50-MeV RUN OF THE IOTA/FAST ELECTRON ACCELERATOR*

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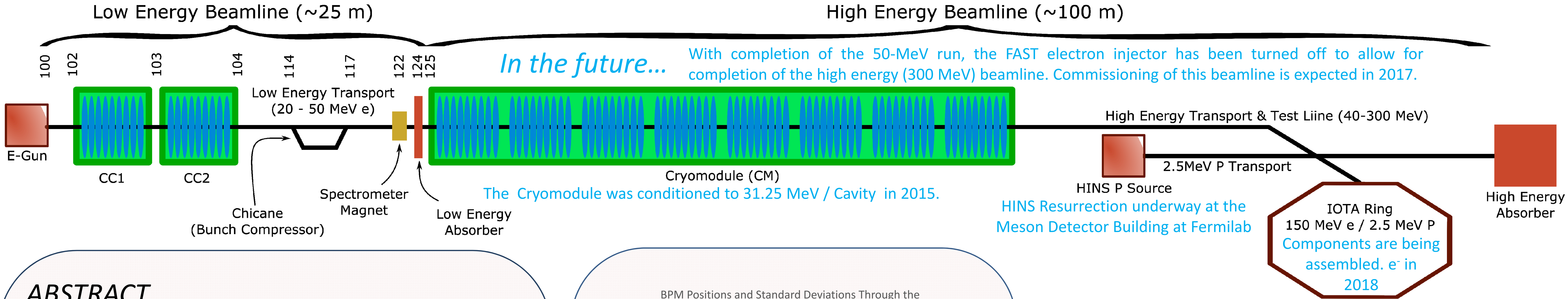
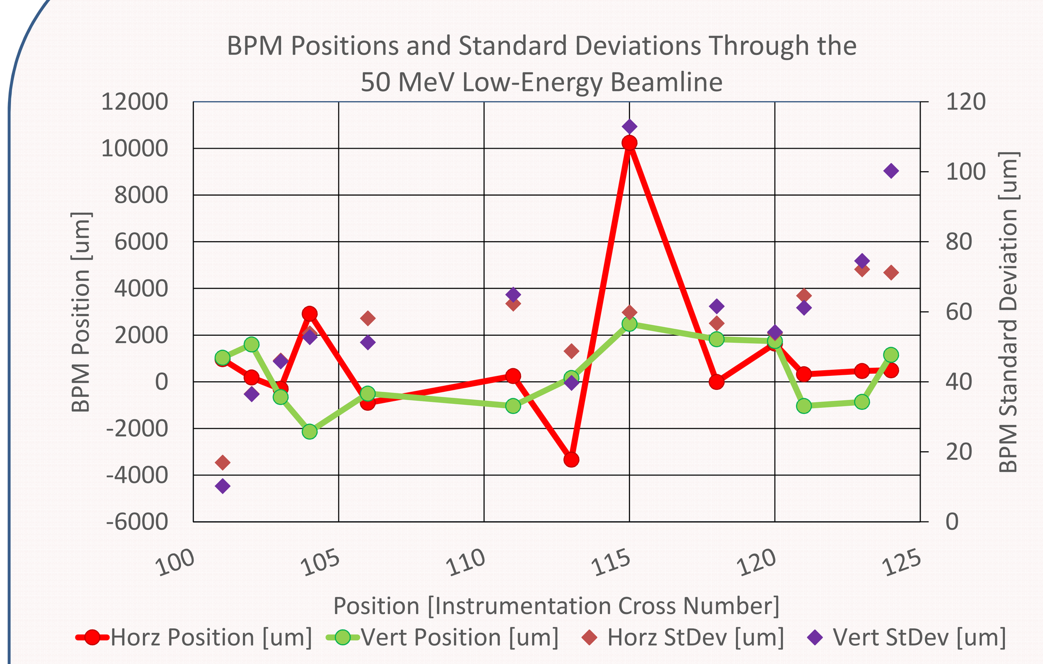


ABSTRACT

The low-energy section of the photoinjectror-based electron linear accelerator at the Fermilab Accelerator Science & Technology (FAST) facility was recently commissioned to an energy of 50 MeV. This linear accelerator relies primarily upon pulsed SRF acceleration and an optional bunch compressor to produce a stable beam within a large operational regime in terms of bunch charge, total average charge, bunch length, and beam energy. Various instrumentation was used to characterize fundamental properties of the electron beam including the intensity, stability, emittance, and bunch length. While much of this instrumentation was commissioned in a 20 MeV running period prior, some (including a new Martin-Puplett interferometer) was in development or pending installation at that time. All instrumentation has since been recommissioned over the wide operational range of beam energies up to 50 MeV, intensities up to 4 nC/pulse, and bunch structures from ~1 ps to more than 50 ps in length.

The table below contains a summary of FAST Beam parameters. Those verified previously, but not as part of the 50 MeV run, are denoted with an asterisk.

Parameter	FAST Value
Beam Energy	20 MeV – 50 MeV
Bunch Charge	< 10 fC – 3.2 nC per pulse
Bunch Train (Macropulse)	0.5 – 9* MHz for up to 1 ms (3 MHz nominal)
Train Frequency	1 – 5* Hz
Bunch Length	Range: 0.9 – 70* ps (Nom: 5 ps)
Bunch Emittance for 50 pC/pulse	Horz: 1.6 ± 0.2 µm Vert: 3.4 ± 0.1 µm

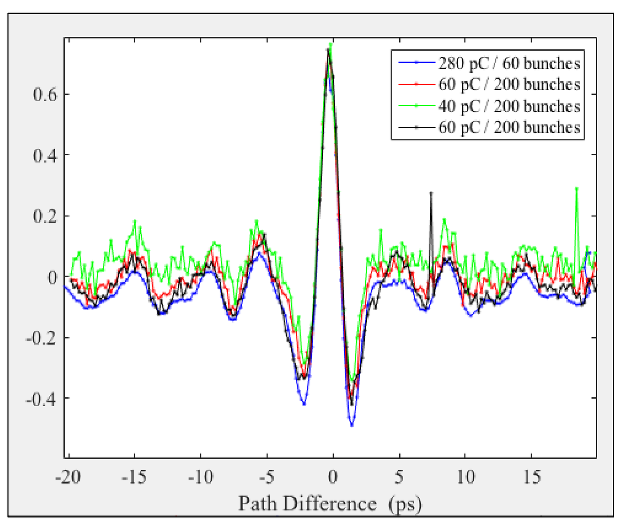


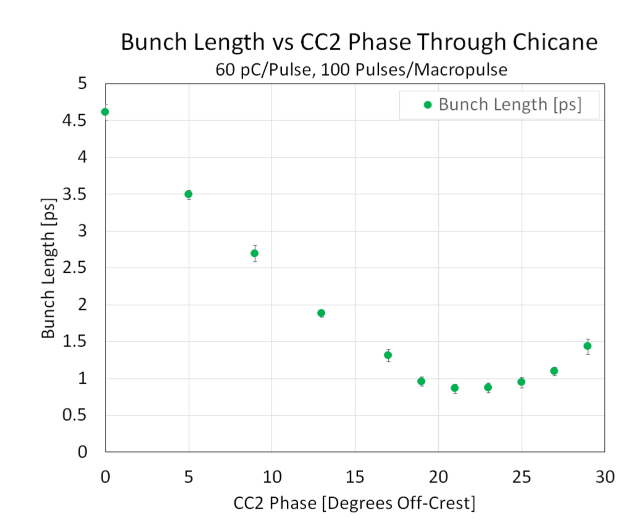
Beam Position Monitors

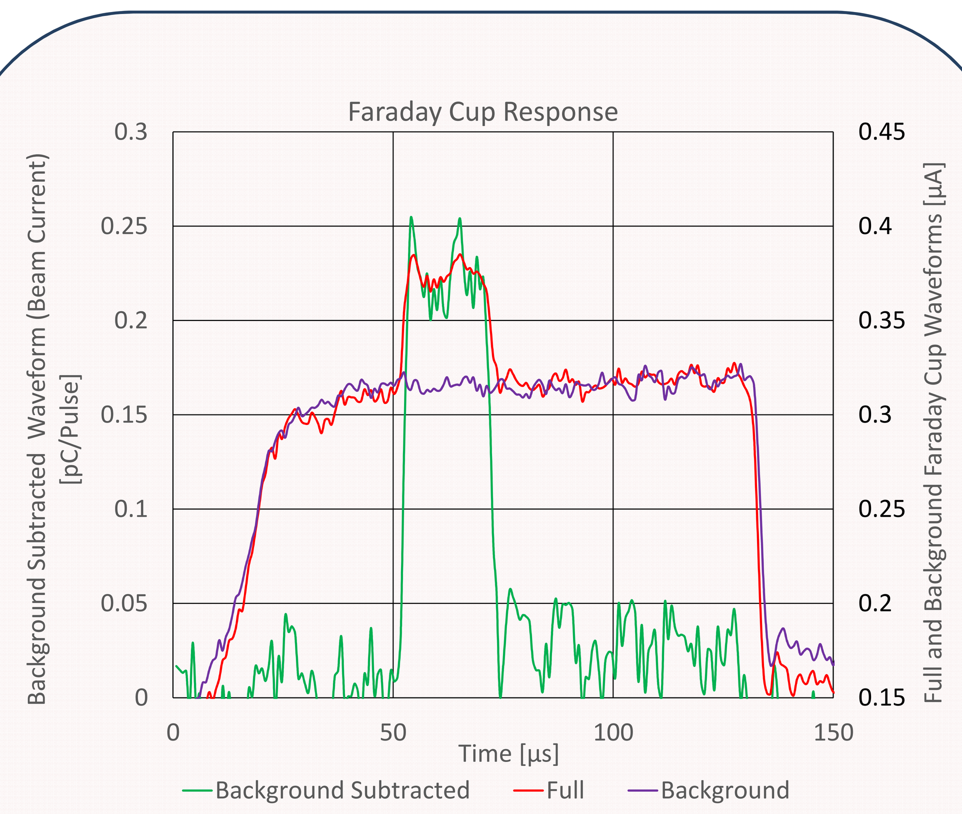
BPMs are distributed along the FAST beamline and used for tuning the beam to an established beam path for each of the measurements shown here. They were also relied upon directly for measurement of the beamline stability (above), HOM integration, and Capture (TESLA-style SRF) Cavity transport matrix measurement.

Bunch Length Measurement

The Martin-Puppelet Interferometer and electron beamline streak camera were used to measure a compressed bunch length as short as 0.86 ps. Both use Optical Transition Radiation (OTR) from the TPM at instrumentation cross at X121, where a thin foil is inserted into the beam plane. A ceramic gap monitor is also installed and will be able to provide a self-calibrated readback of the bunch length. in the future.

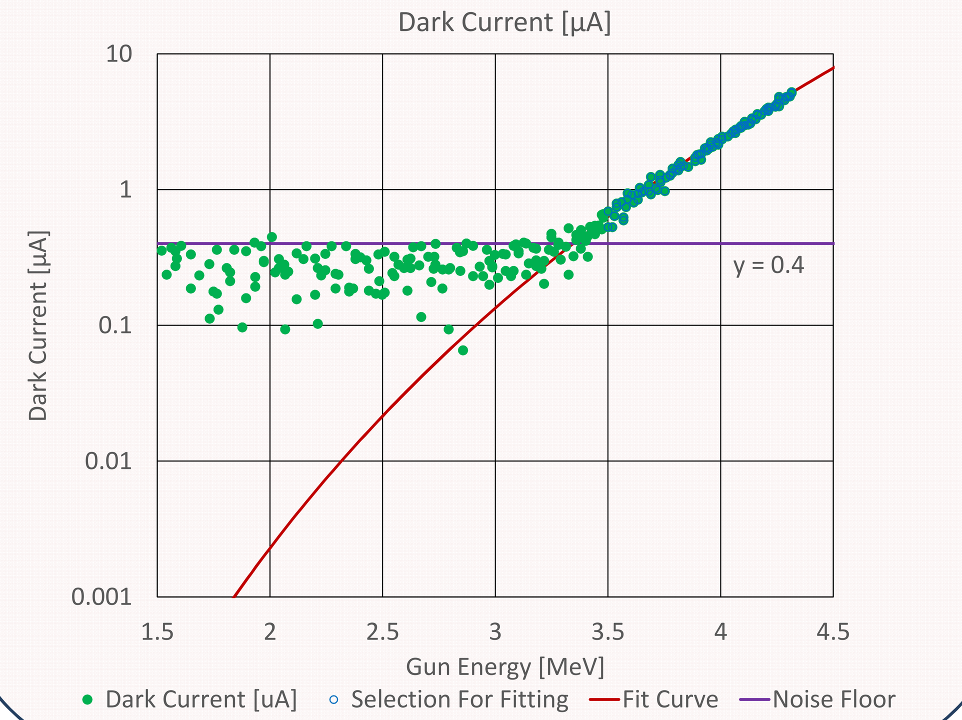






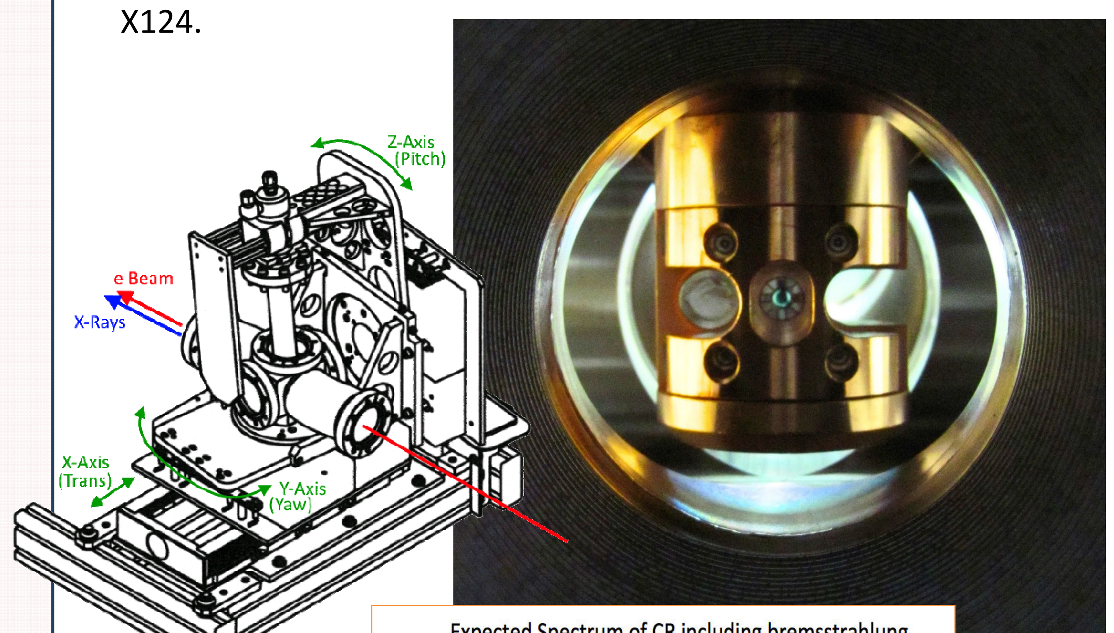
Crystal Channeling

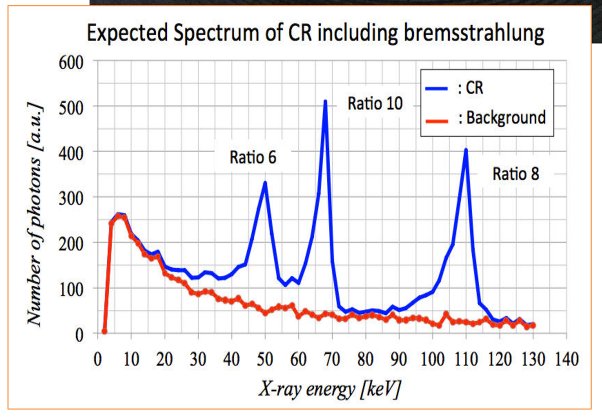
The crystal channeling effort in this run employed a goniometer (right) to place a diamond crystal into the electron beam path with a the transverse axis, and then alignment to a channel with two rotational axes. Single-photon x-ray spectrometers were placed at the end of the low-energy beamline. These required low bunch charges (~50 fC/pulse) but also considerable mitigation of dark current from the gun, because the dark current dwarfs the bunch charge signal at such low charge as shown above. This was done by shortening the gun pulse length, running at a lower gun gradient (~3.5 MeV instead of 4.5 MeV output energy as seen below), collimating the gun output, and momentum-scraping through the chicane.



Goniometer

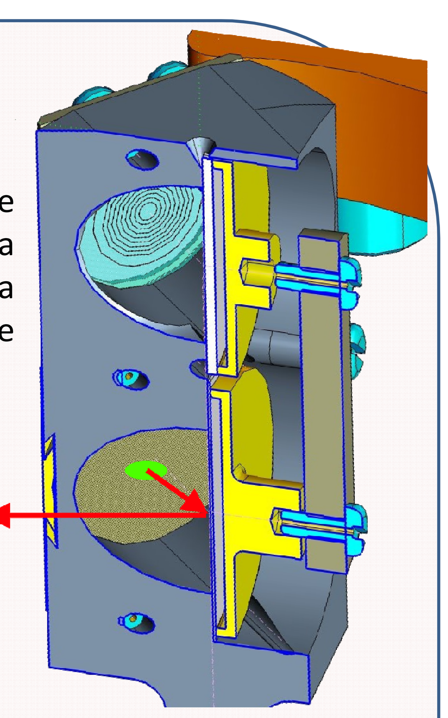
The goniometer used for crystal channeling is a 3-axis instrument installed at X120 with a diamond crystal, thin foil and open channel along the lateral axis shown below from the beam's eye view. In the event of crystal channeling, peaks were expected to emerge in the bremsstrahlung background x-ray energy spectrum measured at X124.

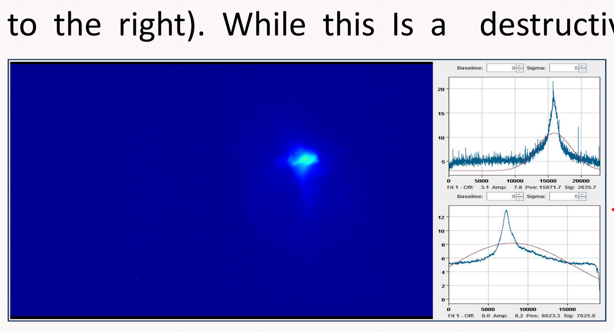


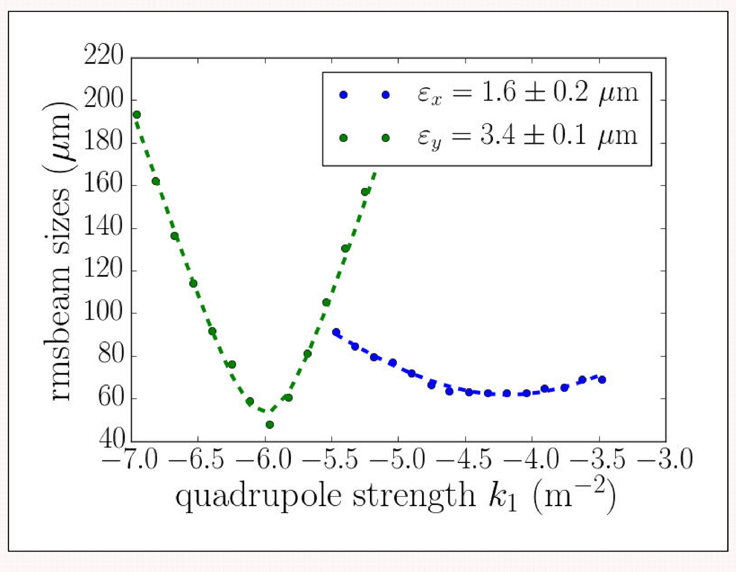


TPMs and the Electron Beam Emittance

The electron beam emittance is measured with a quadrupole current scan while monitoring the resulting change in spot size. This is done by inserting a transverse profile monitor (TPM) so that the primary beam is incident on a Cerium-doped YAG screen (shown to the right). While this Is a destructive measurement, the YAG screen scintillates to allow for direct measurement of the transverse beam size. The camera monitoring the YAG screen at instrumentation cross X121 measured the transverse profile of the beam as the quadrupole Q120 current was scanned through a range limited by the beam image size on the YAG screen. These beam images were fit to a Gaussian for each breakpoint along the quadrupole scan. Once the scan was complete, the quadrupole currents [A] put in terms of magnet strength [m-2] and the sigmas [px] in terms of RMS Beam sizes [µm]. These are fit and the emittances extracted from the model as shown to the right.

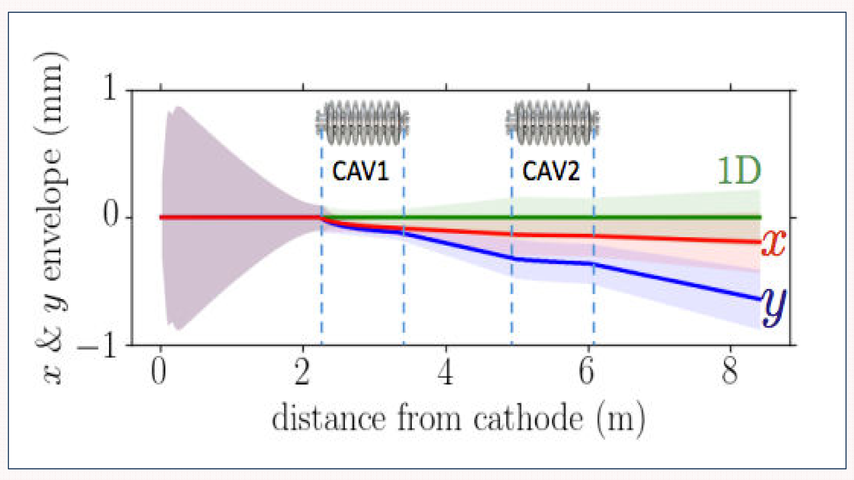


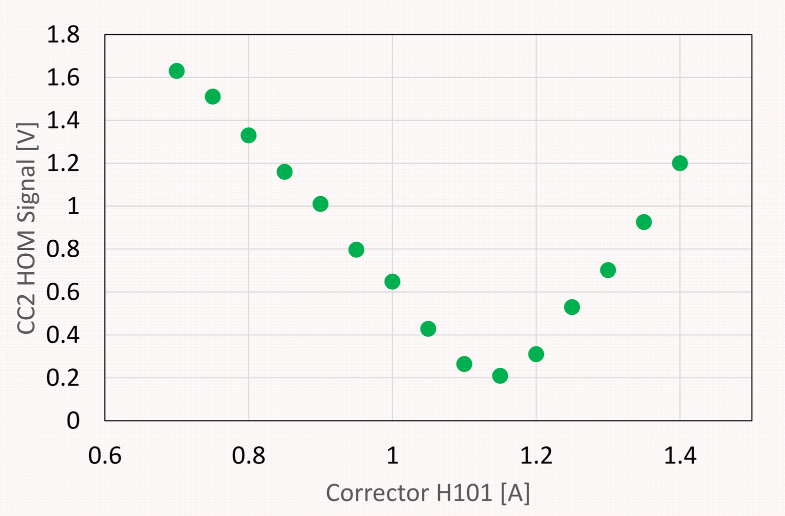


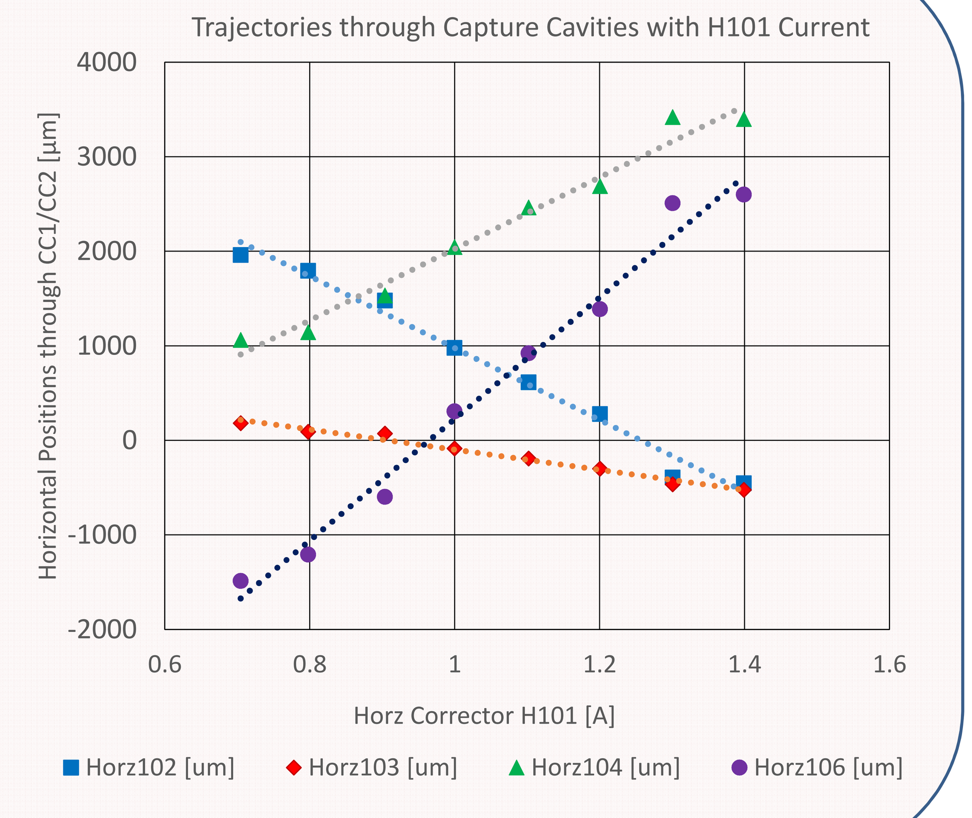


HOM Integration / Cavity Transport Matrix Measurement

The beam trajectory through the CC1 and CC2 SRF cavities immediately downstream of the gun depends strongly on input beam position and will affect development of higher order modes (HOMs) and higher emittances downstream. To understand beam transport through the cavities, a transport matrix measurement was made (results presented at LINAC2016), and the CC HOM detector signals were minimized, as shown below.







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