Neutronics of YALINA-Booster Subcritical Assembly for ADS Studies

Kiyavitskaya A., Bournos V., Serafimovich I., Mazanik S., Fokov Yu., Routkovskaia C., Edchik I., Kulikovskaya A.

Joint Institute for Power&Nuclear Research - Sosny NAS, Belarus

Y. Gohar, G. Aliberti, F. Kondev, D. Smith, A.Talamo, Z. Zhong, Gohar Y., Kondev F.

Argonne National Laboratory, USA

I. Bolshinski

Idaho National Laboratory, USA

AccApp'09, ITM, Vienna, 4-9 May 2009

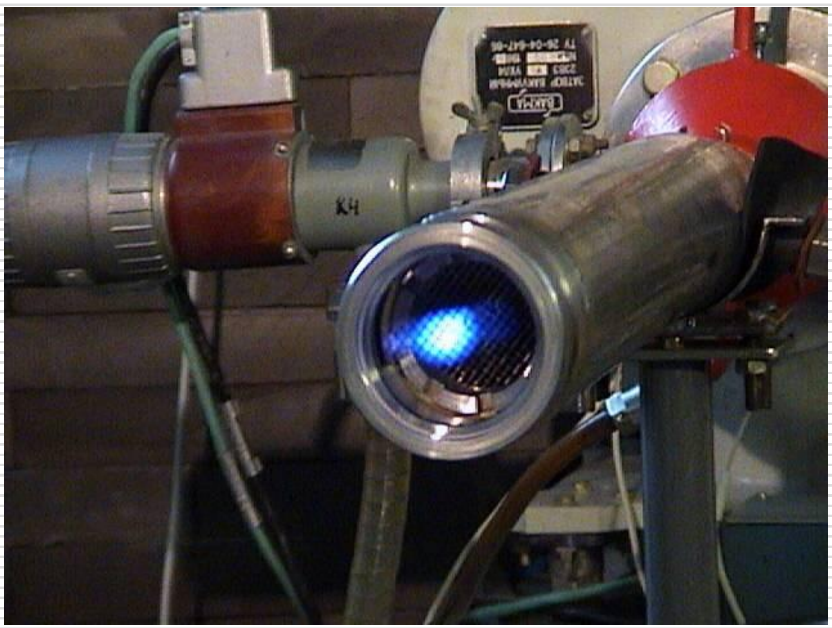
Subcritical facility YALINA

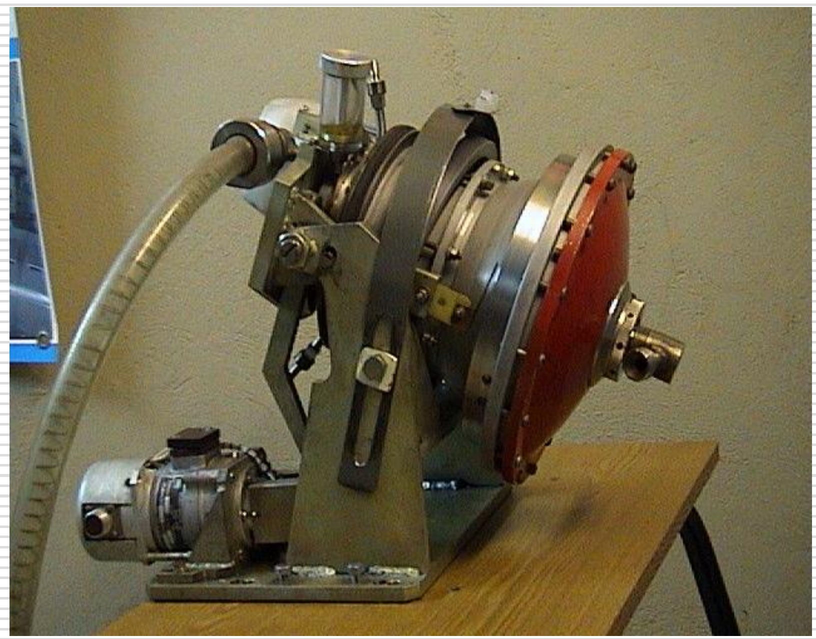
High intensity neutron generator

- can operate in continuous and pulse modes
  - Pulse mode:
  - Allows to generate neutron pulses with duration **0.5μs - 100μs** and repetition frequency **1Hz-10KHz**
  - Provides extended possibilities for:
    - Investigation of multiplying media kinetics
    - Development of the methods of sub-criticality level monitoring
    - Elaboration of the theoretical approaches for description the peculiarities of neutron fields formation in deeply sub-critical systems

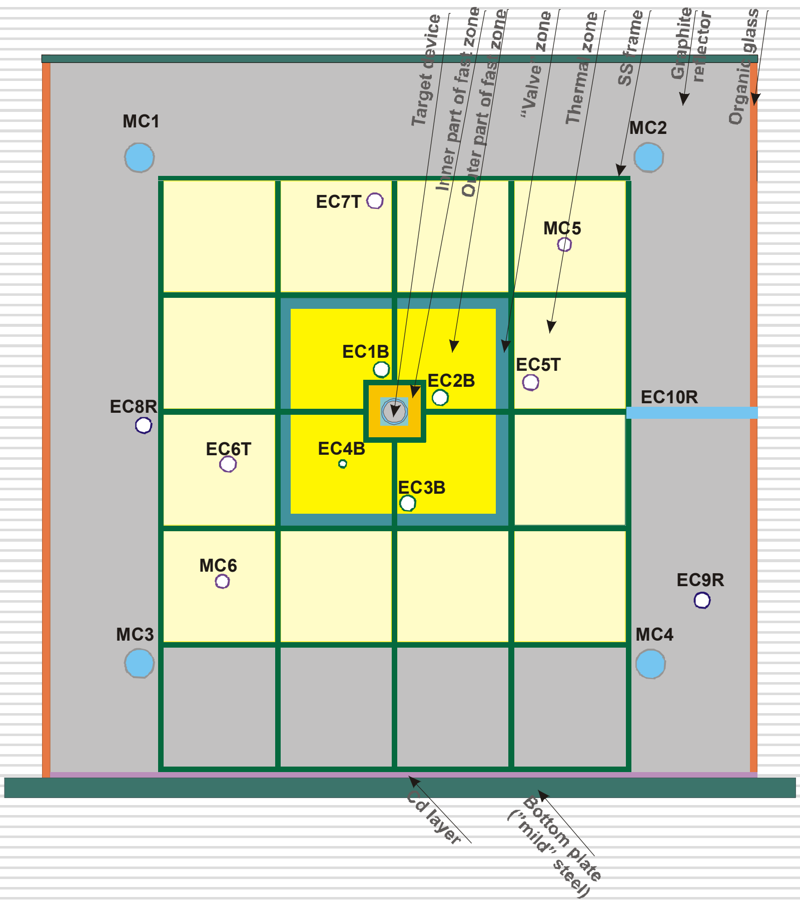
Characteristics of the targets

Target diameter, mm	45	230
Rotation speed, rpm	560	560
Beam current, mA	1 – 2	1 - 12
Neutron energy, MeV	2,5; 14	2,5; 14



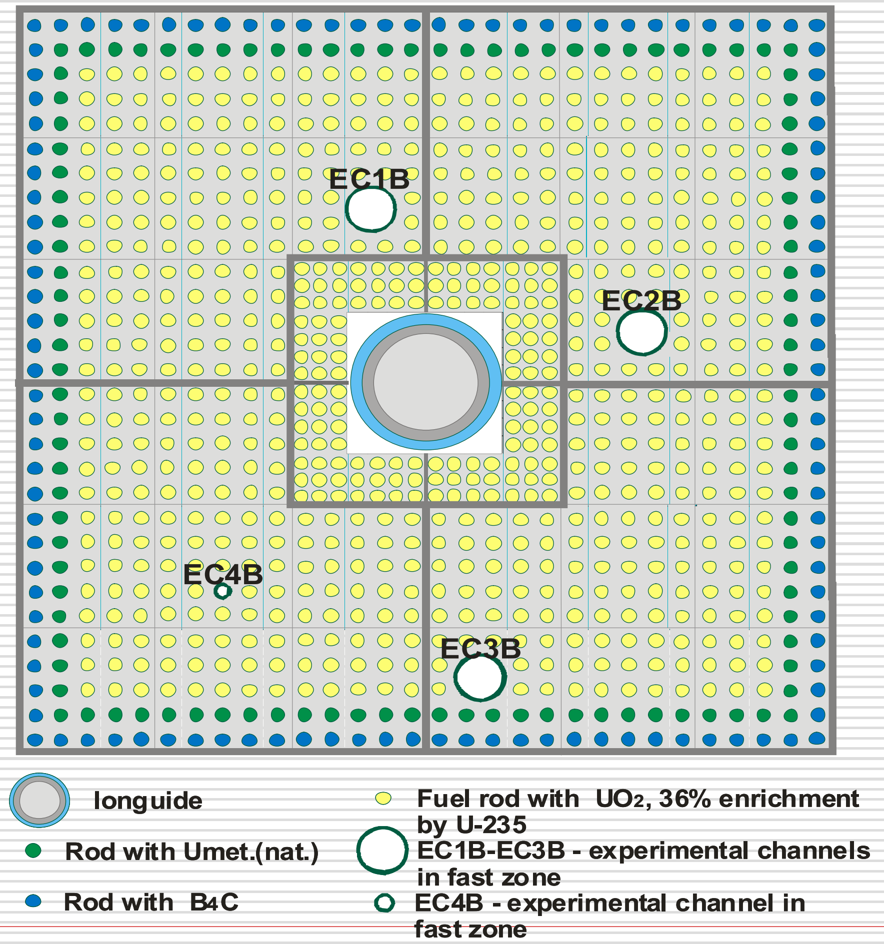


YALINA-Booster assembly
X-Y cross sectional view



EC1B-EC4B – experimental channels in fast zone;
EC5T-EC7T – experimental channels in thermal zone;
EC8R-EC10R – experimental channels in reflector,
MC5, MC6 – measuring channels in thermal zone,
MC1-MC4 – measuring channels in reflector

X-Y cross section of YALINA-Booster with 132 fuel rods in the inner part and 563 fuel rods (UO_2, 36%) in the outer part of fast zone



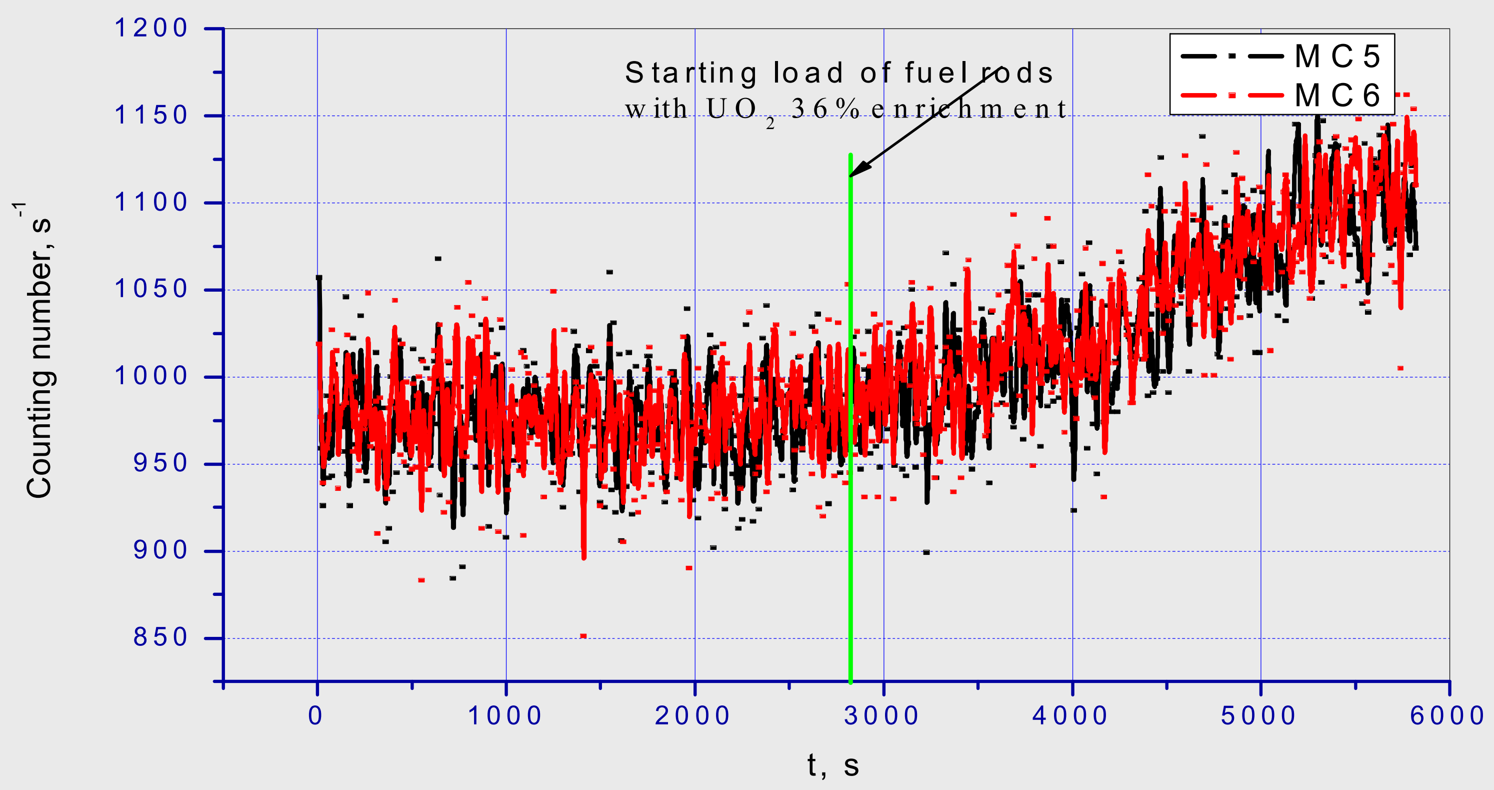
YALINA-Booster assembly

- Assembly consists of fast and thermal zones with a one directional coupling between them.
- The fuel materials of the fast zone are metallic uranium (90% enrichment) and uranium oxide (36% enrichment) and the fuel rods are loaded in lead metal.
- The thermal zone has uranium dioxide fuel (10% enrichment) and polyethylene moderator.
- Between the two zones boron carbide and natural uranium rods are used to provide the one directional coupling between the two zones.
- Graphite reflector is used around the thermal zone.

YALINA-Booster assembly

- The thermal zone surrounds the absorber zone and it consists of
  - 108 polyethylene subassemblies,
  - each having 16 holes for loading EK-10 fuel rods.
- EK-10 fuel rod - Uranium dioxide with 10% ^{235}U enrichment in magnesium oxide
- There are three experimental channels in the thermal zone, EC5T-EC7T.
- The thermal zone is surrounded in the radial direction by a 250 mm graphite reflector.
- There are three experimental channels in the reflector zone, two axial (EC8R, EC9R) and one radial (EC10R).

Counting rate of ^{3}He detectors before and start of loading of 36% fuel in the inner fast zone

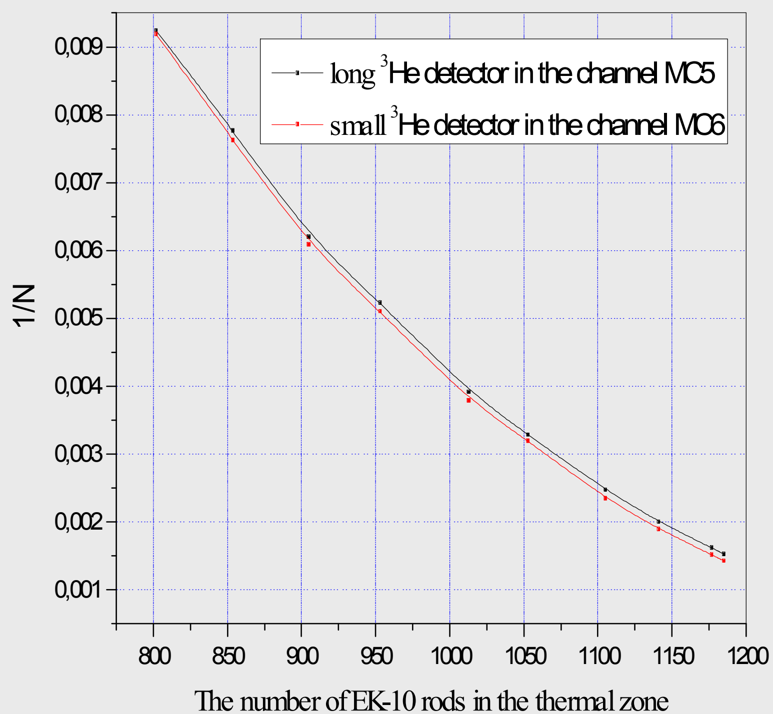


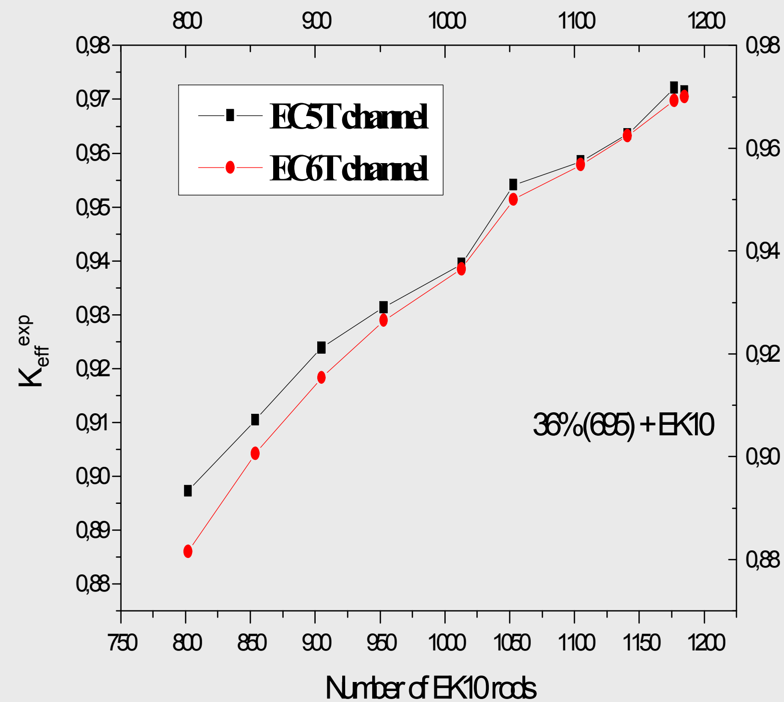
PNS measurements

- For the PNS experiment a measurement channel has been crated on the basis of ^{3}He detector of 12NH type and preamplifier ACHNA98A, worked out specially for PNS measurements, with short recovery time after overrun. Bias voltage is +1100 V.
- To monitor the subcriticality level during fuel load ^{3}He detector was placed into EC2T channel in such way that it's sensitive layer to be always at Z=0.
- Knowing the experimental value of reactivity (in units of dollar) and the effective fraction of delayed neutrons from MCNP calculation, the neutron multiplication constant can be obtained from the relation

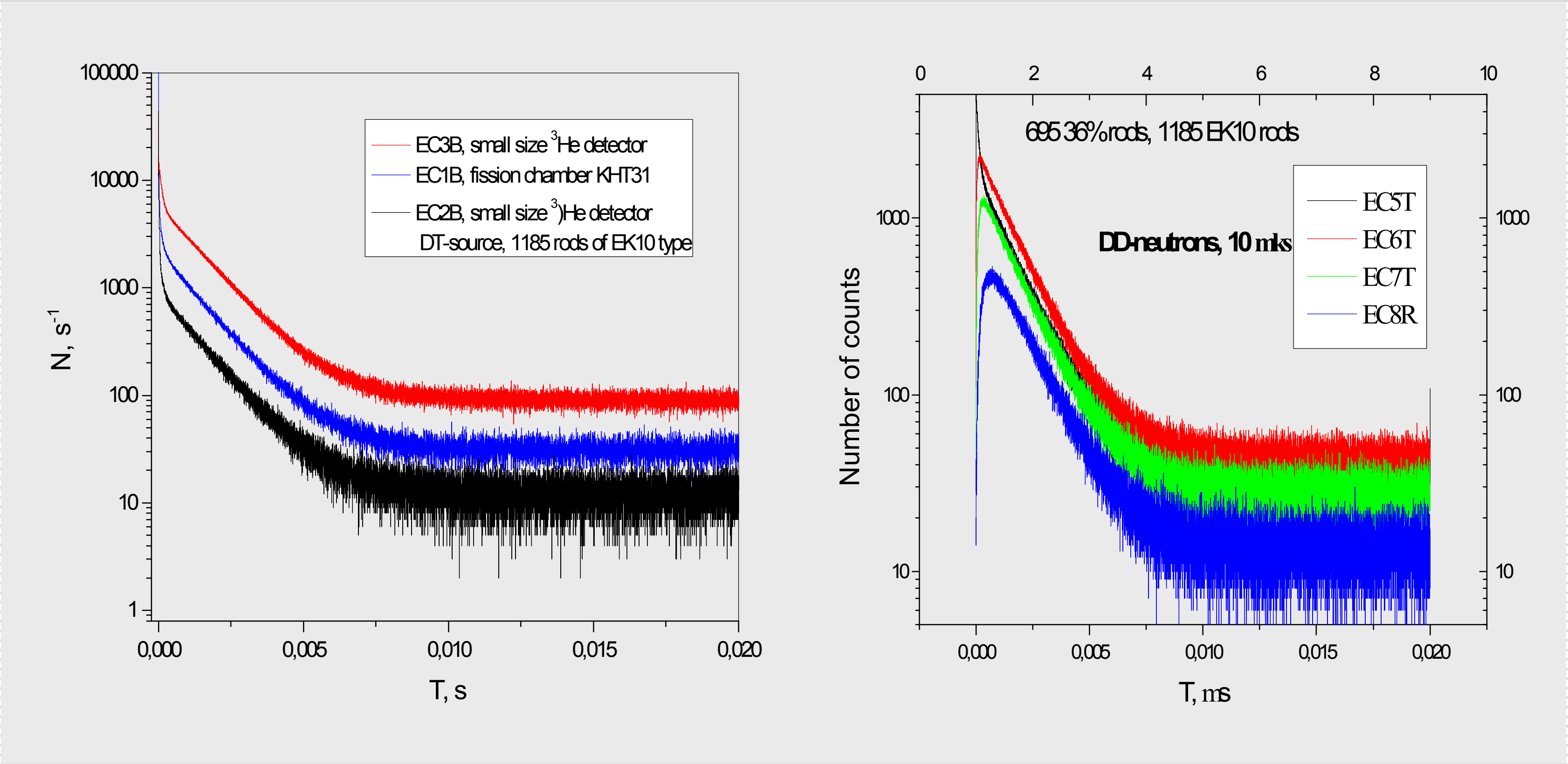
$$k_{eff} = \frac{1}{1 - \left[\frac{\rho}{\beta_{eff}}\right]^{\exp} \beta_{eff}^{MCNP}}$$

Reciprocal counting method. PNS measurements

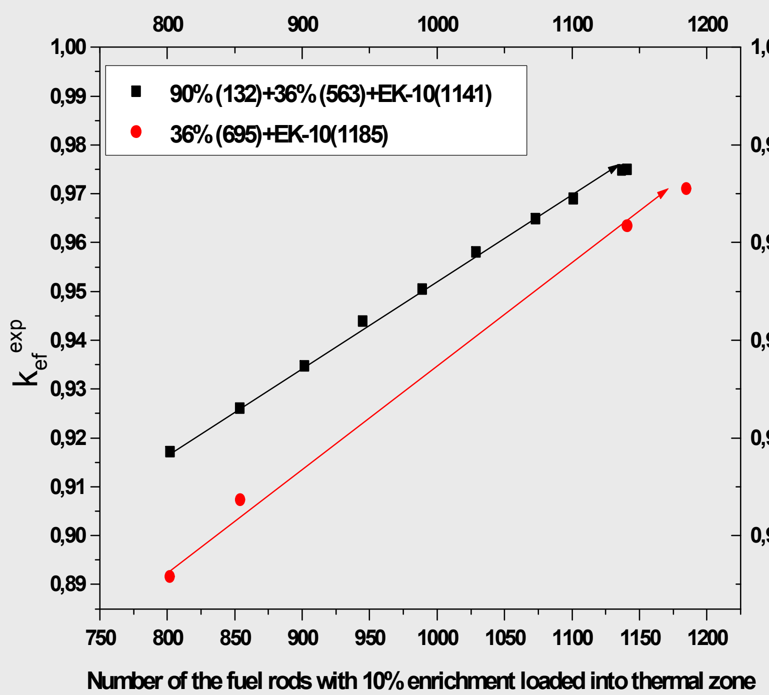


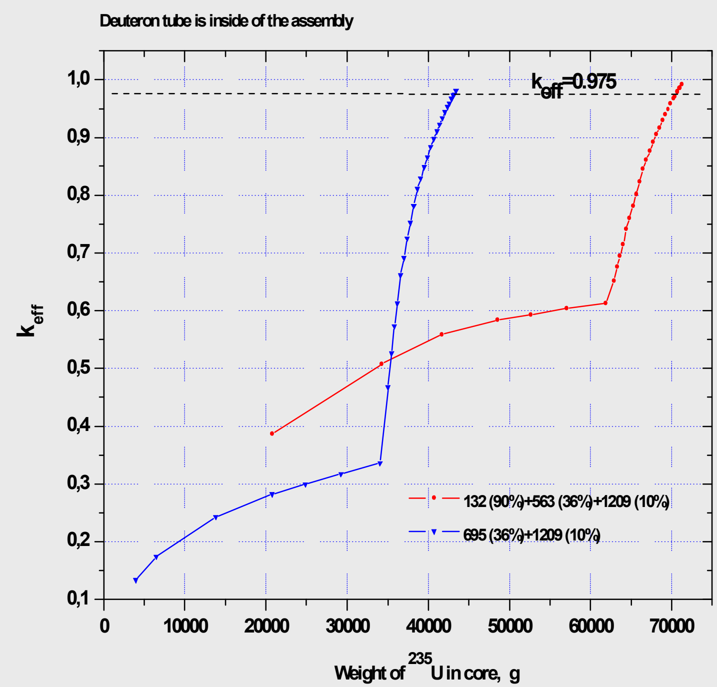


Time dependence of the counting rates of fission chamber KHT-31 and small size ^{3}He detector

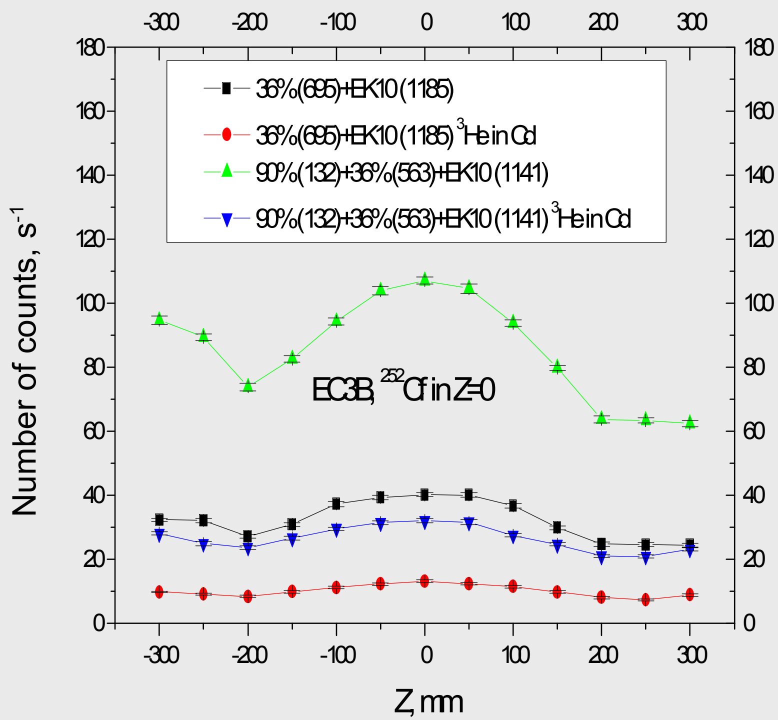


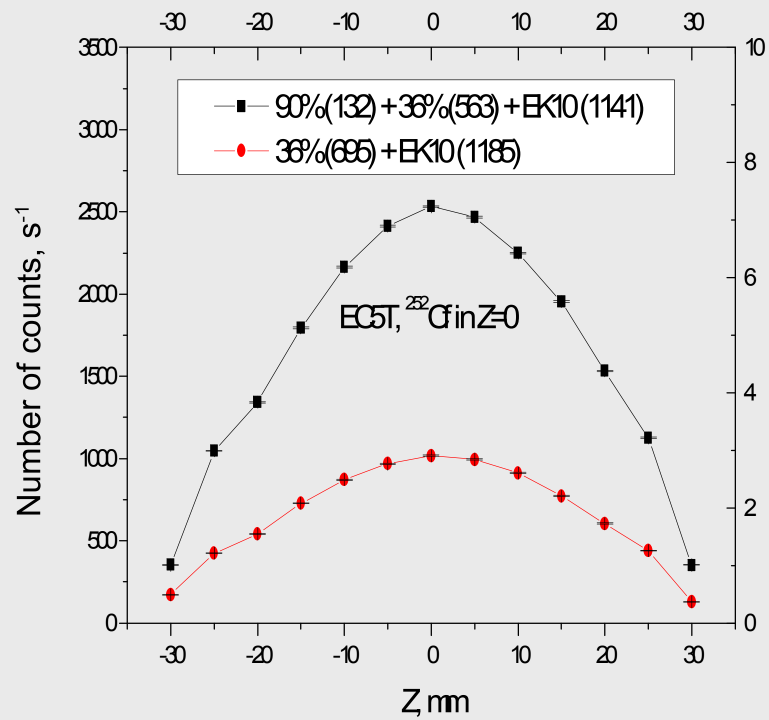
Comparison of the “reference” YALINA-Booster configuration performance with that of a new configuration. Experiment



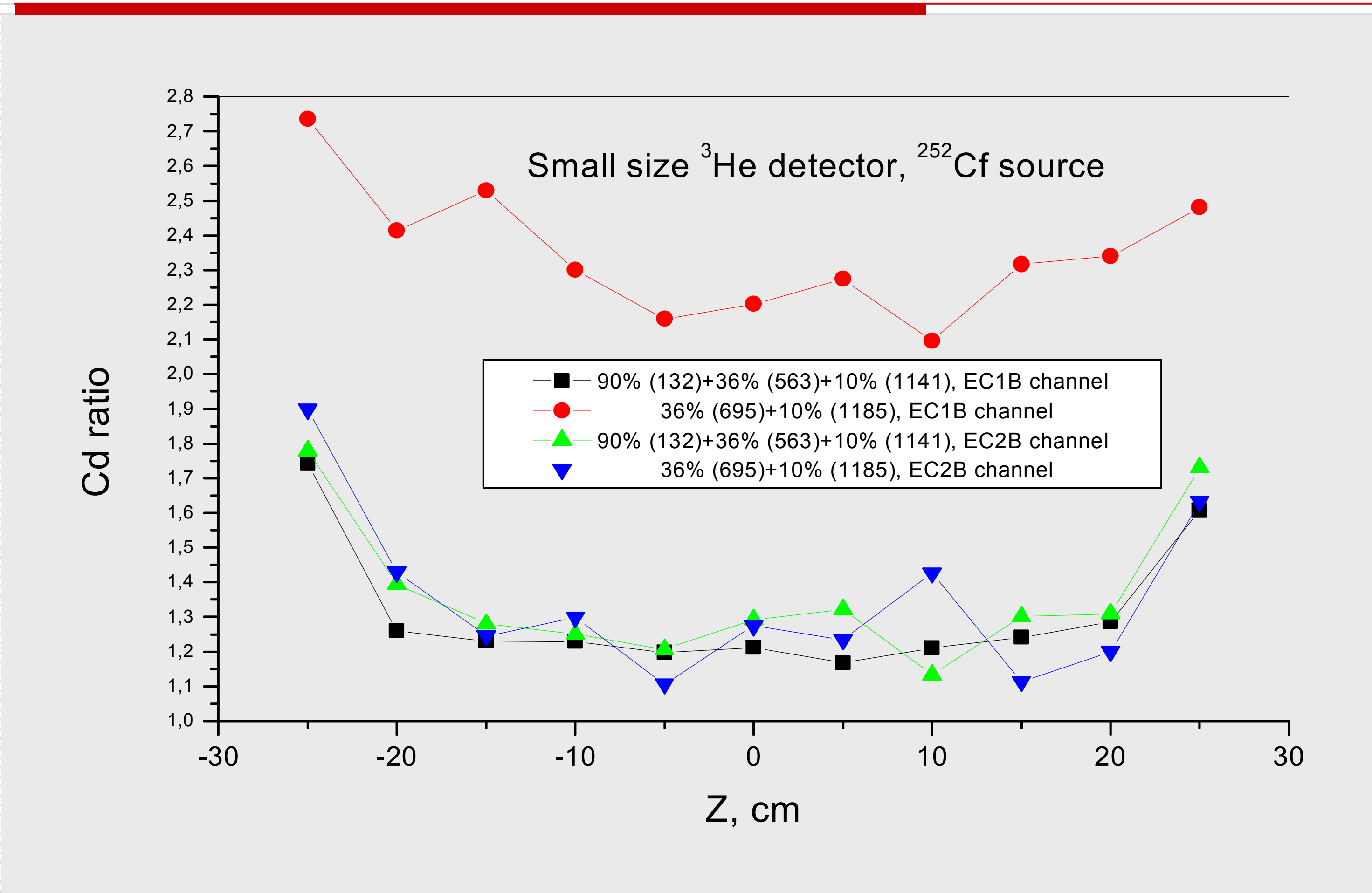


Counting rate of small size ^3He detector in the original and new core configurations of YALINA-Booster along the experimental channels EC3B and EC5T.





Cadmium ratio along the experimental channels EC1B and EC2B



Conclusion

The YALINA-Booster assembly is designed for performing ADS experimental studies. The experimental data are used to benchmark and validate methods and computer codes for designing and licensing ADS by external neutron sources. YALINA-Booster experiments performed during the conversion of the inner part of the fast zone to use nuclear fuel with reduced uranium enrichment reached the following conclusions:

- The reaction rate measurements in the different experimental channels performed during the fuel loading confirmed the validity of the selected procedure to load and start up the YALINA-Booster facility.

Conclusion (cont.)

- The experimental results obtained by the use of PNS area method improves as the effective multiplication factor exceeds 0.8. The delayed neutron fraction value is used based on calculations but it needs experimental verification.
- The discrepancy between the experimental (PNS method) and calculated effective multiplication factor is less than 0.5% without eliminating the spatial effects.
- Replacement of metallic uranium fuel of 90 % enrichment in the inner part of the fast zone by uranium dioxide of 36 % enrichment results in lower contribution of fast zone to the total reactivity of the assembly, softening neutron spectrum in the inner part of the fast zone.
- The kinetic parameters (neutron generation time, effective fraction of delayed neutrons, etc.) are defined by the thermal zone.
- Neutron spectrum in the thermal zone remains unchanged.

THANK YOU!

Questions and comments:

anna@sosny.bas-net.by