Status of Beam Induced Background Study

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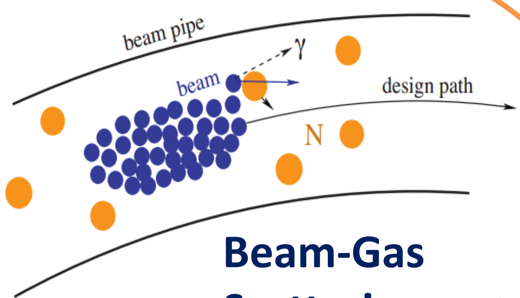
on behalf of MDI Group

CEPC-SPPC Group Meeting
Beihang University
2016-9-3

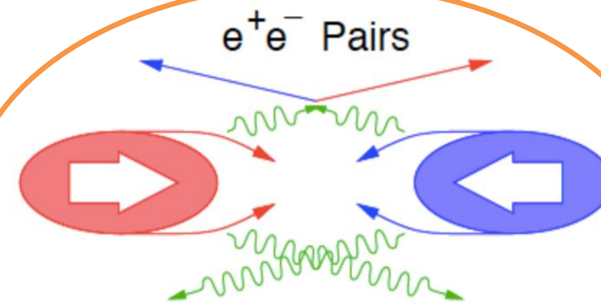
Outline

- Overview of beam induced background at CEPC
- Progress of synchrotron radiation study
- Summary and outlook

Sources of Beam Induced Background



Beam-Gas Scattering



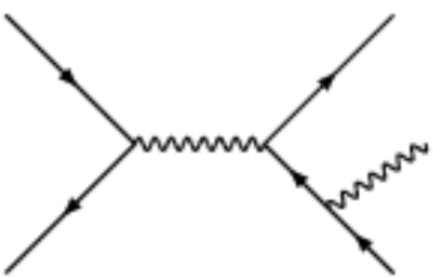
Beamstrahlung

IP1

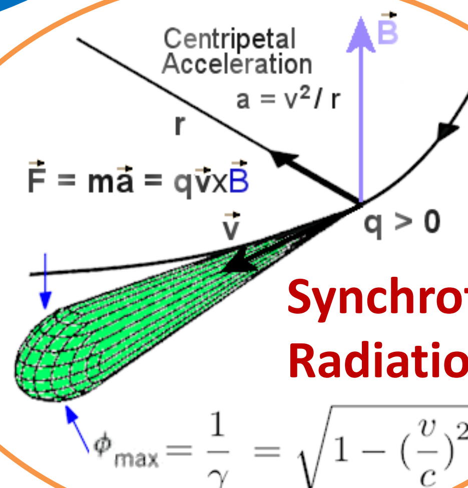
50 bunches
Revolution frequency: **5475.46** Hz
$\mathbf{3.7 \times 10^{11}}$ particles/Bunch
L: $\mathbf{2 \times 10^{34} cm^{-2} s^{-1}}$

IP3

Beam Lost Particles
Energy Loss > 2%

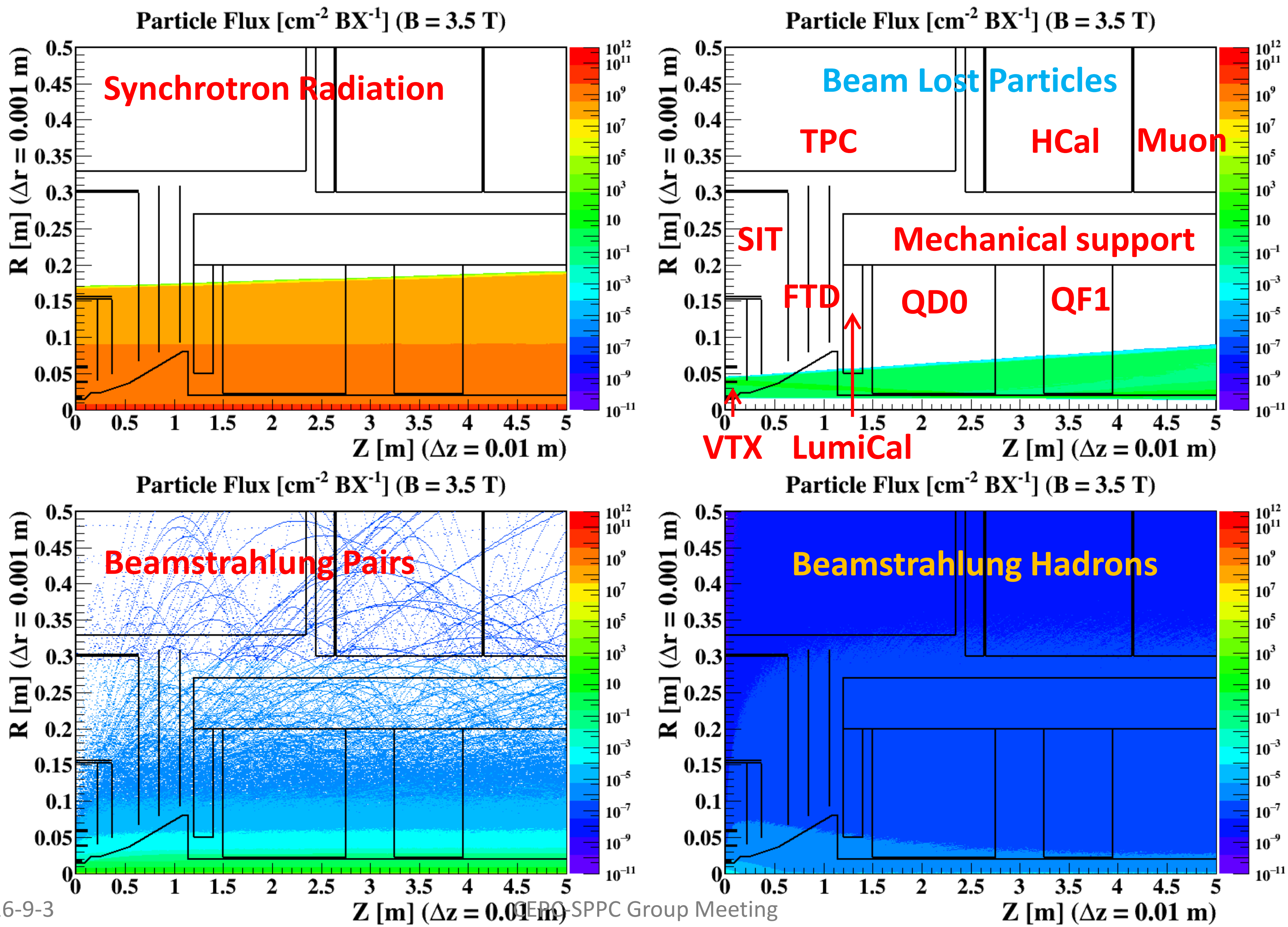


Radiative Bhabha

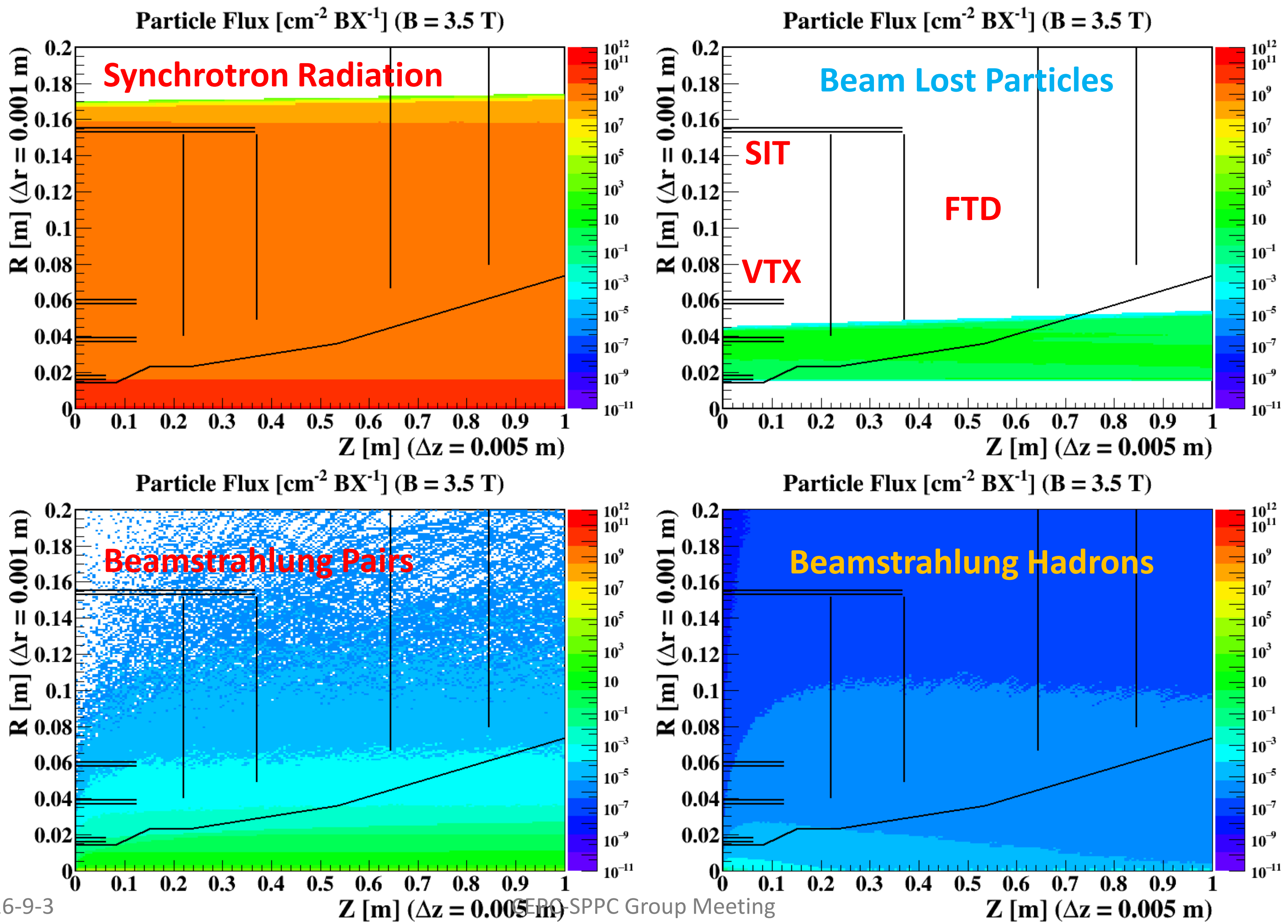


Synchrotron Radiation

Particle Flux at IR $[cm^{-2}BX^{-1}]$



Particle Flux at VTX [$cm^{-2}BX^{-1}$]

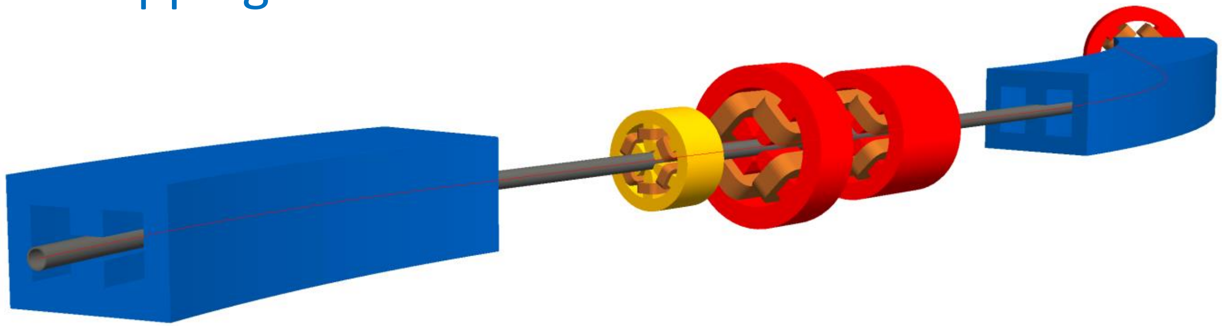


Summary of Beam Induced Background

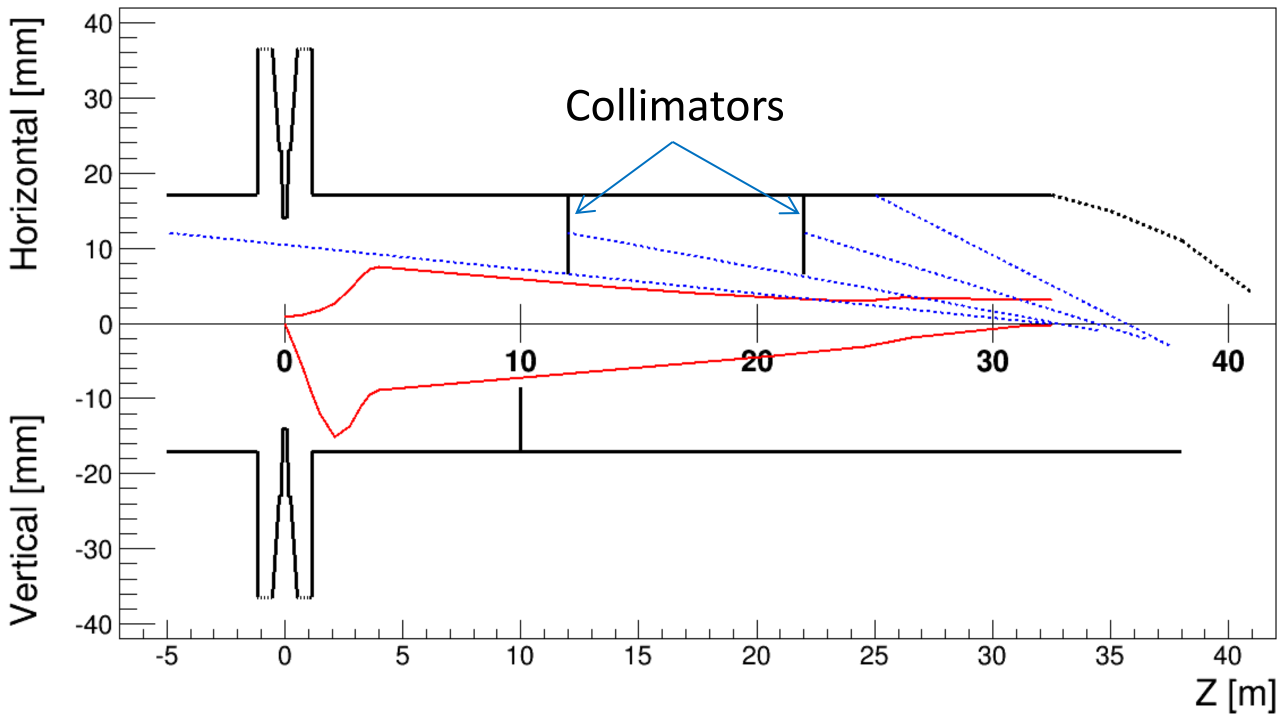
Background Type	Generators	Sub-type	Particle Flux at VTX $[cm^{-2}BX^{-1}]$	Particle Energy [GeV]	Priority
Synchrotron Radiation	*Geant4; BDSIM*	*Dipole*	**~ 10^{10}**	**~ 0.001**	★★★
		Quadrupole	**~ 10^{6}**	**~ 0.007**	
Beam Lost Particles	*BBBrem; SAD*	*Radiative Bhabha*	**~ 10**	**~ 120**	★★
		Beam Gas Scattering	↑	↑	
Beamstrahlung	*Guinea-Pig++; PYTHIA6*	*Pairs*	**~ 10^{-2}**	**~ 0.05**	★
		Hadrons	**~ 10^{-5}**	**~ 2**	

Tools for Synchrotron Radiation Study

- Existing code
  - Developed in Fortran. Difficult for maintenance.
  - Difficult to define complex IR geometry (to study scattering of photons).
- Decide to develop a new tool for synchrotron radiation study
  - Core idea: track beam particles in 6 dimensions and generate synchrotron photons with Monte Carlo method
  - BDSIM:
    - A particle tracking code for accelerator based on Geant4
    - Construct the accelerator elements and magnetic field by reading lattice file
  - Extract the synchrotron photon information from G4UserSteppingAction in Geant4

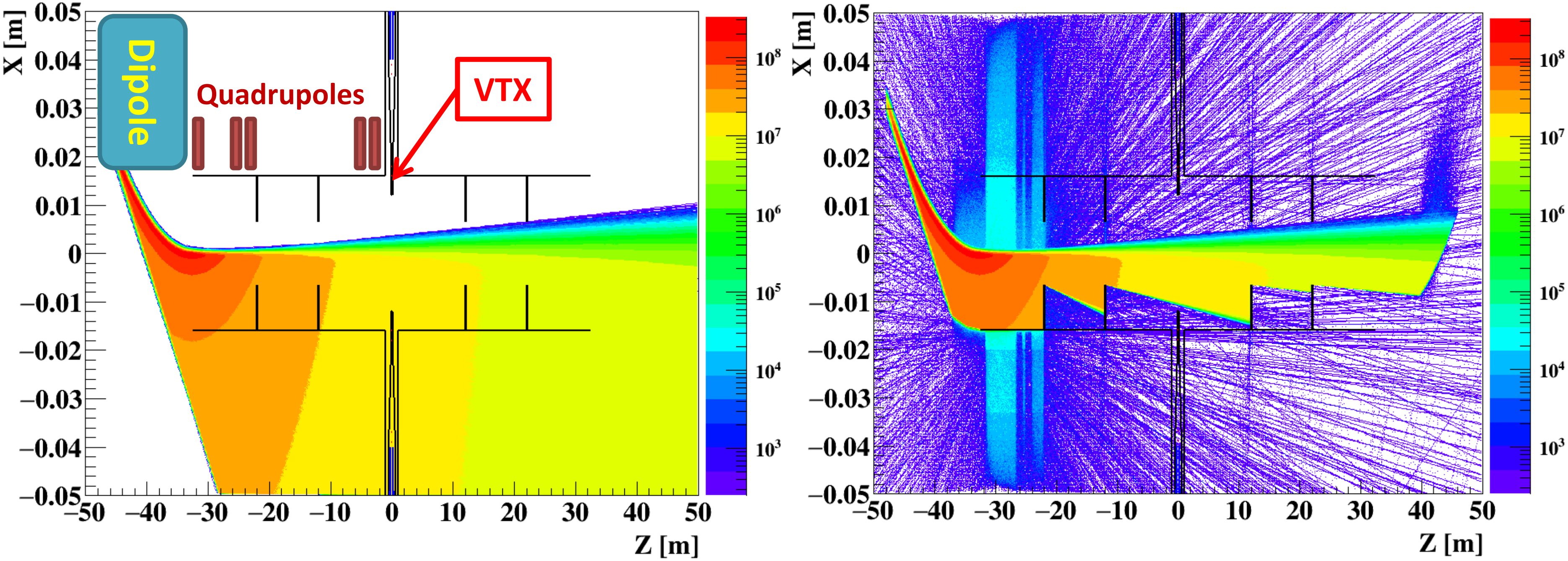


Collimators for Synchrotron Radiation



- Collimators for synchrotron radiation from dipole are designed
- Material: Tungsten
- Thickness: 10 cm

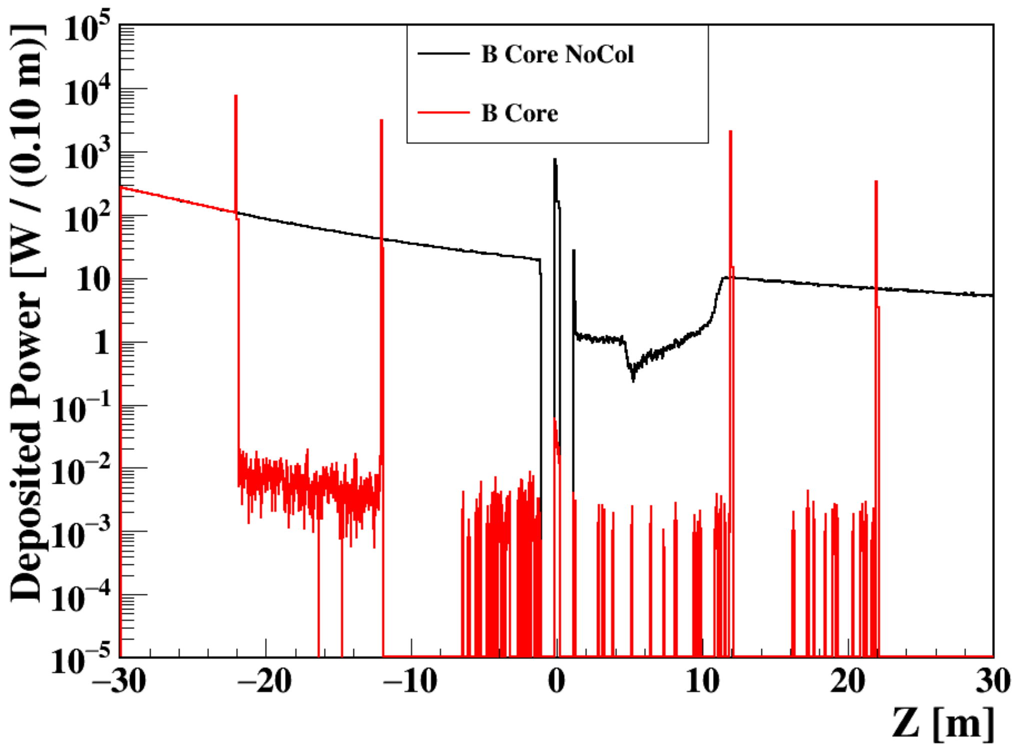
Synchrotron from Last Dipole



Horizontal

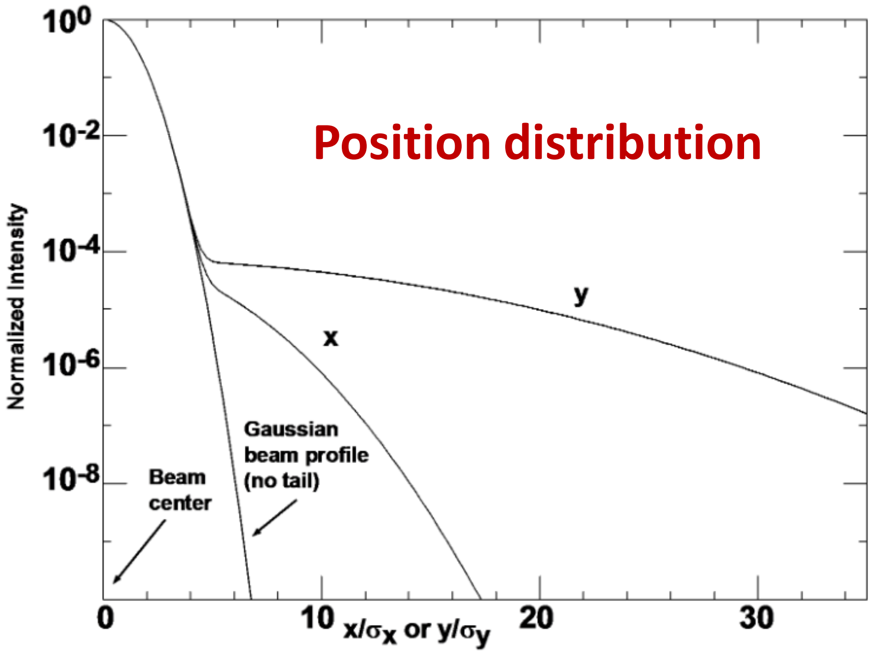
- In horizontal direction, synchrotron from dipole magnets can be well suppressed by the collimators
- Scattered photons could be further suppressed by adding shielding

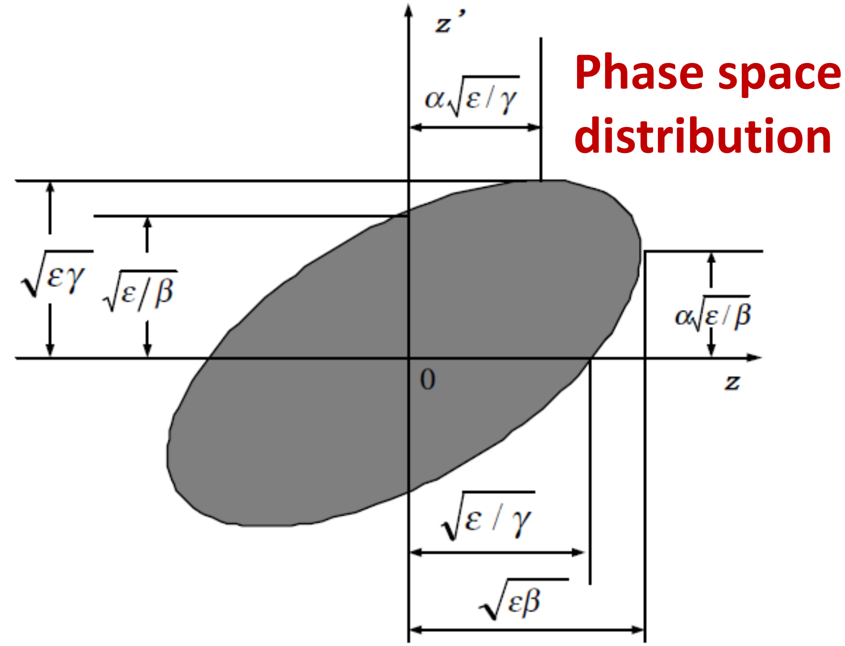
Power of Synchrotron from Last Dipole



- The collimators could suppressed the synchrotron radiation with a factor of 10^4. For further suppression:
  - Reduce the critical energy of synchrotron radiation (1 MeV → 100 keV)
  - Increase the thickness of collimators
- Power deposited at collimators are about 10 kW

Beam Halo



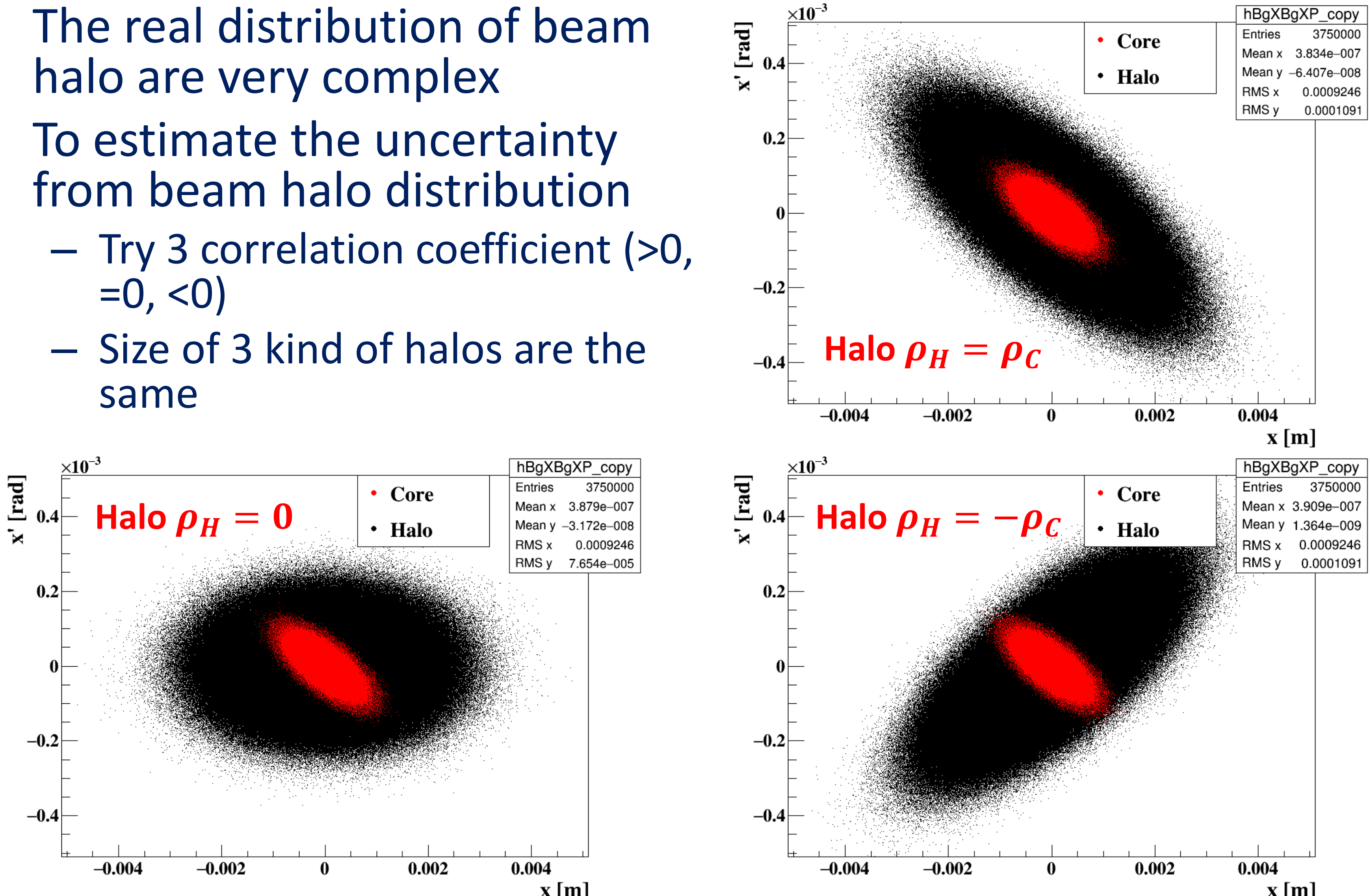


- Particles in beam halo will produce more and harder photons when passing through quadrupoles
- Use a double Gaussian distribution to describe the distribution in size
  - Narrow Gaussian for beam core, Wide Gaussian for beam halo
  - $\sigma_x^{halo} = 3.4\sigma_x^{core}$; $\sigma_y^{halo} = 10\sigma_y^{core}$
  - **Fraction of beam halo: assumed to be 0.5%**

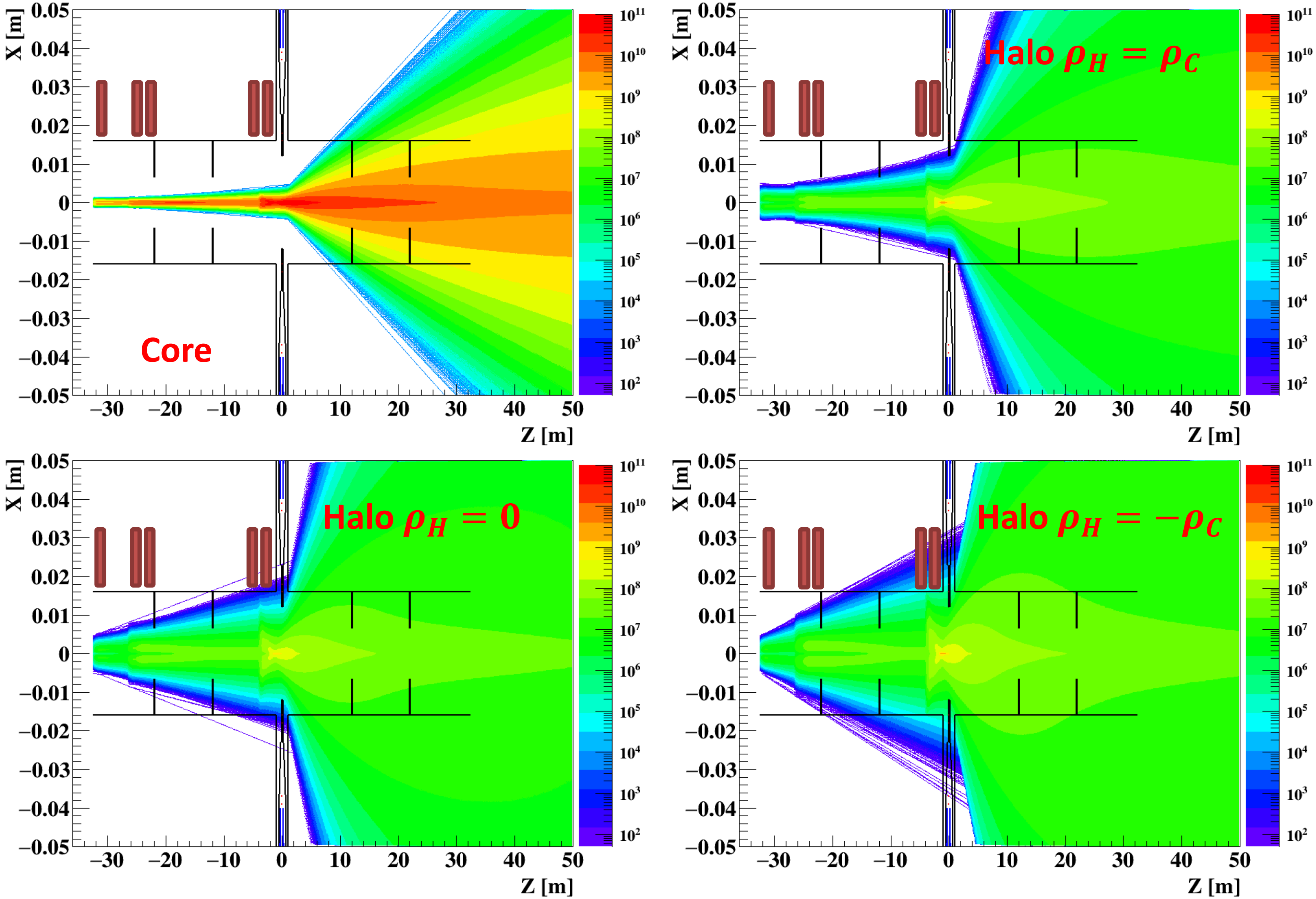
From Mike Sullivan

Distribution of Beam Halo

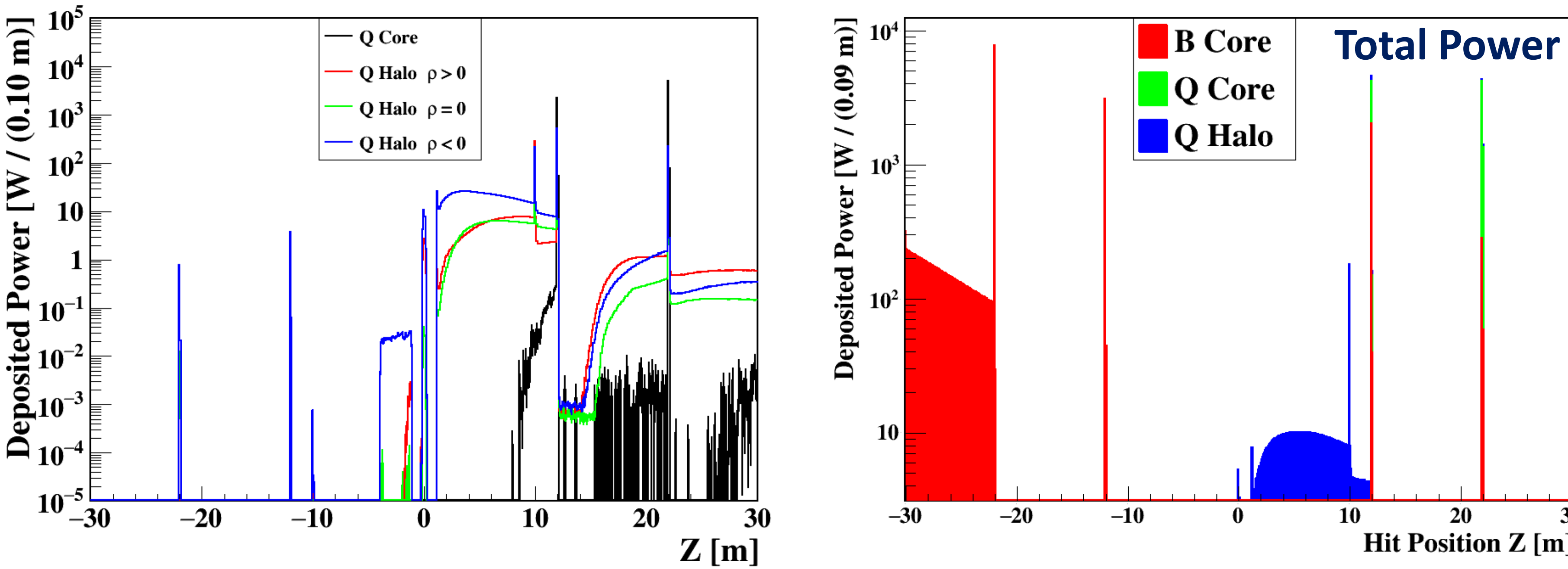
- The real distribution of beam halo are very complex
- To estimate the uncertainty from beam halo distribution
  - Try 3 correlation coefficient (>0, =0, <0)
  - Size of 3 kind of halos are the same



Synchrotron from Quadrupoles



Power Deposited at Beam Pipe



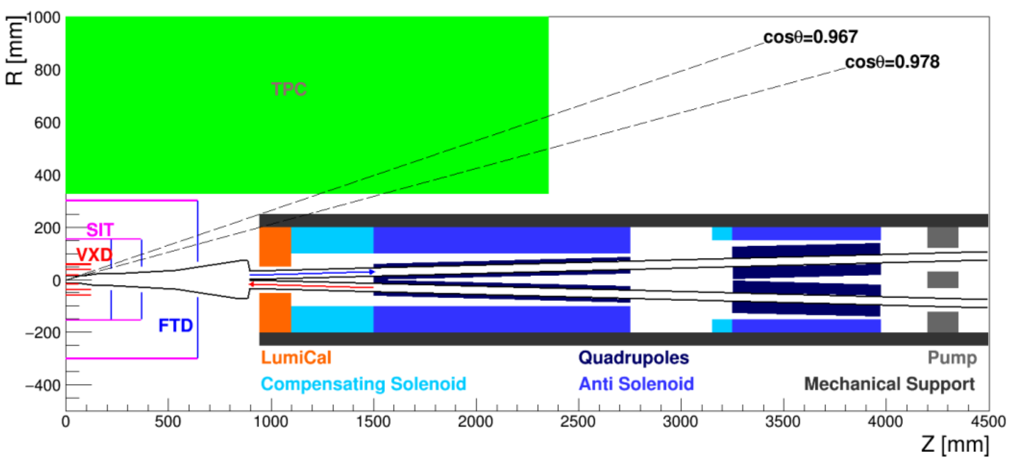
- Most power will be absorbed by collimators
- The level of beam halo particles should be kept in a reasonable level to suppress the synchrotron radiation from quadrupoles

Summary of Progresses

- Synchrotron radiation should be the most important background at CEPC
- Developed a new tool to study the synchrotron radiation more conveniently
  - Developed with Geant4 (C++, Object Oriented)
  - Can be used both to generate synchrotron photons and simulate the interaction between photons and materials

Summary of Further Studies

- Critical energy of the last dipole magnet should be kept at about 100 keV
  - Stop synchrotron photons much easier
- Level of beam halo particles
  - 0.5% of beam core in the simulation
  - Want to suppress it as much as possible
- Cooling of collimators for synchrotron radiation
  - Power deposited ~ 10 kW
- Could we set a boundary between detector and accelerator in the polar angle?
  - A fiducial region of detector according to the cross-section?

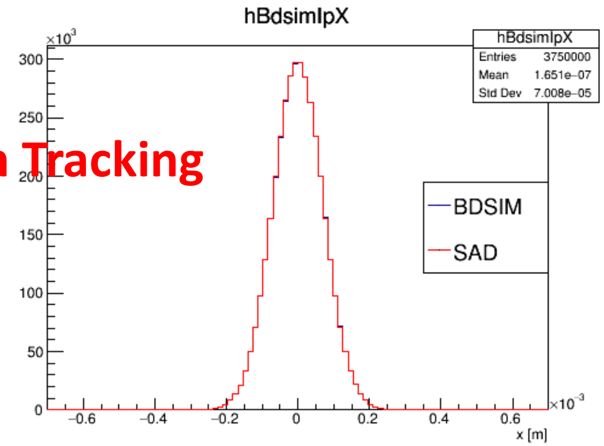


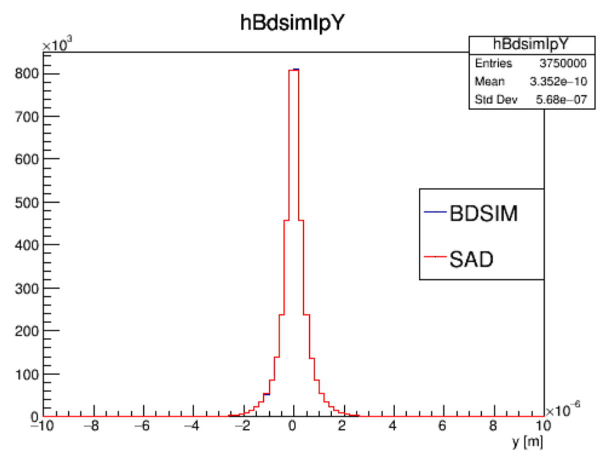
Thank You

Backup

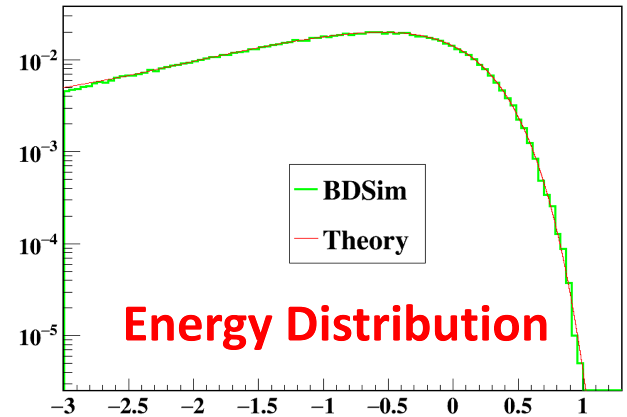
Validation of the New Method

Beam Tracking

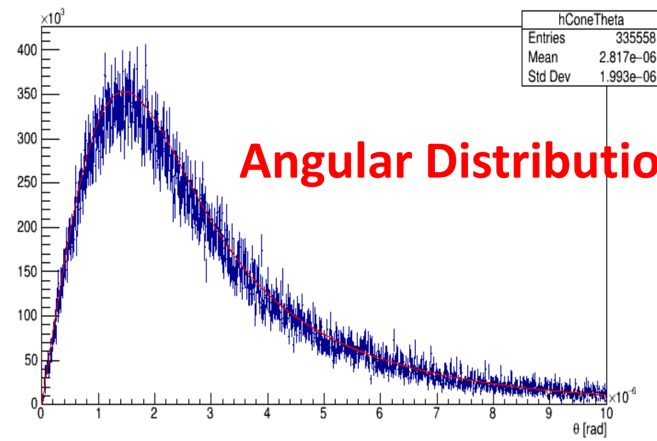




Energy Distribution



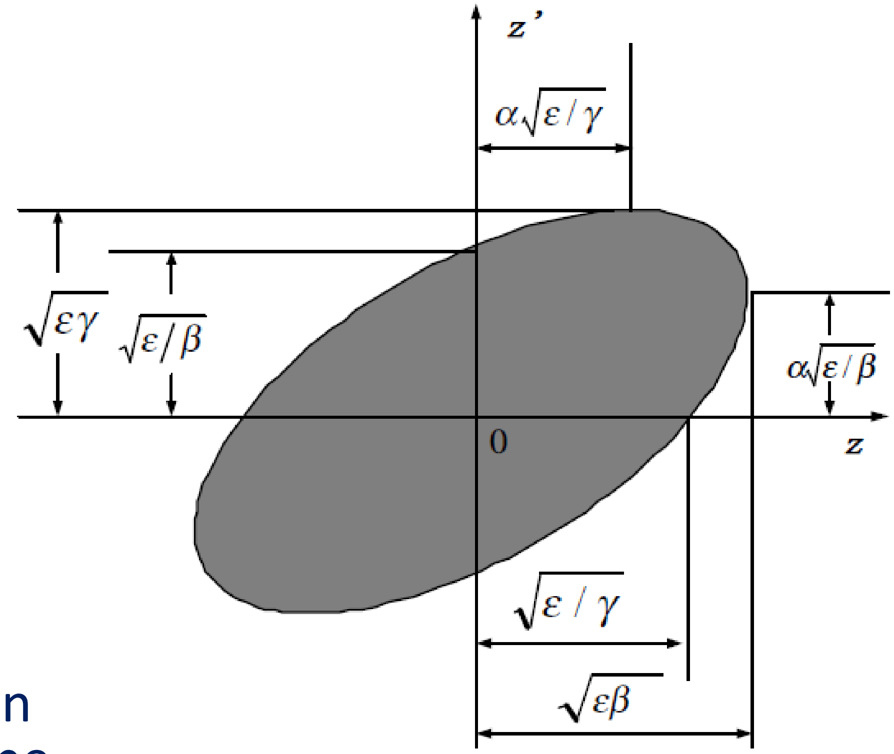
Angular Distribution



- Tracking beam particles in the interaction region (not long distance), the accuracy of BDSIM (Geant4) and SAD are the same
- The distributions of generated synchrotron photons agree with the classical electrodynamic theory

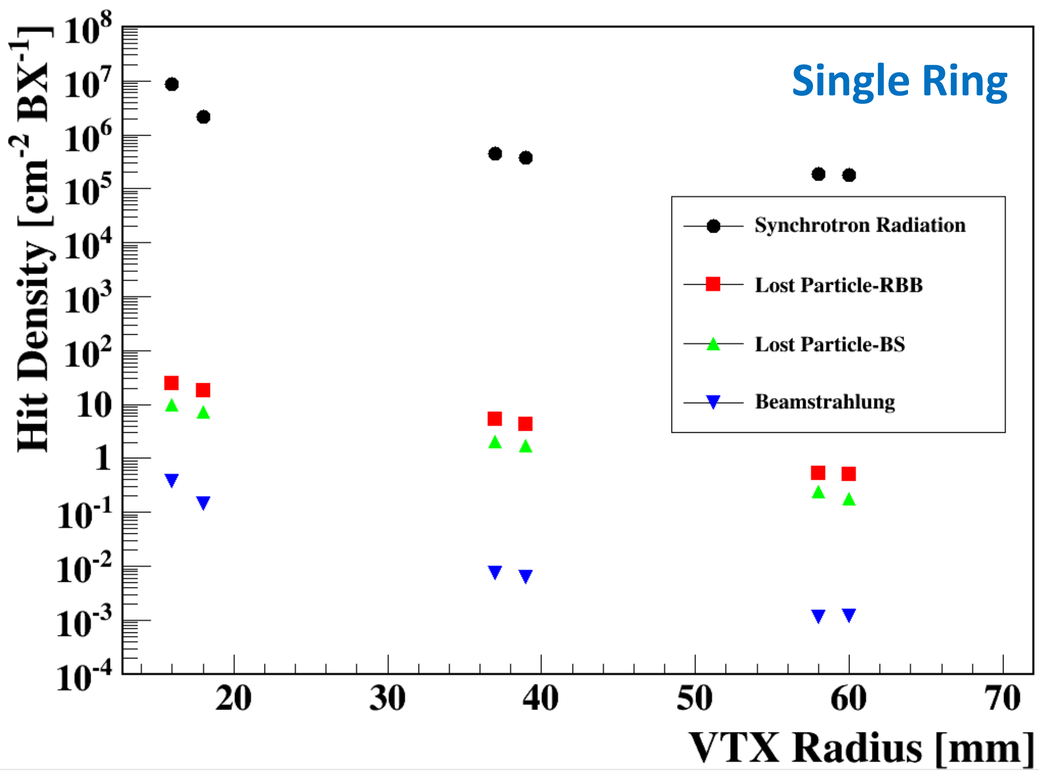
Distribution of Beam Particles in Phase Space

- Twiss parameters
  - $\alpha = -\frac{1}{2}\frac{d\beta(s)}{ds}$
  - $\gamma = \frac{1+\alpha^2}{\beta}$
- $\sigma_x = \sqrt{\varepsilon\beta}$
- $\sigma_{x'} = \sqrt{\varepsilon\gamma}$
- When $\alpha \neq 0$, x and x' are correlated in phase space
  - $\rho = -\frac{\alpha}{\sqrt{1+\alpha^2}}$
  - The distribution of synchrotron photons from beam halo will be affected
- The real distribution of beam halo in phase space is not clear by now



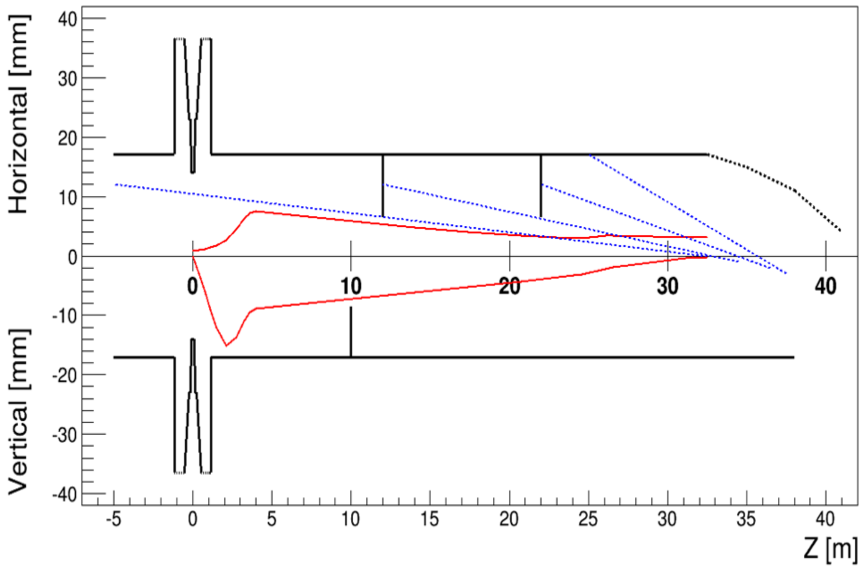
$$\gamma x^2 + 2\alpha x x' + \beta x'^2 = \varepsilon$$

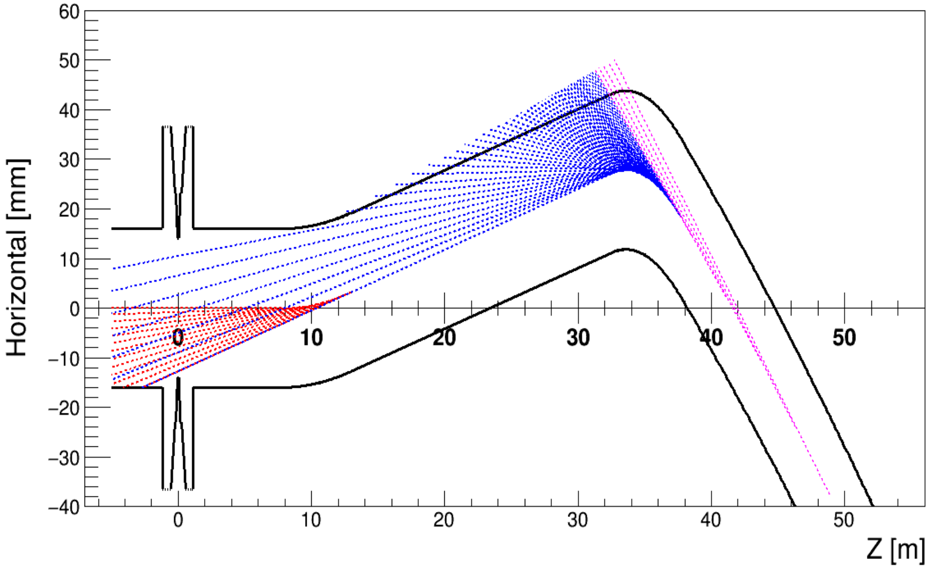
Hit Density Without Shielding



- Synchrotron radiation is the most important issue because of the huge photon flux
- The beamstrahlung in the partial double ring might be more serious than that in single ring due to the modification of beam pipe.
- Shielding and protection are essential to reach the physical requirements

Methods to Suppress Background Level





- Synchrotron Radiation
  - Shielding the synchrotron photons with collimators
  - Let the synchrotron photons pass through the IR by well designed beam orbit.
- Lost Beam Particles
  - Add collimators along the storage ring.

Average Energy of Particles