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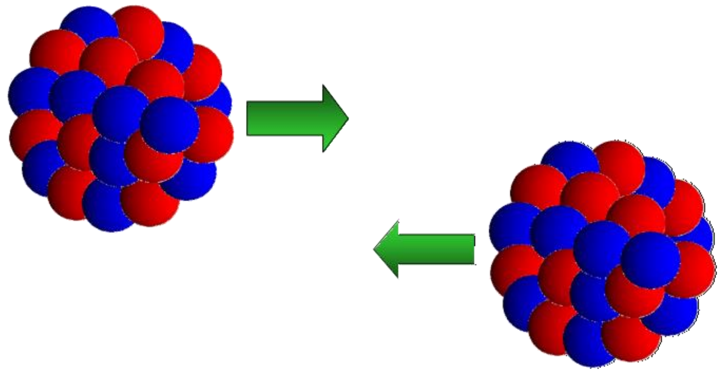
Hakim Sabzevari University

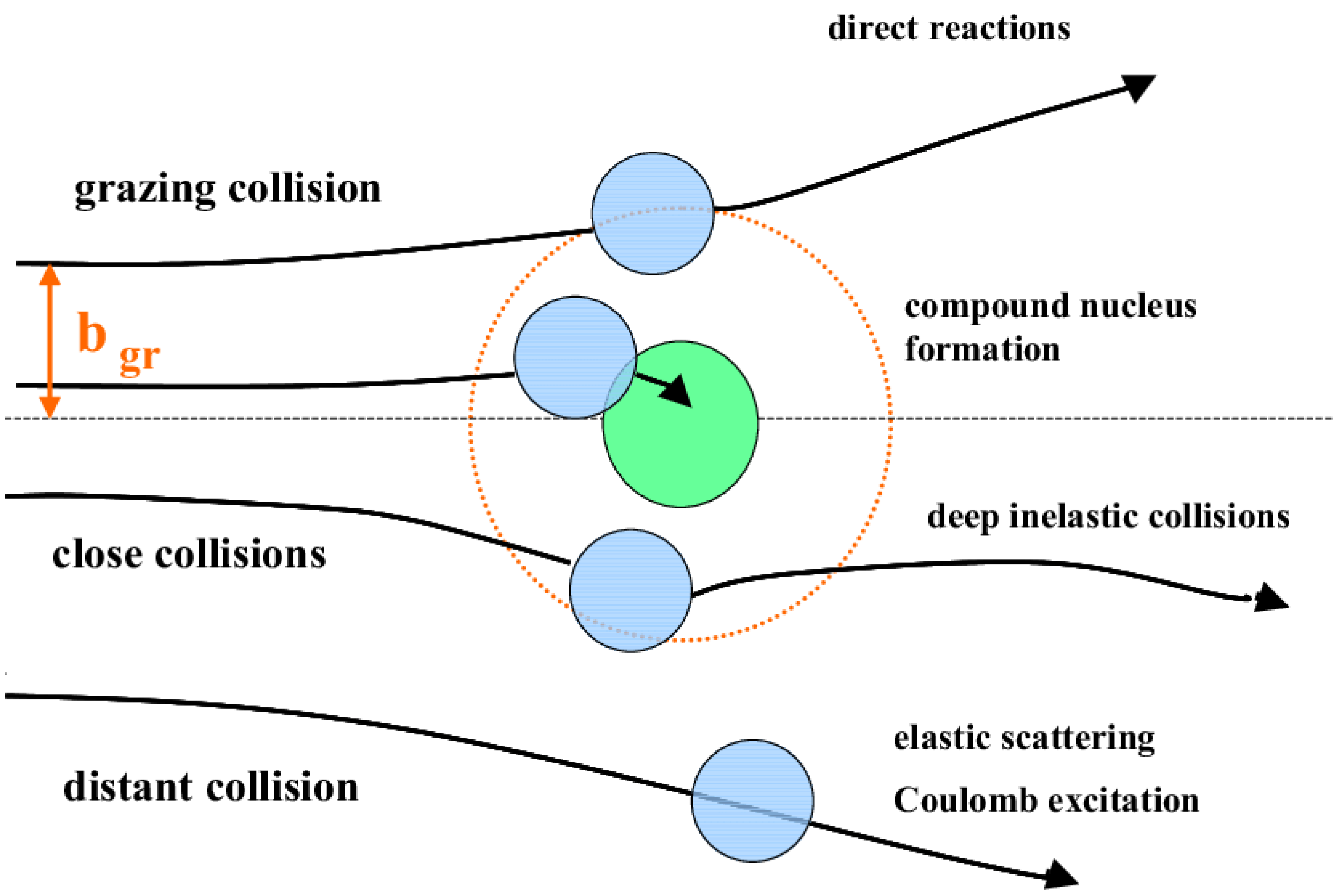
Heavy ions fusion reaction:
a brief report of recent advances



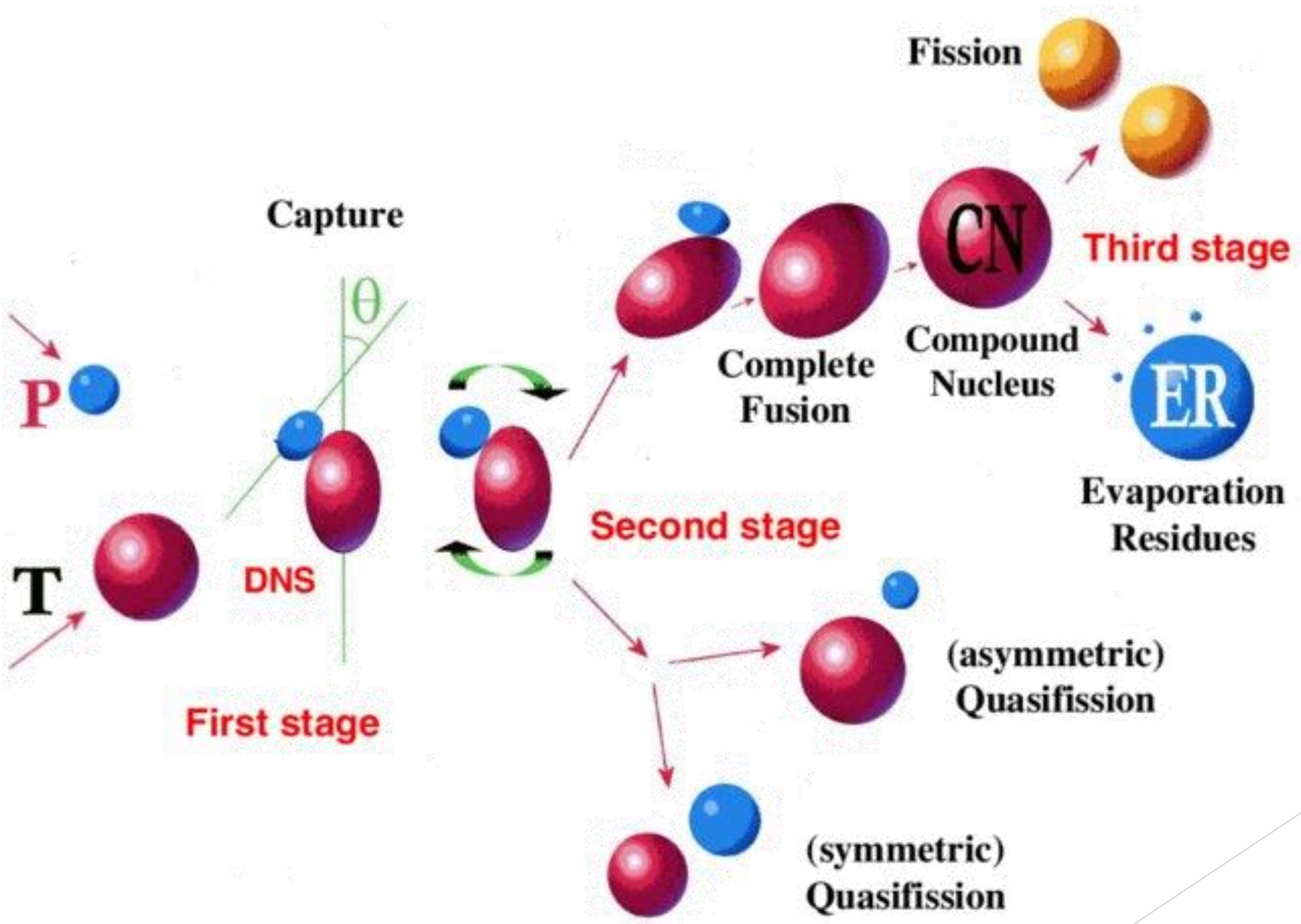
R. Gharaei

May 2023

Different channels of heavy-ion collisions

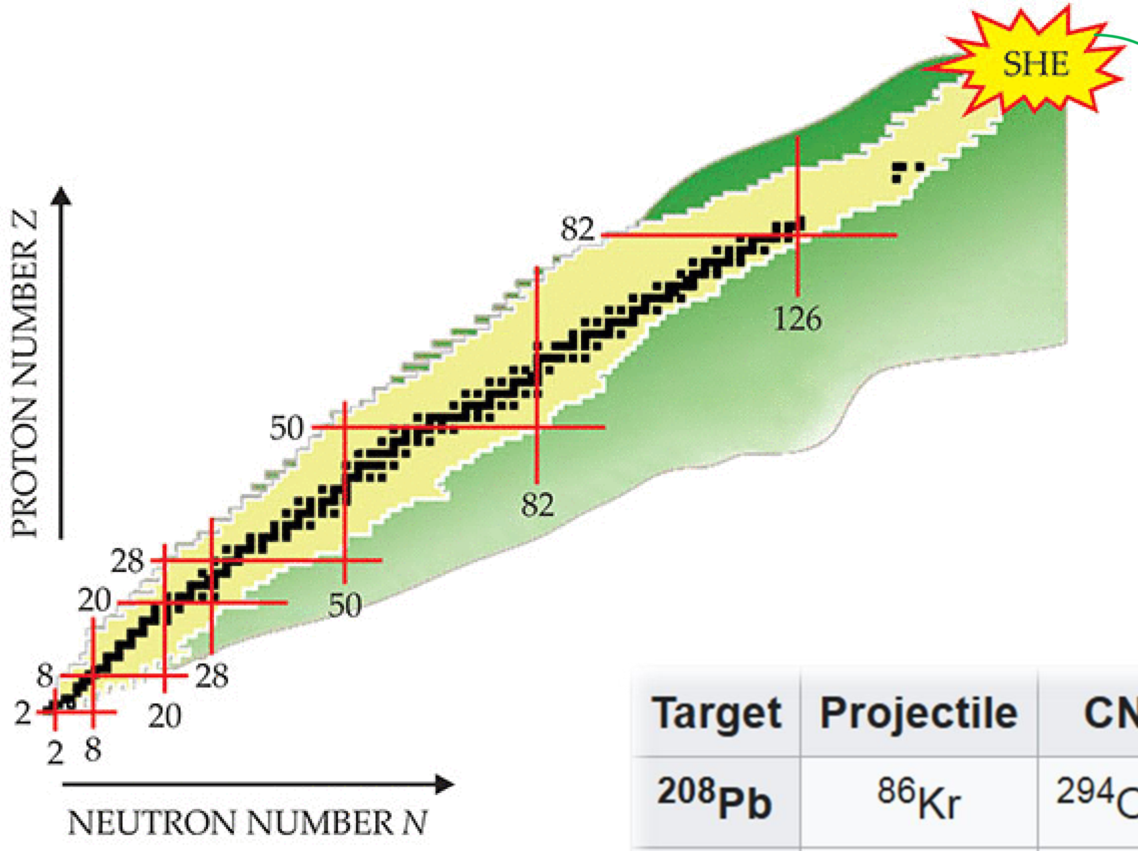


Competition between different channels in fusion reactions



Some of recent studies ……!!

1. Formation of new exotic nuclear isotopes



Target	Projectile	CN	Channel (product)
^{208}Pb	^{86}Kr	^{294}Og	1n (^{293}Og)
^{208}Pb	^{85}Kr	^{293}Og	1n (^{292}Og)
^{252}Cf	^{48}Ca	^{300}Og	3n (^{297}Og)
^{251}Cf	^{48}Ca	^{299}Og	3n (^{296}Og)

Cold fusion

Hot fusion

PHYSICAL REVIEW C **103**, 064616 (2021)

Theoretical study of evaporation-residue cross sections of superheavy nuclei

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(Received 29 April 2021; accepted 16 June 2021; published 28 June 2021)

Based on the empirical coupled-channel model for calculating capture cross section and the statistical model for calculating survival probability, we propose an analytical formula for describing the fusion probability. The cold-fusion and hot-fusion reactions leading to superheavy nuclei have been systematically investigated. For both the cold-fusion and hot-fusion reactions, the measured evaporation-residual (ER) cross sections can be reproduced acceptably well by using the formula with the same parameter set. Simultaneously, the ER cross sections for some reactions producing elements $Z = 119$ and 120 are studied. It is found that the projectile-target combinations ^{50}Ti + ^{249}Bk and ^{50}Ti + ^{249,251}Cf are considered as the most promising reactions for the syntheses of the next two superheavy elements beyond Og. The maximal ER cross section for ^{50}Ti + ^{249}Bk is 48.2 fb at the incident energy $E_{c.m.} = 226$ MeV. For ^{50}Ti + ^{249,251}Cf, the maximal ER cross section is about 10 fb at the incident energies around $E_{c.m.} = 232$ MeV.

DOI: 10.1103/PhysRevC.103.064616

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Nuclear Physics A ●●● (●●●●) ●●●●●●

NUCLEAR PHYSICS A

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Heavy particle radioactivity of superheavy element Z = 126

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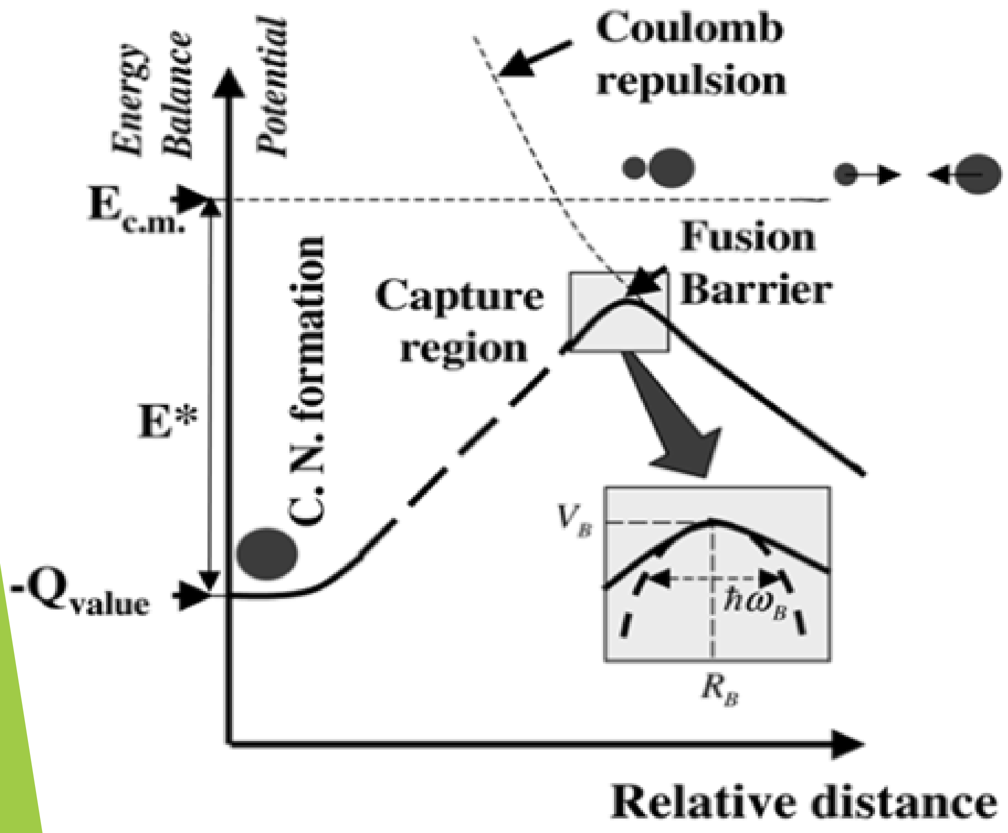
Received 2 August 2021; received in revised form 26 August 2021; accepted 27 August 2021

Abstract

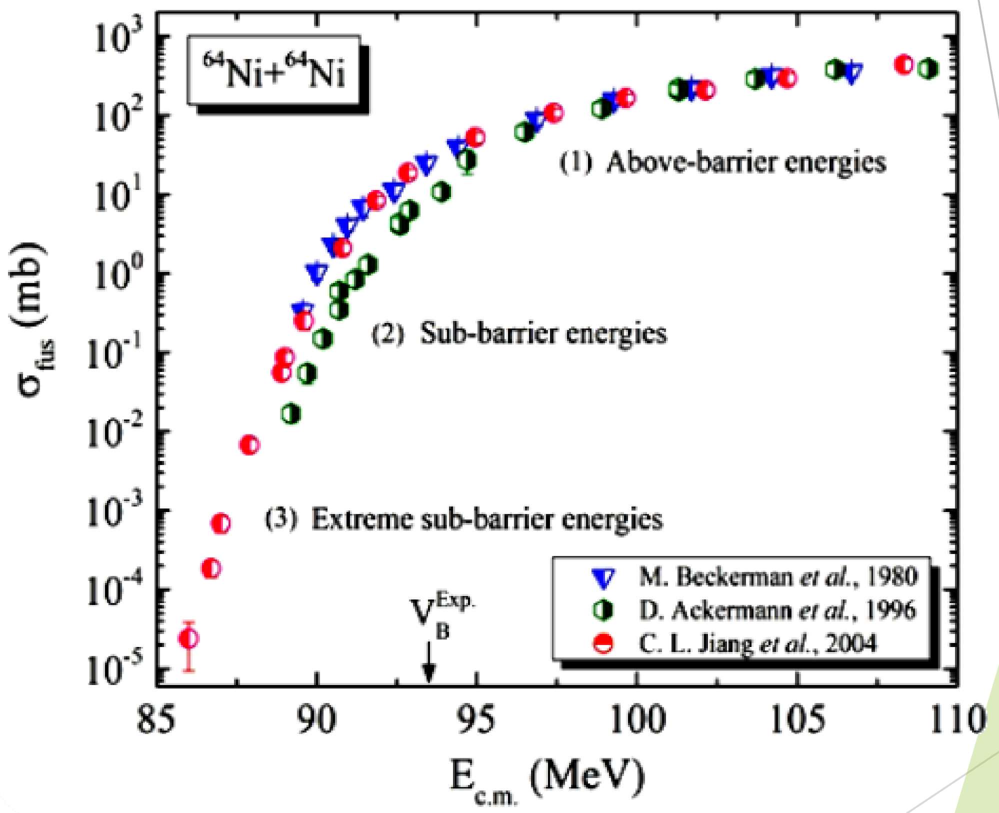
The concept of heavy particle radioactivity is studied using modified generalised liquid drop model (MGLDM) in the superheavy element Z = 126. The eight different proximity functions and different mass excess values were used to evaluate cluster/HPR. The logarithmic half-lives using different proximity functions and mass excess values are compared with that of experiments. The HPR of ^{60}Ni to ^{102}Ru have been studied in the superheavy region ^{306}126 to ^{326}126. The HPR half-lives has been compared with the different decay modes such as α-decay, β-decay and spontaneous fission. 9 HPR emitters, 4 α emitters, 1 β^+ emitter and 7 spontaneous fission nuclei were identified in the superheavy nuclei $^{306-314}$126, $^{315-318}$126, ^{319}126 and $^{320-326}$126 respectively.

Keywords: Superheavy nuclei; Alpha-decay; Cluster-decay; Q-values

From theoretical point of view …..



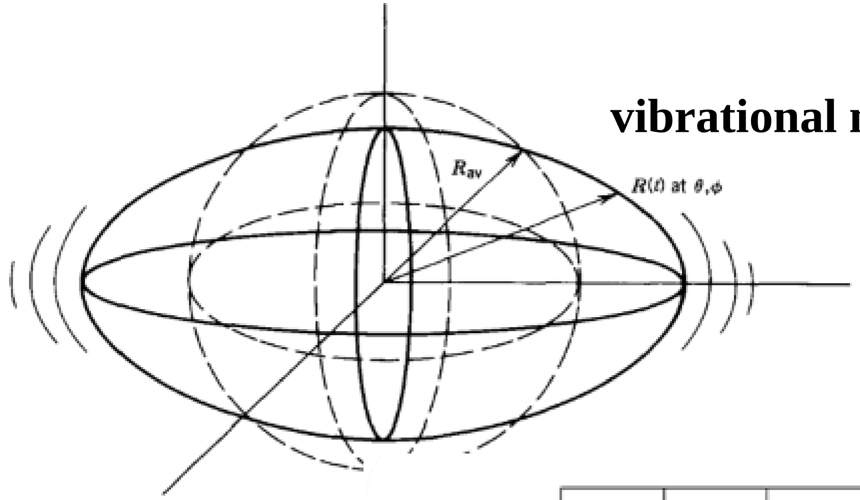
Interaction potential



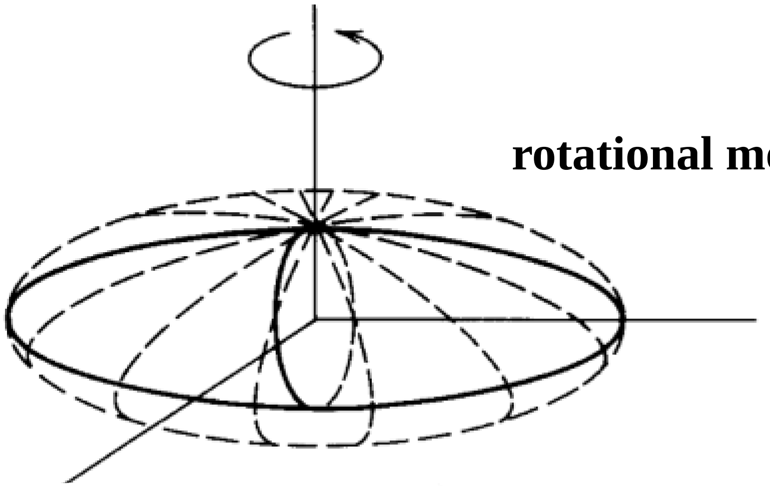
Fusion cross sections

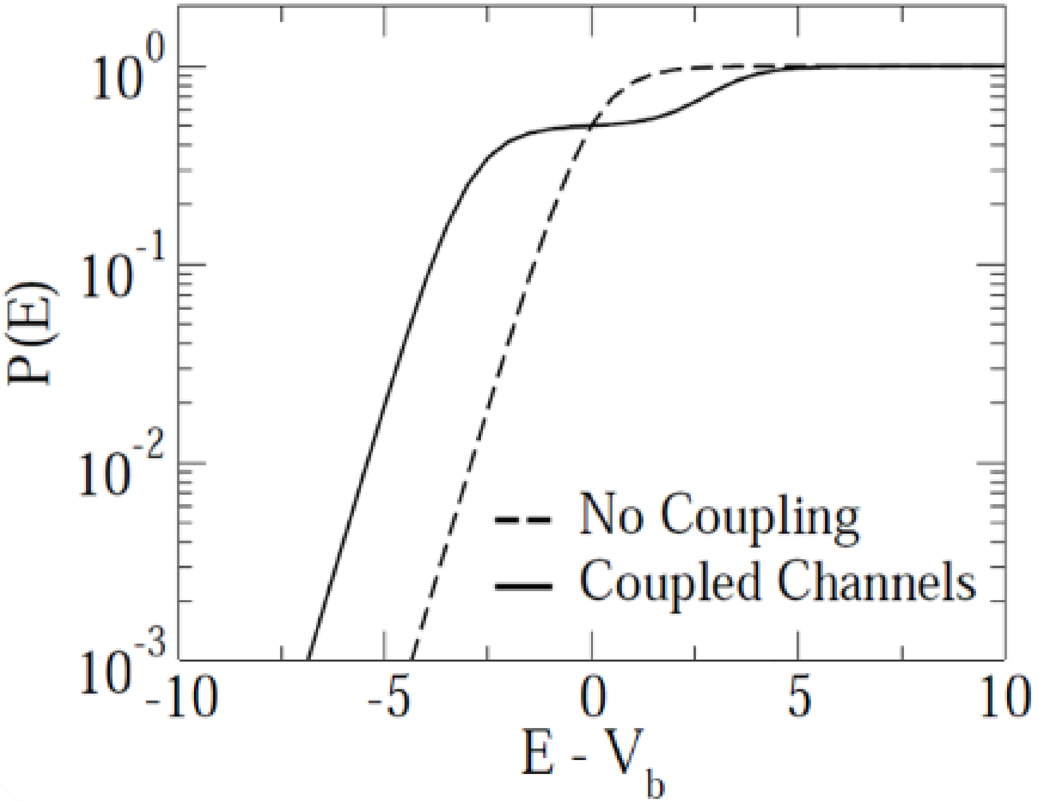
Coupled-channel approach

vibrational mode

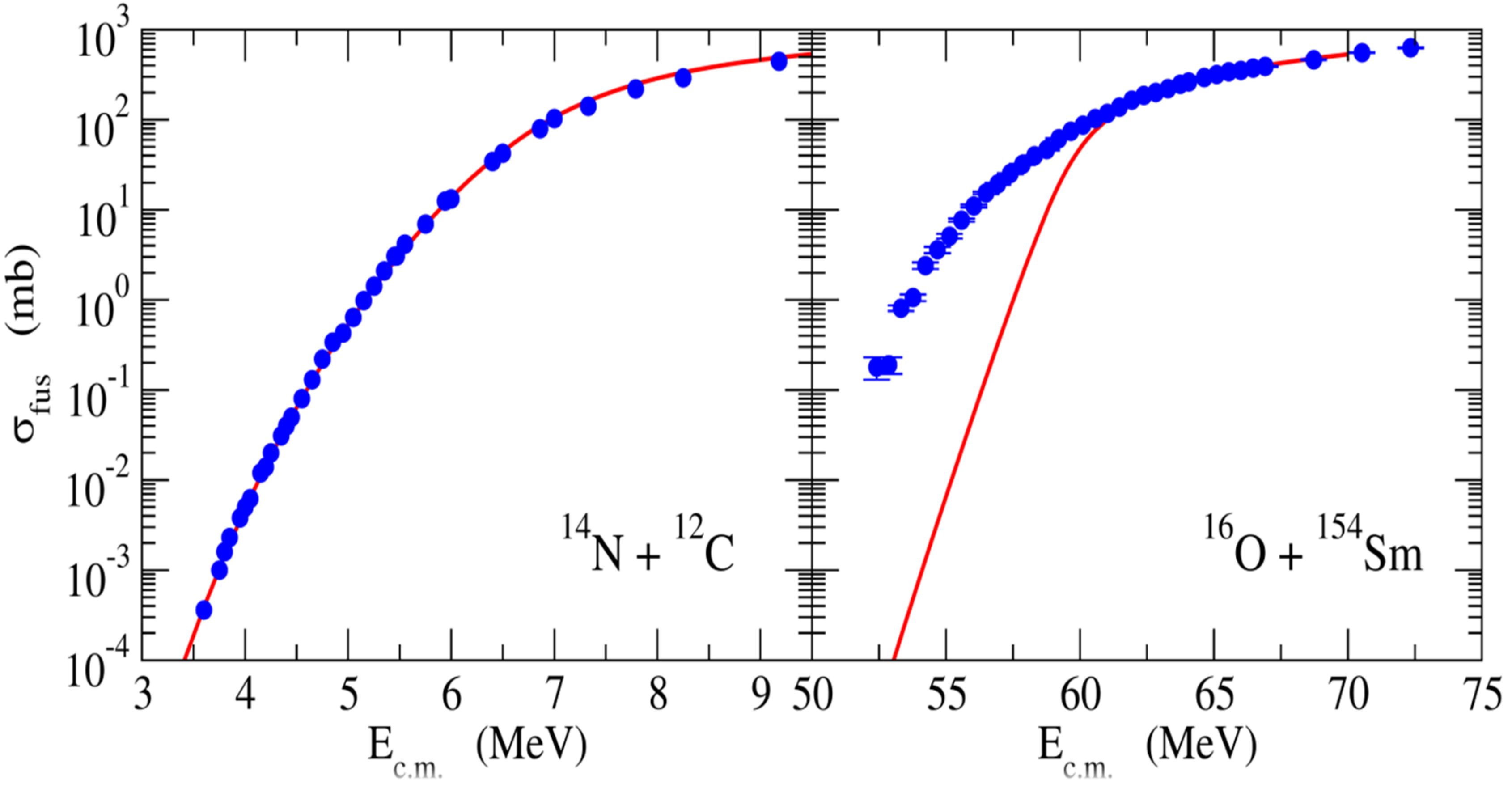


rotational mode

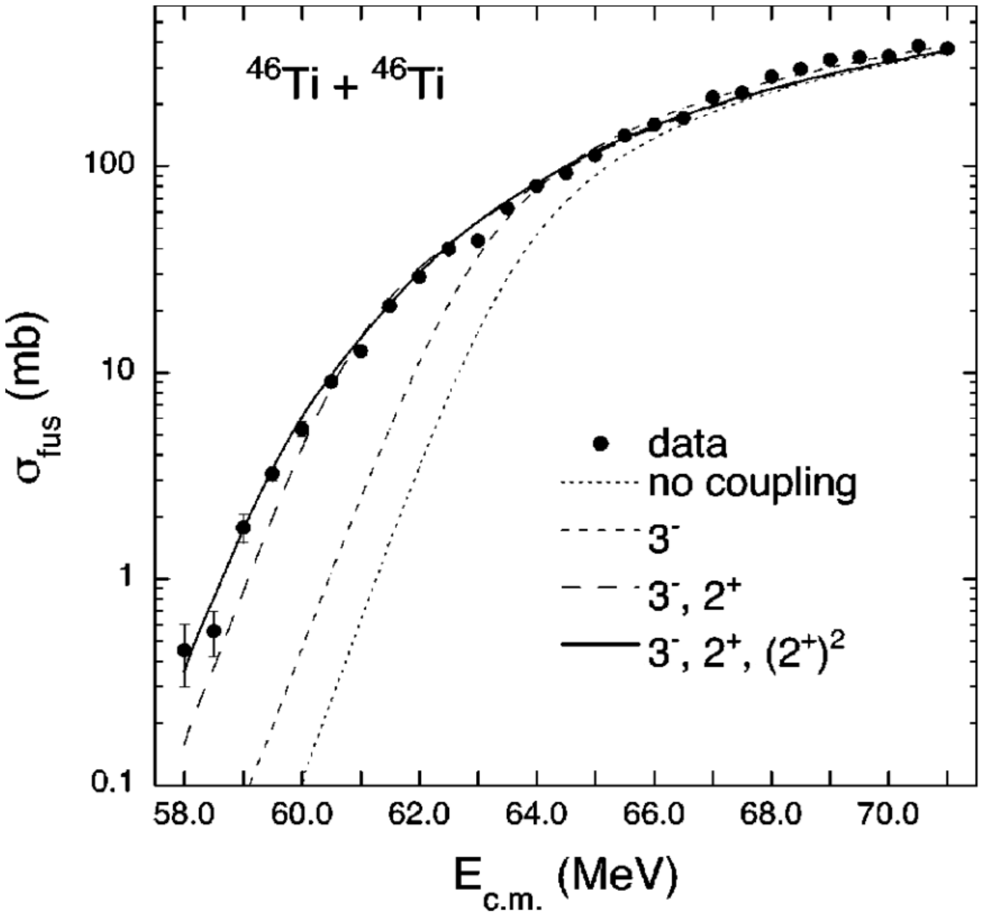


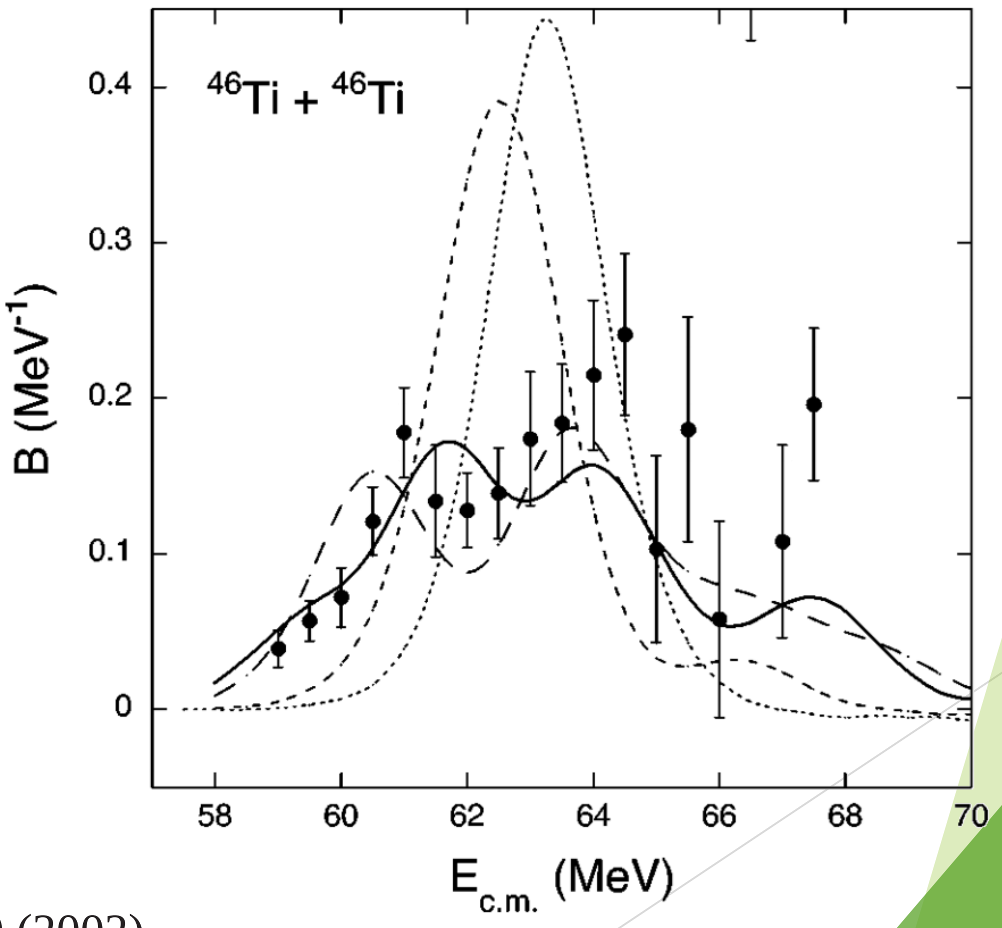


Theoretically, the simplest approach for heavy-ion fusion reactions is to use the one dimensional potential model where both the projectile and the target are assumed to be structureless.



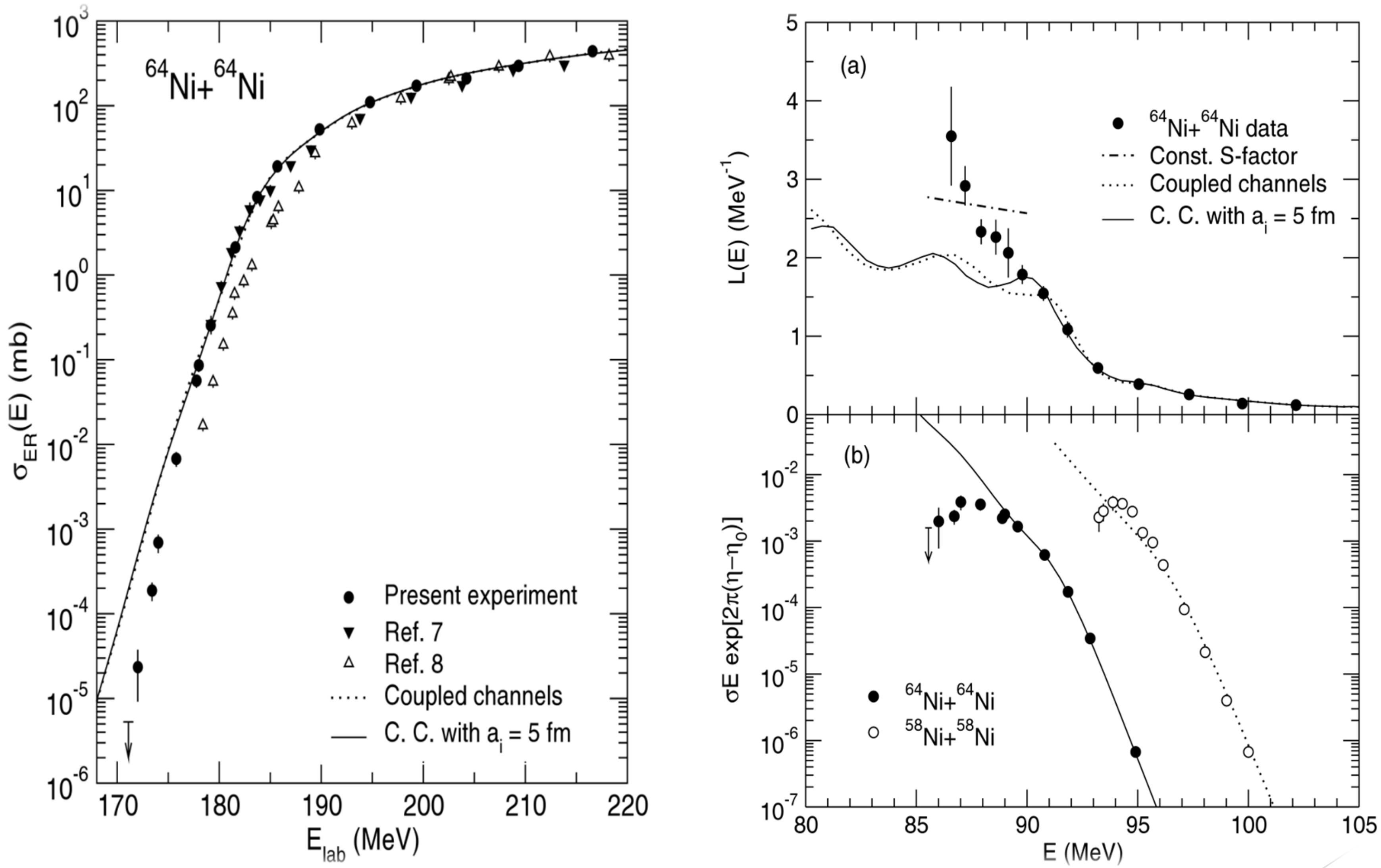
- K. Hagino, N. Rowley, and M. Dasgupta, Phys. Rev. C 67, 054603 (2003).



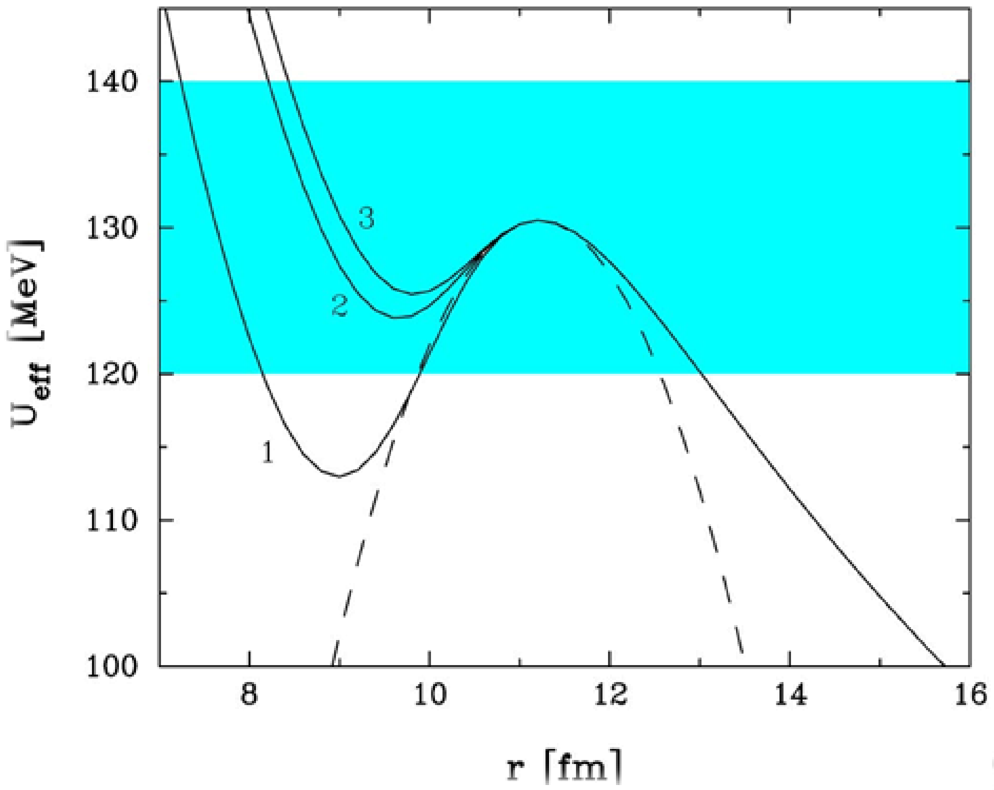


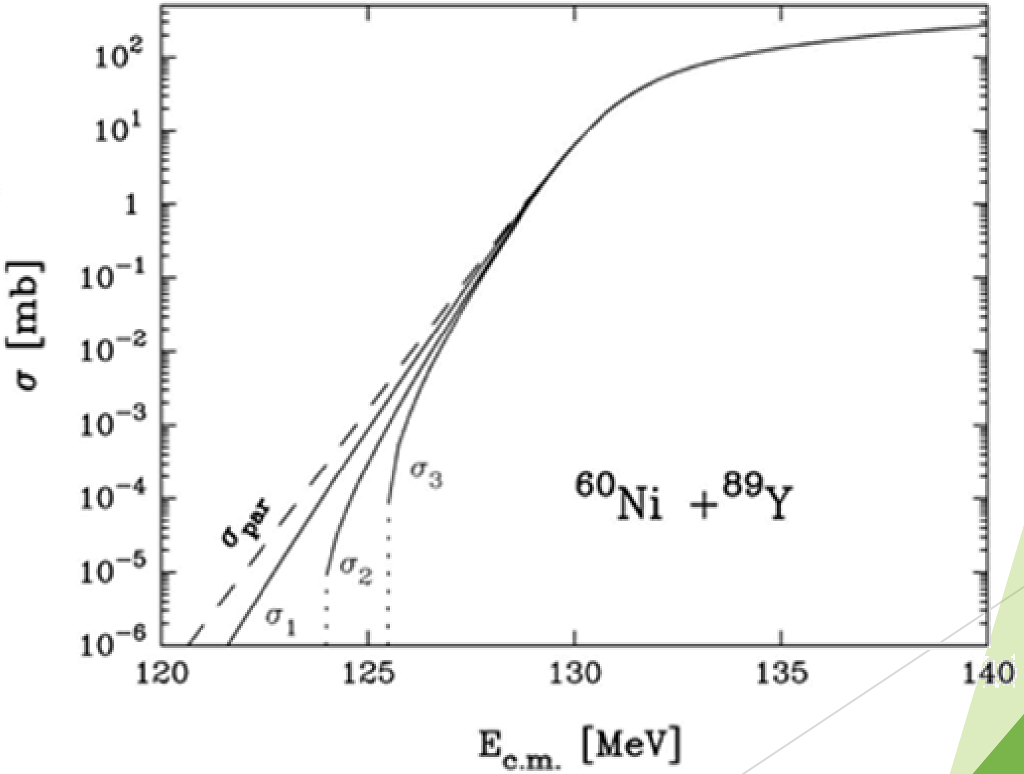
A. M. Stefanini, et al., Phys. Rev. C 65, 034609 (2002).

2. An unexpected behavior: fusion hindrance..?!!



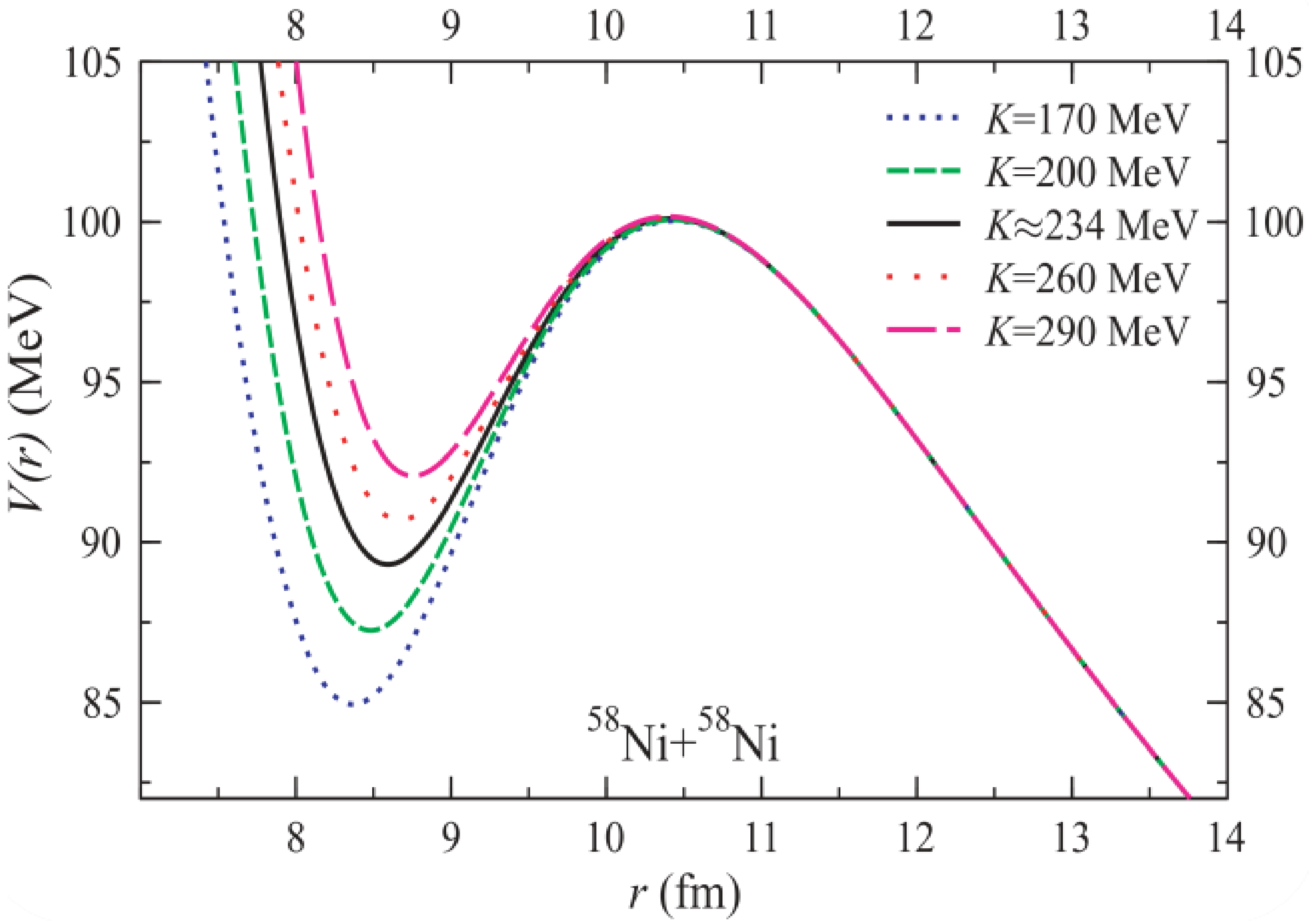
C. L. Jiang et al., Phys. Rev. Lett. 89, 052701 (2002).



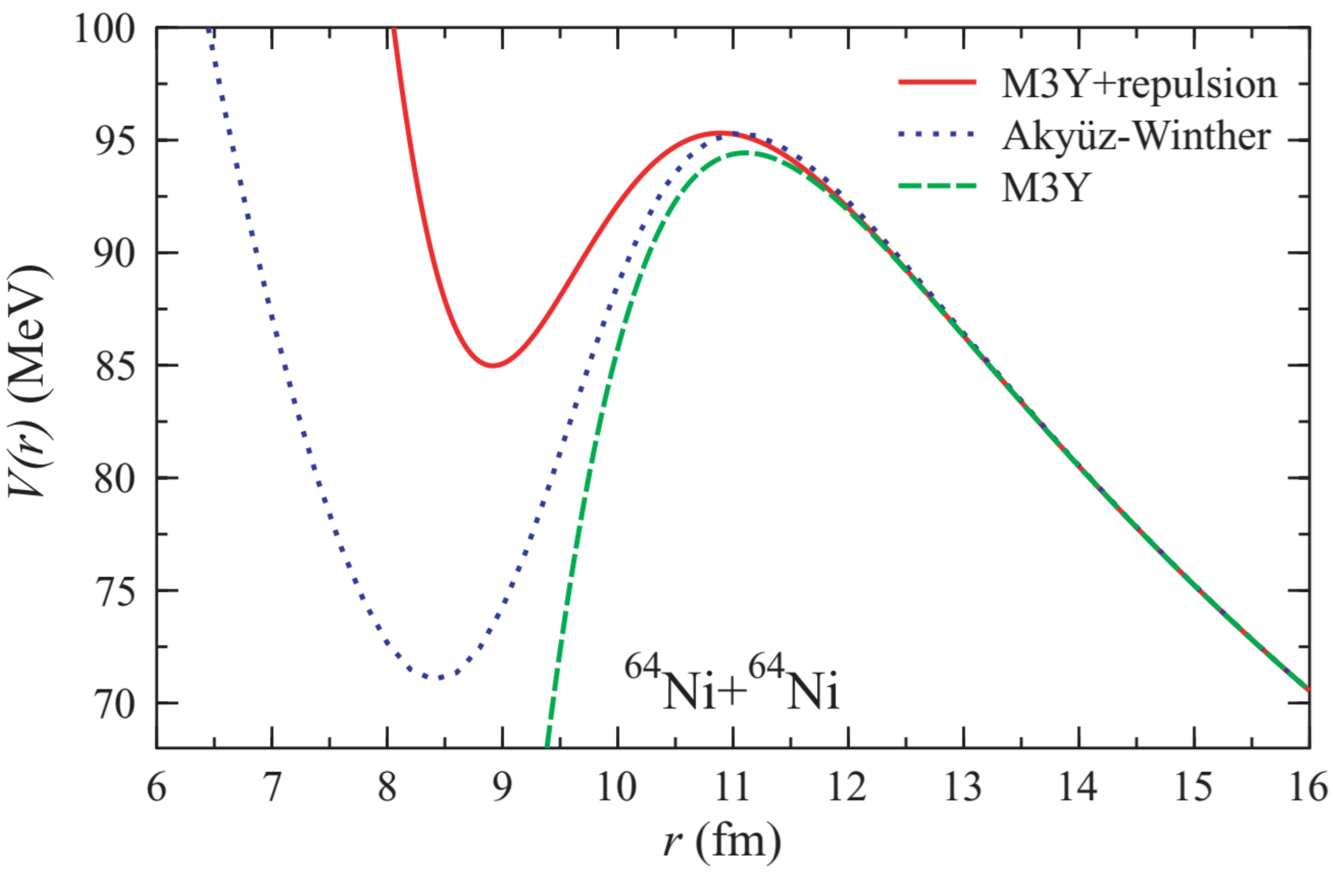


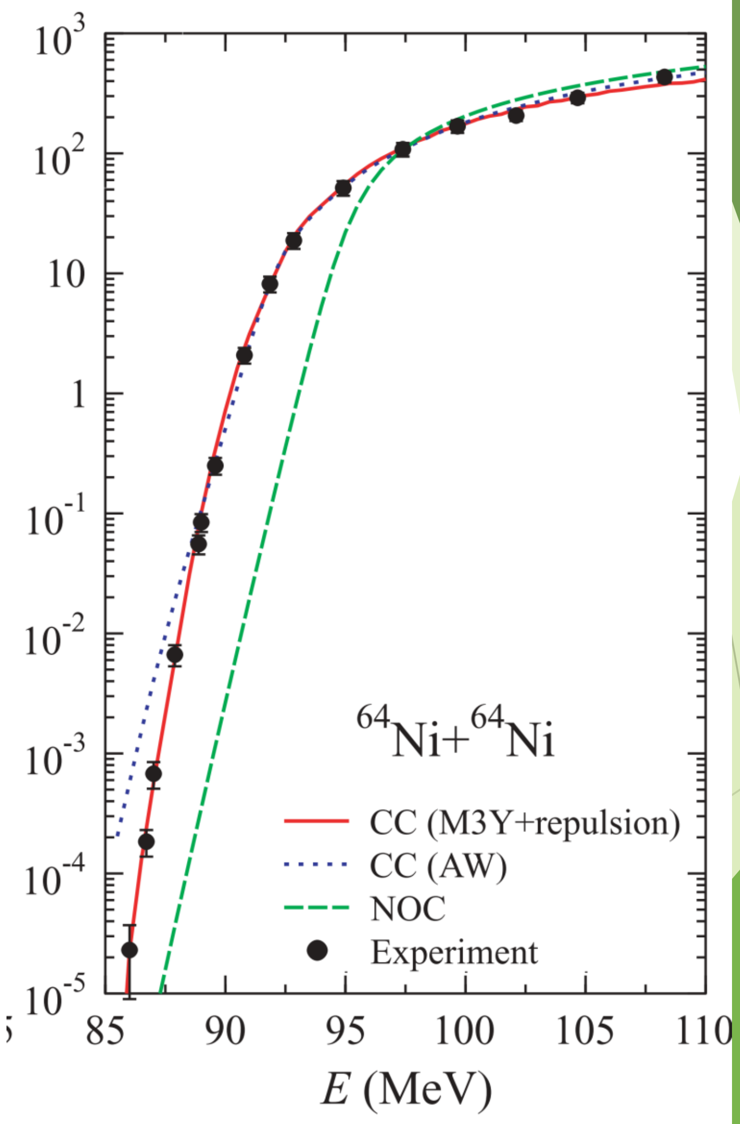
- C. H. Dasso1 and G. Pollarolo, Phys. Rev. C 68, 054604 (2003).

Nuclear matter incompressibility and short relative distances



- S. Misicu and H. Esbensen, Phys. Rev. Lett. 96, 112701 (2006).
- S. Misicu and H. Esbensen, Phys. Rev. C 75, 034606 (2007).





Note: The semiempirical Akyuz-Winther (AW) potential is parametrized as a Woods-Saxon potential.

- S. Misicu and H. Esbensen, Phys. Rev. C 75, 034606 (2007).

PHYSICAL REVIEW C **100**, 044619 (2019)

Fusion hindrance and Pauli blocking in ^{58}Ni + ^{64}Ni

A. M. Stefanini,[1] G. Montagnoli,[2] M. Del Fabbro,[2] G. Colucci,[2] P. Čolović,[3] L. Corradi,[1] E. Fioretto,[1] F. Galtarossa,[1] A. Goasduff,[2] J. Grebosz,[4] M. Heine,[5] G. Jaworski,[6] M. Mazzocco,[2] T. Mijatovic,[3] S. Szilner,[3] M. Bajzek,[3] D. Brugnara,[1] M. Siciliano,[1] and I. Zanon[7,1]
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(Received 27 August 2019; published 31 October 2019)

IOP Publishing Journal of Physics G: Nuclear and Particle Physics
J. Phys. G: Nucl. Part. Phys. **44** (2017) 045108 (15pp) https://doi.org/10.1088/1361-6471/aa5f7d

Analysis of the low- and high-energy fusion cross sections: the case of ^{58}Ni+^{54}Fe

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Received 7 October 2016, revised 20 January 2017
Accepted for publication 9 February 2017
Published 1 March 2017

CrossMark

PRL **113,** 022701 (2014) PHYSICAL REVIEW LETTERS week ending 11 JULY 2014

Fusion Hindrance for a Positive-Q-Value System ^{24}Mg + ^{30}Si

C. L. Jiang,[1,*] A. M. Stefanini,[2] H. Esbensen,[1] K. E. Rehm,[1] S. Almaraz-Calderon,[1] B. B. Back,[1] L. Corradi,[2] E. Fioretto,[2] G. Montagnoli,[3] F. Scarlassara,[3] D. Montanari,[3] S. Courtin,[4] D. Bourgin,[4] F. Haas,[4] A. Goasduff,[5] S. Szilner,[6] and T. Mijatovic[6]
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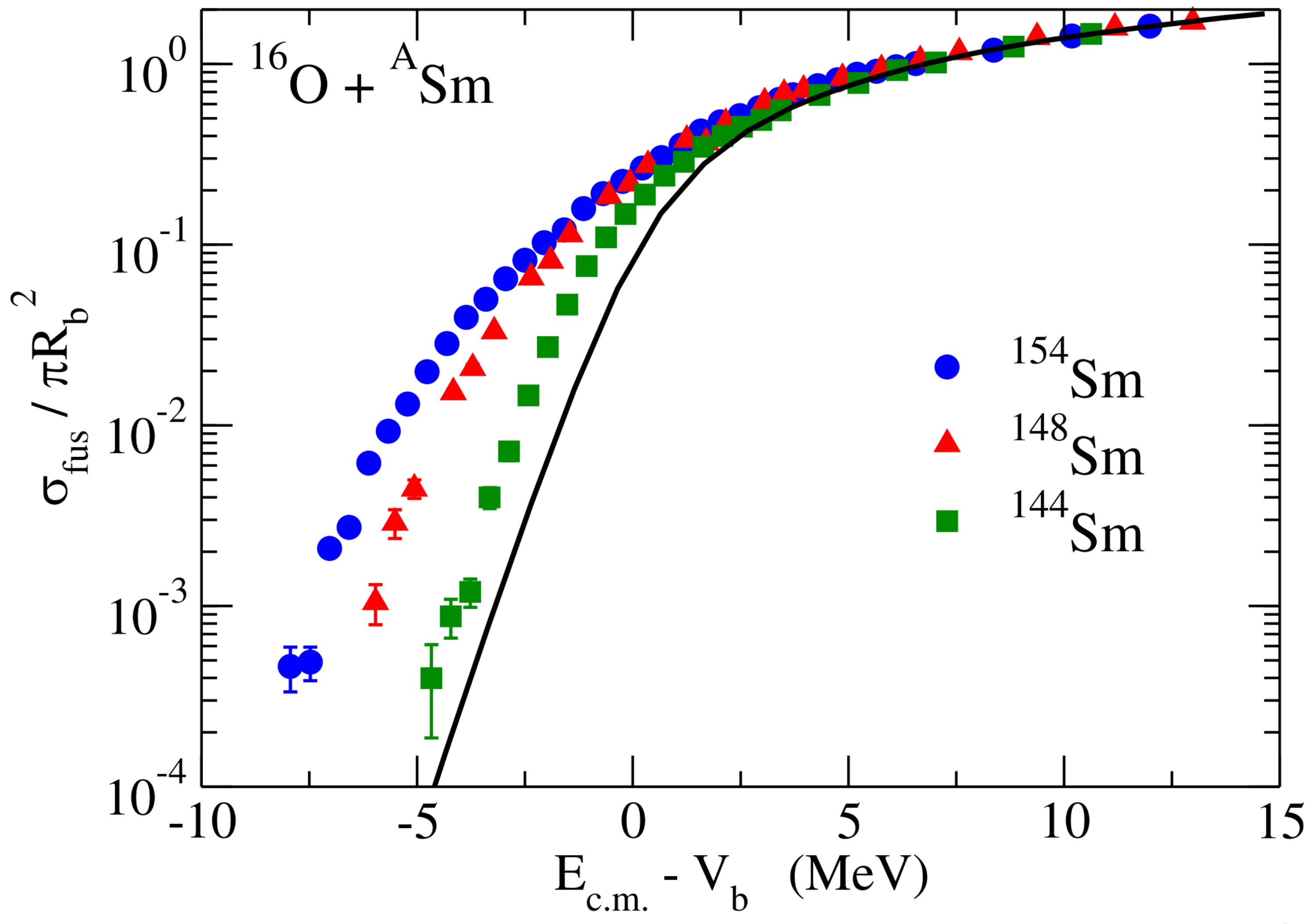
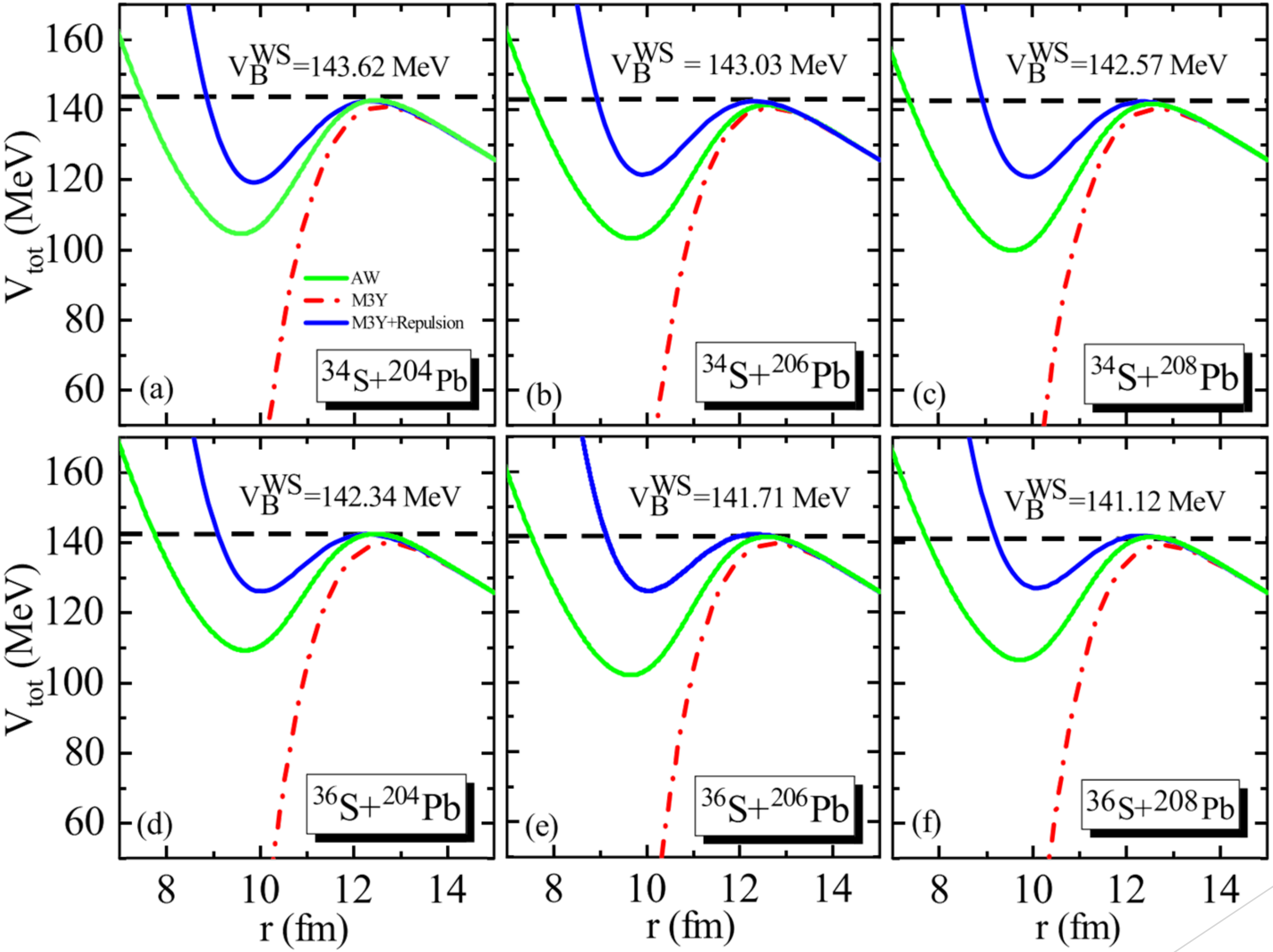
(Received 2 May 2014; published 10 July 2014)

3. Isotopic dependence in experimental approach



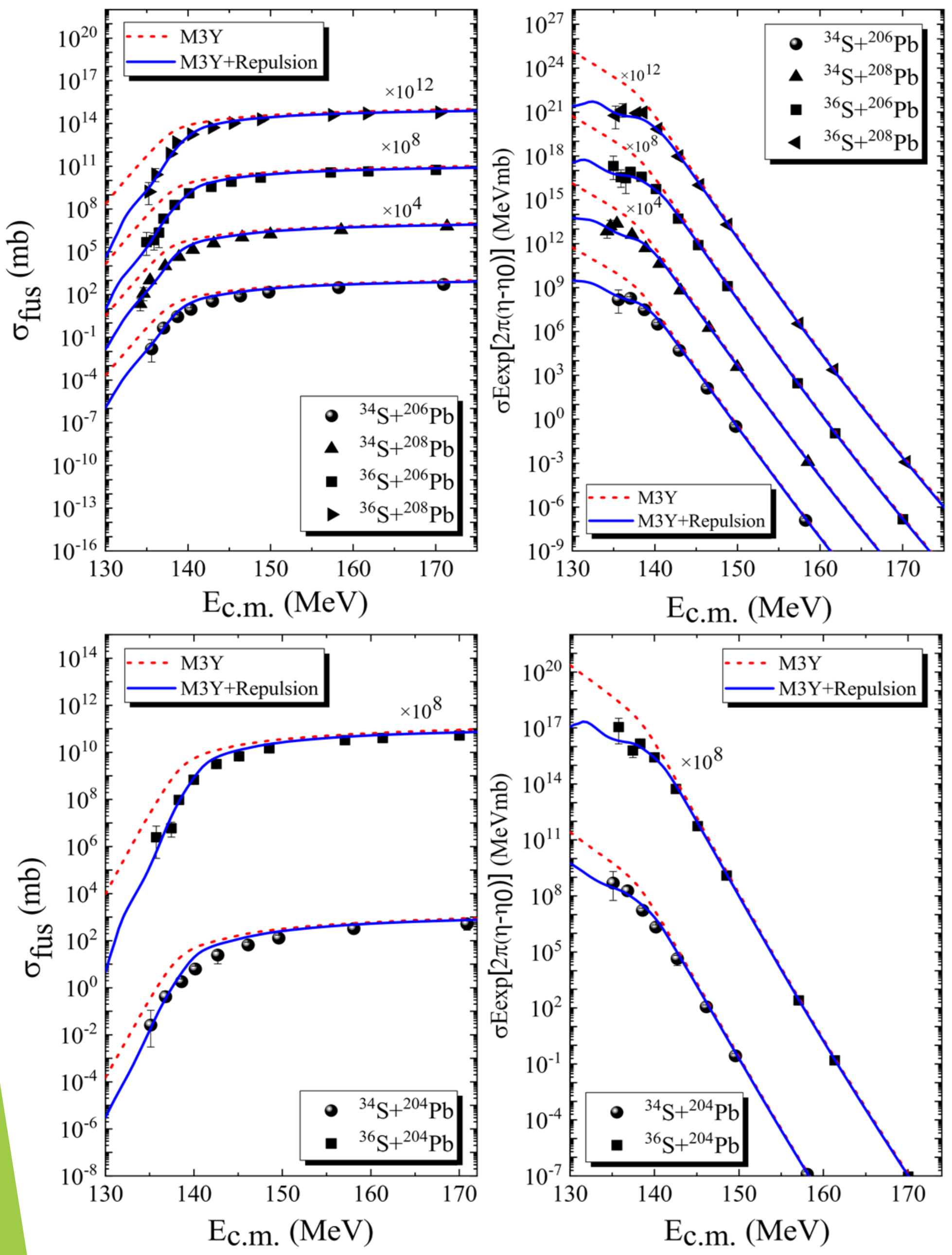
- J. R. Leigh, M. Dasgupta, et al., Phys. Rev. C 52, 3151 (1995).

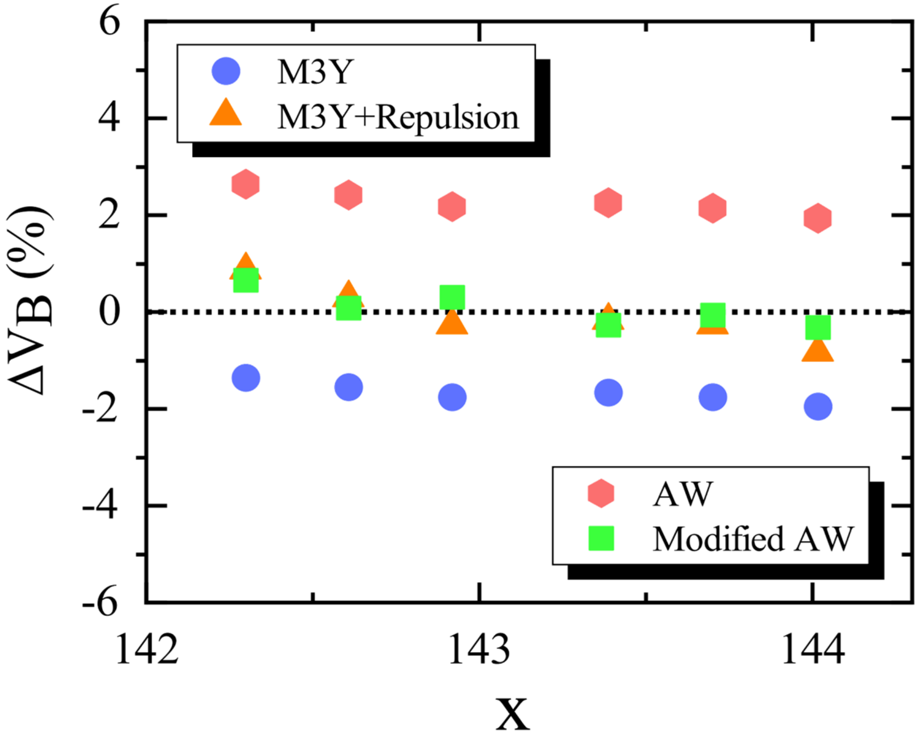
Isotopic dependence in theoretical approach

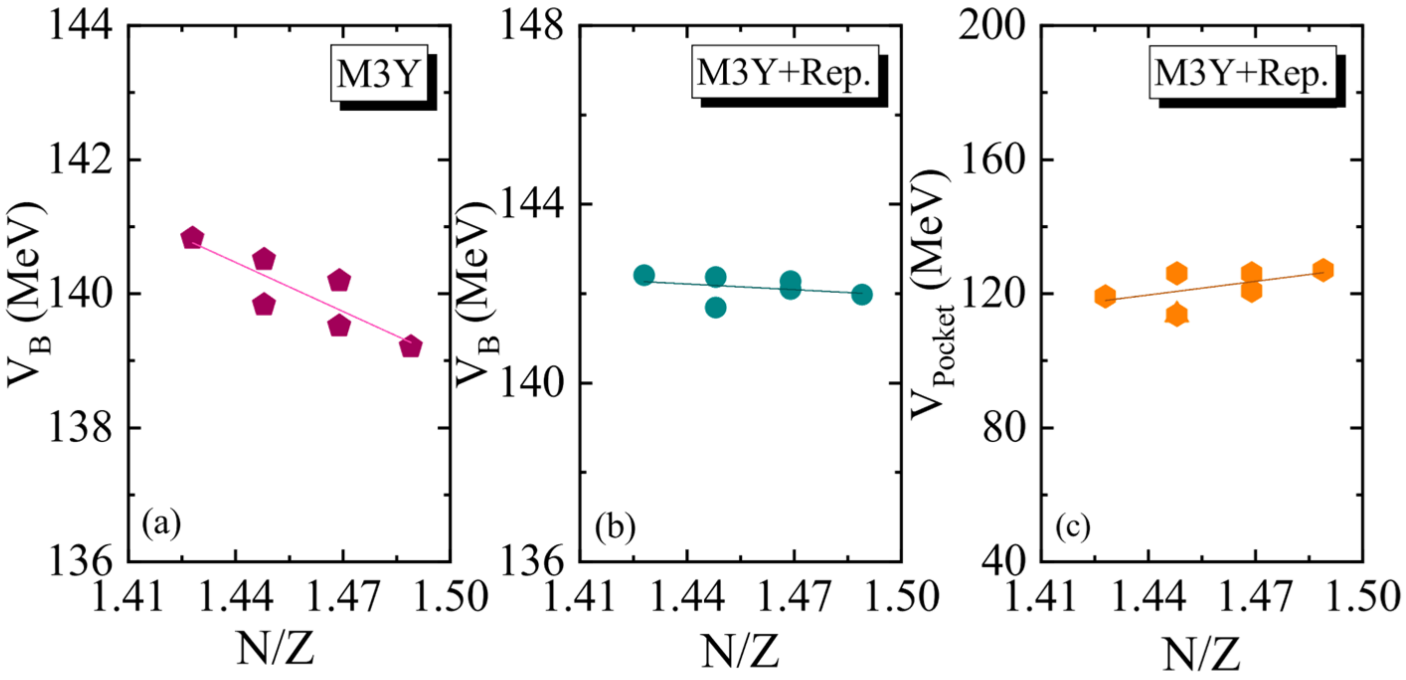


R. Gharaei, H. Hasanzade , Nucl. Phys. A 1013, 122223 (2021).

Validation of calculated values

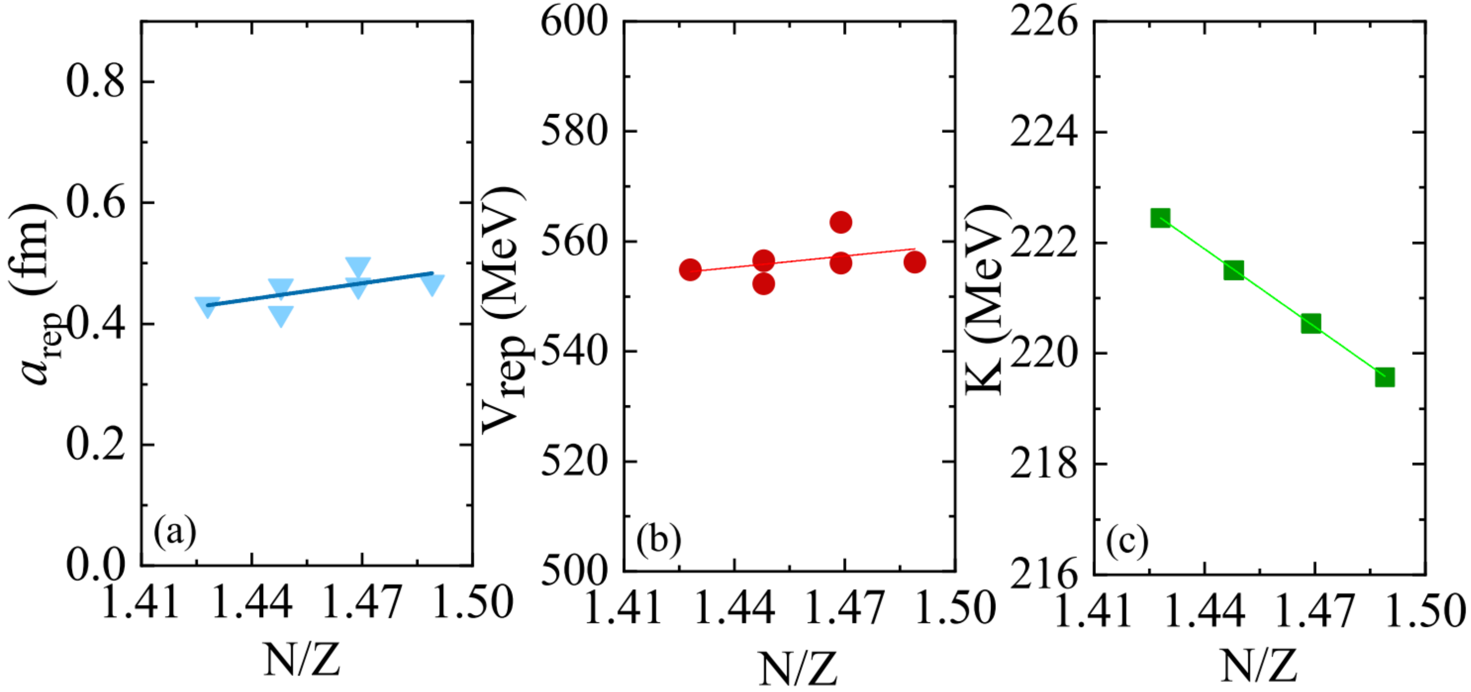






Parameterization of data

$$\begin{cases} a_{rep} = 0.8690(\frac{N}{Z}) - 0.8104 \\ V_{rep} = 67.8253(\frac{N}{Z}) + 457.6434 \end{cases}$$



R. Gharaei, H. Hasanzade , Nucl. Phys. A 1013, 122223 (2021).

PHYSICAL REVIEW C **97**, 044613 (2018)

Isotopic effects in sub-barrier fusion of Si + Si systems

G. Colucci,[1] G. Montagnoli,[1] A. M. Stefanini,[2] H. Esbensen,[3] D. Bourgin,[4] P. Čolović,[5] L. Corradi,[2] M. Faggian,[1,*]
E. Fioretto,[2] F. Galtarossa,[2,6] A. Goasduff,[1] J. Grebosz,[7] F. Haas,[4] M. Mazzocco,[1] F. Scarlassara,[1] C. Stefanini,[1] E. Strano,[1]
S. Szilner,[5] M. Urbani,[1,†] and G. L. Zhang[1,8]
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(Received 23 January 2018; published 23 April 2018)

PHYSICAL REVIEW C **82**, 041601(R) (2010)

Fusion hindrance for Ca + Ca systems: Influence of neutron excess

C. L. Jiang,[1] A. M. Stefanini,[2] H. Esbensen,[1] K. E. Rehm,[1] L. Corradi,[2] E. Fioretto,[2] P. Mason,[3] G. Montagnoli,[3]
F. Scarlassara,[3] R. Silvestri,[2] P. P. Singh,[2] S. Szilner,[4] X. D. Tang,[5] and C. A. Ur[3]
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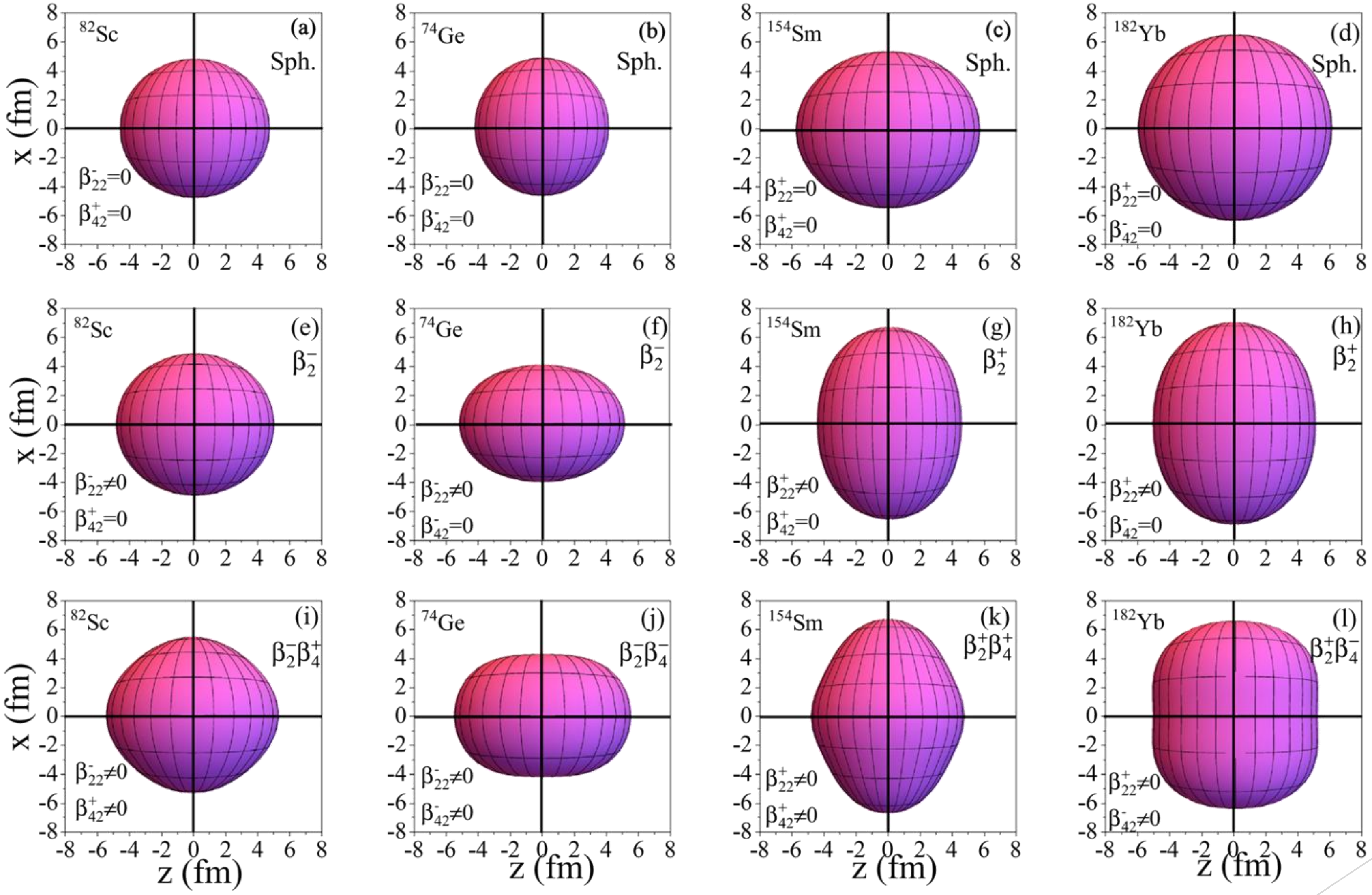
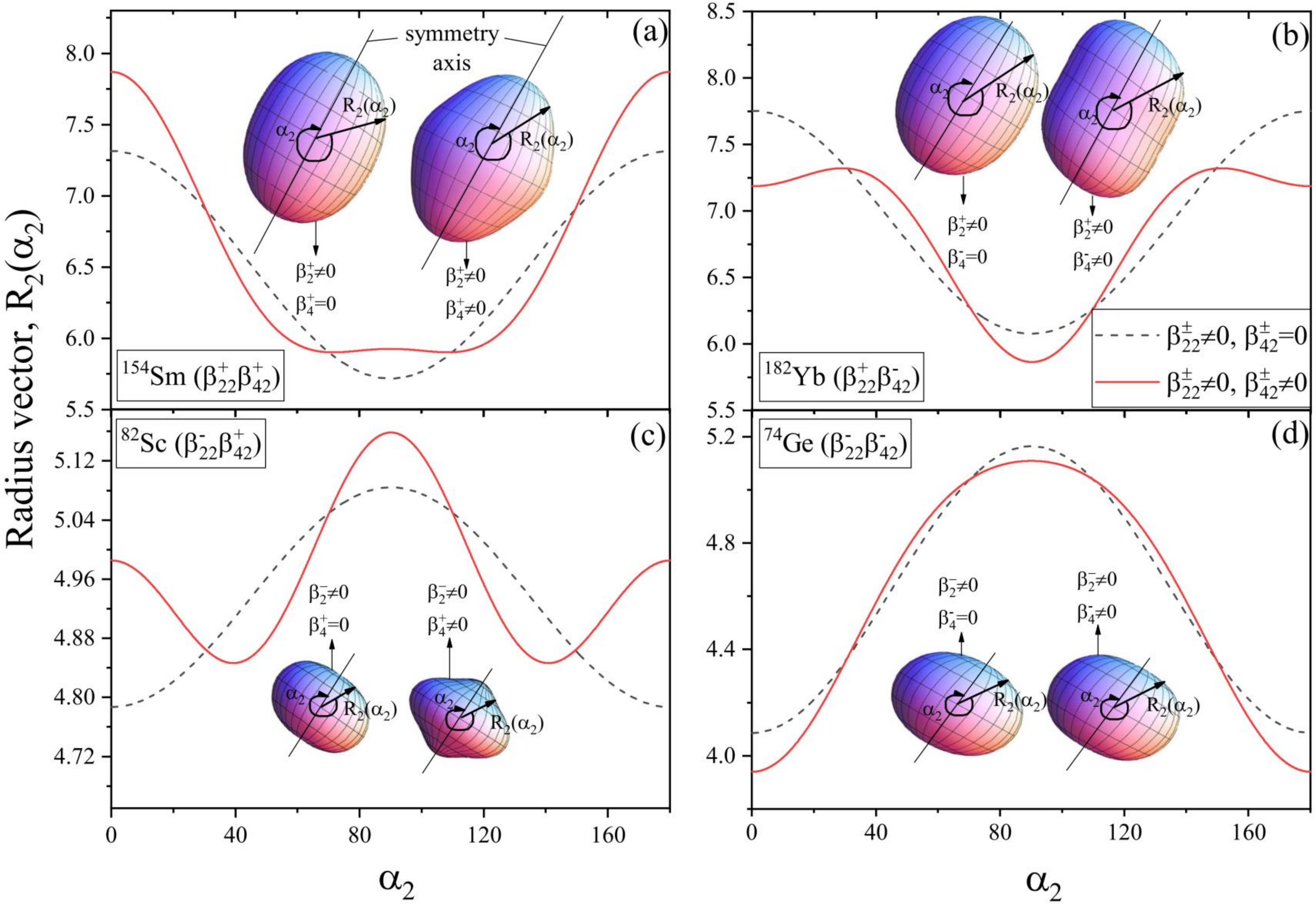
(Received 20 September 2010; published 19 October 2010)

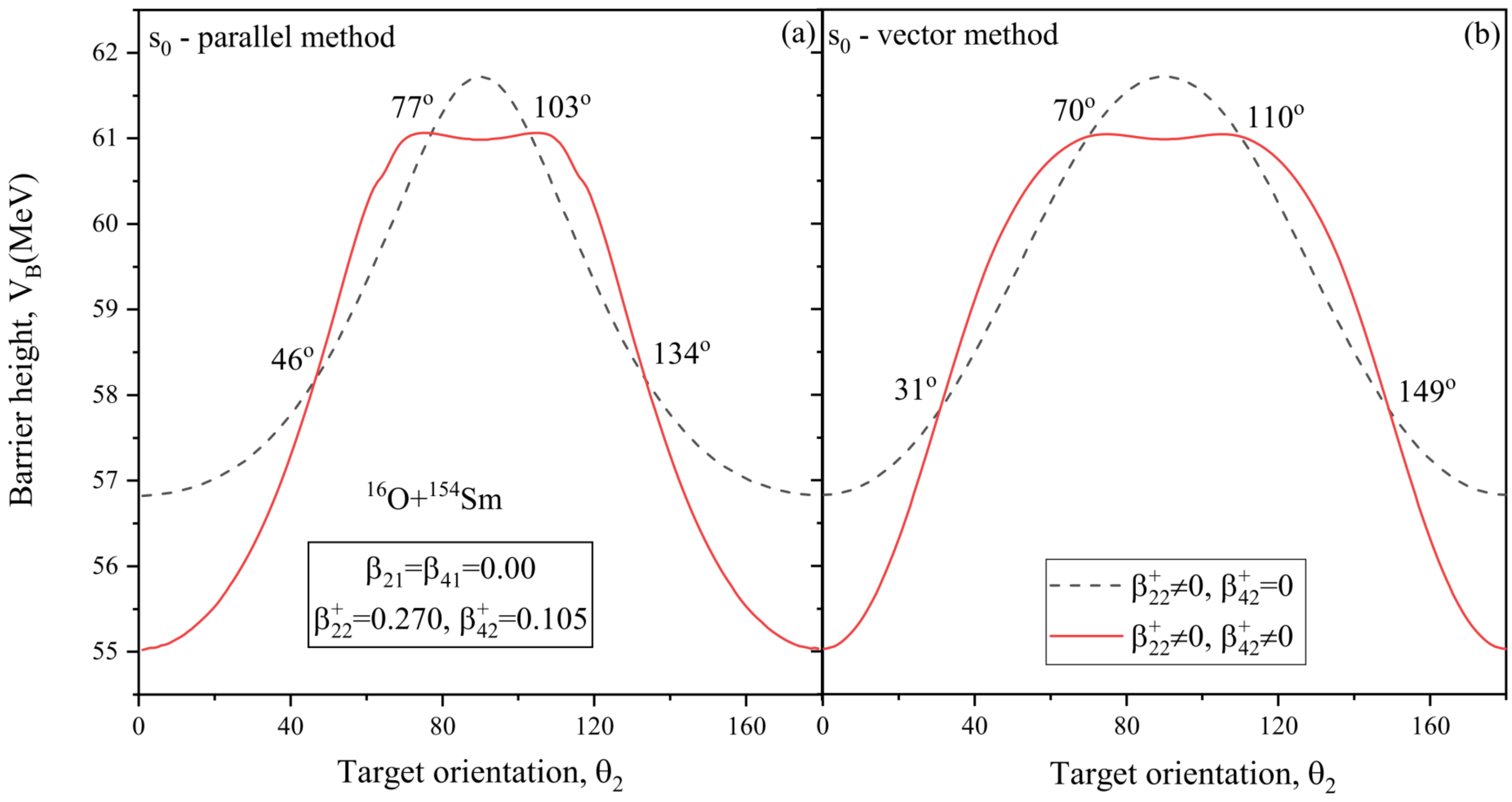
4. Deformation effects



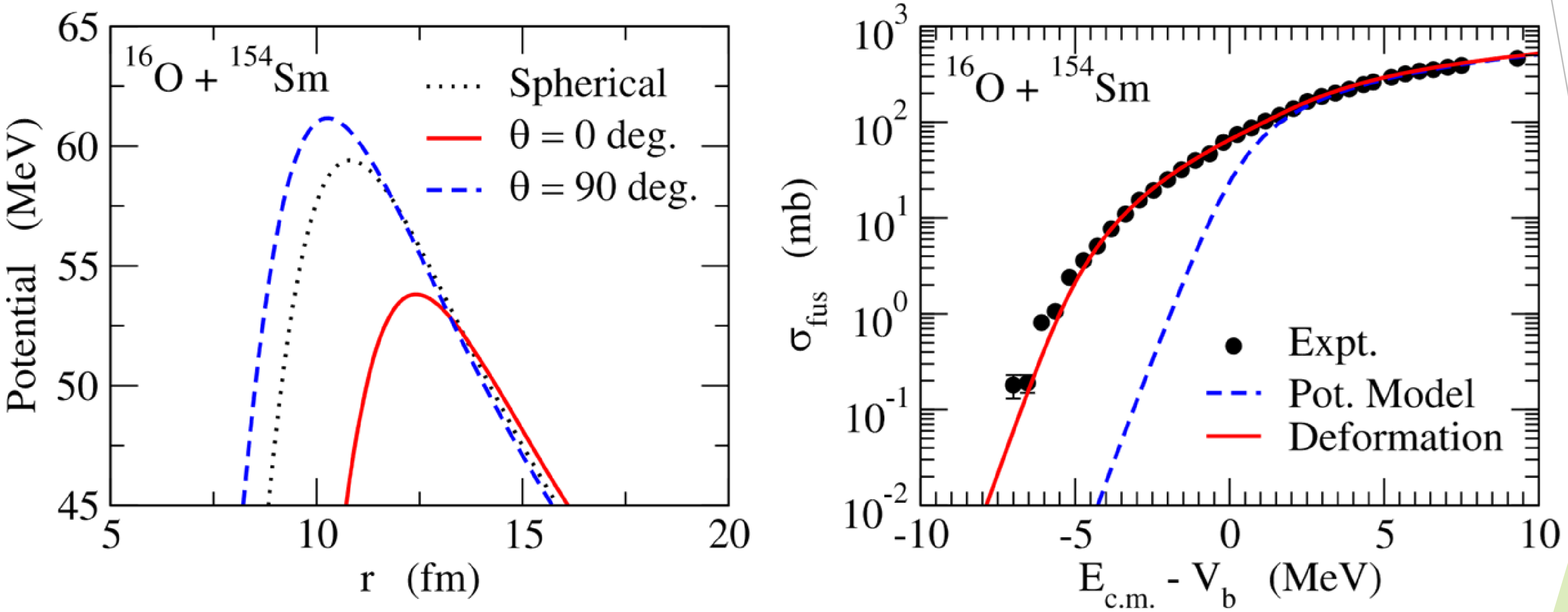
- Harshit Sharma, et al., Eur. Phys. J. A 59, 71 (2023).



- Harshit Sharma, et al., Eur. Phys. J. A 59, 71 (2023).

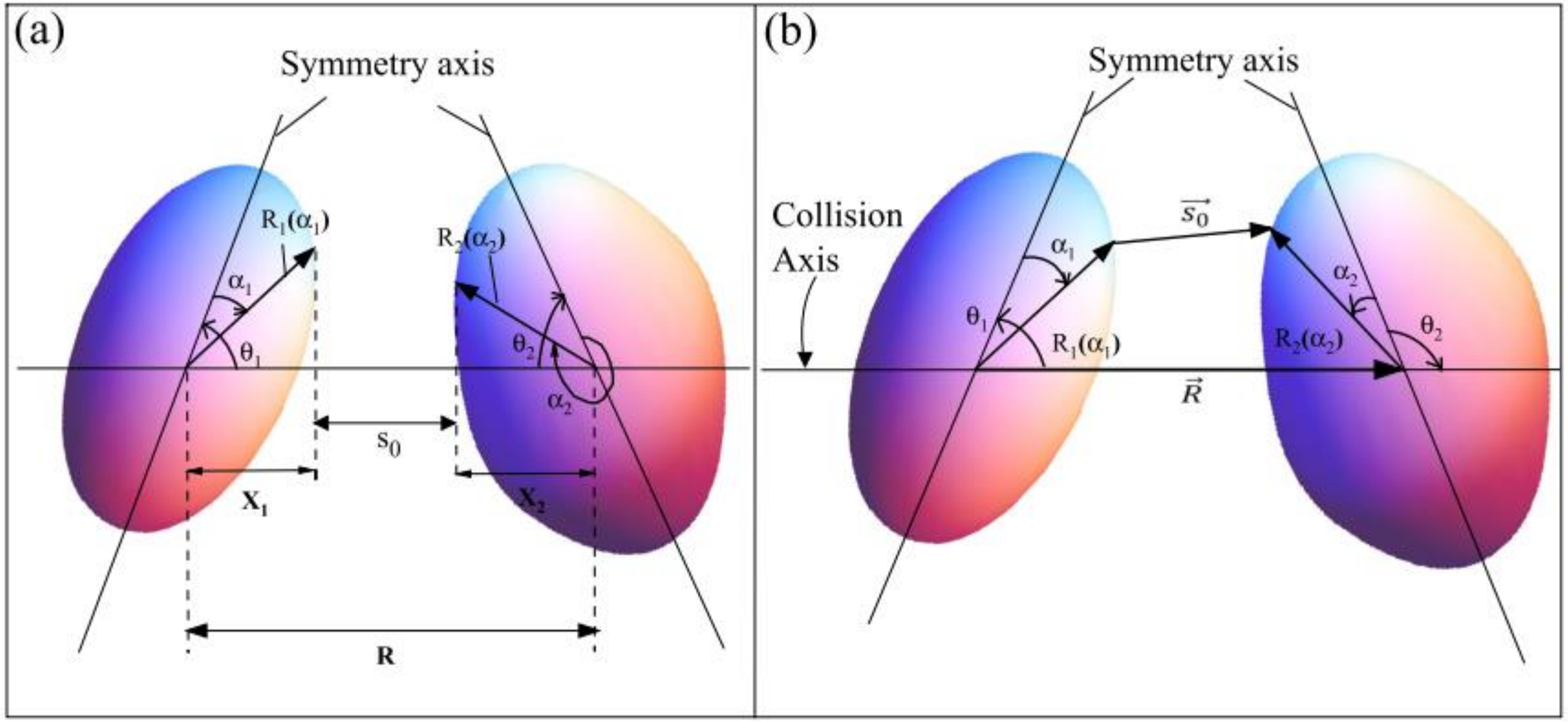


- Harshit Sharma, et al., Eur. Phys. J. A 59, 71 (2023).



- J. R. Leigh, M. Dasgupta, et al., Phys. Rev. C 52, 3151 (1995).

Thanks for your attention



(a)
Symmetry axis
R1(α1)
R2(α2)
α1
θ1
θ2
α2
s0
X1
X2
R
(b)
Symmetry axis
Collision
Axis
s0
α1
θ1
R1(α1)
α2
θ2
R2(α2)
R