high-K (oblate) deformation-aligned rotational bands built upon few quasi-particle configurations. The high K of such bands would favor M1 over E2 transitions among members of the band[3]. If the associated moment of inertia were equal to the rigid sphere value (i.e., if pairing effects were unimportant and the deformation mild) and the mean spin of the band members were ≈16ħ, we would expect a number of M1 transitions of ∿160 keV; each such transition would yield a K X-ray ∿60% of the time.

There are indeed a number of such strongly coupled rotational bands which have been identified at low excitation in the neutron-poor (A=189-199) Tl isotopes.[2,4] However, there is essentially no relevant information available about the energy levels in the Pb isotopes in the appropriate region of spin. We have therefore run very recently an X-γ and γ-γ coincidence experiment (using one large-volume Ge(Li) and two intrinsic Ge detectors), designed to search for low-energy γ-rays from the proposed highly converting transitions, with particular emphasis on (the previously unknown) transitions feeding the 12^+ isomeric state ($T_{1/2}$= 212 ns) in ^{198}Pb. The ^{198}Pb was populated with a high value of $\langle M_K \rangle$ (≈ 2.0) in 68-MeV ^{7}Li+^{197}Au, and with lower $\langle M_K \rangle$ (≈ 1.1) in 55 MeV ^{6}Li+^{197}Au, in order to seek correlations between the X-ray multiplicity and features of the γ-ray coincidence yields. The high-statistics singles γ spectra acquired reveal a large number of weak, previously unidentified, lines between ∿ 100 and ∿ 300 keV. Association of these lines with particular nuclides, and information on the (singles) angular distributions (and hence multipolarities), await replay of the ∿ 50 event tapes collected.

One additional recent extension to our X-ray program has involved accurate measurements of the absolute cross sections for target (atomic-collision) X-ray production at $E_{^6Li}$ = 55 MeV, made simultaneously with measurements of the forward-angle (Rutherford) elastic scattering cross section using left-right monitor detectors in the 64"-diameter scattering chamber. We are particularly interested in the results for a series of Pt isotopes (A=194, 195, 196, 198), since our previous similar measurements at higher bombarding energy suggested a possible small, but unexpected, isotopic dependence of the target X-ray cross section. The data from this experiment are currently being analyzed.

1) H.J. Karwowski, S.E. Vigdor, W.W. Jacobs, S. Kailas, P.P. Singh, F. Soga, and W.D. Ploughe, Phys. Rev. Lett. 42, 1732 (1979).

2) A.J. Kreiner, M. Fenzl, and W. Kutschera, Nucl. Phys. A308, 147 (1978).

3) J.O. Newton, S.H. Sie, and G.D. Dracoulis, Phys. Rev. Lett. 40, 625 (1978); L.K. Peker, J.H. Hamilton, and J.O. Rasmussen, Phys. Rev. Lett. 41, 457 (1978).

4) F.S. Stephens, in "Elementary Modes of Excitation in Nuclei," ed. A. Bohr and R.A. Broglia (North Holland, Amsterdam, 1977) p. 172.

THE DECAY OF HOT, HIGH-SPIN NUCLEI PRODUCED IN ^{6}Li-INDUCED FUSION

S.E. Vigdor, H.J. Karwowski, W.W. Jacobs, S. Kailas, P.P. Singh, F. Soga, and T.G. Throwe
Indiana University Cyclotron Facility, Bloomington, Indiana 47405

We are continuing our program of measurements and statistical model analysis of the competition among decay modes of compound nuclei (CN) formed at high spin (up to ∿ 35 ħ) and excitation energy (up to ∿ 100 MeV) in ^{6}Li-induced fusion reactions. Our aim has been to measure as many observables characterizing the decay as possible, in order to constrain the statistical model analysis to a much greater degree than in previous work of this sort, in the hope that one may then extract from the analysis meaningful information about the nuclear structure (e.g., effective fission barrier heights, level densities, particle binding energies, moments of inertia) of "hot," high-spin nuclei.

We have so far measured decay properties for ^{6}Li bombardment of ^{181}Ta, $^{194,198}Pt$, ^{197}Au, and ^{208}Pb at nominal bombarding energies of 55, 75, 85, and 95 MeV. The 55 MeV data (including also some measurements for $^{195,196}Pt$) are presently being reduced. We have compared experimental results with statistical model calculations of the following quantities, all as a function of target and bombarding energy: the absolute total cross sections for fission (σ_{fiss}), α-particle evaporation (σ_{α}), Z=1 particle evaporation ($\sigma_{Z=1}$, including observed p,d, and t yields), and all (^{6}Li,xn) reactions (σ_{xn}); the fission-fragment angular distributions W(θ) [which are conveniently characterized by the anisotropy $\gamma_{fiss} \equiv W(170°)/W(90°)$]; backward-angle energy spectra of emitted protons and α's; and the mass distribution of (^{6}Li,xn) products (determined from singles γ-ray spectra for selected targets and energies). The experimental techniques have been summarized previously.[1,2] Although all of the charged-particle decay properties have been determined from singles measurements, our identification of the observed products as arising from residues of fusion, as opposed to other types of reaction, is strongly supported by the results of a recent particle-particle coincidence run. In particular, the latter results rule out significant contributions from fission or charged-particle evaporation following either forward-peaked direct reactions (or "incomplete fusion") or prior charged-particle emission from the CN. The four measured

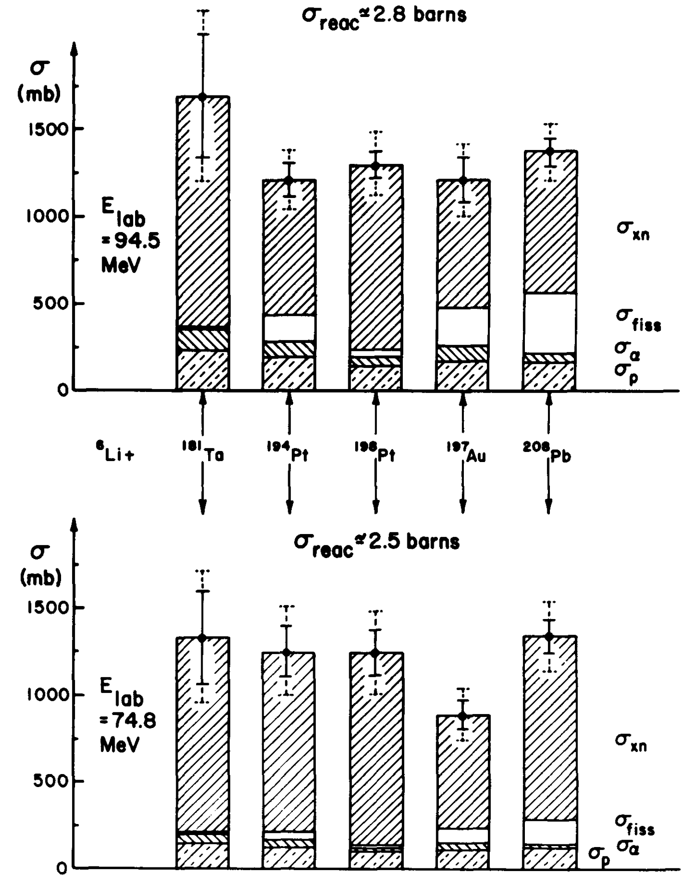

Figure 1. Decomposition of the measured fusion cross section for five targets at two energies. The error bars reflect the overall measurement uncertainties in the absolute cross sections, estimated with (dashed bars) or without (solid bars) the inclusion of a ±10% systematic error in σ_{xn} to allow for possible deviations of the actual K x-ray multiplicity distribution from the assumed Poisson distribution.

cross sections σ_{fiss}, σ_{α}, $\sigma_{Z=1}$, and σ_{xn} are then logically mutually exclusive, and sum to give the experimental total fusion cross section σ_{fus}, as illustrated for five targets at two bombarding energies in Fig. 1.

The statistical model analysis of these data has been carried out using the code MB-II (Ref. 3), modified to include calculation of the fission-fragment angular distribution, as described in Ref. 4. The statistical model calculations are highly sensitive to a wide range of parameters,

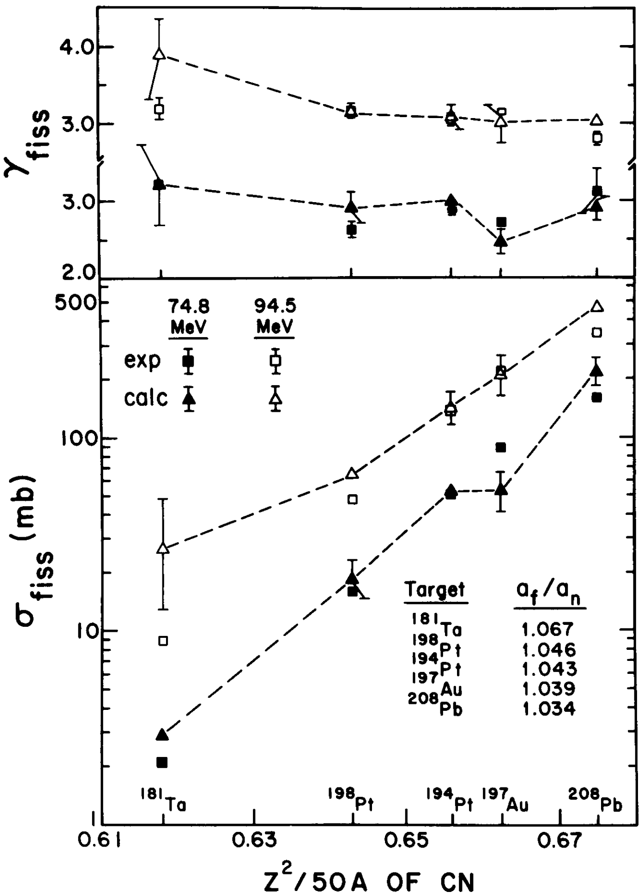

Figure 2. Measured and calculated fission anisotropies and cross sections at two bombarding energies vs. the compound-nucleus fissility (see Ref. 6). The calculations employ nuclear structure predictions of the non-interacting Fermi gas and rotating-liquid-drop models. No parameters have been adjusted to optimize the fit to the measurements. The representative error bars shown for the calculated values arise from the measurement uncertainties in the total fusion cross sections. The dashed lines connect the calculated values.

describing the structure of the decaying nuclei (as a function of neutron and proton numbers, spin, and excitation energy), the initial spin distribution in the CN, and the barrier transmission probabilities for emitted particles. In this situation, one can attach some significance to the comparison of calculations and measurements only if as many of these parameters as possible are constrained to values consistent with other available information. In the calculations shown in Figs. 2-4, we have in fact fixed all parameters to what we judge to be the most reasonable starting values. The CN spin distribution is taken to have a diffuse (Fermi-function) high-spin fall-off, with the same diffuseness as characterizes optical model partial-wave reaction cross sections for these systems, but centered around a lower spin value, appropriate to reproduce the measured σ_{fus}. Inverse reaction cross sections for particle emission are calculated using n, p, and α optical model parameters determined from low-energy elastic scattering measurements specifically for tar-

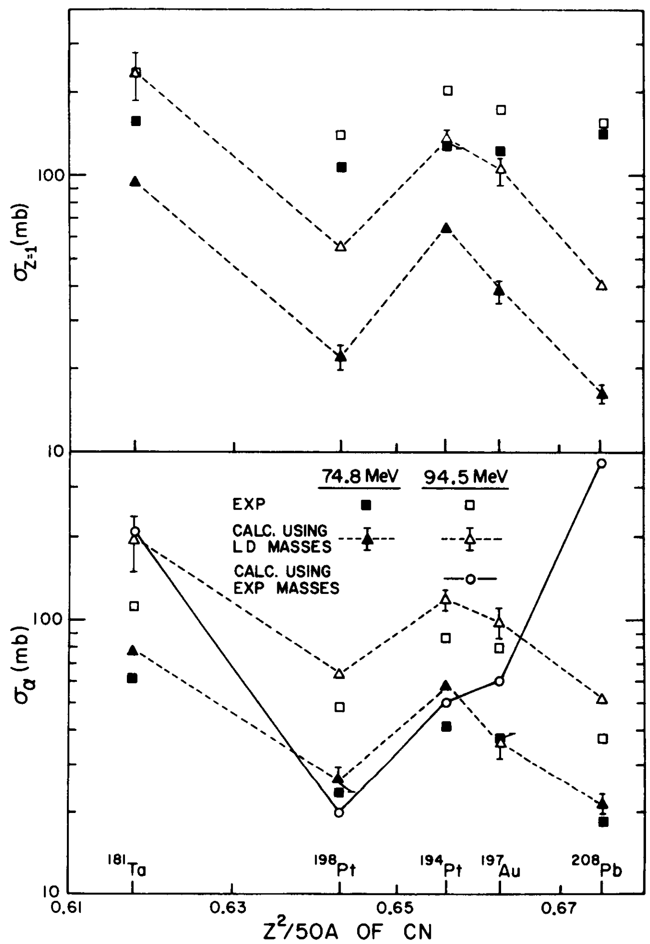

Figure 3. Comparison of measured and calculated total cross sections for evaporation of Z=1 particles and of α-particles. The calculations connected by the dashed lines employ the fixed parameter values described in the text and Fig. 2. The 94.5 MeV calculations connected by the solid lines, employing the same parameters except for the replacement of liquid-drop by experimental nuclear masses, illustrate the sensitivity of σ_α to shell corrections to the particle binding energies.

gets in the Pb region. The (equilibrium-deformation) level density parameters relevant to n, p, and α emission have been set equal to A/9.0 (A=mass number of residual nucleus), a value based on smoothed shell-model single-particle spectra in the Pb region.[5] All other nuclear structure parameters have been fixed according to the predictions of a particularly simple nuclear model, that of a two-component, non-interacting Fermi gas (NIFG) confined to a nucleus whose shape is given by the rotating liquid-drop model (RLDM, Ref. 6). Thus, nuclear masses (and particle binding energies), yrast and saddle-point energies and moments of inertia, are all given by the RLDM. The influential ratio (a_f/a_n) of level density parameters for the saddle-point and equilibrium deformations deviates from unity, to the extent expected[7] for the deformation-dependence of the single-particle level density in a NIFG with a realistic (diffuse-surface) particle density distribution.

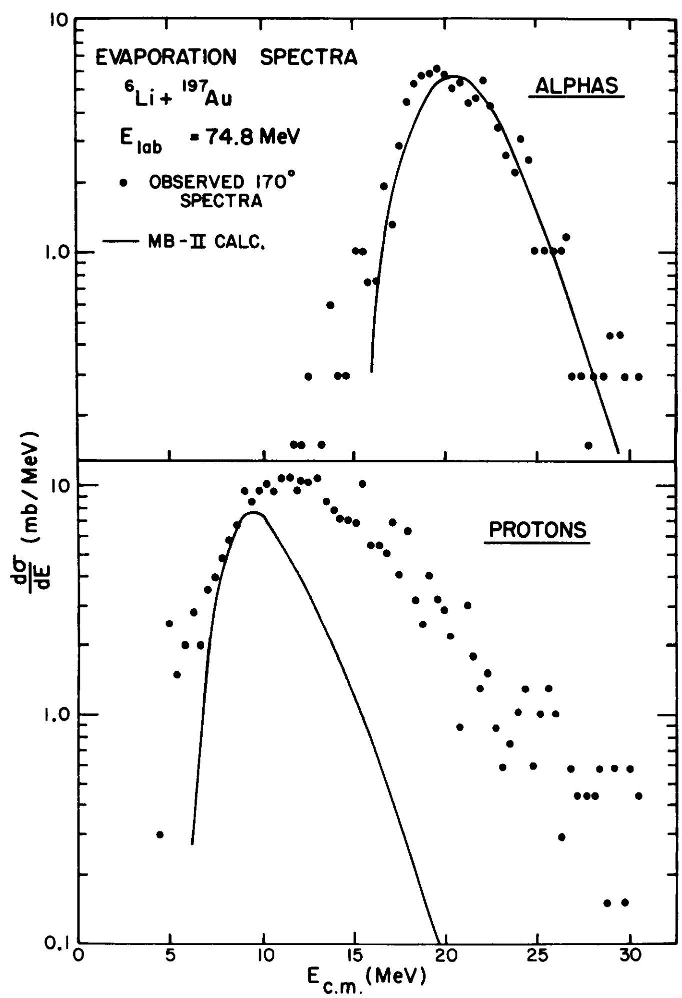

Figure 4. Comparison of the measurements and zero-adjustable-parameter calculations for the evaporated-particle energy spectra. The points represent angle-integrated cross sections $d\sigma/dE_{cm}$ deduced, under the assumption of isotropy, from the observed spectra at $\theta_{lab}=170^o$.

The overall agreement between these zero-adjustable-parameter calculations and the measurements (see Figs. 2-4) is remarkably good. The high quality of simultaneous agreement with fission cross sections and anisotropies observed in Fig. 2, as a function of target and bombarding energy, is particularly impressive, since σ_{fiss} and γ_{fiss} exhibit strong and quite different sensitivities to a number of parameters (see Ref. 4). In those few cases where significant deviations between calculated and measured values are observed in Fig. 2, they appear to track with "anomalies" in the measured fusion cross sections (see Fig. 1). The α-evaporation cross sections (especially the target dependence, Fig. 3) and energy spectra (Fig. 4) are also very well reproduced. In contrast, the large discrepancies between the calculated and measured Z=1 evaporation cross sections (Fig. 3) can be traced in the energy spectra (Fig. 4) to the anomalously large observed yield of high-energy protons, even at far backward angles. No reasonable change in nuclear structure parameters could possibly account for the observed yield of high-energy protons; this feature must reflect contributions from a mechanism (as yet undetermined, but see Ref. 8) other than evaporation from thermally equilibrated fusion products. A similar remark applies to an overestimate (by ~10% for ^{6}Li+^{197}Au) in the calculations (not shown) of the mean number of neutrons emitted per (^{6}Li,xn) reaction.

The quality of agreement found in Figs. 2-4 suggests that at the present level of reliability of the statistical model it is not necessary to include microscopic (shell and/or pairing) corrections or other modifications to the NIFG-RLDM structure in order to understand the overall decay properties of hot, high-spin nuclei. This conclusion conflicts with recent suggestions made on the basis of less complete programs of measurement and analysis.[9] In order to enhance sensitivity to such structure corrections, one needs to devise more selective measurements (we have suggested examples in Ref. 4) and to address other ambiguities in the statistical model treatment.

1) S.E. Vigdor, et al., 1978 IUCF Technical and Scientific Report, p. 106; S.E. Vigdor, et al., Proc. Symp. on High-Spin Phenomena in Nuclei, Argonne, March, 1979 (ANL/PHY-79-4), p. 511.

2) H.J. Karwowski, et al., Phys. Rev Lett. 42, 1732 (1979).

3) M. Beckerman and M. Blann, Univ. of Rochester internal report UR-NSRL-135 (1977), unpublished.

4) S.E. Vigdor et al., Phys. Lett. B, in press.

5) L.G. Moretto, Proc. 3rd IAEA Symp. on the Physics and Chemistry of Fission (Int. Atomic Energy Agency, Vienna, 1974) Vol. I, p. 329.

6) S. Cohen, F. Plasil, and W.J. Swiatecki, Ann. Phys. 82, 557 (1974).

7) C.J. Bishop, et al., Nucl. Phys. A198, 161 (1972).

8) H.W. Bertini, R.T. Santoro, and W.W. Hermann, Phys. Rev. C14, 590 (1976).

9) M.Beckerman and M. Blann, Phys. Rev. Lett. 38, 272 (1977) and Phys. Rev. C17, 1615 (1978); R.L. Ferguson, et al., Bull Am. Phys. Soc. 24, 825 (1979); M. Faber and M. Ploszajczak, Z. Phys. A291, 331 (1979).

IMPROVEMENTS TO THE STATISTICAL MODEL TREATMENT OF HIGH-SPIN COMPOUND NUCLEI

S.E. Vigdor, H.J. Karwowski, and P. Yip*
Indiana University Cyclotron Facility, Bloomington, Indiana 47405

In our attempts to constrain nuclear structure parameters at high spin by studying the decay modes of fusion products, it has become clear that one needs not only more careful and systematic measurements of the decay properties, but also expanded and improved versions of the standard statistical model analysis codes. We have already implemented one major improvement to the code MB-II (Ref. 1), incorporating the capability to calculate the fission-fragment angular distribution W(θ). As we have described in a recent publication[2], this feature represents an important addition to the code, since it does not require introducing any significant new assumptions, while W(θ) does provide significant new constraints on the spin distribution of the compound nucleus (CN) and on the "chance" distribution of the observed fission. (The chance distribution refers to the relative contributions of fission directly from the CN vs. fission following the emission of one, two, three, etc., neutrons from the CN.) The calculation is based on the model of Halpern and Strutinski,[3] according to which W(θ), for a given total angular momentum (J) of the fissioning nucleus, depends on the statistical distribution of angular momentum projection values (K, $0 \leq K \leq J$) along the nuclear symmetry axis at the saddle-point deformation. Details concerning the calculation can be found in Refs. 2 and 4.

In Fig. 1 we present calculations for four different sets of parameters (all without any particular physical significance) which are intended to illustrate the sensitivity of W(θ) [as characterized by the ani-