EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

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

Post-accelerated polarized beams at the REX-LINAC

G. Georgiev[1], M. Hass[2], D.L. Balabanski[3], E. Fiori[1], A. Gottberg[4], A. Herlert[5], L. Hemmingsen[6], K. Johnston[5], M. Lindroos[5], J. Ljungvall[1], T. Nilsson[7], J. Pakarinen[5], K. Riisager[8], C. Sotty[1], M. Stachura[6], H. Tornqvist[5,7], J. Van de Walle[9], D. Voulot[5], F. Wenander[5], W.-D. Zeitz[10]
and the TF-beta-NMR collaboration

1. CSNSM, Orsay, France
2. Dept. of Particle Physics, the Weizmann Institute, Rehovot, Israel
3. INRNE, BAS, Sofia, Bulgaria
4. Free University Berlin, Berlin, Germany
5. ISOLDE, CERN, Geneva, Switzerland
6. IGM, LIFE, University of Copenhagen, Denmark
7. Chalmers University of Technology, Göteborg, Sweden
8. Department of Physics and Astronomy, University of Aarhus, Denmark
9. KVI Groningen, The Netherlands
10. Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Germany

Spokesperson: G. Georgiev
Contactperson: F. Wenander

Abstract

At present there is a running project at ISOLDE for polarizing ion beams using the Tilted Foils technique. With the present Letter of Intent we would like to present the idea and reserve the possibility of including the Tilted Foils apparatus within the REX-LINAC of HIE-ISOLDE. Provided successful this would offer a variety of polarized beams within the full energy range covered by the HIE-ISOLDE REX-LINAC.

CERN-INTC-2010-058 / INTC-I-124
23/05/2010

1. Introduction

The standard way of observing the nuclei in the Nature is with their spins randomly oriented in space. The possibility of getting their spins oriented, with a well defined direction that can be chosen in advance, is of great interest. This could increase the sensitivities of many experimental techniques with several orders of magnitudes and in specific cases give an access to observables that cannot be attained by other means. Therefore the interest towards polarized radioactive species is manifold and spans over a wide range of subjects e.g. Biophysics, Solid-State Physics, Nuclear Physics etc. Depending on the specific experiment a wide range of beam energies might be desirable e.g. from the standard low-energy ISOL beams (30 – 60 keV) up to energies well above the Coulomb barrier (few MeV/u).

The low-energy polarized beams might, in general, be easier accessible by several methods. However, when higher energy is required the difficulties increase significantly especially when a post-acceleration of an already polarized beam needs to be performed. Several cases have been reported for post-acceleration of polarized stable beams by means of optical pumping [1, 2] using Tandem and/or LINAC machines. In addition there has been a measurement reported for using the Tilted Foils (TF) technique and post-accelerating the polarized stable beam through a LINAC [3]. With the present LoI we would be aiming at the application of the TF polarization and the post-acceleration of *radioactive* beams at HIE-ISOLDE, similarly to the work performed in Ref. [3].

In the Tilted Foils technique an ion beam is passing through a stack of thin foils, tilted at an oblique angle with respect to the beam direction. The interaction of the beam ions with surface at the exit of each of the foils induces a polarization of the electron spins [4] (atomic polarization), which is subsequently transferred to the nuclear spins [5]. The advantages of the TF polarization technique are in its relative simplicity and universality – no dependence of the polarization on the chemical properties of the polarized species is observed up to now. Its eventual shortcoming might be in the relatively low level of polarization experimentally observed up to now (about 10%). Therefore we have started a project (I83) for detailed study of the process of TF polarization as a function of the beam velocity for a variety of chemical elements and masses.

2. Physics case

The experimental techniques that could profit most from the availability of post-accelerated radioactive beams at HIE-ISOLDE are related to nuclear transfer reaction studies and Coulomb excitations. Using polarized beams in nuclear transfer reactions one could obtain the analyzing power and determine unambiguously both the orbital- and spin- angular momenta of the populated states.

The use of polarized beams in Coulomb-excitation experiments is especially advantageous for odd-mass nuclei. The asymmetry of the gamma-ray angular distribution can give more constraints both on the spins and parities of the studies levels. As a direct example one can cite the recent studies of the odd-mass Cu nuclei [6] in which low-lying states of unknown spin/parities were observed for the first time being populated in the Coulomb excitation of ^{71}Cu and ^{73}Cu. Based on systematics those states were suggested to have $I^{\pi} = 1/2^{-}$. Measuring the angular distribution from a Coulomb excitation with polarized beam would allow experimental determinations of those assignments.

Another example of an experiment in which the use of polarized beams can be very much advantageous is the Coulomb excitation study of the odd-mass ^{93,95,97,99}Rb isotopes (IS493). From those nuclei there are excited states known only in ^{93}Rb. For all the rest a possible use of polarized beams might appear essential for the correct spin-parity assignments of any states observed.

3. Experimental setup

The experimental setup would consist of the presently existing C-REX or T-REX setups for Coulomb-excitation and transfer-reaction studies in combination with the Miniball array. Possible modification of the angular positioning of the Miniball detectors might appear necessary for specific cases.

4. Beam requirements

The success of this project depends on two major points. The first one is the success of the detailed study of the TF polarization process as a function of the beam energy and species, which is a subject of the LoI I83, endorsed by the INTC in 2009. At present the beta-NMR setup is installed at the second beamline after REX in a quasi-permanent position (the setup can be moved away of necessary but experiments can be performed on the same beamline without moving it as well). The continuation of this project would require similar space available after the HIE-ISOLDE REX-LINAC.

At our present level of understanding the best energy regime for obtaining the highest level of polarization is between 200 keV/u and 1 MeV/u. The second important point is related to the possibility of **implementing the TF apparatus within the REX-LINAC** at energies similar to the mentioned above. With the present room-temperature LINAC this could be done either after the RFQ or after the first accelerating cavity. The aim of the present letter of intent is to reserve the possibility of including the TF apparatus in the new superconducting LINAC to be constructed. Typical linear dimensions of the TF apparatus would be about 20 – 30 cm.

5. Safety aspects

The same as for current REX-ISOLDE experiments.

6. References

[1] D. Kramer *et al.*, Nucl. Instr. Meth. Phys. Res. **220** (1984) 123
[2] E.G. Meyers *et al.*, Nucl. Instr. Meth. Phys. Res. **A334** (1993) 271
[3] J. Bendahan *et al.*, ZPA **331** (1988) 343
[4] T. Tolk *et al.*, Phys. Rev. Lett. 47 (1981) 487
[5] M. Hass *et al.*, Nucl. Phys. A414 (1984) 316
[6] I. Stefanescu *et al.*, Phys. Rev. Lett. 100 (2008) 112502