Institute for High Energy Physics of
NRC Kurchatov Institute

THE POSSIBILITIES OF USING SAPPHIRE SENSORS FOR ION RADIATION THERAPY

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Relevance

1. High radiation resistance gives reason to believe that the element will not degrade over time;
2. It is necessary to develop new equipment within the framework of the Luch U-70 project based on the IHEP (Institute for High Energy Physics);
3. The development of new methods for detecting ionizing radiation is an important vector of technology development in the current geopolitical situation.

Sapphire as a sensitive element

Properties	Sapphire	CVD Diamond	Gallium arsenide
density g/cm^3	3,98	3,52	5,32
mosh hardness scale	9	10	4,5
resistivity Om*cm at 200°C	10^{14}	10^{11}	10^{7}
breakedown, V/cm	$\sim 10^{6}$	10^{7}	4×10^{5}
band gap, eV	9,9	5,5	1,43
ionization energy, eV	27-29,7	13	4,2
electron mobility, cm^2/(V*s) at 200°C	600	1500-2400	8500
the number of eh pairs formed by MIP per micron of mileage	22	36	150

Table.1. Comparison of sapphire, diamond and gallium arsenide parameters

Detector design

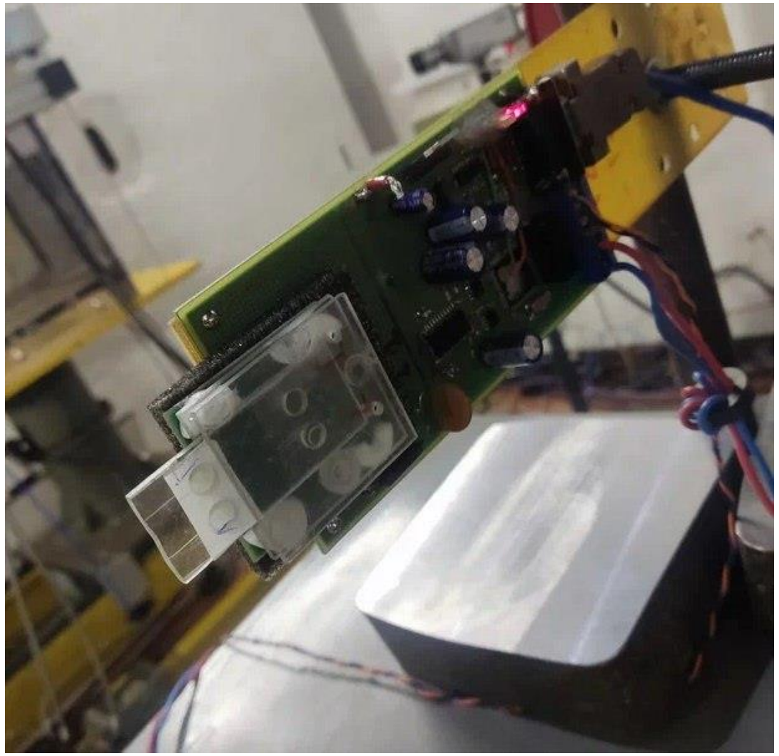

Fig. 1. A sample detector with two sensitive elements is installed along the beam

- The detecting system consists of a board with two sapphire sensing elements, a current source and an integrator.
- The two sensing element made of artificial single crystal sapphire has dimensions of 3x3 mm and a thickness of 150 microns.
- The captured signal (accumulated charge) is displayed in the program and recorded in a file.
- The integration time is chosen so that the entire particle discharge is recorded

Linear dependence of the signal on voltage

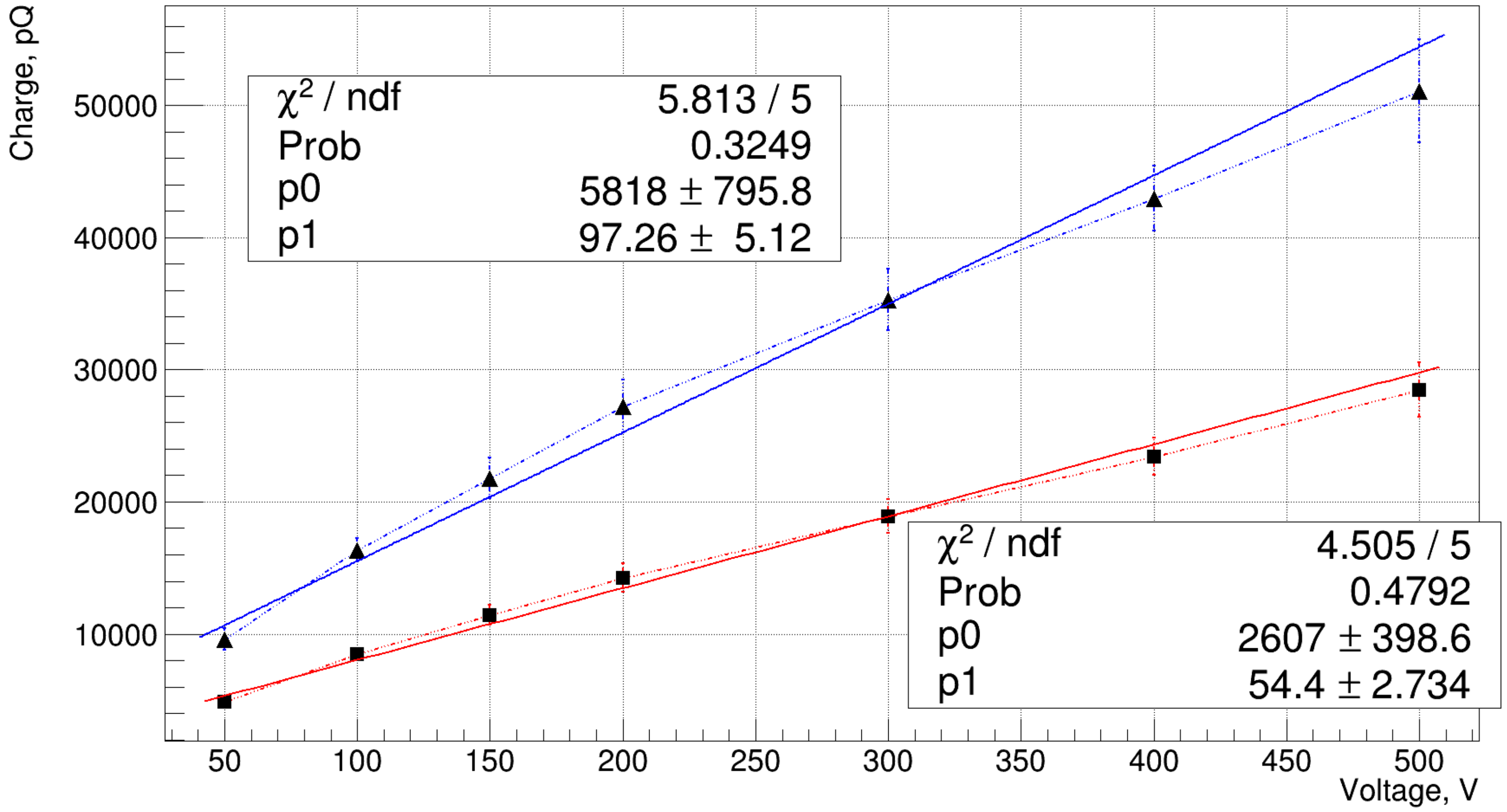

Fig. 3. Dependence of the detector signal on the applied voltage

Linear dependence of the signal on the intensity

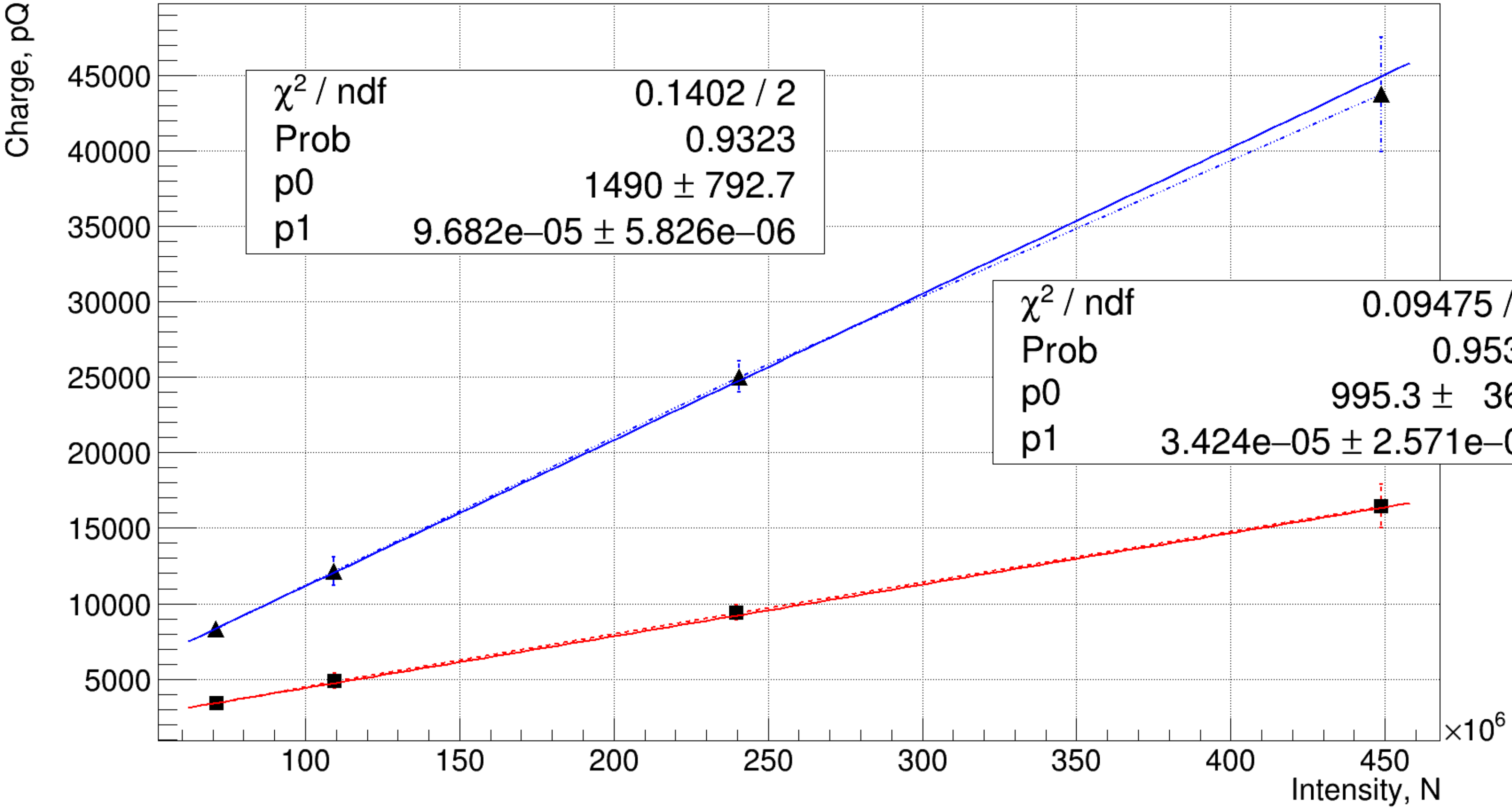

Fig. 4. Dependence of the detector signal on the intensity of the particle beam

Overview of the first results

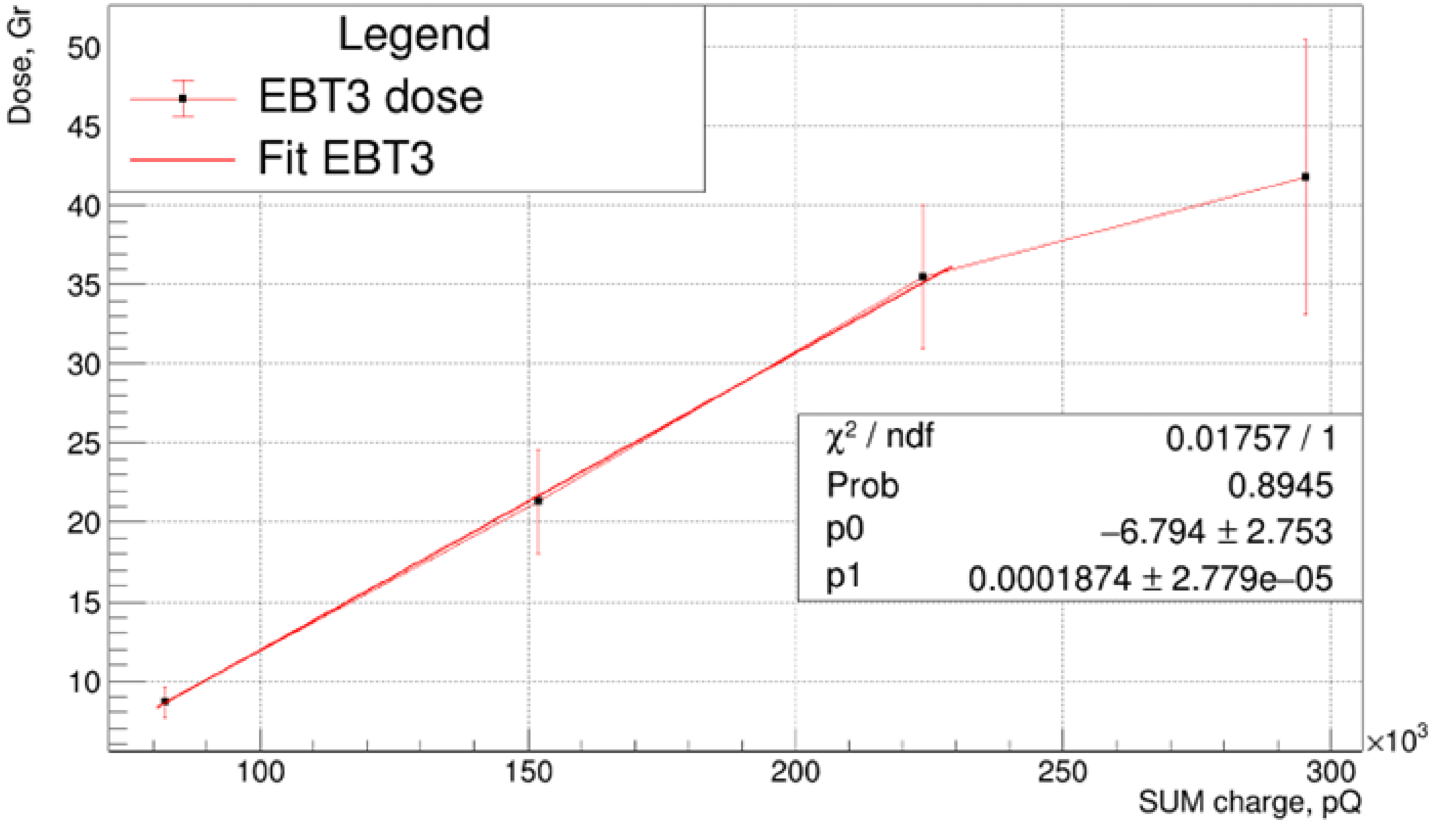

Fig. 5. Calibration dependence of the absorbed dose in the EBT-3 film and the registered charge in the sapphire detector.

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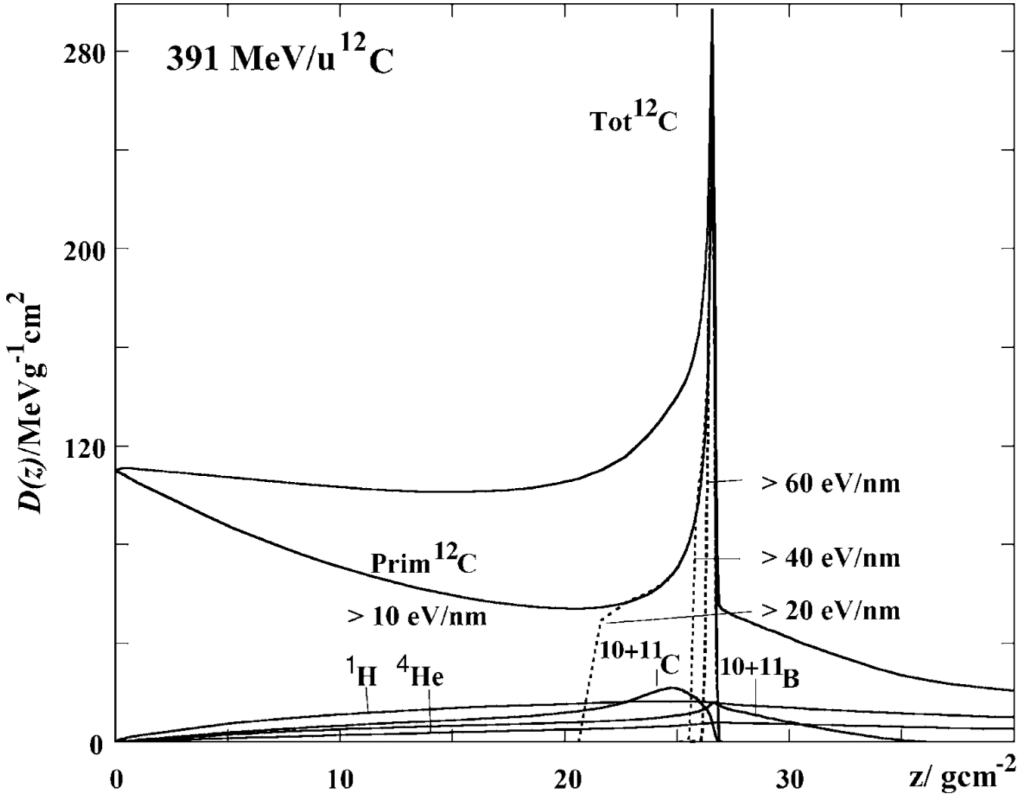

Fig. 7. Modeling of the contribution to the dose from fragments with a small LET.

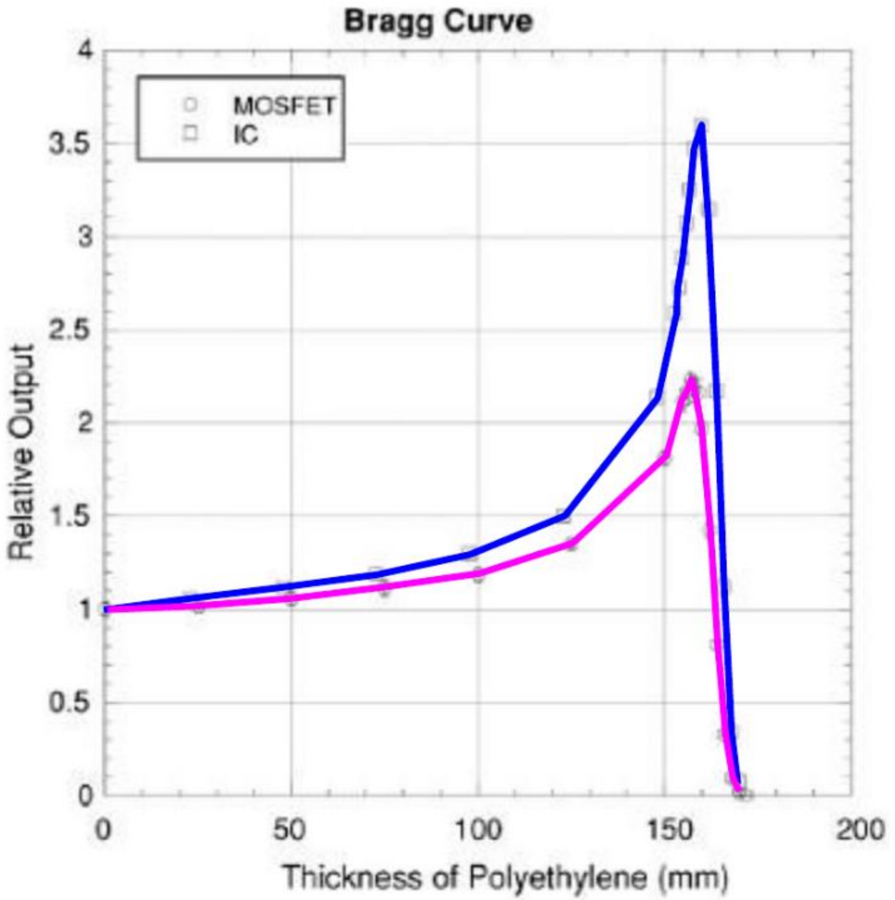

Figure 8. Demonstration of the differences between Bragg peaks for MOSFET and Silicon detectors.

Рис. 7. Johanna Kempe at al 2007 Med. Phys. 34 https://doi.org/10.1118/1.2400621 Рис. 8. Kahno et al 2006 Phis Med Biol 51:6070

The first Bragg Peaks received

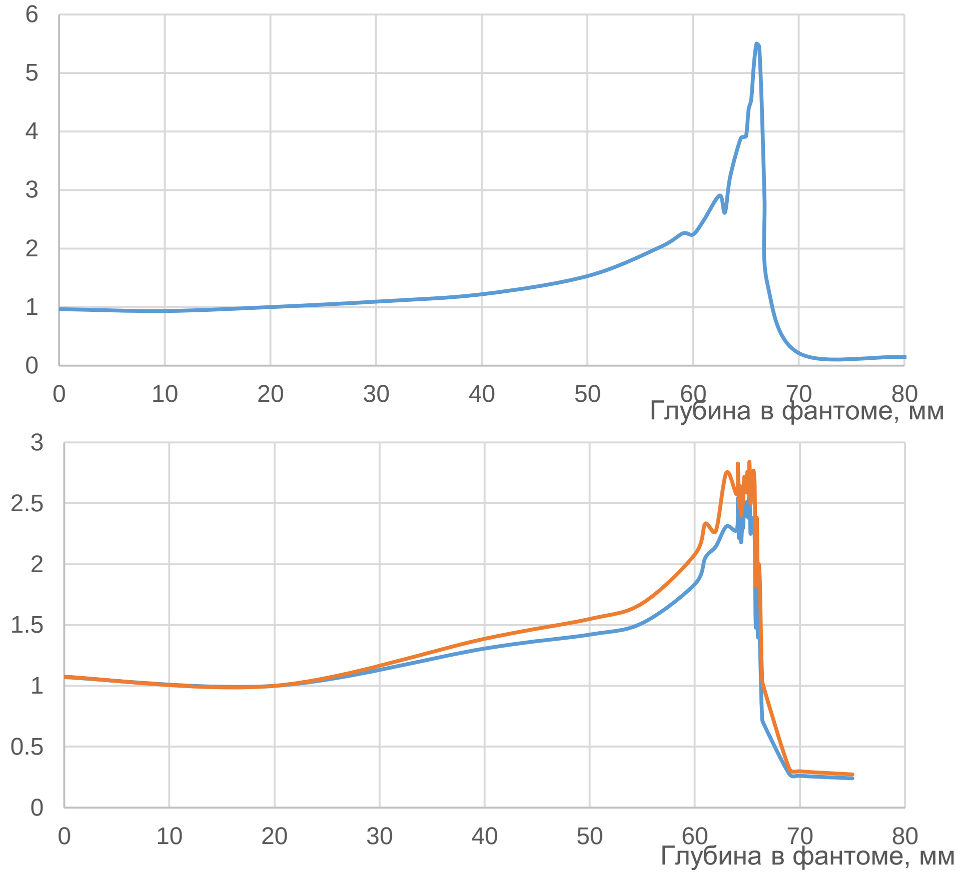

Fig. 9.

Experiments to measure the path of a beam of carbon-12 ions with an energy of 400 MeV per nucleon was carried out in an water phantom.

The top picture shows the Bragg Peak obtained using the PTW ionization chamber.

In the lower picture, the Bragg peak is obtained with the help of a two-channel sapphire detector.

Conclusion

1. A sample of a sapphire single crystal was tested on a carbon beam of the U-70 accelerator;
2. The first data was obtained with a new promising sample of a sapphire-based detecting material;
3. The ways of further use of sapphire-based detectors for the development of medical beam monitoring systems for the Luch U-70 project are outlined.

Thanks for your attention!

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