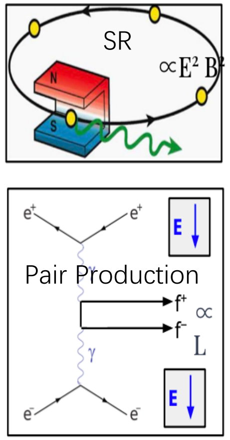
Progress on CEPC MDI Background Study

Haoyu SHI
On Behalf of CEPC MDI Work Group

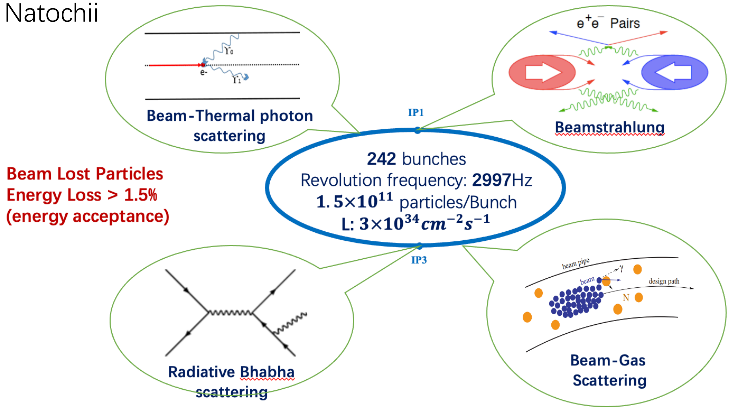
CEPC Physics and Detector Plenary Meeting, 2021.3.17

Radiation Backgrounds



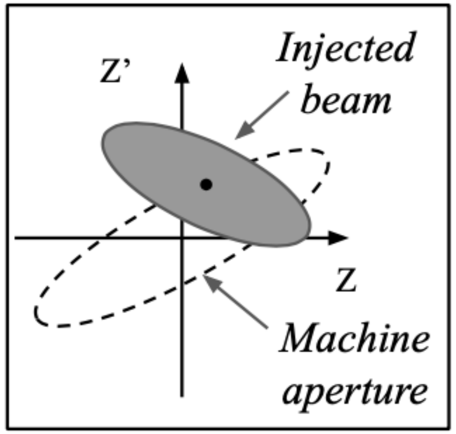
A. Natochii

Photon BG



Beam Loss BG

A. Natochii



Injection BG

Higgs Mode

Background	Beam Lifetime	Marker
Beam Gas Bremsstrahlung	63.8 h	CO, 10^{-7} Pa
Beam Thermal Photon	50.7 h	
Radiative bhabha	74 min	
Beamstrahlung	80 min	

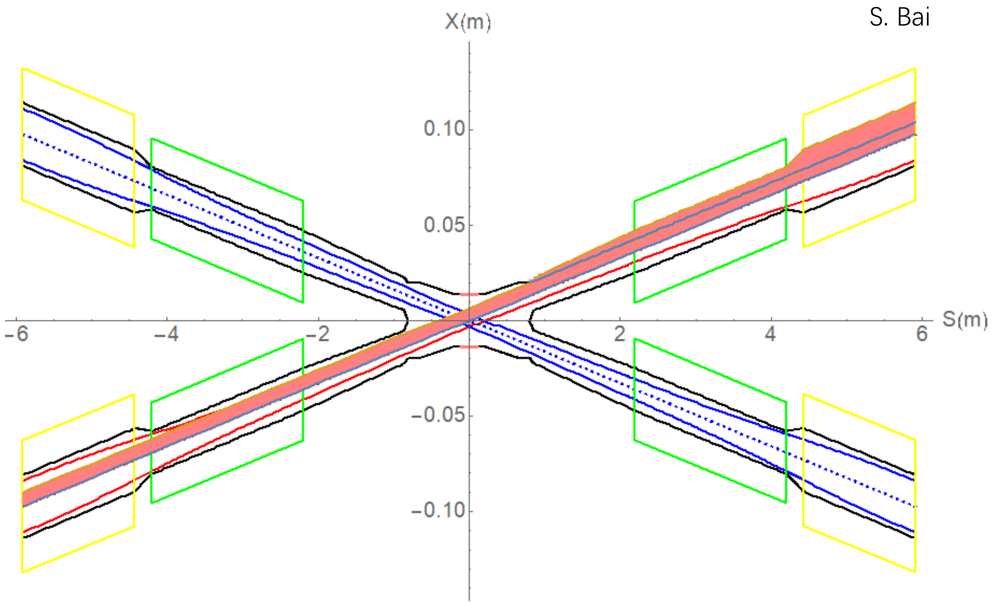
- Photon BG and Beam Loss BG were simulated using different tools. Injection BG is ignored for now.
  - Cross-check and benchmark needed.
- Other BGs are planned to study.

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

Starting with Synchrotron Radiation

- Synchrotron radiation should be dealt with high priority at circular machines when designing the interaction region

Revised beam pipe design to achieve
No direct SR photons hitting the central beam pipe except the extreme beam conditions (e.g. beam off orbit due to magnet errors)

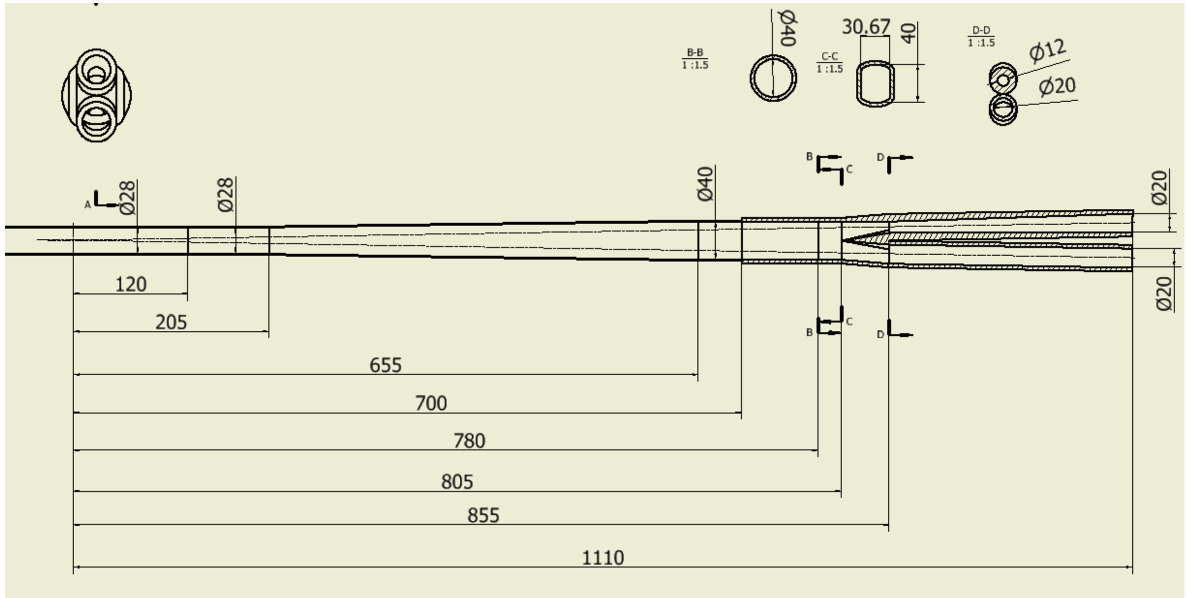


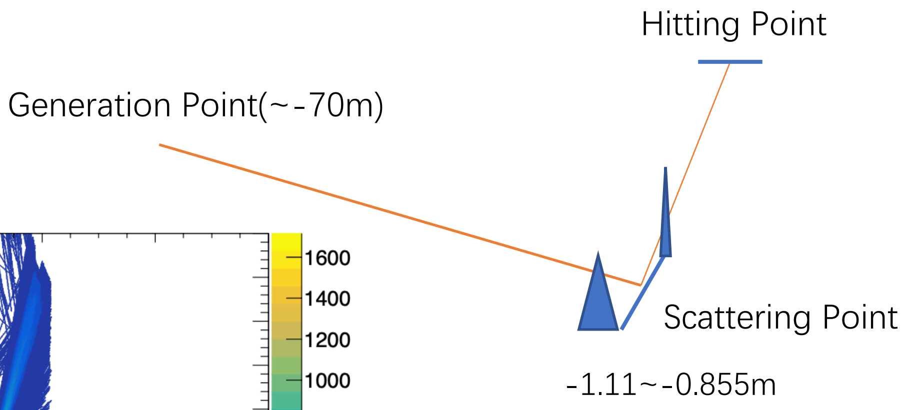
S. Bai

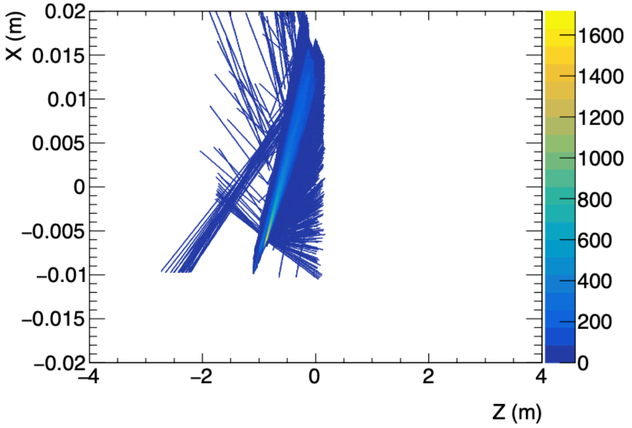
	Power Deposition	Average Power Density
0.805~0.855m	16W	88.9W/cm^2
0.855~2.2m	12.3W	2.54W/cm^2
QD0(2.2m~4.2m)	2.79W	0.39W/cm^2
QD0~QF1(4.2~4.43m)	36.1W	43.6W/cm^2
QF1(4.43m~5.91m)	3W	0.56W/cm^2

Asymmetry design

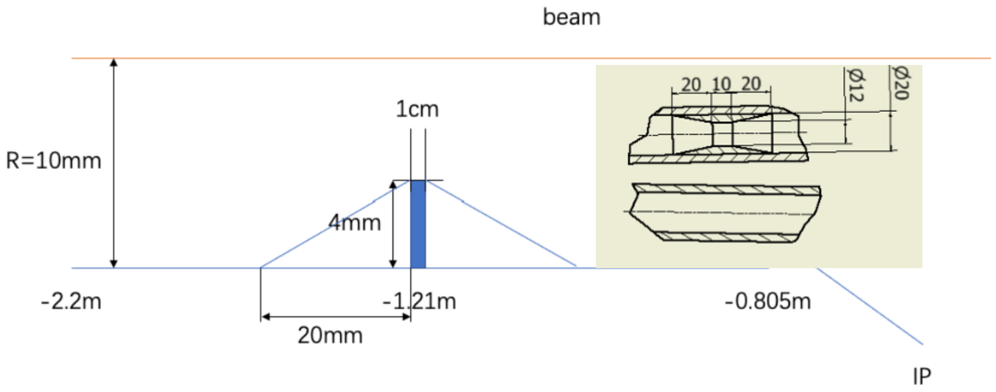
- ~ 37500 photons would hit Be beampipe per bunch
  - Consistent with CDR results
- Most photons hitting Be pipe were generated at ~-70m.
  - Photons should hit the slope at ~-1.11m to -0.855m, and then scattered to Be pipe.
- Masks are needed.
  - We have tried different positions, but it seems hard to decrease the Be hitting numbers.
  - We need to know the source of the photon.

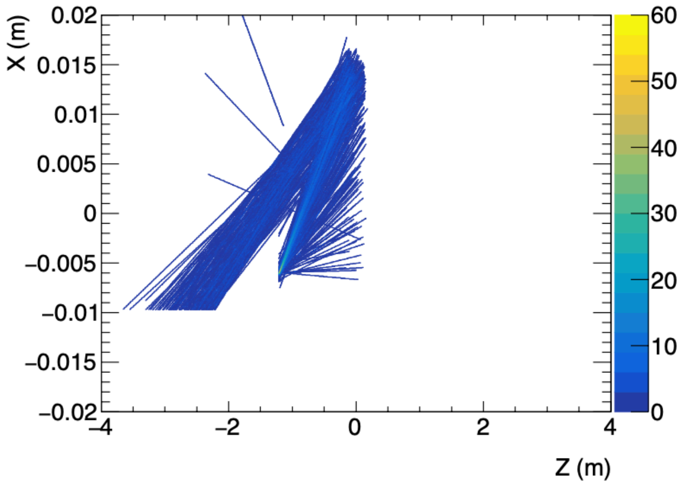


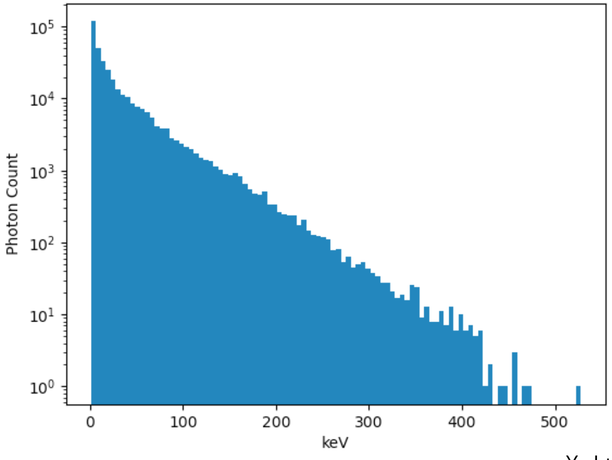




Mitigation – SR Mask

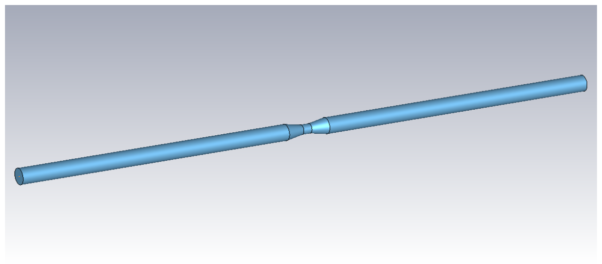


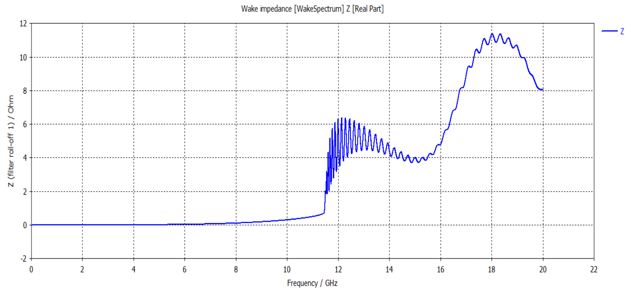




Y. Liu

- Lots of photons are secondaries, generated within QD0
- New mask design:
    - Tungsten
    - 4mm height
    - 10mm long
    - Locates at -1.21m
- ~300 photons/bunch could hit Be beampipe, with a.e. ~100keV

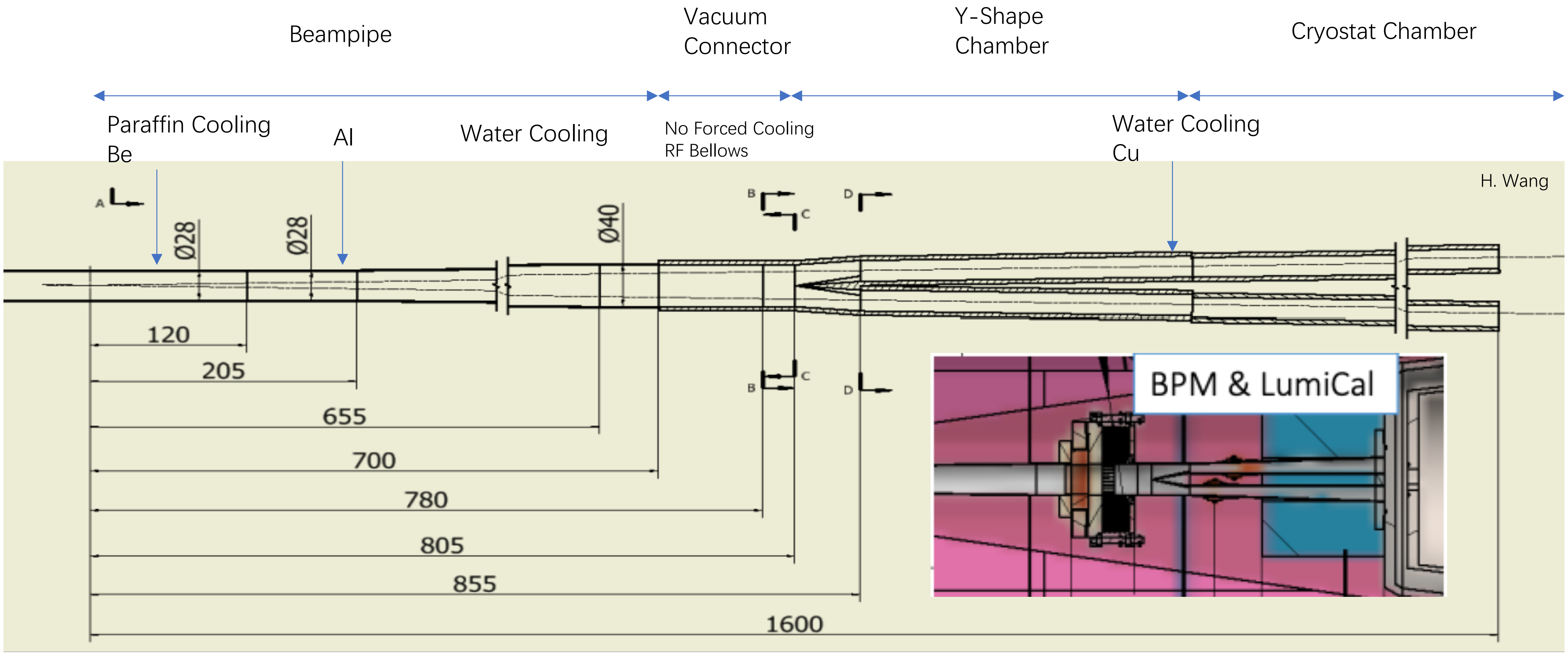




Loss factor(V/pc)	Power &Higgs	Power &W	Power &Z(CDR)	Power &Z(High Lum)
$8.69*10^{-4}$	0.36 w	1.47 w	**5.13w**	**22.61w**

Nearly 20 versions tried in last 10 months

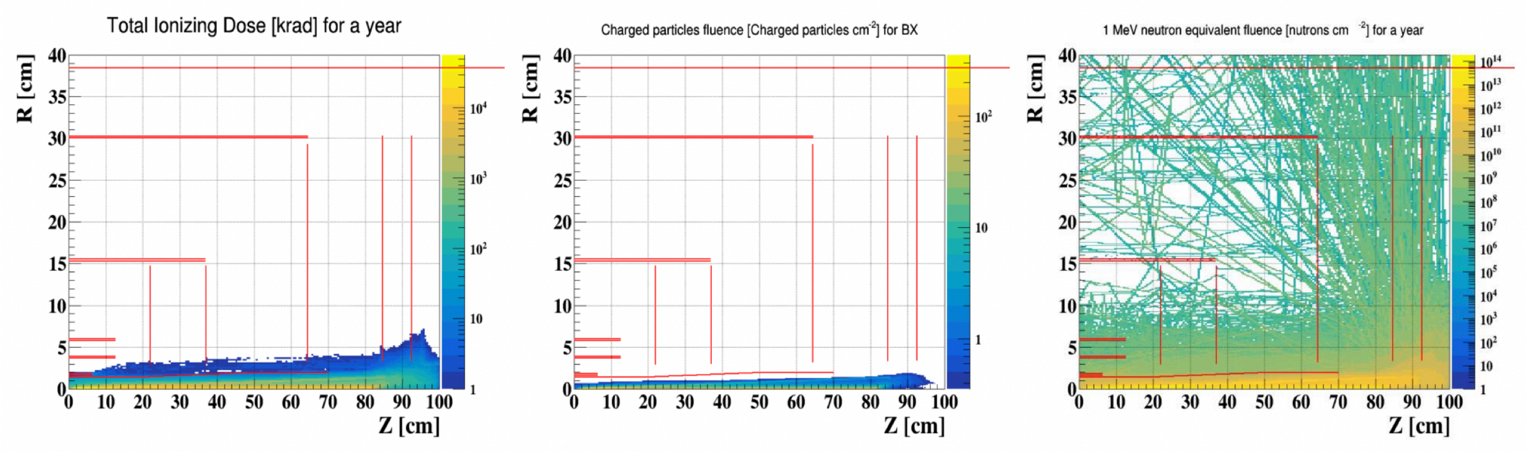
Revised beampipe design



Pair Production

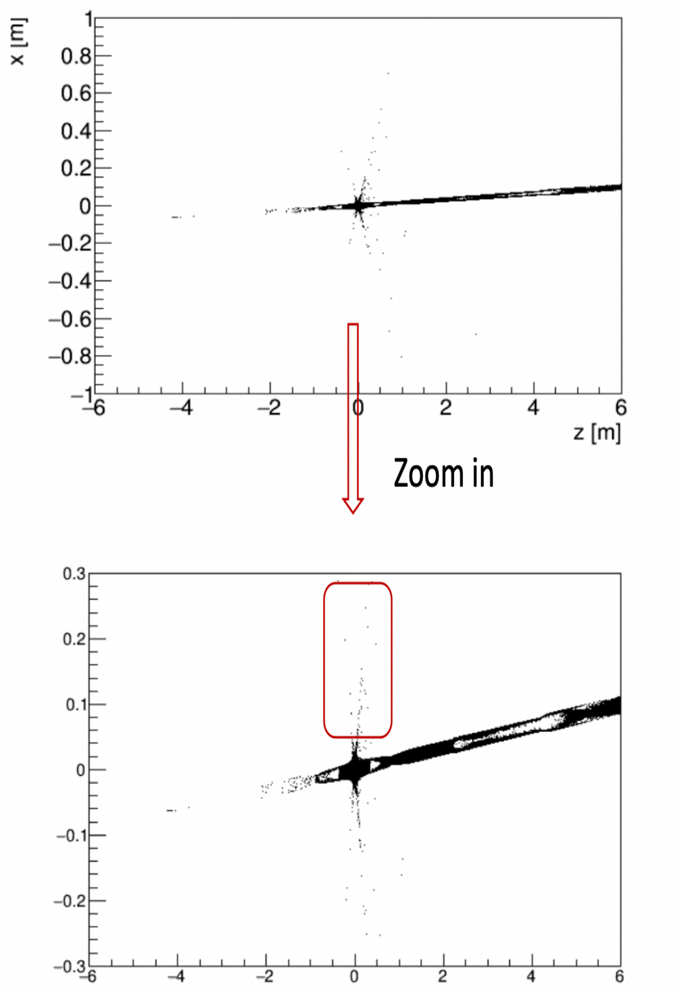
- Detector Impact on 1st layer of vertex detector, with a safety factor of 10

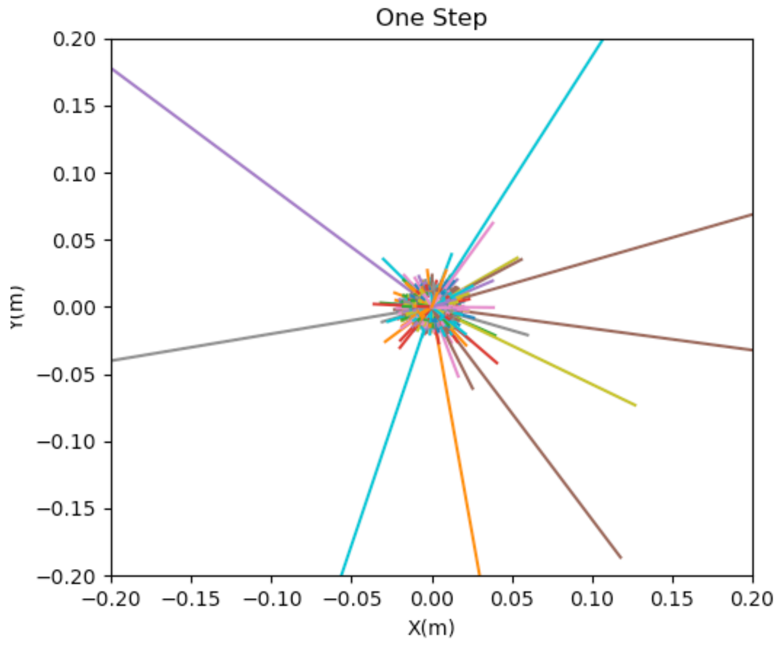
Mode	Hit Density($cm^{-2}\cdot BX^{-1}$)	TID($krad\cdot yr^{-1}$)	1 MeV equivalent neutron fluence ($n_{eq}\cdot cm^{-2}\cdot yr^{-1}$)
Higgs	1.81	499.476	9.68×10^{11}
W?	1.233	4201.818	7.70×10^{12}
Z(2T)?	0.015	225.060	4.18×10^{11}

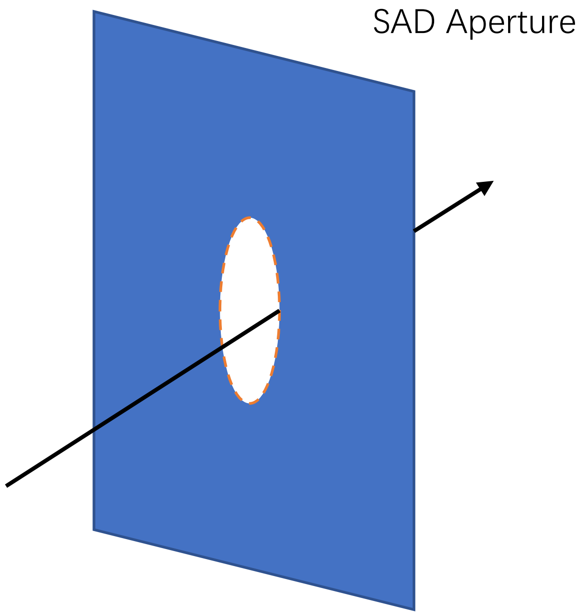


Radiative Bhabha scattering

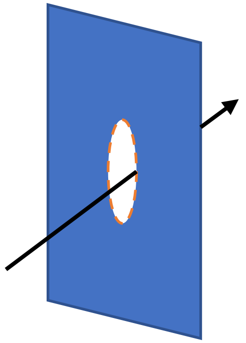
- Lots of loss particles are "outside" of the beampipe.
  - Due to the tracking mechanism of SAD
- The improvement of the tracking method is needed.

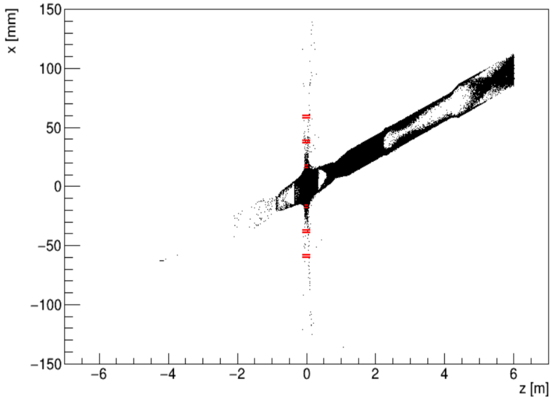




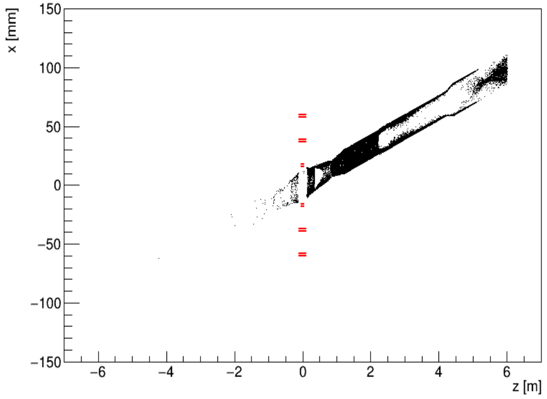


Tracking Method Improvement

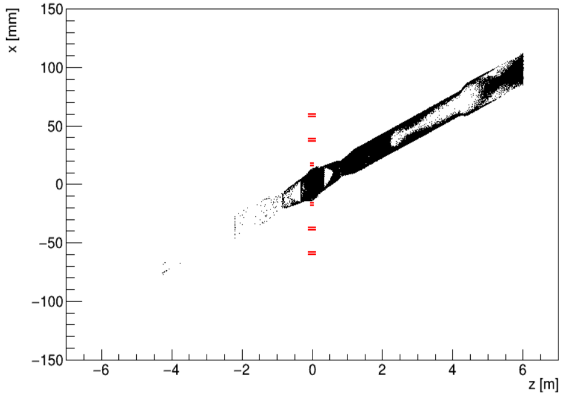




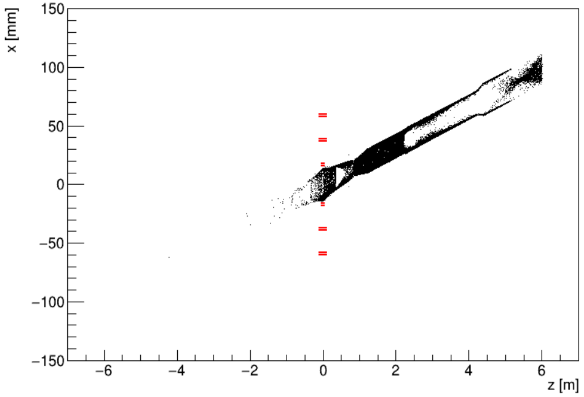
Method 1 – Out



Method 2 – Cut



Method 3 – Before

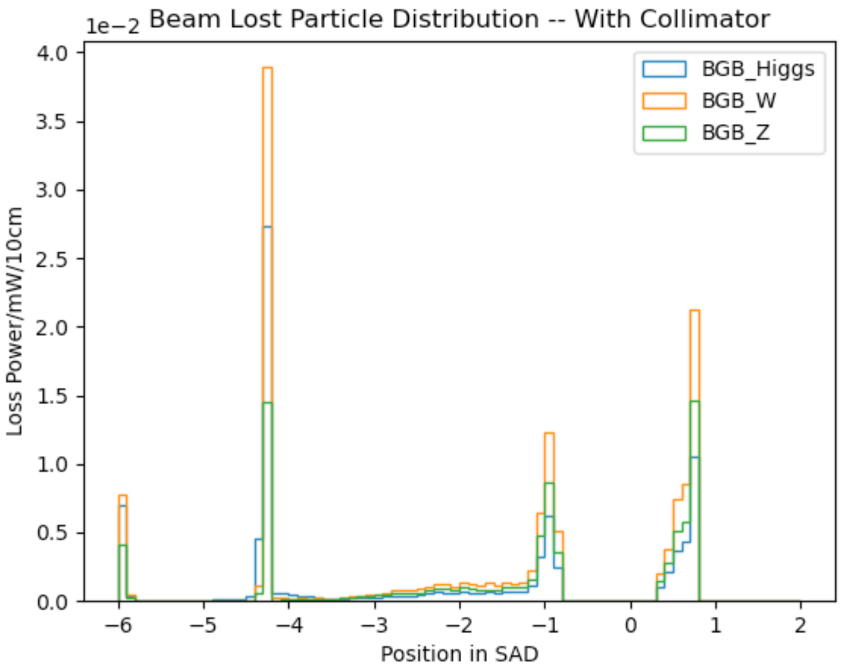


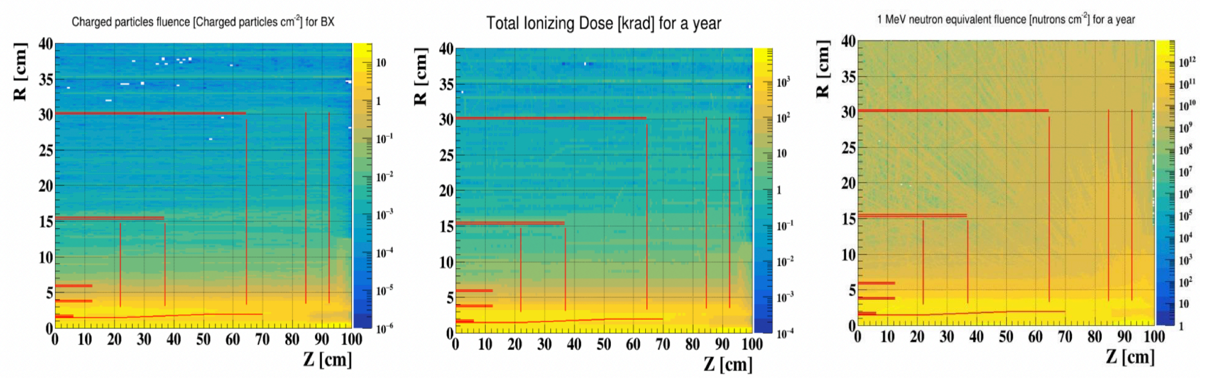
Method 4 – Move

	Method 1 - Out	Method 2 - Cut	Method 3 – Before	Method 4 – Move
Hit Density($\mathbf{cm^{-2} \cdot BX^{-1}}$)	0.155	0.004	0.02	0.0066
TID($\mathbf{krad \cdot yr^{-1}}$)	244.603	2.072	20.3	6.04
1 MeV equivalent neutron fluence ($\mathbf{n_{eq} \cdot cm^{-2} \cdot yr^{-1}}$)	6.62×10^{11}	4.03×10^{9}	3.97×10^{10}	1.12×10^{10}

Beam Gas Bremsstrahlung

- Updated tracking method applied
- Due to tracking method updating, the results decreased from CDR.

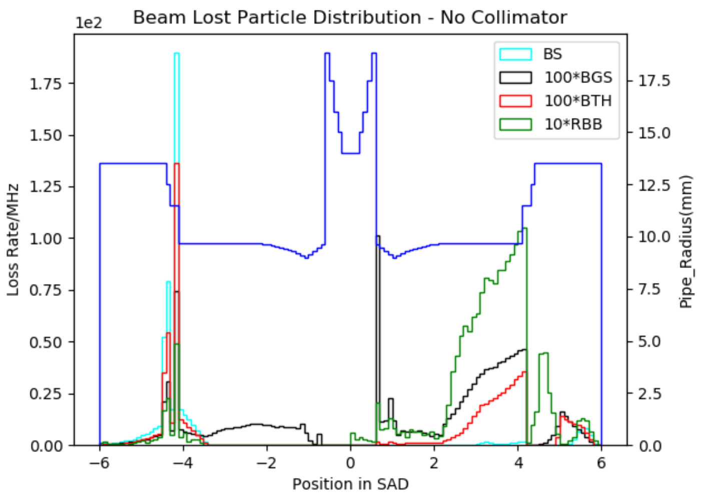


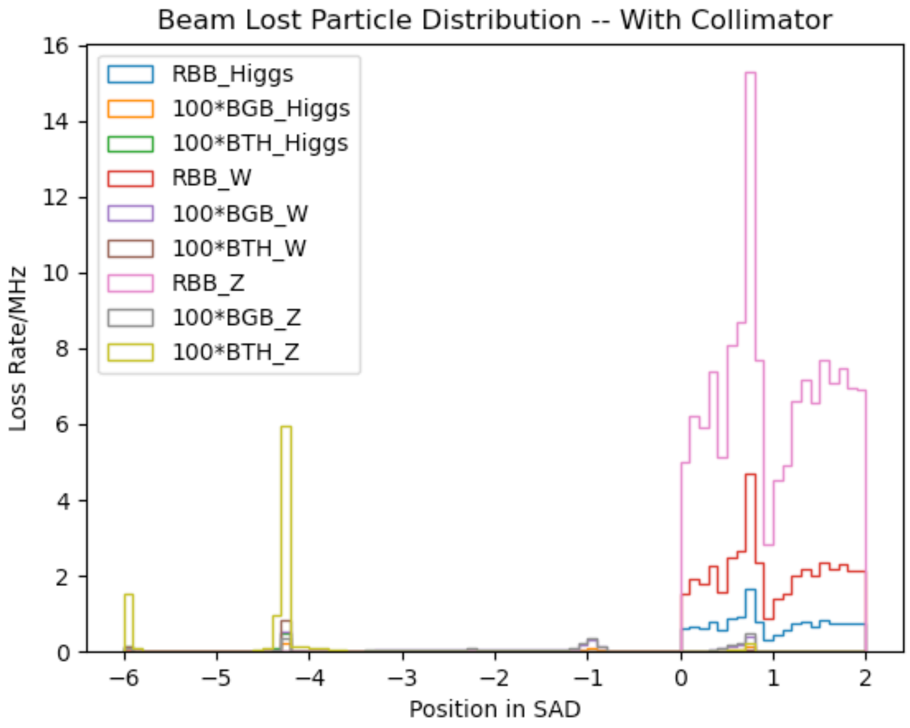


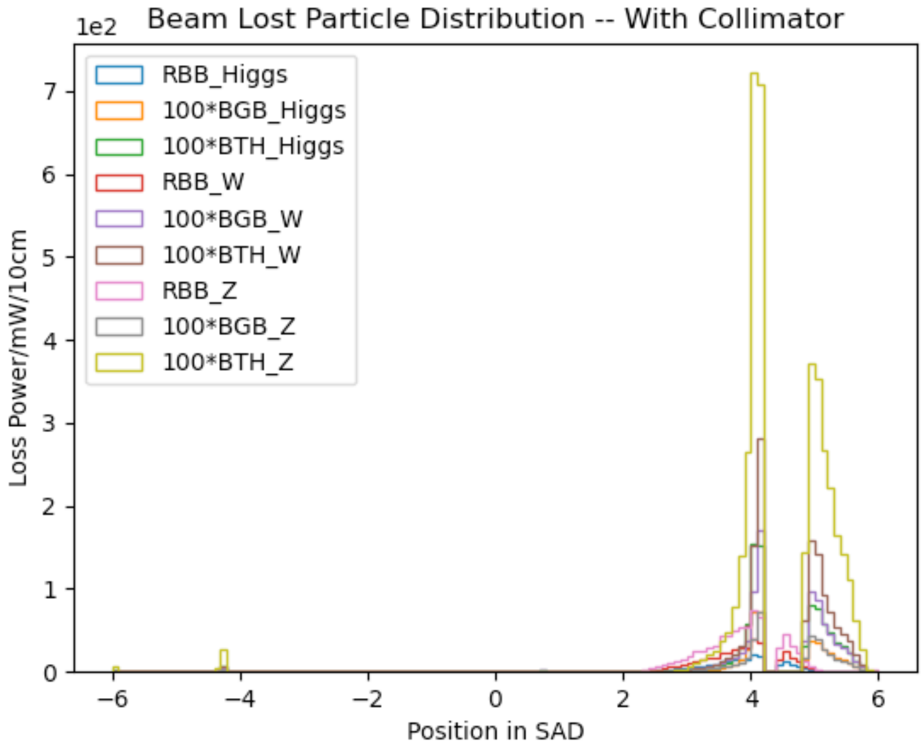
Mode	Hit Density($cm^{-2} \cdot BX^{-1}$)	TID($krad \cdot yr^{-1}$)	1 MeV equivalent neutron fluence ($n_{eq} \cdot cm^{-2} \cdot yr^{-1}$)
Higgs	0.359	363.614	9.84×10^{11}
Z(2T)	0.015	225.060	4.18×10^{11}

Lost distribution

- Downstream lost is higher with collimators.
- The lost within downstream QD0 is significant.
  - Mitigation and shielding are needed.







Detector Impact

- Preliminary results on 1st layer of vertex. Safety factor applied.

Background	Hit Density($cm^{-2} \cdot BX^{-1}$)		TID($krad \cdot yr^{-1}$)		1 MeV equivalent neutron fluence ($n_{eq} \cdot cm^{-2} \cdot yr^{-1}$)	
	Higgs	Z	Higgs	Z	Higgs	Z
Pair production	1.81	0.015	499.476	225.060	9.68×10^{11}	4.18×10^{11}
Synchrotron Radiation	0.026		15.65			
Radiative Bhabha	0.02		20.3		3.97×10^{10}	
Beam Gas	0.359	2.89×10^{-3}	363.614	181.97	9.84×10^{11}	4.99×10^{11}
Beam Thermal Photon	0.02		22.31		6.20×10^{10}	
Total	2.235		921.35		2.537×10^{12}	

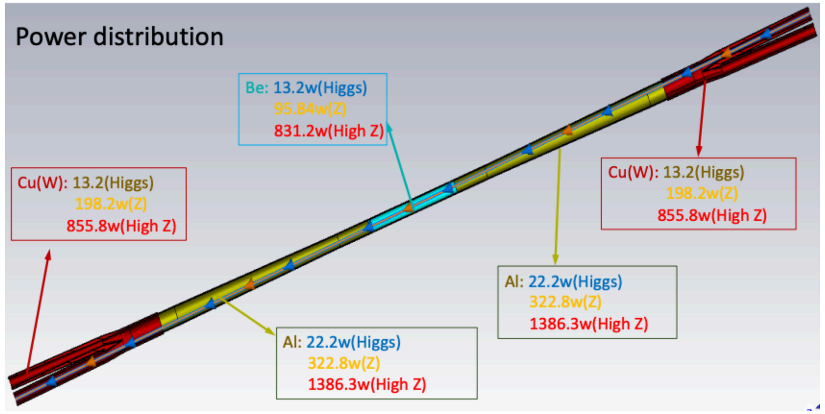
Summary & Outlook

- The finalization of the central beam pipe design has been determined.
  - All background simulation is updating using revised final design.
- Mask was chosen as the shielding of SR.
  - Be hitting number decrease from ~40000 to ~300 per bunch
- Tracking method of beam loss backgrounds has been updated.
- Simulation is performing for all three modes with CDR design and parameters.
  - Higgs mode has been almost finished. W and Z is under simulation.
- We plan to move to high luminosity case in coming months.

Thank You

Backup

HOM analysis for asymmetry



- Maximum HOM Heat load at High-Lumi Z
  - 415.6(Be) + 1386.3(Al) + 855.85 (Cu) W

Y. Liu

距 IP 距离（mm）	形状	内径(mm)	材料	内表面积 (mm²)	备注	总功率&Higgs (W)	功率密度&Higgs (W/cm²)	功率分布&Higgs (W)	总功率&Z (W)	功率密度&Z (W/cm²)	功率分布&Z (W)	总功率&H Z (W)	功率密度&H Z (W/cm²)	功率分布&H Z (W)
0－120	圆直管	直径28	Be	10556		6.6	0.06	6.60	47.92	0.45	47.92	415.6	3.94	415.60
120-205	圆直管	直径28	Al	7477		22.2	0.04	2.71	322.8	0.53	39.44	1386.3	2.27	169.36
205-655	圆锥管	直径28过渡到直径40	Al	48071	taper:1.75			17.44			253.54			1088.85
655-700	圆直管	直径40	Al	5655				2.05			29.83			128.09
700-780	圆直管	直径40	Cu	10052	远程连接装置预留	13.2	0.03	2.60	198.2	0.39	39.05	855.85	1.68	168.64
780-805	圆面过渡到跑道型	水平方向直径40-40，垂直方向直径40-30.7	Cu	3124				0.81			12.14			52.41
805-855	跑道型过渡到两个圆面	上游直径12 下游直径20	Cu	6932				1.79			26.93			116.30
855-1110	上游圆锥管 下游圆直管	上游直径12过渡到20，下游直径20	Cu	30906				8.00			120.08			518.50