ESTIMATION OF THE EFFICIENCY OF BIOLOGICAL SHIELDING FOR THE CIRCULAR HALL OF U-70 ACCELERATOR AT IHEP

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Abstract

Report presents estimation of biological shielding efficiency for annular hall of U-70 accelerator. Distribution of neutron flux in concrete shielding of proton accelerator measurements carried out by method of long-lived isotopes specific activity determination. The experimental data may be compared with Monte-Carlo simulation.

INTRODUCTION

During construction of the new medical channel for carbon ions beam extraction the side concrete shielding of the accelerator was disclosed. We have got a good opportunity to measure depth distribution of the gamma-activity of the shielding on the height of 10 cm from the beam orbit plane. Such measurement allows us to estimate efficiency of the neutron radiation attenuation in the biological shielding of accelerator.

GEOMETRY OF MEASUREMENTS AND BOUNDARY CONDITIONS

Cross-section of the U-70 side shielding is shown in Fig.1. This shielding was partly disclosed for the new channel construction. Point M corresponds to the internal target 35/1 of channel #18. This target was working during previous run of U-70 since 09 to 21.04.2012. Berillium target (with 3×3 mm2 cross-section and 30 mm length) was irradiated by 5×1011 protons with 50 GeV energy during every 9.7 sec cycle. Induced radioactivity was measured along lines 1-4 in the Fig. 1. Measurements were done on the surface of concrete blocks at the level of 2 m from the floor. Beam orbit is laying at the level of 2.15 m from the floor. Blocks were removed from the shielding for the measurements to improve background conditions. One can see measurement points marked, detector and its shielding.

GAMMA-SPECTROMETER

Scintillation gamma-spectrometer with NaI(Tl) crystal was used for the measurements. Crystal size is 40×40 mm2, it was equipped with PMT XP 2212. Parameters were measured in operational conditions, with 50 m cable and rate ~ 103 Hz. 43 calibration sources were used.

GAMMA-ACTIVITY OF THE CONCRETE

Measurements were done in two concrete blocks along lines 1-4 (see in Fig. 1) in set of points placed in 25.4 cm from each other. Typical gamma spectrum is shown in Fig. 2. Two isotopes – ^{22}Na and ^{54}Mn – could be easily identified. ^{22}Na is created by the fast neutrons with energy threshold 13 MeV in the reaction ^{23}Na(n, 2n)^{22}Na, and ^{54}Mn in the reactions ^{55}Mn(n, 2n)^{54}Mn with 11 MeV threshold and ^{54}Fe(n, p)^{54}Mn with 1.5 MeV threshold [1-2]. ^{24}Na is presented in cement, ^{55}Mn and ^{54}Fe are presented in cement, gravel and steel fixtures.

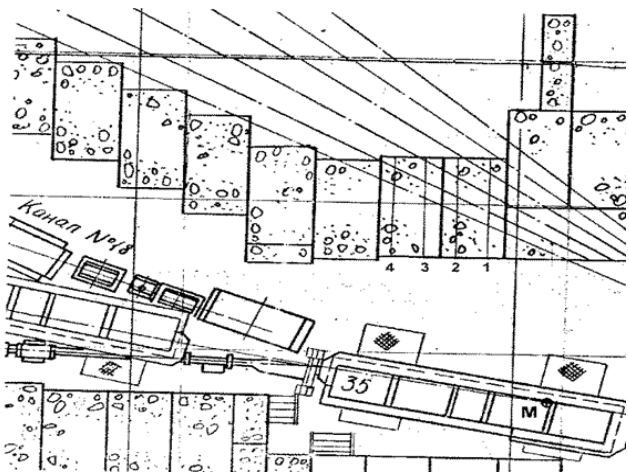

Figure 1: Accelerator equipment and shielding layout in the U-70 circular hall in the region of 34, 35 and 36th magnet blocks.

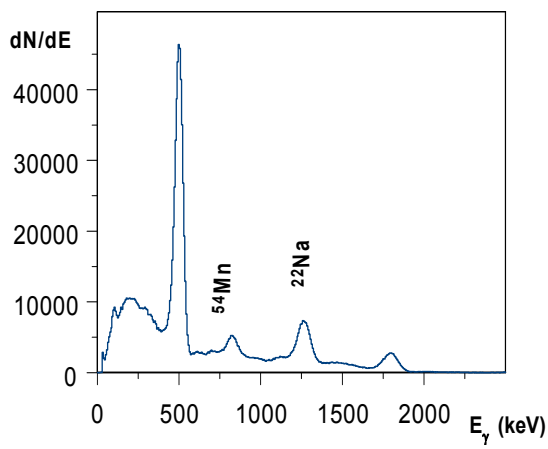

Figure 2: Gamma-spectrum measured on the concrete surface.

ABSOLUTE ACTIVITY OF ^{22}NA AND ^{54}MN ISOTOPES IN CONCRETE

Detector is placed on the concrete surface and measure number of gamma rays (N_γ) in the point from the semi-infinite layer of concrete.

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If specific activity of the concrete (q, in Bq/kg) can be treated as a constant in the vicinity of the point of measurement, Nγ value is equal to 2π×q/μ, where μ is the linear coefficient of gamma rays attenuation in the concrete. Practically detector can "see" semi-spherical volume of the concrete with radius equal to 1/μ.

For ^{22}Na (E_γ = 511 keV) L is equal to 4.87 cm, for ^{22}Na (E_γ = 1274.537 keV) L is equal to 7.53 cm, and for ^{54}Mn (E_γ = 834.838 keV) L is equal to 6.15 cm. Activity measurements with E = 511 keV is most suitable for coordinate resolution, because in this case detector can see less volume of concrete. ^{22}Na is a positron-active nucleus with positron mean energy ~ 200 keV. Range of such e^+ in concrete is near 250 um [3], therefore point of 511 keV photon generation is coincides with ^{22}Na nucleus. Measurements of such photon in the spectrometric mode indicates that this photon does not interact between generation point and detector.

Number of pulses in the total absorption peak for E_γ = 511 keV at all points of measurements are presented in Appendix 1. The same data are presented in the normalized form as a distribution of specific ^{22}Na activity along the side concrete shielding.

CONCLUSION

Result of the measurements can be used for the estimation of U-70 accelerator shielding residual radioactivity, and for the tests of shielding codes.

REFERENCES

[1] Table of Radioactive isotopes. E.Browne and R.B. Firestone. 1980

[2] Table of Isotopes. Seventh ed. By C.M. Lederer and V.S. Shirley, 1978

[3] J.H. Hubbel. Photon mass attenuation and energy-absorption coefficients from 1 keV to 20 MeV. Int. J. Appl. Radiat. Isot. Vol.33, pp.1269 to 1290, 1982

APPENDIX

Table 1: Counts rate in the full absorption peak for Eγ = 511 keV. Measurements along the Line #1.

point	file	L, (cm)	L, (g/cm^2)	S, puls/s	Uncer-tainty,%
1	act157	25.4	59.7	32.06	4
2	act158	50.8	119.4	15.00	4
3	act159	76.2	179.1	7.96	7
4	act160	101.6	238.8	4.34	6
5	act161	127.0	298.5	2.34	7
6	act162	152.4	358.1	1.43	11
7	act163	177.8	417.8	0.79	11
8	act164	203.2	477.5t	0.42	23

Table 2: Counts rate in the full absorption peak for Eγ = 511 keV. Measurements along the Line #2.

point	file	L, (cm)	L, (g/cm^2)	S, puls/s	Uncer-tainty,%
1	act147	25.4	59.7	43.78	3
2	act148	50.8	119.4	20.43	4
3	act149	76.2	179.1	10.59	5
4	act150	101.6	238.8	6.35	5
5	act151	127.0	298.5	2.81	8
6	act152	152.4	358.1	1.80	12
7	act153	177.8	417.8	1.08	12
8	act154	203.2	477.5t	0.63	23

Table 3: Counts rate in the full absorption peak for Eγ = 511 keV. Measurements along the Line #3.

point	file	L, (cm)	L, (g/cm^2)	S, puls/s	Uncer-tainty,%
1	act124	25.4	59.7	61.94	3
2	act125	50.8	119.4	31.67	6
3	act126	76.2	179.1	15.57	6
4	act127	101.6	238.8	9.96	12
5	act128	127.0	298.5	4.14	10
6	act130	152.4	358.1	2.65	15
7	act131	177.8	417.8	1.59	25
8	act132	203.2	477.5t	0.93	40

Table 4: Counts rate in the full absorption peak for Eγ = 511 keV. Measurements along the Line #4.

point	file	L, (cm)	L, (g/cm^2)	S, puls/s	Uncer-tainty,%
1	act137	25.4	59.7	68.92	2
2	act138	50.8	119.4	28.34	4
3	act139	76.2	179.1	16.02	6
4	act140	101.6	238.8	8.48	7
5	act141	127.0	298.5	4.62	7
6	act142	152.4	358.1	2.66	7
7	act143	177.8	417.8	1.37	10
8	act144	203.2	477.5t	0.92	16

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