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EMISSION OF LONG - RANGE CHARGED PARTICLES IN THE FISSION OF ^{235}U INDUCED BY THERMAL NEUTRONS

EMISJA DŁUGOZASIĘGOWYCH CZĄSTEK NAŁADOWANYCH PRZY ROZSZCZEPIENIU ^{235}U PRZEZ NEUTRONY TERMICZNE

ЭМИССИЯ ДЛИННОПРОБЕЖНЫХ ЗАРЯЖЕННЫХ ЧАСТИЦ ПРИ ДЕЛЕНИИ ^{235}U ТЕПЛОВЫМИ НЕЙТРОНАМИ

by
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Abstract

The relative intensities of light particles /protons, deuterons, tritons and helium-six/ associated with thermal neutron fission of ^{235}U were measured. Also events were observed which have been attributed to the heavier nuclei like helium-eight, lithium and beryllium.

Streszczenie

Zmierzono względne wydajności cząstek naładowanych /protonów, deuteronów, trytonów i ^{6}He/ emitowanych przy rozszczepieniu ^{235}U pod wpływem neutronów termicznych. Poza tym rejestrowano przypadki, które przypisano cięższym jądrom takim jak hel - 8, lit i beryl.

Аннотация

Измерялись относительные выходы заряженных частиц (протонов, дейтеронов, тритонов и ^{6}He), эмитированных при делении ^{235}U тепловыми нейтронами. Кроме того, регистрировались случаи, которые были приписаны более тяжелым ядрам таким как гелий - 8, литий и бериллий.

A two parameter analysis of the charged particles population associated with thermal neutron fission of ^{235}U has been performed by means of a semiconductor telescope. The presence of protons, deuterons, tritons and helium - six particles in the fission phenomenon was established. Also events which were attributed to the passage of heavier particles /like helium-eight, lithium and beryllium nuclei/ through the telescope counter have been observed. The results of previous experiments made by other authors in this field and the present one are presented in Table 1.

A schematic diagram of the experimental arrangement is shown in fig.1 The ^{235}U target was prepared by electro spraying deposition on a 200 ug/cm^2 thick aluminium foil. The total thickness of the uranium layer was about 1 mg/cm^2. The counter telescope consisted of two silicon detectors: a totally depleted of 40 μ thickness Δ E detector, followed by an E detector, depleted to a depth of 400 μ. For detection of particles with Z=1 a Δ E detector of 80 μ thickness and a 1,5 mm thick E detector were used. The diameter of the sensitive region in both detectors was 14 mm. The aluminium cover foil protecting the Δ E detector from fission fragments was 5.6 mg/cm^2 thick. The collimator was set before the Δ E detector for defining a more homogeneous region of that detector.

Amplified pulses from detectors were analysed by a two parameter pulse-hight analyser /40 x 40/.

One cycle of measurements consisted of two steps:

a. one run with the whole spectrum of neutrons from the reactor

b. one run with epi-cadmium neutrons.

The difference between the results of these two runs is the self effect arising from thermal neutron induced fission. The coincidence technique with heavy fragments was not applied for two reasons:

a. the coincidence measurements can change the relative yields because the angular distributions for other particles can differ from those for alpha particles.

b. the high negative Q values for all particles involved/besides some low energy protons/ exclude all others known nuclear phenomena as the sources of observed particles, except fission.

The two-parameter spectra shown in fig.2,3,4, represent examples of all particles observed in this experiment. The Δ E and E pulse heights are proportional correspondinaly to the ordinate and the abcissa of these two dimentional plots. The solid lines in these figures represent the loci for various particles calculated on the basis of the relation between the energy loss, Δ E, and the total energy of the particle. For these calculation tables "Range-Energy" based on the formula of Barkas [8] were used.

In fig.2 we can see the two parameter spectrum of protons, deuterons and tritons. The characteristic feature is the low /relatively to its isotopic neighbours/ yield of deutrons. The relative cross-sections for all particles are compiled in Tabel 1. The cover foil and the Δ E detector are cutting the low energy part of the spectra at E_{min}. This energy depends on the kind of particles. The Table 1 data are the values of cross-sections for the production of particles with an energy higher than E_{min}.

The two-parameter spectrum of particles with Z=2 is shown in fig.3. The distinctly separated isotopes ^{4}He, ^{6}He, ^{8}He can be seen. The "diffusion" of some of the relatively abundant α - particles into the region of the ^{3}He locus, is probably due to the channeling effect in the Δ E detectors. This phenomena masks effectively the presence of these rare ^{3}He particles. The measurements of particles with $Z > 2$ were performed in the same experimental arrangements, with an appropriate changed gains in "E" and "Δ E" lines. The two-parameter spectrum obtained in this case is displayed in fig.4. It can be seen that the registered particles lie along the loci for the lithium /Z=3/ and beryllium /Z=4/ isotopes. In a 123 hours run 73 events which can be attributed to ^{8}He have been observed and in a 58 hours run 99 events attributed to lithium and 27 to beryllium isotopes have been registered, Lack of other events permits to estime the upper limit of cross-sections for production of still heavier particles e.g. the boron nucleus with an energy higher than 45 MeV and a carbon nucleus with an energy higher than 55 MeV.

Events registered over the locus of ^{6}He one may attribute either to the emission of heavier nuclei or the simultaneous emission of some charged particles in the fission process. Such cases were observed using the emulsion technique [9, 10]. The simultaneous emission of a proton and an α-particle or a deuteron and an α-particle may be responsible for cases recognized by us as ^{8}He. The simultaneous emission or two α-particles may be registered as lithium, and three α-particles as beryllium [x/]. The evidence is as yet not conclusive what is the relative probability of these two processe.

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x/ The random coincidence /p, α /, /d, α /, and / α, α/ in this experiment was less than 1% from observed events.

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T a b l e I

particles	Intensity relative to emision of 100 α-particles			
	results of previous experiments		results of present experiment	
	^{235}U	^{252}Cf	^{235}U	E_{min} /MeV/
p	-	2,2 /1/	2	4,8
d	-	< 0,5 /1/	0,6	6
t	~5 /2/ 1,3 /3/	6 /1/ ~ 7,5 /4/ ~ 7,5 /5/	5,5	7
He^3	-	< 0,5 /1/	-	-
He^4	100	100	100	10
He^6	-	2 /6/	0,8	12
He^8	-	-	$9x10^{-3}$ *)	14
Li	-	-	$14x10^{-3}$ *)	19
Be	-	-	$4,2x10^{-3}$ *)	29
B	-	-	$< 2 \times 10^{-4}$	45
C	-	-	$< 2 \times 10^{-4}$	55

*) Assuming that all registered events ave attributed to heavy particles.

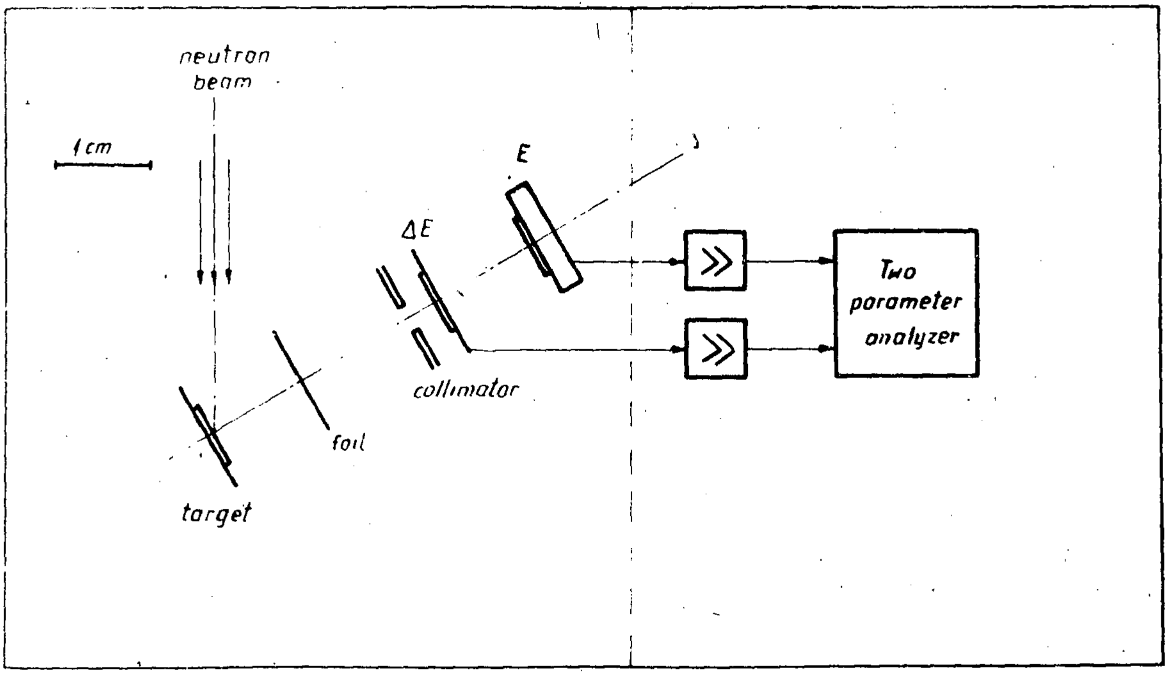

Fig. 1. A schematic diagram of the experimental arrangement

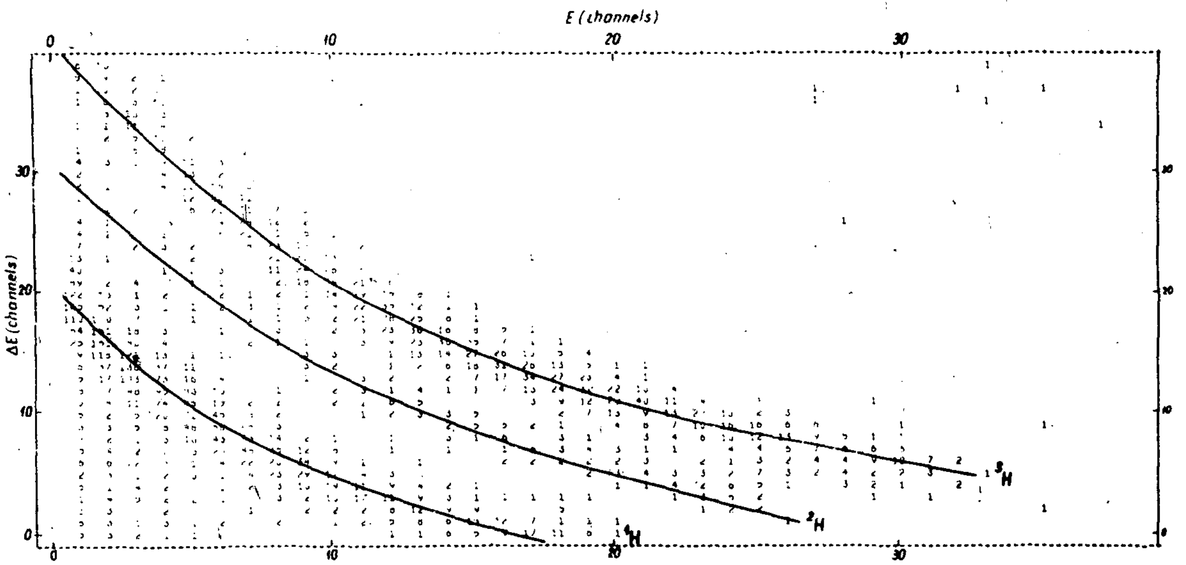

Fig. 2 The two-parameter spectrum for particles with Z = 1 /the ordinate - an energy loss in E detector; abcissa-energy registered in E detector/

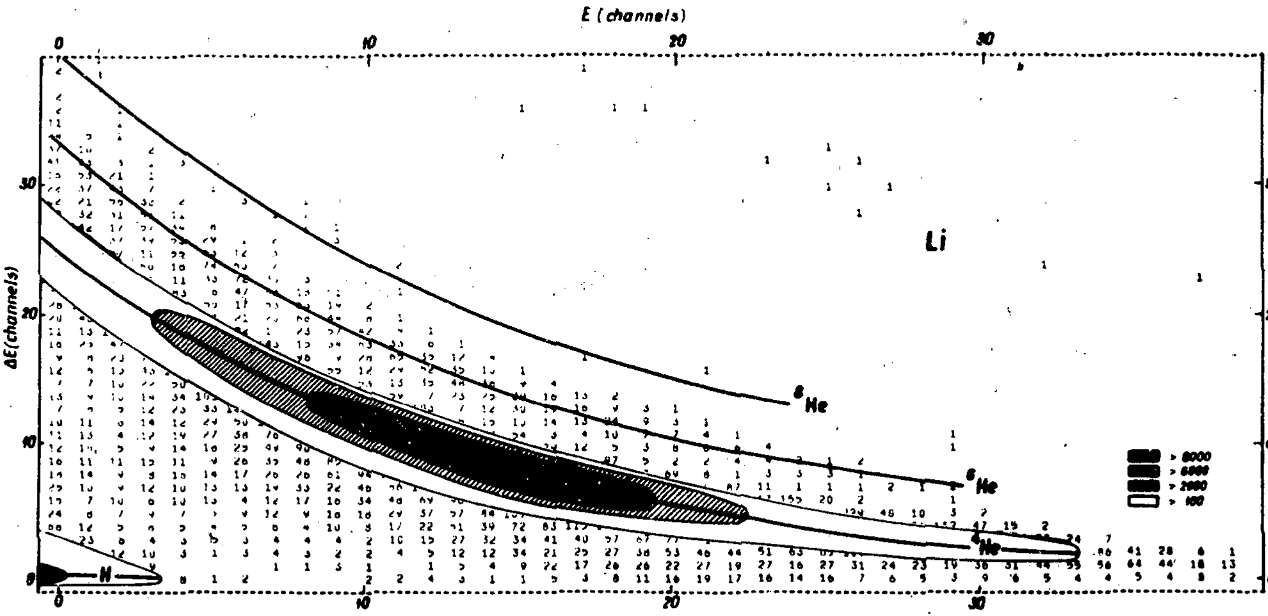

Fig. 3. The two-parameter spectrum for particles with Z = 2

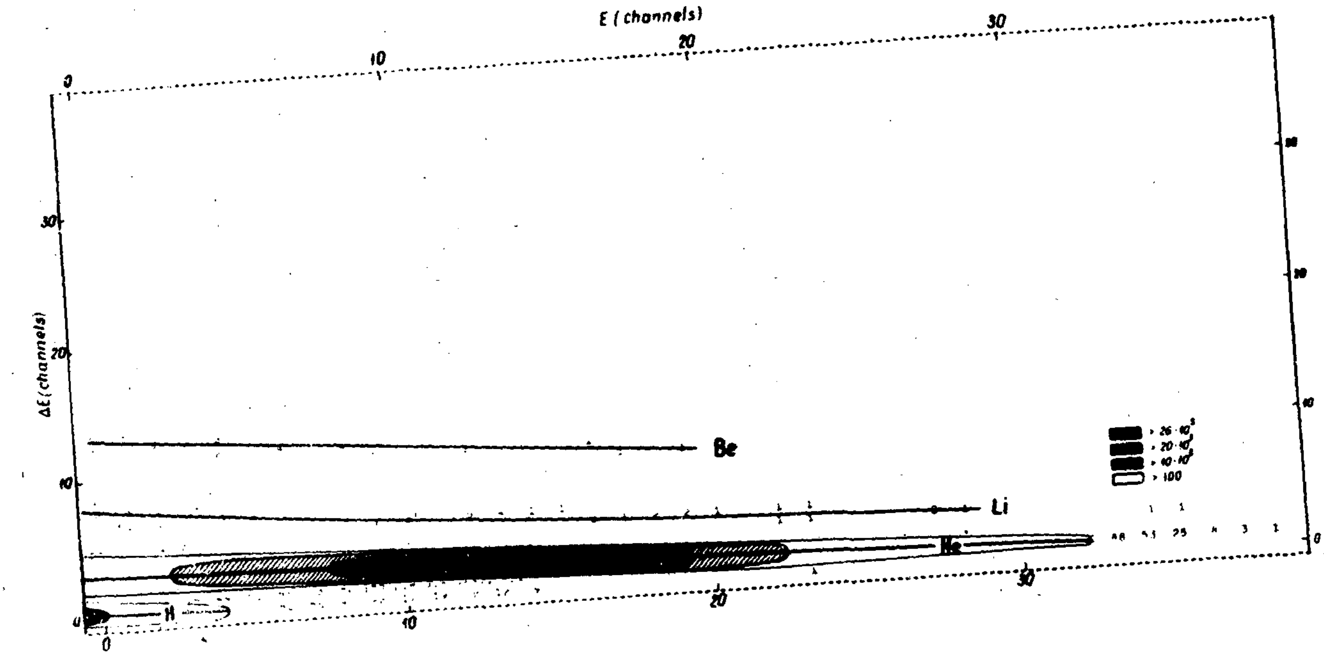

Fig. 4. The two-parameter spectrum for particles with Z $\geqslant$ 2