THE REX-ISOLDE PROJECT

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Abstract

REX-ISOLDE is an experiment at ISOLDE/CERN with a twofold aim: i) to demonstrate a novel efficient scheme for the acceleration of radioactive ions from the online mass separator ISOLDE. ii) to perform first nuclear physics experiments by studying the structure of neutron rich Na,Mg and K,Ca nuclei in the vicinity of the closed neutron shells N=20 and N=28 by Coulomb excitation and neutron transfer reactions. The radioactive ions are first accumulated in a Penning trap, then charge breeded to a charge to mass ratio of ≥1/4.5 in an Electron Beam Ion Source (EBIS) and finally accelerated up to 2.2 MeV/u. The Linac consists of a Radio Frequency Quadrupole (RFQ) accelerator, an interdigital H-type-Structure (IH) and three seven-gap resonators, which allow to vary the energy between 0.8 and 2.2 MeV/u. This paper gives an overview of the different components of the accelerator.

1 INTRODUCTION

REX-ISOLDE (Radioactive Beam EXperiment at ISOLDE) is a pilot experiment with energetic radioactive ions at the new ISOLDE (CERN) [1]. It makes full use of the low energetic 1^+-beams delivered from the on-line mass separator ISOLDE. These ions will be accelerated on the basis of a radically new concept (see fig. 1) . By continuous injection into a Penning trap (REX-TRAP), the 1^+ions are accumulated for 20 ms and cooled by collisions with a buffer gas. Bunches of 10 μs length with improved emittance are then transferred to the EBIS. The dense electron beam of the EBIS, focussed by a strong magnetic field of a solenoid strips the ions up to the stripping limit determined by the electron energy. After a breeding time of 20 ms a 100 μs long bunch is finally extracted.

As the intensity of the radioactive ions is about orders of magnitudes smaller than the intensity of ions from the residual gas, a mass separator between the EBIS and the front end of the LINAC is required. The mass separator consists of an electrostatic 90^0 cylinder deflector and a 90^0 magnetic bender build up in a vertical S-shape. This system has been calculated to third order, providing a q/A-resolution of 1400. The seperator is described more precisely in ref. [2, 3]. The following Linac allows to vary the ion- energy between 0.8 and 2.2 MeV/u. The ions are finally bend onto the target, which might be surrounded by an efficient Ge-detector array (MINIBALL).

2 THE LINEAR ACCELERATOR

2.1 The 4-rod-RFQ

The first acceleration stage of the REX-ISOLDE LINAC is a 4-rod-RFQ which is designed to accelerate radioactive ions with a charge-to-mass ratio larger than 1/4.5 from 5 keV/u to 300 keV/u. The rf quadrupole field provides transverse focusing for the low energy ions while a modulation of the four rods performs a smooth bunching and acceleration of the injected 100 μs bunch. The 4-rod-RFQ is a well tested structure [4], which is already used in the GSI HLI-LINAC [5] and the Heidelberg high-current injector [6]. As the lay-out of the REX-ISOLDE-RFQ is very conservative the maximum voltage which can be obtained should even provide acceleration of ions with charge-to-mass ratios as small as 1/6.5. With a shunt impedance of 100 kΩm the expected power consumption will be about 60 kW.

Design calculations with PARMTEQ have been performed to minimize the divergence of the beam at the exit of the RFQ. It turned out that one can avoid a rapid increase of the radial beam size in the drift tube between the end of the rods and the first triplet of the matching section. Connecting the RFQ to the IH-structure the matching section consists in total of two triplets and a rebuncher.

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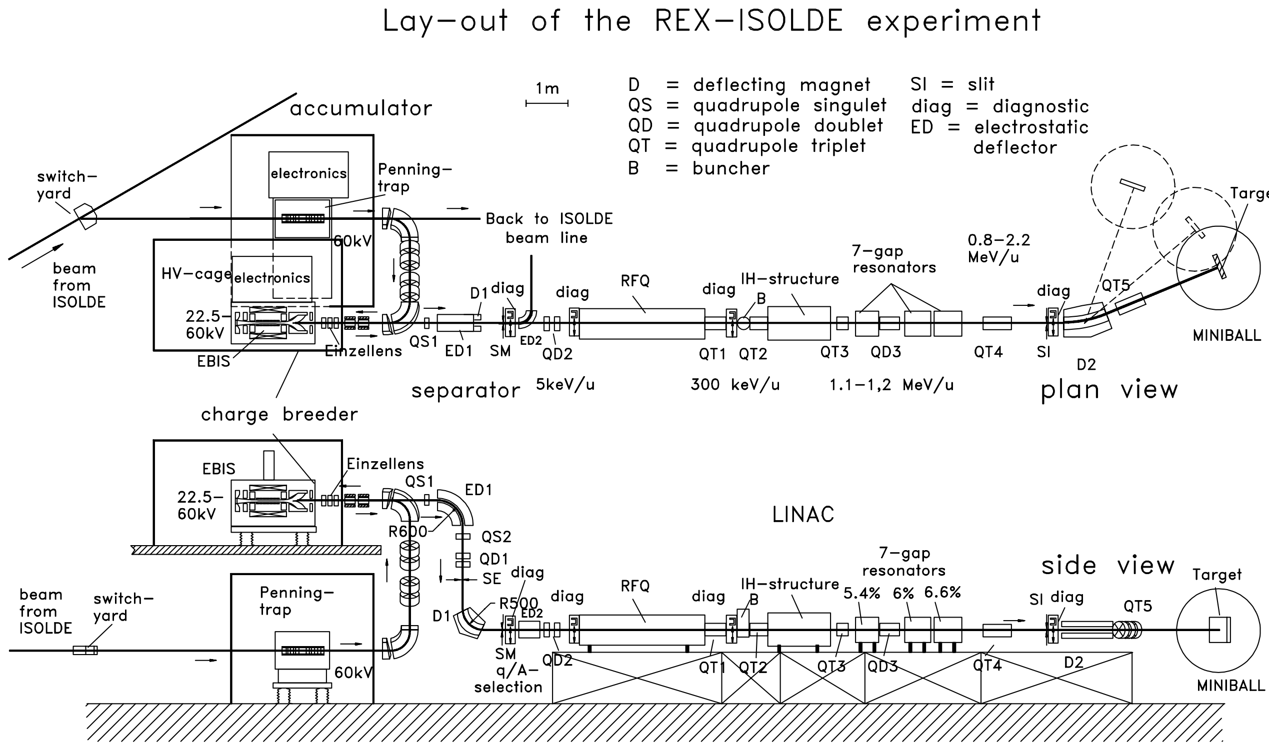

Figure 1: Schematic view of REX-ISOLDE.

2.2 The IH-structure

The IH-struture for REX-ISOLDE is a drift-tube structure which has been scaled from similar structures like the GSI HLI-IH-structure or 'tank 1' of the IH-structure of the lead LINAC at CERN [8, 9]. The beam dynamics concept of the 'Combined Zero Degree Structure' [9] was developed and applied for both IH-DTL's mentioned above and resulted in a very reliable beam operation.

The IH-structure accelerates the ions from 0.3 MeV/u to an extraction energy between 1.1 and 1.2 MeV/u. Switching between the two values of the exit energy of the IH-structure can be achieved by adjusting the gap voltage distribution via capacitive plungers.

The electric field distributions of the drift tube structure have been studied by MAFIA calculations. The required undercut length of the magnetic flux inductors for a flat gap voltage distribution, has been investigated as well. The design distribution and the calculated one fits very well for the different final energies. The lower final energy of the IH-structure is important for deceleration of the ions down to 0.8 MeV/u: a deceleration from 1.2 MeV/u down to 0.8 MeV/u by the 7-gap resonators would lead to a non-acceptable phase spread of the ions at the target. The accepted phase/energy spread of the IH-structure are $\pm 10^0/\pm 2.8\%$ respectively. Assuming a shunt impedance of 300 MΩ/m, the total peak power consumption will be 36 kW.

2.3 The seven-gap resonators

The last section of the accelerator consists of three 7–gap resonators similar to those built for the new high current injector at Heidelberg [10], but operating at a slightly different eigenfrequency. Each resonator has a single resonance structure (see fig. 2), which consists of a copper half shell and three arms attached to both sides. Each arm consists of two hollow profiles, surrounding the drift tubes and carrying the cooling water. Driven in push pull mode, consecutive drift tubes have opposite potential.

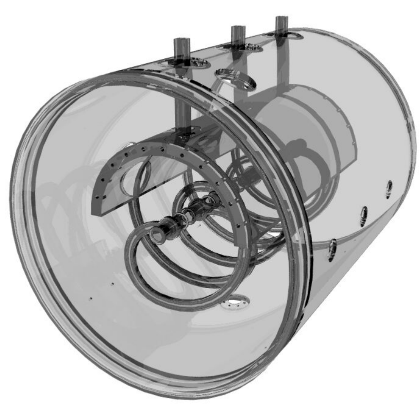

Figure 2: Transparent drawing of a 7-gap resonator.

The development and construction of the three 7–gap–resonators which will allow to vary the energies of the REX-ISOLDE beams between 0.8 and 2.2 MeV/u has been started. Assuming a realistic resonator voltage for each resonator of approximately 1.75 MV at 90 kW incoupled power [11], the design velocities were fixed to 5.4%, 6.0% and 6.6% of the velocity of light. Three downscaled models (1:2.5) were built in order to optimize the shuntimpedance and the field-distribution at the operation frequency of the amplifiers of 101.28 MHz required by CERN standards. The optimization of the 6.0% low power resonator is already finished.

For the down scaled mmodel we have measured a shuntimpedance of 95 MΩ/m and a Q–value of 3350. Therefore a resonator voltage of about 1.8 MV for the power type resonator can be expected. Table 1 compiles the parameters of the 6.0% power type resonator as expected from the down scaled model.

Parameter	6.0% power type resonator
f [MHz]	101.28
Q–value	5300
Z [MΩ/m]	58
N [KW]	90
U_0 [MV]	1.78

Table 1: Parameters for the 6.0%-power-resonator, extrapolated from the down scaled model. f=frequency, Z=shunt impedance, N=power consumption, U_0=resonator voltage.

The development of the resonators was accompanied by extensive MAFIA calculations. The six arms with drift tubes correspond to six coupled oscillators and produce closely spaced modes. To investigate these modes referring to eigenfrequency and voltage distribution in the gaps MAFIA is a very powerful simulation code. It could be demonstrated that spiral-resonators like 7–gap resonators can be simulated to better than 1% in comparison with experimental results (compare fig. 3).

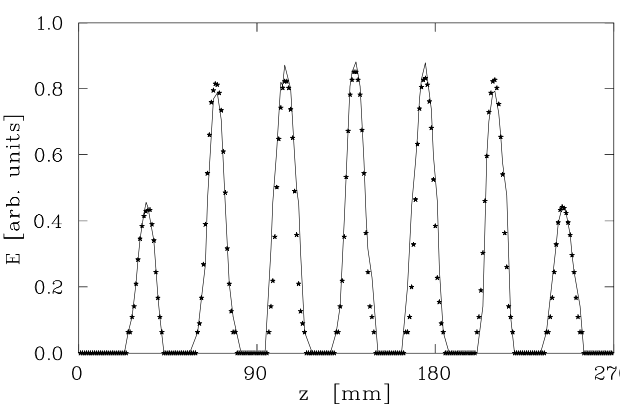

Figure 3: Comparison between the optimized distribution of the electric field in the down scaled 7-gap resonator for $\beta = 6\%$ calculated with MAFIA (solid line) and measured (asterisk).

Extensive beam dynamic calculations were made to optimize the transmission of the beam up to the target. It turns out that for final energies between 0.85 and 2.2 MeV/u nearly 100% transmission can be realized. The acceptance in the x-plane is 1.2 πmm mrad (norm.) and in the y-plane 3.0 πmm mrad (norm.). The bunchlength of the fully accelerated beam (2.2 MeV/u) is 2.4 ns at the target, it can be further improved if necessary by a rebuncher before the target.

3 STATUS

The extension of the ISOLDE experimental hall, starting in January 1996 is finished. The superconducting solenoid for the REX-Trap is delivered and installed at the high voltage platform. The first retardation system is under construction, all mechanical parts including the magnet chamber are in fabrication. The solenoid for the EBIS, a 2 Tesla system, has been ordered and new injection simulations of the injection scheme were performed.

RFQ- and IH-tanks are ordered, for the IH-structure a scaled down model for the parameter optimization is under construction in the mechanical workshop. All three scaled down models of the 7 gap resonators are built and presently optimized by bead perturbation measurements. The full scale tanks are under construction.

The development and construction of all components are expected to keep the time schedule, which foresees the first accelerated beams available in 1999.

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