Synchrotron Radiation in the Machine-Detector Interface of FCC-ee

– Early Collimation Scheme –

Marian Lückhof

Universität Hamburg

FCC-ee MDI Meeting – May 25, 2020

Three Groups of Upstream Bends

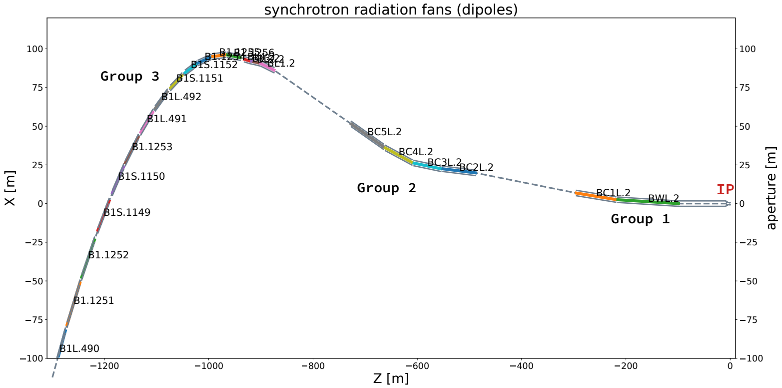


Figure: Top view (2D) on upstream bends, starting in the arc around 1300 m upstream.

Three Groups of Upstream Bends

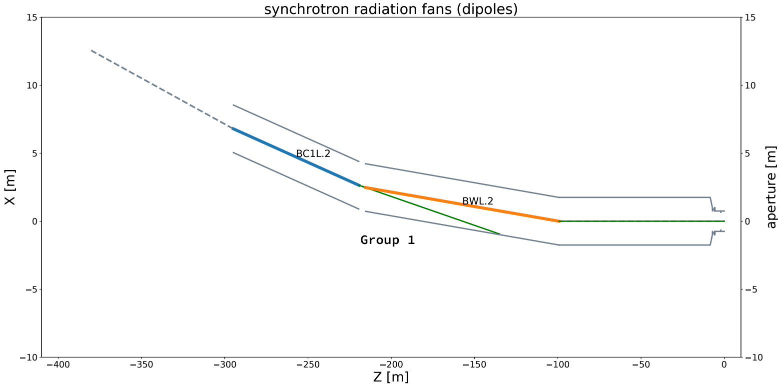


Figure: Top view (2D) on upstream bends, starting in the arc around 400 m upstream. **Transverse dimensions scaled by a factor of 50.**

Has also been discussed in MDI meeting from December 2019.

Synchrotron Radiation Fans – Group 1

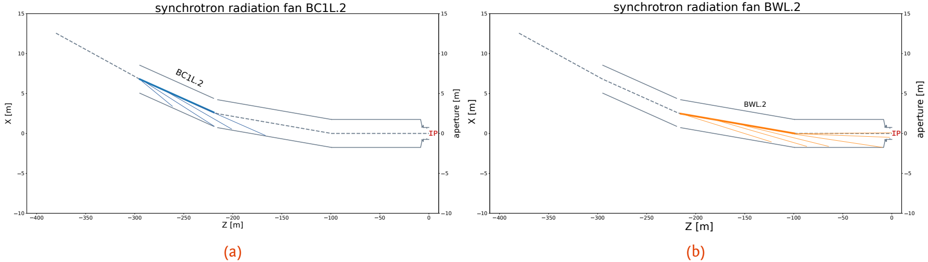
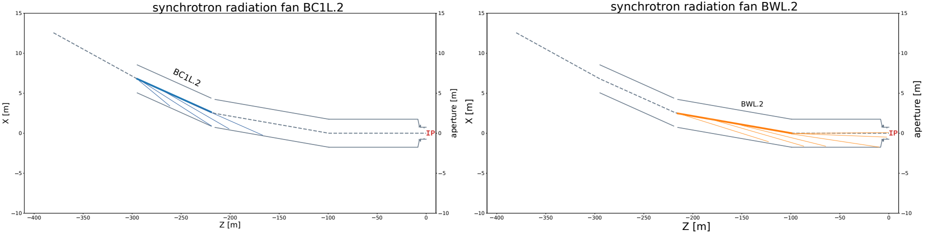


Figure: Sketch of Synchrotron Radiation fans. (a) second to last upstream bend. (b) last upstream bend.

Synchrotron Radiation Fans – Group 1



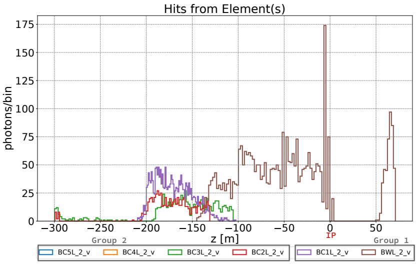
(a) (b)

Figure: Sketch of Synchrotron Radiation fans. (a) second to last upstream bend. (b) last upstream bend.

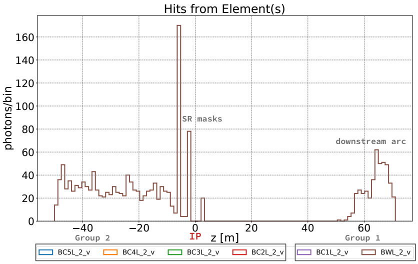
Preliminary conclusion

- 1st iteration: direct hits
- `BC1L.2` seems not relevant
- `BWL.2` exits directly towards straight section
  $\Rightarrow$ most significant contribution to photon background

Synchrotron Radiation Fans – Group 1



(a)



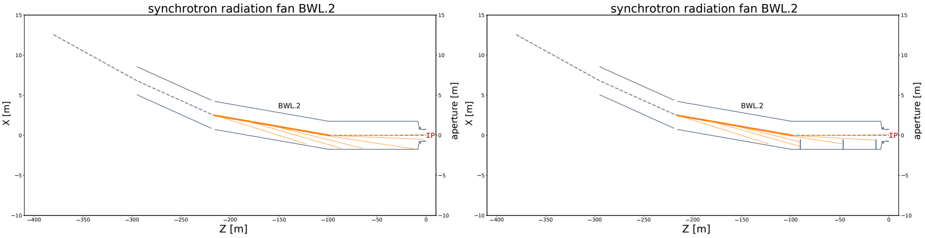
(b)

Figure: Distribution of hits, sorted by elements of origin. (a) from 300 m upstream. (b) close-up: 50 m upstream.

Preliminary conclusion

- 1st iteration: direct hits
- `BC1L.2` seems not relevant
- `BWL.2` exits directly towards straight section
  ⇒ most significant contribution to photon background

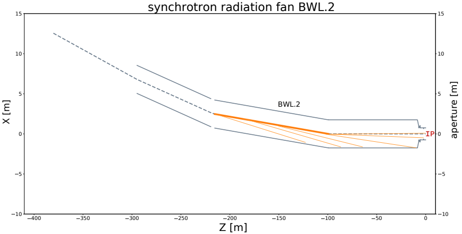
Collimators in the Straight Section



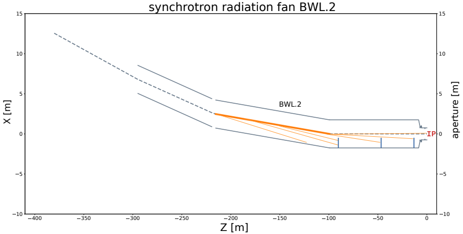
(a) (b)

Figure: Sketch of Synchrotron Radiation fans. (a) last upstream bend. (b) collimators intercepting the radiation fans.

Collimators in the Straight Section



(a)



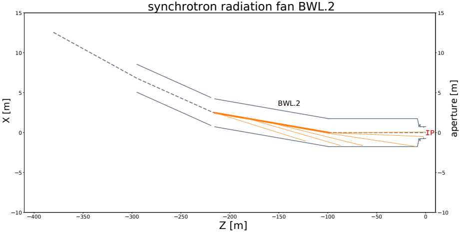
(b)

Figure: Sketch of Synchrotron Radiation fans. (a) last upstream bend. (b) collimators intercepting the radiation fans.

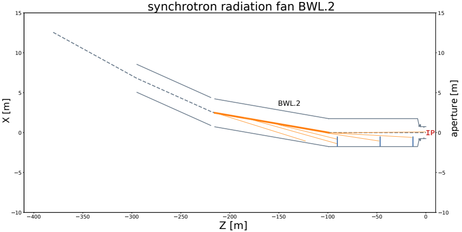
Table: Beam size at certain elements downstream of `BWL.2`

Name	β_x [m]	σ_x [μm]	$10\sigma_x$ [mm]	$15\sigma_x$ [mm]	$20\sigma_x$ [mm]
BWL.2	333.36	697.66	6.98	10.46	13.95
QC3L.2	303.68	665.87	6.66	9.99	13.32
QT1L.2	329.07	693.14	6.93	10.40	13.86
PQC2LE.2	237.60	588.99	5.89	8.83	11.78

Collimators in the Straight Section



(a)



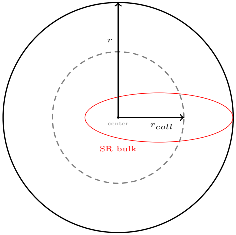
(b)

Figure: Sketch of Synchrotron Radiation fans. (a) last upstream bend. (b) collimators intercepting the radiation fans.

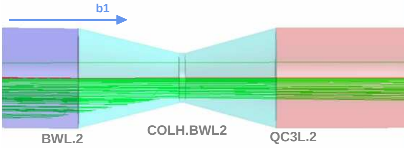
Beam-optics related aspects might be discussed in the next FCC-ee Optics Design Meeting.

Collimators in the Straight Section

(a)



(b)



(c)

Figure: (a) top view on modified geometry in Root display. (b) transverse cross section, showing beam pipe (black), the reduced aperture by collimator (grey, dashed) and a synchrotron radiation bulk indicated (red). (c) top view on a collimator example with photon tracks (green) blocked to some extent.

Baseline Scenario

Simulation Parameters

- top energy ($t\bar{t}$), 182.5 GeV
- horizontal emittance $\epsilon_x = 1.46$ nm
- vertical emittance $\epsilon_y = 2.9$ pm
- Gaussian bunch of 10^3 primaries (1σ)
- starting point 300 m upstream (Group 1)

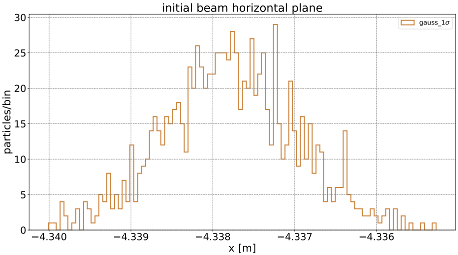


Figure: Initial particle distribution for a Gaussian bunch.

Baseline Scenario

Simulation Parameters

- top energy ($t\bar{t}$), 182.5 GeV
- horizontal emittance $\epsilon_x = 1.46$ nm
- vertical emittance $\epsilon_y = 2.9$ pm
- Gaussian bunch of 10^3 primaries (1σ)
- starting point 300 m upstream (Group 1)

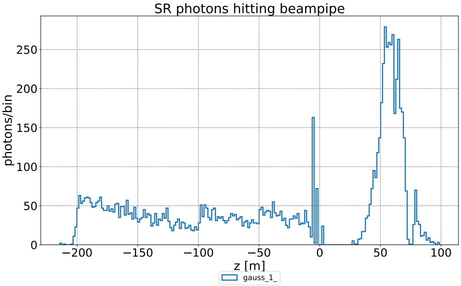


Figure: Result of the simulation with a primary Gaussian bunch of 10^3 primaries, starting 300 m upstream.

Estimate for a Case with Tails

Simulation Parameters

- top energy ($t\bar{t}$), 182.5 GeV
- horizontal emittance $\epsilon_x = 1.46$ nm
- vertical emittance $\epsilon_y = 2.9$ pm
- Ring-type distribution, 10^3 primaries at $20\,\sigma$
  - rather conservative
  - measurements at LEP (horizontal tails)
- starting point 300 m upstream (Group 1)

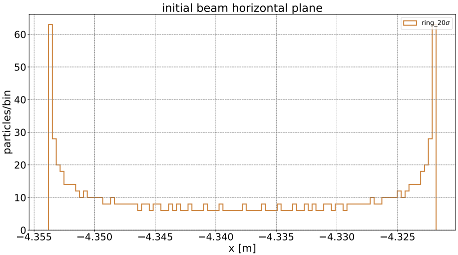


Figure: Initial particle distribution for a ring-type beam.

Estimate for a Case with Tails

Simulation Parameters

- top energy ($t\bar{t}$), 182.5 GeV
- horizontal emittance $\epsilon_x = 1.46\,\text{nm}$
- vertical emittance $\epsilon_y = 2.9\,\text{pm}$
- Ring-type distribution, 10^3 primaries at $20\,\sigma$
  - rather conservative
  - measurements at LEP (horizontal tails)
- starting point 300 m upstream (Group 1)

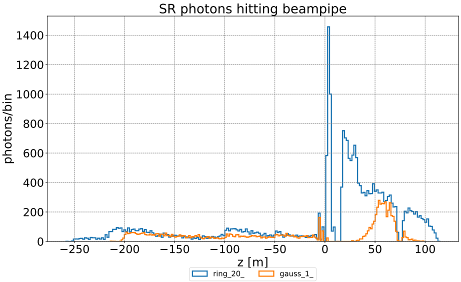


Figure: Result of the simulation with a primary Gaussian bunch of 10^3 primaries, starting 300 m upstream.

Collimation Efficiency Plots

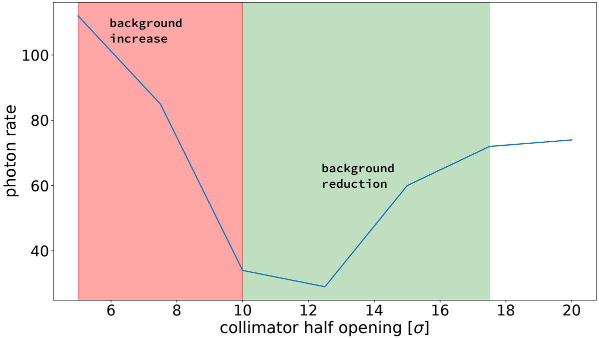
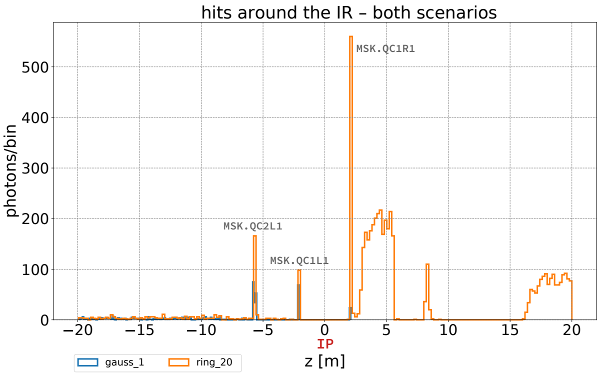


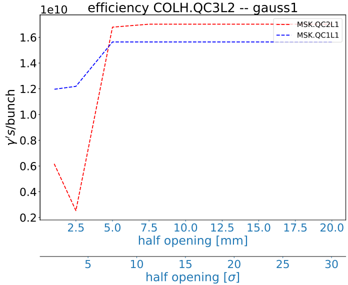
Figure: Shape of the collimation efficiency plots: photon (or background) rate vs. half closure.

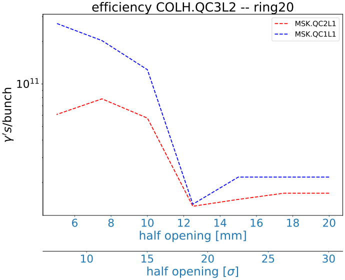
Collimation Efficiency Plots



Register photon rate at upstream SR masks as reference.

Far-out Collimator ≈100 m

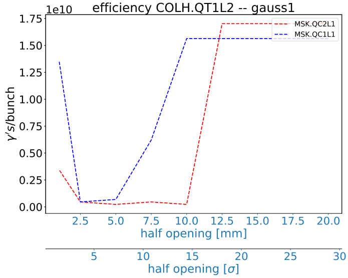


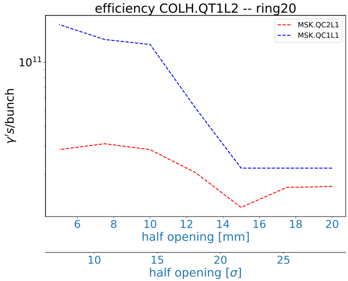


- outer mask: no effect above 5 mm (7.5 σ_x)
- inner mask: no effect above 5 mm (7.5 σ_x)
- generally less effective at inner mask

- outer mask: reduction with closures between 17.5 mm to 12.5 mm (25 σ_x)
- inner mask: reduction with 15 mm to 12.5 mm
- steep rise in the photon rate $<$12.5 mm (19 σ_x)

Intermediate Collimator $\approx$50 m

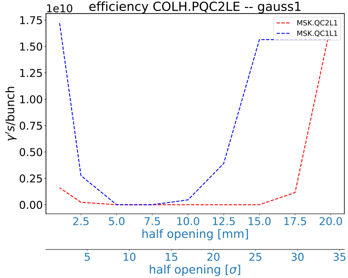


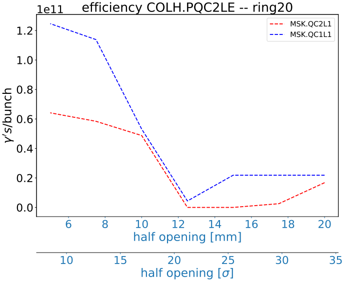


- outer mask: effective from 12.5 mm down to below 5 mm (17.5 σ_x to 5 σ_x)
- inner mask: narrow minimum between 10 mm to 2.5 mm (15 σ_x to 5 σ_x)
- more flexibility for outer mask

- outer mask: minimum from 17.5 mm to 15 mm (25 σ_x to 21 σ_x)
- inner mask: no reduction at any setting
- steep rise in the photon rate $<$12.5 mm (19 σ_x), especially inner mask

Near Collimator ≈10 m

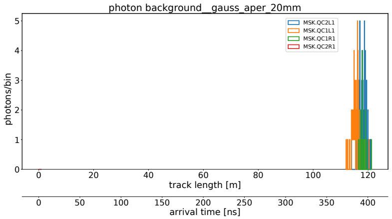


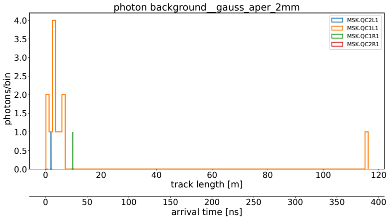


- outer mask: broad minimum from $>30\,\sigma_x$
- inner mask: most effective here, reduction from $25\,\sigma_x$ to $8\,\sigma_x$
- some margin for settings at both locations

- outer mask: broad minimum $35\,\sigma_x$ to $21\,\sigma_x$
- inner mask: less efficient, $25\,\sigma_x$ to $21\,\sigma_x$
- steep rise in the photon rate <12.5 mm ($21\,\sigma_x$)

Photon Arrival Time – Effect with COLH.PQC2LE





- with 20 mm closure only photons from far away
- no scattering from near elements

- observation changes with narrow closure
- photons striking the masks from only $\leq$10 m
- collimator closed too far
  $\Rightarrow$ turns into a scattering source

Outlook & Conclusion

Initial Collimation Proposal

- placed three collimators upstream of the IR
- iterated through generic set of settings
- we observe different efficiency
- depending on conditions and location
- simulation data shows expected behavior
- close and intermediate collimator seem to offer more flexibility (Gaussian bunch)
- far-out collimator shows effect for ring-type distribution

Next Steps

- collimation study can be refined
- Baseline xray reflection in Geant4?
- misalignment/orbit deviations
- tails in MDISim

Additional Work

- Vacuum group provided test geometry in `gdml` (M. Ady)
- first import to Geant4 successful
- updated central chamber geometry (detector group, E. Perez)
- needs to be combined with MDISim model
- IR fieldmap

Thank you for your attention.