The calculation of the YALINA BOOSTER zero power sub critical assembly driven by external neutron sources: Brazillian contribution

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Abstract.
The YALINA-Booster is an experimental zero power Accelerator Driven Reactor (ADS), which consists of a sub-critical assemby driven by external neutron sources. It has a fast spectrum booster zone in the center, surrounded by a thermal one. The sub-critical core is driven by external neutron sources. Several experiments have been proposed in the framework of IAEA Coordinated Reserch Project (CRP) on ADS. This work shows results obtained by IPEN modelling and simulating experiments proposed at CRP, using the MCNP code. The comparison among our results, the experimental one and the results obtained by other participants is being done by CRP coordinators. This coolaborative work has an important role in the qualification and improvement of calculational methodologies.

Keywords: Nuclear Engeneering, Accelerator Driven Systems, Benchmarck
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INTRODUCTION

The ADS concept has been proposed by Bowman et al. in 1992 [1] for transmutating transuranics and long-lived fission products of spent nuclear fuel from Light Water Reactors. This concept takes advantage of the low capture to fission ratio of transuranics isotopes (TRU) on fast spectrum and the intrinsic safety due to the sub-criticality, allowing a high TRU fraction even with a lower delayed neutron fraction. The ADS can also be utilized for energy production, as proposed by Rubbia et al [2]. Until now, a power transmutation ADS had not been constructed, but experimental research has been performed using small research reactors, such as MASURCA [3], TRADE [4] and YALINA [10, 11]. This work shows obtained results for the YALINA-Booster facility as defined in the IAEA benchmark specifications [5].

THE YALINA BOOSTER FACILITY

The Yalina has been assembled at JIPNR of the National Academy of Sciences of Belarus. The facility description can be found in several reports, and shortly consists of a booster fast zone, enclosed by a thermal neutron zone, driven by a (d,d) or (d,t) neutron source at core center. The experiments in the framework of IAEA CRP and the calculations requested can be found in the technical specification [5]. In short,

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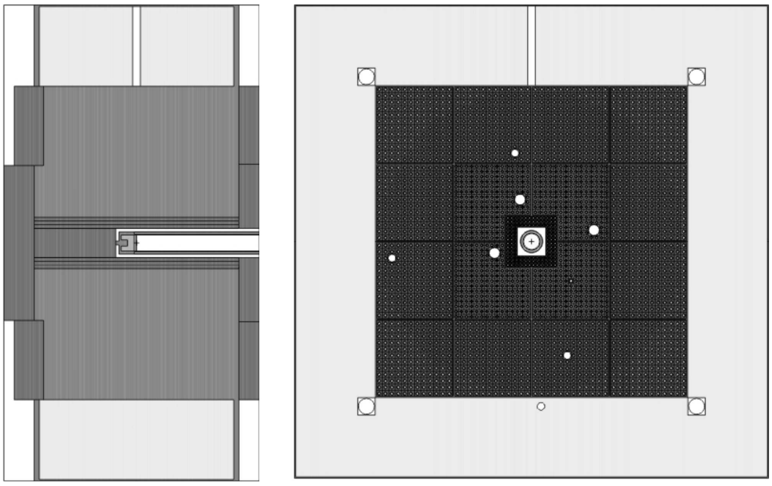

FIGURE 1. MCNP model, XZ (left) and XY (right)

the requested calculations are multiplication factors (k_{eff}), effective delayed neutron fraction (β_{eff}), neutron spectra and reactions rate distributions [6].

CALCULATIONAL METHODOLOGY AND RESULST

MCNP5 was utilized in all this benchmark exercise. MCNP is a general-purpose Monte Carlo transport code [7, 9], which uses a pointwise cross section. In this calculation all the cross sections comes from the ENDFB-VI evaluation at room temperature. Thermal treatment are accounted for using $S(\alpha, \beta)$ when avaliable, i.e, for graphite and polyethilene, or free-gas treatment. The cross section for ^{204}Pb is missing and this nuclide was accounted as the most abundant Pb isotope. The geometrical model provide by MCNP is showed in Fig. 1.

The k_{eff} has been evaluated by the KCODE mode of MCNP5, using 500 cycles of 10000 histories. We can define the prompt multiplication factor (k_{prompt}) as the calculated multiplication factor when delayed neutron fraction β is set to zero. For the effective delayed neutron fraction calculation (β_{eff}) was calculated as the ratio between k_{eff} and k_{prompt} [8]:

$$\beta_{eff} = \frac{k_{eff} - k_{prompt}}{k_{eff}} \tag{1}$$

The source multiplication factor was calculated using the average numbers of neutrons produced by each source neutron:

$$k_{src} = \frac{\langle P\phi \rangle}{\langle P\phi \rangle + \langle S \rangle}, \tag{2}$$

where P is the neutron production operator of Boltzmann equation, ϕ is the neutron flux and S is the neutron source, and the brackets denotes integration over all phase

TABLE 1. Neutronic Parameters

Neutronic Parameter	Value	Relative Error	Value	Relative Error
	config. 902 EK-10		**config. 1141 EK-10**	
k_{eff} (Fission Source)	0.93697	0.00005	0.98758	0.00005
k_{prompt} (Fission Source)	0.92995	0.00004	0.98019	0.00010
k_{src} (DD Source)	0.98273	0.01	0.99519	0.01
k_{src} (DT Source)	0.98910	0.01	0.99698	0.01
mean neutron generation time [μ s]				
(Fission Source)	93.5	1.8	86	2
prompt neutron lifetime [μ s]				
(Fission Source)	87.6	1.6	85.2	1.7
β_{eff} [pcm]				
(Fision Source)	749	16	748	15

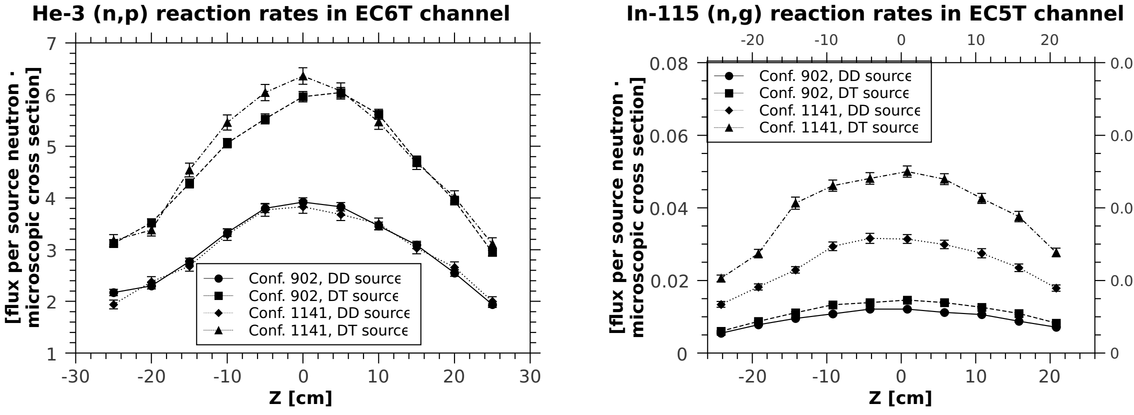

FIGURE 2. 3He(n,p) reaction rate in EC6T experimental channel (left) and 115In(n,g) in EC5T (right)

space. Table 1 contains the main neutronic integral parameters obtained and Fig. 2 and 3 show reaction rates and neutron spectra at thermal experimental channels.

CONCLUSIONS

The Yalina-Booster facility was modelled in detail and the tasks proposed in the specification were performed. Preliminary results agree with other participants results [10, 11] and comparisons with experimental data is being performed by the project coordinators. Two core configurations were modeled (902 and 1141 EK10 fuel rods), and coupled to different neutron sources. We have calculated axial and radial distributions, neutron spectra, and the neutron fluxes evolution after a neutron pulse for the two core configurations. Additional results and the comparison with experimental data will be published as an IAEA TECDOC.

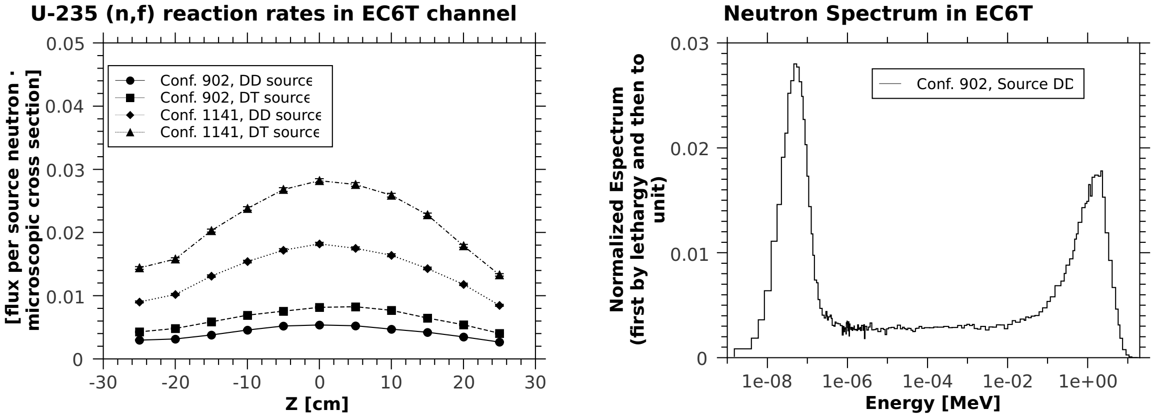

FIGURE 3. 235U(n,f) reaction rate at EC2B experimental channel (left), and neutron spectra at EC2B experimental channel (right) using DD source

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