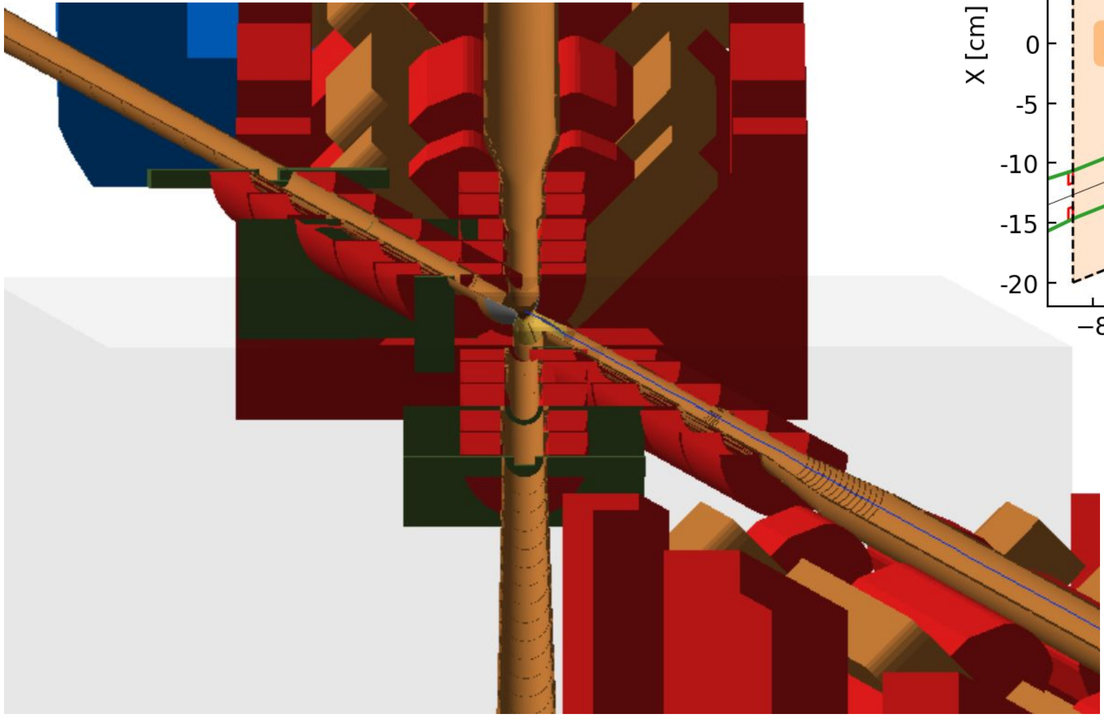
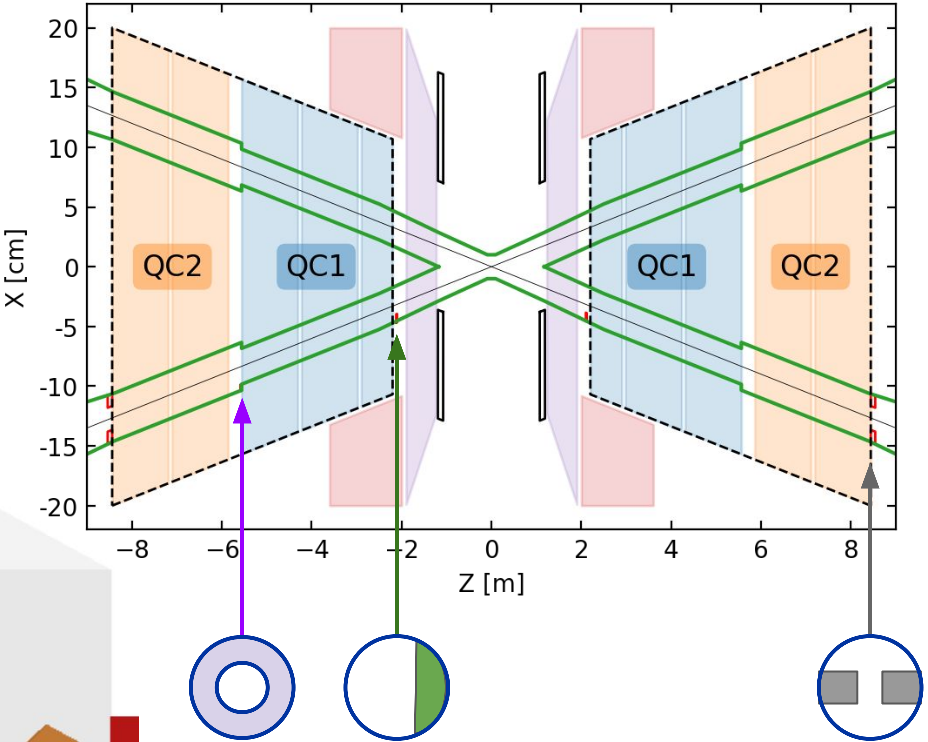
Synchrotron radiation background due to off-axis, on-energy top up injection at 45.6 GeV

Outline

- The lattice (V22) and parameters for the study
- Description of the study
- Results

FCC-ee lattice | IR design





Parameters for the SR background study due to injection

The emittance of the injected beam is **0.235 nm.rad** (ref) as opposed to 0.71 nm.rad for the circulating beam.

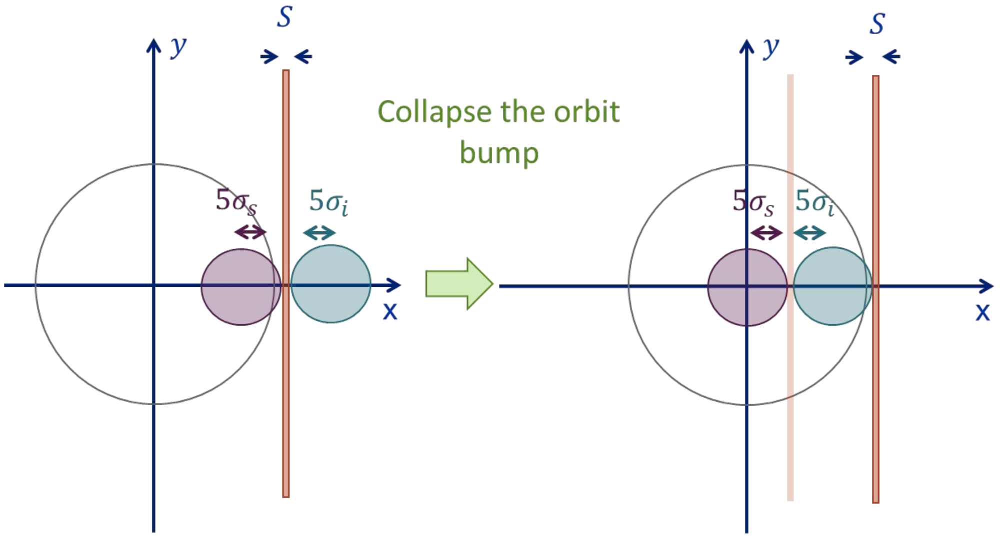
The injected beam has **10%** of the circulating beam current.

The horizontal damping time is **2336 turns**; 120 turns → 5%, 520 turns → 20%, and filamentation is not considered.

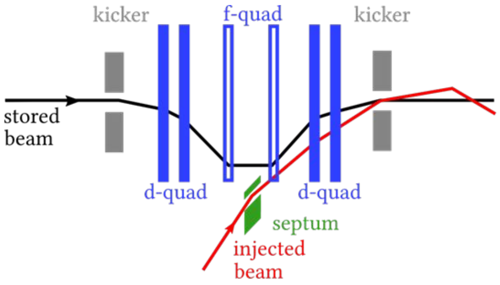
Injected beam centroid evolving along a **5** σ^{core} + **5** σ^{inj} + septum (0.2 σ^{core}) ≡ **8** σ^{core} trajectory in the horizontal phase space.

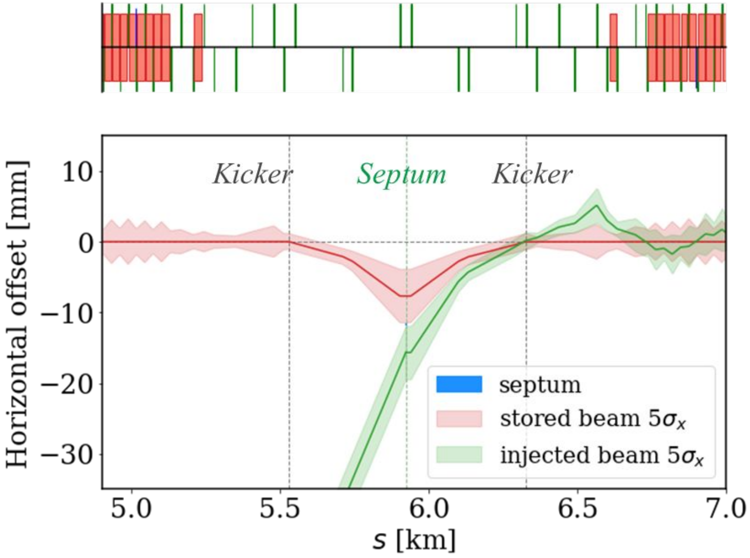
Tracking from QC2L onwards with the latest 4 IPs lattice (V22); 2 masks available to protect the FF quads and central chamber.

Top up injection - I



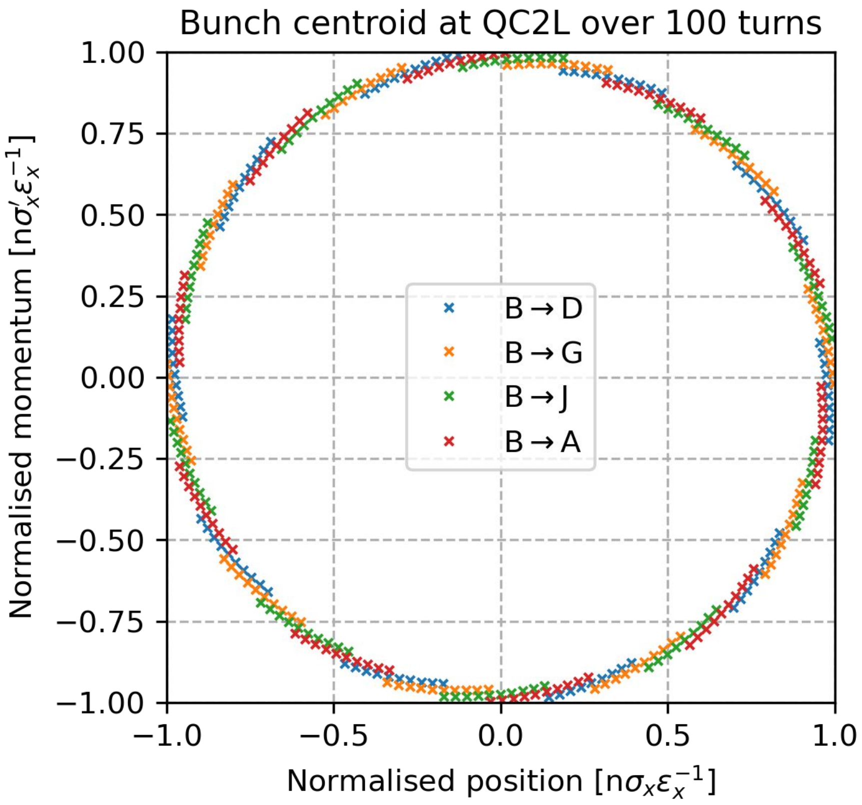
from eeFACT2022, R. Ramjiawan

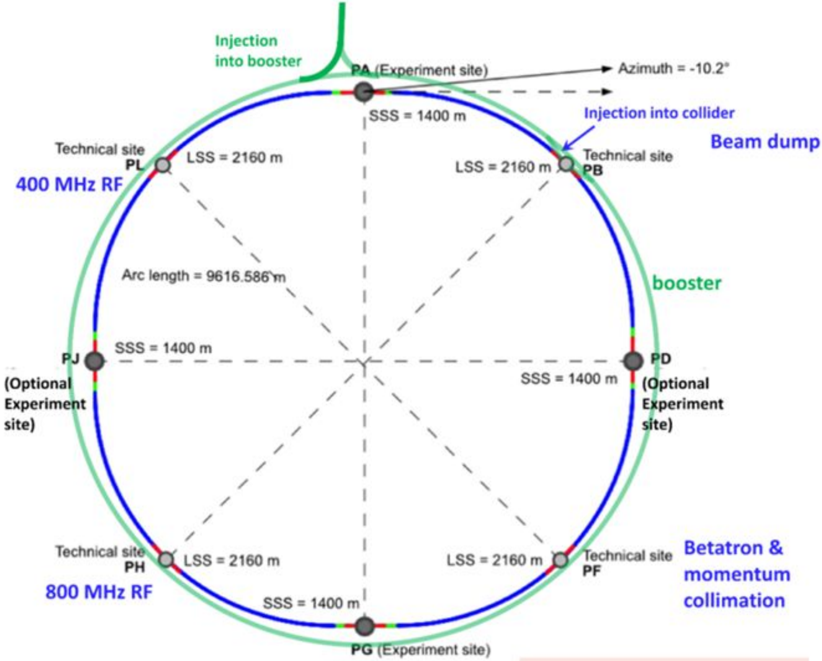




Optics design at point B with V18 lattice

Top up injection - II





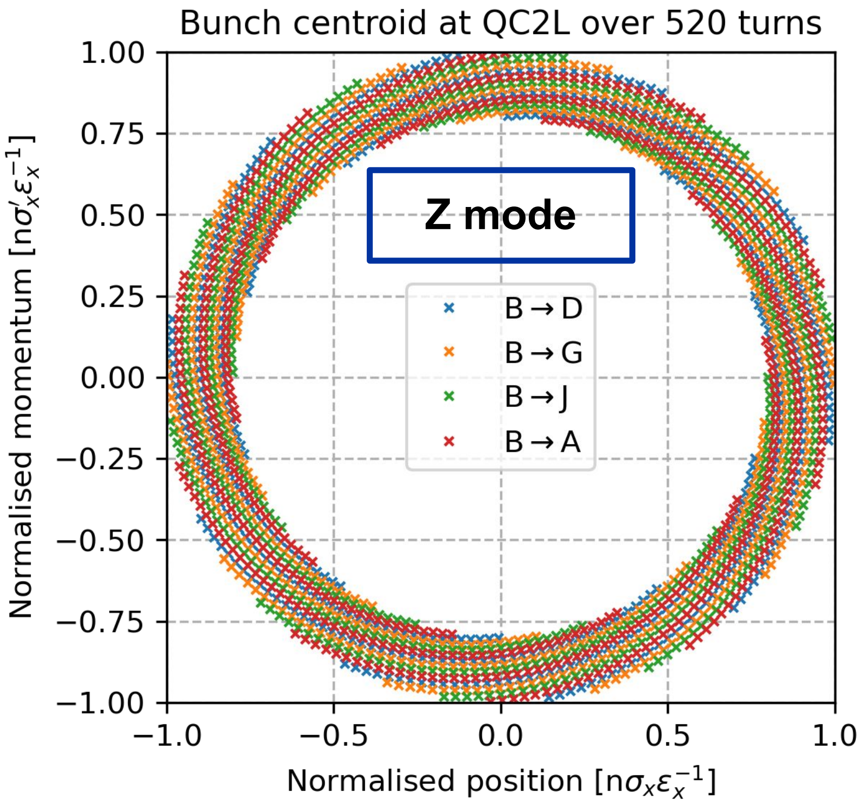
K. Oide, J. Gutleber

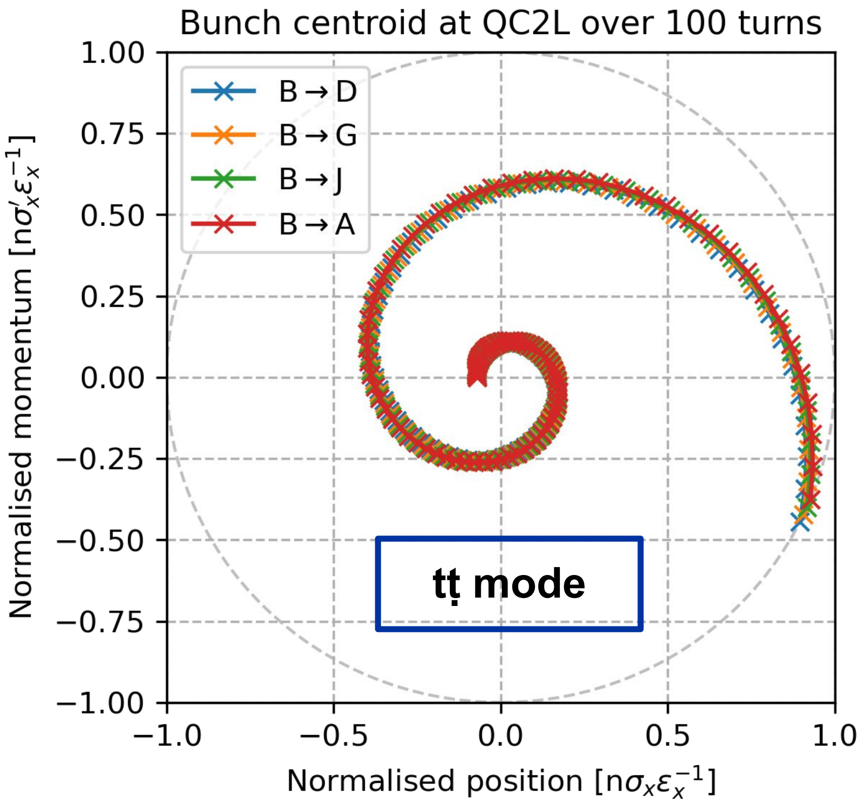
Initial condition (0,1) = 1 unit of horizontal momentum at injection (Point B, bump closed)

The horizontal damping time is 2336 turns @ Z

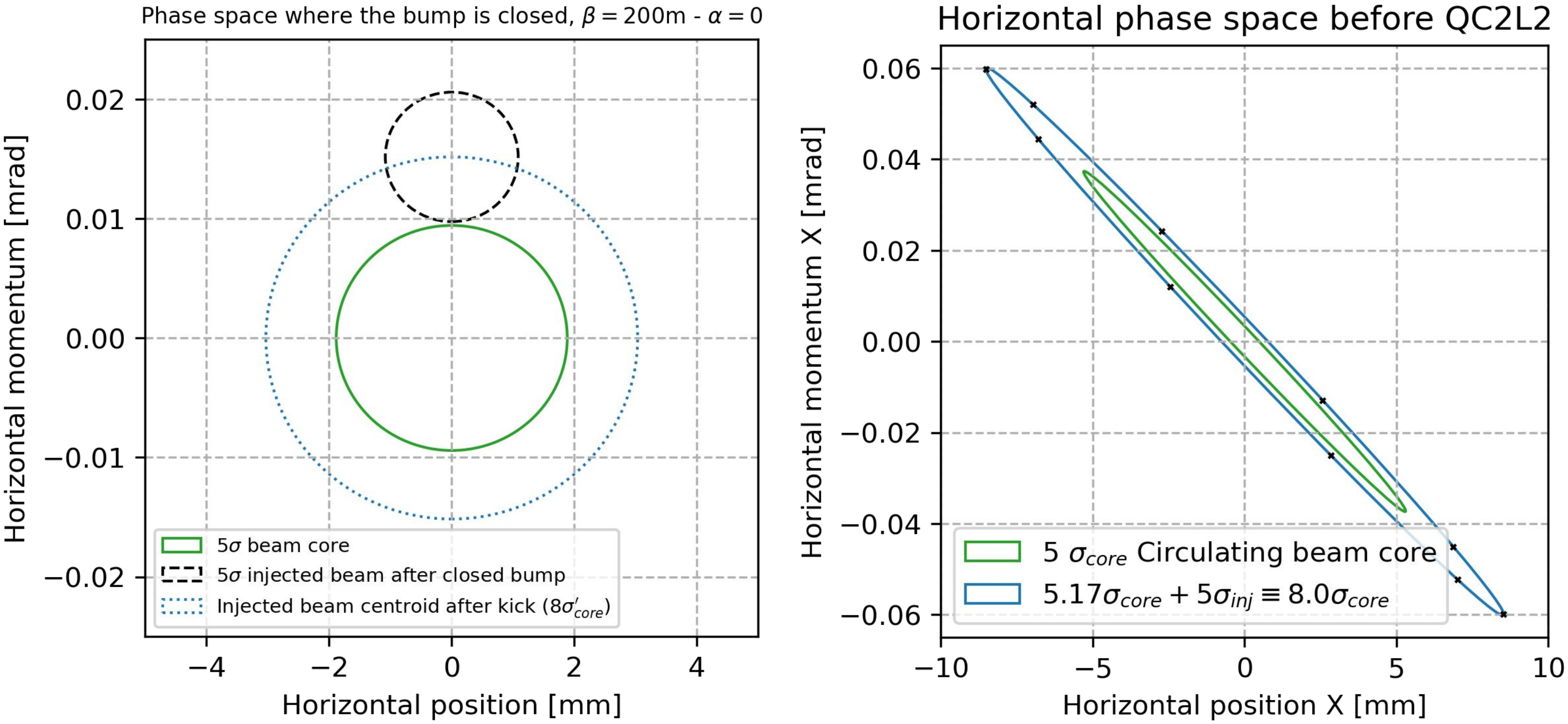
A cross represents one turn and adds a phase advance of *0.6 rad or 36.2 deg per turn hence a* ***period of 11 turns.***

Top up injection - III

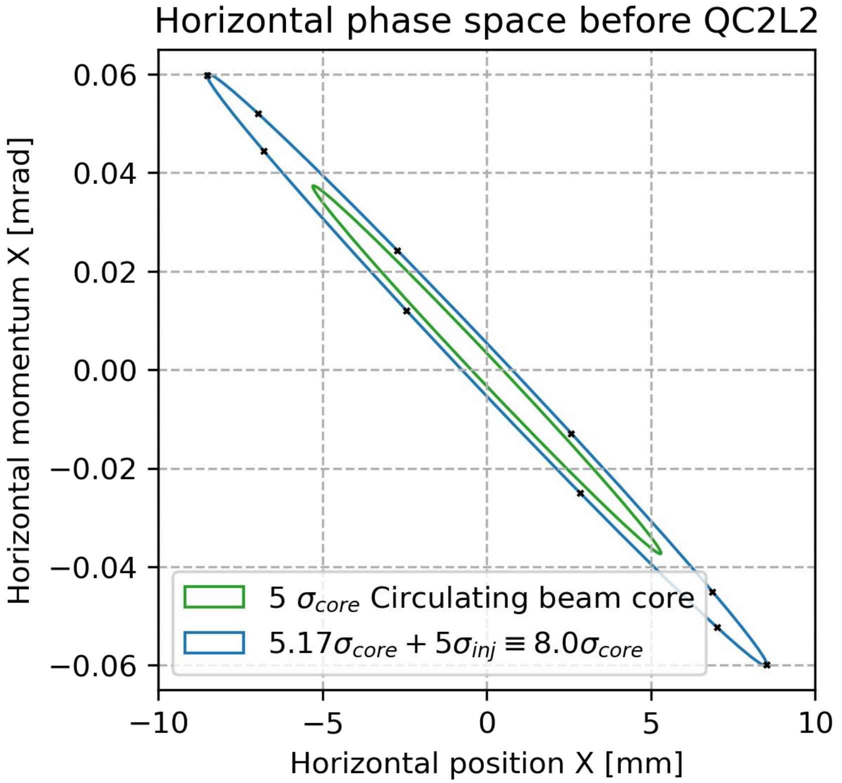


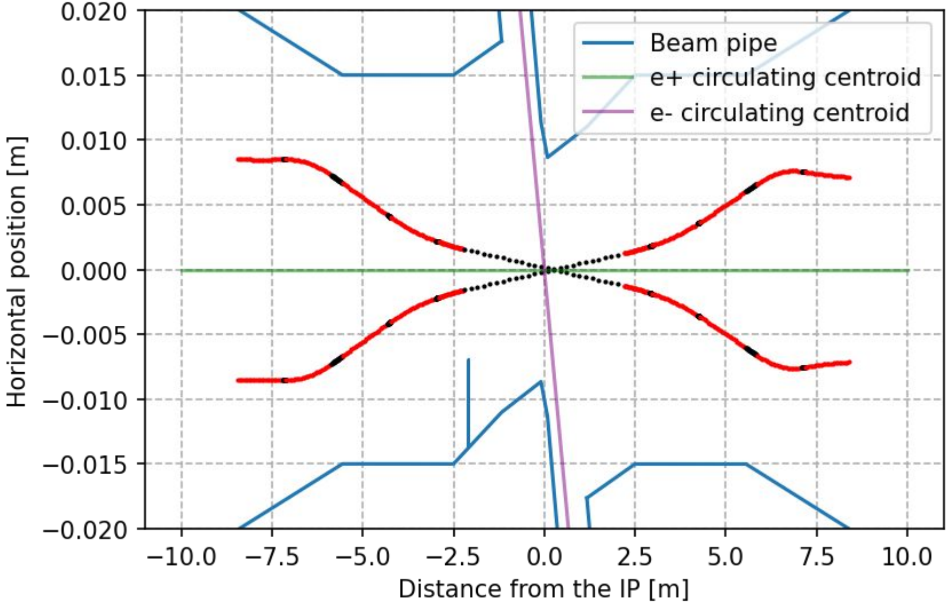


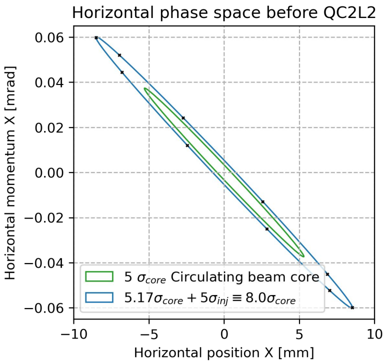
Top up injection in the horizontal phase space

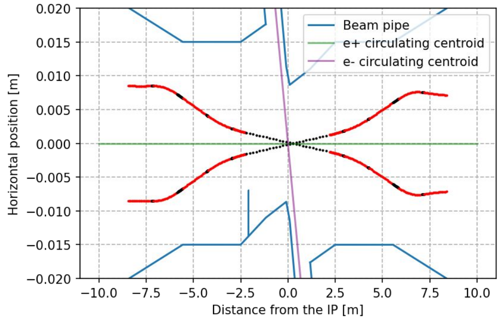


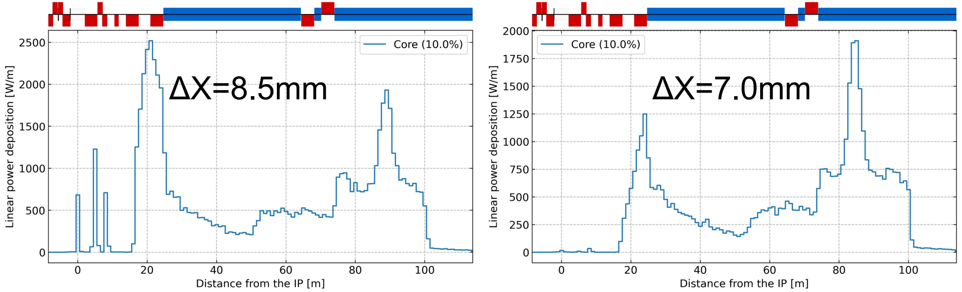
Top up injection in the horizontal phase space






Horizontal phase space before QC2L2
Horizontal momentum X [mrad]
Horizontal position X [mm]
5 σ_{core} Circulating beam core
$5.17\sigma_{core} + 5\sigma_{inj} \equiv 8.0\sigma_{core}$


Beam pipe
e+ circulating centroid
e- circulating centroid
Horizontal position [m]
Distance from the IP [m]


ΔX=8.5mm
ΔX=7.0mm
Core (10.0%)
Linear power deposition [W/m]
Distance from the IP [m]

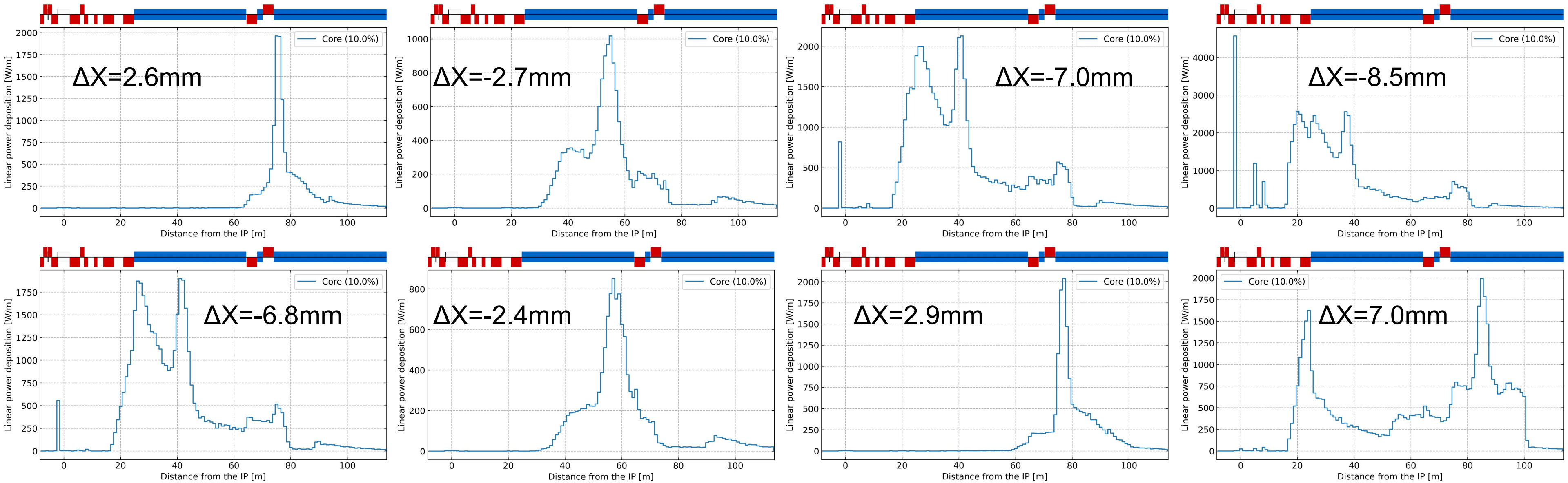
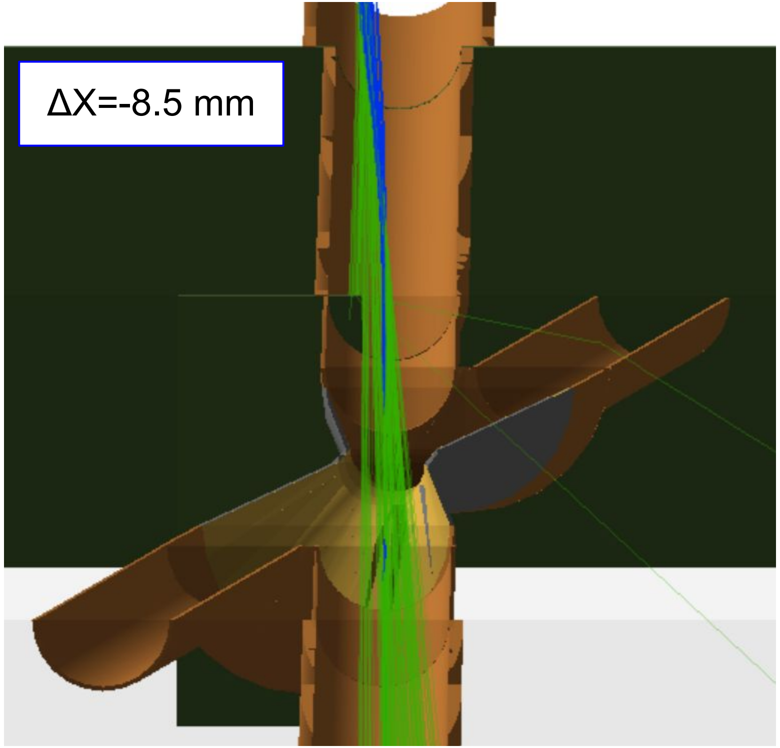
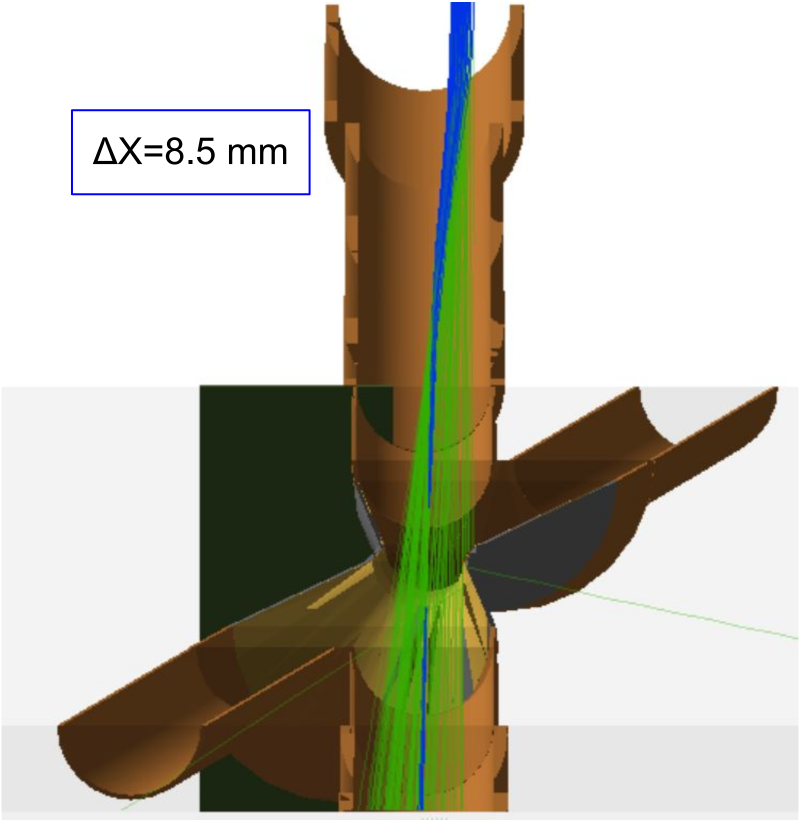
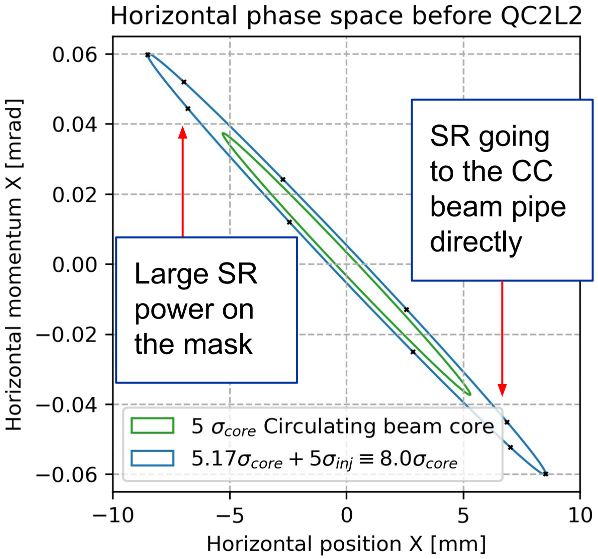

ΔX=2.6mm
ΔX=-2.7mm
ΔX=-7.0mm
ΔX=-8.5mm
ΔX=-6.8mm
ΔX=-2.4mm
ΔX=2.9mm
ΔX=7.0mm
Core (10.0%)
Linear power deposition [W/m]
Distance from the IP [m]

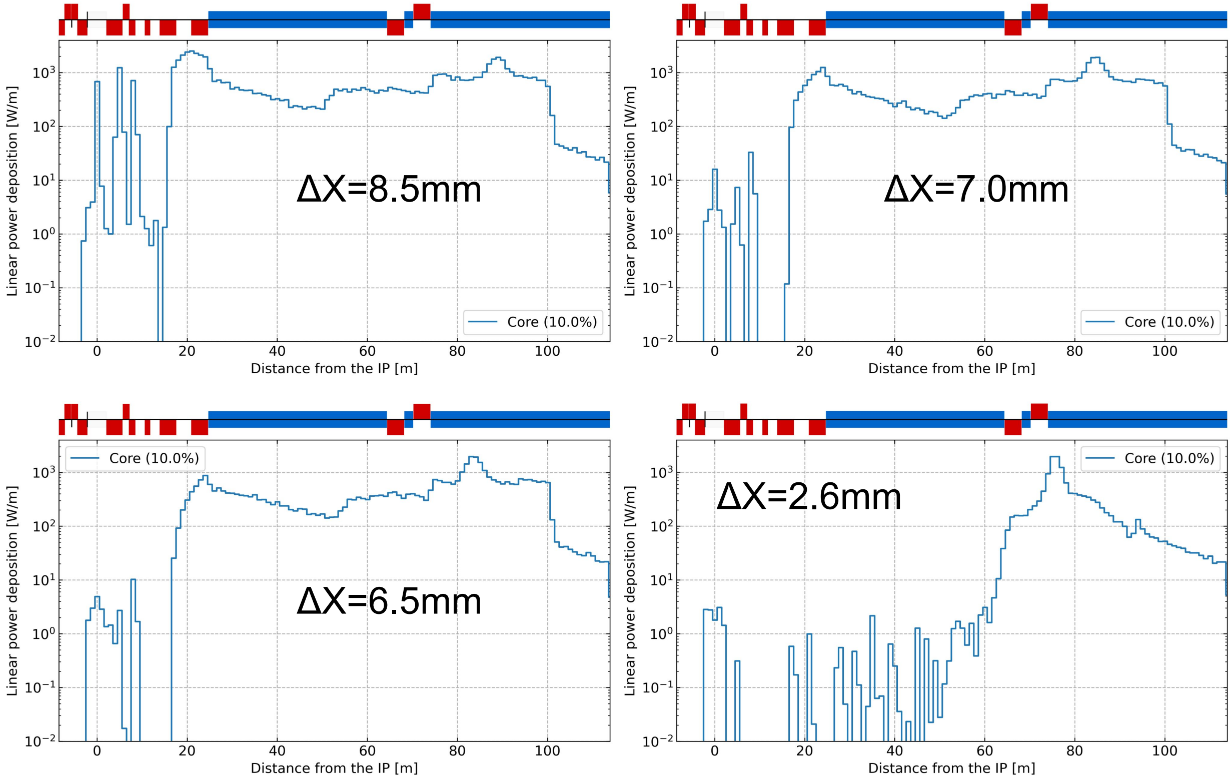
Illustration of the two extremes



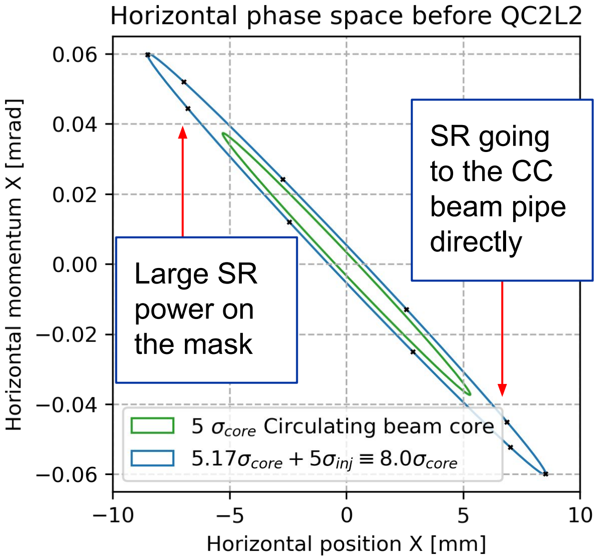


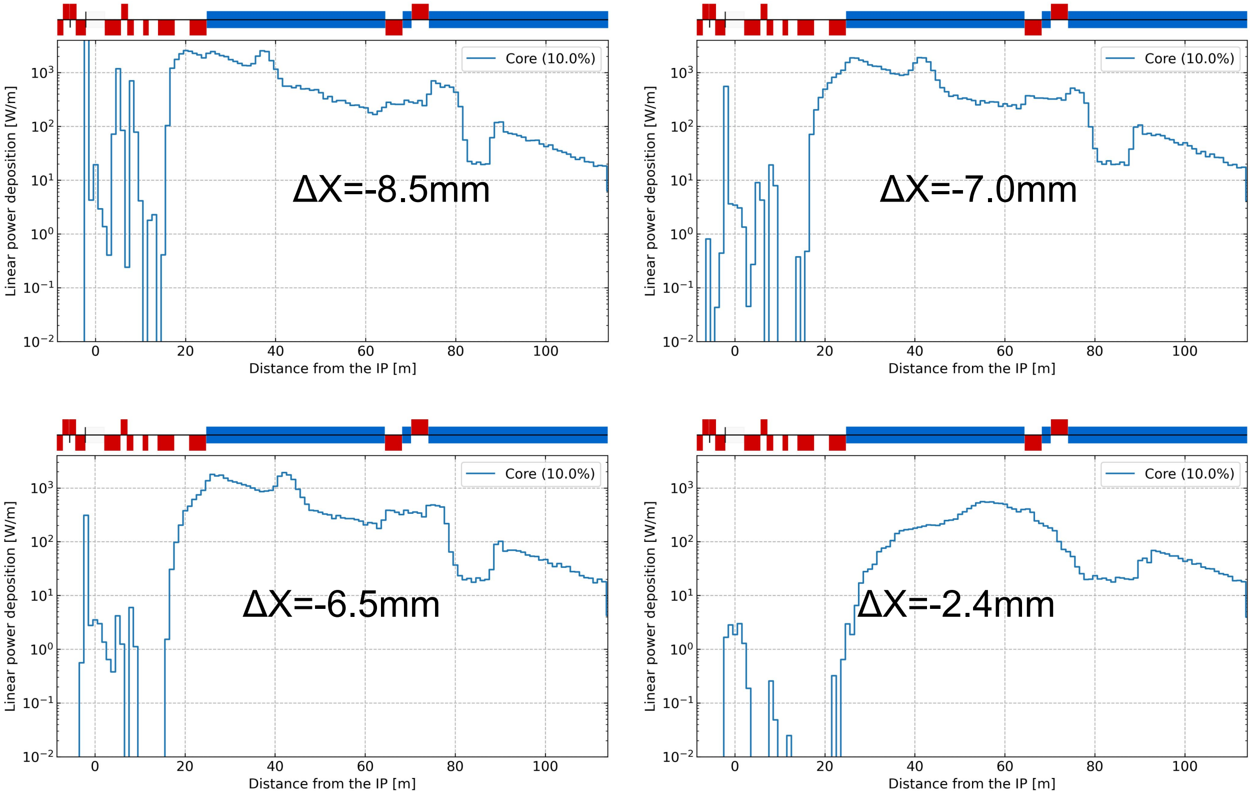
Positive horizontal displacement (away from the mask)





Negative horizontal displacement (towards from the mask)





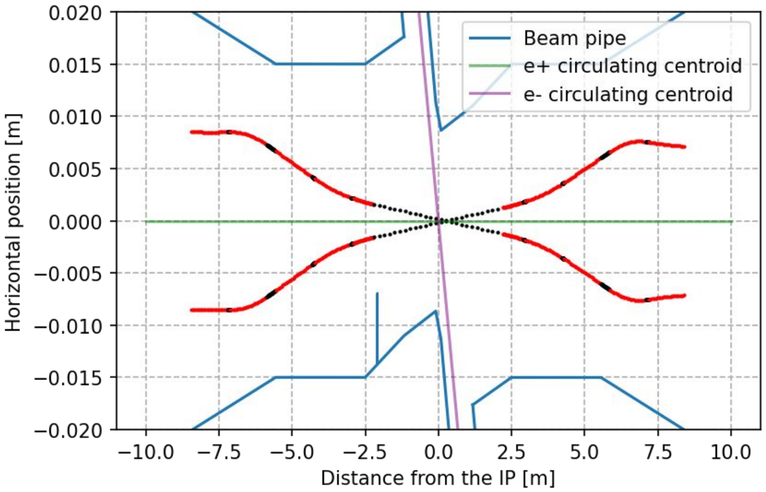
Solution ?

Reduce the constraints on injection:

- originally **5** σ^{core} + **5** σ^{inj} + septum ($0.2\sigma^{core}$)
- **4** σ^{core} + **4** σ^{inj} + septum ($0.2\sigma^{core}$) leads to a maximum of ± **7.0 mm** orbit offset
- **4** σ^{core} + **3** σ^{inj} + septum ($0.2\sigma^{core}$) leads to a maximum of ± **6.5 mm** orbit offset

100% i_e	P [kW]
QC2L1	4.3
QC1L2	1.3
Solenoid	**78**
QC1R2	1.3
QC2R1	6.5

10% i_e	P [kW]	feed down
QC2L1	**27**	**23**
QC1L2	8	6.7
Solenoid	8	-
QC1R2	5	3.7
QC2R1	**43**	**36.5**



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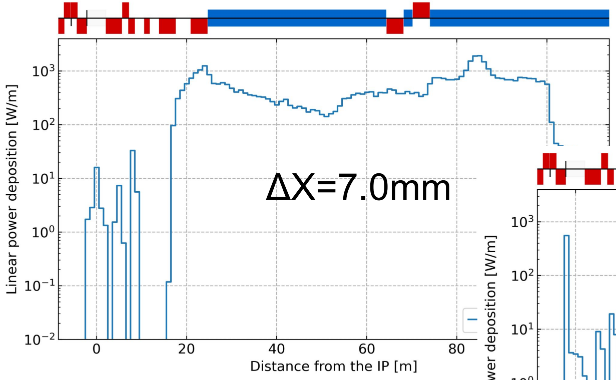

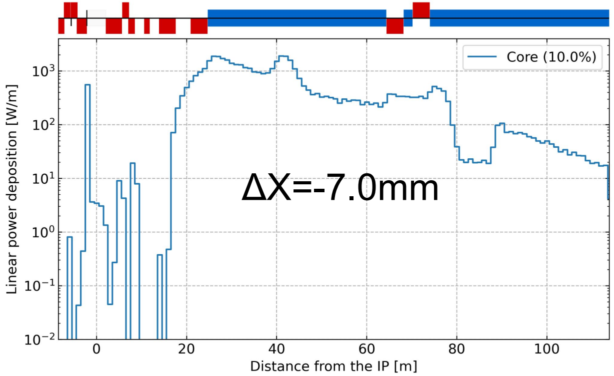

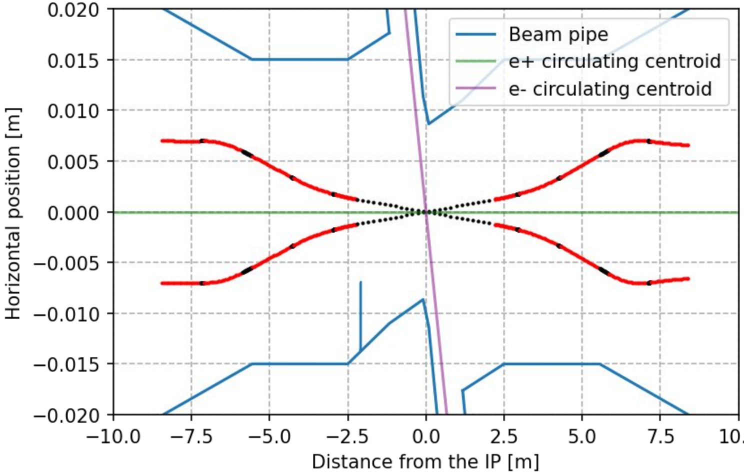

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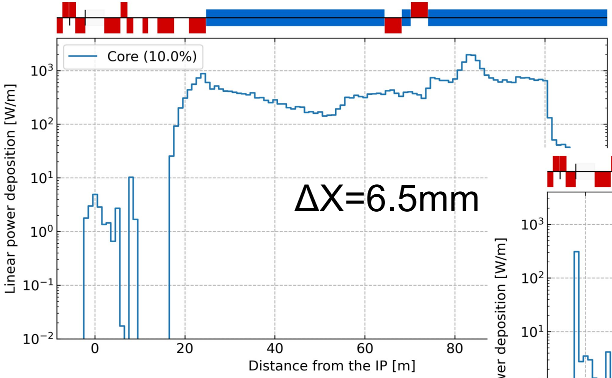
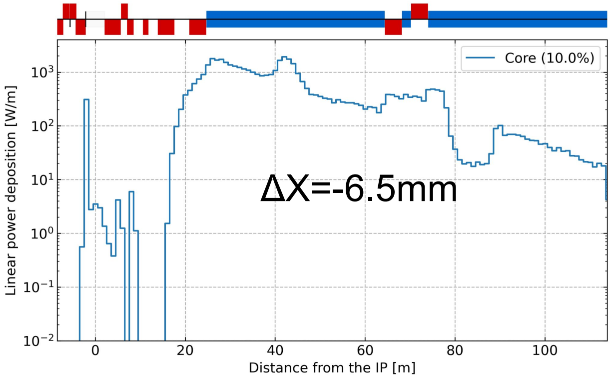
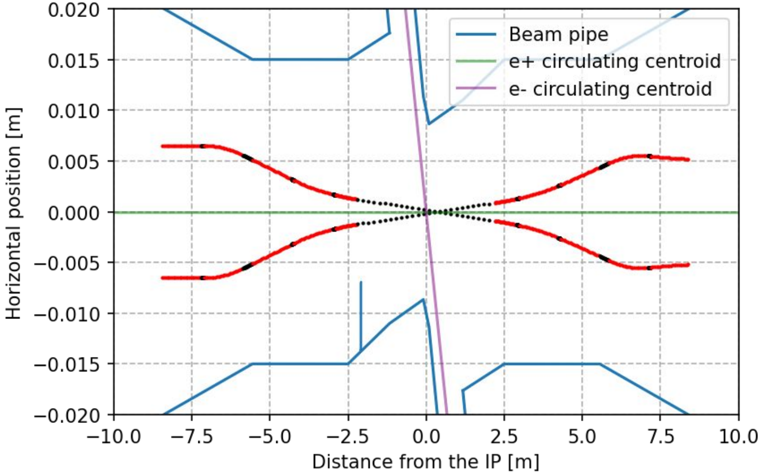
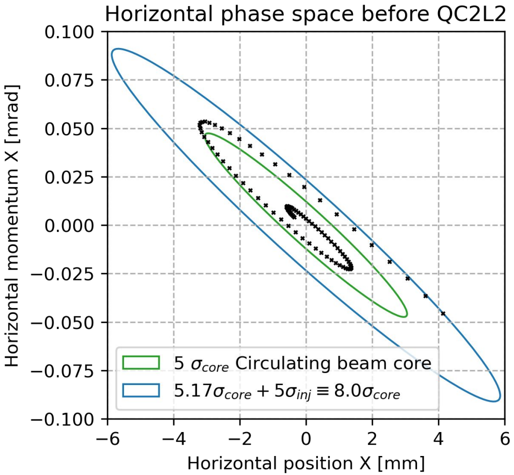
- ~~**4** σ^{core} + **4** σ^{inj} + septum ($0.2\sigma^{core}$) leads to a maximum of ± **7.0 mm** orbit offset~~
- **4** σ^{core} + **3** σ^{inj} + septum ($0.2\sigma^{core}$) leads to a maximum of ± **6.5 mm** orbit offset

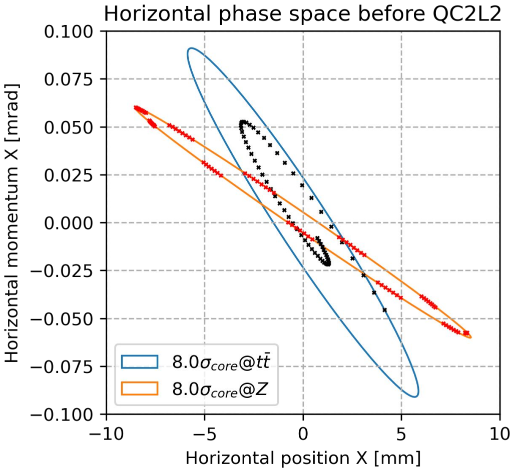


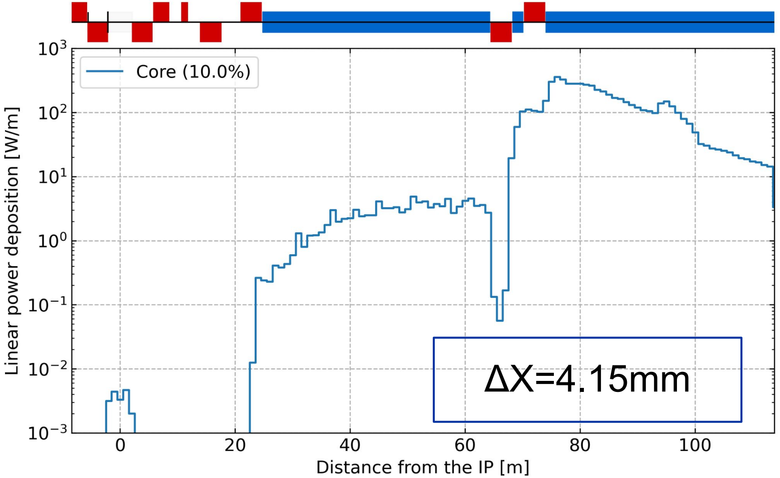


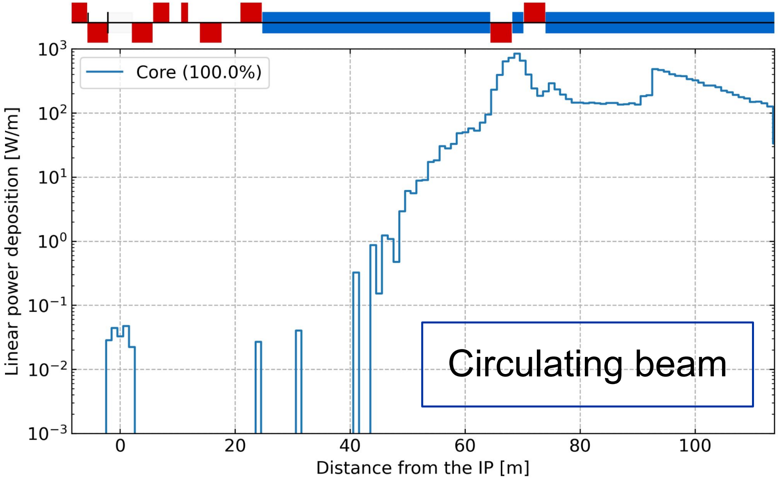


Comparison with tt mode









- The max horizontal displacement is 5.9mm (@ tt) and 8.5mm (@ Z)
- The ellipse tilt is -49° (@ tt) and -23° (@ Z).
- Perhaps the Z optics could be modified ?

Simulations settings

10 runs of 100,000 primary positrons (or 10 runs of 50,000 primary positrons)

Beam distribution: **Gaussian distribution** from Twiss parameters to represent **the core**

or **Halo uniform distribution** 4 to 10 (or more) σ_x (and σ_y) to represent **the tails**

Physics list : *Synchrotron_radiation* physics and *em_peneloppe* (particle-matter interaction)

Energy / Range cuts:

e+/e- **1 mm** ~ 990 eV (air/vacuum), 2.3 MeV W, 1.4 MeV Cu

e+/e- **5 um** ~ 53 keV W, 60 keV Cu

gamma **1 mm** ~ 990 eV (air/vacuum), 1 keV W, 1 keV Cu

gamma **5 um** ~ 4.8 keV W, 2.2 keV Cu

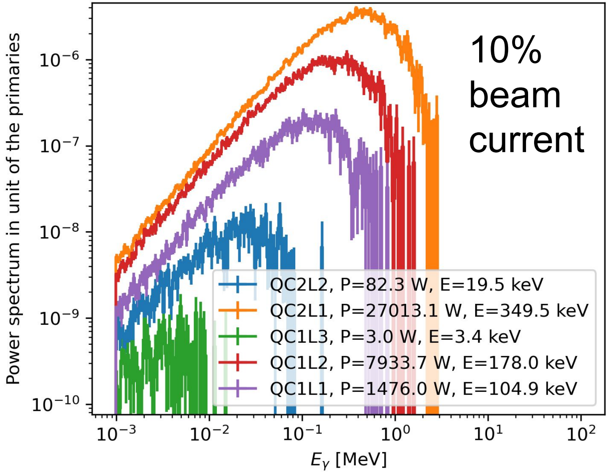
Physics list - em_penelope: https://geant4.web.cern.ch/node/1621

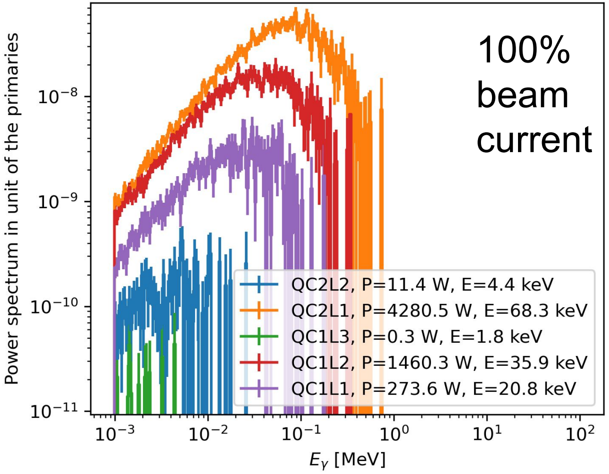
The model approach and the available Penelope model

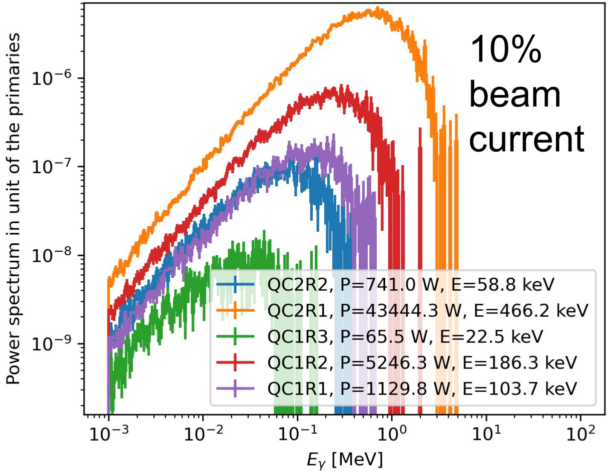
Physics process	Particle(s)	Old Penelope Process	New Penelope Model
Rayleigh scattering	gamma	G4PenelopeRayleigh	**G4PenelopeRayleighModel**
Compton scattering	gamma	G4PenelopeCompton	**G4PenelopeComptonModel**
Photo-electric effect	gamma	G4PenelopePhotoElectric	**G4PenelopePhotoElectricModel**
Pair production	gamma	G4PenelopeGammaConversion	**G4PenelopeGammaConversionModel**
Ionisation	$e^{\pm}$	G4PenelopeIonisation	**G4PenelopeIonisationModel**
Bremsstrahlung	$e^{\pm}$	G4PenelopeBremsstrahlung	**G4PenelopeBremsstrahlungModel**
Positron annihilation	e^{+}	G4PenelopeAnnihilation	**G4PenelopeAnnihilationModel**

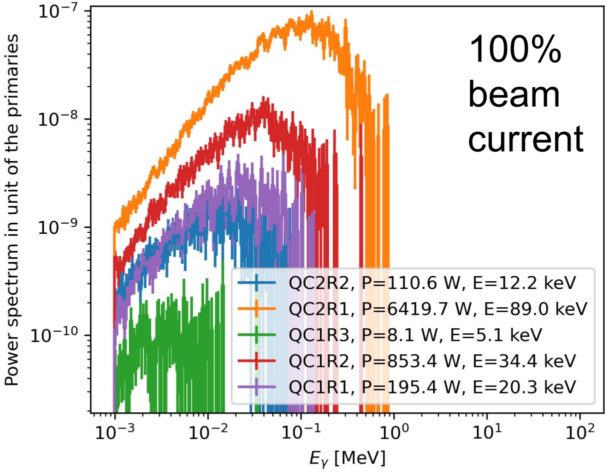
Note that **fluorescence is activated by default** in **G4EmLivermorePhysics, G4EmLivermorePolarizedPhysics and G4EmPenelopePhysics, G4EmStandardPhysics_option3, and G4EmStandardOption4 physics constructors** while Auger production and PIXE are not. For Geant4 10.5 UI commands "auger" and "augerCascade" are fully equivalent, the last will be removed in the next major release.

SR from quads for Z mode

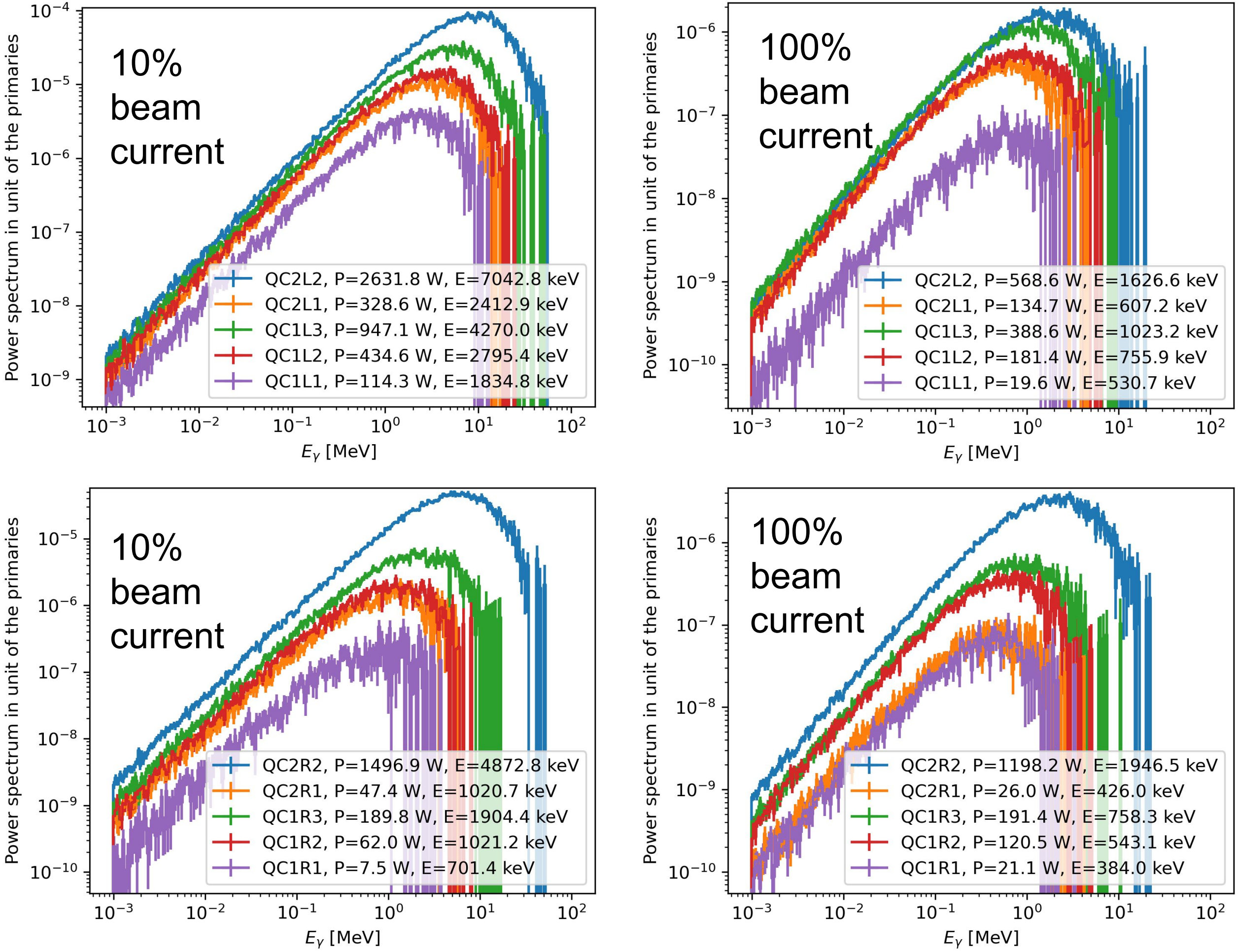








SR from quads for tt mode



same emittance for injected beam and collider beam.