QPT 2023, Dec14-19, Zhuhai

Nuclear cluster structure effect in O+O collisions at RHIC energy

Speaker: Xin-Li Zhao (赵新丽)

Coauthors: Guo-Liang Ma(马国亮), You Zhou (周铀)
Chao Zhang (张潮), Zi-Wei Lin (林子威)

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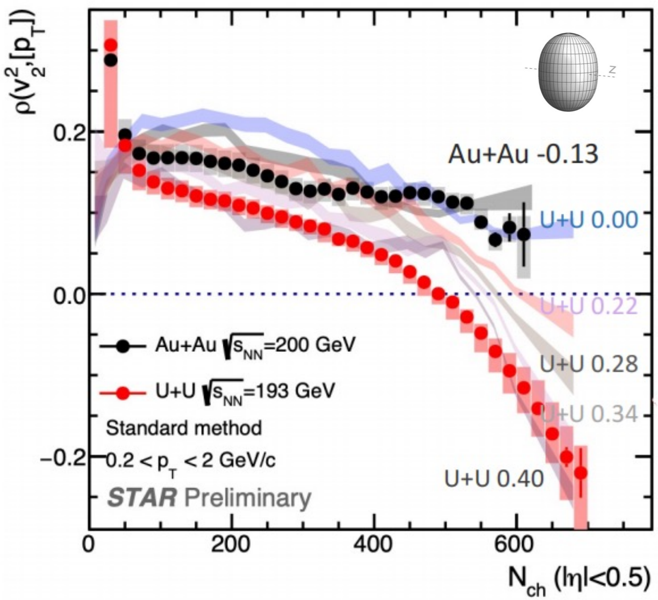
上海核物理理论中心
WUHAN UNIVERSITY OF TECHNOLOGY
ECU

Outline

- Introduction
- Improved AMPT
- O+O results and discussions
- Summary

Nuclear structures at high-energy HIC

J. Y. Jia, S. L. Huang, C. J. Zhang, PRC 105, 014906 (2022)



^{238}U

PHYSICAL REVIEW LETTERS **130,** 212302 (2023)

Evidence of Hexadecapole Deformation in Uranium-238 at the Relativistic Heavy Ion Collider

Wouter Ryssens,[1,*] Giuliano Giacalone,[2] Björn Schenke,[3] and Chun Shen[4,5]

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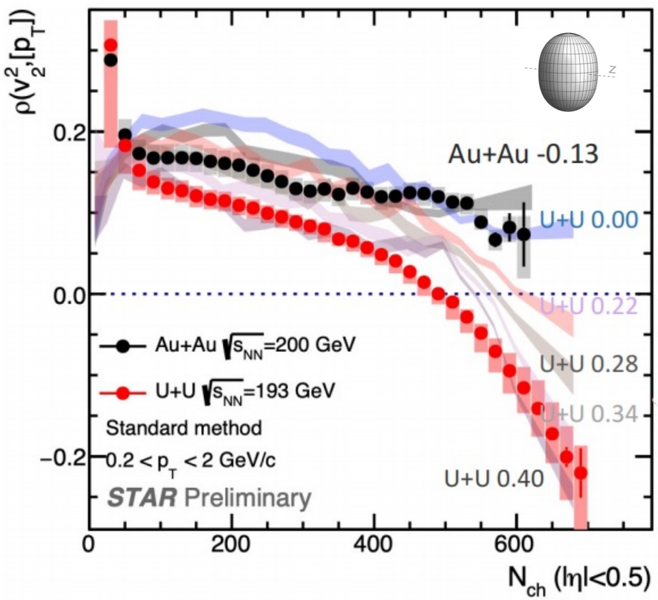

^{238}U

^{96}Zr

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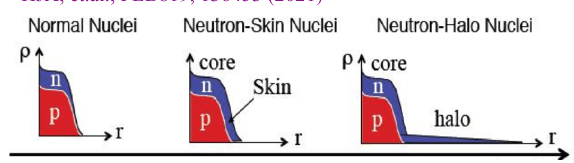
PHYSICAL REVIEW LETTERS **125**, 222301 (2020)

Probing the Neutron Skin with Ultrarelativistic Isobaric Collisions

Hanlin Li,[1] Hao-jie Xu,[2,*] Ying Zhou,[3] Xiaobao Wang,[2] Jie Zhao,[4] Lie-Wen Chen,[3,†] and Fuqiang Wang[2,4,‡]

Determine the neutron skin type by STAR data

HJX, et.al., PLB819, 136453 (2021)

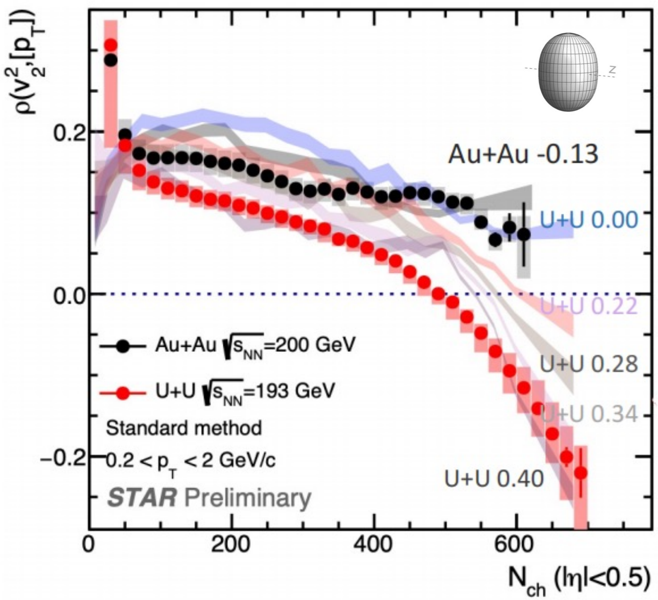


- Neutron-skin nuclei and neutron-halo nuclei for Zr

	^{96}Ru		^{96}Zr	
	R	*a*	*R*	*a*
p	5.085	0.523	5.021	0.523
skin-type n	5.085	0.523	5.194	0.523
halo-type n	5.085	0.523	5.021	0.592

Nuclear structures at high-energy HIC

J. Y. Jia, S. L. Huang, C. J. Zhang, PRC 105, 014906 (2022)



^{238}U

^{96}Zr

^{129}Xe

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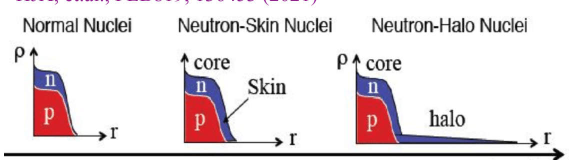

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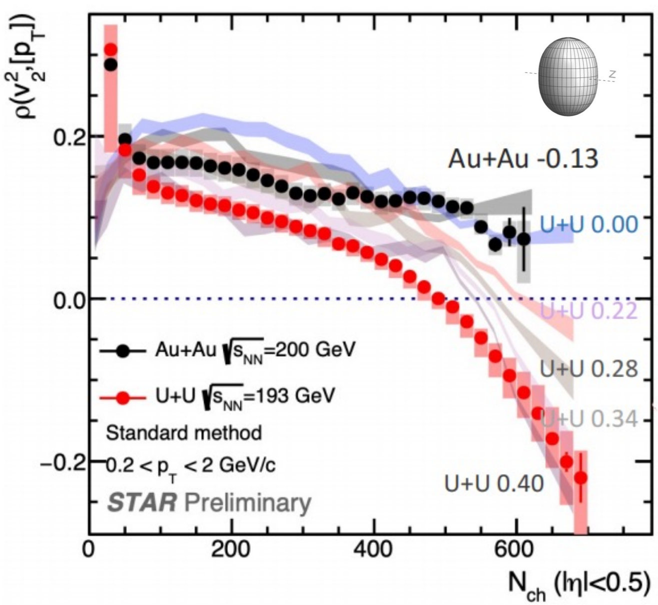
PHYSICAL REVIEW LETTERS **128,** 082301 (2022)

Evidence of the Triaxial Structure of ^{129}Xe at the Large Hadron Collider

Benjamin Bally,[1] Michael Bender,[2] Giuliano Giacalone,[3] and Vittorio Somà[4]

Nuclear structures at high-energy HIC

J. Y. Jia, S. L. Huang, C. J. Zhang, PRC 105, 014906 (2022)



^{238}U

^{96}Zr

^{129}Xe

^{208}Pb

PHYSICAL REVIEW LETTERS **130,** 212302 (2023)

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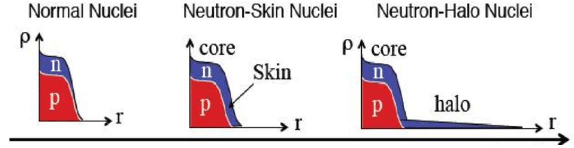

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PHYSICAL REVIEW LETTERS **128,** 082301 (2022)

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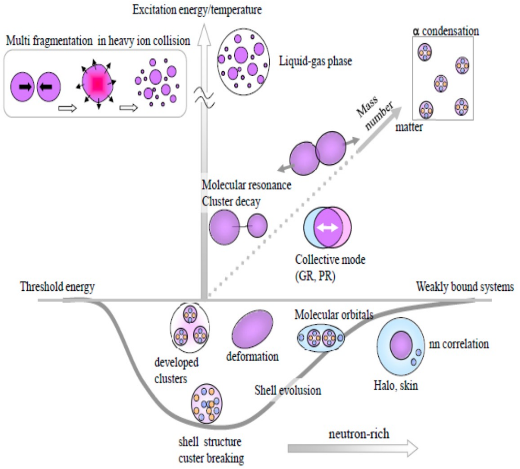
Benjamin Bally,[1] Michael Bender,[2] Giuliano Giacalone,[3] and Vittorio Somà[4]

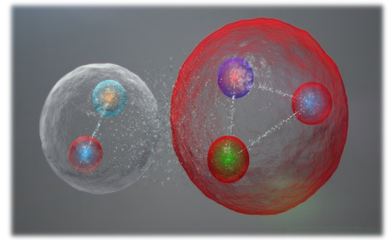
PHYSICAL REVIEW LETTERS **131,** 202302 (2023)

Determination of the Neutron Skin of ^{208}Pb from Ultrarelativistic Nuclear Collisions

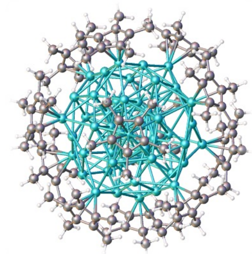
Giuliano Giacalone,[1] Govert Nijs,[2] and Wilke van der Schee[3,4]

Cluster structures in physics





5-quark cluster

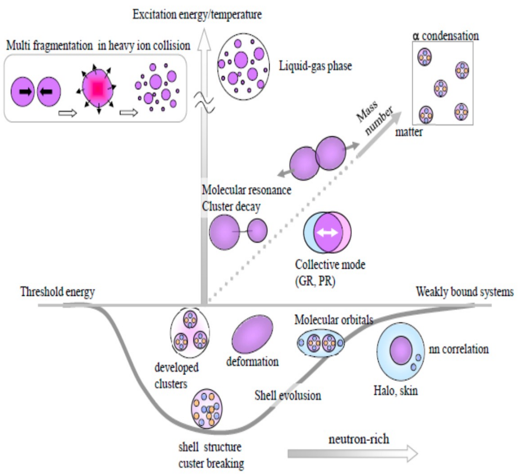


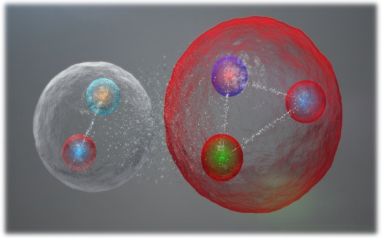
Multi-atom cluster

Galaxy cluster

- Clusters play an extremely important role at all levels of matter.

Cluster structures in physics





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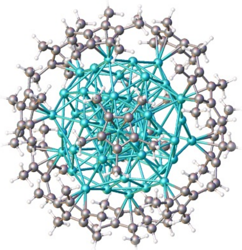

Multi-atom cluster

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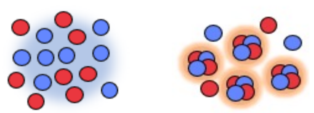
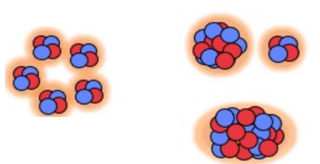
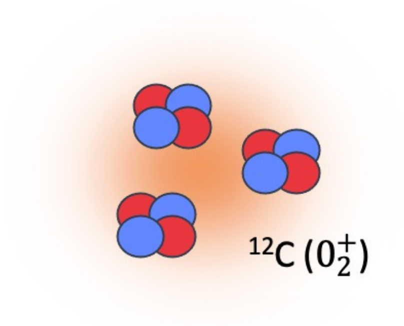


Nucleosynthesis in astrophysics

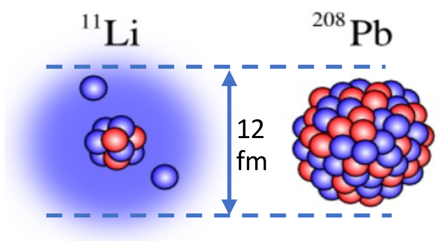


Nuclear excitation

During the nuclear excitation, phase transitions occur then form nuclear clusters.



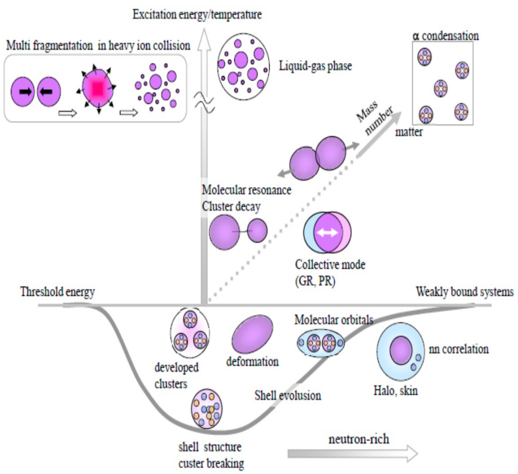
3α Bose-Einstein condensate

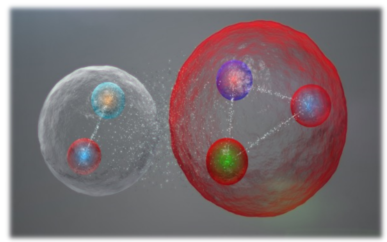


Halo type for ^{11}Li

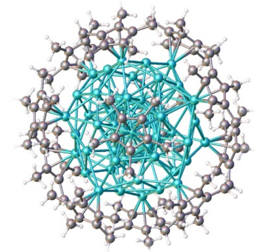
- ➢ Clusters play an extremely important role at all levels of matter.

Cluster structures in physics



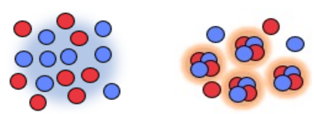


5-quark cluster

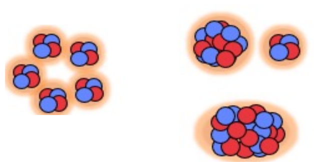


Multi-atom cluster

Galaxy cluster



Nucleosynthesis
in astrophysics



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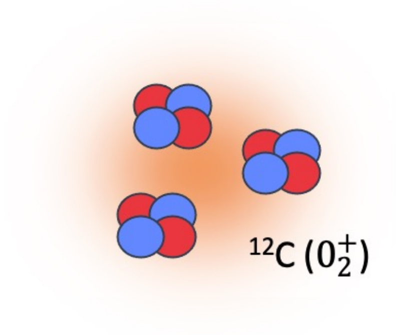

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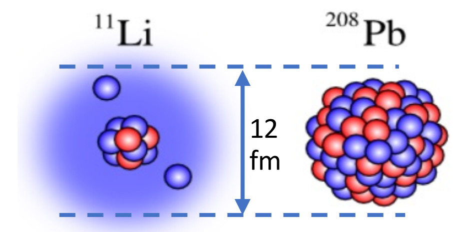
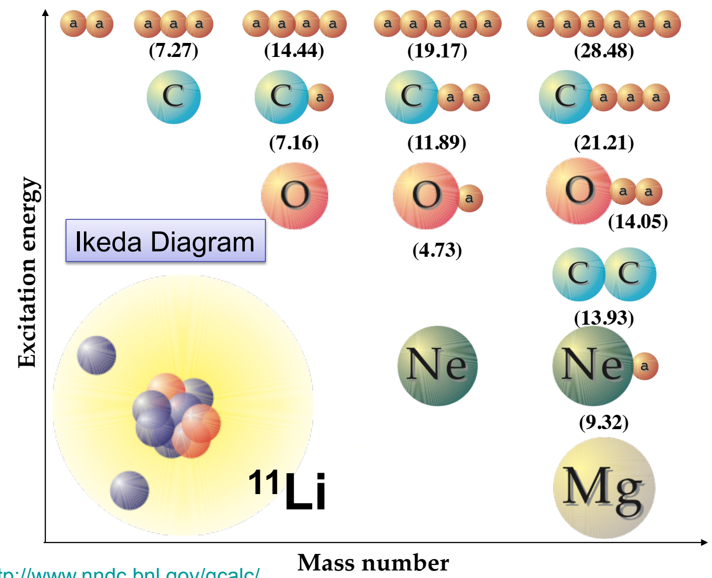


Halo type for ^{11}Li

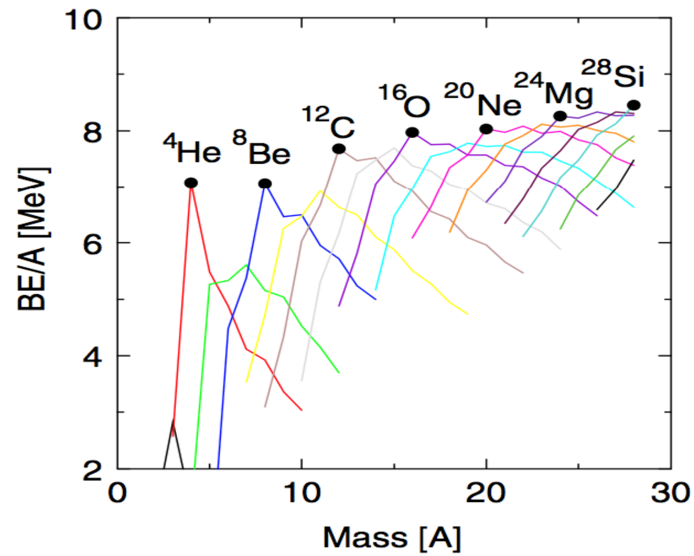
- Clusters play an extremely important role at all levels of matter.
- Understanding and describing cluster structure are an important scientific problem.

Cluster structure for ^{16}O

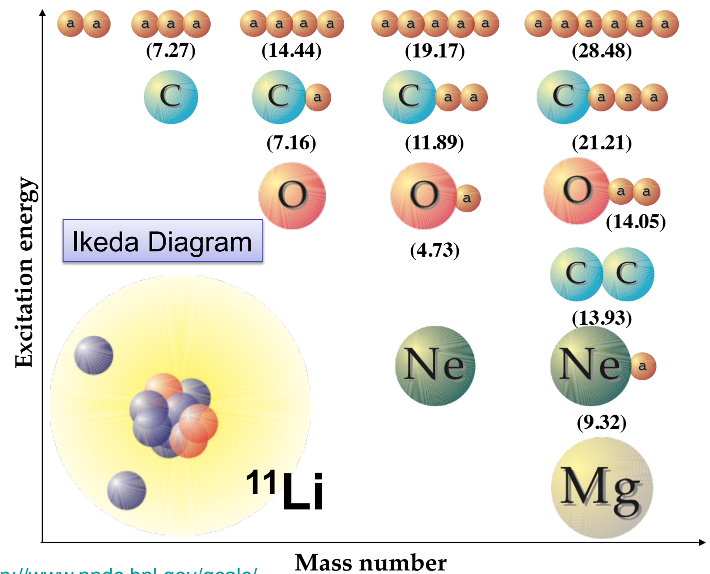


http://www.nndc.bnl.gov/qcalc/

sequence of reaction channels



Cluster structure for ^{16}O



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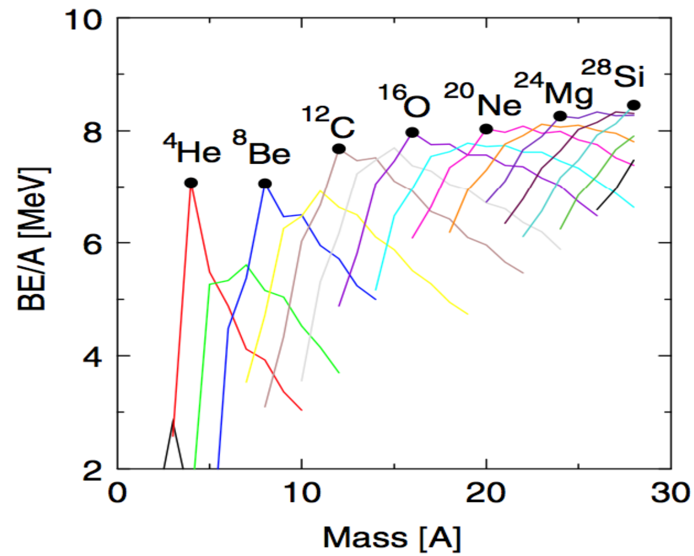


PHYSICAL REVIEW C **97**, 021304(R) (2018)

Rapid Communications

"Container" evolution for cluster structures in ^{16}O

Y. Funaki

PRL **101**, 082502 (2008) PHYSICAL REVIEW LETTERS week ending 22 AUGUST 2008

α-Particle Condensation in ^{16}O Studied with a Full Four-Body Orthogonality Condition Model Calculation

Y. Funaki,[1] T. Yamada,[2] H. Horiuchi,[3,4] G. Röpke,[5] P. Schuck,[6,7] and A. Tohsaki[3]

STAR results for O+O collisions

From Jin-Hui Chen's talk, QPT2023

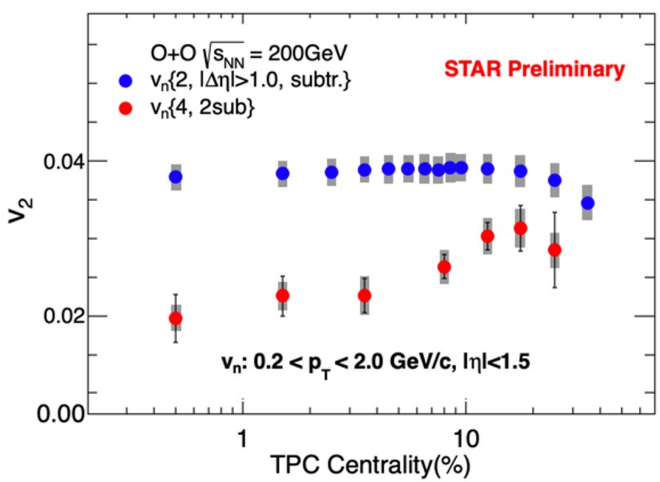
Flow in O+O collisions

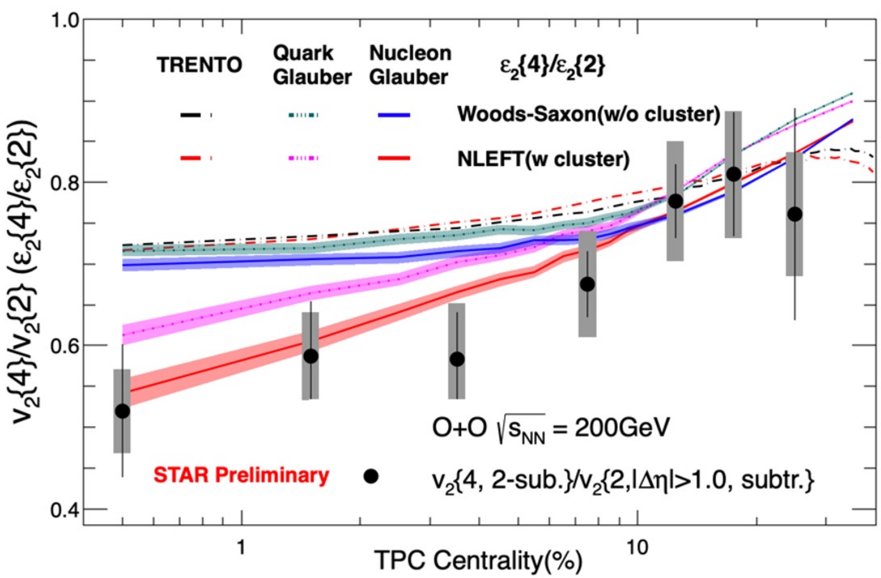
Huang Shengli

Measurements of the Elliptic and Triangular Azimuthal Anisotropies in Central $^{3}\mathrm{He}+\mathrm{Au}$, $d+\mathrm{Au}$ and $p+\mathrm{Au}$ Collisions at $\sqrt{s_{NN}}=200$ GeV

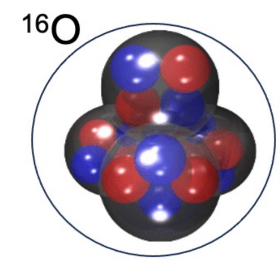
M. I. Abdulhamid *et al.* (STAR Collaboration)
Phys. Rev. Lett. **130**, 242301 – Published 15 June 2023

V_2(HeAu) ≈ v_2(dAu) > v_2(pAu)
V_3(HeAu) ≈ v_3(dAu) ≈ v_3(pAu)





***α*-cluster**



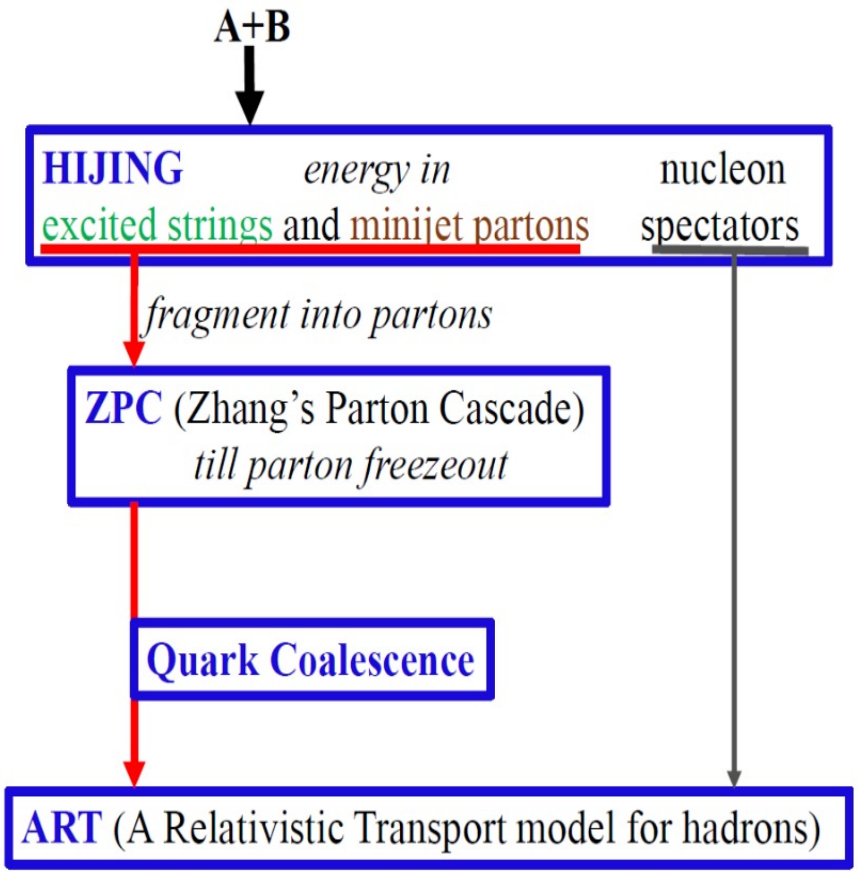
Quark Glauber:
PRC**94**,024914(2016)
TRENTO:
PRC92,011901(2015)
Calculated by Giuliano

- **$v_2\{4\}$ drops much faster** than $v_2\{2\}$ in central O+O collisions
- $\varepsilon_2\{4\}/\varepsilon_2\{2\}$ from nucleon or quark Glauber model with clusters (e.g. α clusters) describes $v_2\{4\}/v_2\{2\}$ better than without

11

Nuclear structures in improved AMPT

A Transport Muti-Phase (AMPT) Model



Z.W. Lin, C.M. Ko, B.A. Li, B. Zhang, S. Pal, PRC **72**, 064901 (2005)

Nuclear structures in improved AMPT

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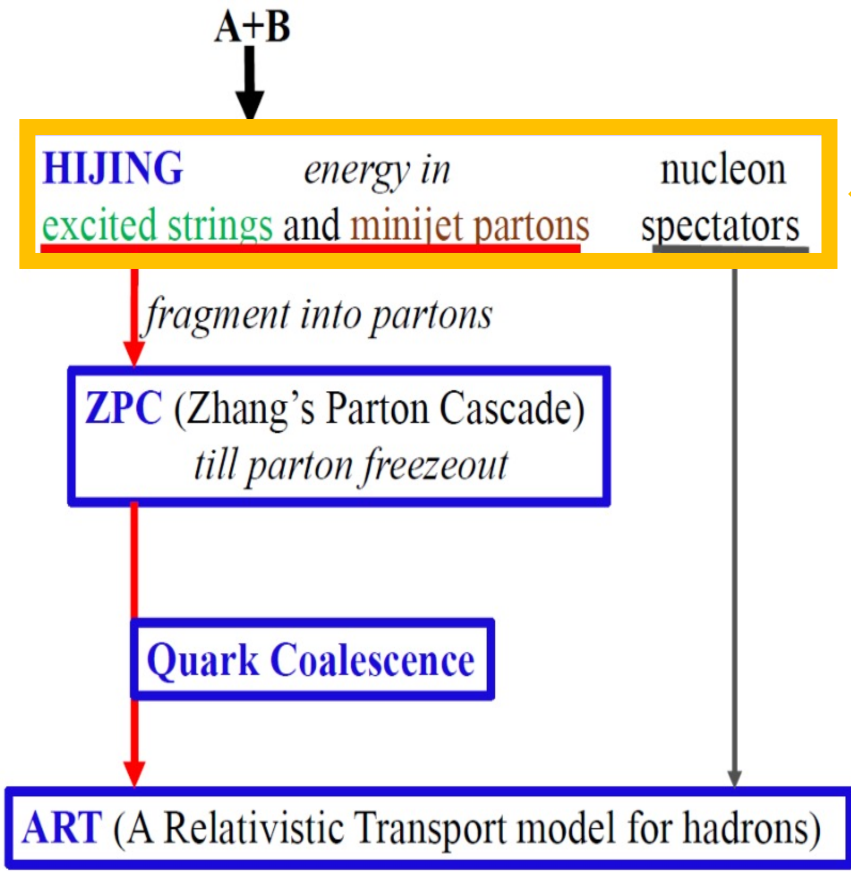
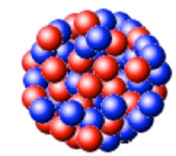
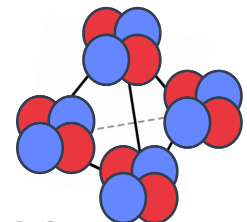
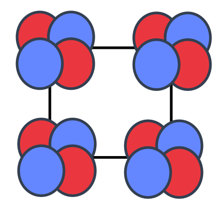
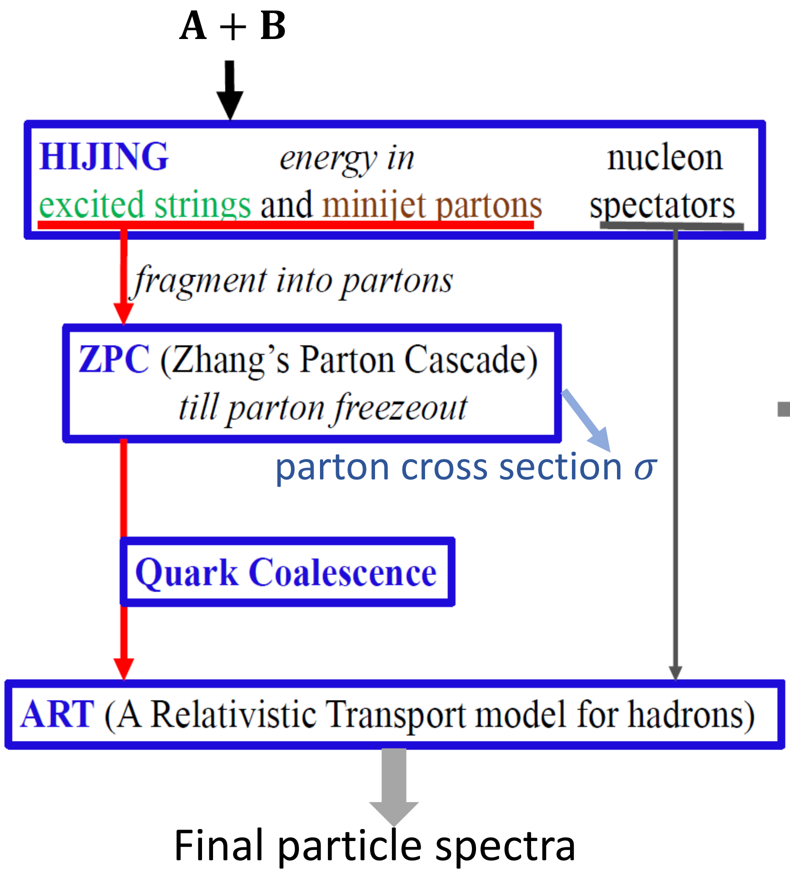


1. Woods-Saxon 
2. Tetrahedron 
3. Square 
4. *ab initio*

Z.W. Lin, C.M. Ko, B.A. Li, B. Zhang, S. Pal, PRC **72**, 064901 (2005)

Improved Version of the String Melting AMPT



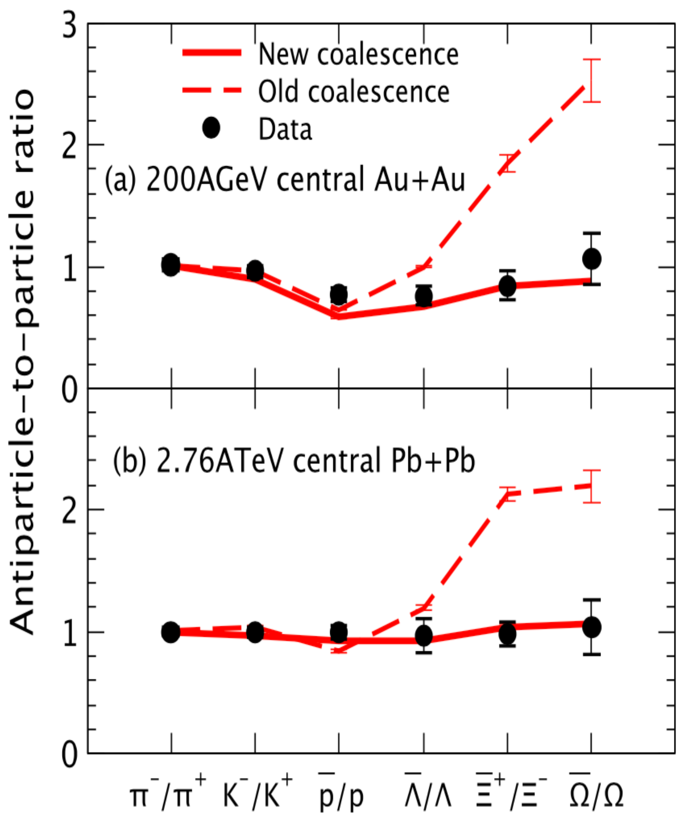
\+

1. New quark coalescence model.
2. Improved heavy quark productions.
3. Modern set of parton distribution functions in proton and impact parameter-dependent nuclear shadowing.

Zi-Wei Lin, Liang Zheng, NUCL SCI TECH (2021) 32:113

Improved AMPT Results

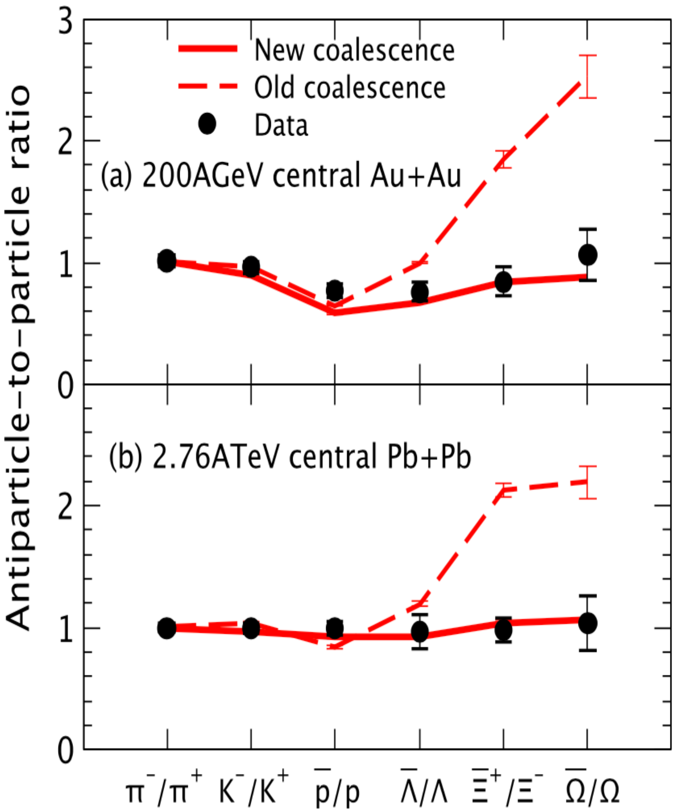
Zi-Wei Lin, Liang Zheng, NUCL SCI TECH 32:113 (2021)



- The baryon ratios in AMPT with new coalescence are consistent with data.

Improved AMPT Results

Zi-Wei Lin, Liang Zheng, NUCL SCI TECH 32:113 (2021)



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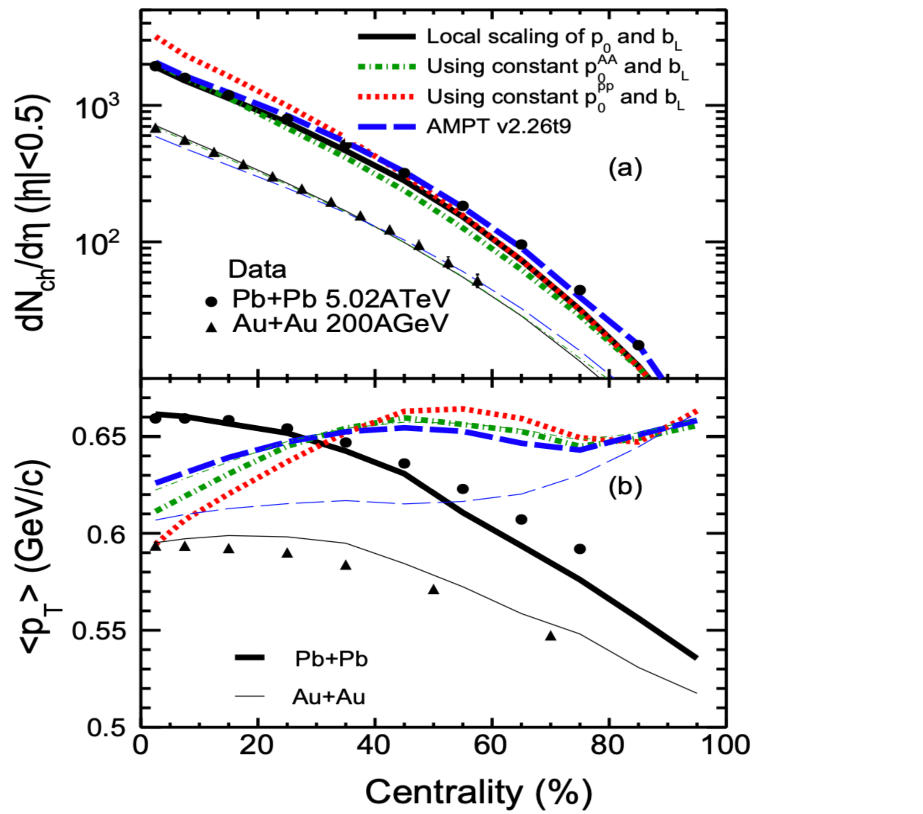
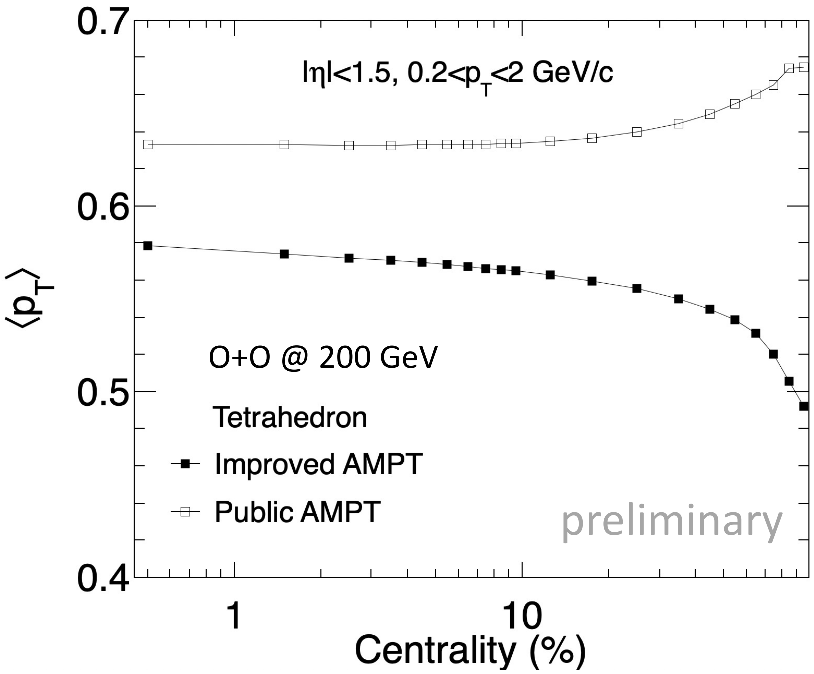
Chao Zhang, Liang Zheng, Shusu Shi, Zi-Wei Lin, PRC 104, 014908 (2021)



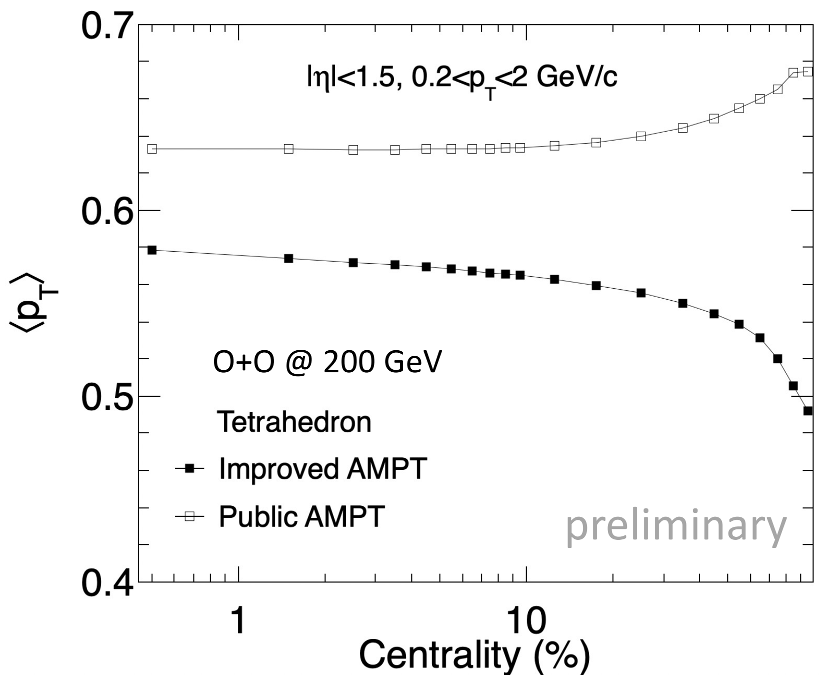
- Improved AMPT model describes the centrality dependences of charged particles and $\langle p_T \rangle$ rather well.

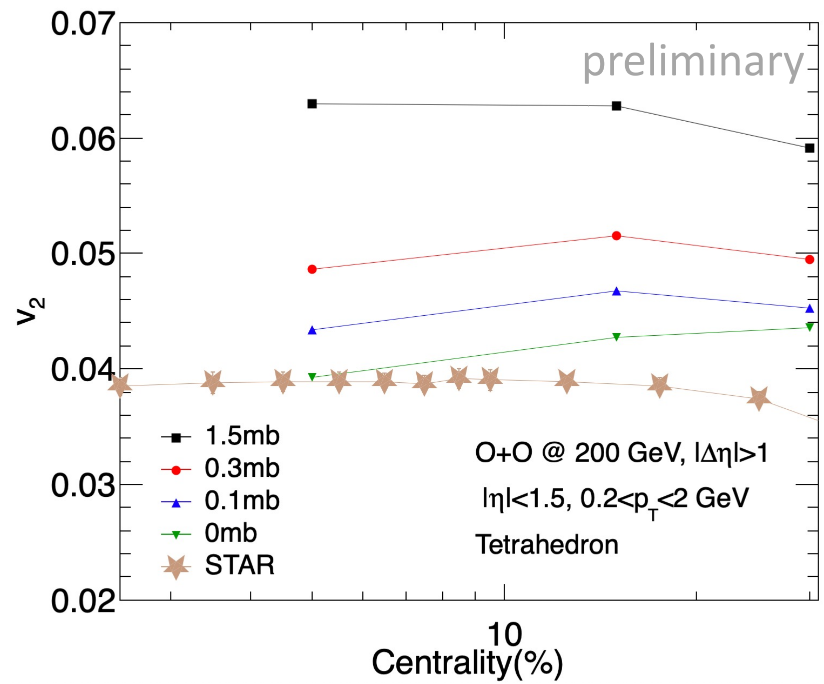
$\langle p_T \rangle$ & v_2 in improved AMPT



- $\langle p_T \rangle$ is reasonable in improved AMPT for O+O collisions.

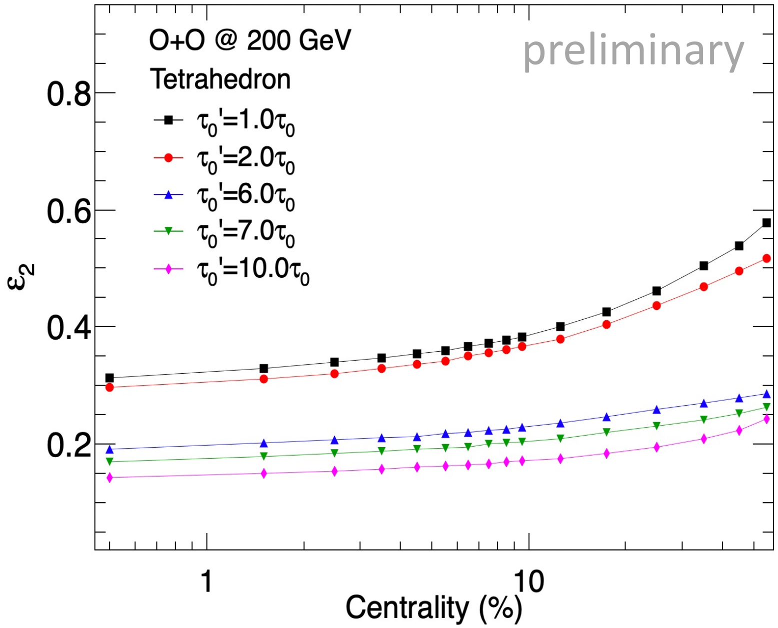
$\langle p_T \rangle$ & v_2 in improved AMPT

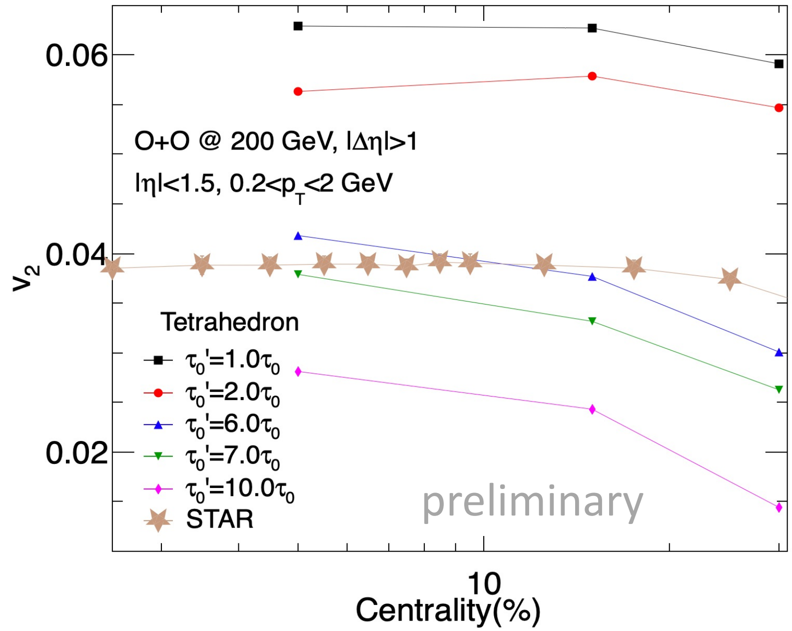




- $\langle p_T \rangle$ is reasonable in improved AMPT for O+O collisions.
- Improved AMPT failed to reproduce data.
- The impact parameter dependence of v_2 is significant in AMPT.

ε_2 & v_2 in improved AMPT



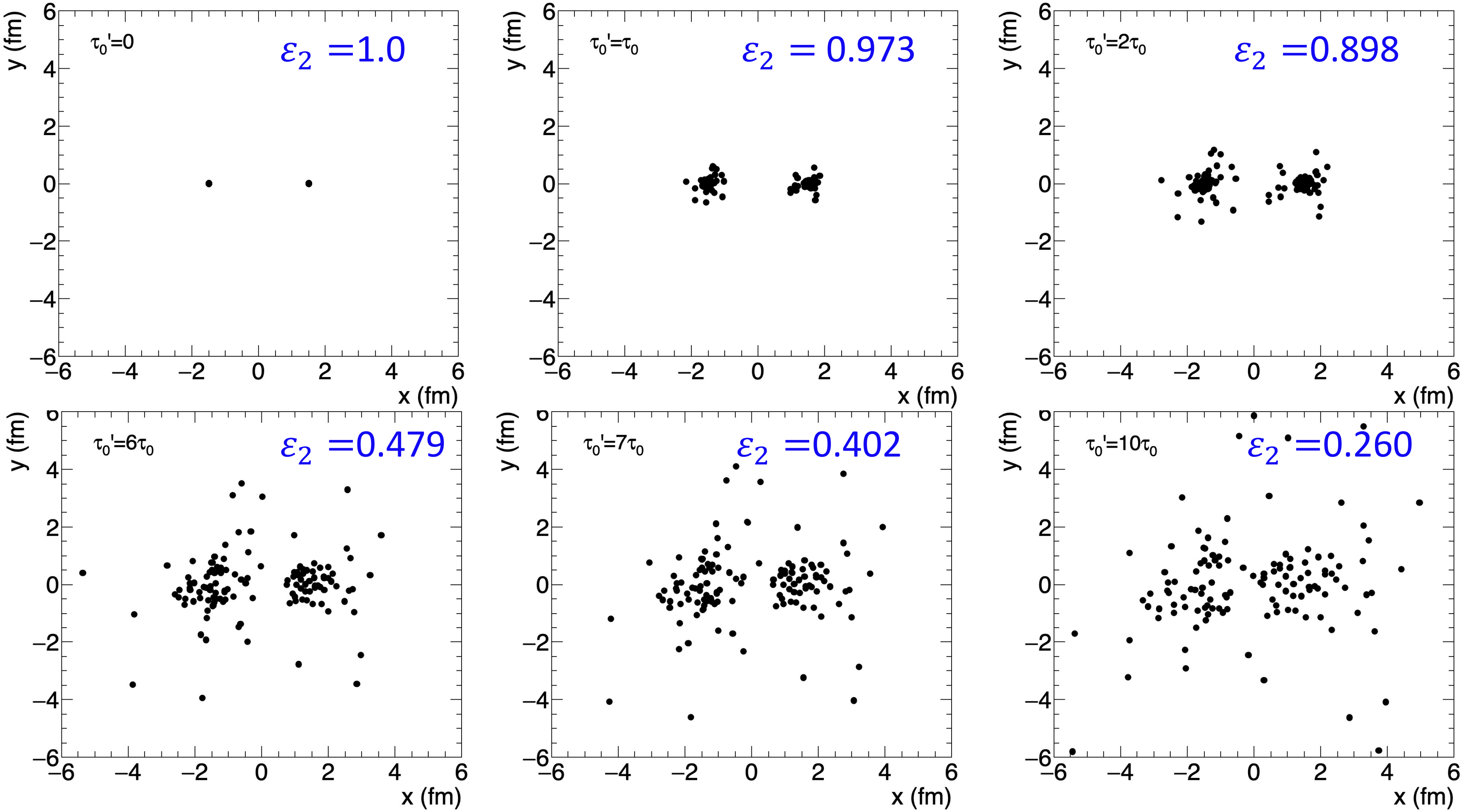


The formation time for each parton

$\tau_0' = const \cdot E/m_T^2,\ \tau_0 = E/m_T^2$

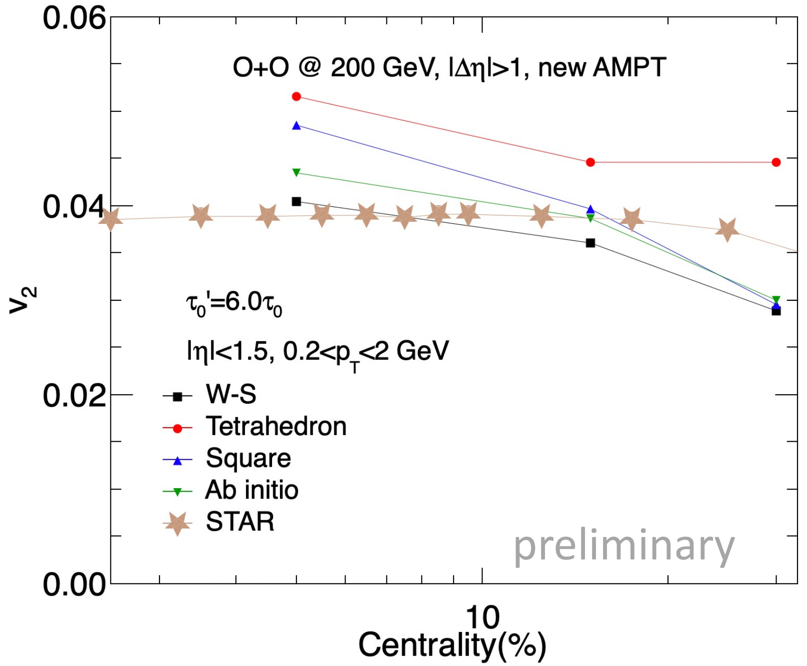
- The formation time dependence of ε_2 & v_2 is significant in AMPT.
- v_2 at $\tau_0' = 6\tau_0$ is close to data.

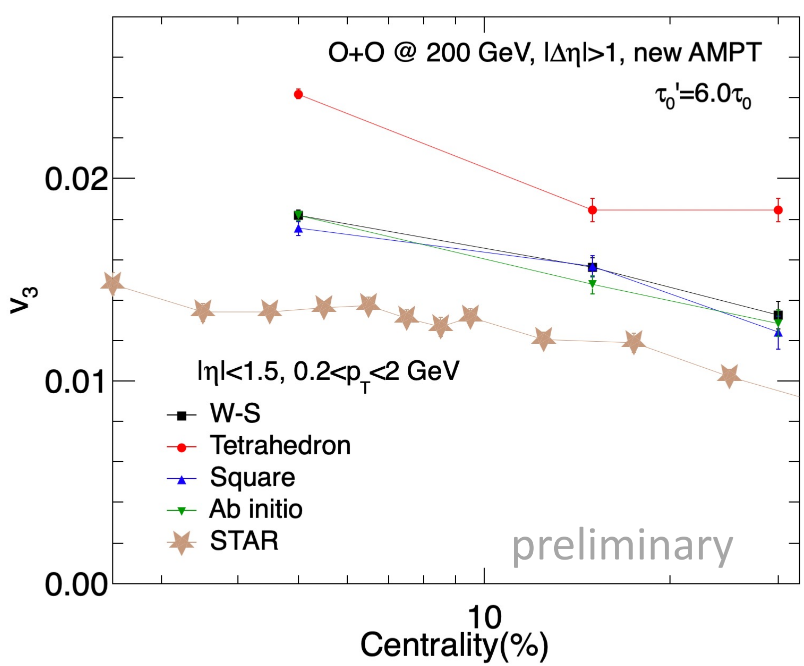
Initial parton distributions for different τ_0'



- The formation time affects the distributions of initial partons, then affects ε_2 & v_2.

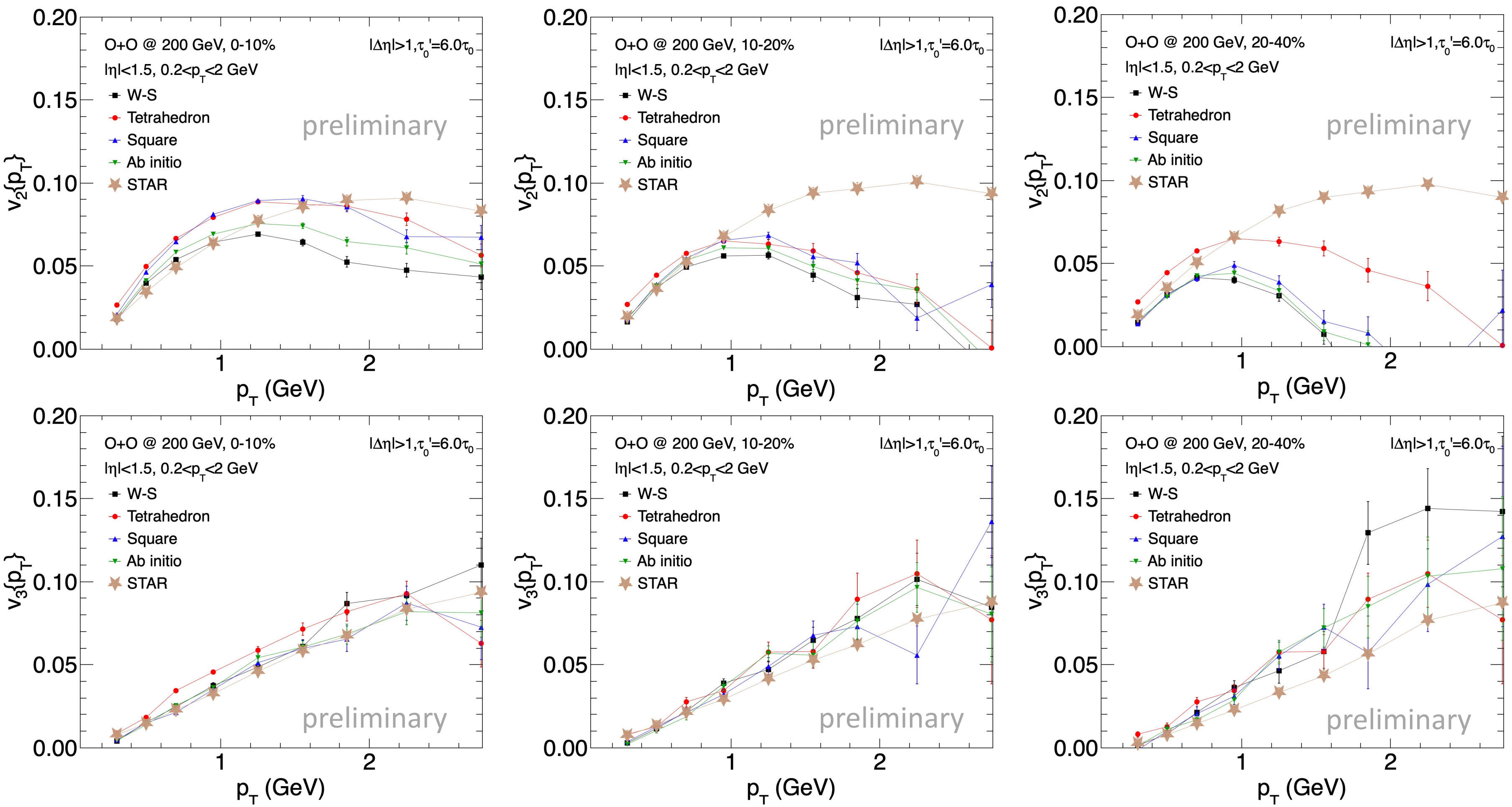
v_2 & v_3 in improved AMPT





- The effect of cluster structure is significant for v_2 and v_3.
- The v_2 results are close to data and higher than data at central collisions but lower at mid-central collisions.
- The v_3 results are higher than data.

$v_2(p_T)$ & $v_3(p_T)$ in improved AMPT



- $v_2(p_T)$ results are lower than data at $p_T > 1$ GeV.
- $v_3(p_T)$ results are close to data.

Summary

- Improved AMPT roughly reproduce the STAR data.
- Different nuclear structures including cluster have obviously effect on v_2.
- Formation time has significant effect on v_2 in O+O collisions.

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Thank you for your attention!