THEORETICAL STUDY OF REACTIONS LEADING TO PRODUCTION OF NEW SUPERHEAVY NUCLEI

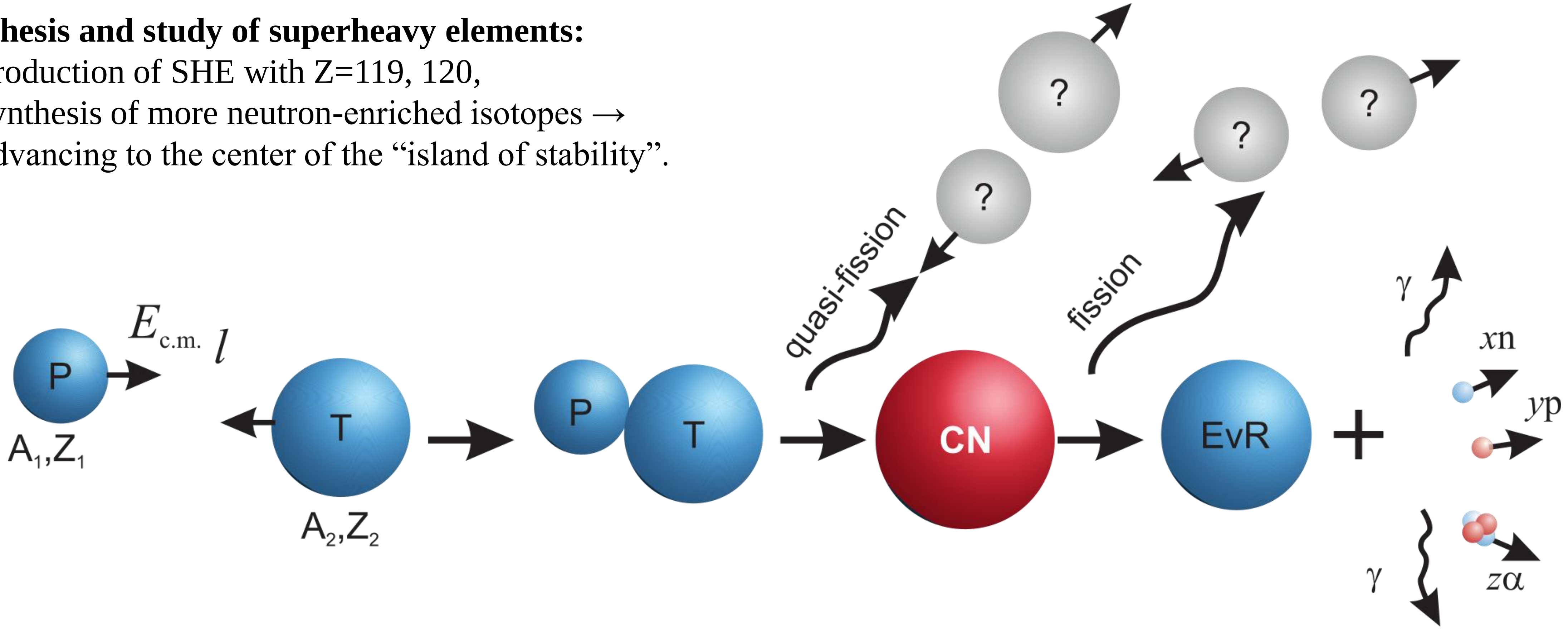
N.Yu. Kurkova, A.V. Karpov

Alushta, 2022

Motivation

Synthesis and study of superheavy elements:

- production of SHE with Z=119, 120,
- synthesis of more neutron-enriched isotopes →
- advancing to the center of the "island of stability".



Study of the stages of complete fusion reactions:

- main channels of reactions,
- competition of quasi-fission and fusion-fission processes,
- mechanism of fusion.

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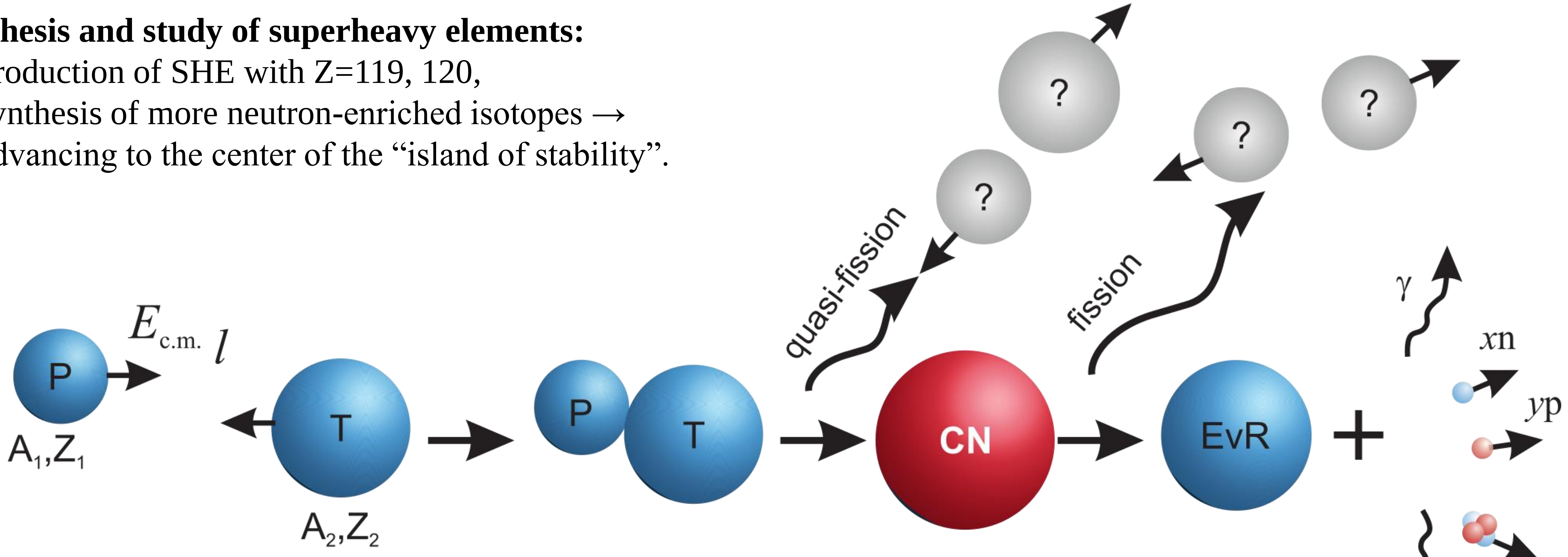

$$\sigma_{\mathrm{ER}}^{xn,yp,z\alpha}(E)=\frac{\pi}{k^2}\sum_{l=0}^{\infty}(2l+1)P_{\mathrm{cont}}(E,l)P_{\mathrm{CN}}(E^*,l)P_{xn,yp,z\alpha}(E^*,l)$$

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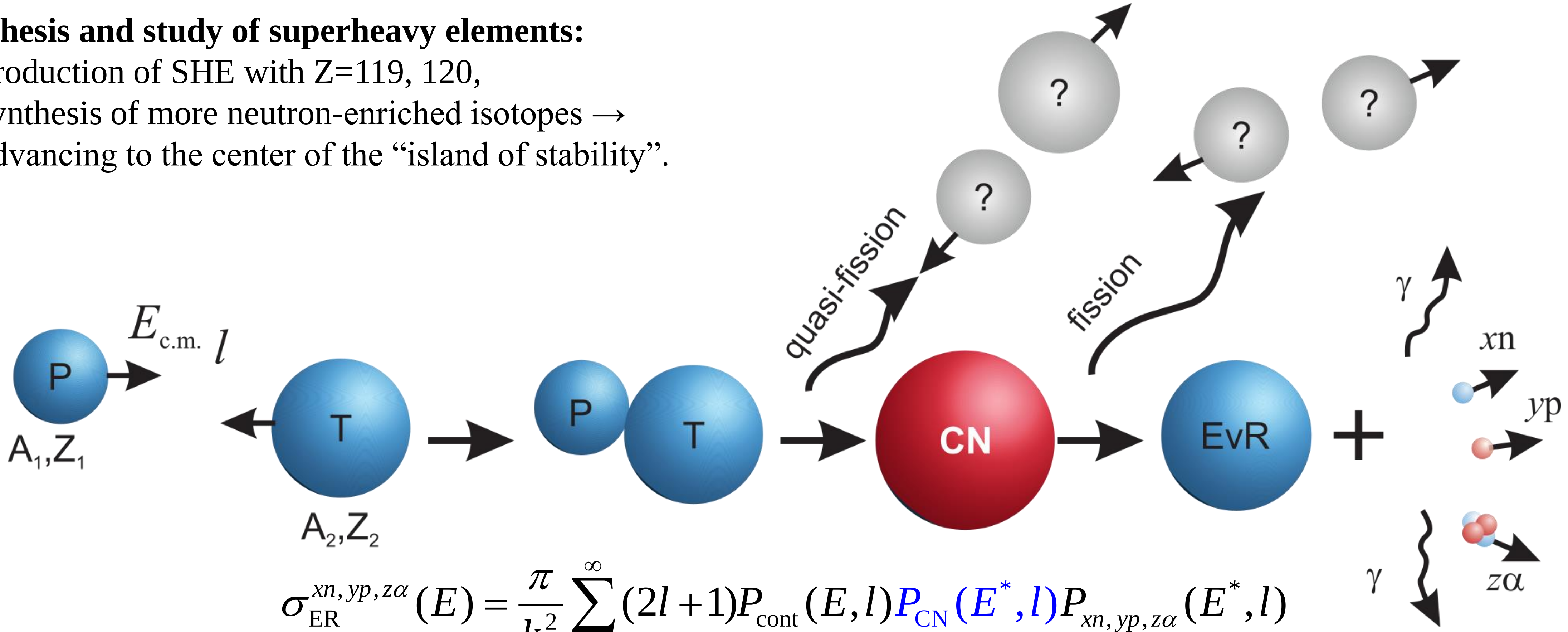

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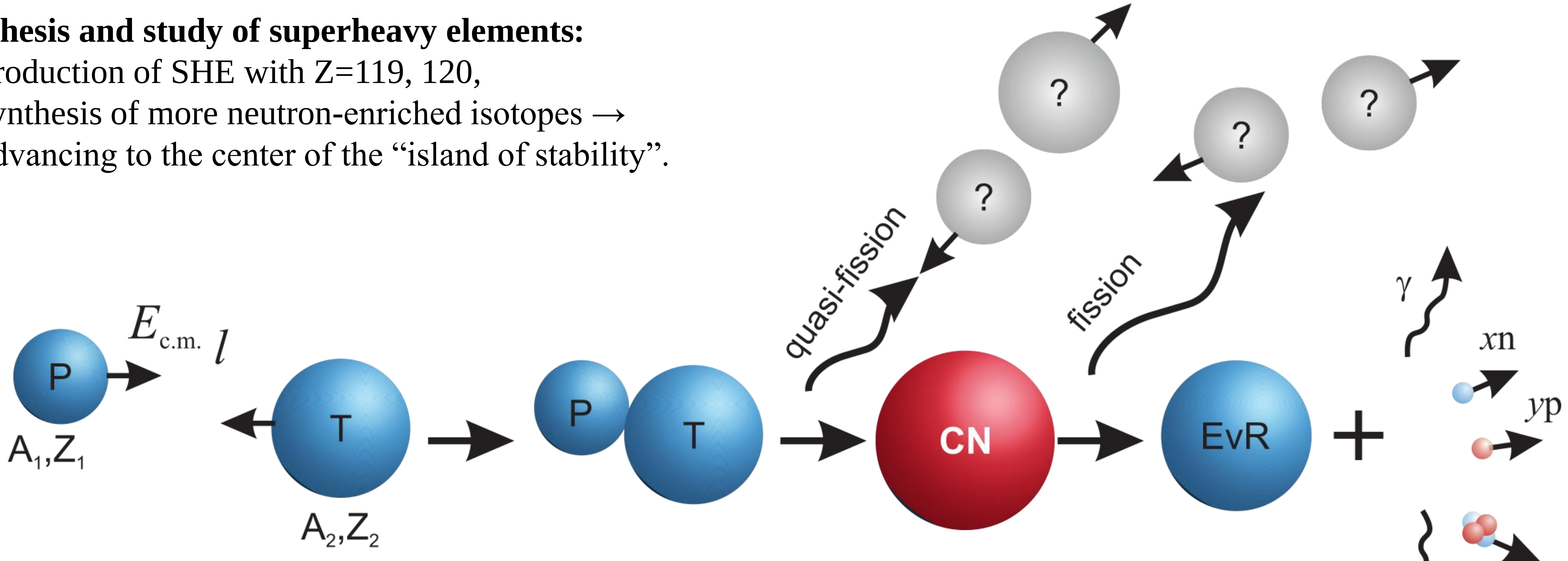

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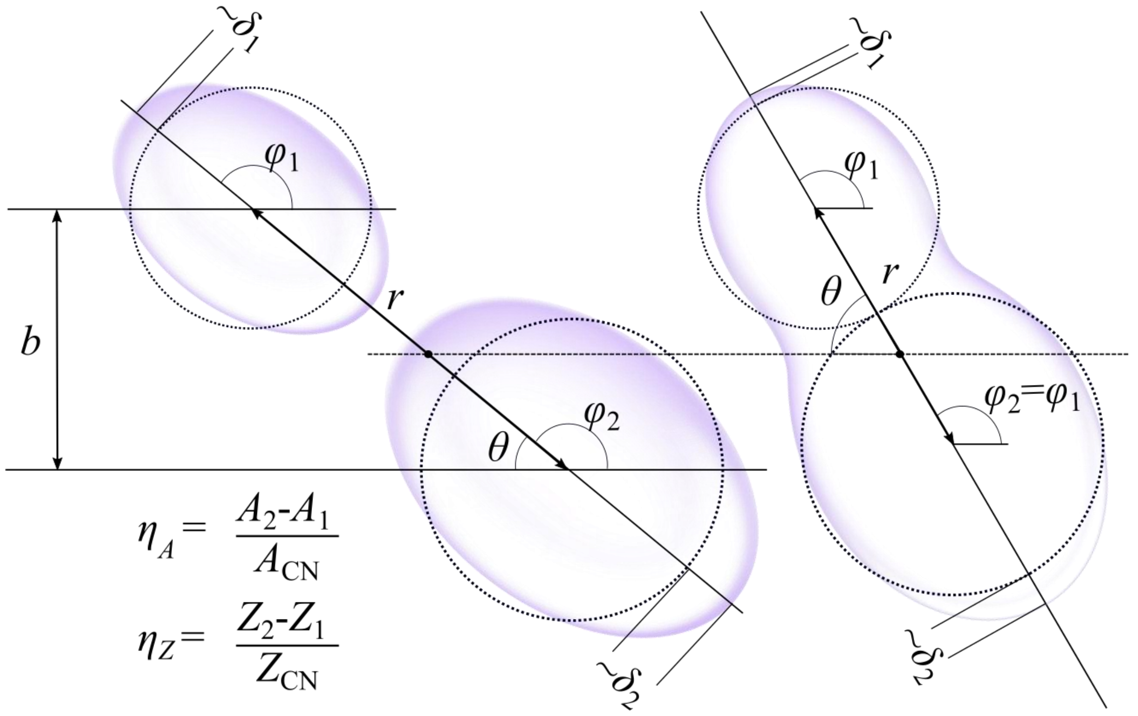
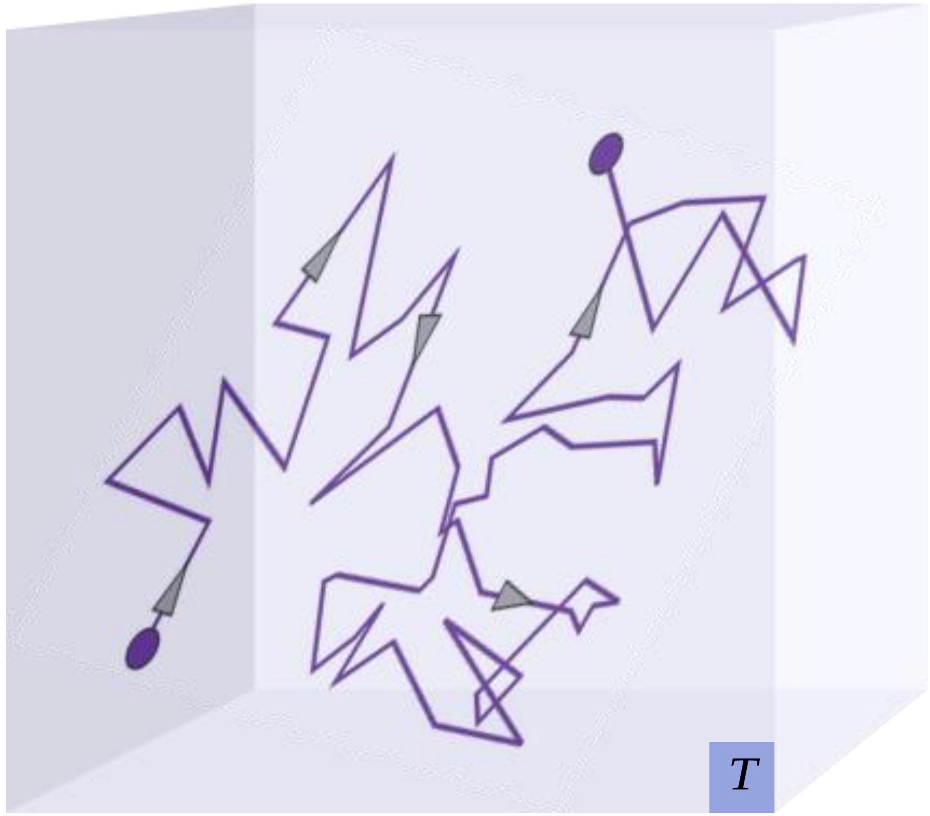
Dynamical model of nucleus-nucleus collisions





$$\begin{cases} \dot{q}_i = \mu_{ij} p_j , \\ \dot{p}_i = F_i^{\text{driving}} + F_i^{\text{friction}} + F_i^{\text{random}} \end{cases}$$

The model has been developed in A.V. Karpov and V.V. Saiko, Physical Review C 96 (2017) 024618;
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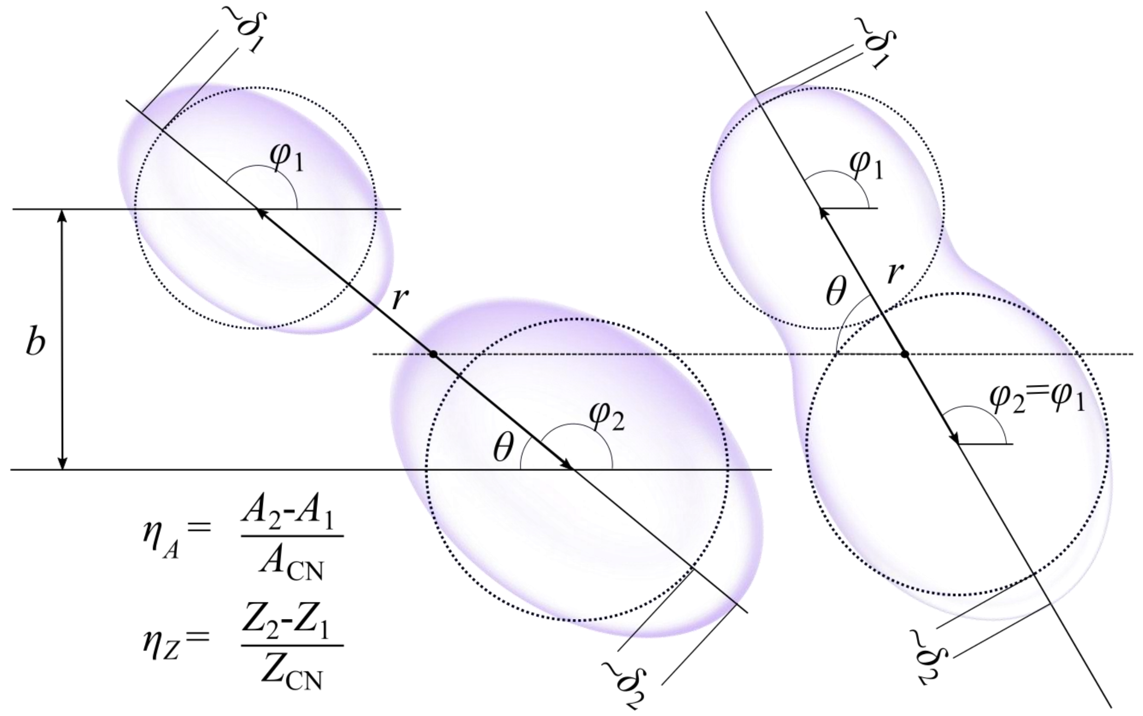

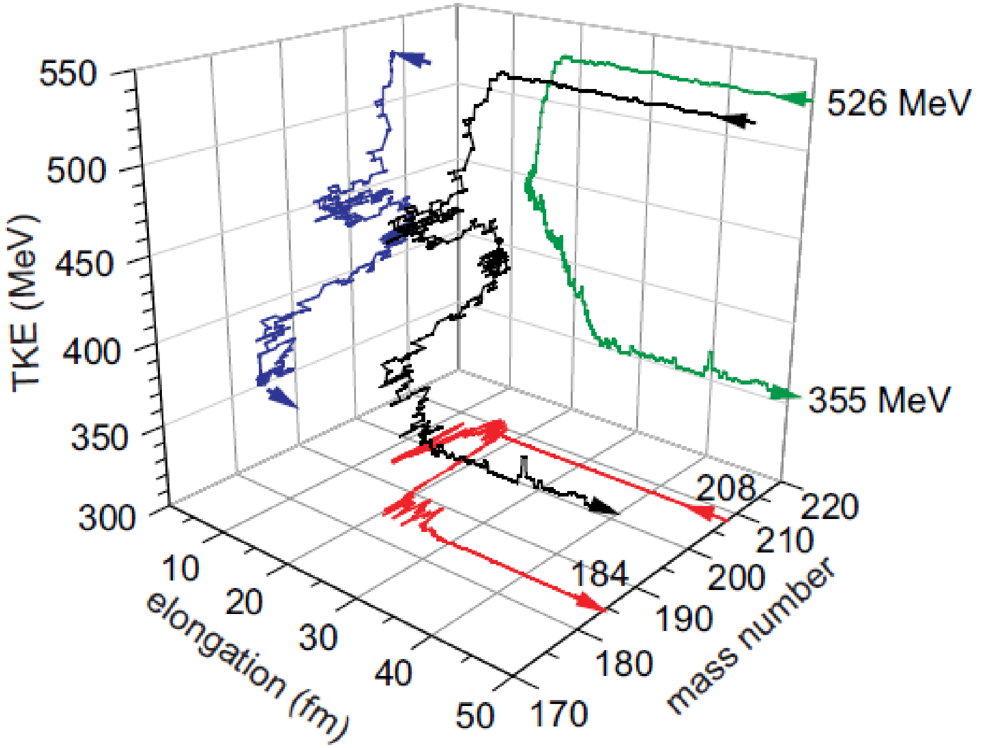

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$$\frac{d^4\sigma}{dM\,dZ\,dE\,d\Omega}(M,Z,E,\theta) = \int_0^{b_{\max}} \frac{\Delta N(b,E,\theta)}{N_{\text{tot}}(b)} \frac{b\,db}{\sin\theta\,\Delta M\,\Delta Z\,\Delta\theta\,\Delta E}$$

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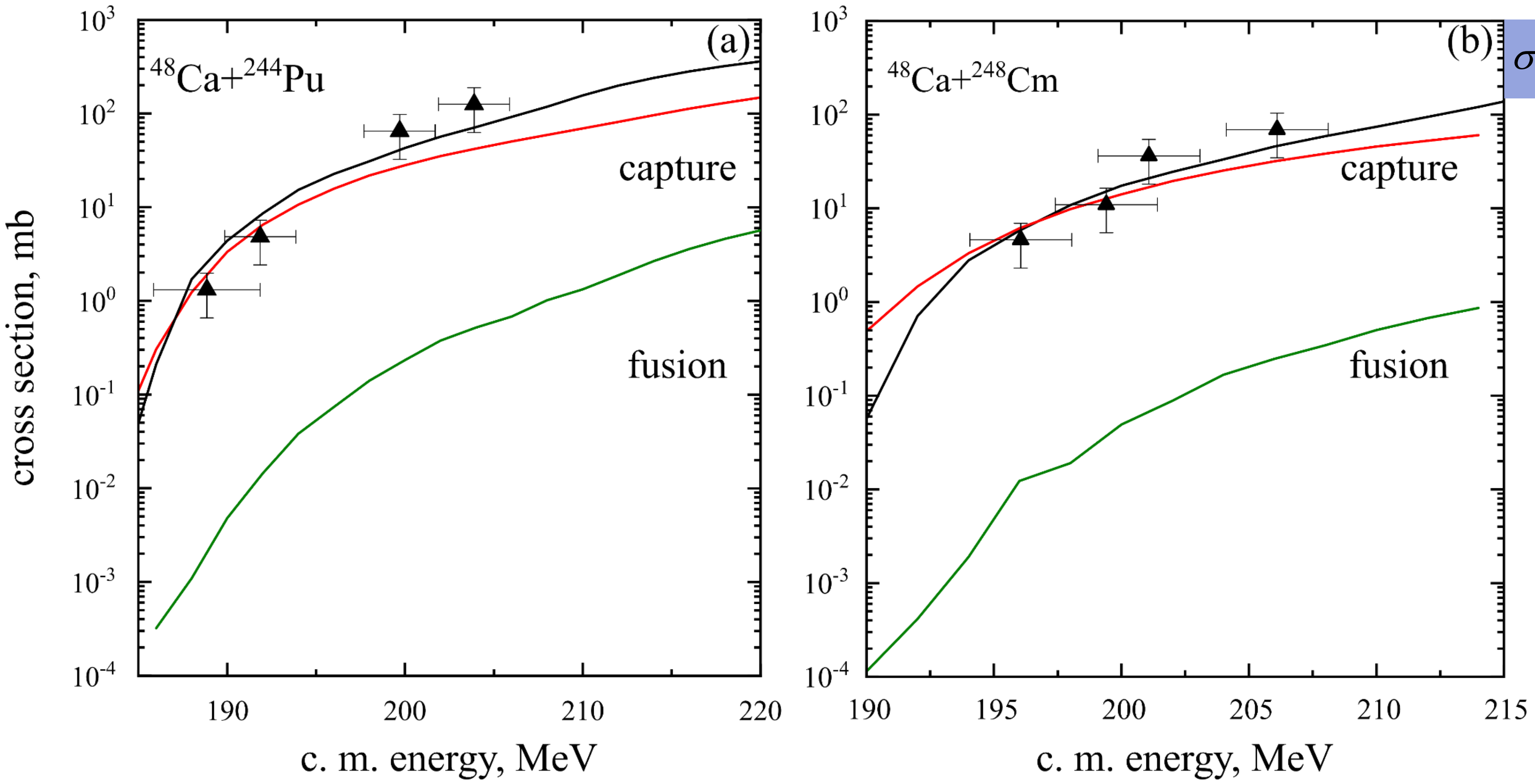
Capture and fusion cross sections



$\sigma_{fus} / \sigma_{capt} \sim 0.1\%$

— – the channel coupling model (NRV);

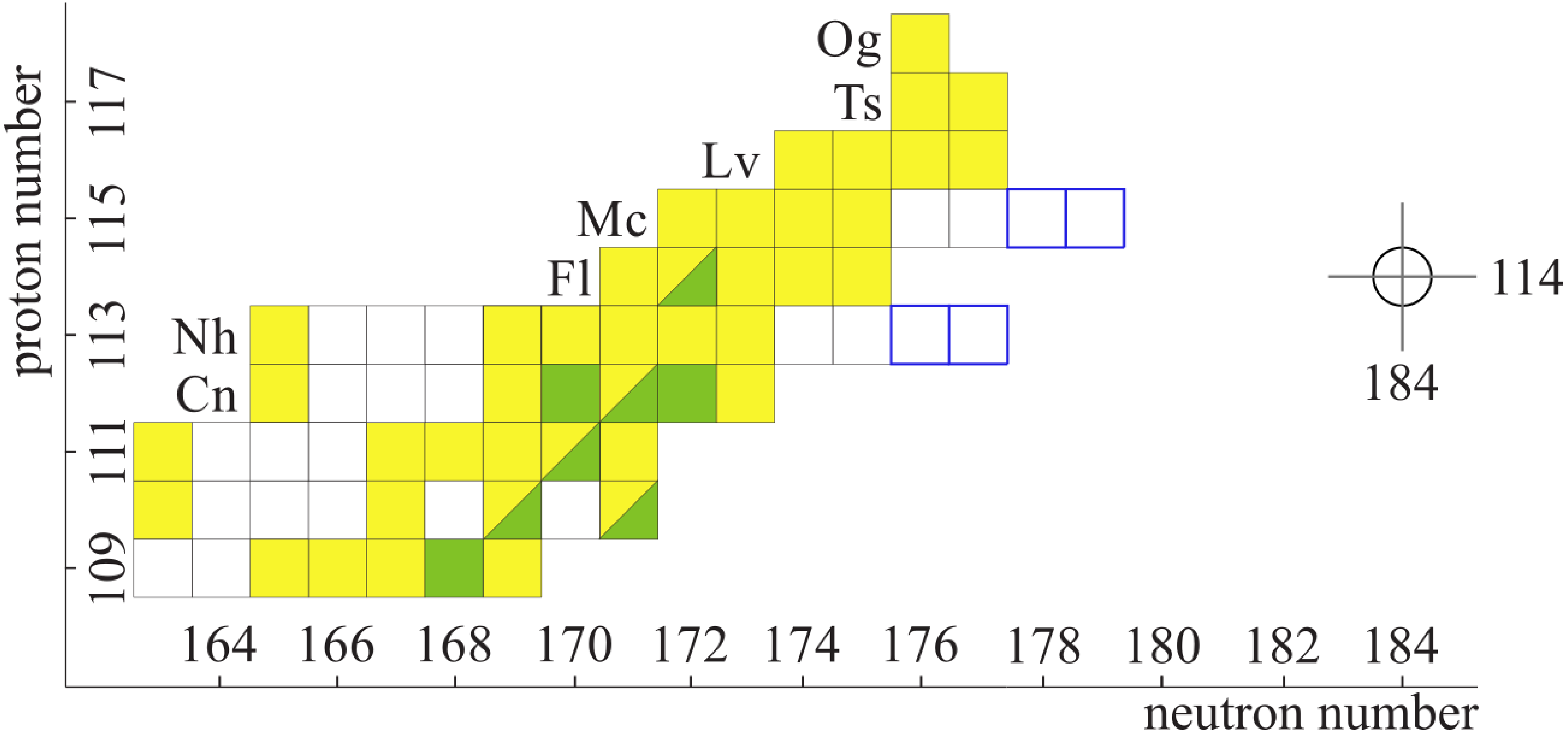
—, — – current model;

▲ – E. M. Kozulin, et al., Phys. Rev. C 90 (2014) 054608.

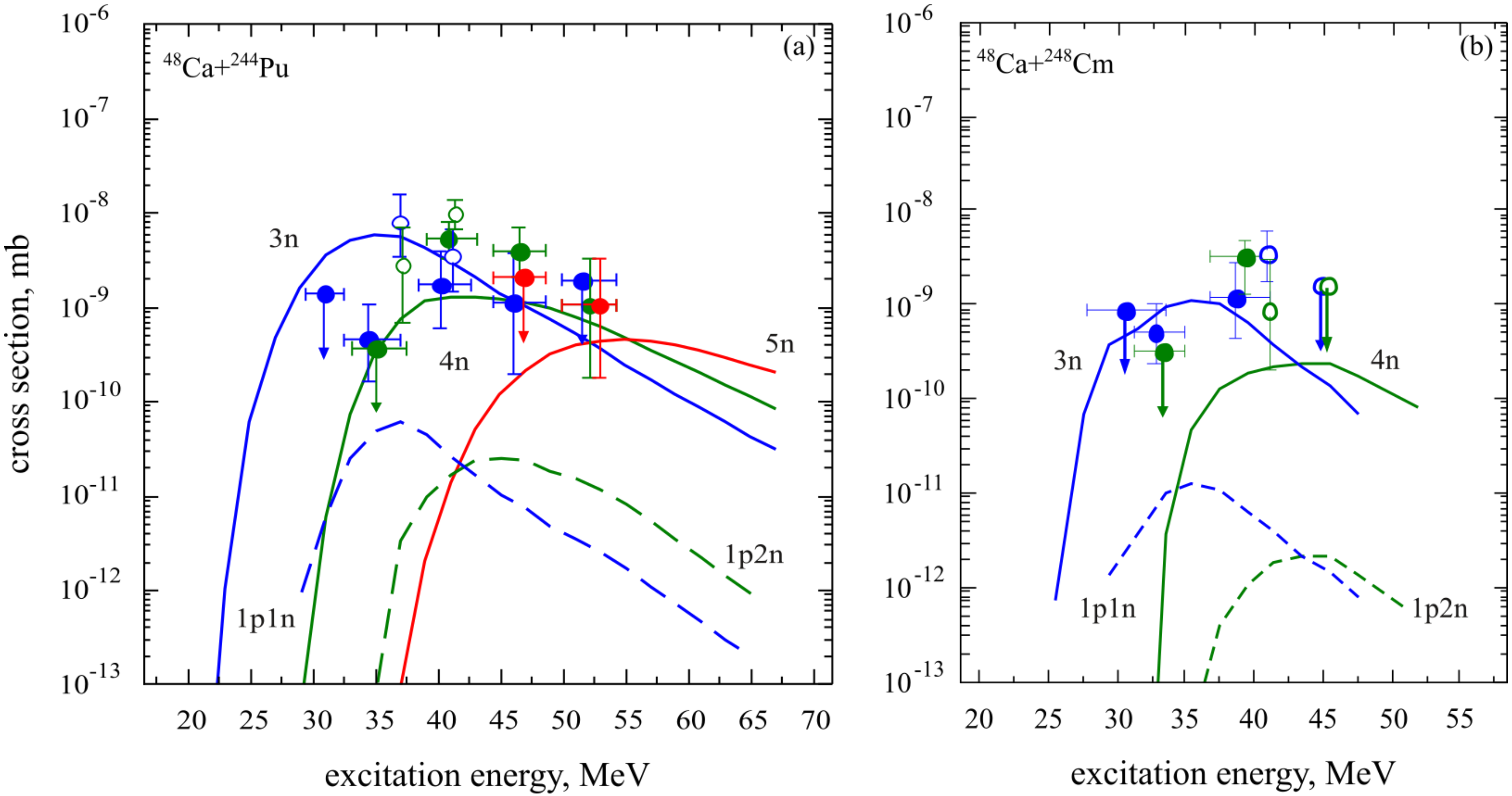
Synthesis of neutron-enriched isotopes in pxn-channels

$^{48}Ca + ^{244}Pu \rightarrow ^{292}Fl^{*} \rightarrow ^{289\text{-}290}Nh + 1p + (1\text{-}2)n$

$^{48}Ca + ^{248}Cm \rightarrow ^{296}Lv^{*} \rightarrow ^{293\text{-}294}Mc + 1p + (1\text{-}2)n$



Evaporation residue cross sections in xn- and pxn-channels



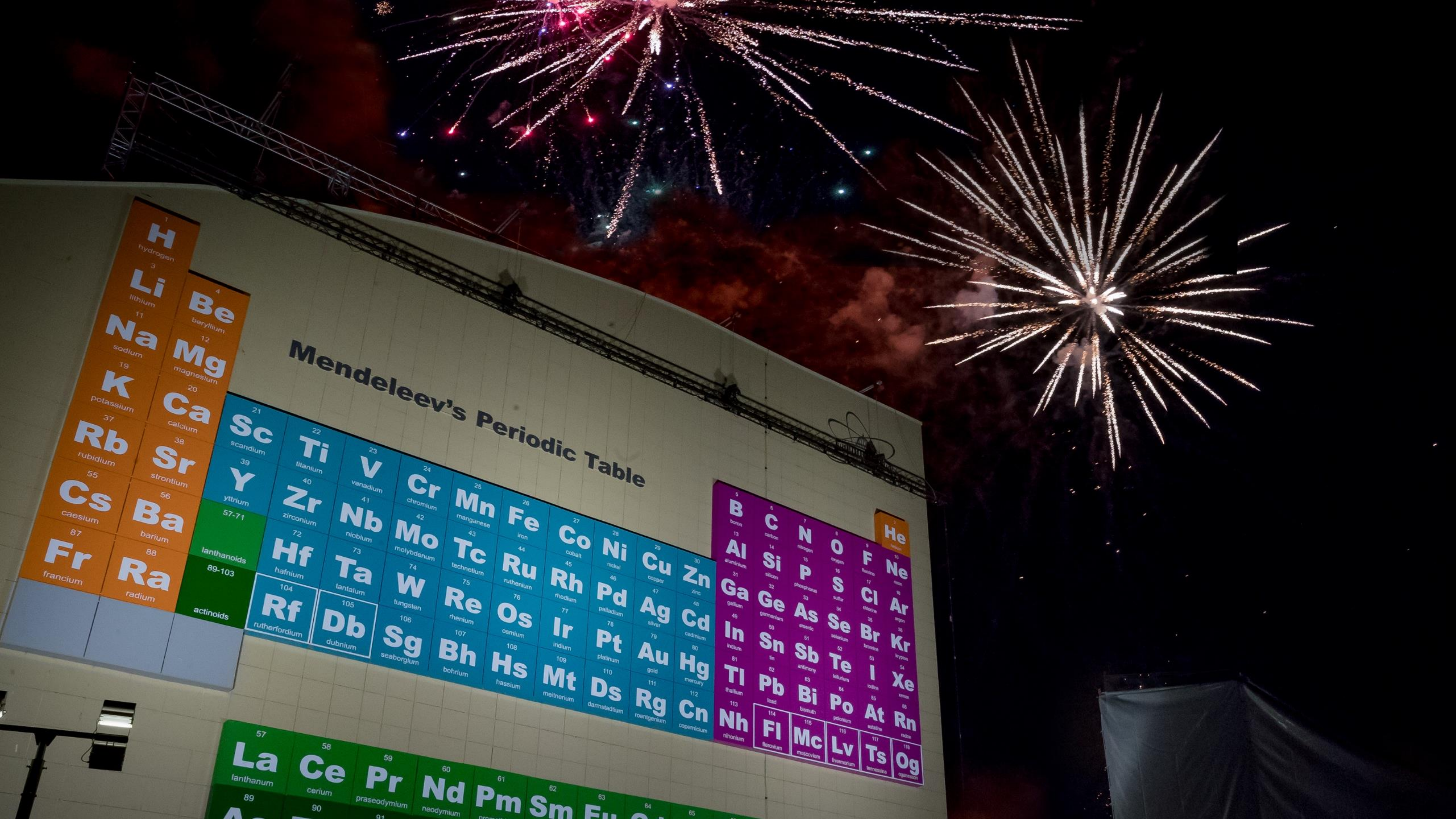
$\sigma^{pn}_{\mathrm{EvR}} / \sigma^{3n}_{\mathrm{EvR}} \sim 1\%$

$\sigma^{p2n}_{\mathrm{EvR}} / \sigma^{4n}_{\mathrm{EvR}} \sim 1\%$

● – experimental data from JINR,

○ – experimental data from GSI.

See Yu. Ts. Oganessian and V.K. Utyonkov, Reports on Progress in Physics 78 (2015) 036301 and references therein.


Mendeleev's Periodic Table
H hydrogen
Li lithium
Be beryllium
Na sodium
Mg magnesium
K potassium
Ca calcium
Rb rubidium
Sr strontium
Cs caesium
Ba barium
Fr francium
Ra radium
57-71 lanthanoids
89-103 actinoids
Sc scandium
Ti titanium
V vanadium
Cr chromium
Mn manganese
Fe iron
Co cobalt
Ni nickel
Cu copper
Zn zinc
Y yttrium
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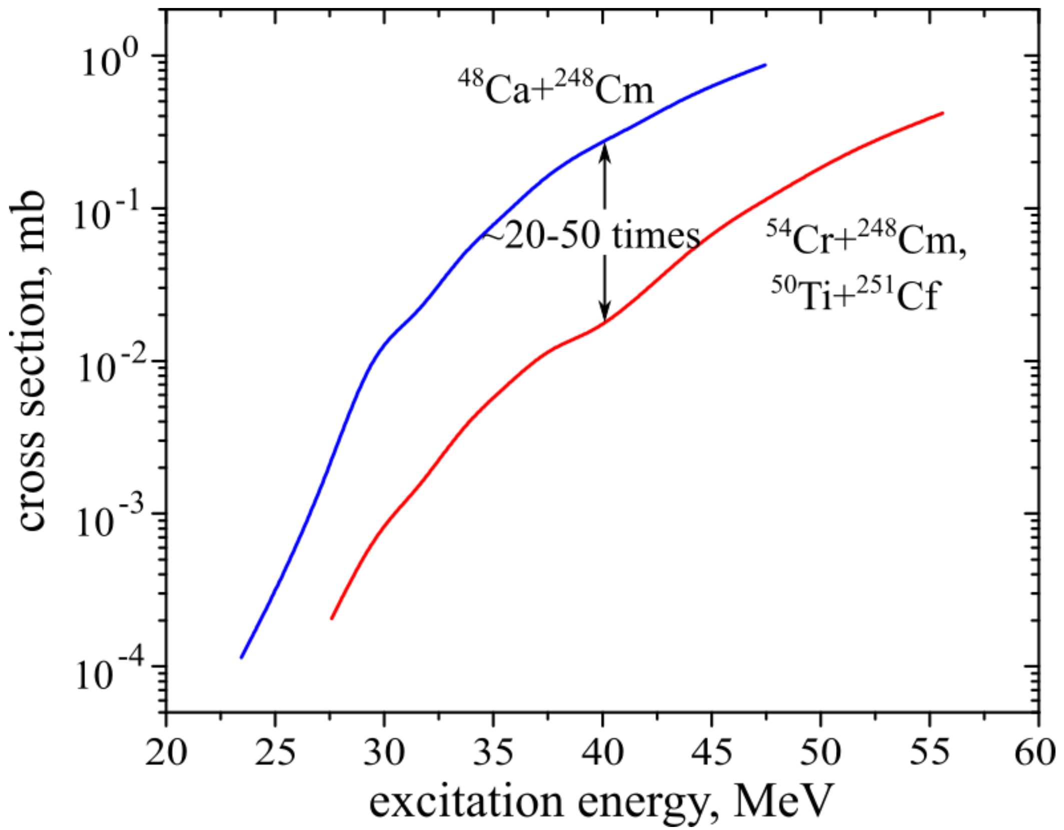
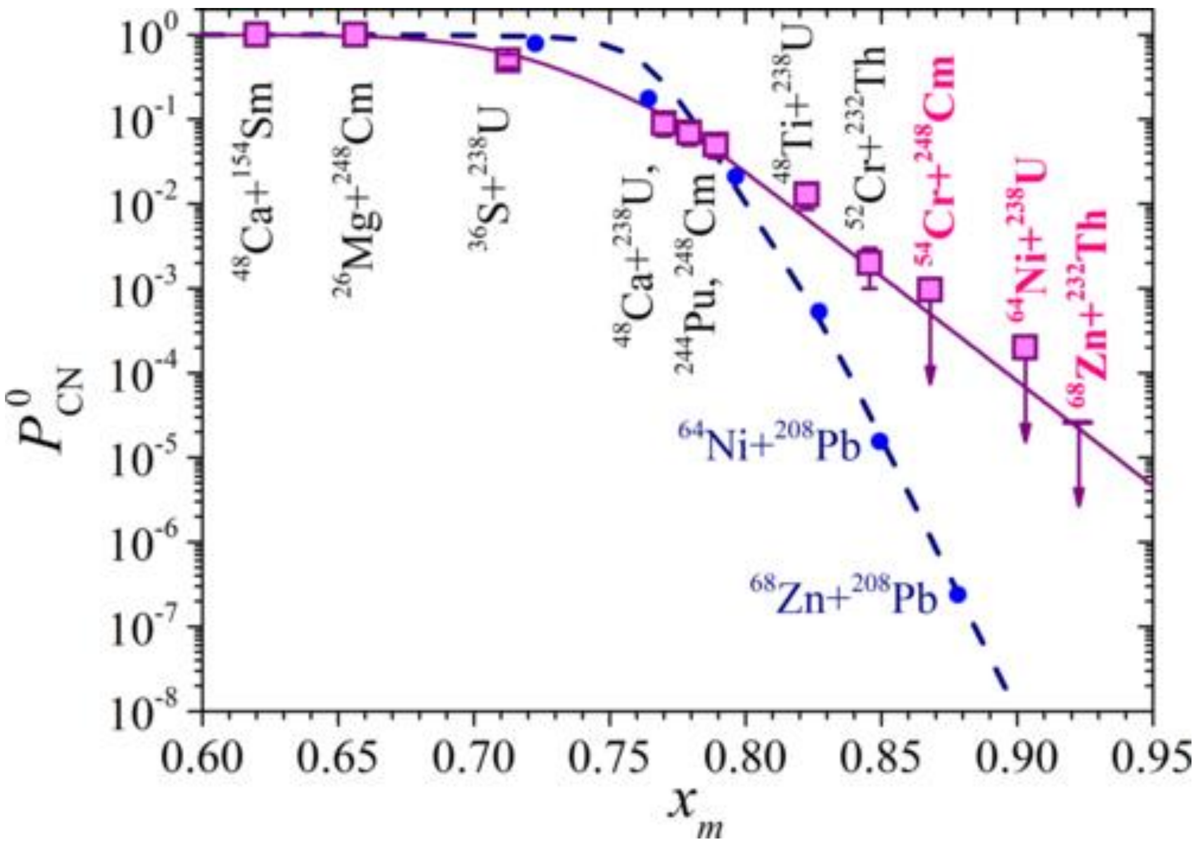
Mt meitnerium
Ds darmstadtium
Rg roentgenium
Cn copernicium
B C N O F Ne
Al Si P S Cl Ar
Ga Ge As Se Br Kr
In Sn Sb Te I Xe
Tl Pb Bi Po At Rn
Nh Fl Mc Lv Ts Og
He
La lanthanum
Ce cerium
Pr praseodymium
Nd neodymium
Pm Sm

Analysis of reactions leading to formation of the elements 119 and 120

$$\sigma_{\rm ER}^{xn,yp,z\alpha}(E) = \frac{\pi}{k^2}\sum_{l=0}^{\infty}(2l+1)P_{\rm cont}(E,l)P_{\rm CN}(E^*,l)P_{xn,yp,z\alpha}(E^*,l)$$





K. Novikov, et al., Phys. Rev. C 102 (2020) 044605

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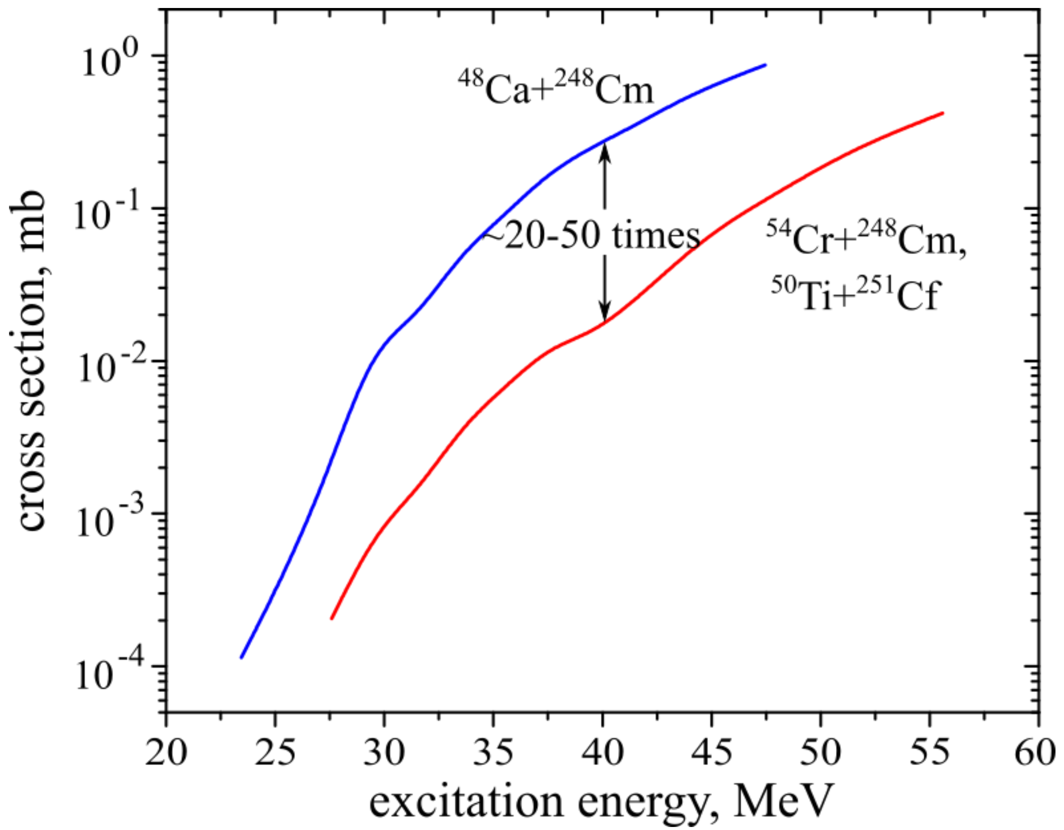

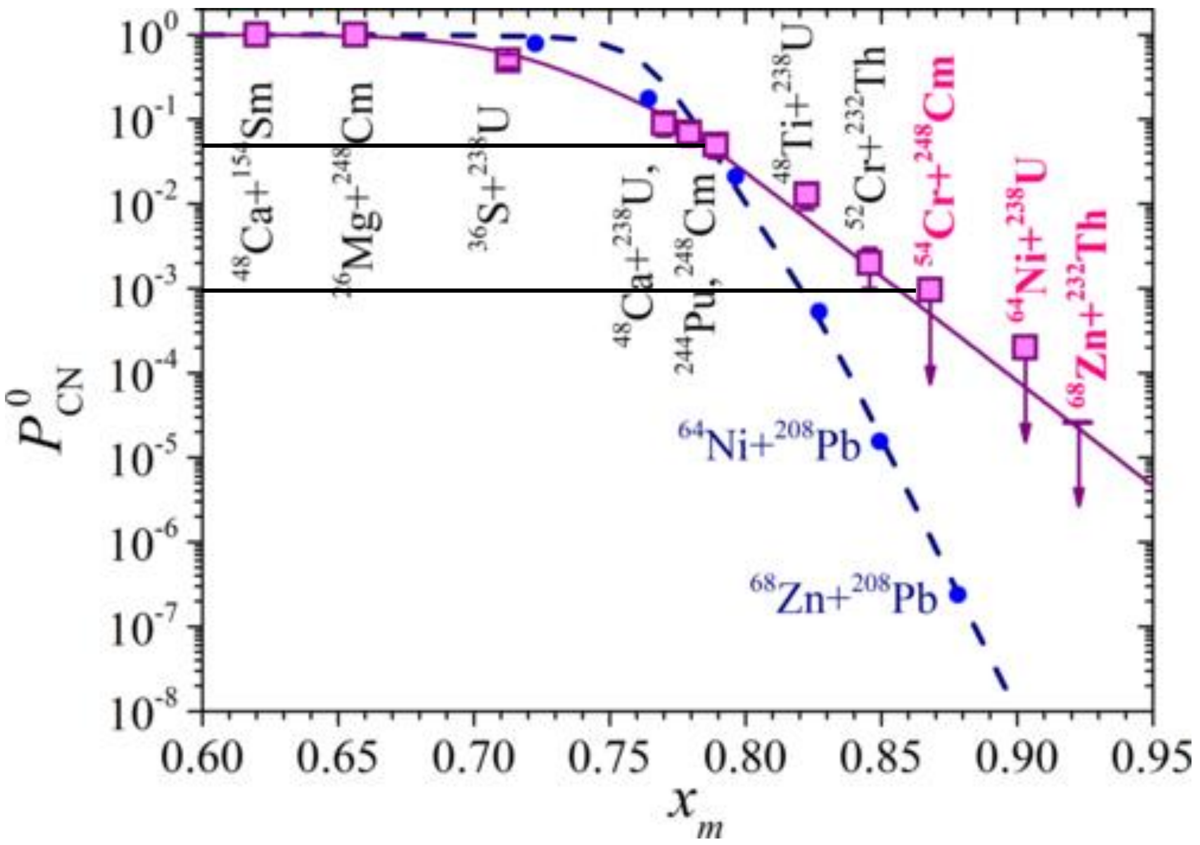

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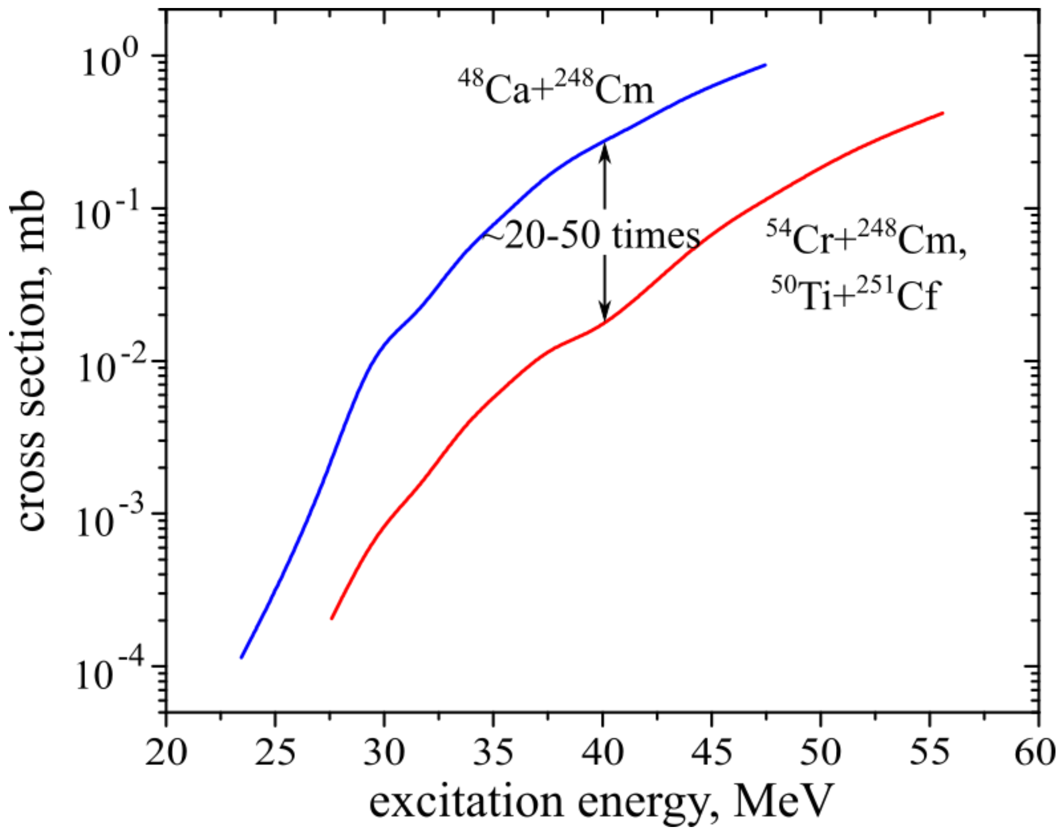

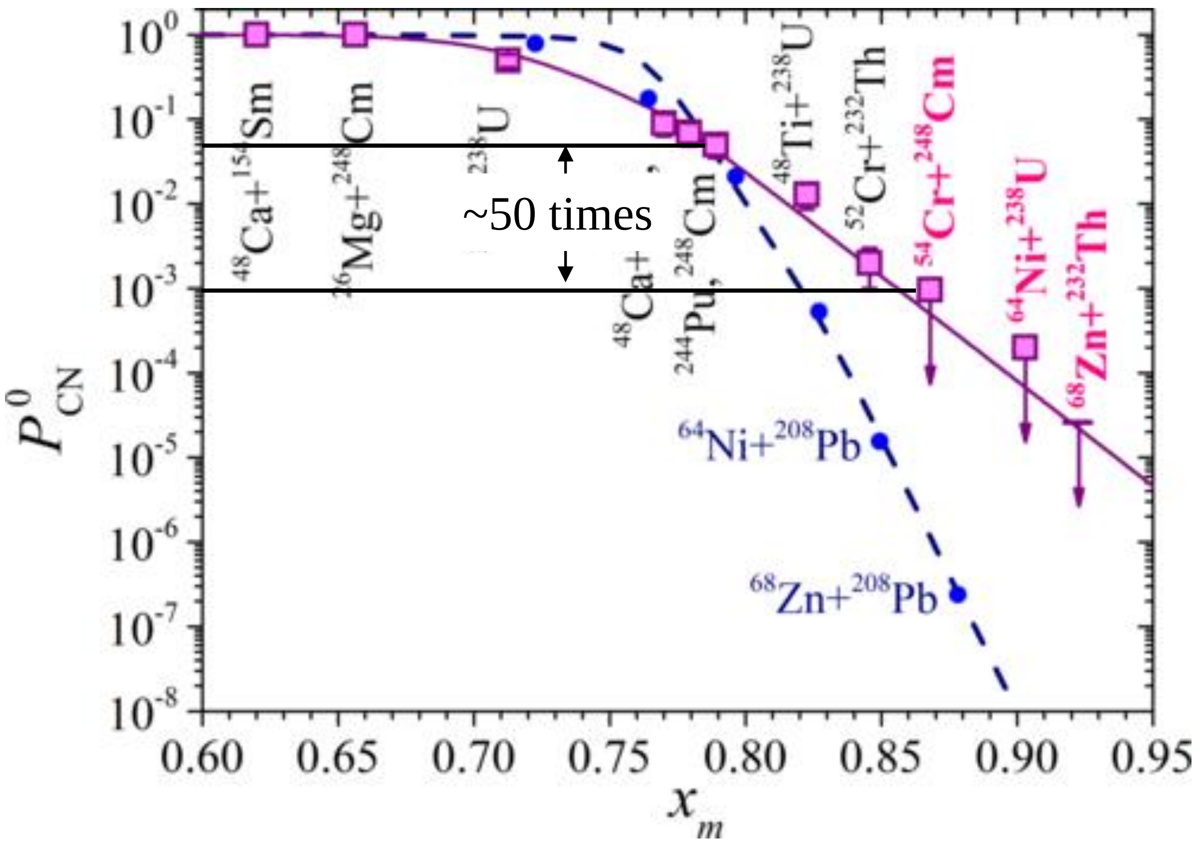

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Fission barriers

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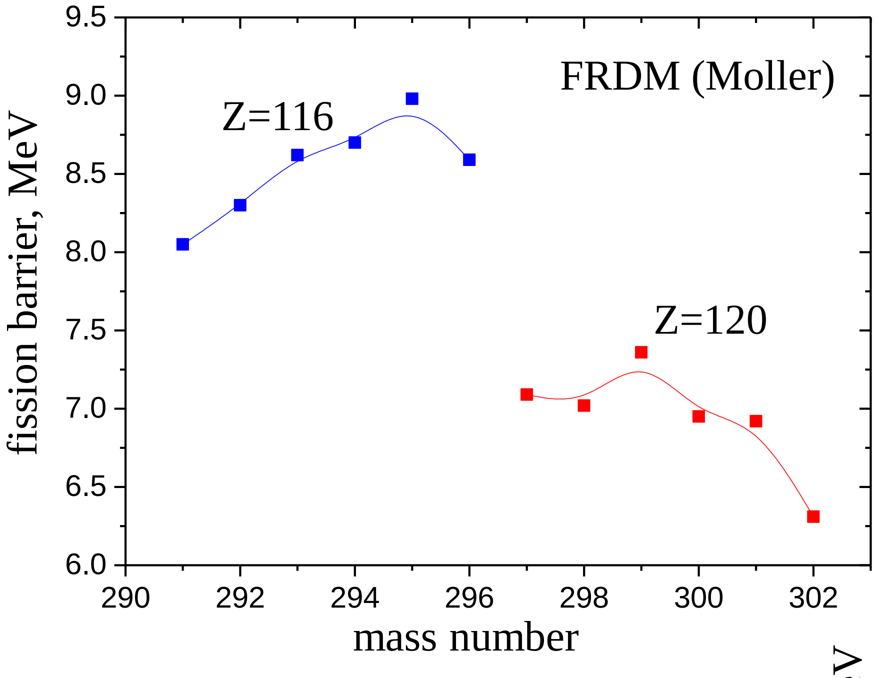

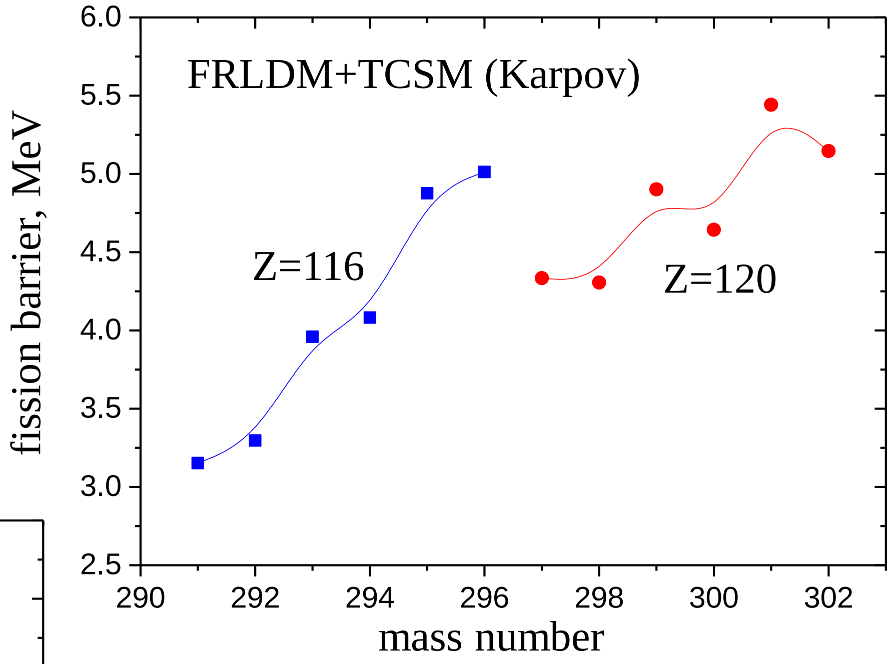

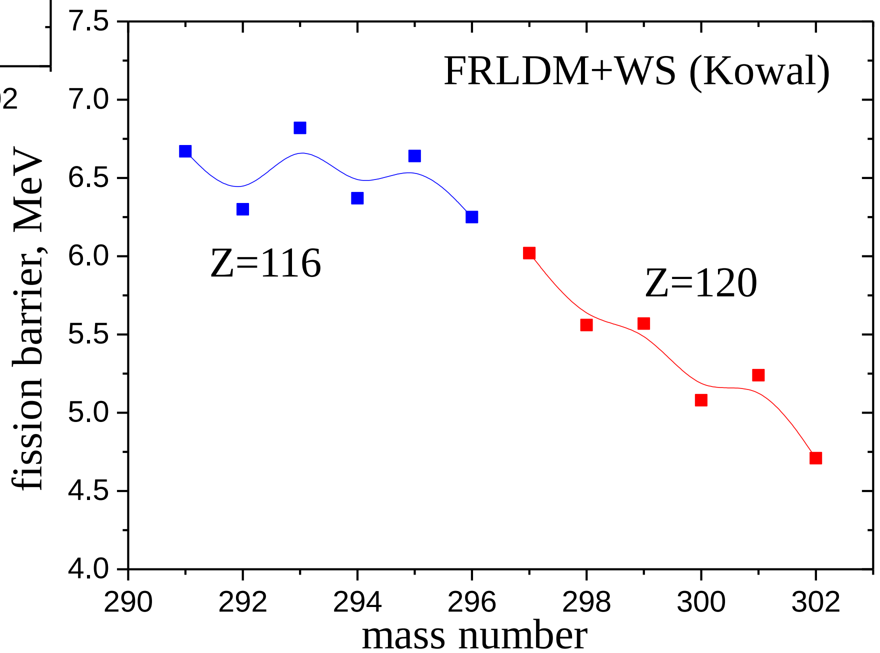

Conclusions

Analysis of ^{48}Ca + actinides reactions:

- fusion cross sections are about 0.1% of capture cross sections,
- survival cross sections in the channels with proton evaporation can be 1% of those in the neutron-evaporation channels.

Production of SHE with Z=119, 120:

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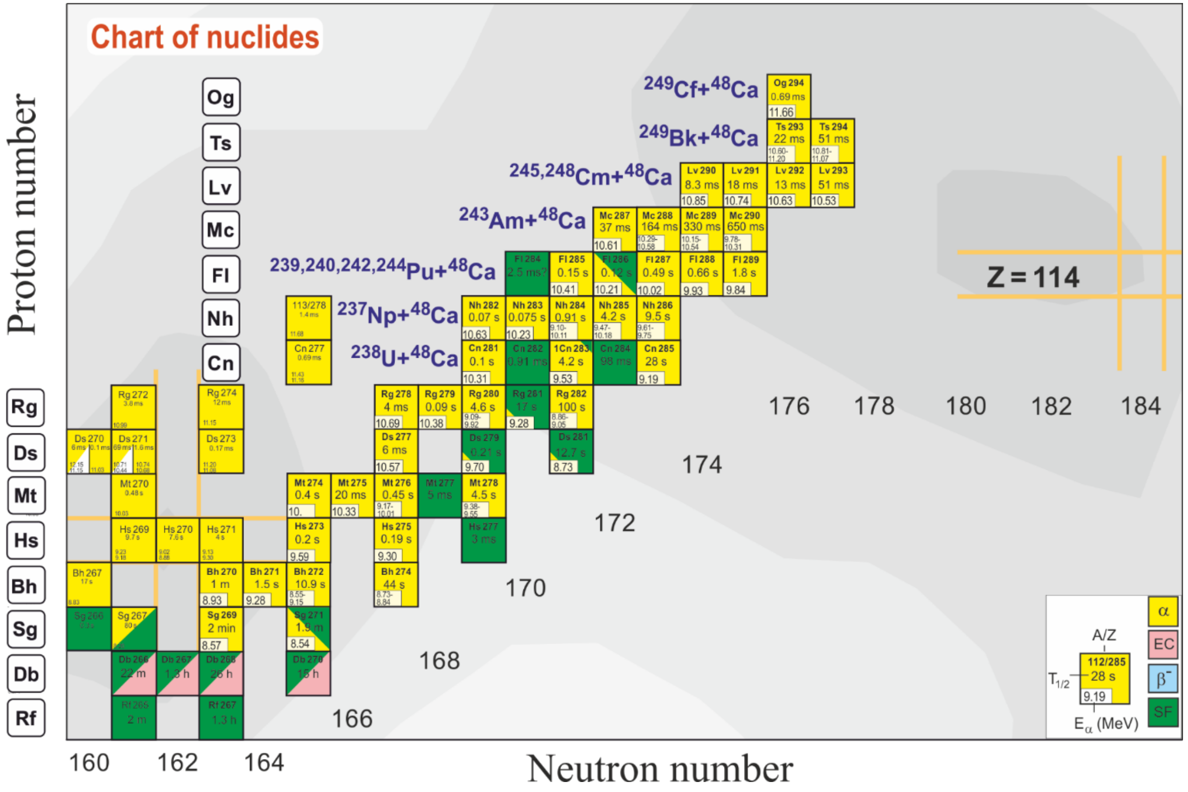

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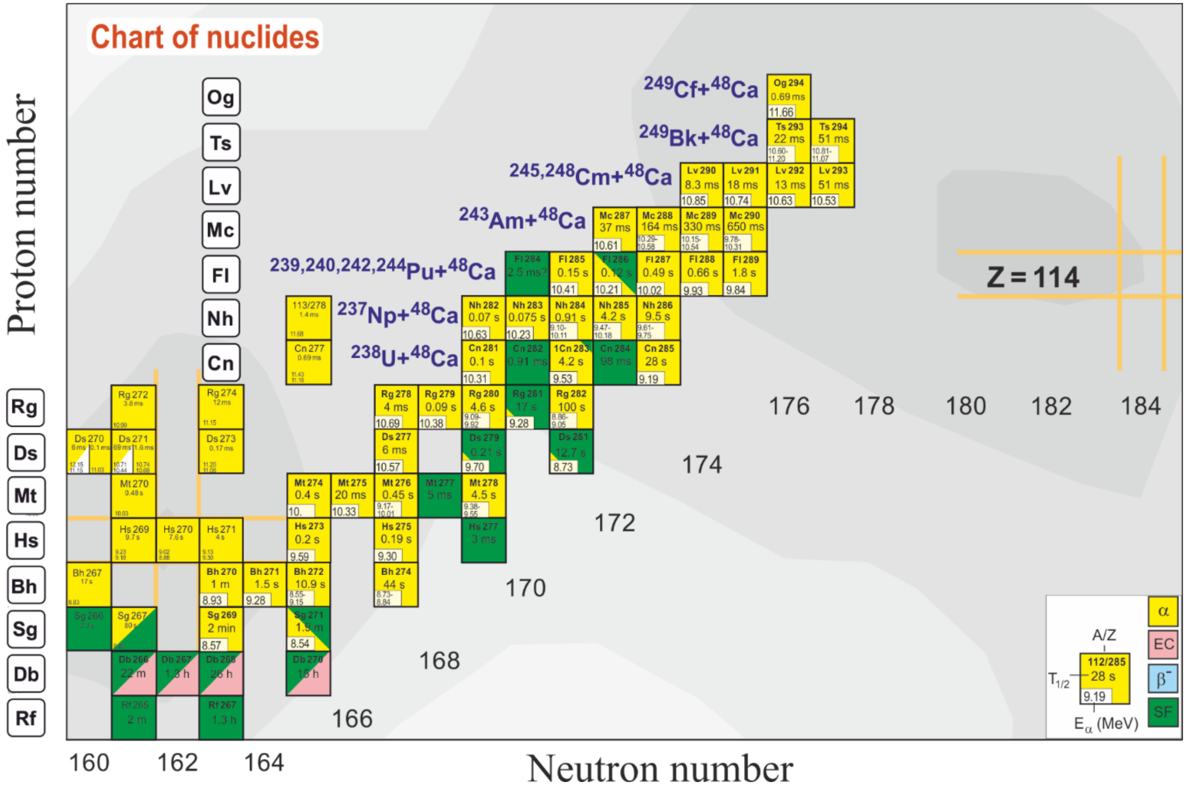

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Thanks for your attention! ☺

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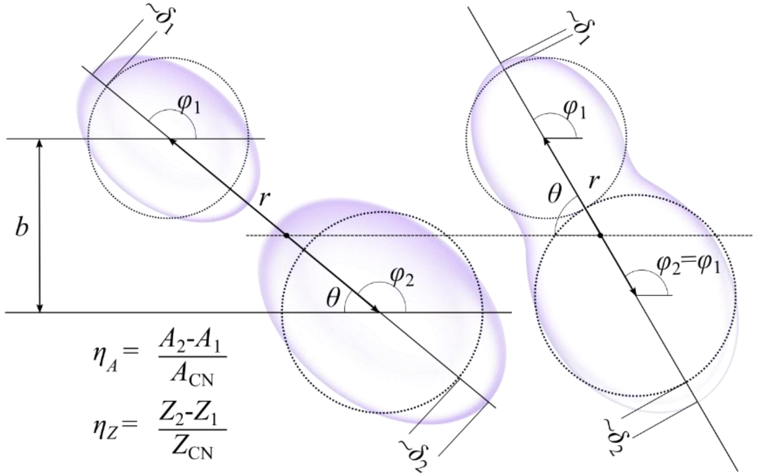

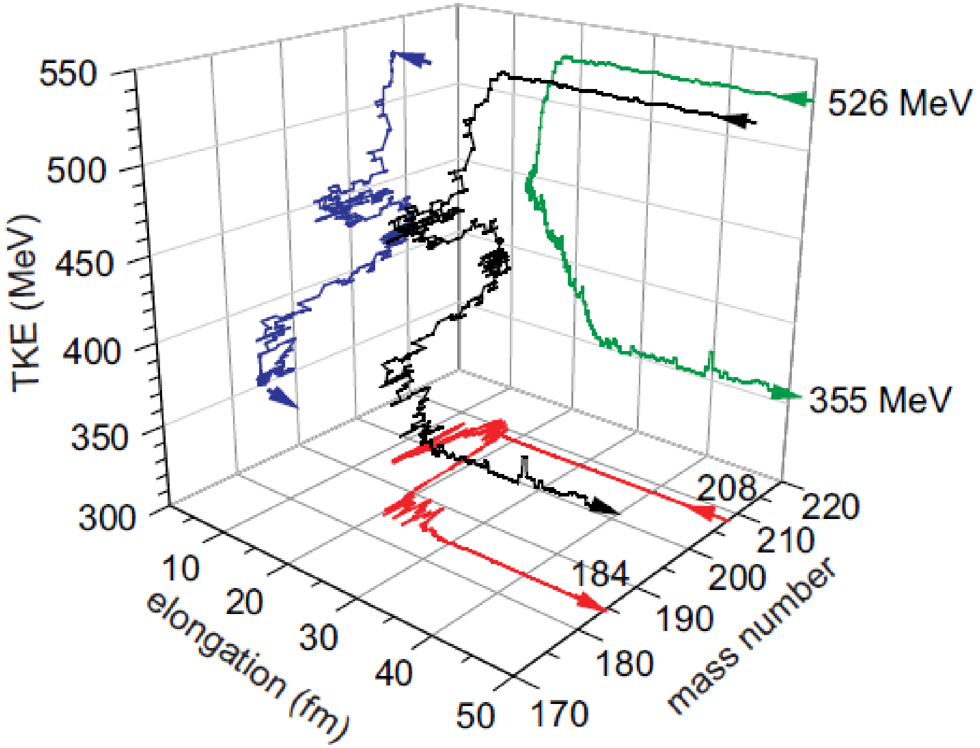

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$$F_i^{\text{driving}} = T\left(\frac{\partial S}{\partial q_i}\right)_{E_{\text{tot}}} , S = 2\sqrt{aE^*} ,$$

$$F_i^{\text{friction}} = -\sum_{j,k} \gamma_{jk} \mu_{jk} p_k ,$$

$$F_i^{\text{random}} = \sum_j \Gamma_{ij} \xi_j (t)$$

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