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ELI-NP GAMMA BEAM SYSTEM – CURRENT PROJECT STATUS

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Abstract

The Gamma Beam System at the ELI-NP (Extreme Light Infrastructure – Nuclear Physics) under construction in Bucharest-Magurele, Romania, aims at producing high brilliance gamma-rays, based on the laser Compton back-scattering, up to 3.5 and 19.5 MeV out of two interaction chambers. The design of a warm radio frequency linac is optimized to meet a unique source specification i.e. high brilliance, small relative bandwidth, tunable energy, and high spectral density. Together with the technological development in the field of high energy/high quality lasers it will open new opportunities for nuclear physics research in fields like nuclear photonics, nuclear astrophysics, photo-fission, and production of exotic nuclei, applications in industry, medicine, and space science. The S-band laser driven RF gun and two accelerating sections constitute the injector. Then the beam is accelerated by C-band linac up to 350 and 720 MeV. The GBS was designed and is being constructed by the EuroGammaS Association – a consortium of European academic and research institutions and industrial partners.

This paper gives an overview of the facility, describes the linac system and summarizes the project status.

INTRODUCTION

The Gamma Beam System (GBS) at ELI-NP was designed to provide gamma beam with unprecedented features: continuous tunable γ-ray energy over a broad range from 0.2 to 19.5MeV, high spectral density about 10^4photons/sec/eV, small relative bandwidth $< 0.5\%$, high degree of polarization $> 95\%$, and high peak brilliance $10^{20} \div 10^{23}$ N_{ph}/sec mm^2 mrad^2 0.1% [1].

The high brightness electron beam will be provided by a warm multi-bunch RF linear accelerator, operating with repetition rate 100 Hz. Electrons will be formed in trains of 32 micro-bunches of 250pC each, separated at 16ns from each other, repeating every 10ms. To achieve small emittance with low energy spread a particular care was paid to a damping of higher-order modes to reduce the beam break-up effects and beam loading effects of the cavities due to the short-time separation between the electron micro-bunches [2, 3]. The expected parameters of the electron beam at the high energy interaction point are given in the Table 1 [1].

The experimental activities with gamma beams at ELI-NP are evolving on three main lines of research: fundamental research, applied physics and gamma beam diagnostic tools development. In Fig. 1 the location of the GBS in the ELI-NP building is illustrated. The main experimental halls dedicated to measurements with gamma beams are indicated on the figure.

Table 1: Electron Beam Parameters at High Energy Interaction Point [1]

Energy	720MeV
Bunch charge	250 pC
Bunch length	1 ps
Norm. transverse emittance	0.4 mm·mrad
Bunch energy spread	0.04÷0.1 %
Energy variation along macro-bunch	0.1%
Energy jitter shot to shot	0.1%
Time arrival jitter	< 0.5 ps
Pointing jitter	1 µm
Focal spot size	~ 15 µm
Number of bunches per RF pulse	32
Bunch-to-bunch distance	16 ns
RF pulse repetition rate	100 Hz

The ELI-NP facility covers an area of approx. 33 000m^2. It will be a user facility. The civil construction comprised office building, a guest house and a canteen. ELI-NP is hosted by the Horia Hulubei National Institute of Physics and Nuclear Engineering (IFIN-HH) [4].

GBS DESCRIPTION

A schematic view of the GBS layout is shown in Fig. 2. The electron source is a 1.6 cell gun BNL/SLAC/UCLA type. Nevertheless it was fabricated with a new technique developed at LNF-INFN that does not involve brazing and, consequently, avoiding a thermal stress on copper. Several other improvements were implemented to increase the peak field at the cathode but reducing the break down rate probability [5]. The gun is equipped with a copper photocathode and there is a focusing solenoid at the exit of the gun for emittance compensation due to the space charge effects. The accelerating field at the cathode is 120MV/m and energy gain is 5.7MeV. The S-band TW accelerating sections will act as a bunch compressor decreasing the bunch length from 10 to 1ps in the velocity bunching process. There are twelve independent coils mounted on the first S-band section. The S-band sections will be driven by independent klystrons. A separate klystron will feed the RF gun and two S-band transverse deflecting structures, for the measurement of the longitudinal charge profile, located after injector and at the entrance of the high energy linac.

The C-band linac is divided into two segments – the low energy linac (LEL) and the high energy linac (HEL)

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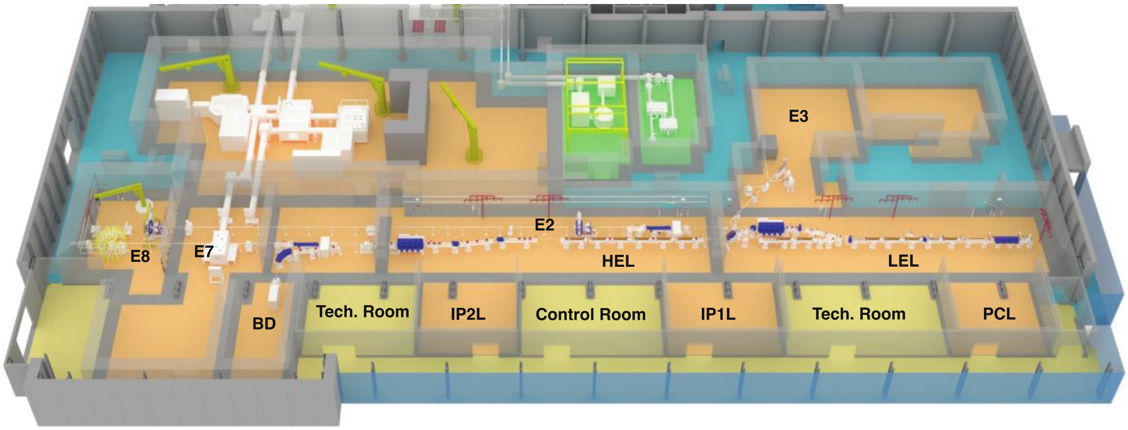

Figure 1: Partial layout of the ELI-NP experimental building showing the Gamma Beam System and the experimental halls where measurements with gamma beams will be performed. On the figure: LEL = Low energy linac, HEL = High energy linac, BD = beam dump, PCL = Photo-cathode laser, IP1L = Low energy interaction laser, IP2L = High energy interaction laser, E2, E8 = nuclear physics experiments hall, E3 = hall for experiments with positrons, E7 = hall for combined laser-gamma beam experiments.

(see Fig. 1). The beam is transported by dogleg type transfer lines to the low energy interaction point (IP1) and to the high energy interaction point (IP2).

The eight C-band sections are fed by individual klystrons, and the last four are grouped into two sections per klystron. All RF Units use ScandiNova K2 solid state modulators as the power source to drive Toshiba klystrons. The microwave source for the C-band sections is the 5.712GHz, 50MW klystron Toshiba E37212, and for S-band sections – 2.856GHz, 60MW, Toshiba E37314.

A network of rectangular waveguides distributes the power to the RF structures. There are several major diagnostic sections – after the injector, at the end of LEL and HEL, and before IP1 and IP2.

The cryo-cooled Ti:sapphire ~10ps laser in UV range (266nm), 150μJ/pulse will produce a train of 32 pulses at photocathode at repetition rate of 100Hz. Two identical lasers, Yb:YAG J-class type, will be used at the interaction points (IP lasers), each emitting sequences of single pulses of 3.5ps duration, 0.2J energy, and 515nm wavelength [1]. An optical system, the multi-pass recirculator, will allow circulating 32 times each IP laser pulse within a time window less than 600ns, and with no significant degradation of the pulse quality. It will lock the laser pulses to the RF clock. The recirculator system provides a fixed electron-laser beam crossing angle. This is one of the most advanced conceptual developments and most challenging technological device to be implemented in the GBS [6].

Appropriate collimators to filter out the energy spectrum and the gamma beam characterization system will be used. The gamma beam characterization system consists of a beam position imager, a Compton spectrometer, a sampling calorimeter, and a resonant scattering spectrometer. Two similar systems will be used for the low and the high energy branches, optimized for the different energy regimes [1].

PROJECT PROGRESS

The GBS building is available since September 2016. Figure 3 shows one of the accelerator bays in the ELI-NP building ready to host the GBS.

The implementation of the GBS is scheduled to be performed in several stages. The first stage consisting in the delivery of the components compatible with a system able to deliver 1 MeV gamma rays was successfully accomplished in 2015. Stages II and III imply the delivery, installation, testing, and commissioning of the low energy gamma beam system while Stage IV corresponds to the full system installation and commissioning.

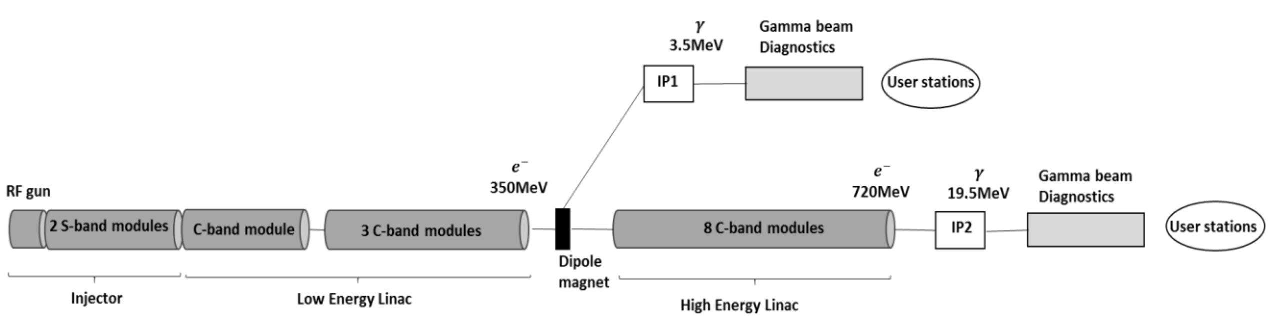

Figure 2: Schematic layout of the Gamma Beam System.

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The Stage I system comprises the photoinjector, one C-band structure, one interaction laser, and the auxiliary components.

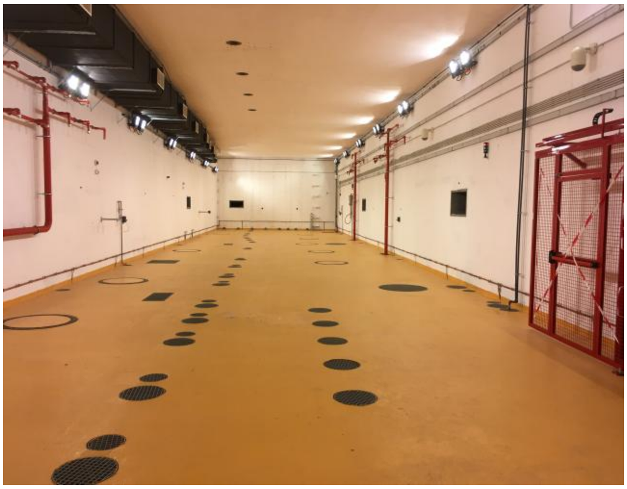

Figure 3: Accelerator Bay in the ELI-NP building to host the components of the Gamma Beam System.

The accelerating structures, magnets, and beam diagnostic components were assembled on the girders and tested at INFN Frascati and STFC Daresbury. The completed modules were back-filled with dry nitrogen and transported to ELI-NP where they are waiting to be installed in the GBS tunnel. A network of reference points in accelerator tunnel was completed for the alignment of the system. In Fig. 4 the picture of one of the linac module with C-band section assembled on the girder stored at ELI-NP is shown.

Figure 4: Picture of one linac module at ELI-NP.

One C-band structure was conditioned at full RF power by Research Instrument at the Bonn University. Conditioning of the rest of C-band sections will be done at ELI-NP after the installation of the linac.

The S-band RF gun and sections were all tested at low power and conditioned at full power in Bonn.

The RF Units were successfully tested at the factory and transported to warehouse at ELI-NP. Conditioning of all klystrons at full RF power will take place after installation in klystron gallery at ELI-NP. One S-band and one C-band RF Unit were used for conditioning of the RF gun and accelerating sections in Bonn, Germany.

Waveguide components as well as mechanical supports for waveguides are transported and stored at ELI-NP.

The diagnostic devices for electron beam are manufactured, tested at factory and ready for installation. All magnets, vacuum pumps were tested at factory and nowadays are delivered to ELI-NP. Tests of the power supplies for magnets were done in factory.

The hardware for control system is delivered to ELI-NP. Clean rooms for the lasers are installed.

CONCLUSION

In the paper an overview of the Gamma Beam System was presented. The design of the GBS RF linac was optimized to guarantee the required level of performance for the high brilliance Compton gamma ray source. For this purpose, the manufacturer of the GBS has made several developments: the RF gun was fabricated using a new technique with several improvements from the electromagnetic point of view, C-band technology for the linac was chosen as a good compromise between acceleration gradient and compactness. The electromagnetic and mechanical design was optimized to control beam loading and beam breakup issues in multi-bunch operation. It was developed a new optical recirculator for the laser pulses at the interaction point and assuring a constant crossing angle between laser and electron beam, and optimizing its flux. The Stage I components are delivered to ELI-NP, and are ready for the installation. All of them were tested at factories. The performance of Stages II and III of the GBS installation is in delay.

The full Gamma Beam System is planned to be completed by July 2019.

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