CEBAF INJECTOR AT 200 kV: K-LONG BUNCH CHARGE WITH SPIN FLIPPER OFF/ON

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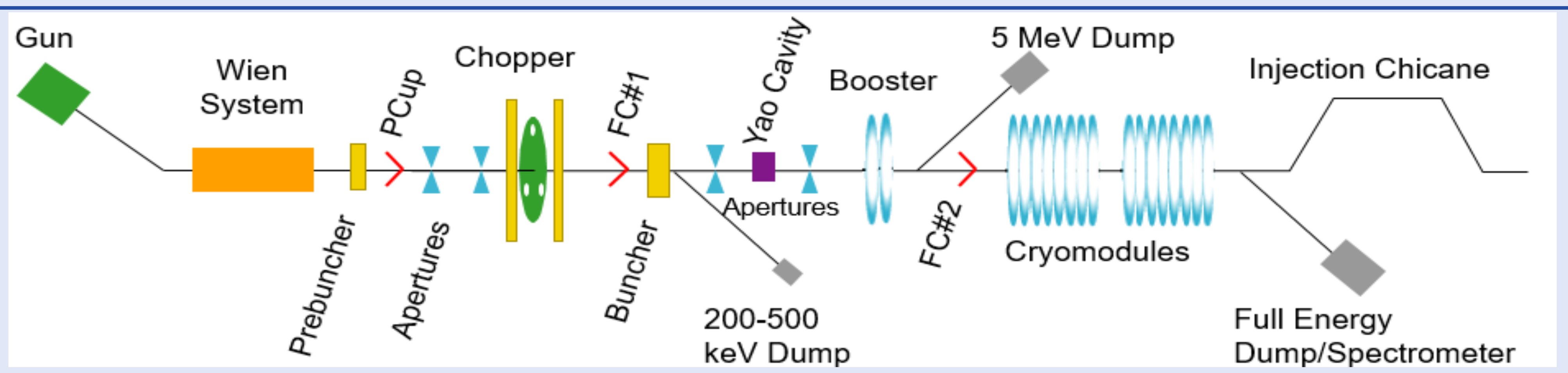
ABSTRACT

The forthcoming K-Long experiment in Jefferson Lab's Hall D presents distinct beam requirements, marked by a notably low bunch repetition rate and an unusually high bunch charge. Furthermore, the CEBAF Injector requires a parity quality beam for experiments such as the Measurement of a Lepton-Lepton Electroweak Reaction (MOLLER). In this study, to prepare for the upcoming K-Long experiment, using the optimized settings of the magnetic elements and RF amplitude and phases, we conducted simulations covering a range of bunch charge beams, from low to high specifications, while considering concurrent operations across all four Halls at CEBAF. Through these simulations, we systematically analyzed beam transmission as well as the transverse and longitudinal beam characteristics, examining the impact of Spin Flipper settings in both ON and OFF states.

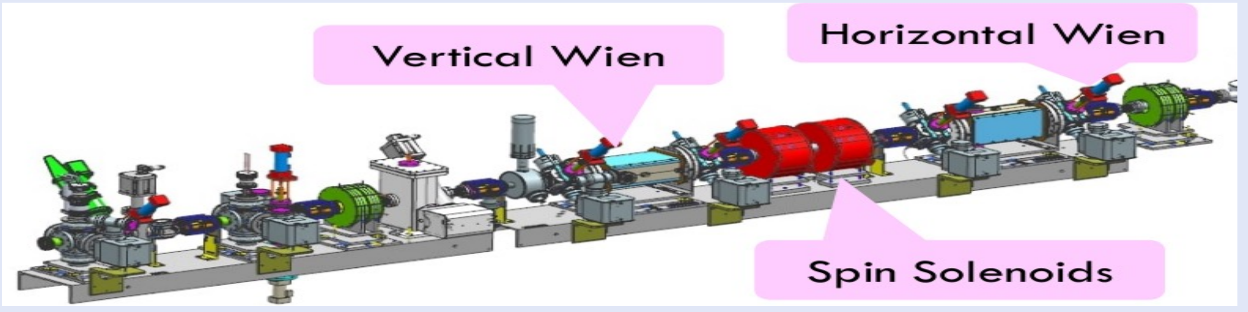
INTRODUCTION

A Wien filter is a device with static electric and magnetic fields orthogonal to each other and arranged in such a way as to provide a net spin rotation without deflecting the beam. The Continuous Electron Beam Accelerator Facility (CEBAF) injector has two Wien filters along with two spin flipper solenoid magnets in between them for the spin orientations required for the experimental target. The first Wien filter (vertical) downstream of the DC photo-gun rotates the polarization from longitudinal to vertical. The second Wien filter (horizontal) rotates the polarizations in-plane to compensate precession of CEBAF transport magnets. The Solenoids in between ensure additional polarization rotations.



CEBAF Injector layout with upgraded beamline elements.

SIMULATION DETAILS



Schematic of CEBAF Wien system set up.

- These all elements are incorporated into the General Particle Tracer (GPT) model.
- The Gaussian beam with a transverse beam size of 0.55 mm, and a laser pulse length of 45 ps.
- Simulations were performed for 10,000 macroparticles with the Spin flipper OFF/ON.
- The transverse emittance is given by, $\epsilon_{n,\perp} = \sigma_\perp \sqrt{\frac{MTE}{mc^2}}$, MTE = 30.691 meV.
- Spin flipper OFF: VWien is OFF and spins flipper solenoid $\sum FGs = 0°$.
- Spin flipper ON: VWien is ON ($\pm 90°$), spin-flip left/right and Spin flipper solenoid $\sum FGs = 90°$.

SIMULATED BEAM CHARACTERISTICS

Beam Characteristics upstream of the first full cryomodules in the CEBAF injector

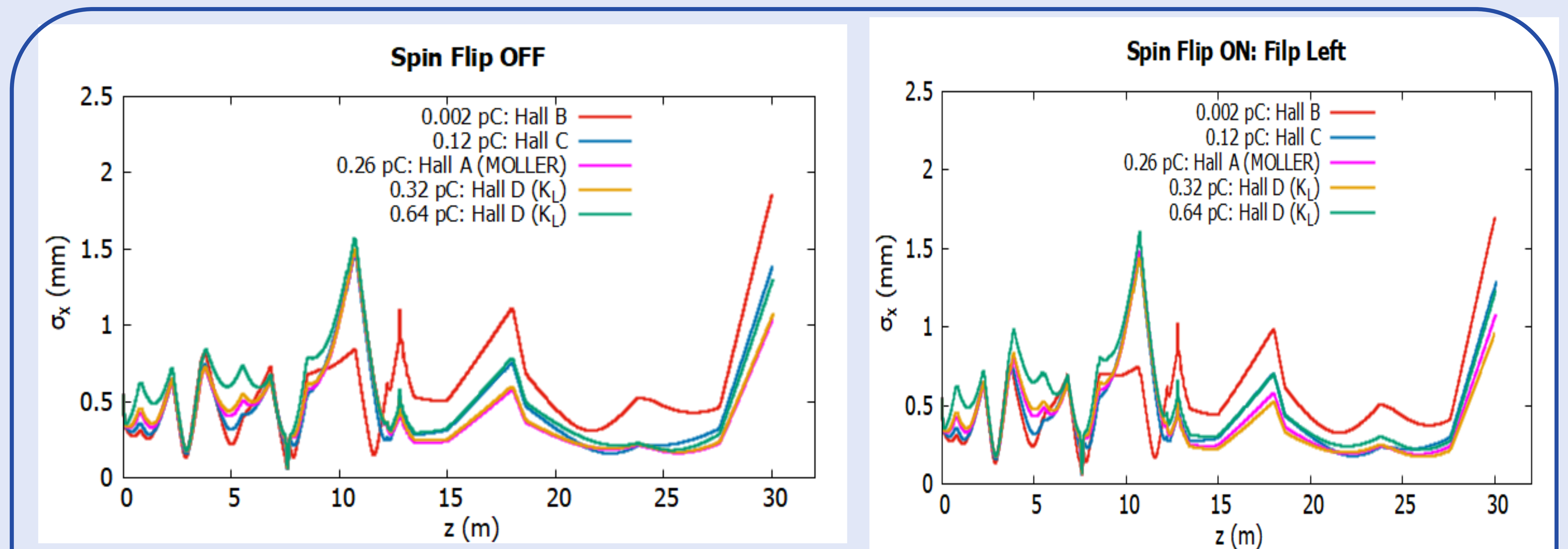
SPIN FLIPPER OFF

beam characteristics	bunch specifications				
	2fC: Hall B	0.12pC: Hall C	0.26pC: Hall A (MOLLER)	0.32pC: Hall D (K_L base)	0.64pC: Hall D (K_L goal)
beam transmission (%)	99.52	94.40	97.84	99.28	95.75
bunch length (ps)	1.12	0.55	0.37	0.38	0.67
$\epsilon_{nx}, \epsilon_{ny}$ (mm-mrad)	0.84, 0.42	0.27, 0.29	0.20, 0.25	0.21, 0.29	0.26, 0.32
σ_x , σ_y (mm)	1.86, 3.36	1.39 , 1.53	1.04, 1.55	1.08, 1.68	1.30, 1.85
$\frac{\sigma_{E_k}}{E_k}$ (%)	1.40	0.65	0.63	0.69	1.04

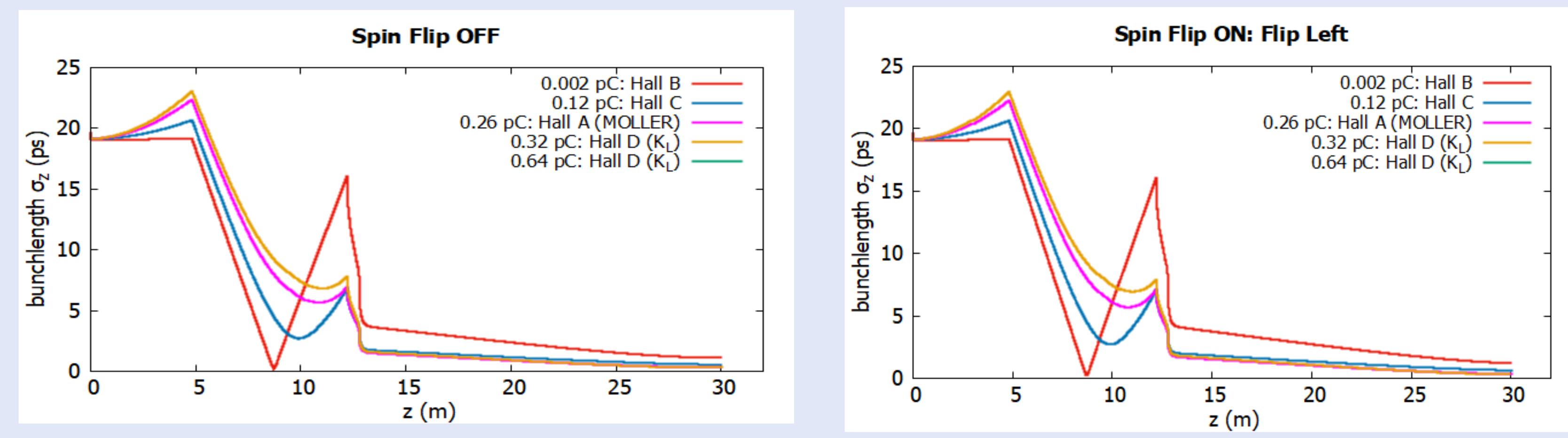
SPIN FLIPPER ON (Flip Left/Flip Right)

beam characteristics	bunch specifications				
	2fC: Hall B	0.12pC: Hall C	0.26pC: Hall A (MOLLER)	0.32pC: Hall D (K_L base)	0.64pC: Hall D (K_L goal)
beam transmission (%)	99.95	96.61	99.93	97.96	99.89
bunch length (ps)	1.21	0.63	0.38	0.37	0.70
$\epsilon_{nx}, \epsilon_{ny}$ (mm-mrad)	0.78, 0.32	0.29, 0.29	0.27, 0.29	0.23, 0.27	0.35, 0.41
σ_x , σ_y (mm)	1.70, 2.53	1.29 , 1.52	1.08, 1.58	0.96, 1.53	1.23, 2.07
$\frac{\sigma_{E_k}}{E_k}$ (%)	1.50	0.70	0.67	0.74	1.16

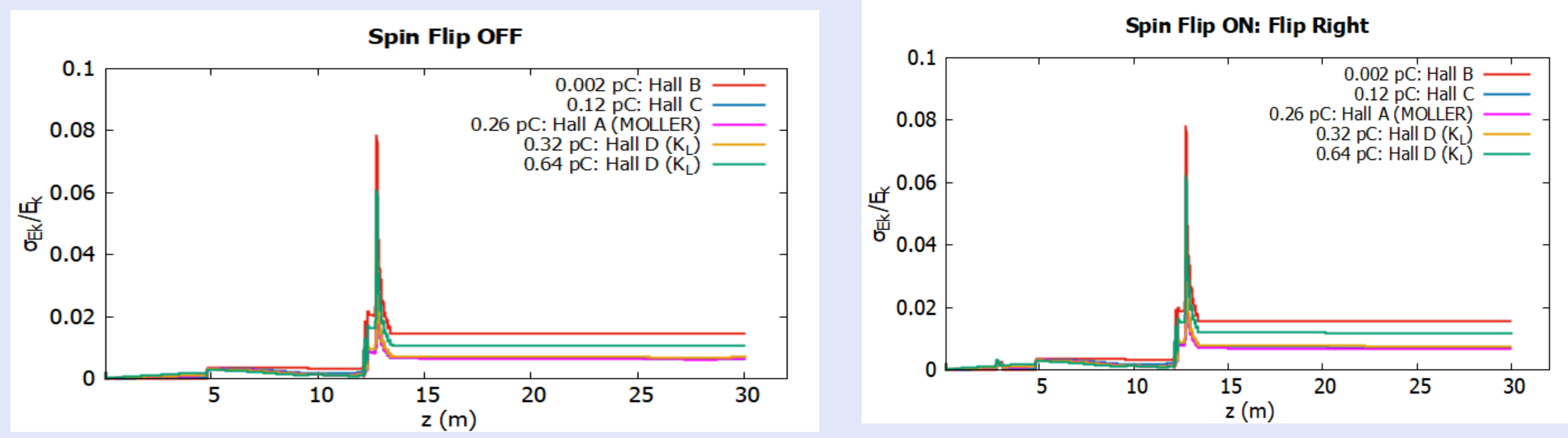
***There is no significant difference in the beam characteristics with spin flip left and right. The average KE after the quarter cryomodules is 6.98 MeV.**



Horizontal beam sizes for different bunch charge specifications along the injector



Bunch length variation along the beamline for different bunch charge specifications.



Energy spread σ_{E_k}/E_k for different bunch charge specifications for four experimental Halls.

OUTLOOK AND FUTURE WORK

- CEBAF Injector simulation with the spin rotator (VWien + spin solenoids) was performed to see the effects of spin manipulation on the beam transmission and beam characteristics. Simulations indicate good transmission and beam quality at twice the baseline of the K-long bunch charge. At optimized settings for a high charge, simultaneous operation with Halls A, B, C, and D is indicated, with minor differences in the transverse beam optics with the Spin flipper OFF and ON.
- The CEBAF Gun voltage now is 180 kV. A plan has been made for optimizing the CEBAF injector at 180 kV. After getting the optimized settings, simulation can be performed by setting the Spin flipper ON and OFF using the Wien system (both VWien and HWien) and Spin solenoids. This will help to find the compatibility of the MOLLER on the K-Long experiment.

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ACKNOWLEDGEMENTS

This material is based on research work supported by the U.S. Department of Energy under contract No. DE – AC05 – 06OR23177.

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