A transport beamline solution to control optically accelerated proton beams

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Abstact

Laser-target interaction represents a very promising field for several potential applications, from the nuclear physics to the radiobiology. However optically accelerated particle beams are characterized by some extreme features, not suitable for many applications. Therefore, beyond the improvements at the laser-target interaction level, many researchers are spending their efforts for the development of specific beam transport devices in order to obtain controlled and reproducible output beams.In this background, the ELIMED (ELI-Beamlines MEDical applications) project was born. Within 2017, a dedicated transport beam-line coupled with dosimetric systems, named ELIMED, will be installed at the Extreme Light Infrastructure Beamlines (ELI-Beamlines) facility in Prague (CZ),as a part of the ELIMAIA (ELI Multidisciplinary Applications of laserâĂŞIon Acceleration) beamline.

Introduction

Many experimental as well as theoretical studies demonstrate that proton/ion beams acceleration (up to hundreds of MeVs) based on the interaction of high power (order of PW) lasers with matter can represent a concrete future alternative in the field of particle acceleration [1]. However the energy and the angular spread of laser-driven beams represent the main issues for a muldisciplinary application and different solutions for dedicated beam-transport lines as well as diagnostics and dosimetric systems have been proposed [2, 3, 4]. Bearing in mind these purposes the ELIMED (ELI-Beamlines MEDical applications) collaboration was defined. In detail,at the end of 2012, the ELIMED initiative was presented at the ISAC (International Scientific Advisory Committee) of ELI-Beamlines and finally accepted at the end of 2013. In 2013 the ELI-Beamlines Institute officially started the realization of the ELIMAIA (ELI Multidisciplinary Applications of laser-Ion Acceleration) beamline, specifically dedicated to the ion acceleration and to their applications. Finally, as a result of a public tender, launched in 2014 by the FZU (ELI-Beamlines),the INFN-LNS has been officially appointed to realize the beam transport, the dosimetric and irradiation section in the ELIMAIA room.

The transport beam line @ ELIMAIA

Ions accelerated by laser-matter interaction are characterized by high intensities, multiple-species and charge states, a wide energy spectrum and a large energy-dependent angular distribution. Therefore,in order to make these beams suitable for multidisciplinary applications, the design of specific beam line transport elements, coupled to appropriate diagnostic devices, seems to be mandatory. The main aims of the transport elements will be the control of the optically accelerated ions final energy and angular distributions, the beam-line reliability as well as the flexibility and reproducibility of the final beam spot size and dose distribution. The beam transport solution that will be proposed for the ELIMAIA beamline will consist of two main elements: a collecting-focusing system and an energy selector.

The aim of the collection system is to collect the particle within a certain energy range, correct the angular divergence of the beam and inject the particles in the selection system. The beams coming out from this first part of the beam-line will have characteristics similar to the conventional beams and, hence, easy to transport and shape with conventional magnetic lenses, such as resistive quadrupoles and steerers, which will be placed in the last part of the beam-line. The above description of the beam-line, makes it clear that the ESS is the core element around whom all the other magnetic devices have to be designed and realized.

In order to understand the different mechanical and experimental issues, crucial for the design and the realization of the ELIMAIA beamline, a prototype has been already realized at INFN-LNS. It consists of a collecting-focusing sector and of an energy selector system (ESS), as well. As regarding the quadrupole system prototype, it is composed of four remotely controlled permanent quadrupoles with magnetic field gradients of 110T/m and 114T/m, 20mm bore and with lengths of 40 and 80mm, respectively [9]. This system allows to cover a wide energy operational range, from 0 up to 30 MeV. The final beam energy refinement is then obtained by means of the second transport device, i. e. the energy selector, elesewhere detailed shown [5, 6, 7, 8]. The ESS prototype has been already tested with conventional protons up to 12 MeV, at INFN-LNS and INFN-LNL, as well as with non-conventional beams at the Queens' University of Belfast. Recently also the focusing and collecting system prototype has been tested with 10 MeV conventional proton beams, delivered by the Tandem at INFN-LNS. Figure 1 reports the comparison between the 10 MeV proton beam spot distribution predicted by the optics simulations and the experimental data taken using Gafchromic film, EBT3 type. As shown, a quite good agreement between the simulation output and the measured spot size has been obtained. Simulations have been performed using the TraceWin analytical code.

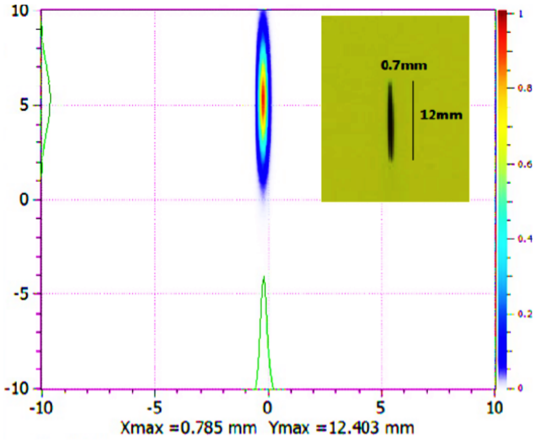

Figure 1: *Comparison between the simulated optics results and the experimental data for the 10 MeV proton beam spot along the PMQs system.*

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