Effect of nuclear structure on particle production in heavy-ion collisions using the AMPT model

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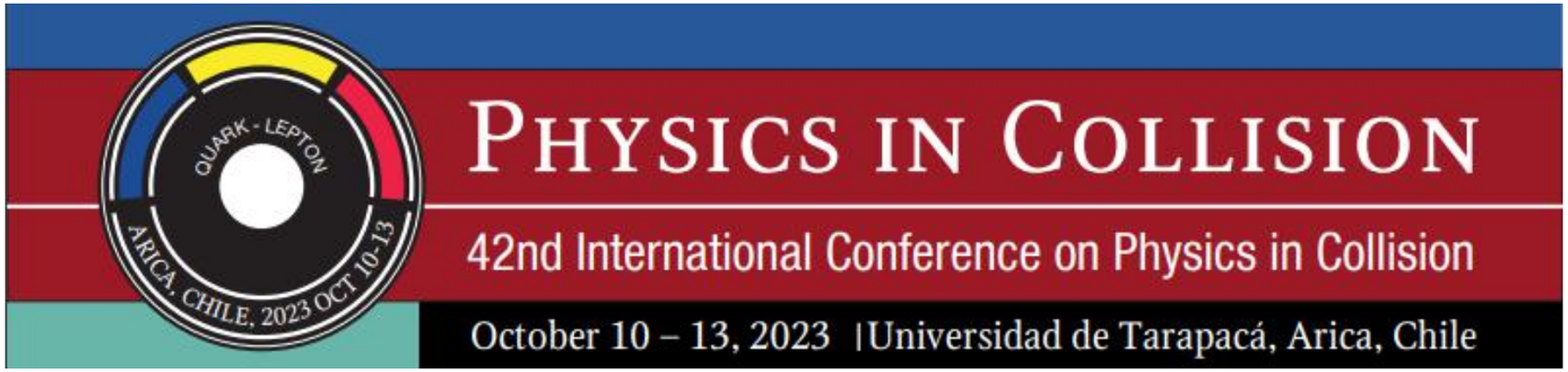


Outline

- Introduction
- Transverse momentum spectra
- Particle yield and Mean p_T
- Particle ratios
- System size dependence
- Summary

Introduction: AMPT Model

- A multi-phase transport model (AMPT) string melting version 2.26t9 with a partonic cross-section of 3 mb.
- Nucleon distribution of nuclei in AMPT model is modeled using the Wood-Saxon function as:

$$\rho(r,\theta) = \frac{\rho_0}{1 + e^{[\{r - R(\theta,\phi)\}/a]}},$$

R_0: Radius parameter
β_2 : Quadruple deformity
β_3 : Octupole deformity
$Y_{l,m}(\theta,\varphi)$: Spherical harmonics

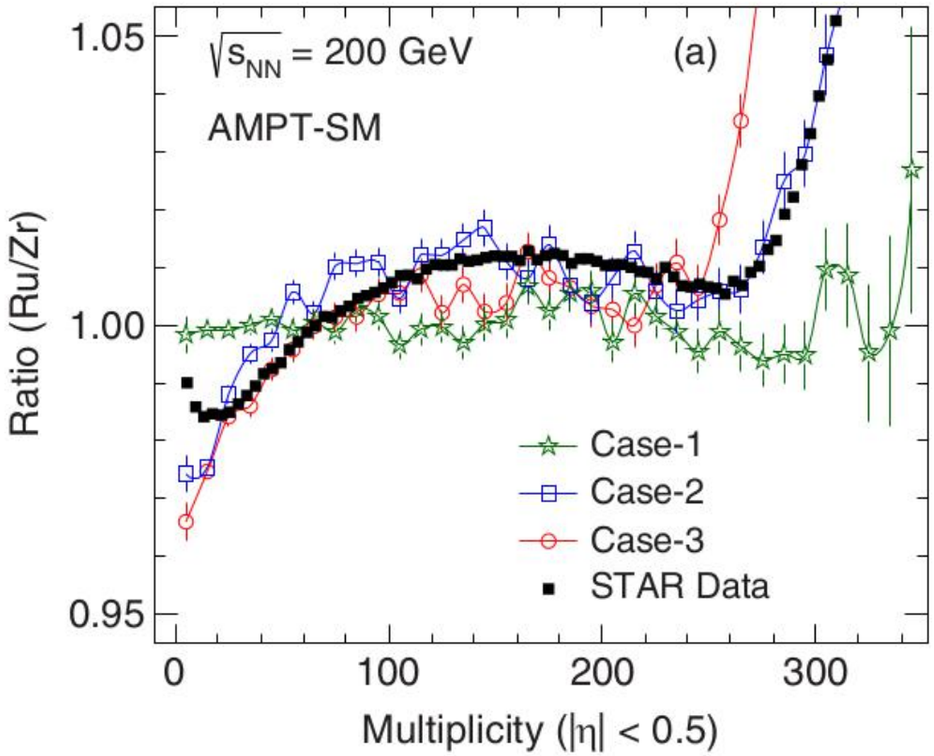
- Nuclear deformation is characterized by modified radius parameter:

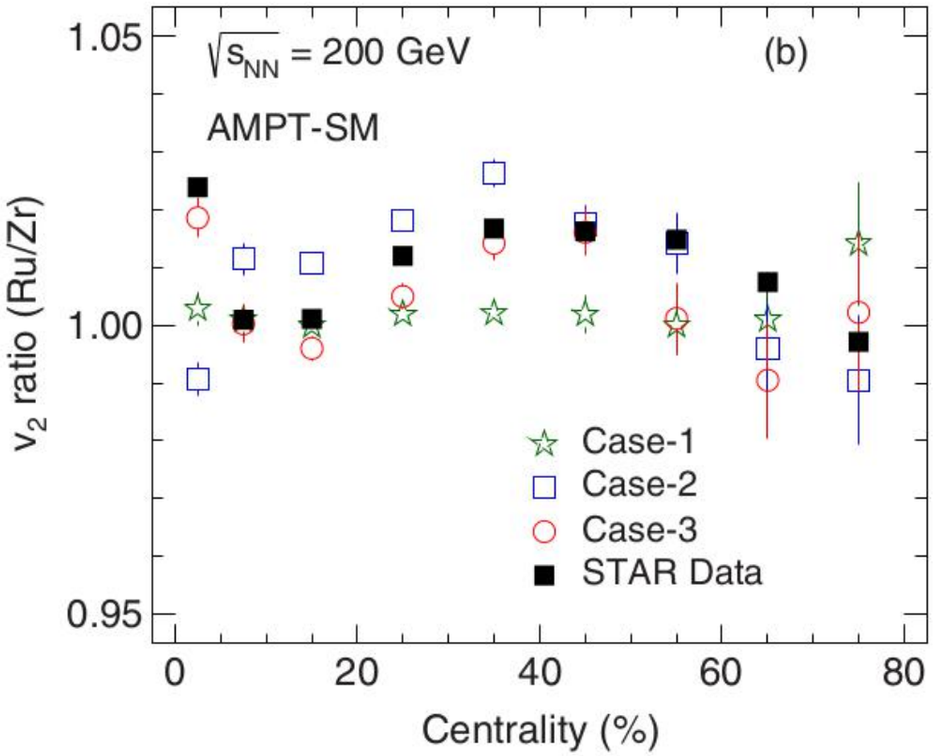
$$R(\theta,\phi) = R_0[1 + \beta_2 Y_{2,0}(\theta,\phi) + \beta_3 Y_{3,0}(\theta,\phi)]$$

- Various deformation configurations for the isobar nuclei ($^{96}_{44}$Ru and $^{96}_{40}$Zr) in the AMPT model:

	Ru			Zr		
Parameter	case 1	case 2	case 3	case 1	case 2	case 3
R_0	5.096	5.067	5.090	5.096	4.965	5.090
a	0.540	0.500	0.460	0.540	0.556	0.520
β_2	0	0	0.162	0	0	0.060
β_3	0	0	0	0	0	0.200

Comparison with experimental results

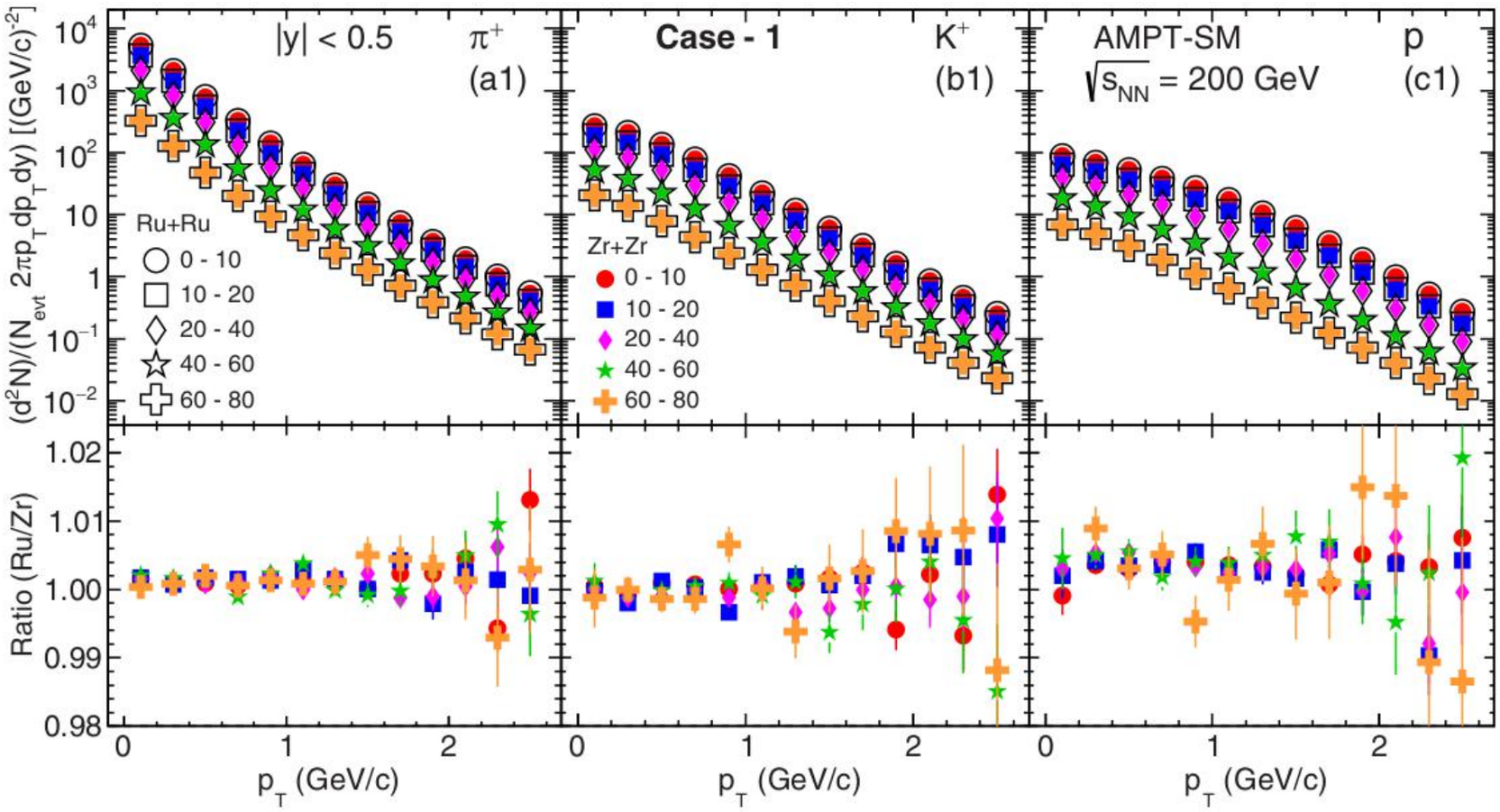




This work: *P. Sinha et al., Phys. Rev. C 108, 024911 (2023)*
STAR: *M. S. Abdallah et al., Phys. Rev. C 105, 014901 (2022)*

- **Multiplicity ratio:** Case-2 of the AMPT model better describes the STAR experimental data
  → Indicates influence of the nuclear size and thickness variation
- **Elliptic flow (v_2) ratio:** Case-3 describes data in central collisions, while both case-2 and 3 describe in peripheral collisions
  → Indicates influence of nuclear deformation in central collisions
  → Implies peripheral collisions are primarily affected by the nuclear skin

Transverse Momentum Spectra



- Case 1: same nuclear size w/o deformation
- Case 2: different nuclear size w/o deformation
- Case 3: different nuclear size with deformation

- Transverse momentum (p_T) spectra of identified hadrons (π, K, and p) at midrapidity ($|y| < 0.5$) in isobar (Ru+Ru and Zr+Zr) collisions at $\sqrt{s_{NN}} = 200$ GeV using the AMPT model.
- Case 1: No deviation observed from unity between the p_T spectra of identified hadrons in Ru+Ru and Zr+Zr collisions within statistical uncertainties.

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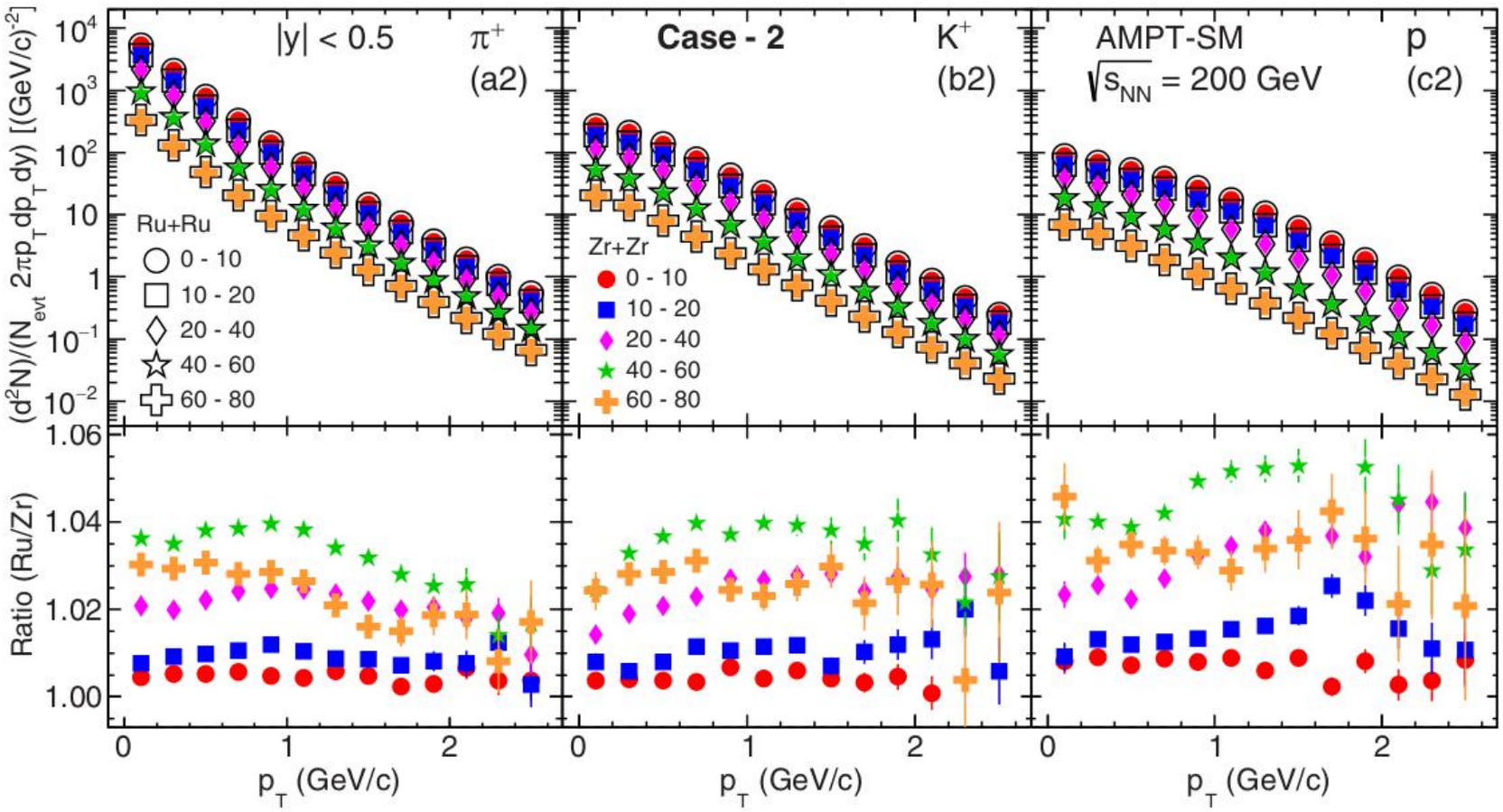
Transverse Momentum Spectra

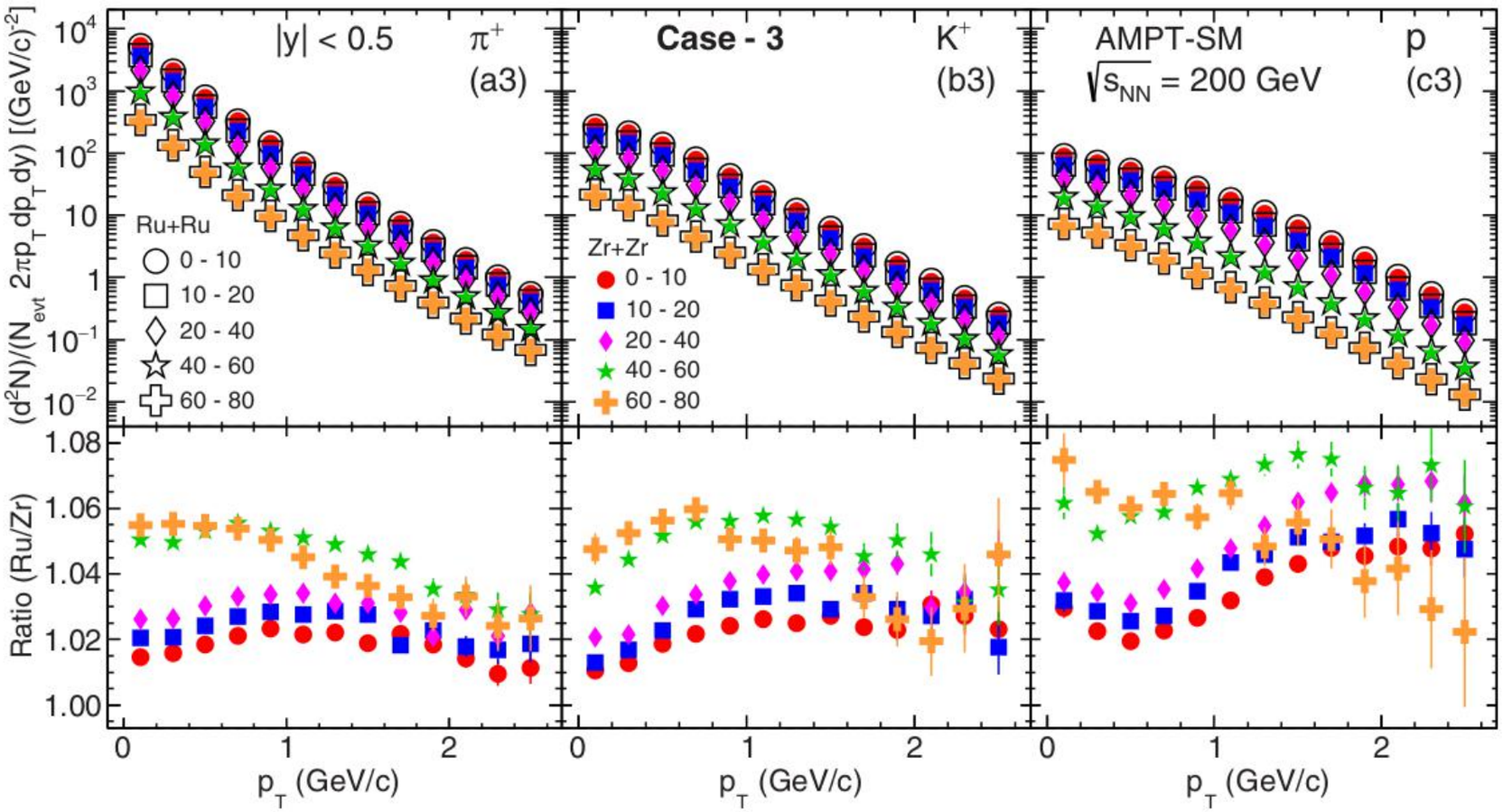


- Case 1: same nuclear size w/o deformation
- Case 2: different nuclear size w/o deformation
- Case 3: different nuclear size with deformation

- Transverse momentum (p_T) spectra of identified hadrons (π, K, and p) at midrapidity ($|y| < 0.5$) in isobar (Ru+Ru and Zr+Zr) collisions at $\sqrt{s_{NN}}$ = 200 GeV using the AMPT model.
- Case 2: Deviation of 4% to 6% observed between the p_T spectra of identified hadrons in Ru+Ru and Zr+Zr collisions.
- Deviation increases from central to peripheral collisions.

This work: P. Sinha et al., Phys. Rev. C 108, 024911 (2023)

Transverse Momentum Spectra



- Case 1: same nuclear size w/o deformation
- Case 2: different nuclear size w/o deformation
- Case 3: different nuclear size with deformation

- Transverse momentum (p_T) spectra of identified hadrons (π, K, and p) at midrapidity ($|y| < 0.5$) in isobar (Ru+Ru and Zr+Zr) collisions at $\sqrt{s_{NN}} = 200$ GeV using the AMPT model.
- Case 3: Inclusion of deformation causes deviation to increase upto 6%-8% between the p_T spectra of identified hadrons in Ru+Ru and Zr+Zr collisions.

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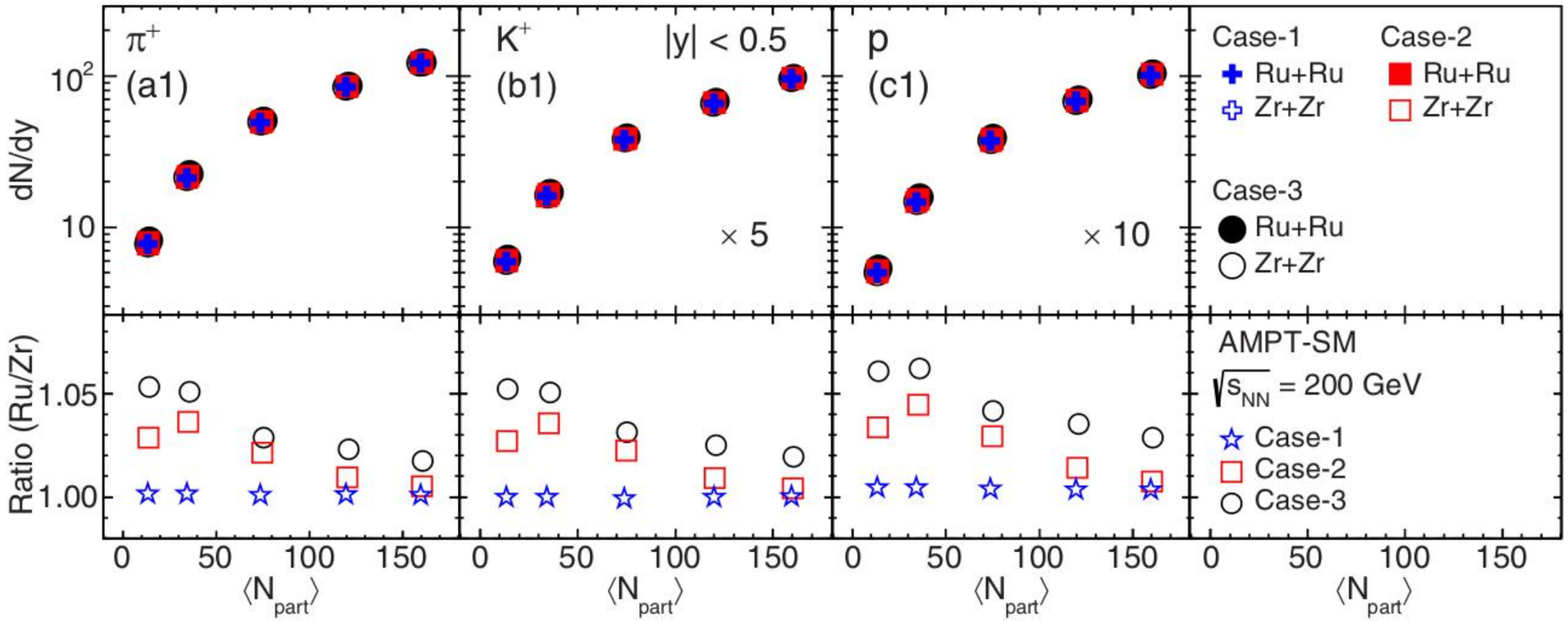
Particle Yield (dN/dy)



- p_T-integrated yield (dN/dy) of identified hadrons (π, K, and p) at midrapidity (|y| < 0.5) in isobar (Ru+Ru and Zr+Zr) collisions at $\sqrt{s_{NN}}$ = 200 GeV using the AMPT model.
- Significant deviation (upto 6%) observed in the ratio of particle yields with the inclusion of different deformation and nuclear size in Ru+Ru and Zr+Zr collisions.
- Deviation increases towards peripheral collisions.

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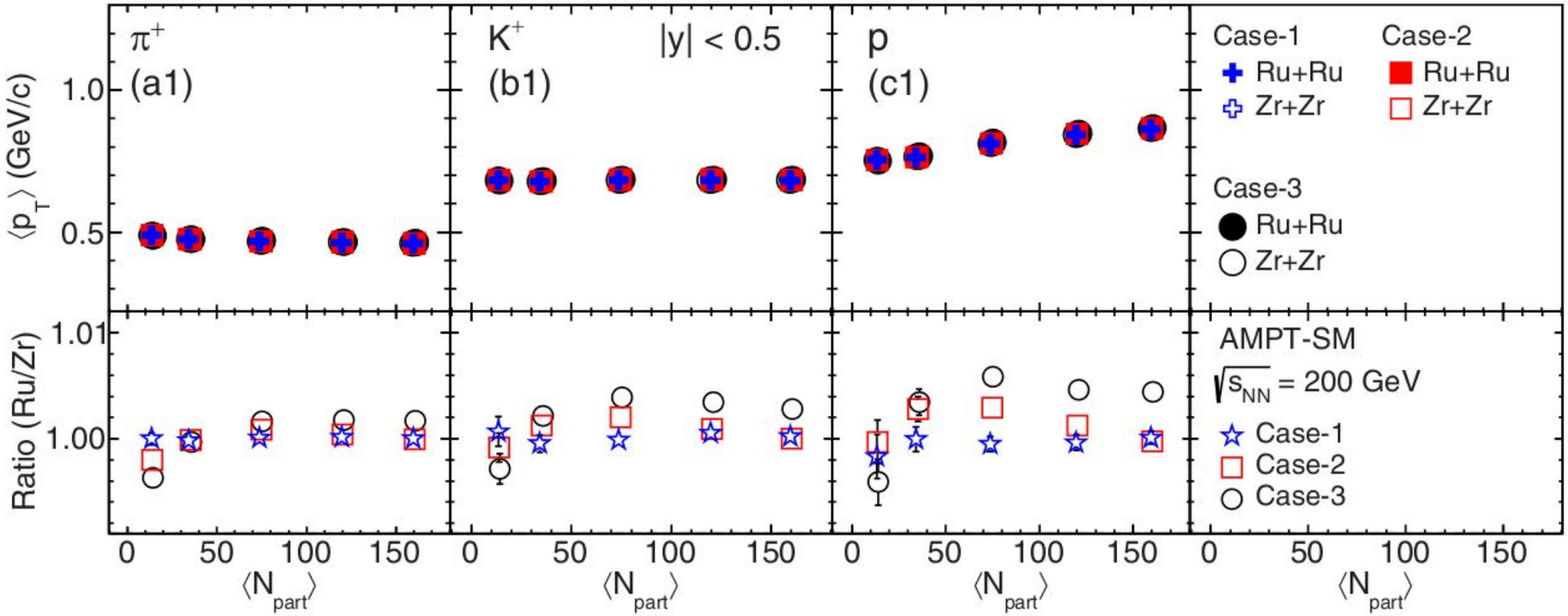
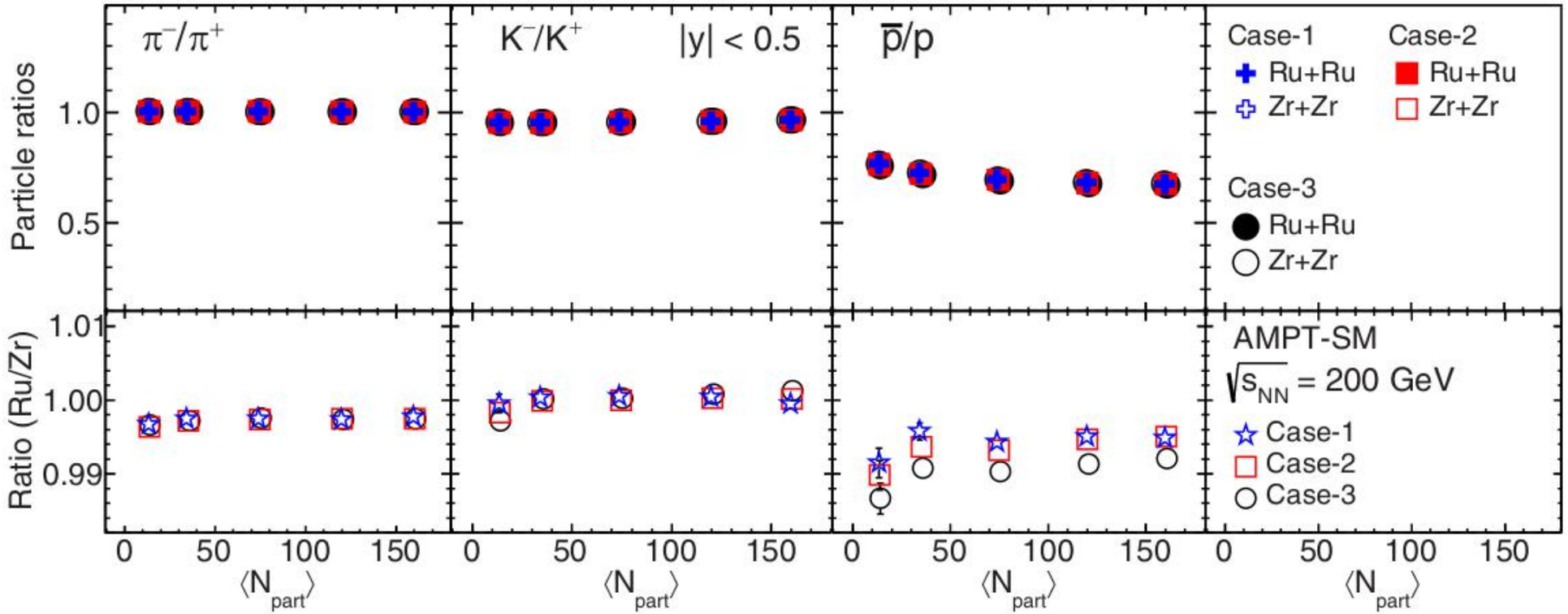
Average Transverse Momentum



- Average transverse momentum (<p_T>) of identified hadrons (π, K, and p) at midrapidity (|y| < 0.5) in isobar (Ru+Ru and Zr+Zr) collisions at $\sqrt{s_{NN}}$ = 200 GeV using the AMPT model.
- Small deviation (< 1%) observed for <p_T> ratio with and without different deformation and nuclear size in Ru+Ru and Zr+Zr collisions.

This work: P. Sinha et al., Phys. Rev. C 108, 024911 (2023)

Particle Ratios



- Ratio of π^-/π^+ between the two isobars is lower than unity
  → Indicating effect of isospin
- Ratio of p-bar/p is further lower than unity compared to π^-/π^+
  → Indicating additional baryon stopping effect
- Ratio of K^-/K^+ is close to unity between the two isobars
  → Indicating dominance of pair production mechanism

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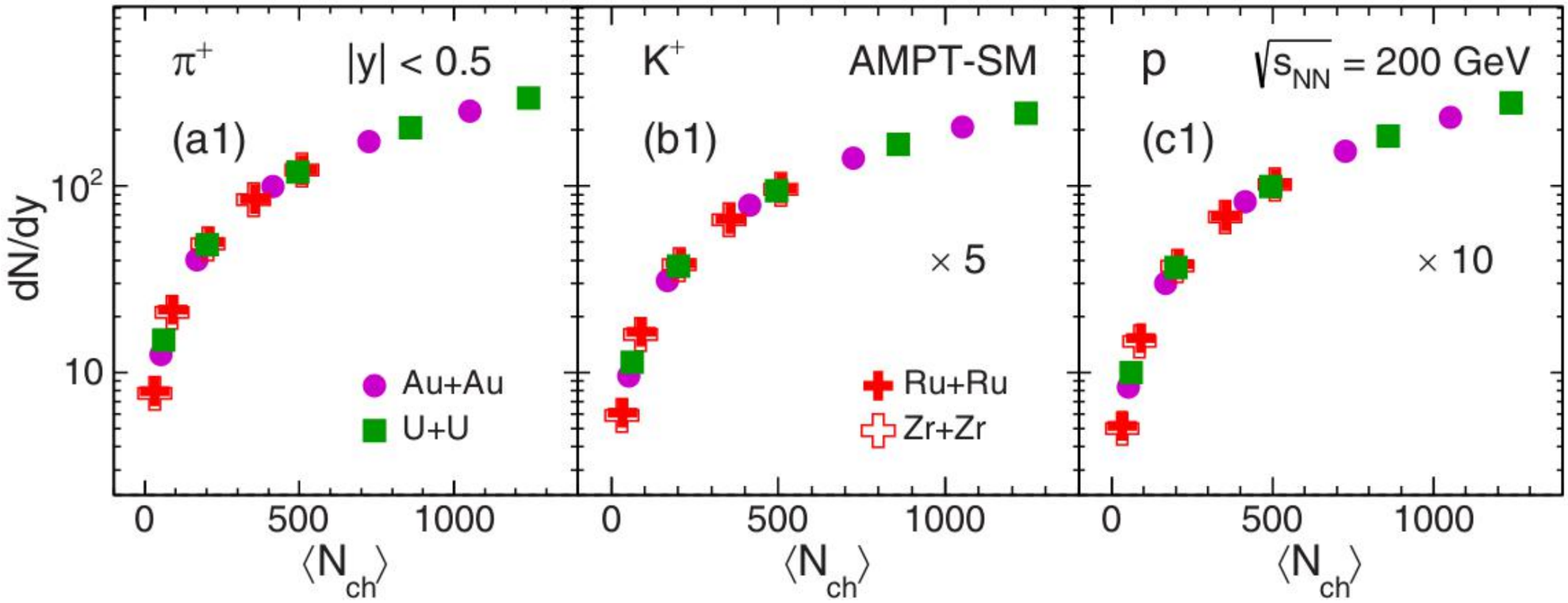
System Size dependence



- Particle yields increase with increasing multiplicity (<Nch>) for all the particle species in all collision systems.
- Particle yields for different colliding systems show a smooth variation with <Nch>.

  → Indicate system size dependence of particle production at $\sqrt{s_{NN}}$ = 200 GeV

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Summary

- Nuclear configuration (Case-2) of the AMPT model seems to better describe multiplicity ratio from the STAR experimental data.
- Nuclear configuration (Case-2 and 3) of the AMPT model seems to describe elliptic flow (v_2) ratio from the STAR experimental data.

	Ru			Zr		
Parameter	case 1	case 2	case 3	case 1	case 2	case 3
R_0	5.096	5.067	5.090	5.096	4.965	5.090
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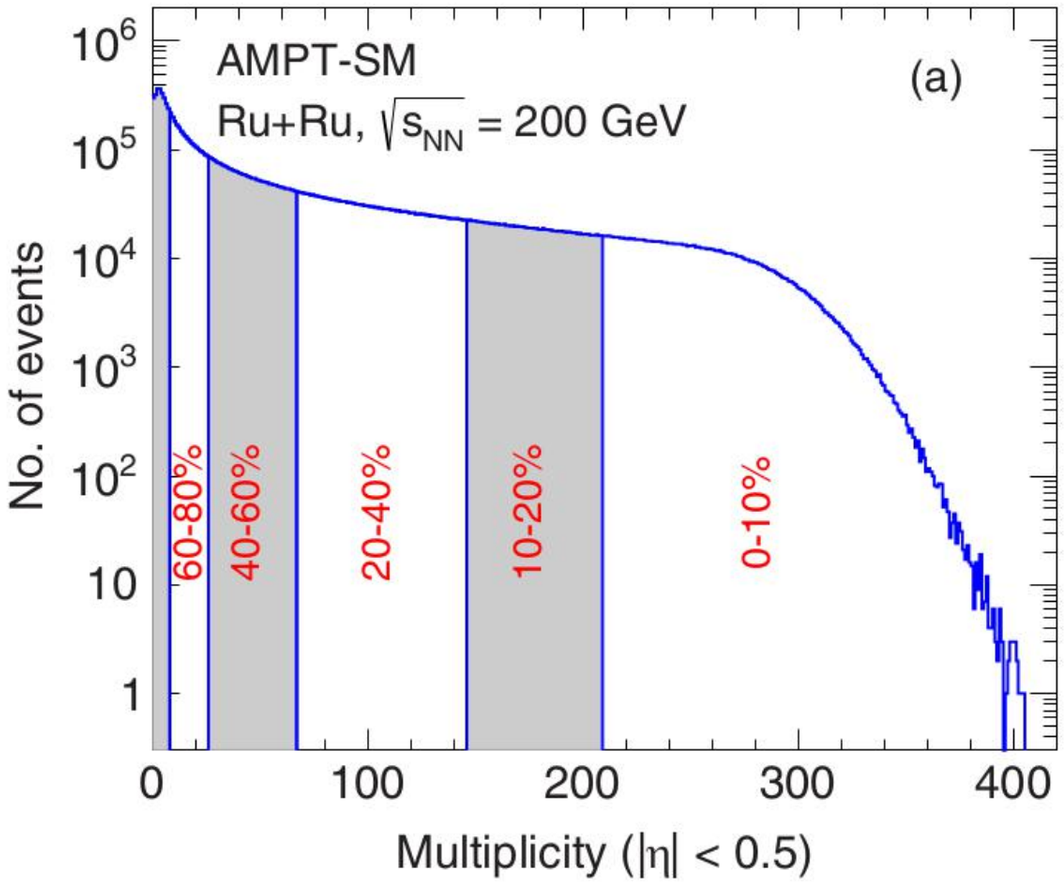
β_3	0	0	0	0	0	0.200

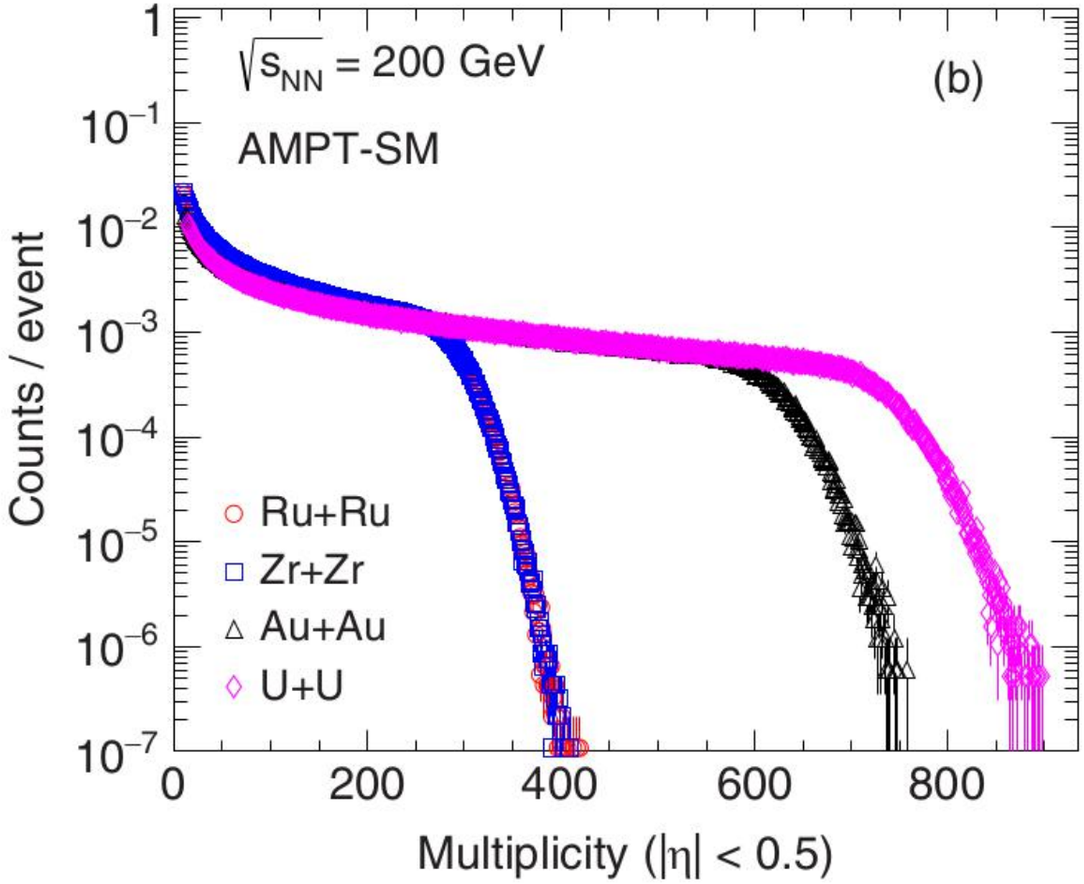
- p_T-spectra, particle yields (dN/dy) from the isobar collisions provide access to nuclei deformation.
- Particle yields show a smooth variation with different colliding system and multiplicity (<Nch>)
  → Indicating system size dependence of particle production at $\sqrt{s_{NN}} = 200$ GeV.
- Ratio of particle ratios between isobar collisions indicate possible
  → Indicating effect of isospin and baryon stopping effect

Thank you for your attention!

Backup

Centrality Selection





- Centrality selection is based on reference multiplicity ($|\eta| < 0.5$) similar to the experiment.
- Comparison of reference multiplicity distribution in isobar collisions (Ru+Ru, Zr+Zr) with other heavy-ion collision systems.