Nuclear Instruments and Methods in Physics Research B 317 (2013) 506–509

Contents lists available at ScienceDirect

Nuclear Instruments and Methods in Physics Research B

journal homepage: www.elsevier.com/locate/nimb

# Recommissioning of JYFLTRAP at the new IGISOL-4 facility

V.S. Kolhinen [a,*], T. Eronen [b], D. Gorelov [a], J. Hakala [a], A. Jokinen [a], K. Jokiranta [a], A. Kankainen [a,1], M. Koikkalainen [a], J. Koponen [a], H. Kulmala [a], M. Lantz [c], A. Mattera [c], I.D. Moore [a], H. Penttilä [a], T. Pikkarainen [a], I. Pohjlainen [a], M. Reponen [a], S. Rinta-Antila [a], J. Rissanen [a,2], C. Rodríguez Triguero [d], K. Rytkönen [a], A. Saastamoinen [a,3], A. Solders [c], V. Sonnenschein [a], J. Äystö [e]

[a] Department of Physics, P.O. Box 35(YFL), FI-40014 University of Jyväskylä, Finland
[b] MPI für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany
[c] Uppsala University, P.O. Box 256, SE-75105 Uppsala, Sweden
[d] School of Computing, Engineering and Mathematics, University of Brighton, Brighton BN2 4JG, UK
[e] HIP, P.O. Box 64, FI-00014 University of Helsinki, Finland

ARTICLE INFO

*Article history:*
Received 17 March 2013
Received in revised form 21 May 2013
Accepted 2 July 2013
Available online 23 August 2013

*Keywords:*
Penning trap
JYFLTRAP
IGISOL

ABSTRACT

The JYFLTRAP double Penning-trap system was moved to a new location along with the Ion Guide Isotope Separator On-line (IGISOL) facility at the Accelerator Laboratory of the University of Jyväskylä. The move made it possible to upgrade various parts of the facility. For example, separate beam lines for JYFLTRAP and the collinear laser spectroscopy station were constructed after the radio-frequency quadrupole cooler and buncher. In this contribution we give an overview of the new JYFLTRAP facility and results from the first stable ion-beam tests.



## 1. Introduction

JYFLTRAP was originally constructed at the IGISOL facility [1] of the University of Jyväskylä, Department of Physics, Finland, in the early 2000s to be used as an ion beam purifier and for high-precision mass spectrometry [2,3]. During the years of operation, atomic masses of more than 200 short-lived nuclei were measured and the trap was used to remove unwanted isobaric contaminants in numerous decay-spectroscopy experiments that mostly studied neutron-rich nuclei far from the valley of beta stability, see e.g. Ref. [4]. In the final years of operation at the previous IGISOL facility, JYFLTRAP reached high enough mass resolving power to resolve close-lying nuclear isomeric states [5] and to make atomic mass measurements well below the level of $10^{-8}$ precision [6].

The forthcoming move to the new location to be served by rare-ion beams from the new IGISOL-4 facility, allowed implementation of upgrades to the setup. The two permanent experimental installations, the collinear laser spectroscopy station [7] and JYFLTRAP, received high priority in the planning. Also, since new techniques, such as charge breeding and multi-reflection time-of-flight (MR-TOF) separators, were forseen as future investments, provisions for accommodating these devices were implemented. In this article we describe the upgrades that were implemented to the setup and show some preliminary results from the recommisioned Penning-trap facility.

## 2. IGISOL-4 overview

The construction of a new experimental hall started in the fall of 2008 in order to house the new 30 MeV cyclotron and the new IGISOL-4 facility. More details of the facility are presented elsewhere (I.D. Moore) [8] and here we only briefly describe the main components of the setup which are shown in Fig. 1 [8,9]. IGISOL-4 can use beams from both the existing K130 and the new K30 cyclotron (beam lines marked with (1) and (2) in Fig. 1, respectively). The nuclear reactions (often proton-induced fission of $^{238}$U or fusion-evaporation reactions) occur in the target chamber (3), which houses the IGISOL gas cell [10]. As the target chamber is set to 30 kV potential, the extracted ions are accelerated to an energy of 30$q$ keV. The continuous beam is guided through the 15° bender (5) and an intermediate section with a 90° bender that connects the beam line from the off-line station on the roof to the main IGISOL beam line (6) and a 55° dipole magnet (7) ($M/\Delta M \approx$500). The experimental area contains the electrostatic switchyard at

* Corresponding author. Tel.: +358 408054088.
*E-mail address:* veli.kolhinen@jyu.fi (V.S. Kolhinen).
1 Present address: University of Edinburgh, Edinburgh EH9 3JZ, UK.
2 Present address: Nuclear Science Division, LBNL, Berkeley, CA 94720, USA.
3 Present address: Cyclotron Institute, Texas A&M University, College Station, TX 77843-3366, USA.

0168-583X/$ - see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.nimb.2013.07.050

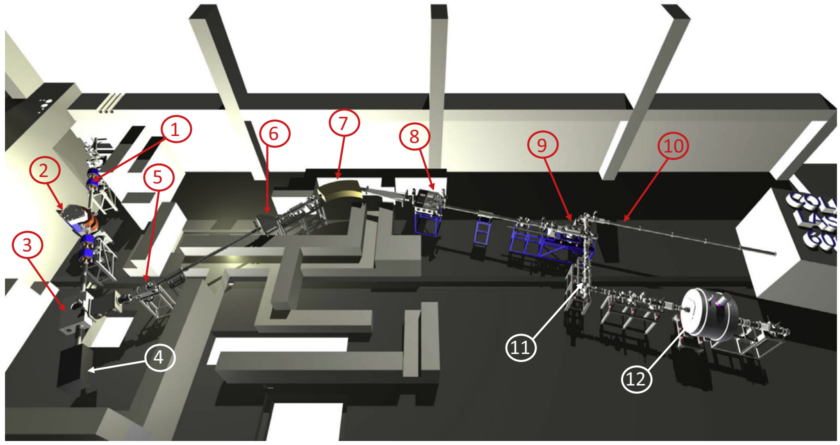


**Fig. 1.** Illustration of the IGISOL hall and the experimental area beam lines. The numbering is as follows: (1) K130 cyclotron beam line, (2) K30 cyclotron beam line, (3) IGISOL target chamber, (4) beam dump, (5) 15° bender, (6) 90° bender with vertical line, (7) 55° dipole magnet, (8) electrostatic switchyard, (9) RFQ cooler/buncher, (10) collinear laser spectroscopy line, (11) RFQ-to-Penning-traps transfer beam line, (12) Penning traps.

the focal plane of the dipole magnet (8), the radio-frequency quadrupole (RFQ) cooler/buncher (9), a collinear laser line (10), an RFQ-to-Penning-traps transfer beam line (11), and the Penning traps (12).

A separate off-line ion source is being constructed on the roof of the IGISOL target cave and is connected via a separate beam line to the 90° bender (6). A parallel implementation of off-line and on-line ion sources will make it possible to run the test ion sources simultaneously and almost independently to that of the on-line ion guide system. This will give more off-line test beam time since no cooling down time is anymore required after the on-line runs which usually heavily activates the front-end area. Moreover, it allows one to use an absolute mass calibration for the on-line Penning-trap experiments by using a carbon-cluster laser ablation ion source. The design and further details of the off-line ion source can be found in Ref. [11].

A new electrostatic switchyard at the focal plane of the IGISOL separator magnet consists of an adjustable slit system, 10° kicker plates and 30° bender plates allowing the beam from IGISOL to be directed straight to the central beam line towards the RFQ or to the left or right beam line (side beam lines are not shown in Fig. 1). The switchyard has been designed so that it allows one to take mass $A$ towards the RFQ cooler/buncher and masses $A+1$ and $A-1$ to the left and right beam line, respectively. Therefore, one is able to perform several experiments simultaneously, for example, decay spectroscopy with mass $A-1$ in the side beam line and a Penning-trap experiment with mass $A$, or the use of one line for yield monitoring while running a spectroscopy experiment with long-living ion species in second line.

## 3. RFQ cooler/buncher and the RFQ-to-Penning trap transfer-beam line

The RFQ cooler/buncher is exactly the same device as at the previous IGISOL-3 facility [12]. The 30$q$ keV beam is electrostatically decelerated to about 50$q$ eV by raising the whole RFQ to a high voltage platform of about 29.9 kV. The (optionally bunched) beam is extracted from the RFQ with an energy of 800$q$ eV. The beam can either be transported left towards the collinear laser spectroscopy station or right towards the Penning traps. The connecting low-energy beam line between the RFQ cooler/buncher and the JYFLTRAP Penning-trap system [2,3] is significantly longer than before and will allow the addition of new devices at a later state, such as a charge breeder and/or MR-TOF mass spectrometer/separator. A charge breeder would make it possible to create highly-charged ions for mass measurements and thus one could reach better precision in the Penning trap [13]. An MR-TOF mass spectrometer would allow a faster isobaric cleaning process and a bigger throughput than a purification Penning trap and therefore, one could perform mass measurements in a shorter time [14] and also with ions that are produced with a larger amount of contaminant species.

The transfer beam line also houses a HV insulator after the RFQ cooler/buncher device and a pulsable drift tube, which is used as an electromagnetic lift for the ions, within that insulator. The insulator allows the Penning traps and the RFQ to be run independently: while the RFQ is used for collinear laser spectroscopy, the Penning traps can be independently used for tests using an off-line ion source connected, for instance, to one of the ports of the quadrupole bender chambers (see Fig. 2, (5)).

For beam diagnostics there are two Faraday cups (FC) in the connecting line between the RFQ cooler/buncher and the Penning traps and a Faraday cup and a micro-channel plate detector (MCP) after the Penning traps. There is also a place for a silicon detector in the same position. The Faraday cups are used in beam tuning with high beam current ($I > 1$ pA) whereas the MCP is needed to detect trapped ions after they have been ejected from the trap.

## 4. Penning traps

The two Penning traps of JYFLTRAP are housed within the 7.0-T superconducting solenoid manufactured by Magnex Ltd. The first trap, the purification trap, is filled with a dilute amount of helium gas [2]. The second trap, the precision trap, is used for high-precision atomic mass measurements and for ultra-high mass separation [3,15]. The solenoid has been mounted in the opposite direction to that of the previous laboratory, due to the experience gained from earlier shimmings which indicated that the purification trap could be shimmed to better homogeneity than the precision trap. The magnetic field was fine-tuned by using shimming coils and thin ferromagnetic metal strips. Relative homogeneities of $\Delta B/B \leqslant 1.57$ ppm and $\Delta B/B \leqslant 0.28$ ppm were obtained in 1 cm$^3$ volumes in the location of the purification trap and precision trap centers, respectively. Inhomogeneities cause frequency shifts