Progress of the Development of the ELI-NP GBS High Level Applications

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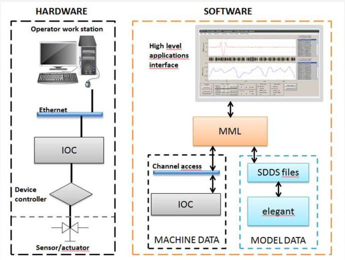
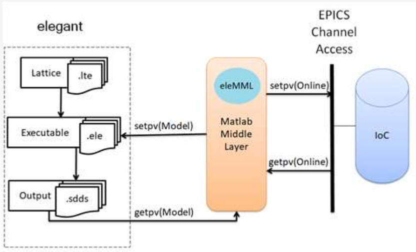
Abstract

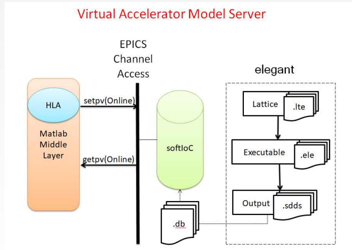
The Gamma Beam system (GBS) is a high brightness LINAC to be installed in Magurele (Bucharest) at the ELI-NP (Extreme Light Infrastructure - Nuclear Physics) newly build laboratory. The accelerated electrons, with energies ranging from 280 to 720 MeV, will be made to collide with a high power laser to produce tunable high energy photons (0.2 MeV-20MeV) with high intensity (10^{13} photons/s), high brilliance and spectral purity (0.1 %BW), through the Compton backscattering process. This light source facility will be open to users for nuclear photonics and nuclear physics advanced experiments. Tested high level applications will play a key role in commissioning an operation. In this paper we report the progress made and the status of the development of the dedicated high level applications. We also report on the measurements to test on the FERMI LINAC of the beam-based alignment method for correcting residual dispersion, which would spoil machine performance.

eleMML: elegant integration in Matlab Middle Layer

Matlab Middle Layer (MML)[5] is a library of Matlab files that enable the development of control applications for particle accelerators control, making machine operation more similar to running simulations. An operator can access Process Variables (PVs) on the machine control system I/O Controllers (IOC) or on a machine model. Integrating the physics engine of elegant[4] with the power of MATLAB enables to develop and test applications on the ELI-GBS virtual machine, through the Self Describing Data Sets (SDDS) file protocol. The result is eleMML i.e. the software tools developed and modified to interface MML with elegant and to use the latter as our physics engine for the "model" operation of High Level Applications. An overview of the architecture of eleMML is presented below.





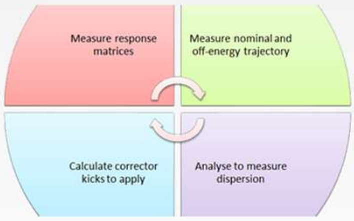


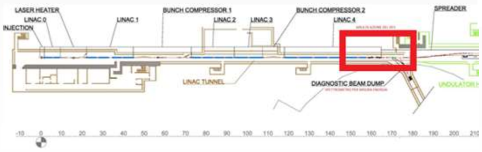
In preparation for the commissioning and operations of ELI-NP GBS, a dedicated "virtual accelerator" (VA) or "Model Server" has been created. This virtual test platform simulates the LINAC response to HLA commands. The soft IOC PVs can be configured directly from simulated sdds output files, and put on the CA process variables relative to hardware devices or general machine.

Trajectory control application: testing at FERMI

Beam trajectory control is important to maintain quality beam at the IP and subsequent properties of the radiation for the experiments. As the GBS will operate in a wide range of energies and electron beam parameters settings, LINAC properties need to be optimized for all the WPs of the machine. Ideal operational condition occur when the electron beam trajectory lies on the line that connects the electric and magnetic centers of all the elements. One of the most robust trajectory correction methods is the Dispersion Free Steering (DFS)[1]. We made a test of the DFS technique at Fermi, an important FEL facility in Basovizza, Italy. The acceleration, compression and transport of the electron beams occupies approximately the first 300 m of the machine The bunch charge was 700 pC and the energy at the starting point of the correction was 1.2 GeV. We used 5 horizontal and vertical correctors on a section of the LINAC (red box in Fig 1.b) comprising the last accelerating section and the transport line to the undulators' hall. We took 10 BPM samples for each dispersion measurement. The result of the DFS correction is summarised below.

(a)





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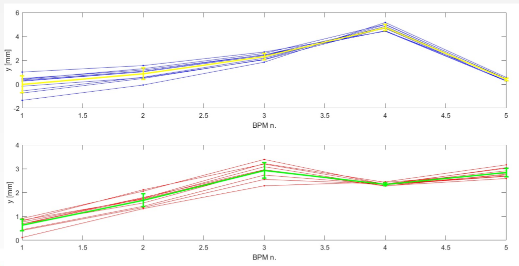

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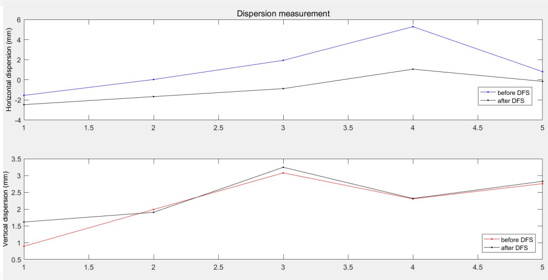


(d)

Fig. 1 a) Conceptual diagram of the steps of the measurement b) LINAC layout, the red box highlighting the section on which DFS was performed a) Before-correction: horizontal(top) and vertical(bottom) dispersion measurement. Ten trajectory samples have been acquired and the plot shows the fluctuation due to launching conditions of the beam at the entrance of the LINAC. b) Measured dispersion (averaged on ten samples) before and after applying DFS correction

Bunch Length Measurement with RF Deflector

A less complex but very useful tool for commissioning of the machine is the bunch length measurement[2,3]. The results of the elegant simulations have been pushed on the VA and the bunch length measurement application has been tested. We report here the schematic procedure and diagram of the measurement and the screenshots of the high level application.

Measurement Acquisition:

1. **RFD off**: measurement of the **vertical spot size at screen** $\sigma_{ys,off}$;
2. **RFD on**: measurements of the **vertical bunch centroid at screen** for different values of the deflecting voltage phase φ_i in a small range centered in 0 rad (or π rad):
3. **RFD on**: measurement of the **vertical spot size at screen** varying the deflecting voltage phase φ in a small range centered in 0 rad (or π rad): $\sigma_{ys}(\varphi)$;

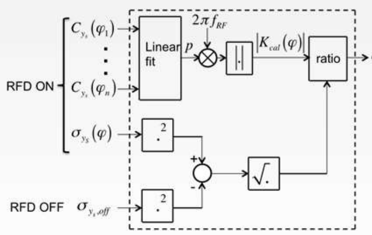
Data Elaboration:

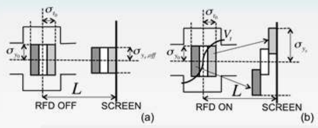
a. calculate the slope p of the plotted vertical bunch centroid at screen versus φ by means of a linear fit, and then calculate the **calibration factor** $K_{cal}(\varphi)$ by multiplying the deflecting voltage angular frequency by the slope *p*:

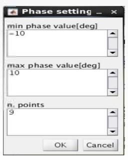
$$K_{cal}(\varphi) = 2\pi f_{RF} \frac{dC_{y_s}}{d\varphi};$$

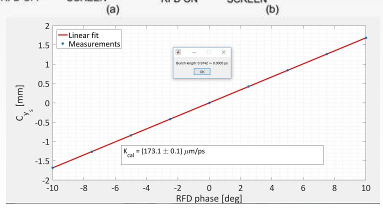
a. evaluation of the **measured bunch length** $\sigma_{t0,m}$:

$$\sigma_{t_0,m} = \frac{\sqrt{\sigma^2_{y_s}(\varphi) - \sigma^2_{y_s,off}}}{|K_{cal}(\varphi)|}.$$









Summary

We have presented the status of the development of high level application for ELI-NP GBS. Integrating elegant with MML has generated the novel eleMML architecture and allowed us to test tools for the commissioning on a virtual accelerator. For complex application such as Dispersion Free Steering, we have tested the algorithm on an existing LINAC, the Fermi one. Another completed application important for commissioning is the bunch length measurement with the RF deflector. With eleMML framework, collaborative development of more high level applications for each working group will be possible, enabling to simulate some commissioning before the machine is actually built. Further development of GUIs and of other applications is in progress.

References

[1] M. Borland, "elegant: A Flexible SDDS-Compliant Code for Accelerator Simulation" , Advanced Photon Source LS-287, September 2000.

[2] J. Corbett, A. Terebilo, G. Portmann, "Accelerator Control Middle Layer," PAC 2003.

[3] G. Campogiani, et al., "Electron beam trajectory and optics control in the ELI-NP gamma beam system," *NIM A.* Vol. 865, pp. 51 – 54, 2017. Physics and Applications of High Brightness Beams 2016.

[4] D. Alesini et al. "Sliced Beam Parameter Measurements". In: Proc. of DIPAC, Basel, Switzerland. 2009.

[5] L. Sabato, et al. "Metrological Characterization of the Bunch Length Measurement by Means of a RF Deflector at the ELI-NP Compton Gamma source," in *Proceedings, 7th International Particle Accelerator Conference (IPAC 2016): Busan, Korea, May 8-13, 2016*, p. MOPMB018, 2016.

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