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NEUTRON PRODUCTION IN FISSILE TARGETS UNDER THE ION BEAM IRRADIATION

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Energy losses of a bombarding particle increase intensively with the increasing of its charge due to ionization processes. On the other hand, the number of created high-energy neutrons increases in inelastic collisions of heavier projectiles with target nuclei at similar collision energy E(amu), which, on the contrary, forces down the ionization energy losses. It is shown by means of Monte Carlo simulation of internuclear cascades that the competition of these processes results in the highest neutron yield when deutron beams are being employed. For example, replacement of the proton beam with deutron or α-particle beams raises the neutron yield in an extended uranium target by $10 - 20\%$ in the energy region $E = 1$ GeV/amu which is the most challenging from the point of view of an electronuclear reactor design, just as a transition to carbon beam decreases the neutron production approximately by a quarter (at lower energies even more) [1]. However, this conclusion contradicts the experimental data of K.D.Tolstov's group who investigated the neutron multiplication in lead target at $E = 3.65$ Gev/amu [2 – 5]. According to these data, the use of the α-particle or carbon ion beams decreases the energy losses by $28 \pm 6\%$ and $19 \pm 6\%$ respectively in comparison with the proton beam. The neutron yield and the production of plutonium (or ^{233}U) nuclei inside the electronuclear reactor increases at the respective rate.

Taking into account the importance of the question of the design of such a system we repeated the Monte Carlo calculations using an improved model and more precise parameters (in particular, improved nuclear cross- sections [6]) and investigated the sensitivity of our calculations in respect to variations of the model parameters. Extended (practically infinite) cylindrical target manufactured of natural uranium with radius 60 cm, length 90 cm is considered as well as in our previous calculations. It is supposed that the bombarding particle beam is introduced into the target through a narrow channel with length 26 cm along the central axis. The results of the calculation for $E = 1$ Gev/amu are shown in Fig. Five hundred of initial bombarding particles have been sampled in each case.

One can see that the improvement of the model and the raising of the number of sampled cases don't change the conclusion about maximal neutron yield under the influence of deutrons and its decreasing to $75 - 70\%$ at the proton level while using carbon ions. The discrepancy is too large to be excluded by any variation of parameters. For instance, if the relation $a_f = 1.14a_n$ for energy state density parameters of excited nuclei in processes of evaporation and fission is used [1] instead of the usually employed equal values $a_f = a_n$ then the neutron yield increases approximately by 10%, however the value of the ratio $N_n(^{12}C)/N_n(p) = 0.7 - 0.8$ is not affected.(The value $N_n(^{12}C)$ is given per one intranuclear nucleon).

Calculations modelling the experiments [2–5] with a lead target [2] have shown that $N_n(^{12}C)/N_n(p) = 0.65$ at $E = 1$ GeV/amu and 0.75 at $E = 3.65$ GeV/amu.

One can attain an agreement with the Tolstov's group experiments only by supposition that our current notions about the high-energy ($E > 1$ Gev/amu) nucleus-nucleus interactions mechanism are essentially wrong which pro-

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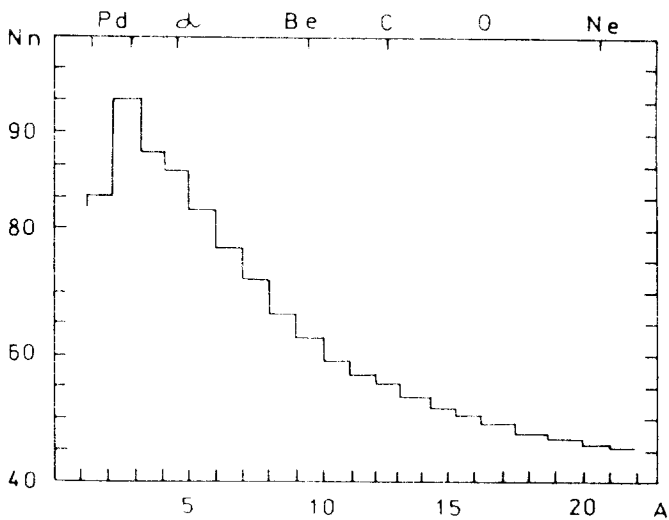
[1] These values recommended as a result of careful calculations made by S.G. Mashnik [7] allowed in some cases to get better description of the nuclear fissibility

[2] Target diameter and length equal respectively 50 and 80 cm, beam channel length along the target axis equals 20 cm.

vides significantly lower probability of the channels with almost complete disintegration of a target nucleus into nucleons. According to current theoretical estimations such a probability does not exceed a few percent. At the some time one needs the disintegration probability to be one order of magnitude higher to explain the $N_n(^{12}C)/N_n(p)$ ratio, observed by the Tolstov's group. Exactly this value is obtained from the analysis of photoemulsion experiments at 3.65 Gev/amu [5]: 6% for p+Pb interactions and 22% for α+Pb collisions. This principal question requires first of all experimental investigation.

One has to emphasize that the Monte Carlo simulation of neutron yield under the proton beams agrees with available experimental data in the wide energy region from few dozens MeV up to 70 GeV [8, 9].

In conclusion we glad to thank Dr. D.Chultem for discussions of the questions considered in this paper.



Neutron yield under the action of ions with mass number A (per one intranuclear nucleon).

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Барашенков В.С. и др.
Выход нейтронов в делящихся мишенях
под действием пучков ионов

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Монте-карловское моделирование транспорта частиц в делящихся средах показывает, что выход нейтронов максимален при использовании пучка дейтронов и быстро снижается при переходе к более тяжелым ядрам. Этот вывод не согласуется с результатами анализа дубненских опытов со свинцовым блоком. Обсуждаются возможные причины расхождений.

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Barashenkov V.S. et al.
Neutron Production in Fissile Targets under the Ion Beam Irradiation

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It is shown as a result of Monte Carlo simulation of particle transport through fissile media that neutron yield is the highest while using the deuteron beam and sharply decreases in case of heavier bombarding nuclei. However, this conclusion contradicts the Dubna experiments with a lead target. Possible reasons of such a disagreement are discussed.

The investigation has been performed at the Laboratory of Computing Techniques and Automation, JINR.

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