

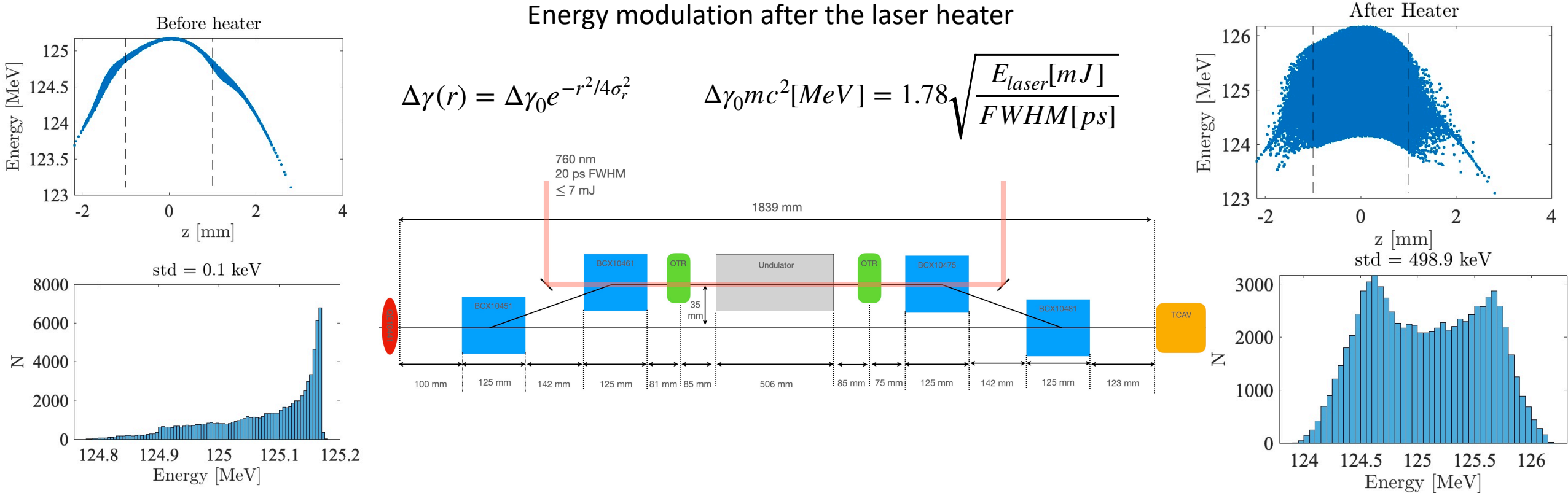
Benefits of the laser heater at FACET-II

E-300 Collaboration Meeting

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October 5, 2022

What is the laser heater and what does it do?



- The laser heater is a device designed to increase the energy spread of the electron beam at the exit of the injector
- It consists of a 9 period undulator and a four dipole chicane located downstream of L0b and upstream of TCAV0
- The FACET-II laser heater closely follows the LCLS design (see [1]-[5])

Why do we want the laser heater at FACET-II?

1. Control of the peak current at the FACET Interaction Point (IP).
 - 1.1. Reduction of the IP emittance, achieved by reducing the peak current in the bunch compressors to limit Coherent Synchrotron Radiation (CSR).
2. Reduction of the jitter in peak current at the IP.
3. Suppression of the micro-bunching instability and consequent emission of COTR

1. Control of the peak current and emittance at the IP

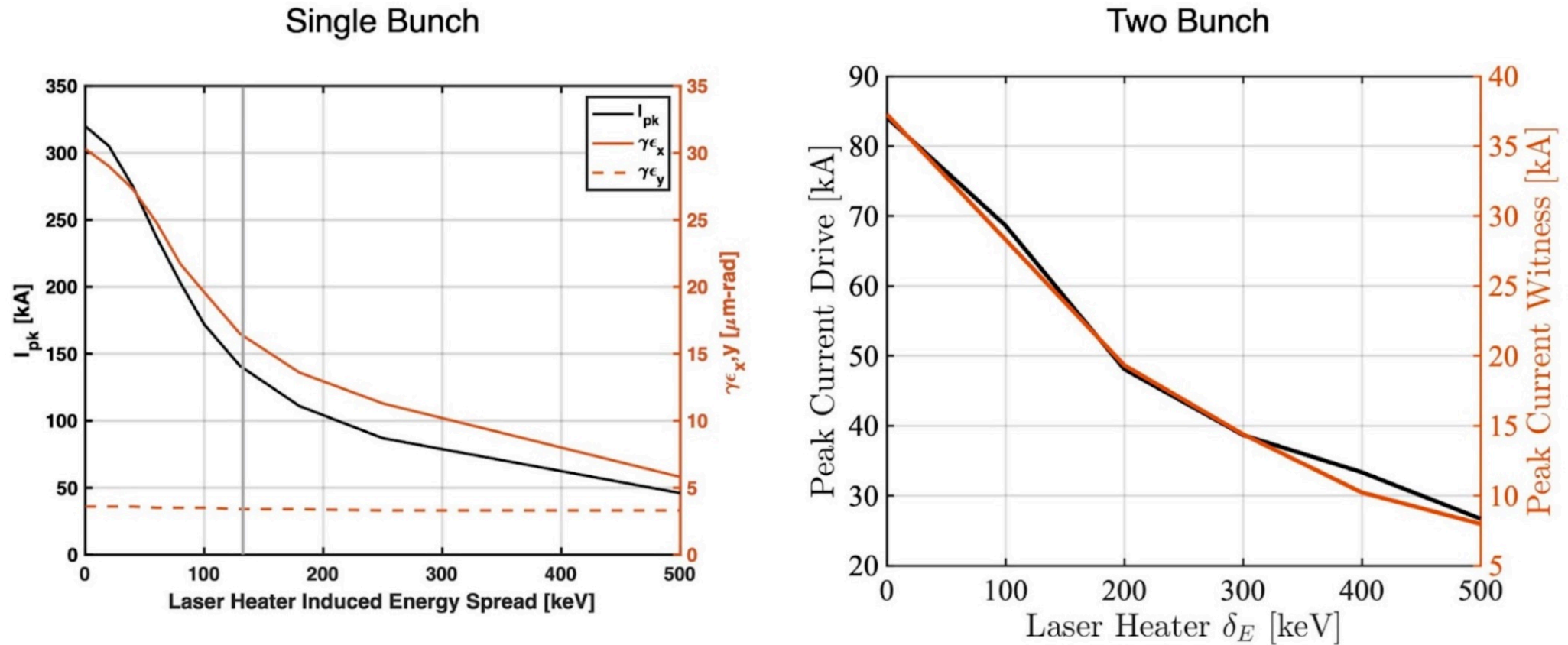
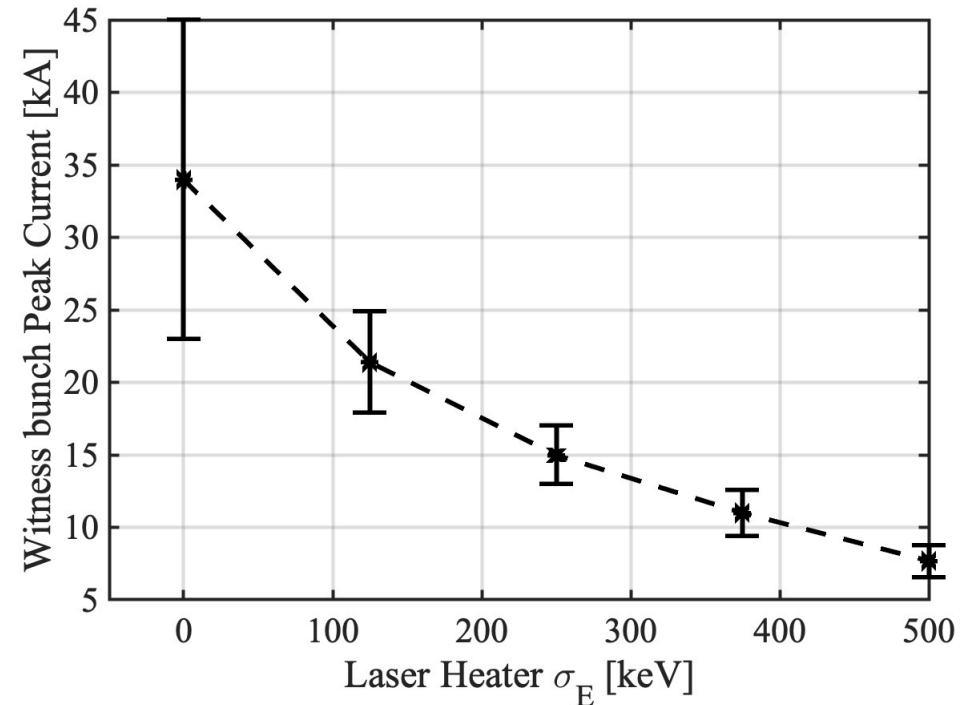
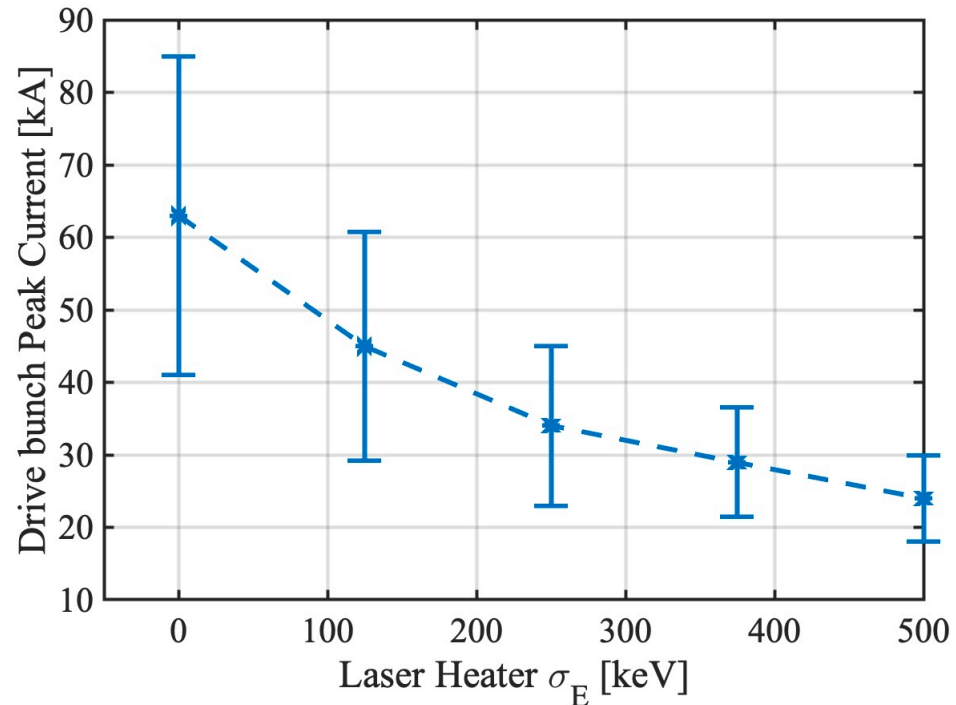


Figure 1: (left) Peak current and emittance as a function of laser heater energy for the single bunch 2nC nominal running parameters of FACET-II. (right) Peak current as a function of RMS laser heater energy modulation for the nominal two-bunch run parameters (1.5/0.5 nC for drive/witness beam).

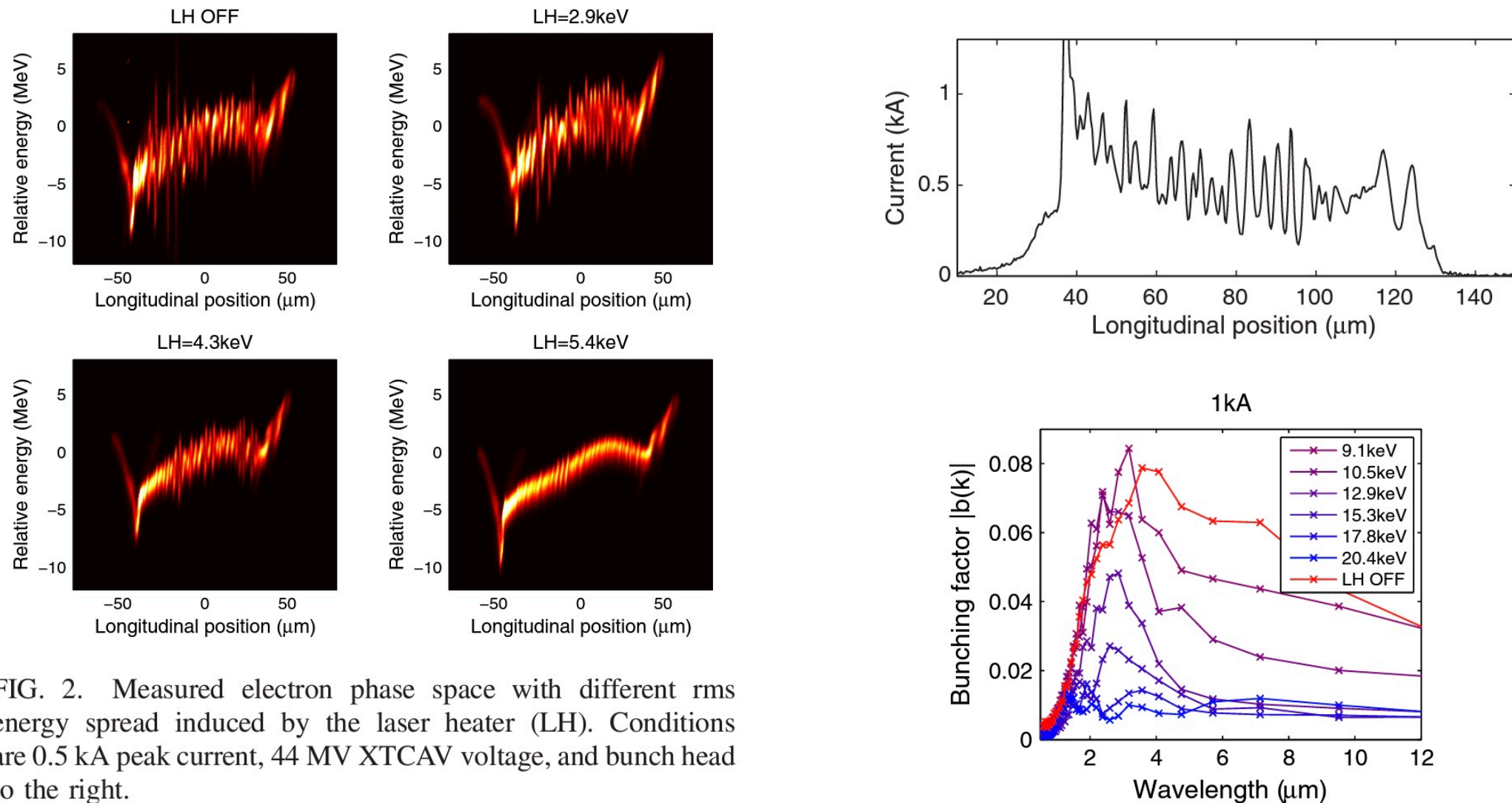
2. Reduction of the peak current jitter at the IP (two bunch)

500 simulations per LH value $N_p = 1e5$, 1D CSR On



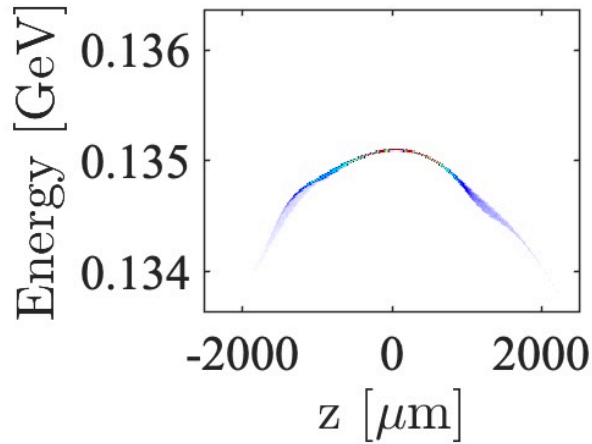
	LH = 0 keV	125 keV	250 keV	375 keV	500 keV
Drive Bunch I_{pk} (mean+/- std) [kA]	63 ± 22	45 ± 16	34 ± 11	29 ± 7.6	24 ± 6
Witness Bunch I_{pk} (mean+/- std) [kA]	34 ± 11	21 ± 3.5	15 ± 2	11 ± 1.6	7.7 ± 1.1

3. Suppression of micro bunching instability at LCLS

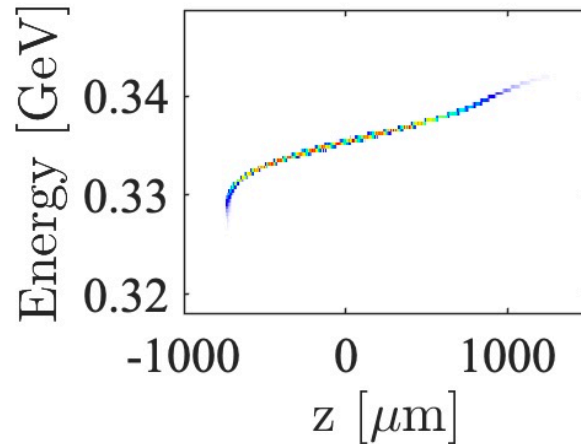


3. Microbunching simulations for FACET-II (heater off)

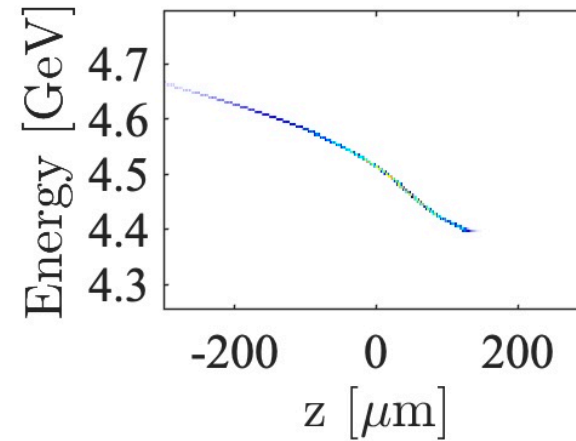
After injector



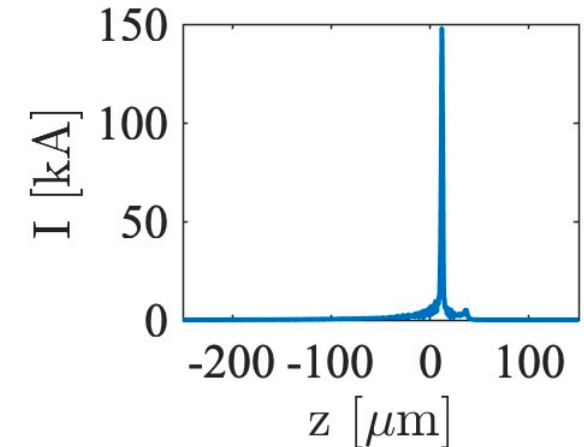
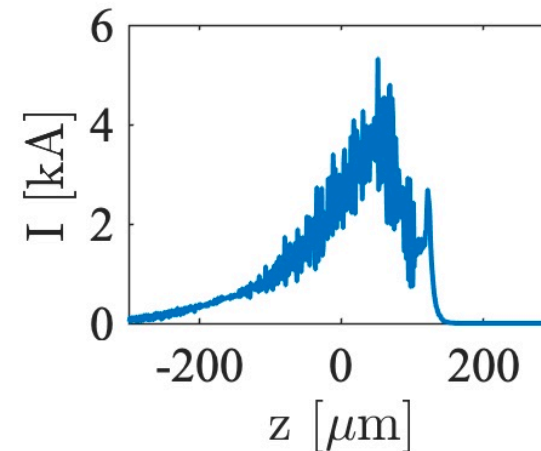
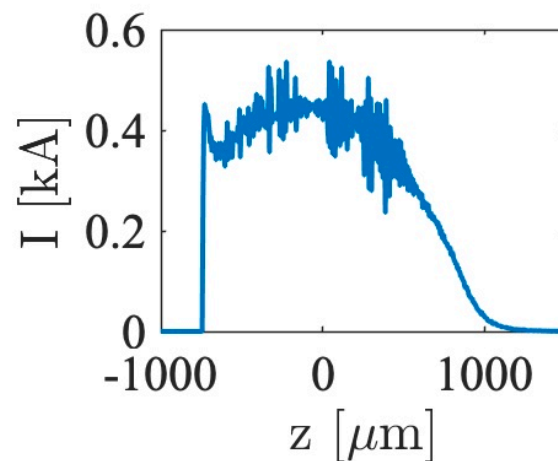
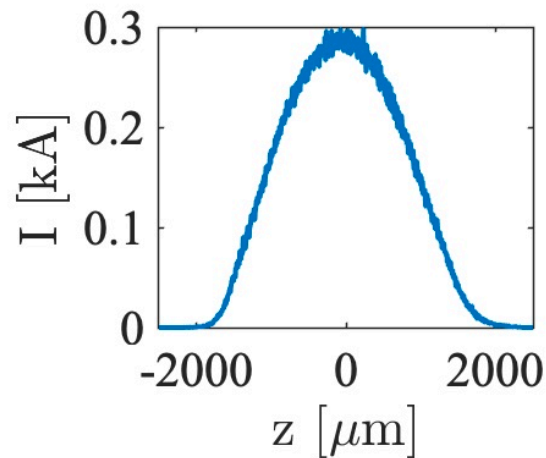
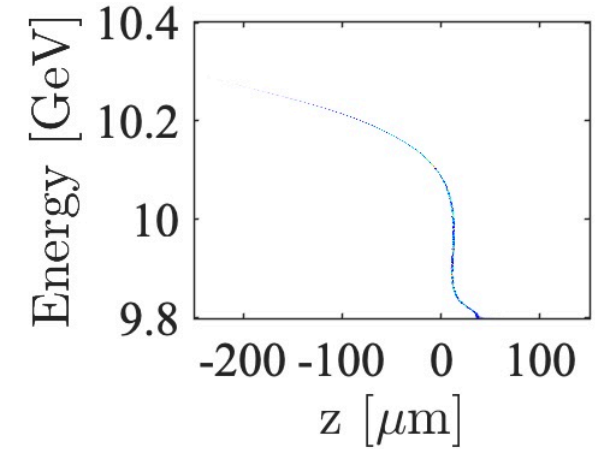
After BC11



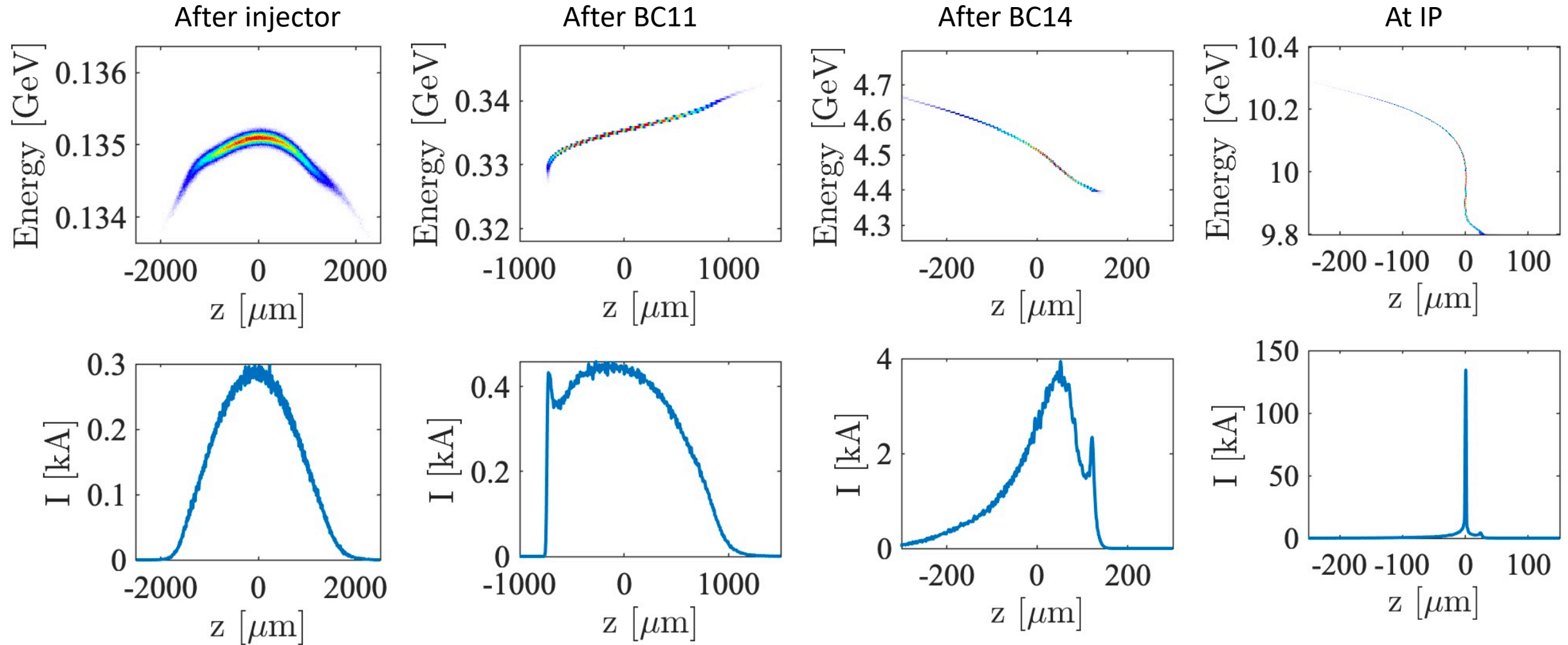
After BC14



At IP



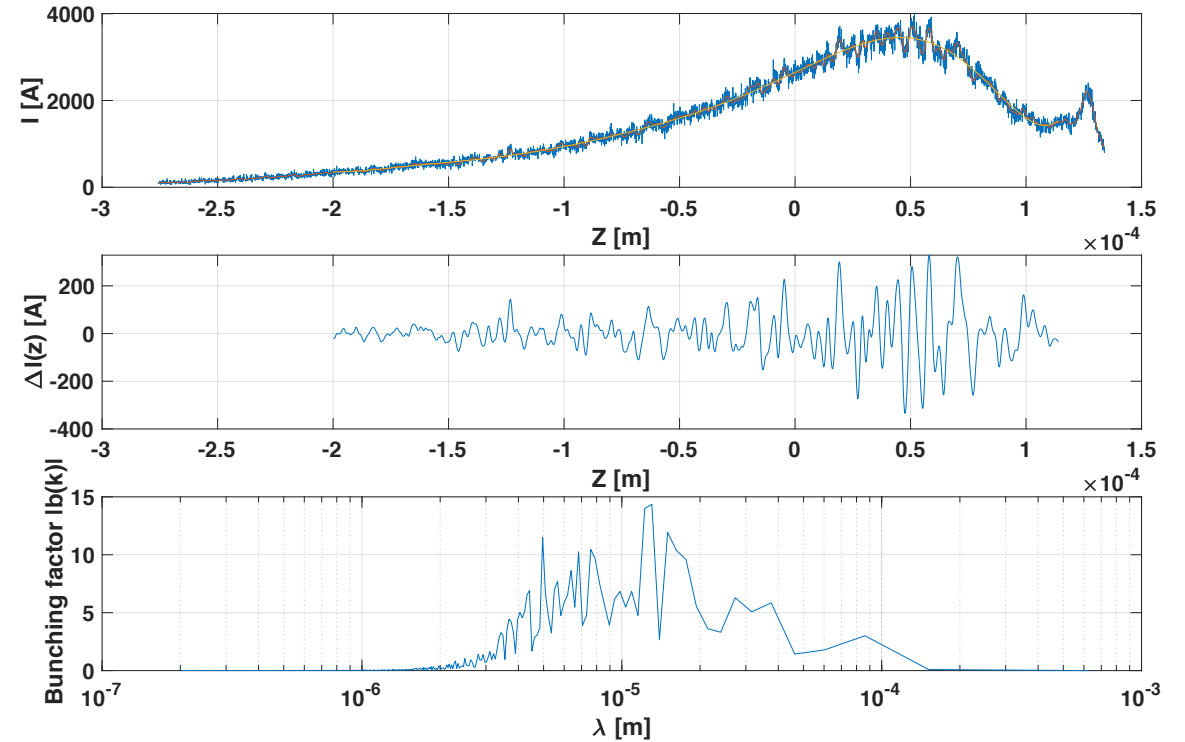
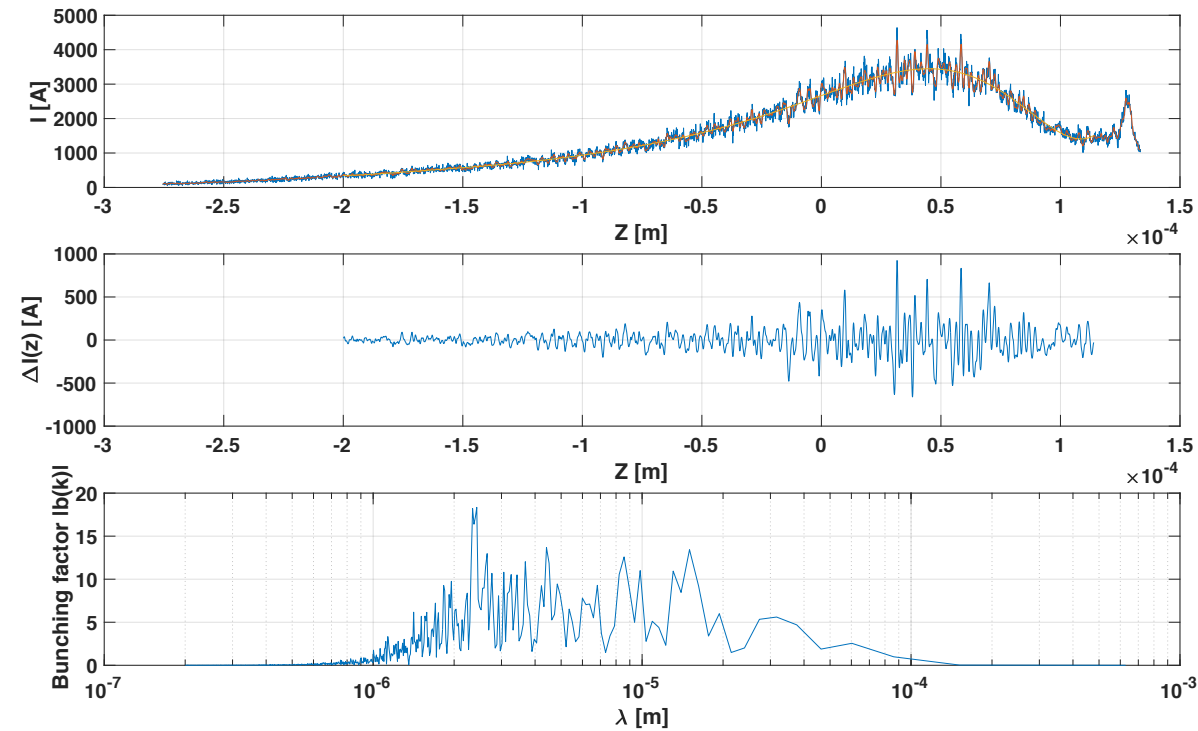
3. Microbunching simulations for FACET-II (heater on 50 keV)



Heater on vs heater off bunching factors

Heater Off

Heater On (50 keV)



Beam tracker to the end of BC14 with 1M macro-particles

Status and timeline for the LH installation

Operations Progress:

- Single bunch 1.6-2nC delivery to continue until winter downtime
- TCAV0 hopefully operational before winter downtime

Chicane Dipole Installation:

- Chicane dipoles + beam pipe installed in the vault. OTR targets installed.

Undulator Installation:

- Undulator magnets are on site at SLAC. Construction and assembly by magnetic measurements group has started. Targeted installation before December shutdown.

Laser Optics Installation:

- LSS certification done last week. Awaiting LSO approval (expected this Friday)
- Laser heater compressor installed and pulse length measured at 9ps FWHM. Laser room to vault transport pipe installed. Optical table installed next to the undulator. Next steps are spatial + temporal overlap with e-beam.

LH system will start commissioning in Fall 2022

References

- [1] P. Emma LCLS PRD 1.2-004, Revision 2,
- [2] P. Emma LCLS PRD 1.2-007, Revision 1
- [3] R. Carr LCLS ESD 1.2.124
- [4] Z. Huang et al., Measurements of the linac coherent light source laser heater and its impact on the x-ray free electron laser performance, Phys. Rev. STAccel. Beams 13, 020703 (2010).
- [5] Z. Huang et al., Suppression of microbunching instability in the linac coherent light source, PRSTAB 7, 074401 (2004)
- [6] FACET laser heater requirements document (in progress) https://docs.google.com/document/d/1Xku2n1apbFHsdBRUckTMy6oqUhX3a_rWKNEXd4DCwIM/edit#heading=h.wvsg22f2zl5u

Extra Slides

Single bunch example with max RMS energy spread

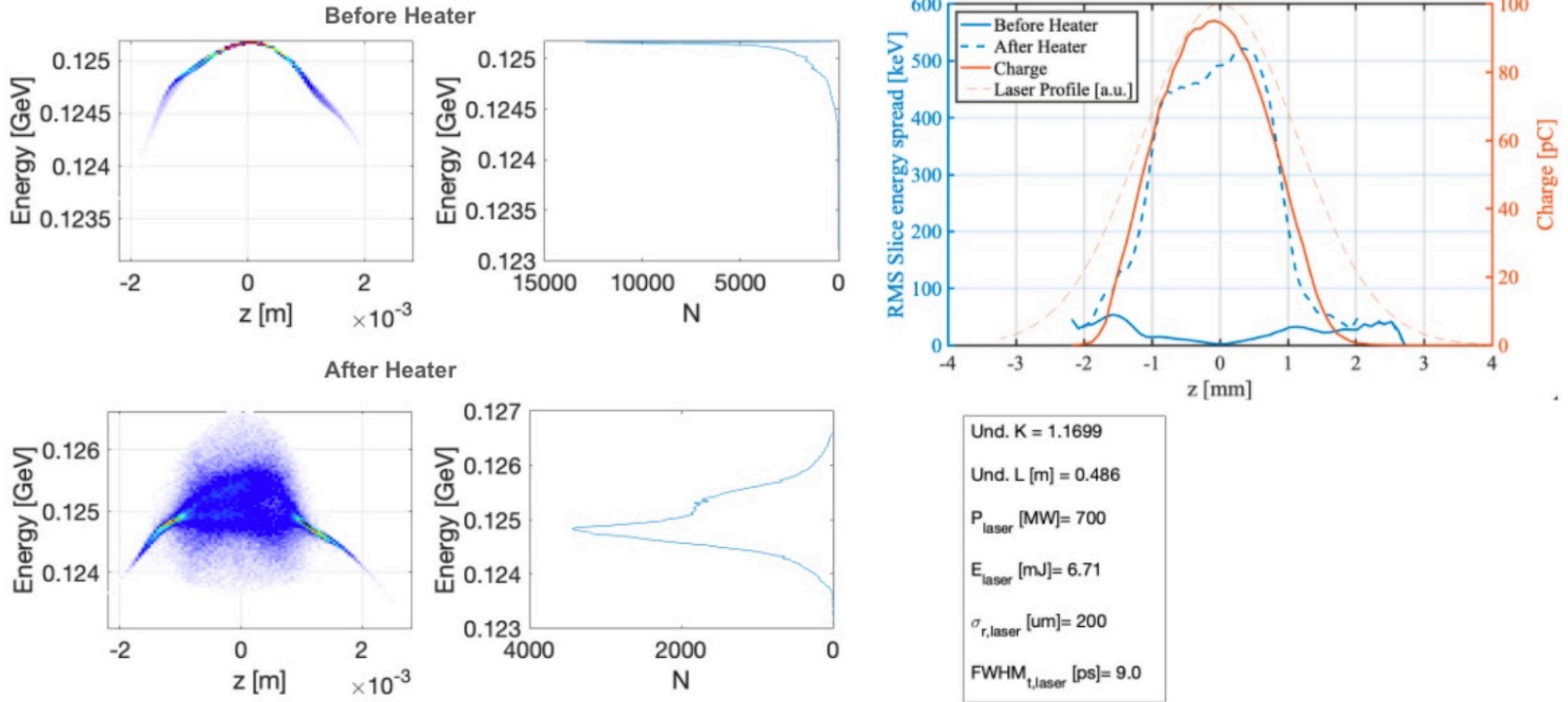


Figure 4: Longitudinal phase space before and after the laser heater for a 2nC single bunch run configuration with a max RMS slice energy spread of 500 keV. Simulation parameters are shown in the bottom right inset.

Closing the gap between the actual current and what XTCAV can measure

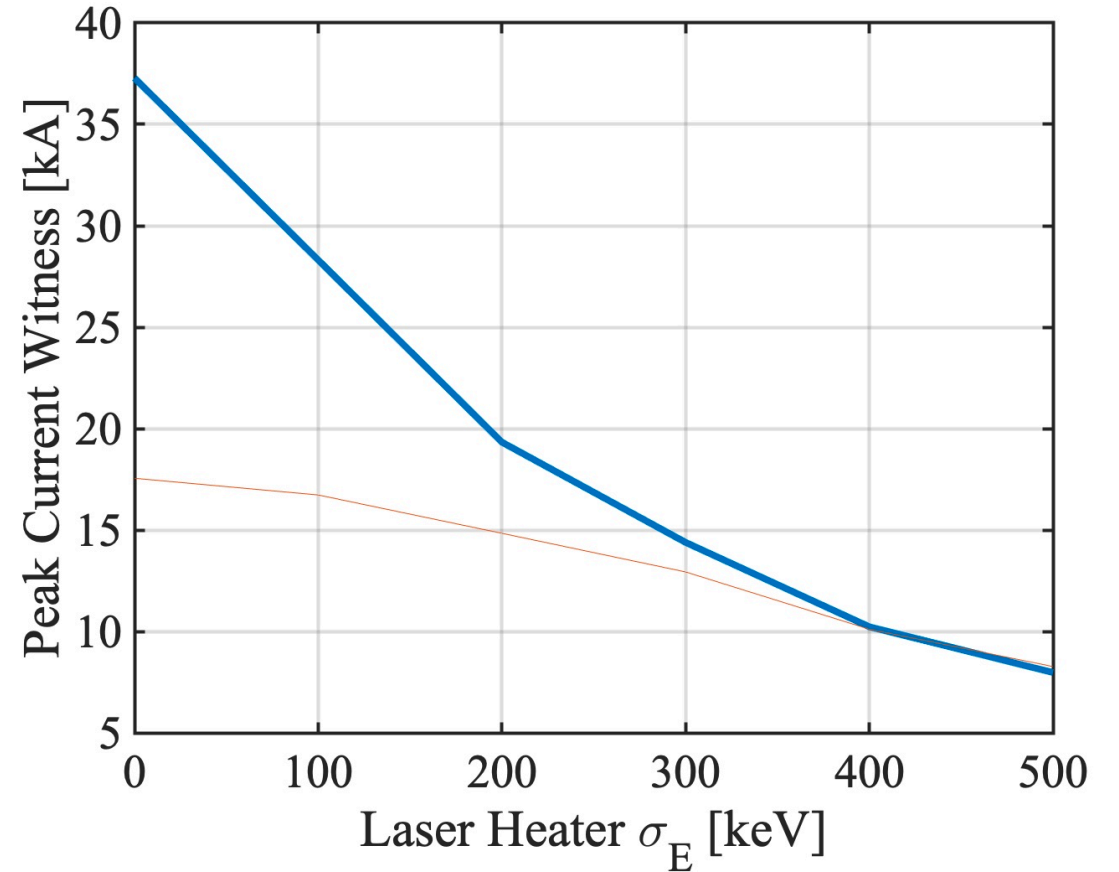
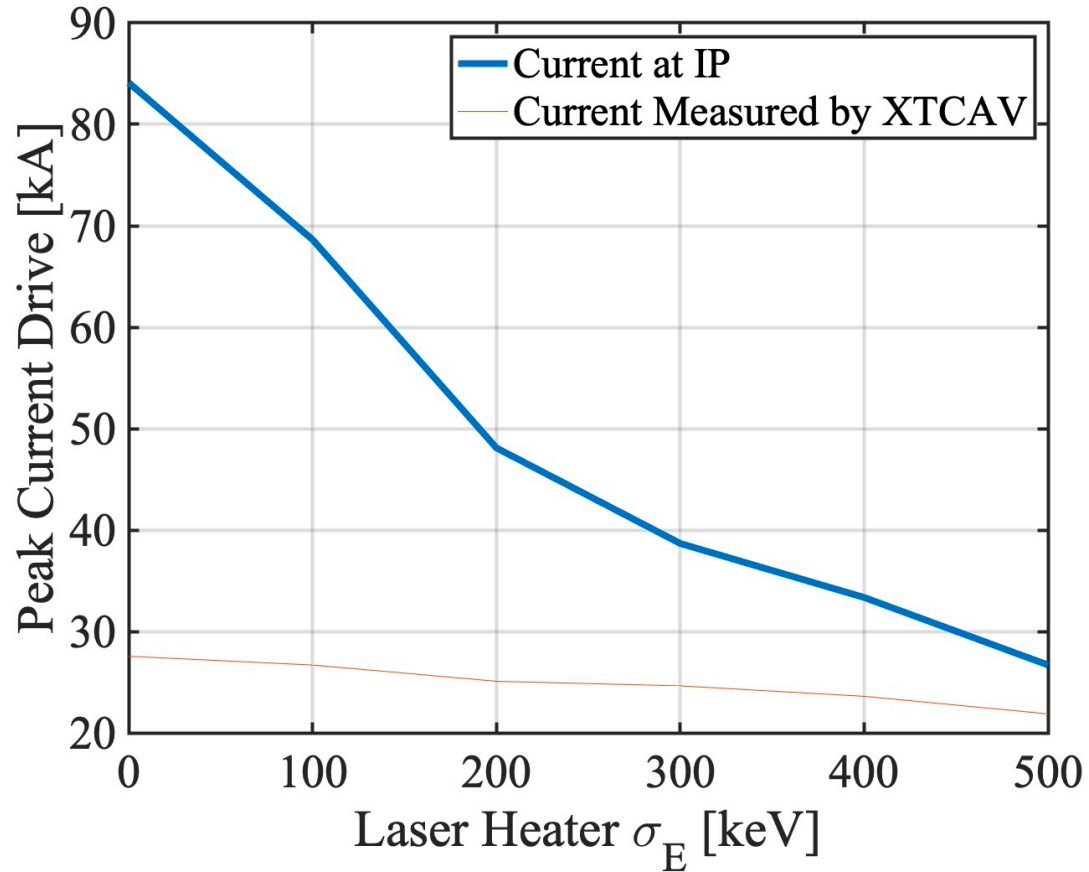


Table 1: Main parameters for the FACET-II laser heater.

Parameter	Nominal Value	Range	Unit
Electron Energy	125	125-135	MeV
Transverse RMS e-beam size	200	-	μm
Undulator Period	5.4	-	cm
Peak Undulator Field	0.232	-	T
Peak Undulator Parameter	1.17	-	-
Undulator Length	48.6	-	cm
Number of undulator periods	9	-	-
Laser Wavelength	760	-	nm
Laser RMS spot size	200	-	μm
Laser Peak Power	175	0-700	MW
Laser Pulse Energy	4	0-6.7	mJ
Laser Pulse Duration FWHM	20	-	ps
RMS energy spread generated	250	0-500	keV

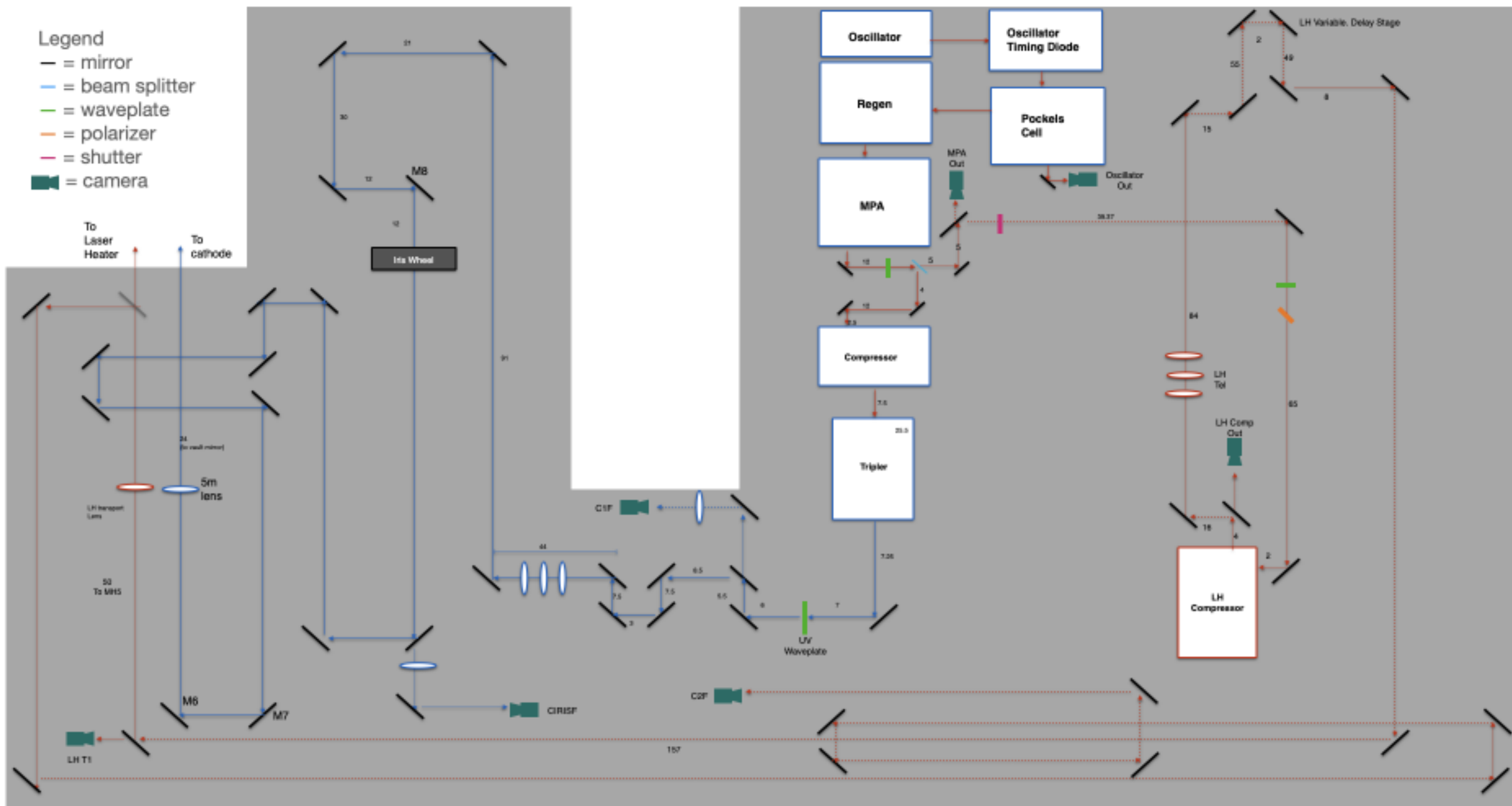
Cathode UV, LH IR and e-beam simulation parameters for single and two-bunch operating modes

Parameter	Single Bunch	Drive Beam	Witness Beam	Unit
Charge at laser heater [nC]	2	1.5	0.5	nC
FWHM UV laser pulse length on cathode	7 (4)	5.25 (4)	2 (4)	ps
Radius of Cut Gaussian UV pulse on cathode	2.68	2.68	2.68	mm
E-beam FWHM pulse length at laser heater	6.8	5.43	3.9	ps

Table 2: UV laser parameters at the cathode and corresponding electron beam parameters at the laser heater for the single and two-bunch injector simulations. The FWHM UV laser pulse length on the cathode shows the original values specified in the FACET-II TDR and the value in brackets of 4ps representing the current laser configuration.

Sketch of Sector 10 Laser Transport. Distances in inches unless otherwise specified 1/31/2022

- Legend
- = mirror
 - = beam splitter
 - = waveplate
 - = polarizer
 - = shutter
 - 📷 = camera



Sketch of Sector 10 Laser Heater Transport.

Distances in **mm** unless otherwise specified 3/14/2022

MH2 to LH center ~ 1212 mm
 MH1 to LH center ~ 860 mm

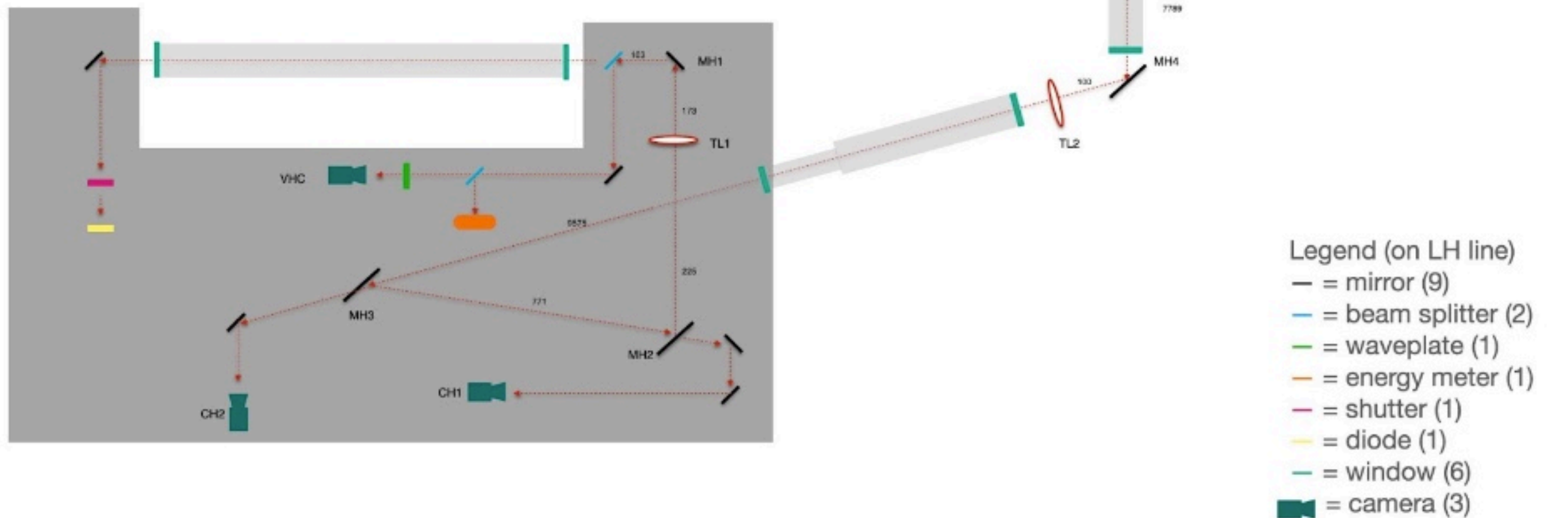
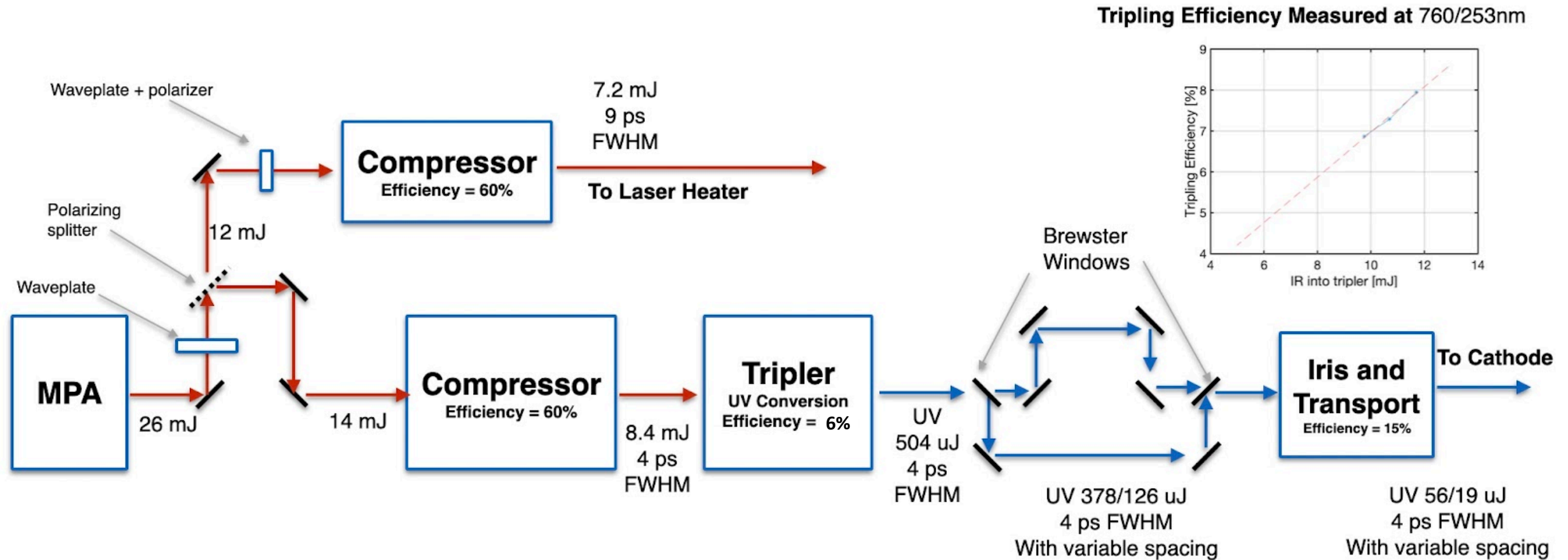
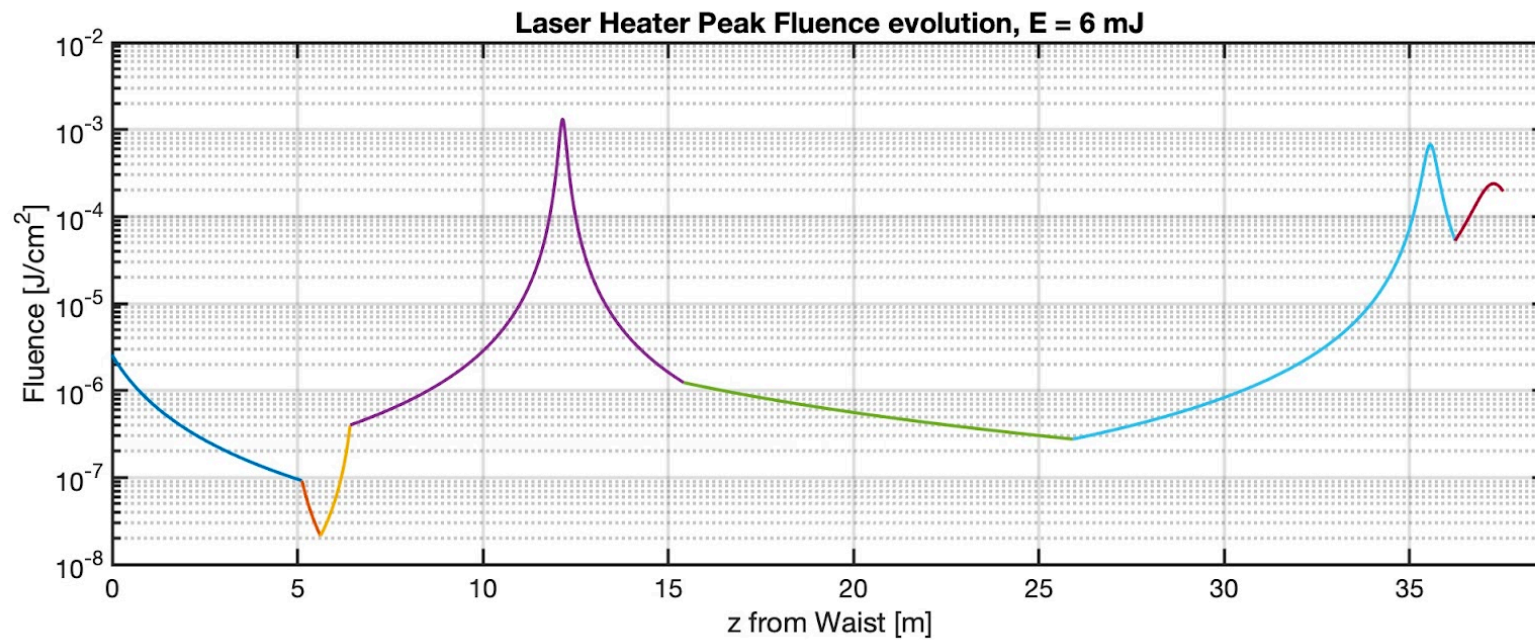
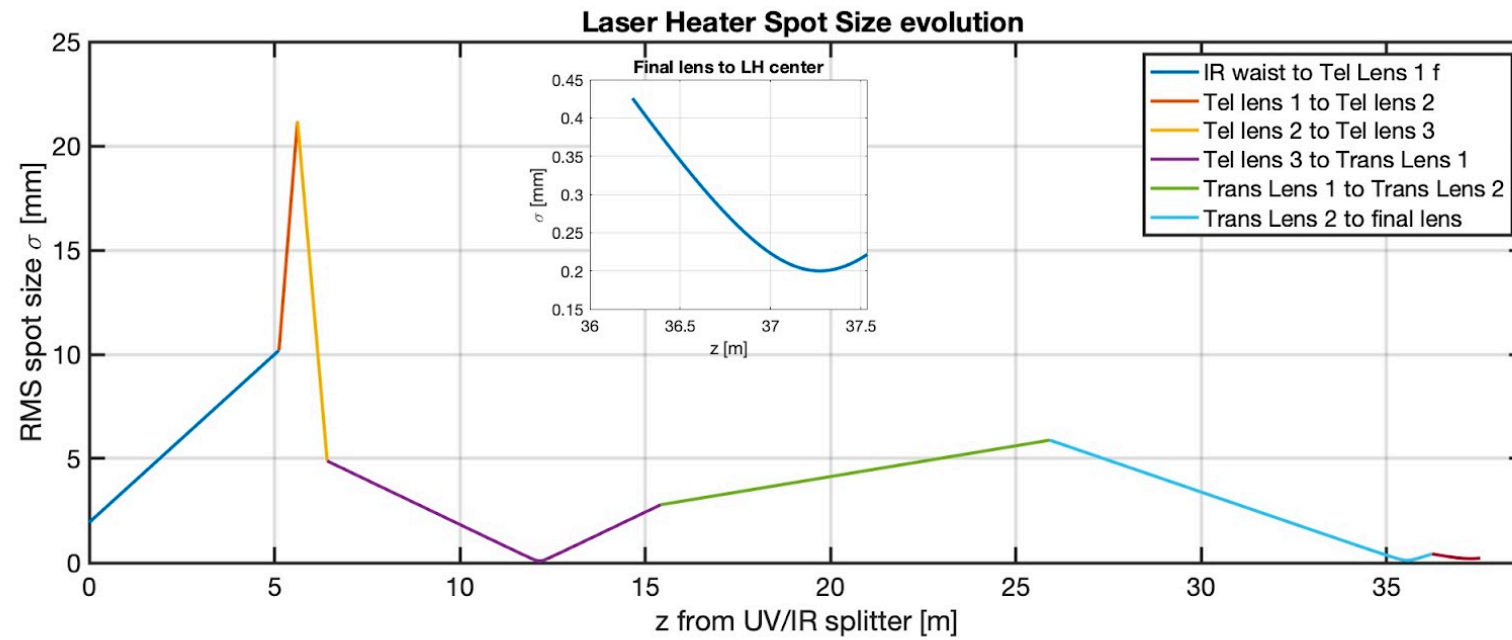


Figure 8: Sketch of the FACET Laser heater transport from the laser room to the vault. Focal lengths for the transport lenses $f = 5\text{m}, 6.5\text{m}, 0.5\text{m}$.

Sketch of LH and UV energy and pulse length evolution along the laser transport





Two bunch example with max RMS energy spread

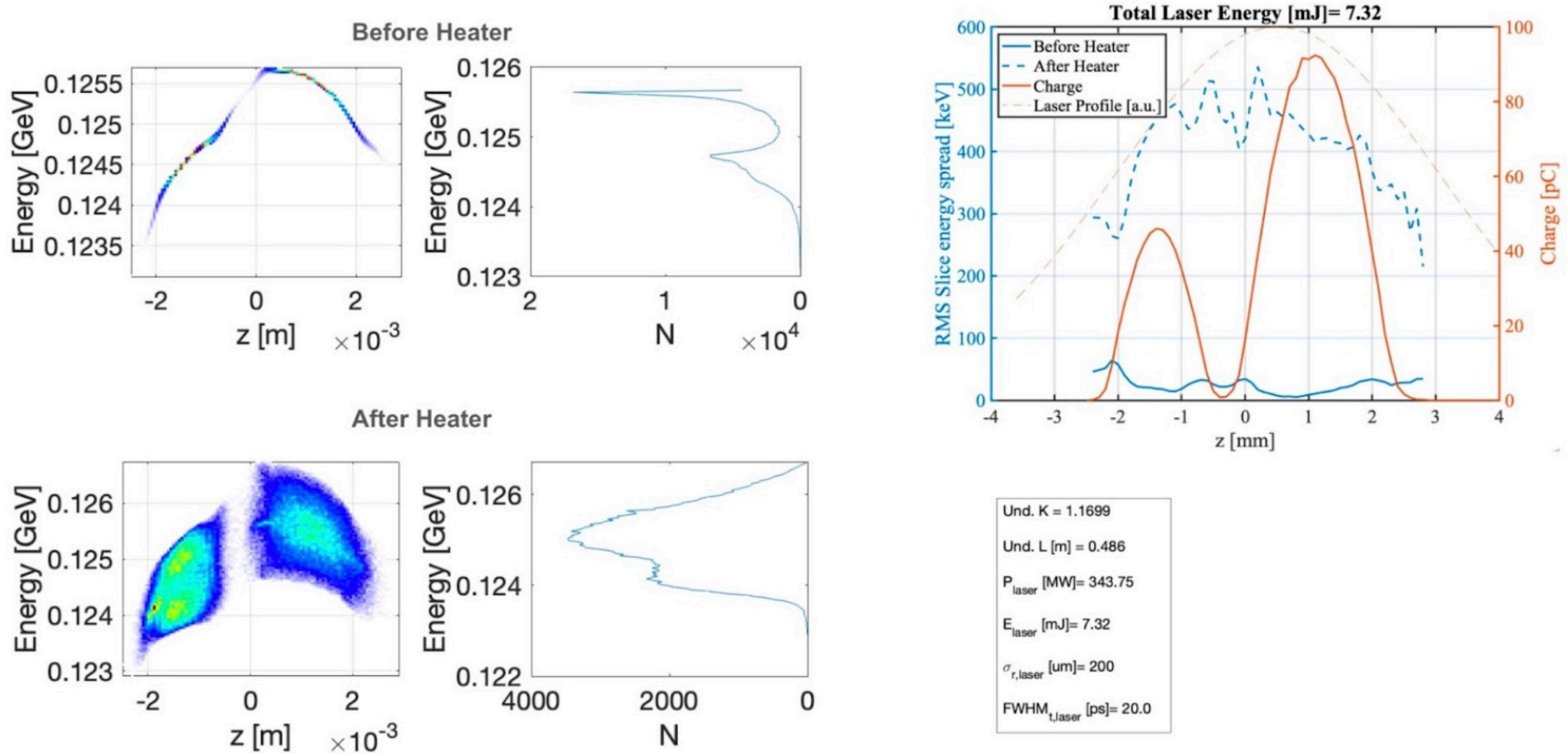
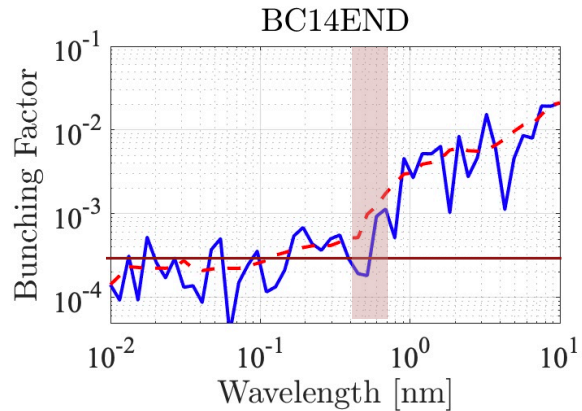
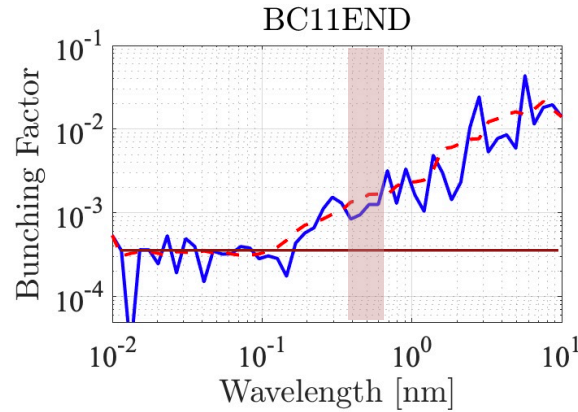
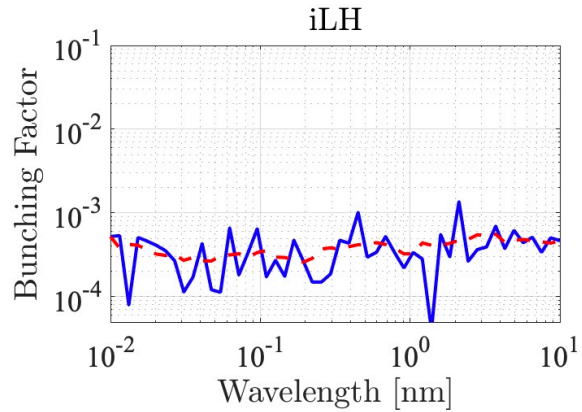


Figure 5: Longitudinal phase space before and after the laser heater for a 1.5/0.5 nC two bunch run configuration with a max RMS

3. Tracking simulations with micro bunching for FACET-II (heater on vs off)

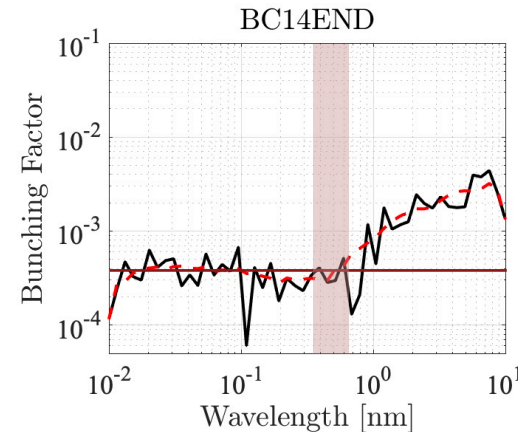
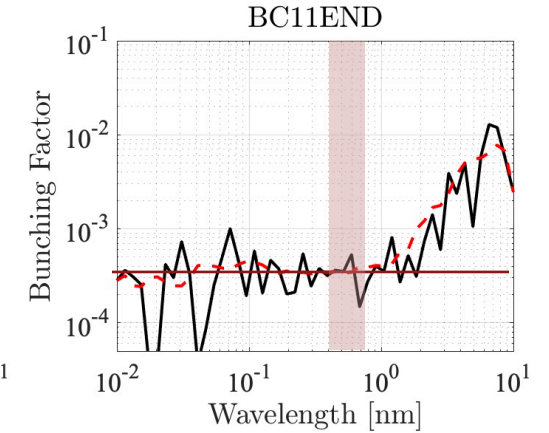
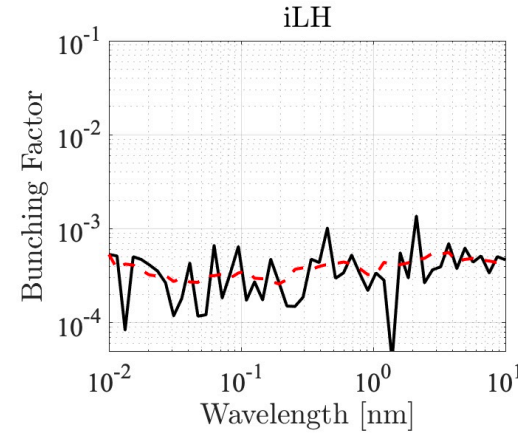
$N_p = 7e6$, CSR off

Heater Off



Some amount of bunching at visible wavelengths after BC11 and BC14

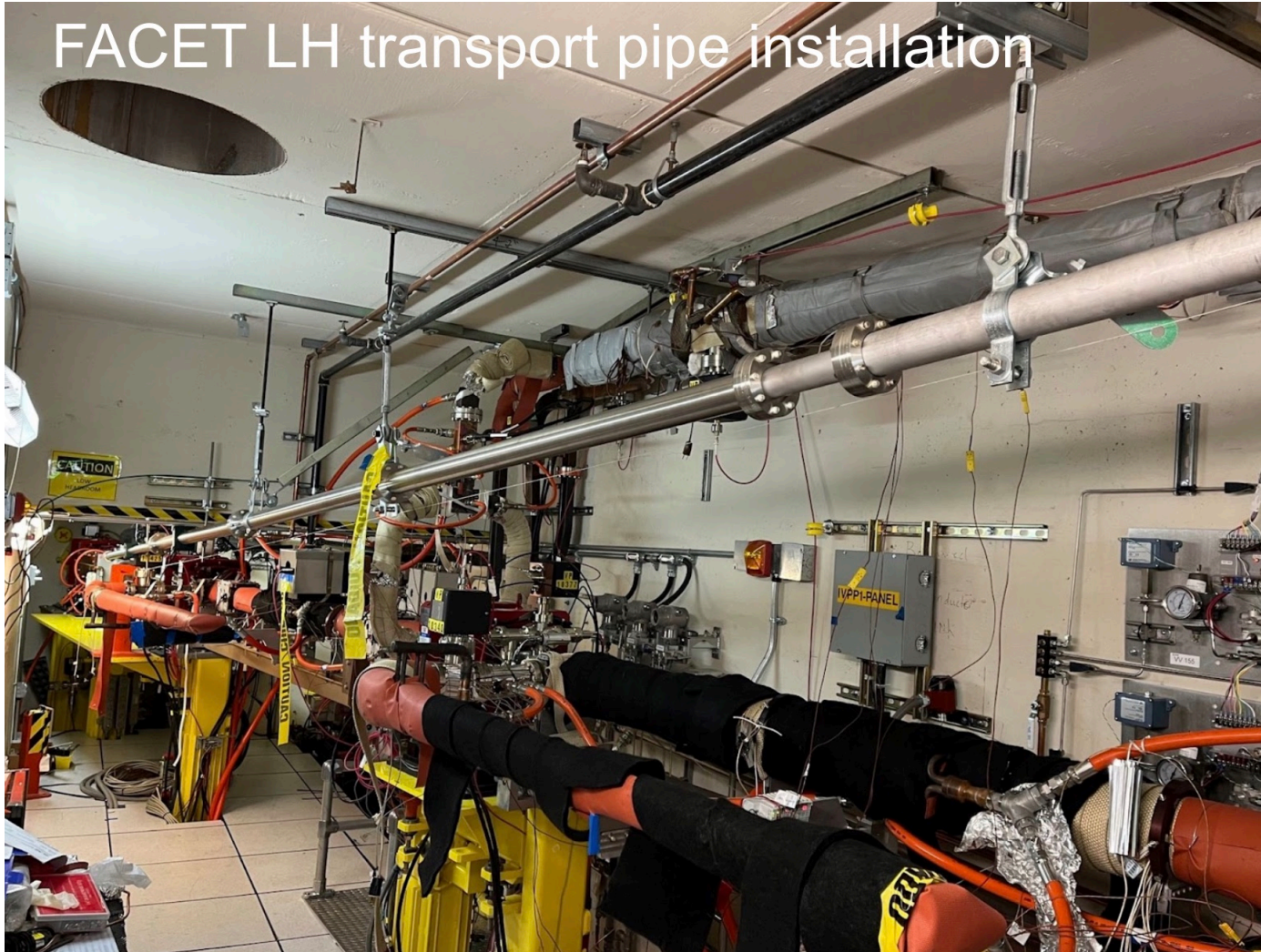
Heater On (50 keV)



Bunching suppressed to shot noise level $1/\sqrt{N_p} = 4e-4$ by 50 keV of laser heater modulation

Installation Pictures

FACET LH transport pipe installation



Vault Ceiling Optics Box pictures

