Precision hydrodynamic predictions for particle production in isobar collisions at RHIC

By Andreas Kirchner

Giacalone G., Grossi E., Floerchinger S., Capellino F.

UNIVERSITÄT
HEIDELBERG
ZUKUNFT
SEIT 1386

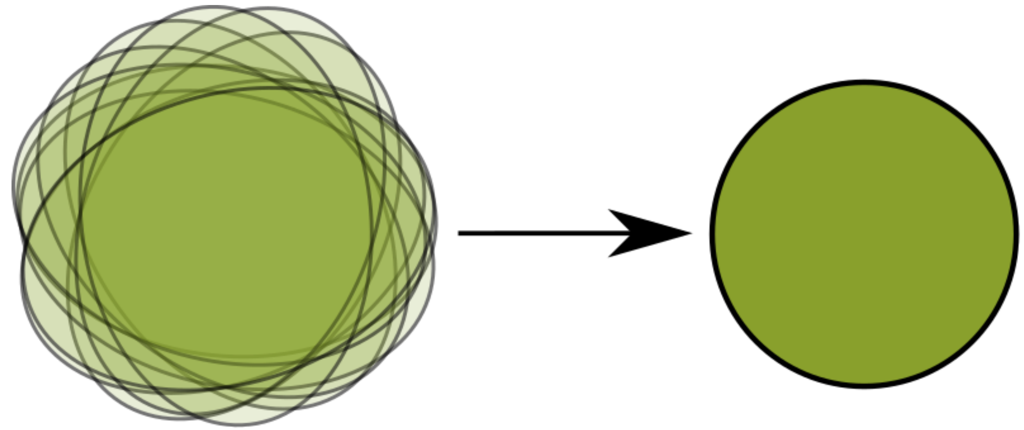
isoQuant
SFB1225

FluiduM overview

1811.01870 Floerchinger, Grossi, Lion

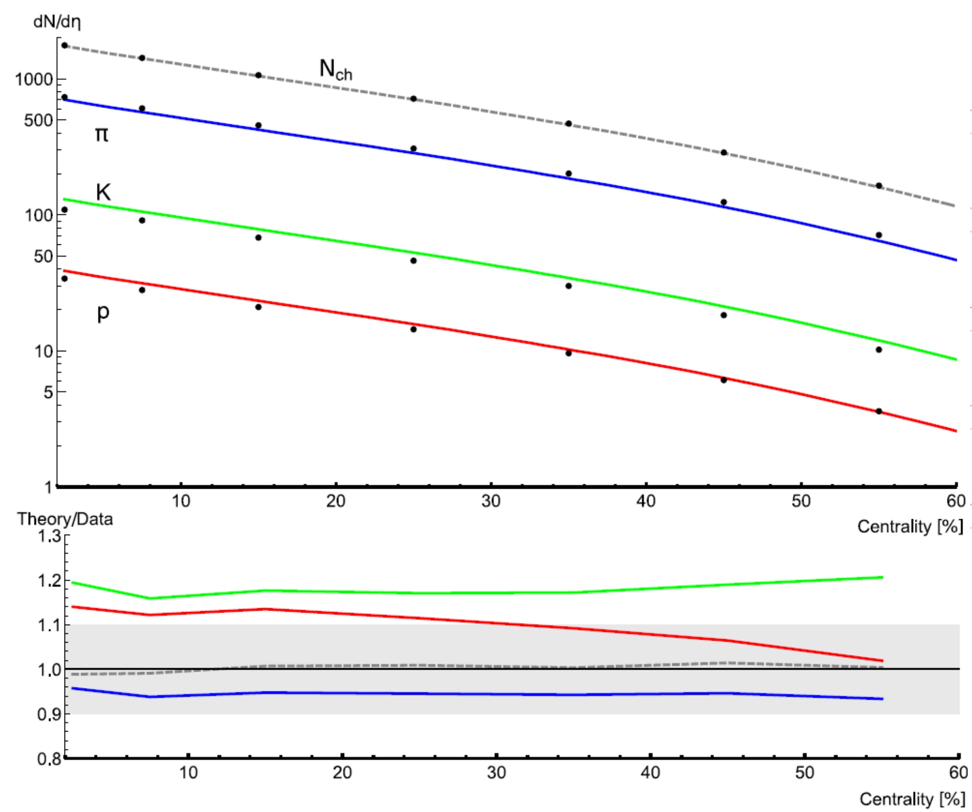
Describe event ensemble instead of single event
→ symmetric background
→ BG-fluctuation splitting

$$\Phi(\tau, r, \varphi, \eta) = \Phi_0(\tau, r) + \epsilon \Phi_1(\tau, r, \varphi, \eta)$$



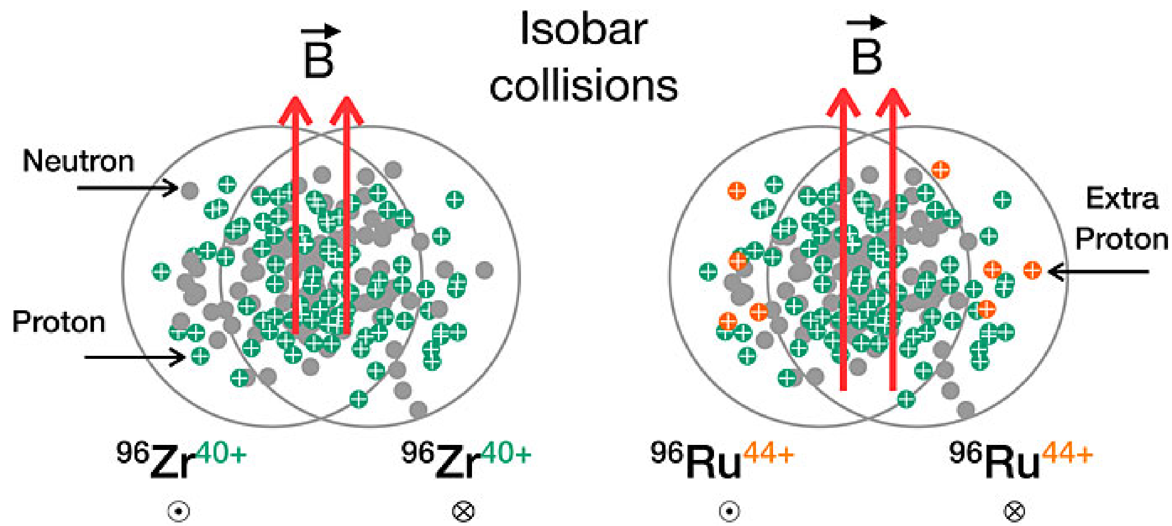
1+1D BG equations of motion for second order relativistic Israel-Stewart hydrodynamics

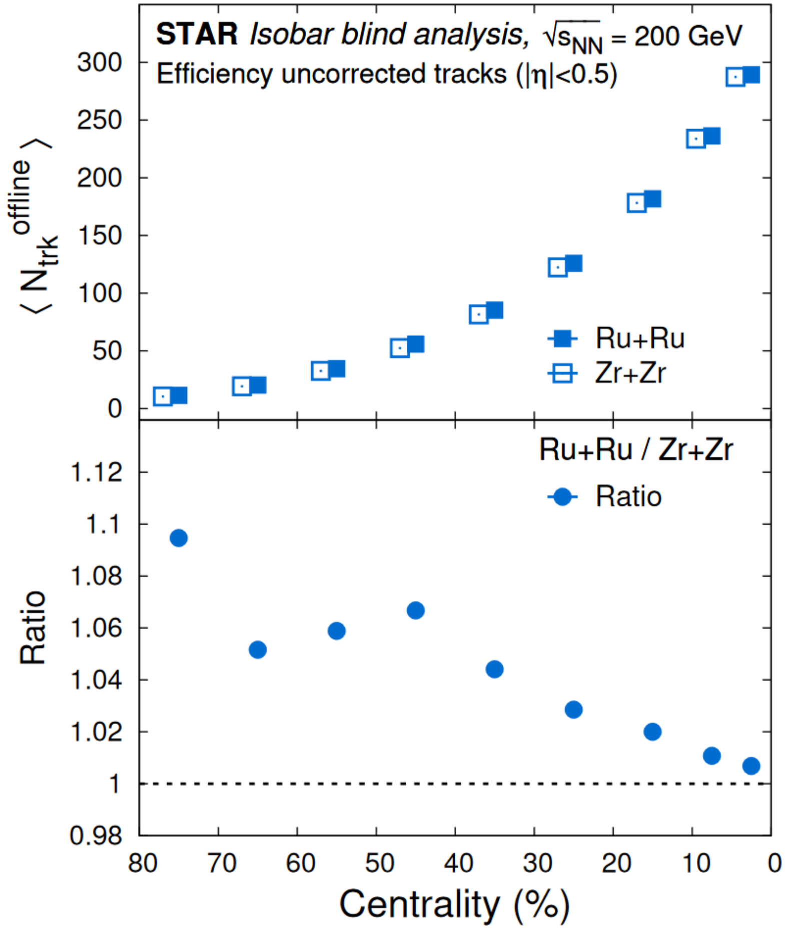
- Background expansion gives average quantities (yields and $<p_T>$)
- Able to reproduce multiplicities from ALICE measurements



Particlization+Resonance decays:
Cooper-Frye with FastReso (1809.11049)

Isobar collisions @RHIC





Isobar Zr+Zr and Ru+Ru collisions @200GeV
→ Original goal: find signatures of electromagnetic field (e.g Chiral magnetic effect)
→ High precision data (4B collisions for each system)
→ Signatures of EM-field investigated in ratios of observables (departures from unity)

Expectation: same multiplicity
Experimental data: Percent level deviations from unity

→ **WHY?**

STAR Collaboration (2109.00131)

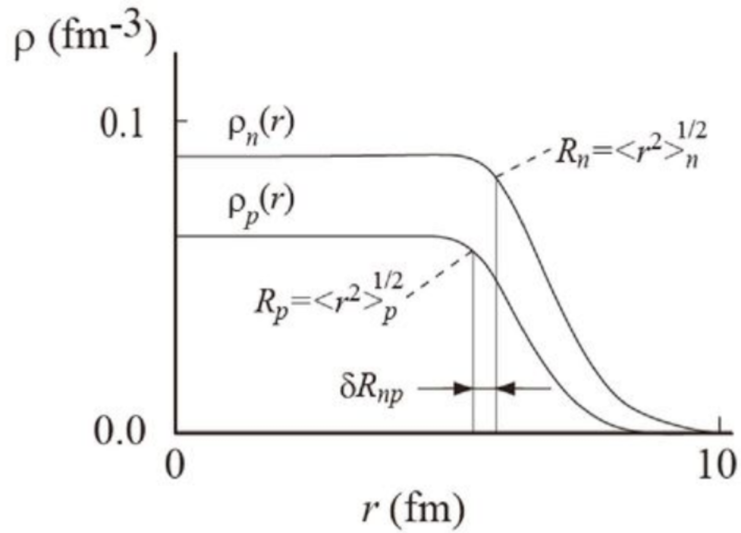
Origin of the differences: nuclear structure

Main diff.: number of protons/neutrons
→ bigger neutron skin in Zr
→ different nuclear geometry
Woods-Saxon parametrization:

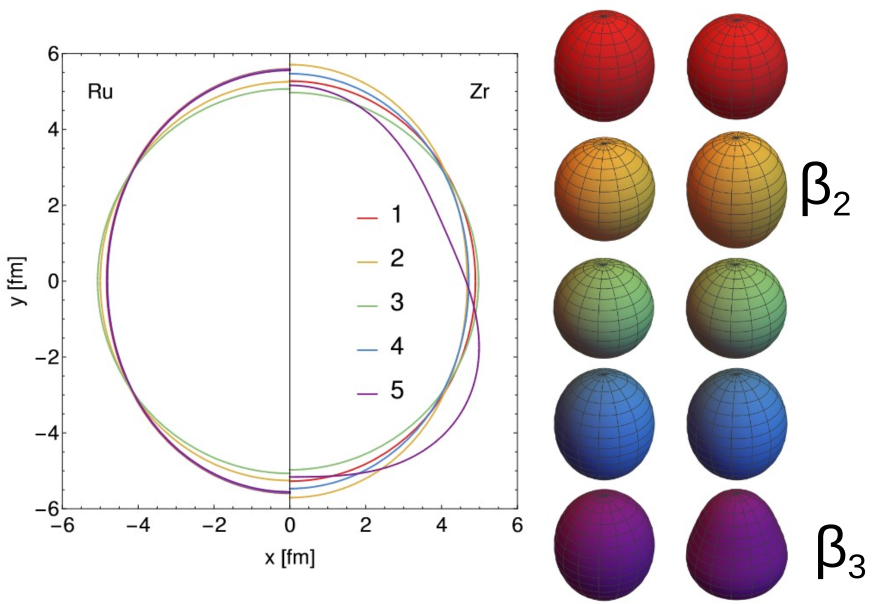
$$\rho(r,\theta,\phi) \propto \frac{1}{1+e^{[r-R_0(1+\beta_2 Y_2^0(\theta,\phi)+\beta_3 Y_3^0(\theta,\phi))]/a_0}}$$

Half-width radius Nuclear deformations Diffusitvity

Diffusivity related to neutron skin thickness



(2112.13771)

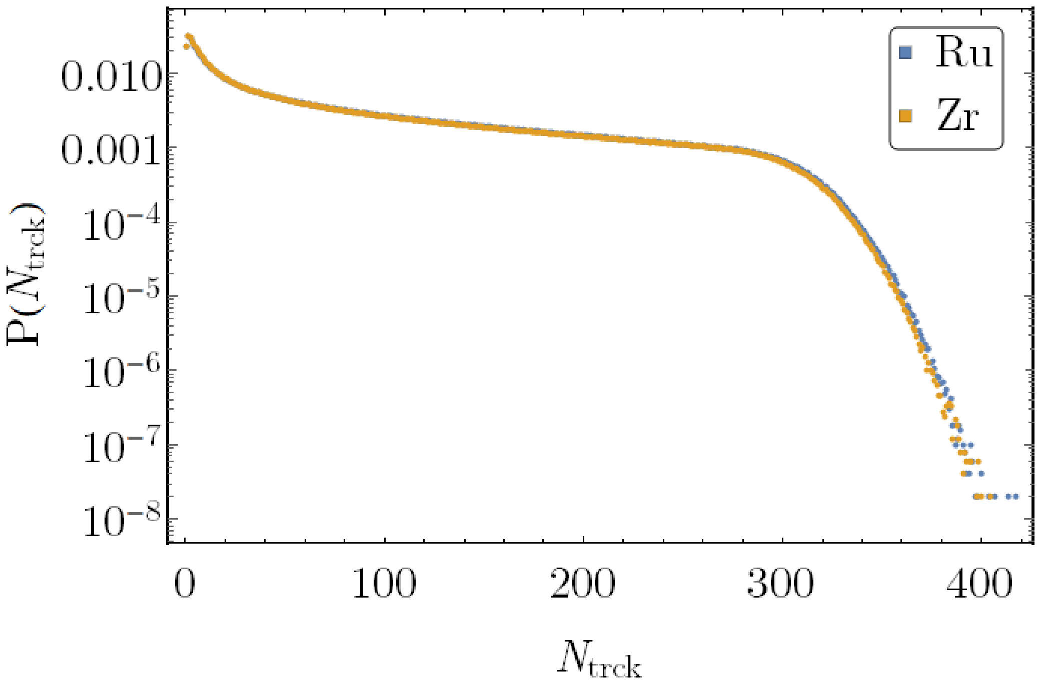


Multiplicity ratio dominated by neutron skin (2111.14812, 2111.15559, 2112.13771, 1808.06711, 2103.05595)

But only transport/initial state/limited hydro calculations
→ **FluiduM**

Setup

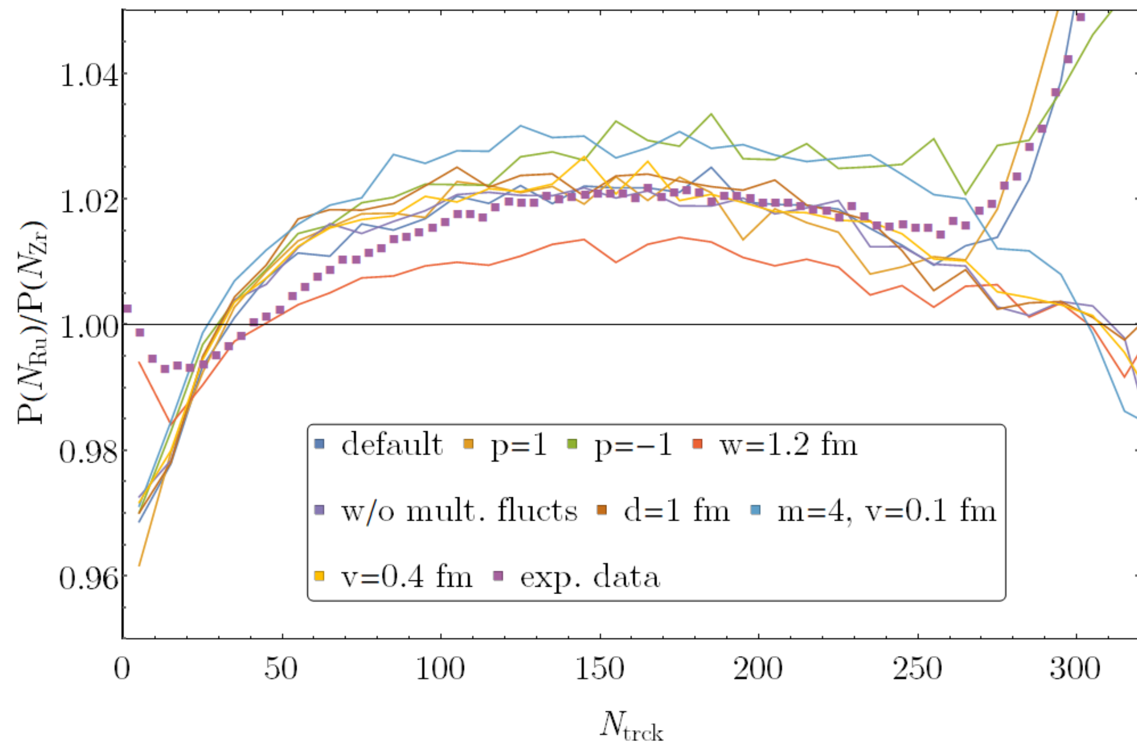
- Run TrenTo for initial state
- Define 0.5% centrality bins using 50M minimum bias events
- Run 400k events in select bins ($\rightarrow$ effectively 80M events)
- Scan large range of nuclear (R, a, $\beta_{2,}$ β_3), collision (k $\rightarrow$ multiplicity fluctuation, p $\rightarrow$ energy depostition, w $\rightarrow$ nucleon size, d $\rightarrow$ nucleon repulsive core, m $\rightarrow$ number of partons, v $\rightarrow$ parton size) and QGP (η/s,ζ/s, T_{fo}, τ_0) parameters



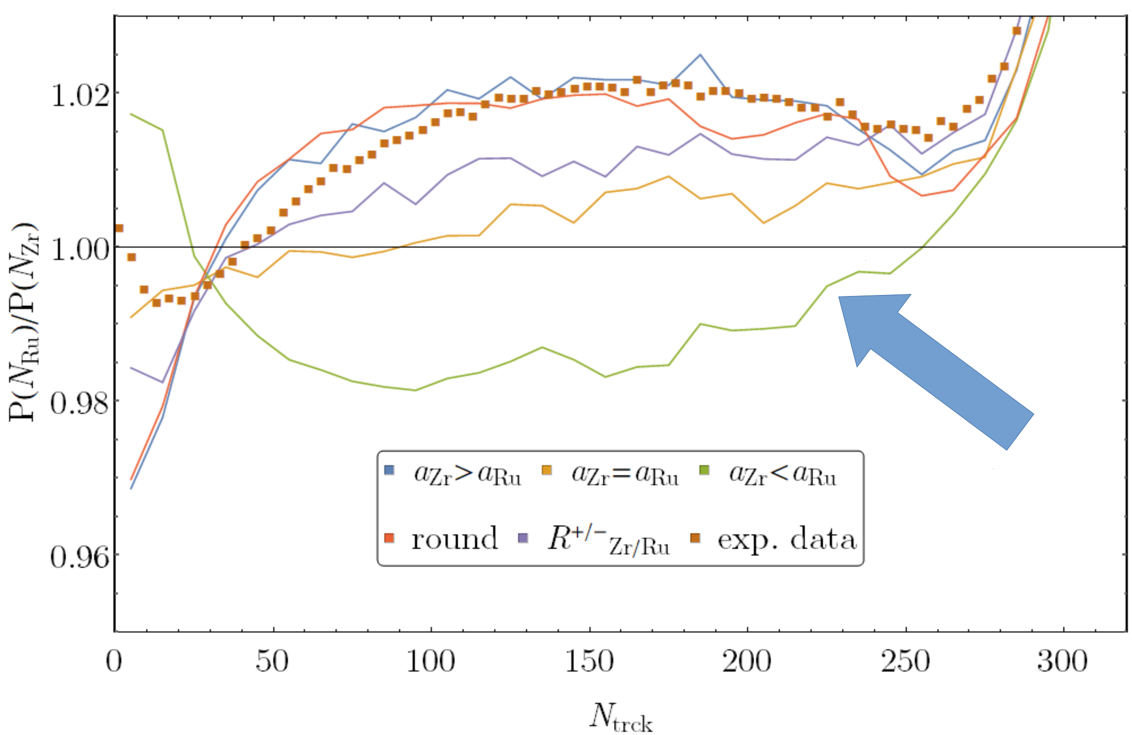
Histogram multiplicity through linear rescaling of TrenTo entropy

Initial State Results

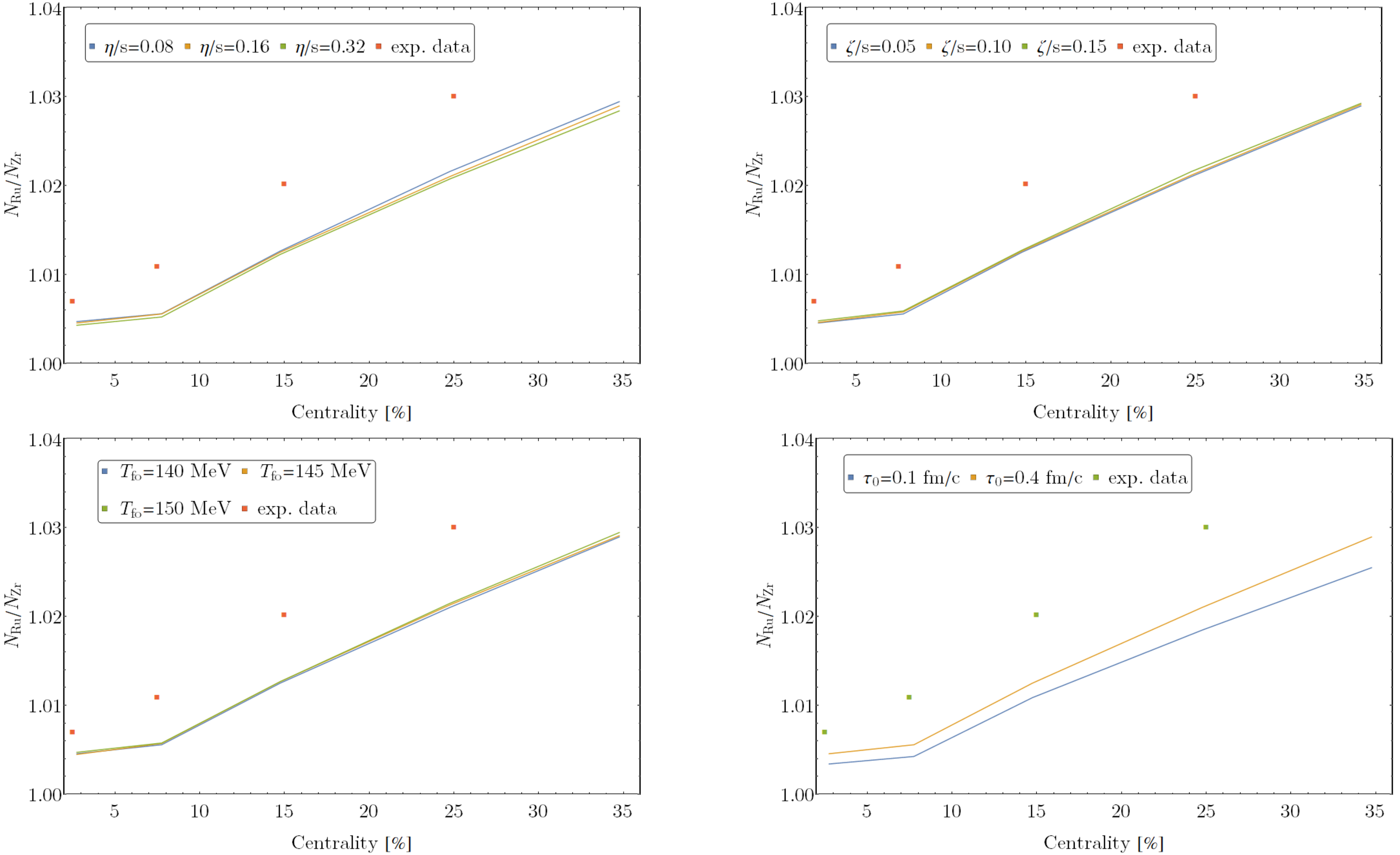
Histogram multiplicity ratio dominated by diffusivity



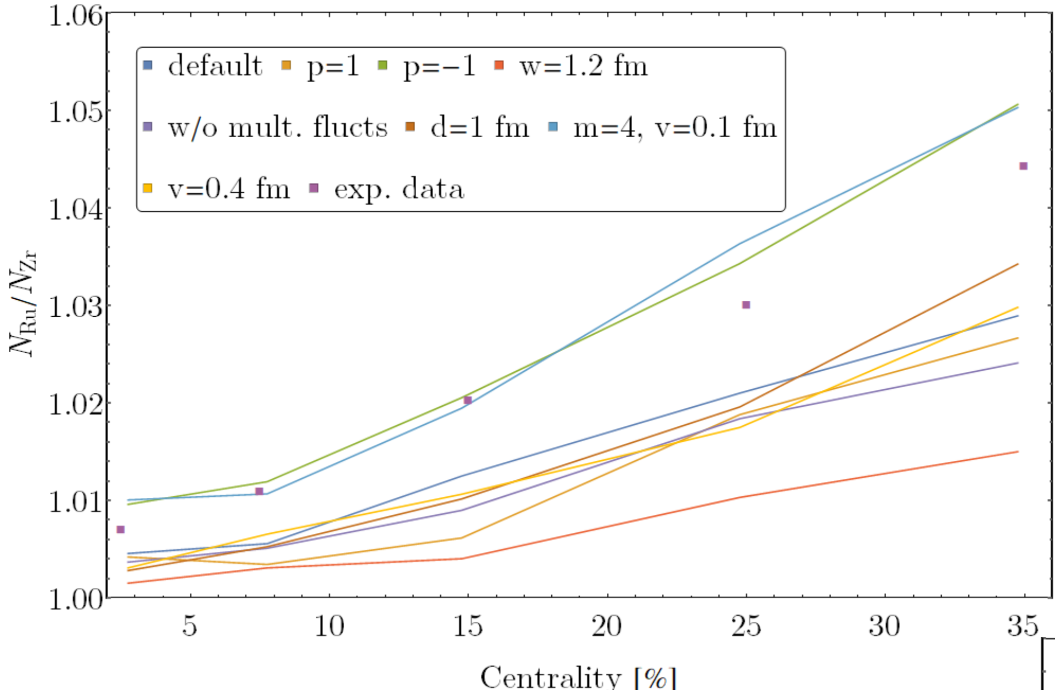
Default: p=0, w=0.5 fm, k=1



Final state results
QGP parameters



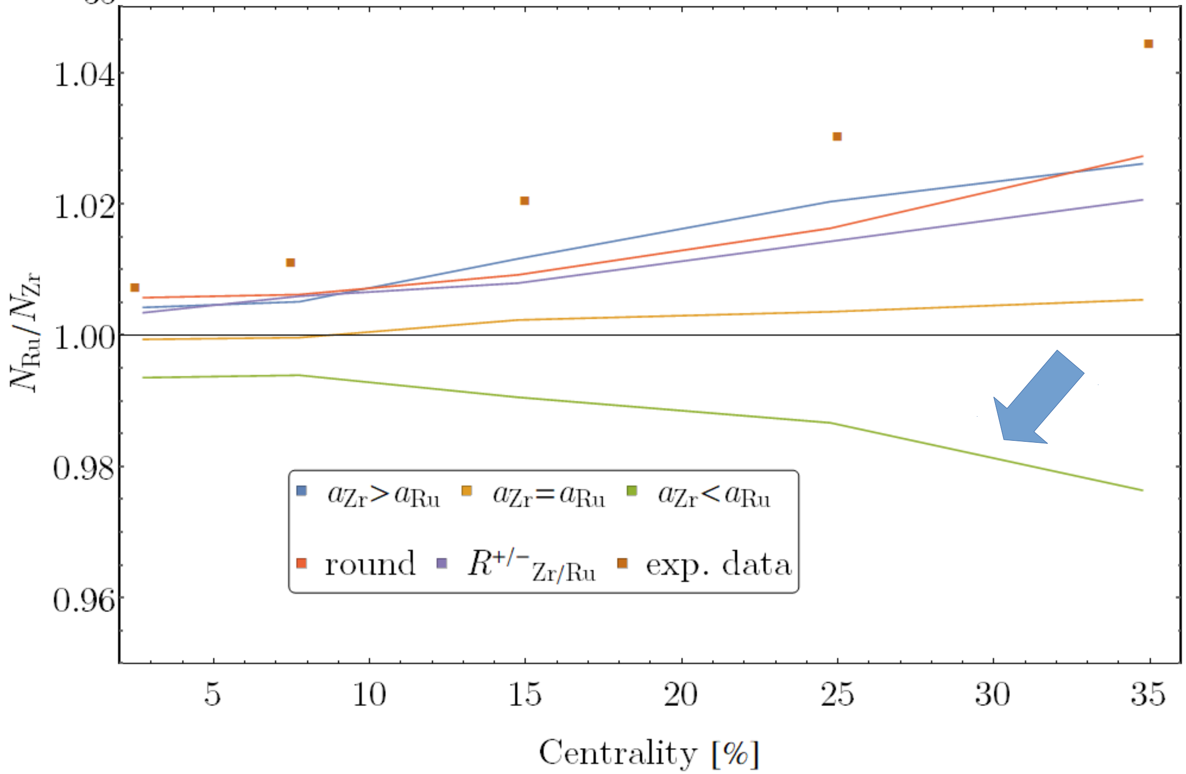
Final state results



Multiplicity ratio dependent on "degree of sharpness" of QGP

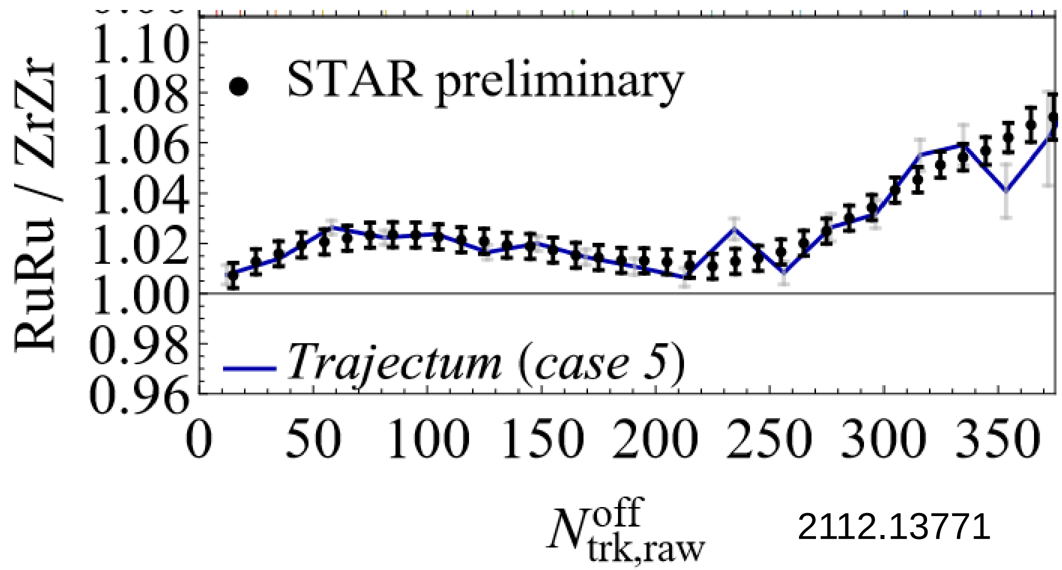
Default: p=0, w=0.5 fm, k=1

Multiplicity ratio dominated by diffusivity

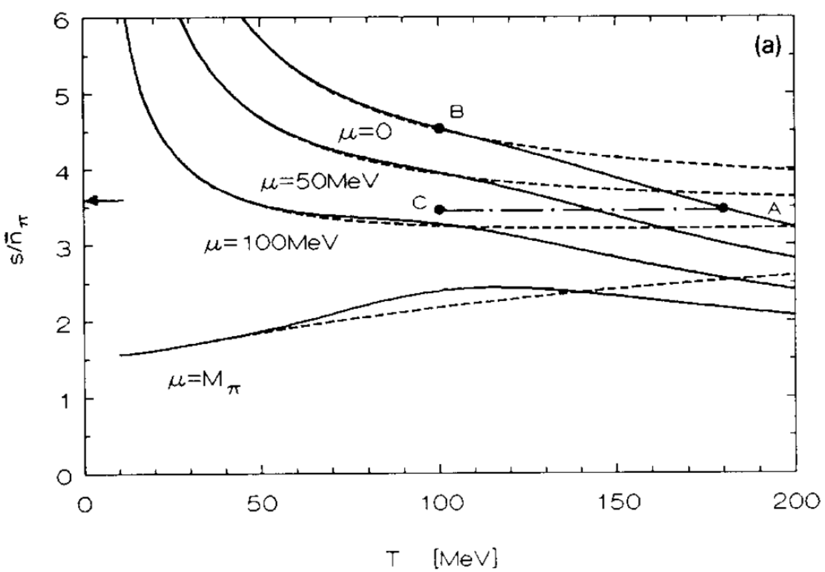


Outlook

Extend scan to more observables (mean pT & flow coefficients)



2112.13771



Include more physics in hadronic phase (e.g. PCE)

Bebie et. al., 1992

Improve BG-fluct splitting with Hatree-Fock

$$\partial_\tau \Psi^a + \bar{\mathcal{B}}^a{}_b \partial_r \Psi^b - \bar{\mathcal{S}}^a + \frac{1}{2}\left[\frac{\partial^2 \bar{\mathcal{B}}^a{}_b}{\partial \Psi^c \partial \Psi^d}\,\partial_r \Psi^b - \frac{\partial^2 \bar{\mathcal{S}}^a}{\partial \Psi^c \partial \Psi^d}\right] C^{cd}(x,x)$$
$$+\left[\frac{\partial \bar{\mathcal{B}}^a{}_b}{\partial \Psi^c}\,\partial_r + \frac{\partial \bar{\mathcal{C}}^a{}_b}{\partial \Psi^c}\,\partial_\varphi + \frac{\partial \bar{\mathcal{D}}^a{}_b}{\partial \Psi^c}\,\partial_\eta\right] C^{bc}(x,x')\Big|_{x'=x} = \delta(\tau - \tau_{\text{in}})\,\Psi^a_{\text{in}}(r)$$