Letter of Clarification

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In its February 2009 meeting the INTC has evaluated our proposal "Study of oblate nuclear shapes and shape coexistence in neutron-deficient rare earth isotopes" (CERN – INTC – 2009 – 009/P – 257). In its report,

> *the Committee* ***endorsed*** *the physics case and requested a Letter of Clarification which addresses the issue of contamination suppression needed and tests of RILIS schemes before recommendation for approval by the Research Board.*

In this letter of clarification we discuss the technical progress for the development of beams of rare earth elements made over the last months and the consequences for the feasibility of the proposed experiment. The physics case comprises studies of four isotopes of rare earth elements with neutron number N=78: ^{138}Nd, ^{140}Sm, ^{142}Gd, and ^{144}Dy. Theoretical calculations predict a transition from prolate shape in ^{140}Sm to oblate in ^{142}Gd, and it was proposed to study these two nuclides using the technique of projectile Coulomb excitation. As such beams have never been produced at ISOLDE, testing and development work was required. The chemical properties of the rare earth elements are very similar, so that resonant laser ionization is mandatory. In particular the question of beam contamination due to surface ionization needed to be addressed in order to evaluate the feasibility of the project.

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An improvement in the reduction of unwanted surface ionization in the RILIS was expected to come from the use of a new high-temperature, low work function cavity of gadolinium hexaboride (GdB_6). Tests with such a cavity have been performed on the GPS separator in June 2009 over a period of three days. Currents have been measured for different mass settings and the beam composition has been analyzed by measuring the beta and gamma decay of the ions. During the tests the laser ionization scheme for Nd atoms has been applied and laser on/off measurements were performed. An enhancement factor of 6 was found between the measurements with laser on and off for Nd beams at temperatures of 2000°C and 1800°C for the target and transfer line, respectively. The tests show that surface ionization in the GdB_6 cavity is significantly suppressed compared to standard W or Ta cavities. In this way it was possible to produce a ^{139}Nd beam with approximately 50% purity, with the main contaminants being ^{139}Pm and ^{139}Sm. The tests also yielded additional experimental data on production cross sections for various nuclides in the region of interest. More details and results from the tests can be found in a technical report prepared by V. Fedosseev and T. Stora.

The test has shown that it is possible to produce beams of rare earth elements with intensities and purities that are sufficient for a successful Coulomb excitation experiment. The results are very encouraging for the proposed experiment since the suppression of unwanted surface ionization should work equally well for the production of other rare earth elements. Despite the positive results for the production of Nd beams we see no strong motivation to start the experimental program with a measurement on ^{138}Nd. Among the four nuclei under consideration ^{138}Nd is the least interesting to understand the evolution of shapes in this region of the nuclear chart. The production of a mass A=138 beam is furthermore likely to suffer from contamination of the stable ^{138}Ba isobar. The production of a ^{140}Sm beam seems in fact easier in comparison to the ^{138}Nd case. The only stable A=140 isobar is ^{140}Ce, which was shown to be unproblematic in the tests of June 2009. We therefore adhere to our original plan to start the experimental program with a measurement on ^{140}Sm.

After the positive results of the test with the GdB_6 cavity we feel confident that a ^{140}Sm beam of sufficient purity and intensity can be produced. Nevertheless, exact numbers for the beam purity can only be given after an on-line test of the laser ionization scheme for Sm. Such a scheme exists, but remains to be tested at ISOLDE. With this letter we would like to ask that a test of the Sm RILIS scheme be scheduled with high priority early in 2010. If this test confirms our expectations, a Coulomb excitation experiment with ^{140}Sm beam could be scheduled in the Miniball campaign of 2010. Based on the data obtained during the Nd test, we expect a beam intensity of better than 10^5 particles per second after acceleration. Originally we had expected $4{\cdot}10^5$ pps based on old yield measurements obtained with the SC driver. To achieve the goals described in the proposal for ^{140}Sm we estimate that 15 shifts of beam time are needed. More precise numbers for the beam intensity and purity will be available after a test of the RILIS scheme.

The continuation of the program with a measurement on ^{142}Gd requires more testing and development work. We feel that this part of the experimental program should only be attempted after a successful production run with ^{140}Sm. We therefore propose to postpone this part of the program until first results are available for ^{140}Sm.