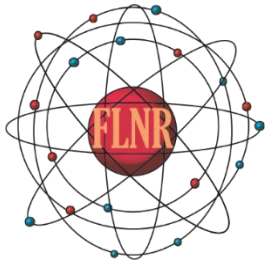
"Joint Institute for Nuclear Research"
Flerov Laboratory of Nuclear Reactions
Dubna, Russia



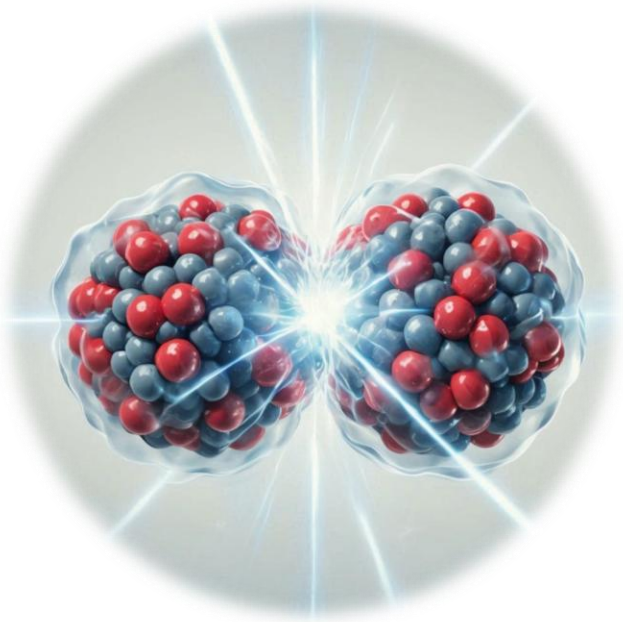
GRAND and SHELS facilities: performance and experimental results

Speaker: Alyona Kuznetsova

«India-JINR Workshop»
Nov 10-12, 2025, NISER Bhubaneswar, India

Outline

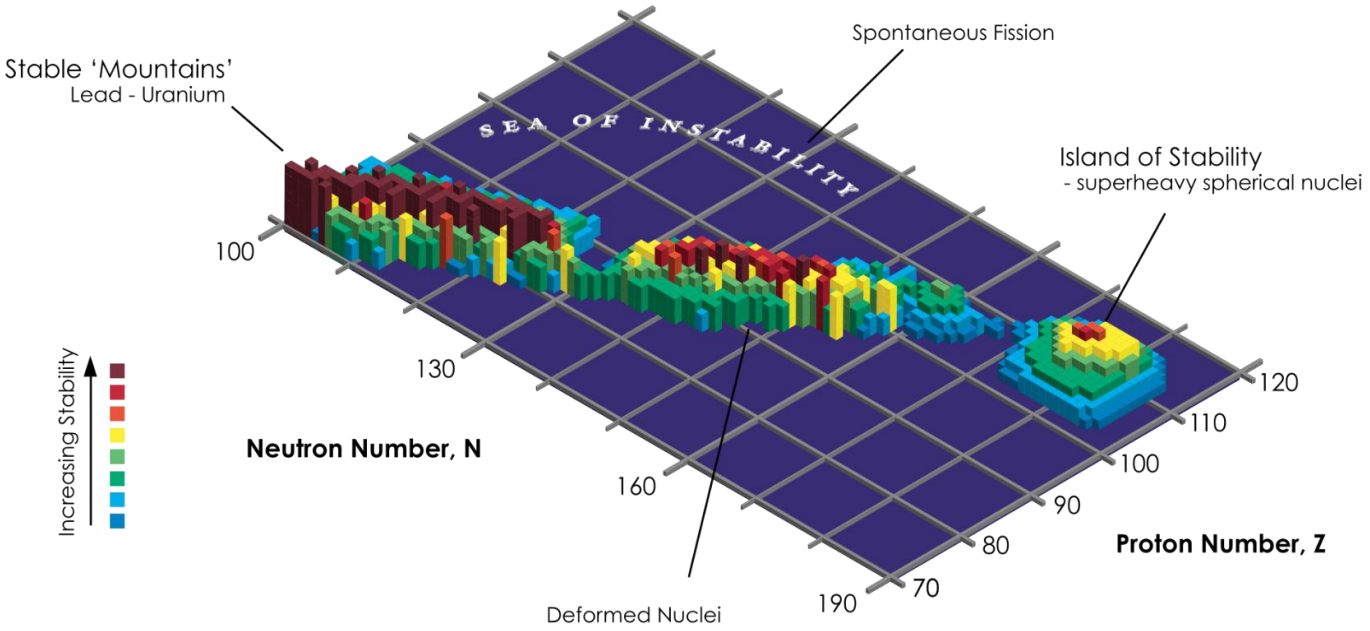
- Main goals of experiments
- Regions of interest
- Facilities review
- Detection systems and their characteristics
- Overview of 2023-2025 experiments
- Future plans



Main goals of experiments

- Complete fusion reactions with heavy ions
- Synthesis of new isotopes.
- Decay properties and structure of heavy and super heavy nuclei using α-,β-,γ-spectroscopy.
- The dynamic of spontaneous fission process
- Multinucleon transfer reactions

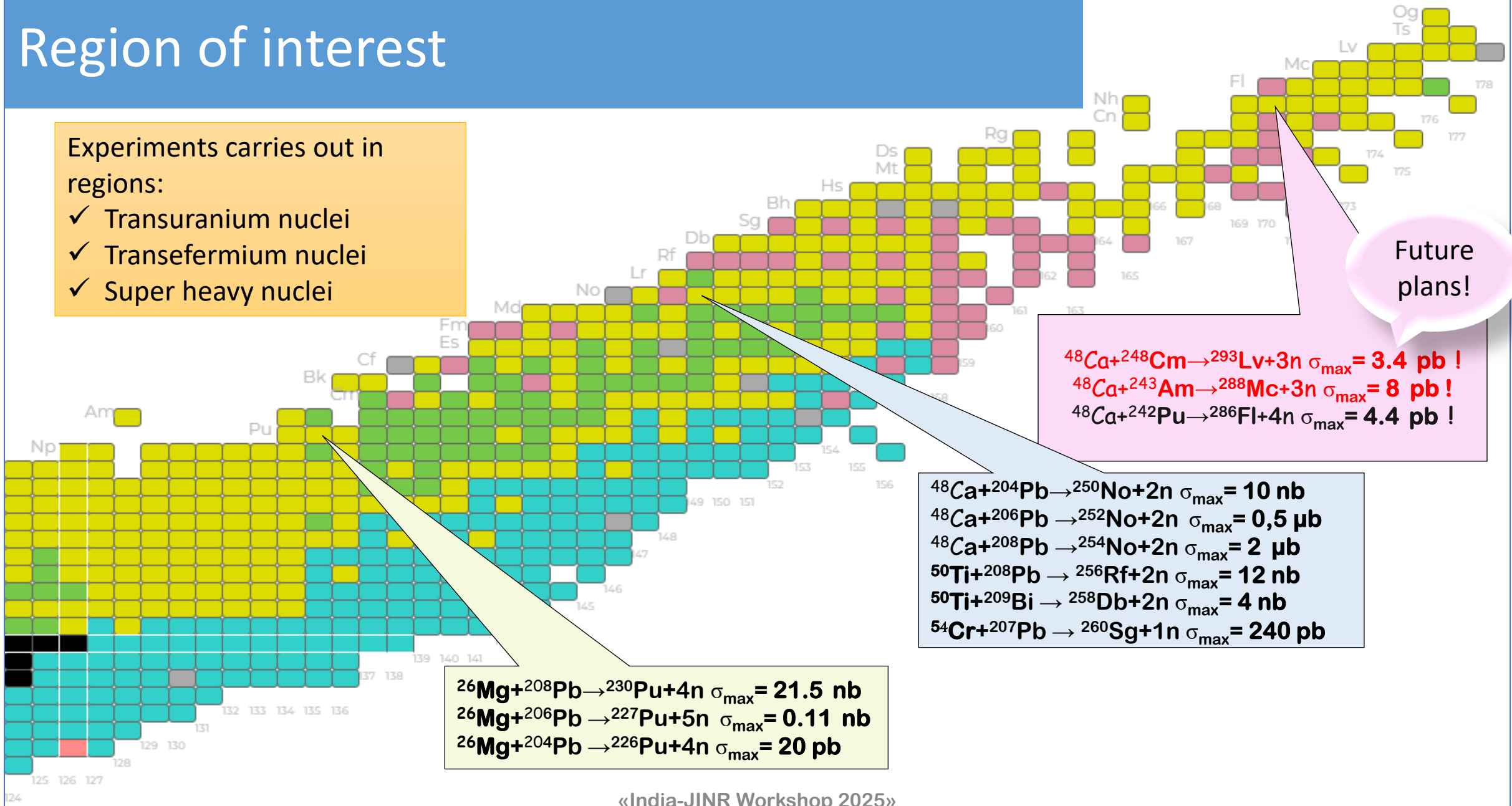
Devaraja H.M. “Systematic studies to produce heavy above-target nuclides in multinucleon transfer reactions”



Region of interest

Experiments carries out in regions:

- ✓ Transuranium nuclei
- ✓ Transefermium nuclei
- ✓ Super heavy nuclei



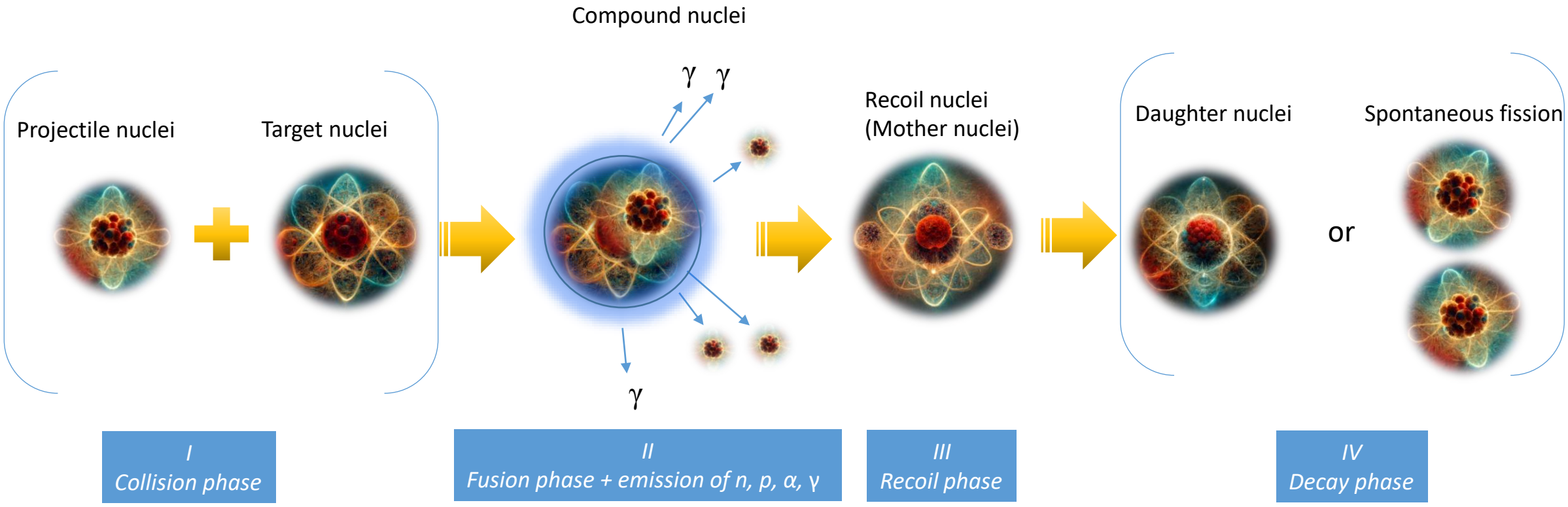
Future plans!

$^{48}Ca+^{248}Cm \rightarrow ^{293}Lv+3n$ σ_{max}= 3.4 pb !
$^{48}Ca+^{243}Am \rightarrow ^{288}Mc+3n$ σ_{max}= 8 pb !
$^{48}Ca+^{242}Pu \rightarrow ^{286}Fl+4n$ σ_{max}= 4.4 pb !

$^{48}Ca+^{204}Pb \rightarrow ^{250}No+2n$ σ_{max}= 10 nb
$^{48}Ca+^{206}Pb \rightarrow ^{252}No+2n$ σ_{max}= 0,5 μb
$^{48}Ca+^{208}Pb \rightarrow ^{254}No+2n$ σ_{max}= 2 μb
$^{50}Ti+^{208}Pb \rightarrow ^{256}Rf+2n$ σ_{max}= 12 nb
$^{50}Ti+^{209}Bi \rightarrow ^{258}Db+2n$ σ_{max}= 4 nb
$^{54}Cr+^{207}Pb \rightarrow ^{260}Sg+1n$ σ_{max}= 240 pb

$^{26}Mg+^{208}Pb \rightarrow ^{230}Pu+4n$ σ_{max}= 21.5 nb
$^{26}Mg+^{206}Pb \rightarrow ^{227}Pu+5n$ σ_{max}= 0.11 nb
$^{26}Mg+^{204}Pb \rightarrow ^{226}Pu+4n$ σ_{max}= 20 pb

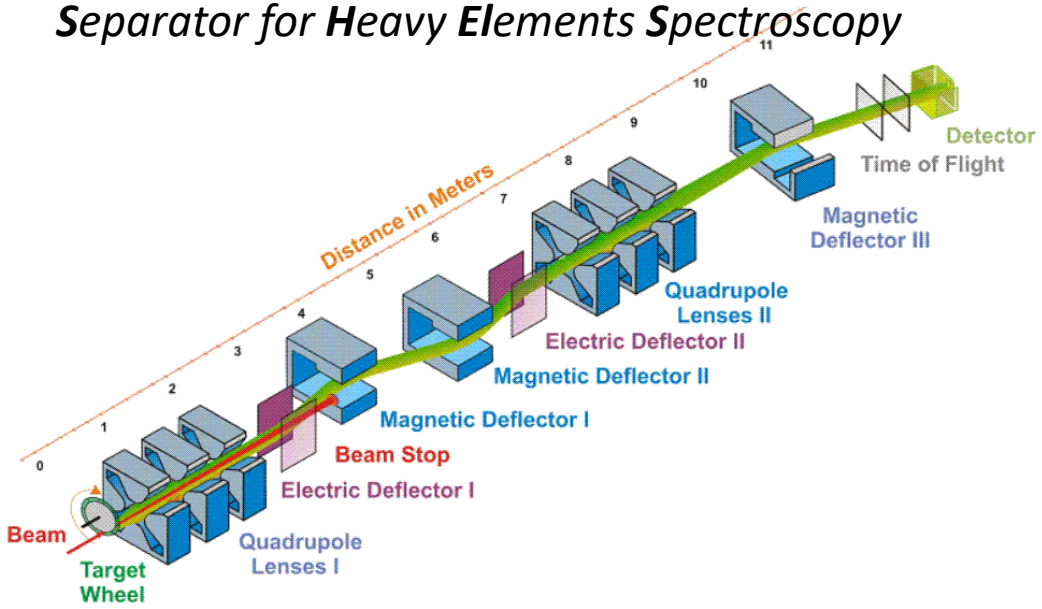
Complete fusion and decay process



SHELS & U-400

Separator SHELS

***S**eparator for **H**eavy **El**ements **S**pectroscopy*



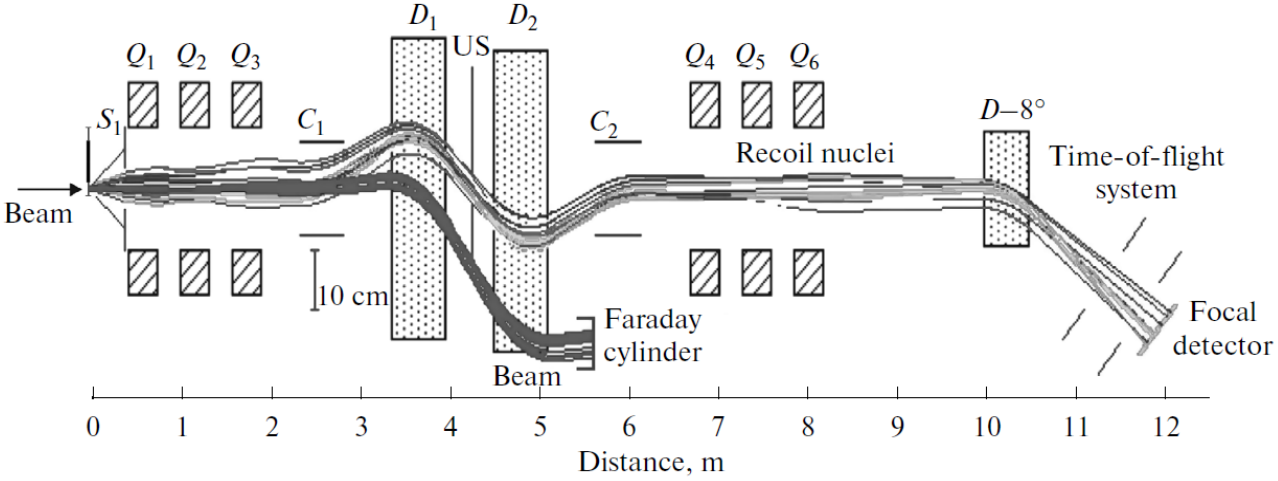
- SHELS[a] is a velocity filter designed to separate recoil nuclei from the primary beam. The separator is 12 m long and has a QQQEDDEQQQD scheme.
- The transmission efficiency of SHELS reaches 45%, depending on the type of reaction.
- The U-400 cyclotron provides a beam of 0.5–1.5 pμA (from Li to Bi) directed onto the target wheel.

U-400 cyclotron

- U-400[b] is designed for production of accelerated ions in the range of A=4 ÷ 209 with E=3 ÷ 29 MeV/nucleon.
- Cyclotron is 4m in diameter, D=4 m, with K=650 energy factor.

[a] *A.V. Yeremin, A.G. Popeko, O.N. Malyshev et al. Physics of Particles and Nuclei Letters, 2015, Vol. 12, No. 1, pp. 35–42.*
[b] *https://flerovlab.jinr.ru/u400-accelerator-complex/*

SHELS



the principal components of the separator.

Dipole Magnets

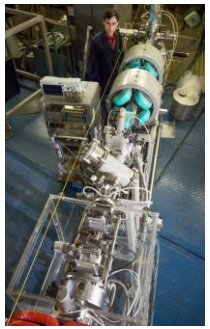
Effective length: 59.7 cm;
Dipole aperture: 13.5 cm;
Maximum field strength: 0.8 T;
Rated deflection angle: 21.8°.

HV Electrostatic Deflectors

Effective length: 65.7 cm;
Distance between plates: 10 - 20 cm;
Maximum field gradient: 40 kV/cm;
Rated deflection angle: 8°.

Quadrupole Lenses

Maximum field gradient: 13 T/m;
Effective length: 38 cm;
Aperture radius: 10 cm.

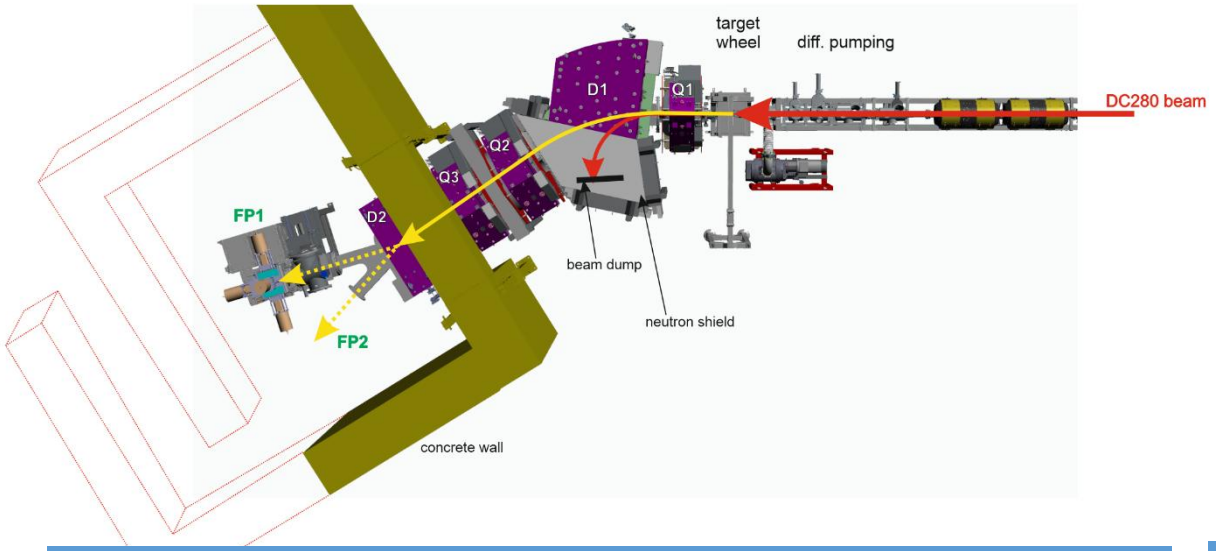


Beam line and target box

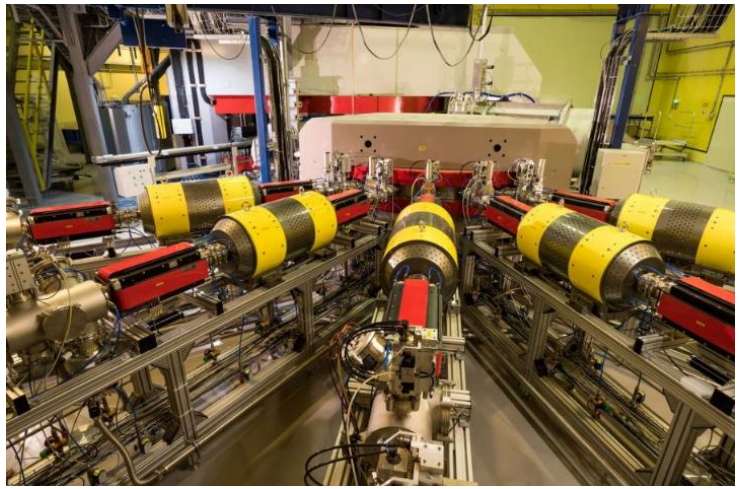
GRAND & DC-280

Separator GRAND

Gas-filled Recoil Analyzer and Nuclei Detector



DC-280 cyclotron



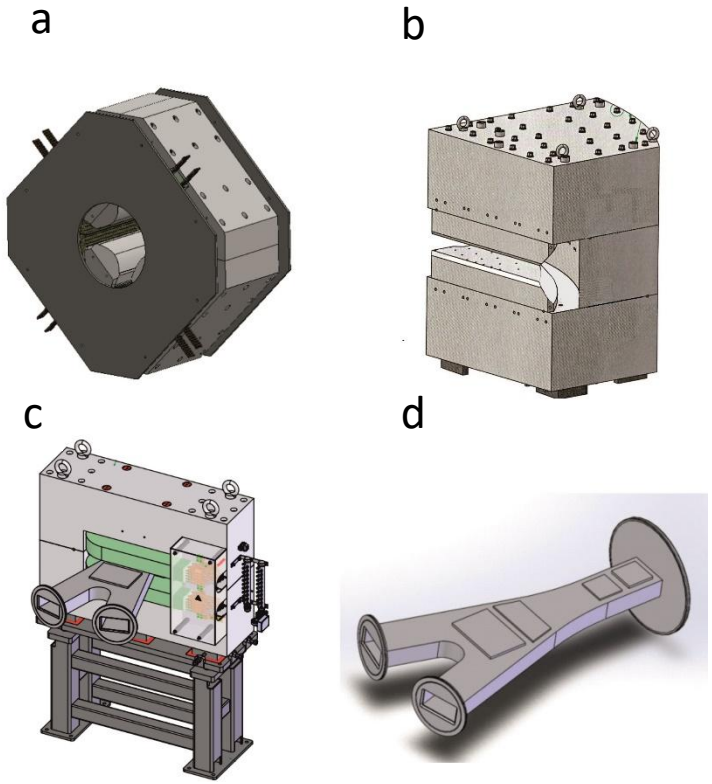
- GRAND[a,b] is a new gas-filled recoil separator created for The Super Heavy Element Factory [c].
- GRAND is intended for the study of SHE decay spectroscopy and chemical properties.

- The high-intensity universal DC-280[d] cyclotron (A ≤ 238, E ≤ 10 MeV/A, I ≤ 20 pμA).
- The Super Heavy Element Factory will increase the overall production of super heavy nuclei by one-two orders of magnitude with respect to presently achieved rates. This will enable the studies of nuclear /atomic structure of heaviest atoms and open the door to the discoveries of new elements above Z=118 and of isotopes closer to the predicted shell closure at N=184.

[a] *A.A. Kuznetsova // Bulletin of the Russian Academy of Sciences: Physics, 2023, Vol. 87, No. 8, pp. 1105–1111*
[b] *A.V. Yeremin, et al. //PEPAN Letters, Vol. 21, No. 3, 2024. pp. 518–525*
[d] *Gulbekian G. G., Dmitriev S. N., and. Itkis M. G, Phys. Part. Nucl. Lett. 16, 866 (2019).*

[c] *https://flerovlab.jinr.ru/she-factory/*

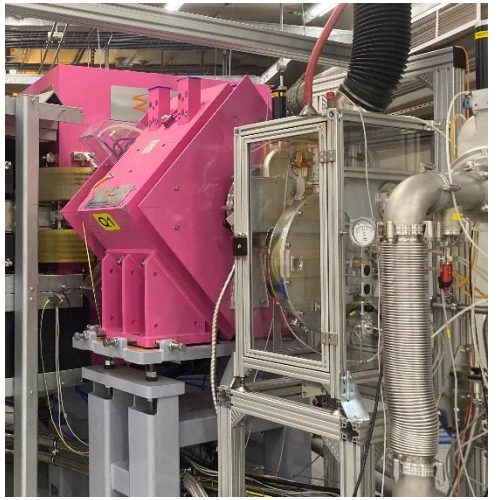
GRAND



Elements of the separator: (a) quadrupole lens; (b) dipole magnet with angle of rotation 31.6°; (c) dipole magnet with angles of rotation ±15.2°; and (d) vacuum chamber into which particles are fed for different detector chambers.

GRAND

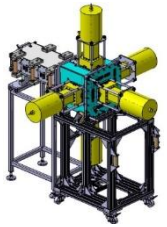
Comparison of two targets 480 and 240 mm.



Target box

GABRIELA for nuclear spectroscopy

Gamma Alpha Beta Recoil Investigation with the Electromagnetic Analyser



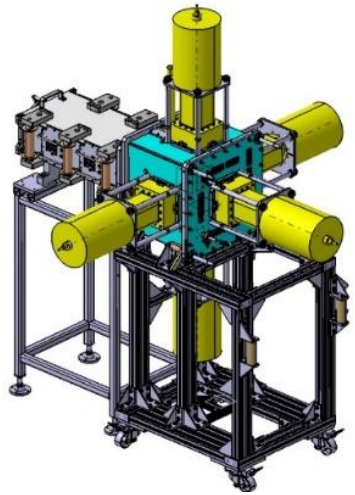
- Complex of Si-detectors
- Ge-detectors (Clovers)

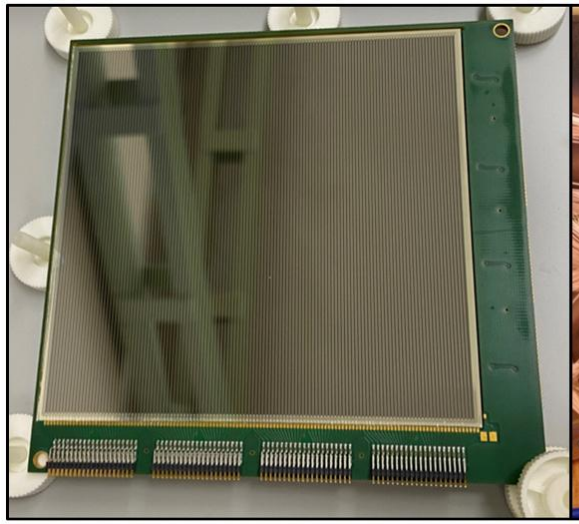
Time-Of-Flight system
- 2 foils and 4 MCP (70x90 mm^2)

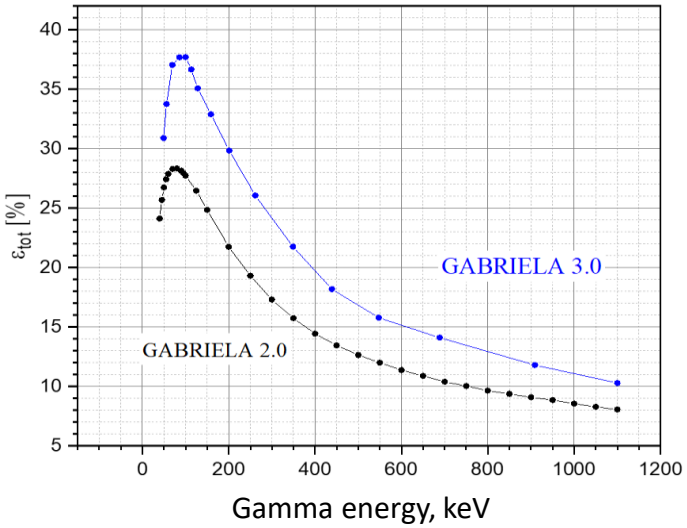
- The concrete wall is designed to protect the detectors from radiation.

Detectors of GABRIELA

Characteristics of the GABRIELA:







Focal Si-detector (DSSSD)
- Size: 100x100mm^2 or 128x128 strips;
- 16384 pixels;
- Thickness: 500µm.

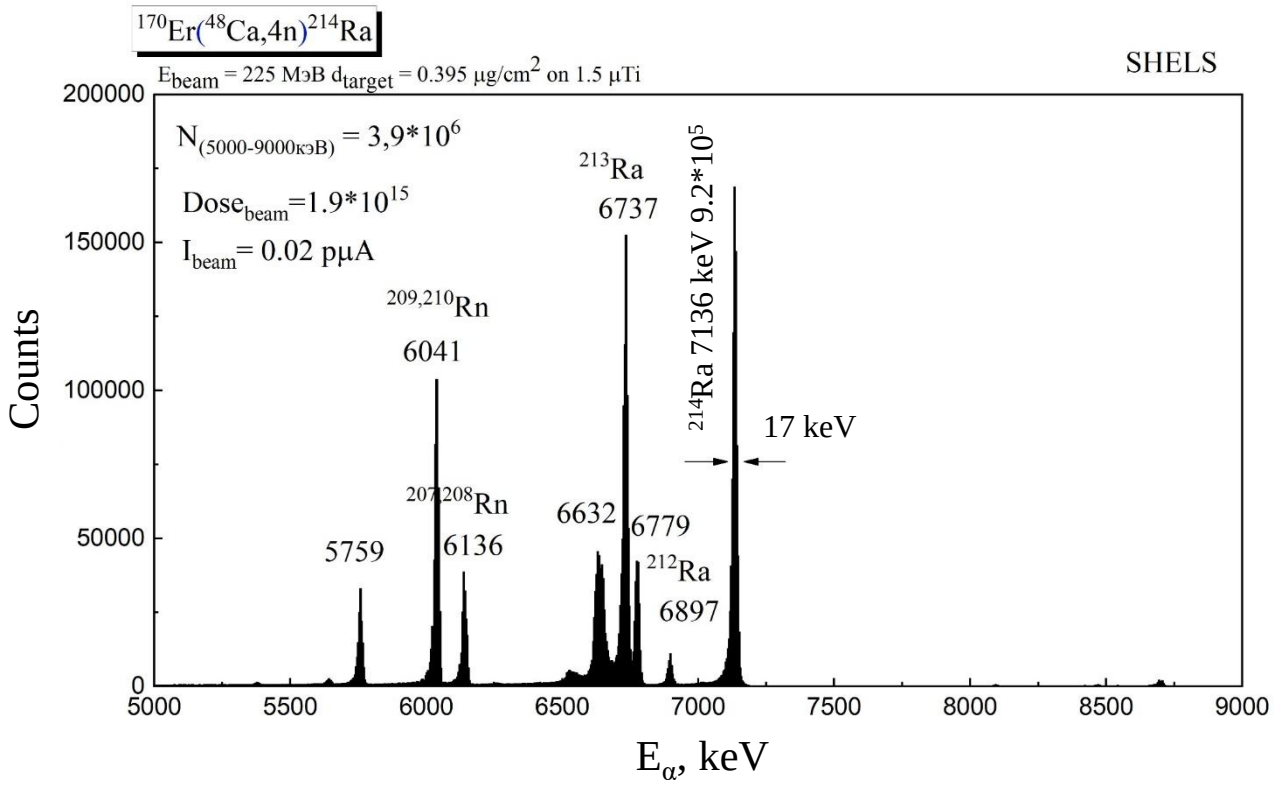
Tunnel Si-detectors (DSSSD)
- Size: 50x60mm^2, 8 plates;
- Thickness: 700 µm;

DSSD	FWHM [keV]	Thresholds [keV]
Focal plane 100x100 mm^2 128x128 strips Thickness: 500 µm	10.8±0.6 keV - 320 keV electrons; 16.5±0.8 keV - 7.92 MeV alphas	40-60
8 Tunnel 50x60 mm^2 16x32 strips Thickness: 700 µm (CE)	14.4±1.2 keV - 320 keV electrons 120±11 keV - 7.92 MeV alphas	60-100

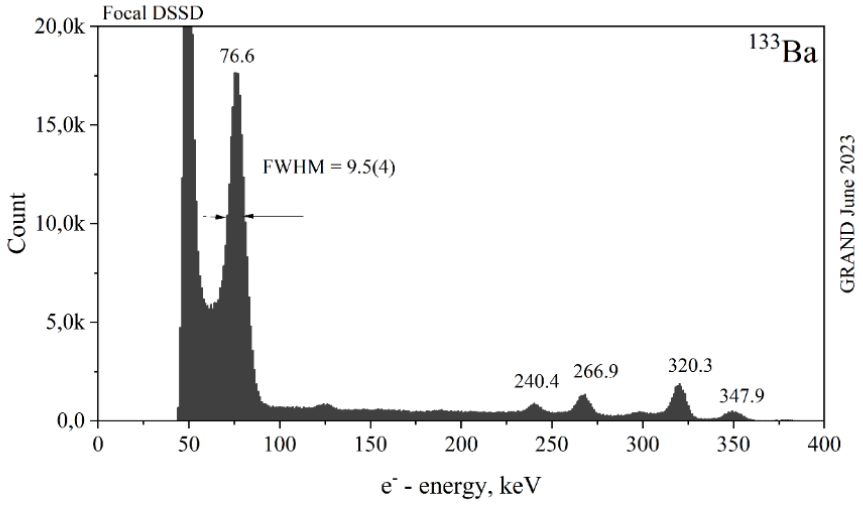
5 Ge-detectors (HPGe)
- Clovers (a 4-crystal diameter 100 mm, length 70 mm)
- BGO
- A low neutron background is required!

5 Clovers (HPGe)	1.7±0.7 keV – 0.1 MeV gamma 2.3±1.0 keV –1 MeV gamma

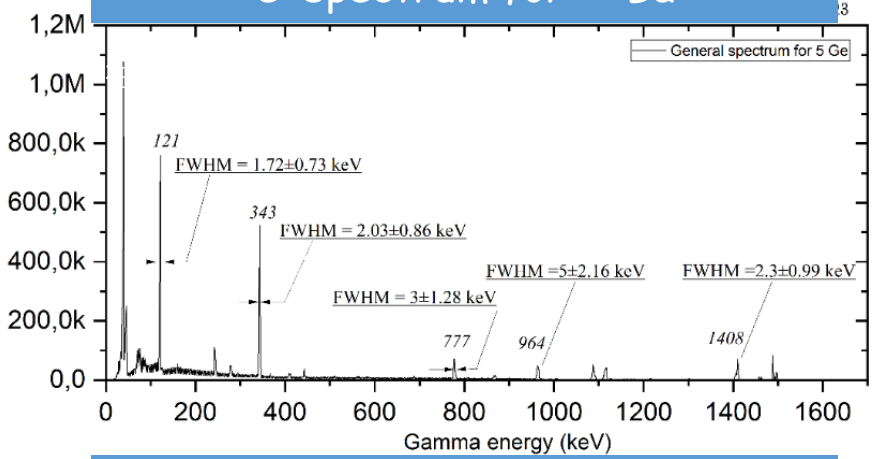
Energy resolution



α-spectrum of nuclei synthesized in the test reaction ^{48}Ca+^{170}Er

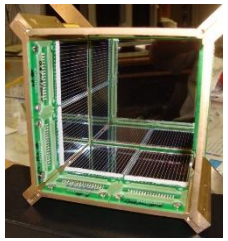


e⁻spectrum for ^{133}Ba



Gamma-spectrum for ^{152}Eu

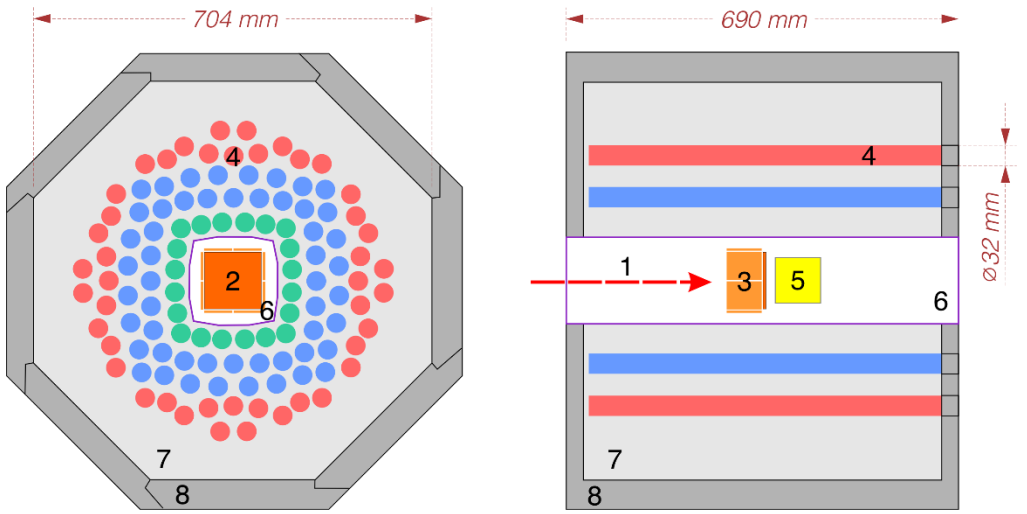
Spontaneous fission of SHE with SFiNx[1]



Box of Si-detectors

SFiNx[a]

Spontaneous Fission, Neutrons and X-rays

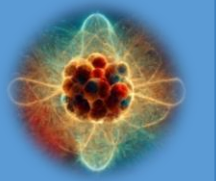


The legend:	
1 – evaporation residues	4 – 116 ^{3}He-counters (7 atm)
2 – focal-plane 128×128-strip DSSD	5 – 9 CLLBC scintillators
3 – tunnel 32×16-strip DSSDx8	6 – vacuum chamber
	7 – moderator
	8 – shield

Neutron detection efficiency ε_n = 55±1%

[a] Isaev A. V. et al. The SFiNx detector system PEPAN Letters 19 (2022) P. 37–45

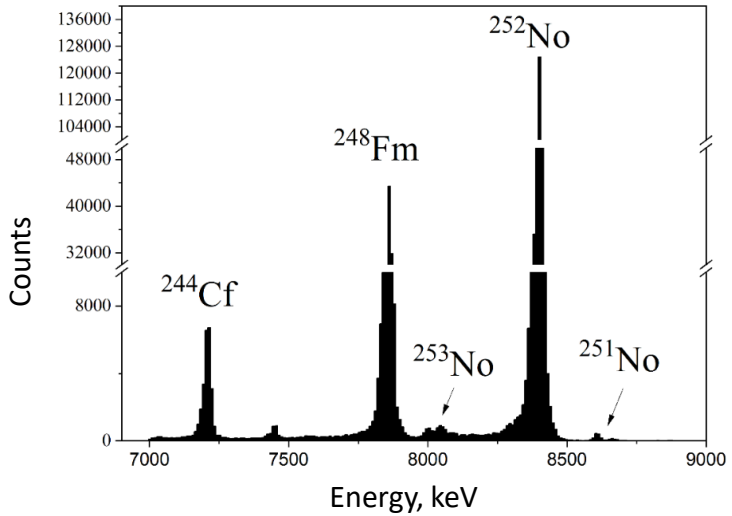
Experiments for 2023-2025 years

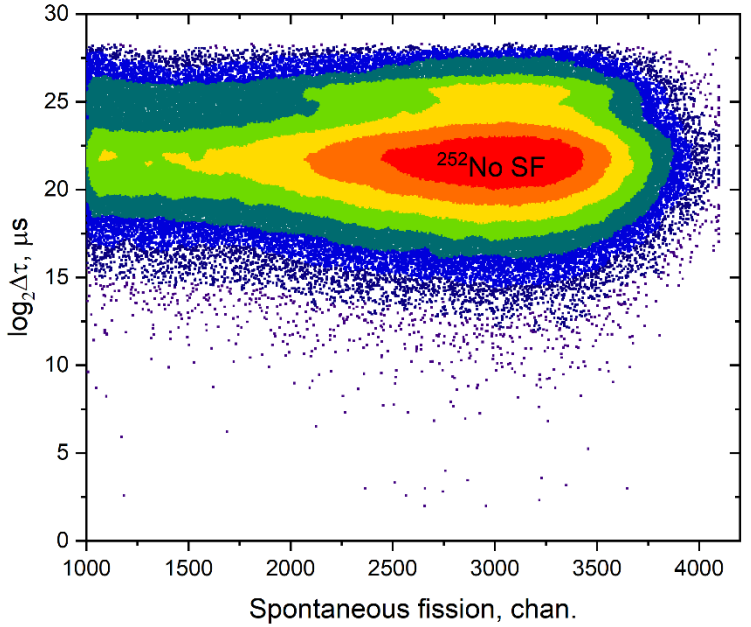


Year	Reactions	Compound nuclei	Purpose of the experiment	Set-up + detector system
2023	$^{136}Xe+^{238}U$	-	MNT reactions	SHELS+SFINX
	$^{26}Mg+^{238}U$	^{264}Rf	SF neutrons, MNT reactions	SHELS+SFINX
	$^{40}Ar+^{206}Pb$	^{246}Fm	SF neutrons	SHELS+SFINX
	$^{48}Ca+^{208}Pb$	^{256}No	Testing detection system	GRAND+GABRIELA
	$^{54}Cr+^{207}Pb$	^{261}Sg	SF neutrons, MNT reactions	SHELS+SFINX
	$^{48}Ca+^{204}Pb$	^{252}No	α-, β-, γ-spectroscopy + SF, measure a cross section for EvR	GRAND+GABRIELA
	$^{26}Mg+^{204,206,208}Pb$	$^{230,232,234}Pu$	α-, β-, γ-spectroscopy + SF, measure a cross section for EvR	GRAND+GABRIELA
2024	$^{40}Ar+^{209}Bi$	^{249}Md	SF neutrons, delayed nuclear fission (βDF)	SHELS+SFINX
	$^{48}Ca+^{206}Pb$	^{254}No	Testing big target	GRAND+GABRIELA
	$^{48}Ca+^{242}Pu$	^{290}Fl	SHE study and chemical, measure a cross section for EvR	GRAND+GABRIELA+CryoDetector
	$^{54}Cr+^{207}Pb$	^{261}Sg	SF neutrons, MNT reactions	SHELS+SFINX
2025	$^{22}Ne+^{238}U$	^{260}No	SF neutrons, MNT reactions, measure a cross section for EvR	SHELS+SFINX
	$^{26}Mg+^{238}U$	^{264}Rf	SF neutrons, MNT reactions, measure a cross section for Ev	SHELS+SFINX
	$^{48}Ca+^{242}Pu$	^{290}Fl	SHE study and chemical, measure a cross section for EvR	GRAND+GABRIELA+CryoDetector
	$^{52}Cr+^{207}Pb$	^{259}Sg	SF neutrons, MNT reactions in progress now…	SHELS+SFINX

^{252}No

- Reaction ^{48}Ca+^{206}Pb





- tests of a new big target with a diameter of 480 mm and a thickness of 690 μg/sm^2.
- Integral flux was collected of 9.4·10^{18} ions by the intensity beam ≤ 6 pμA.

Statistic of isotopes ^{252}No:

✓ ER-α correlations ~ 3.5·10^5

✓ ER-SF(γ) correlations ~ 1,7·10^5 → **1-1.5 fissions/s of ^{252}No!**

The half life time was measured to be $T_{1/2}$(SF) = 2.46 s

Alpha decay ~ 65 %

^{252}No
2.44 с
8372, 8415
IT 109 мс
b_α~65%
b_{EC}~1.7%
b_{SF}~33%

^{248}Fm
34.5 с
7830, 7870
b_α~95%
b_{EC}~5%
b_{SF}~0.1%

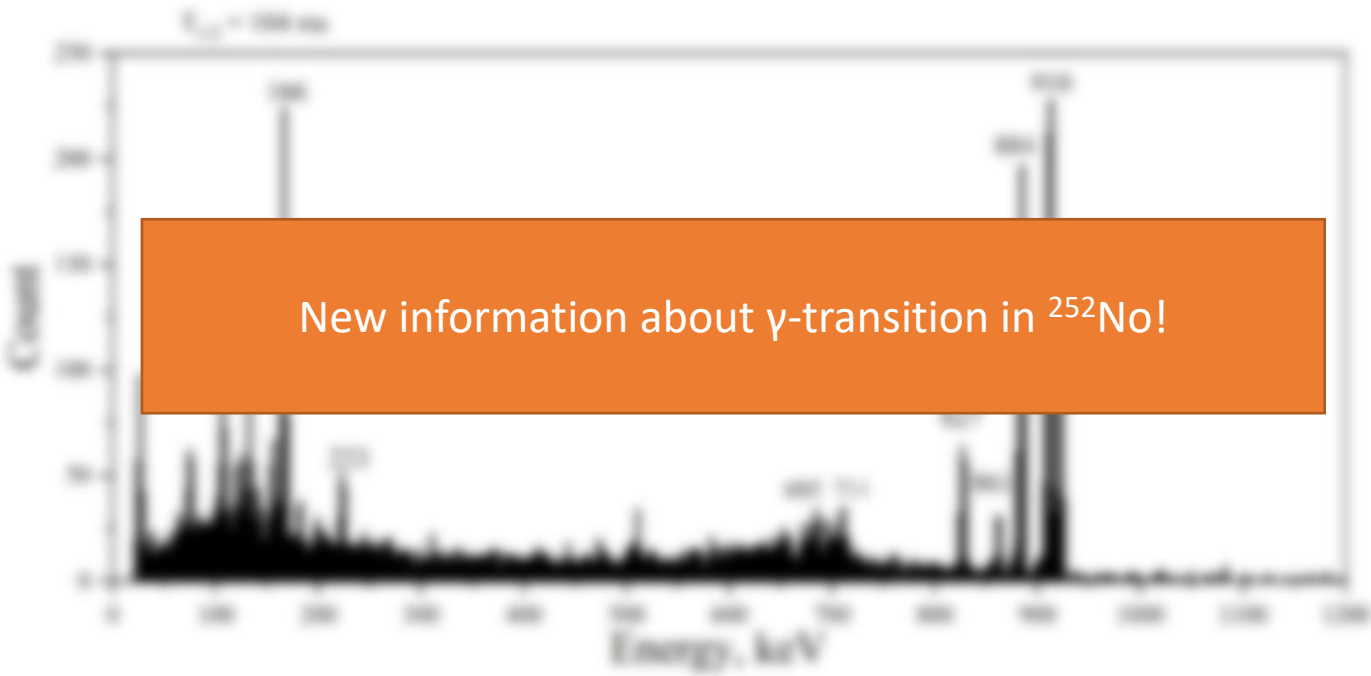
^{244}Cf
19 м
7174, 7209
b_α~100%

Literature data

https://www-nds.iaea.org/

Gamma spectroscopy for ^{252m}No

- Large statistic for the gamma analyze



New information about γ-transition in ^{252}No!

Gamma spectrum for the isomeric state in ^{252}No with $T_{1/2}$ = 104 ms.

Analysis in progress!

^{252}No
2.44 с
8372, 8415
IT 109 мс
b_α~65%
b_{EC}~1.7%
b_{SF}~33%

^{248}Fm
34.5 с
7830, 7870
b_α~95%
b_{EC}~5%
b_{SF}~0.1%

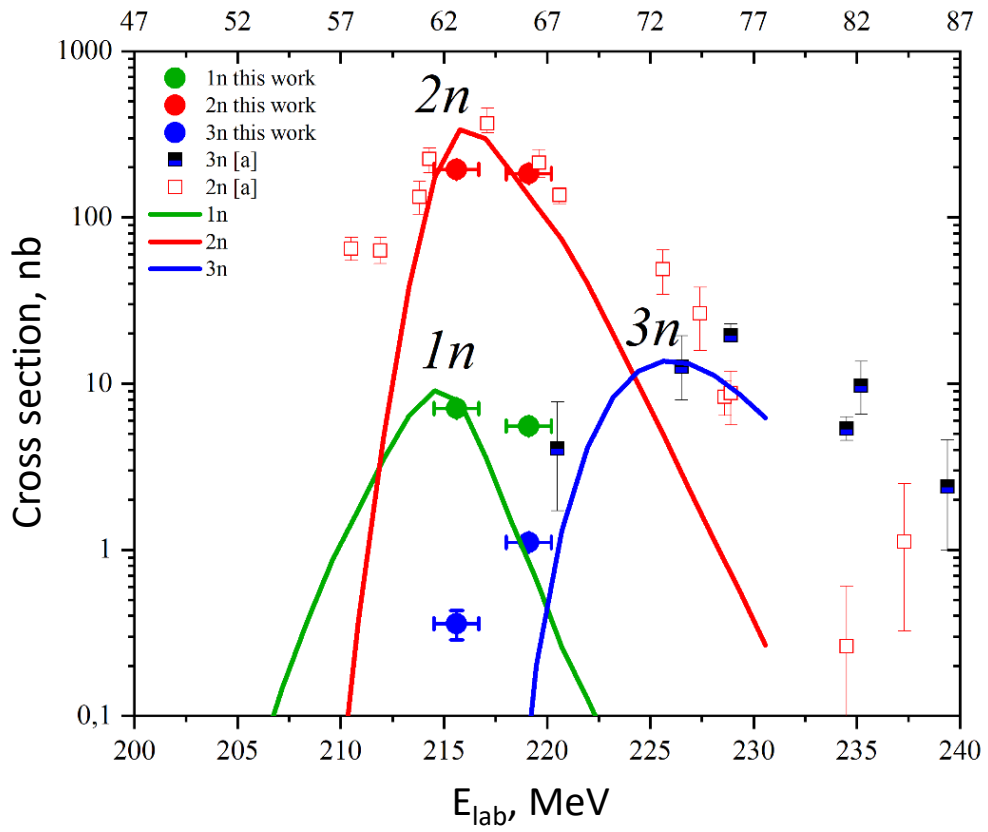
^{244}Cf
19 м
7174, 7209
b_α~100%

Literature data

https://www-nds.iaea.org/

Fusion-evaporation cross sections for the reaction $^{48}Ca+^{206}Pb$

Reaction $^{48}Ca+^{206}Pb \rightarrow ^{252}No+2n$



[a] Belozerov et. Al., European Physical Journal, A 16 (2003) 447
[b] Karpov A. V. et all, Phys. Part. Nucl. Lett., 2018. V. 15. P. 247.

Experimental cross-section for 1n, 2n, 3n evaporation channels in complete fusion reaction $^{48}Ca+^{206}Pb$. Dots – the experiment data, dashed lines – theoretical estimates, which were made by NRV [b].

^{252}No
2.44 с
8372, 8415
IT 109 мс
b_α~65%
b_{EC}~1.7%
b_{SF}~33%

^{248}Fm
34.5 с
7830, 7870
b_α~95%
b_{EC}~5%
b_{SF}~0.1%

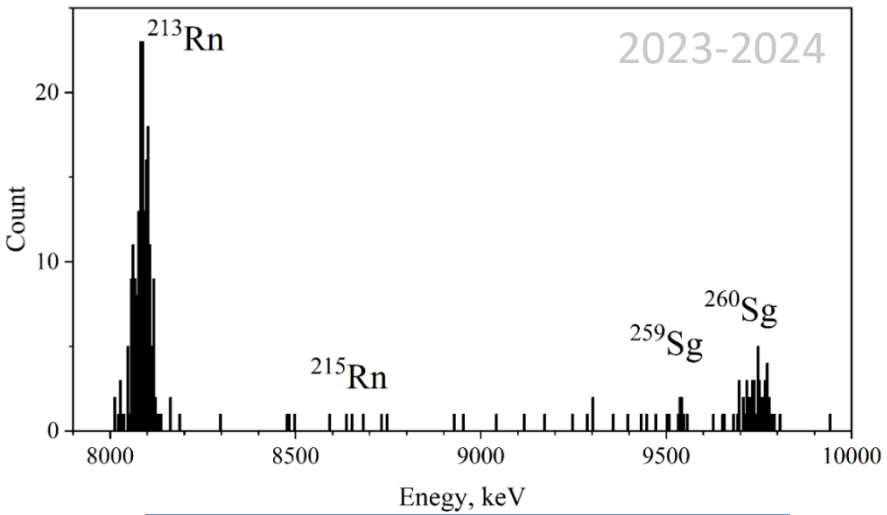
^{244}Cf
19 м
7174, 7209
b_α~100%

Literature data

https://www-nds.iaea.org/

^{260}Sg

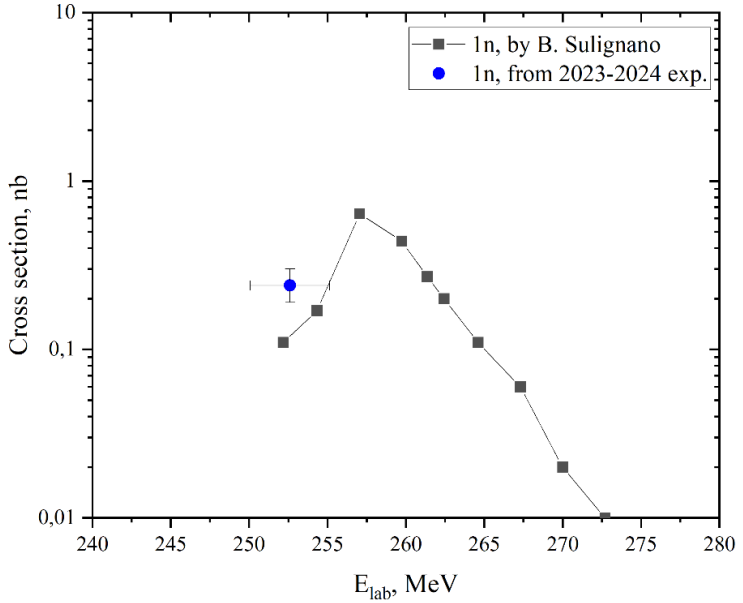
- Reaction ^{54}Cr+^{207}Pb →^{261}Sg+1n



α-spectrum for the reaction ^{54}Cr+^{207}Pb.

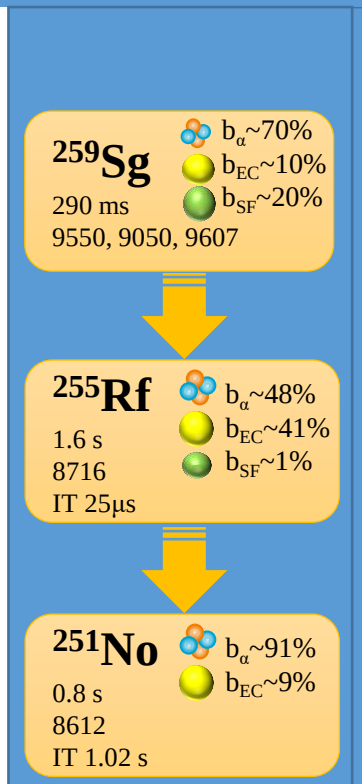
Statistic of isotopes ^{260}Sg for 2 exp.:
- ✓ ER-α correlations ~ 50
- ✓ ER-SF correlations ~ 358

Measured decay modes of ^{260}Sg
B_α = 28 %
B_{SF} = 72 %

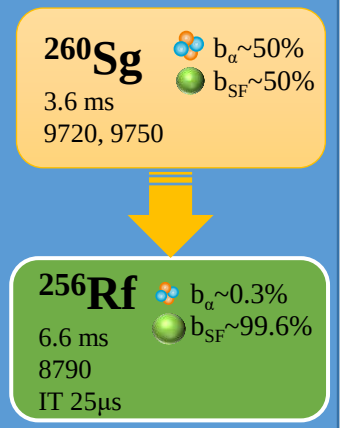


Experimental cross-section for 1n evaporation channels in complete fusion reaction ^{54}Cr+^{207}Pb. Dots – the experiment data from our experiment and work by B. Sulignano [a].

[a] B. Sulignano "Search for K isomers in ^{252,254}No and ^{260}Sg and investigation of their nuclear Structure". Thesis submitted for attaining the degree". 2007.



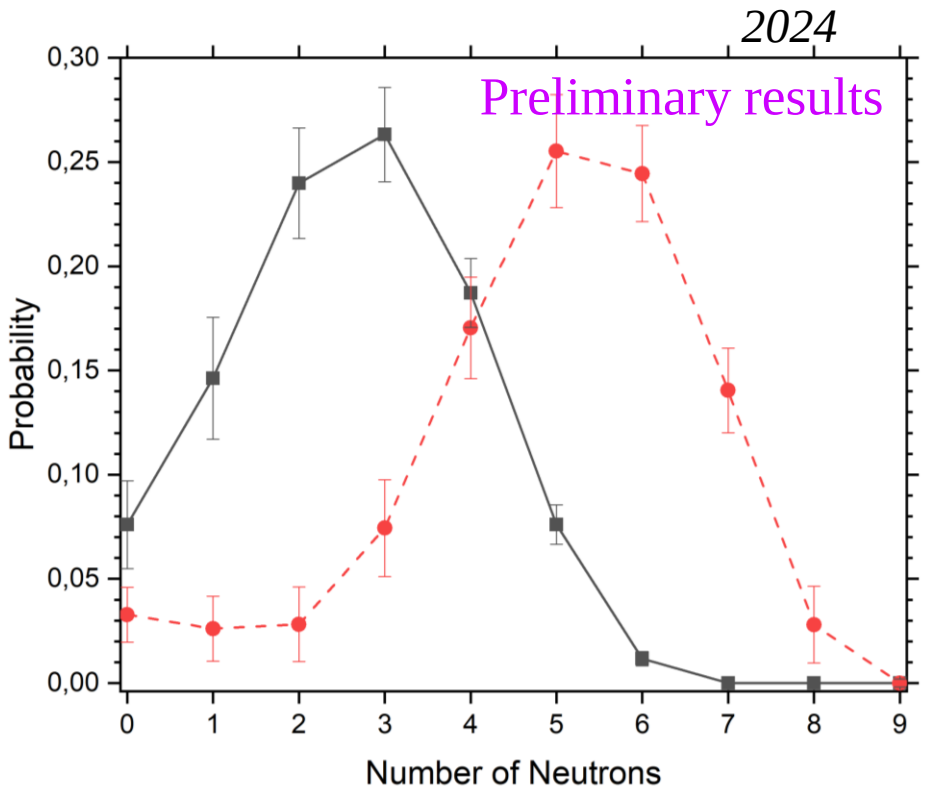
https://www-nds.iaea.org/



https://www-nds.iaea.org/

The neutron multiplicity of SF for ^{260}Sg

Reaction	^{54}Cr + ^{207}Pb
Target PbS	350 μg/cm^2 2 μm Ti; ^{207}Pb > 99%
$E_{1/2}$, MeV	263±3
σ_{max}, nb	~0.3
ε_n, %	55±1
Δt, ms	0 – 40
$\sum_{SF}$	**171**
$\sum_n$	447
$\overline{\nu}$	4.8±0.4
σ^2_ν	2.6
P_n	received for the first time
$T_{1/2}$, ms	~4
b_{SF}	< 0.3



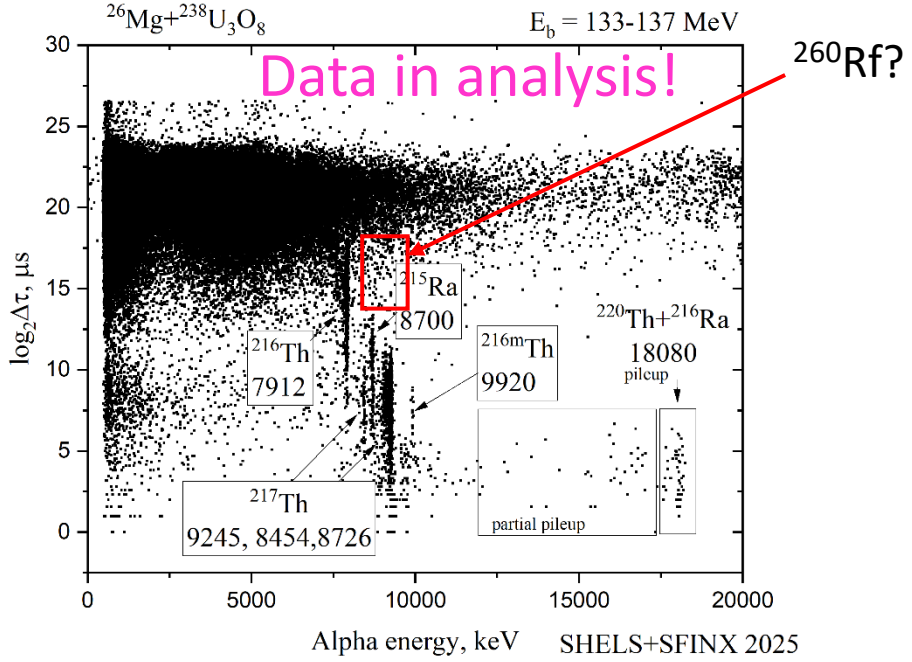
PFN multiplicity distribution observed in experiments for the SF of ^{260}Sg. Black curved line – experimental data, red – restored by the Tikhonov method of statistical regularization[1].

- The Tikhonov method of statistical regularization was successfully adapted for the SFiNx detection system experimental data analysis[1]

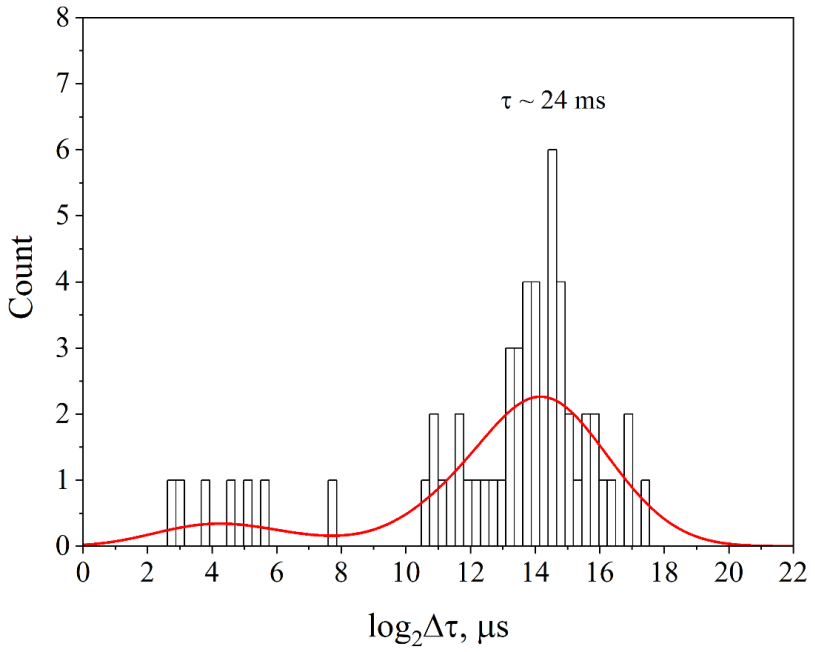
[1] R.S. Mukhin, V.N. Dushin, A.V. Eremin, et. al, Physics of Particles and Nuclei Letters, Vol. 18, No. 4, pp. 439–444 (2021)

^{260}Rf

- Reaction ^{26}Mg+^{238}U →^{264}Rf+4n



α-energy-lifetime correlation spectrum for ^{260}Rf analysis.



Lifetime distribution of ^{260}Rf nuclei which was received of SF and products of MNT reactions.

- ❑ We found 60 ER-SF correlations of ^{260}Rf.
- ❑ The lifetime of ^{260}Rf was measured to be τ ≈ 24 ms.

^{260}Rf
22.2 ms
b$_{SF}$~100%

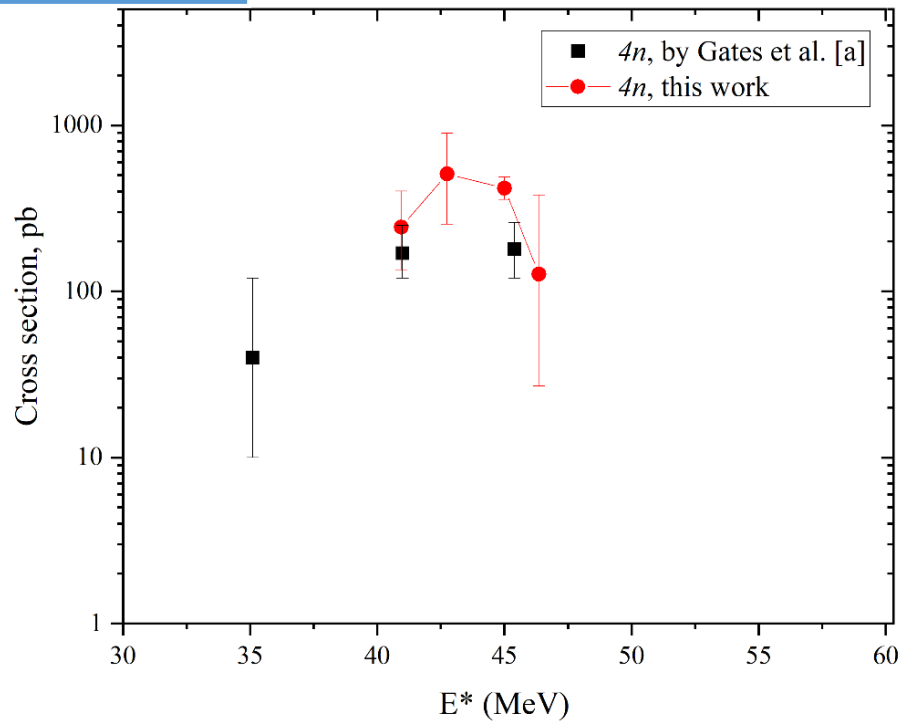
J.M. Gates et al. Phys. Rev. C. 2008 V. 77. P. 034603. DOI: 10.1103/PhysRevC.77.034603

Literature data

https://www-nds.iaea.org/

Fusion-evaporation cross sections for the reaction $^{26}Mg+^{238}U$

- Reaction $^{26}Mg+^{238}U \rightarrow ^{260}Rf+4n$



[a] J.M. Gates et al. Phys. Rev. C. 2008 V. 77. P. 034603.

Experimental cross-section for 4n, evaporation channel in complete fusion reaction $^{26}Mg+^{238}U$. Red dots – the experiment data from SHELS exp. in Dubna, black dots – the BGS experiment (Berkeley, 2008) [a].

^{260}Rf b_{SF}~100%
22.2 ms

J.M. Gates et al. Phys. Rev. C. 2008 V. 77. P. 034603. DOI: 10.1103/PhysRevC.77.034603

Literature data

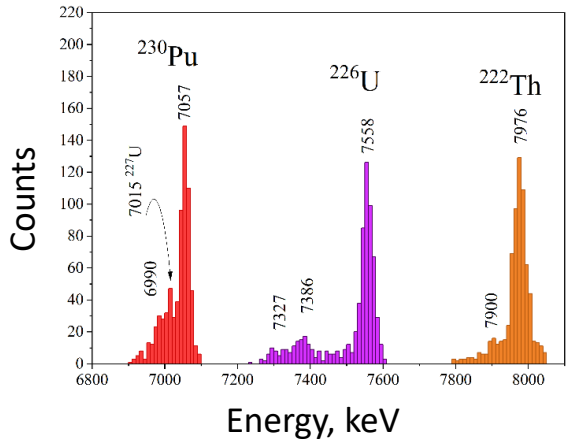
https://www-nds.iaea.org/

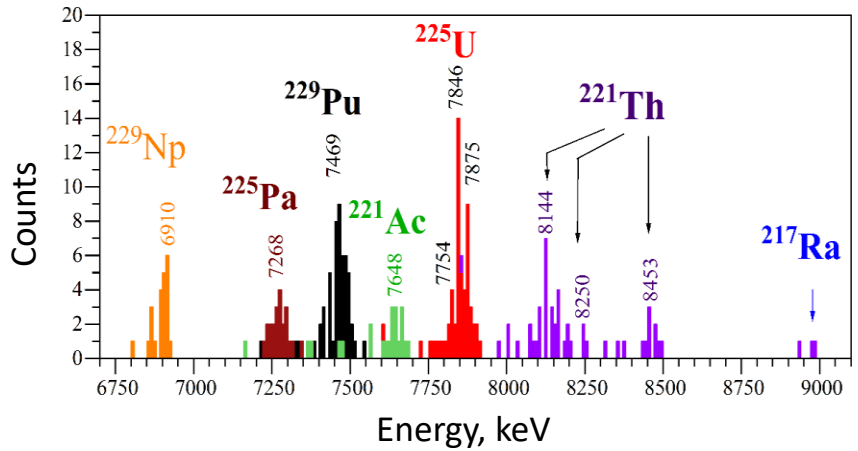
Isotopes of Pu with A = 226-230

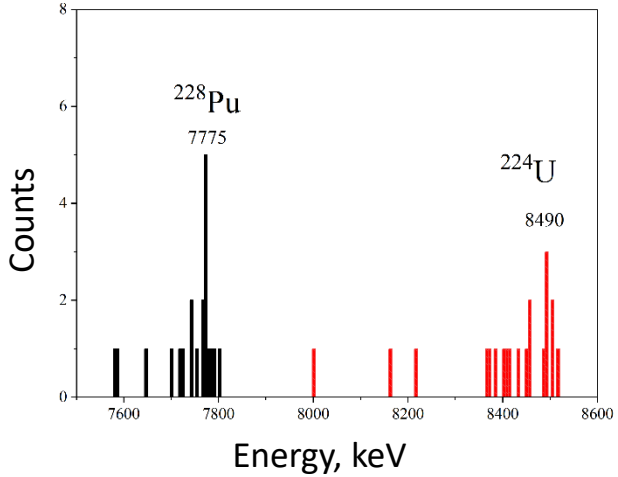
Reaction	Nuclei
$^{26}Mg+^{208}Pb$	$^{229,230}Pu$
$^{26}Mg+^{206}Pb$	$^{227\text{-}229}Pu$
$^{26}Mg+^{204}Pb$	$^{226,227}Pu$

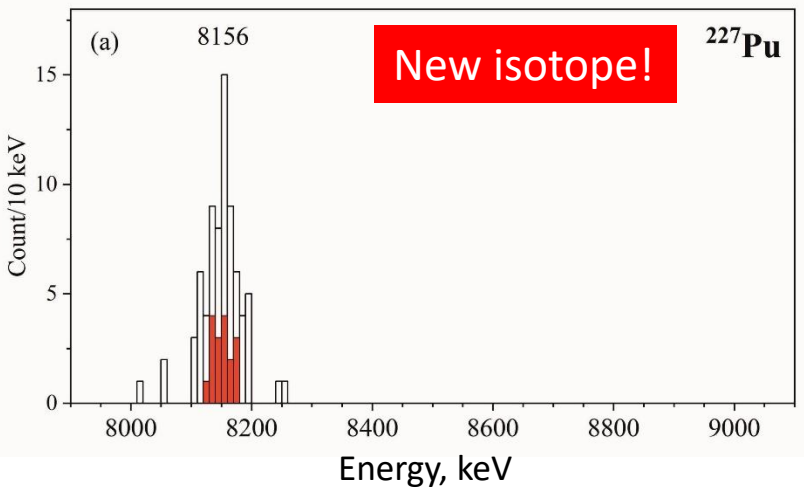
Parameters of experiment

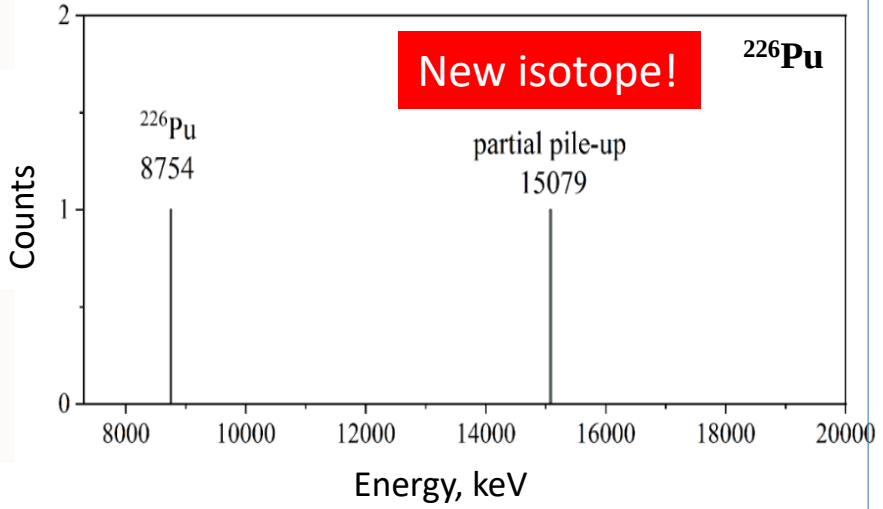
- The beam energy : 137-150 MeV
- The average charge of ^{26}Mg: **6+**
- The beam intensity (DC280): 1-2 pμA
- Transmission GRAND: 6%







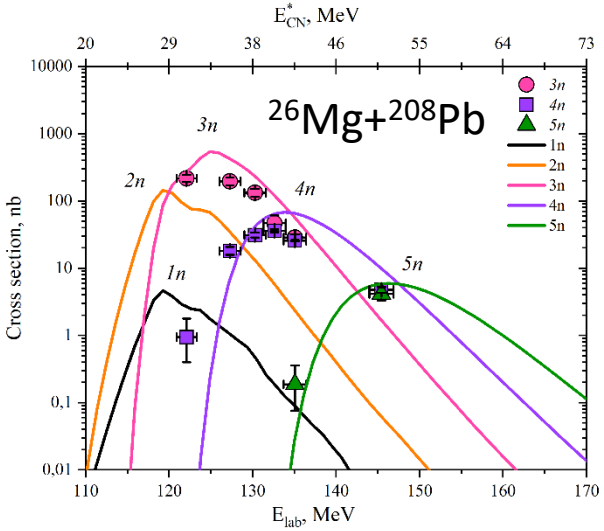


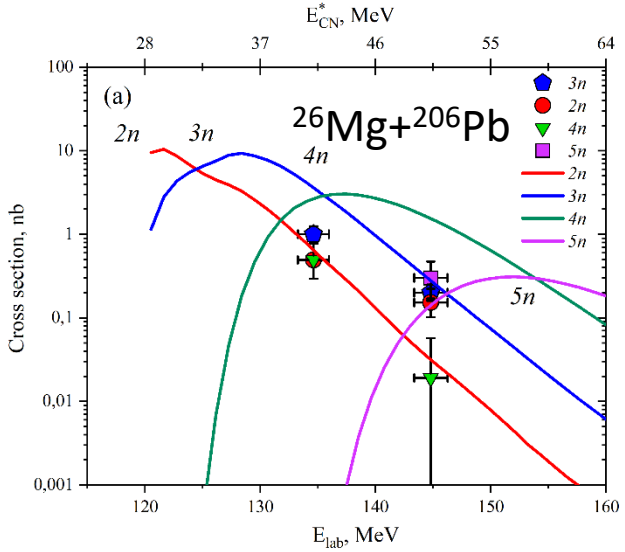


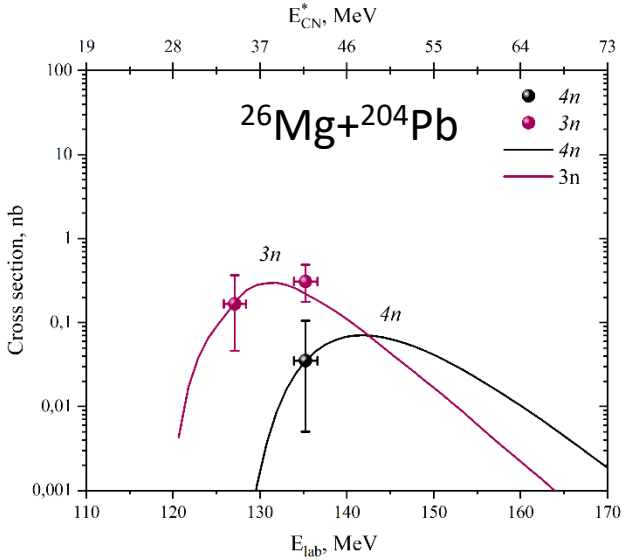
Evaporation residues formation cross-section

Reaction	Nuclei
$^{26}Mg+^{208}Pb$	$^{229,230}Pu$
$^{26}Mg+^{206}Pb$	$^{227\text{-}229}Pu$
$^{26}Mg+^{204}Pb$	$^{226,227}Pu$[1]

[1] *A.A. Kuznetsova, A.I. Svirikhin, A.V. Isaev et al, Physics of Particles and Nuclei Letters, ISSN 1547-4771, 2025, Vol. 22, No. 2, pp. 406–412. © Pleiades Publishing, Ltd., 2025.*



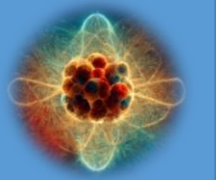




Evaporation residues formation cross-section for reactions $^{26}Mg+^{204,206,208}Pb$; dots – the experimental data, lines – theoretical estimates**.

*** Karpov A. V. et all, Phys. Part. Nucl. Lett., 2018. V. 15. P. 247.*

Conclusions

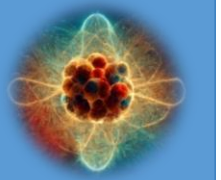


- Nuclei from different regions of the nuclear map were investigated.
- The GRAND transmission was found to be higher than that achieved with SHELS.

	$^{48}Ca+^{206}Pb \rightarrow ^{254}No^*$	$^{26}Mg+^{204,206,208}Pb \rightarrow ^{230,232,234}Pu^*$
SHELS	45 %	3 %
GRAND	65 %	6 %

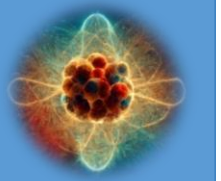
- For the first time for GF-separators, an intensity of 6 pμA was achieved.
- The high-intensity ion beams makes it possible to achieve high statistics of recoil nuclei, which is crucial for the synthesis and study of super-heavy elements.

Conclusions



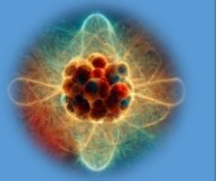
^{252}No **^{48}Ca+^{206}Pb**	• A significant dataset for ^{252}No was collected for gamma-ray analysis. A publication based on these results is planned for 2026. • The evaporation residue cross section of the reaction ^{48}Ca+^{206}Pb was measured.
^{260}Rf **^{54}Cr+^{207}Pb**	• Sixty spontaneous fission events of ^{260}Rf were observed, and its lifetime was measured to be approximately 24 ms. • The analysis of alpha decay data is ongoing. • The excitation function of evaporation residues in the 4n channel was determined. Our results provide a complement to those obtained earlier. A publication is planned for 2026.
^{260}Sg **^{26}Mg+^{238}U**	• Over two experiments, 50 alpha decays and 358 spontaneous fission events of ^{260}Sg were recorded. • The decay modes of ^{260}Sg were clarified. • The neutron yield in the spontaneous fission of ^{60}Sg was measured. • The evaporation residue cross section for the reaction ^{54}Cr+^{207}Pb was measured; for the 4n channel, it was found to be 0.24±0.005 nb. A publication based on these results is planned for 2026.
$^{226\text{-}230}$Pu **^{26}Mg+^{204,206,208}Pb**	• Two new isotopes, ^{226}Pu and ^{227}Pu, were discovered. • The decay modes for $^{227-230}$Pu were measured. • Excitation functions of evaporation residues in the reactions ^{26}Mg+^{204,206,208}Pb were determined. • Statistics for Pu, U, Th, and other nuclei were collected for gamma-ray analysis. The publication is being prepared.

Publications for 3 years



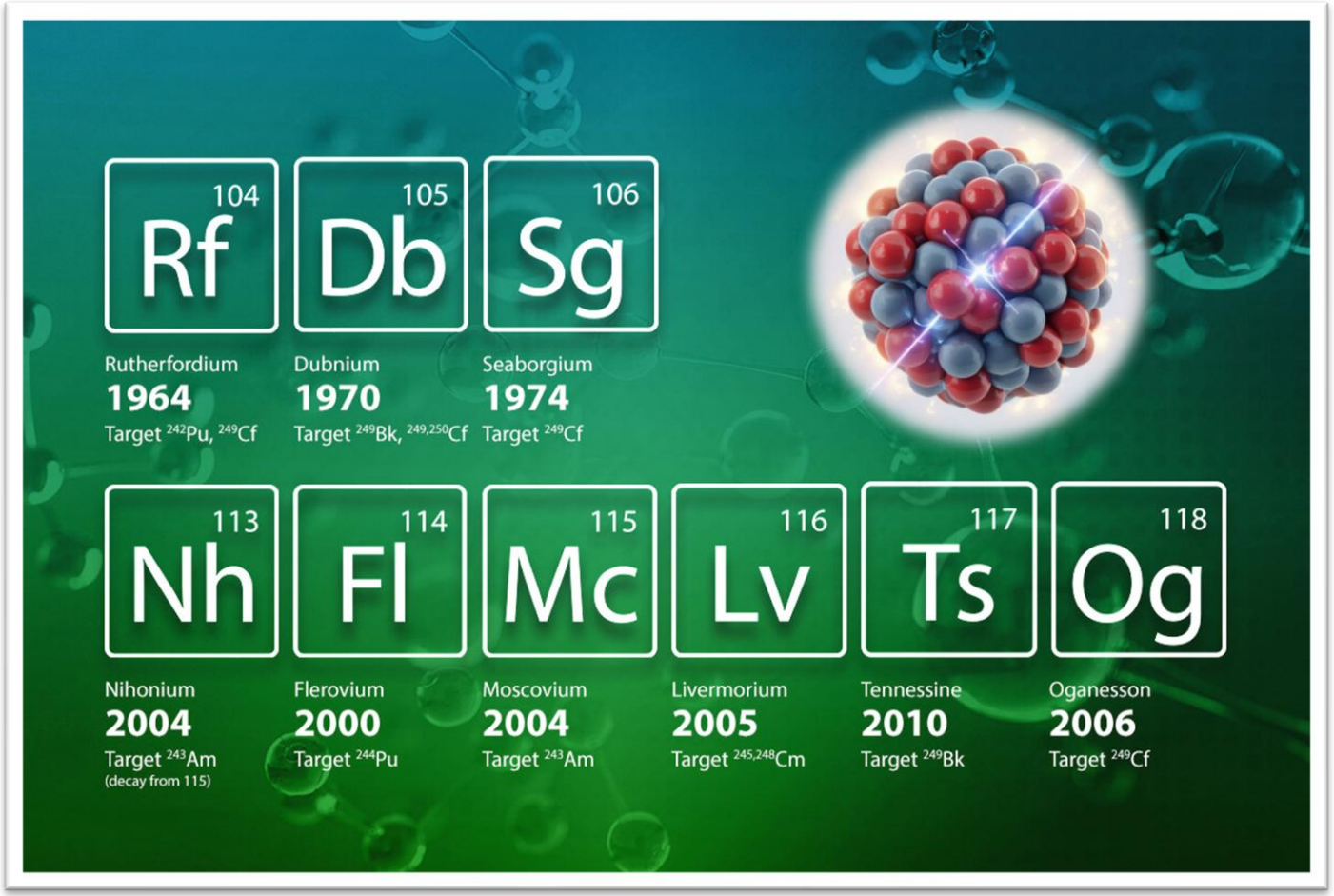
1. M. Forge, et al. First experimental measurement of spin splitting and evidence for a second 0^+ state in ^{254}No, **submitted to Phys. Rev. Lett.**
2. P. Brionnet, et al. Structure studies of ^{257}Db through combined alpha, gamma and internal-conversion-electron spectroscopy, **submitted to Physical Review C.**
3. A.V. Isaev, et al. The SFiNx detector system (current status), **PEPAN Letters** 22 №2 300-303 (2025).
4. H.M. Devaraja, et al. Systematic studies to produce heavy above-target nuclides in multinucleon transfer reactions, **Physical Letters B** 862 139353 (2025).
5. A.A. Kuznetsova, et al. Properties of Radioactive Decay of the New Nucleus ^{227}Pu, **PEPAN Letters**, 22, № 2(259). C.244–253 (2025).
6. R.S. Mukhin, et al. Prompt neutron emission in ^{250}No spontaneous fission associated with ground and isomeric states decay, **Chinese Physics C** 48 №6 064002 (2024).
7. A.V. Yeremin, et al. GRAND Universal Gas-Filled Separator: First Experimental Results, **PEPAN Letters** 21 3(254) 647–659 (2024).
8. A. Rahmatinejad, et al. Evolution of fission properties in Fermium region, **International Journal of Modern Physics E** 2441018 (2024).
9. K. Kessaci, et al. Cascade of high-K isomers in ^{255}No, **Physical Review C** 110 054310 (2024).
10. R. S. Mukhin, et al. Prompt neutron multiplicity from spontaneous fission of ^{244}Fm, **Eur. Phys. J. A** 60 223 (2024).
11. R. S. Mukhin, et al. Analysis of the shape of multiplicity distributions of prompt neutrons emitted in spontaneous fission, **J Radioanal Nucl Chem** 333, 1559–1564 (2024).
12. M. Forge, et al. New results on the decay spectroscopy of ^{254}No with GABRIELA@SHELS, **Journal of Physics Conference Series** 2586 012083 (2023).
13. A.V. Isaev, et al. Structure of the prompt neutron multiplicity distribution in the spontaneous fission of ^{256}Rf, **Physics Letters B** 843 138008 (2023).
14. R. Chakma, et al. Investigation of isomeric states in ^{255}Rf, **Physical Review C** 107, 014326 (2023).

Future plans

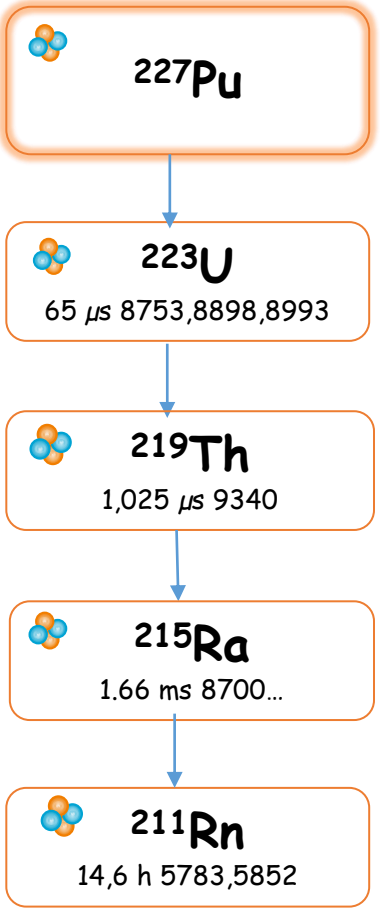


- **SHELS, GRAND -** it is planned to continue studying the formation cross-section and decay properties of light transuranium nuclei ($^{226\text{-}228}$Pu, $^{236\text{-}238}$Cf, $^{231\text{-}233}$Am).
- **SHELS, GRAND -** for transfermium region will be studied the decay schemes and nuclear structure of the nuclei in the influence range of the closed shell N = 152 ($^{256\text{-}260}$Rf, $^{256\text{-}258}$Db, $^{257\text{-}260}$Sg).
- **GRAND -** to study the nuclei lying in the vicinity of the deformed shell N = 162, and further. The capabilities of the SHE Factory and GRAND make it possible to study the SHE-nuclei decay properties ($^{286\text{-}288}$Fl, ^{288}Mc).
  σ → 5-10 pb !!!

Thank you for your attention!



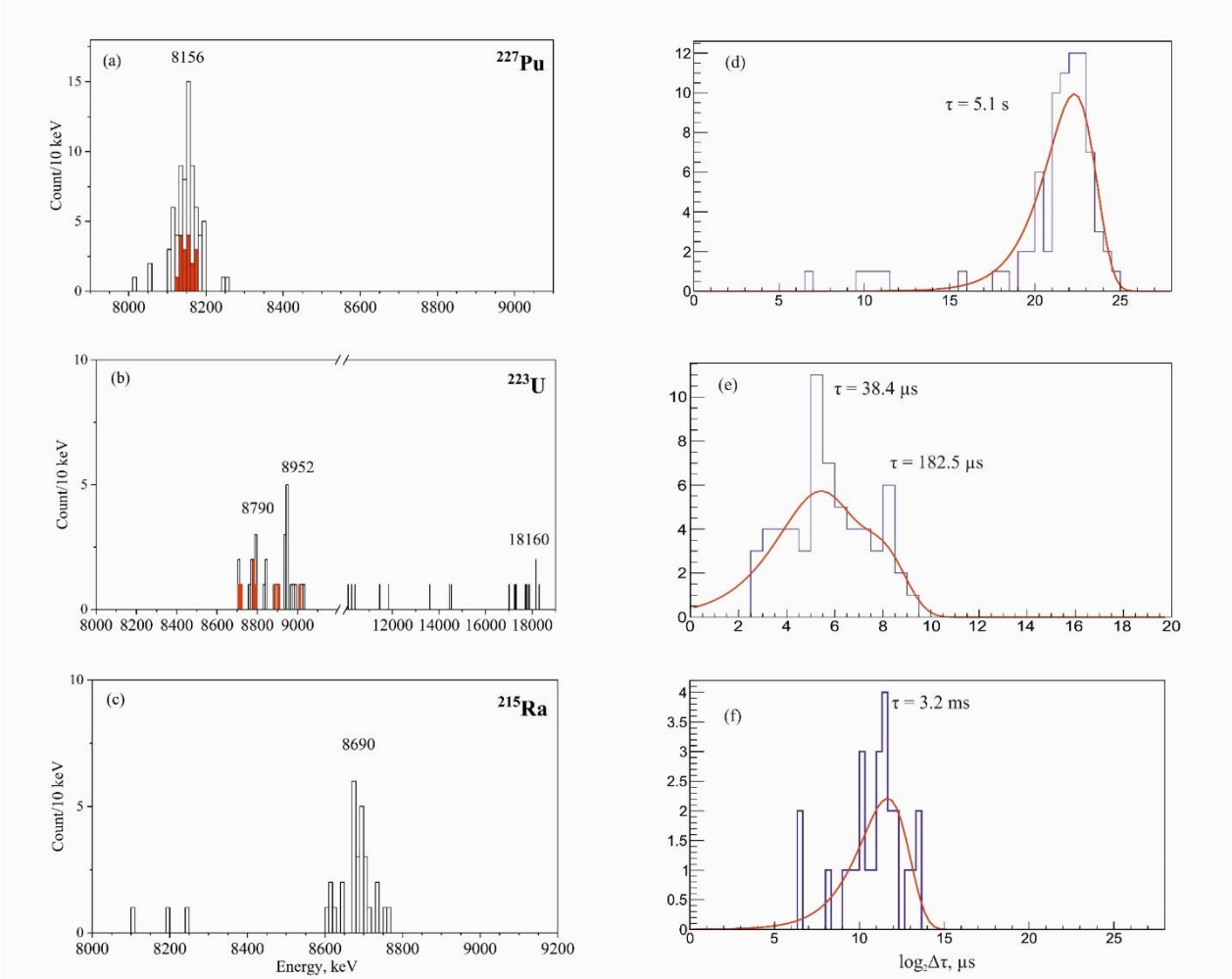
New isotope ^{227}Pu



- ✓ 60 chains in reaction ^{26}Mg+^{206}Pb
- ✓ 32 chains in reaction ^{26}Mg+^{204}Pb

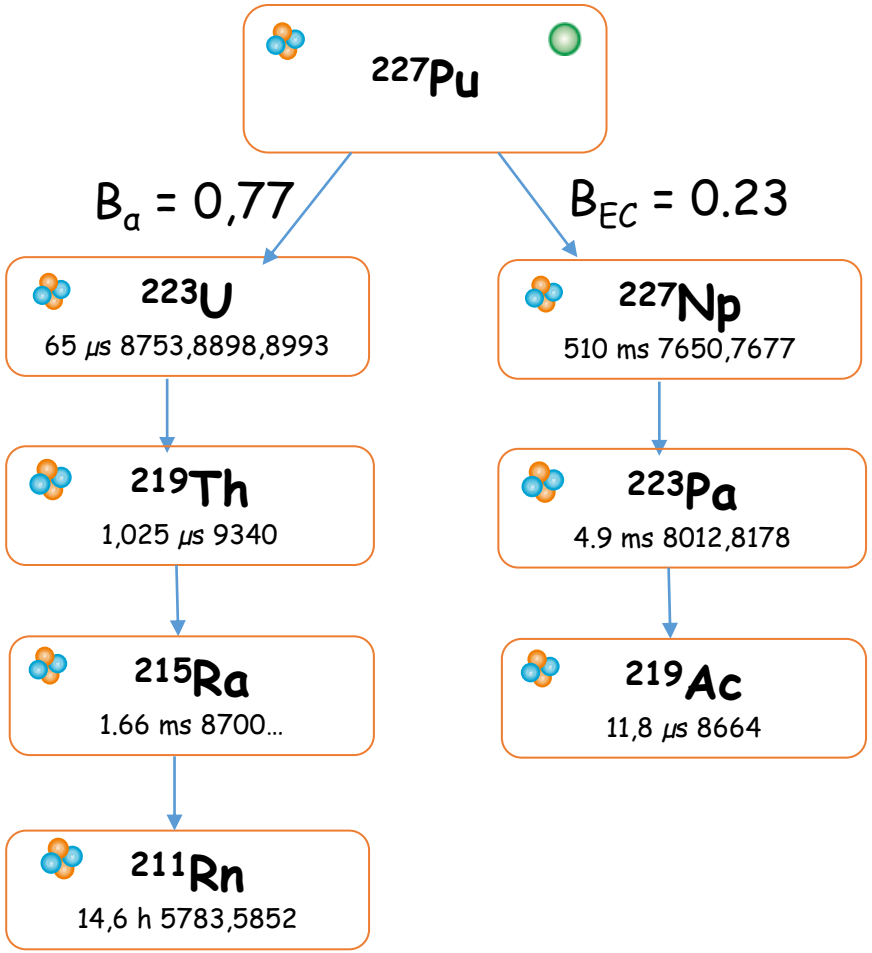
Experiment	Theory
E_α = (8156±26) keV Q_α = 8302 keV	E_α = 8153 keV Q_α = 8300±200 keV
$T_{1/2} = 3.5^{+0.5}_{-0.4}$ s	$T_{1/2}$ = 0,9 s

** "Properties of Radioactive Decay of the New Nucleus ^{227}Pu" http://www1.jinr.ru/Preprints/2024/50(P7-2024-50).pdf

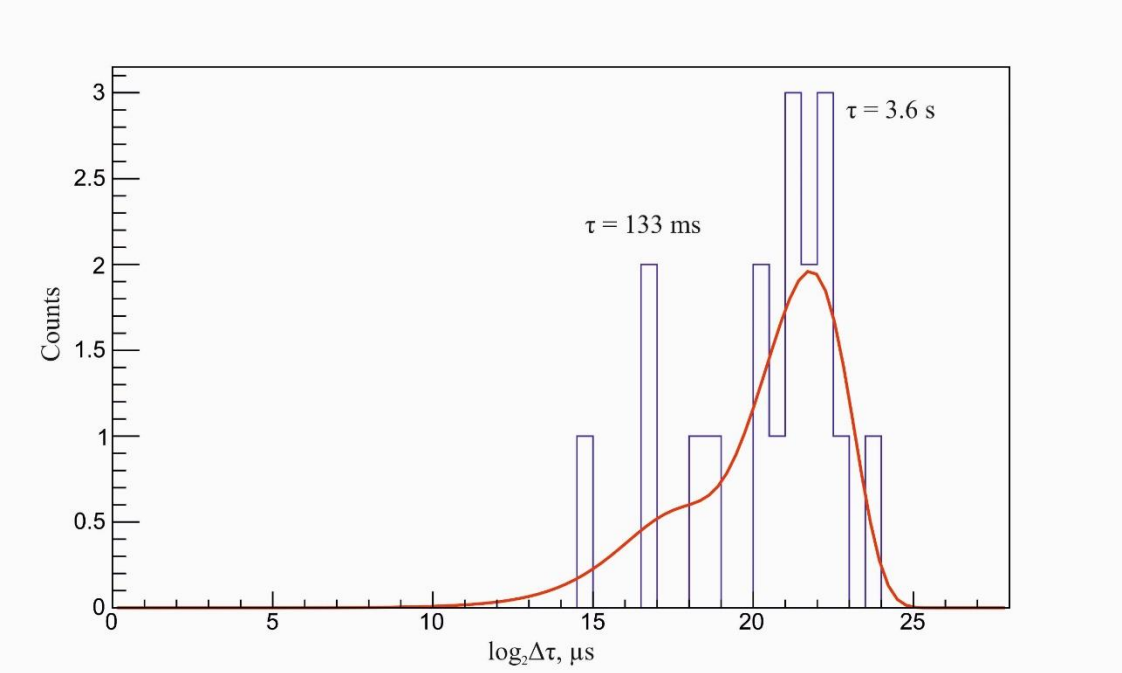


a) *The α-spectrum of ^{227}Pu was obtained in the reactions ^{26}Mg+^{204}Pb and ^{26}Mg+^{206}Pb, the red histogram, received via ER-α_1-α_4 correlations,* ***b)*** *The α-spectrum of ^{223}U, the red histogram, received in the reaction ^{26}Mg+^{204}Pb,* ***c)*** *the α-spectrum of ^{215}Ra,* ***d)*** *the time distribution of Δτ(ER-α_1),* ***e)*** *Δτ(α_1-α_2),* ***f)*** *Δτ(α_2-α_4).*

EC for ^{227}Pu



- 12 ER(^{227}Pu)-^{227}Np-^{223}Pa chains were found.
- EC half-life is $T_{1/2}$ (ER+^{227}Np) = $2.5^{+0.8}_{-0.5}$ s
- ^{227}Np has E_α = (7626±24) keV and (7687±21) keV
- EC branch for ^{227}Pu is B_{EC} = 0.23±0.10.



The time distribution of Δτ(^{227}Pu+^{227}Np) and Δτ(^{227}Np) obtained in the reactions ^{26}Mg+^{204}Pb and ^{26}Mg+^{206}Pb