THE PROJECT SPES AT LEGNARO NATIONAL LABORATORIES

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Abstract

At LNL INFN is under construction a Rare Isotope Facility (SPES) based on a 35-70 MeV proton cyclotron, able to deliver two beams with a total current up to 0.5 mA, an ISOL fission target station and an existing ALPI superconducting accelerator as a post accelerator (up to 10 MeV/u for A/q=7). In this paper, some highlights are presented: the isotope separation part (low, medium and high-resolution classes), some highlights of the mechanical and RF aspects of the RFQ and the end to end simulation (from the charge breeder to the end of ALPI). High selectivity and high transmission for a beam of a very low intensity, plus the specific challenges related to the use of ALPI (with a reduced longitudinal acceptance) and related to the specific lay out led to specific and common problems which have been solved during the design stage.

INTRODUCTION

SPES, acronym of Selective Production of Exotic Species, is a CW radioactive ion beam facility under construction at LNL INFN in Italy. It will produce and accelerate neutron-rich radioactive ions, in order to perform nuclear physics experiments, which will require beams above Coulomb barrier.

The main functional steps of the facility are shown in Fig.1: the primary beam delivered by the cyclotron, the beam from the fission target (as an example, up to 10^{13} particle/s of ^{132}Sn), the beam cooler, the separators, the charge breeder and the accelerator (the existing ALPI with a new RFQ injector). The use of the continuous beam from the +1 source, which can use different configuration types LIS, PIS, SIS, maximizes the RNB efficiency but need a CW post accelerator (RFQ and ALPI). The beam is prepared for the post-accelerator stage with a charge breeder device (an ECR that woks in continuous). The energy on the transfer lines are determined by the chosen RFQ input energy (5.7 keV/u); for this reason, all the devices where the beam is approximately stopped (production target, charge breeder and RFQ cooler) lay at a voltage proportional to the ratio A/q. The charge state range (3.5<A/q<7) is bounded by the RFQ field level for the upper limit and by the minimum voltage on q=1 transport line.

METHOD FOR SIMULATIONS

The main software used for the simulations is TraceWin [1] a 3D multiparticle tracker, capable of field map usage. In such a way, the quarter-wave cavities of the linac ALPI were simulated via field-maps in order to take into account all nonlinear order effects. Due to that, the TraceWin code is capable to set all beam line for the runs of the LNL installed accelerators [2].

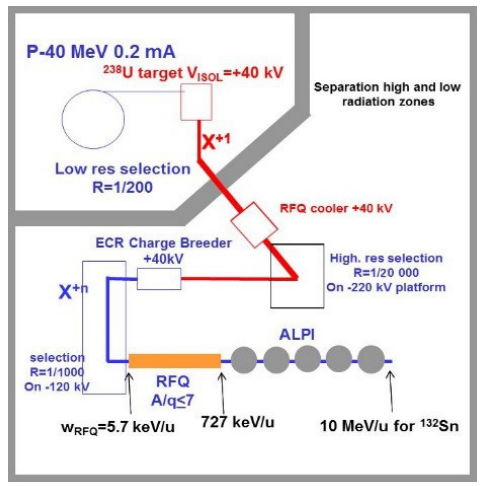

Figure 1: functional scheme of the SPES facility. There are two main areas: the 1+ line and the n+ line, where 1+ and n+ indicates the beam charge state.

THE SEPARATION STAGES

The general layout of the SPES facility is presented in Fig. 2.

The reference beam for the beam dynamics simulations is chosen to be the ^{132}Sn, extracted at 40 kV at the end of the target extraction system. It has been chosen a q=19 after the charge breeder i.e. A/q= 6.9, in such a way to test the maximum required electromagnetic fields of the line elements of the facility.

There are three normalized rms emittance regimes: after the target, it is chosen to be $\varepsilon_{n,rms}$=0.007 mm mrad, with an equivalent geometric emittance at 99% of $\varepsilon_{geo,99\%}$= 80.18 mm mrad. Then, the beam cooler prepares the beam to the HRMS stage, reducing the emittance down by a factor 5. After the CB, the emittance for the BD calculation is assumed to be $\varepsilon_{n,rms}$=0.1 mm mrad. As far as the longitudinal phase space is concerned, a uniform distribution between ±20 eV (reduced to ±1 eV

ISBN 978-3-95450-131-1

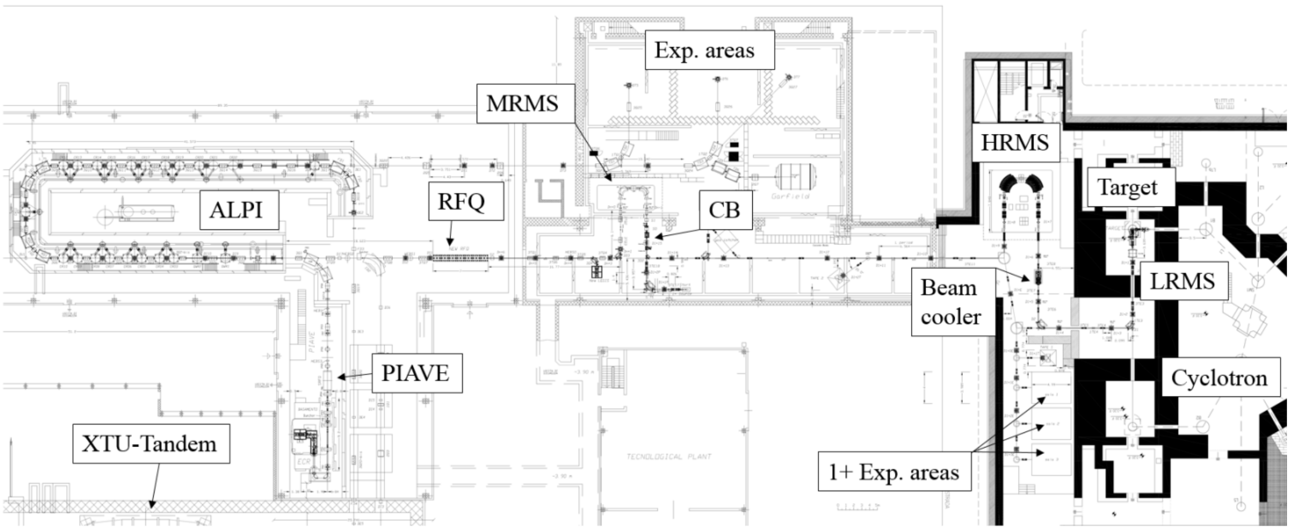

Figure 2: Full SPES layout with main areas.

after the beam cooler [3,4,5]) is considered. After the CB, the energy spread are set to ±15 eV. The low resolution section (LRMS) is the part of the line between the target and the beam cooler. Two mass spectrometers are placed between the target and the beam cooler: the Wien Filter and a 90° dipole. The overall resolution is of 1/200 in mass, sufficient to separate the isobars from the other isotopes.

Two similar type of spectrometers, the High Resolution Mass Spectrometer and the Medium Resolution Mass Spectrometer are provided for the SPES project. Both are composed by two 90° magnet with a multipole (up to 12° order pole) between them, placed onto platforms.

The HRMS is used to obtain the ions of interest, because it removes isobar ions coming from the source and the MRMS is used to clean the nominal beam from contaminants introduced by charge breeder.

After the 1/200 isotopes separator, the isobars separation is represented by HRMS placed on a 260 kV platform (the effect is a reduced divergence and energy spread). This separator is constituted by six quadrupole lens, two exapole lens, two dipoles and one multipole lens placed in the symmetry plane of the system to fix the curvature aberration. It is able to separate different isobar with $\Delta M\ /\ M$ =1/20000 and $\Delta W\ /\ W$ = ±1 eV (due to the beam cooler) like shown in Fig. 3 below. The optics improvement is still ongoing but it shows a fully resolving capability of isobars separated of 1/20000 in mass. It is important to take into account that its performance depend on the beam cooler efficiency. After the charge breeder, the next spectrometer is the MRMS, placed on a 120 kV platform (for the same reasons of the HRMS). The goal in resolving power of this spectrometer is 1000 with the interest beam fully separated. The Table 1 shows the overall capabilities of the two spectrometers.

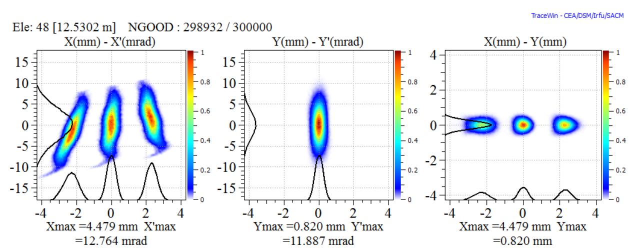

Figure 3: phase space at the HRMS image point. The three beam are separated of 1/20000 with ± 1eV energy spread.

Table 1: Medium and High Spectrometer Performances

Parameter	MRMS	*HRMS*
Input emit. n. rms mm mrad	0.1	0.0014
Emittance growth	10%	7%
Full res. ΔW = ±1 eV	1/1500	1/36000

After the selection, the beam is sent to the RFQ through a matching line.

THE SPES RFQ

The SPES RFQ is designed in order to accelerate beams with A/q ratios from 3 to 7 from the Charge Breeder through the MRMS and the selection and injection lines up to the MEBT. The main parameters of the RFQ are listed in Table 2. The RFQ is composed of 6 modules about 1.2 m long each. Each module is basically composed of a Stainless Steel Tank (AISI LN 304) and four OFE Copper Electrodes.

A copper layer will be electrodeposited on the tank inner surface and a spring joint between tank and electrode is used in order to seal the RF.

The voltage law is a linear function along z V(z)=V(0)+a·z with a=3.177 kV/m and V(0) depending on the A/q of the ion to be accelerated. Such law is

ISBN 978-3-95450-131-1

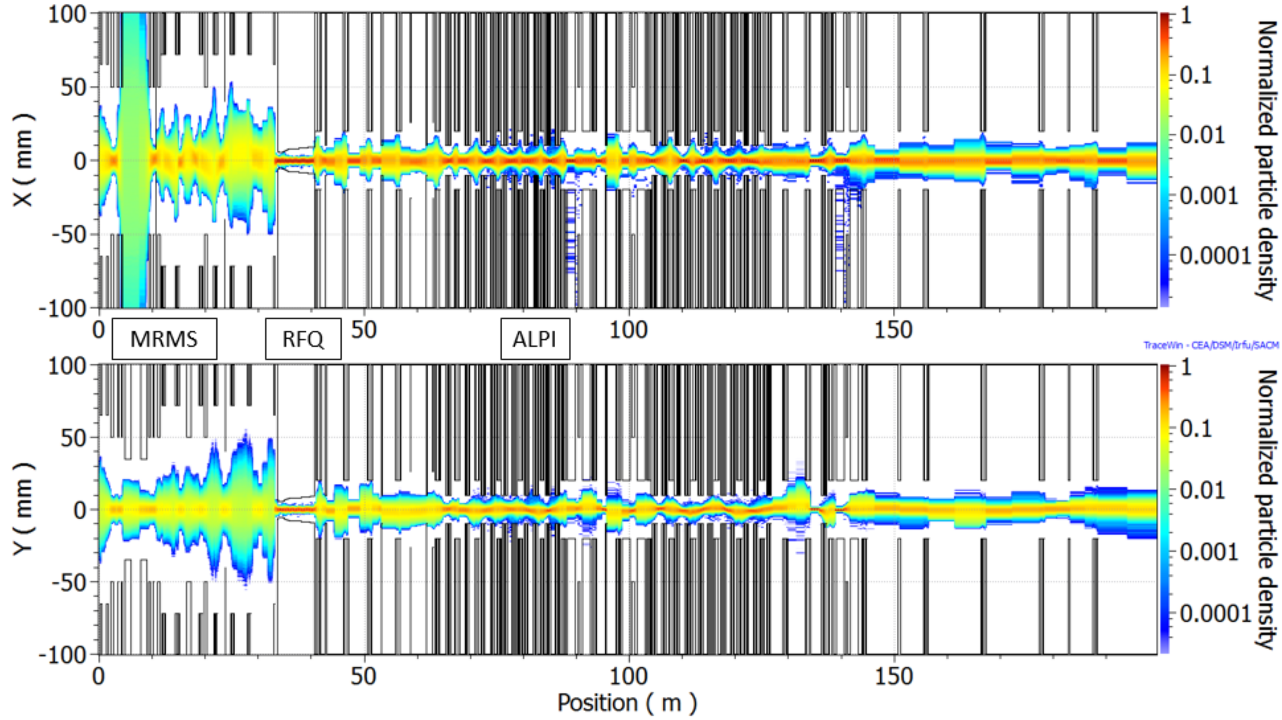

Figure 4: Multiparticle normalised-densities y and x of the whole line CB-RFQ-ALPI- Experimental hall.

Table 2: Main RFQ Parameters

Parameter [units]	**Design value**
Operational mode	CW
Frequency [MHz]	80
In/out. Energy [keV/u]	5.7-727 (β=0.0035-0.0359)
Vane length L [m]	6.95
RF Power [kW] (+30%)	98

implemented by designing the RFQ in order to obtain a constant TE_{21} cut-off frequency fc=79.5 MHz along the structure and by properly shaping the vane undercuts at the Low and High Energy Ends of the RFQ. In order to compensate the R0 variations, the capacitive region is varied along the RFQ. The electrode thickness is equal to 48 mm and the tank inner radius R is equal to 377 mm [6].

END TO END BEAM DYNAMICS SIMULATION

An end-to-end simulation from the CB to the end of ALPI was performed. The beam travels from the CB to the third hall, see fig. 4. The final kinetic energy is 1.2 GeV ($\Delta E / E < \pm$ 0.4%) with total losses of 14% in the nominal case. In Fig. 3 the multiparticle densities are shown for the x and y coordinates. An error study from the RFQ exit to the experimental hall was carried out.

The single preliminary errors study shows that the errors related to the QW cavities drive the losses through ALPI. The present precision of the cavity placement and on the synchronous phase setting is shown in Table 3. Therefore intrinsic losses of about 30% are foreseen unless new improvements.

Table 3: errors applied to the ALPI LINAC

Parameter	**Value**	**Average losses**
Cavity displacement	±1 mm	30%
Phase error	±1°	15%
Input beam phase error	±2°	10%

CONCLUSIONS

Several highlights of the SPES project were shown. The high-resolution mass separator is under refinement while the WF and the MRMS are under procurement. An end to end simulation of the line from the CB to the experimental hall was done, showing an overall transmission >85% in the nominal case. The full error study is under analysis.

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ISBN 978-3-95450-131-1