Longitudinal flow decorrelation in ^{96}Zr+^{96}Zr and ^{96}Ru+^{96}Ru collisions within a multiphase transport model

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Aug. 09, 2022

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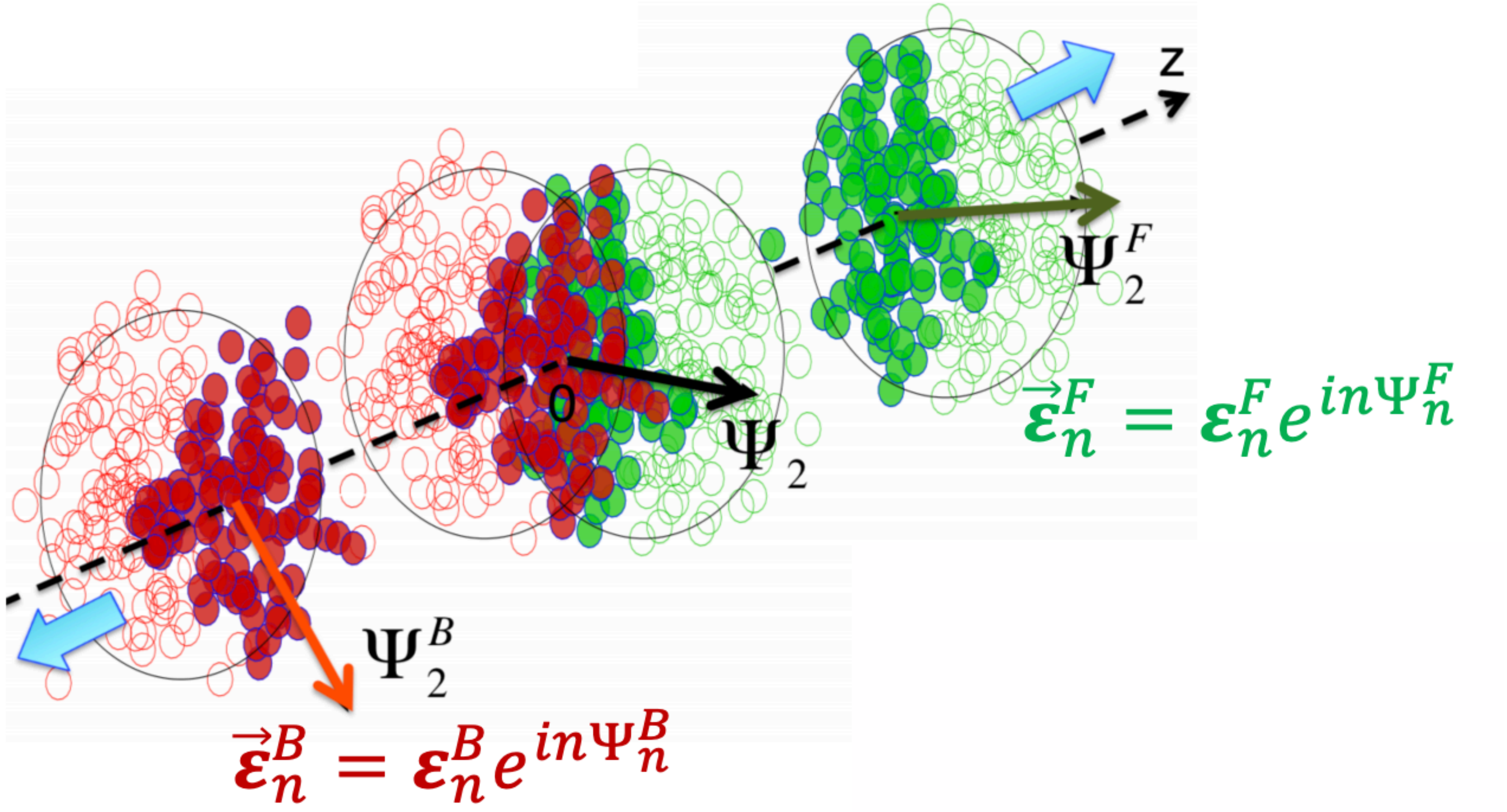
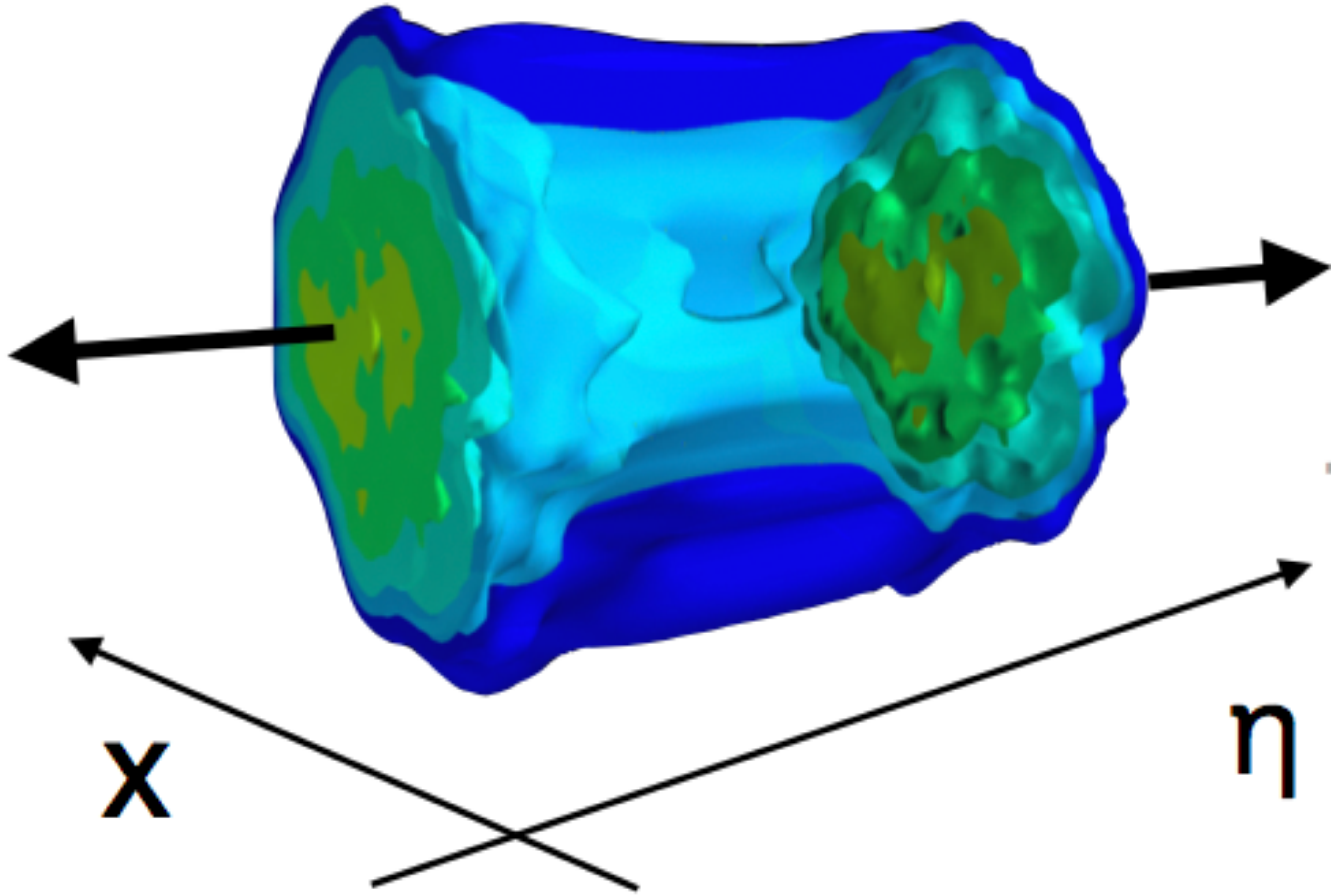
中国物理学会高能物理分会第十一届全国会员代表大会暨学术年会

山东大学(青岛)
SHANDONG UNIVERSITY, QINGDAO
Stony Brook University

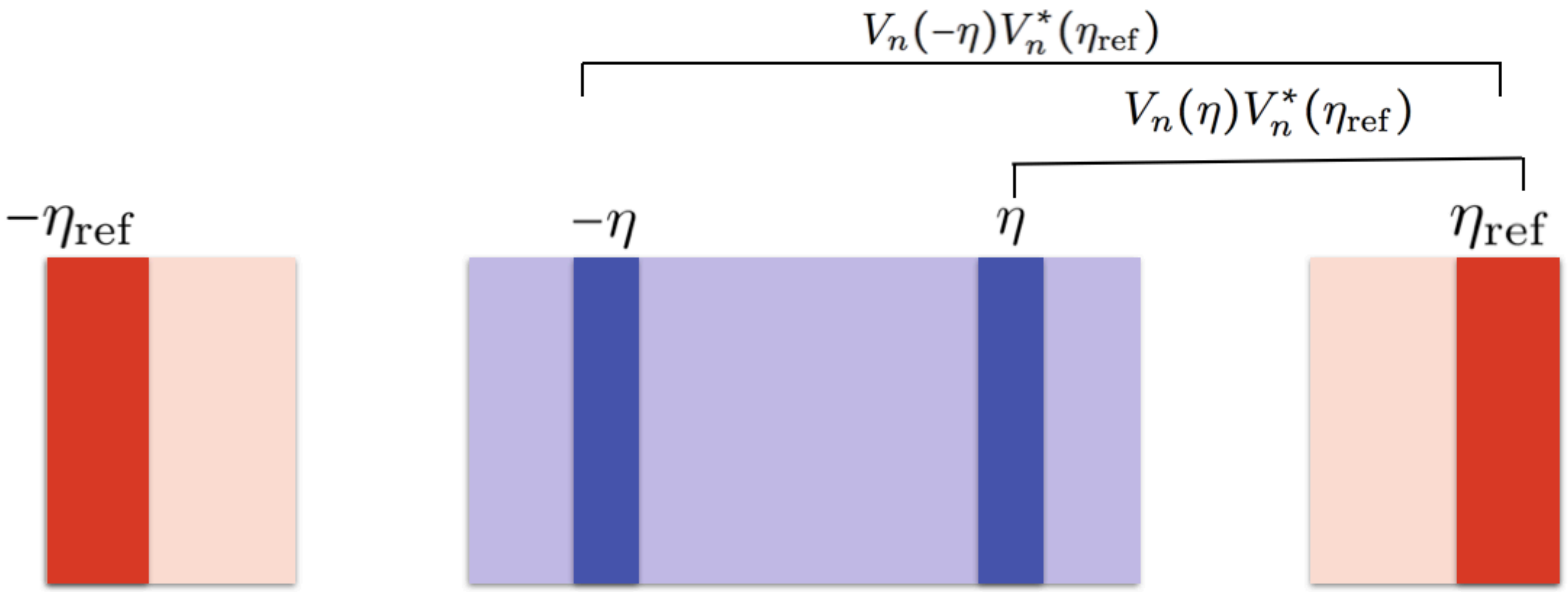
Longitudinal dynamics of in heavy-ion collisions





Longitudinal fluctuation can provide full space-time evolution of QGP.

Flow decorrelation observable



A large η gap is imposed to avoid short-range correlations.

Factorization ratio, r_n, is constructed as a measure of the flow decorrelation

$$r_n(\eta) = \frac{\langle V_n(-\eta)V_n^*(\eta_{\rm ref})\rangle}{\langle V_n(\eta)V_n^*(\eta_{\rm ref})\rangle} = \frac{\langle v_n(-\eta)v_n(\eta_{\rm ref})\cos n(\Psi_n(-\eta)-\Psi_n(\eta_{\rm ref}))\rangle}{\langle v_n(\eta)v_n(\eta_{\rm ref})\cos n(\Psi_n(\eta)-\Psi_n(\eta_{\rm ref}))\rangle}$$

CMS, Phys. Rev. C 92 (2015) 034911

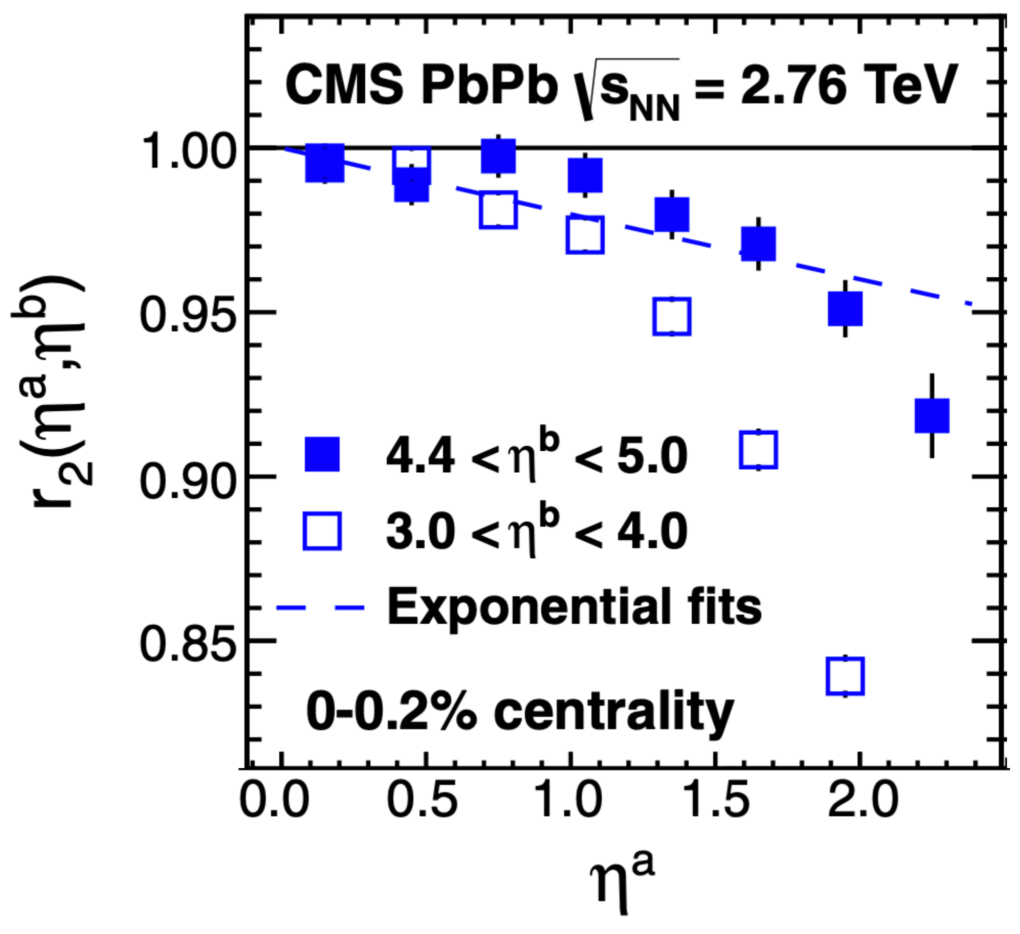
J. Jia, P. Huo, G. Ma and MWN, J. Phys. G: Nucl. Part. Phys. 44 (2017) 075106

If no decorrelation, $r_n(\eta) = 1$;

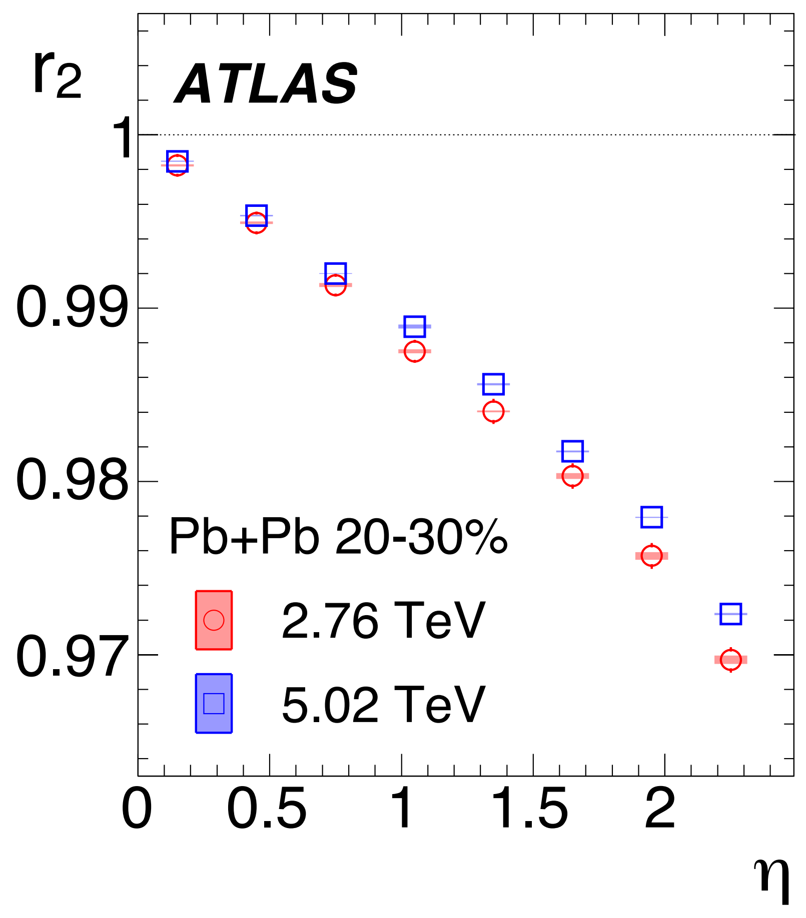
The deviation of $r_n(\eta)$ away from 1 will direct quantify flow decorrelation.

Current results on longitudinal dynamics

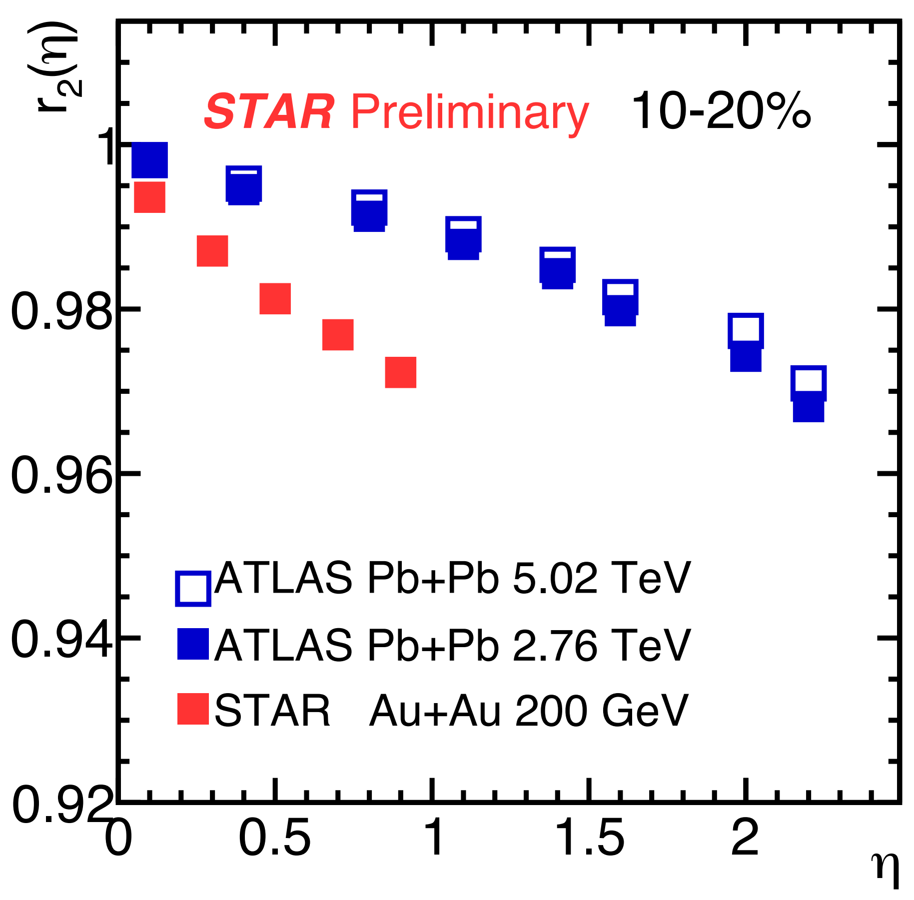
CMS, Phys. Rev. C 92 (2015) 034911



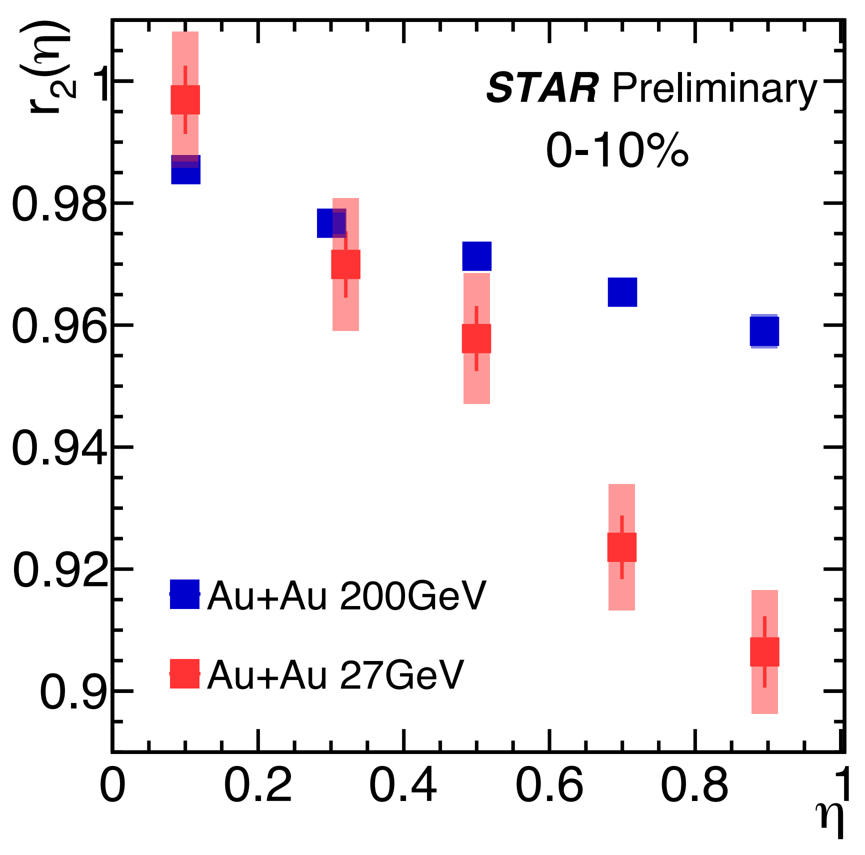
ATLAS, Eur. Phys. J. C (2018) 78:142



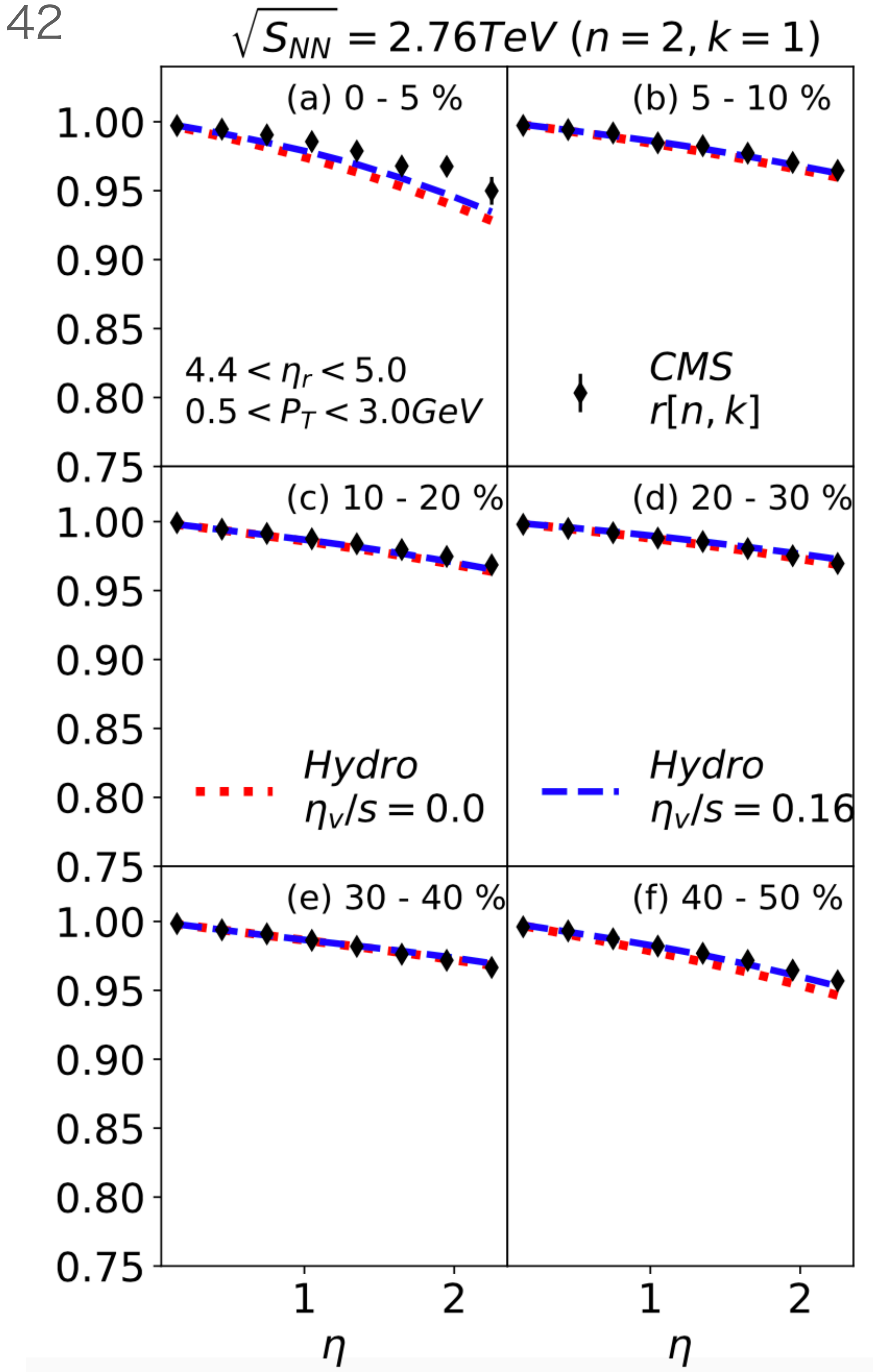
MWN, QM2018

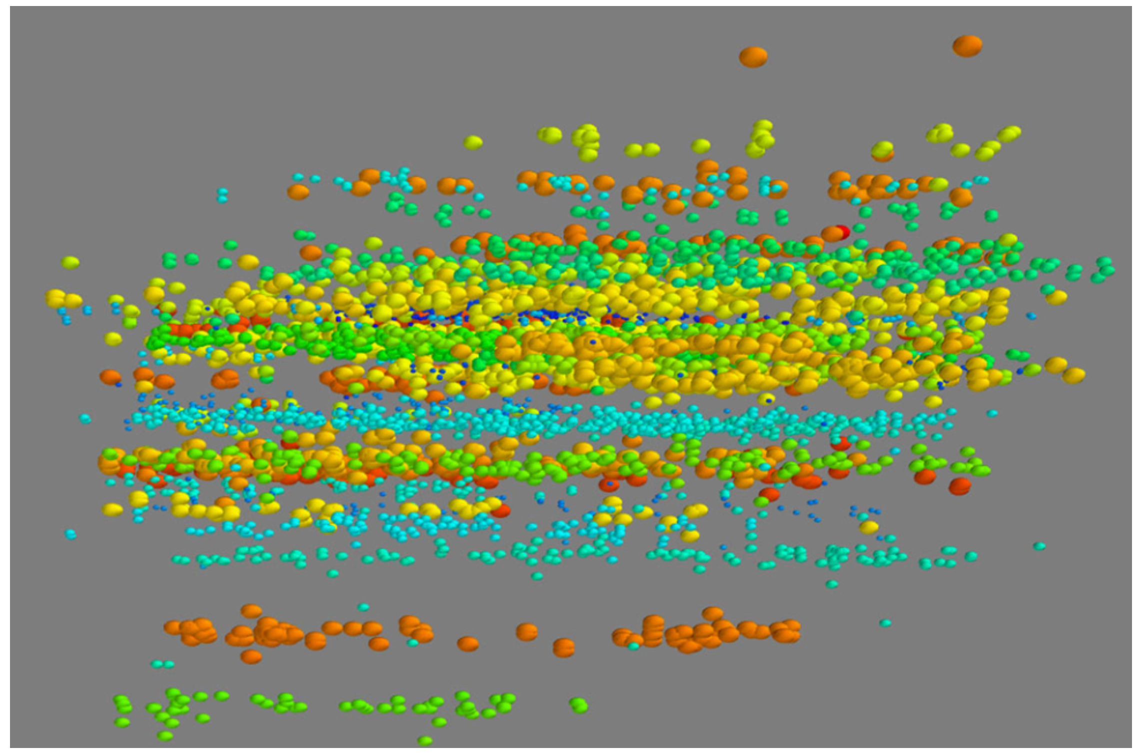


MWN, QM2019



- **r_n is well measured at LHC and RHIC.**





L. Pang, H. Petersen, G. Qin, V. Roy and X. Wang, Eur. Phys. J. A (2016) 52: 97

X. Wu, L. Pang, G. Qin and X. Wang, Phys. Rev. C 98, 024913 (2018)

P. Bozek, W. Broniowski, Physics Letters B 752 (2016) 206–211

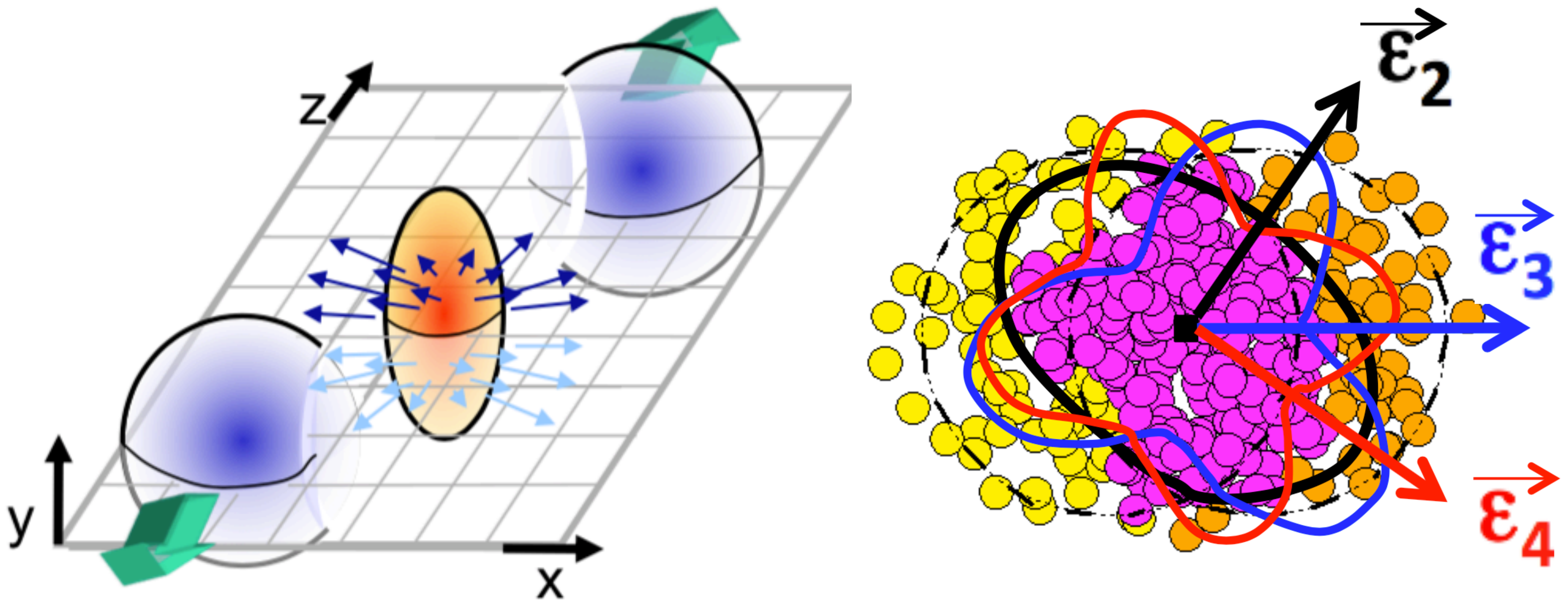
A. Sakai, K. Murase and T. Hirano, Phys. Rev. C **102**, 064903 (2020)

…

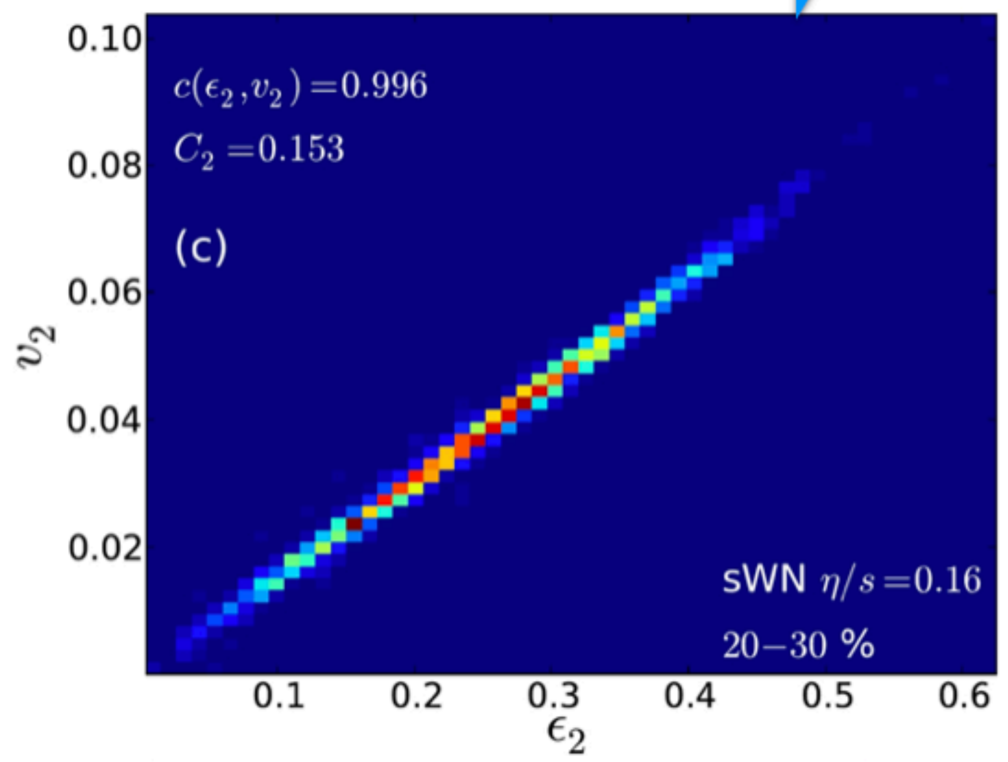
- **r_n is insensitive to shear viscosity**
- **Crucial observable for 2+1 D → 3+1 D hydro.**

Connecting initial state to final state: geometry response

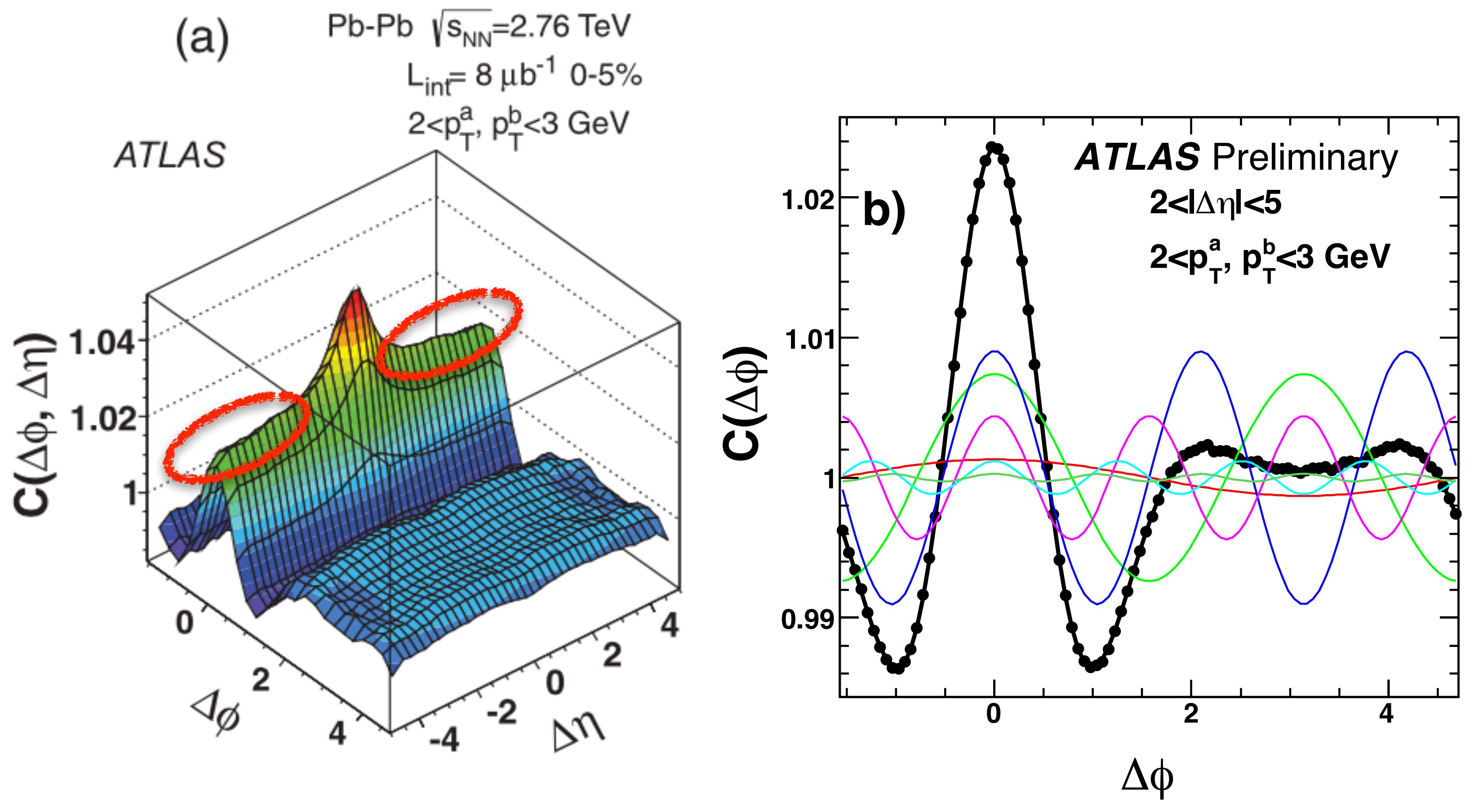
initial state



几何响应
(geometry response)

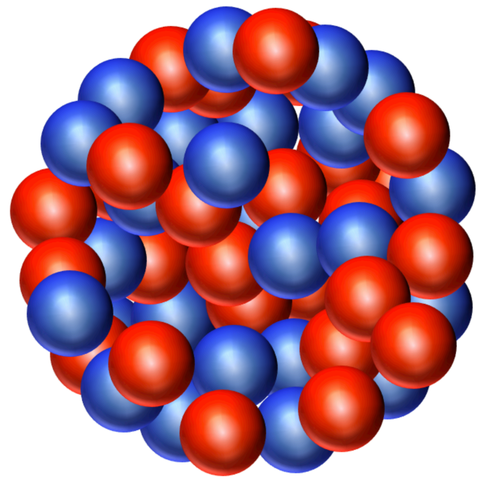


final state

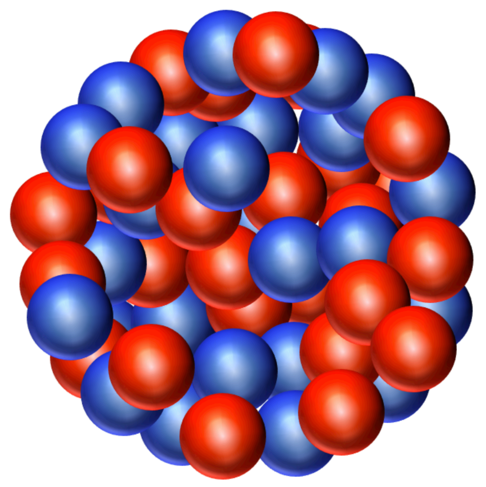


$$V_n \propto \mathcal{E}_n$$

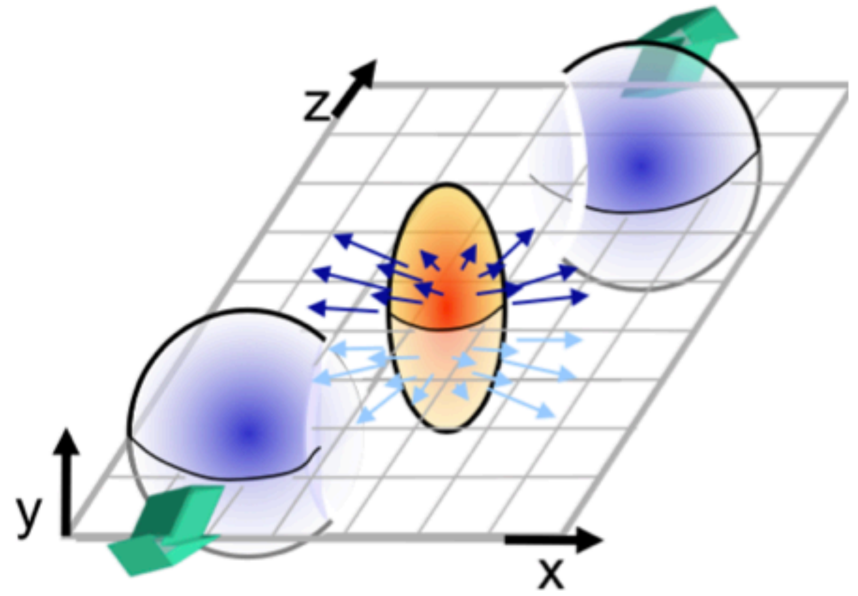
Connecting initial state to final state: geometry response

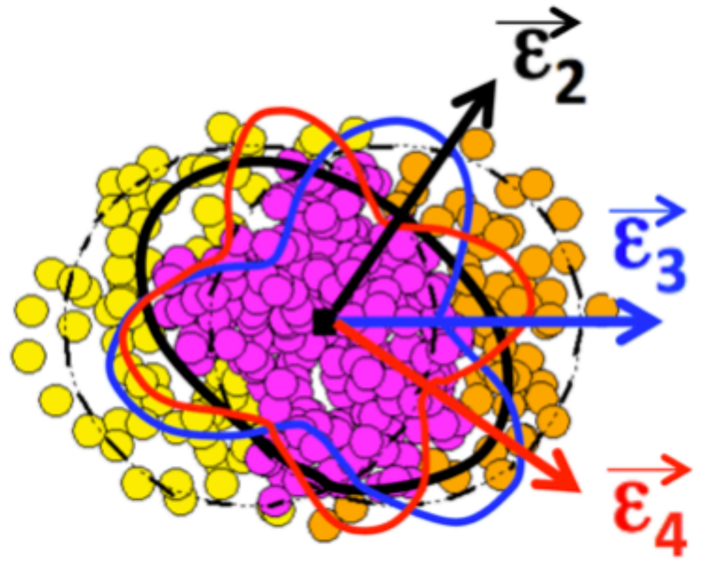


Nuclear Structure

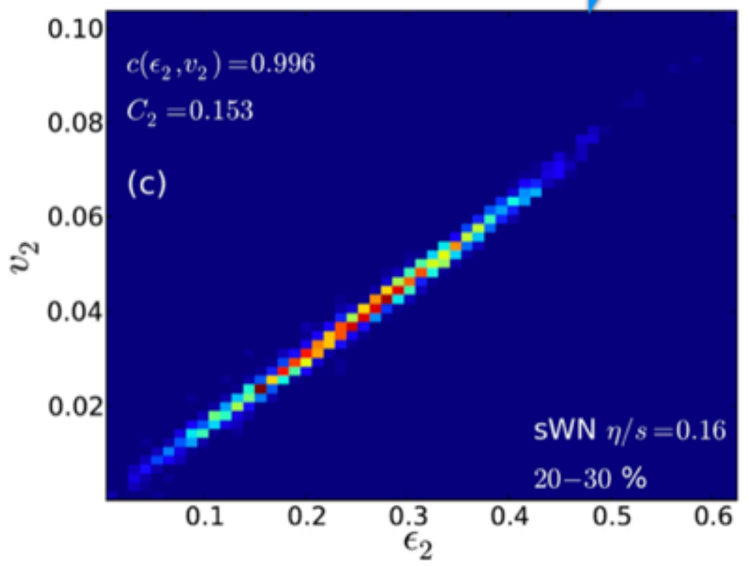


initial state



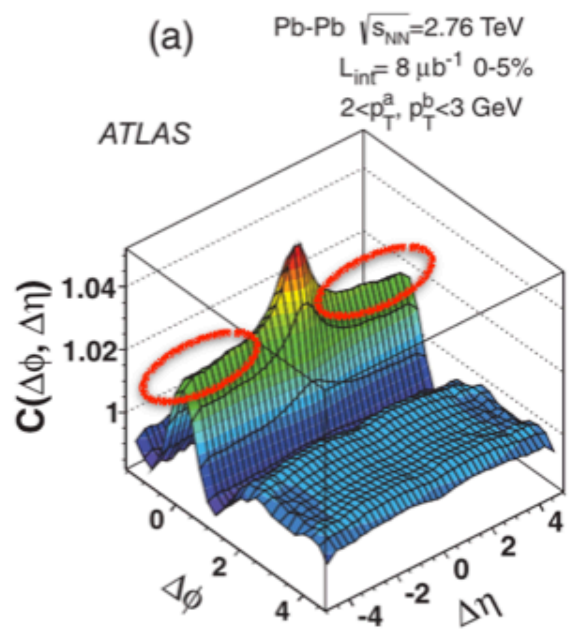


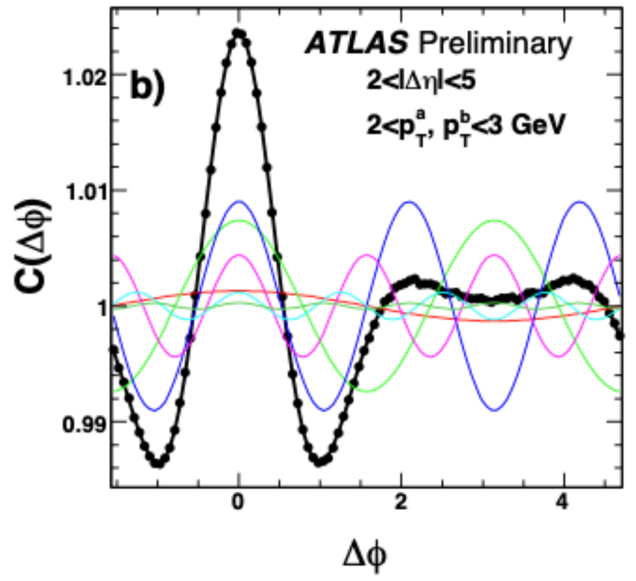
几何响应
(geometry response)



$$V_n \propto \mathcal{E}_n$$

final state

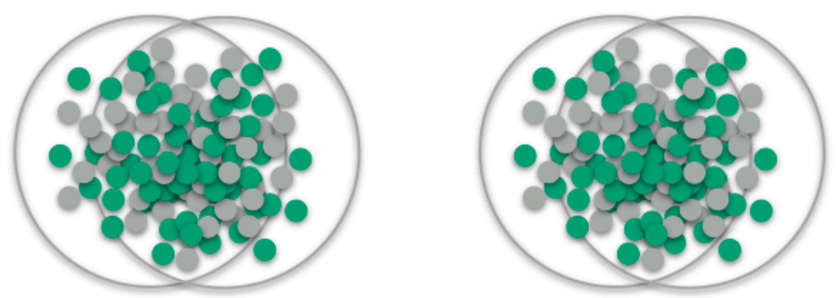




Nuclear structures are important for heavy-ion initial state and final state evolution.

Nuclear structure studies with the unique isobar collisions

同量异位素碰撞



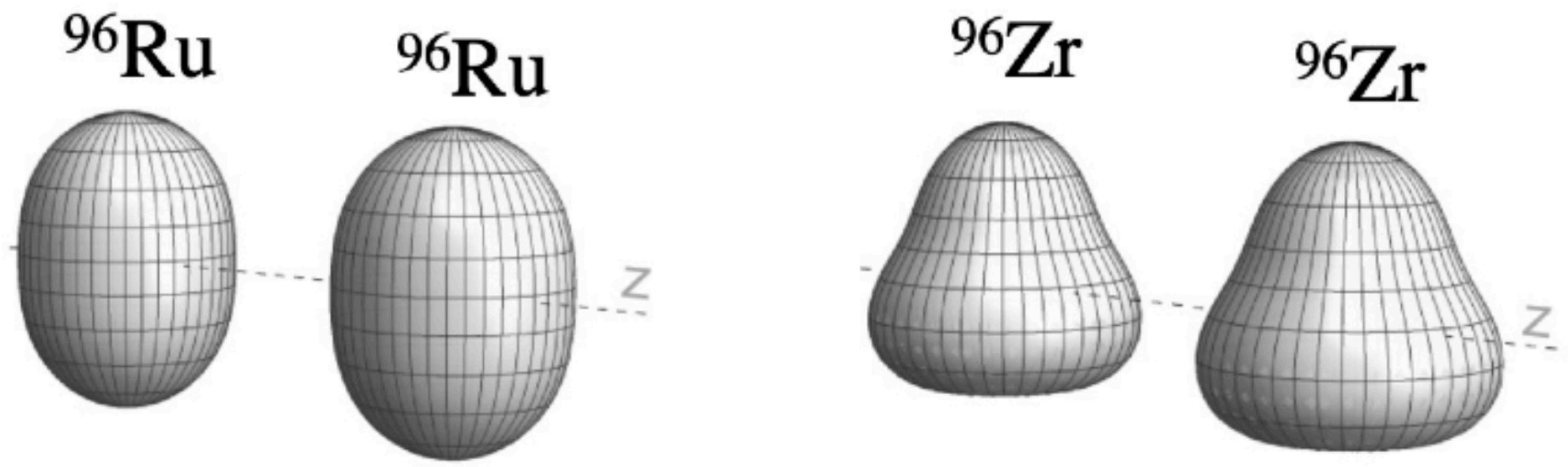
- **Same system size (same mass number A)**
- **Ideal system to study nuclear structure**

$$\frac{\mathcal{O}_{\mathrm{Ru+Ru}}}{\mathcal{O}_{\mathrm{Zr+Zr}}} \stackrel{?}{=} 1$$

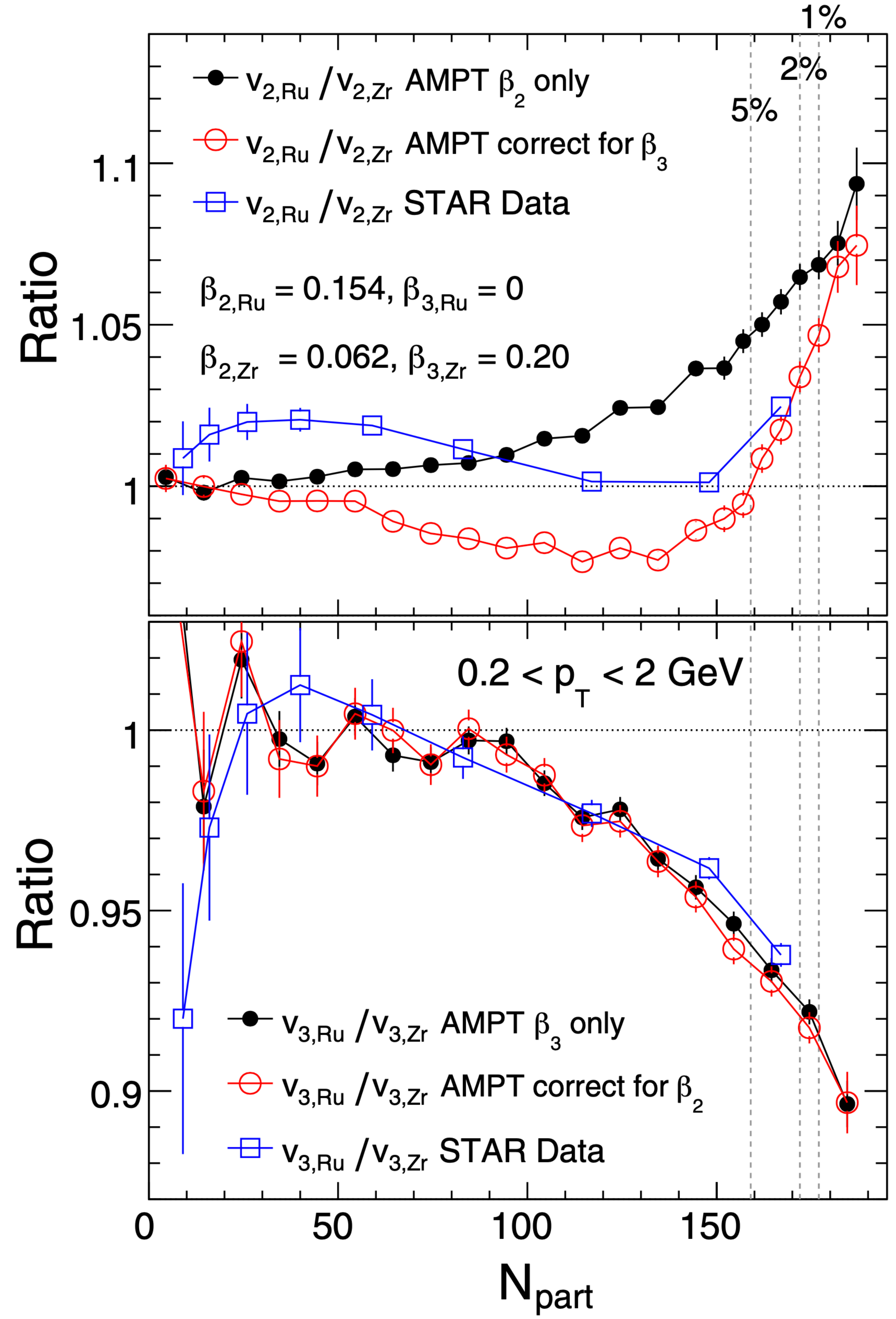
AMPT with Woods-Saxon form of spatial distribution of nucleons

$$\rho(r,\theta,\phi) = \frac{\rho_0}{1+e^{\left(r-R_0\left(1+\sum_n \beta_n Y_n^0(\theta,\phi)\right)\right)/a_0}}$$

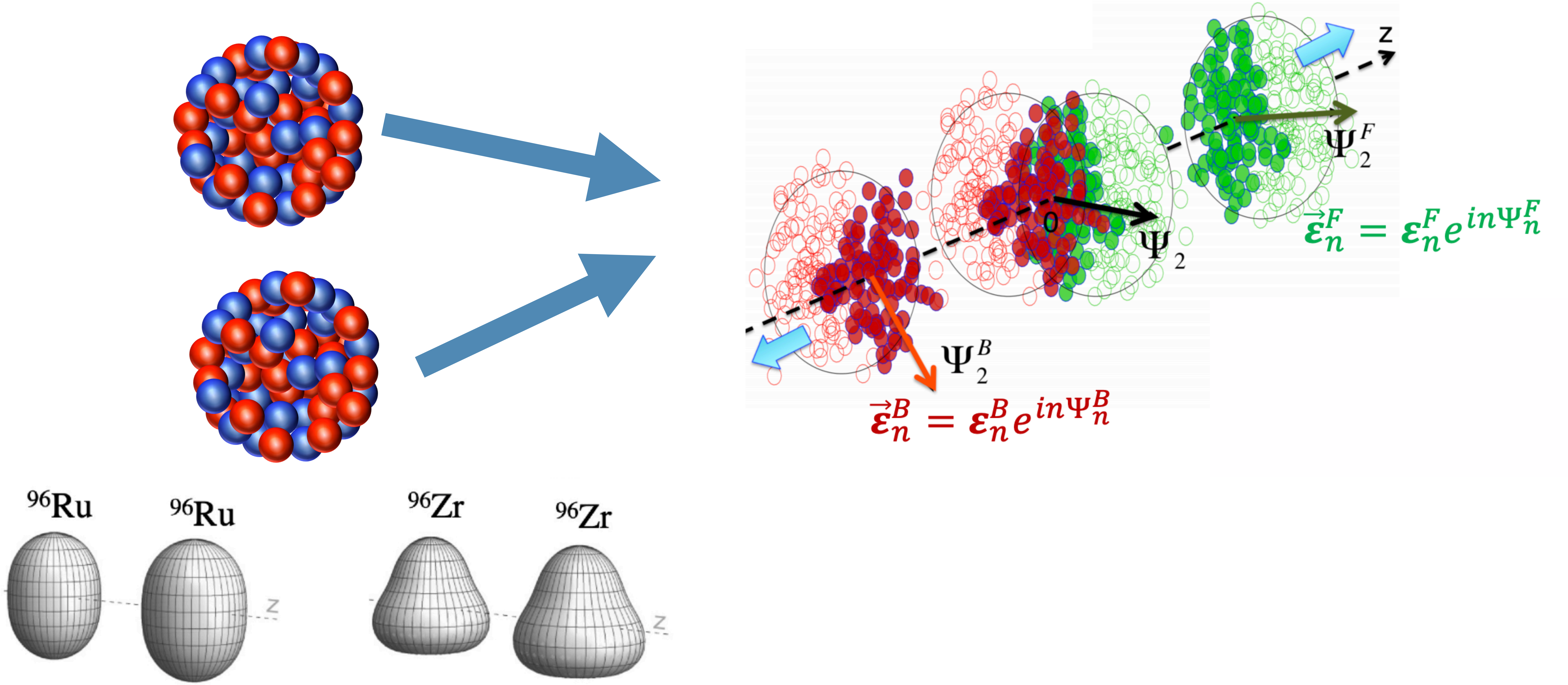
Species	β_2	β_3	a_0	R_0
Ru	0.162	0	0.46 fm	5.09 fm
Zr	0.06	0.20	0.52 fm	5.02 fm



C.Zhang and J. Jia, Phys. Rev. Lett. 128, 022301 (2022)

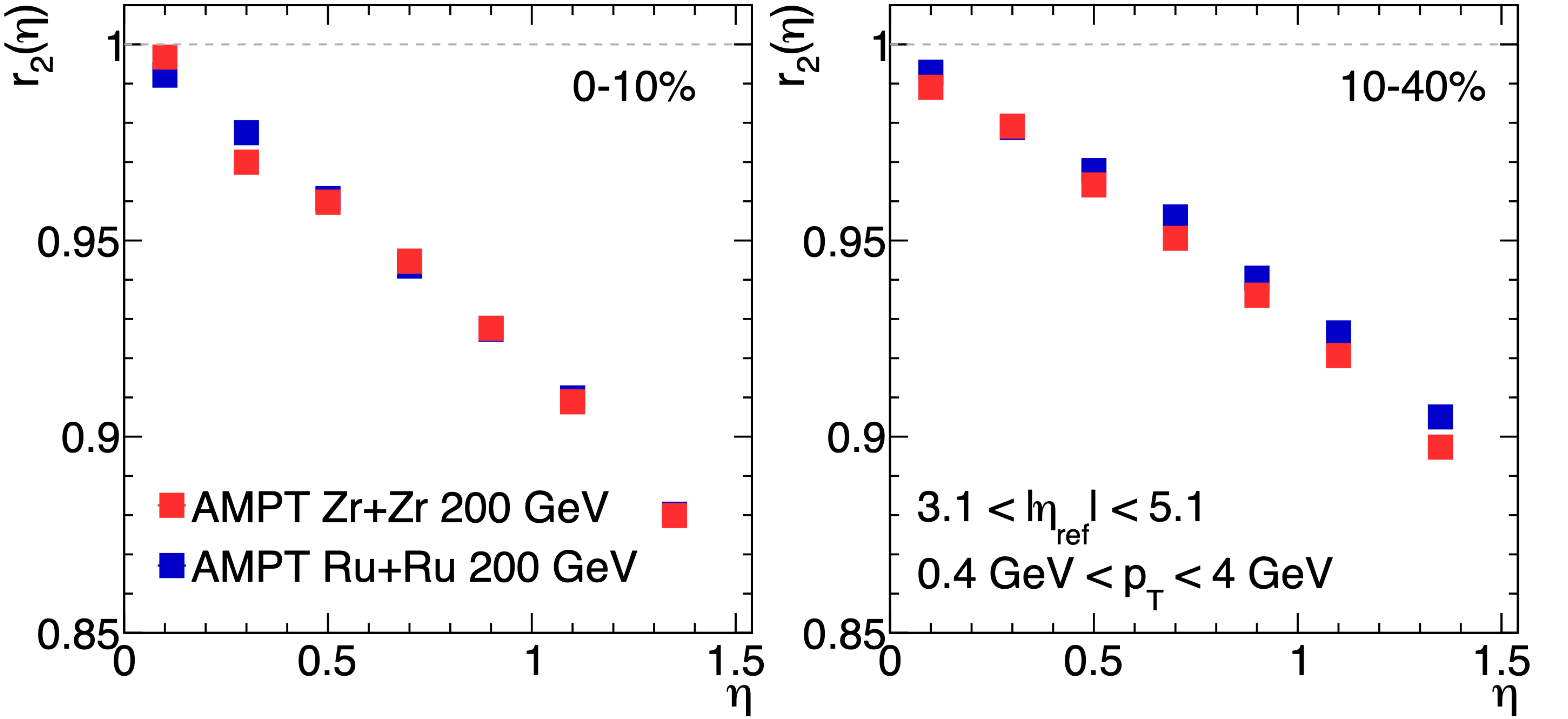


residual effect, e.g., neutron skin, not included in this study, see H. Li, H. Xu, Y. Zhou, X. Wang, J. Zhao, L. Chen, and F. Wang, Phys. Rev. Lett. 125, 222301 (2020)

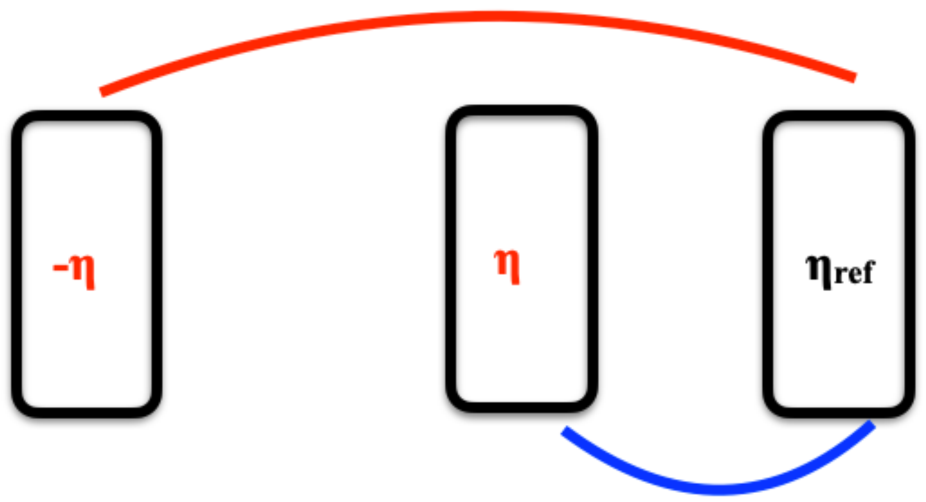


Nuclear structure → Longitudinal dynamics ?

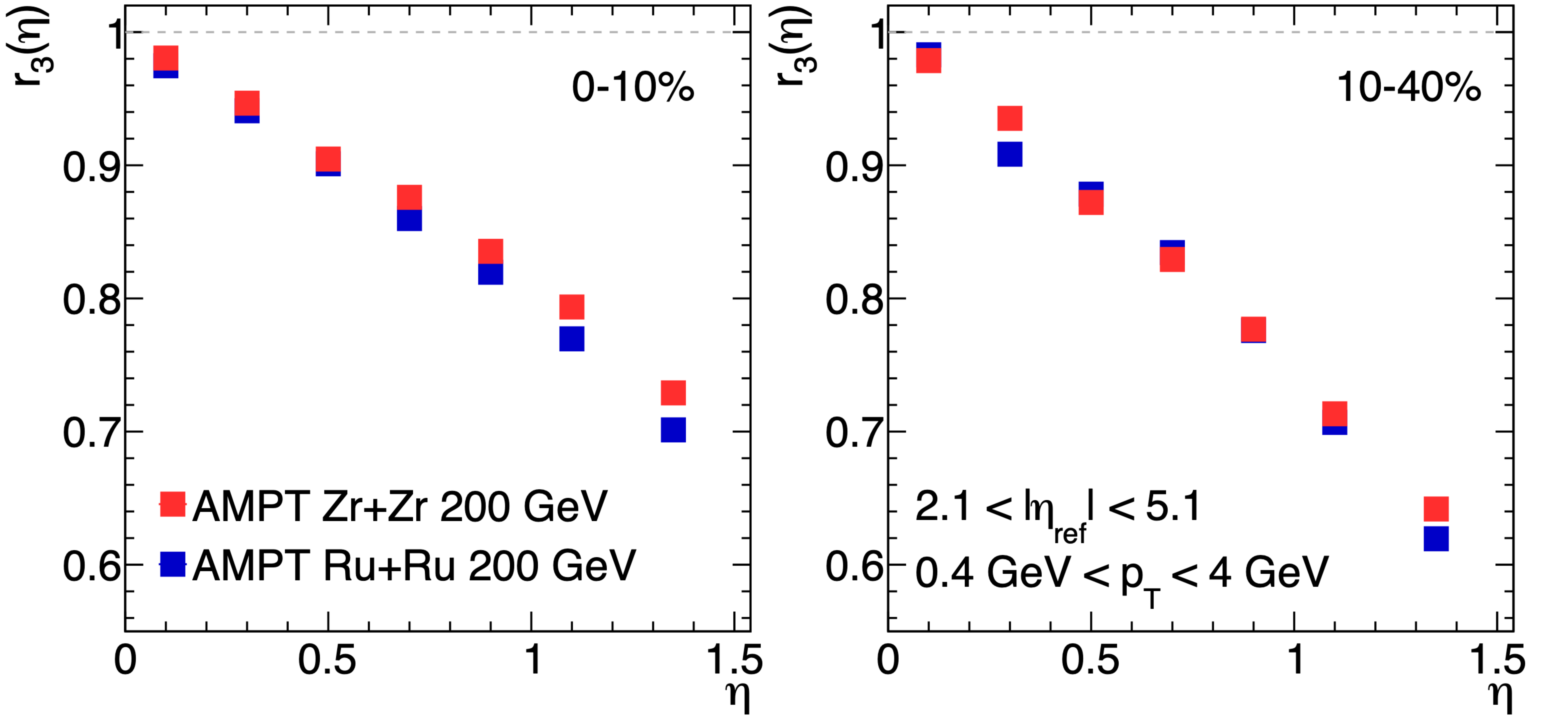
v_2 decorrelation in isobar within AMPT



- $r_2(\eta)$ is consistent in 0-10% for Ru+Ru and Zr+Zr.
- Slight deviation in 10-40%, especially at large rapidity range.



v_3 decorrelation in isobar within AMPT



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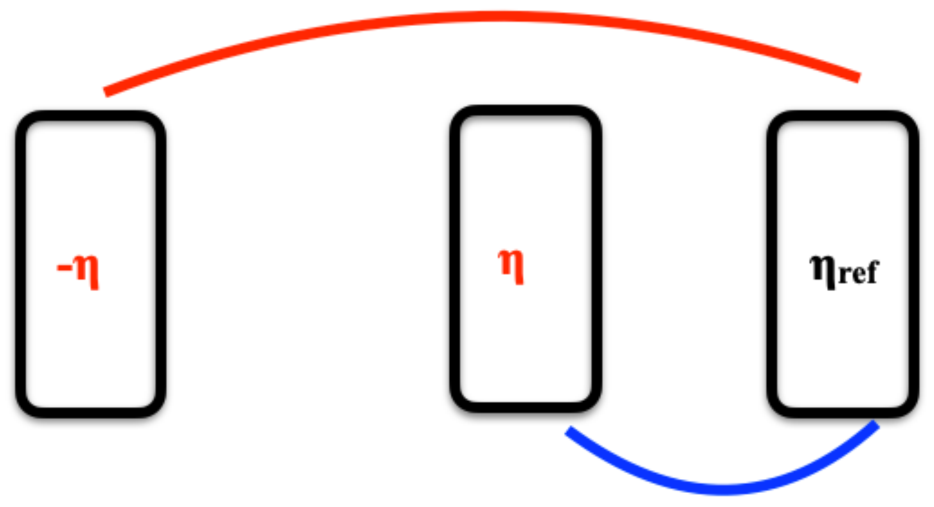
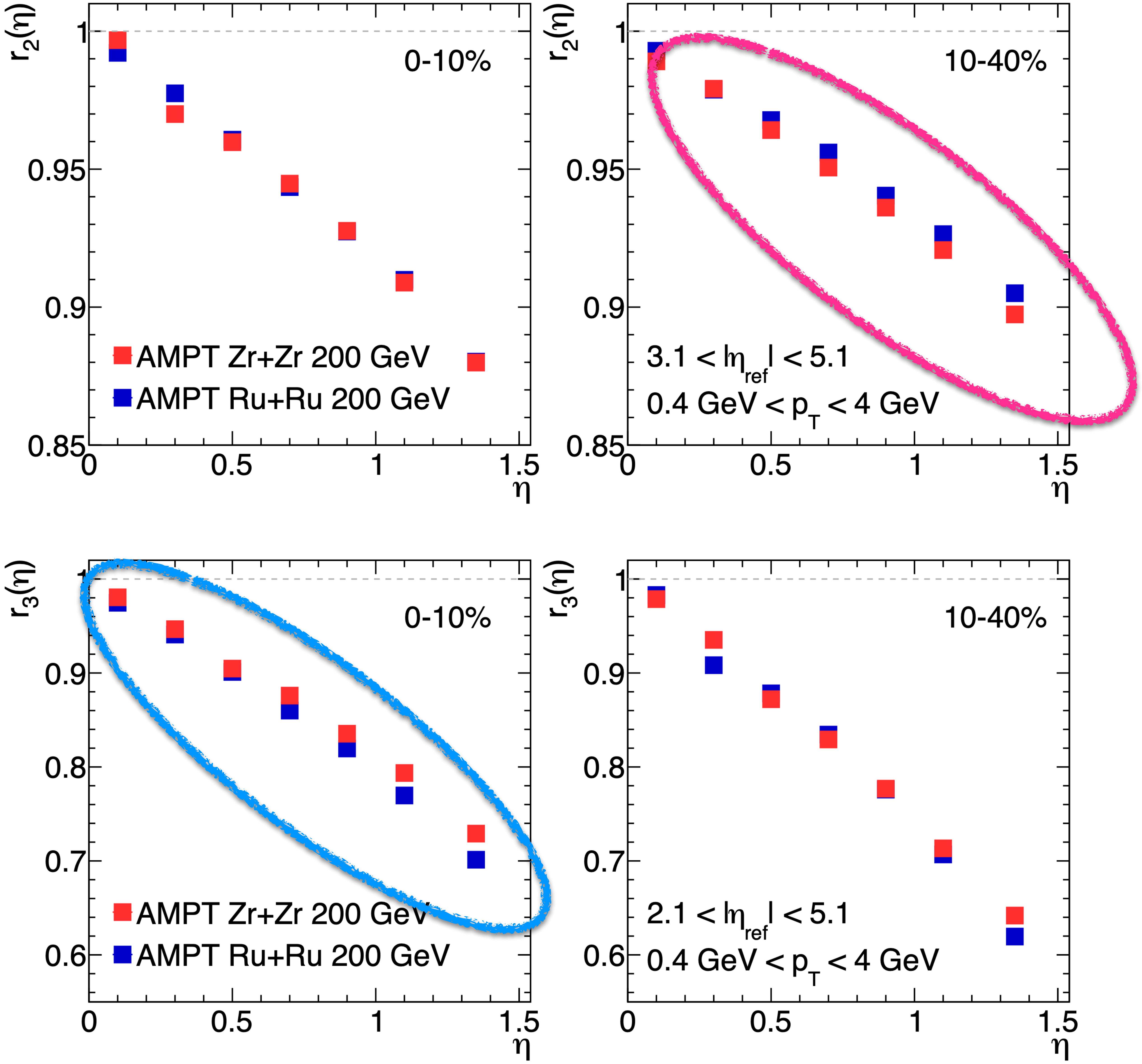
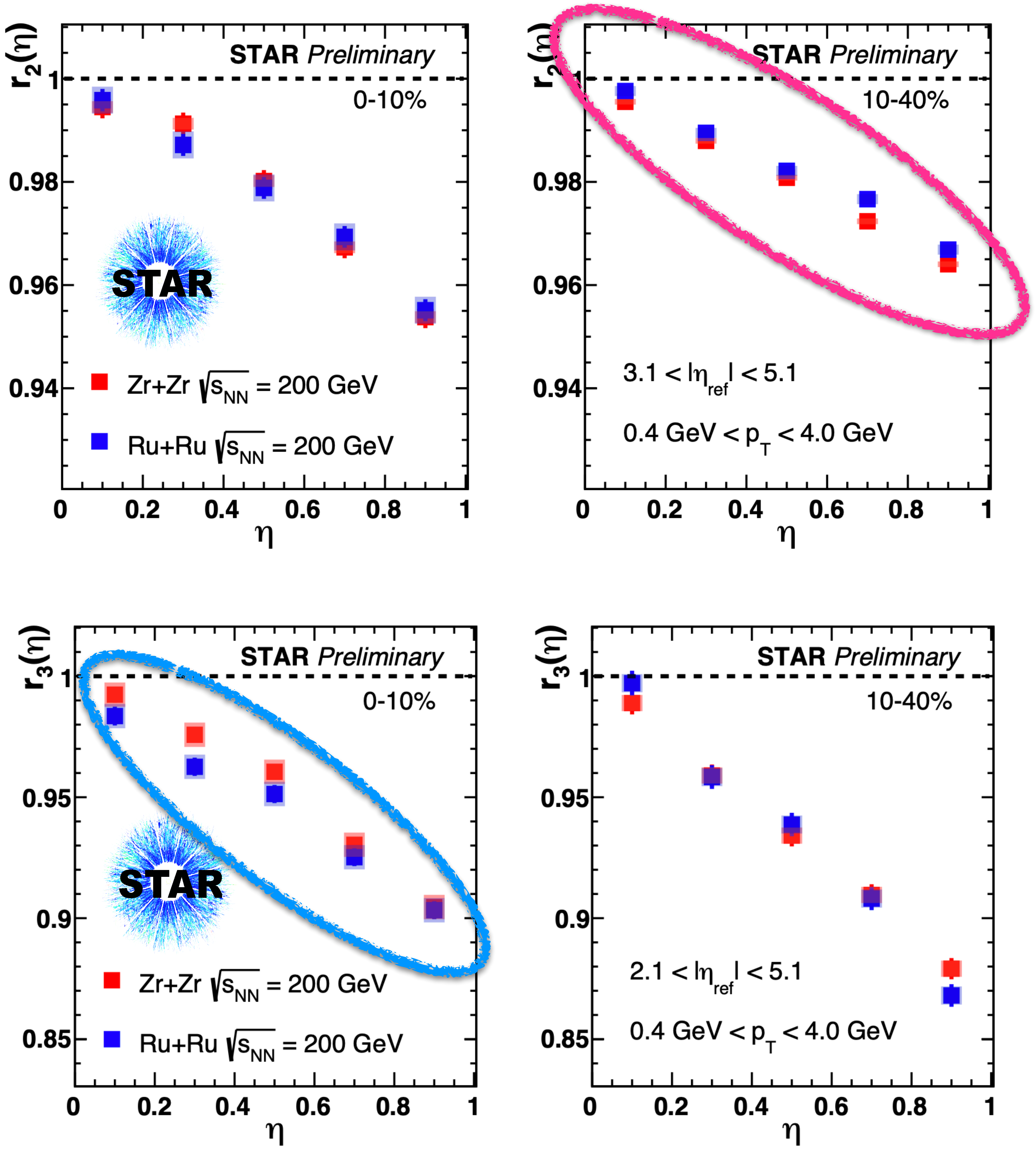


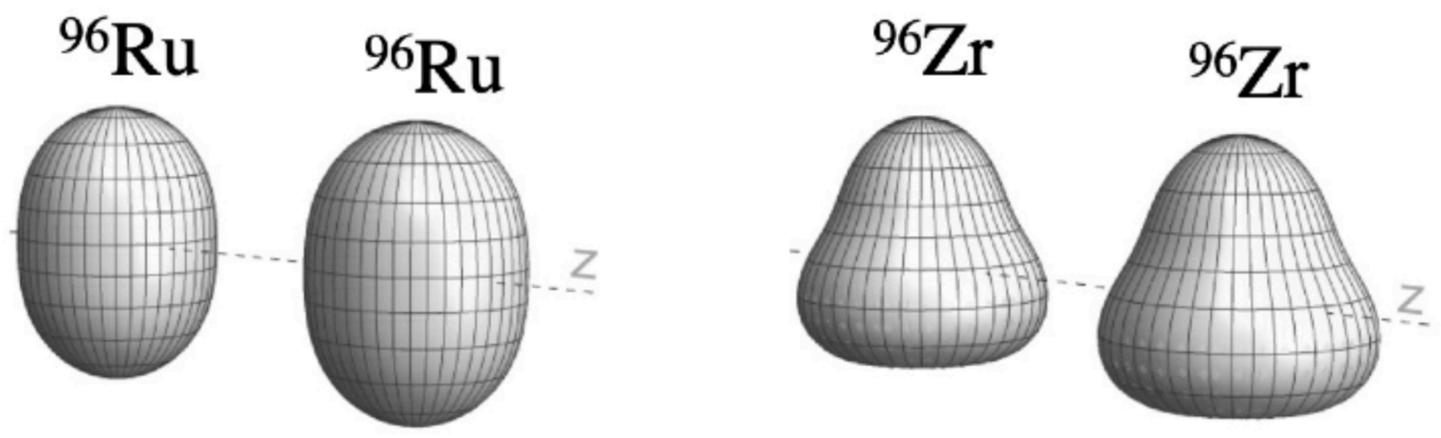
AMPT vs. STAR results



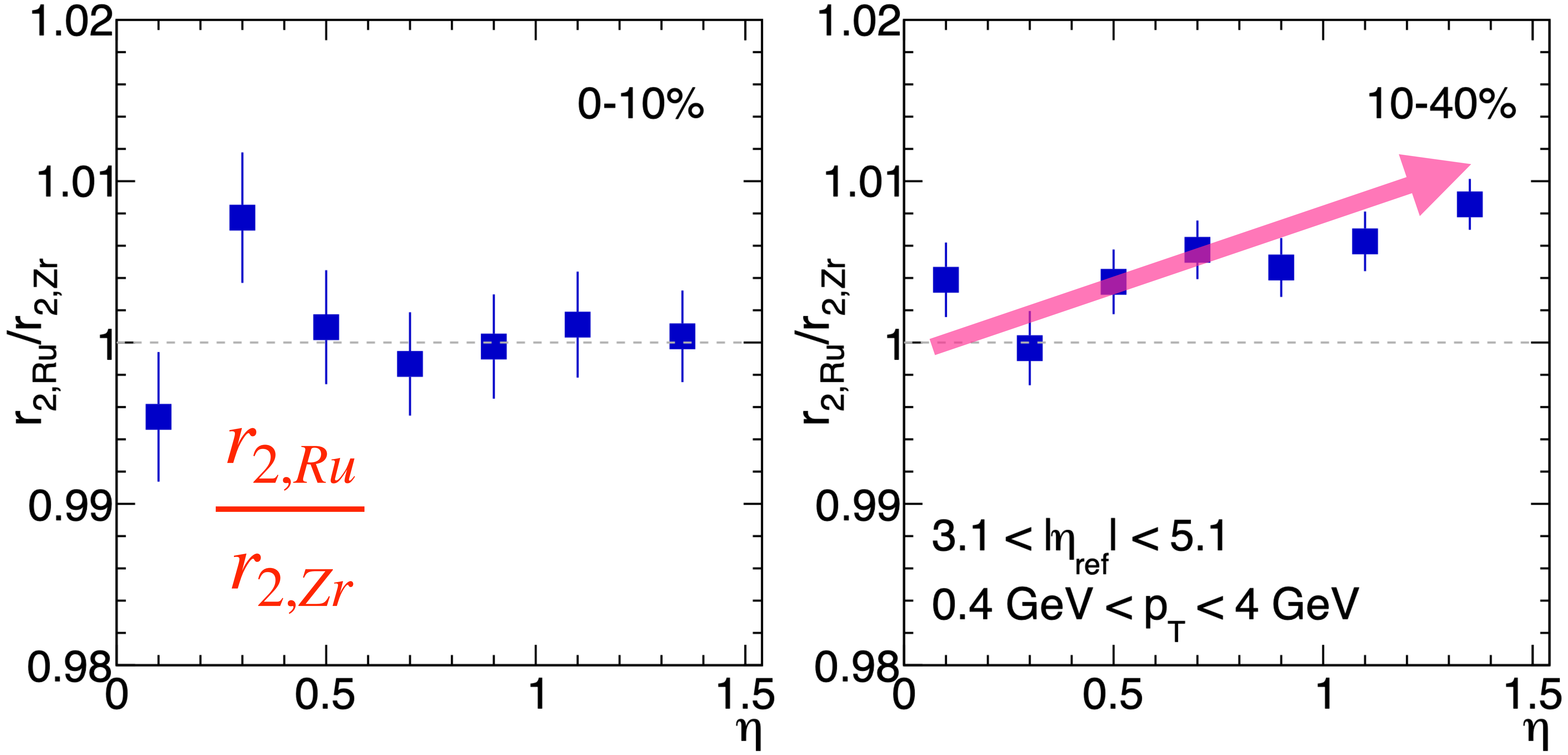
Gaoguo Yan(闫高国), QM2022

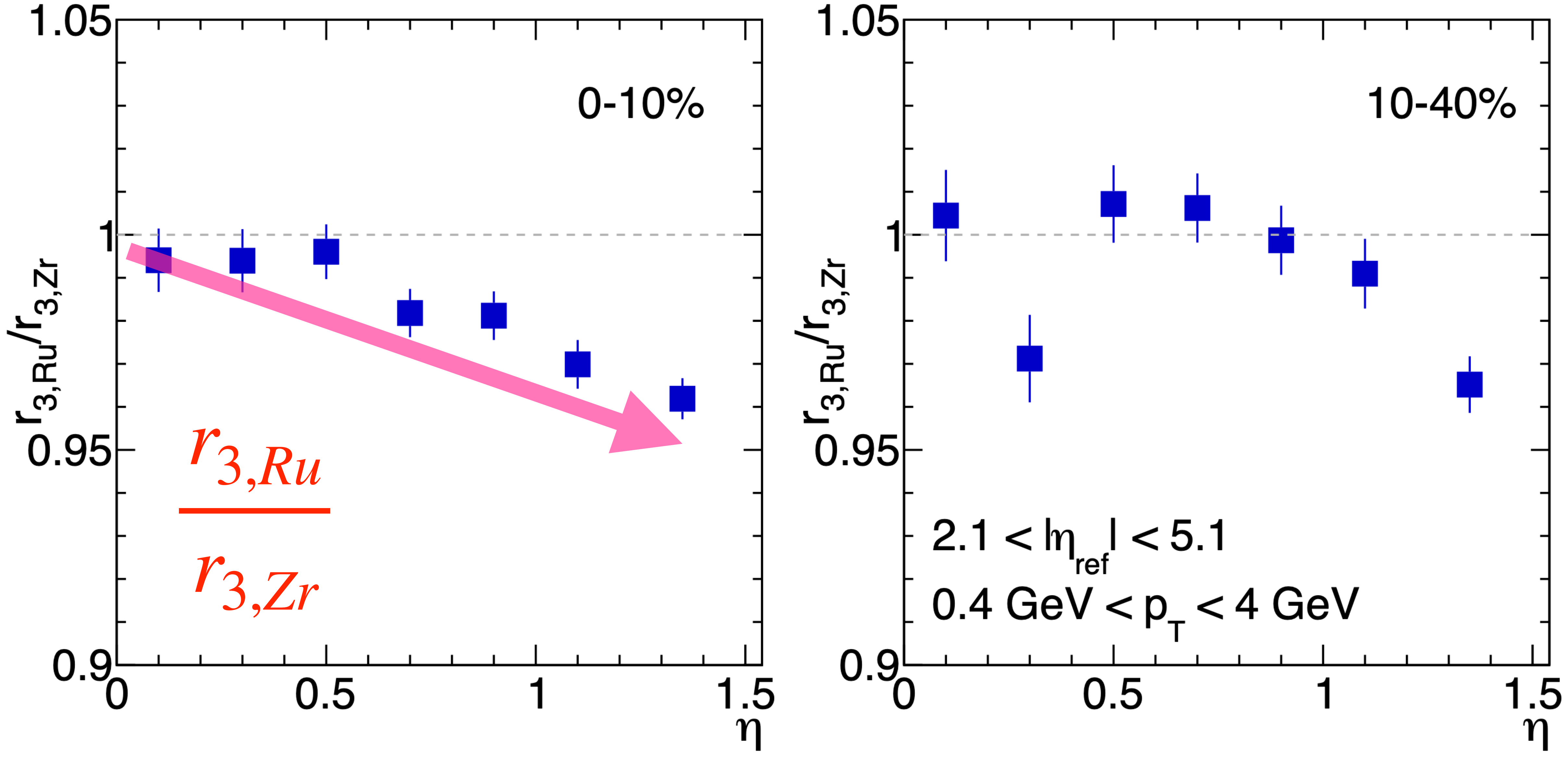


Isobar ratio of r_n



$$\frac{\mathcal{O}_{\mathrm{Ru+Ru}}}{\mathcal{O}_{\mathrm{Zr+Zr}}} \stackrel{?}{=} 1$$





- **No clear difference in 0-10%**
- **1% difference in 10-40% due to the presence of large β_3 in Zr.**

- **Up to 4% difference in 0-10%.**

larger average geometry → less fluctuation → less decorrelation

Summary

- **Significant deviation from unit is observed for the isobar ratio of r_n in the presence of deformation, especially for r_3.**
- **Longitudinal flow decorrelation can provide new constrains on the nuclear structure study in heavy-ion collisions.**