# PRIMARY BEAM DYNAMIC SIMULATION OF DOUBLE DRIFT DOUBLE BUNCHER SYSTEM FOR SPES PROJECT

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*Abstract*

SPES (Selective Production of Exotic Species) is a facility intended for production of neutron-rich Radioactive Ion Beams (RIBs) at the National Institute of Nuclear Physics (INFN-LNL, Legnaro, Italy). Exotic nuclei production based on the ISOL (Isotope Separation On-Line) technology using UCx target. Neutron-rich nuclei will be generated by uranium fission under the influence of proton beam from cyclotron. After that, RIBs will be reaccelerated by the ALPI (Acceleratore Lineare Per Ioni). RFQ (Radio Frequency Quadrupole) will be used as a front-end part of the ALPI. Double Drift Double Buncher system is planned to be install before RFQ for transmission increasing. This article is dedicated to beam dynamic simulation and laying-out of transport line at section before ALPI.

## INTRODUCTION

SPES project is in progress at the Legnaro National Laboratory of the National Institute of Nuclear Physics (INFN-LNL, Italy). Facility layout is shown in Fig.1.

Therefore, there is complex system for preparing of ion beam before ALPI. This system includes ion beam transport lines, Beam Cooler, Charge Breeder, HRMS and MRMS (high and medium resolution mass separators) and superconductive RFQ [1]. 5 MHz Low Energy Buncher has to be installed upstream RFQ for experiments, which require order of 100 ns beam length. So-called Double Drift Double Buncher system was chosen [2]. It includes two double gap structures (first and second harmonics – 5MHz and 10MHz correspondingly) installed at some distance from each other. The aim of this work was the optimization of beam transport line between MRMS and RFQ. Beam lines from buncher to RFQ before and after optimization are shown on Fig.2.

Optimization tasks:

- beam matching with RFQ
- increasing transmission
- reduce to zero dispersion at the input to RFQ
- particle losses minimization

Beam line includes buncher, magnetic quadruple triplets, solenoid and diagnostic chambers. Matching was carried out by varying the disposition of transport line elements and magnetic forces of focusing elements. The task is complicated by the fact, that disposition varying along beam line is limited because of transport line passes through two walls.

The beam line included 5MHz buncher, two quadruple magnet triplets and solenoid [3]. This work was involved determination of 10MHz buncher and focusing elements location in order to meet the aim.

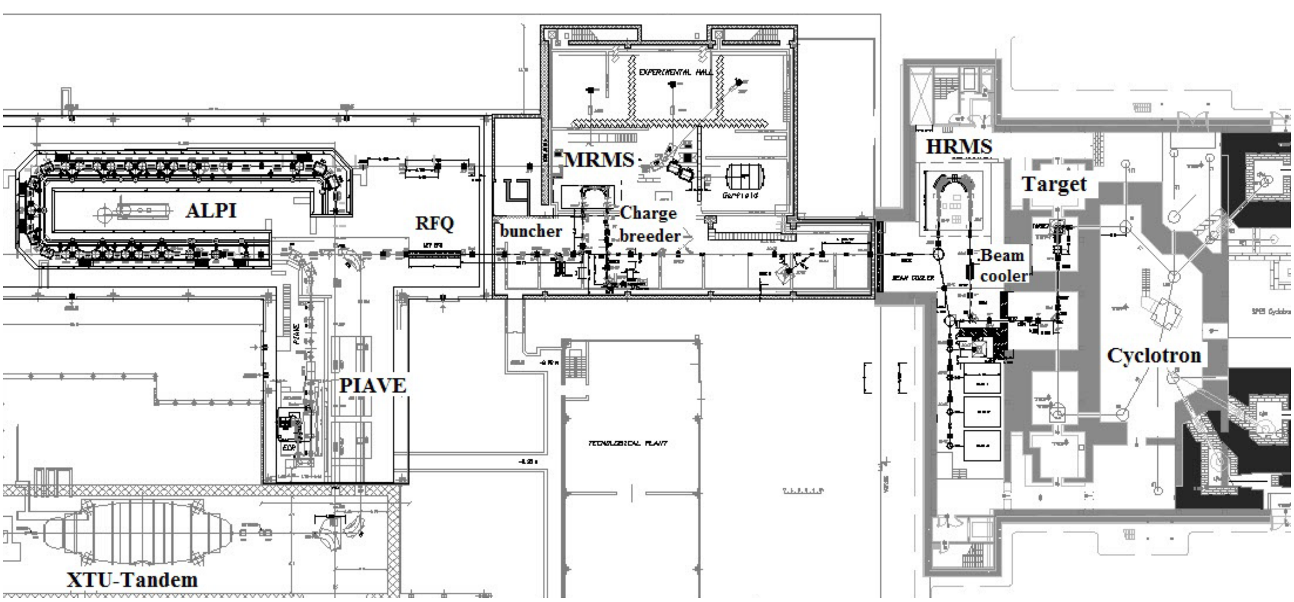


Figure 1: SPES facility layout.

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## BEAM DYNAMIC SIMULATION

The main software used for the simulation is TraceWin [4]. Beam dynamic simulation was performing for $^{132}Sn^{19+}$ ion beam at 760 keV. Initial parameters are shown in Table 1.

Table 1: Initial Beam Emittance Parameters

| | X-X' | Y-Y' |
|---|---|---|
| Emit[rms] [Norm] Pi.mm.mrad | 0.1000 | 0.1000 |
| Emit[99.00%] [Norm] Pi.mm.mrad | 0.8087 | 0.8004 |
| Beta (Twiss parameter) mm/Pi.mrad | 0.7041 | 0.7041 |
| Alpha (Twiss parameter) | -3.2274 | -3.2274 |

First priority problem was determination of second buncher localization in order to effective increasing transmission. According to [5] the most effective bunching with distance between bunchers in range from 1.319 m to 1.522 m. Beam dynamic simulation for front-end part of the beam line was carried out. Particle beam losses variation with distance between bunchers analysis was carried out. A particle loss depending on distance between bunchers is shown in Fig.3. As is seen from graph, beam particle losses increase with distance between bunchers. In order to reduce losses the quadruple magnet triplet 3TQ6 between was offered. As is seen from Fig.4 number of came down second buncher particles decreases with increasing distance between triplet 3TQ6 and first buncher. For this reason, triplet 3TQ6 location has to be as close to first buncher as possible. Based on the above distance between bunchers is 1522 mm, distance mentioned between first buncher and quadruple magnet triplet 3TQ6 is 200 mm.. The magnetic field values in 3TQ6 are shown in Table 2.

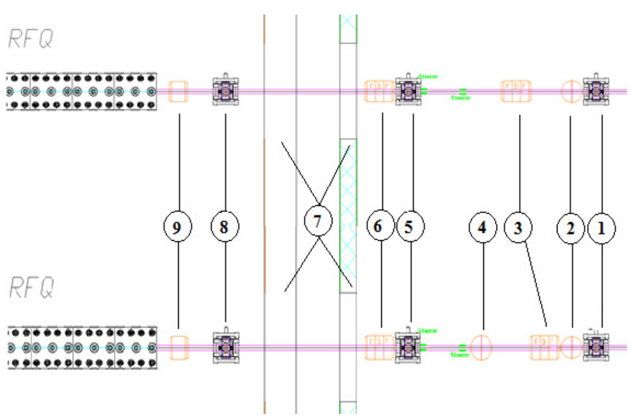


Figure 2: Beam line before (top figure) and after (bottom figure) optimization. 1, 5, 8 – diagnostic chambers, 2 – 5 MHz buncher, 3 – magnetic quadruple triplet 3TQ6, 4 – 10 MHz buncher, 6 – magnetic quadruple triplet 3TQ1, 7 – walls, 9 – solenoid S2.

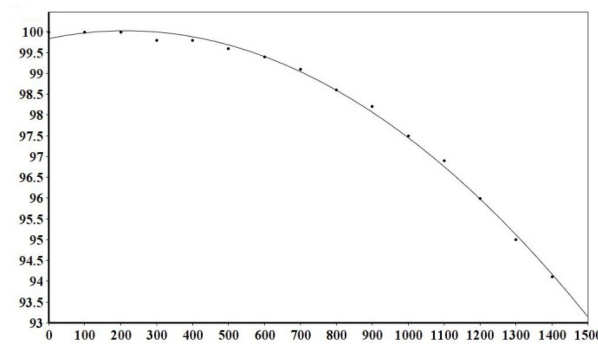


Figure 3: Distance between bunchers – particle transmission curve.

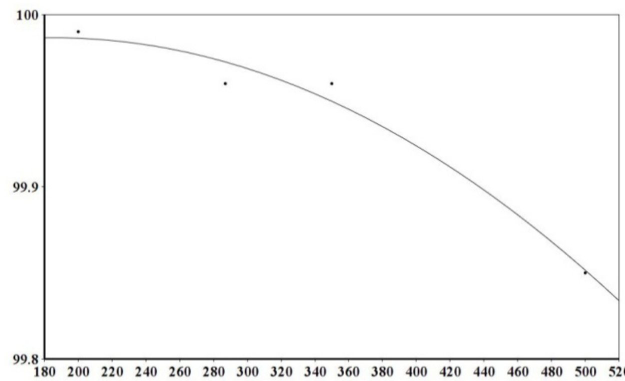


Figure 4: Distance between buncher and 3TQ6 triplet – particle transmission curve.

Table 2: The magnetic Field Values in the Focusing Elements

| Focusing element | 3TQ6 | 3TQ1 | S2 |
|---|---|---|---|
| 1st quad gradient, T/m | -1.69 | -0.61 | |
| 2nd quad gradient, T/m | 1.70 | 0.86 | |
| 3rd quad gradient, T/m | -1.69 | -0.61 | |
| Strength of a magnetic field, T | | | 0.39 |

At the next step, the beam dynamic simulation for next part of the beam line was carried out. Localization and magnetic fields in magnetic quadruple triplet 3TQ1 and solenoid S2 were determined with account for room specifics. Magnetic field from Table 1 provides zero dispersion at the RFQ entrance. RFQ transmission in/out particles was 99186/53999. As result, distance between second buncher and triplet 3TQ1 is 1797 mm, distance between solenoid S2 and RFQ is 364 mm. The magnetic field values in 3TQ1and S2 shown in Table 1.

The particle beam envelope from first buncher to RFQ is shown in Fig. 5.

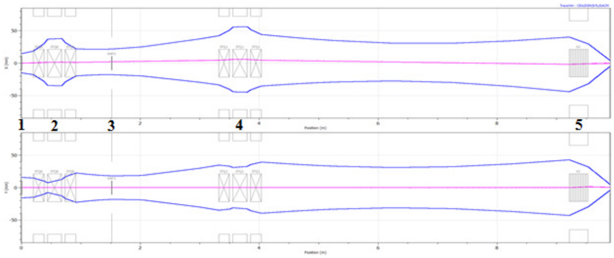

Figure 5: The particle beam envelope from first buncher to RFQ. 1 – 5MHz buncher, 2 – magnetic quadruple triplet 3TQ6, 3 – 10 MHz buncher, 4 – magnetic quadruple triplet 3TQ1, 5 – solenoid S2.

Output file for optimized beam line shown on Fig. 6.

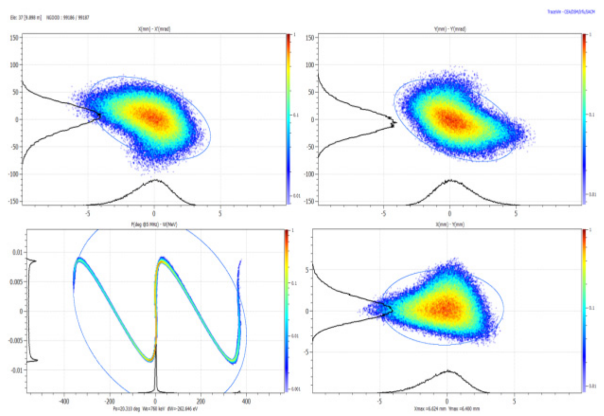

Figure 6: Output file for optimized beam line.

Input file for RFQ shown on Fig. 7.

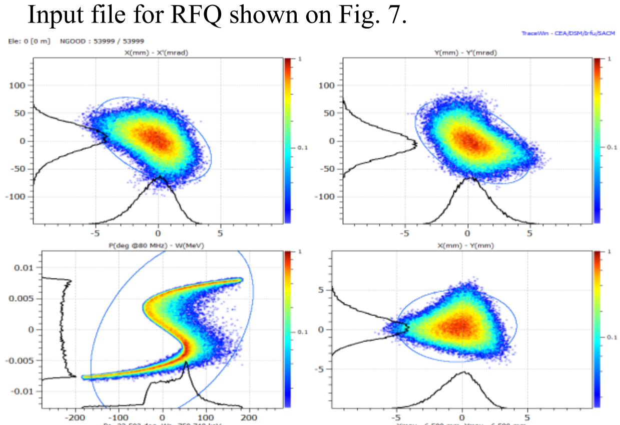

Figure 7: Input file for RFQ

Beam emittance parameters presented in Table 2.

Table 3: Beam Emittance Parameters at RFQ Input

| | X-X’ | Y-Y’ |
|---|---|---|
| Emit[rms] [Norm] Pi.mm.mrad | 0.1119 | 0.1118 |
| Emit[99.00%] [Norm] Pi.mm.mrad | 1.0857 | 1.0715 |
| Beta (Twiss parameter) mm/Pi.mrad | 0.0680 | 0.0687 |
| Alpha (Twiss parameter) | 0.5139 | 0.5219 |

Output file after RFQ shown on Fig. 8.

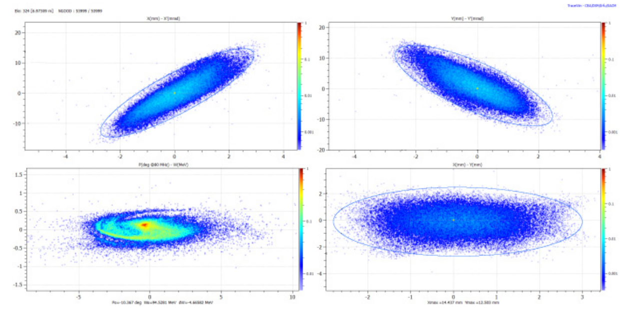

Figure 8: Output file for RFQ.

## CONCLUSION

During the work beam dynamic simulation for transport line between MRMS and RFQ was carried out. The quadruple magnetic triplet between bunchers was offered. Location of buncher, quadruple triplets and solenoid were determined. Fields in quadruple triplets and solenoid were adjusted. Particle losses in the beam line are about 0.001%. Dispersion at the RFQ entrance reduced to 0. Beam matching with RFQ was performed.

## ACKNOWLEDGEMENT

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