Radiation damage experiments

Natalia Kopeć [1,*]; Marcin Bielewicz [2,3]; Sławomir Mianowski [2]; Lucio Fidel Rebolledo Herrera [4]; Edmundo Marquez [4]

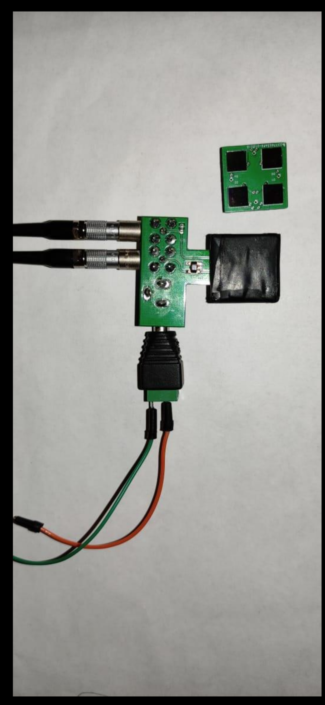
[1] University of Silesia, Katowice, Poland; [2] National Centre for Nuclear Research, Otwock, Poland;
[3] Joint Institute for Nuclear Research, Dubna, Russia; [4] Benemérita Universidad Autónoma de Puebla, Puebla, Mexico
* Contact Person: nataliakopec.fizyk@gmail.com

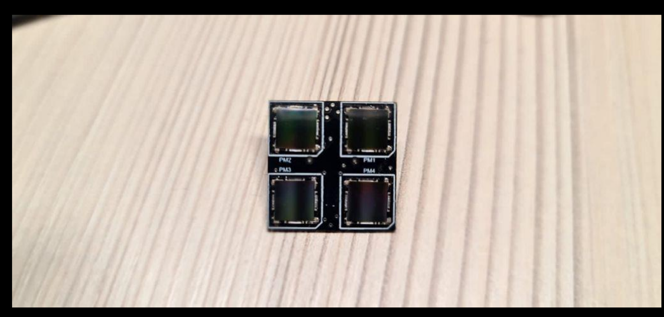
Abstract

The purpose of the current study was to investigate the effects of radiation on scintillators with SiPM sensors and electronics elements. These components will be part of the MCORD (MPD Cosmic Ray Detector) and miniBeBe (Beam to Beam central detector) subdetectors of MPD (Multi Purpose Detector) which is one of the main parts of the NICA collider new project. Three experiments were prepared in which the proton, neutron and heavy ion (Ar-40) beams were used to irradiate of those elements. Changes in the samples were checked during and after irradiation. The obtained results present significant changes in SiPMs and plastic scintillators performance.

Samples

To irradiation we used plastic scintillators, SiPM sensors and electronic board with amplifiers.





Conclusions

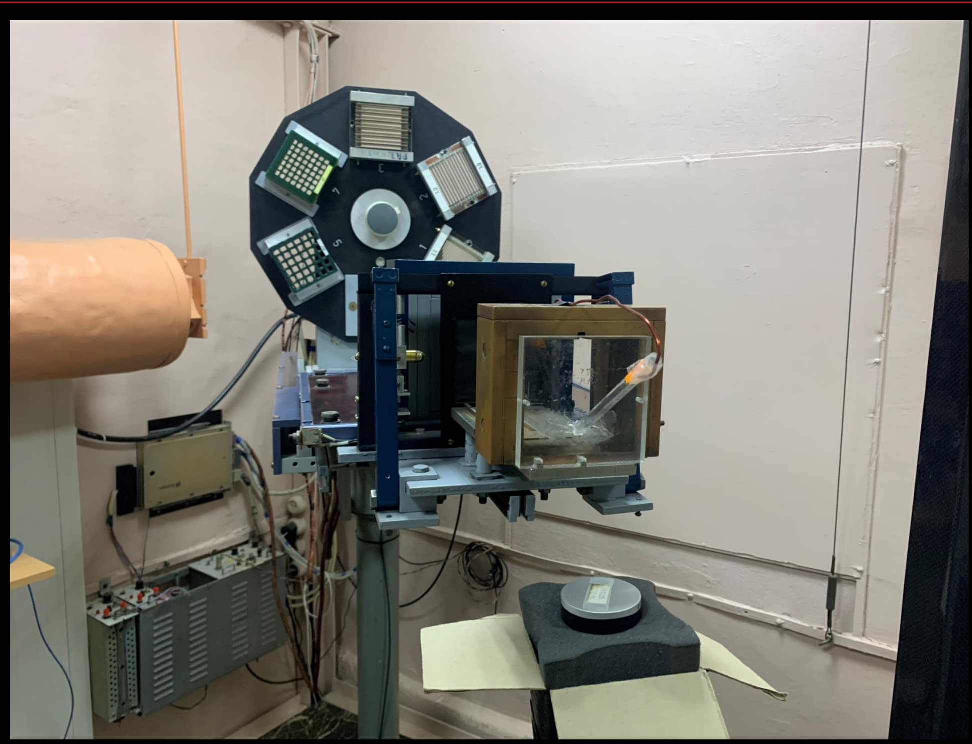
Experiments were carried out to check the effect of radiation on scintillators and electronic systems. The experiments were performed with the use of a proton beam from the LNP Lab Cyclotron "PHASOTRON", neutron beam from pulsed IBR2 fast reactor and heavy ion beam (Ar-40) from cyclotron on LNR laboratory in Dubna, Russia. The main purpose of the experiments was to check the level of sensitivity of components to various types of radiation. SiPM's sensitivity to neutron, proton radiation (previously known) and heavy ions was confirmed. During the first hour of irradiation of the elements with a neutron beam, we noticed big changes in the operation of the systems and finally elements have been destroyed. The obtained preliminary results show that SiPM sensors and electronic elements show much higher sensitivity than expected.

Proton beam

- Time of experiments: September 21 & 28, 2021
- Equipment: Cyclotron „PHASOTRON" and experimental chanell for medical purpose
- Beam: protons
- Energy: 150 MeV
- Intensity protons: 10^4- 10^7 n/s/cm^2

On September 21 the calibration factor was K = 9110 mU/Gy. The counting rate of the monitor chamber 2290 mU/min = 38.17 mU/sec corresponds to the proton flux n = $5*10^6$ cm $^{-2}$ sec $^{-1}$. September 21 samples were irradiated based on this dosimetric calibration.

Number of exposition	Time [s]	The counting rate of the monitor chamber [mU]	Flux [protons/ cm^2]
1	100	4681	0.591 $*10^9$
2	100	4681	0.591 $*10^9$
3	1000	46810	5.91 $*10^9$
4	1000	46810	5.91 $*10^9$
5	5573	2680860	32.93 $*10^9$
6	20	936	0.118 $*10^9$



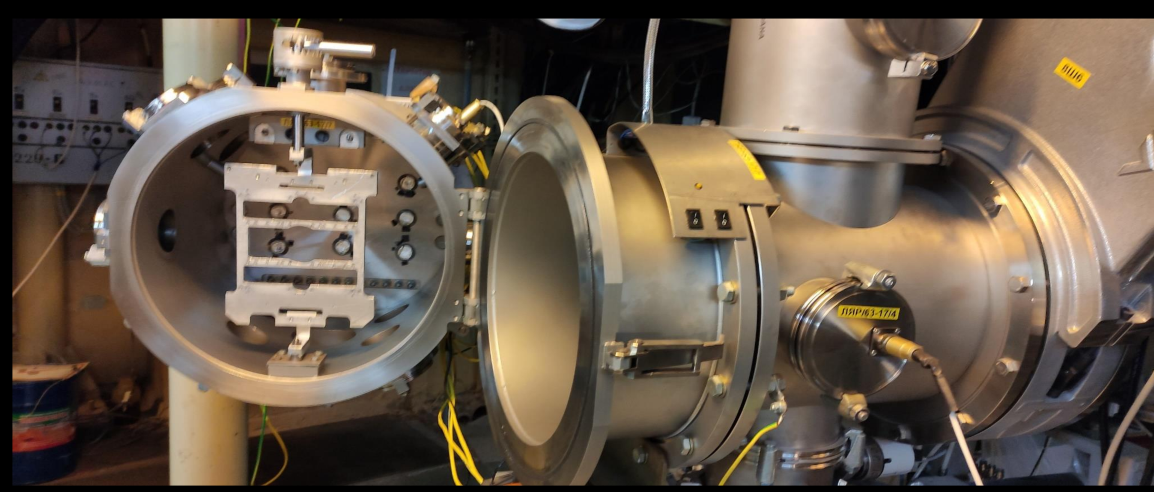
Neutron Beam

- Time of experiment: 20.IX-2.X.2021.
- Equipment: IBR2 vertical chanell of fast reactor
- Beam: Fast and neutrons
- Spectrum: Broad spectrum of neutron energies with a maximum of about 1-10 MeV
- Minimal Density Flux: 10^6 n/s/cm^2.
- Constant time of irradiation: 10^6 s
- Total fluence is 10^{12} n/cm^2.

Heavy Ion beam

- Time of experiment: 7.X.2021.
- Equipment: Cyclotron on LNR lab
- Beam: Ar - 40
- Energy: 13,26 MeV/n

Number of exposition	Time [s]	Fluency [m^{-2}]
1	23	~1,4*10^6
2	107	~5,06* 10^6
3	296	~5*10^6



Preliminary Results

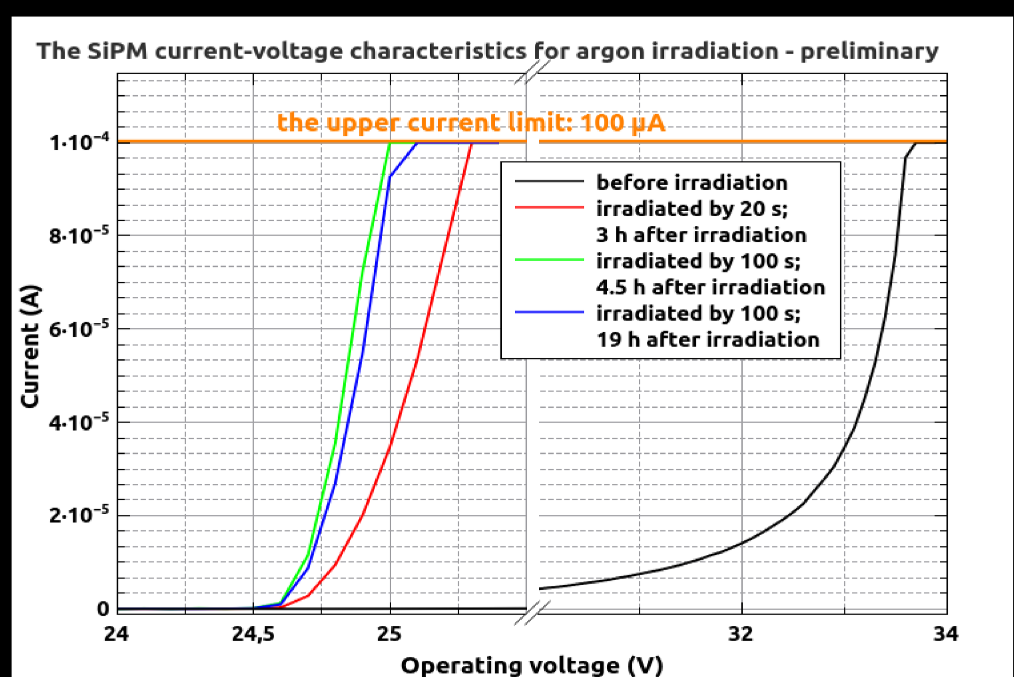


Fig.1 Preliminary SiPM current-voltage characteristics for argon irradiation. Changes in I–V characteristics with the increase in argon fluence (20 s and 100 s irradiation time).

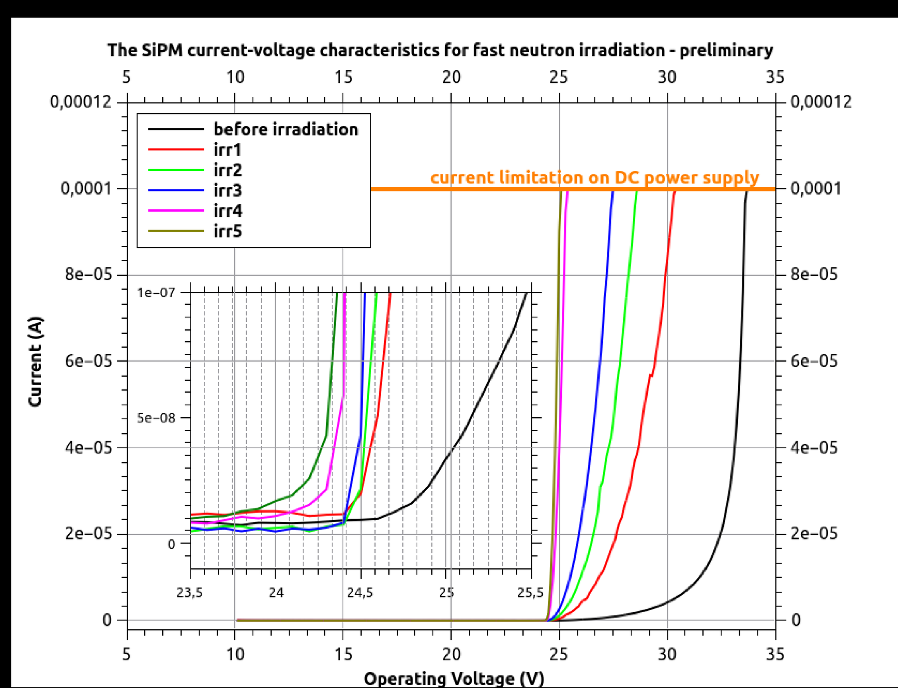


Fig.2 Preliminary current-voltage characteristics for SensL SiPMs measured during the neutron irradiation.

Changes in I–V characteristics with the increase in neutron fluence. The black curve shows the data before irradiation.

It is cleary seen very fast current increase, which is in agreement with data presented at [4] for different SiPM type.

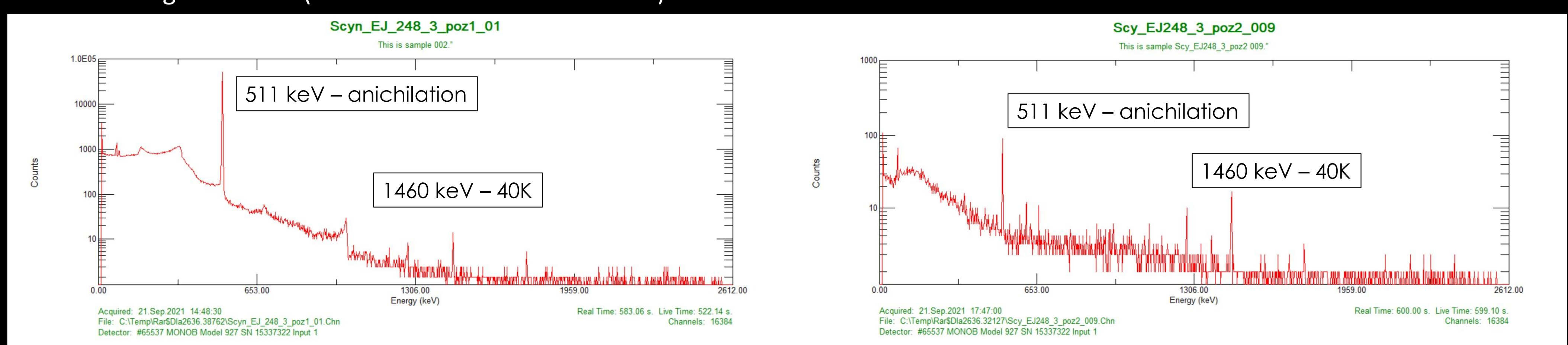


Fig.3 Examples of gamma spectroscopy of scintillators irradiated with a proton beam. The first measurement is about 20 minutes after the end of exposure (on the left). Second measurement around 2 hours after exposure (on the right).

References

1. V. Golovatyuk, V. Kekelidze, V. Kolesnikov, O. Rogachevsky and A. Sorin,The Multi-Purpose Detector (MPD) of the collider experiment,Eur. Phys. J. A (2016) 52: 212
2. M. Bielewicz et al. MCORD - MPD Cosmic Ray Detector a new features. In European Physical Journal Web of Conferences, volume 204 of European Physical Journal Web of Conferences, page 07016, September 2019.
3. R. Acevedo Kado et al., The conceptual design of the miniBeBe detector proposed for NICA-MPD, Journal of Instrumentation Vol.16(02) (2021) p.02002
4. S. Mianowski et al., Study of MPPC damage induced by neutrons, Nuclear Instruments and Methods in Physics Research, Volume 906, 21 October 2018, Pages 30-36

Acknowledgement

Thank you very much for all your help and active participation in the experiments to the equipment staff at the Laboratory of Neutron Physics, Laboratory of Nuclear Problems and Laboratory of Nuclear Reactions at the Joint Institute for Nuclear Research (JINR), Dubna.