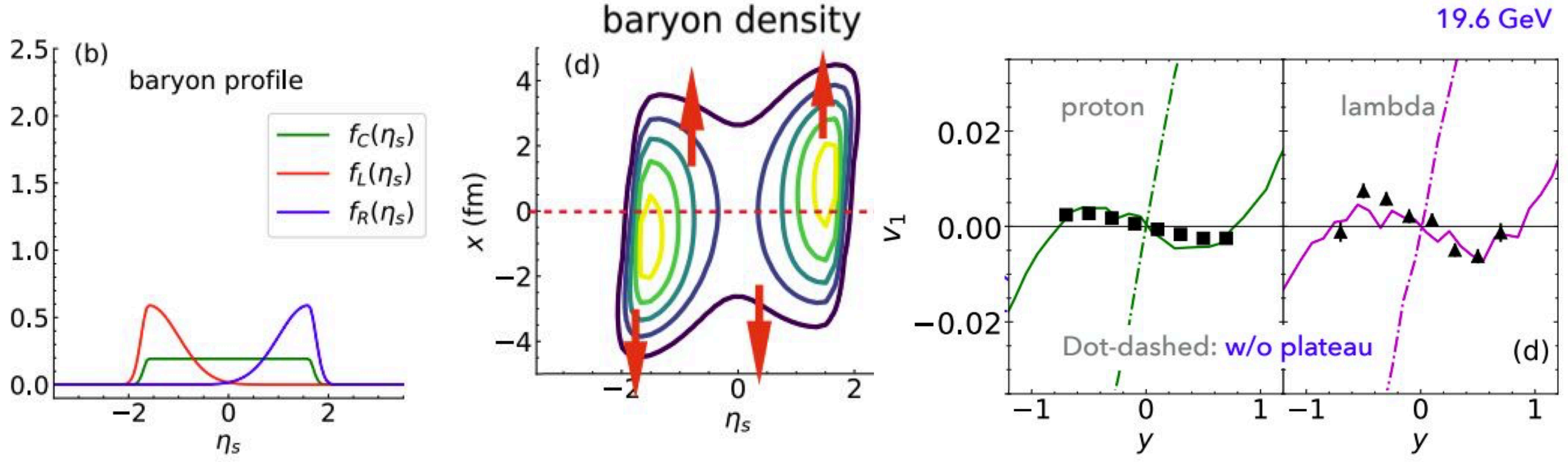
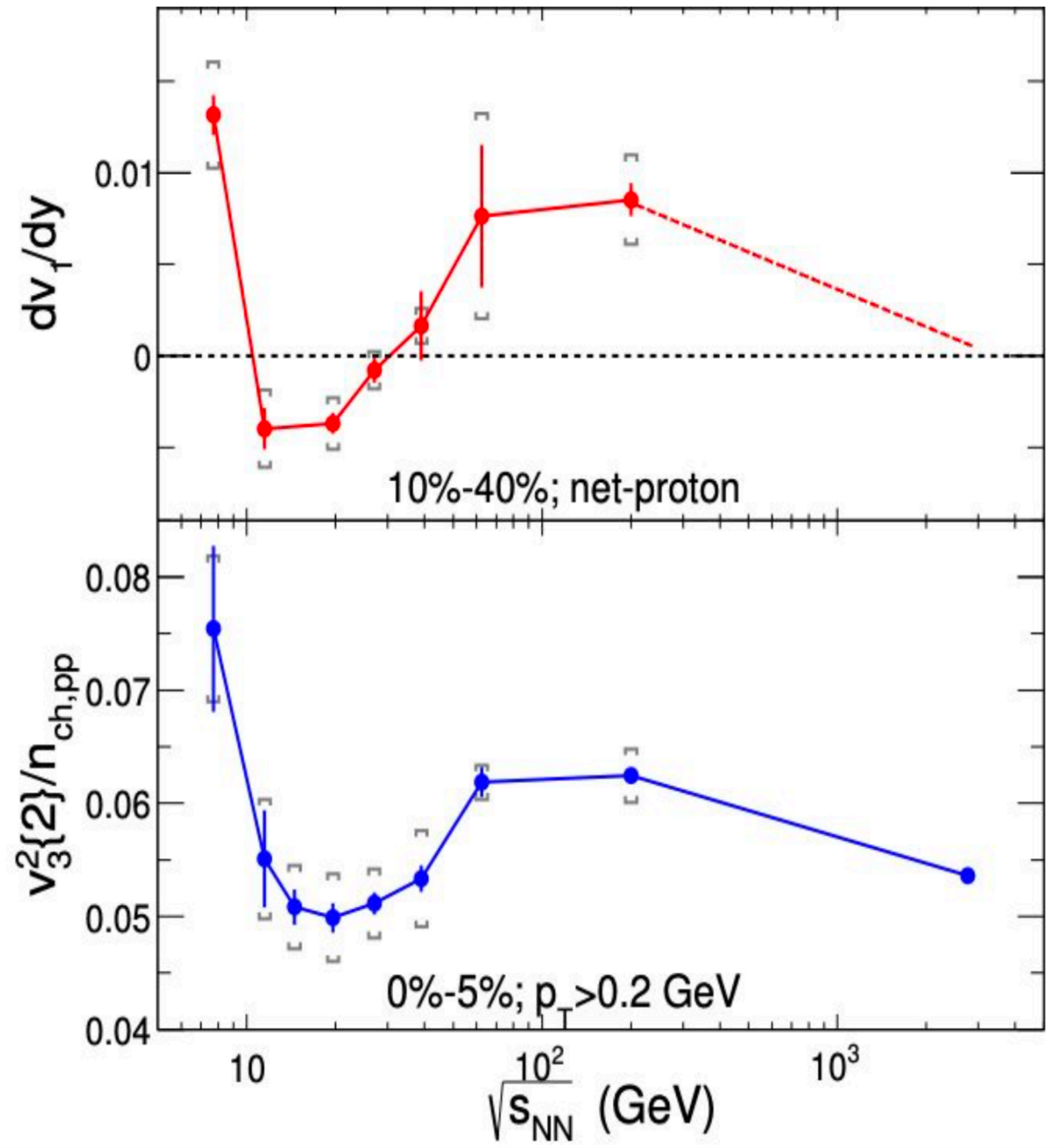
Flow in the collider region

Minimum in dv_1/dy: mostly due to baryon stopping?

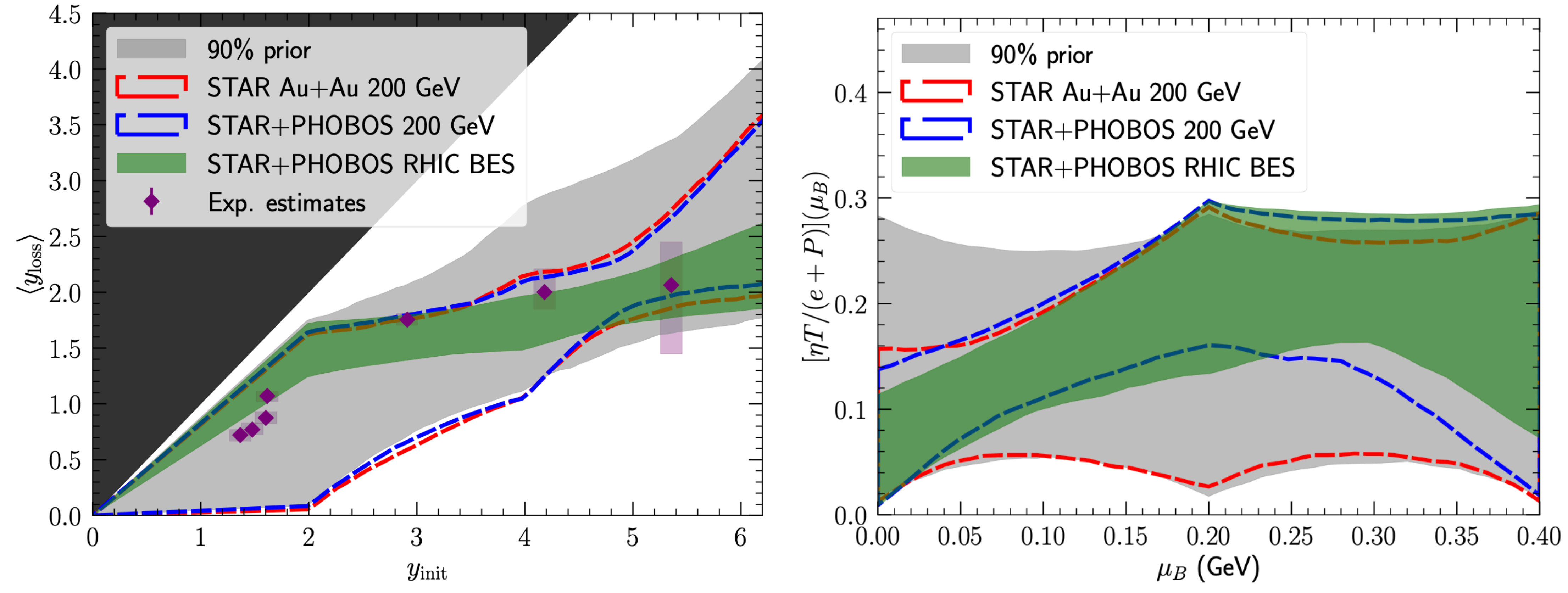
- parametric initial conditions reproduce the minimum



L. Du, C. Shen, S. Jeon, C. Gale, *Phys.Rev.C* 108 (2023) 4, L041901, arXiv:2211.16408



- Bayesian study: change in stopping & viscosity around $\sqrt{s} \sim 20$ GeV



C. Shen, B. Schenke, W. Zhao, *Phys.Rev.Lett.* 132 (2024) 7, 072301, arXiv:2310.10787

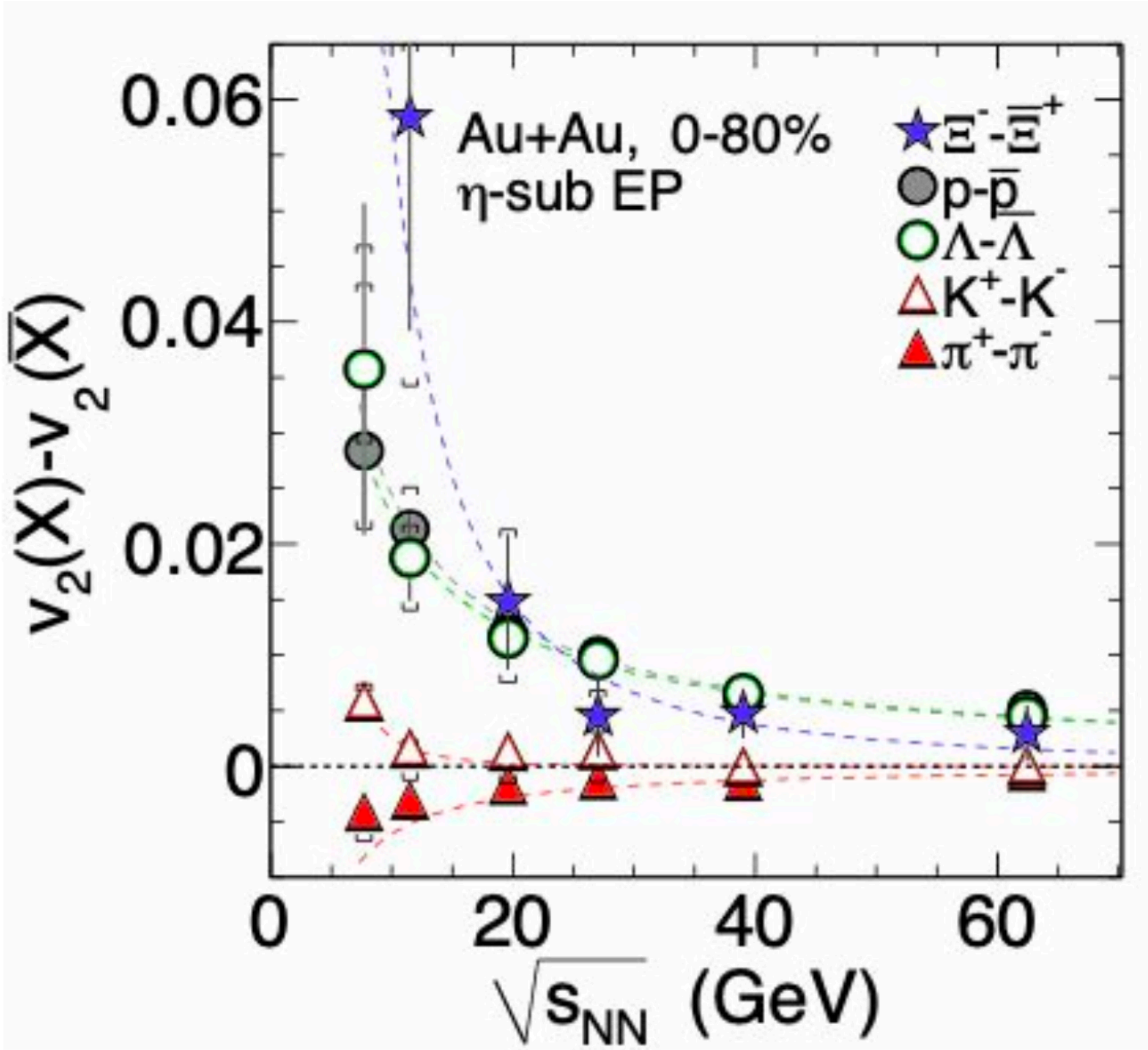
some models without a softening describe the dip,
some models with a softening don't describe the dip

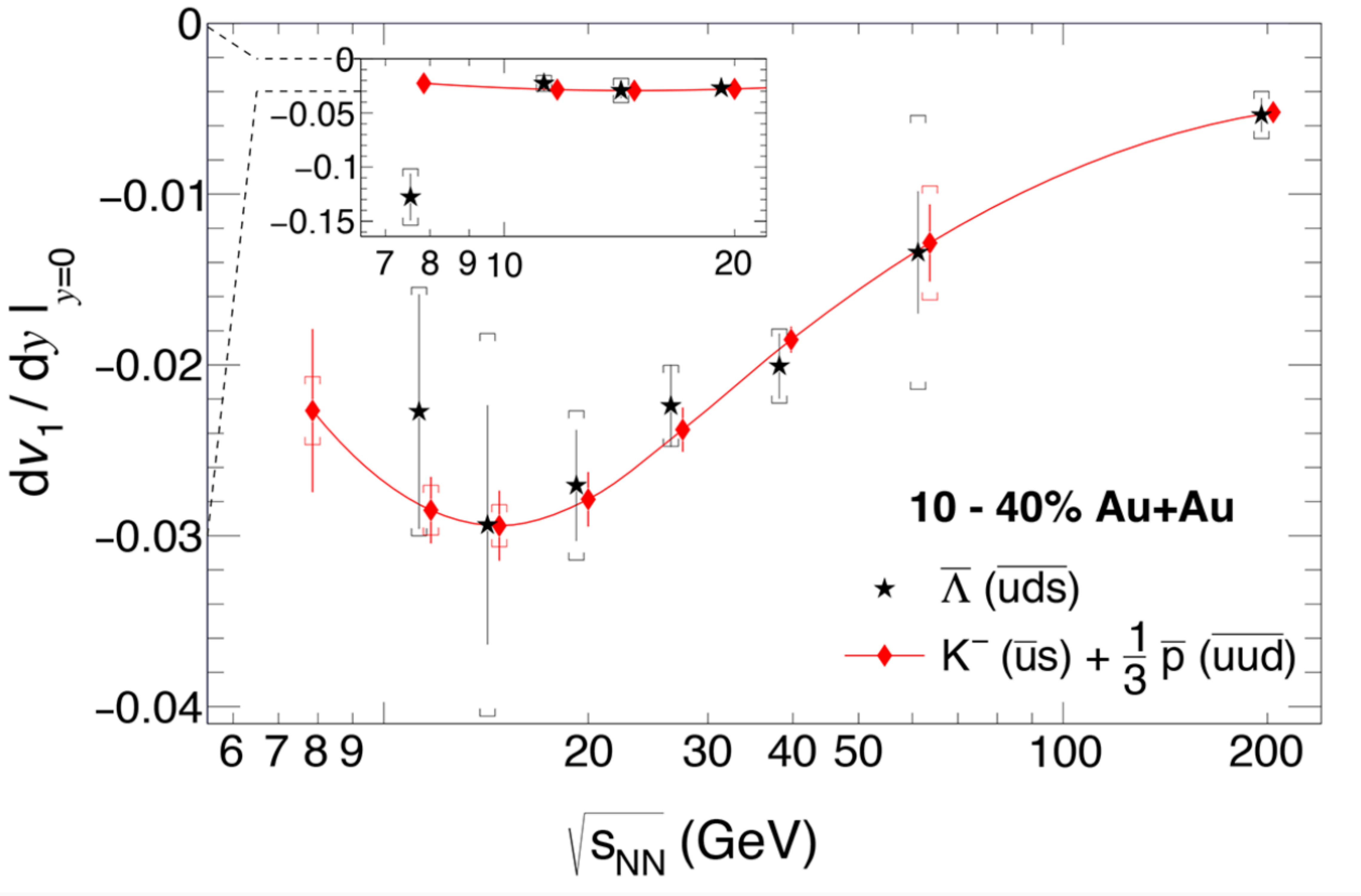
- stopping mechanisms must be studied and tested in models
- could BES-II data provide constraining power?
- we need dN/dy measurements

Flow in the collider region

Is the particle anti-particle dependence understood?

Experimentalists extensively explored the idea of transported vs. produced quarks. Combining this idea with NCQ scaling describes a lot of trends.



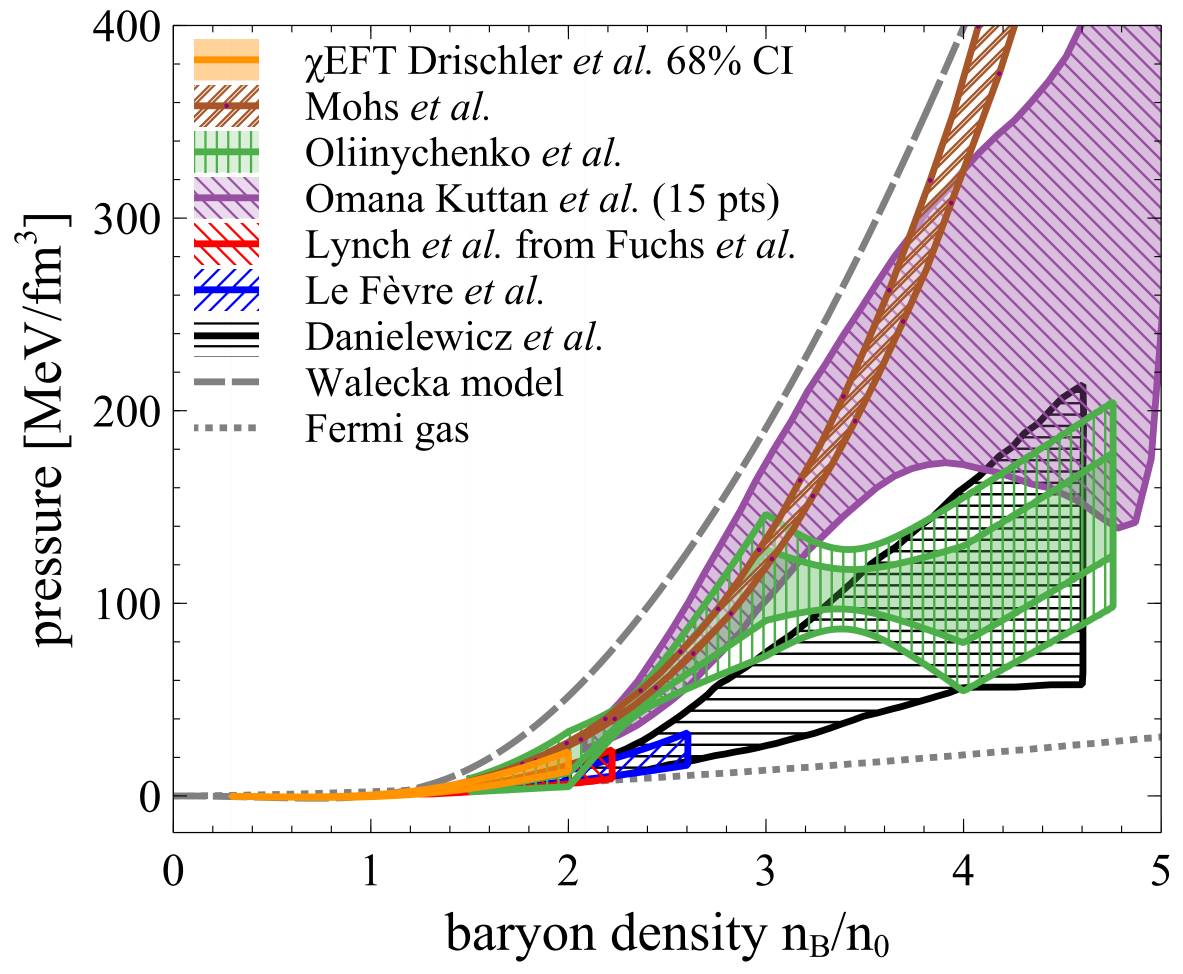


- Can we model this idea dynamically?
- Do models correctly describe the full suite of observables?

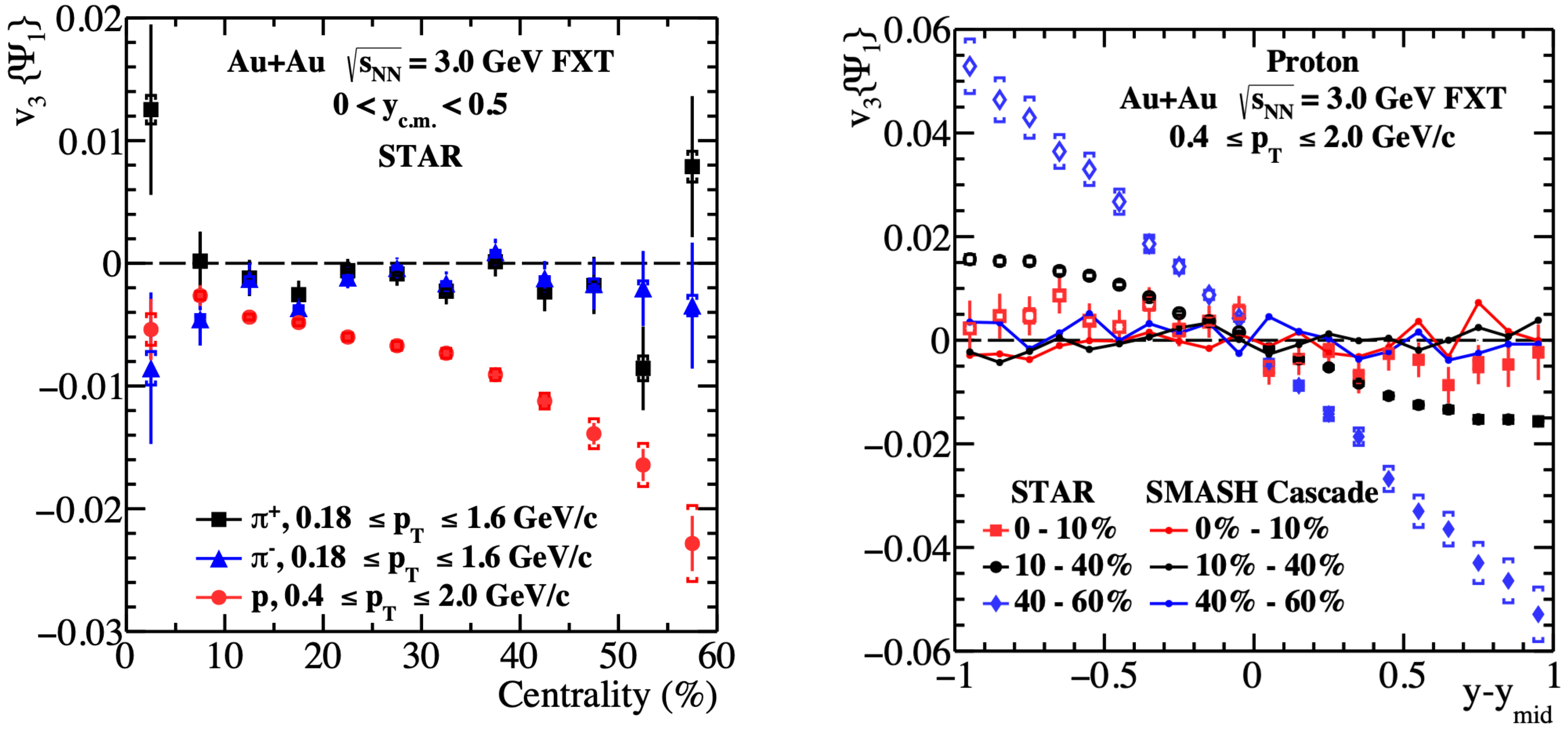
Flow in the FXT region

Can transport be used to extract the EOS?

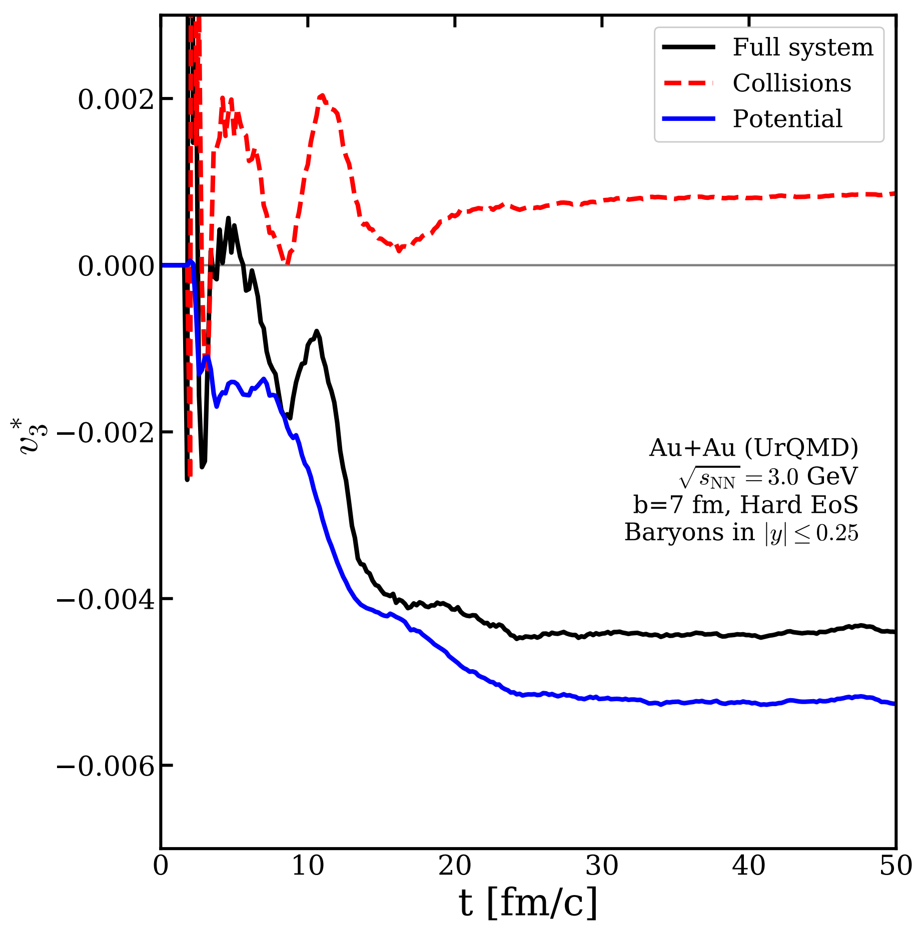
- Bayesian extraction of the EOS from comparisons to data needs modeling improvements:
  — momentum dependence of the potential
  — in-medium cross-sections
  — evaluation of results against constraining power of observables
- new observable @FXT: $v_3(\Psi_1)$



adapted from L. Du, M. Stephanov, A. Sorensen, *Int.J.Mod.Phys.E* 33 (2024) 07, 2430008



STAR, *Phys.Rev.C* 109 (2024) 4, 044914, arXiv: 2309.12610

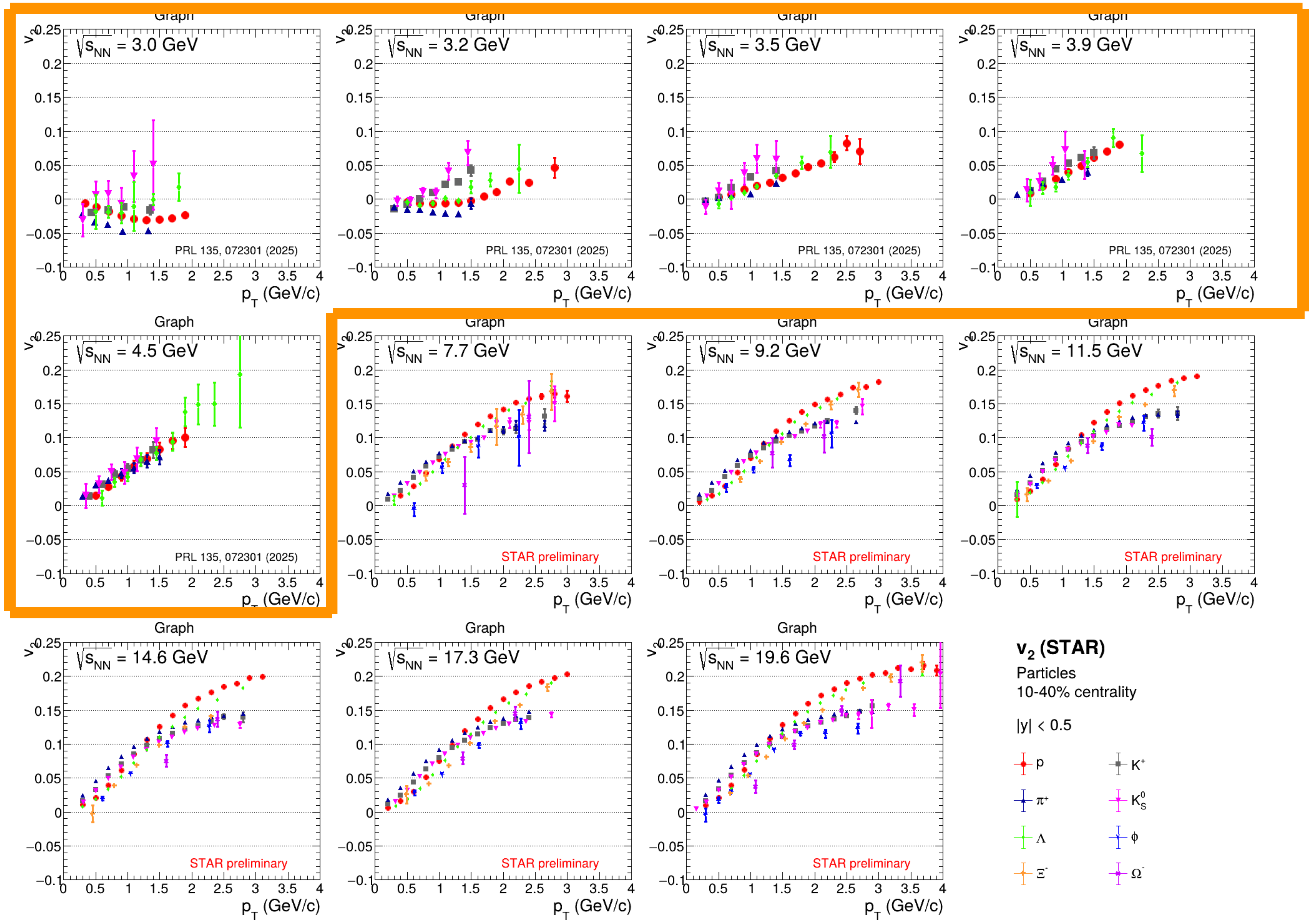


T. Reichert, in progress

- we need dN/dy measurements to constrain fundamental input in models (elementary cross sections, in-medium cross sections)
- $v_n(p_T)$ to constrain p-dependence
- apples to apples comparisons of measurements and model results: analyses beyond event plane method

NCQ scaling and lack thereof: a sign of… what?

Can NCQ scaling be used to make statements about the degrees of freedom @FXT? No.



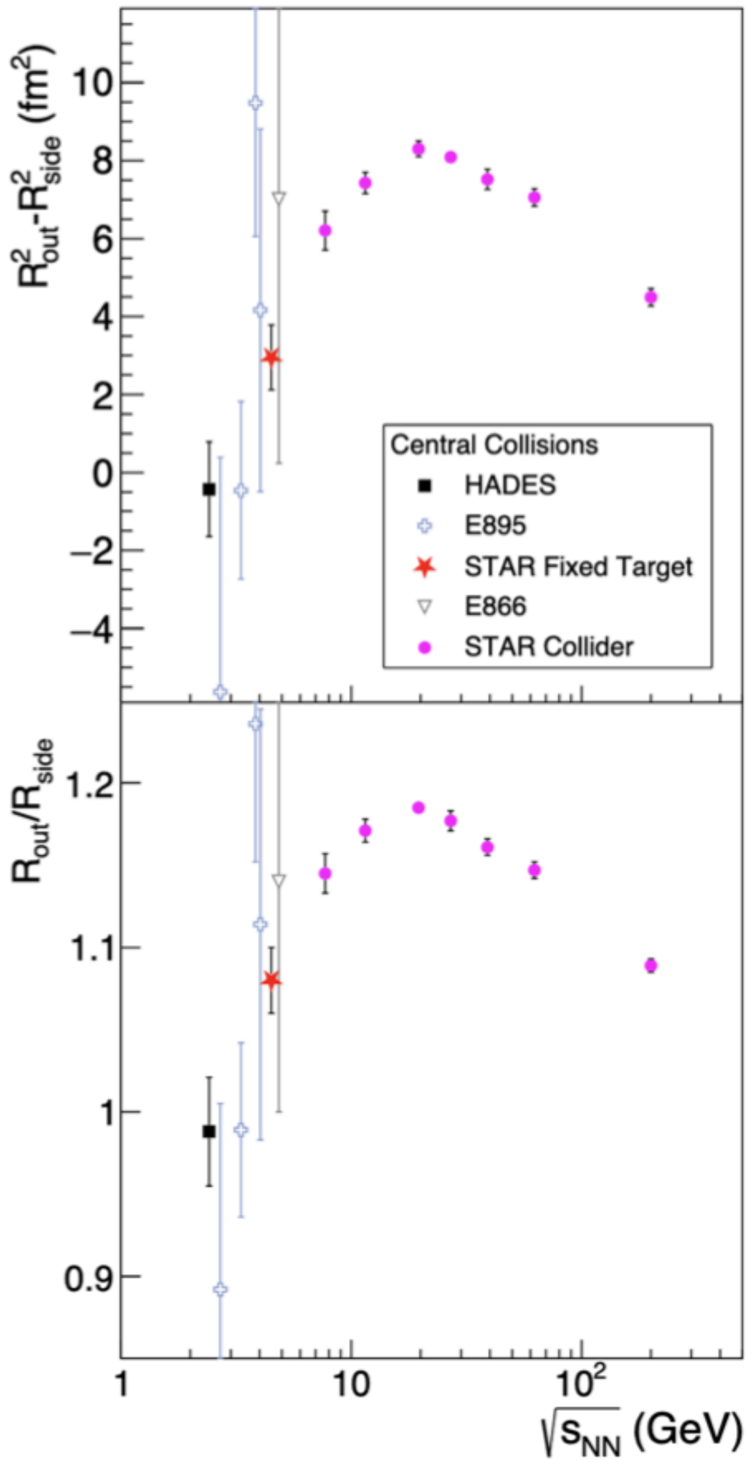
FXT

- data @FXT does not allow to compare baryon and meson flow as @ collider energies
- unclear how mean-fields and/or spectators would affect NCQ scaling

- expectations in various scenarios should be developed before statements about the significance of NCQ scaling are made

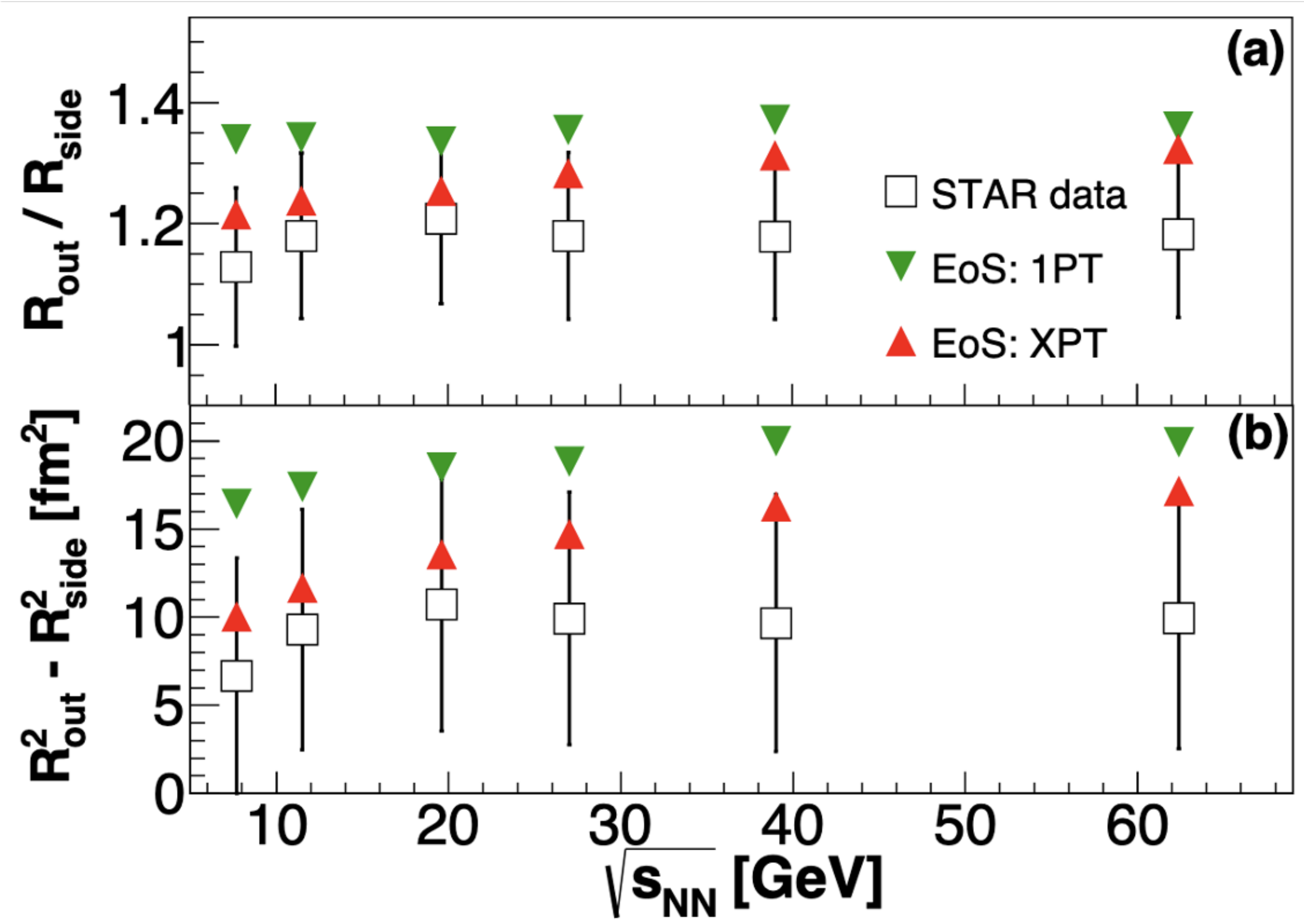
HBT

What does HBT tell us about the system?

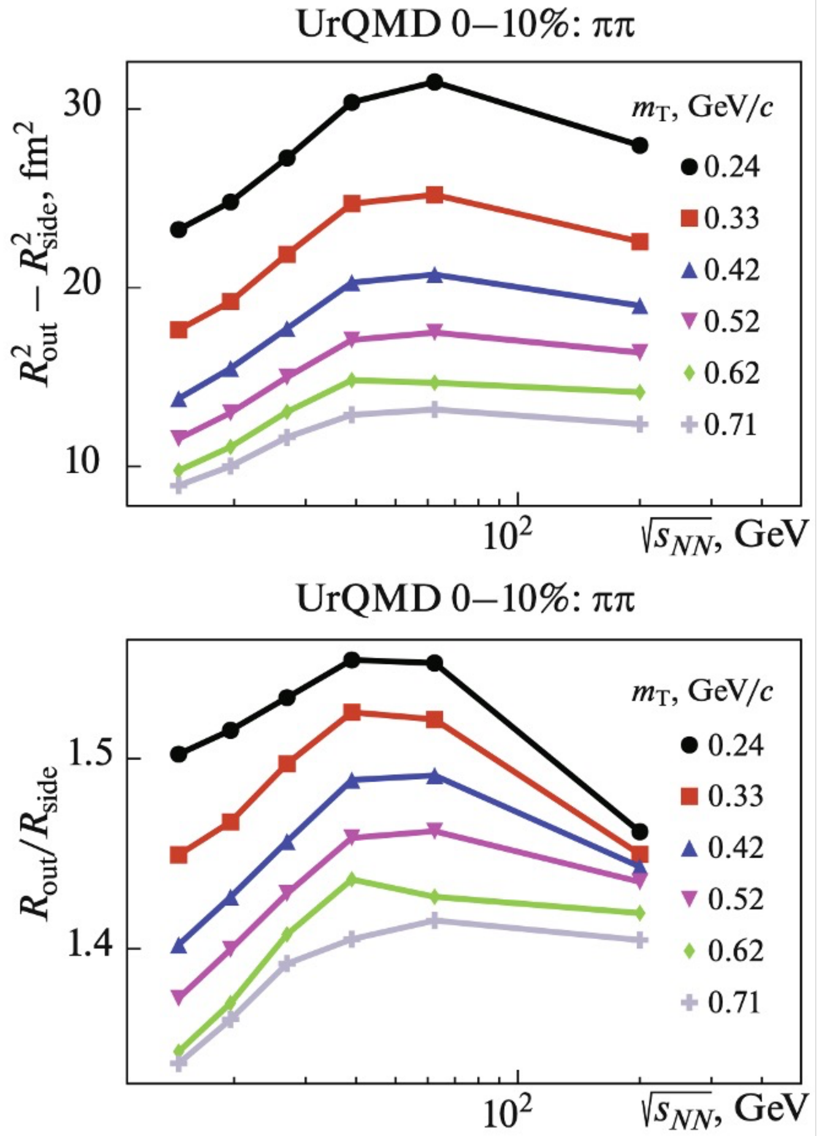


- HBT found to be very constraining in some Bayesian analyses
- HBT also produces a peak in $R^2_{\text{out}} - R^2_{\text{side}}$ at 20 GeV
- HBT tilt angle extraction shows the change in dynamics below 7.7 GeV

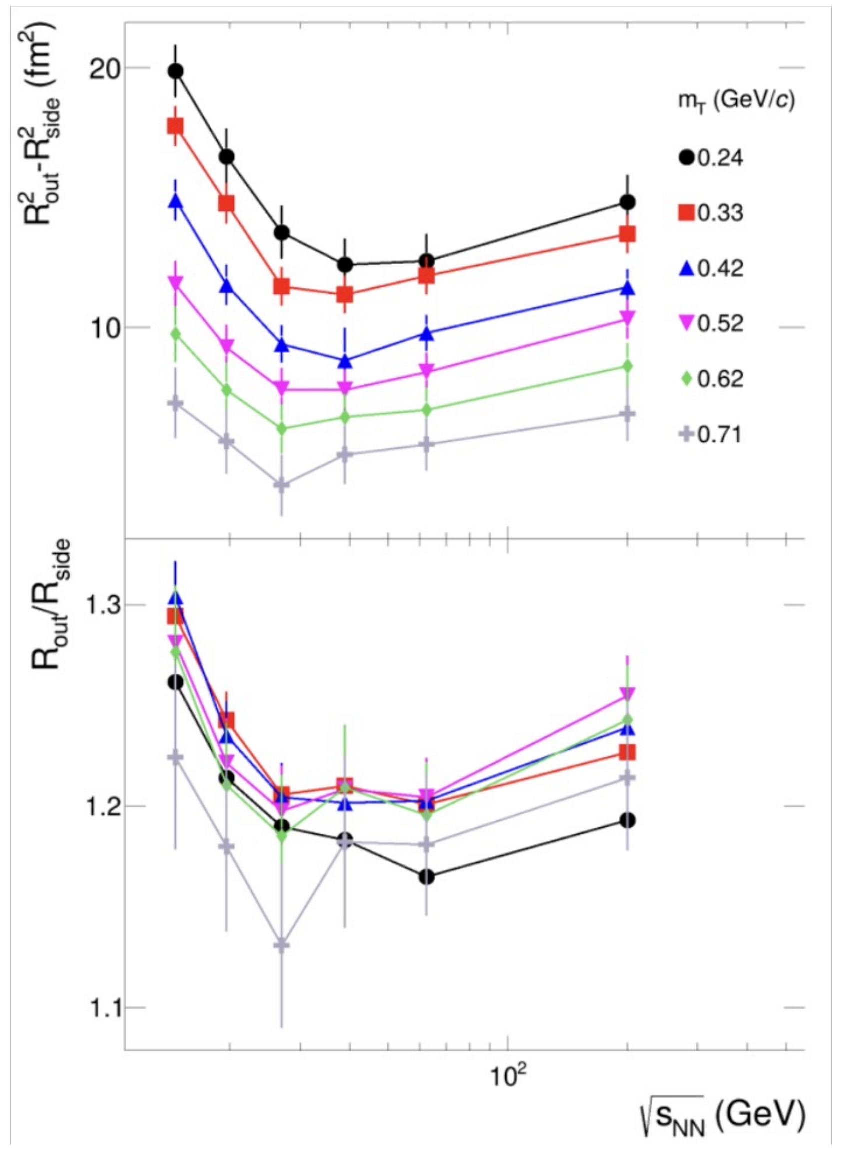
vHHLE + UrQMD

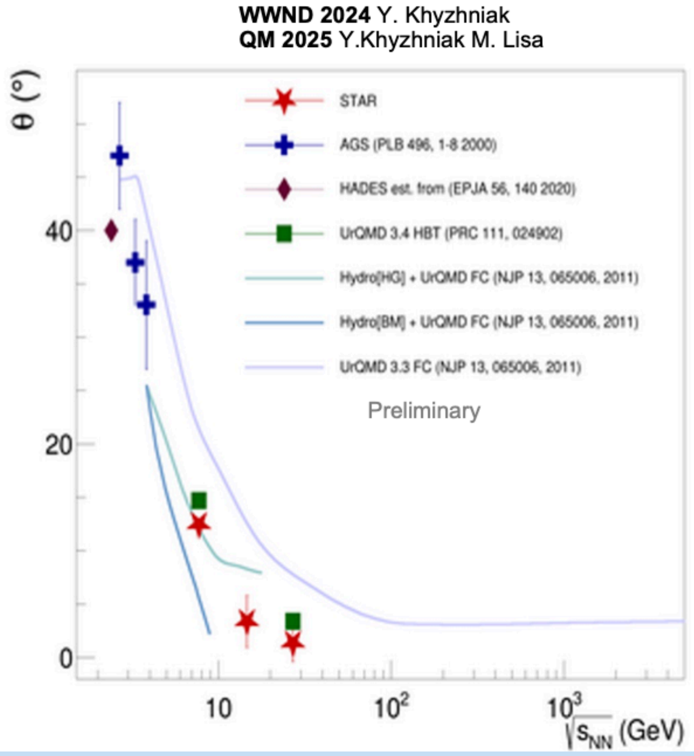


UrQMD



vHHLE + SMASH

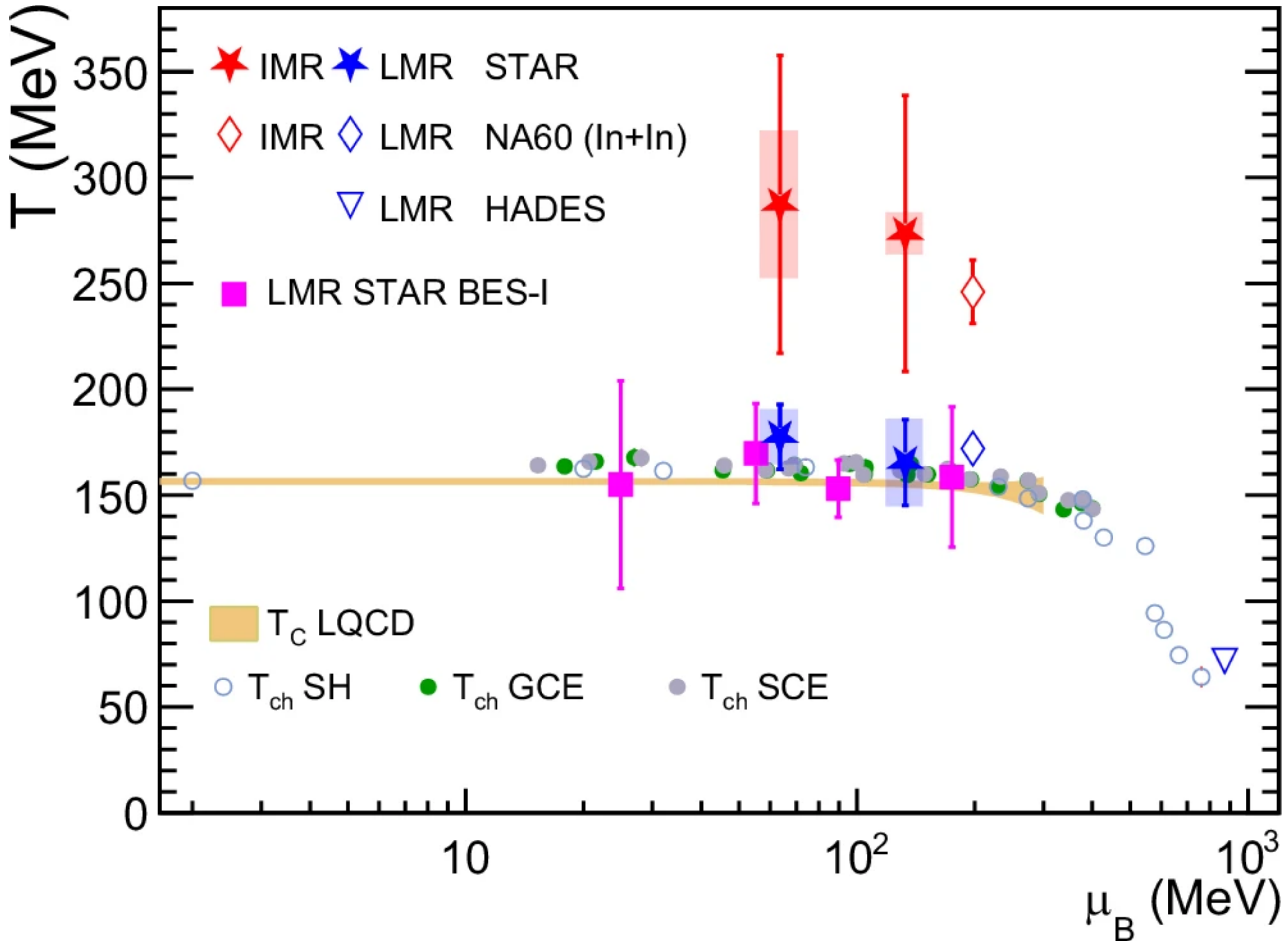




- Can p and $\bar{p}$ identical pair HBT results shed complimentary light about potential differing production mechanisms to dv_1/dy and net-p fluctuation measurements?
- Can we understand the spread in simulation predictions?

EM probes

Can dilepton and photon measurements tell us something about chiral symmetry restoration or the CP?



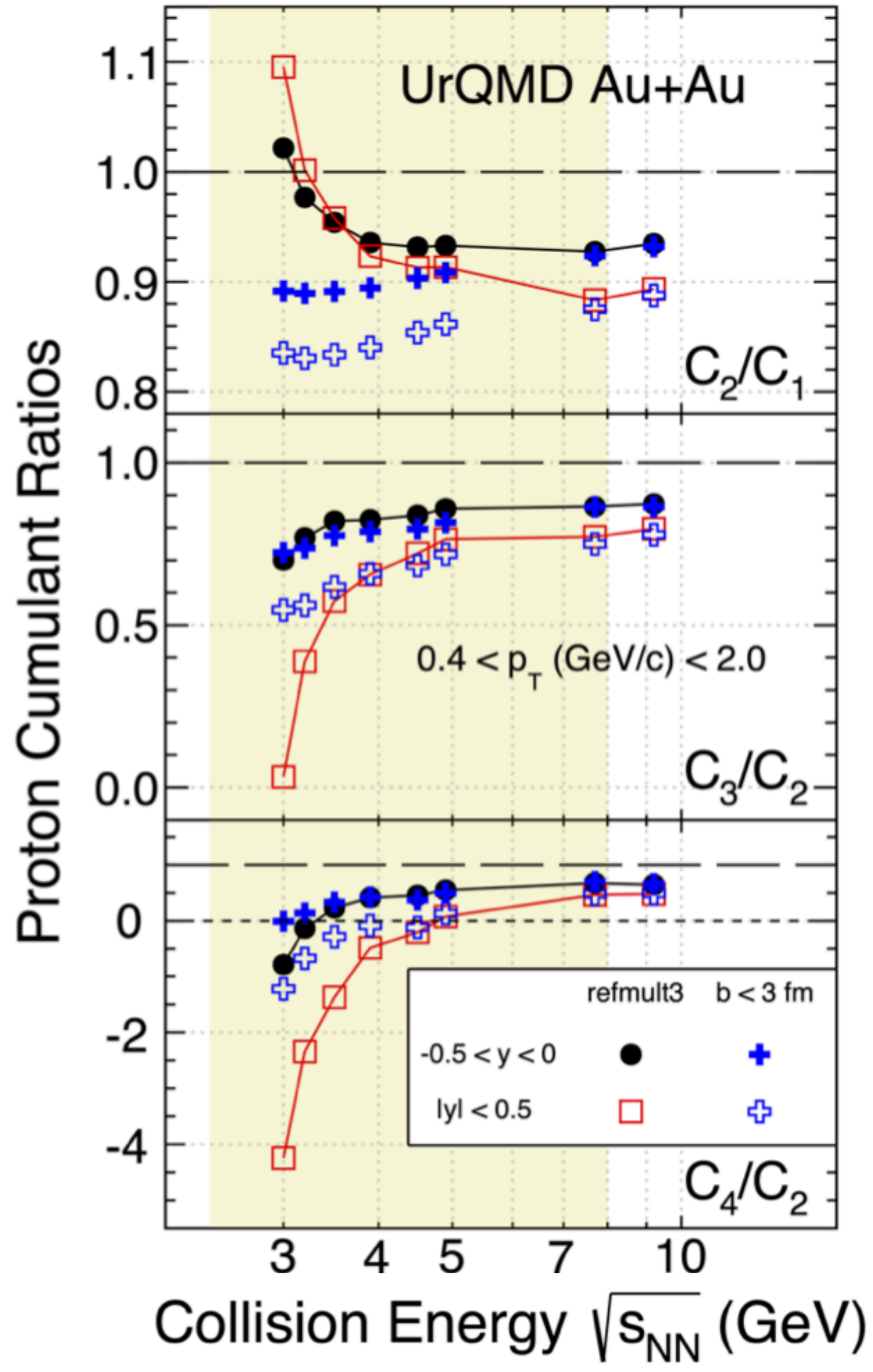
Data on temperature in the IMR provide a consistent picture of a hot expanding system with temperatures above 200 MeV, even at low energies.

Detecting signals due to CP potentially very difficult.

- Can we disambiguate the effects from chiral symmetry restoration from in-medium effects?
- Don't we now know enough about the evolution to pin down how much can come from the hadronic phase? If not, what do we need?
- Can CBM see the low mass region well enough to detect signals of the CP?

Lower-order fluctuations

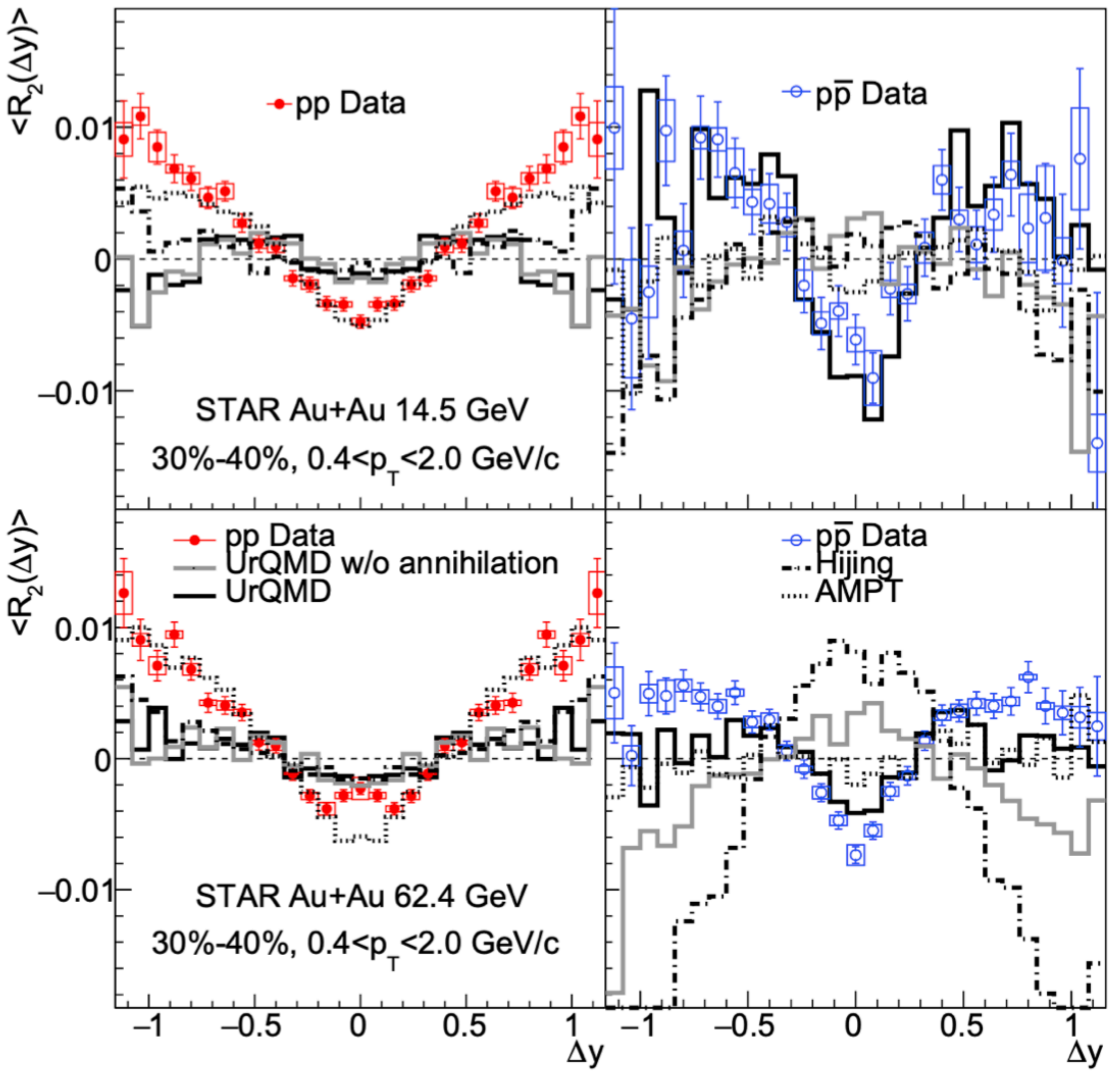
Are C_2, C_2/C_1 results well understood?



X. Zhang, Y. Zhang, X. Luo, N. Xu, arXiv:2506.18832

- C_2: easier to measure and interpret than C_3, C_4
- still, results may be strongly affected by correction procedures

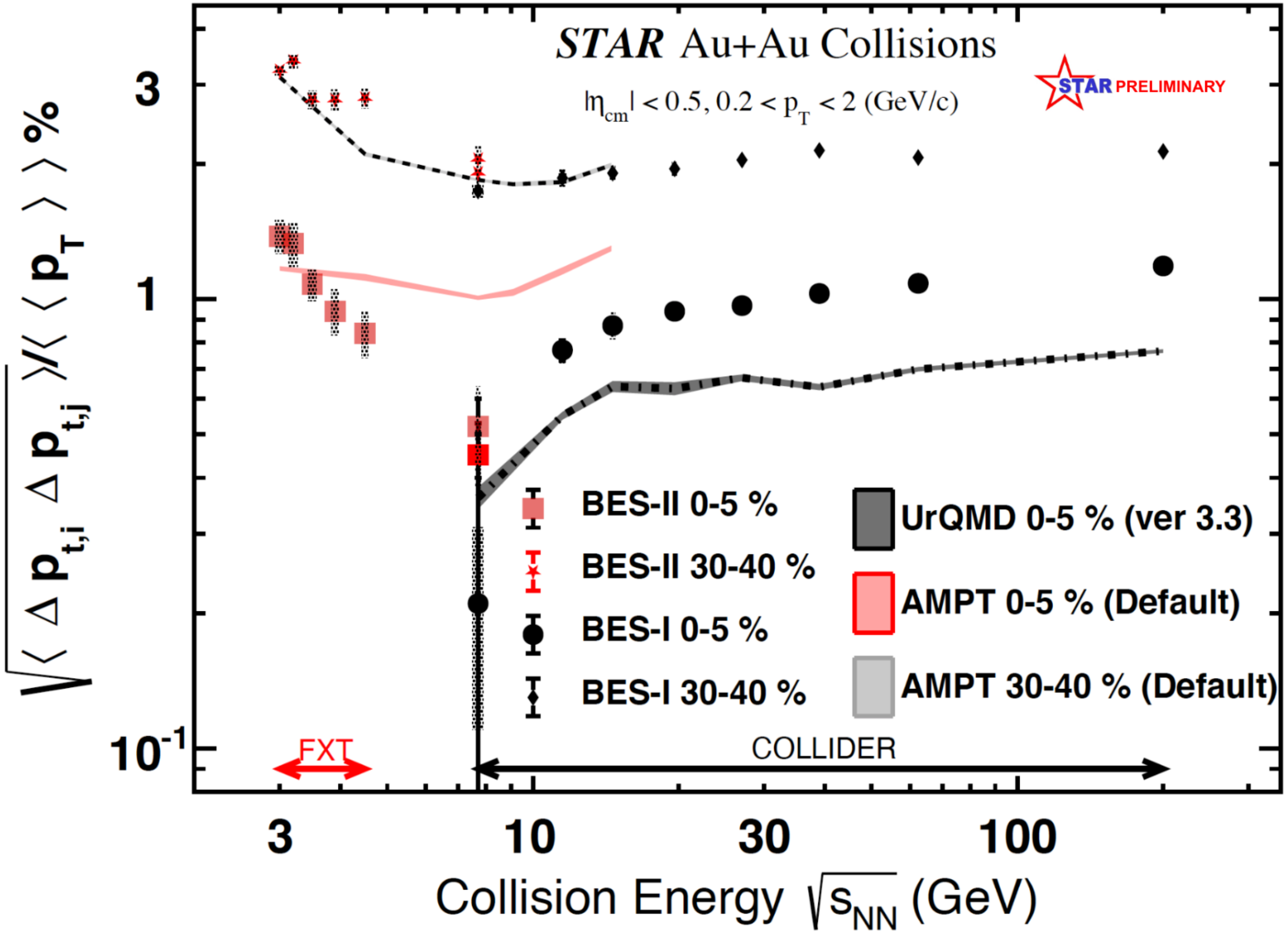
- 2-particle correlations ($\Delta\phi$, $\Delta\eta$, Δp_T) are more easily corrected for detector effects
- they reveal the rich physics behind the single number C_n, challenging models and interpretations



- use multiple methods and compare results
- show results with and without volume corrections
- (define volume!)
- do differential analyses, also @FXT

Lower-order fluctuations

Should we pay more attention to p_T fluctuations?

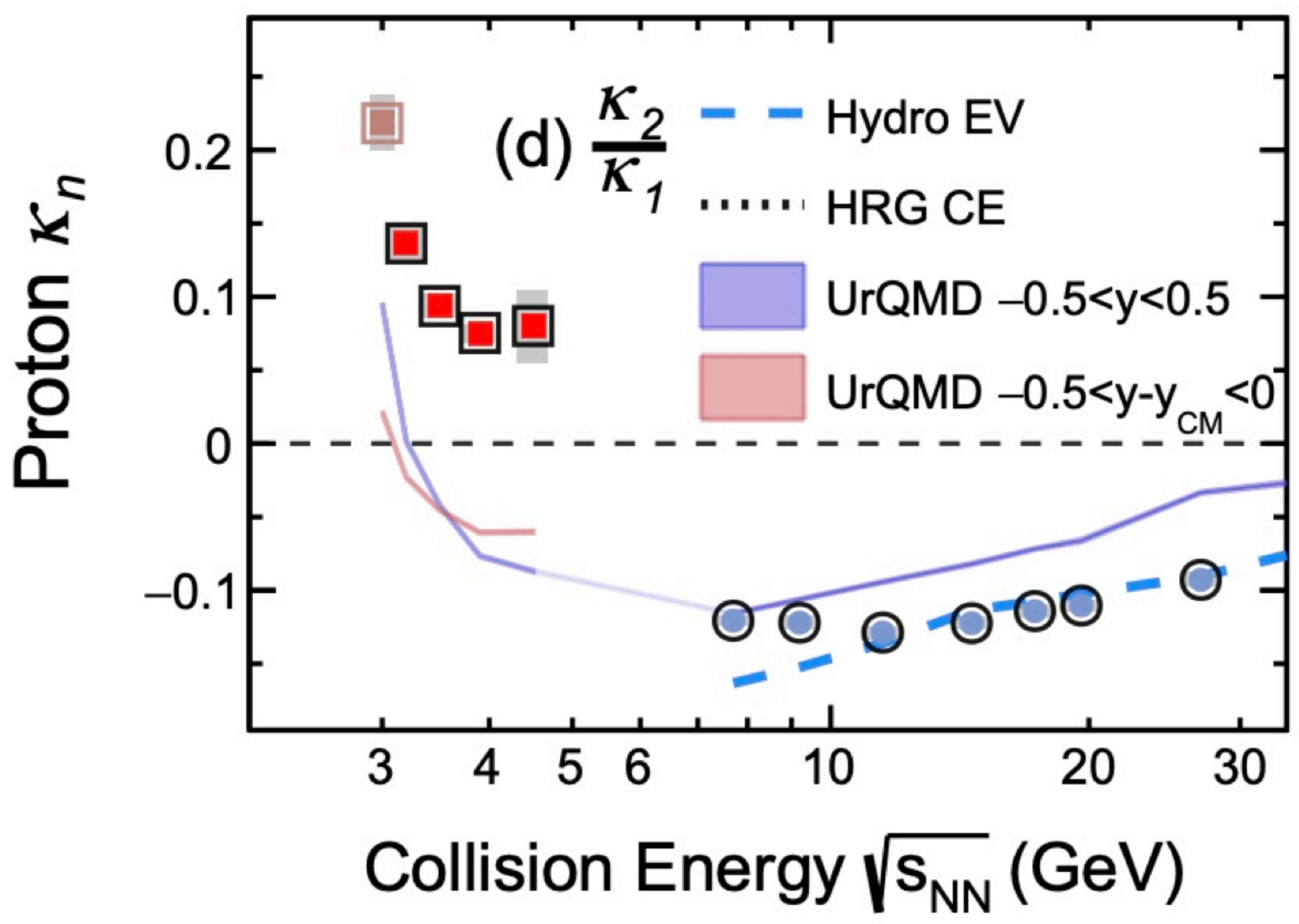


- this observable does not suffer uncertainties from CBWC and still shows the same trends as net proton cumulants in the FXT
- can be used in addition to net proton cumulants (using a wider range of observables is a must)

- Can model calculations shed light on this observable?

Lower-order fluctuations

Hydro with baryon conservation and repulsion (excluded volume) describes the data trends as energy decreases. Below 10 GeV, data start to increase above this model.

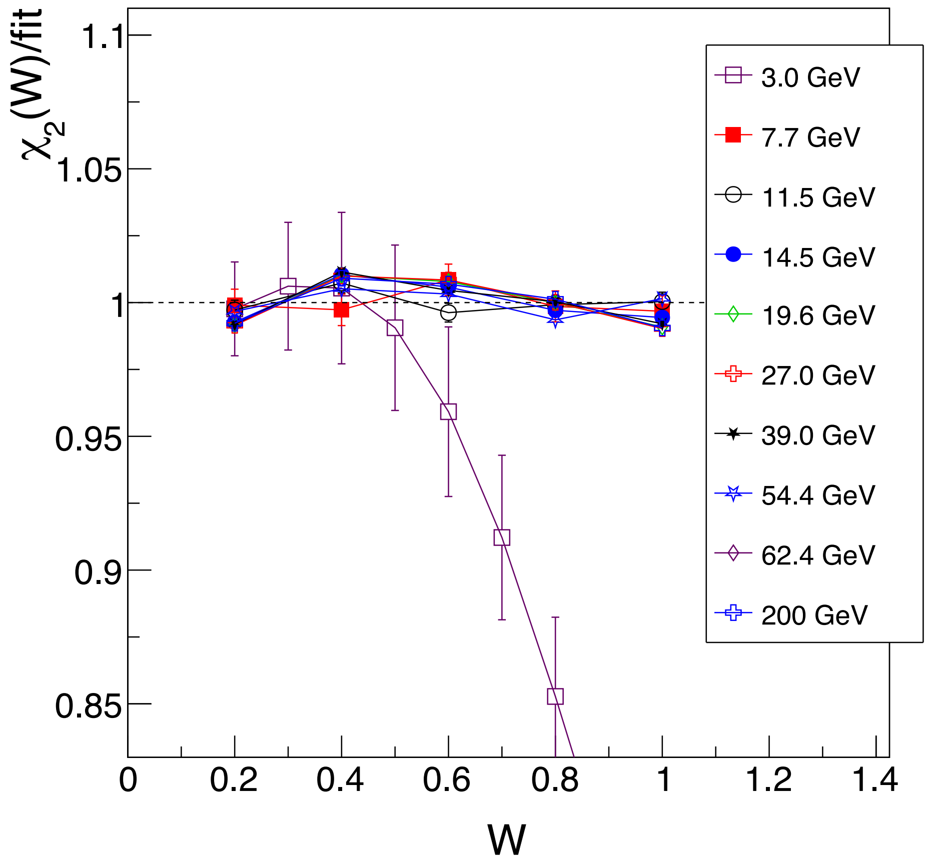


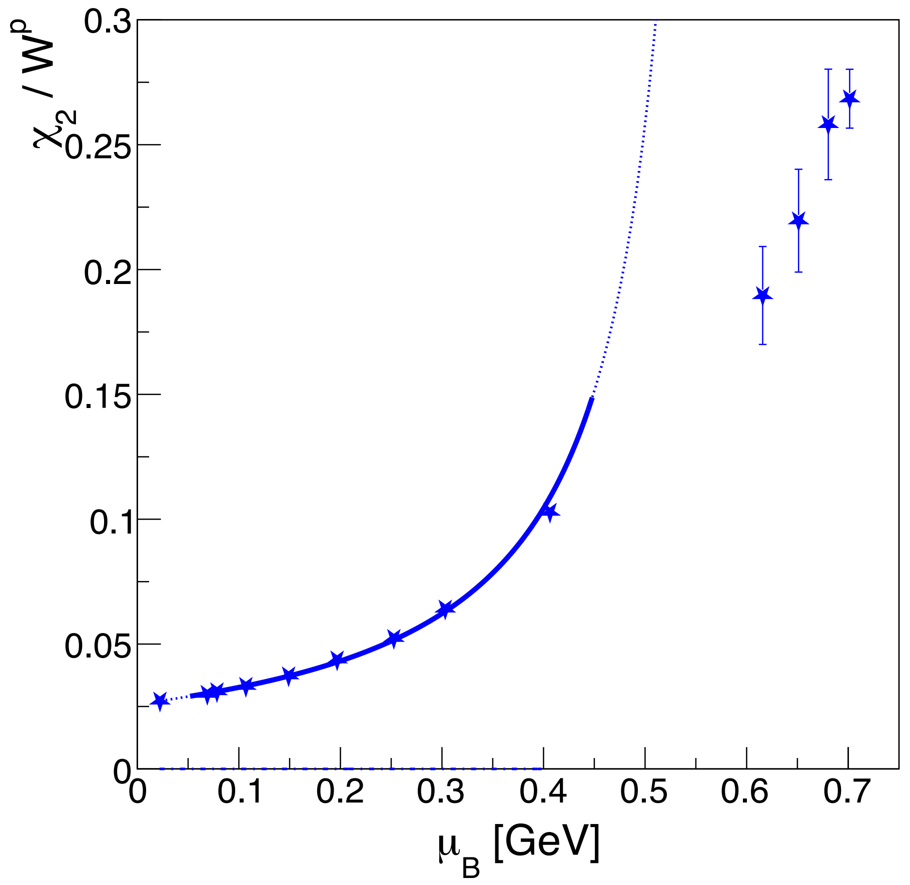
- Data in FXT increases. Is this the attractive interactions near the CP?
- The complex dynamics of the system and a baseline need to be better understood to reach a conclusion.

- Bigger picture: what is the best way to model these fluctuations? Hydro+? Transport with a noise term added?

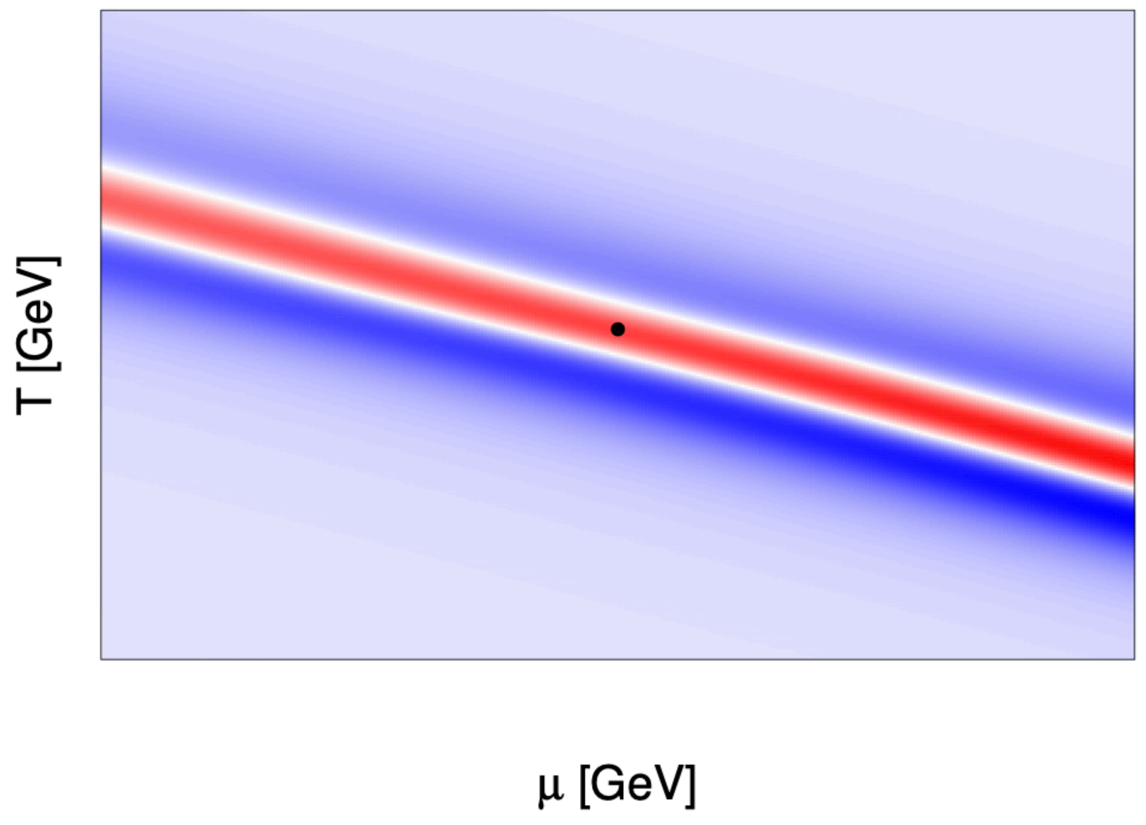
Lower-order fluctuations: finite-size scaling

What drives the scaling behavior of susceptibilities extracted from STAR BES cumulants?

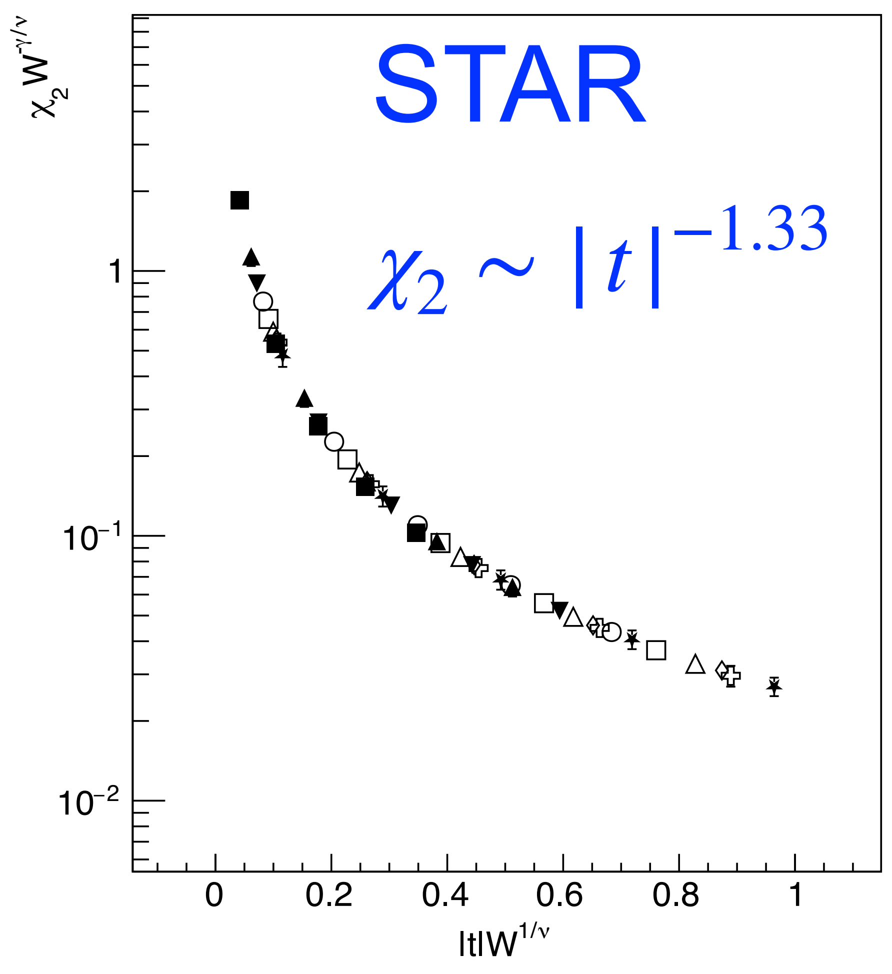


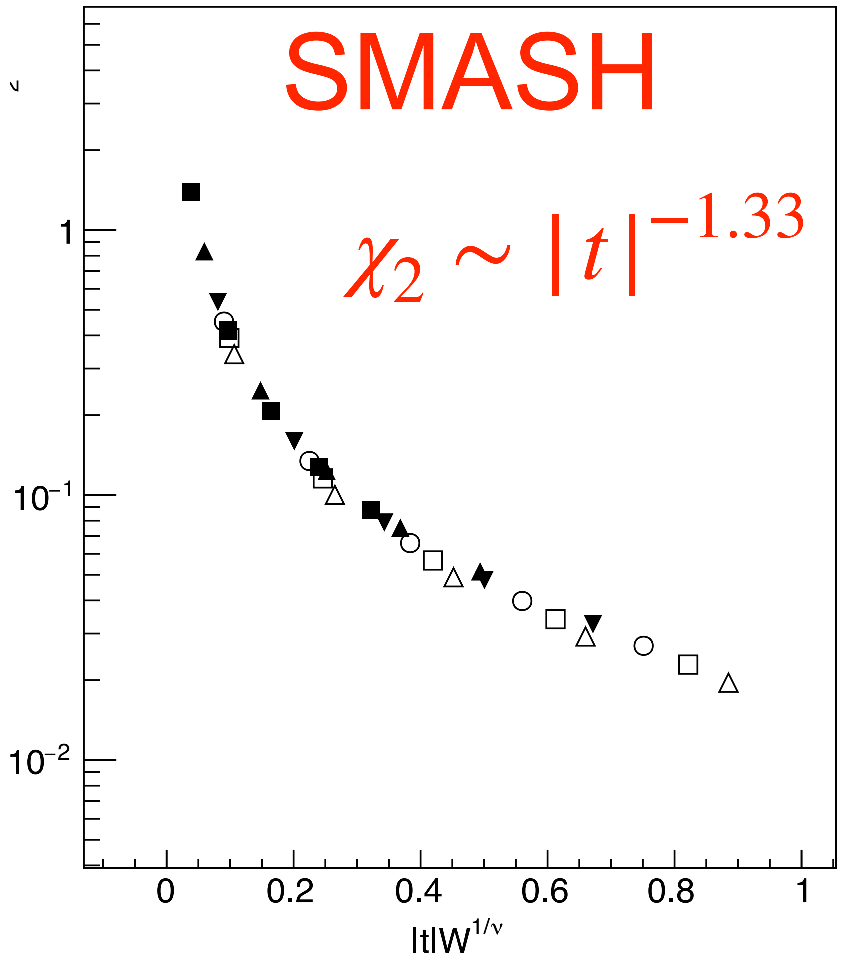


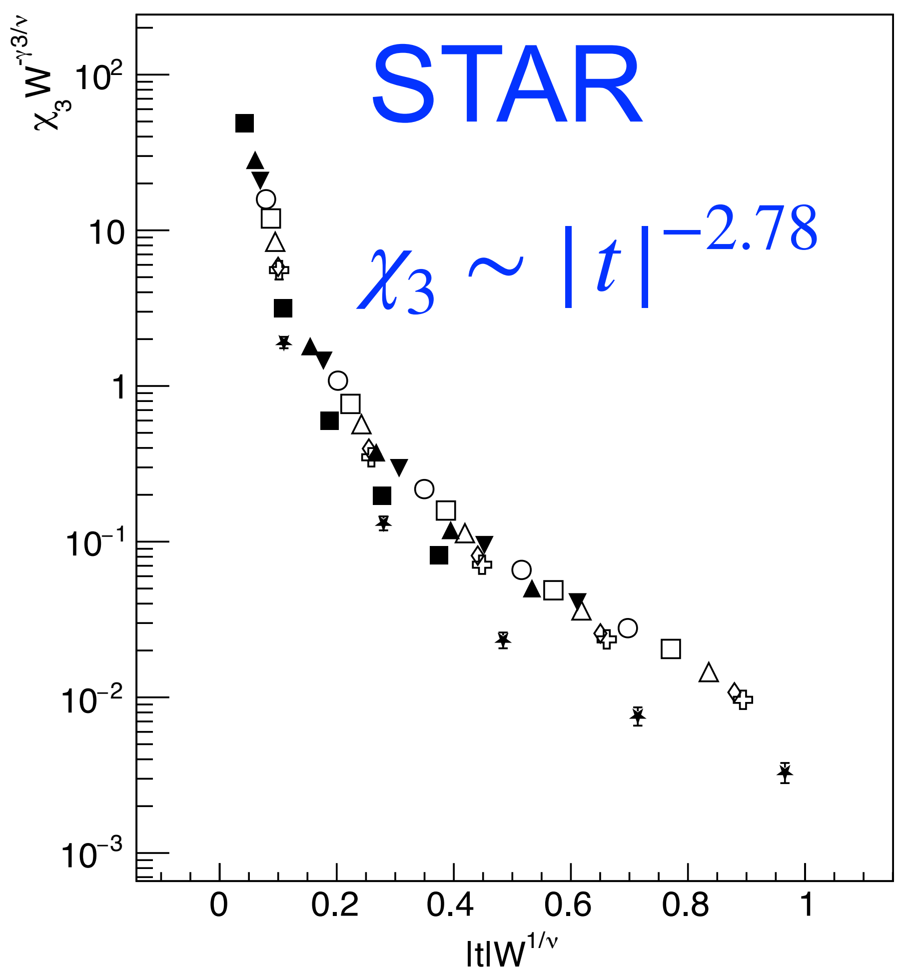
- the data scale all the way up to $\sqrt{s} = 200$ GeV
- the trends is captured even in a hadronic cascade
- the extracted critical point position is reasonable
- χ_3 and the Binder cumulant provide consistent picture
- model studies in finite systems show a large region where fluctuations matter

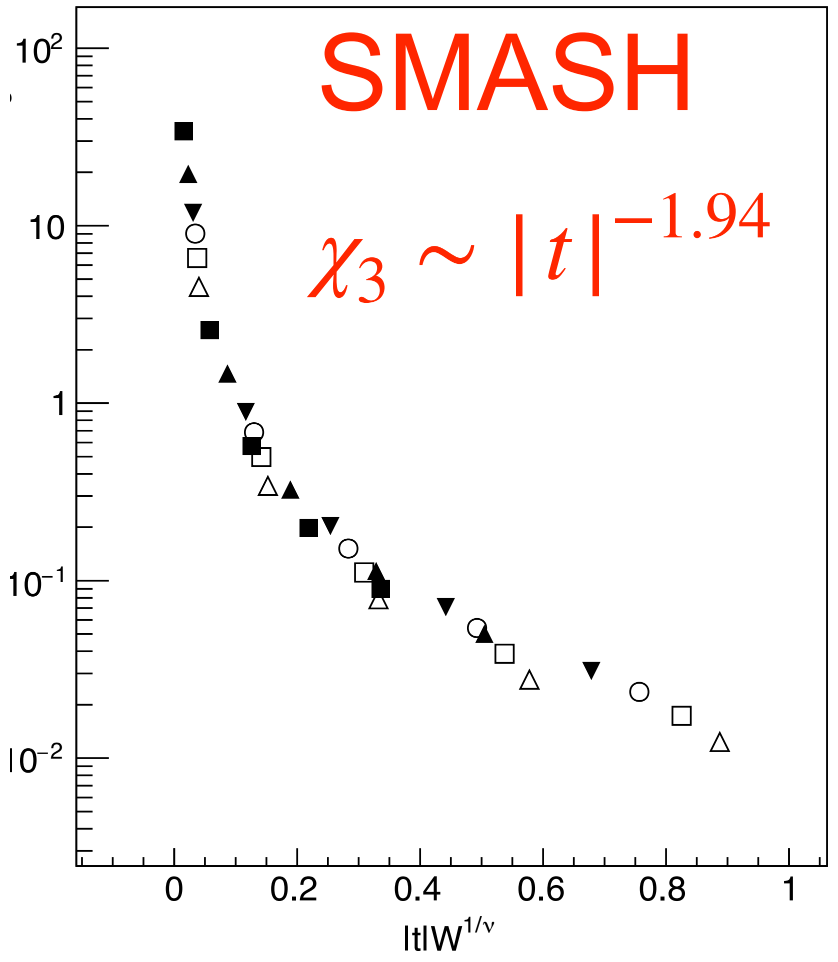


- Is this more than a coincidence?
- What does it mean if (regular + critical) fluctuations behave as a power law with critical exponents? Can one subtract the regular part?







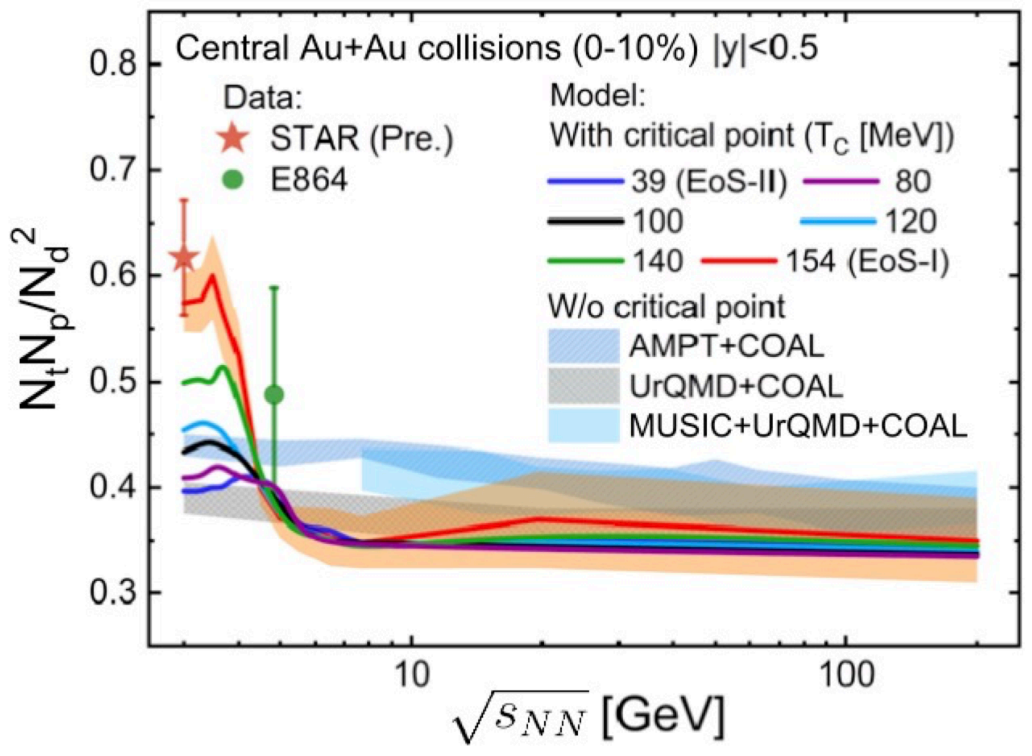


A. Sorensen, P. Sorensen, arXiv:2405.10278

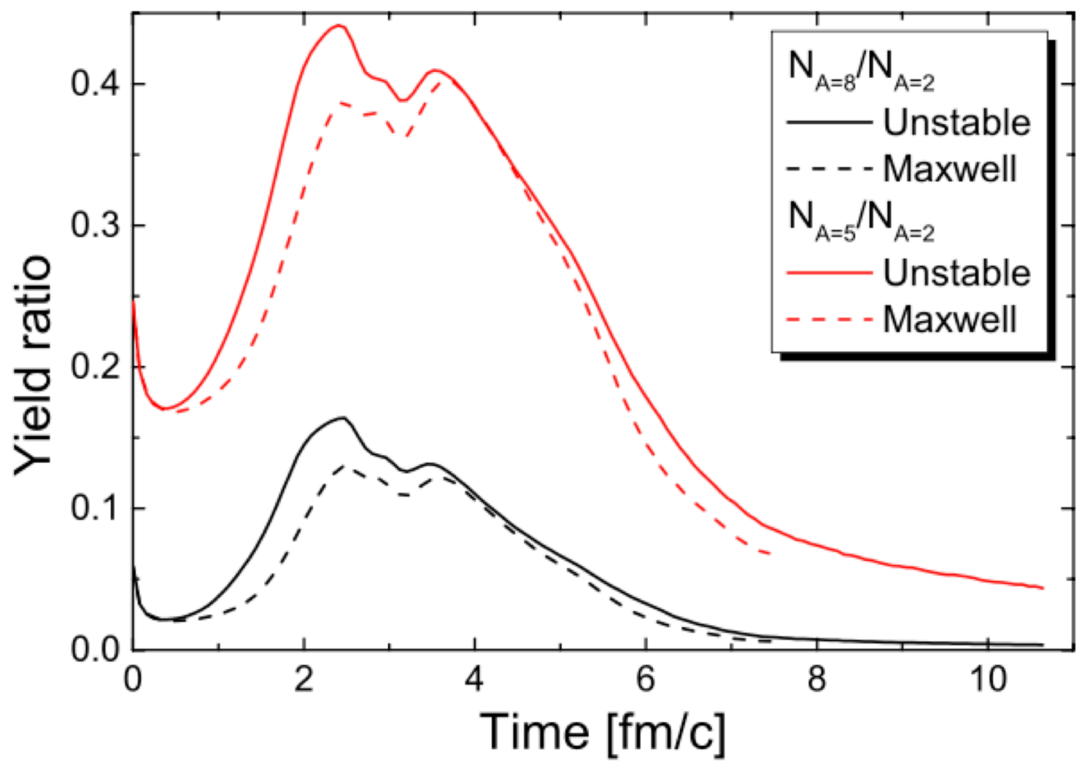
Cluster production

Is enhanced cluster production around $\sqrt{s} \approx 20 - 30$ GeV a sign of the transition?

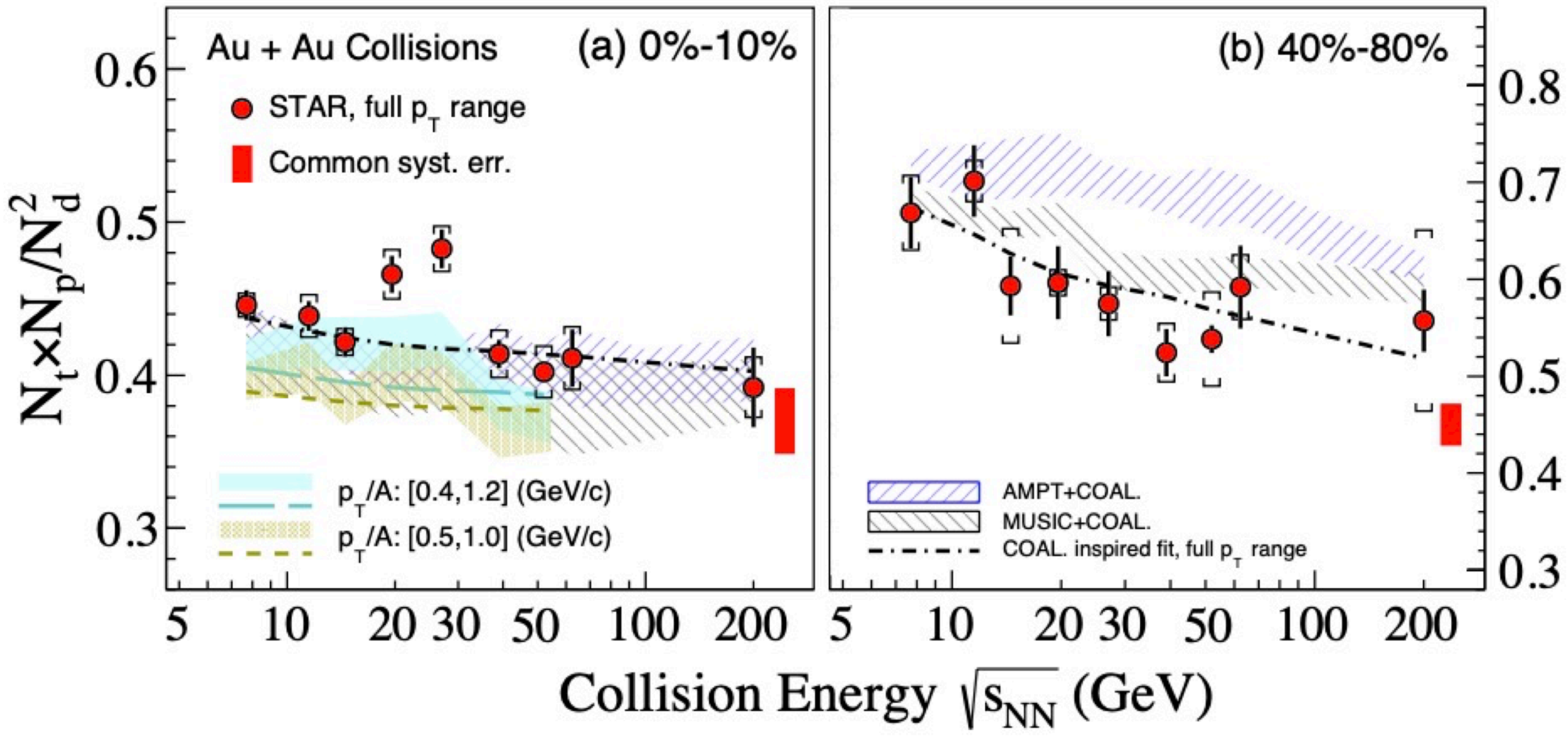
- models provide conflicting results (spinodal decomposition occurring against the vacuum vs. against dense hadronic phase)



K. Sun, L. Chen, C.M. Ko, *et al*., *Nuclear Techniques* 46, 040012 (2023)

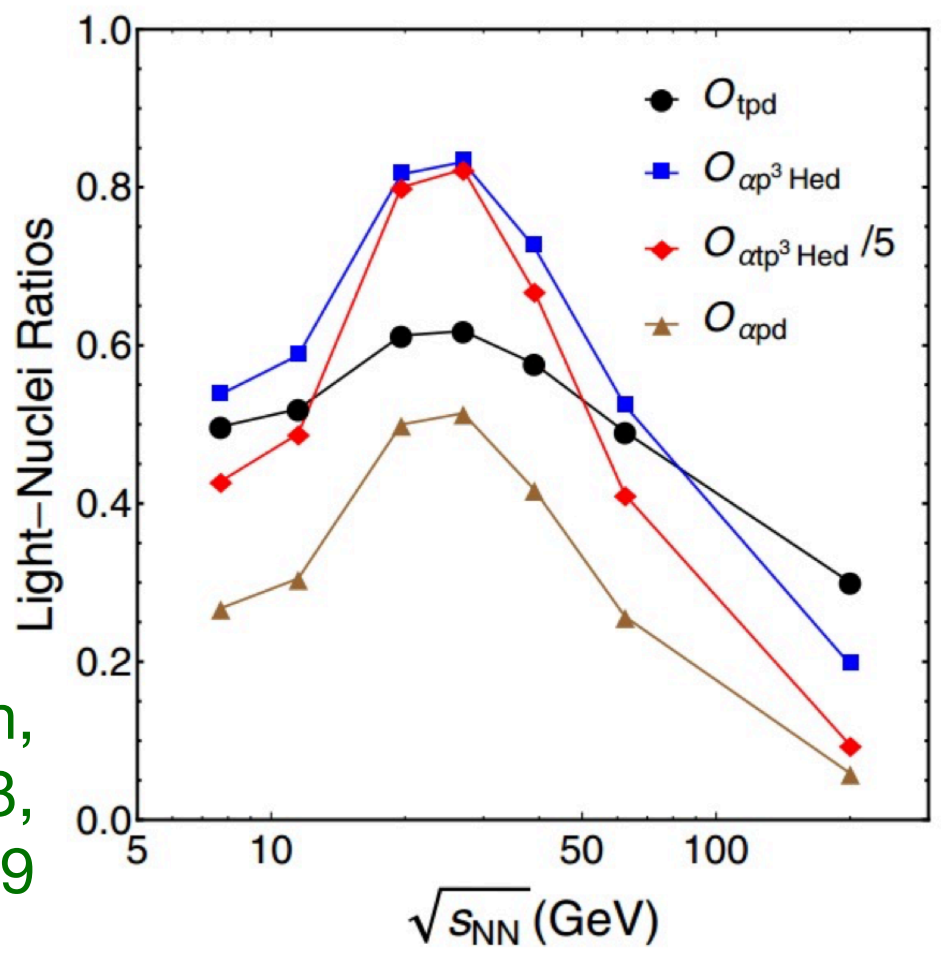


J. Steinheimer, J. Randrup, V. Koch, *Phys.Rev.C* 89 (2014) 3, 034901, arXiv:1311.0999



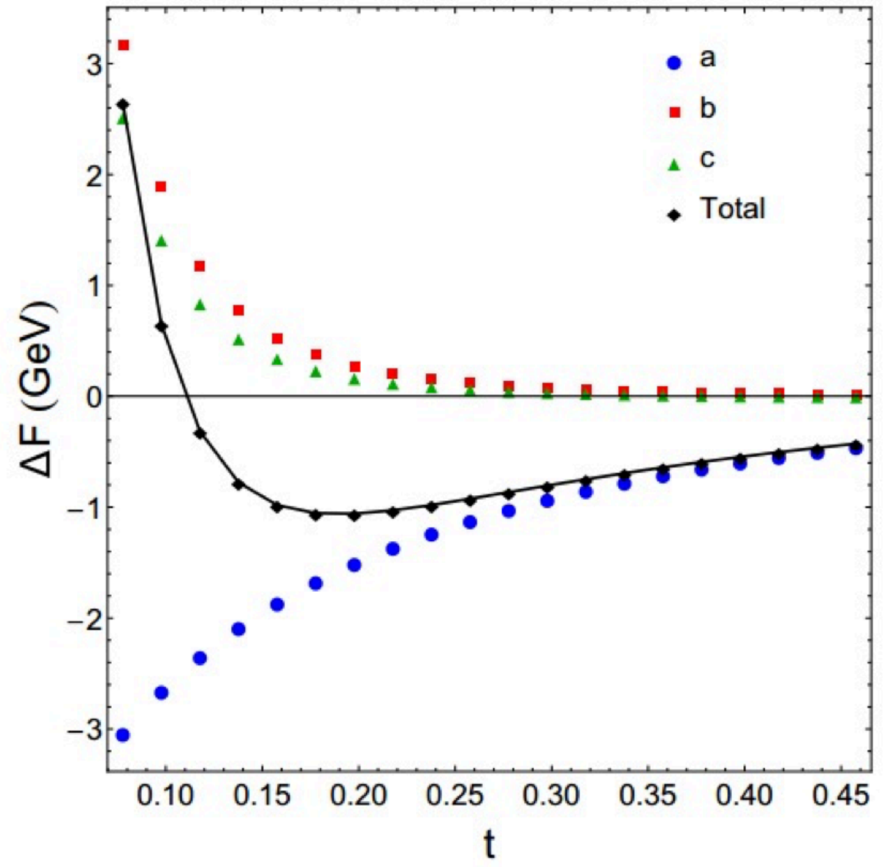
STAR, *Phys.Rev.Lett.* 130 (2023) 202301, arXiv:2209.08058

- modification of the nuclear force leads to enhanced clustering



E. Shuryak, M. Torres-Rincon, *Phys.Rev.C* 101 (2020) 3, 034914, arXiv:1910.08119

- realistically, include higher-order terms in σ field interactions which provide repulsion: clustering becomes *suppressed* near the CP



D. DeMartini, E. Shuryak, *Phys.Rev.C* 104 (2021) 2, 024908, arXiv:2010.02785

- BES-II data is coming (FXT?)
- What needs to happen with theory and modeling?

Summary of requests

Experimentalists:

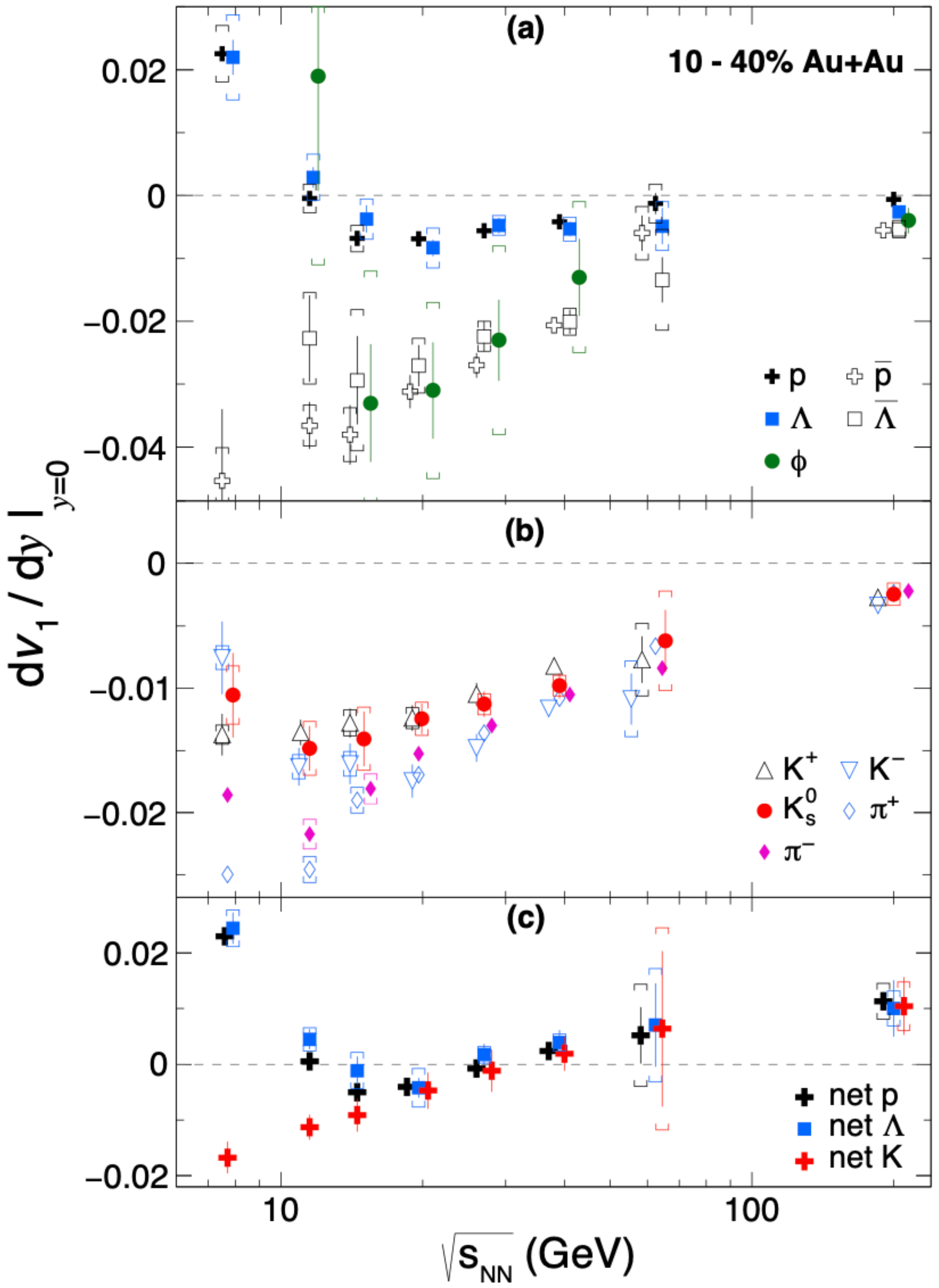
- Provide clear details about all centrality definitions and v_n techniques used
- Provide non-CBWC corrected $C_1,\ C_2,\ C_3,\ C_4$ measurements, not just ratios
- PID p_T and rapidity spectra for all energies
- Provide measurements that elucidate baryon stopping dynamics
- Provide fluctuation measurements done with multiple correction methods
- Make clearer how to obtain preliminary data points, not just plots

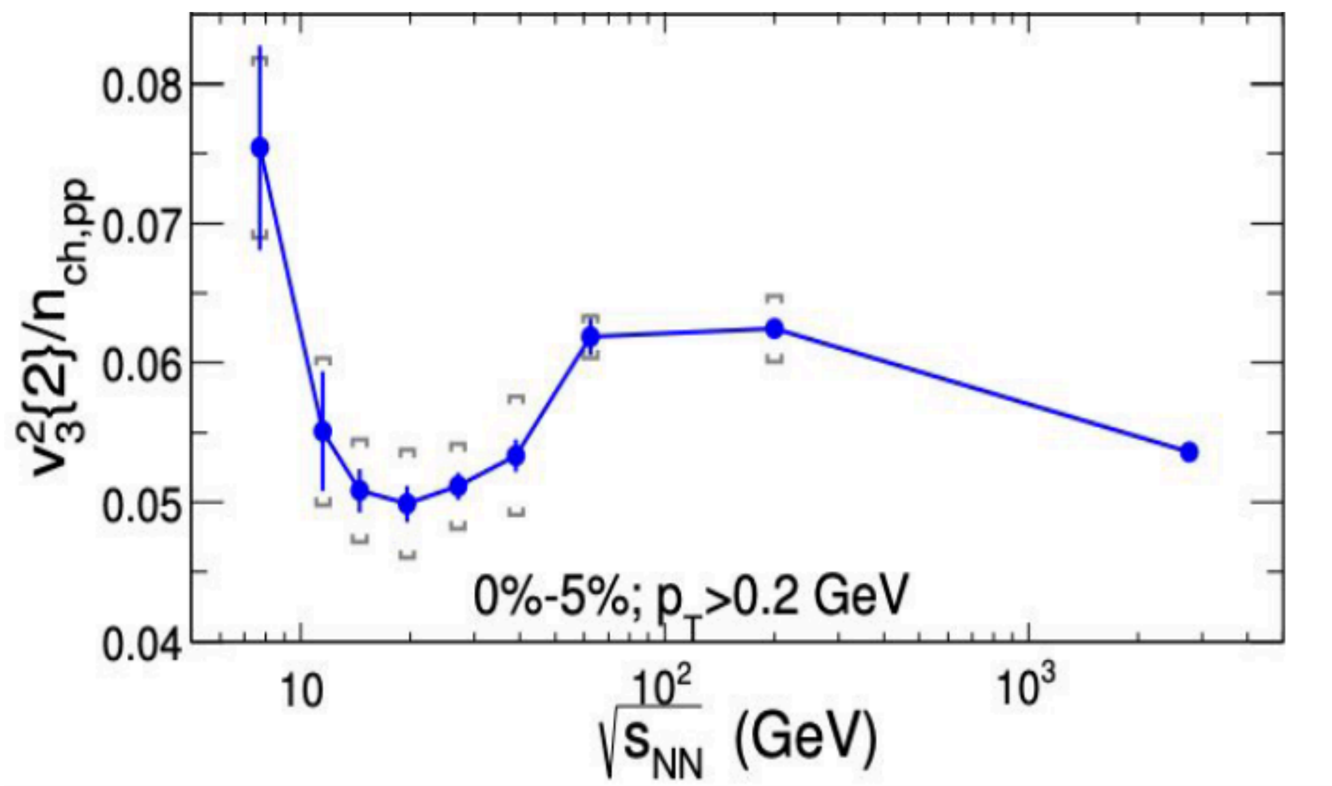
Theorists:

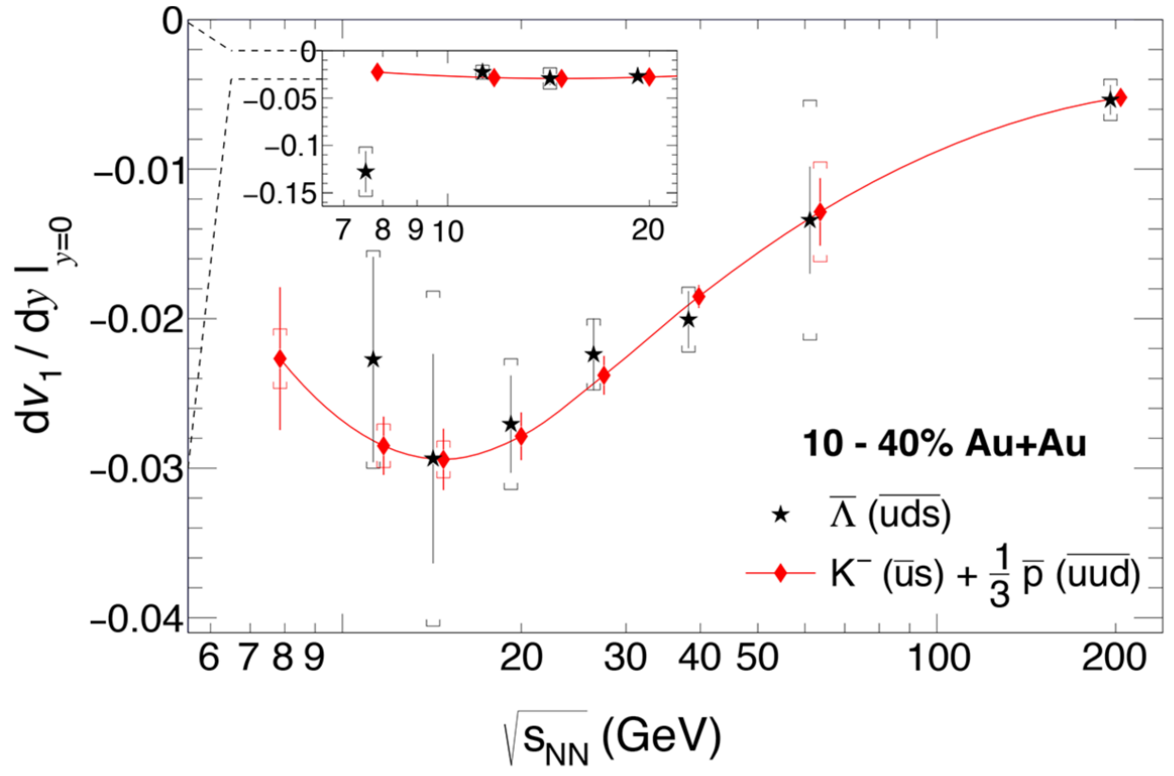
- Provide modular codes so one can test effects of one change when all else is the same
- Develop robust models of baryon transport
- Provide extensive model comparisons with high-statistics data sets
- Perform comparisons between transport codes, identify sources of discrepancies (physics vs. algorithms), minimize then estimate uncertainties due to unconstrained ingredients

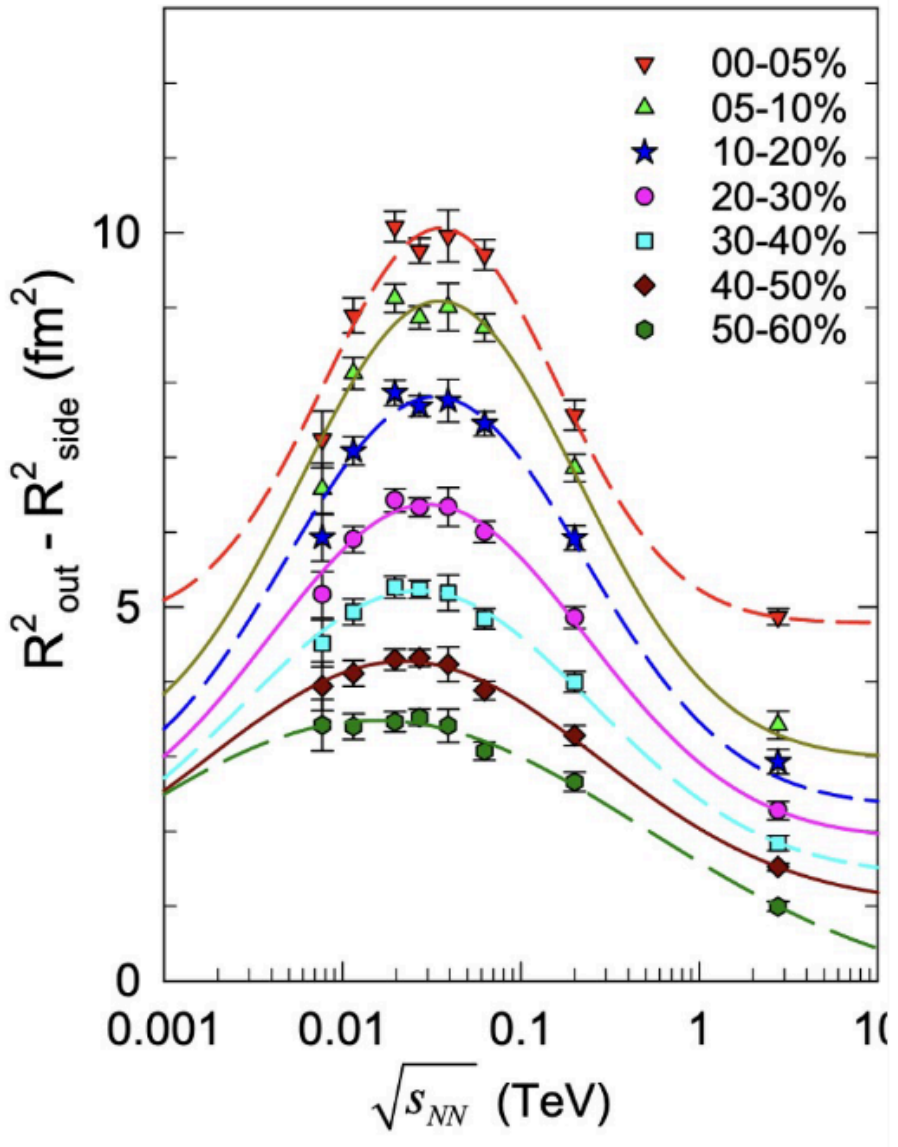
Lots of dips and peaks

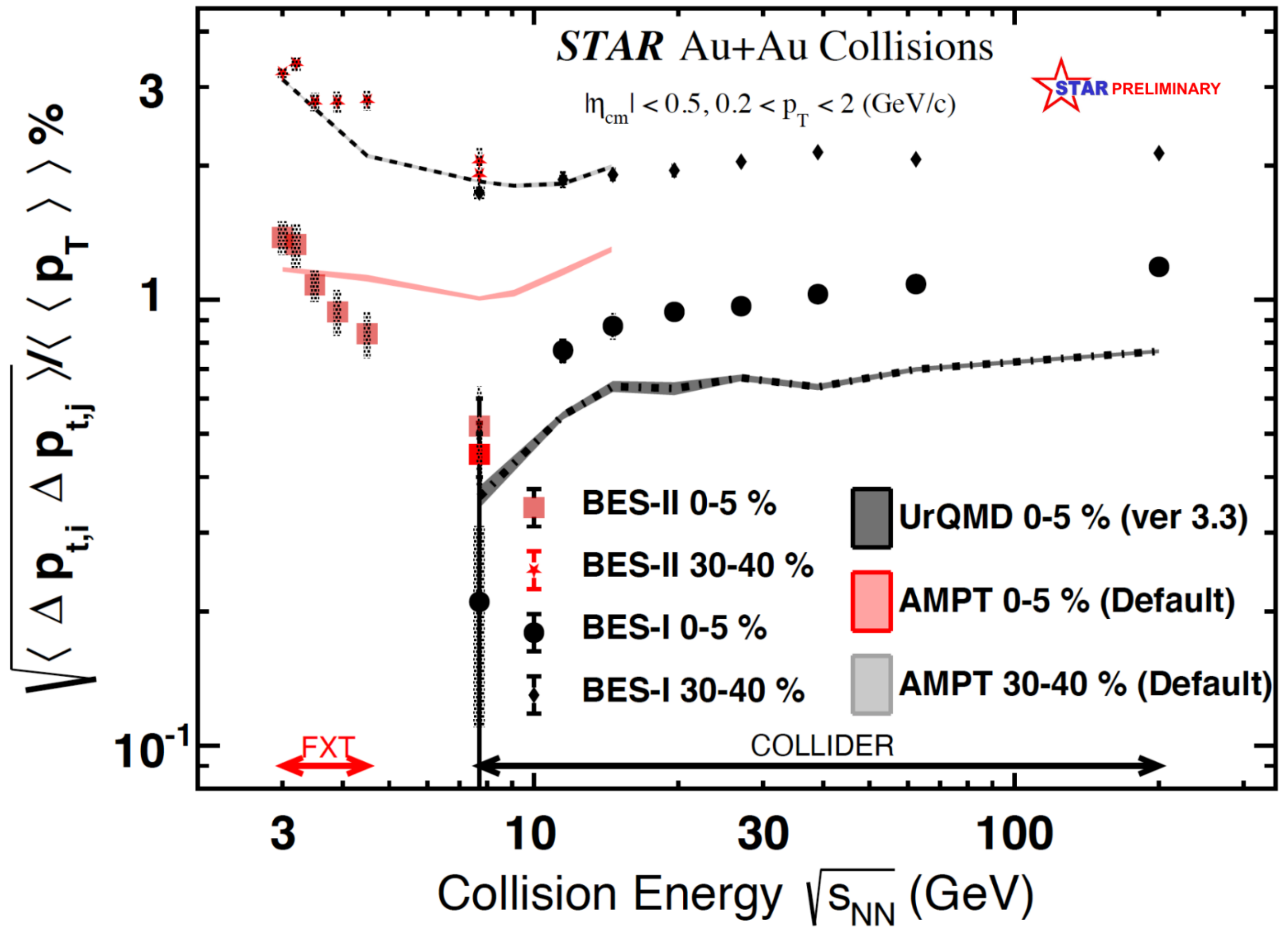
PRL 120 (2018) 6, 062301

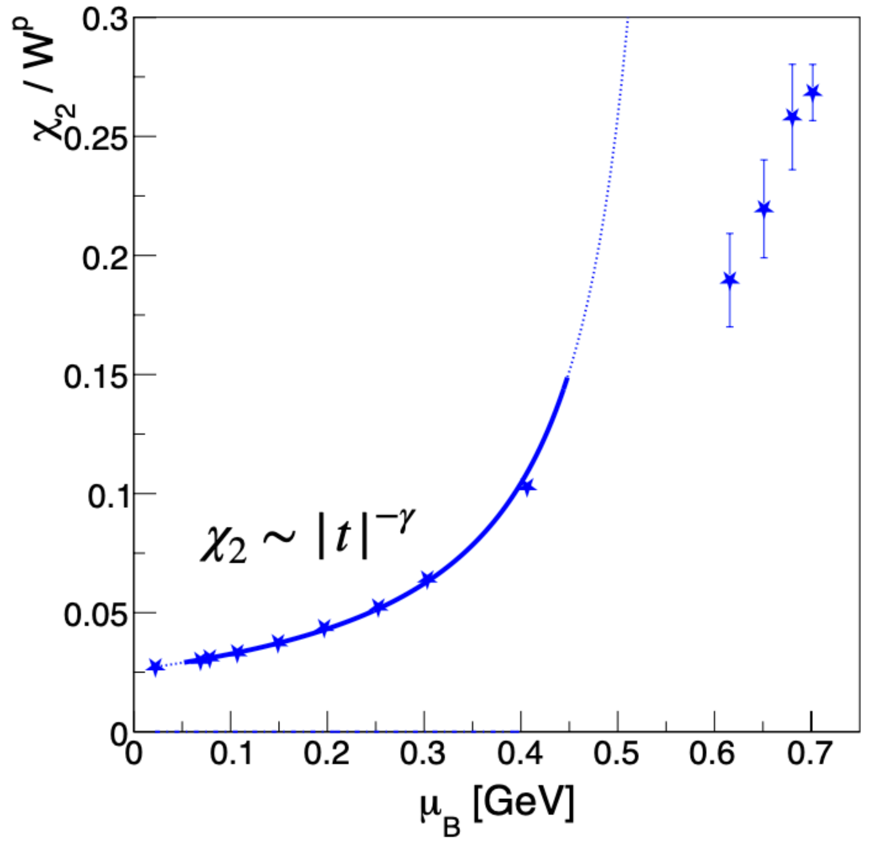


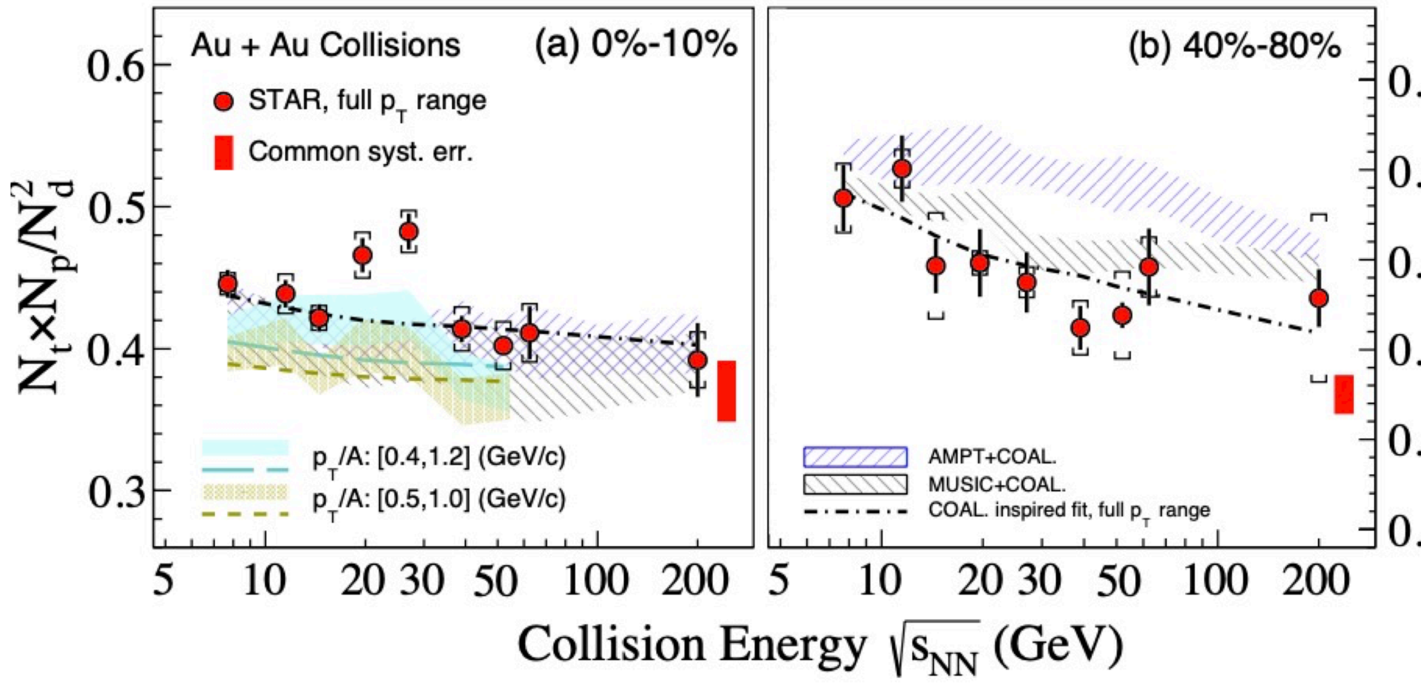












STAR, *Phys.Rev.Lett.* 130 (2023) 202301, arXiv:2209.08058