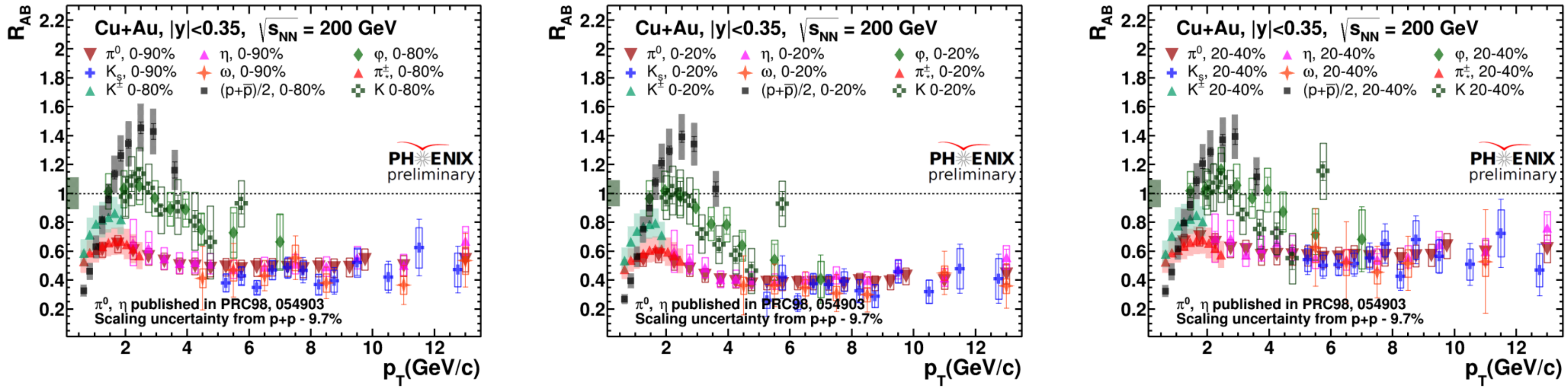
- Jet quenching

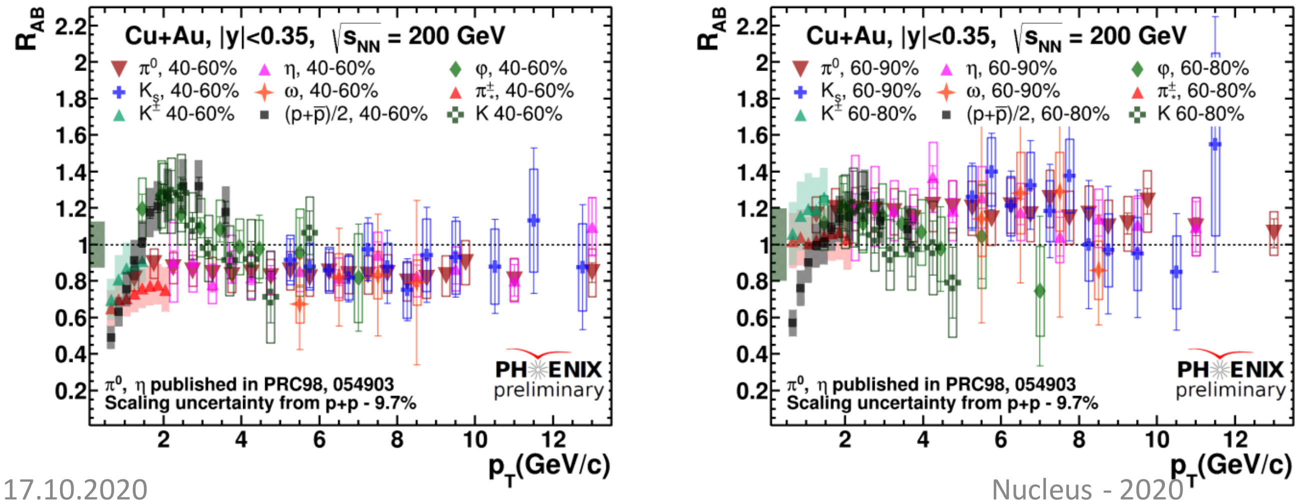


Light hadron R_{AB} in Cu+Au, $\sqrt{s_{NN}}$ = 200 GeV

POLYTECH

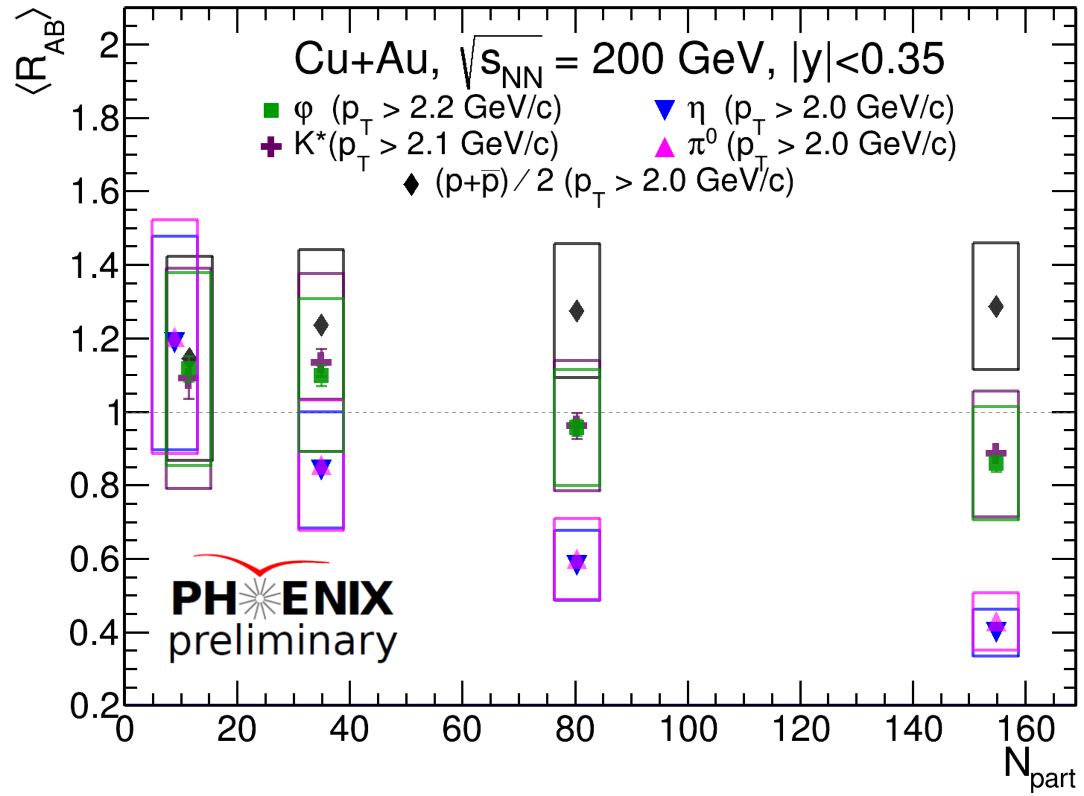
PHENIX

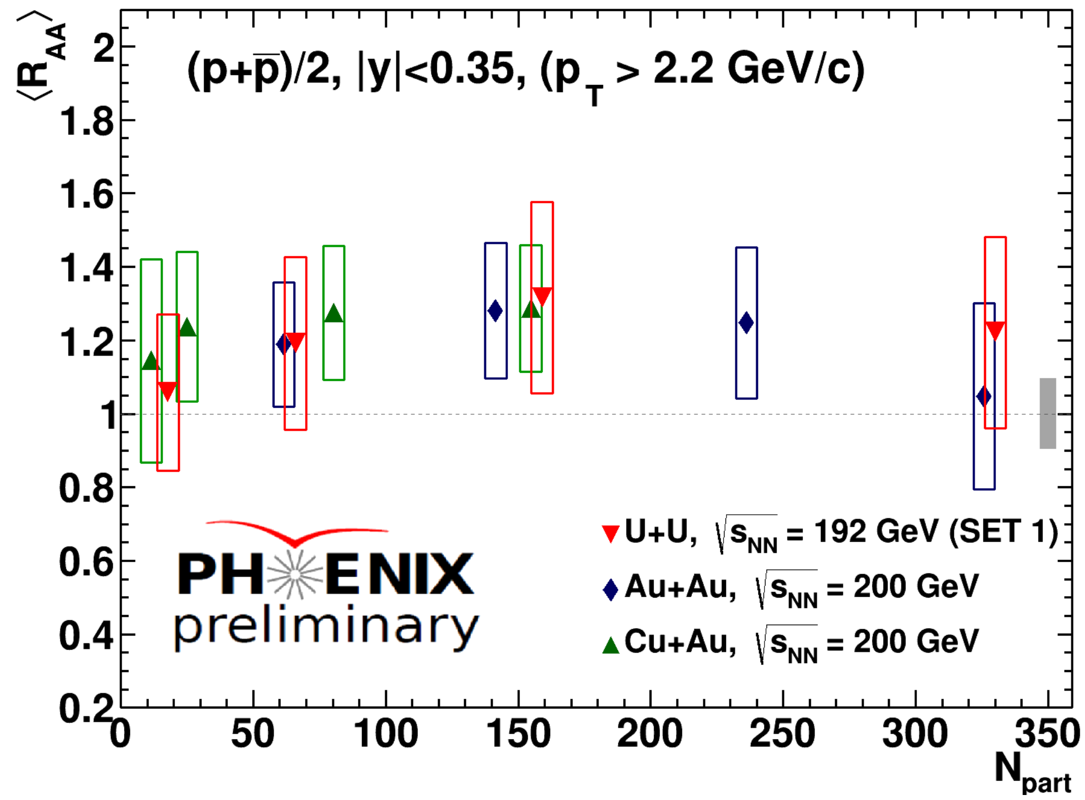




- This differences gradually disappear with decreasing centrality.

Integrated R_{AB} as a function of N_{part}





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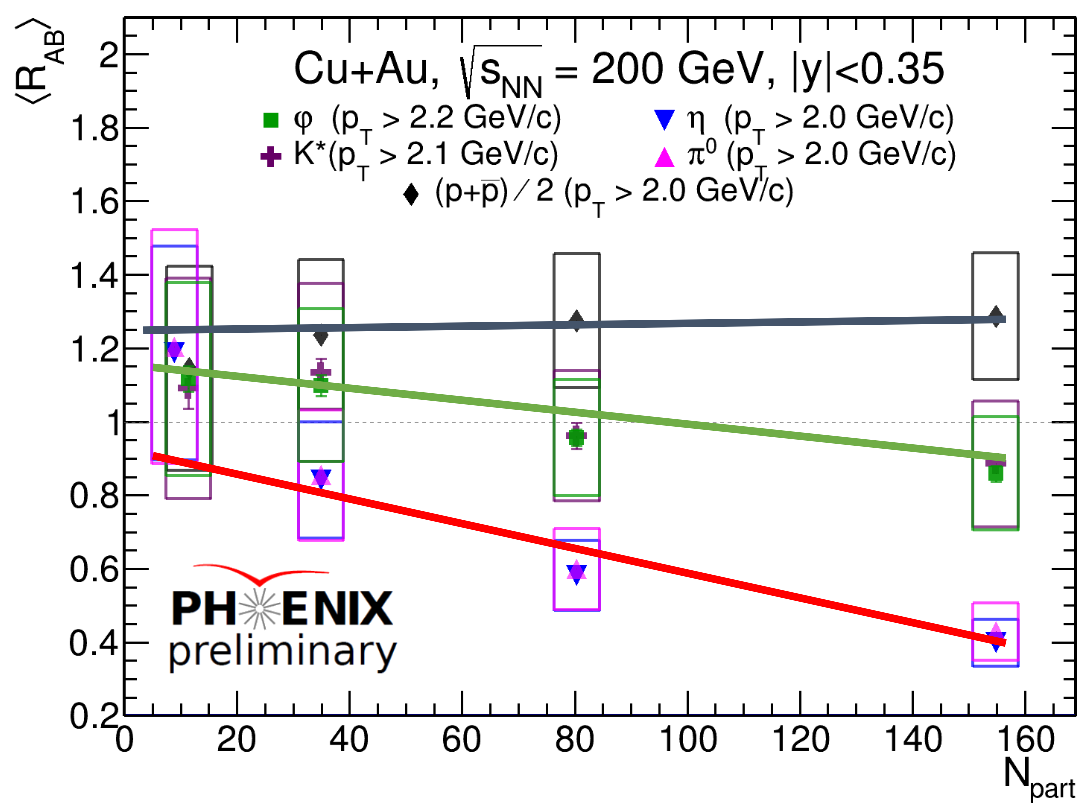

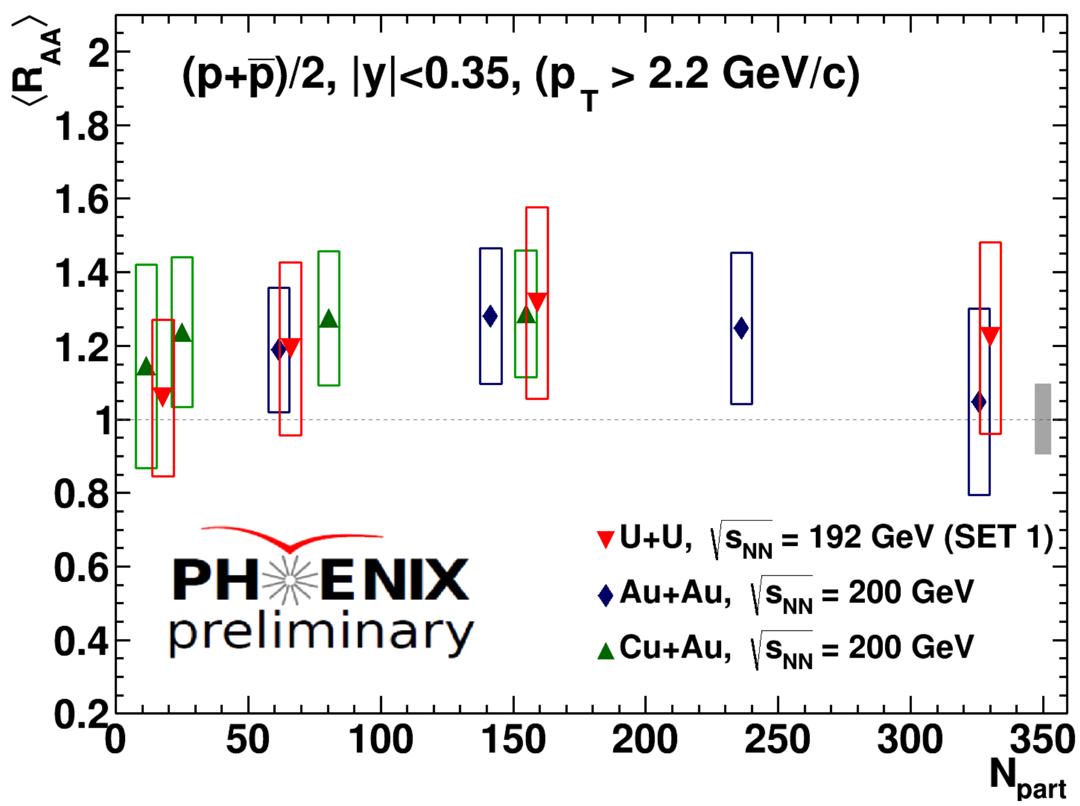

$$R_{AB_{\pi^0,\eta}} < R_{AB_{K^*,\varphi}} < R_{AB_p}$$

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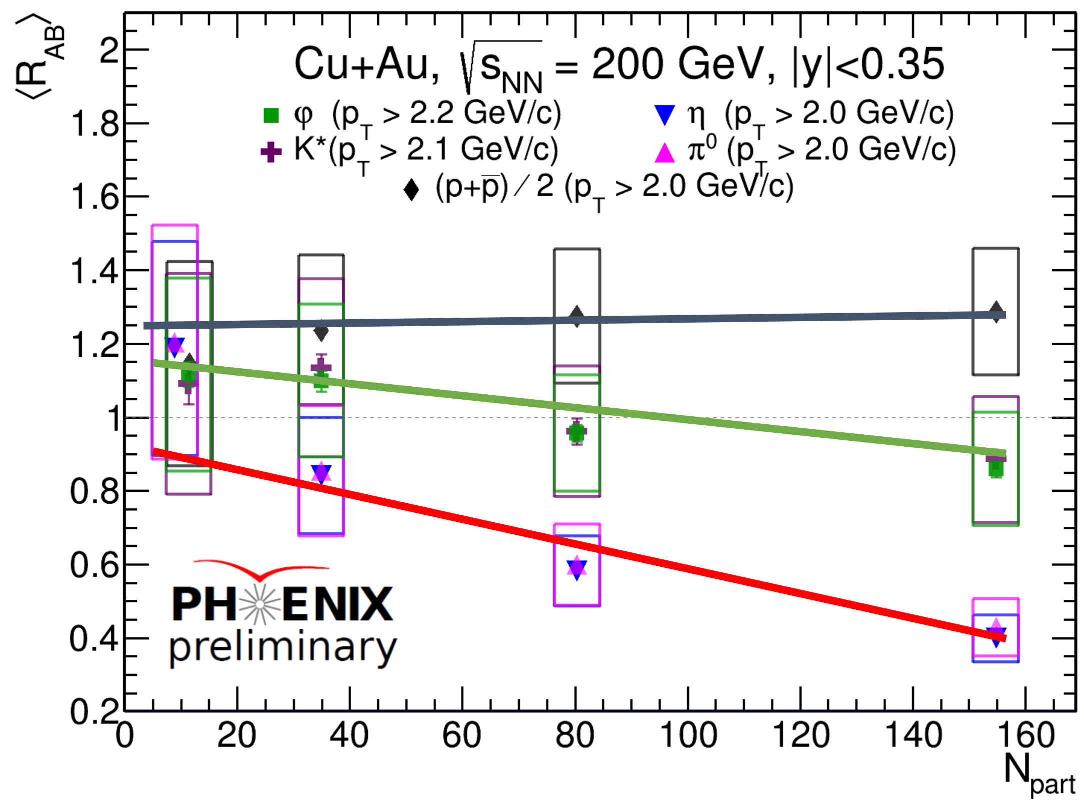
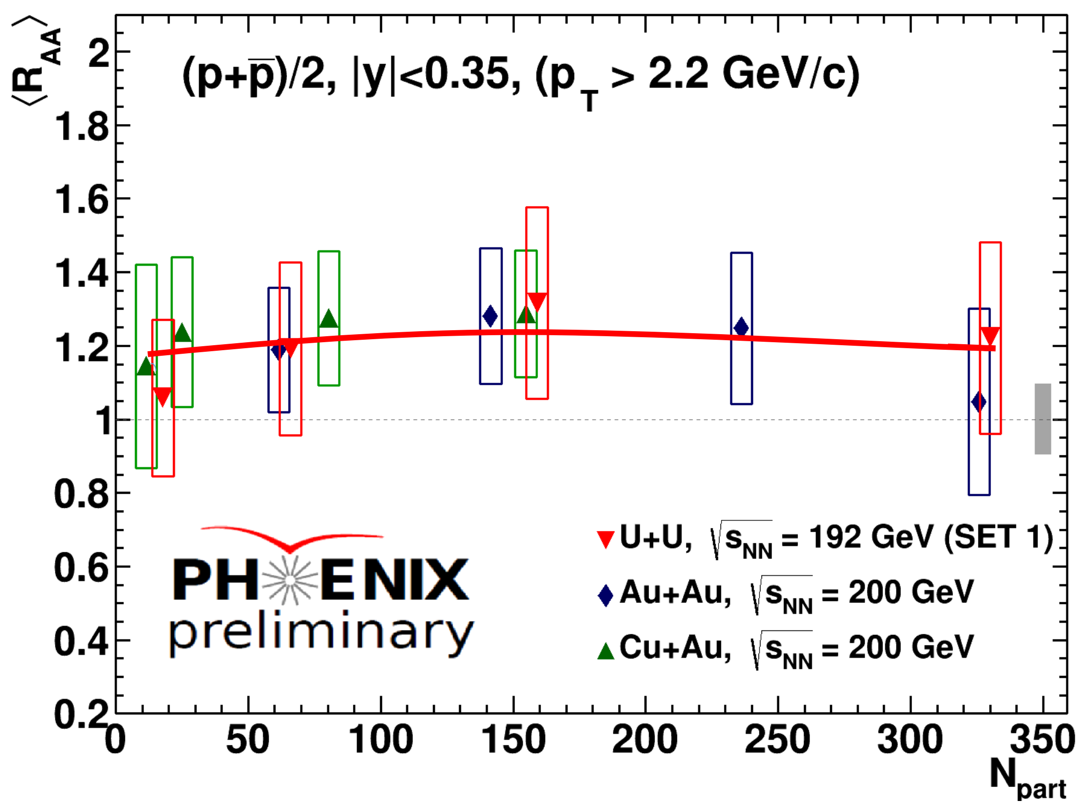
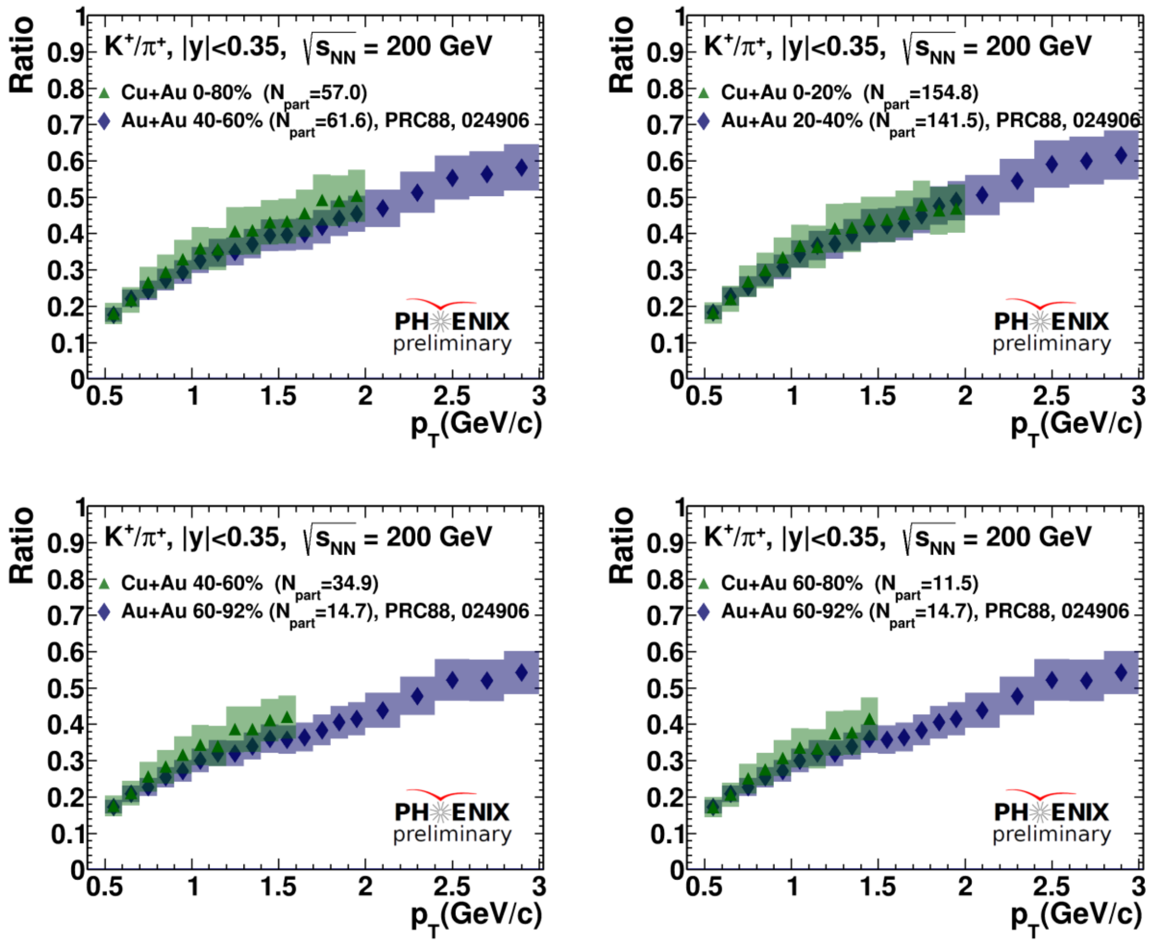




$$R_{AB\,\pi^0,\eta} < R_{AB\,K^*,\varphi} < R_{AB\,p}$$

- Scales with N_{part}
- No dependence on collision geometry

K^+/π^+ ratios in Cu+Au, $\sqrt{s_{NN}} = 200$ GeV



- Strong p_T dependence
- Weak centrality dependence
- In agreement with Au+Au

Conclusion

- Production and suppression of the $(p+\bar{p})/2$ seems to scale with the average size of the nuclear overlap region and do not depend on the details of its shape;
- For the most central Cu+Au collisions proton yields are enhanced ($R_{AB} > 1$) at 2 GeV/c $< p_T <$ 5 GeV/c, while π^0-mesons yields are suppressed and φ –meson R_{AB} values are around 1. Observed difference in R_{AB} values for protons, φ and π^0-mesons disappears from central to peripheral collisions.
- The observation of these patterns in many collision systems can provide further constraints to quark recombination models.

Thank you for attention!