

Machine Development – Sector 20 Stability

FACET-II Planning Meeting, March 2023

Glen White / FACET-II Optics Designer/ AD-ARD Beam Physics

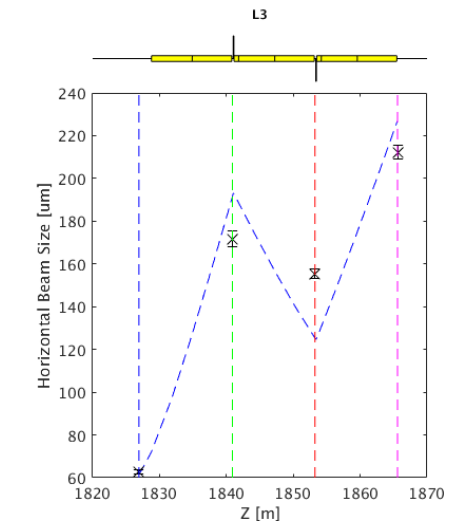
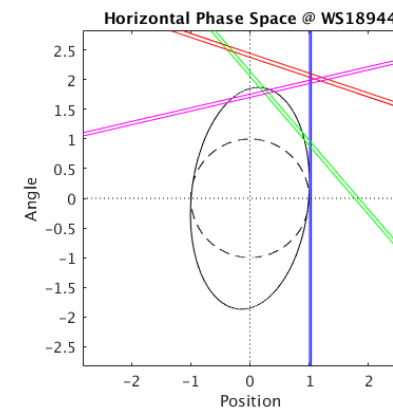
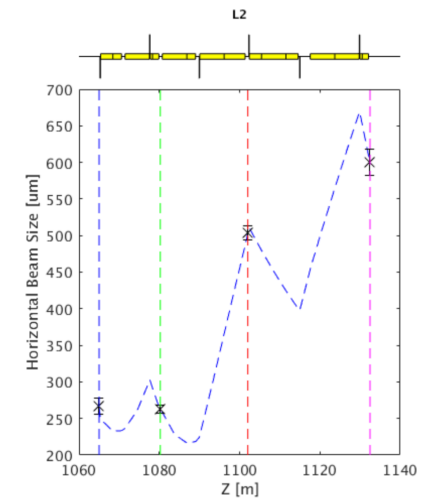
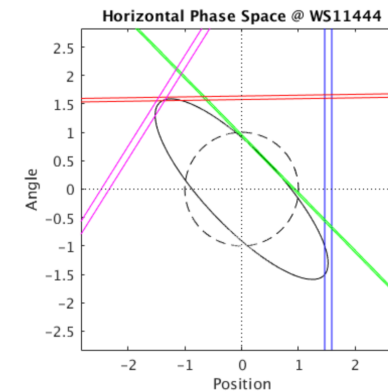
March 14, 2023



FACET-II
Facility for Advanced
Accelerator Experimental Tests

Linac Operational Measurements – 8/7/22 (pencil beam)

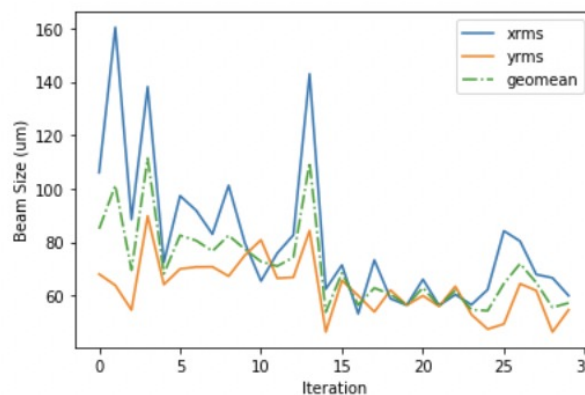
- Measurements taken 8/7/2022
 - Multi-wire (4 wirescanners)
- L2 (L111/12)
 - $\gamma\epsilon_x = 8.2 \mu\text{m-rad}$, BMAG = 1.1
 - $\gamma\epsilon_y = 4.5 \mu\text{m-rad}$, BMAG = 1.9
- L3 (L118/19)
 - $\gamma\epsilon_x = 12.6 \mu\text{m-rad}$, BMAG = 1.2
 - $\gamma\epsilon_y = 8.8 \mu\text{m-rad}$, BMAG = 1.4
- Operational issues affecting emittance & stability
 - Fast orbit excursions during wire scans
 - Improvements to control system links to SCP over downtime to enable jitter-subtraction
 - Extreme sensitivity to orbit in L1 / beginning of L2
 - MD studies scheduled to further investigate
 - Diurnal variation in klystron phases (see next slide)



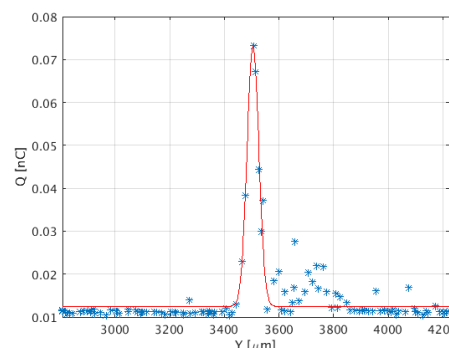
Emittance growth in Linac (L1-L3) typically 2X-3X after tuning

Sector 20 Operational Measurements – 8/7/22 (pencil beam)

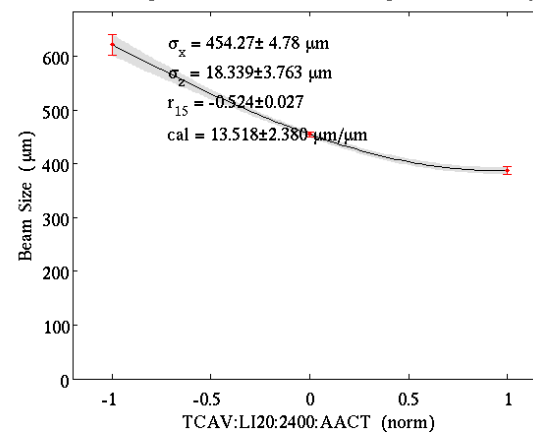
- Measurements taken 8/7/2022 (wirescanner), 8/4/2022 (XTCAV)
- Wire-scanner measurements (IPWS1) with $\beta^* = 0.5$ m
 - $\sigma_x^* = 23.2 \mu\text{m}$
 - $\sigma_y^* = 21.5 \mu\text{m}$
 - $\sigma_z = 18.3 \mu\text{m}$
- Wire breakage
 - ongoing problem due to high charge density
- Similar sensitivity to dispersion leakage seen in FACET
 - Use sextupole movers in BC20 to control
- First checkout of “ML tuning”
 - Bayesian optimization tool applied to Sextupole mover system for S1 & S2 sextupoles (L & R)



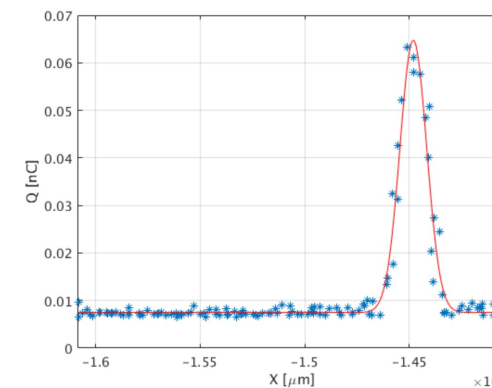
Scan showing signs of broken wires on card



TCAV bunch length on CAMR:LI20:107 04-Aug-2022 16:34:30 Asymmetric



Newly fixed card



Efforts ongoing to address phase stability in Linac

IP Jitter Tool

FACET Matlab GUIs (on facet-srv01)

Matlab GUIs

Data Acquisition

- Profile Monitor...
- Multi-Profile Monitor...
- Wire Scans...
- Emittance Measurement...
- TCAV/Bunch Length Meas...
- Correlation Plots...
- OLD Correlation Plots**
- IP Jitter Tool**
- BSA GUI...
- FACET Orbit Response...
- Jitter GUI...
- Klys Diag GUI...
- EOS Online GUI...
- FACET DAQ
- New WireScanner
- Multi-Wire Scan

Utilities/Tools

- Import SCP_CRR Data...
- Plot History...
- FLEM...**
- Optics Matching**
- Orbit
- Feedbacks
- BC20 Tuning
- RF Phase Scans...
- Beta Matching...
- FACET Dispersion Meas...
- Wake Loss Scan...
- IP Steering...
- Bowtie Plot
- NEW Bowtie Plot**
- Sextupole GUI
- Dither Anything ...
- SYAG Dispersion Meas...
- Bump Generator

Optics

- S20 Config**
- Waist Analysis...

S10 Injector

- Gun Energy Calc
- Cathode Services
- Gun Watcher...
- Schottky Scan

Notch Collimator

- Notch Tool
- Tomography Scan

Summary Displays

- Klystrons Usage Stats...

E203 boards

- E203 Grating drive Tester

Simulators / Models

- LITrack ES
- LITrack...
- Lucretia Live Model

Terahertz Displays

- Knife Edge Scans...

Laser

- Timing Shift...
- Laser Archiver Utility
- S10 Injector Laser Tools
- S20 Laser Tools
- Matlab PVs...
- GOTO Watcher...
- MatlabServer Status...

F2_IPjitter (on facet-srv01)

IP Reconstructed Waist Jitter Plots

$\Delta y \sim 0.5 \sigma_y$

Design Optics @ IP Waist [Energy (GeV) top-left edit field]

	X	Y
NEMIT (um-rad)	20.0	20.0
BETA (cm)	50.0	50.0
SIGMA (um)	22.6	22.6
SIGMA' (urad)	45.2	45.2

Fit Information

BPM data from archiver: 07-Aug-2022 15:20:00
 IP X waist fit @ Z=1992.049 (m) = LCUBE +50.8 mm
 IP Y waist fit @ Z=1991.308 (m) = M5FF +1.8 mm
 RMS X Position jitter @ IP Waist = 114.62 (um) = 5.07 (sigma)
 RMS Y Position jitter @ IP Waist = 11.21 (um) = 0.50 (sigma)
 RMS X Angle jitter = 64.54 (urad) = 1.43 (sigma)
 RMS Y Angle jitter = 121.02 (urad) = 2.68 (sigma)

BPMS

M5FF / BPMS:LI20:3156 M1EX / BPMS:LI20:3265

Fetch Live Data

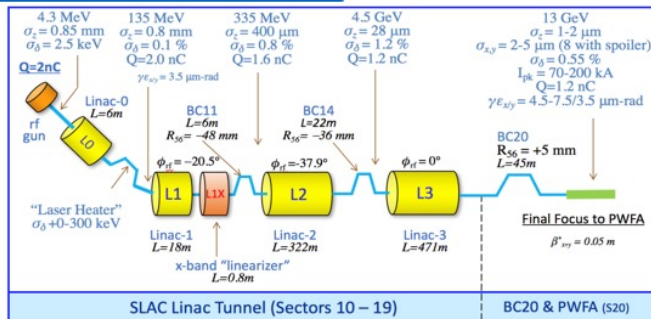
Pulses: 300

Get Archive Data

PRODUCTION FACET 03/09/2023 14:21:11

Model / Other Machine Jitter Levels ~ X2 larger than expect

FACET-II @ SLAC

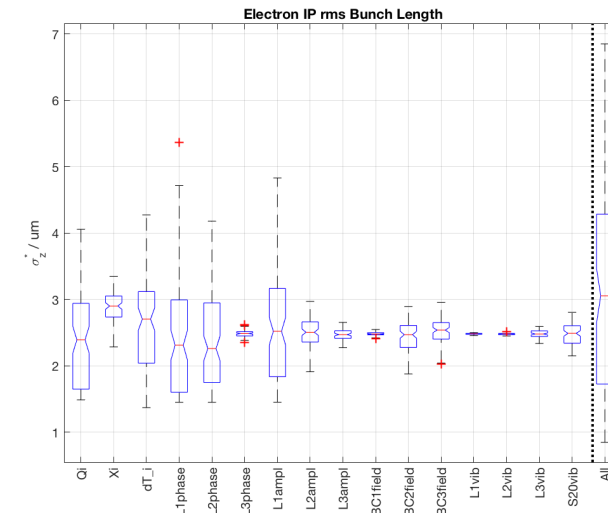


Monte Carlo Simulation Parameters

Property	Unit	FACET	Upgraded
Source Charge Fluctuation	%	1	0.1
Source Electron Position Fluctuation (laser spot jitter on cathode)	% σ_{xy}	3	3
Initial Electron Laser Timing Error	fs	200	10
L1 Phase Jitter	degS	0.1	0.01
L2/L3 Phase Jitter	degS	0.25	0.01
LOP Phase Jitter	degS	0.1	0.01
L1 Amplitude Jitter	%	0.1	0.01
L2/L3/LOP Amplitude Jitter	%	0.25	0.01
BC0 & BC11 Magnet Strength Jitter	dB/B	1e-5	1e-6
BC14 & BC20 Magnet Strength Jitter	dB/B	1e-4	1e-6
L1/L2/L3/S20 Magnet Vibration (x/y), rms	μ m	1.5/0.5	0.02/0.02
e- injector Magnet Vibration (x&y), rms	μ m	0.1	0.02

Upgraded: Engineering estimates of max performance given unlimited R&D scope (assuming no technology breakthroughs)

Beam Parameter	Symbol	Unit	Design	rms Jitter: FACET	rms Jitter: Upgraded
Horizontal position	x	μ m	0	5.5	0.36
Vertical position	y	μ m	0	1.6	0.12
Horizontal angle	x'	μ rad	0	103	8.0
Vertical angle	y'	μ rad	0	8.6	4.5
Arrival time	t	fs	0	103	6.7
Horizontal rms beam size	σ_x	μ m	8	1.4	0.13
Vertical rms beam size	σ_y	μ m	8	0.05	0.02
rms Bunch length	σ_z	μ m	1	2.5	0.13
Peak current	I_{pk}	kA	70	20.9	4.4



Expect ~1.5 μ m bunch length jitter
-> Currently measure ~3.5 μ m

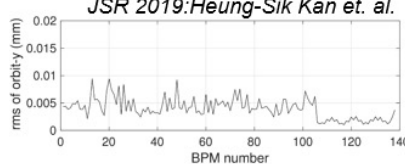
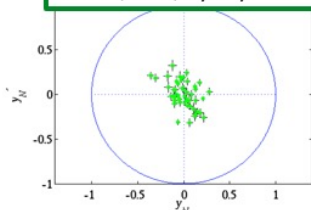
FELS

FEL 2008: F Decker et. al.

LCLS (2008) $\Delta_y / \sigma_y \sim 10\%$

PAL-XFEL (2019) $\Delta_y / \sigma_y \sim 10\%$

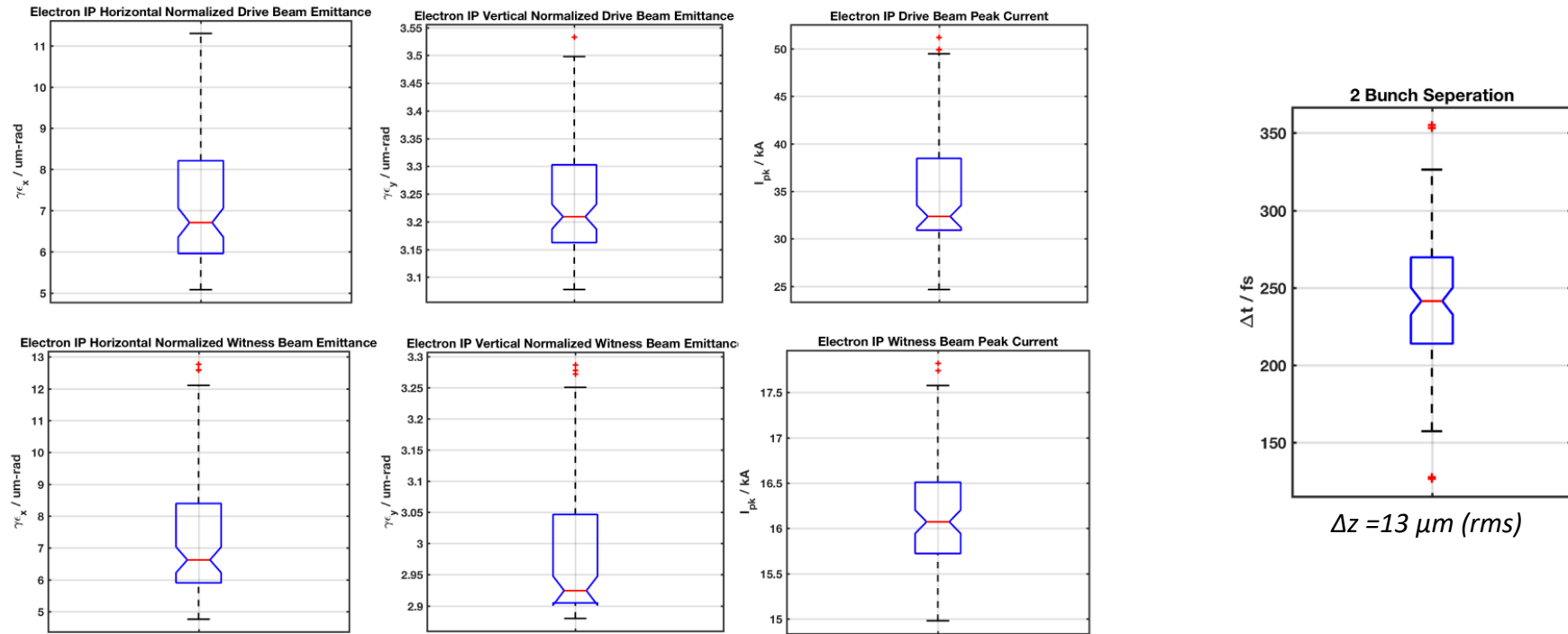
JSR 2019: Heung-Sik Kan et. al.



Expect ~2 μ m vertical jitter @ $\beta^* = 5$ cm (say 6 μ m @ 50cm)
-> Currently measure ~11 μ m

Many existing Linac-based accelerators exhibit ~10% beam size jitter
FACET-II $I_{pk} \gg$ FEL's: expect ~20% y jitter, or down to 1.5% with cost-no-object upgrades

2-Bunch Jitter – Modeled Expectations



Parameter @ IP	Drive Bunch	Witness Bunch
ϵ_x ($\mu\text{m-rad}$) (90%)	7.2 +/- 1.6	7.4 +/- 2.0
ϵ_y ($\mu\text{m-rad}$) (90%)	3.2 +/- 0.1	3.0 +/- 0.1
Δt (fs)	243 +/- 45	
I_{pk} (kA)	35.5 +/- 6.6	16.1 +/- 0.6

MD Options Currently Being Considered

- Introduction of further transverse feedbacks
 - L1 launch
 - L2 launch
 - S20 launch
- Other Feedbacks?
 - Currently only “slow” feedbacks to fix ~temperature drifts, consideration of faster feedbacks requires more work and possibly hardware
- Improvements to BL measurements
 - Expect microbunching to pollute BL feedback signals
 - Observed in past that bunch length changes even if BC14 BLEN signal remains fixed
 - Laser heater helps?
 - Investigate optical filtering for edge radiation
 - More complex BLEN detector? (Frisch/Maxwell special) – definitely helpful for S20
- Upgrade BC11 & BC14 energy feedback low-level RF
- Incorporate BC20 BLEN windowing into S20 wire-scans
- XTCAV SLED
- S15 Tcav
- S17/S18 fast phase shifter hardware
- SCAV beamline