

Medium formation in small systems?

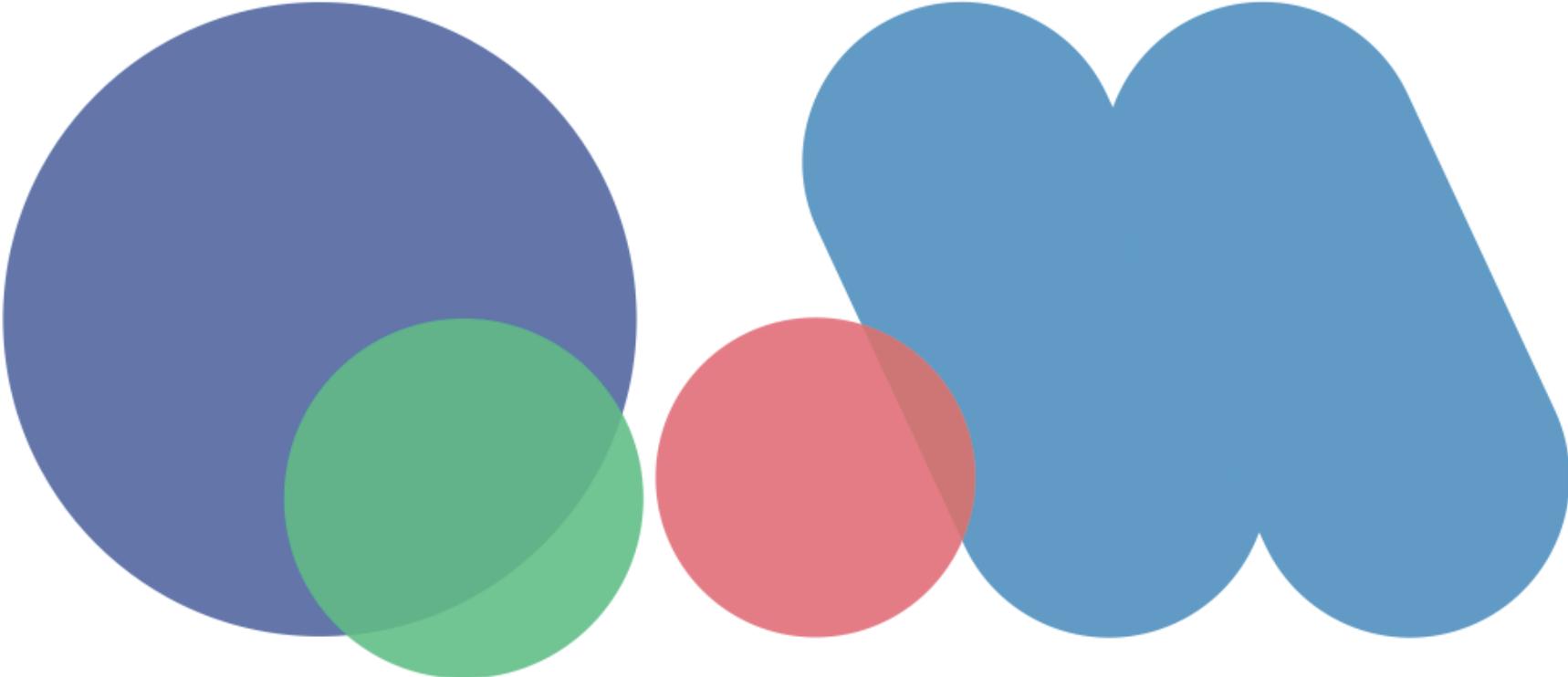
Experimental results from RHIC

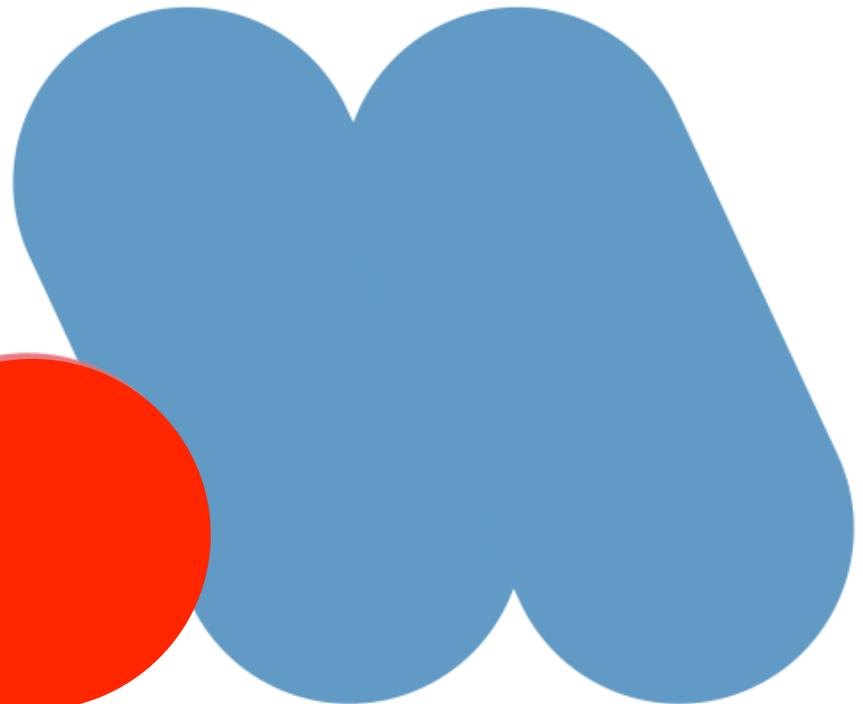
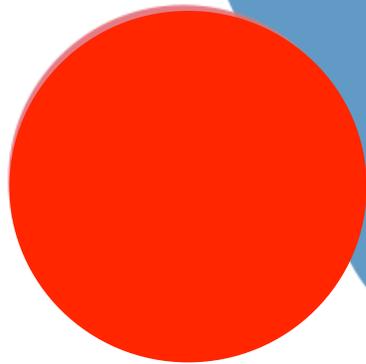
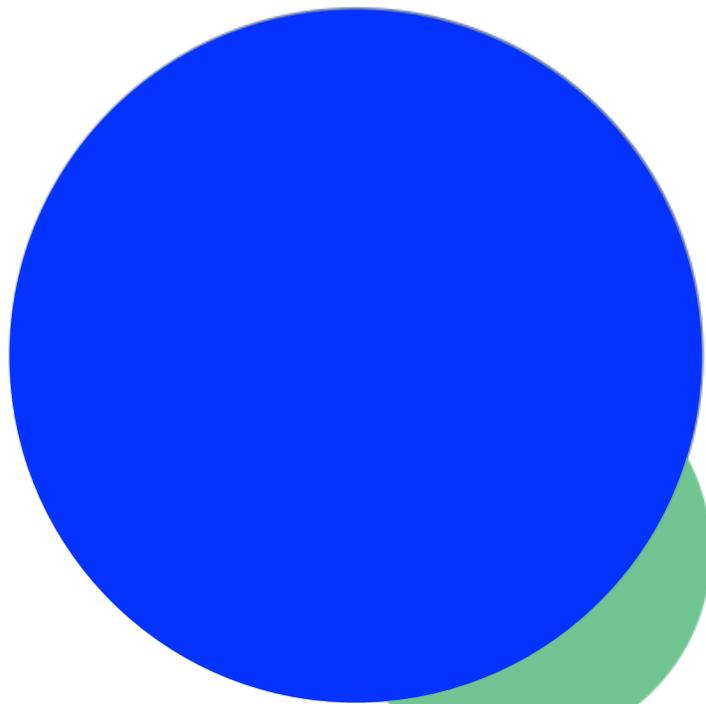
Paul Stankus

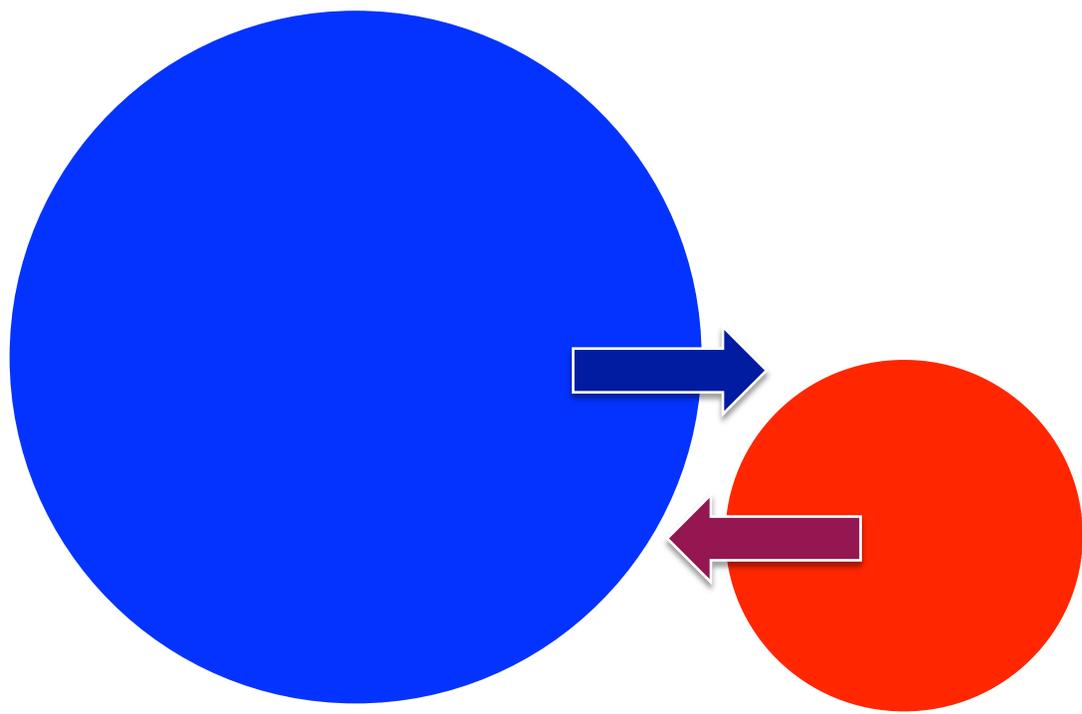
Oak Ridge National Lab

Quark Matter 2015, Kobe, Japan



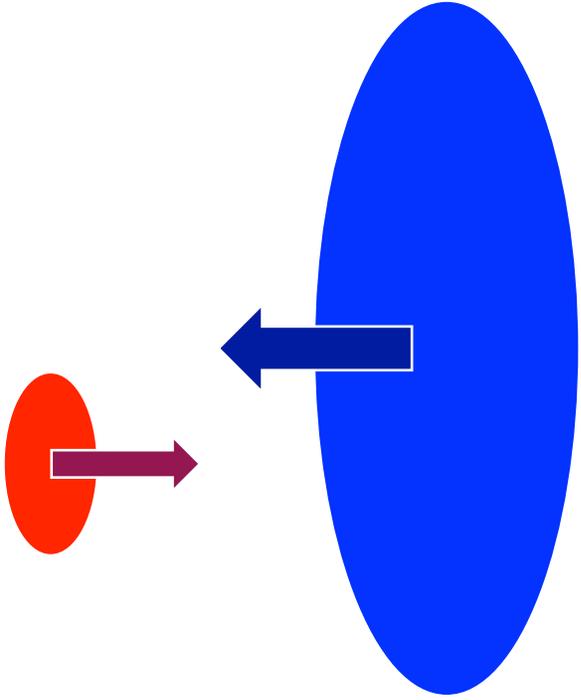


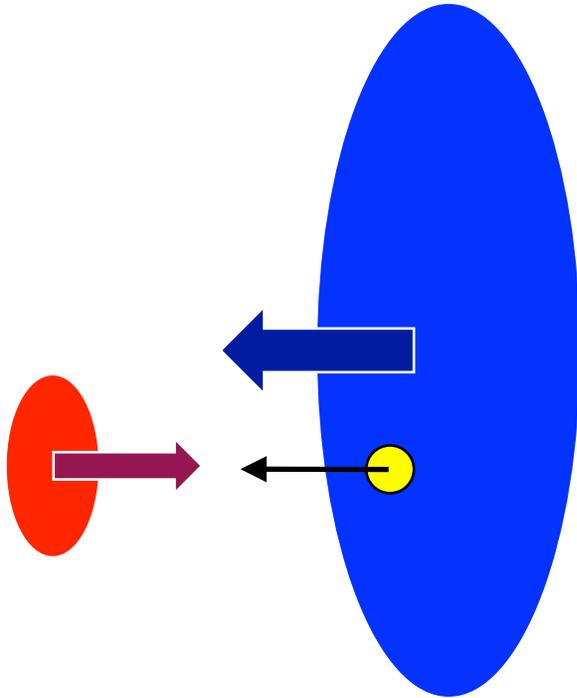




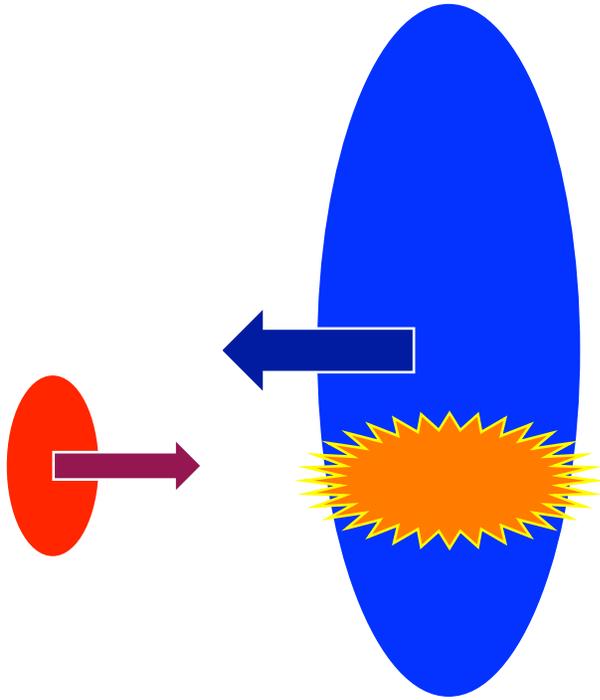
Au

d

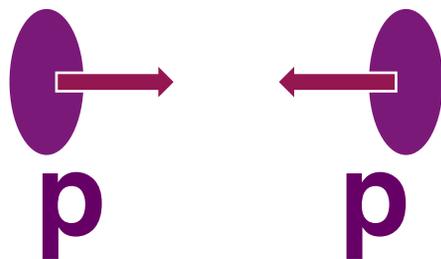
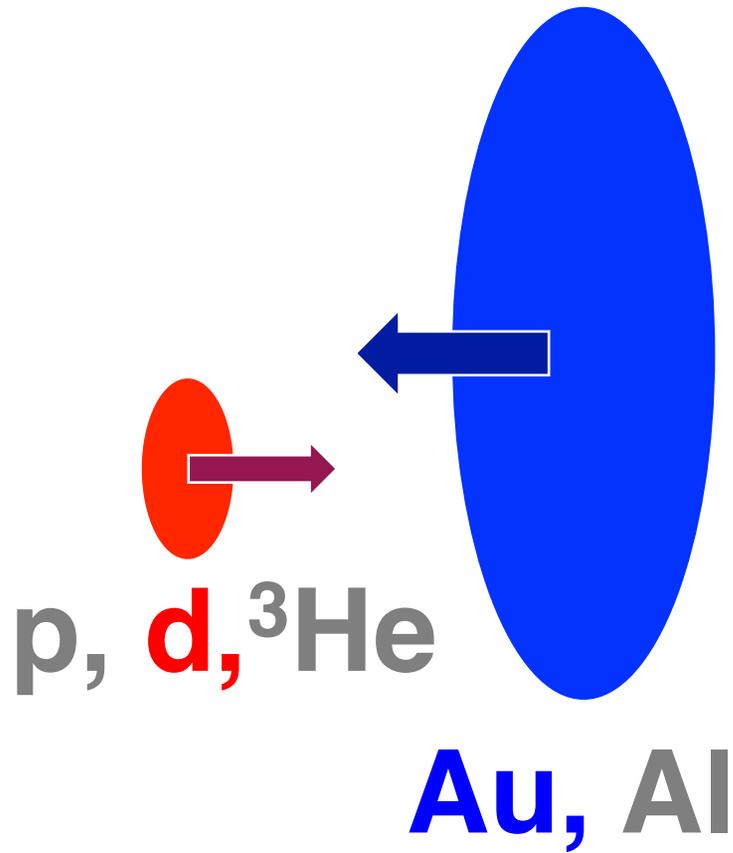




Old Idea
d+Au reveals
“initial-state” CNM
effects



New Idea
Significant “final
state effects”,
medium creation in
small system



Broad checklist

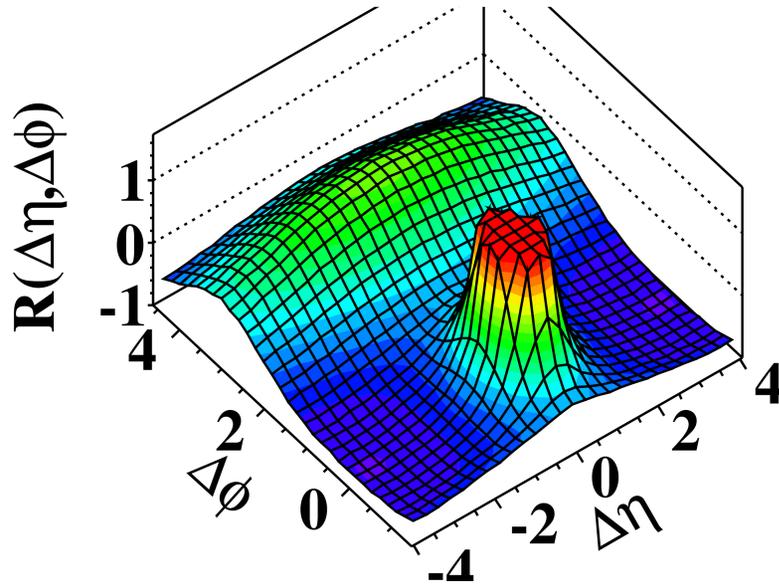
- Flow-like correlations
- Heavy flavor production
- High- p_T hadrons (jet quenching)



Flow-like correlations

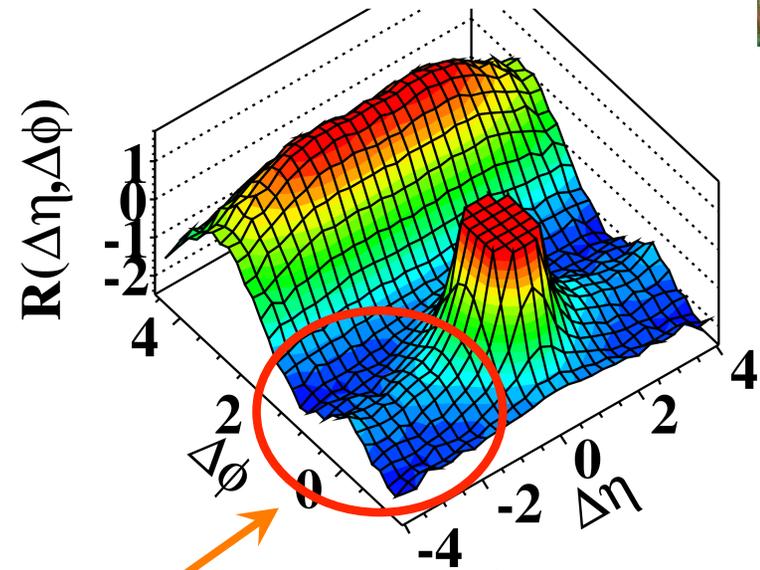


(b) CMS MinBias, $1.0\text{GeV}/c < p_T < 3.0\text{GeV}/c$



CMS p+p, JHEP 09 (2010) 091

(d) CMS $N \geq 110$, $1.0\text{GeV}/c < p_T < 3.0\text{GeV}/c$



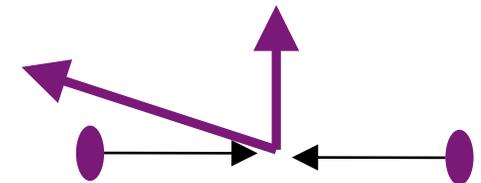
Near Side

Long Range

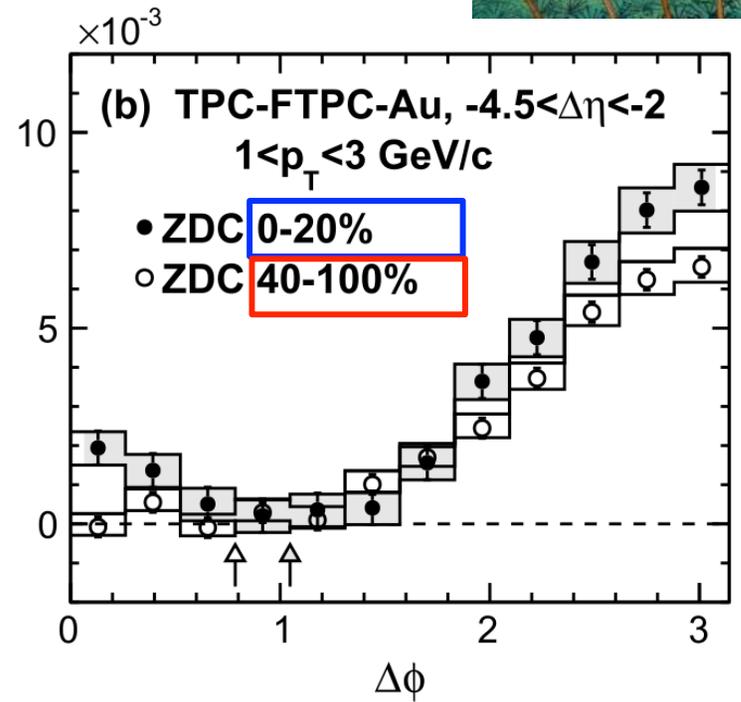
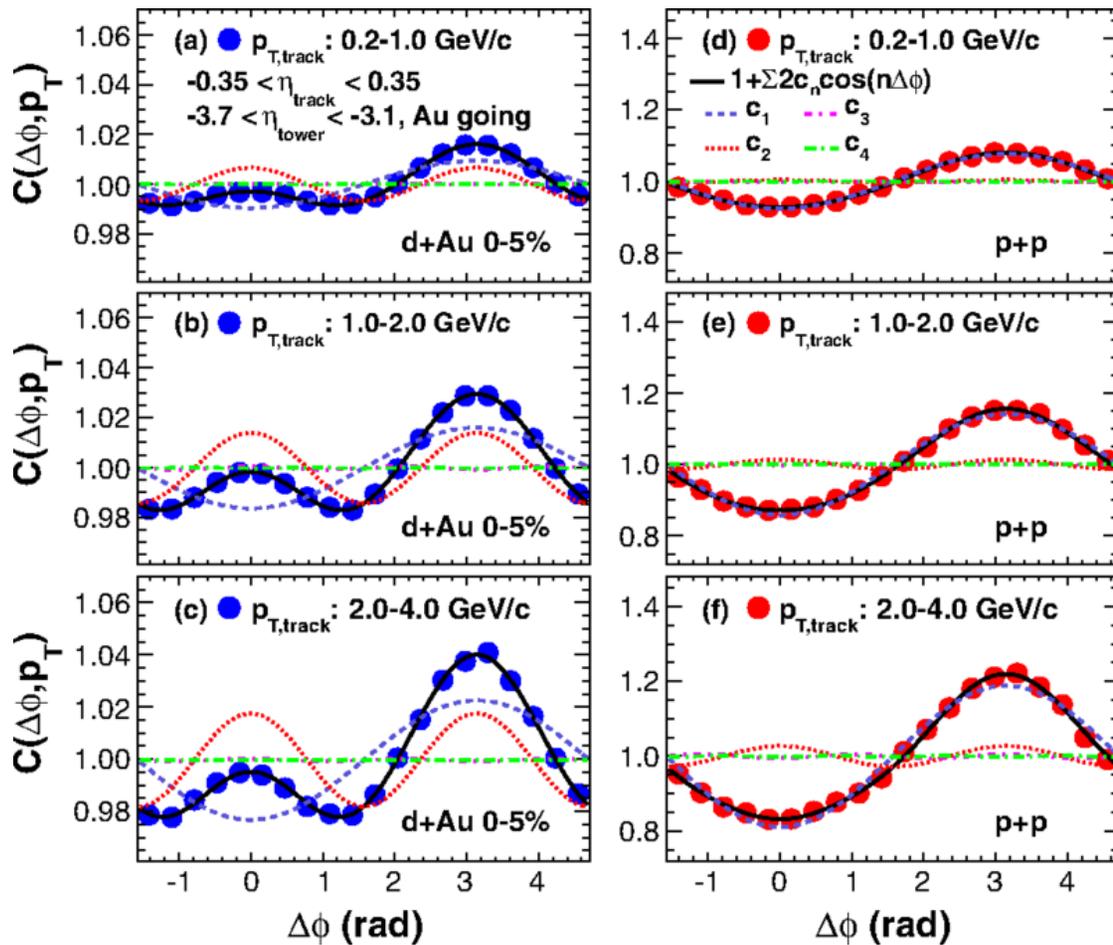


Flow checklist:

- Factorization
- Geometry influence
- p_T dependence



Long-range correlations in d+Au

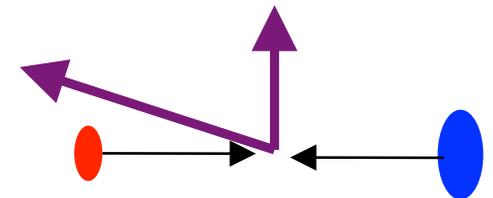


STAR, PLB 747, (2015) 265-271

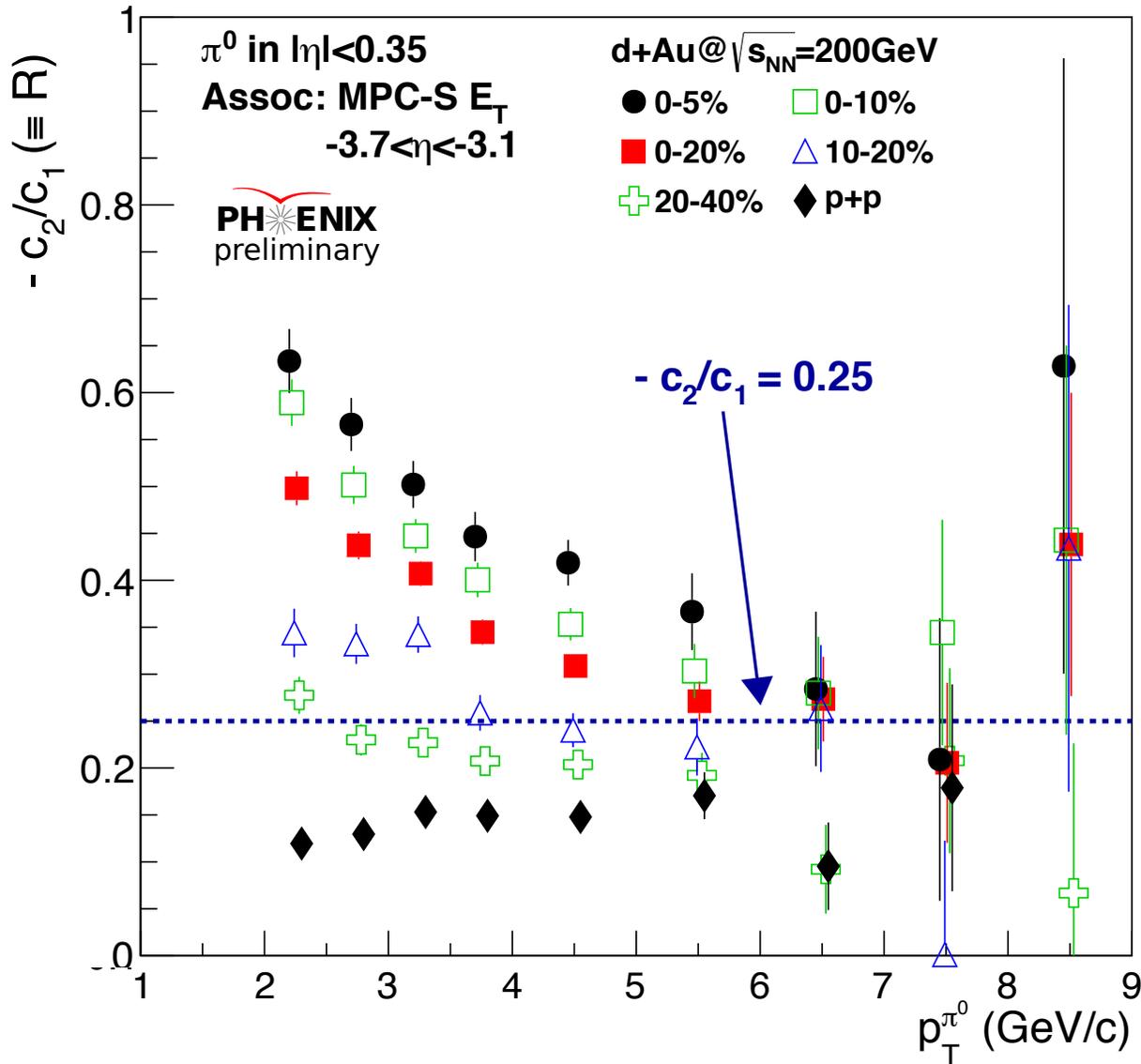
d+Au 0-5%

p+p min-bias

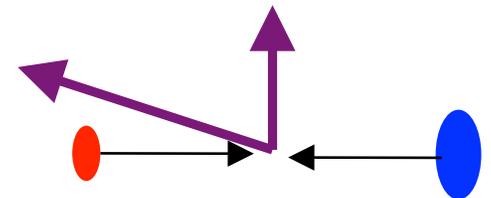
PHENIX, PRL 114, 192301 (2015)



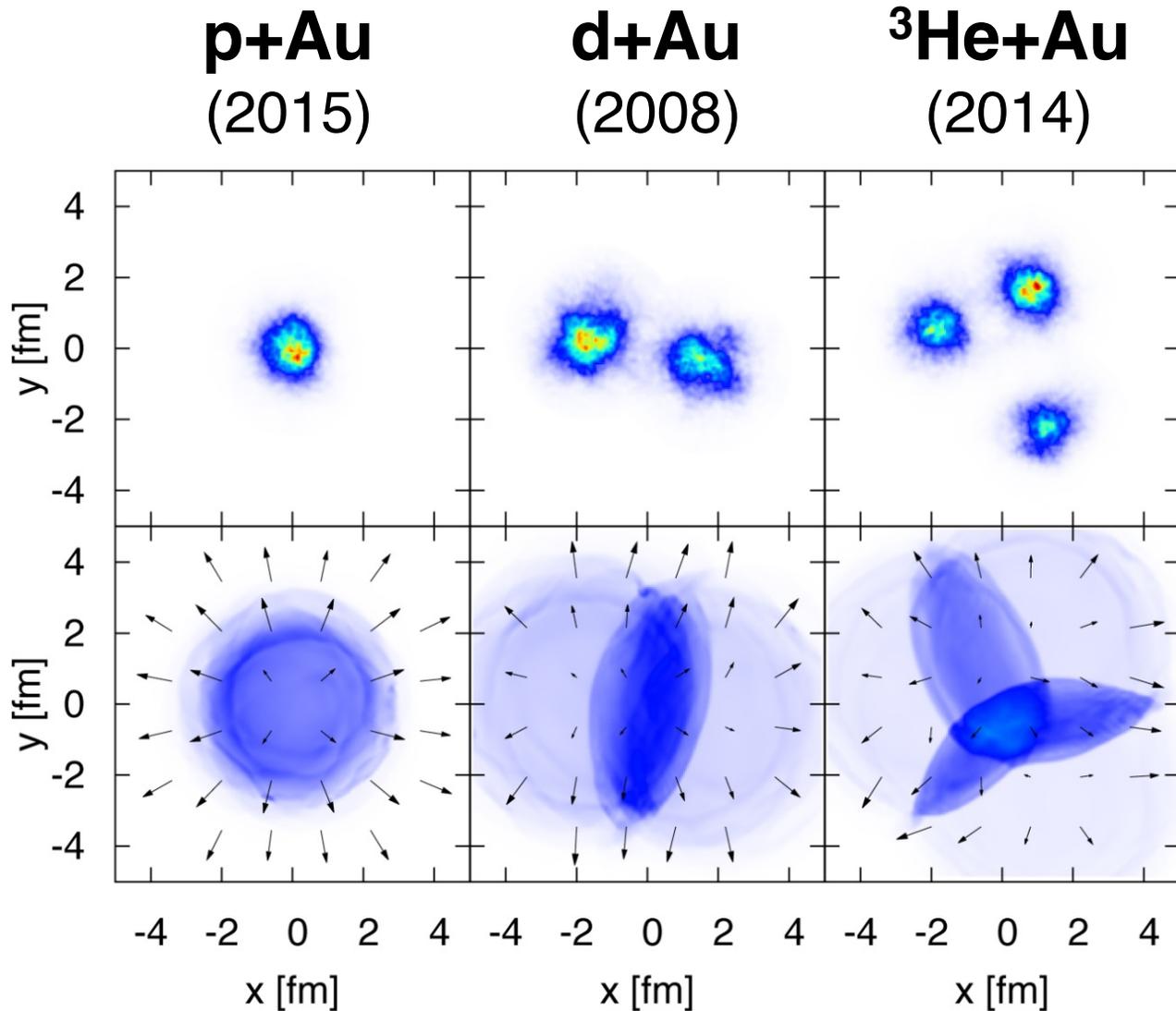
Shape: $-c_2/c_1 \sim \text{Near/Away}$



↑ Near-side peak visible



Geometry control at RHIC



Initial State

Final State

Phys. Rev. Lett. 113,
112301 (2014), figure
courtesy of B. Schenke

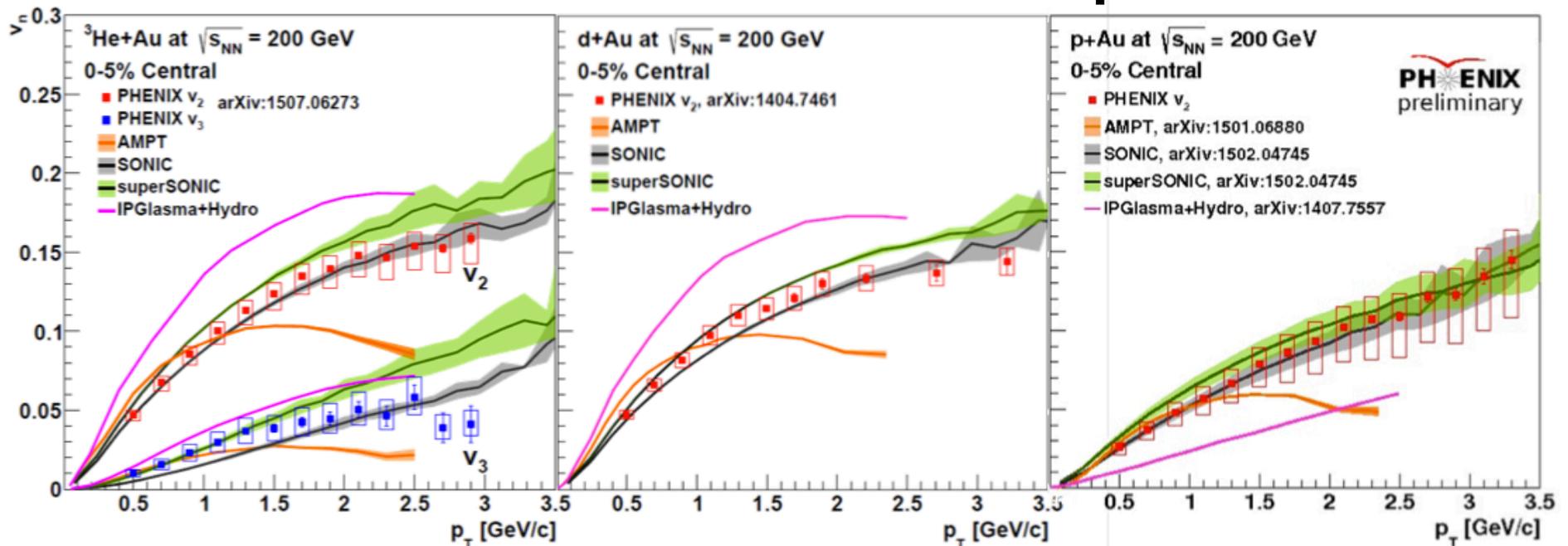
Full palette of v_2, v_3



$^3\text{He}+\text{Au}$

$\text{d}+\text{Au}$

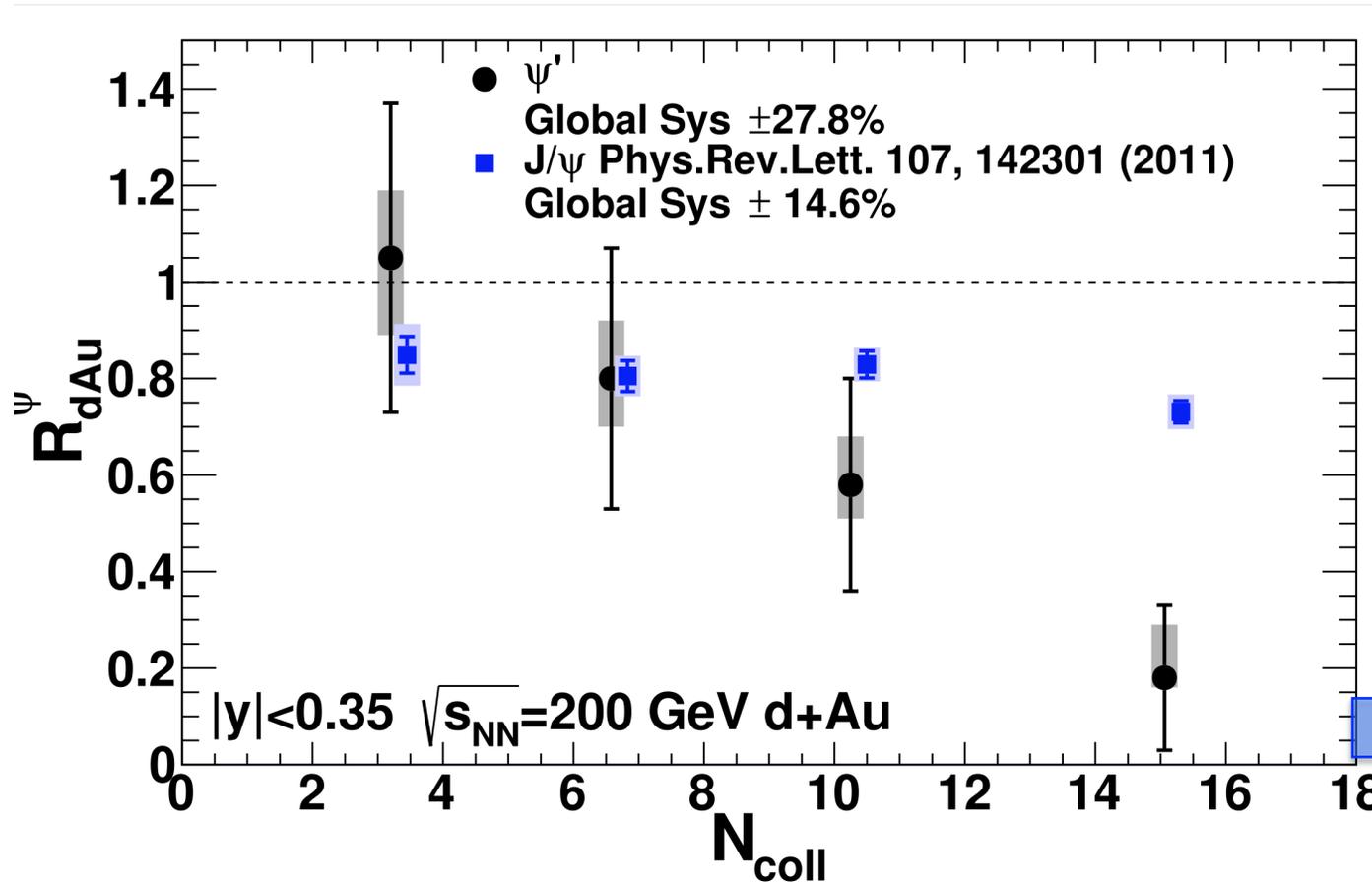
$\text{p}+\text{Au}$



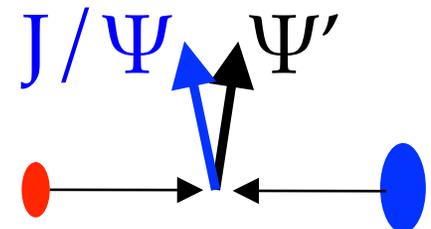
PHENIX, PRL 114, 192301 (2015)
PHENIX, PRL 115, 142301 (2015)
AMPT: arXiv:1501.06880
SONIC: arXiv:1502.04745
IP+Hydro: arXiv:1407.7557

Clear influence of initial geometries
Fit by both hydro and parton cascade

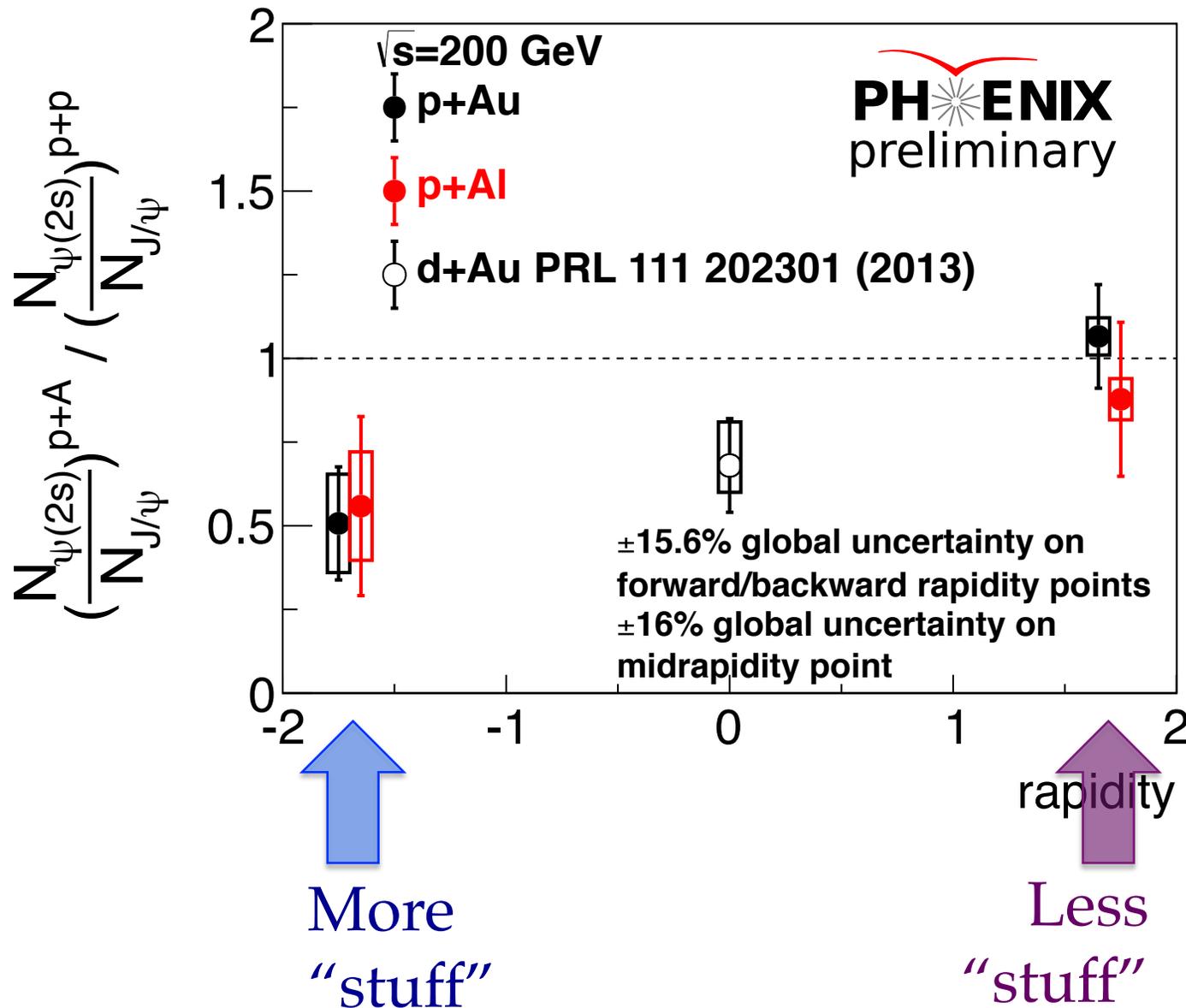
$\Psi(2s)$ relative suppression



PHENIX, PRL 111, 202301 (2013)



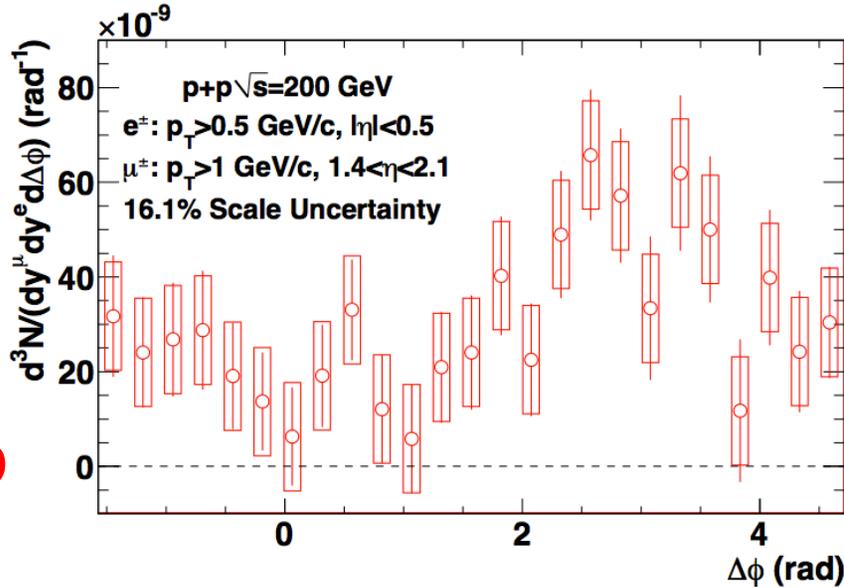
$\Psi(2s)$ relative suppression



Open charm de-correlation

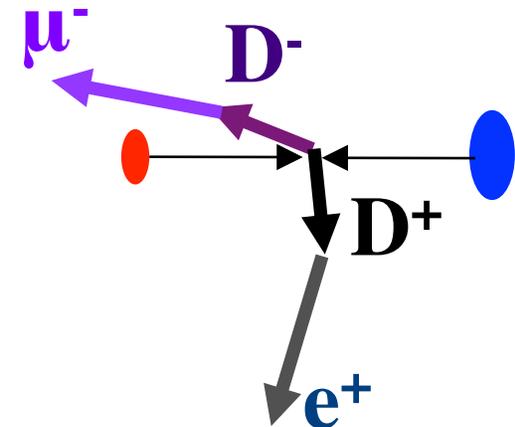
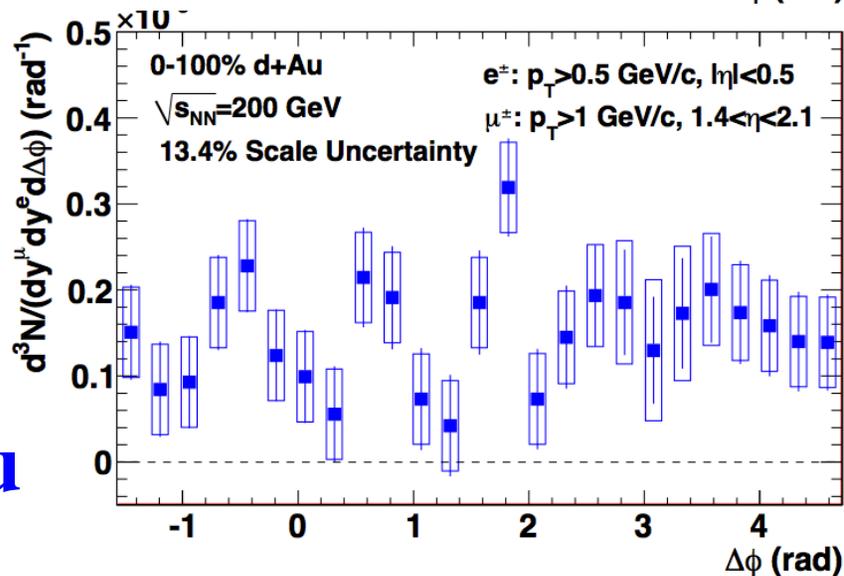


p+p

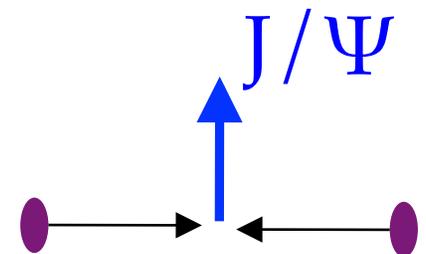
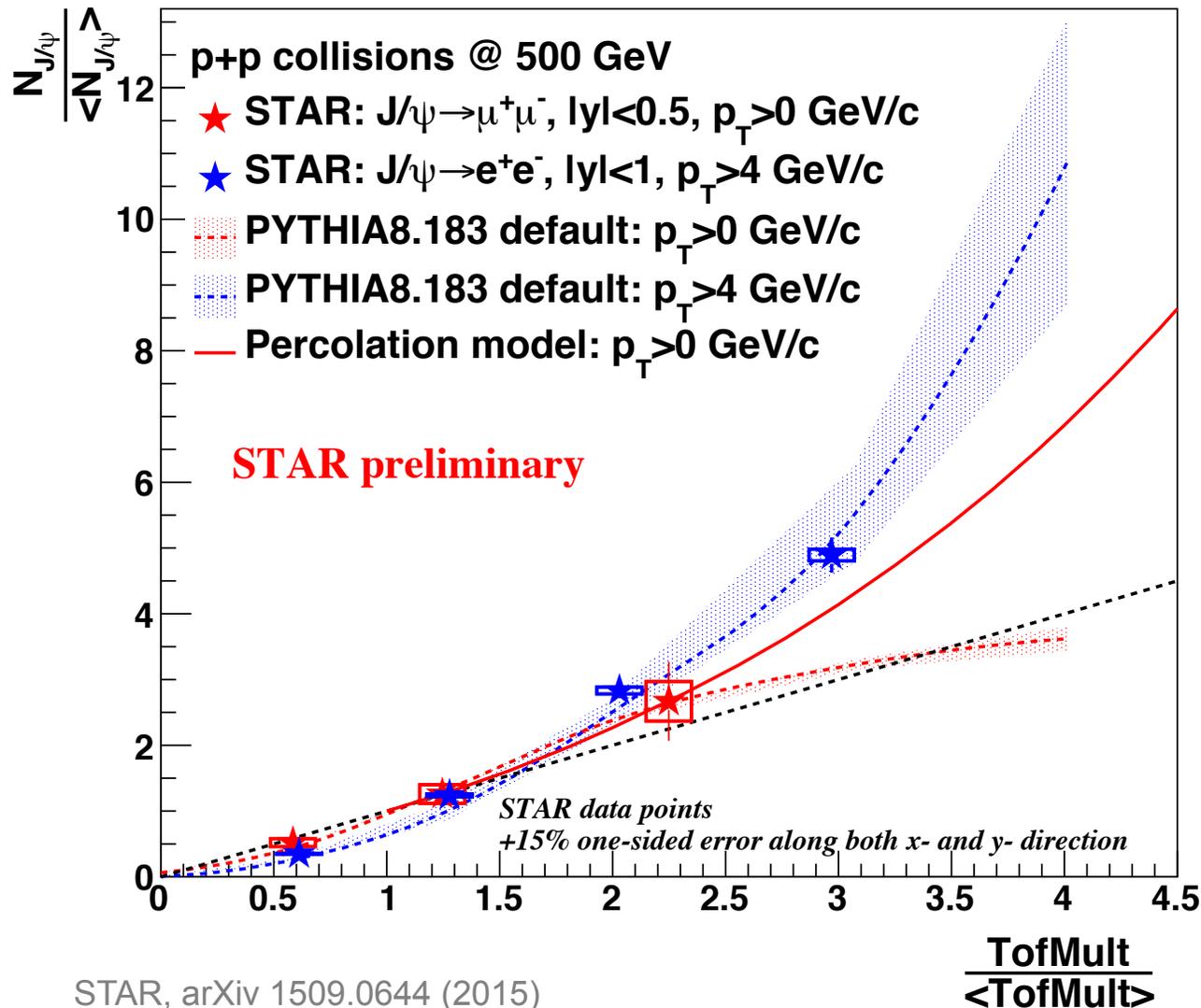


What is the site of any re-scattering?

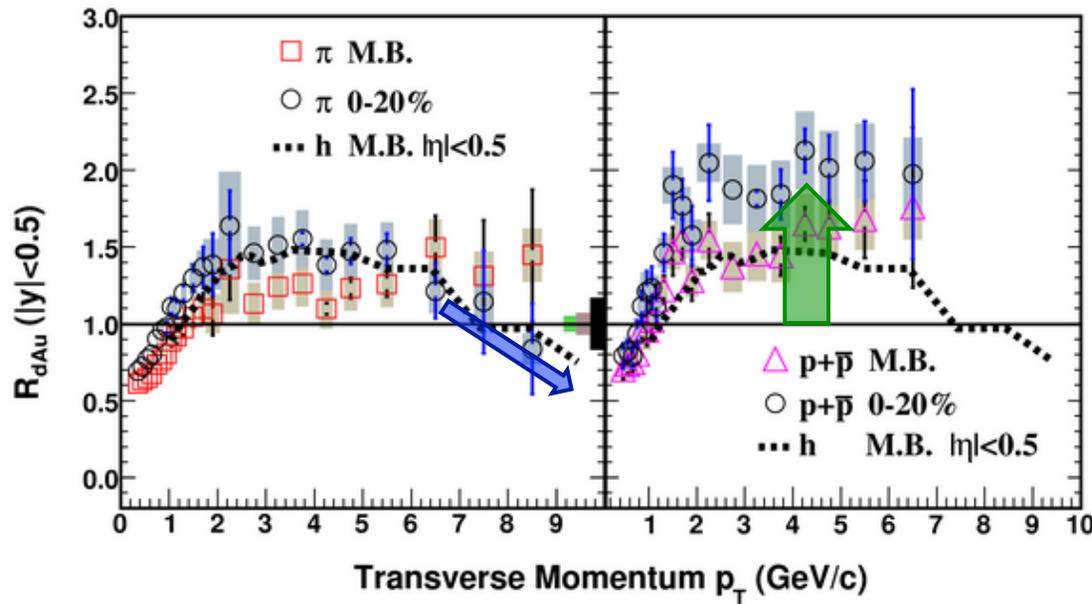
d+Au



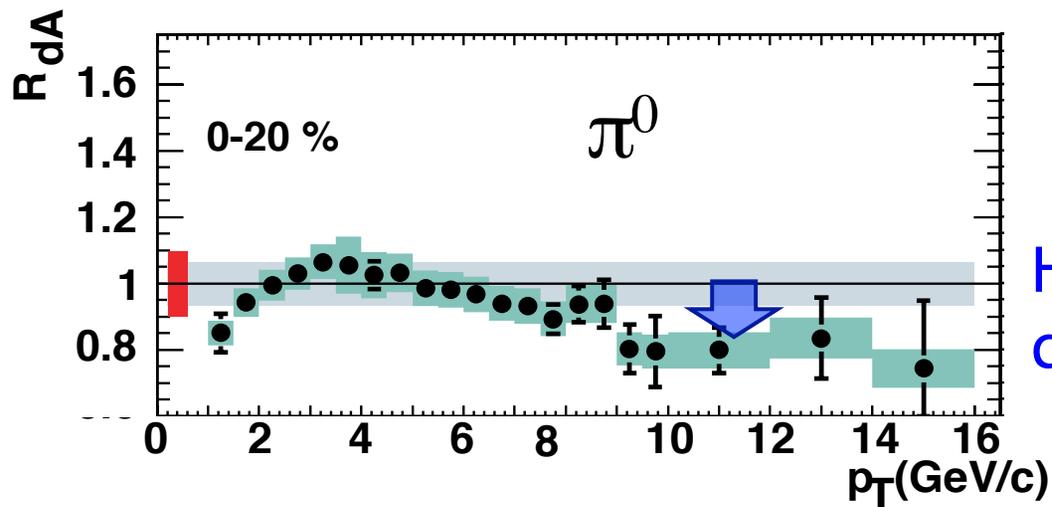
J/Ψ vs p+p multiplicity



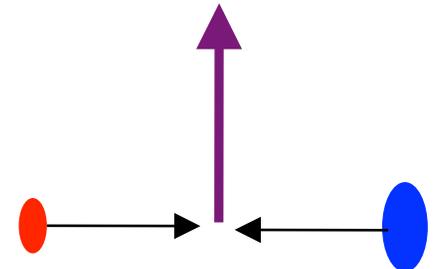
Hadron R_{dAu}



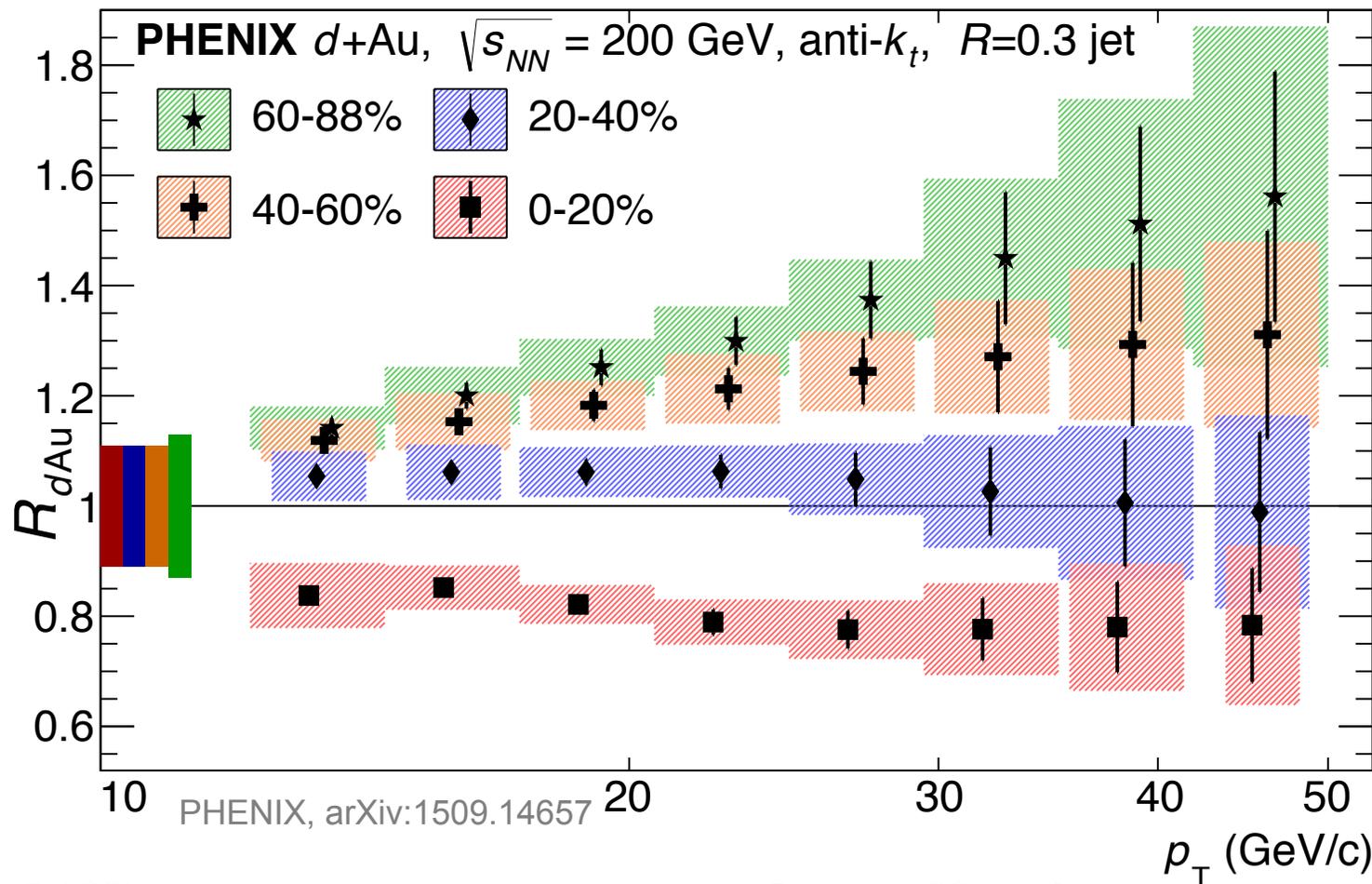
Cronin;
Radial flow?



Hint of jet
quenching?



Jets in d+Au



Difficult to understand as a CNM effect!

Strong hard/soft correlation - proton configurations?

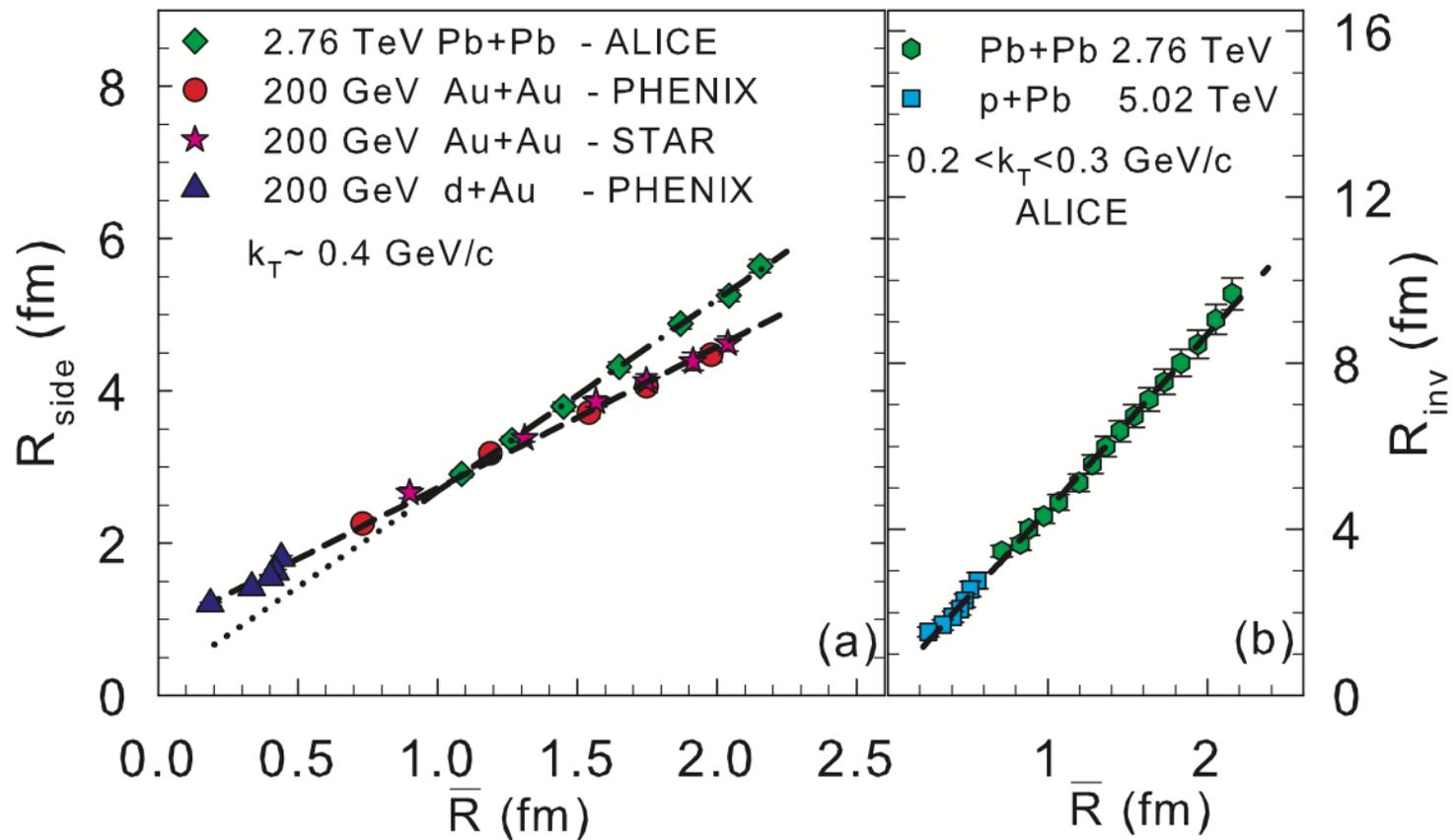
Checklist/Summary

- Flow-like, long-range correlations in p,d,³He+Au follow hydro-like patterns, clearly **reflect initial geometries**
- Evidence for **in-medium re-scattering of heavy flavor** from $\Psi(2s)/\Psi(1s)$ relative suppression and open charm de-correlation
- Traditional jet/high- p_T **quenching *not* in evidence**; un-intuitive R_{dAu} indicates important soft/hard process relationships
- **Recommendation:** Important for theory calculations to reflect **exact experimental event class** definitions

Extra material

HBT in small systems

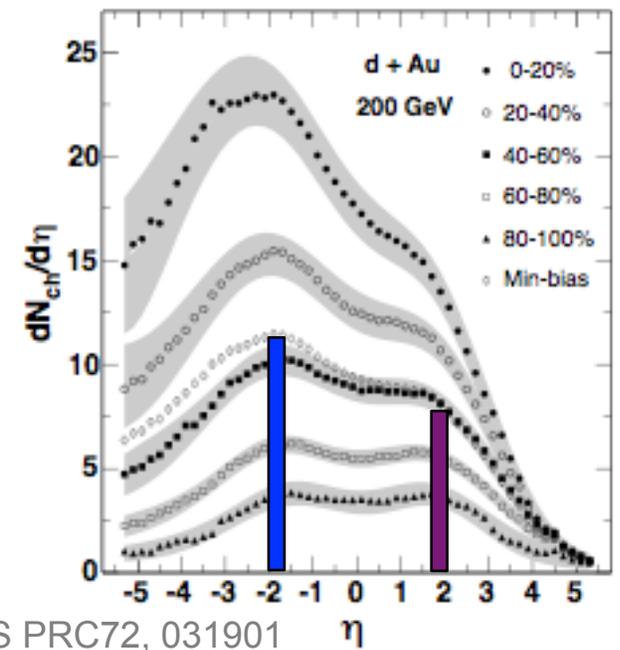
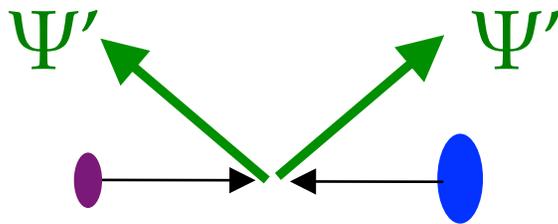
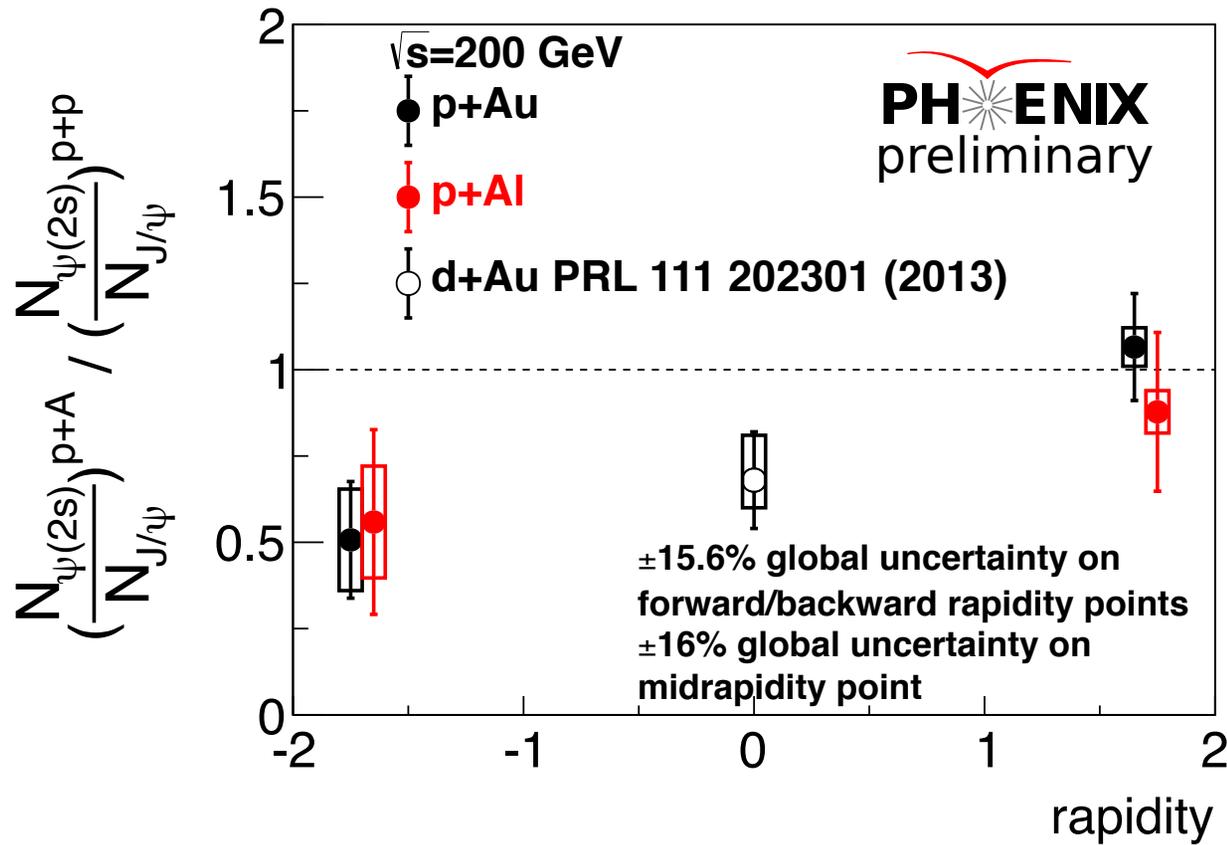
Perfectly smooth continuum between d+Au, Au+Au systems; also p+Pb and Pb+Pb



arXiv:1404.5291

$$1/\bar{R} = \sqrt{(1/\sigma_x^2 + 1/\sigma_y^2)} \quad \leftarrow \text{Initial state size parameter}$$

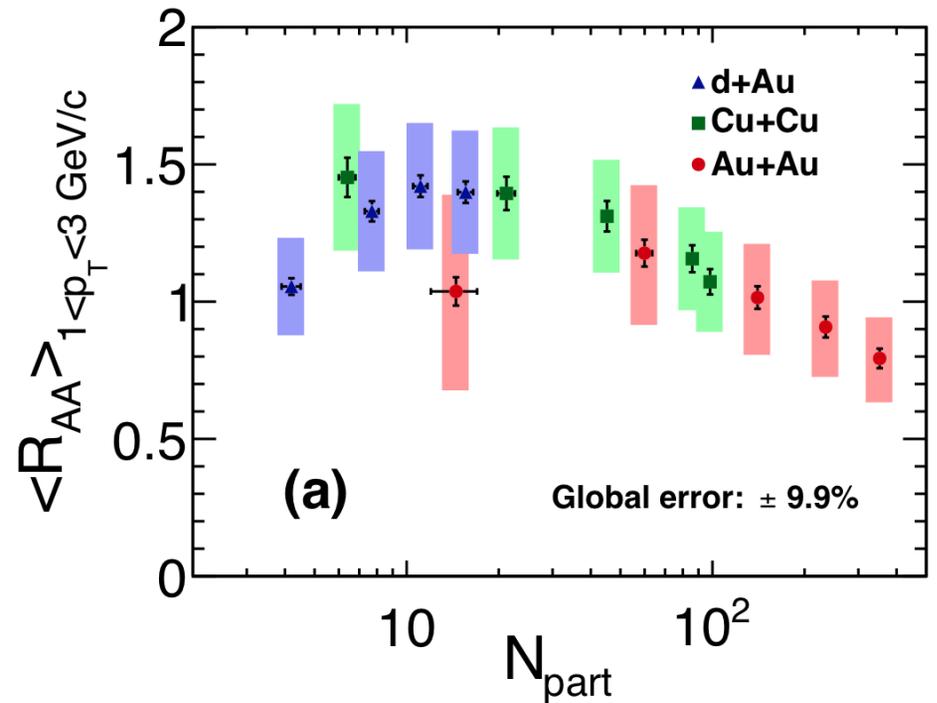
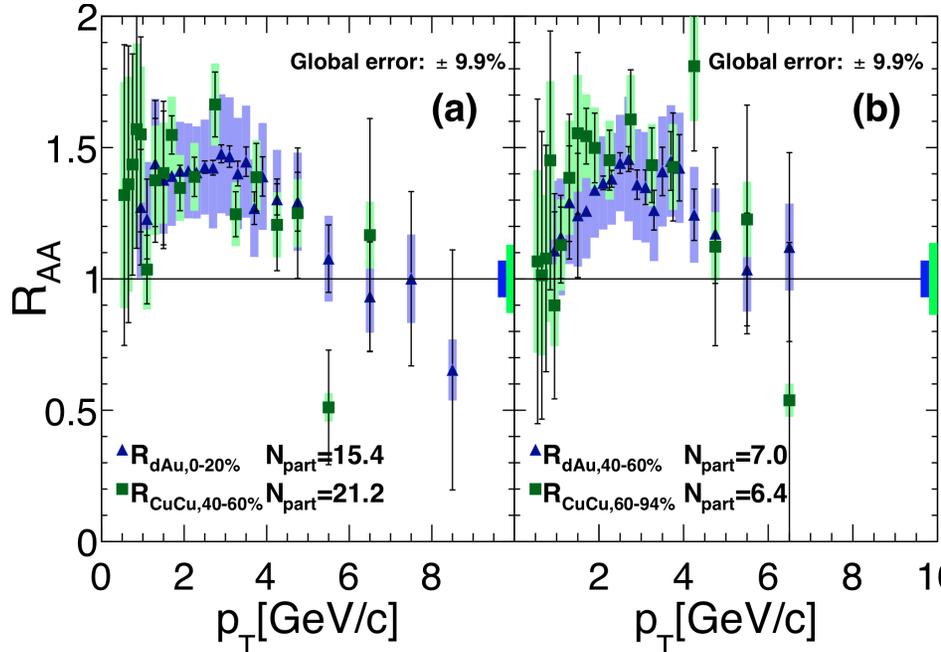
$\Psi(2s)$ relative suppression



Charm boost follows N_{Part}

Heavy-flavor electrons in three systems

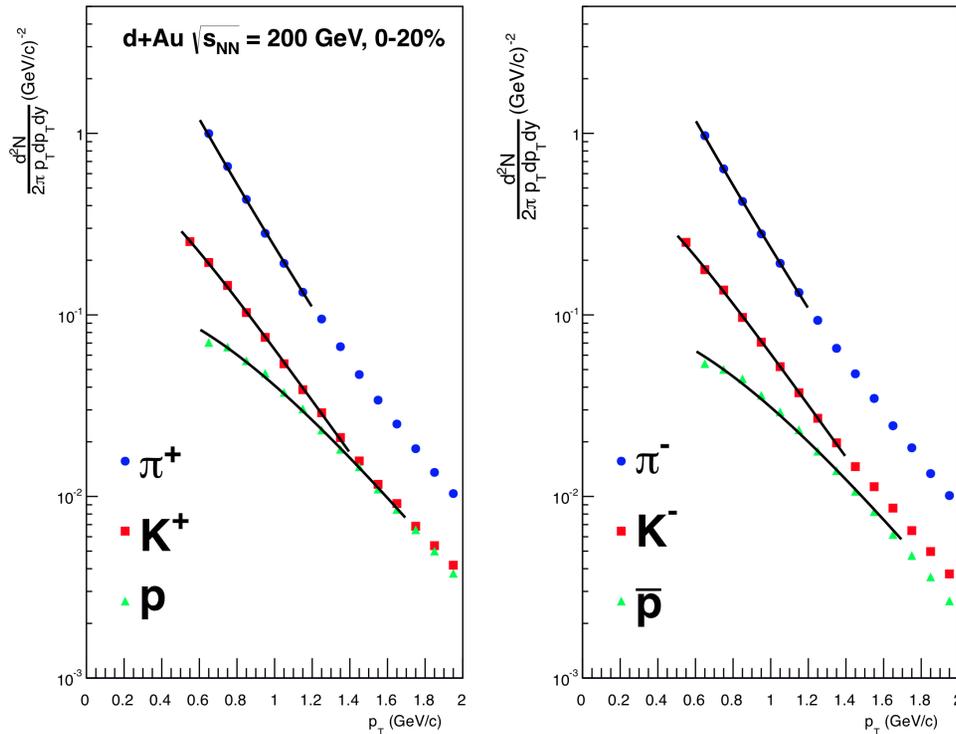
d+Au meets Cu+Cu



arXiv:1310.8286

Single charm is pushed but never destroyed; is trend with N_{Part} indicative of medium effect?

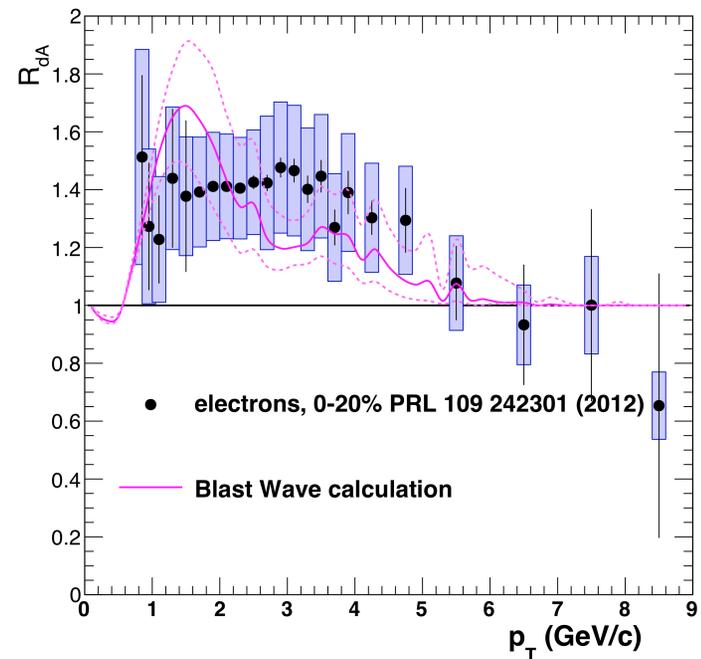
Radial flow in d+Au?



Blast-wave fits to identified light hadron spectra

A. Sickles, Phys. Lett. B731 51-56 (2014),
 “Possible Evidence for Radial Flow of Heavy Mesons in d+Au Collisions”

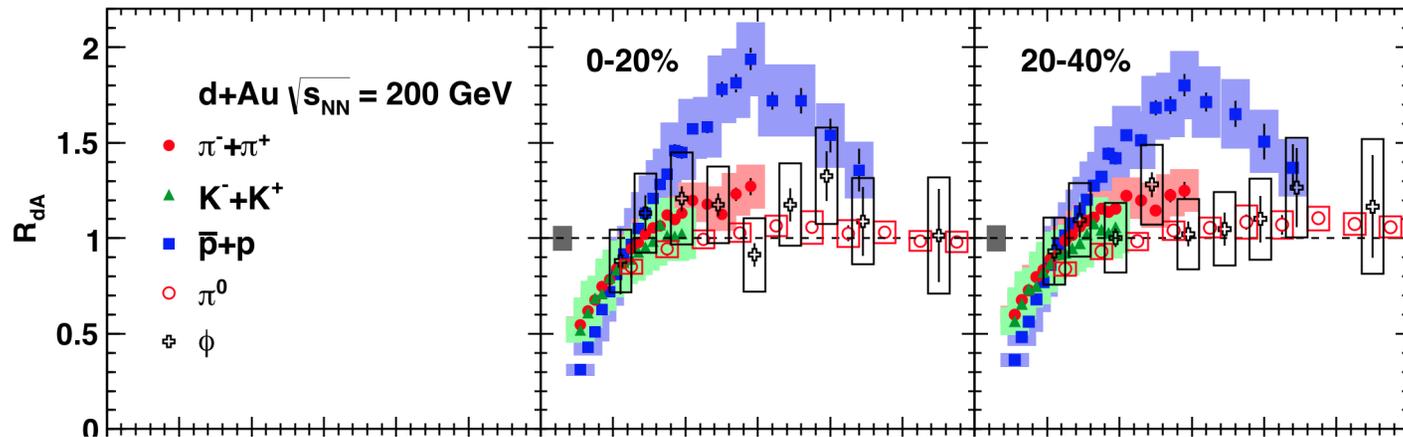
Was it the source of the Cronin effect?



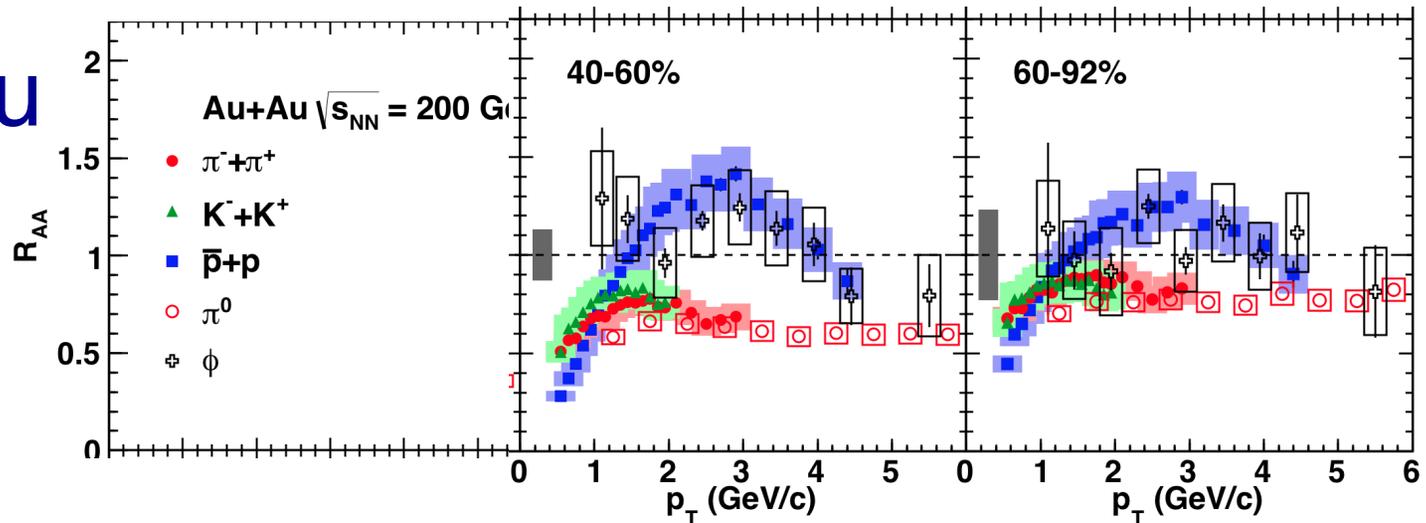
Heavy-flavor (charm) electron R_{dAu}

Central d+Au vs Periph Au+Au

d+Au



Au+Au

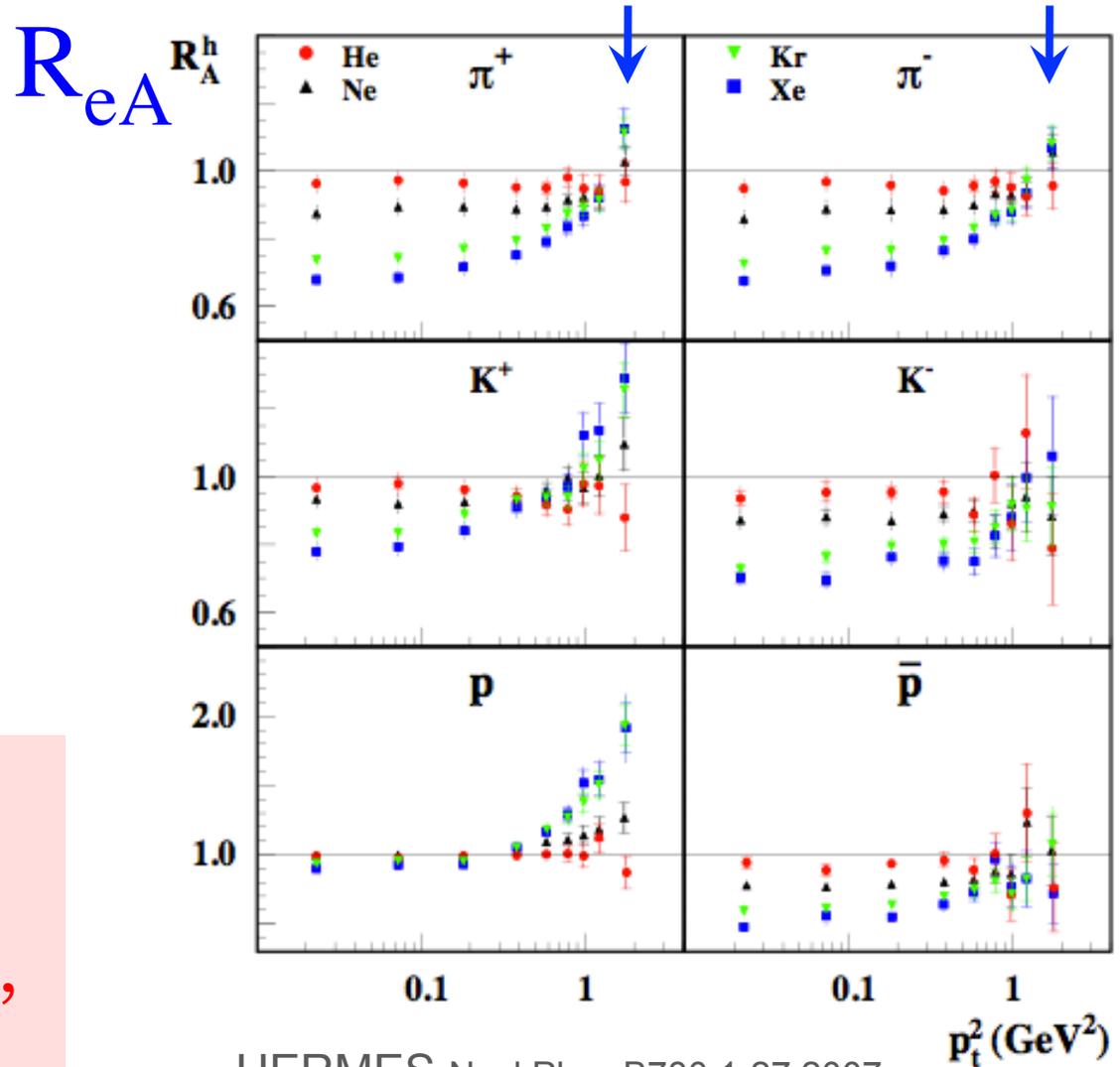


Caution: Cronin rides in $e+A$

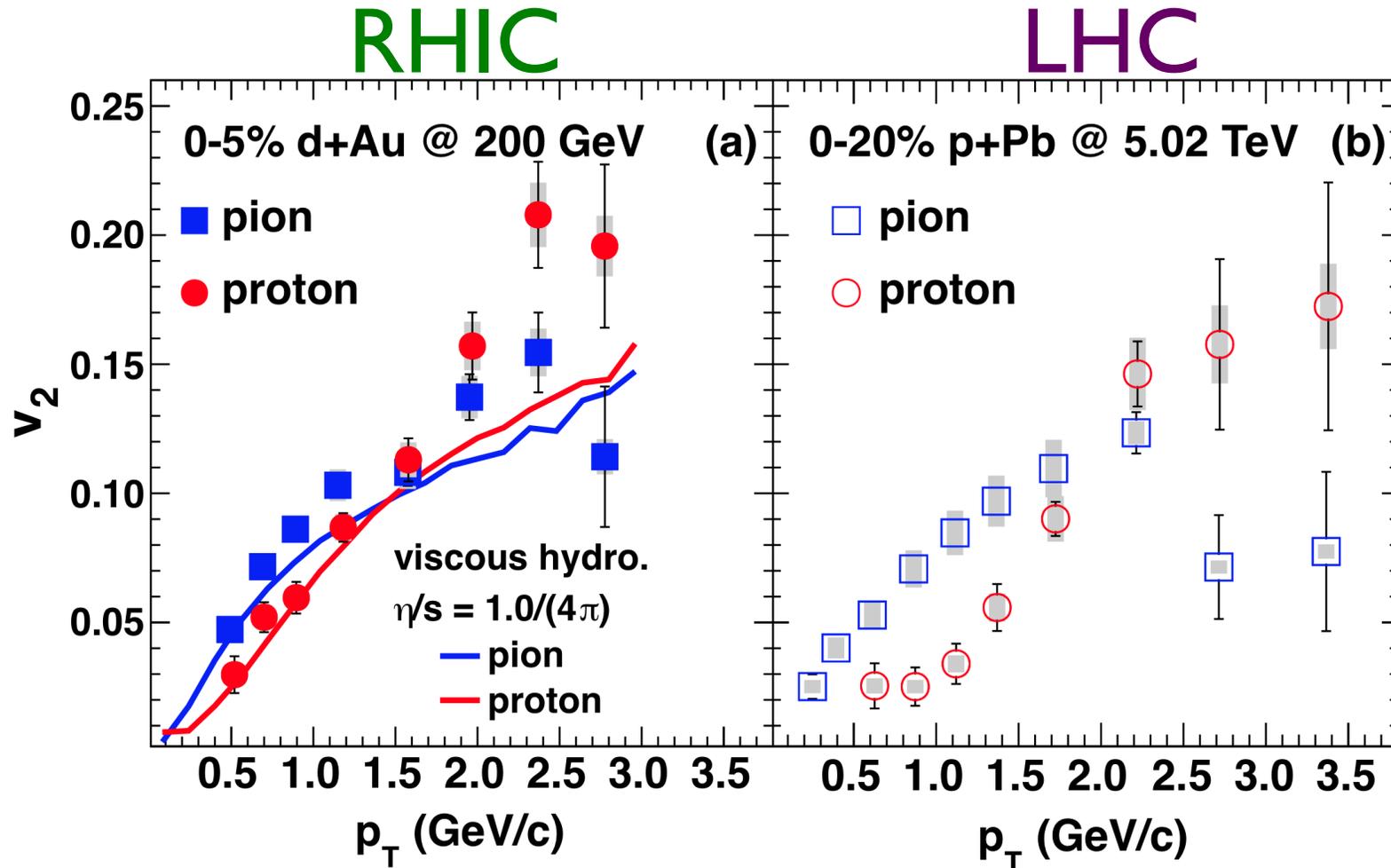
Enhancement of
(+) hadron yields at
 $p_T \sim 1-1.5 \text{ GeV}/c$
is seen with
increasing A in $e+A$.

Pattern is *sort of* like
radial flow?

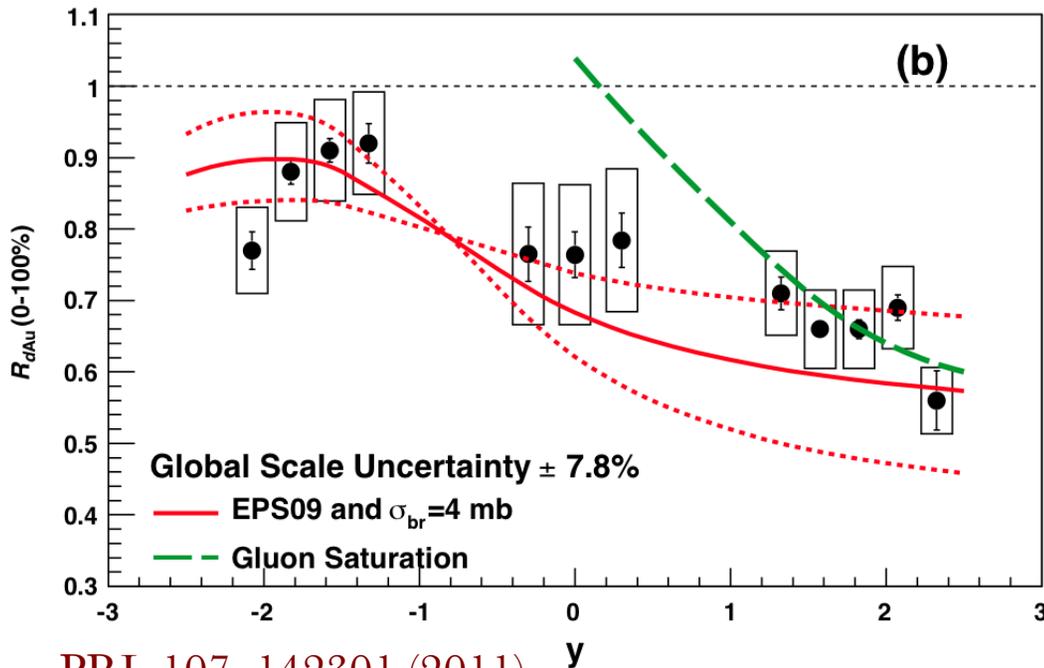
Moral: Need to
look at small
systems with full,
proper models



Mass splitting of v_2 (EP)



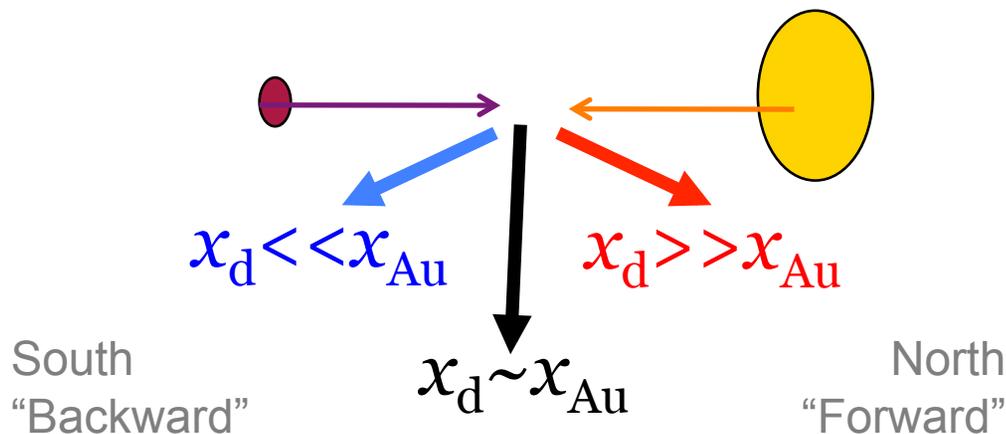
d+Au to forward/backward J/Psi



PRL 107, 142301 (2011)

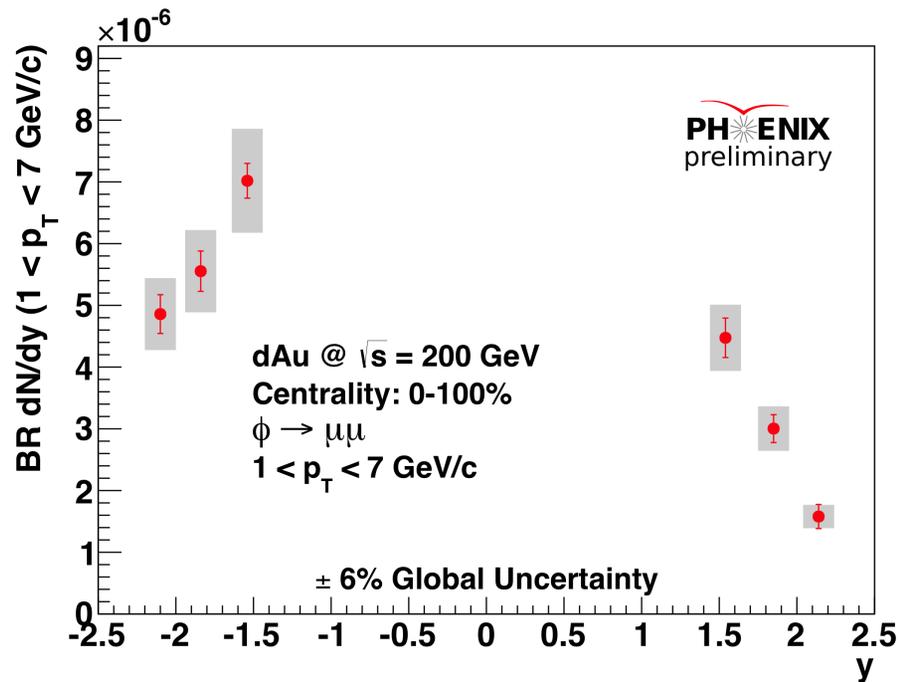
R_{dAu} for J/Psi in min-bias d+Au

For inclusive d+Au, CNM modifications capture forward/backward difference (but geometry dependence is harder).

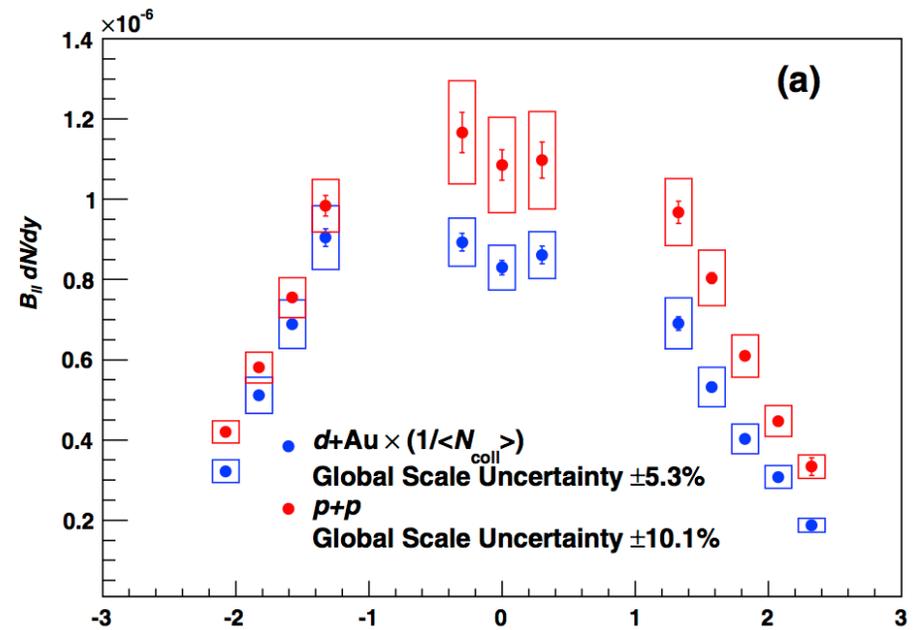


Sort-of-heavy flavor in d+Au

d+Au \rightarrow ϕ



d+Au \rightarrow J/ Ψ



PRL **107**, 142301 (2011)