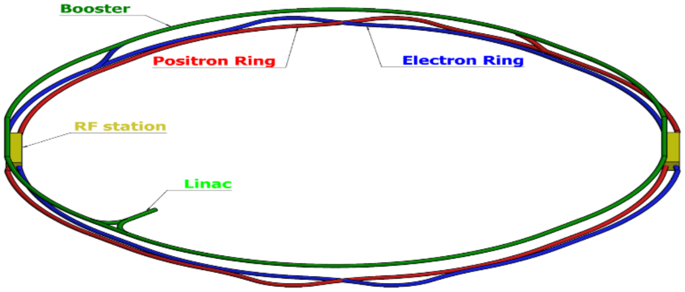


# MDI: Background Estimation

Hongbo Zhu (IHEP)

CEPC Detector Mini-Review, 10 November 207

# CDR

CHAPTER 10

## CEPC INTERACTION REGION AND DETECTOR INTEGRATION



The machine-detector interface (MDI) represents one of the most challenging topics for the CEPC projects. It shall cover common issues related to both machine and detector designs. Topics described in this chapter include the interaction region layout, detector backgrounds, luminosity instrumentation, and concerns regarding machine and detector integration. Comprehensive understandings are necessary to address properly relevant issues and achieve optimal, along with compromises, overall performance of the machine and detector combined.

### 10.1 Interaction region layout

The interaction region (IR) receives several updates to cope with the recent double-ring design of the machine. It features an increased focal lengthen ($L^* = 1.5$ m $\rightarrow 2.2$ m), defined as the distance between the final focusing magnet (QD0) and the interaction point (IP). This allows enlarged separation between to the two single apertures of the QD0. Compensating magnets, positioned in front of the QD0 and surrounding both QD0 and OF1 and constructed with superconducting coils, are introduced to cancel out the impacts of the detector solenoid on the beam. The outer radius of the magnets defines the detector acceptance of $|\cos\theta| \leq 0.993$ in the forward region. The luminosity calorimeter ("Lumi-Cal"), located in front of the compensating magnet, is designed to measure the integrated luminosity to a precision of $10^{-3}$. The tracking disks in the forward region are re-located to cope with the limited space and shall be re-optimized with more studies.

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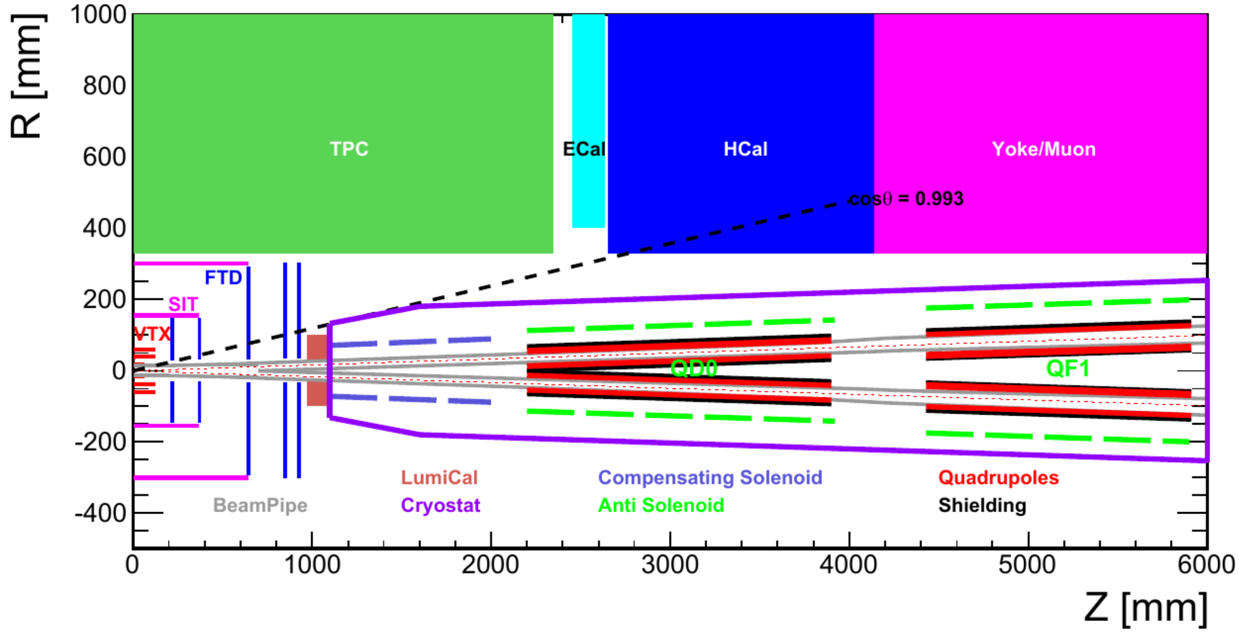
# Interaction Region Layout




- Opening issues
  - Forward tracking optimization (geometry + cable routing)
  - Central Beryllium beam pipe extension
  - LumiCal integration
  - Detector shielding
  - Beam monitor
  - **More …**

*Studies required but can be done*

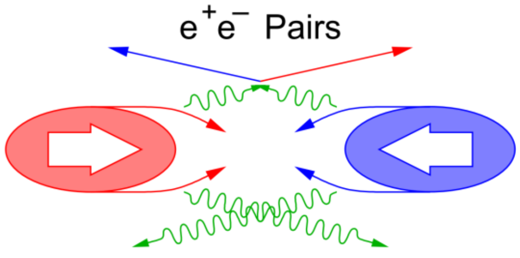
*Refer to the SuperKEKB scheme "remote connection" but with additional constraints*

*Concepts to be added/described*

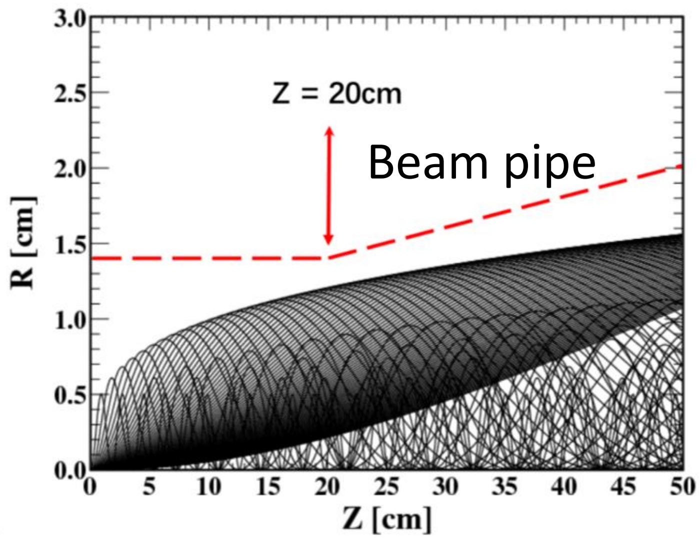
# Radiation Backgrounds

- Beam induced backgrounds
  - Beamstrahlung
  - Pair production
  - Hadronic background
- Machine induced backgrounds
  - Synchrotron radiation
  - Radiative Bhabha scattering
  - Beamstrahlung
  - Beam-gas interaction
  - Beam injection
  - Beam dumps
  - … and more

# Beamstrahlung




- Charged particles deflected by the strong field of the opposite bunch will emit radiation → beamstrahlung
- Keep machine/detector components far away from the kinematic-edge formed by particles from pair production




*Helical trajectories formed charged particles from the pair edge*

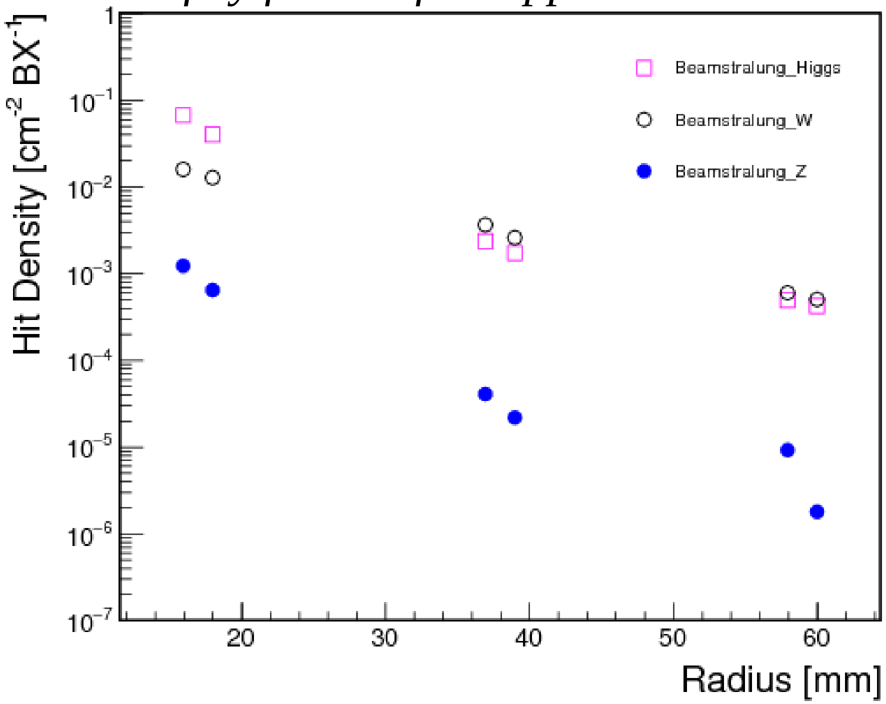
*Constraints (+ solenoid) on beam pipe to be added*

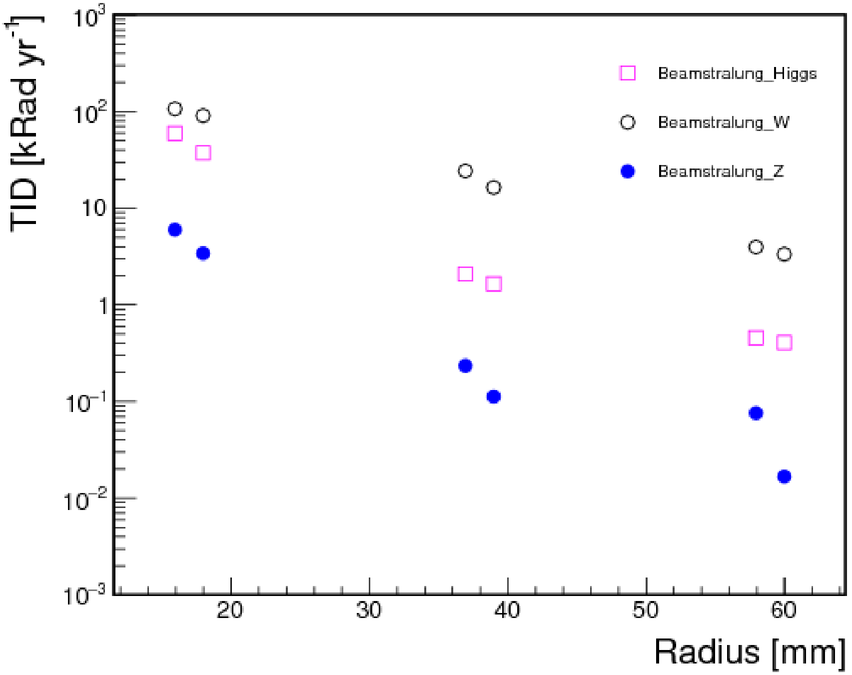
# Pair Production

*W. Xu and X. Wang*

- Beamstrahlung and pair production simulated with the Guinea-Pig program; interfaced to detector simulation

*Safety factor of 10 applied*



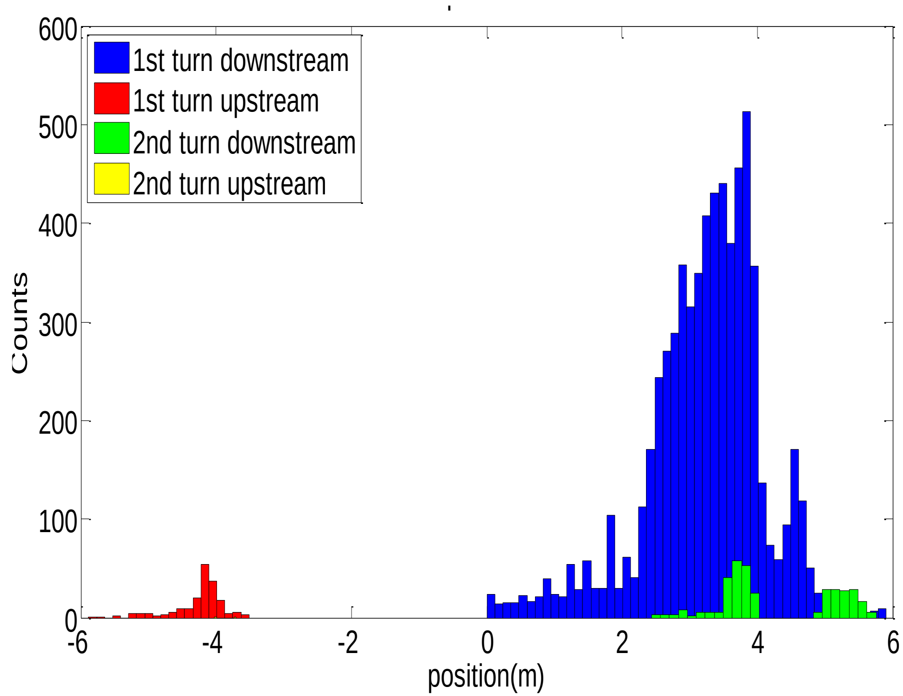

*Negligible hadronic backgrounds to be included*

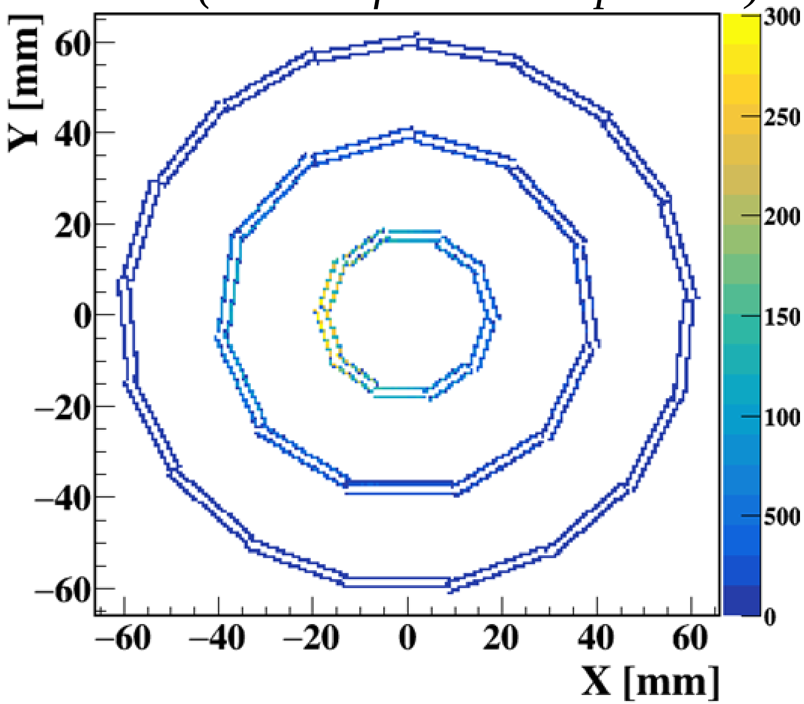
# Radiative Bhabha Scattering

*W. Xu, X. Wang and S. Bai*

- Beam lost particles (radiative Bhabha scattering, beamstrahlung, beam gas interaction ...) might get lost in the IR and cause particle shower if hitting machine/detector components → dominant background for Belle II

*Asymmetric distribution in x (nature of beam lost particle)*



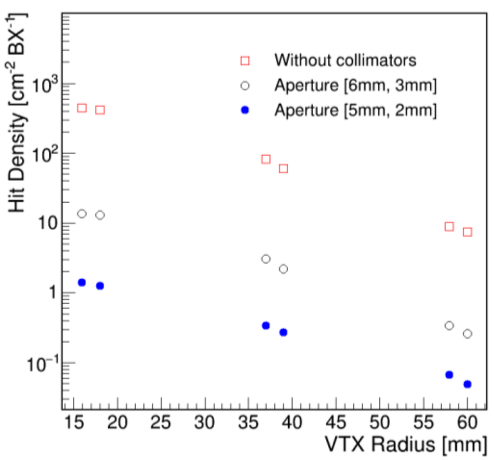
# Collimators

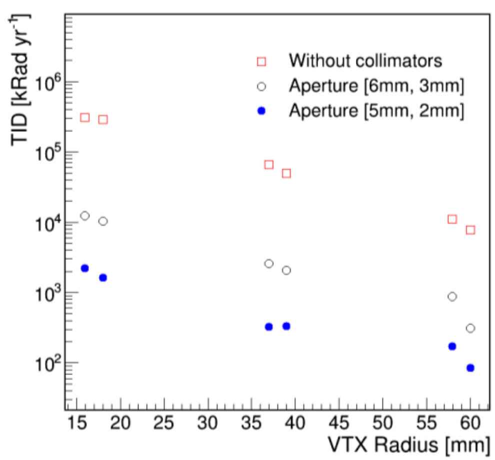
*Description of collimator design and its principle to be added;*

*Z results remain questionable, not working lattice*

- Collimators introduced to suppress effectively the detector backgrounds (without disturbing the beam).

| | Position | Distance to IP/m | Beta function/m | Horizontal Dispersion/m | Phase | BSC/2/m | Range of half width allowed/mm |
|---|---|---|---|---|---|---|---|
| APTX1 | D1I.1884 | 2206.08 | 108.35 | 0.24 | 348.62 | 0.010242 | 1~10 |
| APTX2 | D1I.1909 | 1713.85 | 104.60 | 0.24 | 350.37 | 0.010115 | 1~10 |
| APTY1 | D1I.1897 | 1956.16 | 116.81 | 0.12 | 349.32 | 0.004128 | 1~4.1 |
| APTY2 | D1I.1908 | 1745.21 | 125.22 | 0.16 | 350.07 | 0.004168 | 1~4.1 |

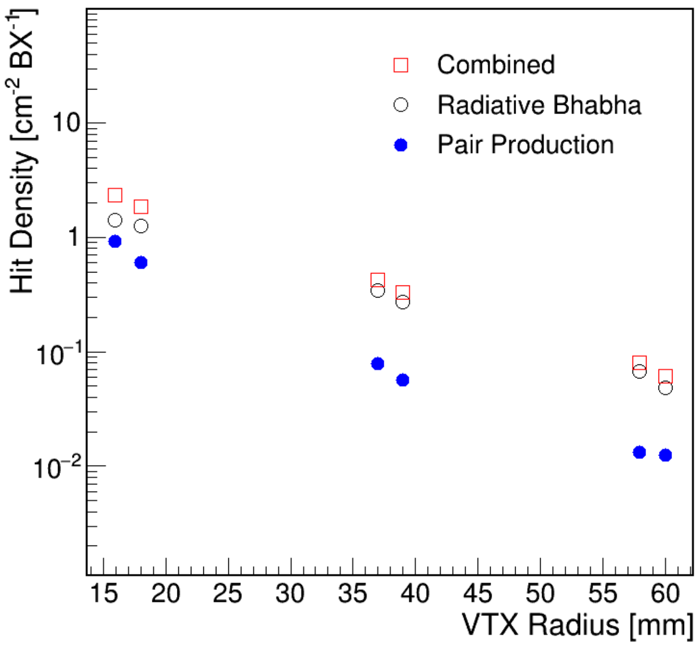


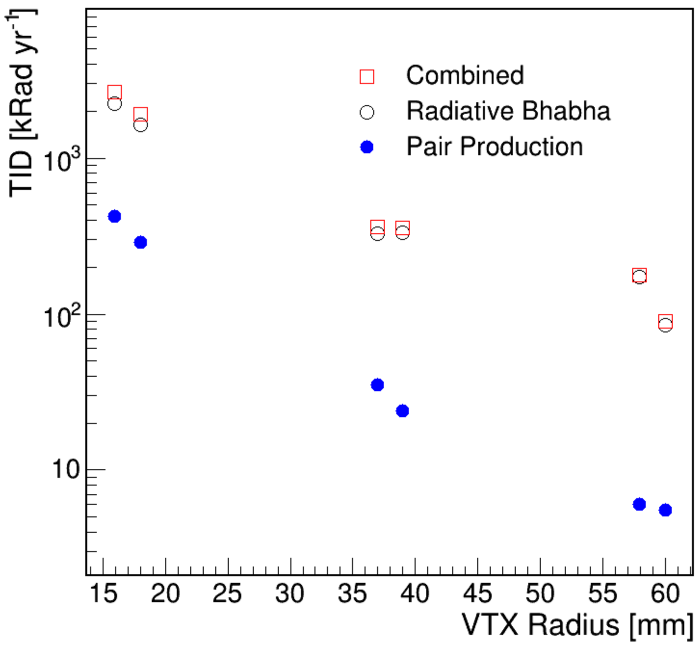




- Significant reduction in hit density and TID
- Effective (not shown) to suppress backgrounds from beam lost particle due to beamstrahlung

# Combined Results

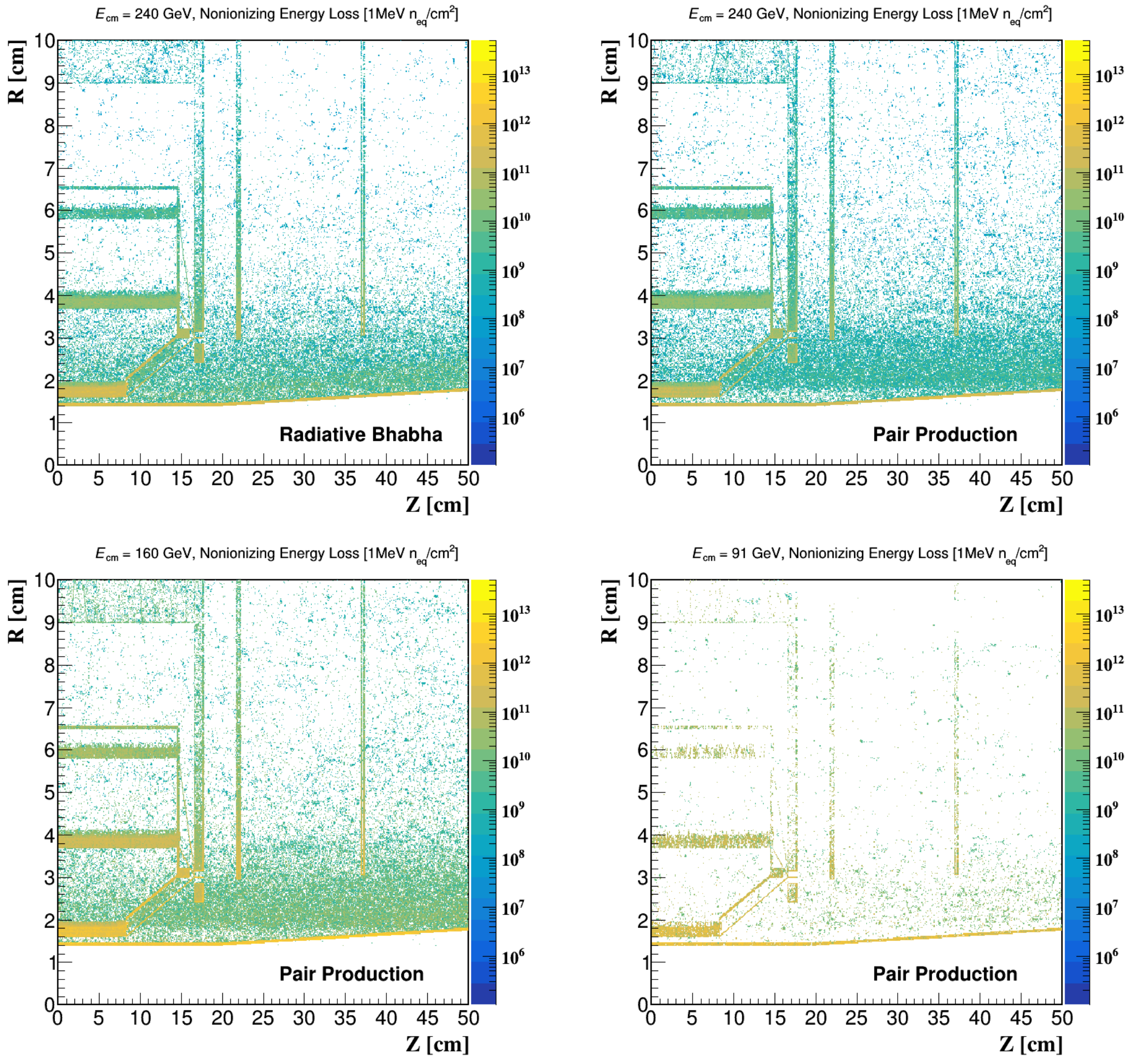
- Radiative Bhabha scattering and pair production combined yield 2.5 hits/cm$^2$·BX, annual TID ~ 2.5 MRad and NIEL ~$10^{12}$ $n_{eq}$/cm$^2$ ← safety factors of 10 applied



# NIEL Distributions

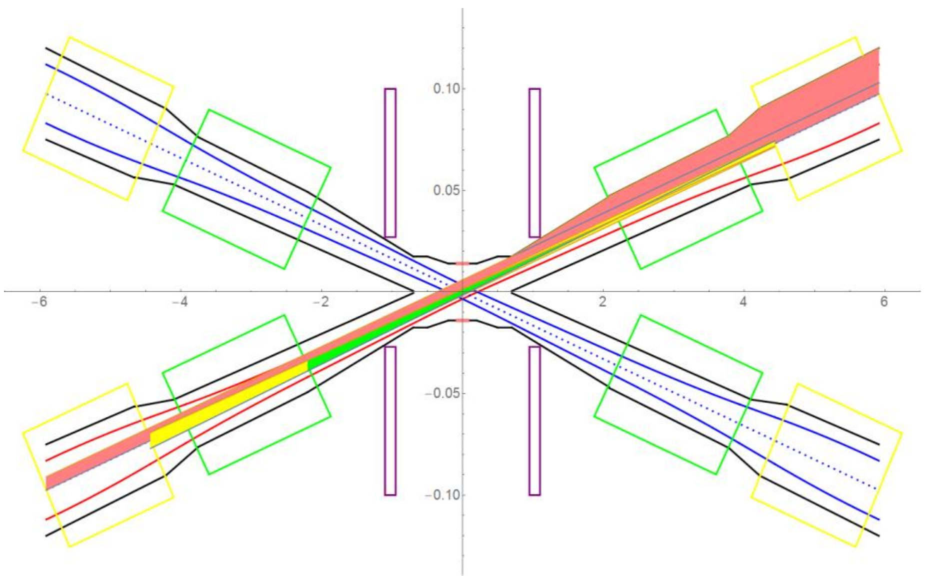
*Results to be updated*



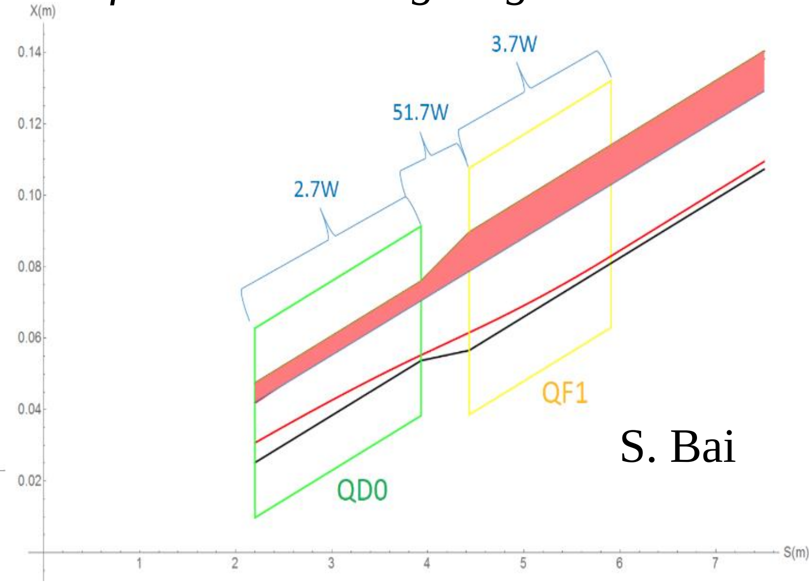
# Synchrotron Radiation

- Special and crucial background at circular machines

*SR photons from the last dipole and final focusing quadrupoles*



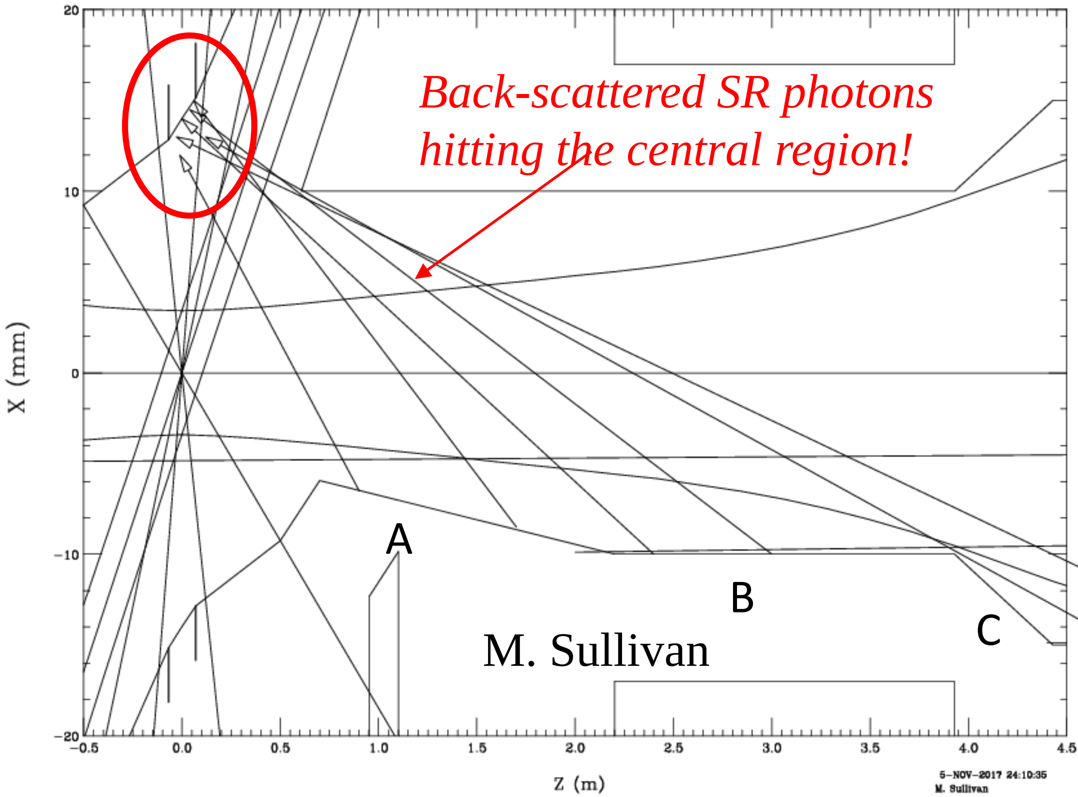

*Power deposition of SR photons from the bending magnet*

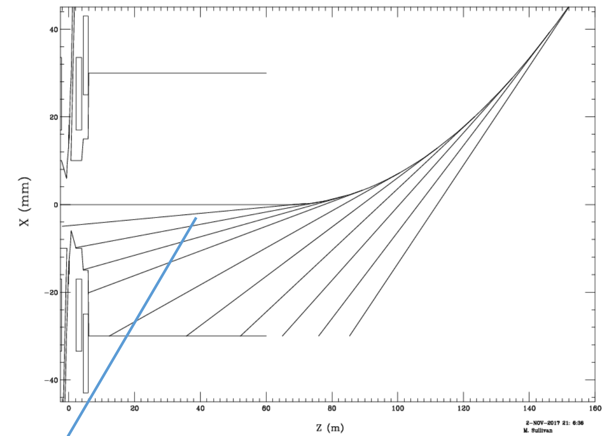


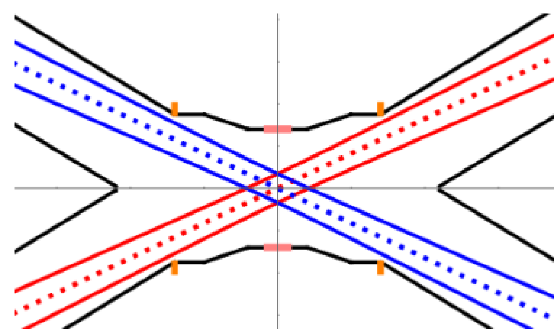

S. Bai

# Central Region

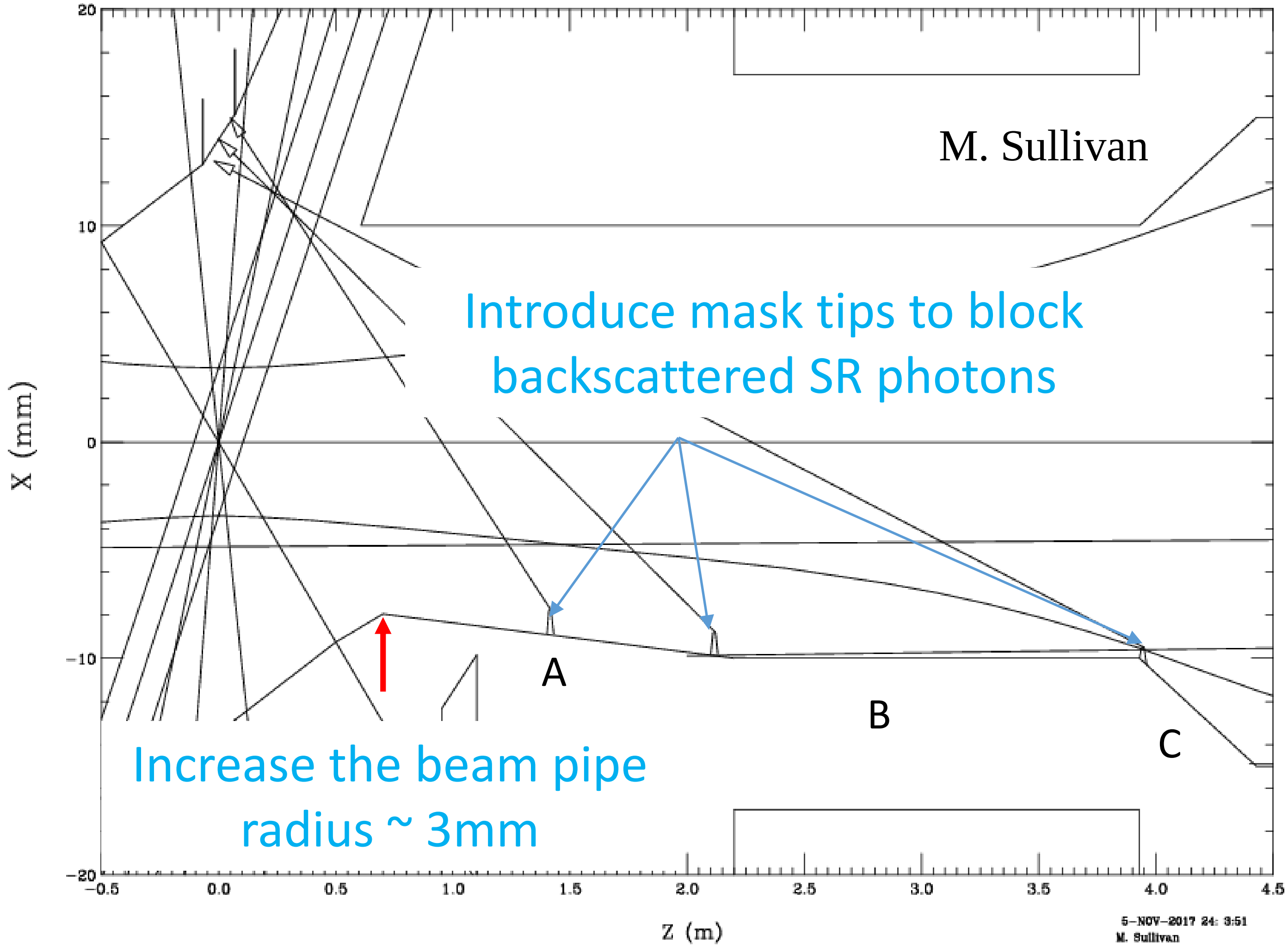
- Direct  and back-scattered SR photons should be avoided as much as possible.



# SR Photon Suppression



*Updated numbers since workshop, to be cross-checked with BDSim*

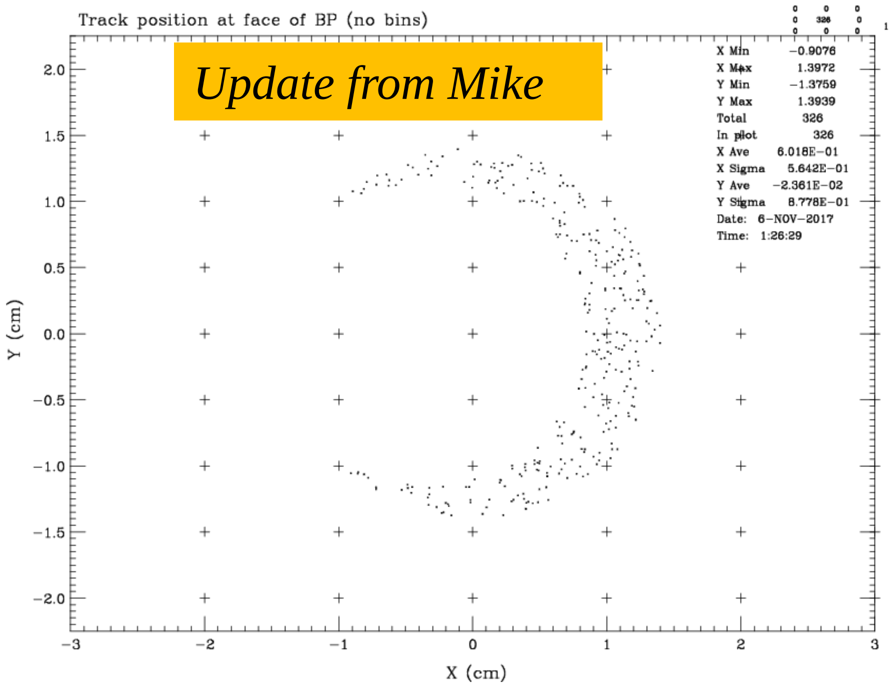
# Effectiveness of Mask Tips

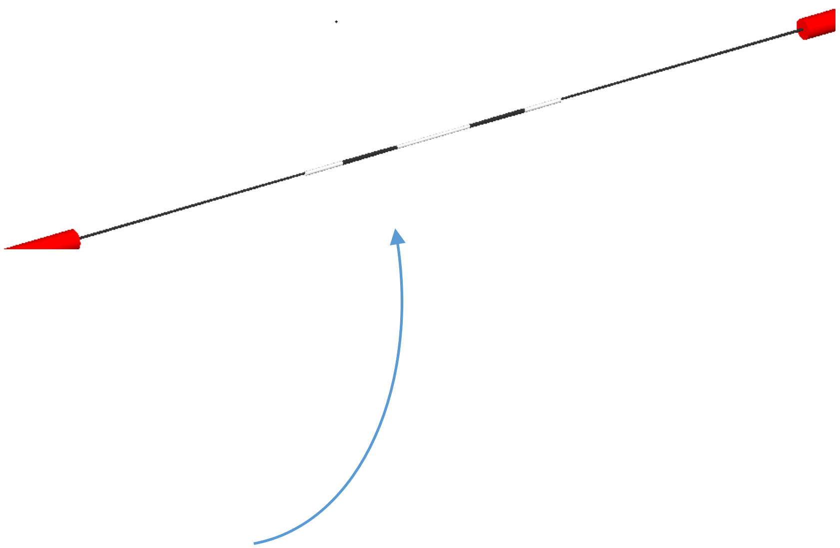
| Surface | Where (m) | Watts | Incident Photons | Scattered fraction | CP SA fraction | Est. hits on CP |
|---|---|---|---|---|---|---|
| A | 0.7-2.2 | 37.25 | 1.27e10 | .03 | 4.7e-5 | 1.8e4 |
| B | 2.2-3.93 | 2.07 | 7.06e8 | .03 | 1.04e-5 | 220 |
| C | 3.93-4.43 | 41.03 | 1.40e10 | .03 | 0.0 | 0.0 |
| D | 4.43-5.91 | 2.55 | 8.71e8 | .03 | 3.7e-6 | 97 |

| Surface | Where | Watts | Incident photons | Scattered fraction | CP SA fraction | Est. hits on CP |
|---|---|---|---|---|---|---|
| A | 0.7-2.2 | | | | | |
| B | 2.2-3.93 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| C | 3.93-4.43 | 41.03 | 1.40e10 | .03 | 0.0 | 0.0 |
| D | 4.43-5.91 | 2.55 | 8.71e8 | .03 | 3.7e-6 | ~97 |
| Mask 2.1 | 1.5 mm | 11.16 | 3.81e9 | | 0.0 | 0.0 |
| Tip at 1.4 | 500 um | 4.56 | 1.56e9 | | | 56 |
| Tip at 2.1 | 500 um | 4.56 | 1.56e9 | | | 25 |
| Tip at 3.93 | 500 um | 4.27 | 1.46e9 | | | ~6.5 |

# Validation with BDSim

*K. Li*



- *Detailed beam pipe structure being implemented*
- *Mask tips to be implemented and their effectiveness to be verified*
- *Backgrounds in detectors to be estimated*

# Summary

- Have studied detector backgrounds due to beamstrahlung (pair production), radiative Bhabha scattering and synchrotron radiation (partly) …

- Need to complete calculation of detector backgrounds from "the other sources"

- To propose preliminary designs of collimators, masks and detector shielding … *repeat all the calculation*