The neutron multiplicity study at spontaneous fission of short-lived isotopes (z > 100) using VASSILISSA recoil separator

Svirikhin A.I.

Joint Institute for Nuclear Research, Dubna, Russia

Manipal University, Madhav Nagar, India

MANIPAL UNIVERSITY

iThemba LABS
Laboratory for Accelerator Based Sciences

Laboratory for Accelerator-Based Sciences, South Africa

Institute for Nuclear Research and Nuclear Energy, Bulgaria

INRNE

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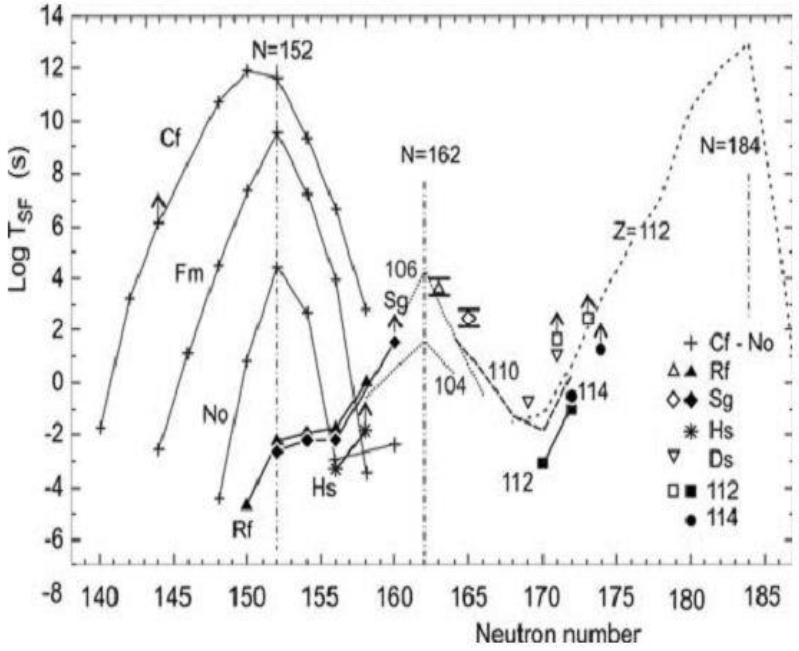
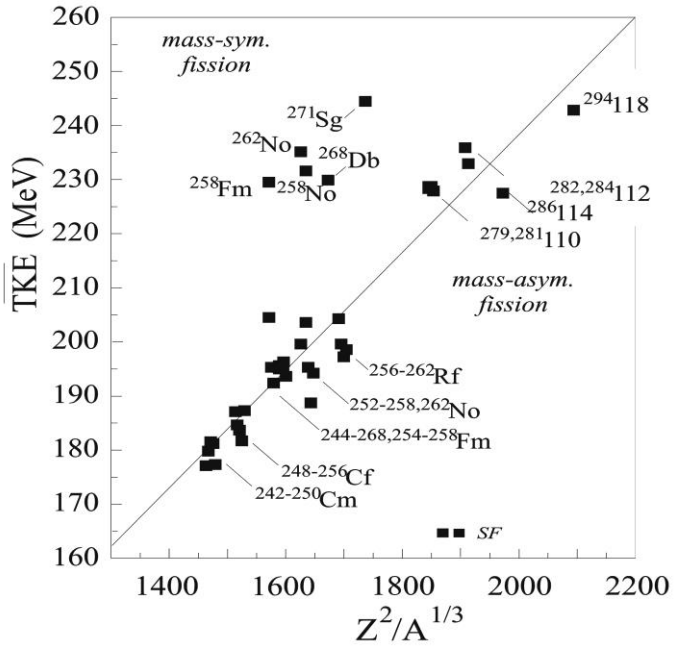
Presently the available information on the spontaneous fission of heavy elements mainly concerns partial half lives, TKE and mass distributions of fission fragments from spontaneous fission.





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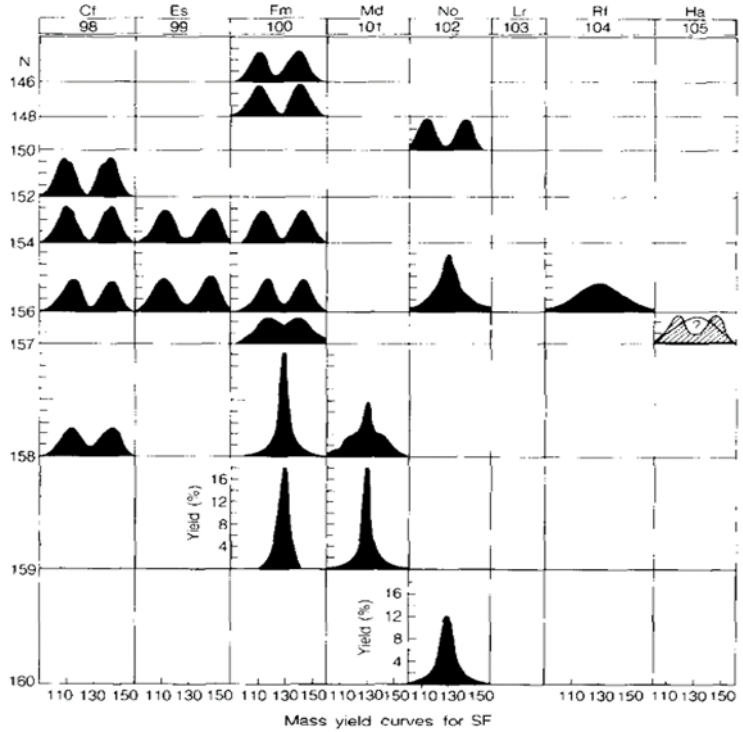
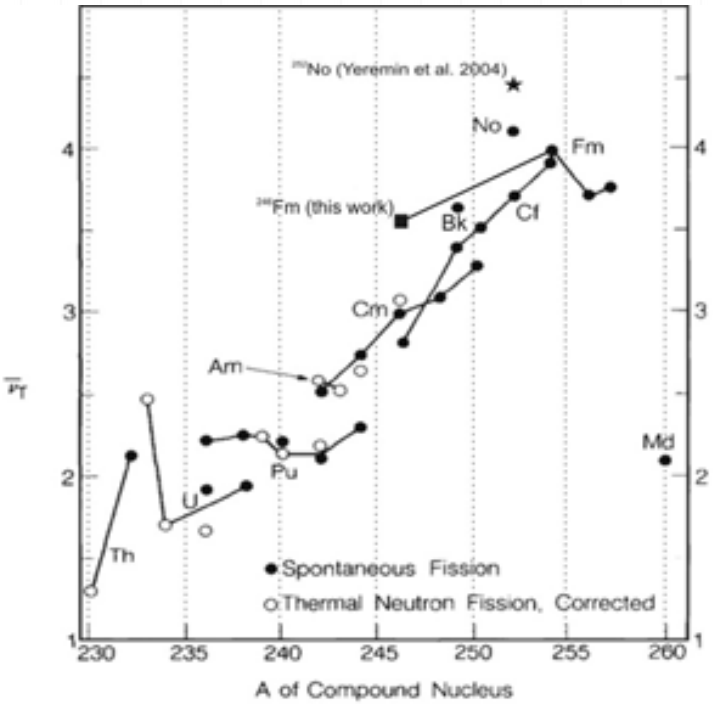
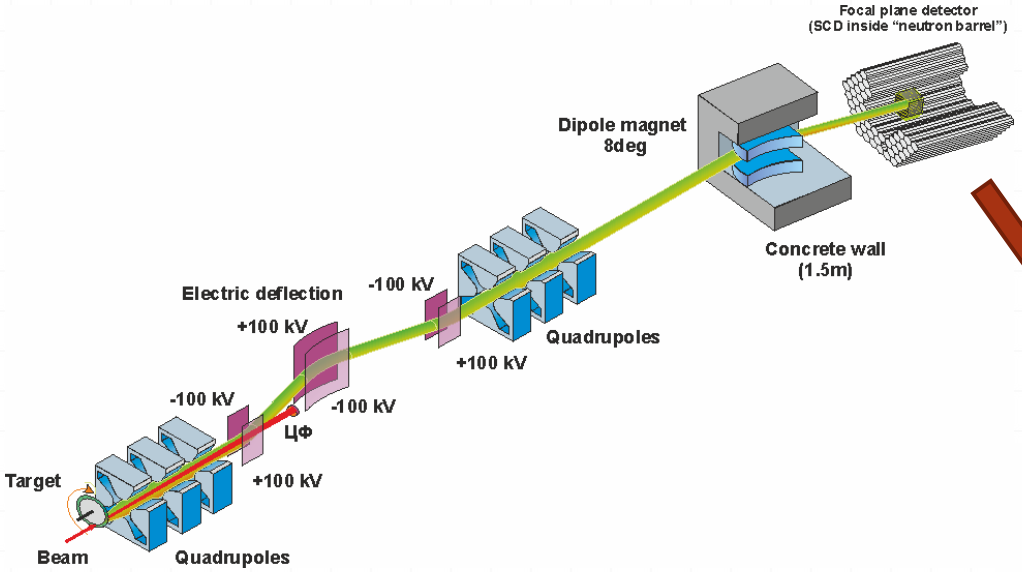


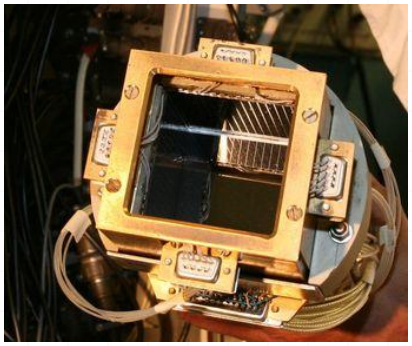


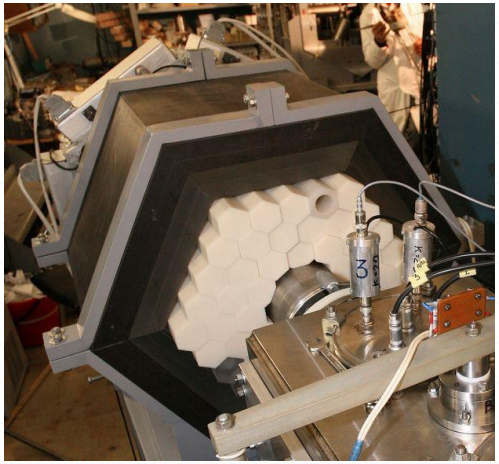
In the past a multiplicity distribution of prompt neutrons emitted in spontaneous fission was measured for elements not heavier than Fm.

Experimental setup

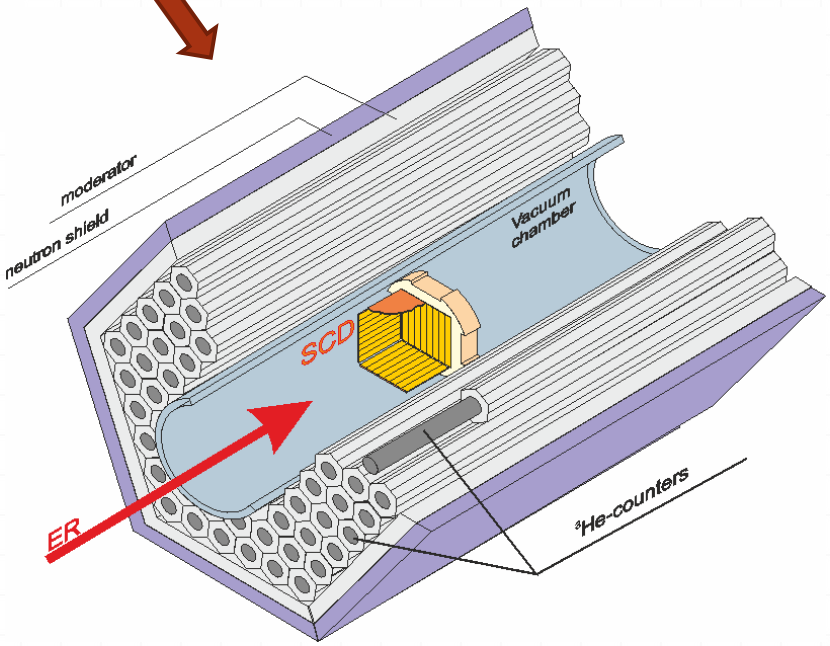


$T_{1/2}$
b_{SF}
TKE



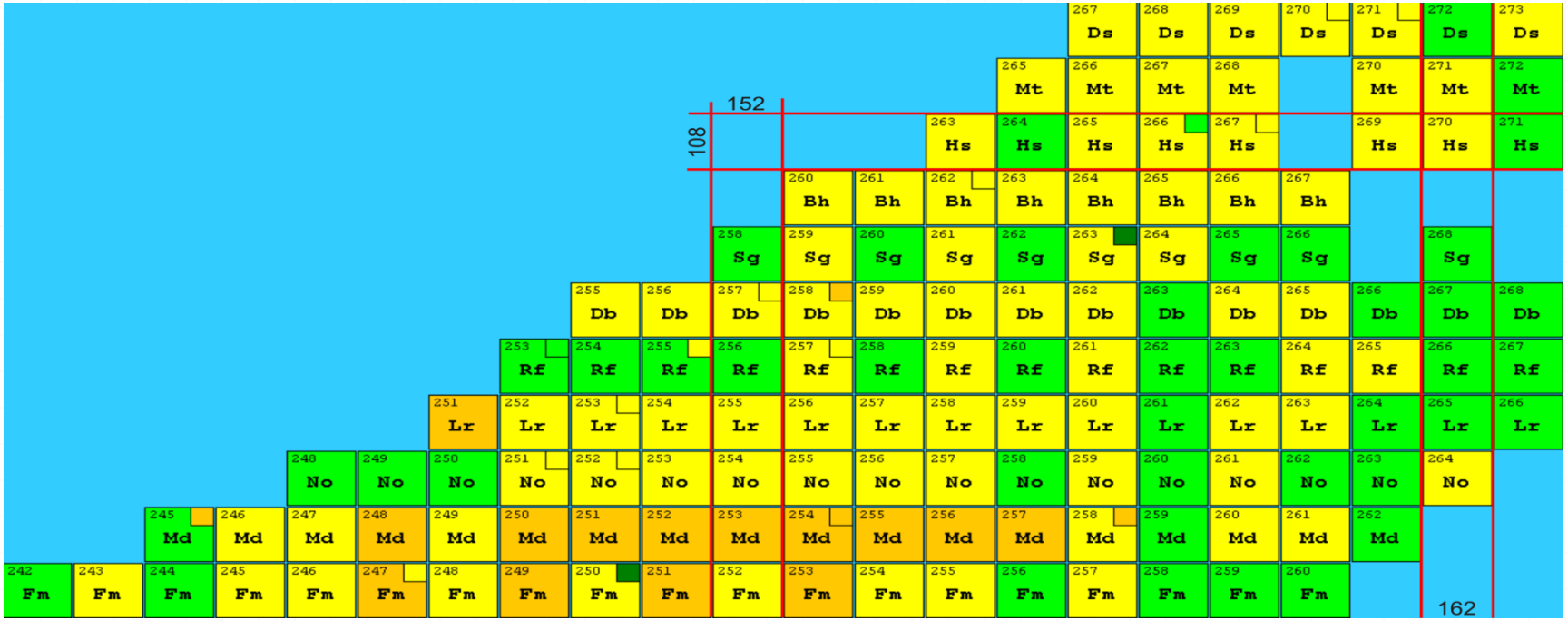


Multiplicity distribution, Av. number of neutrons per SF

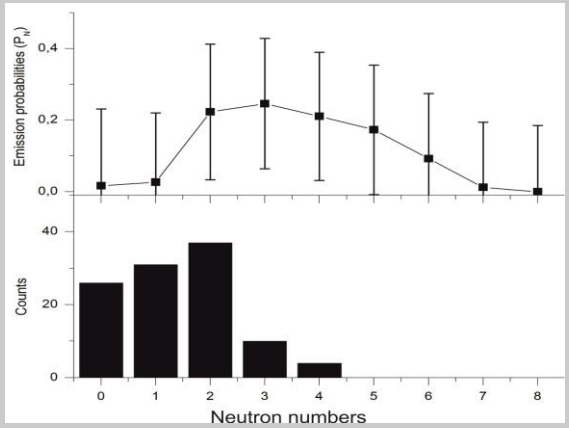
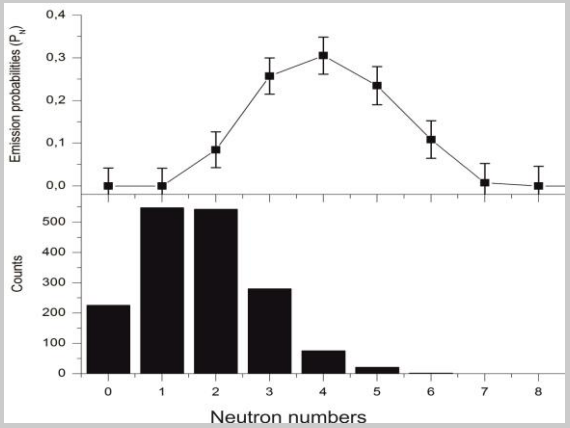
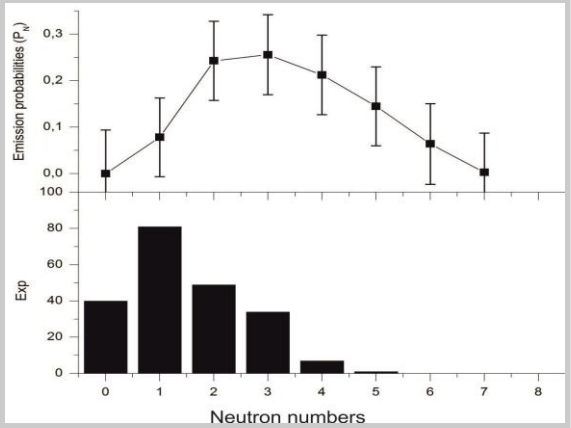


Experiments

- Determination of the SF-branching ratio
- Measuring of partial half-lives
- Estimating kinetic energies of spontaneous fission fragments
- Measuring of the average number of neutrons emitted in SF
- Determination of neutron multiplicity distributions



Experiments

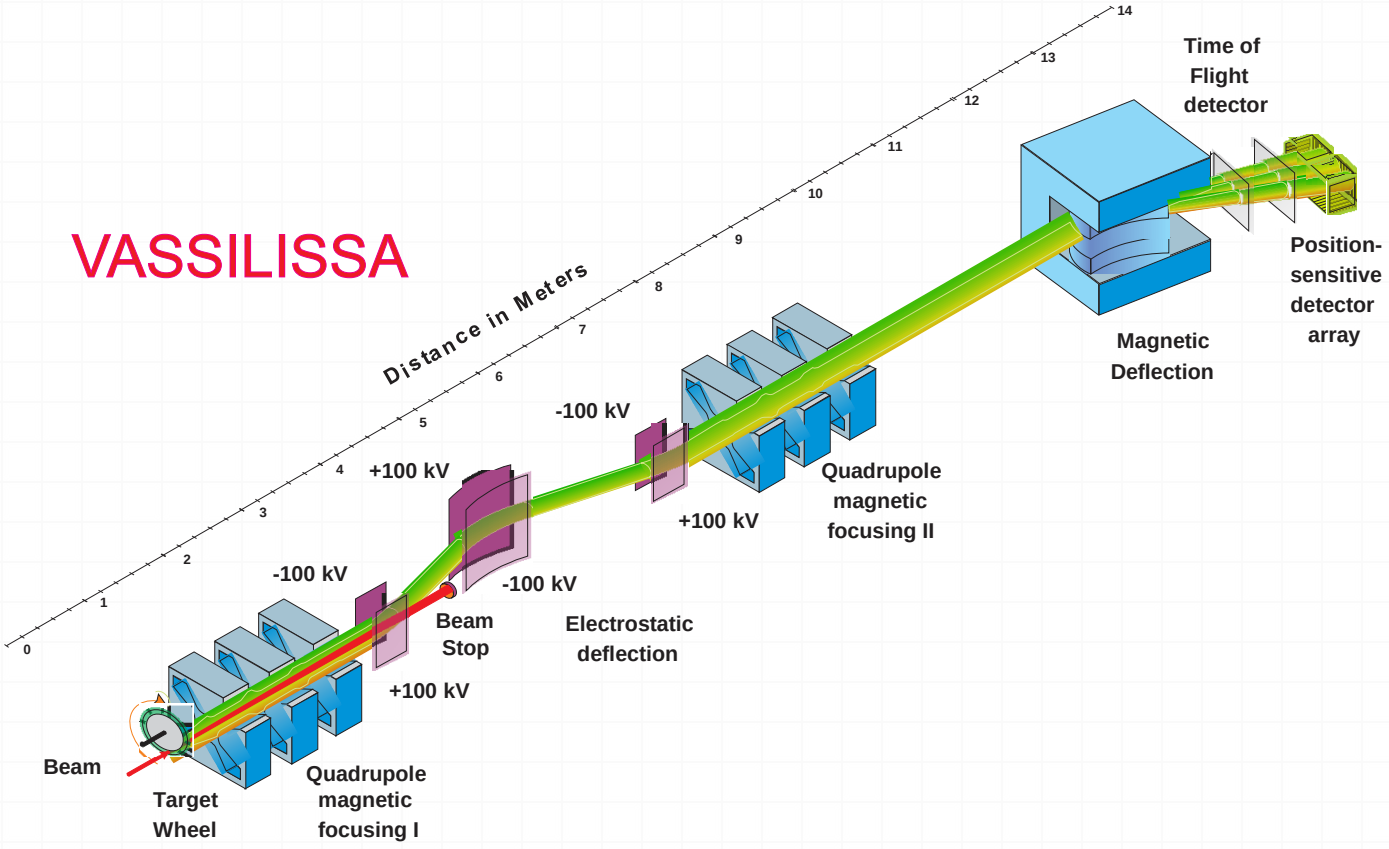
$^{40}Ar(^{208}Pb,2n)^{246}Fm$	$^{48}Ca\ (^{206}Pb,2n)\ ^{252}No$	$^{40}Ar\ (\ ^{206}Pb,2n)\ ^{244}Fm$
Target: ^{208}Pb (97.2%), 280μg/sm^2 ^{40}Ar-beam: $E_{1/2}$ = 186 ± 2 MeV 0.5 pμA (3x10^{12} pps) **σ ≈ 6 nb**	Target: ^{206}Pb (97%), 350μg/sm^2 ^{48}Ca-beam: $E_{1/2}$ = 217 ± 2 MeV 0.5 pμA (3x10^{12} pps) **σ ≈ 200 nb**	Target: ^{206}Pb (97%), 350μg/sm^2 ^{48}Ca-beam: $E_{1/2}$ = 186 ± 2 MeV 0.5 pμA (3x10^{12} pps) **σ ≈ 3 nb**
108 SF events b_{SF} = (5±3) % (lit.: 8 %) $T_{1/2}$ = (1.3±0.2)s (lit.: 1.1c и 1.2c)	**2000** SF events Calibration TKE =198,7 MeV *Bemis C.E. et.al., Phys.Rev. C15. 1977*	**212** SF events b_{SF} = 100% $T_{1/2}$ = 3.47±0.26 ms (lit. 3.12±0.08) *TKE =195 ±14 MeV*
		
ν = 3,6±0,5	**ν = 4,06 ± 0,12** **(ν = 4,15 ± 0,30** Yeremin A.V. et. al., Nucl. Instr. Meth. A539. 2005**)**	**ν = 3,3 ± 0,3**

Experiments

Isotope	Calculated[a] average number of neutrons,	Measured average number of neutrons,	Calculated[a] average TKE (MeV)	Measured average pre-neutron TKE (MeV)
^{252}No	4.1	4.06±0.12[this work]	201	202.4±1.2
^{244}Fm	3.5	3.3±0.3[this work]	196	198±15[this work]
^{246}Fm	3.6	3.6±0.5[this work]	196	199±4
^{248}Cm	3.1	3.13±0.01	183	182
^{252}Cf	3.6	3.77±0.01	186	184.1±1.3

In the present work we used an improved scission-point model (*see A.V. Andreev, Eur. Phys. J.* ***A 30****, (2006)*) which is powerful in description of various experimental data on binary and ternary fission of heavy nuclei: mass and charge distributions of fission fragments, their kinetic energies, prompt fission neutron multiplicities, etc.

Experiments

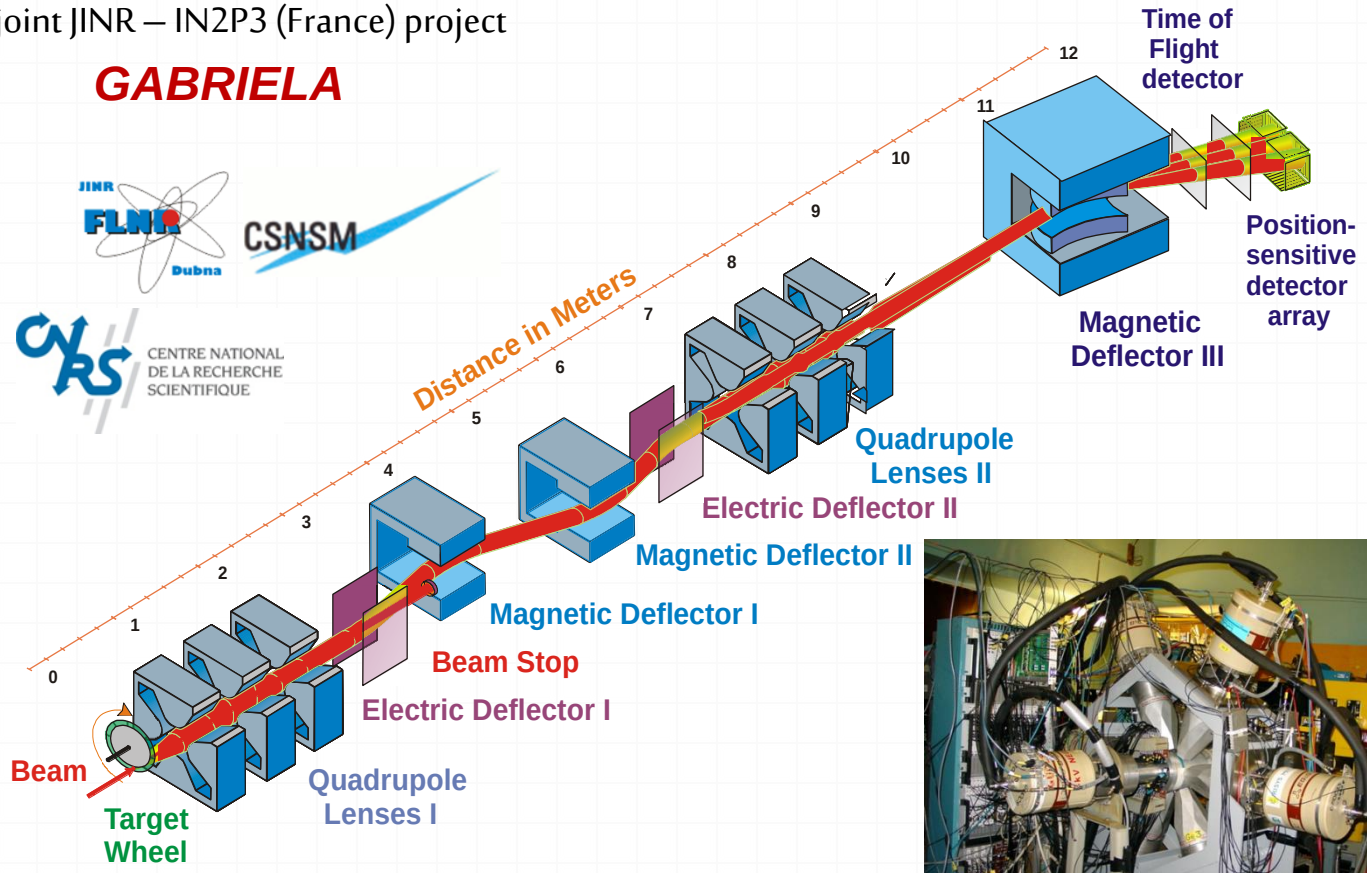


Experiments

SHELS – Separator for Heavy Element Spectroscopy

The joint JINR – IN2P3 (France) project

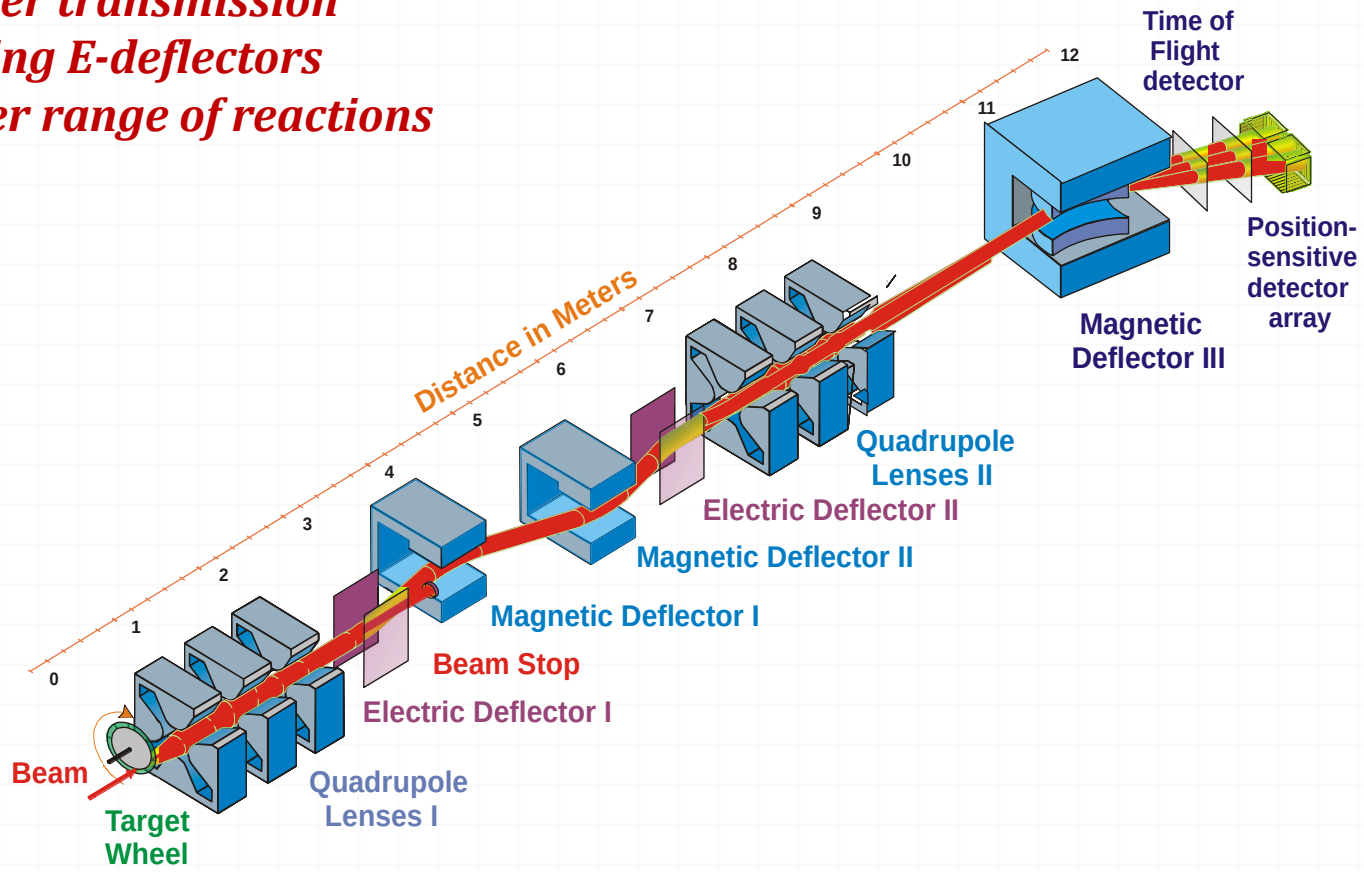
GABRIELA



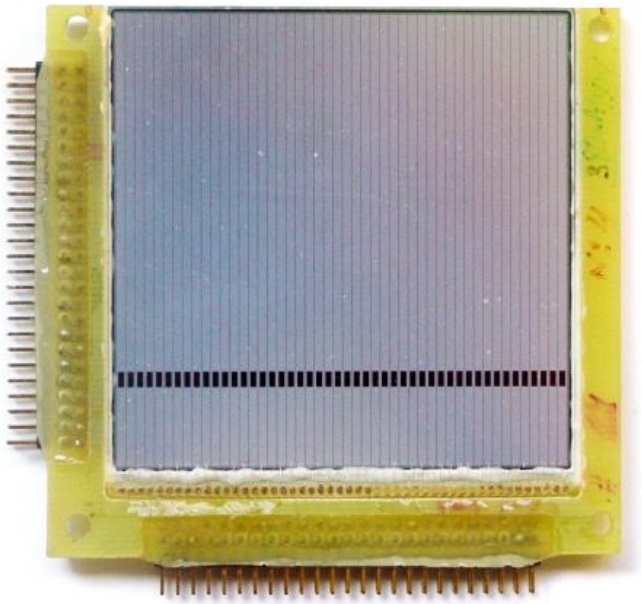
Experiments

SHELS – Separator for Heavy Element Spectroscopy

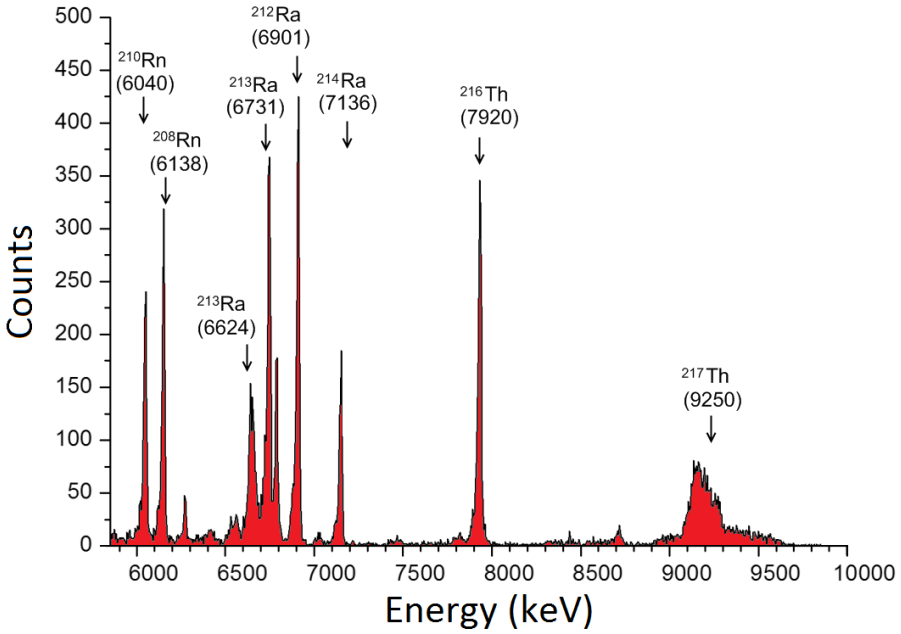
- *Higher transmission*
- *Moving E-deflectors*
- *Wider range of reactions*



Experiments

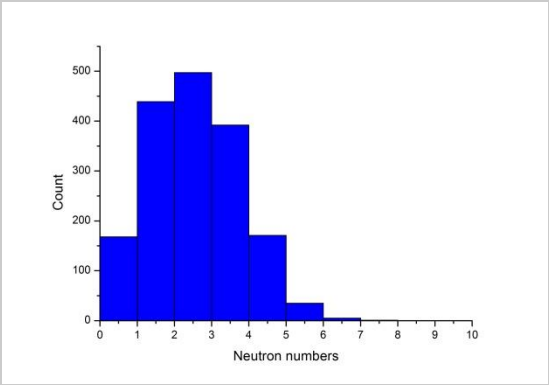


The new DSSD:
- ❖ 48×48 strips;
- ❖ the thickness is 300 μm;
- ❖ the sensitive area is 58 mm^2;
- ❖ the pos. resolution is 1.2 mm^2

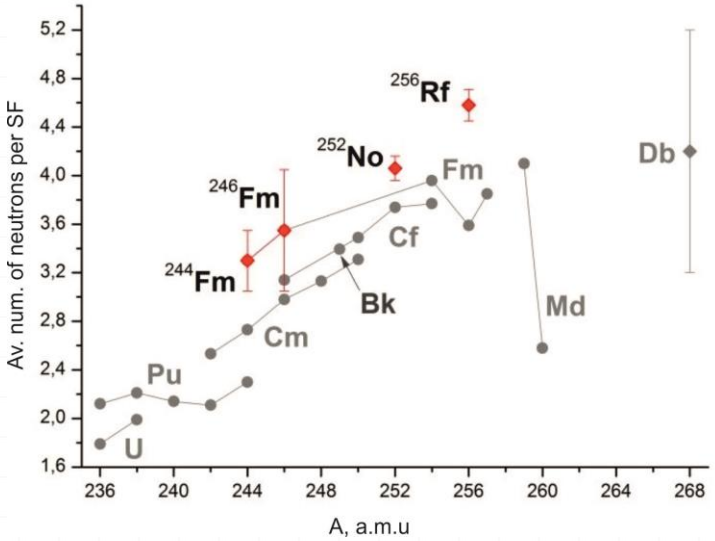


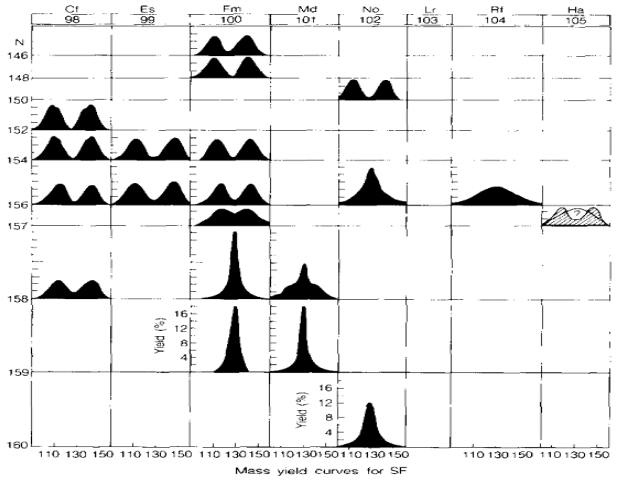
Spectrum of α particles, obtained from an isolated strip from the face side of the focal detector.
Reaction $^{48}Ca + {}^{174}Yb \rightarrow {}^{222}Th^*$.
Energy resolution approx. 20 keV for each strip

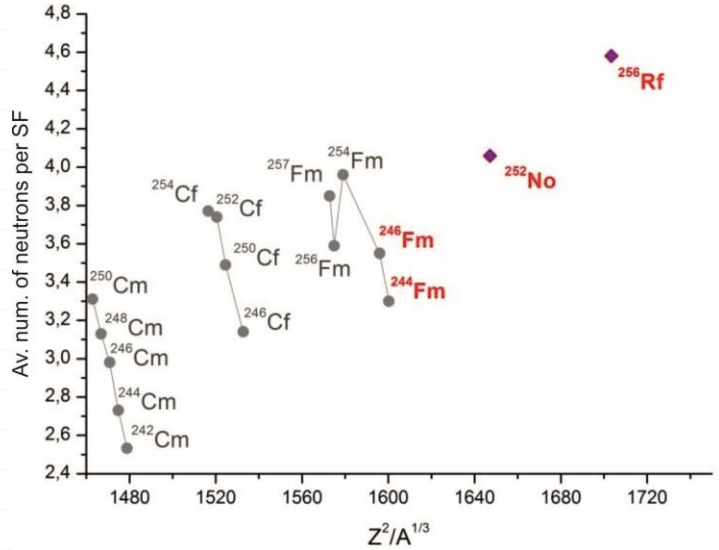
New results

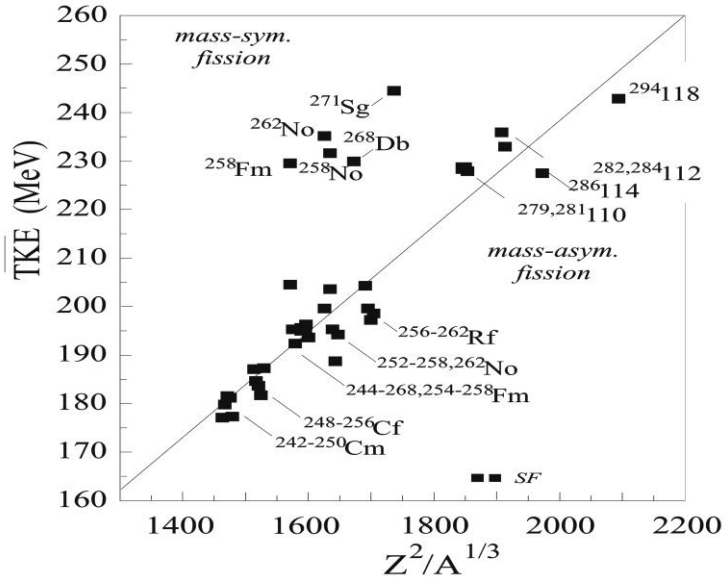
$^{50}Ti(^{208}Pb,2n)^{256}Rf$	$^{48}Ca(^{208}Pb,2n)^{254}No$	$^{204}Pb(^{48}Ca, 2n)^{250}No$
Target: ^{208}Pb (97.2%) (^{206}Pb, ^{207}Pb ≈ 2.5%) 300μr/cm^2 ^{50}Ti beam: $E_{1/2}$ = 186 ± 2 МэВ 0.5 pμA (3x10^{12} pps) σ ≈ 10 nb	Target: ^{208}Pb (97.2%) (^{206}Pb, ^{207}Pb ≈ 2.5%) 300μr/cm^2 ^{48}Ca-beam: $E_{1/2}$ = 217 ± 2 MeV 0.2 pμA (1.2x10^{12} pps) σ ≈ 1500 nb	Target: ^{204}Pb 350μr/см^2 ^{48}Ca-beam: 0.5 pμA (1.2x10^{12} pps) σ ≈ 13 nb
1700 SF b_{SF} ≈ 100 % $T_{1/2}$ = 6 ms	b_{SF} = 0.17 % $T_{1/2}$ = 51 s	b_{SF} ≈ 100 % $T_{1/2}$ = 4.2 μs
	**In the process**	
ν = 4,58±0,13		

Summary


Av. num. of neutrons per SF
A, a.m.u
256Rf
252No
246Fm
244Fm
Db
Fm
Cf
Bk
Md
Cm
Pu
U

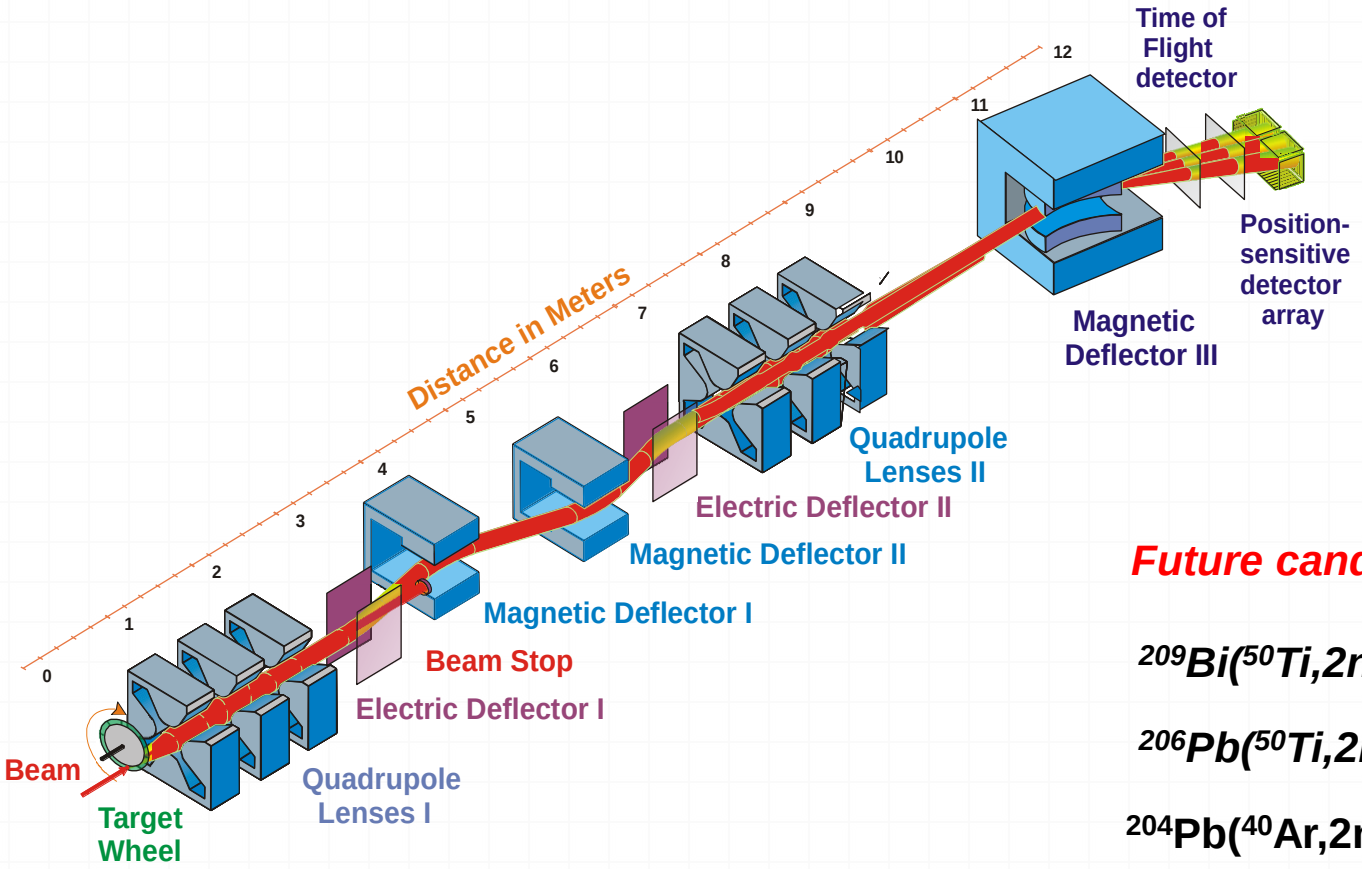

Cf 98
Es 99
Fm 100
Md 101
No 102
Lr 103
Rf 104
Ha 105
N
Yield (%)
Mass yield curves for SF


Av. num. of neutrons per SF
Z²/A^1/3
256Rf
252No
254Fm
257Fm
254Cf
252Cf
246Fm
244Fm
250Cf
256Fm
250Cm
248Cm
246Cm
244Cm
242Cm
246Cf


mass-sym. fission
mass-asym. fission
TKE (MeV)
Z²/A^1/3
271Sg
262No
268Db
258Fm
258No
294118
282,284112
286114
279,281110
256-262Rf
252-258,262No
244-268,254-258Fm
248-256Cf
242-250Cm
SF

Future plans

SHELS – Separator for Heavy Element Spectroscopy



Future candidates

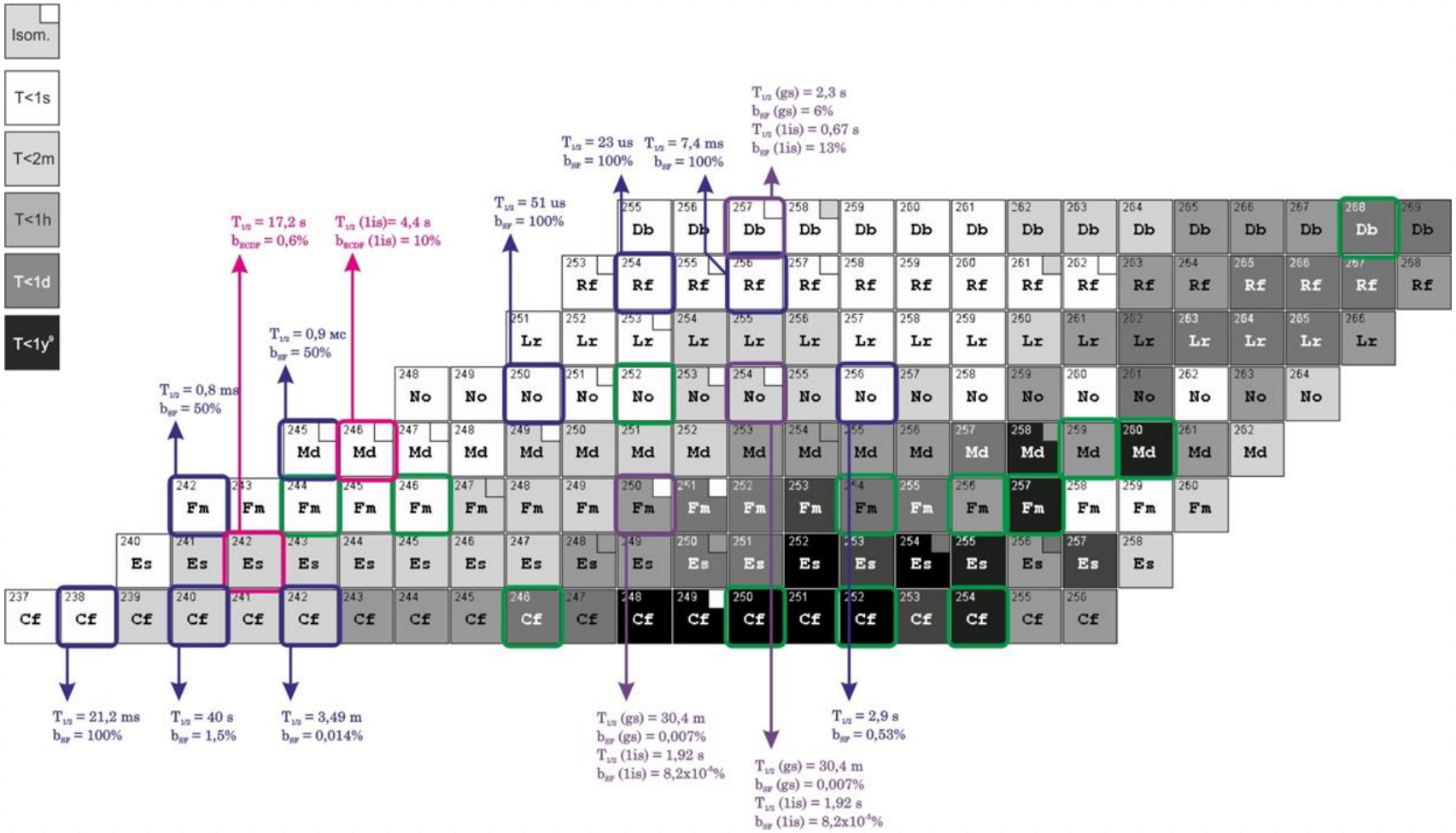
$^{209}Bi(^{50}Ti,2n)^{257}Db$

$^{206}Pb(^{50}Ti,2n)^{254}Rf$

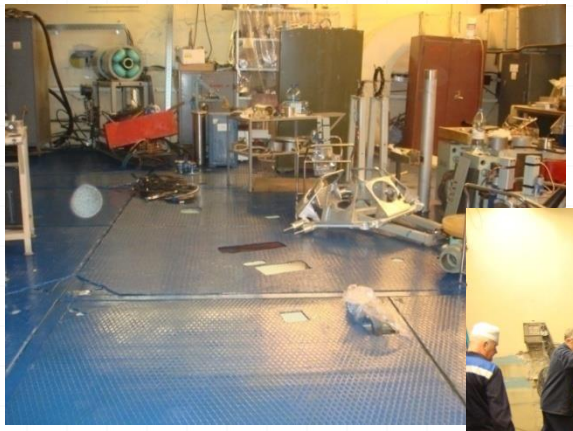
$^{204}Pb(^{40}Ar,2n)^{242}Fm$

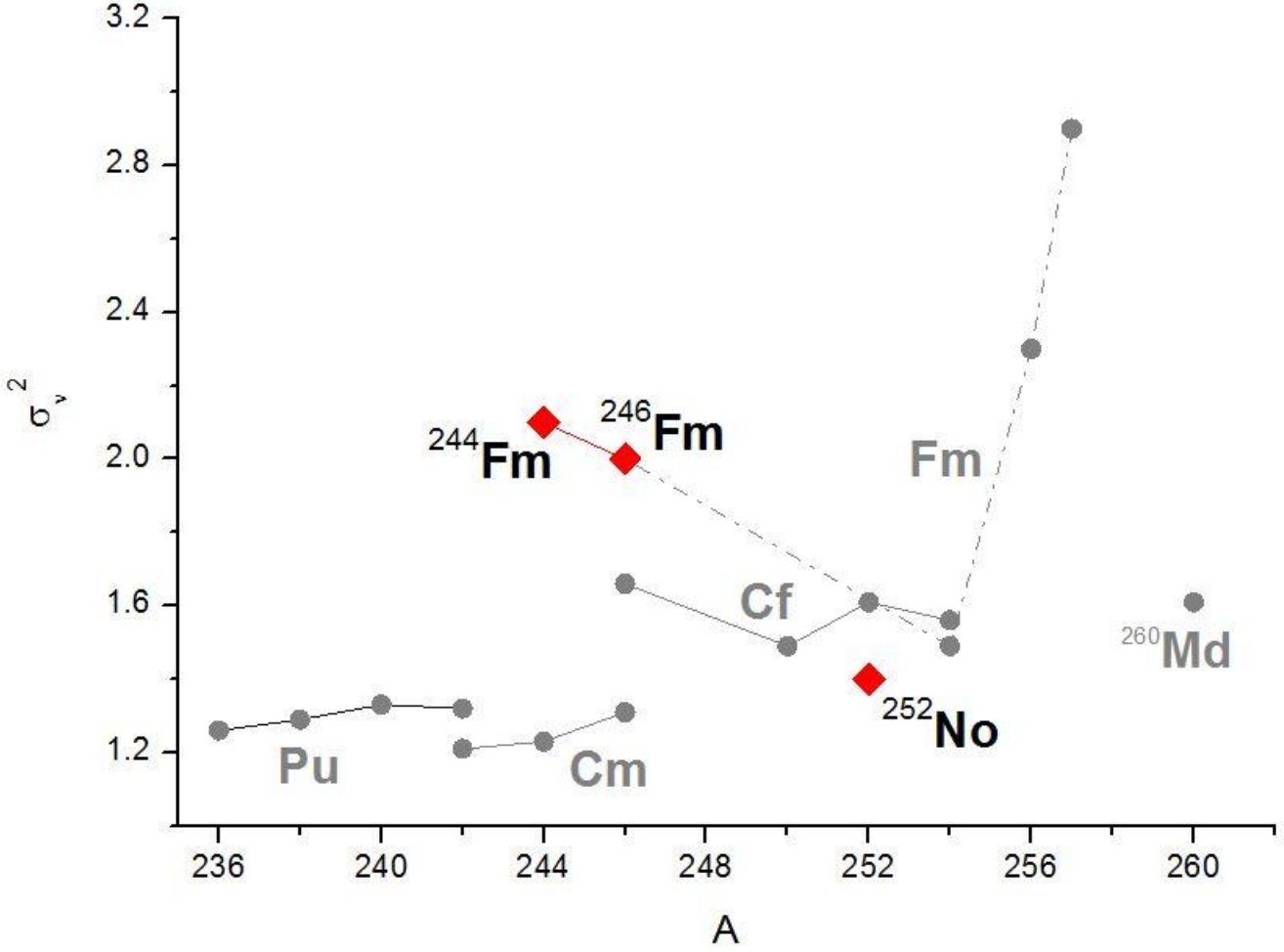
Future plans

It is planned to continue studying the spontaneous fission of short-lived neutron-deficient isotopes produced in the reactions with heavy ions on the modernized VASSILISSA separator.

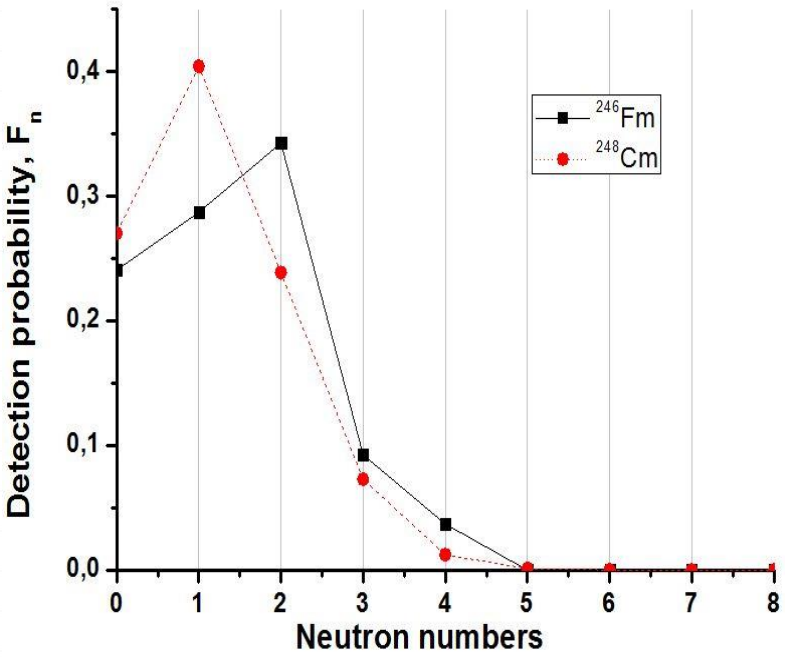


Thank you for your attention !!!

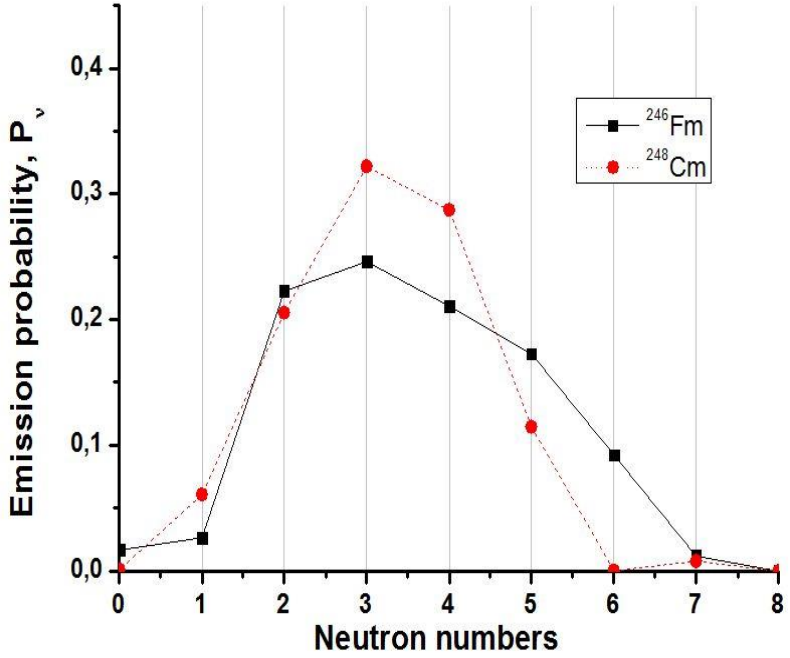



3.2
2.8
2.4
2.0
1.6
1.2
σ_v^2
^{244}Fm
^{246}Fm
Fm
Cf
^{260}Md
^{252}No
Pu
Cm
236
240
244
248
252
256
260
A

Comparison of neutron multiplicity distribution of ^{246}Fm and ^{248}Cm



The normalized multiplicity distribution of detected neutrons for ^{246}Fm and ^{248}Cm is shown



The determined by statistical regularization method multiplicity distributions of emitted neutrons for ^{246}Fm and ^{248}Cm is presented