Experiment on the Isotropy of Alpha-Alpha Angular Correlation in the Serial Decay of ^{228}Th and ^{226}Ra

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Experiment on the angular correlation between consecutive alphas emitted in the serial decay of ^{228}Th and ^{226}Ra are performed on the stars produced in emulsion. The correlation distributions follow isotropy.

Introduction

In a doubly even nucleus, alpha emission takes place isotropically. In case of successive alpha emissions as in the serial decay of ^{228}Th and ^{226}Ra, the angular correlation function $\omega(\Theta)\ \mathrm{d}\Omega = 1.\ \mathrm{d}\Omega$, where $\omega(\Theta)$ is the probability per unit solid angle that the second alpha is emitted into the element of solid angle $\mathrm{d}\Omega$ at an angle Θ with the first one. The correlation thus depends only on the geometry. Normalising the correlation function, the probability of the spherically symmetric emission of two consecutive alphas between Θ and $\Theta + \mathrm{d}\Theta$ is $W(\Theta)\ \mathrm{d}\Theta = \frac{1}{2} \sin \Theta\ \mathrm{d}\Theta$. The probability of finding these angles projected on a plane, between Φ and $\Phi + \mathrm{d}\Phi$ is

$$W(\Phi)\ \mathrm{d}\Phi = \left(\frac{1}{2\,\pi}\right)\ \mathrm{d}\Phi\,.$$

Wilkins [1] performed an experiment in emulsion to measure the angles between the alphas from Th and Ra stars. His result was not in agreement with the isotropic alpha emission. However well-established the principle of isotropic alpha emision in doubly even nuclei might be, experimental record in this regard for ^{228}Th and ^{226}Ra series is deserving. Such correlation experiments are carried out with alpha stars produced from ^{228}Th and ^{226}Ra in emulsion plate and the results are reported here in brief.

Experiment and Results

The details of the experiments about the production of ^{228}Th stars in emulsion plate and measurement of the angles between successive alphas have been reported previously [2] with preliminary results. Since then more data have been collected. Experiments on the production of ^{226} Ra stars and measurements of angles between successive alphas are done in the same way and wil not be described. For convenience, the decay scheme of ^{228}Th and ^{226}Ra are shown below symbolising the successive alphas as α_1, α_2, etc. in both cases.

$$\begin{tikzcd}[column sep=small] & & & & & & {}^{212}\mathrm{Po} \arrow[dr, "\alpha_5"] & \\ {}^{228}\mathrm{Th} \arrow[r, "\alpha_1"] & {}^{224}\mathrm{Ra} \arrow[r, "\alpha_2"] & {}^{220}\mathrm{Rn} \arrow[r, "\alpha_3"] & {}^{216}\mathrm{Po} \arrow[r, "\alpha_4"] & {}^{212}\mathrm{Pb} \arrow[r, "\beta^-"] & {}^{212}\mathrm{Bi} \arrow[ur, "\beta^-"] \arrow[dr, "\alpha_6"'] & & {}^{208}\mathrm{Pb} \\ & & & & & & {}^{208}\mathrm{Tl} \arrow[ur, "\beta^-"'] & \end{tikzcd}$$

$$^{226}\mathrm{Ra} \xrightarrow{\alpha_1} {}^{222}\mathrm{Rn} \xrightarrow{\alpha_2} {}^{218}\mathrm{Po} \xrightarrow{\alpha_3} {}^{214}\mathrm{Pb} \xrightarrow{\beta^-} {}^{214}\mathrm{Bi} \xrightarrow{\beta^-} {}^{214}\mathrm{Po} \xrightarrow{\alpha_4} {}^{210}\mathrm{Pb}$$

Decay scheme of ^{228}Th and ^{226}Ra.

The angles $\alpha_1\alpha_2$, etc. projected on the focal plane of the eye-piece of the goniometer are measured from the stars produced from ^{228}Th and ^{226}Ra series. The angles $\alpha_1\alpha_2$, etc. mean the angle between alphas from ^{228}Th and ^{224}Ra in the thorium star and between ^{226}Ra and ^{222}Rn in the uranium star and so on. The space angles corresponding to the projected angles are obtained with the help of a stereographic projection net. A total of 4596 angles in ^{228}Th stars and 3598 in ^{226}Ra stars have been measured out of which the angles used for the experimental distributions are given in Table 1.

^{228}Th star		^{226}Ra star	
angles	number	angles	number
$\alpha_2\alpha_3$	1111	$\alpha_1\alpha_2$	1198
$\alpha_3\alpha_4$	1137	$\alpha_2\alpha_3$	1200
$\alpha_4\alpha_5$	1132	$\alpha_3\alpha_4$	1200

Table 1. Total number of angles used for the distribution.

The probability distribution of the emission angles $\alpha_2\alpha_3$, $\alpha_3\alpha_4$ and $\alpha_4\alpha_5$ in ^{228}Th series are shown in Figs. $1-3$ respectively and the angles $\alpha_1\alpha_2$, $\alpha_2\alpha_3$ and $\alpha_3\alpha_4$ in the ^{226}Ra series in Figs. $4-6$, respectively. The distribution of space angles is normalised with $\frac{1}{2}\sin\Theta$, shown by the solid curve and that of the projected angles with $\dfrac{1}{2\,\pi}$ also shown by the solid line. For rarity of five-prong Th stars sufficient data for angles $\alpha_1\alpha_2$ for significant distribution have not been obtained. Angles $\alpha_4\alpha_6$ in Th series are also not considered for distribution as there is uncertainty in the identification of alphas from ^{212}Bi. The results agree well with the isotropic emission of alphas from their respective nuclei.

Discussion

Though the nuclei with mass number greater than 220 have a stable spheroidal deformation, quantum mechanical consideration rules out the possibility of obtaining anisotropic corerlation between alphas from ^{228}Th and ^{224}Ra and also from ^{226}Ra and ^{222}Rn, as is expected from the non-spherical alpha barrier of these nuclei. Classically alphas should be emitted preferentially from the tips of the spheroidal nucleus, but in the successive decays of doubly even alpha emitters, the orientation of the nuclear body axis is distributed and

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1 T. R. Wilkins, Phys. Rev. **49**, 639 [1936].

2 M. M. Biswas, B. K. Gupta, P. K. Sen, and P. C. Bhattacharya, Z. Naturforsch. **21 a**, 902 [1966].

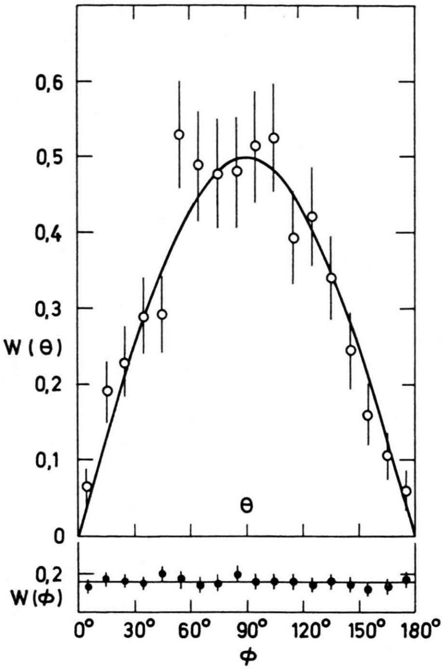


Fig. 1.

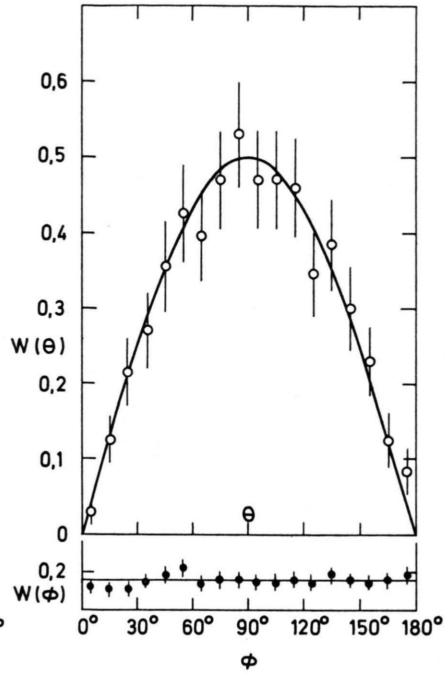


Fig. 2.

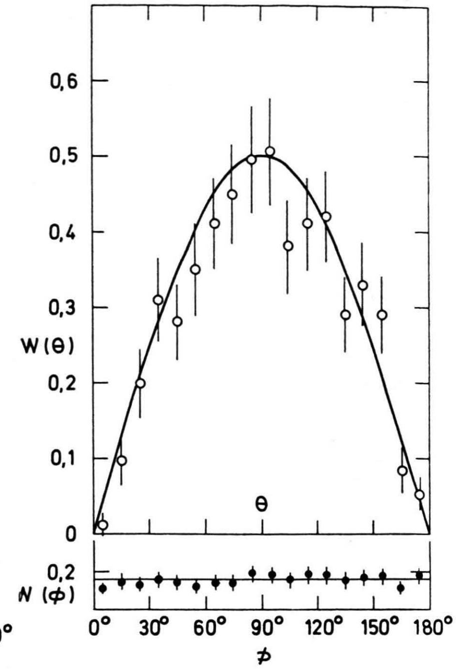
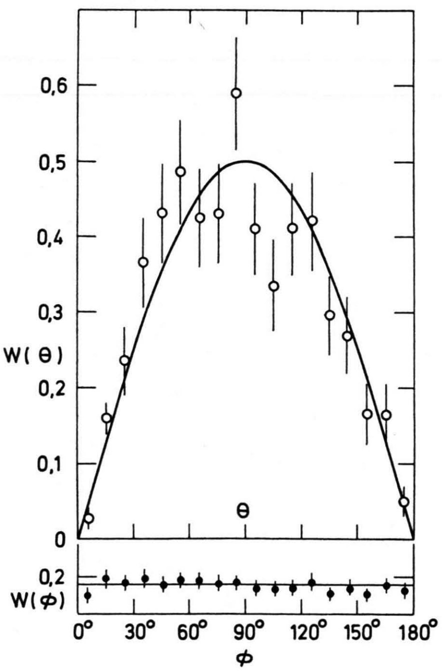


Fig. 3.



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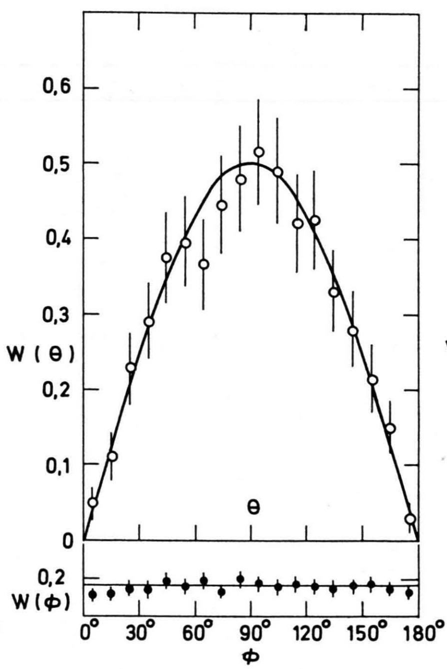

Fig. 5.

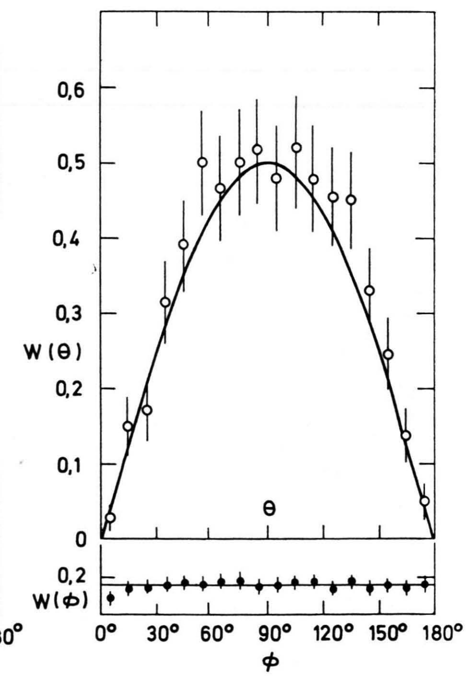

Fig. 6.

Fig. 1. Upper: Distribution of angles between alphas from ^{224}Ra and ^{220}Rn; the solid curve is $\frac{1}{2}\sin\Theta$. Lower: Distribution of projected angles between the same alphas; the straight line is $W(\Phi) = \dfrac{1}{2\pi}$.

Fig. 2. As in Fig. 1 for alphas from ^{220}Rn and ^{216}Po.
Fig. 3. As in Fig. 1 for alphas from ^{216}Po and ^{212}Po.
Fig. 4. As in Fig. 1 for alphas from ^{226}Ra and ^{222}Rn.
Fig. 5. As in Fig. 1 for alphas from ^{222}Rn and ^{218}Po.
Fig. 6. As in Fig. 1 for alphas from ^{218}Po and ^{214}Po.

hence there could be no anisotropic relation between alphas emitted from ^{228}Th and ^{224}Ra and also from ^{226}Ra and ^{222}Rn.

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