The Iranian Light Source Facility

1. Introduction

Synchrotron radiation as a versatile research tool has experienced an unprecedented expansion with the advent of several dedicated synchrotron radiation sources since about 1980. Today a large and continuously growing community of researchers representing a variety of disciplines depends on light sources as an essential part of their research programs. In order to meet the demands of cutting-edge research, increasingly advanced synchrotron radiation facilities have been constructed around the world. The number of such synchrotron radiation facilities now exceeds 75 with more than 20,000 users per year and with predicted strong continued growth in the future. Whereas standard research can be performed using conventional small light sources spanning the infrared over visible and UV-range up to X-rays, for cutting-edge research synchrotron radiation is required due to its extremely high intensity, completely continuous spectrum and well-defined properties. It has to be pointed out, that all conventional light sources are restricted to certain wavelengths or limited wavelength ranges, whereas synchrotron radiation allows the selection of any desired wavelength not available otherwise. Thus – in popular language – synchrotron light allows to shed light on the samples in full color, whereas conventional light sources give the black-and-white view. Synchrotron radiation is generated in particle accelerators, and thus its success is based on the improvements in accelerator physics.

Unfortunately, Iran is lagging in this important field behind the rest of the world, in particular a national facility which can provide the numerous academic institutes and industrial establishments in the country with the many benefits of accelerated particle beams is lacking. To improve upon this situation we face a big challenge. Fortunately, we have good reason to be hopeful and optimistic. Due to the large number of highly-qualified graduates and the human resources available, and also due to the present industrial capacity of the country, we are in a unique position to address this deficiency.

The choice of a particular type of accelerator facility for research in our country has to be dictated by potential user demand rather than by an ambition to explore accelerator technology. Iran is a member of SESAME (**S**ynchrotron-light for **E**xperimental **S**cience and **A**pplications in the **M**iddle **E**ast). Presently several Iranian high-energy physicists are collaborating with CERN through IPM. Therefore, establishing a national laboratory for high-energy physics research with the existing number of users which is not likely to grow drastically in the foreseeable future cannot be a priority.

After several official meetings and many informal discussions, the consensus has been reached that under the present circumstances, the establishment of a National Accelerator Laboratory with a dedicated synchrotron light source facility dedicated solely to research that uses synchrotron radiation from the infrared to hard X-rays, is the most promising option that entails the greatest benefit to the scientific community of Iran.

An Iranian light source would also serve as a significant impetus for multidisciplinary collaboration between scientists from different research areas and from different institutions. The benefits of such scientific cross-pollinations are huge. The rapid development of the macromolecular field would not have been possible without synchrotron-related collaboration between physicists and biologists. Even outside of research-driven industry the need for personnel trained in a multidisciplinary environment is ever increasing. Currently, the only way for Iranian scientists to access such advanced facilities is to go overseas. However, this limits the scientific research to whatever possibilities are available, and the research cannot be optimized for the specific requirements of Iranian scientists and new developments within the Iranian science scene.

During the last decade many Iranian scientists and engineers have undergone training in both the field of accelerators and the applications of synchrotron radiation within the framework of the training programs of SESAME. Most of the trainees have demonstrated a great degree of talent and ingenuity working in synchrotron laboratories around the world. In addition many Iranian universities and research institutes have actively joined this national endeavor towards building a light source and utilizing the possibilities synchrotron radiation has to offer by training research students in the related fields. We will have to take advantage of their expertise at various stages of the design and construction of the Iranian Light Source Facility.

The applications of synchrotron radiation at Iranian Light Source will cover research in

- Material science
- Surface science
- Nano-science and technology
- Environmental Sciences
- Chemical processes
- Geochemistry
- Archaeometry and Archaeology
- Life sciences
- Medicine – diagnosis and treatment
- Pharmaceutical industry

The Iranian Light Source Facility (ILSF) is an open project fully complying with the international scientific standards. All the design and progress reports will be presented at local and international conferences and published in international journals accessible to scientists all over the world. To realize this project, the intention is to work and collaborate with other light sources around the world. Users from abroad shall be welcome to set up their experiments in this new facility upon the acceptance of their proposals by the appropriate review boards. The layout and performance of the planned facility shall be based on the most recent advances and significantly improved with respect to other facilities which were planned many years ago and realized only recently. This will add to the *attractiveness of* ILSF for outside users, and improves the possibilities for multinational collaborations. An international Machine Advisory Committee will be installed in order to discuss the design of the accelerator complex and to follow up on the design of the different components as well the construction of the complex. An international Scientific Advisory Committee

(SAC) will also be set up in order to discuss the scientific case and the layout of the beamlines, and to follow up the progress during their installation. Both committees will work closely together to enable a seamless transition between the construction of the accelerator and the launching of experiments.

2. Project Description

The Iranian Light Source Facility shall consist of a 3-GeV storage ring with a circumference of roughly 300m (see Fig. 1). The design The design is an improved version of other modern light sources. The synchrotron radiation is emitted by electrons orbiting in the storage ring at nearly the speed of light (> 99.9999%). They are created by thermionic emission in an electron gun, accelerated at first in a linear accelerator (Linac), followed by a booster synchrotron to achieve full energy. These ultrafast electrons are transferred into the storage ring, where they are stored in a circular ultra-high vacuum tube. Because the electrons emit radiation and thus lose much energy, they have to be reaccelerated in high-power radio frequency cavities included in the storage ring to stay on track. In the storage ring an extremely perfect vacuum is required to prevent collisions of electrons with gas atoms at rest, otherwise electrons are lost and the generation of synchrotron radiation stops.

The emittance will be about 3 nmrad and the stored electron current about 400mA. These values are excellent in comparison to other synchrotron light sources recently built. Overall, there are 32 straight sections where insertion devices can be installed. Most components are already available at other light sources,

To provide safety from radiation, the storage ring will be erected in a sheilding tunnel. The vacuum beamlines for guiding the synchrotron radiation to the experiments pass through the tunnel walls to the outside and into the experimental hall with a diameter of 130m enclosing the tunnel. This will allow beamlines of lengths up to 46m. Adjacent to the experimental hall an area is provided for the building complex comprising of the laboratories as well as offices for the ILSF staff. The laboratories shall include facilities for the preparation of the experiments as well as development and maintenance of the machine and the beamlines.

The area enclosed by the storage ring tunnel is the so-called service area. All infrastructure for the operation of the accelerator complex (storage ring, booster synchrotron, Linac and transfer lines) are located in this area. The inner radius of the service area is roughly 65 meters. This space is enough for the installation of the booster synchrotron with a circumference of 144m. the booster synchrotron has an emittance of roughly 14nmrad, which leads to a small beam cross-section and optimized injection into the storage ring.

It was decided to house the booster and the storage ring in different buildings in order to decouple the assembling and commissioning of the booster synchrotron and the storage ring.

The Linac shall be located between the service area and the booster synchrotron. The energy of the Linac was chosen to be 150 MeV in order to make the ramping process at injection energy, smooth.

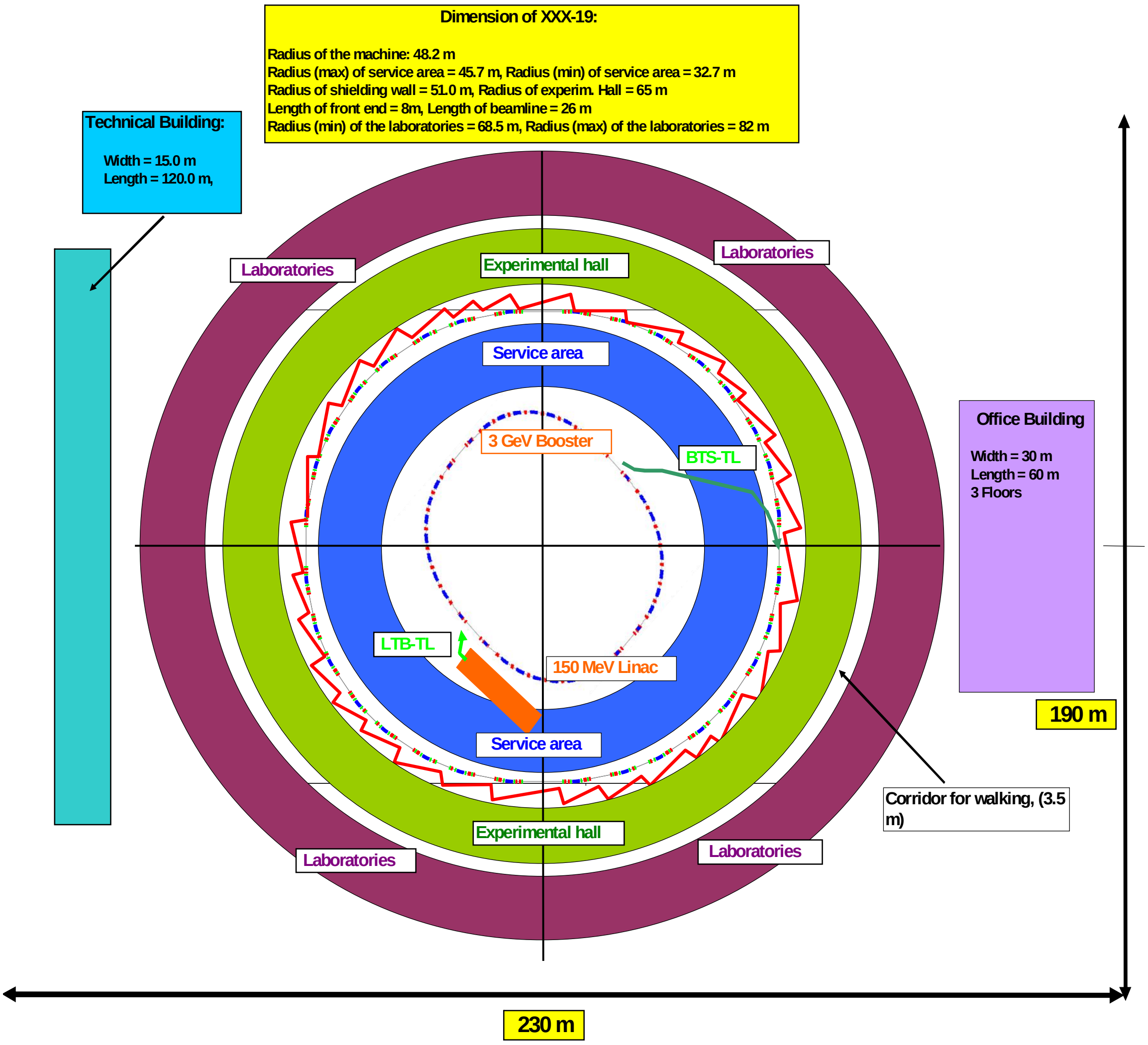

Fig. 1 - The schematic of the Iranian Light source Facility

An office complex and a technical building, with respective areas of 60×30 m^2 and 120×16 m^2 are also planned. The overall size of the Iranian Light Source Facility will thus be 230 m × 190 m.

2.1 The Storage Ring

The overall layout of the storage ring is given in Fig. 2. The storage ring has a four-fold symmetry, with 4 long straight sections (L = 8m) and a circumference of 297.6m. The lattice functions within a quadrant are given in Fig. 3. The storage ring will have 3 different straight sections for the accommodation of insertion devices: 4 long sections (L=8m), 20 medium-length sections (L=4m), and 12 short sections (L=2.82m). The long sections are required for beam injection and 5 short sections are needed for machine operation. The cross-section of the stored beam at the center of these straight sections are: $\sigma(x)$ = 334?m, $\sigma(y)$ = 11.6?m for the long sections; $\sigma(x)$ =

162?m, $\sigma(y)$ = 6.7?m for the medium-length sections; and $\sigma(x)$ = 250µm, $\sigma(y)$ = 9.7?m for the short sections.

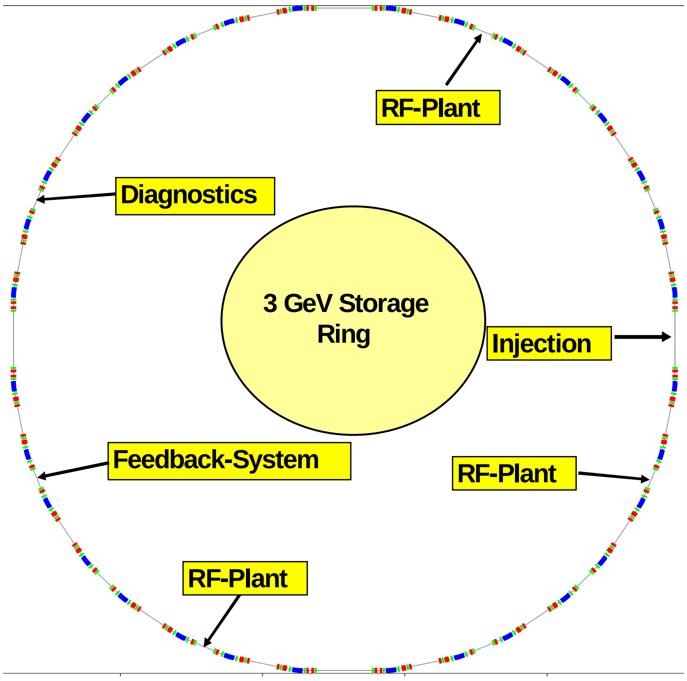

Fig. 2 - Overall layout of the storage ring.

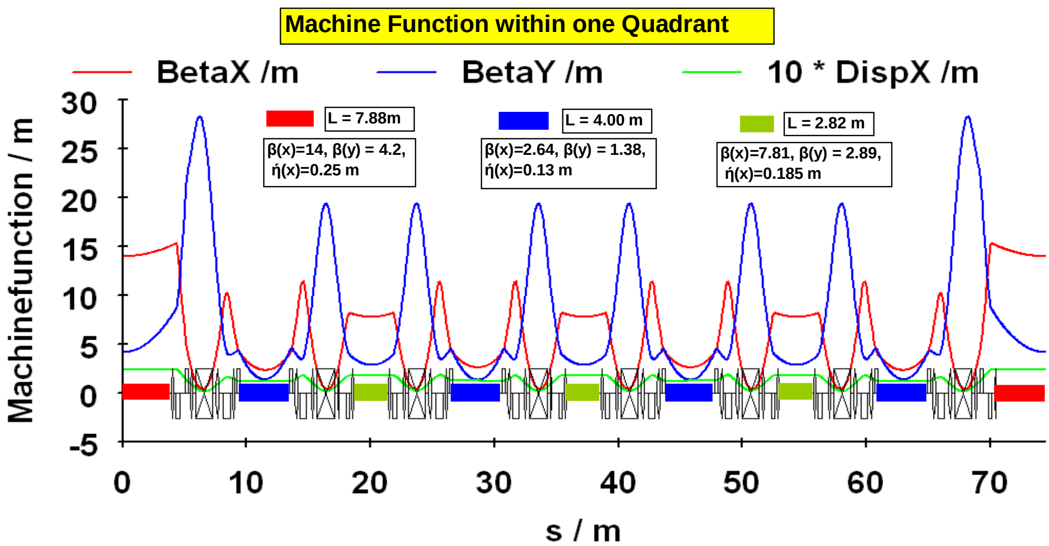

Fig. 3 - Lattice and machine functions within one quadrant of the storage ring.

2.2 Booster Synchrotron

The overall layout of the booster synchrotron is given in Fig. 4. The booster has a four-fold symmetry with 4.4m-long straight sections between the quadrants. The four straight sections are needed for beam injection, extraction, and the RF-cavities. The circumference of the booster is 144 m and the emittance at the ejection energy is 13.6nmrad, which is pretty low and guarantees a smooth injection into the storage ring. The booster repetition frequency should be 1 Hz.

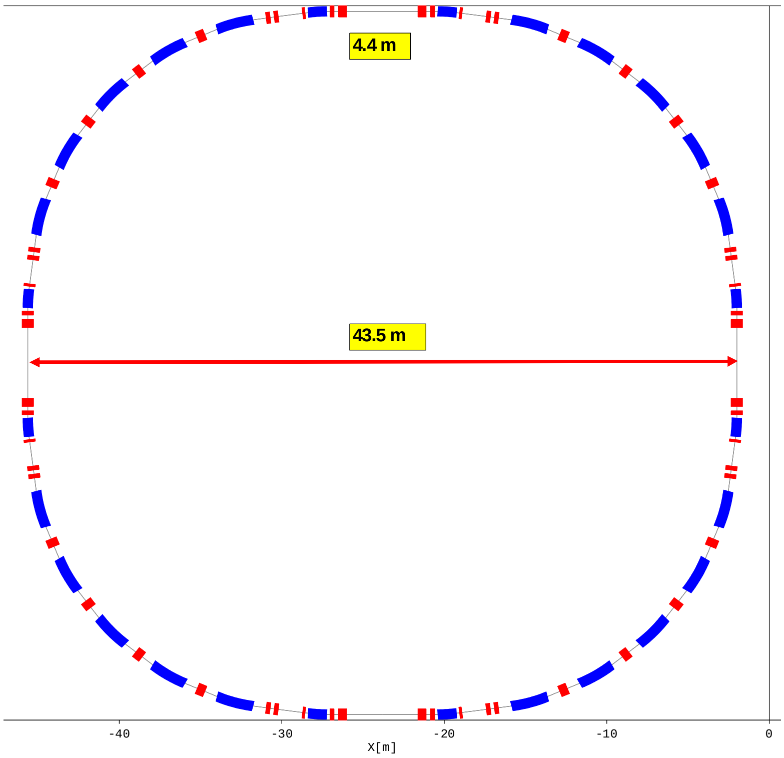

Fig. 4 - Overall layout of the booster synchrotron: the bending magnets are shown in blue and the quadrupoles in red.

2.3 150-MeV Linac

Fig. 5 shows the overall layout of the Linac. It is comprised of a 90kV electron gun, the bunching system, and 3 accelerator structures. The bunching system consists of a 500 MHz and another 3 GHz pre-buncher as well as a 3GHz buncher. The energy of the beam at exit from the buncher can be as high as 15MeV. Within each accelerator structure the beam will be accelerated by roughly 50 MeVs. The final energy of the Linac will be thus between 150 and 165MeV.

The required magnetic and RF systems are not shown in Fig. 5. The brilliance of the synchrotron radiation coming from in-vacuum undulators with a period length of 21 mm is given in Fig. 6.

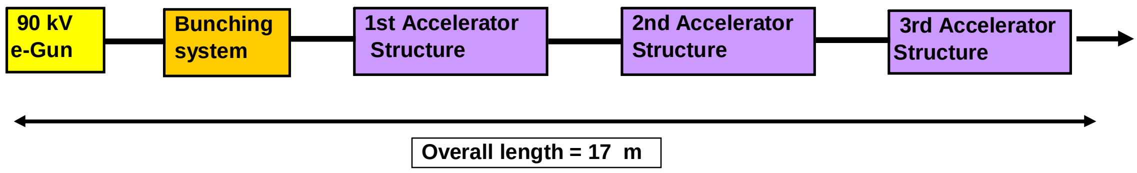

Fig. 5 - Overall layout of the 150 MeV Linac

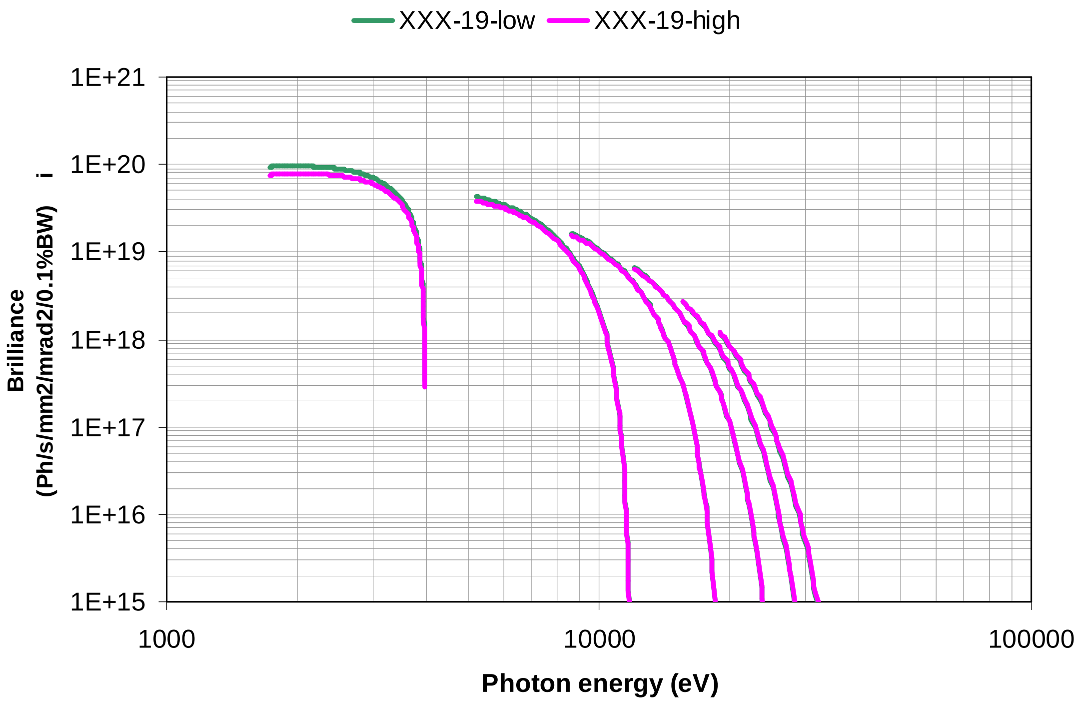

Fig. 6 - Brilliance of the radiation coming from an in-vacuum undulator (low refers to the medium-length straight sections and high refers to the short straight sections of Fig. 3).

3. Time Schedule

A provisionary time schedule is given in Fig. 7. At present the ILSF-team is working on the conceptual design report (CDR), which should be finished by the end of 2011. After CDR, the different components have to be designed in detail and a report that includes the technical specifications has to be drawn up. The technical specifications shall be the basis for call for tender. The call for tender process is finished with the signing of the contract. It is assumed that most of the components have to be purchased abroad. The so-called design phase should be finished by the end of 2013. The production of all components should be completed by the end of 2015. At the end of 2015 the Linac should already be commissioned. The installation phase is from 2016 to 2018. The booster should be commissioned in 2017 and the storage ring in 2018. The users of ILSF should be able to start their operations at the end of 2018
The time schedule closely follows that of the ALBA project. The state of the ALBA project at the beginning of 2004 can be compared with that of ILSF at the beginning

of 2012. ALBA will start its user operations at the end of 2011 – 8 years after the start of the project.

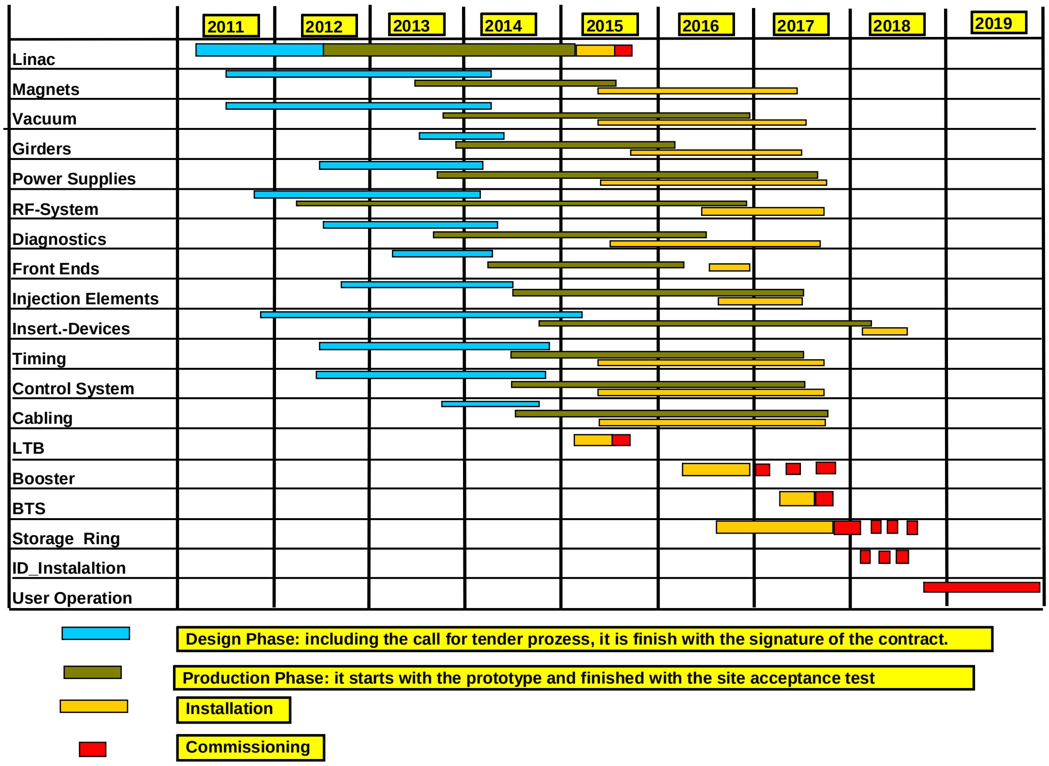

Fig. 7 - Overall time schedule of the project.

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