Petersburg Nuclear Physics Institute

Investigation of the possibilities of heavy actinide isotopes production in high-flux reactor PIK

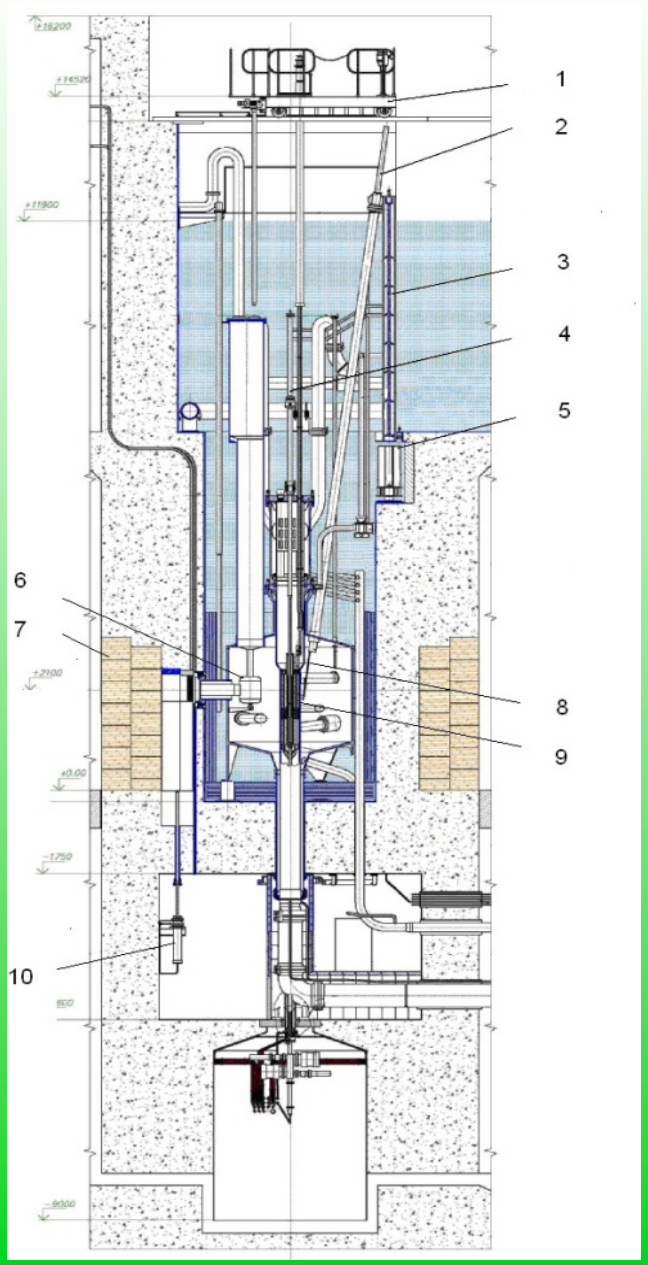
M.S. Onegin

2015 Super Heavy Elements Symposium

Reactor PIK

2011 – Criticality reached
2013 – Construction finished
2014 – 2017 Licensing and neutron stations and installation construction
2018 – Power operation scheduled

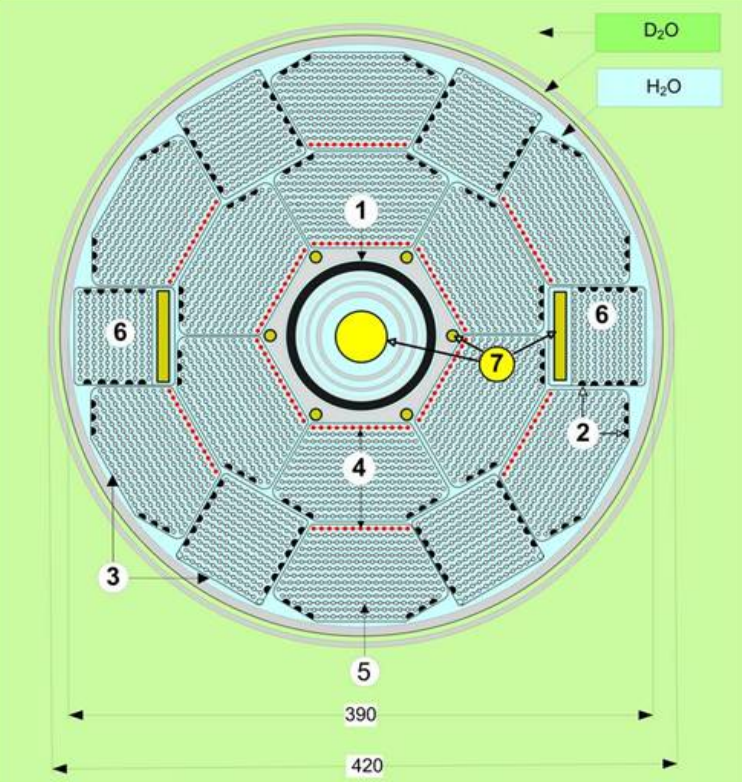
The maximum heat output	100 MW
Heat transfer agent	water
Reflector	heavy water
Number of horizontal experimental channels	10
Number inclined experimental channels	6
Number of vertical experimental channels	6



Vertical cut of reactor PIK

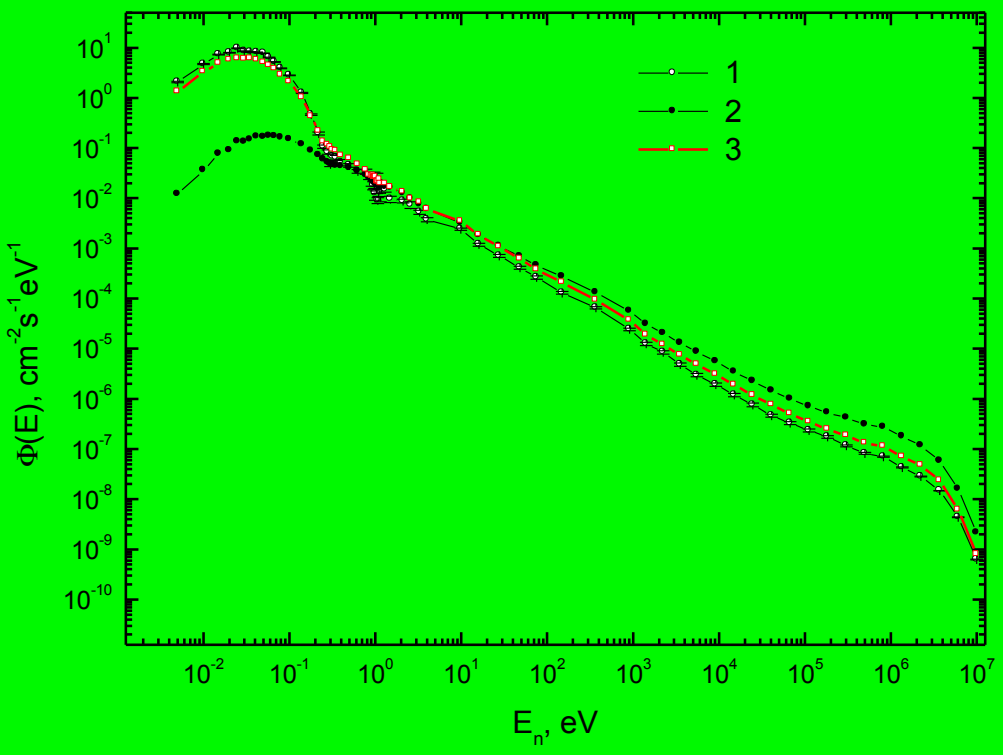
1. Fuel handling machine
2. Control rod disconnect driveline
3. Hydraulic lock
4. Central experimental channel
5. Transfer device cylinder
6. Cold neutron source
7. Biological shielding
8. Control rod
9. Reactor core
10. Driving gear of channel gate

PIK core



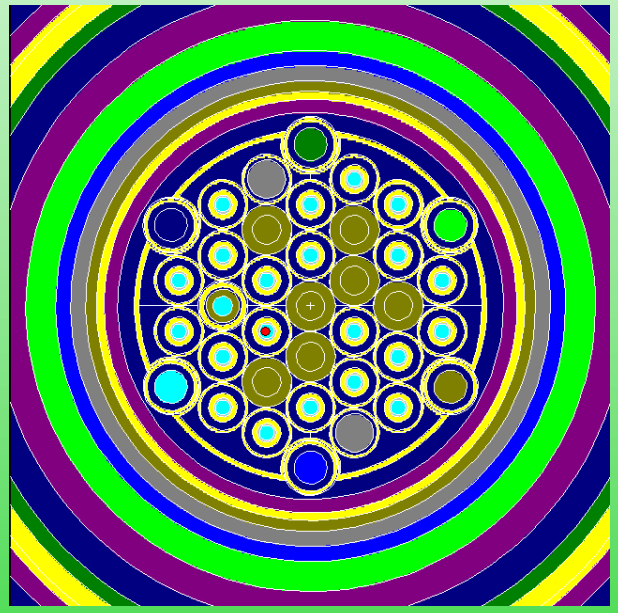
1. Hafnium central control rod
2. Burnable rods
3. Fuel assemblies Zr case
4. Profiled Fuel elements
5. Fuel elements
6. Fuel assemblies with irradiation volumes
7. Volumes for samples irradiation

CEC volume for sample irradiation has a cylindrical form of 40 mm diameter and 500 mm height
There is the possibility to take out samples during reactor operation



Neutron spectrums

1. Central experimental channel - PIK
2. Core - PIK
3. HFIR

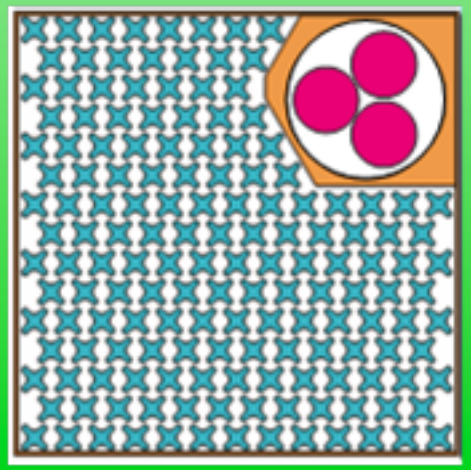


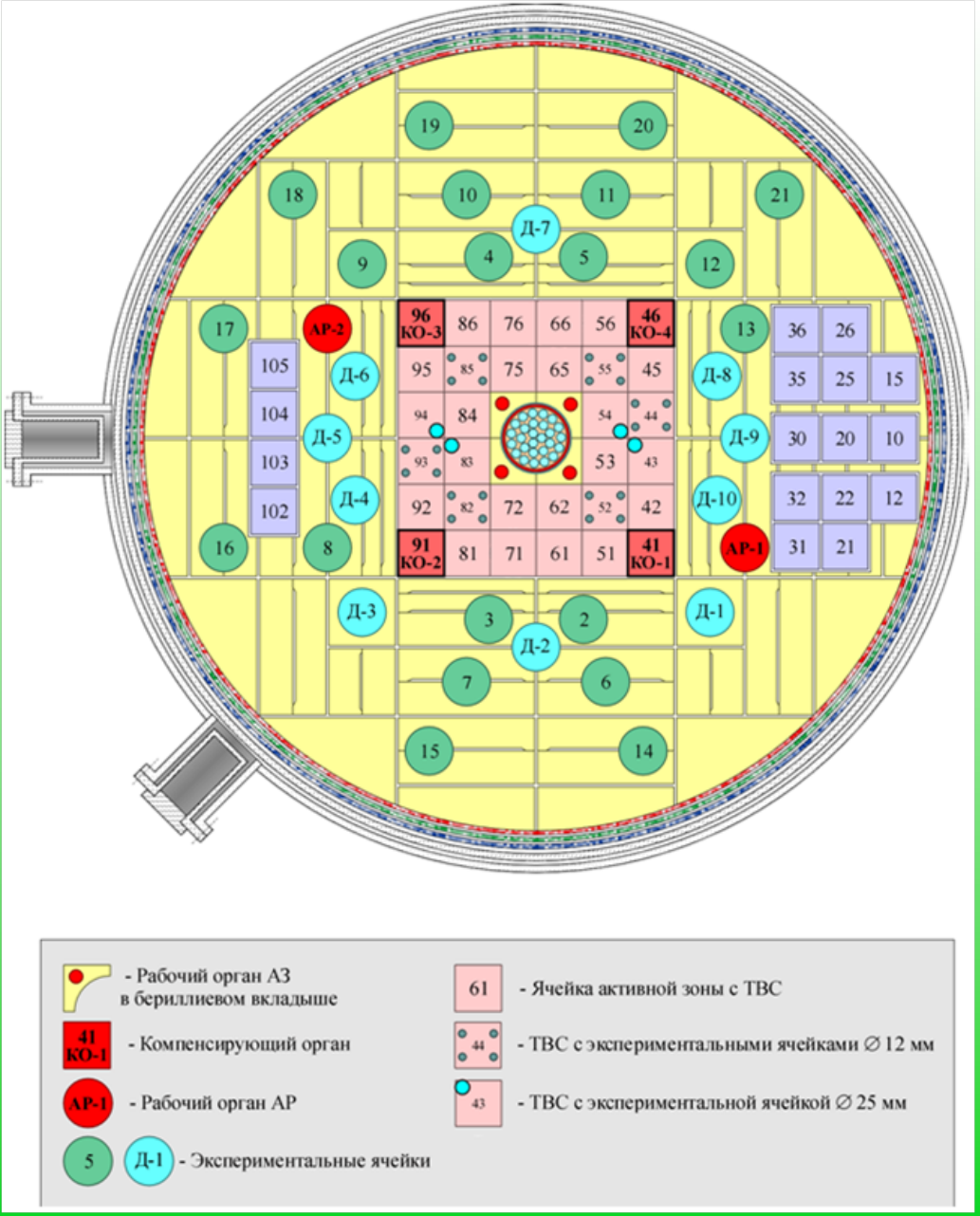
HFIR Water trap

Place	Φ_{th}, $cm^{-2}s^{-1}$	Φ_{tot}, $cm^{-2}s^{-1}$
PIK CEC	5×10^{15}	8.6×10^{15}
PIK core	2×10^{14}	3×10^{15}
SM-3 CWT	1.4×10^{15}	3.2×10^{15}
SM-3 core	2.2×10^{14}	3.1×10^{15}
HFIR	1.9×10^{15}	3.64×10^{15}

Reactor SM-3 Dimitrovgrad

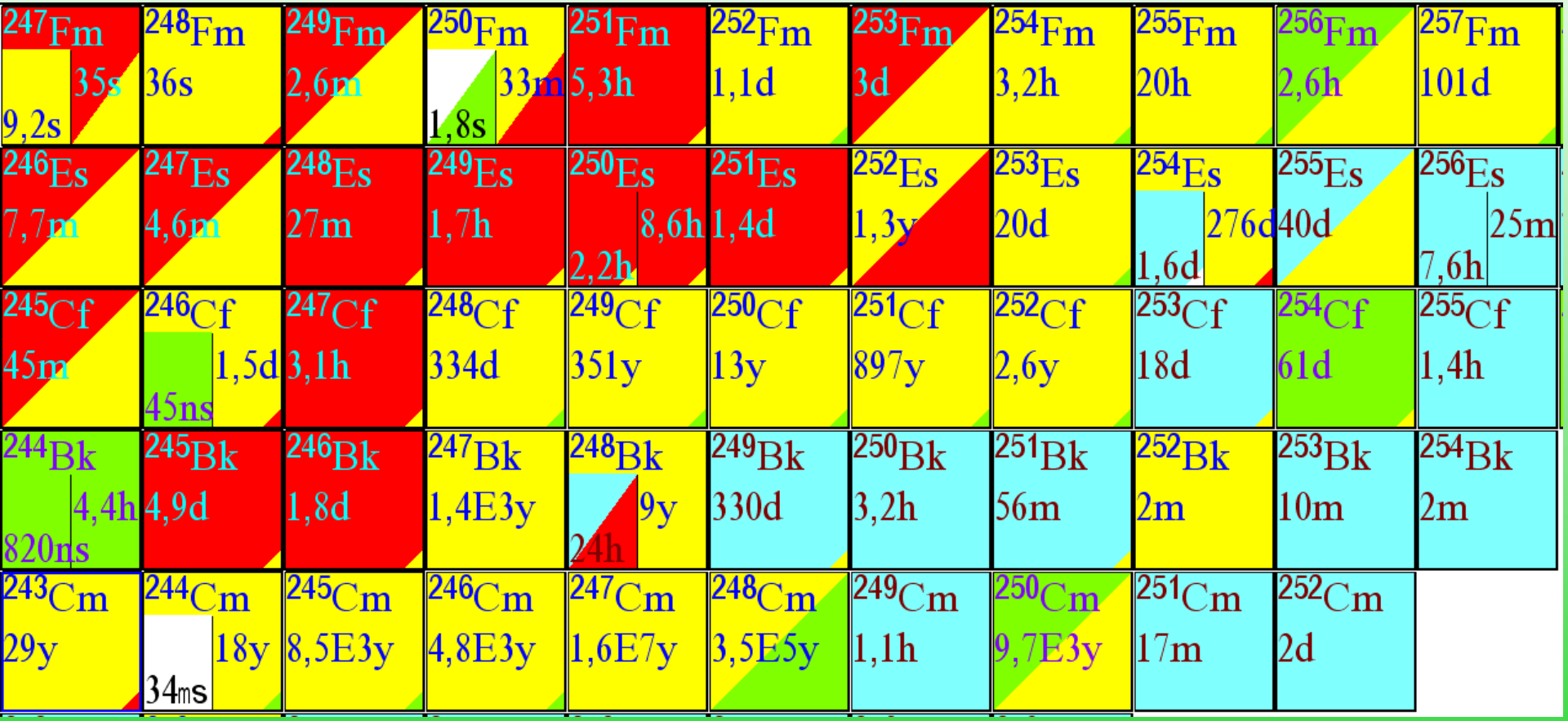
Power – 100 MW
Reflector - Beryllium



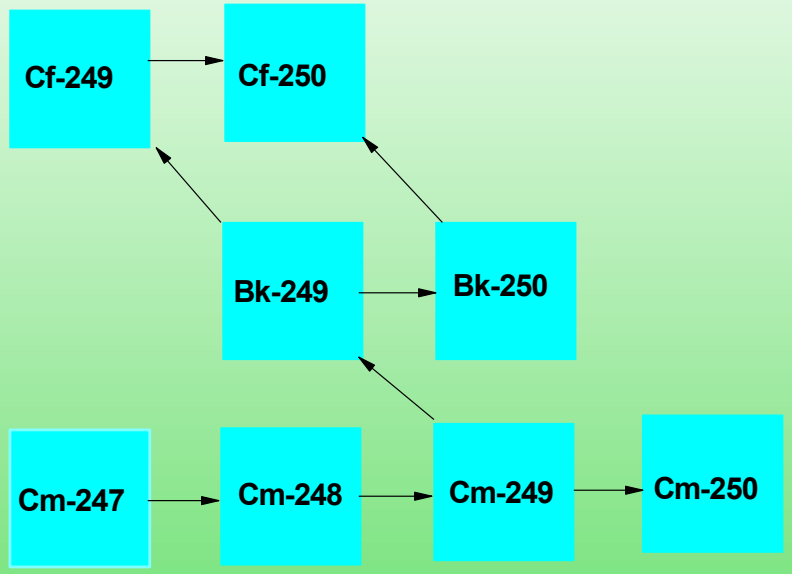


- Рабочий орган АЗ в бериллиевом вкладыше
- 41 КО-1 - Компенсирующий орган
- АР-1 - Рабочий орган АР
- 5 Д-1 - Экспериментальные ячейки
- 61 - Ячейка активной зоны с ТВС
- 44 - ТВС с экспериментальными ячейками ∅ 12 мм
- 43 - ТВС с экспериментальной ячейкой ∅ 25 мм

Possible targets



Production of Bk-249



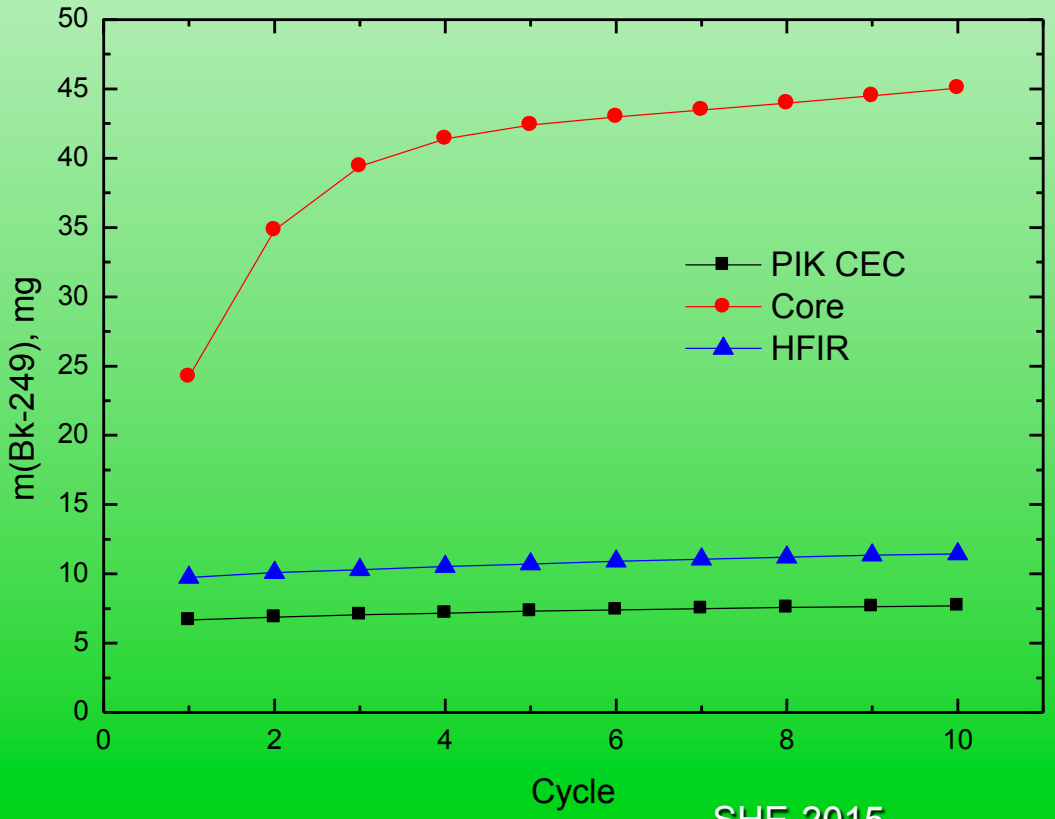
Isotope	$T_{1/2}$
Cm-249	64.15 min
Bk-249	330 days
Bk-250	3.212 h

$$C_{Bk9} = \frac{\sigma_a^{Cm8}}{\sigma_a^{Bk9}} C_{Cm8}$$

Cross section, barns

Reaction	CEC of PIK	PIK core	Reactor HFIR
Cm248(n,γ)Cm249	4,8	6,3	5,9
Bk249(n,γ)Bk250	625	109	506

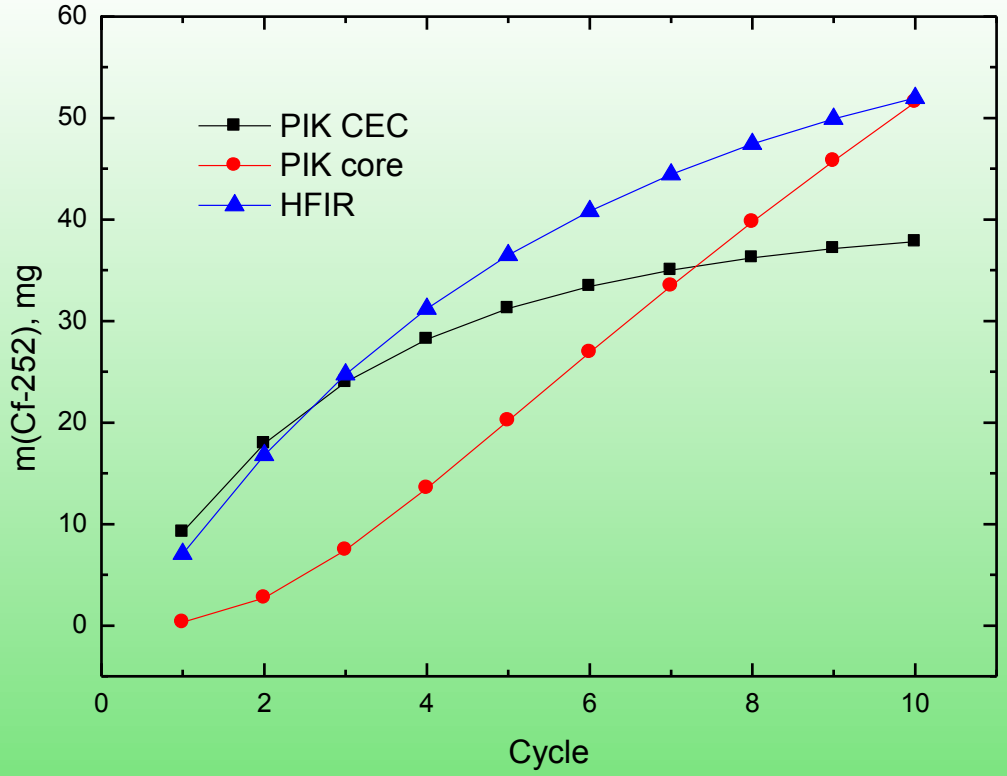
Place	Mass of produced Bk-249, mg
PIK CEC	7.7
PIK core	45.1
SM-3 CC	~ 5
SM-3 core	41.2
HFIR	11.4



Target

Target mass – 10.3 g
Element – Cm

Isotope	Fraction, %
Cm-244	30
Cm-246	60
Cm-248	10



Cf-252 production

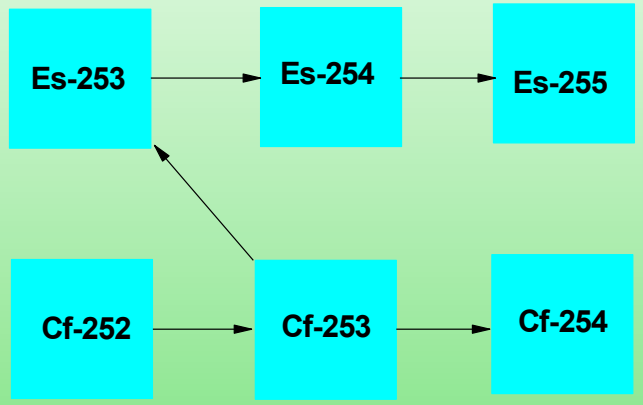
Target – 10.3 g of Cm

Isotope	%
Cm-244	20.45
Cm-246	69.1
Cm-248	8.31

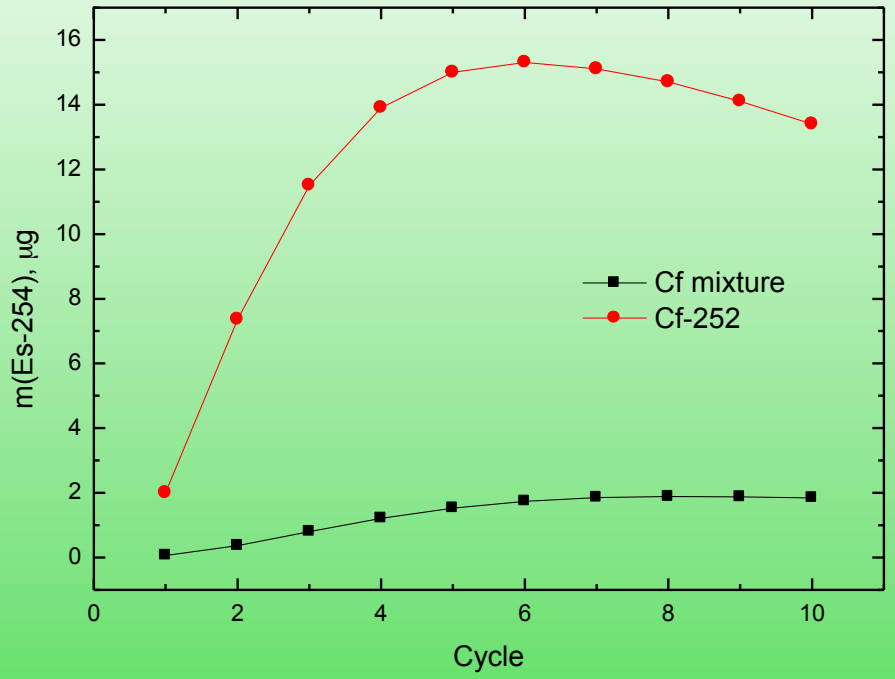
Isotope composition of produced Cf, %

Isotope	PIK CEC	PIK core	HFIR
249	0.07	5.3	0.6
250	8.0	24.8	9.9
251	2.0	17.3	2.5
252	90	52.7	86.9

Es-254 production



Production in the **core** of reactor PIK



Two possibilities of target composition considered:

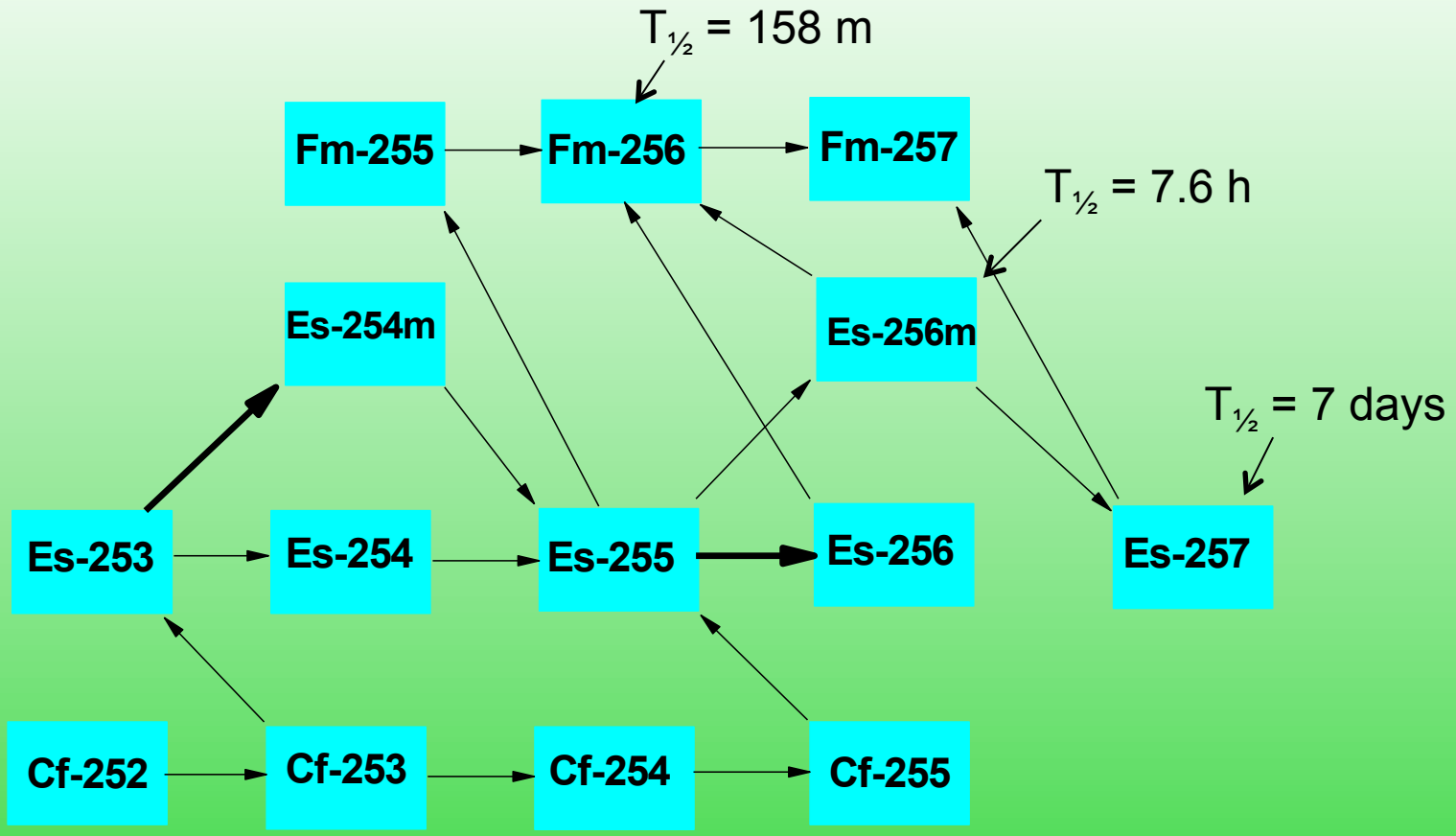
- Pure Cf-252 target – 100 mg
- Complex isotope composition of Cf target – 100 mg

Target

Isotope	%
249	76
250	12.5
251	9.5
252	1.7

In the CEC of reactor PIK it is possible to produce only about 2 µg of Es-254 isotope

Fm-257 production



Reaction	Cross section, b	Uncertainty, b	Experimental data
Fm256(n,γ)Fm257	45	-	No
Fm257(n,γ)Fm258	27	85	No
Fm257(n,f)	1722	16	No

Target – Cf-252 – 100 mg

Production for 50 days in PIK CEC

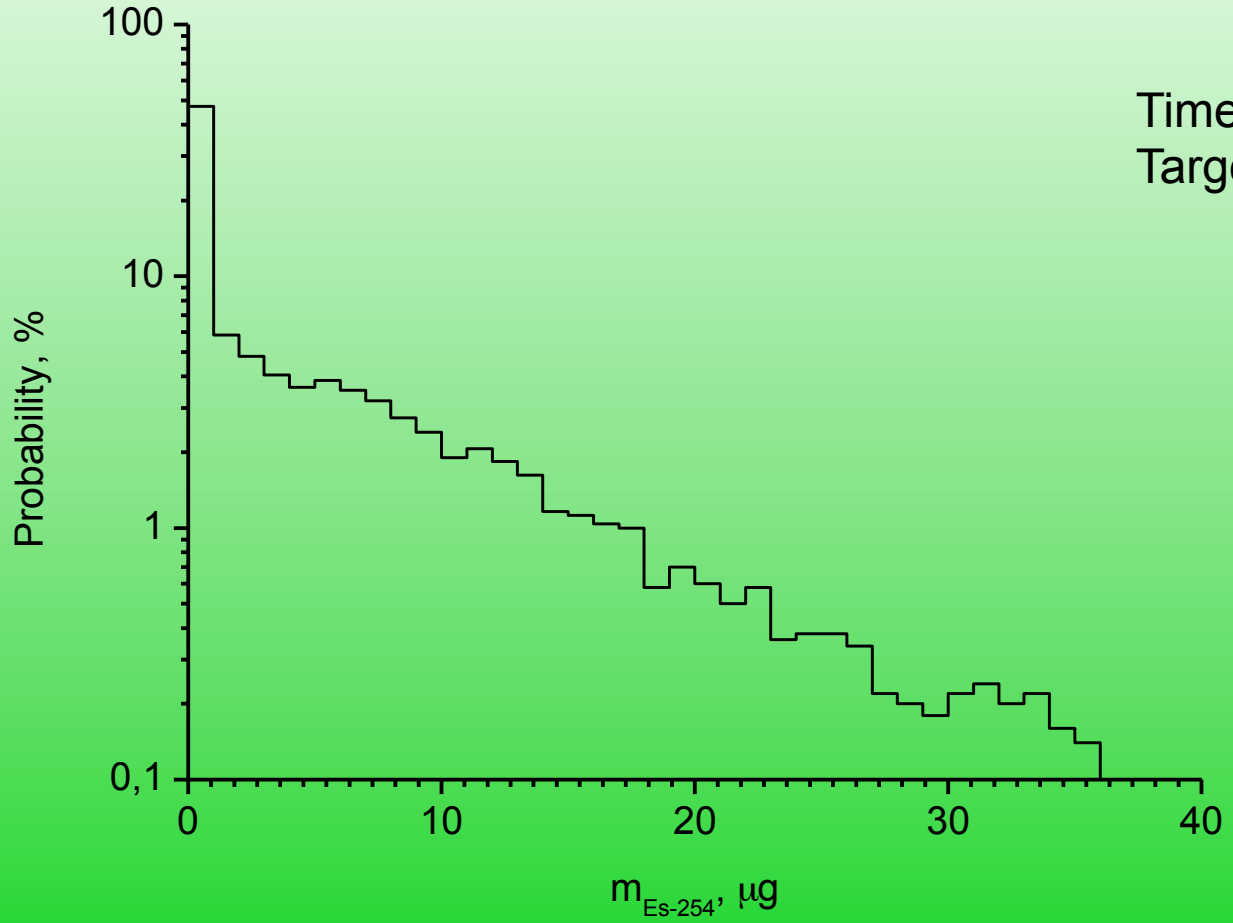
Cross section of reaction $^{256}Fm(n,\gamma)^{257}Fm$, barn	Mass of produced Fm-257 isotope, μg
0	0.00014
45	0.013

Possible amount of produced isotopes

Isotope	Mass	Condition
Cm-250	4.6 μg	PIK CEC
Bk-248	0.1 μg	PIK core
Bk-249	45 mg	PIK core
Cf-249	5 mg	PIK core
Cf-250	23.5 mg	PIK core
Cf-251	16 mg	PIK core
Cf-252	51 mg	PIK core
Cf-254	160 μg	PIK CEC
Es-253	430 μg	PIK CEC
Es-254	15 μg	PIK core
Es-255	100 μg	PIK CEC
Fm-255	1.3 μg	PIK CEC
Fm-257	0.00014 -0.013 μg	PIK CEK

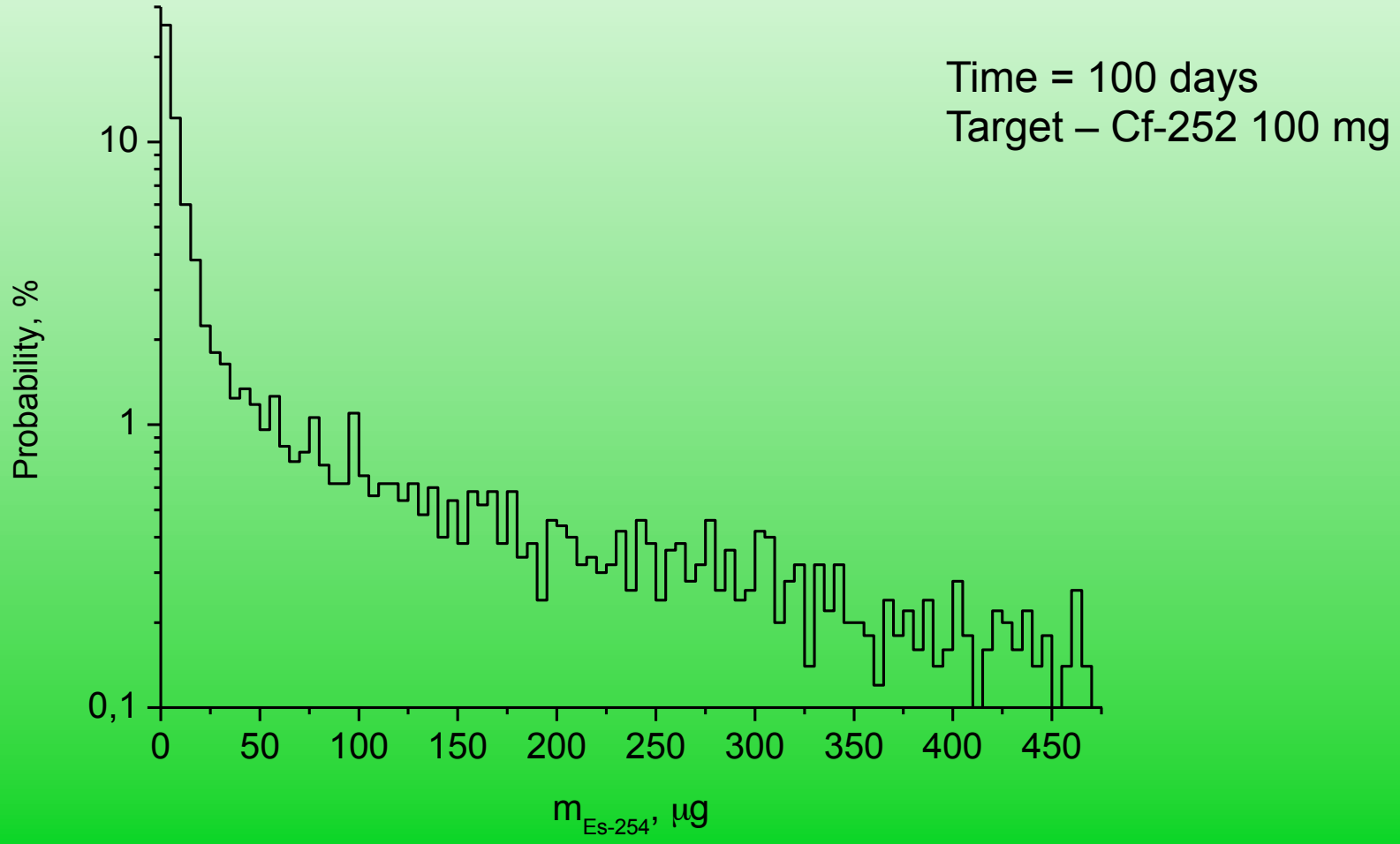
Thank you for the attention!

Es-254 mass production in Central Experimental Channel of PIK reactor



Time = 20 days
Target – Cf-252 100 mg

Es-254 mass production in the core of reactor PIK



Cross section of different reactions in CEC (Calculated using EASY-2007 Data Library)

Reaction	Cross section, b	Uncertainty, b	Experimental data quality
Cf252(n,γ)Cf253	12.3	29	4
Cf252(n,f)	20.3	25	4
Cf253(n,γ)Cf254	11.7	33	2
Cf253(n,f)	677	38	2
Es253(n,γ)Es254	7.8	61	2
Es253(n,γ)Es254m	238.4	60	2
Es253(n,f)	314	400	0
Es254(n,γ)Es255	17.8	29	2
Es254(n,f)	1110	31	4
Es254m(n,γ)Es255	1045	13	2
Es255(n,γ)Es256	82.9	120	0
Es255(n,γ)Es256m	1.3	120	0
Es255(n,f)	91	84	0

Quality of experimental data

0 – No experimental data exist

2 – Limited differential data which agree with the library (week agreement)

4 – Differential data which agrees with the library (strong agreement)