Physics Letters B 700 (2011) 362–364

Contents lists available at ScienceDirect

Physics Letters B

www.elsevier.com/locate/physletb

A note on the examination of isospin effects in multi-dimensional Langevin fission dynamics

W. Ye *, F. Wu, H.W. Yang

Department of Physics, Southeast University, Nanjing 210096, People's Republic of China

ARTICLE INFO

Article history:
Received 24 January 2011
Received in revised form 29 April 2011
Accepted 17 May 2011
Available online 19 May 2011
Editor: J.-P. Blaizot

Keywords:
Compound nucleus decay
Isospin effect
Nuclear dissipation

ABSTRACT

In [W. Ye, F. Wu, H.W. Yang, Phys. Lett. B 647 (2007) 118] prescission protons and α particles of high-isospin ^{206}Pb were shown to be almost independent of the dissipation strength k_s. Subsequently, in [P.N. Nadtochy, et al., Phys. Lett. B 685 (2010) 258] prescission light charged particles (LCPs) were shown to have approximately the same sensitivity as neutrons to k_s for ^{206}Pb and ^{204}Hg nuclei. In this Letter we point out that the reason for the apparent contradictory conclusions is that the authors in the latter did not compute the changes in the absolute yields of prescission LCPs multiplicities with increasing k_s and compare them with typical experimental uncertainties. It is shown that the expected changes are very small in the case of neutron-rich ^{206}Pb and ^{204}Hg systems, which are within experimental error bars. This indicates that, from the viewpoint of experiment, LCPs emission of ^{206}Pb and ^{204}Hg is insensitive to dissipation.

In a recent study of isospin effects on prescission particles of three Pb isotopes, i.e. ^{194}Pb, ^{200}Pb and ^{206}Pb, we showed [1] that the sensitivity of prescission proton (p_{pre}) and α-particle (α_{pre}) multiplicities to the nuclear dissipation strength has a dependence on the isospin of the systems and that the sensitivity almost disappears for high-isospin ^{206}Pb nuclei. Subsequently, Nadtochy et al. [2] performed similar calculations with Langevin models that showed approximately the same higher sensitivity of p_{pre} and α_{pre} of ^{206}Pb as its n_{pre} to the dissipation strength. They concluded that "prescission neutron, proton and α-particle multiplicities have approximately the same sensitivity to the dissipation strength for a given nucleus. This is at variance with conclusions of recent papers." Here we examine this apparent conflict in the conclusions. Because light particle multiplicities are a main source of information on the nature and magnitude of nuclear dissipation, a consistent conclusion is important for planning dedicated experiments and hence deserves careful investigation.

First, it is relevant to mention that in our work [1] it has been shown for low-isospin systems ^{194}Pb both n_{pre} and light charged particles (LCPs), i.e. p_{pre} and α_{pre}, are sensitive to dissipation. Thus, the difference in conclusions reported in [2] and [1] is only about the case of high-isospin system ^{206}Pb [3]. Second, we have made a quantitative numerical analysis for calculated data, see, e.g. those in [4] (which is also Ref. [9] cited in [2]). But our method is different from that used in [2] because in [4] we compared the sensitivity of LCPs emission to friction for three Cf isotopes by analyzing the change in their absolute yields with system isospin and friction strength.

Now let us turn to the conclusion drawn by the authors in [2] (see above). The reason they reached it is based on a similar ratio (i.e., the ratio of the predicted particle multiplicity at dissipation strength $k_s = 1$ to that at $k_s = 0.1$) for neutron, proton, and α for a given nucleus, including ^{206}Pb and ^{204}Hg. However, they did not compute the change in absolute yields of these particle multiplicities as k_s varies from 0.1 to 1. This has a consequence for the resulting conclusion. In other words, we think even if the ratio of the predicted neutron, proton and α multiplicities for a given nucleus or the predicted ratio of a certain type of particle emission (e.g. α emission) for two systems (^{194}Pb vs. ^{206}Pb or ^{182}Hg vs. ^{204}Hg) is comparable, it does not suggest that different particles are of a similar sensitivity to dissipation for a given nucleus and that the sensitivity of a certain type of particle emission to dissipation is comparable for two systems with different isospins.

In order to illustrate our viewpoint more clearly, we first take α emission of ^{182}Hg and ^{204}Hg as an example. It is seen from Table 3 in [2] that the ratio of α_{pre} is predicted to be 3.09 and 3.10 for ^{182}Hg and ^{204}Hg. According to [2], the α particles should have a similar sensitivity to dissipation for the two Hg systems. We disagree with the conclusion. The reason is as follows. The absolute

* Corresponding author.
E-mail address: yewei@seu.edu.cn (W. Ye).

0370-2693
doi:10.1016/j.physletb.2011.05.034

Table 1
Comparison of the calculated differences in one-dimensional (1D) prescission neutron (Δn_{pre}), proton (Δp_{pre}) and α-particle ($\Delta\alpha_{pre}$) multiplicity for three Pb isotopes, ^{194}Pb, ^{200}Pb and ^{206}Pb, at $k_s = 0.5$ and 1 with those at $k_s = 0.1$. Note that the following numerical values are based on the data given in Tables 1 and 2 in [2].

C.N.	k_s	Δn_{pre}	Δp_{pre}	$\Delta\alpha_{pre}$
^{194}Pb	0.5	0.7755	3.627×10^{-2}	2.379×10^{-2}
	1.0	1.2690	5.673×10^{-2}	3.721×10^{-2}
^{200}Pb	0.5	0.8280	7.920×10^{-3}	2.300×10^{-3}
	1.0	1.3455	1.692×10^{-2}	5.980×10^{-3}
^{206}Pb	0.5	0.9695	1.980×10^{-3}	2.240×10^{-4}
	1.0	1.4404	2.970×10^{-3}	1.792×10^{-3}

Table 2
Comparison of the 3D calculated differences in prescission neutron (Δn_{pre}), proton (Δp_{pre}) and α-particle ($\Delta\alpha_{pre}$) multiplicity for two Hg isotopes, ^{182}Hg and ^{204}Hg, at $k_s = 0.5$ and 1 with those at $k_s = 0.1$. Note that the following numerical values are based on the data given in Tables 3 and 4 in [2].

C.N.	k_s	Δn_{pre}	Δp_{pre}	$\Delta\alpha_{pre}$
^{182}Hg	0.5	0.272	9.212×10^{-2}	5.301×10^{-2}
	1.0	0.52	0.1617	0.11913
^{204}Hg	0.5	0.7904	2.000×10^{-4}	5.162×10^{-4}
	1.0	1.4352	8.000×10^{-4}	1.218×10^{-3}

yields of α particles are very low for high-isospin ^{204}Hg. Thus, determining the low multiplicities in the neutron-rich system is much more effected by experimental uncertainties. Table 4 in [2] shows that at $k_s = 0.1$, $\alpha_{pre} = 0.057$ (for ^{182}Hg) and 5.8×10^{-4} (for ^{204}Hg). Furthermore, using the data presented in Table 3 in [2], one can work out the actual change in α_{pre} (i.e. $\Delta\alpha_{pre}$) as k_s increases from 0.1 to 1, which is 0.11913 and 1.218×10^{-3} for ^{182}Hg and ^{204}Hg, respectively. The latter is two orders of magnitude smaller than the former. For convenience, we list the calculation changes in absolute yields of various particle multiplicities with friction for the three Pb isotopes (Table 1) and the two Hg isotopes (Table 2).

Because current experimental error bars for measured prescission LCPs (e.g. α particles) are at least larger than 10^{-3} [for example, see Table IV in Ref. [37] cited in [2]; Specifically, the experimental value of α_{pre} of ^{200}Pb is 0.050(7) with the error bar being 7×10^{-3}], this demonstrates that for ^{204}Hg the theoretically predicted change [2] in the absolute yield of prescission α particles, $\Delta\alpha_{pre}$, with increasing k_s could be within the experimental error bar; that is, from the viewpoint of experiment, for ^{204}Hg its α emission is insensitive to dissipation. But the ^{182}Hg system has a totally different picture because its α_{pre} changes by 0.119. The change is much greater than the experimental error bar and hence it is meaningful in experiments.

Moreover, we note that as k_s rises from 0.1 to 1, the n_{pre} of ^{204}Hg rises by 1.4352, which exceeds the error bar of experimental n_{pre}. This is opposite to the case of α-particle emission. It thus indicates that from experimental viewpoint, a similar ratio predicted for neutrons and α particles (here for high-isospin system ^{204}Hg) does not mean these two different types of particles have a comparable sensitivity to dissipation.

As to the numerical analysis for three Pb isotopes, the situation is alike because LCPs emission of high-isospin ^{206}Pb is at least a factor of 10 lower than that of low-isospin ^{194}Pb. Because the error bars of measured p_{pre} and α_{pre} of ^{200}Pb given in [2] are respective 4×10^{-3} and 7×10^{-3}, the expected changes in the magnitude of both p_{pre} and α_{pre} (for ^{206}Pb) with raising k_s, as shown in Table 1, could be within the experimental error bars, in contrast with the case of ^{194}Pb. Therefore, for ^{206}Pb its LCPs are almost independent of dissipation. The conclusion is in agreement with that reached in our work [1].

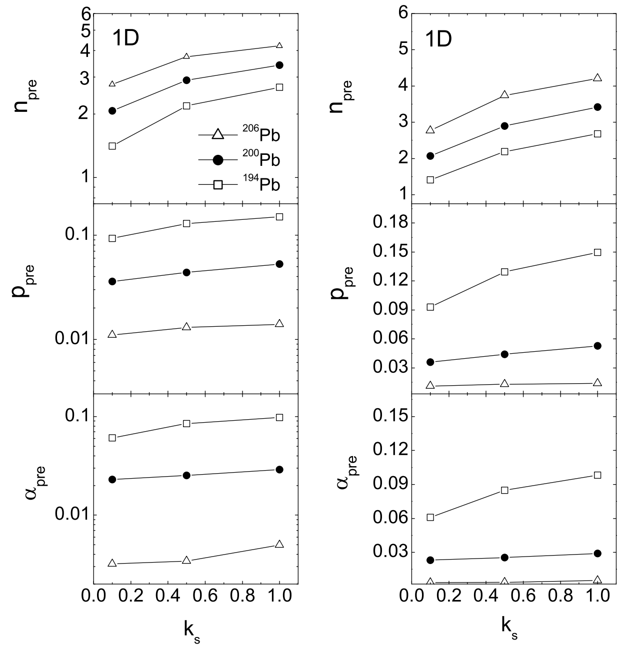

Fig. 1. Calculated 1D prescission neutron (n_{pre}), proton (p_{pre}) and α-particle (α_{pre}) multiplicities for three Pb isotope as a function of k_s. Left: particle multiplicities are plotted on a logarithmic scale, adopted from the left panel in Fig. 1 in [2]. Right: The same particle multiplicities are plotted on a linear scale. Note that these two different types of scales used to present the particle multiplicities have the same starting and ending values. As seen, the right panel is analogous to Fig. 3 in [1], indicating that 1D calculation results in [2] are actually consistent with ours [1].

A recent calculation [5] showed that $k_s = (0.25–0.5)$ is needed to reproduce measured prescission neutron multiplicities and other physical quantities. The result implies that although the value of k_s has a very apparent uncertainty, it is not greater than 0.5. Given the restriction on the realistic magnitude of k_s, one can easily see when k_s varies from 0.1 to 0.5, the change in the prescission absolute yield of α particles will be reduced down to 2.24×10^{-4} for high-isospin ^{206}Pb (see Table 1) and to 5.162×10^{-4} for high-isospin ^{204}Hg (see Table 2). Obviously, the amplitudes of these changes are far below the current experimental error bar of 1×10^{-3}. This reinforces our previous analysis involving the two high-isospin systems.

It is worth pointing out that although the specific values of particle multiplicities at various friction strengths for the three Pb isotopes, reported in [1] and [2], are somewhat different, the change trends of prescission neutrons and LCPs with system isospin and friction predicted in the two works are analogous, as can be easily seen in Fig. 1. On a purely theoretical level, the prescission proton and α multiplicities are sensitive to dissipation, also for neutron-rich systems. However, as done previously, a comparison with typical uncertainties of such kind of experiments shows that it is more difficult or it may even be impossible to determine them experimentally using typical present experimental technique, if they fall below a certain absolute level. Thus, a presentation of the expected multiplicities on a linear scale might be more appropriate, if one wants to judge their observability (see Fig. 1). Taken together, the different prediction between [2] and [1] is due to the inadequacy of the numerical analysis method used by the former for dealing with the sensitivity of LCPs of high-isospin ^{206}Pb (or ^{204}Hg) to friction.

In summary, for low-isospin systems ^{194}Pb where LCPs are an important decay channel, both [2] and [1] consistently predict a sensitivity of both neutrons and LCPs to nuclear dissipation. The reason for this is that the condition of low isospin can increase LCPs emission appreciably. But for high-isospin systems ^{206}Pb and ^{204}Hg where LCPs evaporation is very weak, the authors in [2] did not calculate the changes in the absolute yields of prescission LCPs multiplicities with increasing k_s in this case. We compare the calculation results with typical experimental uncertainties, and show that these expected changes in LCPs multiplicities are within experimental error bars. This indicates that, from experimental viewpoint, LCPs emission in neutron-rich nuclei ^{206}Pb and ^{204}Hg is insensitive to dissipation.

Acknowledgements

The authors thank the anonymous referee for his suggestions. This work is supported by National Natural Science Foundation of China under Grant No. 11075034.

References

[1] W. Ye, F. Wu, H.W. Yang, Phys. Lett. B 647 (2007) 118.
[2] P.N. Nadtochy, et al., Phys. Lett. B 685 (2010) 258.
[3] P.N. Nadtochy, private communication.
[4] W. Ye, Phys. Rev. C 80 (2009) 011601(R).
[5] P.N. Nadtochy, et al., Phys. Rev. C 65 (2002) 064615.