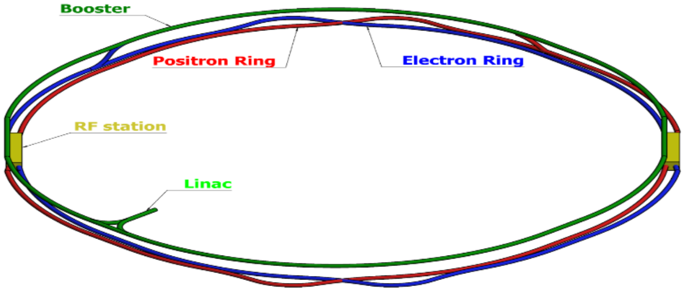


Radiation Backgrounds at CEPC

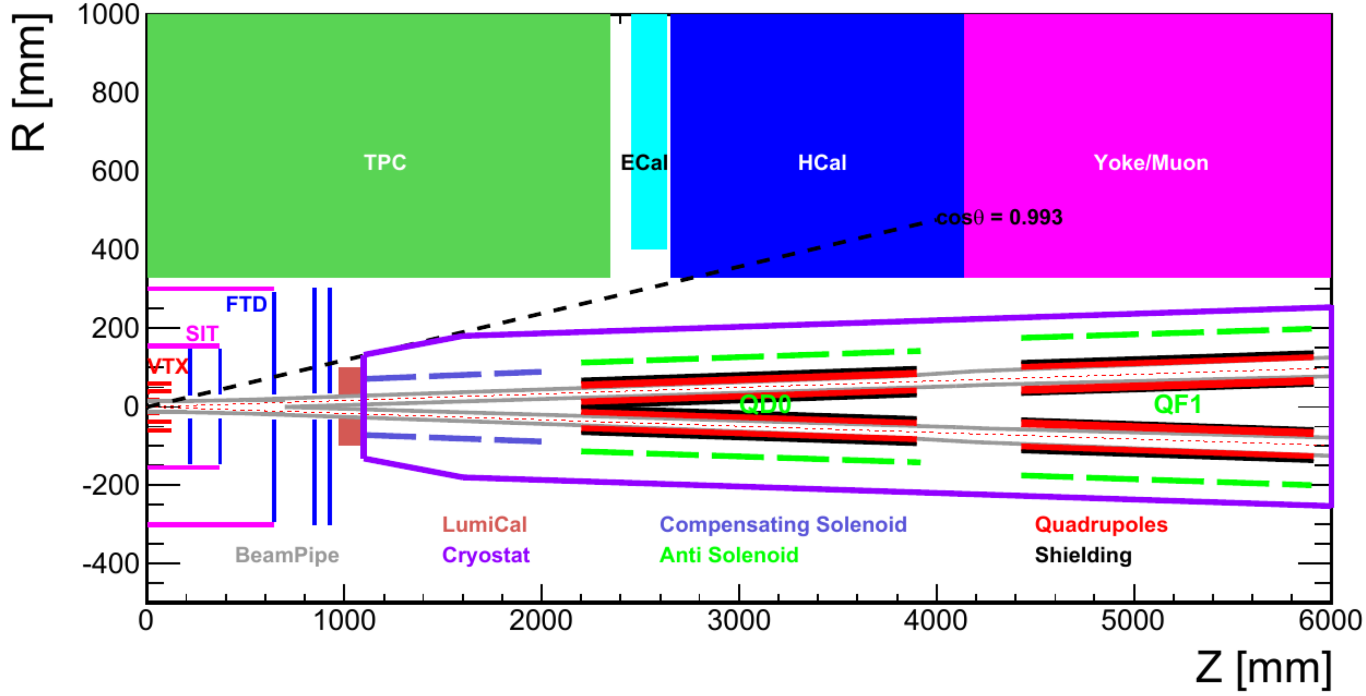
Hongbo Zhu (IHEP)
On behalf of the CEPC MDI group

International Workshop on High Energy Circular Electron Positron Collider
6 – 8 November, 2017

Outline

- Interaction region (IR) Layout
- Background categorization and estimation
- Summary and plan

Interaction Region



- More Updates: forward tracking optimization (geometry + cable routing), central Beryllium beam pipe extension, detector shielding, and more …
- Machine/detector integration

Machine Parameters

	Higgs	W	Z
Number of IPs	2		
Energy (GeV)	120	80	45.5
Circumference (km)	100		
SR loss/turn (GeV)	1.68	0.33	0.035
Half crossing angle (mrad)	16.5		
Piwinski angle	2.75	4.39	10.8
N_e/bunch (10^{10})	12.9	3.6	1.6
Bunch number	286	5220	10900
Beam current (mA)	17.7	90.3	83.8
SR power /beam (MW)	30	30	2.9
Bending radius (km)	10.9		
Momentum compaction (10^{-5})	1.14		
β_{IP} x/y (m)	0.36/0.002		
Emittance x/y (nm)	1.21/0.0036	0.54/0.0018	0.17/0.0029
Transverse σ_{IP} (um)	20.9/0.086	13.9/0.060	7.91/0.076
ξ_x/ξ_y/IP	0.024/0.094	0.009/0.055	0.005/0.0165
V_{RF} (GV)	2.14	0.465	0.053
f_{RF} (MHz) (harmonic)	650 (217500)		
Nature bunch length σ_z (mm)	2.72	2.98	3.67
Bunch length σ_z (mm)	3.48	3.7	5.18
HOM power/cavity (kw)	0.46 (2cell)	0.32(2cell)	0.11(2cell)
Energy spread (%)	0.098	0.066	0.037
Energy acceptance requirement (%)	1.21		
Energy acceptance by RF (%)	2.06	1.48	0.75
Photon number due to beamstrahlung	0.25	0.11	0.08
Lifetime due to beamstrahlung (hour)	1.0		
Lifetime (hour)	0.33 (20 min)	3.5	7.4
F (hour glass)	0.93	0.96	0.986
L_{max}/IP ($10^{34}cm^{-2}s^{-1}$)	2.0	4.1	1.0

Go higher

- **Bunch spacing**: ~ 500/50/30 ns for Higgs, W and Z

Radiation Backgrounds

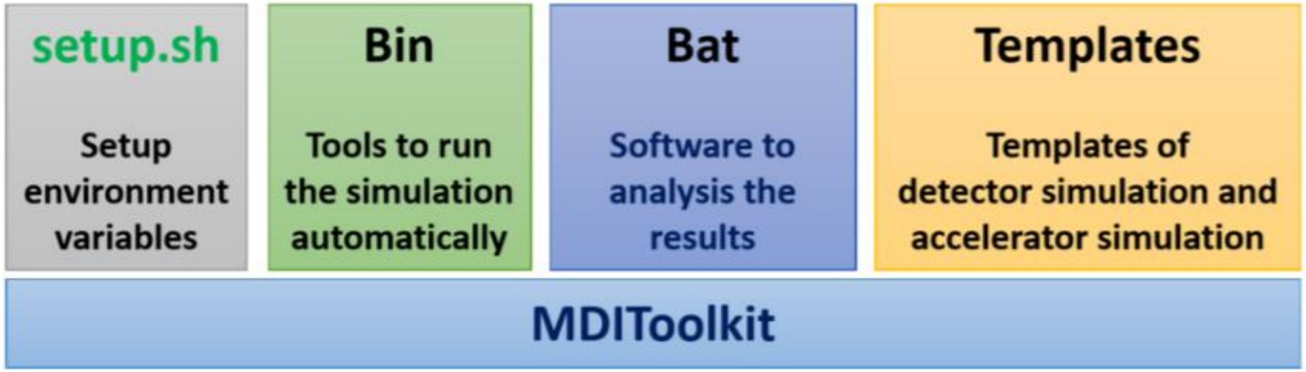
- Much less harsher than LHC, but not detector background free
- Beam induced backgrounds → *Unavoidable source, could be barely suppressed with parameter tuning*
  - Beamstrahlung
  - Pair production
  - Hadronic background
- Machine induced backgrounds → *Possible reduction with improved machine design*
  - Synchrotron radiation
  - Radiative Bhabha scattering
  - Beamstrahlung
  - Beam-gas interaction
  - Beam injection
  - Beam dumps
  - … and more

(Radiative Bhabha scattering, Beamstrahlung, Beam-gas interaction:) Beam lost particles (energy acceptance of 1.5%)

MDIToolkit

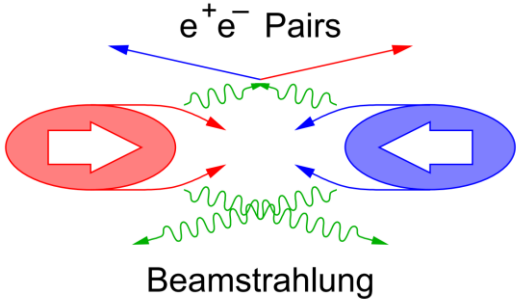
Q. Xiu

- Our former postdoc integrated most of the event generators, particle tracking and detector simulation (+ customized code development) into one framework → making background standardized and easier

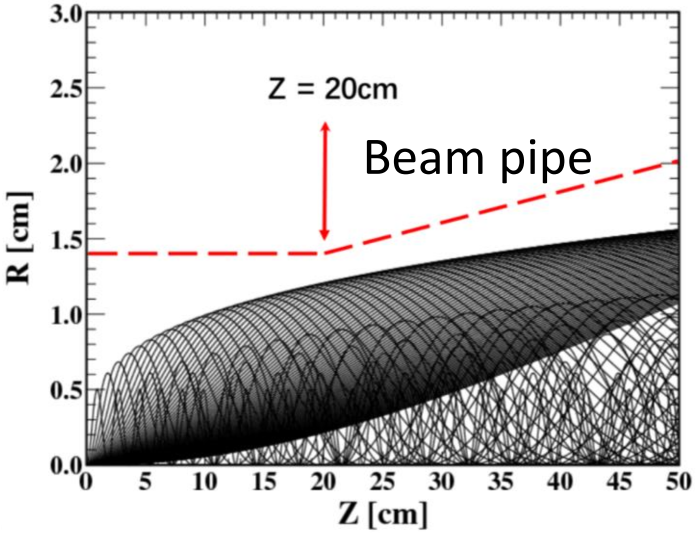


- Most of the presented results based on this framework
- Maintenance and further development underway

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

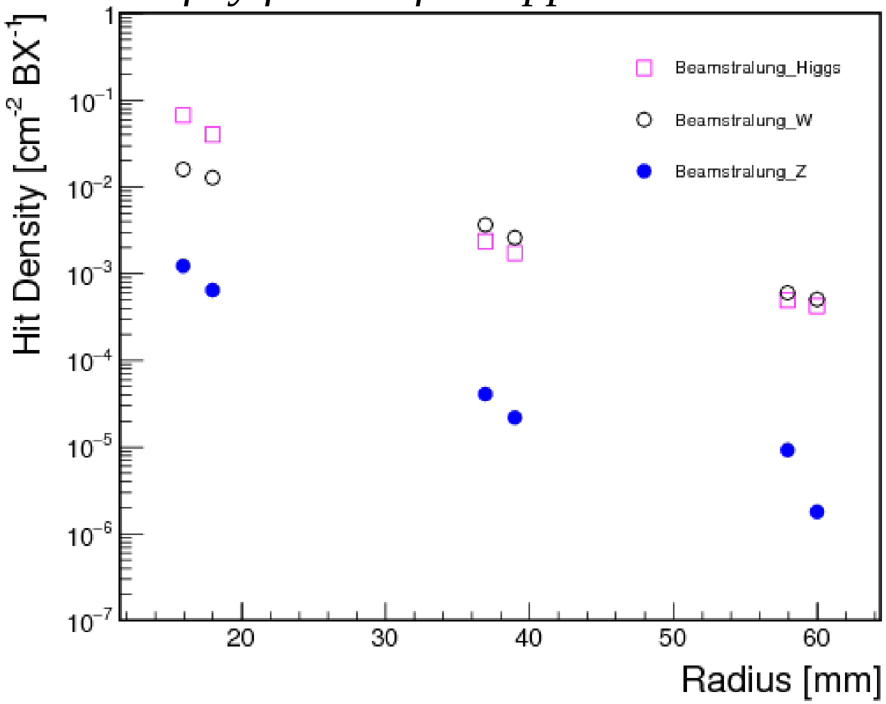
Most of the charged particles from pair production are confined within the beam pipe and not interacting with any machine/detector components.

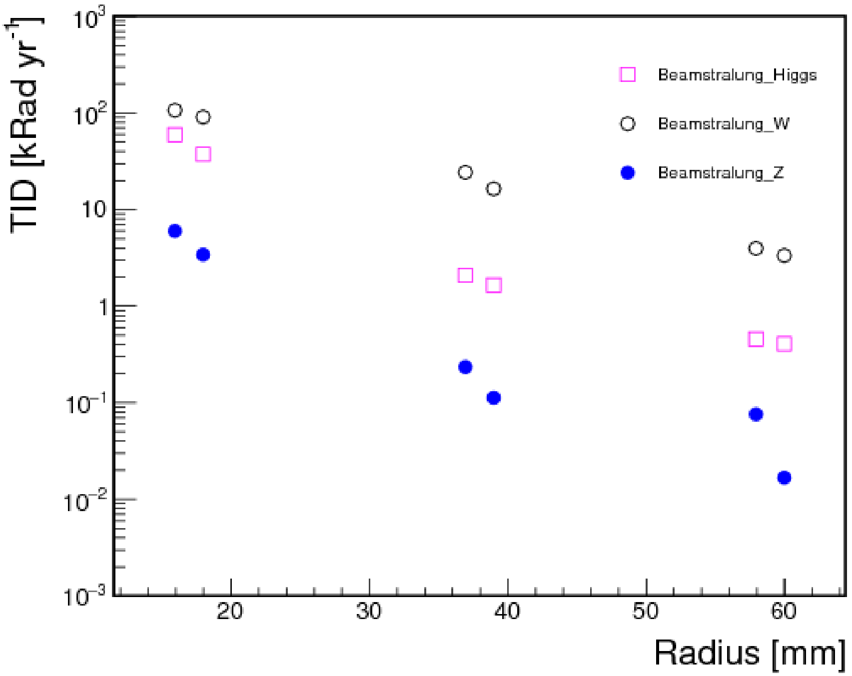
Pair Production

W. Xu and X. Wang

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

Safety factor of 10 applied





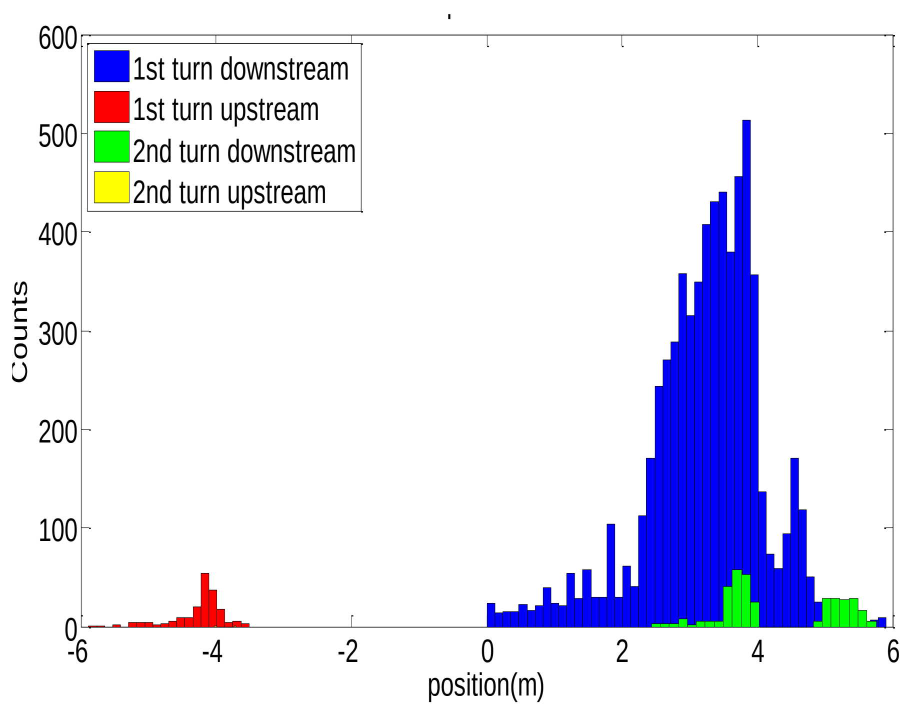
Hadronic backgrounds not shown but negligible

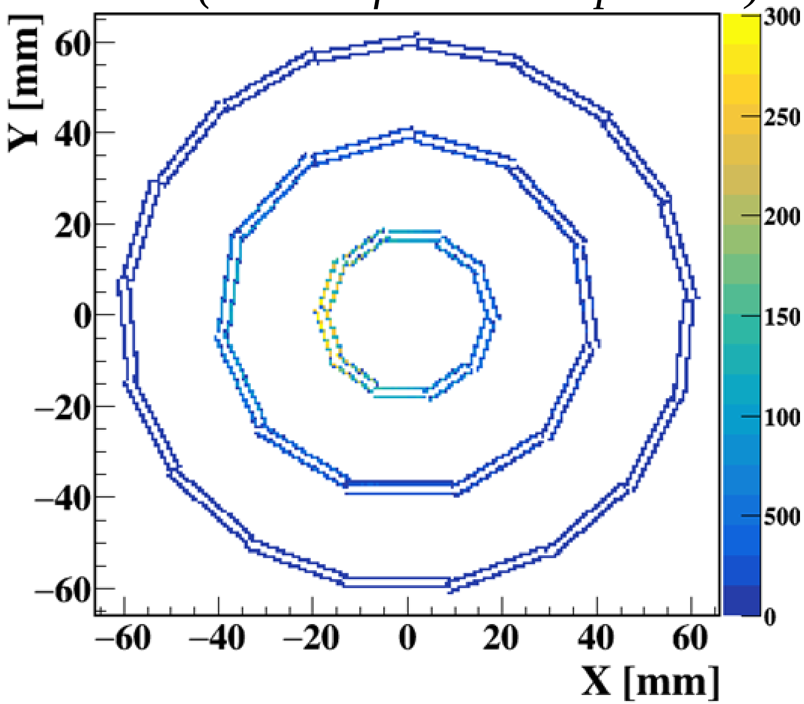
Radiative Bhabha Scattering

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)

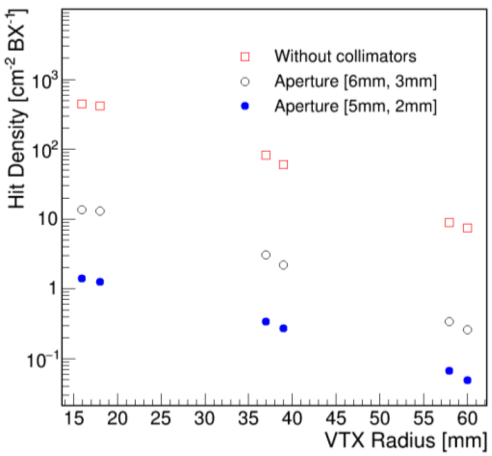


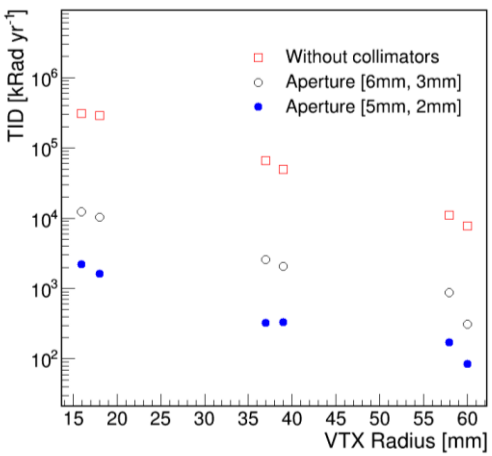


Collimators

- 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

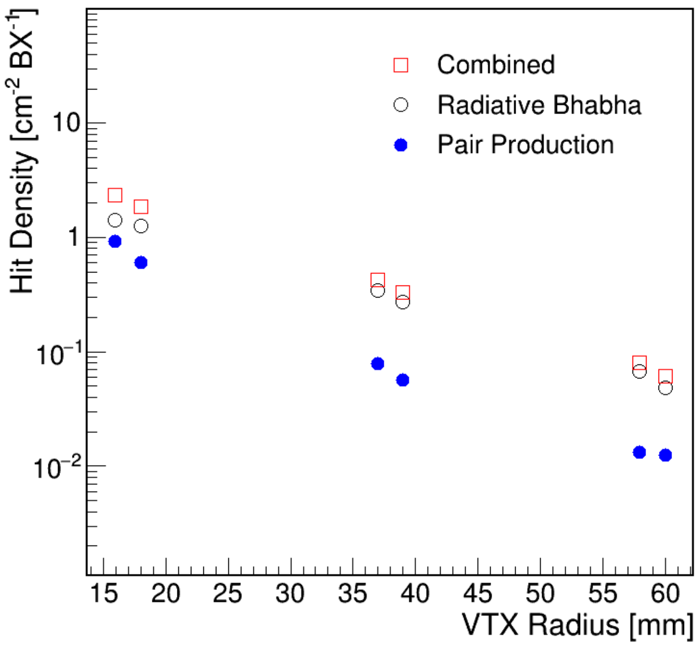


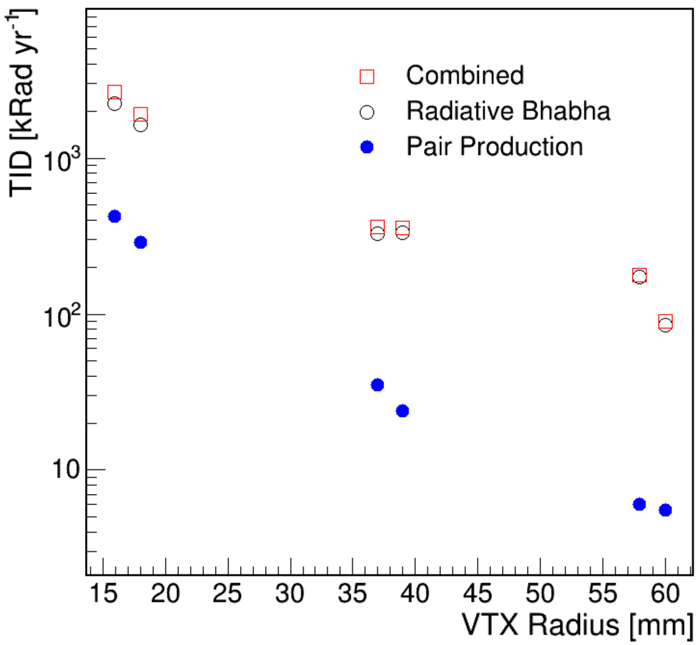


- Significant reduction in hit density and TID
- Effective (not shown) to suppress backgrounds from beam lost particle due to beamstrahlung

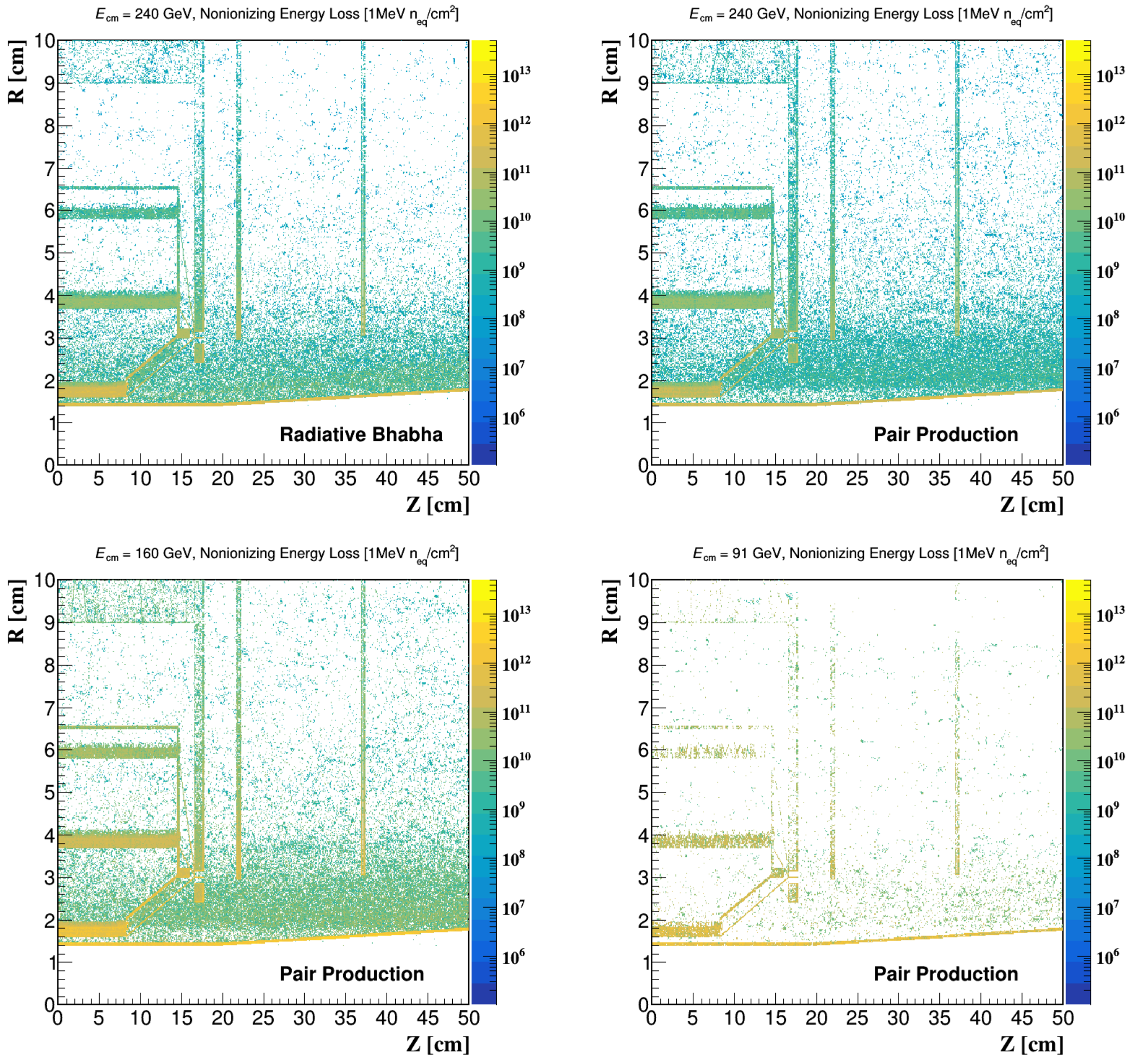
Combined Results

- 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





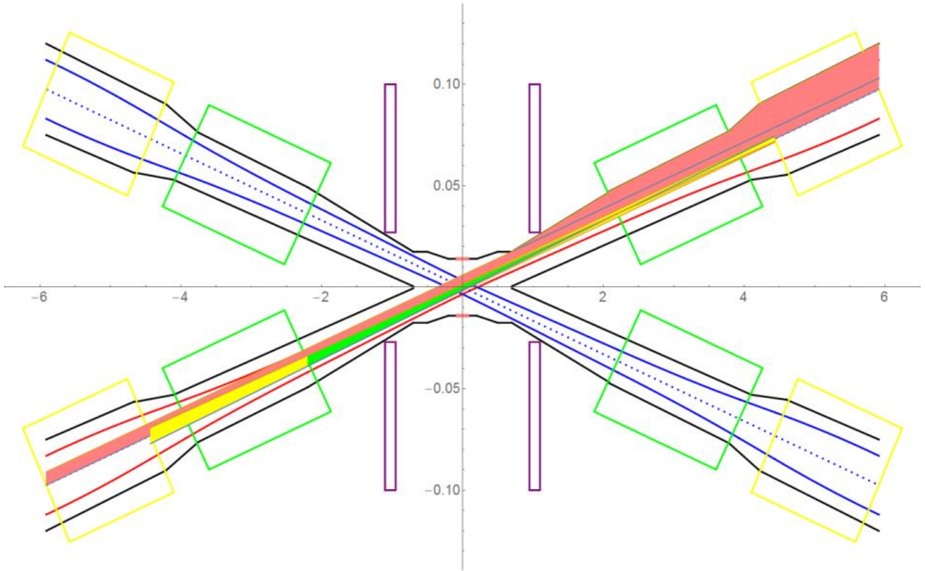
NIEL Distributions



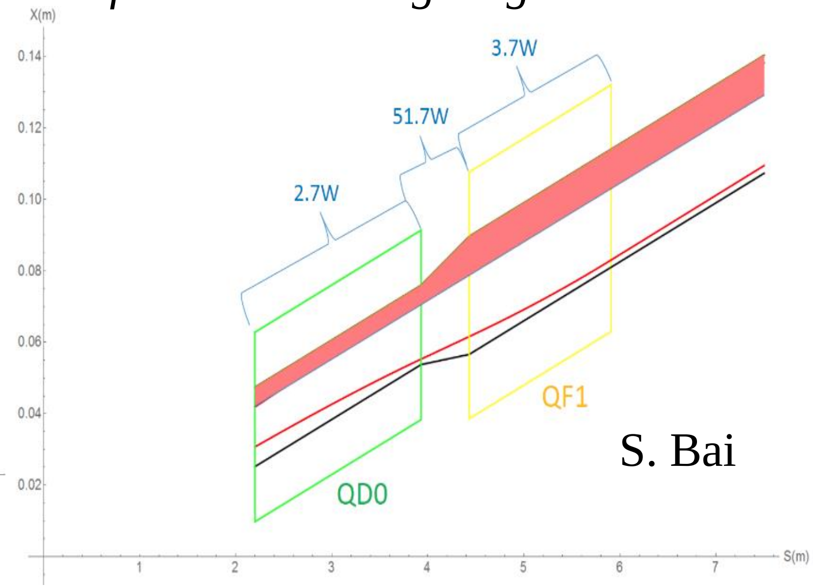
Synchrotron Radiation

- Special and crucial background at circular machines

SR photons from the last dipole and final focusing quadrupoles



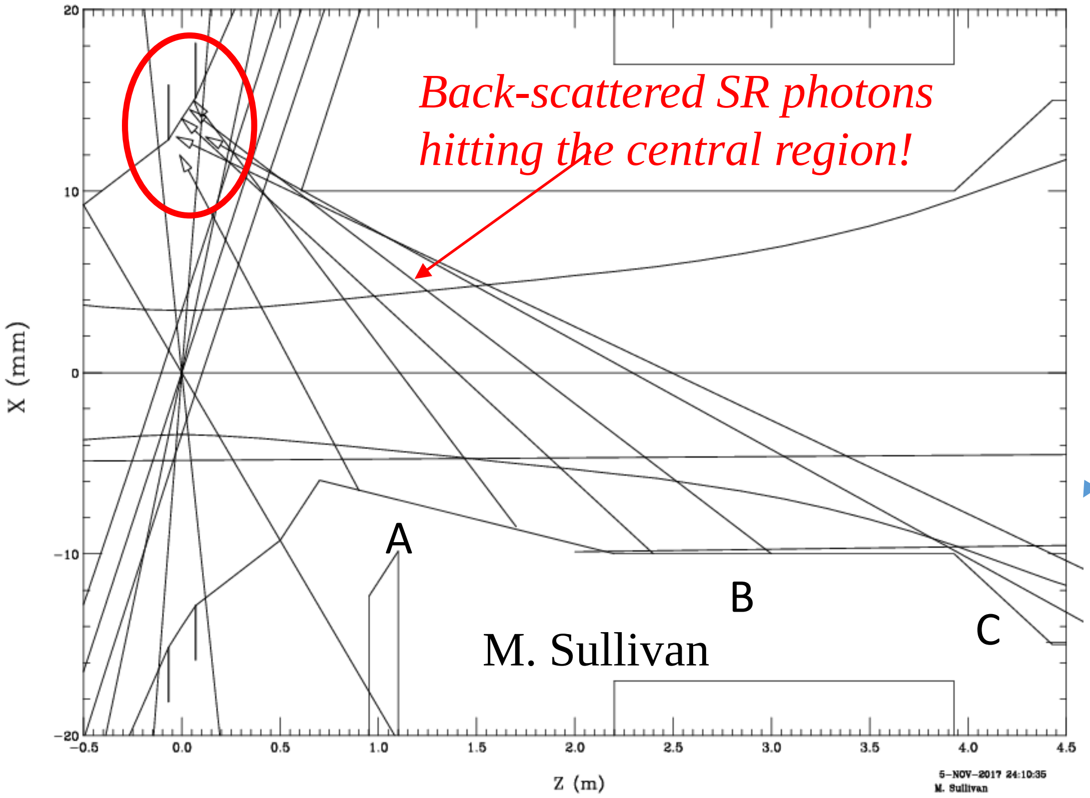
Power deposition of SR photons from the bending magnet

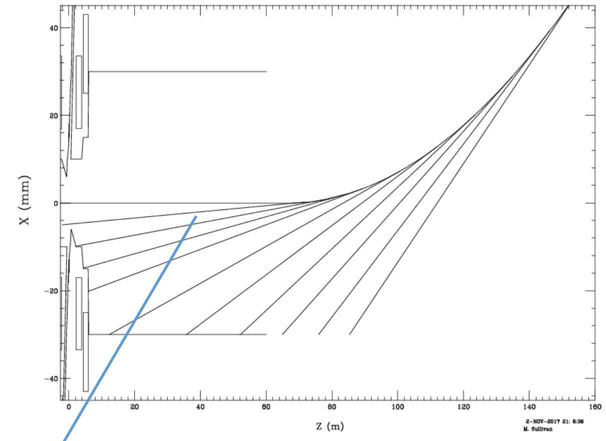


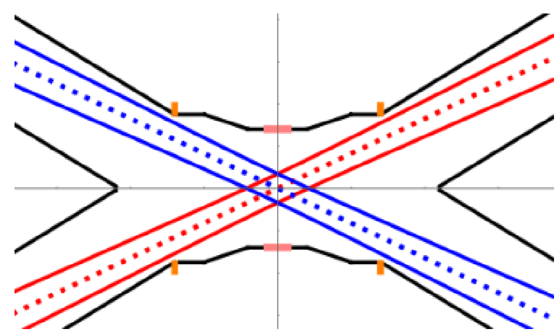
S. Bai

Central Region

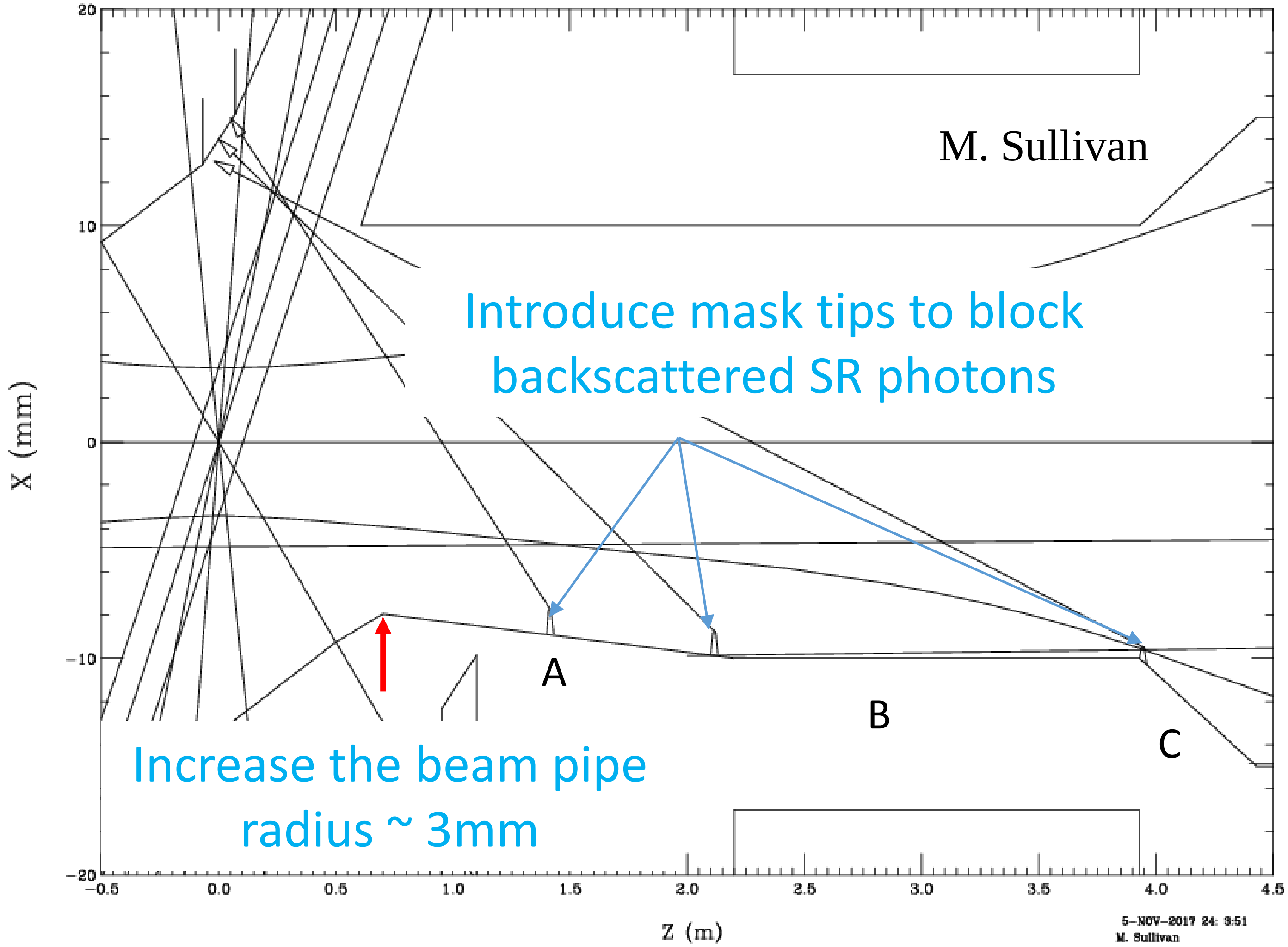
- Direct and back-scattered SR photons should be avoided as much as possible.







SR Photon Suppression



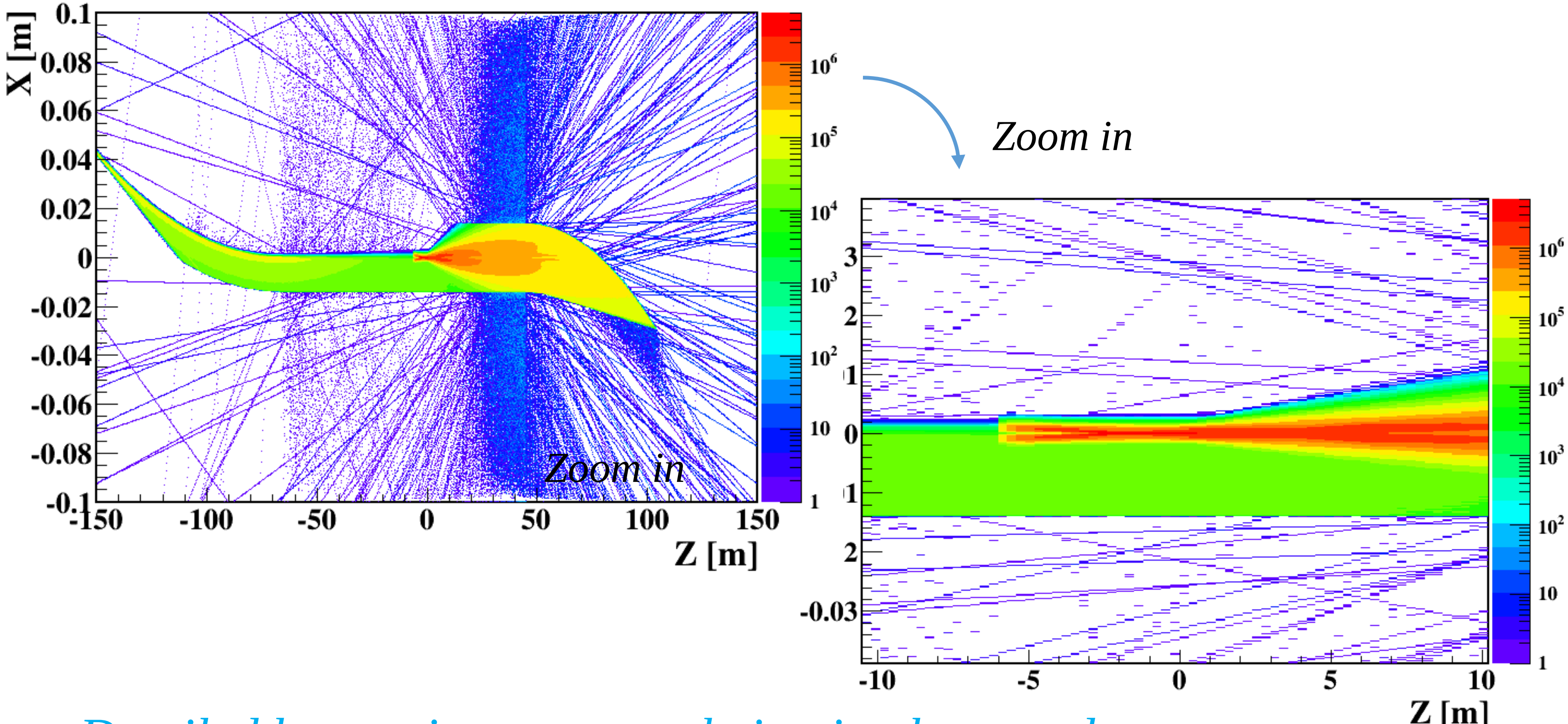
Effectiveness of Mask Tips

Surface	Where	Watts	Incident Photons	Scattered fraction	CP SA fraction	Est. hits on CP
A	0.7-2.2	37.25	1.27e10	.009	4.7e-5	5.2e3
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*