MECHANICAL LAYOUT AND CIVIL INFRASTRUCTURES OF THE SPARX-FEL COMPLEX*

S. Tomassini, C. Biscari, R. Boni, M. Esposito, A. Ghigo, L. Palumbo, C. Vaccarezza, INFN-LNF, Frascati, Italy
M. Del Franco, L. Giannessi, ENEA C.R. Frascati, Italy
C. Quaresima, N. Zema, CNR, Rome, Italy

Abstract

The SPARX-FEL project consists in an X-ray-FEL facility driven by an electron beam characterized by ultra-high peak brightness at the energy of 1.5 and 2.4 GeV. This facility will be built in the Tor Vergata University area in Rome. The paper describes the engineering aspects of the mechanical design of the accelerator, photo-injector, LINACs, bunch compressors, beam distribution, undulators and experimental stations. Moreover the integration of accelerator with the civil infrastructures is discussed.

INTRODUCTION

The SPARX-FEL project [1] is planned as an evolutionary research infrastructure aiming at the realization of a source of coherent X-rays, covering the range of wavelengths going from 0.6 to 40 nm at the fundamental harmonics, and able to reach the angstrom region using the third and fifth harmonics. The machine and the related infrastructures have been designed by a project team in the framework of a collaboration among the major national research institutes, CNR, ENEA, INFN, the University of Roma "Tor Vergata", in strong partnership with many Italian and foreign universities well recognized for their expertise on FELs.

MECHANICAL LAYOUT

The SPARX facility consists of a 150 MeV photoinjector followed by a first LINAC, bringing the operating energy up to 1.5 GeV and a second LINAC for an optimized operating energy of 2.4 GeV (maximum energy is 2.64 GeV). The electron beam drives three parallel undulators. Two beamlines for each undulator source have been foreseen.

Photoinjector

A more detailed description of the machine shows that the SPARX photoinjector is based on the matured experience of SPARC [2] and it follows the same basic design (Fig. 1).

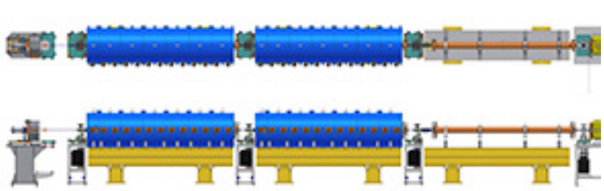

Figure 1: Top and side view of the SPARX Photoinjector.

* Work supported by MIUR, Contract FIRB-RBAP04XM5-001

The low energy beam diagnostics

The 150 MeV beam is characterized with a dedicated diagnostics section, 11 m long that includes the spectrometer for energy and energy spread measurements, emittance and slice emittance measurements and pulse length and longitudinal phase space measurements using an RF deflector. A laser heater chicane is also foreseen. The complete description of the lines is shown in Fig. 2.

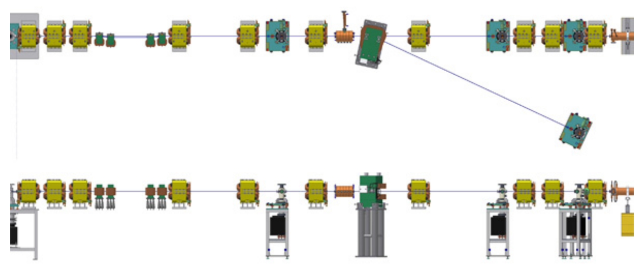

Figure 2: The 150 MeV Diagnostics Section (up: top view, bottom: side view).

LINACS, Transfer Lines and Compressors

As shown in Fig. 3, the 150 MeV beam from the photoinjector is boosted up to 1.5 GeV by three LINACs.

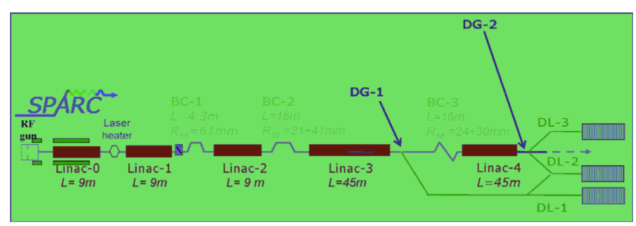

Figure 3: SPARX acceleration and compression schematic layout using SPARC injector.

The first LINAC is made of three accelerating structures (LINAC1) and is followed by the first bunch compressor (BC1). The second LINAC (LINAC2) is also made of three accelerating structures and is followed by the second bunch compressor BC2 (Fig. 4 and Fig. 5). These two LINACs are 11 m long each, while the bunch compressors are 12 and 24 m long respectively.

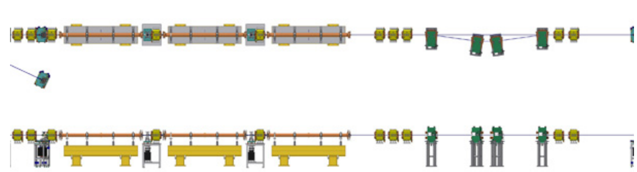

Figure 4: LINAC1 and BC1 (top view and side view).

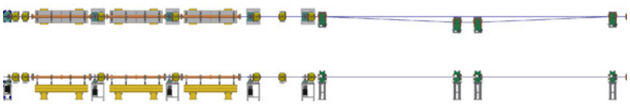

Figure 5: LINAC2 and BC2 (top view and side view).

The third LINAC is made of 15 RF structures that accelerate the beam up to 1.5 GeV (Fig. 6). The total length of this section is 55m.

Figure 6: Top and side view of LINAC3.

Figure 7 shows details of vacuum pumps and quadrupoles placed in the drifts in between consecutive accelerating structures (quadrupoles are ~30 cm long, accelerating structures 3 m long).

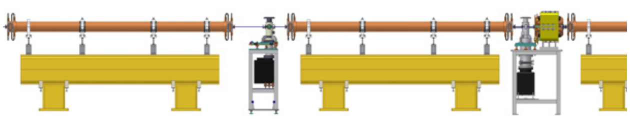

Figure 7: LINAC3 Module, detail.

The transfer lines and the third bunch compressor (BC3) downstream the LINAC3 are shown in the following figure; because of the small exit angle the magnetic elements are longitudinally shifted to avoid installation interference. This section will also host diagnostics devices to measure the electron bunches at 1.5 GeV.

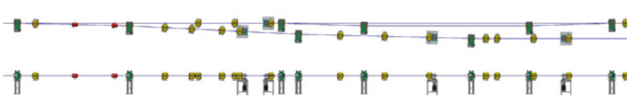

Figure 8: TL1 Transfer Line and BC3, total length is 47 m

The final LINAC (LINAC4), 52 m long, is composed by 15 RF structures, that can accelerate the beam up to 2.64 GeV (Fig. 9), before being sent into the undulators.

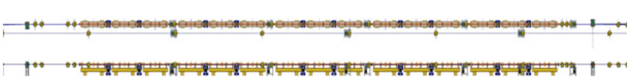

Figure 9: LINAC4 (top view and side view).

In LINAC4 the quadrupoles are foreseen every three accelerating structures (Fig. 10), therefore the total length is shorter than in LINAC3.

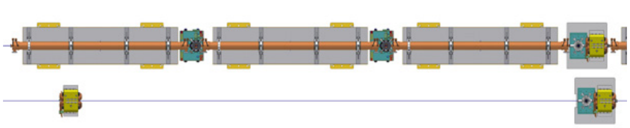

Figure 10: Accelerating sections of LINAC4 Module, detail (accelerating sections are 3 m long).

The transfer lines designed to send the beam from the LINAC to the different undulators are shown in (Fig. 11). Because of the small deflecting angles, a special lattice has been designed avoiding conflicts between magnetic elements and electron beam vacuum chambers.

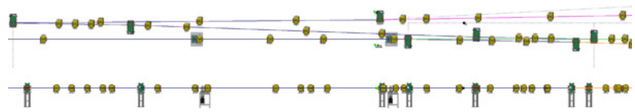

Figure 11: Beam distribution transfer lines; total length 45m.

Undulator Lines

Three undulator lines are foreseen to cover the photon spectral range of the project [1], the low energy one at 1.5 GeV on the right side following the beam direction (i.e. the undulators that are on the lower part of the Fig. 12), the high energy one on the left side following the beam direction (i.e. the upper side of the figure). The central one is a multi-stage undulator in which both low and high energy electron beams can be sent. The three undulators are, from the left to right, about 44 m, 55 m and 45 m long respectively.

Figure 12: Undulators (top view, the electron beam is coming from the left side).

The following picture (Fig. 13) shows in detail undulators with quadrupole and diagnostics inserted.

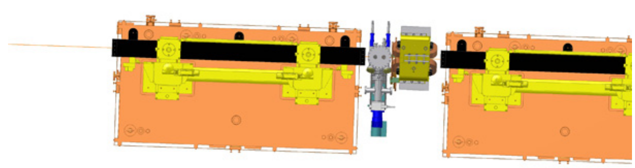

Figure 13: Undulator section detail.

At the end of the undulators sections the bending magnets necessary to send the electron beam to the dump are shown with the photon beam lines front end (Fig. 14).

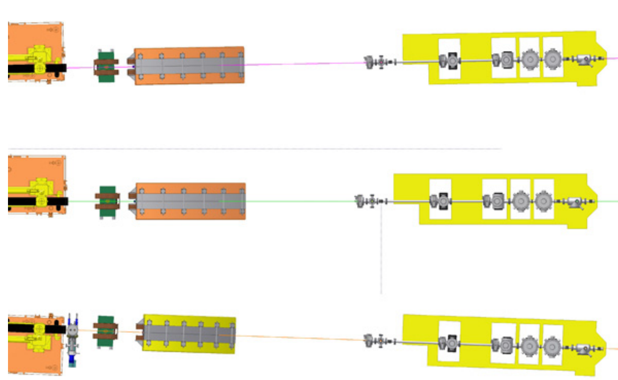

Figure 14: Dumping magnets and photon lines front-end.

Photon Beamlines

The SASE and Seeded FEL photons produced in the undulators propagate in beam lines with suitable optical components. The optical line configurations allow the simultaneous use of different experimental stations (Fig. 15).

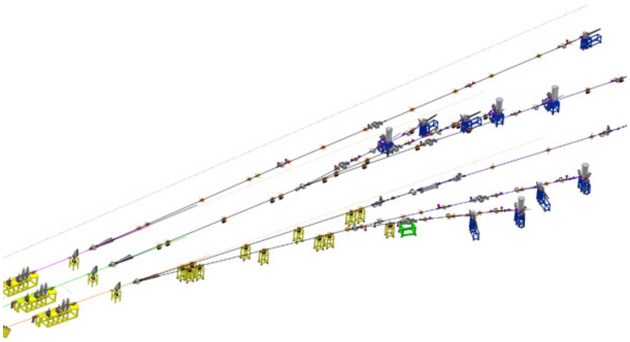

Figure 15: Optical beam lines and experimental stations.

CIVIL INFRASTRUCTURES

The SPARX facility will be housed in a complex of civil buildings, the most part of which are underground. The surface buildings consist of a big building at the head of the facility and another one at the end of the LINAC, just above the undulator hall (Fig. 16). The latter will house the control room, a meeting room, a computing room, some offices and several storage rooms and laboratories.

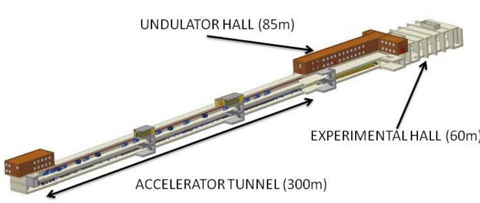

Figure 16: SPARX civil infrastructure.

The underground buildings consist of a service building at the beginning of the LINAC, and of three main halls for a total length of a bit more than 400 m. The first hall will house the injector and the LINAC, the second hall will house the undulators and the third one will house the experimental lines and devices. LINAC and undulator halls will be divided in two overlapped tunnels. The lower tunnels will house the accelerator components, while the upper ones will house all the backing equipment such as klystrons and power supplies.

The underground buildings will be entirely built with reinforced concrete. The thickness of the walls will meet radiation safety requirements. The side walls are 1 m thick, the basement of the building is 1.2 m thick, while the two overlapped tunnels are separated by a 1.5 m thick layer of concrete. The LINAC tunnel is 5 m wide and 4 m high with a total length of 260 m. The beam line is placed at 1.5 m from the left wall (Fig. 13), leaving therefore enough space on the right side of the beam line for the transit of forklifts and small electrical lift trucks for the transport of components, supports and other material.

The undulator hall will be 12 m wide and 85 m long. In the same way as for the LINAC hall it will be divided in two overlapped tunnels. The lower one will have a height of 4 m and it will house the machine components. The upper one will house a magnetic measuring machine and a workshop containing some supporting devices. The latter will be 5.5 m high and a bridge crane will be installed in it.

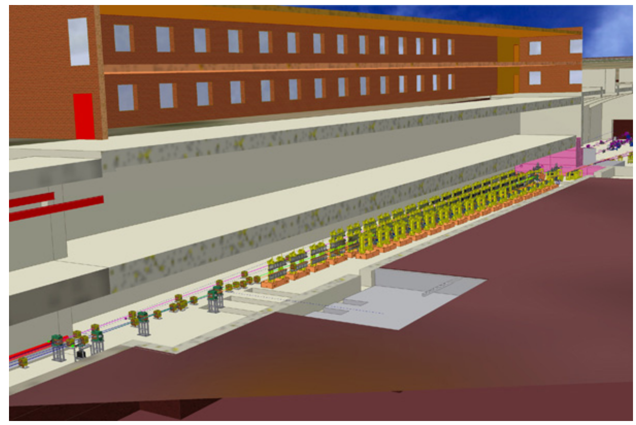

Figure 17: The undulator hall.

The Experimental Hall will be 30 m wide, 60 m long and 10.5 m high. The structure of the building will be reinforced by six arches, placed at a distance of 8.7 m one from another. The latter will have a total width of 40 m. By closing the external perimeter defined by the arches some more rooms could be obtained and used as supporting laboratories or storage rooms (Fig. 18).

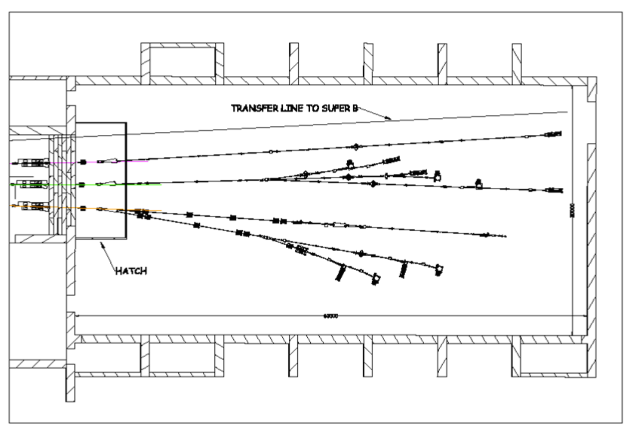

Figure 18: Footprint of the Experimental Hall.

AKNOWLEDGMENTS

The authors especially express their deep appreciation to A. Zolla and M. Brolatti of the SPARX group for their valuable suggestions and kind help in the mechanical design.

REFERENCES

[1] www.sparx-fel.it, SPARX-TDR.
[2] SPARC Project Team, Sparc Injector TDR www.lnf.infn.it/acceleratori/sparc/.