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Simulation of Spectra’s Evolution During Propagation of the Neutron Fluxes in Solid Bodies

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Abstract

The results of numerical modeling for leakage neutron spectra, for diffusion time and for absorption neutron spectra during propagation of neutron flux in spheres, which consists of nominal density solid bodies of nucleus C^{12}, Ni^{nat} and Ta^{181}, 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 also necessary to compare 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.Tantalum isotope Ta^{181}, nominal density solid body metal sphere;

2. Nickel natural isotope composition $\mathbf{Ni^{nat}}$ metal sphere;

3. Graphite spheres with natural isotope mixture $\mathbf{C^{12}}$ (98.9%) and $\mathbf{C^{13}}$.

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

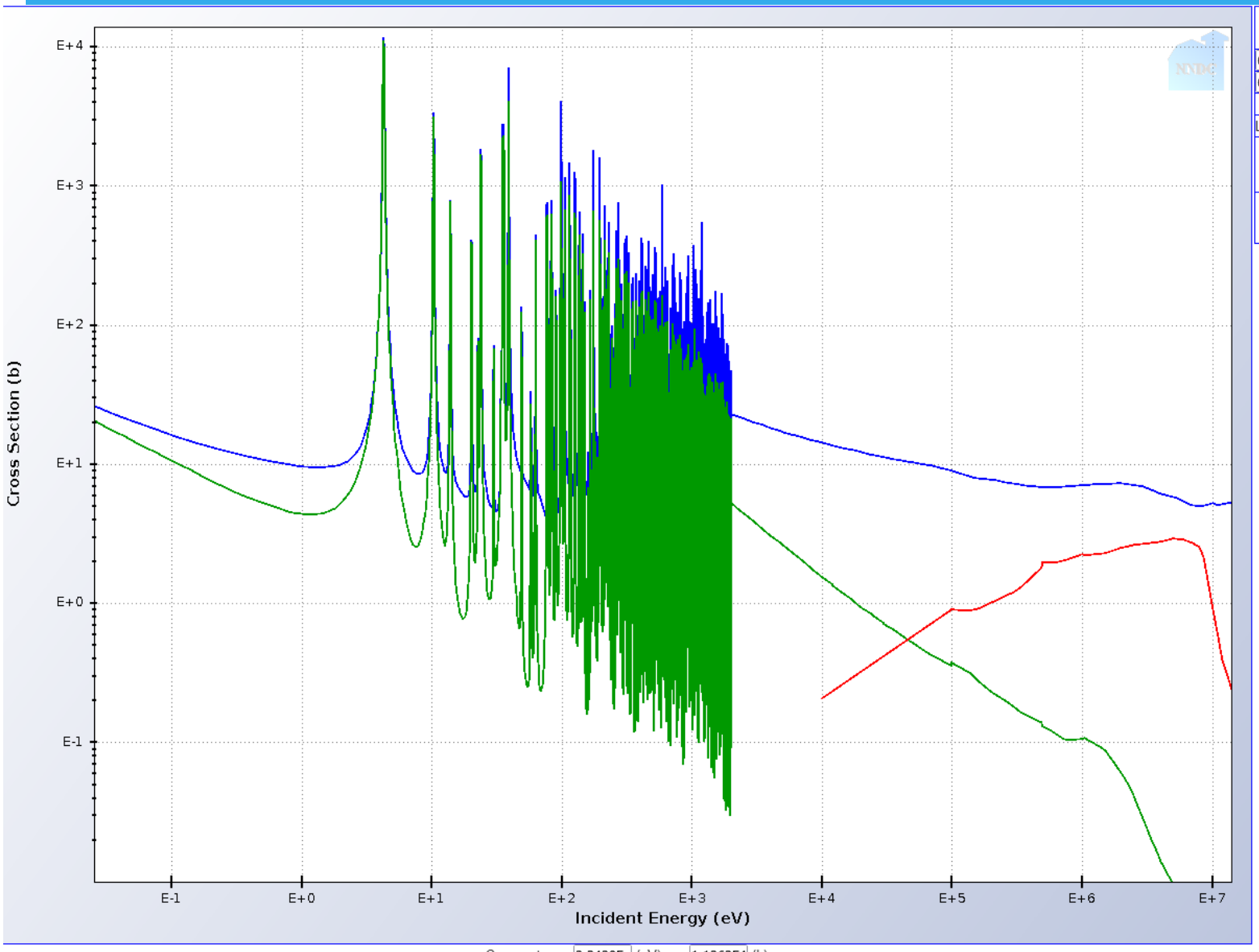
There is a sphere of metal, which has nominal density p, radius **1<R<100 cm** and consists of defined isotope or their mixture with known cross sections and matrix of inelastic scattering group transitions [3]. At time t=0 in the center of the sphere are emitted N neutrons which have energy E0, MeV.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

* Average time of neutron's diffusion to external surface of the sphere (when r = R for each neutron);
* 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=1,000,000** 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 Ta^{181} : total cross section (blue line), capture (green), inelastic scattering (red line). Data from the Brookhaven National Laboratory [5].



ABBN-78 constants for Ta^{181}

BNAB 28-GROUP NEUTRON CONSTANTS FOR TA(73,180.94800)

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	5.3770	.0000	.0000	.0050	2.3630	3.0090	.8590
0	.105E+02-	.140E+02	5.2710	.0000	.0000	.0030	2.4000	2.8680	.8280
1	.650E+01-	.105E+02	5.1110	.0000	.0000	.0000	2.6350	2.4760	.7690
2	.400E+01-	.650E+01	5.8700	.0000	.0000	.0040	2.8610	3.0050	.8020
3	.250E+01-	.400E+01	6.7934	.0000	.0000	.0260	2.7194	4.0480	.7350
4	.140E+01-	.250E+01	7.2712	.0000	.0000	.0660	2.4662	4.7390	.5900
5	.800E+00-	.140E+01	7.1371	.0000	.0000	.1020	2.2151	4.8200	.4140
6	.400E+00-	.800E+00	6.8934	.0000	.0000	.1250	1.9034	4.8650	.2710
7	.200E+00-	.400E+00	7.3647	.0000	.0000	.1890	1.2077	5.9680	.1730
8	.100E+00-	.200E+00	8.2646	.0000	.0000	.3060	.9186	7.0400	.1050
9	.465E-01-	.100E+00	10.0130	.0000	.0000	.6640	.6710	8.6780	.0550
10	.215E-01-	.465E-01	11.7832	.0000	.0000	1.1690	.3812	10.2330	.0260
11	.100E-01-	.215E-01	13.3239	.0000	.0000	1.7290	.2469	11.3480	.0130
12	.465E-02-	.100E-01	15.2118	.0000	.0000	2.4940	.0588	12.6590	.0070
13	.215E-02-	.465E-02	17.7500	.0000	.0000	3.8170	.0000	13.9330	.0050
14	.100E-02-	.215E-02	24.6420	.0000	.0000	6.8140	.0000	17.8280	.0040
15	.465E-03-	.100E-02	33.9360	.0000	.0000	12.7060	.0000	21.2300	.0040
16	.215E-03-	.465E-03	42.4860	.0000	.0000	22.9560	.0000	19.5300	.0040
17	.100E-03-	.215E-03	67.6320	.0000	.0000	33.5860	.0000	34.0460	.0040
18	.465E-04-	.100E-03	60.9650	.0000	.0000	29.4850	.0000	31.4800	.0040
19	.215E-04-	.465E-04	189.7610	.0000	.0000	132.5860	.0000	57.1750	.0040
20	.100E-04-	.215E-04	113.3860	.0000	.0000	102.1520	.0000	11.2340	.0040
21	.465E-05-	.100E-04	19.8910	.0000	.0000	12.1800	.0000	7.7110	.0040
22	.215E-05-	.465E-05	521.6270	.0000	.0000	489.0750	.0000	32.5520	.0040
23	.100E-05-	.215E-05	9.6440	.0000	.0000	4.6300	.0000	5.0140	.0040
24	.465E-06-	.100E-05	10.1970	.0000	.0000	4.7980	.0000	5.3990	.0040
25	.215E-06-	.465E-06	11.8610	.0000	.0000	6.3160	.0000	5.5450	.0040
26	THERMAL		18.6290	.0000	.0000	12.9960	.0000	5.6330	.0040

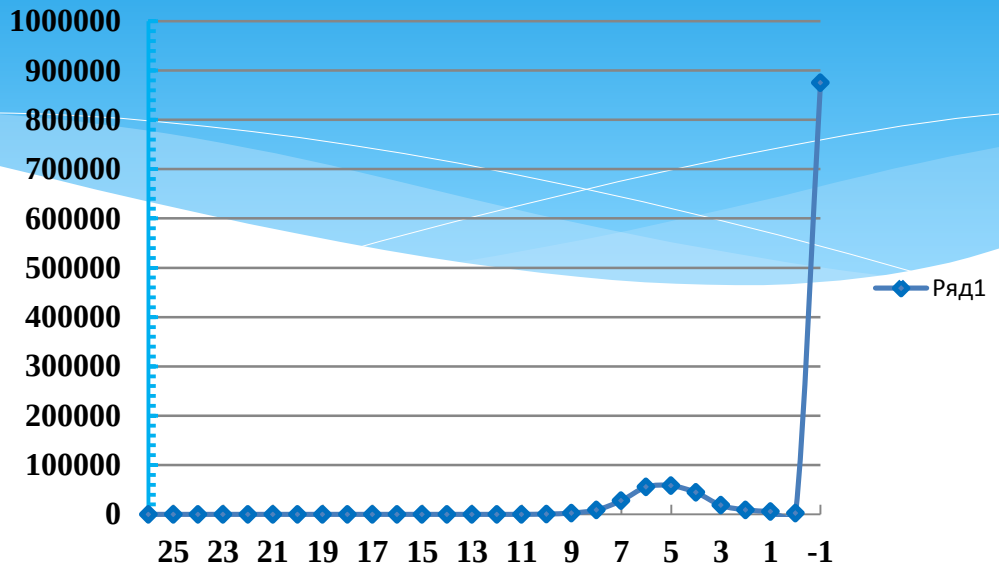
SIGMA IN (I,I+K) AT K EQUAL:

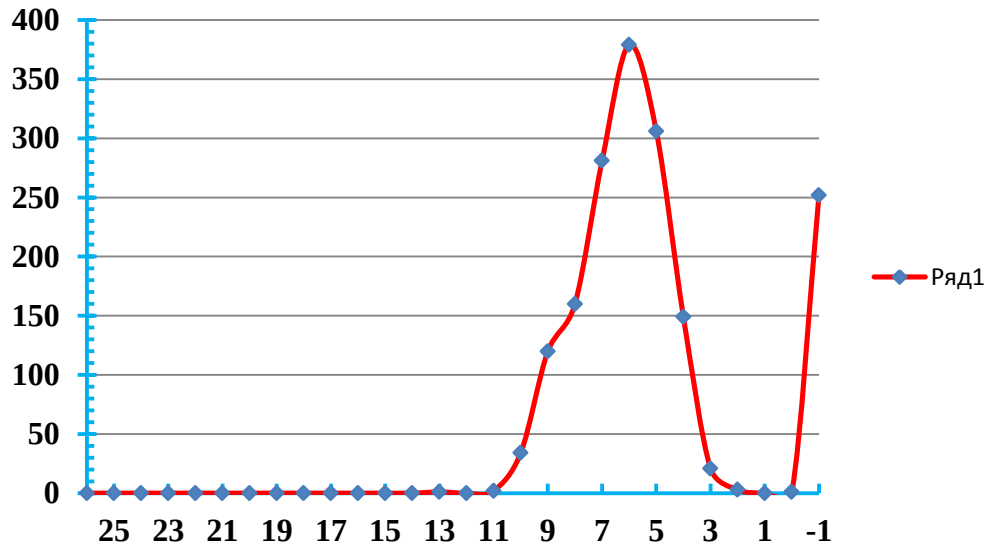
I	K= 0	K= 1	K= 2	K= 3	K= 4	K= 5	K= 6	K= 7	K= 8	K= 9	K=10	K=11	SUMMA
-1	.0003	.0369	.1344	.2006	.3986	.9196	1.1214	1.0159	.4668	.1448	.0419	.0102	4.4914
0	.0196	.1191	.1851	.3562	.8573	1.1139	1.0663	.5168	.1668	.0493	.0121	.0027	4.4652
1	.0148	.0934	.2100	.5757	.7548	.6876	.3491	.1268	.0404	.0103	.0023	.0005	2.8657
2	.0198	.1225	.5213	.8362	.7954	.3844	.1298	.0392	.0097	.0022	.0004	.0001	2.8610
3	.0855	.3671	.8081	.8394	.4084	.1487	.0469	.0119	.0027	.0006	.0001	.0000	2.7194
4	.5463	.6139	.5539	.3743	.2321	.1041	.0315	.0079	.0017	.0004	.0001	.0000	2.4662
5	1.0839	.8686	.1731	.0537	.0251	.0080	.0021	.0005	.0001	.0000	.0000	.0000	2.2151
6	1.1756	.5773	.1119	.0265	.0082	.0030	.0007	.0002	.0000	.0000	.0000	.0000	1.9034
7	.8928	.2379	.0694	.0063	.0010	.0002	.0001	.0000	.0000	.0000	.0000	.0000	1.2077
8	.7934	.1040	.0158	.0042	.0010	.0002	.0000	.0000	.0000	.0000	.0000	.0000	.9186
9	.5798	.0912	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.6710
10	.2713	.1099	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.3812
11	.0989	.1235	.0245	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.2469
12	.0000	.0367	.0169	.0041	.0009	.0002	.0000	.0000	.0000	.0000	.0000	.0000	.0588

ABBN-78 Group №	Energy interval	Outgoing spectrum	Capture spectrum
-1	14.5-14.0 MeV	875382	252
0	14.0-10.5 MeV	2439	1
1	10.5 – 6.5 MeV	5826	0
2	6.5 – 4.0 MeV	9049	3
3	4.0 – 2.5 MeV	18340	21
4	2.5 – 1.4 MeV	44337	149
5	1.4 – 0.8 MeV	58092	306
6	0.8 – 0.4 MeV	55514	379
7	0.4 – 0.2 MeV	27882	281
8	0.2 – 0.1 MeV	9055	160
9	100 – 46.5 KeV	2694	120
10	46.5 – 21.5 KeV	682	34
11	21.5 – 10 KeV	51	2
12	10 – 4.65 KeV	12	0
13	4.65 – 2.15 KeV	1	1
14	2.15 – 1 KeV	1	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 Ta^{181} R= 1 cm

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

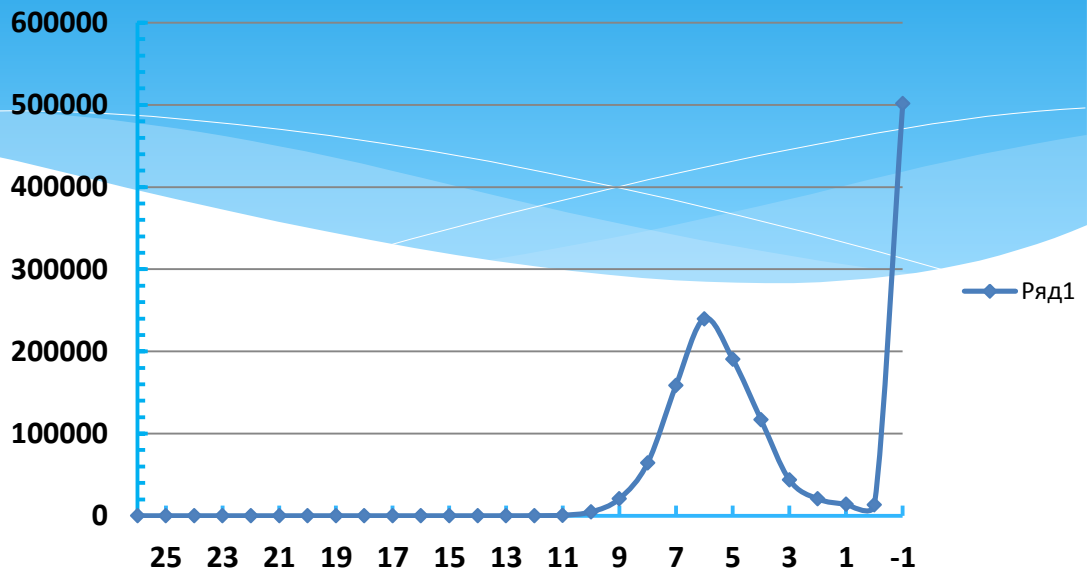


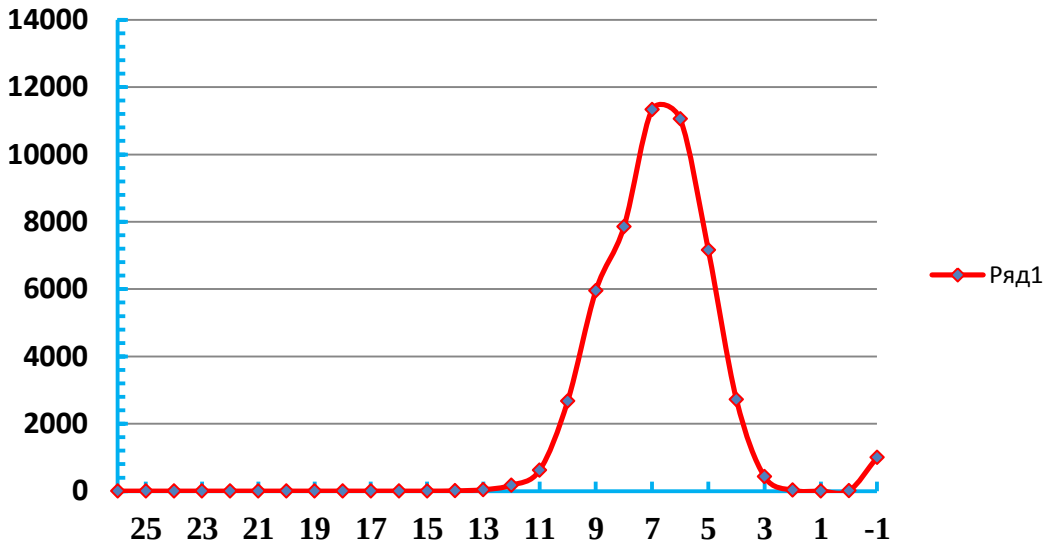


ABBN-78 Group №	Energy interval	Outgoing spectrum	Capture spectrum
-1	14.5-14.0 MeV	501593	1002
0	14.0-10.5 MeV	13305	12
1	10.5 – 6.5 MeV	14328	0
2	6.5 – 4.0 MeV	20623	26
3	4.0 – 2.5 MeV	43725	427
4	2.5 – 1.4 MeV	116866	2719
5	1.4 – 0.8 MeV	190620	7162
6	0.8 – 0.4 MeV	239824	11055
7	0.4 – 0.2 MeV	158777	11328
8	0.2 – 0.1 MeV	64309	7850
9	100 – 46.5 KeV	20716	5953
10	46.5 – 21.5 KeV	4704	2673
11	21.5 – 10 KeV	736	617
12	10 – 4.65 KeV	136	175
13	4.65 – 2.15 KeV	27	42
14	2.15 – 1 KeV	1	8
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 Ta^{181} R= 5 cm

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

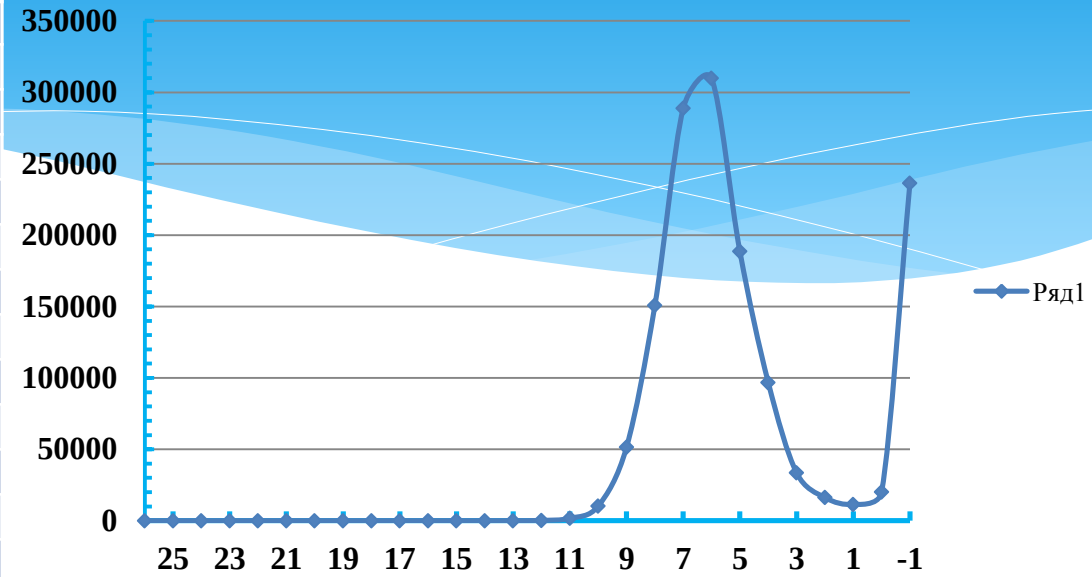


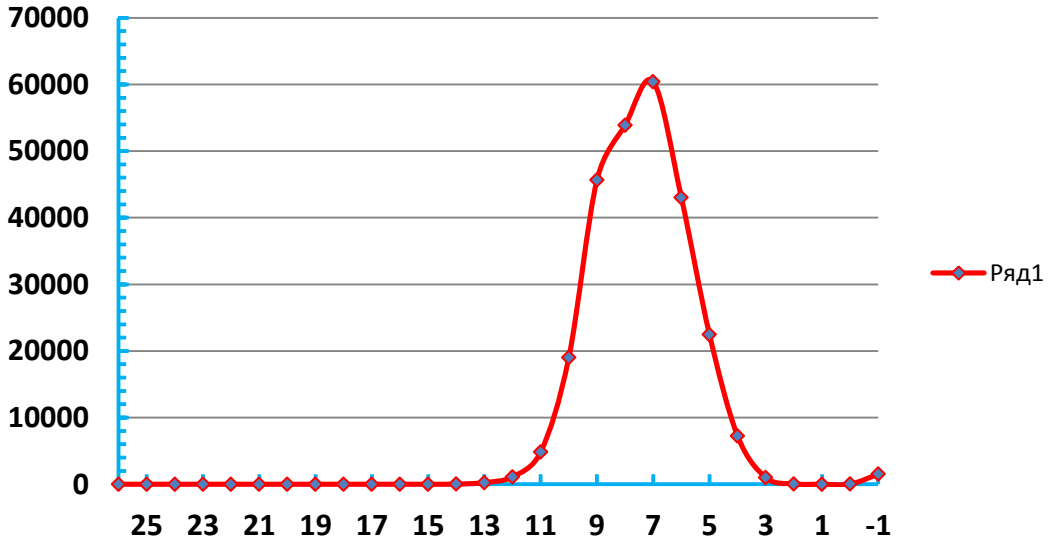


ABBN-78 Group №	Energy interval	Outgoing spectrum	Capture spectrum
-1	14.5-14.0 MeV	236268	1512
0	14.0-10.5 MeV	20092	24
1	10.5 – 6.5 MeV	11498	0
2	6.5 – 4.0 MeV	16229	58
3	4.0 – 2.5 MeV	33604	1014
4	2.5 – 1.4 MeV	96860	7233
5	1.4 – 0.8 MeV	188556	22463
6	0.8 – 0.4 MeV	309833	43039
7	0.4 – 0.2 MeV	288747	60412
8	0.2 – 0.1 MeV	150668	53869
9	100 – 46.5 KeV	51440	45650
10	46.5 – 21.5 KeV	10274	18987
11	21.5 – 10 KeV	1692	4826
12	10 – 4.65 KeV	236	1111
13	4.65 – 2.15 KeV	43	246
14	2.15 – 1 KeV	2	20
15	1 – 0.465 KeV	0	3
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 Ta^{181} R= 10 cm

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

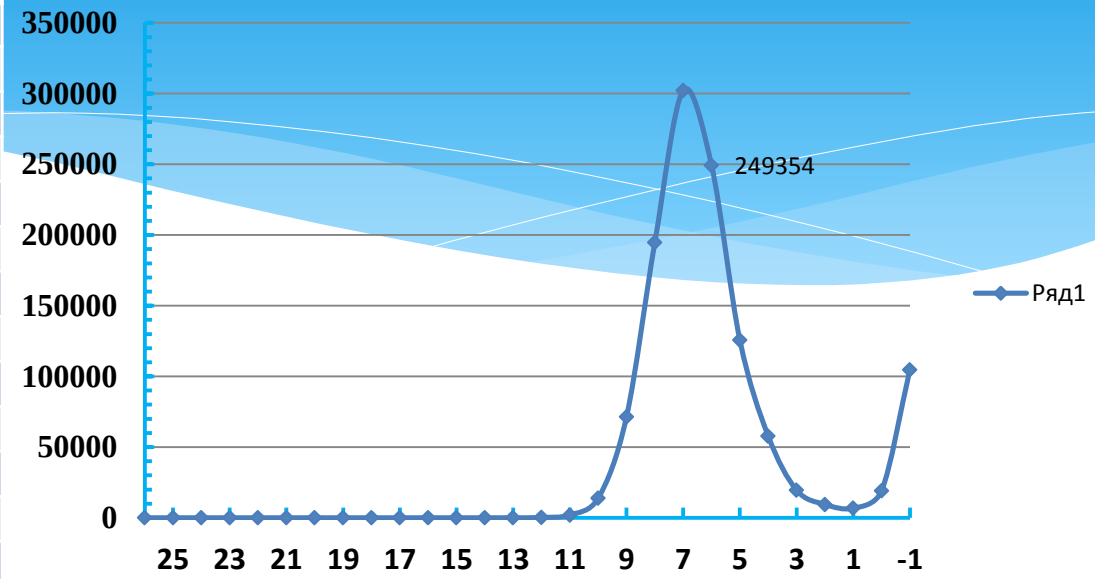


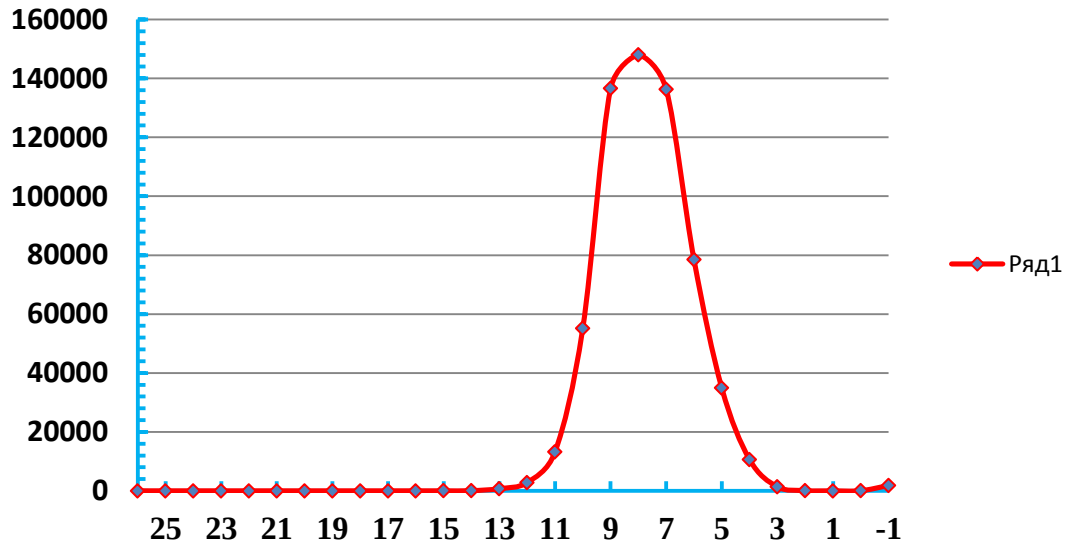


ABBN-78 Group №	Energy interval	Outgoing spectrum	Capture spectrum
-1	14.5-14.0 MeV	104660	1815
0	14.0-10.5 MeV	19133	45
1	10.5 – 6.5 MeV	6813	0
2	6.5 – 4.0 MeV	9491	90
3	4.0 – 2.5 MeV	19621	1373
4	2.5 – 1.4 MeV	57792	10591
5	1.4 – 0.8 MeV	125625	34876
6	0.8 – 0.4 MeV	249354	78468
7	0.4 – 0.2 MeV	302240	136324
8	0.2 – 0.1 MeV	194837	147959
9	100 – 46.5 KeV	71464	136555
10	46.5 – 21.5 KeV	13872	55129
11	21.5 – 10 KeV	2005	13151
12	10 – 4.65 KeV	234	2812
13	4.65 – 2.15 KeV	36	732
14	2.15 – 1 KeV	0	52
15	1 – 0.465 KeV	1	7
16	465 – 215 eV	1	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 Ta^{181} R= 15 cm

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

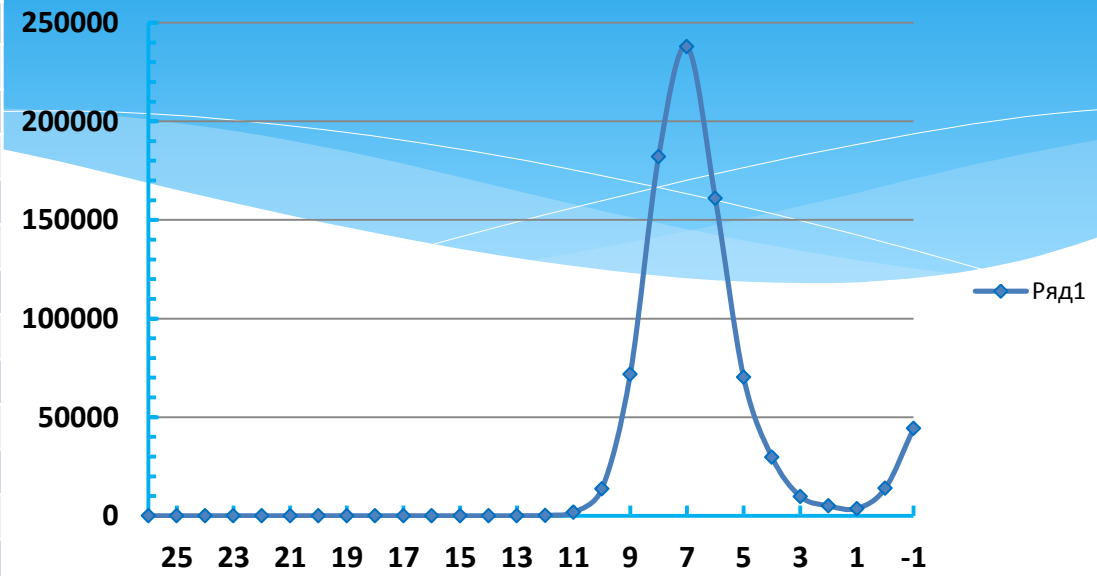


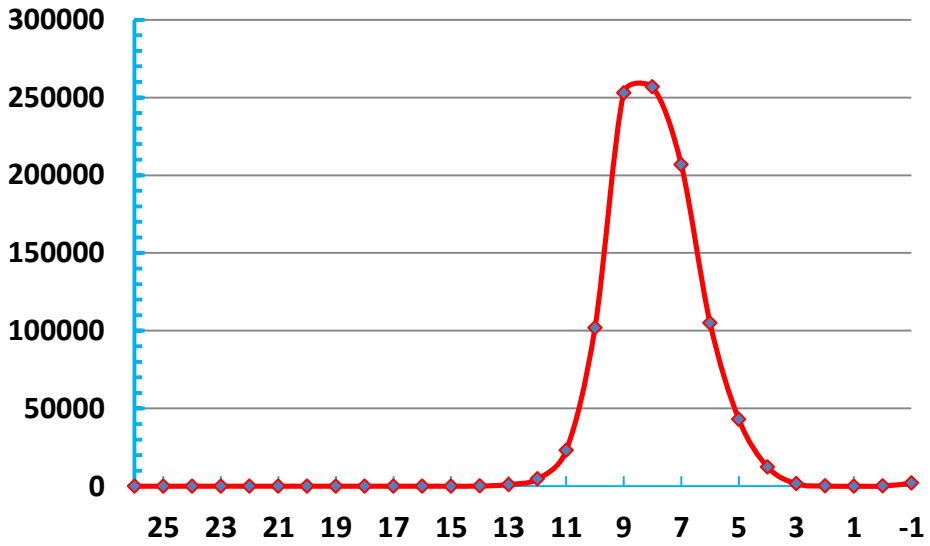


ABBN-78 Group №	Energy interval	Outgoing spectrum	Capture spectrum
-1	14.5-14.0 MeV	44385	1929
0	14.0-10.5 MeV	14012	73
1	10.5 – 6.5 MeV	3697	0
2	6.5 – 4.0 MeV	5039	97
3	4.0 – 2.5 MeV	9827	1533
4	2.5 – 1.4 MeV	29753	12387
5	1.4 – 0.8 MeV	70246	43044
6	0.8 – 0.4 MeV	161071	104996
7	0.4 – 0.2 MeV	237916	206737
8	0.2 – 0.1 MeV	182062	256729
9	100 – 46.5 KeV	71741	252891
10	46.5 – 21.5 KeV	13658	101853
11	21.5 – 10 KeV	1836	22921
12	10 – 4.65 KeV	253	4609
13	4.65 – 2.15 KeV	21	1055
14	2.15 – 1 KeV	0	75
15	1 – 0.465 KeV	0	12
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 Ta^{181} R= 20 cm

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

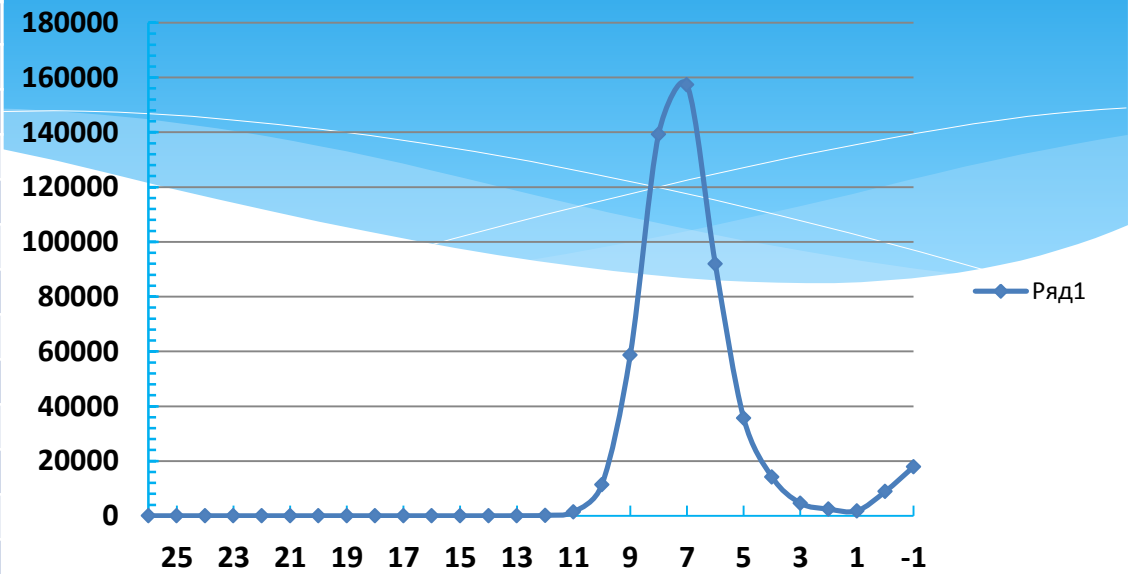


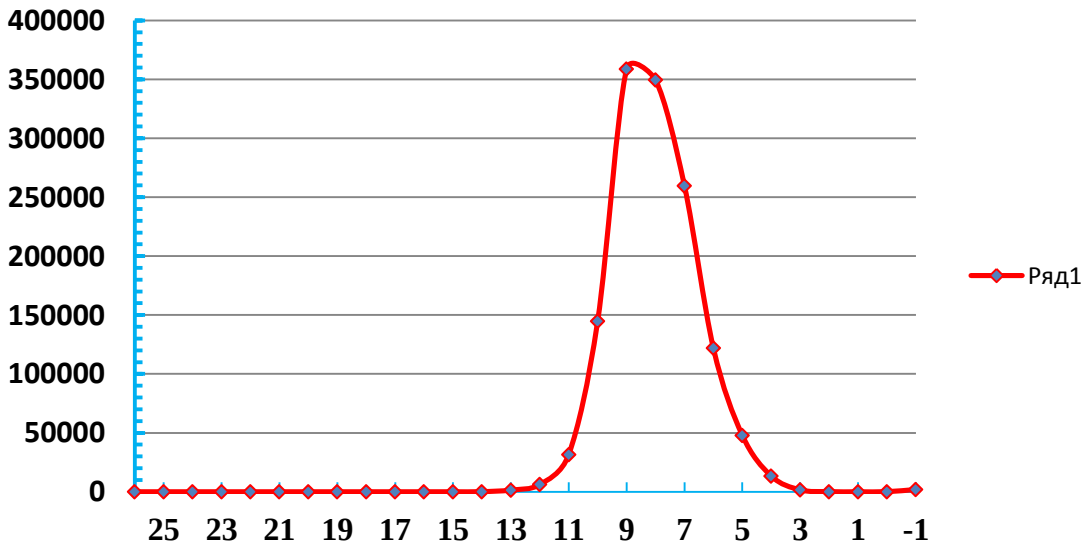


ABBN-78 Group №	Energy interval	Outgoing spectrum	Capture spectrum
-1	14.5-14.0 MeV	17935	1926
0	14.0-10.5 MeV	8891	100
1	10.5 – 6.5 MeV	1832	0
2	6.5 – 4.0 MeV	2460	106
3	4.0 – 2.5 MeV	4638	1614
4	2.5 – 1.4 MeV	14188	13341
5	1.4 – 0.8 MeV	35730	47903
6	0.8 – 0.4 MeV	92012	121866
7	0.4 – 0.2 MeV	157374	259709
8	0.2 – 0.1 MeV	139331	349476
9	100 – 46.5 KeV	58675	358831
10	46.5 – 21.5 KeV	11367	144915
11	21.5 – 10 KeV	1437	31604
12	10 – 4.65 KeV	185	6180
13	4.65 – 2.15 KeV	21	1459
14	2.15 – 1 KeV	1	102
15	1 – 0.465 KeV	0	13
16	465 – 215 eV	0	2
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 Ta^{181} R= 25 cm

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

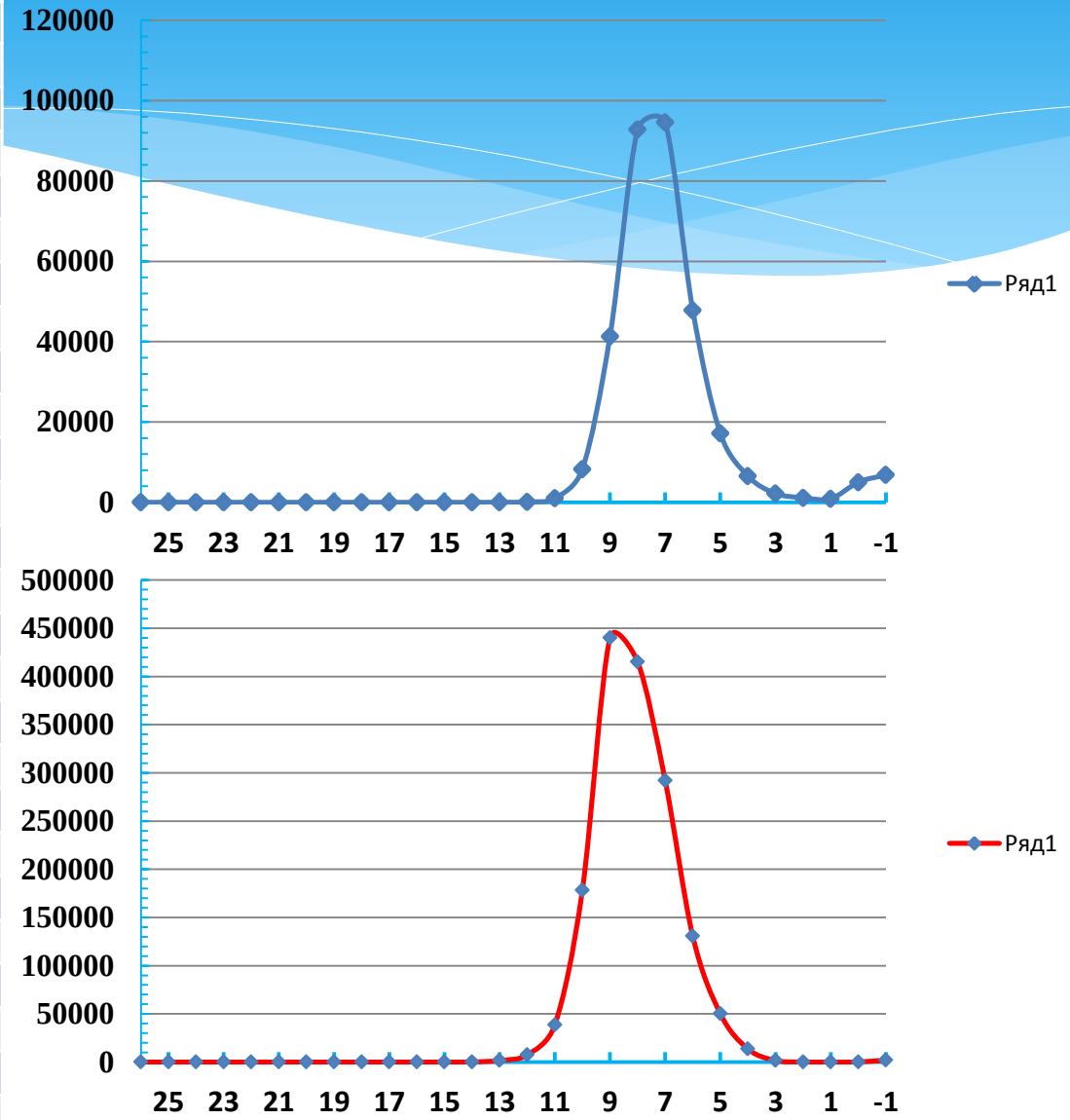




ABBN-78 Group №	Energy interval	Outgoing spectrum	Capture spectrum
-1	14.5-14.0 MeV	6832	2064
0	14.0-10.5 MeV	5026	114
1	10.5 – 6.5 MeV	910	0
2	6.5 – 4.0 MeV	1154	98
3	4.0 – 2.5 MeV	2216	1650
4	2.5 – 1.4 MeV	6552	13629
5	1.4 – 0.8 MeV	17147	50169
6	0.8 – 0.4 MeV	47837	130685
7	0.4 – 0.2 MeV	94598	292229
8	0.2 – 0.1 MeV	92798	415298
9	100 – 46.5 KeV	41343	440077
10	46.5 – 21.5 KeV	8285	178383
11	21.5 – 10 KeV	1033	38475
12	10 – 4.65 KeV	108	7468
13	4.65 – 2.15 KeV	20	1664
14	2.15 – 1 KeV	0	129
15	1 – 0.465 KeV	0	16
16	465 – 215 eV	0	2
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 Ta^{181} R= 30 cm

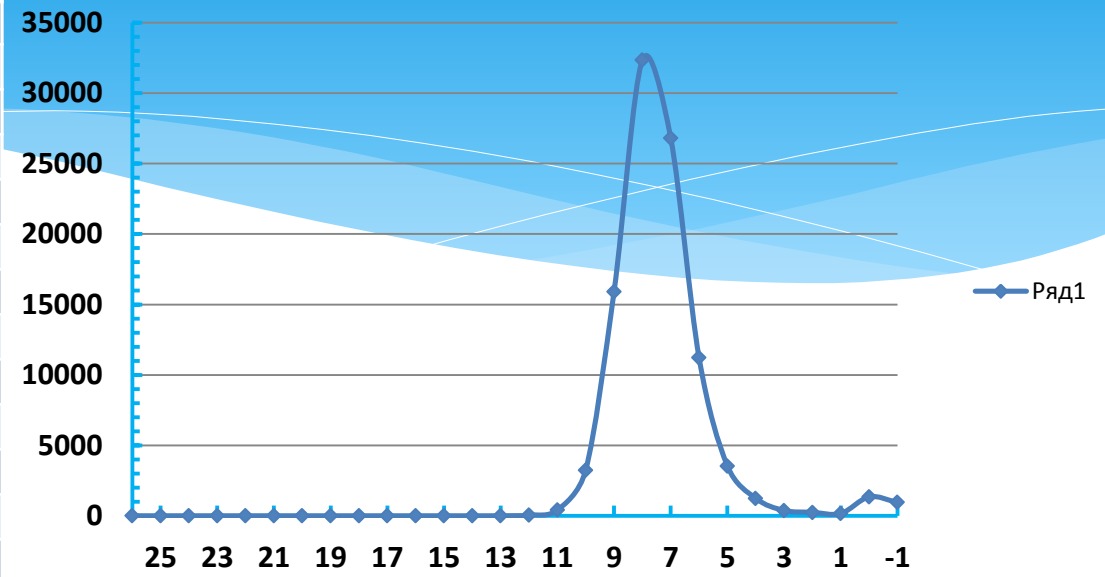
Outgoing spectrum (upper picture, blue curve) and capture spectrum (picture below, red line).

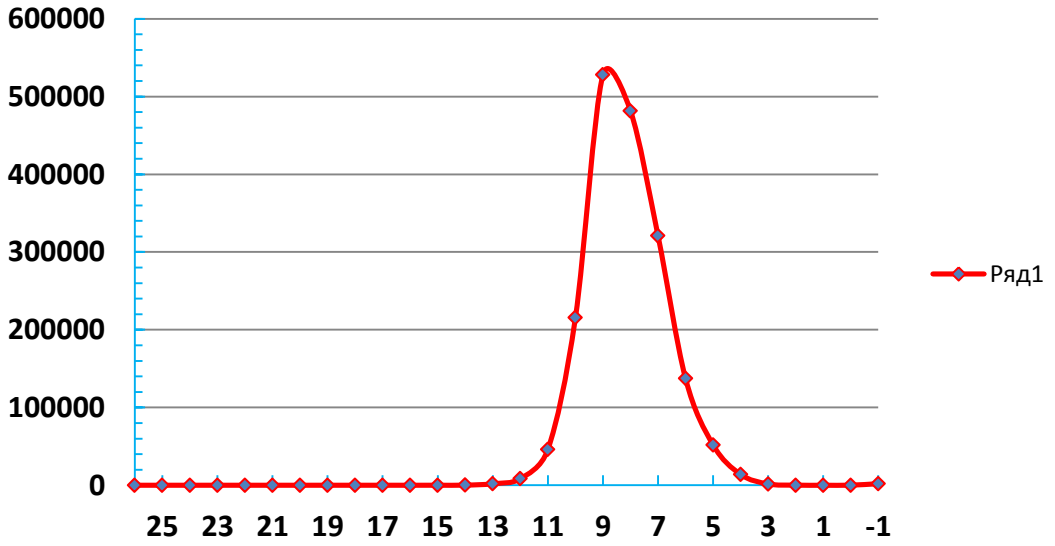


ABBN-78 Group №	Energy interval	Outgoing spectrum	Capture spectrum
-1	14.5-14.0 MeV	959	2019
0	14.0-10.5 MeV	1344	100
1	10.5 – 6.5 MeV	166	0
2	6.5 – 4.0 MeV	248	110
3	4.0 – 2.5 MeV	380	1663
4	2.5 – 1.4 MeV	1240	13908
5	1.4 – 0.8 MeV	3542	51891
6	0.8 – 0.4 MeV	11221	137234
7	0.4 – 0.2 MeV	26812	320797
8	0.2 – 0.1 MeV	32362	481645
9	100 – 46.5 KeV	15912	527966
10	46.5 – 21.5 KeV	3242	215431
11	21.5 – 10 KeV	409	45958
12	10 – 4.65 KeV	51	8458
13	4.65 – 2.15 KeV	5	1929
14	2.15 – 1 KeV	0	138
15	1 – 0.465 KeV	0	21
16	465 – 215 eV	0	2
17	215 – 100 eV	0	1
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 Ta^{181} R= 40 cm

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

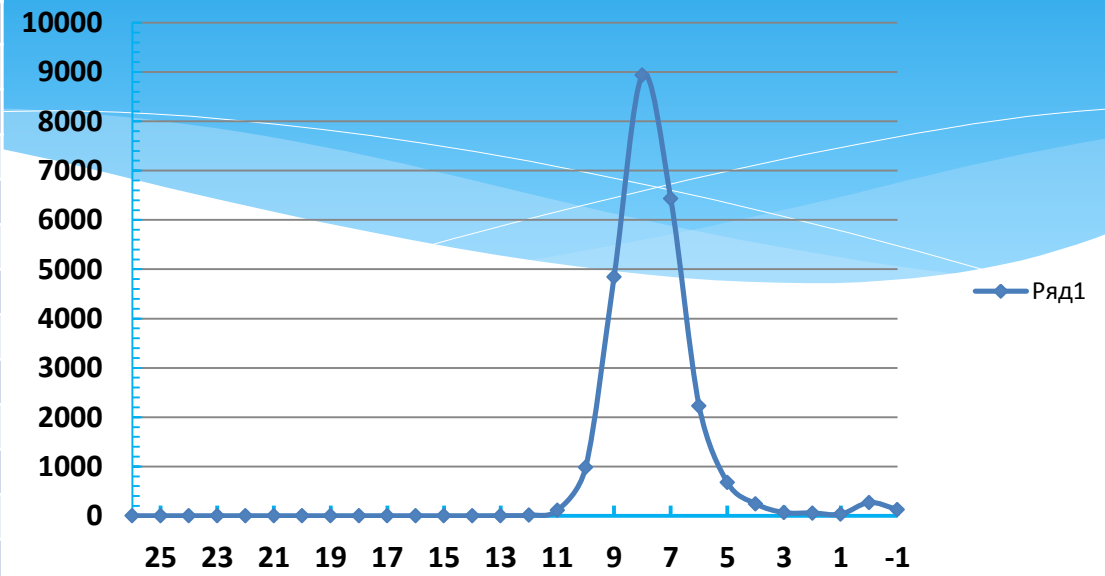


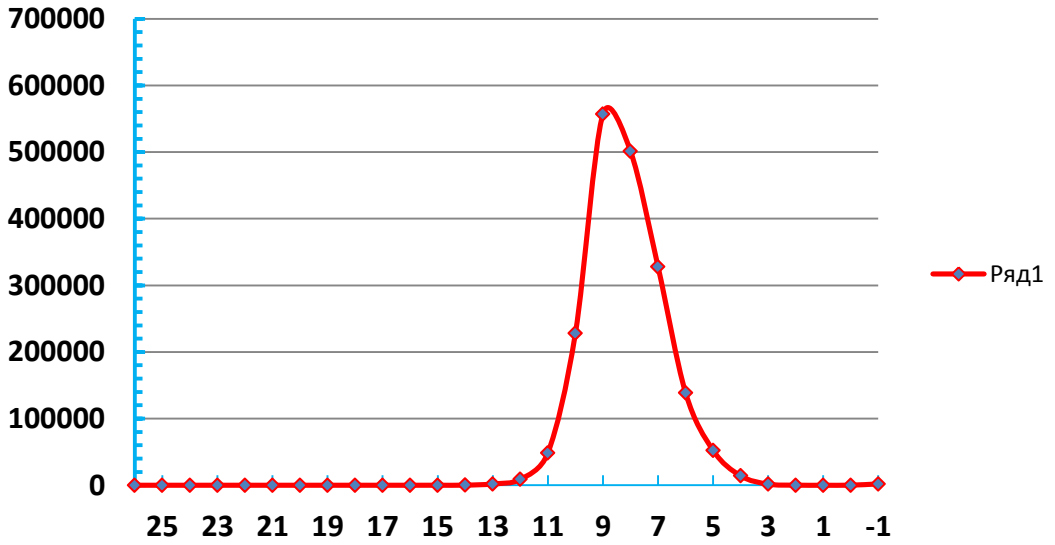


ABBN-78 Group №	Energy interval	Outgoing spectrum	Capture spectrum
-1	14.5-14.0 MeV	129	2004
0	14.0-10.5 MeV	270	126
1	10.5 – 6.5 MeV	33	0
2	6.5 – 4.0 MeV	58	111
3	4.0 – 2.5 MeV	66	1697
4	2.5 – 1.4 MeV	244	14105
5	1.4 – 0.8 MeV	675	52394
6	0.8 – 0.4 MeV	2232	138910
7	0.4 – 0.2 MeV	6433	327987
8	0.2 – 0.1 MeV	8936	501362
9	100 – 46.5 KeV	4844	557217
10	46.5 – 21.5 KeV	985	228181
11	21.5 – 10 KeV	110	48506
12	10 – 4.65 KeV	13	8858
13	4.65 – 2.15 KeV	3	1992
14	2.15 – 1 KeV	0	147
15	1 – 0.465 KeV	0	19
16	465 – 215 eV	0	3
17	215 – 100 eV	0	1
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 Ta^{181} R= 50 cm

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

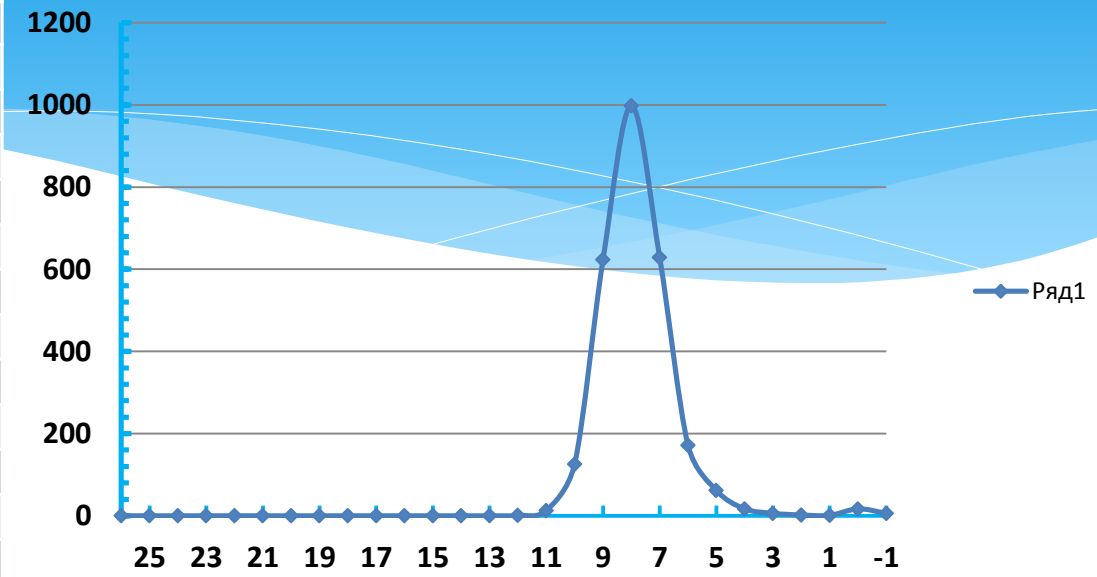


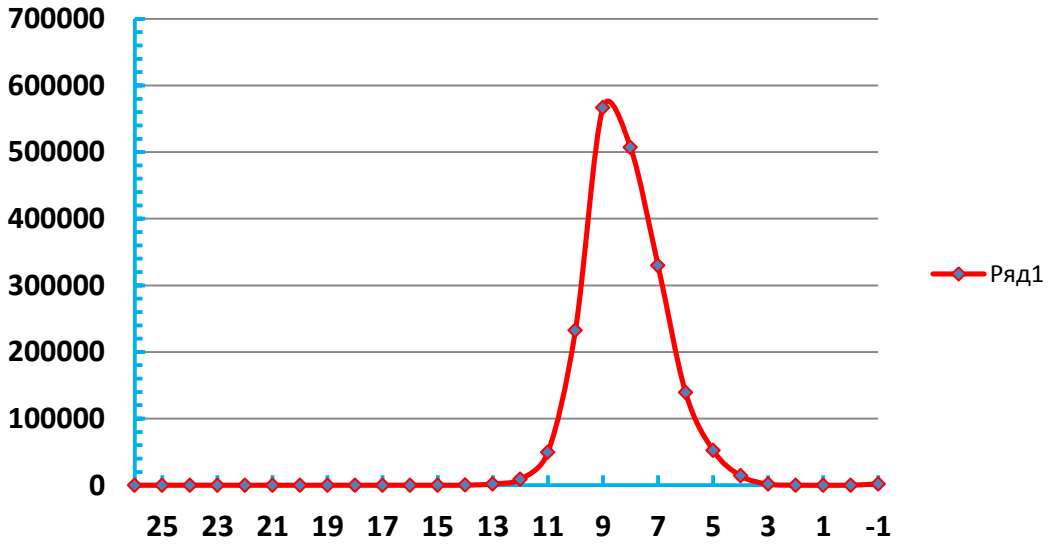


ABBN-78 Group №	Energy interval	Outgoing spectrum	Capture spectrum
-1	14.5-14.0 MeV	6	2000
0	14.0-10.5 MeV	17	121
1	10.5 – 6.5 MeV	1	0
2	6.5 – 4.0 MeV	2	107
3	4.0 – 2.5 MeV	6	1715
4	2.5 – 1.4 MeV	17	14117
5	1.4 – 0.8 MeV	62	52432
6	0.8 – 0.4 MeV	172	139380
7	0.4 – 0.2 MeV	629	329994
8	0.2 – 0.1 MeV	998	507204
9	100 – 46.5 KeV	623	566537
10	46.5 – 21.5 KeV	126	232389
11	21.5 – 10 KeV	13	49229
12	10 – 4.65 KeV	1	9016
13	4.65 – 2.15 KeV	0	2019
14	2.15 – 1 KeV	0	147
15	1 – 0.465 KeV	0	19
16	465 – 215 eV	0	3
17	215 – 100 eV	0	1
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 Ta^{181} R= 65 cm

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

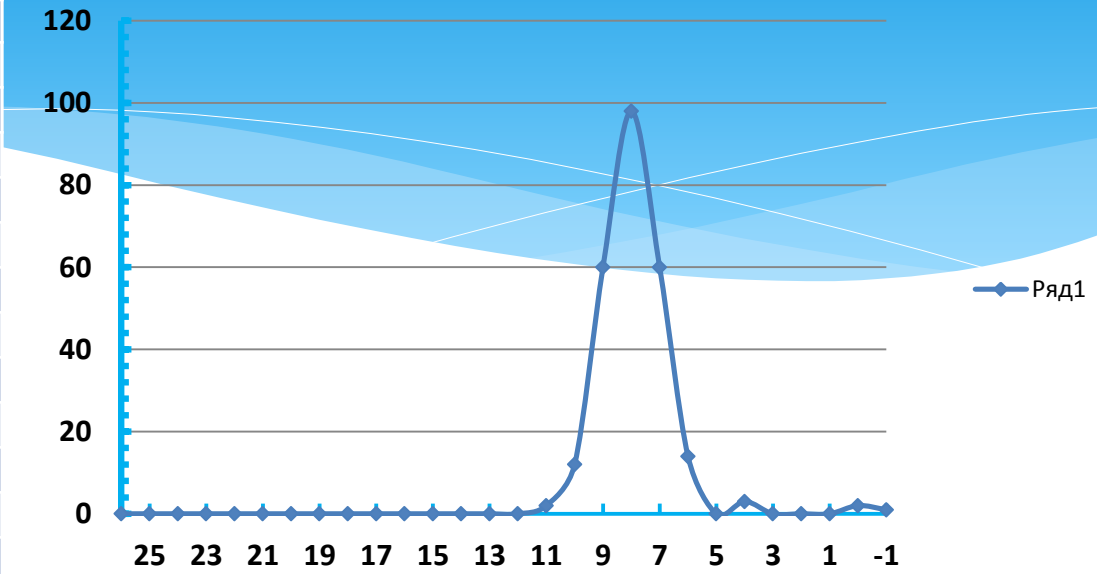


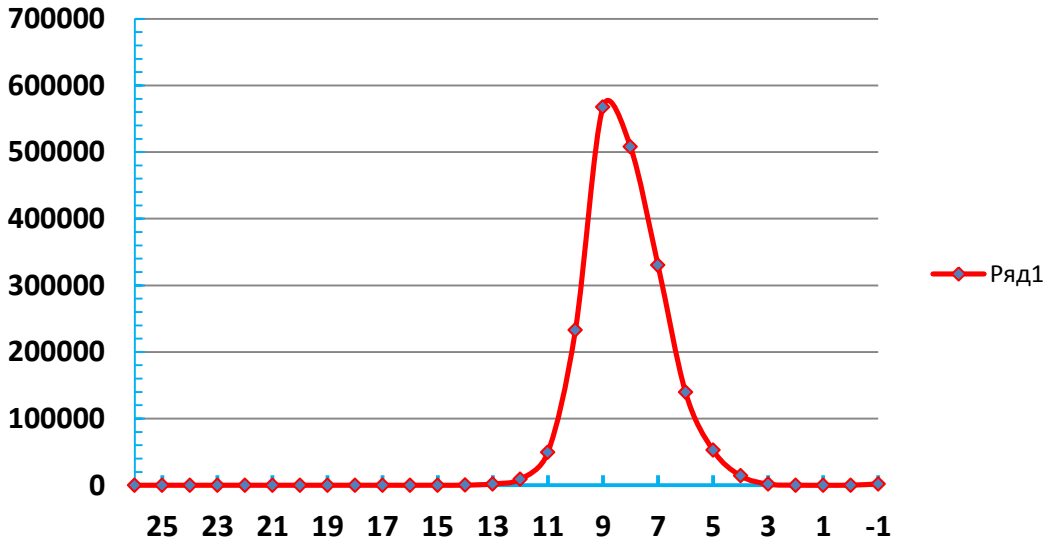


ABBN-78 Group №	Energy interval	Outgoing spectrum	Capture spectrum
-1	14.5-14.0 MeV	1	1996
0	14.0-10.5 MeV	2	122
1	10.5 – 6.5 MeV	0	0
2	6.5 – 4.0 MeV	0	107
3	4.0 – 2.5 MeV	0	1708
4	2.5 – 1.4 MeV	3	14106
5	1.4 – 0.8 MeV	0	52499
6	0.8 – 0.4 MeV	14	139491
7	0.4 – 0.2 MeV	60	330182
8	0.2 – 0.1 MeV	98	507775
9	100 – 46.5 KeV	60	567549
10	46.5 – 21.5 KeV	12	232864
11	21.5 – 10 KeV	2	49281
12	10 – 4.65 KeV	0	9041
13	4.65 – 2.15 KeV	0	2023
14	2.15 – 1 KeV	0	148
15	1 – 0.465 KeV	0	20
16	465 – 215 eV	0	3
17	215 – 100 eV	0	1
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 Ta^{181} R= 80 cm

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



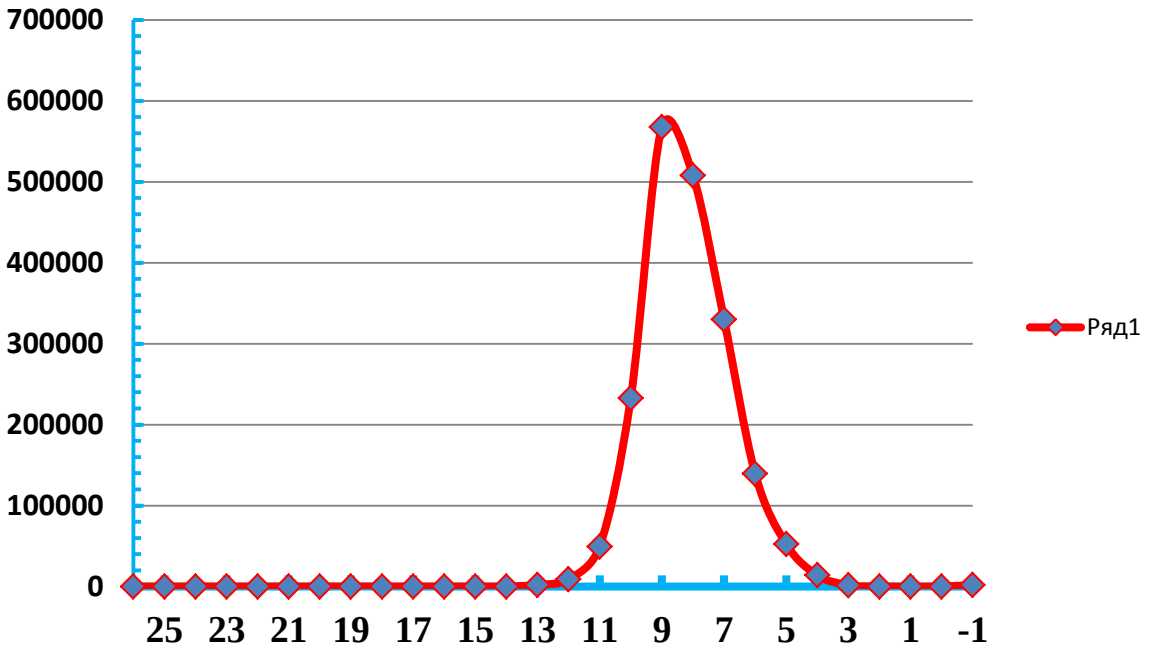


ABBN-78 Group №	Energy interval	Outgoing spectrum	Capture spectrum
-1	14.5-14.0 MeV	0	1994
0	14.0-10.5 MeV	0	122
1	10.5 – 6.5 MeV	0	0
2	6.5 – 4.0 MeV	0	107
3	4.0 – 2.5 MeV	0	1708
4	2.5 – 1.4 MeV	0	14099
5	1.4 – 0.8 MeV	0	52500
6	0.8 – 0.4 MeV	0	139495
7	0.4 – 0.2 MeV	1	330214
8	0.2 – 0.1 MeV	3	507853
9	100 – 46.5 KeV	3	567658
10	46.5 – 21.5 KeV	1	232902
11	21.5 – 10 KeV	0	49298
12	10 – 4.65 KeV	0	9047
13	4.65 – 2.15 KeV	0	2027
14	2.15 – 1 KeV	0	148
15	1 – 0.465 KeV	0	20
16	465 – 215 eV	0	3
17	215 – 100 eV	0	1
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 Ta^{181} R= 100 cm Capture spectrum (red curve)

Majority of initial 14.1 MeV neutrons in infinite Ta^{181} media are captured at energies **800 KeV<En<21.5 KeV**.

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



Spectrums in metal Tantalum Ta^{181} spheres

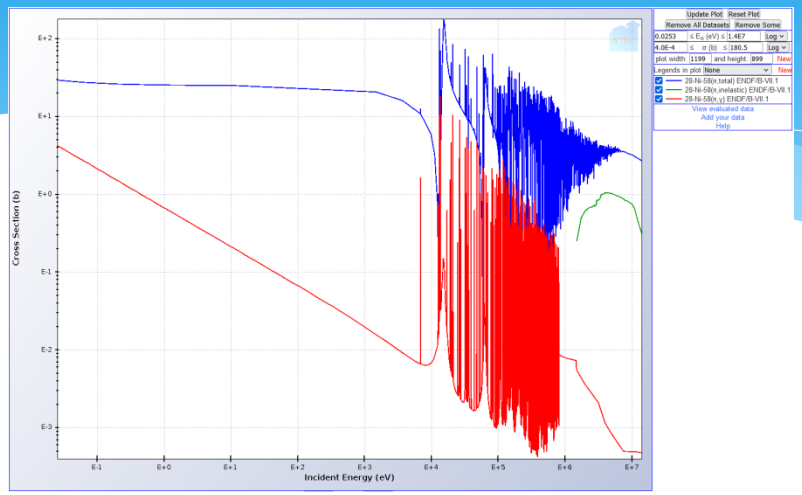
ABBN-78 Group №	Energy Interval	R = 1 cm		R = 5 cm		R = 10 cm		R = 15 cm		R = 20 cm		R = 25 cm	
		Outgoing Spectrum	Capture Spectrum	Outgoing Spectrum	Capture Spectrum	Outgoing Spectrum	Capture Spectrum	Outgoing Spectrum	Capture Spectrum	Outgoing Spectrum	Capture Spectrum	Outgoing Spectrum	Capture Spectrum
-1	14.5-14.0 MeV	875382	252	501593	1002	236268	1512	104660	1815	44385	1929	17935	1926
0	14.0-10.5 MeV	2439	1	13305	12	20092	24	19133	45	14012	73	8891	100
1	10.5-6.5 MeV	5826	0	14328	0	11498	0	6813	0	3697	0	1832	0
2	6.5-4.0 MeV	9049	3	20623	26	16229	58	9491	90	5039	97	2460	106
3	4.0-2.5 MeV	18340	21	43725	427	33604	1014	19621	1373	9827	1533	4638	1614
4	2.5-1.4 MeV	44337	149	116866	2719	96860	7233	57792	10591	29753	12387	14188	13341
5	1.4-0.8 MeV	58092	306	190620	7162	188556	22463	125625	34876	70246	43044	35730	47903
6	0.8-0.4 MeV	55514	379	239824	11055	309833	43039	249354	78468	161071	104996	92012	121866
7	0.4-0.2 MeV	27882	281	158777	11328	288747	60412	302240	136324	237916	206737	157374	259709
8	0.2-0.1 MeV	9055	160	64309	7850	150668	53869	194837	147959	182062	256729	139331	349476
9	100-46.5 KeV	2694	120	20716	5953	51440	45650	71464	136555	71741	252891	58675	358831
10	46.5 –21.5 KeV	682	34	4704	2673	10274	18987	13872	55129	13658	101853	11367	144915
11	21.5– 10 KeV	51	2	736	617	1692	4826	2005	13151	1836	22921	1437	31604
12	10– 4.65 KeV	12	0	136	175	236	1111	234	2812	253	4609	185	6180
13	4.65– 2.15 KeV	1	1	27	42	43	246	36	732	21	1055	21	1459
14	2.15 – 1 KeV	1	0	1	8	2	20	0	52	0	75	1	102
15	1– 0.465 KeV	0	0	0	0	0	3	1	7	0	12	0	13
16	465– 215 eV	0	0	0	0	0	0	1	0	0	1	0	2
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		11.40 MeV	2.70 MeV	5.90 MeV	785 KeV	3.20 MeV	444 KeV	2.03 MeV	327 KeV	1.44 MeV	273 KeV	1.095 MeV	246 KeV
Diffusion/Absorption time of spectra, nanoseconds		0.337	0.776	4.68	9.05	16.73	28.21	32.99	49.03	49.94	66.03	66.57	78.26
Number of neutrons		1109357	1709	1390290	51049	1416042	260467	1177179	619979	845517	1010942	546077	1339147

Spectrums in metal Tantalum Ta^{181} spheres

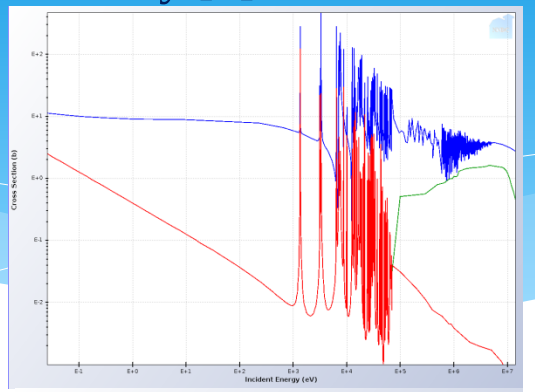
ABBN-78 Group №	Energy Interval	R = 30 cm		R = 40 cm		R = 50 cm		R = 65 cm		R = 80 cm		R = 100 cm	
		Outgoing Spectrum	Capture Spectrum	Outgoing Spectrum	Capture Spectrum	Outgoing Spectrum	Capture Spectrum	Outgoing Spectrum	Capture Spectrum	Outgoing Spectrum	Capture Spectrum	Outgoing Spectrum	Capture Spectrum
-1	14.5-14.0 MeV	6832	2064	959	2019	129	2004	6	2000	1	1996	0	1994
0	14.0-10.5 MeV	5026	114	1344	100	270	126	17	121	2	122	0	122
1	10.5-6.5 MeV	910	0	166	0	33	0	1	0	0	0	0	0
2	6.5-4.0 MeV	1154	98	248	110	58	111	2	107	0	107	0	107
3	4.0-2.5 MeV	2216	1650	380	1663	66	1697	6	1715	0	1708	0	1708
4	2.5-1.4 MeV	6552	13629	1240	13908	244	14105	17	14117	3	14106	0	14099
5	1.4-0.8 MeV	17147	50169	3542	51891	675	52394	62	52432	0	52499	0	52500
6	0.8-0.4 MeV	47837	130685	11221	137234	2232	138910	172	139380	14	139491	0	139495
7	0.4-0.2 MeV	94598	292229	26812	320797	6433	327987	629	329994	60	330182	1	330214
8	0.2-0.1 MeV	92798	415298	32362	481645	8936	501362	998	507204	98	507775	3	507853
9	100-46.5 KeV	41343	440077	15912	527966	4844	557217	623	566537	60	567549	3	567658
10	46.5 –21.5 KeV	8285	178383	3242	215431	985	228181	126	232389	12	232864	1	232902
11	21.5– 10 KeV	1033	38475	409	45958	110	48506	13	49229	2	49281	0	49298
12	10– 4.65 KeV	108	7468	51	8458	13	8858	1	9016	0	9041	0	9047
13	4.65– 2.15 KeV	20	1664	5	1929	3	1992	0	2019	0	2023	0	2027
14	2.15 – 1 KeV	0	129	0	138	0	147	0	147	0	148	0	148
15	1– 0.465 KeV	0	16	0	21	0	19	0	19	0	20	0	20
16	465– 215 eV	0	2	0	2	0	3	0	3	0	3	0	3
17	215– 100 eV	0	0	0	1	0	1	0	1	0	1	0	1
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		870 KeV	232 KeV	621 KeV	218 KeV	479 KeV	215 KeV	332 KeV	213 KeV	343 KeV	213 KeV	109 KeV	213 KeV
Diffusion/Absorption time of spectra, nanoseconds		82.18	86.93	111.59	96.57	137.07	100.26	173.84	101.67	197.15	101.91	215.88	101.88
Number of neutrons		325859	1572150	97893	1809271	25031	1883620	2673	1906430	252	1908916	8	1909196

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

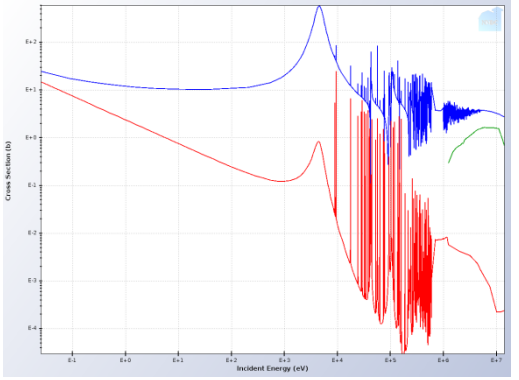
Ni^{58}
(67.76% in Ni^{nat})



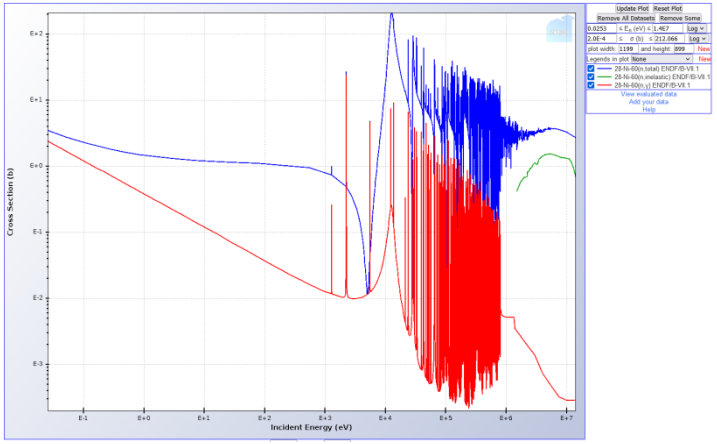
Ni^{61}
(1.25% in Ni^{nat})



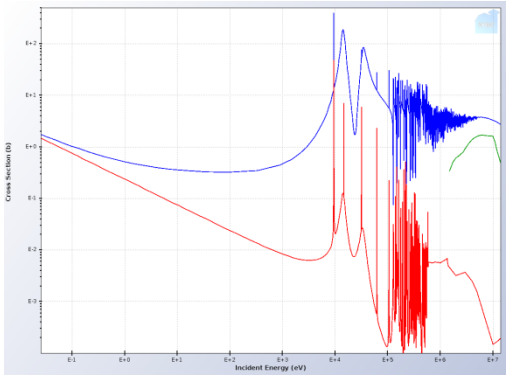
Ni^{62}
(3.66% in Ni^{nat})



Ni^{60}
(26.16% in Ni^{nat})



Ni^{64}
(1.16% in Ni^{nat})



ABBN-78 constants for $28Ni^{nat}$

BNAB 28-GROUP NEUTRON CONSTANTS FOR NI(28, 58.71000)

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	2.7100	.0000	.0000	.4500	1.1600	1.1000	.9140
0	.105E+02- .140E+02	3.0300	.0000	.0000	.5500	1.0900	1.3900	.8890
1	.650E+01- .105E+02	3.5300	.0000	.0000	.5000	1.2700	1.7600	.7890
2	.400E+01- .650E+01	3.5600	.0000	.0000	.3400	1.3000	1.9200	.6010
3	.250E+01- .400E+01	3.3700	.0000	.0000	.1500	1.0000	2.2200	.4490
4	.140E+01- .250E+01	3.1700	.0000	.0000	.0400	.5000	2.6300	.3100
5	.800E+00- .140E+01	3.2300	.0000	.0000	.0090	.0000	3.2210	.1420
6	.400E+00- .800E+00	3.5700	.0000	.0000	.0080	.0000	3.5620	.1320
7	.200E+00- .400E+00	5.1300	.0000	.0000	.0110	.0000	5.1190	.0830
8	.100E+00- .200E+00	5.5600	.0000	.0000	.0190	.0000	5.5410	.0380
9	.465E-01- .100E+00	7.8800	.0000	.0000	.0300	.0000	7.8500	.0170
10	.215E-01- .465E-01	11.0200	.0000	.0000	.0480	.0000	10.9720	.0130
11	.100E-01- .215E-01	42.3200	.0000	.0000	.1050	.0000	42.2150	.0120
12	.465E-02- .100E-01	14.0000	.0000	.0000	.0180	.0000	13.9820	.0110
13	.215E-02- .465E-02	19.9000	.0000	.0000	.0420	.0000	19.8580	.0110
14	.100E-02- .215E-02	16.4200	.0000	.0000	.0370	.0000	16.3830	.0110
15	.465E-03- .100E-02	17.2270	.0000	.0000	.0270	.0000	17.2000	.0110
16	.215E-03- .465E-03	17.3400	.0000	.0000	.0400	.0000	17.3000	.0110
17	.100E-03- .215E-03	17.3580	.0000	.0000	.0580	.0000	17.3000	.0110
18	.465E-04- .100E-03	17.3850	.0000	.0000	.0850	.0000	17.3000	.0110
19	.215E-04- .465E-04	17.4250	.0000	.0000	.1250	.0000	17.3000	.0110
20	.100E-04- .215E-04	17.4840	.0000	.0000	.1840	.0000	17.3000	.0110
21	.465E-05- .100E-04	17.5700	.0000	.0000	.2700	.0000	17.3000	.0110
22	.215E-05- .465E-05	17.6960	.0000	.0000	.3960	.0000	17.3000	.0110
23	.100E-05- .215E-05	17.8910	.0000	.0000	.5910	.0000	17.3000	.0110
24	.465E-06- .100E-05	18.1530	.0000	.0000	.8530	.0000	17.3000	.0110
25	.215E-06- .465E-06	18.5500	.0000	.0000	1.2500	.0000	17.3000	.0110
26	THERMAL	21.7000	.0000	.0000	4.4000	.0000	17.3000	.0110

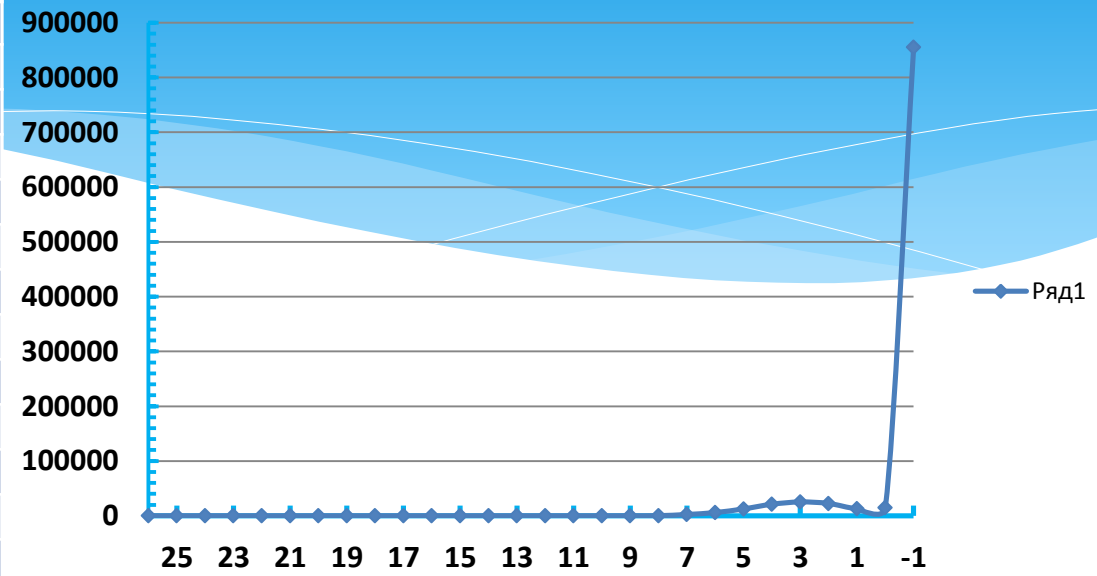
SIGMA IN (I,I+K) AT K EQUAL:

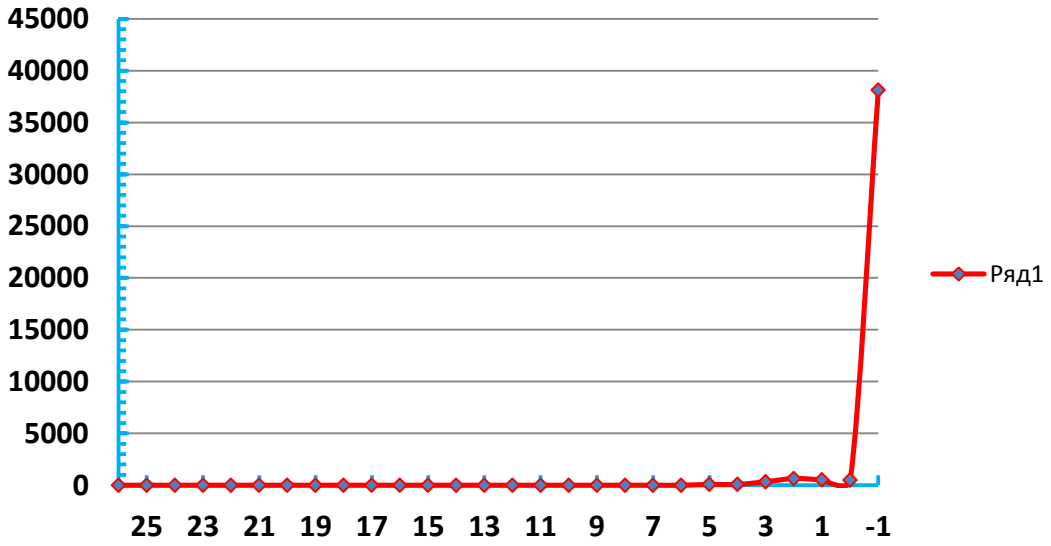
I	K= 0	K= 1	K= 2	K= 3	K= 4	K= 5	K= 6	K= 7	K= 8	K= 9	K=10	K=11	SUMMA
-1	.0000	.1100	.1800	.3000	.3100	.2300	.1200	.0500	.0200	.0000	.0000	.0000	1.3200
0	.0300	.1100	.1600	.2600	.2700	.1600	.0800	.0300	.0100	.0000	.0000	.0000	1.1100
1	.0100	.0500	.1800	.3700	.3200	.2200	.0800	.0300	.0100	.0000	.0000	.0000	1.2700
2	.0300	.2800	.3100	.3300	.2200	.0900	.0300	.0100	.0000	.0000	.0000	.0000	1.3000
3	.0300	.3600	.3100	.1700	.0900	.0300	.0100	.0000	.0000	.0000	.0000	.0000	1.0000
4	.0000	.1300	.2000	.1000	.0500	.0200	.0000	.0000	.0000	.0000	.0000	.0000	.5000
5	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
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	855171	38129
0	14.0-10.5 MeV	14702	502
1	10.5 – 6.5 MeV	12915	531
2	6.5 – 4.0 MeV	22591	647
3	4.0 – 2.5 MeV	25269	334
4	2.5 – 1.4 MeV	21138	81
5	1.4 – 0.8 MeV	12632	77
6	0.8 – 0.4 MeV	5956	0
7	0.4 – 0.2 MeV	2430	3
8	0.2 – 0.1 MeV	283	0
9	100 – 46.5 KeV	96	0
10	46.5 – 21.5 KeV	0	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 Nickel Ni^{nat} R= 1 cm

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

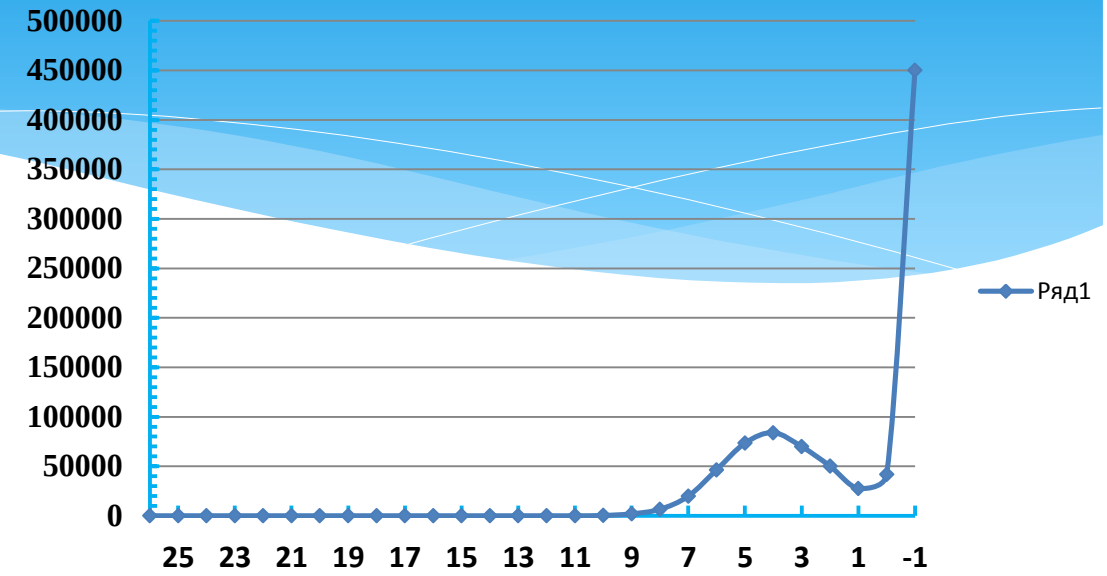


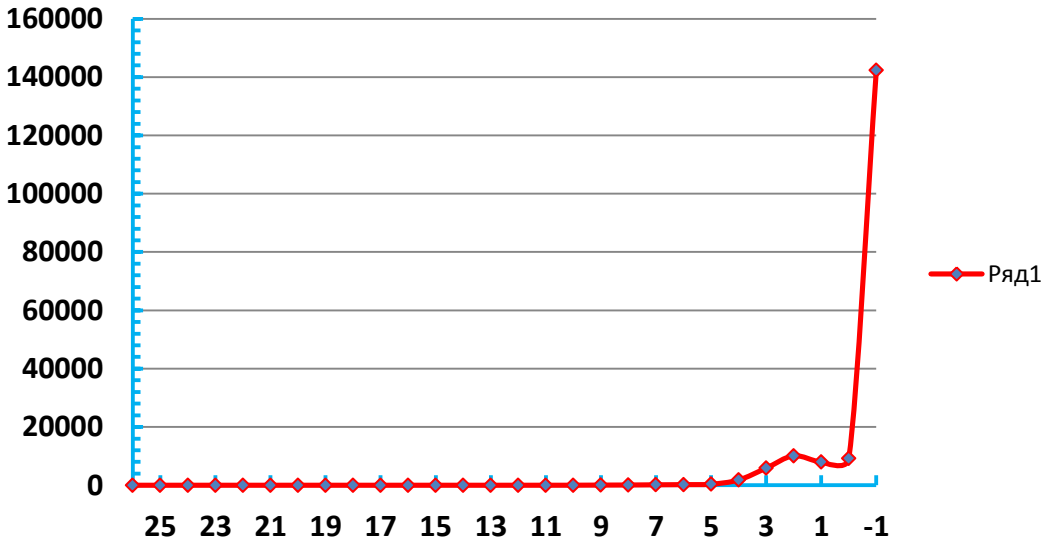


ABBN-78 Group №	Energy interval	Outgoing spectrum	Capture spectrum
-1	14.5-14.0 MeV	450166	142319
0	14.0-10.5 MeV	42000	9147
1	10.5 – 6.5 MeV	27704	7996
2	6.5 – 4.0 MeV	50266	10105
3	4.0 – 2.5 MeV	69927	5872
4	2.5 – 1.4 MeV	84013	1806
5	1.4 – 0.8 MeV	73447	365
6	0.8 – 0.4 MeV	46477	212
7	0.4 – 0.2 MeV	19851	154
8	0.2 – 0.1 MeV	6586	82
9	100 – 46.5 KeV	1998	54
10	46.5 – 21.5 KeV	353	12
11	21.5 – 10 KeV	9	4
12	10 – 4.65 KeV	39	0
13	4.65 – 2.15 KeV	7	0
14	2.15 – 1 KeV	1	0
15	1 – 0.465 KeV	0	0
16	465 – 215 eV	2	0
17	215 – 100 eV	1	0
18	100 – 46.5 eV	2	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 Nickel Ni^{nat} R= 5 cm

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

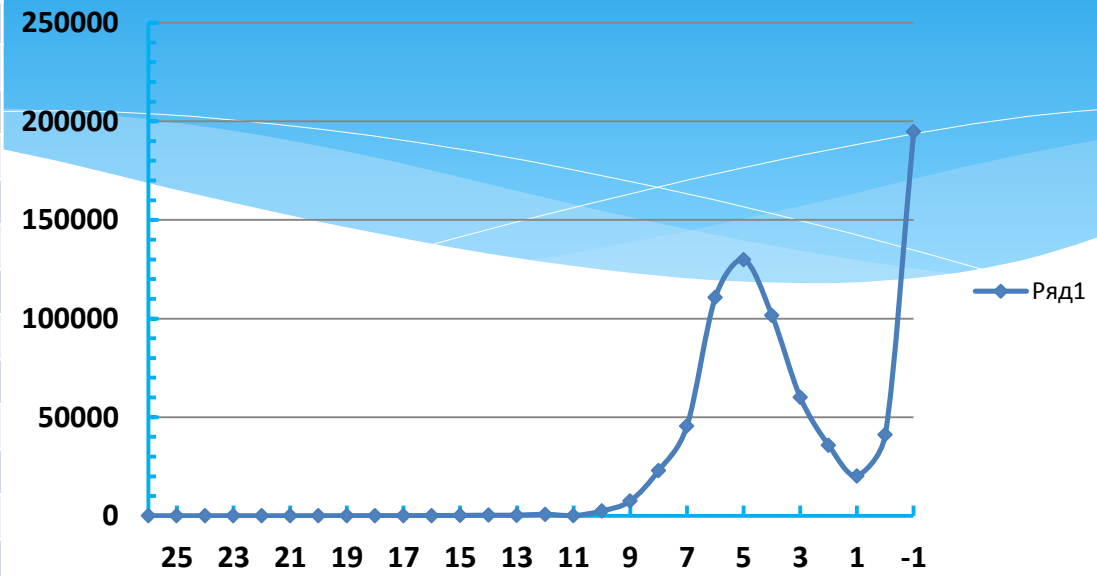


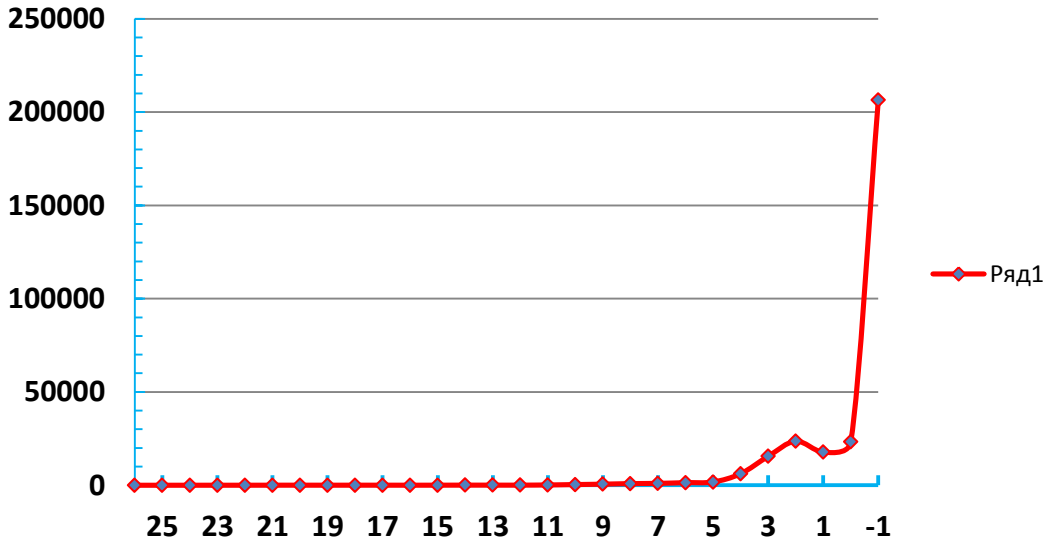


ABBN-78 Group №	Energy interval	Outgoing spectrum	Capture spectrum
-1	14.5-14.0 MeV	194766	206527
0	14.0-10.5 MeV	41196	23213
1	10.5 – 6.5 MeV	20216	17815
2	6.5 – 4.0 MeV	35792	23643
3	4.0 – 2.5 MeV	60063	15499
4	2.5 – 1.4 MeV	101659	6164
5	1.4 – 0.8 MeV	129886	1747
6	0.8 – 0.4 MeV	110650	1397
7	0.4 – 0.2 MeV	45453	998
8	0.2 – 0.1 MeV	22918	882
9	100 – 46.5 KeV	7540	578
10	46.5 – 21.5 KeV	2453	370
11	21.5 – 10 KeV	145	151
12	10 – 4.65 KeV	758	53
13	4.65 – 2.15 KeV	308	55
14	2.15 – 1 KeV	327	60
15	1 – 0.465 KeV	198	31
16	465 – 215 eV	118	24
17	215 – 100 eV	86	31
18	100 – 46.5 eV	70	33
19	46.5 – 21.5 eV	40	23
20	21.5 – 10 eV	31	36
21	10 – 4.65 eV	16	29
22	4.65 – 2.15 eV	2	12
23	2.15 – 1.0 eV	3	10
24	1.0 – 0.465 eV	1	7
25	0.465 – 0.215 eV	0	0
26	0.215 – 0.001 eV	0	0

Sphere of Nickel Ni^{nat} R= 10 cm

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

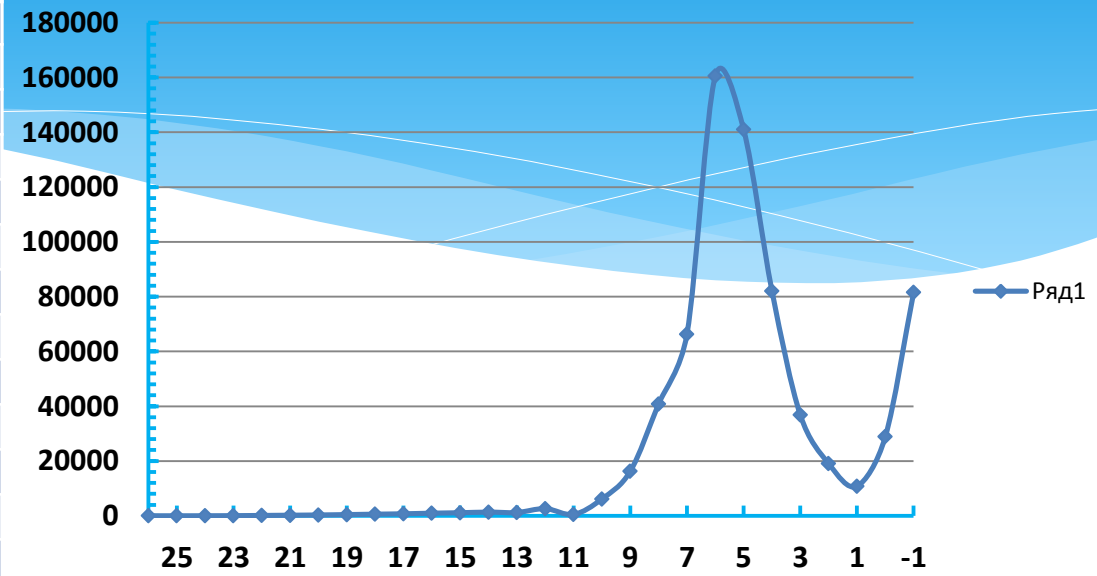


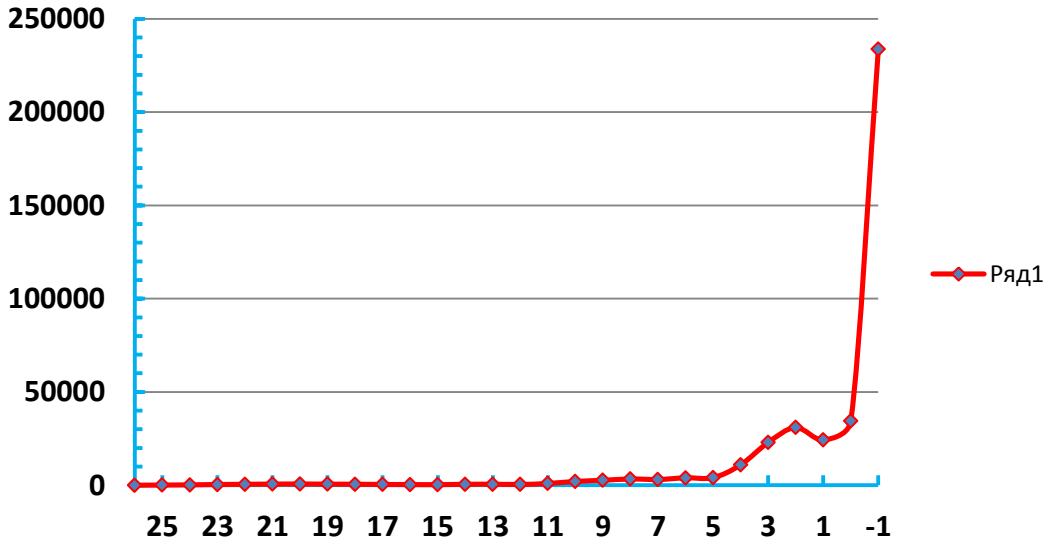


ABBN-78 Group №	Energy interval	Outgoing spectrum	Capture spectrum
-1	14.5-14.0 MeV	81574	233769
0	14.0-10.5 MeV	28894	34452
1	10.5 – 6.5 MeV	10797	24270
2	6.5 – 4.0 MeV	19060	30944
3	4.0 – 2.5 MeV	36823	22946
4	2.5 – 1.4 MeV	82094	10911
5	1.4 – 0.8 MeV	141048	4079
6	0.8 – 0.4 MeV	160519	3982
7	0.4 – 0.2 MeV	66310	3075
8	0.2 – 0.1 MeV	40876	3356
9	100 – 46.5 KeV	16249	2643
10	46.5 – 21.5 KeV	6150	2030
11	21.5 – 10 KeV	523	939
12	10 – 4.65 KeV	2619	414
13	4.65 – 2.15 KeV	1203	557
14	2.15 – 1 KeV	1355	509
15	1 – 0.465 KeV	1119	322
16	465 – 215 eV	956	366
17	215 – 100 eV	730	424
18	100 – 46.5 eV	597	531
19	46.5 – 21.5 eV	437	588
20	21.5 – 10 eV	304	671
21	10 – 4.65 eV	215	616
22	4.65 – 2.15 eV	128	507
23	2.15 – 1.0 eV	51	382
24	1.0 – 0.465 eV	15	205
25	0.465 – 0.215 eV	3	90
26	0.215 – 0.001 eV	0	9

Sphere of Nickel Ni^{nat} R= 15 cm

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

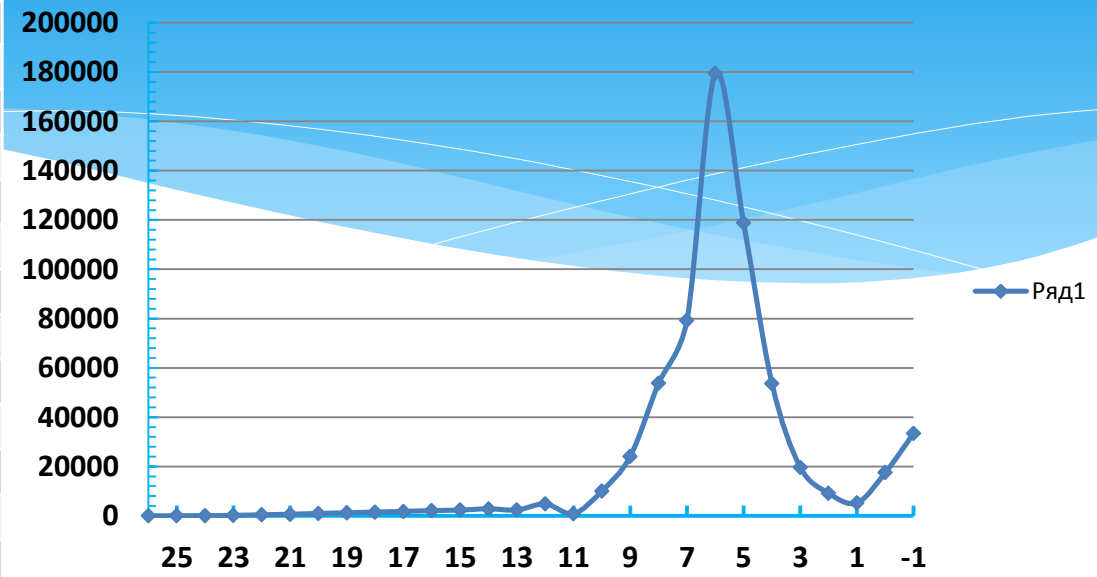


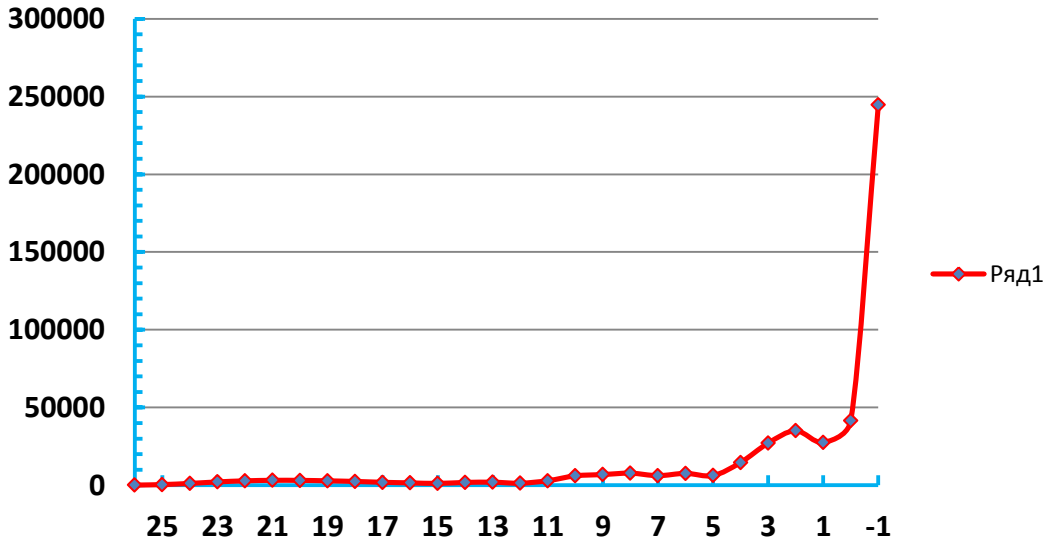


ABBN-78 Group №	Energy interval	Outgoing spectrum	Capture spectrum
-1	14.5-14.0 MeV	33423	244697
0	14.0-10.5 MeV	17527	41597
1	10.5 – 6.5 MeV	5292	27506
2	6.5 – 4.0 MeV	9147	35056
3	4.0 – 2.5 MeV	19677	27119
4	2.5 – 1.4 MeV	53721	14641
5	1.4 – 0.8 MeV	118846	6247
6	0.8 – 0.4 MeV	179442	7653
7	0.4 – 0.2 MeV	79291	6149
8	0.2 – 0.1 MeV	53821	7747
9	100 – 46.5 KeV	24119	6884
10	46.5 – 21.5 KeV	10111	6038
11	21.5 – 10 KeV	893	2931
12	10 – 4.65 KeV	4814	1316
13	4.65 – 2.15 KeV	2363	1954
14	2.15 – 1 KeV	2840	1809
15	1 – 0.465 KeV	2333	1178
16	465 – 215 eV	2118	1528
17	215 – 100 eV	1789	1886
18	100 – 46.5 eV	1507	2448
19	46.5 – 21.5 eV	1240	2837
20	21.5 – 10 eV	952	3132
21	10 – 4.65 eV	637	3166
22	4.65 – 2.15 eV	414	2833
23	2.15 – 1.0 eV	182	2142
24	1.0 – 0.465 eV	59	1169
25	0.465 – 0.215 eV	17	421
26	0.215 – 0.001 eV	0	98

Sphere of Nickel Ni^{nat} R= 20 cm

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

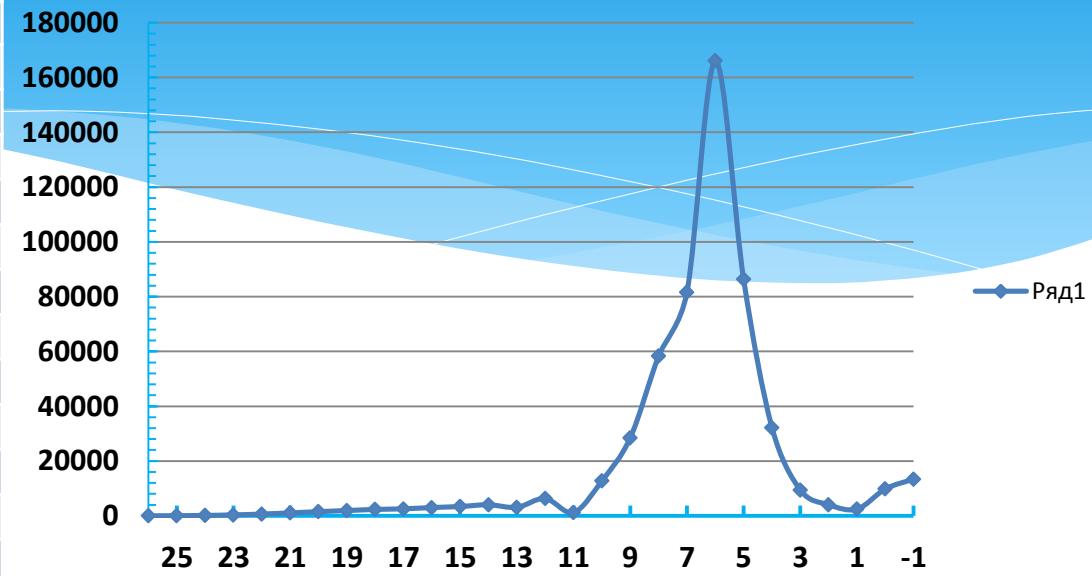


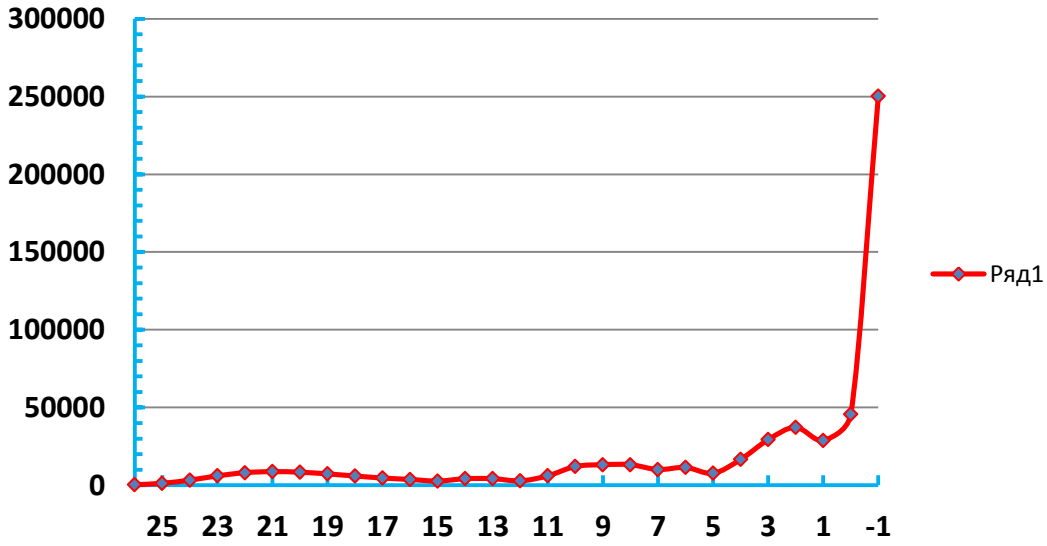


ABBN-78 Group №	Energy interval	Outgoing spectrum	Capture spectrum
-1	14.5-14.0 MeV	13413	250264
0	14.0-10.5 MeV	9806	45677
1	10.5 – 6.5 MeV	2457	28865
2	6.5 – 4.0 MeV	4064	37242
3	4.0 – 2.5 MeV	9437	29315
4	2.5 – 1.4 MeV	32203	16570
5	1.4 – 0.8 MeV	86346	7728
6	0.8 – 0.4 MeV	166124	11458
7	0.4 – 0.2 MeV	81613	10096
8	0.2 – 0.1 MeV	58290	13223
9	100 – 46.5 KeV	28469	13221
10	46.5 – 21.5 KeV	12768	12073
11	21.5 – 10 KeV	1217	6086
12	10 – 4.65 KeV	6323	2820
13	4.65 – 2.15 KeV	3103	4229
14	2.15 – 1 KeV	4033	4199
15	1 – 0.465 KeV	3399	2697
16	465 – 215 eV	3016	3720
17	215 – 100 eV	2555	4639
18	100 – 46.5 eV	2333	5930
19	46.5 – 21.5 eV	1925	7285
20	21.5 – 10 eV	1519	8389
21	10 – 4.65 eV	1071	8771
22	4.65 – 2.15 eV	634	8084
23	2.15 – 1.0 eV	335	6033
24	1.0 – 0.465 eV	144	3301
25	0.465 – 0.215 eV	43	1262
26	0.215 – 0.001 eV	2	335

Sphere of Nickel Ni^{nat} R= 25 cm

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

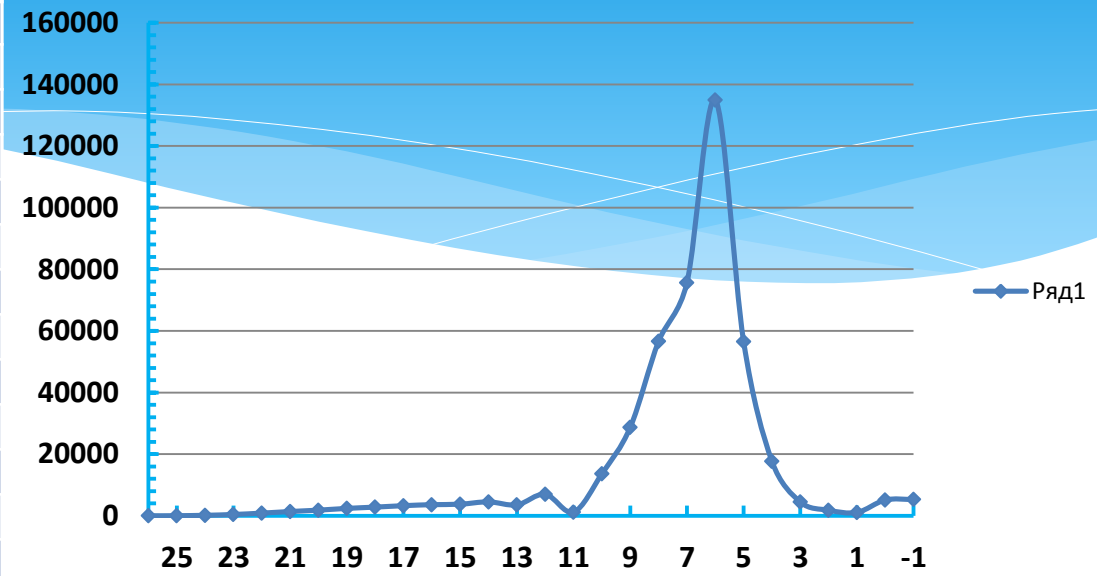


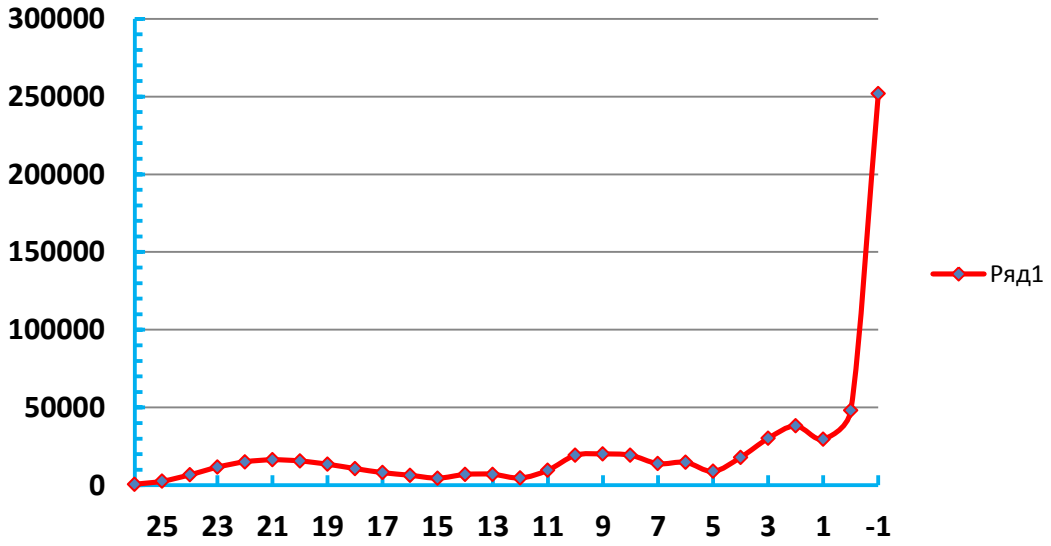


ABBN-78 Group №	Energy interval	Outgoing spectrum	Capture spectrum
-1	14.5-14.0 MeV	5306	251973
0	14.0-10.5 MeV	5146	48052
1	10.5 – 6.5 MeV	1104	29602
2	6.5 – 4.0 MeV	1817	38148
3	4.0 – 2.5 MeV	4495	30139
4	2.5 – 1.4 MeV	17685	17913
5	1.4 – 0.8 MeV	56539	8912
6	0.8 – 0.4 MeV	134926	14768
7	0.4 – 0.2 MeV	75659	13869
8	0.2 – 0.1 MeV	56635	19321
9	100 – 46.5 KeV	28717	20097
10	46.5 – 21.5 KeV	13647	19288
11	21.5 – 10 KeV	1213	9672
12	10 – 4.65 KeV	7013	4653
13	4.65 – 2.15 KeV	3555	7049
14	2.15 – 1 KeV	4538	6951
15	1 – 0.465 KeV	3772	4566
16	465 – 215 eV	3624	6414
17	215 – 100 eV	3290	8103
18	100 – 46.5 eV	2820	10719
19	46.5 – 21.5 eV	2409	13509
20	21.5 – 10 eV	1840	15621
21	10 – 4.65 eV	1400	16368
22	4.65 – 2.15 eV	875	15075
23	2.15 – 1.0 eV	433	11614
24	1.0 – 0.465 eV	171	6721
25	0.465 – 0.215 eV	36	2596
26	0.215 – 0.001 eV	5	637

Sphere of Nickel Ni^{nat} R= 30 cm

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

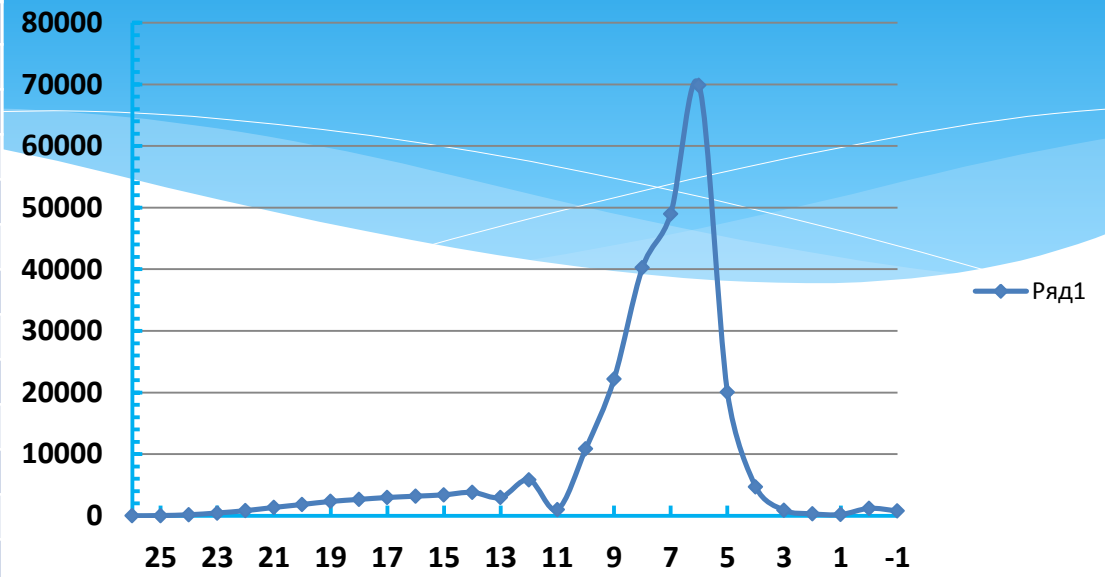


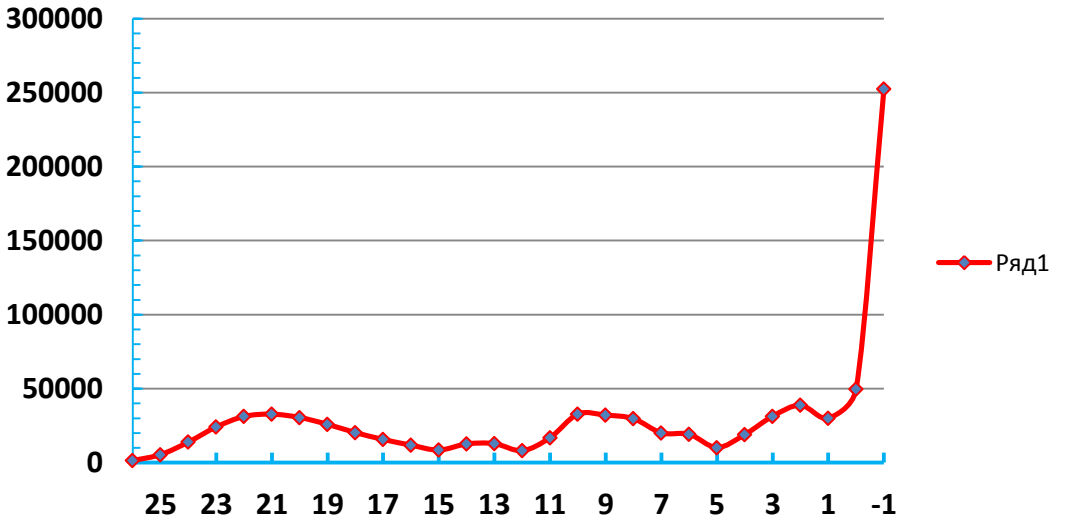


ABBN-78 Group №	Energy interval	Outgoing spectrum	Capture spectrum
-1	14.5-14.0 MeV	799	252566
0	14.0-10.5 MeV	1213	49787
1	10.5 – 6.5 MeV	209	30040
2	6.5 – 4.0 MeV	324	38788
3	4.0 – 2.5 MeV	915	31372
4	2.5 – 1.4 MeV	4701	18989
5	1.4 – 0.8 MeV	20074	10218
6	0.8 – 0.4 MeV	69853	19169
7	0.4 – 0.2 MeV	49006	20120
8	0.2 – 0.1 MeV	40244	29705
9	100 – 46.5 KeV	22190	32125
10	46.5 – 21.5 KeV	10850	32815
11	21.5 – 10 KeV	1035	16903
12	10 – 4.65 KeV	5850	8137
13	4.65 – 2.15 KeV	2983	12852
14	2.15 – 1 KeV	3810	12628
15	1 – 0.465 KeV	3406	8510
16	465 – 215 eV	3185	11829
17	215 – 100 eV	2973	15684
18	100 – 46.5 eV	2662	20328
19	46.5 – 21.5 eV	2335	25891
20	21.5 – 10 eV	1842	30492
21	10 – 4.65 eV	1361	32755
22	4.65 – 2.15 eV	837	31212
23	2.15 – 1.0 eV	461	24105
24	1.0 – 0.465 eV	171	13928
25	0.465 – 0.215 eV	44	5444
26	0.215 – 0.001 eV	3	1409

Sphere of Nickel Ni^{nat} R= 40 cm

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

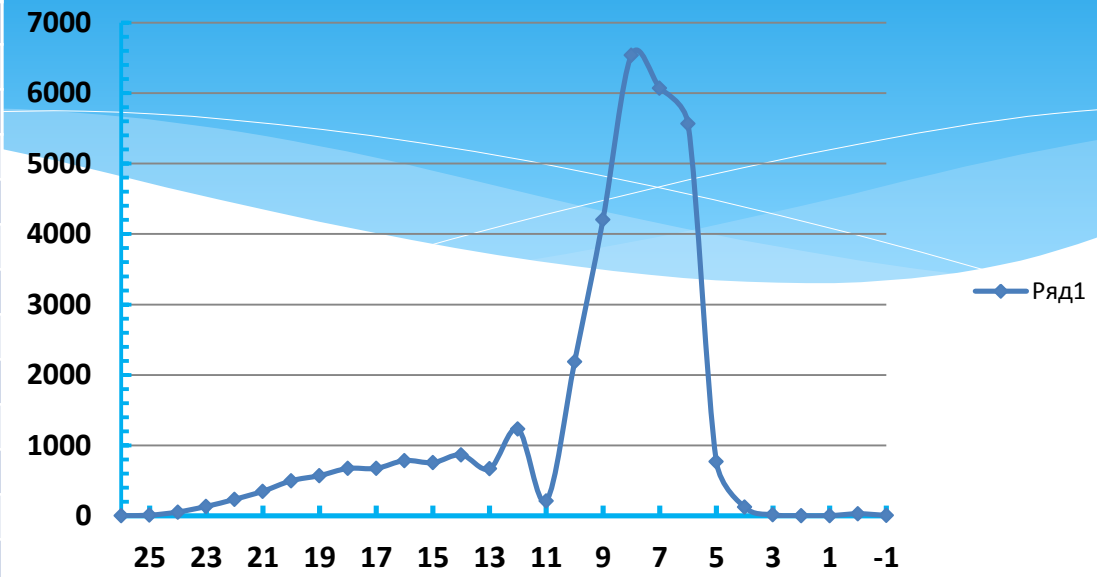


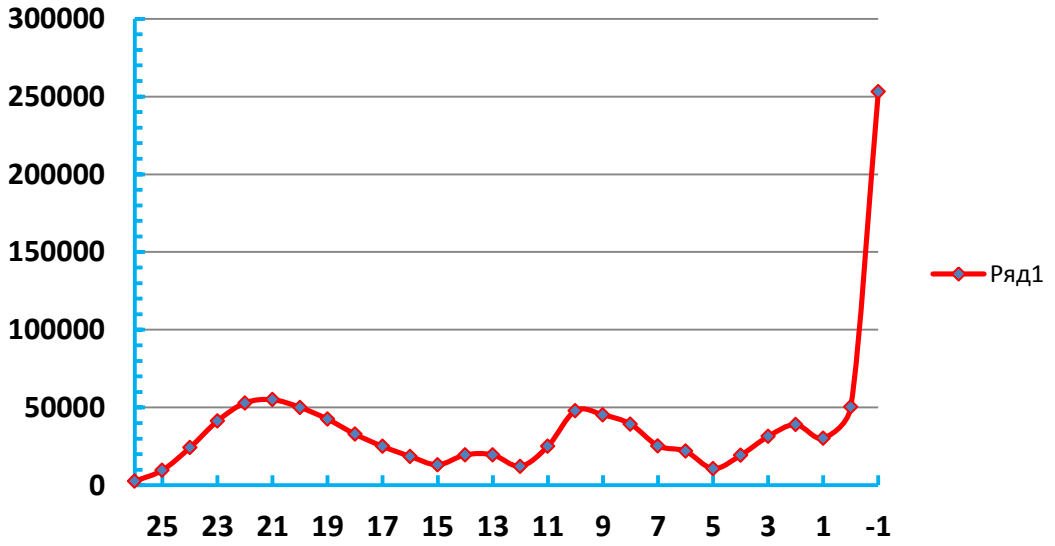


ABBN-78 Group №	Energy interval	Outgoing spectrum	Capture spectrum
-1	14.5-14.0 MeV	6	253196
0	14.0-10.5 MeV	29	50393
1	10.5 – 6.5 MeV	3	30189
2	6.5 – 4.0 MeV	2	38985
3	4.0 – 2.5 MeV	14	31417
4	2.5 – 1.4 MeV	123	19255
5	1.4 – 0.8 MeV	772	10702
6	0.8 – 0.4 MeV	5568	21914
7	0.4 – 0.2 MeV	6073	25355
8	0.2 – 0.1 MeV	6539	39331
9	100 – 46.5 KeV	4206	45299
10	46.5 – 21.5 KeV	2189	47991
11	21.5 – 10 KeV	212	25062
12	10 – 4.65 KeV	1233	12191
13	4.65 – 2.15 KeV	668	19555
14	2.15 – 1 KeV	867	19547
15	1 – 0.465 KeV	755	13159
16	465 – 215 eV	785	18567
17	215 – 100 eV	673	24973
18	100 – 46.5 eV	673	32842
19	46.5 – 21.5 eV	571	42489
20	21.5 – 10 eV	498	50069
21	10 – 4.65 eV	349	55013
22	4.65 – 2.15 eV	234	52935
23	2.15 – 1.0 eV	133	41259
24	1.0 – 0.465 eV	54	24156
25	0.465 – 0.215 eV	9	9651
26	0.215 – 0.001 eV	2	2604

Sphere of Nickel Ni^{nat} R= 65 cm

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

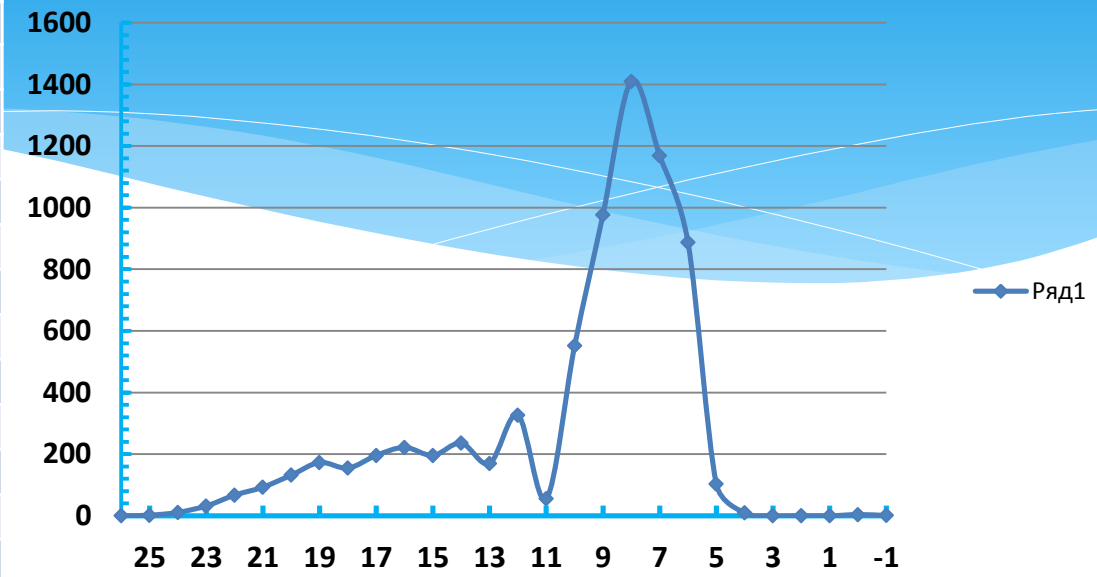


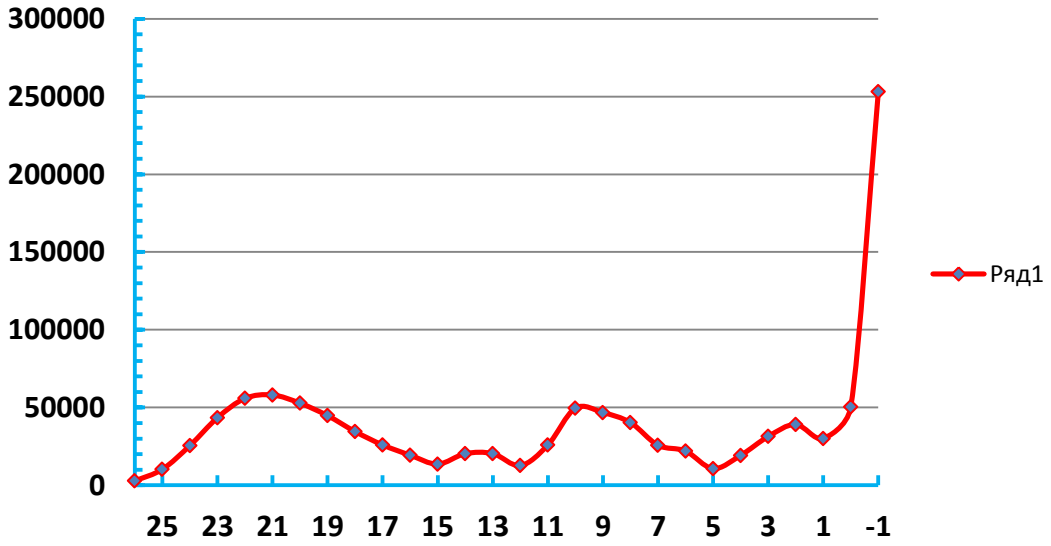


ABBN-78 Group №	Energy interval	Outgoing spectrum	Capture spectrum
-1	14.5-14.0 MeV	1	253034
0	14.0-10.5 MeV	4	50438
1	10.5 – 6.5 MeV	0	30051
2	6.5 – 4.0 MeV	0	39086
3	4.0 – 2.5 MeV	0	31349
4	2.5 – 1.4 MeV	10	19194
5	1.4 – 0.8 MeV	103	10713
6	0.8 – 0.4 MeV	887	22004
7	0.4 – 0.2 MeV	1169	25733
8	0.2 – 0.1 MeV	1410	40306
9	100 – 46.5 KeV	977	46729
10	46.5 – 21.5 KeV	552	49568
11	21.5 – 10 KeV	55	25866
12	10 – 4.65 KeV	327	12664
13	4.65 – 2.15 KeV	170	20371
14	2.15 – 1 KeV	236	20305
15	1 – 0.465 KeV	196	13620
16	465 – 215 eV	222	19339
17	215 – 100 eV	196	25919
18	100 – 46.5 eV	155	34524
19	46.5 – 21.5 eV	173	44763
20	21.5 – 10 eV	132	52770
21	10 – 4.65 eV	93	58062
22	4.65 – 2.15 eV	67	55854
23	2.15 – 1.0 eV	32	43392
24	1.0 – 0.465 eV	11	25499
25	0.465 – 0.215 eV	2	10241
26	0.215 – 0.001 eV	0	2757

Sphere of Nickel Ni^{nat} R= 80 cm

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

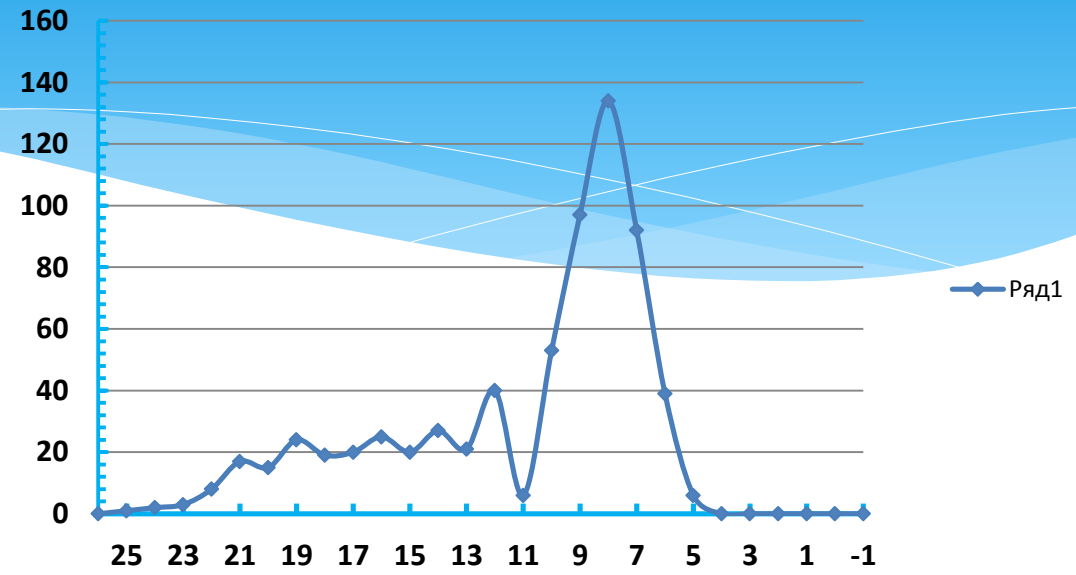


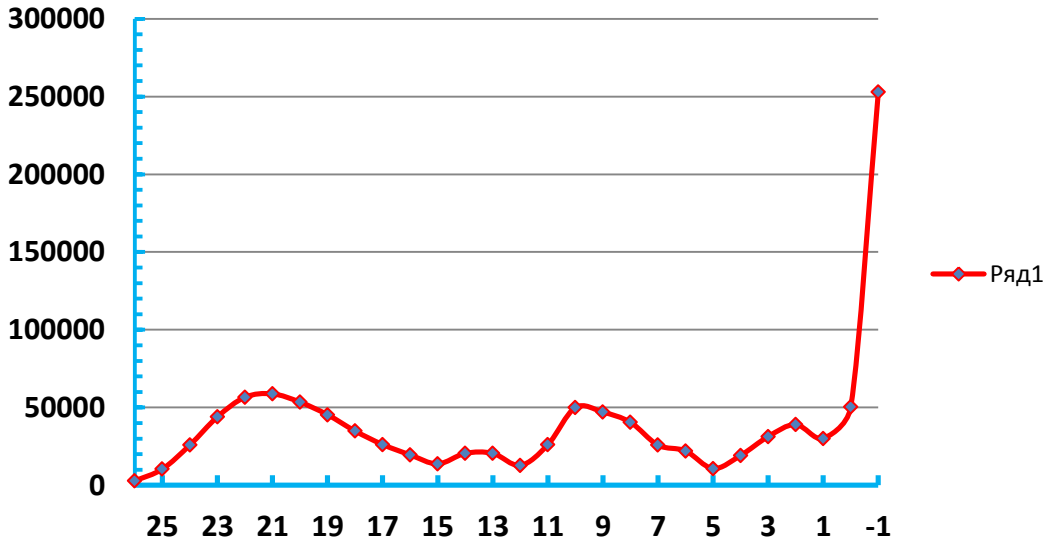


ABBN-78 Group №	Energy interval	Outgoing spectrum	Capture spectrum
-1	14.5-14.0 MeV	0	252935
0	14.0-10.5 MeV	0	50467
1	10.5 – 6.5 MeV	0	30104
2	6.5 – 4.0 MeV	0	39034
3	4.0 – 2.5 MeV	0	31327
4	2.5 – 1.4 MeV	0	19175
5	1.4 – 0.8 MeV	6	10748
6	0.8 – 0.4 MeV	39	22076
7	0.4 – 0.2 MeV	92	25809
8	0.2 – 0.1 MeV	134	40473
9	100 – 46.5 KeV	97	47003
10	46.5 – 21.5 KeV	53	49961
11	21.5 – 10 KeV	6	26066
12	10 – 4.65 KeV	40	12770
13	4.65 – 2.15 KeV	21	20533
14	2.15 – 1 KeV	27	20498
15	1 – 0.465 KeV	20	13767
16	465 – 215 eV	25	19533
17	215 – 100 eV	20	26183
18	100 – 46.5 eV	19	34874
19	46.5 – 21.5 eV	24	45327
20	21.5 – 10 eV	15	53449
21	10 – 4.65 eV	17	58778
22	4.65 – 2.15 eV	8	56613
23	2.15 – 1.0 eV	3	43979
24	1.0 – 0.465 eV	2	25874
25	0.465 – 0.215 eV	1	10398
26	0.215 – 0.001 eV	0	2794

Sphere of Nickel Ni^{nat} R= 100 cm

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

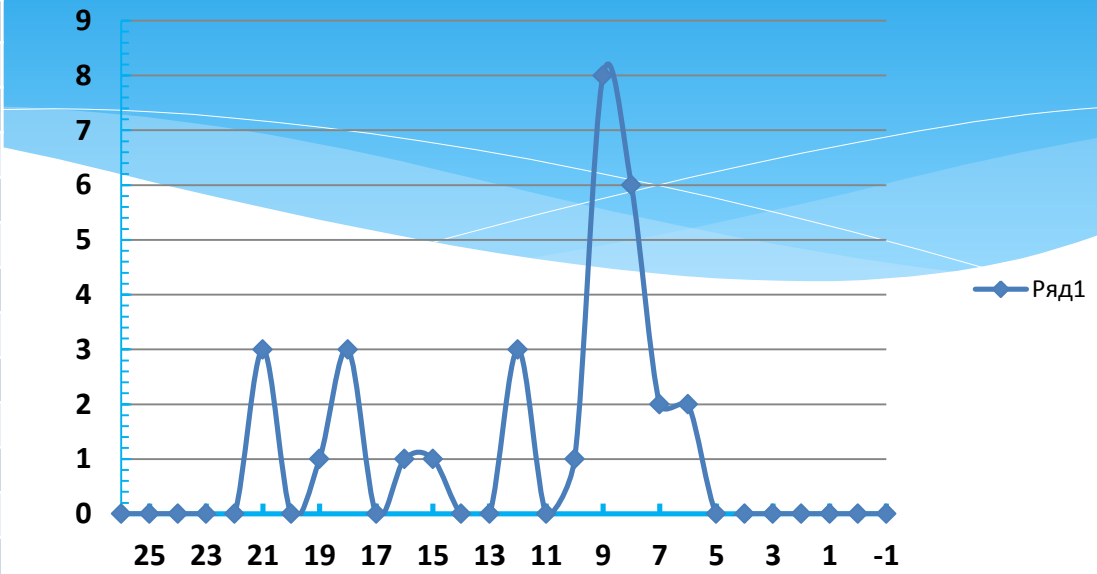


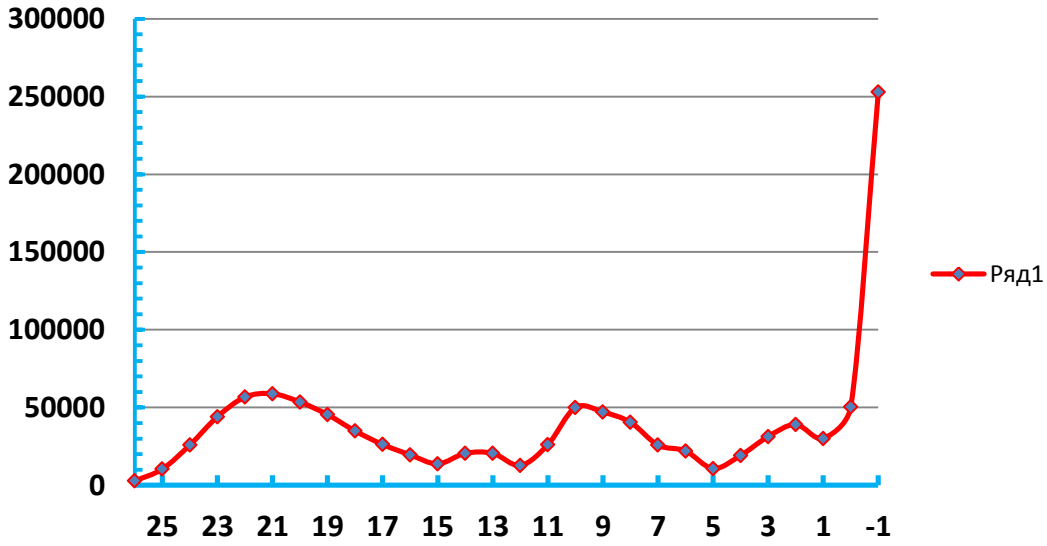


ABBN-78 Group №	Energy interval	Outgoing spectrum	Capture spectrum
-1	14.5-14.0 MeV	0	252911
0	14.0-10.5 MeV	0	50480
1	10.5 – 6.5 MeV	0	30097
2	6.5 – 4.0 MeV	0	39041
3	4.0 – 2.5 MeV	0	31330
4	2.5 – 1.4 MeV	0	19170
5	1.4 – 0.8 MeV	0	10752
6	0.8 – 0.4 MeV	2	22062
7	0.4 – 0.2 MeV	2	25820
8	0.2 – 0.1 MeV	6	40494
9	100 – 46.5 KeV	8	47032
10	46.5 – 21.5 KeV	1	50005
11	21.5 – 10 KeV	0	26084
12	10 – 4.65 KeV	3	12772
13	4.65 – 2.15 KeV	0	20536
14	2.15 – 1 KeV	0	20522
15	1 – 0.465 KeV	1	13781
16	465 – 215 eV	1	19544
17	215 – 100 eV	0	26215
18	100 – 46.5 eV	3	34915
19	46.5 – 21.5 eV	1	45395
20	21.5 – 10 eV	0	53518
21	10 – 4.65 eV	3	58847
22	4.65 – 2.15 eV	0	56706
23	2.15 – 1.0 eV	0	44041
24	1.0 – 0.465 eV	0	25926
25	0.465 – 0.215 eV	0	10412
26	0.215 – 0.001 eV	0	2797

Sphere of Nickel Ni^{nat} R= 120 cm

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





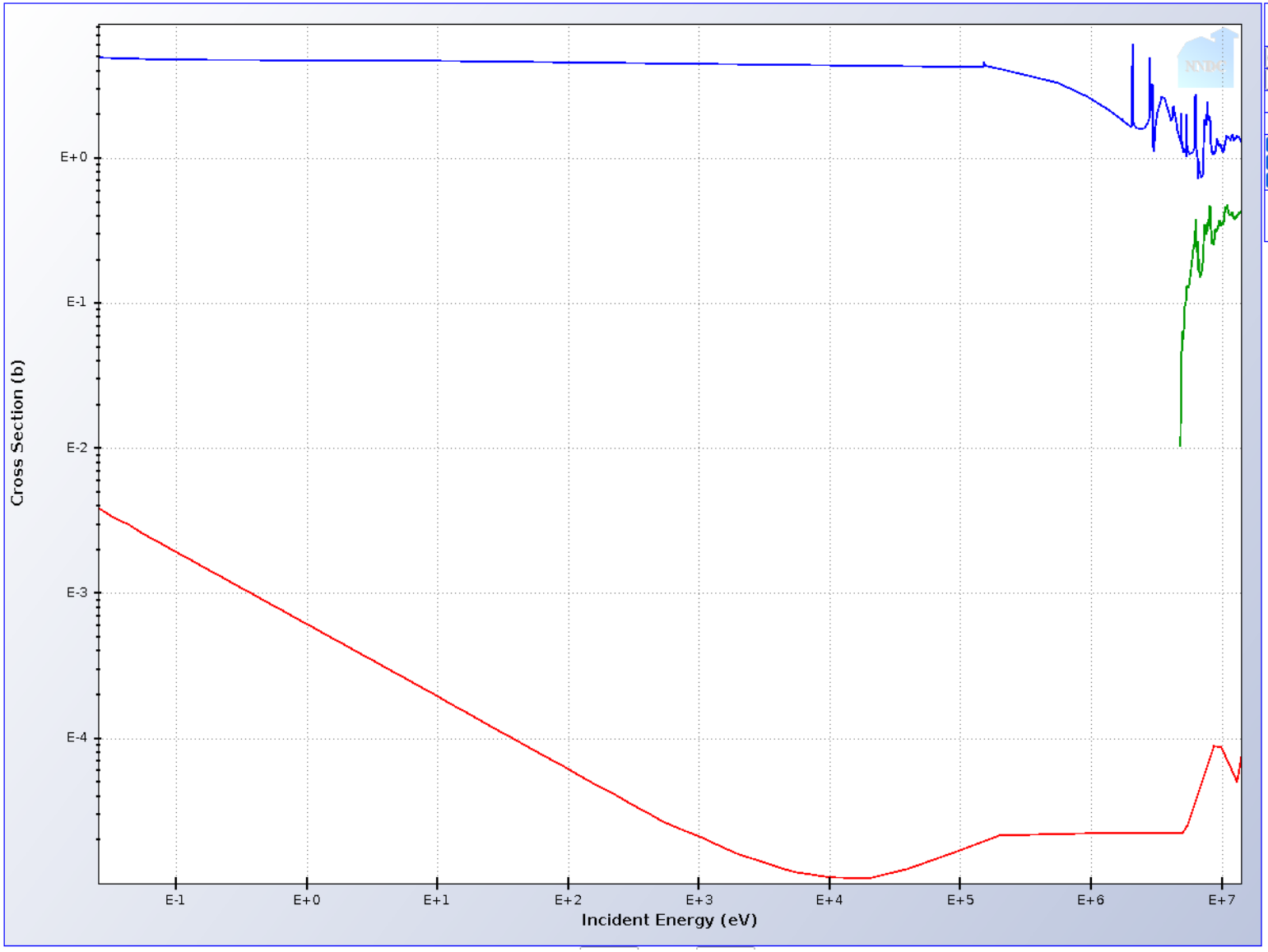
Spectrums in metal Nickel (p=8.90 g/cm3) Ni^{nat} spheres

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	855171	38129	450166	142319	194766	206527	81574	233769	33423	244697	13413	250264
0	14.0-10.5 MeV	14702	502	42000	9147	41196	23213	28894	34452	17527	41597	9806	45677
1	10.5-6.5 MeV	12915	531	27704	7996	20216	17815	10797	24270	5292	27506	2457	28865
2	6.5-4.0 MeV	22591	647	50266	10105	35792	23643	19060	30944	9147	35056	4064	37242
3	4.0-2.5 MeV	25269	334	69927	5872	60063	15499	36823	22946	19677	27119	9437	29315
4	2.5-1.4 MeV	21138	81	84013	1806	101659	6164	82094	10911	53721	14641	32203	16570
5	1.4-0.8 MeV	12632	77	73447	365	129886	1747	141048	4079	118846	6247	86346	7728
6	0.8-0.4 MeV	5956	0	46477	212	110650	1397	160519	3982	179442	7653	166124	11458
7	0.4-0.2 MeV	2430	3	19851	154	45453	998	66310	3075	79291	6149	81613	10096
8	0.2-0.1 MeV	283	0	6586	82	22918	882	40876	3356	53821	7747	58290	13223
9	100-46.5 KeV	96	0	1998	54	7540	578	16249	2643	24119	6884	28469	13221
10	46.5 –21.5 KeV	0	0	353	12	2453	370	6150	2030	10111	6038	12768	12073
11	21.5– 10 KeV	0	0	9	4	145	151	523	939	893	2931	1217	6086
12	10– 4.65 KeV	0	0	39	0	758	53	2619	414	4814	1316	6323	2820
13	4.65– 2.15 KeV	0	0	7	0	308	55	1203	557	2363	1954	3103	4229
14	2.15 – 1 KeV	0	0	1	0	327	60	1355	509	2840	1809	4033	4199
15	1– 0.465 KeV	0	0	0	0	198	31	1119	322	2333	1178	3399	2697
16	465– 215 eV	0	0	2	0	118	24	956	366	2118	1528	3016	3720
17	215– 100 eV	0	0	1	0	86	31	730	424	1789	1886	2555	4639
18	100– 46.5 eV	0	0	2	0	70	33	597	531	1507	2448	2333	5930
19	46.5– 21.5 eV	0	0	0	0	40	23	437	588	1240	2837	1925	7285
20	21.5– 10 eV	0	0	0	0	31	36	304	671	952	3132	1519	8389
21	10– 4.65 eV	0	0	0	0	16	29	215	616	637	3166	1071	8771
22	4.6 – 2.15 eV	0	0	0	0	2	12	128	507	414	2833	634	8084
23	2.1 – 1.0 eV	0	0	0	0	3	10	51	382	182	2142	335	6033
24	1.0– 0.465 eV	0	0	0	0	1	7	15	205	59	1169	144	3301
25	0.46 – 0.215 eV	0	0	0	0	0	0	3	90	17	421	43	1262
26	0.215– 0.001 eV	0	0	0	0	0	0	0	9	0	98	2	335
Average Neutron Energy		12.89 MeV	13.74 MeV	9.02 MeV	12.74 MeV	5.48 MeV	11.85 MeV	3.23 MeV	10.97 MeV	1.94 MeV	9.80 MeV	1.24 MeV	8.49 MeV
Diffusion/Absorption time of spectra, nanoseconds		0.232	0.100	2.48	0.596	13.54	6.93	54.61	122.02	134.09	525.48	232.09	1221
Number of neutrons		973183	40234	872849	178128	774695	299388	700649	383587	626575	462182	536642	553512

Spectrums in metal Nickel (p=8.90 g/cm3) Ni^{nat} spheres

ABBN-78 Group №	Energy Interval	R = 30 cm		R = 40 cm		R = 65 cm		R = 80 cm		R = 100 cm		R = 120 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	5306	251973	799	252566	6	253196	1	253034	0	252935	0	252911
0	14.0-10.5 MeV	5146	48052	1213	49787	29	50393	4	50438	0	50467	0	50480
1	10.5-6.5 MeV	1104	29602	209	30040	3	30189	0	30051	0	30104	0	30097
2	6.5-4.0 MeV	1817	38148	324	38788	2	38985	0	39086	0	39034	0	39041
3	4.0-2.5 MeV	4495	30139	915	31372	14	31417	0	31349	0	31327	0	31330
4	2.5-1.4 MeV	17685	17913	4701	18989	123	19255	10	19194	0	19175	0	19170
5	1.4-0.8 MeV	56539	8912	20074	10218	772	10702	103	10713	6	10748	0	10752
6	0.8-0.4 MeV	134926	14768	69853	19169	5568	21914	887	22004	39	22076	2	22062
7	0.4-0.2 MeV	75659	13869	49006	20120	6073	25355	1169	25733	92	25809	2	25820
8	0.2-0.1 MeV	56635	19321	40244	29705	6539	39331	1410	40306	134	40473	6	40494
9	100-46.5 KeV	28717	20097	22190	32125	4206	45299	977	46729	97	47003	8	47032
10	46.5 –21.5 KeV	13647	19288	10850	32815	2189	47991	552	49568	53	49961	1	50005
11	21.5– 10 KeV	1213	9672	1035	16903	212	25062	55	25866	6	26066	0	26084
12	10– 4.65 KeV	7013	4653	5850	8137	1233	12191	327	12664	40	12770	3	12772
13	4.65– 2.15 KeV	3555	7049	2983	12852	668	19555	170	20371	21	20533	0	20536
14	2.15 – 1 KeV	4538	6951	3810	12628	867	19547	236	20305	27	20498	0	20522
15	1– 0.465 KeV	3772	4566	3406	8510	755	13159	196	13620	20	13767	1	13781
16	465– 215 eV	3624	6414	3185	11829	785	18567	222	19339	25	19533	1	19544
17	215– 100 eV	3290	8103	2973	15684	673	24973	196	25919	20	26183	0	26215
18	100– 46.5 eV	2820	10719	2662	20328	673	32842	155	34524	19	34874	3	34915
19	46.5– 21.5 eV	2409	13509	2335	25891	571	42489	173	44763	24	45327	1	45395
20	21.5– 10 eV	1840	15621	1842	30492	498	50069	132	52770	15	53449	0	53518
21	10– 4.65 eV	1400	16368	1361	32755	349	55013	93	58062	17	58778	3	58847
22	4.6 – 2.15 eV	875	15075	837	31212	234	52935	67	55854	8	56613	0	56706
23	2.1 – 1.0 eV	433	11614	461	24105	133	41259	32	43392	3	43979	0	44041
24	1.0– 0.465 eV	171	6721	171	13928	54	24156	11	25499	2	25874	0	25926
25	0.46 – 0.215 eV	36	2596	44	5444	9	9651	2	10241	1	10398	0	10412
26	0.215– 0.001 eV	5	637	3	1409	2	2604	0	2757	0	2794	0	2797
Average Neutron Energy		855 KeV	7.32 MeV	484 KeV	5.76 MeV	224 KeV	4.59 MeV	175 KeV	4.47 MeV	116 KeV	4.45 MeV	94.96 KeV	4.44 MeV
Diffusion/Absorption time of spectra, nanoseconds		337.22	1985	536.87	3161	996.84	4269	1206	4395	1649	4429	1878	4433
Number of neutrons		438670	652350	253336	837801	33240	1058099	7180	1084151	669	1090548	31	1091205

Neutron cross sections of C^{12}:
total cross section (blue line), capture (red), inelastic scattering (green line).
Data from the Brookhaven National Laboratory [5].



ABBN-78 constants for C^{12}

BNAB 28-GROUP NEUTRON CONSTANTS FOR C(6, 12.01115)

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	1.2700	.0000	.0000	.0810	.4380	.7510	.6175
0	.105E+02-	.140E+02	1.3500	.0000	.0000	.0900	.4540	.8060	.4436
1	.650E+01-	.105E+02	1.2000	.0000	.0000	.0600	.2620	.8780	.2682
2	.400E+01-	.650E+01	1.5100	.0000	.0000	.0000	.0590	1.4510	.3247
3	.250E+01-	.400E+01	2.0700	.0000	.0000	.0000	.0000	2.0700	.0164
4	.140E+01-	.250E+01	1.8400	.0000	.0000	.0000	.0000	1.8400	.0869
5	.800E+00-	.140E+01	2.4800	.0000	.0000	.0000	.0000	2.4800	.1323
6	.400E+00-	.800E+00	3.2300	.0000	.0000	.0000	.0000	3.2300	.1191
7	.200E+00-	.400E+00	3.8600	.0000	.0000	.0000	.0000	3.8600	.0972
8	.100E+00-	.200E+00	4.2500	.0000	.0000	.0000	.0000	4.2500	.0787
9	.465E-01-	.100E+00	4.4900	.0000	.0000	.0000	.0000	4.4900	.0683
10	.215E-01-	.465E-01	4.6200	.0000	.0000	.0000	.0000	4.6200	.0600
11	.100E-01-	.215E-01	4.6800	.0000	.0000	.0000	.0000	4.6800	.0573
12	.465E-02-	.100E-01	4.7000	.0000	.0000	.0000	.0000	4.7000	.0560
13	.215E-02-	.465E-02	4.7200	.0000	.0000	.0000	.0000	4.7200	.0560
14	.100E-02-	.215E-02	4.7200	.0000	.0000	.0000	.0000	4.7200	.0560
15	.465E-03-	.100E-02	4.7200	.0000	.0000	.0000	.0000	4.7200	.0560
16	.215E-03-	.465E-03	4.7300	.0000	.0000	.0000	.0000	4.7300	.0560
17	.100E-03-	.215E-03	4.7300	.0000	.0000	.0000	.0000	4.7300	.0560
18	.465E-04-	.100E-03	4.7301	.0000	.0000	.0001	.0000	4.7300	.0560
19	.215E-04-	.465E-04	4.7301	.0000	.0000	.0001	.0000	4.7300	.0560
20	.100E-04-	.215E-04	4.7301	.0000	.0000	.0001	.0000	4.7300	.0560
21	.465E-05-	.100E-04	4.7302	.0000	.0000	.0002	.0000	4.7300	.0560
22	.215E-05-	.465E-05	4.7303	.0000	.0000	.0003	.0000	4.7300	.0560
23	.100E-05-	.215E-05	4.7305	.0000	.0000	.0004	.0000	4.7300	.0560
24	.465E-06-	.100E-05	4.7307	.0000	.0000	.0007	.0000	4.7300	.0560
25	.215E-06-	.465E-06	4.7310	.0000	.0000	.0010	.0000	4.7300	.0560
26	THERMAL		4.7324	.0000	.0000	.0034	.0000	4.7290	.0560

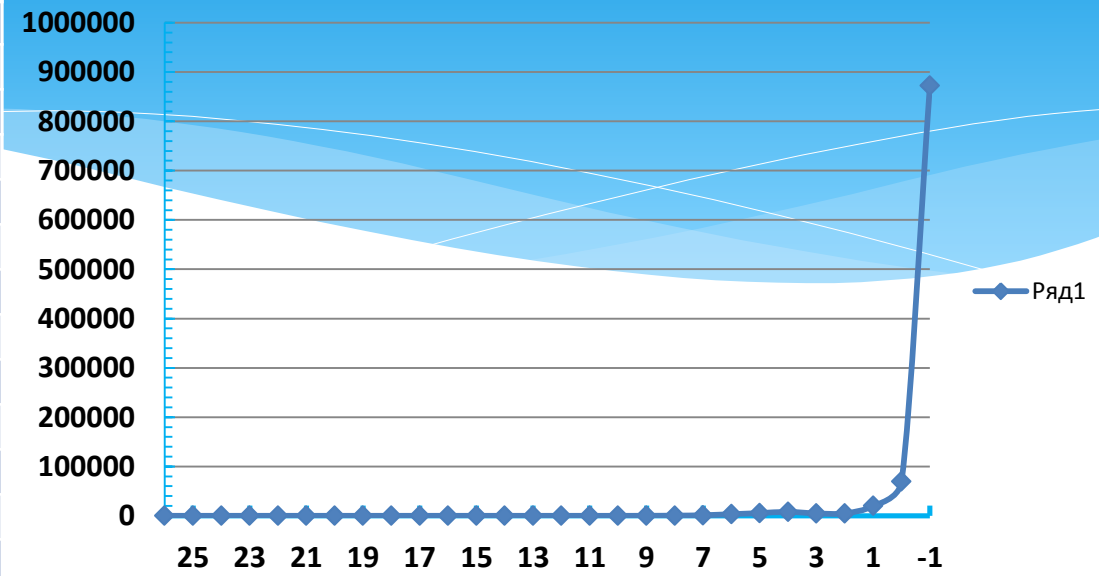
SIGMA IN (I,I+K) AT K EQUAL:

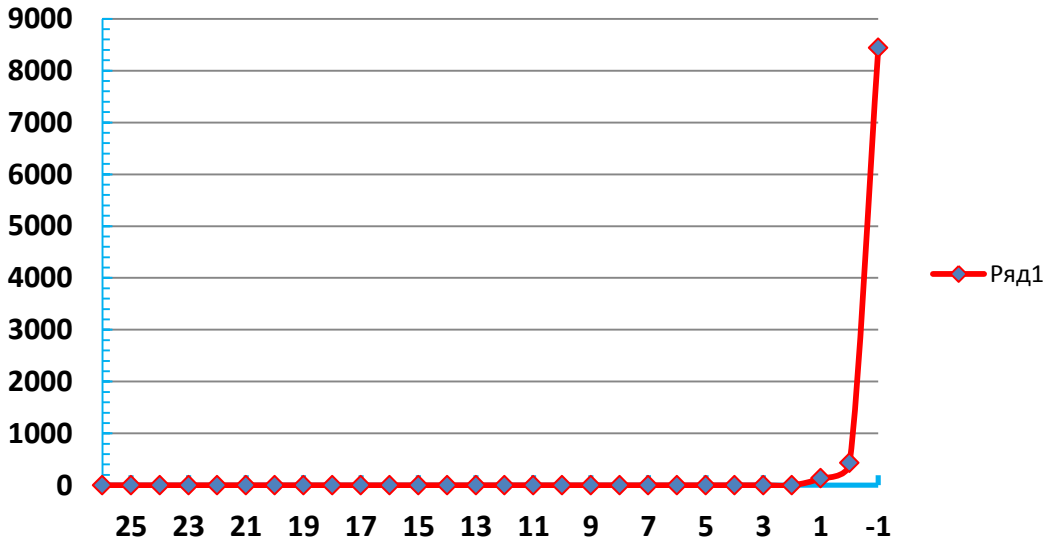
I	K= 0	K= 1	K= 2	K= 3	K= 4	K= 5	K= 6	K= 7	K= 8	K= 9	K=10	K=11	SUMMA
-1	.0000	.0000	.1970	.0310	.0450	.0710	.0500	.0300	.0100	.0030	.0010	.0000	.4380
0	.0000	.0600	.2860	.0230	.0340	.0260	.0160	.0060	.0020	.0010	.0000	.0000	.4540
1	.0000	.0200	.0940	.1270	.0200	.0010	.0000	.0000	.0000	.0000	.0000	.0000	.2620
2	.0000	.0000	.0060	.0260	.0180	.0060	.0020	.0010	.0000	.0000	.0000	.0000	.0590
3	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
4	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
5	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
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	872291	8441
0	14.0-10.5 MeV	69757	428
1	10.5 – 6.5 MeV	20476	136
2	6.5 – 4.0 MeV	5067	0
3	4.0 – 2.5 MeV	4886	0
4	2.5 – 1.4 MeV	7960	0
5	1.4 – 0.8 MeV	5536	0
6	0.8 – 0.4 MeV	3312	0
7	0.4 – 0.2 MeV	1180	0
8	0.2 – 0.1 MeV	376	0
9	100 – 46.5 KeV	148	0
10	46.5 – 21.5 KeV	6	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 graphite (p=2.26 g/cm3) C^{12} R= 1 cm

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

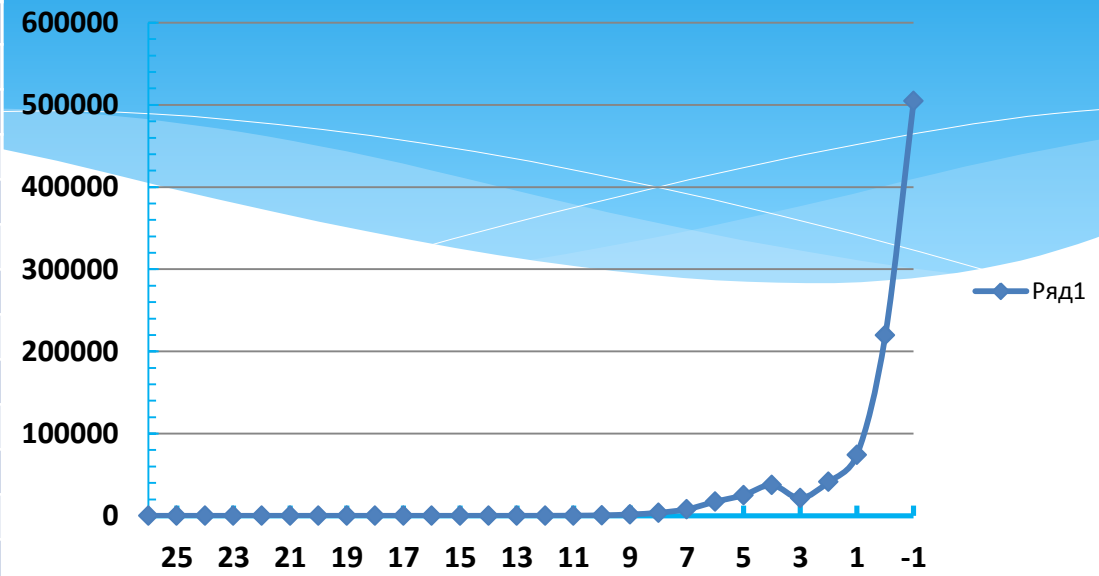


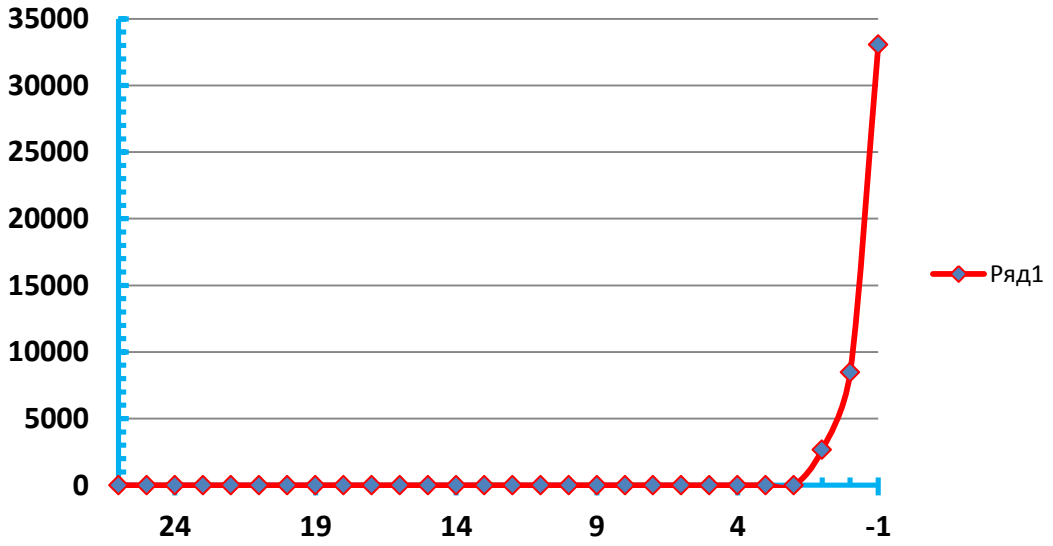


ABBN-78 Group №	Energy interval	Outgoing spectrum	Capture spectrum
-1	14.5-14.0 MeV	504962	33060
0	14.0-10.5 MeV	219675	8464
1	10.5 – 6.5 MeV	74214	2655
2	6.5 – 4.0 MeV	41273	0
3	4.0 – 2.5 MeV	21492	0
4	2.5 – 1.4 MeV	37456	0
5	1.4 – 0.8 MeV	25204	0
6	0.8 – 0.4 MeV	17174	0
7	0.4 – 0.2 MeV	7996	0
8	0.2 – 0.1 MeV	3704	0
9	100 – 46.5 KeV	1693	0
10	46.5 – 21.5 KeV	623	0
11	21.5 – 10 KeV	238	0
12	10 – 4.65 KeV	76	0
13	4.65 – 2.15 KeV	20	0
14	2.15 – 1 KeV	14	0
15	1 – 0.465 KeV	6	0
16	465 – 215 eV	1	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 graphite (p=2.26 g/cm3) C^{12} R= 5 cm

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

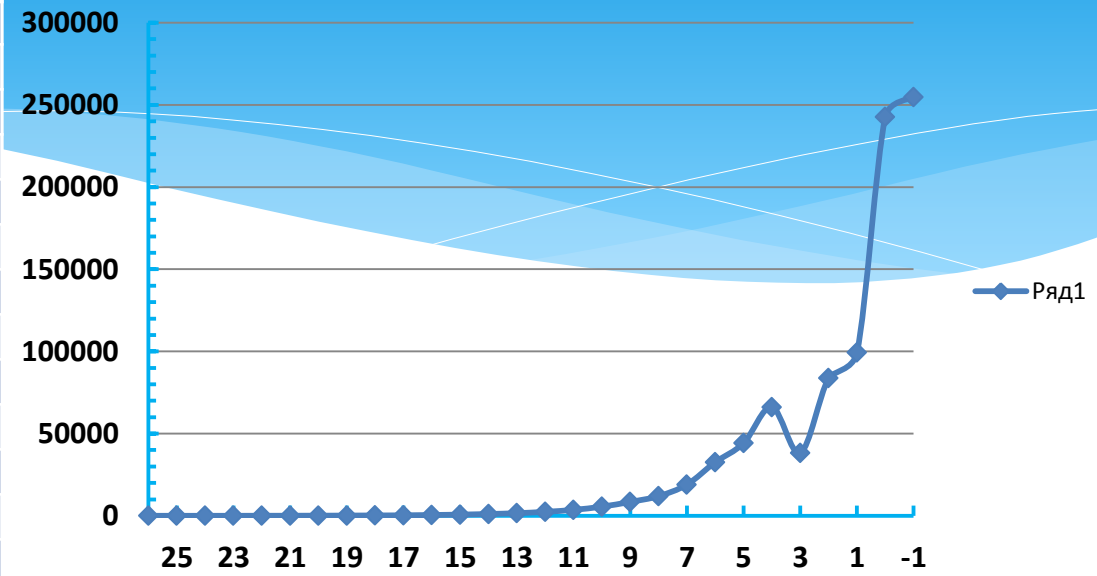


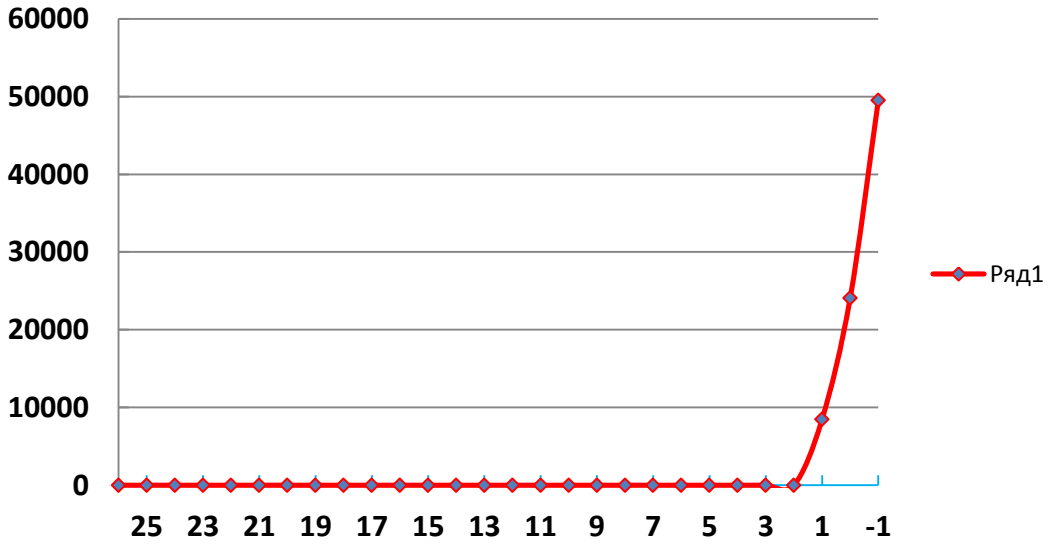


ABBN-78 Group №	Energy interval	Outgoing spectrum	Capture spectrum
-1	14.5-14.0 MeV	254733	49511
0	14.0-10.5 MeV	242671	24083
1	10.5 – 6.5 MeV	99406	8460
2	6.5 – 4.0 MeV	83829	0
3	4.0 – 2.5 MeV	38228	0
4	2.5 – 1.4 MeV	66182	0
5	1.4 – 0.8 MeV	44184	0
6	0.8 – 0.4 MeV	32629	0
7	0.4 – 0.2 MeV	19000	0
8	0.2 – 0.1 MeV	11957	0
9	100 – 46.5 KeV	8471	0
10	46.5 – 21.5 KeV	5584	0
11	21.5 – 10 KeV	3636	0
12	10 – 4.65 KeV	2432	0
13	4.65 – 2.15 KeV	1608	0
14	2.15 – 1 KeV	1116	0
15	1 – 0.465 KeV	742	0
16	465 – 215 eV	511	0
17	215 – 100 eV	315	0
18	100 – 46.5 eV	239	0
19	46.5 – 21.5 eV	163	0
20	21.5 – 10 eV	107	0
21	10 – 4.65 eV	71	0
22	4.65 – 2.15 eV	49	0
23	2.15 – 1.0 eV	24	0
24	1.0 – 0.465 eV	16	0
25	0.465 – 0.215 eV	14	0
26	0.215 – 0.001 eV	28	1

Sphere of graphite (p=2.26 g/cm3) C^{12} R= 10 cm

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

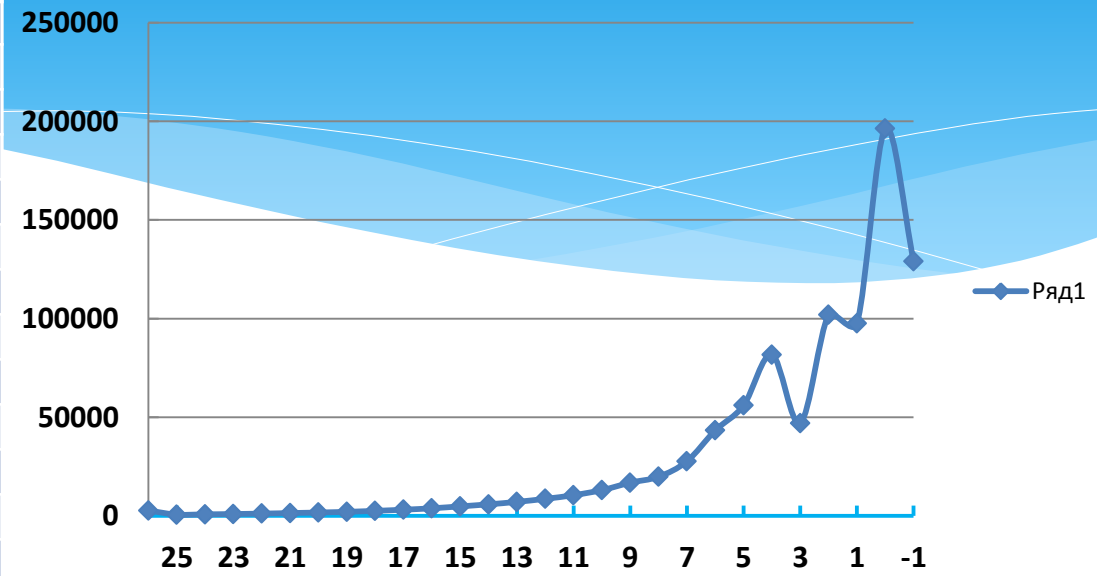


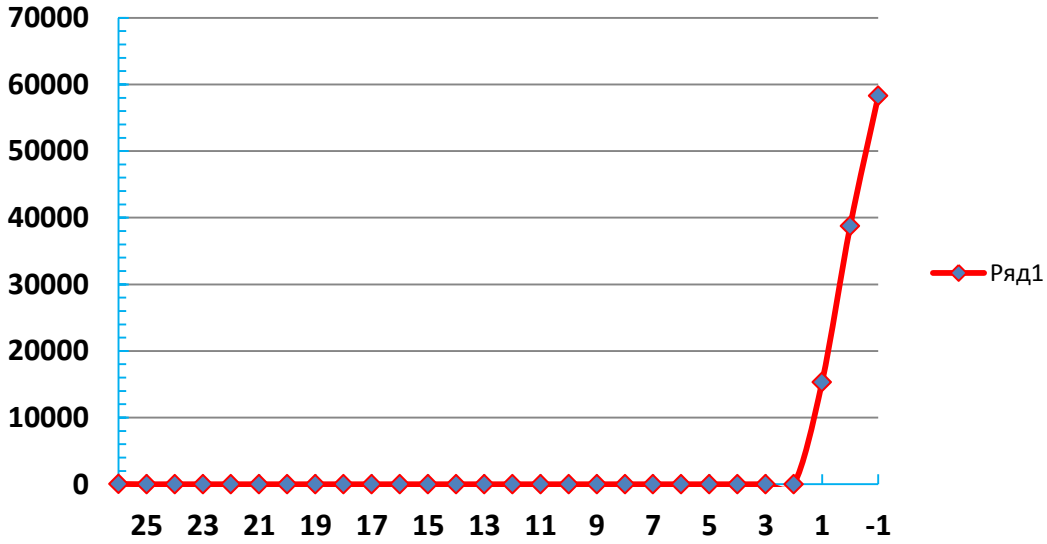


ABBN-78 Group №	Energy interval	Outgoing spectrum	Capture spectrum
-1	14.5-14.0 MeV	129018	58304
0	14.0-10.5 MeV	196308	38736
1	10.5 – 6.5 MeV	97619	15294
2	6.5 – 4.0 MeV	101929	0
3	4.0 – 2.5 MeV	47005	0
4	2.5 – 1.4 MeV	81702	0
5	1.4 – 0.8 MeV	56003	0
6	0.8 – 0.4 MeV	43343	0
7	0.4 – 0.2 MeV	27642	0
8	0.2 – 0.1 MeV	19820	0
9	100 – 46.5 KeV	16797	0
10	46.5 – 21.5 KeV	13022	0
11	21.5 – 10 KeV	10461	0
12	10 – 4.65 KeV	8613	0
13	4.65 – 2.15 KeV	7074	0
14	2.15 – 1 KeV	5817	0
15	1 – 0.465 KeV	4792	1
16	465 – 215 eV	3820	2
17	215 – 100 eV	3106	0
18	100 – 46.5 eV	2523	0
19	46.5 – 21.5 eV	2022	0
20	21.5 – 10 eV	1685	0
21	10 – 4.65 eV	1393	1
22	4.65 – 2.15 eV	1131	1
23	2.15 – 1.0 eV	909	1
24	1.0 – 0.465 eV	759	4
25	0.465 – 0.215 eV	620	2
26	0.215 – 0.001 eV	2674	47

Sphere of graphite (p=2.26 g/cm3) C^{12} R= 15 cm

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

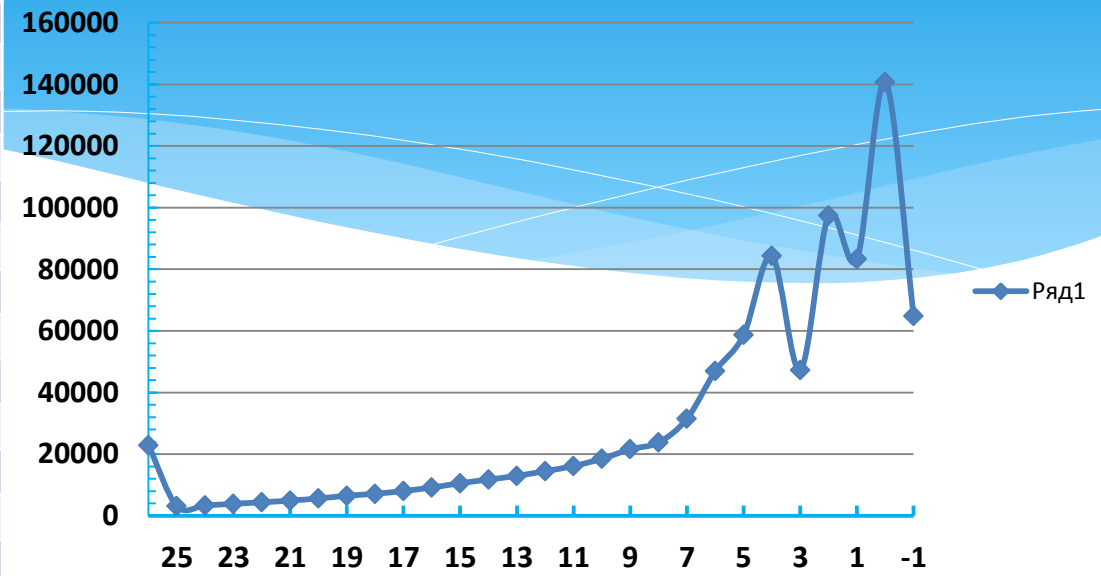


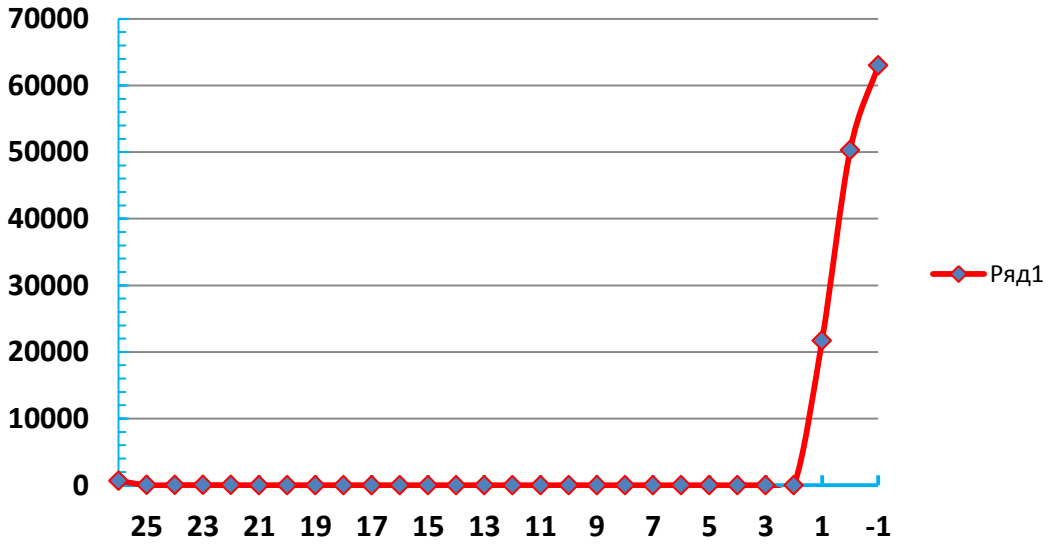


ABBN-78 Group №	Energy interval	Outgoing spectrum	Capture spectrum
-1	14.5-14.0 MeV	64846	63008
0	14.0-10.5 MeV	140756	50282
1	10.5 – 6.5 MeV	83333	21714
2	6.5 – 4.0 MeV	97411	0
3	4.0 – 2.5 MeV	47257	0
4	2.5 – 1.4 MeV	84329	0
5	1.4 – 0.8 MeV	58673	0
6	0.8 – 0.4 MeV	46944	0
7	0.4 – 0.2 MeV	31500	0
8	0.2 – 0.1 MeV	23803	0
9	100 – 46.5 KeV	21608	0
10	46.5 – 21.5 KeV	18508	0
11	21.5 – 10 KeV	16155	0
12	10 – 4.65 KeV	14505	0
13	4.65 – 2.15 KeV	12970	0
14	2.15 – 1 KeV	11769	0
15	1 – 0.465 KeV	10578	2
16	465 – 215 eV	9192	1
17	215 – 100 eV	8063	3
18	100 – 46.5 eV	7148	4
19	46.5 – 21.5 eV	6506	5
20	21.5 – 10 eV	5634	6
21	10 – 4.65 eV	4946	6
22	4.65 – 2.15 eV	4386	14
23	2.15 – 1.0 eV	3907	26
24	1.0 – 0.465 eV	3400	19
25	0.465 – 0.215 eV	3156	26
26	0.215 – 0.001 eV	22939	662

Sphere of graphite (p=2.26 g/cm3) C^{12} R= 20 cm

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

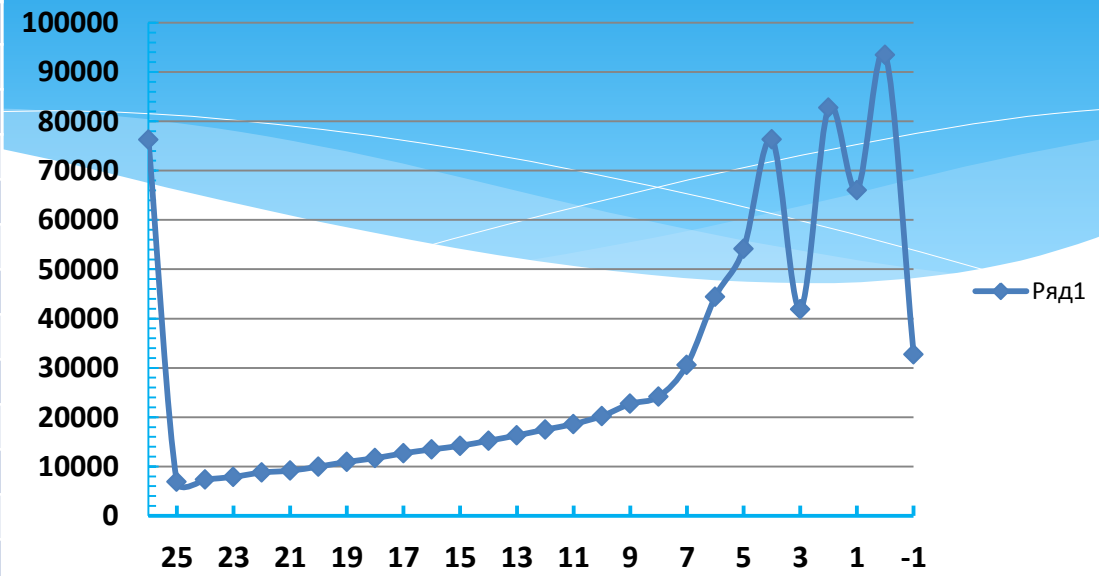


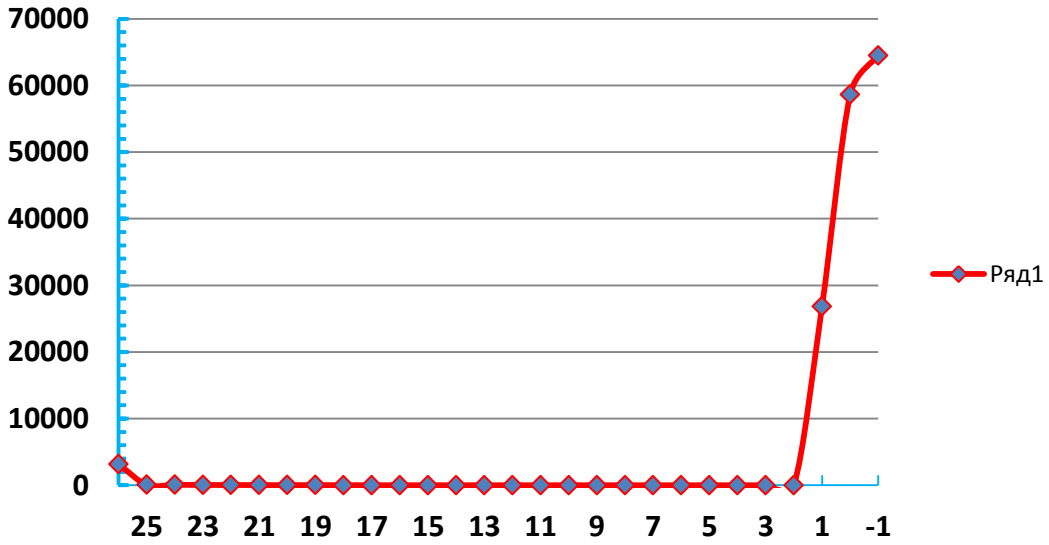


ABBN-78 Group №	Energy interval	Outgoing spectrum	Capture spectrum
-1	14.5-14.0 MeV	32711	64496
0	14.0-10.5 MeV	93513	58606
1	10.5 – 6.5 MeV	66047	26845
2	6.5 – 4.0 MeV	82755	0
3	4.0 – 2.5 MeV	41872	0
4	2.5 – 1.4 MeV	76360	0
5	1.4 – 0.8 MeV	54136	0
6	0.8 – 0.4 MeV	44416	0
7	0.4 – 0.2 MeV	30621	0
8	0.2 – 0.1 MeV	24183	0
9	100 – 46.5 KeV	22715	0
10	46.5 – 21.5 KeV	20243	0
11	21.5 – 10 KeV	18614	0
12	10 – 4.65 KeV	17497	0
13	4.65 – 2.15 KeV	16301	0
14	2.15 – 1 KeV	15226	2
15	1 – 0.465 KeV	14201	3
16	465 – 215 eV	13467	4
17	215 – 100 eV	12691	6
18	100 – 46.5 eV	11686	11
19	46.5 – 21.5 eV	10940	15
20	21.5 – 10 eV	9972	16
21	10 – 4.65 eV	9159	23
22	4.65 – 2.15 eV	8777	34
23	2.15 – 1.0 eV	7909	39
24	1.0 – 0.465 eV	7392	68
25	0.465 – 0.215 eV	6938	80
26	0.215 – 0.001 eV	76253	3157

Sphere of graphite (p=2.26 g/cm3) C^{12} R= 25 cm

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

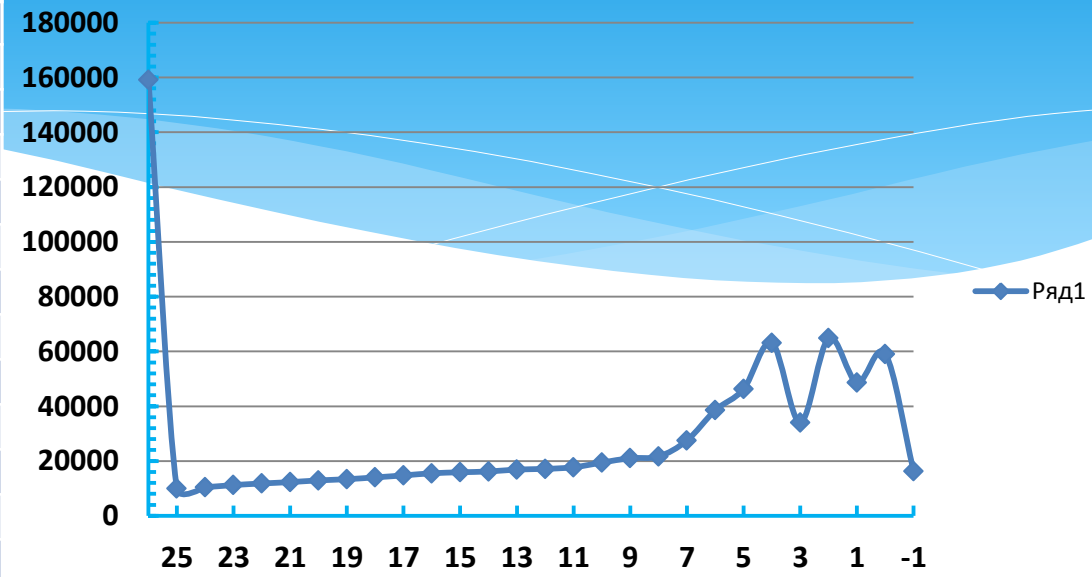


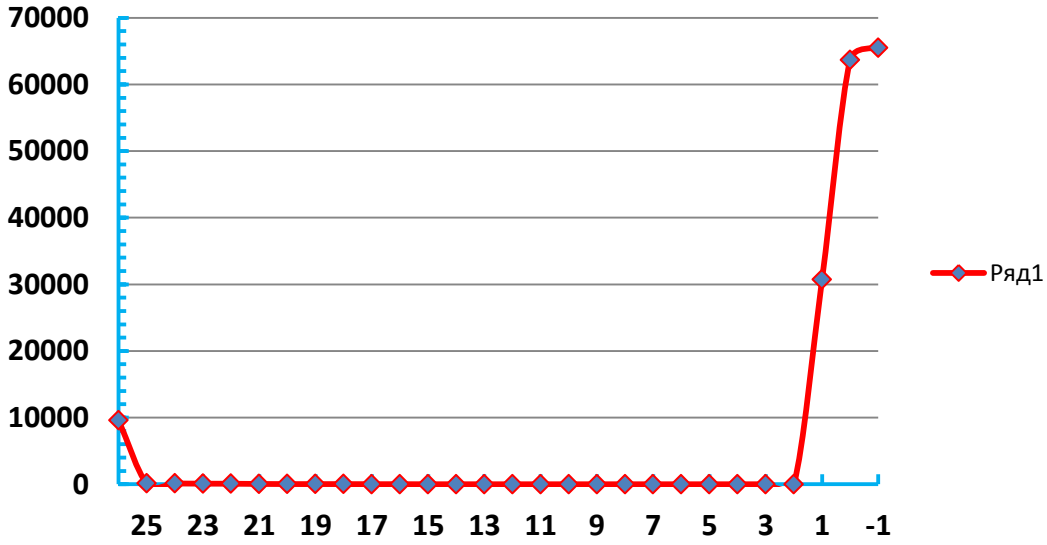


ABBN-78 Group №	Energy interval	Outgoing spectrum	Capture spectrum
-1	14.5-14.0 MeV	16278	65504
0	14.0-10.5 MeV	59089	63680
1	10.5 – 6.5 MeV	48647	30720
2	6.5 – 4.0 MeV	64849	0
3	4.0 – 2.5 MeV	34028	0
4	2.5 – 1.4 MeV	63188	0
5	1.4 – 0.8 MeV	46285	0
6	0.8 – 0.4 MeV	38548	0
7	0.4 – 0.2 MeV	27491	0
8	0.2 – 0.1 MeV	21655	0
9	100 – 46.5 KeV	21048	0
10	46.5 – 21.5 KeV	19422	0
11	21.5 – 10 KeV	17730	0
12	10 – 4.65 KeV	17125	0
13	4.65 – 2.15 KeV	16894	0
14	2.15 – 1 KeV	16186	2
15	1 – 0.465 KeV	15899	2
16	465 – 215 eV	15526	12
17	215 – 100 eV	14750	12
18	100 – 46.5 eV	14030	24
19	46.5 – 21.5 eV	13364	23
20	21.5 – 10 eV	12929	28
21	10 – 4.65 eV	12307	46
22	4.65 – 2.15 eV	11799	78
23	2.15 – 1.0 eV	11238	88
24	1.0 – 0.465 eV	10445	117
25	0.465 – 0.215 eV	10026	141
26	0.215 – 0.001 eV	159154	9593

Sphere of graphite (p=2.26 g/cm3) C^{12} R= 30 cm

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

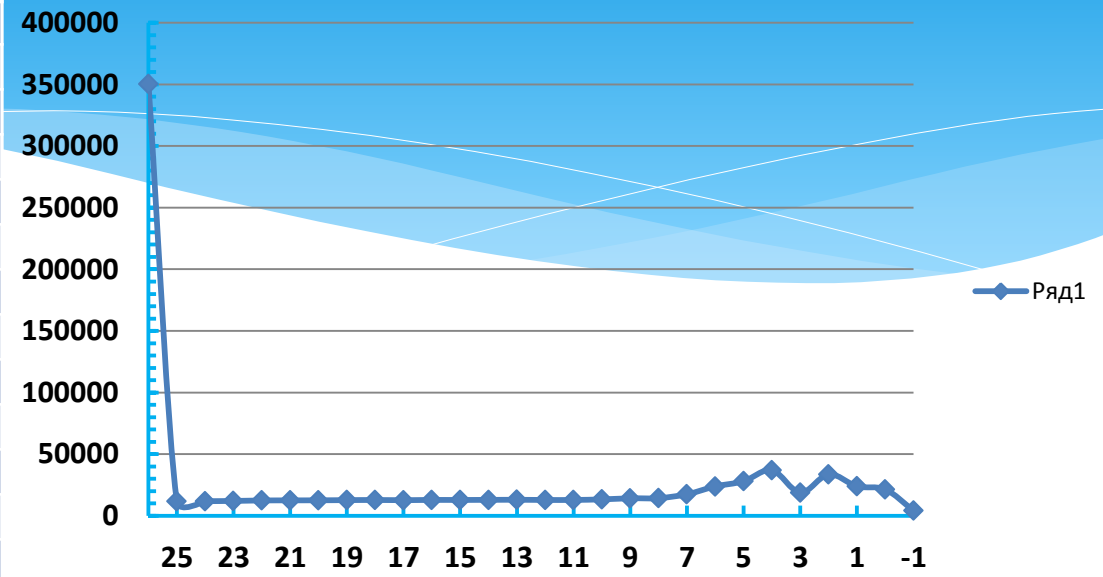


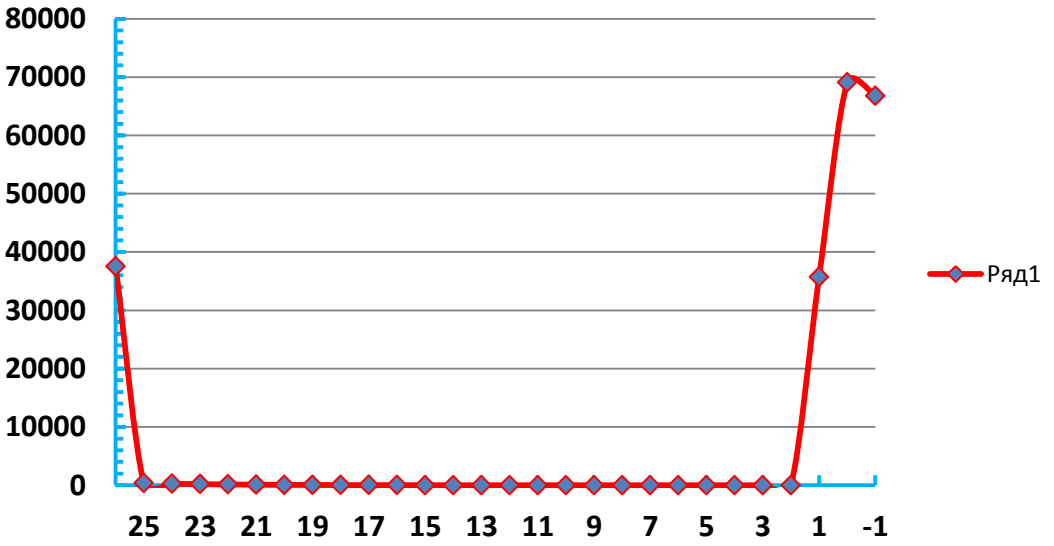


ABBN-78 Group №	Energy interval	Outgoing spectrum	Capture spectrum
-1	14.5-14.0 MeV	4167	66796
0	14.0-10.5 MeV	21384	69082
1	10.5 – 6.5 MeV	23925	35723
2	6.5 – 4.0 MeV	33686	0
3	4.0 – 2.5 MeV	18747	0
4	2.5 – 1.4 MeV	37010	0
5	1.4 – 0.8 MeV	28040	0
6	0.8 – 0.4 MeV	23844	0
7	0.4 – 0.2 MeV	17488	0
8	0.2 – 0.1 MeV	14324	0
9	100 – 46.5 KeV	14215	0
10	46.5 – 21.5 KeV	13335	0
11	21.5 – 10 KeV	12868	0
12	10 – 4.65 KeV	12854	0
13	4.65 – 2.15 KeV	13021	0
14	2.15 – 1 KeV	12946	4
15	1 – 0.465 KeV	12866	11
16	465 – 215 eV	12901	22
17	215 – 100 eV	12687	23
18	100 – 46.5 eV	12841	31
19	46.5 – 21.5 eV	12727	49
20	21.5 – 10 eV	12593	65
21	10 – 4.65 eV	12524	96
22	4.65 – 2.15 eV	12460	138
23	2.15 – 1.0 eV	12069	191
24	1.0 – 0.465 eV	11893	263
25	0.465 – 0.215 eV	11894	372
26	0.215 – 0.001 eV	350289	37536

Sphere of graphite (p=2.26 g/cm3) C^{12} R= 40 cm

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

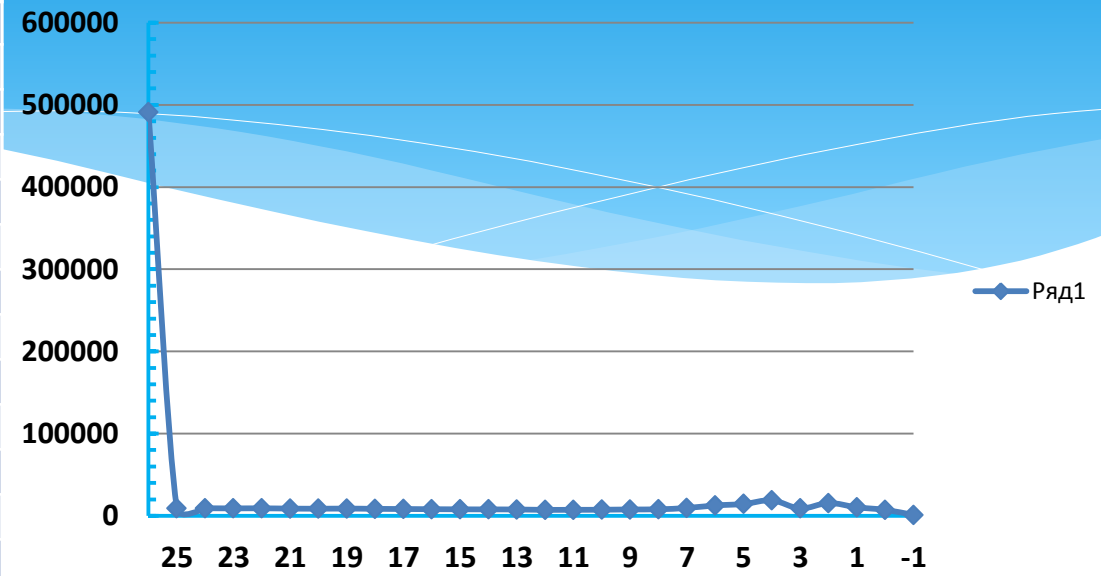


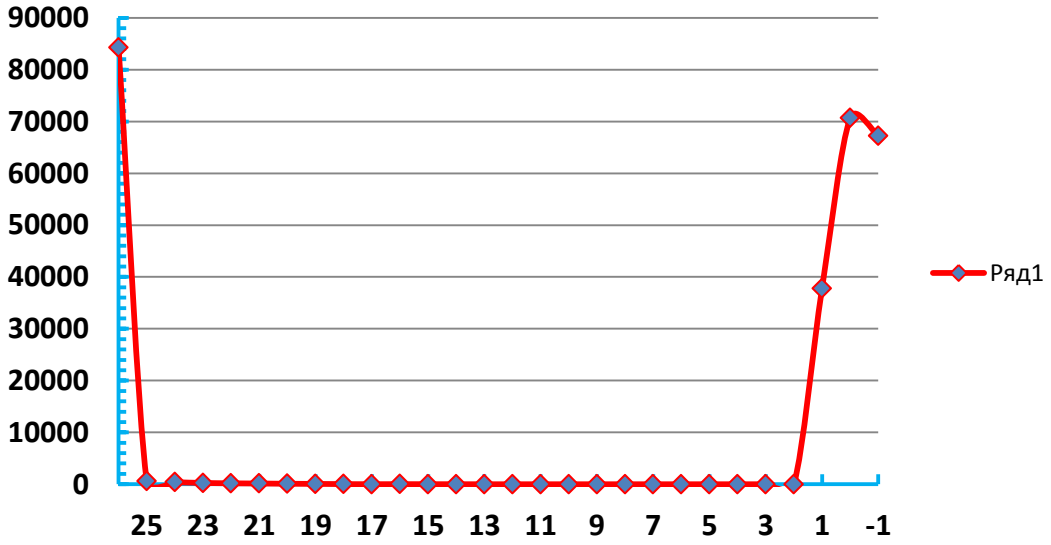


ABBN-78 Group №	Energy interval	Outgoing spectrum	Capture spectrum
-1	14.5-14.0 MeV	1020	67220
0	14.0-10.5 MeV	7209	70661
1	10.5 – 6.5 MeV	10346	37775
2	6.5 – 4.0 MeV	15545	0
3	4.0 – 2.5 MeV	8942	0
4	2.5 – 1.4 MeV	18803	0
5	1.4 – 0.8 MeV	14393	0
6	0.8 – 0.4 MeV	12629	0
7	0.4 – 0.2 MeV	9547	0
8	0.2 – 0.1 MeV	7922	0
9	100 – 46.5 KeV	7744	0
10	46.5 – 21.5 KeV	7395	0
11	21.5 – 10 KeV	7331	0
12	10 – 4.65 KeV	7256	0
13	4.65 – 2.15 KeV	7702	0
14	2.15 – 1 KeV	7799	9
15	1 – 0.465 KeV	7909	12
16	465 – 215 eV	8048	20
17	215 – 100 eV	8270	12
18	100 – 46.5 eV	8476	30
19	46.5 – 21.5 eV	8819	68
20	21.5 – 10 eV	8639	97
21	10 – 4.65 eV	8781	142
22	4.65 – 2.15 eV	9137	181
23	2.15 – 1.0 eV	9040	251
24	1.0 – 0.465 eV	9218	399
25	0.465 – 0.215 eV	9291	593
26	0.215 – 0.001 eV	491072	84247

Sphere of graphite (p=2.26 g/cm3) C^{12} R= 50 cm

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

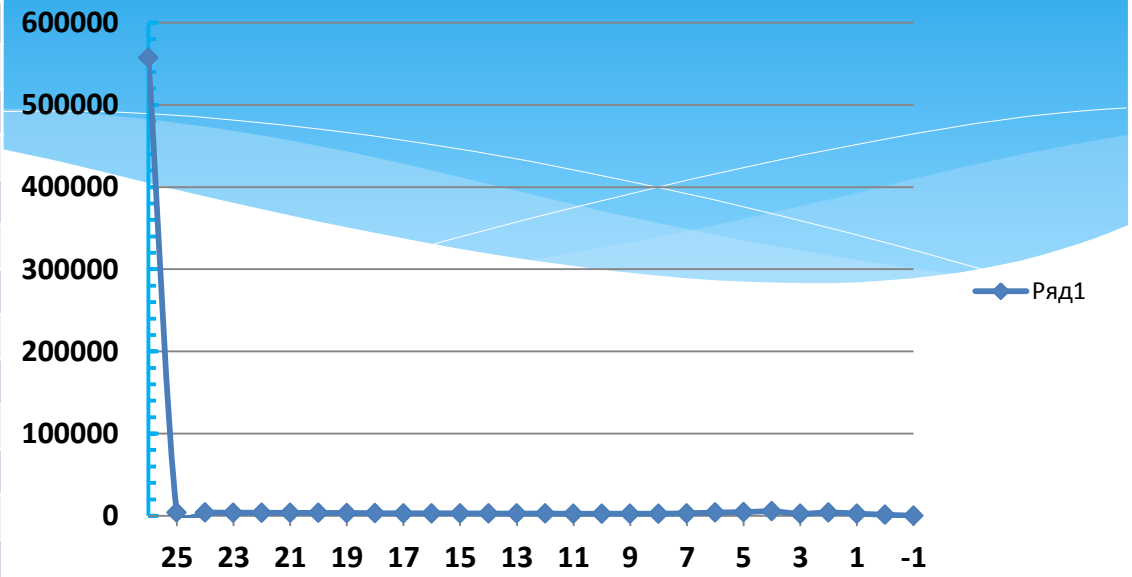


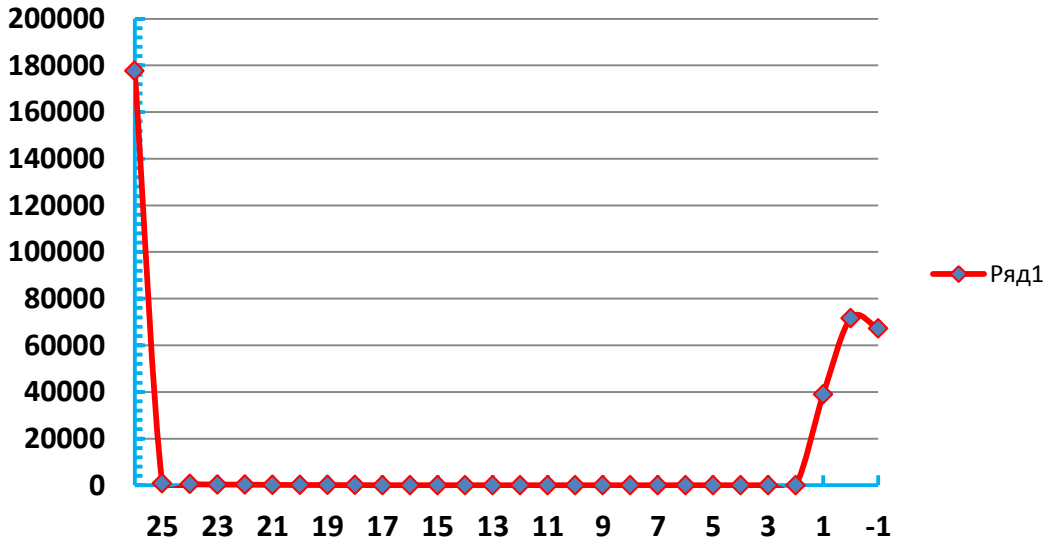


ABBN-78 Group №	Energy interval	Outgoing spectrum	Capture spectrum
-1	14.5-14.0 MeV	129	67269
0	14.0-10.5 MeV	1296	71634
1	10.5 – 6.5 MeV	2669	38939
2	6.5 – 4.0 MeV	4065	0
3	4.0 – 2.5 MeV	2555	0
4	2.5 – 1.4 MeV	5503	0
5	1.4 – 0.8 MeV	4501	0
6	0.8 – 0.4 MeV	3977	0
7	0.4 – 0.2 MeV	3078	0
8	0.2 – 0.1 MeV	2582	0
9	100 – 46.5 KeV	2649	0
10	46.5 – 21.5 KeV	2552	0
11	21.5 – 10 KeV	2531	0
12	10 – 4.65 KeV	2741	0
13	4.65 – 2.15 KeV	2727	0
14	2.15 – 1 KeV	2796	5
15	1 – 0.465 KeV	3014	20
16	465 – 215 eV	3074	21
17	215 – 100 eV	3091	31
18	100 – 46.5 eV	3156	46
19	46.5 – 21.5 eV	3462	79
20	21.5 – 10 eV	3509	121
21	10 – 4.65 eV	3592	157
22	4.65 – 2.15 eV	3769	259
23	2.15 – 1.0 eV	3855	308
24	1.0 – 0.465 eV	3979	454
25	0.465 – 0.215 eV	4233	727
26	0.215 – 0.001 eV	557249	177596

Sphere of graphite (p=2.26 g/cm3) C^{12} R= 65 cm

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

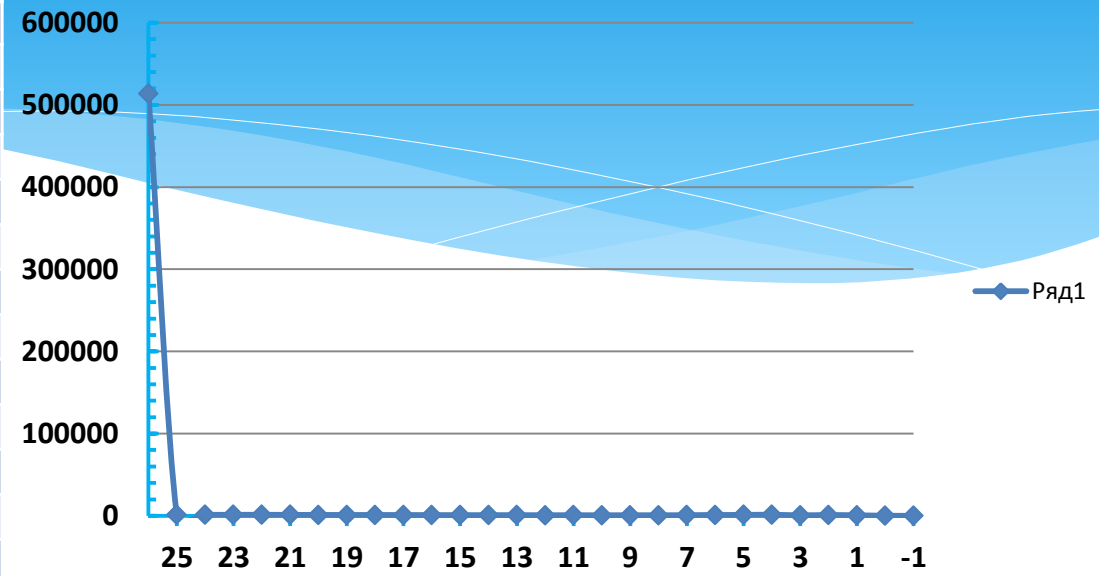


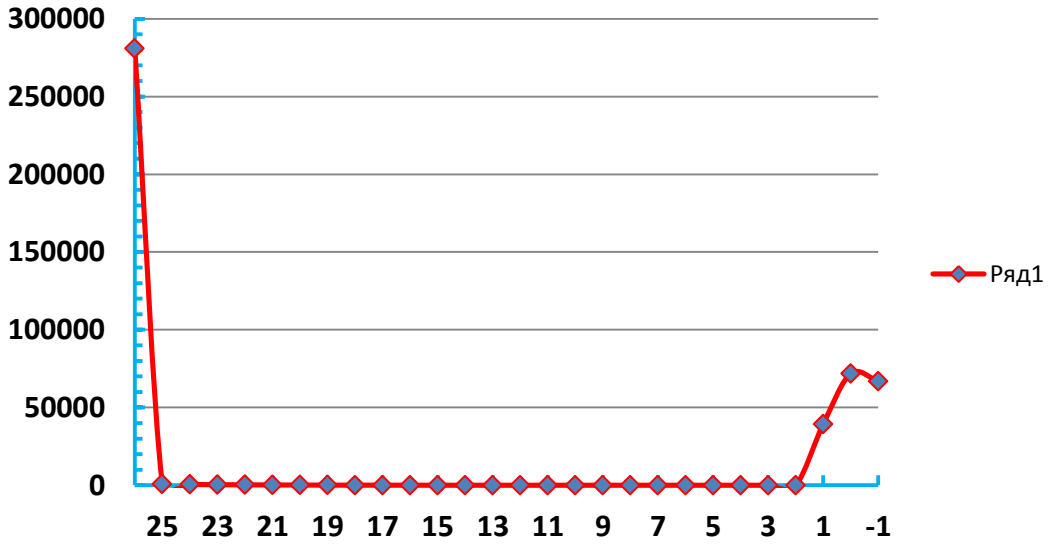


ABBN-78 Group №	Energy interval	Outgoing spectrum	Capture spectrum
-1	14.5-14.0 MeV	17	66876
0	14.0-10.5 MeV	183	71870
1	10.5 – 6.5 MeV	643	39304
2	6.5 – 4.0 MeV	1030	0
3	4.0 – 2.5 MeV	621	0
4	2.5 – 1.4 MeV	1364	0
5	1.4 – 0.8 MeV	1150	0
6	0.8 – 0.4 MeV	1038	0
7	0.4 – 0.2 MeV	807	0
8	0.2 – 0.1 MeV	725	0
9	100 – 46.5 KeV	749	0
10	46.5 – 21.5 KeV	691	0
11	21.5 – 10 KeV	768	0
12	10 – 4.65 KeV	749	0
13	4.65 – 2.15 KeV	834	0
14	2.15 – 1 KeV	820	10
15	1 – 0.465 KeV	879	16
16	465 – 215 eV	910	26
17	215 – 100 eV	1019	38
18	100 – 46.5 eV	1024	57
19	46.5 – 21.5 eV	1074	78
20	21.5 – 10 eV	1106	130
21	10 – 4.65 eV	1147	187
22	4.65 – 2.15 eV	1312	275
23	2.15 – 1.0 eV	1233	367
24	1.0 – 0.465 eV	1289	565
25	0.465 – 0.215 eV	1434	805
26	0.215 – 0.001 eV	513917	280863

Sphere of graphite (p=2.26 g/cm3) C^{12} R= 80 cm

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

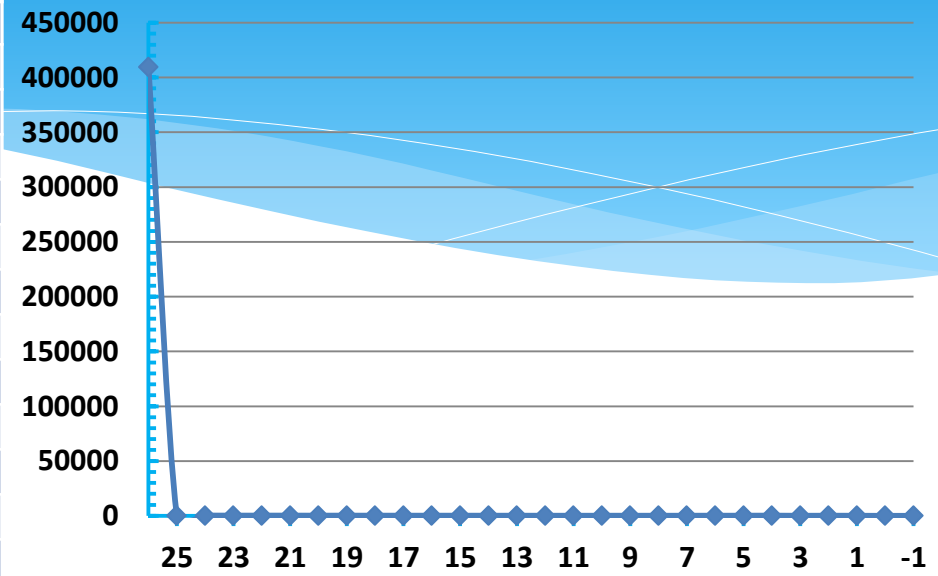


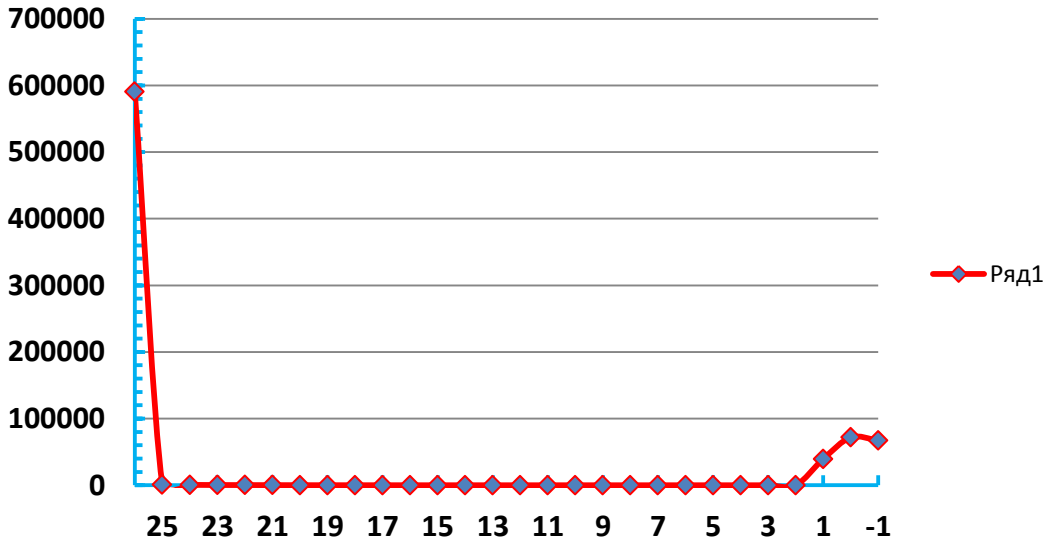


ABBN-78 Group №	Energy interval	Outgoing spectrum	Capture spectrum
-1	14.5-14.0 MeV	0	67073
0	14.0-10.5 MeV	15	71857
1	10.5 – 6.5 MeV	79	39486
2	6.5 – 4.0 MeV	122	0
3	4.0 – 2.5 MeV	72	0
4	2.5 – 1.4 MeV	195	0
5	1.4 – 0.8 MeV	153	0
6	0.8 – 0.4 MeV	124	0
7	0.4 – 0.2 MeV	115	0
8	0.2 – 0.1 MeV	95	0
9	100 – 46.5 KeV	115	0
10	46.5 – 21.5 KeV	111	0
11	21.5 – 10 KeV	98	0
12	10 – 4.65 KeV	110	0
13	4.65 – 2.15 KeV	124	0
14	2.15 – 1 KeV	133	10
15	1 – 0.465 KeV	150	13
16	465 – 215 eV	144	25
17	215 – 100 eV	150	41
18	100 – 46.5 eV	175	51
19	46.5 – 21.5 eV	191	77
20	21.5 – 10 eV	183	133
21	10 – 4.65 eV	221	188
22	4.65 – 2.15 eV	220	265
23	2.15 – 1.0 eV	217	359
24	1.0 – 0.465 eV	266	560
25	0.465 – 0.215 eV	257	820
26	0.215 – 0.001 eV	409606	590394

Sphere of graphite (p=2.26 g/cm3) C^{12} R= 100cm

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





Spectrums in graphite (p=2.26 g/cm3) C^{12} 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	872291	8441	504962	33060	254733	49511	129018	58304	64846	63008	32711	64496
0	14.0-10.5 MeV	69757	428	219675	8464	242671	24083	196308	38736	140756	50282	93513	58606
1	10.5-6.5 MeV	20476	136	74214	2655	99406	8460	97619	15294	83333	21714	66047	26845
2	6.5-4.0 MeV	5067	0	41273	0	83829	0	101929	0	97411	0	82755	0
3	4.0-2.5 MeV	4886	0	21492	0	38228	0	47005	0	47257	0	41872	0
4	2.5-1.4 MeV	7960	0	37456	0	66182	0	81702	0	84329	0	76360	0
5	1.4-0.8 MeV	5536	0	25204	0	44184	0	56003	0	58673	0	54136	0
6	0.8-0.4 MeV	3312	0	17174	0	32629	0	43343	0	46944	0	44416	0
7	0.4-0.2 MeV	1180	0	7996	0	19000	0	27642	0	31500	0	30621	0
8	0.2-0.1 MeV	376	0	3704	0	11957	0	19820	0	23803	0	24183	0
9	100-46.5 KeV	148	0	1693	0	8471	0	16797	0	21608	0	22715	0
10	46.5 –21.5 KeV	6	0	623	0	5584	0	13022	0	18508	0	20243	0
11	21.5– 10 KeV	0	0	238	0	3636	0	10461	0	16155	0	18614	0
12	10– 4.65 KeV	0	0	76	0	2432	0	8613	0	14505	0	17497	0
13	4.65– 2.15 KeV	0	0	20	0	1608	0	7074	0	12970	0	16301	0
14	2.15 – 1 KeV	0	0	14	0	1116	0	5817	0	11769	0	15226	2
15	1– 0.465 KeV	0	0	6	0	742	0	4792	1	10578	2	14201	3
16	465– 215 eV	0	0	1	0	511	0	3820	2	9192	1	13467	4
17	215– 100 eV	0	0	0	0	315	0	3106	0	8063	3	12691	6
18	100– 46.5 eV	0	0	0	0	239	0	2523	0	7148	4	11686	11
19	46.5– 21.5 eV	0	0	0	0	163	0	2022	0	6506	5	10940	15
20	21.5– 10 eV	0	0	0	0	107	0	1685	0	5634	6	9972	16
21	10– 4.65 eV	0	0	0	0	71	0	1393	1	4946	6	9159	23
22	4.6 – 2.15 eV	0	0	0	0	49	0	1131	1	4386	14	8777	34
23	2.1 – 1.0 eV	0	0	0	0	24	0	909	1	3907	26	7909	39
24	1.0– 0.465 eV	0	0	0	0	16	0	759	4	3400	19	7392	68
25	0.46 – 0.215 eV	0	0	0	0	14	0	620	2	3156	26	6938	80
26	0.215– 0.001 eV	0	0	0	0	28	1	2674	47	22939	662	76253	3157
Average Neutron Energy		13.51 MeV	13.97 MeV	11.47 MeV	13.53 MeV	9.03 MeV	13.14 MeV	6.83 MeV	12.86 MeV	4.99 MeV	12.60 MeV	3.53 MeV	12.25 MeV
Diffusion/Absorption time of spectra, nanoseconds		0.21	0.098	1.67	0.52	14.13	1.58	444.99	44.00	4500	741.72	19818	4281
Number of neutrons		990995	9005	955821	44179	917945	82055	887607	112393	864222	135778	846595	153405

Spectrums in graphite (p=2.26 g/cm3) C^{12} 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	16278	65504	4167	66796	1020	67220	129	67269	17	66876	0	67073
0	14.0-10.5 MeV	59089	63680	21384	69082	7209	70661	1296	71634	183	71870	15	71857
1	10.5-6.5 MeV	48647	30720	23925	35723	10346	37775	2669	38939	643	39304	79	39486
2	6.5-4.0 MeV	64849	0	33686	0	15545	0	4065	0	1030	0	122	0
3	4.0-2.5 MeV	34028	0	18747	0	8942	0	2555	0	621	0	72	0
4	2.5-1.4 MeV	63188	0	37010	0	18803	0	5503	0	1364	0	195	0
5	1.4-0.8 MeV	46285	0	28040	0	14393	0	4501	0	1150	0	153	0
6	0.8-0.4 MeV	38548	0	23844	0	12629	0	3977	0	1038	0	124	0
7	0.4-0.2 MeV	27491	0	17488	0	9547	0	3078	0	807	0	115	0
8	0.2-0.1 MeV	21655	0	14324	0	7922	0	2582	0	725	0	95	0
9	100-46.5 KeV	21048	0	14215	0	7744	0	2649	0	749	0	115	0
10	46.5 –21.5 KeV	19422	0	13335	0	7395	0	2552	0	691	0	111	0
11	21.5– 10 KeV	17730	0	12868	0	7331	0	2531	0	768	0	98	0
12	10– 4.65 KeV	17125	0	12854	0	7256	0	2741	0	749	0	110	0
13	4.65– 2.15 KeV	16894	0	13021	0	7702	0	2727	0	834	0	124	0
14	2.15 – 1 KeV	16186	2	12946	4	7799	9	2796	5	820	10	133	10
15	1– 0.465 KeV	15899	2	12866	11	7909	12	3014	20	879	16	150	13
16	465– 215 eV	15526	12	12901	22	8048	20	3074	21	910	26	144	25
17	215– 100 eV	14750	12	12687	23	8270	12	3091	31	1019	38	150	41
18	100– 46.5 eV	14030	24	12841	31	8476	30	3156	46	1024	57	175	51
19	46.5– 21.5 eV	13364	23	12727	49	8819	68	3462	79	1074	78	191	77
20	21.5– 10 eV	12929	28	12593	65	8639	97	3509	121	1106	130	183	133
21	10– 4.65 eV	12307	46	12524	96	8781	142	3592	157	1147	187	221	188
22	4.6 – 2.15 eV	11799	78	12460	138	9137	181	3769	259	1312	275	220	265
23	2.1 – 1.0 eV	11238	88	12069	191	9040	251	3855	308	1233	367	217	359
24	1.0– 0.465 eV	10445	117	11893	263	9218	399	3979	454	1289	565	266	560
25	0.46 – 0.215 eV	10026	141	11894	372	9291	593	4233	727	1434	805	257	820
26	0.215– 0.001 eV	159154	9593	350289	37536	491072	84247	557249	177596	513917	280863	409606	590394
Average Neutron Energy		2.43 MeV	11.69 MeV	1.10 MeV	10.05 MeV	484 KeV	8.24 MeV	135 KeV	6.09 MeV	36.52 KeV	4.72 MeV	5.66 KeV	3.70 MeV
Diffusion/Absorption time of spectra, nanoseconds		54444	15202	199367	77014	444274	202405	957056	476478	1585213	809223	2519006	1265172
Number of neutrons		829930	170070	789598	210402	738283	261717	642334	357666	538533	461467	409606	590394

Precision of the calculated data

Authors are interested to define precision of our calculated data, both present work describing neutron fluxes in spheres of $\mathbf{Ta^{181}}$, $\mathbf{Ni^{nat}}$, $\mathbf{C^{12}}$ and already published data [8] for $\mathbf{B^{10}}$, $\mathbf{Ti^{nat}}$, $\mathbf{U^{238}}$, also as [7] which describes propagation of neutron fluxes in natural isotope composition metal spheres of tungsten 74$\mathbf{W^{nat}}$, steel 26$\mathbf{Fe^{nat}}$, and sodium isotope $\mathbf{Na^{23}}$.

For this purpose, we emphasized attention to value of neutron multiplication coefficient in infinitely large area of $\mathbf{U^{238}}$ for one neutron generation with fission spectrum. This important value was measured in plenty experiments with high precision and is [3, p.116] equal to 1.174.

ABBN-78 Group №	Energy interval of energy group, MeV	Neutrons of initial fission spectrum in energy group	Sum of neutrons in all captured spectrum, produced by initial neutrons of this energy group
-1	14.0-14.5	0	---
0	10.5-14.0	0	---
1	6.5-10.5	16,000	36,305
2	4.0-6.5	87,000	141,857
3	2,5-4.0	183,000	272,458
4	1.4-2.5	269,000	358,062
5	0.8-1.4	203,000	210,917
6	0.4-0.8	142,000	142,284
7	0.2-0.4	61,000	61,005
8	0.1-0.2	25,000	25,000
9	0.0465-0.1	9,000	9,000
10	0.0215-0.0465	3,000	3,000
11	0.01-0.0215	1,000	1,000
12	0.00465-0.01	1,000	1,000
Sum of all groups	14 Mev-10 keV	1,000,000	1,261,915

Check inside 1 meter sphere of nominal density U^{238} for fission neutron spectrum multiplication, showed, that initial neutron flux multiplied into 1.261915 times. Statistical precision for 1,000,000 neutrons of initial fission spectrum is better than share of delayed neutrons. Calculated leakage for central neutron source in R=1 meter U^{238} metal sphere is equal to 0.0031%.

It's necessary to mention, that we observe sum of all neutron generations i.e. sum of infinite geometry progression, case with K<1:

Sum = 1.261915 = 1/(1-K)

thus, K= 0.208 and for capture of single neutron generation we have multiplication **1.208** times. Instead of experimental value **1.174** with difference **0.034** absolute units.

At the same time, authors of ABBN-78 declare precision of group constants [3, p.109] equal to (**+0.04…-0.02**) absolute units.

Thus, precision of our calculated data was found inside interval of precision, which has implemented neutron group constants value, which is declared by it's authors.

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 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 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]. Present work prepares calculated spectrums to compare 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.

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.

5.

With statistics around 1,000,000 neutrons, providing discreteness calculation precision component better than value of delayed neutron's share, performance of the program allows to calculate big quantity of variants using modern personal computer.

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Thank you for your attention!