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PHENIX Measurements of Identified Charged Hadrons and Forward ϕ-meson in Small and Large Systems

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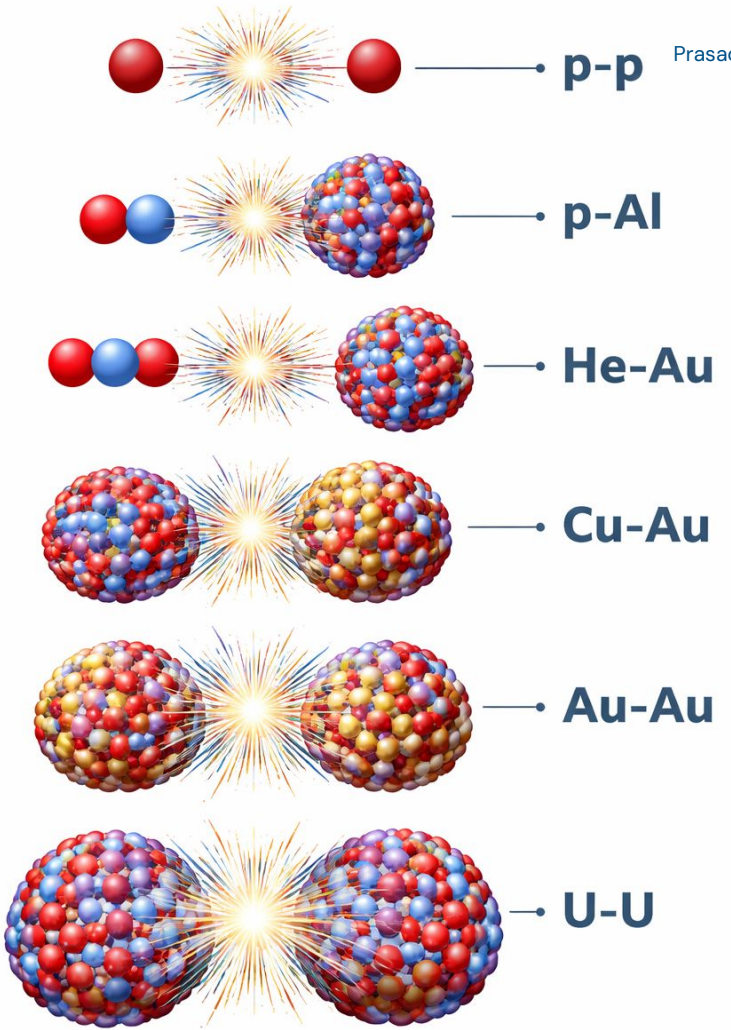
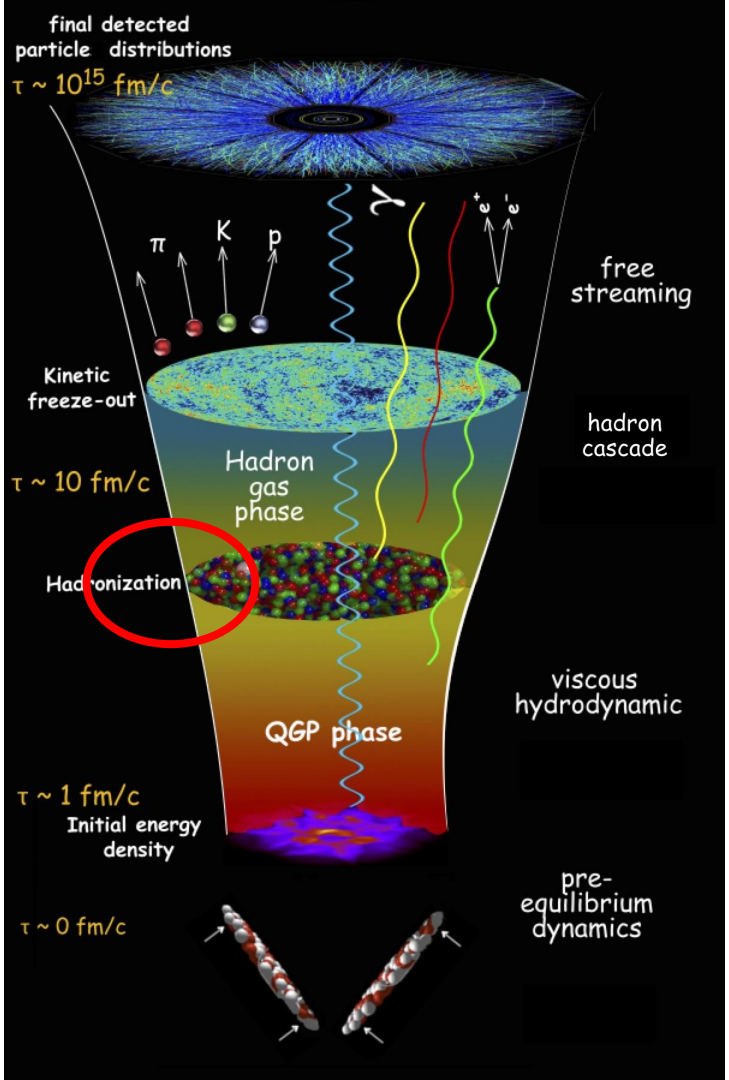
Strangeness in Quark Matter 2026, UCLA

1. Heavy ion physics
2. PHENIX setup
3. Charged hadrons
4. Vector mesons
5. Elliptic flow



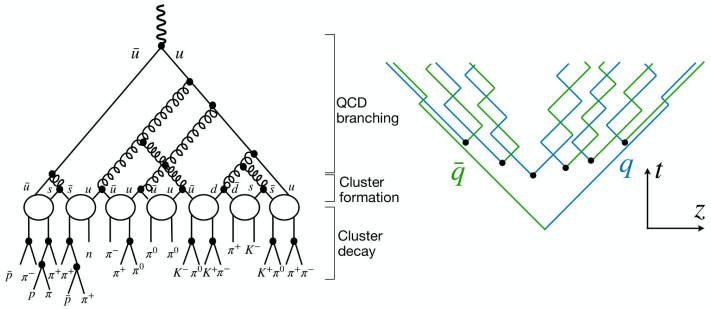
Heavy ion physics

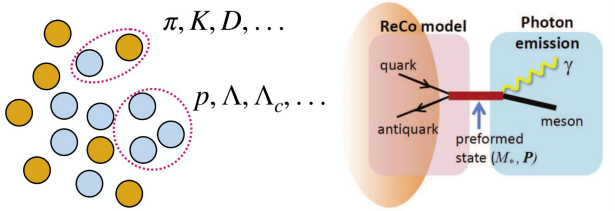
- The quark-gluon plasma (QGP) comprises deconfined, strongly interacting quarks and gluons, at extremely high temperature and density
- This medium behaves as a strongly interacting fluid
- As the system cools and expands, it undergoes hadronization
- Particles produced after hadronization carry information about the medium

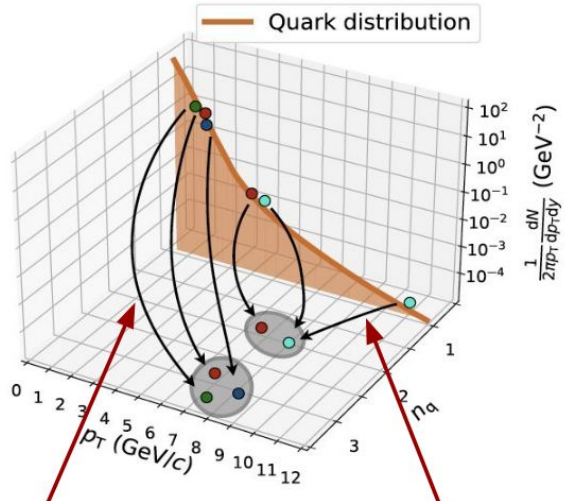


Hadronization

- Nearby quarks can combine through quark recombination to form mesons or baryons
- This would lead to enhancement in baryon versus meson production in the large systems, quantified using particle ratios and nuclear modification factor



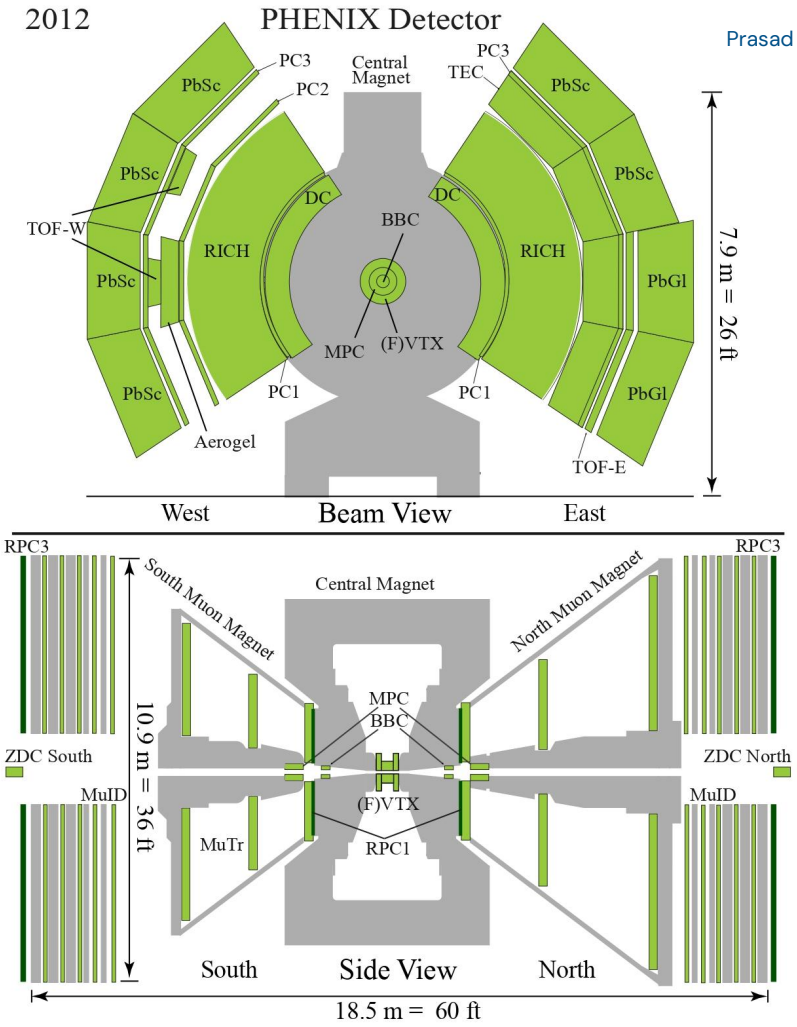




- In the QGP, strange quarks are produced through gluon interactions
- This would lead to strangeness enhancement in the large systems

PHENIX setup

- Beam-Beam Counter BBC :
  - Minimum bias trigger
  - Event start time
  - Centrality
- (Forward) Silicon Vertex Detector (F)VTX :
  - Event vertex
- Time-of-Flight TOF :
  - Particle identification
- Drift Chamber DC :
  - Momentum + charge determination
- Muon Tracker MuTr, Muon Identifier MuID :
  - Dimuon pair identification



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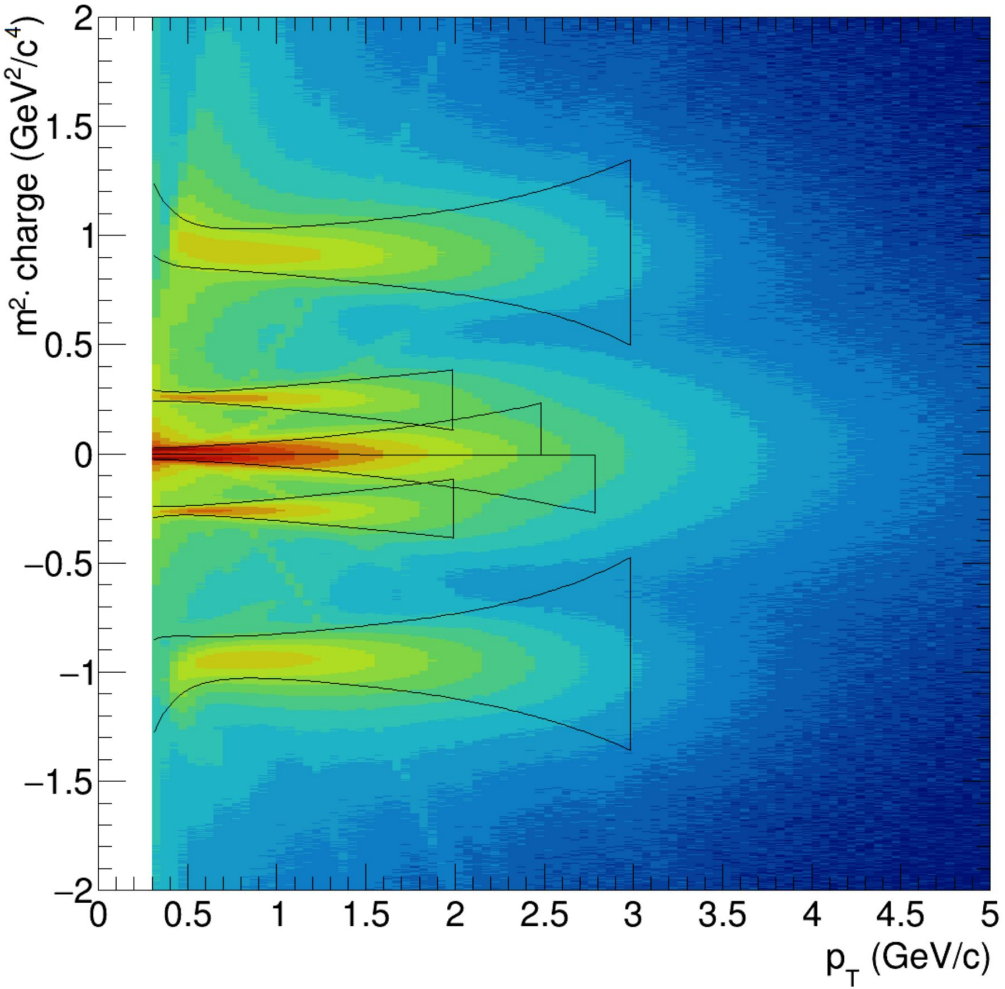
Charged hadron identification

- Charged particle identification using TOF and DC

$$m^2 = \frac{p^2}{c^2}\left(\frac{t_{TOF}^2}{(L/c)^2} - 1\right)$$

- Spectra from p+p serve as a baseline reference



Particle ratio in small systems

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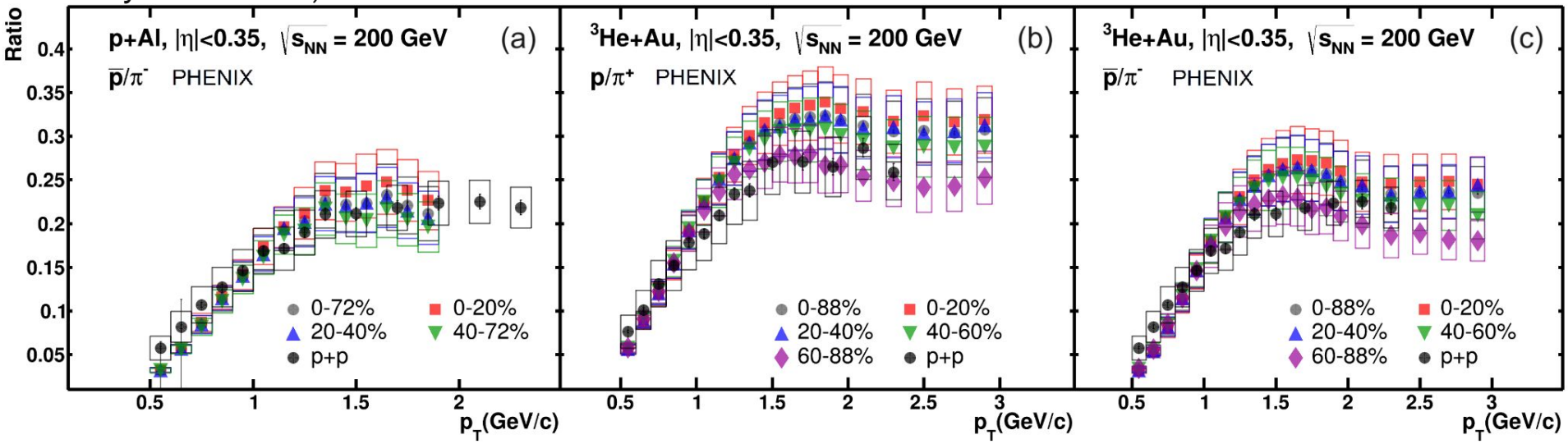

- Enhancement of baryon production is one of the signatures of QGP formation
- Small systems show modest enhancement compared to p+p

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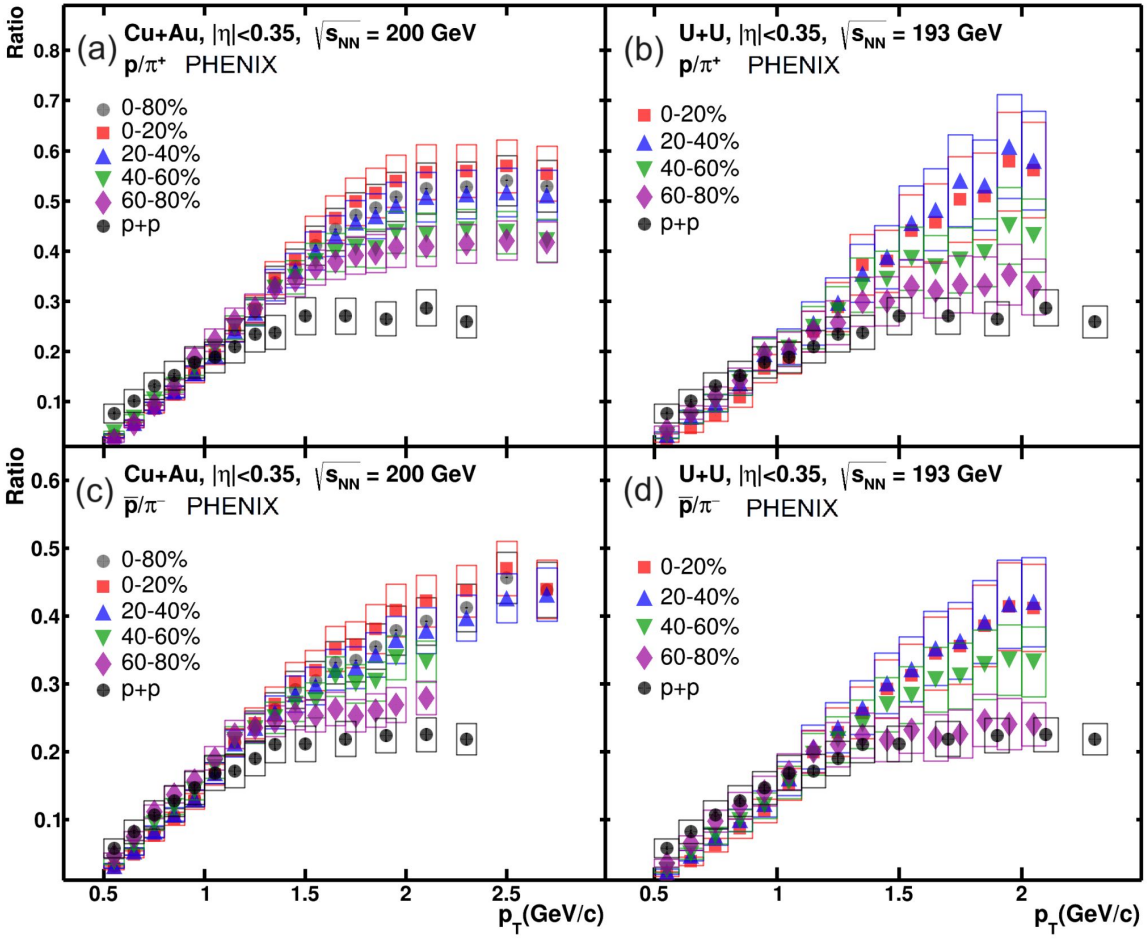
Particle ratio in large systems

- Central collisions show significant enhancement in baryons
- In central collisions, p/π ratios reach the values of 0.6
- In peripheral collisions, p/π ratios are smaller than 0.4
- K/π also shows enhancement, indicating strangeness enhancement



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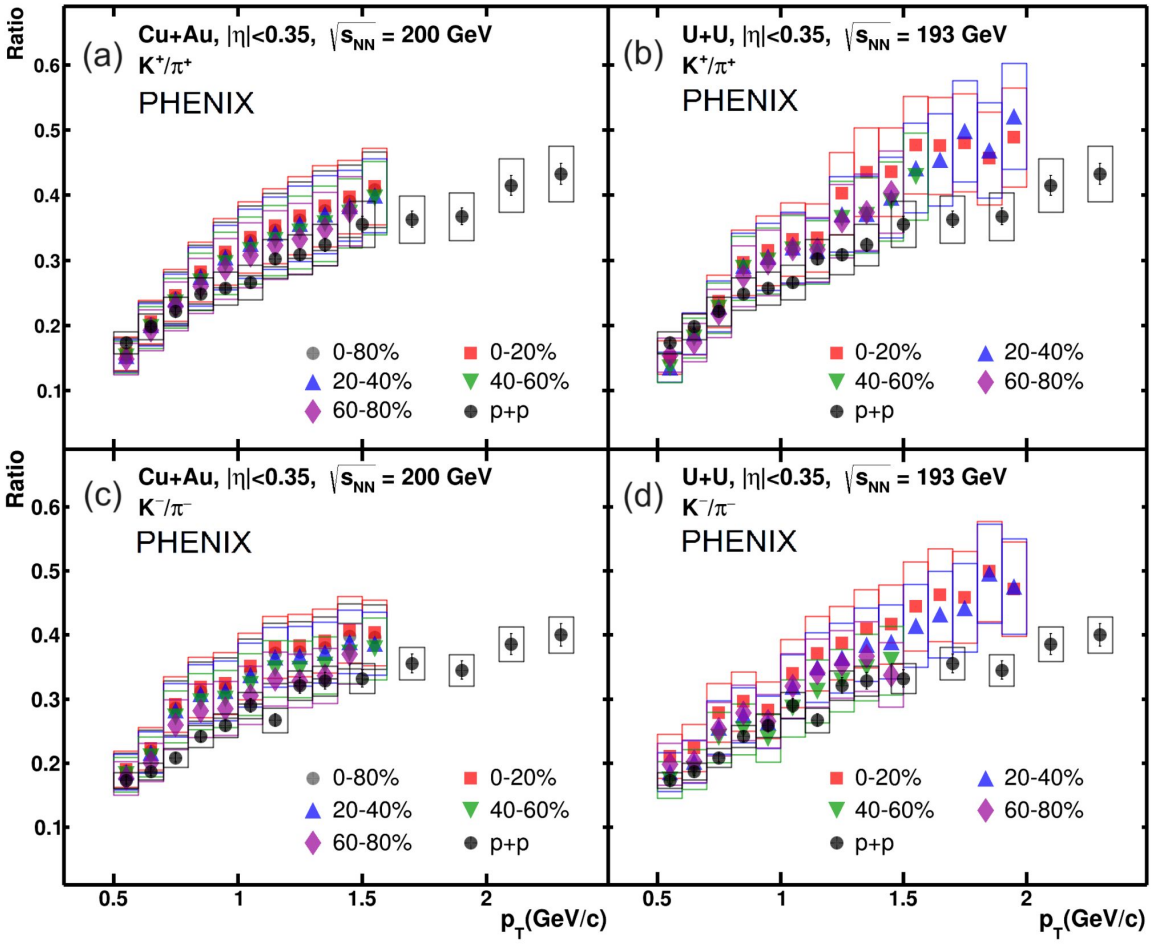

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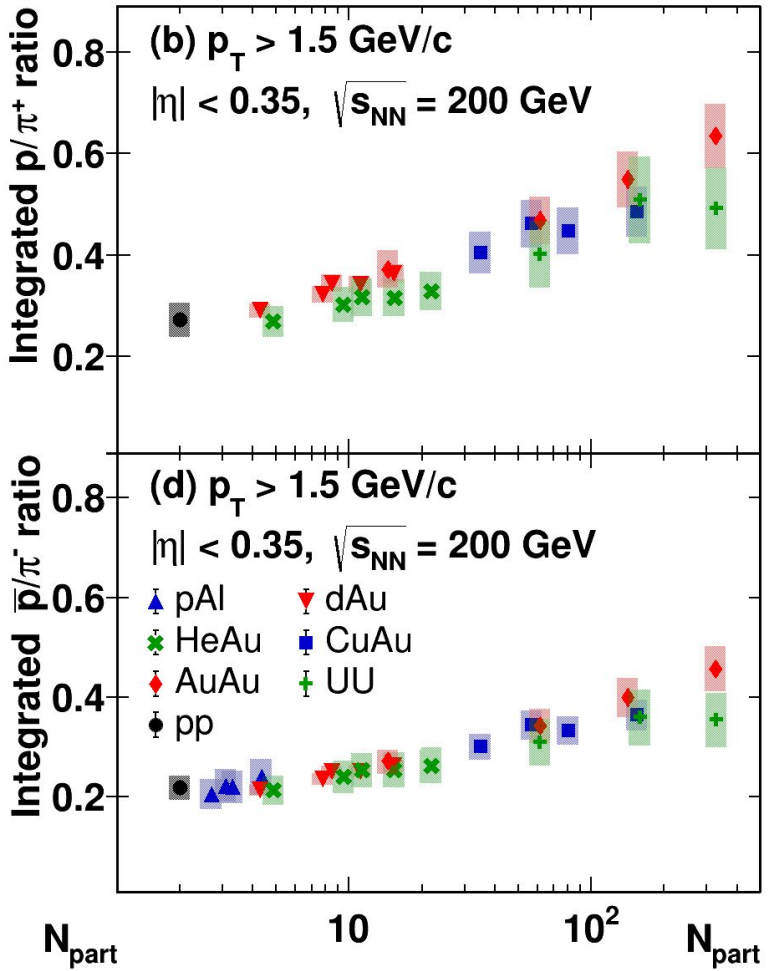
Why study ϕ-meson

- Baryons show enhancement, and mesons show suppression
- This suggests quark recombination in the medium
- The ϕ has a mass similar to the proton, but is a meson
- This allows to test mass effects vs recombination effects
- Additionally, it is a pure $s\bar{s}$ state, thus an ideal system to study strangeness enhancement



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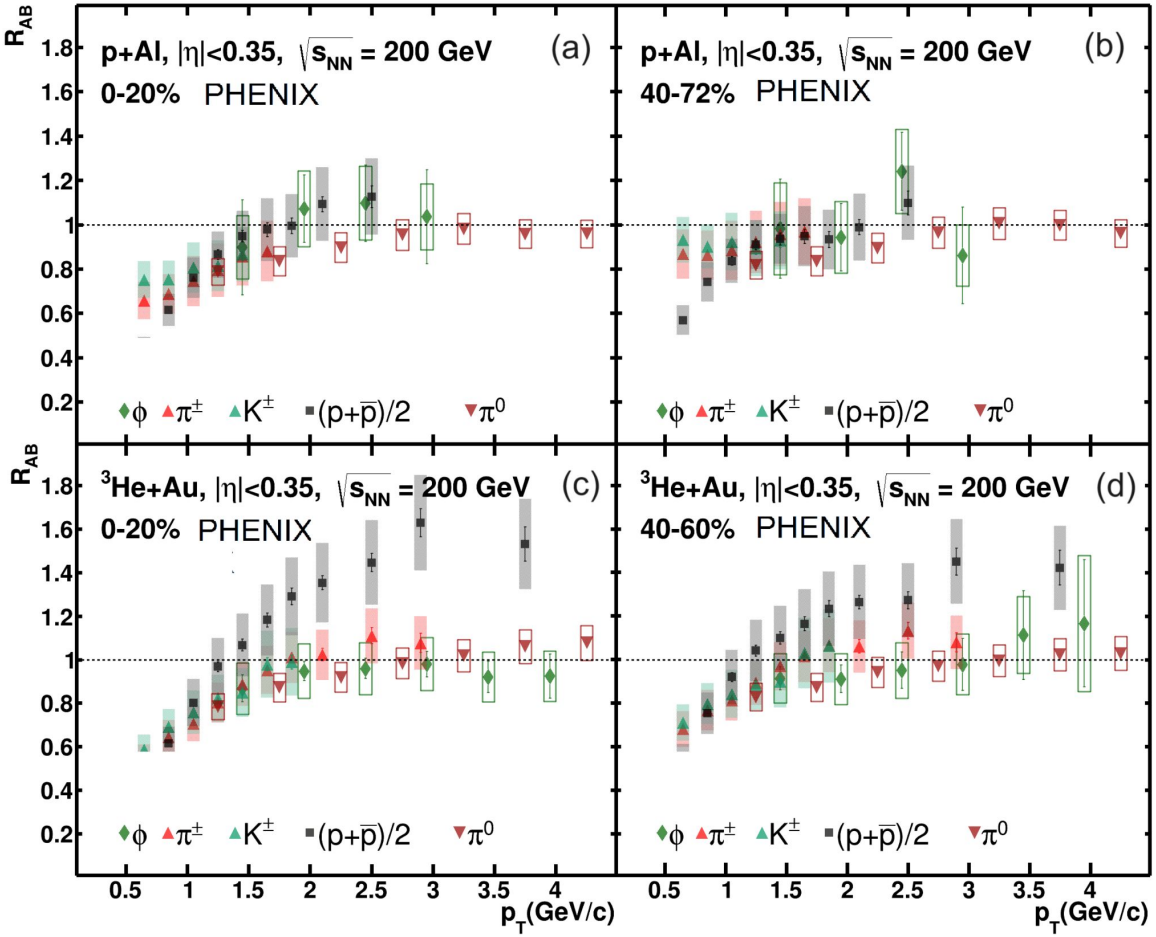
Nuclear modification

- In p+Al collisions, all R_{AB} values are in agreement, showing zero enhancement in proton to meson production
- In large collision systems, protons are enhanced over ϕ values
- This suggests differences in baryon versus meson production instead of a simple mass dependence
- This provides evidence for recombination of quarks in the medium



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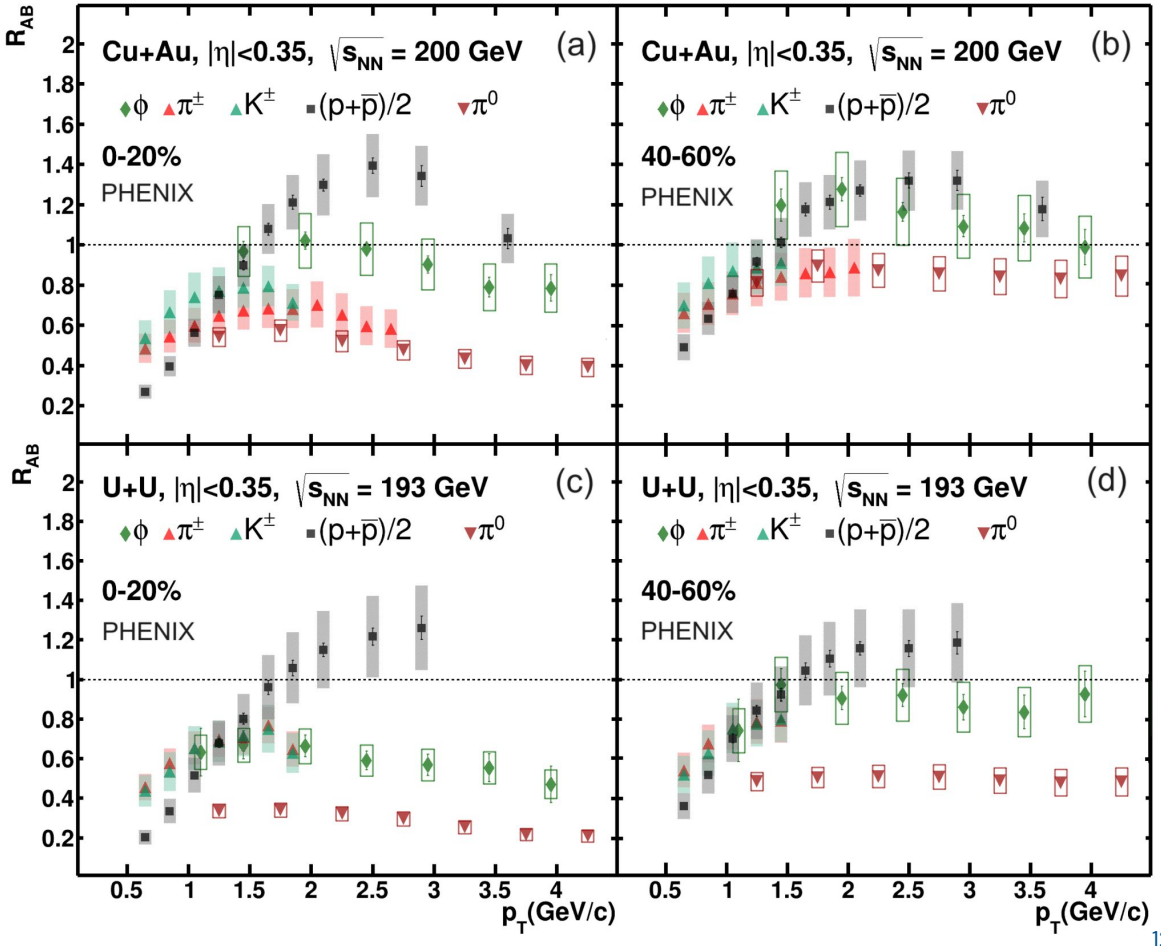

Low mass vector mesons

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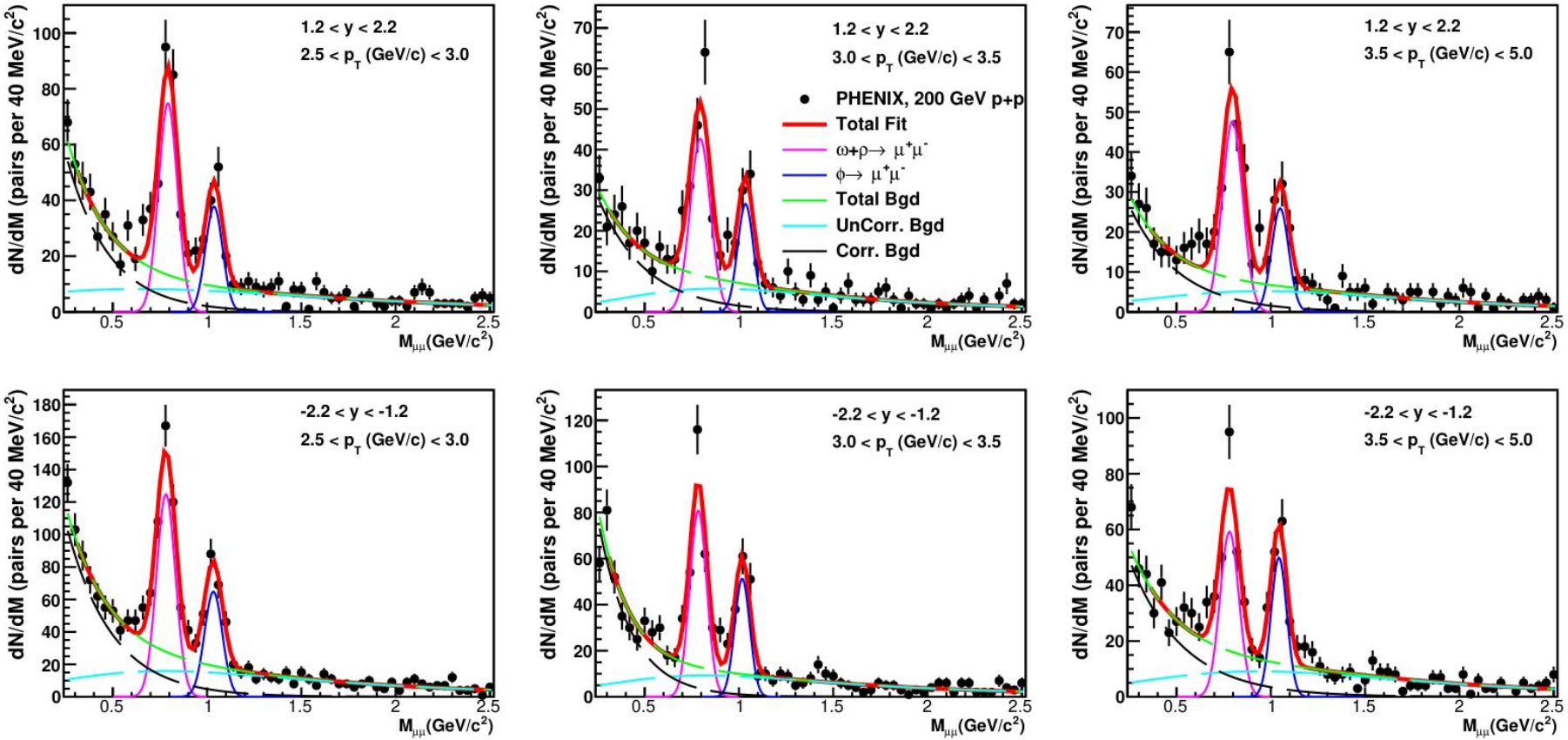

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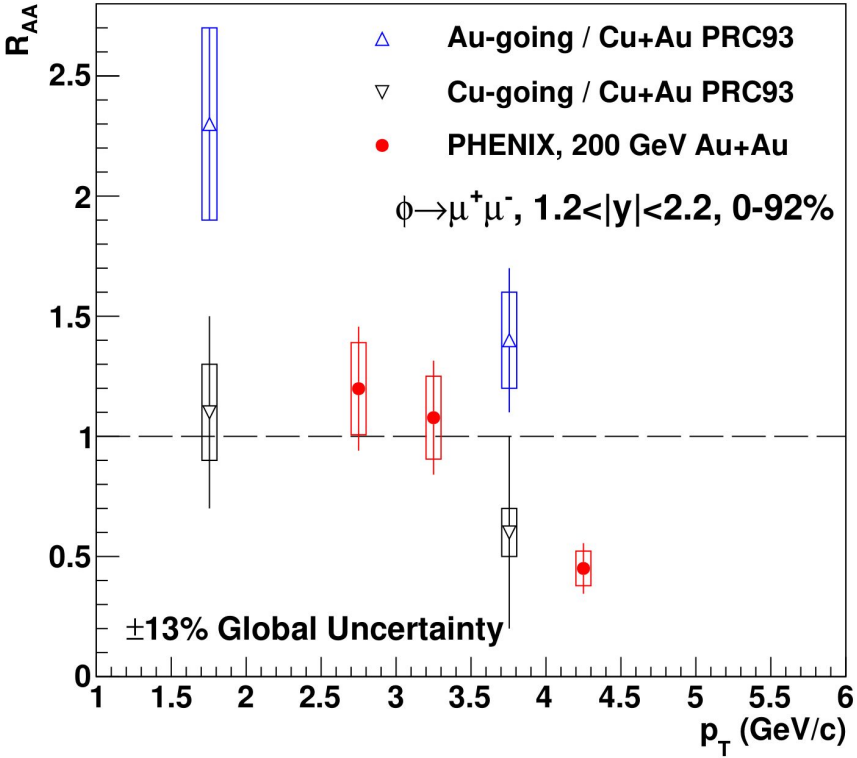

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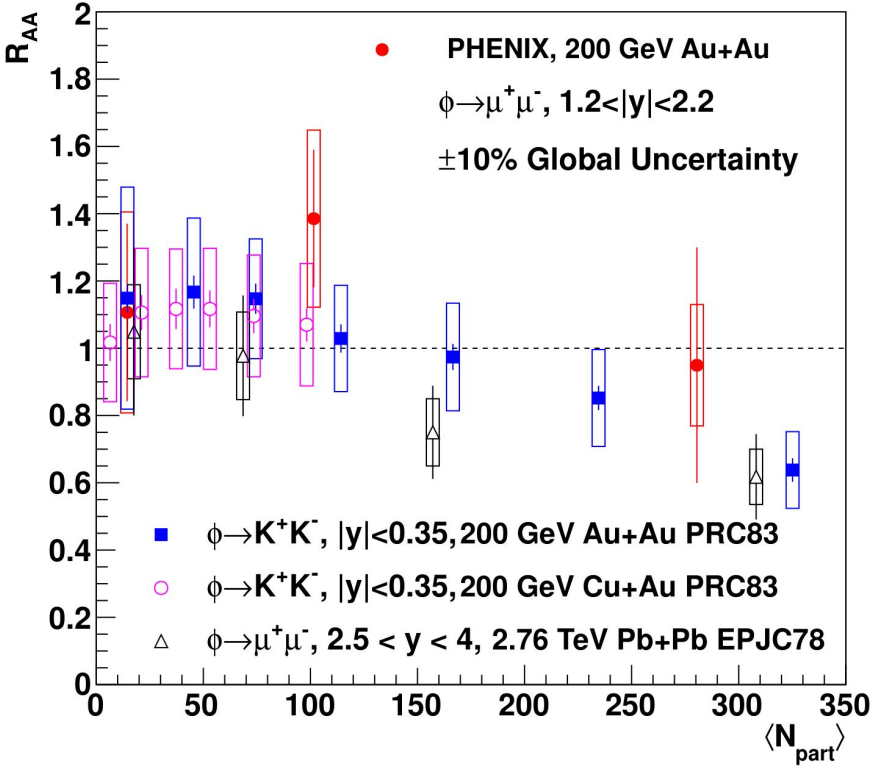

ϕ-meson nuclear modification

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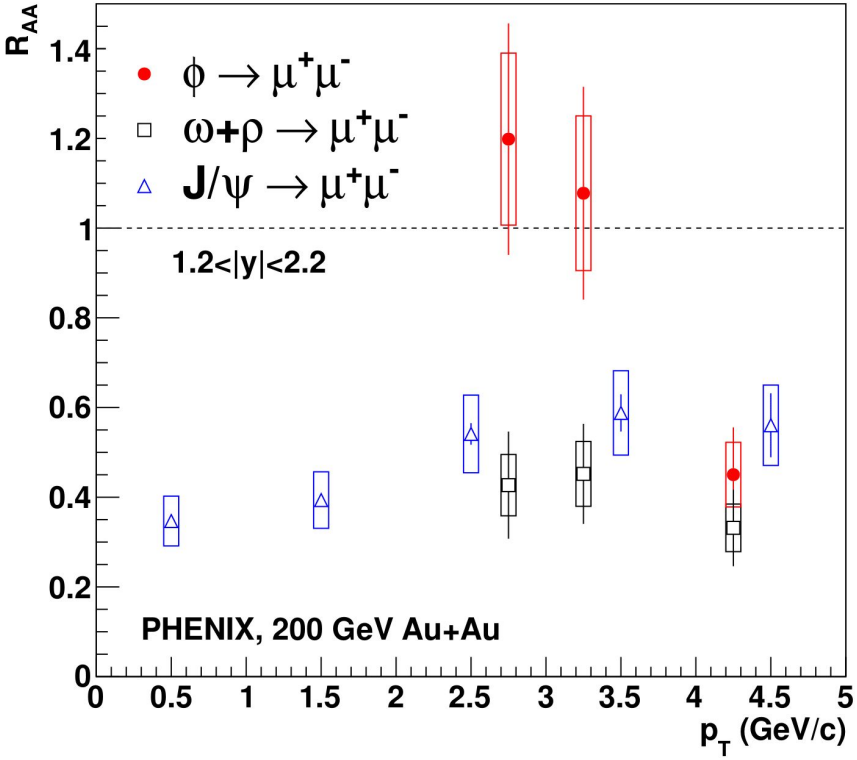

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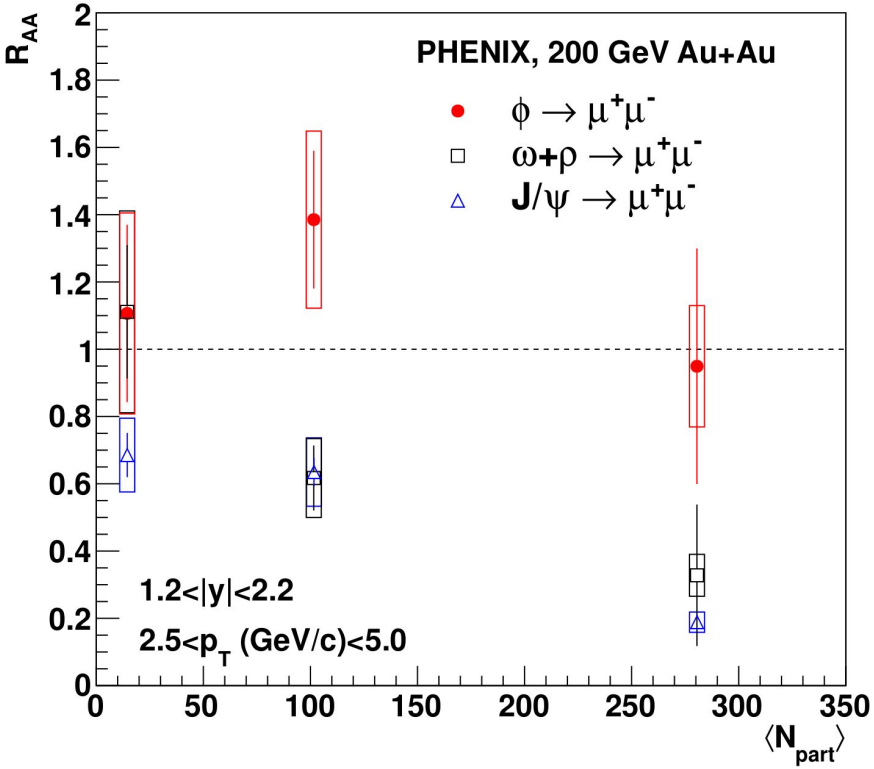
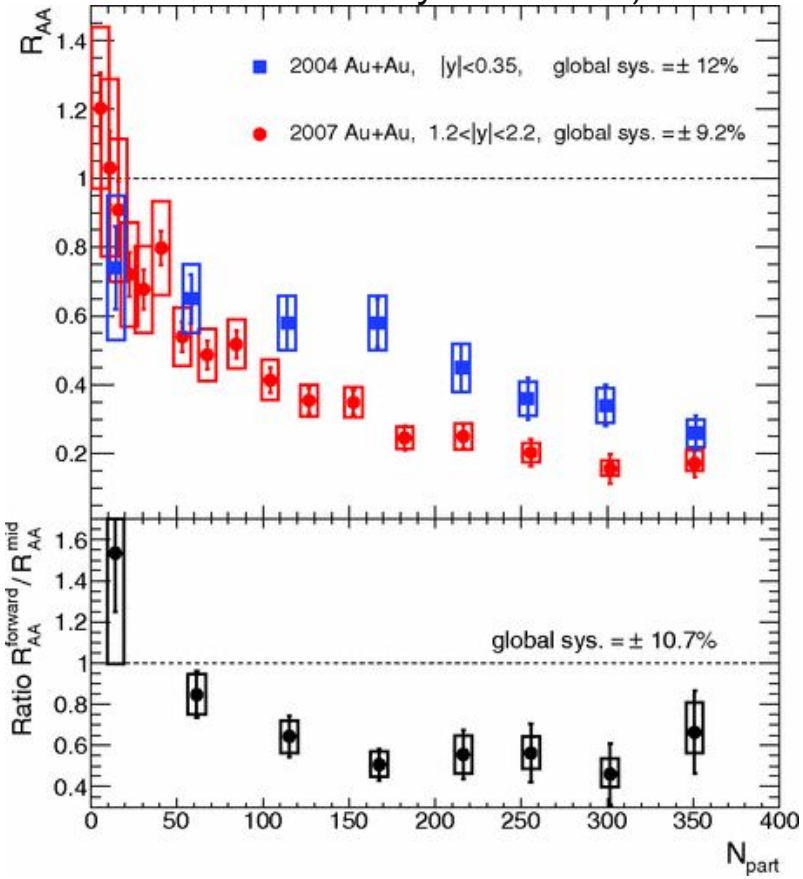
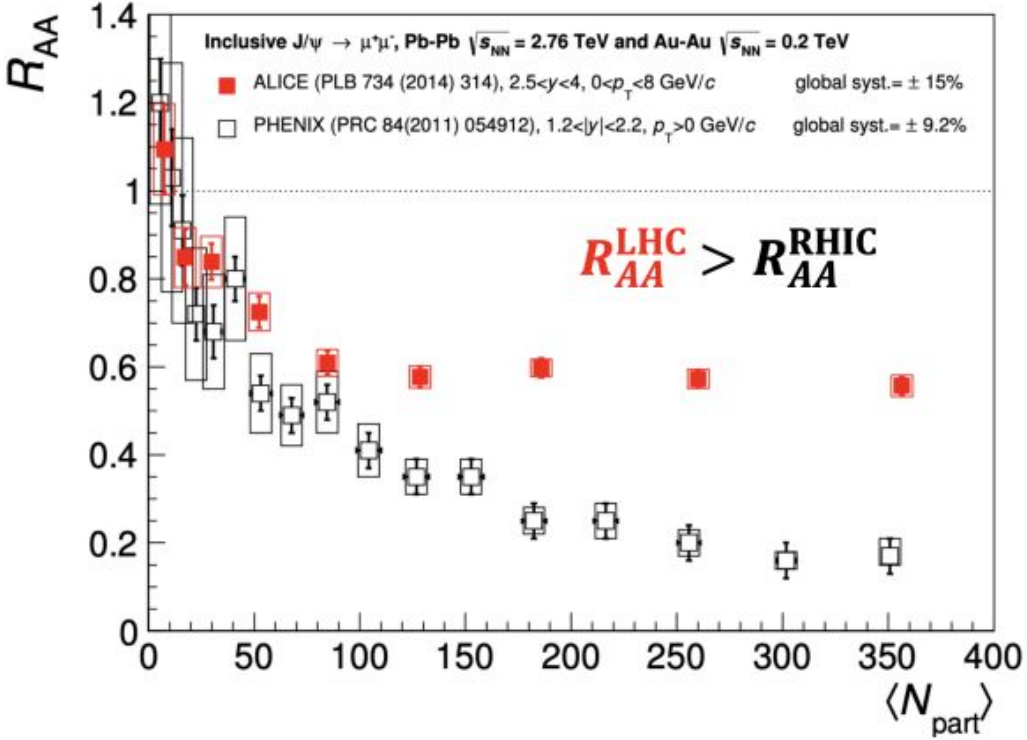


Strangeness enhancement

Phys. Rev. C 84, 054912



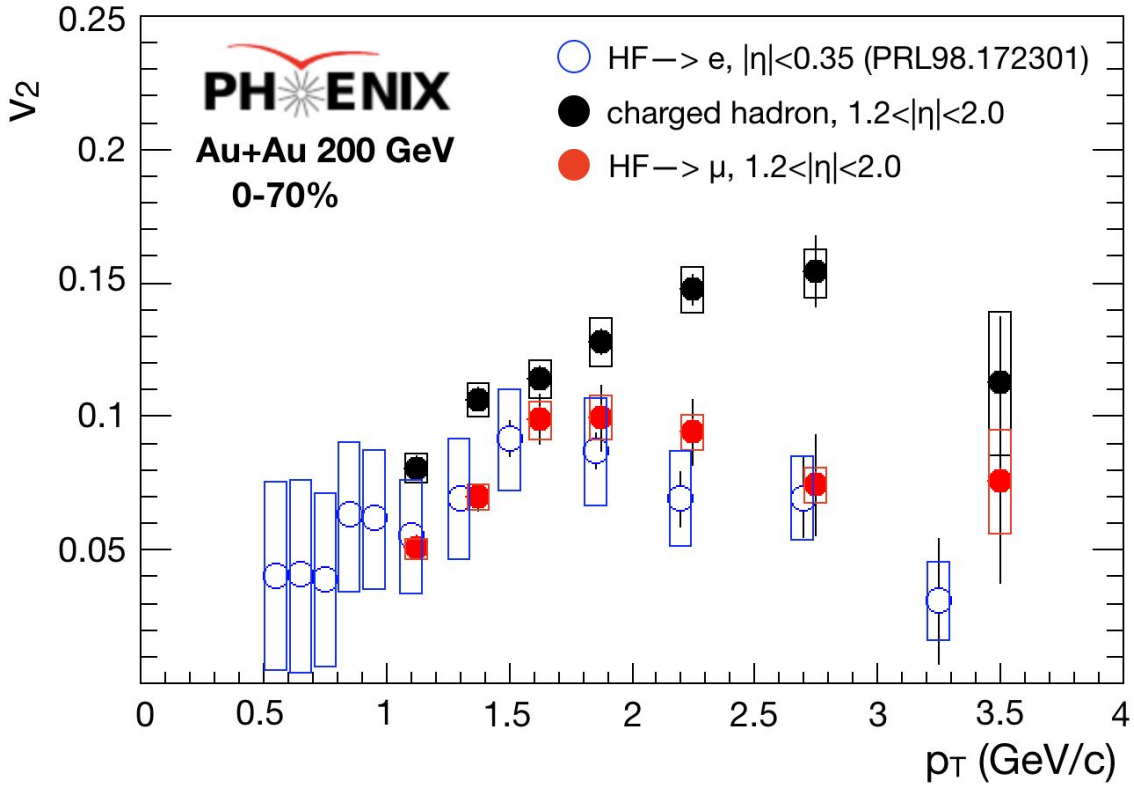


Heavy flavor J/Ψ

Elliptic flow

- Charged hadrons show strong elliptic flow in forward rapidity
- Heavy-flavor electron and muon show similar magnitude
- This indicated heavy quarks participate in the collective flow of the medium, but less than charged hadrons

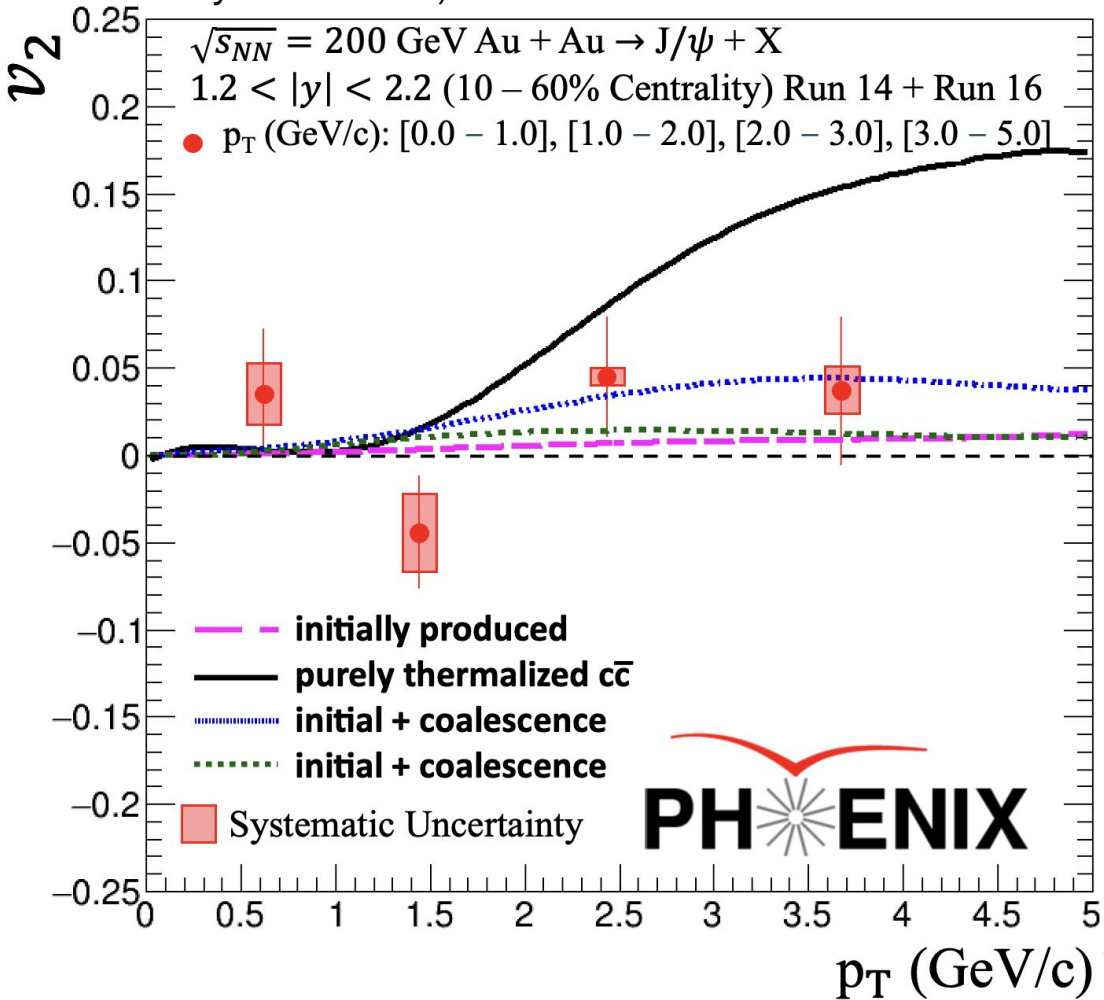
Phys. Rev. C 112, 034902



Elliptic flow

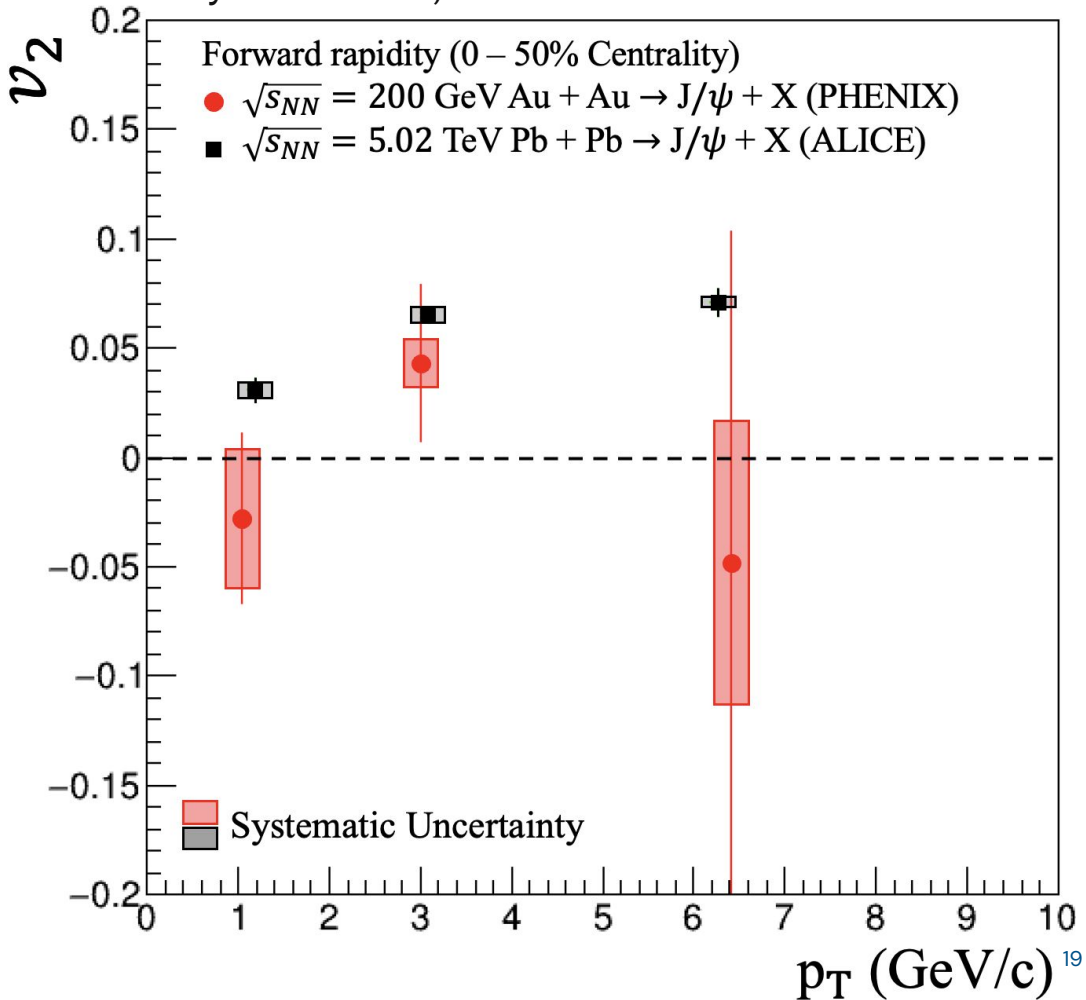
- Model comparisons :
  - Initially produced J/Ψ : formed in early hard scattering, expected small v_2
  - Regeneration via charm recombination : $c\bar{c}$ recombine in the medium, inherits collective flow
- Results indicate some hint of a recombination $c\bar{c}$ in the medium

Phys. Rev. C 112, 014904

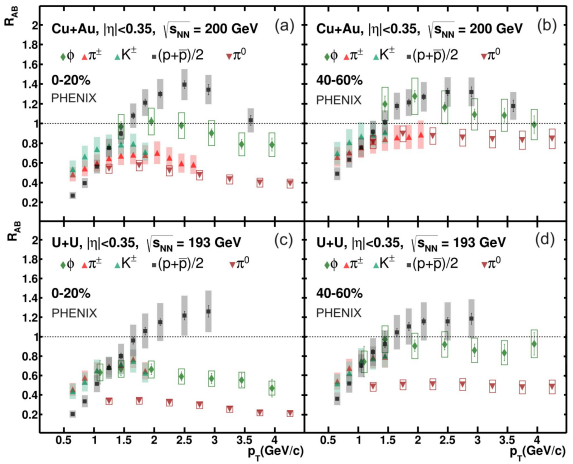


Elliptic flow

- PHENIX results at forward rapidity show large uncertainties but consistent with zero flow
- Forward and mid-rapidity results at RHIC are consistent, but with large uncertainties
- ALICE results show non-zero flow
- This could indicate J/Ψ regeneration at high energies



Results summarized



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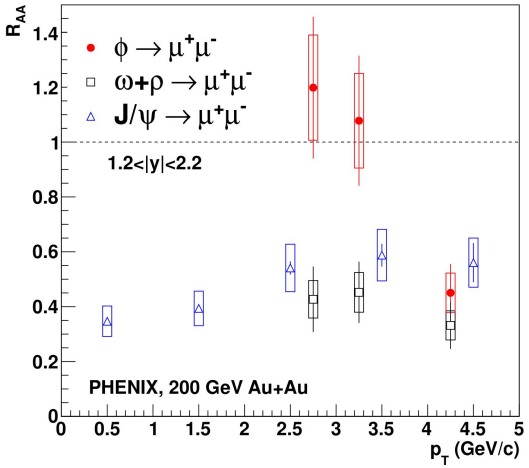
Baryon enhancement

Central collisions in large systems show almost twice p/π as p+p collision



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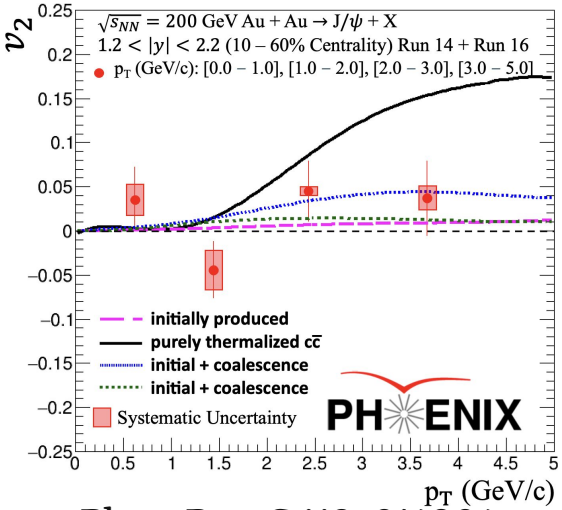
Strangeness enhancement

The ϕ−meson shows enhancement, while the other mesons are suppressed



Phys. Rev. C 112, 014904

Elliptic flow

The J/Ψ elliptic flow shows hint to recombination of $c\bar{c}$ in the medium

Thank you for your attention