Feasibility of determining spent fuel characteristics from neutron activation analysis

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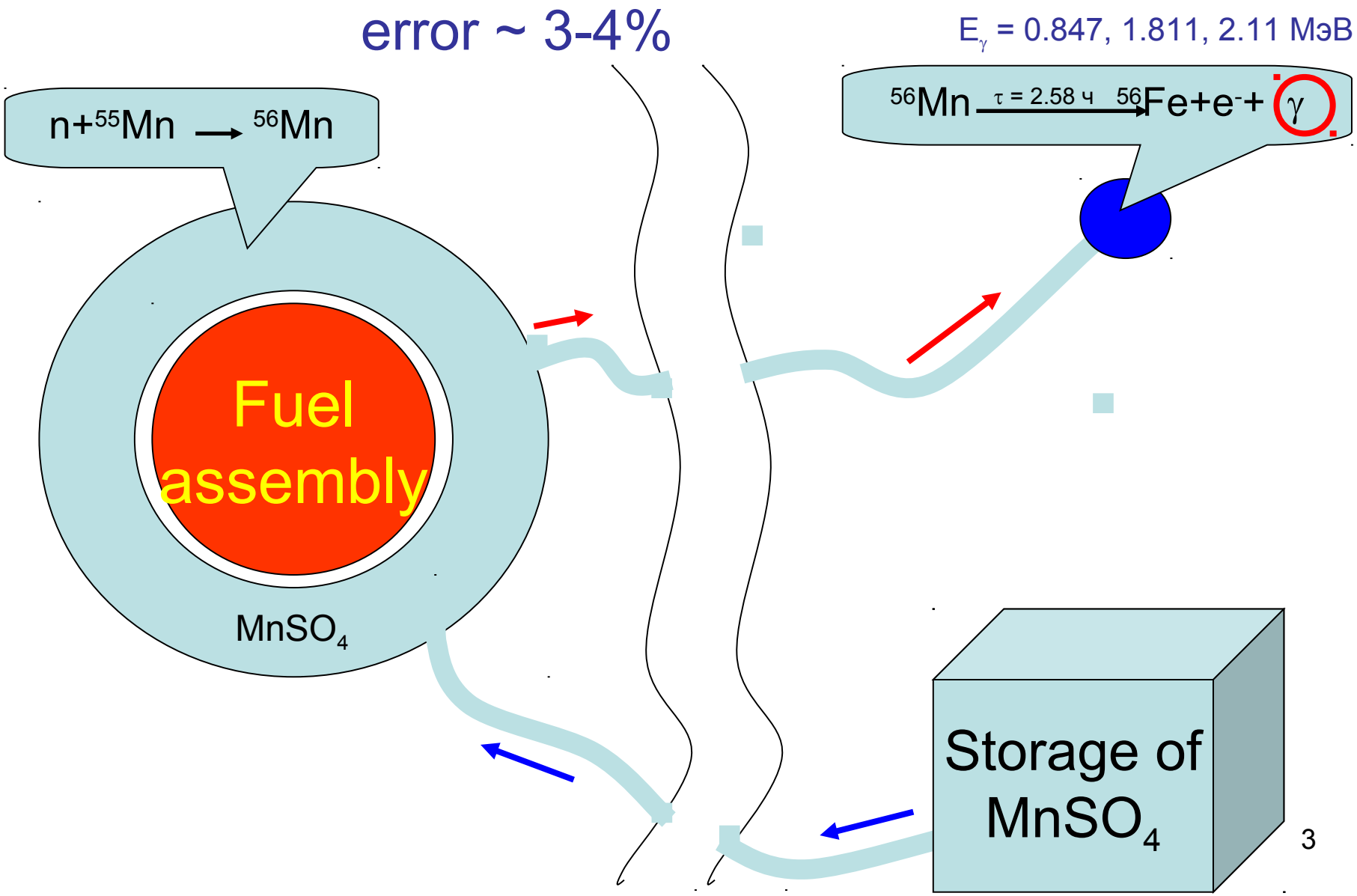
Determination of spent fuel characteritics

Method	Plus	Minus
radiochemistry	accuracy ~ 1%	labor intensive
γ-spectroscopy	fast	influence of γ-background
fork method	fast	influence of γ-background

Neuron activation analysis



Key questions

Does the axial distribution influence measurements?

Can the concentration of actinides be related to neutron intensity?

Calculation of an infinite lattice of fuel assemblies

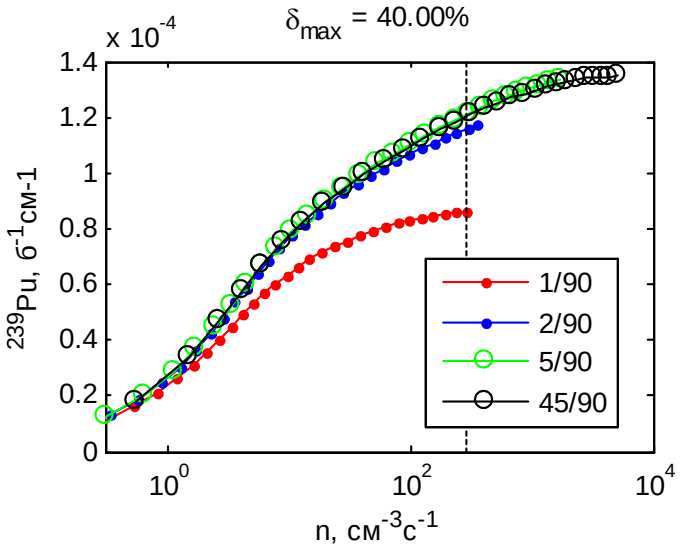
- Enrichment 4.4%
- Time: 890 effective days (~2.5 years)
- 90 layers over height
- Absorber withdrawal: 0 and 100%
- H_3BO_3 content: 0 and 5 g/kg

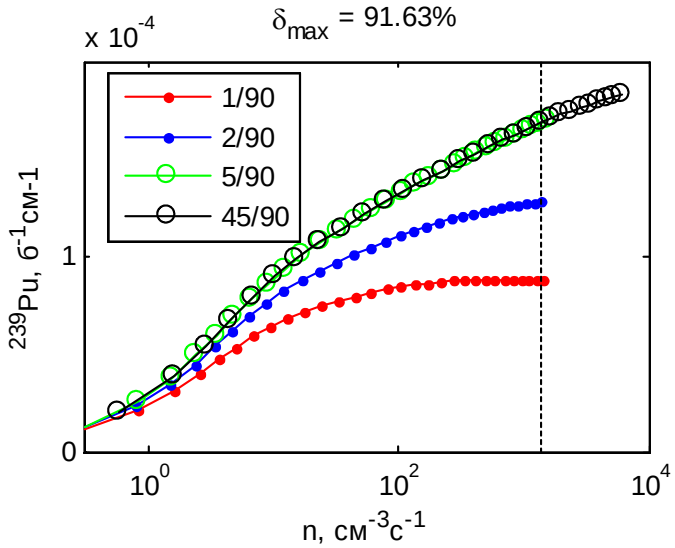
Neutron yield from actinide decay

	^{238}Pu	^{239}Pu	^{240}Pu	^{242}Pu	^{244}Cm
fission, n $s^{-1}g^{-1}$	$2{,}61 \cdot 10^3$	0,022	$1{,}02 \cdot 10^3$	$1{,}72 \cdot 10^3$	$1{,}08 \cdot 10^7$
α-decay, n $s^{-1}g^{-1}$	$1{,}33 \cdot 10^4$	38,2	141	2,09	$7{,}71 \cdot 10^4$

^{239}Pu concentration versus neutron intensity at different heights

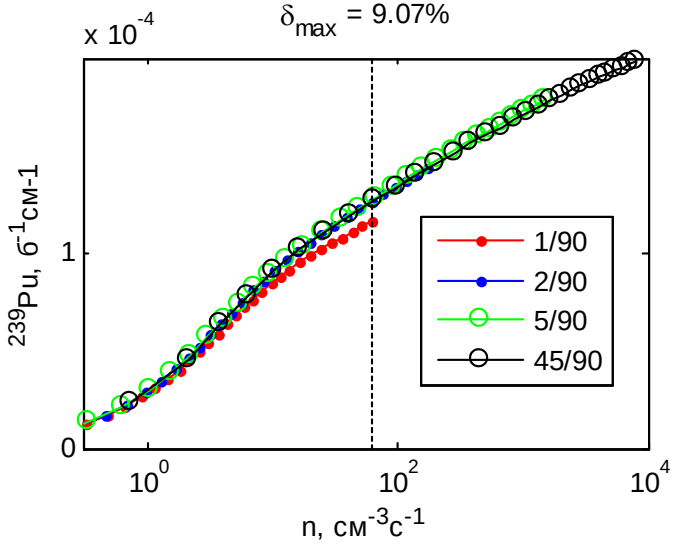
h = 100%
cB = 0
g/kg
δ = 40%

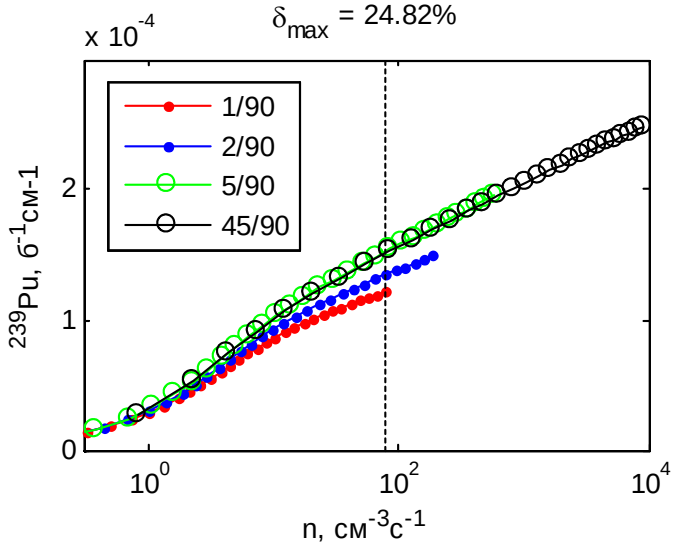




h = 0%
cB = 0
g/kg
δ = 92%

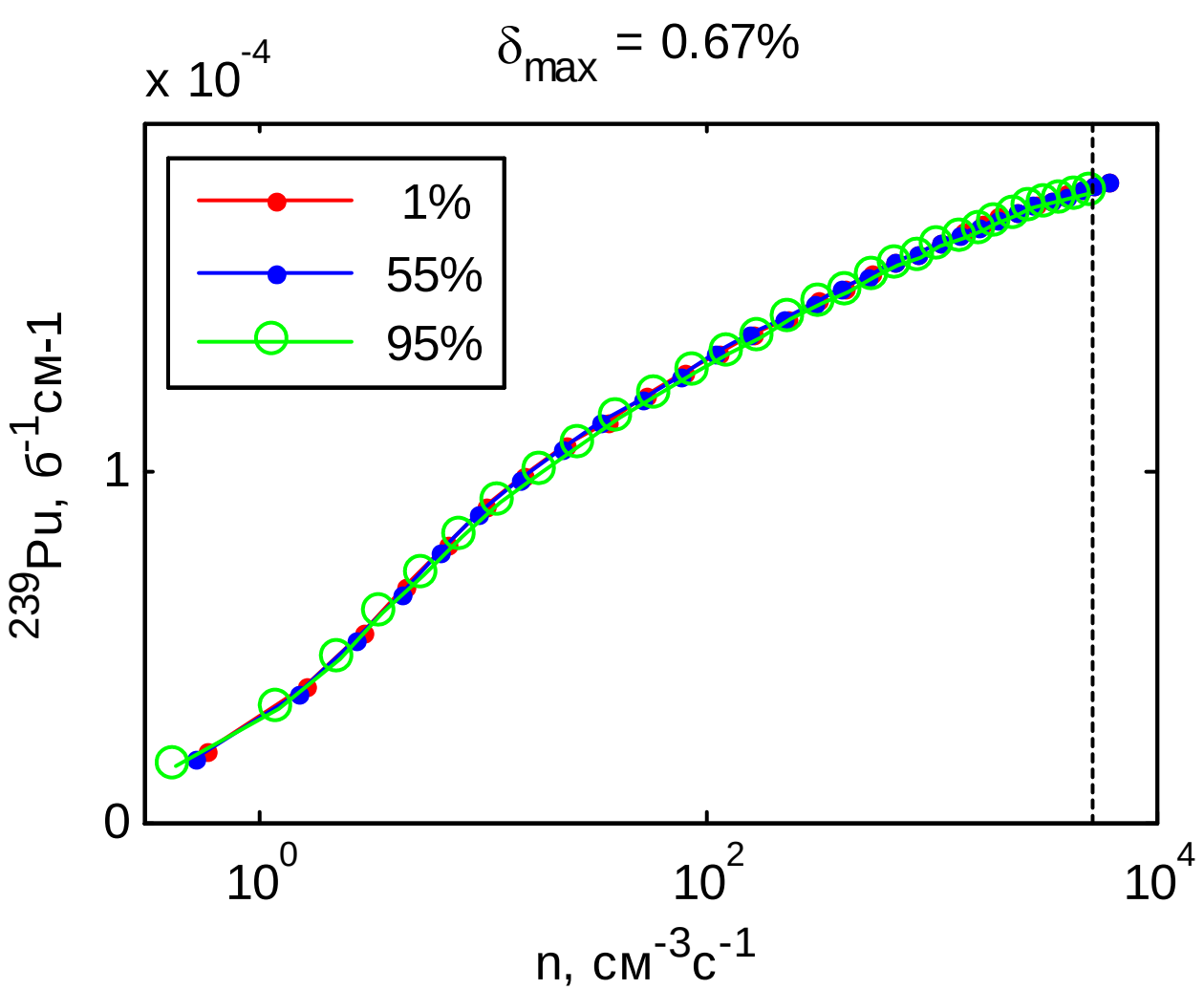
h = 100%
cB = 5
g/kg
δ = 9%

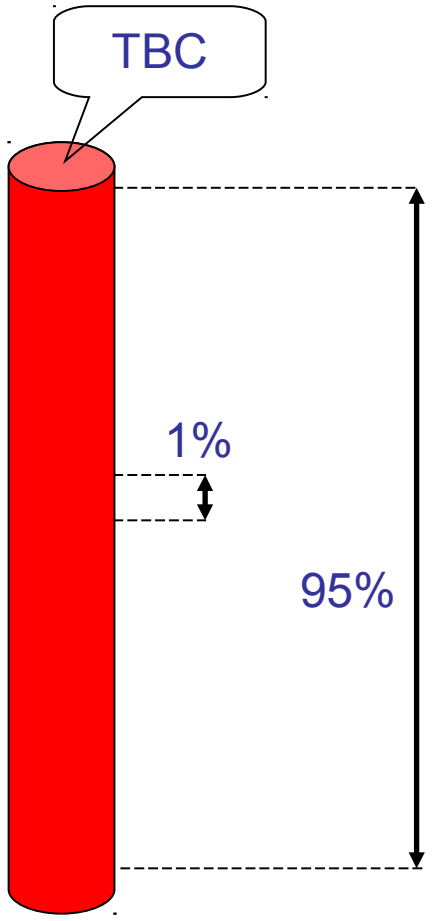




h = 0%
cB = 5
g/kg
δ = 23%

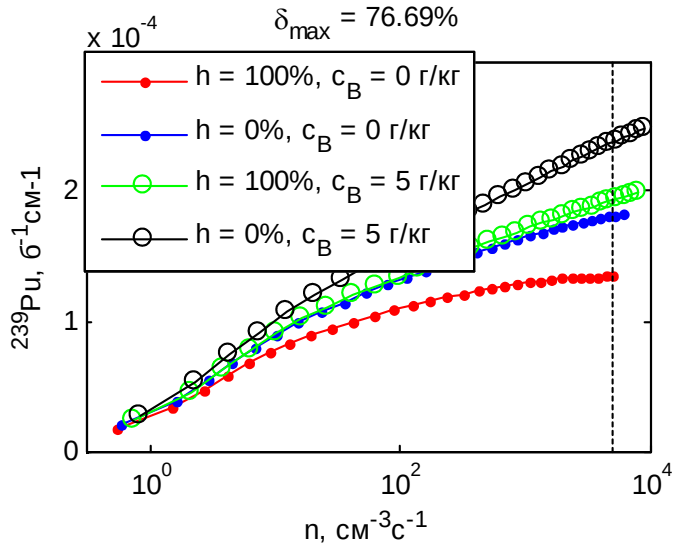
^{239}Pu concentration versus intensity measured over different height sections (h = 0%, c_B = 0 g/kg)

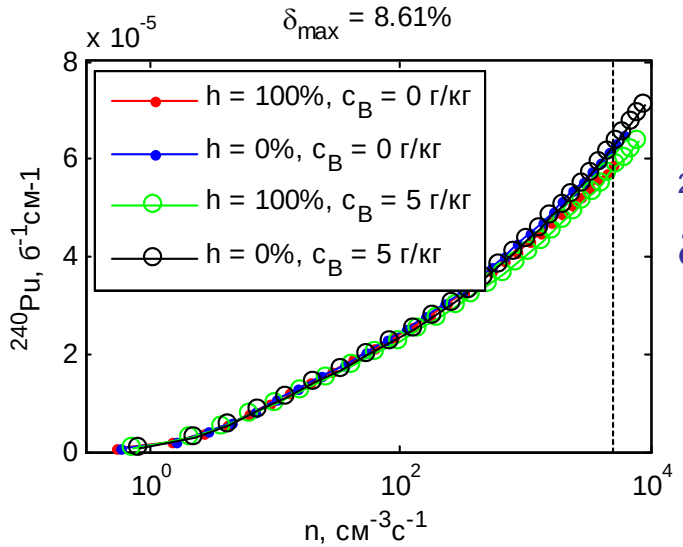




Plutonium concentrations versus neutron intensity

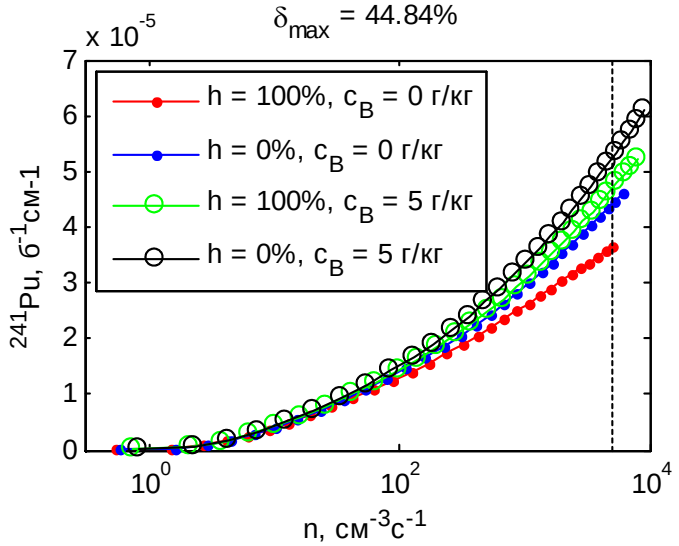
^{239}Pu
δ = 77%

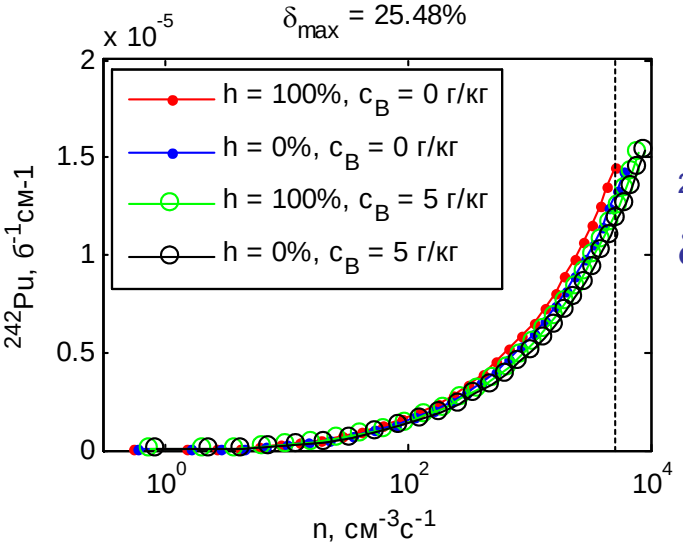




^{240}Pu
δ = 9%

^{241}Pu
δ = 45%



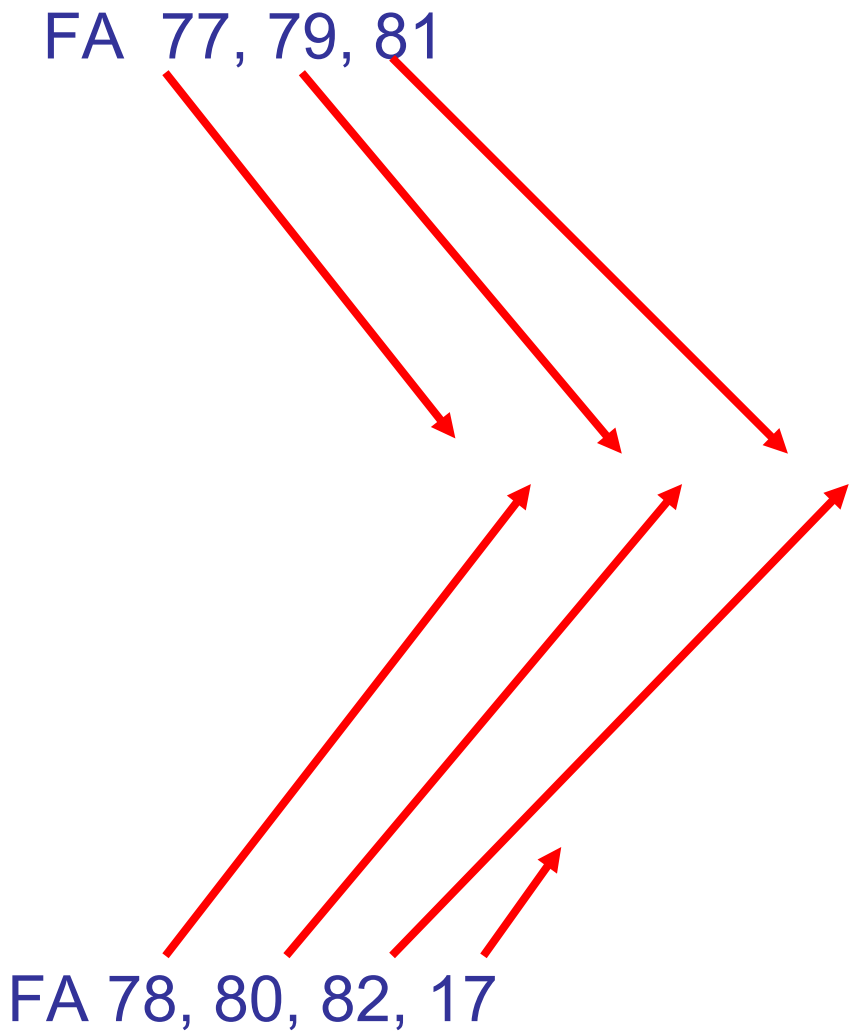


^{242}Pu
δ = 25%

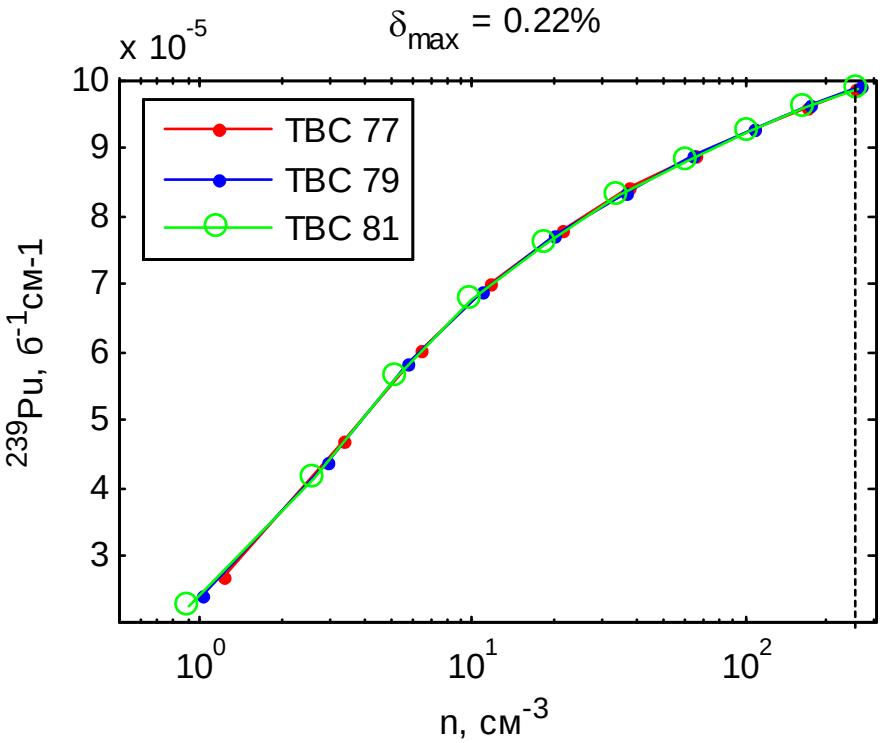
VVER-1000 campaign calculation

- Enrichment 1.6, 2.4, 3.6%
- Time: 300 effective days
- Thermal hydraulics
- Boron control of criticality
- No burnable absorber

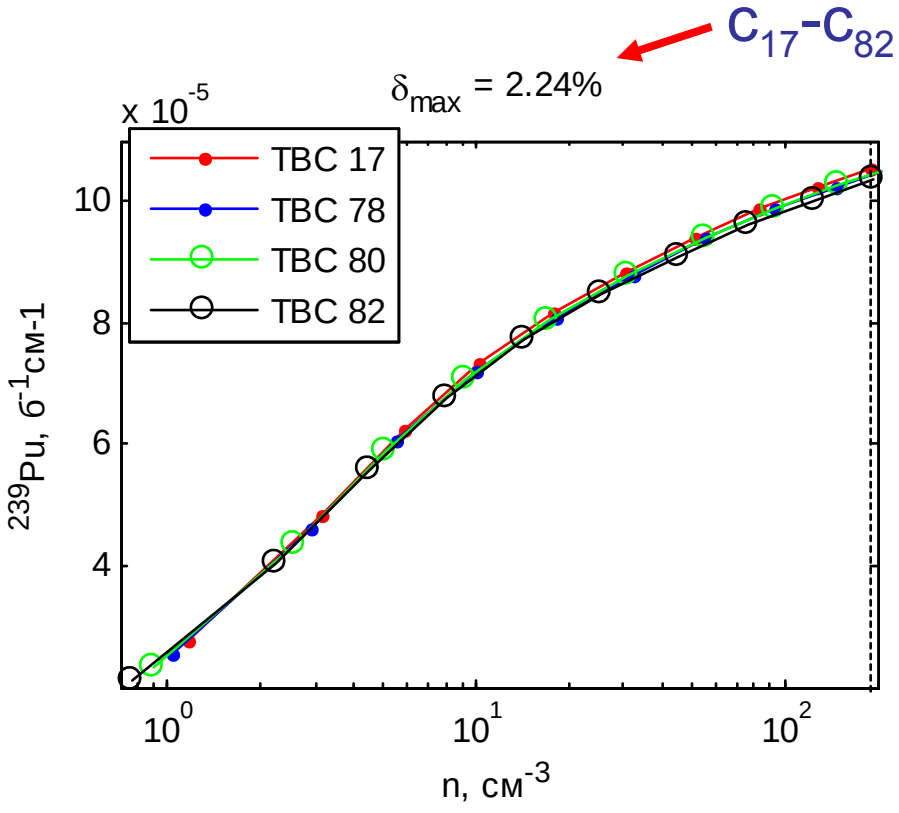
Fuel column cartogram
Block 1 of Volgodonsk NPP



Effect of position in core

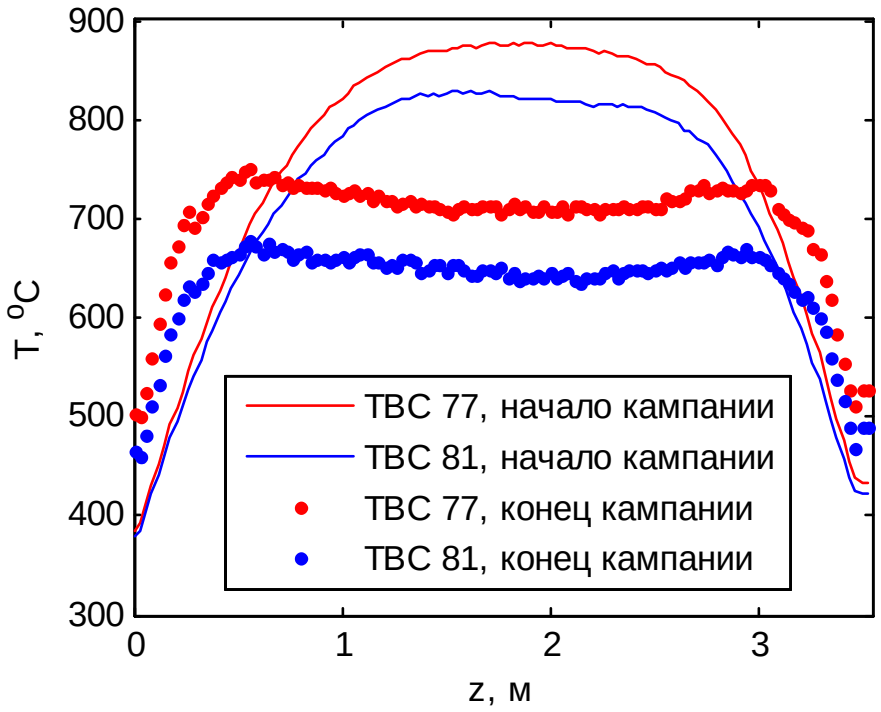


^{239}Pu concentration
Enrichment 1.6%

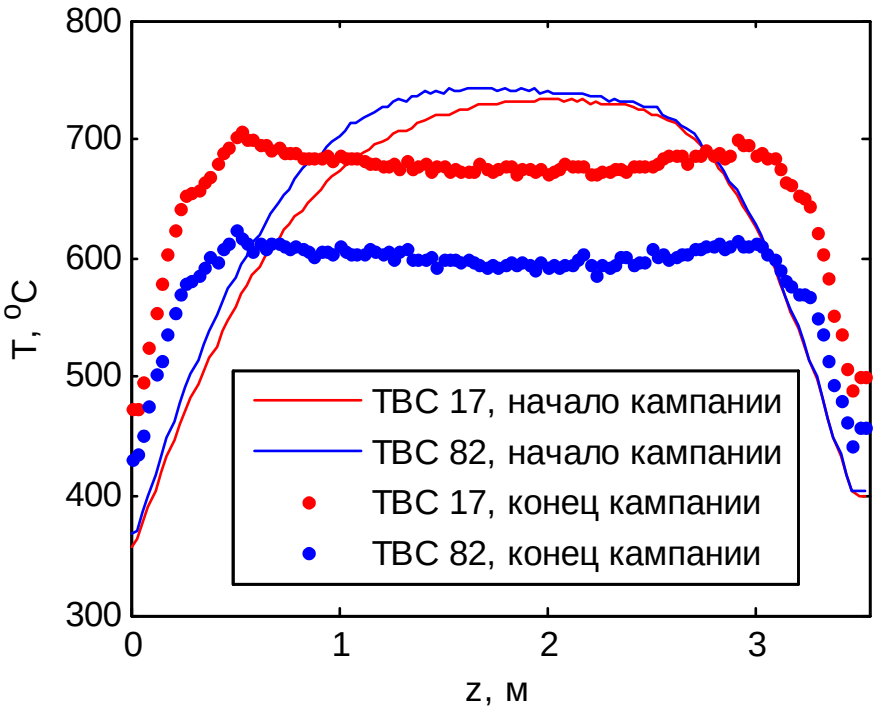


^{239}Pu concentration
Enrichment 2.4%

Average fuel temperature

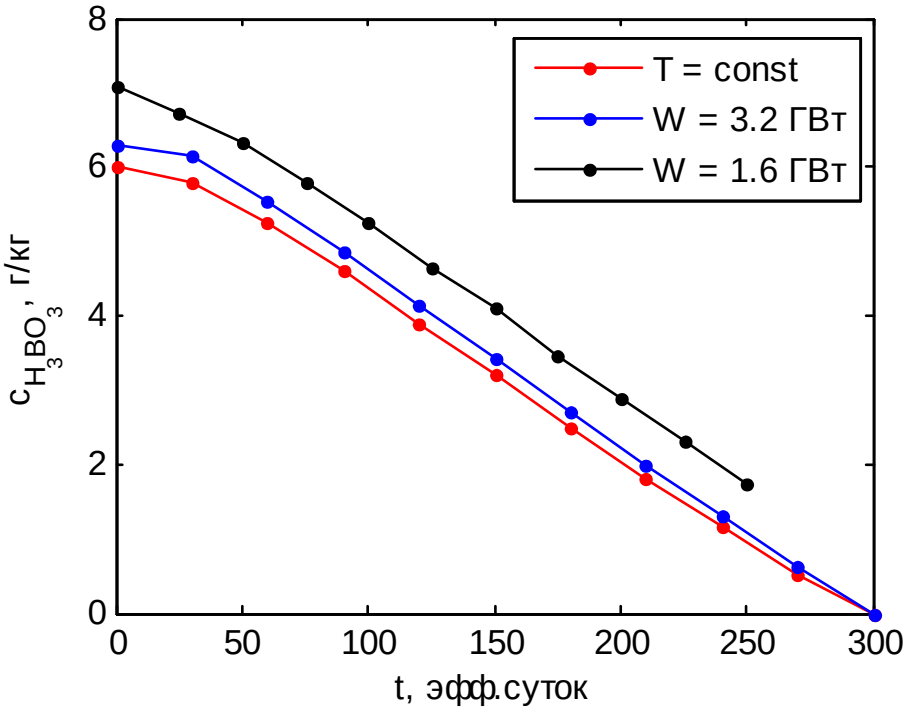


Average fuel temperature
Enrichment 1.6%

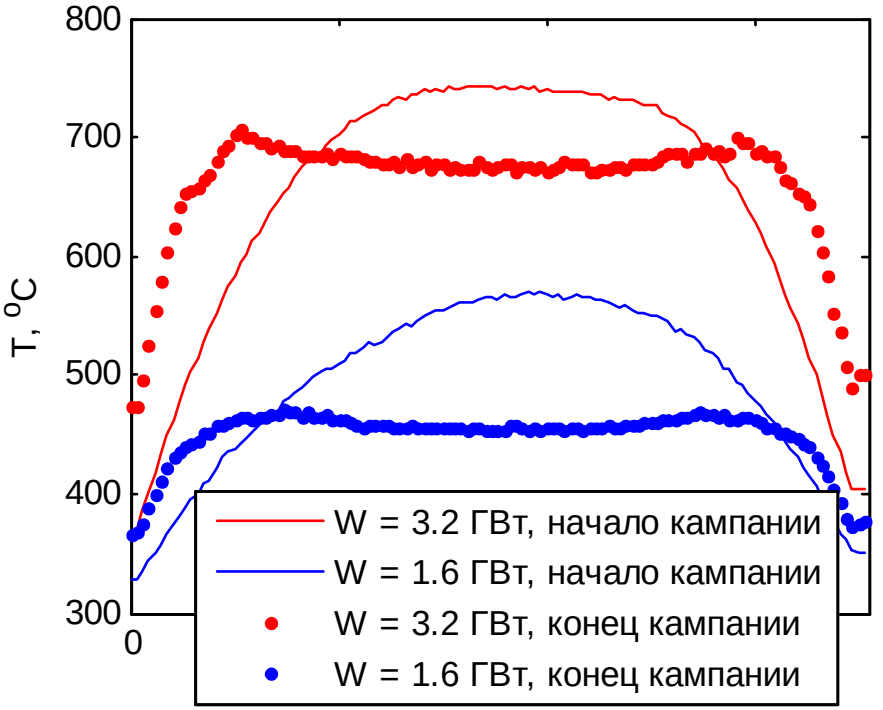


Average fuel temperature
Enrichment 2.4%

The effect of operating conditions

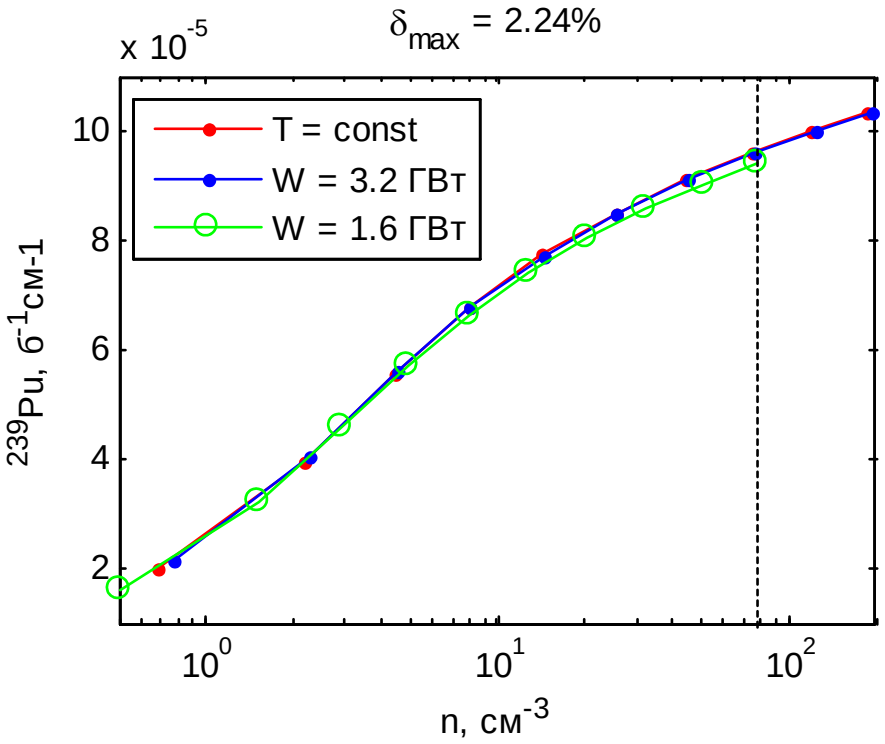


Boron concentration

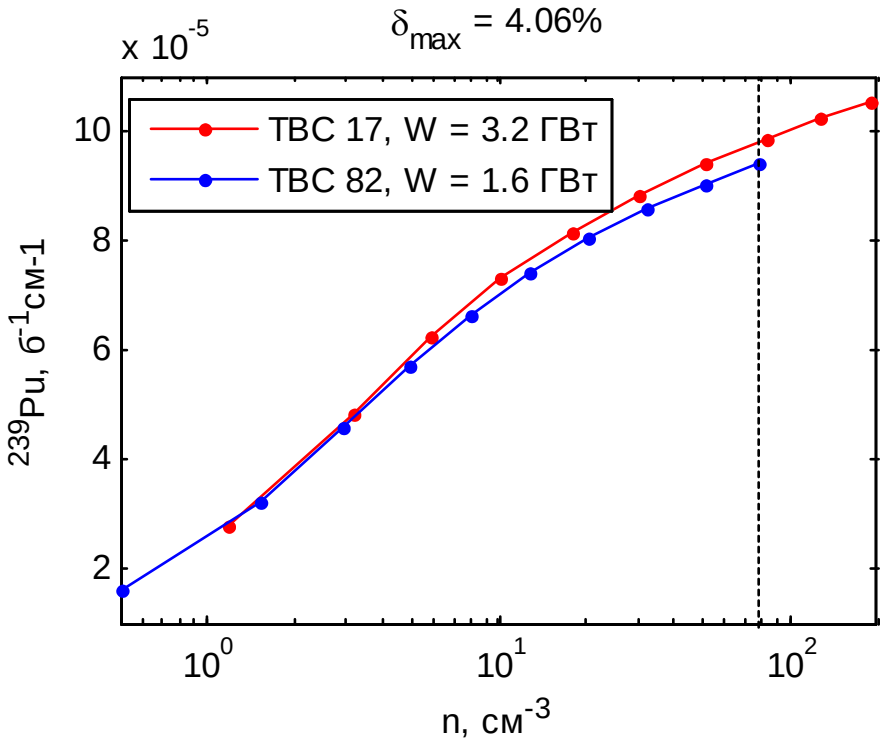


Average fuel temperature in FA 82

The effect of operating conditions



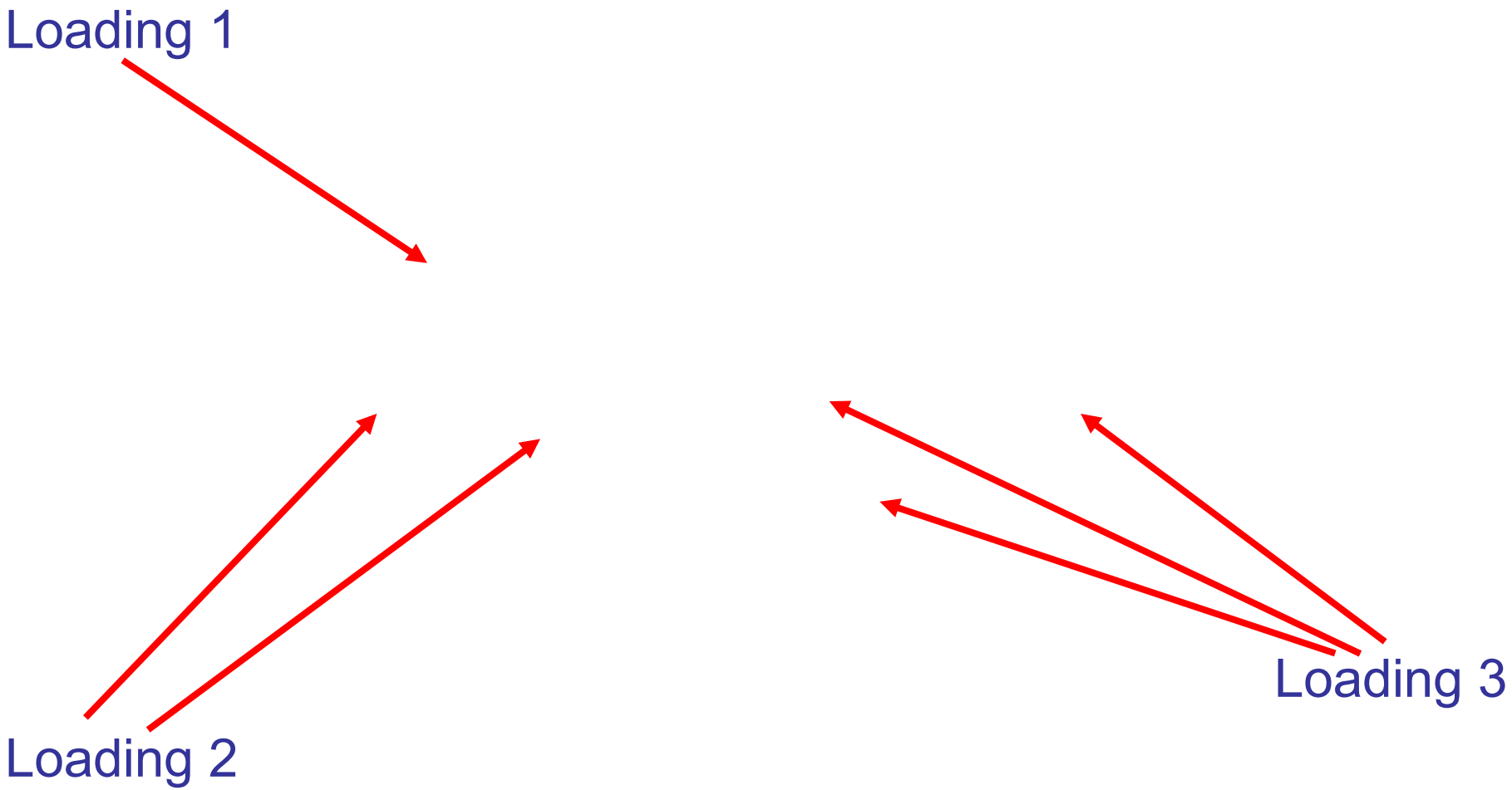
^{239}Pu concentration in FA 82



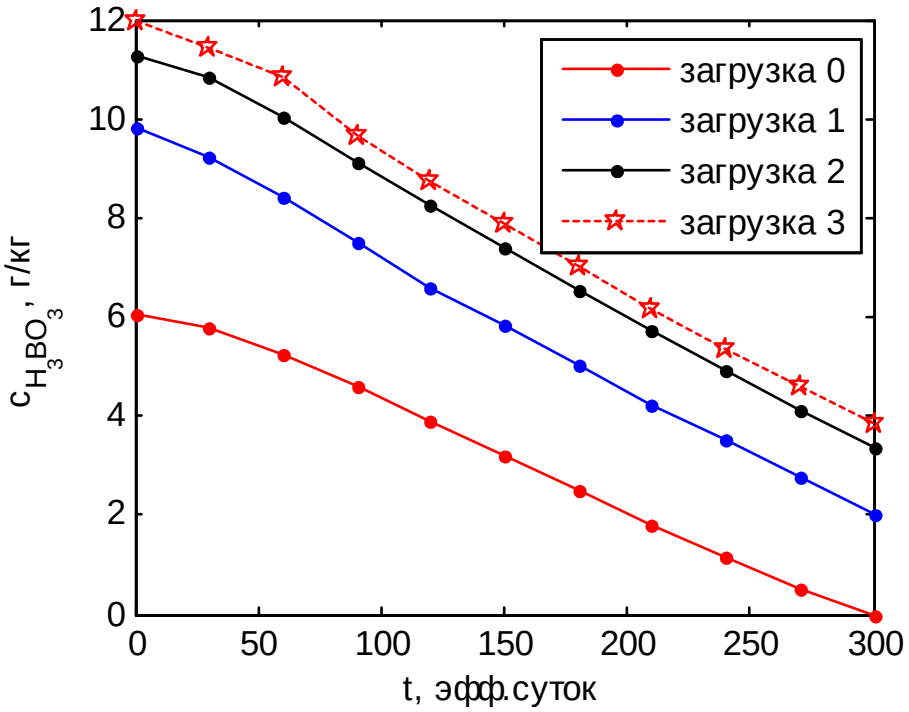
^{239}Pu concentration in FA 17 and 82

The effect of loading

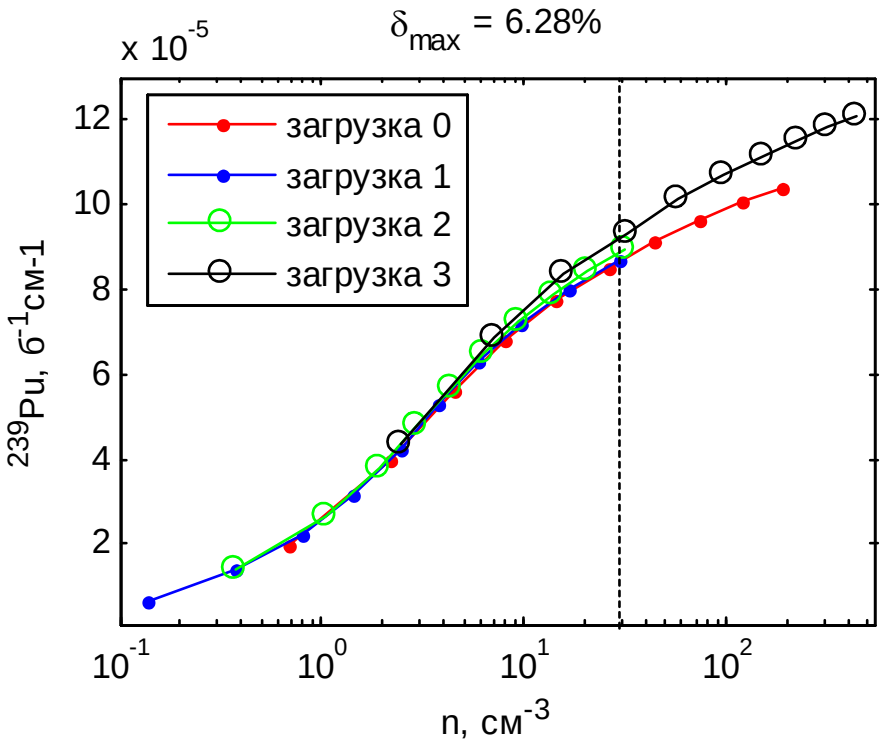
FA with enrichment 1.6% are replaced by FA with enrichment 3.6%



The effect of loading

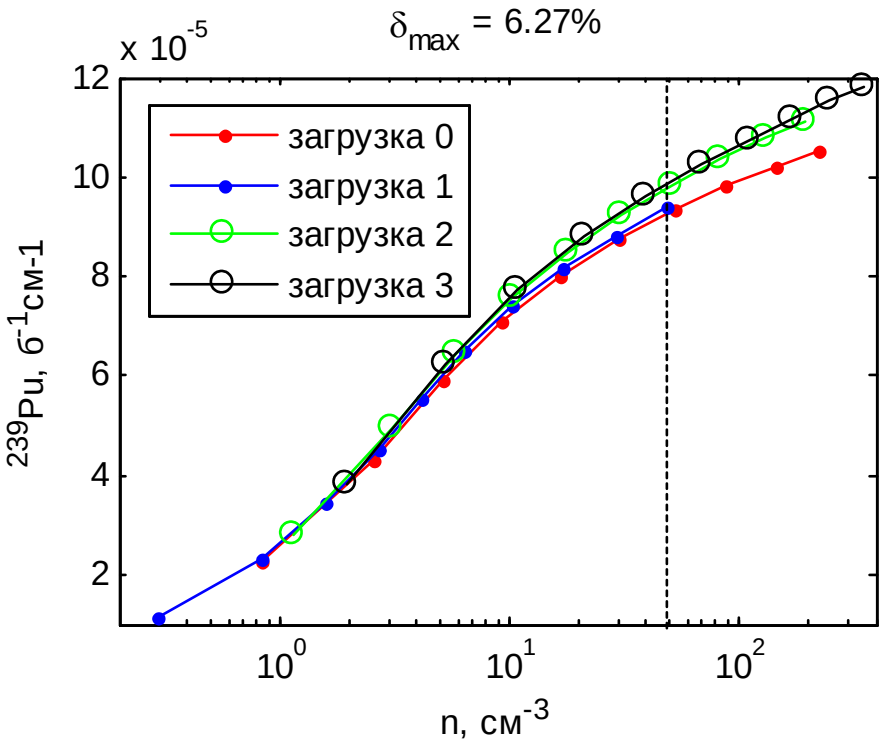


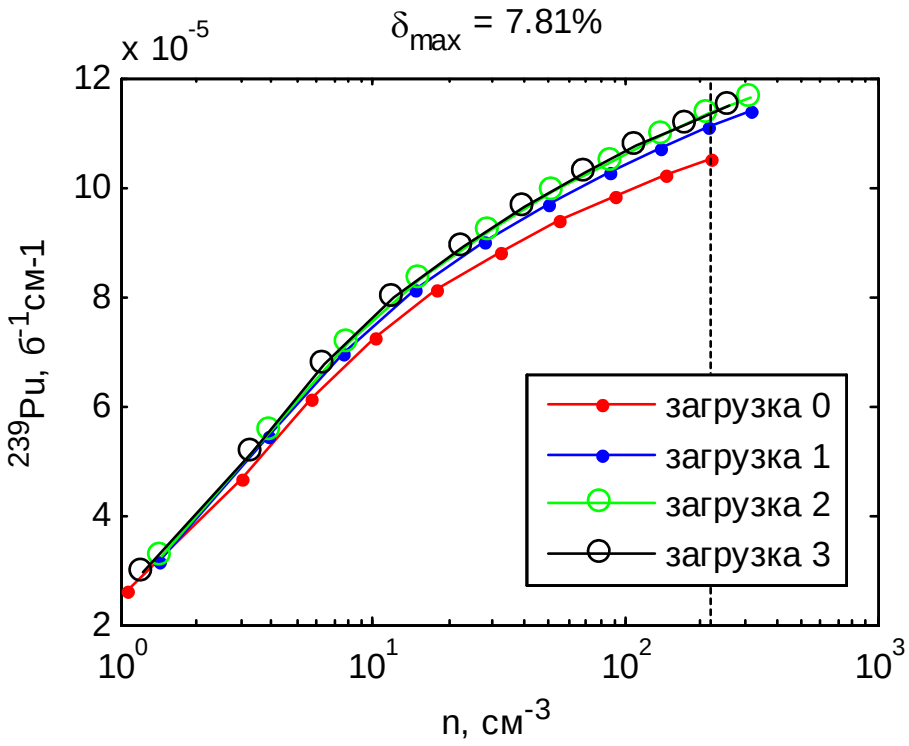
Boron concentration



^{239}Pu concentration in FA 82

The effect of loading





^{239}Pu concentration in FA 80

^{239}Pu concentration in FA 78

Conclusion

- Position in core: ~ 2%
- Operating conditions (upper estimate): ~ 2%; quite realistic → 0
- Core loading: highest uncertainty up to 8% Is it possible to level it?
- With the measurement error of about 3-4%, the overall error is optimistically estimated to be ~ 5-6%.