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ON THE POSSIBILITY OF HEAVY ION ACCELERATION AT THE INTERACTION OF HIGH ENERGY NUCLEONS WITH NUCLEI

Флеров Г.Н., Гангрский Ю.П., Орлова О.А.

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К вопросу о возможности ускорения тяжелых ионов при взаимодействии нуклонов высокой энергии с ядрами

Измерена верхняя граница сечения (2×10^{-33} см) образования ядер отдачи большой энергии при взаимодействии релятивистских нейтронов с ядрами тантала. Для регистрации ядер отдачи использовались пороговые диэлектрические детекторы.

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Flerov G.N., Gangrsky Yu.P., Orlova O.A.

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On the Possibility of Heavy Ion Acceleration at the Interaction of High Energy Nucleons with Nuclei

The upper limit of the production cross section of recoil nuclei in the interactions of relativistic neutrons with the tantalum target was measured.

Neutrons were received in the interaction of 76 GeV protons with Fe nuclei.

For detecting recoil nuclei and fission fragments mylar films were used.

The neutron flux passing through the target was estimated to be 10^{11} cm^{-2}. The target square was 44 cm^2.

The upper limit of the production cross section of recoil nuclei is estimated to be 2.10^{-33} cm^2.

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At the present time in a number of the laboratories the synthesis and study of transuranic element properties is being carried out. Two methods are being used for this purpose:

1) irradiation of heavy ions with neutron fluxes of high intensity;
2) bombarding of heavy nuclei with heavy ions of an energy sufficient for overlapping the Coulomb barrier.

The former method proved to be not effective enough, since it cannot be applied to produce elements with $Z > 101$. The rest of transuranic elements produced by now up to Ns($Z = 105$) have been synthesized using the latter method. All these elements were formed in the full fusion reaction between a target nucleus and a projectile followed with a few neutron evaporation. But it may be that the fission of excited superheavy nuclei with $Z \geqslant 150$ formed as the result of full fusion of U nuclei or U and Xe nuclei will be more promising /1/. Hence, for succes - sful work the synthesis of transuranic elements and, in particular, for reaching the stability island predicted by theorists in the region of $Z = 114$ it is necessary to have ions heavier than xenon with an energy higher than the Coulomb Barrier(for example, in the U + U reaction the Coulomb barrier energy is as high as 1.3 Bev).

However, there is no possibility to obtain intense fluxes of such ions in existing accelerators. Apparently, it will be possible in the near future. So, in Berkeley(USA) the reconstruction of the linear heavy ion accelerator(HILAC) is planned to be completed by 1972. High energy heavy ions up to U will be accelerated with this machine.

Of interest is the consideration of other methods of producing high energy heavy ions, in particular, relativistic particle scattering on heavy element nuclei. In the scattering of these particles to large angles a recoil nucleus receives a sufficiently high energy(e.g. a 30 Gev proton when being scattered to an angle of 180^{o} transfers to an uranium nucleus 11.8 Gev energy which is noticeably higher than the Coulomb barrier in the U + U reaction). It should be pointed out, that from the data on the high energy proton interaction with nucleons and nuclei a cross section of this process is expected to be very small. However, due to a long range of the relativistic particles in the matter one may hope to observe effects having extremely small cross sections.

Recently the experiments on the search for superheavy transuranic elements when using high energy protons were carried out in the Rutherford Laboratory(England) by Marinov et al./2/. They irradiated a tungsten target with 24 Gev protons at CERN synchrocyclotron and separated chemically fractions of different elements. A spontaneously fissioning emitter was detected in the mercury fraction. Since mercury does not undergo spontaneous fission, this source was ascribed by the authors of work/2/ to an element with atomic number 112, a chemical analogue of mercury, which could be a fission product of a superheavy nucleus obtained from the reaction of a target nucleus and a tungsten recoil nucleus. According to their estimate, to explain the observed yield of this spontaneously fissioning emitter the cross section for proton scattering to large angles with the transfer to a tungsten nucleus of an energy more than 1 Gev(which is the Coulomb barrier energy in the reaction W + W) should be not less than $10^{-30} cm^2$.

This method of production of transuranic elements could be of great importance and we carried out an experiment on measuring the production cross section of tantalum recoil nuclei at the scattering of high energy neutrons. The neutron beam was obtained at the interaction of 76 Gev protons accelerated in the IHEP synchrocyclotron (Serpukhov). The continuous neutron spectrum had a boundary energy of about 76 Gev(Fig. 2).
A set of 20 thick Ta foils was placed at the distance of 20 m from the target at 0^o angle to the proton beam. Such a geometry of the experiment allowed to use neutrons with the maximum energy, since these neutrons fly towards the proton beam, whereas neutrons of a small energy resulting from the cascade process, were more isotropically distributed.

Recoil nuclei were detected with dielectric detectors/3/ which were insensitive to ions with $Z \geqslant 20$. The high energy neutrons induced the fission of tungsten nuclei and fission fragments naturally made tracks on the detectors. To separate fission fragment tracks from those of recoil nuclei the use was made of the detector consisting of three 50μ Mylar films. Fission fragments which range is not longer than 15μ, make tracks only in the film placed in the vicinity of the tantalum foil. At the same time tantalum recoil nuclei with an energy over 1 Gev have a range longer than 50μ /4/ and should therefore make tracks in the second film too. However, the scanning of this film after its etching with the 20% NaOH solution provided no track which diameter would be equal to that of a track from a common fission fragment.

The neutron flux having passed through the tantalum foil was estimated from the known value of the proton beam as well as from the number of tracks on the film in the vicinity of tantalum. Besides, the fission fragment yield was estimated in the reaction of neutrons with Ag and U. The neutron integral flux calculated in this way amounted to $10^{11} cm^{-2}$. Nearly equal values of the neutron fluxes calculated from the measured fragment yield for Ag, Ta and U nuclei with very different fission thresholds indicate that the main part of the neutron spectrum has an energy in the range of several dozens of MeV.
The measurement of the neutron for other angles with respect to the proton beam direction revealed a rapid decrease in the neutron flux with the increasing angle which is also characteristic for the high energy neutrons formed at the collision of primary protons with nuclear neutrons.

From the neutron flux obtained in this way as well as from the calculated value of tantalum effective layer from which recoil nuclei could fly out with an energy more than 1 Gev, the upper limit of the cross section of high energy recoil nuclei originated from relativistic particle scattering was determined to be $2x10^{-33} cm^2$. Such a low cross section value does not permit relativistic neutron fluxes to be used for the transuranic element synthesis. The upper limit measured in this work is by a factor of 500 less than that determined in ref./2/.
Consideration must be given to different conditions of the experiments performed: in work/2/ they used 24 Gev protons, where-

as we used neutrons in the wide energy range. There should be no difference in the nature of interaction of bombarding nucleons with the target due to the charge symmetry of nuclear forces, however, further experiments are necessary for the final solution of the problem.

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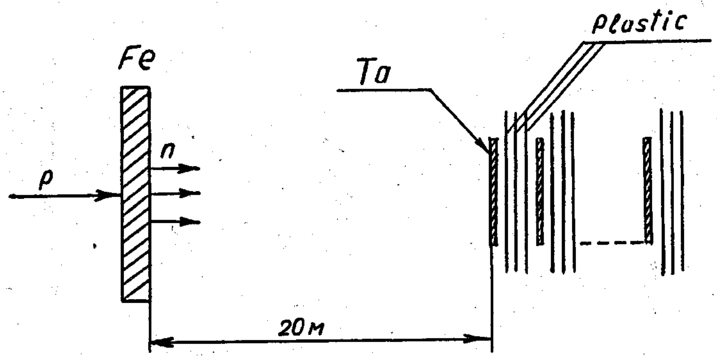
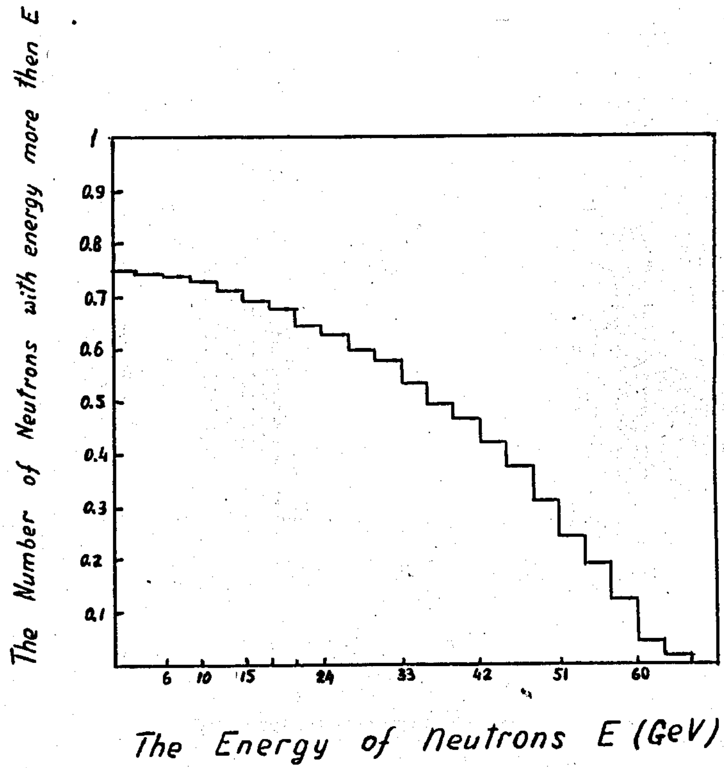


1. The scheme of the experiment.



2. The integral neutron spectrum received from calculations of interactions of 70 Gev protons with Fe nuclei.