CEBAF INJECTOR FOR K_L BEAM CONDITIONS*

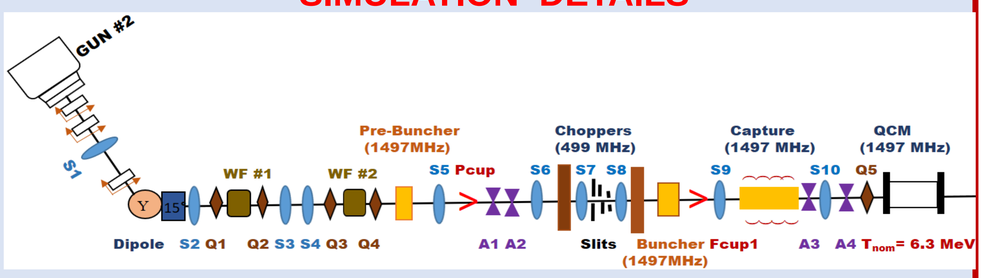
S . Pokharel[1,2 #], A. S. Hofler[2], G. A. Krafft[1,2] R. Kazimi[2], M. Bruker[2], J. Grames[2], S. Zhang[2]

[1] *Center for Accelerator Science, Old Dominion University, Norfolk, VA 23529, U.S.A.*
[2] *Thomas Jefferson National Accelerator Facility, Newport News, VA 23606, USA.*

ABSTRACT

The Jefferson Lab K_L experiment [1] will run at the Continuous Electron Beam Accelerator Facility (CEBAF) with a much lower bunch repetition rate (7.80 MHz or 15.59 MHz) than nominally used (249.5 MHz or 499 MHz). While the proposed average current of 2.5 - 5.0 μA is relatively low compared to the maximum CEBAF current of approximately 180 μA, the corresponding bunch charge is atypically high for CEBAF injector operation. In this work, we investigated the evolution and transmission of low-rep-rate, high-bunch charge (0.32 to 0.64 pC) beams through the CEBAF injector. Using the commercial software General Particle Tracer, we have simulated and analyzed the beam characteristics for both values of bunch charge. We performed these simulations with the existing injector using a 130 kV gun voltage. We have calculated and measured the transmission as a function of the photocathode laser spot size and pulse length. We report on the findings of these simulations and optimum parameters for operating the experiment.

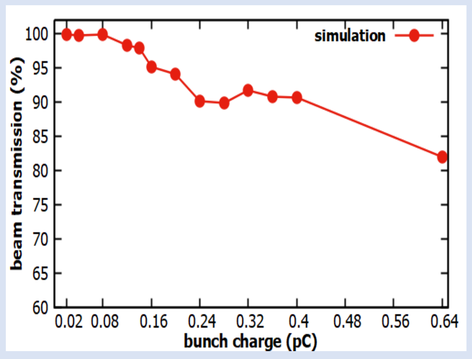
SIMULATION DETAILS



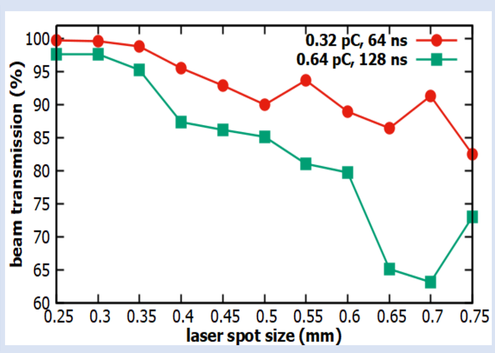
Layout of cathode to quarter cryomodule of CEBAF at Jlab.

- Simulations Performed using General Particle Tracer (GPT).
- Injector model focuses on the beam line between the gun and the captured solenoid S6 (MFA0I03) upstream of the Chopper 1 RF cavity and retains the pre-upgraded injector beam line downstream from S6 (MFA0I03) onward.
- The beam originates on a 130 keV photocathode.
- Beam of Gaussian distribution in t, x, y , p_x and p_y.
- The nominal settings are transverse beam sizes, $4\sigma_x$ = 2.237 mm, and $4\sigma_y$ = 2.093 mm, laser pulse length (FWHM) is 45 ps, the transverse emittance is 0.061 mm-mrad.
- The beam current is varied from 5 μA to 160 μA for 250 MHz laser frequency. The applied macro particle number is 10000.
- The laser spot size and the laser pulse length at cathode are varied.

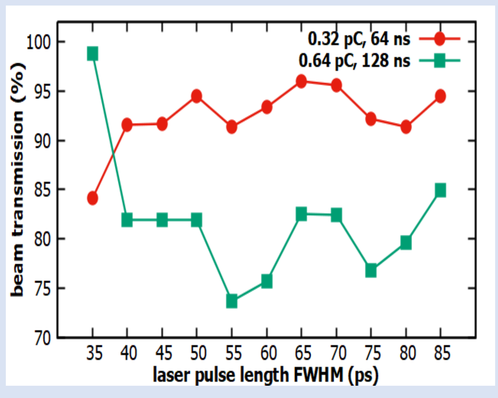
SIMULATION RESULTS



Beam transmission through the apertures vs. bunch charge.



Beam transmission with variation of laser spot size.



Beam transmission with variation of laser pulse length.

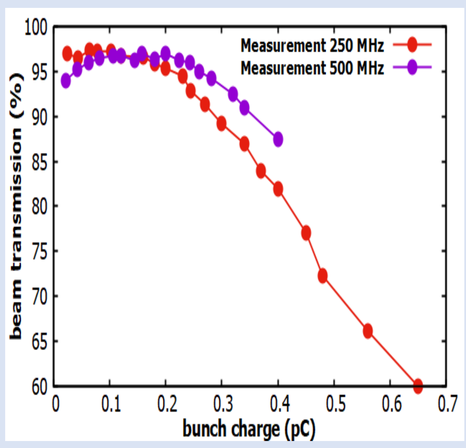
- Transmission decreases with increase in bunch charge.
- Beam transmission depends on the laser spot size and laser pulse length for different spacing of bunch.
- Beam transmission increases with increase in laser pulse length.
- Beam transmission decreases with increase in laser spot size.

ACKNOWLEDGMENTS

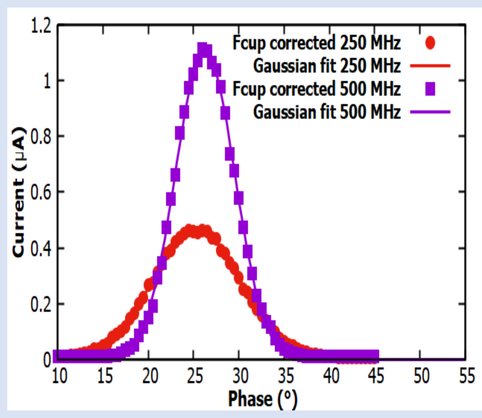
This material is based upon the work supported by the U.S. Department of Energy, Office of Science, Office of Nuclear Physics under contract No. DE-AC05-06OR23177.

#spokh003@odu.edu, spokh@jlab.org

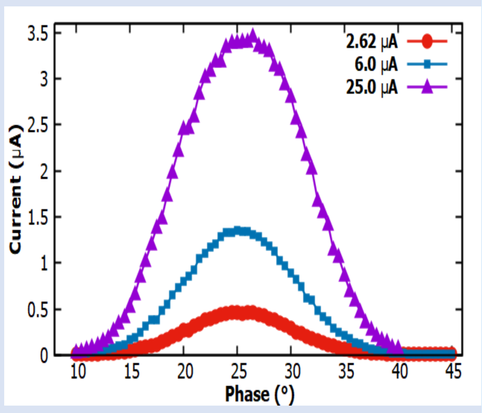
MEASUREMENTS



Beam transmission through the apertures A1, A2 and MS vs. bunch charge for different laser drive frequency.

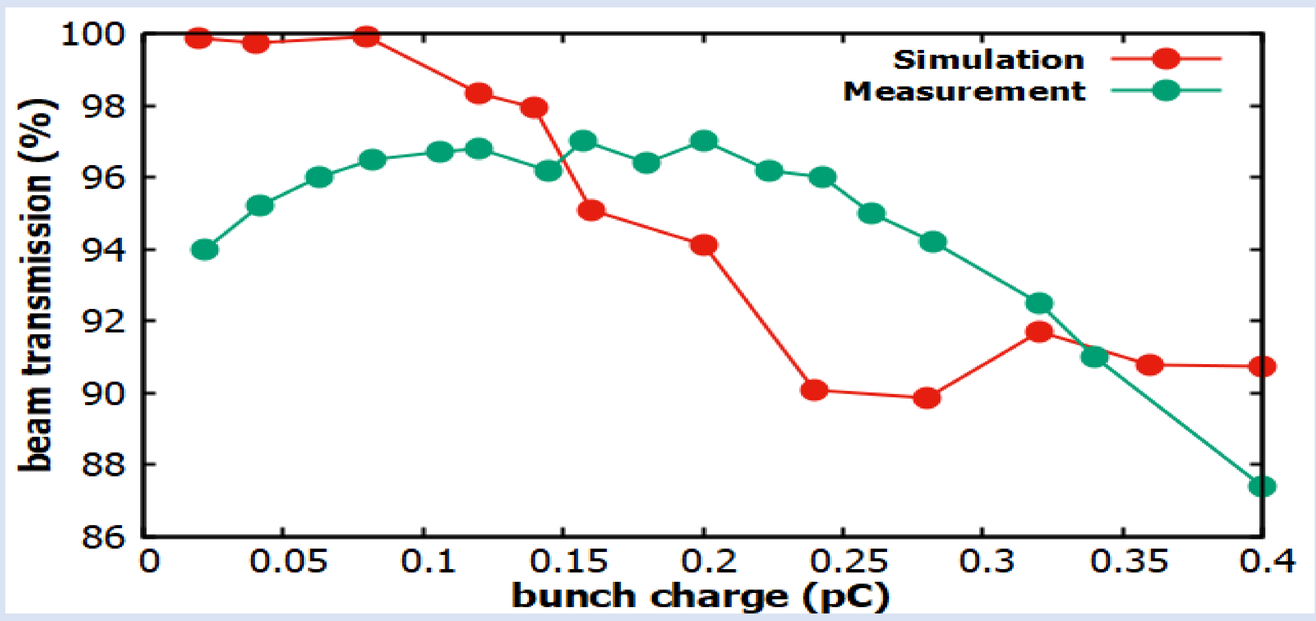


Chopper scan for measuring beam pulse length for different beam frequency created by the drive laser.



Chopper scan at various beam current from the gun 250 MHz drive frequency.

COMPARISON MEASUREMENTS AND SIMULATIONS



Comparison between simulations and measurements for beam transmission vs. bunch charge at 500 MHz drive frequency of laser.

OUTLOOK

- With existing gun (130 kV), we simulated the Continuous Electron Beam Accelerator Facility (CEBAF) upgraded injector model for K-Long experiment for low and high charge/bunch using General Particle Tracer (GPT).
- During the simulations, the laser pulse length and laser spot size at cathode were varied to see the effects of these parameters in the beam interception though the apertures.
- Measurement were done for low and high charge for two different laser drive frequency mode and compared with the simulation results.
- From the measurements, we found that maximum bunch charge from the gun that is transmitted through the apertures is 0.4 pC at 500 MHz drive frequency with about 12% loss and in good agreement with the simulations. However, for the 250 MHz drive frequency the maximum bunch charge from the gun met the K-Long experiment requirement but the losses in the apertures are high, about 39%.
- The charge that can be transmitted from the injector is about 0.35 pC for 500 MHz drive frequency and 0.40 pC for 250 MHz drive frequency.
- From the chopper scanning technique, we have found that for different drive frequency modes of the laser, the pulse lengths are different. The FWHM pulse length for 500 MHz drive frequency 42.50±0.22 ps and is close to the simulated pulse length. But, the FWHM pulse length for 250 MHz drive frequency is 63.83 ± 0.27 ps and is more larger than the simulated pulse length.

FUTURE WORKS

A planned injector upgrade with a 200 kV gun and new RF acceleration scheme is planned for 2023. This upgrade is expected to further benefit the K-Long experiment. New simulations for this experiment and studies with the K-Long drive laser are planned.

REFERENCES

[1] M. Amaryan, et al. “Strange hadron spectroscopy with secondary KL beam in hall D“ arXiv:2008.08215v3 [nucl-ex] 4 Mar, (2021).

[2] Pulsar Physics, General Particle Tracer, http://www.pulsar.nl/gpt/.

[3] S. B. Van Der Geer, et al. "3D space-charge model for GPT simulations of high brightness electron bunches.” Institute of Physics Conference Series. Vol. 175, (2005).

[4] Y. Chen, I. Zagorodnov, and M. Dohlus, "Beam dynamics of realistic bunches at the injector section of the European X-ray Free-Electron Laser." Physical Review Accelerators and Beams, 23(4), 044201 (2020).