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Upgrade and yields of the IGISOL facility

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Abstract

The front end of the Jyväskylä IGISOL facility was upgraded in 2003 by increasing its pumping capacity and by improving the radiation shielding. In late 2005, the skimmer electrode of the mass separator was replaced by a sextupole ion guide, which improved the mass separator efficiency up to an order of magnitude. The current design of the facility is described. The updated yield data, achieved with and without the additional JYFLTRAP purification, using both fusion evaporation reactions and particle induced fission is presented to give an overview of the capability of the facility. These data have been determined either by radioactivity measurements or by direct ion counting after the Penning trap system.

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1. Introduction

The IGISOL facility in the accelerator laboratory of the University of Jyväskylä has throughout the years undergone several changes and evolutions. Only the ion guide technique [1] at the heart of the facility has remained more or less untouched for more than 20 years. The latest complete overview of IGISOL facility is given in [2] and of the yields in [3]. Since then, the IGISOL facility front end has been upgraded, which was briefly reported in [4]. After this report, a major change has been the replacement of the conventional skimmer system by a double RF sextupole (SPIG) electrode [5,6], with which increase of ion yields has been significant.

The IGISOL facility consists of an ion guide system with its gas feeding and differential pumping system, dipole magnet, switchyard, beam lines to experimental setups, RF cooler [7], JYFLTRAP [8], collinear laser spectroscopy line [9,10] and the laser ionisation facility FURIOS [11]. This article is restricted mainly to the ion guides and the separator front end; reports on progress at JYFLTRAP [12–14], laser ionisation [15] and other ion sources [16] are found elsewhere in this issue.

In the basic ion guide technique [1] the reaction target is located inside a small (a few cm^3) gas cell, filled with flowing carrier noble gas, typically helium. The nuclear reaction recoils from the target are stopped and thermalised in the helium. During the thermalisation process the initially high

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charge state lowers via charge exchange reactions, until the majority of ions are extracted from the gas cell with the gas flow as singly charged. The typical carrier gas pressure varies from a few tens to a few hundreds of millibars, which reflects the optimal thickness of gas layer to stop the recoil ions. Beyond the gas cell exit nozzle the neutral carrier gas expands and is pumped away, while the ions are guided with electric fields through a further differential pumping section to an acceleration stage of a mass separator.

The basic ion guide described above is used for light ion (p, d, ^{3}He, α) induced fusion reactions. Other varieties of the ion guide are designed specifically for fission [17], heavy ion induced fusion reactions ("HIGISOL" ion guide) [18] and also for deep inelastic transfer reactions [19]. In the fission ion guide the target and the primary beam are separated from the stopping volume by a thin metal foil (typically $\approx$1 mg/cm^2 of nickel), which prevents the plasma created by the primary beam spreading in the stopping cell. The fission fragments that have an isotropic angular distribution and high enough energy to penetrate the metal foil and enter the stopping volume. In the HIGISOL ion guide the target is located outside of the gas cell and only the heavy ion induced fusion reaction products are allowed to enter through a large metal window. The separation of the primary beam is based on the larger angular distribution of the reaction products as compared to the primary beam, which is stopped in a 7 mm diameter carbon block in front of the ion guide. In both the light ion and the fission ion guides the production target is located inside the ion guide and the gas flow is cooling the targets, while the HIGISOL target is cooled only by conduction and radiation. Recently, a rotating target has been introduced for HIGISOL. Finally, an ion guide for deep inelastic transfer reactions is a cross-breed of the fission and heavy ion guides that utilizes the large emittance angle of the transfer reaction products in its design [19].

In the following, the current technical realization of the IGISOL facility whose layout is shown in Fig. 1 is described, underlining the changes and improvements taken place in the 2003 front end upgrade [4]. The performance of the IGISOL including the achieved ion yields for different production reactions is discussed.

2. Technical description

A wide selection of primary beams is available from the K-130 cyclotron. The selection includes heavy ion beams as well as intense light ion beams. Proton beams with intensities higher than 50 μA are provided for medical isotope production on a regular basis using a negative hydrogen ion source and a stripper foil ejection. Before the IGISOL front end upgrade beam intensities of this order could not be delivered to IGISOL since the radiation level in the experimental area of the recoil mass separator RITU behind the 1.5 m thick concrete wall of the IGISOL cave exceeded 1 μSv/h. This was due to beam related secondary neutrons that emerged in the direction of the primary beam. In the upgrade the shielding thickness in the primary beam direction was increased to 2.5 m of concrete. This was estimated to give four orders of magnitude improvement in attenuation of neutrons created by the most energetic proton beams available at the IGISOL.

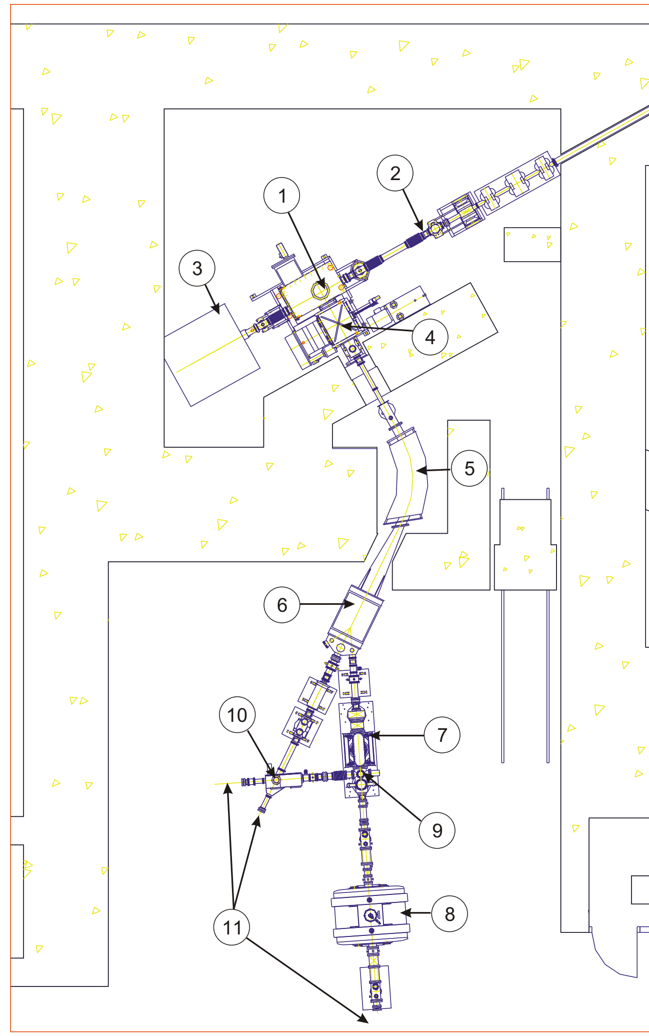

Fig. 1. The IGISOL facility floor level layout after the front end upgade. (1) Target chamber (2) K-130 cyclotron beam line (3) light ion beam dump (4) extraction chamber (5) dipole magnet (6) switchyard (7) radiofrequency cooler (8) JYFLTRAP (9) miniquadrupole beam deflector (10) electrostatic deflector and beamline upstairs to collinear laser experiments and (11) beam lines for experimental setups.

The primary beam from K-130 cyclotron is focused to the target through a 7 mm water-cooled collimator with a magnetic quadrupole lens and an XY-steering magnet. The coupling of the cyclotron beam line high vacuum to the low vacuum in the target chamber is done without beam windows using differential pumping by a water cooled 2000 l/s Alcatel Crystal 200 oil diffusion pump. The windowles coupling of the high and low vacuum regions allows use of heavy ion beams without intensity limitations due to heating of the beam windows.

The heavy ion beams enter the target chamber volume where the degrading foil and rotating target systems are