Progress of MDI

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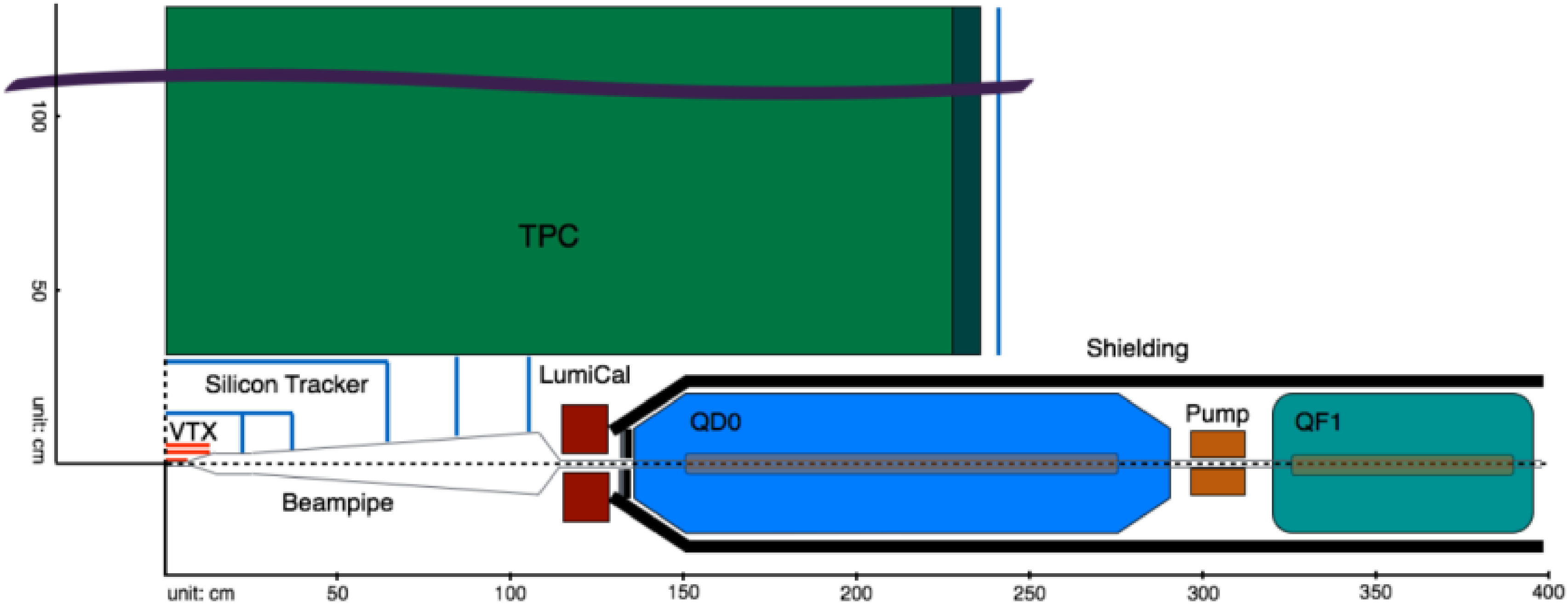
Outline

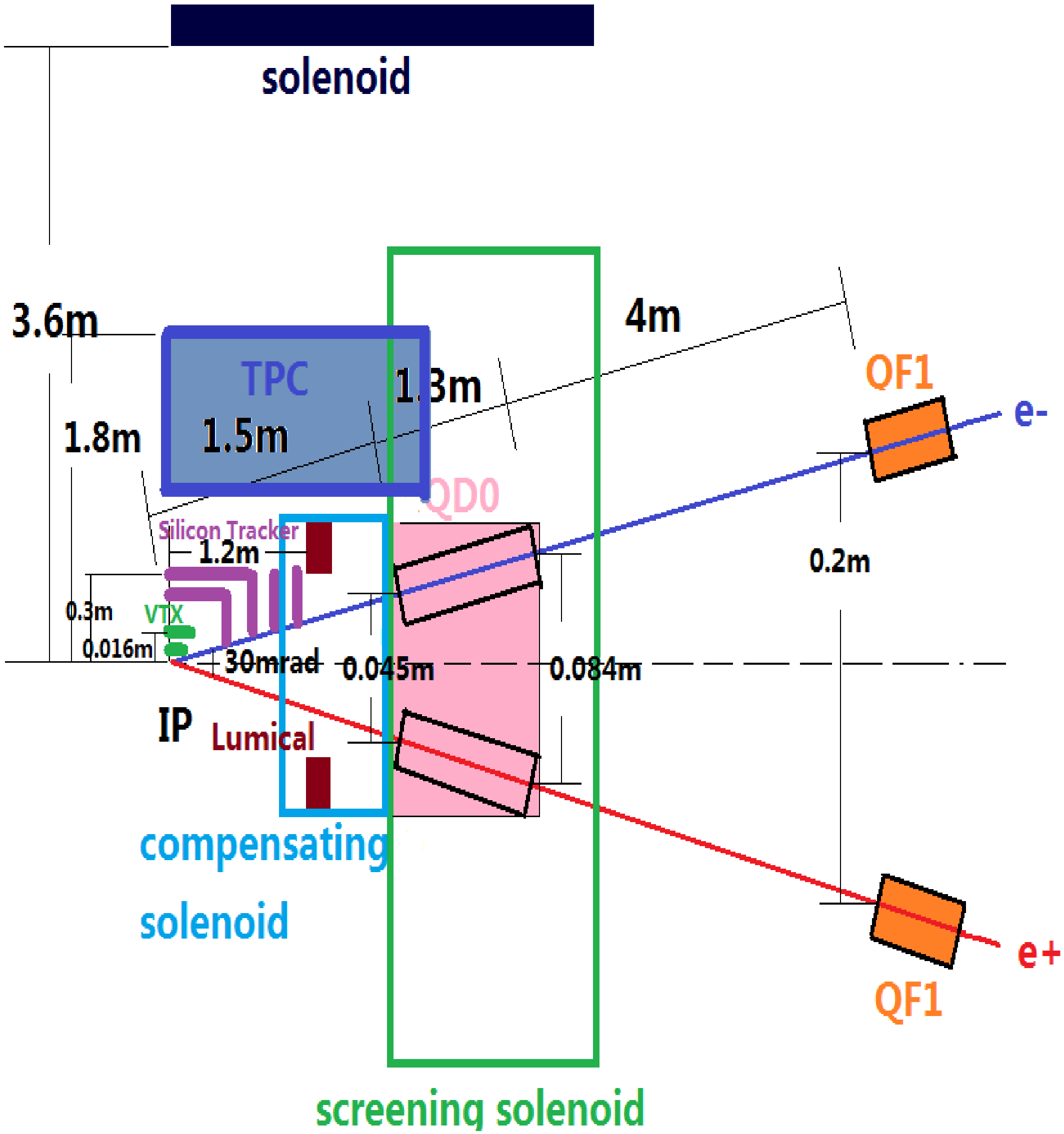
- Tasks of MDI
  - IR lattice and layout design
  - Final Focusing magnets
  - Luminosity Measurement
  - Beam Induced Background Estimation
  - Detector shielding and radiation protection
  - Mechanics and integration
- Regular group meetings
  - Indico: http://indico.ihep.ac.cn/category/323/
  - Twiki: cepc.ihep.ac.cn/~cepc/cepc_twiki/index.php/Machine_Detector_Interface
- Will compare the difference between single ring and partial double ring.

IR Layout -- Single Ring



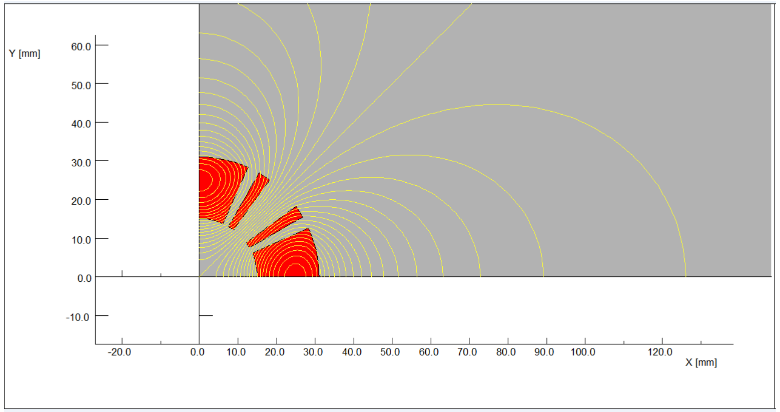
- L* = 1.5m
- To meet requirements from both accelerator and detector
- Suppress the beam backgrounds as more as possible

IR Layout -- Partial Double Ring

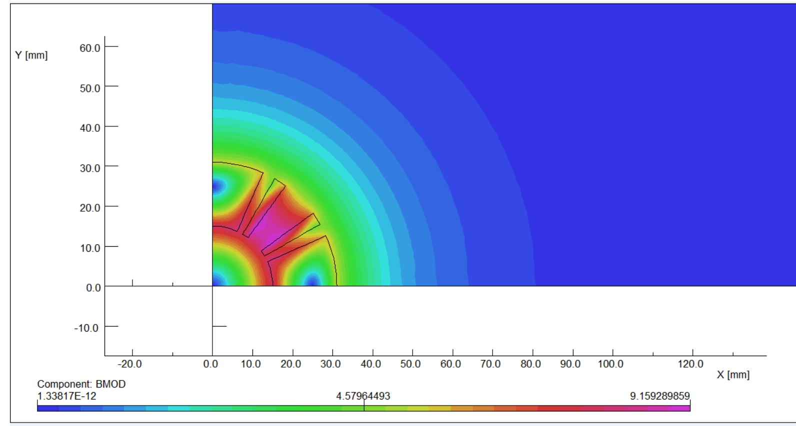


- Crossing Angle = $30mrad$
- L* = 1.5m
- Influence on the detector is under studying

Final Focusing Magnetic -- Single Ring



2D flux lines

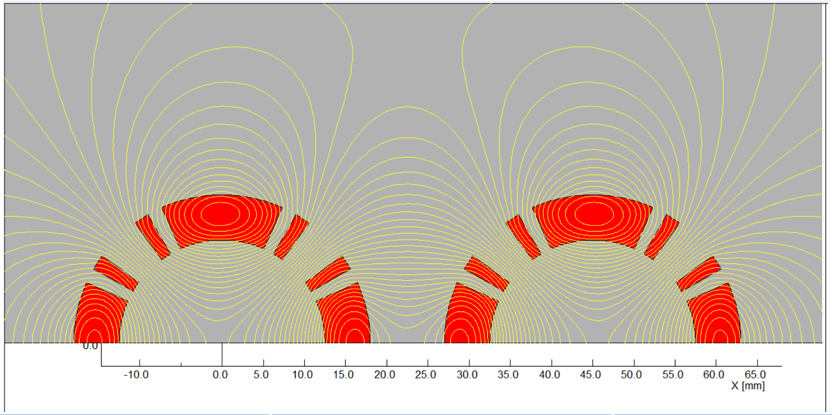


Magnetic flux density distribution

Magnet	Length	Field Gradient(T/m)	Coil Inner Radius (mm)	Coil Outer Radius (mm)
QD	1.25	304 → ~**200**	20	37
QF	0.72	309 → ~**110**	20	37

- Coils in Rutherford type Nb_3Sn cables clamped by stainless steel collar
- The field gradient will be decreased to match the feasibility in technology

Final Focusing Magnetic – Partial Double Ring

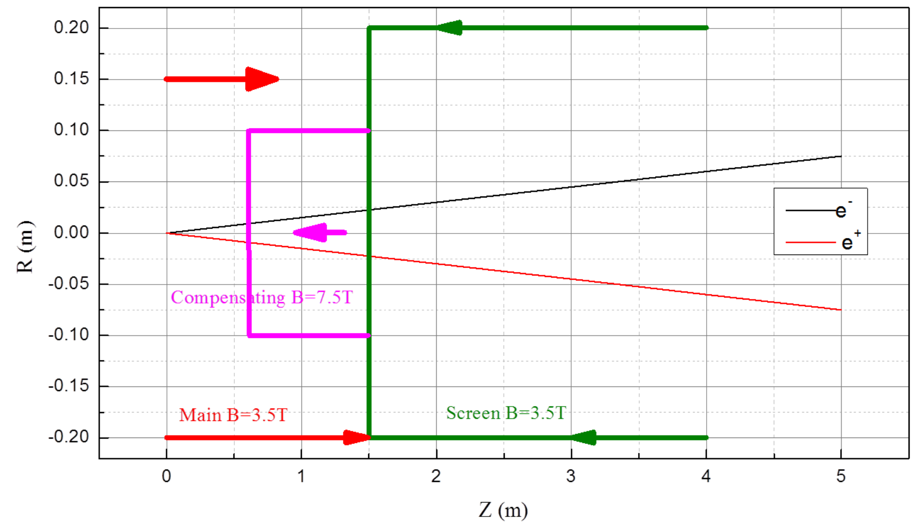


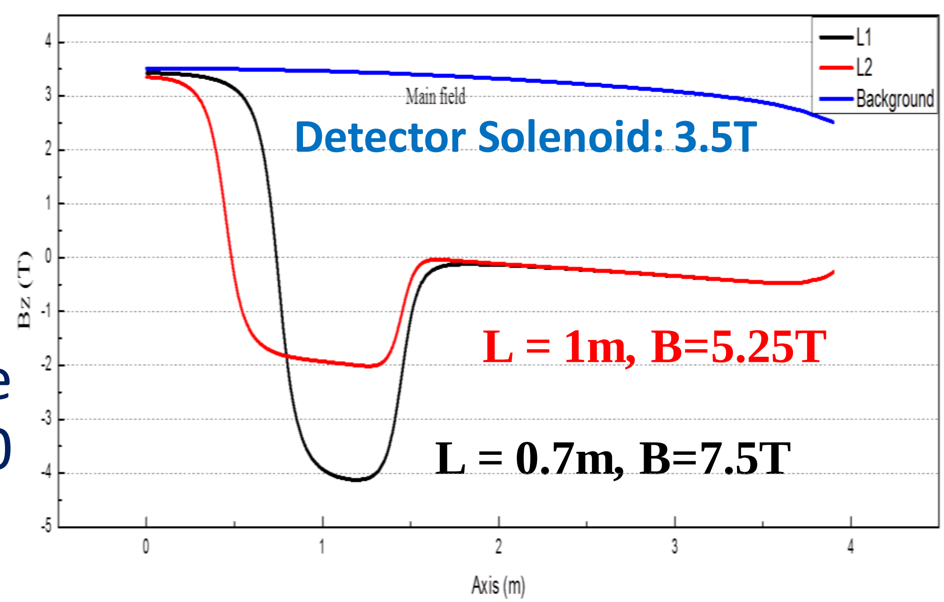
Magnet	Length	Field Gradient(T/m)	Coil Inner Radius (mm)	Coil Outer Radius (mm)
QD	1.25	**~200**	**12.5**	**18.5**
QF	0.72	**~110**	20	37

- 2 isolated QD are required to make sure e+ e- pass through the center of the quadrupoles separately.
- The thickness of the coil is tightly limited by the radius of beam pipe and the distance between two beam pipes.
- Cross talk of field between two quadrupoles need be further studied.

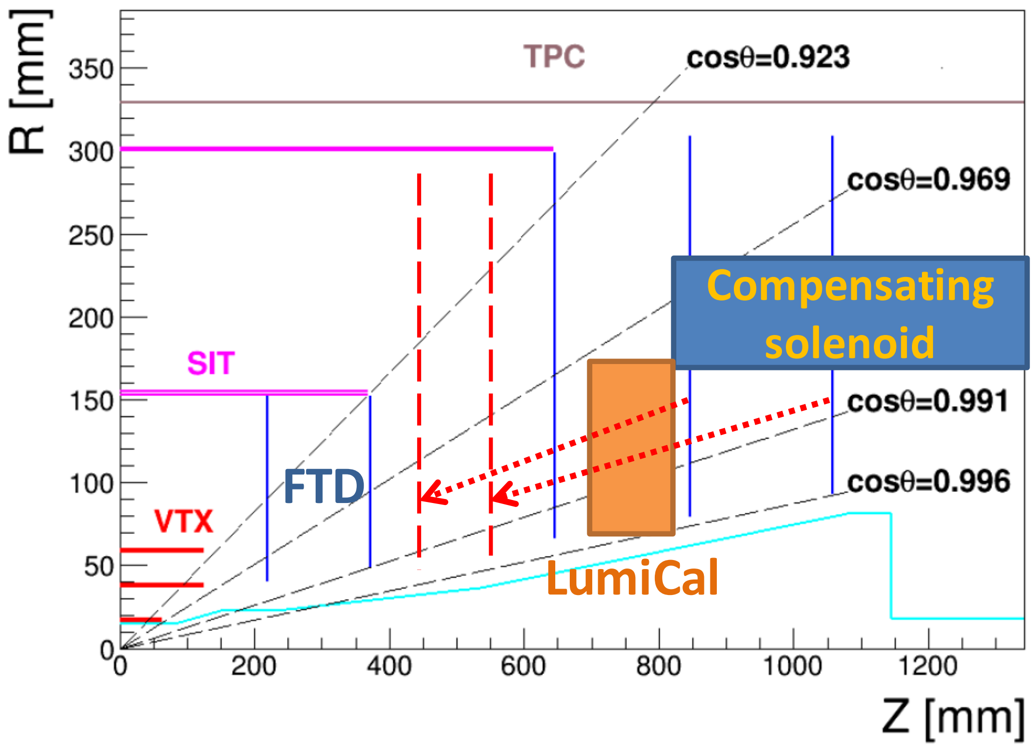
Anti-solenoid Design

- Solenoid field of detector will cause the beam coupling between horizontal and vertical direction, which will degrade the luminosity
- $\int B_z ds = 0$
  - The coupling should be cancelled before beam enter the quadrupoles (Compensating solenoid)
  - The longitudinal field inside the quadrupole should be 0 (Screening solenoid)





Influences on the Detector



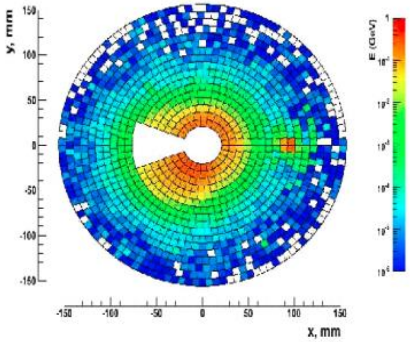
- length of anti-solenoid is 0.7m
  - The FTD detector need be more compact
  - Dead area to TPC (Reduce Length of TPC ?)
  - Very tight space for LumiCal
  - More backscattered backgrounds to VTX and FTD

Can the Anti-Solenoid be Shorter?

- Stronger magnets (Larger Size)
  - 8T @ 4.2K:
  - Known Maximum: 11.7T
    - Lower temperature, higher cost, worse maintainability
- Reduce the detector field
- Anyway, the IR will be more crowded

Detector Solenoid \ Anti-Solenoid	7.5T	8T
3.5T	**0.7m**	**0.66m**
3T	**0.6m**	**0.56m**

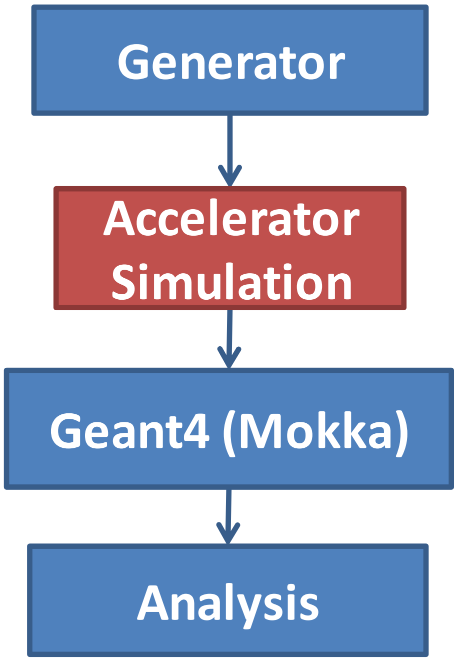
Luminosity Calorimeter



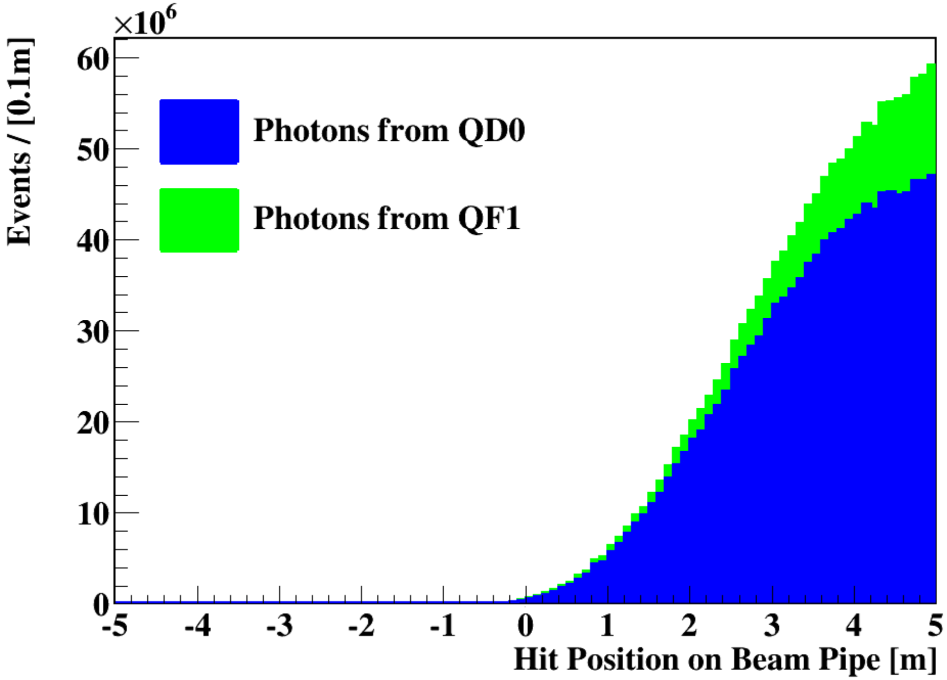
- To determine the luminosity: $L = \frac{N_{Bhabha}}{\sigma_{Bhabha}}$
- The accuracy of the luminosity measurement is determined by the fiducial volume of the detector
  - Contain the whole shower for event selection
  - Accumulate enough events to reduce statistical error
- In the partial double ring , the LumiCal will centered on outgoing beam.
  - The fiducial volume of the detector will be suppressed by the other beam pipe.
- The required accuracy and detector parameters need be further studied.

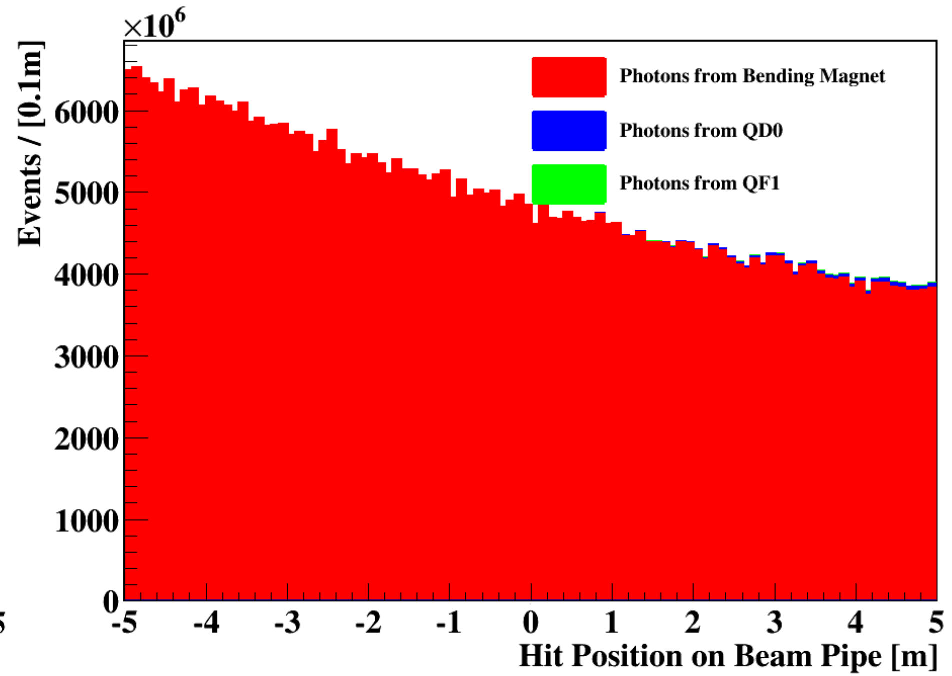
Source of Beam Backgrounds at CEPC

- Synchrotron Radiation
  - Bending Magnetic
  - Quadrupoles
- Lost Particles
  - Radiative Bhabha
  - Beamstrahlung
  - Beam-Gas Scattering
- Beamstrahlung
  - Pair production
  - Hadronic background



Flux of Synchrotron Radiation





Number of photons hit the beam pipe in each 10 cm

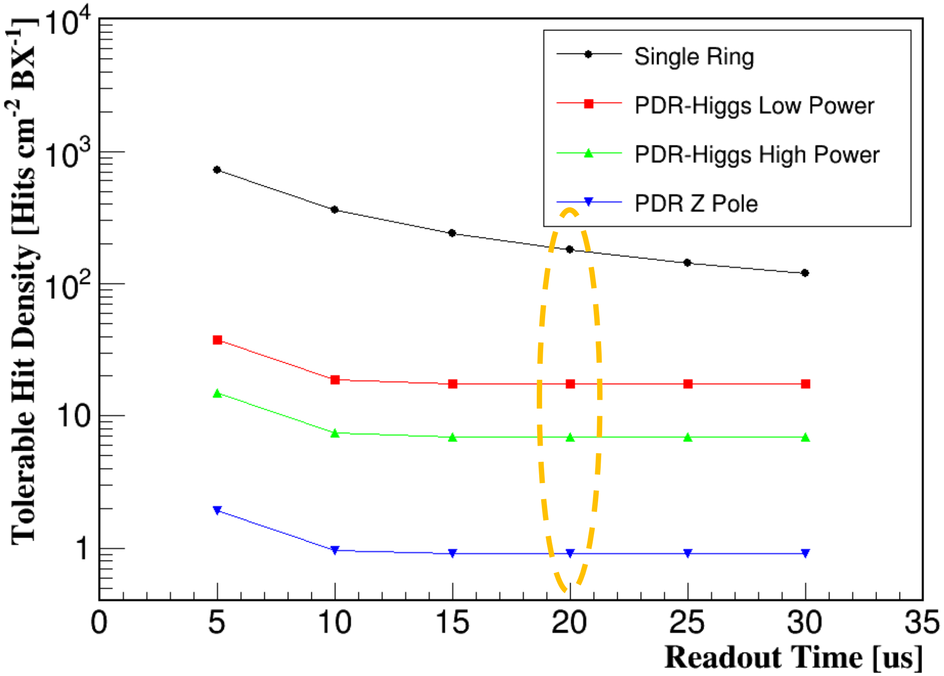
- Beam pipe radius 16mm (Uniform)
- Photons from the bending magnets will be dominant
- Quadrupoles can not be neglected due to the back scattering effects

Framework for Background Simulation

- Have established a framework for background simulation on the IHEP computing platform.
  - Generator:
    - Guinea-Pig++: Beamstrahlung
    - BBBrem: Radiative Bhabha
    - Self developed codes: Beam-gas scattering and other backgrounds
  - Accelerator Simulation:
    - SAD (Strategic Accelerator Design): Beam particle tracking
    - BDSIM: Also used as generator for synchrotron radiation
  - Detector Simulation:
    - Geant4 (Mokka)
    - Fluka
- Interfaces between all the software have been implemented.
- Developed a toolkit to use these software conveniently

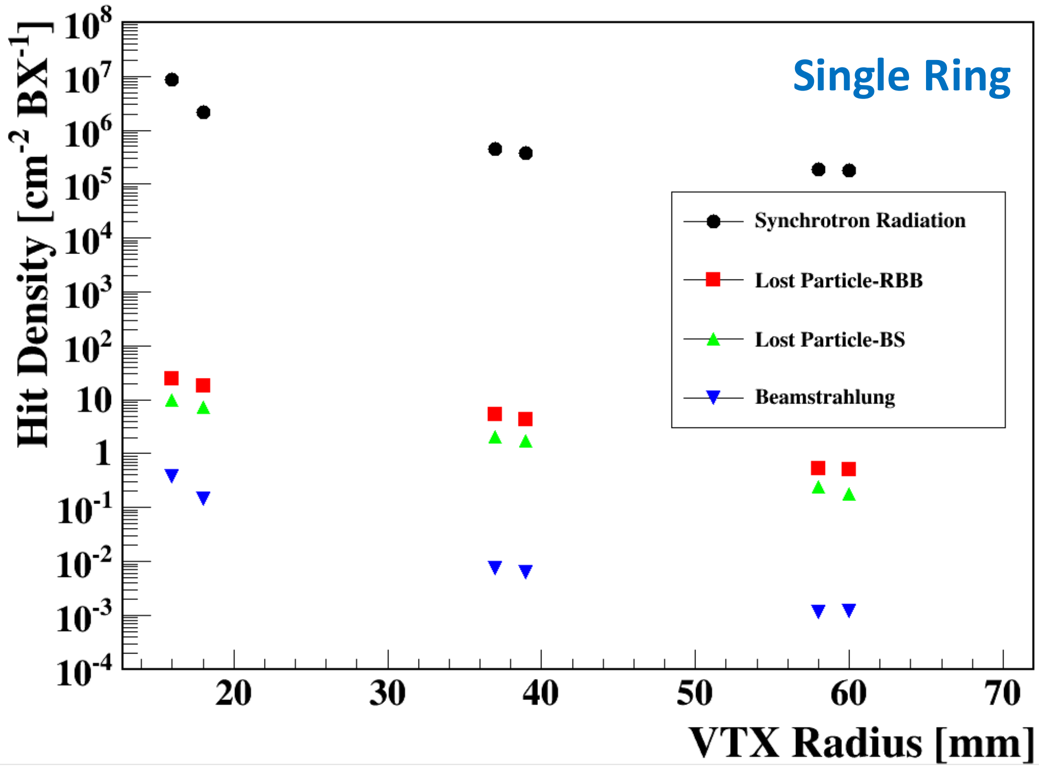
Physical Requirement to Background Level

- Vertex Detector Requirement: Occupancy not exceeding 1%
  - VTX Pixel Density: $5 \times 10^5\ cm^{-2}$ (Pixel pitch: $\sim 14\ \mu m$)
  - Safe factor: 5
- The tolerable hit density in partial double ring will be much lower than that of single ring.



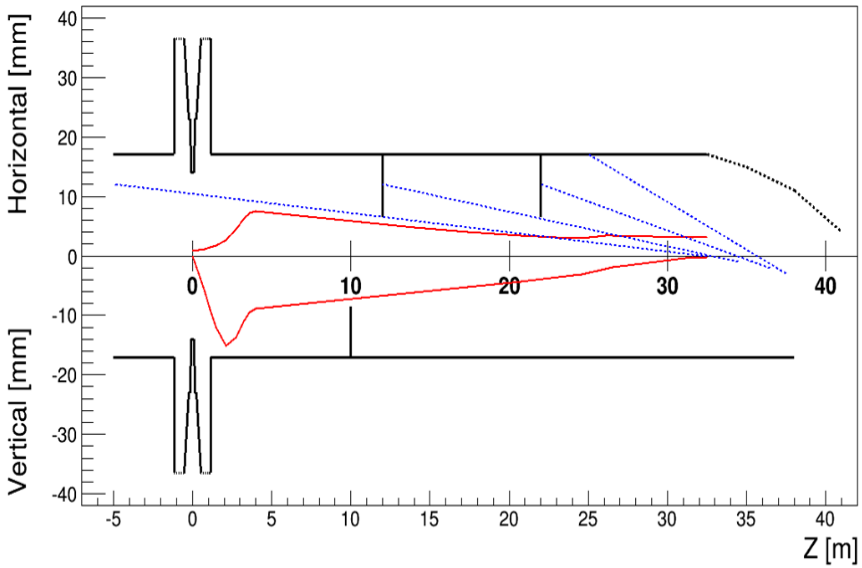
Parameters	Single Ring	PDR-H Low Power	PDR-H High Power	PDR Z Pole
Number of Bunches	50	57	144	1100
Bunch Spacing (μs)	3.6	0.187	0.074	0.0097
Hit Density in VTX ($\text{Hits} \cdot cm^{-2} \cdot BX^{-1}$)	< 200	< 20	< 10	< 1

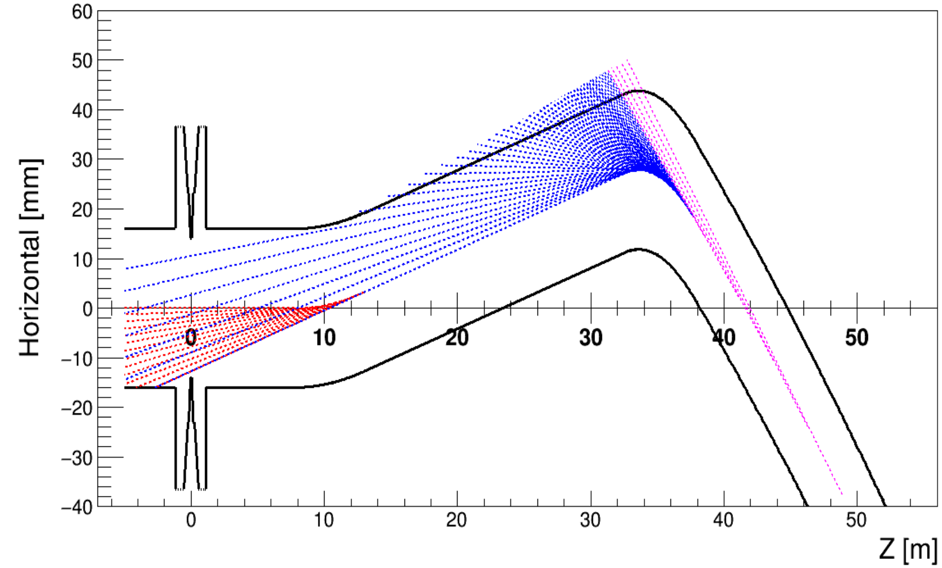
Hit Density Without Shielding



- 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

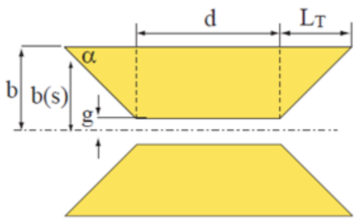




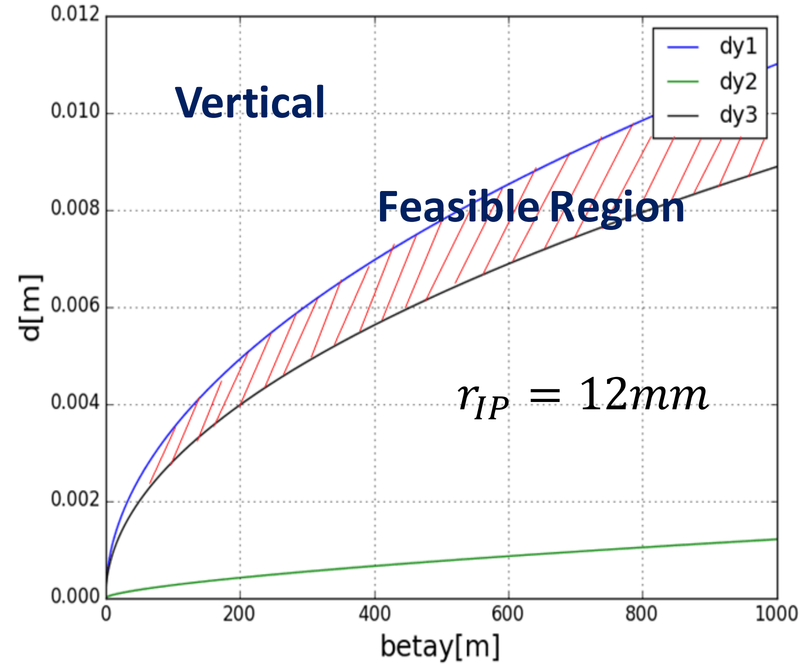
- Synchrotron Radiation
  - Shielding the synchrotron photons with collimators
  - Let the synchrotron photons pass through the IR by well designed beam orbit.
- Lost Beam Particles
  - Add collimators along the storage ring.

Preliminary Design of Collimators

- Shape and Material
  - Trapezium
  - Tungsten



- Position and Aperture d_c
  - Stop efficiency → Upper limit
  - TMCI (Transverse mode coupling instability) → Lower limit
  - Vertical injection → Lower limit
  - Will study more limitations

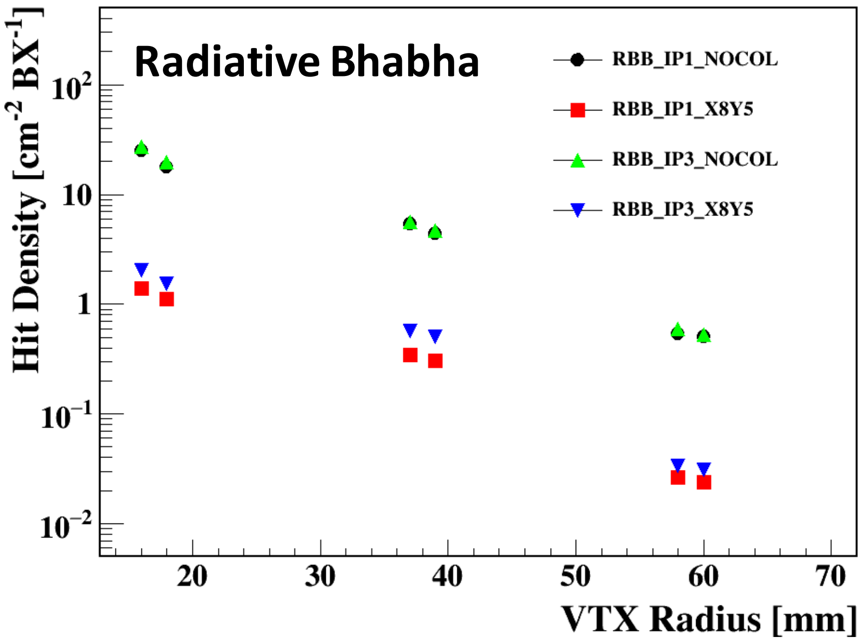


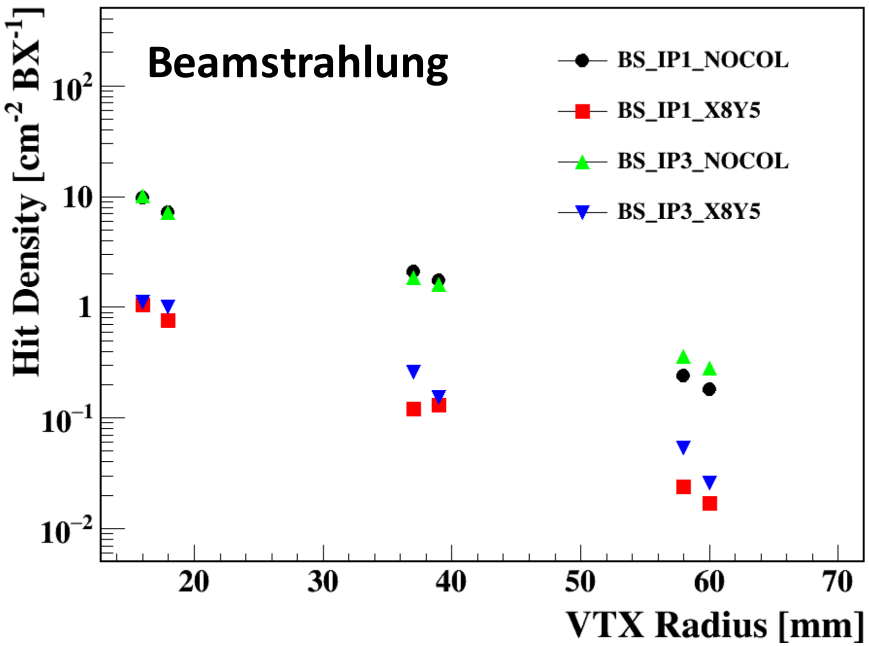
- **Upper Limit:** $d_c \le \frac{r_{IR}}{\sqrt{\beta_{IR,\max}}}\sqrt{\beta_c}$

- **TMCI:** $d_c \ge \left(\frac{0.215AIZ_0c}{C_1 f_s E/e}\right)^{\frac{2}{3}}\left(\frac{\alpha}{\sigma_z}\right)^{\frac{1}{3}}\beta_c^{\frac{2}{3}}$

- **Injection:** $d_c \ge \sqrt{a\beta_c}$

Effects of Collimators on Lost Particles





- The hit density due to lost particles at VTX are significantly suppressed by collimators
- Shielding of other backgrounds are under studying

Effect of Synchrotron Radiation on Detectors

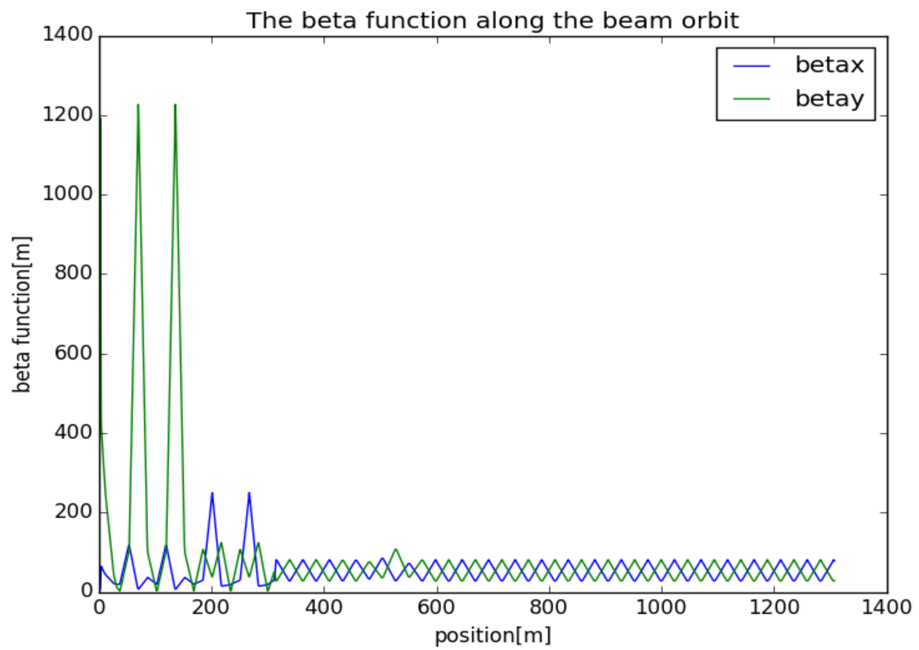
- A small error will cause large fluctuation in the results due to the very large photon flux.
- Based on Geant4
- Typical photon energy: several keV ~ several hundreds keV. (Physics list should be optimized for this energy region)
- Suppressing the scattering photons will be one of the most important issues. (Material and geometry of collimators and beam pipe)

Summary

- Single Ring
  - Lots of progresses have been made in: IR design, final focusing magnets, luminosity calorimeter, background estimation and detector shielding
  - The beam pipe design, mechanics and integration have not been covered yet.
- Partial Double Ring
  - Most topics are in the starting stage. But will be the main battlefield in future.
  - Great challenging to balance the requirements from both the detector and accelerator
  - Need more new ideas

Thank You

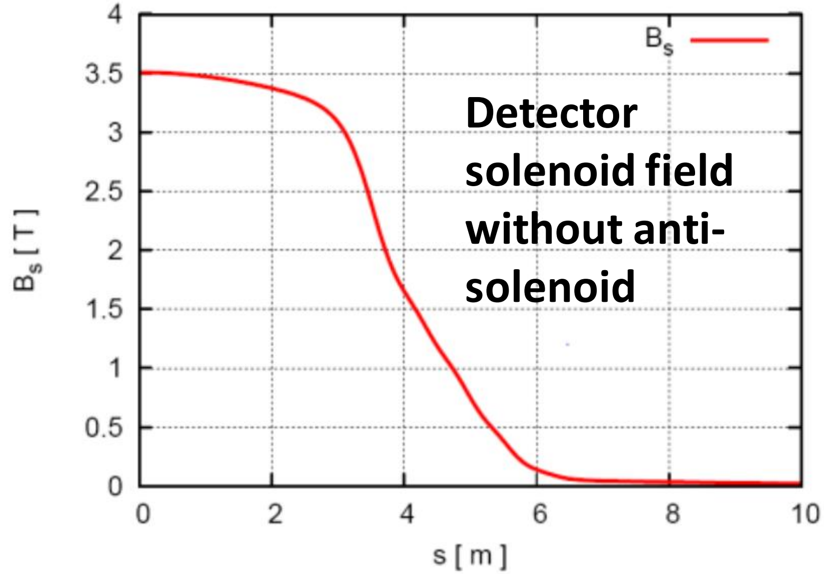
Back Up

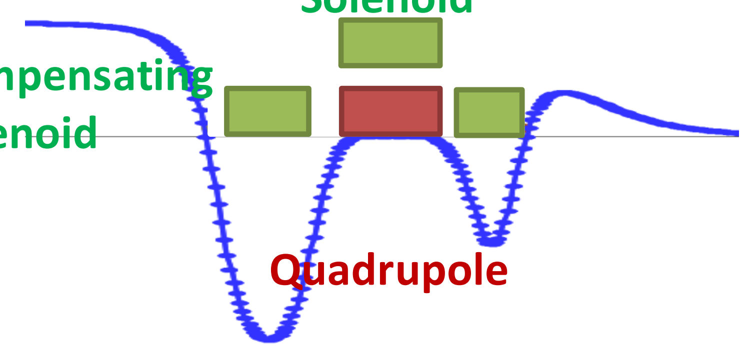


Name	Position	Distance to IP[m]	Beta function[m]	Range of half width allowed[mm]
APTX1	DRHS12FFS.4	-200.412	βx = 238.91	0.6-34.1
APTX2	DRHS22FFS.4	-266.412	βx = 238.91	0.6-34.1
APTY1	DRHFFS.7	-283.212	βy = 124.05	3.3-5.4
APTY2	DRHFFS.8	-217.212	βy = 124.05	3.3-5.4

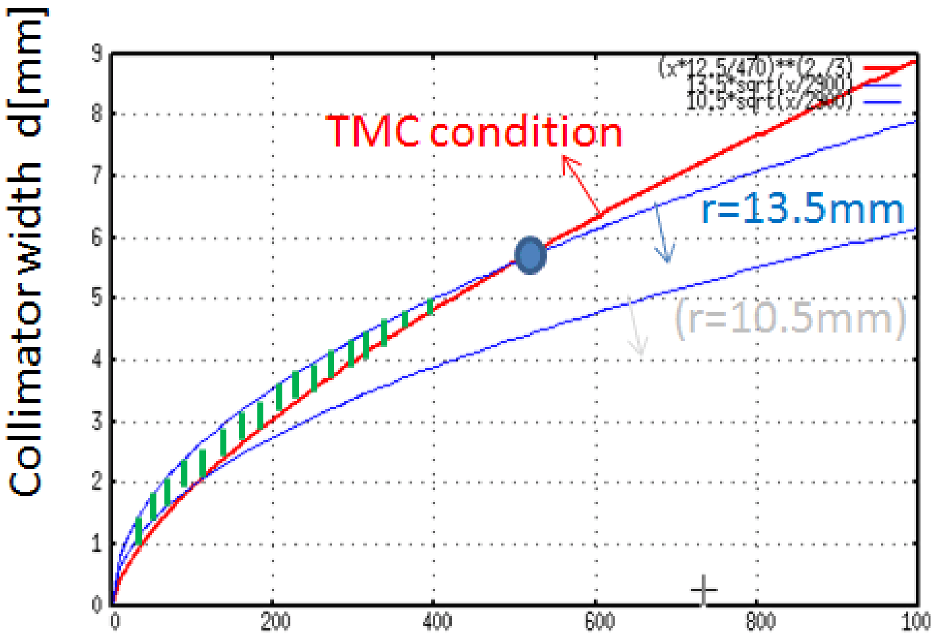
Anti-solenoid Design

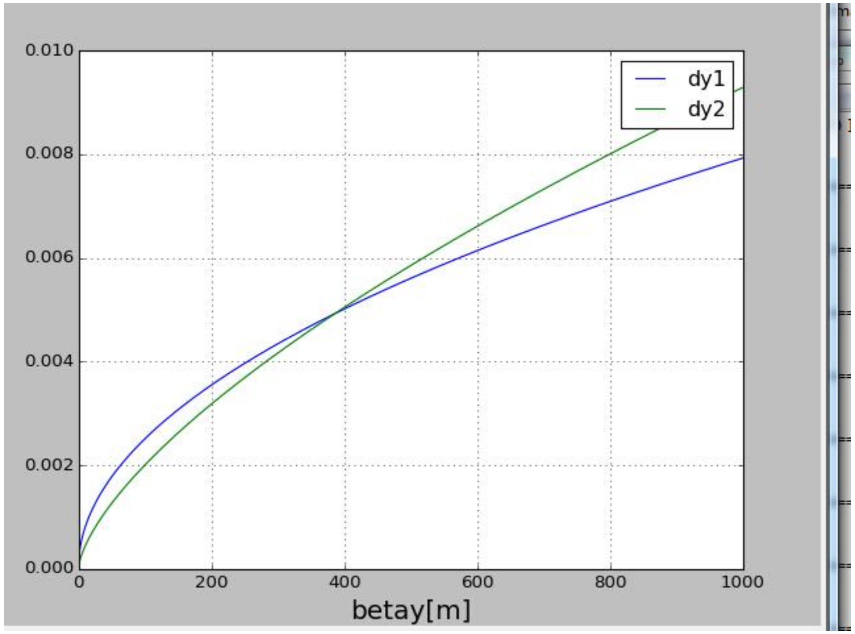
- Solenoid field of detector will cause the beam coupling between horizontal and vertical direction, which will degrade the luminosity
- $\int B_z ds = 0$
  - The coupling should be cancelled before beam enter the quadrupoles (Compensating solenoid)
  - The longitudinal field inside the quadrupole should be 0 (Screening solenoid)
- Coils of anti-solenoid will be made of NbTi-Cu Conductor





Super KEKB


Collimator width d[mm]
(x*12.5/470)**(2./3)
13.5*sqrt(x/2900)
10.5*sqrt(x/2900)
TMC condition
r=13.5mm
(r=10.5mm)
0
1
2
3
4
5
6
7
8
9
0
200
400
600
800
100


dy1
dy2
0.010
0.008
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200
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