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2.12 Fusion near the Barrier with Polarized Heavy Ions*

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Recently, a large number of experiments have studied the heavy ion fusion cross section near and well below the Coulomb barrier[1]. This interest was stimulated by the fact, while for lighter systems the observed cross sections below the barrier are well understood by a 1-dim. barrier penetration model, whereas this model systematically underpredicts the subbarrier fusion cross section for heavier systems. There is a basic agreement that additional degrees of freedom have to be taken into account in the description of such data. The purpose of this contribution is to show that measurements with polarized heavy ions (here ^{23}Na with nuclear spin 3/2) allow for the determination of an additional, independent quantity, the tensor analyzing power for fusion, T_{20}^{fus} , which is sensitive to nuclear structure effects through coupling to excited states of the nuclei. Such experiments can now be performed using the polarized heavy ion source at the Heidelberg MP-Tandem accelerator[2].

We present here data for the system ^{23}Na + ^{48}Ti. For it the Q values for transfer reactions are negative. Thus one can approximate the direct part of the cross section by the inelastic cross section, so that the fusion cross section can be split up according to $\sigma^{fus} = \sigma^{reac} - \sigma^{inel}$. The cross sections on the right hand side are calculated with the coupled channel program ECIS and a Woods-Saxon parametrization of the Akyüz & Winter potential[3]. Furthermore inelastic excitations are mainly restricted to the low lying states of projectile and target. In the desired energy range beams of polarized ^{23}Na can be produced with fairly high alignment (determined by Coulomb excitation of the projectile[4])using in addition to the MP-Tandem the Heidelberg postaccelerator to decelerate the beam[5]. In the experiment the fusion products were detected with time-of-flight technique at an angular range of 3^0 to 21.5^0

Fig. 1 shows the excitation function of the fusion cross section in comparison with coupled channel calculations[6], which reproduce the experimental data quite well. Compared to a 1-dim. calculation (···) σ^{fus} is only slightly enhanced below the barrier if one adds: reorientation of the projectile in its ground state (——), excitation of the projectile(- -) , excitation of the target (---) and projectile and target excitation (— - —). The small enhancement below the barrier is in contrast to other systems in this mass range. This may be due to the fact that the spectroscopic deformation of ^{23}Na is quite small.

The influence of excitation on fusion below the barrier is more clearly seen on T_{20}^{fus}. Fig. 2 shows the experimental data for T_{20}^{fus} together with calculations, again for reorientation of the ground state of the projectile and additional excitations of projectile and target. Far above the barrier T_{20}^{fus} is essentially zero and rises to a large positive value near the barrier. In semiclassical models[7,8] this behavior can be assigned to the positive spectroscopic quadrupole moment of ^{23}Na. Furthermore, below the barrier the calculation show that T_{20}^{fus} is strongly influenced by target excitation. Currently data exists only for energies down to the barrier. Since the model predicts that the analyzing powers are much more sensitive than the cross sections to the kind of coupling present in the subbarrier fusion, it is planned to continue the experiments with aligned heavy ions to energies well below the barrier.

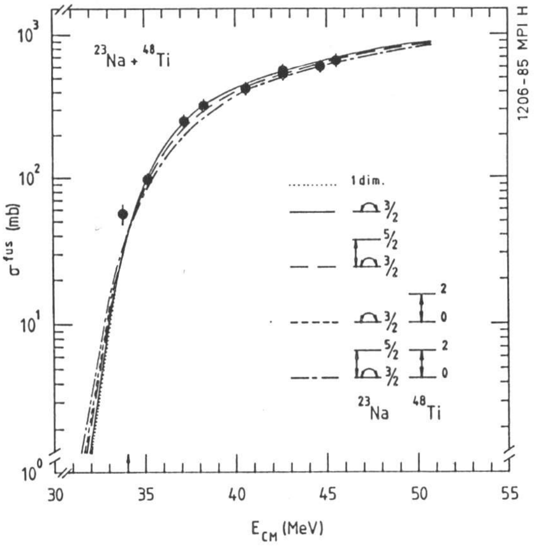

Fig. 1: Excitation function of the fusion cross section and theoretical predictions from various assumptions on the coupling schemes in projectile and target. The arrow indicates the S-wave barrier.

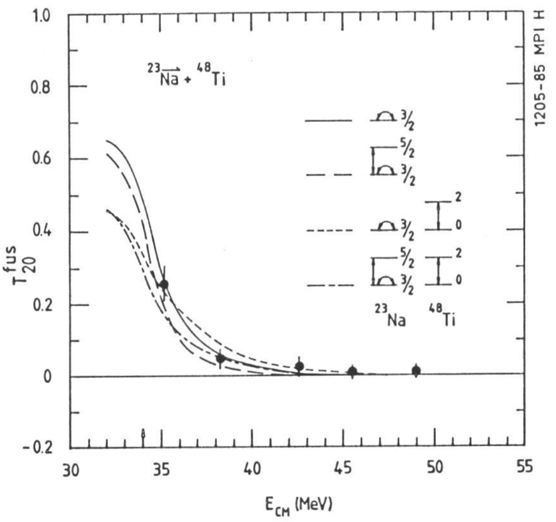

Fig. 2: Tensor analyzing power T_{20}^{fus} as function of CM-energy. The symbols are the same as in Fig. 1. A 1-dim. model would yield $T_{20}^{fus}=0$!

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