Neutron Noise Measurements in the YALINA-Booster Experiments

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Abstract. In addition to the pulsed neutron source measurements and the continuous source beam-trip and current-to-flux measurements performed in the YALINA-Booster facility, also presented in this conference, a set of neutron noise measurements has been performed to achieve a complete characterization of the core. The neutron noise measurements have been performed in three different configurations covering a subcriticality range from 0.85 to 0.977. The Rossi-α neutron noise technique has been applied to detector counts from two channels in the thermal part of the core. The Rossi-α results are compared to the experimental prompt neutron decay constants obtained from the pulsed neutron source measurements. A first approach fitting procedure reveals a need of three exponentials to describe the Rossi-α histograms. It has been found that at deep subcriticality, the fundamental mode decay may coincide with or be close to a higher eigenmode, thus making it difficult to determine the prompt neutron decay constant correctly.

1. Introduction

A set of ^{252}Cf-based neutron noise measurements has been performed at the zero-power subcritical facility YALINA-Booster as a part of the IP-EUROTRANS experiments presented in this conference[1-3]. A preliminary Rossi-α analysis has been performed for three subcriticality levels of 0.977, 0.95 and 0.85 and the α-values are compared to those obtained through pulsed neutrons source (PNS) measurements[1].

2. Experimental Setup

The subcritical fast-thermal core YALINA-Booster[4] and its different configurations are described in detail in another paper of this conference[1]. However, for convenience the core is depicted in FIG. 1. Noise measurements have been performed for the configurations SC0, SC3a and SC6 using He-3 detectors with a length of 25 cm in the experimental channels of the thermal zone (EC5T, EC6T). A loading description of the configurations is given in TABLE I. The detectors have a dead time of about 3.5 μs for which the Rossi-α histograms in end must be corrected. Two different ^{252}Cf-sources of intensities $1 \cdot 10^5$ (INK5) and $1.5 \cdot 10^6$ (INK7) neutrons per second were used during the measurements. Data were collected by using a counter/timer that stores the arrival time of each event for subsequent analysis.

TABLE I: CORE CONFIGURATIONS.

	Zone and fuel enrichment				Expected[1] k_{eff}
	Inner booster		Outer booster	Thermal zone	
	90%	36%	36%	10%	
SC0	132	-	563	1141	0.977
SC3a	-	132	563	1077	0.950
SC6	-	132	563	726	0.850

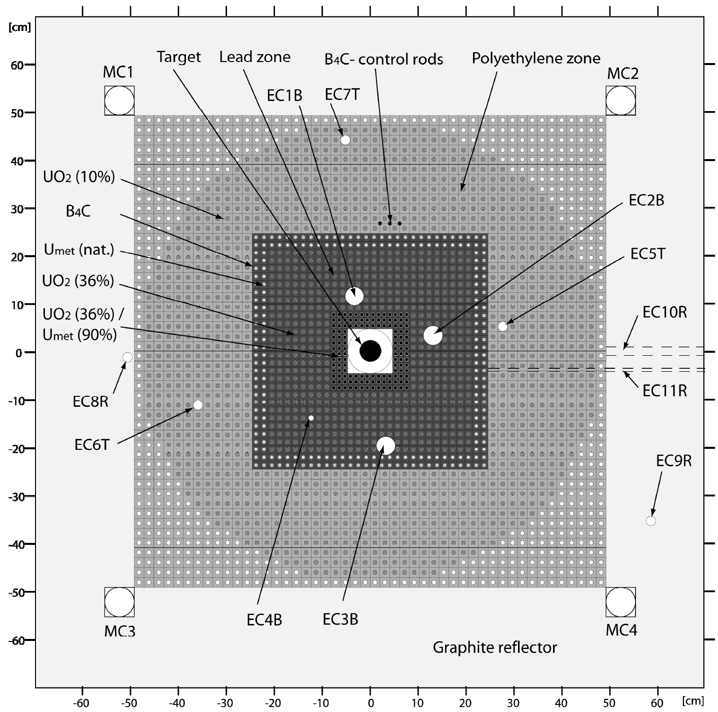

FIG. 1. Schematic cross-sectional view of the YALINA-Booster reactor core (SC0).

3. Experimental Results

3.1. Rossi-*α*

The one-energy group auto-correlation function, is described by

$$p(t)dt = -\frac{\varepsilon D_\nu}{2\alpha\Lambda^2} e^{\alpha t} dt + F\varepsilon dt \,, \tag{1}$$

where *p* is the probability density of having a second count after time *t* within *dt* given there was a count at time zero. Further, *ε* is the so called detection efficiency, describing the fraction of neutrons detected to all neutrons in the system, D_ν is the Diven factor given by

$$D_\nu = \frac{\overline{\nu(\nu-1)}}{\overline{\nu}^2} \tag{2}$$

and *F* is the neutron production rate in the system. Consequently *Fε* is the counting rate of the detector. The prompt neutron decay constant is given by

$$\alpha = \frac{\rho - \beta_{eff}}{\Lambda} \,, \tag{3}$$

with parameters commonly used in literature. By normalizing the probability density to the count rate and dividing by the bin size, the Rossi-*α* histograms, *R*(*t*), from different detectors, configurations or neutron sources can be compared to each other. At the same time, the often unknown detection efficiency cancels out:

$$R(t) = -\frac{D_\nu}{2\alpha\Lambda^2 F} e^{\alpha t} + 1 \,. \tag{4}$$

In the continuation, Eq. (4) will be referred to as the Rossi-*α* distribution or the auto-correlation.

3.2. Experimental Results

Rossi-α histograms grouped per configuration can be found in FIG. 2 to FIG. 4.

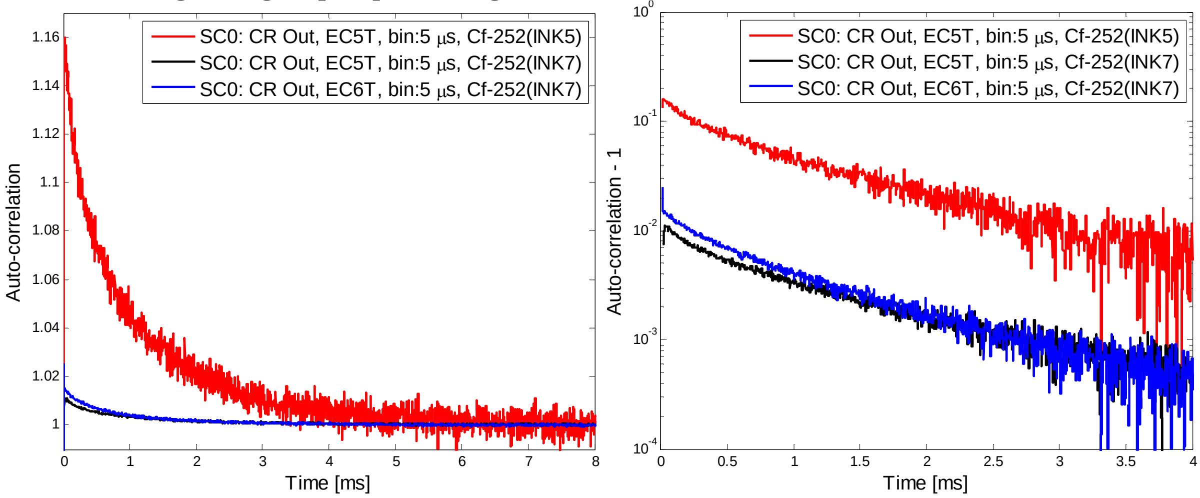

FIG. 2. Rossi-α histograms for configuration SC0.

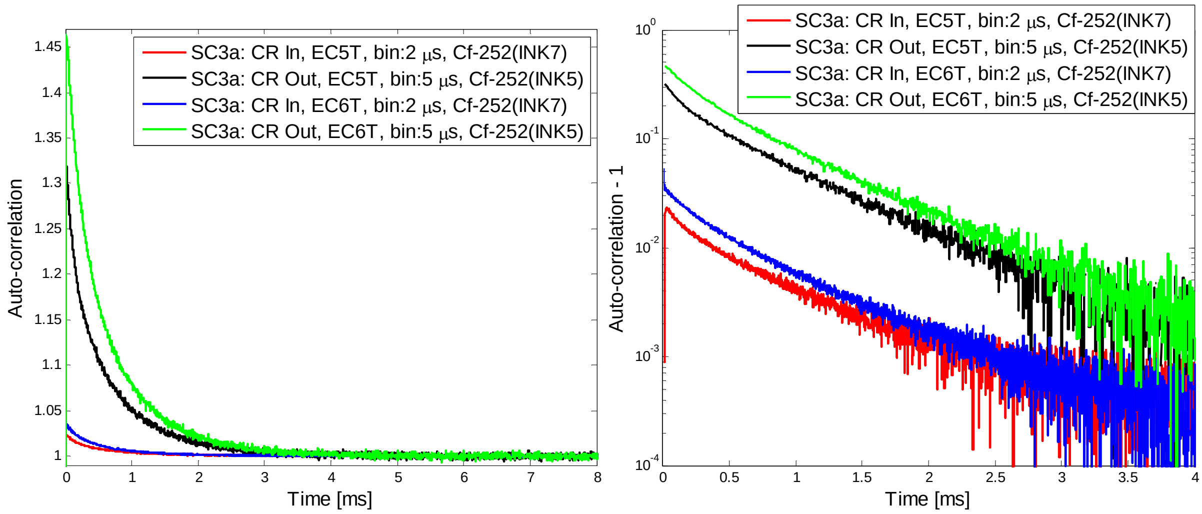

FIG. 3. Rossi-α histograms for configuration SC3a.

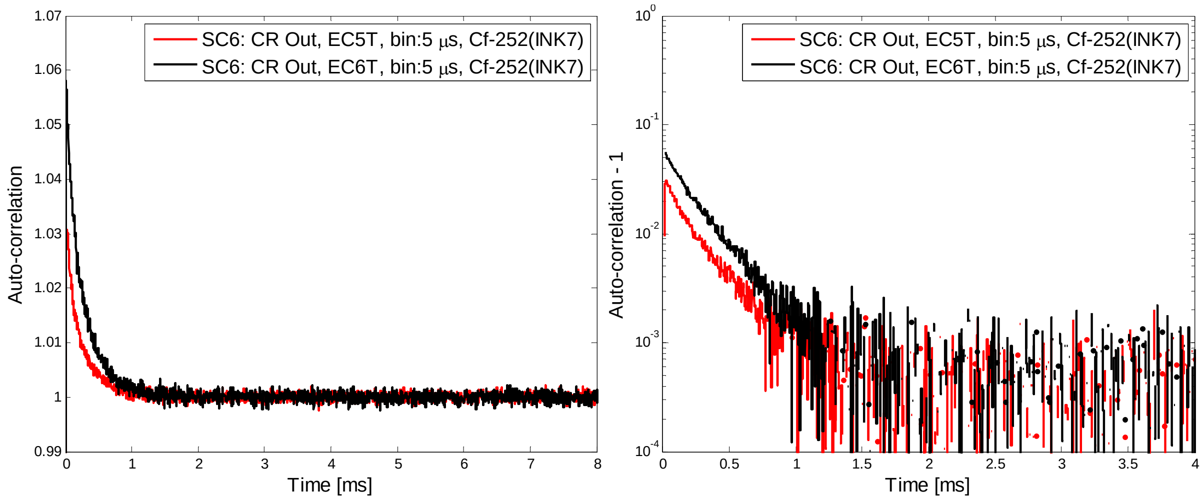

FIG. 4. Rossi-α histograms for configuration SC6.

As can be seen in FIG. 2 to FIG. 4, the Rossi-α histograms do not obey a single exponential decay as described by the one-group theoretical framework. In the fitting procedure it was found that three exponentials are needed to obtain a good fit for configuration SC0 and SC3a and two exponentials for configuration SC6. An example of fitting can be found in FIG. 5 and FIG. 6. The results are summarized in
TABLE II together with values from the PNS measurements[1]. Due to the limited time the higher eigenmodes are active (less than 1 ms), the accuracy of the fittings is low. Despite the high uncertainties some interesting observations can be done.

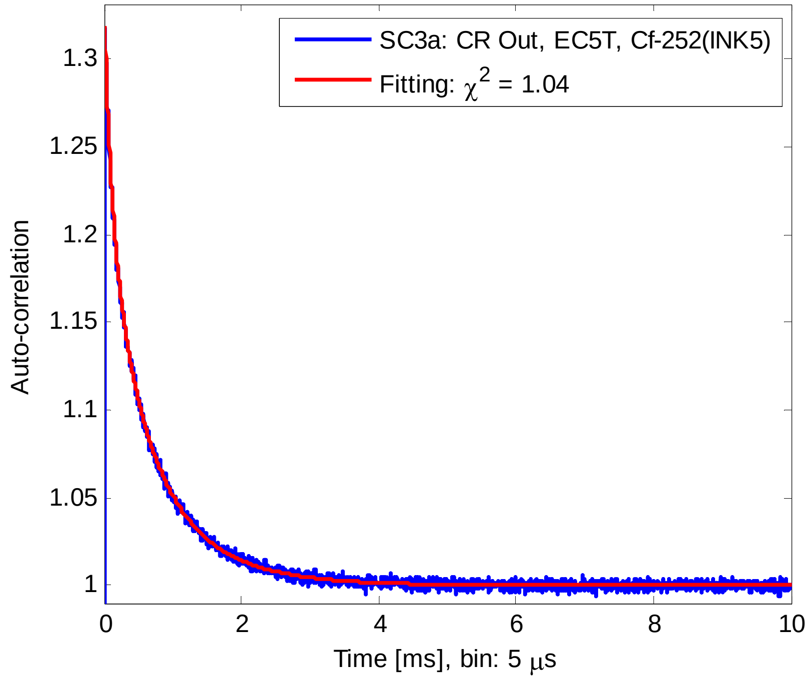

FIG. 5. Rossi-α histogram and fitting in linear scale.

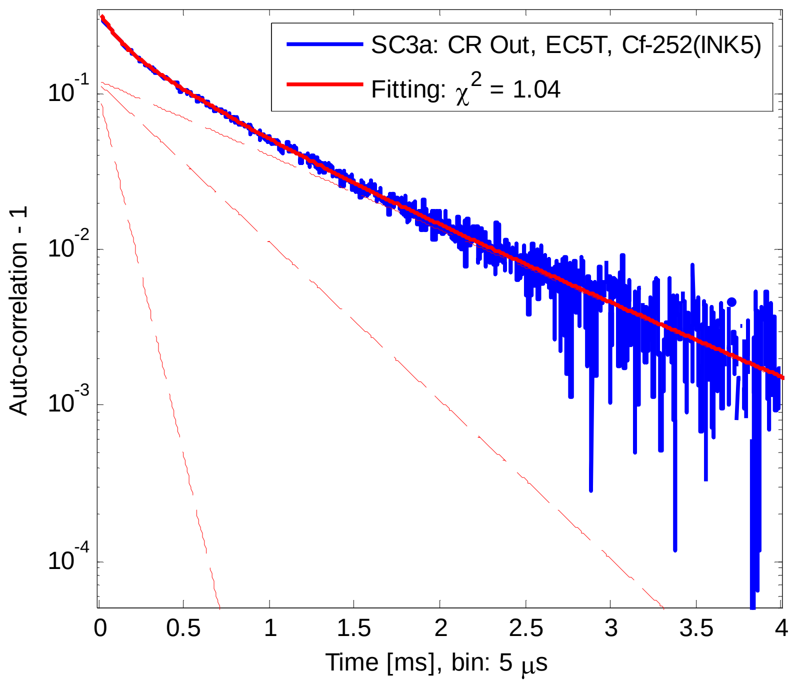

FIG. 6. Rossi-α histogram and fitting in logarithmic scale. The contribution from individual exponentials is indicated by dashed lines.

In FIG. 2 to FIG. 4 it can clearly be seen that the Rossi-α distribution reaches higher values in the correlated part (low t) when using the weak source (INK5). This is simply an effect of having F, which is proportional to the source strength, in the denominator of Eq. (4).
For SC0 and SC3a the prompt neutron decay constants from the PNS measurements seem to be reproduced by the Rossi-α measurements, however, a more precise analysis must be performed before making a fair judgement.
For SC6 the situation is more complex. It seems like the fundamental mode decay coincides with, or is close to, the higher eigenmode found the be around -2500 s^{-1} in the other configurations. This causes the observed α_0 to deviate strongly from the expected value obtained in the PNS measurement. Probably, the decay constant obtained through the Rossi-α measurement is biased and would give a false indication of the subcritical state. In this case, which is even worse, the Rossi-α measurement underestimates the reactivity level. Thus, using the Rossi-α technique during loading procedures in heterogeneous systems without detailed knowledge of possible higher eigenmodes is questionable.

TABLE II: EXPERIMENTAL RESULTS.

Conf.	EC	CR	Source	α_2 [s^{-1}]	α_1 [s^{-1}]	α_0 [s^{-1}]	α_{PNS} [s^{-1}]
SC0	EC5T	Out	INK5	-13025 ± 3411	-2737 ± 422	-694 ± 22	-638 ± 3*
			INK7	-9439 ± 12266	-2230 ± 2483	-707 ± 145	
	EC6T	Out	INK7	-7324 ± 21960	-2269 ± 2225	-700.26 ± 155	
SC3a	EC5T	In	INK7	-8938 ± 2521	-2071 ± 1085	-1096 ± 356	-1081 ± 15
		Out	INK5	-10781 ± 535	-2342 ± 230	-1102 ± 63	-1053 ± 9
	EC6T	In	INK7	-9589 ± 5447	-2679 ± 671	-1124 ± 132	-1091 ± 3
		Out	INK5	-6076 ± 520	-2188 ± 436	-1101 ± 96	See EC5T
SC6	EC5T	Out	INK7	-11391 ± 1336	-	-2997 ± 150	-2614 ± 13
	EC6T	Out	INK7	-9093 ± 1320	-	-3249 ± 140	See EC5T

* Estimation from measurements in EC1B and EC2B.

6. Conclusions

In the Rossi-α analysis of noise data from three configurations of the subcritical assembly YALINA-Booster it was found that there exist two higher eigenmodes in addition to the fundamental mode. For the most deep subcritical configuration SC6 one higher eigenmode coincides or is close to the fundamental mode, thus disabling the possibility to correctly extract the fundamental mode itself. This has an impact on the possibility to apply the Rossi-α method during core loadings since the reactivity can be underestimated. For SC0 and SC3a it seems like the prompt neutron decay constant from PNS measurements are reproduced, but more careful analysis is needed to make a fair judgement.

Acknowledgements

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