# Commissioning of REX-ISOLDE ◇

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REX-ISOLDE [1] an experiment with post accelerated radioactive ion beams at the ISOLDE facility at CERN did now produce first radioactive beams with 2 MeV/u energy within two commissioning runs of the whole set-up. REX-ISOLDE allows the post acceleration of radioactive ions from ISOLDE to target energies between 0.8 and 2.2 MeV/u. Despite to test a new technology of charge multiplication and post acceleration, experiments with light neutron-rich nuclei using Coulomb excitation, fusion and neutron transfer reactions are planned using the MINIBALL detector array [2]. In addition scattering experiments with halo nuclei are proposed using the second beam line of the REX-ISOLDE set-up. Therefore the LINAC, which consists of a radio frequency quadrupole (RFQ) accelerator, an interdigital H-type (IH) structure and three seven gap split ring resonators, must deliver beams of isotopes of very different mass-to-charge ratio, with variable target energies and with good beam quality.

In year 2001 REX-ISOLDE has been fully installed and all elements have been tested successfully. The charge state breeder of REX-ISOLDE [3], which consists on a large Penning trap and an Electron Beam Ion Source (EBIS) has successfully bred ions from a test ions source as well as radioactive ions from the ISOLDE mass separators. This is the first charge state booster in the world which breeds very low intensities of radioactive ions before injection into a LINAC. Tests have been done with Na-, K- and Al-isotopes. The REXEBIS has produced the first charge bred ions in August 2001 and has been running nearly non-stop September until December. It has delivered stable $^{39}K^{10+}$ and $^{23}Na^{6+}$ beams generated in the ion source in front of REXTRAP. The $Na^{7+}$ current exceeded 70 pA or $6*10^7$ p/s. Stable $^{27}Al^{7+}$ and $^{23}Na^{6+}$ from ISOLDE and also the first radioactive $^{26}Na^{7+}$ and $^{24}Na^{7+}$ beams (just $5*10^5$ p/s) have been charge bred and accelerated for detector tests. A breeding efficiency of about 15% in one charge state could be reached for Na and K, where the trap efficiency of about 40% is not included. In fig.1 an example of a charge state spectrum with and without injected Na ions from REXTRAP is shown. Despite some problems with the electron gun, which had one breakdown after about 1500 hours of operation and displayed slow changes of the emission conditions, the EBIS is working remarkably stable. Future efforts will be put in the shift to higher the particle masses and to higher intensities which can be handled by the charge breeder. Therefore a new cooling scheme is under investigation using the rotating wall method [4]. In addition breeding tests with heavier masses (La form the cathode) is planned to determine the required confinement time and the heating losses.

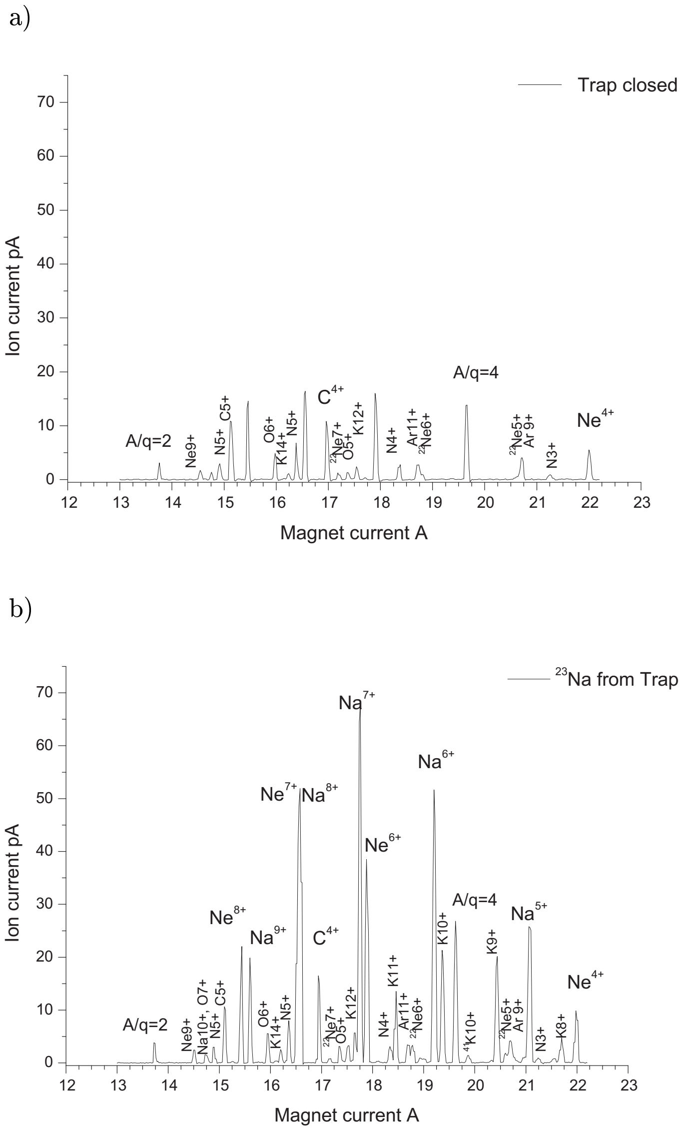


Fig. 1: a) Charge state spectrum without ions injected from the trap and b) Charge bred $^{23}$Na-ions injected from the REXTRAP.

The S-shaped beam line between the EBIS beam line and the LINAC is a mass separator which separates the few highly-charged radioactive ions out of the ions from the

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residual gas. The separator is achromatic due to the use of a Nier-type set-up. The separator has been designed with the code Cosy infinity(C) with a theoretical resolution of $(A/q)/\Delta(A/q) = 110$. Isotopes from the EBIS could be separated by the REX mass separator with a resolution of $(A/q)/\Delta(A/q)$=100. The total transmission of the mass separator is about 75-90%. Losses due to charge exchange in the separator result from the rather high rest gas pressure of $10^{-6}$ mbar. Therefore UHV-diagnostic boxes are planned for the separator section in order to reduce the outgasing rate of those devices.

The different LINAC structures have been successively tested with rest gas beams from the EBIS in order to determine the right amplitude and phase settings. Due to the lack of the high resolution phase shifter modules so far, the commissioning is not yet completed. However in two beam times, the REX-ISOLDE LINAC could accelerate charge bred ions of $^{23}$Na, $^{24}$Na, $^{25}$Na, $^{26}$Na and $^{39}$K to 2 MeV/u with only two of the 7-gap resonators. In addition the LINAC is able to transport beams with A/q<4.5 to the target region at 0.3 MeV/u (RFQ-energy) and at 1.2 MeV/u (final energy of the IH-structure). The transmission of the LINAC has been about 70-80% without steering and with no fine adjustment of the phases. The beams could be focussed through a 3 mm aperture in front of the target.

In the test beam time in November an overall transmission of Na-isotopes of about 2% through the whole REX-ISOLDE system could be reached. All resonators in the ISOLDE hall are located in the experimental area. Due to space restrictions, no additional concrete shielding can be installed in the hall. Therefore the structures with the highest gap voltages (380 kV) must be shielded with lead. From TIS restrictions we have to stay below 10 $\mu$S/h at the lead shield surface for the highest power level and for the 10% duty cycle. Especially the pumping ports of the 7-gap cavities have to be shielded, because X-rays which escape through those ports can disturb the measurements at the MINIBALL position.

In the commissioning beam time radioactive sodium beams have been guided on a $^{58}$Ni target for Coulomb excitation experiments and on a $^{9}$Be-target to study neutron transfer reactions. For that purpose a temporary target set-up including a Si-strip-detector and one MINIBALL triple cluster detector has been installed. In the beam time the $\gamma$- and particle detection and the data acquisition system could be tested. An example is given in fig.2, which shows a $\gamma$-spectrum taken from the n-transfer reaction between $^{24}$Na and $^{9}$Be in coincidence with the two particle detection in the Si-detector. The $^{8}$Be$->2\alpha$ decay allows a clean signature for the n-transfer, which can be seen in fig.2b in comparison to the spectrum in coincidence with the Si-detector (fig.2a). The high resolution $\gamma$-spectra allow identification of the populated levels. The spectra reveal that very little is known about nuclei only one or two neutrons away from stability. The $\gamma$-background in the target area, competitive reaction channels and different target materials have been studied as well. Gating of the detector with the short EBIS extraction pulse allow a good underground reduction.

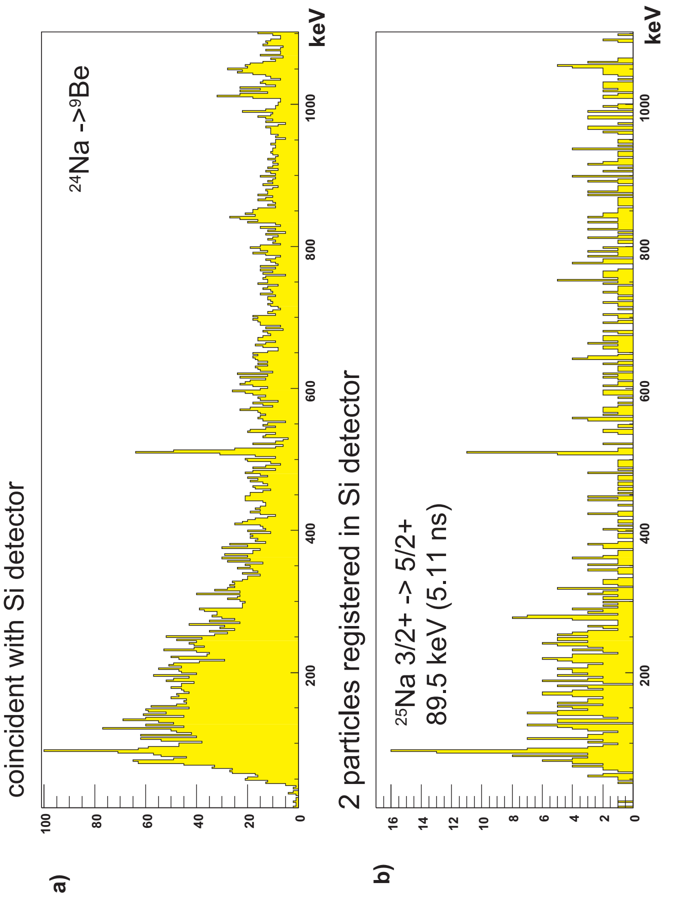


Fig. 2: $\gamma$-ray spectrum of $^{24}$Na from the second commissioning run

The commissioning of the LINAC will be completed using a He-test ion source which will be installed in front of the REX-separator magnet. Measurements of the energy spreads, emittance measurements and fine tuning of the phase- and amplitude settings are foreseen in the next year. In 2002 three beam times are foreseen for further runs with Na-isotopes, with $^{9}$Li and with Mg-isotopes. It is foreseen to use the full MINIBALL setup including 8 triple cluster Ge-detectors, which will be installed until April 2002 in the $65^o$-beam line. The Li-experiment will be performed with the second beam line in the $20^o$-direction. Both beam lines will be available until April 2002. A bunch of proposals are in preparation in order to make use of the unique experimental possibilities using Coulex-, fusion- and transfer reactions at 2.2 MeV/u beam energy.

## References

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[3] O. Kester and D. Habs, AIP conference proceedings **572** (2000) 217
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