The XXVII International Scientific Conference of
Young Scientists and Specialists
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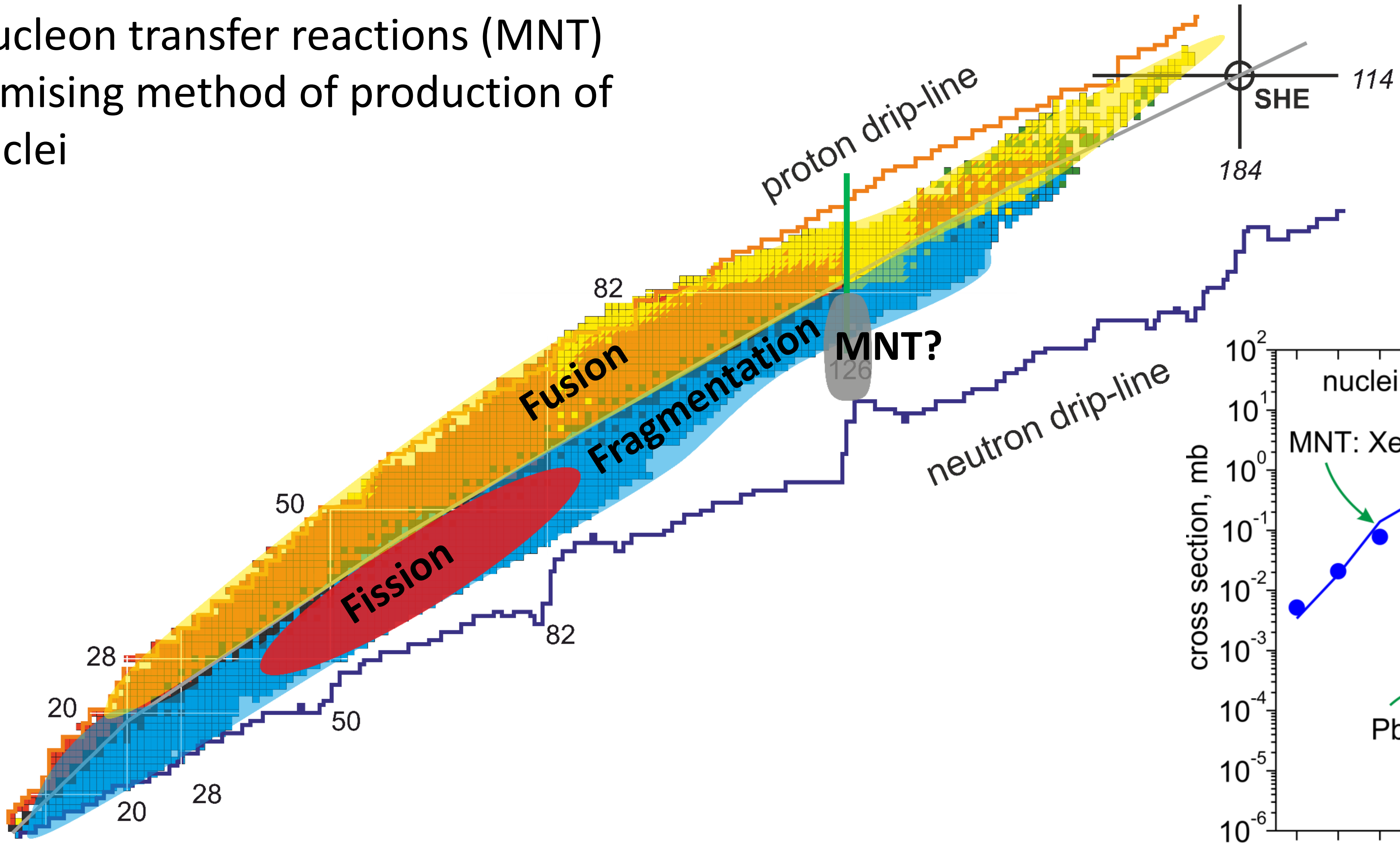
30.10 – 03.11

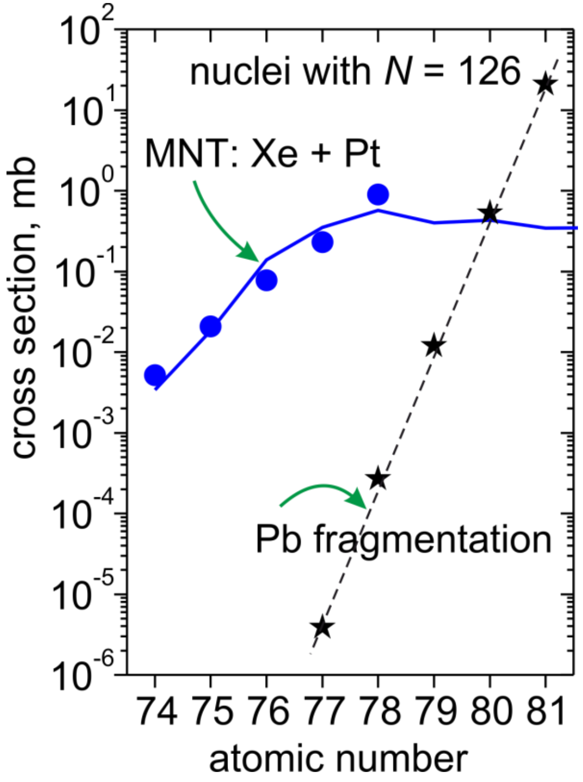
Production of heavy neutron-rich nuclei with the magic number N=126 in the multinucleon transfer reactions induced by radioactive ion beams

Vyacheslav Saiko and Alexander Karpov

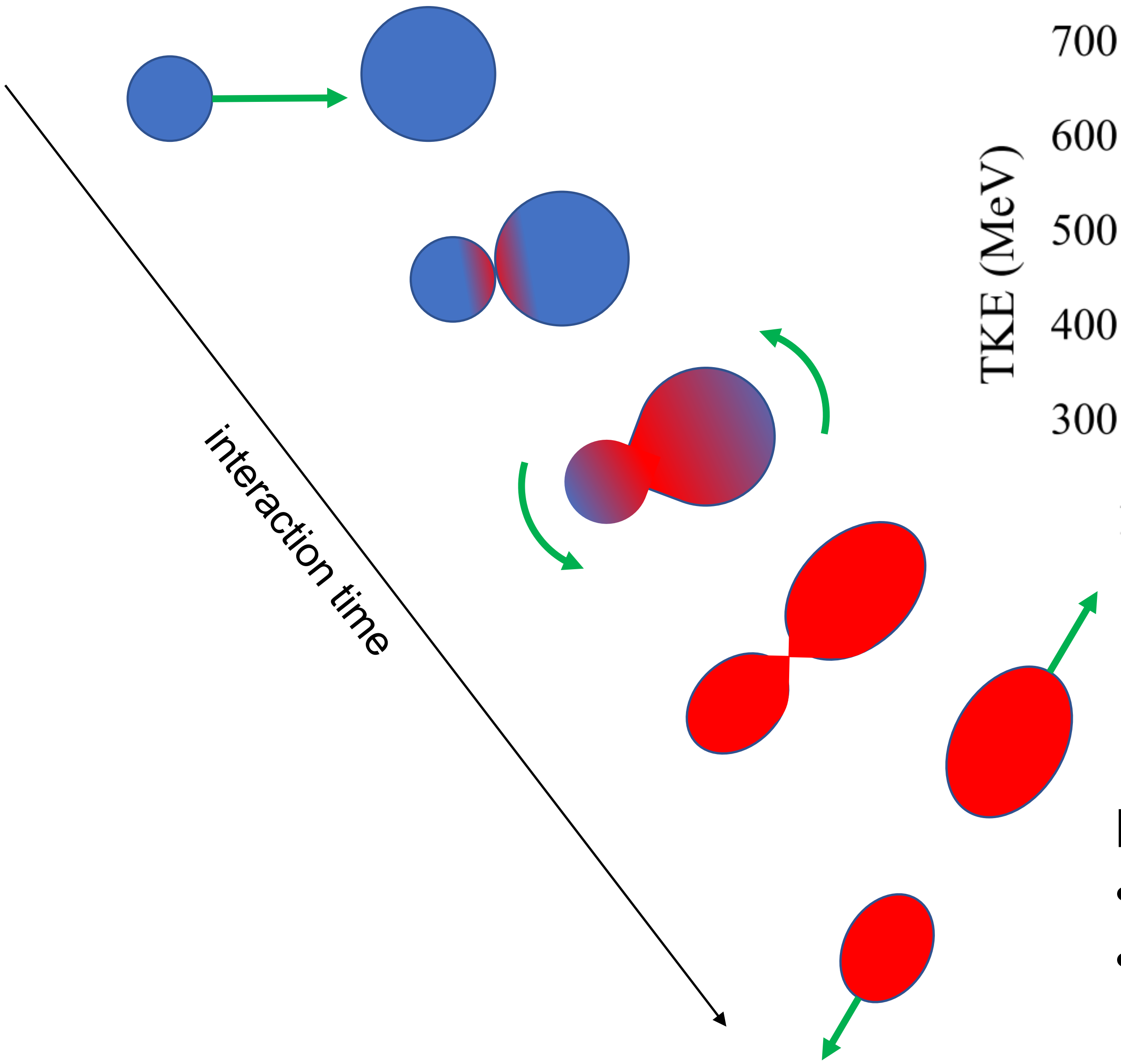
Methods of production of new nuclei

Multinucleon transfer reactions (MNT) is a promising method of production of new nuclei

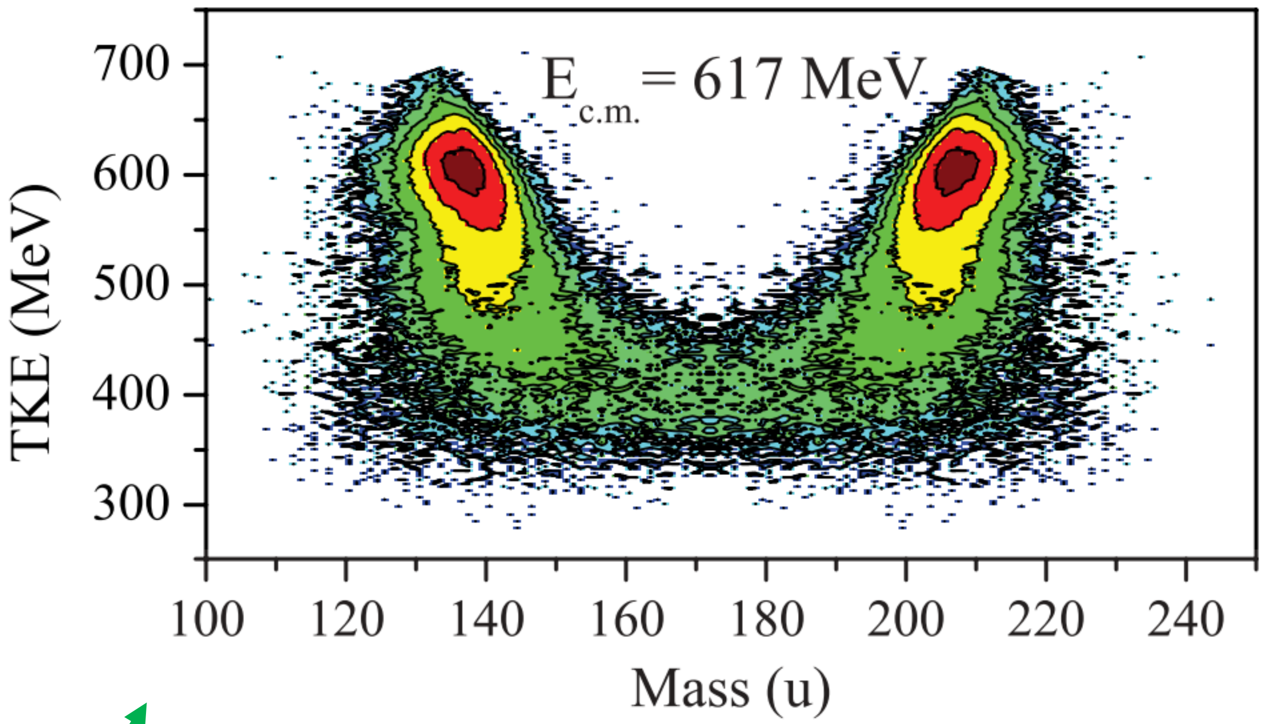




Multinucleon transfer reactions



$^{136}Xe + ^{208}Pb$



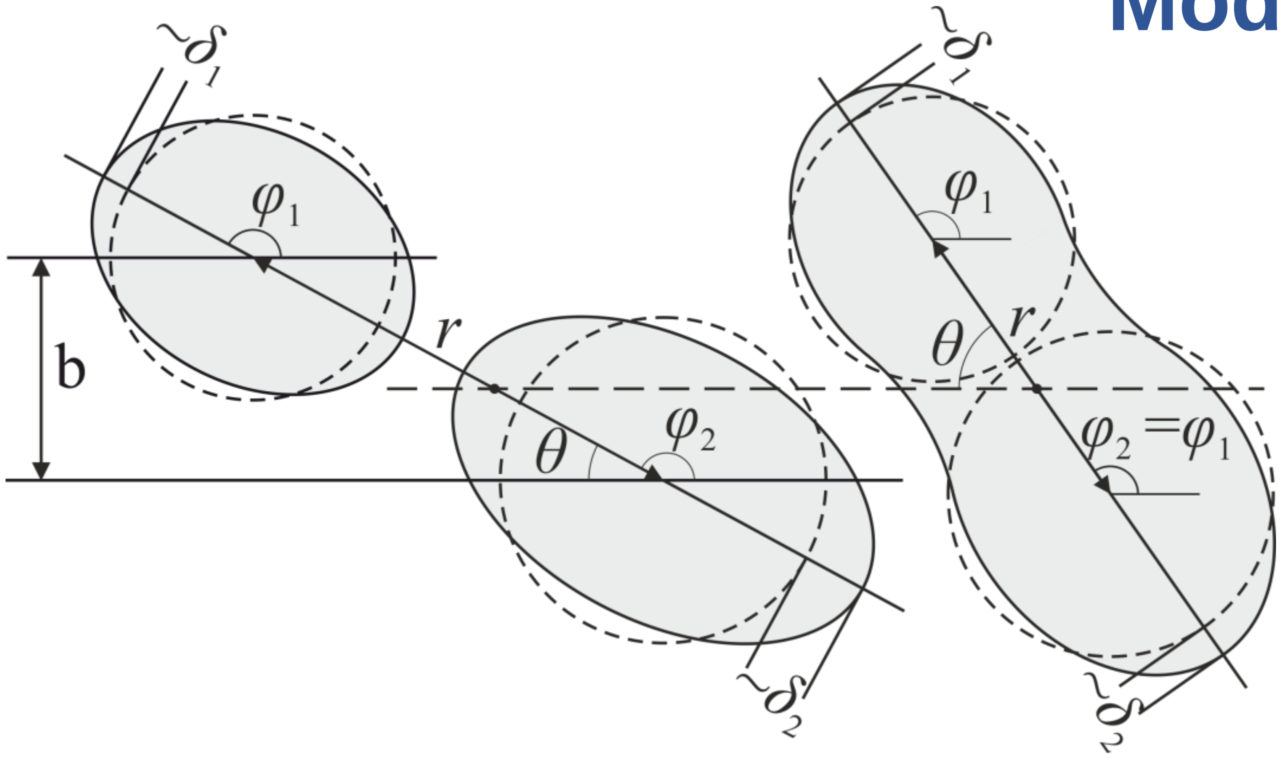
exp.: E.M. Kozulin, et. al,
Phys. Rev. C 86, 044611 (2012)

Main features:

- Transfer of a large number of nucleons
- Dissipation of initial kinetic energy

Model

A.V. Karpov and V.V. Saiko,
Phys. Rev. C 96, 024618 (2017)
Phys. Rev. C 99, 014613 (2019)



$$\dot{q}_i = \mu_{ij} p_j,$$

$$\dot{p}_i = T\left(\frac{\partial S}{\partial q_i}\right)_{E_{tot}} - \sum_{j,k} \gamma_{ij} \mu_{jk} p_k + \sum_j \theta_{ij} \xi_j$$

system of Langevin equations

driving, friction and random forces

r – distance between centers of nuclei
$\delta_{1,2}$ – ellipsoidal deformations
η_A – mass asymmetry
η_Z – charge asymmetry
θ – angle between symmetry axis and beam direction
$\varphi_{1,2}$ – angles of rotation of nuclei in the reaction plane

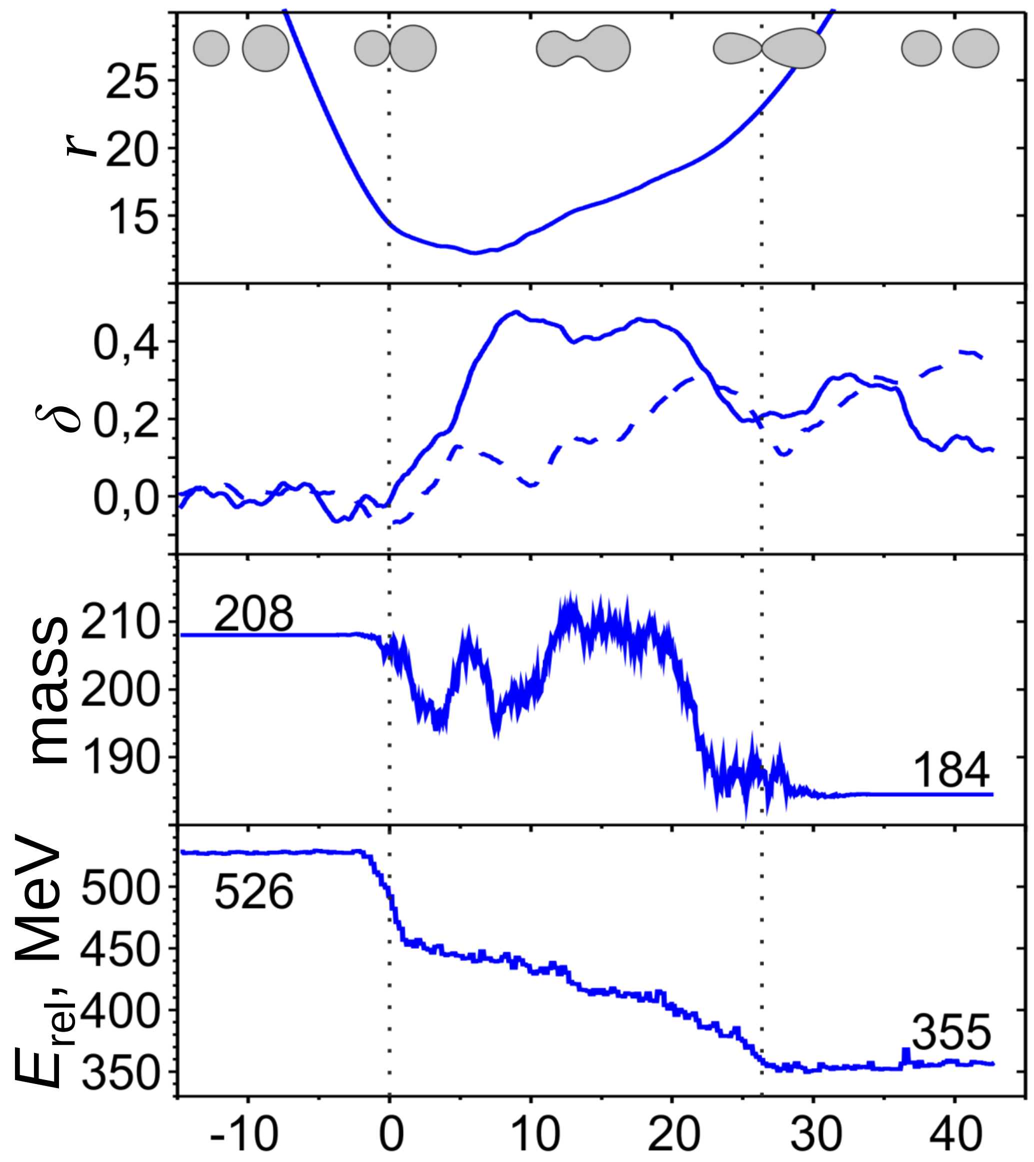
$$\eta_A = \frac{A_1 - A_2}{A_{CN}} \qquad \eta_Z = \frac{Z_1 - Z_2}{Z_{CN}}$$

$\mu_{ij} = m_{ij}^{-1}$ – mass tensor
γ_{ij} – dissipation tensor
θ_{ij} – amplitude of random force
ξ_i – random value

Model

A.V. Karpov and V.V. Saiko,
Phys. Rev. C 96, 024618 (2017)
Phys. Rev. C 99, 014613 (2019)

a collision of $^{136}Xe + ^{208}Pb$



each **trajectory** of a collision provides:

- Z and A of fragments,
- scattering angle,
- kinetic energy,
- excitation energy,
- reaction time,
- …

Final fragments are simulated by means of

- **statistical model** of decay of heavy excited nuclei,
- **GEF** code

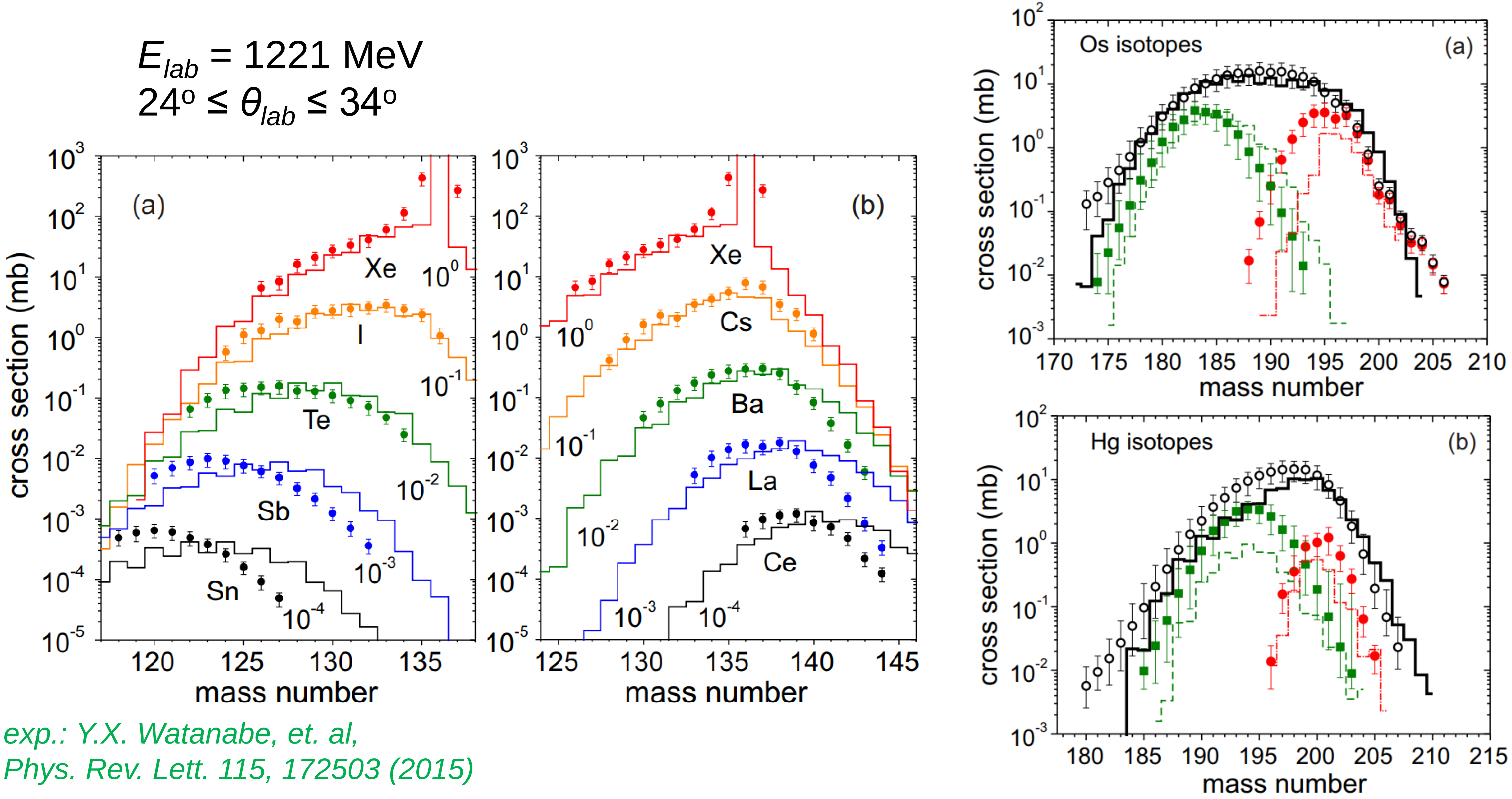
http://nrv.jinr.ru

http://www.khschmidts-nuclear-web.eu/GEF.html

differential reaction cross section:

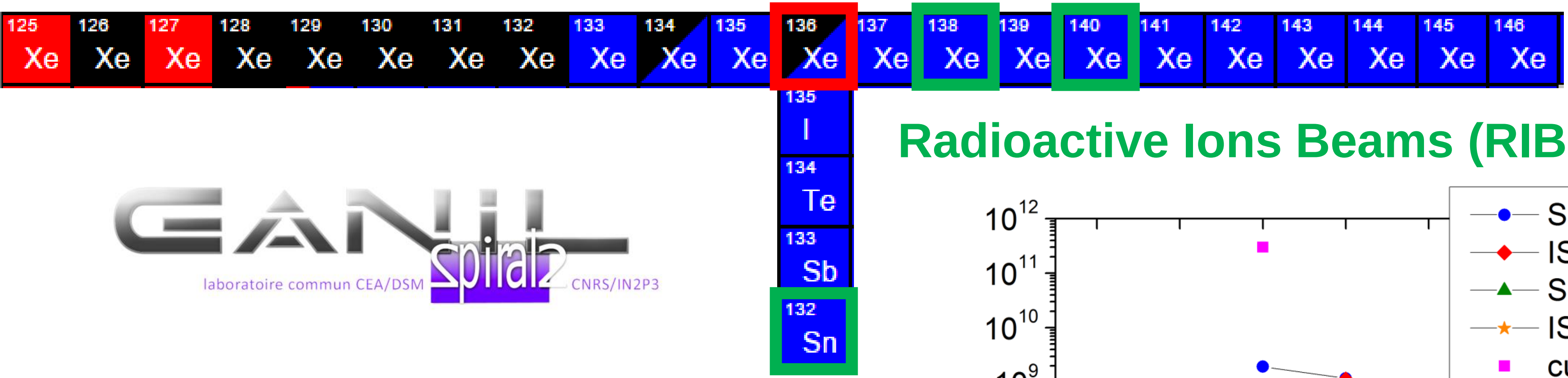
$$\frac{d^4\sigma}{dZdAd\Omega dE}(Z,A,E,\theta) = \int_0^{b_{max}} \frac{\Delta N(b,Z,A,E,\theta)\,bdb}{N_{tot}(b)\Delta Z\Delta A\sin\theta\Delta\theta\Delta E}$$

MNT in the $^{136}Xe + ^{198}Pt$ reaction



exp.: Y.X. Watanabe, et. al,
Phys. Rev. Lett. 115, 172503 (2015)

Extension of the approach



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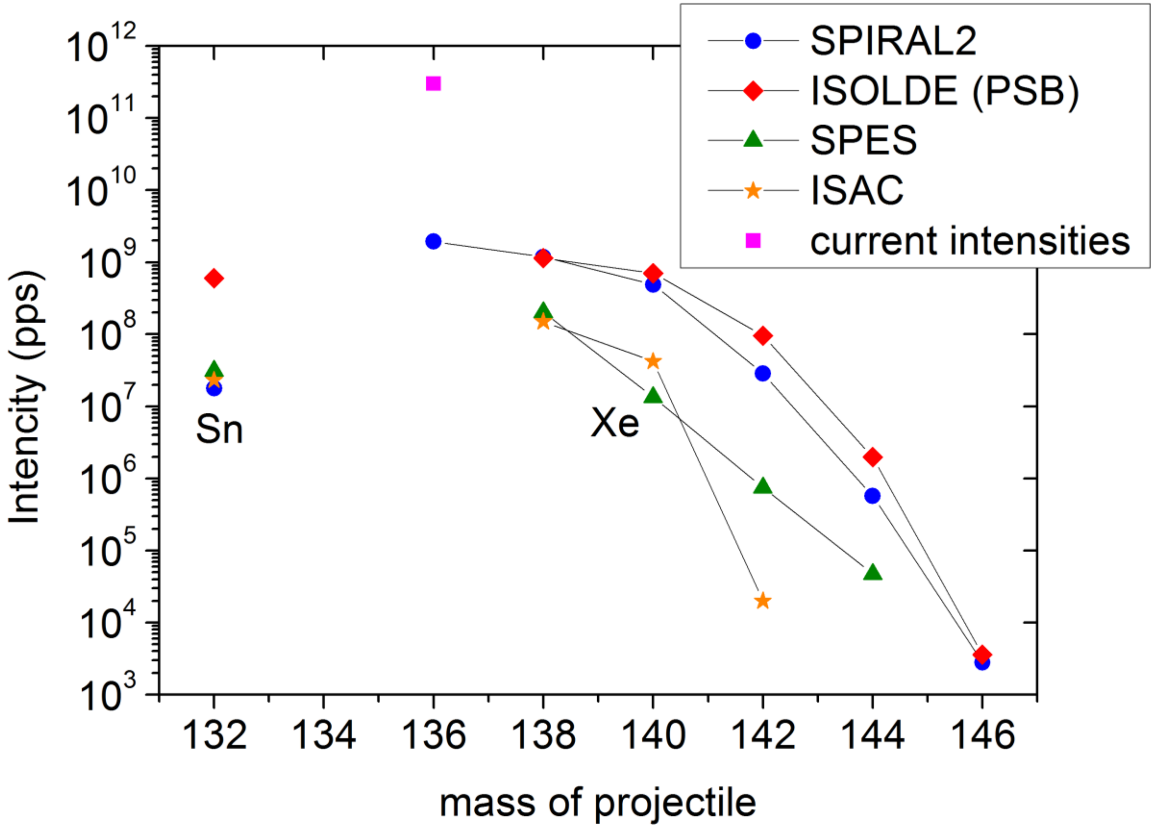
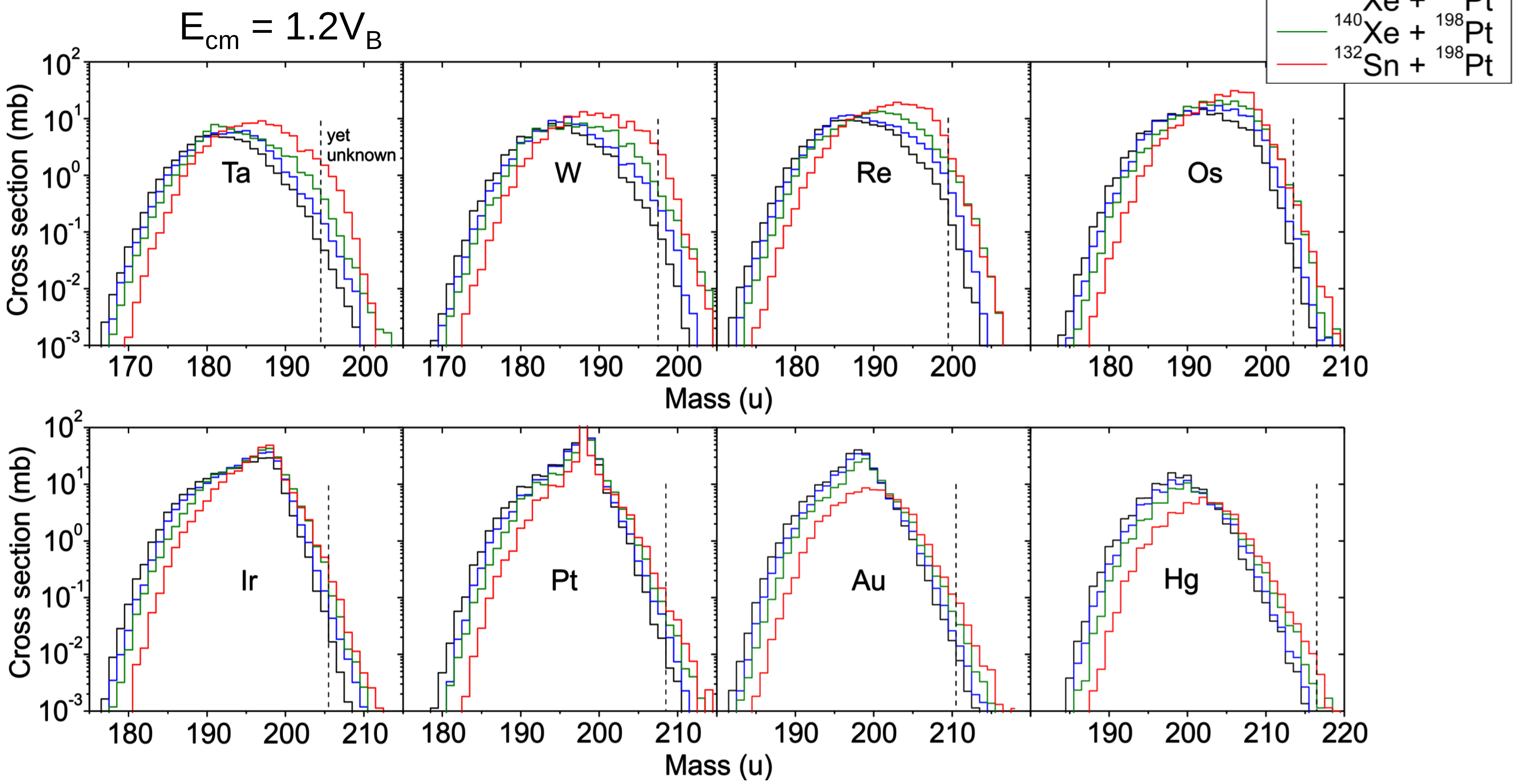
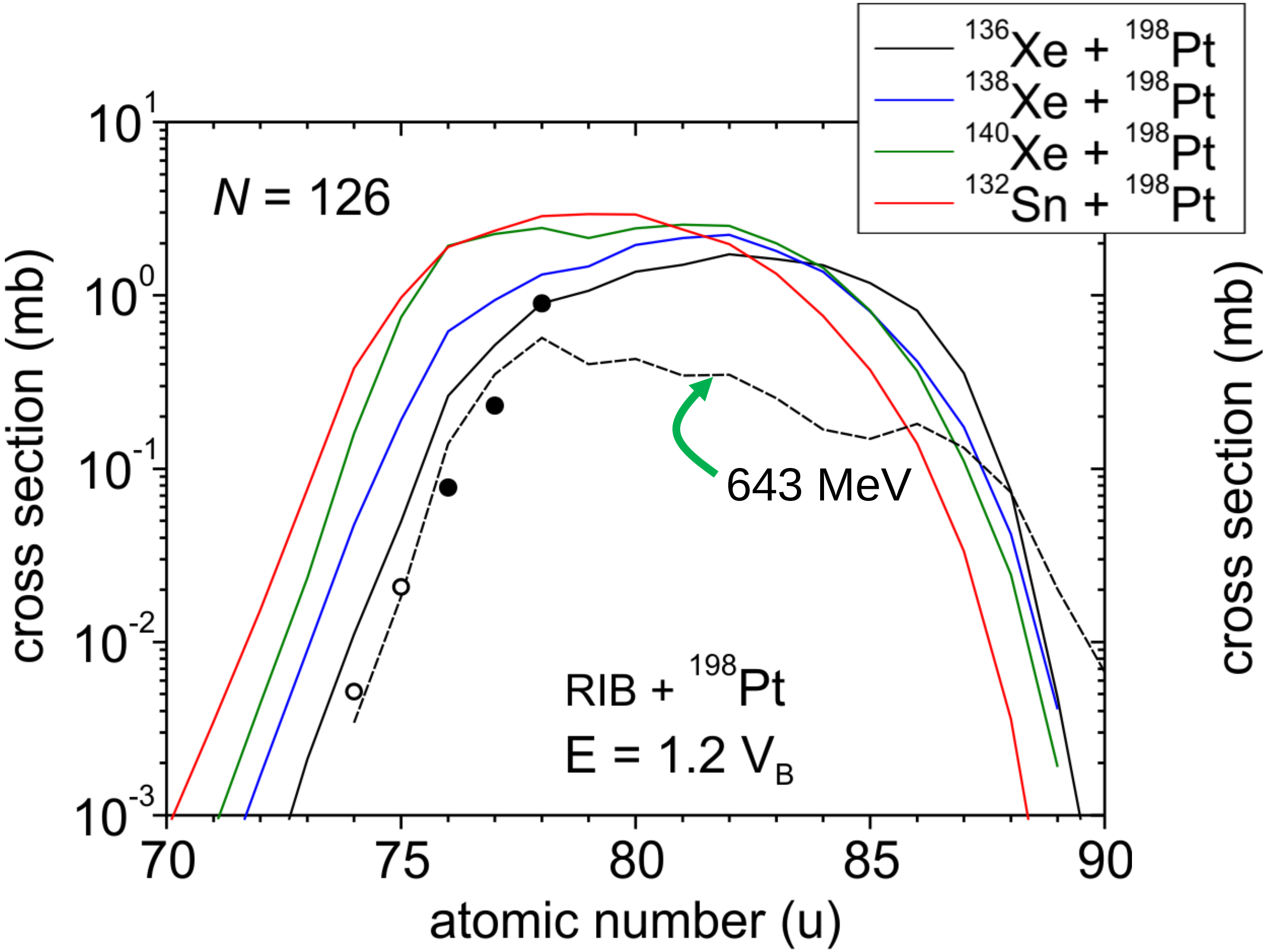
Radioactive Ions Beams (RIBs)

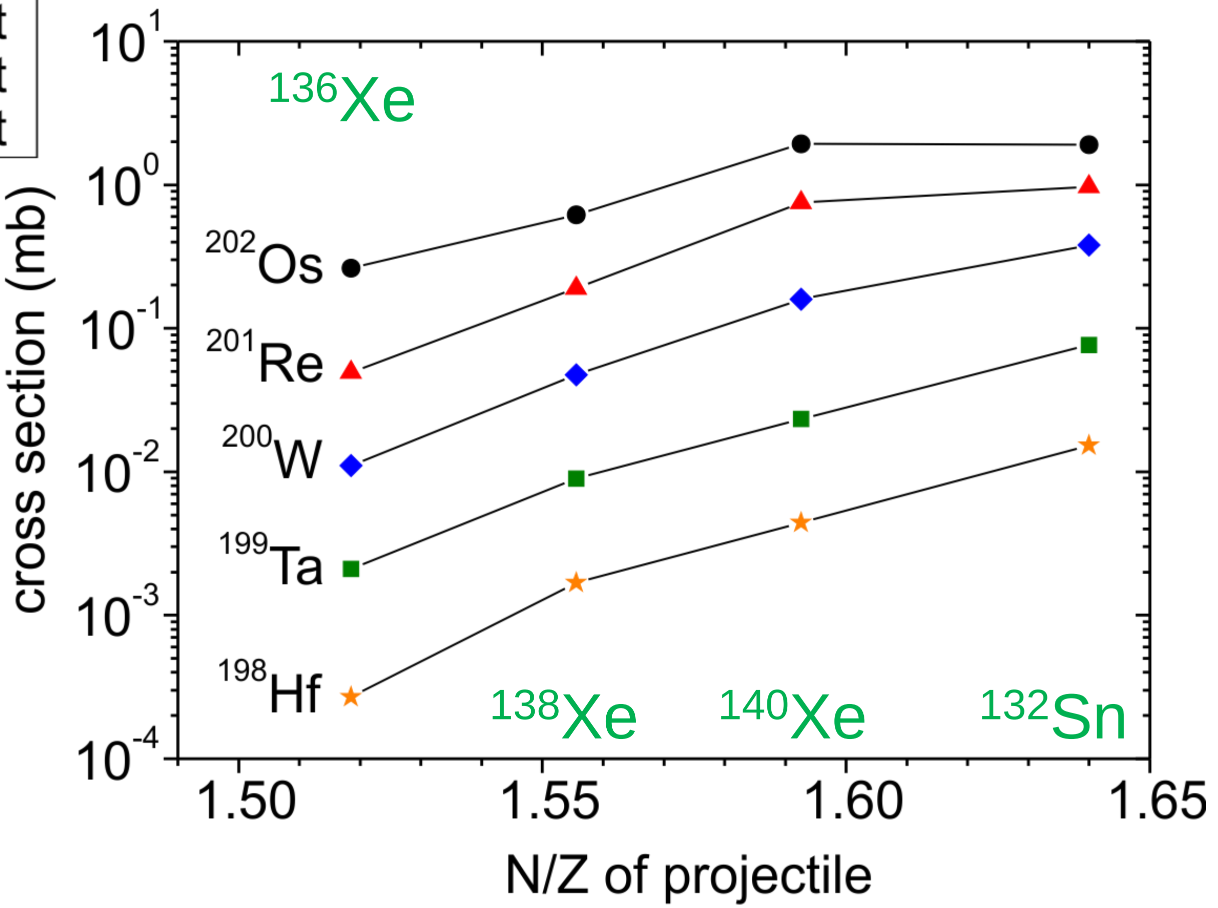


Production cross sections



Production cross sections

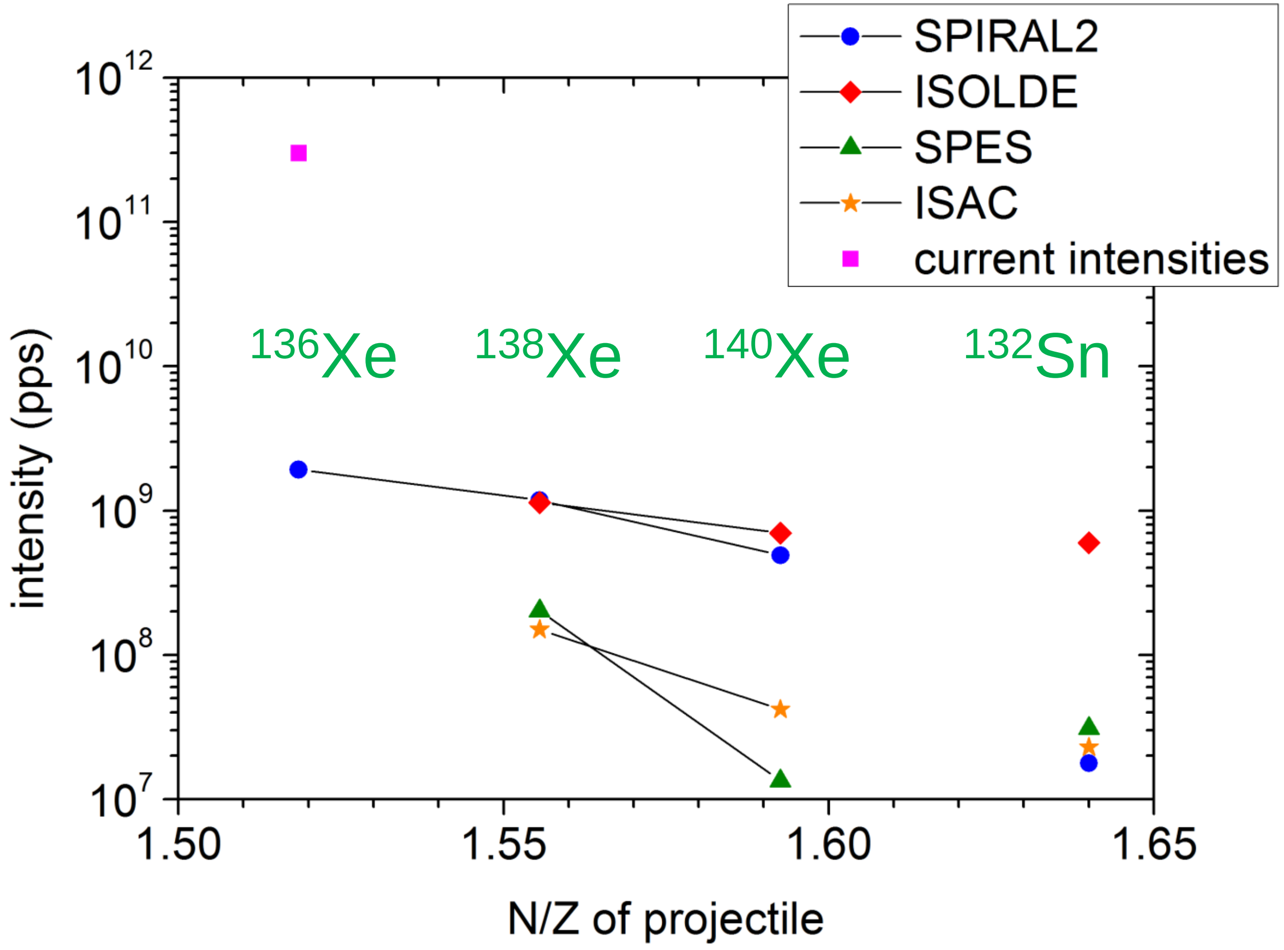


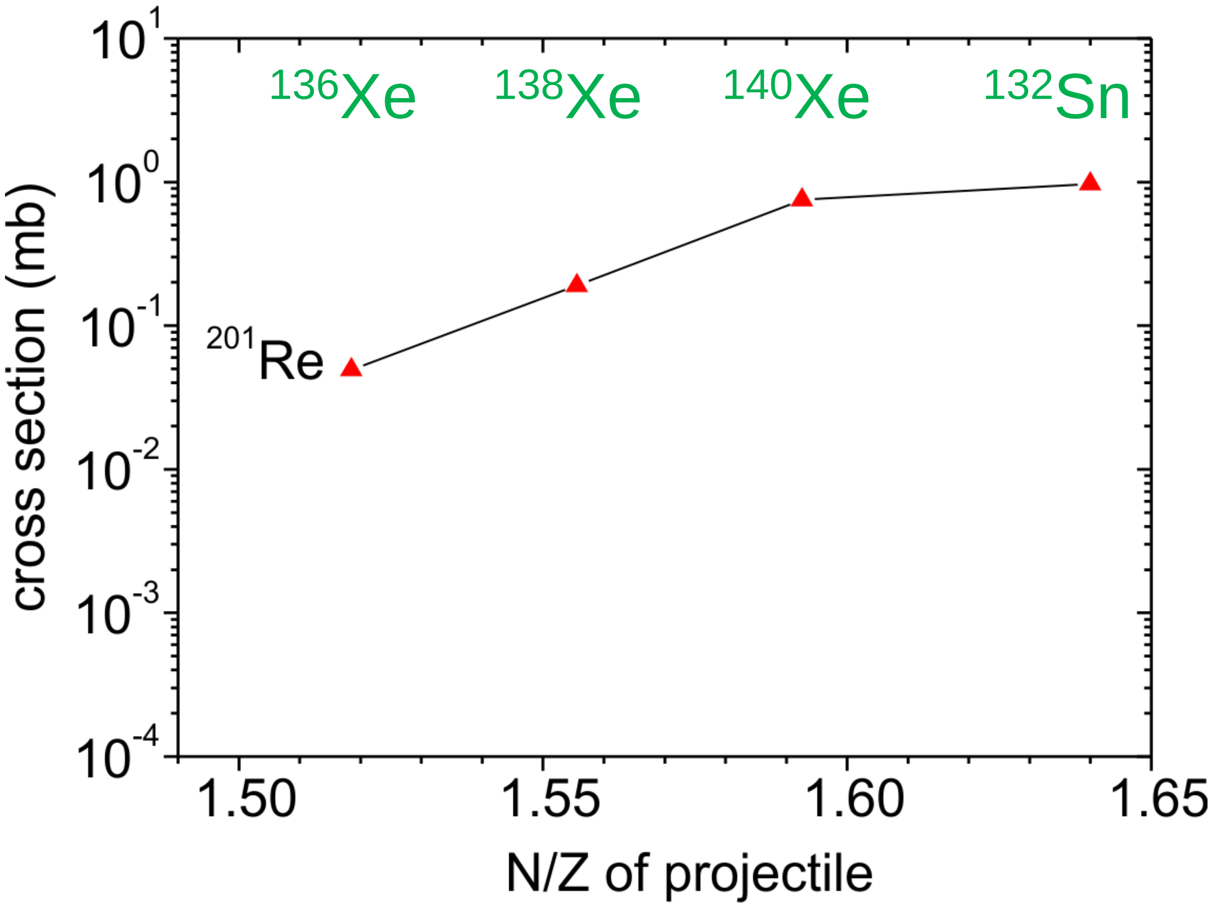


exp.: ^{136}Xe + ^{198}Pt @ 643 MeV
Y.X. Watanabe, et. al,
Phys. Rev. Lett. 115, 172503 (2015)

Production cross section depend on isospin of projectile

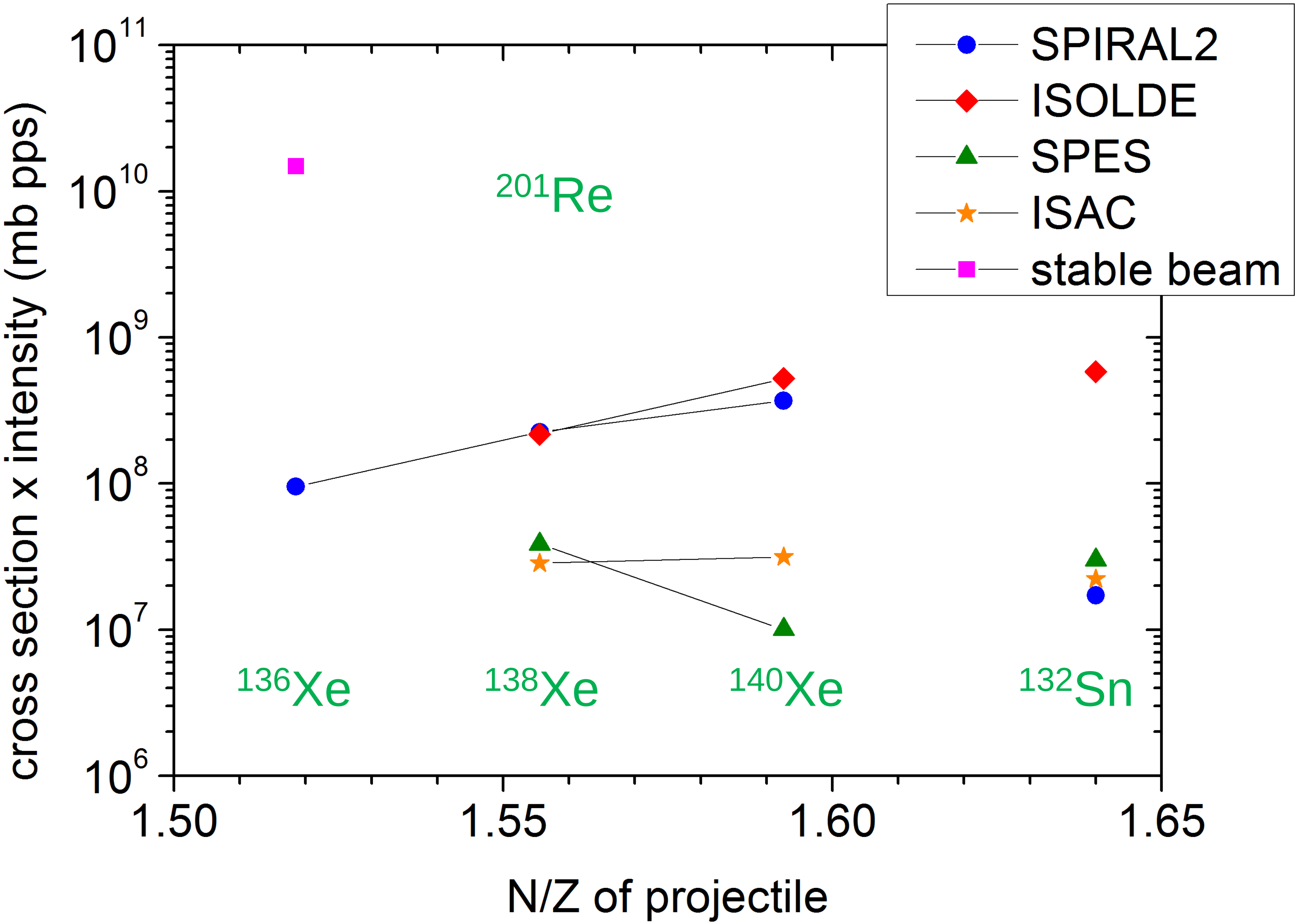
Predicted yields of yet-unknown ^{201}Re





Yield ~ intensity x cross section

Predicted yields of yet-unknown isotope ^{201}Re



Conclusions

1. Multinucleon transfer reactions with radioactive ion beams and ^{198}Pt target were studied at comparable energies within the multidimensional dynamic model of nucleus-nucleus collisions based on Langevin equations.

2. The more neutron-rich projectile the higher production cross sections of neutron-enriched isotopes of elements lighter than the target in the multinucleon transfer reactions.

3. Cross sections of yet-unknown neutron-enriched nuclide ^{201}Re with the magic number N = 126 reach the level of ~1 mb in the reactions ^{140}Xe, ^{132}Sn + ^{198}Pt.

3. Nowadays, the available intensities of radioactive ion beams are quite low to provide yields of neutron-enriched heavy products in the MNT reactions higher than in the MNT reactions with stable beams.


AYSS-2023
Welcome remarks
Thank you for attention!