Status of HIGISOL a new version equipped with SPIG and electric field guidance

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Article

Status of HIGISOL, a new version equipped with SPIG and electric field guidance *

R. Béraud [a], G. Canchel [a], A. Emsallem [a], P. Dendooven [b], J. Huikari [b], W. Huang [b], Y. Wang [b], K. Peräjärvi [b], S. Rinta-Antila [b], A. Jokinen [b], V.S. Kolhinen [b], A. Nieminen [b], H. Penttilä [b], J. Szerypo [b], J. Äystö [b], B. Bruyneel [c] and A. Popov [d]

[a] *Institut de Physique Nucléaire de Lyon, IN2P3-CNRS et Université Claude Bernard Lyon 1, 43, Bd du 11 Novembre 1918, F-69622 Villeurbanne Cedex*

[b] *Department of Physics, University of Jyväskylä, P.O. Box 35, 40351 Jyväskylä, Finland*

[c] *Instituut voor Kern-en Stralingsfysica, K.U. Leuven, Celestijnenlaan 200D, B-3001 Leuven, Belgium*

[d] *St Petersburg Nuclear Physics Institute, Gatchina 188350 St Petersburg, Russia*

A new HIGISOL chamber devoted to the study of short-lived products from heavy-ion-induced fusion-evaporation reactions is proposed. It enables, via the extraction of ions by means of a SPIG (SextuPole rf Ion Guide), to improve the Mass Resolving Power by a factor 2.5 compared to the previous system using a skimmer-ring assembly. The gas cell was also equipped with an electric field for faster transportation of recoiling ions to the nozzle where they are ejected with the gas jet. The first results obtained both with a radioactive α-source and cyclotron beam will be reported.

1. Introduction

The HIGISOL system implemented at the K = 130 cyclotron in Jyväskylä since 1996 gives readily, for short-lived products of H.I. induced fusion-evaporation reactions, a yield of $\sim$ 100 ions/(s.mbarn.μA$_{\mathrm{part}}$) [1]. The technique is fast (ms range), applicable to all elements, but, as the overall efficiency

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is rather low ($\sim$ 1%), its use is presently restricted to very refractory elements where no ISOL techniques can compete. The survival time of singly-charged ions is reduced to a few ms in high pressure He buffer gas needed to stop high energy recoils. Therefore, it is of utmost importance to diminish the mean evacuation time of reaction products and for this purpose, the addition of an electric field guidance has proven to be an appropriate solution[2].

2. Experimental results

2.1. Description of the new chamber

Figure 1 shows the new target- and recoil chamber assembly installed on-line at the Jyväskylä cyclotron. The main differences, regarding our previous set-up described in[1] are both a larger He pressurized recoil chamber with its axis parallel to the He flow and a primary beam stopper outside (replacing the channel). According to the He flow simulations using the techniques described

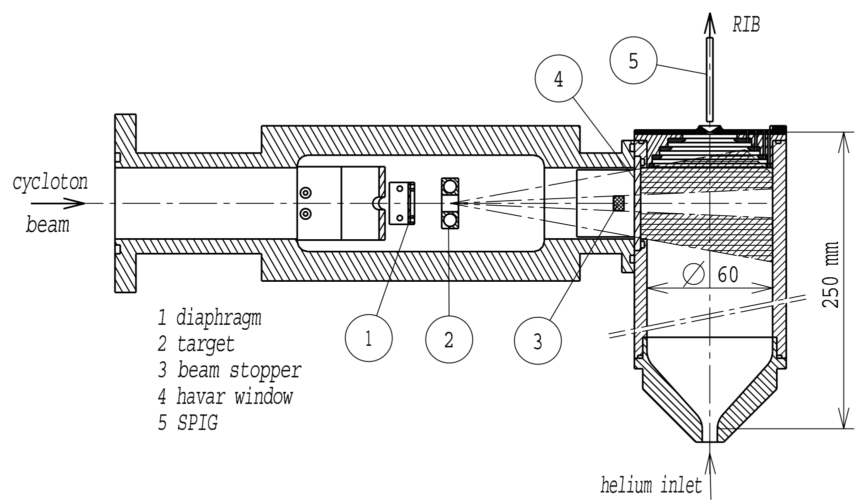

Figure 1. *Schematic drawing of the new HIGISOL chamber.*

in[3], this long chamber should provide much more homogeneous He evacuation than our previous one[4]. In counterpart, the effective stopping volume is reduced from ~ 100 cm^3 to ~ 60 cm^3. In order to prevent the cyclotron H.I. beam from interacting with buffer gas, we have installed a cylindrical beam stopper ($\phi_e = 7$

mm) placed at a 5mm distance from the havar entrance window (thickness = 2 mg/cm^2). In figure 2, it is shown that the efficiency remains constant within a large range of ^{36}Ar beam intensity (0.8 to 4.0 10^{12} pps). This clearly demonstrates that the "plasma effect" (if any !) is now kept independent of the primary beam intensity. Moreover, this intensity is no longer limited by the exit window survival as it was in our previous chamber with the channel.

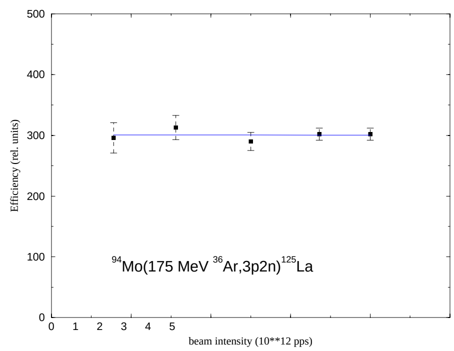

Figure 2. *Relative efficiency of HIGISOL as a function of ^{36}Ar primary beam intensity.*

2.2. RF sextupole instead of skimmer

The transportation of ions from the pressurized chamber to the high vacuum region using a radiofrequency sextupole was proposed in ref[5] and also in ref[6] at Jyväskylä. Such a device has been successfully installed at Leuven[7]. The SPIG (SextuPole Ion Guide) allows a much larger pumping speed of buffer gas in the extraction region providing lower density and therefore less collisions between gas atoms and ions to be guided towards the acceleration stage. Consequently, this results in two advantages : -i) a much smaller energy spread ($\sim$ 1 eV) compared to the skimmer system ($\sim$ 100 eV) and-ii) the possibility to use higher buffer gas pressure, increasing thus the stopping efficiency of the cell. In case of 500 hPa He pressure, the Mass Resolving Power (MRP) obtained with the SPIG is about 1100 whereras it was only $\sim$ 400 using the skimmer. Moreover, the MRP is independent of He pressure. It is the result of a soft collisions regime in the extraction-SPIG region and this could also explain the large amount of molecular ions, formed in the recoil chamber, which can fly through the RF sextupole without dissociation. Adding a DC voltage (up to 225 V) to the RF one (U_{RF} = 600V, ν_{RF} = 2.2

MHz) didn't help to dissociate them. For Ce and La elements the amount of CeO^+ and LaO^+ ions compared to Ce^+ and La^+ ones was strongly dependent on the grade of the gas used. The ratio $M^+/(M^+ + MO^+)$ could vary in a very broad range (95% - 5 %).

2.3. Electric field guidance

Figure 3 shows a detailed drawing of the ensemble of electrodes designed to get a focusing field towards the exit hole. A simulation of the equipotential surfaces has been obtained using the SIMION (vers. 6.0) code including a viscuous force. The electrodes are made of stainless steel whereas the insulator is standard araldite glue.

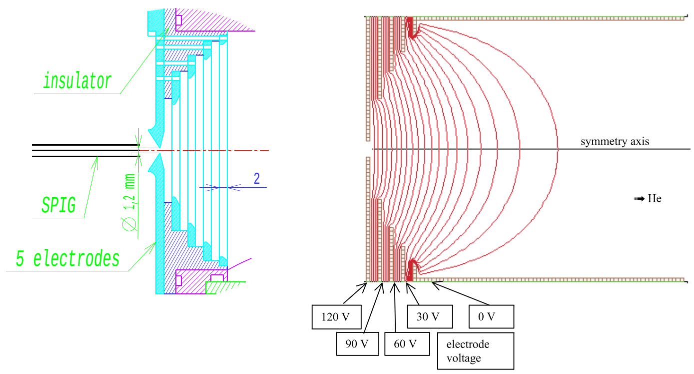

Figure 3. *Drawing of the electrodes system and mapping of equipotential curves.*

2.3.1. Off-line tests

A ^{223}Ra ($T_{1/2}$ = 11.43 d) α-source is placed at the tip of a needle movable along the symmetry axis of the chamber. This allows absolute efficiency measurement as a function of the extraction hole-source distance. Figure 4 shows the ability of the electric field to extract, with constant efficiency, mass-separated ions (^{219}Rn) which are thermalized far away from the exit hole (up to 4 cm). However the drop of efficiency at short distance (compared to the "no field" case) should be avoided providing a more focusing field very close to the nozzle.

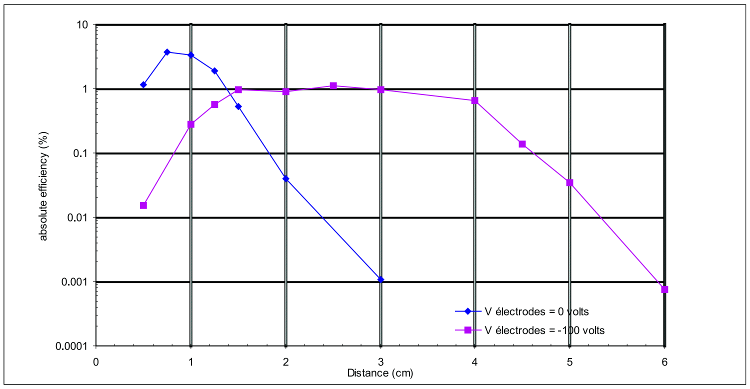

Figure 4. *Absolute efficiency for* ^{219}*Rn recoils as a function of exit hole-source distance.*

2.3.2. On-line tests

The efficiency for recoils from the ^{223}Ra source has been measured as a function of field strength. In presence of the cyclotron beam, we note a decrease of the yield when the voltage is increasing whatever the recoils are. In figure 5 is presented the number of α counts as a function of the electric field value. It is worth noting that the distance source-exit hole is large enough so that the transit time of ions ($\geq$ 50 ms without field) is much longer than the survival time (2-3 ms). The "no beam" curve in figure 5 shows that with V=0, the ions are not extracted. A special point to be emphazised is that with the beam, an appreciable amount of activity is extracted. The ^{219}Rn ions are re-ionised by the plasma produced via the reaction products when stopping in He. In this case the mechanism is much similar as for a classical plasma source. The number of

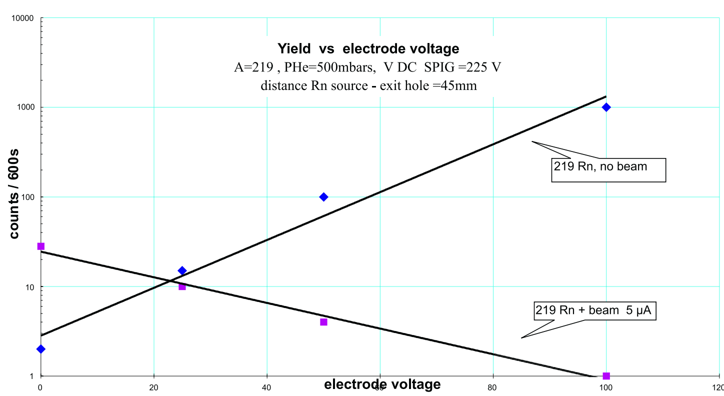

Figure 5. *Relative efficiency as a function of electric field strength.*

ions delivered by the source being constant, this is an experimental evidence of the occurrence of reionization processes via collisions with recoiling nuclei and secondary particles produced by the H.I. beam. This effect has been previously mentioned in our original work about HIGISOL[8].

3. Conclusion

In this work we have shown the advantages of the RF sextupole extraction system which provides much better MRP and that the stopper enables the use of very intense H.I. beams. The electric field allows to collect ions in a much larger volume, a revised version of our electrodes system (under construction) should avoid losses at short distance and therefore improve efficiency in the near future. In presence of beam, the situation is much more complex due to field perturbations induced very likely by the secondary particles, non-suppressed beam and subsequent ionisation of the buffer gas.

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