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Evolution of Spectra During Propagation of Neutron Fluxes in Rhenium, Molybdenum and Aluminum

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Abstract

The results of numerical modeling for leakage neutron spectra and absorption neutron spectra, which are being formed during propagation of neutron fluxes inside spheres, which consists of nominal density metals Re^{nat}, Mo^{nat} and Al^{27}, are presented. The spherically symmetric task of neutron flux diffusion from a 14.1 MeV central neutron source to the outer surface of spheres, is reviewed. The simulation was carried out using the Monte Carlo code 'Shield' [1,2] with 28 energy grouped ABBN-78 neutron constants [3].

The task was carried out within the framework to determine, how material selection choice, for target station of linear accelerator's proton beam, influences on integral outgoing neutron flux, it's energy spectrum, and diffusion time. Possibility to recreate capture spectrum of the target station, from experimentally measured by TOF-method leakage neutron spectrum, is being discussed.

Obtained calculated data are reserved to compare them with similar data, calculated using 299-group ABBN-93 neutron group constants [4], for calibration purposes. Presented data also can be compared both with experimental leakage neutron TOF spectra measured at the spallation neutron source RADEX, and with calculation results of codes which use introduction of cross sections as continuous curves instead of energy groups.

Introduction

Integral experiments are united integral check of all main types of nuclear constants, of cross sections libraries [5] for interactions of neutrons with nuclei. This idea was expressed already in early works [6].

Aim of this work is to describe pure effect of spectrum's evolution during propagation of the neutron flux inside solid body of chosen material with defined density and known group cross sections [3]. Obtained data allow to compare, how choice of target station's material influences on outgoing spectrum in neutron guide.

As examples of solid body media, in present work we chose as materials spheres of different radiuses:

1. Rhenium natural isotope mixture Re^{nat}, nominal density solid body metal spheres;
2. Molybdenum natural isotope mixture $\mathbf{Mo^{nat}}$ nominal density metal spheres;
3. Aluminum nominal density metal spheres, consisting of pure isotope $\mathbf{Al^{27}}$.

Neutron flux inside metal sphere: description of the implemented calculation model

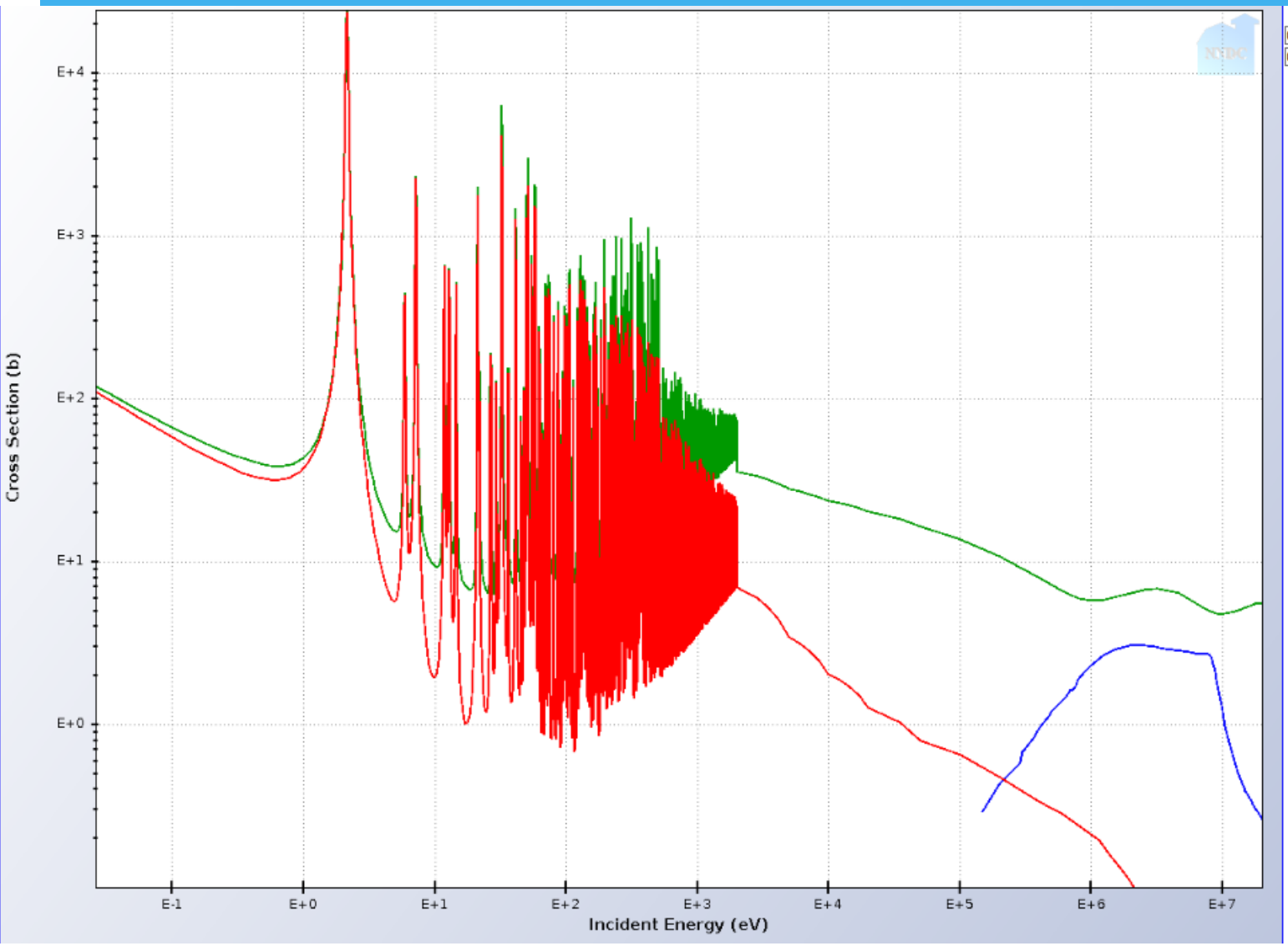
There is a sphere of metal, which has nominal density p, radius **1<R<100 cm** and consists of defined isotope or their mixture with known cross sections and matrix of inelastic scattering group transitions [3]. At time t=0 in the center of the sphere are emitted N neutrons which have energy E0, MeV. Must be calculated:

* Average time of neutron's diffusion for outgoing neutrons, before they reach external surface of the sphere (when r = R for each neutron);
* Average time of diffusion for captured neutrons spectrum;
* Energy spectrum of leaking neutron flux, which is flying from sphere's external surface and can be measured by TOF method;
* Energy spectrum of absorbed neutrons.

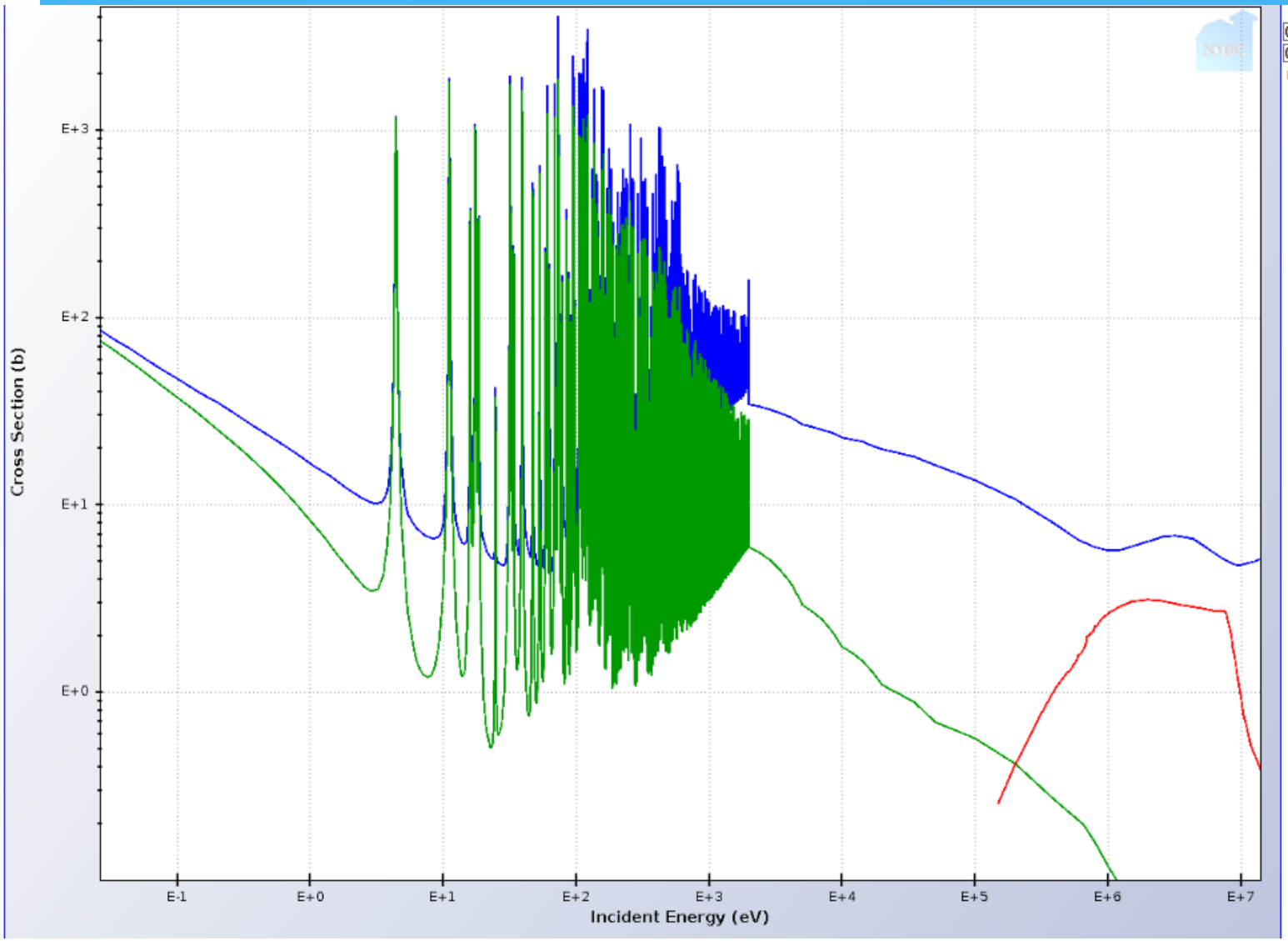
Start number of neutrons is taken **N=10,000,000** for each variant spectrum.
Start energy of neutrons is taken **E0=14.1 MeV**.

Authors also calculated spectrums with start energies 3.0 MeV and 0.6 MeV typical for spallation neutrons and for photonuclear (gamma,n) neutron sources correspondingly. These spectrums with start energies in 3rd and 6th ABBN-78 energy groups allow to appreciate, how results depends on start energy of neutron.

Neutron cross sections of Re^{185} (37% in natural mixture) and Re^{187} (62,93% in nature). Re^{185}: total cross section (green line), capture (red), inelastic scattering (blue line). Data from the Brookhaven National Laboratory [5].



Neutron cross sections of Re^{185} (37% in natural mixture) and Re^{187} (62,93% in nature). Re^{187}: total cross section (blue line), capture (green), inelastic scattering (red line). Data from the Brookhaven National Laboratory [5].



ABBN-78 constants for Re^{nat}

BNAB 28-GROUP NEUTRON CONSTANTS FOR RE(75,186.20000)

MAIN GROUP CONSTANTS

GR.	ENERGY (MEV)	S-TOT	S-FIS	AVER NU	S-CAP	S-IN	S-EL	COS EL
-1	.140E+02- .145E+02	5.3492	.0000	.0000	.0010	2.6281	2.7201	.8764
0	.105E+02- .140E+02	5.2435	.0000	.0000	.0010	2.6415	2.6010	.8554
1	.650E+01- .105E+02	5.1710	.0000	.0000	.0010	2.7102	2.4598	.8013
2	.400E+01- .650E+01	6.1018	.0000	.0000	.0092	2.8215	3.2711	.8048
3	.250E+01- .400E+01	6.9794	.0000	.0000	.0397	2.9910	3.9487	.7179
4	.140E+01- .250E+01	7.0292	.0000	.0000	.0928	3.0588	3.8776	.6354
5	.800E+00- .140E+01	6.5122	.0000	.0000	.1564	2.5613	3.7945	.5005
6	.400E+00- .800E+00	6.3959	.0000	.0000	.2430	1.4512	4.7017	.3179
7	.200E+00- .400E+00	7.0193	.0000	.0000	.3499	.6654	6.0040	.2101
8	.100E+00- .200E+00	8.2999	.0000	.0000	.4897	.1674	7.6428	.1301
9	.465E-01- .100E+00	10.1629	.0000	.0000	.6051	.0000	9.5578	.0694
10	.215E-01- .465E-01	12.6102	.0000	.0000	.8787	.0000	11.7315	.0330
11	.100E-01- .215E-01	15.8798	.0000	.0000	1.4554	.0000	14.4244	.0160
12	.465E-02- .100E-01	20.4052	.0000	.0000	2.5911	.0000	17.8141	.0080
13	.215E-02- .465E-02	26.8792	.0000	.0000	4.7432	.0000	22.1360	.0060
14	.100E-02- .215E-02	20.3538	.0000	.0000	5.7548	.0000	14.5990	.0040
15	.465E-03- .100E-02	32.7273	.0000	.0000	12.1359	.0000	20.5914	.0040
16	.215E-03- .465E-03	74.0842	.0000	.0000	32.1994	.0000	41.8848	.0040
17	.100E-03- .215E-03	102.4487	.0000	.0000	54.2494	.0000	48.1993	.0040
18	.465E-04- .100E-03	107.0259	.0000	.0000	70.7600	.0000	36.2659	.0040
19	.215E-04- .465E-04	76.0953	.0000	.0000	56.5632	.0000	19.5321	.0040
20	.100E-04- .215E-04	79.1991	.0000	.0000	70.9846	.0000	8.2145	.0040
21	.465E-05- .100E-04	42.4083	.0000	.0000	35.0392	.0000	7.3691	.0040
22	.215E-05- .465E-05	415.8179	.0000	.0000	384.9457	.0000	30.8722	.0040
23	.100E-05- .215E-05	350.5811	.0000	.0000	331.8095	.0000	18.7716	.0040
24	.465E-06- .100E-05	27.4788	.0000	.0000	19.3910	.0000	8.0878	.0040
25	.215E-06- .465E-06	34.5306	.0000	.0000	25.6420	.0000	8.8886	.0040
26	THERMAL	65.1291	.0000	.0000	55.7373	.0000	9.3918	.0040

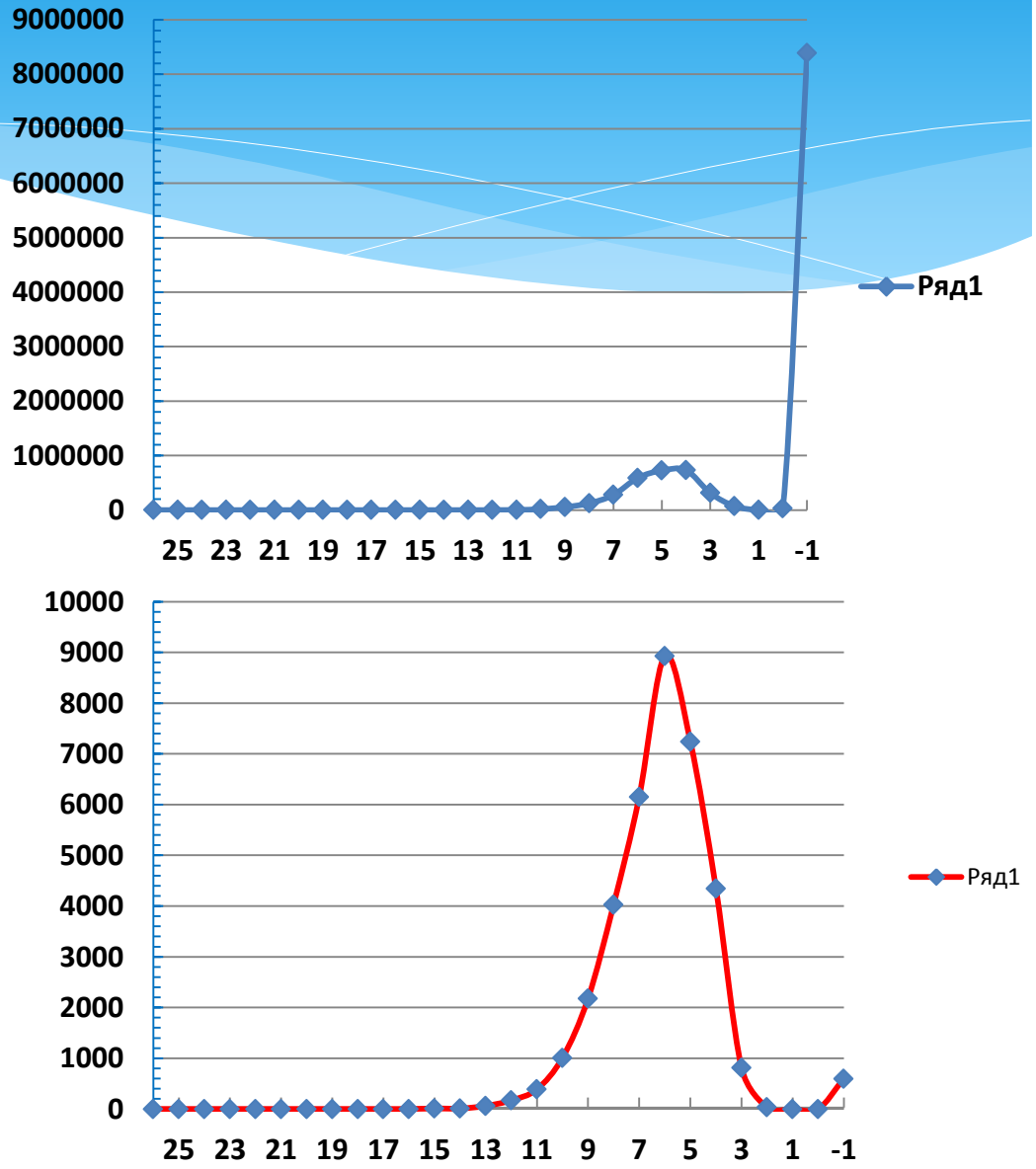
SIGMA IN (I,I+K) AT K EQUAL:

I	K= 0	K= 1	K= 2	K= 3	K= 4	K= 5	K= 6	K= 7	K= 8	K= 9	K=10	K=11	SUMMA
-1	.0339	.0705	.0024	.1401	.5952	1.3750	1.2703	.8985	.3380	.1037	.0301	.0068	4.8645
0	.1151	.0047	.0907	.5157	1.3159	1.2904	.9397	.3609	.1121	.0328	.0075	.0017	4.7872
1	.1722	.0420	.0244	.2987	.7289	.9448	.5192	.1948	.0629	.0151	.0034	.0008	3.0072
2	.2658	.0682	.0491	.3110	.8371	.7454	.3642	.1352	.0350	.0082	.0019	.0004	2.8215
3	.3634	.1772	.0667	.5021	.8679	.6208	.2843	.0824	.0203	.0047	.0010	.0002	2.9910
4	.6126	.5590	.1864	.4721	.6222	.4096	.1452	.0394	.0096	.0021	.0005	.0001	3.0588
5	.7125	1.0204	.3280	.2122	.1737	.0814	.0248	.0064	.0015	.0003	.0001	.0000	2.5613
6	.6166	.6201	.1455	.0482	.0143	.0047	.0014	.0003	.0001	.0000	.0000	.0000	1.4512
7	.1726	.3321	.1425	.0132	.0039	.0009	.0002	.0000	.0000	.0000	.0000	.0000	.6654
8	.0000	.0641	.0697	.0255	.0063	.0014	.0003	.0001	.0000	.0000	.0000	.0000	.1674
9	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
10	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
11	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
12	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000

ABBN-78 Group №	Energy interval	Outgoing spectrum	Capture spectrum
-1	14.5-14.0 MeV	8388228	599
0	14.0-10.5 MeV	29901	1
1	10.5 – 6.5 MeV	1292	0
2	6.5 – 4.0 MeV	73839	34
3	4.0 – 2.5 MeV	313895	812
4	2.5 – 1.4 MeV	733123	4347
5	1.4 – 0.8 MeV	726025	7243
6	0.8 – 0.4 MeV	589679	8933
7	0.4 – 0.2 MeV	277586	6152
8	0.2 – 0.1 MeV	123993	4031
9	100 – 46.5 KeV	55261	2178
10	46.5 – 21.5 KeV	16952	1010
11	21.5 – 10 KeV	3703	388
12	10 – 4.65 KeV	832	170
13	4.65 – 2.15 KeV	141	61
14	2.15 – 1 KeV	33	9
15	1 – 0.465 KeV	5	10
16	465 – 215 eV	0	0
17	215 – 100 eV	0	0
18	100 – 46.5 eV	0	0
19	46.5 – 21.5 eV	0	0
20	21.5 – 10 eV	0	0
21	10 – 4.65 eV	0	0
22	4.65 – 2.15 eV	0	0
23	2.15 – 1.0 eV	0	0
24	1.0 – 0.465 eV	0	0
25	0.465 – 0.215 eV	0	0
26	0.215 – 0.001 eV	0	0

Sphere Re^{185} Re^{187} R= 1 cm

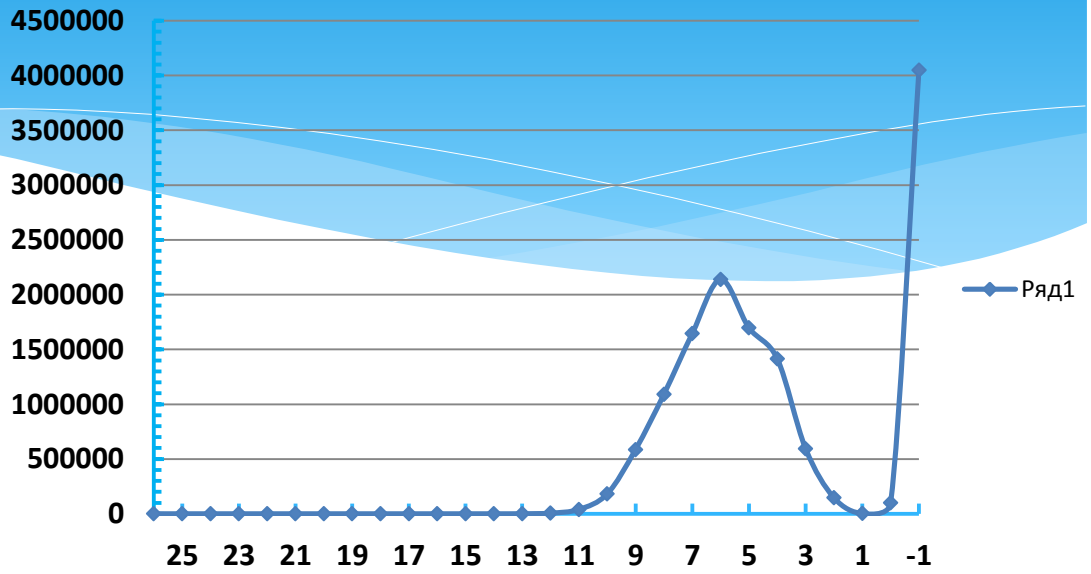
Outgoing spectrum (upper picture, blue curve) and capture spectrum (picture below, red line).

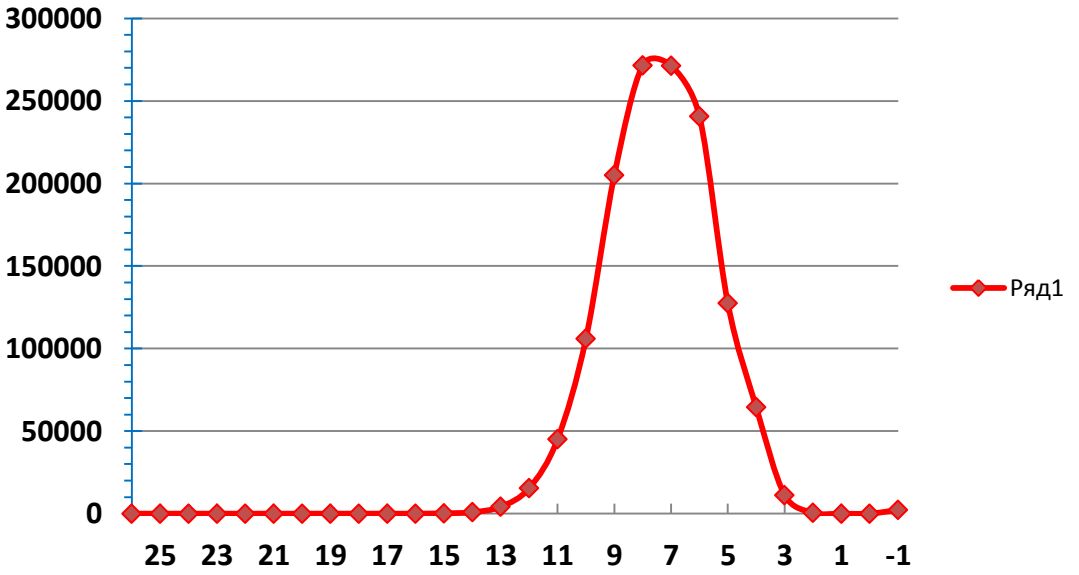


ABBN-78 Group №	Energy interval	Outgoing spectrum	Capture spectrum
-1	14.5-14.0 MeV	4050250	2219
0	14.0-10.5 MeV	99540	33
1	10.5 – 6.5 MeV	2901	0
2	6.5 – 4.0 MeV	146982	618
3	4.0 – 2.5 MeV	594603	11264
4	2.5 – 1.4 MeV	1416080	64457
5	1.4 – 0.8 MeV	1697768	127445
6	0.8 – 0.4 MeV	2138822	240721
7	0.4 – 0.2 MeV	1644927	271390
8	0.2 – 0.1 MeV	1090440	271610
9	100 – 46.5 KeV	586801	205020
10	46.5 – 21.5 KeV	181929	106015
11	21.5 – 10 KeV	39991	45079
12	10 – 4.65 KeV	6325	15419
13	4.65 – 2.15 KeV	828	4196
14	2.15 – 1 KeV	156	831
15	1 – 0.465 KeV	16	216
16	465 – 215 eV	0	3
17	215 – 100 eV	0	0
18	100 – 46.5 eV	0	0
19	46.5 – 21.5 eV	0	0
20	21.5 – 10 eV	0	0
21	10 – 4.65 eV	0	0
22	4.65 – 2.15 eV	0	0
23	2.15 – 1.0 eV	0	0
24	1.0 – 0.465 eV	0	0
25	0.465 – 0.215 eV	0	0
26	0.215 – 0.001 eV	0	0

Sphere Re^{185} Re^{187} R= 5 cm

Outgoing spectrum (upper picture, blue curve) and capture spectrum (picture below, red line).

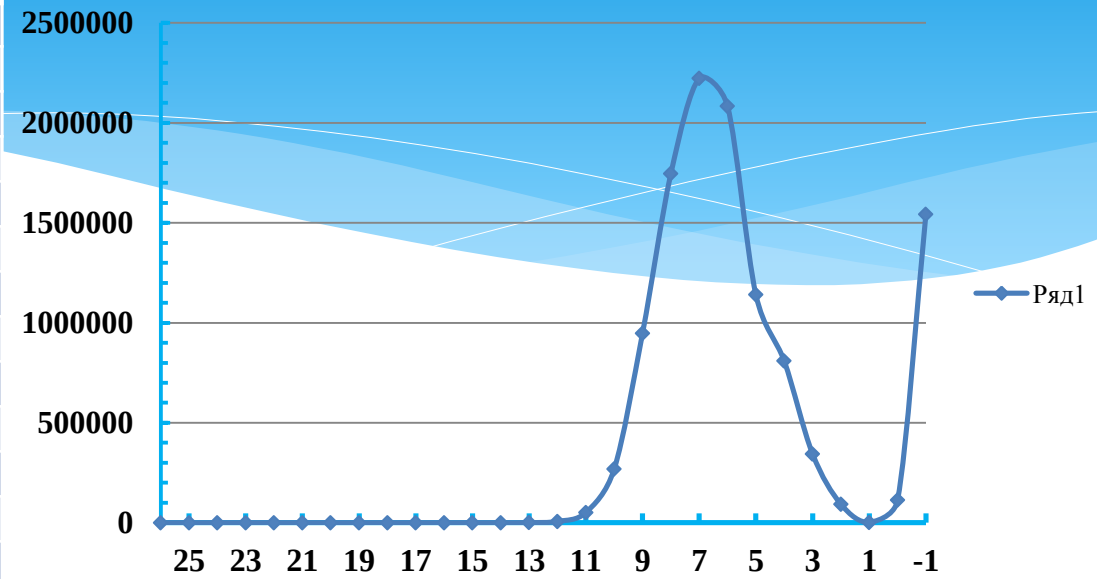


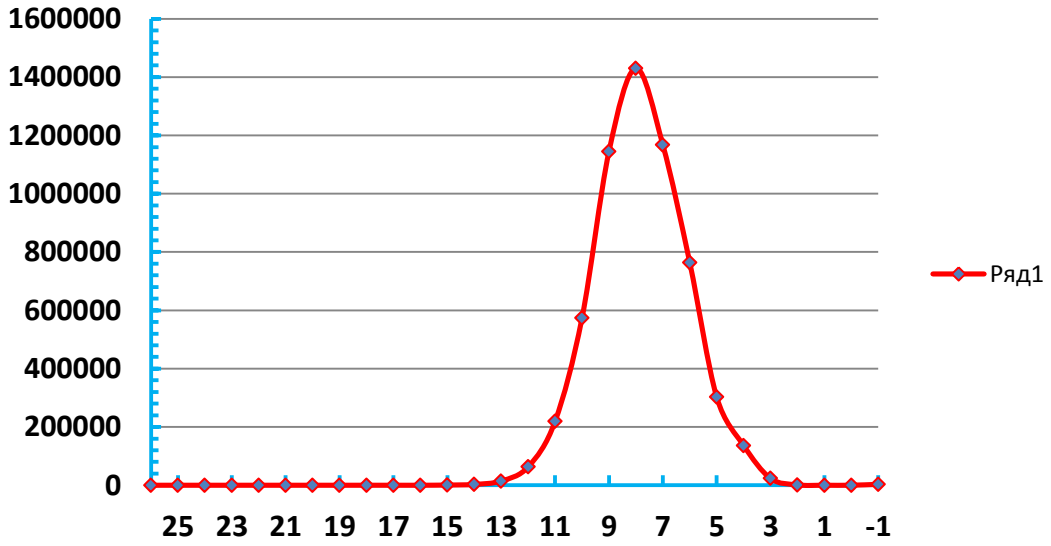


ABBN-78 Group №	Energy interval	Outgoing spectrum	Capture spectrum
-1	14.5-14.0 MeV	1543254	3182
0	14.0-10.5 MeV	113228	110
1	10.5 – 6.5 MeV	1955	2
2	6.5 – 4.0 MeV	92827	1257
3	4.0 – 2.5 MeV	344540	23547
4	2.5 – 1.4 MeV	809062	136378
5	1.4 – 0.8 MeV	1140563	302358
6	0.8 – 0.4 MeV	2083720	763759
7	0.4 – 0.2 MeV	2223477	1167618
8	0.2 – 0.1 MeV	1745891	1429706
9	100 – 46.5 KeV	947630	1144470
10	46.5 – 21.5 KeV	268236	573598
11	21.5 – 10 KeV	51266	219163
12	10 – 4.65 KeV	6766	63012
13	4.65 – 2.15 KeV	680	14464
14	2.15 – 1 KeV	144	2897
15	1 – 0.465 KeV	19	670
16	465 – 215 eV	0	9
17	215 – 100 eV	0	0
18	100 – 46.5 eV	0	0
19	46.5 – 21.5 eV	0	0
20	21.5 – 10 eV	0	0
21	10 – 4.65 eV	0	0
22	4.65 – 2.15 eV	0	0
23	2.15 – 1.0 eV	0	0
24	1.0 – 0.465 eV	0	0
25	0.465 – 0.215 eV	0	0
26	0.215 – 0.001 eV	0	0

Sphere Re^{185} Re^{187} R= 10 cm

Outgoing spectrum (upper picture, blue curve) and capture spectrum (picture below, red line).

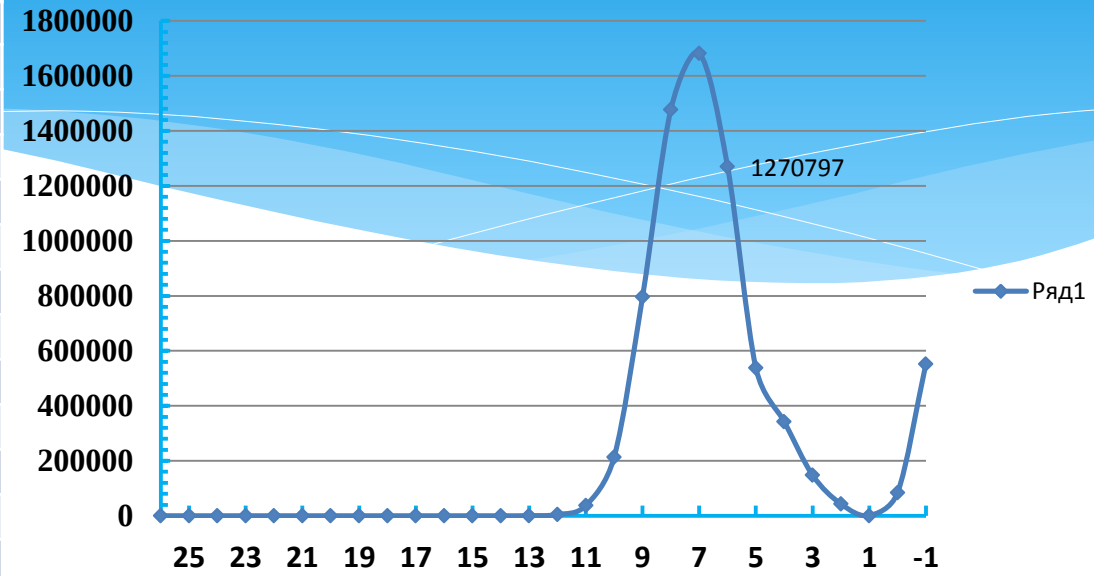


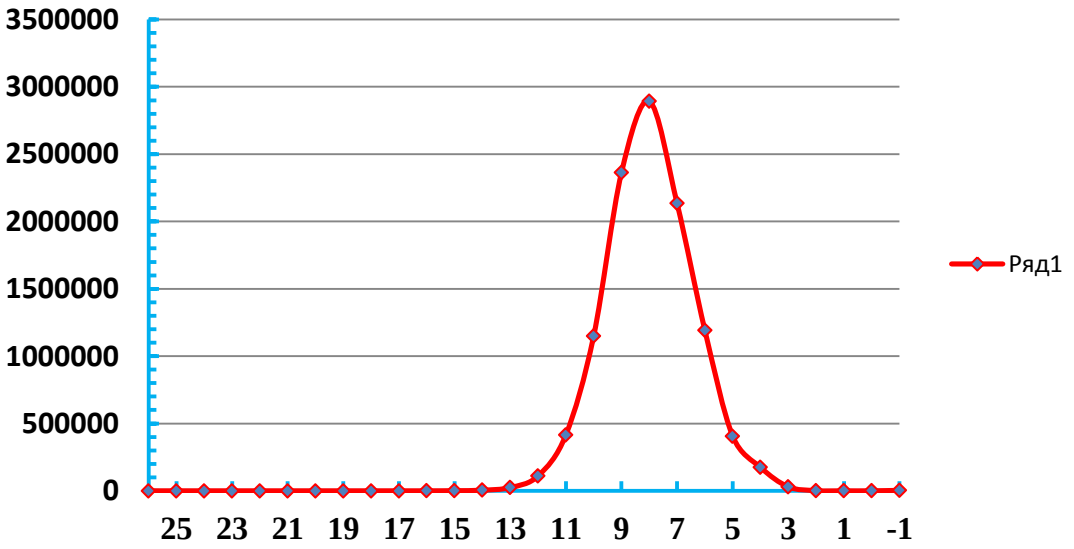


ABBN-78 Group №	Energy interval	Outgoing spectrum	Capture spectrum
-1	14.5-14.0 MeV	552598	3491
0	14.0-10.5 MeV	84293	135
1	10.5 – 6.5 MeV	1019	7
2	6.5 – 4.0 MeV	43309	1683
3	4.0 – 2.5 MeV	148176	29785
4	2.5 – 1.4 MeV	342930	174443
5	1.4 – 0.8 MeV	537771	405903
6	0.8 – 0.4 MeV	1270797	1192442
7	0.4 – 0.2 MeV	1682685	2135032
8	0.2 – 0.1 MeV	1477637	2893796
9	100 – 46.5 KeV	796243	2362180
10	46.5 – 21.5 KeV	214014	1148172
11	21.5 – 10 KeV	37343	414659
12	10 – 4.65 KeV	4596	110450
13	4.65 – 2.15 KeV	498	24274
14	2.15 – 1 KeV	74	4813
15	1 – 0.465 KeV	9	1071
16	465 – 215 eV	0	16
17	215 – 100 eV	0	0
18	100 – 46.5 eV	0	0
19	46.5 – 21.5 eV	0	0
20	21.5 – 10 eV	0	0
21	10 – 4.65 eV	0	0
22	4.65 – 2.15 eV	0	0
23	2.15 – 1.0 eV	0	0
24	1.0 – 0.465 eV	0	0
25	0.465 – 0.215 eV	0	0
26	0.215 – 0.001 eV	0	0

Sphere Re^{185} Re^{187} R= 15 cm

Outgoing spectrum (upper picture, blue curve) and capture spectrum (picture below, red line).

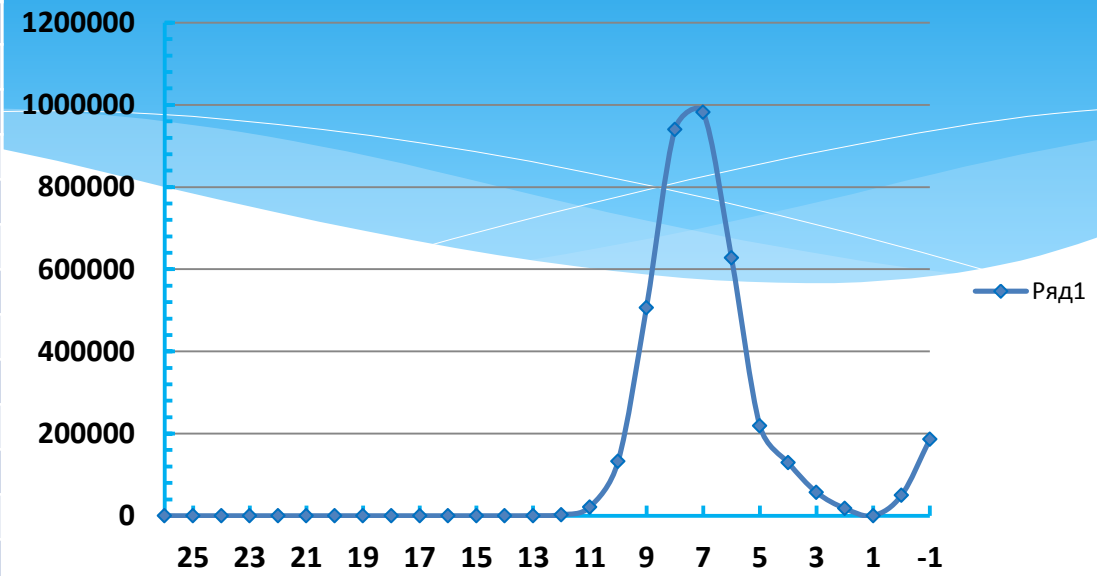


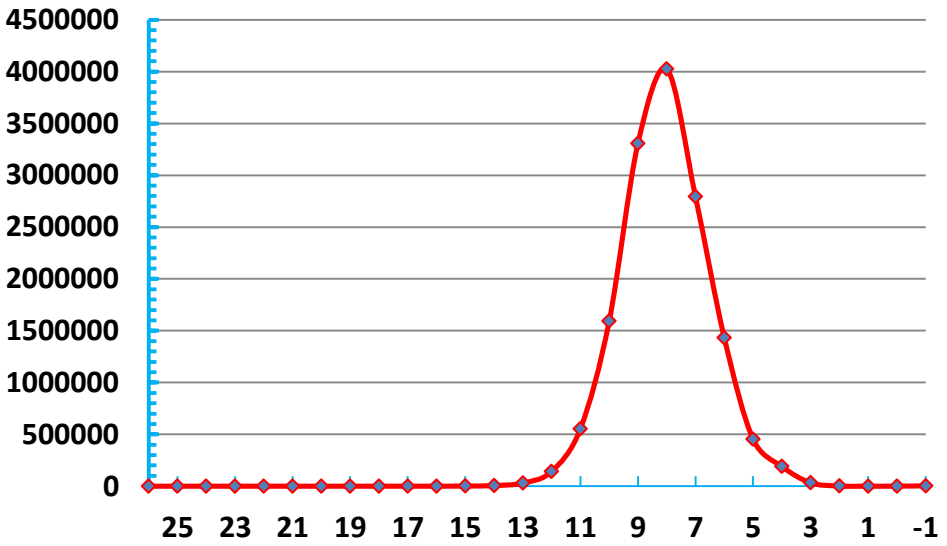


ABBN-78 Group №	Energy interval	Outgoing spectrum	Capture spectrum
-1	14.5-14.0 MeV	186253	3659
0	14.0-10.5 MeV	50032	171
1	10.5 – 6.5 MeV	498	4
2	6.5 – 4.0 MeV	18084	1854
3	4.0 – 2.5 MeV	57247	32762
4	2.5 – 1.4 MeV	129527	190575
5	1.4 – 0.8 MeV	219362	453654
6	0.8 – 0.4 MeV	627975	1432910
7	0.4 – 0.2 MeV	982251	2793296
8	0.2 – 0.1 MeV	939970	4026215
9	100 – 46.5 KeV	506869	3307253
10	46.5 – 21.5 KeV	132570	1591255
11	21.5 – 10 KeV	21598	553186
12	10 – 4.65 KeV	2511	142069
13	4.65 – 2.15 KeV	275	30478
14	2.15 – 1 KeV	53	6062
15	1 – 0.465 KeV	8	1407
16	465 – 215 eV	0	13
17	215 – 100 eV	0	0
18	100 – 46.5 eV	0	0
19	46.5 – 21.5 eV	0	0
20	21.5 – 10 eV	0	0
21	10 – 4.65 eV	0	0
22	4.65 – 2.15 eV	0	0
23	2.15 – 1.0 eV	0	0
24	1.0 – 0.465 eV	0	0
25	0.465 – 0.215 eV	0	0
26	0.215 – 0.001 eV	0	0

Sphere Re^{185} Re^{187} R= 20 cm

Outgoing spectrum (upper picture, blue curve) and capture spectrum (picture below, red line).

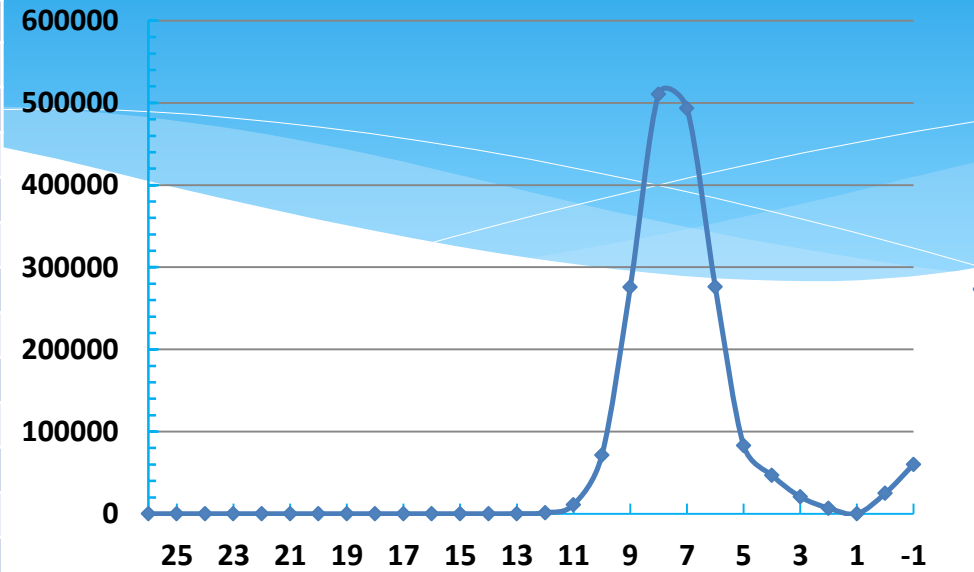


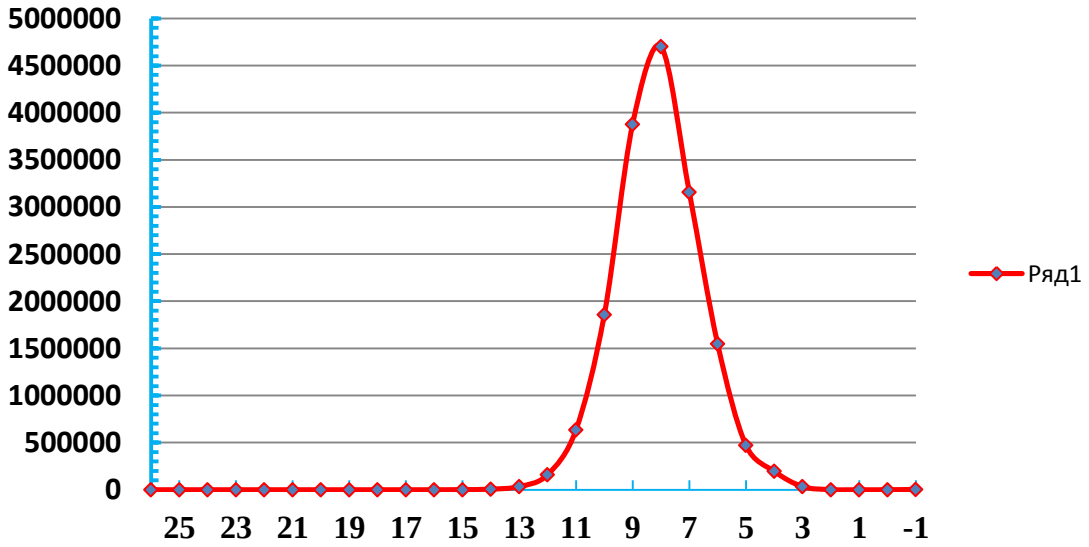


ABBN-78 Group №	Energy interval	Outgoing spectrum	Capture spectrum
-1	14.5-14.0 MeV	60265	3661
0	14.0-10.5 MeV	25003	190
1	10.5 – 6.5 MeV	221	4
2	6.5 – 4.0 MeV	6919	1891
3	4.0 – 2.5 MeV	20633	33536
4	2.5 – 1.4 MeV	46893	195774
5	1.4 – 0.8 MeV	83173	471602
6	0.8 – 0.4 MeV	276156	1549059
7	0.4 – 0.2 MeV	493398	3158688
8	0.2 – 0.1 MeV	510684	4701736
9	100 – 46.5 KeV	275687	3878769
10	46.5 – 21.5 KeV	71361	1855976
11	21.5 – 10 KeV	11153	633901
12	10 – 4.65 KeV	1279	160393
13	4.65 – 2.15 KeV	137	33798
14	2.15 – 1 KeV	25	6764
15	1 – 0.465 KeV	1	1578
16	465 – 215 eV	0	21
17	215 – 100 eV	0	0
18	100 – 46.5 eV	0	0
19	46.5 – 21.5 eV	0	0
20	21.5 – 10 eV	0	0
21	10 – 4.65 eV	0	0
22	4.65 – 2.15 eV	0	0
23	2.15 – 1.0 eV	0	0
24	1.0 – 0.465 eV	0	0
25	0.465 – 0.215 eV	0	0
26	0.215 – 0.001 eV	0	0

Sphere Re^{185} Re^{187} R= 25 cm

Outgoing spectrum (upper picture, blue curve) and capture spectrum (picture below, red line).

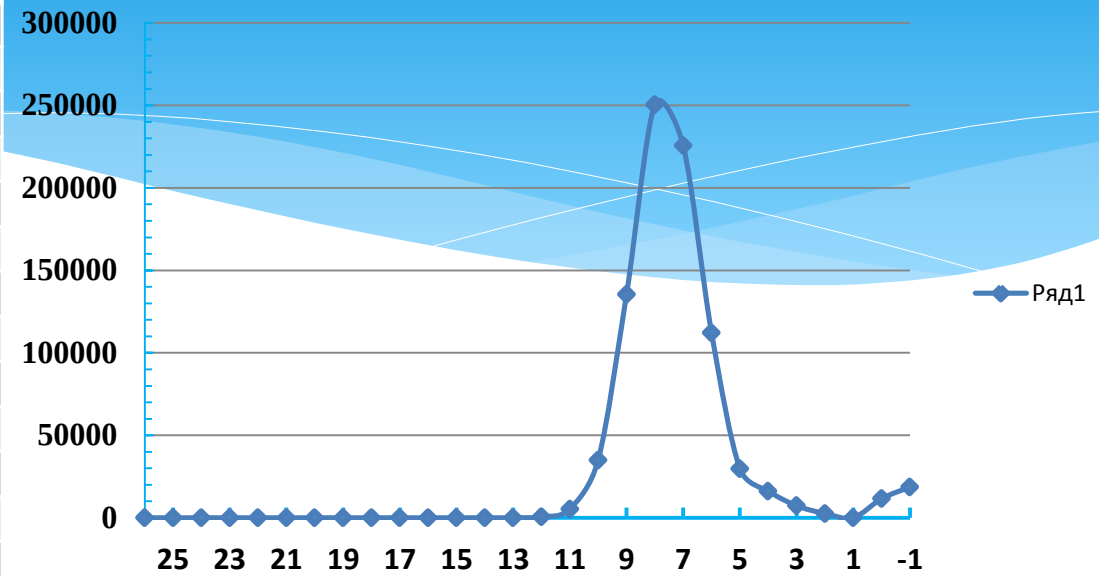


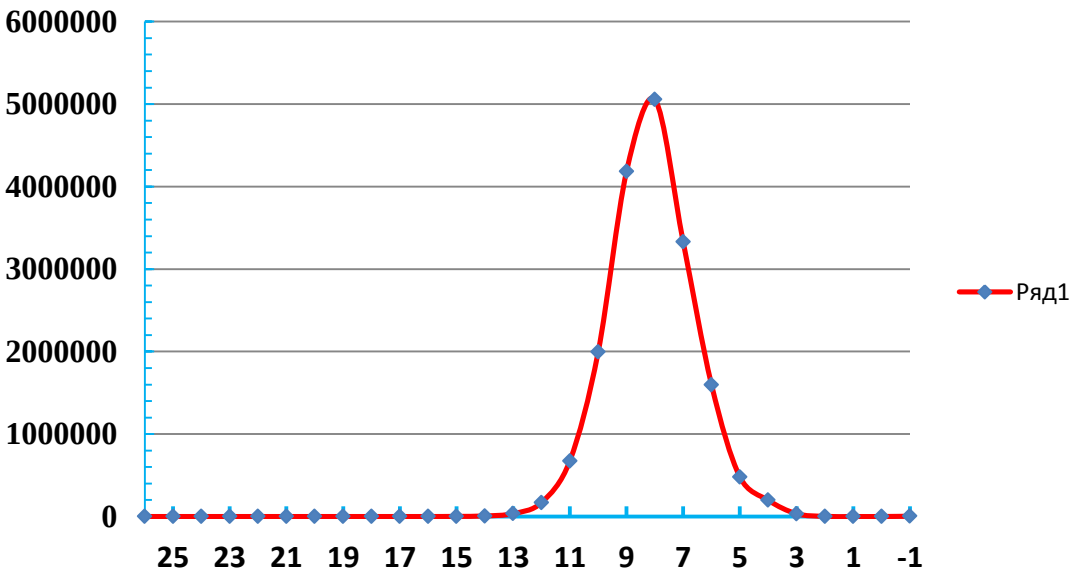


ABBN-78 Group №	Energy interval	Outgoing spectrum	Capture spectrum
-1	14.5-14.0 MeV	18629	3672
0	14.0-10.5 MeV	11632	195
1	10.5 – 6.5 MeV	89	5
2	6.5 – 4.0 MeV	2578	1941
3	4.0 – 2.5 MeV	7366	33960
4	2.5 – 1.4 MeV	16235	197676
5	1.4 – 0.8 MeV	29853	479411
6	0.8 – 0.4 MeV	112217	1597130
7	0.4 – 0.2 MeV	225637	3329706
8	0.2 – 0.1 MeV	250544	5054980
9	100 – 46.5 KeV	135402	4183316
10	46.5 – 21.5 KeV	35055	1995315
11	21.5 – 10 KeV	5366	674464
12	10 – 4.65 KeV	604	169446
13	4.65 – 2.15 KeV	65	35664
14	2.15 – 1 KeV	17	6998
15	1 – 0.465 KeV	1	1705
16	465 – 215 eV	0	20
17	215 – 100 eV	0	0
18	100 – 46.5 eV	0	0
19	46.5 – 21.5 eV	0	0
20	21.5 – 10 eV	0	0
21	10 – 4.65 eV	0	0
22	4.65 – 2.15 eV	0	0
23	2.15 – 1.0 eV	0	0
24	1.0 – 0.465 eV	0	0
25	0.465 – 0.215 eV	0	0
26	0.215 – 0.001 eV	0	0

Sphere Re^{185} Re^{187} R= 30 cm

Outgoing spectrum (upper picture, blue curve) and capture spectrum (picture below, red line).

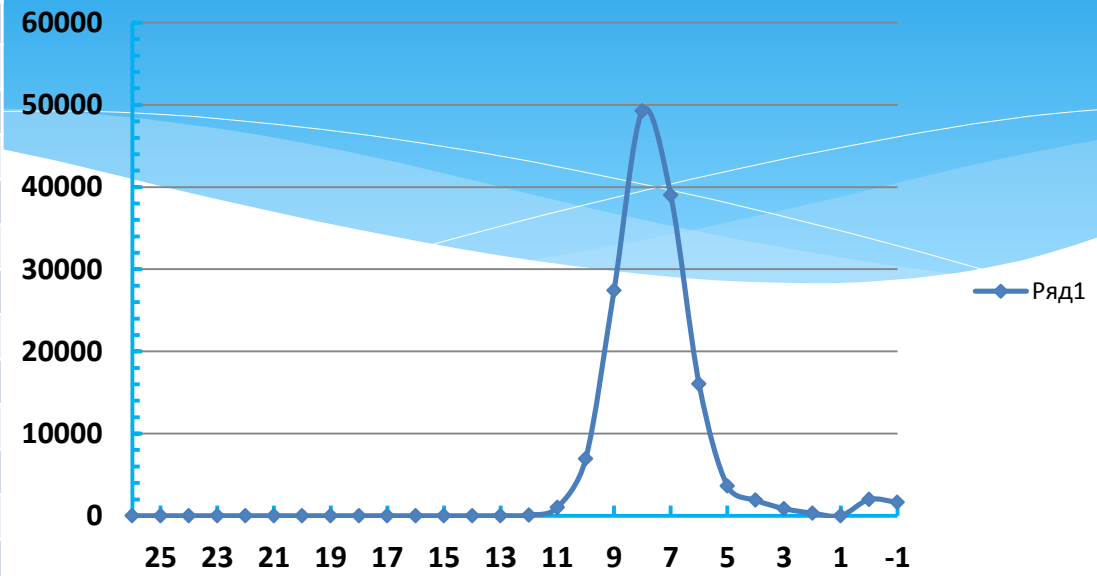


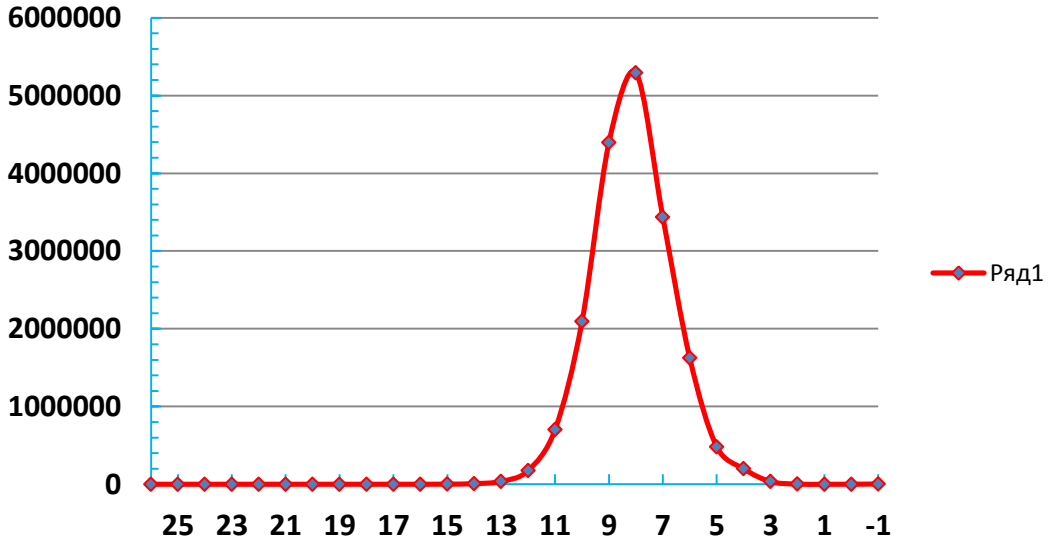


ABBN-78 Group №	Energy interval	Outgoing spectrum	Capture spectrum
-1	14.5-14.0 MeV	1646	3668
0	14.0-10.5 MeV	1988	191
1	10.5 – 6.5 MeV	14	5
2	6.5 – 4.0 MeV	325	1946
3	4.0 – 2.5 MeV	876	34241
4	2.5 – 1.4 MeV	1906	198953
5	1.4 – 0.8 MeV	3632	482672
6	0.8 – 0.4 MeV	16050	1623884
7	0.4 – 0.2 MeV	39037	3438097
8	0.2 – 0.1 MeV	49262	5293964
9	100 – 46.5 KeV	27445	4395470
10	46.5 – 21.5 KeV	6930	2092627
11	21.5 – 10 KeV	1026	702166
12	10 – 4.65 KeV	97	175483
13	4.65 – 2.15 KeV	13	36877
14	2.15 – 1 KeV	1	7347
15	1 – 0.465 KeV	1	1761
16	465 – 215 eV	0	22
17	215 – 100 eV	0	0
18	100 – 46.5 eV	0	0
19	46.5 – 21.5 eV	0	0
20	21.5 – 10 eV	0	0
21	10 – 4.65 eV	0	0
22	4.65 – 2.15 eV	0	0
23	2.15 – 1.0 eV	0	0
24	1.0 – 0.465 eV	0	0
25	0.465 – 0.215 eV	0	0
26	0.215 – 0.001 eV	0	0

Sphere Re^{185} Re^{187} R= 40 cm

Outgoing spectrum (upper picture, blue curve) and capture spectrum (picture below, red line).

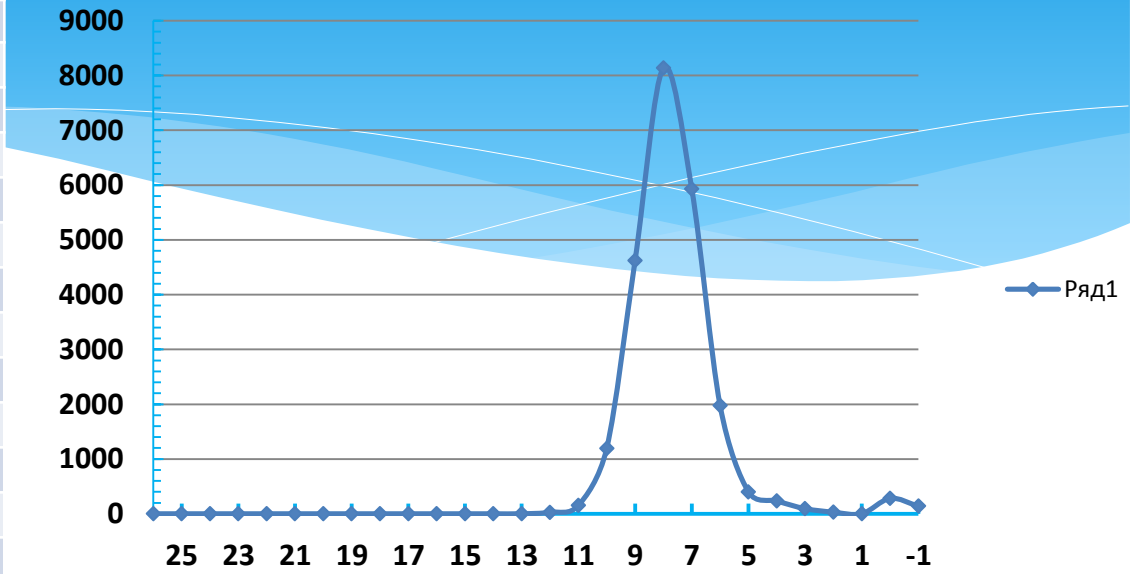


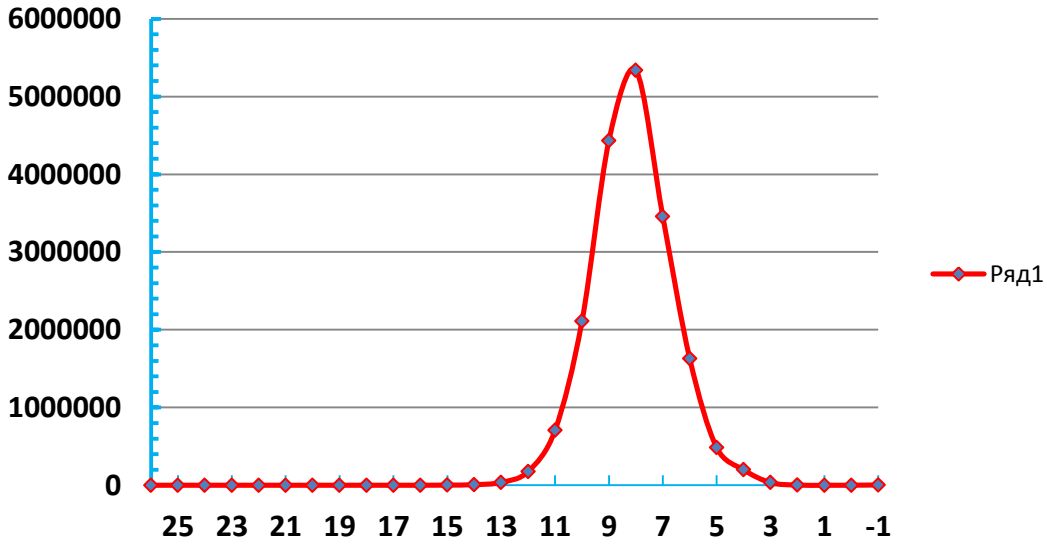


ABBN-78 Group №	Energy interval	Outgoing spectrum	Capture spectrum
-1	14.5-14.0 MeV	140	3696
0	14.0-10.5 MeV	281	194
1	10.5 – 6.5 MeV	1	5
2	6.5 – 4.0 MeV	30	1958
3	4.0 – 2.5 MeV	94	34243
4	2.5 – 1.4 MeV	235	198898
5	1.4 – 0.8 MeV	402	483031
6	0.8 – 0.4 MeV	1978	1627487
7	0.4 – 0.2 MeV	5931	3456098
8	0.2 – 0.1 MeV	8139	5337868
9	100 – 46.5 KeV	4622	4434496
10	46.5 – 21.5 KeV	1195	2110743
11	21.5 – 10 KeV	154	707209
12	10 – 4.65 KeV	28	176461
13	4.65 – 2.15 KeV	1	37084
14	2.15 – 1 KeV	0	7371
15	1 – 0.465 KeV	0	1769
16	465 – 215 eV	0	22
17	215 – 100 eV	0	0
18	100 – 46.5 eV	0	0
19	46.5 – 21.5 eV	0	0
20	21.5 – 10 eV	0	0
21	10 – 4.65 eV	0	0
22	4.65 – 2.15 eV	0	0
23	2.15 – 1.0 eV	0	0
24	1.0 – 0.465 eV	0	0
25	0.465 – 0.215 eV	0	0
26	0.215 – 0.001 eV	0	0

Sphere Re^{185} Re^{187} R= 50 cm

Outgoing spectrum (upper picture, blue curve) and capture spectrum (picture below, red line).

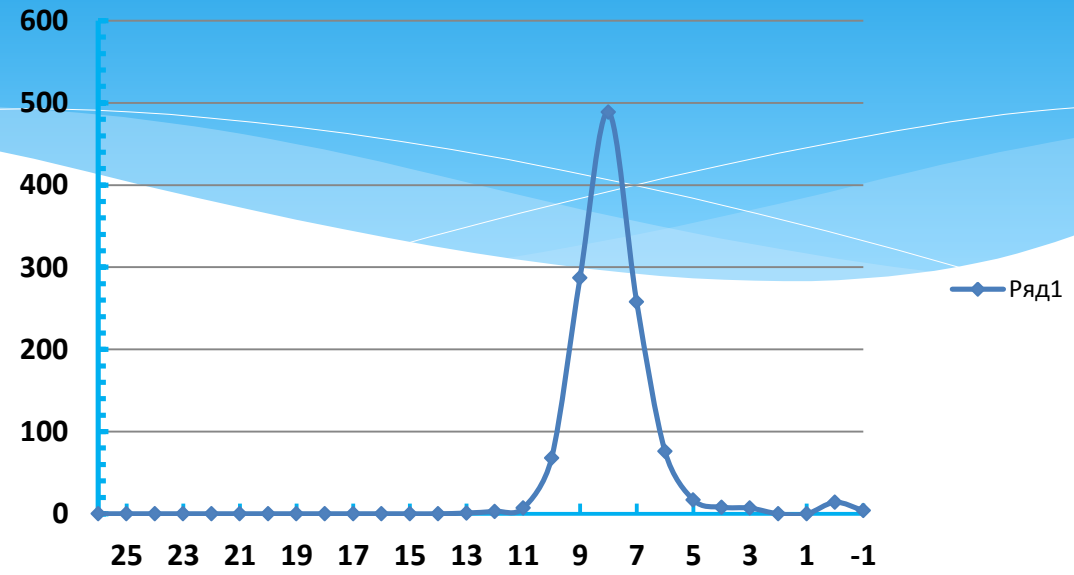


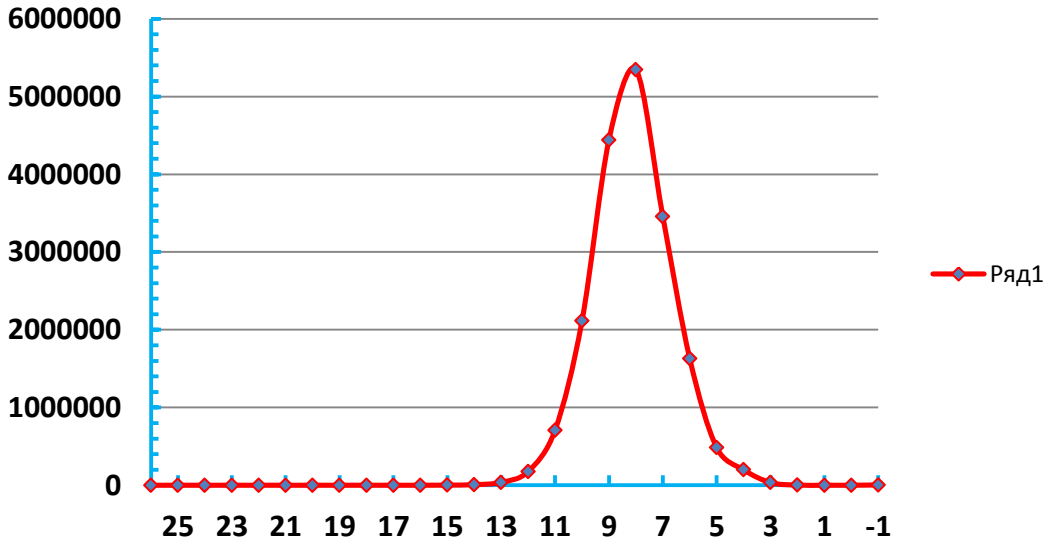


ABBN-78 Group №	Energy interval	Outgoing spectrum	Capture spectrum
-1	14.5-14.0 MeV	4	3693
0	14.0-10.5 MeV	14	191
1	10.5 – 6.5 MeV	0	5
2	6.5 – 4.0 MeV	0	1961
3	4.0 – 2.5 MeV	7	34247
4	2.5 – 1.4 MeV	8	198865
5	1.4 – 0.8 MeV	17	483067
6	0.8 – 0.4 MeV	76	1628186
7	0.4 – 0.2 MeV	258	3458775
8	0.2 – 0.1 MeV	489	5345328
9	100 – 46.5 KeV	287	4441533
10	46.5 – 21.5 KeV	68	2113904
11	21.5 – 10 KeV	7	708154
12	10 – 4.65 KeV	3	176613
13	4.65 – 2.15 KeV	1	37178
14	2.15 – 1 KeV	0	7380
15	1 – 0.465 KeV	0	1778
16	465 – 215 eV	0	23
17	215 – 100 eV	0	0
18	100 – 46.5 eV	0	0
19	46.5 – 21.5 eV	0	0
20	21.5 – 10 eV	0	0
21	10 – 4.65 eV	0	0
22	4.65 – 2.15 eV	0	0
23	2.15 – 1.0 eV	0	0
24	1.0 – 0.465 eV	0	0
25	0.465 – 0.215 eV	0	0
26	0.215 – 0.001 eV	0	0

Sphere Re^{185} Re^{187} R= 65 cm

Outgoing spectrum (upper picture, blue curve) and capture spectrum (picture below, red line).

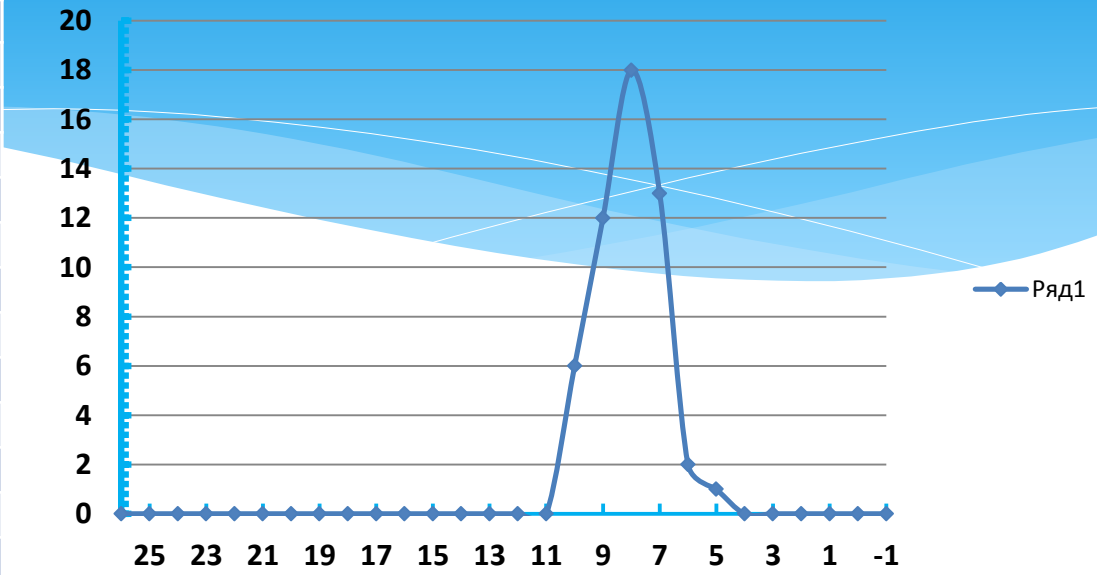


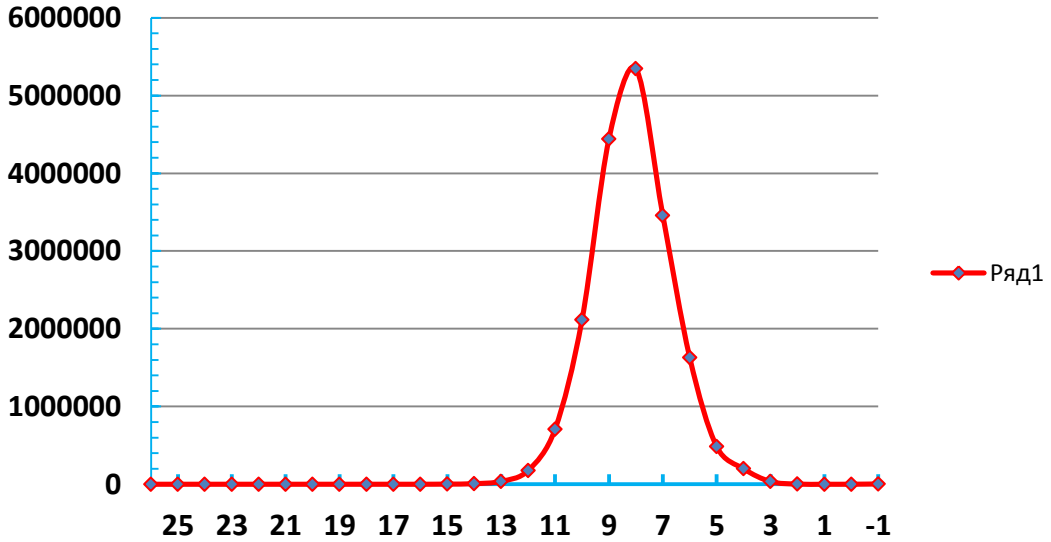


ABBN-78 Group №	Energy interval	Outgoing spectrum	Capture spectrum
-1	14.5-14.0 MeV	0	3696
0	14.0-10.5 MeV	0	191
1	10.5 – 6.5 MeV	0	5
2	6.5 – 4.0 MeV	0	1960
3	4.0 – 2.5 MeV	0	34248
4	2.5 – 1.4 MeV	0	198858
5	1.4 – 0.8 MeV	1	483116
6	0.8 – 0.4 MeV	2	1628200
7	0.4 – 0.2 MeV	13	3458848
8	0.2 – 0.1 MeV	18	5345761
9	100 – 46.5 KeV	12	4441921
10	46.5 – 21.5 KeV	6	2114131
11	21.5 – 10 KeV	0	708188
12	10 – 4.65 KeV	0	176621
13	4.65 – 2.15 KeV	0	37176
14	2.15 – 1 KeV	0	7379
15	1 – 0.465 KeV	0	1777
16	465 – 215 eV	0	22
17	215 – 100 eV	0	0
18	100 – 46.5 eV	0	0
19	46.5 – 21.5 eV	0	0
20	21.5 – 10 eV	0	0
21	10 – 4.65 eV	0	0
22	4.65 – 2.15 eV	0	0
23	2.15 – 1.0 eV	0	0
24	1.0 – 0.465 eV	0	0
25	0.465 – 0.215 eV	0	0
26	0.215 – 0.001 eV	0	0

Sphere Re^{185} Re^{187} **R= 80 cm**

Outgoing spectrum (upper picture, blue curve) and capture spectrum (picture below, red line).



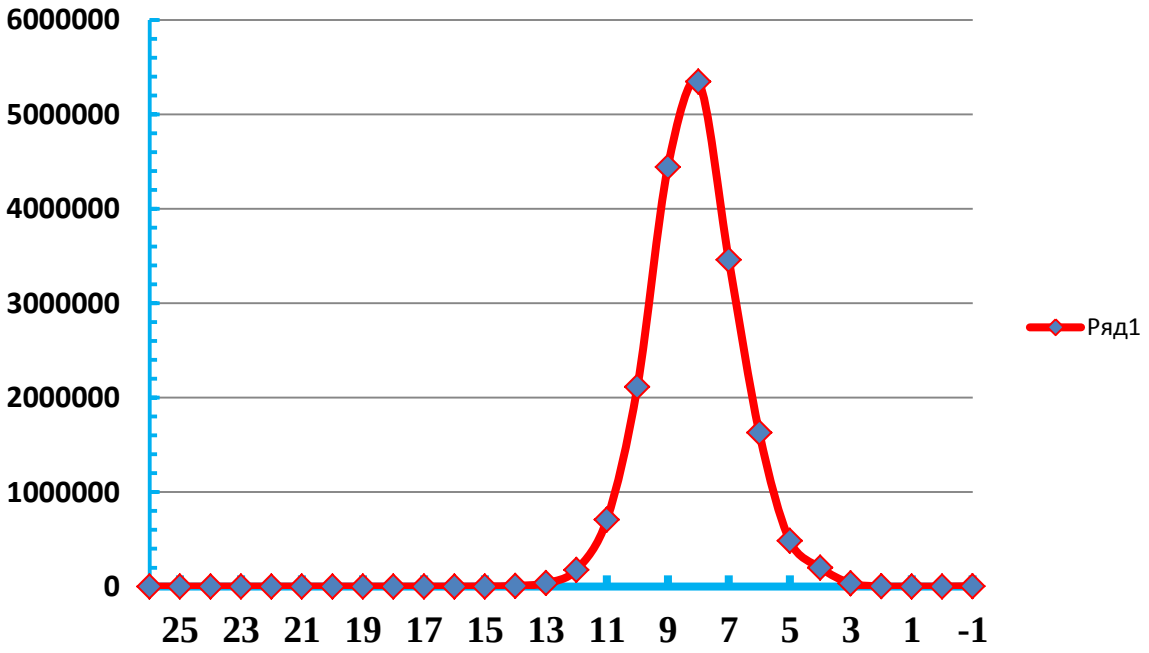


ABBN-78 Group №	Energy interval	Outgoing spectrum	Capture spectrum
-1	14.5-14.0 MeV	0	3696
0	14.0-10.5 MeV	0	191
1	10.5 – 6.5 MeV	0	5
2	6.5 – 4.0 MeV	0	1960
3	4.0 – 2.5 MeV	0	34248
4	2.5 – 1.4 MeV	0	198857
5	1.4 – 0.8 MeV	0	483113
6	0.8 – 0.4 MeV	0	1628204
7	0.4 – 0.2 MeV	0	3458869
8	0.2 – 0.1 MeV	1	5345776
9	100 – 46.5 KeV	0	4441930
10	46.5 – 21.5 KeV	0	2114132
11	21.5 – 10 KeV	0	708194
12	10 – 4.65 KeV	0	176622
13	4.65 – 2.15 KeV	0	37177
14	2.15 – 1 KeV	0	7379
15	1 – 0.465 KeV	0	1777
16	465 – 215 eV	0	22
17	215 – 100 eV	0	0
18	100 – 46.5 eV	0	0
19	46.5 – 21.5 eV	0	0
20	21.5 – 10 eV	0	0
21	10 – 4.65 eV	0	0
22	4.65 – 2.15 eV	0	0
23	2.15 – 1.0 eV	0	0
24	1.0 – 0.465 eV	0	0
25	0.465 – 0.215 eV	0	0
26	0.215 – 0.001 eV	0	0

Metal sphere Re^{185} Re^{187} R= 100 cm Capture spectrum (red curve)

Majority of initial 14.1 MeV neutrons in infinite Re^{185} Re^{187} media are captured at energies **800 KeV<En<21.5 KeV**.

It's necessary to note especially, that maximum of both spectra are around 100 KeV i.e. neutron fluxes with such energies already can be measured by existing TOF spectrometers.



Spectrums in metal Rhenium spheres

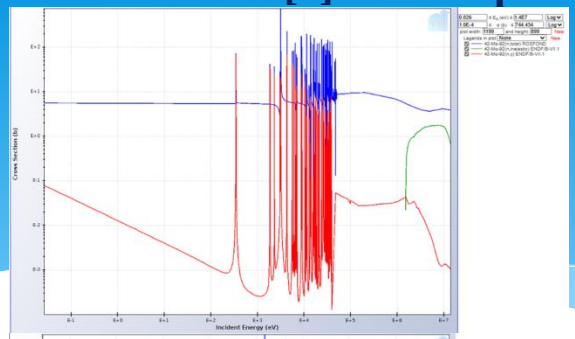
ABBN-78 Group №	Energy Interval	R = 1 cm		R = 5 cm		R = 10 cm		R = 15 cm		R = 20 cm		R = 25 cm	
		Outgoing Spectrum	Capture Spectrum	Outgoing Spectrum	Capture Spectrum	Outgoing Spectrum	Capture Spectrum	Outgoing Spectrum	Capture Spectrum	Outgoing Spectrum	Capture Spectrum	Outgoing Spectrum	Capture Spectrum
-1	14.5-14.0 MeV	8388228	599	4050250	2219	1543254	3182	552598	3491	186253	3659	60265	3661
0	14.0-10.5 MeV	29901	1	99540	33	113228	110	84293	135	50032	171	25003	190
1	10.5-6.5 MeV	1292	0	2901	0	1955	2	1019	7	498	4	221	4
2	6.5-4.0 MeV	73839	34	146982	618	92827	1257	43309	1683	18084	1854	6919	1891
3	4.0-2.5 MeV	313895	812	594603	11264	344540	23547	148176	29785	57247	32762	20633	33536
4	2.5-1.4 MeV	733123	4347	1416080	64457	809062	136378	342930	174443	129527	190575	46893	195774
5	1.4-0.8 MeV	726025	7243	1697768	127445	1140563	302358	537771	405903	219362	453654	83173	471602
6	0.8-0.4 MeV	589679	8933	2138822	240721	2083720	763759	1270797	1192442	627975	1432910	276156	1549059
7	0.4-0.2 MeV	277586	6152	1644927	271390	2223477	1167618	1682685	2135032	982251	2793296	493398	3158688
8	0.2-0.1 MeV	123993	4031	1090440	271610	1745891	1429706	1477637	2893796	939970	4026215	510684	4701736
9	100-46.5 KeV	55261	2178	586801	205020	947630	1144470	796243	2362180	506869	3307253	275687	3878769
10	46.5 –21.5 KeV	16952	1010	181929	106015	268236	573598	214014	1148172	132570	1591255	71361	1855976
11	21.5– 10 KeV	3703	388	39991	45079	51266	219163	37343	414659	21598	553186	11153	633901
12	10– 4.65 KeV	832	170	6325	15419	6766	63012	4596	110450	2511	142069	1279	160393
13	4.65– 2.15 KeV	141	61	828	4196	680	14464	498	24274	275	30478	137	33798
14	2.15 – 1 KeV	33	9	156	831	144	2897	74	4813	53	6062	25	6764
15	1– 0.465 KeV	5	10	16	216	19	670	9	1071	8	1407	1	1578
16	465– 215 eV	0	0	0	3	0	9	0	16	0	13	0	21
17	215– 100 eV	0	0	0	0	0	0	0	0	0	0	0	0
18	100– 46.5 eV	0	0	0	0	0	0	0	0	0	0	0	0
19	46.5– 21.5 eV	0	0	0	0	0	0	0	0	0	0	0	0
20	21.5– 10 eV	0	0	0	0	0	0	0	0	0	0	0	0
21	10– 4.65 eV	0	0	0	0	0	0	0	0	0	0	0	0
22	4.6 – 2.15 eV	0	0	0	0	0	0	0	0	0	0	0	0
23	2.1 – 1.0 eV	0	0	0	0	0	0	0	0	0	0	0	0
24	1.0– 0.465 eV	0	0	0	0	0	0	0	0	0	0	0	0
25	0.46 – 0.215 eV	0	0	0	0	0	0	0	0	0	0	0	0
26	0.215– 0.001 eV	0	0	0	0	0	0	0	0	0	0	0	0
Average Neutron Energy		11.65 MeV	988 keV	5.01 MeV	448 KeV	2.50 MeV	308 KeV	1.67 MeV	257 KeV	1.24 MeV	235 KeV	985 KeV	225 KeV
Diffusion/Absorption time of spectra, nanoseconds		0.3839	0.9589	5.6485	11.25	18.87	28.04	34.33	41.22	49.69	49.69	64.46	55.28
Number of neutrons		11334490	35978	13698360	1366536	11373260	5846200	7193992	10902350	3875083	14566820	1882988	16687340

Spectrums in metal Rhenium spheres

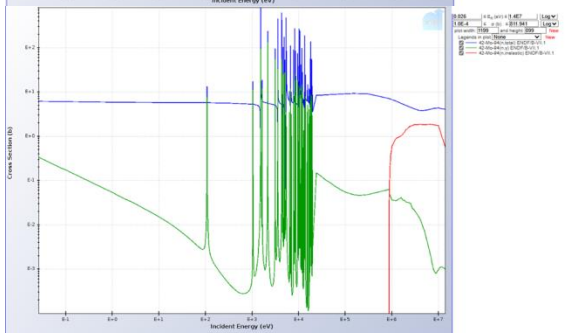
ABBN-78 Group №	Energy Interval	R = 30 cm		R = 40 cm		R = 50 cm		R = 65 cm		R = 80 cm		R = 100 cm	
		Outgoing Spectrum	Capture Spectrum	Outgoing Spectrum	Capture Spectrum	Outgoing Spectrum	Capture Spectrum	Outgoing Spectrum	Capture Spectrum	Outgoing Spectrum	Capture Spectrum	Outgoing Spectrum	Capture Spectrum
-1	14.5-14.0 MeV	18629	3672	1646	3668	140	3696	4	3693	0	3696	0	3696
0	14.0-10.5 MeV	11632	195	1988	191	281	194	14	191	0	191	0	191
1	10.5-6.5 MeV	89	5	14	5	1	5	0	5	0	5	0	5
2	6.5-4.0 MeV	2578	1941	325	1946	30	1958	0	1961	0	1960	0	1960
3	4.0-2.5 MeV	7366	33960	876	34241	94	34243	7	34247	0	34248	0	34248
4	2.5-1.4 MeV	16235	197676	1906	198953	235	198898	8	198865	0	198858	0	198857
5	1.4-0.8 MeV	29853	479411	3632	482672	402	483031	17	483067	1	483116	0	483113
6	0.8-0.4 MeV	112217	1597130	16050	1623884	1978	1627487	76	1628186	2	1628200	0	1628204
7	0.4-0.2 MeV	225637	3329706	39037	3438097	5931	3456098	258	3458775	13	3458848	0	3458869
8	0.2-0.1 MeV	250544	5054980	49262	5293964	8139	5337868	489	5345328	18	5345761	1	5345776
9	100-46.5 KeV	135402	4183316	27445	4395470	4622	4434496	287	4441533	12	4441921	0	4441930
10	46.5 –21.5 KeV	35055	1995315	6930	2092627	1195	2110743	68	2113904	6	2114131	0	2114132
11	21.5– 10 KeV	5366	674464	1026	702166	154	707209	7	708154	0	708188	0	708194
12	10– 4.65 KeV	604	169446	97	175483	28	176461	3	176613	0	176621	0	176622
13	4.65– 2.15 KeV	65	35664	13	36877	1	37084	1	37178	0	37176	0	37177
14	2.15 – 1 KeV	17	6998	1	7347	0	7371	0	7380	0	7379	0	7379
15	1– 0.465 KeV	1	1705	1	1761	0	1769	0	1778	0	1777	0	1777
16	465– 215 eV	0	20	0	22	0	22	0	23	0	22	0	22
17	215– 100 eV	0	0	0	0	0	0	0	0	0	0	0	0
18	100– 46.5 eV	0	0	0	0	0	0	0	0	0	0	0	0
19	46.5– 21.5 eV	0	0	0	0	0	0	0	0	0	0	0	0
20	21.5– 10 eV	0	0	0	0	0	0	0	0	0	0	0	0
21	10– 4.65 eV	0	0	0	0	0	0	0	0	0	0	0	0
22	4.6 – 2.15 eV	0	0	0	0	0	0	0	0	0	0	0	0
23	2.1 – 1.0 eV	0	0	0	0	0	0	0	0	0	0	0	0
24	1.0– 0.465 eV	0	0	0	0	0	0	0	0	0	0	0	0
25	0.46 – 0.215 eV	0	0	0	0	0	0	0	0	0	0	0	0
26	0.215– 0.001 eV	0	0	0	0	0	0	0	0	0	0	0	0
Average Neutron Energy		813 KeV	219 KeV	607 KeV	216 KeV	490 KeV	215.8 KeV	411 KeV	215.7 KeV	177 KeV	215.7 KeV	165.3 KeV	215.7 KeV
Diffusion/Absorption time of spectra, nanoseconds		78.59	58.69	105.6	60.97	130.4	61.54	163.7	61.67	187.1	61.68	44.25	61.68
Number of neutrons		851290	17765604	150249	18489374	23231	18618633	1239	18640880	52	18642098	1	18642152

Neutron cross sections [5] for isotopes of Mo^{nat} : total cross section, capture, inelastic scattering

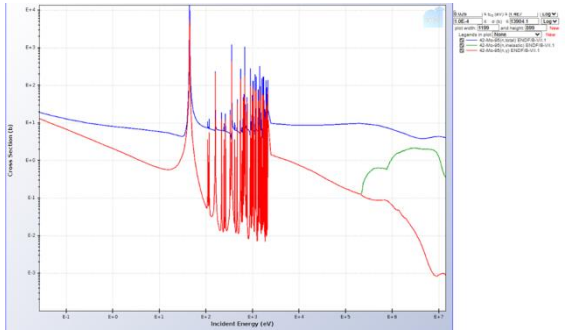
Mo^{92}
(15.86%)



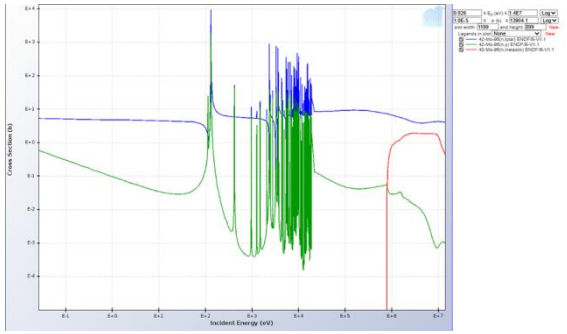
Mo^{94}
(9.12%)



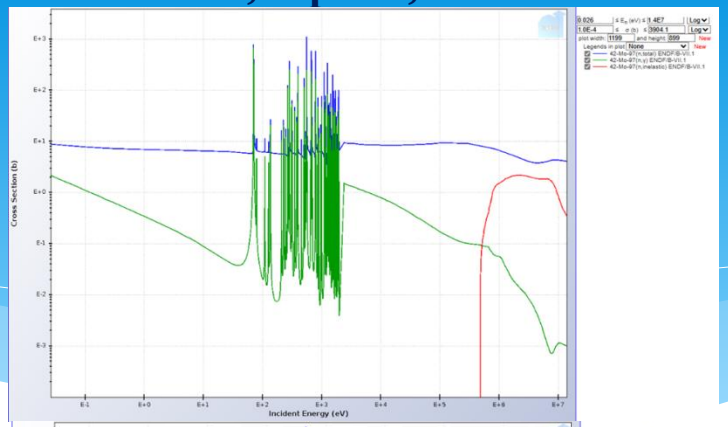
Mo^{95}
(15.7%)



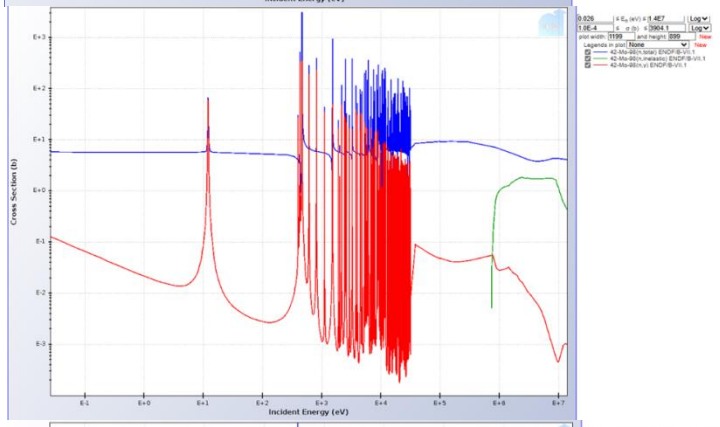
Mo^{96}
(16.5%)



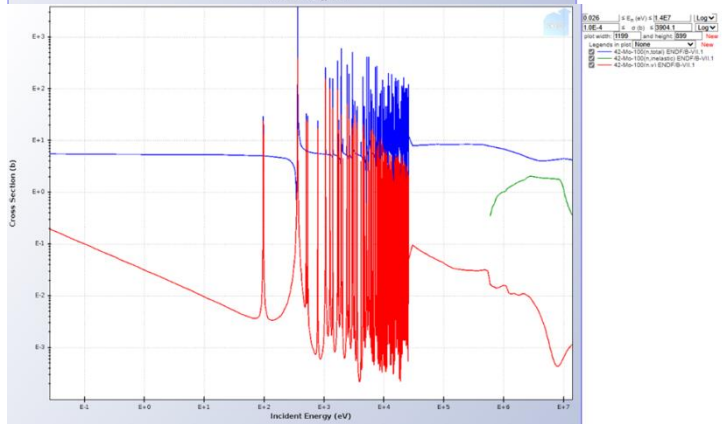
Mo^{97}
(9.45%)



Mo^{98}
(23.75%)



Mo^{100}
(9.62%)



ABBN-78 constants for Mo^{nat}

BNAB 28-GROUP NEUTRON CONSTANTS FOR MO(42, 95.94000)

MAIN GROUP CONSTANTS

GR.	ENERGY (MEV)	S-TOT	S-FIS	AVER NU	S-CAP	S-IN	S-EL	COS EL
-1	.140E+02- .145E+02	4.0390	.0000	.0000	.1750	1.6270	2.2370	.8340
0	.105E+02- .140E+02	4.1700	.0000	.0000	.1400	1.6500	2.3800	.8330
1	.650E+01- .105E+02	4.1930	.0000	.0000	.0260	1.8230	2.3440	.7360
2	.400E+01- .650E+01	3.8396	.0000	.0000	.0190	1.8376	1.9830	.5690
3	.250E+01- .400E+01	4.1228	.0000	.0000	.0170	1.8408	2.2650	.4750
4	.140E+01- .250E+01	5.1817	.0000	.0000	.0270	1.5147	3.6400	.4570
5	.800E+00- .140E+01	6.5454	.0000	.0000	.0370	.8794	5.6290	.4230
6	.400E+00- .800E+00	8.0119	.0000	.0000	.0550	.1639	7.7930	.3260
7	.200E+00- .400E+00	9.0334	.0000	.0000	.0550	.0364	8.9420	.2150
8	.100E+00- .200E+00	9.2490	.0000	.0000	.0660	.0000	9.1830	.1190
9	.465E-01- .100E+00	8.9030	.0000	.0000	.1000	.0000	8.8030	.0580
10	.215E-01- .465E-01	8.5670	.0000	.0000	.1730	.0000	8.3940	.0270
11	.100E-01- .215E-01	8.9070	.0000	.0000	.2640	.0000	8.6430	.0150
12	.465E-02- .100E-01	9.2310	.0000	.0000	.4200	.0000	8.8110	.0100
13	.215E-02- .465E-02	10.2270	.0000	.0000	.6530	.0000	9.5740	.0080
14	.100E-02- .215E-02	8.5760	.0000	.0000	.7160	.0000	7.8600	.0070
15	.465E-03- .100E-02	13.1670	.0000	.0000	1.5630	.0000	11.6040	.0070
16	.215E-03- .465E-03	10.2620	.0000	.0000	1.4990	.0000	8.7630	.0070
17	.100E-03- .215E-03	23.1500	.0000	.0000	3.8240	.0000	19.3260	.0070
18	.465E-04- .100E-03	8.5420	.0000	.0000	1.4330	.0000	7.1090	.0070
19	.215E-04- .465E-04	50.6260	.0000	.0000	20.8070	.0000	29.8190	.0070
20	.100E-04- .215E-04	5.9050	.0000	.0000	.6310	.0000	5.2740	.0070
21	.465E-05- .100E-04	5.5230	.0000	.0000	.1430	.0000	5.3800	.0070
22	.215E-05- .465E-05	5.6430	.0000	.0000	.2110	.0000	5.4320	.0070
23	.100E-05- .215E-05	5.7830	.0000	.0000	.3240	.0000	5.4590	.0070
24	.465E-06- .100E-05	5.9610	.0000	.0000	.4880	.0000	5.4730	.0070
25	.215E-06- .465E-06	6.2080	.0000	.0000	.7270	.0000	5.4810	.0070
26	THERMAL	7.0970	.0000	.0000	1.6010	.0000	5.4960	.0070

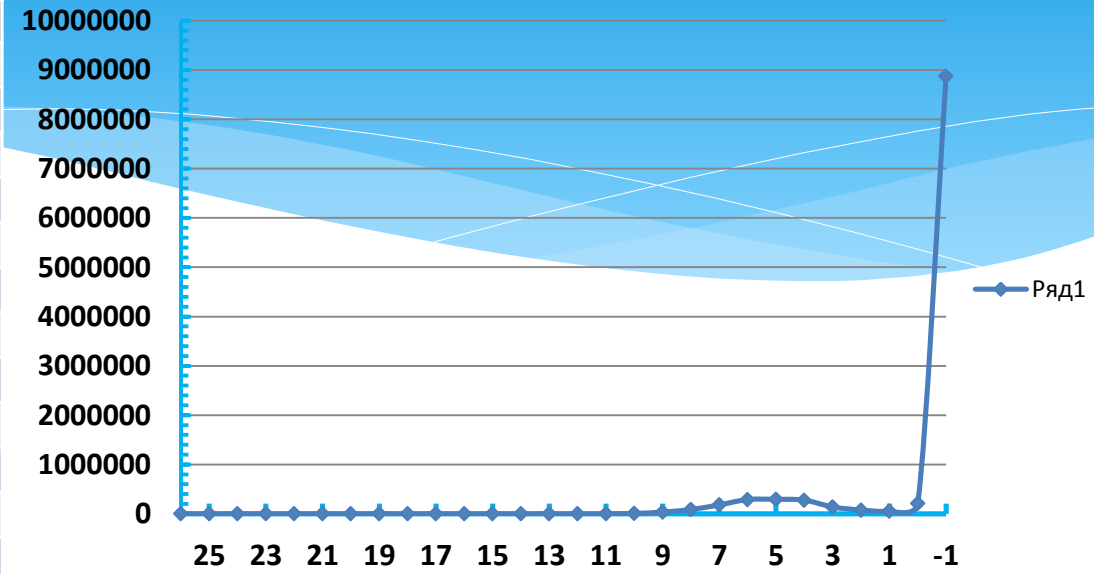
SIGMA IN (I,I+K) AT K EQUAL:

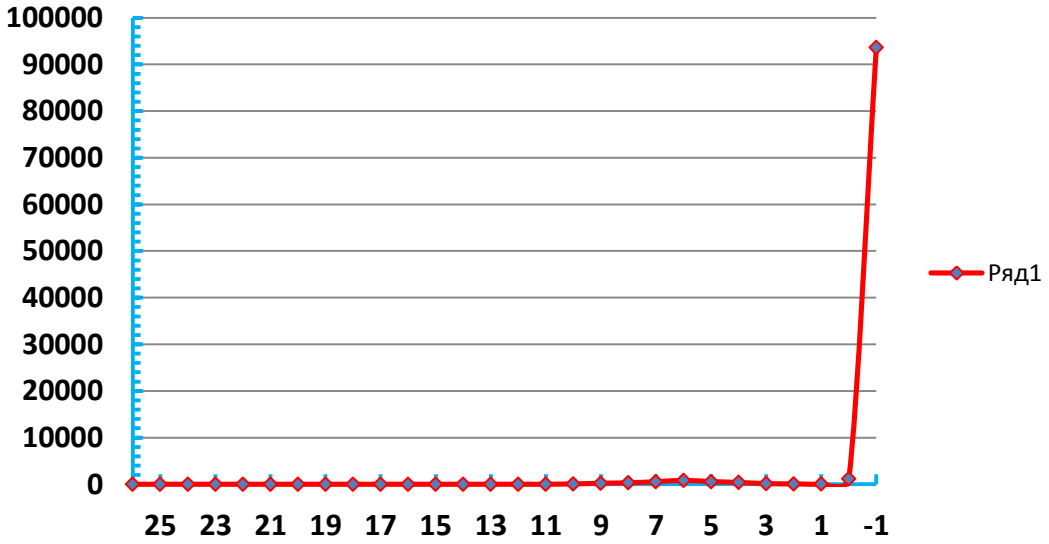
I	K= 0	K= 1	K= 2	K= 3	K= 4	K= 5	K= 6	K= 7	K= 8	K= 9	K=10	K=11	SUMMA
-1	.0003	.1620	.1197	.1580	.2783	.5315	.5283	.4853	.2994	.1425	.0579	.0122	2.7754
0	.1141	.1469	.1454	.2615	.5045	.5057	.4676	.2982	.1428	.0584	.0125	.0029	2.6605
1	.0812	.1936	.1915	.3748	.3648	.3264	.2024	.0968	.0398	.0086	.0020	.0005	1.8824
2	.0824	.2370	.3680	.3883	.3671	.2280	.1089	.0451	.0098	.0023	.0006	.0001	1.8376
3	.0912	.4711	.4539	.4063	.2516	.1092	.0443	.0101	.0024	.0006	.0001	.0000	1.8408
4	.1255	.4999	.5154	.2343	.0954	.0341	.0079	.0017	.0004	.0001	.0000	.0000	1.5147
5	.0359	.3308	.3325	.1333	.0392	.0065	.0011	.0001	.0000	.0000	.0000	.0000	.8794
6	.0368	.0743	.0311	.0143	.0056	.0014	.0003	.0001	.0000	.0000	.0000	.0000	.1639
7	.0000	.0230	.0098	.0027	.0007	.0002	.0000	.0000	.0000	.0000	.0000	.0000	.0364
8	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
9	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
10	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
11	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
12	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000

ABBN-78 Group №	Energy interval	Outgoing spectrum	Capture spectrum
-1	14.5-14.0 MeV	8873145	93605
0	14.0-10.5 MeV	207765	1125
1	10.5 – 6.5 MeV	55426	66
2	6.5 – 4.0 MeV	76899	85
3	4.0 – 2.5 MeV	138607	132
4	2.5 – 1.4 MeV	276850	393
5	1.4 – 0.8 MeV	294330	565
6	0.8 – 0.4 MeV	288406	827
7	0.4 – 0.2 MeV	181801	543
8	0.2 – 0.1 MeV	86733	311
9	100 – 46.5 KeV	35588	219
10	46.5 – 21.5 KeV	7642	72
11	21.5 – 10 KeV	185	3
12	10 – 4.65 KeV	24	2
13	4.65 – 2.15 KeV	3	0
14	2.15 – 1 KeV	0	0
15	1 – 0.465 KeV	0	0
16	465 – 215 eV	0	0
17	215 – 100 eV	0	0
18	100 – 46.5 eV	0	0
19	46.5 – 21.5 eV	0	0
20	21.5 – 10 eV	0	0
21	10 – 4.65 eV	0	0
22	4.65 – 2.15 eV	0	0
23	2.15 – 1.0 eV	0	0
24	1.0 – 0.465 eV	0	0
25	0.465 – 0.215 eV	0	0
26	0.215 – 0.001 eV	0	0

Sphere of Molybdenum Mo^{nat} R= 1 cm

Outgoing spectrum (upper picture, blue curve) and capture spectrum (picture below, red line).

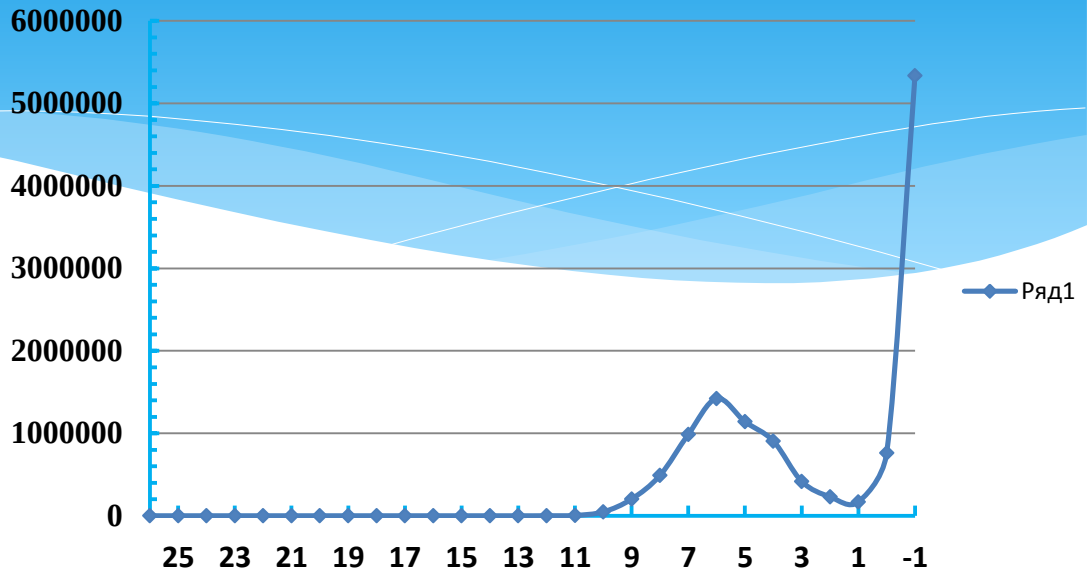


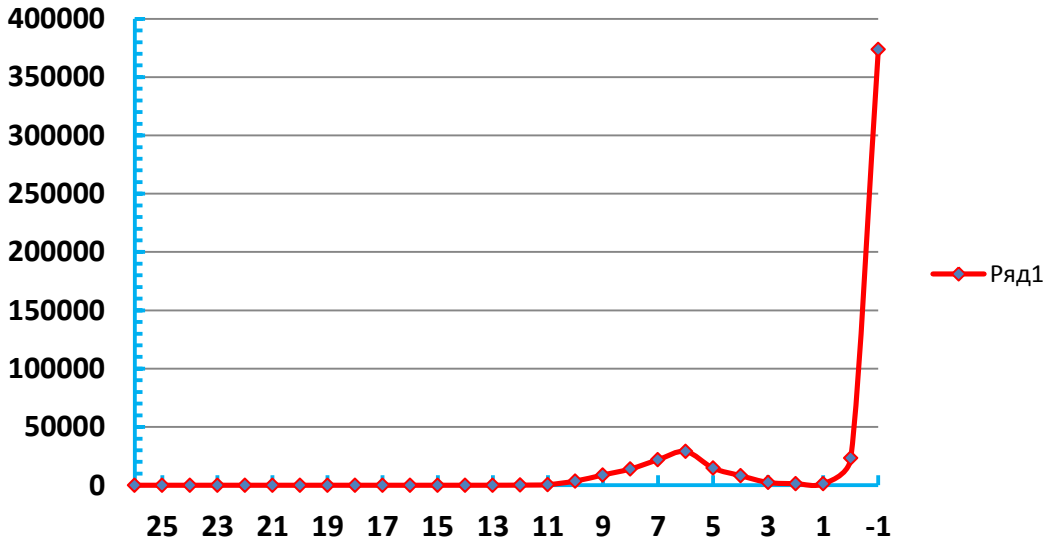


ABBN-78 Group №	Energy interval	Outgoing spectrum	Capture spectrum
-1	14.5-14.0 MeV	5336555	373665
0	14.0-10.5 MeV	762299	23203
1	10.5 – 6.5 MeV	167916	1380
2	6.5 – 4.0 MeV	230527	1373
3	4.0 – 2.5 MeV	418180	2377
4	2.5 – 1.4 MeV	906595	8228
5	1.4 – 0.8 MeV	1141307	14703
6	0.8 – 0.4 MeV	1422598	28979
7	0.4 – 0.2 MeV	987165	21880
8	0.2 – 0.1 MeV	489384	13985
9	100 – 46.5 KeV	203013	8812
10	46.5 – 21.5 KeV	47443	3586
11	21.5 – 10 KeV	4931	549
12	10 – 4.65 KeV	655	120
13	4.65 – 2.15 KeV	96	29
14	2.15 – 1 KeV	8	6
15	1 – 0.465 KeV	0	0
16	465 – 215 eV	0	0
17	215 – 100 eV	0	0
18	100 – 46.5 eV	0	0
19	46.5 – 21.5 eV	0	0
20	21.5 – 10 eV	0	0
21	10 – 4.65 eV	0	0
22	4.65 – 2.15 eV	0	0
23	2.15 – 1.0 eV	0	0
24	1.0 – 0.465 eV	0	0
25	0.465 – 0.215 eV	0	0
26	0.215 – 0.001 eV	0	0

Sphere of Molybdenum Mo^{nat} R= 5 cm

Outgoing spectrum (upper picture, blue curve) and capture spectrum (picture below, red line).

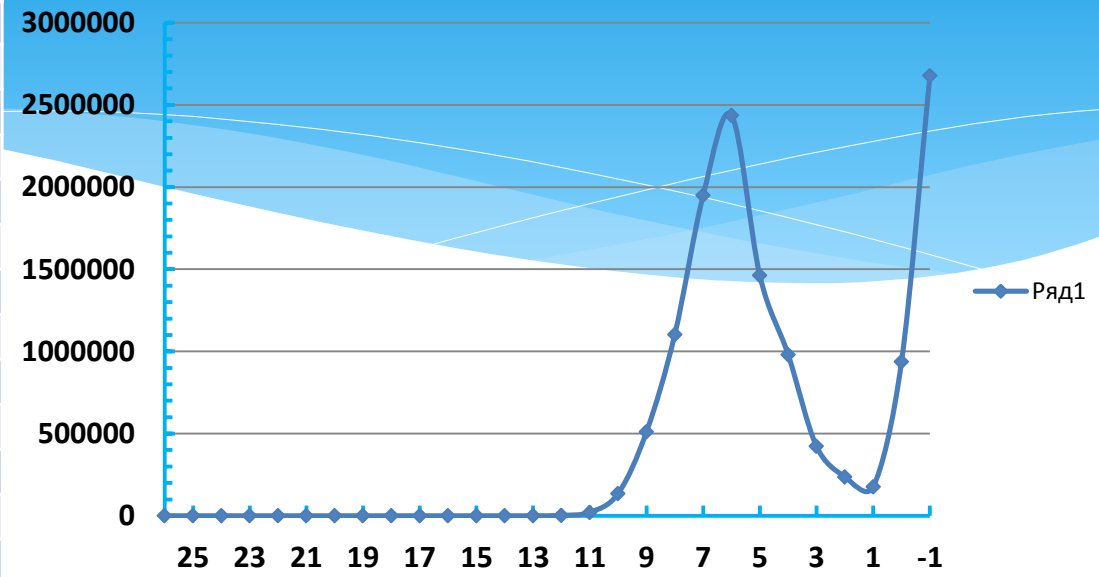


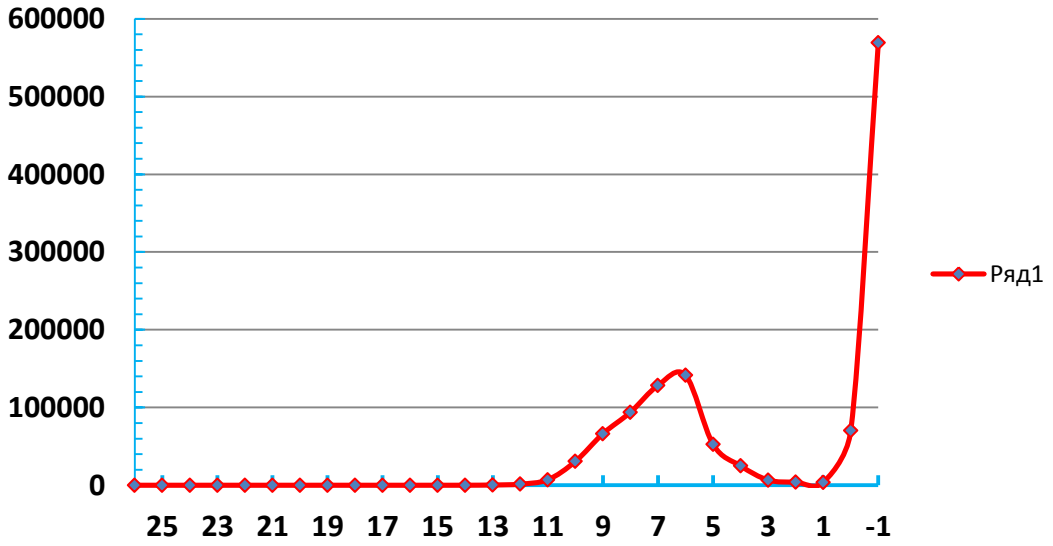


ABBN-78 Group №	Energy interval	Outgoing spectrum	Capture spectrum
-1	14.5-14.0 MeV	2677497	569408
0	14.0-10.5 MeV	937748	70249
1	10.5 – 6.5 MeV	176422	3722
2	6.5 – 4.0 MeV	237385	3917
3	4.0 – 2.5 MeV	422523	6646
4	2.5 – 1.4 MeV	980418	24933
5	1.4 – 0.8 MeV	1462132	52525
6	0.8 – 0.4 MeV	2437010	141484
7	0.4 – 0.2 MeV	1949498	128526
8	0.2 – 0.1 MeV	1103458	93931
9	100 – 46.5 KeV	510610	66334
10	46.5 – 21.5 KeV	135768	30668
11	21.5 – 10 KeV	21244	7080
12	10 – 4.65 KeV	2673	1445
13	4.65 – 2.15 KeV	385	318
14	2.15 – 1 KeV	30	36
15	1 – 0.465 KeV	0	0
16	465 – 215 eV	0	0
17	215 – 100 eV	0	0
18	100 – 46.5 eV	0	0
19	46.5 – 21.5 eV	0	0
20	21.5 – 10 eV	0	0
21	10 – 4.65 eV	0	0
22	4.65 – 2.15 eV	0	0
23	2.15 – 1.0 eV	0	0
24	1.0 – 0.465 eV	0	0
25	0.465 – 0.215 eV	0	0
26	0.215 – 0.001 eV	0	0

Sphere of Molybdenum Mo^{nat} R= 10 cm

Outgoing spectrum (upper picture, blue curve) and capture spectrum (picture below, red line).

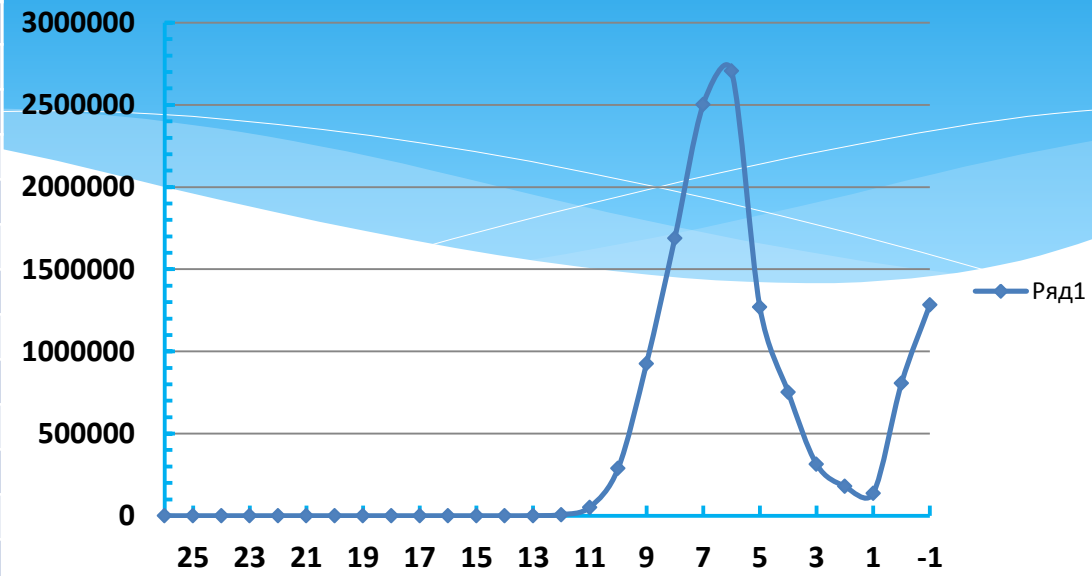


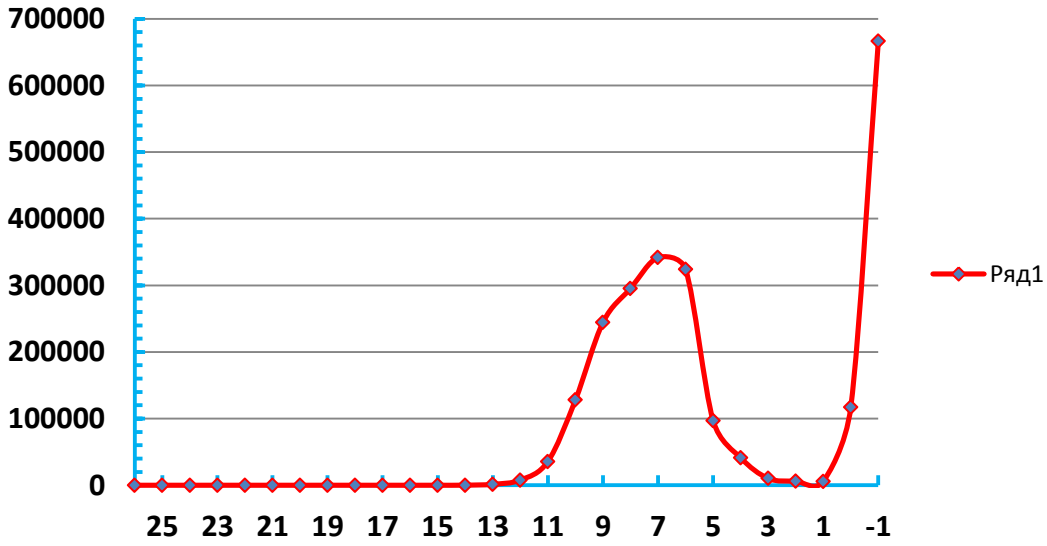


ABBN-78 Group №	Energy interval	Outgoing spectrum	Capture spectrum
-1	14.5-14.0 MeV	1284341	666310
0	14.0-10.5 MeV	807137	117094
1	10.5 – 6.5 MeV	136898	5843
2	6.5 – 4.0 MeV	179083	6083
3	4.0 – 2.5 MeV	314343	10245
4	2.5 – 1.4 MeV	752450	41276
5	1.4 – 0.8 MeV	1270056	97071
6	0.8 – 0.4 MeV	2706411	323896
7	0.4 – 0.2 MeV	2502366	341813
8	0.2 – 0.1 MeV	1689061	295364
9	100 – 46.5 KeV	925330	244270
10	46.5 – 21.5 KeV	288064	127905
11	21.5 – 10 KeV	52442	35670
12	10 – 4.65 KeV	6985	7779
13	4.65 – 2.15 KeV	802	1453
14	2.15 – 1 KeV	78	133
15	1 – 0.465 KeV	0	0
16	465 – 215 eV	0	0
17	215 – 100 eV	0	0
18	100 – 46.5 eV	0	0
19	46.5 – 21.5 eV	0	0
20	21.5 – 10 eV	0	0
21	10 – 4.65 eV	0	0
22	4.65 – 2.15 eV	0	0
23	2.15 – 1.0 eV	0	0
24	1.0 – 0.465 eV	0	0
25	0.465 – 0.215 eV	0	0
26	0.215 – 0.001 eV	0	0

Sphere of Molybdenum Mo^{nat} R= 15 cm

Outgoing spectrum (upper picture, blue curve) and capture spectrum (picture below, red line).

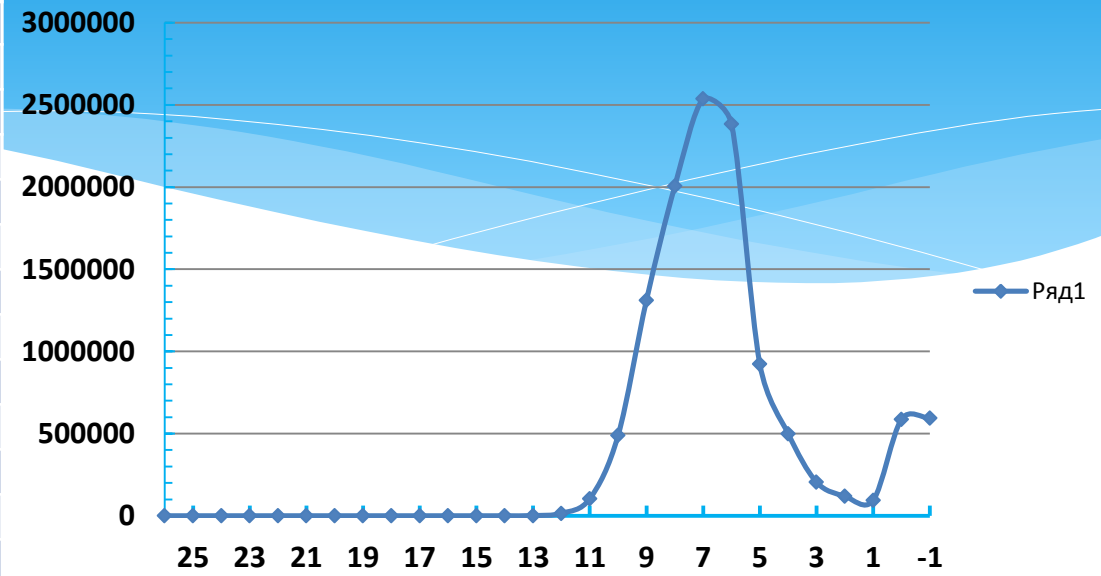


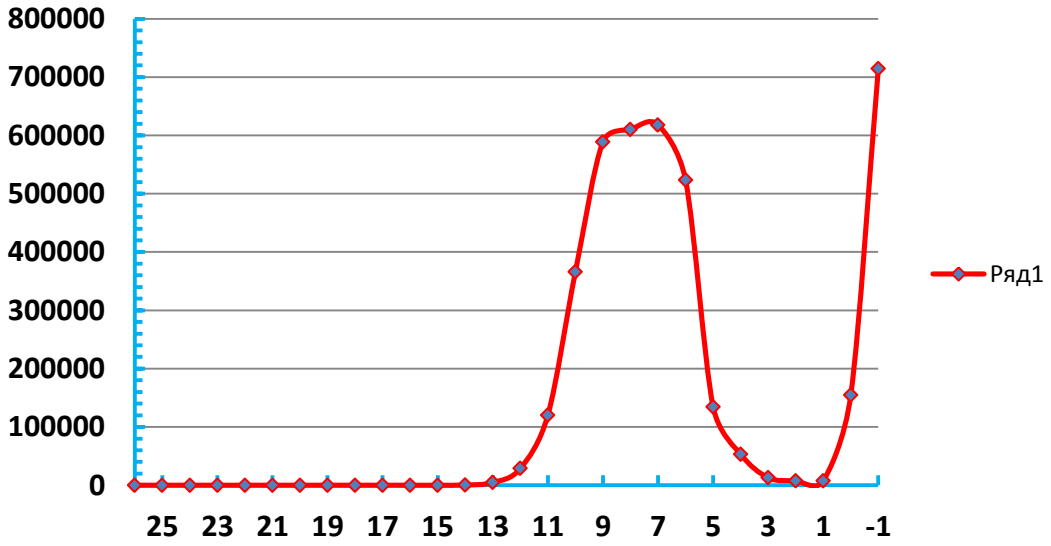


ABBN-78 Group №	Energy interval	Outgoing spectrum	Capture spectrum
-1	14.5-14.0 MeV	594141	714578
0	14.0-10.5 MeV	587695	154521
1	10.5 – 6.5 MeV	94285	7583
2	6.5 – 4.0 MeV	119413	7639
3	4.0 – 2.5 MeV	205364	12974
4	2.5 – 1.4 MeV	499925	53265
5	1.4 – 0.8 MeV	922786	134575
6	0.8 – 0.4 MeV	2383779	523656
7	0.4 – 0.2 MeV	2536985	618161
8	0.2 – 0.1 MeV	2006166	610305
9	100 – 46.5 KeV	1311700	588949
10	46.5 – 21.5 KeV	489883	366125
11	21.5 – 10 KeV	104496	120335
12	10 – 4.65 KeV	15332	28730
13	4.65 – 2.15 KeV	1462	4638
14	2.15 – 1 KeV	143	389
15	1 – 0.465 KeV	1	12
16	465 – 215 eV	0	0
17	215 – 100 eV	0	0
18	100 – 46.5 eV	0	0
19	46.5 – 21.5 eV	0	0
20	21.5 – 10 eV	0	0
21	10 – 4.65 eV	0	0
22	4.65 – 2.15 eV	0	0
23	2.15 – 1.0 eV	0	0
24	1.0 – 0.465 eV	0	0
25	0.465 – 0.215 eV	0	0
26	0.215 – 0.001 eV	0	0

Sphere of Molybdenum Mo^{nat} R= 20 cm

Outgoing spectrum (upper picture, blue curve) and capture spectrum (picture below, red line).

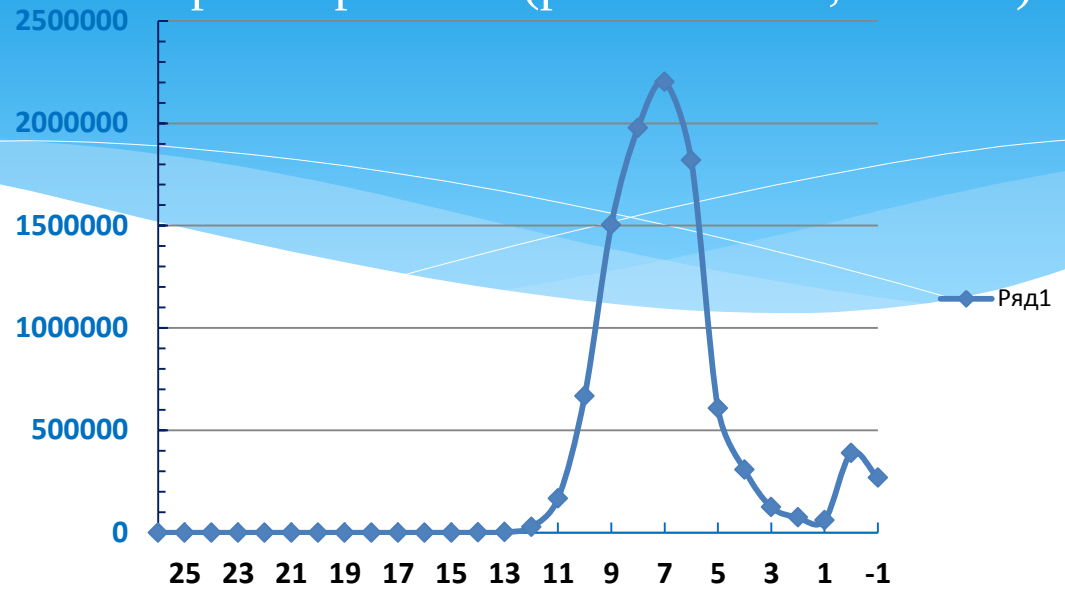


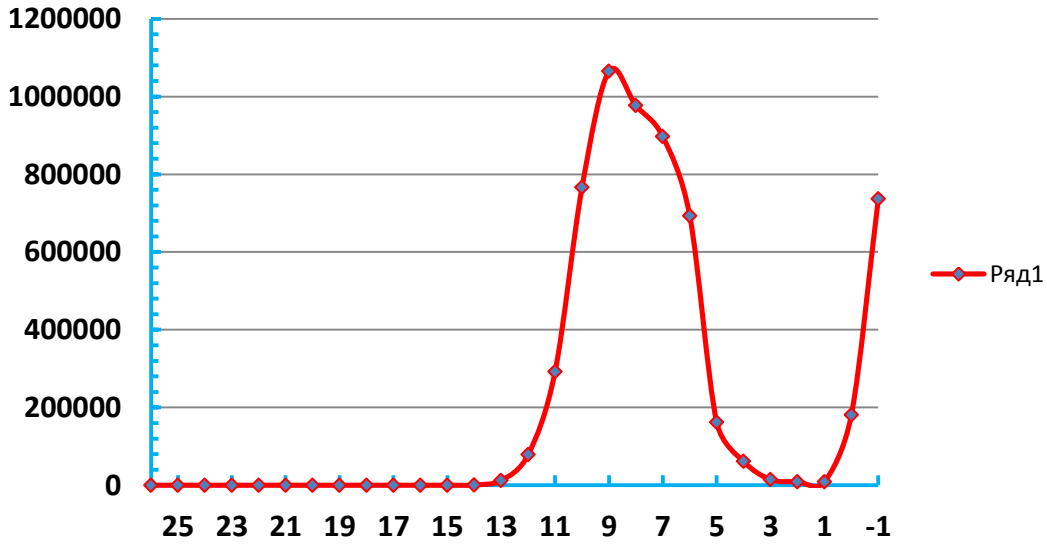


ABBN-78 Group №	Energy interval	Outgoing spectrum	Capture spectrum
-1	14.5-14.0 MeV	267759	736417
0	14.0-10.5 MeV	388094	181171
1	10.5 – 6.5 MeV	60160	8749
2	6.5 – 4.0 MeV	74129	9032
3	4.0 – 2.5 MeV	124793	14612
4	2.5 – 1.4 MeV	306703	61238
5	1.4 – 0.8 MeV	607321	161853
6	0.8 – 0.4 MeV	1818367	693201
7	0.4 – 0.2 MeV	2201342	896819
8	0.2 – 0.1 MeV	1976754	977097
9	100 – 46.5 KeV	1502327	1065102
10	46.5 – 21.5 KeV	666386	766141
11	21.5 – 10 KeV	166718	292256
12	10 – 4.65 KeV	27456	78625
13	4.65 – 2.15 KeV	2562	12240
14	2.15 – 1 KeV	208	957
15	1 – 0.465 KeV	2	16
16	465 – 215 eV	0	1
17	215 – 100 eV	0	0
18	100 – 46.5 eV	0	0
19	46.5 – 21.5 eV	0	0
20	21.5 – 10 eV	0	0
21	10 – 4.65 eV	0	0
22	4.65 – 2.15 eV	0	0
23	2.15 – 1.0 eV	0	0
24	1.0 – 0.465 eV	0	0
25	0.465 – 0.215 eV	0	0
26	0.215 – 0.001 eV	0	0

Sphere of Molybdenum Mo^{nat} R= 25 cm

Outgoing spectrum (upper picture, blue curve) and capture spectrum (picture below, red line).

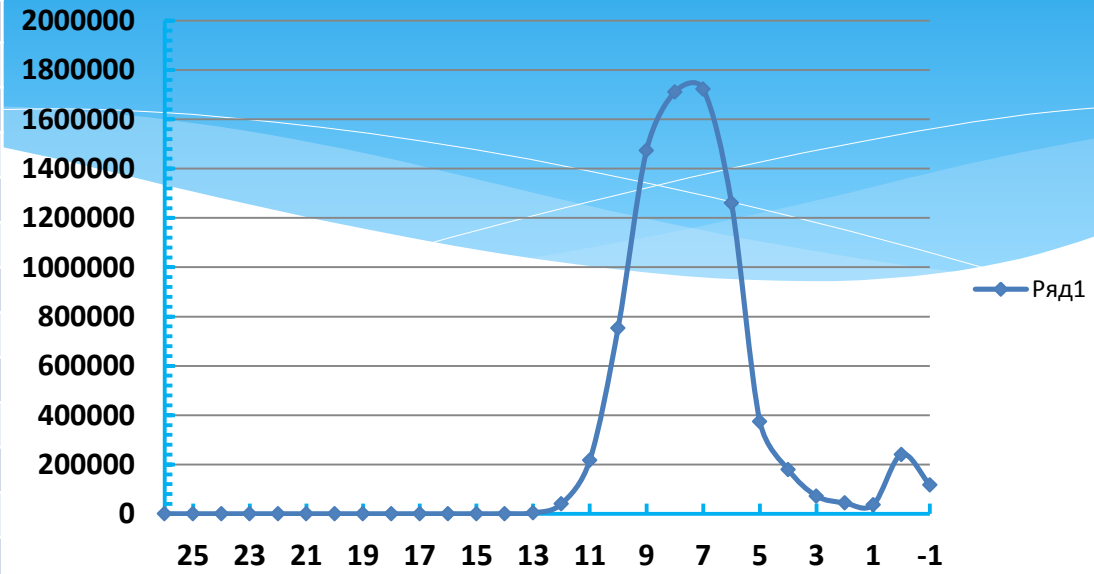


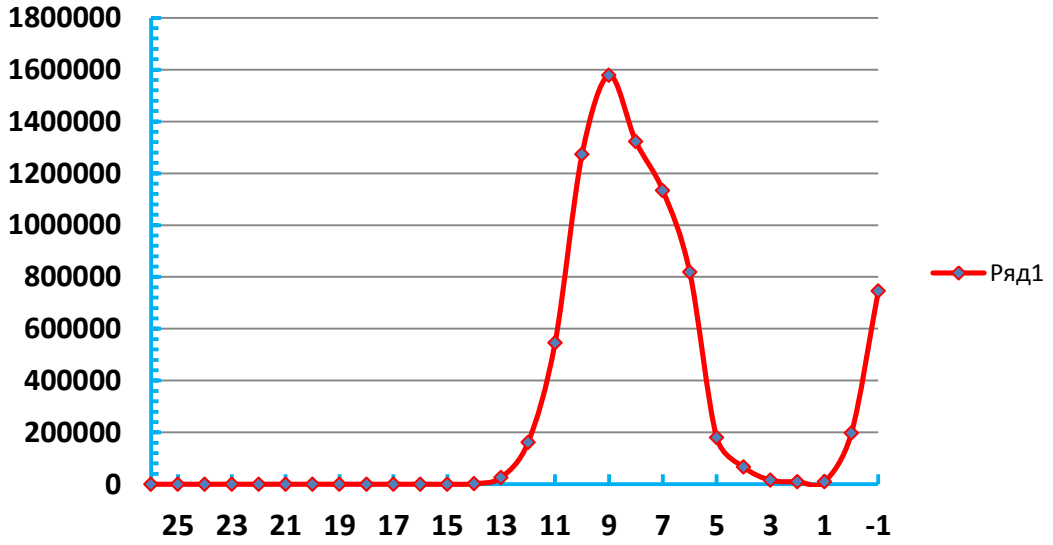


ABBN-78 Group №	Energy interval	Outgoing spectrum	Capture spectrum
-1	14.5-14.0 MeV	117144	745974
0	14.0-10.5 MeV	240866	196826
1	10.5 – 6.5 MeV	36797	9403
2	6.5 – 4.0 MeV	44271	9586
3	4.0 – 2.5 MeV	72229	15520
4	2.5 – 1.4 MeV	179669	66210
5	1.4 – 0.8 MeV	374774	179843
6	0.8 – 0.4 MeV	1261117	818423
7	0.4 – 0.2 MeV	1722536	1133283
8	0.2 – 0.1 MeV	1711196	1322434
9	100 – 46.5 KeV	1473120	1577929
10	46.5 – 21.5 KeV	753874	1272327
11	21.5 – 10 KeV	216963	545901
12	10 – 4.65 KeV	40266	161746
13	4.65 – 2.15 KeV	3873	26124
14	2.15 – 1 KeV	312	2094
15	1 – 0.465 KeV	2	57
16	465 – 215 eV	0	0
17	215 – 100 eV	0	0
18	100 – 46.5 eV	0	0
19	46.5 – 21.5 eV	0	0
20	21.5 – 10 eV	0	0
21	10 – 4.65 eV	0	0
22	4.65 – 2.15 eV	0	0
23	2.15 – 1.0 eV	0	0
24	1.0 – 0.465 eV	0	0
25	0.465 – 0.215 eV	0	0
26	0.215 – 0.001 eV	0	0

Sphere of Molybdenum Mo^{nat} R= 30 cm

Outgoing spectrum (upper picture, blue curve) and capture spectrum (picture below, red line).

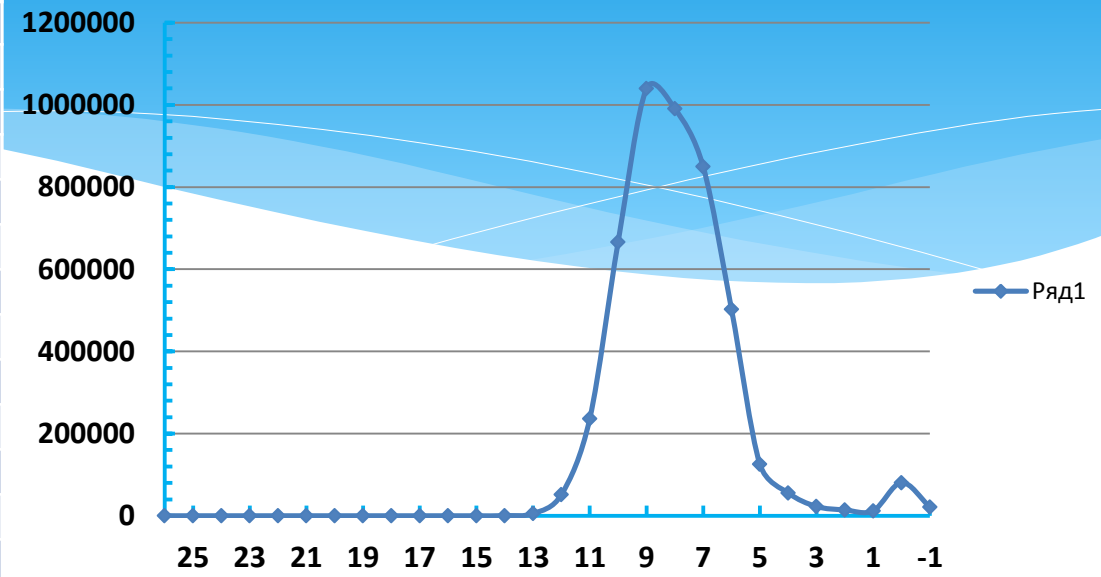


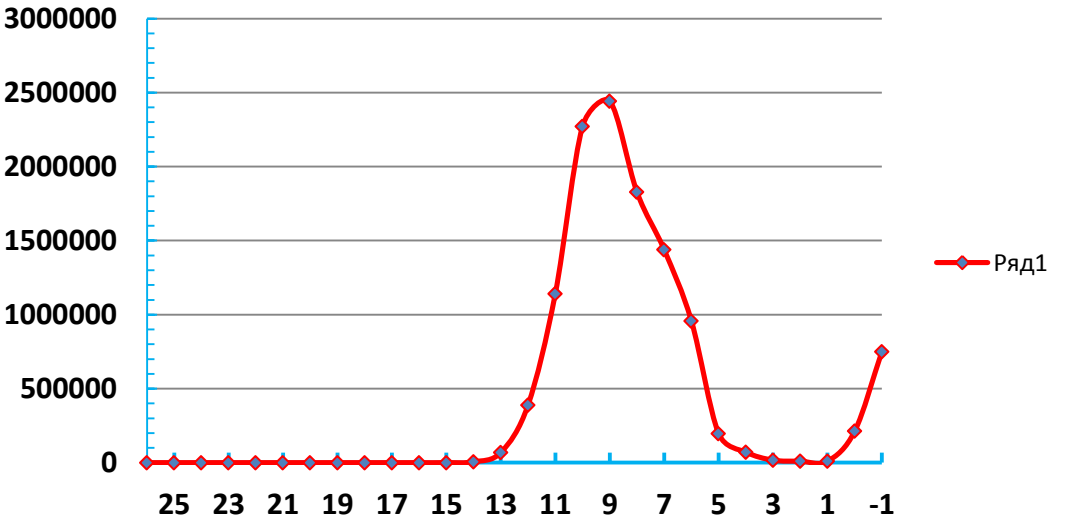


ABBN-78 Group №	Energy interval	Outgoing spectrum	Capture spectrum
-1	14.5-14.0 MeV	21602	750798
0	14.0-10.5 MeV	80854	212569
1	10.5 – 6.5 MeV	12258	9863
2	6.5 – 4.0 MeV	14395	9873
3	4.0 – 2.5 MeV	22645	16621
4	2.5 – 1.4 MeV	55917	71135
5	1.4 – 0.8 MeV	125718	196518
6	0.8 – 0.4 MeV	502693	957645
7	0.4 – 0.2 MeV	849891	1438635
8	0.2 – 0.1 MeV	990753	1828149
9	100 – 46.5 KeV	1039941	2443182
10	46.5 – 21.5 KeV	666292	2271943
11	21.5 – 10 KeV	236634	1140826
12	10 – 4.65 KeV	51790	389781
13	4.65 – 2.15 KeV	5480	68576
14	2.15 – 1 KeV	459	5711
15	1 – 0.465 KeV	6	200
16	465 – 215 eV	0	3
17	215 – 100 eV	0	0
18	100 – 46.5 eV	0	0
19	46.5 – 21.5 eV	0	0
20	21.5 – 10 eV	0	0
21	10 – 4.65 eV	0	0
22	4.65 – 2.15 eV	0	0
23	2.15 – 1.0 eV	0	0
24	1.0 – 0.465 eV	0	0
25	0.465 – 0.215 eV	0	0
26	0.215 – 0.001 eV	0	0

Sphere of Molybdenum Mo^{nat} R= 40 cm

Outgoing spectrum (upper picture, blue curve) and capture spectrum (picture below, red line).

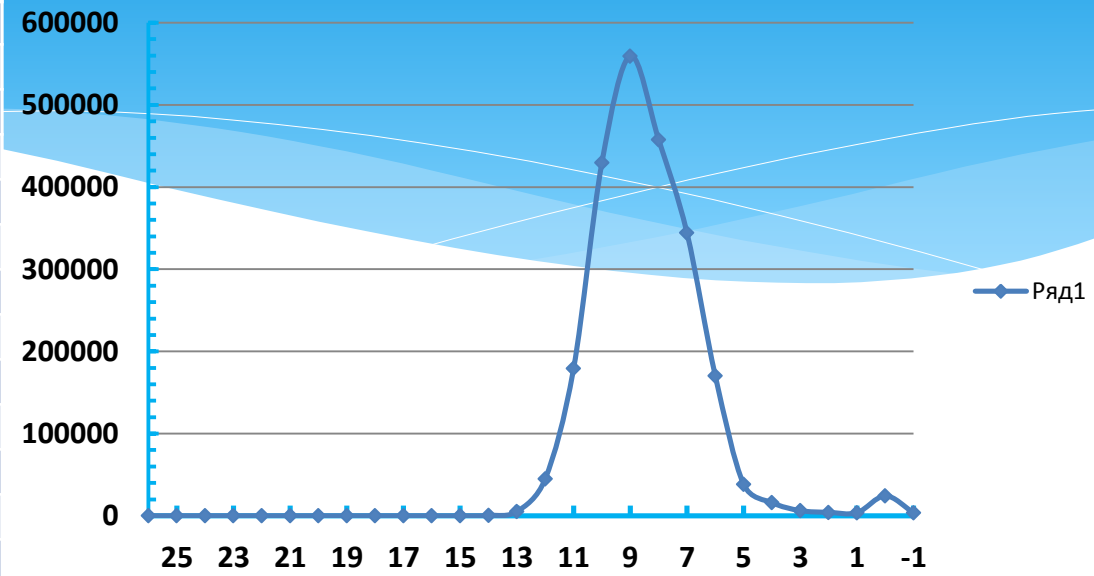


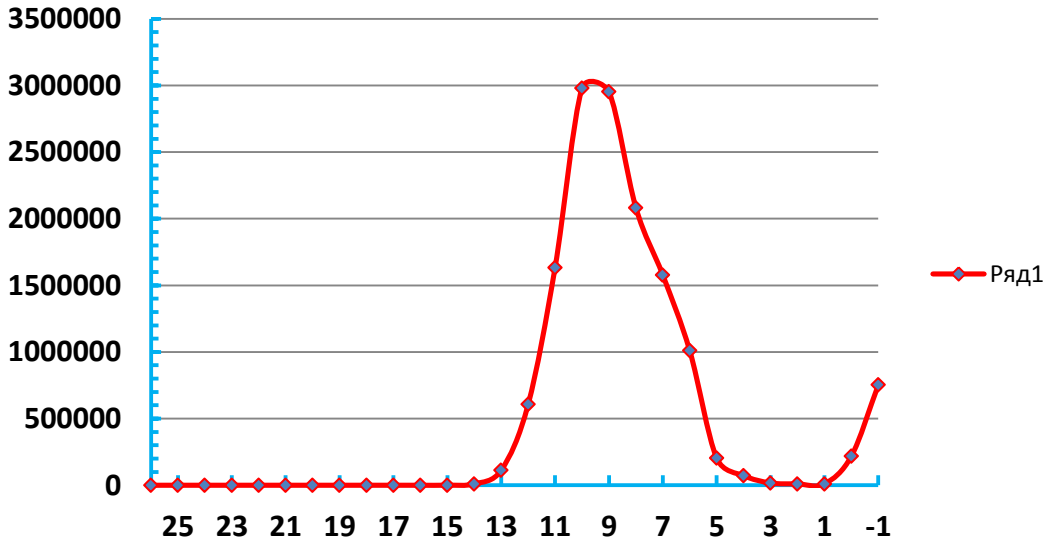


ABBN-78 Group №	Energy interval	Outgoing spectrum	Capture spectrum
-1	14.5-14.0 MeV	3658	752405
0	14.0-10.5 MeV	24312	218274
1	10.5 – 6.5 MeV	3766	10200
2	6.5 – 4.0 MeV	4218	10236
3	4.0 – 2.5 MeV	6318	17007
4	2.5 – 1.4 MeV	16074	72185
5	1.4 – 0.8 MeV	38363	202813
6	0.8 – 0.4 MeV	170468	1009224
7	0.4 – 0.2 MeV	344462	1576396
8	0.2 – 0.1 MeV	457850	2082553
9	100 – 46.5 KeV	559464	2952244
10	46.5 – 21.5 KeV	429798	2979281
11	21.5 – 10 KeV	179140	1633039
12	10 – 4.65 KeV	44978	606018
13	4.65 – 2.15 KeV	5194	112781
14	2.15 – 1 KeV	481	10109
15	1 – 0.465 KeV	8	403
16	465 – 215 eV	1	4
17	215 – 100 eV	0	0
18	100 – 46.5 eV	0	0
19	46.5 – 21.5 eV	0	0
20	21.5 – 10 eV	0	0
21	10 – 4.65 eV	0	0
22	4.65 – 2.15 eV	0	0
23	2.15 – 1.0 eV	0	0
24	1.0 – 0.465 eV	0	0
25	0.465 – 0.215 eV	0	0
26	0.215 – 0.001 eV	0	0

Sphere of Molybdenum Mo^{nat} R= 50 cm

Outgoing spectrum (upper picture, blue curve) and capture spectrum (picture below, red line).

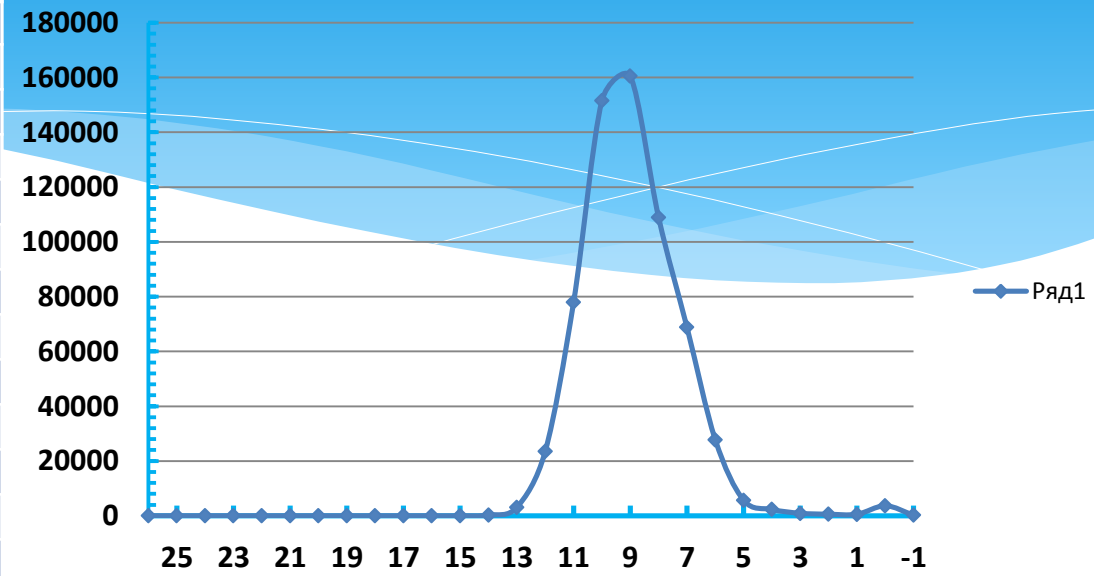


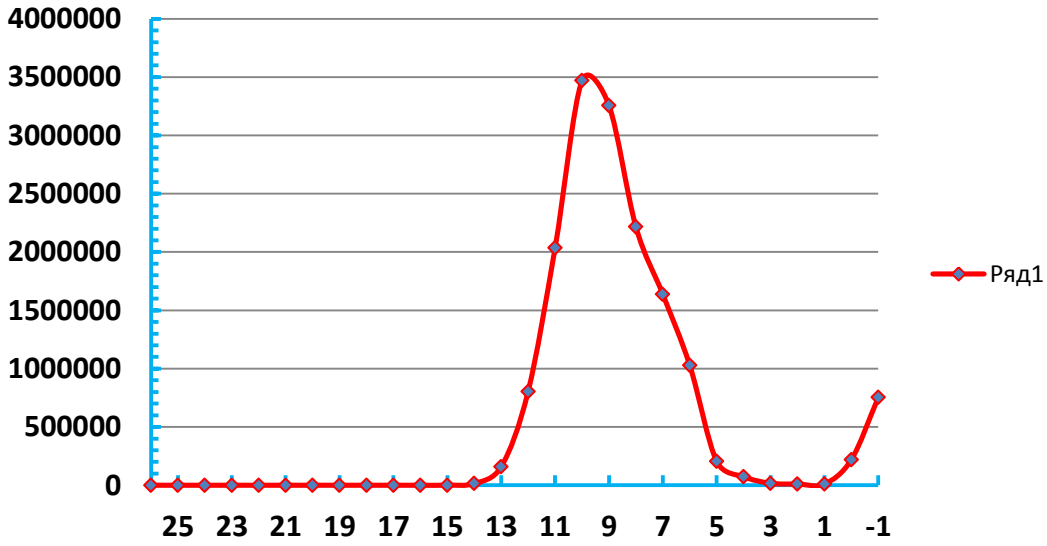


ABBN-78 Group №	Energy interval	Outgoing spectrum	Capture spectrum
-1	14.5-14.0 MeV	232	752751
0	14.0-10.5 MeV	3651	220096
1	10.5 – 6.5 MeV	559	10237
2	6.5 – 4.0 MeV	586	10229
3	4.0 – 2.5 MeV	924	16960
4	2.5 – 1.4 MeV	2330	73213
5	1.4 – 0.8 MeV	5711	204406
6	0.8 – 0.4 MeV	27783	1028069
7	0.4 – 0.2 MeV	68873	1636802
8	0.2 – 0.1 MeV	108920	2216530
9	100 – 46.5 KeV	160522	3258144
10	46.5 – 21.5 KeV	151567	3469658
11	21.5 – 10 KeV	77921	2034554
12	10 – 4.65 KeV	23552	804597
13	4.65 – 2.15 KeV	3117	158854
14	2.15 – 1 KeV	274	14528
15	1 – 0.465 KeV	3	654
16	465 – 215 eV	0	6
17	215 – 100 eV	0	0
18	100 – 46.5 eV	0	0
19	46.5 – 21.5 eV	0	0
20	21.5 – 10 eV	0	0
21	10 – 4.65 eV	0	0
22	4.65 – 2.15 eV	0	0
23	2.15 – 1.0 eV	0	0
24	1.0 – 0.465 eV	0	0
25	0.465 – 0.215 eV	0	0
26	0.215 – 0.001 eV	0	0

Sphere of Molybdenum Mo^{nat} R= 65 cm

Outgoing spectrum (upper picture, blue curve) and capture spectrum (picture below, red line).

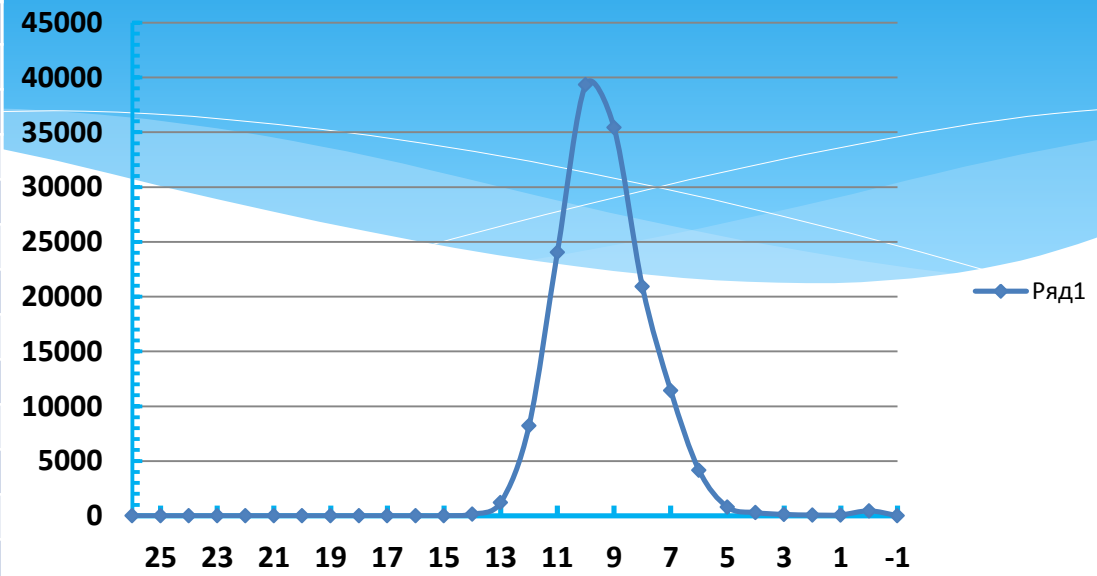


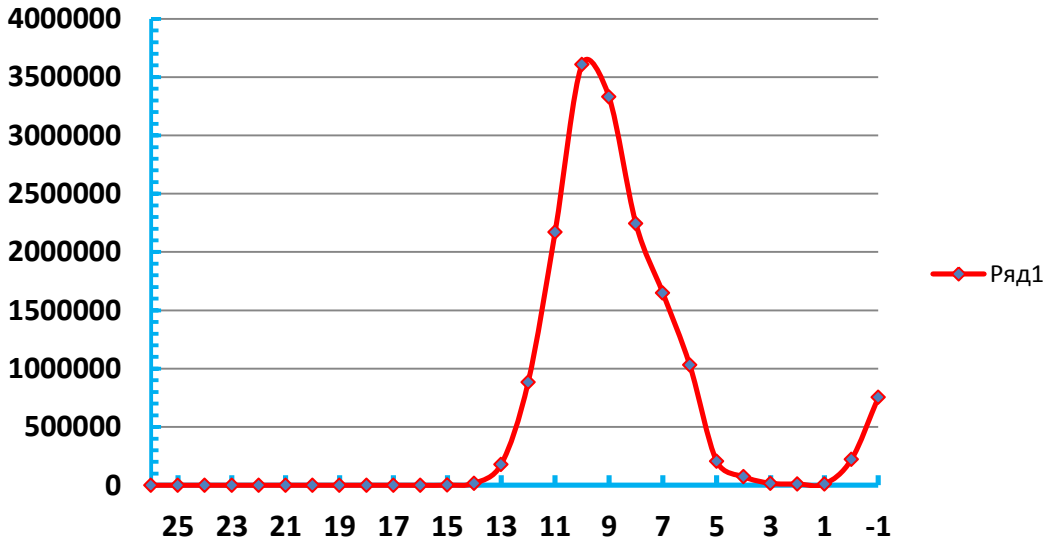


ABBN-78 Group №	Energy interval	Outgoing spectrum	Capture spectrum
-1	14.5-14.0 MeV	18	752852
0	14.0-10.5 MeV	453	220745
1	10.5 – 6.5 MeV	85	10270
2	6.5 – 4.0 MeV	71	10251
3	4.0 – 2.5 MeV	124	16953
4	2.5 – 1.4 MeV	296	73088
5	1.4 – 0.8 MeV	806	204940
6	0.8 – 0.4 MeV	4154	1030835
7	0.4 – 0.2 MeV	11432	1648640
8	0.2 – 0.1 MeV	20923	2243898
9	100 – 46.5 KeV	35431	3331545
10	46.5 – 21.5 KeV	39347	3609347
11	21.5 – 10 KeV	24039	2170057
12	10 – 4.65 KeV	8213	882432
13	4.65 – 2.15 KeV	1222	179052
14	2.15 – 1 KeV	148	16923
15	1 – 0.465 KeV	3	777
16	465 – 215 eV	0	10
17	215 – 100 eV	0	0
18	100 – 46.5 eV	0	0
19	46.5 – 21.5 eV	0	0
20	21.5 – 10 eV	0	0
21	10 – 4.65 eV	0	0
22	4.65 – 2.15 eV	0	0
23	2.15 – 1.0 eV	0	0
24	1.0 – 0.465 eV	0	0
25	0.465 – 0.215 eV	0	0
26	0.215 – 0.001 eV	0	0

Sphere of Molybdenum Mo^{nat} R= 80 cm

Outgoing spectrum (upper picture, blue curve) and capture spectrum (picture below, red line).

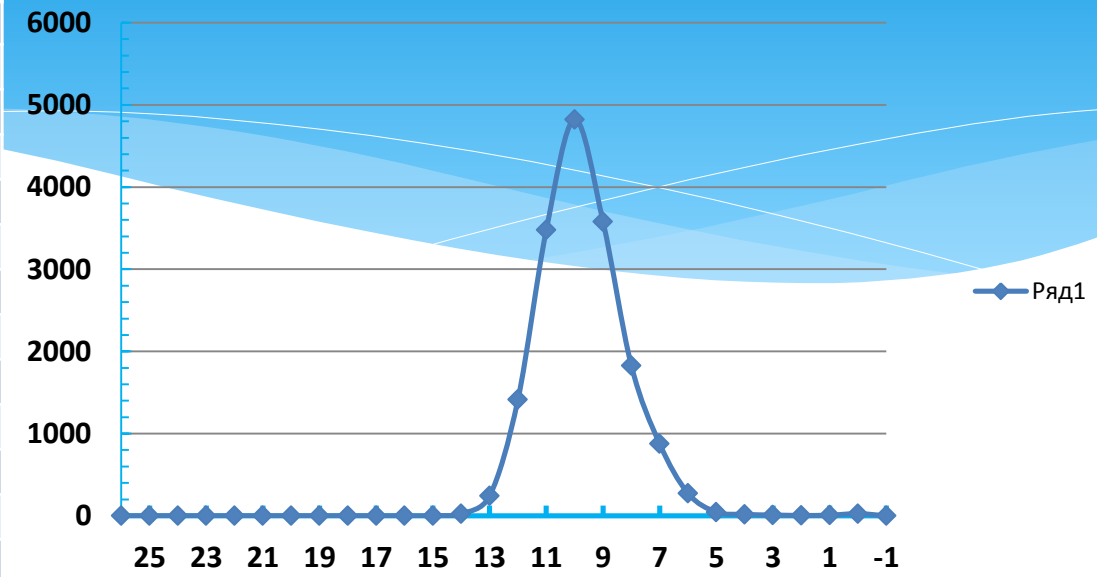


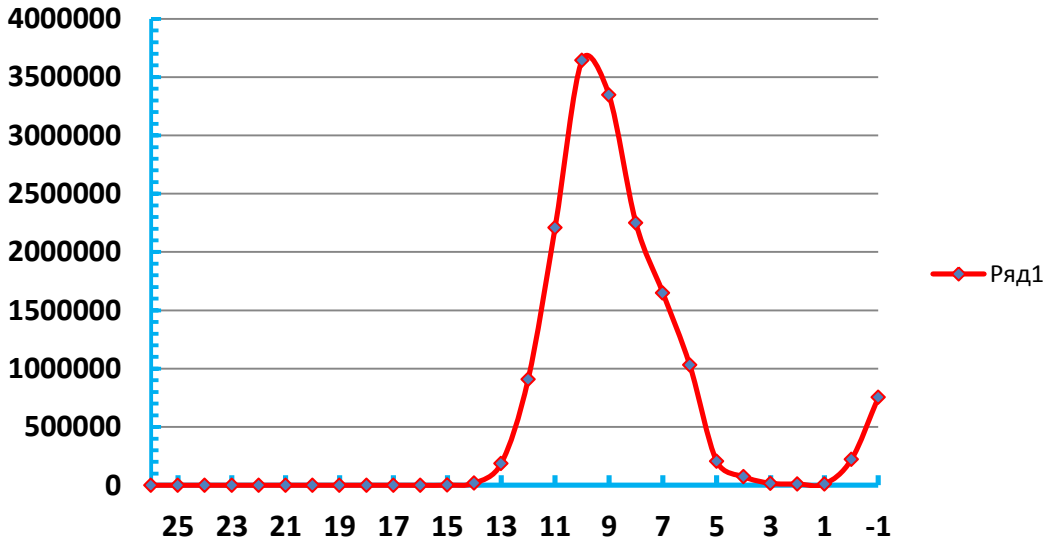


ABBN-78 Group №	Energy interval	Outgoing spectrum	Capture spectrum
-1	14.5-14.0 MeV	0	752918
0	14.0-10.5 MeV	26	220644
1	10.5 – 6.5 MeV	8	10273
2	6.5 – 4.0 MeV	4	10252
3	4.0 – 2.5 MeV	10	16971
4	2.5 – 1.4 MeV	17	73275
5	1.4 – 0.8 MeV	46	204929
6	0.8 – 0.4 MeV	274	1030856
7	0.4 – 0.2 MeV	876	1650055
8	0.2 – 0.1 MeV	1829	2249199
9	100 – 46.5 KeV	3582	3347359
10	46.5 – 21.5 KeV	4823	3644781
11	21.5 – 10 KeV	3479	2208605
12	10 – 4.65 KeV	1415	907770
13	4.65 – 2.15 KeV	242	186346
14	2.15 – 1 KeV	27	17872
15	1 – 0.465 KeV	1	808
16	465 – 215 eV	0	9
17	215 – 100 eV	0	0
18	100 – 46.5 eV	0	0
19	46.5 – 21.5 eV	0	0
20	21.5 – 10 eV	0	0
21	10 – 4.65 eV	0	0
22	4.65 – 2.15 eV	0	0
23	2.15 – 1.0 eV	0	0
24	1.0 – 0.465 eV	0	0
25	0.465 – 0.215 eV	0	0
26	0.215 – 0.001 eV	0	0

Sphere of Molybdenum Mo^{nat} R= 100 cm

Outgoing spectrum (upper picture, blue curve) and capture spectrum (picture below, red line).





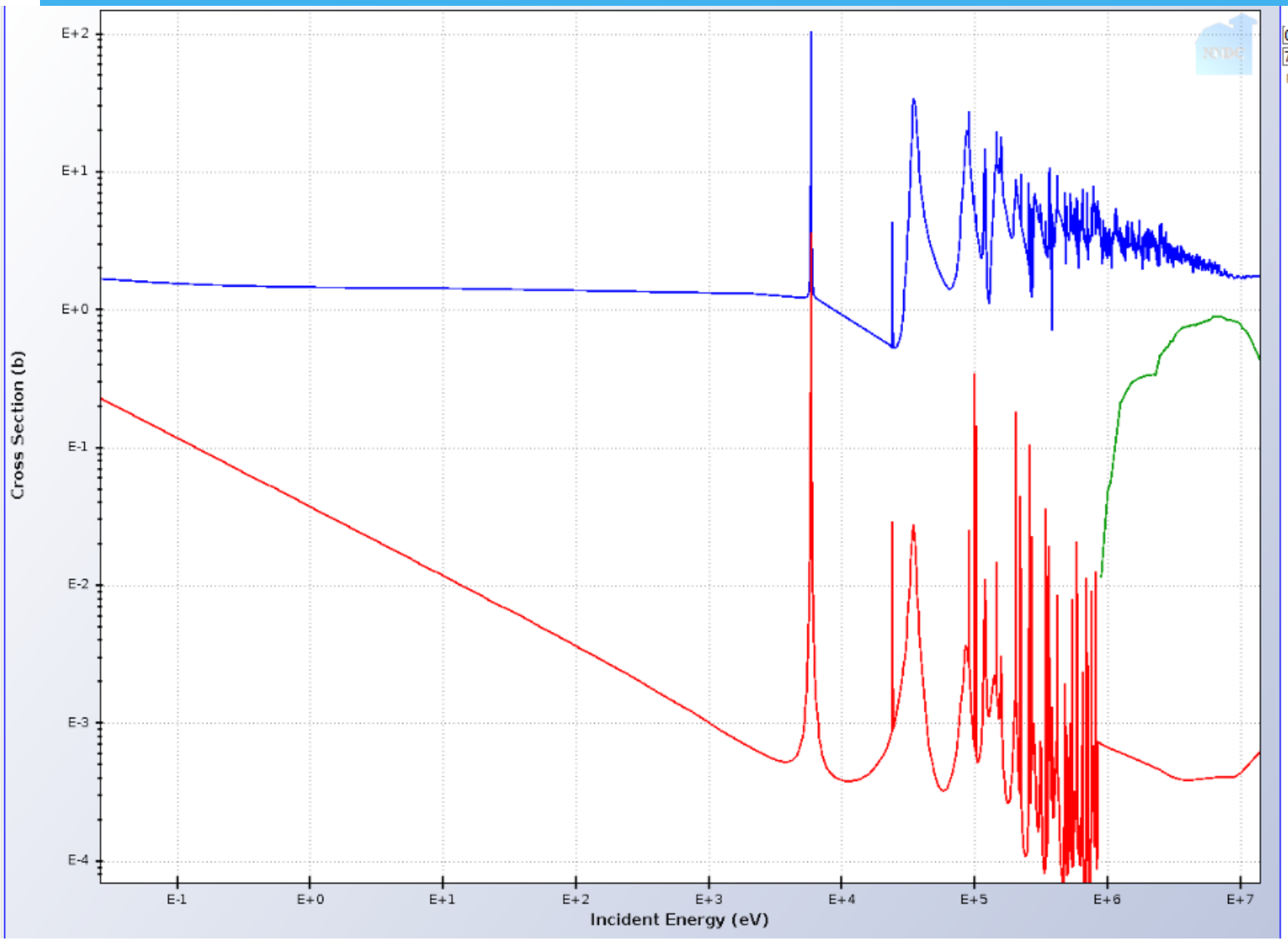
Spectrums in metal Molybdenum spheres

ABBN-78 Group №	Energy Interval	R = 1 cm		R = 5 cm		R = 10 cm		R = 15 cm		R = 20 cm		R = 25 cm	
		Outgoing Spectrum	Capture Spectrum	Outgoing Spectrum	Capture Spectrum	Outgoing Spectrum	Capture Spectrum	Outgoing Spectrum	Capture Spectrum	Outgoing Spectrum	Capture Spectrum	Outgoing Spectrum	Capture Spectrum
-1	14.5-14.0 MeV	8873145	93605	5336555	373665	2677497	569408	1284341	666310	594141	714578	267759	736417
0	14.0-10.5 MeV	207765	1125	762299	23203	937748	70249	807137	117094	587695	154521	388094	181171
1	10.5-6.5 MeV	55426	66	167916	1380	176422	3722	136898	5843	94285	7583	60160	8749
2	6.5-4.0 MeV	76899	85	230527	1373	237385	3917	179083	6083	119413	7639	74129	9032
3	4.0-2.5 MeV	138607	132	418180	2377	422523	6646	314343	10245	205364	12974	124793	14612
4	2.5-1.4 MeV	276850	393	906595	8228	980418	24933	752450	41276	499925	53265	306703	61238
5	1.4-0.8 MeV	294330	565	1141307	14703	1462132	52525	1270056	97071	922786	134575	607321	161853
6	0.8-0.4 MeV	288406	827	1422598	28979	2437010	141484	2706411	323896	2383779	523656	1818367	693201
7	0.4-0.2 MeV	181801	543	987165	21880	1949498	128526	2502366	341813	2536985	618161	2201342	896819
8	0.2-0.1 MeV	86733	311	489384	13985	1103458	93931	1689061	295364	2006166	610305	1976754	977097
9	100-46.5 KeV	35588	219	203013	8812	510610	66334	925330	244270	1311700	588949	1502327	1065102
10	46.5 –21.5 KeV	7642	72	47443	3586	135768	30668	288064	127905	489883	366125	666386	766141
11	21.5– 10 KeV	185	3	4931	549	21244	7080	52442	35670	104496	120335	166718	292256
12	10– 4.65 KeV	24	2	655	120	2673	1445	6985	7779	15332	28730	27456	78625
13	4.65– 2.15 KeV	3	0	96	29	385	318	802	1453	1462	4638	2562	12240
14	2.15 – 1 KeV	0	0	8	6	30	36	78	133	143	389	208	957
15	1– 0.465 KeV	0	0	0	0	0	0	0	0	1	12	2	16
16	465– 215 eV	0	0	0	0	0	0	0	0	0	0	0	1
17	215– 100 eV	0	0	0	0	0	0	0	0	0	0	0	0
18	100– 46.5 eV	0	0	0	0	0	0	0	0	0	0	0	0
19	46.5– 21.5 eV	0	0	0	0	0	0	0	0	0	0	0	0
20	21.5– 10 eV	0	0	0	0	0	0	0	0	0	0	0	0
21	10– 4.65 eV	0	0	0	0	0	0	0	0	0	0	0	0
22	4.6 – 2.15 eV	0	0	0	0	0	0	0	0	0	0	0	0
23	2.1 – 1.0 eV	0	0	0	0	0	0	0	0	0	0	0	0
24	1.0– 0.465 eV	0	0	0	0	0	0	0	0	0	0	0	0
25	0.46 – 0.215 eV	0	0	0	0	0	0	0	0	0	0	0	0
26	0.215– 0.001 eV	0	0	0	0	0	0	0	0	0	0	0	0
Average Neutron Energy		13.47 MeV	13.67 MeV	8.04 MeV	11.21 MeV	4.55 MeV	7.68 MeV	2.78 MeV	4.95 MeV	1.83 MeV	3.28 MeV	1.28 MeV	2.32 MeV
Diffusion/Absorption time of spectra, nanoseconds		0.320	0.118	3.817	2.03	16.67	14.36	41.88	46.29	78.92	96.78	123.1	154.6
Number of neutrons		10523400	97948	12118670	502875	13054800	1201222	12915850	2322205	11873560	3946435	10191080	5955527

Spectrums in metal Molybdenum spheres

ABBN-78 Group №	Energy Interval	R = 30 cm		R = 40 cm		R = 50 cm		R = 65 cm		R = 80 cm		R = 100 cm	
		Outgoing Spectrum	Capture Spectrum	Outgoing Spectrum	Capture Spectrum	Outgoing Spectrum	Capture Spectrum	Outgoing Spectrum	Capture Spectrum	Outgoing Spectrum	Capture Spectrum	Outgoing Spectrum	Capture Spectrum
-1	14.5-14.0 MeV	117144	745974	21602	750798	3658	752405	232	752751	18	752852	0	752918
0	14.0-10.5 MeV	240866	196826	80854	212569	24312	218274	3651	220096	453	220745	26	220644
1	10.5-6.5 MeV	36797	9403	12258	9863	3766	10200	559	10237	85	10270	8	10273
2	6.5-4.0 MeV	44271	9586	14395	9873	4218	10236	586	10229	71	10251	4	10252
3	4.0-2.5 MeV	72229	15520	22645	16621	6318	17007	924	16960	124	16953	10	16971
4	2.5-1.4 MeV	179669	66210	55917	71135	16074	72185	2330	73213	296	73088	17	73275
5	1.4-0.8 MeV	374774	179843	125718	196518	38363	202813	5711	204406	806	204940	46	204929
6	0.8-0.4 MeV	1261117	818423	502693	957645	170468	1009224	27783	1028069	4154	1030835	274	1030856
7	0.4-0.2 MeV	1722536	1133283	849891	1438635	344462	1576396	68873	1636802	11432	1648640	876	1650055
8	0.2-0.1 MeV	1711196	1322434	990753	1828149	457850	2082553	108920	2216530	20923	2243898	1829	2249199
9	100-46.5 KeV	1473120	1577929	1039941	2443182	559464	2952244	160522	3258144	35431	3331545	3582	3347359
10	46.5 –21.5 KeV	753874	1272327	666292	2271943	429798	2979281	151567	3469658	39347	3609347	4823	3644781
11	21.5– 10 KeV	216963	545901	236634	1140826	179140	1633039	77921	2034554	24039	2170057	3479	2208605
12	10– 4.65 KeV	40266	161746	51790	389781	44978	606018	23552	804597	8213	882432	1415	907770
13	4.65– 2.15 KeV	3873	26124	5480	68576	5194	112781	3117	158854	1222	179052	242	186346
14	2.15 – 1 KeV	312	2094	459	5711	481	10109	274	14528	148	16923	27	17872
15	1– 0.465 KeV	2	57	6	200	8	403	3	654	3	777	1	808
16	465– 215 eV	0	0	0	3	1	4	0	6	0	10	0	9
17	215– 100 eV	0	0	0	0	0	0	0	0	0	0	0	0
18	100– 46.5 eV	0	0	0	0	0	0	0	0	0	0	0	0
19	46.5– 21.5 eV	0	0	0	0	0	0	0	0	0	0	0	0
20	21.5– 10 eV	0	0	0	0	0	0	0	0	0	0	0	0
21	10– 4.65 eV	0	0	0	0	0	0	0	0	0	0	0	0
22	4.6 – 2.15 eV	0	0	0	0	0	0	0	0	0	0	0	0
23	2.1 – 1.0 eV	0	0	0	0	0	0	0	0	0	0	0	0
24	1.0– 0.465 eV	0	0	0	0	0	0	0	0	0	0	0	0
25	0.46 – 0.215 eV	0	0	0	0	0	0	0	0	0	0	0	0
26	0.215– 0.001 eV	0	0	0	0	0	0	0	0	0	0	0	0
Average Neutron Energy		943 KeV	1.77 MeV	557.1 KeV	1.25 MeV	362.2 KeV	1.05 MeV	218.8 KeV	945.3 KeV	146.3 KeV	918.1 KeV	97.12 KeV	910.9 KeV
Diffusion/Absorption time of spectra, nanoseconds		171.0	208.4	267.3	290	359.2	340.8	488.5	378.5	602.1	392.5	739.4	397.0
Number of neutrons		8249009	8083680	4677328	11812030	2288553	14245170	636525	15910290	146765	16402620	16659	16532920

Neutron cross sections of Al^{27}:
total cross section (blue line), capture (red), inelastic scattering (green line)
Data from the Brookhaven National Laboratory [5].



ABBN-78 constants for Al^{27}

BNAB 28-GROUP NEUTRON CONSTANTS FOR AL(13, 26.98150)

MAIN GROUP CONSTANTS

GR.	ENERGY (MEV)	S-TOT	S-FIS	AVER NU	S-CAP	S-IN	S-EL	COS EL
-1	.140E+02- .145E+02	1.7430	.0000	.0000	.2290	.8630	.6510	.7425
0	.105E+02- .140E+02	1.7260	.0000	.0000	.2190	.8690	.6380	.7064
1	.650E+01- .105E+02	1.8540	.0000	.0000	.1090	.8280	.9170	.5954
2	.400E+01- .650E+01	1.1960	.0000	.0000	.0240	.7580	.4140	.4984
3	.250E+01- .400E+01	2.6930	.0000	.0000	.0030	.5400	2.1500	.3812
4	.140E+01- .250E+01	2.9970	.0000	.0000	.0004	.2880	2.7086	.3434
5	.800E+00- .140E+01	3.3690	.0000	.0000	.0004	.0780	3.2906	.3124
6	.400E+00- .800E+00	4.0007	.0000	.0000	.0007	.0000	4.0000	.2016
7	.200E+00- .400E+00	3.9010	.0000	.0000	.0010	.0000	3.9000	.1021
8	.100E+00- .200E+00	5.2030	.0000	.0000	.0030	.0000	5.2000	.0528
9	.465E-01- .100E+00	5.0020	.0000	.0000	.0020	.0000	5.0000	.0333
10	.215E-01- .465E-01	7.3960	.0000	.0000	.0060	.0000	7.3900	.0277
11	.100E-01- .215E-01	1.0010	.0000	.0000	.0010	.0000	1.0000	.0260
12	.465E-02- .100E-01	2.6000	.0000	.0000	.0600	.0000	2.5400	.0249
13	.215E-02- .465E-02	1.4007	.0000	.0000	.0007	.0000	1.4000	.0249
14	.100E-02- .215E-02	1.4010	.0000	.0000	.0010	.0000	1.4000	.0249
15	.465E-03- .100E-02	1.4015	.0000	.0000	.0015	.0000	1.4000	.0249
16	.215E-03- .465E-03	1.4021	.0000	.0000	.0021	.0000	1.4000	.0249
17	.100E-03- .215E-03	1.4031	.0000	.0000	.0031	.0000	1.4000	.0249
18	.465E-04- .100E-03	1.4046	.0000	.0000	.0046	.0000	1.4000	.0249
19	.215E-04- .465E-04	1.4067	.0000	.0000	.0067	.0000	1.4000	.0249
20	.100E-04- .215E-04	1.4100	.0000	.0000	.0100	.0000	1.4000	.0249
21	.465E-05- .100E-04	1.4150	.0000	.0000	.0150	.0000	1.4000	.0249
22	.215E-05- .465E-05	1.4210	.0000	.0000	.0210	.0000	1.4000	.0249
23	.100E-05- .215E-05	1.4310	.0000	.0000	.0310	.0000	1.4000	.0249
24	.465E-06- .100E-05	1.4460	.0000	.0000	.0460	.0000	1.4000	.0249
25	.215E-06- .465E-06	1.4670	.0000	.0000	.0670	.0000	1.4000	.0249
26	THERMAL	1.4241	.0000	.0000	.0241	.0000	1.4000	.0249

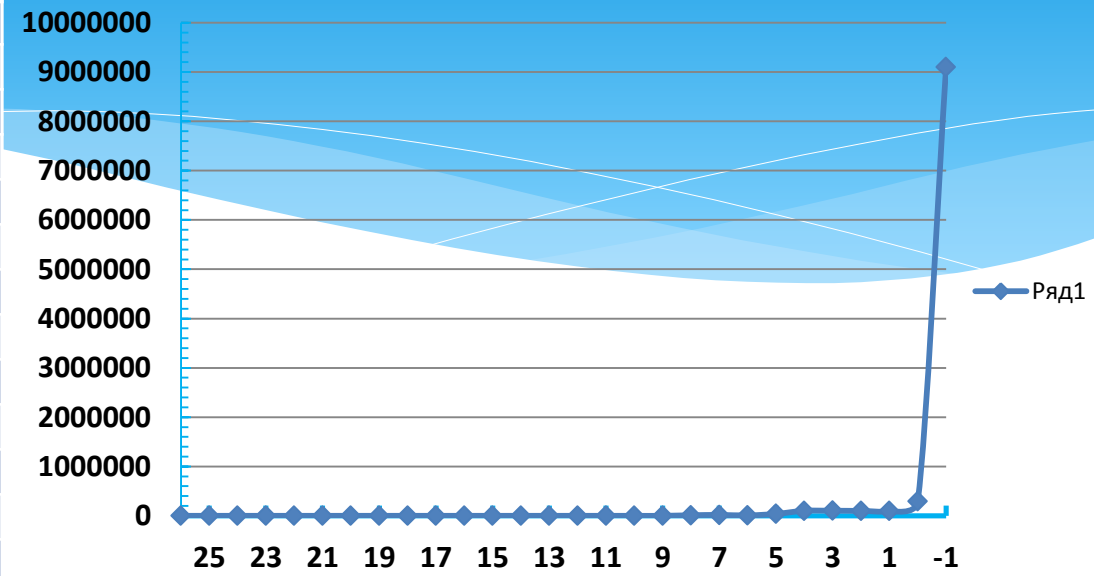
SIGMA IN (I,I+K) AT K EQUAL:

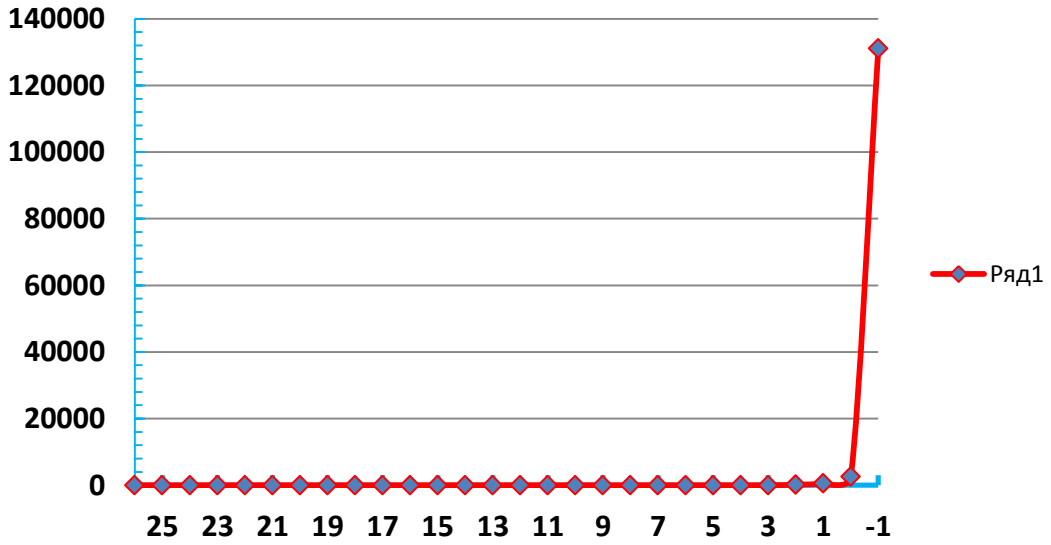
I	K= 0	K= 1	K= 2	K= 3	K= 4	K= 5	K= 6	K= 7	K= 8	K= 9	K=10	K=11	SUMMA
-1	.0000	.0700	.1760	.1740	.1780	.1680	.0600	.0100	.0310	.0200	.0000	.0000	.8870
0	.0100	.1570	.1880	.1870	.1950	.0900	.0320	.0080	.0020	.0000	.0000	.0000	.8690
1	.0310	.2410	.2000	.1880	.0970	.0540	.0130	.0030	.0010	.0000	.0000	.0000	.8280
2	.0590	.2660	.2410	.1350	.0390	.0140	.0030	.0010	.0000	.0000	.0000	.0000	.7580
3	.0400	.2450	.1010	.1040	.0390	.0080	.0020	.0010	.0000	.0000	.0000	.0000	.5400
4	.0090	.1430	.1160	.0130	.0040	.0020	.0010	.0000	.0000	.0000	.0000	.0000	.2880
5	.0000	.0110	.0440	.0170	.0050	.0010	.0000	.0000	.0000	.0000	.0000	.0000	.0780
6	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
7	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
8	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
9	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
10	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
11	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
12	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000

ABBN-78 Group №	Energy interval	Outgoing spectrum	Capture spectrum
-1	14.5-14.0 MeV	9104096	131087
0	14.0-10.5 MeV	293915	2530
1	10.5 – 6.5 MeV	97534	574
2	6.5 – 4.0 MeV	99946	143
3	4.0 – 2.5 MeV	103655	17
4	2.5 – 1.4 MeV	102029	2
5	1.4 – 0.8 MeV	39298	0
6	0.8 – 0.4 MeV	8304	0
7	0.4 – 0.2 MeV	18635	3
8	0.2 – 0.1 MeV	11799	1
9	100 – 46.5 KeV	284	0
10	46.5 – 21.5 KeV	16	0
11	21.5 – 10 KeV	0	0
12	10 – 4.65 KeV	0	0
13	4.65 – 2.15 KeV	0	0
14	2.15 – 1 KeV	0	0
15	1 – 0.465 KeV	0	0
16	465 – 215 eV	0	0
17	215 – 100 eV	0	0
18	100 – 46.5 eV	0	0
19	46.5 – 21.5 eV	0	0
20	21.5 – 10 eV	0	0
21	10 – 4.65 eV	0	0
22	4.65 – 2.15 eV	0	0
23	2.15 – 1.0 eV	0	0
24	1.0 – 0.465 eV	0	0
25	0.465 – 0.215 eV	0	0
26	0.215 – 0.001 eV	0	0

Sphere of Aluminum Al^{27} R= 1 cm

Outgoing spectrum (upper picture, blue curve) and capture spectrum (picture below, red line).

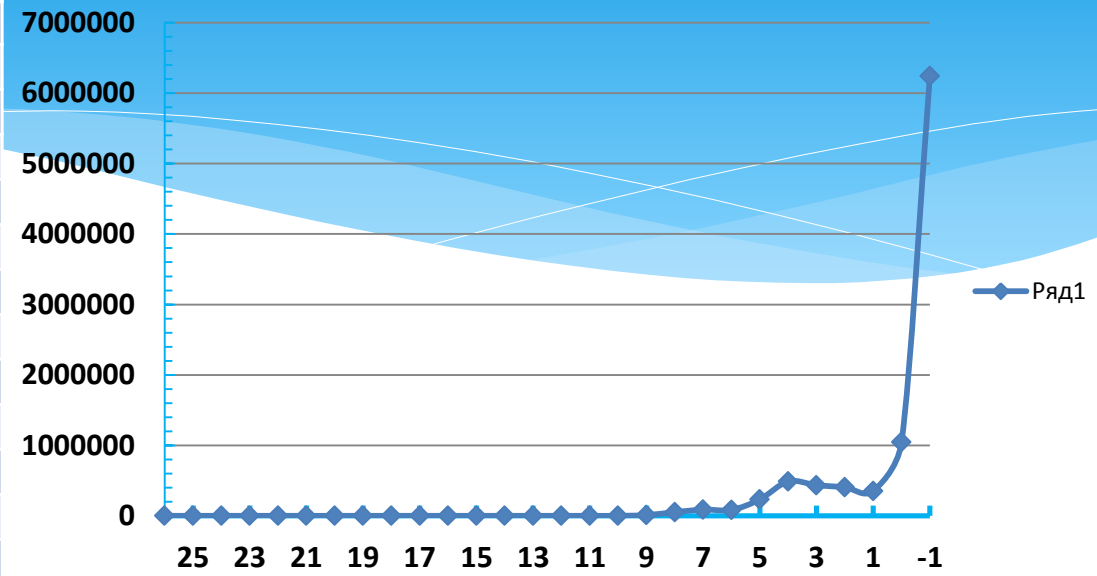


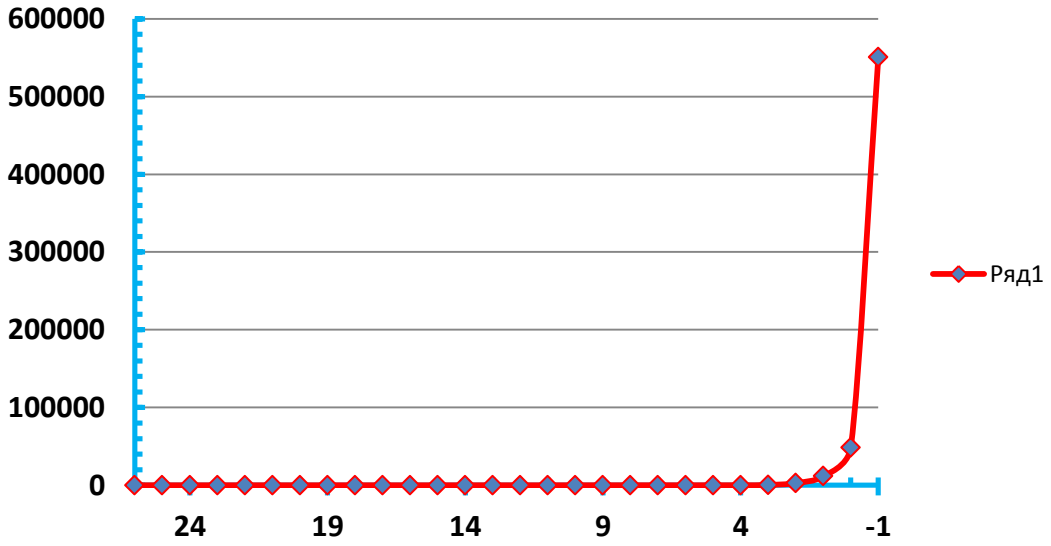


ABBN-78 Group №	Energy interval	Outgoing spectrum	Capture spectrum
-1	14.5-14.0 MeV	6245903	550813
0	14.0-10.5 MeV	1046755	48633
1	10.5 – 6.5 MeV	353772	11817
2	6.5 – 4.0 MeV	404786	2743
3	4.0 – 2.5 MeV	434991	388
4	2.5 – 1.4 MeV	488060	75
5	1.4 – 0.8 MeV	232694	30
6	0.8 – 0.4 MeV	85037	10
7	0.4 – 0.2 MeV	87676	24
8	0.2 – 0.1 MeV	52962	50
9	100 – 46.5 KeV	9938	6
10	46.5 – 21.5 KeV	523	3
11	21.5 – 10 KeV	98	0
12	10 – 4.65 KeV	0	0
13	4.65 – 2.15 KeV	0	0
14	2.15 – 1 KeV	0	0
15	1 – 0.465 KeV	0	0
16	465 – 215 eV	0	0
17	215 – 100 eV	0	0
18	100 – 46.5 eV	0	0
19	46.5 – 21.5 eV	0	0
20	21.5 – 10 eV	0	0
21	10 – 4.65 eV	0	0
22	4.65 – 2.15 eV	0	0
23	2.15 – 1.0 eV	0	0
24	1.0 – 0.465 eV	0	0
25	0.465 – 0.215 eV	0	0
26	0.215 – 0.001 eV	0	0

Sphere of Aluminum Al^{27} R= 5 cm

Outgoing spectrum (upper picture, blue curve) and capture spectrum (picture below, red line).

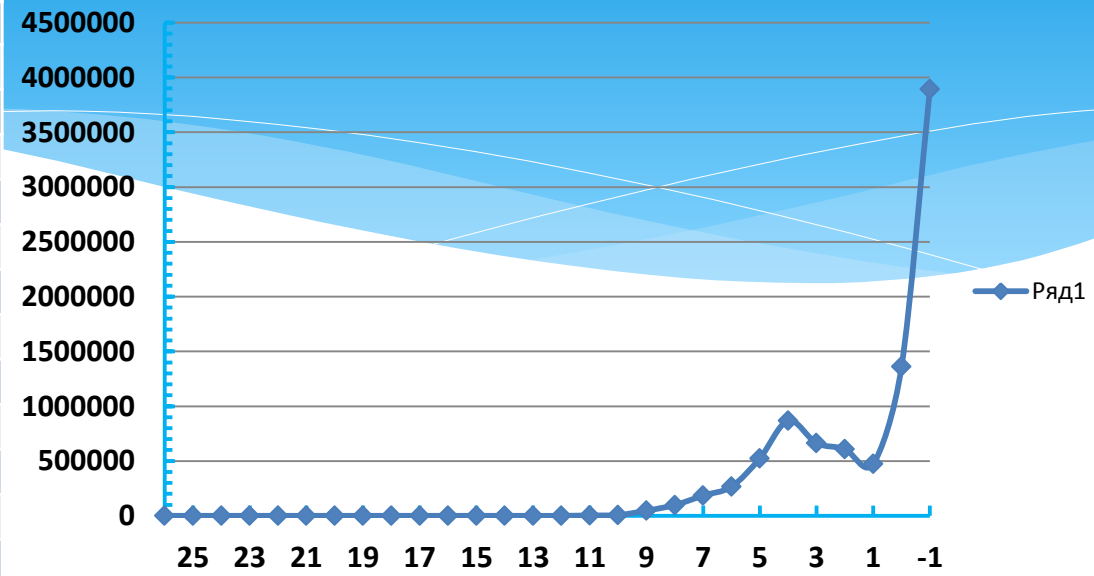


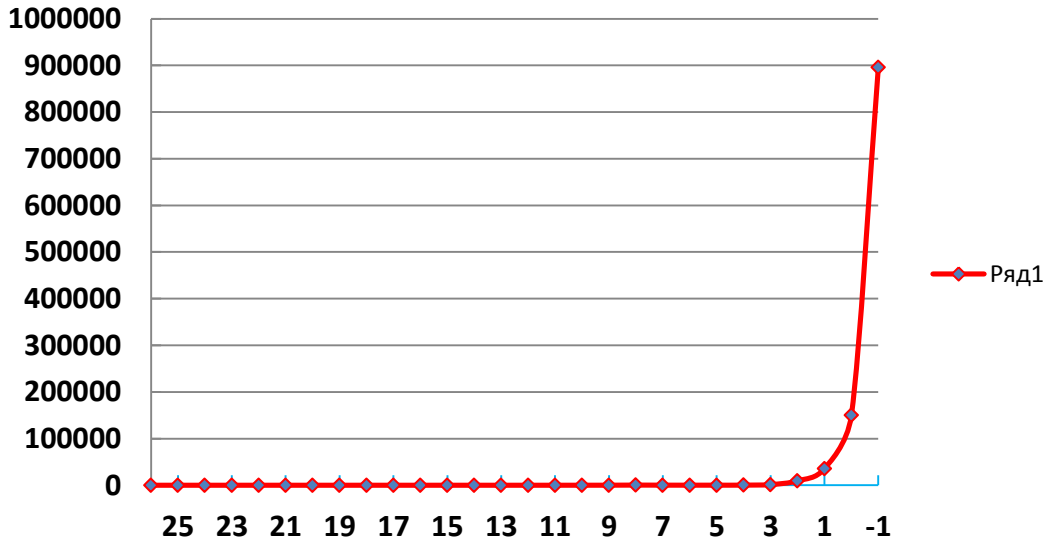


ABBN-78 Group №	Energy interval	Outgoing spectrum	Capture spectrum
-1	14.5-14.0 MeV	3893544	895717
0	14.0-10.5 MeV	1360828	149809
1	10.5 – 6.5 MeV	473810	35857
2	6.5 – 4.0 MeV	609452	9455
3	4.0 – 2.5 MeV	663553	1436
4	2.5 – 1.4 MeV	868383	271
5	1.4 – 0.8 MeV	524477	130
6	0.8 – 0.4 MeV	266557	141
7	0.4 – 0.2 MeV	184454	169
8	0.2 – 0.1 MeV	98445	319
9	100 – 46.5 KeV	46626	83
10	46.5 – 21.5 KeV	7101	58
11	21.5 – 10 KeV	3652	4
12	10 – 4.65 KeV	0	0
13	4.65 – 2.15 KeV	0	0
14	2.15 – 1 KeV	0	0
15	1 – 0.465 KeV	0	0
16	465 – 215 eV	0	0
17	215 – 100 eV	0	0
18	100 – 46.5 eV	0	0
19	46.5 – 21.5 eV	0	0
20	21.5 – 10 eV	0	0
21	10 – 4.65 eV	0	0
22	4.65 – 2.15 eV	0	0
23	2.15 – 1.0 eV	0	0
24	1.0 – 0.465 eV	0	0
25	0.465 – 0.215 eV	0	0
26	0.215 – 0.001 eV	0	0

Sphere of Aluminum Al^{27} R= 10 cm

Outgoing spectrum (upper picture, blue curve) and capture spectrum (picture below, red line).

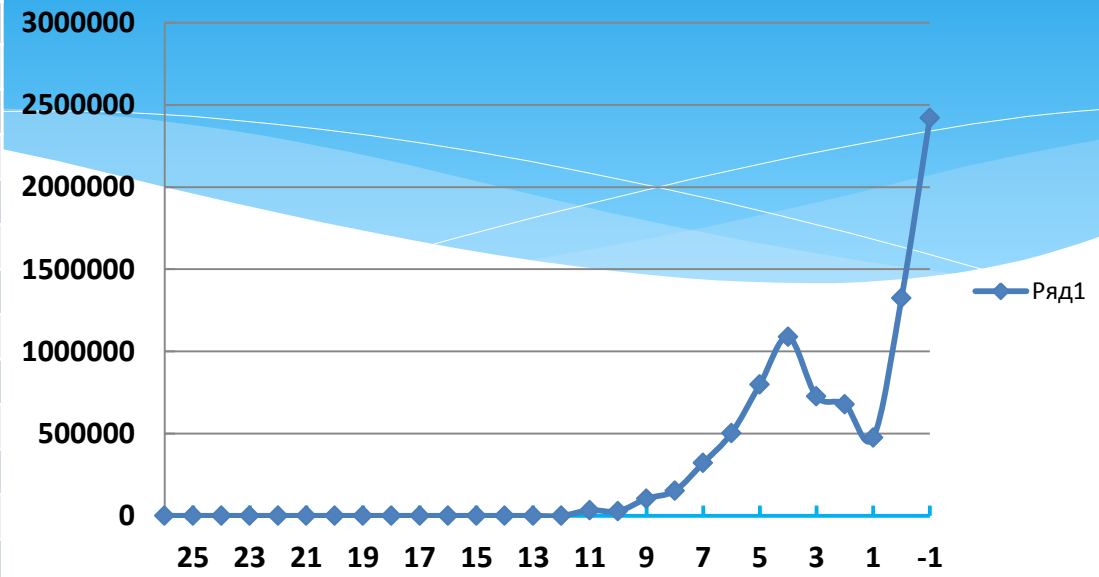


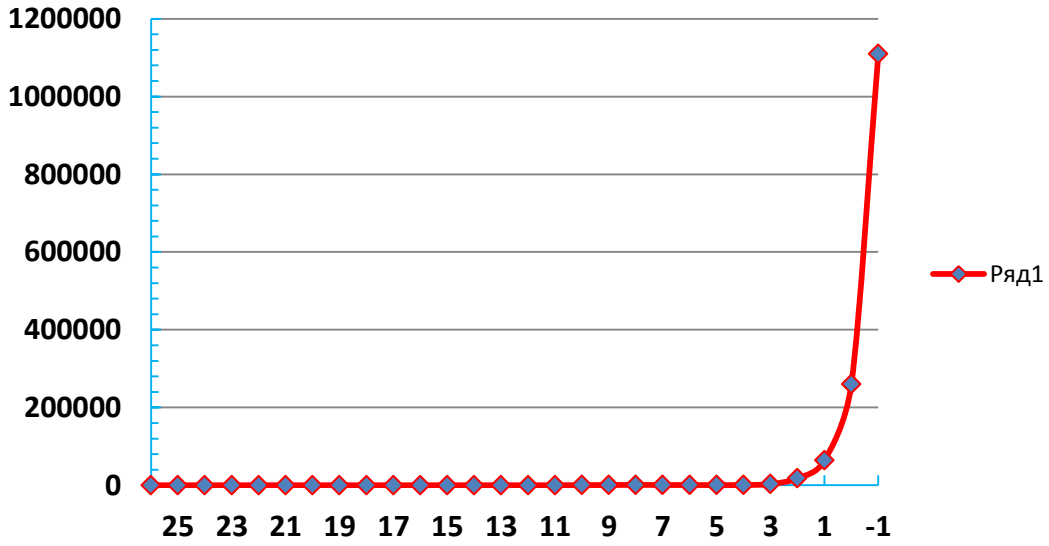


ABBN-78 Group №	Energy interval	Outgoing spectrum	Capture spectrum
-1	14.5-14.0 MeV	2421191	1109638
0	14.0-10.5 MeV	1325079	259931
1	10.5 – 6.5 MeV	475117	63802
2	6.5 – 4.0 MeV	679269	17970
3	4.0 – 2.5 MeV	726686	2960
4	2.5 – 1.4 MeV	1088996	590
5	1.4 – 0.8 MeV	798856	407
6	0.8 – 0.4 MeV	502803	539
7	0.4 – 0.2 MeV	321327	507
8	0.2 – 0.1 MeV	152670	985
9	100 – 46.5 KeV	104486	408
10	46.5 – 21.5 KeV	27830	402
11	21.5 – 10 KeV	34317	35
12	10 – 4.65 KeV	33	1
13	4.65 – 2.15 KeV	3	0
14	2.15 – 1 KeV	0	0
15	1 – 0.465 KeV	0	0
16	465 – 215 eV	0	0
17	215 – 100 eV	0	0
18	100 – 46.5 eV	0	0
19	46.5 – 21.5 eV	0	0
20	21.5 – 10 eV	0	0
21	10 – 4.65 eV	0	0
22	4.65 – 2.15 eV	0	0
23	2.15 – 1.0 eV	0	0
24	1.0 – 0.465 eV	0	0
25	0.465 – 0.215 eV	0	0
26	0.215 – 0.001 eV	0	0

Sphere of Aluminum Al^{27} R= 15 cm

Outgoing spectrum (upper picture, blue curve) and capture spectrum (picture below, red line).

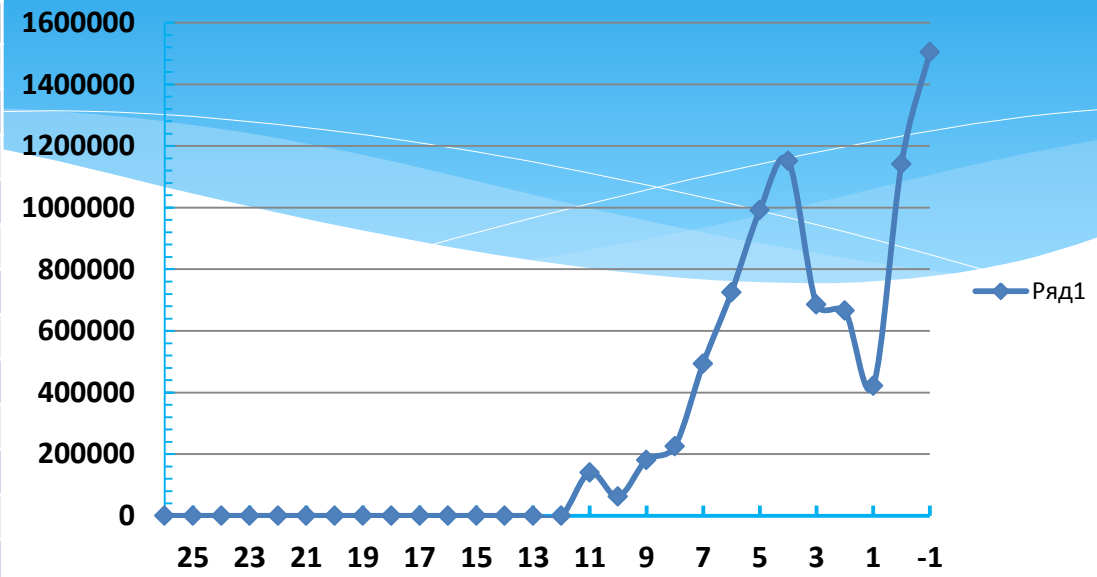


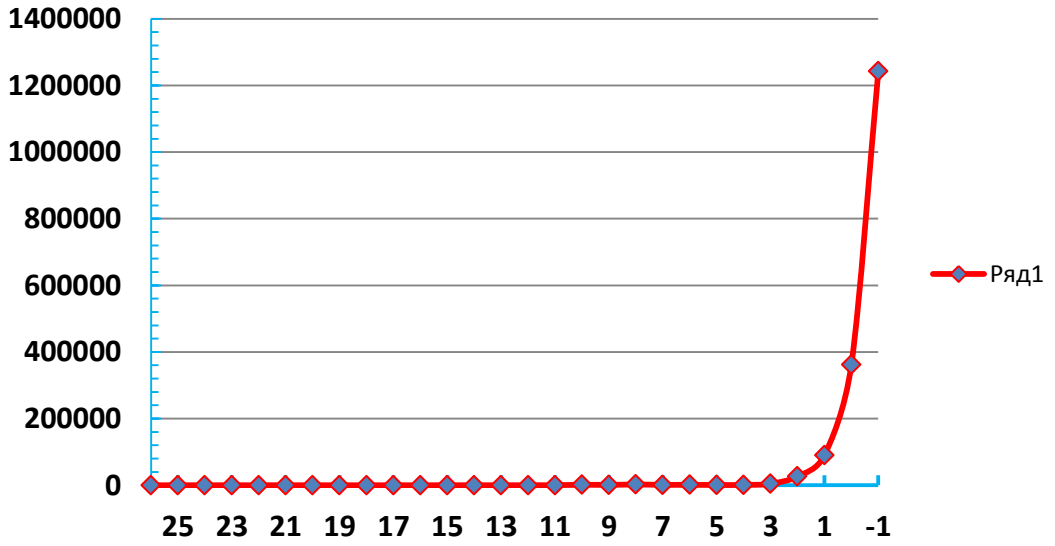


ABBN-78 Group №	Energy interval	Outgoing spectrum	Capture spectrum
-1	14.5-14.0 MeV	1504861	1242732
0	14.0-10.5 MeV	1141868	362210
1	10.5 – 6.5 MeV	421545	90185
2	6.5 – 4.0 MeV	666554	26626
3	4.0 – 2.5 MeV	685874	4564
4	2.5 – 1.4 MeV	1152384	972
5	1.4 – 0.8 MeV	991740	815
6	0.8 – 0.4 MeV	725141	1237
7	0.4 – 0.2 MeV	493873	1203
8	0.2 – 0.1 MeV	225551	2263
9	100 – 46.5 KeV	181399	1110
10	46.5 – 21.5 KeV	62402	1403
11	21.5 – 10 KeV	140635	201
12	10 – 4.65 KeV	573	61
13	4.65 – 2.15 KeV	88	0
14	2.15 – 1 KeV	2	0
15	1 – 0.465 KeV	0	0
16	465 – 215 eV	0	0
17	215 – 100 eV	0	0
18	100 – 46.5 eV	0	0
19	46.5 – 21.5 eV	0	0
20	21.5 – 10 eV	0	0
21	10 – 4.65 eV	0	0
22	4.65 – 2.15 eV	0	0
23	2.15 – 1.0 eV	0	0
24	1.0 – 0.465 eV	0	0
25	0.465 – 0.215 eV	0	0
26	0.215 – 0.001 eV	0	0

Sphere of Aluminum Al^{27} R= 20 cm

Outgoing spectrum (upper picture, blue curve) and capture spectrum (picture below, red line).

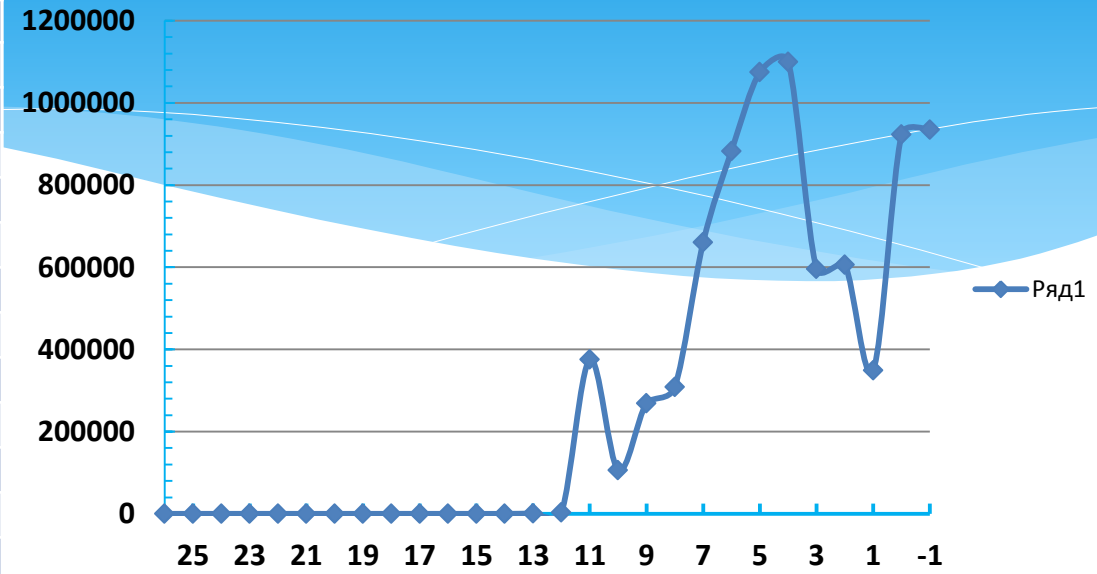


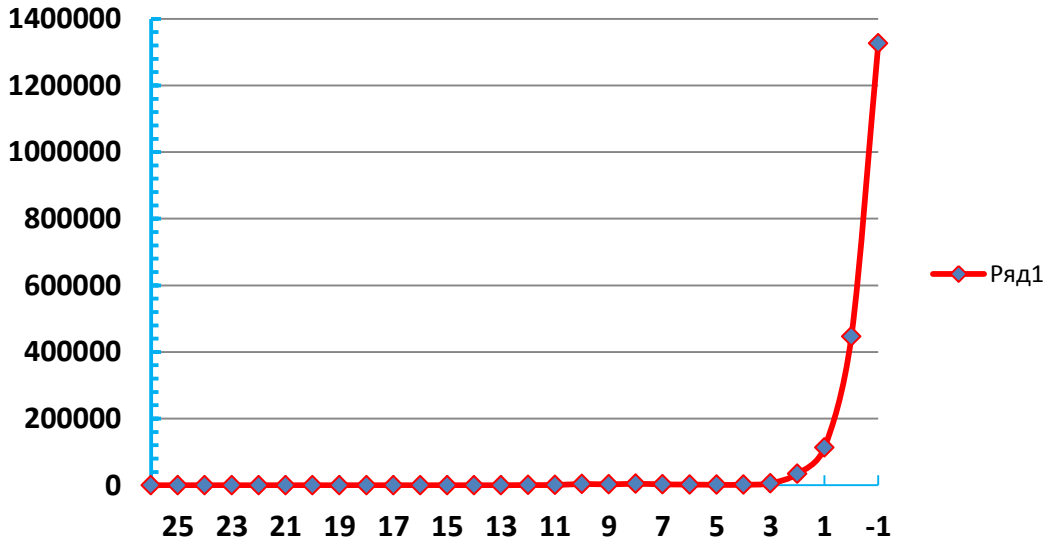


ABBN-78 Group №	Energy interval	Outgoing spectrum	Capture spectrum
-1	14.5-14.0 MeV	935061	1326174
0	14.0-10.5 MeV	922833	446374
1	10.5 – 6.5 MeV	349483	112867
2	6.5 – 4.0 MeV	606200	34575
3	4.0 – 2.5 MeV	596305	5849
4	2.5 – 1.4 MeV	1100299	1427
5	1.4 – 0.8 MeV	1075094	1307
6	0.8 – 0.4 MeV	882795	2111
7	0.4 – 0.2 MeV	660370	2525
8	0.2 – 0.1 MeV	309021	4522
9	100 – 46.5 KeV	268963	2524
10	46.5 – 21.5 KeV	106569	3749
11	21.5 – 10 KeV	375783	675
12	10 – 4.65 KeV	3766	613
13	4.65 – 2.15 KeV	992	1
14	2.15 – 1 KeV	52	0
15	1 – 0.465 KeV	2	0
16	465 – 215 eV	0	0
17	215 – 100 eV	0	0
18	100 – 46.5 eV	0	0
19	46.5 – 21.5 eV	0	0
20	21.5 – 10 eV	0	0
21	10 – 4.65 eV	0	0
22	4.65 – 2.15 eV	0	0
23	2.15 – 1.0 eV	0	0
24	1.0 – 0.465 eV	0	0
25	0.465 – 0.215 eV	0	0
26	0.215 – 0.001 eV	0	0

Sphere of Aluminum Al^{27} R= 25 cm

Outgoing spectrum (upper picture, blue curve) and capture spectrum (picture below, red line).

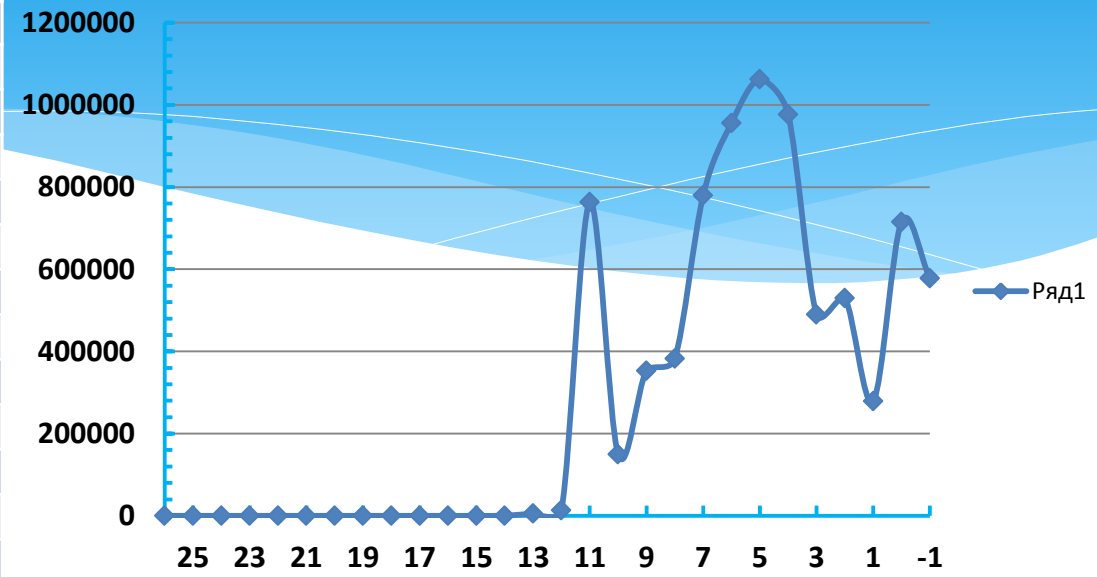


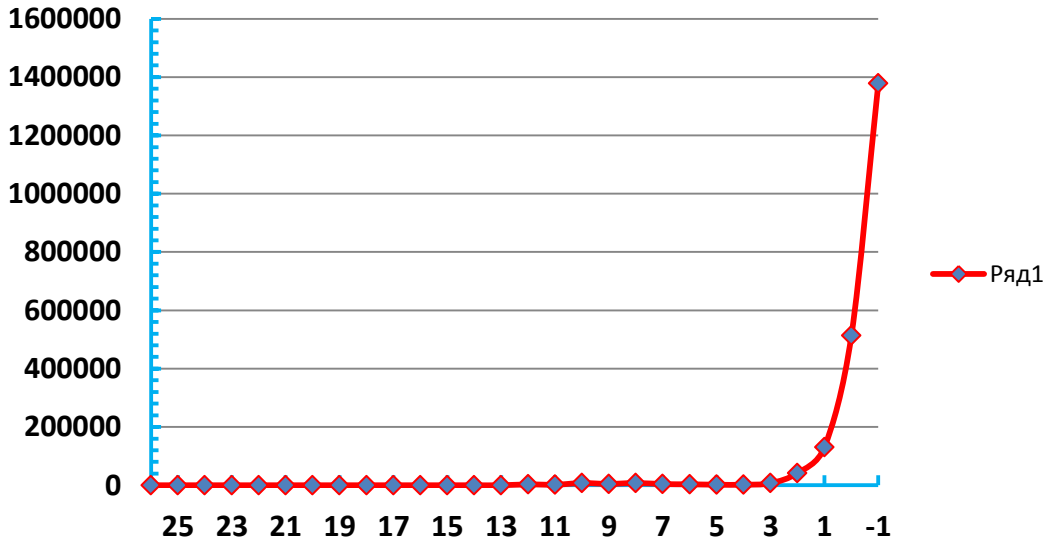


ABBN-78 Group №	Energy interval	Outgoing spectrum	Capture spectrum
-1	14.5-14.0 MeV	578001	1378373
0	14.0-10.5 MeV	715442	513110
1	10.5 – 6.5 MeV	278766	130614
2	6.5 – 4.0 MeV	529932	41940
3	4.0 – 2.5 MeV	490569	7129
4	2.5 – 1.4 MeV	977063	1792
5	1.4 – 0.8 MeV	1062204	1898
6	0.8 – 0.4 MeV	955926	3256
7	0.4 – 0.2 MeV	779753	3984
8	0.2 – 0.1 MeV	382366	7689
9	100 – 46.5 KeV	353306	4591
10	46.5 – 21.5 KeV	149710	7476
11	21.5 – 10 KeV	763675	1816
12	10 – 4.65 KeV	13904	2904
13	4.65 – 2.15 KeV	5687	14
14	2.15 – 1 KeV	511	3
15	1 – 0.465 KeV	45	0
16	465 – 215 eV	6	0
17	215 – 100 eV	1	0
18	100 – 46.5 eV	0	0
19	46.5 – 21.5 eV	0	0
20	21.5 – 10 eV	0	0
21	10 – 4.65 eV	0	0
22	4.65 – 2.15 eV	0	0
23	2.15 – 1.0 eV	0	0
24	1.0 – 0.465 eV	0	0
25	0.465 – 0.215 eV	0	0
26	0.215 – 0.001 eV	0	0

Sphere of Aluminum Al^{27} R= 30 cm

Outgoing spectrum (upper picture, blue curve) and capture spectrum (picture below, red line).

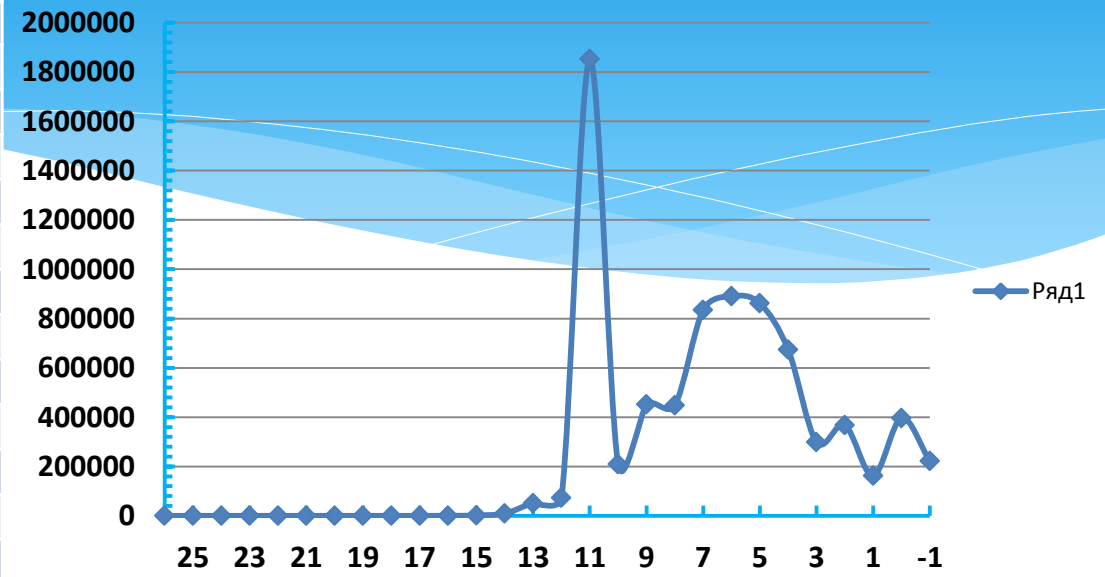


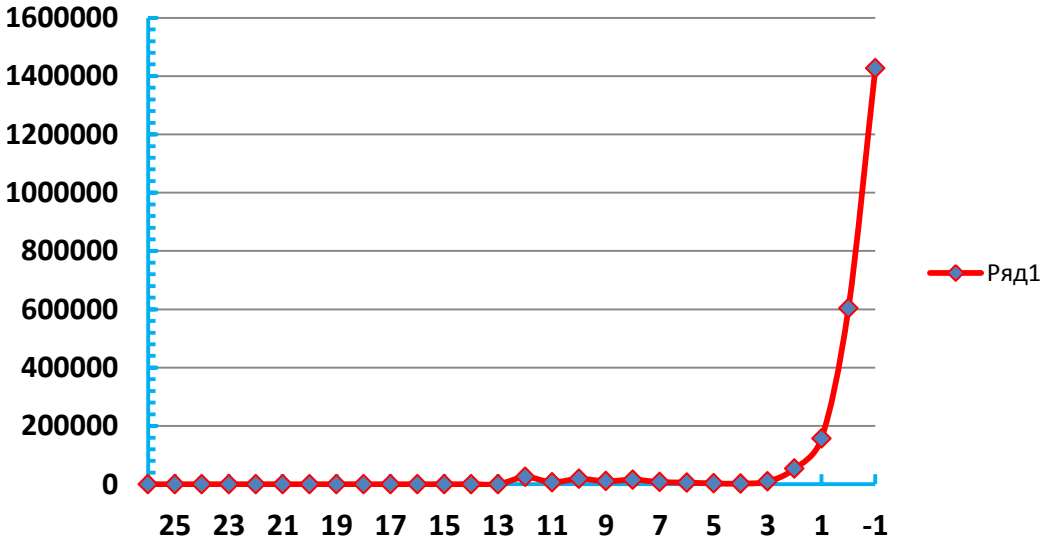


ABBN-78 Group №	Energy interval	Outgoing spectrum	Capture spectrum
-1	14.5-14.0 MeV	222187	1427062
0	14.0-10.5 MeV	395981	603013
1	10.5 – 6.5 MeV	162186	156638
2	6.5 – 4.0 MeV	367499	53249
3	4.0 – 2.5 MeV	298950	9197
4	2.5 – 1.4 MeV	673850	2356
5	1.4 – 0.8 MeV	862055	2842
6	0.8 – 0.4 MeV	890714	5653
7	0.4 – 0.2 MeV	834823	7668
8	0.2 – 0.1 MeV	448127	15415
9	100 – 46.5 KeV	452139	10299
10	46.5 – 21.5 KeV	209570	18366
11	21.5 – 10 KeV	1852319	6783
12	10 – 4.65 KeV	72722	24653
13	4.65 – 2.15 KeV	51518	161
14	2.15 – 1 KeV	9608	41
15	1 – 0.465 KeV	1754	16
16	465 – 215 eV	326	1
17	215 – 100 eV	55	0
18	100 – 46.5 eV	9	0
19	46.5 – 21.5 eV	1	0
20	21.5 – 10 eV	0	0
21	10 – 4.65 eV	0	0
22	4.65 – 2.15 eV	0	0
23	2.15 – 1.0 eV	0	0
24	1.0 – 0.465 eV	0	0
25	0.465 – 0.215 eV	0	0
26	0.215 – 0.001 eV	0	0

Sphere of Aluminum Al^{27} R= 40 cm

Outgoing spectrum (upper picture, blue curve) and capture spectrum (picture below, red line).

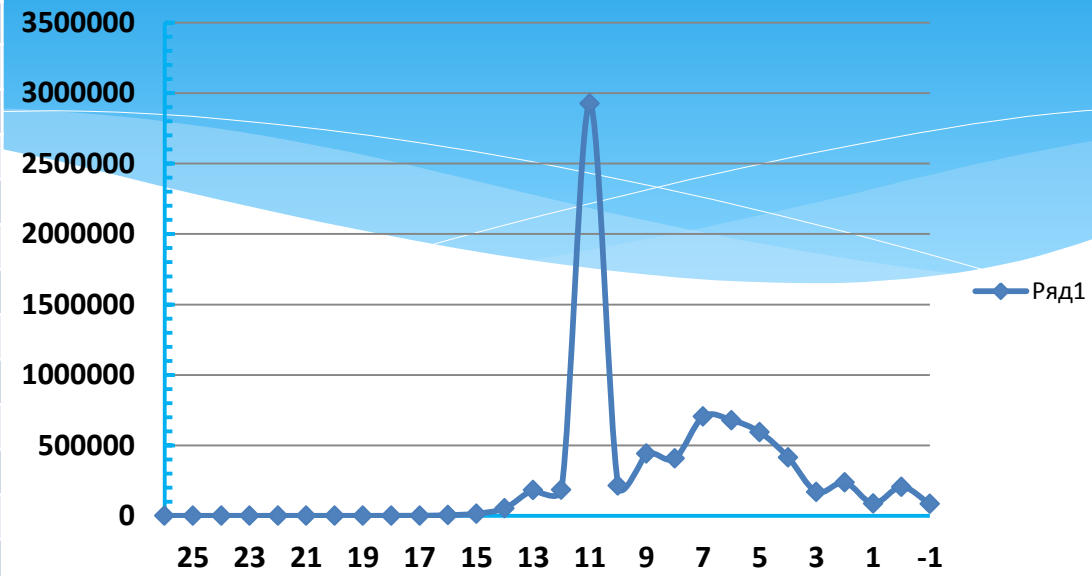


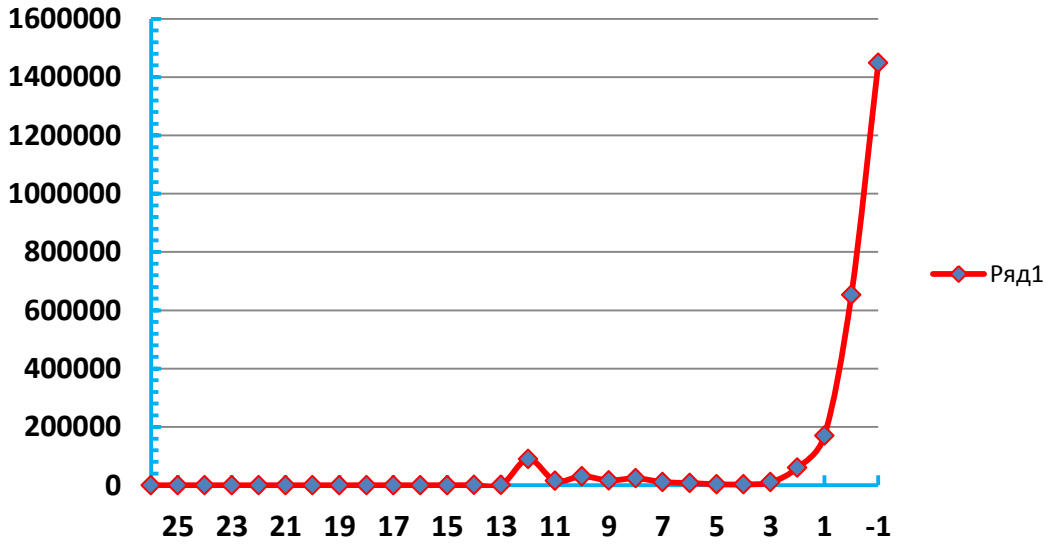


ABBN-78 Group №	Energy interval	Outgoing spectrum	Capture spectrum
-1	14.5-14.0 MeV	84206	1448851
0	14.0-10.5 MeV	205580	652816
1	10.5 – 6.5 MeV	87538	170268
2	6.5 – 4.0 MeV	237591	60143
3	4.0 – 2.5 MeV	170147	10272
4	2.5 – 1.4 MeV	414522	2861
5	1.4 – 0.8 MeV	593900	3499
6	0.8 – 0.4 MeV	678576	7640
7	0.4 – 0.2 MeV	704384	11003
8	0.2 – 0.1 MeV	406821	23791
9	100 – 46.5 KeV	441632	16551
10	46.5 – 21.5 KeV	214732	30968
11	21.5 – 10 KeV	2926486	14969
12	10 – 4.65 KeV	183860	89963
13	4.65 – 2.15 KeV	181681	726
14	2.15 – 1 KeV	53715	332
15	1 – 0.465 KeV	15523	126
16	465 – 215 eV	4523	63
17	215 – 100 eV	1269	28
18	100 – 46.5 eV	379	18
19	46.5 – 21.5 eV	113	4
20	21.5 – 10 eV	27	2
21	10 – 4.65 eV	3	0
22	4.65 – 2.15 eV	2	0
23	2.15 – 1.0 eV	0	0
24	1.0 – 0.465 eV	0	0
25	0.465 – 0.215 eV	0	0
26	0.215 – 0.001 eV	0	0

Sphere of Aluminum Al^{27} R= 50 cm

Outgoing spectrum (upper picture, blue curve) and capture spectrum (picture below, red line).

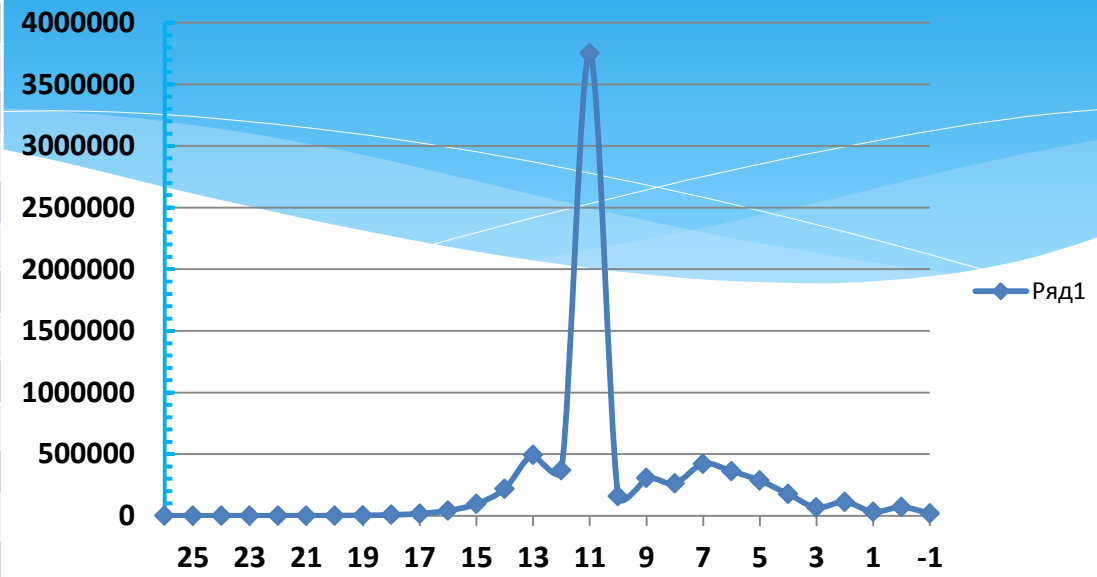


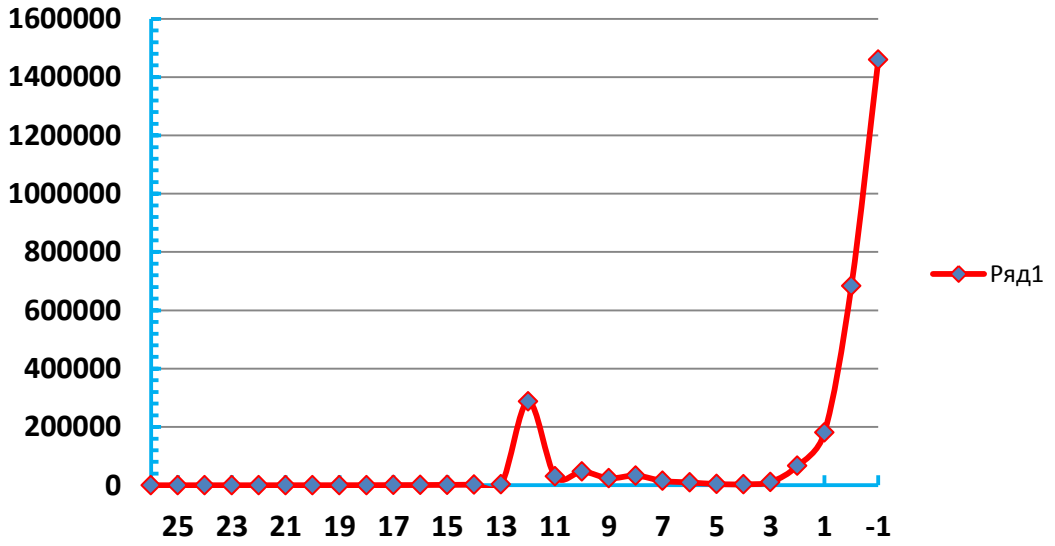


ABBN-78 Group №	Energy interval	Outgoing spectrum	Capture spectrum
-1	14.5-14.0 MeV	19881	1459987
0	14.0-10.5 MeV	70339	683259
1	10.5 – 6.5 MeV	32615	180337
2	6.5 – 4.0 MeV	112806	66169
3	4.0 – 2.5 MeV	67462	11140
4	2.5 – 1.4 MeV	176756	3239
5	1.4 – 0.8 MeV	285793	4175
6	0.8 – 0.4 MeV	362902	9546
7	0.4 – 0.2 MeV	422223	14736
8	0.2 – 0.1 MeV	263720	33013
9	100 – 46.5 KeV	306709	24001
10	46.5 – 21.5 KeV	159433	47002
11	21.5 – 10 KeV	3753239	30744
12	10 – 4.65 KeV	370390	287877
13	4.65 – 2.15 KeV	495576	3065
14	2.15 – 1 KeV	220254	1926
15	1 – 0.465 KeV	96447	1301
16	465 – 215 eV	41986	780
17	215 – 100 eV	18018	516
18	100 – 46.5 eV	7861	279
19	46.5 – 21.5 eV	3181	186
20	21.5 – 10 eV	1370	107
21	10 – 4.65 eV	543	79
22	4.65 – 2.15 eV	208	39
23	2.15 – 1.0 eV	79	18
24	1.0 – 0.465 eV	22	10
25	0.465 – 0.215 eV	7	4
26	0.215 – 0.001 eV	1	2

Sphere of Aluminum Al^{27} R= 65 cm

Outgoing spectrum (upper picture, blue curve) and capture spectrum (picture below, red line).

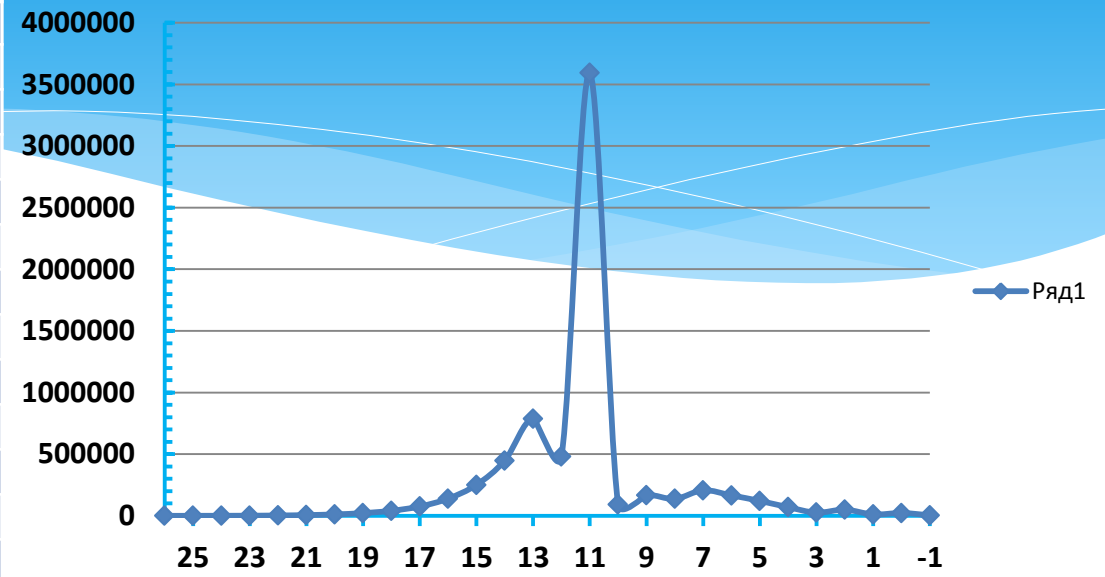


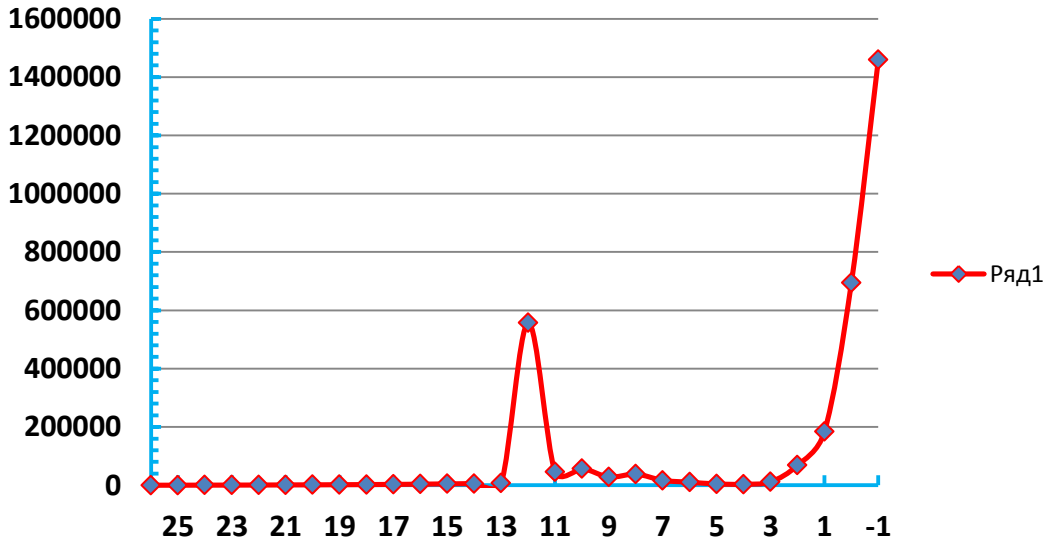


ABBN-78 Group №	Energy interval	Outgoing spectrum	Capture spectrum
-1	14.5-14.0 MeV	4503	1459871
0	14.0-10.5 MeV	23055	694538
1	10.5 – 6.5 MeV	11104	183682
2	6.5 – 4.0 MeV	49893	68490
3	4.0 – 2.5 MeV	25911	11566
4	2.5 – 1.4 MeV	70007	3321
5	1.4 – 0.8 MeV	121010	4516
6	0.8 – 0.4 MeV	165502	10307
7	0.4 – 0.2 MeV	207156	16706
8	0.2 – 0.1 MeV	137493	37954
9	100 – 46.5 KeV	168331	28357
10	46.5 – 21.5 KeV	90772	57022
11	21.5 – 10 KeV	3594942	45910
12	10 – 4.65 KeV	481635	557747
13	4.65 – 2.15 KeV	788568	7047
14	2.15 – 1 KeV	448870	5664
15	1 – 0.465 KeV	251082	4714
16	465 – 215 eV	139694	3652
17	215 – 100 eV	75596	2911
18	100 – 46.5 eV	40816	2290
19	46.5 – 21.5 eV	22075	1861
20	21.5 – 10 eV	11561	1424
21	10 – 4.65 eV	5875	1120
22	4.65 – 2.15 eV	2843	752
23	2.15 – 1.0 eV	1232	562
24	1.0 – 0.465 eV	567	356
25	0.465 – 0.215 eV	203	197
26	0.215 – 0.001 eV	159	50

Sphere of Aluminum Al^{27} R= 80 cm

Outgoing spectrum (upper picture, blue curve) and capture spectrum (picture below, red line).

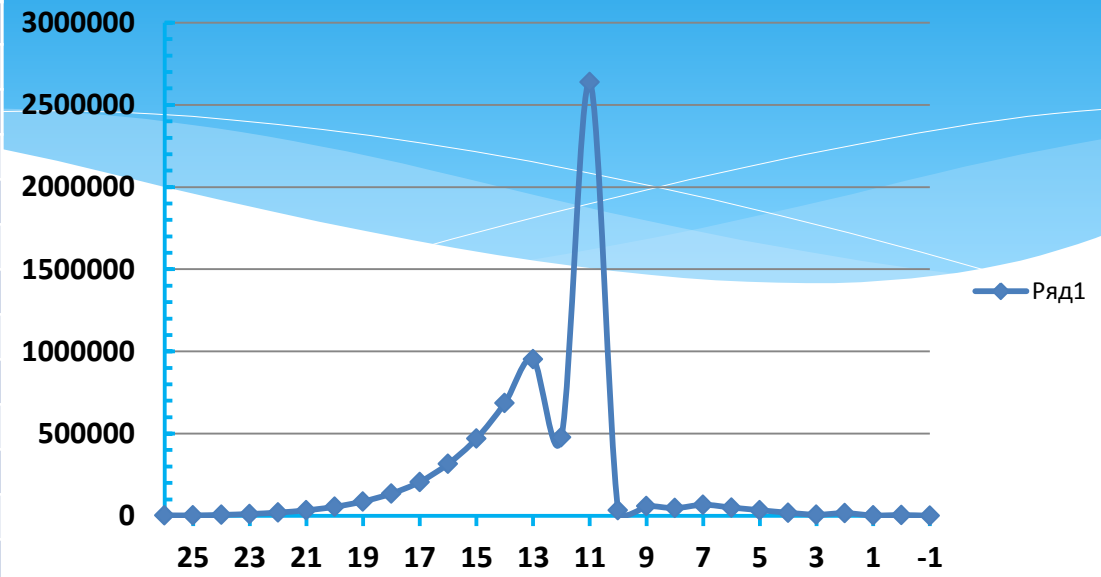


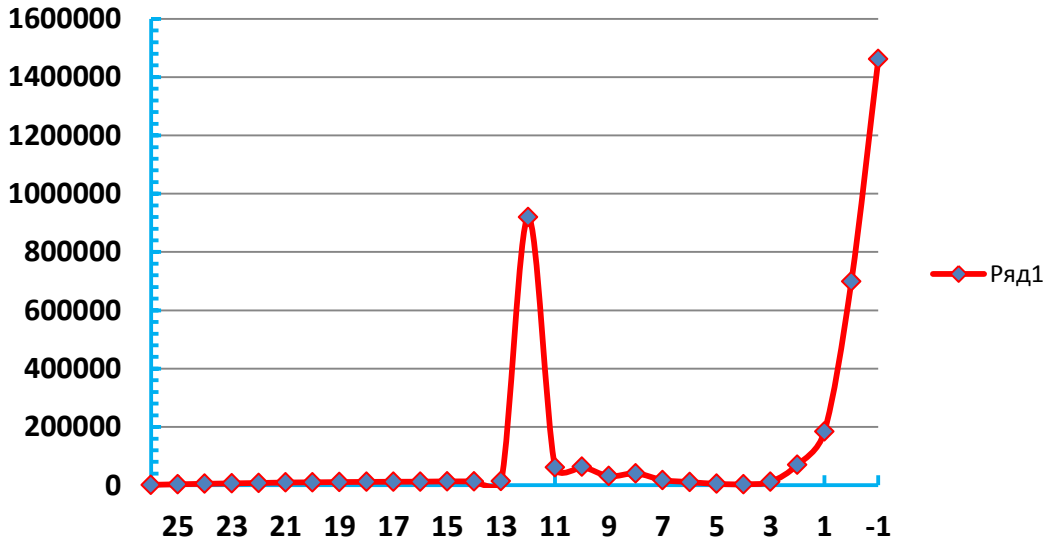


ABBN-78 Group №	Energy interval	Outgoing spectrum	Capture spectrum
-1	14.5-14.0 MeV	675	1461720
0	14.0-10.5 MeV	4676	699103
1	10.5 – 6.5 MeV	2567	184301
2	6.5 – 4.0 MeV	16088	70260
3	4.0 – 2.5 MeV	6940	11774
4	2.5 – 1.4 MeV	18769	3415
5	1.4 – 0.8 MeV	34303	4730
6	0.8 – 0.4 MeV	50277	10890
7	0.4 – 0.2 MeV	67095	17683
8	0.2 – 0.1 MeV	46727	40624
9	100 – 46.5 KeV	59910	31204
10	46.5 – 21.5 KeV	33811	63126
11	21.5 – 10 KeV	2639292	61292
12	10 – 4.65 KeV	478231	919742
13	4.65 – 2.15 KeV	953171	13594
14	2.15 – 1 KeV	685545	13092
15	1 – 0.465 KeV	469272	13225
16	465 – 215 eV	316088	12256
17	215 – 100 eV	206154	12048
18	100 – 46.5 eV	135314	11476
19	46.5 – 21.5 eV	87413	10891
20	21.5 – 10 eV	54689	10050
21	10 – 4.65 eV	33439	9327
22	4.65 – 2.15 eV	19802	7762
23	2.15 – 1.0 eV	11202	6450
24	1.0 – 0.465 eV	5734	4972
25	0.465 – 0.215 eV	2482	3319
26	0.215 – 0.001 eV	2974	1382

Sphere of Aluminum Al^{27} R= 100cm

Outgoing spectrum (upper picture, blue curve) and capture spectrum (picture below, red line).





Spectrums in metal Aluminum spheres

ABBN-78 Group №	Energy Interval	R = 1 cm		R = 5 cm		R = 10 cm		R = 15 cm		R = 20 cm		R = 25 cm	
		Outgoing Spectrum	Capture Spectrum	Outgoing Spectrum	Capture Spectrum	Outgoing Spectrum	Capture Spectrum	Outgoing Spectrum	Capture Spectrum	Outgoing Spectrum	Capture Spectrum	Outgoing Spectrum	Capture Spectrum
-1	14.5-14.0 MeV	9104096	131087	6245903	550813	3893544	895717	2421191	1109638	1504861	1242732	935061	1326174
0	14.0-10.5 MeV	293915	2530	1046755	48633	1360828	149809	1325079	259931	1141868	362210	922833	446374
1	10.5-6.5 MeV	97534	574	353772	11817	473810	35857	475117	63802	421545	90185	349483	112867
2	6.5-4.0 MeV	99946	143	404786	2743	609452	9455	679269	17970	666554	26626	606200	34575
3	4.0-2.5 MeV	103655	17	434991	388	663553	1436	726686	2960	685874	4564	596305	5849
4	2.5-1.4 MeV	102029	2	488060	75	868383	271	1088996	590	1152384	972	1100299	1427
5	1.4-0.8 MeV	39298	0	232694	30	524477	130	798856	407	991740	815	1075094	1307
6	0.8-0.4 MeV	8304	0	85037	10	266557	141	502803	539	725141	1237	882795	2111
7	0.4-0.2 MeV	18635	3	87676	24	184454	169	321327	507	493873	1203	660370	2525
8	0.2-0.1 MeV	11799	1	52962	50	98445	319	152670	985	225551	2263	309021	4522
9	100-46.5 KeV	284	0	9938	6	46626	83	104486	408	181399	1110	268963	2524
10	46.5 –21.5 KeV	16	0	523	3	7101	58	27830	402	62402	1403	106569	3749
11	21.5– 10 KeV	0	0	98	0	3652	4	34317	35	140635	201	375783	675
12	10– 4.65 KeV	0	0	0	0	0	0	33	1	573	61	3766	613
13	4.65– 2.15 KeV	0	0	0	0	0	0	3	0	88	0	992	1
14	2.15 – 1 KeV	0	0	0	0	0	0	0	0	2	0	52	0
15	1– 0.465 KeV	0	0	0	0	0	0	0	0	0	0	2	0
16	465– 215 eV	0	0	0	0	0	0	0	0	0	0	0	0
17	215– 100 eV	0	0	0	0	0	0	0	0	0	0	0	0
18	100– 46.5 eV	0	0	0	0	0	0	0	0	0	0	0	0
19	46.5– 21.5 eV	0	0	0	0	0	0	0	0	0	0	0	0
20	21.5– 10 eV	0	0	0	0	0	0	0	0	0	0	0	0
21	10– 4.65 eV	0	0	0	0	0	0	0	0	0	0	0	0
22	4.6 – 2.15 eV	0	0	0	0	0	0	0	0	0	0	0	0
23	2.1 – 1.0 eV	0	0	0	0	0	0	0	0	0	0	0	0
24	1.0– 0.465 eV	0	0	0	0	0	0	0	0	0	0	0	0
25	0.46 – 0.215 eV	0	0	0	0	0	0	0	0	0	0	0	0
26	0.215– 0.001 eV	0	0	0	0	0	0	0	0	0	0	0	0
Average Neutron Energy		14.87 MeV	14.06 MeV	12.47 MeV	13.82 MeV	9.81 MeV	13.65 MeV	7.59 MeV	13.51 MeV	5.86 MeV	13.38 MeV	4.52 MeV	13.24 MeV
Diffusion/Absorption time of spectra, nanoseconds		0.23	0.096	1.51	0.482	4.75	0.968	11.78	1.50	25.78	2.21	50.81	3.47
Number of neutrons		9879511	134357	9443195	614592	9000882	1093449	8658663	1458175	8394490	1735582	8193588	1945293

Spectrums in metal Aluminum spheres

ABBN-78 Group №	Energy Interval	R = 30 cm		R = 40 cm		R = 50 cm		R = 65 cm		R = 80 cm		R = 100 cm	
		Outgoing Spectrum	Capture Spectrum	Outgoing Spectrum	Capture Spectrum	Outgoing Spectrum	Capture Spectrum	Outgoing Spectrum	Capture Spectrum	Outgoing Spectrum	Capture Spectrum	Outgoing Spectrum	Capture Spectrum
-1	14.5-14.0 MeV	578001	1378373	222187	1427062	84206	1448851	19881	1459987	4503	1459871	675	1461720
0	14.0-10.5 MeV	715442	513110	395981	603013	205580	652816	70339	683259	23055	694538	4676	699103
1	10.5-6.5 MeV	278766	130614	162186	156638	87538	170268	32615	180337	11104	183682	2567	184301
2	6.5-4.0 MeV	529932	41940	367499	53249	237591	60143	112806	66169	49893	68490	16088	70260
3	4.0-2.5 MeV	490569	7129	298950	9197	170147	10272	67462	11140	25911	11566	6940	11774
4	2.5-1.4 MeV	977063	1792	673850	2356	414522	2861	176756	3239	70007	3321	18769	3415
5	1.4-0.8 MeV	1062204	1898	862055	2842	593900	3499	285793	4175	121010	4516	34303	4730
6	0.8-0.4 MeV	955926	3256	890714	5653	678576	7640	362902	9546	165502	10307	50277	10890
7	0.4-0.2 MeV	779753	3984	834823	7668	704384	11003	422223	14736	207156	16706	67095	17683
8	0.2-0.1 MeV	382366	7689	448127	15415	406821	23791	263720	33013	137493	37954	46727	40624
9	100-46.5 KeV	353306	4591	452139	10299	441632	16551	306709	24001	168331	28357	59910	31204
10	46.5 –21.5 KeV	149710	7476	209570	18366	214732	30968	159433	47002	90772	57022	33811	63126
11	21.5– 10 KeV	763675	1816	1852319	6783	2926486	14969	3753239	30744	3594942	45910	2639292	61292
12	10– 4.65 KeV	13904	2904	72722	24653	183860	89963	370390	287877	481635	557747	478231	919742
13	4.65– 2.15 KeV	5687	14	51518	161	181681	726	495576	3065	788568	7047	953171	13594
14	2.15 – 1 KeV	511	3	9608	41	53715	332	220254	1926	448870	5664	685545	13092
15	1– 0.465 KeV	45	0	1754	16	15523	126	96447	1301	251082	4714	469272	13225
16	465– 215 eV	6	0	326	1	4523	63	41986	780	139694	3652	316088	12256
17	215– 100 eV	1	0	55	0	1269	28	18018	516	75596	2911	206154	12048
18	100– 46.5 eV	0	0	9	0	379	18	7861	279	40816	2290	135314	11476
19	46.5– 21.5 eV	0	0	1	0	113	4	3181	186	22075	1861	87413	10891
20	21.5– 10 eV	0	0	0	0	27	2	1370	107	11561	1424	54689	10050
21	10– 4.65 eV	0	0	0	0	3	0	543	79	5875	1120	33439	9327
22	4.6 – 2.15 eV	0	0	0	0	2	0	208	39	2843	752	19802	7762
23	2.1 – 1.0 eV	0	0	0	0	0	0	79	18	1232	562	11202	6450
24	1.0– 0.465 eV	0	0	0	0	0	0	22	10	567	356	5734	4972
25	0.46 – 0.215 eV	0	0	0	0	0	0	7	4	203	197	2482	3319
26	0.215– 0.001 eV	0	0	0	0	0	0	1	2	159	50	2974	1382
Average Neutron Energy		3.46 MeV	13.1 MeV	1.98 MeV	12.70 MeV	1.10 MeV	12.14 MeV	450 KeV	11.03 MeV	181 KeV	9.89 MeV	56.74 KeV	8.59 MeV
Diffusion/Absorption time of spectra, nanoseconds		90.66	6.01	226.3	21.15	452.8	60.34	1068	185.7	2418	535.1	6546	2624
Number of neutrons		8037867	2106589	7806393	2343413	7607210	2544894	7289821	2863537	6940546	3212587	6442640	3709708

Precision of the calculated data

In order to check precision of our calculated data and compare program's calculation results with literature benchmarks for critical assemblies, we calculated neutron propagation in $\mathbf{Pu^{239}}$ sphere.

Sphere with radius 4.9 cm, density 19.737 g/cm^3 and mass 9.726 kg, showed multiplication ratio K=412. Start number of primary 40,000 neutrons provides statistical precision for neutron flux multiplication ratio around 0.5%.

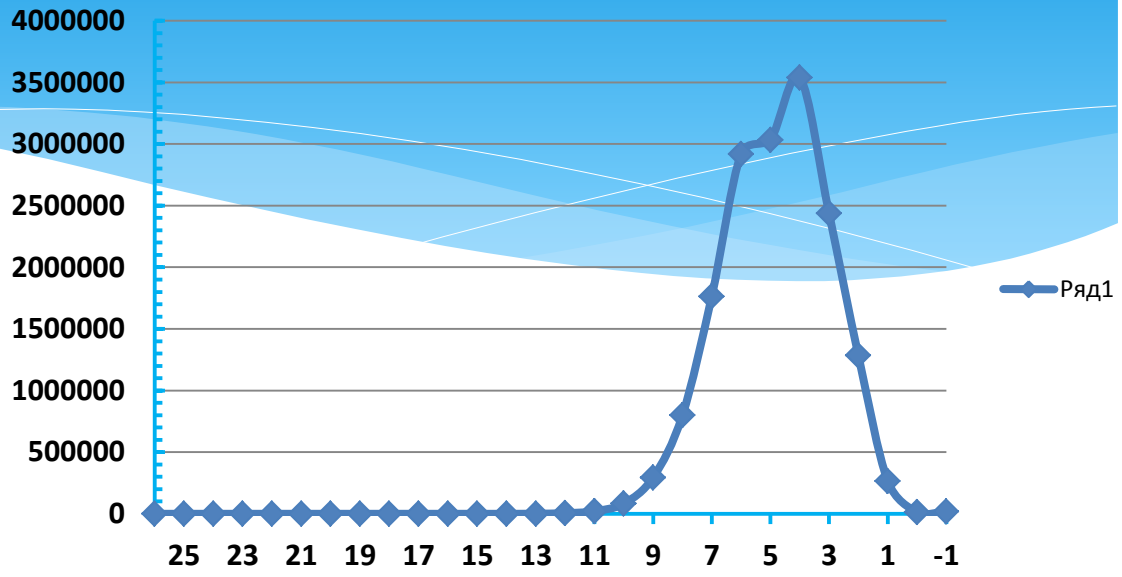
Outgoing spectrum of 16,486,400 secondary neutrons, which can be measured by TOF method, has average energy 1,771,156 eV. Capture spectrum of 350,648 secondary neutrons has average energy 593,472 eV. Number of fissions is 7,924,914.

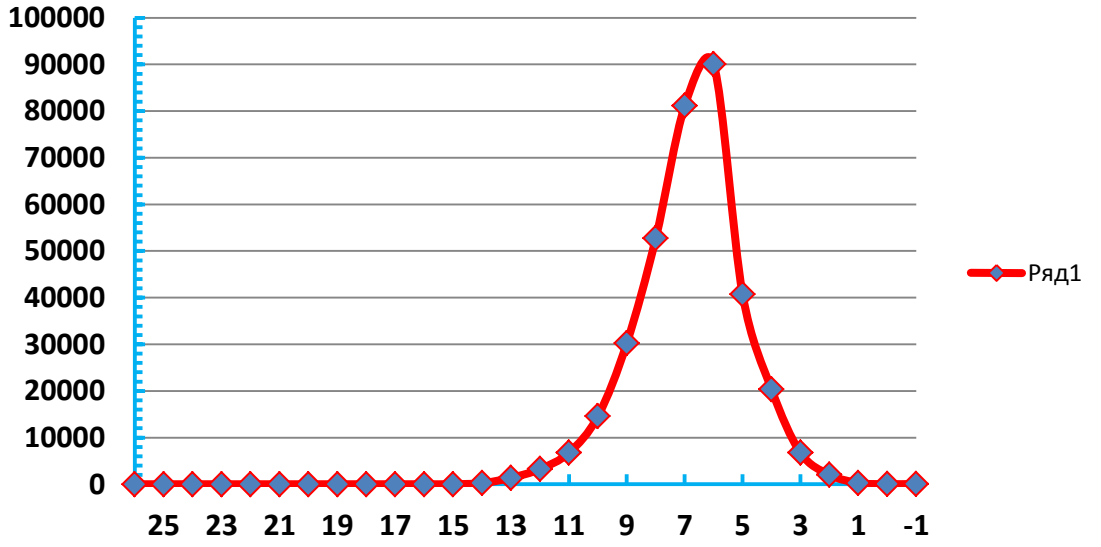
Calculated critical volume and critical mass, after extrapolation to neutron flux multiplication ratio K=infinity, are in good correlation with literature data. Neutron spectra are planned to compare with calculation results, obtained from the work of the program together with the 299-group ABBN-93 system of neutron group cross sections.

ABBN-78 Group №	Energy interval	Outgoing spectrum	Capture spectrum
-1	14.5-14.0 MeV	19189	66
0	14.0-10.5 MeV	15138	21
1	10.5 – 6.5 MeV	266548	279
2	6.5 – 4.0 MeV	1285278	2056
3	4.0 – 2.5 MeV	2437565	6772
4	2.5 – 1.4 MeV	3539460	20354
5	1.4 – 0.8 MeV	3033277	40738
6	0.8 – 0.4 MeV	2920087	90063
7	0.4 – 0.2 MeV	1764281	81117
8	0.2 – 0.1 MeV	799593	52726
9	100 – 46.5 KeV	295053	30257
10	46.5 – 21.5 KeV	83147	14569
11	21.5 – 10 KeV	21167	6748
12	10 – 4.65 KeV	5256	3249
13	4.65 – 2.15 KeV	1248	1378
14	2.15 – 1 KeV	116	232
15	1 – 0.465 KeV	0	19
16	465 – 215 eV	1	4
17	215 – 100 eV	0	0
18	100 – 46.5 eV	0	0
19	46.5 – 21.5 eV	0	0
20	21.5 – 10 eV	0	0
21	10 – 4.65 eV	0	0
22	4.65 – 2.15 eV	0	0
23	2.15 – 1.0 eV	0	0
24	1.0 – 0.465 eV	0	0
25	0.465 – 0.215 eV	0	0
26	0.215 – 0.001 eV	0	0
Sum	14.5E6-0.001 ev	16486400	350648

Sphere of Plutonium Pu^{239} R= 4.9 cm

Outgoing spectrum (upper picture, blue curve) and capture spectrum (picture below, red line).





Modeling results of numerical calculation shows:

1)

Leakage neutron spectrum which can be measured by TOF method, and absorption spectrum, are two different neutron spectrums. In common case, they have maximum number of neutrons in different energy groups. Their correlation can be found making variant numerical calculations, especially considering, that spectrums /and their average energies, diffusion times/ changes monotonously – at least, if we speak about plenty practically important cases - during increasing thickness of substance, which the neutron flux is diffusing through.

2)

In the case of big assemblies, which radius many times exceeds transport free path of neutrons, their spectrum has average energy around 100 keV. This energy is many times smaller, than average energy of initial fission spectrum which is ~2 MeV. Such energies around ~100 KeV can be measured by existing TOF spectrometers, which have resolution factor ~ 6 nanoseconds/meter and better. This conclusion is one of practically important modeling results.

3)

Substances with small absorption cross section and intermediate masses of nuclei, such as aluminum Al27, nickel 28Ni, titanium 22Ti, steel 26Fe, sodium Na23, in the case of big enough thicknesses, produce spectrum similar to spectrum Fermi. Fermi spectrum, in which neutron flux $\Phi \sim (1/E)$ is analytical idealization for the case, when exist no leakage and no absorption. Integration $(1/E)*dE$ results, that if lethargy interval on energy axis is constant, then each of 28 energy groups has equal quantity of neutrons.

4)

During propagating of neutrons from the center to external surface of the sphere, their average energy decrease: at first rapidly due to inelastic cross section until energy is above it's threshold for selected nuclide. After energy becomes smaller than inelastic threshold, spectrum continues to moderate slowly due to elastic cross section. Substances like 75Re, Ta181, U238, 74W which has high capture cross section in resonance neutron energy area, absorb majority of neutrons above 14^{th} group i.e. above 1 KeV.

Conclusion

1. Integral experiments are integral check of all main types of nuclear constants, of cross sections for interaction of neutrons with nuclei, as suggested in [6]. In present work authors make a supplement for the prepared stock of calculated spectrums, by adding data for Rhenium, Molybdenum and Aluminum. These data are basis for comparison, both with 299-group calculation results, and with future experimental TOF spectra.

Such experiments can be made also with subcritical assemblies. Neutron spectrums of large fast breeder reactors with diluted fissile material has average energy around ~140 KeV. This value turns out measureable already by existing TOF spectrometers, which have resolution factor 6 nanoseconds per meter and better.

2. Outgoing spectrum and capture spectrum differ one from another. Outgoing spectrum can be measured by TOF method, while capture spectrum is needed to calculate fast neutron reactor's breeding ratio. Using experimentally observable TOF outgoing neutron leakage spectrum, it's possible to reconstruct capture spectrum using numerical modeling.

3. Due to big durations of diffusion time in the case of big assemblies, comparable to microsecond, spectrums of large subcritical assemblies with radius comparable to 1 meter, can be measured by TOF method only using long TOF bases. Their length must be several hundreds meters to provide energy resolution, high enough for spectrum average neutron energy around 140 KeV. Thus, results of numerical calculation allows to determine for each nuclide or their alloy composition: spheres of what radiuses? And their corresponding spectra, can be measured on a given TOF spectrometer with known resolution factor and intensity/

4. Future work includes comparing present 28-group spectrums with 299-group ABBN-93 calculation results for their calibration. Also comparing with calculation results of codes, which use introduction of cross sections as continuous curves instead of energy groups. Most interesting calculation results we plan to check experimentally on TOF bases of the INR RAS proton linear accelerator's spallation neutron source RADEX.

5. With statistics 100,000,000 neutrons for each variant, performance of the 28-group version of the program allows to calculate big quantity of variants per year, using several modern personal computers. Available statistics provides discreteness calculation precision component better than value of delayed neutron's share. High enough statistics define, that for majority of energy groups, their data difference between ABBN-78 and ABBN-93 is not due to statistical scatter but due to the difference in cross section's precision. In a precision setting, the results of integral experiments are the basis for adjusting group neutron constants intended for calculation of nuclear rectors and radiation shields.

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Thank you for your attention!