Stony Brook University

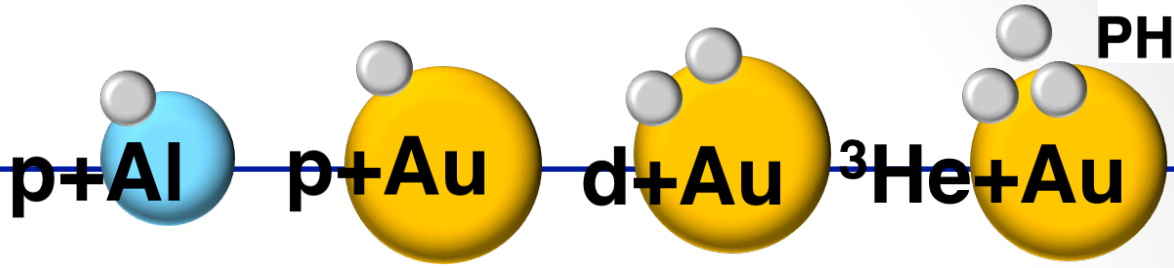
PHENIX

Systematic Study of Highly Asymmetric Systems Using π^0, $h^{\pm}$, ϕ Production at PHENIX

Norbert Novitzky for PHENIX collaboration

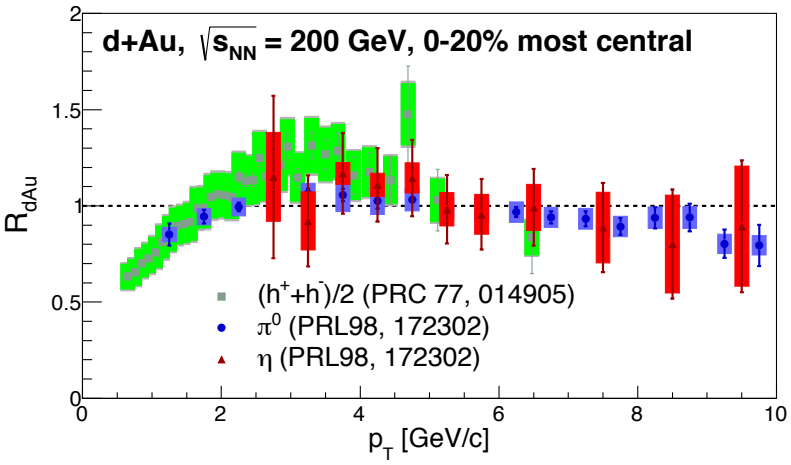
Stony Brook University

Outline

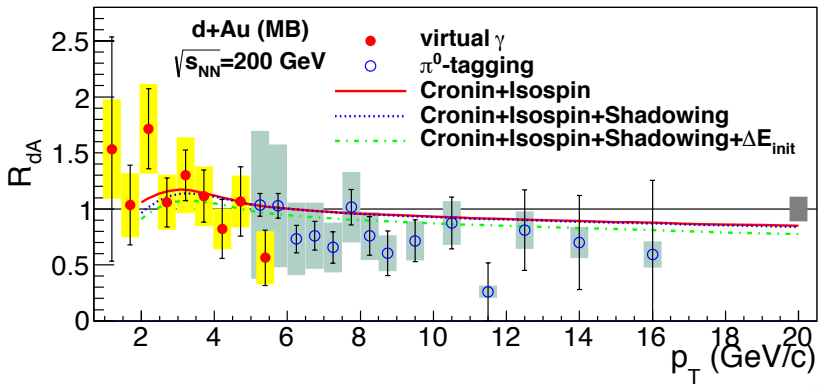


- Motivation:
  - Small system collisions and collectivity
- π^0 measurement at mid-rapidity: p+Au, d+Au and ^{3}He+Au:
  - Minimum bias
  - Centrality comparisons
  - Interpretations, model comparisons
- Nuclear modification at forward and backward rapidity:
  - Charged hadrons in p+Au and p+Al
  - ϕ meson in p+Al, p+Au and ^{3}He+Au
- Summary

Motivation



Phys. Rev. C **87** (2013), 054907



Why were we interested in d+Au collisions:

- To confirm the high-p_T hadron suppression in Au+Au is due to final state effects, and not cold nuclear matter (CNM) effects
- CNM effects include: k_T broadening, shadowing, CNM energy loss, …

Measured R_{dAu}:

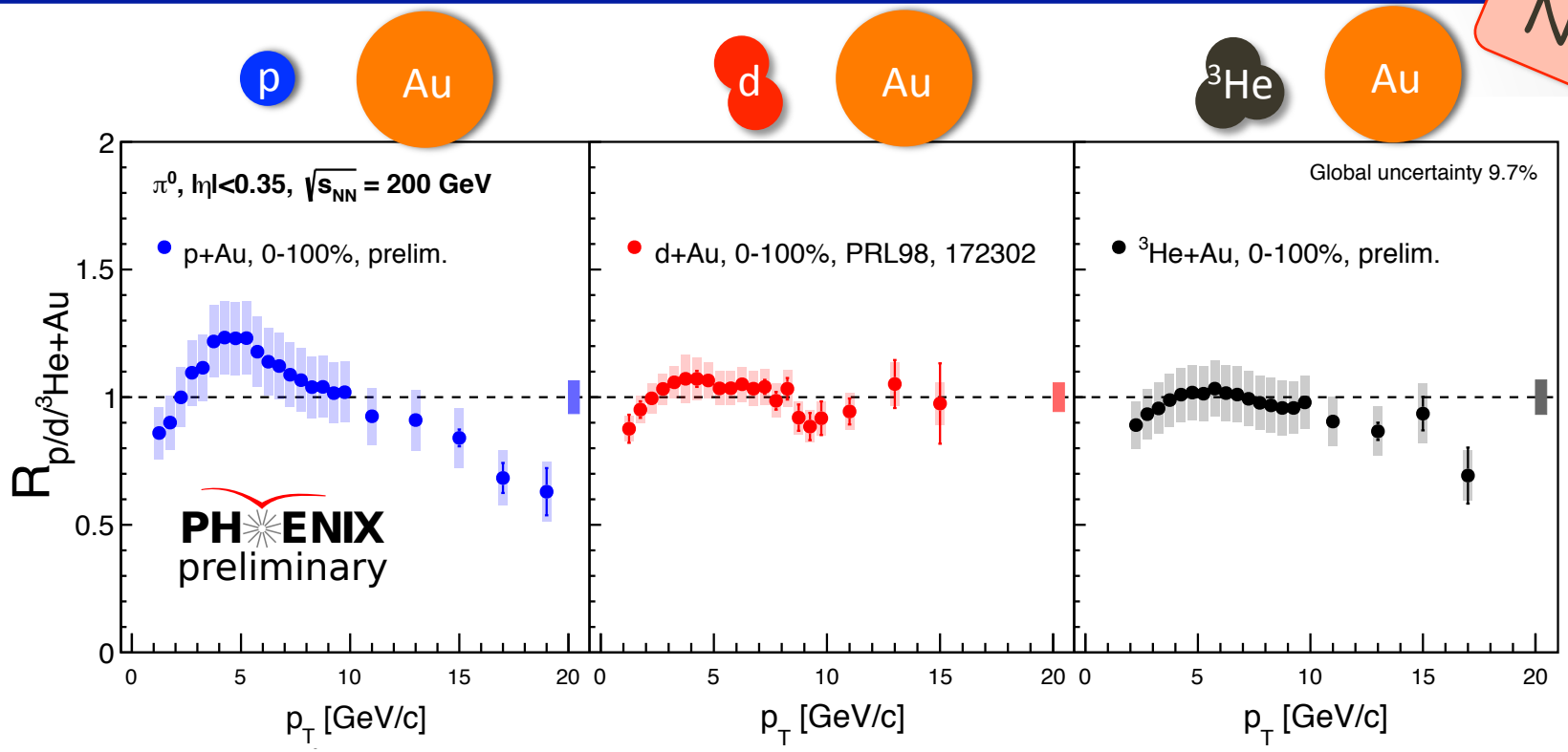
- Hadrons and direct photons are consistent with unity up to high-p_T

Strong flow like A+A is seen in most central d+Au collisions.
Is a mini-QGP formed?

Flow in small systems
Qiao Xu, Wed 11:20

Nuclear Modification, min. bias

NEW



Comparison of small system nuclear modifications:

- Enhancement at p_T = 5 GeV/c indicates a system size dependence

Is there a hint for suppressions at high-p_T?

π^0 in small systems
Nicole Apadula, Poster

R_{p+Au} – centralities

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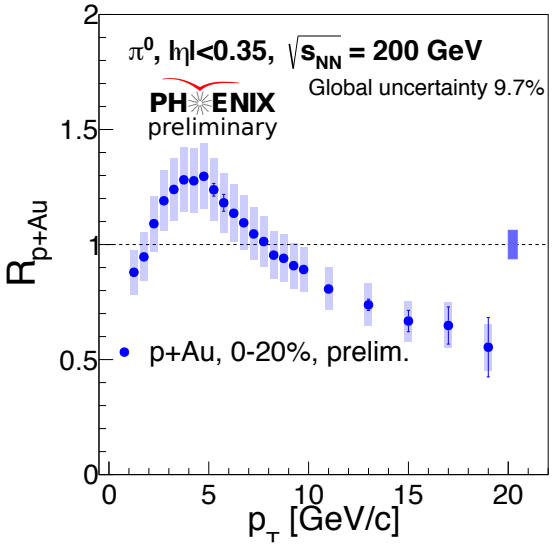

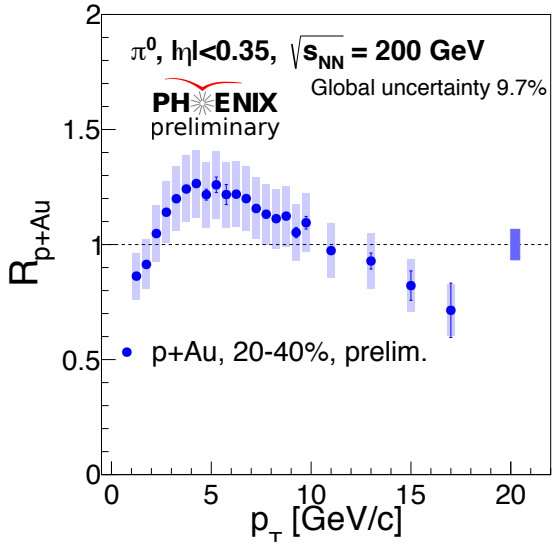

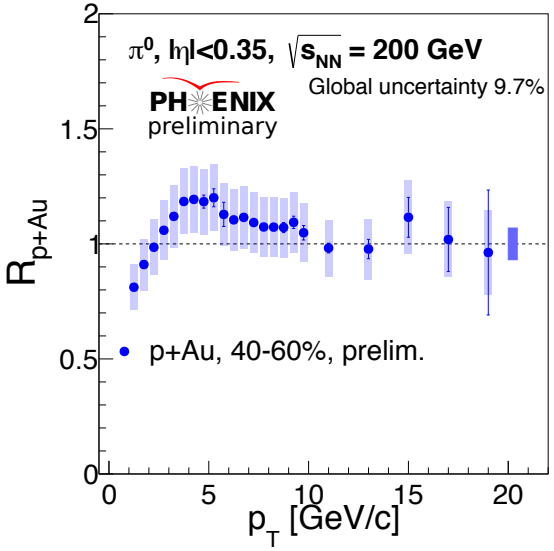

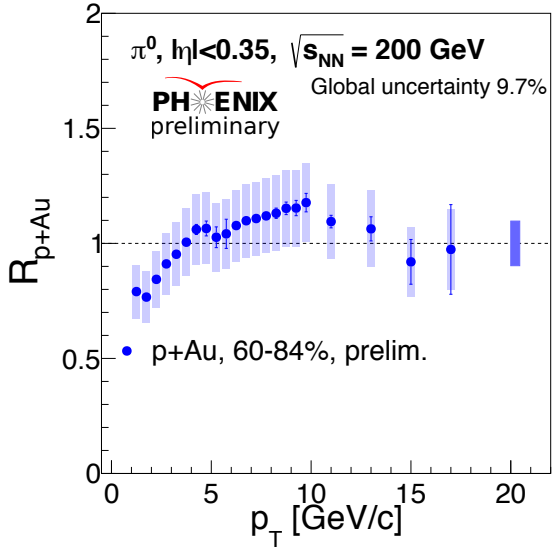

Nuclear modification in centralities:

- Centrality determined similarly as for large systems (PRC90,034902)
- **p+Au results shows large centrality dependence**

$R_{p/d+Au}$ – centralities

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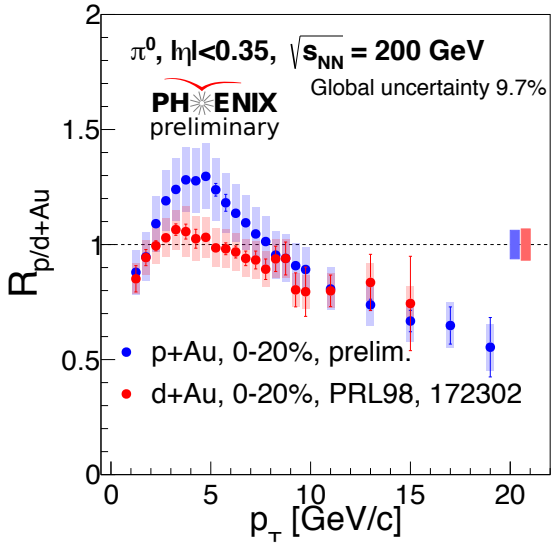

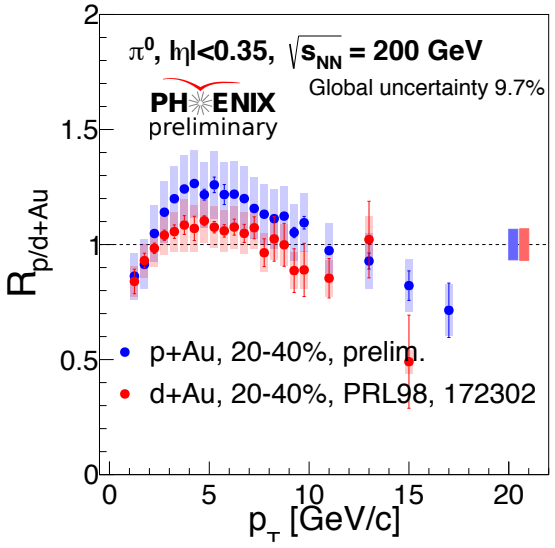

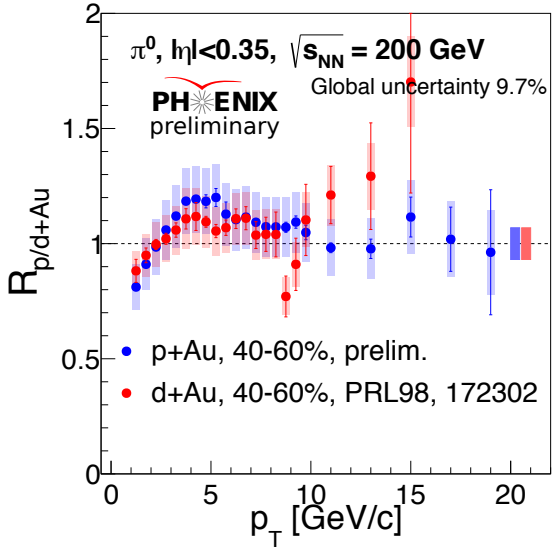

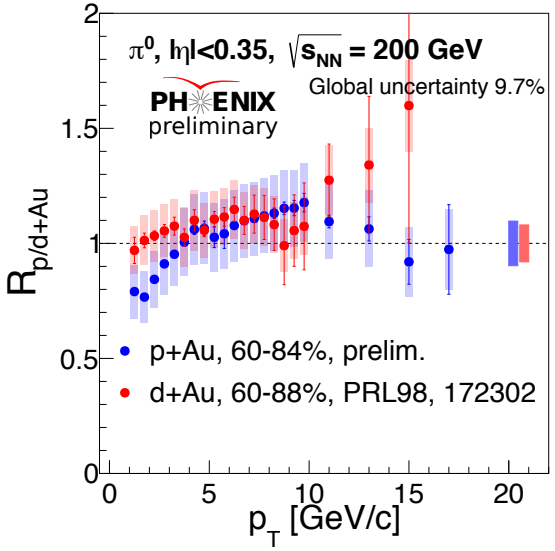

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- **d+Au results agrees with p+Au at high-p_T**

$R_{p/d/^3He+Au}$ – centralities

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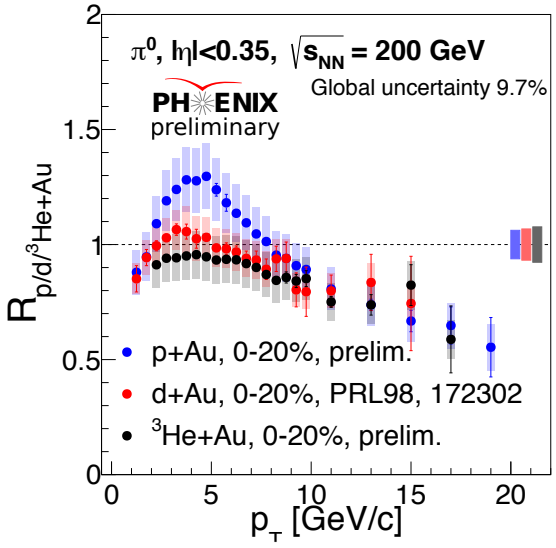
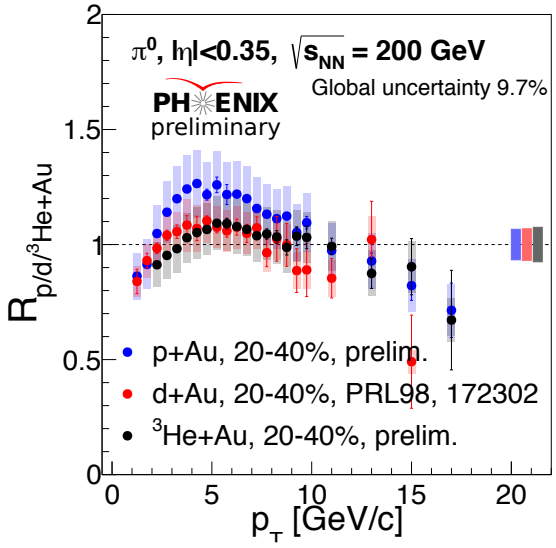
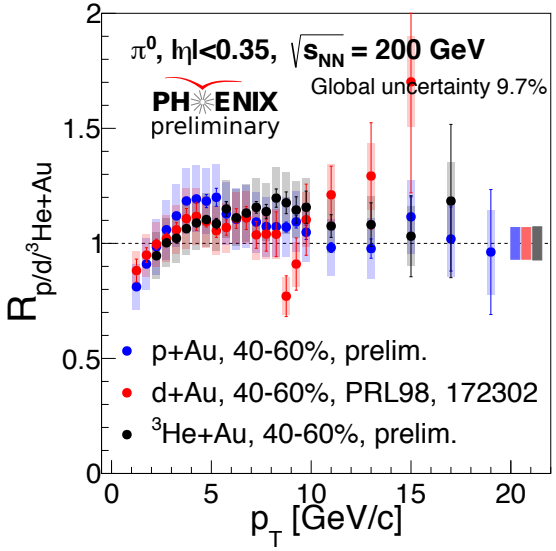
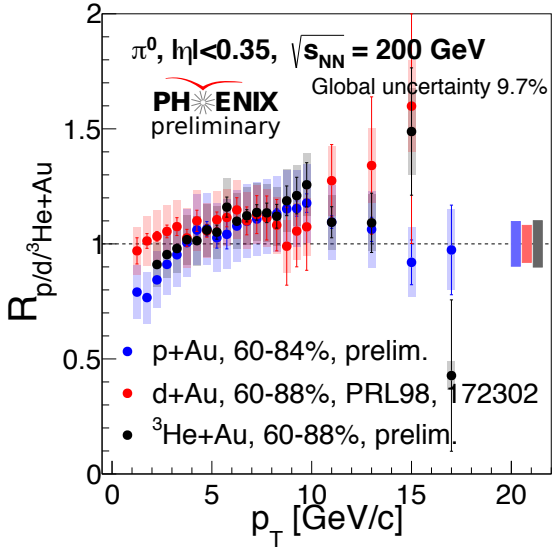








Nuclear modification in centralities:

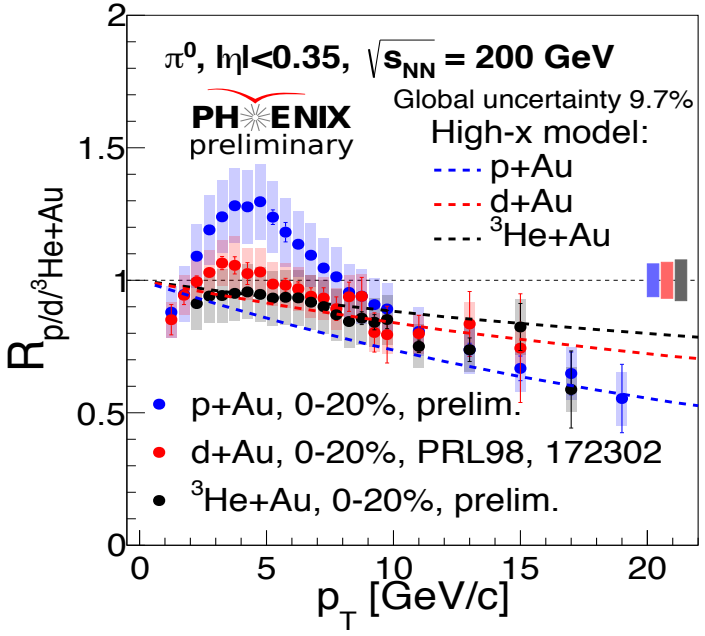
- Centrality determined similarly as for large systems (PRC90,034902)
- **p+Au results shows large centrality dependence**
- **d+Au results agrees with p+Au at high-p_T**
- **^{3}He+Au results agree with p+Au and d+Au at high-p_T**
- **At moderate p_T an ordering is seen in most central collisions**

High-x proton size fluctuations

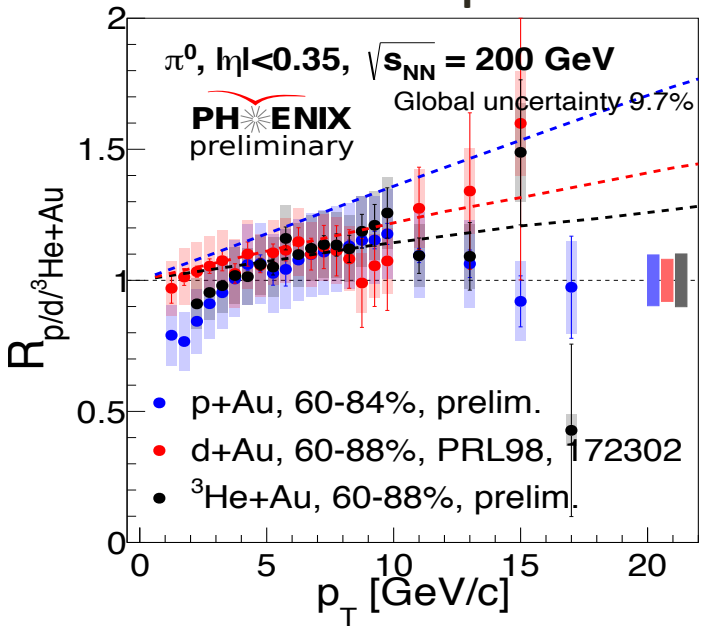
Model comparison

based on Phys.Rev. C94 (2016), 024915
private comm. with D. McGlinchey

Most Central



Most Peripheral

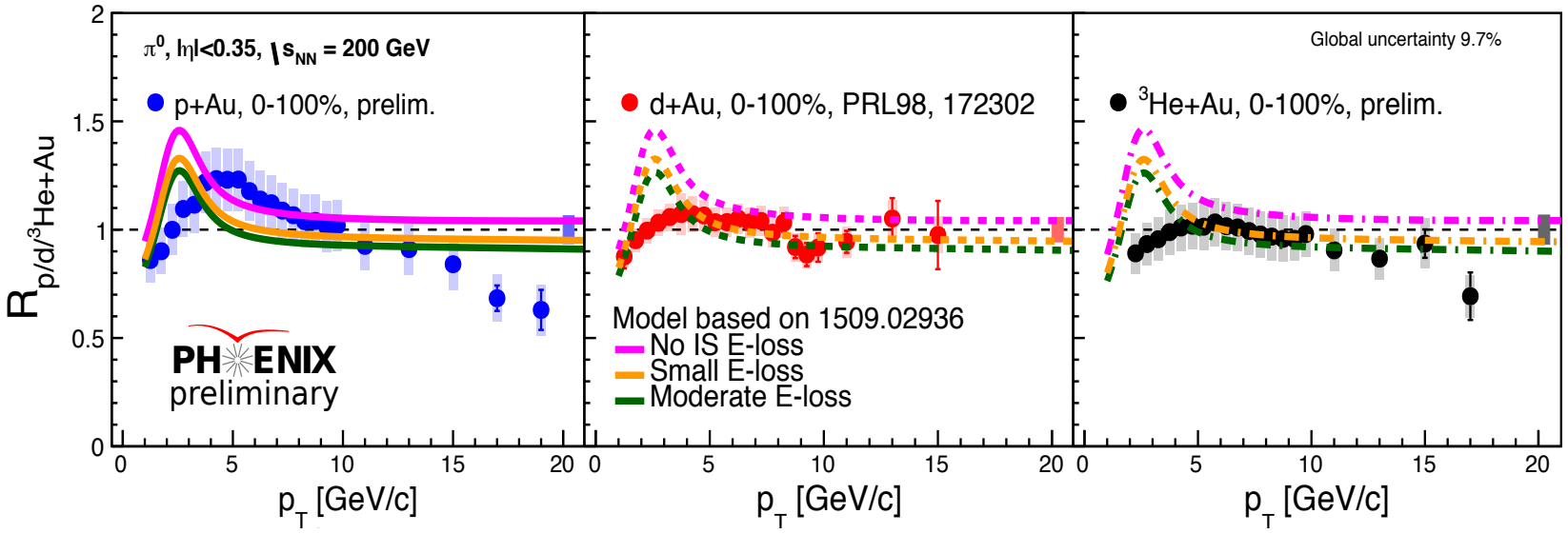


- The model predicts clear ordering in most central and peripheral collisions
- The predicted trend is not seen in data

Cold nuclear energy loss

Model comparison

based on Phys.Rev.D 93, 074030
private comm. with I. Vitev



- Different energy loss scenarios (*moderate*) are comparable to the data at high-p_T

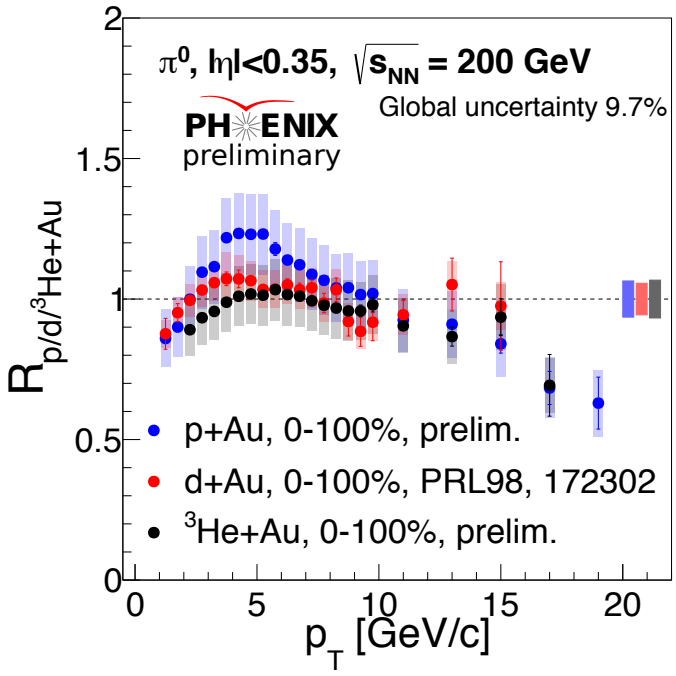
- Enhancement at low-p_T misses the position and the system dependency

Multiple scattering in HIJING++

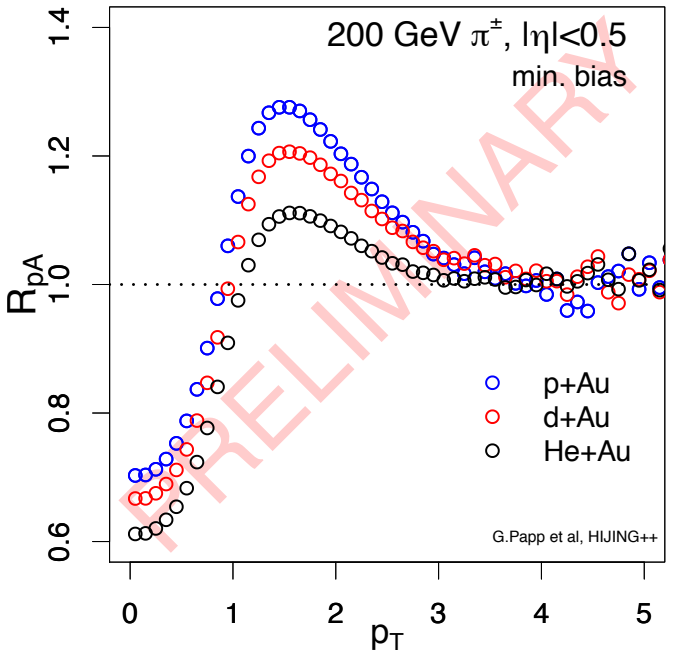
Model comparison

based on 1701.08496
private comm. with G. Papp

PHENIX Data



HIJING++ simulation



- HIJING++ simulation shows similar trend between collision systems: multiple scattering + shadowing effect
- In HIJING++ the Cronin peak around p_T = 1.5-2GeV/c, much lower than in the data (p_T ~ 5 GeV/c)

Summary of model comparisons

	Enhancement		
	Ordering	Peak position	High-p_T
High-x proton size fluc.	☐	☐	✗
Cold Nuclear E-loss	✗	✗	✓
HIJING++, multiple scatt.	✓	✗	☐

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What is the ***physics mechanism*** behind the enhancement?

Summary of model comparisons

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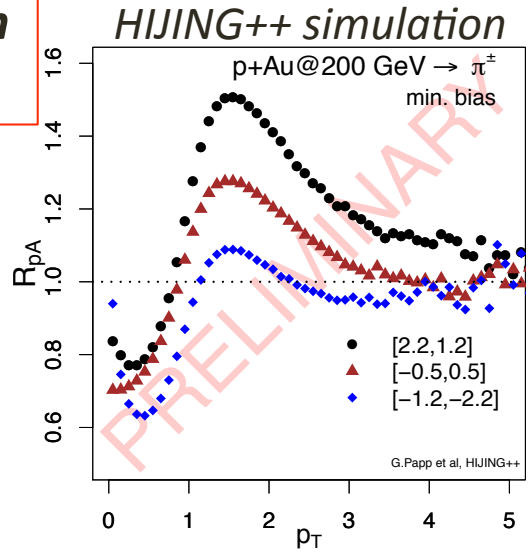
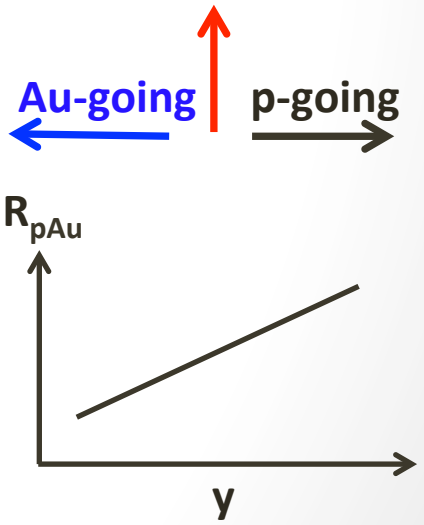
	Ordering	Peak position	High-p_T
High-x proton size fluc.	☐	☐	✗
Cold Nuclear E-loss	✗	✗	✓
HIJING++, multiple scatt.	✓	✗	☐

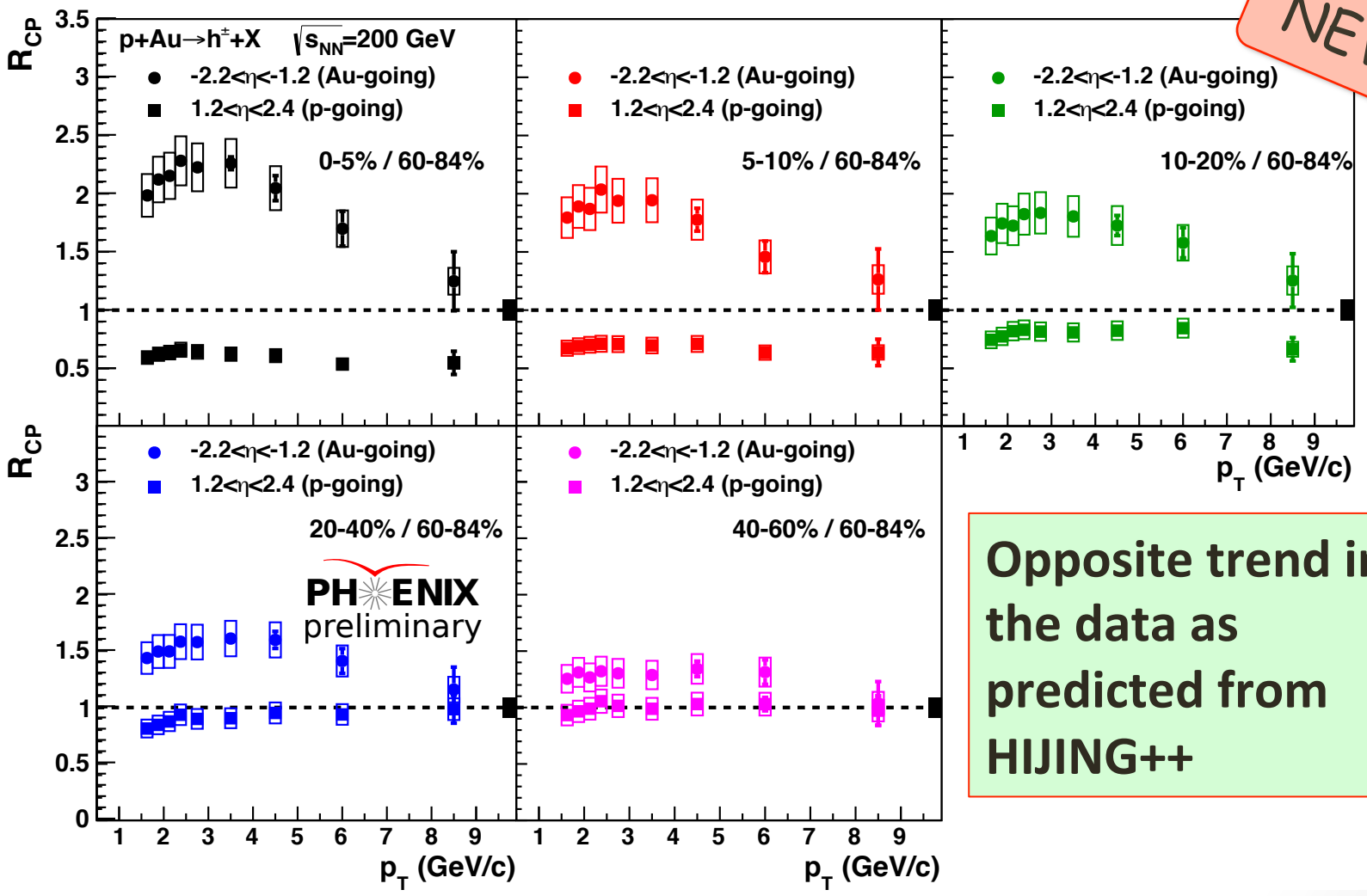
What is the ***physics mechanism*** behind the enhancement?

The multiple scattering in HIJING predicts **larger** (**smaller**) enhancement in the **forward** (**backward**) in comparison to **mid-rapidity**



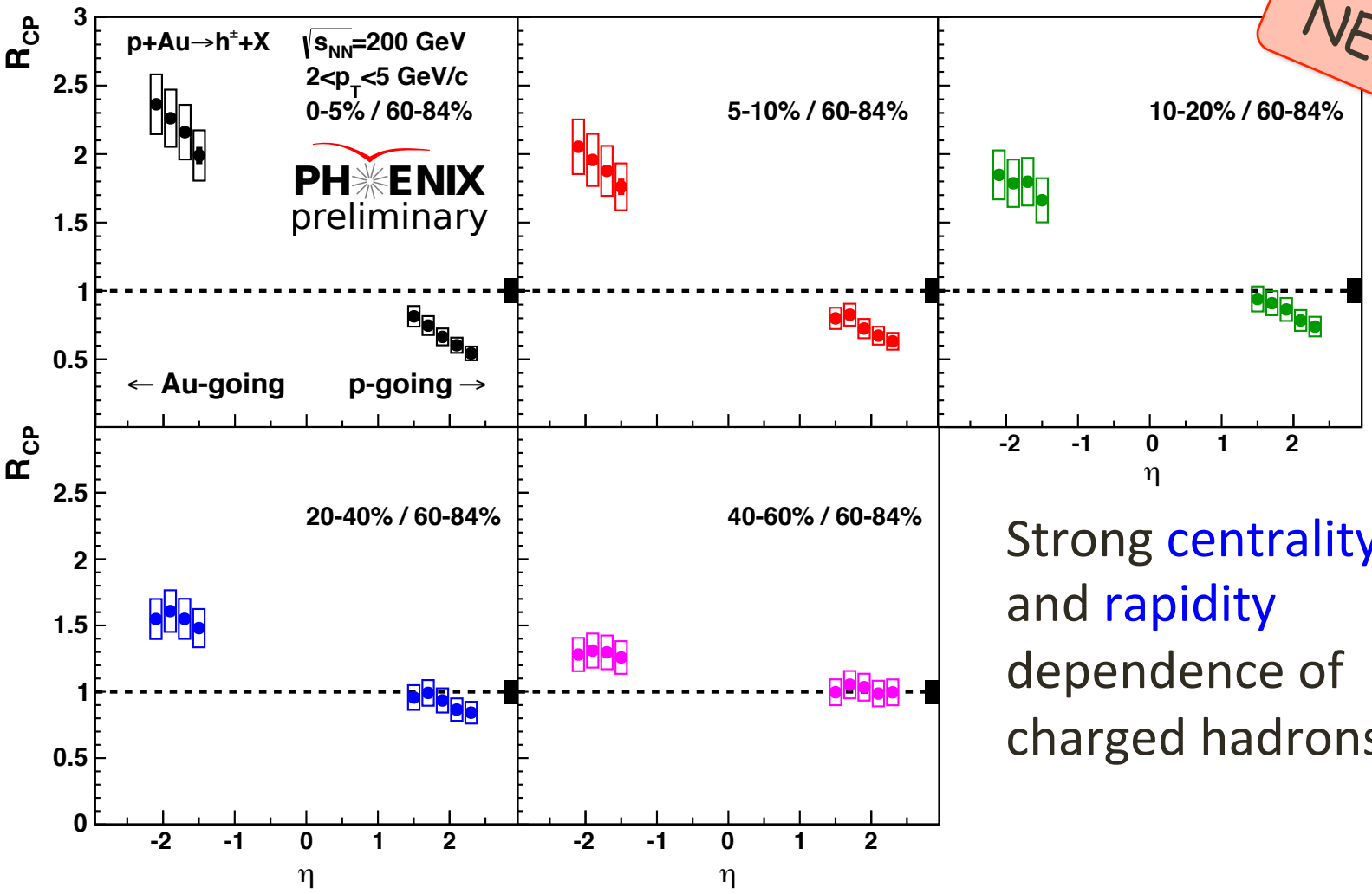


Looking forward and backward



Opposite trend in the data as predicted from HIJING++

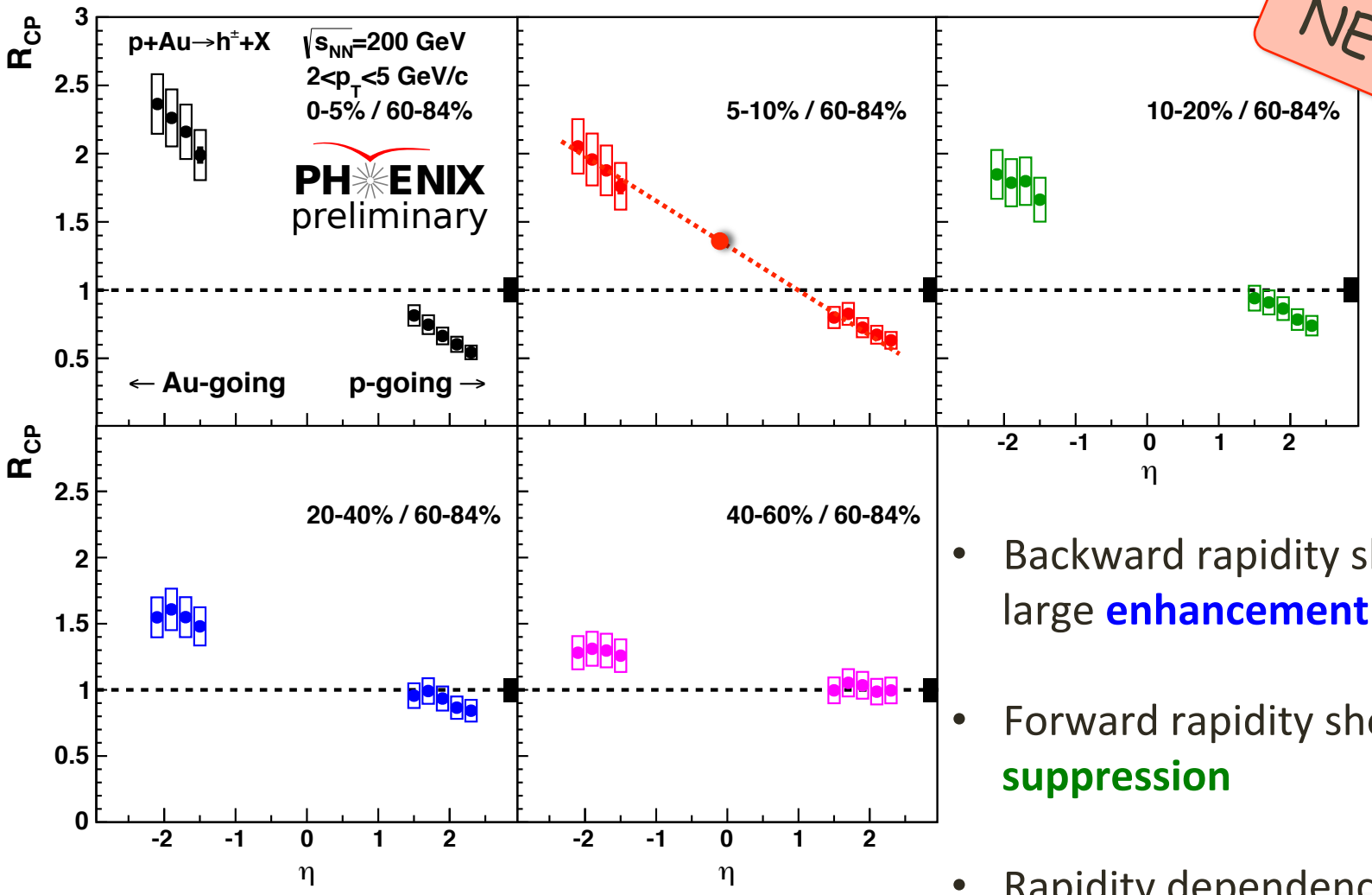
Looking forward and backward



Strong centrality and rapidity dependence of charged hadrons

Opposite trend in the data as predicted from HIJING++

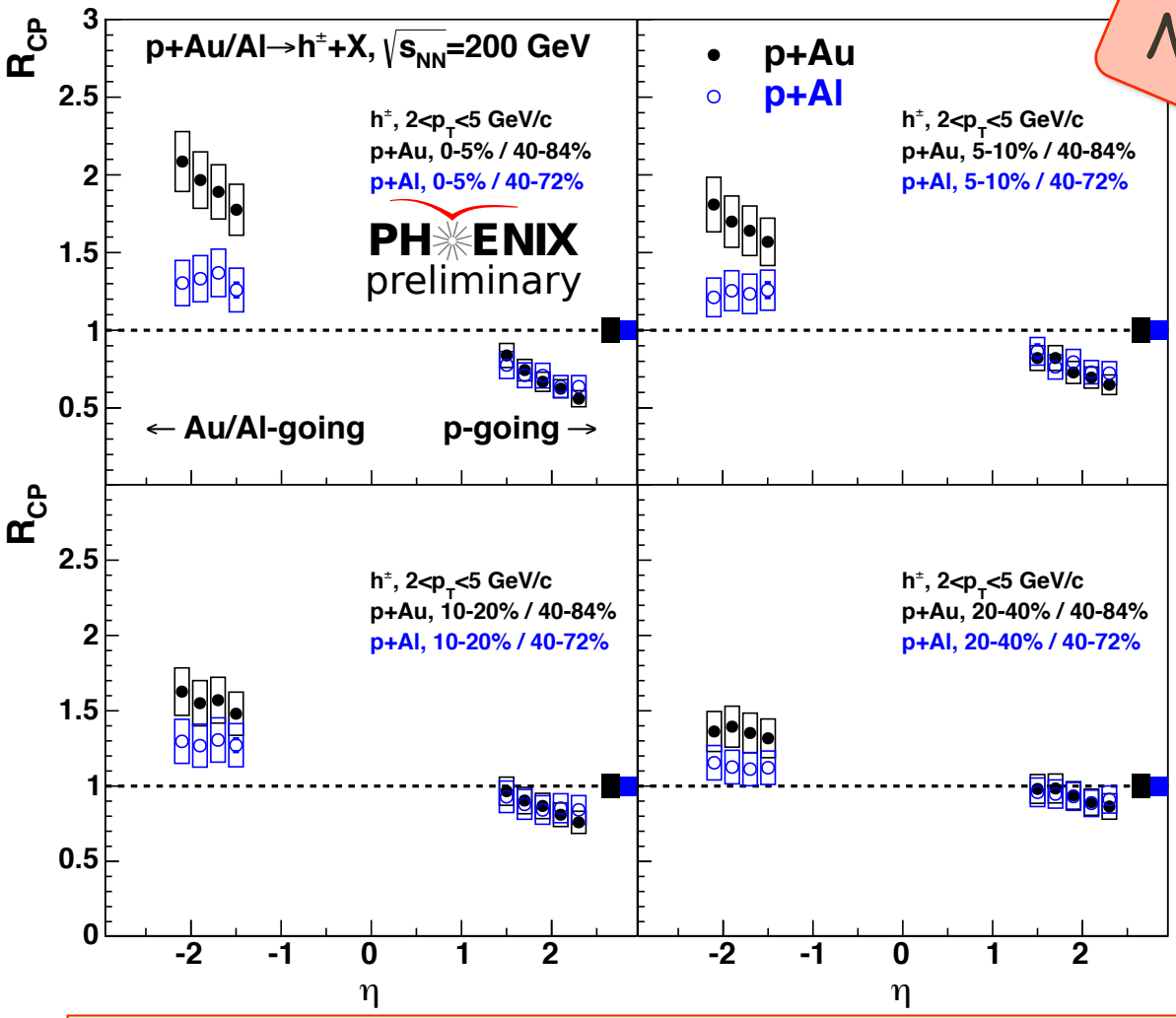
Looking forward and backward



- Backward rapidity shows large **enhancement**
- Forward rapidity shows **suppression**
- Rapidity dependence follows a **linear function**

Opposite trend in the data as predicted from HIJING++

System size dependence



NEW

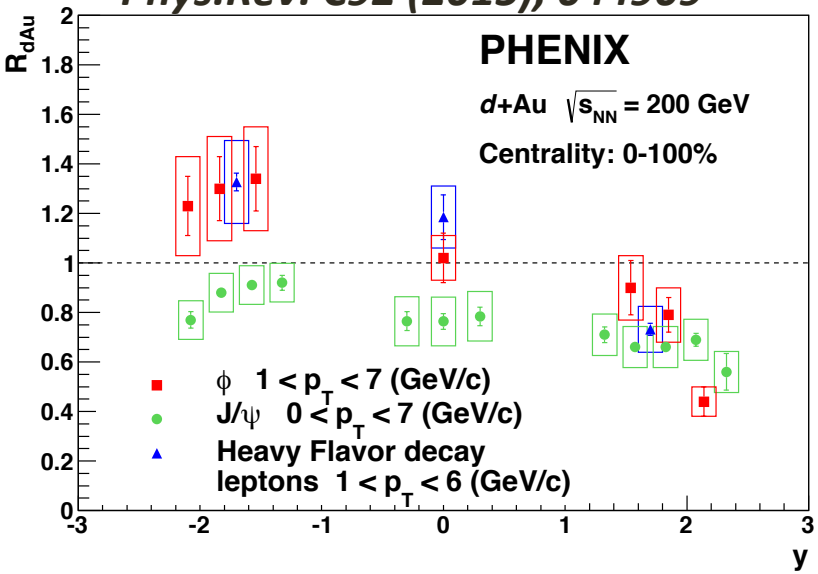
Comparison of R_{CP} in same centralities in p+Au and p+Al collisions:

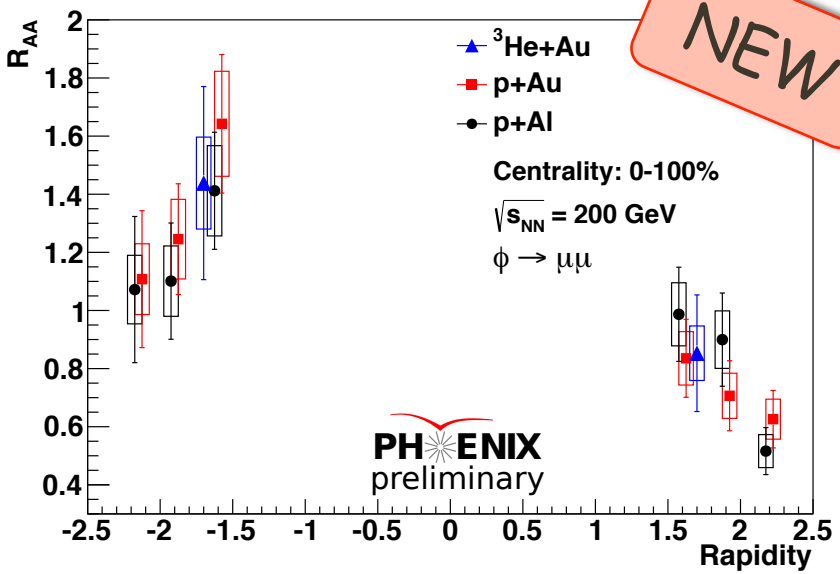
- **Forward** hadrons shows **same suppression**
- **Backward** hadron production show smaller **enhancement** in p+Al than in p+Au collisions

What is the physics behind the backward enhancement?
Is it connected with the mid-rapidity enhancement?

Comparison to ϕ production

Phys.Rev. C92 (2015), 044909





$\phi(s\bar{s})$ production as function of rapidity:

- The minimum bias nuclear modification factor is comparable in p+Al, p+Au, d+Au and ^{3}He+Au collisions at $\sqrt{s}$ = 200 GeV.
- The background enhancement shows no observable deviation between the systems

ϕ in small systems
Murad Sarsour, Poster

Heavy flavor in small systems
Sanghoon Lim, Wed 17:10

Is there a particle species (mass) dependency in the rapidity distribution?

Summary

- PHENIX measured π^0 production at mid-rapidity in p+Au, d+Au and ^{3}He+Au at 200 GeV.
  - $R_{p/d/^3He+Au} < 1$ at high-p_T
  - Moderate-p_T indicates ordering of $R_{pAu} > R_{dAu} > R^3_{HeAu}$ in min. bias and most central collisions.

- Charged hadron R_{CP} in p+Au and p+Al:
  - Backward rapidity is enhanced in both p+Au and p+Al
    - $R_{pAu} > R_{pAl}$
  - Forward rapidity is suppressed in both p+Au and p+Al
    - $R_{pAu} = R_{pAl}$

- ϕ measurement in minimum bias p+Al, p+Au, d+Au and He+Au:
  - The data shows no dependency on system size for the R_{AA}

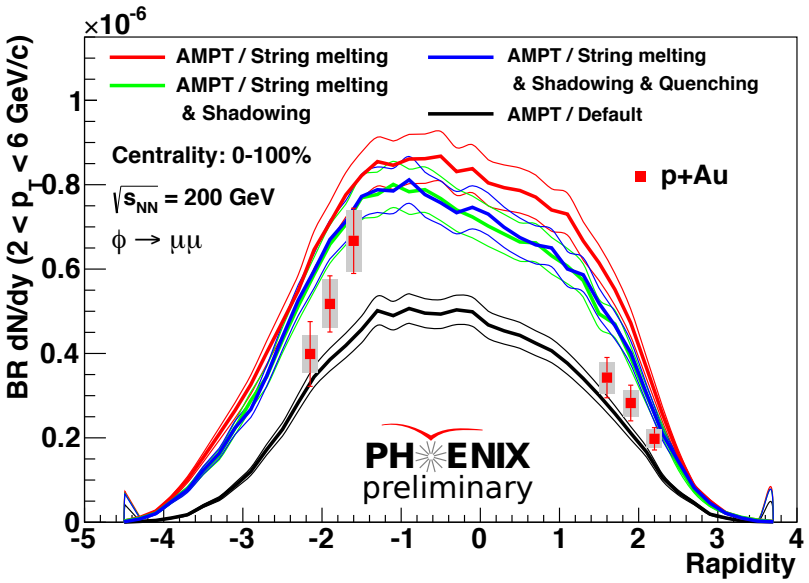
Backups

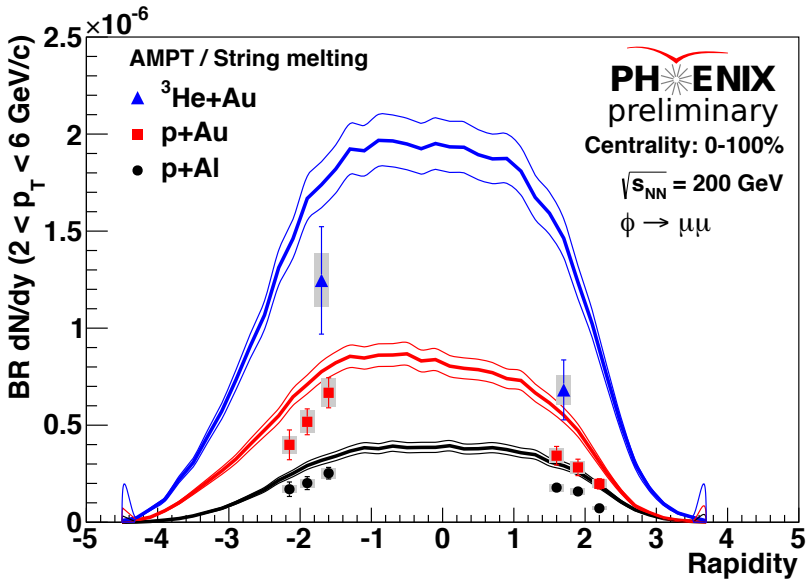
x-value for enhancement

y	$p_T = 2$ GeV/c	$p_T = 3$ GeV/c	$p_T = 4$ GeV/c	$p_T = 5$ GeV/c
-2.2	9.07e-02	1.36e-01	1.81e-01	2.26e-01
-2.0	7.43e-02	1.11e-01	1.48e-01	1.85e-01
-1.8	6.08e-02	9.09e-02	1.21e-01	1.51e-01
-1.6	4.98e-02	7.45e-02	9.92e-02	1.24e-01
-1.4	4.08e-02	6.10e-02	8.12e-02	1.01e-01
-1.2	3.34e-02	4.99e-02	6.65e-02	8.31e-02
0.0	1.00e-02	1.50e-02	2.00e-02	2.50e-02
1.2	3.03e-03	4.53e-03	6.03e-03	7.54e-03
1.4	2.48e-03	3.71e-03	4.94e-03	6.17e-03
1.6	2.03e-03	3.04e-03	4.04e-03	5.05e-03
1.8	1.66e-03	2.48e-03	3.31e-03	4.14e-03
2.0	1.36e-03	2.03e-03	2.71e-03	3.39e-03
2.2	1.11e-03	1.67e-03	2.22e-03	2.77e-03

Table 1: x-value calculation: $x = \sqrt{p_T^2 + m_q^2}/\sqrt{s} \cdot e^{-y}$, where $m_q = 200$ MeV

ϕ and AMPT comparison





High-x proton fluctuation model