PHENIX results on collectivity in small systems

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Vanderbilt University

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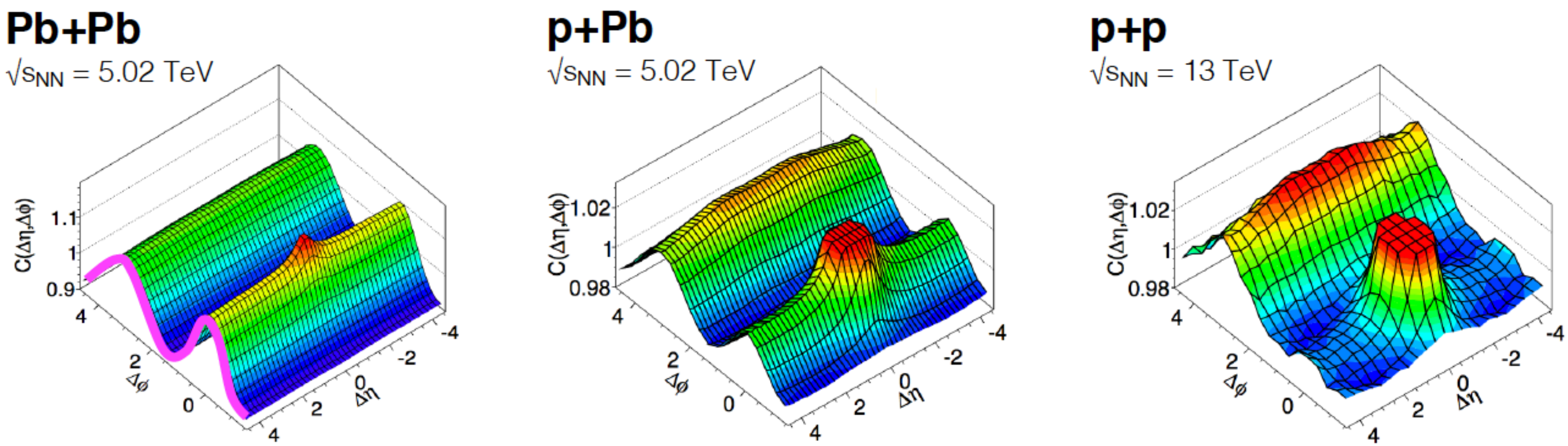
Motivation



Phys. Rev. Lett. 116, 172301

- Ridge observed in small systems
- Where does the flow in small systems come from?
  - Initial geometry translated into final flow
  - Initial state momentum correlation

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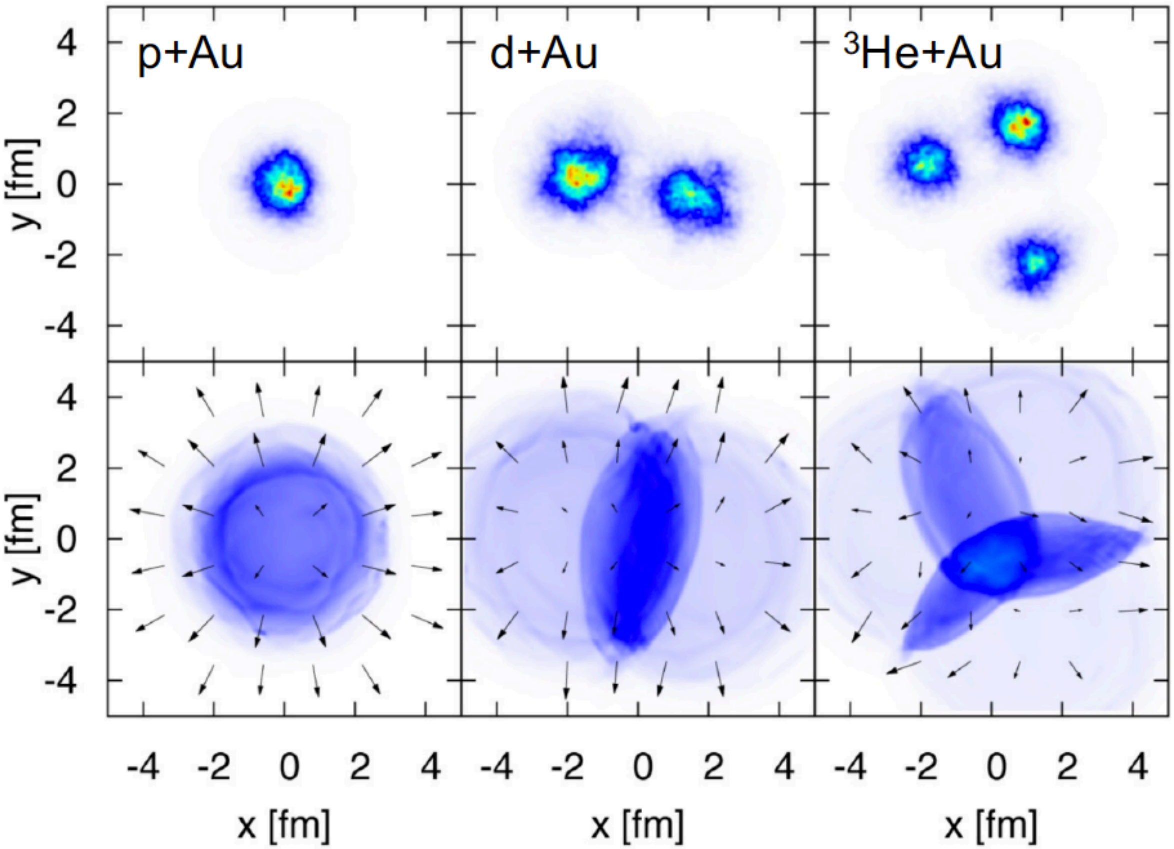
Geometry scan



- $\varepsilon_2(^3HeAu) \sim \varepsilon_2(dAu) > \varepsilon_2(pAu)$
- $\varepsilon_3(^3HeAu) > \varepsilon_3(dAu) \sim \varepsilon_3(pAu)$

?

- $v_2(^3HeAu) \sim v_2(dAu) > v_2(pAu)$
- $v_3(^3HeAu) > v_3(dAu) \sim v_3(pAu)$

Ref : Reaching for the horizon: The 2015 long range plan for nuclear science

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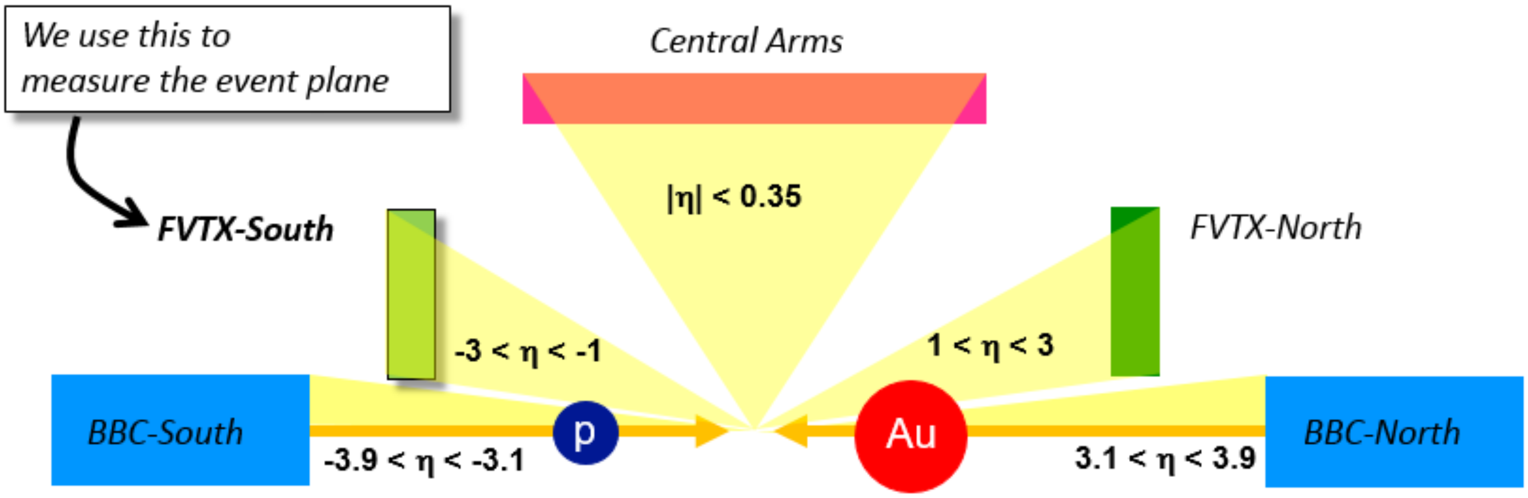
Experimental method

We used event plane method to calculate v_2



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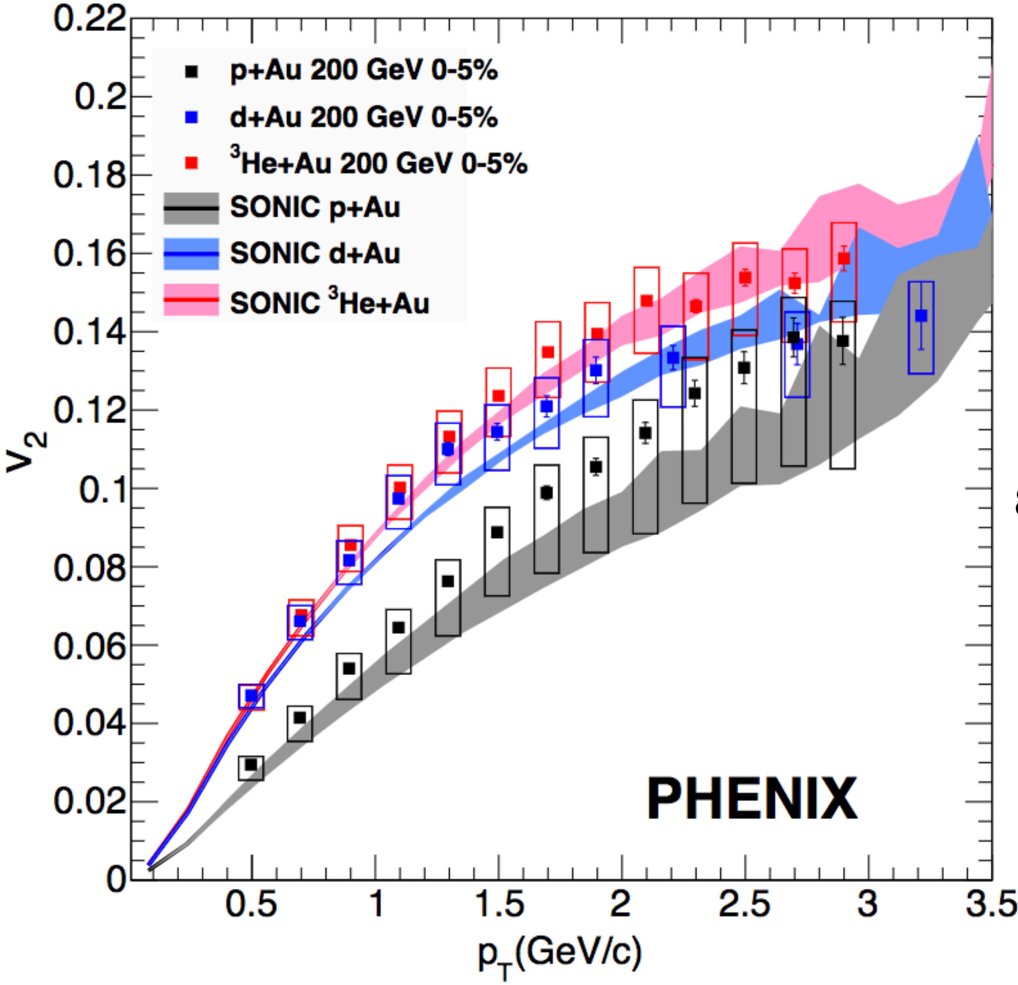
GEOMETRY SCAN

v_2 in p/d/^{3}He+Au



$\varepsilon_2(^3\text{HeAu}) \sim \varepsilon_2(\text{dAu}) > \varepsilon_2(\text{pAu})$

- $v_2(^3\text{HeAu}) \sim v_2(\text{dAu}) > v_2(\text{pAu})$, consistent with eccentricity
- SONIC model describes the data well

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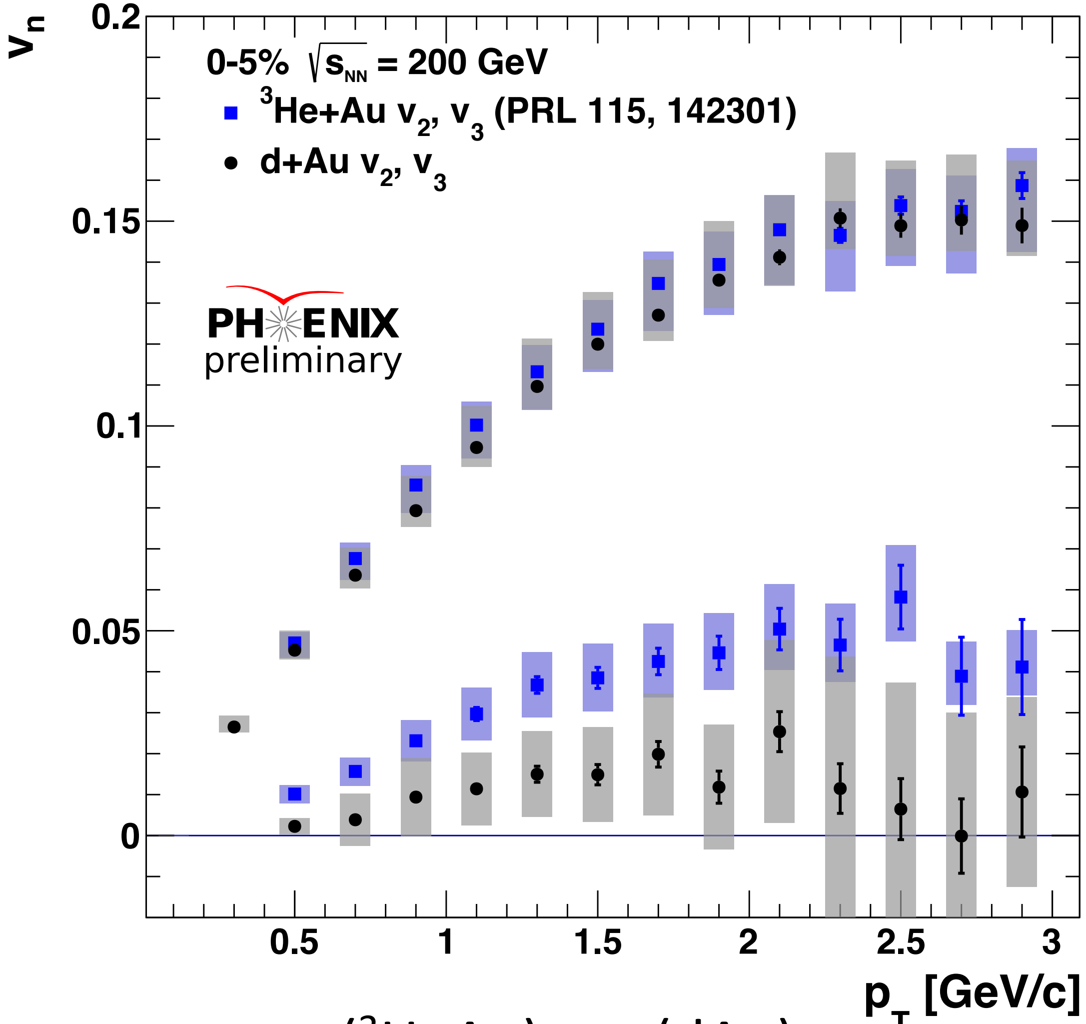
v_3 in d/^{3}He+Au



v_2

$\varepsilon_3(^3HeAu) > \varepsilon_3(dAu)$

v_3

- $v_3(^3HeAu) > v_3(dAu)$
- Initial geometry translates into final state flow

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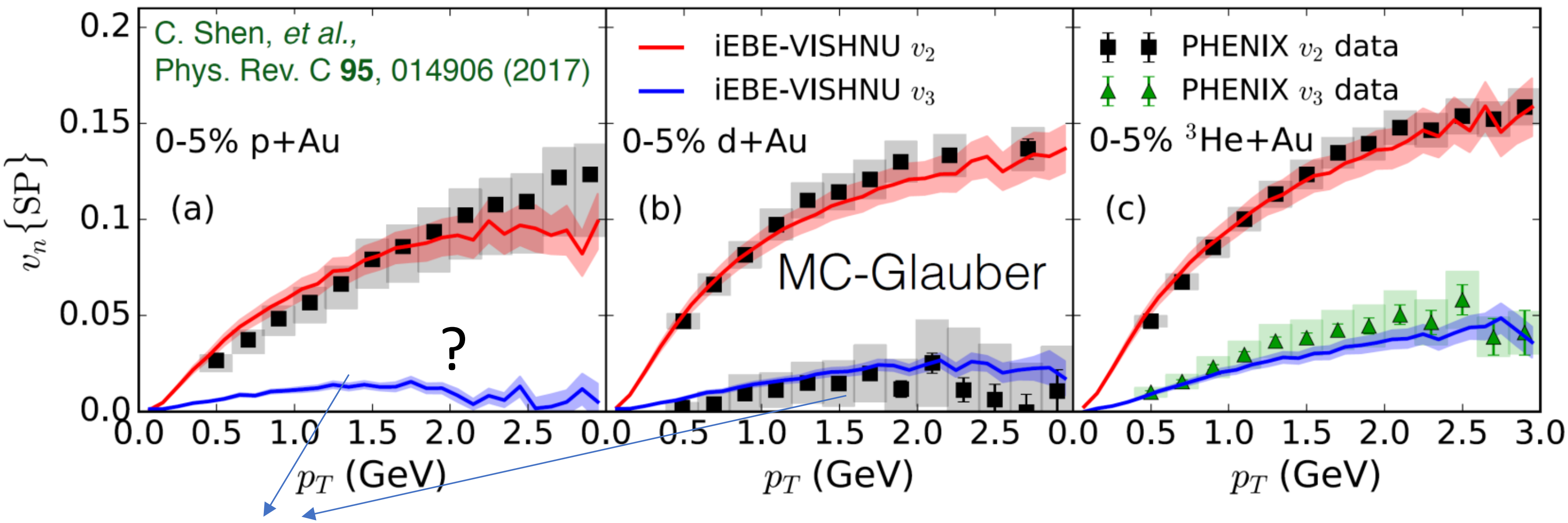
Theory and the combined v_2/v_3 data



Look for updates at QM18

Spatial eccentricity	p+Au	d+Au	^{3}He+Au
$\langle\varepsilon_2\rangle$	0.23±0.01	0.54±0.04	0.50±0.02
$\langle\varepsilon_3\rangle$	0.16±0.01	0.18±0.01	0.28±0.02

- Simultaneous description of both v_2 and v_3 provides a unique model test: excellent agreement with hydro for all available measurements.

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FLOW OF IDENTIFIED PARTICLES

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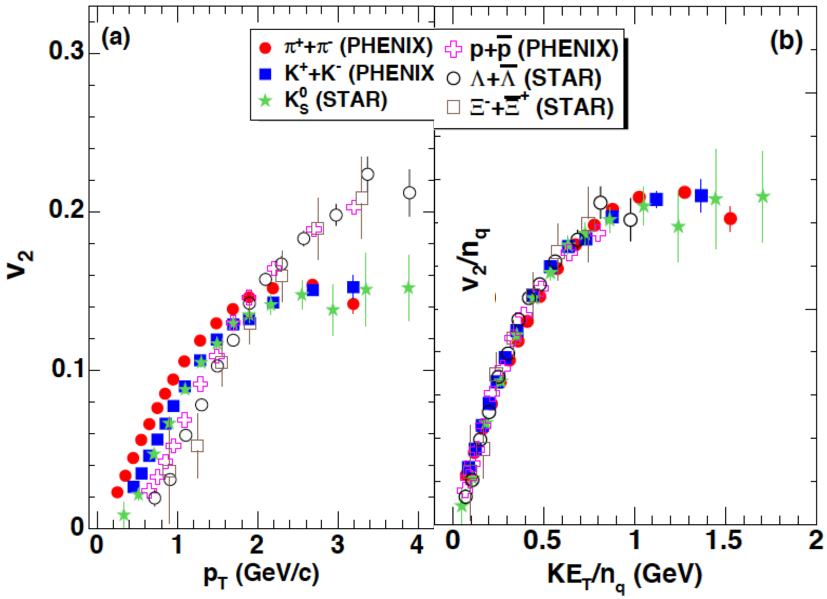
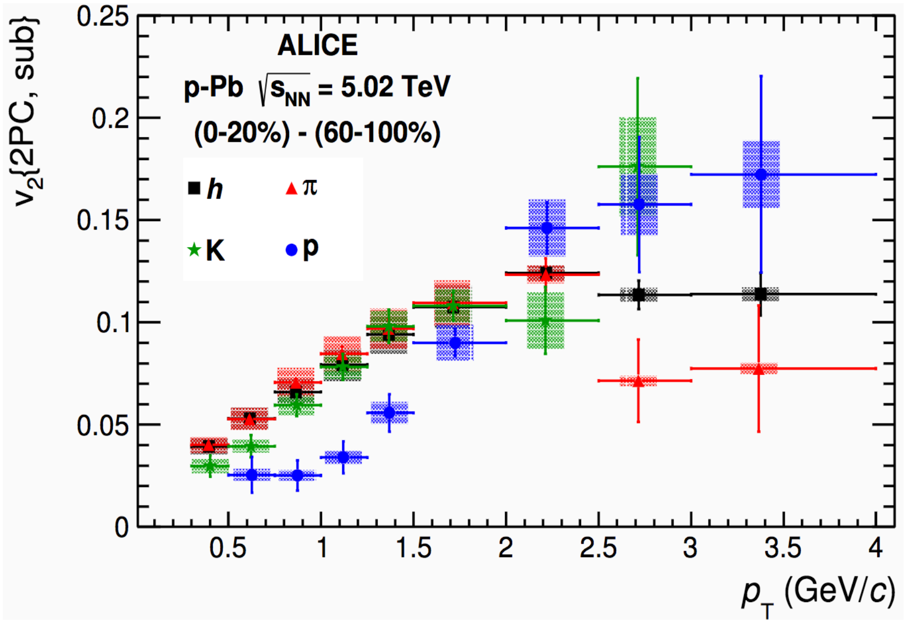
Identified particle flow

Phys.Rev.Lett.98, 162301(2007)



Quark number scaling in Au+Au at 200 GeV

Phys.Lett.B726, 164 (2013)



Mass ordering of v_2 in p+Pb at 5 TeV

What happens in small systems at RHIC energies ?

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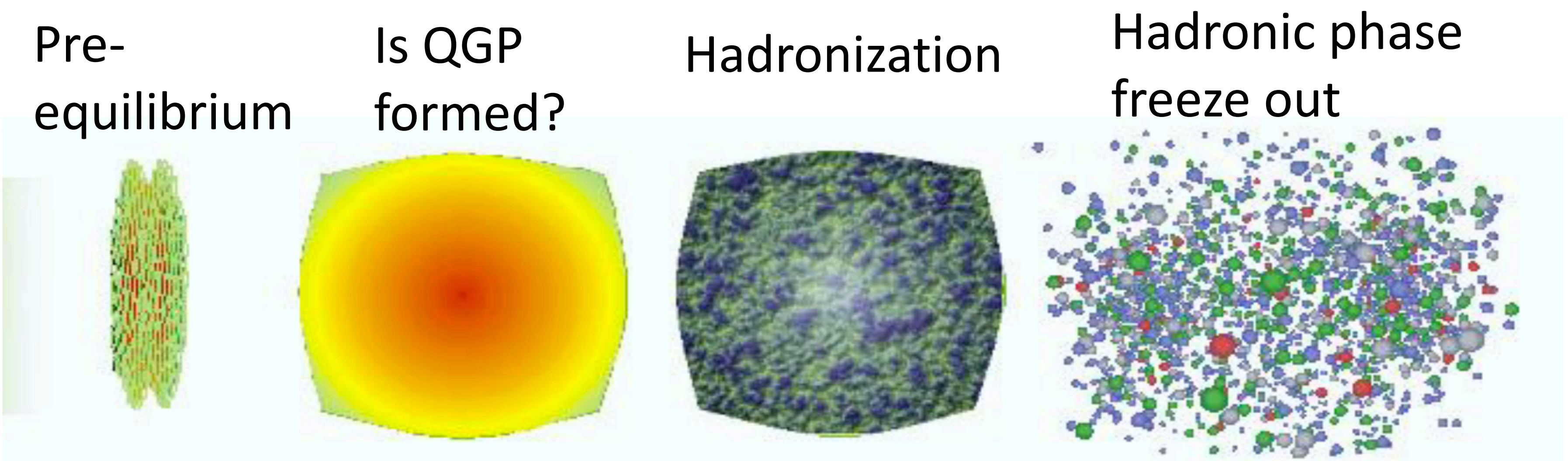
Evolution of the collision



Models compared to data	What we want to learn?
SONIC vs superSONIC	Role of pre-flow
SONIC and iEBE vs AMPT	Role of hadronization by recombination
iEBE and AMPT with vs without hadronic rescattering	Role of hadronic rescattering

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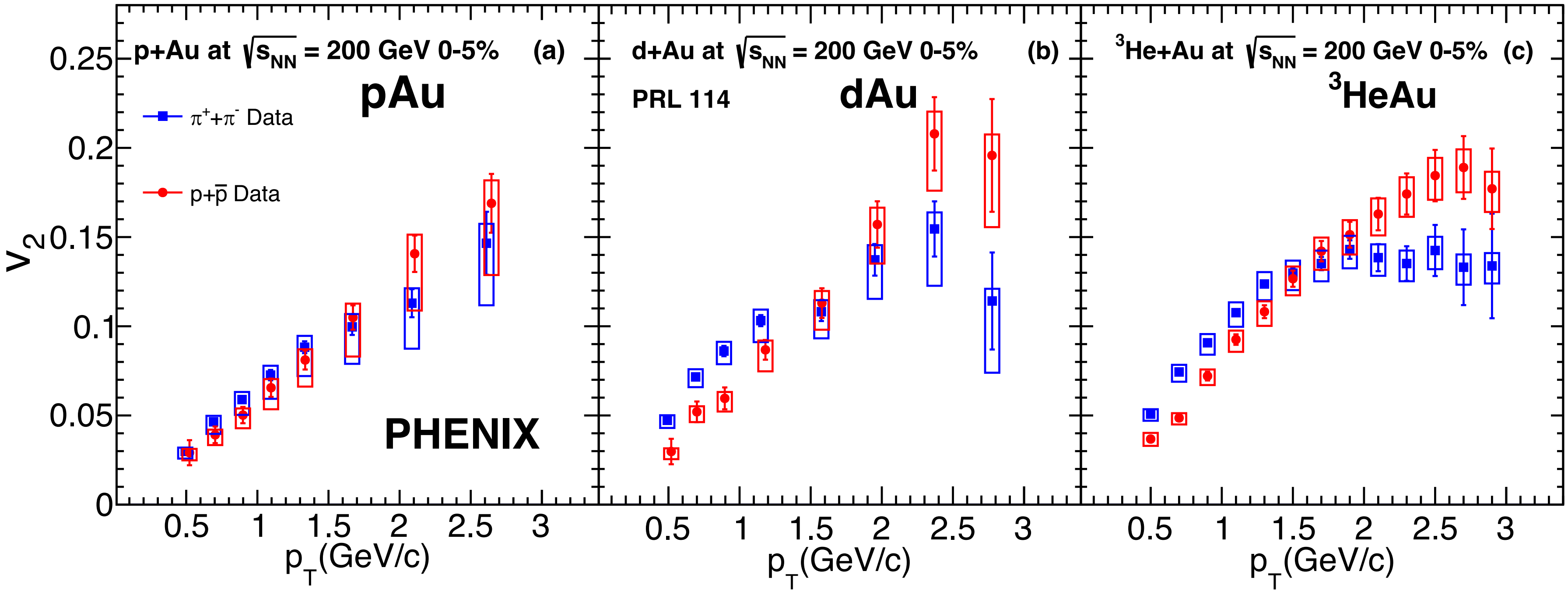
Identified particle v_2 in p/d/^{3}He+Au



- Mass splitting observed in all three systems
- Splitting more obvious in d/^{3}He+Au than in pAu

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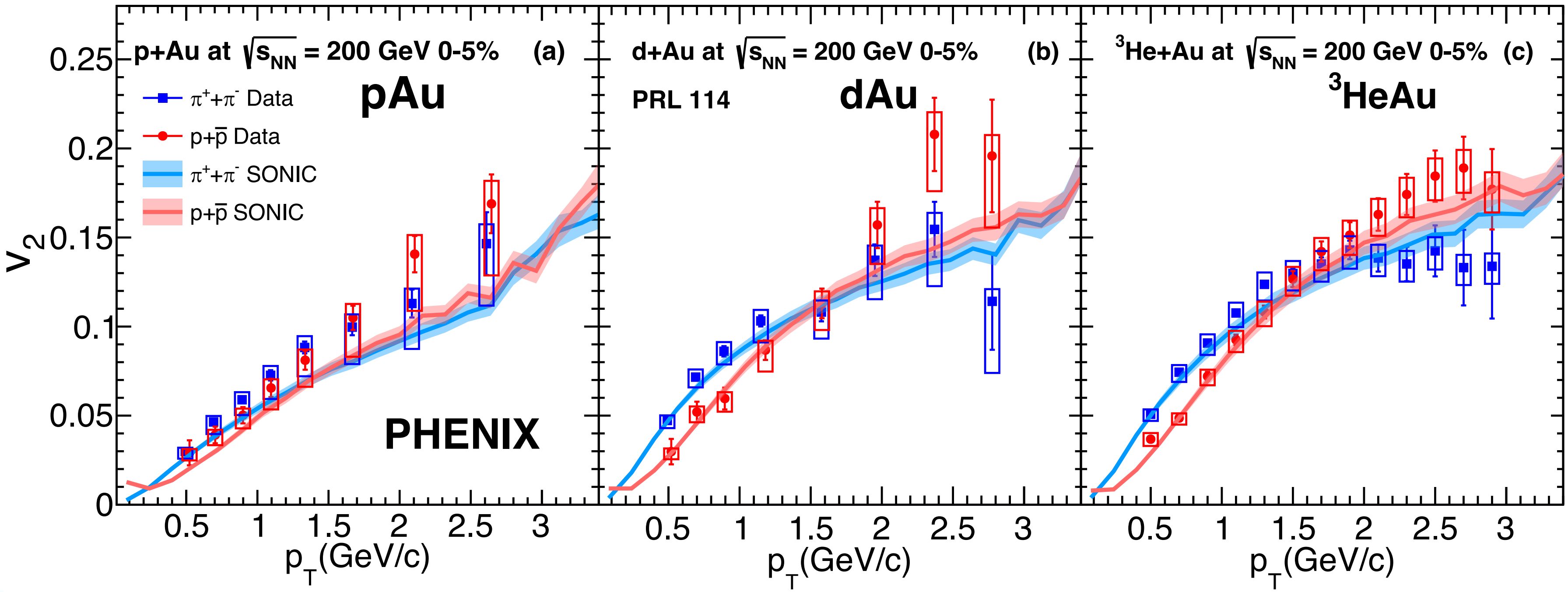
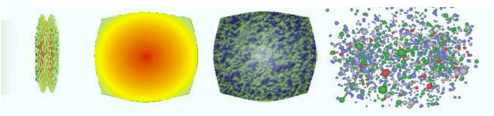
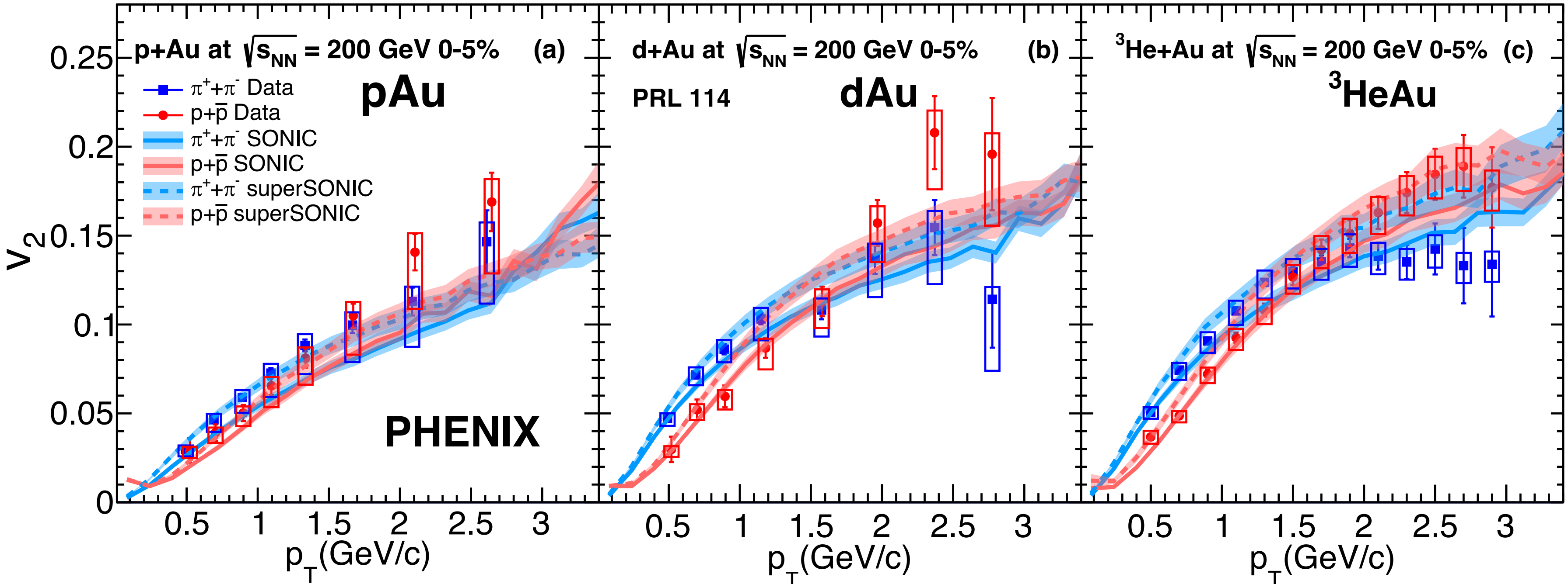
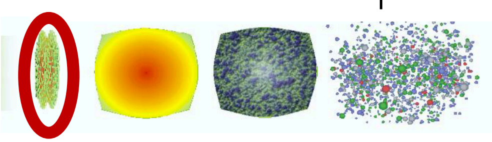
Hydro w/o pre-equilibrium stage





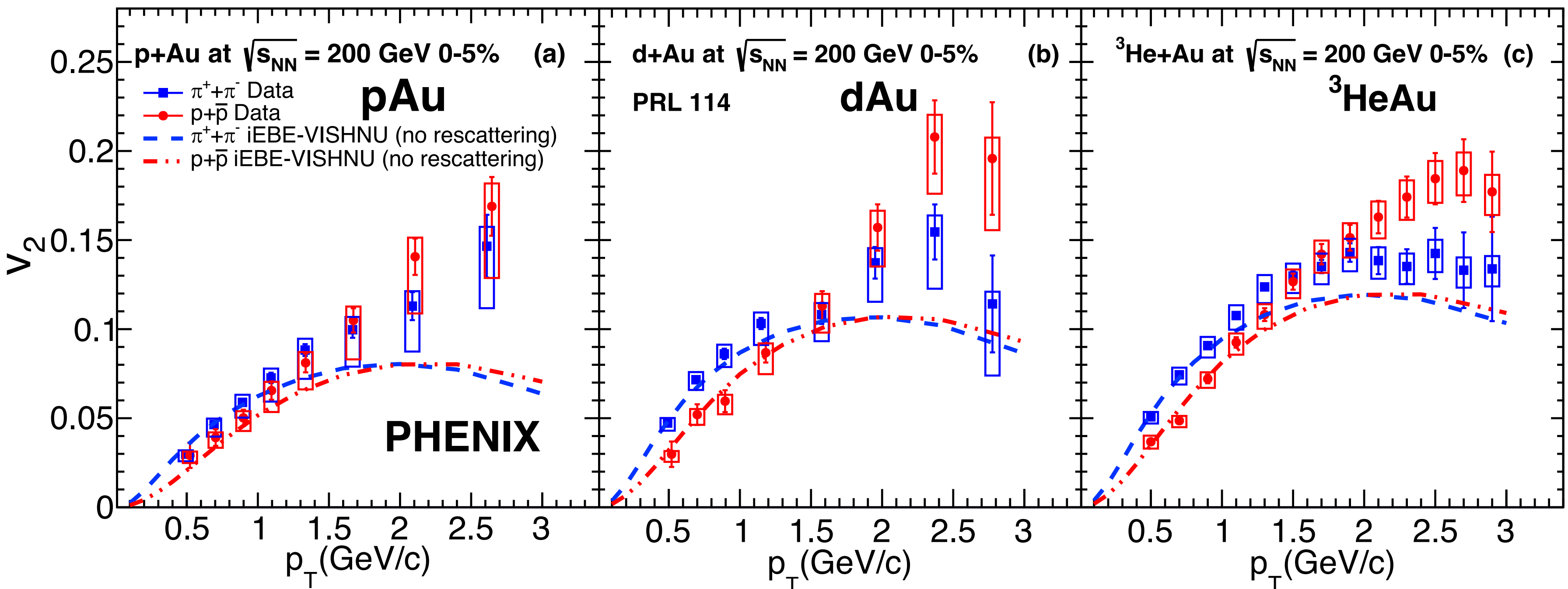
Hydro with pre-equilibrium stage

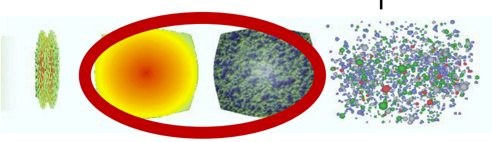




- Both calculations predict mass splitting at low p_T , which is smaller in p+Au than in d+Au and ^{3}He+Au as seen in the data
- Pre-equilibrium flow increases v_2 for both pions and protons and brings the result closer to the data.

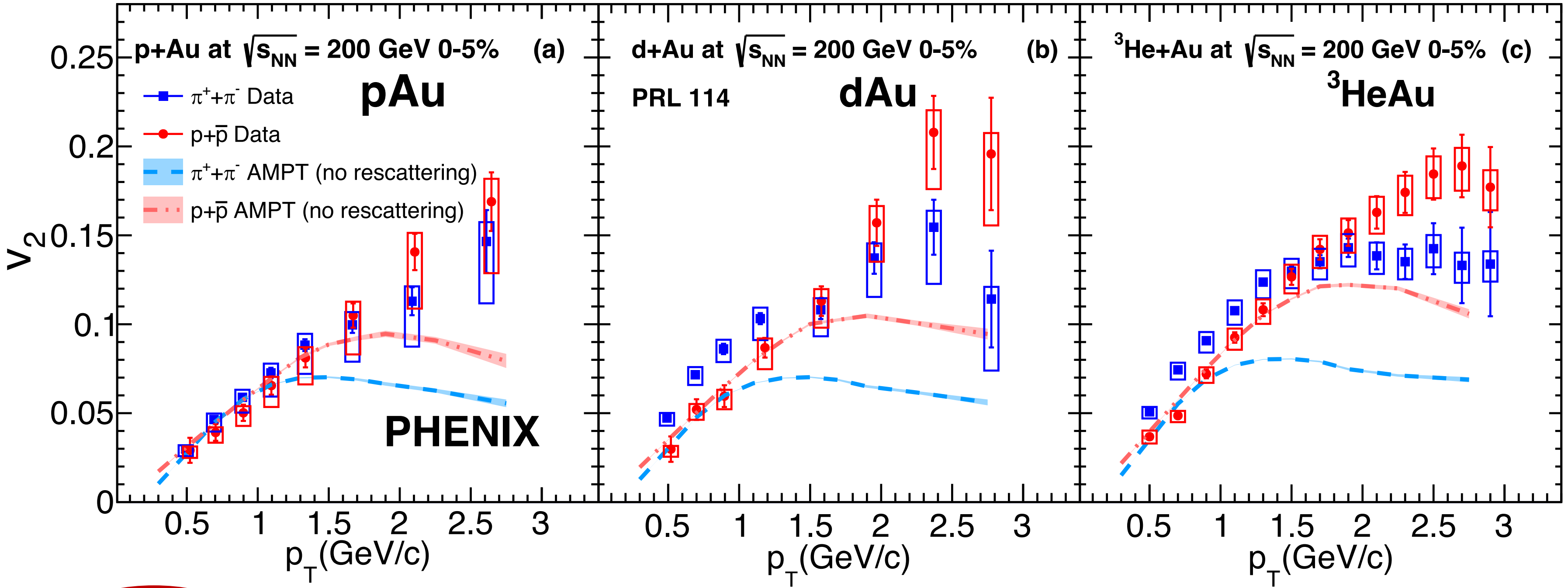
Partonic stage and hadronization

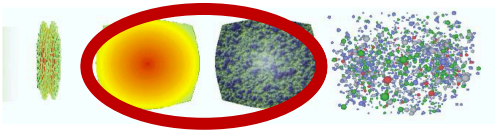




In the hydro models the mass splitting in v_2 at low p_T arises in the partonic phase due to the common flow field.

Partonic stage and hadronization





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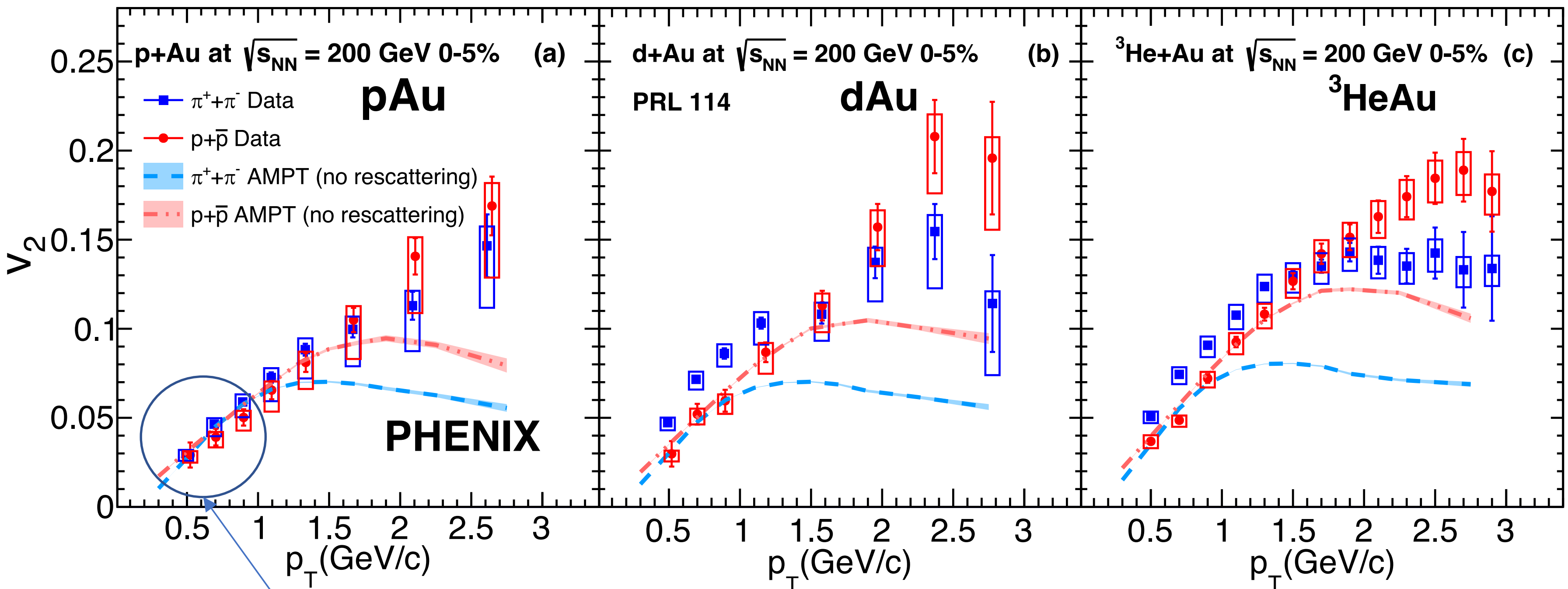
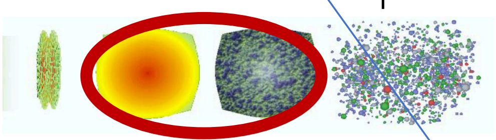
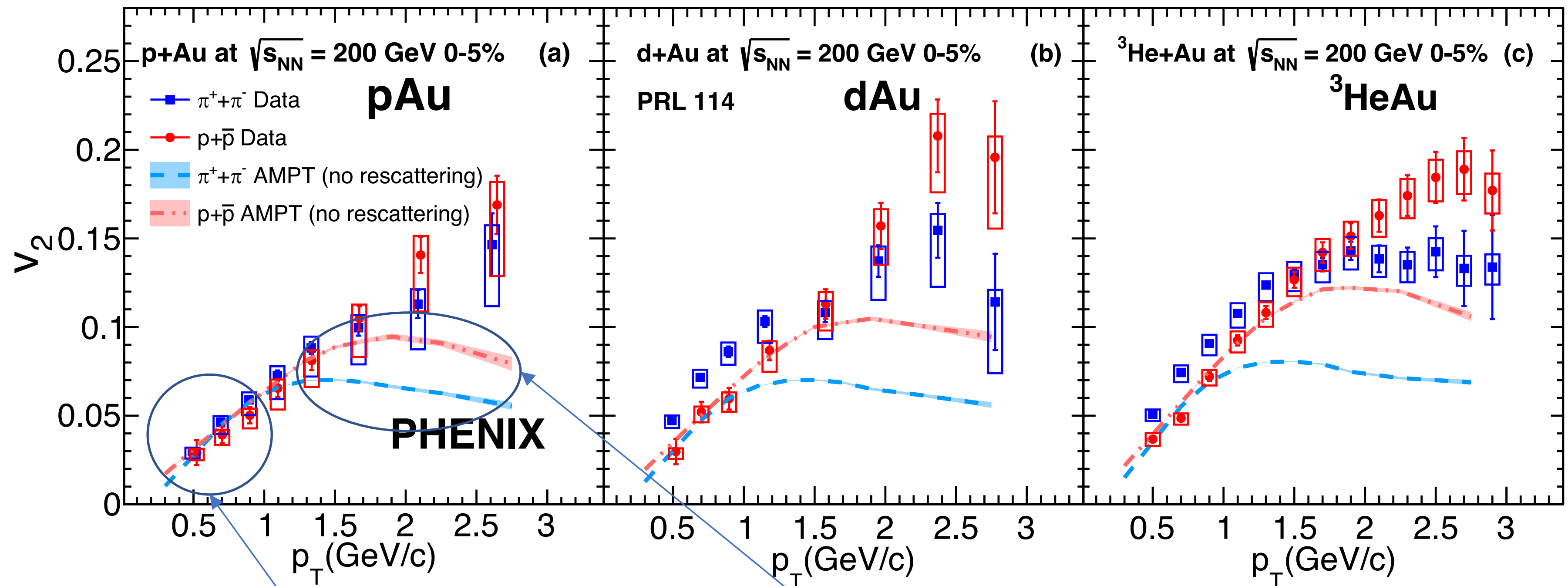
Partonic stage and hadronization

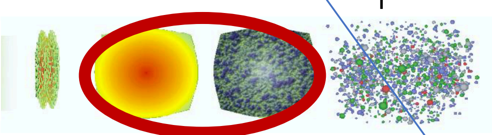




No splitting at low p_T

Partonic stage and hadronization





No splitting at low p_T

Splitting at high p_T comes from hadronization by recombination

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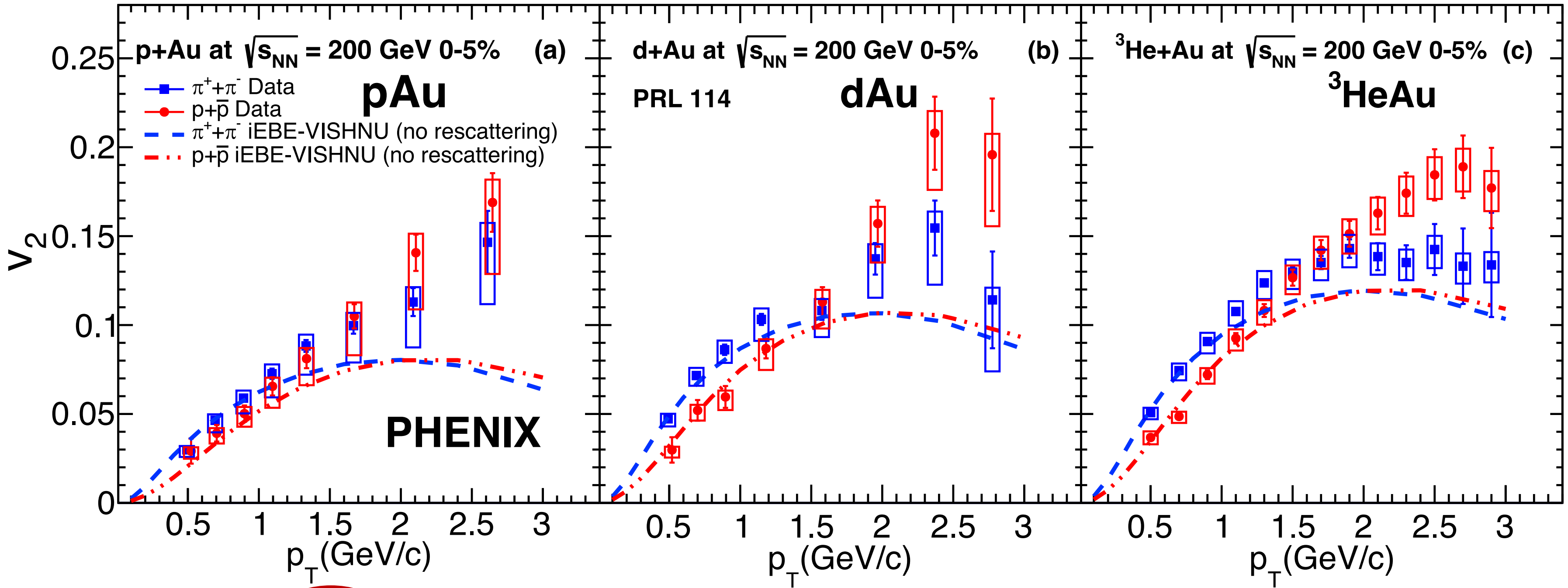
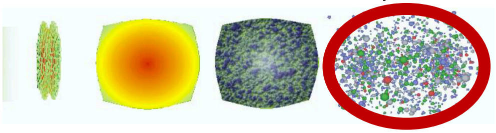
Hadron rescattering stage





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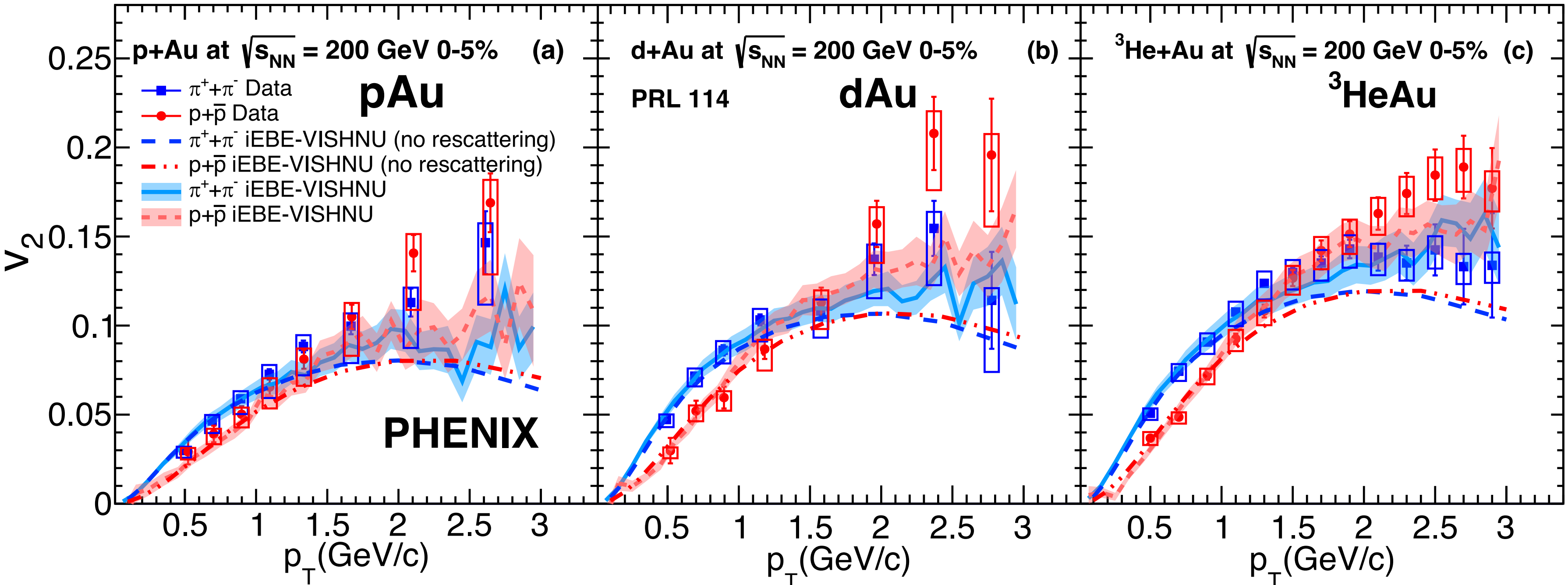
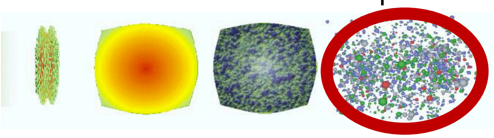
Hadron rescattering stage





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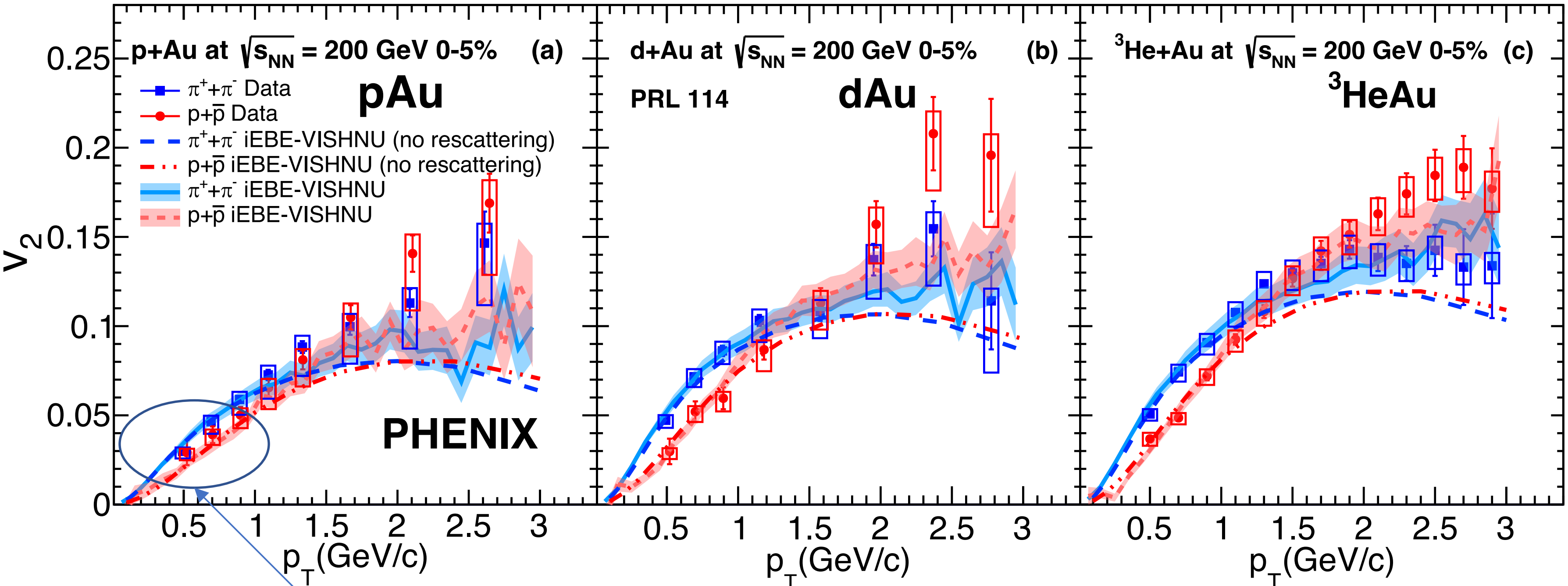
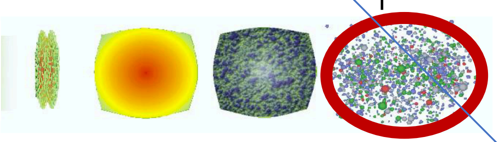
Hadron rescattering stage





No influence at low p_T

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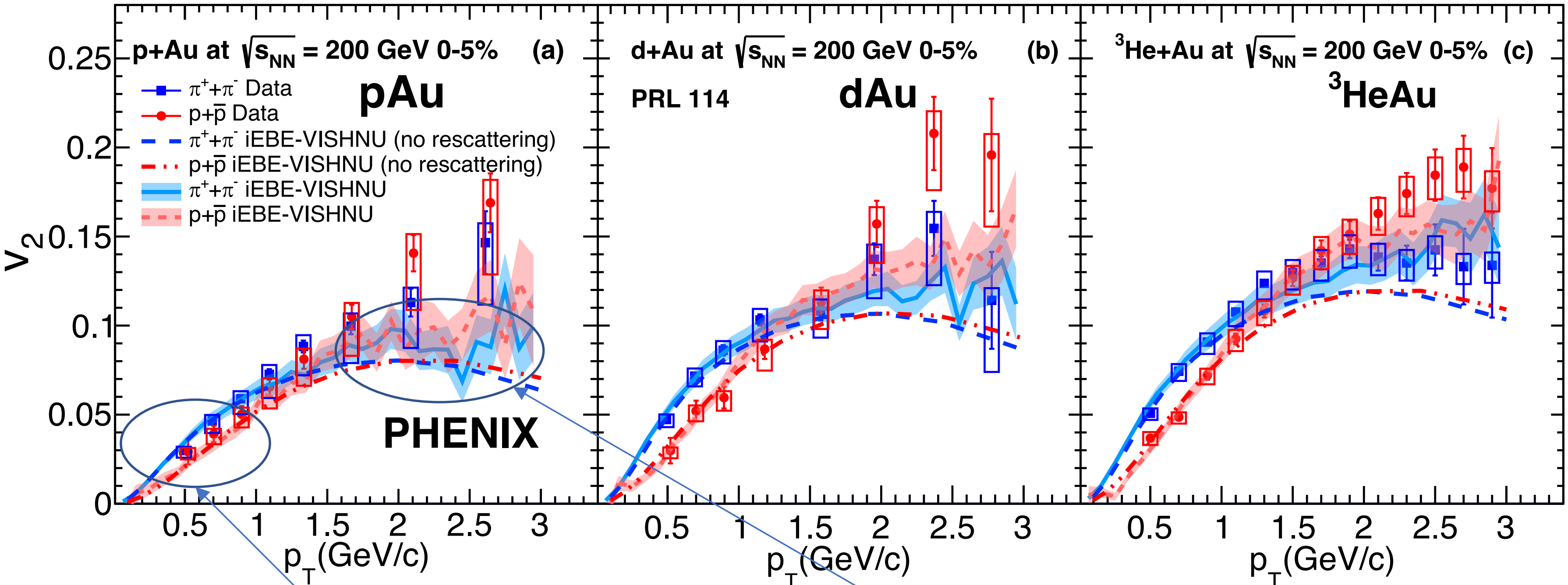
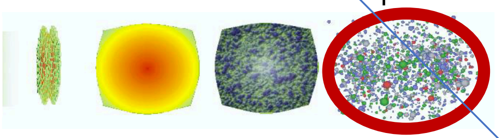
Hadron rescattering stage





No influence at low p_T

The v_2 at higher p_T is larger

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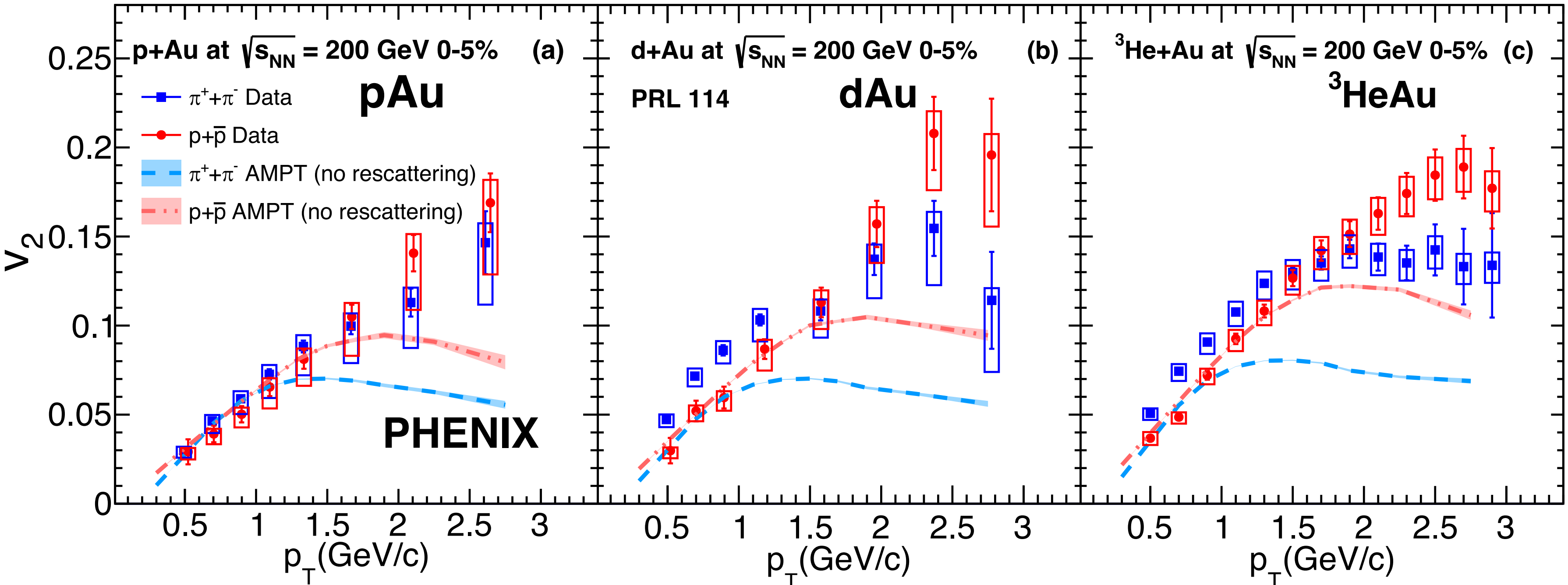
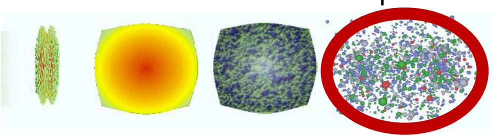
Hadron rescattering stage





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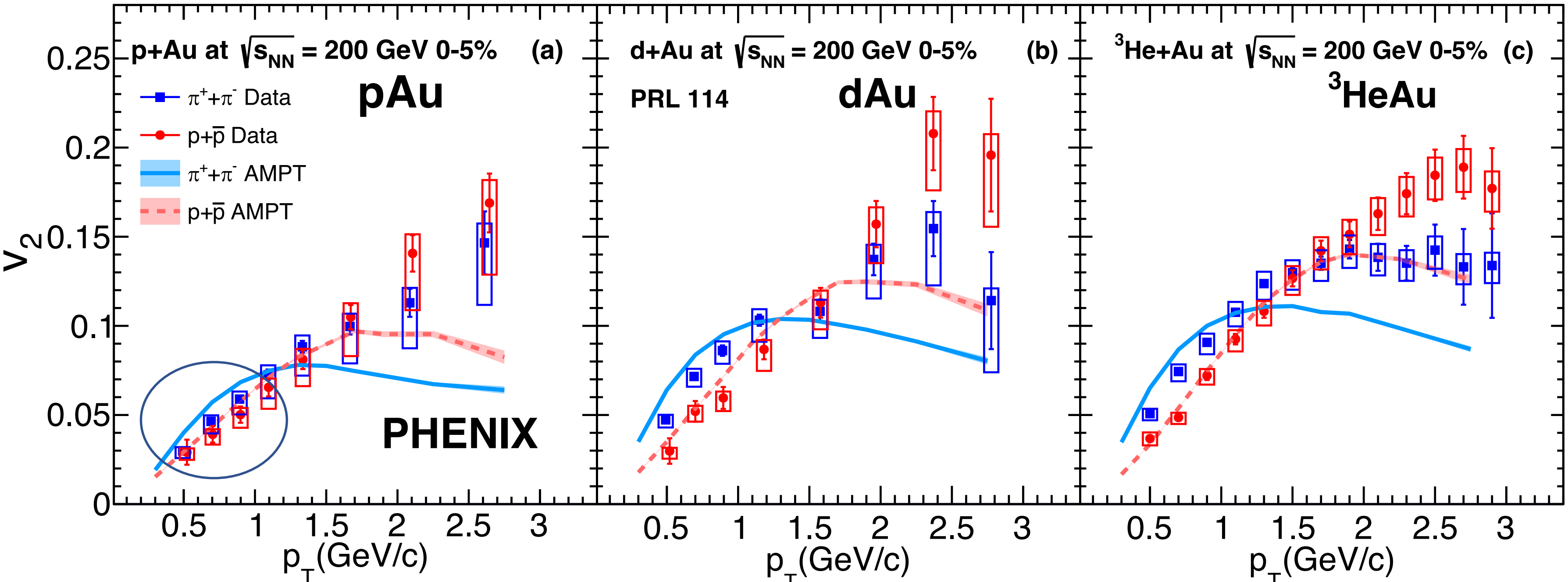
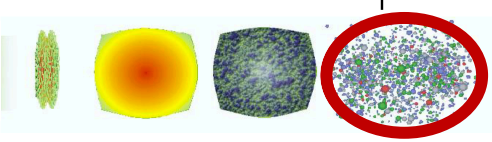
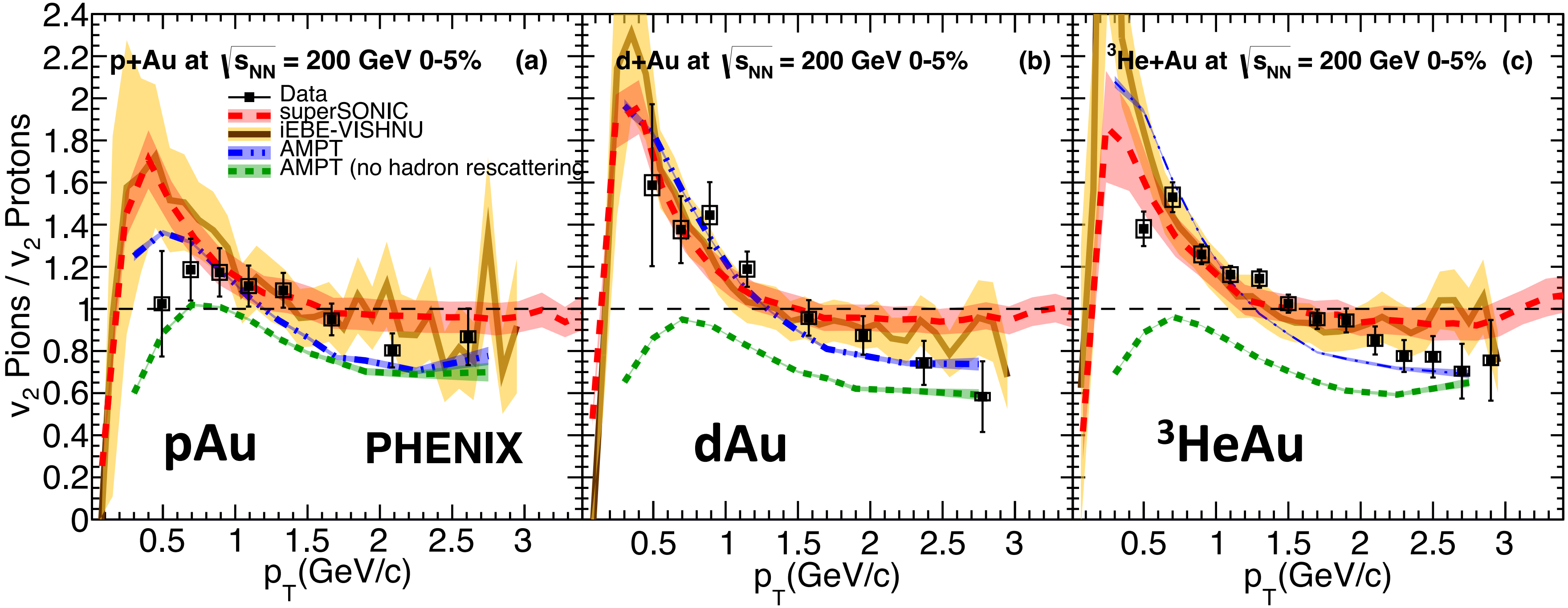
Hadron rescattering stage





Mass splitting at low p_T can also come from hadron rescattering

Pion v_2 over proton v_2



Slope: -0.22 ± 0.07 -0.4 ± 0.07 -0.34 ± 0.03

- Data in all systems exhibit a similar trend (systematics cancel in ratio)
- Both hydro and AMPT describe the mass splitting at low p_T.
- Hadronization by recombination can predict the ratio right at high p_T

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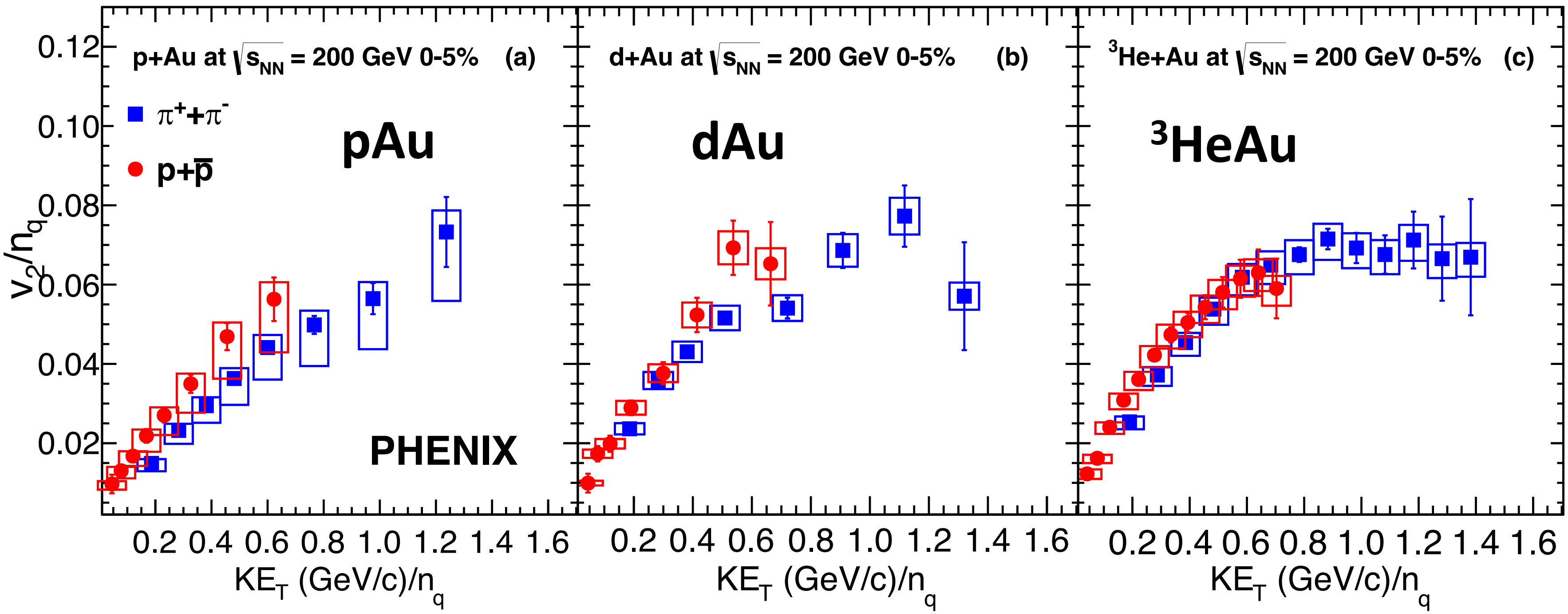
Quark scaling



- Approximate scaling in all three systems
- Works better in larger systems

Summary

- Initial geometry translates into final state flow
- Mass splitting in v_2 is observed in all three systems:
  $p/d/^3He + Au$ collisions
- Both hydro and AMPT describe the mass splitting at low p_T
  - hydro - from early stages through common flow velocity
  - AMPT - from late-stage hadronic rescattering
  - Different hadronic rescattering models (UrQMD and ART) have different predictions
- Reverse mass order at high p_T described by recombination
- The quark scaling motivated by recombination is observed in the three small systems, more obvious in d+Au and ^3He+Au collisions, where the multiplicity is higher

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Thanks

Backup