Bunch Length Measurements at the CEBAF Injector at 130 kV

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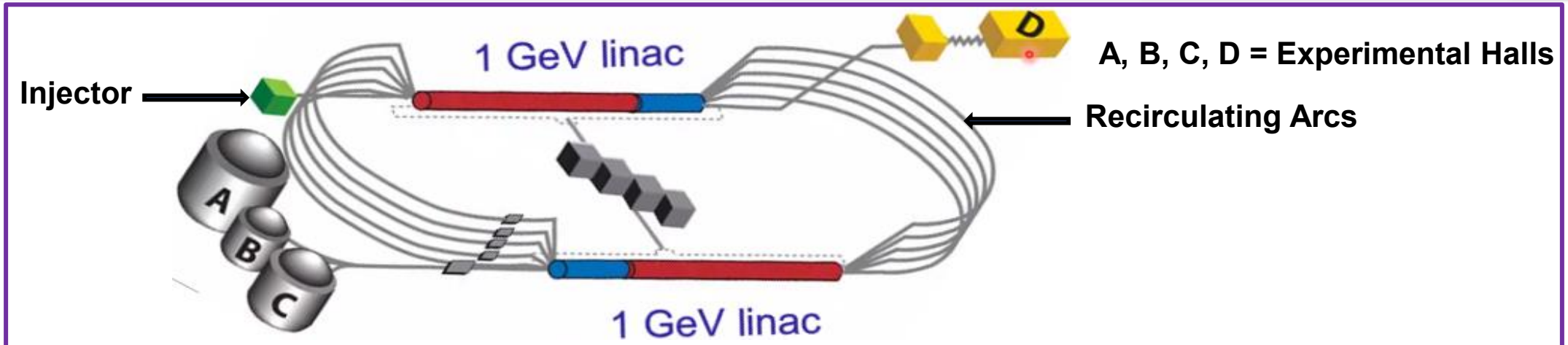
Outline

- Continuous Electron Beam Accelerator Facility (CEBAF) Injector
- Chopper and the Measurement Technique
- Laser Parameters for Simulation
- Results: Simulations and Measurements
- Summary and Outlook

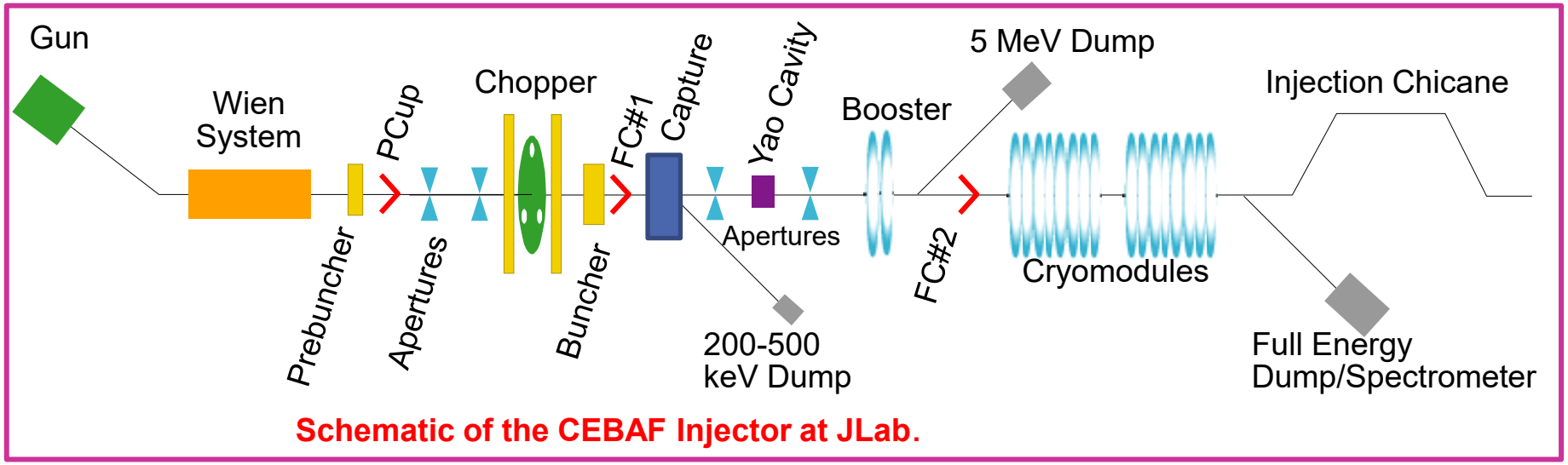
Continuous Electron Beam Accelerator Facility

Aerial view of CEBAF accelerator complex at Jefferson Lab. The four experimental halls are highlighted. The unique design of this accelerator allows four experimental halls to be operated simultaneously.

CEBAF Injector



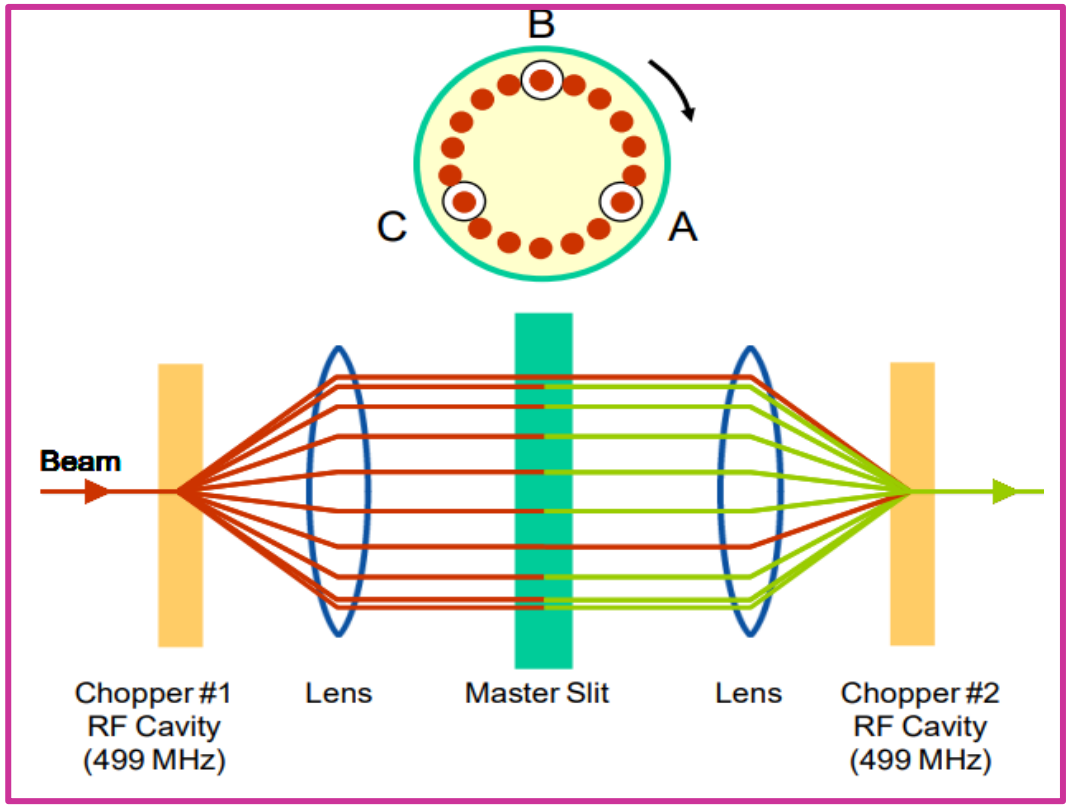
Schematic Representation of CEBAF Accelerator at JLab.



Schematic of the CEBAF Injector at JLab.

CEBAF Injector Chopping System

- Beam from 130 kV gun passes through two 499 MHz chopper cavities, two solenoid lenses, master slit in between
- Transverse orthogonal magnetic fields rotate the beam in circle of ~1.5 cm radius.
- Slits at 240°, 0°, and 120° allow bunches of electrons to pass



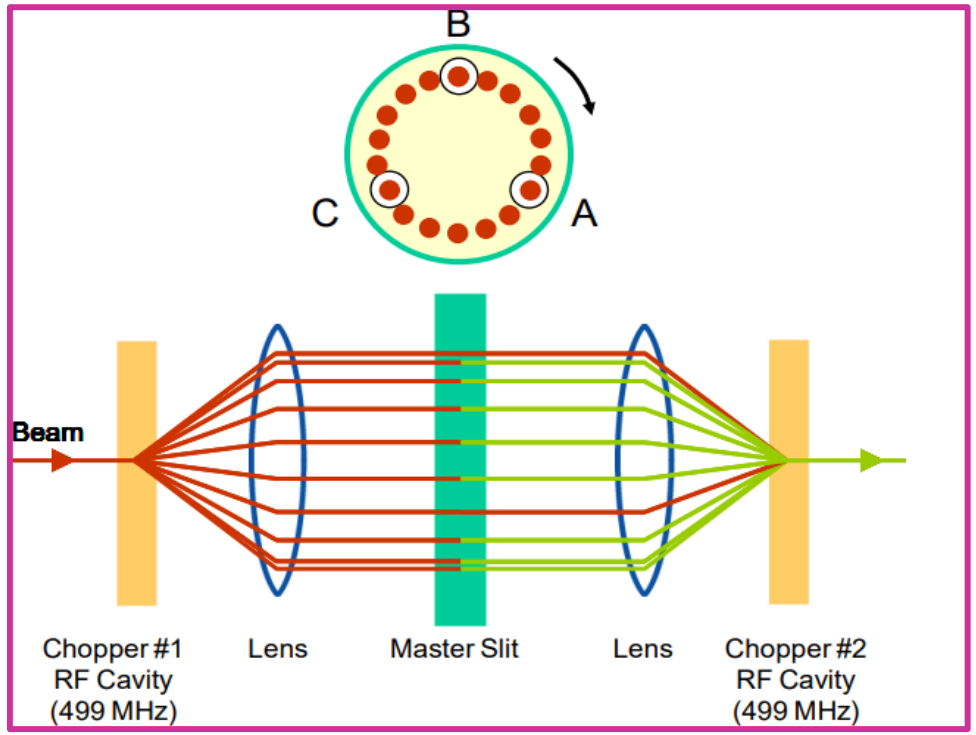
Three beam chopping system.

Y. Wang, "CEBAF overview" HUGS 2010

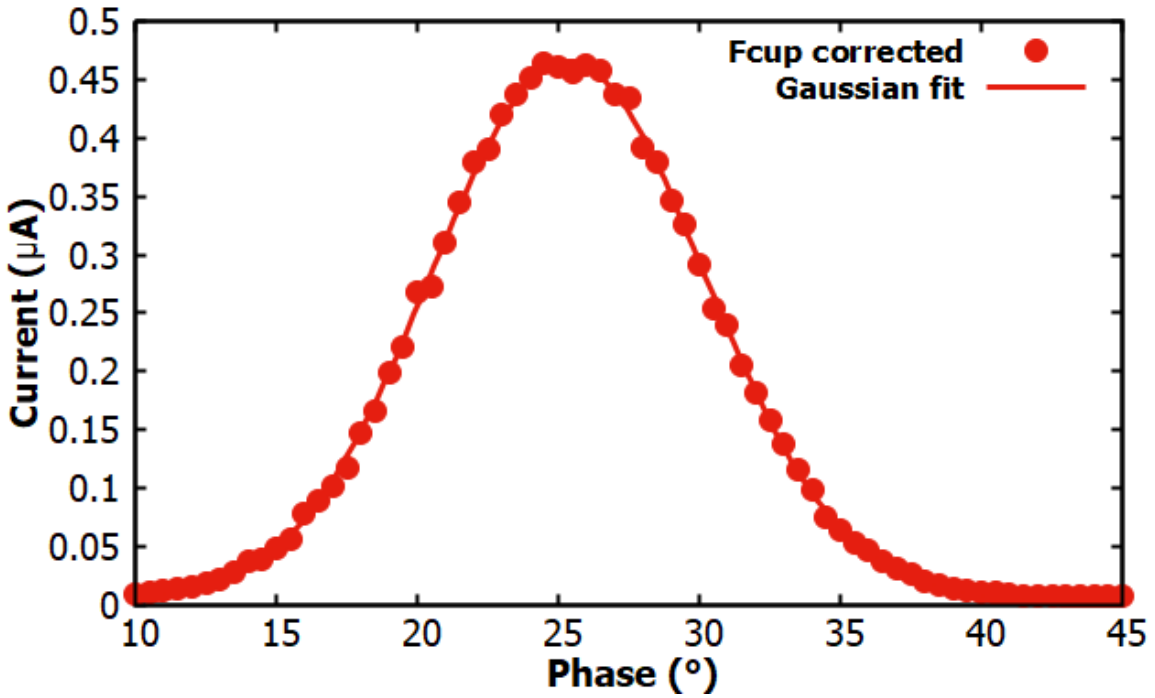
R. Abbott, et al, Proceedings. Intl. Linac conf. 1994

Chopper Phase Scanning Technique

- Faraday Cup in conjunction with the chopper used for measuring bunch length
- Chopper selects a small fraction of the longitudinal phase
- Recording Faraday cup current as chopper phase is scanned, longitudinal profile obtained

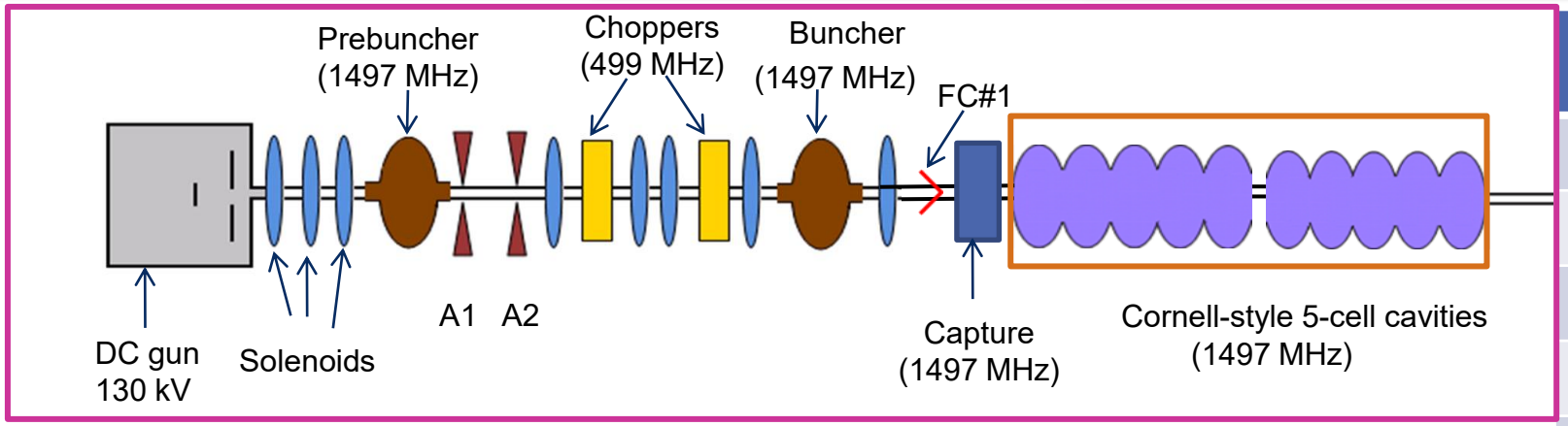


Three beam chopping system



Chopper Scan for 2.5 μA beam at 249.5 MHz Prebuncher off.

Laser Parameters



CEBAF Injector Layout

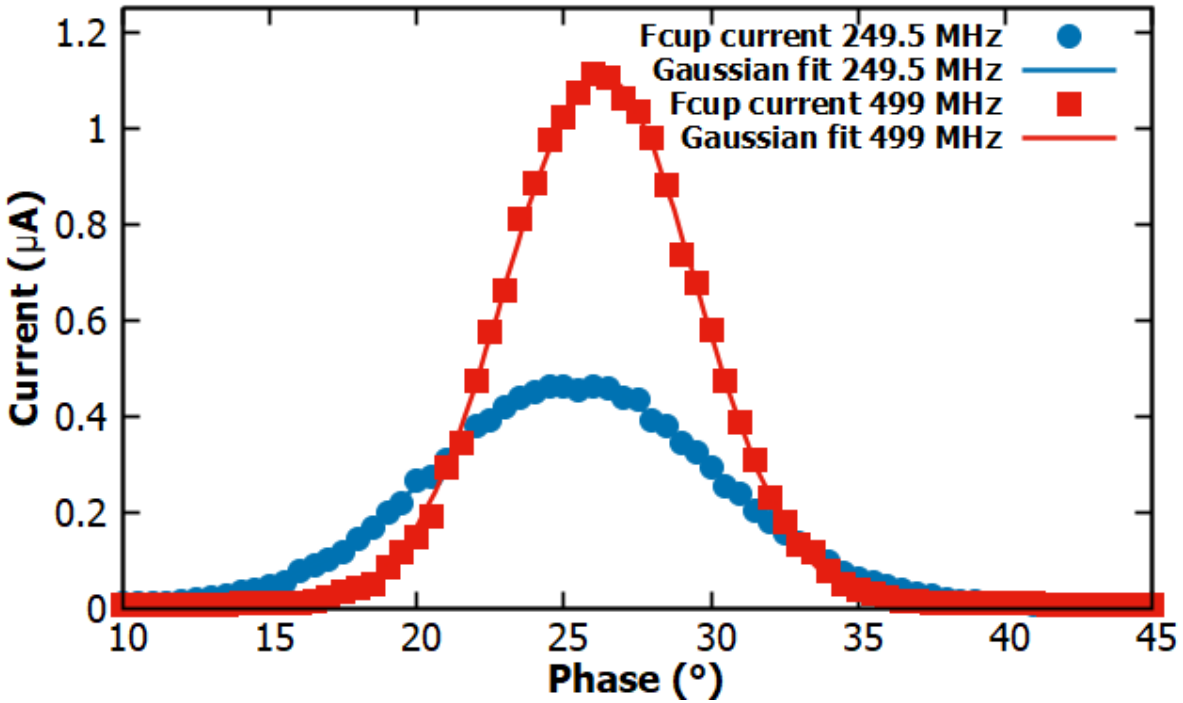
Elements	Center Distance from the cathode
Prebuncher	5.363
A1	6.48 m
A2	7.156
Choppers	7.60 m
Buncher	8.884
Faraday Cup#1	9.45
Capture	10.178
First 5-cell	12.426
Second 5-cell	13.185

- Particle distribution at cathode Gaussian distributions for t, x, y, p_x, and p_y:
  - 2-200 μA, 10 k macroparticles
  - Transverse rms beam size on cathode

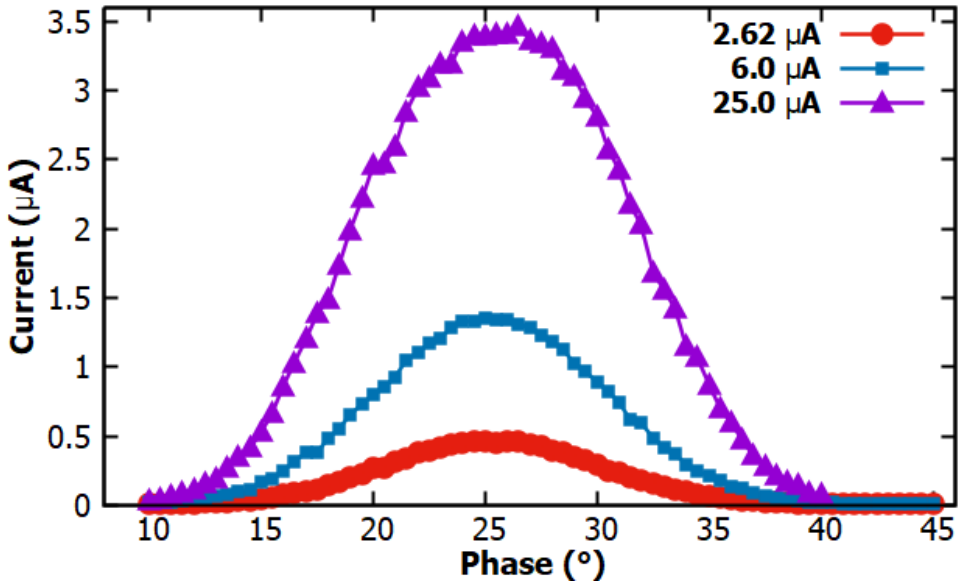
  σ_x = 0.55925 mm, σ_y = 0.52325 mm (previously measured)
  - Transverse emittance 0.061 mm mrad
  - Laser pulse lengths 62.5 ps (FWHM) for 249.5 MHz, and 41.6 ps (FWHM) for 499 MHz drive lasers

Simulations using General particle Tracer (GPT)

Results: Measurements at low charge (current)



Chopper phase scan for measuring beam pulse length for 249.5/499 MHz laser drive frequency at 10 fC electron bunch with PB OFF

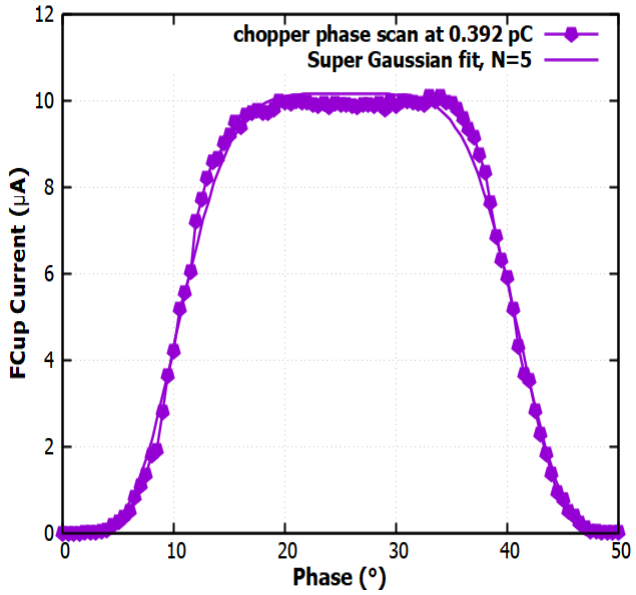


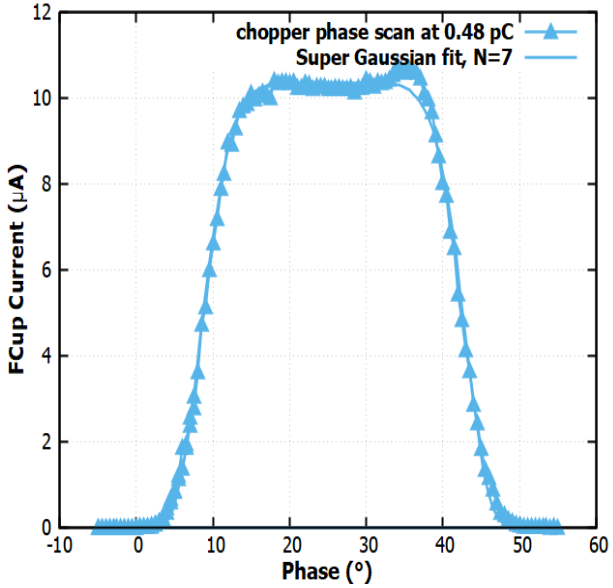
Chopper phase scan for different beam current for 249.5 MHz laser drive frequency with PB OFF, 27.10 ps, 28.10 ps and 35. 87 ps

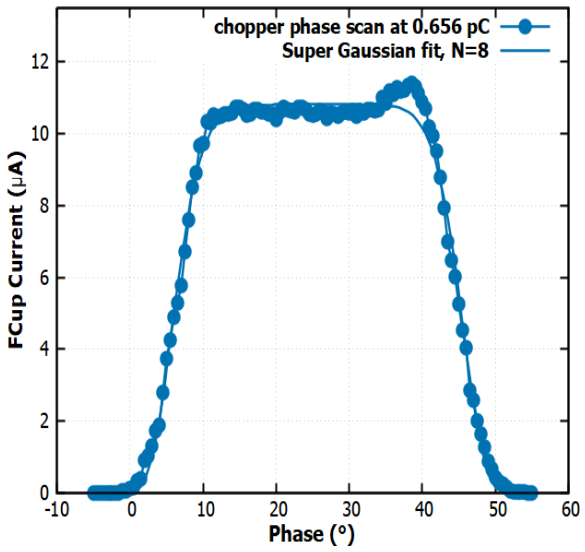
Longitudinal profile at the chopper scan is Gaussian,

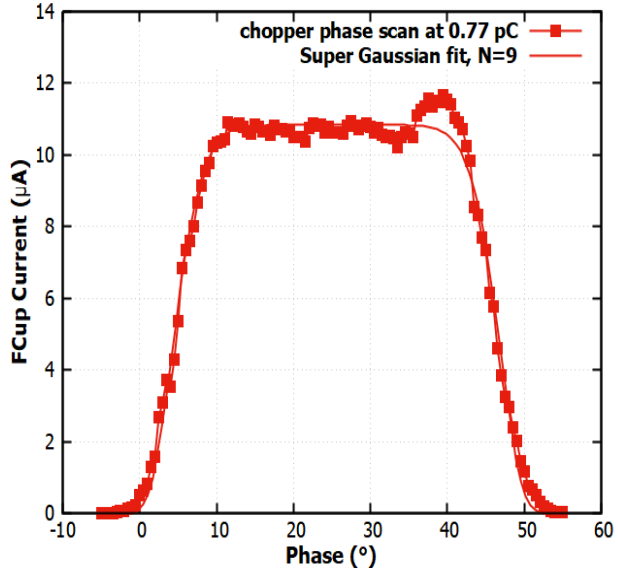
$$f(x) = \frac{a}{\sigma\sqrt{2\pi}} \exp\left(-\frac{(x-\mu)^2}{2\sigma^2}\right)$$

Results: Measurements at high charge (current)









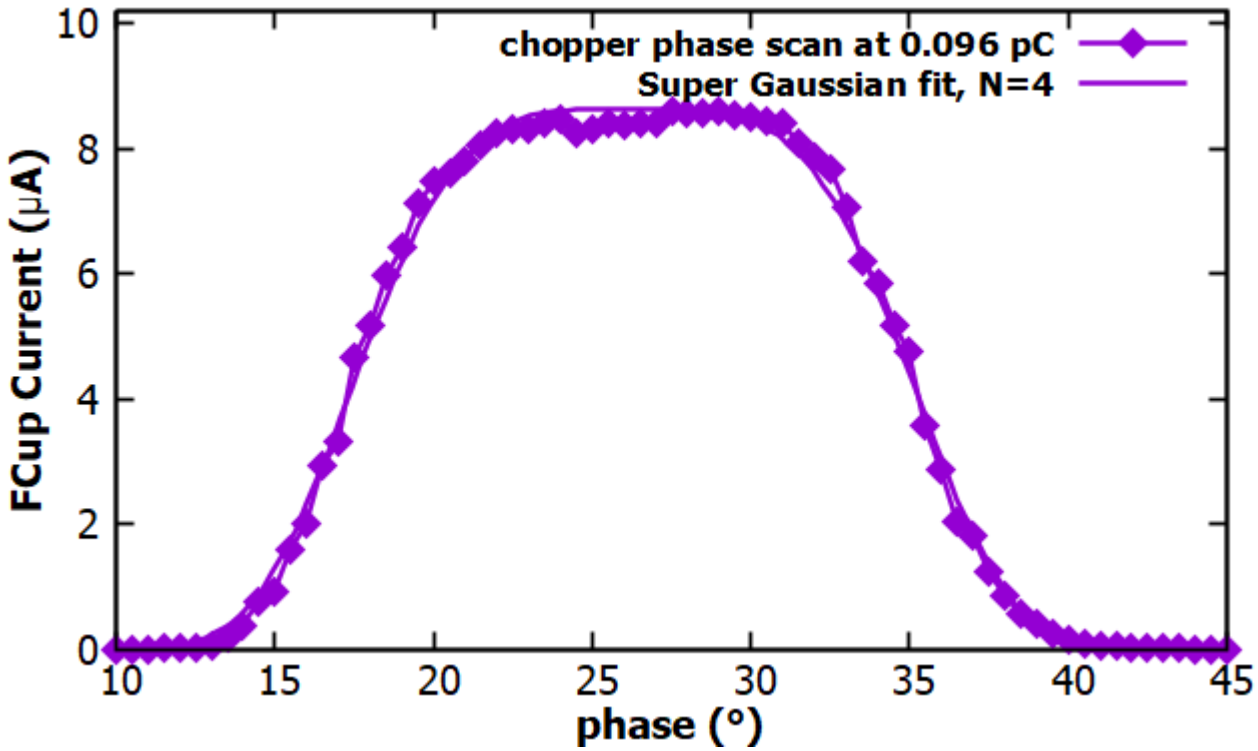
Chopper phase scan at 249.50 MHz frequency of the drive laser

Longitudinal profile at the chopper is Super Gaussian,

$$f(x) = \frac{a}{\sigma_0\sqrt{2\pi}}\exp\left(-\frac{(abs(x-\mu))^N}{2\sigma_0^N}\right) \quad \text{with } \sigma = \sigma_0.\left(\frac{\pi}{2}\right)^{\frac{2}{N}-1}$$

F.-J. Decker , AIP Conf. Proceedings. 333, 550 (1995)

Results: Measurements at high charge (current)

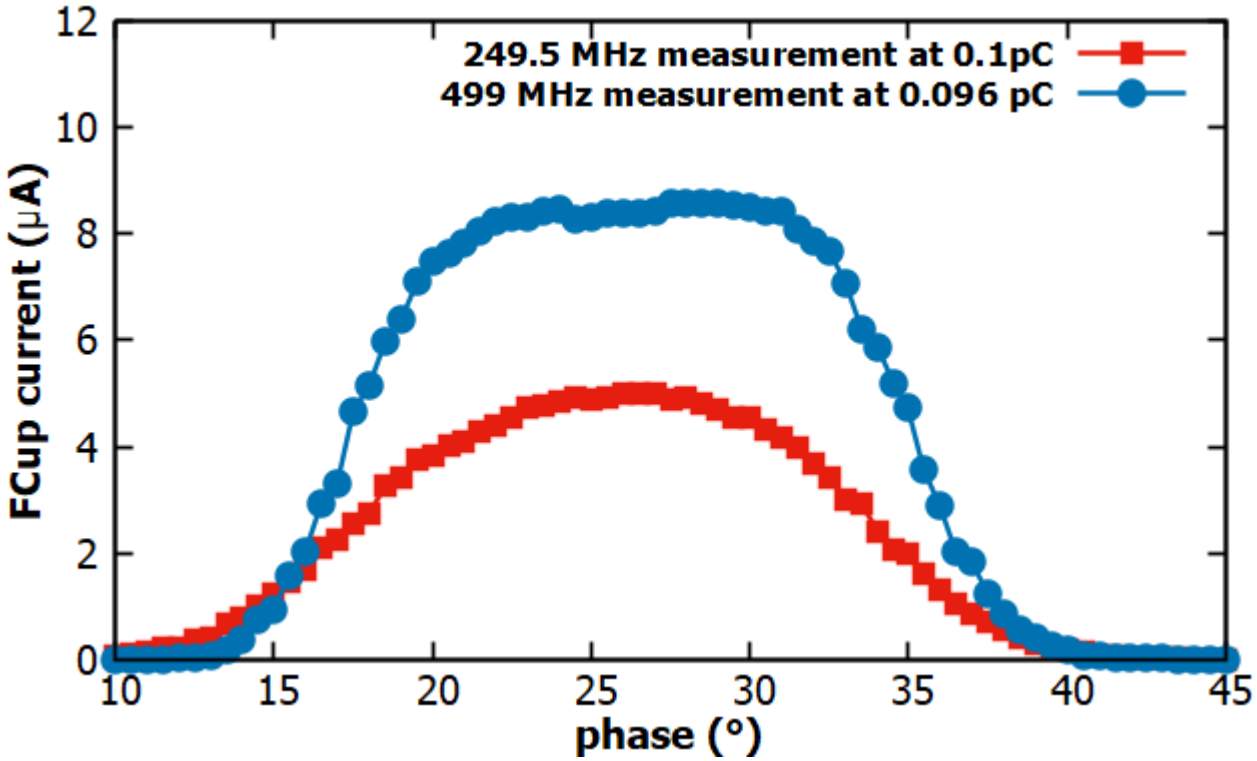


Chopper phase scan at 499 MHz frequency of the drive laser Prebuncher OFF

Longitudinal profile at the chopper is Super Gaussian

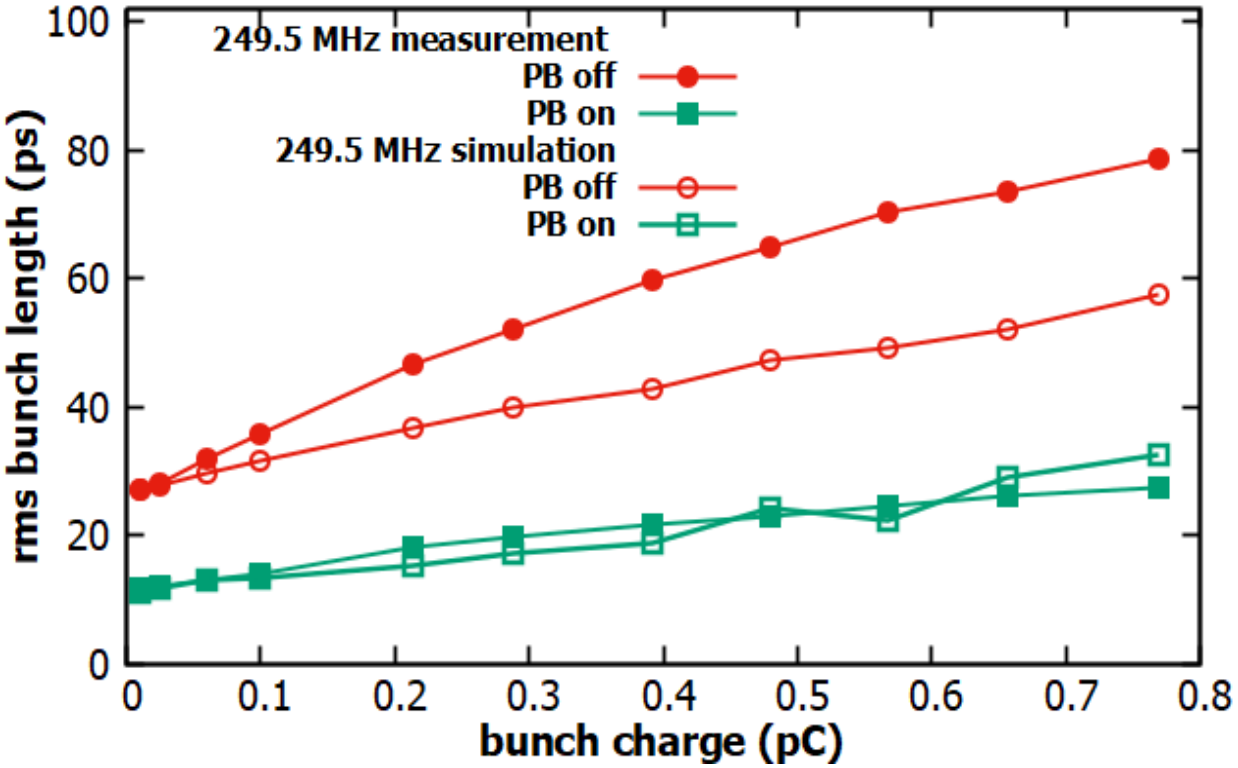
Results: Measurements Comparison

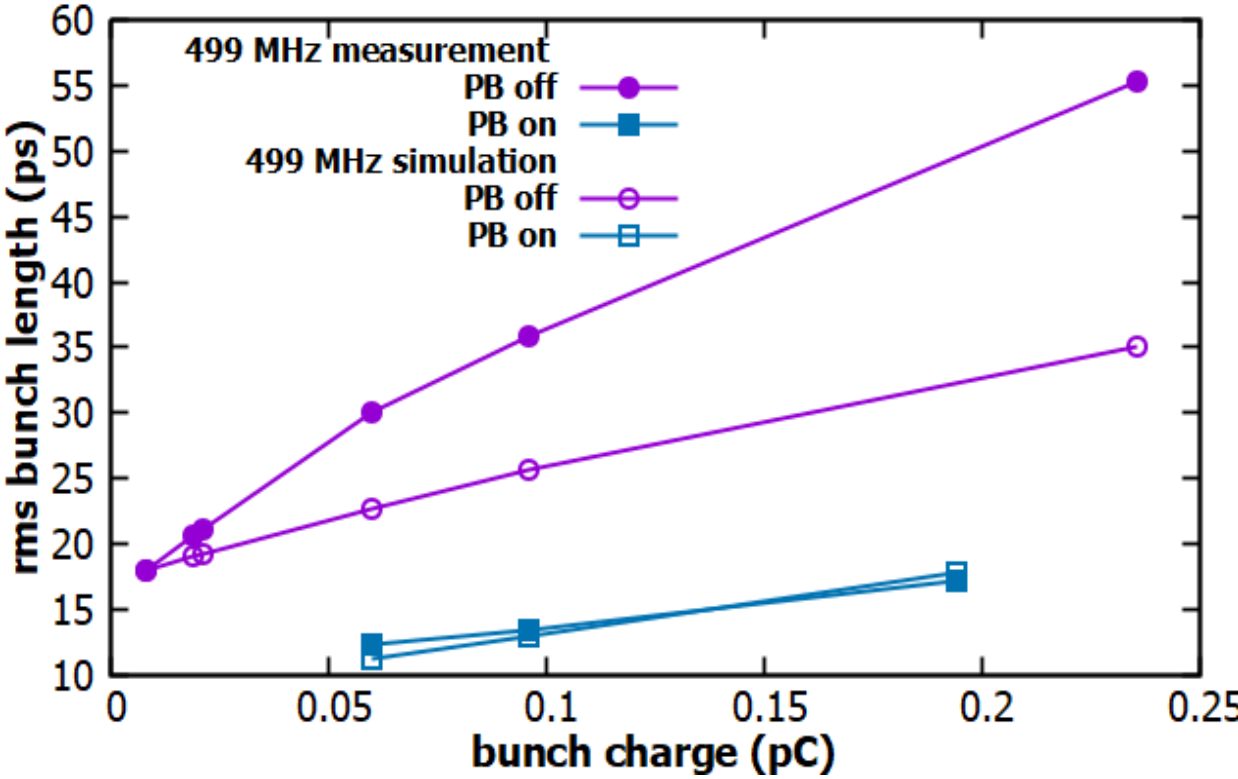
- The bunch lengths for the same charge are equal



Longitudinal bunch profile at the chopper Prebuncher OFF.

Results: Measurements and Simulations





Comparison between measurement and Simulation with/without Prebuncher on.

Summary & Outlook

- Simulated CEBAF injector model using GPT to investigate evolution in bunch length of beams injector, analyzed beam to get bunch lengths at Chopper with 130 kV gun.
- Performed chopper phase scanning measurements to validate the model.
- With Prebuncher OFF bunch profile is Gaussian at low (< 40 fC) charge but Super Gaussian at higher (> 90 fC) charge. With PB ON bunch profile is Gaussian for both low and high charges.
- There is good agreement between measurements and corresponding simulations when PB is ON, but not when it is OFF.

Acknowledgement

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Questions, Comments, Suggestions ??