International Conference 50 years of Cold Fusion

Yerevan Armenia, Nov. 20-23 2024

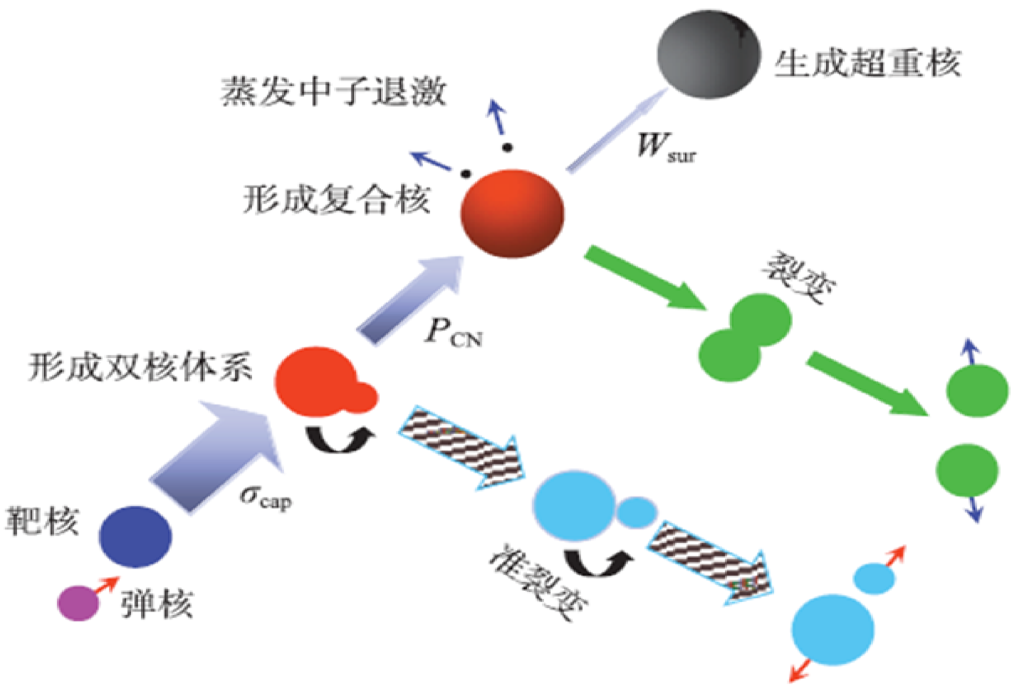
From fusion and quasifission to fission and decay for SHE

Lu Guo

University of Chinese Academy of Sciences, Beijing, China

Background

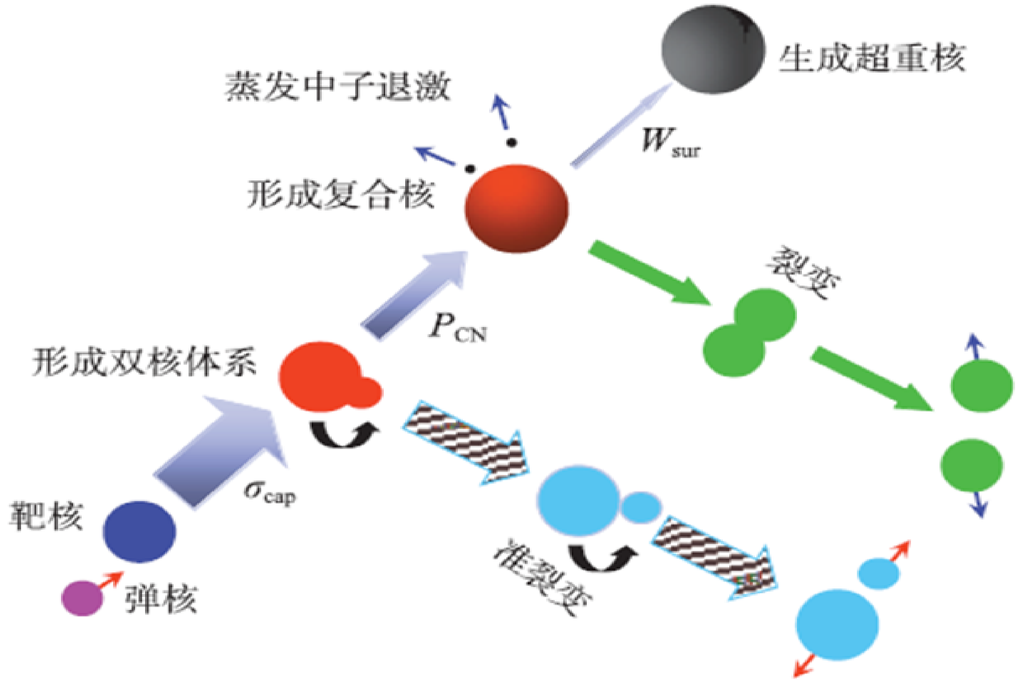
- Heavy-ion fusion reaction
  - cold fusion: using ^{208}Pb (^{209}Bi) as target, the heaviest is up to Z=113 so far
  - hot fusion: using ^{48}Ca as projectile, the heaviest is up to Z=118 so far
- Quasifission and fusion-fission are the primary mechanism in preventing SHE formation



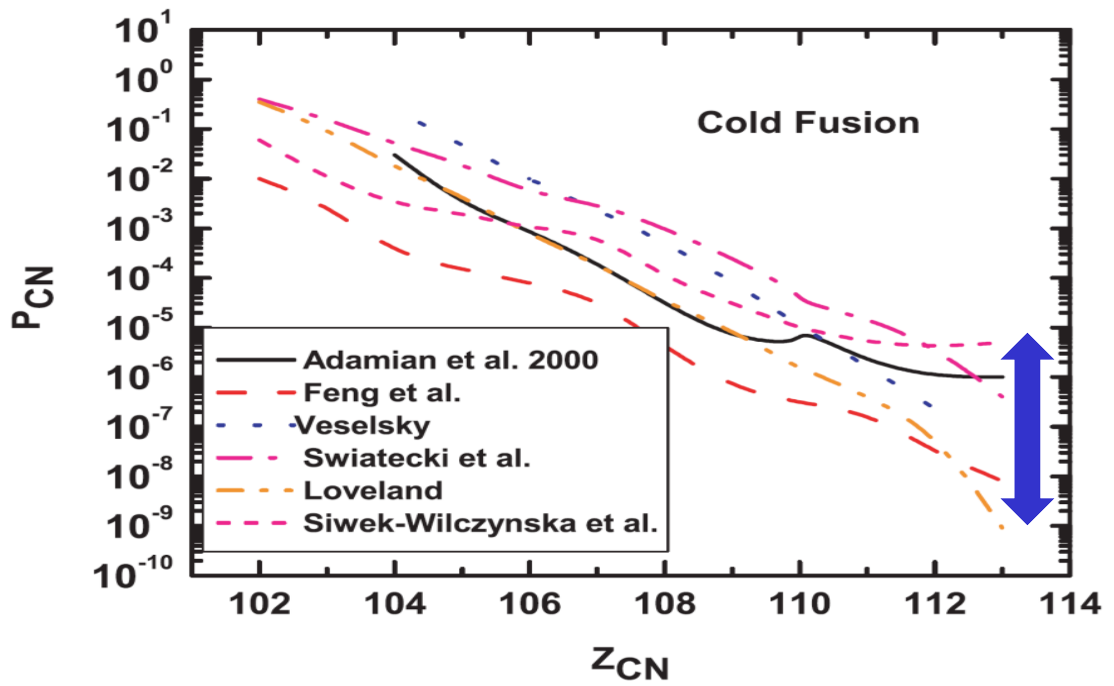
S. G. Zhou, Nucl. Phys. Rev 34, 318 (2017)

Background

- Heavy-ion fusion reaction
  - cold fusion: using ^{208}Pb (^{209}Bi) as target, the heaviest is up to Z=113 so far
  - hot fusion: using ^{48}Ca as projectile, the heaviest is up to Z=118 so far
- Quasifission and fusion-fission are the primary mechanism in preventing SHE formation
- Fusion probability is several orders of magnitude difference among the different phenomenological models



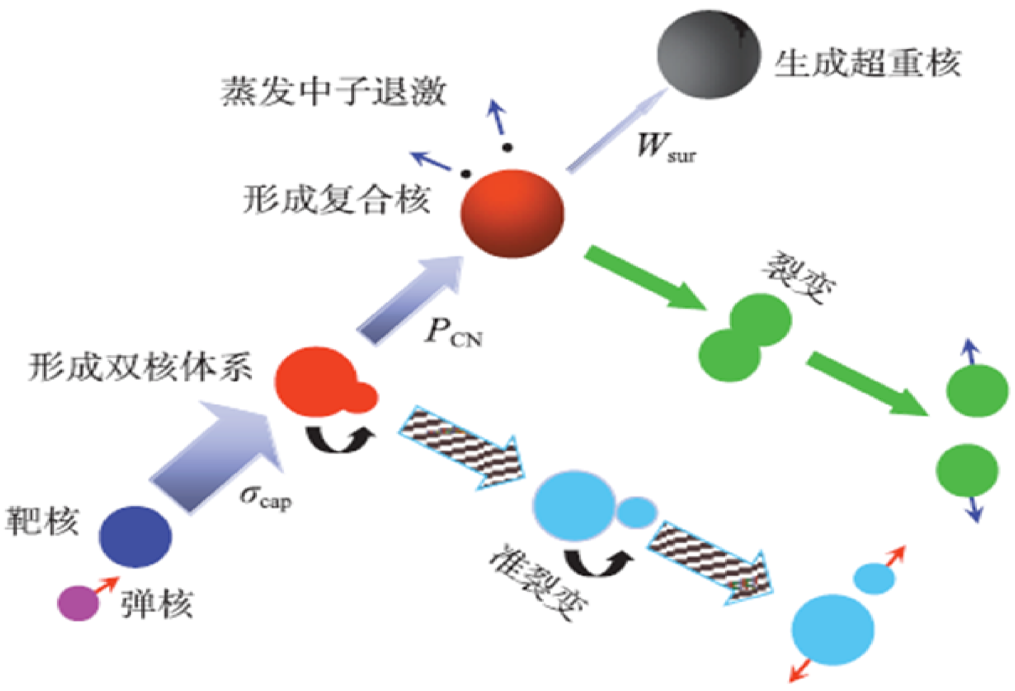
S. G. Zhou, Nucl. Phys. Rev 34, 318 (2017)



R. S. Naik et al, Phys. Rev. C76, 054604 (2007)

Background

Synthesis and identification of SHE involves the physical process



S. G. Zhou, Nucl. Phys. Rev 34, 318 (2017)

Content

Part I: cold and hot fusion

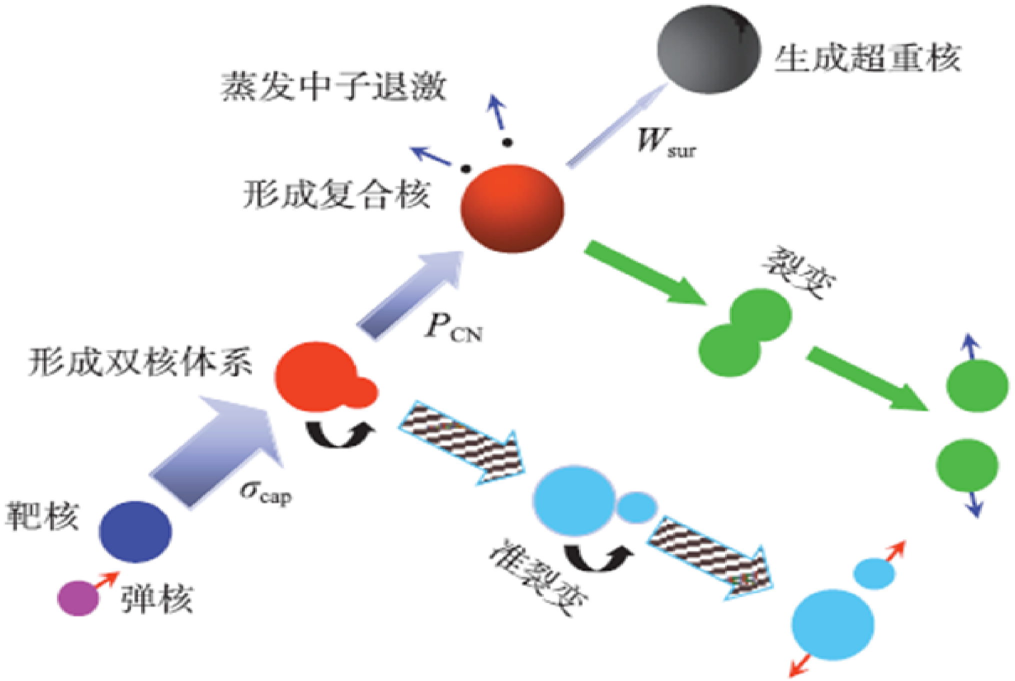
Part II: quasifission

Part III: fission

Part IV: alpha decay

Background

Synthesis and identification of SHE involves the physical process



S. G. Zhou, Nucl. Phys. Rev 34, 318 (2017)

Content

Part I: cold and hot fusion

Part II: quasifission

Part III: fission

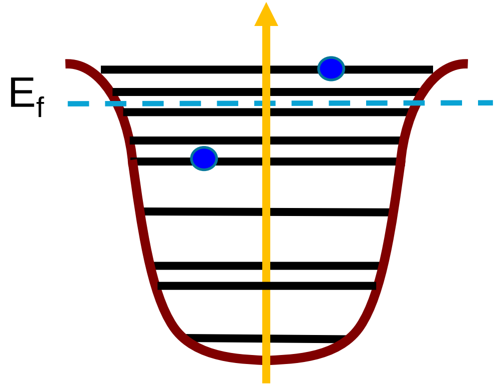
Part IV: alpha decay

Part V: multinucleon transfer reactions

time-dependent Hartree-Fock

$$S = \int_{t_1}^{t_2} \langle \Psi(t) | H - i\hbar\partial_t | \Psi(t) \rangle \, dt,$$

$$H = \sum_{i=1}^{A} t_i + \sum_{i<j}^{A} v_{ij}$$

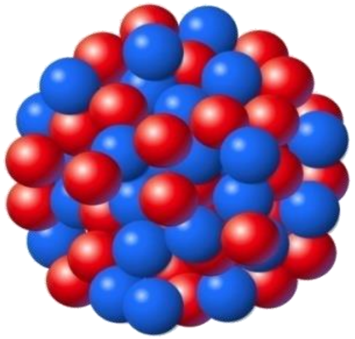


$$\Psi(r_1, r_2, \cdots, r_A, t) = \frac{1}{\sqrt{A!}} \det|\varphi_\lambda(r_i, t)|,$$

$$i\hbar \frac{\partial \varphi_\lambda}{\partial t} = h\varphi_\lambda$$

Advantages:

- **Fully microscopic, parameter-free theory in heavy-ion collisions;**
- **Nuclear structure and reactions in a unified framework (same EDF);**
- **Dynamical and quantum effects are automatically incorporated**;



Limitations:

- **Quantum tunneling is missing;**

Lu Guo, J. A. Maruhn, and P. G. Reinhard, Phys. Rev. C 76, 014601 (2007)
Lu Guo, J. A. Maruhn, and P. G. Reinhard, Phys. Rev. C 77, 041301(R) (2008)

Part I: cold and hot fusion dynamics

Theoretical framework for fusion evaporation reactions

Fusion evaporation reactions

$$\sigma_{\mathrm{ER}}(E_{\mathrm{c.m.}}, x) = \int_0^1 d\cos(\theta_P) \int_0^1 d\cos(\theta_T) \times \frac{\pi}{k^2} \sum_J (2J+1) T_J(E_{\mathrm{c.m.}}, \theta_T, \theta_P) \times P_{\mathrm{CN}}(\theta_P, \theta_T, E_{\mathrm{c.m.}}, J) W_{\mathrm{sur}}(E^*_{\mathrm{CN}}, x, J).$$

Theoretical framework for fusion evaporation reactions

Fusion evaporation reactions

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capture ⟷

$$\times \frac{\pi}{k^2} \sum_J (2J+1) T_J(E_{\rm c.m.}, \theta_T, \theta_P)$$

fusion and survival ⟷

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- Capture process: Schrodinger equation for penetration probability

$$\left[\frac{-\hbar^2}{2\mu}\frac{d^2}{dR^2} + \frac{J(J+1)\hbar^2}{2\mu R^2} + V_{\mathrm{DC\text{-}FHF}}(R) - E_{\mathrm{c.m.}}\right]\psi(R) = 0$$

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- Fusion Process: fusion-by-diffusion (FbD) model for fusion probability

$$P_{\mathrm{CN}}(\theta_P, \theta_T, E_{\mathrm{c.m.}}, J) = \frac{1}{2}\left[1 - \mathrm{erf}\left(\frac{\Delta V_J(\theta_P, \theta_T)}{T_J(\theta_P, \theta_T)}\right)\right],$$

Theoretical framework for fusion evaporation reactions

Fusion evaporation reactions

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- Survival Process: statistical model for survival probability

$$W_{\mathrm{sur}}(E^*_{\mathrm{CN}}, x, J) = P(E^*_{\mathrm{CN}}, x) \prod_i^x \left(\frac{\Gamma_n(E^*_i, J)}{\Gamma_n(E^*_i, J) + \Gamma_f(E^*_i, J)}\right),$$

Fusion dynamics involving halo nuclei

PHYSICAL REVIEW C **107**, L011601 (2023)

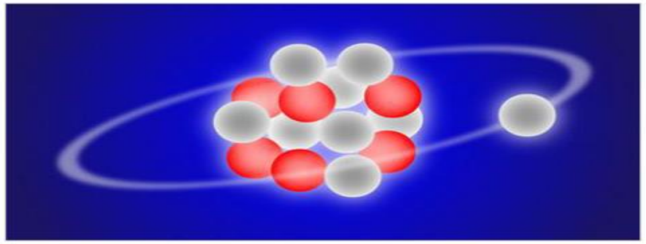
Letter | Featured in Physics

Letter发表、被Physics遴选为亮点工作同步报道

Microscopic study of fusion reactions with a weakly bound nucleus: Effects of deformed halo

Xiang-Xiang Sun (孙向向) and Lu Guo (郭璐)*
School of Nuclear Science and Technology, University of Chinese Academy of Sciences, Beijing 100049, China
and CAS Key Laboratory of Theoretical Physics, Institute of Theoretical Physics, Chinese Academy of Sciences, Beijing 100190, China

Physics ABOUT BROWSE PRESS COLLECTIONS



SYNOPSIS

Targeting a Nuclear Halo

January 4, 2023

New modeling explains the relatively high fusion reaction probabilities of halo nuclei, which are composed of a dense core surrounded by a "satellite" of one or two nucleons

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Physics SYNOPSIS

$^{14,15}C+^{232}Th$

Targeting a Nuclear Halo

New modeling explains the relatively high fusion reaction probabilities of halo nuclei, which are composed of a dense core surrounded by a "satellite" of one or two nucleons.

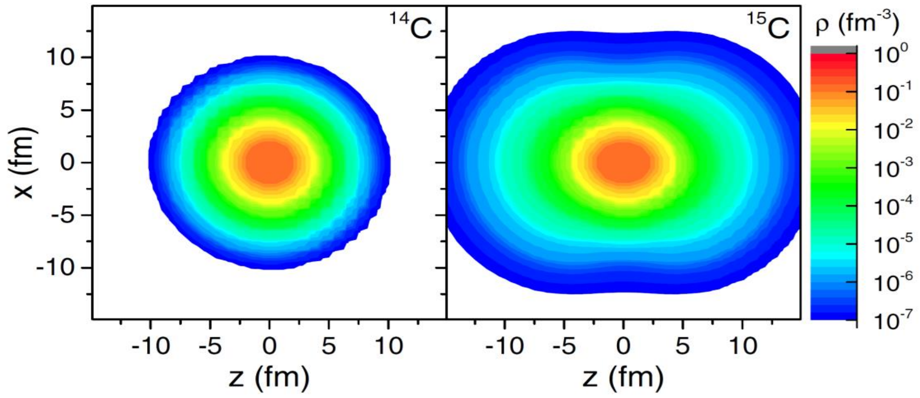
By Michael Schirber

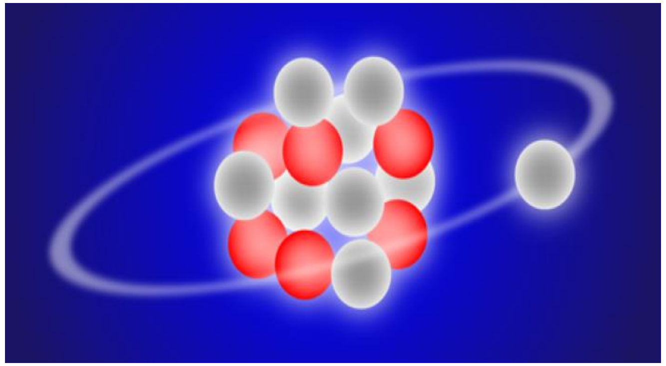
新的模型方法解释了晕核相对高的熔合反应几率…

X. X. Sun and Lu Guo, Phys. Rev. C 101, L011601 (2023); Schirber, Physics 16, s2 (2023)

Fusion dynamics involving halo nuclei

$^{14,15}C+^{232}Th$

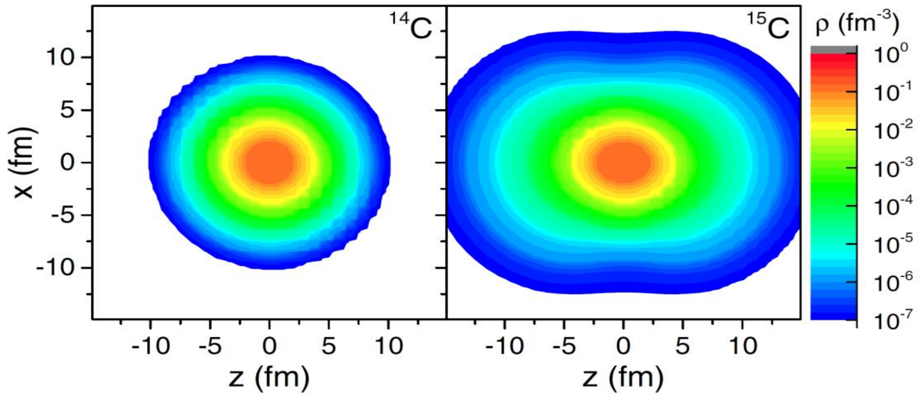


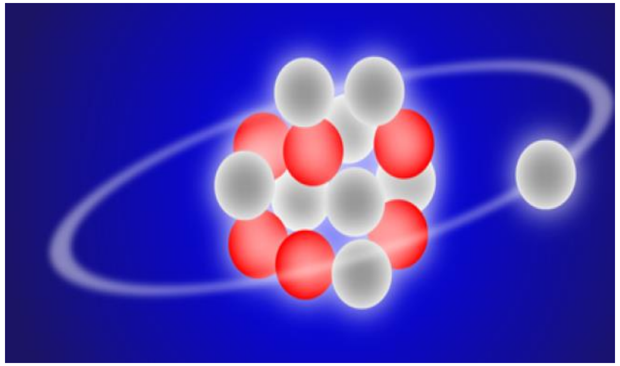


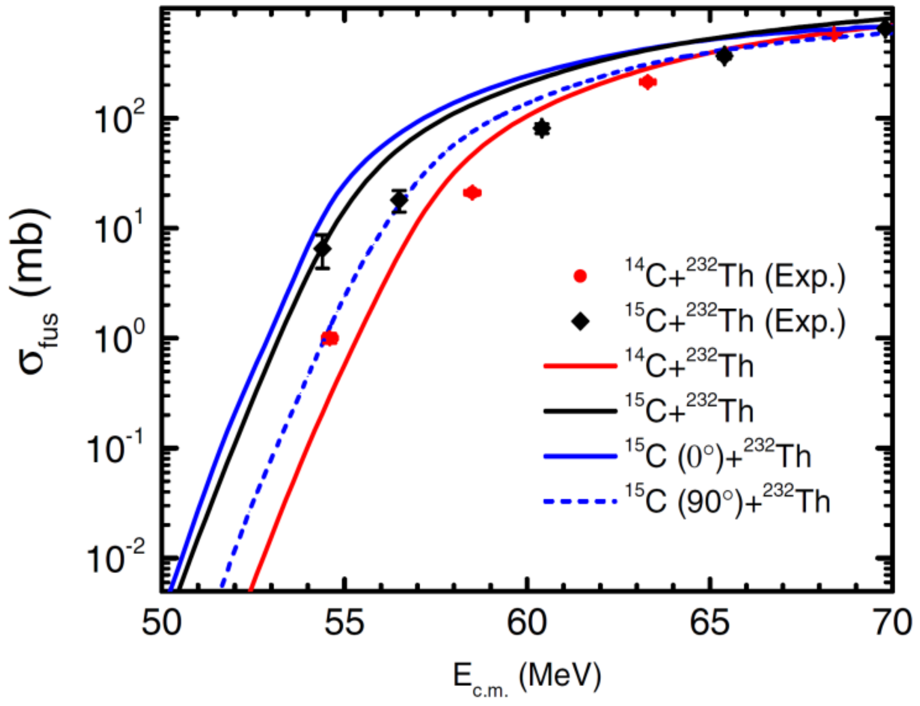
- Spherical neutron magic^{14}C, deformed one-neutron halo ^{15}C + ^{232}Th;

Fusion dynamics involving halo nuclei

$^{14,15}C+^{232}Th$



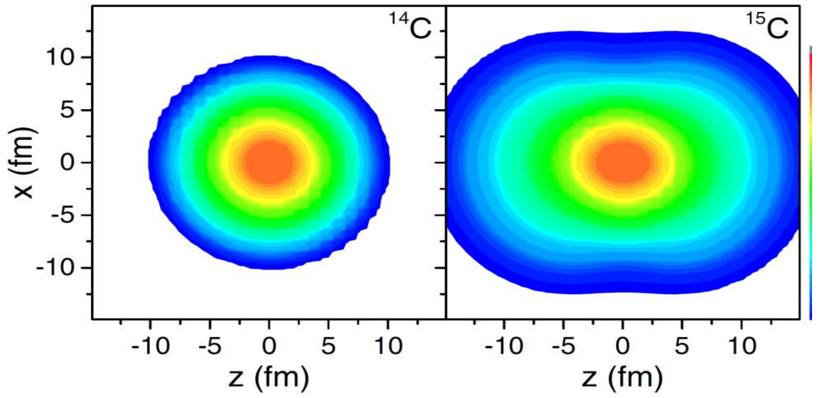


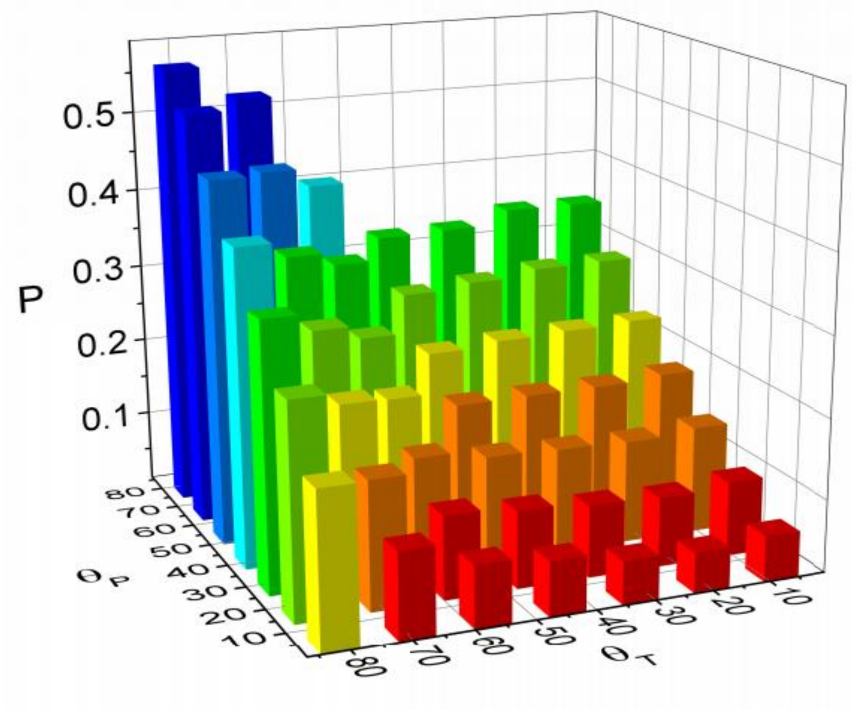


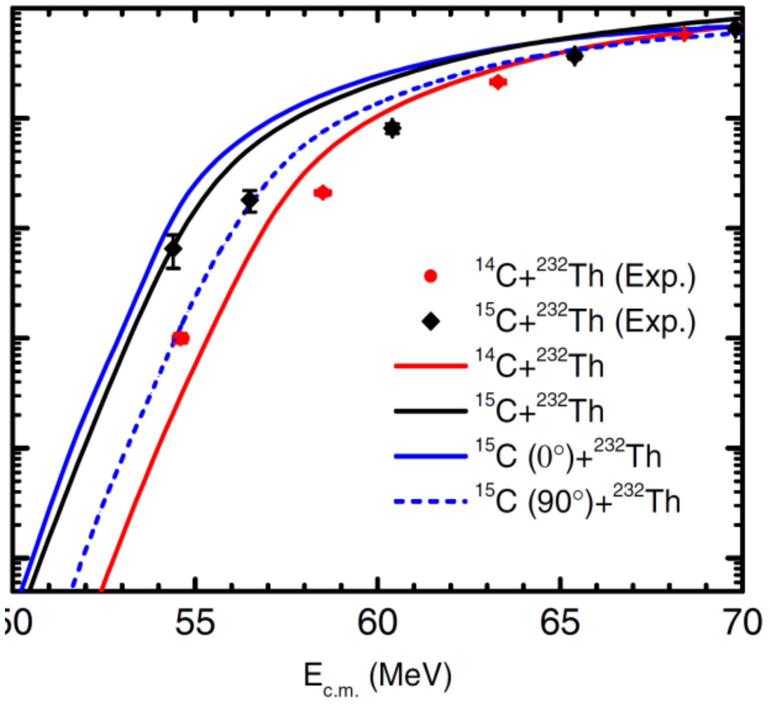
- Spherical neutron magic ^{14}C, deformed one-neutron halo ^{15}C + ^{232}Th;
- Parameter-free microscopic calculations well reproduce the enhancement of cross sections at sub-barrier; reveal the underlying mechanism of this enhancement, which is driven by the halo structure of ^{15}C;

Fusion dynamics involving halo nuclei

$^{14,15}C+^{232}Th$



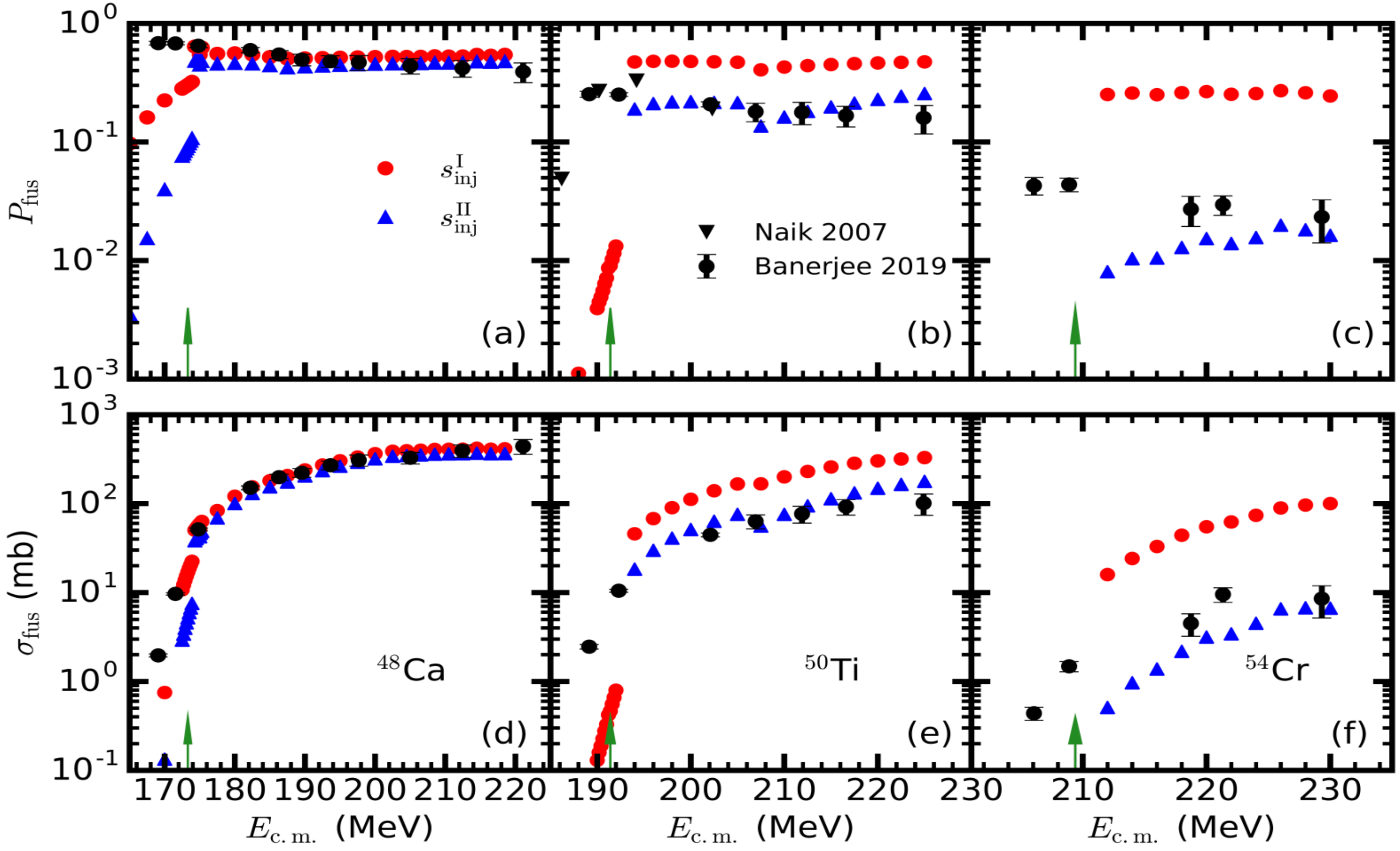




- Spherical neutron magic^{14}C, deformed one-neutron halo ^{15}C + ^{232}Th;
- Parameter-free microscopic calculations well reproduce the enhancement of cross sections at sub-barrier; reveal the underlying mechanism of this enhancement, which is driven by the halo structure of ^{15}C;
- One-neutron transfer probabilities are more sensitive to the orientations of 15C than 232Th;
- Notable effect of halo structure on reaction dynamics.

Cold fusion dynamics

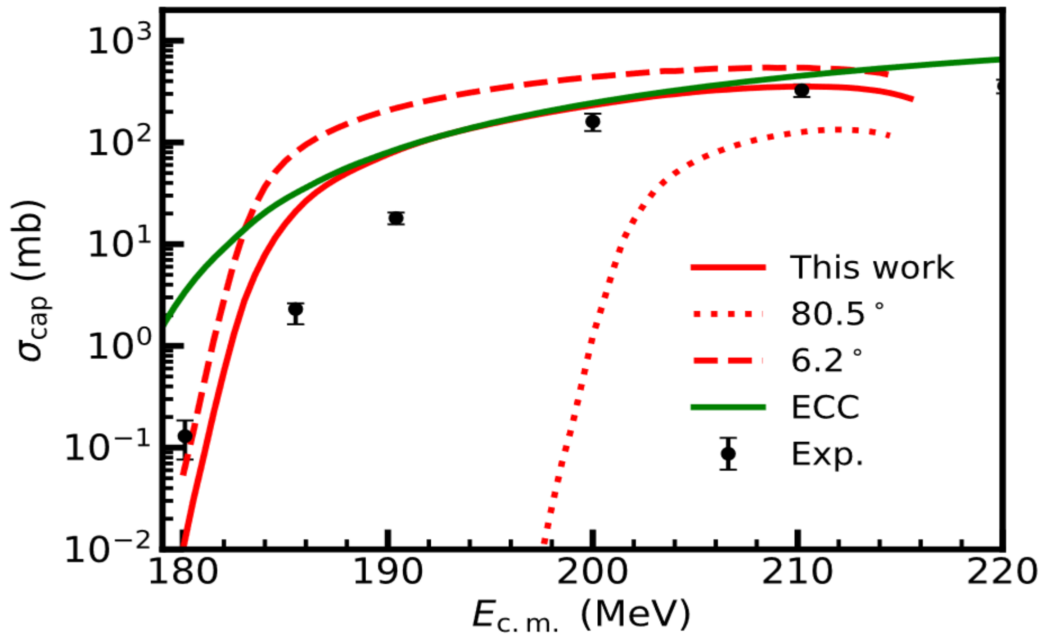
Compound-nucleus formation in cold-fusion reactions ^{48}Ca, ^{50}Ti, ^{54}Cr+^{208}Pb



- Above the capture barrier, our calculations reproduce the measured fusion probability reasonably well.
- The restrictions from microscopic dynamics theory TDHF improve the predictive power of coupled-channels and diffusion calculation

X. X. Sun and Lu Guo, Phys. Rev. C 105, 054610 (2022)

Hot fusion dynamics



PHYSICAL REVIEW C **107**, 064609 (2023)

Editors' Suggestion

编辑推荐

Microscopic study of the hot-fusion reaction $^{48}Ca + ^{238}U$ with the constraints from time-dependent Hartree-Fock theory

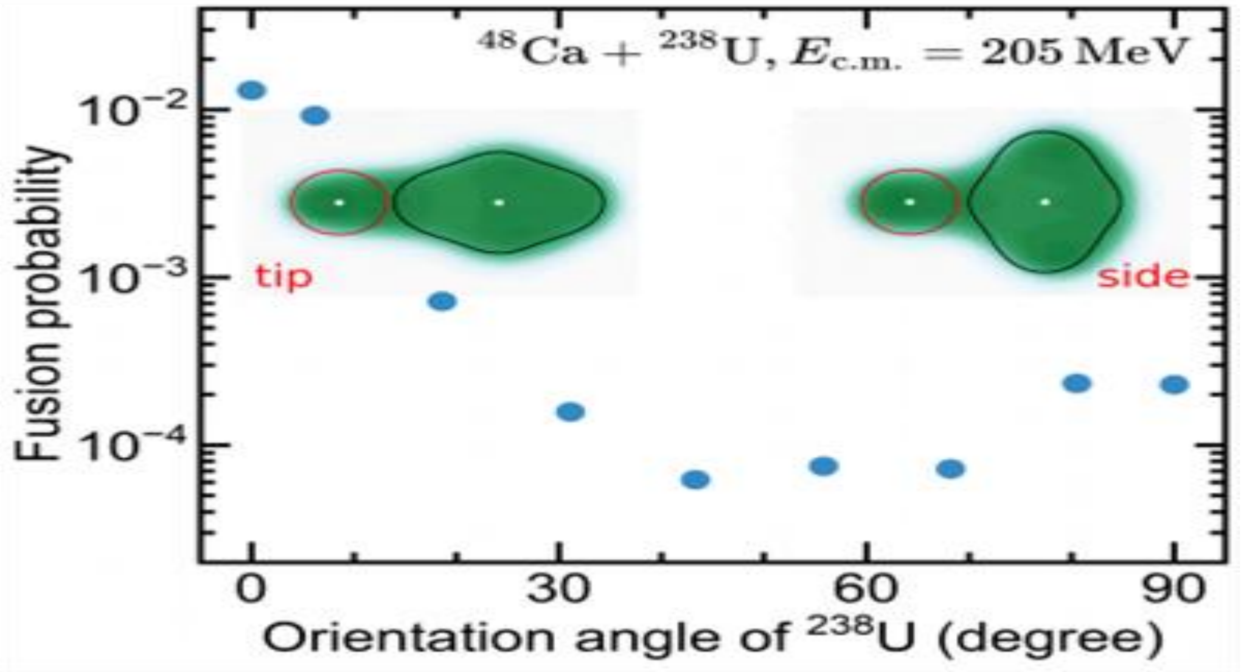
Xiang-Xiang Sun (孙向向) and Lu Guo (郭璐)*

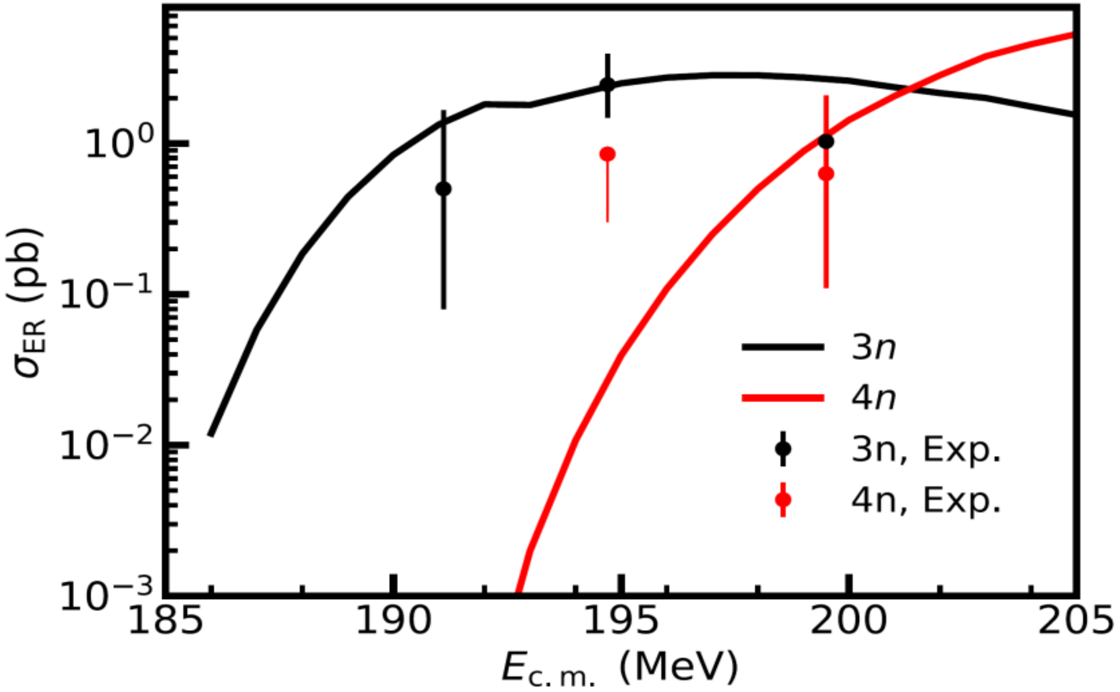
School of Nuclear Science and Technology, University of Chinese Academy of Sciences, Beijing 100049, China and CAS Key Laboratory of Theoretical Physics, Institute of Theoretical Physics, Chinese Academy of Sciences, Beijing 100190, China

- The orientation effects of U are self-consistently included in the capture and fusion processes
- The calculated capture cross sections agree well with the experimental data.
- The capture cross sections are strongly dependent on the orientations with several orders of magnitude

X. X. Sun and Lu Guo, Phys. Rev. C 107, 064609 (2023)

Hot fusion dynamics





- The TDHF evolutions with different orientations and incident energies are used to extract the injection distance, which is the only input of the fusion-by-diffusion model for fusion probabilities.
- The fusion probabilities are strongly dependent on the orientations and the present calculations without any free parameters show that the tip-orientation collision is favorable for both the capture process and the formation of compound nucleus
- our calculations reproduce the experimental evaporation-residue cross sections

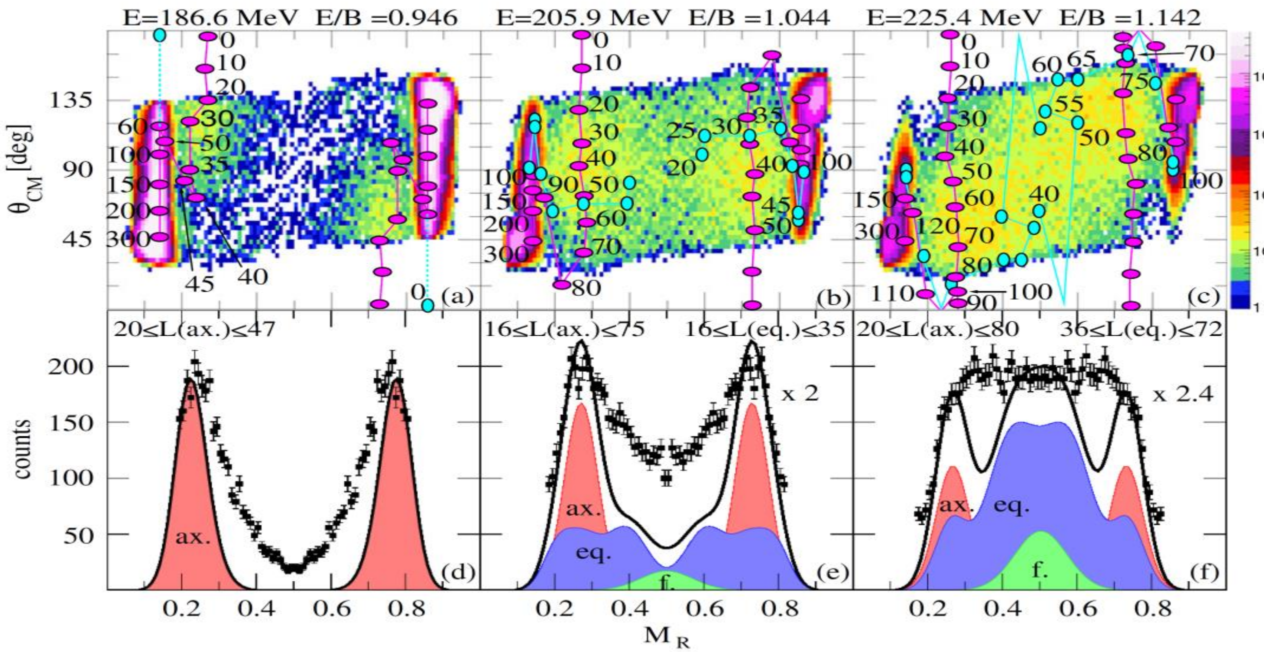
X. X. Sun and Lu Guo, Phys. Rev. C 107, 064609 (2023)

Part II: quasifission

Quasifission dynamics

Quasifission is the main reaction channel hindering the SHE formation

$^{40,48}Ca+^{238}U$ PRL113,182502 (2014)



$^{48}Ti+^{238}U$ PRL119,222502 (2017)

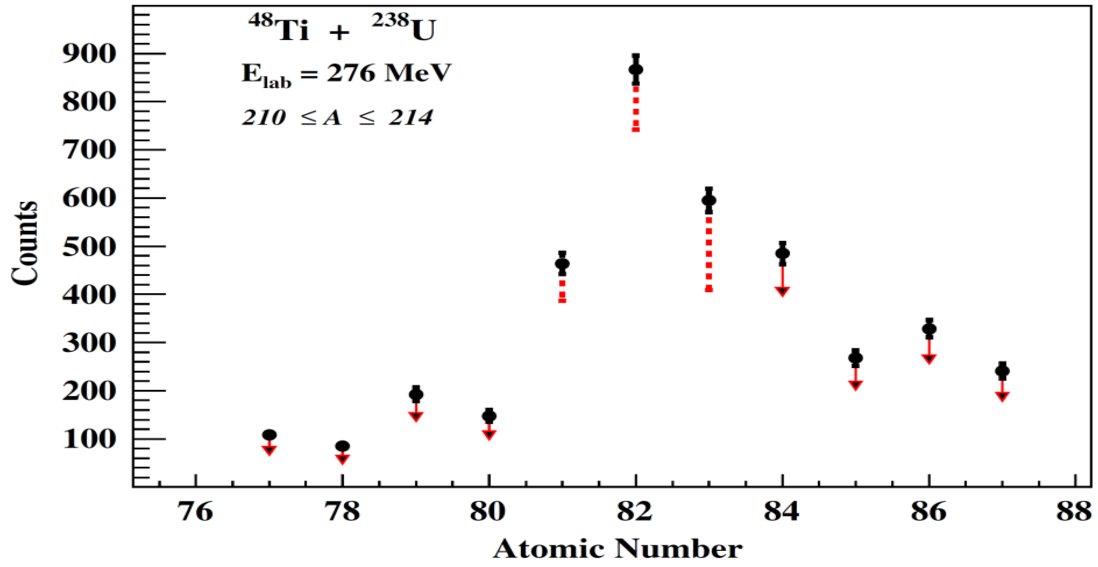


FIG. 5. Atomic number distribution for the quasifission fragments with $210 \le A \le 214$ (see the text for details).

- Experimental indication of shell effects initially came from mass-yield measurements;
- To unambiguously confirm shell effects, proton or neutron numbers distributions have to be measured;
- Atomic number distribution in the fragments have been measured, confirming the role of Z=82 magic shell;

Quasifission dynamics

First evidence for the impact of tensor force on the dynamical shell effects

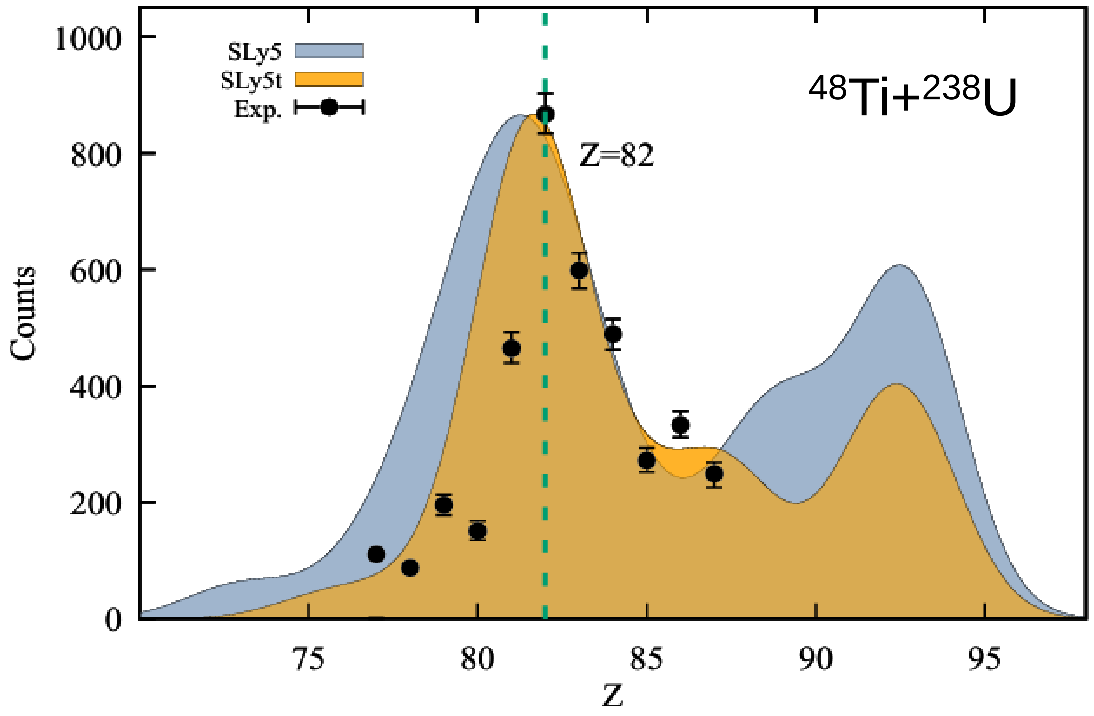


FIG. 9. Charge distribution for the quasifission reactions of ^{48}Ti$+^{238}$U using the SLy5 and SLy5t forces. The experimental data is from [26].

$$\sigma_\lambda \propto \int_{b_{\min}}^{b_{\max}} b\,\mathrm{d}b \int_0^{\frac{\pi}{2}} \mathrm{d}\beta \sin(\beta) P_b^{(\lambda)}(\beta) \ ,$$

- the parameter-free microscopic TDHF study;
- the charge distribution shows much better agreement with experiments for the SLy5t
- the prominence of shell effects is manifested not only through shifts in peak positions but also through narrower yield distributions

L. Li, Lu Guo, K. Godbey, A. S. Umar, Phys. Lett. B 833,137349 (2022)

L. Li, Lu Guo, K. Godbey, A. S. Umar, Phys. Rev. C (in press)

Quasifission dynamics

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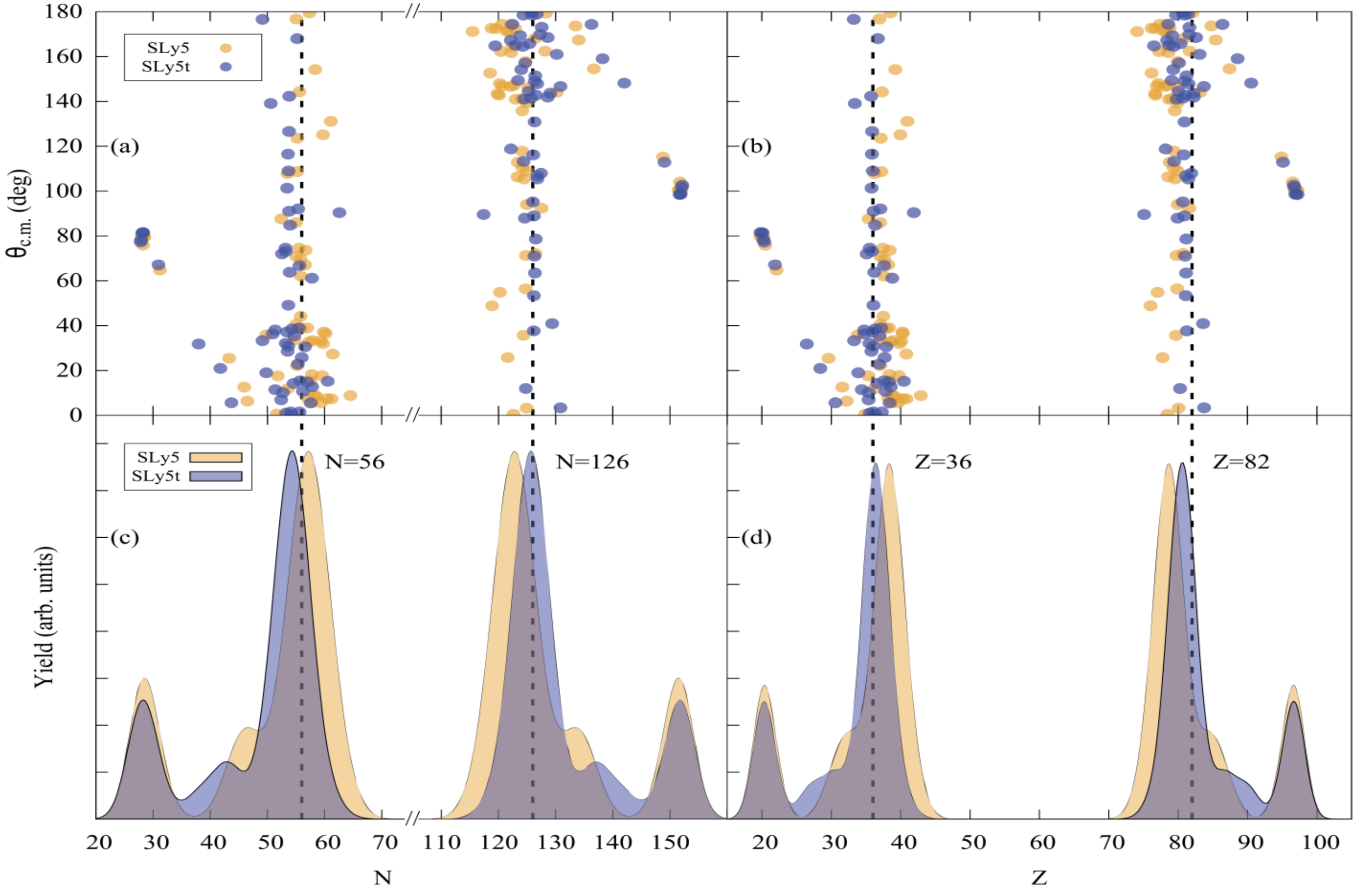


$^{48}Ca+^{249}Bk$

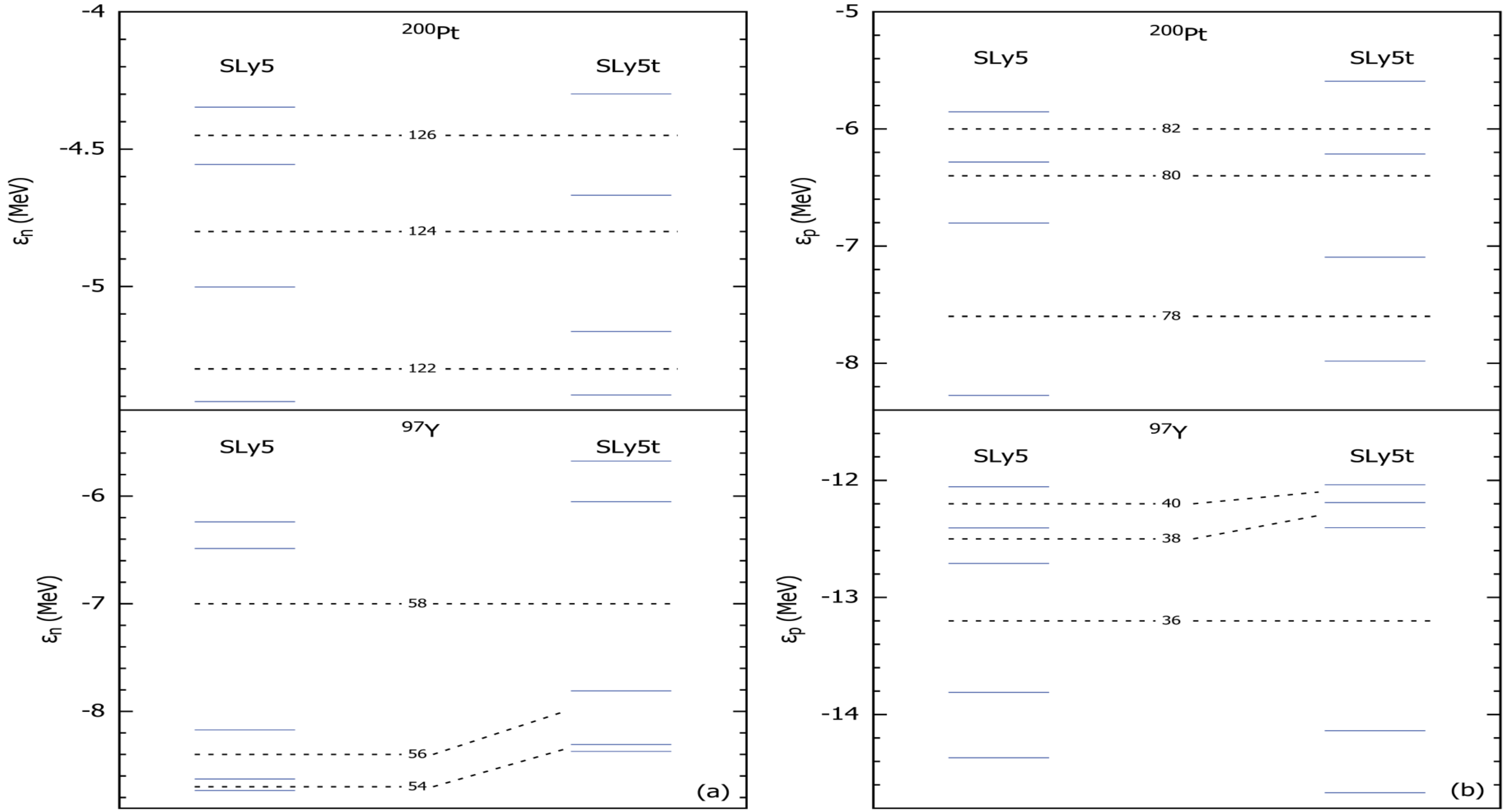
The inclusion of tensor force causes the spherical shell effects to become more prominent at Z=82, N=126

L. Li, Lu Guo, K. Godbey, A. S. Umar, Phys. Lett. B 833,137349 (2022)

L. Li, Lu Guo, K. Godbey, A. S. Umar, Phys. Rev. C (in press)

Quasifission dynamics

First evidence that tensor force not only influences shell evolution in nuclear structure, but also in quasifission dynamics



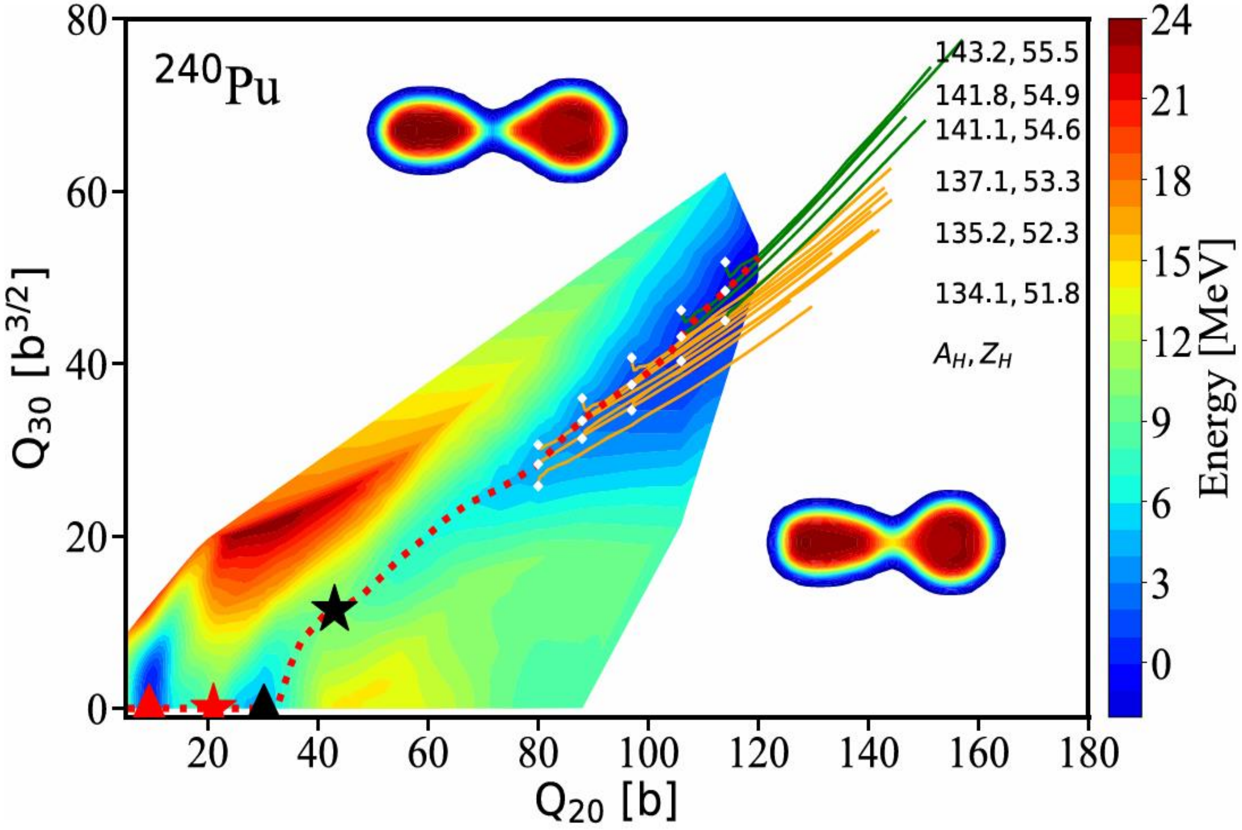
L. Li, Lu Guo, K. Godbey, A. S. Umar, Phys. Lett. B 833,137349 (2022)

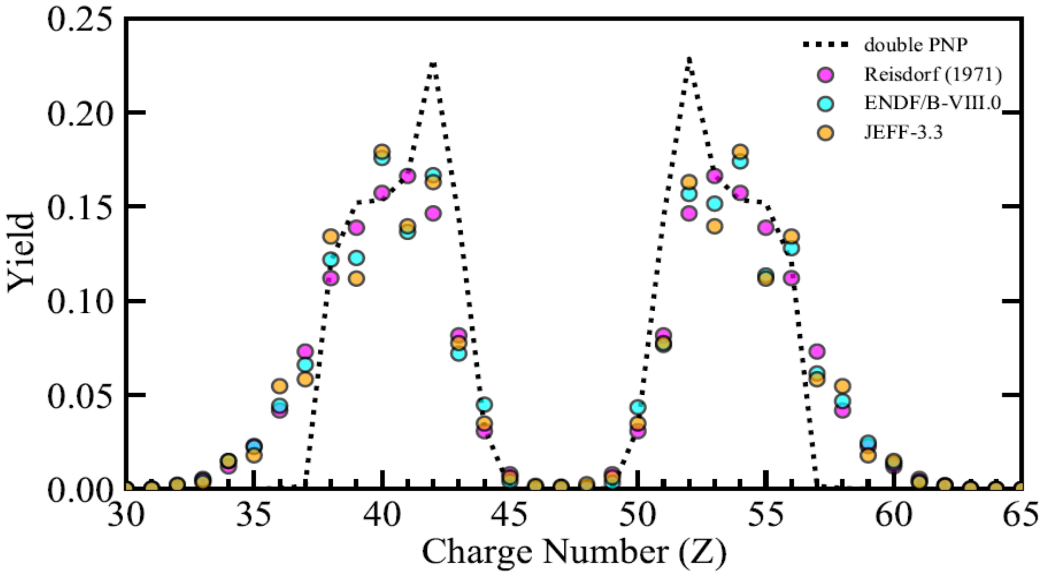
L. Li, Lu Guo, K. Godbey, A. S. Umar, Phys. Rev. C (in press)

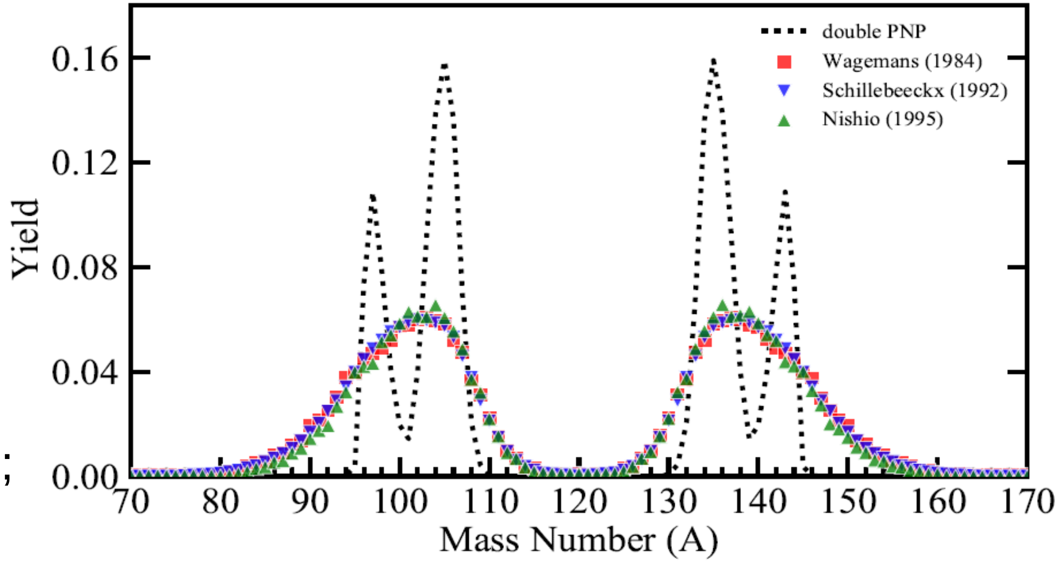
Outline

Part III: fission

Fission dynamics

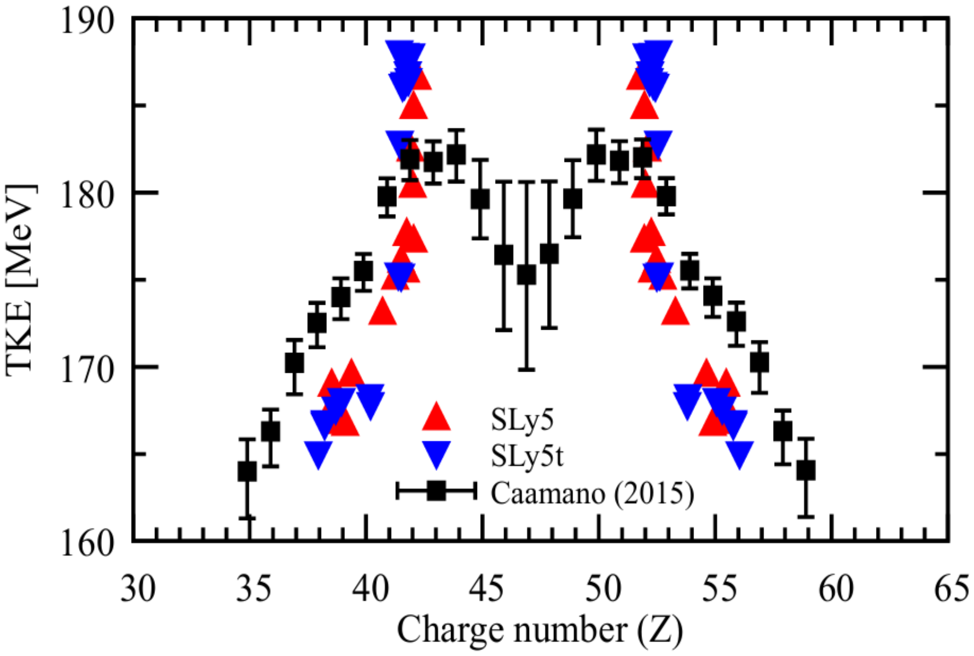


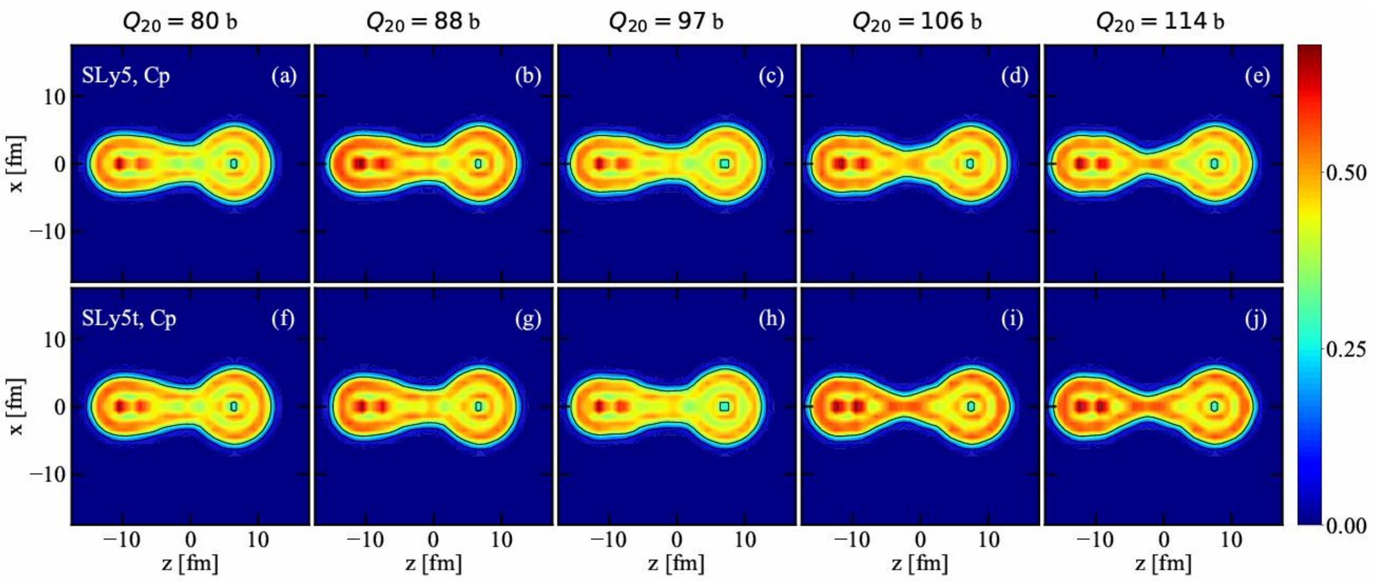




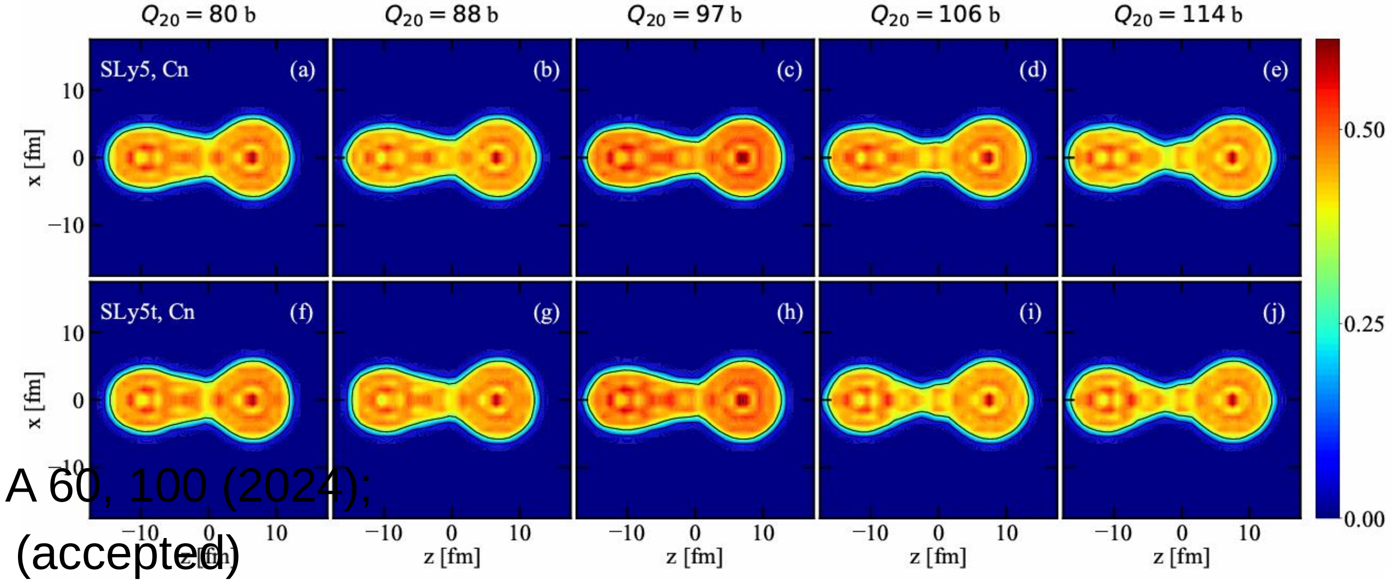
Y. Huang, X. X. Sun, and Lu Guo, Eur. Phys. J. A 60, 100 (2024);
Y. Huang, X. X. Sun, and Lu Guo, Phys. Rev. C (accepted)

Fission dynamics





igure 6. The proton localization functions C_p for five configurations along the static fission pathway. The corresponding quadrupole moments e displayed on the top of each column. The upper panel shows the results with SLy5 and the bottom panel for SLy5t.



Y. Huang, X. X. Sun, and Lu Guo, Eur. Phys. J. A 60, 100 (2024);
Y. Huang, X. X. Sun, and Lu Guo, Phys. Rev. C (accepted)

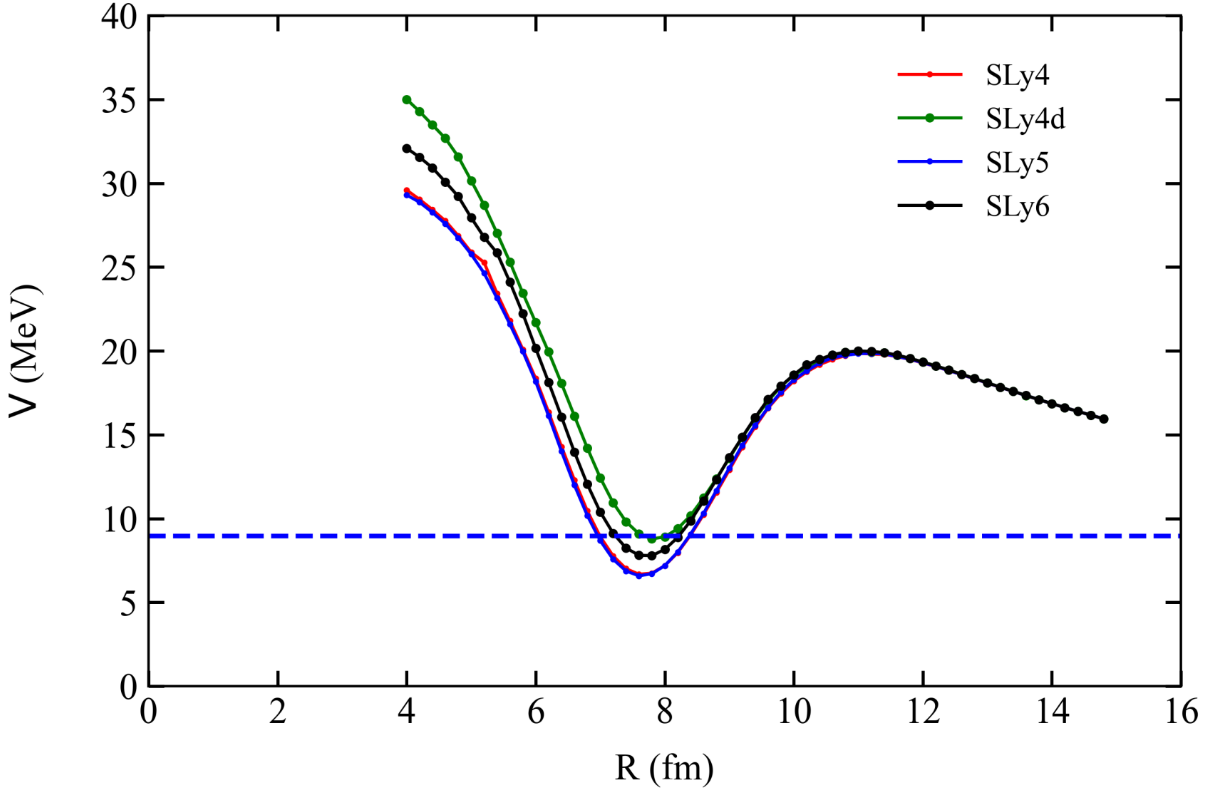
Figure 7. Similar to Fig. 6 but for the neutron localization functions C_n.

Part IV: alpha decay

Half-life of α decay

Preliminary

α + ^{208}Pb   DC-TDHF



$$T_{1/2} = \frac{\hbar \ln 2}{\Gamma}$$

$$\Gamma_\alpha = PF\frac{\hbar^2}{4\mu}\exp\left[-2\int_{r_2}^{r_3} dr k(r)\right],$$

$$k(r) = \sqrt{\frac{2\mu}{\hbar^2}|Q - V(r)|}.$$

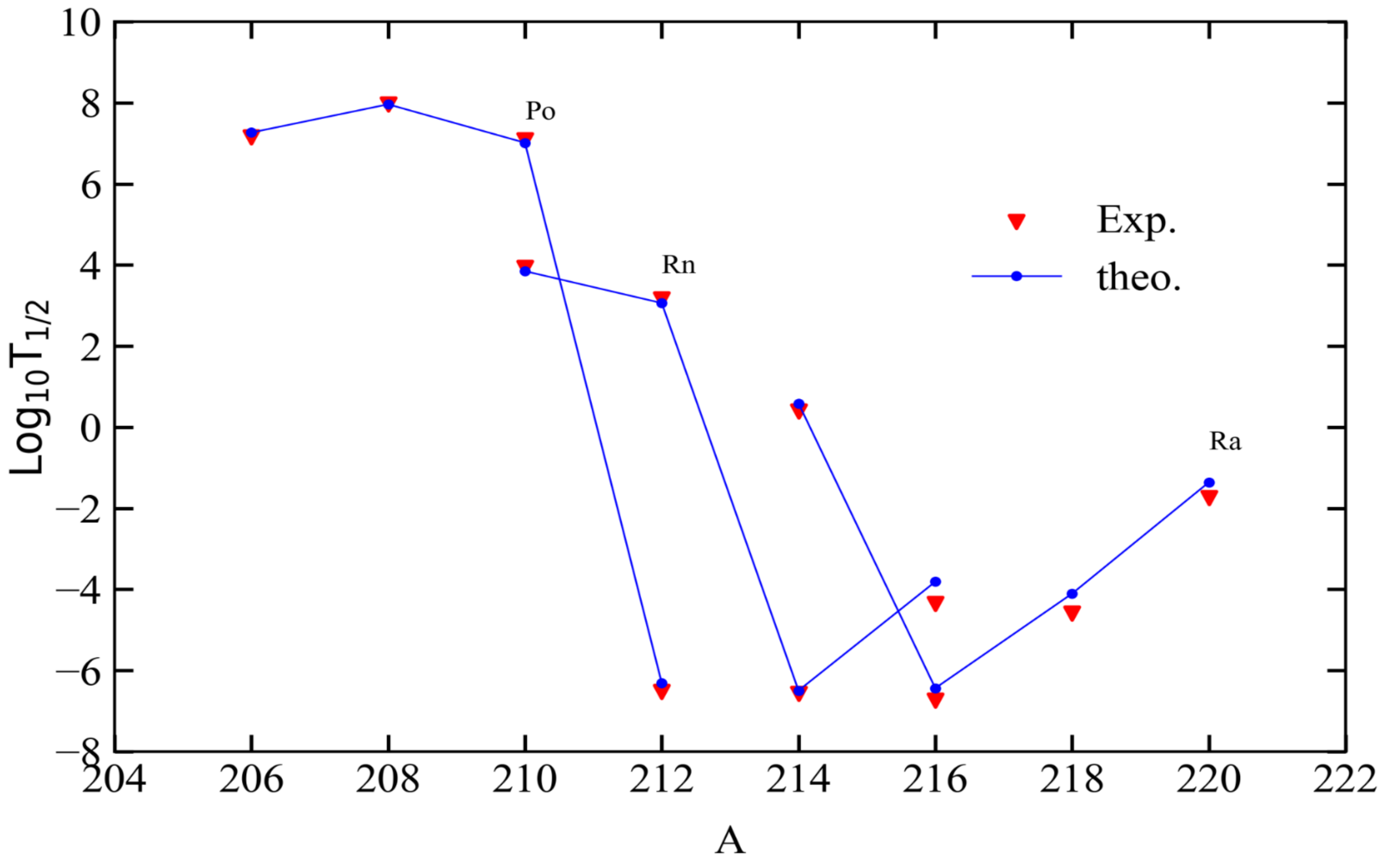
Buck et al, Phys. Rev. Lett. 65, 2975 (1990)

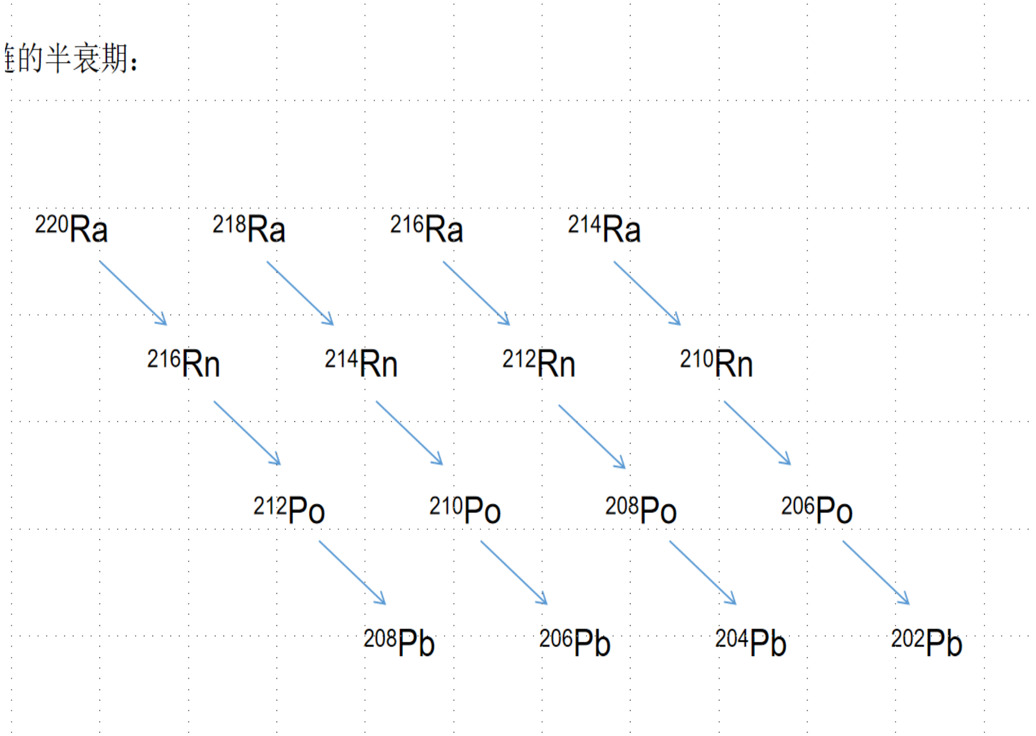
S. C. Li and Lu Guo, Phys. Rev. C (in preparation)

Half-life of α decay

Preliminary

$\alpha + {}^{208}Pb$ DC-TDHF





S. C. Li and Lu Guo, Phys. Rev. C (in preparation)

Part V: multinucleon transfer reaction

Multinucleon transfer reaction

production of new exotic nuclei via multi-nucleon transfer reaction

PHYSICAL REVIEW C **91**, 064615 (2015)

^{136}Xe + ^{208}Pb reaction: A test of models of multinucleon transfer reactions

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(Received 28 February 2015; published 22 June 2015)

The yields of over 200 projectile-like fragments (PLFs) and target-like fragments (TLFs) from the interaction ($E_{c.m.}$ = 450 MeV) ^{136}Xe with a thick target of ^{208}Pb were measured using Gammasphere and off-line γ-ray

ARGONE

VOLUME 43, NUMBER 20 PHYSICAL REVIEW LETTERS 12 NOVEMBER 1979

Three-Particle Exclusive Measurements of the Reactions ^{238}U + ^{238}U and ^{238}U + ^{248}Cm

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Physikalisches Institut der Universität Heidelberg, D-6900 Heidelberg, Federal Republic of Germany

PHYSICAL REVIEW C **88**, 054615 (2013)

Reexamining the heavy-ion reactions ^{238}U + ^{238}U and ^{238}U + ^{248}Cm and actinide production close to the barrier

J. V. Kratz,* M. Schädel,† and H. W. Gäggeler‡
Gesellschaft für Schwerionenforschung mbH, 64291 Darmstadt, Germany
(Received 19 July 2013; revised manuscript received 18 October 2013; published 20 November 2013)

Recent theoretical work has renewed interest in radiochemically determined isotope distributions in reactions of ^{238}U projectiles with heavy targets that had previously been published only in parts. These data are being reexam-

GSI

PRL **115**, 172503 (2015) PHYSICAL REVIEW LETTERS week ending 23 OCTOBER 20

Pathway for the Production of Neutron-Rich Isotopes around the $N = 126$ Shell Closure

Y. X. Watanabe,[1,*] Y. H. Kim,[2,3,†] S. C. Jeong,[1,‡] Y. Hirayama,[1] N. Imai,[1,§] H. Ishiyama,[1,‡] H. S. Jung,[1] H. Miyatake, S. Choi,[2,3] J. S. Song,[2,3,4] E. Clement,[5] G. de France,[5] A. Navin,[5,‖] M. Rejmund,[5] C. Schmitt,[5] G. Pollarolo,[6] L. Corradi E. Fioretto,[7] D. Montanari,[8] M. Niikura,[9,¶] D. Suzuki,[9,**] H. Nishibata,[10] and J. Takatsu[10]
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[7]*Istituto Nazionale di Fisica Nucleare, Laboratori Nazionali di Legnaro, I-35020 Legnaro, Italy*
[8]*Dipartimento di Fisica, Università di Padova, and Istituto Nazionale di Fisica Nucleare, I-35131 Padova, Italy*
[9]*Institut de Physique Nucléaire (IPN), IN2P3-CNRS, F-91406 Orsay Cedex, France*
[10]*Department of Physics, Osaka University, Osaka 560-0043, Japan*
(Received 26 June 2015; published 23 October 2015)

Absolute cross sections for isotopically identified products formed in multinucleon transfer in the ^{136}Xe + ^{198}Pt system at ~8 MeV/nucleon are reported. The isotopic distributions obtained using a large

KEK

PHYSICAL REVIEW C **86**, 044611 (2012)

Mass distributions of the system ^{136}Xe + ^{208}Pb at laboratory energies around the Coulomb barr A candidate reaction for the production of neutron-rich nuclei at $N = 126$

E. M. Kozulin,[1] E. Vardaci,[2] G. N. Knyazheva,[1] A. A. Bogachev,[1] S. N. Dmitriev,[1] I. M. Itkis,[1] M. G. Itkis,[1] A. G. Knyaz T. A. Loktev,[1] K. V. Novikov,[1] E. A. Razinkov,[1] O. V. Rudakov,[1] S. V. Smirnov,[1] W. Trzaska,[3] and V. I. Zagrebaev[1]
[1]*Flerov Laboratory of Nuclear Reaction, Joint Institute for Nuclear Research, 141980 Dubna, Moscow region, Russia*
[2]*Dipartimento di Scienze Fisiche dell'Universitá degli Studi di Napoli "Federico II" and Istituto Nazionale di Fisica Nucleare, Sezione di Napoli, Napoli, Italy*
[3]*Department of Physics, University of Jyväskylä, Jyväskylä, Finland*
(Received 23 May 2012; revised manuscript received 13 August 2012; published 10 October 2012)

Reaction products from the system ^{136}Xe + ^{208}Pb at ^{136}Xe ions laboratory energies of 700, 870, and 1020 MeV were studied by two-body kinematics and by a catcher-foil activity analysis to explore the theoretically proposed suitability of such reaction as a means to produce neutron-rich nuclei in the neutron shell closure N = 126. Cross

DUBNA

Multinucleon transfer reaction

MNT may be the promising way in…, which are difficult to be produced by other methods.

PRL **115,** 172503 (2015) PHYSICAL REVIEW LETTERS week ending 23 OCTOBER 2015

Pathway for the Production of Neutron-Rich Isotopes around the $N = 126$ Shell Closure

Y. X. Watanabe,[1,*] Y. H. Kim,[2,3,†] S. C. Jeong,[1,‡] Y. Hirayama,[1] N. Imai,[1,§] H. Ishiyama,[1,‡] H. S. Jung,[1] H. Miyatake,[1] S. Choi,[2,3] J. S. Song,[2,3,4] E. Clement,[5] G. de France,[5] A. Navin,[5,||] M. Rejmund,[5] C. Schmitt,[5] G. Pollarolo,[6] L. Corradi,[7] E. Fioretto,[7] D. Montanari,[8] M. Niikura,[9,¶] D. Suzuki,[9,**] H. Nishibata,[10] and J. Takatsu[10]
[1]*Institute of Particle and Nuclear Studies, High Energy Accelerator Research Organization (KEK), Tsukuba, Ibaraki 305-0801, Japan*
[2]*Department of Physics and Astronomy, Seoul National University, Seoul 08826, Korea*

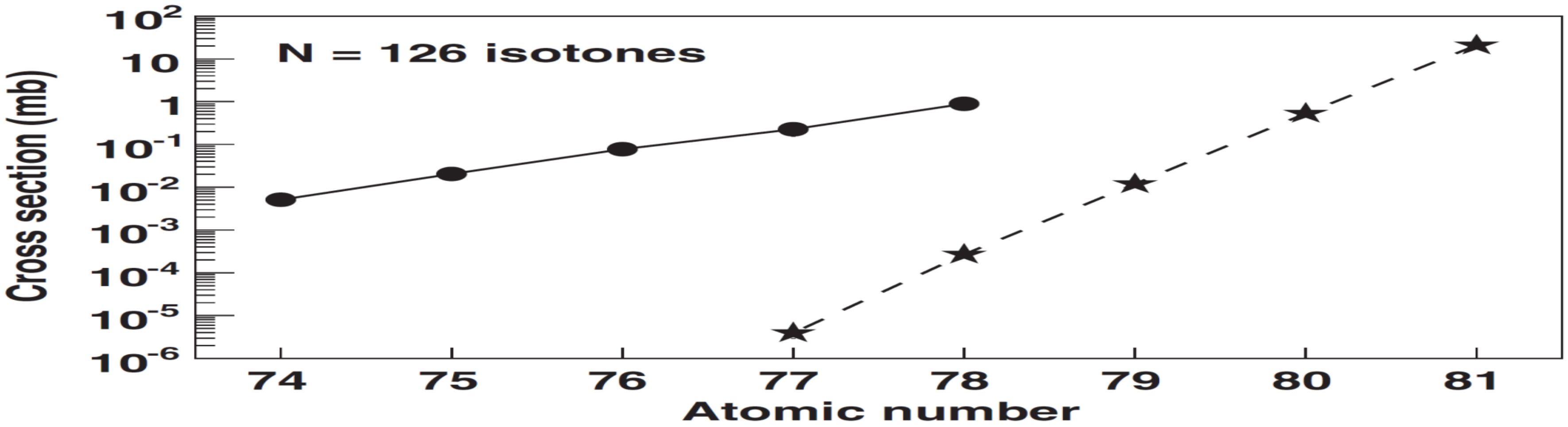

FIG. 4. Experimentally deduced cross sections for the production of the $N = 126$ isotones as a function of the atomic number. The filled circles are from the present work and the filled stars are from the fragmentation of ^{208}Pb(1 GeV/nucleon) + Be [28]. The solid and dashed lines are to guide the eye.

Multinucleon transfer reaction

TDHF studies of multi-nucleon transfer reaction

TDHF gives the average number of transferred nucleons for all reaction channels.

How to obtain the transferred nucleon number for each reaction channel?

Multinucleon transfer reaction

TDHF studies of multi-nucleon transfer reaction

TDHF gives the average number of transferred nucleons for all reaction channels

How to obtain the transferred nucleon number for each reaction channel?

particle number projection method (PNP)

particle number projection operator:

$$\hat{P}_n = \frac{1}{2\pi}\int_0^{2\pi} d\theta e^{i(n-\hat{N}_{V_P})\theta}$$

transfer probability for each channel:

$$P_n = \langle \Psi | \hat{P}_n | \Psi \rangle$$

transfer cross sction of primary products:

(TDHF+PNP)

$$\sigma_{N,Z}(E) = 2\pi \int_{b_{\min}}^{b_{\text{cut}}} b P_{N,Z}(b,E)\, db$$

C. Simenel, Phys. Rev. Lett. **105**, 192701 (2010)

Multinucleon transfer reaction

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transfer cross sction of primary products:

(TDHF+PNP)

$$\sigma_{N,Z}(E) = 2\pi \int_{b_{\min}}^{b_{\text{cut}}} b P_{N,Z}(b,E)\, db$$

Statistical decay method (GEMINI++)

direct comparison with experimental measurement

$$P_{N',Z'} = \sum_{N \geq N'} \sum_{Z \geq Z'} P_{N,Z} P_{\text{decay}}(E^*_{N,Z}, J_{N,Z}, N, Z; N', Z')$$

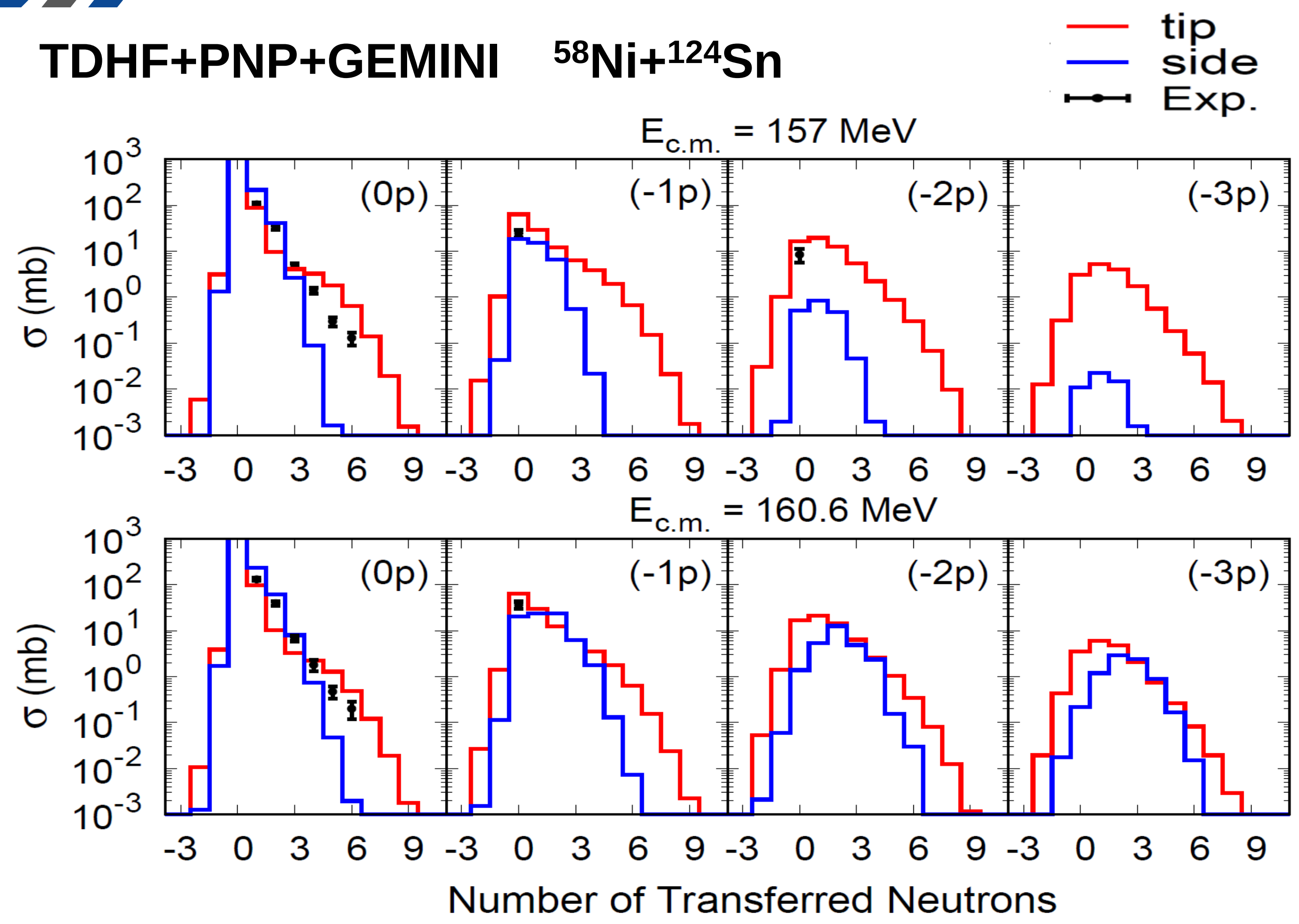
transfer cross section of secondary products:

(TDHF+PNP+GEMINI)

$$\sigma_{N',Z'}(E) = 2\pi \int_{b_{\min}}^{b_{\text{cut}}} b P_{N',Z'}(b,E)\, db$$

Multinucleon transfer reaction

TDHF+PNP+GEMINI $^{58}Ni+^{124}Sn$

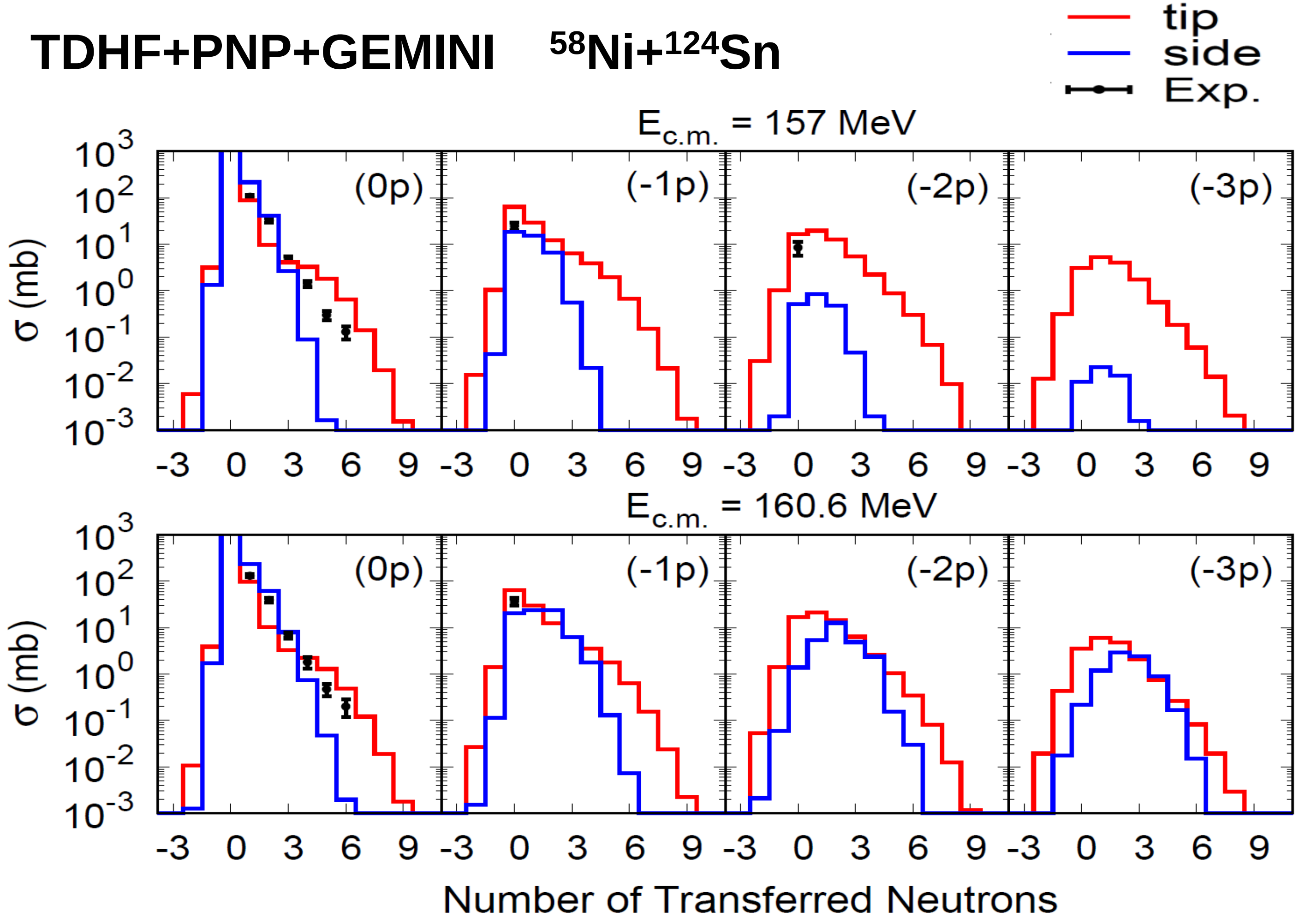


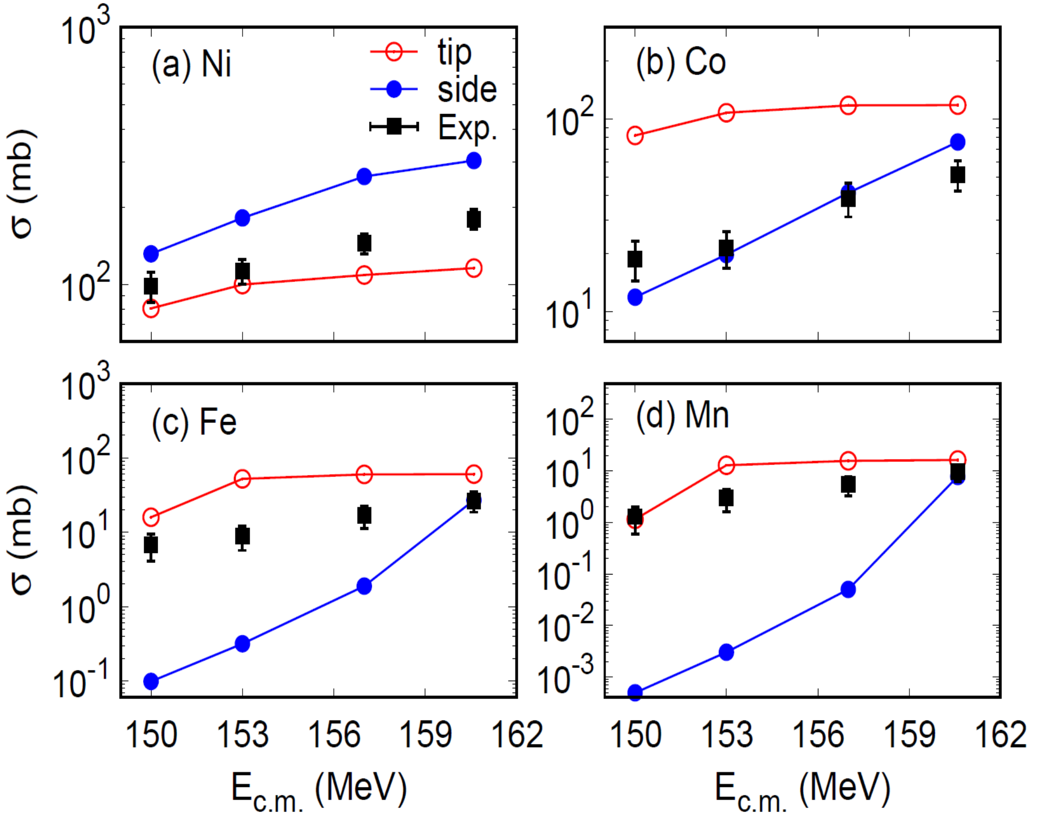
- Parameter-free and fully microscopic calculations;
- TDHF+PNP+GEMINI method well accounts for the experiment.;

Z. J. Wu and Lu Guo, Phy. Rev. C 100, 014612 (2019)

Multinucleon transfer reaction

TDHF+PNP+GEMINI $^{58}Ni+^{124}Sn$





- Parameter-free and fully microscopic calculations;
- TDHF+PNP+GEMINI method well accounts for the experiment.;

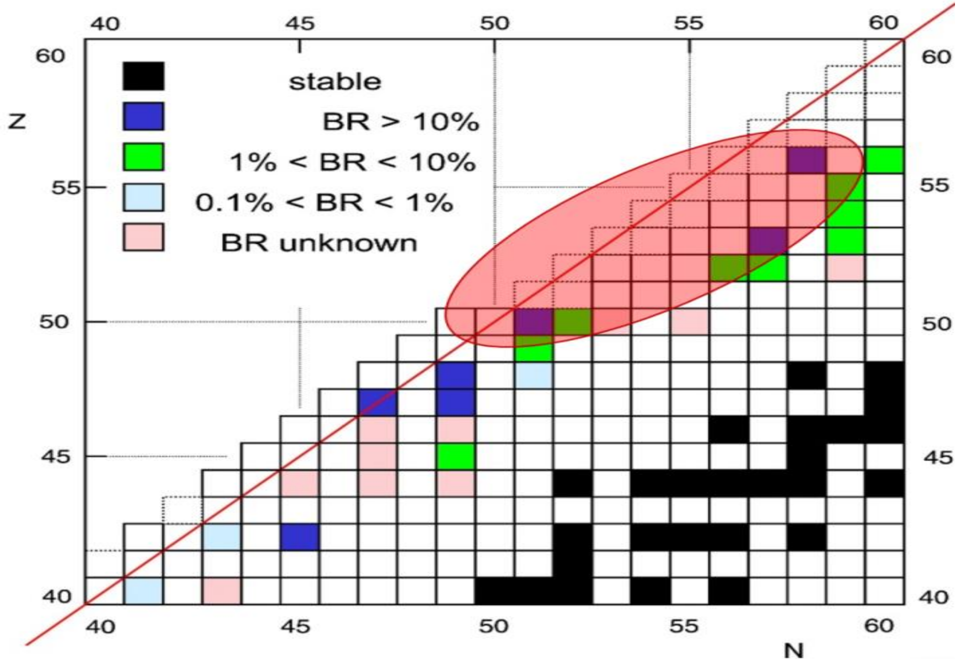
Z. J. Wu and Lu Guo, Phy. Rev. C 100, 014612 (2019)

Multinucleon transfer reaction

Production of proton-rich nuclei in ^{100}Sn region

- ^{100}Sn has an unexpected large Gamow-Teller strength measured ;
- Experiments identify a new island of cluster radioactivity;
- End point of astrophysical rp-process (Sn-Sb-Te cycle);

Nature 486, 341 (2012);
PRL116, 162501 (2016);
PRL 97, 082501 (2006);
PRL121, 182501 (2018);



Conventional experimental methods:

- Fragmentation process
- Fusion-evaporation reaction

- Fusion: ^{54}Fe(^{58}Ni,4n)^{108}Xe, ^{108}Xe→^{104}Te→^{100}Sn α-decay chain;
- The production cross section of ^{108}Xe is less than 1nb;

  PRL121, 182501 (2018);

→ Explore new possibility to reach and beyond proton drip line

Multinucleon transfer reaction

MNT reaction $^{58}Ni+^{112}Sn$

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Production of proton-rich nuclei in the vicinity of ^{100}Sn via multinucleon transfer reactions

Zhenji Wu (吴振基)[a], Lu Guo (郭璐)[a,b,*], Zhong Liu (刘忠)[c,a], Guangxiong Peng (彭光雄)[a,d]

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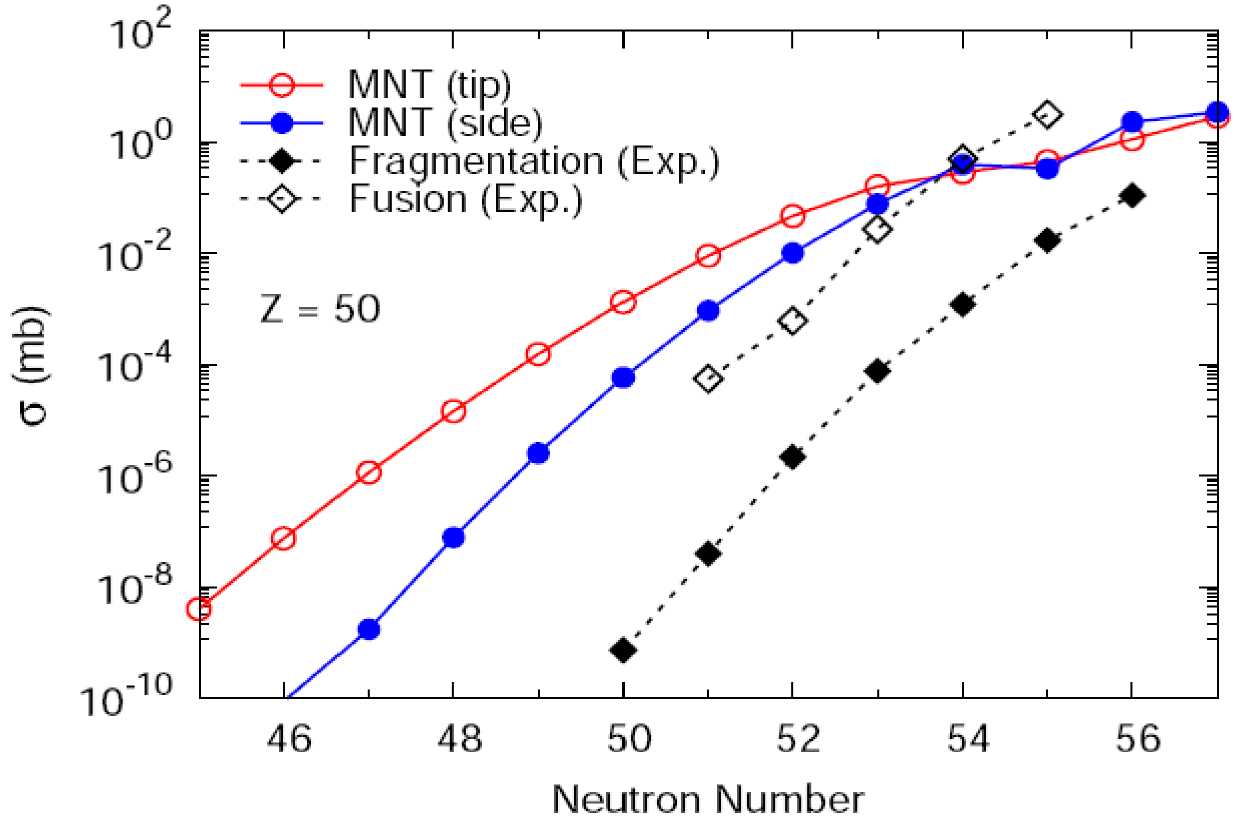
[b] CAS Key Laboratory of Theoretical Physics, Institute of Theoretical Physics, Chinese Academy of Sciences, Beijing 100190, China
[c] Institute of Modern Physics, Chinese Academy of Sciences, Lanzhou 730000, China
[d] Synergetic Innovation Center for Quantum Effects and Application, Hunan Normal University, Changsha 410081, China



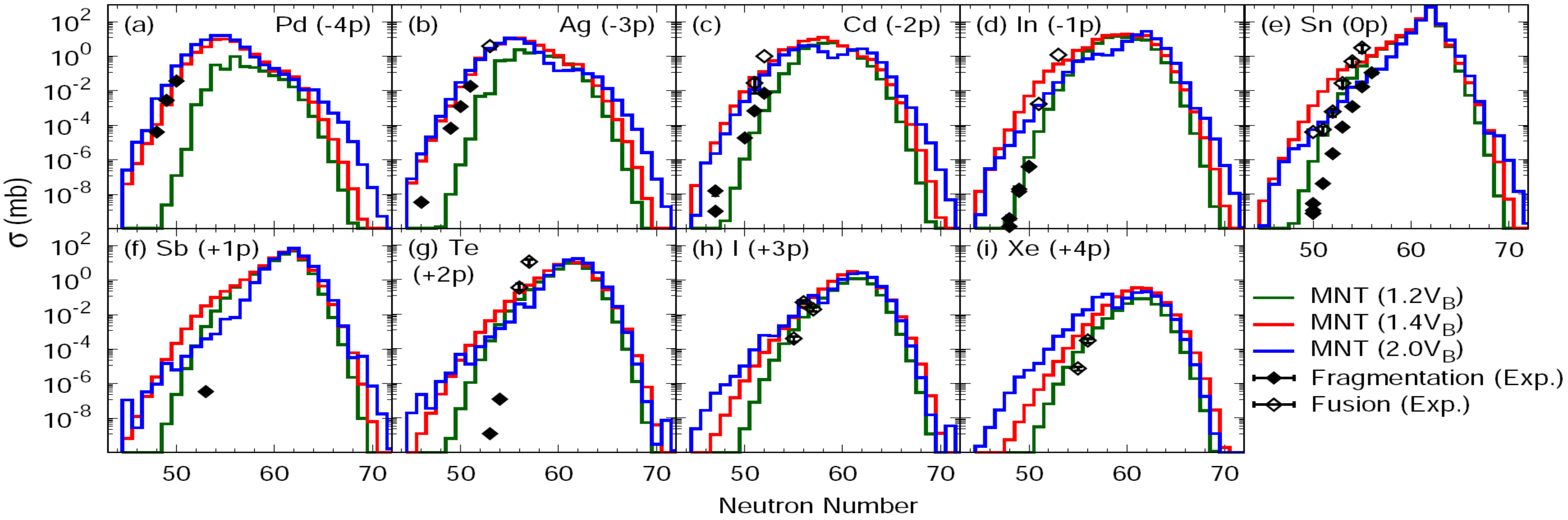
- σ of Sn isotopes in MNT are several orders of magnitudes higher, indicating an enormous advantage to discover new proton-rich isotopes;
- Combined effect of several factors, i.e., shell structure, neck dynamics, charge equilibrium;

Z. J. Wu, Lu Guo, Zhong Liu, GX Peng, Phys. Lett. B 825, 136886 (2022)

Multinucleon transfer reaction

Production of proton-rich nuclei in ^{100}Sn region

MNT reaction $^{58}Ni+^{112}Sn$: energy dependence

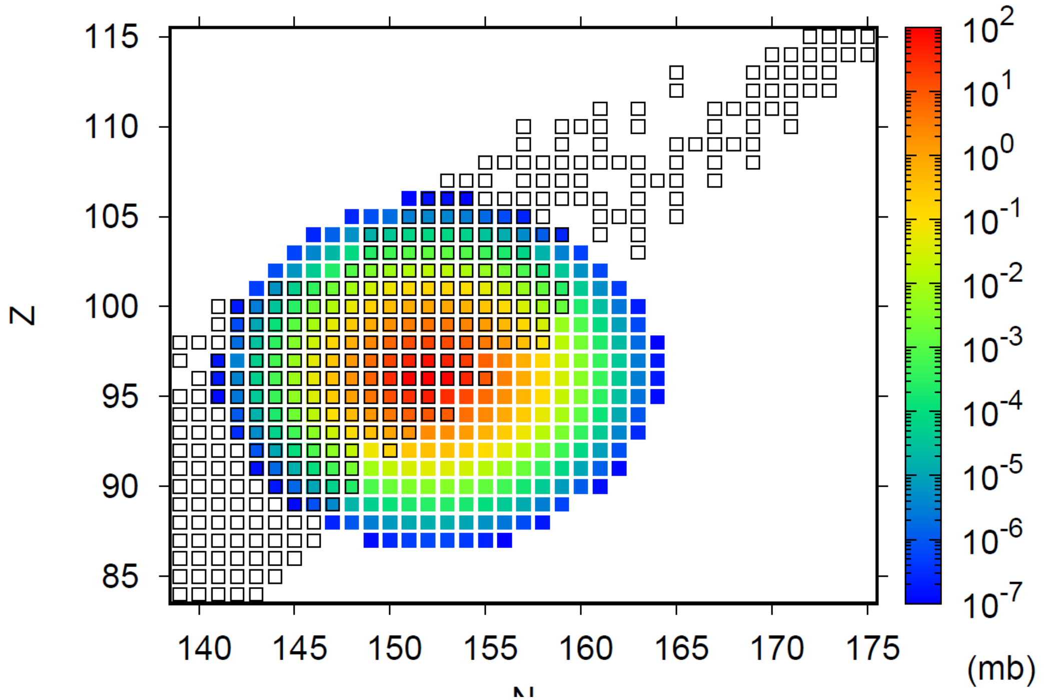


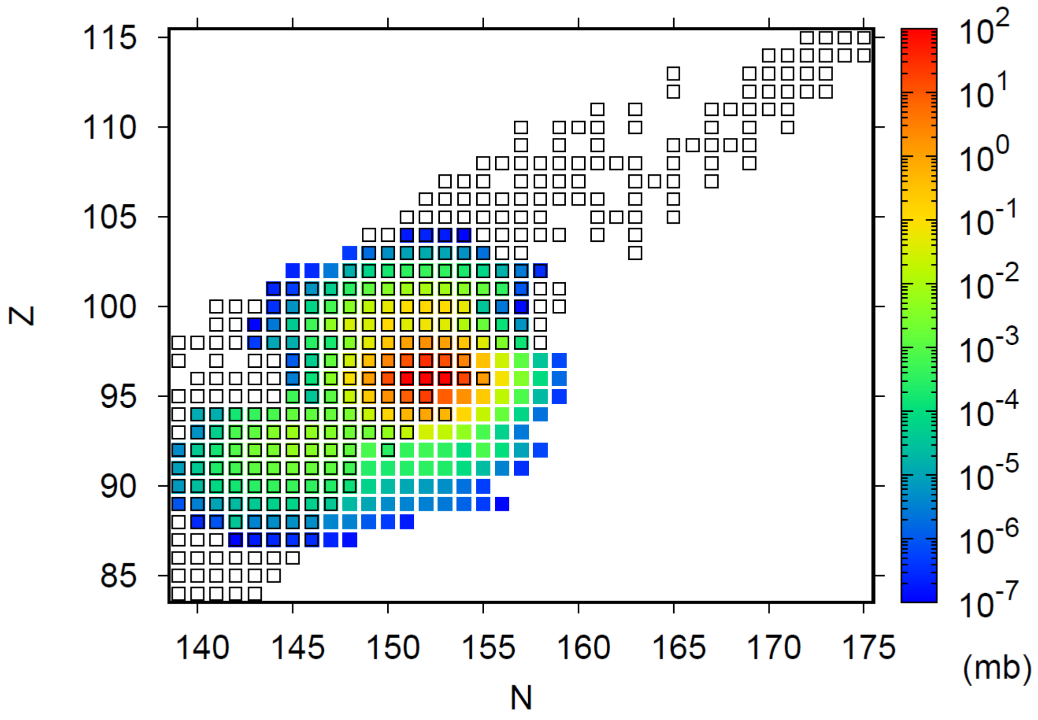
- About 19 new proton-rich isotopes with cross sections of larger than 1 nb are predicted to be produced

Z. J. Wu, Lu Guo, Zhong Liu, GX Peng, Phys. Lett. B 825, 136886 (2022)

Multinucleon transfer reaction

Possible production of heavy and superheavy elements $^{238}U + ^{248}Cm$



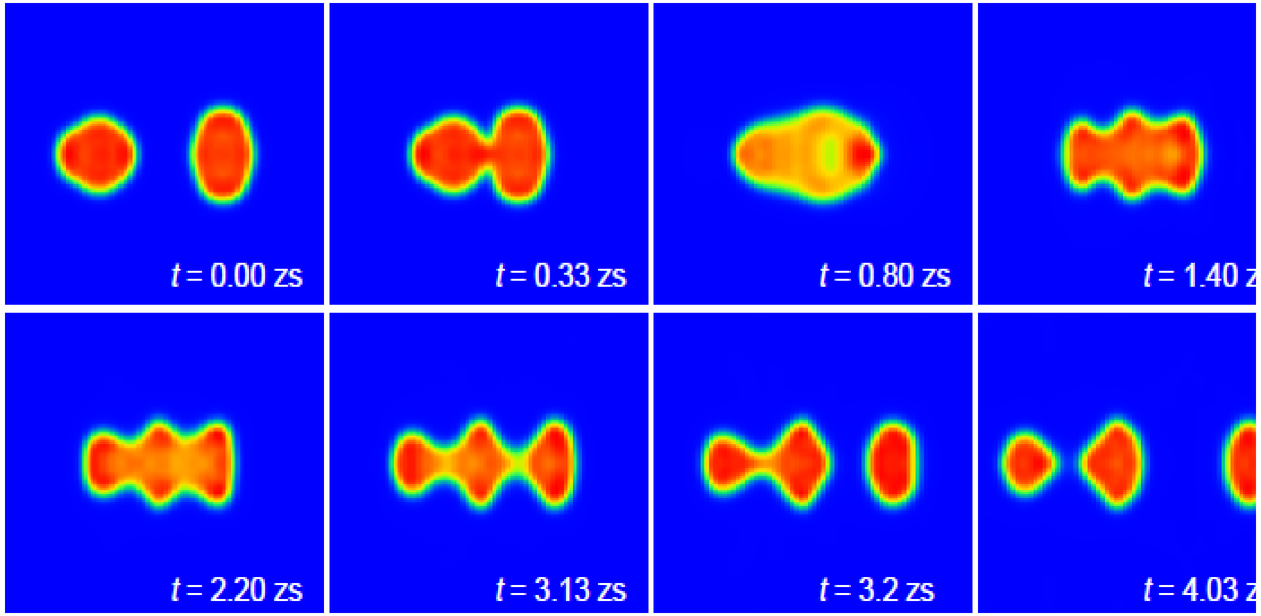


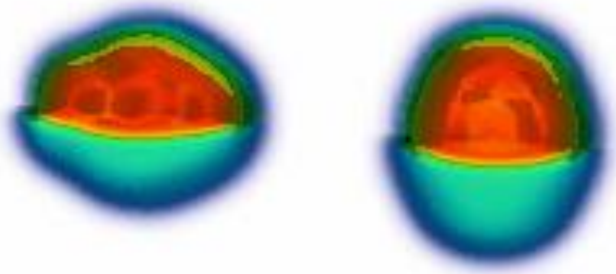
With an appropriate reaction system, the projectile evolves to the doubly magic nuclide and transfer neutrons to the target, and consequently very neutron-rich heavy nuclides and particularly very neutron-rich super-heavy nuclides are expected to be produced.

Multinucleon transfer reaction

Possible production of heavy and superheavy elements $^{238}U + ^{248}Cm$

Ternary quasifission





A=143.93	A=181.10	A=160.07
Z=56.27	Z=69.08	Z=62.65
N=89.66	N=112.01	N=97.42

Summary and Perspectives

Summary

- Develop the microrscopic theoretical methods to study SHE production
- The fusion mechanism involving the exotic nuclei
- Cold fusion reactions and hot fusion reactions for the production of superheavy
- Quasifission mechanism and shell effects
- Multinucleon transfer reactions

Perspectives

- basis space, especially with pairing (TDHFB, TDHF+BCS)
- beyond the independent-particle approximation (TDRPA)
- the role of two-body collisions and fluctuation effects

Thanks for your attention!

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