EPJ Web of Conferences **62**, 07008 (2013)
DOI: 10.1051/epjconf/20136207008

Study of fission reactions induced by ^{4,6}He and ^{7}Li beams on ^{209}Bi and ^{208}Pb targets

S.M. Lukyanov, A.A. Hassan, Yu.E. Penionzhkevich, and N.K. Skobelev

Flerov Laboratory of Nuclear Reactions, Joint Institute for Nuclear Research, 141980 Dubna, Moscow region, Russia

Abstract. Study of fission reactions induced by ^{4,6}He and ^{7}Li beams on ^{209}Bi and ^{208}Pb targets, leading to the production of ^{210,212}A compound nuclei, was performed. It was shown that the fission excitation functions for the three reactions ^{4,6}He + ^{209}Bi and ^{7}Li + ^{208}Pb had similar behavior within the experimental error for a broad range of energy. More likely, halo structure of ^{6}He is not reflected on the fission reaction mechanism. Otherwise, a large value of the fusion cross section was observed so far, as it could be expected in the case of weakly bound character of ^{6}He projectile.

1. Introduction

In the past few years, in different scientific centers, intensive experimental studies have been performed using secondary beams formed from the radioactive products of nuclear reactions [1, 2]. Lately there has been a growing trend to use secondary beams as a means of investigating the interaction cross sections of these exotic nuclei with the target nuclei. These data help getting information on the structure of nuclei far from the line of stability, on the distribution of nuclear matter and on charge radii. These data help getting information on the structure of nuclei far from the line of stability, on the distribution of nuclear matter and on charge radii.

The study of fusion reactions involving weakly-bound or radioactive beams ^{6,8}He [1–4] are one of the most challenging experimental and theoretical problems in nuclear physics. It is well established that the coupling of collective degrees of freedom to the fusion channel enhances significantly the tunneling probability at sub-barrier energies. On the other hand, the low binding energy of radioactive nuclei may cause important loss of incoming flux due to the breakup process.

The effects on the reaction mechanisms due to the exotic structure of weakly-bound or radioactive nuclei are expected to be greatest one in ^{6}He because of its halo nature. Clearly, the available data in the literature for ^{6}He induced fusion reactions are not sufficient to draw any firm conclusion about a possible suppression above the barrier. Measurement of the all ^{209}Bi(^{6}He, xn) decay-channels and fission at higher energies are important in the determination dynamics of the collision.

The present paper is an attempt to elucidate the fission peculiarity in the case of the ^{6}He projectile. To elucidate the possible effect of the influence of the halo structure on the fusion-fission mechanism, we fuse the same compound nucleus ^{215}At in the different entrance channels ^{6}He(^{209}Bi, f),

Article available at http://www.epj-conferences.org or http://dx.doi.org/10.1051/epjconf/20136207008

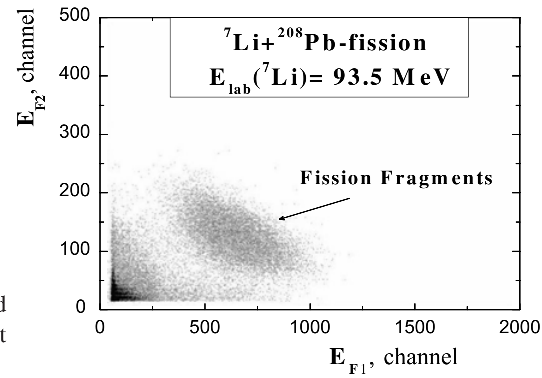

Figure 1. The two-dimensional plot of two correlated fission fragments obtained in the reaction $^{7}Li + ^{208}Pb$ at $E(^{7}Li) = 93.5$ MeV.

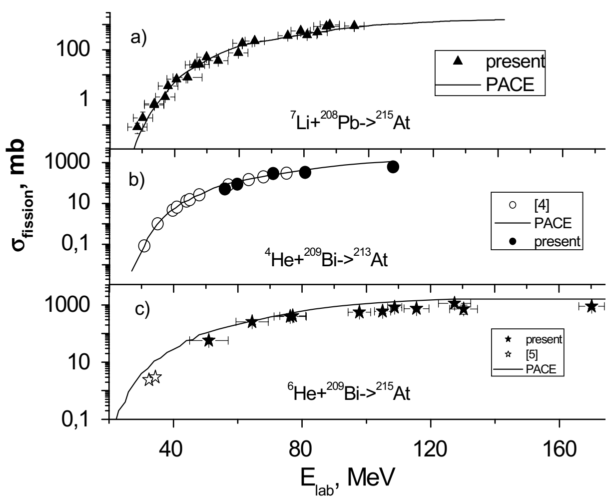

Figure 2. Fission excitation functions for three reactions $^{4,6}He + ^{209}Bi$ and $^{7}Li + ^{208}Pb$. Our experimental data are shown by solid symbols. Data from Ref. [4, 5] are shown by the open symbols. The line represents the theoretical calculations using PACE-4 code.

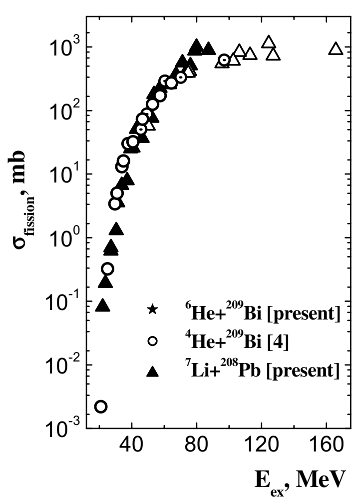

Figure 3. Reduced fission excitation functions (fission cross section values versus excitation energy E_{ex}) for three reactions $^{4,6}He + ^{209}Bi$ and $^{7}Li + ^{208}Pb$.

^{7}Li (^{208}Pb, f), in addition we were able to compare the fission for the neighboring compound nuclei ^{213}At in the reaction $^{4}He(^{209}Bi, f)$ and ^{216}Rn in $^{7}Li(^{209}Bi, f)$ reactions.

2. Experimental method

The fission fragments were measured by the on-line method. The study was performed at energies near the Coulomb barrier up to 220 MeV. Two correlated fission fragments were registered in coincidence by a couple of silicon detectors in "on-line" method. These silicon detectors were placed at a defined position to get two correlated fission fragments according to the kinematics. These detectors were calibrated with fission fragments from a thin ^{244}Cm source. As an example, a double dimensional matrix of the two correlated fission fragments (yield versus the fission fragment energies E_{F1} and E_{F2}) is shown in Figure 1.

The incident energy of the projectile was changed by the Al absorbers and purified by the dipole and slits systems to avoid large energy spread.

Fission cross sections at energies near the barrier were measured. Figure 2a shows the fission excitation function obtained in the reaction $^{7}Li + ^{208}Pb$ at energy near the barrier and up to 100 MeV. Figure 2b shows the fission excitation functions obtained in the reaction $^{4}He + ^{209}Bi$. Figure 2c shows the fission excitation function obtained in the reaction $^{6}He + ^{209}Bi$ at energy 50 up to 180 MeV. In addition to our experimental result, data from [5] is presented too. Solid symbols are corresponding to the present measurement and data form [4, 5] is shown by open ones. The lines represent the theoretical calculations using PACE-4 code.

The comparison between the fission excitation functions for the three reactions $^{4,6}He + ^{209}Bi$ and $^{7}Li + ^{208}Pb$ can shed a light on study of the fission mechanism reaction induced by weakly bound nuclei. Studied reactions are leading to the same composite nuclei $^{213,215}At$. This comparison is shown in Figure 3, where the reduced excitation functions (fission cross section values versus excitation energy E_{ex}) are given for all studied reactions.

Figure 3 indicates that the fission cross sections for the three reactions $^{4,6}He + ^{209}Bi$ and $^{7}Li + ^{208}Pb$ are quit the same within the experimental error for a broad range of energies and the fission reaction mechanism in the three reaction systems have the same behavior in the excitation functions. That gives simple evidence that the fusion-fission process in the above-mentioned reactions passed through the compound nucleus, which has no any memory about the colliding nuclei.

Otherwise, a large value of the fusion cross section was observed in the fusion reaction induced by ^{6}He projectile [6, 7], as it could be expected in the case of weakly bound character of ^{6}He projectile [8]. This enhancement is most likely due to the mechanism of "sequential fusion" with an intermediate neutron transfer from ^{6}He to the target with positive Q values.

3. Conclusion

The comparison between the fission excitation functions for the three reactions $^{4,6}He + ^{209}Bi$ and $^{7}Li + ^{208}Pb$ has shown that they are the same within the experimental error for a broad range of energy. One may conclude, that the halo structure of ^{6}He is not reflected on the fission reaction mechanism. So far, a large value of the fusion cross section was observed in the case of the reaction induced by the weakly bound ^{6}He projectile [2, 6, 7]. It is suggested that observed so far enhancement might be arised from coupling to positive Q value neutron transfer channels, resulting in "neutron flow" between the projectile and the target [6, 8].

References

[1] Yu.E. Penionzhkevich *et al*., Eur. Phys. J. **A31**, 185 (2007)
Yu.E. Penionzhkevich *et al*., Phys. Rev. Lett. **96** (2006) 162701

[2] S.M. Lukyanov *et al*. Phys. Lett. **B 670**, 321 (2009)

[3] A. Lemasson *et al*., Phys. Lett. **B 697**, 454 (2011)

[4] M. Itkis *et al.,* Soviet Journal of Nucl. Phys. **19**, p. 701 (1988)

[5] J.J. Kolata *et al.,* Phys. Rev. C **57** N1, R6 (1998)

[6] Yu. Penionzhkevich *et al*., Phys. Rev. Lett.v. **96**, 162701 (2006)

[7] J.J. Kolata *et al.,* Phys. Rev. Lett. v.**81**, p.4580 (1998)

[8] V. Zagrebaev *et al*., Phys. Rev. Lett. 96, 162701 (2006)