

TRANSITIONS TO PROTON STATES IN THE  $^{90}\text{Zr}(p,p')$  REACTION AT 160 MeV

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Differential cross sections have been measured over the angular range from  $10^\circ$  to  $58^\circ$  for the transitions to the  $2^+$ ,  $4^+$ ,  $6^+$  and  $8^+$  ( $g_{9/2}$ ) $^2$  proton states at 2.18 MeV, 3.08 MeV, 3.45 MeV and 3.60 MeV (Figures 1 to 4) and for the transition to the ( $2p_{1/2}1g_{9/2}$ ) $5^-$  proton state. Cross sections were also measured for the collective  $3^-$  state at 2.75 MeV (Fig. 5) and for the  $2_2^+$  state at 3.31 MeV. With a self-supported 24.8 mg/cm $^2$  target enriched to 97.65 percent in  $^{90}\text{Zr}$ , and with the QDDM spectrograph and helical-wire and scintillation detection system, $^1$  an overall resolution of 120 keV was obtained in the first beam run but an overall resolution of 80 keV was achieved in the final

run in September 1977 with dispersion matching. Peaks were stripped with the interactive program $^2$  and the SEL computer in the ORIC Laboratory at Oak Ridge.

No microscopic model calculations are yet available. Collective model calculations are shown (Figures 1 to 6), which include deformation of the spin-orbit potential (DSO). As a first approximation the optical model parameters were from Ref. 3, although the program $^4$  used is a non-relativistic one. Very small deformation parameters were used (0.001) in order to make the coupling unimportant, so that the effect of inclusion of DSO contributions could be clearly seen.

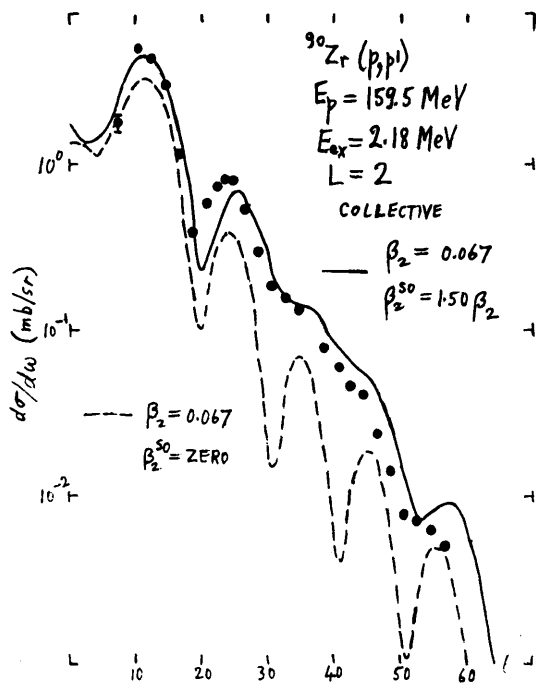


Figure 1

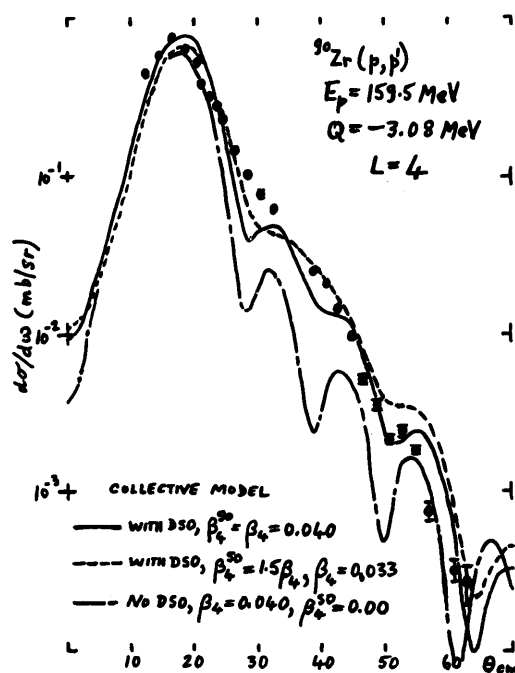


Figure 2

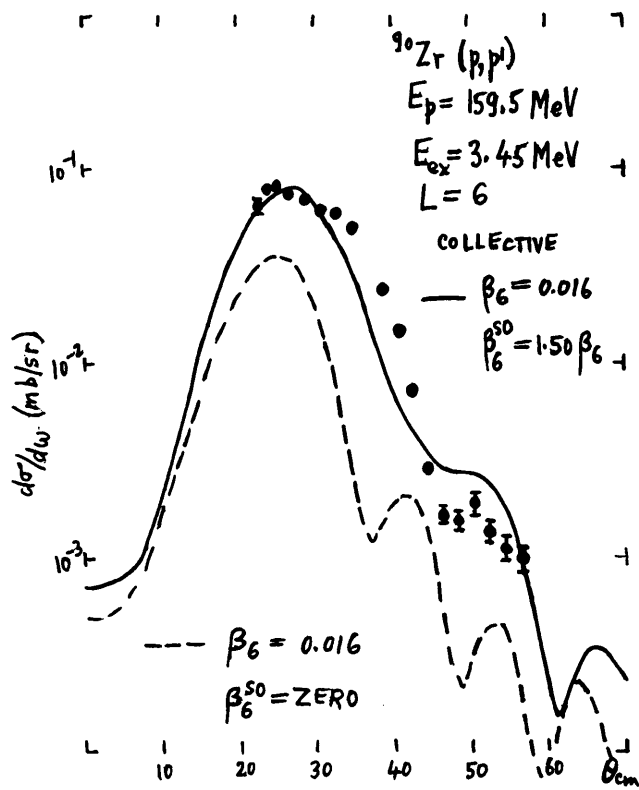


Figure 3

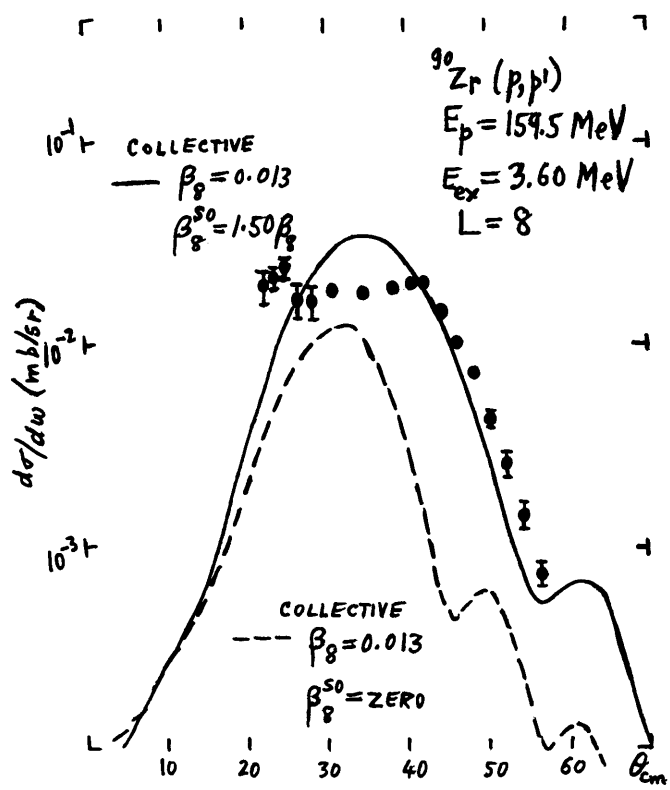


Figure 4

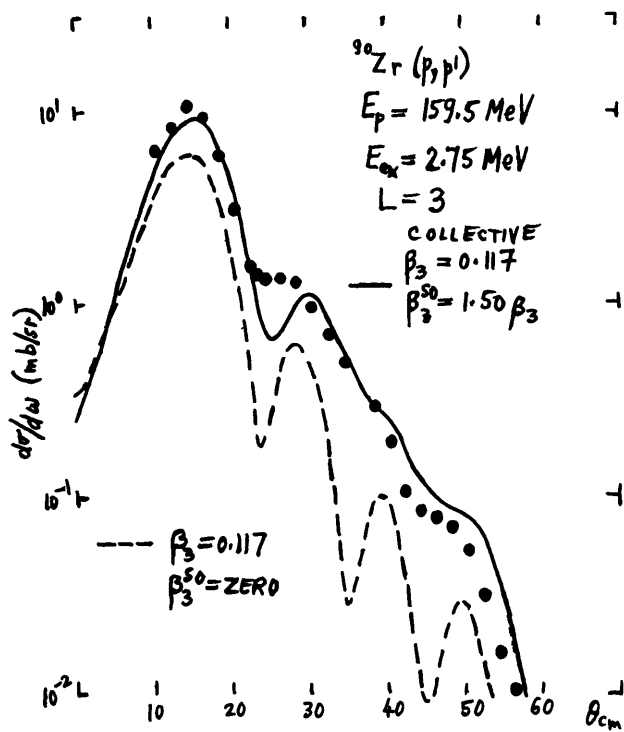


Figure 5

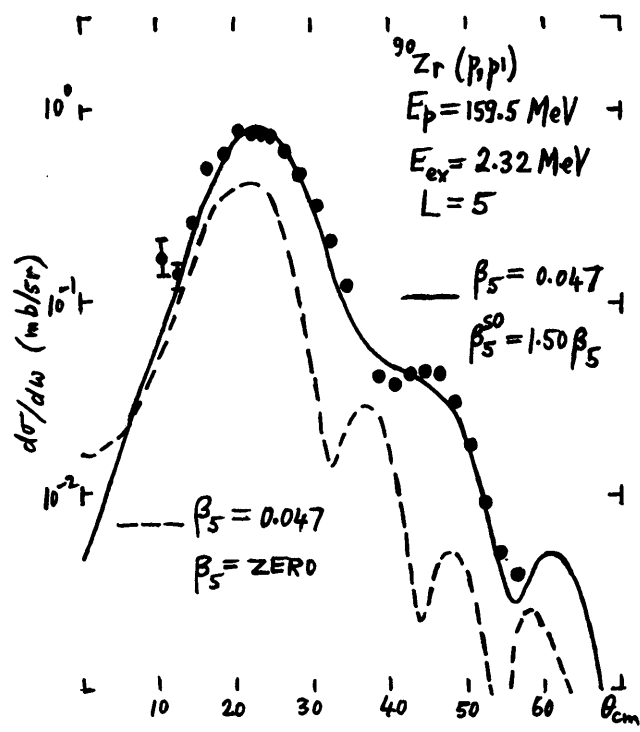


Figure 6

The final collective model parameters shown (Figures 1 to 6) were then obtained by normalizing the collective calculations with  $\beta_L = 0.001$  to each of the corresponding measured cross sections. For comparison we also show collective calculations with the same values of the central deformation parameters, but without the DSO contributions.

The shapes of all the measured cross sections clearly require inclusion of these DSO contributions, and with values of  $\beta_L^{SO}$  much larger than the central  $\beta_L$  for each case, even for the collective  $3^-$  state at 2.75 MeV. No attempt was made to find the optimum values of  $\beta_L^{SO}$ , rather the ratio of  $\beta_L^{SO}$  to central  $\beta_L$  was fixed at 1.50 to look for a possible dependence of this ratio on transferred angular momentum  $L$  with the wide range of  $L$  available in these data. There appears to be little such  $L$ -dependence, and this first choice ratio of 1.50 seems to be close to the optimum required for good fits to most of the measured cross sections. Fits to these data should be superior with a program with relativistic kinematics since those calculations will cause features like minima and maxima to move in slightly to smaller angles.<sup>5)</sup>

Detailed interpretations must await microscopic model calculations, but these collective calculations already point to major effects of the spin-orbit interaction in these  $(p,p')$  cross sections at the projectile energy of 160 MeV. Since these spin-orbit effects are so dominant, we already have asked to repeat this experiment on  $^{90}\text{Zr}$

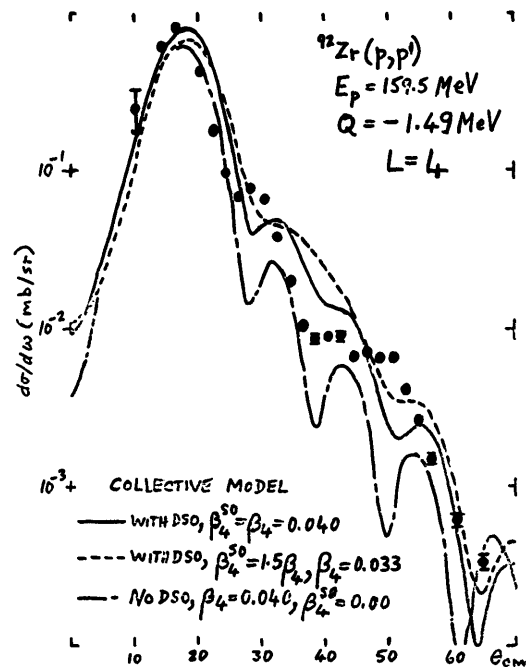


Figure 7

at 120 MeV in order to look for energy dependence of these spin-orbit contributions in changes of the shapes of the corresponding cross sections at the lower energy, yet still at an energy at which the impulse approximation will clearly be appropriate. We have also requested time to repeat our companion experiment on the neutron transitions in  $^{92}\text{Zr}$  at 120 MeV, and later for time to measure inelastic asymmetries for these transitions in  $^{90}\text{Zr}$  and  $^{92}\text{Zr}$  when the polarized beam is available. These requests have been approved by the PAC V; the cross section measurements at 120 MeV will shortly be scheduled, and the asymmetry measurements at 160 MeV will be scheduled later when the polarized beam becomes available for experiments.

Cross sections for transitions in  $^{92}\text{Zr}$  have

also been measured at the same projectile energy of 160 MeV (see next section). Of special interest here is the cross section (Fig. 7) for the L=4 transition to the  $4^+(d_{5/2})^2$  neutron state at 1.49 MeV. The shape of this measured cross section is quite different from the shape of the L=4 transition to the  $4^+(g_{9/2})^2$  proton state in  $^{90}\text{Zr}$  (Fig. 2), and the shape for this neutron transition in  $^{92}\text{Zr}$  is poorly described by the collective calculations even with the DSO contribution included. This situation is reminiscent of the results at the lower projectile energy of 61 MeV, where microscopic model calculations show<sup>6)</sup> there is a much larger valence cross section for this neutron transition in  $^{92}\text{Zr}$ , compared with the core polarization cross section, than for this L=4 proton transition in  $^{90}\text{Zr}$ . This proton transition in  $^{90}\text{Zr}$  is, in fact, heavily dominated by the core polarization contribution.<sup>7)</sup> This difference in the

shapes for the proton and neutron L=4 transitions at 160 MeV is, therefore, very likely due to continuing differences at this higher projectile energy.

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- 1) First IUCF Technical and Scientific Report, pp. 22-24, May, 1977.
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