FACET·II

Facility for Advanced Accelerator Experimental Tests

FACET-II Stability Analysis

2017 FACET-II Science Workshop, October 17-20, 2017

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Overview

Monte Carlo simulations to estimate jitter conditions at experimental S20 IP of FACET-II

- Description of parallel particle tracking infrastructure developed

Baseline FACET-II parameters

- Present “nominal” accelerator jitter parameters
- Beam jitter at IP for baseline electron and positron design

2-Bunch electron parameters

- Beam jitter at IP for 2-bunch delivery using collimators and injector pulse shaping

FACET-II upgraded parameters

- Look at possible upgraded performance estimates

Monte Carlo Simulation

SLAC

Injector

- ***IMPACT-T*** used for injector tracking, including 3-D space charge

L1 – Sector 20 IP

- ***Lucretia***: Matlab toolbox for electron beam design and beam dynamics modeling of single-pass beamlines
  - ISR, CSR, longitudinal and transverse wakes in structures, longitudinal space charge included
  - Treatment of error sources (Magnetic fields, element offsets, RF errors)

Monte Carlo Simulations

- For each jitter parameter, assign a Gaussian-distributed random offset +/- 1 sigma truncation and track bunch (== 1 seed)
- For jitter estimates, use 100 seeds using SLAC compute farm
- Track ensemble of all jitter sources & each error source independently to understand dominant error terms

Baseline Jitter Parameters

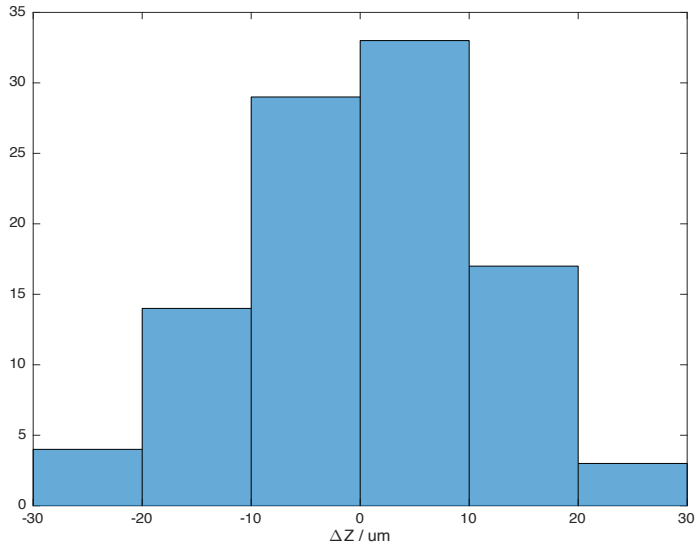
Property	Value
Source Charge Fluctuation	1% (e-) 2% (e+)
Source Position Fluctuation	0.05, 0.2 σ (e-,e+)
Initial Electron Laser Timing Jit.	200 fs
L1X Phase Jitter	0.25 degX
L1S Phase Jitter	0.1 degS
L2 Phase Jitter	0.25 degS
L3 Phase Jitter	0.25 degS
L0P Phase Jitter	0.1 degS
L1X Amplitude Jitter	0.25 %
L1S Amplitude Jitter	0.1 %
L2 Amplitude Jitter	0.25 %
L3 Amplitude Jitter	0.25 %
L0P Amplitude Jitter	0.25 %
BC0 Magnet Strength Jitter	1e-5 dB/B
BC1 Magnet Strength Jitter	1e-4 dB/B
BC2 Magnet Strength Jitter	1e-4 dB/B
BC3 Magnet Strength Jitter	1e-4 dB/B
Magnet Vibration (x/y)	1.5/0.5 µm

- Jitter parameters chosen from FACET and LCLS experience and assuming no significant upgrades of Linac
- Jitter parameters pulse-pulse, uncorrelated
- rms Jitter parameters from Monte Carlo simulations shown below

KPP Parameter	Electron Bunch		Positron Bunch	
	Design Req.	Simulation	Design Req.	Simulation
ε_x (μm-rad) [S19]	<20	4.4 +/- 0.5	<20	10.7 +/- 0.7
ε_y (μm-rad) [S19]	<20	3.3 +/- 0.1	<20	13.0 +/- 1.2
σ_z (μm) [IP]	<20	3.1 +/- 1.5	<20	16.5 +/- 0.2
I_{pk} (kA) [IP]	>10	64 +/- 16	>5	5.8 +/- 0.2

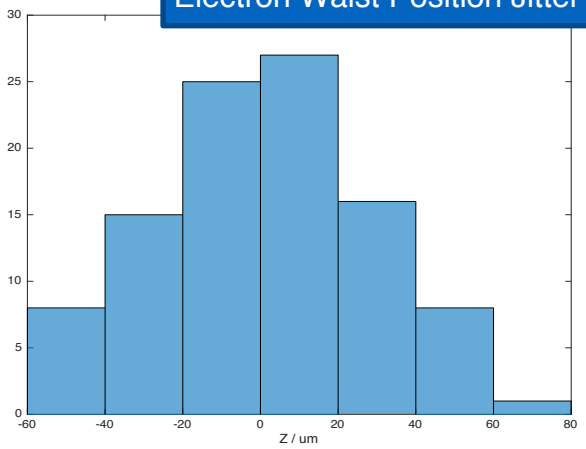
Electron, Positron Bunch Waist Location Jitter

Stage-III Relative electron-positron waist position jitter

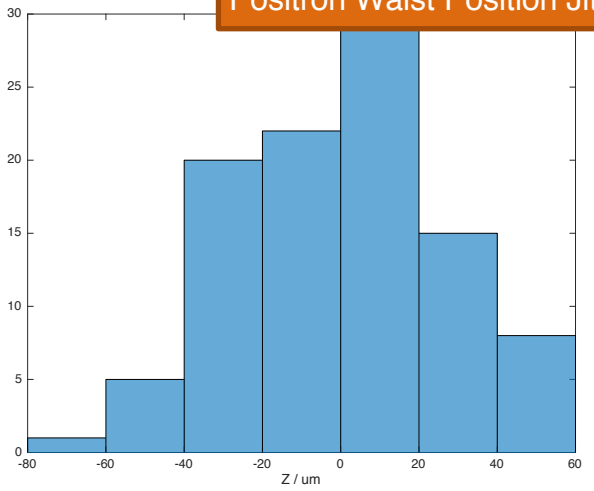


- Relative e- / e+ timing jitter: 11um rms

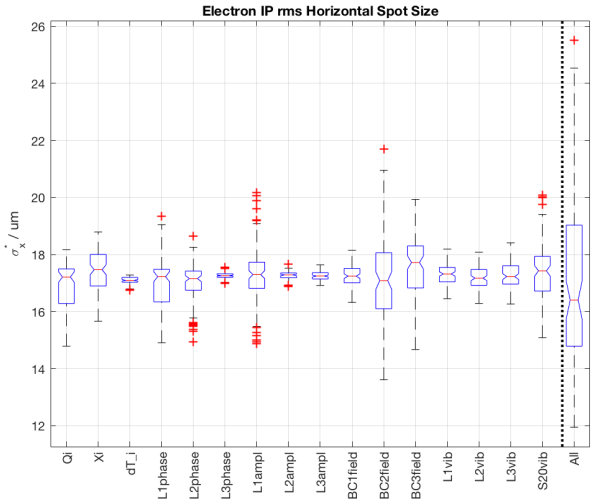
Electron Waist Position Jitter ~ 30 µm

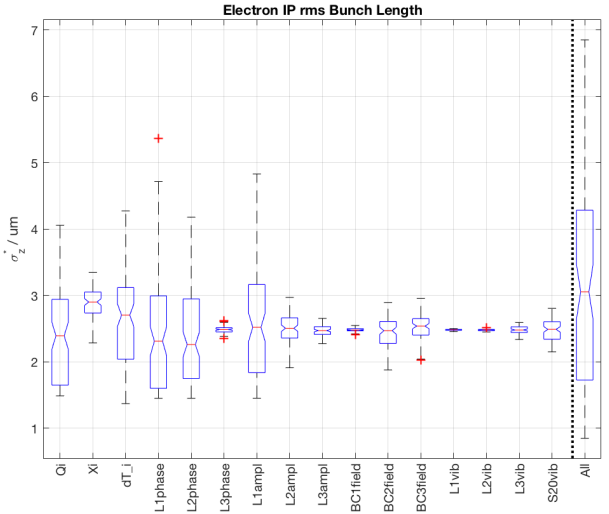


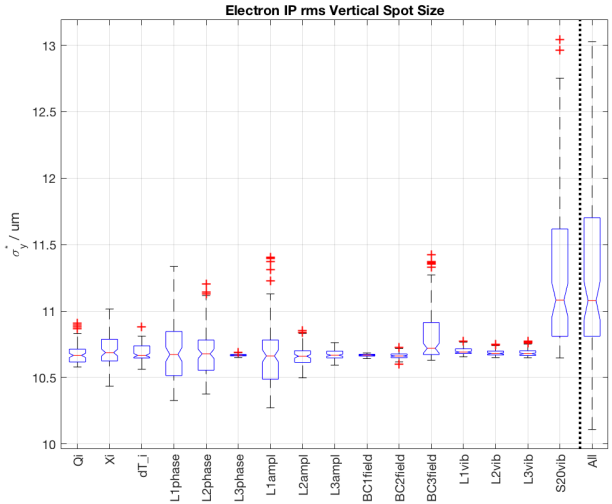
Positron Waist Position Jitter ~ 30 µm

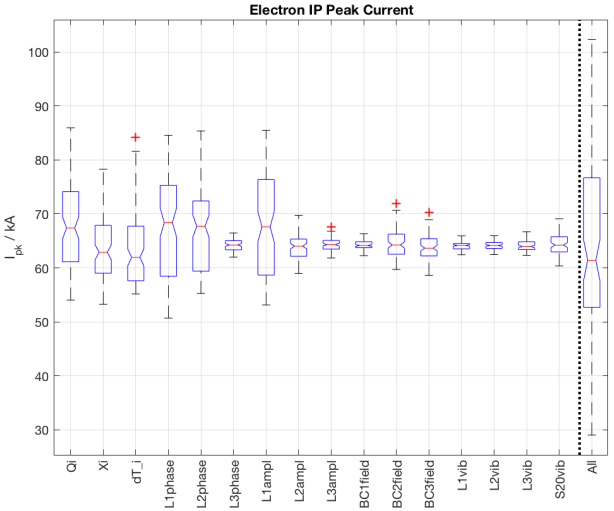


Electron S20 IP Jitter Parameters

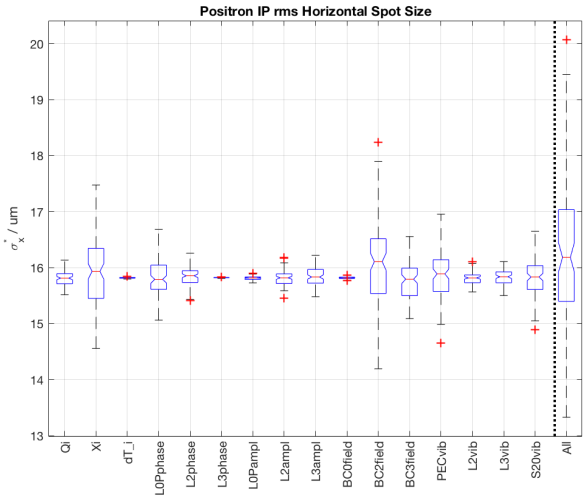


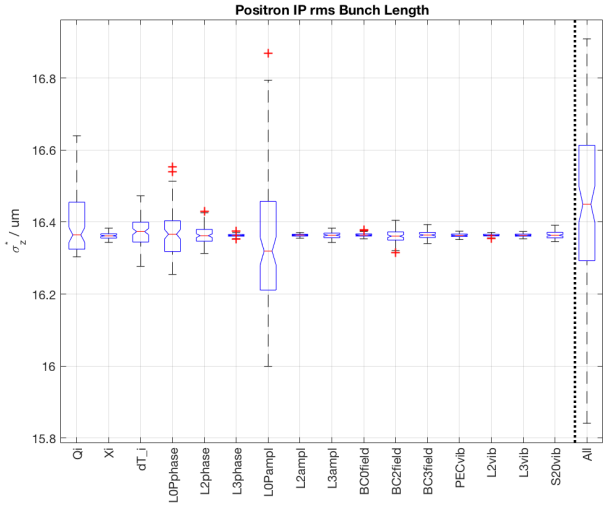


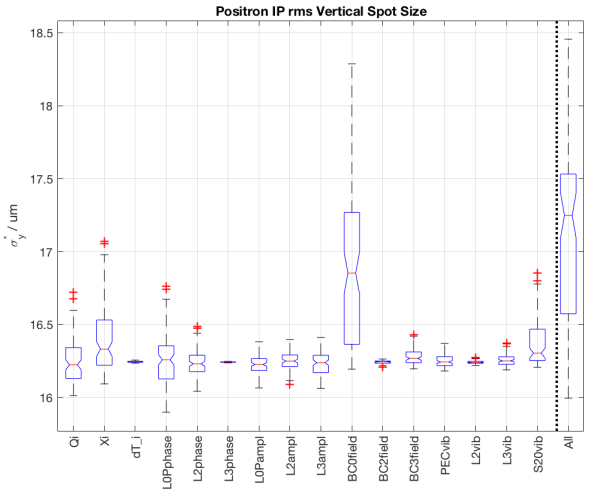


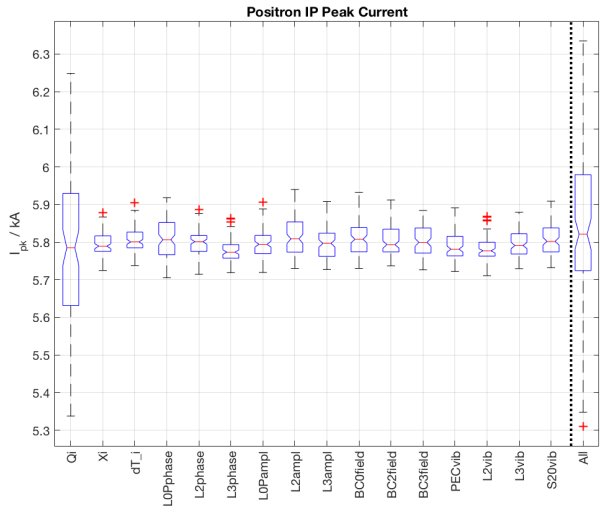


Positron S20 IP Jitter Parameters

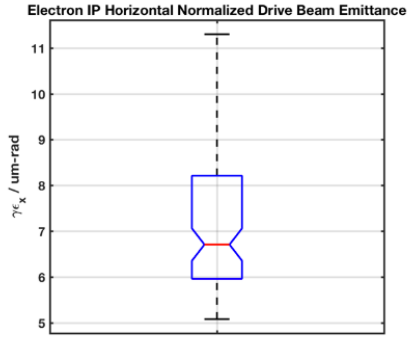


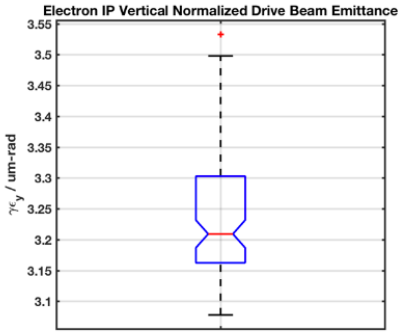


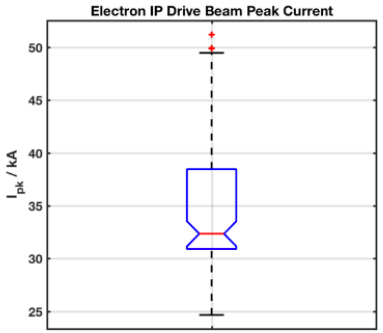


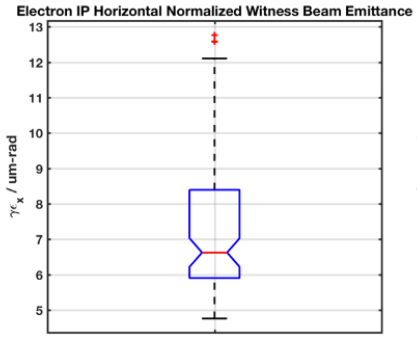


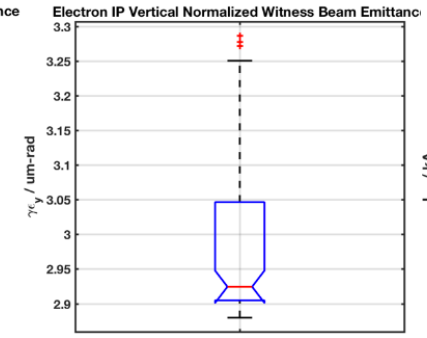
Electron 2-Bunch Configuration Jitter @ S20 IP

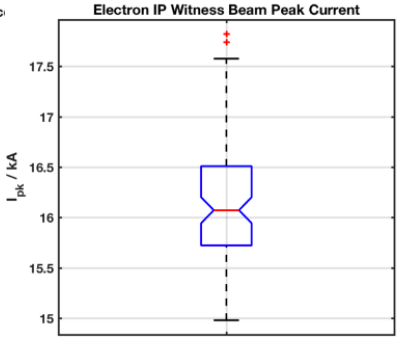


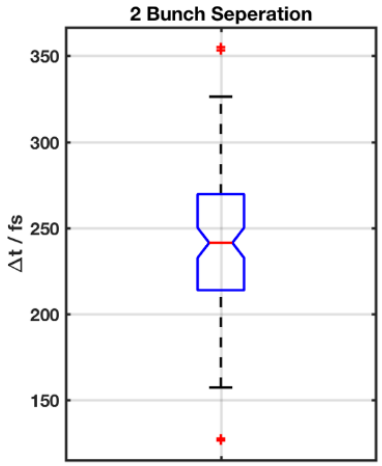












Δz =13 μm (rms)

Parameter @ IP	Drive Bunch	Witness Bunch
ε_x (μm-rad) (90%)	7.2 +/- 1.6	7.4 +/- 2.0
ε_y (μm-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

Jitter parameters with Upgraded FACET-II Options

SLAC

- Consider ultimate performance capabilities
- FACET-II with all upgrade options (detailed in earlier talk)
- “Upgraded” jitter parameters == guess at best achievable technical-limited capability

Property	Unit	FACET	Upgraded
Source Charge Fluctuation	%	1	0.1
Source Electron Position Fluctuation (laser spot jitter on cathode)	% $\sigma_{x,y}$	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
L0P Phase Jitter	degS	0.1	0.01
L1 Amplitude Jitter	%	0.1	0.01
L2/L3/L0P 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	µm	1.5/0.5	0.02/0.02
e- injector Magnet Vibration (x&y), rms	µm	0.1	0.02

Jitter Parameters with Upgraded FACET-II Options

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

Summary

Monte Carlo simulations developed to estimate jitter conditions at experimental S20 IP of FACET-II

- Scripted simulation environment using SLAC batch computing farm for fast (~1/2 day) turn-around for jitter analysis for given FACET-II configuration
- Not currently compatible with 2D CSR simulation option
  - requires GPU for reasonable compute time

Jitter simulation results shown for baseline, 2-bunch electron notch and upgraded parameter configurations

- Like FACET, for high compression configurations: expect considerable pulse-pulse fluctuations, especially in horizontal and longitudinal dimensions