Circular Electron Positron Collider

Interaction Region Design

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On behalf of the MDI WG

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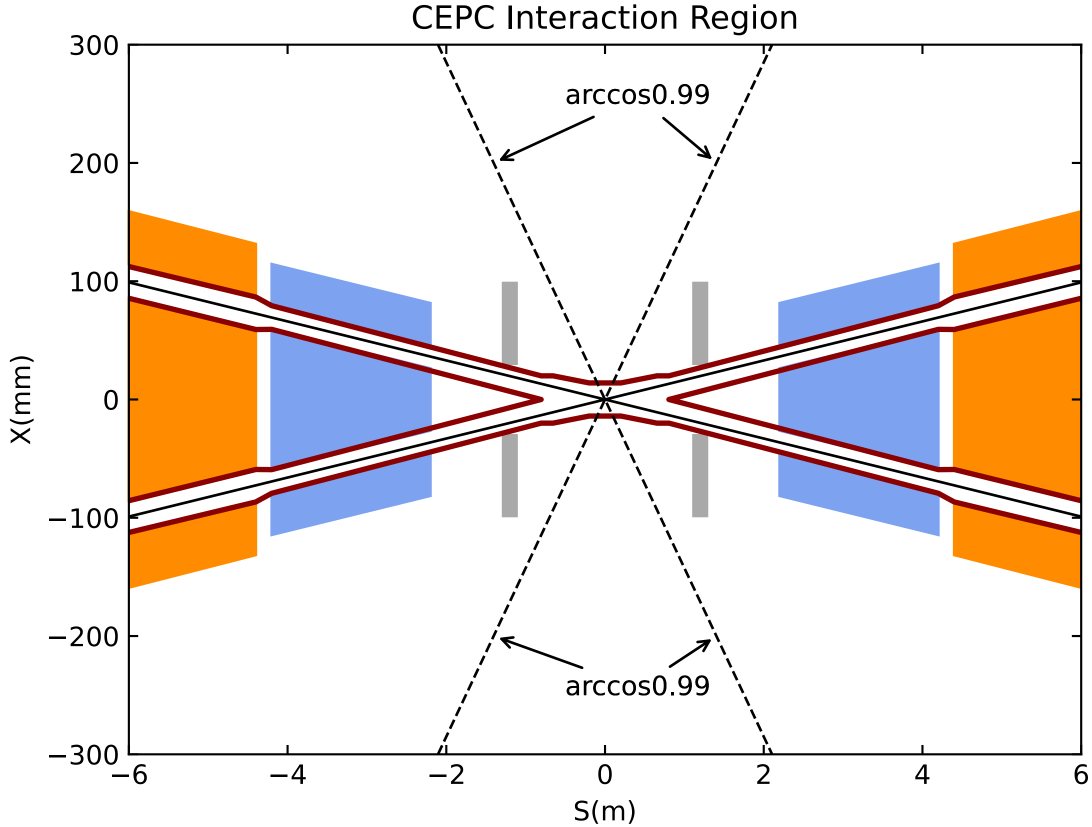
CDR Machine Parameters

	Unit	Higgs	WW	Z
Circumference	km		100	
Crossing angle	mrad		33	
Focal length (L*)	m		2.2	
Beam energy	GeV	120	80	45.6
Beam current	mA	17.4	87.9	461.0
Number of bunches		242	1524	12,000
Particles per bunch	$\times 10^{10}$	15.0	12.0	8.0
Horizontal emittance	nm	1.21	0.54	0.18
Vertical emittance	pm	2.4	1.6	1.6
β_x^*	m	0.36	0.36	0.2
β_y^*	mm	1.5	1.5	1
σ_x^*	μm	20.9	13.9	6.0
σ_y^*	nm	60	49	40
Bunch length	mm	4.4	5.9	8.5
Natural bunch length	mm	2.72.	2.98	2.42
Energy spread	%	0.134	0.098	0.080
Energy acceptance	%	2.06	1.47	1.70
Luminosity	$\times 10^{34}$	3	10	32

- Decided to complete the interaction region design based on the CDR parameters;

Interaction Region Layout

- To accommodate both machine and detector elements in the crowded interaction region to achieve an overall optimal performance (high luminosity, low backgrounds)



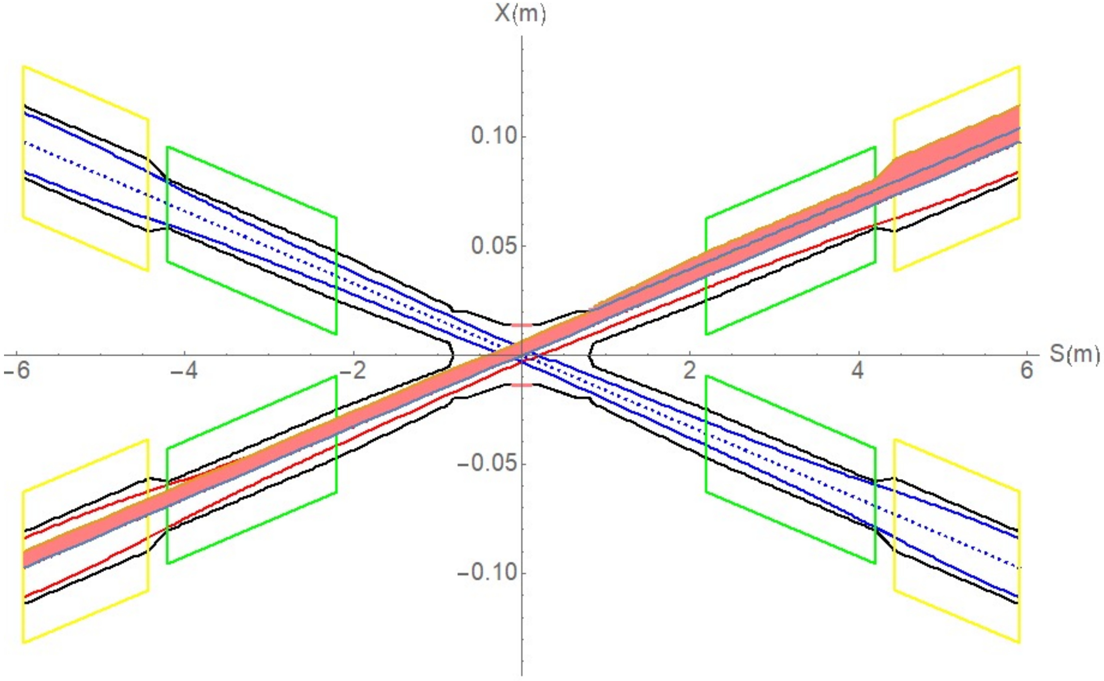
S. Bai

Starting with Synchrotron Radiation

- Synchrotron radiation dealt with high priority at circular machines when designing the interaction region;
  - Sextuple magnets to lower the critical energy of SR photons

Revised beam pipe design to achieve:

No direct SR photons hitting the central beam pipe even under the extreme beam conditions (e.g. beam off orbit due to magnet errors)



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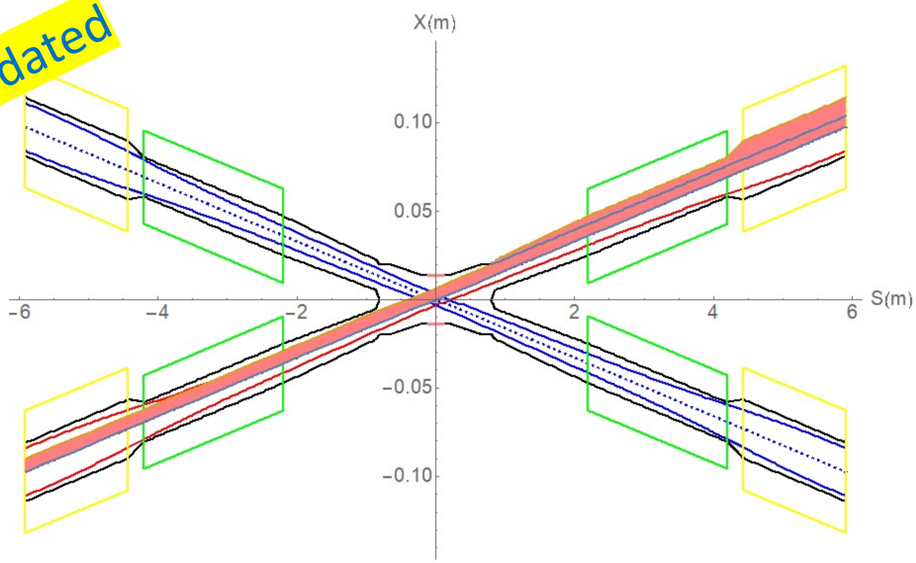
Revised Beam Pipe & Vacuum Chamber Design

Updated



- Another update: ~~asymmetric up & down stream beampipe apertures~~

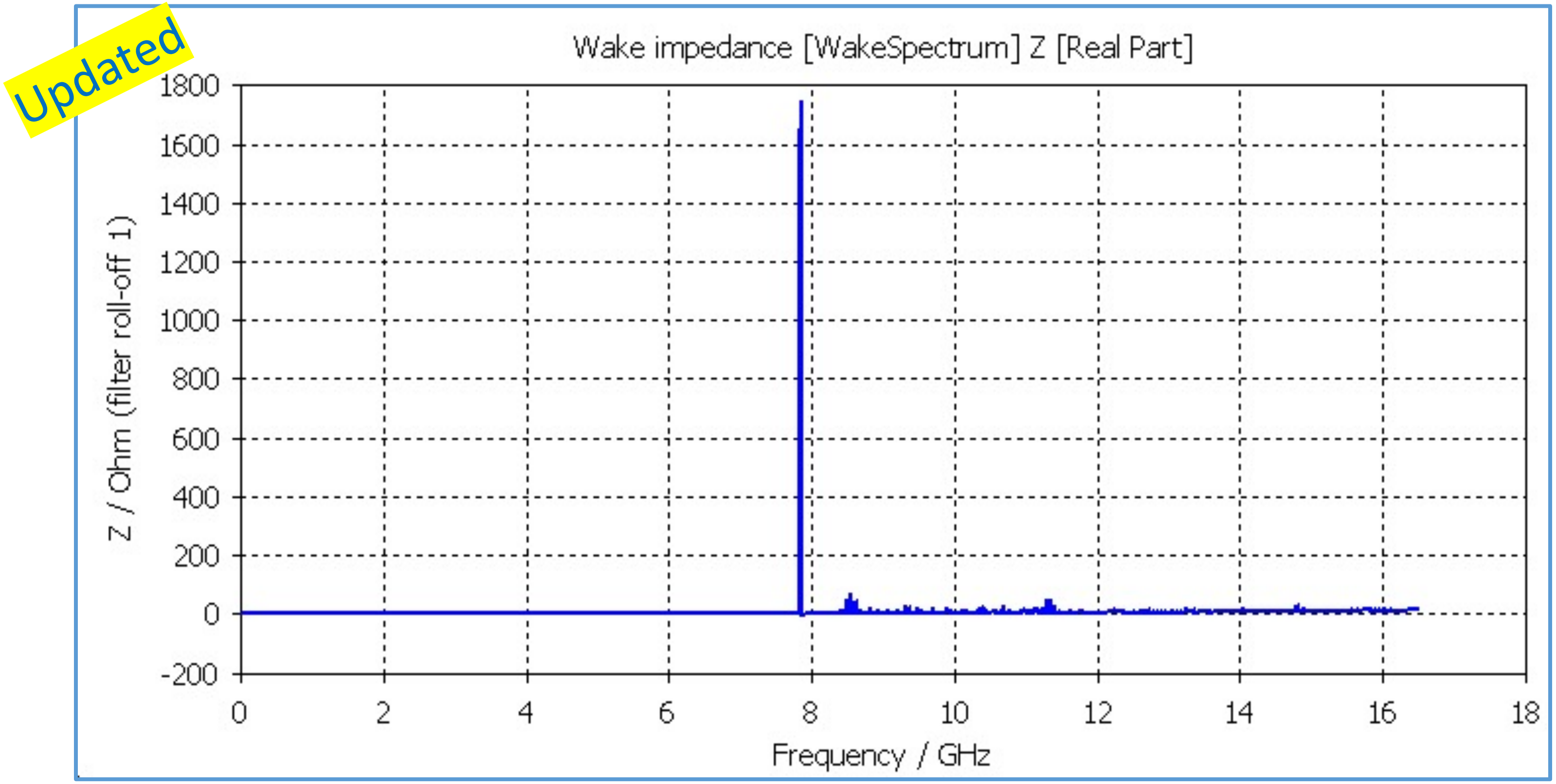
Design dropped

No SR power deposition between ±0.855 m → ± **0.805**m

Segments	Power Deposition	Average Power Density
0.805m~0.855m	36.53 W	88.9 W/cm^2
0.855m~2.2m	2.24 W	2.54 W/cm^2
QD0	2.79 W	0.39 W/cm^2
QD0~QF1	36.1 W	63.6 W/cm^2
QF1	3 W	0.55 W/cm^2

Y. Liu

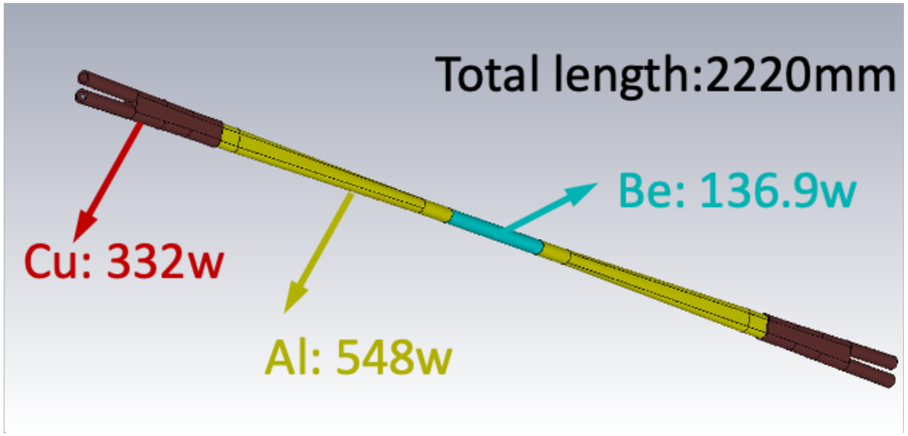
HOM SIMULATION



- Main sources: 1. Power trapped in the IR pipe (f< 11.474GHz); 2. HOM propagated from other part of the ring

Y. Liu

HOM Heat Load Results



- HOM heat load results to be used for FEA thermal analysis for the beam pipes and vacuum chambers

Maximum Power	CDR beam parameters (w)	HOM power density (w/cm^2)	High Luminosity beam parameters (w)	HOM power density (w/cm^2)
Be pipe	50	0.227	136.9	0.622
Al: Transition pipe	342	0.316	1097	1.012
Cu: Y-shape crotch	207	0.158	664	0.507
Total power in IR pipe	592	0.234	1898	0.714

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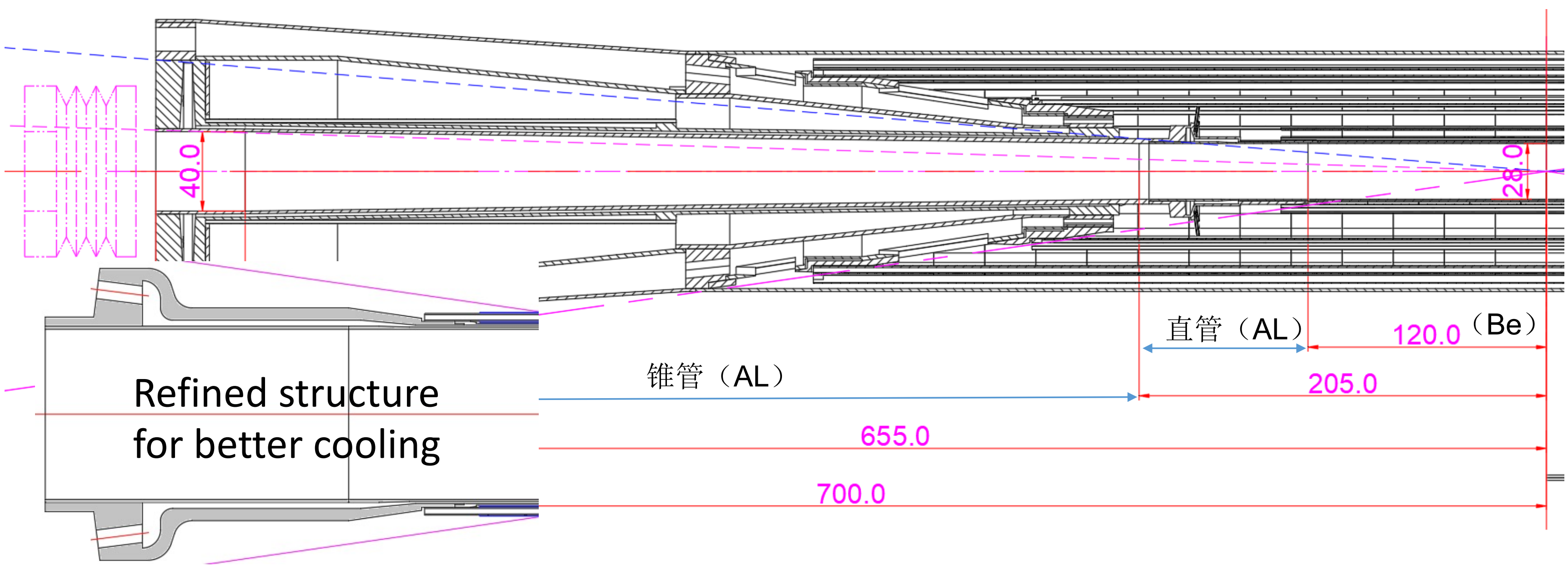
BEAM PIPES

- Beryllium (central) and Aluminum (forward) beam pipes

束流管内部尺寸（加速器提供 ）					
距 IP 距离（mm）	形状	内径(mm)	材料	内表面积(mm^2)	备注
0 – 120	圆直管	直径28	Be	10556	
120-205	圆直管	直径28	Al	7477	
205-655	圆锥管	直径28过渡到直径40	Al	48071	taper:1.75
655-700	圆直管	直径40	Al	5655	



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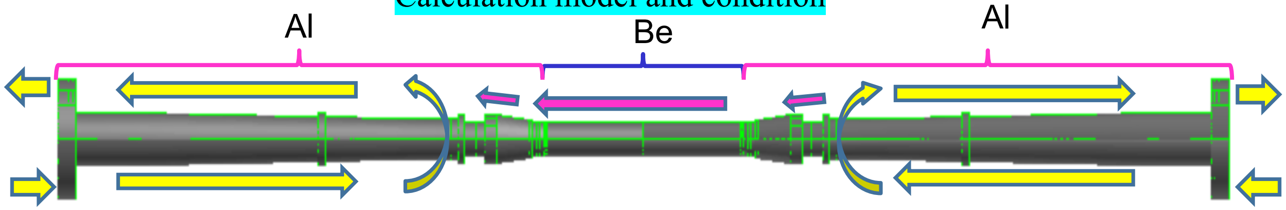
Beam Pipe Thermal Analysis I

FEA results being updated

Calculation model and condition



- Coolant: water
- Inlet temperature: 23°C
- Flow rate: 3.4L/min

- Coolant: paraffin
- Inlet temperature: 23°C
- Flow rate: 2.2L/min

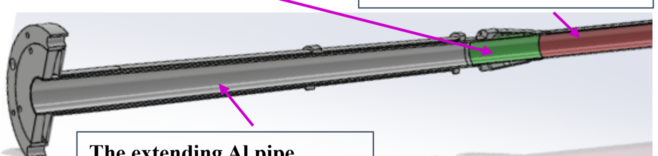
- Coolant: water
- Inlet temperature: 23°C
- Flow rate: 3.4L/min

Viscous model: Laminar

Heat in each part of calculation model

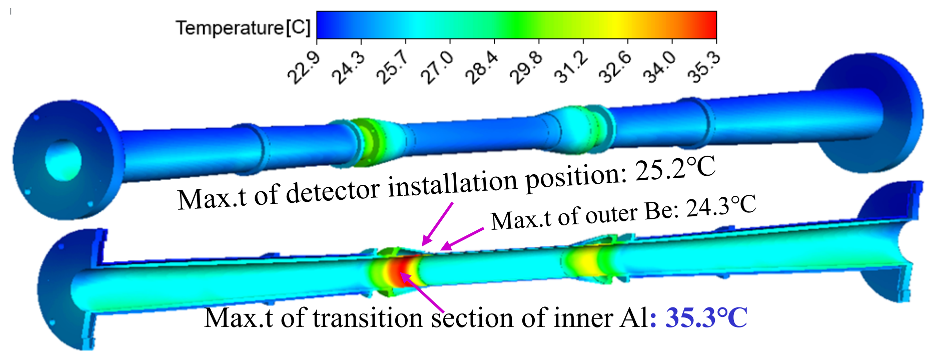
The enlarge cavity of Be pipe:
Z: 77.3W(5492.7W/m^2)
HZ: 332.0W(23589.0W/m^2)

Be pipe:
Z: 47.92W(4539.7W/m^2)
HZ: 415.6W(39371.9W/m^2)



The extending Al pipe
Z: 284.2W(5492.7W/m^2)
HZ: 1220.3W(23589.0W/m^2)

Temperature distribution in Z model



paraffin: Δp=19.8kPa, Δt=3.1°C
water: Δp=14.8kPa, Δt= 1.2°C

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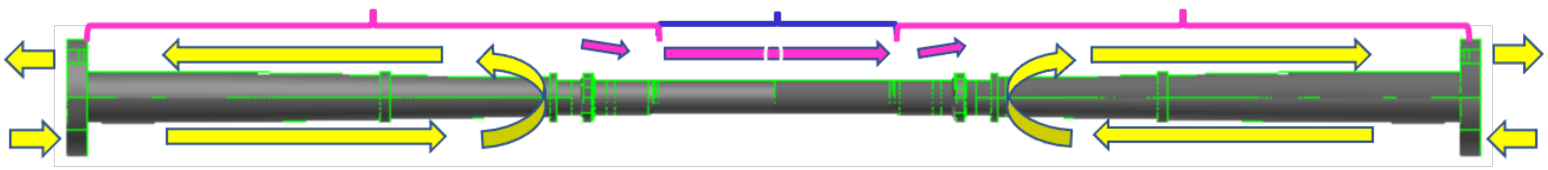
Beam Pipe Thermal Analysis II (CDR Z)

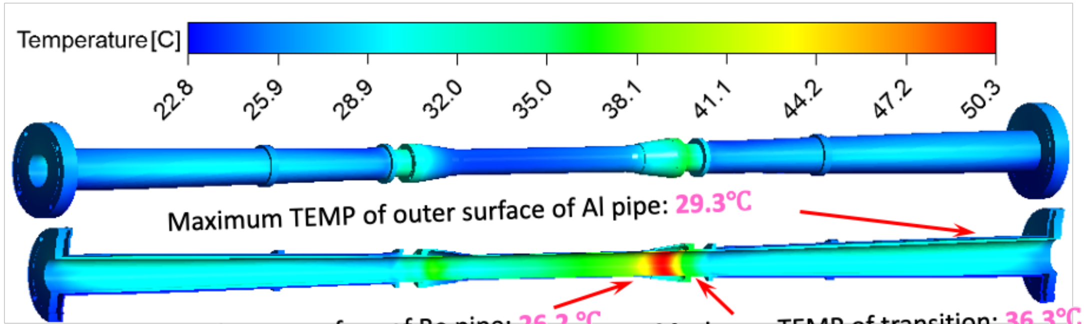
Power dissipation: 1500 W



Calculation model:
laminar

Inlet of Be pipe:
TEMP: 23C°
Velocity: 1.3 m/s
Coolant: paraffin

Inlet of Al pipe:
TEMP: 23C°
Velocity: 1.0 m/s
Coolant: H_2O



Temperature rise:

Be pipe : 3.2 ℃
Transition: 13.3 ℃
Al pipe : 6.3 ℃

Pressure drop:

Be pipe : 19.8 kPa
Al pipe : 19.3 kPa

Conclusion:

Temperature rise and pressure drop within safe range

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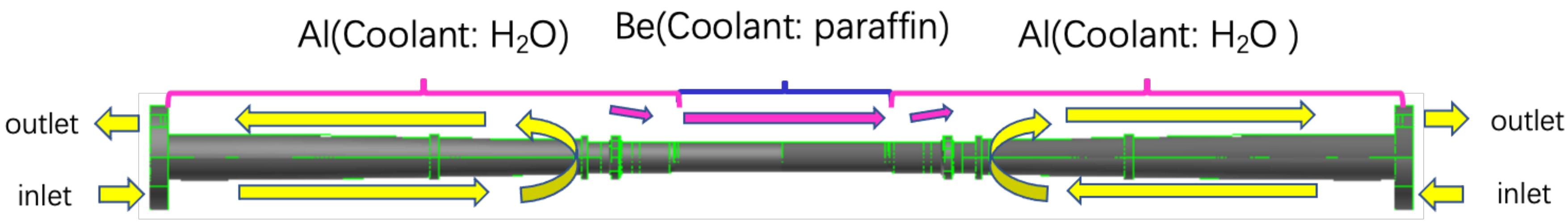
BEAM PIPE THERMAL ANALYSIS III (HL Z)

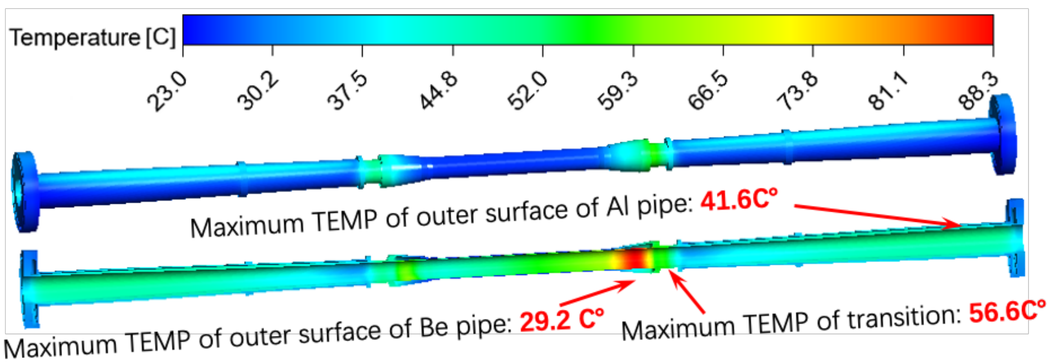
Power dissipation: 5100 W



Calculation model:
laminar

Inlet of Be pipe:
TEMP: 23C°
Velocity: 2.0m/s
Coolant: paraffin

Inlet of Al pipe:
TEMP: 23C°
Velocity: 1.5 m/s
Coolant: H_2O



Temperature rise:
Be pipe : 6.2 ℃
Transition: 33.6 ℃
Al pipe : 18.3 ℃

Pressure drop:
Be pipe : 31.9 kPa
Al pipe : 37.7 kPa

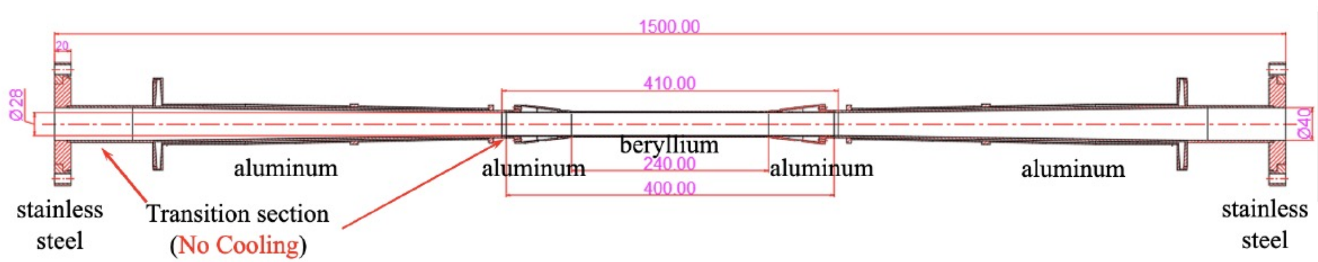
Conclusion:
Increased temperature rise and pressure drop but still within safe range, subject to further optimization

Shrinking the Be beam pipe: Φ28 → Φ20

Feasibility studies already started, full evaluation postponed for the High Luminosity design

- Quantify the impacts of smaller beampipe radius on HOM heat load, radiation backgrounds and tracking/vertexing performance → caveat: studies based on the CDR machine parameters, conclusion might have to change with the involving machine design

- Beampipe shape (central + forward) to be (re-)defined

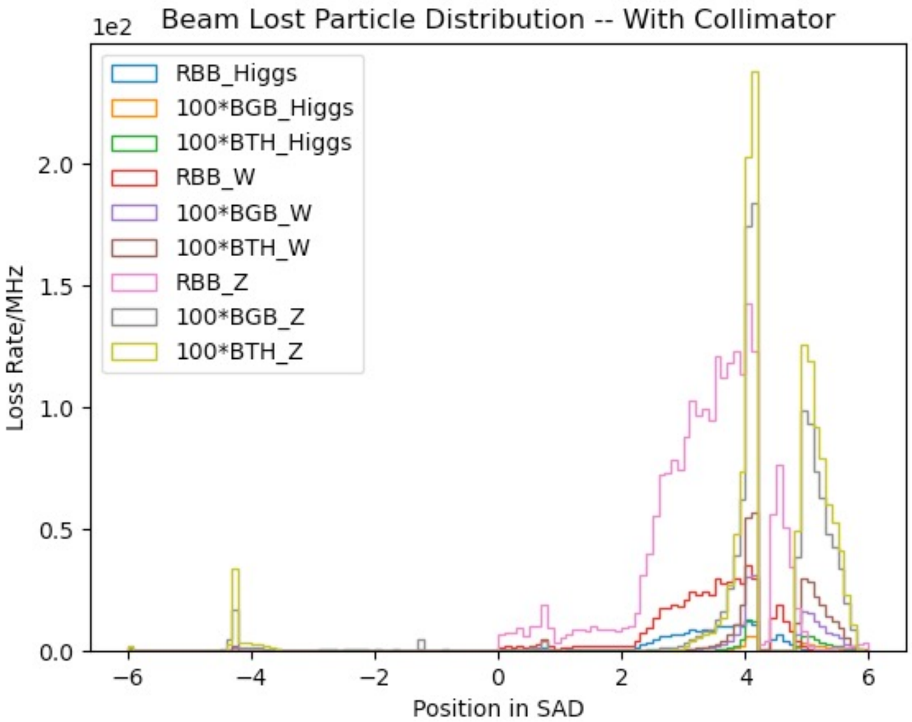


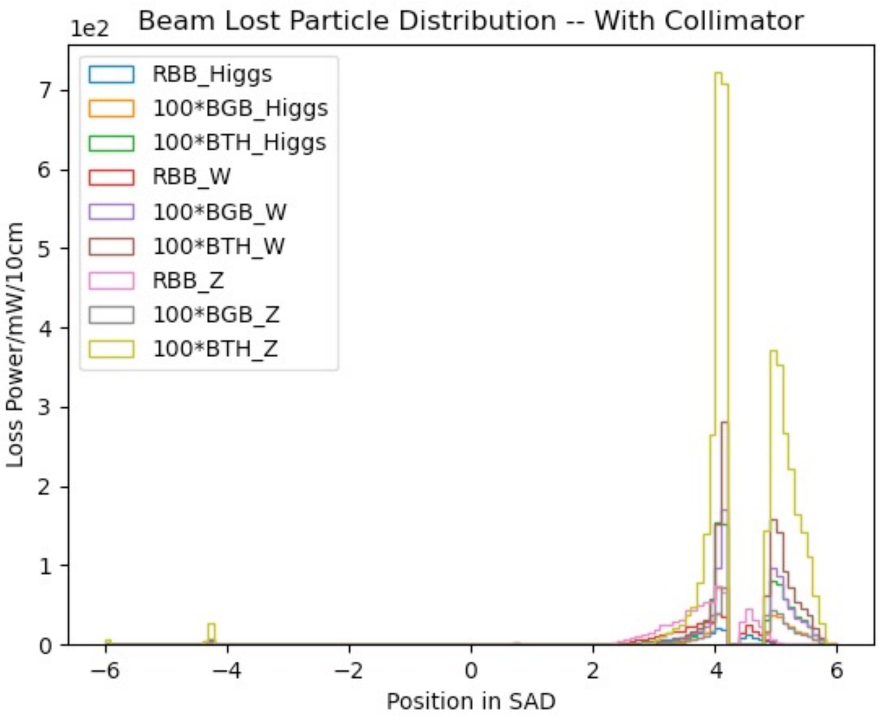
Smaller Be pipe radius preferred to fabricate thinner beampipe (less material)

RADIATION BACKGROUNDS

Details in H. Shi's talk

- Revisited (several times) the detector backgrounds caused by the beam loss particles, in particular beam-gas interactions and beam thermal photon interactions





W. Xu, H. Shi

Updated Background Levels

- Background levels estimated for different sources and machine operation energies
  - SR Hit Number on Be beam pipe per bunch crossing

	Higgs	W	Z
Hit Number	~320	~28	<1

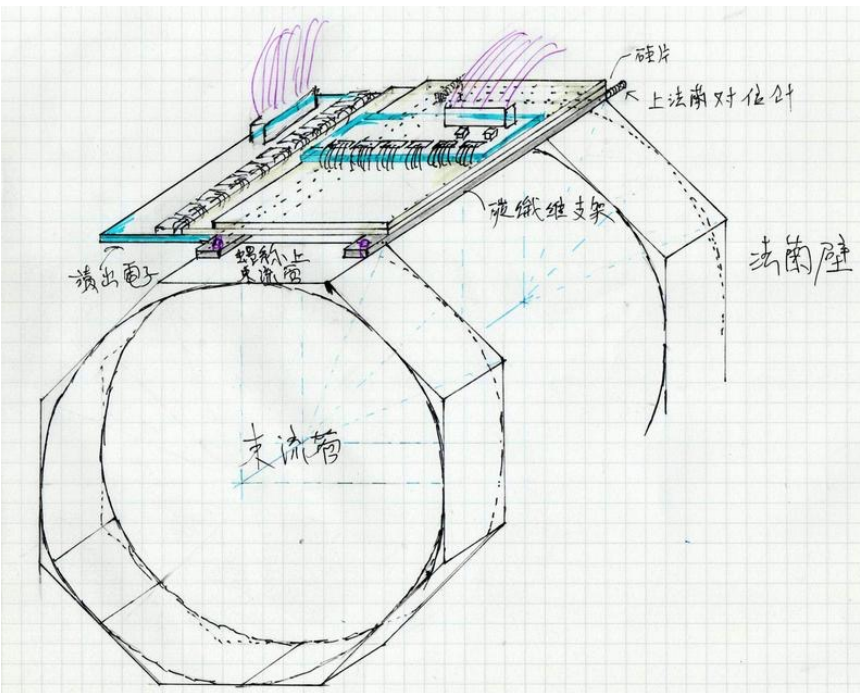
  - Backgrounds at the 1st vertex detector layer

Background	Hit Density ($cm^{-2} \cdot BX^{-1}$)			TID ($Mrad \cdot yr^{-1}$)			1 MeV equivalent neutron fluence ($n_{eq} \times 10^{12} \cdot cm^{-2} \cdot yr^{-1}$)		
	Higgs	W	Z	Higgs	W	Z	Higgs	W	Z
Pair production	1.8	1.2	0.4	0.5	2.1	5.6	1.0	3.8	10.6
Beam Gas	0.4	0.4	0.2	0.36	1.3	4.1	1.0	3.6	11.1
Total	2.2	1.6	0.6	0.86	3.4	9.7	2.0	7.4	21.7
CDR	2.4	2.3	0.25	0.93	2.9	3.4	2.1	5.5	6.2

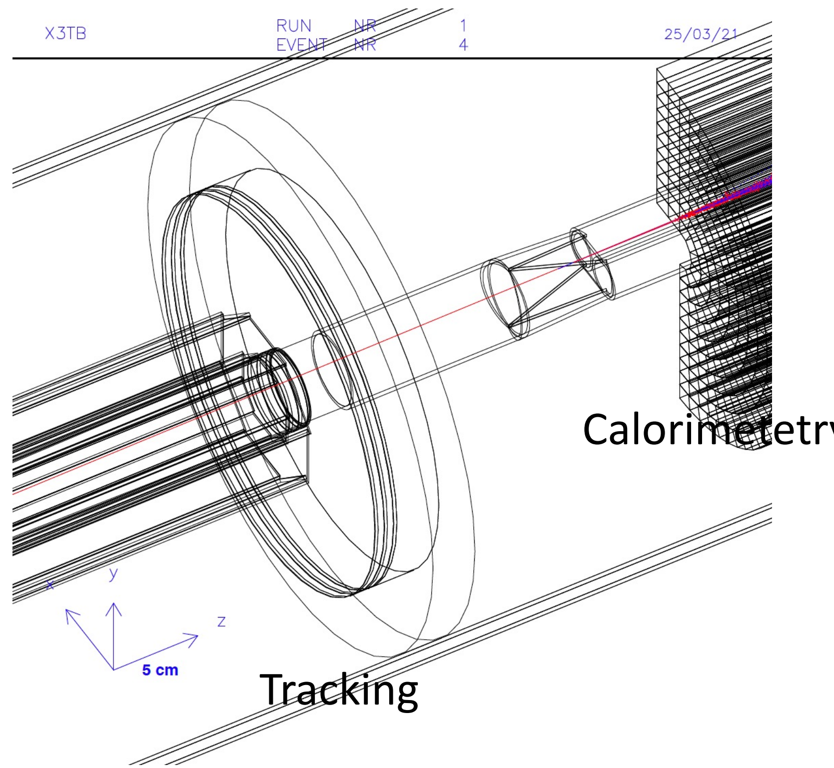
Details in S. Hou's talk

LUMICAL

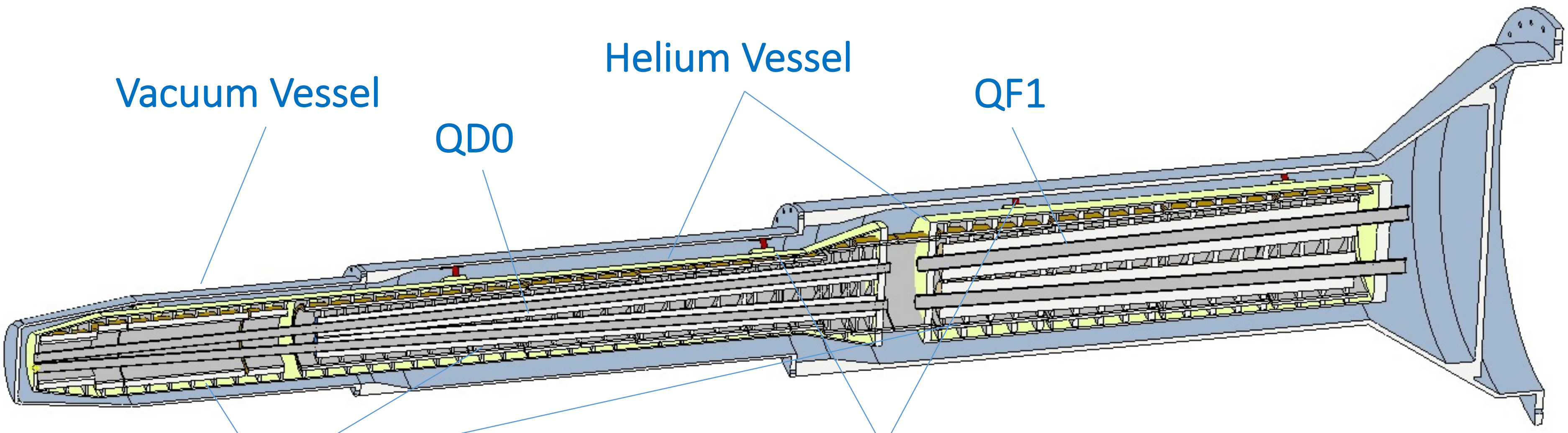
- To achieve precision luminosity measurement as required for precision Higgs/EW measurement;
- Detector design and integration into IR



Tracking Devices



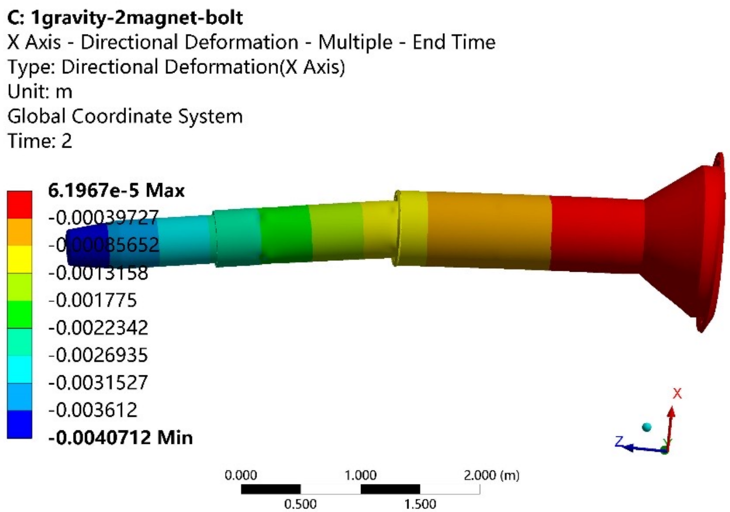
MECHANICS – ACCELERATOR COMPONENTS

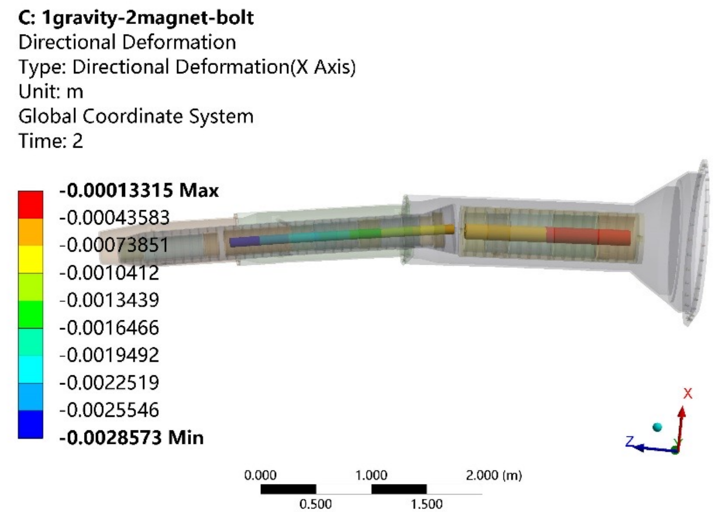


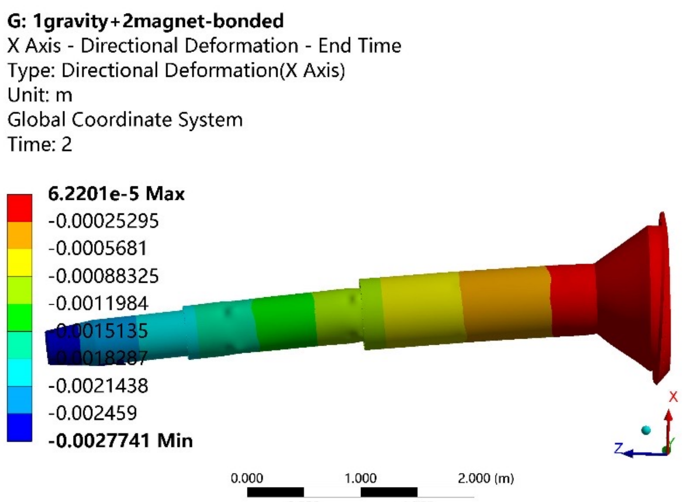
- Nontrivial to install and support the magnets and its auxiliary components with sufficient accuracy and stability

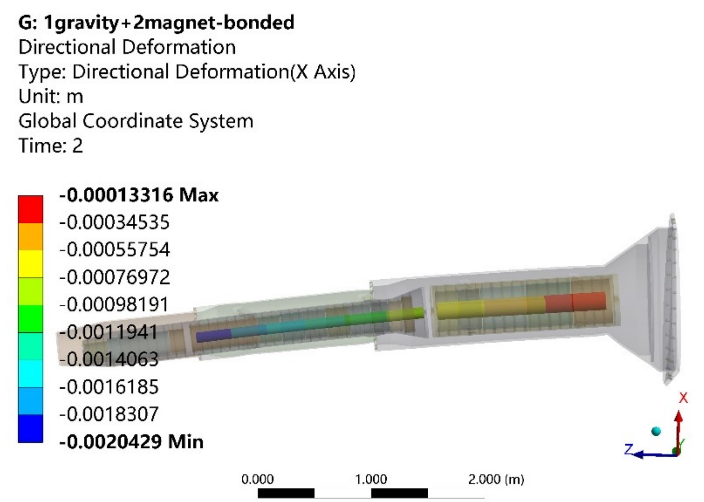
DEFORMATION CALCULATION

High stiffness, low density materials/structure



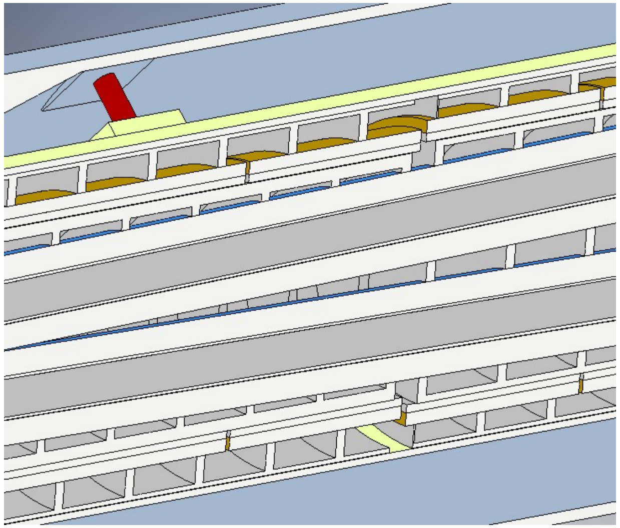






MAGNET SUPPORT

- Refined supporting structure
  - Add outer/inner rings to enhance stiffness



Structure as a solid piece (filled up with stainless steel) preferred, calculation to be repeated with tungsten as required for radiation shielding

Magnet support	uneven deformation in QD0 (um)		uneven deformation in QF1 (um)		Total weight (kg)	Frequency of 1st mode (Hz)
	Vertical	Horizontal	Vertical	Horizontal		
Skeleton	44	5	0.6	0.2	3244	12.7
Solid	7.3	0.6	0.3	0.2	5041	11.3
S-o support	27	1.6	0.7	0.5	3477	13.7

S-o support: skeleton support with outer ring

SUMMARY AND OUTLOOK

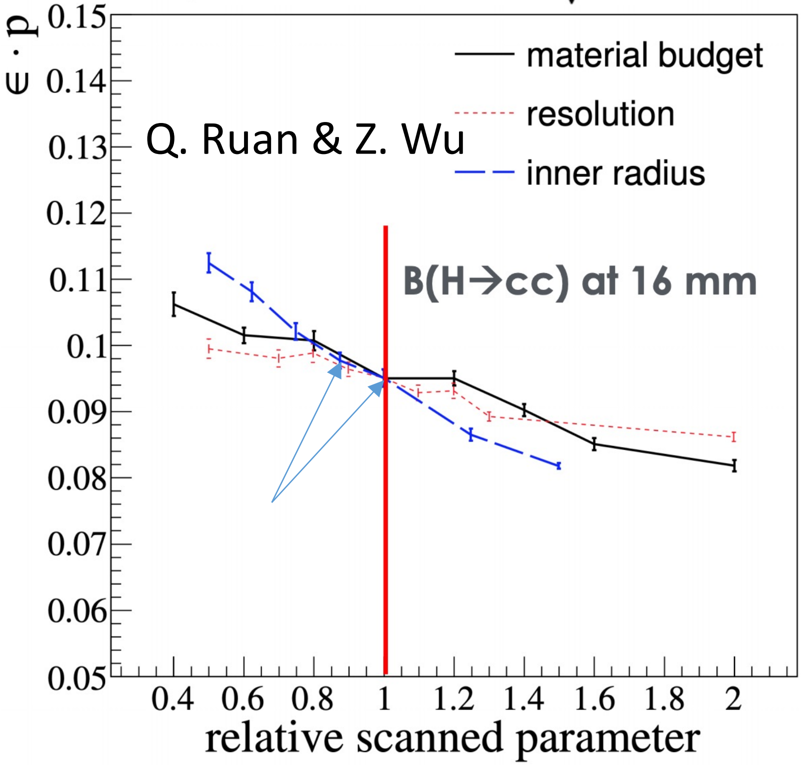
- Interaction Region design re-visited for the CDR machine parameters
  - HOM heat load updated with revised beampipe shape (SR prevention considerations)
  - Central beampipe with cooling structures; FEA thermal analysis to verify the design (being updated)
  - Background levels re-calculated for various sources and operation at different energies
  - LumiCal design updated and integrated into mechanical design

- Results based on CDR machine parameters to be published
- New IR design for the high luminosity machine to be started soon

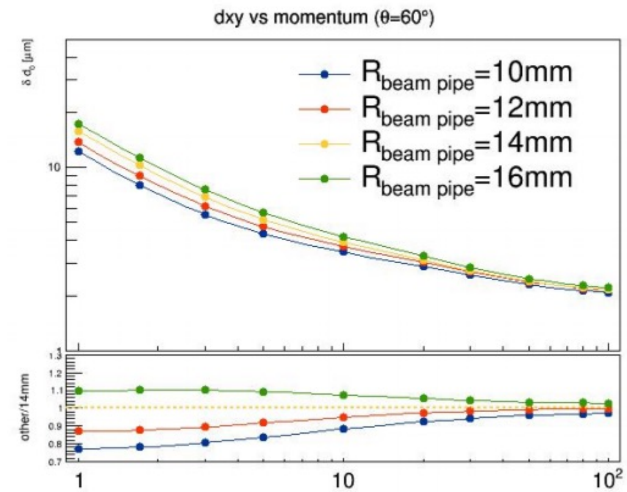
PHYSICS GAINS

- First estimates made with fast simulation and scaling

$$\frac{\delta_\mu}{\mu} \propto \frac{\sqrt{S+B}}{S} \propto \frac{1}{\sqrt{\epsilon \cdot p}}$$



$$\sigma_{d_0}^2 = \sigma_{geom}^2 + \sigma_{MS}^2$$
$$= \left(\frac{\sigma_1 r_2}{r_2 - r_1}\right)^2 + \left(\frac{\sigma_2 r_1}{r_2 - r_1}\right)^2 + \sum_{j=1}^{n_{scatt}} \left(R_j \Delta\Theta_j\right)^2$$



H. Zeng

- Implement the geometry in simulation and run a full analysis to estimate the physics gains

G. Li