

## FUSION OF THE ${}^6\text{Li} + {}^{58}\text{Ni}$ SYSTEM AT SUB-BARRIER ENERGIES

## FUSIÓN DEL SISTEMA ${}^6\text{Li} + {}^{58}\text{Ni}$ A ENERGÍAS SUB-BARRERA

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### Abstract

A fusion excitation function for the  ${}^6\text{Li} + {}^{58}\text{Ni}$  system was measured at energies near and below the Coulomb barrier. We describe the procedure used to deduce the fusion cross sections from the angular distributions measured for the protons evaporated from the compound nucleus, by using the proton multiplicity predicted by the code PACE2. The comparison of our results with those reported for a very similar system,  ${}^6\text{Li} + {}^{59}\text{Co}$ , in reduced units, shows a very good agreement.

**Keywords:** fusion; protons

### Resumen

Se realizó la medición de la función de excitación de fusión para el sistema  ${}^6\text{Li} + {}^{58}\text{Ni}$  a energías cercanas a la barrera coulombiana. Se describe el procedimiento usado para deducir las secciones eficaces de fusión a partir de las

distribuciones angulares de los protones evaporados del núcleo compuesto, usando la multiplicidad de protones predicha por el código PACE2. La comparación de nuestros resultados con los reportados para el sistema  ${}^6\text{Li} + {}^{59}\text{Co}$ , en unidades reducidas, muestra una buena concordancia.

**Palabras clave:** fusión; protones

## Introduction

The fusion of weakly bound nuclei, both stable or radioactive, has been of great interest to experimental and theoretical nuclear physicists [1]. Recently and as the principal part of the present experiment, we have published results [2] for the fusion excitation function of the  ${}^8\text{B} + {}^{58}\text{Ni}$  system around the Coulomb barrier, which were obtained from the detected evaporation protons. Since the  ${}^8\text{B}$  beam is contaminated with several different projectiles having the same magnetic rigidity, mainly  ${}^6\text{Li}$  and  ${}^7\text{Be}$ , it is possible to take advantage of this fact by analyzing the additional systems [3].  ${}^6\text{Li}$  is a stable weakly bound nucleus and the full understanding of the fusion and breakup processes induced by this beam is an important reference for similar studies involving radioactive projectiles.

In the present work, preliminary results for the respective cross sections were determined by using the evaporated protons from the  ${}^6\text{Li} + {}^{58}\text{Ni}$  system. The measurements were taken at different energies below the Coulomb barrier.

## Experimental procedure

In Figure 1 a scheme of the TWINSOL radioactive nuclear beam facility at the University of Notre Dame is shown. The main components of the TWINSOL facility are two big superconducting solenoids, used to collect, transport and analyze the secondary beams. These solenoids act as thick lenses so the projectiles will be focused on a secondary target, establishing the secondary beam to be used in the experiment (in our case  ${}^6\text{Li}$ ). The experiment

was performed in four stages, but in this work we only present preliminary results for three of the four stages, in which a natural Ni target was used.

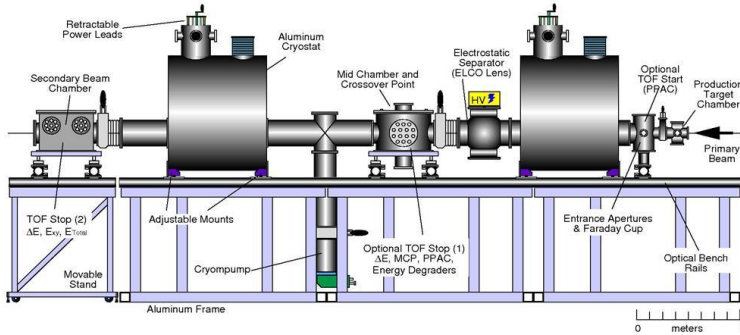


FIGURA 1. *The Twinsol radioactive ion beam facility.*

Several  $\Delta E - E$  silicon surface barrier telescopes were used at backward angles to detect protons evaporated from the fused system,  ${}^{64}\text{Ga}^*$ . Two additional detectors at forward angles served to monitor the beam. In the first stage, three telescopes at  $120^\circ, 135^\circ$  and  $150^\circ$  and a  $1.36 \text{ mg/cm}^2$  natural Ni target were used. For the second and third stages, an additional telescope was included and the respective angles were set at  $112.5^\circ, 127.5^\circ, 142.5^\circ$  and  $157.5^\circ$ . For the second stage the target was a natural Ni foil ( $5.6 \text{ mg/cm}^2$ ), mounted on a  $13 \text{ cm} \times 13 \text{ cm}$  square frame, while for stage three a natural Ni target of thickness  $2.22 \text{ mg/cm}^2$  was used and the frame dimensions were  $8.9 \text{ cm} \times 8.9 \text{ cm}$ .

A sample beam spectrum, corresponding to the  $E_{\text{in}} = 19.4 \text{ MeV}$  run, is shown in Figure 2. The secondary-beam energy-width (FWHM) varied between 0.7 and 1 MeV, while the respective time resolution was between 7 and 12 ns. Three main components of the mixed beam ( ${}^8\text{B}$ ,  ${}^7\text{Be}$  and  ${}^6\text{Li}$ ) are well separated from each other by TOF, but each one has its own contaminants (having the same TOF), which must be dealt with separately.

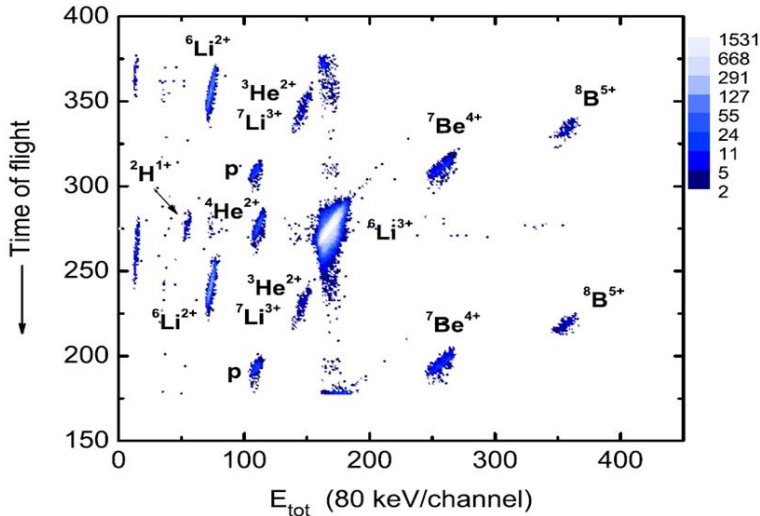


FIGURA 2. *Secondary beam composition.*

## Results and Discussion

The fusion cross sections were estimated by using the proton multiplicities ( $M_p$ ), calculated with the code PACE2 [4], which range from 1.43 to 1.48. The preliminary results for the fusion excitation function of the  ${}^6\text{Li} + {}^{58}\text{Ni}$  system are shown in Figure 3, in reduced form. The barrier for this system is 12.36 MeV, which corresponds to  $E_{c.m.}^{\text{red}} = 0.8$ . In this figure, we also present the experimental data for the total reaction cross section for the same system, which were published in [5], and the results reported earlier for  ${}^6\text{Li} + {}^{59}\text{Co}$  [6, 7].

## Conclusions

The sub-barrier fusion excitation function for the  ${}^6\text{Li} + {}^{58}\text{Ni}$  system was obtained by measuring the evaporation protons. Comparison of these preliminary results with previous data for total reaction cross sections [5] show that at the low energies measured, which are actually below the Coulomb barrier, fusion is the dominant reaction mechanism. Comparison with similar data for  ${}^6\text{Li} + {}^{59}\text{Co}$ , shows excellent agreement.

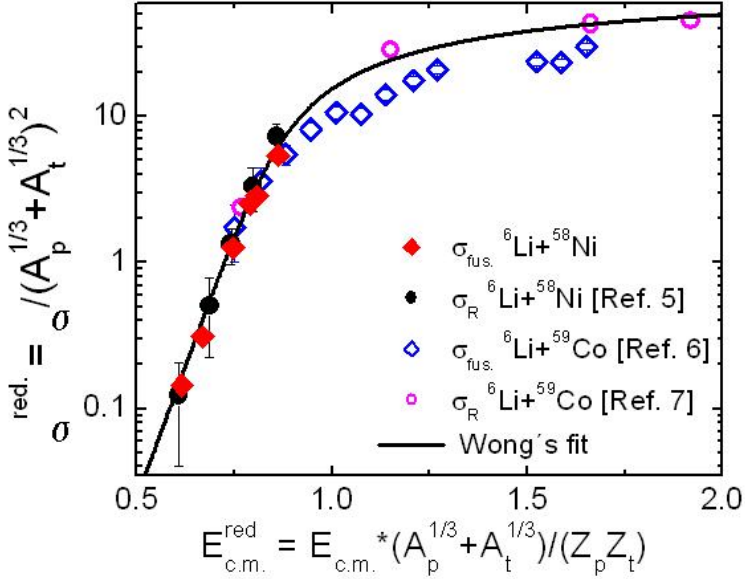


FIGURE 3. Comparison of the reduced data for  ${}^6\text{Li}$  projectiles with targets of  ${}^{58}\text{Ni}$  and  ${}^{60}\text{Co}$ . The solid curve is a Wong-model calculation fitting the total reaction data.

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