FACET-II Sector 19 & 20 Beamline Upgrade

FACET-II Physics Requirements Document – FACET-II-PR-143

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Revision History

Revision	Date Released	Description of Change
R0	May 9, 2017	Original Release
R1	Aug 6, 2018	Add sector 19 upgrade requirements. Change system manager from Nate to Lauren. Sector 20 upgrade options only for electron systems. Added final focus and spectrometer magnet re-design. Consideration of optics design for new “Kraken” chamber location in upstream FFS location. Add project scientist to signatories.

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1 Purpose

The use of a high-brightness photo-injector electron source at FACET-II allows for the opportunity to deliver compressed electron bunches to Sector 20 with much higher peak currents than possible during operations at FACET. When compressing the rms electron bunch length <20 μm, the final bunch compression system in Sector 20 (Figure 4a) becomes a limiting factor for beam quality due to emittance growth through coherent synchrotron radiation (CSR). We summarize here a simplified design for BC20E (Figure 4b) which improves emittance preservation at high bunch compression in particle tracking simulations.

The final focus system of magnets (FFS) is also re-designed here. Differing from FACET, FACET-II is to provide equal horizontal-vertical emittances and has a requirement for round beams in Sector 20 with equal beta functions in both transverse planes. This necessitates a re-design of the spectrometer magnet system to enable chromatic-free re-focusing of the primary waist at downstream diagnostic locations. Additionally, due to the required spectrometer re-design, the Kraken experimental table is relocated earlier in the lattice. To accommodate these new requirements, the FFS optics now consists of two quadrupole triplets, with a final quadrupole triplet providing for the spectrometer focusing system. Due to the photo-injector source and an overall lower chromatic optics design throughout Sector 20, we can now consider a greater demagnification of the transverse beam size than at FACET (a 5cm round beta function at MIP compared with 10cm x 100cm).

While this document concerns just the electron beam subsystems, the bunch compressor design is also compatible with the later addition of a positron arm for future operations with simultaneous delivery of electron and positron bunches to the Sector 20 experimental area. For this reason, the bunch compressor is referred to as “BC20E”, where “BC20P” is the future positron portion of the compressor.

Two minor modifications are made to the Sector 19 Linac: the removal of an s-band accelerating structure (19-8) and the addition of a quadrupole magnet. This improves the optics at the end of Sector 19: the beta functions in the match into BC20 are greatly reduced, and the phase advances between the 4 wirescanners is made more suitable for emittance measurement.

2 Scope

- The optical phase-advance needs adjusting to enable emittance measurement in Sector 19 by adding a quadrupole magnet and re-matching the optics. To make room for this the (unused) 19-8 accelerating structure is to be removed.
- Re-designed BC20E chicane optics to improve beam quality (reduced beam size and increased peak current at Sector 20 interaction point).
- Re-design of FFS to allow for round beta functions and reduced chromatic aberrations at the Sector 20 interaction point. New optics design also allows for placement and use of “Kraken” experimental chamber in the upstream section of the FFS.
- New design for spectrometer system to be compatible with round beams and to reduce chromatic aberrations at a re-focused waist location downstream by the dump.
- Diagnostics, including new longitudinal phase-space measurement layout with x-band transverse deflecting cavity positioned downstream of BC20, streaking in the horizontal plane for longitudinal phase-space diagnostics in the vertically dispersed region by the dump.
- Tracking studies and system performance estimates.
- Magnet requirements.

3 Definitions

Term	Definition
BC20	Compression chicane at start of Sector 20, consisting of electron and (in future) positron optics
BC20E	Electron arm of BC20
BC20P	Future positron arm of BC20
MIP	MIP is a design focus location 2m downstream from Q0FF and at same SLC z co-ordinate as used at FACET
PENT	Design beam focus waist location for injection into the E200 (plasma wakefield collider) experiment
PEXT	Design exit waist location from E200 experiment used for matching purposes to the dump using the spectrometer triplet magnets
FFS	Final focus system (from downstream of BC20 to MIP)
SPECTROMETER	Beamline downstream of MIP to main dump. Consisting of quadrupole triplet and vertical bend.

4 References

Associated Document(s) Reference Number	Document Title
SLAC-R-1072	FACET-II Technical Design Report

5 Responsibilities

Person(s) or Areas Responsible	Define Responsibility
L. Alsberg	Sector 19 & 20 upgrade system manager
G. White	Optics design
N. Lipkowitz	Instrumentation, diagnostics, feedback
E. Bong	Engineering design

6 Layout and Optics Design

6.1 Sector 19 Modifications

The existing FACET beamline optics from Linac Sectors 18 and 19 into the new BC20 chicane is incompatible with the new 4-station wirescanner emittance measurement system due to incorrect optical phase advances between the wirescanner stations. By removing Linac s-band structure 19-8, installing a new quadrupole (Q1979X) and moving quadrupoles Q19801 and Q19901, the beta match into BC20 is improved to be more periodic, with smaller beta functions (see Figure 1 & Figure 2), and has good phase advances between wirescanners (see Table 1).

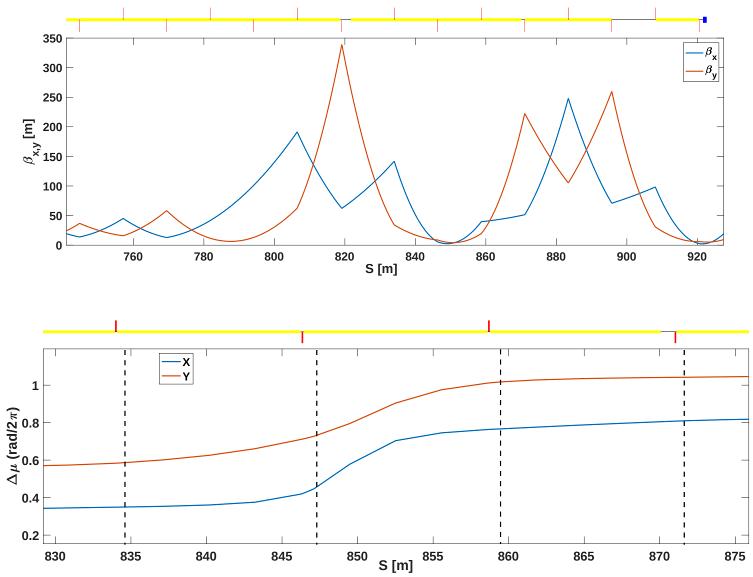


Figure 1: Existing Sector 18 and Sector 19 Twiss parameters required for matching into BC20. Dashed curves on lower phase plot show locations of wirescanners.

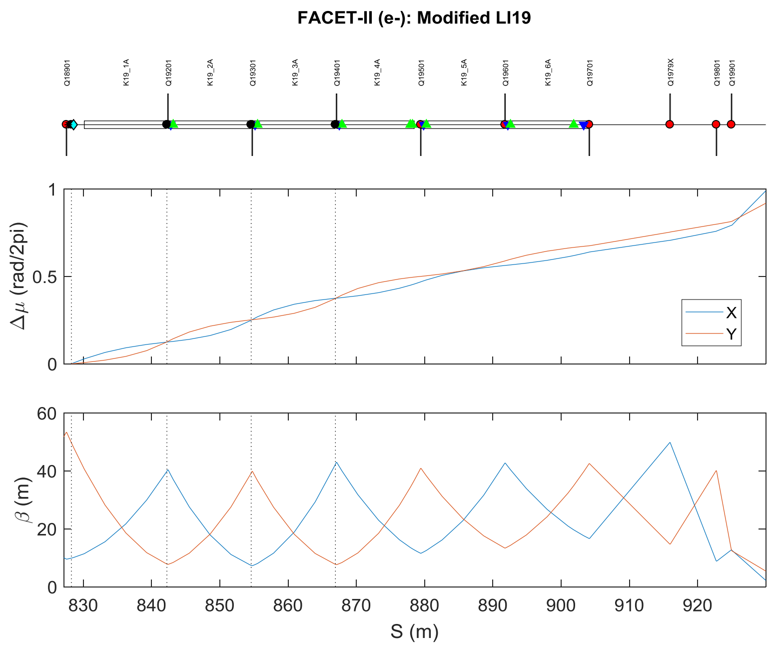


Figure 2: Twiss parameters through emittance measurement station in LI19 and matching into BC20 in upgraded optics configuration. Structure 19-8 has been removed, quadrupoles Q19801 & Q19901 moved and quadrupole Q1979X added.

Table 1: Phase-advance between wirescanner locations in LI19 and beam sizes at wirescanner locations.

Wirescanner Pair	$\Delta\mu_x$ (degree)		$\Delta\mu_y$ (degree)	
	Existing	*Upgraded*	*Existing*	*Upgraded*
WS18944 – WS19144	9.0	44.7	8.0	45.0
WS19144 – WS19244	26.1	45.0	46.2	45.6
WS19244 – WS19344	122.7	45.3	107.5	44.0

Wirescanner	σ_x (μm)		σ_y (μm)	
	Existing	*Upgraded*	*Existing*	*Upgraded*
WS18944	103.2	127.0	231.3	290.0
WS19144	206.2	190.0	91.6	92.7
WS19244	88.4	37.2	203.7	47.0
WS19344	210.5	100.2	90.2	71.2

6.2 BC20E

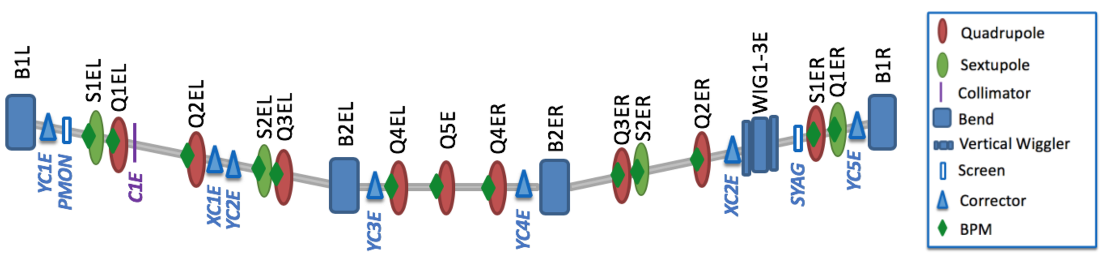
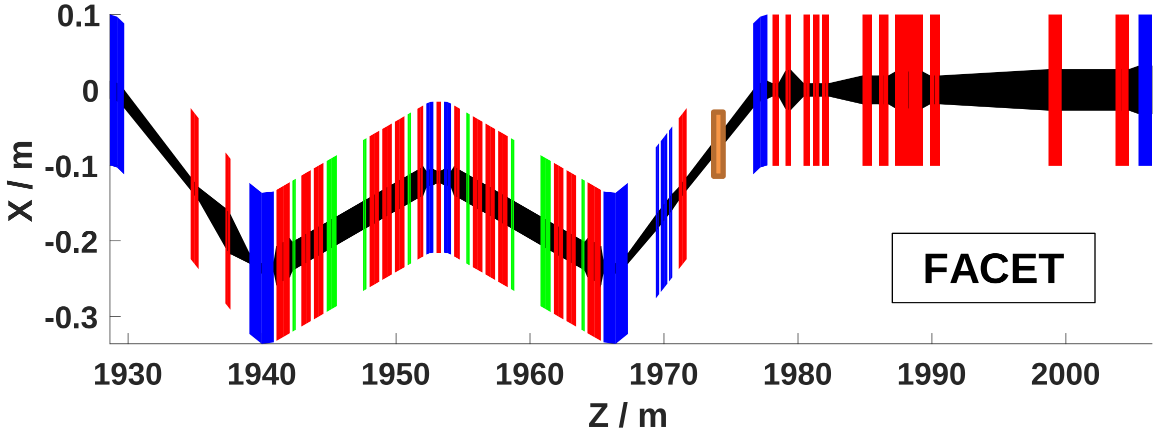


Figure 3: Schematic layout of BC20E chicane devices. Bends B1, B2 are in horizontal plane, WIGE is a vertical wiggler for energy spread diagnostics in conjunction with SYAG screen. Schematic is not to scale.

The optics design for BC20E meets the following requirements:

- Act as the final compression stage in generating a high peak current beam (10-300 kA). The compression factor (R_{56}) should be tunable in the range [0,+5] mm. Where R_{56} convention is used as per Elegant or Lucretia definitions with -ve z values denoting the head of the bunch. *(Note R_{56} sign opposite to that of a standard 4-bend chicane)*
- Minimize transverse emittance growth due to CSR at high peak compression.
- Partially correct for chromaticity and second-order dispersion due to compression chicane and final focus magnets using sextuples in dispersive regions.
- Provide for energy-spread measurements in dispersive regions.
- Dispersion correction is achieved through cam-based mover systems placed under each of the four sextupoles with a movement range +/- 1-2 mm in the horizontal and vertical planes.



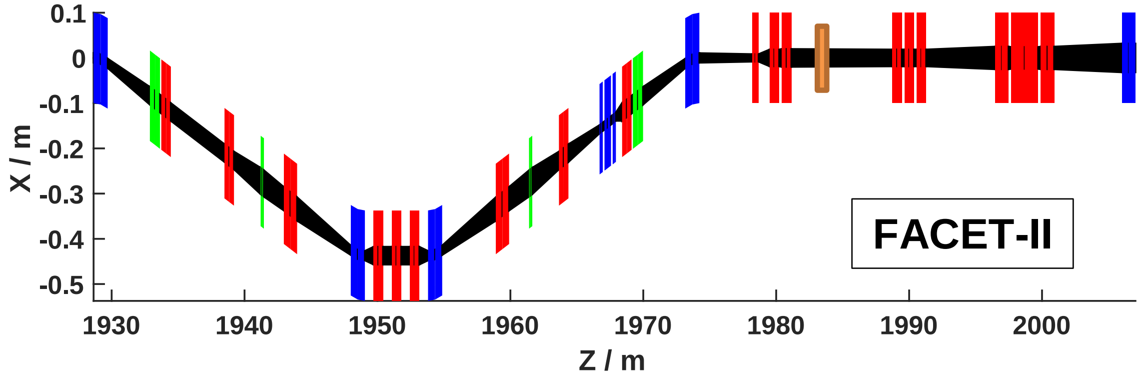


Figure 4 (a): Existing (FACET) Sector 20 electron beamline layout (top). (b) Redesigned BC20E chicane, FFS and dump beamline for FACET-II (bottom). Quadrupole magnets are shown in red, bends are blue, sextupoles are green. The black colored area connects the magnet physical apertures. The XTCAV location is shown as orange rectangles. The first and last bend magnets are unmoved between FACET and FACET-II.

A “double dogleg” arrangement was chosen for BC20E as shown in Figure 5 for the R_{56}=+5mm configuration. This design uses fewer bending magnets compared with the “W chicane” used at FACET and avoids over-compression of the bunch in the center of the chicane, leading to lower emittance degradation due to CSR when transporting a high peak-current electron beam. The trade-off is reduced R_{56} tuneability (0:+5 mm vs. -10:+10 mm), but this is considered an acceptable range for all planned FACET-II experiments. The tuneability in R_{56} is achieved by re-matching of quadrupole magnets; no changes to the bend angles are required. Low betatron function amplitudes are maintained in the chicane (~<100m). This was found to be important during FACET operations to minimize beam loss and aid in delivering stable and reproducible low-emittance beams to the experimental region. Two pairs of sextupole magnets are included for chromaticity and second-order dispersion compensation. A collimator is needed immediately downstream of the first quadrupole magnet for bunch shaping and 2-bunch notch beam configurations as at FACET. A wiggler is included upstream of the final quadrupole in conjunction with a profile monitor screen for use as an energy spectrum monitor, again as used in FACET.

The x-band transverse deflecting cavity used in FACET for bunch length diagnostics is moved from within the chicane to the FFS system. This then serves as a bunch length diagnostic device for both electron and positron beams in future operations. The deflecting cavity is to be changed from delivering a streak in the vertical dimension to the horizontal instead. This will allow 2-d longitudinal phase space diagnostics in the downstream vertically dispersive area in the spectrometer beamline.

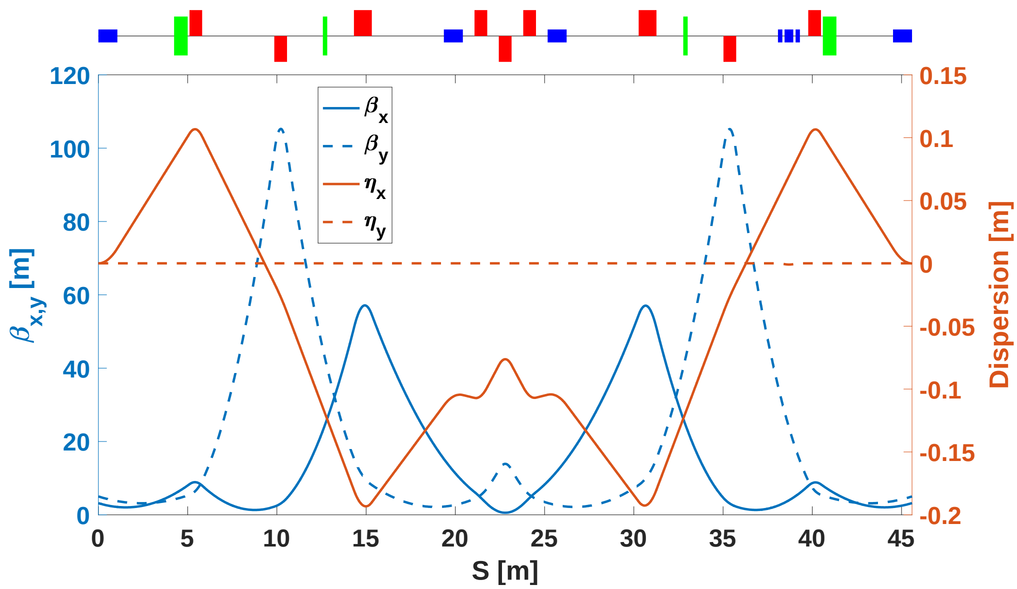


Figure 5(a): Electron chicane optics with R_{56}=+5mm.

Parameter tables for the nominal beam design and considered operating ranges are presented in Table 2 below. Note that the BC20 chicane exhibits mirror symmetry in the Twiss parameters about the center of Q5E.

Table 2: Parameter table for optics design and beam tracking for BC20E chicane. NB: care should be taken in interpreting final bunch parameters due to the highly non-Gaussian nature of the bunch topology.

Parameter	Unit	Nominal Design	Range
Initial Bunch Length	$\sigma_{z,i}$ (μm) (rms)	83	80 – 1,000
Final Bunch Length	$\sigma_{z,f}$ (μm) (fit Gaussian)	0.6	0.6 – 1,000
Initial Peak Current	I_{pk} (kA)	3.9	0.1 – 4
Final Peak Current	I_{pk} (kA)	156	0.1 - 156
Bunch Charge	Q (nC)	2	0.5 – 5.0
Initial/Final Horizontal Twiss	α_x , β_x (m)	0.7559, 3.177	-
Initial/Final Vertical Twiss	α_y , β_y (m)	0.7701, 5.000	-
Energy Spread	δ_E / E (%) (rms)	1.2	0.1 – 1.5
Initial Normalized Emittance (90%)	$\varepsilon_{n,i}$ (x,y) (μm-rad)	3.6, 3.0	4 - 20
Final Normalized Emittance (90%)	$\varepsilon_{n,f}$ (x,y) (μm-rad)	12.0, 9.5	4 - 20
Longitudinal Compression Factor	$R_{5,6}$ (mm)	5	0 – 5

6.3 FFS & Dump/Spectrometer Beamlines

The FFS optics are primarily responsible for matching the beam from BC20 and de-magnifying the beta functions at the plasma entrance (PENT) down to an operational minimum of 5 cm ($\beta_x^* = \beta_y^*$). This is achieved using a triplet of quadrupole magnets after the final BC20 bend and a final focusing quadrupole triplet. MIP is located 2m downstream of the final face of Q0FF, PENT is 2.7m downstream of Q0FF. To service experiments located in the “Kraken” chamber (see Figure 6), the triplet of quadrupole magnets Q5FF, Q4FF and Q3FF are used to focus the electron beam at the Kraken waist (1.2 m downstream of Q3FF) in either a round-beam configuration or with a 100:1 beta function ratio.

The dump beamline consists of a quadrupole triplet, 5.2m downstream of Q0FF. This beamline is responsible for re-imaging the electron waist on a screen just upstream of the main dump. A spectrometer vertical bend magnet (B5D36) deflects the beam downwards towards the dump and generates vertical dispersion at the dump screen for diagnostics of the beam energy profile.

The beamline schematic in Figure 6 below shows the magnet and diagnostics locations, including the x-band deflecting cavity used in conjunction with the dump screen for bunch length measurements and longitudinal profile diagnostics.

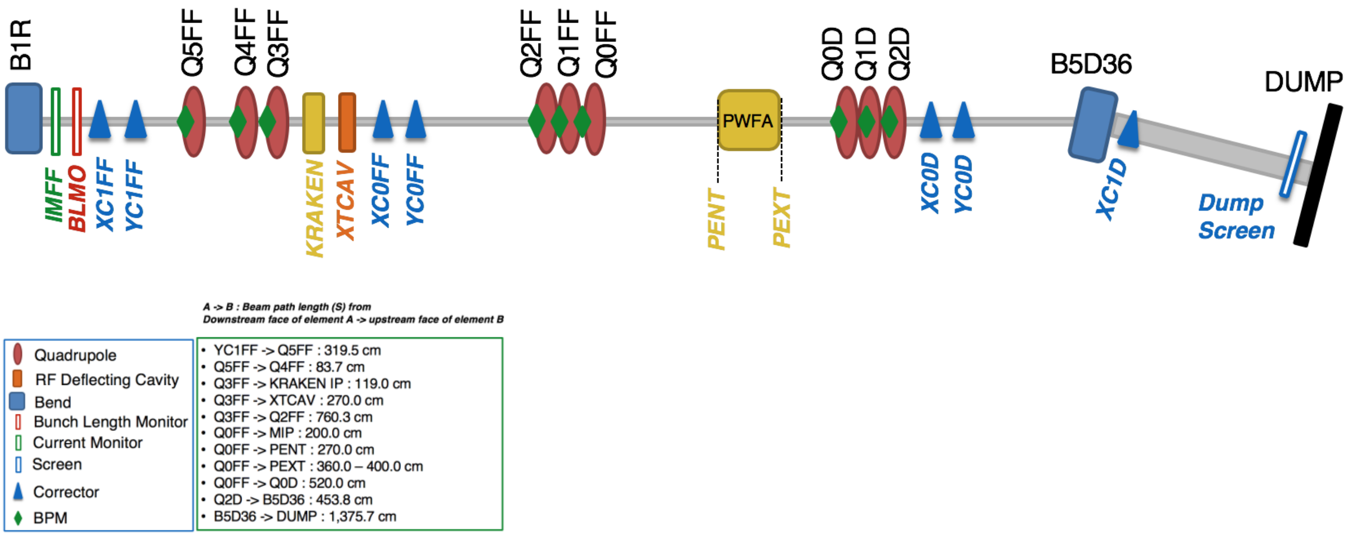


Figure 6: Schematic of FFS and dump/spectrometer beamline devices. Bend B5D36 is in the vertical plane. Schematic is not to scale, drift lengths (S) between magnets and points of interest are shown. The waist location “MIP”, B5D36 bend and the dump are unmoved from FACET.

6.3.1 PWFA Configuration

The FFS optics design is capable of focusing the electron beam to a waist in the experimental IP area (between Q0FF and Q0D) with a beta function down to 2 cm and up to at least 30 m within z = +/- 1 m of PENT (equal in horizontal and vertical planes). Figure 7 below shows the optics functions for the FFS with the beam imaged at the PENT waist location with β=5cm and the spectrometer optics with the waist at PEXT (β=5cm) re-imaged in both planes at the dump screen. The spectrometer optics is compatible with either a 1m or 60cm flat-top length to the plasma channel, with the 1m case shown in the optics plot below. The 60cm case leads to slightly increased chromatic distortions after the spectrometer magnets due to the increased distance of the waist from Q0D.

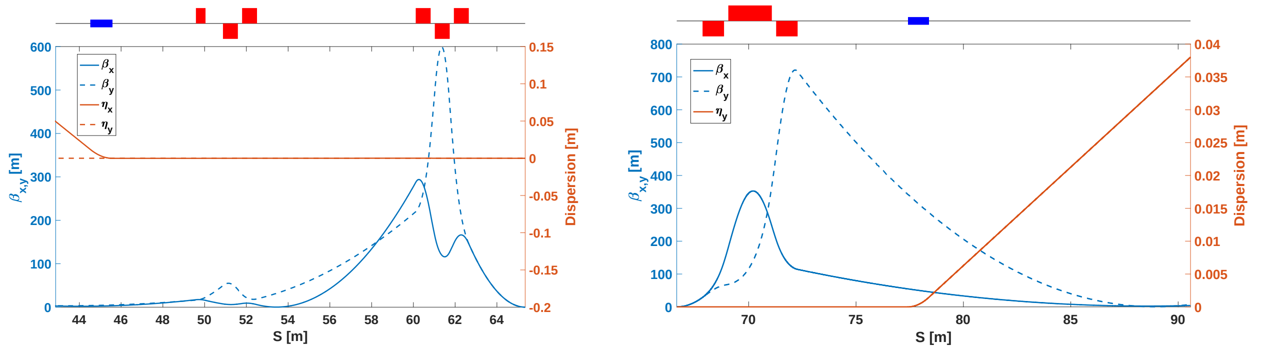


Figure 7: (left) Twiss parameters for Sector 20 FFS. Waist shown at PENT location with β=5cm. (right) Spectrometer optics from PEXT to dump screen with 1m flat-top plasma configuration.

6.3.2 TCAV Measurement Configuration

To enable high-resolution bunch length measurements, larger horizontal beta functions are required in the area of the TCAV. Figure 8 below shows an example configuration used for the TCAV bunch length measurement calculation in Section 10 below.

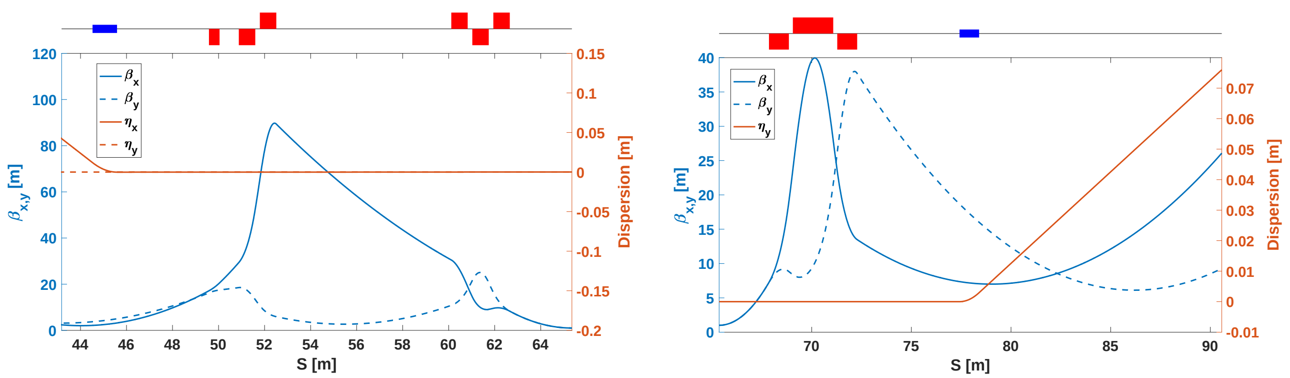


Figure 8: (left) Twiss parameters for Sector 20 FFS. Waist shown at PENT location with β=1m. (right) Spectrometer optics from PENT to dump screen suitable for TCAV measurements.

6.3.3 “Kraken” Table Configurations

The waist location for Kraken table experiments is set at 119 cm downstream of Q3FF. Two optical configurations are required: either a round beam configuration or a flat beam configuration (100:1 β_y:β_x). The Twiss parameters for these options are shown in Figure 9 below. The location of the waist can be moved longitudinally with respect to the Kraken IP location over the range [-20:50] cm whilst keeping the round or 100:1 ratio configuration as shown in Figure 10. Note that the β_y:β_x ratio inverts for $\Delta z_{IP} < 0$.

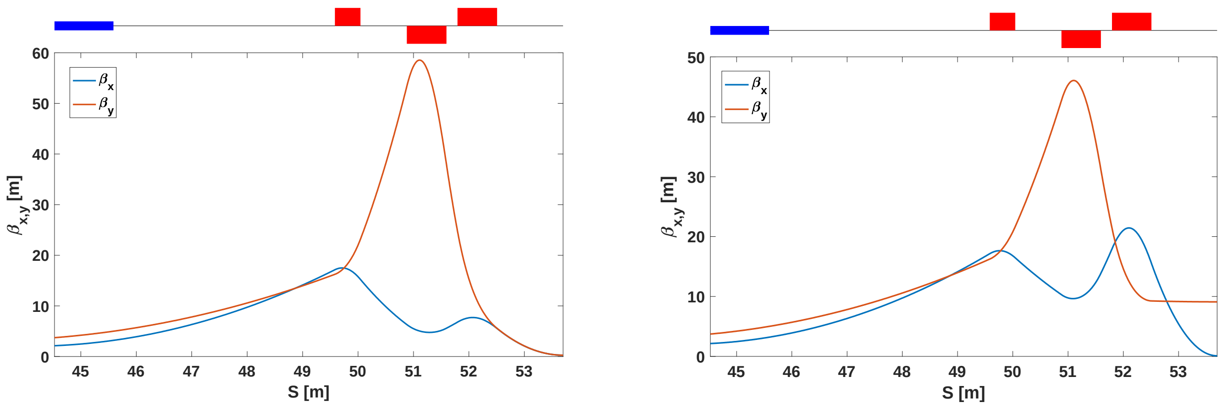


Figure 9: Kraken table optics from exit of BC20 to Kraken table waist, 1.2m downstream from Q3FF. (left) round waist configuration with $\beta_x = \beta_y = 27$ cm at Kraken IP. (right) flat waist (1:100) configuration where $\beta_x = 9.1$ cm, $\beta_y = 910$ cm at Kraken IP.

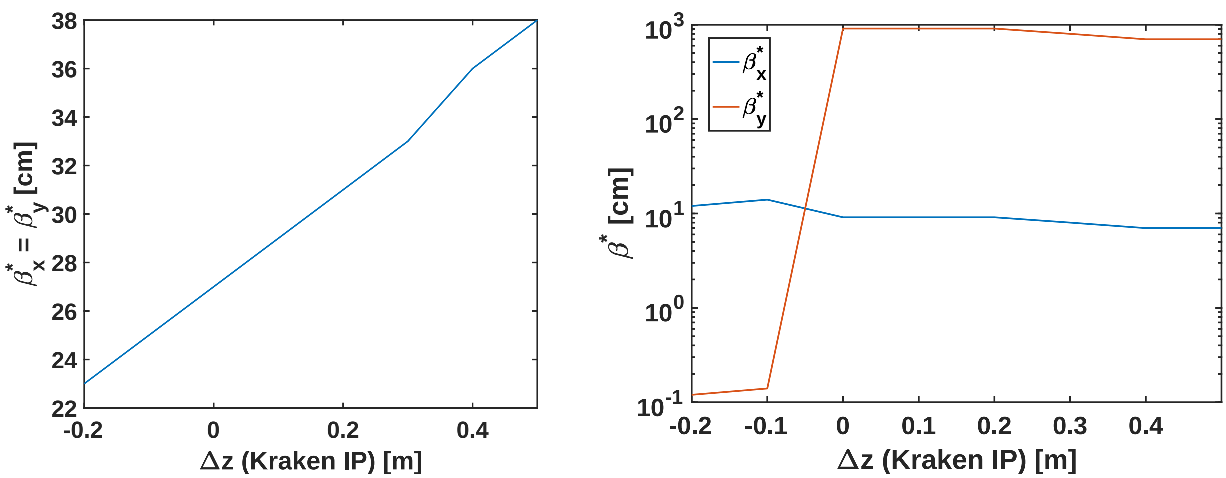


Figure 10: Beta functions at Kraken table IP waist, either in round (left) or 100:1 (right) configuration vs. IP location.

6.3.4 Spectrometer

The spectrometer optics for the nominal configuration is shown in Figure 7 above with the 5 cm beta waist re-focused to the dump measurement screen from the exist of the plasma. This configuration shows the case with a 1m flat top in the plasma channel with the PEXT location 1.6m from the first spectrometer quad (Q0D). An additional configuration with a 0.6m flat-top is also considered - the optics for this setup with a 5 cm beta waist are shown in Figure 11. The change in exit focus waist position modifies the optics in the spectrometer quad region by just a few percent. The maximum permitted emittance of the beam exiting the plasma accelerator which clears the spectrometer magnet apertures is shown in the table below. Also shown is the chromatic performance of the optics in both configurations for the witness bunch parameters described in Section 7.

Table 3: Maximum emittance to pass through spectrometer magnets and chromatic emittance growth through spectrometer for witness beam described in Section 7.

Parameter	Units	PWFA Flat Top = 60cm	PWFA Flat Top = 1m
$\varepsilon_{n,max}$	μm-rad	290	285
$\Delta\varepsilon_x / \varepsilon_x$	%	4.1	2.8
$\Delta\varepsilon_y / \varepsilon_y$	%	4.9	5.2

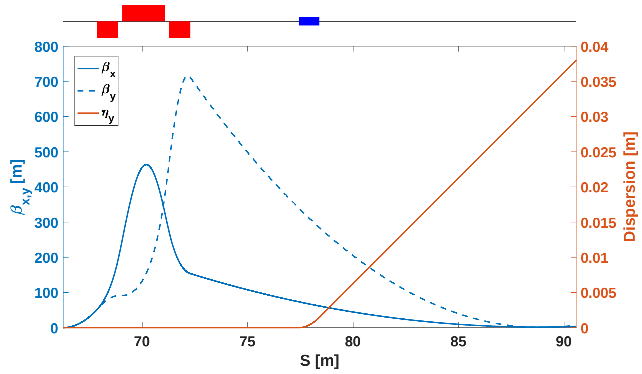


Figure 11: Spectrometer optics with 60cm length PWFA flat-top.

6.3.5 Beam Stay-Clear

The beam stay-clear radius is calculated as 3X rms dispersive beam size added in quadrature to 10X rms betatron beam size calculated from the Twiss parameters assuming a maximum emittance of 20 μm-rad and energy spread of 1.5%. Additionally, 3X the rms horizontal streak from the TCAV operating is also added in quadrature, using a bunch length of 200 um. The beam stay-clear entries for magnets in the tables below are the largest for any of the optics configurations considered in this document. The beam stay-clear calculation as a function of beam position through the Sector 20 optics is shown in Figure 12 below.

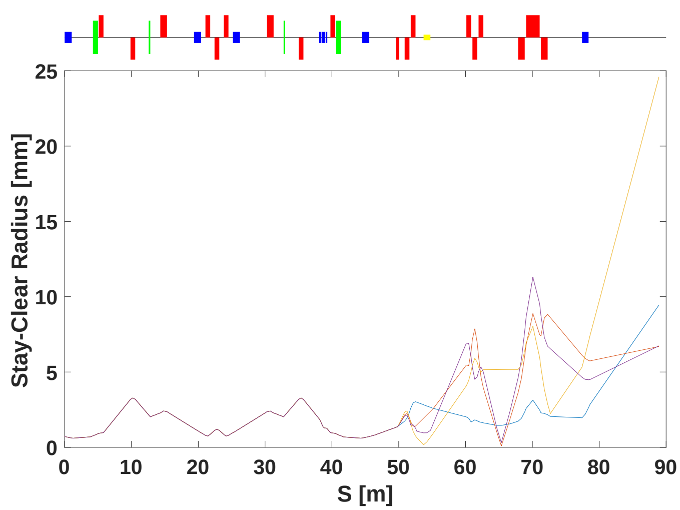


Figure 12: Beam stay-clear radius calculation for the different configurations considered in this document.

7 Particle Tracking

7.1 Source to PENT

A start-to-end 6D particle tracking simulation exists for the TDR design of FACET-II. The Sector 19 and 20 optics were replaced with the new designs detailed here and the compression profile was optimized using the phases of the L1 and L2 acceleration sections. The expected starting configuration for FACET-II is to co-accelerate a 1.6 nC drive bunch and 0.5 nC witness bunch (in the same rf bucket). The longitudinal and transverse tracked particles at the interaction point are shown in Figure 13 for the

witness bunch. The tracking simulation includes treatment of structure wakefields, incoherent and coherent synchrotron radiation and longitudinal space-charge. For the default configuration with $\beta^* = 5$ cm @ PENT, the relative chromatic emittance growth due to BC20 and the FFS optics is 7.2%, 21.1% in the x,y planes respectively. The chromatic dilution of the beam spot size varies with the beta match and IP location with respect to PENT as shown in Figure 14.
An alternative configuration is to accelerate a single 2 nC electron beam, aiming for maximum peak current. The tracked beam with maximum peak current configuration is shown in Figure 15. Note this configuration requires collimation, a laser heater in the injector and an x-band linearizer structure in Sector 11. With the new optics, a peak compression of >300 kA was achieved. This should be compared with a maximum peak current of 76 kA for the TDR Sector 20 design.

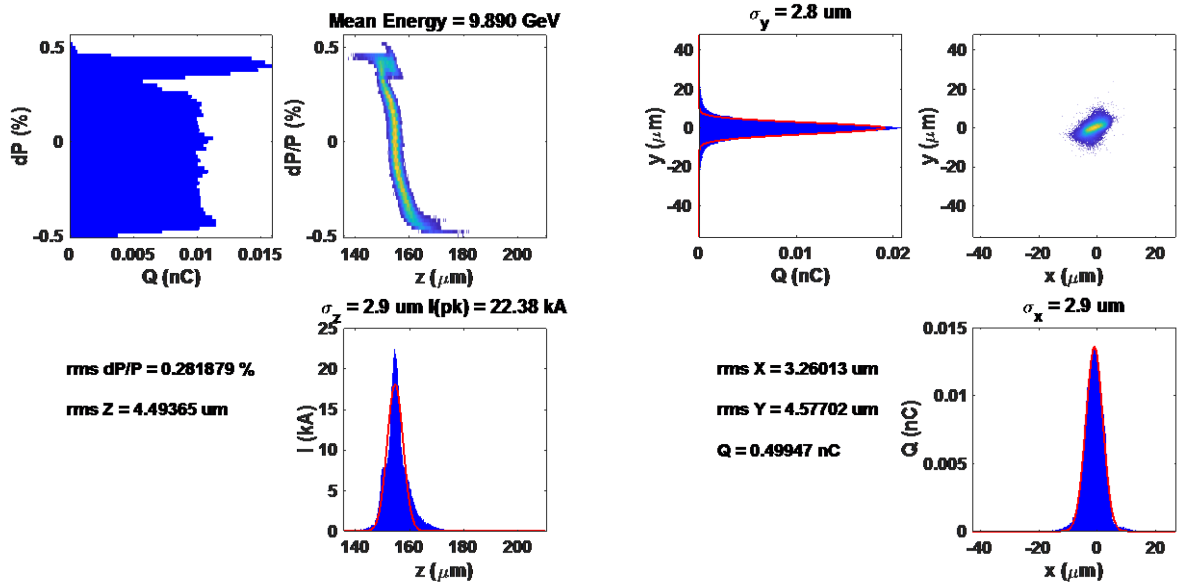


Figure 13: Longitudinal (left) and transverse (right) phase space of tracked macro-particles in the witness bunch at the FACET-II interaction point (entrance to plasma accelerator chamber).

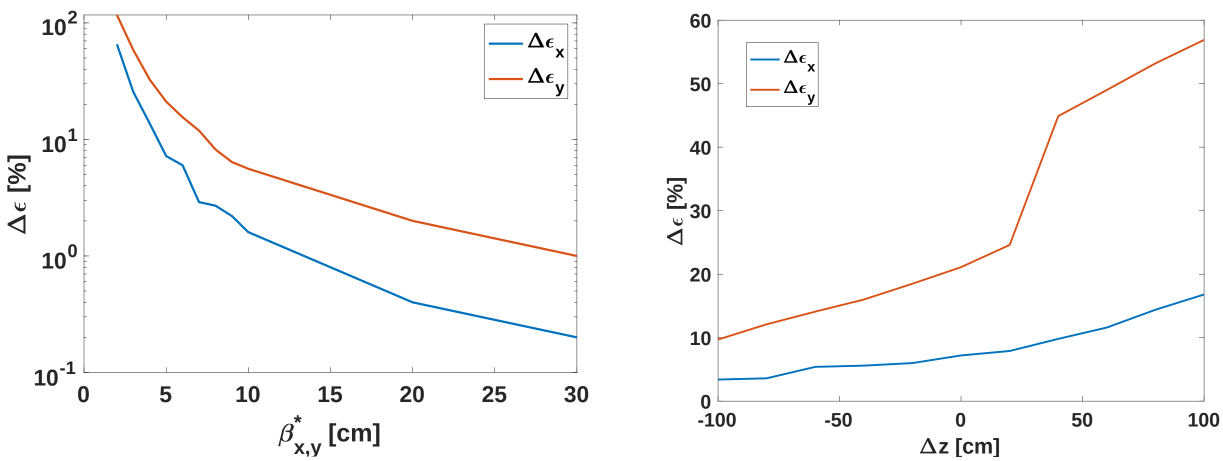


Figure 14: Relative emittance growth of witness bunch @ PENT with varying matched IP beta (left); and with 5 cm beta at waist, longitudinally translated from PENT (right).

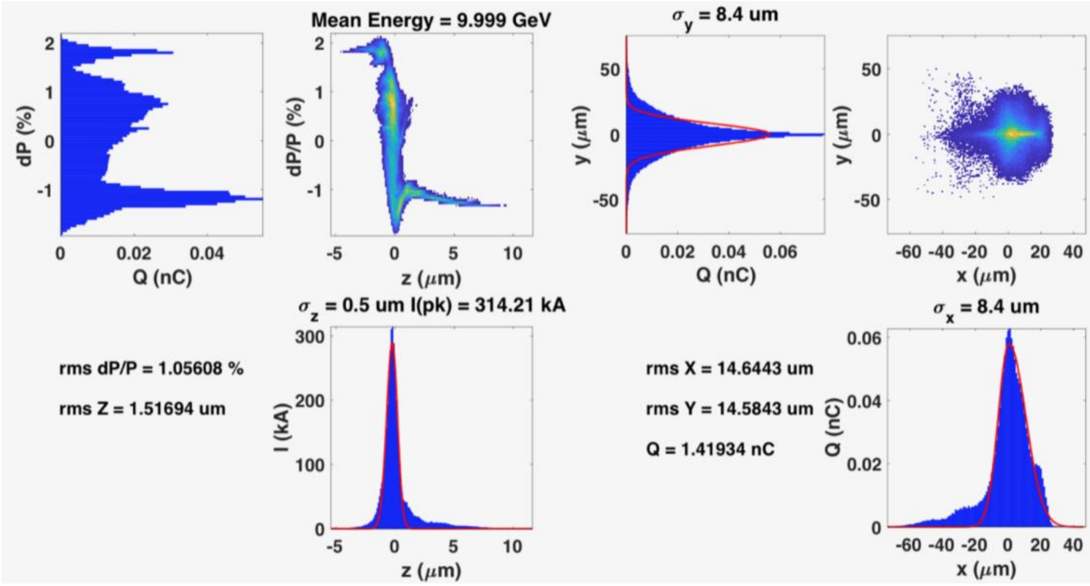


Figure 15: Longitudinal and transverse phase-space at Sector 20 IP showing maximum peak compression of initial 2 nC bunch using collimation, laser heater and linearizer devices in FACET-II.

8 Magnets & RF

Design magnet strengths below are shown for the default optics case with the experimental IP waist at the PENT location with $\beta_x = \beta_y = 5$ cm.

All quadruple magnet power supplies in the FFS and dump beamlines are preferred to be bi-polar to allow for flexibility in optics configuration. Q5FF in particular, the polarity of this quad changes between low and high IP beta function configurations (e.g. see Figure 7 vs. Figure 8).

The beam stay-clear definitions are as described in Section 6.3.5, evaluated at the magnet locations for the data shown in the tables below and represent the required stay-clears for any of the evaluated beamline configurations.

The sextupole magnets were set to minimize transverse emittance growth due to chromaticity and second-order dispersion for the default optics case.

*Apertures quoted in tables below include a 2mm allowance for the vacuum chamber.

8.1 Quadrupoles

Deck Name	Engineering Type	Effective Length / m	Design Int. Strength (gL) / T	Design Pole Tip Field / T	Aperture* (radius) / mm	Beam Stay Clear Radius / mm	Design Energy / GeV
Q1979X	1.085Q4.31	0.1068	3.49763	0.4516	11.8	--	10
Q1EL	1.625Q27.3	0.7142	16.3326	0.4723	18.6	4.9	10
Q2EL	1.625Q27.3	0.7142	-10.9513	0.3166	18.6	1.3	10
Q3EL	2.13Q38.31	1.0	9.9660	0.2698	25.0	9.0	10
Q4EL	1.625Q27.3	0.7142	9.6646	0.2795	18.6	4.9	10
Q5E	1.625Q27.3	0.7142	-22.9557	0.6638	18.6	3.7	10
Q4ER	1.625Q27.3	0.7142	9.6646	0.2795	18.6	4.9	10
Q3ER	2.13Q38.31	1.0	9.9660	0.2698	25.0	9.0	10
Q2ER	1.625Q27.3	0.7142	-10.9513	0.3166	18.6	1.3	10
Q1ER	1.625Q27.3	0.7142	16.3326	0.4723	18.6	4.9	10

Q5FF	0.813Q17.7	0.4608	17.1947	0.1771	8.3	1.5	10
Q4FF	1.625Q27.3	0.7142	-34.2149	0.7048	18.6	2.4	10
Q3FF	1.625Q27.3	0.7142	43.5372	0.8969	18.6	3.0	10
Q2FF	1.625Q27.3	0.7142	23.1552	0.4770	18.6	7.0	10
Q1FF	1.625Q27.3	0.7142	-39.0029	0.8035	18.6	7.9	10
Q0FF	1.625Q27.3	0.7142	23.1552	0.4770	18.6	7.0	10
Q0D	2.13Q38.31	1.0	-34.9248	0.9429	25.0	25.0	20
Q1D	2.05Q78.74	2.026	60.4125	1.5707	24.0	24.0	20
Q2D	2.13Q38.31	1.0	-34.9248	0.9429	25.0	25.0	20

8.2 Sextupoles

Each sextupole magnet should be mounted on a mover system with at least +/- 1 mm of motion range in horizontal and vertical directions for the purpose of dispersion correction. The mover systems should be remotely controllable.

Deck Name	Engineering Type	Effective Length / m	Design Int. Strength / T.m^{-1}	Design Pole Tip Field / T	Aperture* (radius) / mm	Beam Stay Clear Radius / mm
S1EL	1.625S29.2	0.762	1334.6	0.2832	18.6	4.2
S2EL	1.625S9.06	0.244	880.0	0.1867	18.6	5.6
S2ER	1.625S9.06	0.244	880.0	0.1867	18.6	5.6
S1ER	1.625S29.2	0.762	1334.6	0.2832	18.6	4.2

8.3 Dipoles

Stay-clear half-apertures shown are calculated in the non-bend plane according to the formula stated above. The good field region is the full-gap occupying a space expected to accommodate the beam passage and is defined as the transverse distance travelled by the beam through the magnet plus calculated stay-clear region in the bend plane. Design beam energy is 10 GeV except for the B5D36 magnet which is 20 GeV to accommodate the plasma-accelerated witness beam.

Deck Name	Engineering Type / subsection	Bend Plane	Effective Length / m	Design Int. Strength / T.m	Bend Angle / mrad	Full Gap (non-bend plane) / mm	Good field region(bend plane) /mm	Stay Clear Radius (non-bend plane) / mm
B1L	0.906D40.945	X	1.063	0.7535	22.59	21.0	13.0	1.0
B2EL	0.906D40.945	X	1.063	-0.7535	-22.59	21.0	22.6	1.0
B2ER	0.906D40.945	X	1.063	-0.7535	-22.59	21.0	22.6	1.0
WIGE11	2D8.8	Y	0.244	-0.0834	-2.5	18.3	4.2	2.9
WIGE21	2D8.8	Y	0.488	0.1668	5.0	18.3	3.8	3.5
WIGE31	2D8.8	Y	0.244	-0.0834	-2.5	18.3	3.2	4.2
B1R	0.906D40.945	X	1.063	0.7535	22.59	21.0	13.0	1.0
B5D36	5D36	Y	0.978	0.4004	6.0	63.6	15.0	6.5

8.4 Steering Correctors

Bend magnets B1L, B2EL, B2ER, B1R, B5D36 are to contain horizontal trim correctors for orbit correction. Additionally, BC20 contains 7 type 3D8.8MK2 linac correctors (2 horizontally steering and 5 vertically steering) as depicted in Figure 3. The FFS and dump beamlines contain an additional 7 corrector magnets, also of type 3D8.8MK2 as depicted in Figure 6 (4 horizontal correctors and 3 vertical). Bend B5D36 and WIGE wiggler magnets bend in the vertical plane and are also to contain vertical steering trim coils.

8.5 RF

The FACET XTCAV is moved to a location downstream of Q3FF and maintains the same operational requirements as used in FACET.

Deck Name	Max On-Crest Field / MV/m	Frequency / MHz	Effective Length / m	Aperture (radius) / mm	Beam Stay Clear Radius (X) / mm	Beam Stay Clear Radius (Y) / mm
XTCAVFF	20.0	11424	1.0325	4.8	4.20	0.49

9 Collimation

The so-called “notch” and “jaw” collimators used during FACET operations are to be retained in the FACET-II BC20 beamline as depicted in Figure 3 (labelled “C1E”). The primary purpose of this collimation system is to shape the beam in the longitudinal plane for optimal operations with the PWFA experiments.

10 Instrumentation, Diagnostics and Feedback

Each magnet in Sector 20 is expected to contain its own stripline BPM for orbit control, these are of the same type as currently existing in the FACET Sector 20 beamline.
Energy spread diagnostics is provided by two screens (PMON and SYAG) in BC20E which are retained from FACET.
Optics matching and emittance diagnostics is provided in LI19 using the 4 wirescanner system shown in Section 6 above. Transverse diagnostics in the FFS beamline is complicated due to the enhanced peak current of the electron beam compared with FACET operations. Peak currents in excess of 100 kA are expected to destroy intercepting diagnostics with a single-shot. A laserwire system is currently being developed as a transverse diagnostics tool at the time of writing, in addition to other experimental approaches utilizing laser-based diagnostics of the PWFA plasma. Transverse diagnostics may still be possible in the dispersed region upstream of the main dump, for which existing profile screens (depicted in Figure 6 as “Dump Screen”) may be used.

10.1 Longitudinal Diagnostics

The BLMO pyrometer-based bunch length monitor used at FACET is retained in the FACET-II FFS beamline as depicted in Figure 6. Likewise, the x-band transverse deflecting cavity used during FACET operations is retained. It is moved from the BC20 chicane into the FFS optics (where it can also be used for future positron operations with an independent positron arm of the BC20 chicane). The XTCAV is also to be modified to operate in the horizontal plane to allow full longitudinal diagnostics at the dump screen utilizing the vertical dispersion present at that location. The location of the XTCAV is immediately downstream of the Kraken chamber following the Q3FF quadrupole as shown in Figure 6.

The resolution of the XTCAV is given by: $\sigma^2 = \beta_s \epsilon + \sigma_z^2 \beta_T \beta_s \left(k_{rf} \frac{eV_0}{pc} \sin(\Delta\psi) \cos\phi_{rf} \right)^2$ in terms of the rf parameters of the deflecting cavity and the beta functions at the screen (S) and TCAV (T). An example optical configuration suitable for TCAV measurements is shown in Figure 8 with a waist at PENT, β^*=1m, cavity deflects in the horizontal plane with 19.4 μm per μm of (rms) bunch length. The rms horizontal beam size at the dump screen is 65.6 μm. The minimum rms bunch length measurable by the XTCAV system is then limited to about 3.4 μm (ignoring any resolution limits imposed by the measurement system itself).

10.2 Feedback

Several Matlab-based software loops for control of e^- energy and TCAV phase have been in use at FACET and will be retained for the FACET-II e- beam. The existing energy feedback monitors the electron beam energy through BPM readings at the positron source extraction point in Sector 19-7 and adjusts RF phase shifters in Sectors 17 and 18 to regulate beam energy at extraction, and subsequently in Sector 20.