KLF Final Beam Focusing (Draft)

T. Satogata

April 20, 2020

This is a short technical note to evaluate the feasibility of certain beam parameters for the K-Long Factory (KLF) experiment proposal from Sean Dobbs and Igor Strakovsky on 17 Apr 2020. In particular, this note evaluates the feasibility of a 95% full width beam size of 1–2 cm (horizontal) and 5 mm (vertical) at the CPS radiator, with a projected beam minimum beam size at the Be production target in the collimator cave ≈67 m downstream of the CPS radiator.

The document [1] identifies typical beam parameters for CEBAF 12 GeV operations. The relevant parameters for this note are the geometric transverse rms emittances of $\epsilon \approx 6 \times 10^{-9}$ m rad, and the beam energy of ≈12 GeV. The emittances in both transverse planes are dominated by synchrotron radiation in the CEBAF arcs at energies above 9–10 GeV, so they are unlikely to be significantly different than this estimate.

1 Baseline GlueX

The beta functions at the radiator in nominal GlueX tuning are about $\beta_x \approx 250$ m and $\beta_y \approx 170$ m. The rms beam sizes σ can then be calculated via $\sigma = \sqrt{\beta\epsilon}$ [2].

$$\sigma_x = \sqrt{\beta_x \epsilon_x} = \sqrt{(250\,\mathrm{m})(7 \times 10^{-9}\,\mathrm{m\,rad})} \tag{1.1}$$

$$= 1.3\,\mathrm{mm} \tag{1.2}$$

and

$$\sigma_7 = \sqrt{\beta_y \epsilon_y} = \sqrt{(170\,\mathrm{m})(5 \times 10^{-9}\,\mathrm{m\,rad})} \tag{1.3}$$

$$= 0.9\,\mathrm{mm} \tag{1.4}$$

These are relatively consistent with observed beam spot sizes on the GlueX diamond radiator.

2 KLF Request

The effective emittance of 95% of a beam is 6π larger than the rms emittance [2]. For the conservative 95% horizontal total beam size of 1 cm, the horizontal beta function required at the CPS is therefore

$$\beta_x = \sigma_{95}^2/(6\pi\epsilon) \tag{2.5}$$

$$= (5 \times 10^{-3}\,\mathrm{m})^2/(6\pi(6 \times 10^{-9}\,\mathrm{m\,rad})) \tag{2.6}$$

$$= 221\,\mathrm{m} \tag{2.7}$$

This is a reasonable number, in fact not so different than the existing horizontal beta function at the GlueX diamond radiator. The projected beta function at the target is 21.1 m.

For the 95% vertical total beam size of 5 mm, the vertical beta function required at the CPS is therefore

$$\beta_y = \sigma_{95}^2/(6\pi\epsilon) \tag{2.8}$$

$$= (2.5 \times 10^{-3}\,\mathrm{m})^2/(6\pi(6 \times 10^{-9}\,\mathrm{m\,rad})) \tag{2.9}$$

$$= 55\,\mathrm{m} \tag{2.10}$$

This number is too small to provide a focus at the target L =65 m downstream. The minimum beta function should be ≈130 m. Presumably the collaboration does not have a problem with making the beam larger at the CPS radiator. An even larger beta function at the CPS radiator would be better to provide smaller beam at the target, since the relationship between the CPS beta function β_c and target beta function β_t is

$$\beta_c = \beta_t + L^2/\beta_t \ . \tag{2.11}$$

The required beta function scales with the beam size squared, so pushing the 95% full width beam size to 2 cm requires a beta function of ≈880 m. As can be seen in the next section on convergence, this is quite large, and would require substantial rework of the beamline including installation of large-aperture quadrupoles. This would also produce an extremely small beta function at the target of β_t =4.8 m, with correspondingly high divergence necessary at the CPS radiator.

The space between the CPS radiator and Be production target is a drift space. The beam convergence, $\alpha_c \equiv -\beta_c'/2$, required at the CPS dump to produce a waist at the Be production target is

$$\alpha_c = L/\beta_t \tag{2.12}$$

In the horizontal plane this implies $\alpha_c \approx 3$ at the CPS radiator. This convergence is quite steep. Careful checks in upstream optics are necessary to determine whether such a steep convergence is feasible for the 1 cm 95% full width beam case.

References

[1] J. Benesch *et al.*, "12 GeV CEBAF Beam Parameter Tables", JLAB-TN-18-022, 31 March 2018.

[2] A. Chao and M. Tigner, eds., "Handbook of Accelerator Physics and Engineering", 3rd printing, p. 66.