Update MDI study of TPC Technology @ Tera-Z on CEPC

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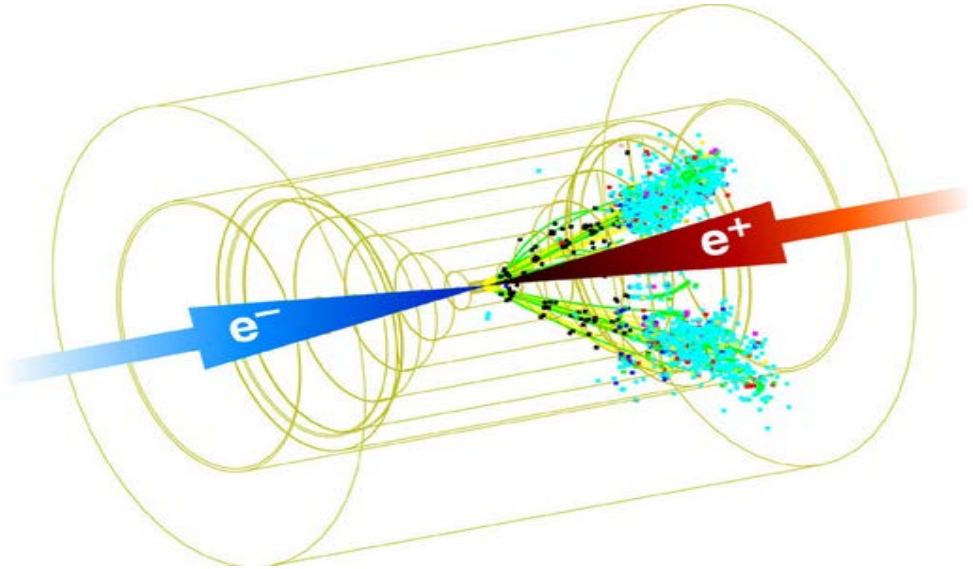
Content

- **MDI of e+e- colliders**
- **MDI study of CEPC**

e^+e^- colliders: Sources of Detector Backgrounds

- Beam-beam interactions (disrupted **primary beam, beamstrahlung photons, e+e- and mu+mu- pairs and hadrons** from beamstrahlung and gg interactions, and extraction line losses) and radiative Bhabhas
  - $e^+e^- \longrightarrow e^+e^-\gamma$ electron-positron scattering

- From the standpoint of integrated background, e+e- circular collider is relatively '**very clean**' machines. Average integrated hadronic fluxes produced at the IP are about several orders of magnitude lower compared to LHC. However, the Tera-Z are not so drastically different.

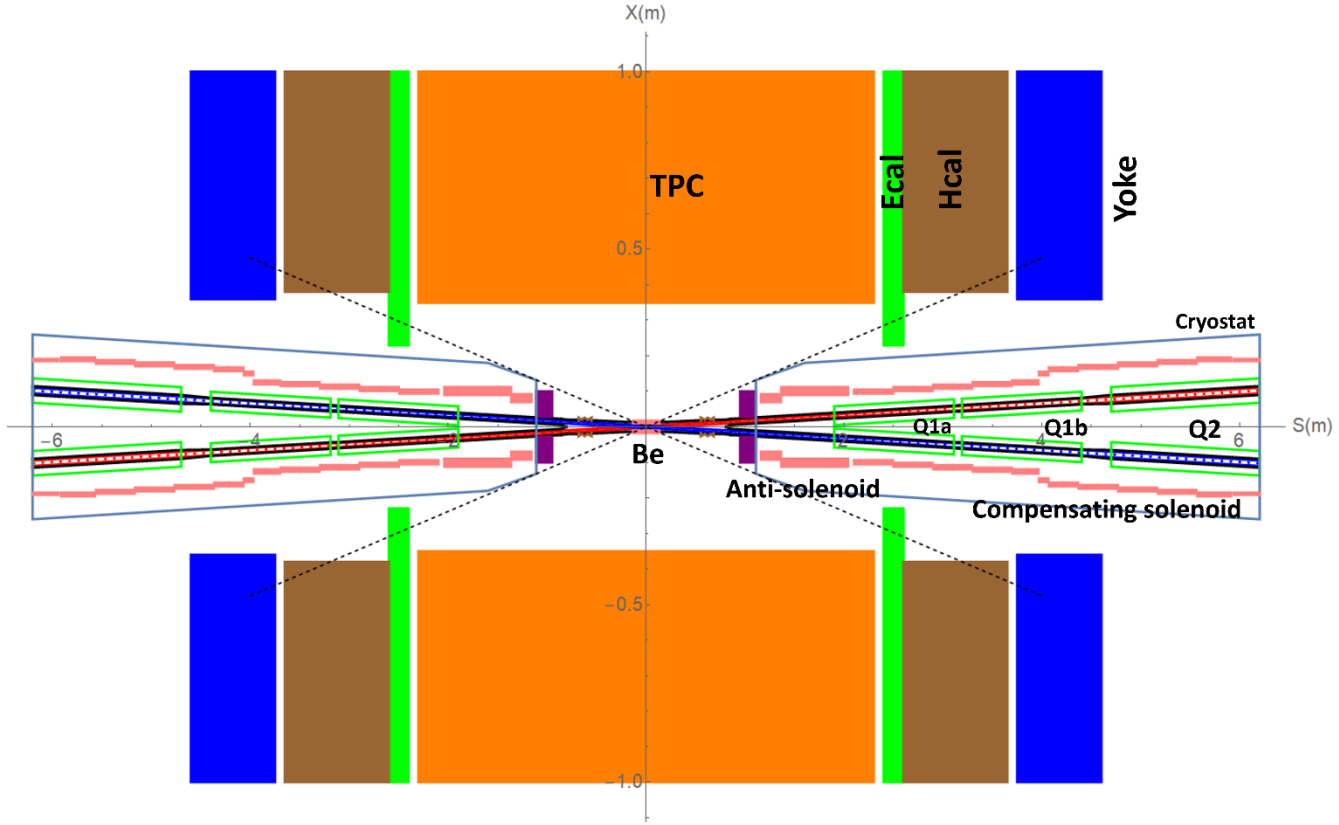


MDI region

e^+e^- colliders: Sources of Detector Backgrounds

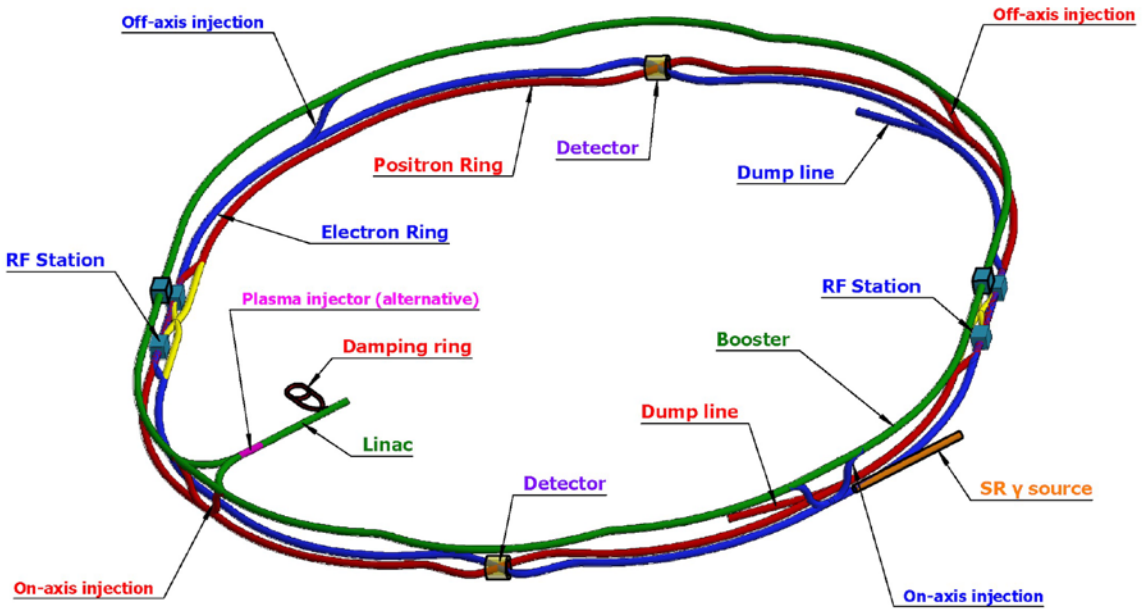
- In general, this source is well understood and under control: it scales with luminosity, one should transport interaction products away from IP and **shield/mask** sensitive detectors, and exploit detector timing
    - Fox example: Make limiting apertures (collimators or shield) as far from IP as possible. Suppress muon flux far from IP by thick magnetic walls.

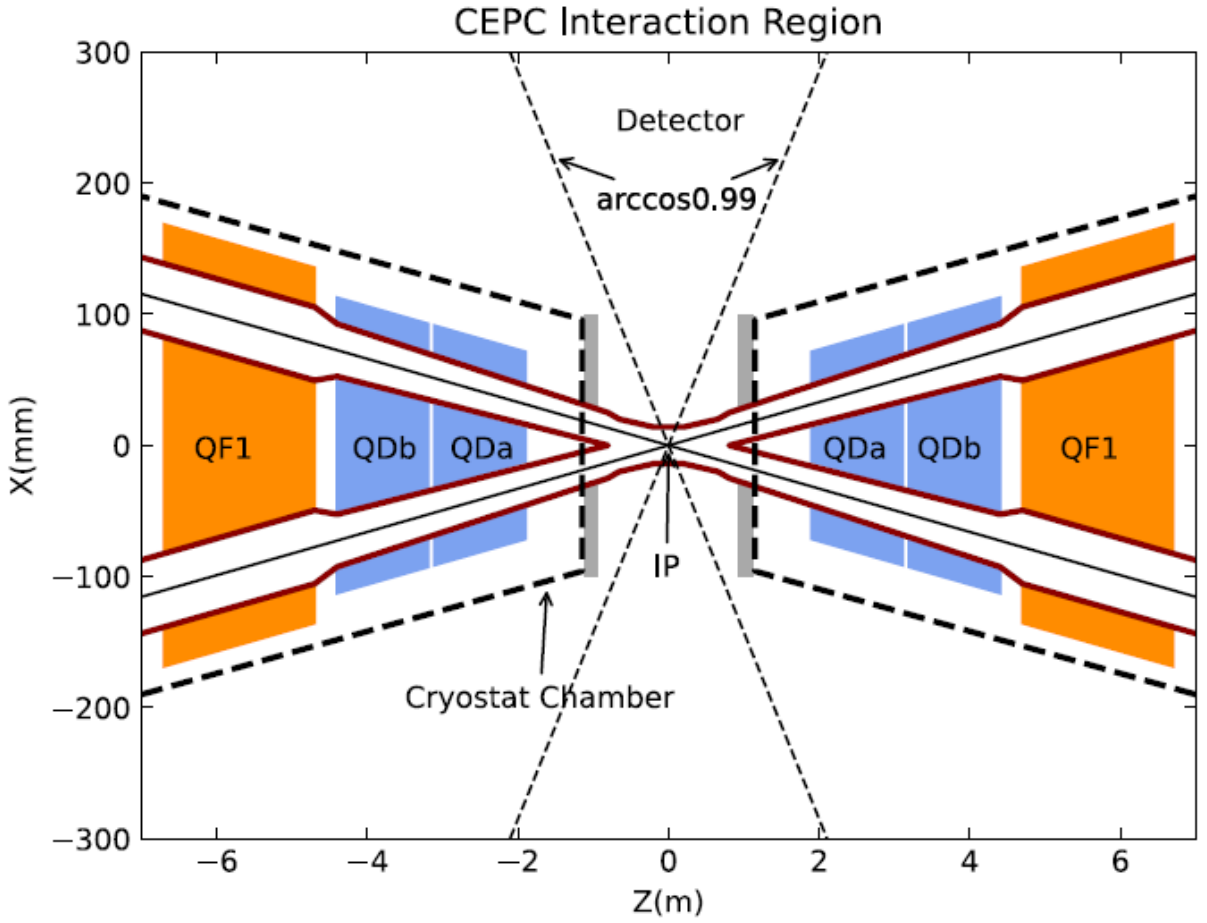
3.0T for Higgs
High luminosity (10^{36})
2.0T for Z
Beam crossing angle of 33mrad



MDI of CEPC (priliminary)

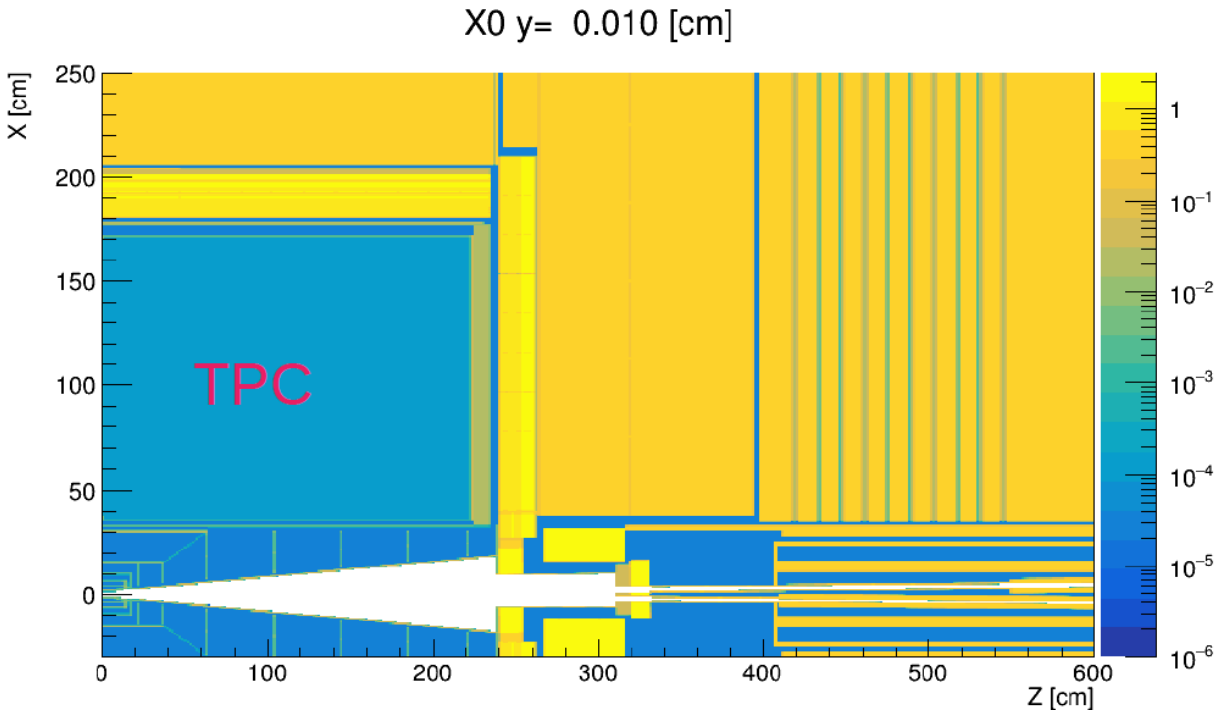
- MDI stands for ”Machine Detector Interface”
  - Interaction Region and other components
  - 2 IPs
  - 33mrad Crossing angle



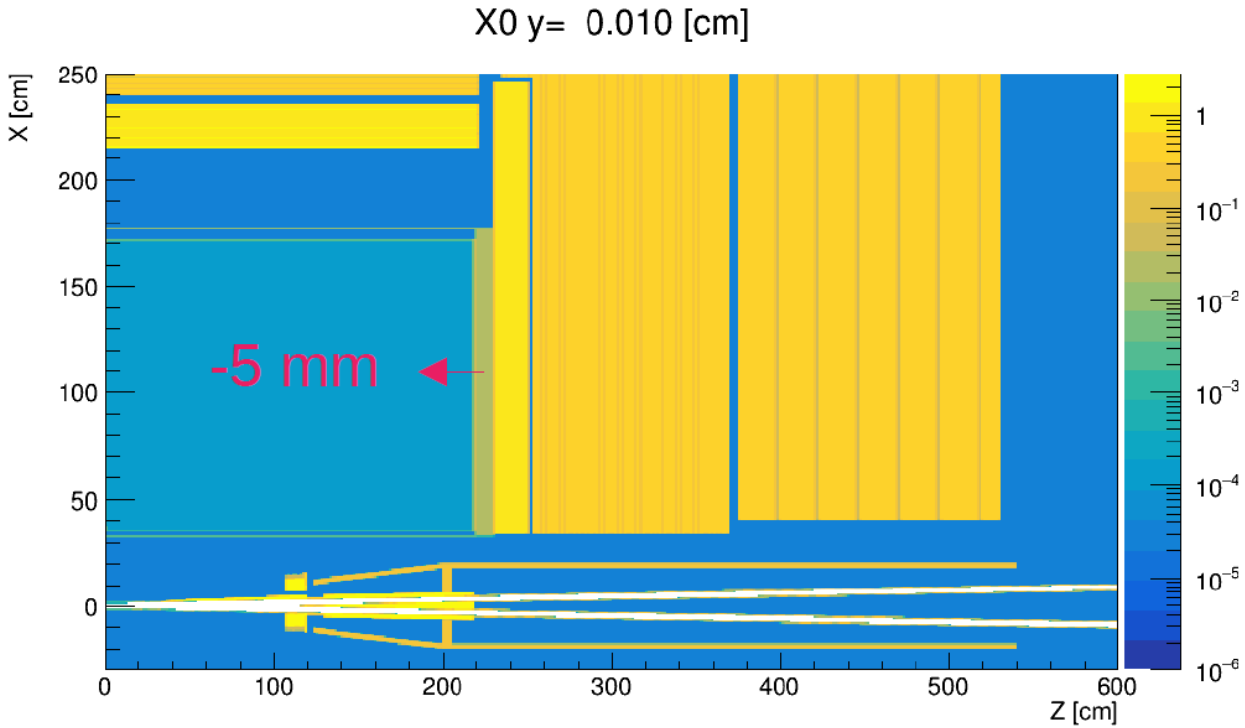


Ions produced by machine-related backgrounds

- Simulated these e+ e- pairs in some detector models
  - TPC only in 2T using ILD size (Daniel Jeans/KEK)
  - TPC only in 2T using FCCee size (Andrea Ciarma/CERN)
  - TPC only in 2T using CEPC size (Haoyu's talk)
- Pass 100 bunch-crossings of bremsstrahlung pairs through G4-based full detector simulation
  - **"uniform" 2T B-field and no anti-DID**



TPC concept only in 2T field using ILD size



TPC concept only in 2T field using FCCee size

What about ions produced by machine-related backgrounds

- Distortions in r-phi due to ions from hadronic Z decays can be up to O(100) μm, but are stable to O(1) μm
- BUT, bremsstrahlung gives **~200X more** TPC primary ions than hadronic Z decays (**preliminary**)
- Anyway, **forward region plays a very important role** room for optimization
  - Some discussion and feedback to Haoyu and Manqi before this meeting

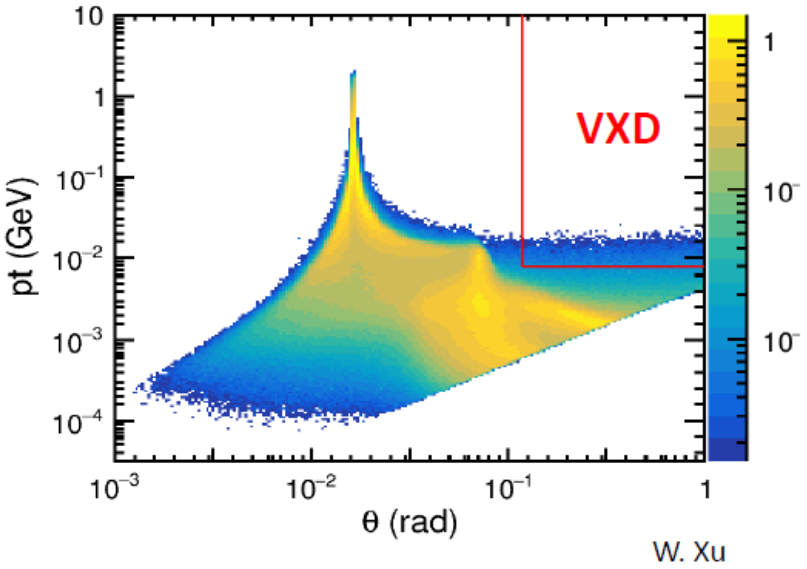
	primary ions / "event"	event rate	primary ions / 0.44 s "TPC frame*"
Z_had ILD_l5_v02 @ 2T	1.27M	54 kHz	30 x10^9
pairs ILD_l5_v02 @ 2T	75 k	33 MHz	1100 x10^9
pairs ILD TPC only @ 2T	15 k	33 MHz	220 x10^9
pairs FCCee w/ TPC	0.43 M	33 MHz	6200 x10^9

* maximum ion drift time in TPC = 0.44s

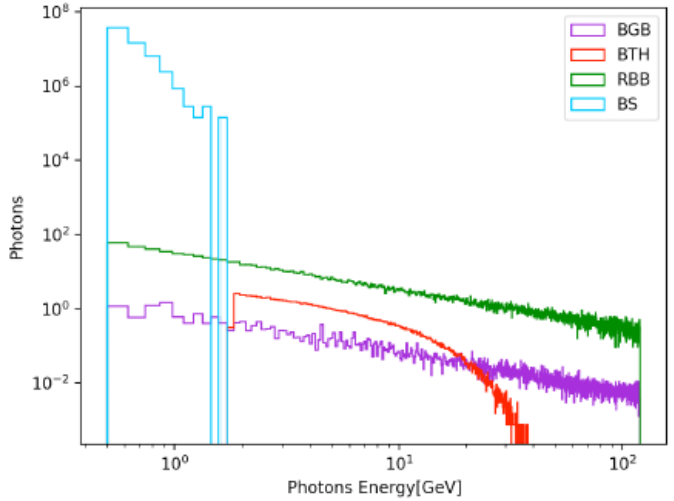
Pair Production/Other Photons from CEPC

- Pair Production(Beamstrahlung) may lead to two different impacts:
  - The impacts on detector, caused by the electrons/positrons produced by photons
  - The impacts on accelerator components outside of the IR, caused by the photons directly.
- The huge deposited power due to the photons(mainly from BS, plus others) might be harmful to the machine, found by FCC.
  - At higgs mode, roughly 93.1 kW@30MW(150kW@50MW)
  - At Z mode, <E>~2.2MeV, ~450kW@30MW(720kW@50MW) in ~11m(22-33m in the first bending magnet).
  - The photons are very hard, contains multi-MeV or even few-GeV photons.

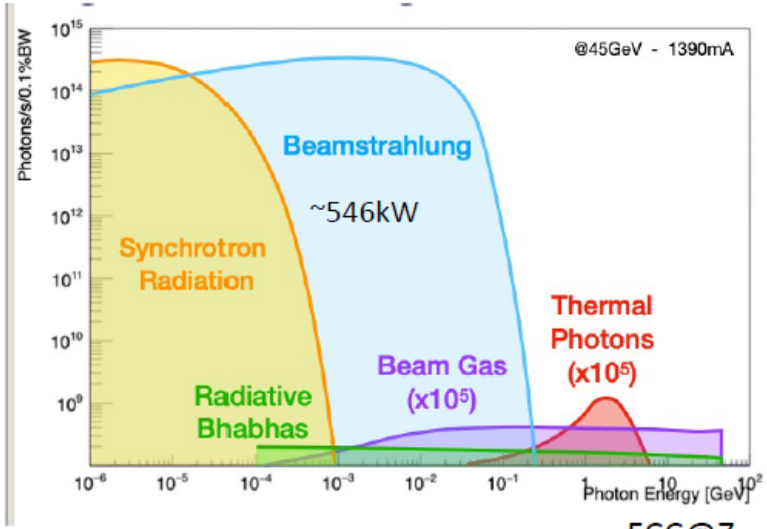
Photon Dump?



W. Xu



CEPC@Higgs



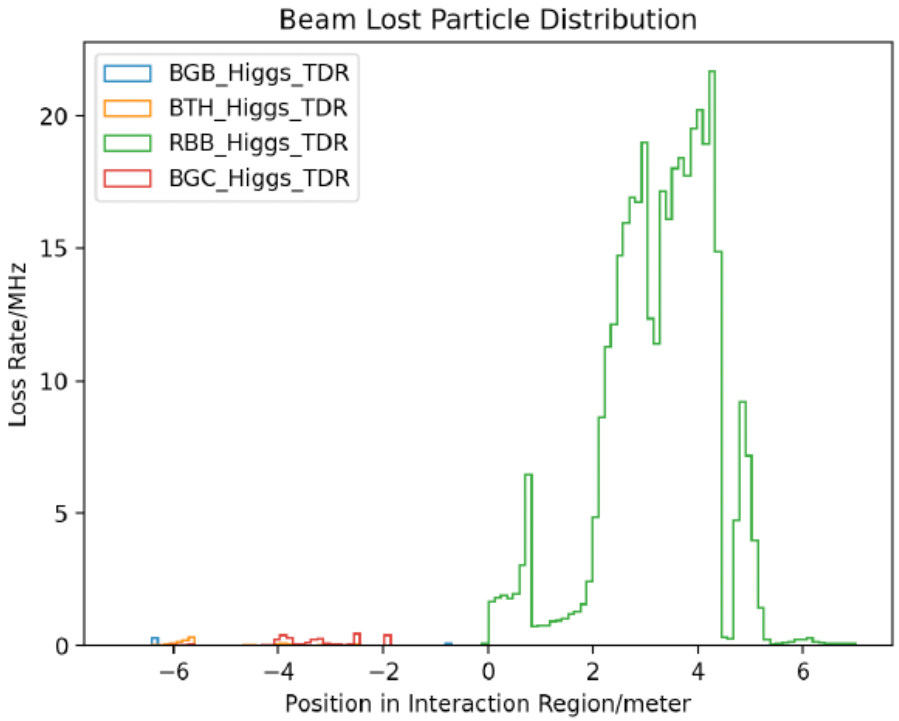
FCC@Z

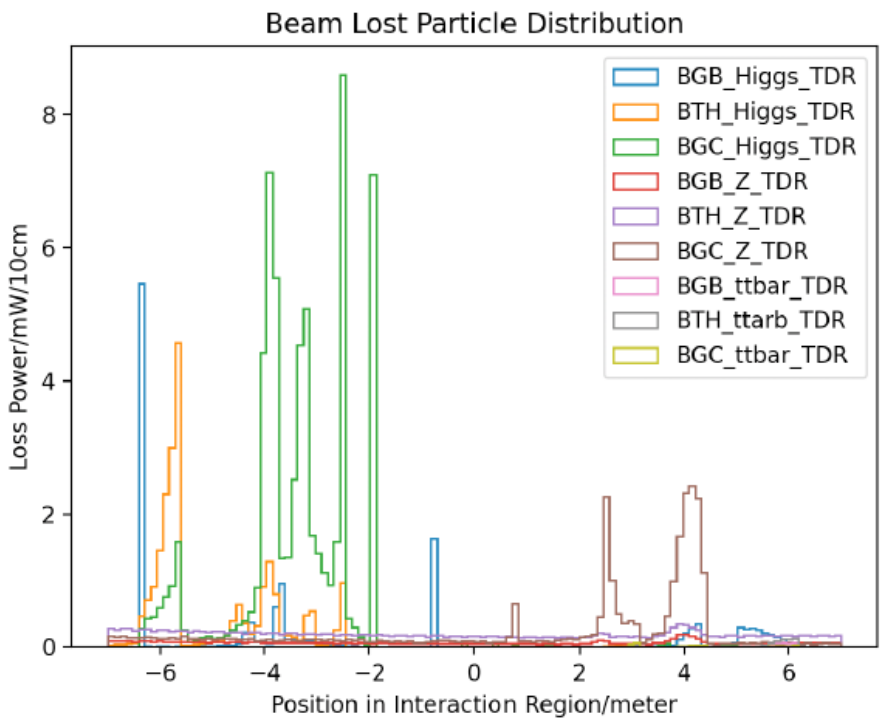
Loss Rate/Loss Power from CEPC

- Errors implemented
  - High order error for magnets
  - Beam-beam effect
- 2 IR considered(sum)
- Loss Rate is in the level of MHz/10cm; Loss Power is in the level of mW/10cm
- Current Collimators could not mitigate BGC effectively. We need more.

$$Loss\ Rate = \frac{Loss\ Number}{Loss\ Time} = \frac{Bunch\ number * Particles\ per\ Bunch * (1 - e^{-1})}{Beam\ Lifetime}$$

@Higgs

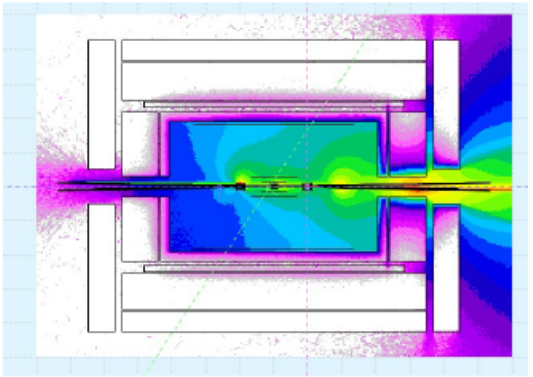




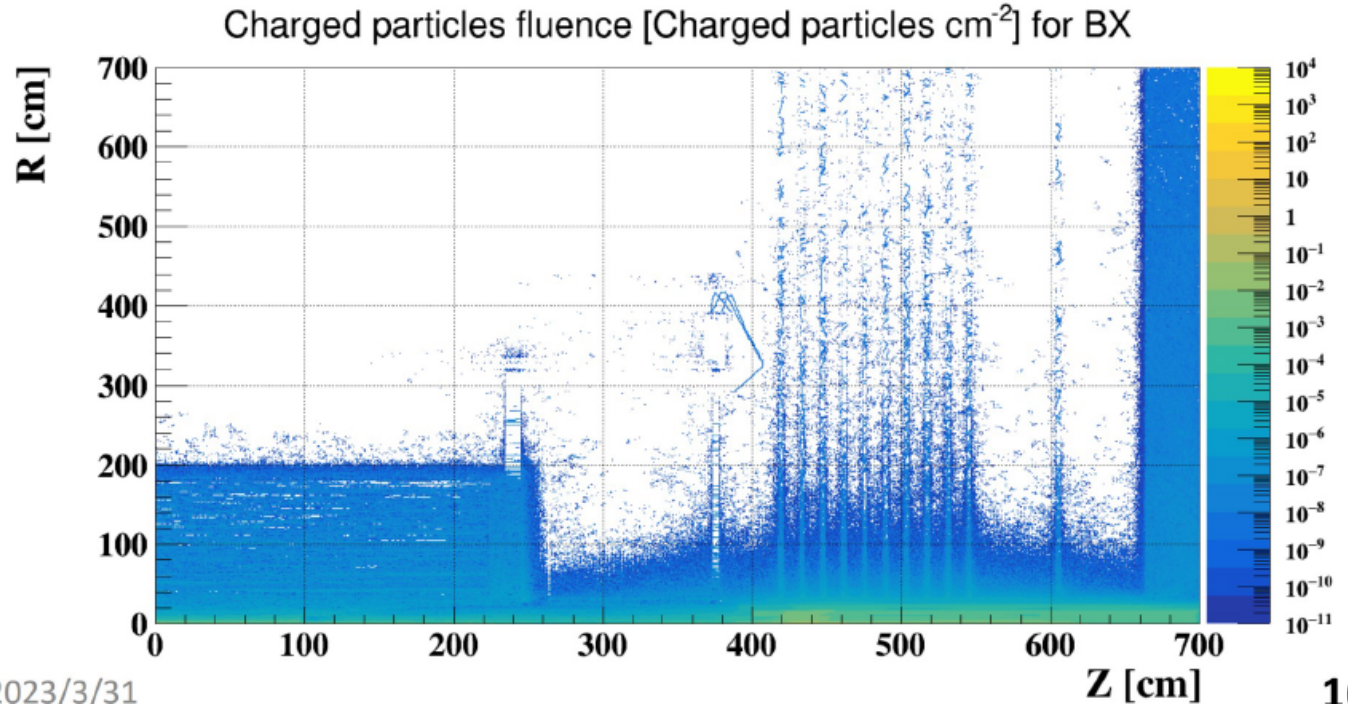
@Higgs
+ttbar
+Z

Detector Simulation from CEPC

- The full detector simulation has been performed.
  - Baseline detector using Mokka/Marlin is updating.
  - 4th detector concept using CEPCSW is performing.
- The impacts on noise caused by beam backgrounds on detector performance need to be noticed.
  - ~50x of physics signal rates @ TPC z-pole



Wei Xu

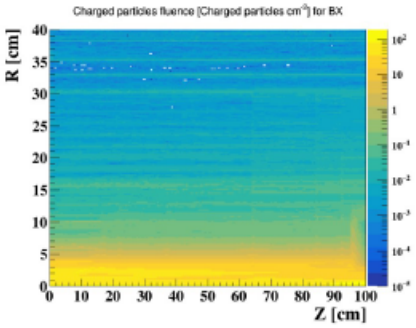


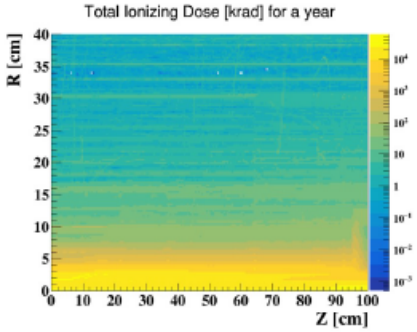
From the Beam-Gas scattering

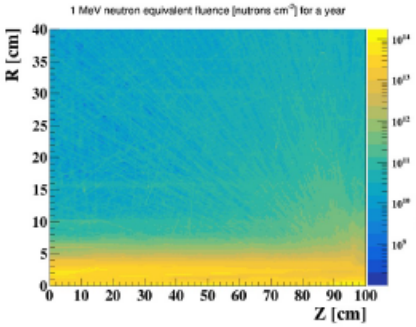
- for the Higgs mode

Fluence is flat along the Z axis

- Secondary scattering particles
- Backscattering







Open question: to be addressed by R&D

- **High Luminosity operation (2 ×10^{36}) @ Z with 2 T B-Field**
- Shield and mask should be optimized in MDI region (only for TPCs)
  - Bremsstrahlung gives **200X or 50X** TPC primary ions than hadronic Z decays ?
  - Use pattern recognition algorithm for identification and rejection ?
  - Background rejection efficiency ?
  - ...

Many thanks!