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

- Starting the Study of a Collimation System -

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Introdcution

Synchrotron Radiation at FCC-ee

- FCC-ee aims for collision energies as high as 365 GeV [2]
- Some experience from LEP [7]:
  - weak bends
  - long straight sections
  - synchrotron radiation as serious background
  - vacuum chamber, electronics, cables & beam instrumentation [1]
  - carefully designed collimation system
  - 45.6 GeV: $E_c \approx 68$ keV (average arc dipole)
- FCC-ee
  - asymmetric layout (weak bends upstream)
  - last bend about a 100 m from IP
  - 182.5 GeV: $E_c \approx 100$ keV (last upstream dipole)
  - limit E_c to 100 keV (last 450 m)
  - limit E_c to 1 MeV (whole machine)
- **Potential for high energy photons, especially at top energy**
- **collimation system should be studied**

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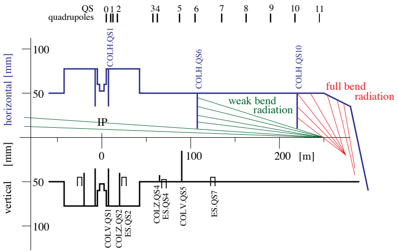

Figure: Schematic layout of the LEP background collimation system [7].

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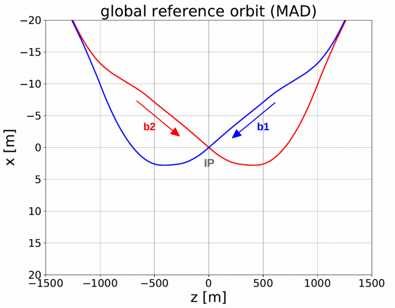

Figure: Asymmetric layout of the FCC-ee IR.

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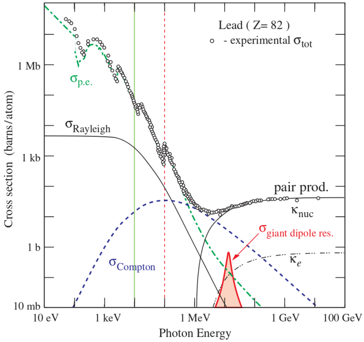

Figure: Photon interaction processes in lead [3].

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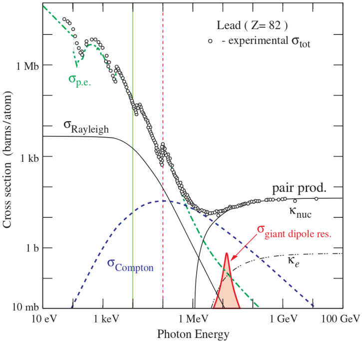

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Characterizing Synchrotron Radiation

Settings for the simulations

- FCC-ee `t_213_sol` at top energy (182.5 GeV)
- 2,000 primaries
- Only beam1 (positron)
- Start 400 m upstream
- Emittance ratio 0.002
- Different beam shapes:
  - pencil beam
  - gaussian (normally distributed, $\sigma_{x,y}$)
  - halo (all particles at certain $\sigma_{x,y}$)

Characterizing Synchrotron Radiation

The simulation can show

- Origin of photons
  - elements
  - different beam types

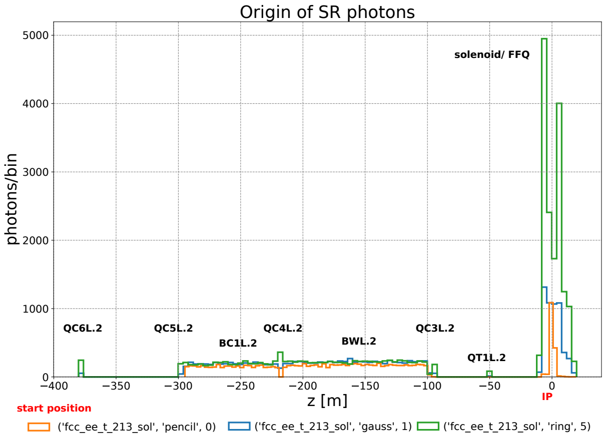

Figure: Photon origins upstream. No photons generated in quadrupoles with pencil beam.

Characterizing Synchrotron Radiation

The simulation can show

- Origin of photons
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- Hits on the beampipe wall
  - for the moment: direct hits
  - masks around IP
  - outgoing beam: heavy load

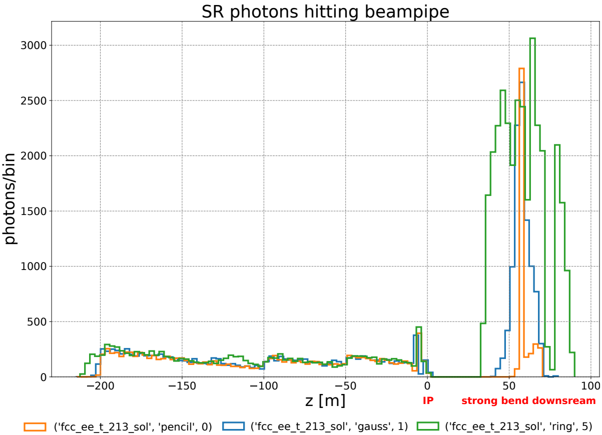

Figure: Distribution of hits (beam pipe) along the beam path.

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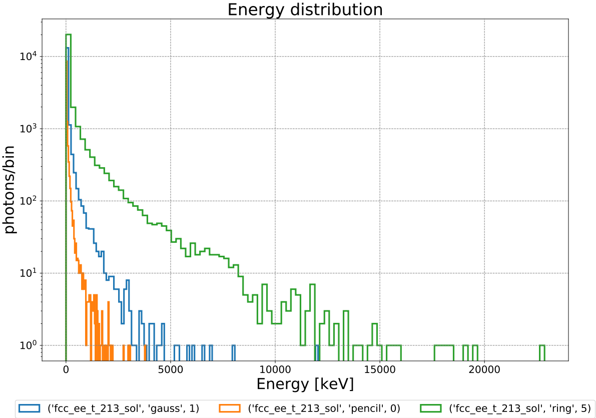

Figure: Energy distribution. Beam with higher energy tail for Gaussian or halo.

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- Energy distribution
- More analysis (development)

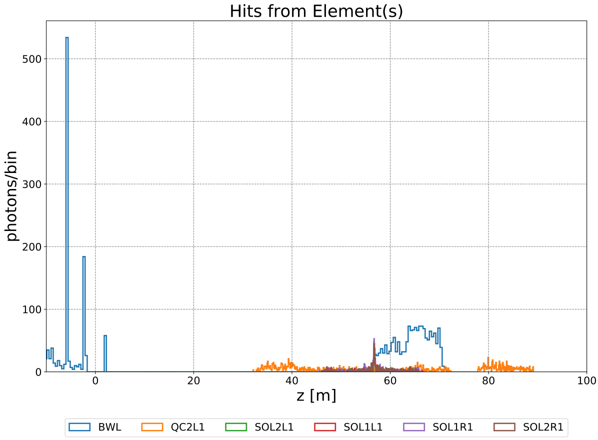

Figure: Looking at hits caused by photons from selected elements.

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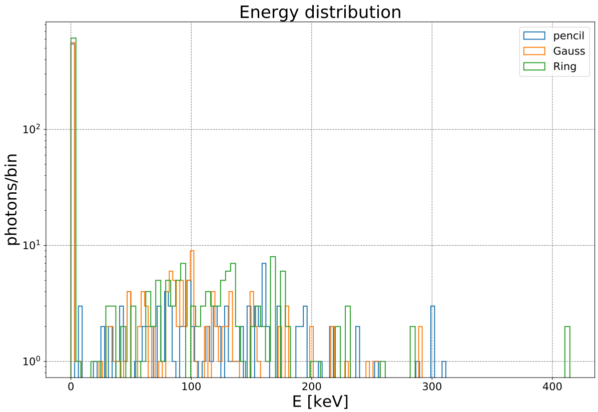

Figure: Photon energies for hits within ± 10 m around IP.

Collimation of Synchrotron Radiation at FCC-ee

Considerations

- Collimators induce scattering
- Far from interaction region
- Settings: beam size
  - $\sigma = \sqrt{\epsilon\beta}$
  - $\epsilon_x = 1.45$ nm
  - $\epsilon_y = 2.91$ pm
- Close to quadrupoles
- Starting with collimators at:
  - Downstream of `BWL.2` (case A)
  - Downstream of `QT1L.2` (case B)
- Start with setting: `COLH` around 15 σ_x

Table: Horizontal beam size at certain magnets upstream

NAME	BETX	σ_x [μm]	$15\sigma_x$ [mm]	$10\sigma_x$ [mm]
BWL.2	333.36	695.25	10.43	6.95
QC3L.2	303.68	663.58	9.95	6.63
QT1L.2	329.07	690.76	10.36	6.91

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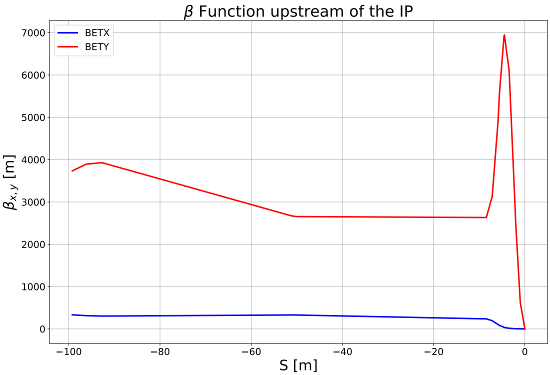

Figure: Horizontal and vertical beta function last 100 m upstream.

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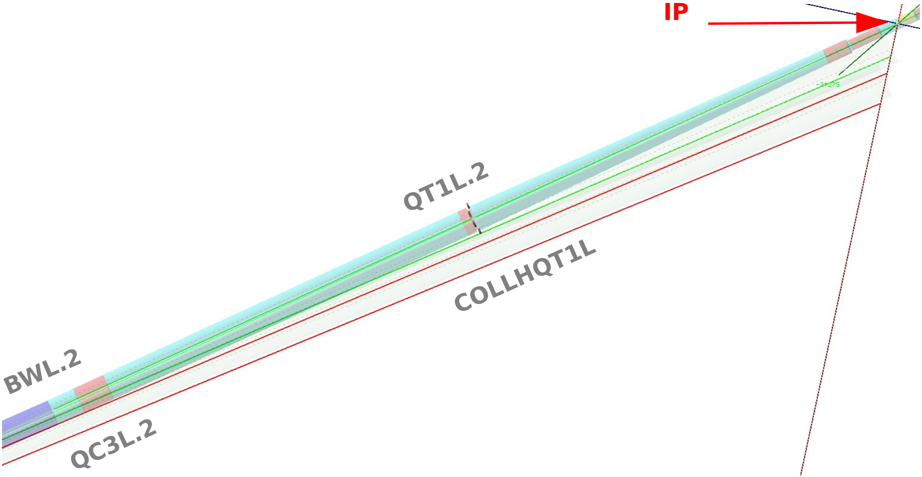

Figure: Top view on radiation fans coming from last two upstream bends. bend start, bend end

Effect in the Interaction Region

Preliminary Results

- First impression:
  - Far collimator (BWL.2, $15\sigma_x$) seems to not reduce direct hits
  - However, at LEP far collimators have been very useful
  - Collimator after QT1L.2 reduces hits close to IP

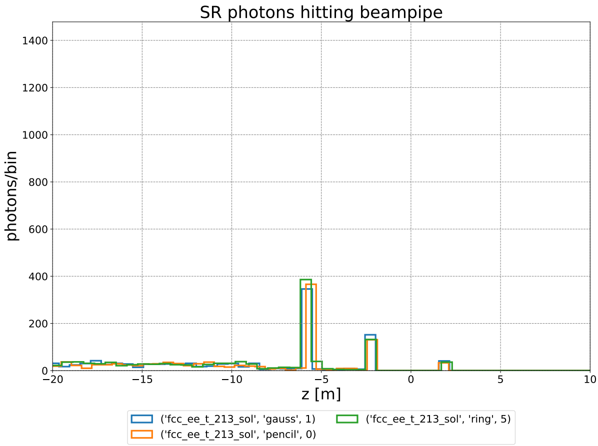

Figure: Photons hits on the beam pipe without any collimation (−20 m to 10 m of the IP).

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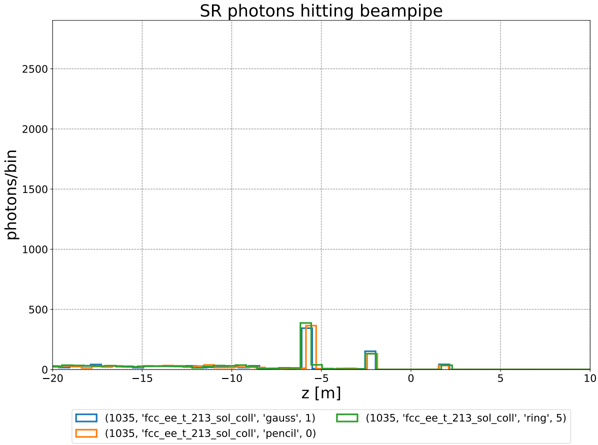

Figure: Hits in the interaction region with collimator after BWL.2 (case A).

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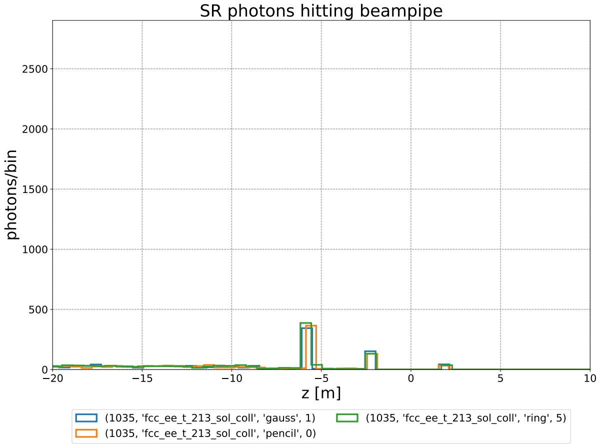

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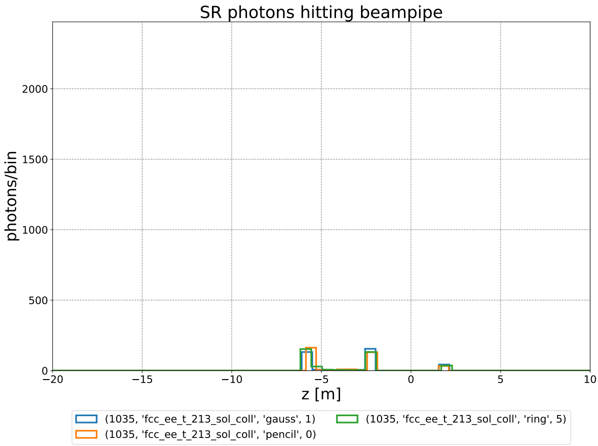

Figure: Hits in the interaction region with collimator after QT1L.2 (case B).

Outlook

Summary

- Preliminary study & proof of principle
- Collimators help to reduce SR background (additional to masks)
- Collimator hierarchy (development)
- Focus on upstream collimators (for now)
- Position and settings vs. effect on the IR

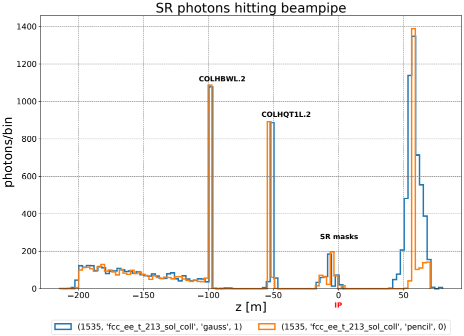

Figure: Example for a combination of collimators.

Outlook

Perspective

- Collimation study in very early phase:
  - no misalignments
  - scattering has to be considered
  - **reflection**
- Collimator study - Optimize:
  - position
  - setting
  - combination
  - material
- Coordinate with beam dynamics (lifetime)
- MDISim still under development
- Benchmark attempt with SuperKEKB ongoing in parallel

Thank you for your attention.

References

[1] R. Bailey, B. Balhan, C. Bovet, B. Goddard, N. Hilleret, J. M. Jim nez, R. Jung, M. Placidi, M. Tavlet, and G. Von Holtey. Synchrotron Radiation Effects at LEP. (CERN-SL-98-046-OP):3 p, Jun 1998.

[2] M. Benedikt, A. Blondel, O. Brunner, M. Capeans Garrido, F. Cerutti, J. Gutleber, P. Janot, J. M. Jimenez, V. Mertens, A. Milanese, K. Oide, J. A. Osborne, T. Otto, Y. Papaphilippou, J. Poole, L. J. Tavian, and F. Zimmermann. Future Circular Collider. Technical Report CERN-ACC-2018-0057, CERN, Geneva, Dec 2018. Submitted for publication to Eur. Phys. J. ST.

[3] M. Boscolo, H. Burkhardt, and M. Sullivan. Machine detector interface studies.

[4] GEANT4. Geant4 - A Simulation Toolkit.

[5] MAD Team. MAD - Methodical Accelerator Design.

[6] ROOT. ROOT - Data Analysis Framework.

[7] G. Von Holtey et al. Study of beam-induced particle backgrounds at the LEP detectors. *Nucl. Instrum. Methods Phys. Res., A*, 403(CERN-SL-97-040-EA):205–246. 68 p, Jun 1997.

Backup slides

Tools

- Toolkit used for simulations: MDISim [3]
- Interface:
  - MAD-X [5]
  - ROOT [6]
  - Geant4 [4]
- No full-turn tracking
- Detailed tracking: last few hundred meters

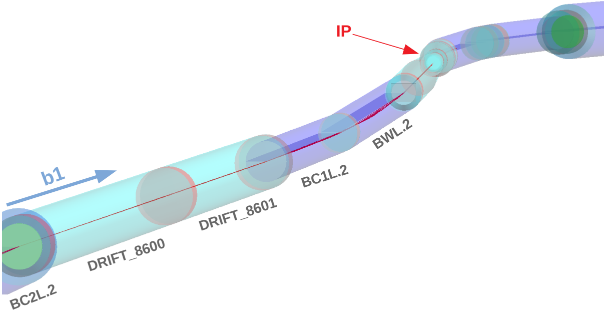

Figure: Due to symmetry starting with single beam studies: b1, e^{+} ...

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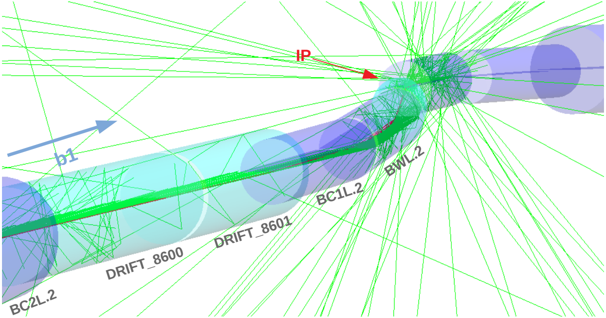

Figure: ... to track beam particles and photons from upstream of the IP.

Collimator Design

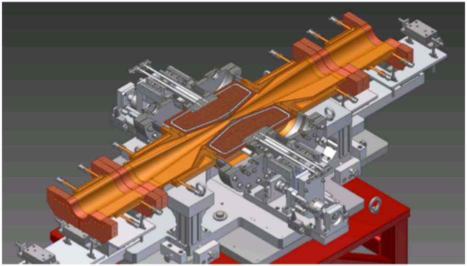

Figure: SuperKEKB horizontal collimator

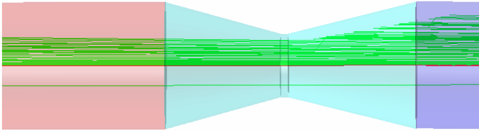

Figure: Realization in MDISim

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