Nuclear Data for Science and Technology (1988 MITO), 1173-1175, Copyright © 1988 JAERI.

ANISOTROPY OF FISSION ANGULAR DISTRIBUTIONS FOR $^{16}O + ^{192}Os$ AND ^{197}Au

M. Ogihara, S. C. Jeong, H. Fujiwara, M. Miyazawa,
Y. H. Pu, W. Galster,
Y. Nagashima, S. M. Lee, T. Mikumo
Institute of Physics and Tandem Accelerator Center
University of Tsukuba, Ibaraki 305, Japan

H. Ikezoe, K. Ideno, Y. Tomita, Y. Sugiyama
Japan Atomic Energy Research Institute
Tokai, Ibaraki-ken 319-11, Japan

T. Matsuse
Faculty of Textile Science and Technology
Shinshu University, Nagano 386, Japan

Abstract : In this article we give an answer to the question whether fission angular distributions are determined at the saddle point or at the scission point. We measured precisely fission angular distributions for ^{16}O-induced fission at various projectile energies. We analyzed the data in terms of the statistical model of Ericson. Through the analysis we conclude that the fission angular distribution is determined at the scission point. From this standpoint, we deduced the average channel spin of fission fragments from the fission angular distributions giving a good agreement with the results obtained by γ-ray multiplicities.

(fission angular distribution, saddle point, scission point, statistical model of Ericson, decoupling angle, average channel spin)

Introduction

Historically fission angular distributions have been mainly accounted for in terms of the rotating liquid drop model (RLDM) [1] and have in general been understood within its framework. The RLDM predicts isotropic fission angular distribution for the compound nucleus with large fissility (Z^2/A) ; this is due to the spherical saddle point shape and consequently due to isotropic K-distribution at the saddle point ($K_0^2 \rightarrow \infty$). However, recent measurements with heavy-projectile like ^{32}S showed large anisotropies of fission angular distribution[2] indicating the limitation of validity of the RLDM in fission angular distribution for the reaction systems with large fissility. The various interpretations are proposed [3]. Then the question arises whether the fission angular distributions are determined at the saddle point or at the scission point[4]. In order to answer to this question, it is necessary to clarify the role of the principal physical quantities to govern the fission angular distribution. In this work precise measurements of the fission angular distributions were carried out as a function of projectile energy. The data were analyzed in terms of the statistical model of Ericson[5]. We conclude that fission angular distribution is determined at the scission point.

Experiments

Measurements of fission angular distribution up to backward angles close to $\theta_L = 180°$ were undertaken with ^{16}O beams on ^{181}Ta, ^{192}Os and ^{197}Au targets at energies ranging from the fusion barrier (V_B) to $E_{CM} - V_B \simeq 70\ MeV$. Experiments were performed with a standard experimental setup by using ionization chambers and surface-barrier detectors ($\Delta E - E$ counter telescopes). Fission fragments could be identified and distinguished well from the other reaction products with these counter telescopes. The angular distributions in the center of mass frame were deduced assuming symmetric fission with the total kinetic energy given by Viola's systematics[6]. This validity was checked by measuring folding angle distribution and total kinetic energies.

Results

The angular distribution deviates from $1/\sin\theta$ at a certain angle and gives a finite anisotropy. Fig.1 shows the anisotropy of the angular distribution as a function of the excitation energy of the compound nucleus. The anisotropy increases with increasing projectile energy and appears to saturate at higher energies. Existing data also show the same trends. This nearly constant anisotropy depends on reaction systems. For the same compound nucleus, the constant anisotropy is larger for heavier projectile. The nearly constant value of the anisotropy comes mainly from the saturation of the average compound nucleus spin for fission.

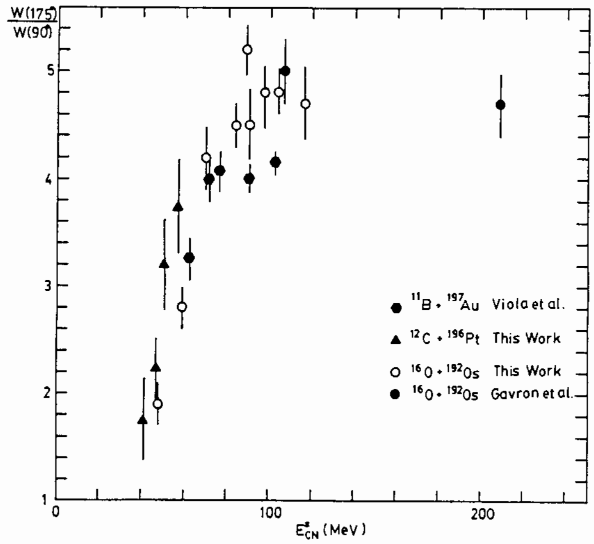

Fig.1 Anisotropy of fission angular distribution as a function of excitation energy of the compound nucleus.

Discussion

According to the statistical model of Ericson, the decoupling of the orbital angular momentum **l** from the compound nucleus spin **J** due to the channel spin $\mathbf{I_f}$ leads to a smearing from $1/\sin\theta$ near beam direction. An angle corresponding to the maximum decoupling of **l** from **J** is termed decoupling angle ϑ_0. The decoupling angle θ_0 can be deduced experimentally with good accuracy from $d\sigma/d\theta$ as an angle where $d\sigma/d\theta$ decreases suddenly at θ_0 as shown in Fig.2. As a consequence of the angular momentum conservation, the decoupling angle ϑ_0 is related with average compound nucleus spin for fission $\langle J\rangle$ and average channel spin $\langle I_f\rangle$ as

$$\sin\vartheta_0 = \langle I_f\rangle/\langle J\rangle \; . \qquad (1)$$

Smearing from $1/\sin\theta$ leads to the finite anisotropy of the fission angular distribution. Therefore the decoupling of **l** from **J** is closely related to the anisotropy of fission angular distribution. The projectile energy dependence of the decoupling angle is actually very similar to that of the anisotropy. The decoupling angle is also nearly constant above a certain energy and is very similar for different entrance channels including heavy-projectile induced fission such as ^{32}S-induced fission. The nearly constant θ_0 is ranging from 160° to 170°. This suggests that as the projectile energy increases **J** becomes much larger than $\mathbf{I_f}$ and consequently **l** is always almost stretched to the direction of **J** in the average for heavy ion induced fission. This is never predicted by the RLDM. From these points of view, we conclude that the fission angular distribution is rather determined at the scission point than at the saddle point.

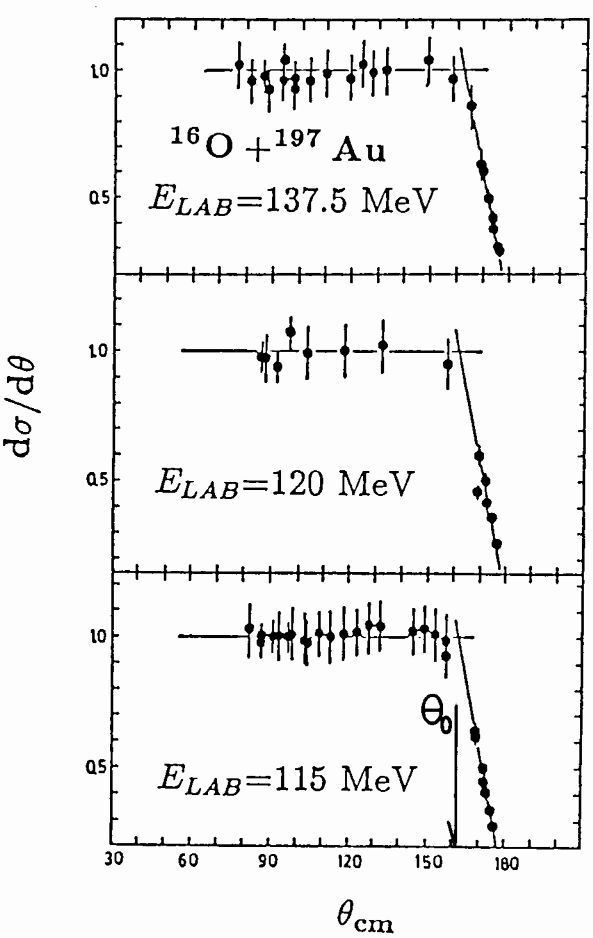

Fig.2 Representative $d\sigma/d\theta$ for $^{16}O + ^{197}Au$ at three projectile energies.

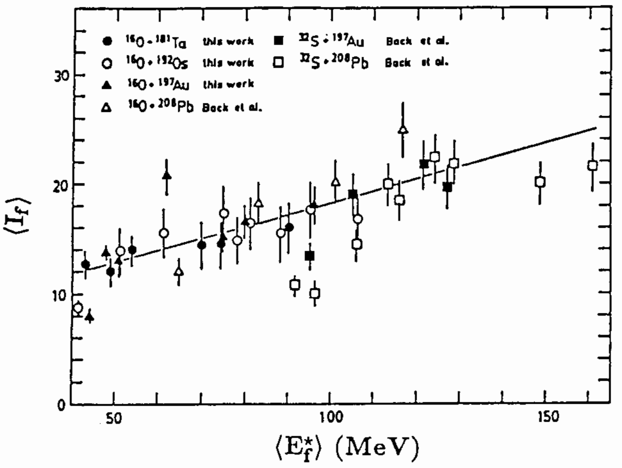

Fig.3 Average channel spin deduced from fission angular distributions as a function of the excitation energy of the fission fragments. The solid line indicates a least square fit to our data.

Furthermore we can deduce the average channel spin of fission fragments $\langle I_f \rangle$ using a knowledge of $\langle J \rangle$ evaluated from heavy-ion fusion-fission cross section [7]. Fig. 3 shows $\langle I_f \rangle$ as a function of average excitation energy of the fission fragments $\langle E_f^* \rangle$. The solid line shows $\langle I_f \rangle = 0.11\langle E_f^* \rangle + 7.5$, where $\langle E_f^* \rangle$ is in MeV. $\langle J \rangle$ deduced from fission angular distributions agree well with the γ-ray multiplicity measurements[8].

The authors would like to acknowledge the support of the academic and technical staff of the Tandem Accelerator Center at University of Tsukuba and JAERI.

REFERENCES

1) S. Cohen, F. Plasil and W. J. Swiatecki, Ann. Phys. **82** 557 (1974)
2) B. B. Back, H. G. Clerk, R. R. Betts, B. G. Glagola and B. D. Wilkins, Phys. Rev. Lett. **46** 1068 (1981)
3) R. Freifelder, M. Prakash and J. M. Alexander, Phys. Rep. **133** 315 (1986)
4) The Symposium on Fission Mechanisms - Saddle or Scission - : The Point of Discussion (Chicago, Sept. 12, 1985)
5) T. Ericson, Advances in Physics **9** 425 (1960)
6) V. E. Viola, Nucl. Data Tables **A5** 391 (1966)
7) T. Nakagawa et al., Proc. of the ' TSUKUBA INTERNATIONAL SYMPOSIUM (Sept. 3-5, 1984) p129
L. C. Vaz and J. M. Alexander, Phys. Rep. **97** 1 (1983)
8) R. Leigh, W. R. Phillips, J. O. Newton, G. S. Foote, D. J. Hinde and G. D. Dracoulis, Phys. Lett. **159B** 9 (1985)
R. P. Schmitt, G. Mouchaty and D. R. Haenni, Nucl. Phys. **A427** 614 (1984)