ISBN: 978-3-95450-132-8 doi:10.18429/JACoW-IPAC2014-THPME032

BEAM TRANSFER STUDIES FOR LINCE EXPERIMENTAL AREAS

L. Acosta*, Universidad de Huelva, E-21071 Huelva, Spain; INFN-Catania I-95123, Catania, Italy
C. Bontoiu, I. Martel, A.R. Pinto-Gómez, Universidad de Huelva, E-21071 Huelva, Spain
J. Lucas, ELYTT Energy, E-28046 Madrid, Spain
A.C.C. Villari, FRIB, Michigan State University, MI 48824-1321, East Lansing, Michigan, USA; Universidad de Huelva, E-21071 Huelva, Spain

Abstract

Beam transport optics of the LINCE Linac experimental areas has been optimized for a few ion species using transfer matrix calculations performed in MAD-X. An alpha spectrometer based on a double bending achromat lattice has been used as dispersion suppressor. This optics design correspond to the first three planned beam lines. Further studies for the beam tracking and magnets design are being developed in order to conclude the whole design of this first LINCE phase.

INTRODUCTION

LINCE [1] is a very recent project related with the construction of a new Linac facility at South Spain, in the province of Huelva, Andalusia. Supporting the early bases of this machine, a big Spanish project called ACELTEC was established. ACELTEC is a project for the developing of nuclear technology, where participate many Spanish companies sharing tasks with Universities. In particular, the University of Huelva is playing an important role for the project development. In this communication we centered the studies in one of the priorities of the project: the establishment of the beam transmission for the experimental beam lines that compose the fist-stage of the LINCE project. Since a very important issue for the industry and the Spanish government is the construction of a facility composed by beam lines dedicated to the applications on industry and medicine, this first conception of the beam transmission is related with three beam lines devoted to applications. Nevertheless, further stages of present project will be addressed not just to applications but also to scientific research in nuclear physics and astrophysics.

In this work we present the optical beam transport design for three beam lines: *i)* radioisotopes production line, *ii)* irradiation of the techno-fusion materials line and *iii)* irradiation of aerospace technology line.

The development to be shown here starts at the output of the acceleration section of the machine, and all the calculations were performed using as input parameters the values calculated for such section. Thus, we may divide the system in four parts: connection system (including an alpha spectrometer, described later), beam-line 1, beam-line 2 and beam-line 3. Considering this developing as a very early stage, we searched a basic model (or cell) to be followed. The cell chosen as a main optics structure was the Double Bending Achromat lattice or Panofsky System [2]. Such lattice is described with the Betatron functions and it is one of the most used models to generate a comparable focusing at the entrance and exit of the beam, including mainly two bending magnets and 6 quadrupoles. The complete optics design of the first stage beam lines of the LINCE project was performed grouping several Panofsky lattices (with some particular modifications in special points).

* luis.acosta@dfa.uhu.es, acosta@lns.infn.it

METHODOLOGY

We took the example from [2] to reproduce our own "working-cell", where we implemented the particular parameters expected and calculated for the beam profile coming from the Linac section. Thus, we start considering the following initial conditions: $\varepsilon_{x,y} = 6 \times 10^{-4}$ πmmrad, $\beta_x = 9.2$ m, $\beta_y = 8.8$ m, $A/Q = 1 - 7$ and energies till $E = 10$ MeV/A, according to the different applications considered for the project. From this information, we start with the construction of our working-cell, using as principal tool, the MAD-X code [3], developed at CERN. After calculating the best distances, lengths and strengths for optical elements with MAD-X, we got the best solution for a working-cell, which is show in Fig. 1.

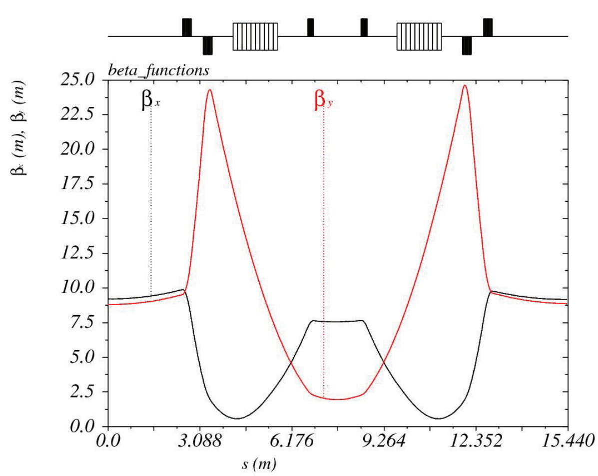

Figure 1: Working-cell used for the beam optics of the LINCE beam lines generated with MAD-X. Cell is based on Double Bending Achromat. It was performed with the output parameters coming from the Acceleration section (See the text for details).

The working cell shown in Fig. 1, was performed using two bending magnets of 45° and 1.5 m of middle arc length. The quadrupoles from entrance and exit have a length of

ISBN: 978-3-95450-132-8 doi:10.18429/JACoW-IPAC2014-THPME032

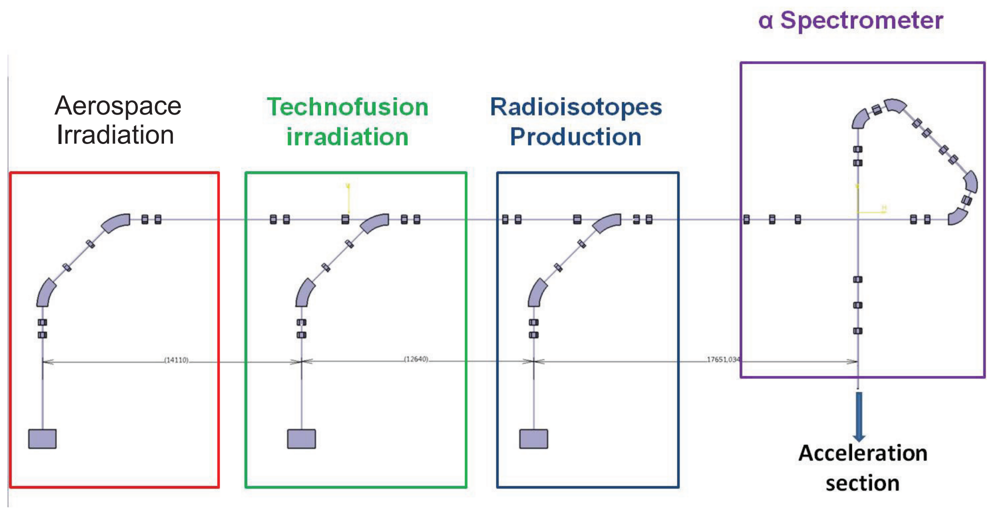

Figure 2: Final configuration of the beam lines for the LINCE project first stage. The three main beam lines can be observed inside rectangles. The alpha spectrometer and the focused connection with the acceleration section are also signposted.

30 cm while the central quadrupoles (those between bending magnets) have a length of 20 cm. The strength for all quadrupoles was fixed around 2.0 m^{-2}. The final configuration of the total elements considered for the first stage of LINCE beam lines was establish as is shown in Fig. 2.

BEAM TRANSPORT OPTICS

As it was mention before, we performed the optics calculation for the whole system of beam lines based on the working-cell shown in Fig. 1. However, each section presents different particular characteristics. In the following subsections, these will be described separately.

Radioisotope Production Line

This beam line is thought to be used for the production of radioisotopes, considering the high intensity of the beam expected for LINCE (around 1 mA). In order to avoid beam losses, this beam line was placed close to the acceleration section, attaining also with it, take advantage of the shielding in this region. Close to the last part of this beam line will be located laboratories devoted to the treatment of the radioisotopes produced. The optics for this beam line includes a section of radioisotopes separation, based on the EXOTIC beam line performed at INFN-Legnaro [4]. The optics of the beam line and the isotopes separation section is shown in Fig. 3.

Irradiation of the Techno-fusion Materials Line

The optics for this beam line in this first approximation is simple, considering that, for the moment, it represents just the first part of a triple beam line. In this stage, we can reduce the present beam line to a current material irradiation beam line, then it still not shows special characteristics. It is placed on the middle part of the laboratory, considering that it will be completed with other two beam lines coming from two 5 MV Tandems which will be placed close to this beam line,

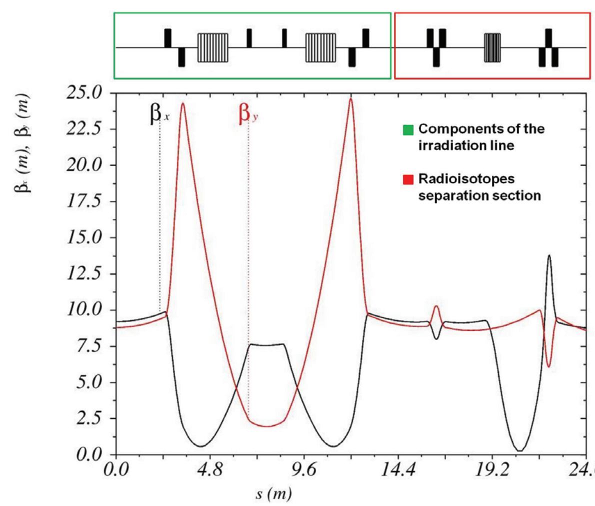

Figure 3: Beam transport optics of the radioisotopes production line.

with the goal to reproduce the radiation conditions inside a fusion reactor [5]. The optics for this section is shown in Fig. 4.

Irradiation of Aerospace Technology Line

This beam line will be dedicated to the irradiation of aerospace electronic components, with the goal to test their radiation resistance [6]. This usually requires to cover a wide irradiation zone. For such reason, a X,Y scanning of the beam is necessary. In order to cover this necessity, we performed calculations for several focal positions of the beam. This effects can be generated with the variation of the electric and magnetic fields in an array composed by two dipoles (one electrostatic and another magnetic). This system, known as Wobbler magnet [7], was included in the last part of the present beam line. The optics of this beam line is shown in Fig. 5.

ISBN: 978-3-95450-132-8 doi:10.18429/JACoW-IPAC2014-THPME032

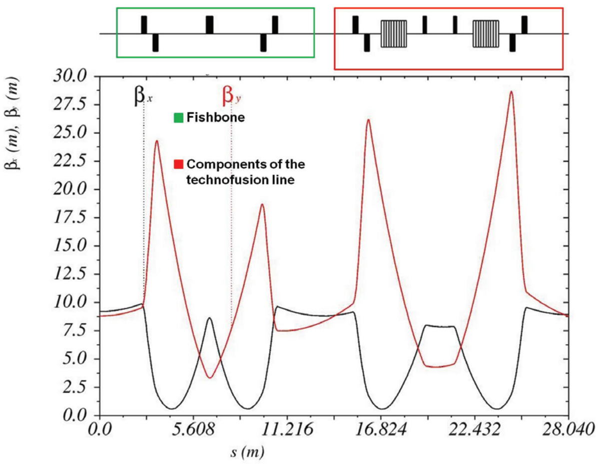

Figure 4: Beam transport optics of the irradiation for the techno-fusion materials line.

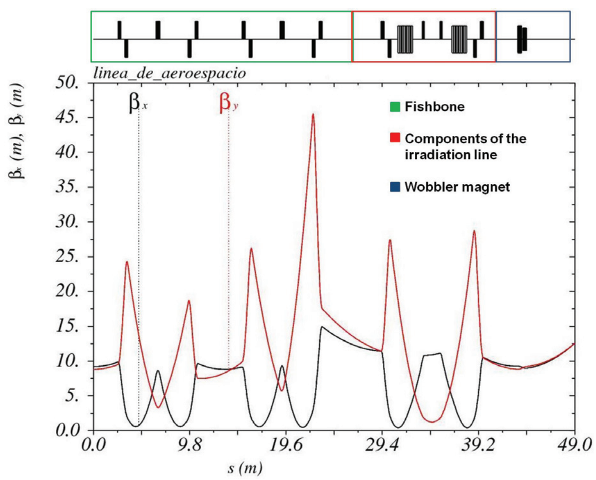

Figure 5: Beam transport optics of the irradiation for the aerospace line.

The Alpha Spectrometer

The last part to be described is related to the alpha spectrometer. This optical configuration was inspired in that performed at GANIL [8], used principally to define the momentum spread and transversal emittance of the beams prior to the experimental zone. Our aim is similar, since it is to have a good definition of the beam characteristics before the various experimental beam lines. For this reason, we placed the alpha spectrometer at the exit of the beam acceleration section. The coupling with Linac exit and the beam lines section were designed using symmetric quadrupoles triplets, avoiding with this to lose the double achromatic characteristics of each individual beam line. The configuration of the spectrometers is also based on the working-cell (Fig. 1), though in this case, the bending magnets are of 67.5° and 1 m of middle arc length, to keep the shape of a rectangle triangle of the system (see Fig. 2). Quadrupole between bending magnets have 40 cm length, while the rest of them a length of 30 cm. The optics of the alpha spectrometer and the coupling triplets is shown in the Fig. 6.

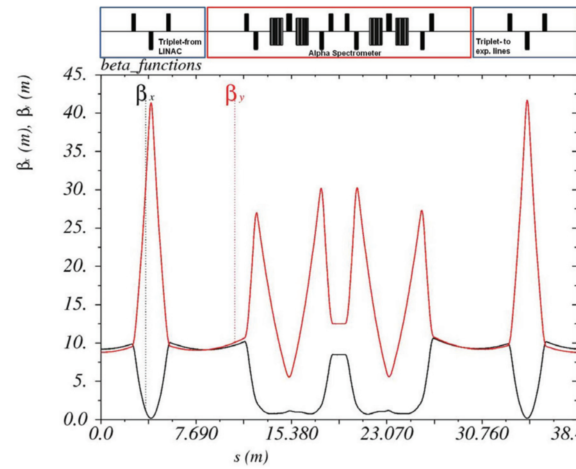

Figure 6: Beam transport optics of the alpha spectrometer and the connection between beam lines and Linac.

SUMMARY

Here was described the present beam transport optics for the first stage of the planned LINCE facility. Calculations developed with MAD-X program have allowed to define the dimension and location of each of the beam lines considered for this early phase. Moreover, the optics of some other particular systems included in the beam lines, were also optimized. Such are the cases of an Isotope Separator, a Wobbler Magnet set and an Alpha Spectrometer. Further studies will be dedicated to generate the magnet designs and beam tracking for the whole beam lines of the facility.

ACKNOWLEDGMENT

This Work is partially supported by Ministerio de Innovación, Economía y Competitividad, under program FEDER INTERCONNECTA and CONSOLIDER INGENIO 2010.

REFERENCES

[1] I. Martel, et. al., IPAC'14, Dresden, Germany, THPME036, These Proceedings, (2014).

[2] H. Wiedemann. *Particle Accelerator Physics*, (Verlag Berlin Heidelberg: Springer, 2007), 179-180.

[3] MAD-web, CERN: `http://mad.web.cern.ch/mad/`

[4] F. Farinon, et. al., Nucl. Instr. Meth. Phys. Res. B 266, (2008), 4097-4102.

[5] D. Jimenez-Rey, et. al., 4th ICFRM 2009. Sapporo, Japan (2009).

[6] A. Virtanen, J. Hyvonen, K. Ranttila, I. Rekikoski, J. Tuppurainen. Nucl. Instr. Meth. Phys. Res. A 426, (1999), 68-71.

[7] Y.S. Kim, J.S. Chai, K.H. Park, W.W. Lee, H.G. Lee, C. W. Chung, B. K. Kang. IPAC'05, Knoxville, USA, (2005).

[8] A. Savalle, et. al., Accelerators Conference web-CERN, (1996).