SPOT SIZE MEASUREMENTS IN THE ELI-NP COMPTON GAMMA SOURCE

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Abstract

A high brightness electron Linac is being built in the Compton Gamma Source at the ELI Nuclear Physics facility in Romania. To achieve the design luminosity a train of 32 bunches, with a nominal charge of 250 pC and 16 ns spacing, will collide with the laser beam in the interaction points. Electron beam spot size is measured with an OTR (optical transition radiation) profile monitors. In order to measure the beam properties, the optical radiation detecting system must have the necessary accuracy and resolution. This paper deals with the studies of different optic configurations to achieve the magnification, resolution and accuracy desired considering design and technological constraints; we will compare several configurations of the optical detection line to justify the one chosen for the implementation in the Linac.

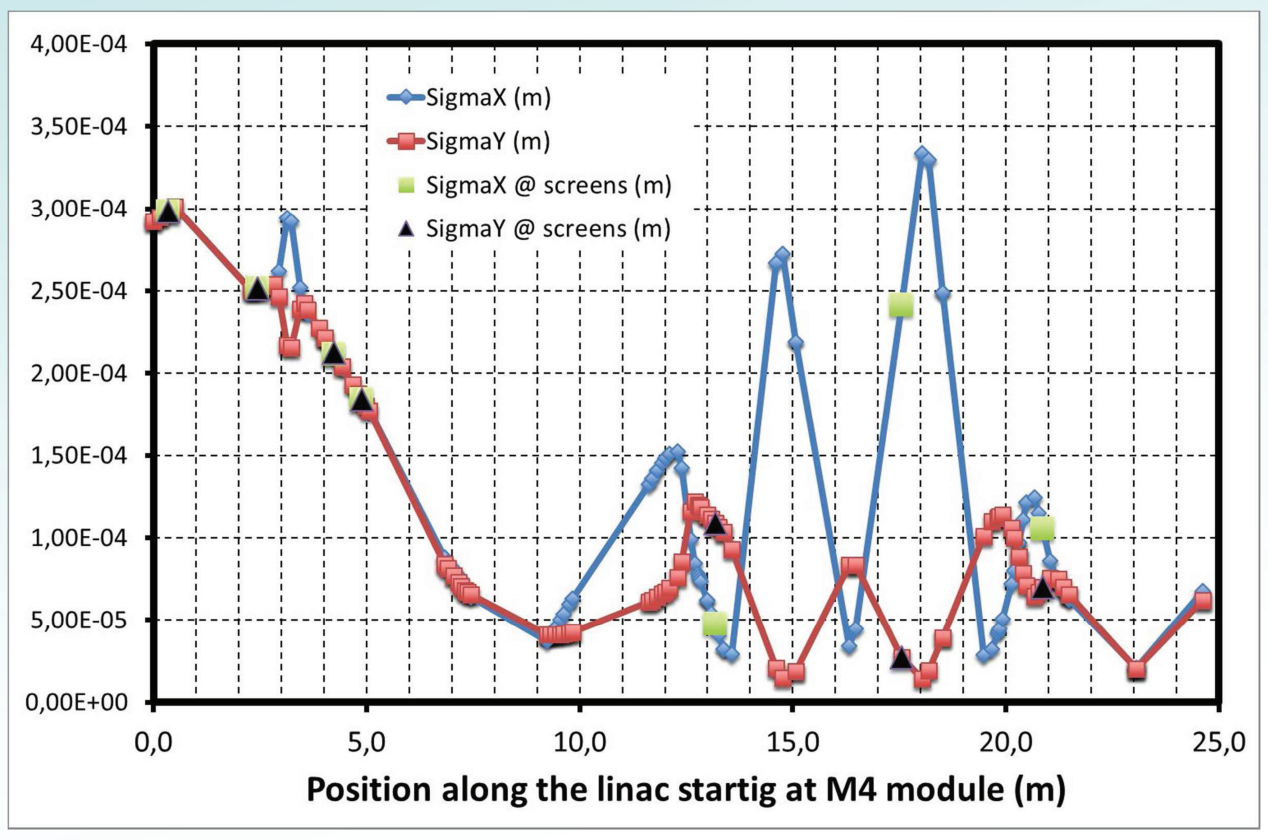
1. Beam Spot Size

The goal of this paper is the characterization of different lenses in terms of resolution and magnification for the optical diagnostics for the ELI-NP-GBS LINAC.

The optical diagnostics systems in ELI-NP-GBS will provide an interceptive method to measure beam spot size and beam position in different positions along the LINAC. In a typical monitor setup, the beam is imaged via OTR using standard lens optics, and the recorded intensity profile is a measure of the particle beam spot [1]. In conjunction with other accelerator components, it will also possible to perform various measurements on the beam, namely: its energy and energy spread (with a dipole or corrector magnet), bunch length (with a RF deflector) and the Twiss parameters (with quadrupoles). The expected beam rms size along the Linac, provided by preliminary beam dynamics simulation, will vary in the 30μm - 1000μm range (as reported in next Figure). An evaluation has been done in order to find the best lenses setups and to find a compromise between resolution, magnification and costs for each position.

In ELI-NP GBS being the size of the beam variable the range of magnification required goes from 1: 1 to 1: 5.

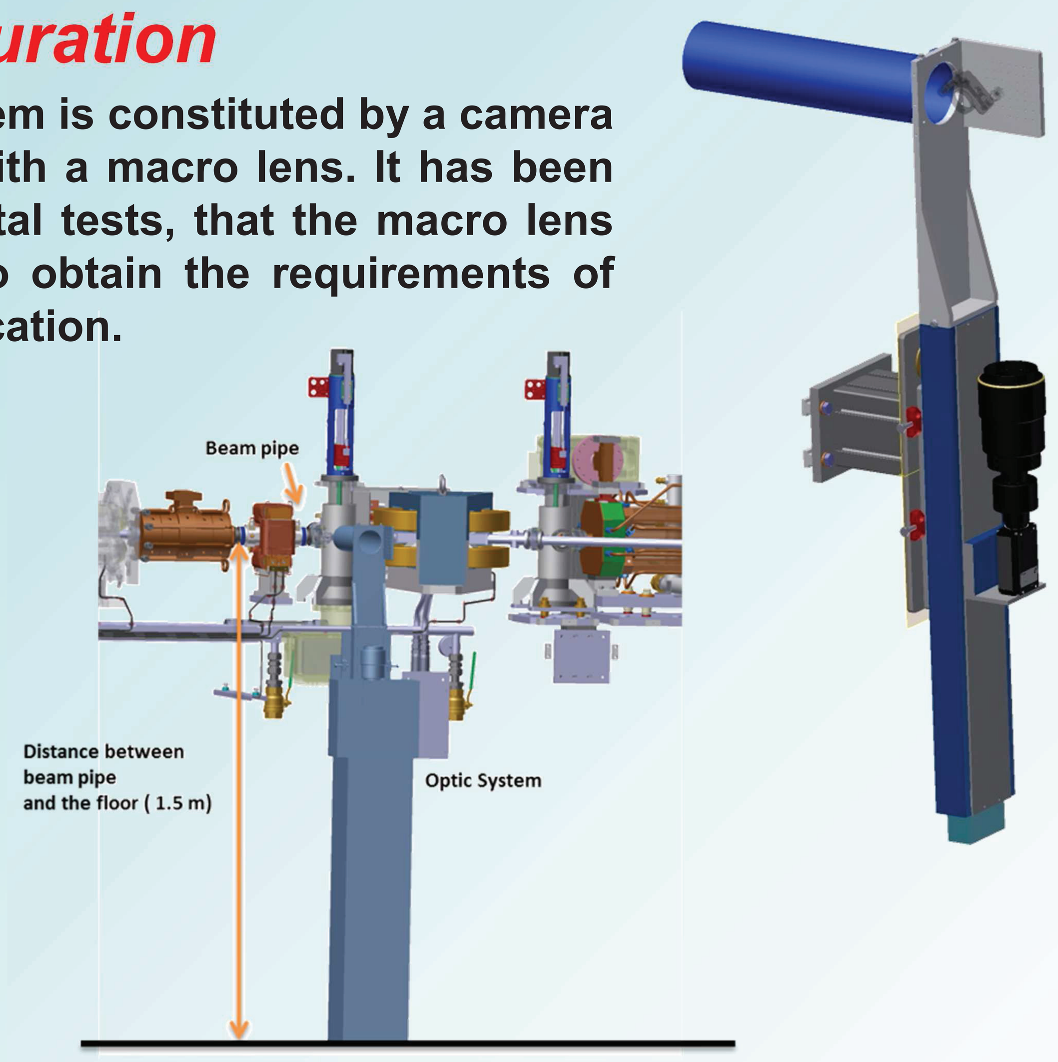
The "USAF 1951" calibration target is useful for the study of the magnification as a function of the distance between the target and the sensor, and the focal length.

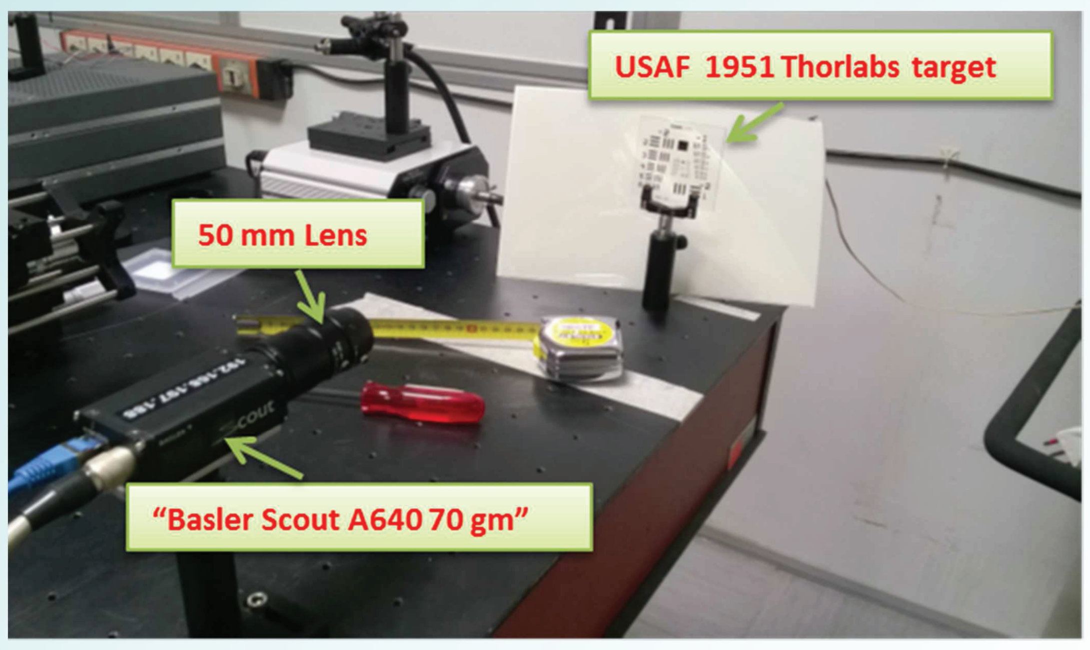


2. Optics Configuration

The optical acquisition system is constituted by a camera Basler scout A640-70 gm with a macro lens. It has been seen, during the experimental tests, that the macro lens is most suitable in order to obtain the requirements of high resolution and magnification.

A movable slide is used to move the system between 60 cm and 130 cm of distance from target. These values represent the maximum and minimum distance between the camera sensor and the OTR because they are linked to the mechanical and geometric constraints since the beam line is placed at 1.5 meters from the floor.



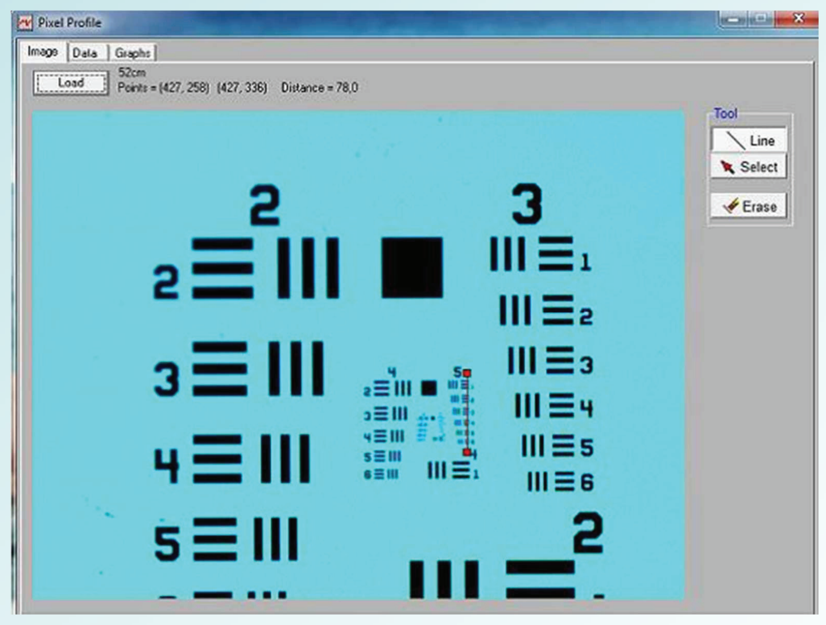


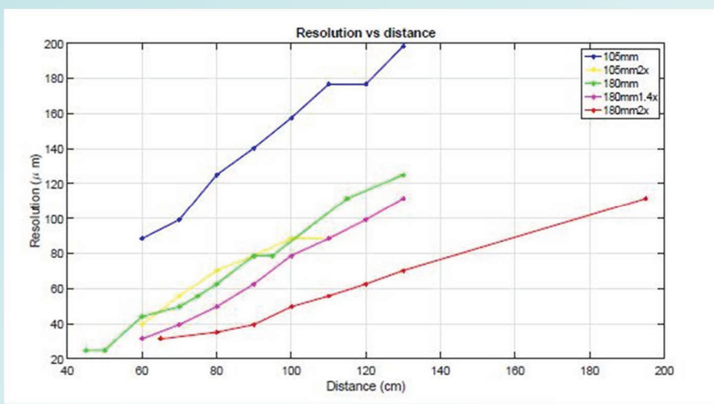
The magnification and the resolution of the images at the minimum and the maximum distances (60 and 130 cm) for various lens setup have been measured. A "Thorlabs" Calibration target based on the "USAF 1951" target is used .

3. Main parameters

Resolution

The "USAF 1951" target allows to test the resolution of the optic setup. We estimate the contrast value by evaluating the rate between the difference in intensity values of the pixels corresponding to the black lines and the one corresponding to the white spaces, and their sum; we consider the lines resolved if the contrast value is above 0.1.





The line series in Figure that respect the specification is the element 1 of the group 5.

Magnification

If we define a parameter x given by $x = 2^{Group+(Element-1)/6}$ that represents the number of line pairs per millimeters, the resolution in millimeters can be calculated as is 1/x; and the sizes of each line which are L =2.5/x for the length, and W = ½x for the width [2]. Making a line profiling from the images that we acquire, we can measure the size in pixels of the line (N) and, knowing the pixel size of the camera sensor (7.4x7.4 μm), the size of the line in the image plane. Therefore, the magnification is M =L/7.4N .

4. Optics Measurements

Best result is a 180 mm lens with tele-converter (2x) that gave us the magnification of 1 and a better resolution.

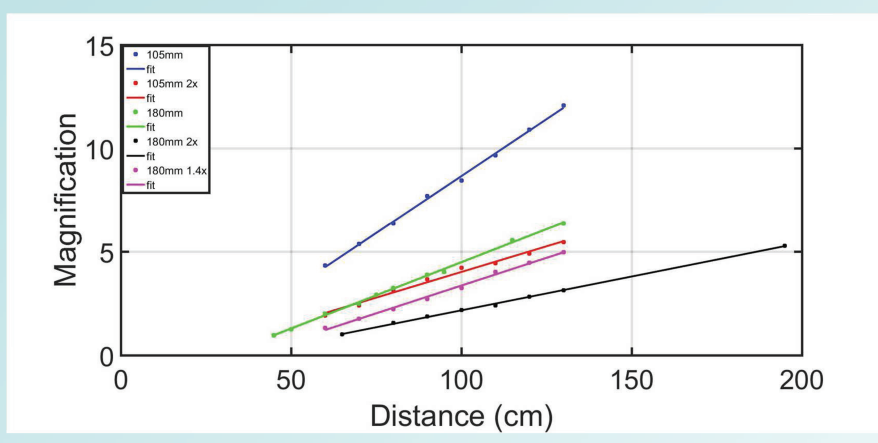
Lens [mm]	Distance [cm]	Resolution [μm]	M	Field of View [mm]
50	60	223	8.33	40x30
105	60	88	4	21x16
	130	198	12	59x44
105 + tele-conv.2x	60	39	1.9	9x7
	130	111	5.5	27x20
180	60	44	2	10x7
	130	125	6	31x23
180+tele-conv. 2x	**60**	**31**	**1**	**5x4**
	130	**70**	**3**	**15x11**
180 + tele-conv.1.4x	60	321	1.3	6x5
	130	111	5	24x18

Tele-converter advantages: cost, magnification and high resolutions.

Disadvantage: the fall of light is equal to two diaphragms for the aperture but in our case this disadvantage is not a problem because the decrease of the luminosity is more evident for longer focal length.

5. Conclusions

In general, the relation between the magnification and the distance is quasi-linear and the slope decreases with the focal length as it can be seen in next figure. Therefore, the best solution in our case is shown by the black line. In this case we do not have the large possibility to change the magnification but, in function of the requirements of this accelerator, this lens is a valid device to study the characteristics of the beam.



A camera system configuration has been selected considering the ratio between magnification, resolution and the costs, consisting of a Basler Scout A640-70 gm camera equipped with 105 mm lens while 180 mm lens with tele-converter 2x will be used in the diagnostic stations collocated in the more critical points along the LINAC (see next Table).

Station	Beam Size (um) X	Beam Size (um) Y	Solution proposed n.1
LELDIASCN002 (energy measurements)	1000	1000	Camera Lens 105 mm+ tele-converter 2x
LELDIASCN003	500	500	Camera Lens 105 mm+ tele-converter 2x
LELDIASCN004	400	400	Camera Lens 105 mm+ tele-converter 2x
LELDIASCN005	280	280	Camera Lens 105 mm+ tele-converter 2x
LELDIASCN006	250	250	Camera Lens 105 mm+ tele-converter 2x
LELDIASCN007 (energy measurements)	180	180	Camera Lens 180 mm+tele-converter 2x
LELDIASCN008 (quad scan, long. measurements)	220	220	Camera Lens 180 mm+tele-converter 2x
LELDIASCN09	100	100	Camera Lens 105 mm+ tele-converter 2x
LETDIASCN01 (beam size under 0.1mm)	80	80	Camera Lens 180 mm+tele-converter 2x
LETDIASCN02 (beam size under 0.1mm)	27	27	Camera Lens 180 mm+tele-converter 2x
LEDDIASCN01 (beam size under 0.1mm)	65	65	Camera Lens 180 mm+tele-converter 2x
LEDDIASCN02	100	100	Camera Lens 105 mm+ tele-converter 2x

References

[1] M. Marongiu *et al*, *"Design issues for the optical transition radiation screens for the ELI-NP Compton Gamma source"*, Nuclear Instruments and Methods in Physics Research (2016) 1–4.

[2] Thorlabs App Note: "Resolution Test Targets", https://www.thorlabs.com/newgrouppage9.cfm?objectgroup_id=4338

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