The effect of fuel conversion from HEU to LEU on main neutronics of YALINA-Booster sub-critical assembly

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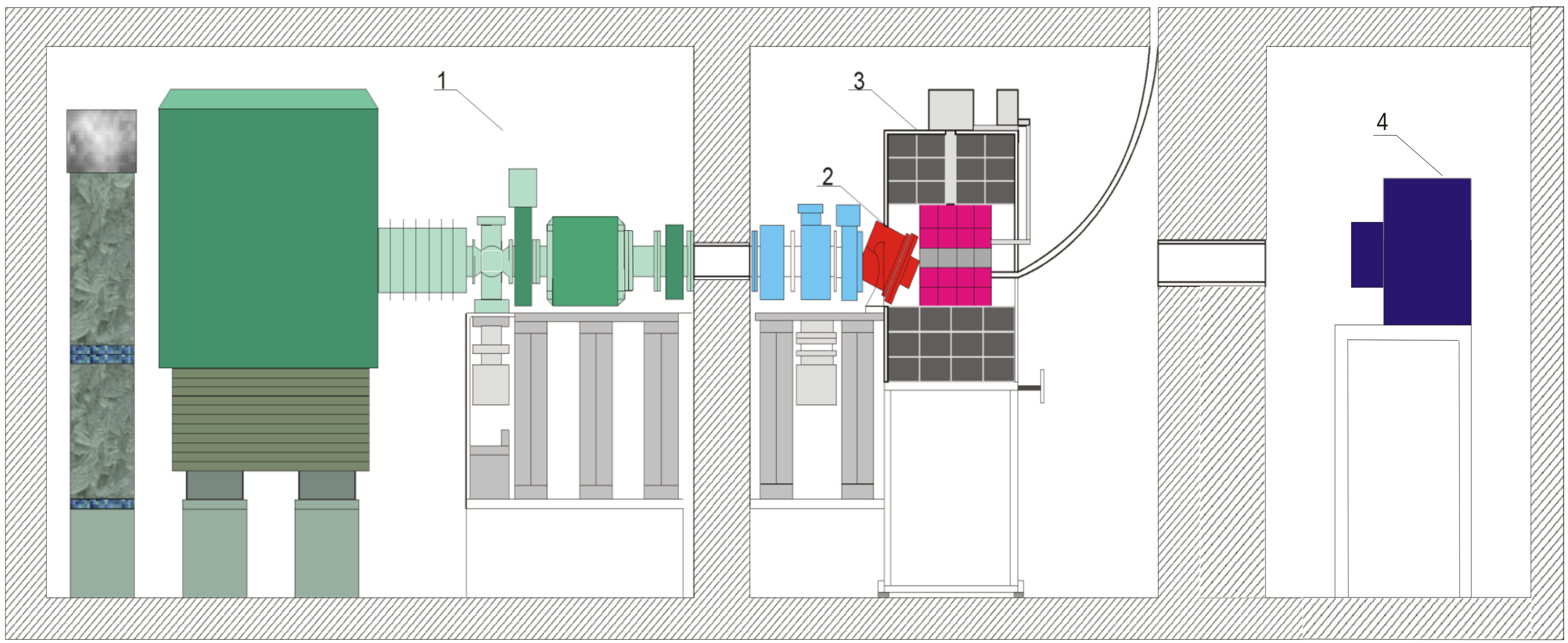
- Conclusion

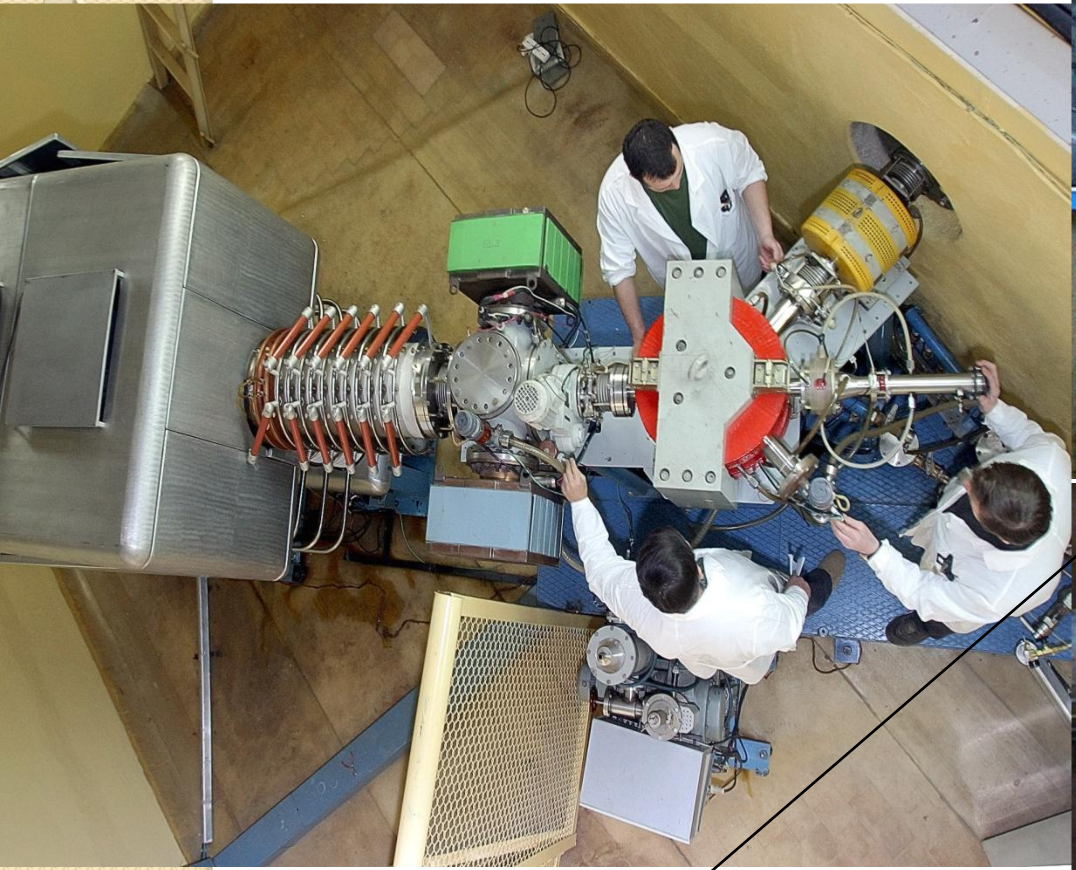
Subcritical facility YALINA

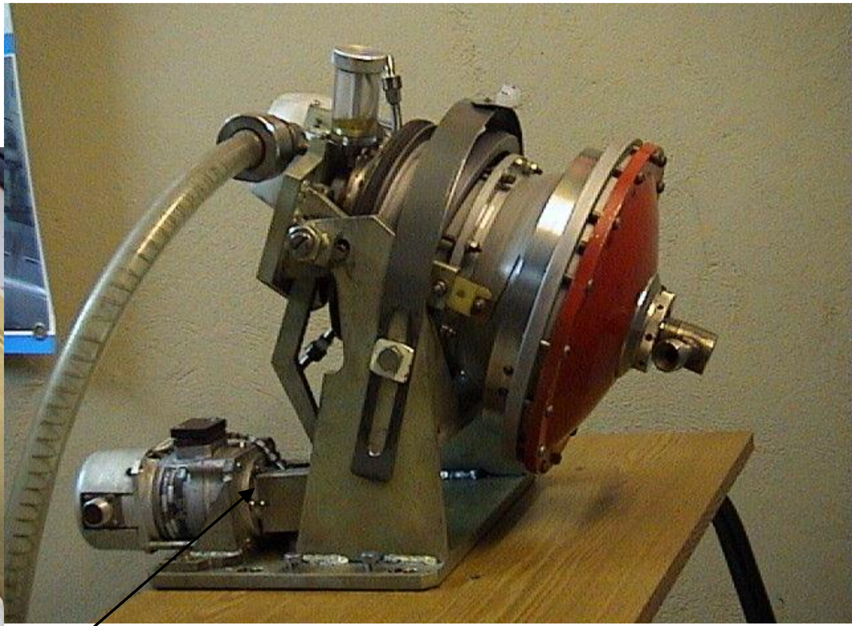


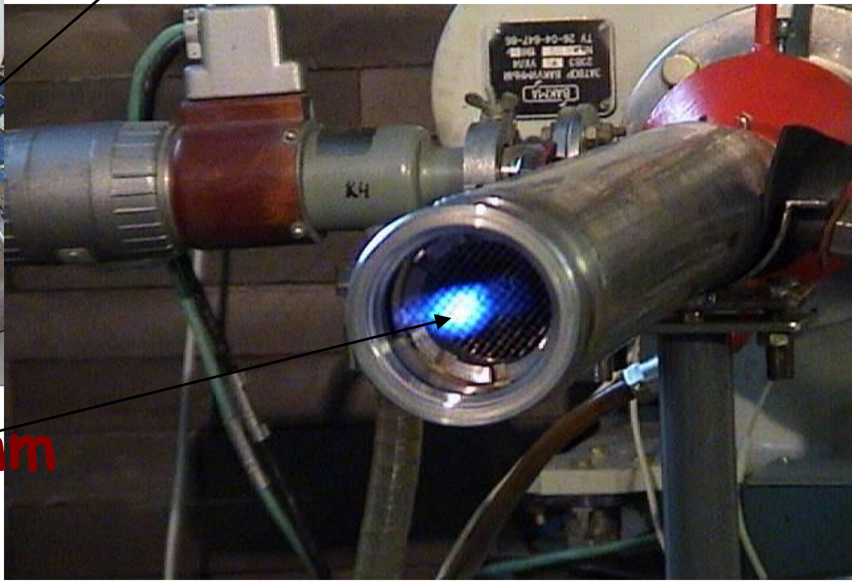
1- ion accelerator, 2 – target unit,
3 – subcritical assembly, 4 – measuring complex

Neutron generator

Ion accelerator





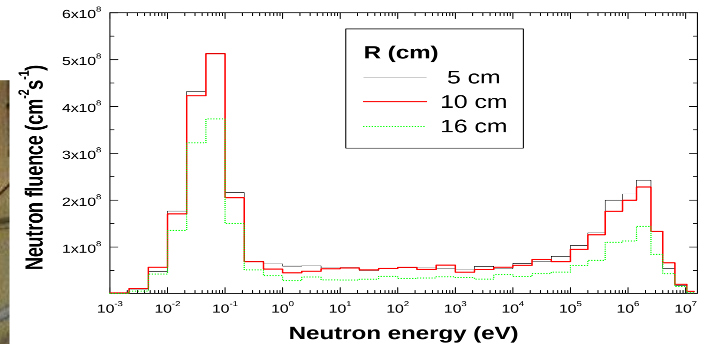


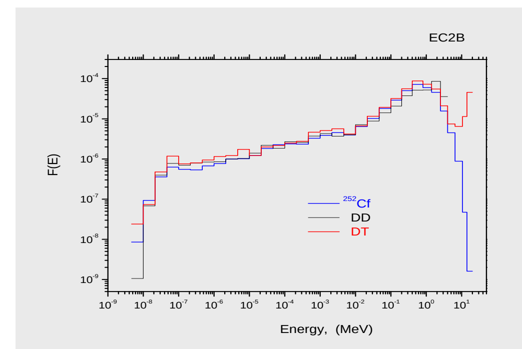
DD- or DT-targets: 230 or 45 mm

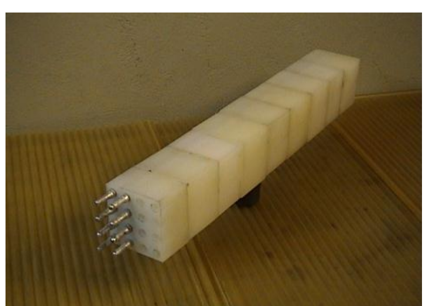
Main parameters of the neutron generator NG-12-1

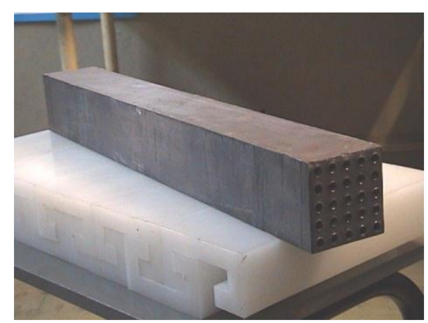
Accelerator	**H+ and D+**	
Beam energy, keV	**100 - 250**	
Beam current, mA	**1 - 10**	**1 – 2**
Pulse duration, s	**(2-60)×10**(-6)**	
Pulse repetition frequency, Hz	**(1 - 8 000)**	
Spot size, cm	**2.0 -3.0**	
Ti^3H target	**230 mm**	**45 mm**
Rotation speed, rpm	**560**	**560**
Maximal yield of neutrons, n/s	**$(1.0 – 1.5)x10^{12}$**	**$1.0x10^{11}$**
Neutron energy, MeV	**13-15**	
TiD target	**230 mm**	**45 mm**
Maximal yield of neutrons, n/s	**$(2 – 3)x10^{10}$**	**$(2-3)x10^9$**
Neutron energy, MeV	**2.0 – 3.1**	

YALINA facility: YALINA-Th and YALINA-Booster





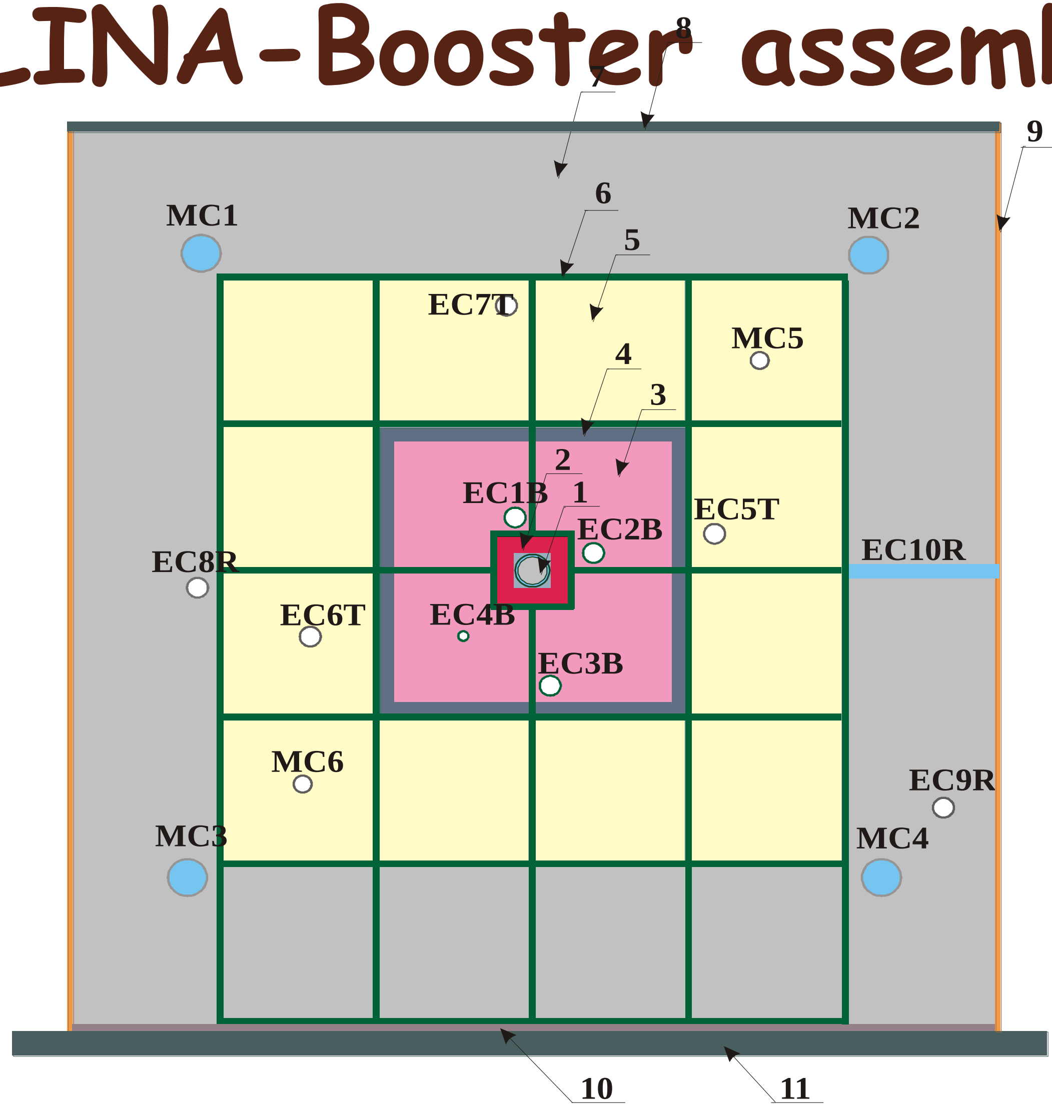




The program of experimental research

- the measurements of sub-criticality levels,
- the measurements of spatial distribution of neutron flux density,
- the measurements of time dependence of neutron flux density by different ion pulse durations,
- the measurements of threshold reaction rates,
- the measurements of transmutation reaction rates,
- neutron spectrum unfolding and so on.

YALINA-Booster assembly

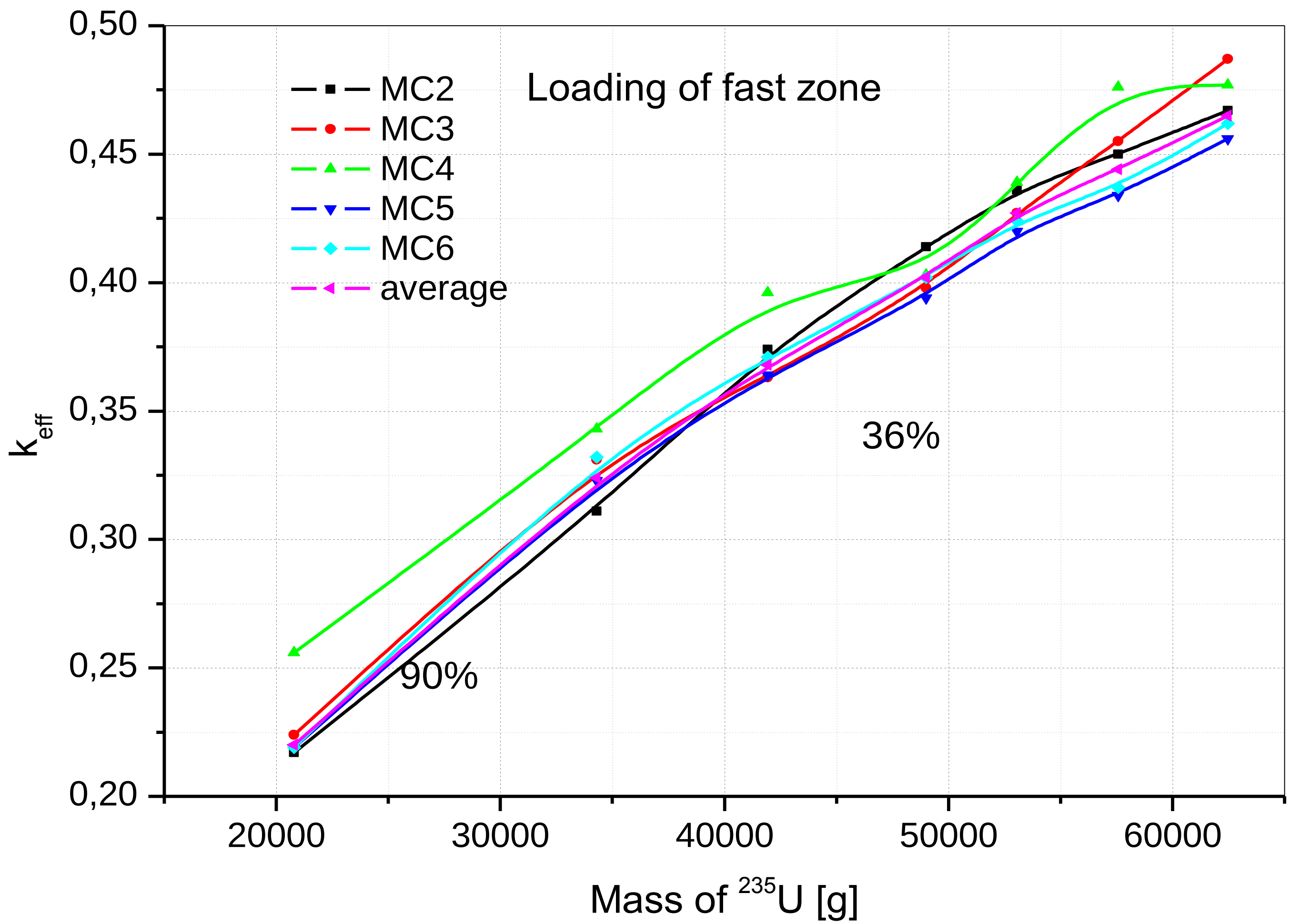


1 - Ionguide, 2 - inner fast zone, 3 - outer fast zone, 4 - absorber, 5 - thermal zone, 6 - SS frame, 7 - graphite reflector, 8 - upper plate, 9 - organic glass sheet, 10 - cadmium layer, 11 - bottom plate

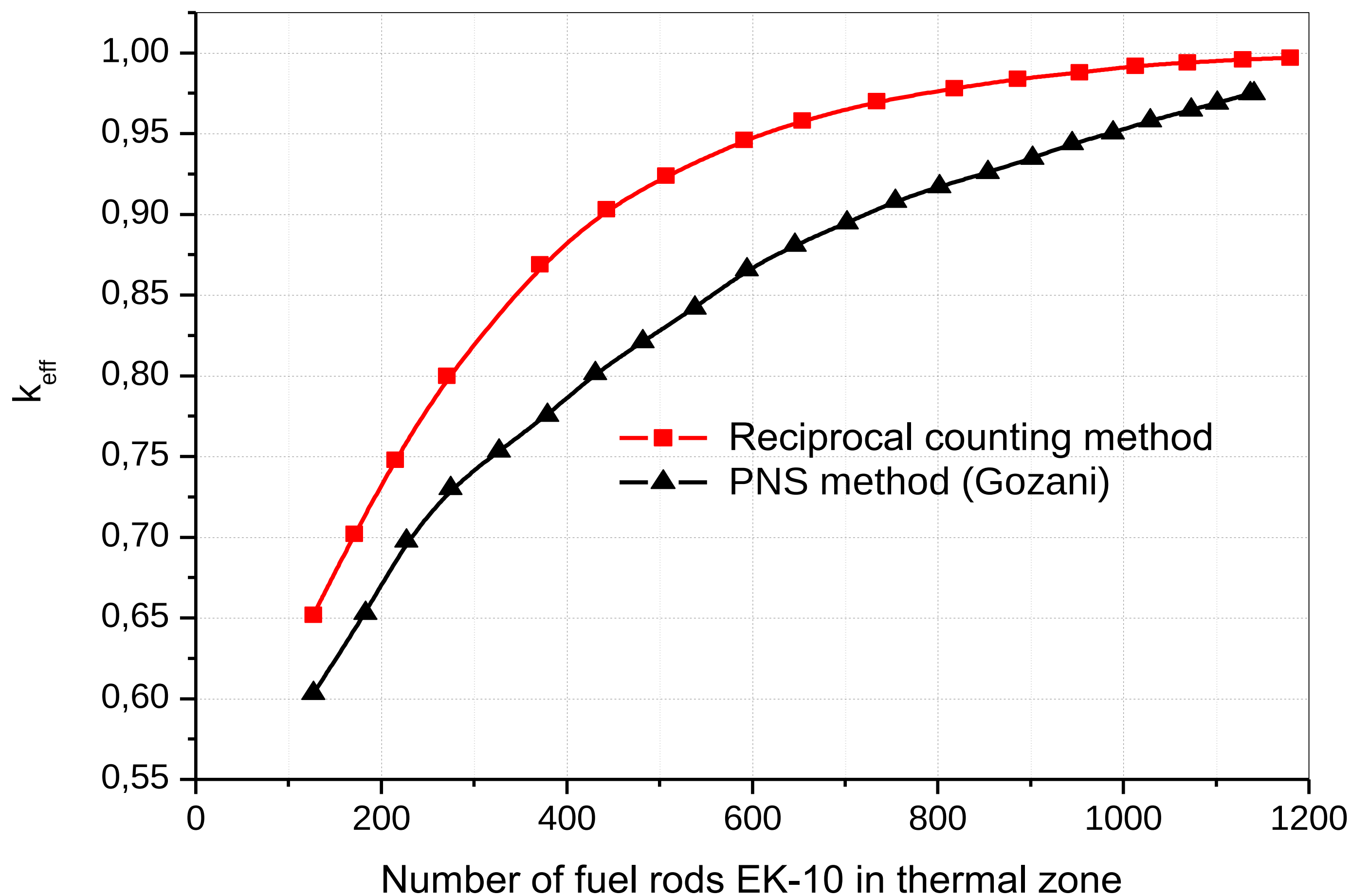
Main configurations of the YALINA-Booster core

- 1st configuration - HEU fuel YALINA-Booster - with 132 fuel rods with Umet. of 90% enrichment by 235U in the inner part of fast zone; 563 fuel rods with UO2 of 36% enrichment by 235U in the outer part of fast zone, 1141 fuel rods (EK-10) with UO2 of 10% enrichment by 235U in thermal zone, ($k_{eff} \leq 0.979$);
- 2nd configuration - YALINA-Booster (1st step of conversion to LEU fuel) -with 695 fuel rods with UO2 of 36% enrichment by 235U in fast zone and 1185 fuel rods (EK-10) with UO2 of 10% enrichment by 235U in thermal zone ($k_{eff} \leq 0.975$);
- 3rd configuration - LEU fuel YALINA-Booster (2nd step of conversion to LEU fuel) with 601 fuel rods with UO2 of 21% enrichment by 235U in fast zone and 1185 fuel rods (EK-10) with UO2 of 10% enrichment by 235U in thermal zone ($k_{eff} \leq 0.960$).
- 4th configuration - configuration with cylindrical fast zone
- The complete description of the configurations is available at the IAEA website (http://www-nfcis.iaea.org/NFCIS).

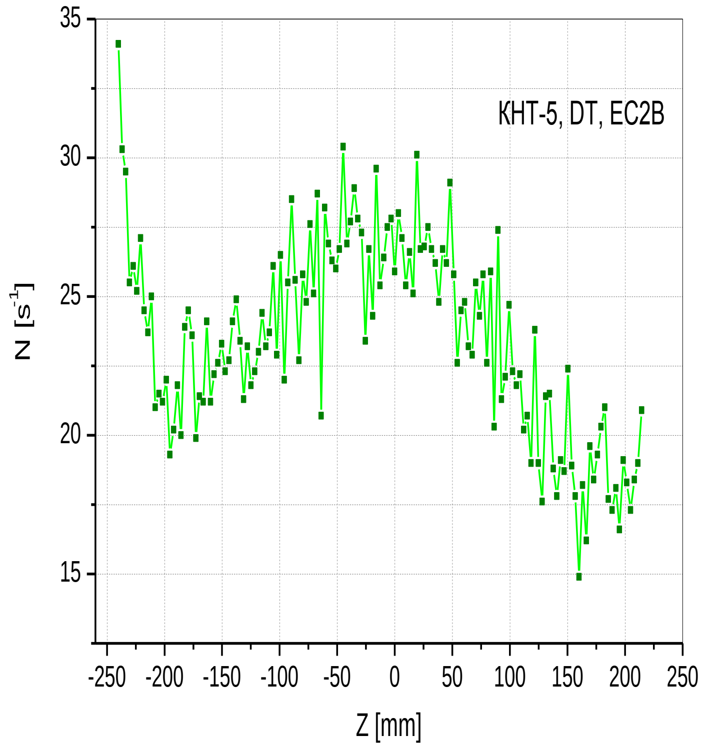
Effective multiplication factor measured by reciprocal counting method during fast zone loading (1st configuration)

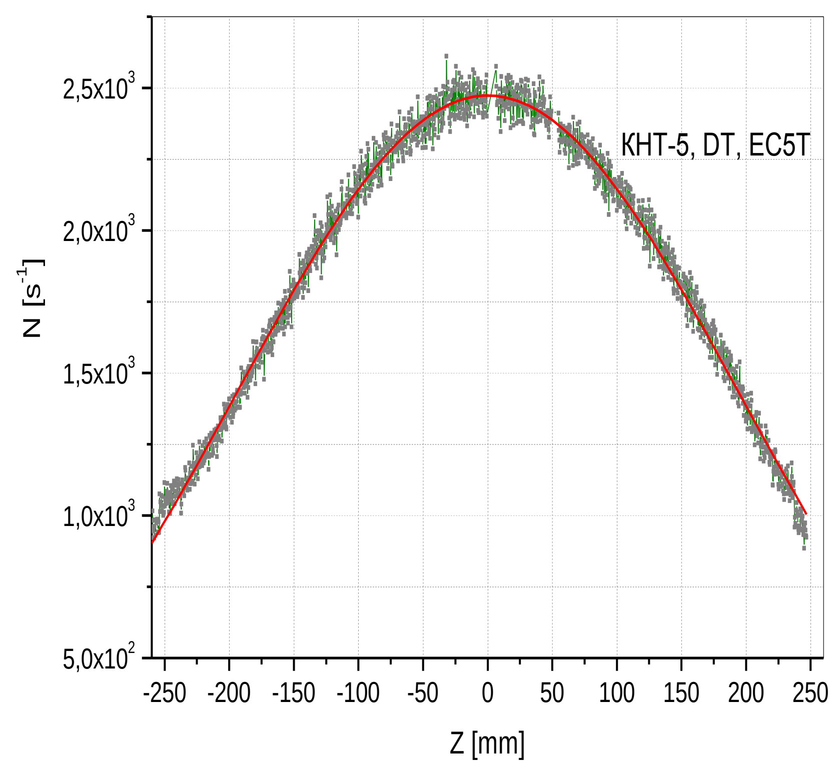


Comparison of k_{eff} measured by PNS method and reciprocal counting method during fuel loading into thermal zone

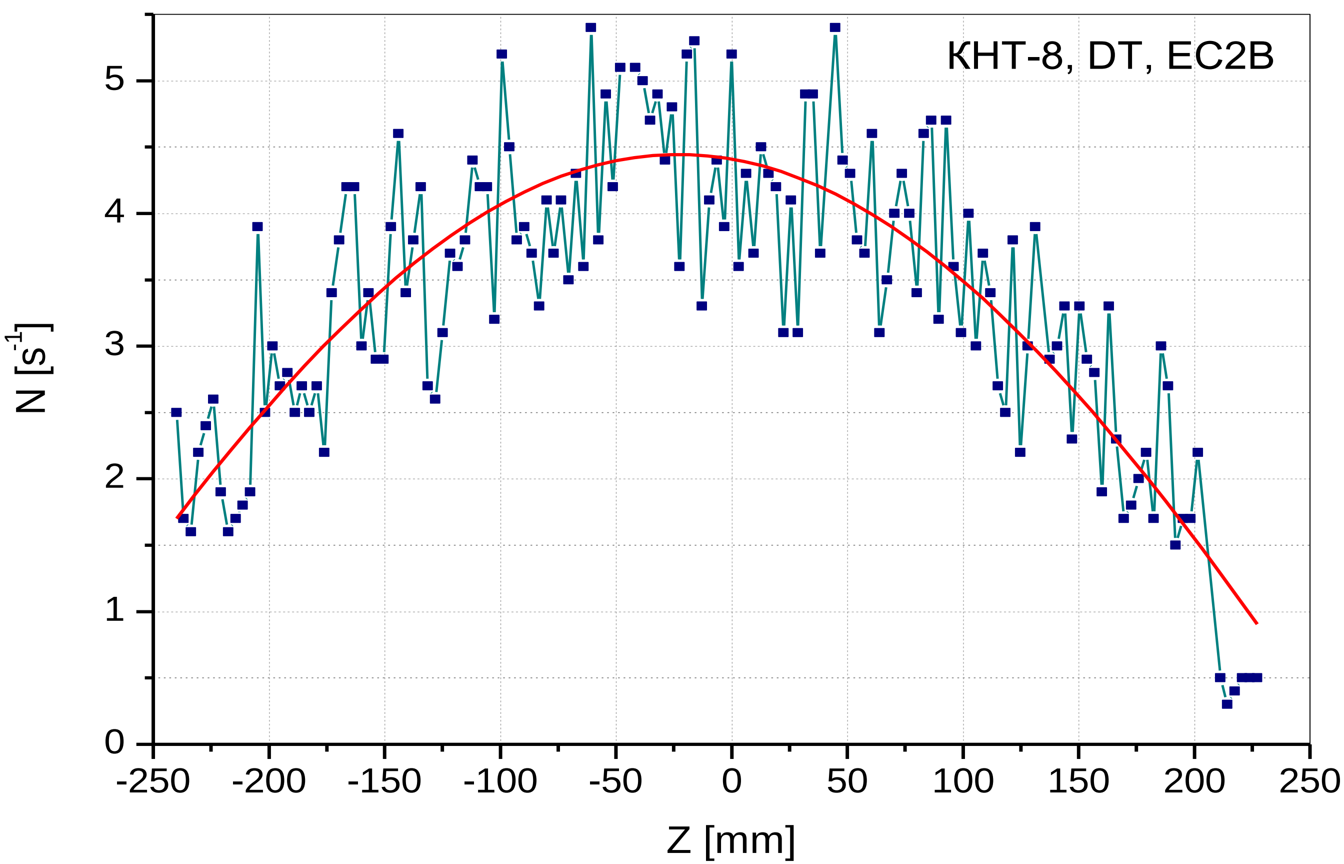


Axial distribution of neutron flux density in experimental channels EC2B (a) and EC5T (b) measured by fission chamber KHT-5 (DT neutron source)

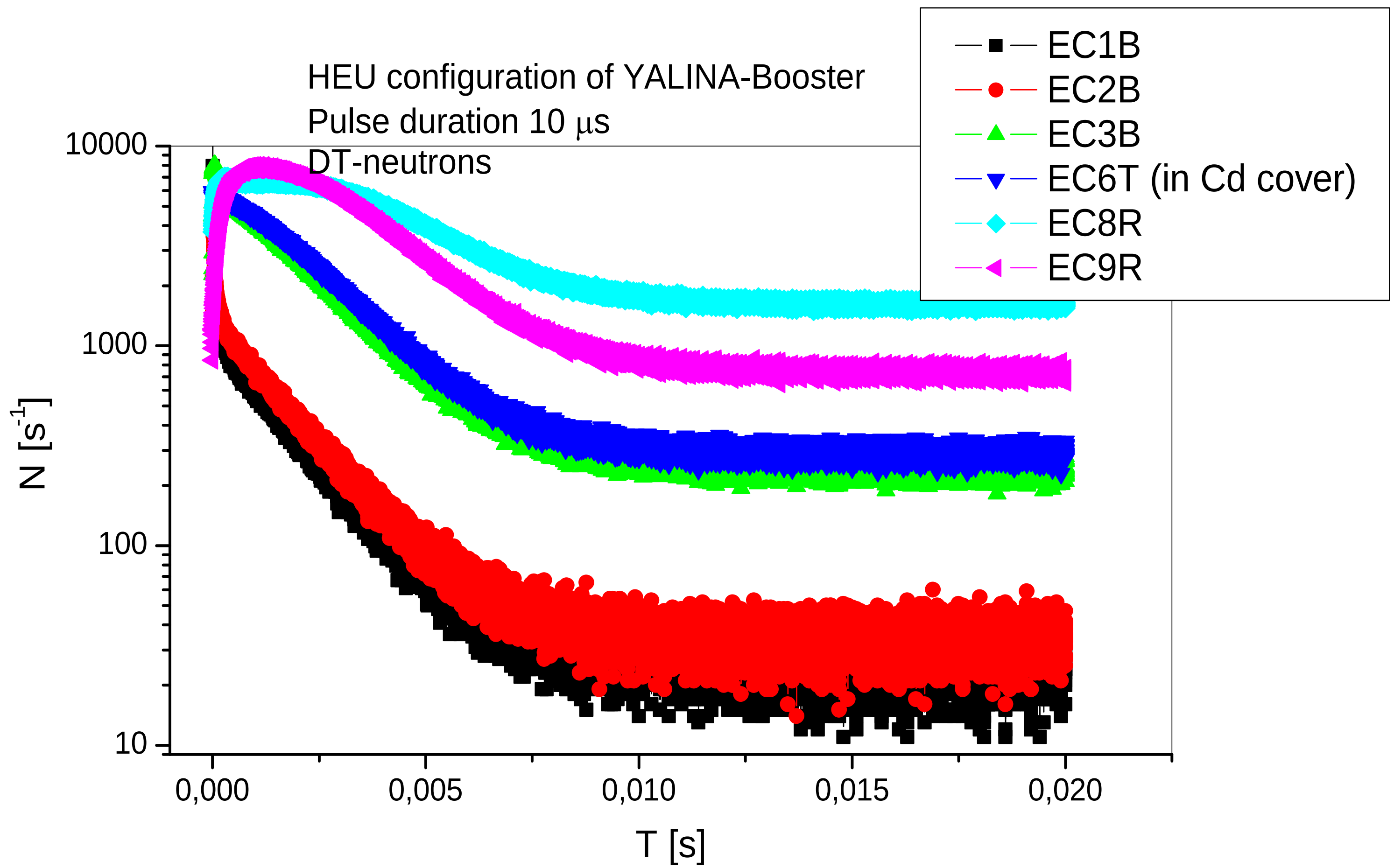




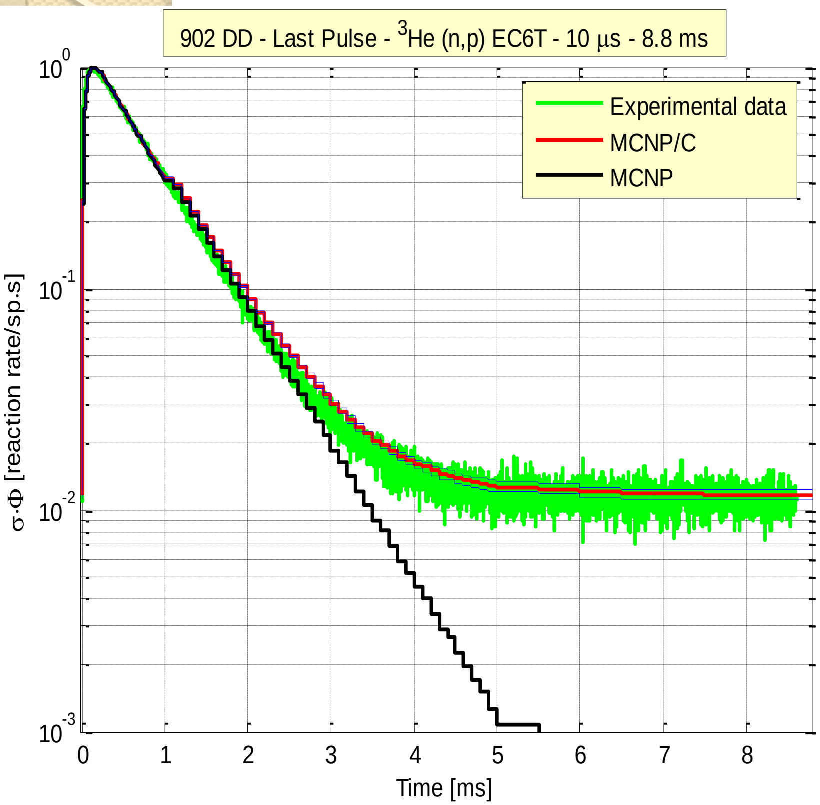
Axial distribution of 238U(n,f) reaction rate measured by fission chamber KHT-8 in the experimental channel EC2B



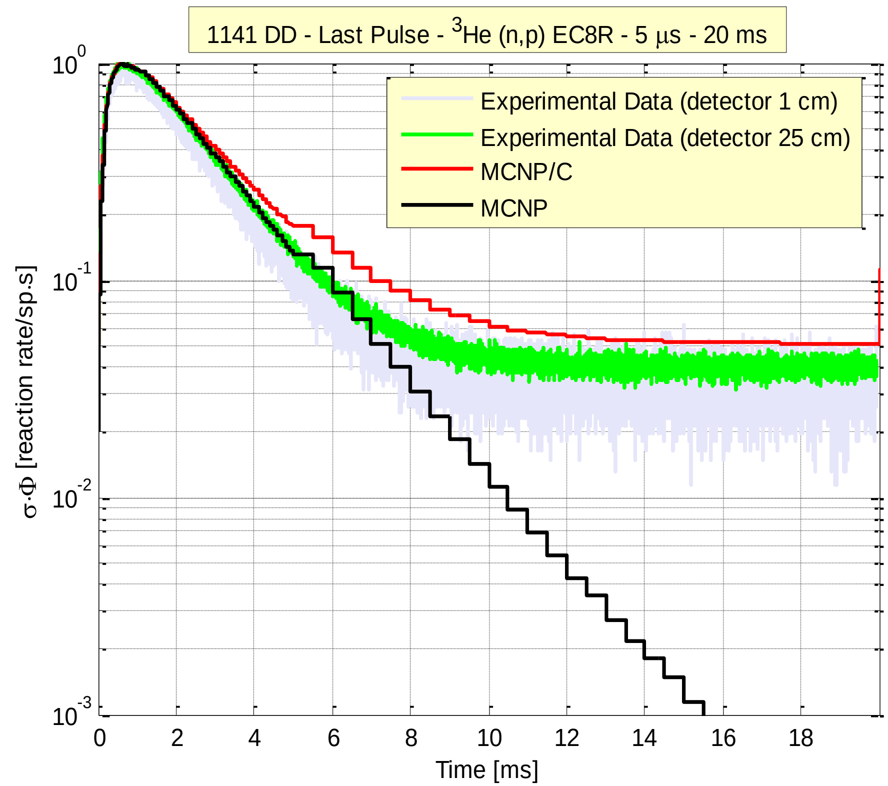
Time behavior of neutron pulse in the experimental channels by ion pulse duration 10 μs



Comparison of experimental and calculated data



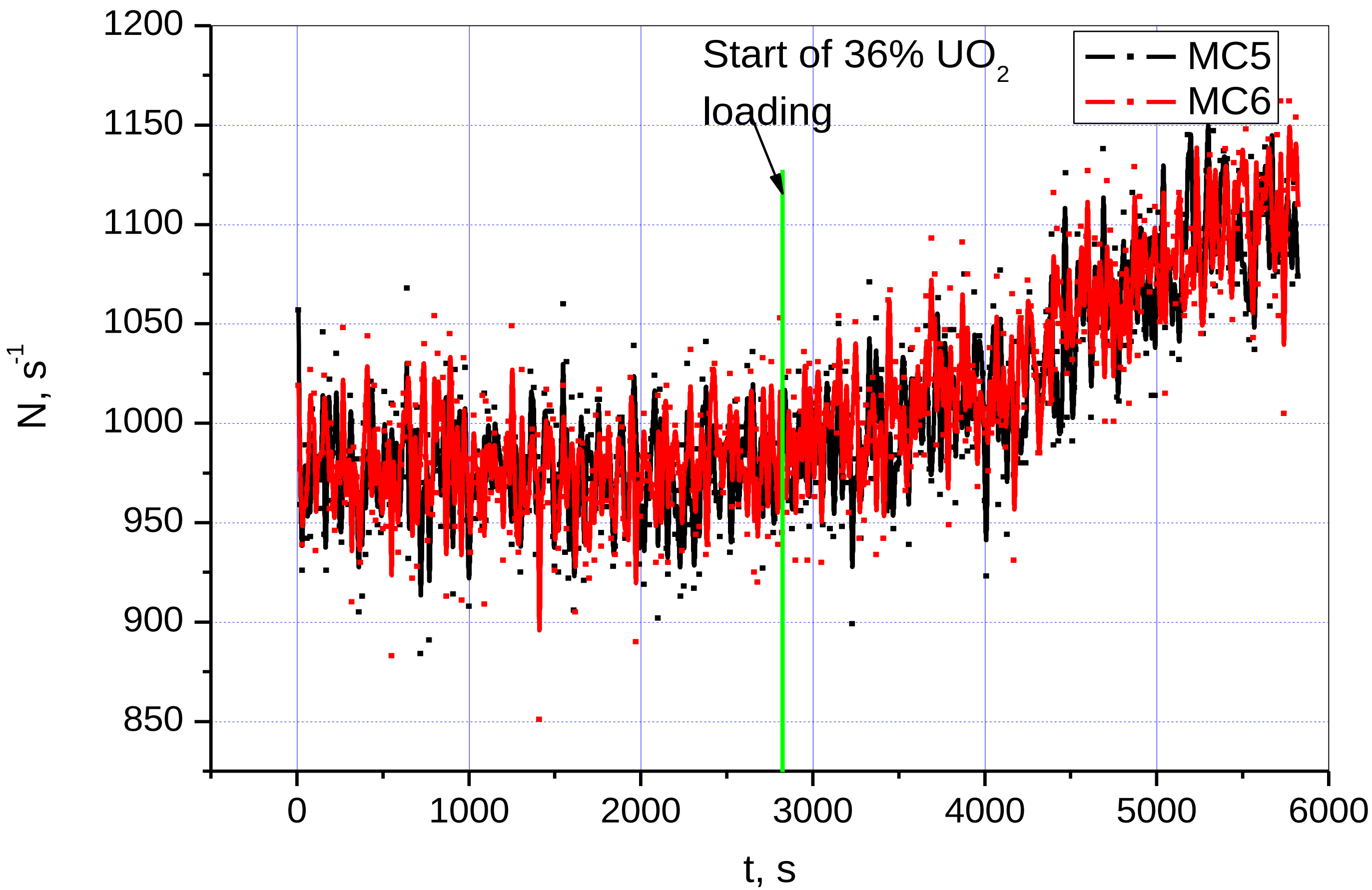
EK6T



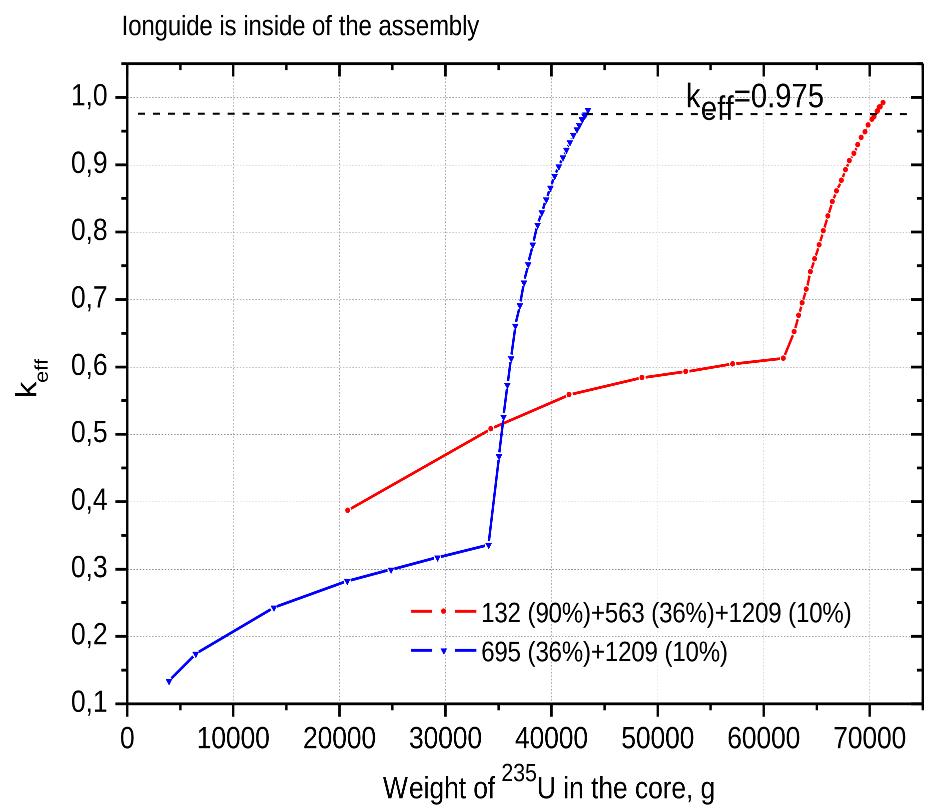
EK8R

YALINA-Booster – 1st configuration

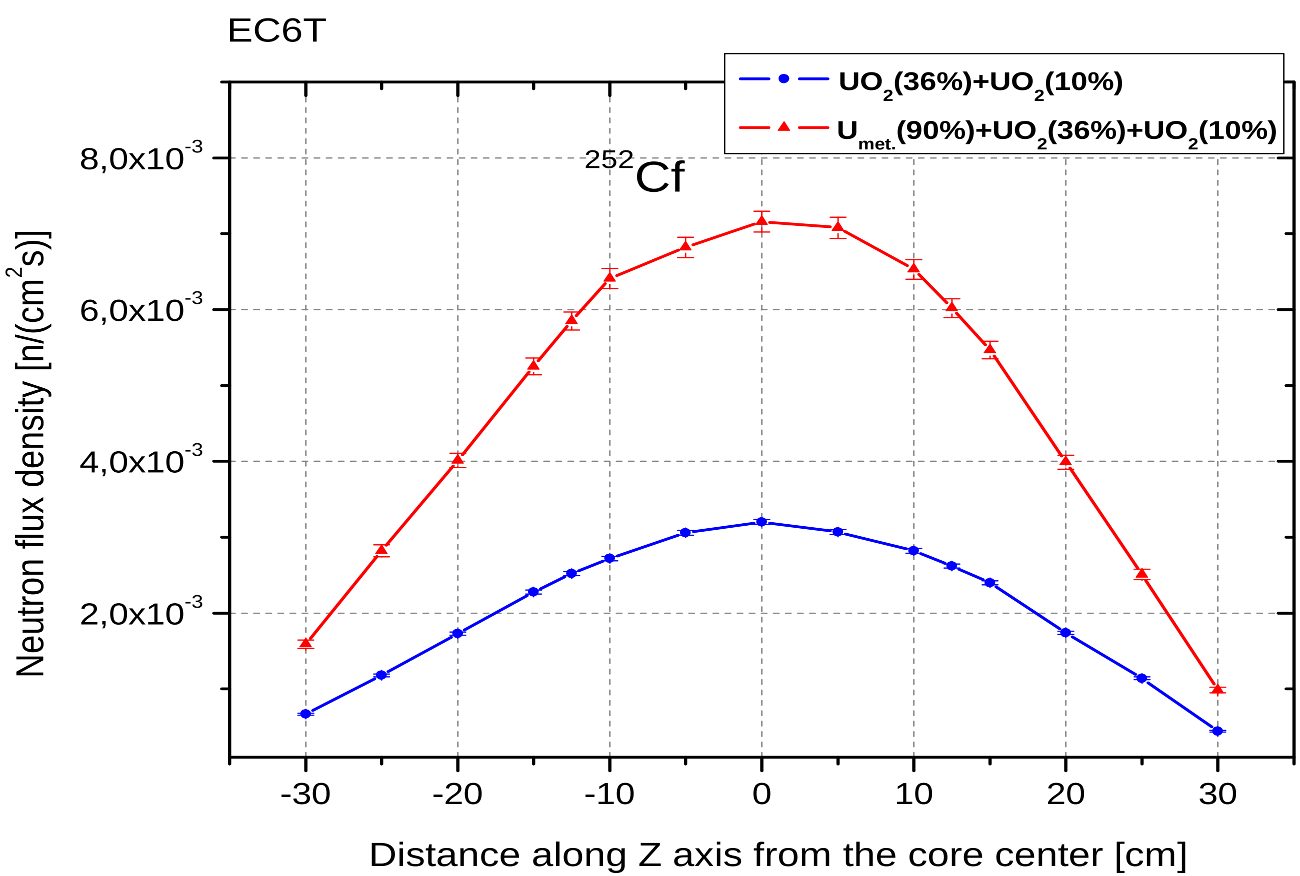
Variation of ^3He detectors' counting rates during load of the 36% enriched UO_2 into the inner part of the fast zone



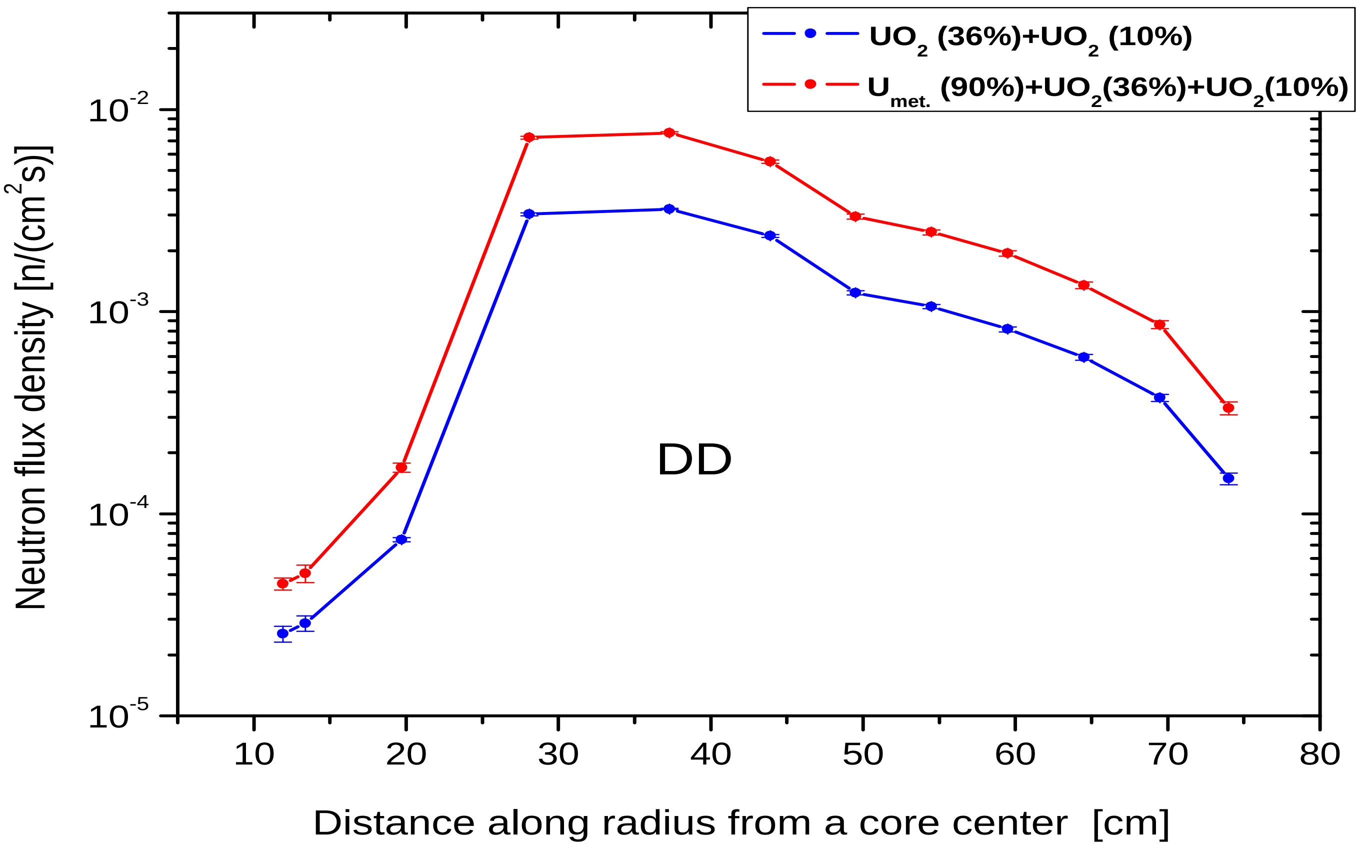
Dependence of k_{eff} upon the number of EK-10 fuel rods loaded into thermal zone of the 1st and 2nd configurations of YALINA-Booster core (calculation)



Axial distribution of neutron flux density in the experimental channel EC6T by ^{252}Cf neutron source (1st and 2nd core configurations, calculation)

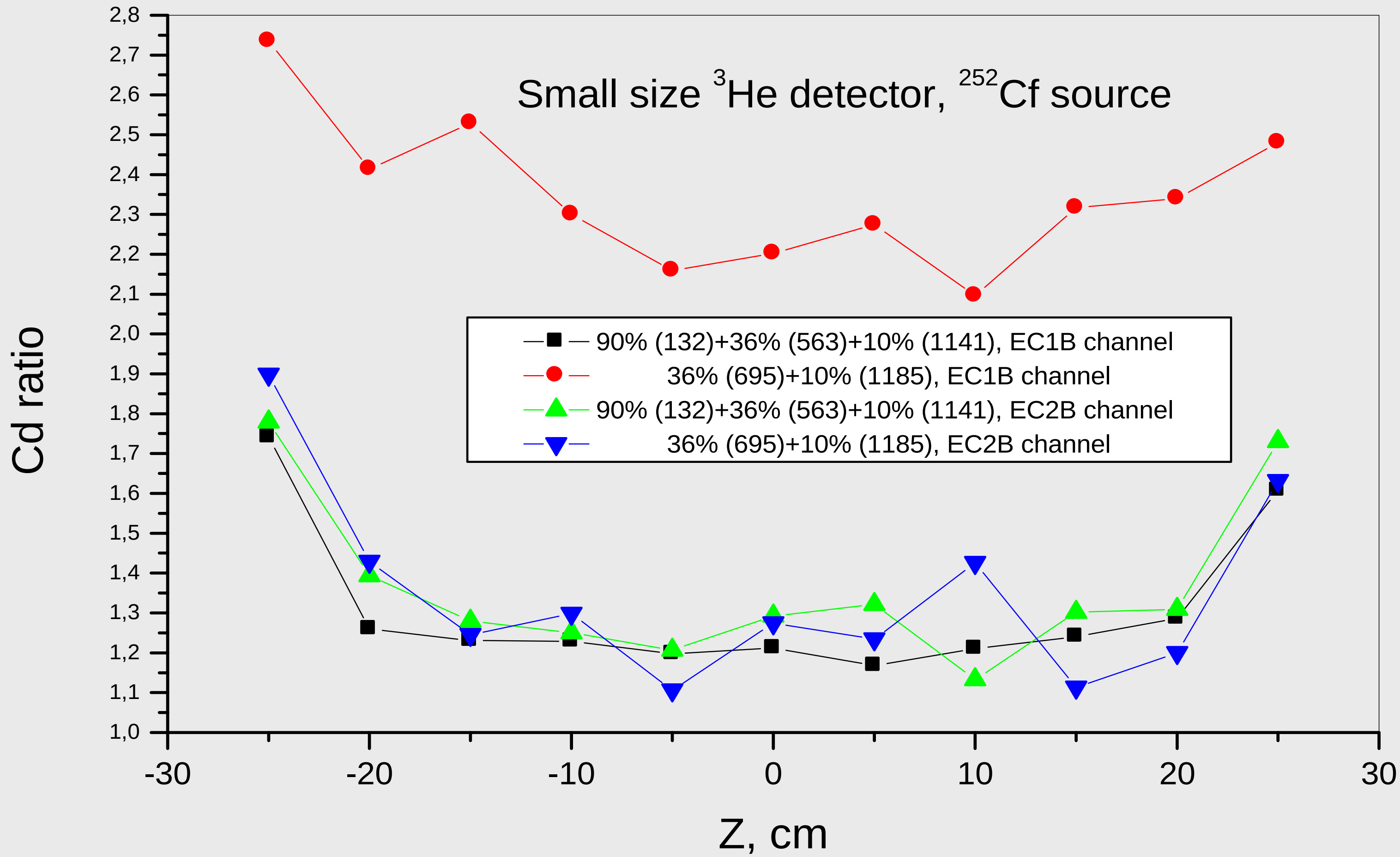


Comparison of radial distribution of neutron flux density in the 1st and 2nd core configurations (calculation)



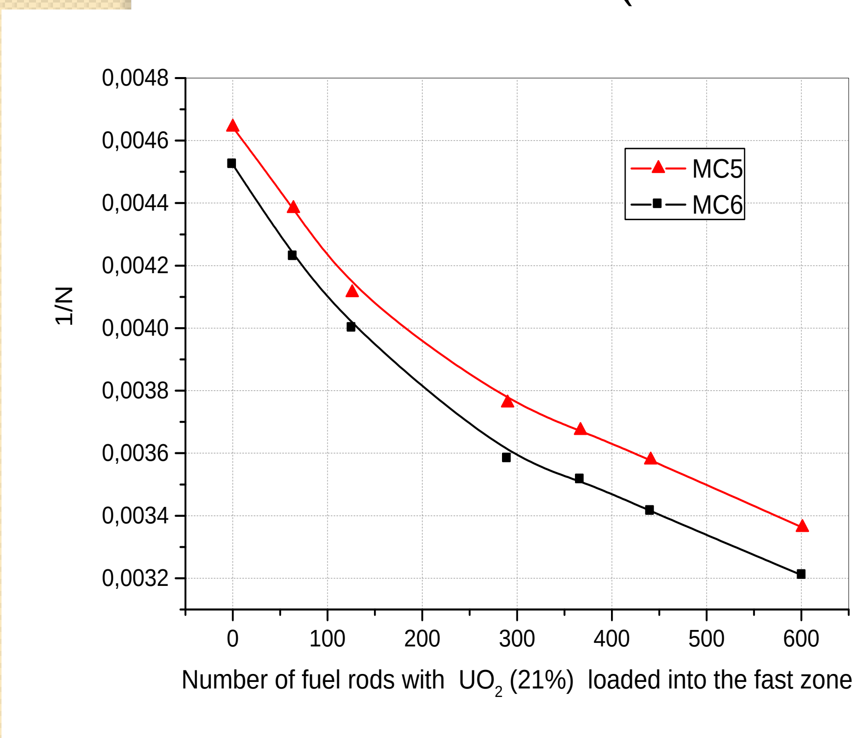
Cd

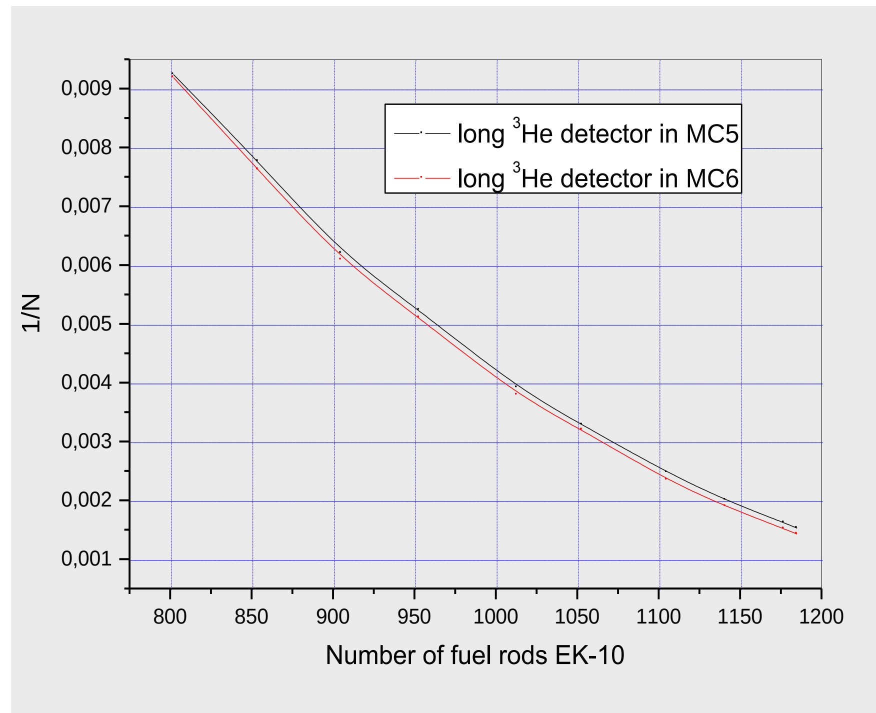
Comparioson YALINA-Booster for the 1st and 2nd configurations



Loading process of fuel rods with 21% UO_2 into fast zone

Reciprocal counting rate curves obtained during loading of fast zone by fuel rods with UO_2 of 36 and 21% enrichment by the loaded thermal zone (1185 rods EK10)

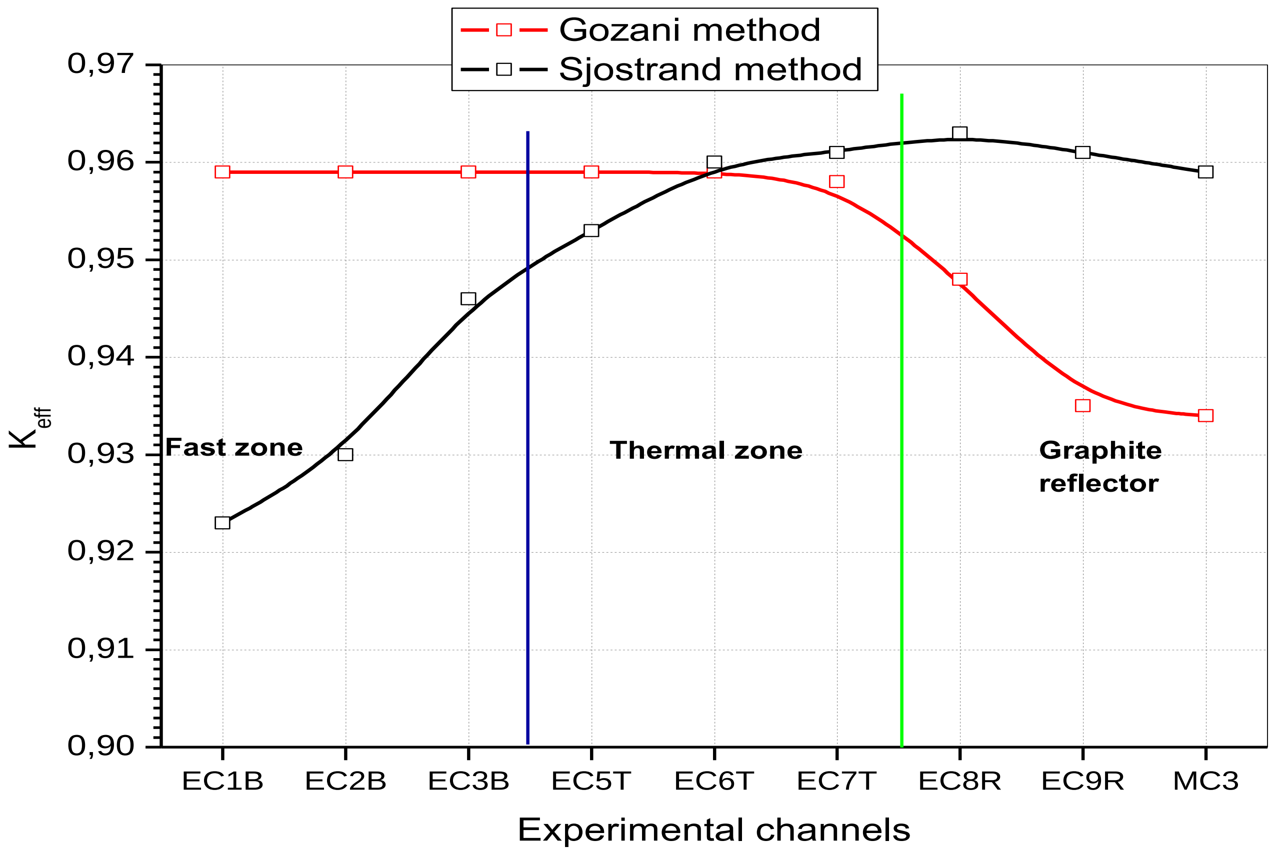




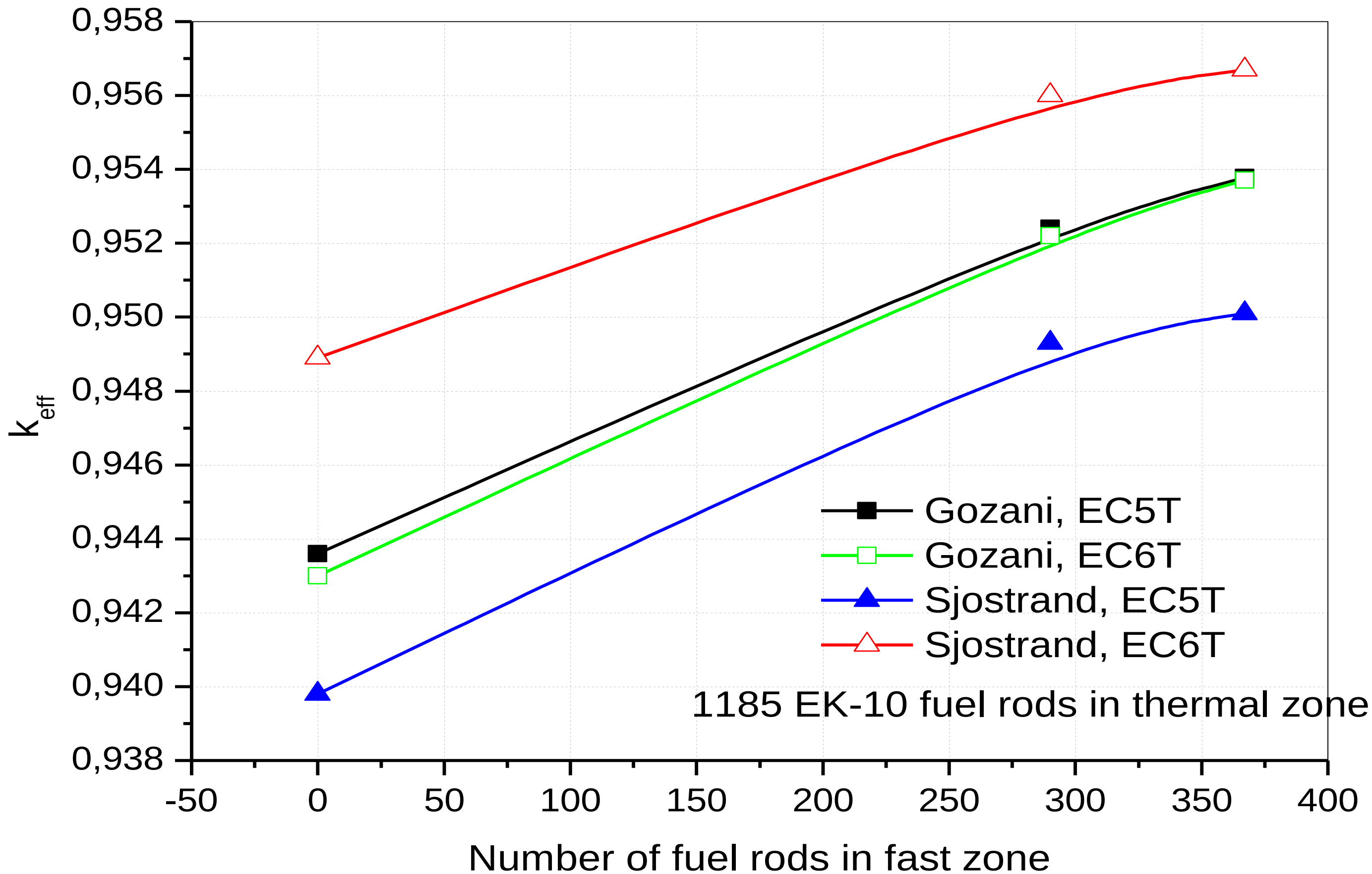
21% UO_2

36% UO_2

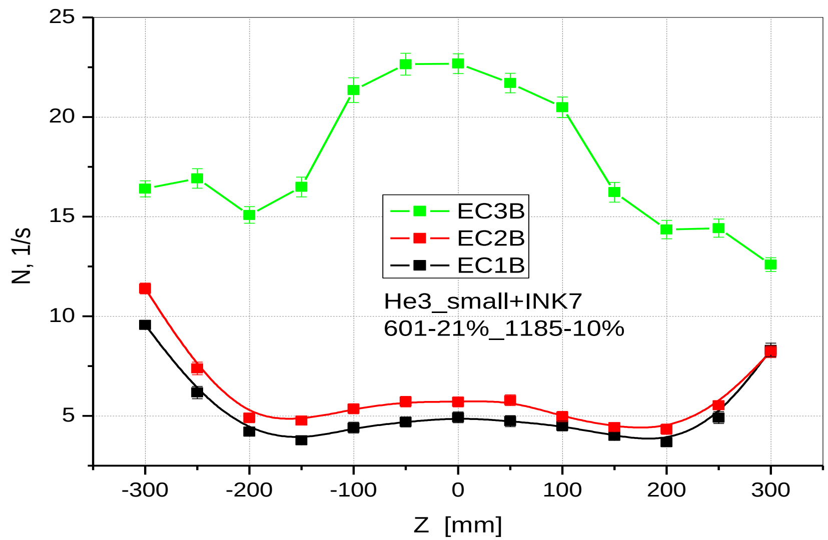
Effective multiplication factor estimated by PNS method by different positions of the detector and data processing techniques for 3rd configuration (by D,D neutron source at Z=0)

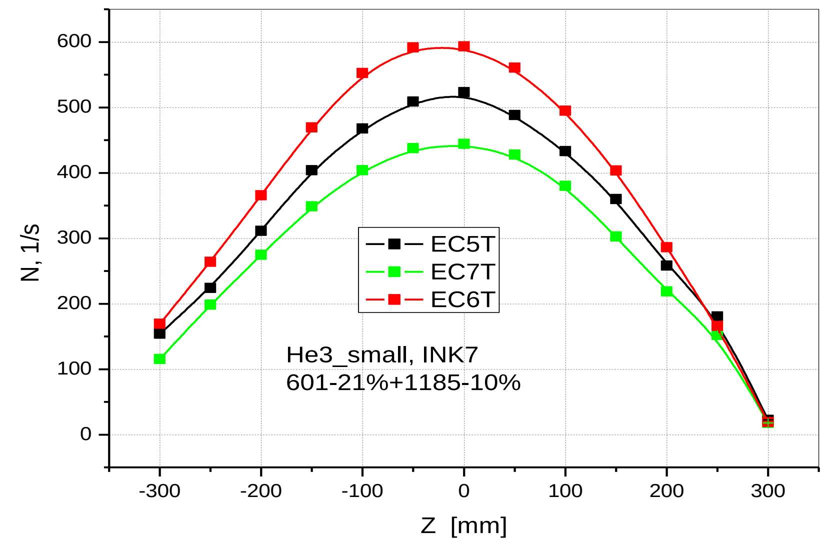


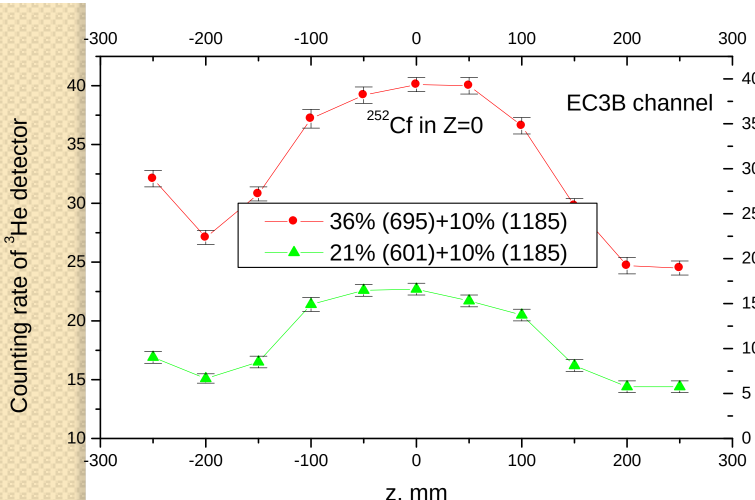
Effective multiplication factor estimated by different techniques of data processing versus number of fuel rods loaded into fast zone

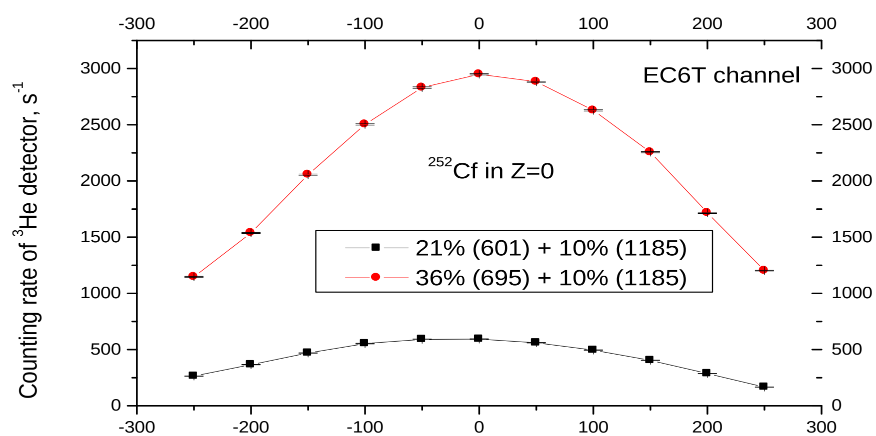


Distribution of small size 3He detector counting rate along the experimental channels of fast (a) and thermal zone (b) by ^{252}Cf neutron source at Z=0

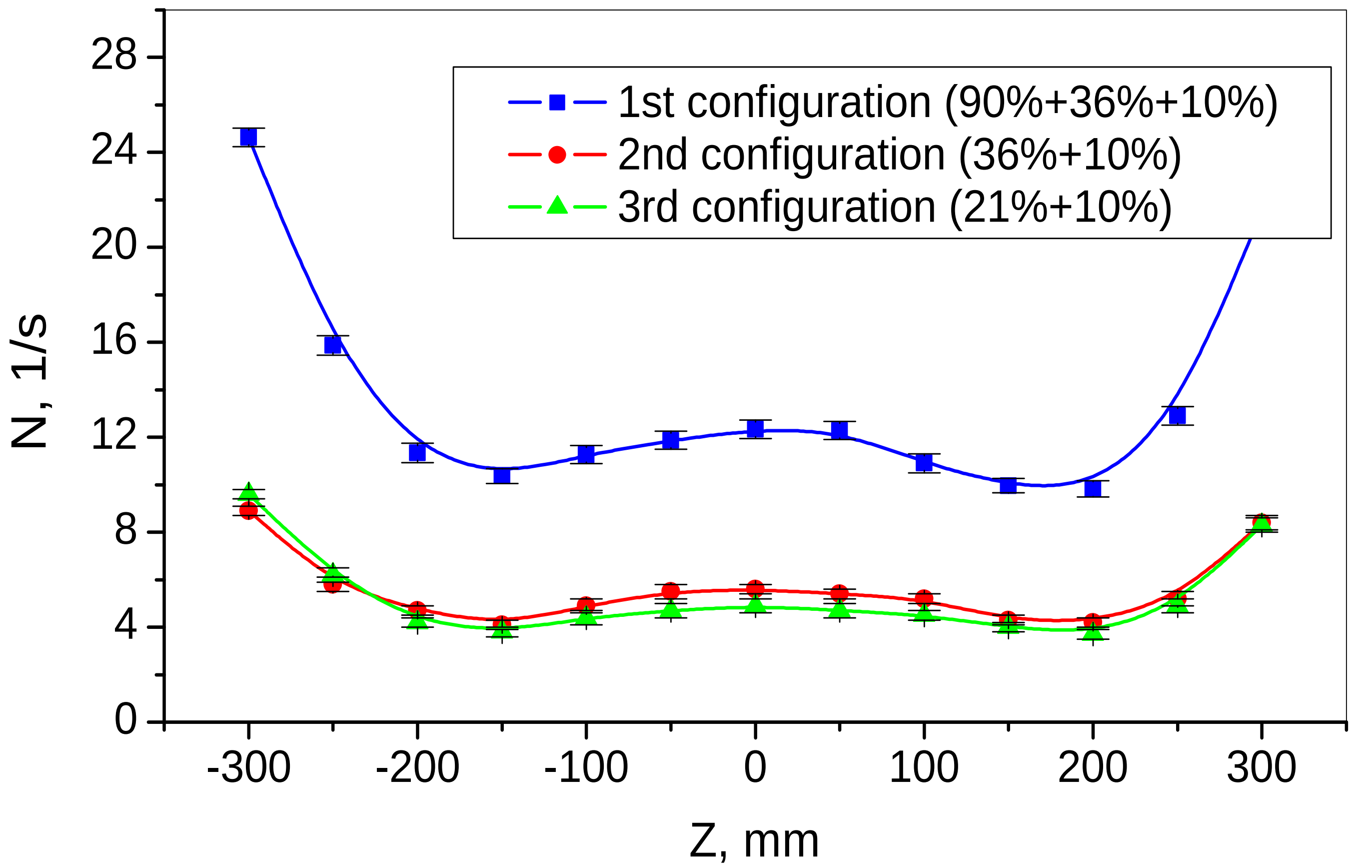








Axial distribution of small size ^{3}He detector counting rate in the experimental channel ECB1 of fast zone by ^{252}Cf neutron source



Conclusion

- The YALINA-Booster assembly was set up to study neutronics of sub-critical systems driven by external neutron sources and to prove the feasibility of ADS.
- The successful operation of this facility is a scientific contribution to the ADS and ADTT investigations from the Republic of Belarus, as well as from the EC and USA international teams.
- The experimental data are used to benchmark and validate methods and computer codes for designing and licensing ADS.

Conclusion (cont'd)

- The area ratio method (Sjöstrand method) allows measure the reactivity with high accuracy in terms of statistical uncertainty.
- However the method is sensitive to spatial effects caused by core heterogeneity and the detector's vicinity to the external neutron source.

Conclusion (cont'd)

- After replacement of 90% enriched metallic uranium by 36% UO_2 in the inner region of fast zone, we had to add some additional amount of 10% UO_2 into thermal zone to raise k_{eff}.
- In this case the main YALINA-Booster neutronics suffered not so remarkably, except for neutron spectrum softening in the inner region of the fast zone.

Conclusion (cont'd)

- The 2nd step of conversion to LEU fuel (21% UO_2 in fast zone) resulted in significant reduction of the effective multiplication factor.
- The value of k_{eff} estimated by MCNP is about 0.961, the experimental one - 0.959, whereas in HEU fuel core configuration it amounted 0.979 and 0.975 respectively.
- There is a chance to maintain the assembly's performance through essential reconstruction of fast and interface zones involving the safety and licensing problems.

Thank you!