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# Dependence of Isospin Effect in the Multiplicity of Pre-Scission Particles on the Angular Momentum*

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**Abstract** The influence of angular momentum in the context of isospin effects on the emission of different light particles for heavy fissioning isotopic sources of $^{189,202,212}$Po and for isobaric sources of $^{202}$Fr, $^{202}$Po and $^{202}$Tl is studied within the framework of the Smoluchowski equation. Calculations show that the isospin effects on particle emission have a strong dependence on the angular momentum. Large angular momentum greatly weakens the influence of nuclear dissipation and isospin on particle emission. This means that to better extract dissipation strength with light particle multiplicities as a probe, it is important to select the compound systems with low spins, in addition to selecting a proper kind of particles for the systems with different isospins.

**Key words** isospin effect, angular momentum, pre-scission particle multiplicity, dissipation, diffusion model

## 1 Introduction

Nuclear viscosity and its dependence on the temperature and/or deformation have been evoked considerable interest in the recent years[1—9]. It is now established that due to dissipation, fission is delayed and this results in an enhanced pre-scission particle emission with respect to the estimation of the standard statistical model. Accordingly the excess particles are used as a probe for nuclear dissipation, see e.g. Ref.[5] for a review.

At present, the influence of isospin on the formation and decay of hot nuclei in heavy-ion collisions has received more and more attention[10,11]. Several interesting phenomena originating from isospin have been discovered[12—17]. However, more experimental and theoretical studies are needed to better understand isospin physics.

In a recent work[18], we have surveyed the effects of isospin of systems on particle emission at a fixed angular momentum and have found that with increasing isospin charged particles cannot provide sensitive observables with respect to the nuclear dissipation strength. Since in heavy-ion-induced fusion-fission reactions the produced compound systems are of different angular momenta, this can affect particle emission. Therefore, in this paper we investigate the role of the angular momentum in the particle emission as a function of viscosity coefficient and in the isospin effects of particle emission. We aim to study its influences on the isospin effects in the emissions of various light particles (neutrons, protons and α particles) as probes to extract the value of nuclear dissipation for different isospin systems.

## 2 Diffusion model

To study particle emission in the diffusion process, we make use of the following extended Smoluchowski equation[19]:

$$\frac{\partial P(x,t)}{\partial t} = \theta \frac{\partial}{\partial x}\left(\frac{\partial U}{\partial x}P(x,t) + \frac{\partial P(x,t)}{\partial x}\right) - \sum_{i=n,p,\alpha} \lambda_i P(x,t). \qquad (1)$$

Here, $P(x,t)$ represents the probability of the system existing at the fission deformation coordinate $x$ and time $t$. $U = V/T$ is a dimensionless potential, $V$ is fission potential and $\theta = T/(\mu\beta)$, where $T$ is the nuclear temperature,

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$\mu$ the reduced mass of the system, and $\beta$ the viscosity coefficient. Fission potential $V$ is a function of the coordinate $x$, consisting of a well and a barrier. The second term on the right-hand side of this equation represents light particle emissions. $\lambda_i = \Gamma_i/\hbar$, $\Gamma_i(i = n, p, \alpha)$ is the particle emission width and can be calculated using the detailed balance principle method as[20]

$$\Gamma_i = \frac{(2I_i + 1)m_i}{\pi^2\hbar^2\rho(E^*, A)}\int_{V_i}^{E^* - B_i}\epsilon\sigma_i(\epsilon)\rho(E^* - V_i - B_i - \epsilon, A - A_i)\mathrm{d}\epsilon, \qquad (2)$$

where $A$ is the mass number of mother nucleus, $\rho$ is the level density, $E^*$ is the excitation energy after substracting the rotational energy. $I_i$, $m_i$, $B_i$, $\sigma_i$, $V_i$ and $A_i$ $(i = n, p, \alpha)$ are the emitted particle spin, mass, binding energy, inverse absorption cross section, emission barrier and mass number, respectively. For neutrons, the emission barrier $V_n = 0$. For protons and $\alpha$ particles their emission barriers are taken from Ref.[21].

For a highly excited compound nucleus, after it releases a particle, the resulting daughter nucleus still has sufficient excitation energy to emit another particle. In this way, a decay chain is formed, and it ends in fission. This decay chain can be described by a set of the coupled equations as follows:

$$\frac{\mathrm{d}}{\mathrm{d}t}P_s(t) = \sum_{i=n,p,\alpha}\lambda_{i,s-1}P^i_{s-1}(t) - \left[\sum_{i=n,p,\alpha}\lambda_{i,s} + \lambda_{f,s}(t)\right]P_s(t). \qquad (3)$$

$$s = 1, 2, \ldots, s_m$$

where $P_s$ is the probability of the $s$-th daughter nucleus. The first ferm on the righthand side is the "source" term, which results from the decay of the $(s-1)$-th nucleus through emission of particles. The second term represents its decay probability via fission or particle emission. The maximum times of evaporating particles for a decay chain is denoted by $s_m$ over which the procuced nucleus is cold enough not to emit particles.

Generally, the number of particles such as neutrons $n_s$ released by the $s$-th daughter nucleus is

$$n_s = \frac{\Gamma_{n,s}}{\hbar}\int_0^\infty P_s(t)\mathrm{d}t, \qquad (4)$$

where $\Gamma_{n,s}$ is neutron emission width of the $s$-th daughter nucleus.

The particle multiplicity $N_i(i = n, p, \alpha)$ is defined as the total number of particles released from all the decay chains:

$$N_i = \sum_{d=1}^{d_m}\sum_{s=1}^{s_m} n_{ds}. \qquad (5)$$

The inner sum here is over the particle multiplicity for a single decay with the proper probability, and the outer sum here is over all possible decay chains. $n_{ds}$ represents particle multiplicity evaporated in the $s$-th on a decay chain denoted by $d$.

The time dependent fission width in the Smoluchowski equation is defined as

$$\Gamma_f(t) = \hbar\lambda_f(t) = \hbar J_f(t)/\pi_f(t). \qquad (6)$$

Here, $\pi(x,t)$ is the probability at the left-hand side of deformation at $x$ and $J(x,t)$ is the probability flow at this deformation. Physically, the reasonable fission point is the scission point, and therefore here we chose the scission point to compute fission width.

Existing probabilities of any nuclei, fission rates and various particle multiplicities are calculated by numerically solving this set of extended Smoluchowski equations. Specific procedures are as follows. First, with Eqs.(1) and (6) one can compute existing probability of the mother nucleus $P(t)$ as a function of time and its fission rates $\Gamma_f(t)$. Three possible daughter nuclei with proper existing probability arising from neutron, proton and $\alpha$ particle emission of the mother nucleus and particle multiplicities stemming from the mother nucleus are calculated using Eqs.(3) and (4) with the initial conditions $P_s(0) = \delta_{s,1}$, i.e. at the beginning, the probability for the mother nucleus is 1, while the probabilities for daughters are zero. Secondly, each of these three born daughter nuclei can produce another three granddaughter nuclei by evaporating these light particles. Again, via Eqs.(1) and (6) the fission rates of the daughter nucleus is obtained, then with the help of Eqs.(3) and (4) various particle multiplicities emitted by this daughter nucleus and the existing probability of these three granddaughter nuclei are worked out, and so on. Total particle multiplicity is determined according to Eq.(5).

## 3 Results and discussions

In this work, an isotopic chain consisting of $^{189}$Po,

$^{202}$Po and $^{212}$Po and an isobaric chain containing $^{202}$Fr, $^{202}$Po and $^{202}$Tl nuclei are chosen to study isospin effects in the framework of the diffusion model coupled with statistical evaporation of light particles. In the calculation angular momentum effect on the particle emission width was taken into account by removing the rotational energy from the excitation energy and modifying the angular momentum of the daughter nuclei. The rotational energy due to angular momentum can be calculated using a rigid body model[22]. The dependence of the fission barrier on the angular momentum and isospin was evaluated with the code barfit which is based on the finite range model of Sierk[22]. This model considers the finite-range effects in the nuclear surface energy by means of a Yukawa-plus-exponential potential and finite surface diffuseness effects in the Coulomb energy. The code has three input parameters, i.e. mass number ($A$), atomic number ($Z$) and angular momentum ($L$). It gives a rather satisfactory description for the change of fission barriers of various nuclei with angular momentum[22].

We show in Table 1 the emitted light particle multiplicities for the Po isotopic sources as functions of isospin and viscosity coefficient at three angular momenta. One can see that particle emission with the isospin of the systems is similar at different angular momenta, namely more neutrons and less charged particles are emitted with increasing isospin. In addition, we find the differences of $N_n$ of $^{212}$Po and $N_p$ ($N_\alpha$) of $^{189}$Po between $\beta = 20$ and $\beta = 2\times10^{21}\,s^{-1}$ is 3.36 and 1.43 (0.49) at $L = 50\hbar$, and they become 2.79 and 0.89 (0.30) at $L = 65\hbar$. These results indicate that the differences of the neutron emission of the high-isospin $^{212}$Po and the charged-particle emission of the low-isospin $^{189}$Po at different $\beta$ are decreased at larger angular momentum. In other words, high angular momentum weakens the sensitivity of particle emission to the variation of $\beta$. The reason is that as angular momentum is very high, particle multiplicity is very small and the influence of $L$ on particle emission is over $\beta$.

**Table 1. Calculated pre-scission neutrons ($N_n$), protons ($N_p$) and α particles ($N_\alpha$) for Po isotopic chain $^{189}$Po, $^{202}$Po and $^{212}$Po as a function of viscosity coefficient ($\beta$) at excitation energy $E^* = 100$MeV for three different angular momenta ($L$).**

| $L = 50\hbar$ $\beta/(10^{21}s^{-1})$ | $^{189}$Po |  |  | $^{202}$Po |  |  | $^{212}$Po |  |  |
|---|---|---|---|---|---|---|---|---|---|
|  | $N_n$ | $N_p$ | $N_\alpha$ | $N_n$ | $N_p$ | $N_\alpha$ | $N_n$ | $N_p$ | $N_\alpha$ |
| 2 | 0.22827 | 0.95077 | 0.36277 | 1.68117 | 0.18827 | 0.20518 | 3.60967 | 0.06050 | 0.08940 |
| 5 | 0.42062 | 1.53730 | 0.56428 | 2.45483 | 0.40371 | 0.35063 | 5.05103 | 0.08104 | 0.10790 |
| 10 | 0.60075 | 1.97813 | 0.71354 | 3.11755 | 0.48796 | 0.42407 | 6.04449 | 0.09039 | 0.11944 |
| 15 | 0.70873 | 2.20706 | 0.79520 | 3.48882 | 0.53810 | 0.46738 | 6.62261 | 0.09395 | 0.12431 |
| 20 | 0.78750 | 2.37637 | 0.85091 | 3.80025 | 0.57346 | 0.49927 | 6.97018 | 0.09585 | 0.12687 |
| $L = 60\hbar$ $\beta/(10^{21}s^{-1})$ | $^{189}$Po |  |  | $^{202}$Po |  |  | $^{212}$Po |  |  |
|  | $N_n$ | $N_p$ | $N_\alpha$ | $N_n$ | $N_p$ | $N_\alpha$ | $N_n$ | $N_p$ | $N_\alpha$ |
| 2 | 0.15462 | 0.73956 | 0.27501 | 0.87133 | 0.15004 | 0.13721 | 2.61989 | 0.03505 | 0.05349 |
| 5 | 0.26015 | 1.16255 | 0.42456 | 1.55554 | 0.25059 | 0.22419 | 3.96728 | 0.04734 | 0.07139 |
| 10 | 0.36426 | 1.53246 | 0.54980 | 2.17243 | 0.33150 | 0.29063 | 4.92651 | 0.05417 | 0.08092 |
| 15 | 0.43240 | 1.75223 | 0.62136 | 2.53921 | 0.37519 | 0.32488 | 5.41805 | 0.05692 | 0.08478 |
| 20 | 0.48721 | 1.91440 | 0.67216 | 2.81473 | 0.40511 | 0.34737 | 5.75438 | 0.05854 | 0.08693 |
| $L = 65\hbar$ $\beta/(10^{21}s^{-1})$ | $^{189}$Po |  |  | $^{202}$Po |  |  | $^{212}$Po |  |  |
|  | $N_n$ | $N_p$ | $N_\alpha$ | $N_n$ | $N_p$ | $N_\alpha$ | $N_n$ | $N_p$ | $N_\alpha$ |
| 2 | 0.03614 | 0.42513 | 0.17102 | 0.72138 | 0.12214 | 0.11183 | 1.98820 | 0.02561 | 0.03967 |
| 5 | 0.09348 | 0.69023 | 0.28116 | 1.28055 | 0.20590 | 0.18489 | 3.16389 | 0.03671 | 0.05625 |
| 10 | 0.17044 | 1.01829 | 0.36509 | 1.78634 | 0.27424 | 0.24220 | 4.08363 | 0.04354 | 0.06538 |
| 15 | 0.22931 | 1.20546 | 0.43173 | 2.09220 | 0.31205 | 0.27285 | 4.49514 | 0.04561 | 0.06873 |
| 20 | 0.27898 | 1.32021 | 0.47730 | 2.33975 | 0.34015 | 0.29479 | 4.78666 | 0.04700 | 0.07045 |

To better study the effects of angular momentum on the isospin dependence of particle emission we investigate the $\beta$ evolution of the differences of various particle multiplicities for these systems. These differences are indicated by $\Delta N_n^{^{202}Po(^{189}Po)}$, $\Delta N_p^{^{202}Po(^{189}Po)}$, etc. The symbol $\Delta N_n^{^{202}Po(^{189}Po)}$ denotes the difference of the neutron multiplicity between $^{202}$Po($N_n$($^{202}$Po)) and $^{189}$Po($N_n$($^{189}$Po)). It is more quantitative to define

$$\Delta N_{\mathrm{i}}^{^{202}\mathrm{Po}(^{189}\mathrm{Po})} \equiv N_{\mathrm{i}}(^{202}\mathrm{Po}) - N_{\mathrm{i}}(^{189}\mathrm{Po}),$$

$$\Delta N_{\mathrm{i}}^{^{212}\mathrm{Po}(^{189}\mathrm{Po})} \equiv N_{\mathrm{i}}(^{212}\mathrm{Po}) - N_{\mathrm{i}}(^{189}\mathrm{Po}),$$

$$\Delta N_{\mathrm{i}}^{^{202}\mathrm{Po}(^{202}\mathrm{Fr})} \equiv N_{\mathrm{i}}(^{202}\mathrm{Po}) - N_{\mathrm{i}}(^{202}\mathrm{Fr}),$$

$$\Delta N_{\mathrm{i}}^{^{202}\mathrm{Tl}(^{202}\mathrm{Fr})} \equiv N_{\mathrm{i}}(^{202}\mathrm{Tl}) - N_{\mathrm{i}}(^{202}\mathrm{Fr}).$$

where $\mathrm{i} = \mathrm{n}, \mathrm{p}, \alpha$.

Fig. 1 shows the differences of the multiplicity of the pre-scission various particles between $^{202}$Po and $^{189}$Po (circles), as well as between $^{212}$Po and $^{189}$Po (squares) as a function of viscosity coefficient at excitation energy $E^* = 100$MeV and at angular momentum $L = 50\hbar$ (left panels), $60\hbar$ (middle panels) and $65\hbar$ (right panels). We take the results at $L = 60\hbar$ as an illustration. When $\beta$ increases from $2 \times 10^{21}$ to $20 \times 10^{21}\,\mathrm{s}^{-1}$, the difference of the neutron multiplicity of $^{202}$Po with that of $^{189}$Po changes from 0.71 to 2.32, whereas that for the difference between $^{212}$Po and $^{189}$Po changes from 2.46 to 5.27. For charged particles, $\Delta N_{\mathrm{p}}^{^{202}\mathrm{Po}(^{189}\mathrm{Po})}$ and $\Delta N_{\alpha}^{^{202}\mathrm{Po}(^{189}\mathrm{Po})}$ at $\beta = 2 \times 10^{21}\,\mathrm{s}^{-1}$ and $\beta = 20 \times 10^{21}\,\mathrm{s}^{-1}$ decrease from $-0.59$ to $-1.50$ and from $-0.14$ to $-0.32$, respectively. For $\Delta N_{\mathrm{p}}^{^{212}\mathrm{Po}(^{189}\mathrm{Po})}$ and $\Delta N_{\alpha}^{^{212}\mathrm{Po}(^{189}\mathrm{Po})}$, the variable ranges are from $-0.70$ to $-1.86$ and from $-0.22$ to $-0.59$ for protons and α particles. This comparison indicates that the differences of the particle emissions between $^{212}$Po and $^{189}$Po are more sensitive to the viscosity strength than the difference between $^{202}$Po and $^{189}$Po. At other angular momenta such as $L = 50\hbar$ and $65\hbar$, a like picture was observed. That is to say, different angular momenta do not alter the trend of different particle emission with isospin.

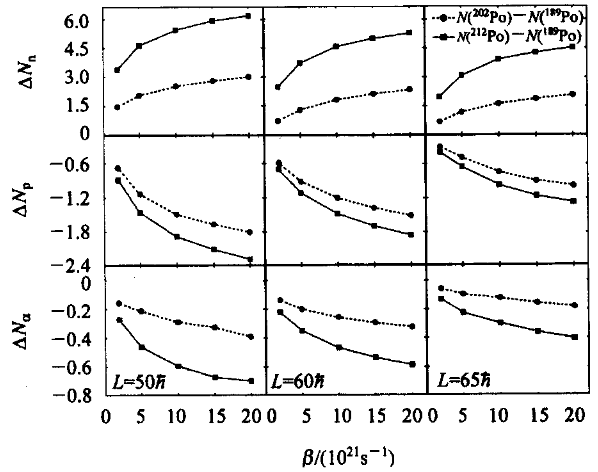

Fig. 1. The differences of the multiplicity of pre-scission neutrons ($\Delta N_{\mathrm{n}}$), protons ($\Delta N_{\mathrm{p}}$) and α particles ($\Delta N_{\alpha}$) between $^{202}$Po and $^{189}$Po (circles), and between $^{212}$Po and $^{189}$Po (squares) as functions of viscosity coefficient at excitation energy $E^* = 100$MeV and at the angular momenta $L = 50\hbar$ (left panels), $60\hbar$ (middle panels) and $65\hbar$ (right panels). Solid points are the calculated results. The lines are to guide the eye.

Furthermore, from Fig. 1 one can see that at $\beta = 2(20) \times 10^{21}\,\mathrm{s}^{-1}$ the values of $\Delta N_{\mathrm{n}}^{^{202}\mathrm{Po}(^{189}\mathrm{Po})}$ and $\Delta N_{\mathrm{n}}^{^{212}\mathrm{Po}(^{189}\mathrm{Po})}$ are 1.45 (3.01) and 3.38 (6.18) for a lower angular momentum $L = 50\hbar$ and they become 0.68 (2.06) and 1.95 (4.50) respectively at a higher angular momentum $L = 65\hbar$. While at $\beta = 2(20) \times 10^{21}\,\mathrm{s}^{-1}$, $\Delta N_{\mathrm{p}}^{^{202}\mathrm{Po}(^{189}\mathrm{Po})}$ and $\Delta N_{\mathrm{p}}^{^{212}\mathrm{Po}(^{189}\mathrm{Po})}$ change from $-0.676$ ($-1.80$) and $-0.89$ ($-2.28$) to $-0.30$ ($-0.98$) and $-0.39$ ($-1.27$) as $L$ increases from $50\hbar$ to $65\hbar$. Likewise, $\Delta N_{\alpha}^{^{202}\mathrm{Po}(^{189}\mathrm{Po})}$ and $\Delta N_{\alpha}^{^{212}\mathrm{Po}(^{189}\mathrm{Po})}$ for $L = 50(65)\hbar$ vary from $-0.157$ ($-0.059$) and $-0.273$ ($-0.131$) to $-0.39$ ($-0.18$) and $-0.69$ ($-0.40$) when $\beta$ varies from 2 to $20 \times 10^{21}\,\mathrm{s}^{-1}$. These results are due to the fact that particle multiplicity decreases with increasing angular momentum and isospin effects on particle emission. Neutron (proton and α particle) emission of a high-(low-) isospin system depends sensitively on the angular momentum, whereas the change of the multiplicity of neutrons (charged particles) of a low- (high-) isospin system with angular momentum is rather small. As a consequence, the difference of particles emitted from the two different isospin systems is decreased at a higher $L$. This indicates that a larger angular momentum decreases the effect of isospin on particle emission.

Shown in Table 2 and Fig. 2 is the particle multiplicities of an isobaric chain nuclei $^{202}$Fr, $^{202}$Po and $^{202}$Tl and the corresponding differences at three different angular momenta. We see here the behavior of particle emission is similar to the case in the Po isotopic sources. From Table 2 one can see increasing angular momentum will decrease the sensitivity of light particles to variation of the viscosity strength. Fig. 2 demonstrates that at any angular momentum, for neutrons (charged particles), all of dashed lines are always below (above) the solid lines, i.e. the absolute differences of the particle multiplicity of the two systems with a smaller isospin difference ($\Delta N^{^{202}\mathrm{Po}(^{202}\mathrm{Fr})}$) are always lower than those of a larger isospin difference

Table 2.　Calculated pre-scission $N_n$, $N_p$ and $N_\alpha$ for an isobaric chain $^{202}$Fr, $^{202}$Po and $^{202}$Tl as a function of viscosity coefficient ($\beta$) at excitation energy $E^* = 100$MeV for three different angular momenta ($L$).

| $L = 50\hbar$ $\beta/(10^{21}s^{-1})$ | $^{202}$Fr | | | $^{202}$Po | | | $^{202}$Tl | | |
|---|---|---|---|---|---|---|---|---|---|
| | $N_n$ | $N_p$ | $N_\alpha$ | $N_n$ | $N_p$ | $N_\alpha$ | $N_n$ | $N_p$ | $N_\alpha$ |
| 2 | 0.38328 | 0.43090 | 0.35256 | 1.68117 | 0.18827 | 0.20018 | 3.73251 | 0.08011 | 0.11937 |
| 5 | 0.73049 | 0.74162 | 0.55643 | 2.45483 | 0.40371 | 0.34563 | 5.10347 | 0.09823 | 0.14215 |
| 10 | 1.07440 | 1.00207 | 0.71468 | 3.11755 | 0.48796 | 0.41407 | 6.01654 | 0.11714 | 0.16143 |
| 15 | 1.29280 | 1.15718 | 0.82775 | 3.48882 | 0.53810 | 0.45238 | 6.45335 | 0.12135 | 0.17286 |
| 20 | 1.46030 | 1.26640 | 0.89530 | 3.80025 | 0.57346 | 0.47927 | 6.86571 | 0.12742 | 0.17921 |

| $L = 60\hbar$ $\beta/(10^{21}s^{-1})$ | $^{202}$Fr | | | $^{202}$Po | | | $^{202}$Tl | | |
|---|---|---|---|---|---|---|---|---|---|
| | $N_n$ | $N_p$ | $N_\alpha$ | $N_n$ | $N_p$ | $N_\alpha$ | $N_n$ | $N_p$ | $N_\alpha$ |
| 2 | 0.30254 | 0.35409 | 0.20377 | 0.87133 | 0.15004 | 0.13721 | 3.22157 | 0.06725 | 0.09049 |
| 5 | 0.53302 | 0.58454 | 0.33159 | 1.55554 | 0.25059 | 0.22419 | 4.51025 | 0.08492 | 0.11247 |
| 10 | 0.75447 | 0.78060 | 0.43709 | 2.17243 | 0.33150 | 0.29063 | 5.32711 | 0.09361 | 0.12283 |
| 15 | 0.89435 | 0.89325 | 0.49602 | 2.53921 | 0.37519 | 0.32488 | 5.72372 | 0.09702 | 0.12677 |
| 20 | 1.00833 | 0.97730 | 0.53853 | 2.81473 | 0.40511 | 0.34737 | 5.99589 | 0.09895 | 0.12893 |

| $L = 65\hbar$ $\beta/(10^{21}s^{-1})$ | $^{202}$Fr | | | $^{202}$Po | | | $^{202}$Tl | | |
|---|---|---|---|---|---|---|---|---|---|
| | $N_n$ | $N_p$ | $N_\alpha$ | $N_n$ | $N_p$ | $N_\alpha$ | $N_n$ | $N_p$ | $N_\alpha$ |
| 2 | 0.28157 | 0.32519 | 0.17935 | 0.72138 | 0.12214 | 0.11183 | 2.81547 | 0.04627 | 0.06361 |
| 5 | 0.47215 | 0.54937 | 0.29013 | 1.28055 | 0.20590 | 0.18489 | 3.84839 | 0.06320 | 0.08074 |
| 10 | 0.65427 | 0.72836 | 0.39845 | 1.78634 | 0.27424 | 0.24220 | 4.61709 | 0.06861 | 0.08870 |
| 15 | 0.76723 | 0.81172 | 0.45827 | 2.09220 | 0.31205 | 0.27285 | 4.98813 | 0.07165 | 0.09117 |
| 20 | 0.84941 | 0.89031 | 0.49101 | 2.33975 | 0.34015 | 0.29479 | 5.20110 | 0.07350 | 0.09243 |

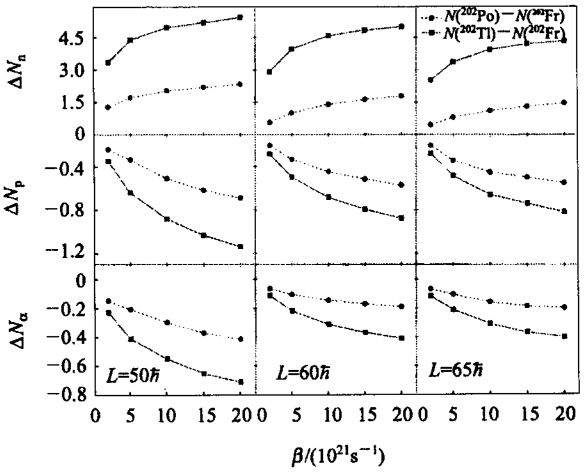

Fig.2.　The multiplicity differences of pre-scission neutrons, protons and $\alpha$ particles between $^{202}$Po and $^{202}$Fr (circles), and between $^{202}$Tl and $^{202}$Fr (squares) as function of viscosity coefficient at the excitation energies $E^* = 100$MeV and at the angular momentum $L = 50\hbar$ (left rows), $60\hbar$ (middle rows) and $65\hbar$ (right rows). Full points are the calculated results. The lines are for guiding eyes.

($\Delta N^{^{202}\mathrm{Tl}(^{202}\mathrm{Fr})}$). This relfects the influence of isospin on particle emission. One also notices the absolute differences gradually become smaller as increasing angular momentum. For instance, as $L$ changes from $50\hbar$ to $65\hbar$, $\Delta N_n^{^{202}\mathrm{Tl}(^{202}\mathrm{Fr})}$ falls from 3.35 (5.41) to 2.53 (4.35) for $\beta = 2(20) \times 10^{21}\mathrm{s}^{-1}$. A smaller difference of the particle multiplicity between $^{202}$Po and $^{202}$Fr was also found. With respect to the charged particles, $\Delta N_p^{^{202}\mathrm{Tl}(^{202}\mathrm{Fr})}$ and $\Delta N_\alpha^{^{202}\mathrm{Tl}(^{202}\mathrm{Fr})}$ at $\beta = 2(20) \times 10^{21}\mathrm{s}^{-1}$ rise from $-0.35$ ($-1.14$) and $-0.25$ ($-0.72$) to $-0.28$ ($-0.80$) and $-0.12$ ($-0.41$) respectively as $L$ rises from $50\hbar$ to $65\hbar$. This means that the change of the absolute difference of particle multiplicity of two different systems with $\beta$ is decreased as $L$ is increased. These results again indicate that higher angular momentum can greatly lower the effect of isospin on particle emission.

## 4 Summary

In conclusion, we studied the influence of angular momentum on the isospin dependence of the pre-scission particles via the Smoluchowski equation. It is shown that a large angular momentum not only weakens the influence of dissipation on the particle multiplicity but decreases the dependence of the pre-scission particles on the isospin as well. Thus, to better extract the value of nuclear dissipation by means of light particle multiplicity, besides choosing a proper kind of particles for systems with different isospins, it is also impotrant to choose these fissioning systems with a low spin.

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# 同位旋对断前粒子发射影响的角动量依赖性*

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**摘要** 对一个同量异位素链$^{202}$Fr,$^{202}$Po,$^{202}$Tl和一个同位素链$^{189,202,212}$Po,用裂变扩散模型考察了角动量对裂变前粒子发射同位旋效应的影响. 发现断前粒子发射的同位旋效应敏感地依赖于系统的自旋. 高的角动量不但弱化了同位旋对粒子蒸发的影响,而且也降低了核耗散对粒子发射的影响. 因此,为了更准确地用粒子多重性来提取核耗散系数,选择一个低自旋的复合系统是重要的.

**关键词** 同位旋效应 角动量 断前粒子多重性 核耗散 裂变扩散模型

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