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V.A.Karnaukhov

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Карнаухов В.А. E1 - 11560

К вопросу о судьбе мюона при мгновенном делении мезоатомов

На основании статистической модели рассматривается процесс атомного захвата мюона осколками при мгновенном делении мезоатома. Показано, что с вероятностью 92% мезон увлекается тяжелым осколком.

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Karnaukhov V.A. E1 - 11560

On Muon Fate in the Prompt Fission of Heavy Mesic Atoms

Atomic muon capture by fragments in prompt mesic atom fission has been considered on the basis of a statistical model. According to this model it should be expected that the muon is attracted by a heavy fragment with an about 92% probability.

The investigation has been performed at the Laboratory of Nuclear Problems, JINR.

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The radiationless 2p–1s transition of muons in the heavy mesic atom is accompanied by fission (prompt fission) with a significant probability. A further muon behaviour is as follows. The meson remains on one of the excited fragments. Since the excitation energy of fragments exceeds the muon binding energy in the 1s -state, there is a possibility for its conversion. This process is similar to the electron conversion of gamma-transitions.

The probability of meson conversion has been calculated in refs.[1-3]. The recent paper[3] has shown that the probability of the process depends significantly on the fact by what fragment a meson is carried away, since meson conversion from the light fragment is about 30 times greater than that from the heavy one. The estimation by means of the formulas of the molecular predissociation theory has allowed the authors of ref.[3] to conclude that a muon is captured to the K-shell of the heavy and light fragments at an about equal rate. In this case a light fragment is mainly responsible for muon reemission, and the total probability of the process is calculated to be equal to 9% (E1) or 30% (E2) normalized to the number of prompt fission events.

Up till now there has been no experimental data available on the probability of meson conversion. However, in ref.[4] some experimental results have been obtained from which it follows that the meson is carried away by a heavy fragment in more than 80% events of prompt fission of the ^{238}U mesic atom. The contradiction of this fact to the prediction of ref.[3] has forced us to estimate the probability of the atomic muon capture by heavy and light fragments on the basis of another model.

The meson in the 1s -state of the heavy mesic atom stays the greater part of time in the nucleus forming with it a unified system. A characteristic time of meson motion in the nucleus is some orders of magnitude smaller than that of the excited nucleus with respect to fission. Therefore, the fission process is adiabatic with respect to meson motion. This allows one to use the statistical model for estimating the probability of various channels of the mesic atom fission resulting from the radiationless transition. Denote by $W_{\mu L}$ and $W_{\mu H}$ fission probability with the meson capture to the K -shell of light and heavy fragments, respectively. These values are proportional to the densities of the final states

$$W_{\mu L} \sim \rho_L(E'_L)\cdot\rho_H(E'_H)\cdot\rho'_K \quad ,$$
$$W_{\mu H} \sim \rho_L(E''_L)\cdot\rho_H(E''_H)\cdot\rho''_K \quad , \qquad (1)$$

where ρ_L and ρ_H are densities of the states of light and heavy fragments, ρ_K is density of the states of the transitional motion of fragments, E_L and E_H are excitation energies of the light and heavy fragments, respectively.

The meson transfer from a light fragment to a heavy one, while the fissioning nucleus is approaching the scission point, gives the energy gain $\Delta E = B_{\mu H} - B_{\mu L}$, where $B_{\mu H}$ and $B_{\mu L}$ are the muon binding energies in the 1s - state of the heavy and light mesic fragments. The reverse muon exchange requires energy consumption. It seems reasonable to assume that this process results mainly in the change of the fragment excitation energy. Thus, we assume in formula (1) that

$$\rho'_K = \rho''_K \ , \quad E''_L + E''_H = E'_L + E'_H + (B_{\mu H} - B_{\mu L}).$$

In the constant temperature model from eq. (1) we obtain

$$W_{\mu H}/W_{\mu L} \simeq \exp[\,(B_{\mu H} - B_{\mu L})/T]\ .$$

For the purpose of evaluation we take xenon and strontium as heavy and light fragments. Then $B_{\mu H} - B_{\mu L} \simeq 2.5$ *MeV* [5]. For nuclear temperature we take a value of 1.0 *MeV* obtained from the fission neutron spectra [6]. This gives $W_{\mu H}/W_{\mu L} \simeq 12$. Hence, it follows that the meson should "land" on a heavy fragment in about 92% of events. This evaluation agrees with the results of ref. [4].

Let us use the obtained value of $W_{\mu H}/W_{\mu L}$ to estimate the muon conversion probability per prompt fission event. For this purpose we take the probability values for muon conversion from heavy and light fragments calculated in ref. [3]. As a result, the total probability of muon conversion is found to be equal to ~2%, and only in one fourth of cases the conversion from heavy fragments takes place (for E1 -transitions).

It seems interesting to measure fragment kinetic energy and the average neutron number for the prompt fission of mesic atoms. These measurements may give important information on the muon influence on fission dynamics and on the mechanism of muon atomic capture by fission fragments.

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