Status on MDI studies

Haoyu SHI

On behalf of the CEPC MDI Working Group

2021.9.8

Outline

- IARC’ s Questions
- Preliminary Results of Full Detector Simulation
- Remain Issues
- Next Step

Questions by IARC in May 2021

- A full simulation including the detector, to evaluate the impact of beam losses in the IR in terms of backgrounds, should be presented.
- A complete scheme of collimation should be presented, including near-IR ones.
- If the radiation shielding is required to reduce backgrounds in the detector, then the material used for the shielding will be the heaviest element in the cryostat. The deformation of the cryostat, and the resultant misalignment for the quadrupoles should be studied.

Questions by IARC in May 2021

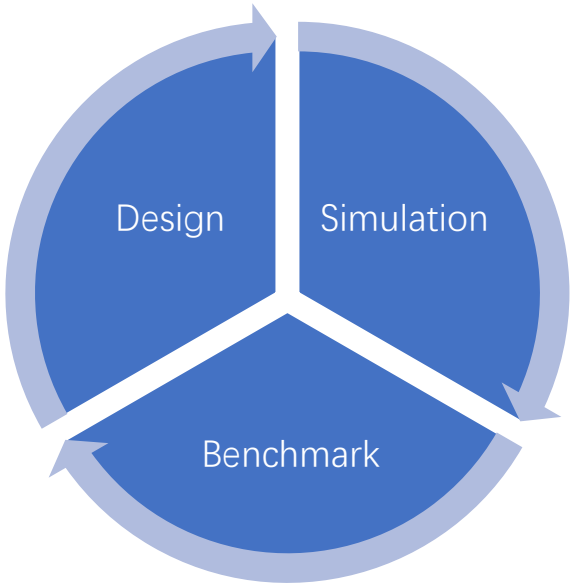
- A full simulation including the detector, to evaluate the impact of beam losses in the IR in terms of backgrounds, should be

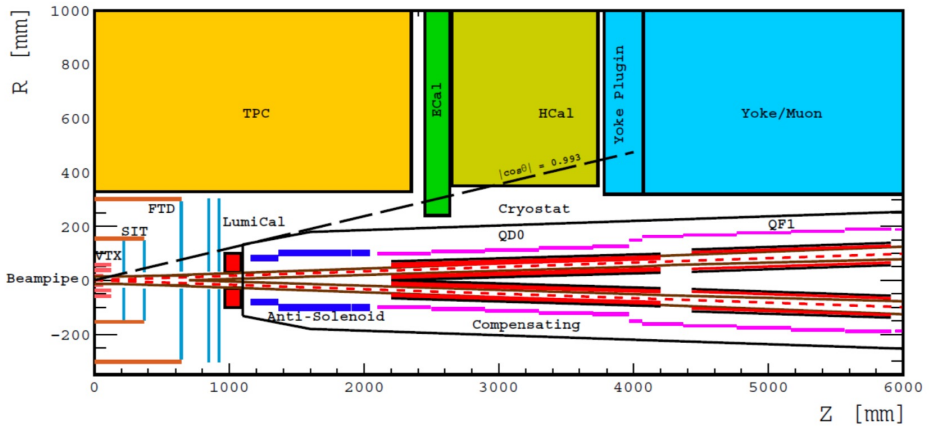
- A Full Detector Simulation Results due to Beam induced Backgrounds

- Optimized Design of Whole Interaction Region based on above results if needed(shielding, cooling, etc.)

and the resultant misalignment for the quadrupoles should be studied.

Radiation Backgrounds

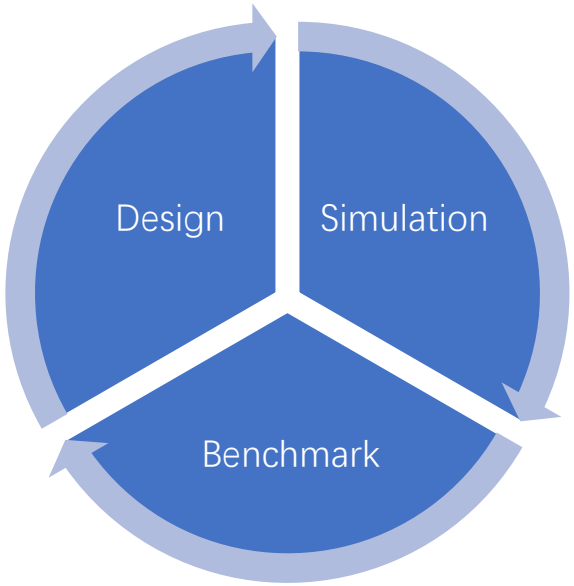


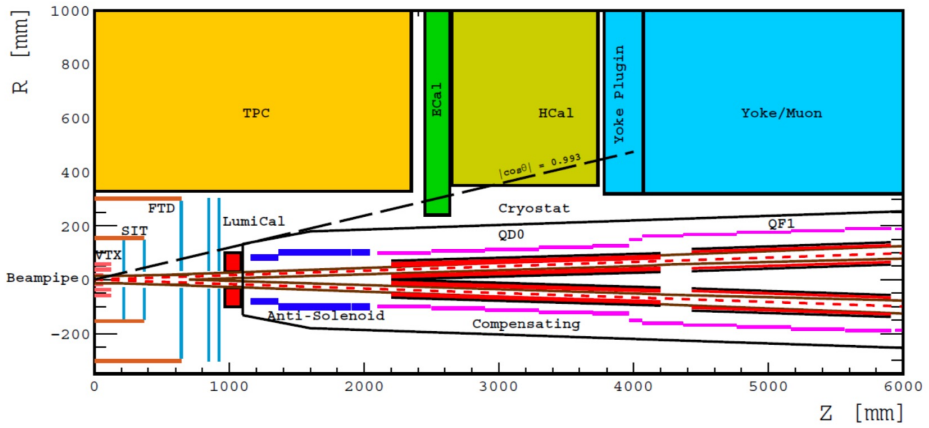


	Higgs	W	Z (3T)	Z (2T)
Number of IPs	2			
Beam energy (GeV)	120	80	45.5	
Circumference (km)	100			
Synchrotron radiation loss/turn (GeV)	1.73	0.34	0.036	
Crossing angle at IP (mrad)	16.5×2			
Piwinski angle	2.58	7.0	23.8	
Number of particles/bunch N_e (10^{10})	15.0	12.0	8.0	
Bunch number (bunch spacing)	242 (0.68μs)	1524 (0.21μs)	12000 (25ns+10%gap)	
Beam current (mA)	17.4	87.9	461.0	
Synchrotron radiation power /beam (MW)	30	30	16.5	
Bending radius (km)	10.7			
Momentum compact (10^{-5})	1.11			
β function at IP β_x^*/β_y^* (m)	0.36/0.0015	0.36/0.0015	0.2/0.0015	0.2/0.001
Emittance $\varepsilon_x/\varepsilon_y$ (nm)	1.21/0.0031	0.54/0.0016	0.18/0.004	0.18/0.0016
Beam size at IP σ_x/σ_y (μm)	20.9/0.068	13.9/0.049	6.0/0.078	6.0/0.04
Beam-beam parameters ξ_x/ξ_y	0.031/0.109	0.013/0.106	0.0041/0.056	0.0041/0.072
RF voltage V_{RF} (GV)	2.17	0.47	0.10	
RF frequency f_{RF} (MHz) (harmonic)	650 (216816)			
Natural bunch length σ_z (mm)	2.72	2.98	2.42	
Bunch length σ_z (mm)	3.26	5.9	8.5	
HOM power/cavity (2 cell) (kw)	0.54	0.75	1.94	
Natural energy spread (%)	0.1	0.066	0.038	
Energy acceptance requirement (%)	1.35	0.4	0.23	
Energy acceptance by RF (%)	2.06	1.47	1.7	
Photon number due to beamstrahlung	0.1	0.05	0.023	
Lifetime _simulation (min)	100			
Lifetime (hour)	0.67	1.4	4.0	2.1
F (hour glass)	0.89	0.94	0.99	
Luminosity/IP L ($10^{34}cm^{-2}s^{-1}$)	2.93	10.1	16.6	32.1

Radiation Backgrounds

One Ring, One IR per Ring





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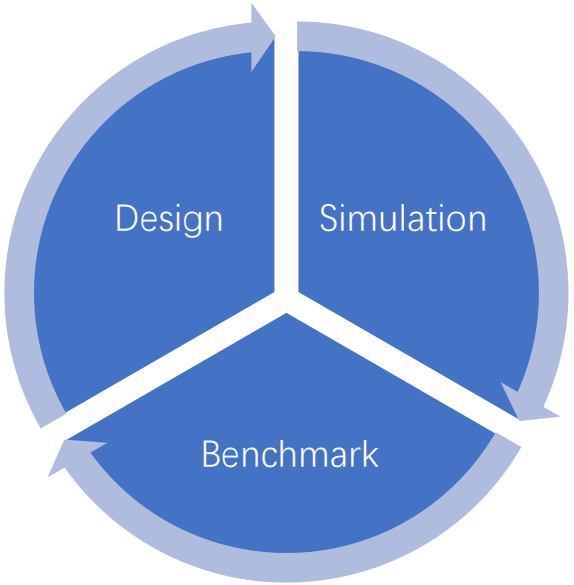
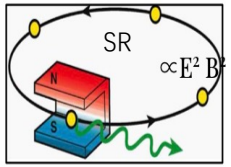
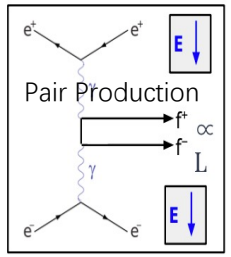


A. Natochii





Photon BG

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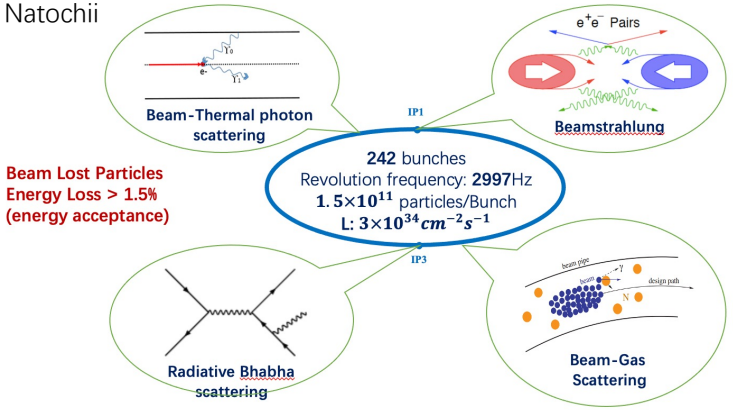
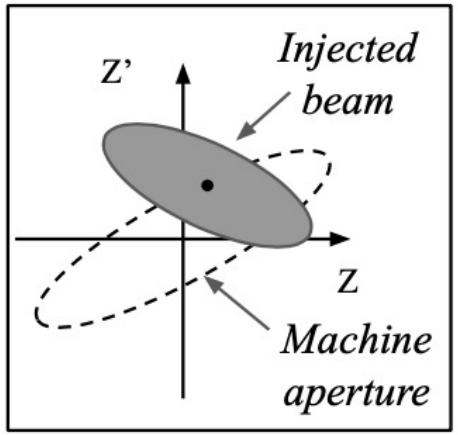


Beam Loss BG

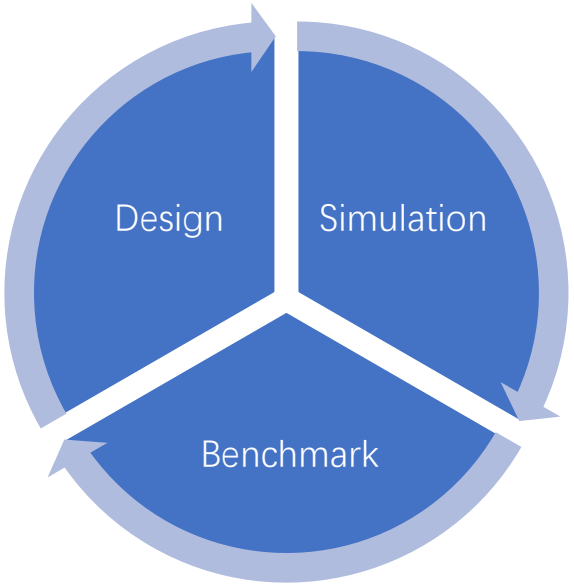


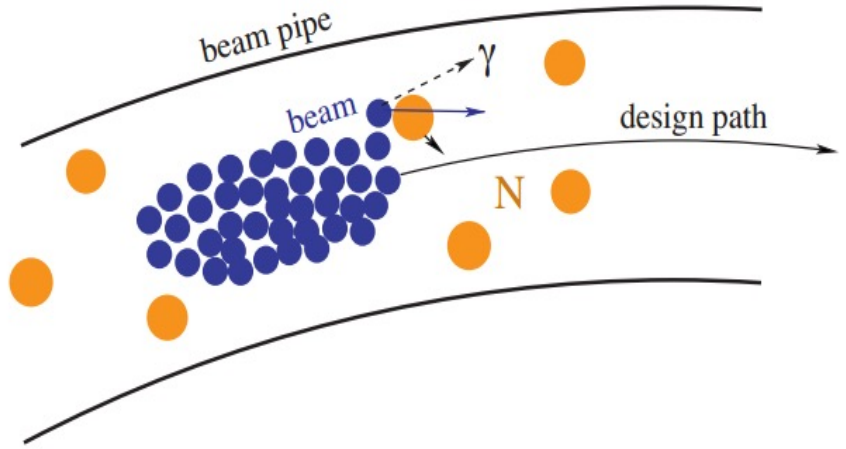
Injection BG

- Working on these following BGs:
  - Beam Gas Coulomb
  - Synchrotron Radiation
  - Photon BG on BGB/BTH/RBB

Background	Generation	Tracking	Detector Simu.
Synchrotron Radiation	BDSim	BDSim/Geant4	Mokka
Beamstrahlung/Pair Production	Guinea-Pig++	SAD	
Beam-Thermal Photon	PyBTH		
Beam-Gas Bremsstrahlung	PyBGB		
Radiative Bhabha	Bbbrem/PyRBB		

Radiation Backgrounds





Photon BG

Beam Loss BG

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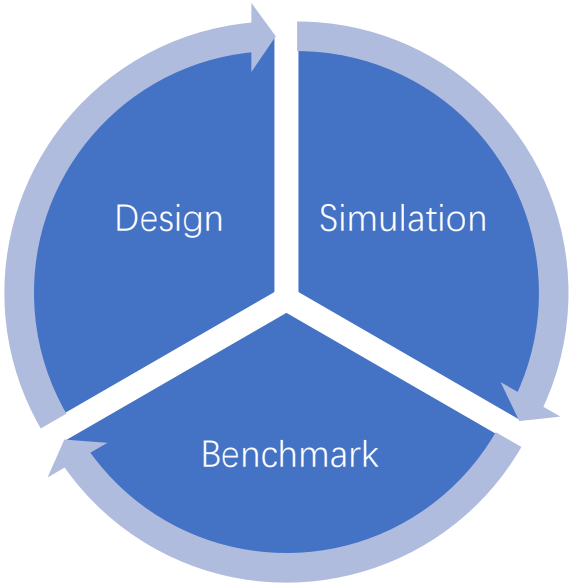
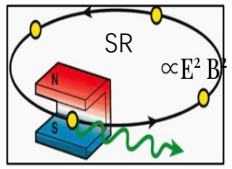
Radiation Backgrounds





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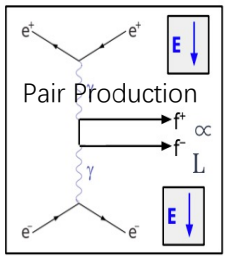
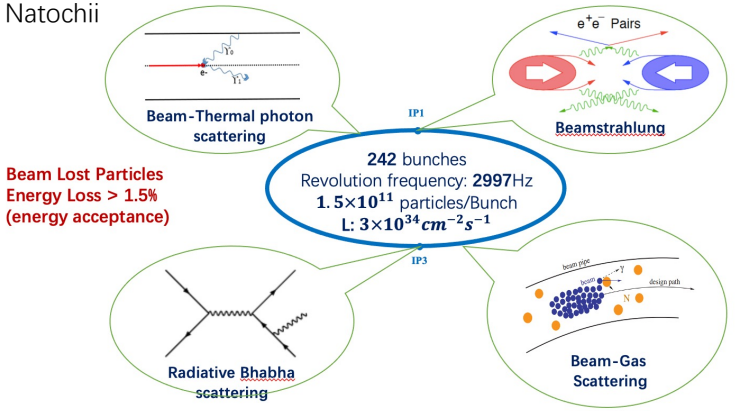


Photon BG



Beam Loss BG

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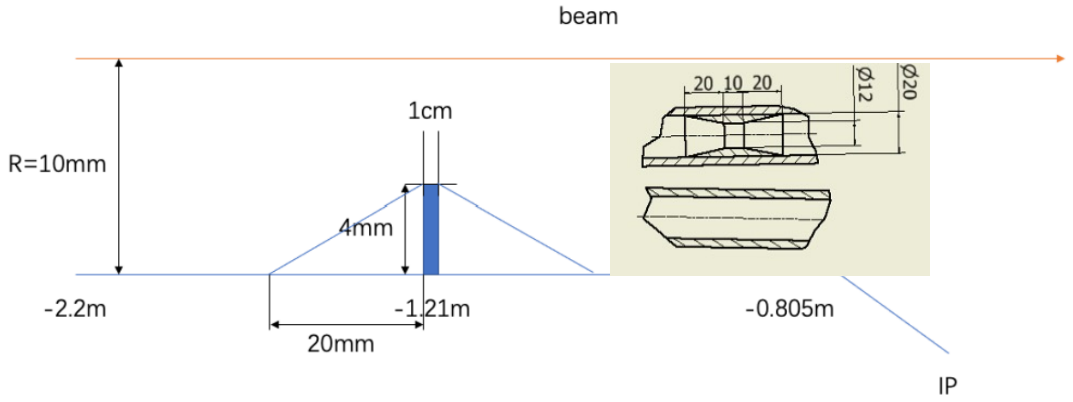
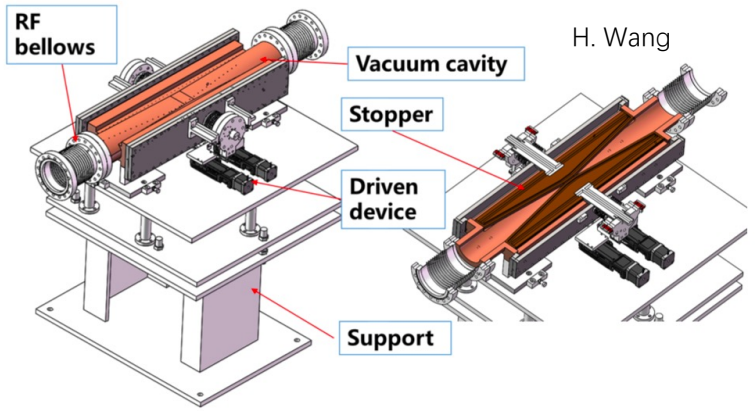
Mitigation Methods

Name	Location	From IP(m)
SR Mask1	Before QD0	4.2
SR Mask2	After QD0	1.21
APTX1	D1I.1897	2139.06
APTX2	D1I.1894	2207.63
APTX3	D1O.10	1832.52
APTX4	D1O.14	1901.09

- Masks and Collimators has been implemented:
  - 2 Masks to suppress SR
  - 4 Sets of Movable Collimators to suppress Beam Loss BGs
    - 5mm(radius) in simulation



SR Masks

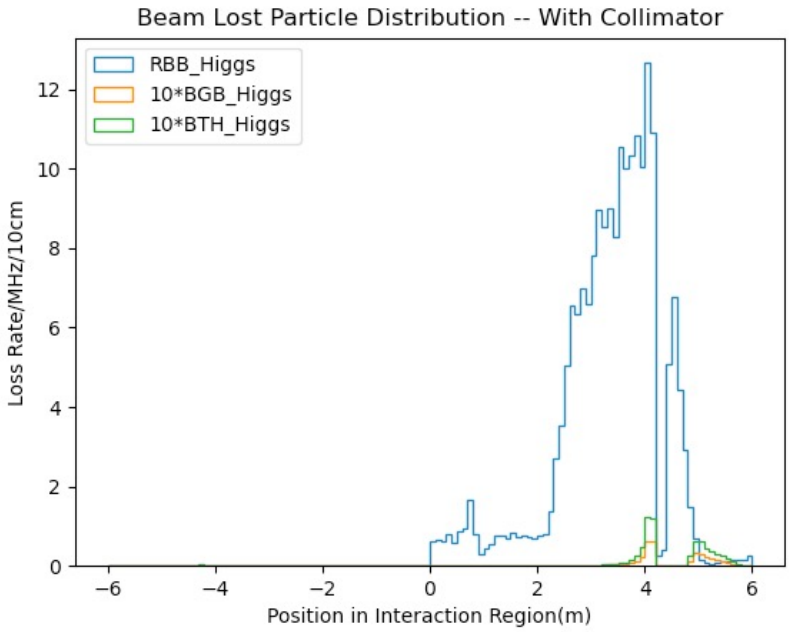


Collimators

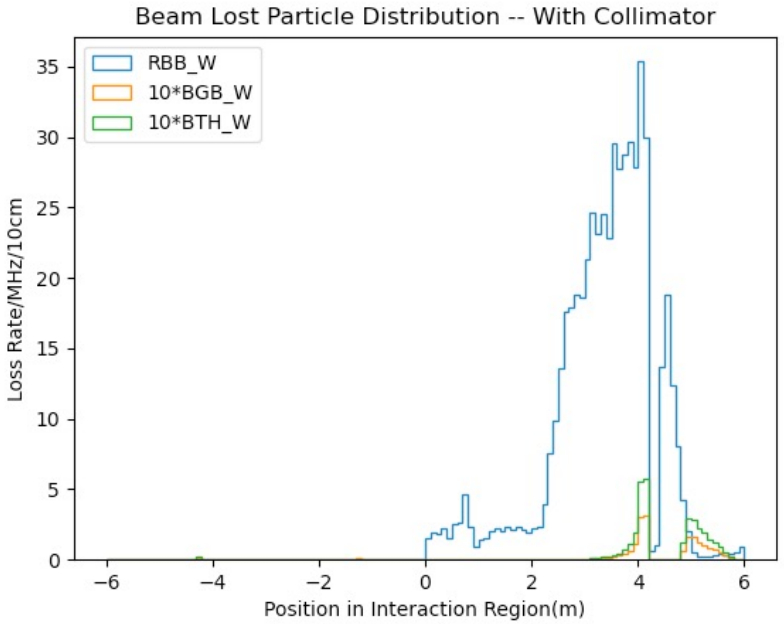
Lost distribution

- Loss Rates increases with particle number increasing.
- RBB loss is much higher than the other two.
  - Consistent with beam lifetime.
  - Higher loss rate does not mean higher detector impact.

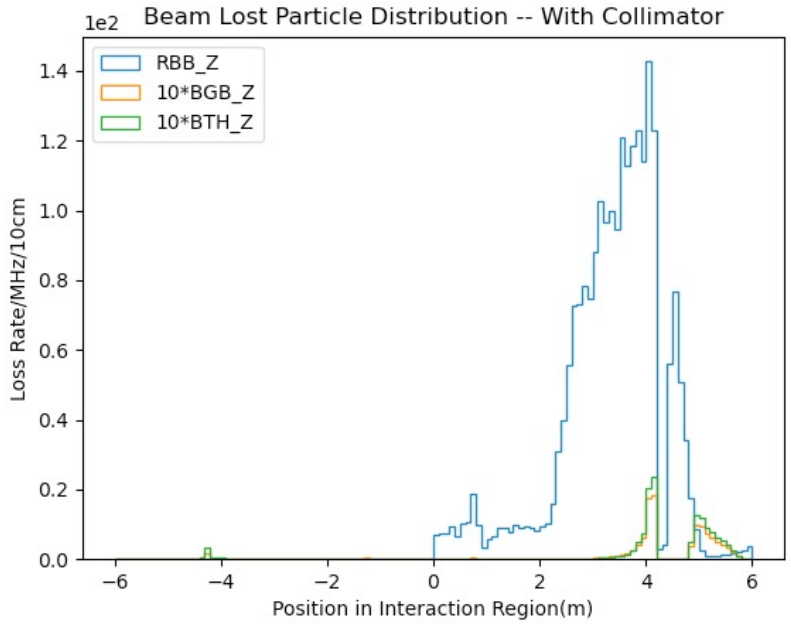
	Beam Lifetime
RBB	1.5 h
BS	1.66 h
BTH	50.7 h
BGB	63.8 h(10^{-7} Pa)



Higgs



W



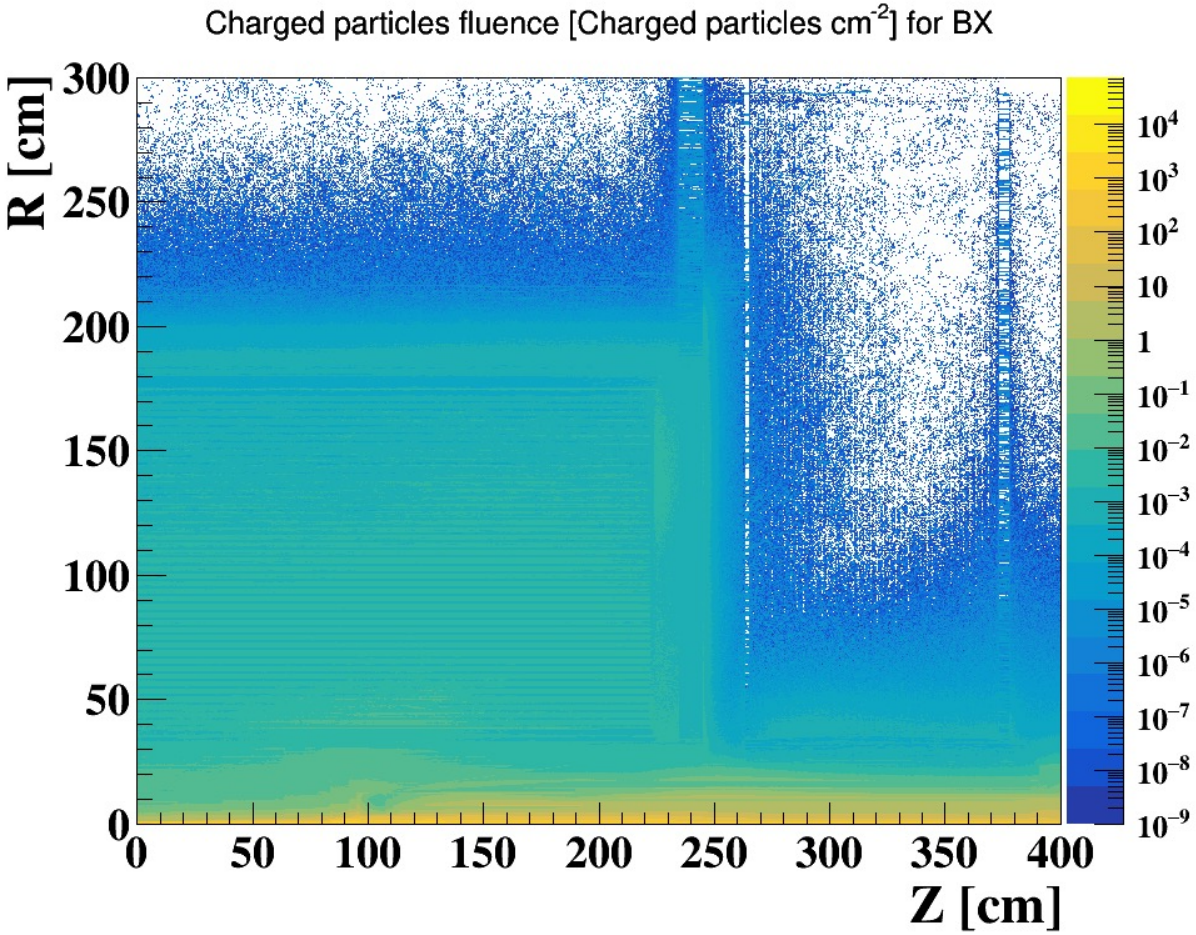
Z

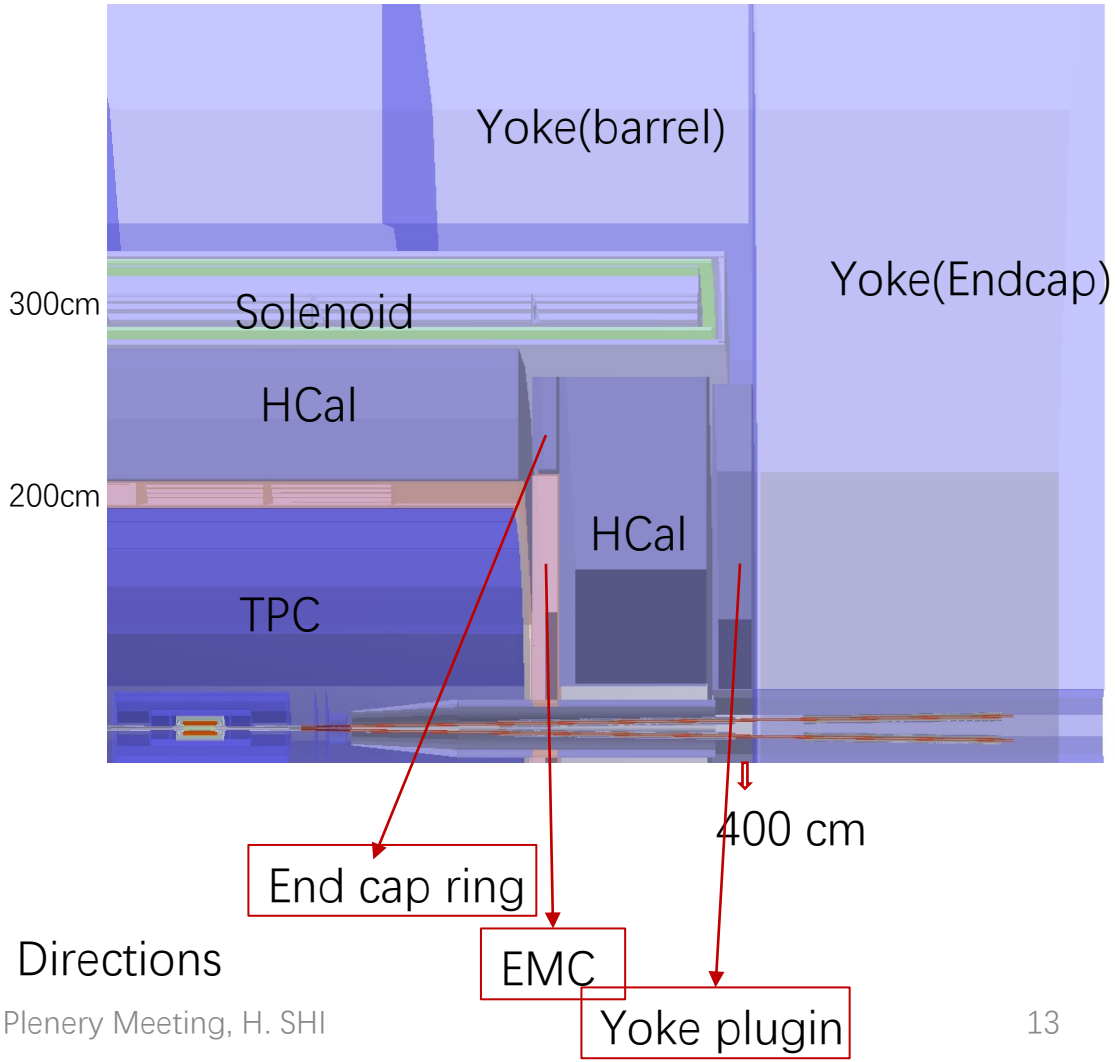
Detector Impacts

- Two Main Concern has been taken for detector impacts:
  - Detecting Efficiency(Occupancy): The ratio of Data/Noise
  - Detector Safety: Radiation Tolerance/Cooling Issues

- Three quantities has been scored:
  - Charged Particle Fluence(Hit Density)
  - Total Ionizing Dose(TID)
  - 1 MeV Silicon Equivalent Fluence(NIEL)
  - A Safety of 10 is always applied to all results

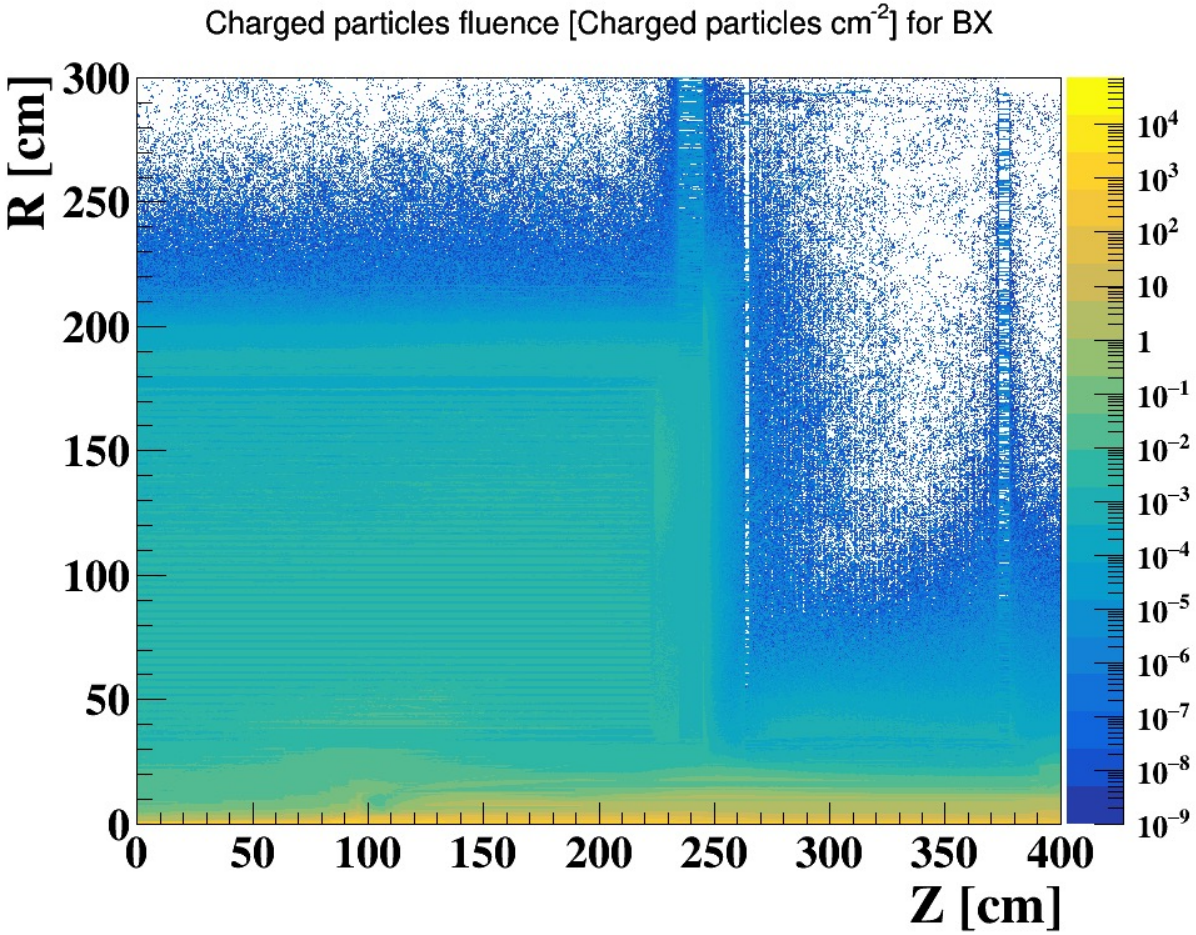
Results – Charged Particle Fluence(CDR H)

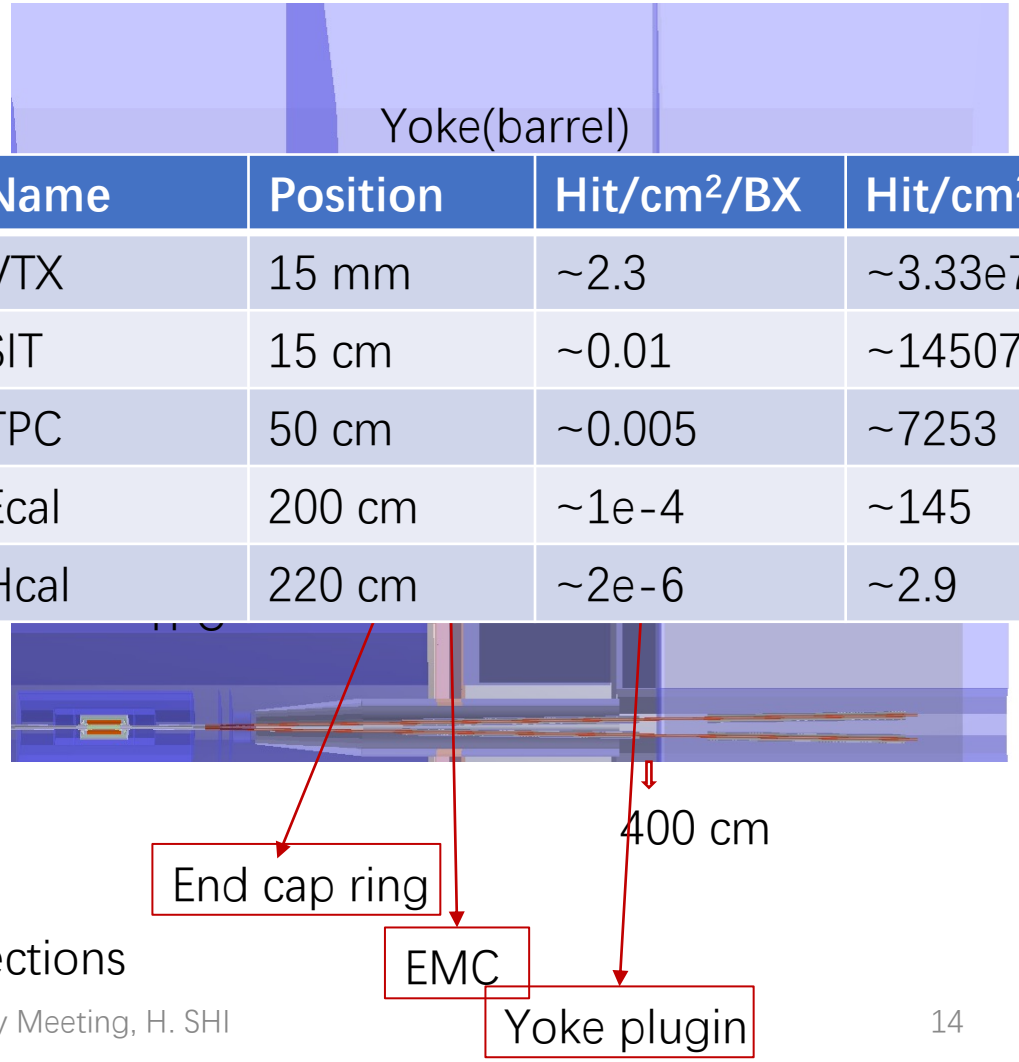




Charged Particles generated by BG could reach Hcal on Both Directions

Results – Charged Particle Fluence (CDR H)



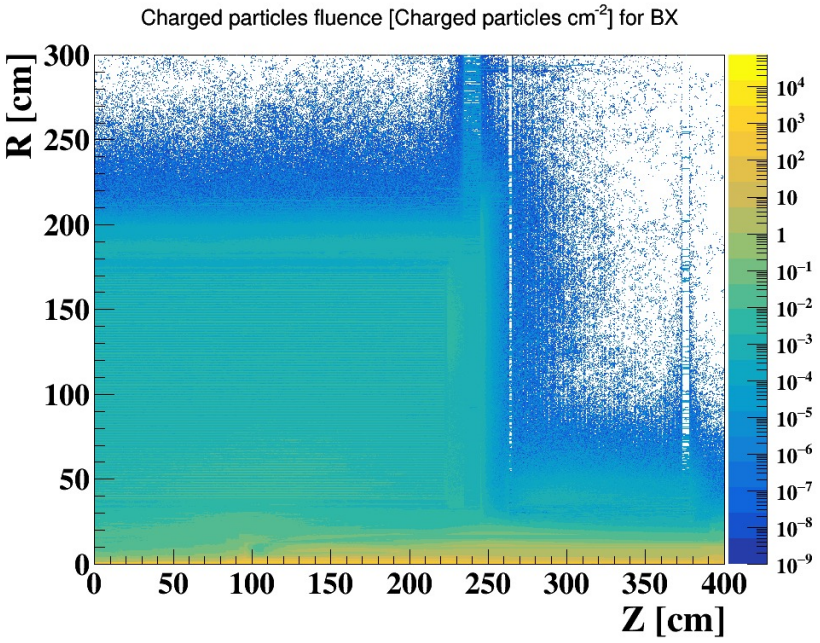


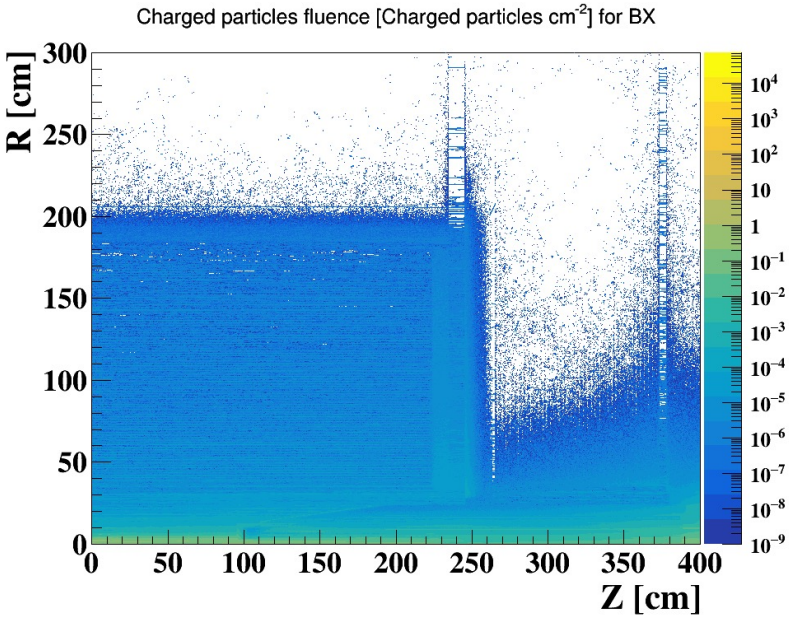
Name	Position	Hit/cm²/BX	Hit/cm²/s
VTX	15 mm	~2.3	~3.33e7
SIT	15 cm	~0.01	~14507
TPC	50 cm	~0.005	~7253
Ecal	200 cm	~1e-4	~145
Hcal	220 cm	~2e-6	~2.9

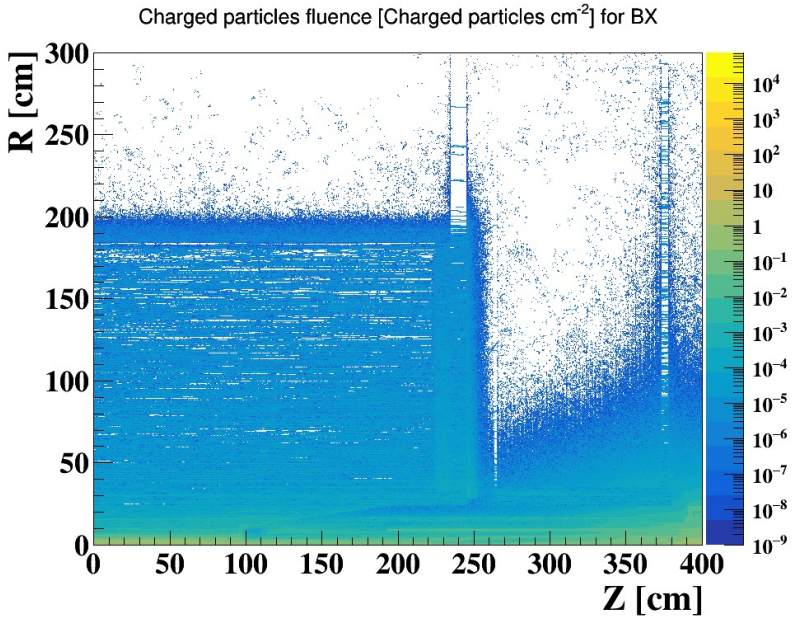
Charged Particles generated by BG could reach Hcal on Both Directions

Results – Charged Particle Fluence (CDR H)

Consist with our previous estimation on Vertex Detectors

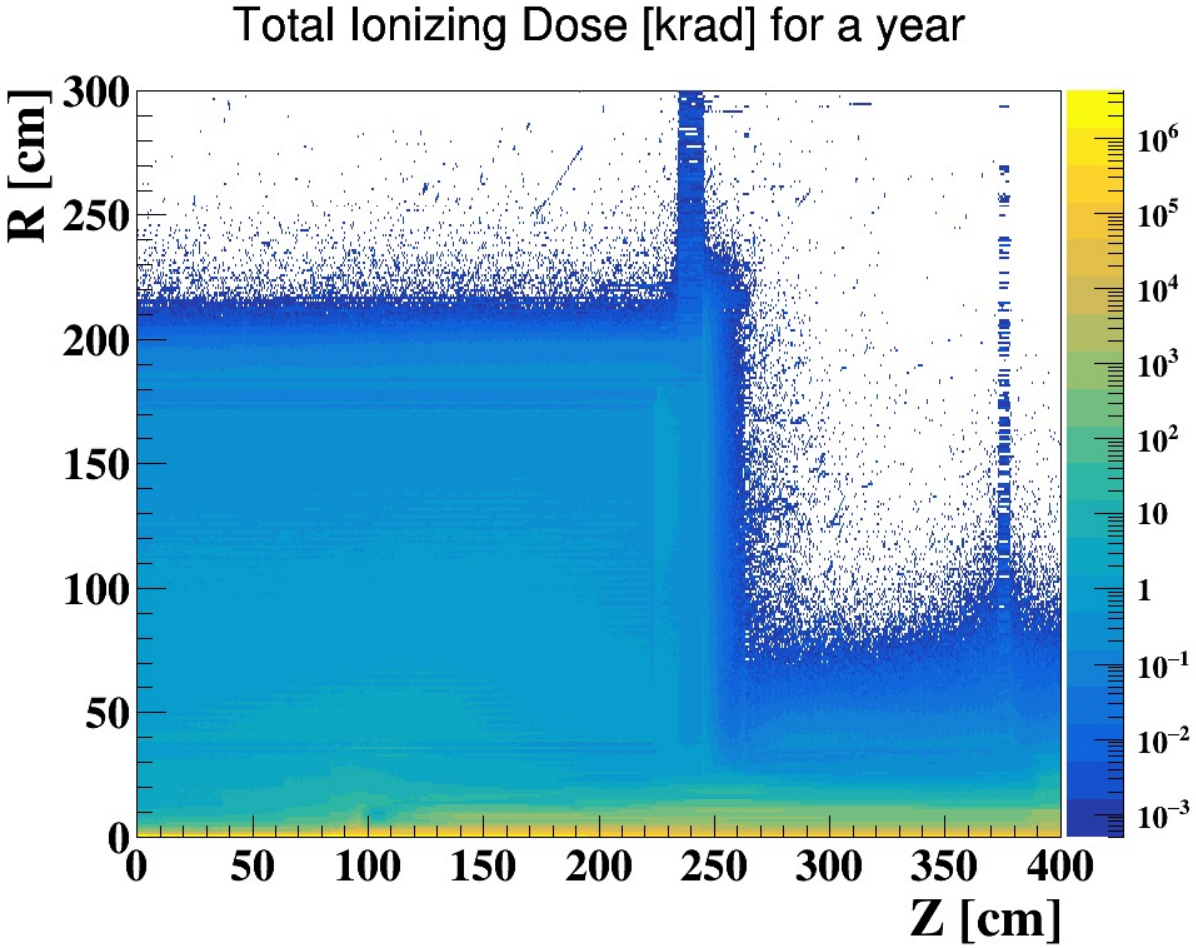






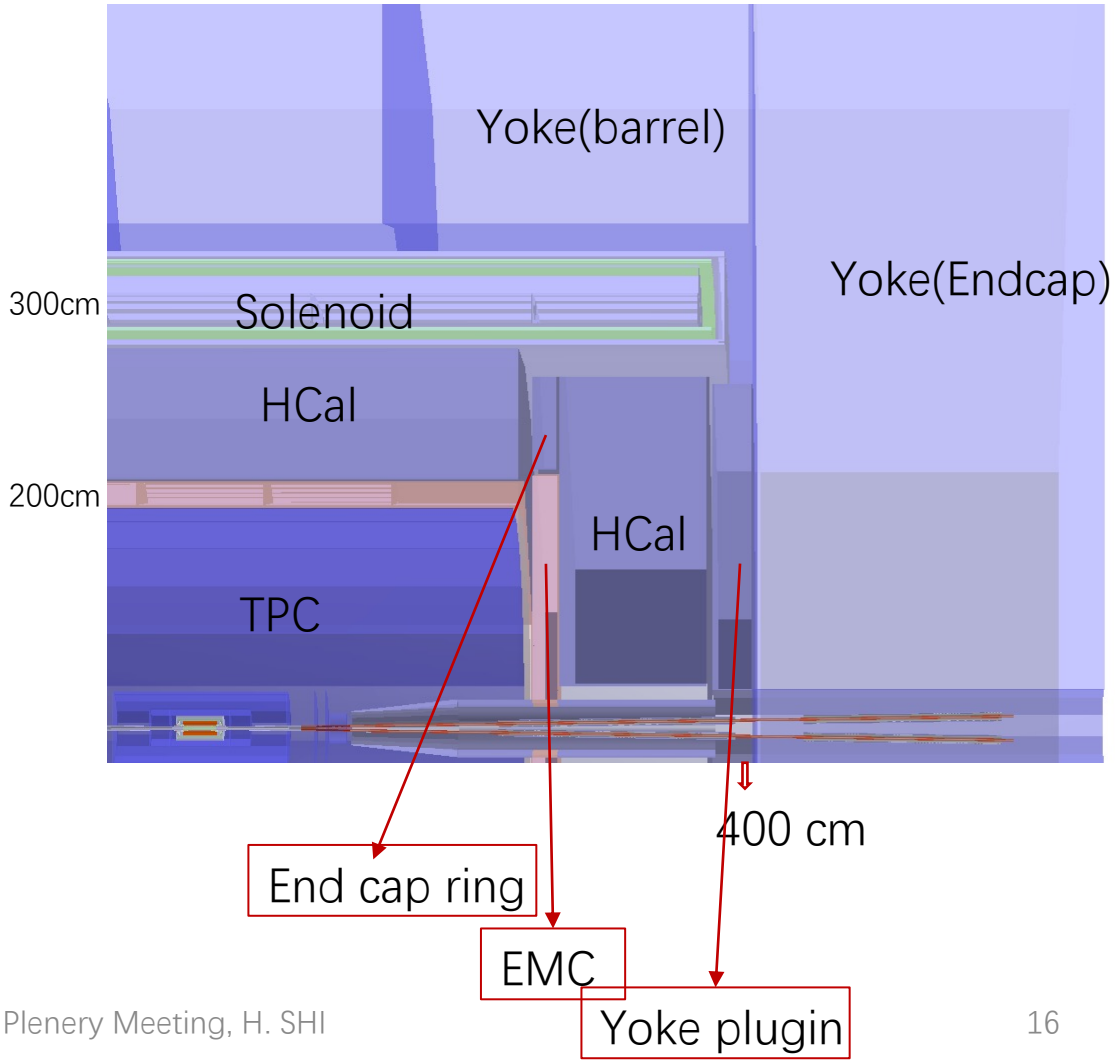
Pairs higher than BGB at the same level BTH

Results – TID (CDR H)



Valid for Silicon Trackers Only

~860 kRad/yr on Vertex 1st Layer
~3 kRad/yr on SIT 1st Layer



Remain Issues of Current Simulation

- Missing Source items:
  - BGC/RBB/SR in Full Detector Simulation
  - Errors
- Updating all the results to 2 IR per ring.
- Check of Consistency: Lattice, Geometry, etc.
- Validation
- Low Code Efficiency
- Safe enough or not?

MDI Task List – Design – Systems

Systems	Design Status	Radiation Safety	Cooling	Installing&Alignment
BPMs	Under Design	Waiting	Waiting	Waiting
Vacuum pumps	Under Design	Not Necessary	Not Necessary	Waiting
Supporting System	?	Not Necessary	Not Necessary	Waiting
Connecting System	Under Design	Waiting	Waiting	Waiting
Cooling System	Under Design	Waiting	-	Waiting
Protection System	Assuming Exist	Assuming Safe	Assuming Cooled	Assuming WD
…				

MDI Task List – Design – Components

Components	Design Status	Radiation Safety	Cooling	Installing&Alignment
Central Beam Pipe	Designed	Checked	Designed	Waiting
Vertex Detector	Under Design	Checked	Under Design	Waiting
LumiCal	Under Design	Checking	Under Design	Waiting
Detector Endcup	Under Design	Checking	Under Design	Waiting
Detector Solenoid	Under Design	Checking	Under Design	Waiting
Croystat Chamber	Under Design	Not Necessary	Not Necessary	Waiting
QD0/QF1	Designed	Checking	Under Design	Waiting
Anti-Solenoid	Under Design	Checking	Under Design	Waiting
Vacuum Chamber	Under Design	Checking	Waiting	Waiting
…				

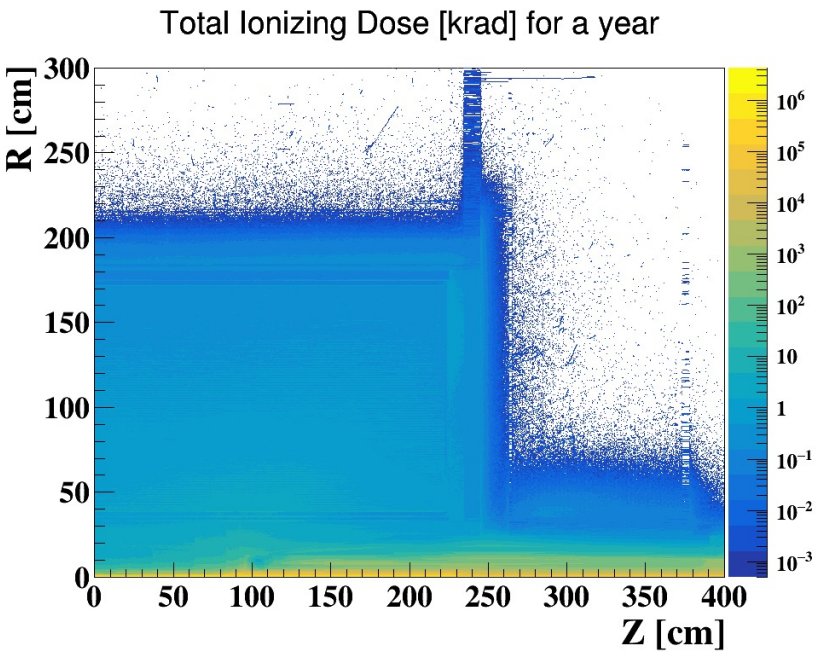
Summary & Outlook

- Full detector simulation performed based on CDR Higgs and baseline detector(Show to IARC in October):
  - Pairs Production/BGB/BTH taken into account
  - The BG particles could reach Hcal, the impacts on detector occupancy needs to be studied.
  - The safety due to BG needs to be studied(limitation?)
- Remain Issues needs to be solved.
- More difficult cases needs to be studied:
  - CDR Z mode, 20mm beam pipe, High-Lumi Cases, etc.

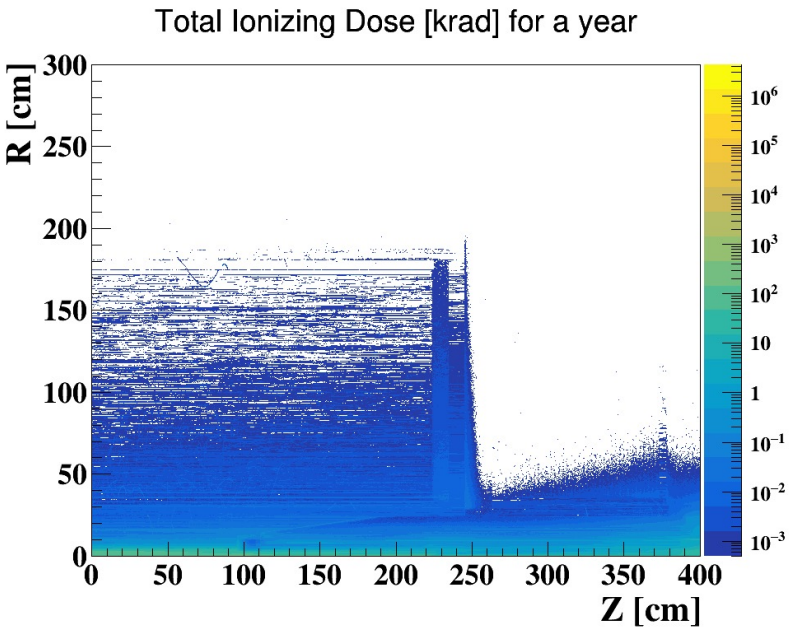
Thank You

Backup

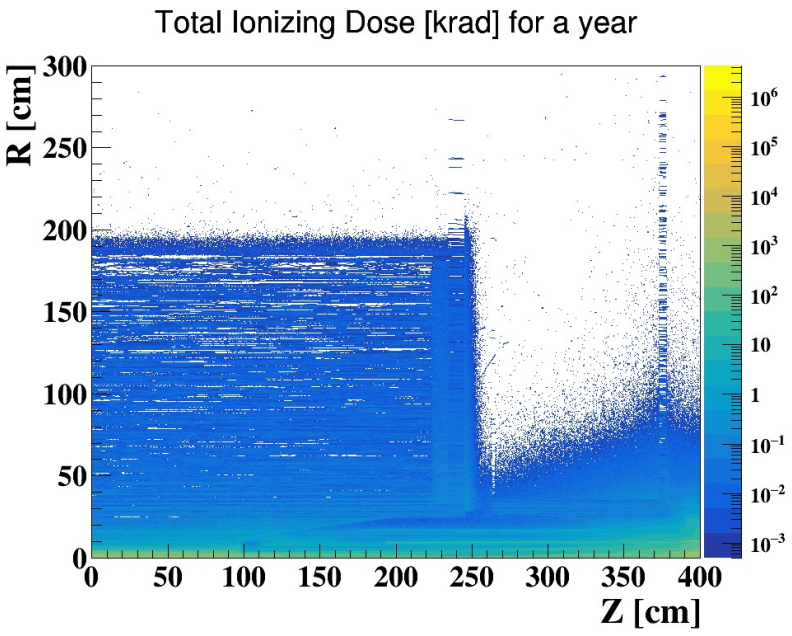
Results – TID



Pairs

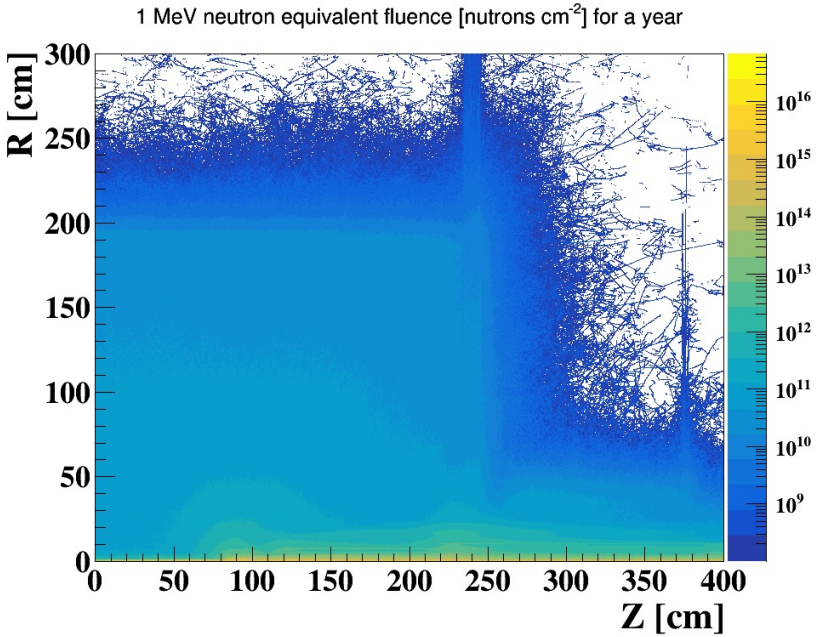


BGB

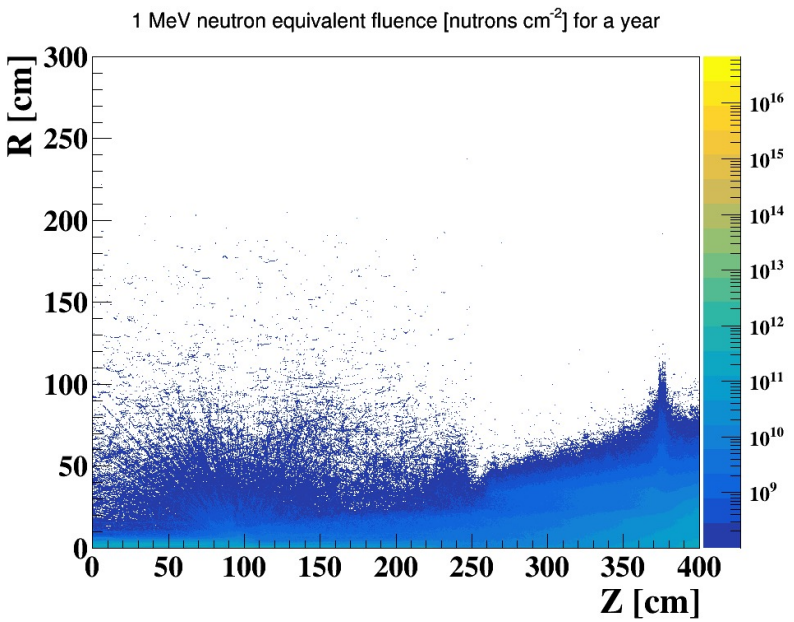


BTH

Results – 1 MeV Equivalent Fluence



Pairs



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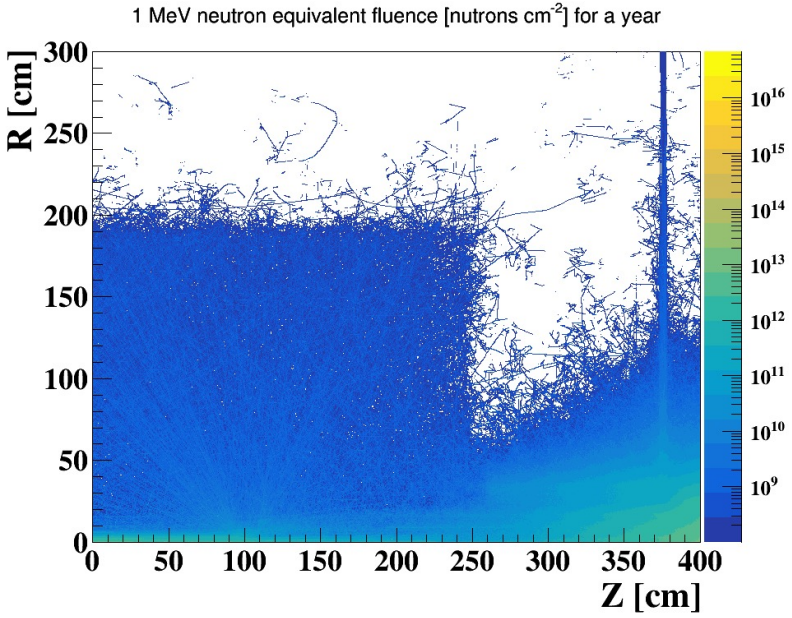
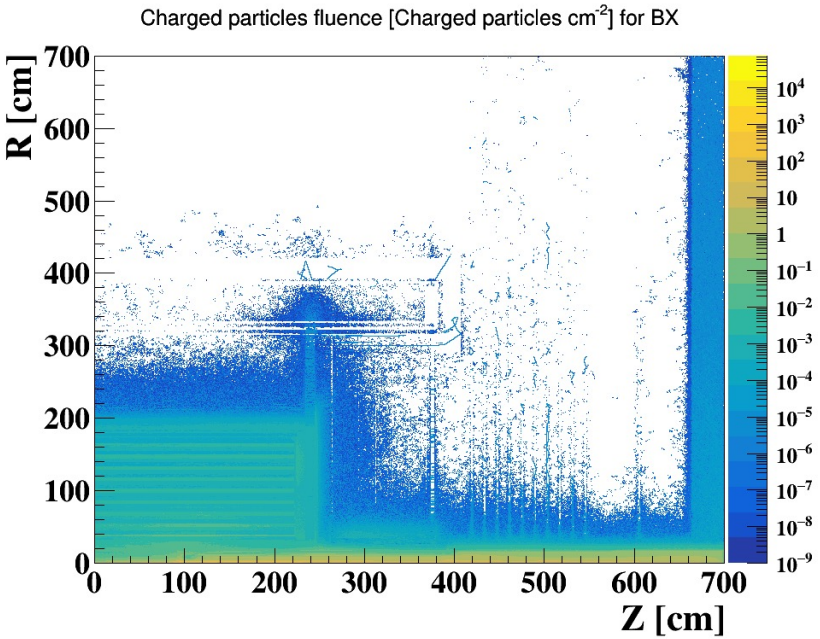
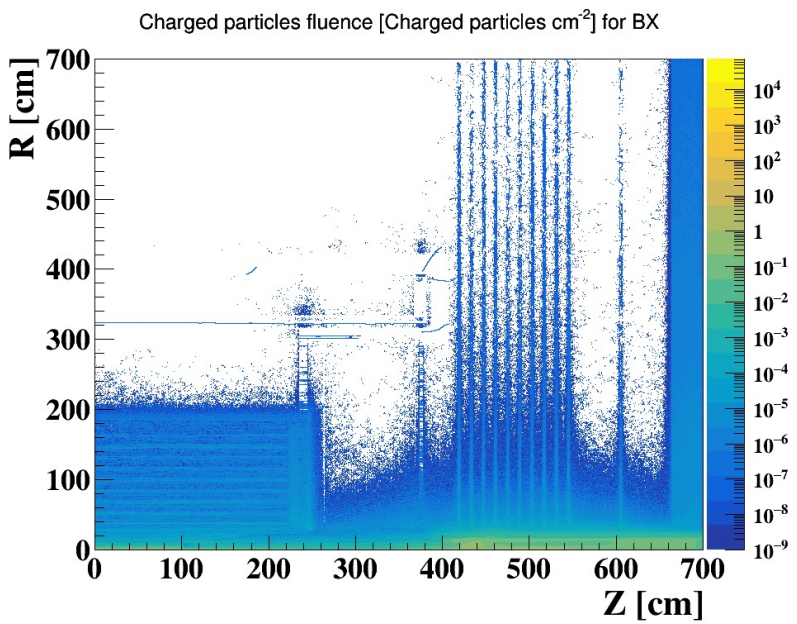


BTH

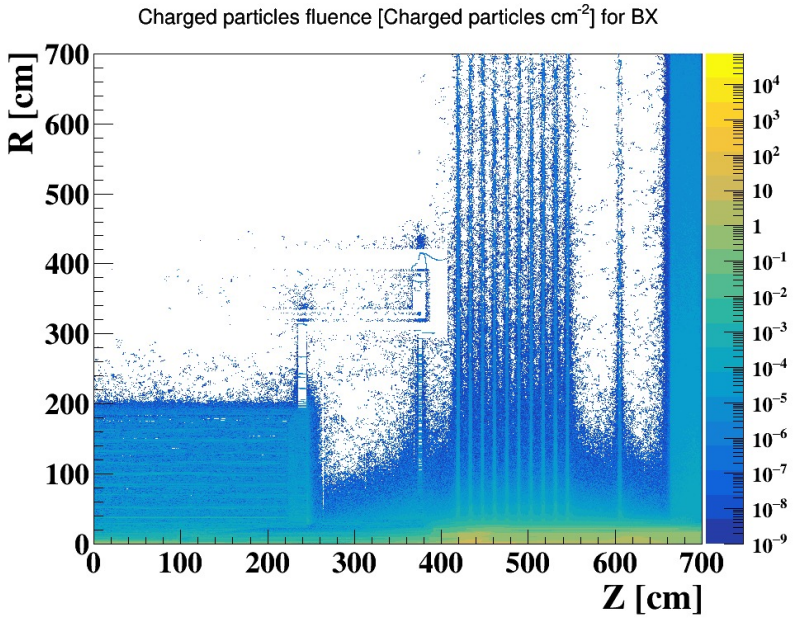
Results – Charged Particle Fluence



Pairs

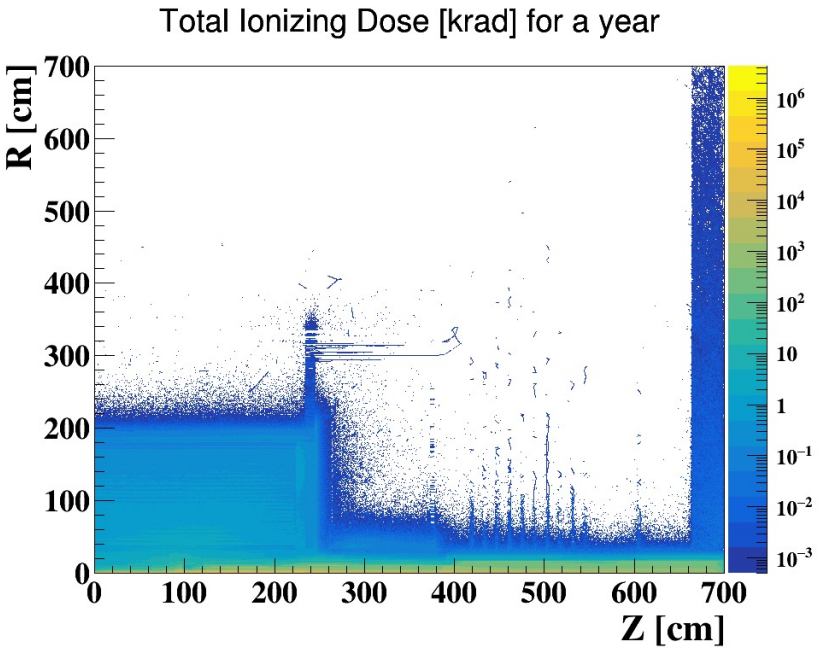


BGB

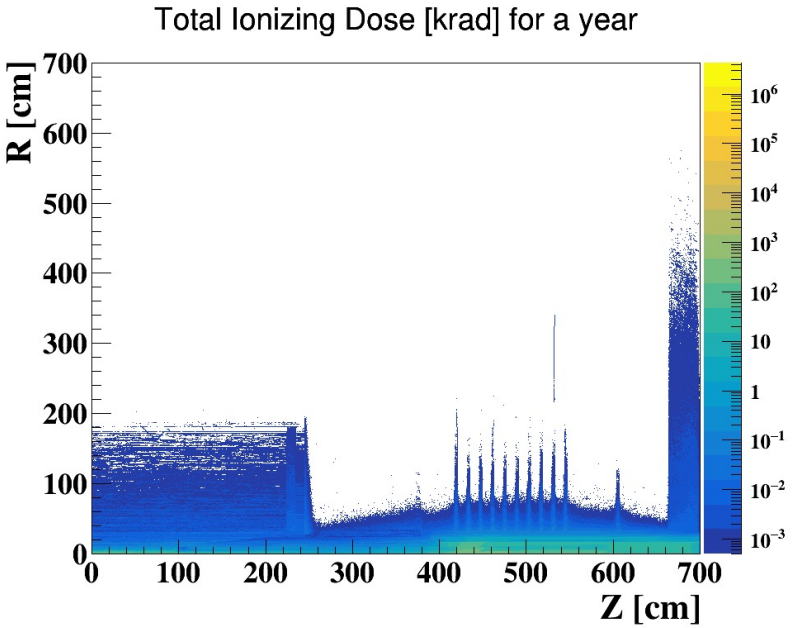


BTH

Results – TID



Pairs



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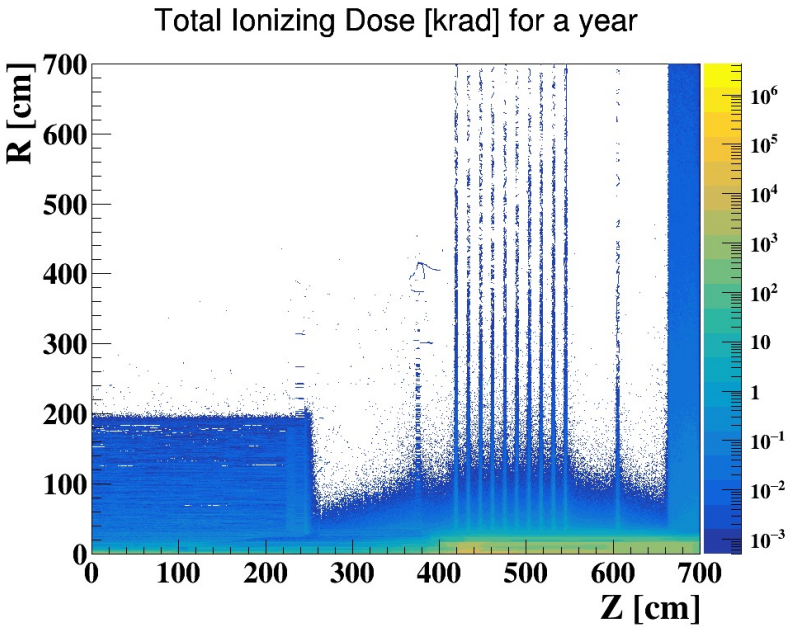

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