The MDI of CEPC

Chenghui Yu

for CEPC team

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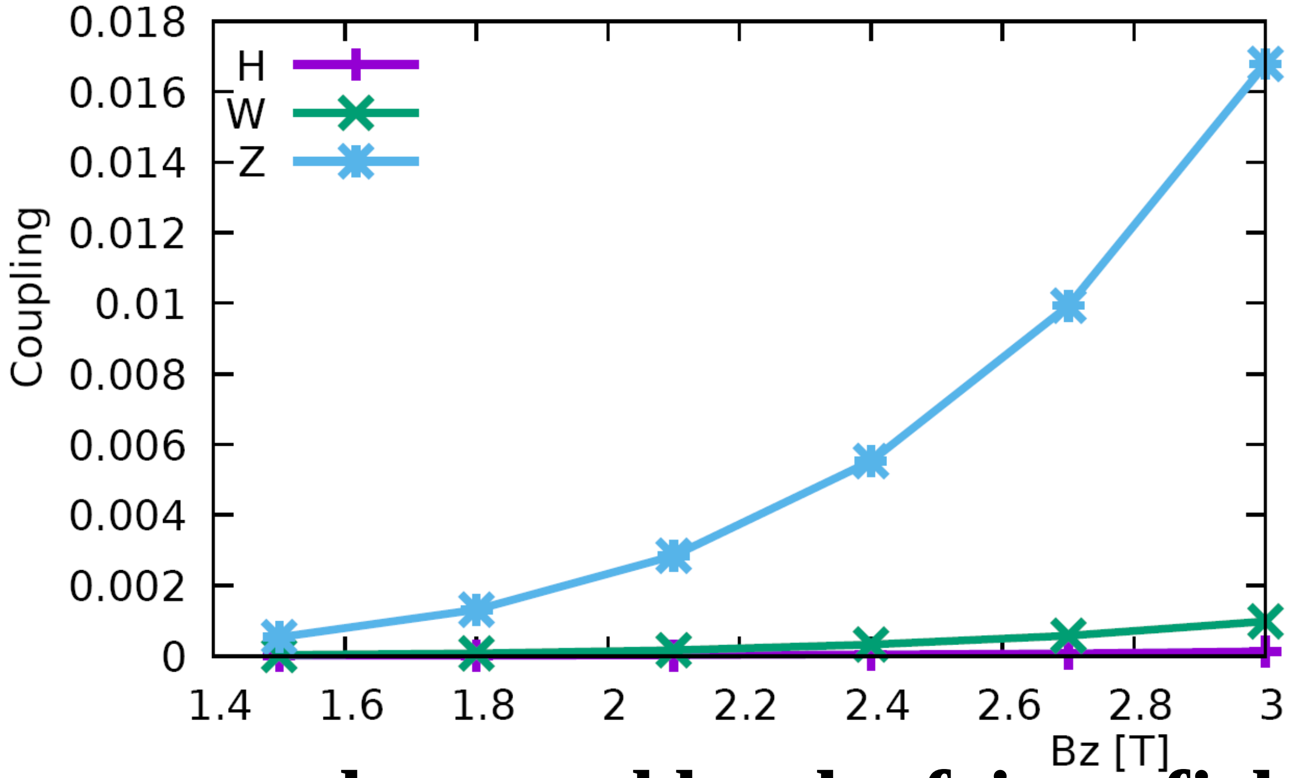
Outline

- **Start from detector solenoid 3.0T**
- **The MDI of CEPC**
- **Assembly nearby the IP**
- **Summary**

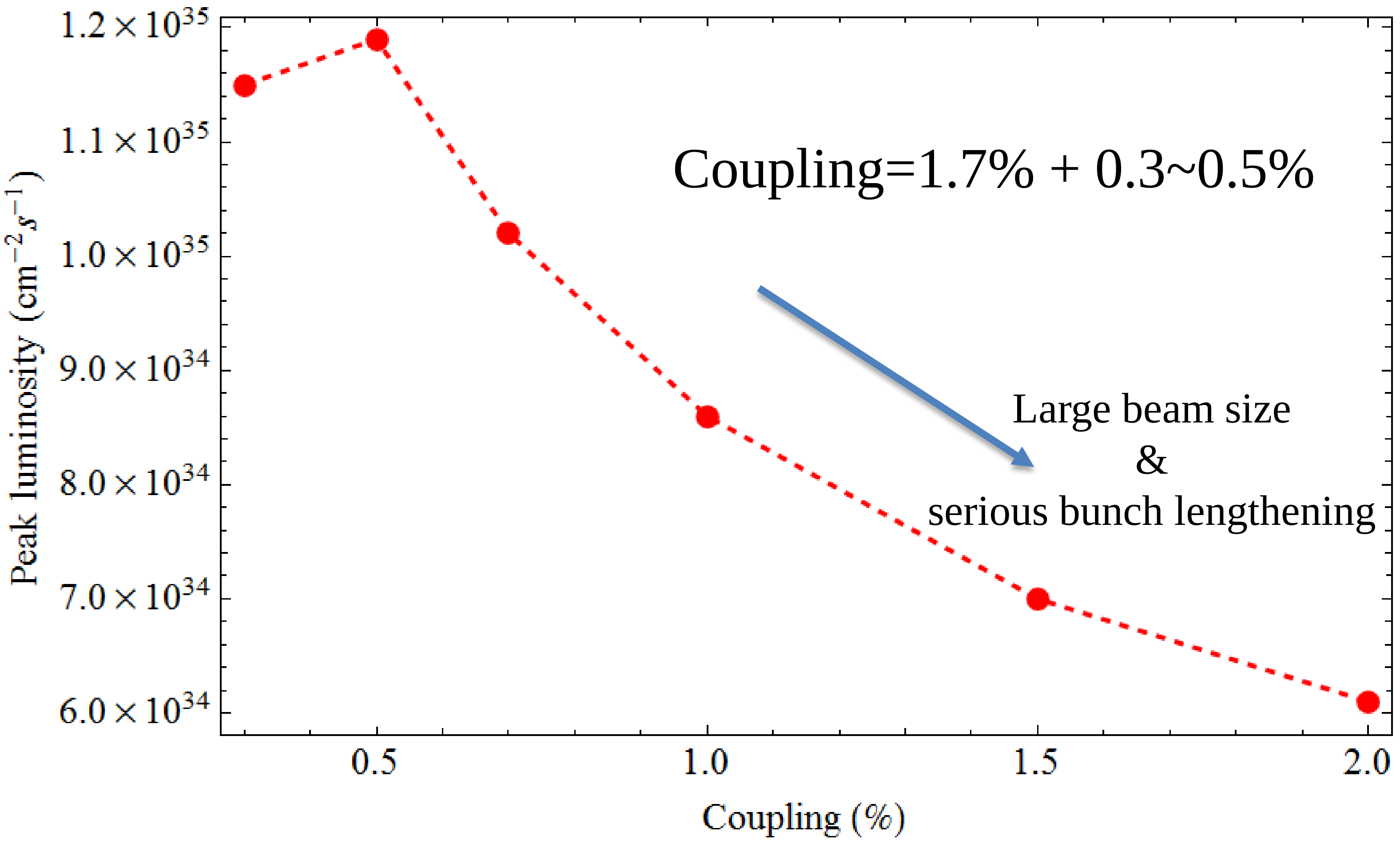
Start from detector solenoid 3.0T



Emittance growth caused by the fringe field of solenoids

Design emitY/emitX	expected contribution	real contribution
H: 3.6pm/1.21nm (0.3%)	0.36pm	0.14pm (0.01%)
W: 1.6pm/0.54nm (0.3%)	0.16pm	0.47pm (0.09%)
Z: 1.0pm/0.17nm (0.5%)	0.09pm	**2.9pm (1.7%)**

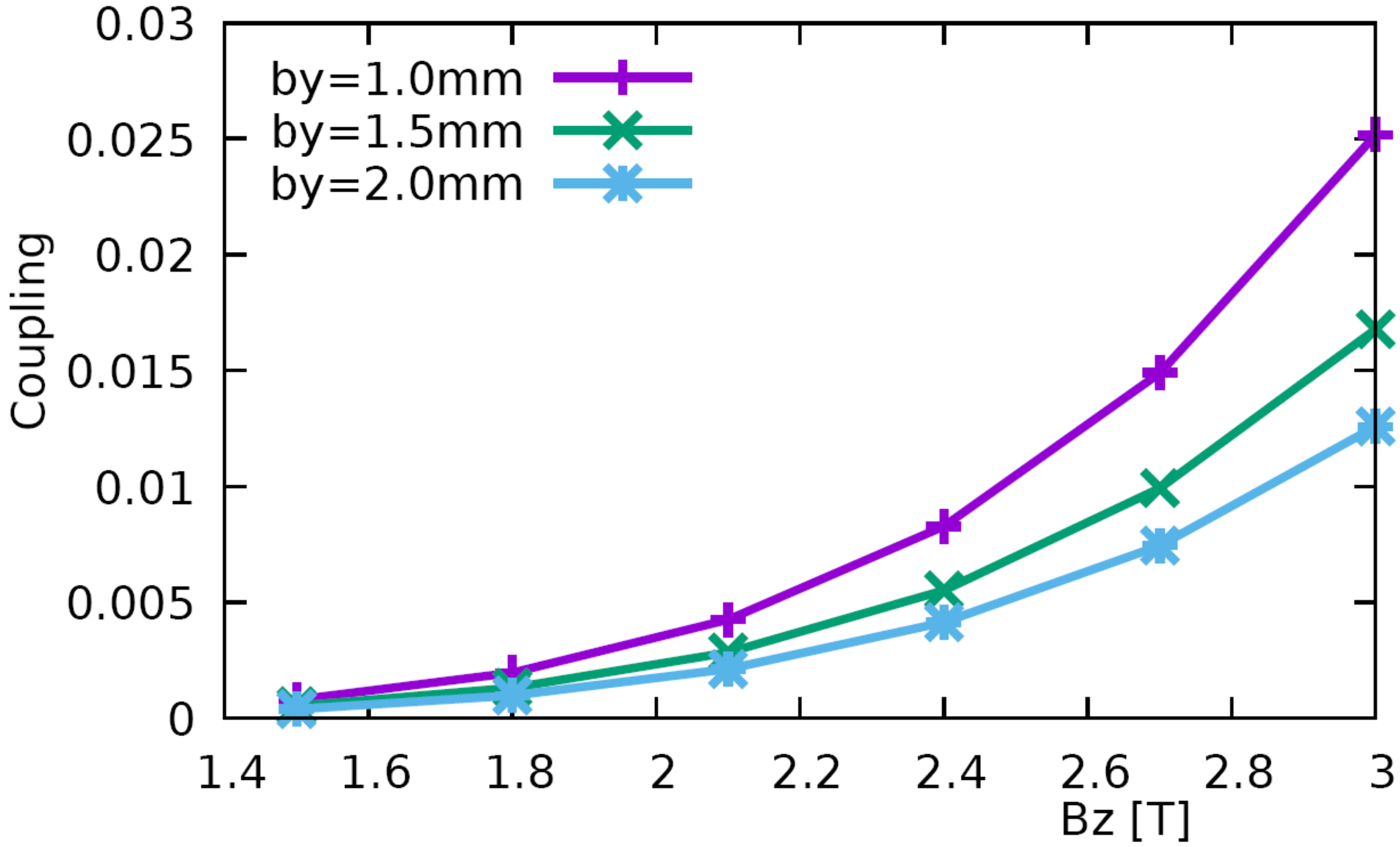
Start from detector solenoid 3.0T



Coupling Vs. Luminosity @ Z

For **the 2Cell cavity** operation, if the coupling lose control **$L \approx L_0/2 \sim L_0/4$**

Start from detector solenoid 3.0T



β_y* Vs. coupling @ Z

Limitation of the luminosity improvement by reducing the β_y*

Start from detector solenoid 3.0T

If CEPC has higher luminosity requirement @Z

Design emitY/emitX	expected contribution	Real contribution
Z: 1.0pm/0.17nm (0.5%)	0.1pm	2.9pm (1.71%)
Z: 1.0pm/0.17nm (0.5%)	**(2T solenoid)**	**0.2pm (0.12%)**
Z: 7.8pm/1.48nm (0.5%)	**1pm**	**2.9pm (0.20%)**

☺

- **Set the detector solenoid at 2T or < 2T during Z operation**

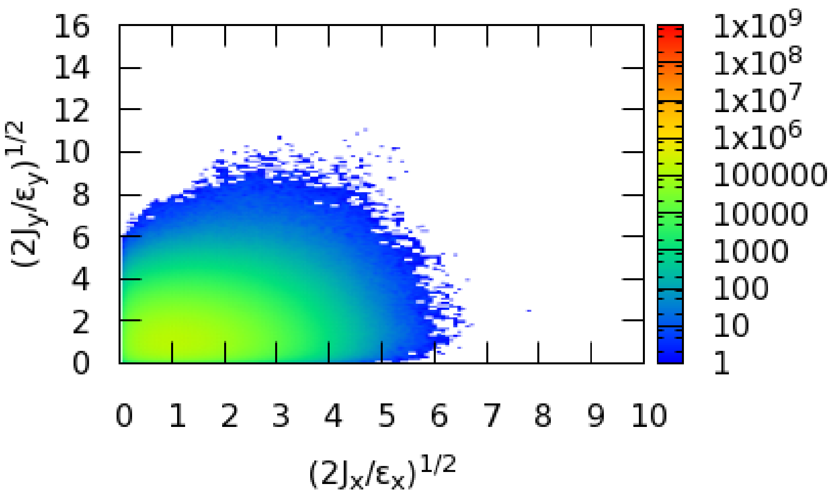
Higher luminosity & Lower difficulty of SC magnet & More free space nearby IP

- **Dedicated lattice for Z with large emittance**

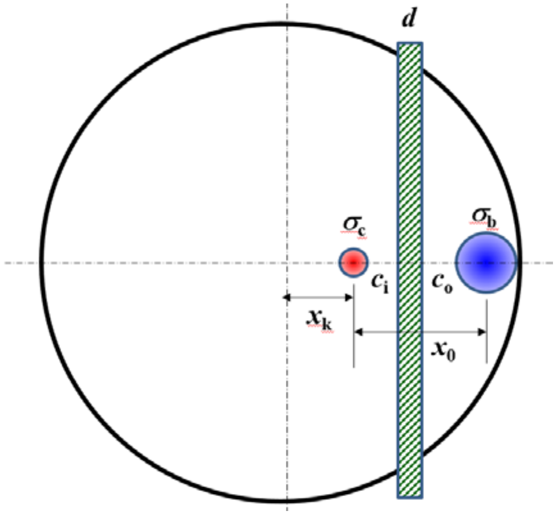
The design of interaction region

The definition of beam stay clear

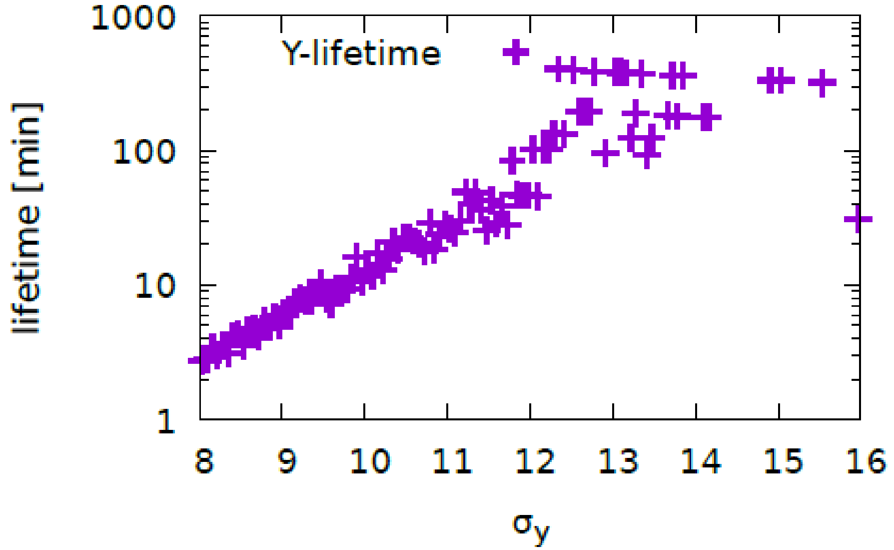
- To satisfy the requirement of injection: **BSC > 13 σ_x**
- To satisfy the requirement of beam lifetime after collision **BSC > 12σ_y**



Beam tail distribution with full crab-waist



BSC>13 σ_x

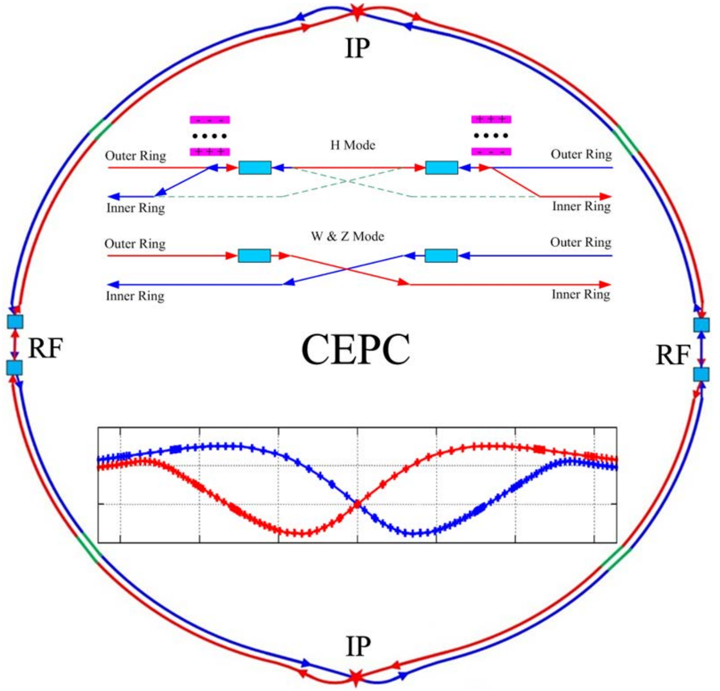


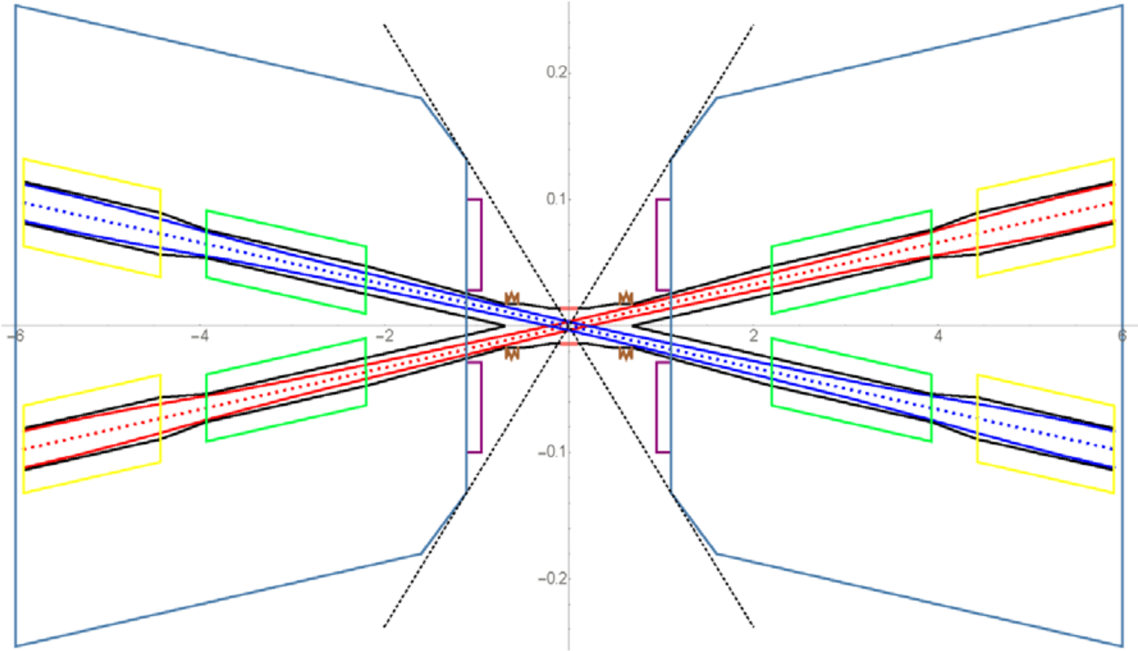
BSC>12 σ_y

BSC_x =±(18σ_x +3mm), BSC_y =±(22σ_y +3mm), While coupling=1%

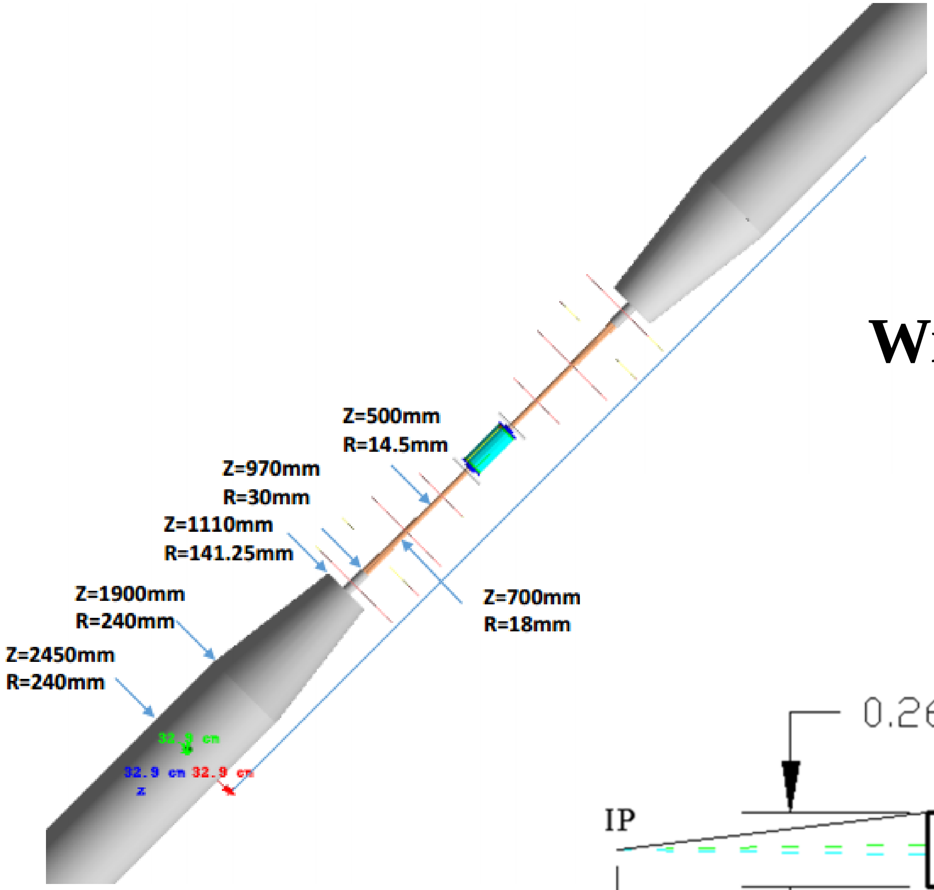
The design of interaction region

- ✓ **L*=2.2m, θc=33mrad, βx*=0.36m, βy*=1.5mm, Detector solenoid=3.0T**
  - Lower strength requirements of anti-solenoids **(~7.2T)**
  - Enough space for the SC quadrupole coils in two-in-one type (Peak field 3.8T & 136T/m) with room temperature vacuum chamber.
  - The control of SR power from the superconducting quadrupoles.



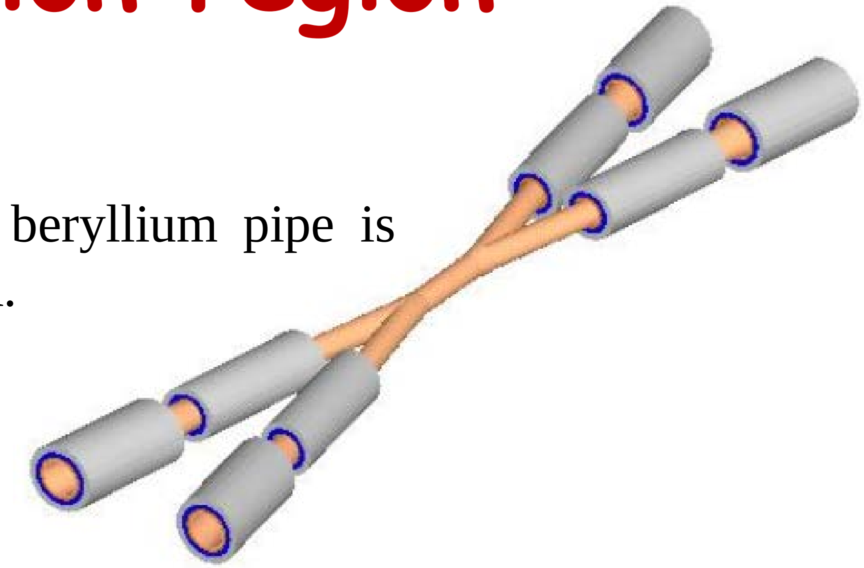


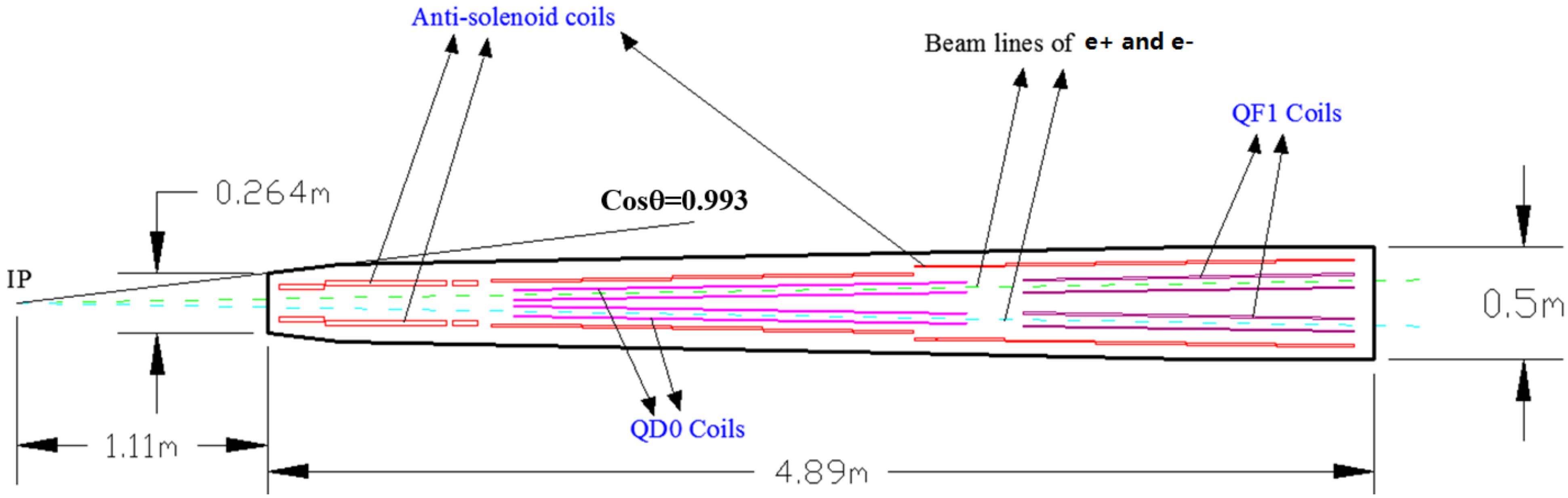
The design of interaction region



The inner diameter of the beryllium pipe is 28mm with the length of ±7cm.

Without tungsten shield.

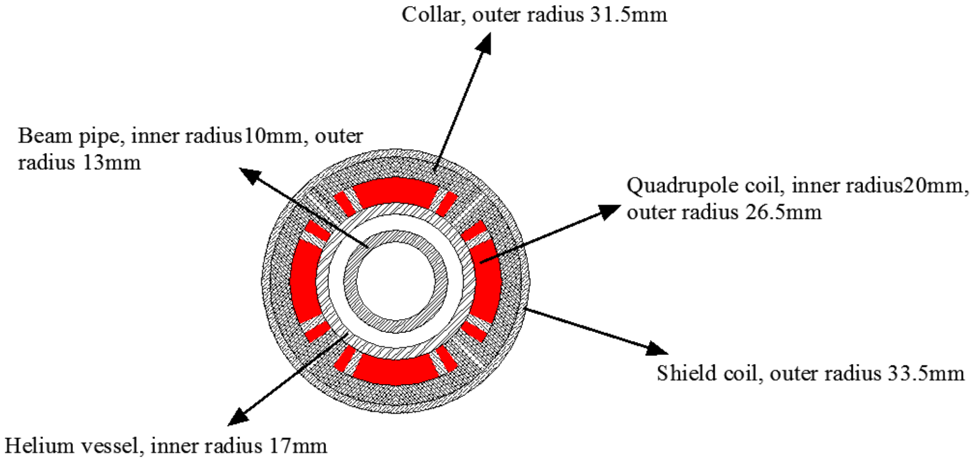




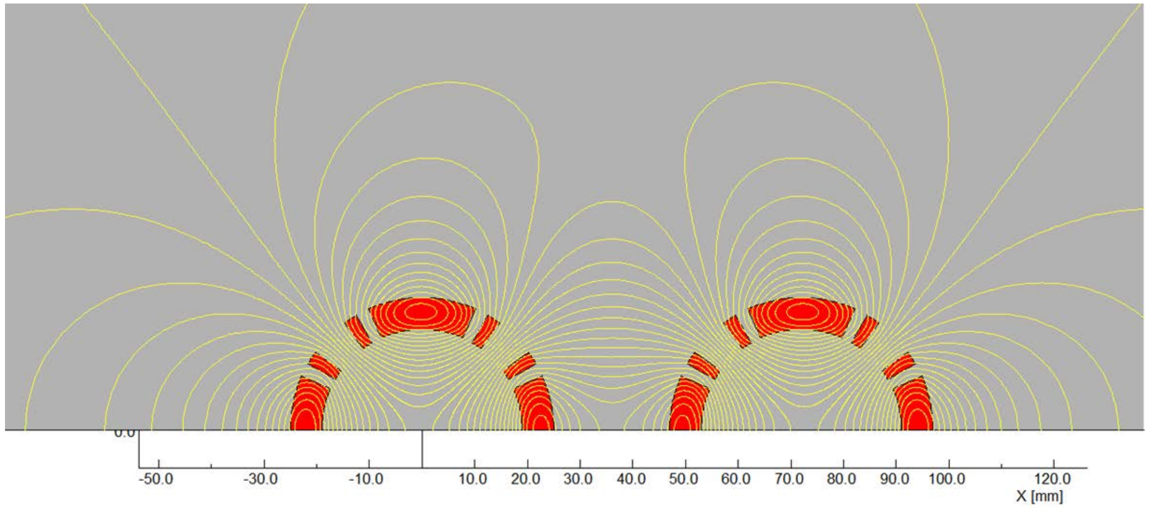
The design of interaction region

Superconducting QD coils

Rutherford NbTi-Cu Cable

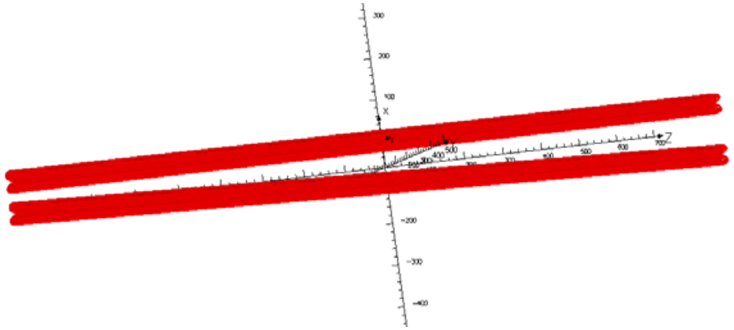


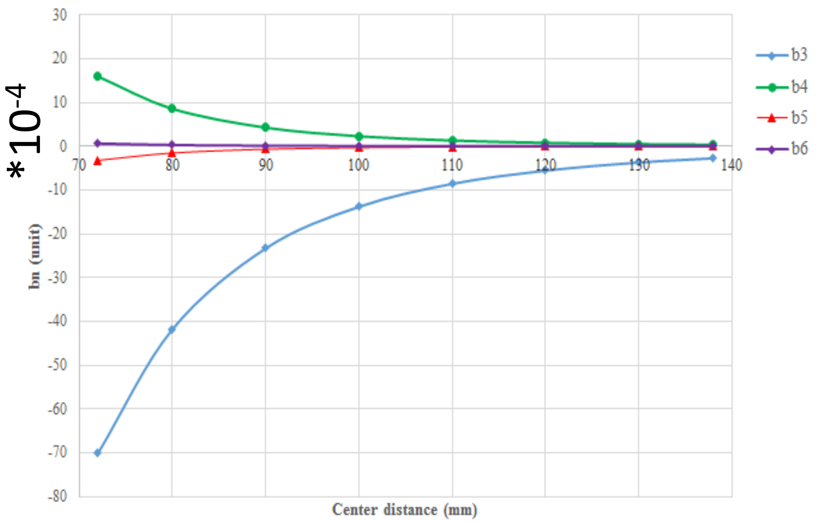
One of QD0 aperture
(Peak field 3.2T)



Field cross talk of two coils

Room-temperature vacuum chamber with a clearance gap of 4 mm



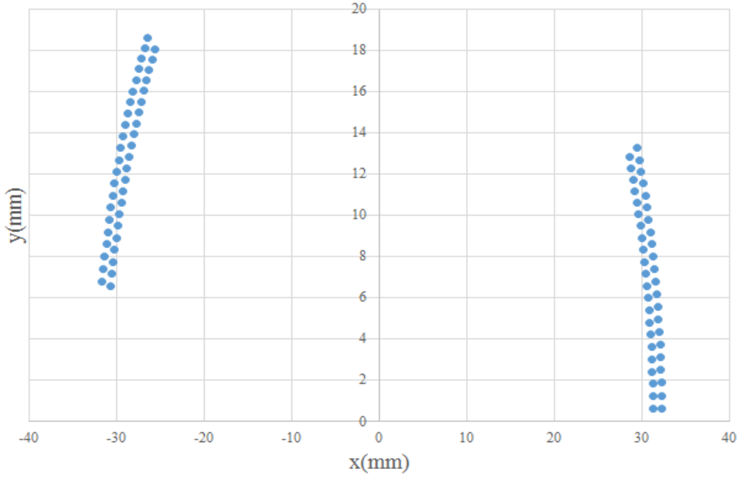


Magnet	Central field gradient (T/m)	Magnetic length (m)	Width of Beam stay clear (mm)	Min. distance between beams centre (mm)
QD0	136	2.0	19.51	72.61

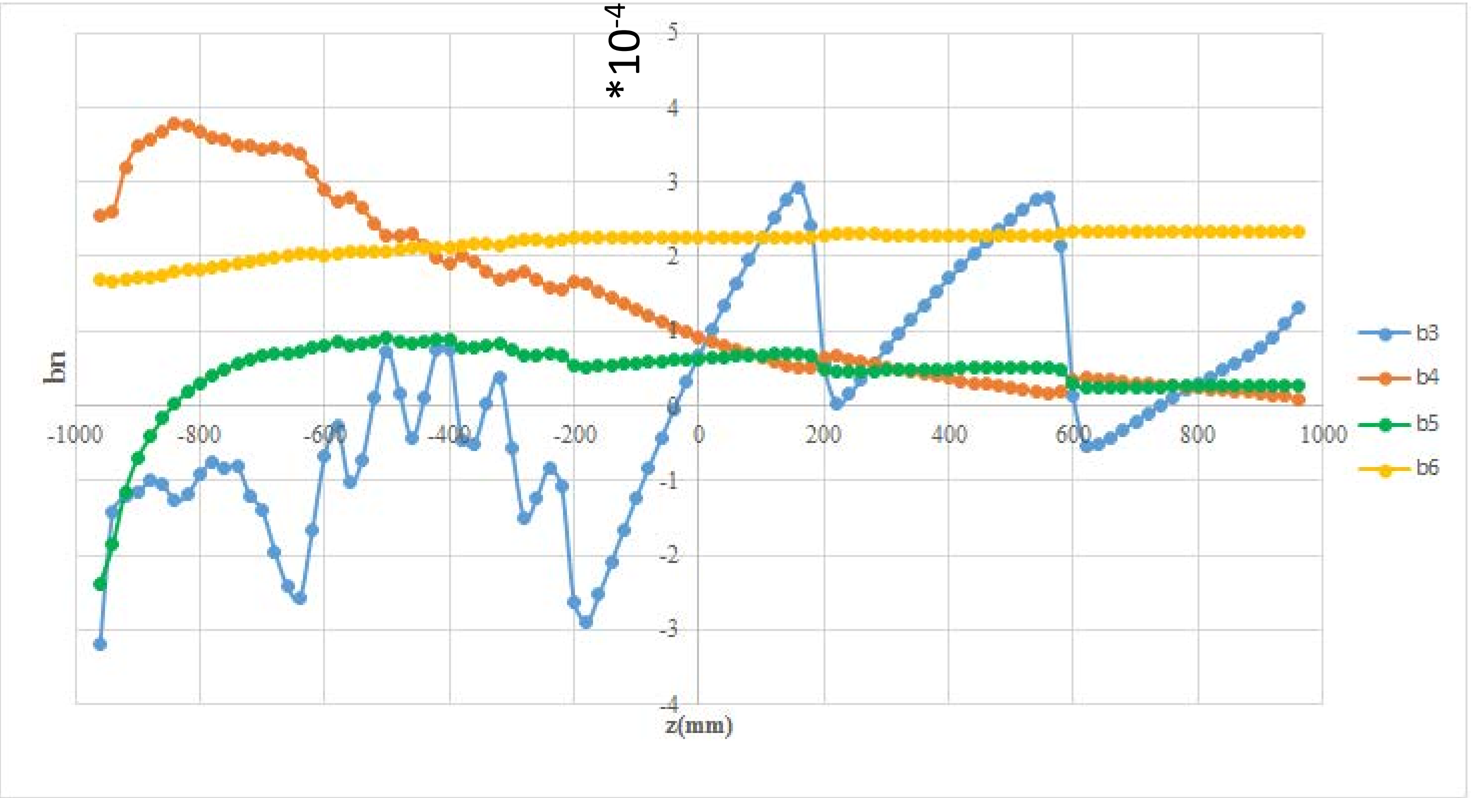
The design of interaction region

Superconducting QD coils

Two layers of shield coil are introduced outside the QD coil to improve the field quality.



The conductor for the shield coil is round NbTi wire with diameter of 0.5mm. There are 44 turns in each pole with different length to optimize the field harmonics along the QD coil.



Integral field harmonics with shield coils（$\times 10^{-4}$）

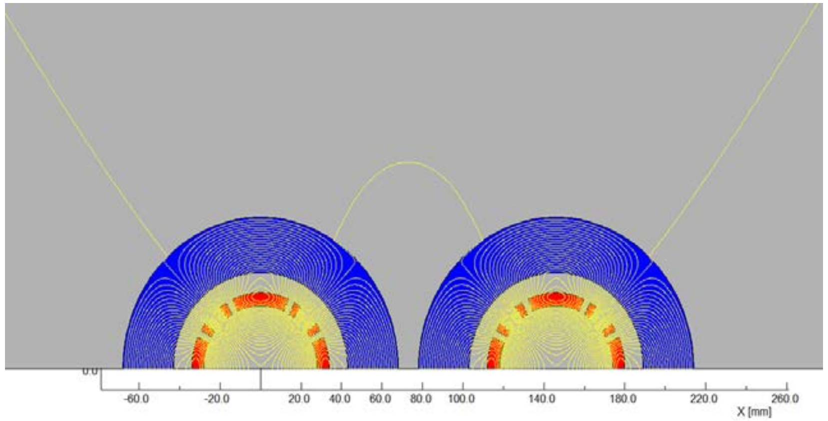
n	B_n/B_2@R=9.8 mm
2	10000
3	-0.57419
4	1.525573
5	0.375555
6	-0.13735
7	0.015413
8	-0.03117
9	-1.70E-03
10	-0.05809

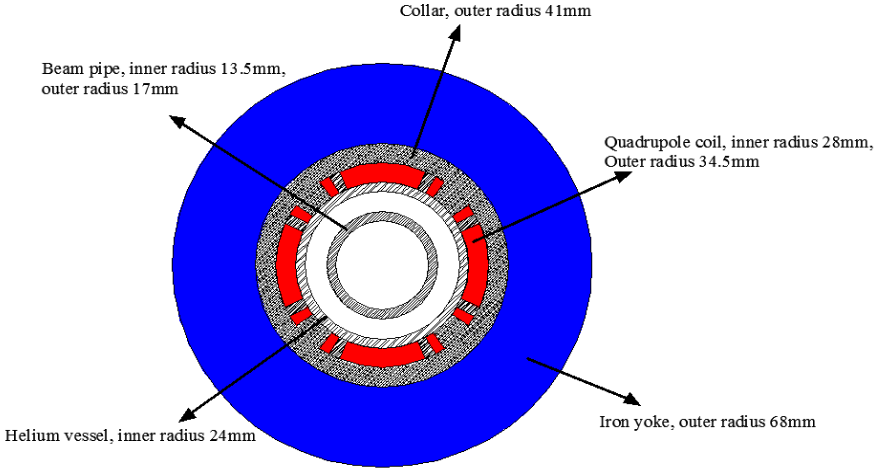
The design of interaction region

Superconducting QD coils

There is iron yoke around the quadrupole coil for QF1. Since the distance between the two apertures is larger enough and the usage of iron yoke, the field cross talk between two apertures of QF1 can be eliminated.

Rutherford NbTi-Cu Cable





One of QF1 aperture
(Peak field 3.8T)

Room-temperature vacuum chamber with a clearance gap of 7 mm

Magnet	Central field gradient (T/m)	Magnetic length (m)	Width of Beam stay clear (mm)	Min. distance between beams centre (mm)
QF1	110	1.48	27.0	146.20

Integral field harmonics with shield coils （$\times 10^{-4}$）

n	B_n/B_2@R=13.5mm
2	10000
6	1.08
10	-0.34
14	0.002

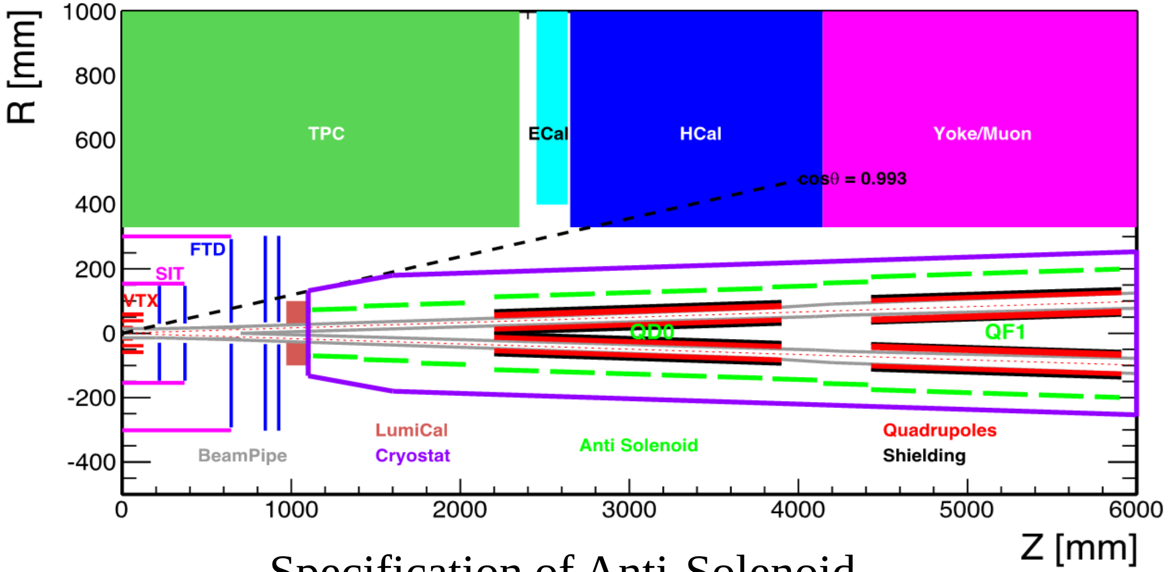
The design of interaction region

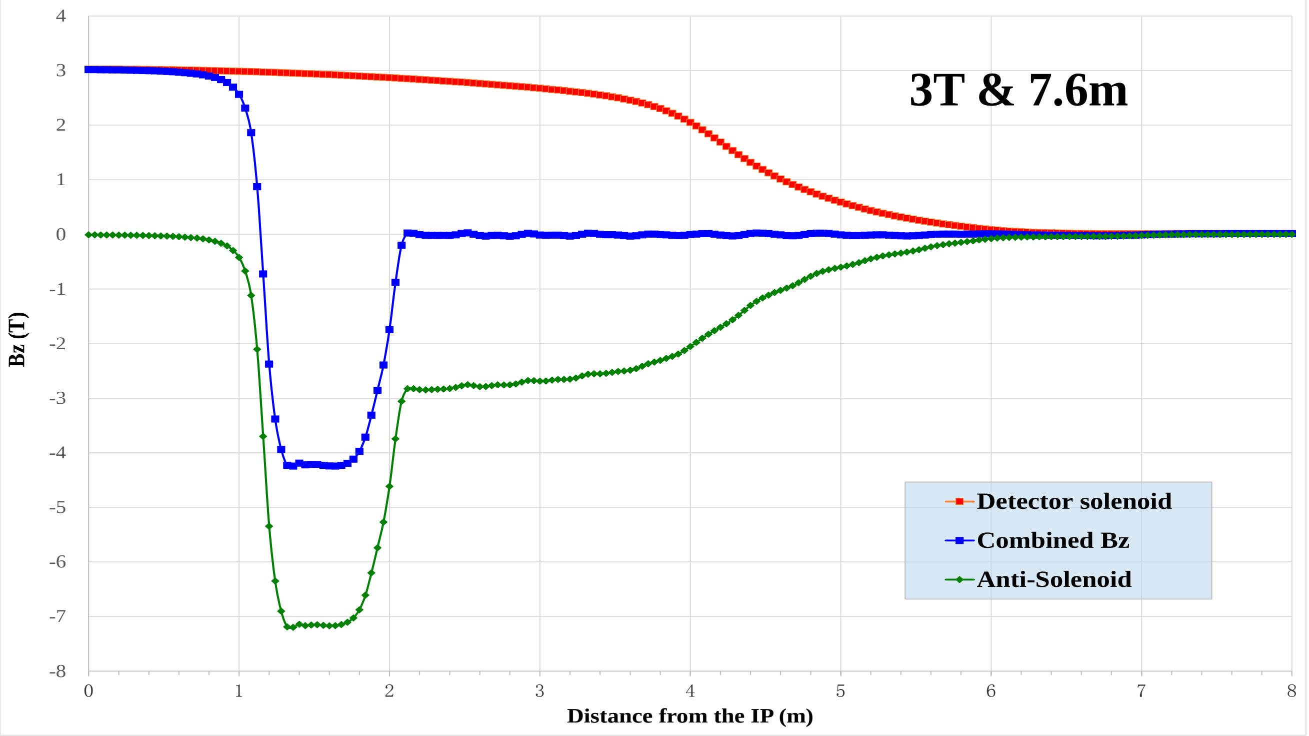
Magnet name	QD0
Field gradient (T/m)	136
Magnetic length (m)	2.0
Coil turns per pole	21
Excitation current (A）	2400
Shield coil turns per pole	44
Shield coil current (A）	126
Coil layers	2
Conductor size (mm)	Rutherford NbTi-Cu Cable, width 3 mm, mid thickness 0.95 mm, keystone angle 1.6 deg
Stored energy (KJ)	19.0
Inductance (H）	0.007
Peak field in coil (T)	3.2
Coil inner diameter (mm)	40
Coil outer diameter (mm)	53
X direction Lorentz force/octant (kN)	54
Y direction Lorentz force/octant (kN)	-112

Magnet name	QF1
Field gradient (T/m)	110
Magnetic length (m)	1.48
Coil turns per pole	29
Excitation current (A）	2250
Coil layers	2
Conductor size (mm)	Rutherford NbTi-Cu Cable, width 3 mm, mid thickness 0.95 mm, keystone angle 1.6 deg
Stored energy (KJ)	30.5
Inductance (H）	0.012
Peak field in coil (T)	3.8
Coil inner diameter (mm)	56
Coil outer diameter (mm)	69
X direction Lorentz force/octant (kN)	110
Y direction Lorentz force/octant (kN)	-120

Specification of QD0 and QF1

The design of interaction region





Specification of Anti-Solenoid

Anti-solenoid	Before QD0	Within QD0	After QD0
Central field（T）	7.2	2.8	1.8
Magnetic length（m）	1.1	2.0	1.98
Conductor (NbTi-Cu, mm)	2.5×1.5		
Coil layers	16	8	4/2
Excitation current（kA）	1.0		
Inductance（H）	1.2		
Peak field in coil (T)	7.7	3.0	1.9
Number of sections	4	11	7
Solenoid coil inner diameter (mm)	120		
Solenoid coil outer diameter (mm)	390		
Total Lorentz force F_z (kN)	-75	-13	88
Cryostat diameter (mm)	500		

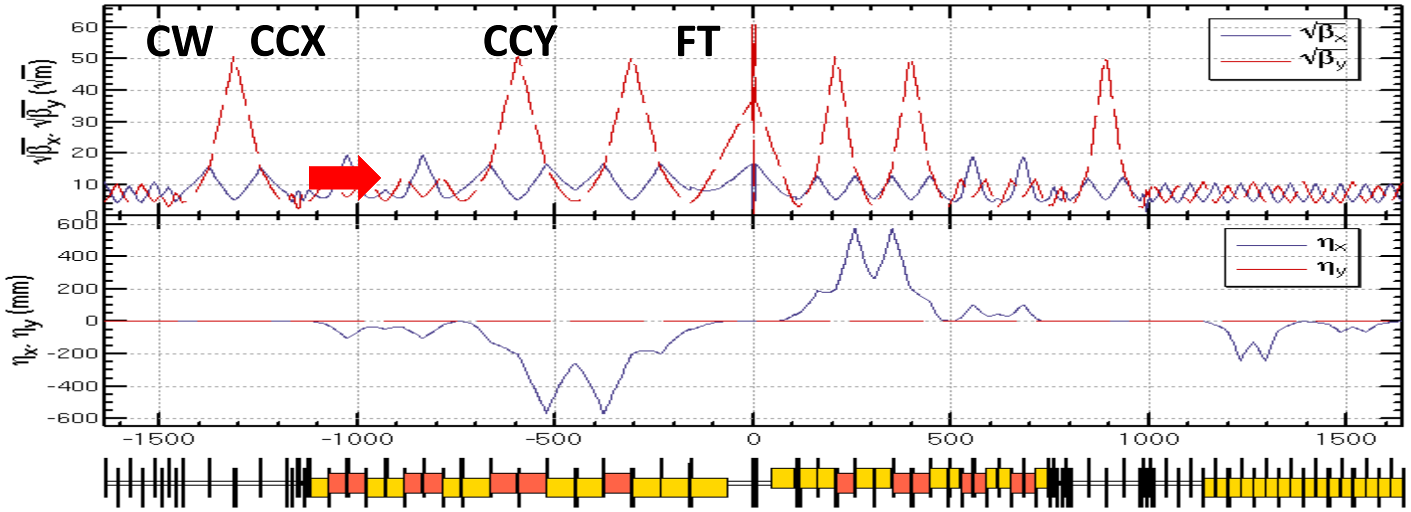
22 anti-Solenoid **sections with different inner coil diameters**

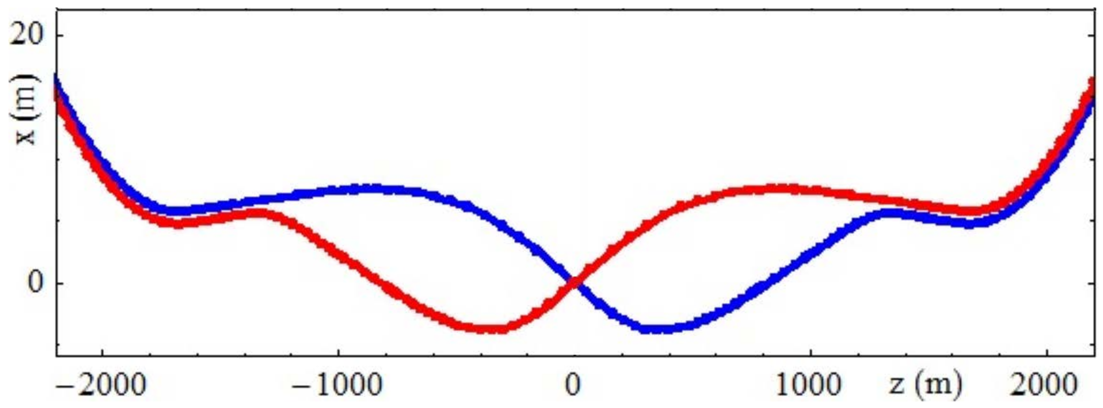
$\int B_z ds$ within 0~2.12m. Bz < 300Gauss away from 2.12m with local cancellation structure

The skew quadrupole coils are designed to make fine tuning of Bz over the QF&QD region instead of the mechanical rotation.

The design of interaction region

Geometry and Lattice

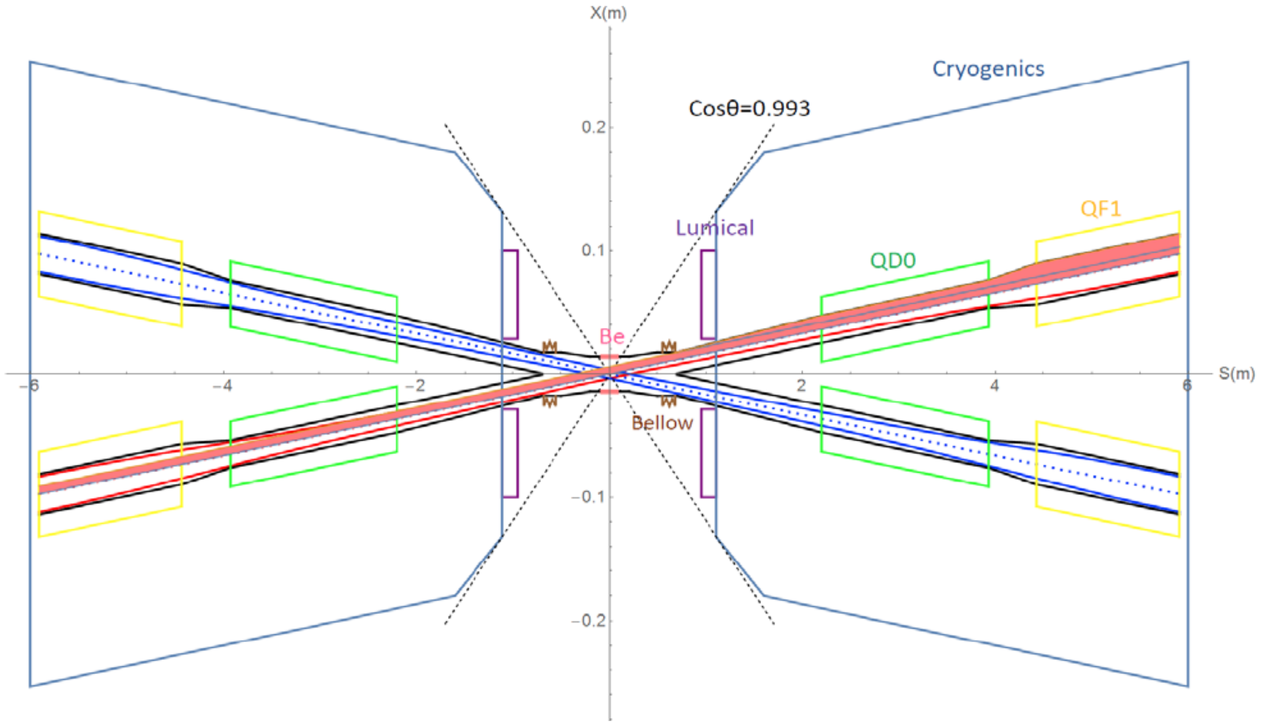




Crab-waist scheme with local chromaticity correction

The design of interaction region

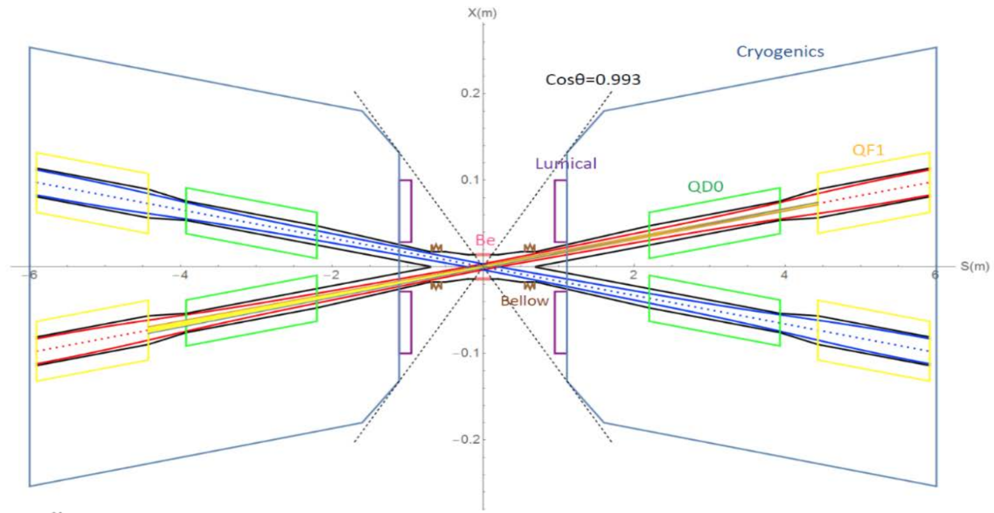
- The central part is Be pipe with the length of 14cm and inner diameter of 28mm.
- IP upstream: **Ec < 120 keV within 400m. Last bend**(66m)**Ec = 45 keV**
- IP downstream: **Ec < 300 keV within 250m**, first bend **Ec = 97 keV**

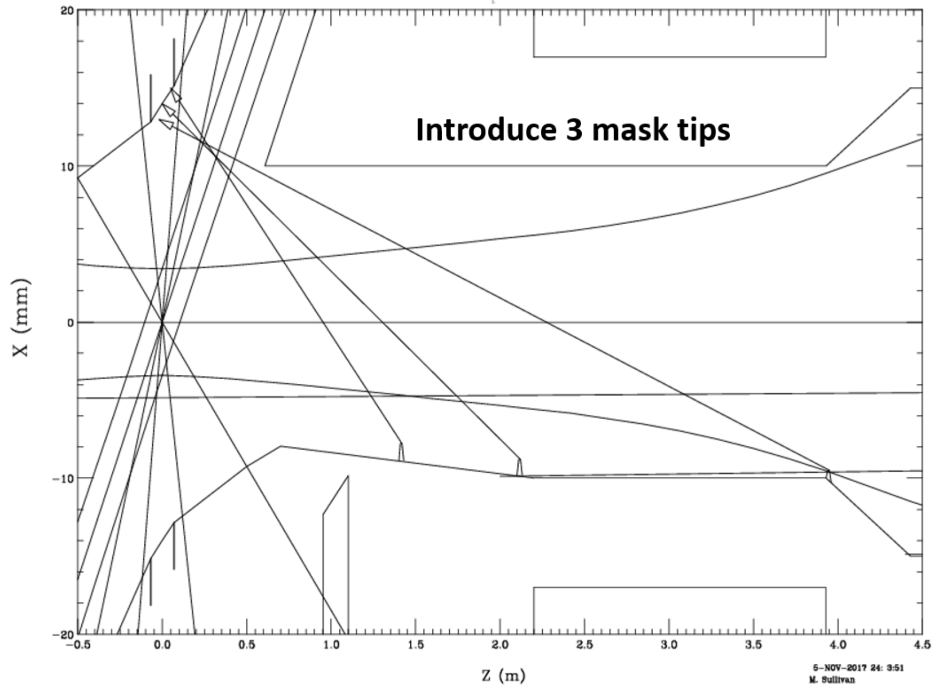


Reverse bending direction of last bends

Background control & SR protection

The design of interaction region





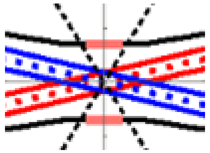
The total SR power generated by the QD magnet is 639W in horizontal and 166W in vertical. The critical energy of photons are about 1.3 MeV and 397keV in horizontal and vertical.

The total SR power generated by the QF1 magnet is 1567W in horizontal and 42W in vertical. The critical energies of photons are about 1.6MeV and 225keV in horizontal and vertical.

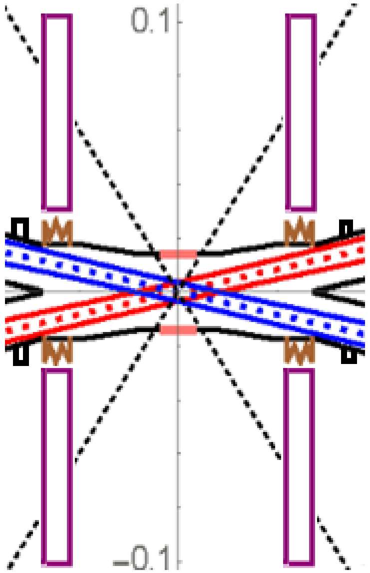
No SR hits directly on the beryllium pipe. SR power contributed within $\pm 6\sigma_x$ will go through the IP.

3 mask tips are added to shadow the beam pipe wall from 0.7 m to 3.93 m reduces the number of photons that hit the Be beam pipe from 2×10^4 to about 200 (100 times lower).

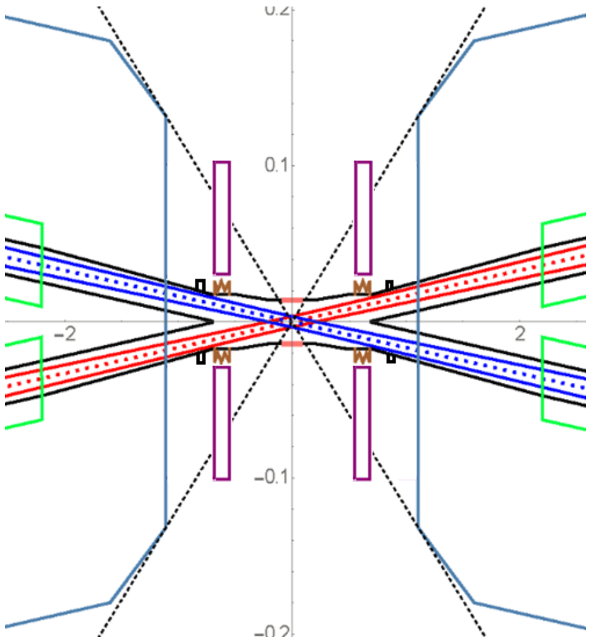
Assembly nearby the IP



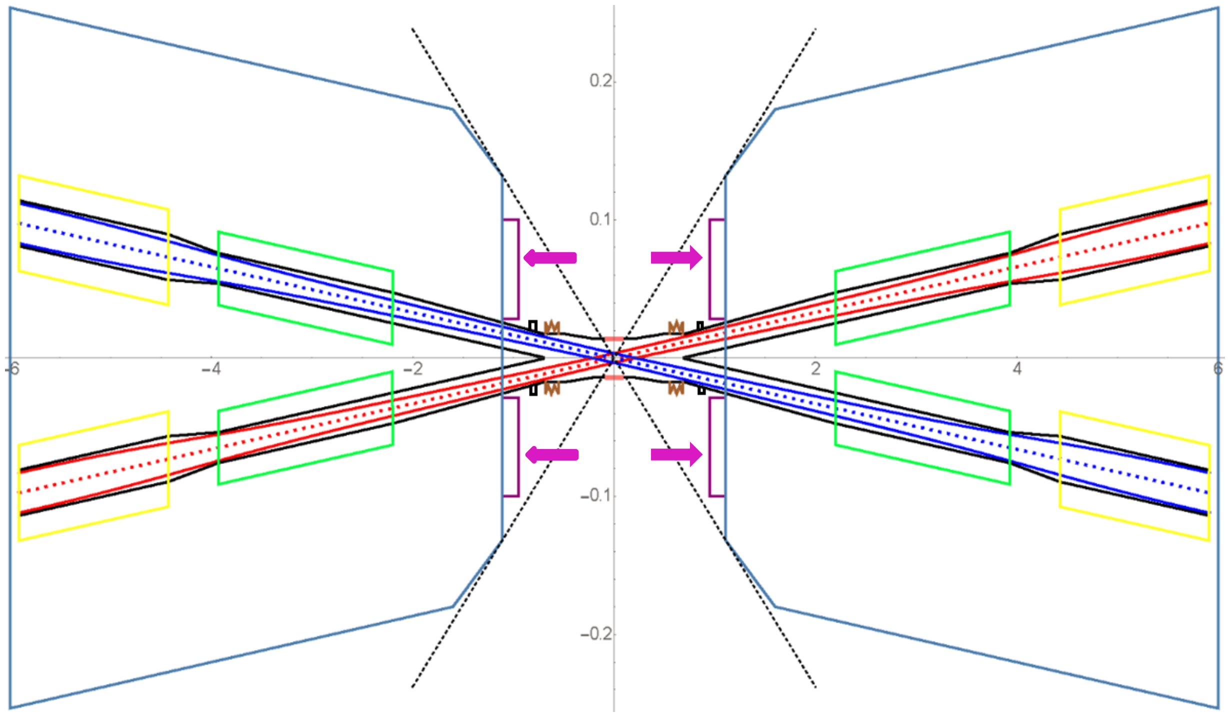
1, IP Chamber
(supporting)



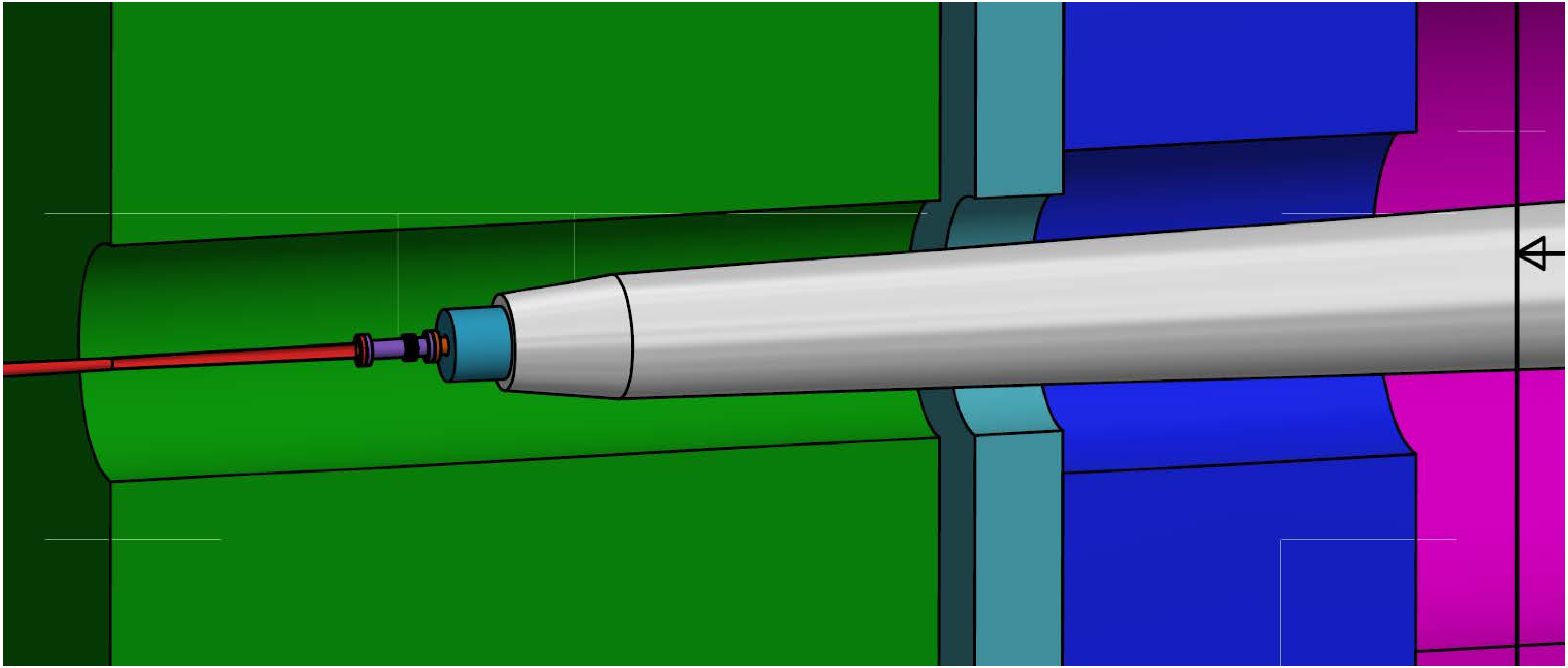
2, Bellows and Lumical (remotely)
(supporting system)



3, SC Magnet and Vacuum chamber (remotely)

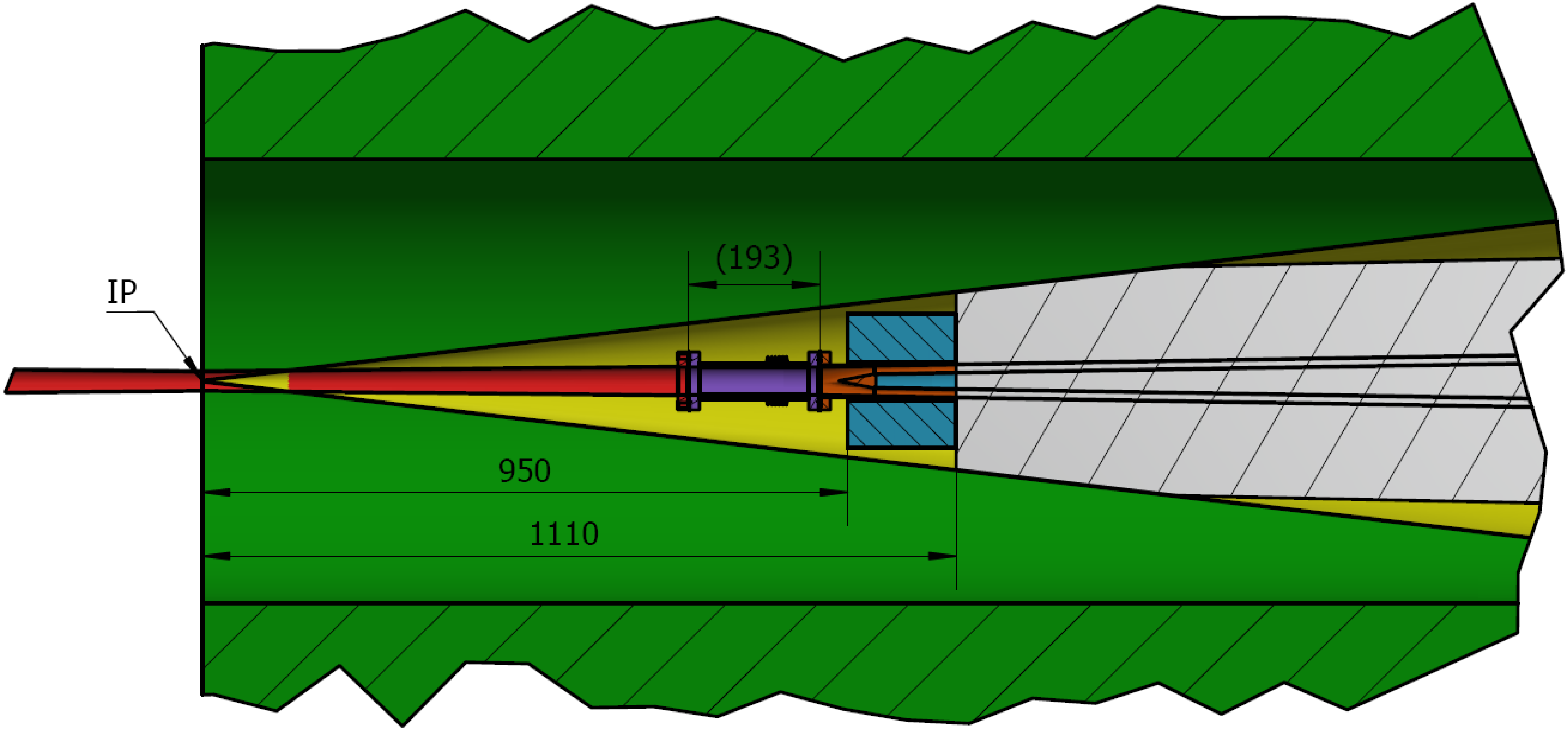


4, Move Lumical back and attach to the cover of cryostat by alignment holes (remotely)



We are studying the special installation tools for the remote connection of bellows.

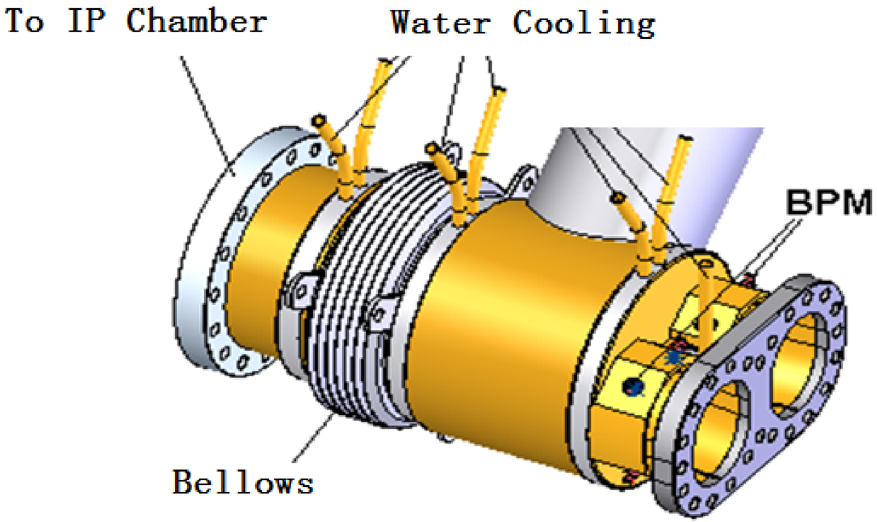
If the space is large enough, LumiCal will be connected together with the SC magnet.

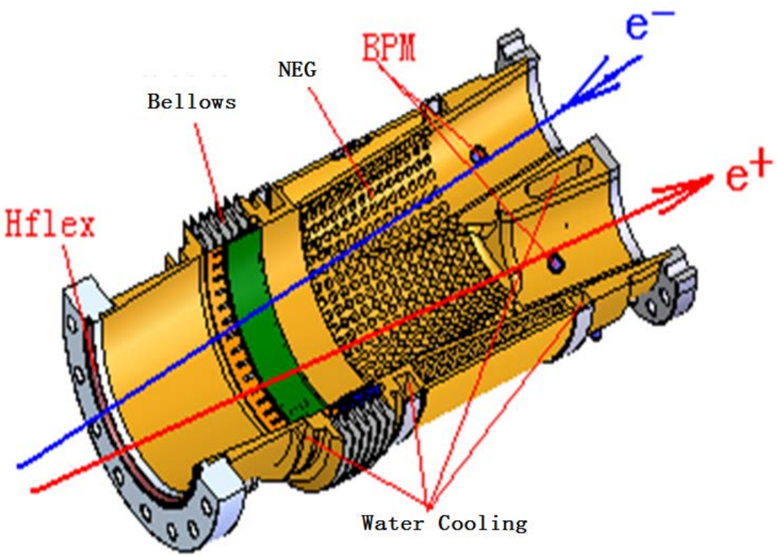


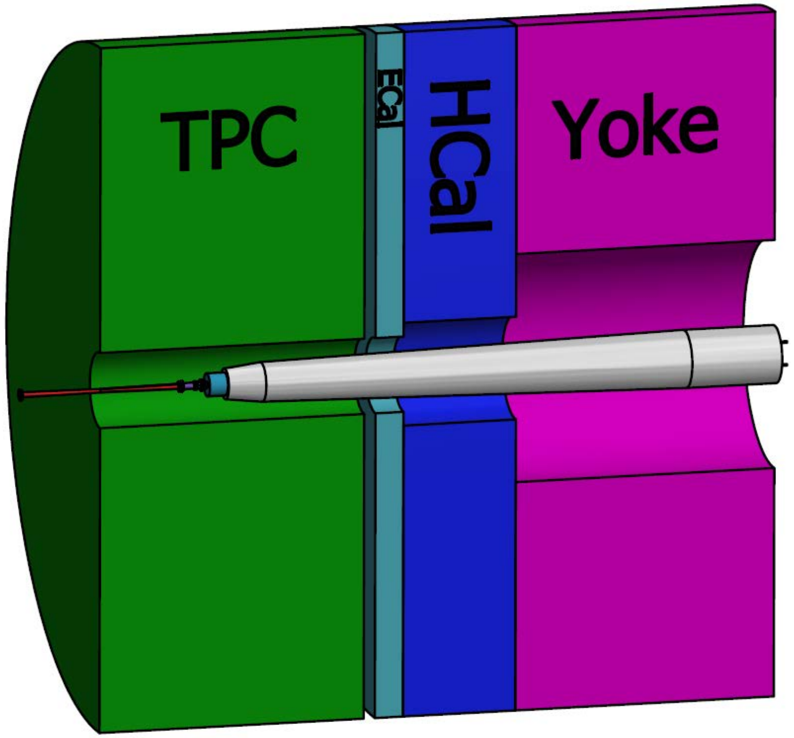
The boundary between detector and accelerator is still not clear. The design of HOM absorber and the special tool can’t be confirmed in short period.

Assembly nearby the IP

Crotch region

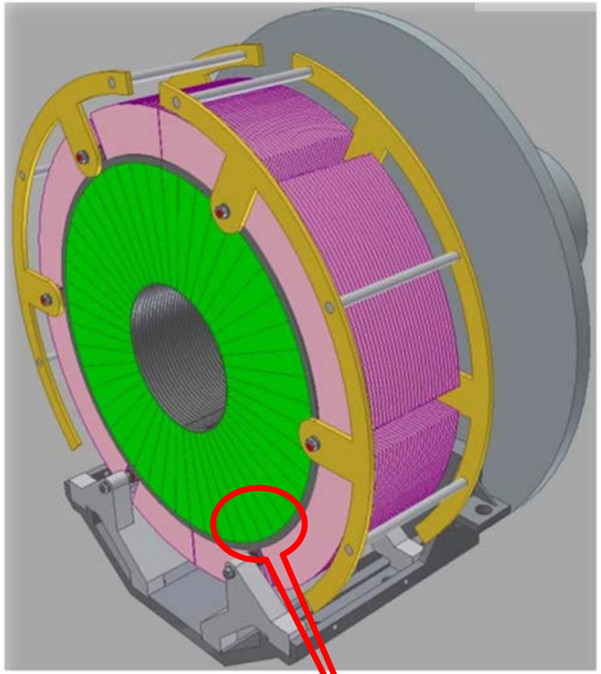






Helicoflex

Parameters of lumiCal

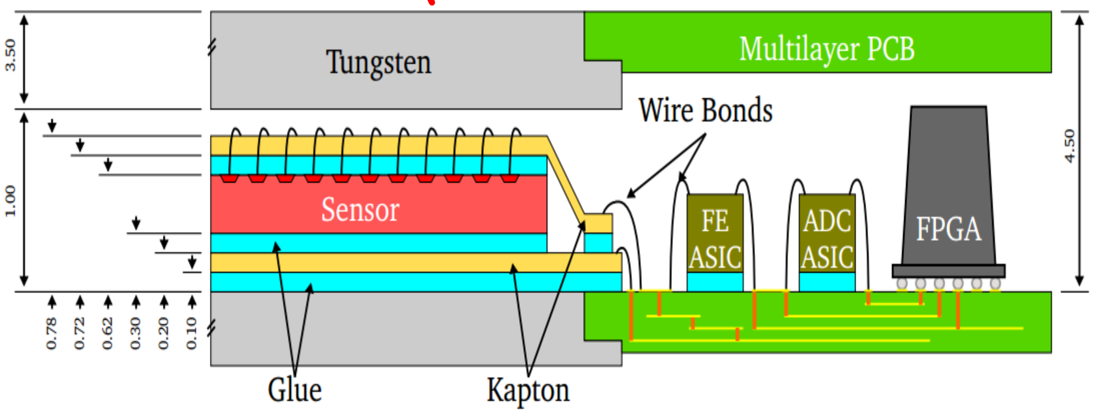


	CEPC	OPAL	ILD
z to IP (m)	.95 ~ 1.11 m	2.5 m	2.5 m
radius (mm)	28 .5 ~ 100 mm	62 - 142 mm	80 – 195 mm
θ range	28.5 ~ 100 mRad	25 - 57 mRad	40 – 69 mRad
Si r-pitch	*Scale by Z to OPAL/ILD*	2.5 mm	1.8 mm
radius precision		4.4 μm	
Ref.		arXiv-0206074v1 EPJC 14 373	Procedia 37 258

Detector: Si & W sandwich

Another option: BGO + diamond ring

Parameter	unit	limit
$\Delta E_{\rm CM}$	MeV	120
$E_{e^+} - E_{e^-}$	MeV	240
$\frac{\delta\sigma_{E_{beam}}}{\sigma_{E_{beam}}}$		Effect cancelled
$\Delta x_{\rm IP}$	mm	2
$\Delta z_{\rm IP}$	mm	10
Beam synchronisation	ps	15
$\sigma_{x_{\rm IP}}$	mm	1
$\sigma_{z_{\rm IP}}$	mm	>10
r_{in}	μm	10
$\sigma_{r_{\rm shower}}$	mm	>1
$\Delta d_{\rm IP}$	μm	500



Summary

- Detector solenoid 3.0T is a relatively hard start point for the accelerator design.
- The finalization of the beam parameters and the specification of special magnets have been finished. The parameters are all reasonable.
- Preliminary procedures for the installation of IP elements are studying. The boundary between detector and accelerator is still not clear. Very long time is needed to confirm the final scheme.
- The optimization to reduce machine cost and improve the luminosity is always under studying.