



Degradation of Si-based detectors parameters under long-term irradiation by ^{252}Cf fission products at room and liquid nitrogen temperatures



S. Bakhlanov^a, N. Bazlov^{a,b}, A. Derbin^a, I. Drachnev^a, O. Konkov^{a,c}, I. Kotina^a,
A. Kuzmichev^a, M. Mikulich^a, V. Muratova^a, M. Trushin^a, E. Unzhakov^a

Corresponding author e-mail: Mikulich_MS@pnpi.nrcki.ru

^a NRC "Kurchatov Institute" - PNPI, Gatchina, Russia

^b V.A.Fok Institute of Physics, St.Petersburg State University, St.Petersburg, Russia

^c Ioffe Physical-Technical Institute of the Russian Academy of Sciences, St. Petersburg, Russia

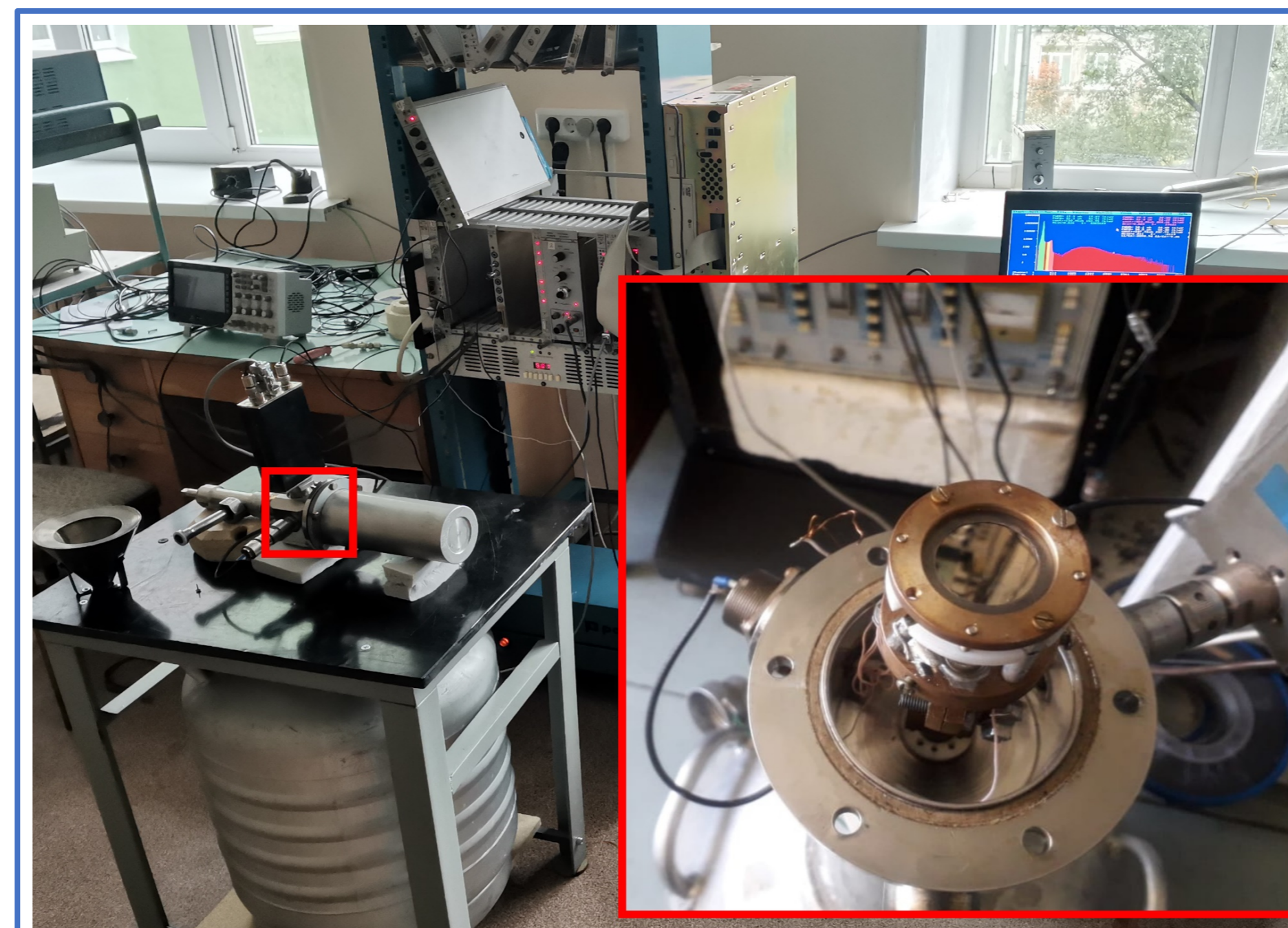
Motivation

A compact calibration neutron source is highly required for a number of current and future nuclear and astrophysical experiments. An appropriate solution could be considered in a combination of ^{252}Cf radionuclide source which undergoes α -decay and spontaneous fission, whereas each spontaneous fission event emits also a number of fast neutrons. With a semiconductor detector such type of solution could detect the fission fragments and provide a time reference of the neutron emission. However, performance of such neutron source could be considerably limited by the radiation defects created in the semiconductor detector during its operation period by the incoming fission fragments and α -particles.

The work goal

The primary objective of our work was focused on the investigation of Si(Li)-detectors degradation parameters under long-term irradiation by ^{252}Cf fission products at room and liquid nitrogen temperatures.

Experimental setup



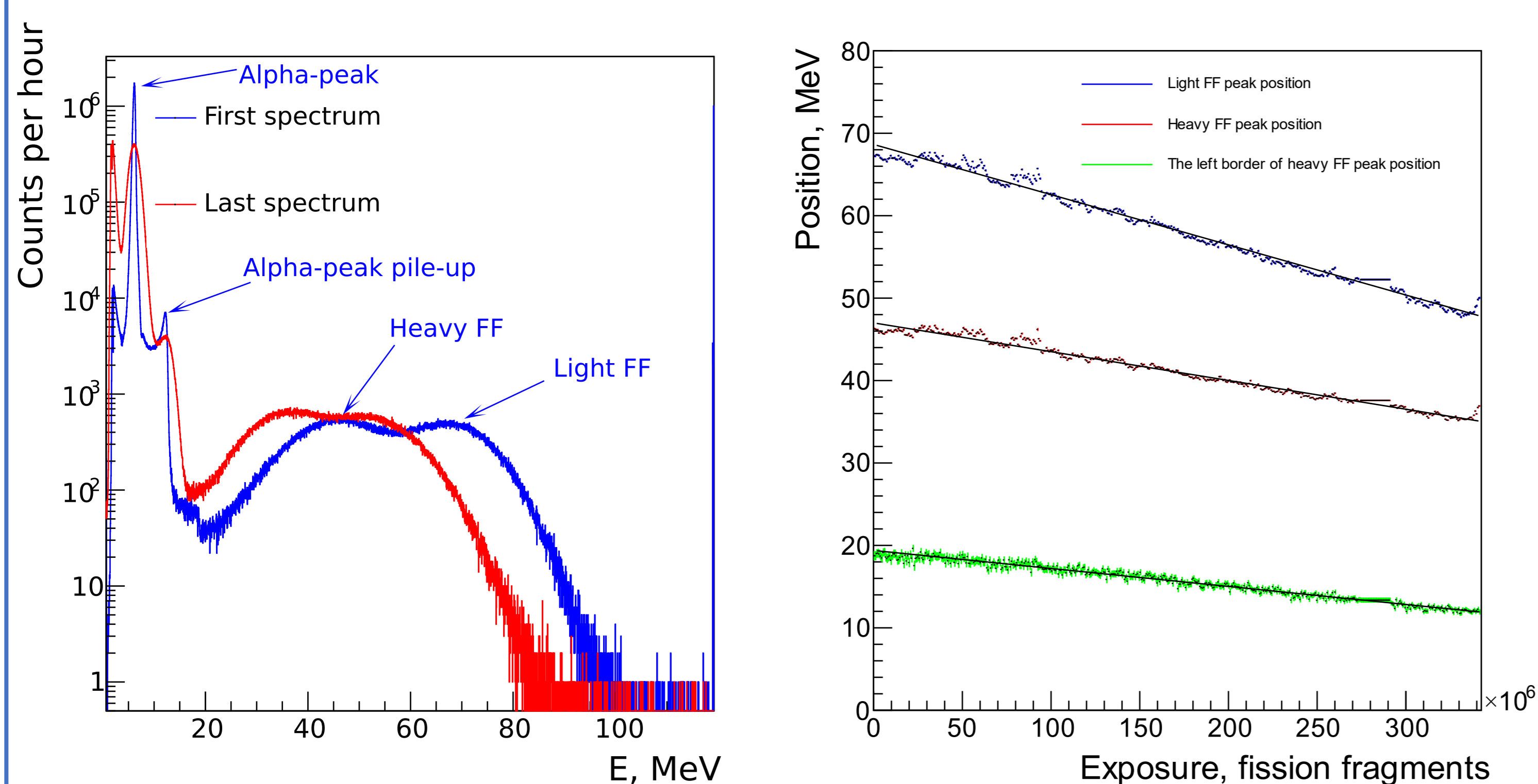
Two Si(Li)-detectors produced by PNPI were irradiated in vacuum chamber by ^{252}Cf fission products during 468 and 741 hours, respectively, at room (RT) and liquid nitrogen (LN) temperature. The resulted numbers of the registered fission fragments (FF) and α -particles were:

Detector 1 (RT) - 3.4×10^8 FF,
 1.5×10^{10} α -particles

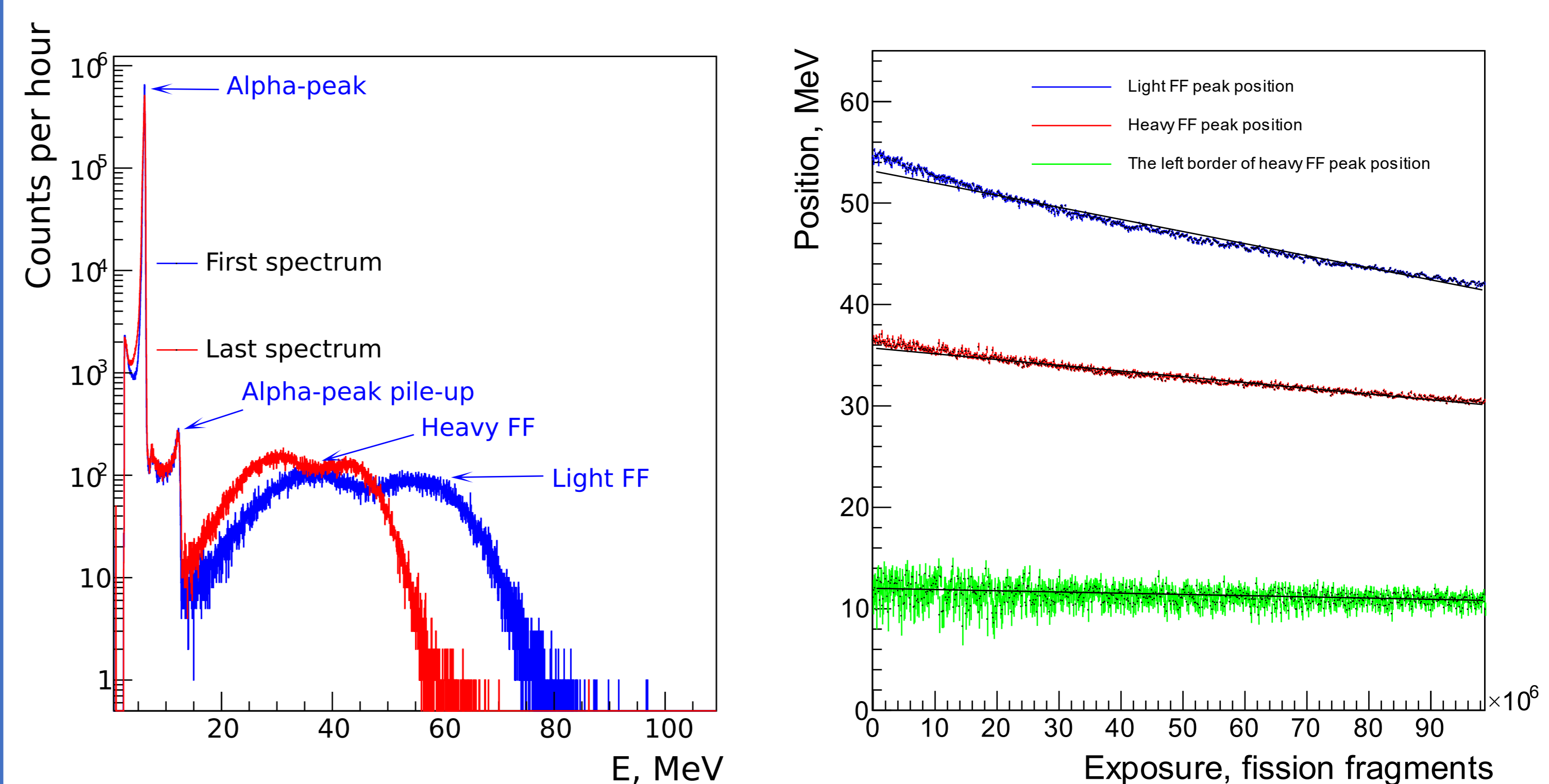
Detector 2 (LN) - 1.0×10^8 FF,
 45×10^{10} α -particles

Experimental results

Detector 1 (RT)



Detector 2 (LN)



Parameters comparison

	Light FF peak shift, keV/FF	Heavy FF peak shift, keV/FF	Border shift, keV/FF	Resource, FF	The border shift was calculated as follows: heavy FF position - 3σ . By the "degradation" of the detector we mean the moment, when α -peak and the left border of heavy FF peak is overlapped. Resource was calculated as $E_\alpha = aR + b$, where E_α - α -peak position; a, b - border shift approximation parameters; R - resource.
Detector 1 (RT)	-6.1×10^{-5}	-3.5×10^{-5}	-2.2×10^{-5}	$\approx 6.1 \times 10^8$	
Detector 2 (LN)	-12×10^{-5}	-5.7×10^{-5}	-1.2×10^{-5}	$\approx 4.9 \times 10^8$	

Summary

- As a result of prolonged irradiation by fission products of ^{252}Cf , a gradual energy-dependent shift of the energy positions of the fission fragments bumps towards the lower energies (i.e. the progressing pulse height defect) was observed, which proceeds nearly linear with the irradiation dose.
- Preliminary results indicate that the investigated detectors can sustain exposure of up to $\approx 5-6 \times 10^8$ (resource) of fission fragments.
- The degradation rates of Si(Li)-detectors operated at RT and LN temperature were found to be approximately equal. Higher rates of FF bumps shift revealed for Detector 2 could be explained by stronger pulse height defect on the non-irradiated Detector 2 as compared with that on Detector 1. Further experiments are necessary to clarify this problem.

References

- [1] N.V. Bazlov, et al., A Beta Spectrometer Based on Silicon Detectors, Instruments and Experimental Techniques, 2018, Vol. 61, No. 3, pp. 323-327
 - [2] M.V. Trushin, et al., Degradation of Si-based detectors parameters under the alpha-particle irradiation, LXX International conference "NUCLEUS - 2020", 11-17 Oct 2020, St. Petersburg.
 - [3] М.С. Микулич, и др., Изменение параметров Si(Li)-детекторов под действием α -частиц, Open Science 2020, Гатчина, 18-20 ноября, 2020
 - [4] Bakhlanov, S. V., et al., (2021). Influence of α -particles irradiation on the performance and defect levels structure of Al/SiO₂/p-type Si surface barrier detector. arXiv:2101.03729.
- The reported study was funded by RFBR, project number 20-02-00571.