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

– Early Collimation Scheme –

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Joint FCC-ee MDI / Detector meeting – July 6, 2020

Geometric Assessments
- Recap – Upstream Dipoles
- Collimator Setup

Simulation Results
- Scenarios
- Collimation Efficiency

Conclusion and Outlook

Three Groups of Upstream Bends

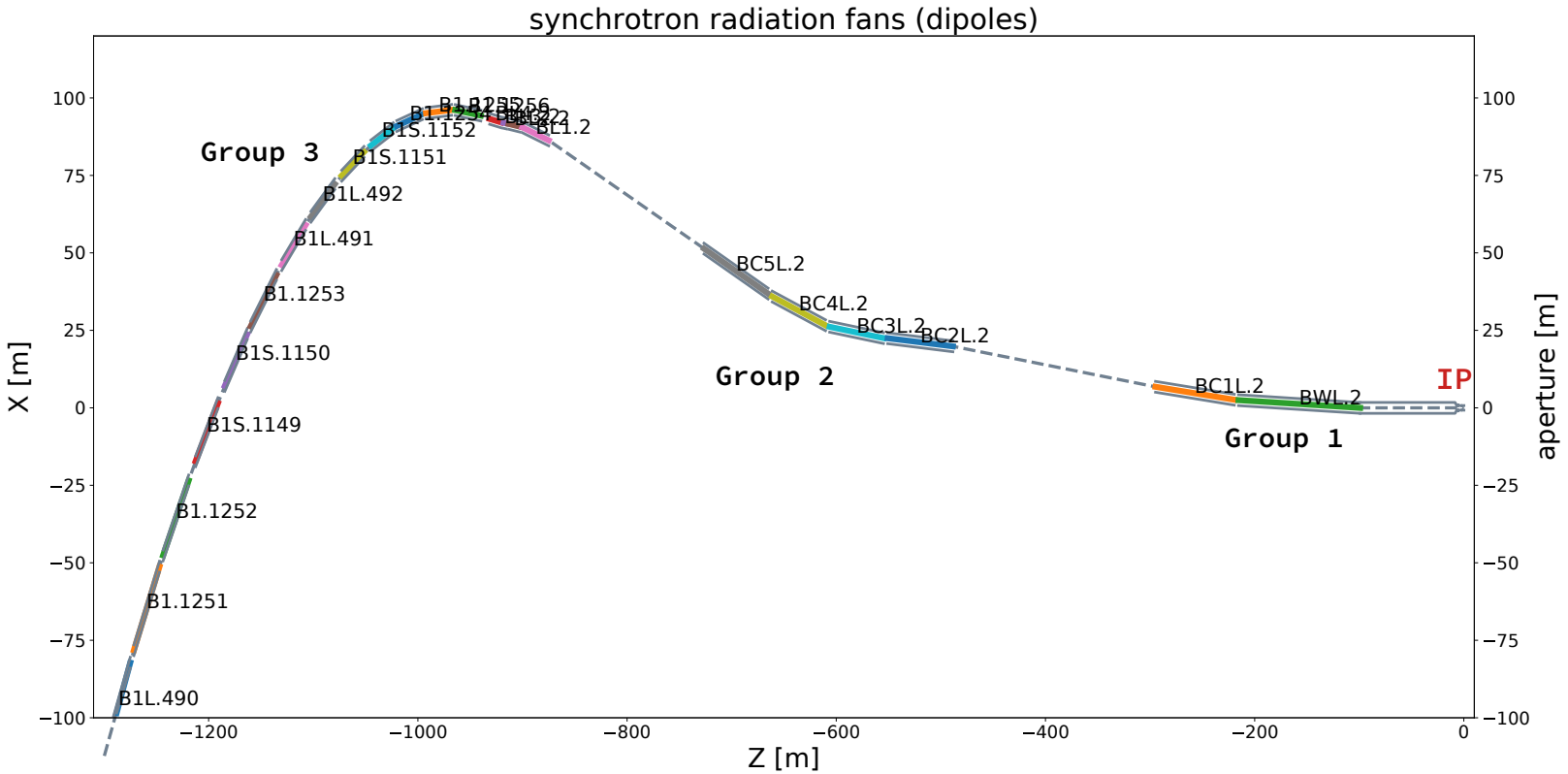


Figure: Top view (2D) on upstream bends, starting in the arc around 1300 m upstream.

Three Groups of Upstream Bends

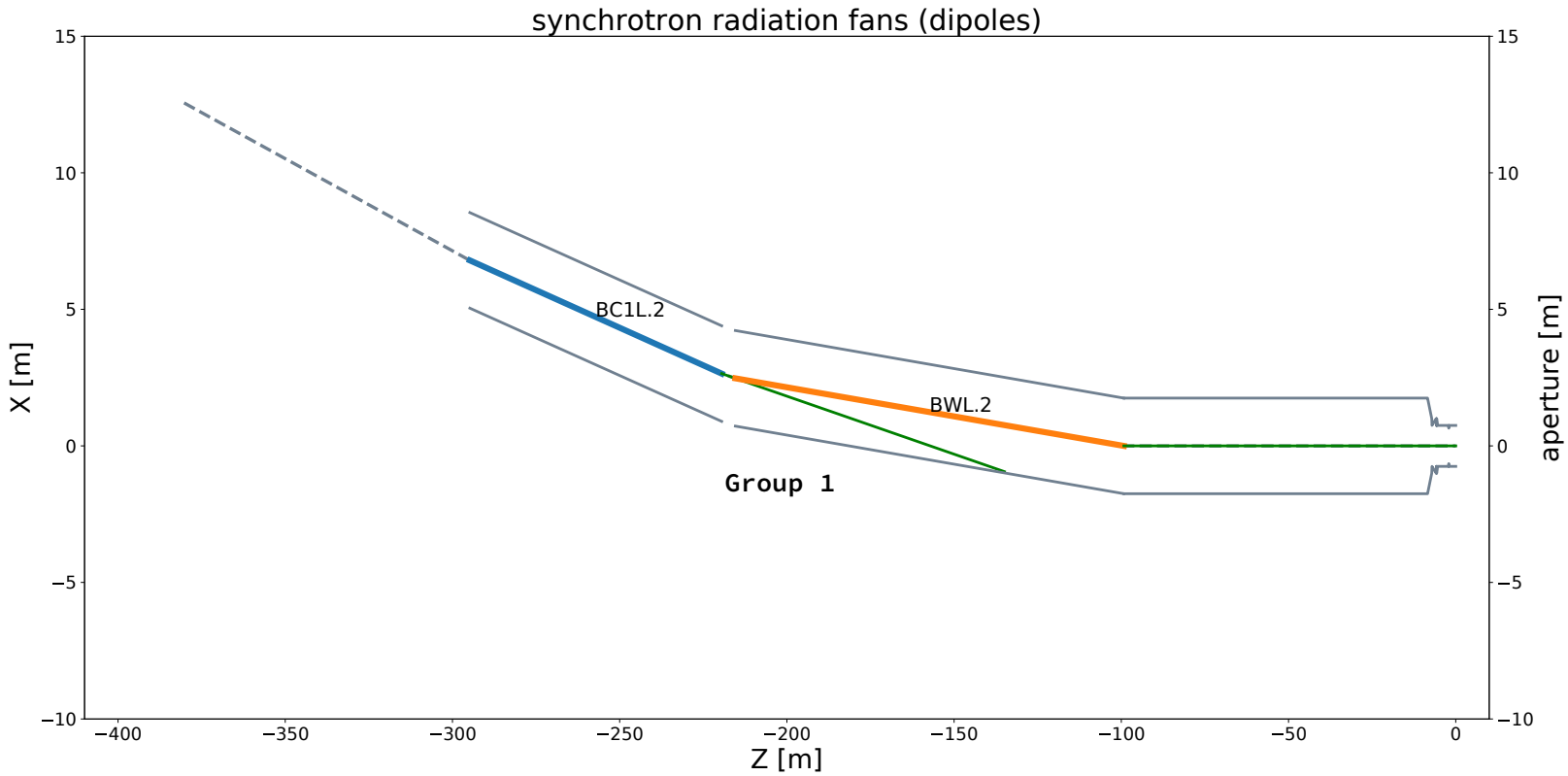
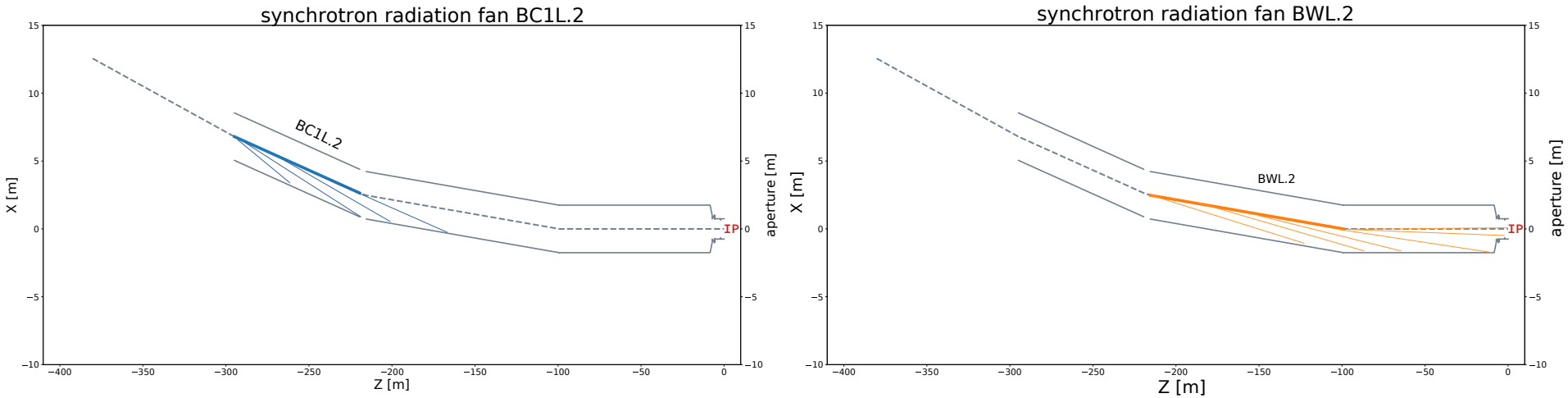


Figure: Top view (2D) on upstream bends, starting in the arc around 400 m upstream. **Transverse dimensions scaled by a factor of 50.**

Has also been discussed in MDI meeting from December 2019.

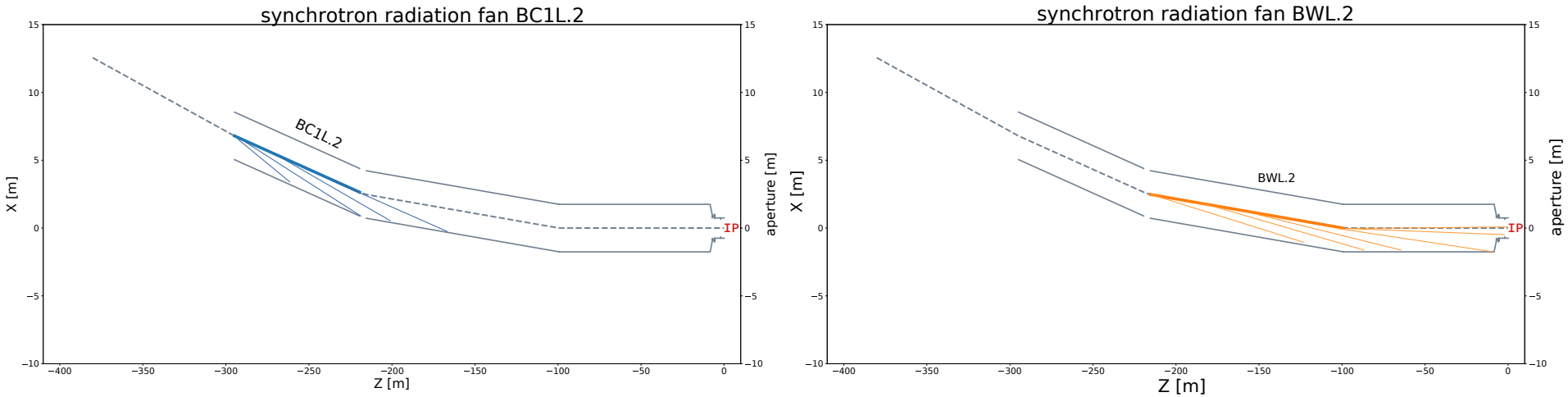
Synchrotron Radiation Fans – Group 1



(a) (b)

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

Synchrotron Radiation Fans – Group 1



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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

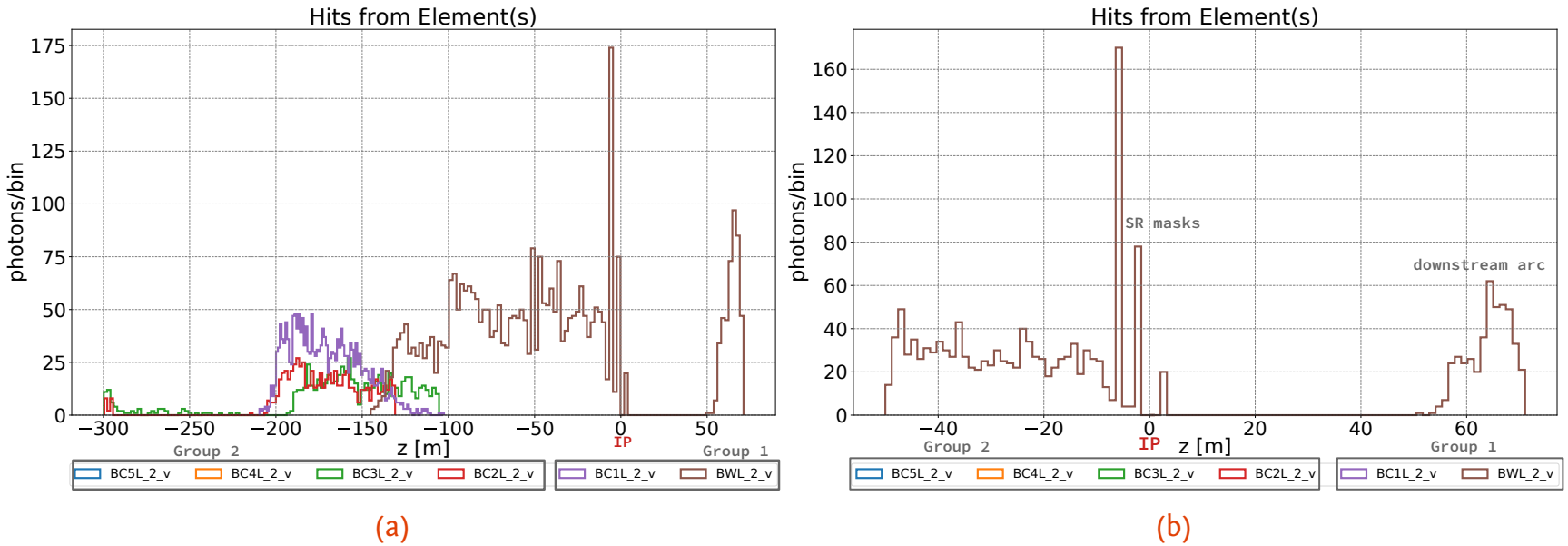

Figure: Distribution of hits, sorted by elements of origin. (a) from 300 m upstream. (b) close-up: 50 m upstream.

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Updates on IR Geometry

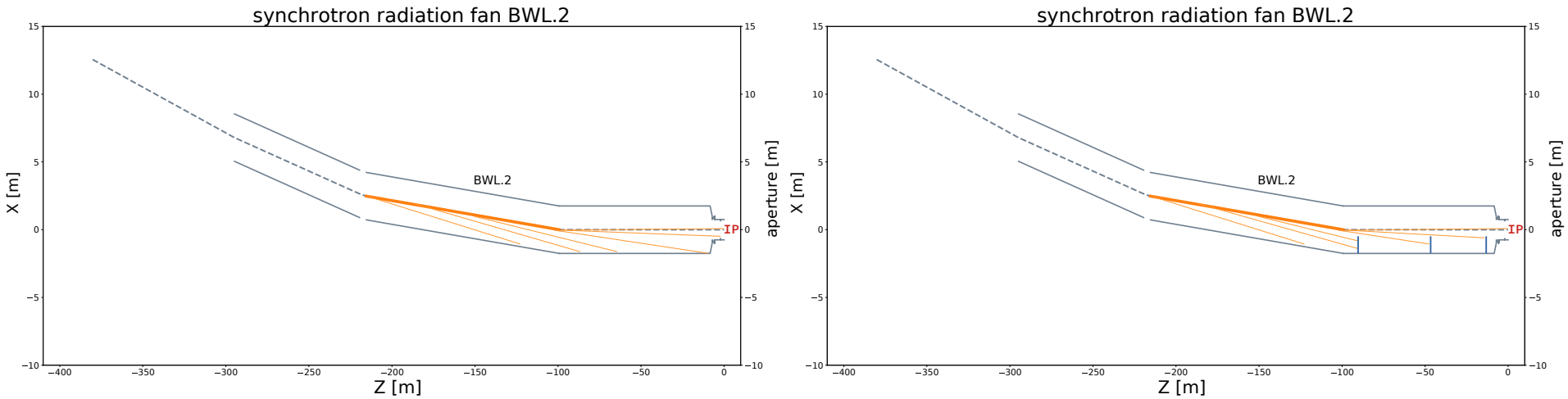

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Figure: Sketch of Synchrotron Radiation fans. (a) last upstream bend. (b) collimators intercepting the radiation fans.

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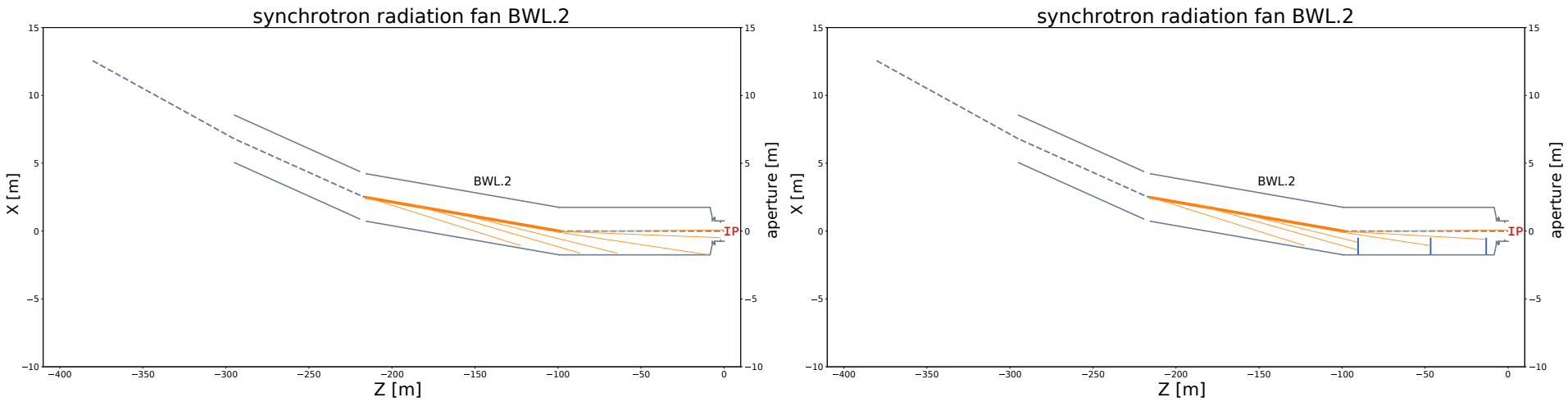

Figure: Sketch of Synchrotron Radiation fans. (a) last upstream bend. (b) collimators intercepting the radiation fans.

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

Updates on IR Geometry

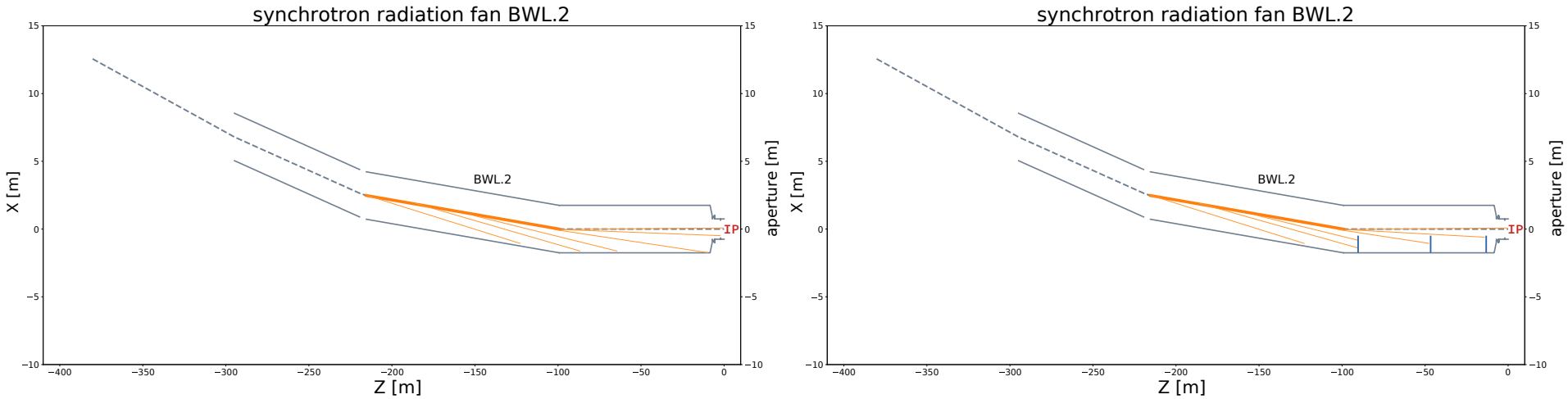

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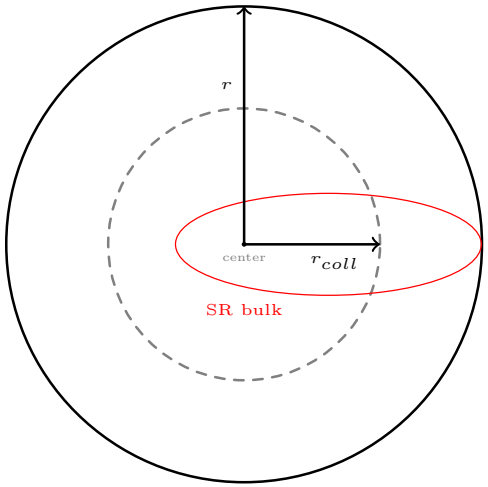
Figure: Sketch of Synchrotron Radiation fans. (a) last upstream bend. (b) collimators intercepting the radiation fans.

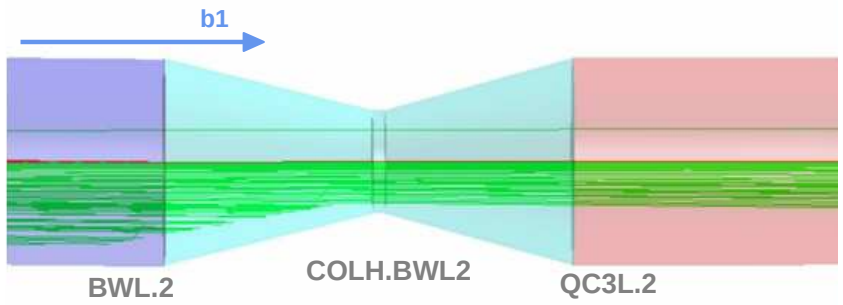
Beam-optics related aspects might be discussed in one of the next FCC-ee Optics Design Meeting.

Updates on IR Geometry

(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.

Updates on IR Geometry

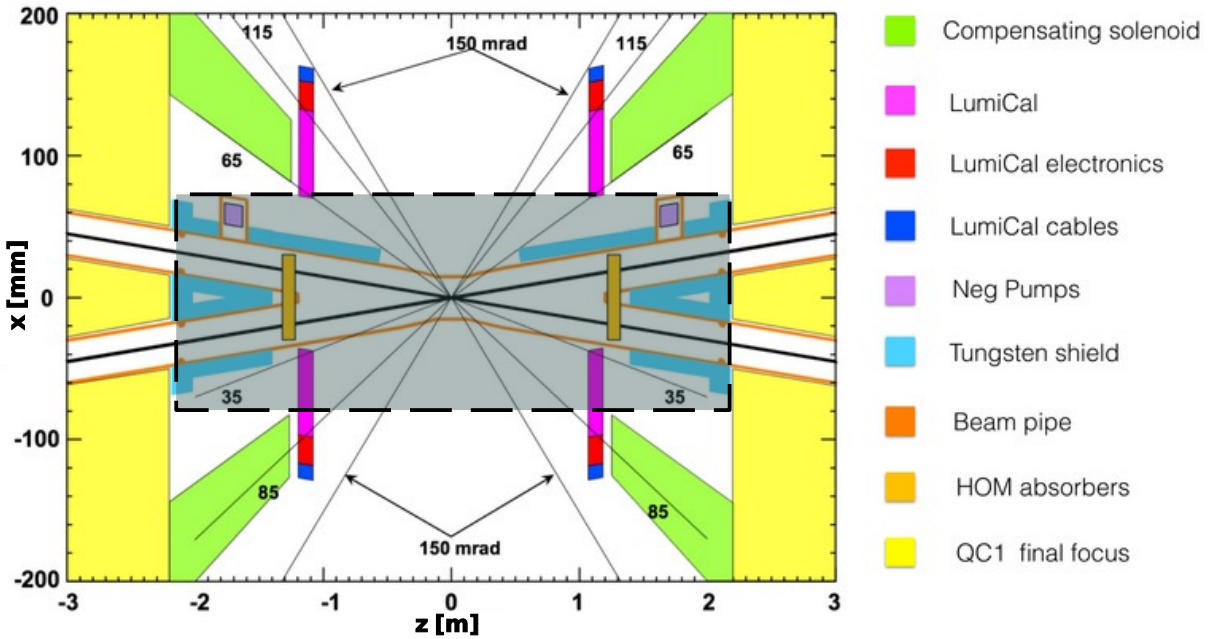


Figure: Current layout for the central interaction region. 3D model available for section between QC1L/R, as highlighted in the picture.

Updates on IR Geometry

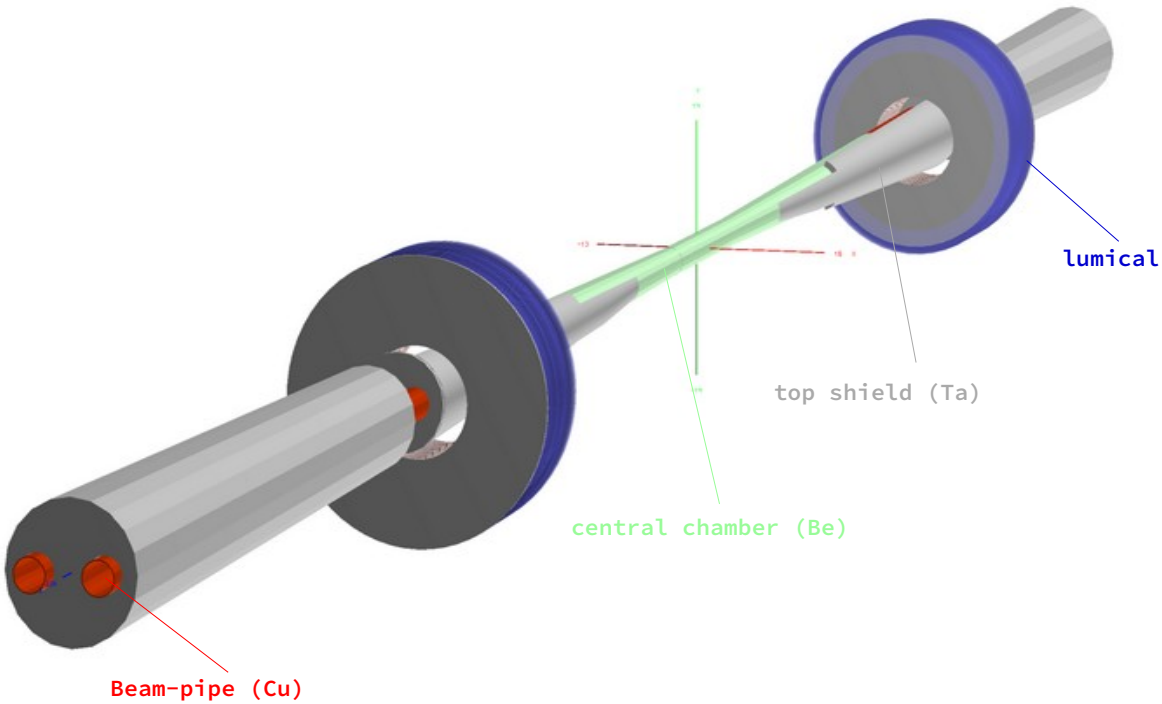


Figure: Updated central chamber model with copper beam-pipe, beryllium pipe, tantalum schield and lumical. It features one upstream synchrotron radiation mask, integrated in the copper beam-pipe.

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
- 10^3 primaries (1σ)
- Particle distributions:
  - Gaussian bunch
  - Ring-type distribution at 20 $\sigma_{x,y}$
  - rather conservative
  - measurements at LEP (horizontal tails)
- starting point 300 m upstream (Group 1)

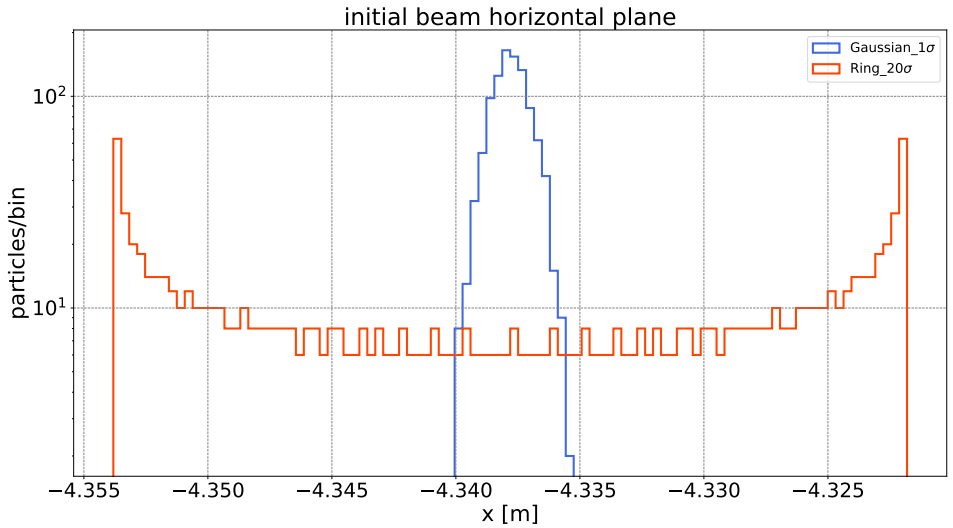


Figure: Initial particle distribution (horizontal plane) for a Gaussian and Ring shape transverse horizontal profile.

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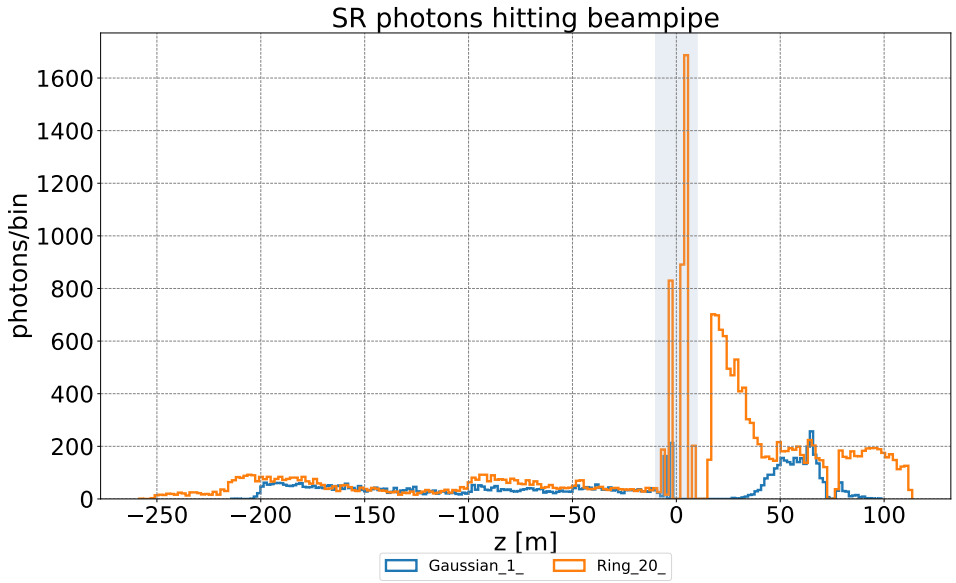

Figure: Result of the simulations with Gaussian bunch and Ring-Type distribution, starting 300 m upstream.

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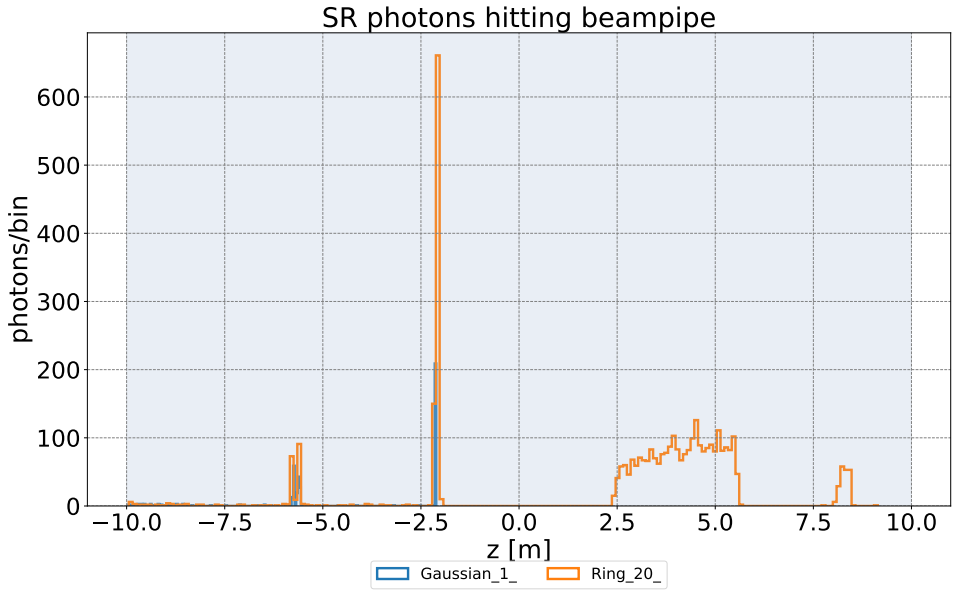


Figure: Hits distribution in the inner IR (±10 m). A Ring-shape transverse profile causes more hits in z from 2.5 m to 10 m.

Collimation Efficiency Plots

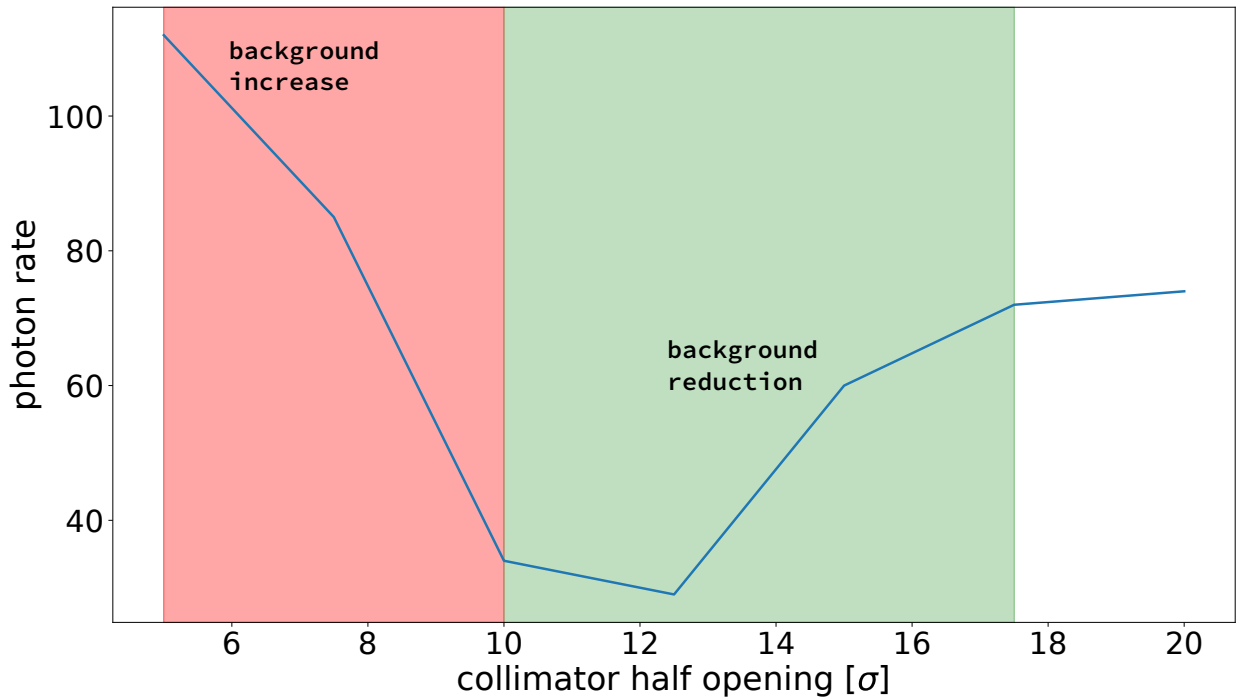


Figure: Shape of the collimation efficiency plots: photon (or background) rate vs. half closure.

Collimation Efficiency Plots

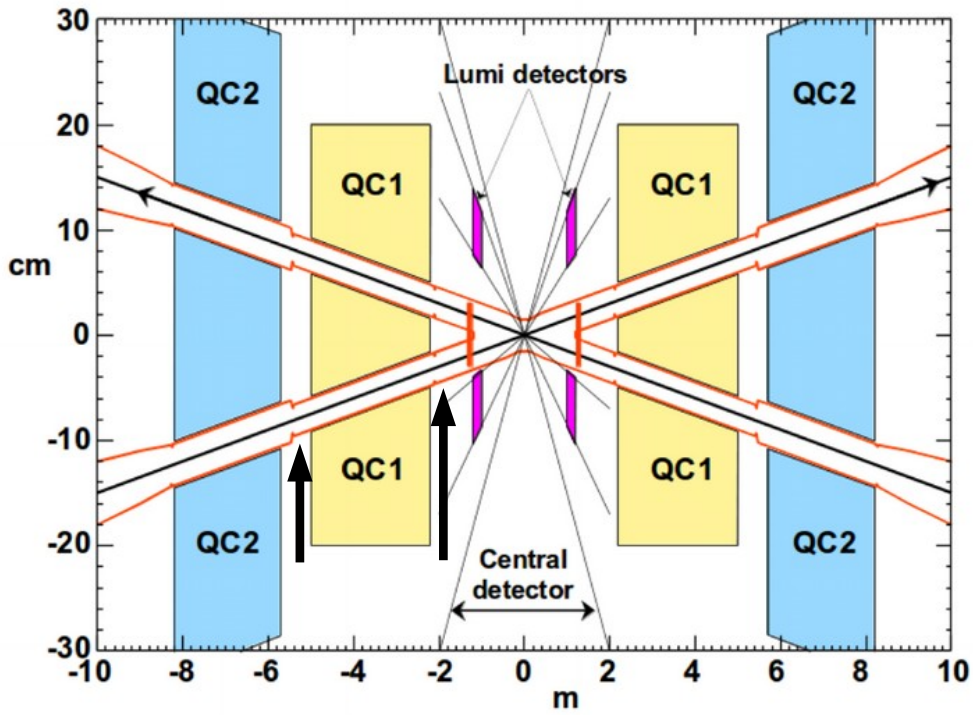
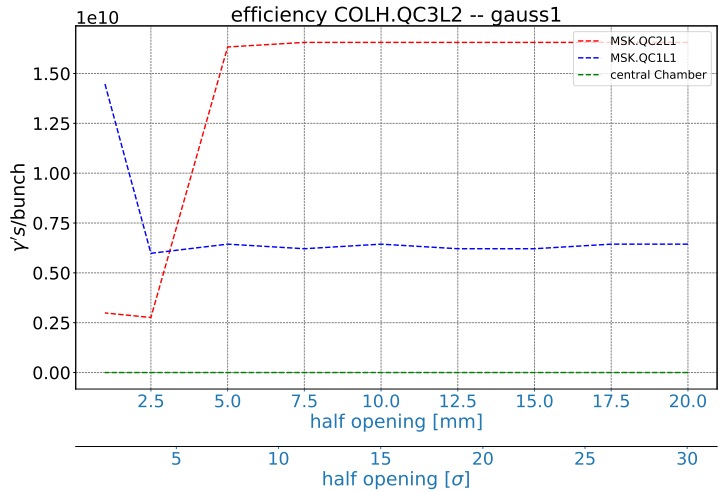


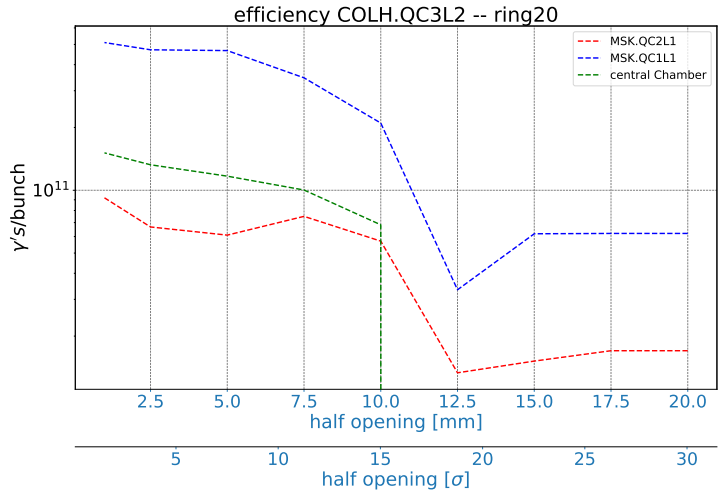
Figure: Top view on central IR. Black arrows indicate location of upstream SR masks.

Register photon rate at upstream SR masks as reference.

Far-out Collimator ≈100 m

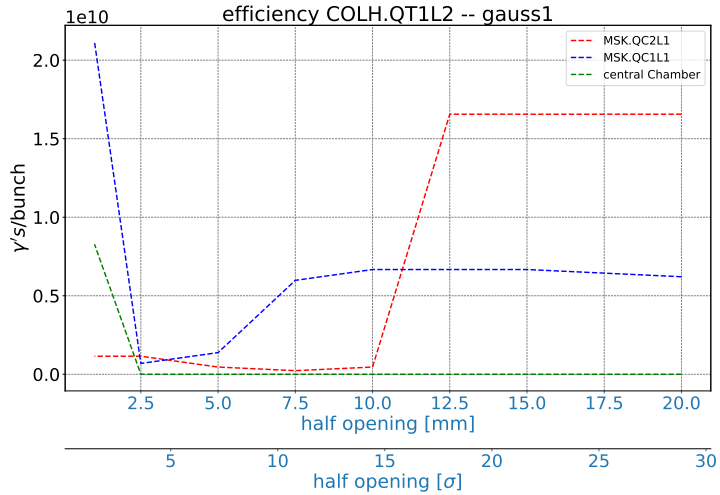


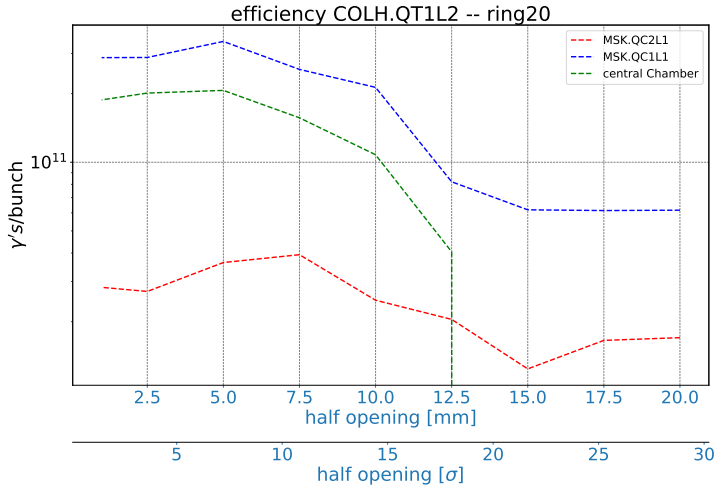
- outer mask: no effect above 5 mm (7.5 σ_x)
- inner mask: only increase in background observed
- central chamber: no hits registered



- 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)
- central chamber: affected from 10 mm closure

Intermediate Collimator ≈50 m

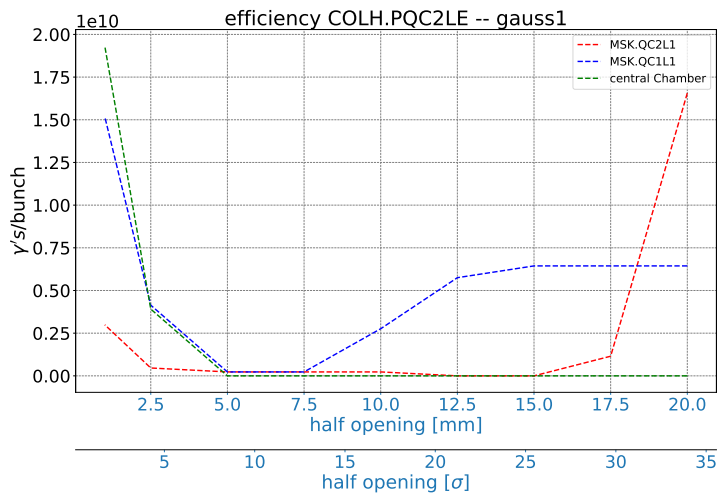


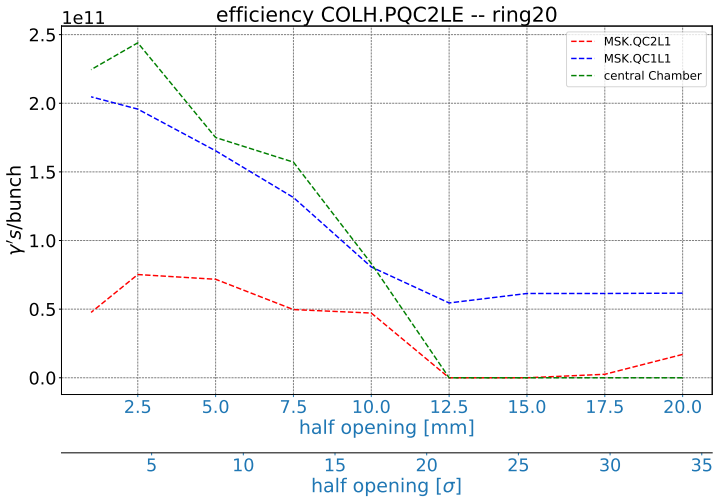


- outer mask: effective from 12.5 mm down to below 5 mm (17.5 σ_x to 5 σ_x)
- inner mask: narrow minimum between 7.5 mm to 2.5 mm (15 σ_x to 5 σ_x)
- more flexibility for outer mask
- central chamber: no hits registered above 5 σ_x closure

- 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 $<$15 mm (22 σ_x)
- central chamber: affected below 20 σ_x

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
- central chamber: affected below $10\,\sigma_x$

- 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 ($21\,\sigma_x$)
- central chamber: affected below $25\,\sigma_x$

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

Additional Work

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

Next Steps

- collimation study now to be refined
- xray reflection in Geant4
- misalignment/orbit deviations
- tails in MDISim

Thank you for your attention.