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

A Spectrometer for Nuclear Reaction Studies at HIE-ISOLDE

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Abstract

This letter of intent discusses the need for a spectrometer for nuclear reaction studies at HIE-ISOLDE. The physics cases that can be addressed with such a device are presented briefly and simulations that have been carried out to evaluate different designs are mentioned. The main purpose of this letter of intent is to bring to attention the floor space and infrastructure needs such a device requires.

1. Introduction

HIE-ISOLDE offers a unique possibility for campaigns of reaction studies using exotic isotopes due to the large number of secondary beams that will become available at the beam energies planned for the facility. Many future experiments may require a spectrometer or similar device for channel selection and/or spectroscopic studies.

2. Physics case

Several physics cases presented in the letters of intent submitted to the INTC for HIE-ISOLDE will benefit from the use a spectrometer or similar device [1,2,3,4,5]. The purpose with this letter of intent is not to repeat those physics cases but instead to indicate the generic character of a channel selection device of this kind and briefly introduce the reactions for which this device would be advantageous.

2.1 Transfer reactions in inverse kinematics

In the case of transfer reactions where the light outgoing particle is a neutron a spectrometer would obviously be a very efficient way to select the reaction channel of interest. If the acceptance of the device is large enough it may also be the best suited instrument for many other transfer reactions. The outgoing reaction cone is rather narrow and symmetrical around the beam-axis for transfer reactions in inverse kinematics. Typically the cone ranges from ±15° for lighter projectiles to about ±1° for heavier beams. There are specific plans for experimental campaigns that aim at studying $N \approx 82$ and $N \approx 126$ transfer reactions. Furthermore reactions relevant for the rp-process, $Z \approx 50$ and $Z \approx 82$ campaigns can include reactions of this type.

2.2 Deep inelastic transfer reactions

In deep inelastic transfer reactions a large number of nuclei, sometimes more than a hundred, are produced in one and the same reaction making a spectrometer indispensable for experiments that need to study each exit channel separately. This type of reaction shows great promise in making nuclei close to the neutron drip line available for spectroscopic studies and are considered a possible road to neutron-rich nuclei such as 78Ni [6]. Deep inelastic reactions have the maximum cross section around the grazing angle (typically 50-70 degrees) and have a wide distribution in momentum-space. Successful experiments of this kind using stable beams have e.g. been carried out with PRISMA at Legnaro National Laboratory (LNL), Italy [7].

2.3 Fusion-evaporation reactions in inverse kinematics

When the intensity upgrade of HIE-ISOLDE is completed fusion-evaporation reactions using radioactive beams may become possible. Selection of fusion-evaporation residues using magnetic devices has been done in many experiments with stable beams in the past. Consequently, a versatile device may be used also in such a program with radioactive beams.

2.4 Simulations

Two different options for spectrometers at HIE-ISOLDE have been considered and simulations have been carried for these using a number of test cases. The first option considered is a mass separator device such as FMA [8] at ANL or EMMA [9] planned for ISAC II at TRIUMF. The other type that has been simulated is a magnetic spectrometer where the identification of the ions requires tracking and ray tracing event-by-event. The starting point for the latter simulations is the

PRISMA spectrometer at LNL mentioned above.

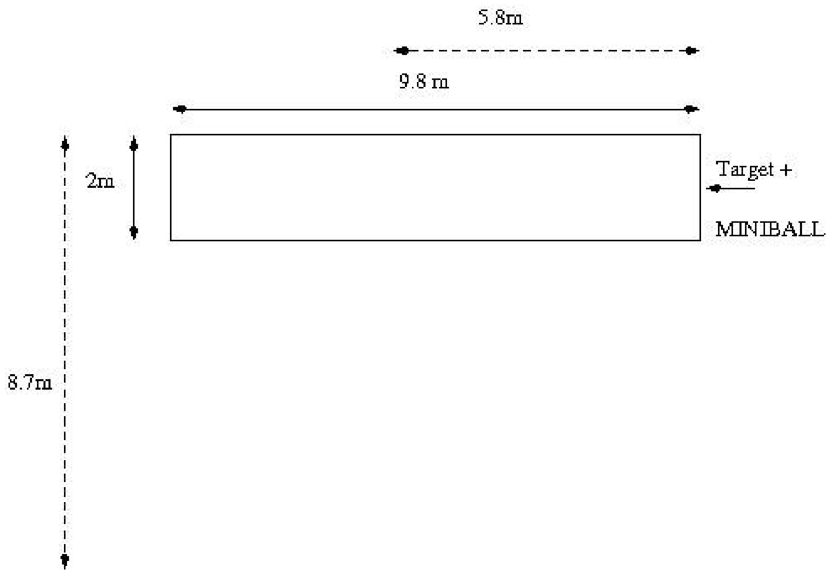

Fig 1: Floor space requirement for a mass spectrometer design. The dotted lines shows the case of 60 degrees rotation.

Referring to the letters of intent it is clear that transfer reactions will be a main focus of the experimental program for the first stage of the HIE-ISOLDE. For this reason we have simulated a set of transfer reactions using realistic HIE-ISOLDE input parameters. The reactions include e.g. d(^{10}Li,^{11}Li)p, d(^{22}Mg, ^{23}Al)n and d(^{132}Sn,^{133}Sn)p. In general, the first type of spectrometer has the advantages of simple data analysis and high precision but has the drawback of a rather limited solid angle (~ 16 msr). The ray-tracing device offers a larger solid angle (~ 80 msr) and is flexible to use, but the instrumentation is a challenge for zero degree studies as it is difficult to block the beam without stopping a large fraction of the reaction products. A ray-tracing spectrometer may consequently require development of high-spacial resolution and high-count rate detectors to meet the demands.

3. Experimental setup

The floorspace needed for the alternatives are given in Fig. 1 and 2. Water cooling is needed for magnets and power supplies in both designs. The foreseen water cooling is estimated to be approximately 400 kW. Space for power supplies, electronic readout and potentially gas systems are also required for the experiments.

4. Beam requirements

For beams and isotopes of interest we again refer to the specific letters of intent. In general intensities of at least 10E4 – 10E5 pps is a requirement. Experiments requiring beam energies ranging from 5 MeV/u up to 10 MeV/u are foreseen and for certain applications one would want to be able to scan a range of energies with the beam. For spectroscopic purposes an energy resolution of 0.1% FWHM would be required. A beam spot of less than 3 mm in radius would be required for the ray tracing spectrometer and preferably less than 2 mm for the mass separator type. The angular divergence at the target should be less than 3 degrees for many applications, but larger divergence can be acceptable given a smaller beam spot. Concerning the time structure of the beam the macroscopic time structure is the main challenge for the read-out at MINIBALL today and a greater spread in the arrival time of the ions would benefit MINIBALL experiments as well as start and focal plane detectors in a separator or spectrometer. Furthermore, pre-bunching or such in order to have a ~100 ns bunch separation for the LINAC would be important for time-of-flight measurements.

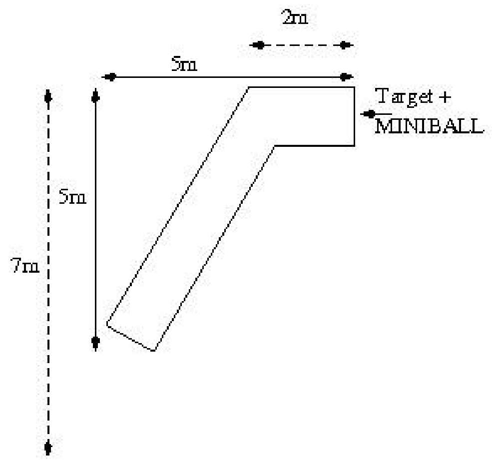

Fig 2: Estimated floor space needed for a raytracing spectrometer. The dotted lines give the space needed in the case of 60 degrees rotation.

5. Safety aspects

For certain choices of isotopes radiation coming from long lived contamination might be an issue at the focal plane or inside the device. This has to be considered in the same manner as radiation issues are treated in the current ISOLDE program.

6. References

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