FCC-ee Synchrotron Radiation Collimators and Masks

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CERN

FUTURE CIRCULAR COLLIDER

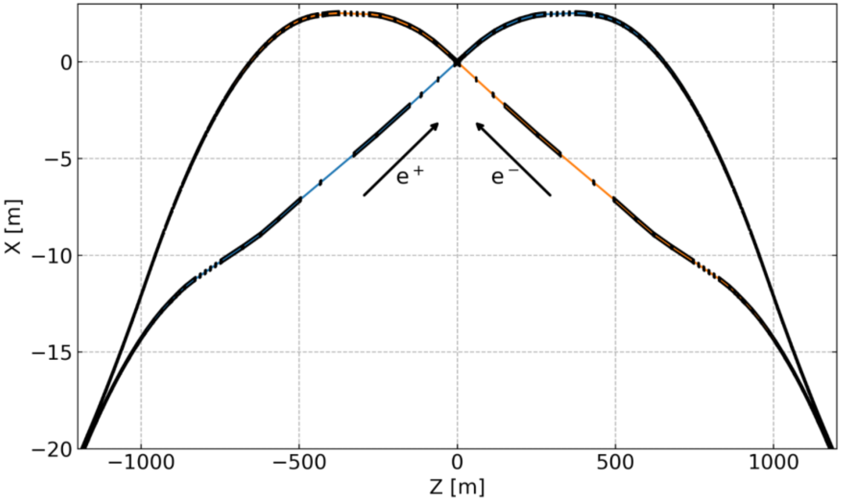
Outline

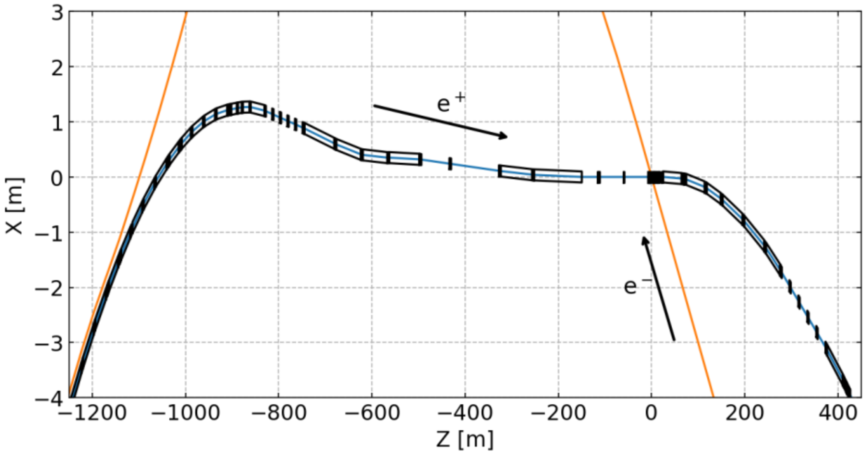
- FCC-ee lattice, aperture profile, masks and collimators
- Direct hits from the last dipole
- Masks and collimators
  - tt mode
  - Z mode
  - W and H modes
- Summary and outlook

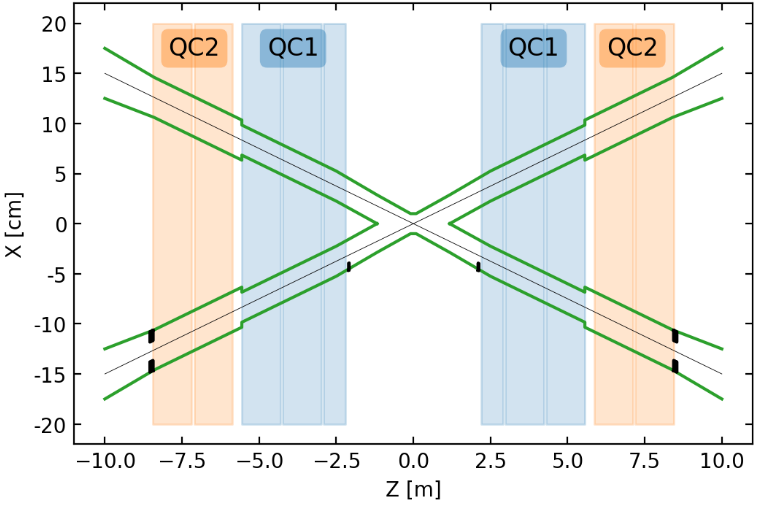
	Beam Energy	Beam Current	H Beam Emittance	V Beam Emittance	$\beta^*_{x,y}$ [mm]
@ Z	45.6 GeV	1280 mA	0.71 nm	1.42 pm	100/0.8
@ W	80.0 GeV	135.0 mA	2.16 nm	4.32 pm	200/1.0
@ H	120.0 GeV	26.7 mA	0.64 nm	1.29 pm	300/1.0
@ tt	182.5 GeV	5.0 mA	1.49 nm	2.98 pm	1000/1.6

Table ref

FCC-ee lattice | 4 IPs





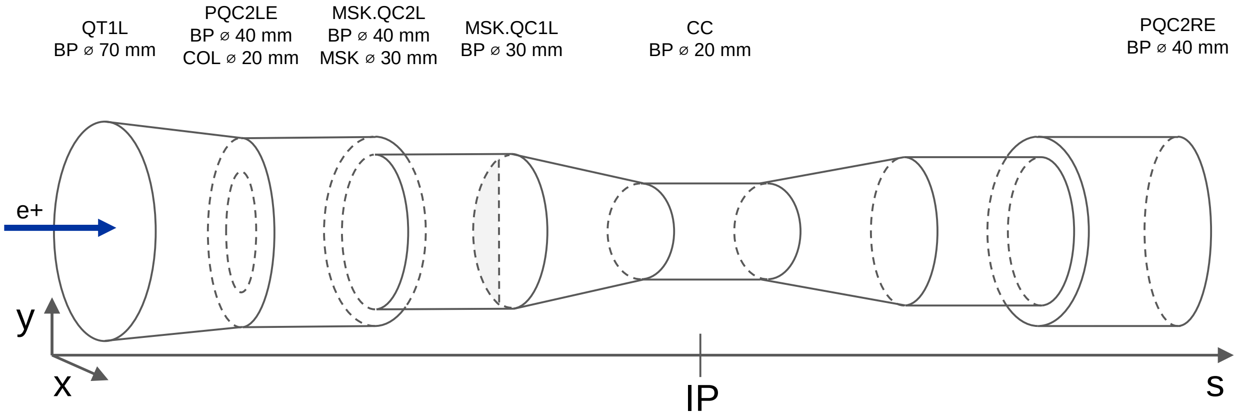


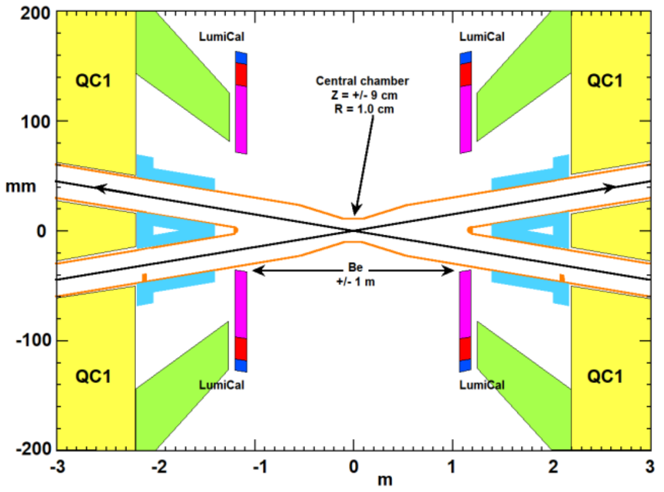
The studies focus on the section from s=-800m to 100m around the IP and specifically on the photon hits in the detector region.

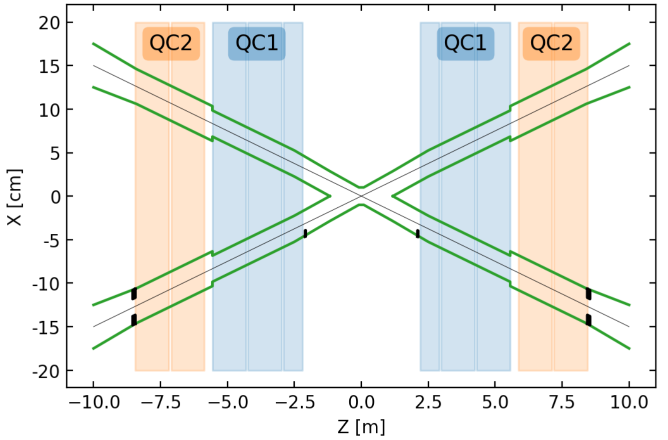
There is a **30 mrad crossing angle** at the IP.

The lattice design upstream the IP is based on weak dipoles and long straight sections. **BC1L and BWL dipoles** have **critical energies below 100 keV** and are located further than 150m from the IP.

FCC-ee lattice | Masks and collimators







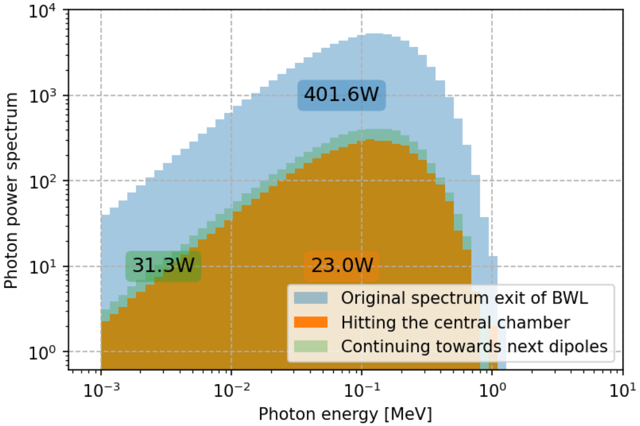
The central beam pipe radius is **10mm** over **18cm** along the Z axis. Due to the 30mrad crossing angle the central chamber is **1.35mm** closer to the beam center.

Masks: s=-2.12m with **9mm** horizontal aperture, s=-5.58m with **15mm** aperture radius.

Collimators: after BWL (s=-144m), after QC3L (s=-112m), after QT1L (s=-39.7m) shields the aperture reduction downstream from (⌀ 70→ ⌀ 40), at PQC2LE (s=-8.4m) shields the aperture reduction downstream at MSK.QC2L (⌀ 40→ ⌀ 30).

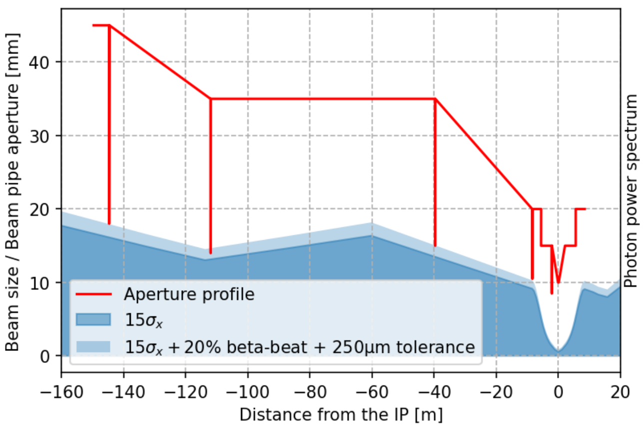
Synchrotron radiation power deposition from BWL (last dipole before the IP)

Unshielded study



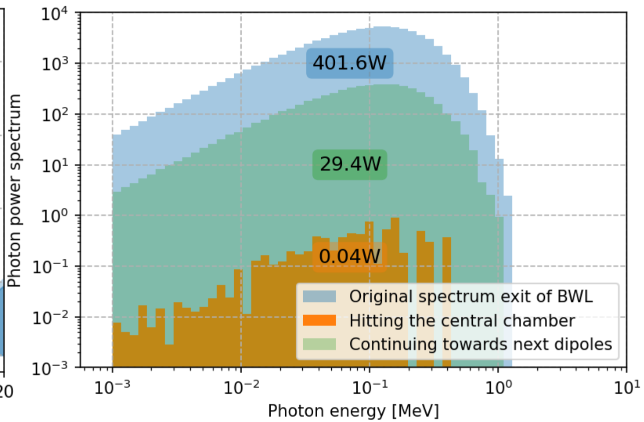
A total of **23W** is deposited in the CC region and **347W** are distributed along the beam line before the IP.
31W continue towards BC1R-BC3R.

Mitigation method



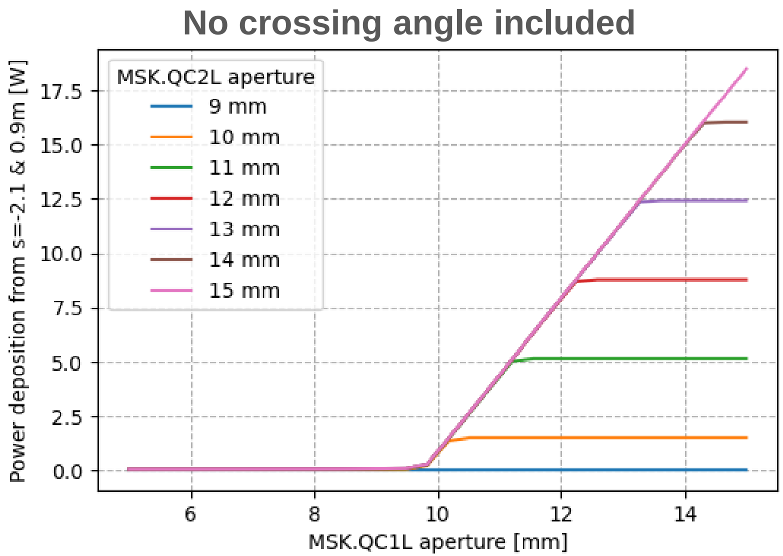
Study of the SR from the last dipole, tracked past the IP to record the photon hits and confine them at specific locations as well as possible.

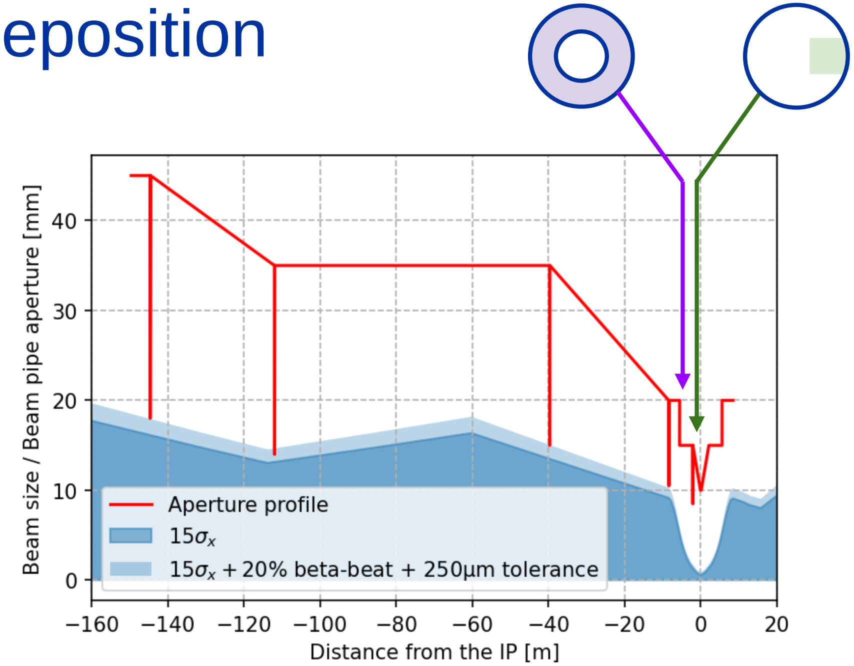
Shielded study



Power spectrum of the photons hitting the beam pipe or continuing towards the dipoles BC1R-BC3R.

Synchrotron radiation power deposition

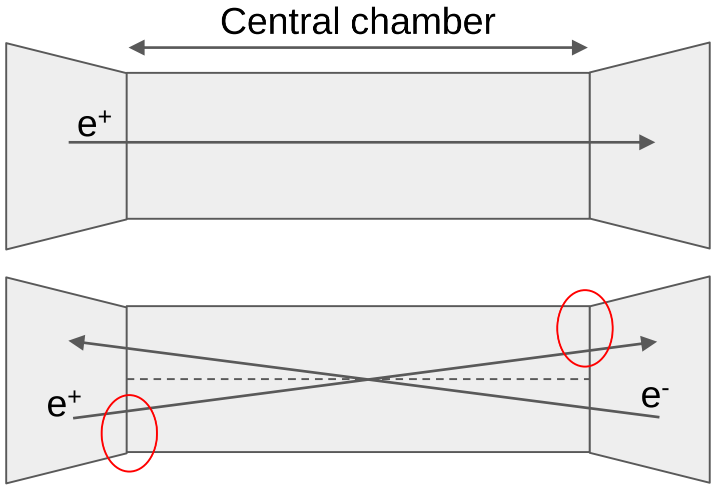


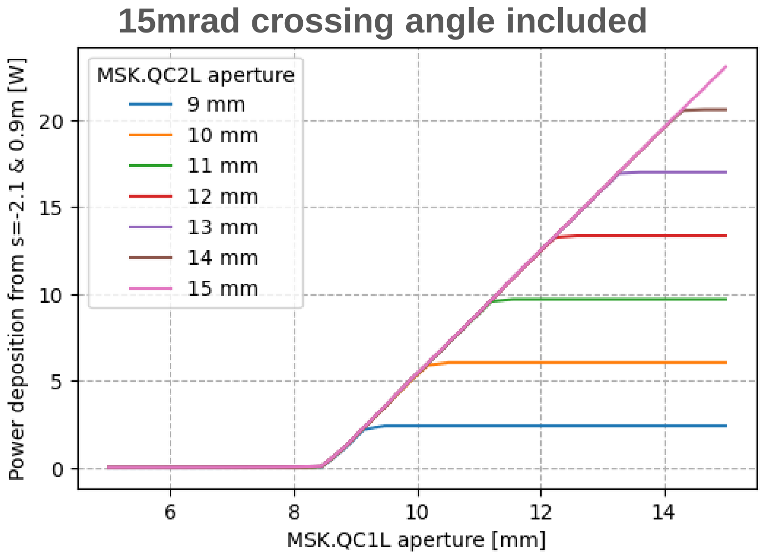


Using only two masks, it is possible to reduce to some mW the power deposited in the CC. A radial aperture of **9mm of the mask between QC1L and QC2L is sufficient to shield the CC but it would go below the protection of the vertical primary collimator hence the second mask is mandatory.**

Conclusion: MSK.QC2L has a **15mm radial aperture and absorbs 18W** and MSK.QC1L **is opened at 9.5mm and absorbs 19W**.

Synchrotron radiation power deposition

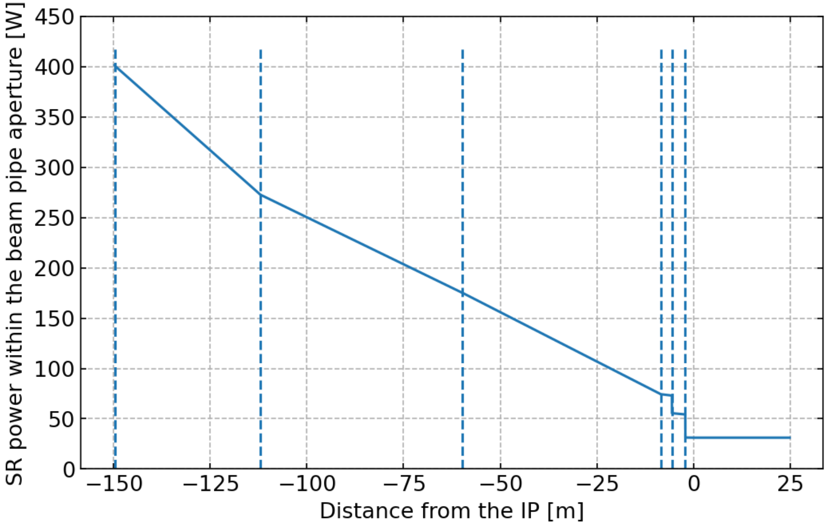




The 15mrad crossing angle reduces the aperture by 1.35mm at both ends of the CC (13.5%). The minimal aperture of MSK.QC1L becomes **8.5mm** instead of **9.5mm.** Besides, an aperture of **9mm** for MSK.QC2L **can not replace MSK.QC1L**.

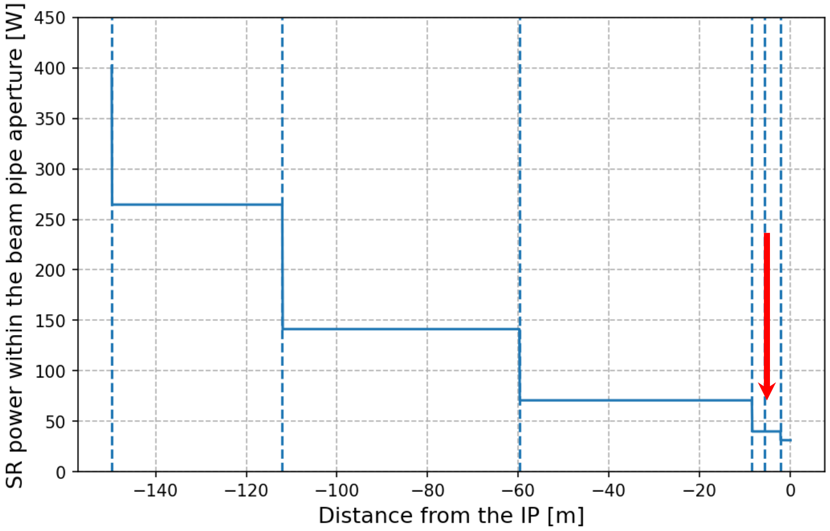
Conclusion: MSK.QC2L has a **15mm radial aperture and absorbs 18W** and MSK.QC1L **is opened at 8.5mm and absorbs 23W**.

Synchrotron radiation collimation scheme

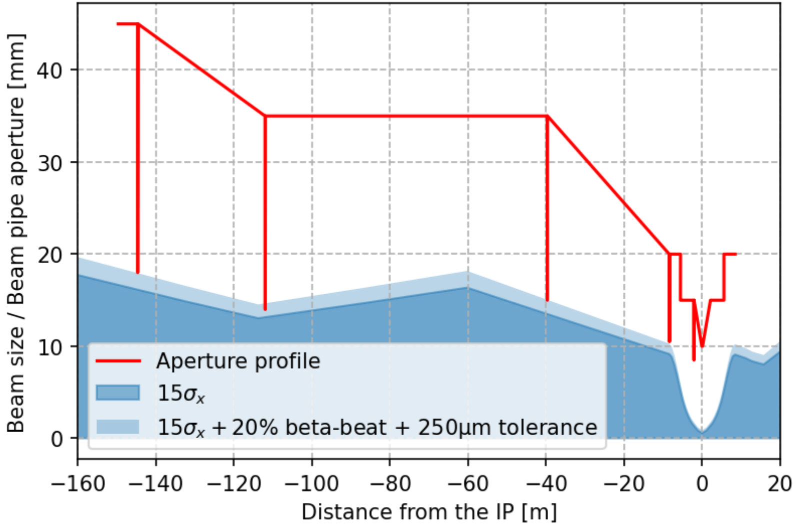


Continuous loss from the exit of BWL (s=-150m) to the mask MSK.QC2L (s=-5.56m).

The placement of collimator confines the losses and protects the thin beam pipe through which SR could damage the detector and/or SC FF magnets.

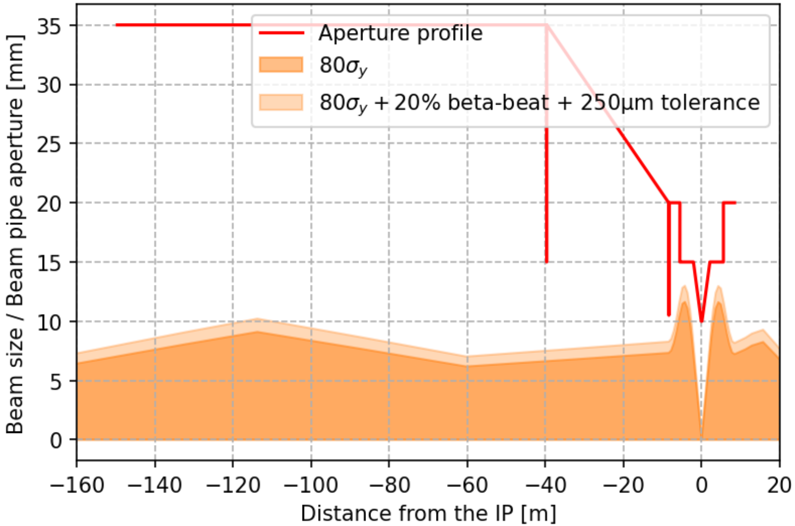


Synchrotron radiation collimation at the tt mode



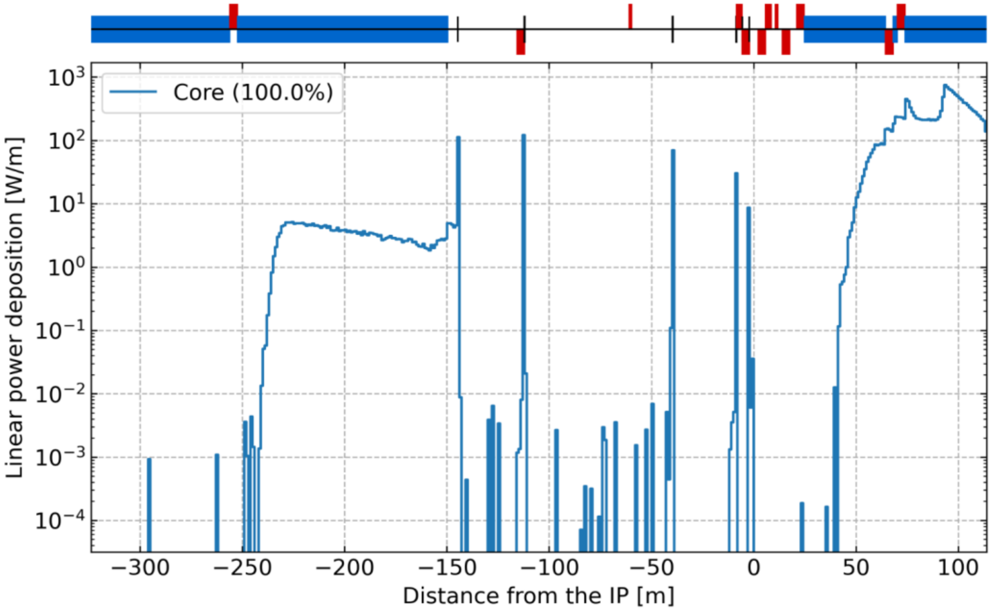
Primary and secondary collimators

Name	nsigma	half-gap [m]	plane
tcp.h.b1	15.0	0.013802	H
tcs.h.b1	17.0	0.011591	H
tcp.v.b1	80.0	0.002466	V
tcs.v.b1	89.5	0.001840	V



The collimators have been adjusted to have a minimum of 15 σ_x horizontal aperture and 80 σ_y vertical aperture.

Synchrotron radiation collimation at the tt mode



Simulations made with a Gaussian positron beam. i.e. no specific tail distributions considered yet and without the synchrotron radiation from the solenoid

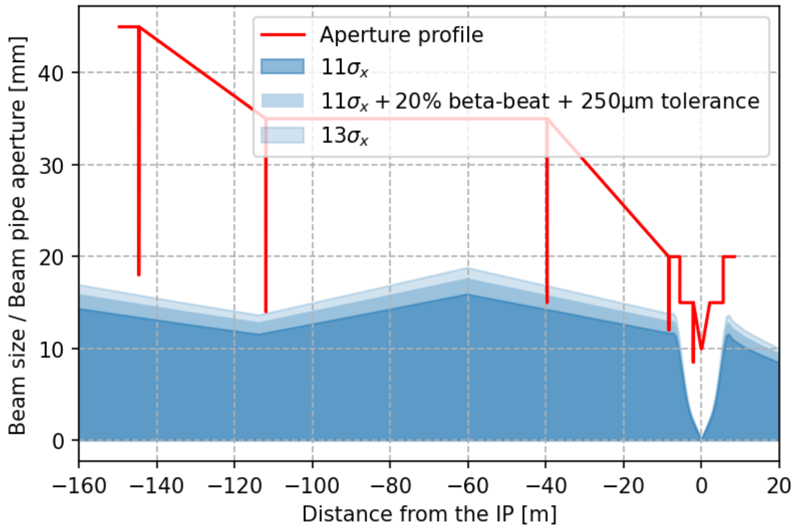
Name	s [m]	nsigma	half-gap [m]	plane
bwl.h	-144.692	16.7	0.018	H
qc3l.h	-112.054	16.1	0.014	H
qt1l.h	-39.747	16.7	0.015	H
qt1l.v	-39.647	180.9	0.015	V
pqc2le.h	-8.64	18.0	0.011	H
pqc2le.v	-8.54	120.0	0.011	V
msk.qc2l	-5.56	43.5/113	R = 0.015	Radial
msk.qc1l	-2.12	93.9	0.0085*	H

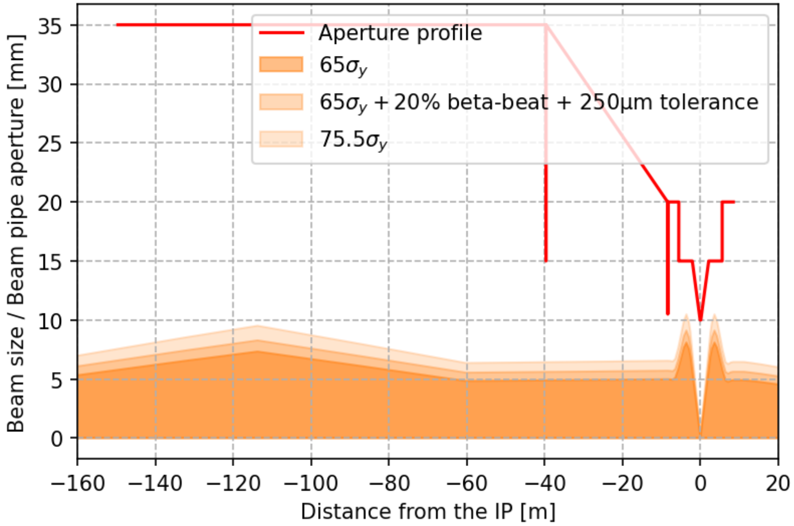
COLL.BWL is 10cm of tungsten absorbing **124W**
COLL.QC3L is 10cm of tungsten absorbing **124W**
COLL.QT1L is 10cm of tungsten absorbing **70W**
COLL.PQC2LE is 10cm of tungsten absorbing **25W**
MSK.QC2L is 2cm of tungsten absorbing **0.1mW**
MSK.QC1L is 2cm of tungsten absorbing **10W**

Synchrotron radiation collimation at the Z mode

Primary and secondary collimators

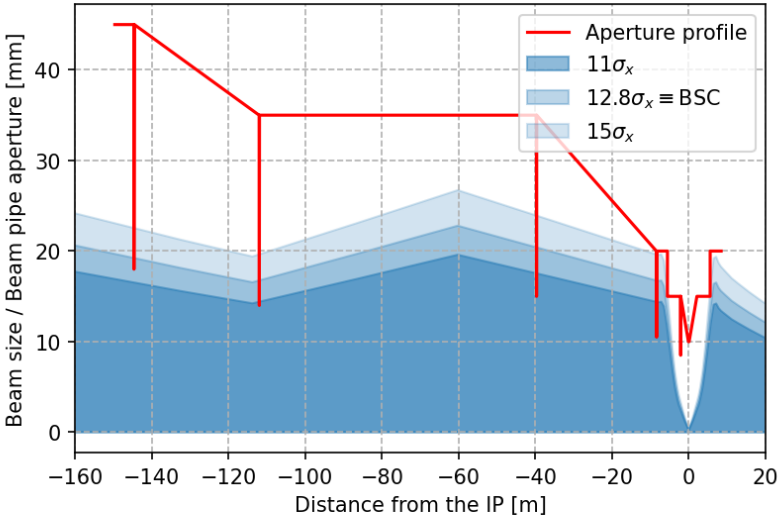
Name	nsigma	half-gap [m]	plane
tcp.h.b1	11.0	0.005504	H
tcs.h.b1	13.0	0.004162	H
tcp.v.b1	65.0	0.002332	V
tcs.v.b1	75.5	0.002030	V

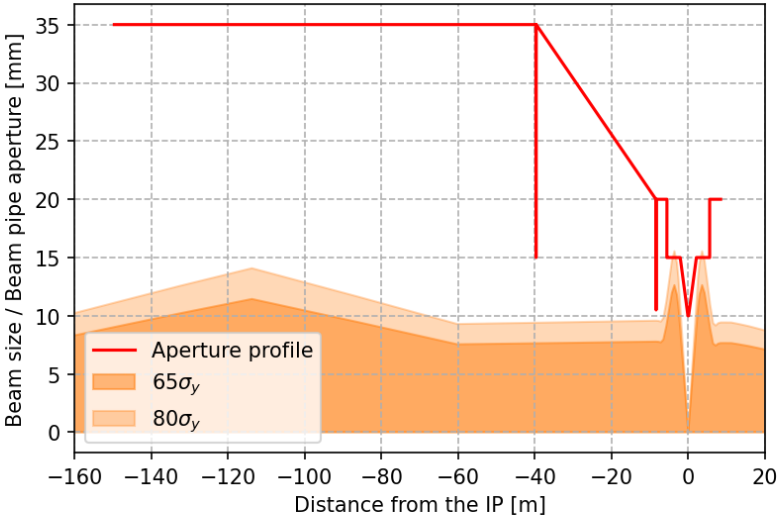




The closest collimator to the IP must be opened to 12mm w.r.t. 11mm for the tt mode in order to be above 11 σ_x horizontally. Vertically the SR collimators are opened above the secondary collimators.

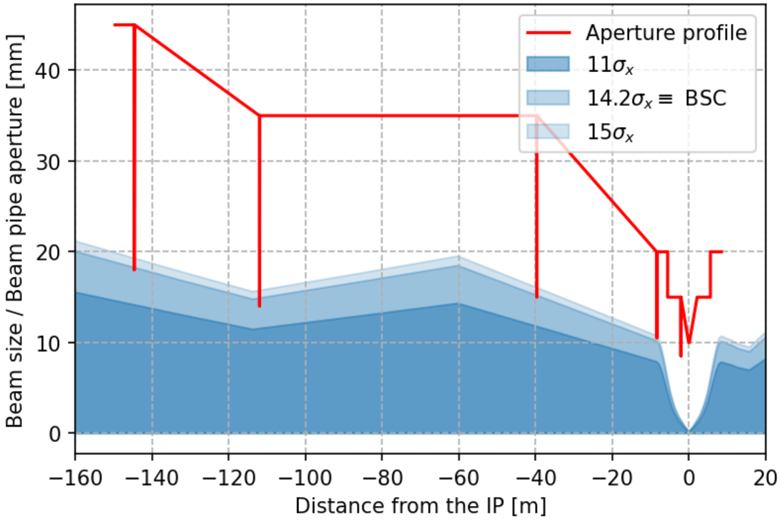
Synchrotron radiation collimation at the W mode

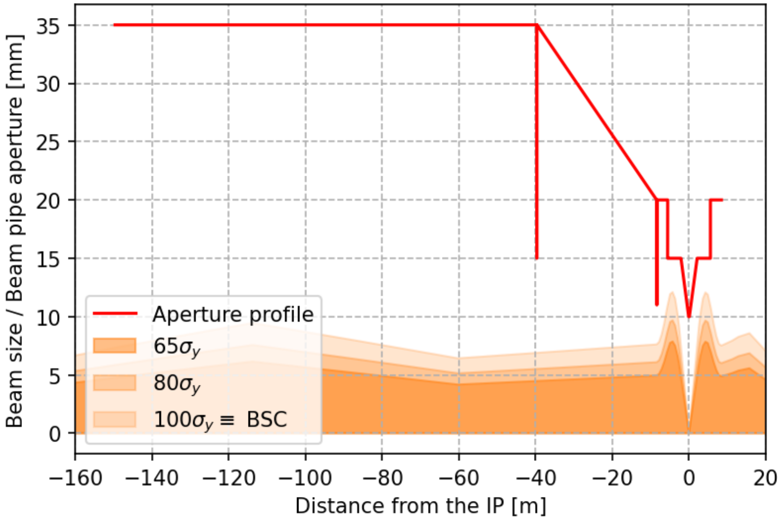




Estimation of the synchrotron radiation collimator apertures based on the latest beam stay clear studies (ref). Due to the larger transverse emittance, the SR collimators would probably be inside the primary and/or secondary collimator settings.

Synchrotron radiation collimation at the H mode





Estimation of the synchrotron radiation collimator apertures based on the latest beam stay clear studies (ref). Again, the synchrotron radiation collimators could be inside the primary/secondary collimator settings.

Summary:

- **The interaction region lattices for the 4 operation modes have been implemented in BDSIM** with the solenoid field map and without the installation of the CAD design of the central beam pipe.
- The central beam pipe can be efficiently shielded with collimators and masks from the synchrotron radiation emitted in the last dipole BWL.
- The **initial synchrotron radiation collimator settings** have been designed for the **Z and tt operation modes** with the objective of being above the primary collimators, if possible above the secondary collimators as well.

Next steps:

- Add the synchrotron radiation collimators to the collimator hierarchy and iterate regarding their positions and apertures. (A. Abramov).
- Include tail distribution to the SR collimation studies
- Study the influence of misalignments, tolerances, and top-up injection on the SR collimation.