LCLS-II Technical Note

Jaw Arrangement of COL0 Halo Collimators During Injector Beam Commissioning

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1. Introduction

Adjustable-gap halo collimators are designed in the LCLS-II beamline to eliminate undesirable electrons in order to avoid excessive radiation due to beam loss in sensitive areas and to reduce activation of accelerator components. The physics requirement for halo collimators are described in LCLSII-2.4-PR-0095 [1].

In a technical note LCLS-II-TN-20-02 [2], use cases for halo collimators are further discussed. One of the use cases is a temporary tune-up dump. According to the present commissioning plan, during the injector beam commissioning period, the downstream linac SRF/cavity commissioning (without beam) will take place in parallel. In this injector commissioning phase, we will use the adjustable halo collimators in the COL0 area (CYC01, CXC01, CYC03, CXC03) to block the photo-electron beam, the dark current from the gun, and the superconducting cavity field emission current. A lockout requirement of the four COL0 collimators has been specified in a recent RP memo [3]. The shielding of the collimators and the acceptable power on the collimator jaws have been discussed in the PRD and the technical note. Here we discuss the jaw position arrangement of the COL0 collimators when used as a temporary tune-up dump.

2. Requirements

The halo collimators are designed that each collimating jaw is able to over-travel the nominal beam centerline by at least 3 mm (assuming the opposing jaw is sufficiently retracted). The two jaws should never collide, but always allow a minimum jaw-to-jaw full-gap of 1 mm. Based on these features, to effectively block beam we would arrange the four COL0 collimators in a **staggered position mode.** During Injector commissioning it is expected that the jaws will be mechanically locked in the staggered position mode so that we don't accidentally open the jaws and let beam through. The staggered position mode minimal requirements are described in the following:

1. The first horizontal collimator (CXC01) jaw pair is set over-travelling the beamline center to the **north** by no less than 2 mm, with full gap between the two jaws of 1 mm or less.
2. The second horizontal collimator (CXC03) jaw pair is set over-travelling the beamline center to the **south** by no less than 2 mm, with full gap between the jaws of 1 mm or less.
3. The first vertical collimator (CYC01) jaw pair is set over-travelling the beamline center **down** by no less than 2 mm, with full gap between the jaws of 1 mm or less.
4. The second vertical collimator (CYC03) jaw pair is set over-travelling the beamline center **up** by no less than 2 mm, with full gap between the two jaws of 1 mm or less.
5. The mechanical design should allow lock-out of the jaw positions of each collimator as described above.

Generally, for best results, the overtravel distance should be set to a maximum and the gaps should be set to a minimum.

Figure-1 below further illustrates the staggered position arrangement of the COL0 collimators.

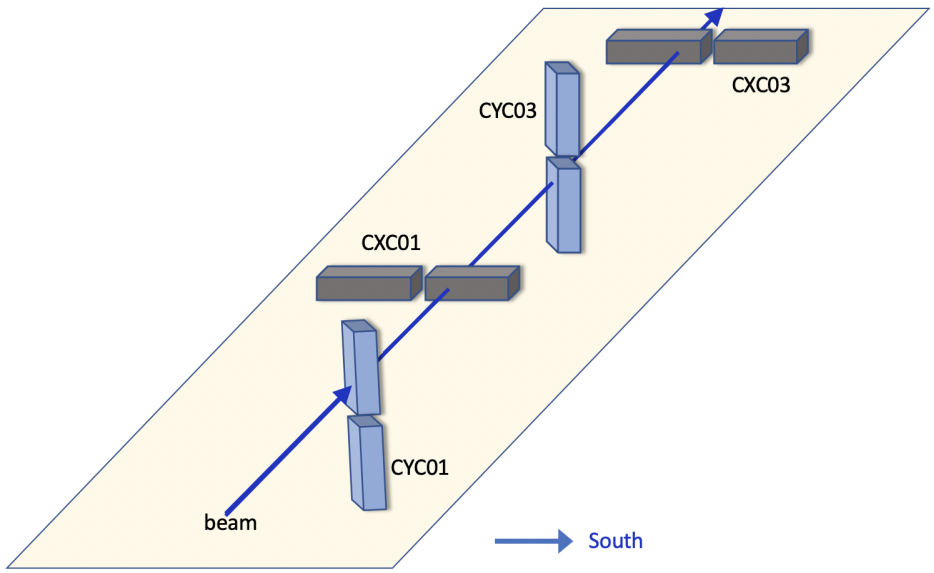

Figure-1: Staggered jaw position of the COL0 collimators when used as temporary, low power beam dump.

3. Elegant tracking

We performed Elegant tracking using the staggered COL0 collimator jaw layout as shown in Figure-1 to verify the particle loss and transmission.

The initial beam should represent both the photo-electron and the dark current beam. The upstream kicker BKRDG0 vacuum chamber (1-m long, 25 mm diameter cylinder) and can be used to define the maximum particle phase space exiting the BKRDG0 chamber. We performed tracking on this type of initial beam (full transverse size 25 mm, and the chosen normalized emittance is about 10 mm-rad) with the staggered collimator jaw arrangement (full gap is 1 mm with a 2-3 mm offset) and found most of the beam was lost in the first collimator, assuming, for simplicity, the generation of secondary particles or edge scattering is ignored. As a result, we would need a very large number of particles to check possible particle transmission through to the fourth collimator. Instead, we squeezed the emittance to make the beam more concentrated over the jaw range (a few mm transverse distribution) to maximize the transmission through the COL0 collimator jaws.

The Elegant tracking starts at the BKRDG0 entrance, with the beam mean energy at 100 MeV, and the relative energy spread is 50% rms (Gaussian distribution with two sigma cutoff, so the energy spreads from zero to 200 MeV). We scanned the emittance from 2 um to 100 um to find the maximum transmission at the jaw setting with over-travel of 3 mm. The result shows the beam with normalized emittance of 10 um is the worst case. The number of macroparticles used in the tracking is 1 million. We use a 10-um emittance beam at the BKRDG0 entrance for all the following simulations. Figure 2 shows the initial beam transverse distribution

and longitudinal phase space at the entrance of the kicker BKRDG0 in the Elegant tracking. In Figure 3, we show the remaining particle numbers after each collimator, with the collimator jaw over-travelling the beamline center at different positions (the collimator jaw full gap is always kept at 1 mm). From Figure 3 we can see when the collimator jaw is over travelling the beamline center by 2 mm or more, there will be less than 1000 macroparticles passing through (<0.1% transmission).

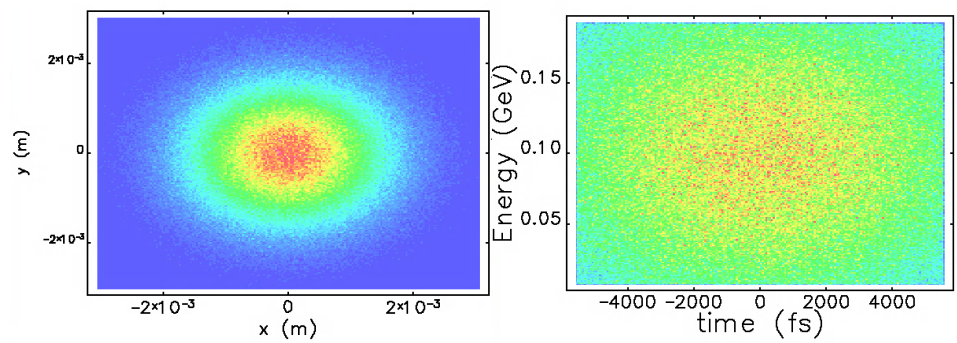

Figure-2: Initial beam transverse distribution and longitudinal phase space at the entrance of the kicker BKRDG0.

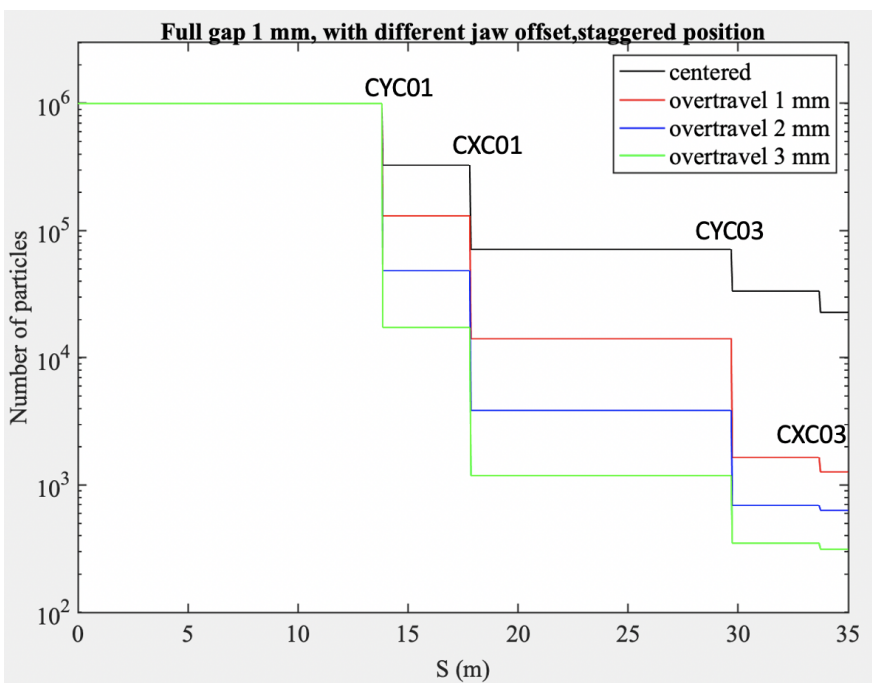

Figure-3: Remaining macroparticles along the beam line with 1E6 initial macroparticles.

In Figure-4, we further illustrate the definition of the jaw position used in the Elegant setting, using the examples of "centered jaw position" and "over-travel beamline center by 2 mm". In both examples, the full gap of the jaws is kept at fixed 1 mm.

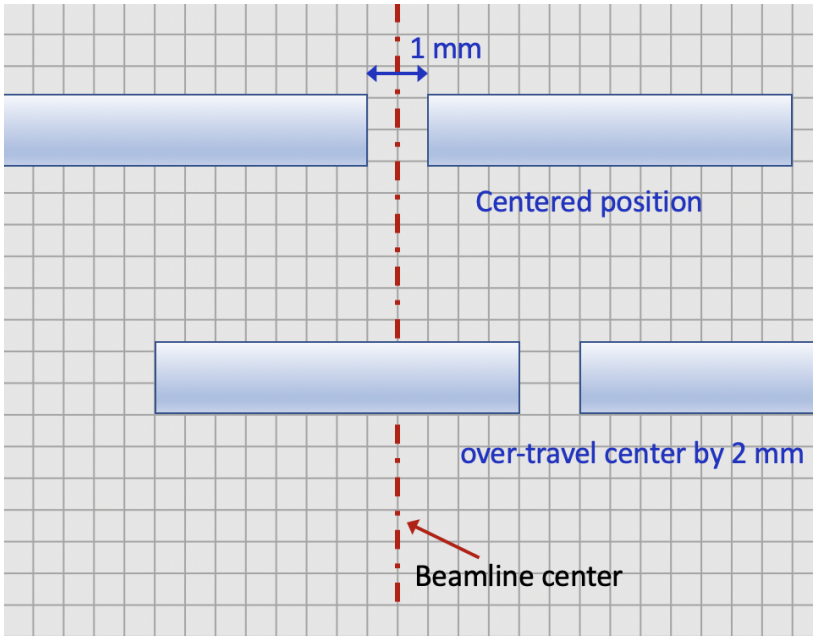

Figure-4: Illustration of the jaw position definition used in Elegant setup. The top one is at "Centered position", and the bottom one is "Over-travel beamline center by 2 mm". In both cases the full gap is 1 mm.

4. Summary

We discussed in this note about the jaw arrangement of the COL0 collimators when they are used to block the electrons as a temporary tune-up dump. For best performance, a pair of collimators should be always set with a staggered position mode. For each single collimator, the over-travelling distance and the gap setting between the two jaws have been discussed. Please note that for other area collimators, if lockout of the jaws is required, the same implementation can be applied.

5. References

1. Halo Collimator System PRD, LCLSII-2.4-PR-0095.
2. LCLS-II tech note, "Use Cases for Hallo Collimators", LCLS-II-TN-20-02.
3. LCLS-II SLAC MEMORANDUM, RP-RPG-210518-MEM-01, "High Level RP Requirements for LCLS-II Commissioning", May 18, 2021.