EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

Letter of Intent to the ISOLDE and Neutron Time-of-Flight Experiments Committee for experiments with HIE-ISOLDE

Transfer reactions at the driplines

V. Bildstein[1], Y. Blumenfeld[2], M.J.G. Borge[3], H.O.U. Fynbo[4], J. Gomez Camacho[5], J. Johansen[4], H.T. Johansson[6], B. Jonson[6], R. Krücken[1], A. Moro[5], T. Nilsson[6], G. Nyman[6], R. Raabe[7], K. Riisager[4], T. Roger[7], H. Simon[8], O. Tengblad[3], K. Wimmer[1] and the T-REX collaboration

[1] Physik-Department E12, Technische Universität München, Garching, Germany
[2] PH Department, CERN, CH-1211 Geneve 23, Switzerland
[3] Instituto de Estructura de la Materia, CSIC, E-28006 Madrid, Spain
[4] Department of Physics and Astronomy, University of Aarhus, DK-8000 Aarhus C, Denmark
[5] Universidad de Sevilla, E-41004 Sevilla, Spain
[6] Fundamental Fysik, Chalmers Tekniska Högskola, Göteborg, Sweden
[7] Instituut voor Kern- en Stralingsfysica, K.U. Leuven, B-3001 Leuven, Belgium
[8] GSI, Planckstr. 1, D-64291 Darmstadt, Germany

Spokesperson: K. Riisager (kvr@phys.au.dk)
Co-spokesperson: O. Tengblad (olof@iem.cfmac.csic.es)

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Abstract

We propose to continue transfer reaction studies for light nuclei close to the dripline. The beam energy increase envisaged in HIE-ISOLDE will allow studies employing the (d,p) and (t,p) reactions to populated states in $^{11-13}$Li.

1. Introduction

Transfer experiments with radioactive beams in inverse kinematics [1] provide powerful probes of nuclear structure. The present limitation on the maximum beam energy at REX-ISOLDE has restricted transfer experiments to light elements where several light neutron-rich nuclei already have been studied: ^{9}Li [2] (IS367), ^{11}Be [3] (IS430), ^{8}Li (IS446), ^{30}Mg [4] (IS470). The increase of beam energy in HIE-ISOLDE would open possibilities for many reactions that are Q-value limited. We present here selected cases for nuclei close to the driplines.

2. Physics case

Transfer reactions that add neutrons to a neutron-rich nucleus can obviously provide interesting nuclear structure information. The (d,p) reaction (S_n = 2.22 MeV) needs beam energies somewhat above 1.2 MeV/u to proceed to a just unbound state and has therefore been employed at the present REX-ISOLDE where the maximum energy is 3 MeV/u. The (t,p) reaction (S_{2n} = 8.48 MeV) needs beam energies above 3 MeV/u unless one populates levels bound by several MeV, such as the successfully done t(^{30}Mg,p)^{32}Mg [4]. We note that ISOLDE is the only facility where reaction experiments have been carried out with a radioactive beam on a tritium target. The energy increase at HIE-ISOLDE will therefore allow a new class of experiments to be performed. We wish to exploit this and focus on the lightest nuclei. ISOLDE with its unique beam-development record will offer more possibilities than explored here (see also the other LoIs on reaction experiments with light nuclei), but we give one example that illustrates the physics potential and the logistic requirements.

The structure of the light neutron-rich nuclei has presented many challenges during the last decades and the physics interest has now expanded to include also the unbound nuclei just beyond the dripline [5]. For the neutron-rich nuclei many efforts have already been made on the unbound hydrogen and helium isotopes as well as on ^{10}Li. The latest results from in-flight fragmentation at GSI [6] gave information on the unbound systems ^{12,13}Li. An experiment at MSU [7] has very recently provided more detail on excited states in ^{12}Li, but there is clearly a need for more information from independent experiments. Furthermore, the unbound excited states of ^{11}Li, although studied for quite some time see e.g. [8,9], are still not sufficiently understood. In all these cases, transfer reactions can clarify and test our understanding of the system. We are therefore proposing to study the reactions t(^{9}Li,p)^{11}Li, d(^{11}Li,p)^{12}Li and t(^{11}Li,p)^{13}Li.

Although the energy upgrade in HIE-ISOLDE is indeed the major factor enabling these experiments to be undertaken, we will benefit significantly also from the intensity upgrade.

The results of the earlier d(^{9}Li,t)^{8}Li and d(^{9}Li,p)^{10}Li experiments [10] indicate that a careful theoretical treatment of the coupling to continuum states is needed at low reaction energies. Previous experience from other unbound systems show that the reaction mechanism anyway needs to be considered carefully (independent of reaction energy) so we plan to work closely with theoretical groups on the analysis of the data.

3. Experimental setup

The experimental setup will be very similar to those already employed in the second beamline [2,3] or at T-REX [4]. Since we are mainly dealing with unbound final states gamma-detection is not an important issue, whereas neutron detection may be beneficial (this will never achieve high efficiency at our beam energy, but may be useful for some selection processes). The space requirements are similar to those at the present Miniball set-up or – if one uses a set-up similar to the one used at the second beamline – with a 2 by 3 m^2 space at the position of the set-up. Access to electricity, pump lines and internet as presently.

Some years ago discussions were started in the ISOLDE community (partly taking place also within the INTAG JRA in EURONS) around the need for a suitable spectrometer for analysis of beam-like fragments emerging from reactions at REX-ISOLDE. In case such a spectrometer is built, the present experiments may benefit from using it, but the resolution requirements are rather different for the present case of light nuclei than they will be for other typical spectrometer users that could be imagined at HIE-ISOLDE. Since the major parts of the present physics case (and similar cases) can be undertaken without a spectrometer we have not pursued this issue, but we would be interested in collaborating with others if sufficient interest emerge.

4. Beam requirements

We have run several times at REX-ISOLDE with ^{9}Li and do not foresee any problems with the intensity or purity of that beam. Even without the intensity upgrade it should give a secondary (accelerated) beam intensity of more than 10^5 ions/s, which is sufficient to perform the experiment within a few days. The primary ^{11}Li intensity obtained so far is about 10^4 ions/s and a previous attempt to postaccelerate it at ISOLDE (IS399) was not successful. However, the scaling and the overall reliability of REX-ISOLDE has already improved so that a secondary beam intensity of several hundred ions/s will be feasible, thereby enabling the (d,p) experiment to be performed. The feasibility of the t+^{11}Li experiment depends on the achievable intensity increase as well as on the

overall cross-sections and can be judged better after the (d,p) experiment has run. Concerning beam purity, we have experience at A=11 with ^{11}Be and this isotope will be the only important contaminant. It can easily be distinguished from ^{11}Li due to its different release properties and have not in the past been of major concern when running specifically on Li-isotopes.
The experiments can be performed already at 5.5 MeV/u. The beam emittance and energy spread should be not worse than those at the present REX-ISOLDE, but we would benefit from improvements on these two parameters. For the ^{9}Li beam a large EBIS-window will be beneficial; for ^{11}Li this is not of concern.

5. Safety aspects

Even for the most intense radioactive beams considered here the radiation levels from decays of the beam or from any reaction-induced activity will be sufficiently low to not cause any problems. However, the employment of the radioactive tritium target needs special safety precautions as have already been mastered in previous experiments (IS470 and IS499).

6. References

1. J.S : Winfield, W.N. Catford and N.A. Orr, Nucl. Instr. Methods A396 (1997) 147.
2. H.B. Jeppesen *et al.*, Nucl. Phys. A748 (2005) 374.
3. J. Johansen, p. 321 in *Nuclear Structure and Dynamics '09*, AIP Conf. Proc. 1165.
4. Th. Kröll *et al.*, p. 363 in *Nuclear Structure and Dynamics '09*, AIP Conf. Proc. 1165.
5. B. Jonson, Phys. Rep. 389 (2004) 1.
6. Yu. Aksyutina *et al.,* Phys. Lett. B666 (2008) 430.
7. C.C. Hall *et al.*, Phys. Rev. C81 (2010) 021302(R).
8. T. Kobayashi, Nucl. Phys. A553 (1993) 465.
9. H. Simon *et al.*, Nucl. Phys. A791 (2007) 267.
10. H.B Jeppesen *et al.*, Phys. Lett. B635 (2006) 17 ; ibid., B642 (2006) 449.