通过相对论重离子碰撞研究中子皮和核物质对称能

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HUZHOU UNIVERSITY(湖州师范学院)

原子核结构与相对论重离子碰撞前沿交叉研讨会

2023年7月31日-8月6日，大连

目录

Based on:

- HJX, X. Wang, H. Li, J. Zhao, Z. Lin, C. Shen, F. Wang, PRL121, 022301 (2018), arXiv:1710.03086
- H. Li, HJX, J. Zhao, Z. Lin, H. Zhang, X. Wang, C. Shen, F. Wang, PRC98, 054907 (2018), arXiv:1808.06711
- H. Li, HJX, Y. Zhou, X. Wang, J. Zhao, L. Chen, F. Wang, PRL125, 222301 (2020), arXiv:1910.06170
- HJX, H. Li, X. Wang, C. Shen, F. Wang, PLB819, 136453 (2021), arXiv:2103.05595
- HJX, H. Li, Y. Zhou, X. Wang, J. Zhao, L. Chen, F. Wang, PRC105, L014901 (2022), arXiv:2105.04052
- HJX, W. Zhao, H. Li, Y. Zhou, L. Chen, F. Wang, PRC108, L011902 (2023), arXiv:2111.14812
- S. Zhao, HJX, Y. Liu, H. Song, PLB840, 137838 (2023), arXiv:2204.02387
- S. Li, R. Wang, J. Wang, H. Xu, S. Pu, Q. Wang, PRD107, 054004 (2023), arXiv:2210.05106
- J. Wang, HJX, F. Wang, arXiv:2305.17114
- Q. Liu, HJX, H. Song, paper in preparation
- STAR Collaboration, PRC105, 014901(2022)

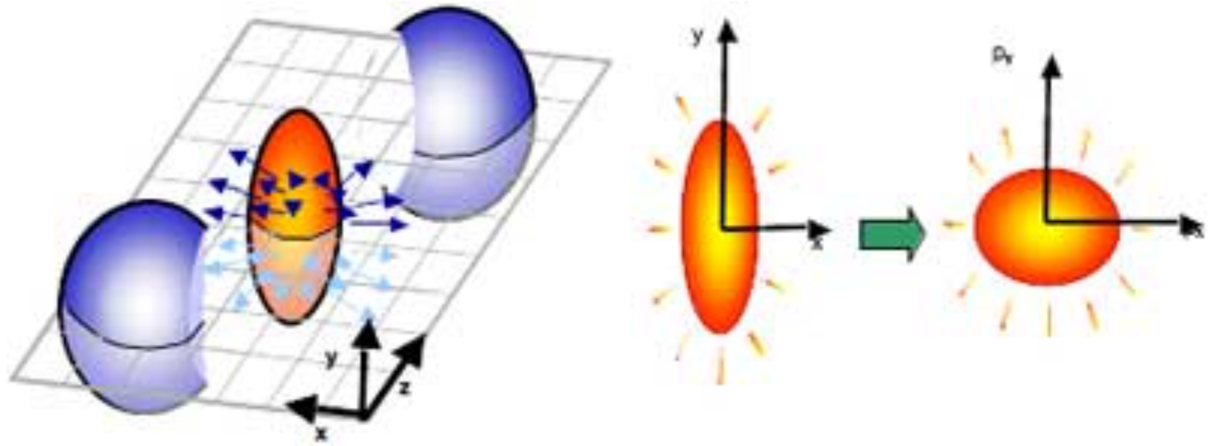
I. 相对论重离子碰撞和核结构

相对论重离子碰撞

Woods-Saxon distributions

$$\rho(r) = \frac{\rho_0}{1 + \exp[(r - R)/a]}$$

$$R = R_0\,[1+\beta_2 Y_2^0(\theta)+\beta_4 Y_4^0(\theta)]$$

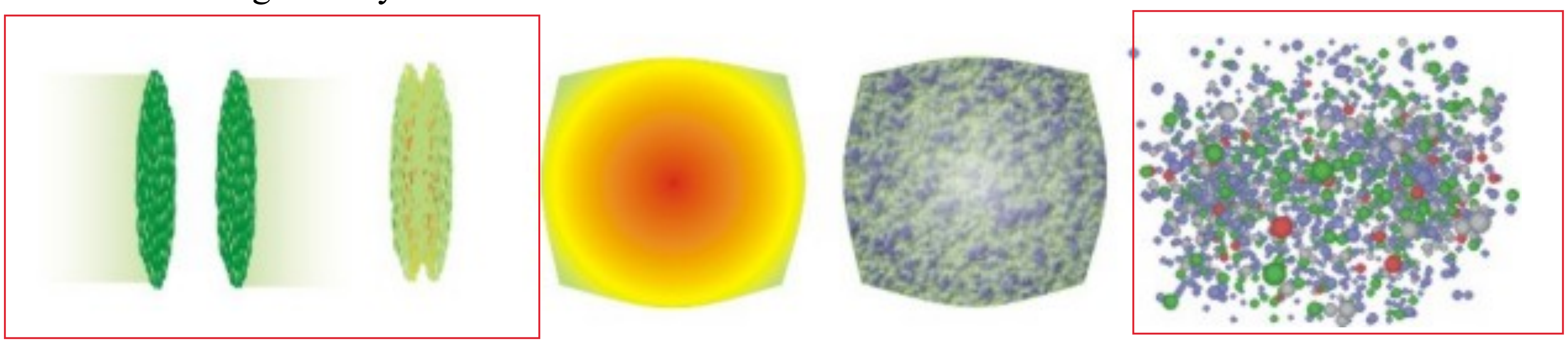


Anisotropic flow,
Flow fluctuations
HBT,
....

Initial geometry

Bulk properties of QGP medium: $\eta/s, \zeta/s, \ldots$

Final observables



❋核结构是相对论重离子碰撞的初始条件

❋相对论重离子碰撞的时间尺度很短 fm/c~10^{-23}s

❋碰撞核不影响碰撞产物的演化

❋单核子密度分布(WS vs DFT)

- 形变 （G. Giacalone,贾江涌）
- 中子皮

❋多核子关联 (马余刚，宋慧超)

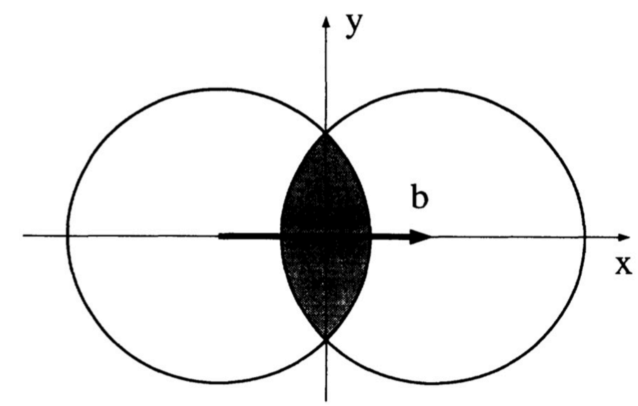
- 集团结构

相对论重离子碰撞中的几何结构

PHYSICAL REVIEW D VOLUME 46, NUMBER 1 1 JULY 1992

Anisotropy as a signature of transverse collective flow

Jean-Yves Ollitrault
Service de Physique Théorique, Centre d'Études de Saclay, F-91191 Gif-sur-Yvette CEDEX, France
(Received 19 February 1992)

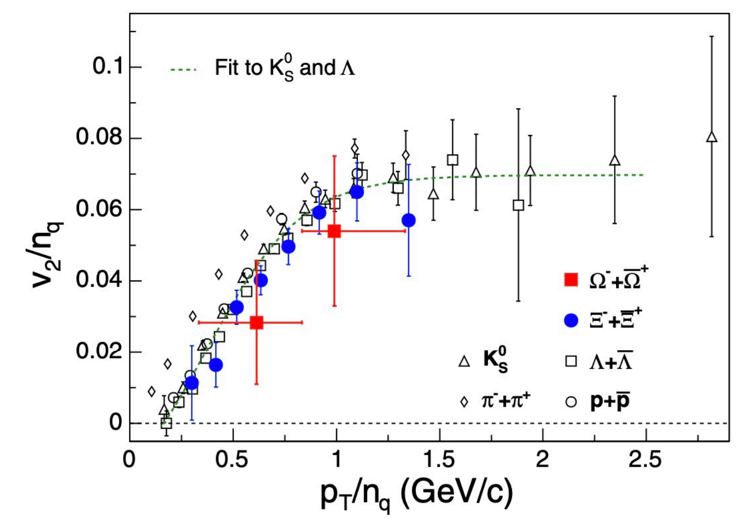


PRL **95,** 122301 (2005) PHYSICAL REVIEW LETTERS week ending 16 SEPTEMBER 2005

Multistrange Baryon Elliptic Flow in Au + Au Collisions at $\sqrt{s_{NN}} = 200$ GeV

STAR Collaboration

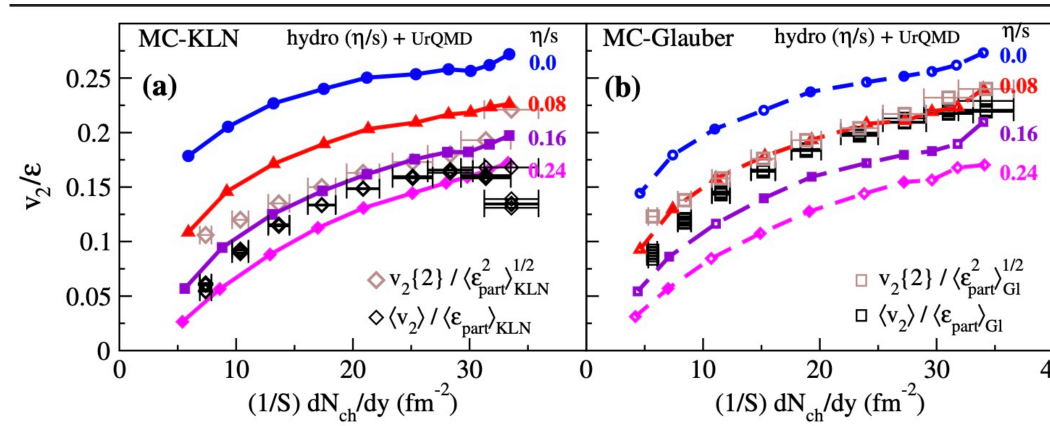
$$E\frac{d^3N}{d^3p} = \frac{1}{2\pi}\frac{d^2N}{p_T dp_T dy}\left(1+\sum_n 2v_n\cos[n(\phi-\Psi_n)]\right),$$



PRL **106,** 192301 (2011) PHYSICAL REVIEW LETTERS week ending 13 MAY 2011

200 *A* GeV Au + Au Collisions Serve a Nearly Perfect Quark-Gluon Liquid

Huichao Song,[1,2] Steffen A. Bass,[3] Ulrich Heinz,[2] Tetsufumi Hirano,[4,1] and Chun Shen[2]



强耦合QCD物质

相对论重离子碰撞中的几何结构

PHYSICAL REVIEW C, VOLUME 61, 021903(R)

Uranium on uranium collisions at relativistic energies

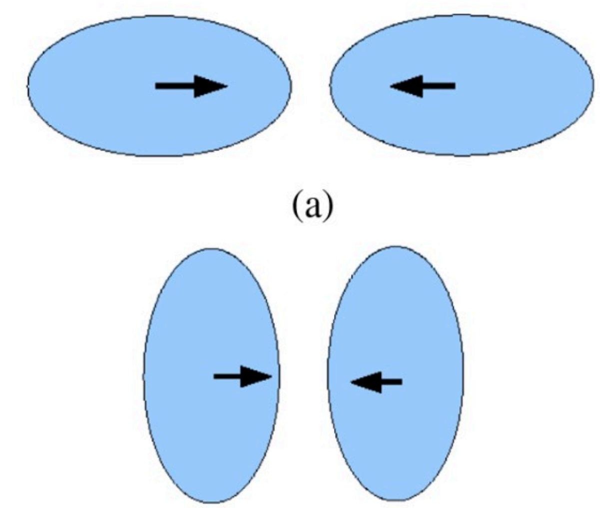
Bao-An Li*
Department of Chemistry and Physics, Arkansas State University, P.O. Box 419, Jonesboro, Arkansas 72467-0419
(Received 12 October 1999; published 12 January 2000)

PHYSICAL REVIEW C, VOLUME 61, 034905

High energy collisions of strongly deformed nuclei: An old idea with a new twist

E. V. Shuryak
Department of Physics and Astronomy, State University of New York at Stony Brook, Stony Brook, New York 11794
(Received 14 July 1999; published 22 February 2000)

S. Voloshin, PRL95, 122301 (2010)



(a)

(b)

PRL **94,** 132301 (2005) PHYSICAL REVIEW LETTERS week ending 8 APRIL 2005

Anisotropic Flow and Jet Quenching in Ultrarelativistic U+U Collisions

Ulrich Heinz and Anthony Kuhlman
Department of Physics, The Ohio State University, Columbus, Ohio 43210, USA
(Received 16 November 2004; published 6 April 2005)

形变核的碰撞构型可以产生不同大小的各向异性流

H. Masui, B. Mohanty, N. Xu, PLB679, 440(2009)
G. Giacalone, PRC99, 024910 (2019)
L. Pang, et.al, arXiv:1906.06429
G. Giacalone, J. Jia, C. Zhang, PRL127, 242301(2021)
J. Jia, PRC105, 014905 (2022)
J. Jia, PRC105, 014906 (2022)
J. Jia, PRC105, 044905 (2022)
B. Bally, et.al, PRL128, 082301(2022)
H. Mantysaari, et.al, arXiv:2303.04866
....

相对论重离子碰撞中的几何结构

侯德富，黄旭光，马国亮

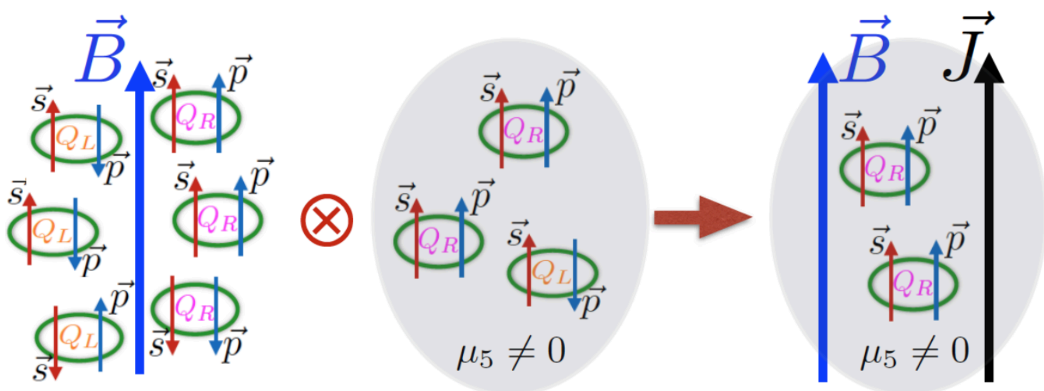
PRL 105, 172301 (2010) PHYSICAL REVIEW LETTERS week ending 22 OCTOBER 2010

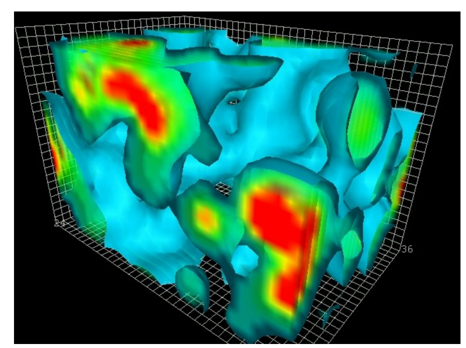
Testing the Chiral Magnetic Effect with Central $U + U$ Collisions

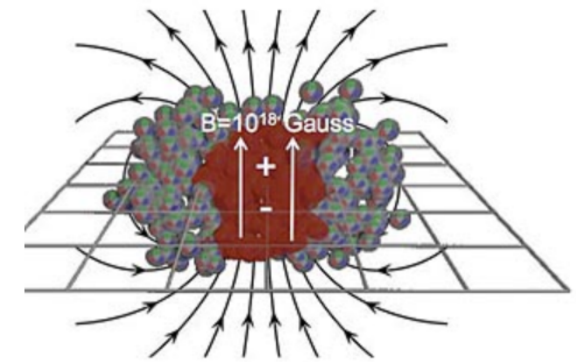
Sergei A. Voloshin
Wayne State University, Detroit, Michigan 48201, USA
(Received 22 June 2010; published 19 October 2010)

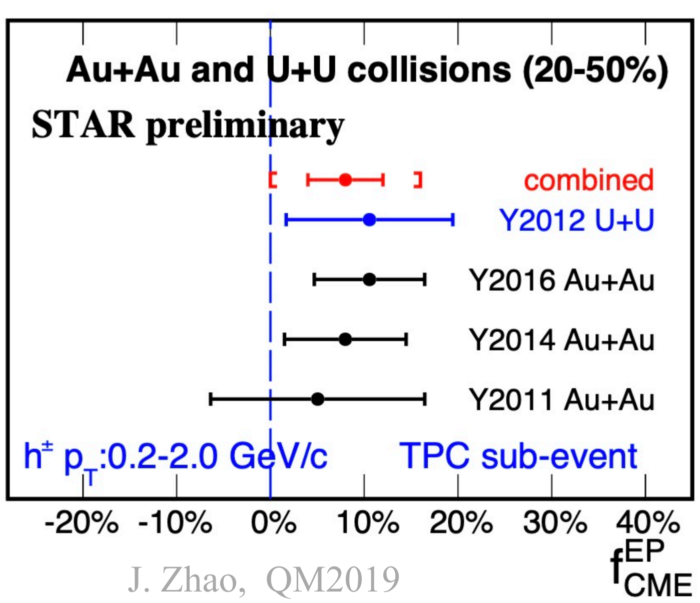
$$\mathbf{J}_{\mathbf{cme}} = \sigma_5 \mathbf{B} = \left(\frac{(Qe)^2}{2\pi^2} \mu_5 \right) \mathbf{B},$$

D. Kharzeev,et.al., PPNP88, 1(2016)









J. Zhao, QM2019

The charge separation dependence on the strength of the magnetic field can be further studied with the collision of isobaric nuclei, such as $^{96}_{44}$Ru and $^{96}_{40}$Zr. These nuclei have the same mass number, but differ by the charge. The multi-particle production in the midrapidity region would be affected very little in the collision of such nuclei, and one would expect very similar elliptic flow. At the same

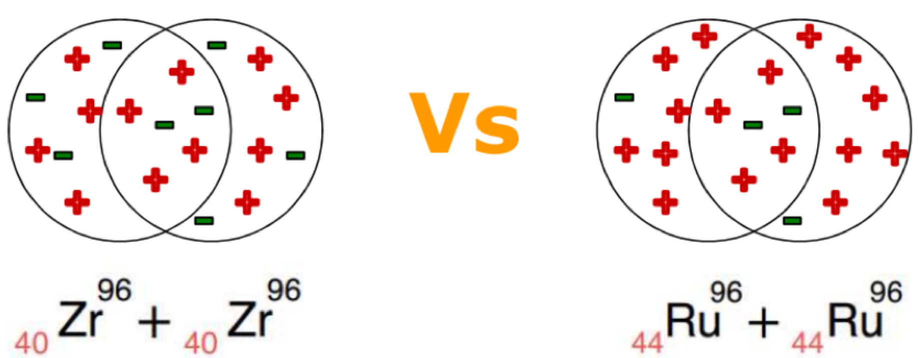
相对论同量异位素核碰撞

PHYSICAL REVIEW C **105**, 014901 (2022)

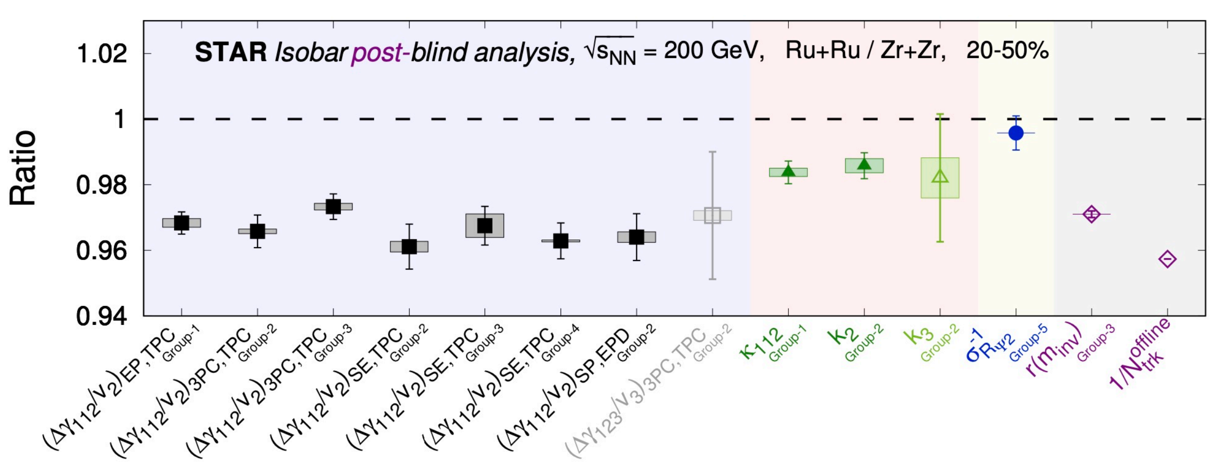
STAR Collaboration

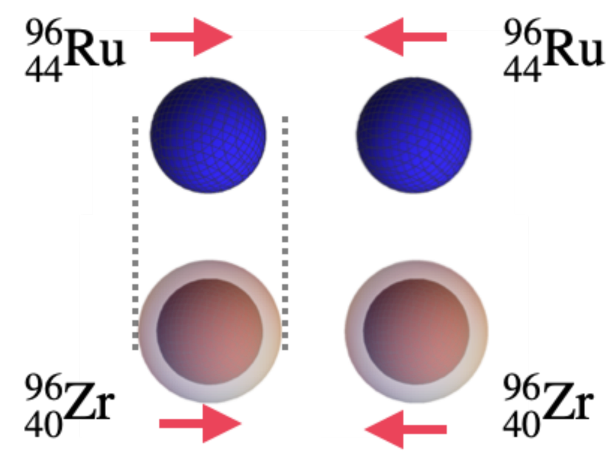
Search for the chiral magnetic effect with isobar collisions at $\sqrt{s_{NN}} = 200$ GeV by the STAR Collaboration at the BNL Relativistic Heavy Ion Collider

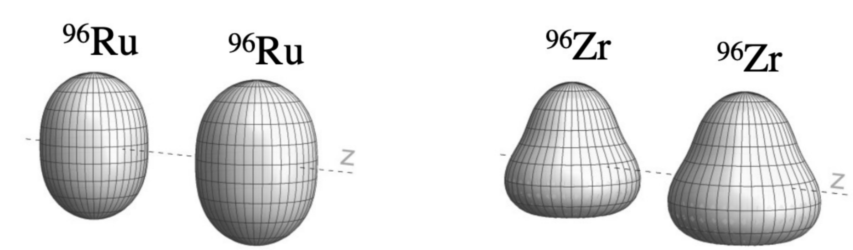
2 Billion events for each collision system!



- Same background
- Different magnetic field => different CME signals







Backgrounds are not identical!!!
Neutron skin
Nuclear deformation
Multi-nucleon correlations?

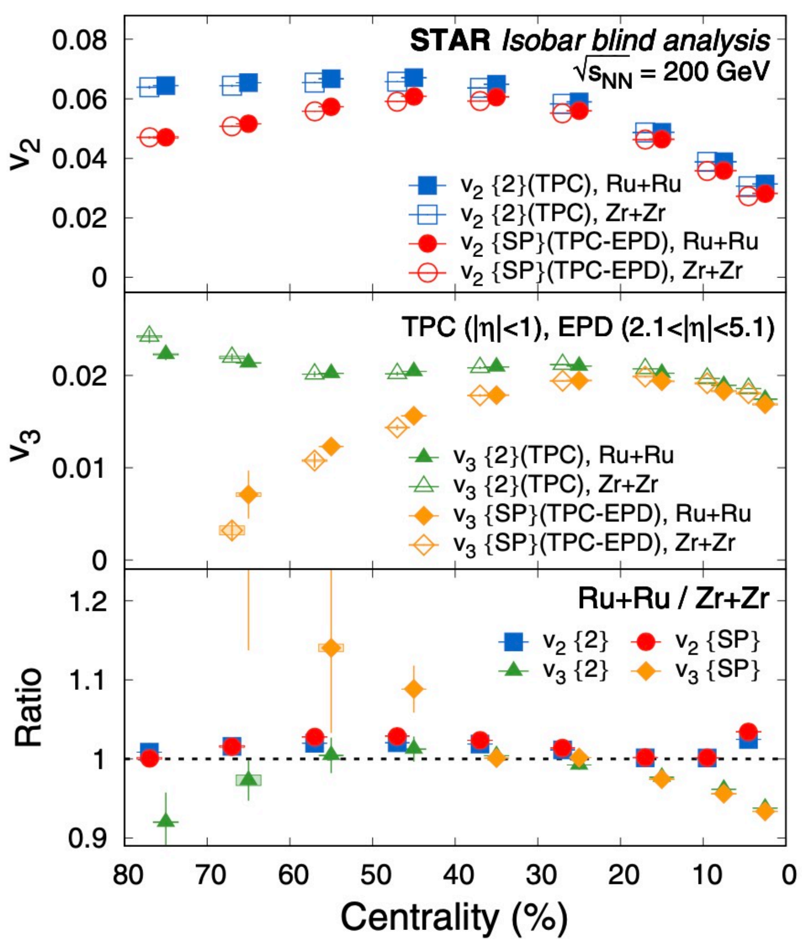
同量异位素核的四级形变和八级形变

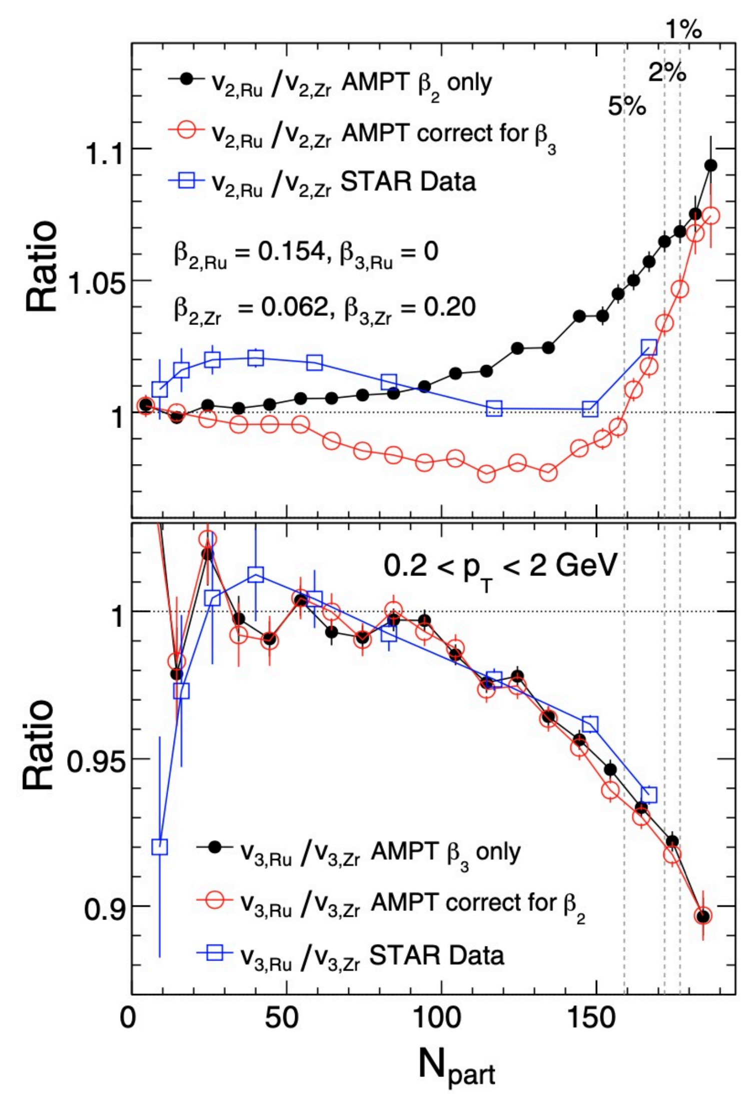
PHYSICAL REVIEW LETTERS **128**, 022301 (2022)

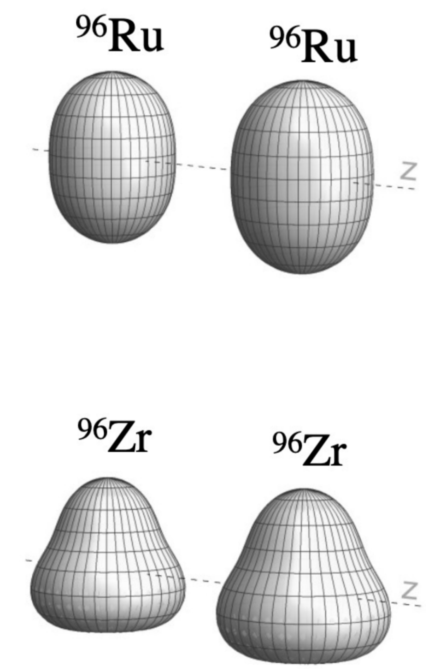
Evidence of Quadrupole and Octupole Deformations in $^{96}Zr + ^{96}Zr$ and $^{96}Ru + ^{96}Ru$ Collisions at Ultrarelativistic Energies

Chunjian Zhang[1] and Jiangyong Jia[1,2,*]
[1]Department of Chemistry, Stony Brook University, Stony Brook, New York 11794, USA
[2]Physics Department, Brookhaven National Laboratory, Upton, New York 11976, USA

(Received 30 September 2021; accepted 9 December 2021; published 11 January 2022)







贾江涌
张春健
宋慧超

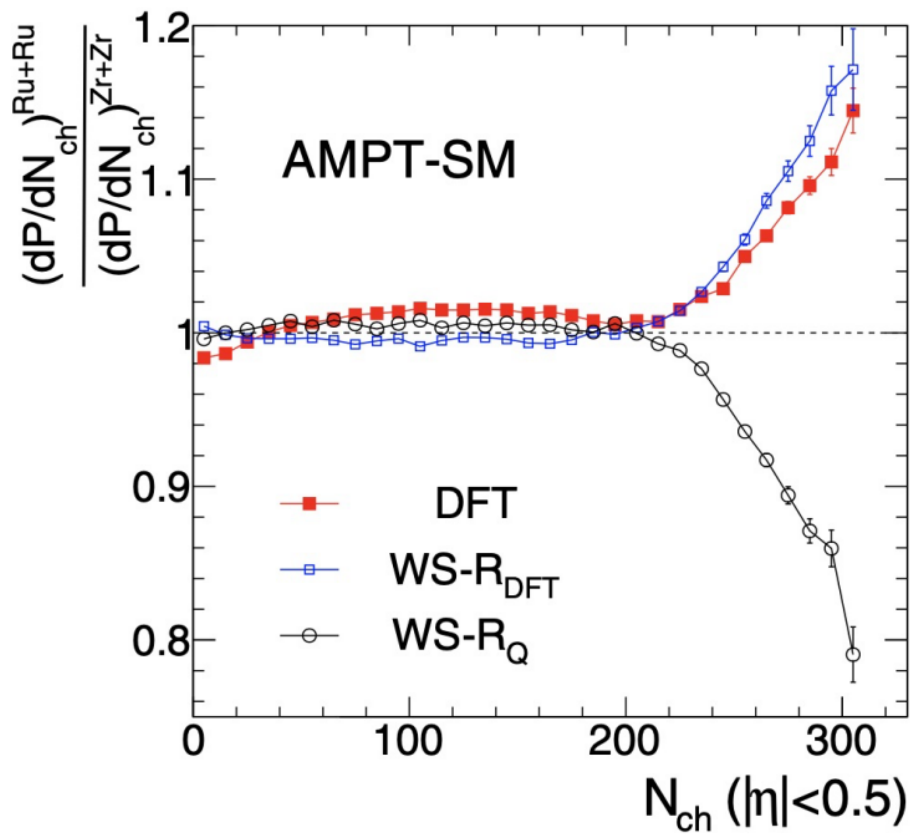
II. 通过同量异位素核碰撞研究核对称能

CME背景：粒子多重数

PHYSICAL REVIEW C **98**, 054907 (2018)

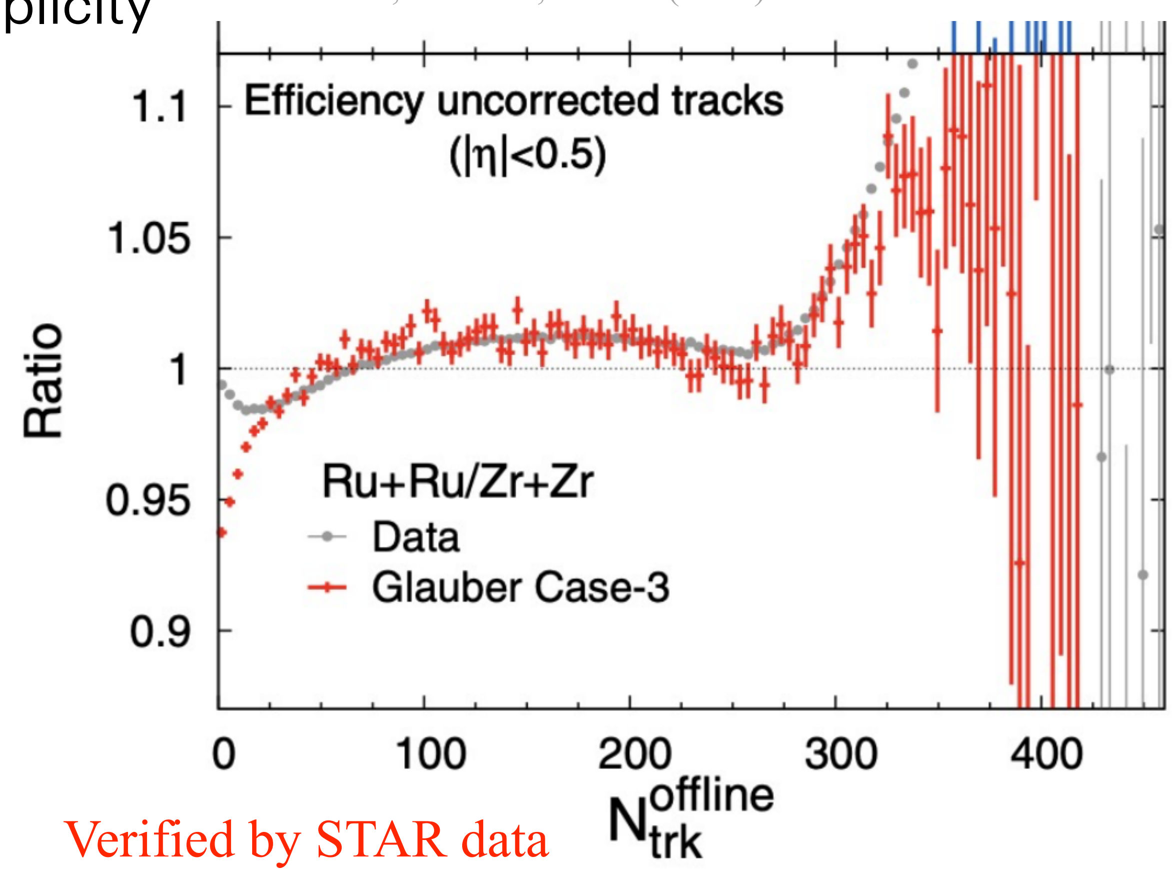
Multiphase transport model predictions of isobaric collisions with nuclear structure from density functional theory

Hanlin Li,[1,*] Hao-jie Xu,[2,†] Jie Zhao,[3,‡] Zi-Wei Lin,[4,5] Hanzhong Zhang,[4] Xiaobao Wang,[2] Caiwan Shen,[2] and Fuqiang Wang[2,3,§]



Multiplicity

STAR, PRC105, 014901(2022)



Verified by STAR data

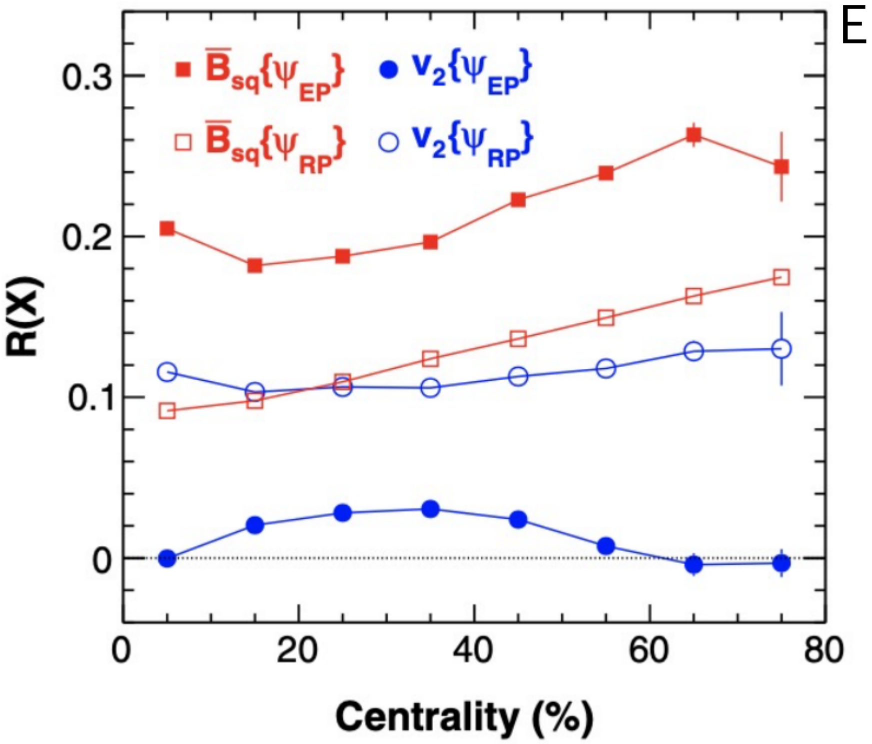
在球形核近似下，RuRu和ZrZr多重数的差异明显！

CME背景：各向异性流

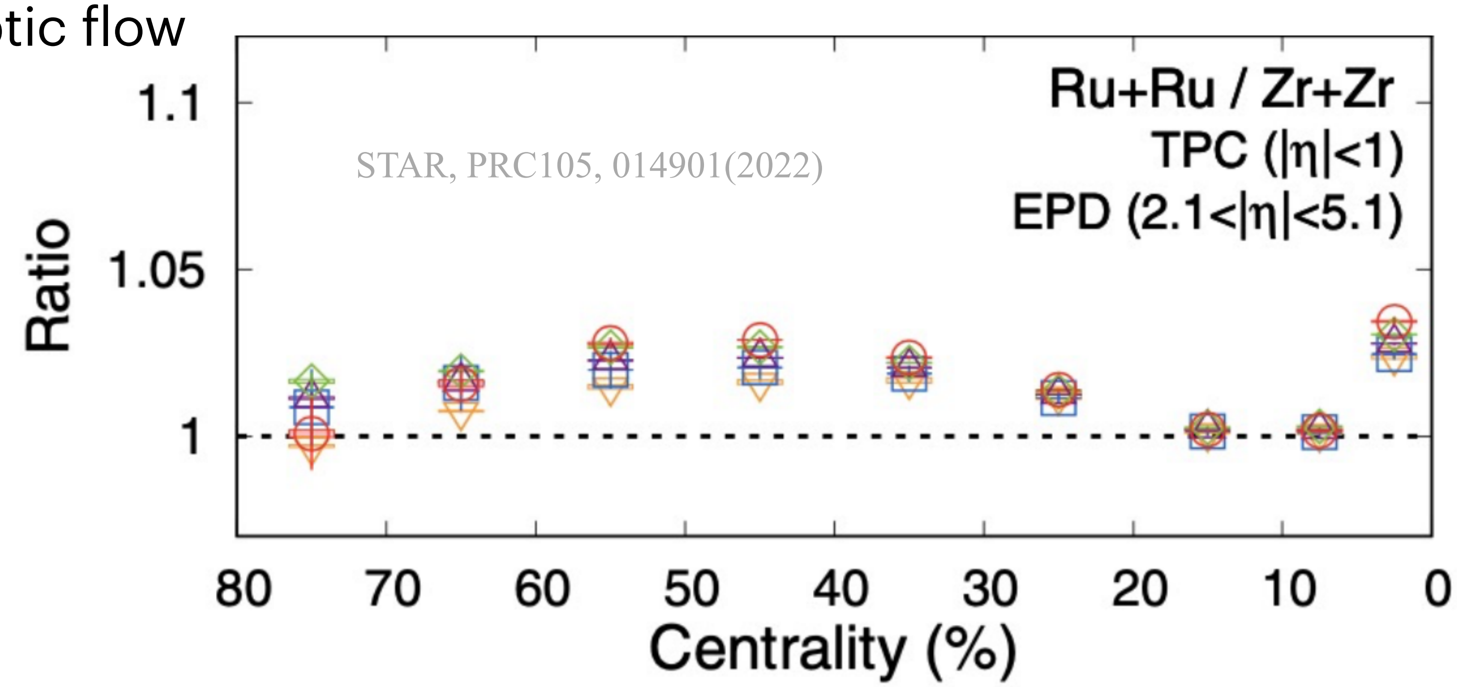
PHYSICAL REVIEW LETTERS **121,** 022301 (2018)

Importance of Isobar Density Distributions on the Chiral Magnetic Effect Search

Hao-jie Xu,[1] Xiaobao Wang,[1] Hanlin Li,[2] Jie Zhao,[3] Zi-Wei Lin,[4,5] Caiwan Shen,[1] and Fuqiang Wang[1,3,*]



Elliptic flow



Verified by STAR data

在球形核近似下，RuRu和ZrZr在非中心碰撞仍然存在v_2的差异！

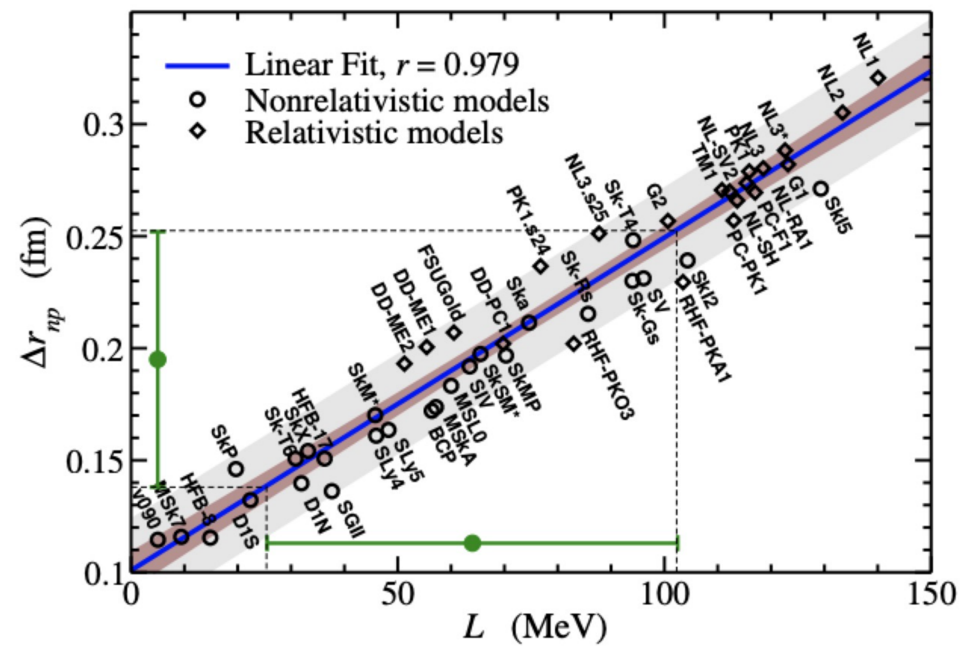
中子皮与对称能

陈列文

$^{96}_{40}\mathrm{Zr}: (N-Z)/A = 0.167$

$^{96}_{44}\mathrm{Ru}: (N-Z)/A = 0.083$

$\Delta r_{np}^{Zr} \gg \Delta r_{np}^{Ru}$



DFT(eSHF): State-of-the-art DFT calculation using extended Skyrme-Hartree-Fock (eSHF) model.

Z. Zhang, L. Chen, PRC94, 064326(2016)

$$E(\rho,\delta) = E_0(\rho) + E_{sym}(\rho)\delta^2 + O(\delta^4); \quad \rho = \rho_n + \rho_p; \quad \delta = \frac{\rho_n - \rho_p}{\rho};$$

B. Brown, PRC85, 5296 (2000)
R. Furnstahl, NPA, 706, 85 (2002)
X. Roca-Maza, et.al. PRL106, 252501 (2011)

Slope parameter :

$$L \equiv L(\rho) = 3\rho\left[\frac{dE_{sym}(\rho)}{d\rho}\right]_{\rho=\rho_0 \text{ saturation density}} \qquad L(\rho_c) = 3\rho_c\left[\frac{dE_{sym}(\rho)}{d\rho}\right]_{\rho=\rho_c=0.11\rho_0/0.16}$$

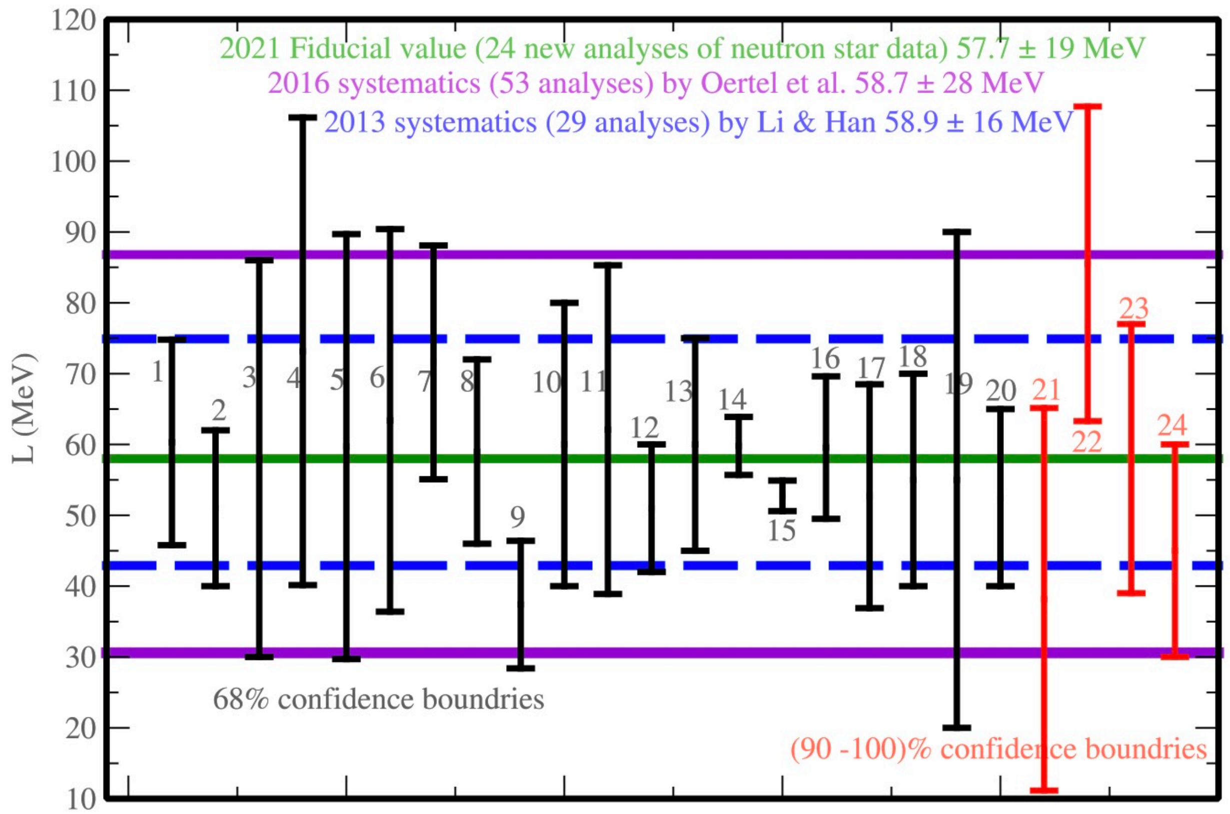
Larger L
Harder EOS ⟷ Need small δ to lower E ⟷ Smaller ρ_n, larger Δr

The symmetry energy is crucial to our understanding of the masses and drip lines of neutron-rich nuclei and the equation of state (EOS) of nuclear and neutron star matter.

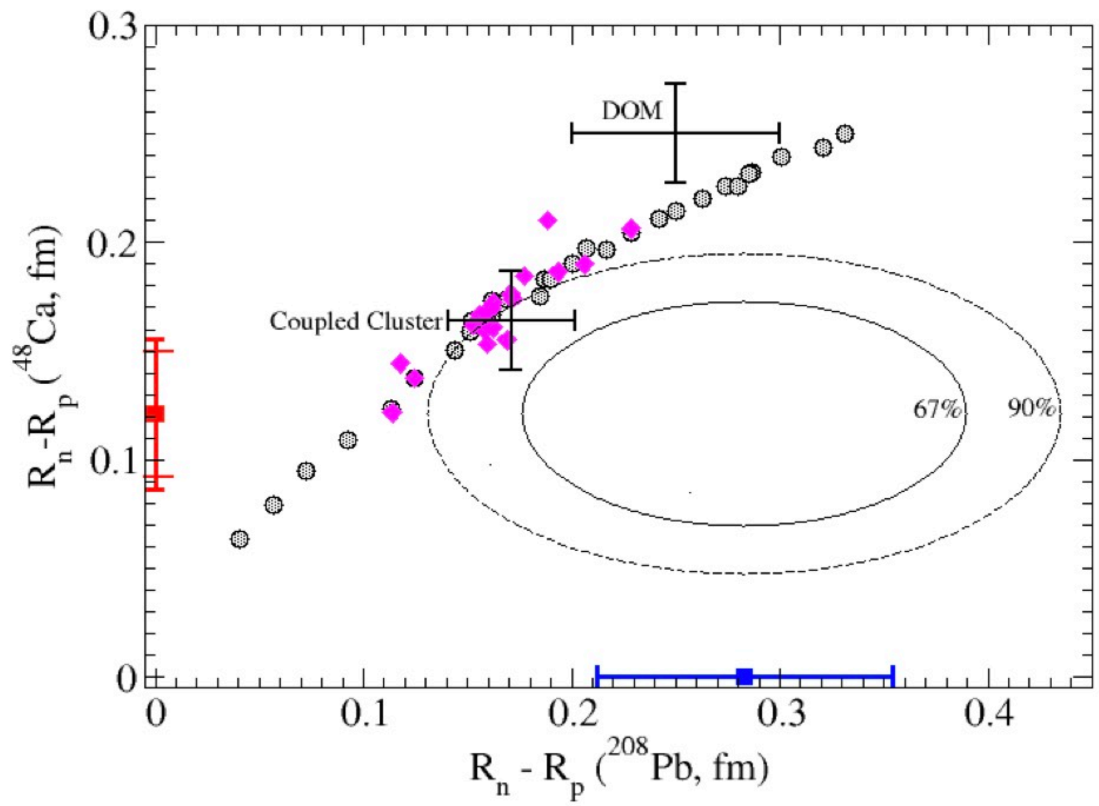
中子皮与对称能

陈列文

B. Li, et.al, Universe 7, 182 (2021)



CREX Collaboration, PRL129, 042501 (2022)



Symmetry energy is transitionally measured by low energy nuclear experiment. Over many decades, the issue is still not fully settled; e.g. world average L parameter is about 50 MeV, PREX electroweak measurement favors 100 MeV whereas CREX favors 30 MeV.

密度泛函理论计算

陈列文

Z. Zhang, PRC94, 064326(2016)
H. Li, HJX, et.al., PRL125, 222301(2020)

SHF: Standard Skyrme-Hartree-Fock (SHF) model
eSHF: Extended SHF model

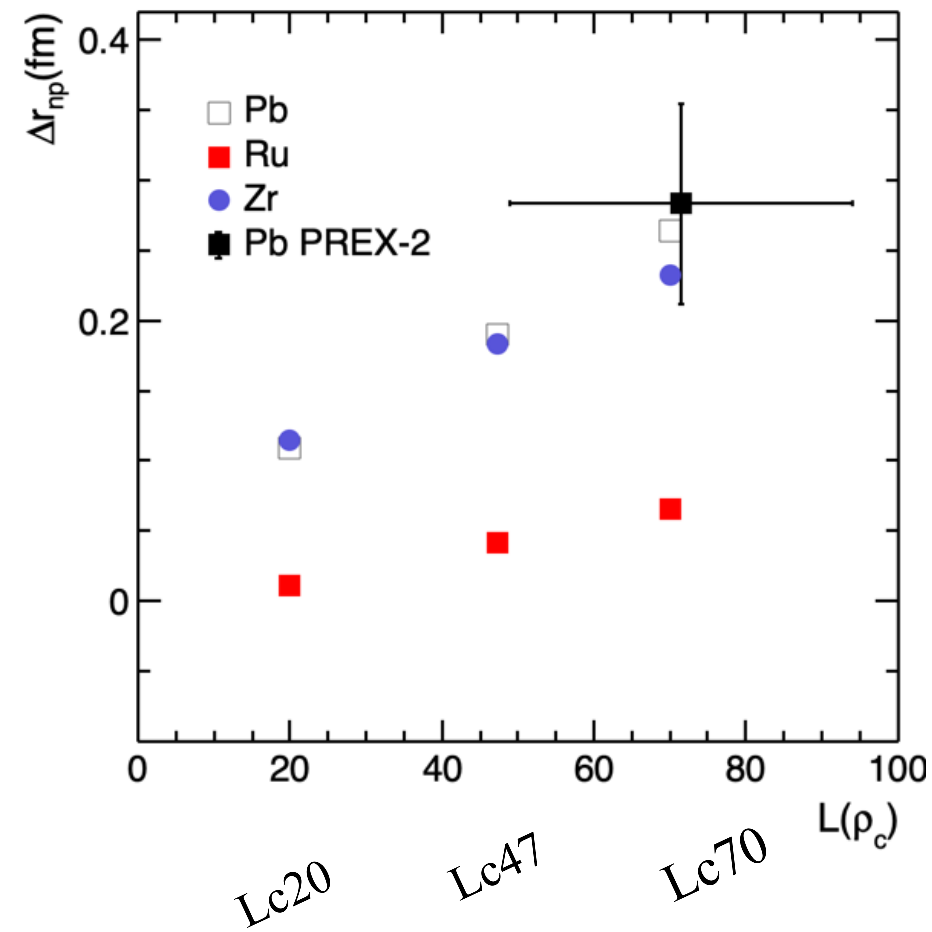
$$
\begin{aligned}
v_{i,j} = \; & t_0(1+x_0P_\sigma)\delta(\boldsymbol{r}) + \frac{1}{6}t_3(1+x_3P_\sigma)\rho^\alpha(\boldsymbol{R})\delta(\boldsymbol{r}) \\
& + \frac{1}{2}t_1(1+x_1P_\sigma)[K'^2\delta(\boldsymbol{r}) + \delta(\boldsymbol{r})K^2] \\
& + t_2(1+x_2P_\sigma)\boldsymbol{K}'\cdot\delta(\boldsymbol{r})\boldsymbol{K} \\
& + \frac{1}{2}t_4(1+x_4P_\sigma)[K'^2\delta(\boldsymbol{r})\rho(\boldsymbol{R}) + \rho(\boldsymbol{R})\delta(\boldsymbol{r})K^2] \\
& + t_5(1+x_5P_\sigma)\boldsymbol{K}'\cdot\rho(\boldsymbol{R})\delta(\boldsymbol{r})\boldsymbol{K} \\
& + iW_0(\boldsymbol{\sigma}_i+\boldsymbol{\sigma}_j)\cdot[\boldsymbol{K}'\times\delta(\boldsymbol{r})\boldsymbol{K}], \qquad (4)
\end{aligned}
$$

Extended

$$E(\rho,\delta) = E_0(\rho) + E_{\rm sym}(\rho)\delta^2 + O(\delta^4)$$

$$\rho = \rho_n + \rho_p; \;\; \delta = \frac{\rho_n - \rho_p}{\rho}$$

$$L(\rho_c) = 3\rho_c\left[\frac{dE_{\rm sym}(\rho)}{d\rho}\right]_{\rho=\rho_c} ; \;\; \rho_c \simeq 0.11\text{fm}^{-3}$$



	$L(\rho_c)$	$L(\rho_0)$	^{96}Zr r_n	r_p	$\Delta r_{\rm np}$	^{96}Ru r_n	r_p	$\Delta r_{\rm np}$	^{208}Pb $\Delta r_{\rm np}$
Lc20	20	13.1	4.386	4.27	0.115	4.327	4.316	0.011	0.109
Lc47	47.3	55.7	4.449	4.267	0.183	4.360	4.319	0.042	0.190
Lc70	70	90.0	4.494	4.262	0.232	4.385	4.32	0.066	0.264
SLy4	42.7	46.0	4.432	4.271	0.161	4.356	4.327	0.030	0.160

测量方法1: Mean multiplicity ratios

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,‡]

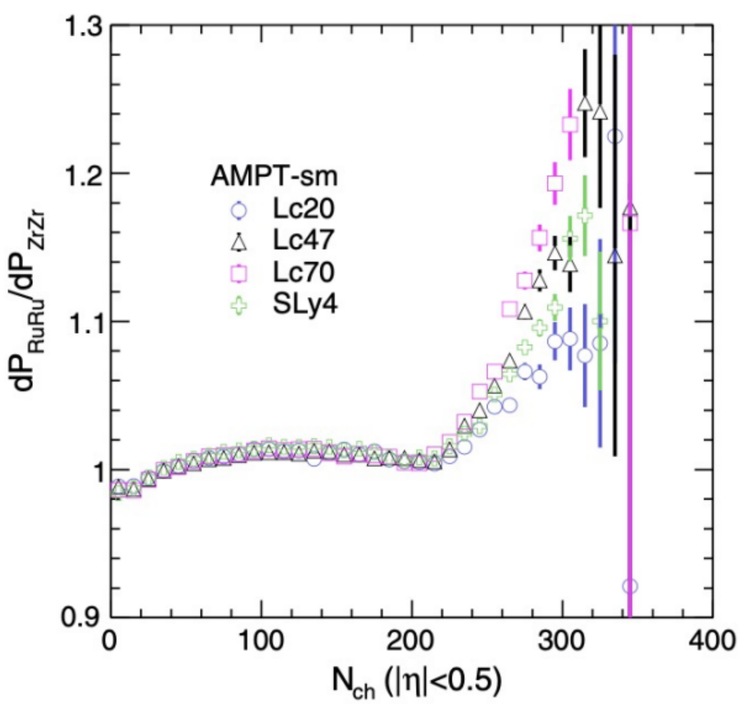
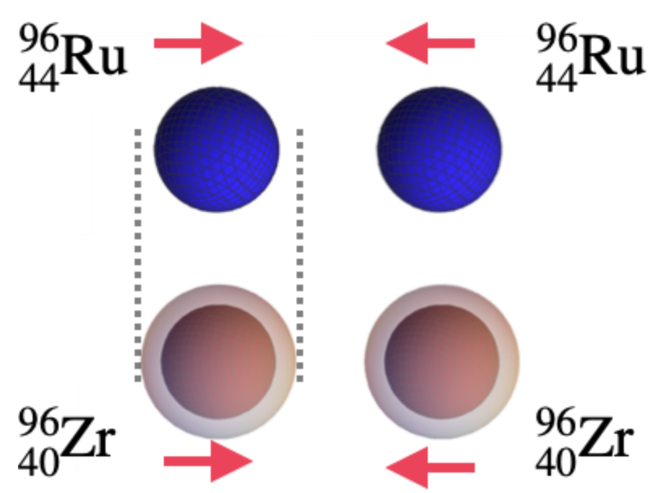
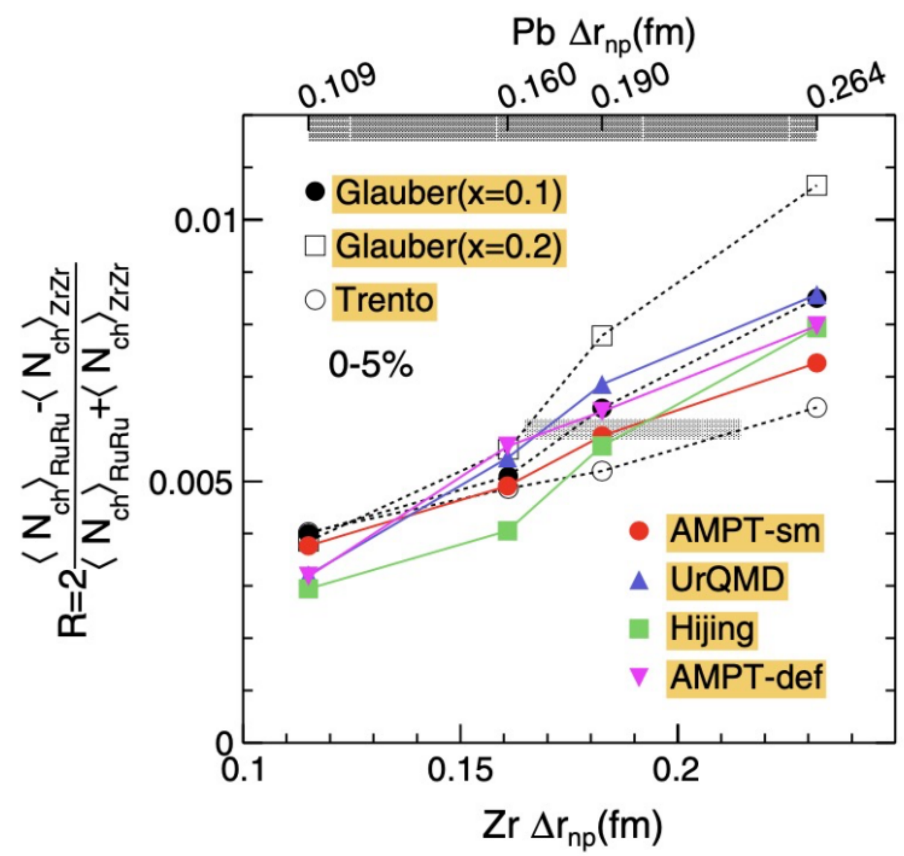


FIG. 3. Ratio of the N_{ch} distribution in Ru + Ru to that in Zr + Zr for various densities in AMPT-sm. The other models are similar.





多重数差异敏感于对称能斜率参数L

中子皮：halo-type 和 skin-type

Physics Letters B 819 (2021) 136453

Contents lists available at ScienceDirect

Physics Letters B

www.elsevier.com/locate/physletb

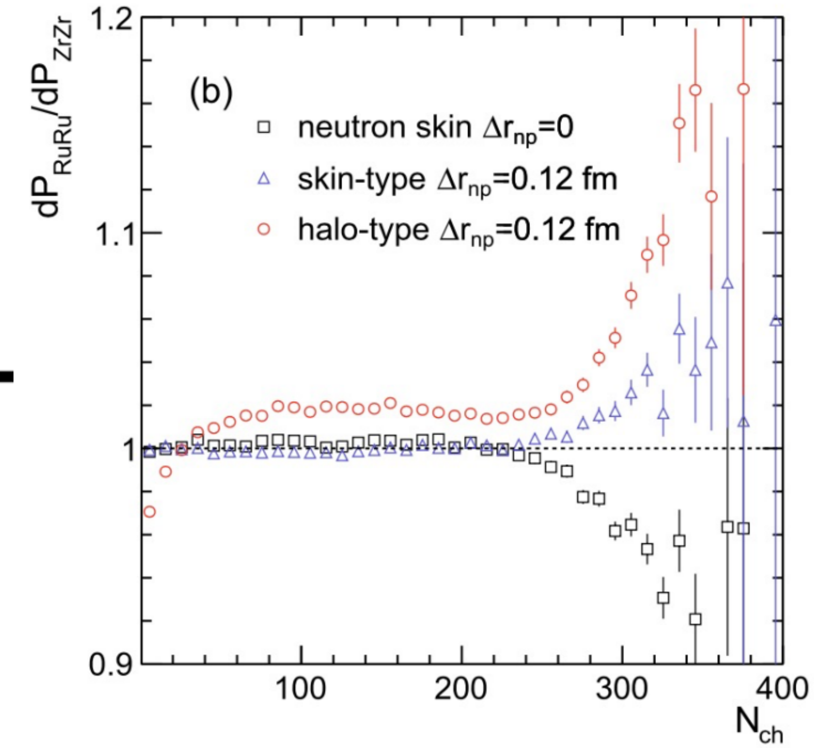
Determine the neutron skin type by relativistic isobaric collisions

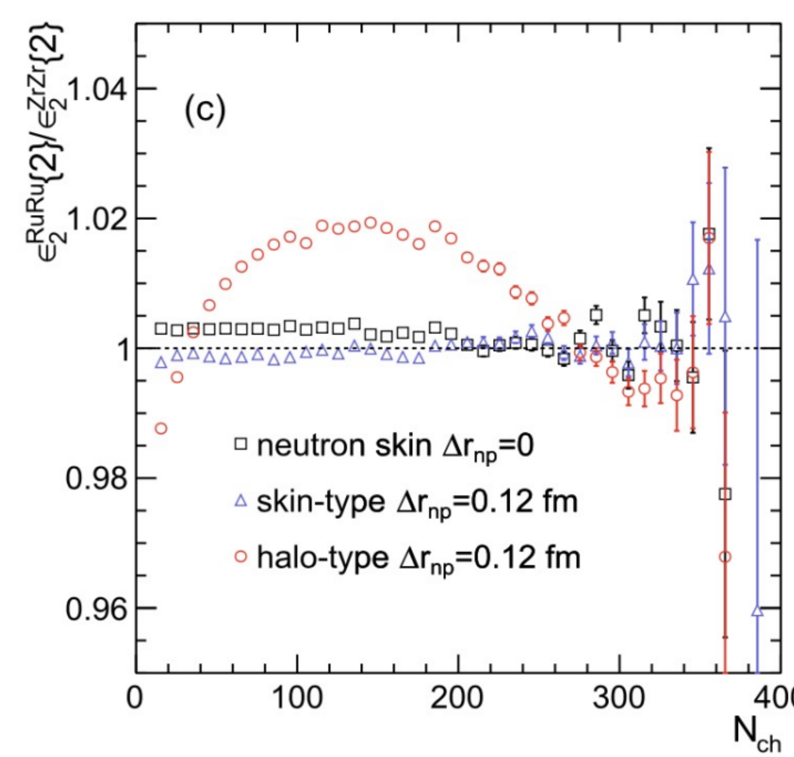
Hao-jie Xu [a,*], Hanlin Li [b], Xiaobao Wang [a], Caiwan Shen [a], Fuqiang Wang [a,c,*]

[a] School of Science, Huzhou University, Huzhou, Zhejiang 313000, China
[b] College of Science, Wuhan University of Science and Technology, Wuhan, Hubei 430065, China
[c] Department of Physics and Astronomy, Purdue University, West Lafayette, IN 47907, USA

Table 1
Skin- and halo-type WS parameterizations (radius parameter R and diffuseness parameter a) of neutron densities based on the measured charge (proton) densities [21] together with neutron skin thicknesses (taken to be Δr_{np}=0 and 0.12 fm [22,23], respectively) for ^{96}Ru and ^{96}Zr. All quoted numbers are in fm.

	^{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





差异敏感于中子皮的类型，DFT计算给出halo-type中子皮.

核密度分布：WS和DFT

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

Table 2
The WS parameterizations (radius parameter R and diffuseness parameter a) of proton and neutron (and nucleon) density distributions for ^{96}Ru and ^{96}Zr, matching to the corresponding $\langle r\rangle$ and $\langle r^2\rangle$ from the DFT-calculated spherical densities with SLy4 skyrme parameter set [1,25]. The WS parameterization of nucleon density assuming a quadrupole deformity parameter $\beta_2 = 0.16$ and matching to the spherical DFT density is also listed. All quoted numbers are in fm.

		^{96}Ru		^{96}Zr	
		R	a	R	a
$\beta_2 = 0$	p	5.060	0.493	4.915	0.521
	n	5.075	0.505	5.015	0.574
	p+n	5.067	0.500	4.965	0.556
$\beta_2 = 0.16$	p	5.053	0.480	4.912	0.508
	n	5.073	0.490	5.007	0.564
	p+n	5.065	0.485	4.961	0.544

Woods-Saxon distributions

$$\rho(r) = \frac{\rho_0}{1 + \exp[(r - R)/a]}$$

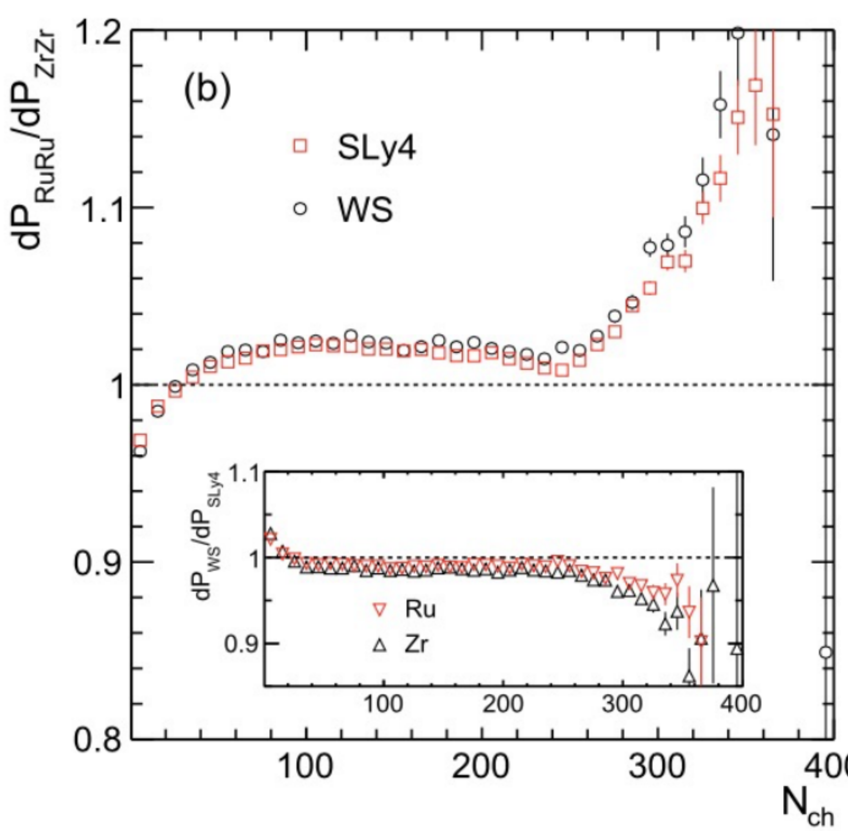
$$R = R_0\,[1+\beta_2 Y_2^0(\theta)+\beta_4 Y_4^0(\theta)]$$

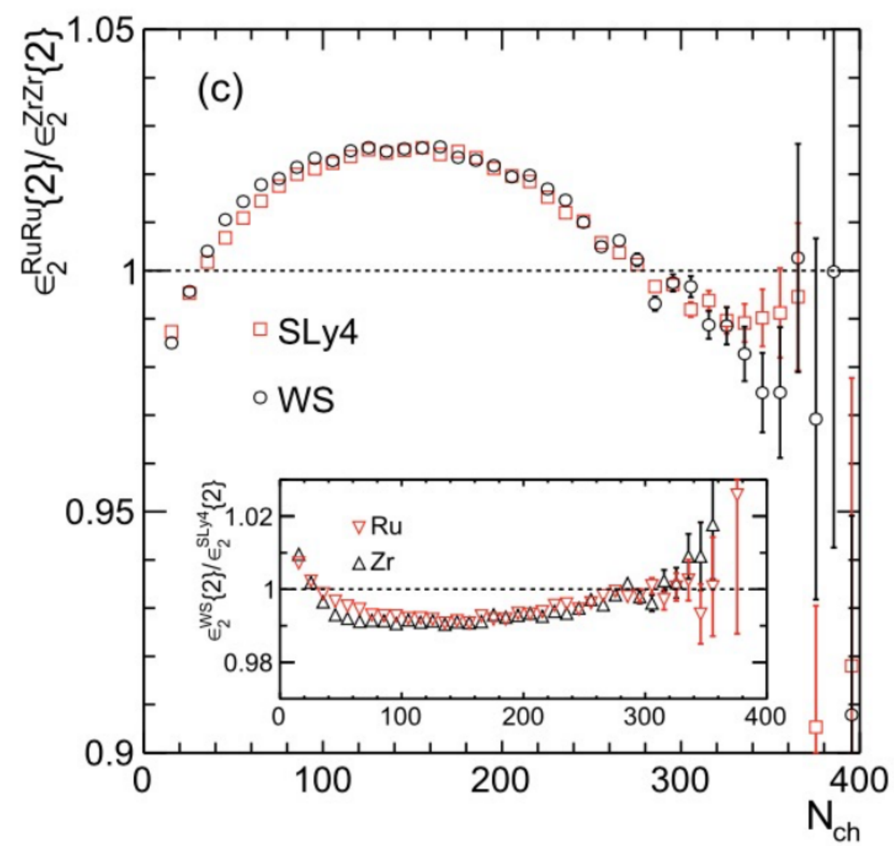
$$\langle r\rangle_{\rm WS} = \langle r\rangle_{\rm DFT}$$

$$\langle r^2\rangle_{\rm WS} = \langle r^2\rangle_{\rm DFT}$$

$$\langle r\rangle_{\rm Def} = \langle r\rangle_{\rm Sph}$$

$$\langle r^2\rangle_{\rm Def} = \langle r^2\rangle_{\rm Sph}$$





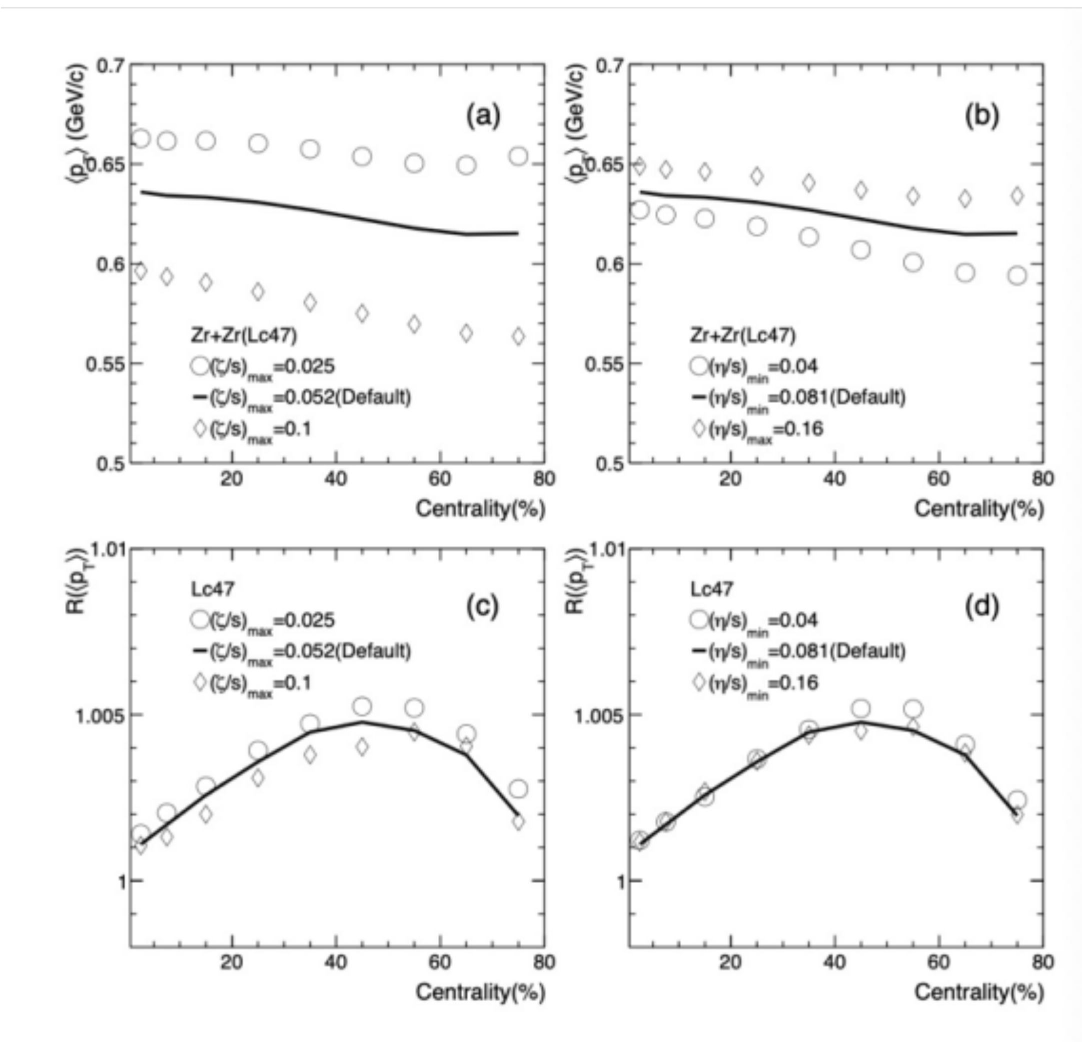
测量方法2: Mean p_T ratios

PHYSICAL REVIEW C **108**, L011902 (2023)

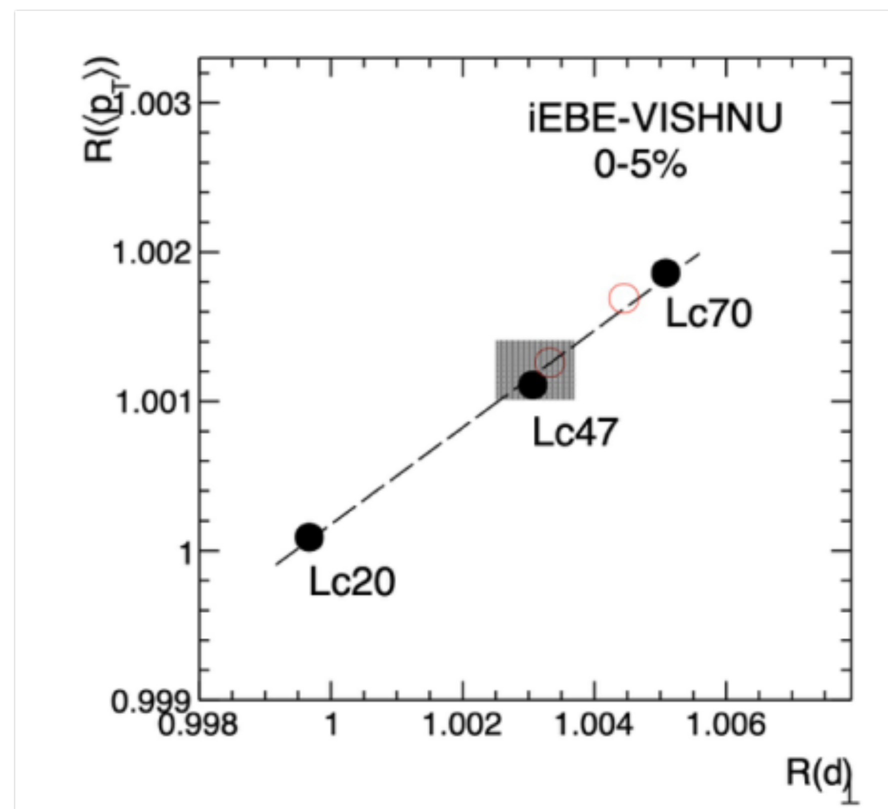
Letter

Probing nuclear structure with mean transverse momentum in relativistic isobar collisions

Hao-jie Xu,[1,2] Wenbin Zhao,[3] Hanlin Li,[4] Ying Zhou,[5] Lie-Wen Chen,[5] and Fuqiang Wang[1,2,6]



$$R(\langle p_T\rangle) \propto R(d_\perp) \propto 1/R(\langle\sqrt{r^2}\rangle)$$

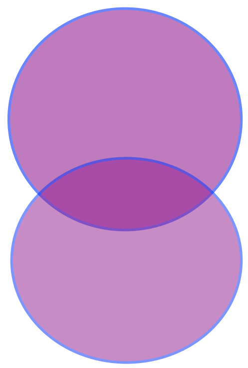


The $R(\langle p_T\rangle)$ is inversely proportional to nuclear size ratio in most central collisions.

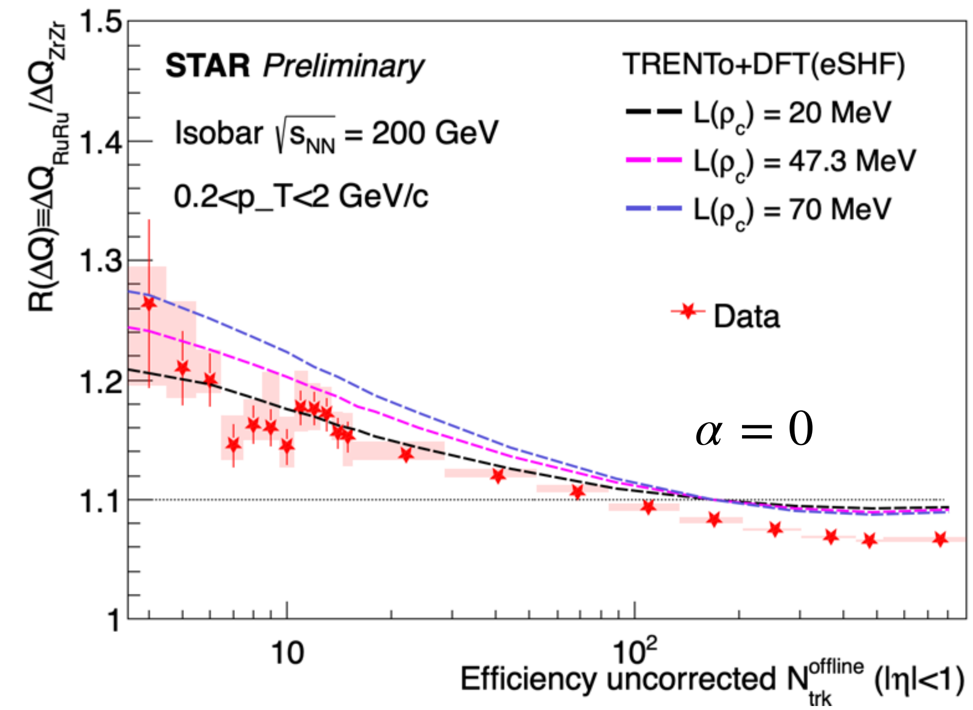
测量方法3: net charge ratios

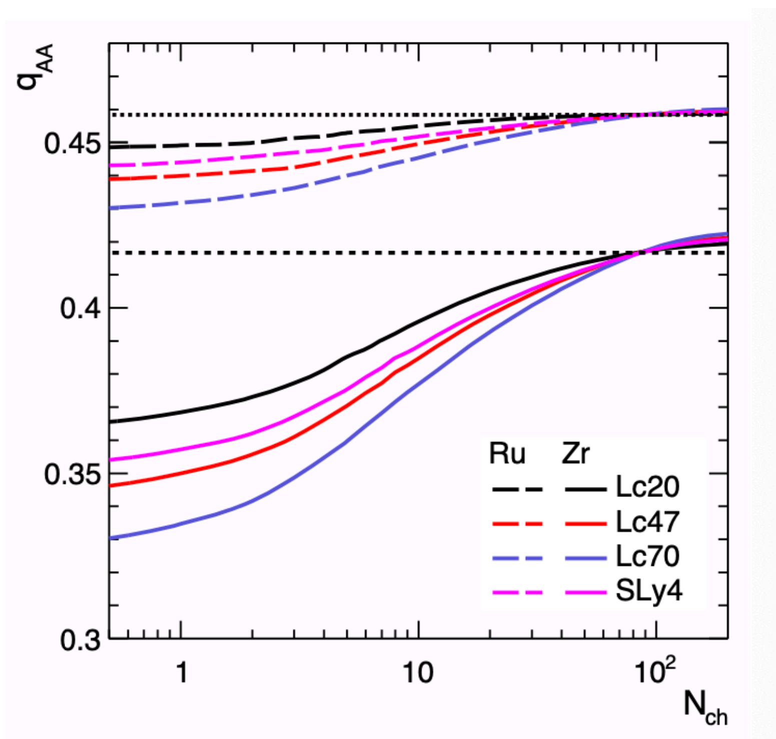
HJX, et.al., PRC105, L011901 (2022)

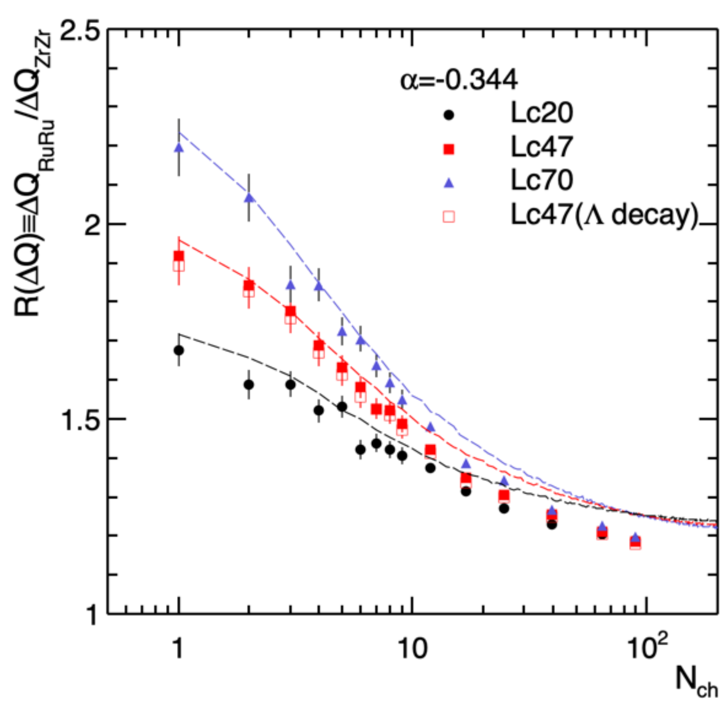
For the colliding nuclei with large neutron skin thickness



more n+n collisions at most peripheral collisions;
Less participant charges, thus less final net-charges







The curves are calculated by superimposition assumption

$$R(\Delta Q) = \frac{q_{RuRu} + \alpha/(1-\alpha)}{q_{ZrZr} + \alpha/(1-\alpha)}$$

where $q_{RuRu/ZrZr}$ are the fraction of protons among the participant nucleons, obtained by the Trento model.

α is the ΔQ ratio in nn to pp interaction:

Pytha: $\alpha = -0.352$; Hijing: $\alpha = -0.389$; UrQMD: $\alpha = -0.344$;

STAR preliminary results

Compare to world wide data

18

State-of-the-art **spherical** DFT with eSHF nuclear potential

Zhang, Chen, PRC94, 064326 (2016)

- Multiplicity ratio:

$L(\rho_c) = 53.8 \pm 1.7 \pm 7.8$ MeV

$L(\rho) = 65.4 \pm 2.1 \pm 12.1$ MeV

$\Delta r_{\mathrm{np,Zr}} = 0.195 \pm 0.019$ fm

$\Delta r_{\mathrm{np,Ru}} = 0.051 \pm 0.009$ fm

- $\langle p_T \rangle$ ratio:

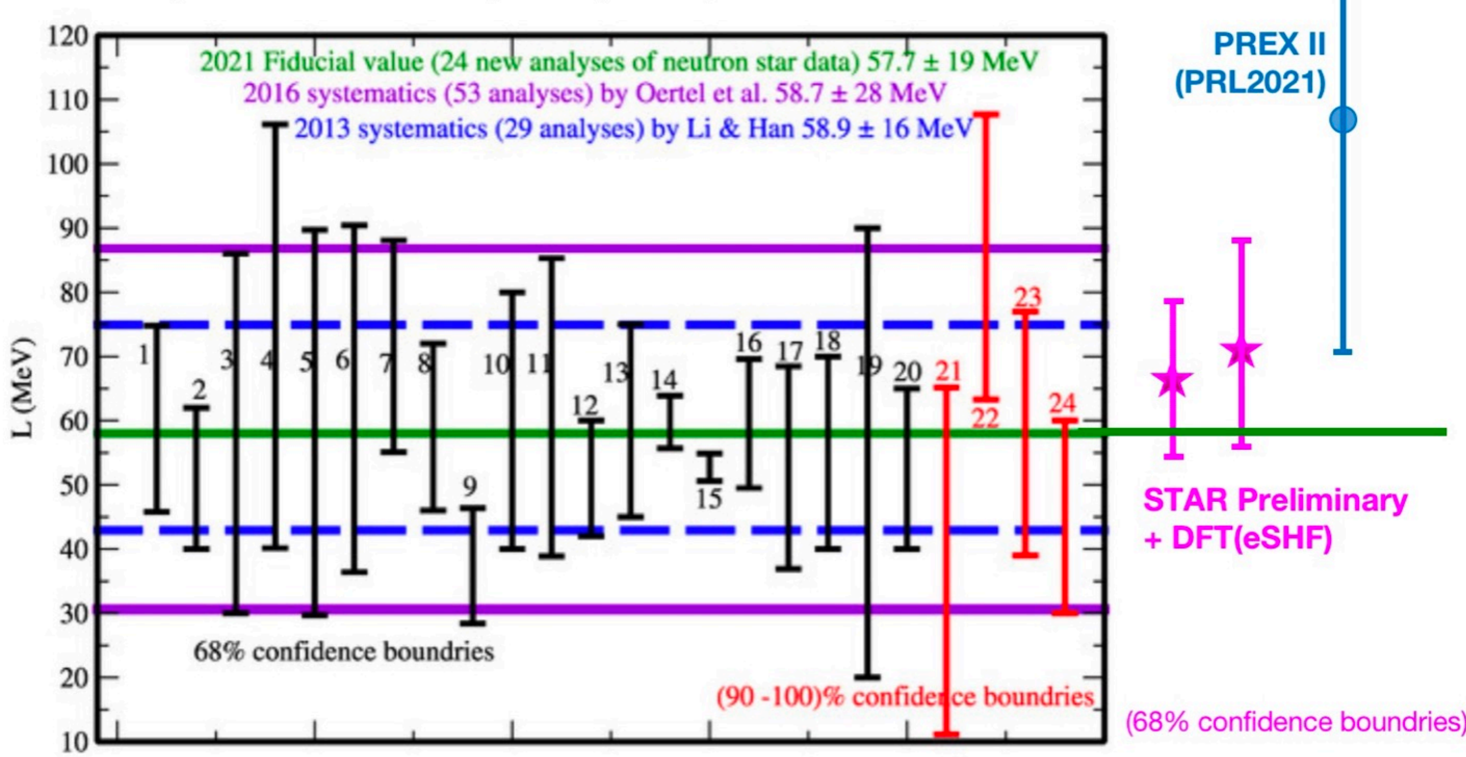
$L(\rho_c) = 56.8 \pm 0.4 \pm 10.4$ MeV

$L(\rho) = 69.8 \pm 0.7 \pm 16.0$ MeV

$\Delta r_{\mathrm{np,Zr}} = 0.202 \pm 0.024$ fm

$\Delta r_{\mathrm{np,Ru}} = 0.052 \pm 0.012$ fm

B. Li, et.al Universe 7, 182 (2021)



Consistent with world wide data with good precision

Haojie Xu

QUARK MATTER KRAKÓW 2022

更多信号

Probing neutron-skin thickness with free spectator neutrons in ultracentral high-energy isobaric collisions

Lu-Meng Liu (Beijing, GUCAS), Chun-Jian Zhang (Stony Brook U.), Jia Zhou (Beijing, GUCAS and SINAP, Shanghai), Jun Xu (SINAP, Shanghai and CAS, SARI, Shanghai), Jiangyong Jia (Stony Brook U. and Brookhaven) et al. (Mar 18, 2022)

Published in: *Phys.Lett.B* 834 (2022) 137441 • e-Print: 2203.09924 [nucl-th]

Detecting nuclear mass distribution in isobar collisions via charmonium

Jiaxing Zhao (SUBATECH, Nantes and Tsinghua U., Beijing), Shuzhe Shi (Stony Brook U.) (Nov 3, 2022)

Published in: *Eur.Phys.J.C* 83 (2023) 6, 511 • e-Print: 2211.01971 [hep-ph]

Hard probes in isobar collisions as a probe of the neutron skin

#

Wilke van der Schee (CERN and Utrecht U.), Yen-Jie Lee (MIT, LNS), Govert Nijs (MIT, Cambridge, CTP), Yi Chen (MIT, LNS) (Jul 21, 2023)

e-Print: 2307.11836 [nucl-th]

Examination of nucleon distribution with Bayesian imaging for isobar collisions

Yi-Lin Cheng (Frankfurt U., FIAS and Fudan U., Shanghai and SINAP, Shanghai and Fudan U. and Beijing, GUCAS), Shuzhe Shi (Tsinghua U., Beijing and Stony Brook U. and SUNY, Stony Brook), Yu-Gang Ma (Fudan U., Shanghai and Fudan U.), Horst Stöcker (Frankfurt U., FIAS and Darmstadt, GSI and Frankfurt U.), Kai Zhou (Frankfurt U., FIAS) (Jan 10, 2023)

Published in: *Phys.Rev.C* 107 (2023) 6, 064909 • e-Print: 2301.03910 [nucl-th]

Photoproduction of $e^+ e^-$ in peripheral isobar collisions

Shuo Lin (Hefei, CUST), Ren-Jie Wang (Hefei, CUST), JIan-Fei Wang (Hefei, CUST), Hao-Jie Xu (Hefei, CUST and Huzhou U.), Shi Pu (Hefei, CUST) et al. (Oct 10, 2022)

Published in: *Phys.Rev.D* 107 (2023) 5, 054004 • e-Print: 2210.05106 [hep-ph]

浦实
杨弛
赵杰
赵文彬

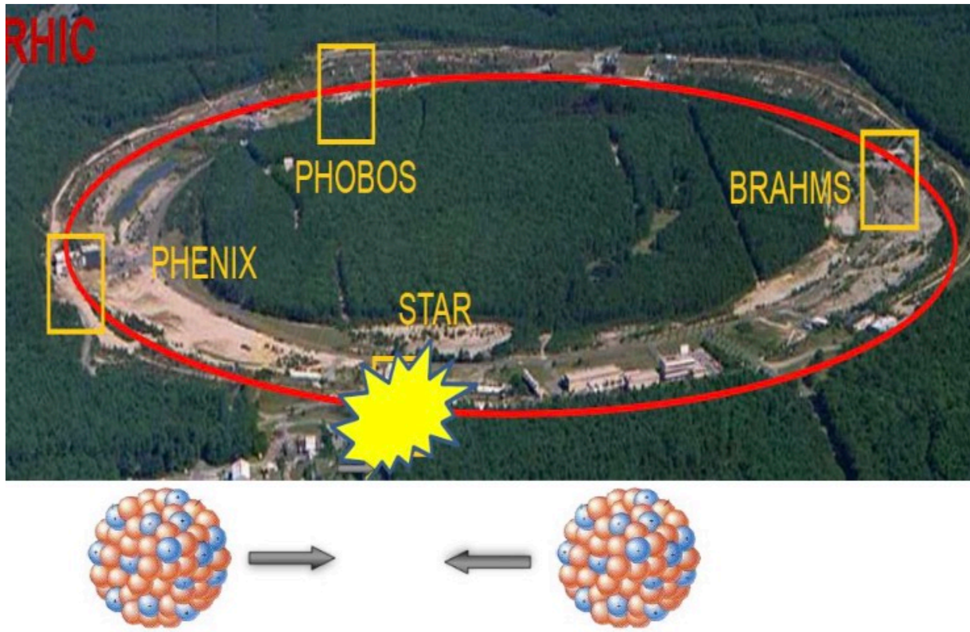
III 中子皮和类同量异位素核碰撞 (Semi-isobar, Au+Au & Pb+Pb)

Determine the neutron skin thickness of ^{208}Pb by relativistic semi-isobaric collisions

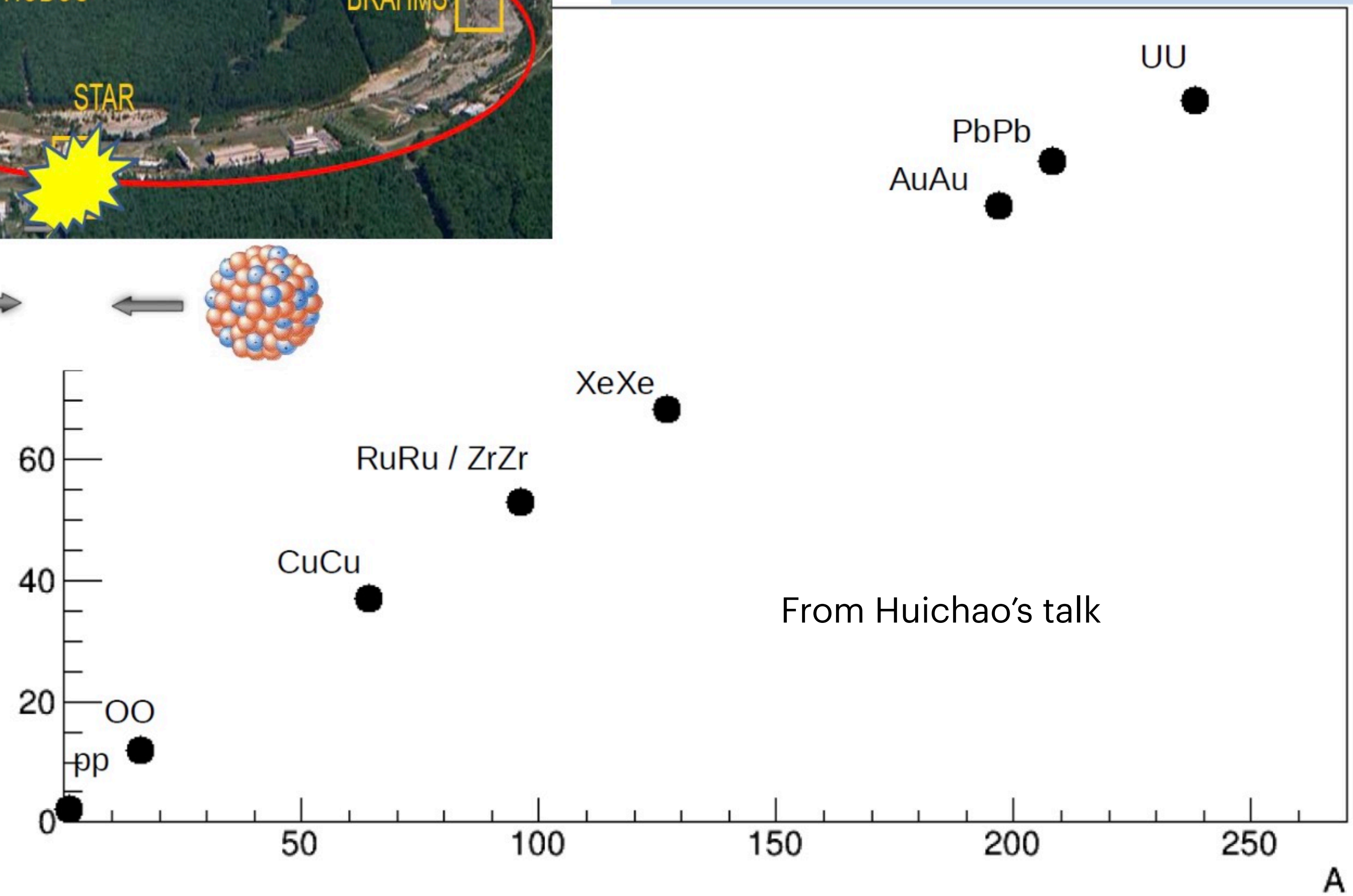
Qi Liu,[1] Hao-jie Xu*,[2,3] and Huichao Song†[1,4,5]

Paper in preparation

类同量异位素核碰撞



Rich collisions systems at RHIC & the LHC



Determine the neutron skin thickness of ^{208}Pb by relativistic semi-isobaric collisions

Qi Liu,[1] Hao-jie Xu*,[2,3] and Huichao Song†[1,4,5]

Paper in preparation

质量数相似:

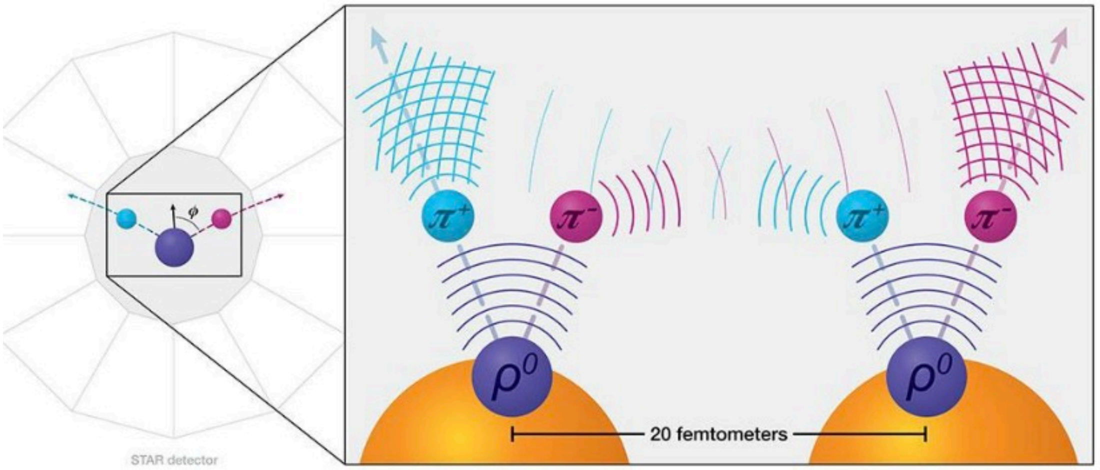
- Pb+Pb & Au+Au

碰撞能量相近:

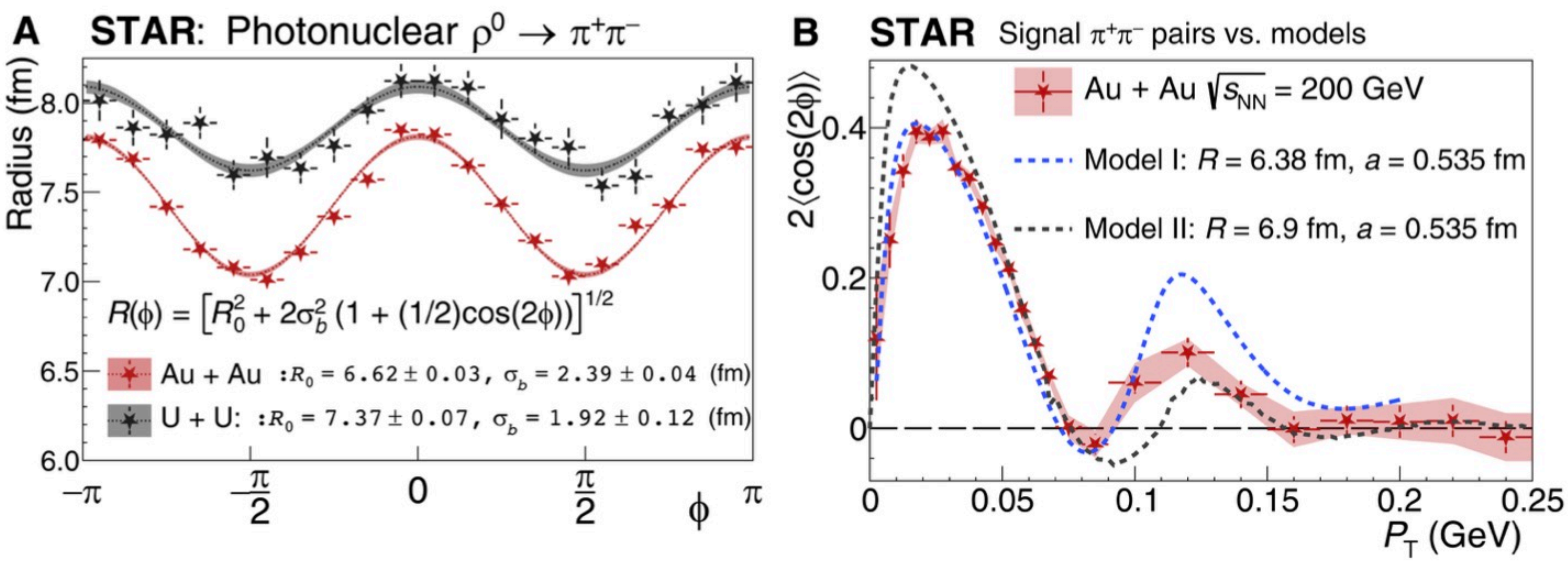
- Au+Au & U+U (贾江涌)
- Pb+Pb & Xe+Xe (周铀)

Au核中子皮

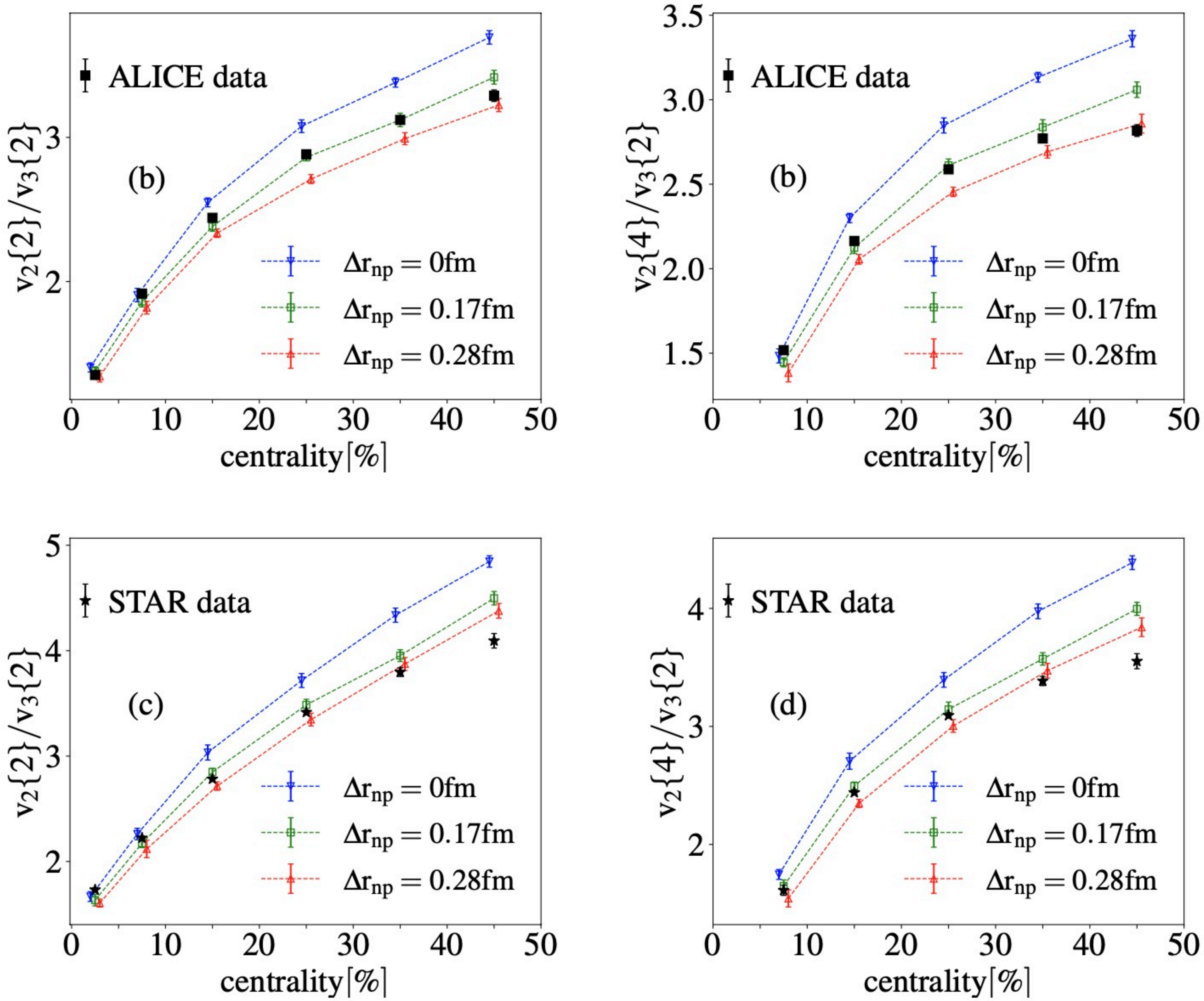
STAR, Sci.Adv. 9, eabq3903 (2023)



Au: $\Delta r_{np} = 0.17$ fm



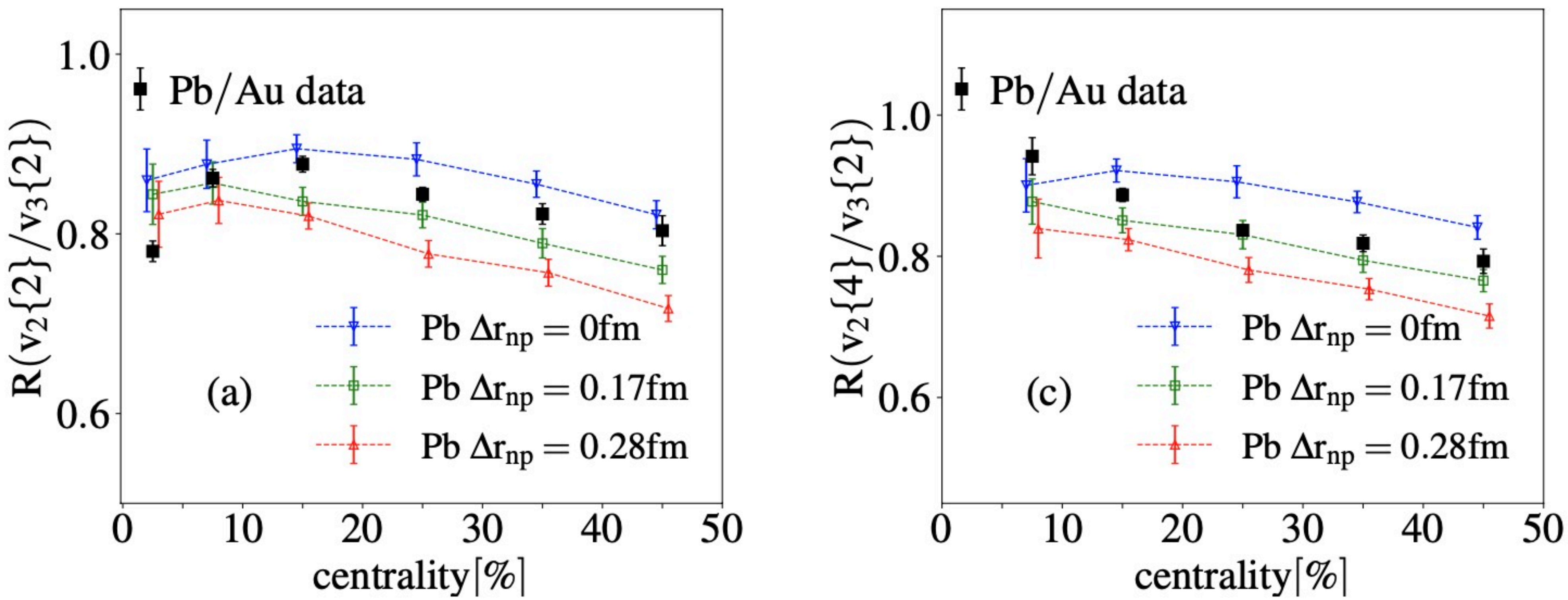
类同量异位素核碰撞 (Semi-isobar)



Q. Liu, HJX, H. Song, paper in preparation

对于单个碰撞系统，中子皮～0.17 fm更好的拟合实验数据

类同量异位素核碰撞 (Semi-isobar)

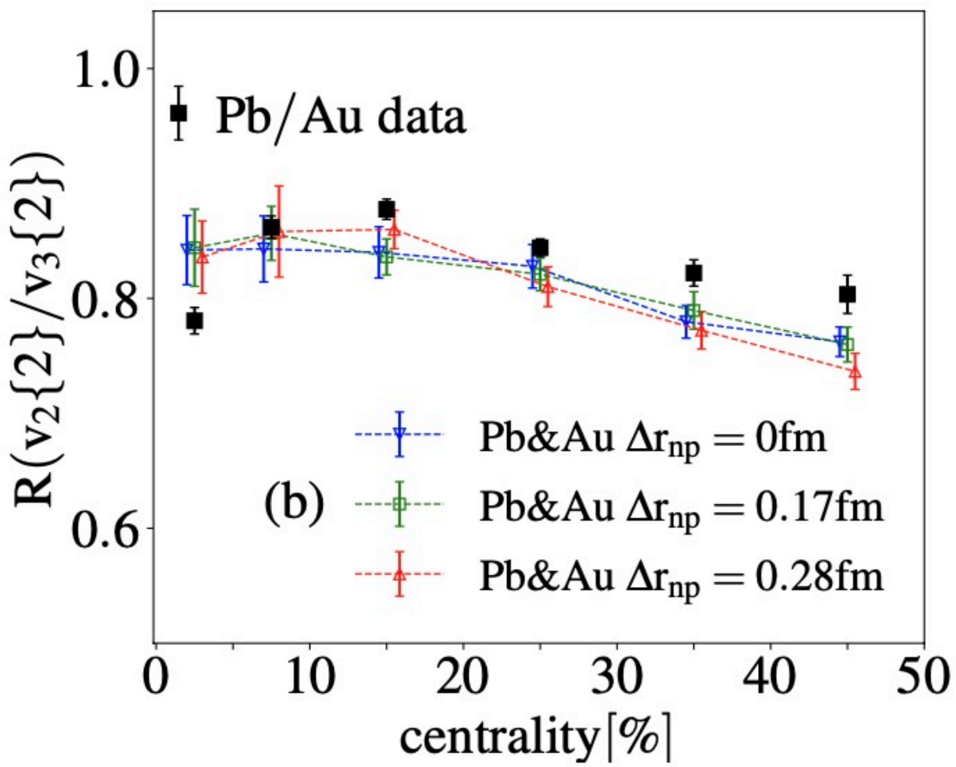


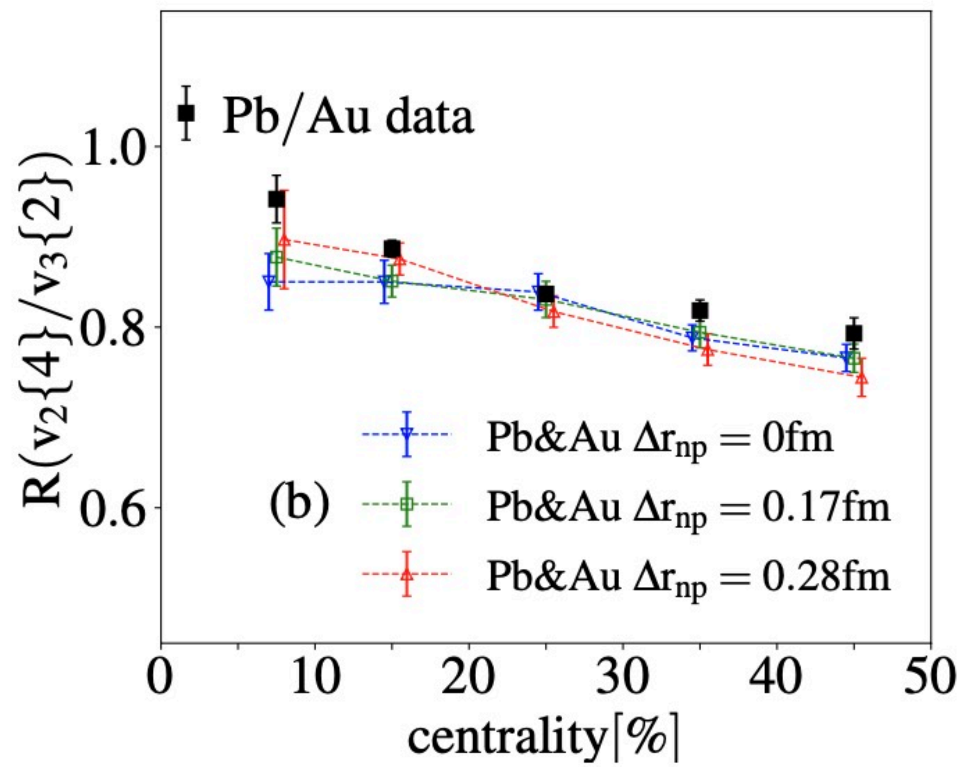
类同量异位素核碰撞的比可以较好的降低系统误差哦

固定Au的中子皮～0.17 fm，则相当大小的Pb的中子皮能更好的拟合实验数据

Q. Liu, HJX, H. Song, paper in preparation

类同量异位素核碰撞 (Semi-isobar)





Au和Pb具有相当大小的中子皮能更好的拟合实验数据

期望在相同碰撞能量下的实验数据

Q. Liu, HJX, H. Song, paper in preparation

总结

- The STAR isobar data indicate **thick halo-type neutron skin in Zr**, consistent with **DFT** calculations
- Precision isobar data can be used to **probe the neutron skin and symmetry energy**
  - Multiplicity distribution ratio; Mean p_T ratio; Net charge ratio; Spectator proton ratio,…
- **Semi-isobar collisions** provides an unconventional way to **determine the neutron skin** with the existing relativistic heavy ion collision data.

……

A	isobars	A	isobars	A	isobars
36	Ar, S	106	Pd, Cd	148	Nd, Sm
40	Ca, Ar	108	Pd, Cd	150	Nd, Sm
46	Ca, Ti	110	Pd, Cd	152	Sm, Gd
48	Ca, Ti	112	Cd, Sn	154	Sm, Gd
50	Ti, V, Cr	113	Cd, In	156	Gd, Dy
54	Cr, Fe	114	Cd, Sn	158	Gd, Dy
64	Ni, Zn	115	In, Sn	160	Gd, Dy
70	Zn, Ge	116	Cd, Sn	162	Dy, Er
74	Ge, Se	120	Sn, Te	164	Dy, Er
76	Ge, Se	122	Sn, Te	168	Er, Yb
78	Se, Kr	123	Sb, Te	170	Er, Yb
80	Se, Kr	124	Sn, Te, Xe	174	Yb, Hf
84	Kr, Sr, Mo	126	Te, Xe	176	Yb, Lu, Hf
86	Kr, Sr	128	Te, Xe	180	Hf, W
87	Rb, Sr	130	Te, Xe, Ba	184	W, Os
92	Zr, Nb, Mo	132	Xe, Ba	186	W, Os
94	Zr, Mo	134	Xe, Ba	187	Re, Os
96	Zr, Mo, Ru	136	Xe, Ba, Ce	190	Os, Pt
98	Mo, Ru	138	Ba, La, Ce	192	Os, Pt
100	Mo, Ru	142	Ce, Nd	198	Pt, Hg
102	Ru, Pd	144	Nd, Sm	204	Hg, Pb
104	Ru, Pd	146	Nd, Sm		

G. Giacalone, J. Jia, V. Soma, PRC104, L041903(2022)

Thank you for your attention!

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Huzhou University(湖州师范学院)