Detector Backgrounds

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On behalf of the CEPC MDI Background Study Group

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Outline

- Introduction
  - What is background? What is the motivation of background study?
  - Which particle would lost? Why?
- Simulation
  - Generator/Tracking
  - Detector Simulation
- Shielding
  - Collimator/Mask
  - Hotspot Shielding
- Summary & Outlook

Introduction

- Detector beam background is the non-signal particles which may get lost in the interaction region, especially in the detector.
  - ”Get lost” means these particles could hit the beam pipe.
- They would be the main reason of radiation damage on components within the interaction region, including detectors and accelerator components.
- If they were detected by the detectors, they may cause “noise”.
- They may also deposit energy, and cause heat load.
- Must be taken into account in the design phase.

Source Analysis

- Effects
  - Single Beam
    - Quantum Effect
    - Touschek Scattering
    - Beam Gas Scattering(Coulomb/Bremsstrahlung)
    - Beam Thermal Photon Scattering
    - Synchrotron Radiation
  - Luminosity Related
    - Beamstrahlung
    - Radiative Bhabha Scattering
  - Injection

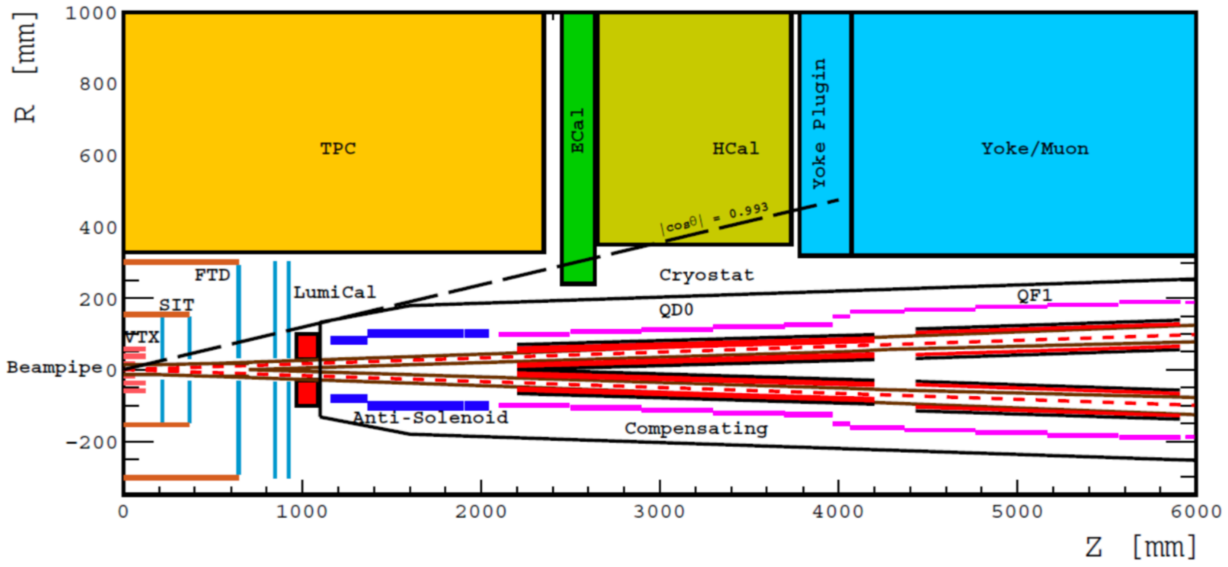
Photons

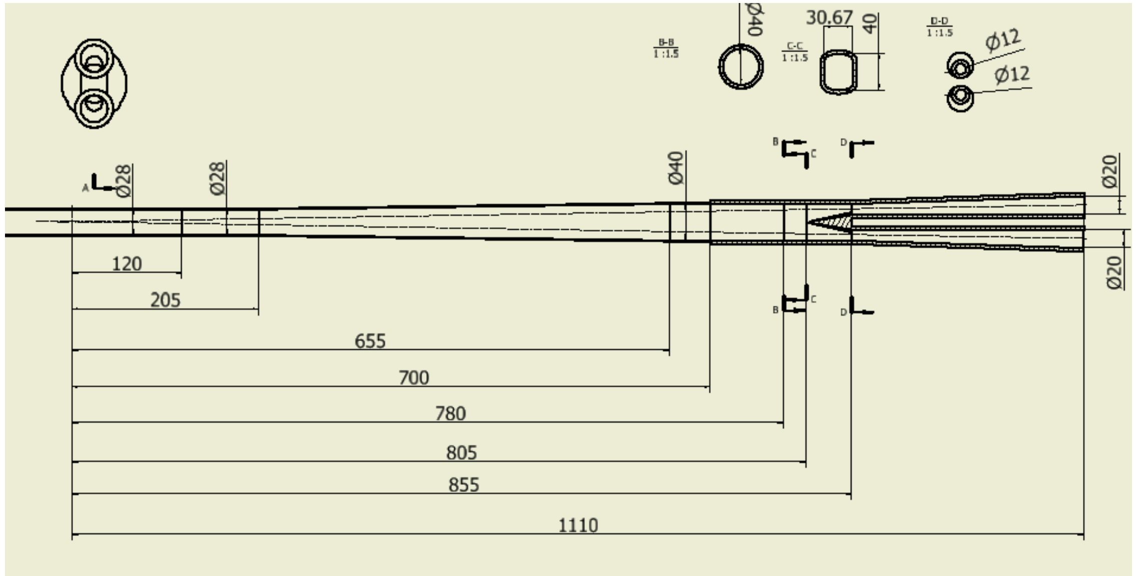
Off Energy
Beam
Particles

Simulation

- Simulation Baseline: CDR + Newly designed central beampipe

H. Wang

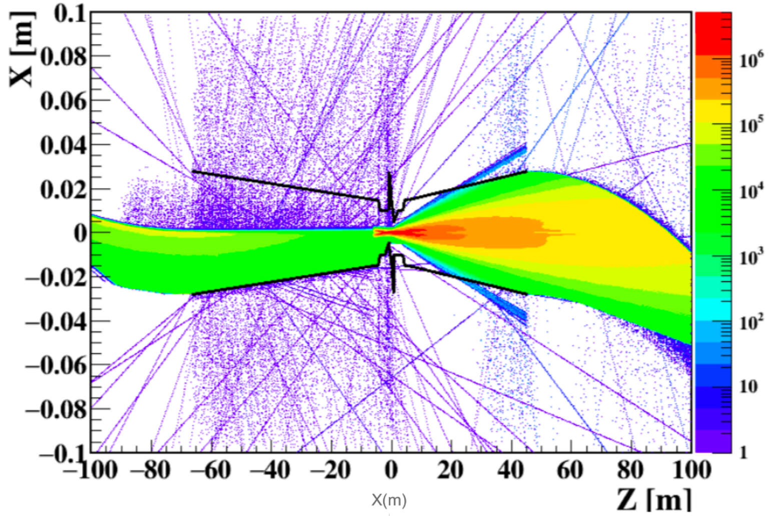




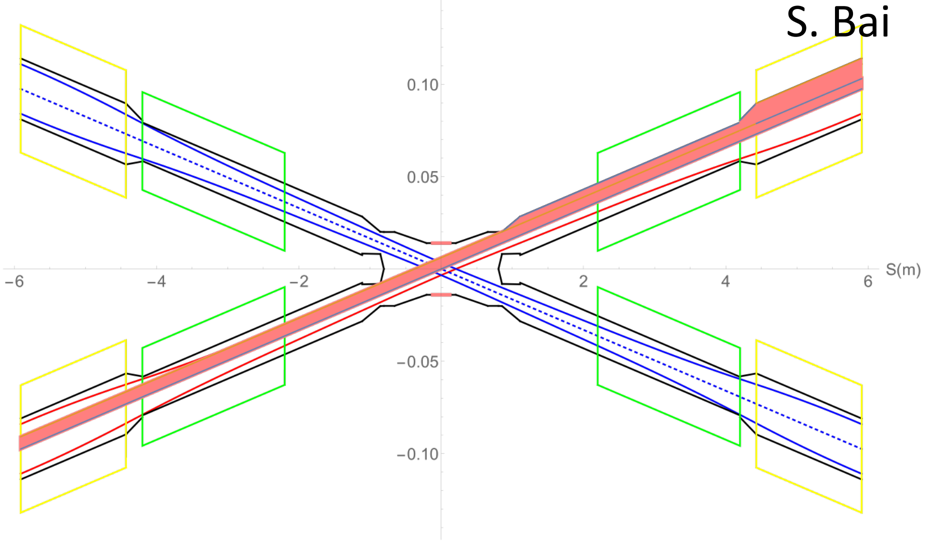
Synchrotron Radiation

- Synchrotron radiation were emitted by magnets when bending beams, sometimes would be critical at circular machines
- Using BDsim&Geant4 as the tool to transport beam particles from the last dipole to the interaction region and record the photons hitting the central beryllium pipe
- The newly designed central beam pipe will let SR pass -855mm~855mm even with the error of (5mm+2mrad)
- Some SR photons may hit the beampipe, and scattered into central beam pipe.
  - Masks might be needed.

K. Li



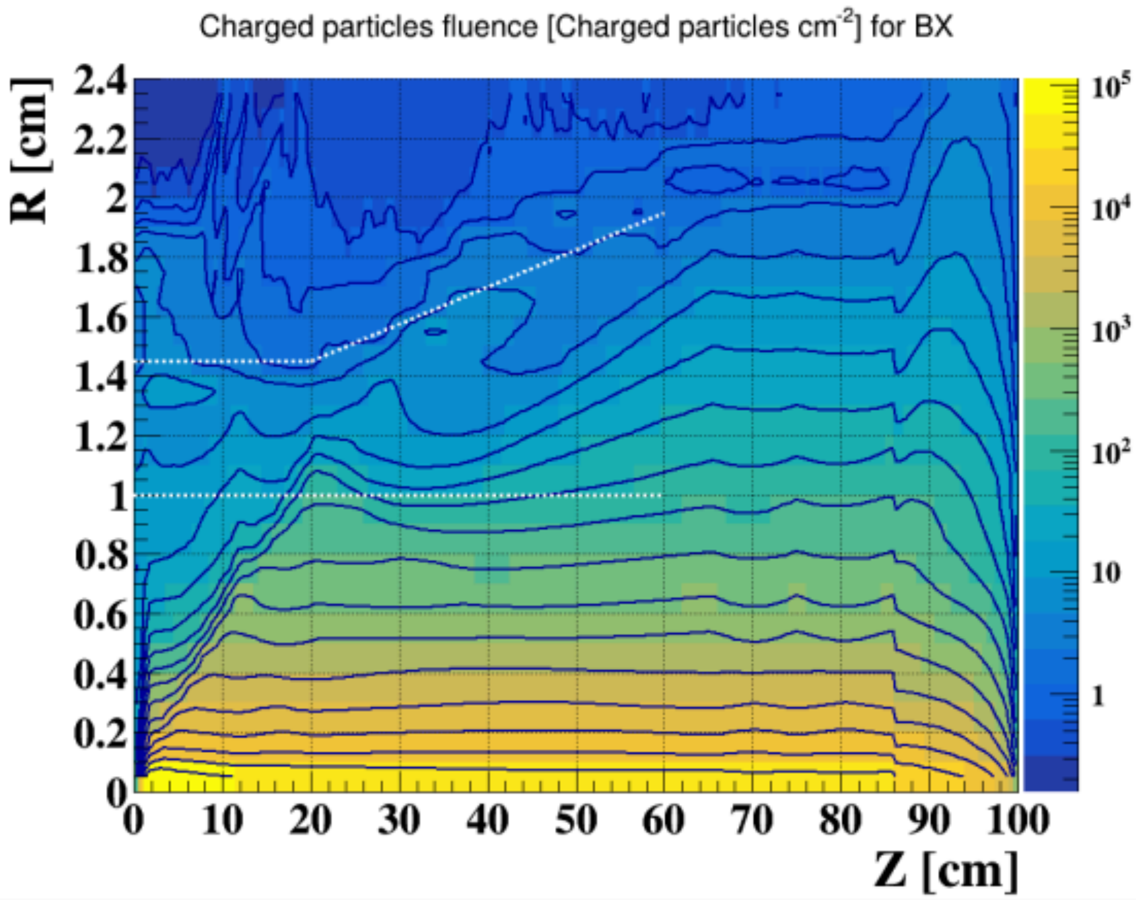
S. Bai



Pair Production

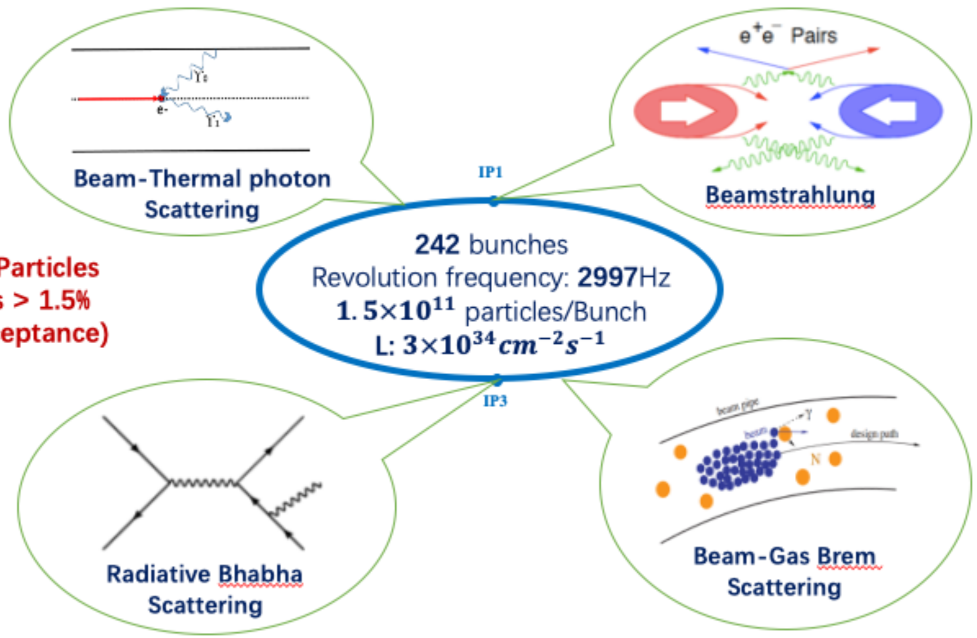
- Charged Particles attract by the opposite beam emit photons(beamstrahlung), followed by an electron-positron pair production.
- Using Gienea-pig++ as the generator and implementing the external magnetic field by code updating.

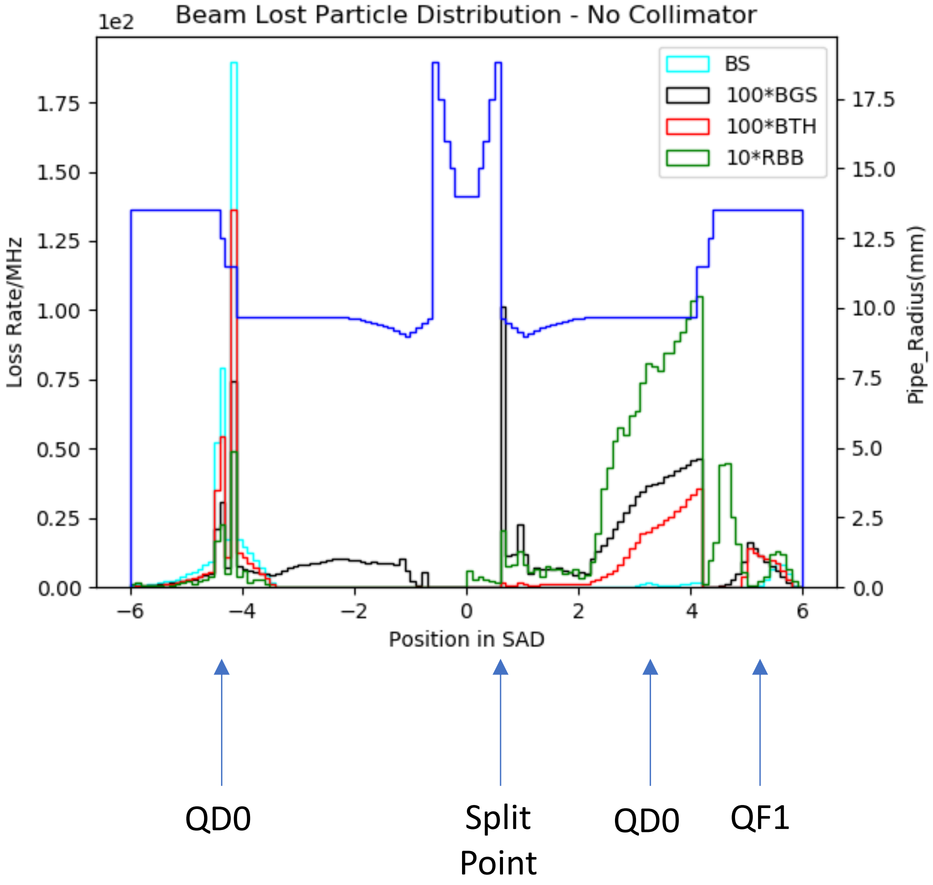
W. Xu



Off Energy Beam Particles

Beam Lost Particles
Energy Loss > 1.5%
(energy acceptance)

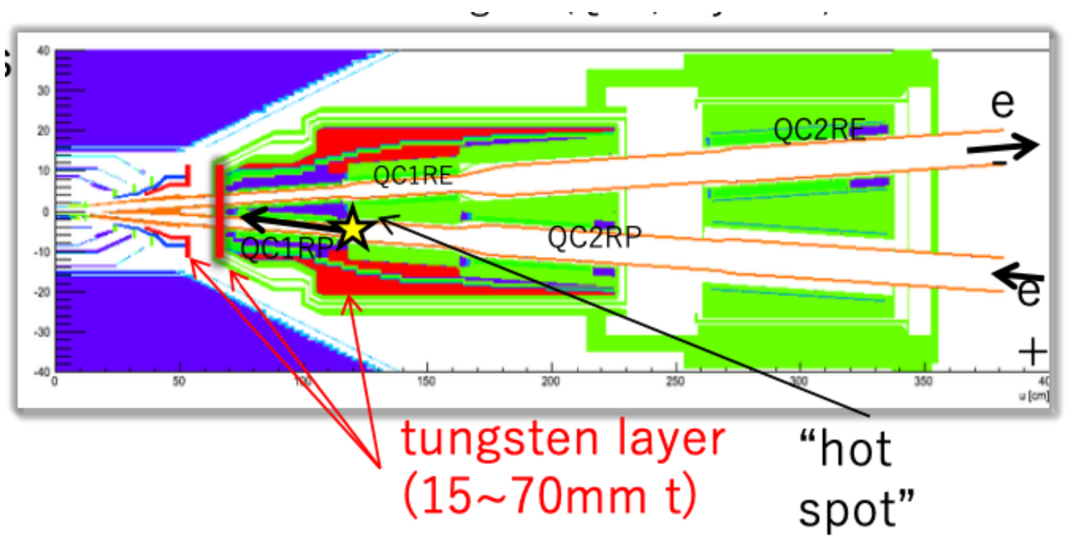




Ways to Mitigate

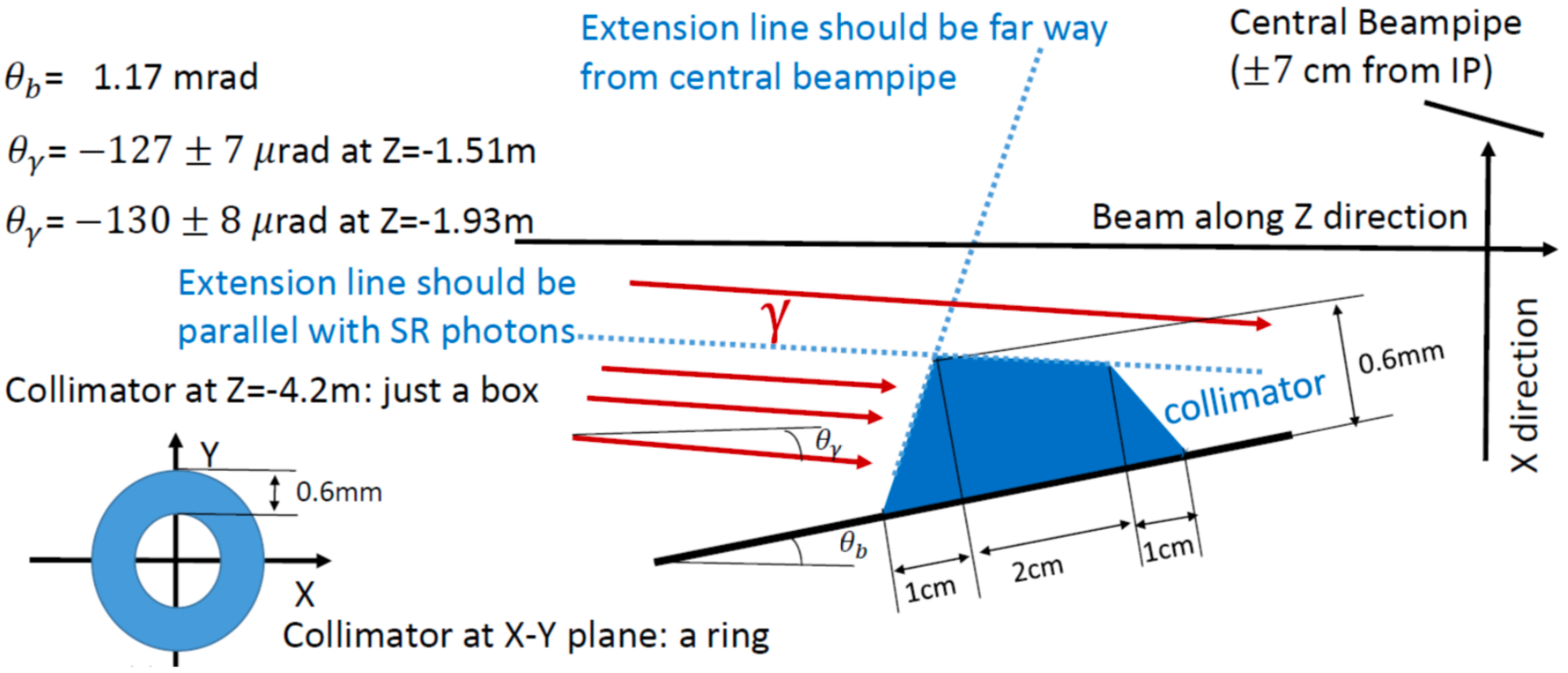
- Add some masks to shield SR
- Add some collimators to cut off off energy beam particles early
- Add some extra-shielding in hotspots

Hotspot in SuperKEKB
H. Nakayama



SR Mask

K. Li



θ_b= 1.17 mrad

θ_γ= -127 ± 7 μrad at Z=-1.51m

θ_γ= -130 ± 8 μrad at Z=-1.93m

- In previous design, we use masks to shield SR from hitting central beampipe. Would we still need it in new design?
- If so, the structure, construction and cooling must be well designed.

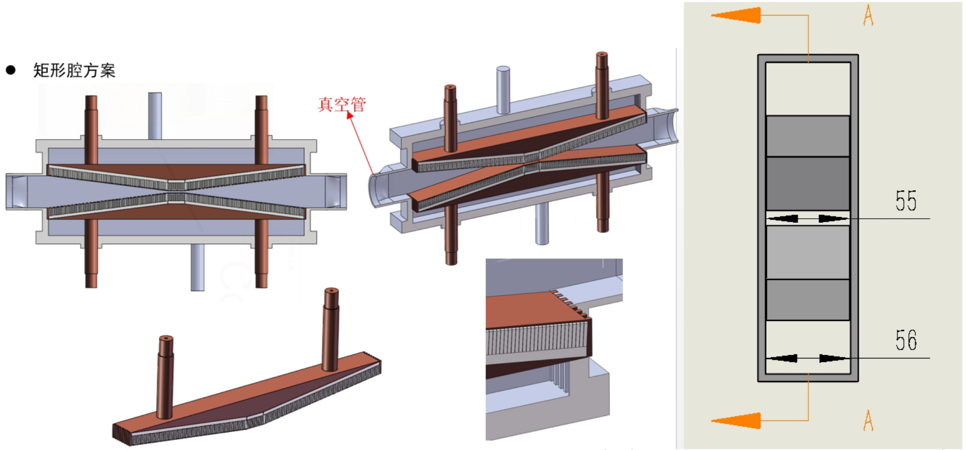
Detector hit numbers down from $7.73*10^4$ to 111 per bunch.
TID down from ~5800 kRad/yr to 15.65 kRad/yr

Collimator

- We only take primary into consideration.

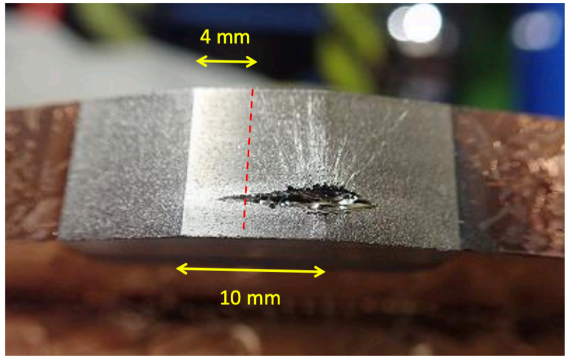
S. Bai

Name	Location	Distance to IP
APTX1	D1I.1897	2139.06
APTX2	D1I.1894	2207.63
APTX3	D1O.10	1832.52
APTX4	D1O.14	1901.09



H. Wang

- The damage of collimator itself

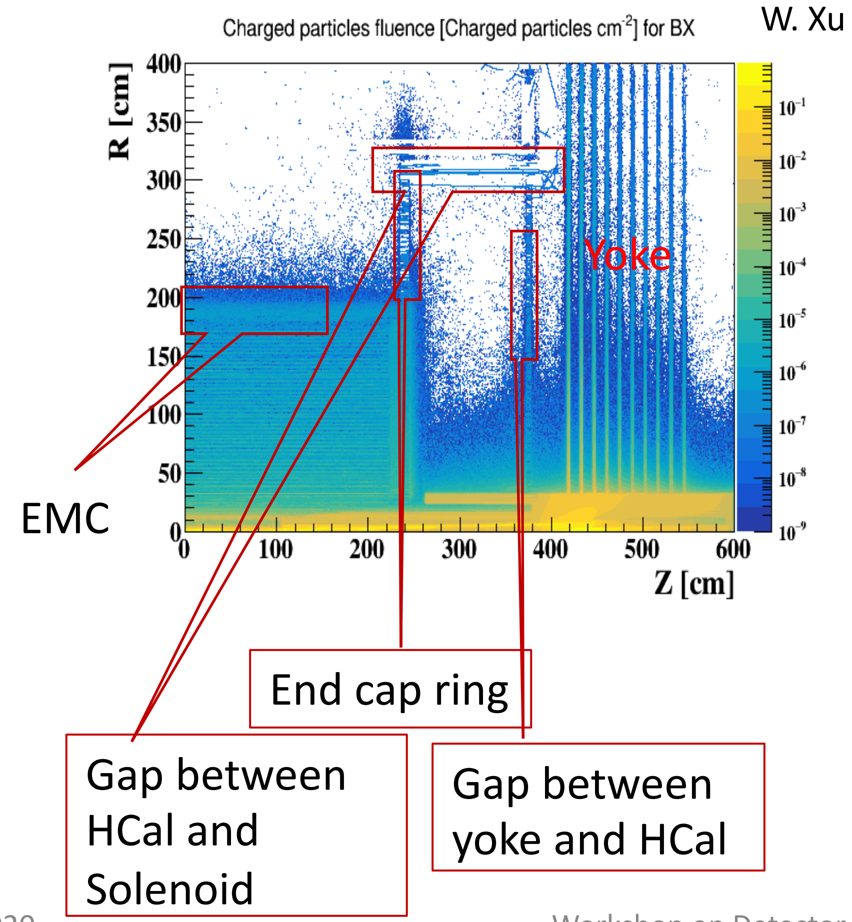


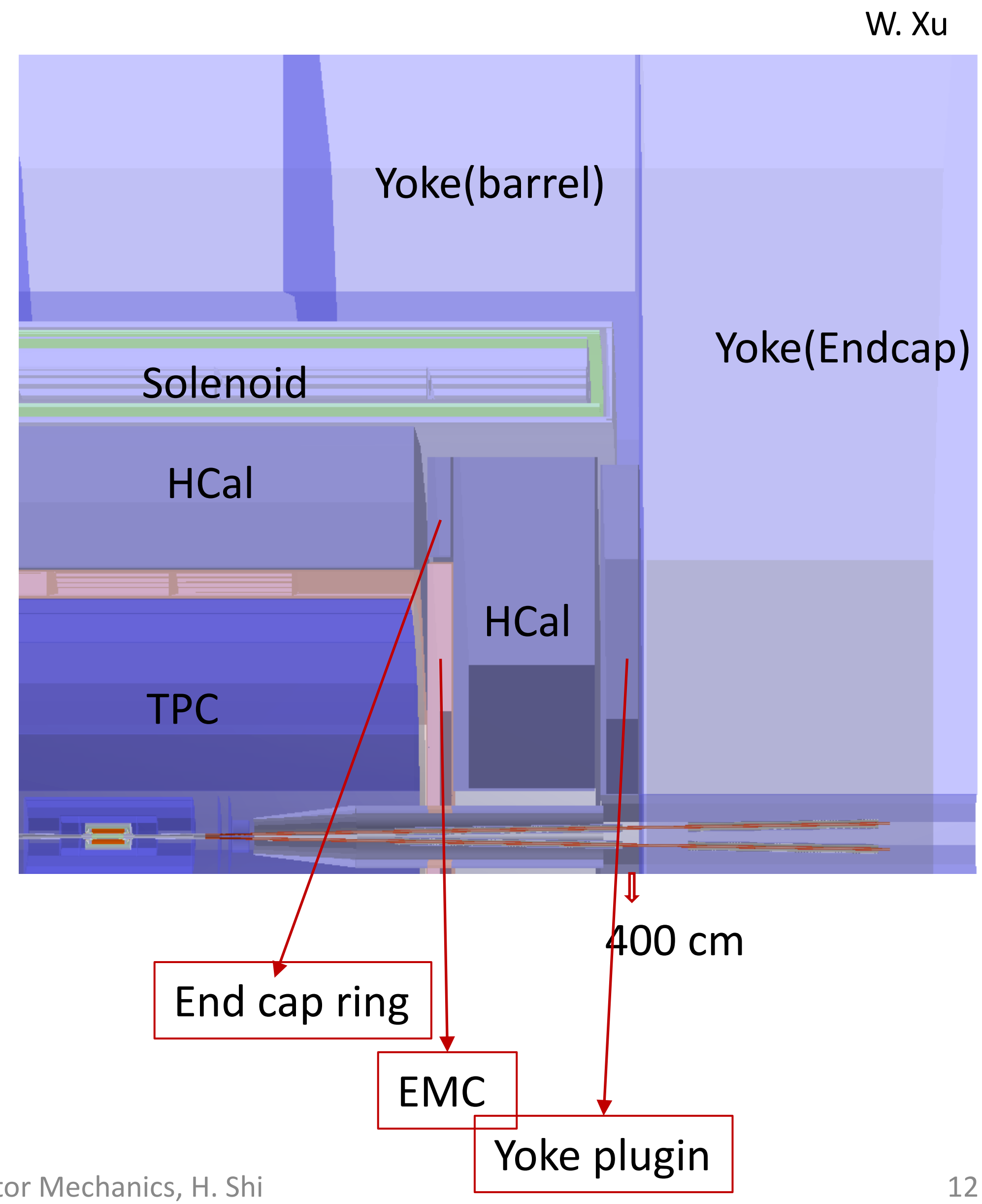
H.Nakayama

- Secondaries in near IR region.

Simulation Results

- Charged Particle fluence of BGB

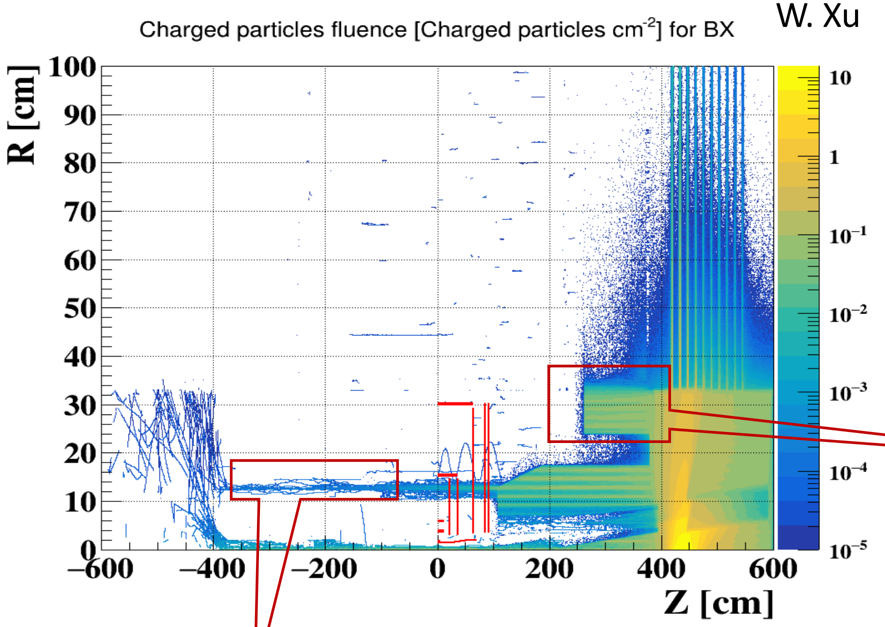




Simulation Results

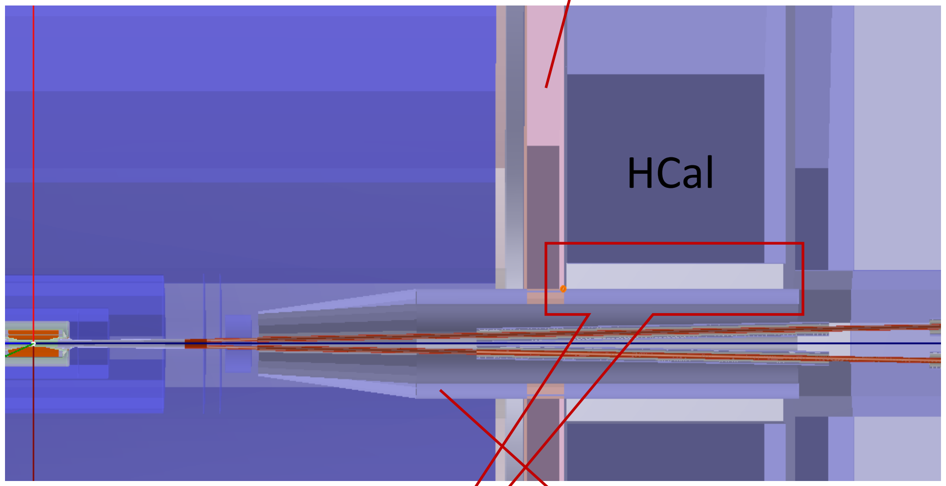
- Charged Particle fluence of BGB
  - Primary particles with $z \in [4,5]$m

W. Xu



W. Xu

ECal



gap

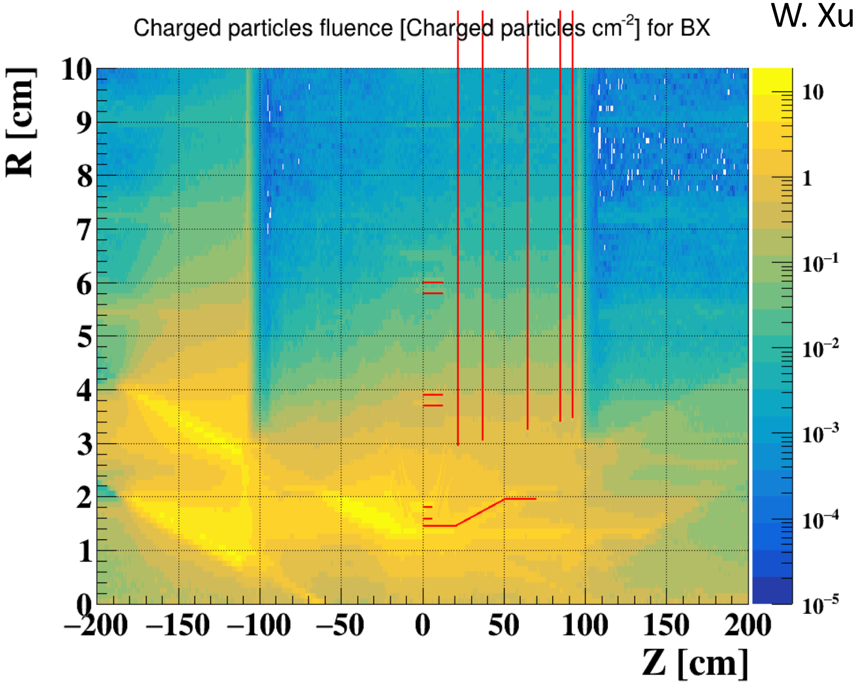
Shielding & Cryostat

Backscattering particles

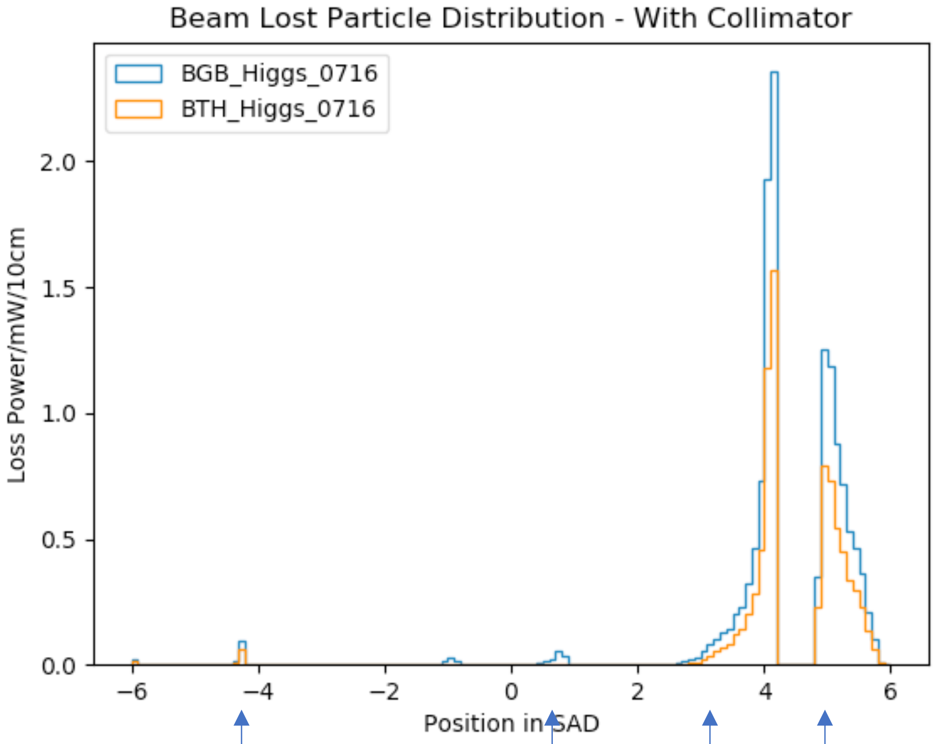
More shielding

- Shielding of the sensitive components and hotspots
  - Magnet/Coil, detector…

W. Xu



BGB, [-2,-1]m



QD0

Split Point

QD0

QF1

More shielding

- Shielding of the sensitive components and hotspots
  - Magnet/Coil, detector…
- Improve key parameters, like vacuum

Beam Gas	0.9607	1235.9	3.37×10^{12}

$10^{-7}Pa$ -> 10^{-8} Pa, or even better?

Experiments - Benchmark

- Important to validate the modellings and Monte Carlo Simulation codes for the CEPC beam background simulation with real data where they are applicable
  - BEPC II/BES III, SuperKEKB/Belle II, LEP I/II…
- Basic Principles
  - Single beam mode: three dominant contributions from Touschek, beam-gas and electronics noise & cosmic rays.
  - $O_{single} = O_{tous} + O_{gas} + O_{noise+\mu} =$
$$S_t \cdot D(\sigma_{x'}) \cdot \frac{I_t \cdot I_b}{\sigma_x \sigma_y \sigma_z} + S_g \cdot I_t \cdot P(I_t) + S_e$$
  - Double beam mode: additional contributions from luminosity related backgrounds, mainly radiative Bhabha scattering
  - $O_{total} = O_{e^+} + O_{e^-} + O_{\mathcal{L}}$

Experiments - Benchmark

$$O = S_t \cdot D(\sigma_{x'}) \cdot \frac{I_t \cdot I_b}{\sigma_x \sigma_y \sigma_z} + S_g \cdot I_t \cdot P(I_t) + S_e$$

- No Beam, Measure noise: S_e
- Single Beam Mode(e-):
  - Touschek backgrounds: with fixed beam energy and beam total current(I_t), varying bunch number(changing I_b), bunch size(σ_y) -> S_t
  - Beam-gas backgrounds: with bunch current and bunch size fixed, increasing the bunch number
- Double Beam Mode:
  - Measure background in e+ with fixed parameters(only one point)
  - Colliding e+ and e- beams

Summary & Outlook

- Detector beam background would effect the component located in the interaction region through several ways.
- It must be well studied starting from the design phase.
- We may use some ways to mitigate, including adding some masks and collimators. They are also must be well designed.
- Extra-shielding may be needed. The designing of it should be started.
- We may update the simulation with the new design and new parameters. Z mode and other possibilities should also be taken into consideration.

Thank You

Backup

Synchrotron Radiation

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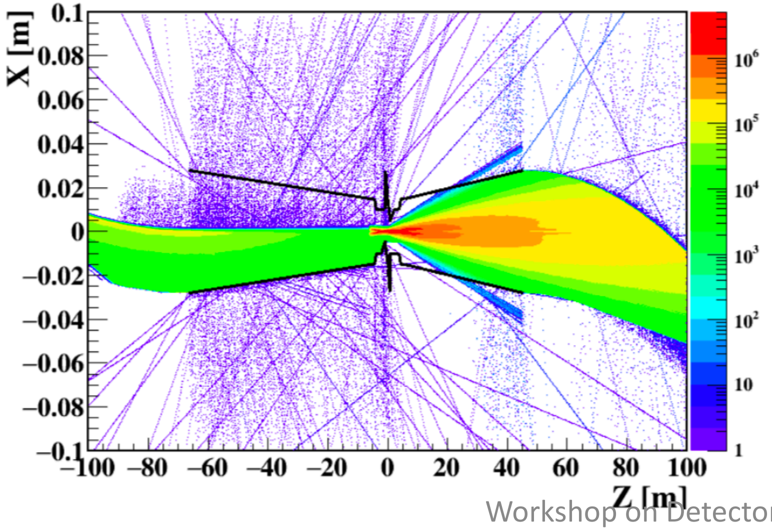
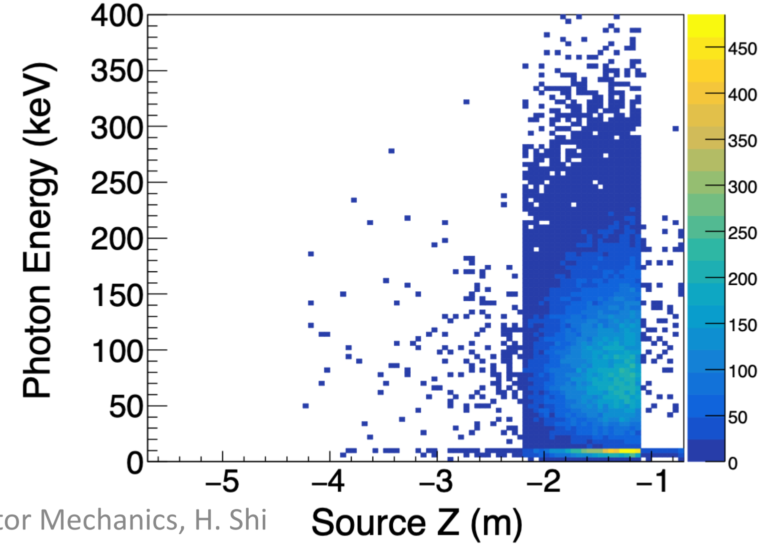
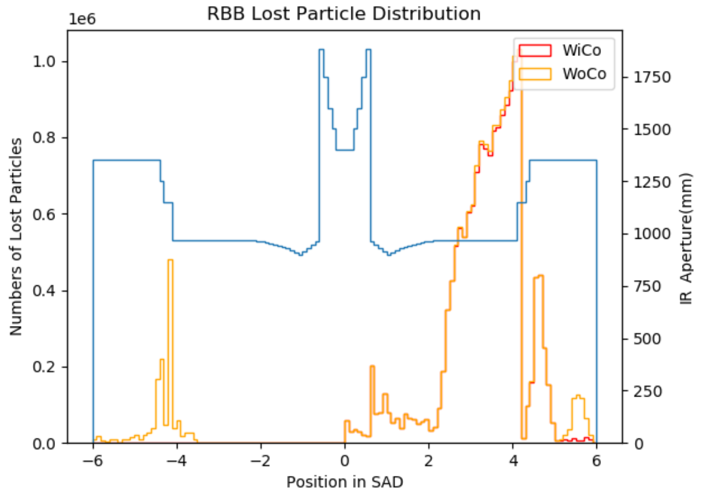
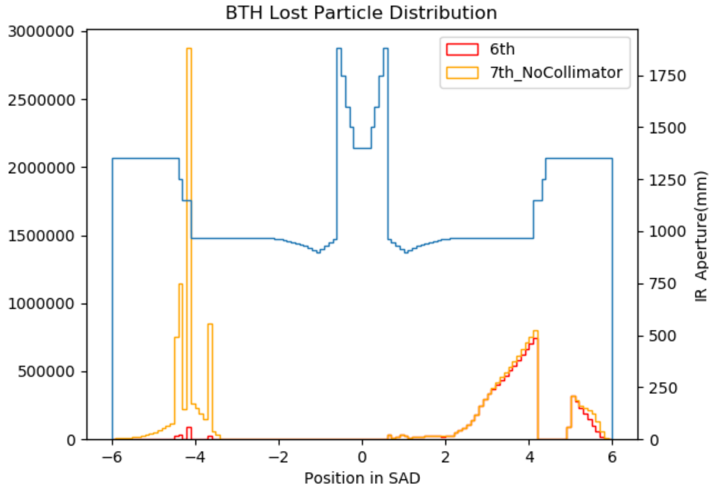
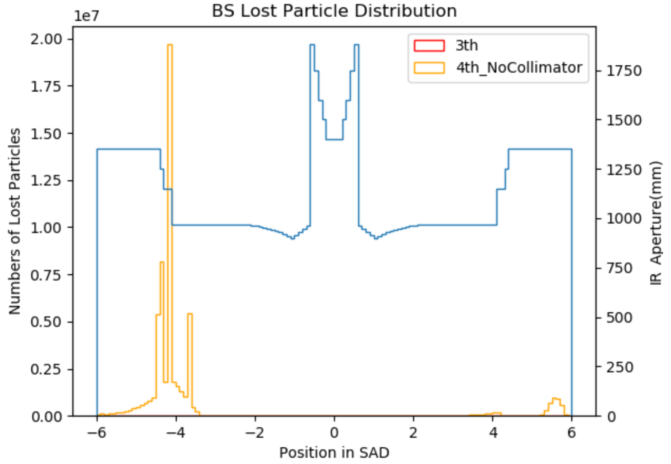


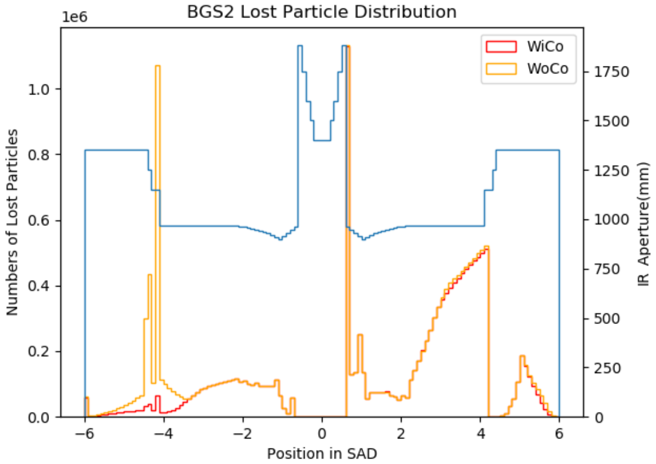


Collimator









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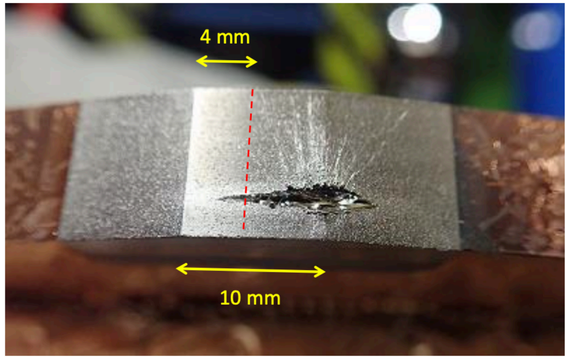

H.Nakayama

- Secondaries in near IR region.

Simulation Results

Initial Results on 1st layer of Vertex. With a safety factor of 10.

Background Type	Hit Density($cm^{-2} \cdot BX^{-1}$)	TID($krad \cdot yr^{-1}$)	1 MeV equivalent neutron fluence ($n_{eq} \cdot cm^{-2} \cdot yr^{-1}$)
Pair production	1.82	491.03	0.92×10^{12}
Radiative Bhabha	0.007	3.376	5.93×10^{9}
Beam Gas	0.9607	1235.9	3.37×10^{12}
Beam Thermal Photon	2.31	2325.49	5.48×10^{12}
Total			9.7303×10^{14}