the gamma-ray transitions we observe. One should contrast this with the result of 150 MeV $\alpha + {}^{62}$Ni α-γ coincidence measurements where the resonance at 16.4 MeV excitation seems to be represented in the coincidence data.

To help clarify the resonance decay anomaly, we have requested beam time to measure singles proton angular distributions and analyzing powers to determine if the 80 MeV proton is strongly populating the giant quadrupole resonance as expected from the literature.[3] Particle-particle coincidence measurements may be necessary to determine if, in fact, the low gamma-ray coincidence yields are due to the resonance excitation.

For general continuum excitation, a comparison of our p-γ coincidence average nucleon removal with that of inclusive gamma-ray measurements yields an estimate of about 24% fusion contribution associated with the 81.5 MeV p + ^{62}Ni reaction. The data indicate that most reactions are associated with the emission of just one fast particle. The data are consistent with the two-step reaction mechanism first proposed by Serber[4]

and a possible momentum-transfer dependence in the first step (deduced from the measured fast particle) is indicated by some details of the final isotope production as a function of angle. A momentum-transfer dependence of final-state populations would necessarily imply a localization of the initial interaction. Comparisons with exciton-model and nucleon-cascade evaporation-model calculations are consistent with the first step involving a nucleon-nucleon interaction, but the system very rapidly evolves to configurations involving many nucleons.

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2) J.D. Wiggins Jr., Particle-Gamma Ray Coincidence Studies on ^{62}Ni, Ph.D. Thesis, IUCF Internal Report 81-(1981).

3) D.C. Kocher et al., Phys. Rev. Lett. 31, 1070 (1973); ibid, Phys. Rev. C14, 1392 (1976).

4) R. Serber, Phys. Rev. 72, 1114 (1947).

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

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Several aspects of our systematic investigation of fission and particle emission from "hot", high-spin fusion products in the Pb region have been brought to an encouraging conclusion: we have demonstrated that it is indeed possible to constrain statistical-model analyses of such decay processes sufficiently to test relevant features of the high-spin nuclear structure quantitatively. In order to do so, we have had to significantly expand the scope and improve the

techniques of both the experiment and the statistical-model calculations, in comparison with previous work. Details concerning various features of the measurement and computational techniques have been reported previously,[1-3] and a complete description of the entire program, and of the nuclear theory questions addressed, has been presented recently.[4]

During the past year our efforts have been concentrated primarily on improving the statistical-

model code MB-II (ref. 5) and re-analyzing the
experimental results. The new major improvements to
the code are (1) the incorporation of a more realistic
treatment of the angular-momentum dependence of level
densities in deformed nuclei, including collective
(rotational) enhancements, and (2) allowance for
simulating the effects of pre-equilibrium nucleon
emission in the early stages of the decay on subsequent
fission and evaporation probabilities. Details of
these modifications are explained in ref. 4. We have
also finalized the experimental results for ^{6}Li
bombarding energies of 74.8, 84.2, and 94.4 MeV,
including small (~ 10%) corrections, based on our
particle-particle coincidence measurements for 95-MeV
^{6}Li + ^{194}Pt, to the proton ($\sigma_{Z=1}$) and α-particle (σ_α)
evaporation cross sections which we had deduced
previously from backward-angle singles charged-particle
spectra.

Several significant features of our current
analysis of the fission and particle emission
characteristics are shown in Figs. 1-4. The
calculations represented in Figs. 1-3 are based on the
assumption that the compound nucleus (CN) has reached
complete thermal equilibrium prior to the first-chance
decay. These calculations employ no adjustable
parameters.[4] In particular, all nuclear structure
parameters (including, for self-consistency, particle
binding energies and the CN ground-state mass) have
been fixed to predictions of the rotating-liquid-drop
(RLDM, ref. 6) and non-interacting Fermi gas (NIFG,
refs. 4,7,8) models; i.e., shell and pairing
corrections to the structure have been completely
neglected. Even in the absence of such microscopic
corrections, there are several (usually neglected)
subtle effects on the structure parameters which
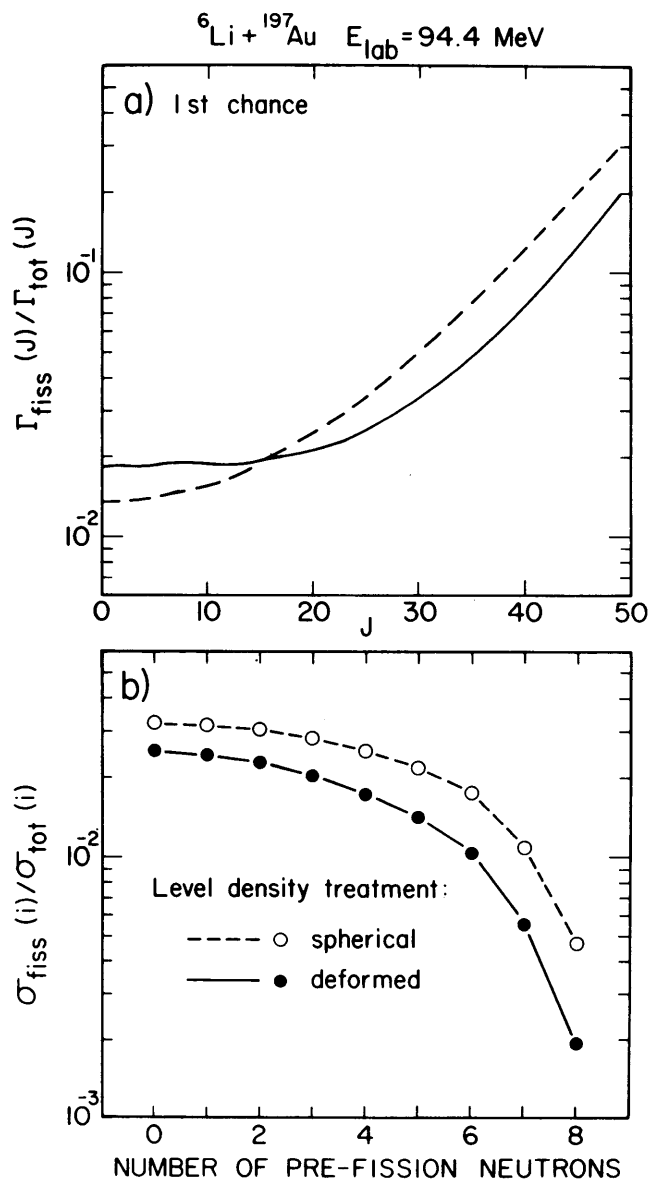strongly influence the calculations. For example, the

Figure 1. Differences in the spin (a) and chance (b)
distributions for fission between calculations
employing the usual spherical treatment (dashed curves)
and the present deformed-nucleus treatment (solid
curves) of level densities.

level density parameters a_f and a_n relevant to fission
and neutron emission, respectively, are not chosen to
be equal, but are rather taken in the (target-
dependent) ratio expected[8] from the deformation-
dependence of the single-particle level density in a
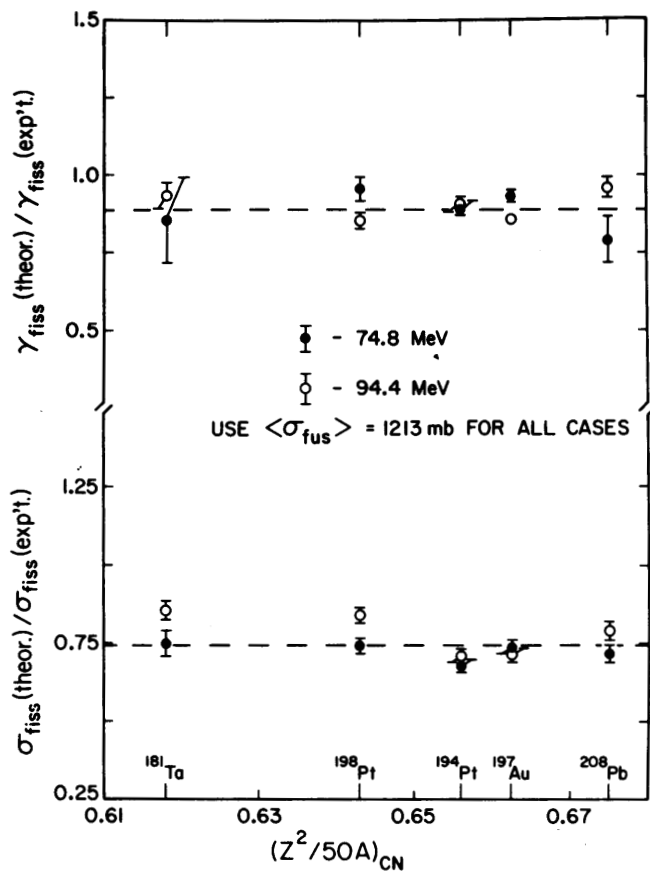NIFG model with a realistic (diffuse-surface) particle

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Figure 2. The ratio of calculated to measured values of the fission cross section and anisotropy following ^{6}Li-induced fusion at two bombarding energies, plotted versus the compound-nucleus fissility. The calculations employ no adjustable parameters and constrain the CN spin distribution in all cases to match the <u>mean</u> measured fusion cross section, rather than individual σ_{fus} results for each target and energy. The dashed lines represent the average values of the ratios. The target nuclei used are indicated on the horizontal axis.

density distribution.

Figure 1 illustrates the typical changes in the calculated spin and chance distributions for fission which result from our improvements to the level-density treatment in MB-II. In Fig. 2 we plot the ratios of predicted to measured values of the fission cross section (σ_{fiss}) and fragment anisotropy (γ_{fiss}) for five targets at two bombarding energies. We find an accurate <u>quantitative</u> reproduction of the observed target-dependence (and, over this admittedly small
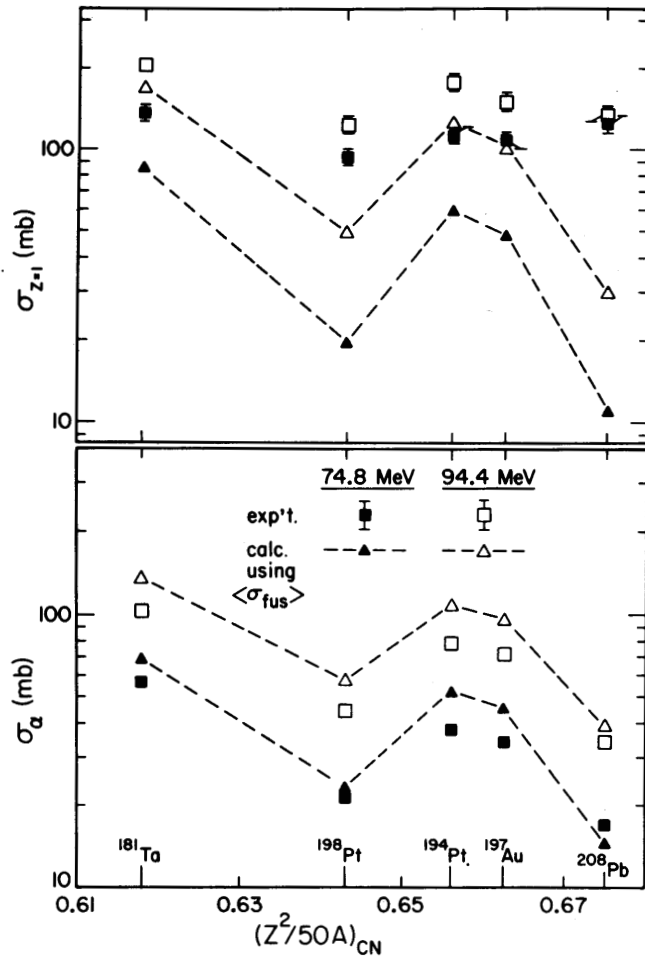

Figure 3. Comparison of measured and calculated cross sections for Z=1 and α-particle emission, for five targets at two bombarding energies. The calculations use the RLDM-NIFG parameter set (see ref. 4) and the mean measured fusion cross section. The dashed lines connect the calculated values.

range of bombarding energies, of the energy dependence as well) of σ_{fiss} and γ_{fiss} by the zero-adjustable-parameter statistical-model calculations. This agreement is very significant in view of the strong sensitivity of the calculations to small changes in input parameters.[4] For example, if we had neglected the target-dependence of a_f/a_n (from 1.067 for ^{6}Li + ^{181}Ta to 1.029 for ^{6}Li + ^{208}Pb) predicted for RLDM-NIFG nuclei, the σ_{fiss} ratios for ^{181}Ta and ^{208}Pb in Fig. 2 would have differed from one another by a factor $\simeq$ 3.5.

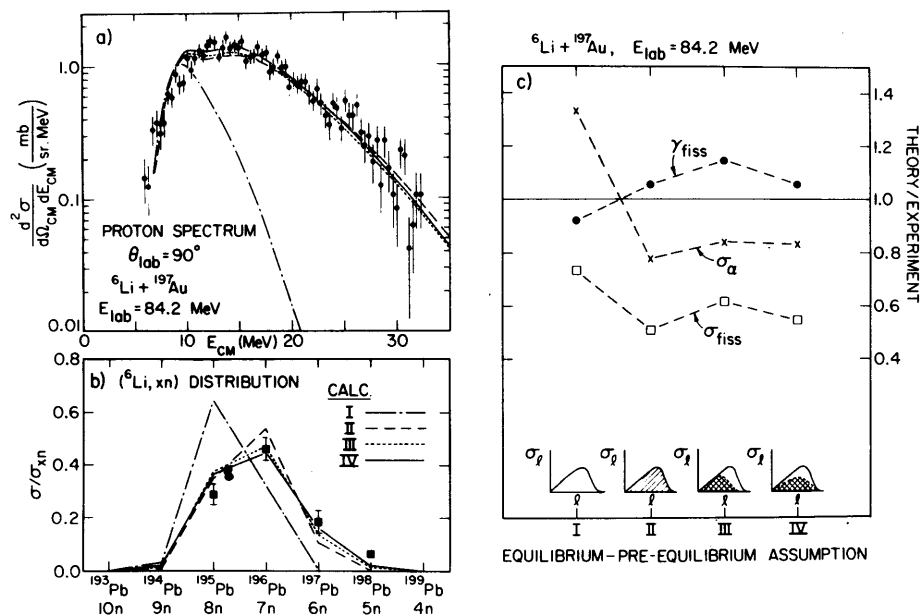The fact that we reproduce the target-dependence of σ_{fiss} and γ_{fiss} so well with a theory completely neglecting shell and pairing corrections suggests that such microscopic structure effects are of negligible importance at the high nuclear temperatures which dominate the observed fission decay. If shell corrections were important, they would be expected to vary dramatically over the range of compound nuclei studied, and to reveal themselves in large, target-dependent fluctuations in the theory-to-experiment ratios in Fig. 2. The unimportance of the microscopic corrections is also apparent in Fig. 3 from the good agreement between calculations and measurements for the variation of σ_α with target nucleus.[4]

The very poor agreement in Fig. 3 in the case of Z=1 particle evaporation is attributable to large pre-equilibrium (PE) contributions to the observed proton spectra even at far backward angles.[4] The discrepancies between the calculations and measurements for the proton spectra, and also for the distribution of (^{6}Li,xn) residual nuclides, can be removed in an ad hoc fashion by allowing in the code for emission of nucleons at the early stages, over some portion of the CN spin distribution, from an effective "hot spot" at anomalously high temperature. The results of calculations incorporating such a PE simulation are compared in Fig. 4 to those for an equilibrium decay calculation and to measurements for 84.2 MeV ^{6}Li + ^{197}Au. The PE calculations are constrained, by

appropriate choice of the effective temperature (τ_{eff}) and of the fraction of σ_{fus} associated with the "hot spot" decay, to reproduce the data in Figs. 4a and 4b. Under this condition, the effect on the calculated values of σ_{fiss}, γ_{fiss}, and σ_α is not terribly sensitive to the number of PE chances allowed or to the spin-space location of the "hot spot." Since the observed features of the PE emission are quite similar for all the systems studied (e.g., τ_{eff} is nearly the same for all cases), we do not expect the PE effects to alter appreciably the calculated target-dependences of σ_{fiss}, γ_{fiss}, and σ_α, or our conclusion concerning the negligible influence of shell corrections on these overall decay characteristics.

The remaining overall quantitative discrepancies between the calculated and measured absolute values for σ_{fiss}, γ_{fiss}, and σ_α (see Fig. 4) are relatively small, in the sense that they could be removed by minor parameter adjustments (e.g., a 1-2% increase in all a_f/a_n values) much smaller than those considered in previous work. However, such adjustments would be of questionable significance, since the observed discrepancies are comparable in magnitude to the uncertainties we expect from remaining theoretical inadequacies in our treatment of deformed-nucleus level densities and of PE effects, from our neglect of deformation effects on barrier penetrabilities, etc.

We foresee future advances in our study of fission and particle decay from high-spin nuclei proceeding along two paths. On the one hand, one should seek to improve the statistical-model treatment further and to understand the origin of the remaining overall quantitative discrepancies we observe. At the same time, our current quantitative success in reproducing target-dependences for high-temperature decay encourages similar comparisons of RLDM-NIFG-based calculations with experimental results in which decay contributions from cold, high-spin nuclei, and hence sensitivity to shell and pairing corrections, have been enhanced. We are presently evaluating the feasibility of enhancing cold-nucleus decay by using a many-detector pre-fission neutron "multiplicity filter."

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

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