Measurements of fusion cross sections for the systems $^{30}\text{Si}+^{30}\text{Si}$ and $^{16}\text{O}+^{30}\text{Si}$

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INTRODUCTION

Many experiments done with different systems explored the behavior of heavy nuclei in a fusion reaction at energies below the Coulomb barrier. An enhancement of the fusion probability was observed at low energies, with respect to the theoretical predictions. These results led to leave the idea that in a reaction the nuclei can be thought as hard “spheres” and to consider the involving of structures of the interacting nuclei and of other degrees of freedom.

The goal of this work was the measurement of fusion cross sections of the two systems $^{30}\text{Si}+^{30}\text{Si}$, $^{16}\text{O}+^{30}\text{Si}$. The measurements were taken at energies around and below the Coulomb barriers ($56\text{ MeV}$ and $26\text{ MeV}$ respectively) in order to obtain their excitation functions and to compare them with known results [1, 2] and with the Coupled-Channel (CC) calculations provided by the CCFULL code [3] for the same systems.

THE EXPERIMENT

The experiment has been performed using the $^{30}\text{Si}$ and $^{16}\text{O}$ beams from the XTU Tandem accelerator of the Laboratori Nazionali di Legnaro of INFN, at energies ranging from $51\text{ MeV}$ to $71\text{ MeV}$ for the first reaction and from $21\text{ MeV}$ to $31\text{ MeV}$ for the second one, with intensities around $10^{-15}\text{ pnA}$. The target thickness was $50\text{ µg/cm}^2$ $^{30}\text{Si}$, on a $30\text{ µg/cm}^2$ carbon layer. The fusion-evaporation residues (ER) were detected by a Time-of-Flight (TOF)-$\Delta E$-Energy telescope, following an electrostatic beam deflector at small angles. In particular we employed two Microchannel Plates detectors (MCP) and an ionization chamber for the first beam, while for the second reaction only one MCP was used because at energies well below the Coulomb barrier the ER energy loss through the apparatus would have been excessive.

Beam control and normalisation between the different runs were ensured by four collimated silicon detectors placed symmetrically around the beam direction at $\theta_{lab} = 16^\circ$. ER angular distributions were measured at $\simeq 70,58\text{ MeV}$ for $^{30}\text{Si}+^{30}\text{Si}$ and $\simeq 30\text{ MeV}$ for $^{16}\text{O}+^{30}\text{Si}$, so to integrate the differential ER cross sections to total fusion cross sections (fission is negligible for the present systems in the measured energy ranges). For the symmetric system $^{30}\text{Si}+^{30}\text{Si}$ the fusion cross section has been normalized to the Mott scattering into the four monitors. We removed the effect of the Mott oscillations by averaging them over an appropriate angular range.

We used CCFULL in order to preliminary estimate the fusion cross sections and to compare them with our measurements, using a standard potential and the couplings to the low-lying $2^+$ and $3^-$ states.

The results are reported in Fig. 1. For $^{30}\text{Si}+^{30}\text{Si}$ the present data agree with the previous ones [1] and extend to much lower cross sections. The very large calculated cross sections indicate that the ion-ion potential needs to be adjusted. For the other system our data disprove the previous results [2] and agree with the CCFULL predictions.

Fig. 1. (upper panel) Excitation function for $^{30}\text{Si}+^{30}\text{Si}$, showing the present data (blue dots), the previous results [1] (red dots) and the result of the CC calculation (green dots). (lower panel) Excitation function for $^{16}\text{O}+^{30}\text{Si}$: the color reference is the same as above, the older measurements are taken from [2].