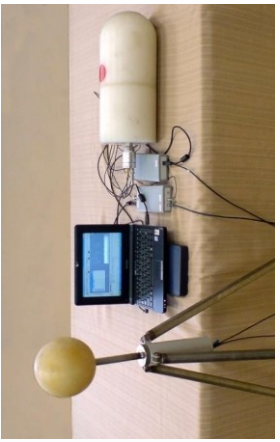


Neutron Fields Measurements at the IREN Facility Behind Biological Shielding

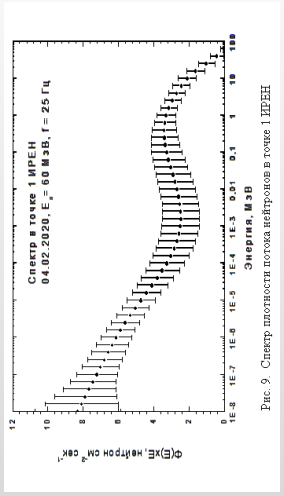
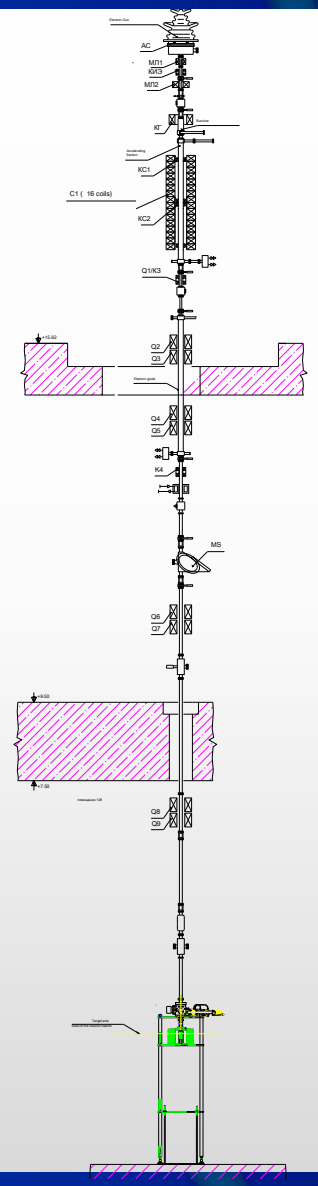
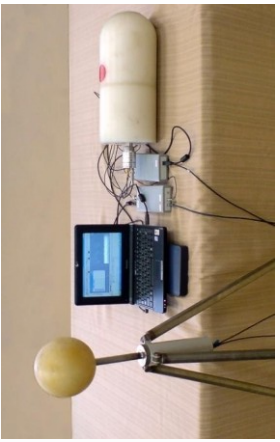


Рис. 9. Спектр плотности потока нейтронов в точке 1 ИРЕН



Yakubov Timur, Timoshenko Gennady, Shvetsov Valery

Department of Radiation Safety, Radiation Biology Laboratory and Frank Laboratory of Neutron Physics, JINR



Content

- IREN status;
- Neutron spectrometry with Bonner spheres;
- JINR Bonner spectrometer;
- Neutron spectra unfolding;
- Experiment and results;
- Conclusion;

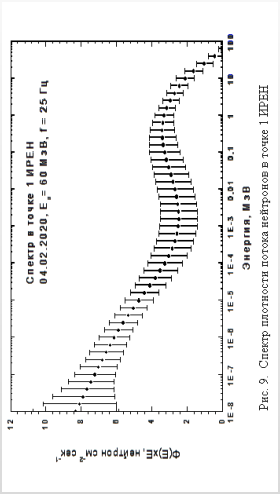
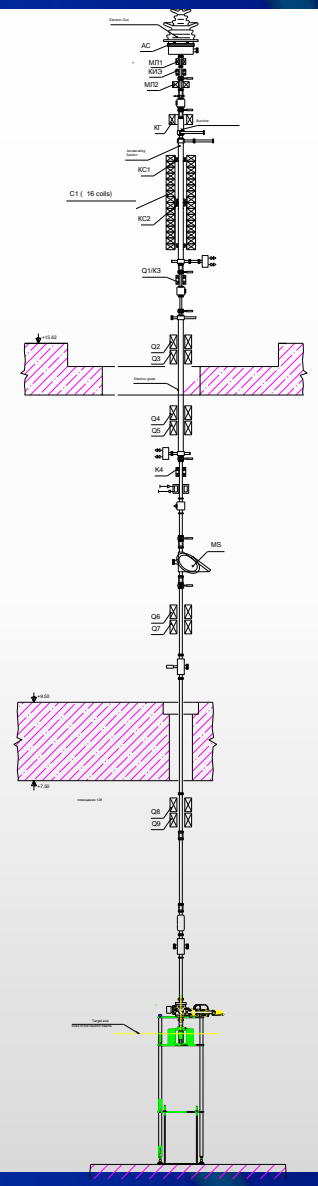
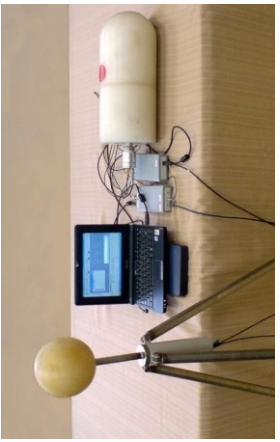
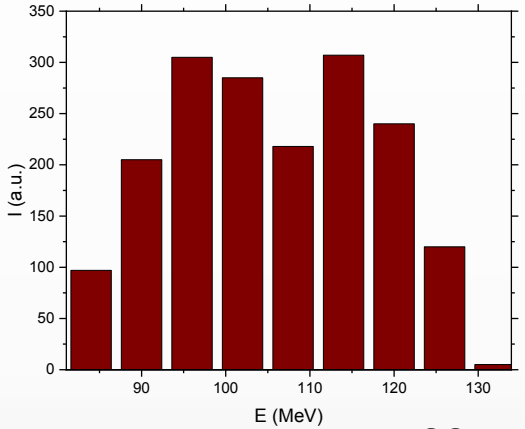


Рис. 9. Спектр плотности потока нейтронов в точке 1 ИРЕН





IREN current status



Electron spectra, E_{av} ~100 MeV

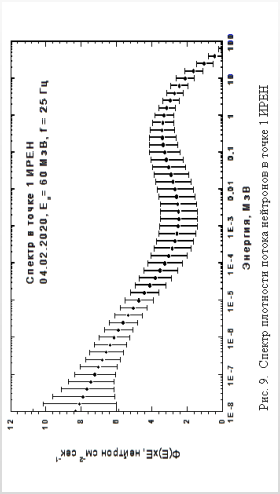
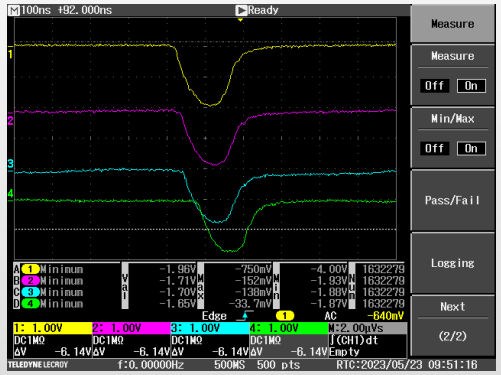
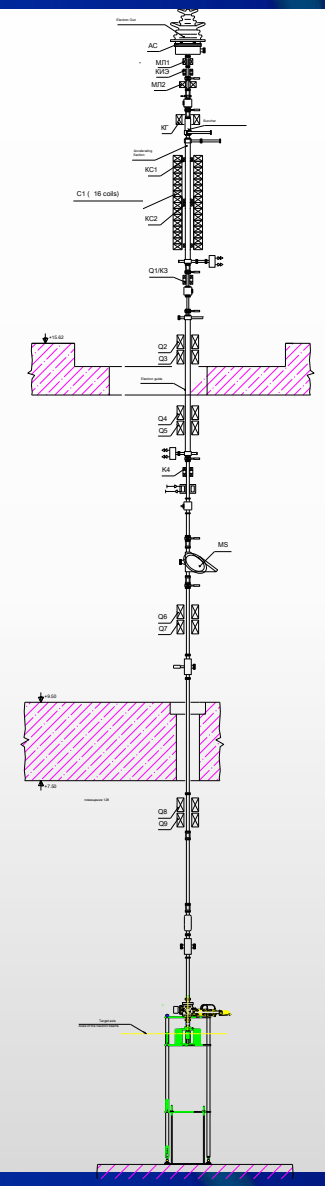


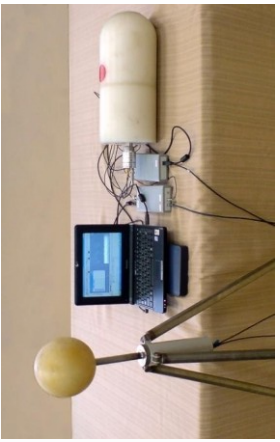
Рис. 9. Спектр плотности потока нейтронов в точке 1 ИРЕН



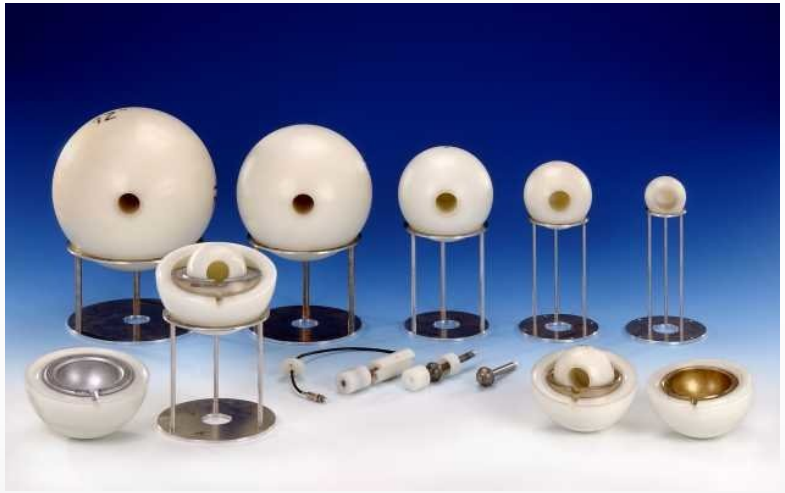
Beam current, 1.8 A

- Peak current 1,8 A
- Average current 10.8 μA
- Energy 100 MeV
- Pulse duration 120 ns
- Repetition rate 50 Hz
- Beam power 1.08 kW
- Neutron yield ~ $2 \cdot 10^{12}$ n/s

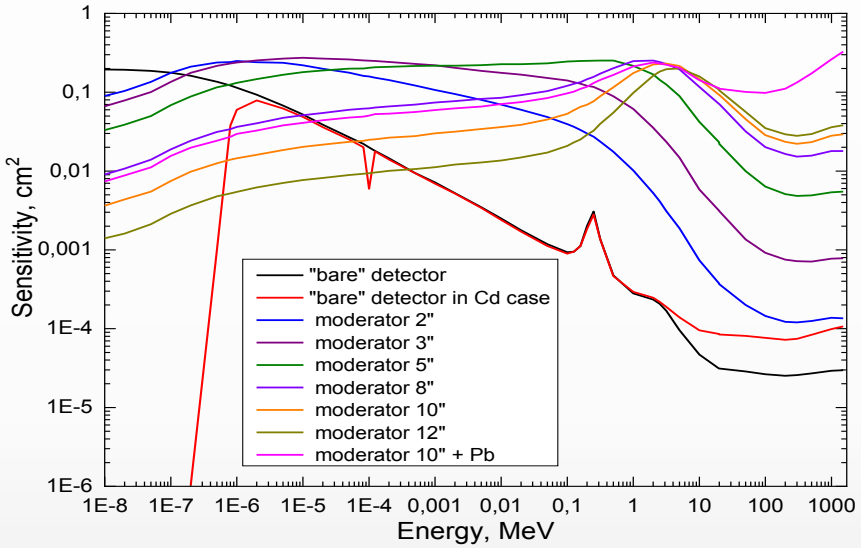




Bonner spectrometer principles



Bonner spheres



Sensitivity functions S(E)

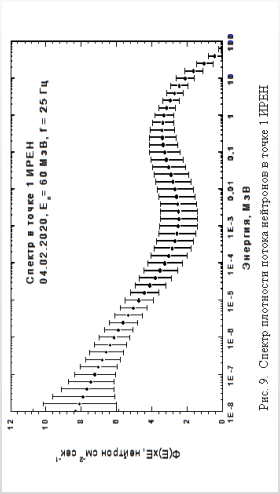
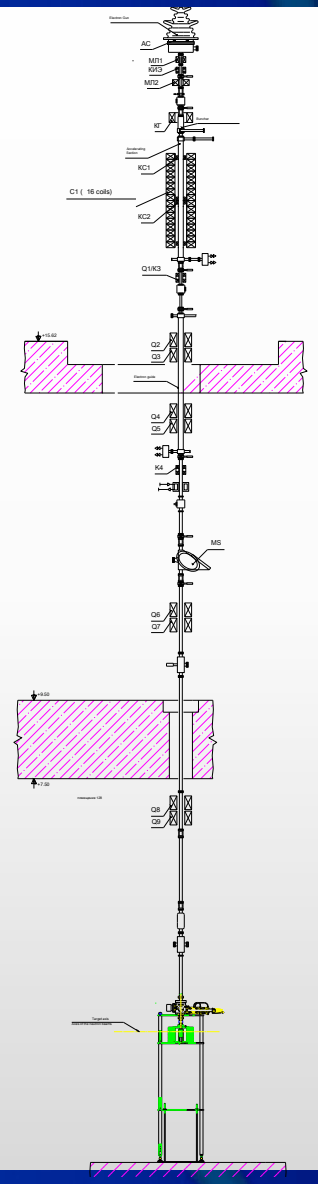
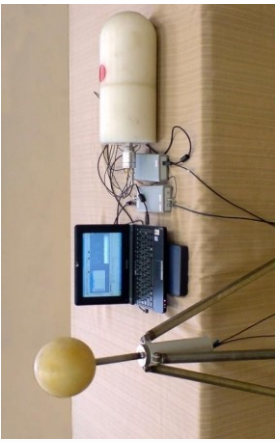


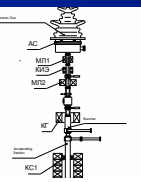
Рис. 9. Спектр плотности потока нейтронов в точке 1 ИРЕН

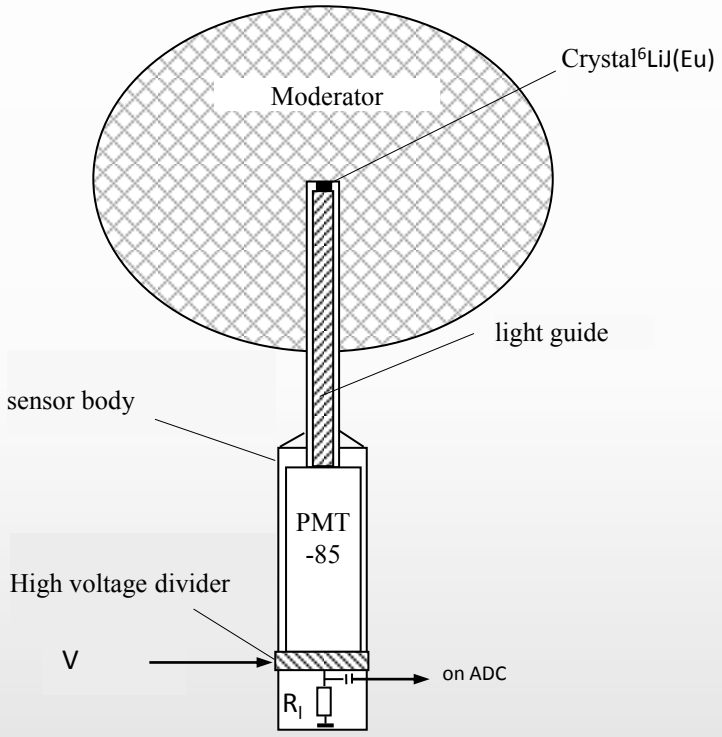
$$I_i = \int \Phi(E) \cdot S(E)\, dE$$



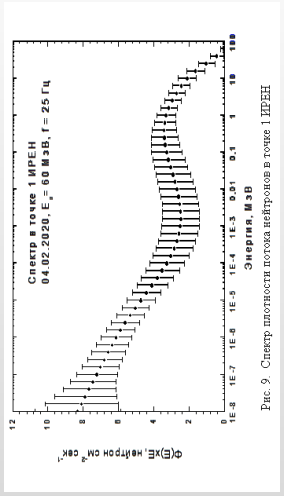


The multisphere spectrometer





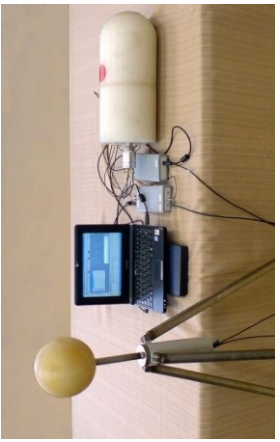
Construction of the JINR multisphere neutron spectrometer. PMT – photomultiplier, R_l – load resistance, ADC – Amplitude Digital Converter

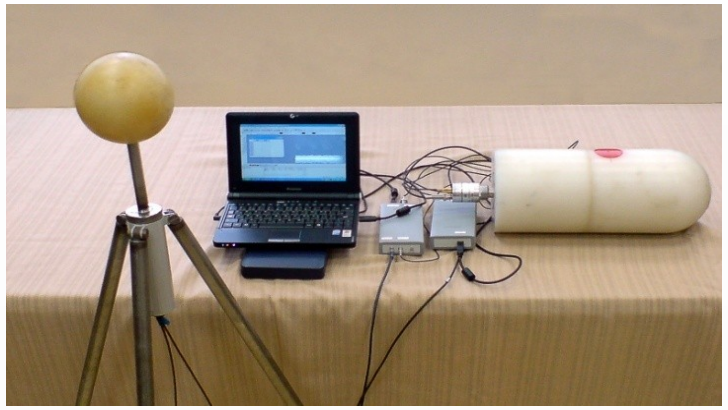


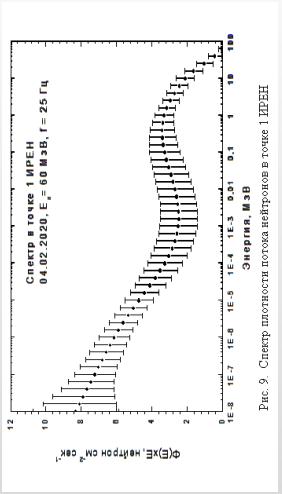
The detector is a LiI(Eu) scintillator 4.3 mm in diameter and 4 mm high, enriched with ^{6}Li (natural Li contains 7,5% ^{6}L and 92,5% ^{7}Li). Under the influence of thermal neutrons with ^{6}Li nuclei, the reaction

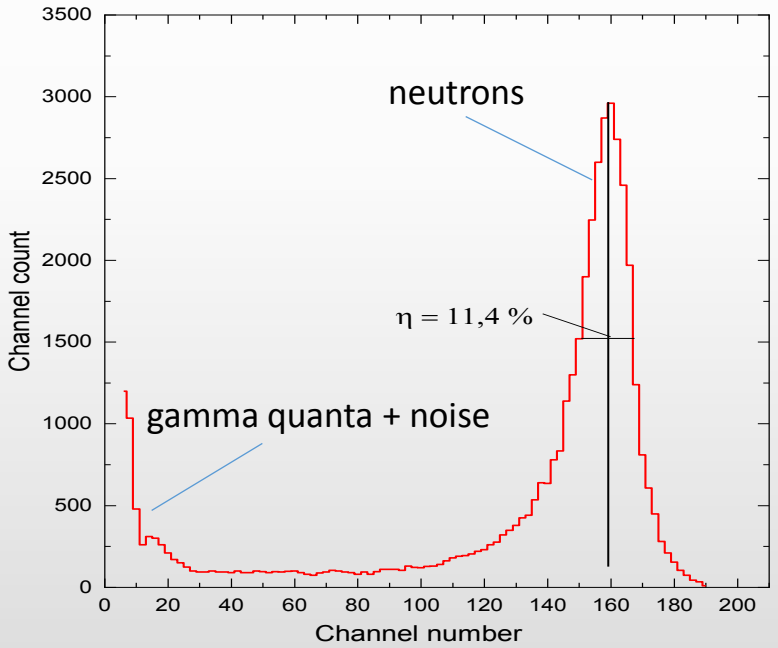
$$n + {}^6Li \rightarrow {}^4He + {}^3H + 4{,}78\ MeV$$

occurs in the scintillator. Both charged particles (alpha and triton) lose a total energy of 4.78 MeV in the scintillator, i.e. when thermal neutrons are detected in the detector, a pulse of almost the same amplitude arises.



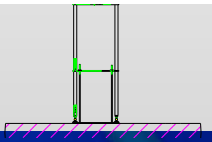


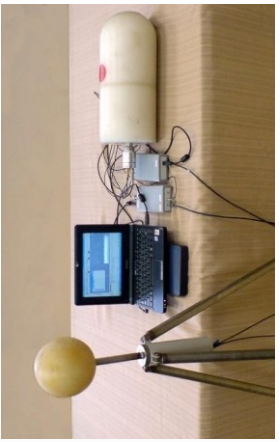


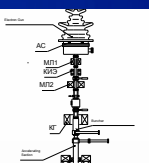


The shape of the instrumental pulse height spectrum from the LiI(Eu) detector when detecting slow neutrons

The JINR spectrometer uses a set of homogeneous polyethylene spheres 50.9; 76.3; 127.2; 178.4; 204.3; 254.1 and 305.5 mm (approximately 2; 3; 5; 7; 8; 10 and 12 inches) in diameter and an additional 10-inch sphere with a lead insert 8 cm in diameter inside for high energy neutrons. The readings of a detector without a sphere and a detector without a sphere but in a Cd sheath that absorbs thermal neutrons are also used.







RECONST Neutron Spectra Reconstruction Program

Reconstruction of neutron spectra from spectrometer readings is performed using the RECONST program, which implements the method of statistical regularization when solving the inverse problem. The RECONST program is written in the FORTRAN-90 language, and for its operation it is necessary to prepare several auxiliary text files with the spectrometer's sensitivity functions, names of the detectors used, their scores and errors, the initial values of the regularization parameter ALFA and the decision bias estimation parameter BETA. Specific parameter values are calculated in the RECONST program by solving the corresponding nonlinear equations and are given in the output file.

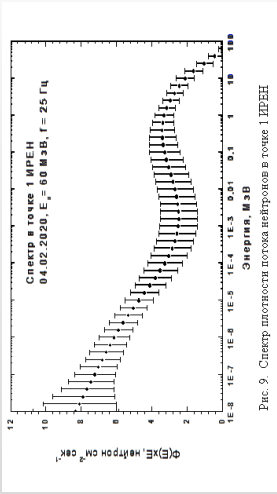
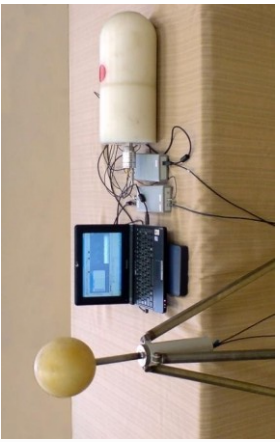


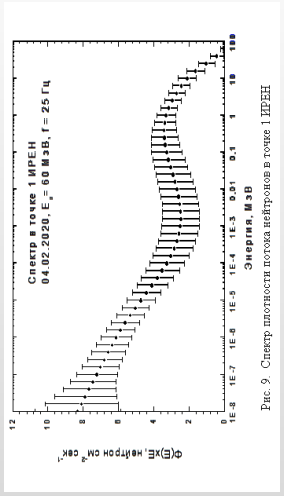
Рис. 9. Спектр плотности потока нейтронов в точке 1 ИРЕН

Before the spectra are restored, it is necessary to preprocess the obtained results, which consists in subtracting the pulses from neutrons under the peak of background events from gamma quanta and noise from the count, and then normalizing the counts to the readings of the monitor counter.



Measurements

Neutron spectra were measured at IREN on February 4th and 5th, 2020 at two points



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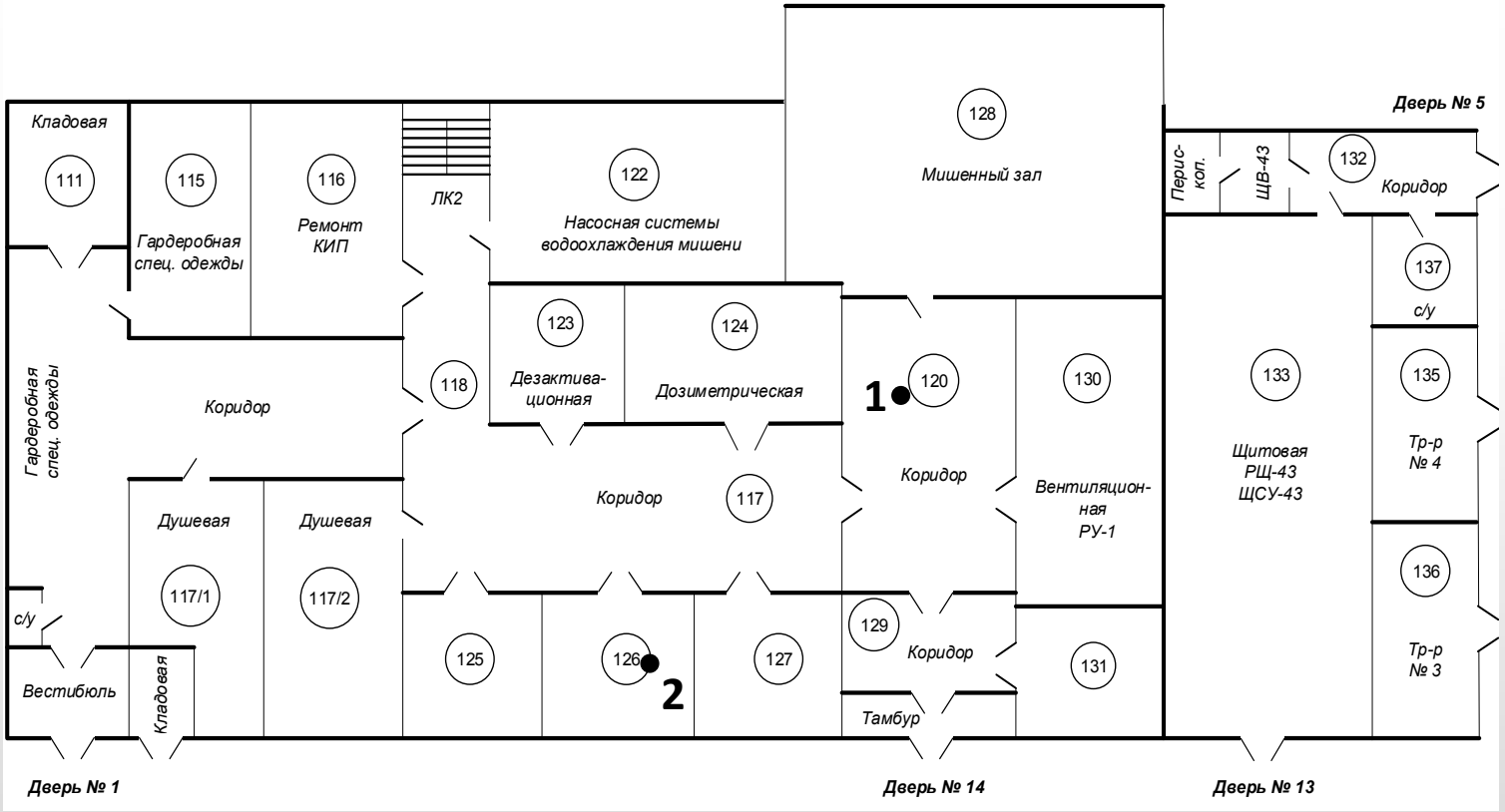
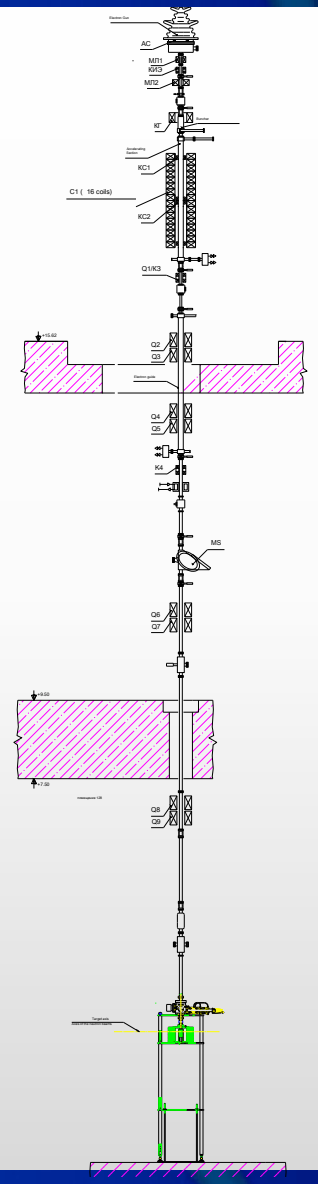
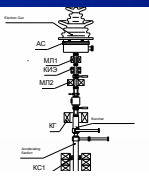
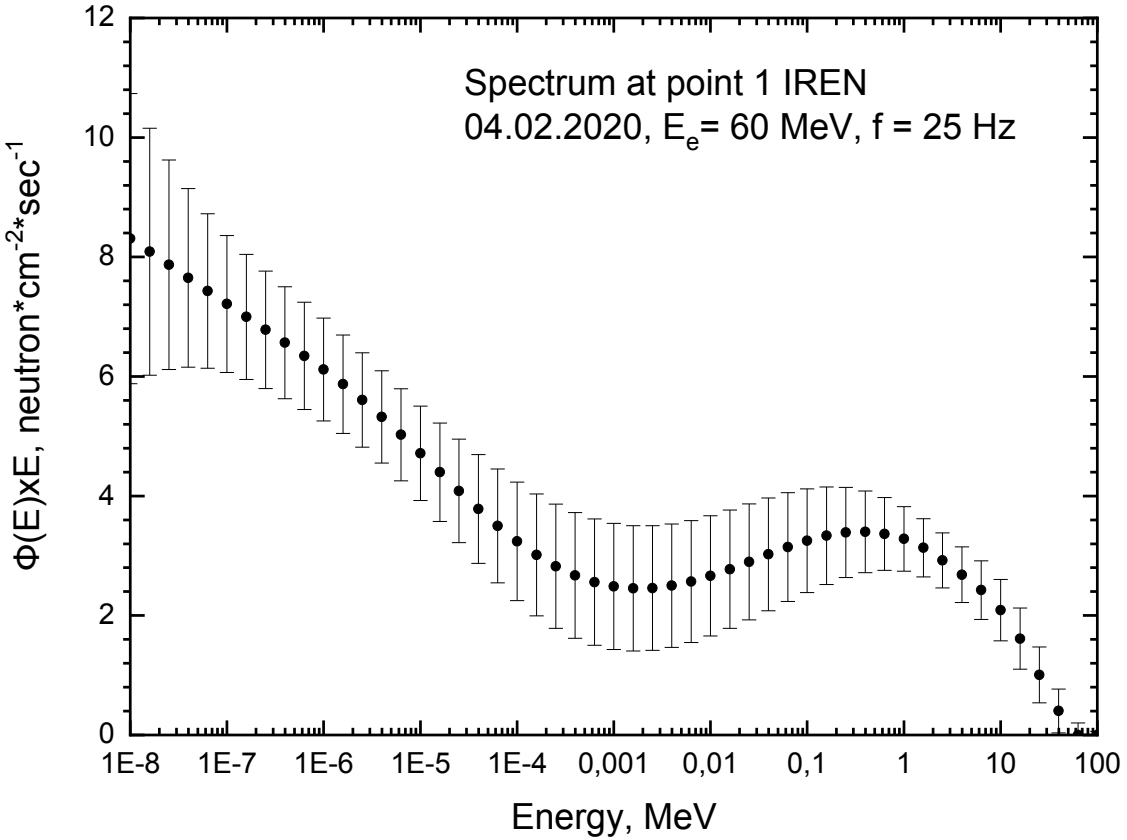


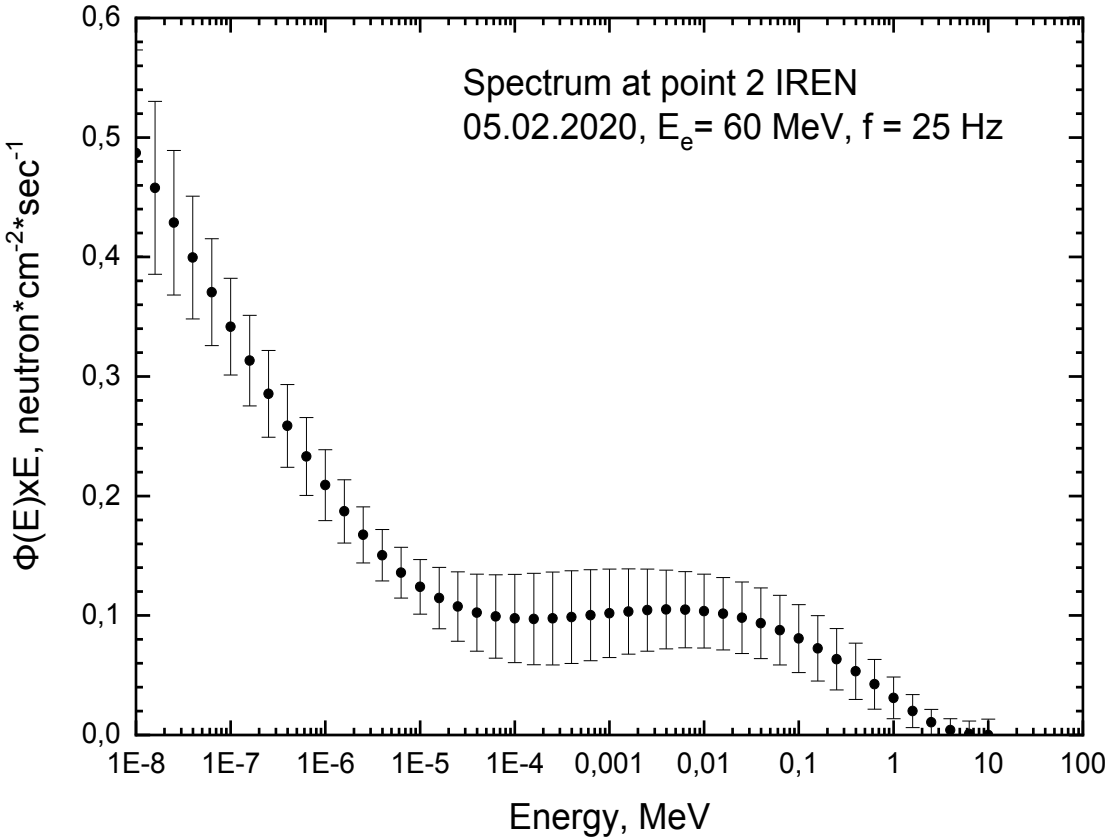
Plan of the 1st floor of building No. 43 and measurement points for neutron spectra

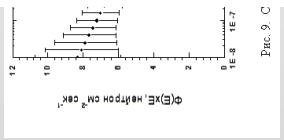


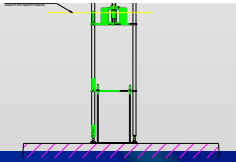
The reconstructed spectra

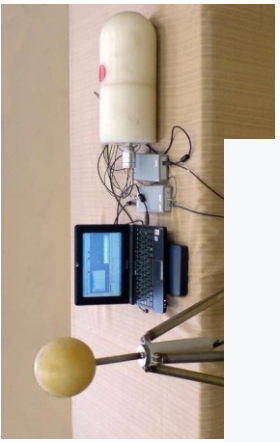




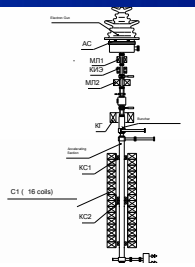


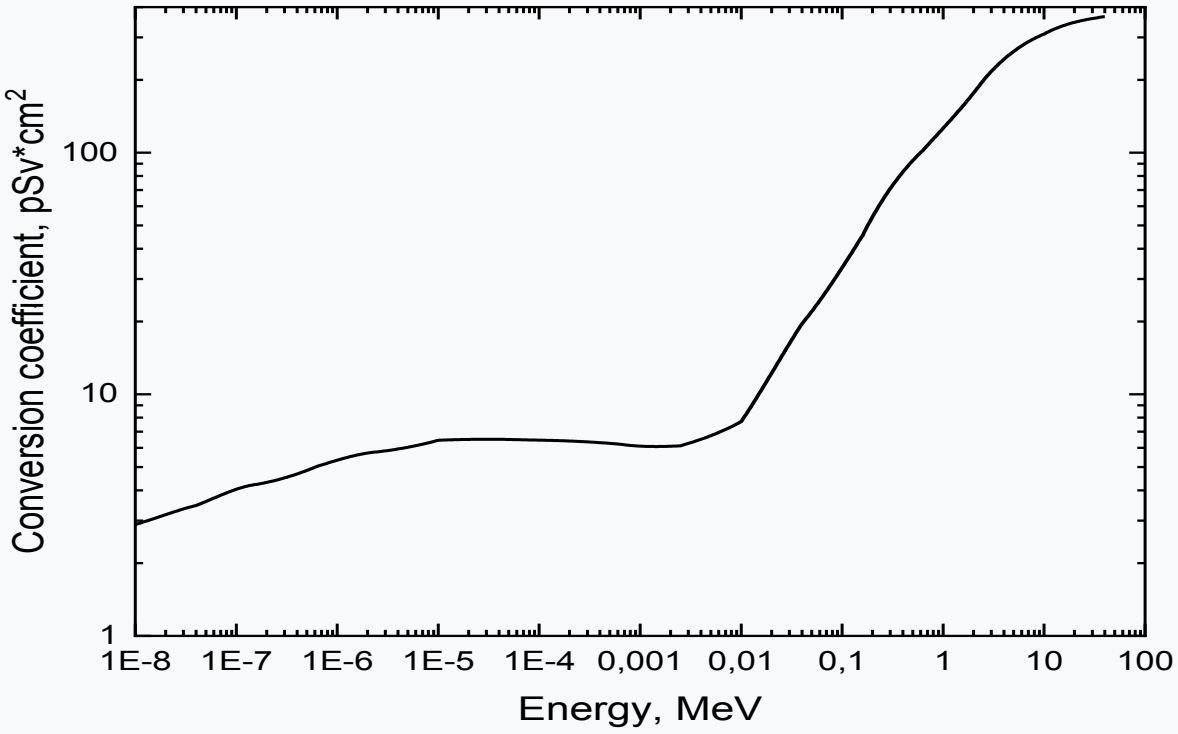






The effective doses of neutrons



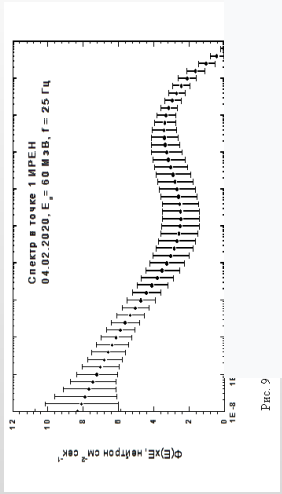


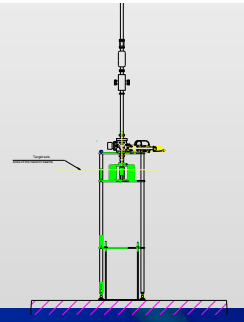
Energy dependence of neutron fluence to effective dose conversion coefficients in ISO geometry

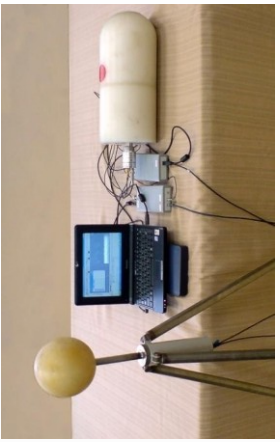
The effective dose of neutrons at point 1 was 23.6 μSv/h, and at point 2 - 0.23 μSv/h.

Point 1 is located in the area restricted for access during IREN operation.
Point 2 is located in the controlled area.

Dose rate for authorized personnel is equal to 12 μSv/h







1. Neutron spectra were measured at two points on the first floor of the IREN facility of the Laboratory of Neutron Physics when an electron beam with an energy of ~ 60 MeV was brought to a tungsten target.
2. Preliminary processing of instrumental spectra was carried out in order to subtract the background and normalize the measurements to the readings of the monitor neutron counter.
3. Neutron spectra at two points were reconstructed using the RECONST program from the readings of a multisphere spectrometer.
4. Based on the reconstructed spectra, the effective neutron doses at the measurement points were obtained.

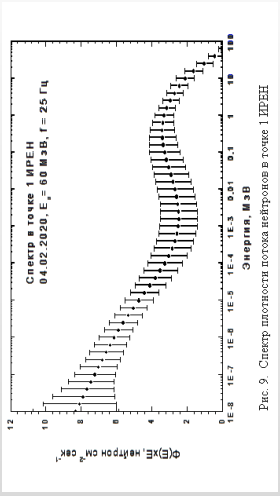
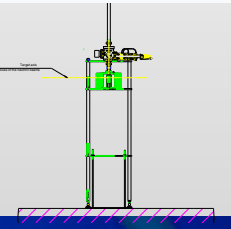
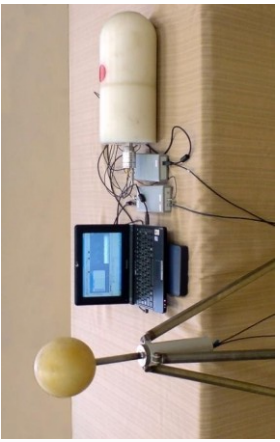
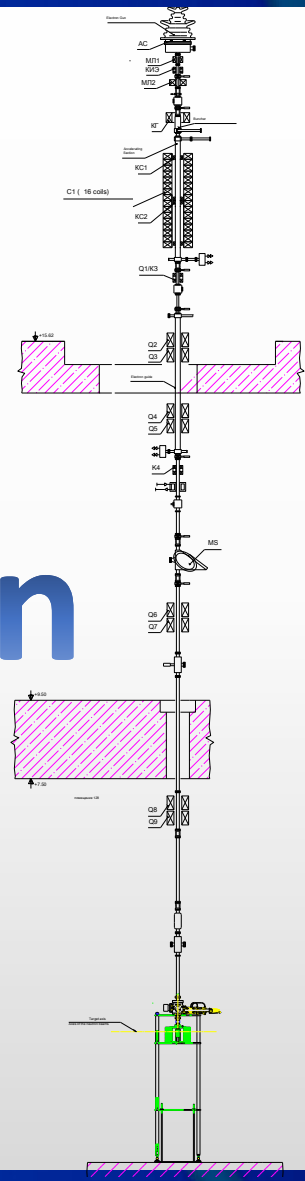


Рис. 9. Спектр плотности потока нейтронов в точке 1 ИРЕН







Thank you for your attention

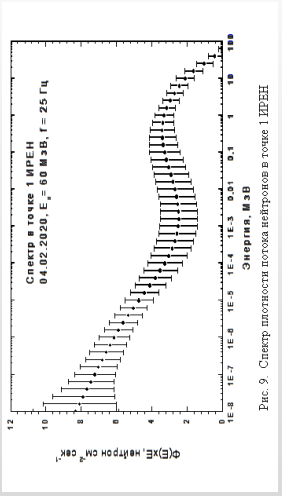
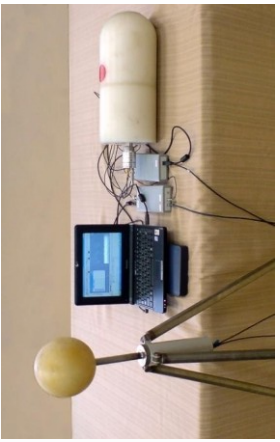


Рис. 9. Спектр плотности потока нейтронов в точке 1 ИРЕН



Measurement results at point 1

Sphere	t, s	M in channels 60-100, counts	$M_{imp.ev.}$, counts	M-$M_{imp.ev}$, counts	$M_{mon.}$, counts	M-$M_{imp.ev}$ brought to $M_{ьщт}$ = 539258
Bare	588	4629	300	4329	539258	4329
Bare + Cd	627	914	0	914	574077	858,6
2″	573	6251	400	5851	520509	6061,7
3″	646	8410	760	7650	581628	7092,7
5″	634	7819	560	7259	551432	7098,7
8″	619	4072	400	3672	540319	3664,8
10″	630	2128	28	2100	543501	2083,6
12″	615	1097	0	1097	528876	1118,5
10″+Pb	656	4710	280	4430	592435	4032,4

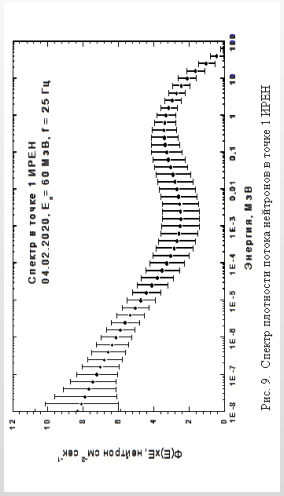


Рис. 9. Спектр плотности потока нейтронов в точке 1 ИРЕН

Measurement results at point 2

Sphere	t, s	M in channels 60-100, counts	$M_{imp.ev.}$, counts	M-$M_{imp.ev.}$, counts	$M_{mon.}$, counts	M-$M_{imp.ev}$ brought to M_{mon} = 539258
Bare	1549	365	60	325	9210	305
Bare + Cd	1505	35	0	35	9021	35,7
2″	1511	399	0	399	8986	408,9
3″	1441	434	0	434	8539	468,1
5″	1550	367	10	357	9224	356,5
8″	1528	129	5	124	8854	129
10″	1890	75	0	78	11302	61
12″	1504	20	0	19	8769	22