COMPARISON BETWEEN SIMULATION AND MEASUREMENT OF A LOW CHARGE ELECTRON BUNCH IN THE ELSA FACILITY

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Abstract

An accelerator scheme based on a photo-injector and a RF linear accelerator operating at 352 MHz has been proposed as a new versatile radiographic facility. 20 electrons pulses of 100 nC each will be extracted at 2.5 MeV, accelerated and focused on a X-Ray conversion target.

Prior to construction of the facility, experiments will be carried out on the CEA-ELSA facility in order to validate the simulation tools and process used for the design. First experiments have been performed at low density. In this paper, we compare these experimental results with the numerical simulations from MAGIC, SFISH and PARTRAN codes.

INTRODUCTION

For short pulses X-rays production, electrons will be extracted from a DC gun photo-injector, accelerated in a RF superconducting linear accelerator and focused on a high Z target material. In this purpose, we are studying the beam dynamics of, high charge up to 100 nC, electron short pulses, 100 ps, made of 20 bunches repeated at 352 MHz.

To validate our simulations, we made experiments on the CEA-ELSA facility. The accelerator scheme is similar to the future facility. In this paper, we present the comparison between experimental results and simulations at low charge and different initial beam radii on the photocathode. Numerical simulations were performed with MAGIC – used for the photo-injector – coupled to the CEA code PARTRAN for the accelerator and final focusing.

ELSA LAYOUT

The CEA-ELSA facility [1] layout is presented on figure 1. The 144 MHz RF photo-injector constituted by a 1/2 resonating cavity is able to deliver 2.5 MeV electron bunches carrying up to 15 nC. The beam is focused by a short solenoidal lens referred to B1. Eight normal conducting cavities operating at 433 MHz accelerate the beam up to 20 MeV. The electrons are then transported with steering magnets and triplets of quads, and focused by a last triplet of quads on a OTR measurement diagnostic station. Beam current is measured thanks to Faraday cup and current transformers. All along the transport, beam profile monitoring based on scintillating and OTR screens measure the beam characteristics at stations referred D1, H1,G1,N2' on figure 1.

MEASUREMENT AT EXTRACTION

A hundred electron bunches (100x100ps @14,4MHz) is extracted from a 20 mm diameter Cs_3Sb cathode by photo-electric effect. The size, power and transverse beam profile of the drive laser which illuminates the photocathode will directly determine the size of the extracted electron beam. In our experiment, the laser diameter has been respectively set to 4, 6 and 8 mm.

Electron beam measurements at extraction occurs in D1, after the B1 magnetic lens and the first 433 MHz 2 cells RF cavity. A scintillating screen in D1, suitable for measurement at low energy is used as a beam diagnostic to capture images of the bunch.

The photo-injector, including B1, is modelled with MAGIC [2] . A coupling tool then allows the results from MAGIC to be exported and used as initial conditions in PARTRAN [3] to simulate the beam transport inside the full accelerator.

Figures 2a, 2b, 2c, present a comparison between simulations and experimental results respectively at 4, 6 and 8 mm diameter for the rms and FWHM sizes. Since X and Y beam sizes are identical, only X values are plotted for the sake of understanding. Every graph point is calculated from averaging values of 5 consecutive shots.

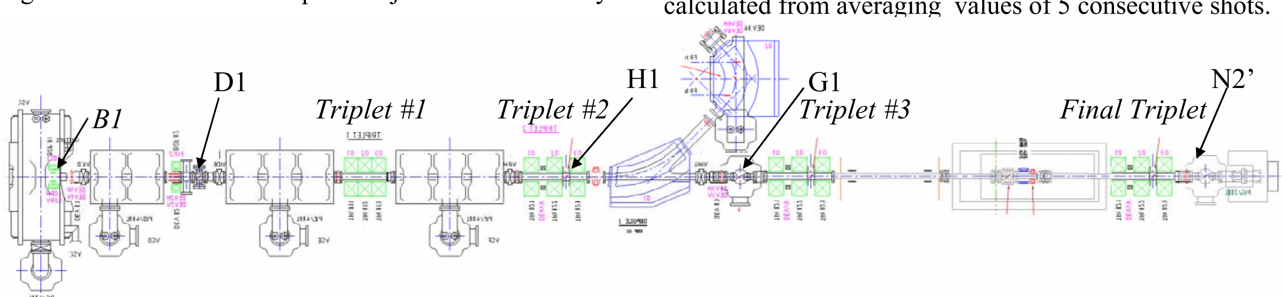

Figure 1: CEA-ELSA experimental layout.

Present resources do not allow to plot relevant full beam sizes. The discrepancy between the curves around the minimum size values is due to the resolution limit of our diagnostic. Bar errors are estimated to be at least 15%. As far as those results are concerned, we observed a good agreement

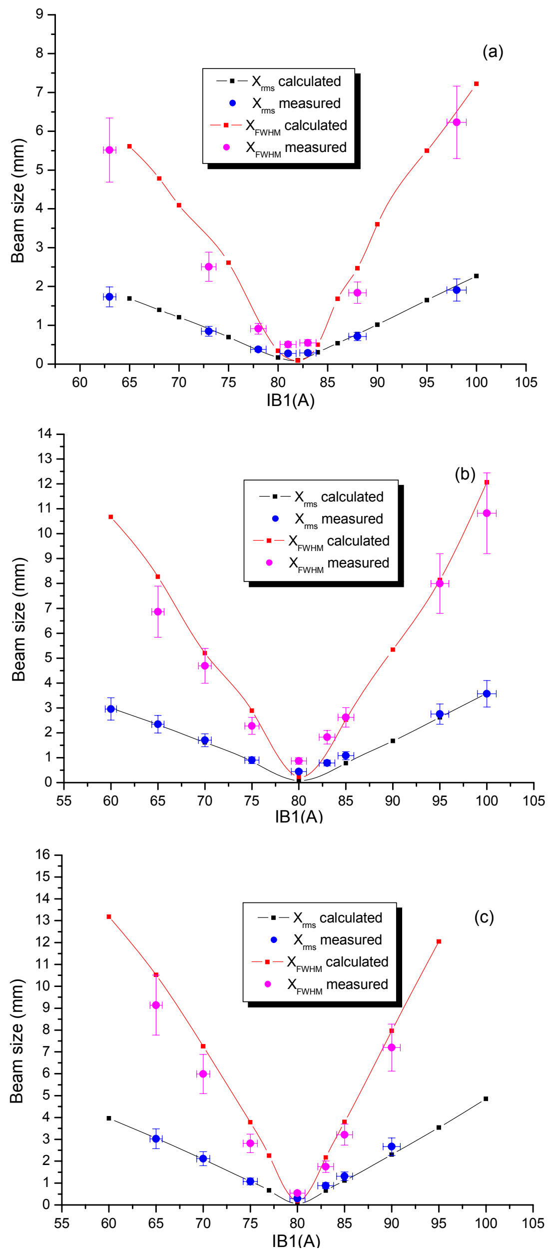

Figure 2: D1 measurement station: rms and FWHM beam sizes versus the solenoid current B1 with laser spot diameters of 4mm (a), 6mm (b), 8 mm (c).

END OF THE LINAC MEASUREMENT

Measurements at final energy occurs in H1 and in G1, when the electron beam has reached 16 MeV after passing through all accelerating RF cavities.

For a current value of the B1 solenoid (70A for a 6 mm beam diameter) which provides a smooth beam transport, we measured the beam size on the OTR screens of H1 station as a function of the triplet #1 currents. Same is done on G1 station versus the triplet #2 currents. The 3 quadrupole currents of each triplet are adjusted to keep a cylindrical beam.

From the beam distribution calculated with MAGIC at the photo-injector exit, the accelerating part of ELSA machine (RF cavities, quadrupoles magnets and drift sections) is simulated with PARTRAN. ELSA quadrupole magnet gradients taking into account remanent magnetic field effects have been determined by previous calibration experiments [4].

Figure 3 presents the comparison between simulations and measurements in H1 station for a laser spot diameter of 6 mm. Beam size measurements were not performed for an initial laser spot diameter of 4 mm.

As far as 6mm is concerned, the agreement between simulation and measurement is quite satisfactory.

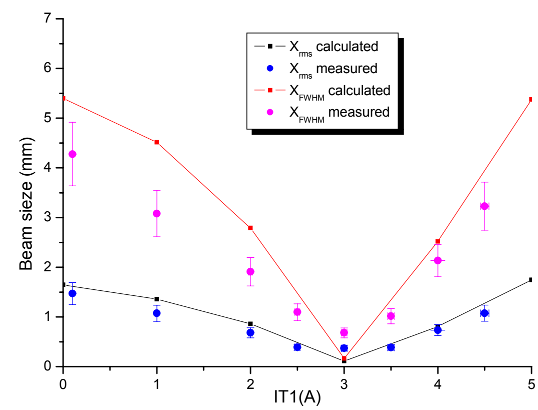

Figure 3: H1 measurement station: rms and FWHM beam sizes versus the fisrt quadrupole current of Triplet #1 (laser spot diameter of 6 mm).

Figure 4 and 5 present the comparison between simulations and measurements in G1 station.

In figure 4, disagreements are observed namely for the FHWM beam sizes. The waist is slipped and the experimental values are larger. This is not explained for the moment.

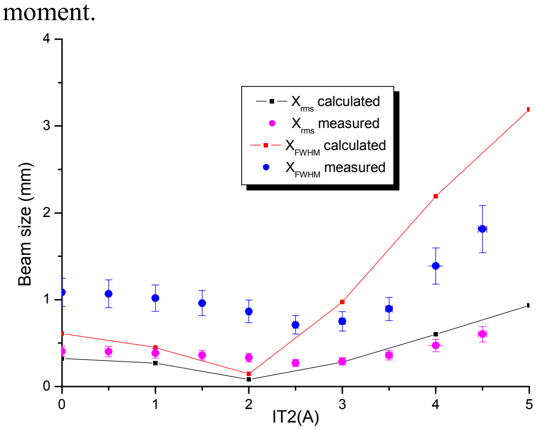

Figure 4: G1 measurement station: rms and FWHM beam sizes versus the first quadrupole current of triplet #2 (laser spot diameter of 4 mm)

The last discrepancies do not show for the 6 mm case.

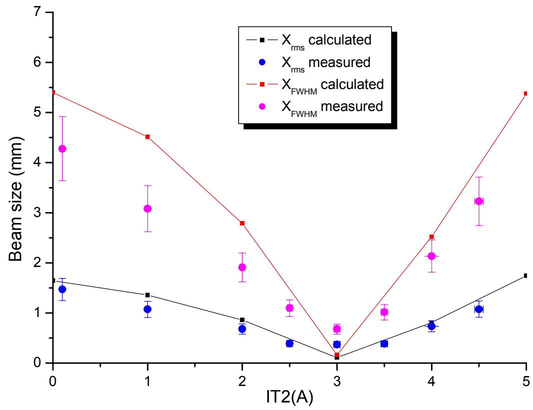

Figure 5: G1 measurement station: rms and FWHM beam sizes versus the first quadrupole current of triplet #2 (laser spot diameter of 6 mm).

FINAL FOCUSING MEASUREMENT

After the linac, the beam is transported to an experimental area and focused by a final quadrupole magnet triplet. Tuning the triplet #3 current to get a smooth beam transport (fig. 6) and keeping constant all other parameters, we then plot the beam size variation in N2' station as a function of the current in the final triplet. The beam profile is observed on an OTR screen placed in N2'.

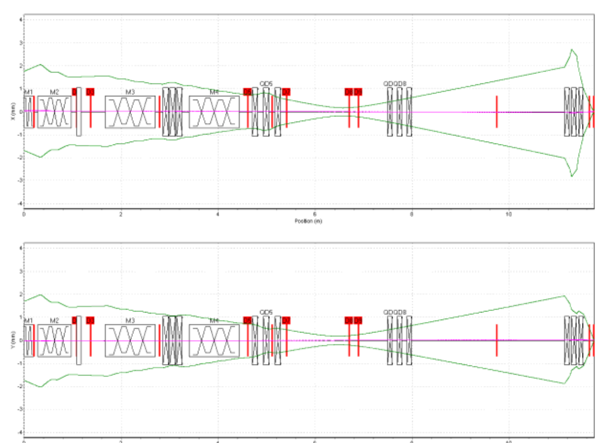

Figure 6: Rms beam envelope with a laser spot diameter of 4 mm (PARTRAN simulation)

The beam profile in N2' for a laser sport size of 4 mm. was only measured. Figure 7 presents the comparison between simulations and measurements.

We still observed a slight discrepancy as for G1 measurement station results.

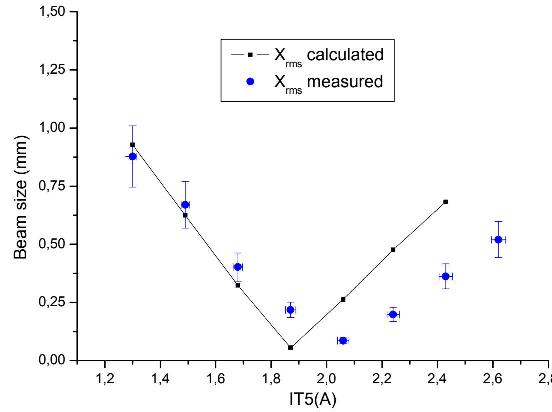

Figure 7: N2’ measurement station: rms beam size versus the final quad current with a laser spot diameter of 4 mm.

CONCLUSION

Simulations of a low charge electron beam in the CEA-ELSA accelerator were done using MAGIC, PARTRAN and SFISH tool box. As far as the rms beam size is concerned, experimental results showed good agreement for different beam initial values set by the laser spot size on the photo-cathode.

Some discrepancies are observed namely on the FWHM beam sizes. Even though, processing experimental data may play a role, all is not fully explained for the moment

This is the first step of validation of the modelling tools used for the accelerator presently under design. This was done at low density beam.

At a next step, we will perform same beam profile measurements along the CEA-ELSA accelerator for a 5 nC electron beam, relevant to space charge mode operation.

ACKNOWLEDGEMENT

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