SUMMARY OF THE CEPC MDI WORKSHOP

Hongbo Zhu

10 June 2020

Summary of the MDI Workshop

https://indico.ihep.ac.cn/event/11801/

CEPC MDI Workshop

from Thursday, 28 May 2020 at **08:00** to Friday, 29 May 2020 at **18:00** (Asia/Shanghai)
at **IHEP (C305)**

- 1.5-day workshop with over 50 participants
- Invited talks combined with working group talks
- J. Gao's summary talk

INVITED TALKS

Summary of the IAS mini-Workshop on MDI *40'*

Speaker: Dr. Toshiaki TAUCHI (High Energy Accelerator Research Organization (KEK))

Material: **Slides** **Slides with references**

MDI Issues during Commissioning and Beyond *40'*

I would like to discuss some of the starting up issues that the MDI design team needs to be prepared for and also how I expect the machine to evolve to the design parameters.

Speaker: Dr. Micheal Sullivan (SLAC)

Material: **Slides**

FCC-ee MDI *30'*

Speaker: Dr. Michael KORATZINOS (CERN and Massachusetts Institute of Technology)

Material: **Slides**

Overview of FCAL *30'*

Speaker: Dr. Maryna Borysova (DESY & Kiev Institute for Nuclear Research (KINR))

Material: **Slides**

Lessons learned with the SLD Vertex Detector, relevant to a future Higgs Factory *30'*

Speaker: Prof. Chris Damerell (Rutherford Appleton Laboratory)

Material: **Slides**

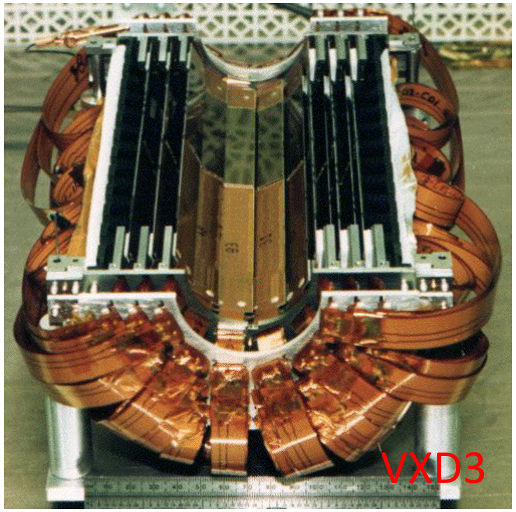
MDI Issues during Commissioning and Beyond

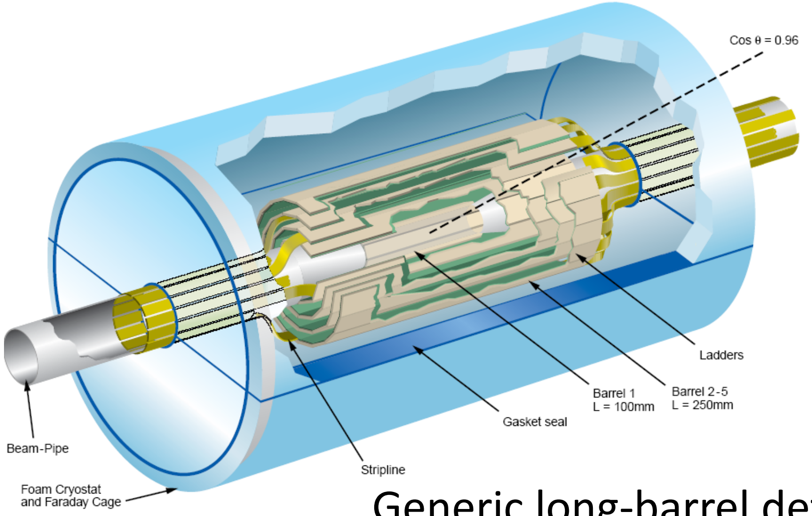
- MDI concerns
  - Maximize the detector acceptance
  - Accommodate the machine lattice
    - Help to fit the final focus magnets into the IR design
  - Help to calculate the backgrounds in the detector
    - Supply the sources of backgrounds to the detector simulation team
  - With engineering help
    - Design and support the final focus magnets
    - Maintain the beams in collision (usually with fast orbit feedback correctors)
    - Design the beam pipe in the detector
  - …

Design in a safety margin

- A safety margin can also protect the design from unexpectedly high backgrounds
  - SuperKEKB and Belle II are struggling with this issue
  - The backgrounds present in the machine are higher than they estimated
- If the design has missed the magnitude of a background then usually this is because some source was missed or the known source is stronger than was estimated
- Simulators almost **never overestimate** a background
- It is very difficult to get good estimates of **all** possible background sources

LESSONS LEARNED WITH THE SLD VERTEX DETECTOR





Generic long-barrel detector for future experiments

- After all this, what lessons did we learn, that might be relevant to CEPC(ee)?
- There's a non-negotiable need for a small radius beampipe (~15 mm), or much physics would be lost. Can this small radius be guaranteed, after what happened at LEP and SLC? Can the LEP-2 conditions be reliably simulated, and results carried forward to CEPC? Does the much larger machine circumference imply a higher risk? [remember the 'loose bolts' incident in the SLC LINAC]
- Presuming a necked-down beampipe is needed (ie it cannot be cylindrical over an extended length) the 'R20 module' installation procedure might be attractive.
- Should one cater for cryogenic operation? This feature gave VXD3 one of it's '9 lives'. Subsequent vertex detectors have suffered damage from unexpected beam glitches at RHIC and Belle-II. Cryogenic operation demands an excellent gas seal, since a small leak would have serious consequences for other detector systems. For this to work, the R20 module approach is preferred or maybe obligatory, as opposed to assembling the detector round the installed beampipe.
- Whatever else, there needs to be a clear procedure for upgrading or replacing the vertex detector at unpredictable time intervals. Putting a delicate detector so close to the beam is inevitably risky. Experience with SLD, then with the STAR vertex detector at RHIC, and with Belle-II (the DEPFET-based vertex detector) show that convenient access for repairs or replacement is a general requirement, if you push for small radius.
- Best of luck with this great adventure!

HIGH ORDER MODE (HOM) HEAT LOAD

Y. Liu

Summary on HOM heating Power for IR （CDR beam parameters）

IR Model	H		W		Z	
Model 0 (28mm-28mm)	P_{trap}: 42w	P_{pro}: 26.8w	P_{trap}: 170.4w	P_{pro}: 108.6w	P_{trap}: 595.2w	P_{pro}:379.4w
	P_{total}: 68.8w		P_{total}: 279w		P_{total}: 974.6w	
Model 1 (28mm-20mm)	P_{trap}:12.3w	P_{pro}:10.2w	P_{trap}:49.8w	P_{pro}:41.6w	P_{trap}:174.2w	P_{pro}:145.5w
	P_{total}: 22.5w		P_{total}: 91.4w		P_{total}: 319.7w	
Model 2 (28mm-20mm)	P_{trap}:15w	P_{pro}:7.1w	P_{trap}:60.7w	P_{pro}:28.9w	P_{trap}:212.3w	P_{pro}:101.2w
	P_{total}: 22.1w		P_{total}: 89.6w		P_{total}: 313.5w	
Model 3 (28mm-20mm)	**P_{trap}:14.2w**	**P_{pro}:6.2w**	**P_{trap}:57.5w**	**P_{pro}:25w**	**P_{trap}:201.1w**	**P_{pro}:87.3w**
	P_{total}: 20.4w		**P_{total}: 82.5 w**		**P_{total}: 288.4w**	
Model 4 (20mm-20mm)	P_{trap}:14.5w	P_{pro}:5.2w	P_{trap}:58.9w	P_{pro}:21.0w	P_{trap}:205.9w	P_{pro}:73.4w
	P_{total}: 19.7w		P_{total}: 79.9w		P_{total}: 279.3w	
Model 5 (28mm-11mm)	P_{trap}:**2.2kw**	P_{pro}:-	P_{trap}:**9.1kw**	P_{pro}:-	P_{trap}:**31.9kw**	P_{pro}:-
	P_{total}:**2.2kw**		P_{total}:**9.1kw**		P_{total}:**31.9kw**	

- Even higher HOM heat load for the high luminosity design

Combine Results - Updated

Higgs Backgrounds on 1st layer of Vertex. With a safety factor of 10.

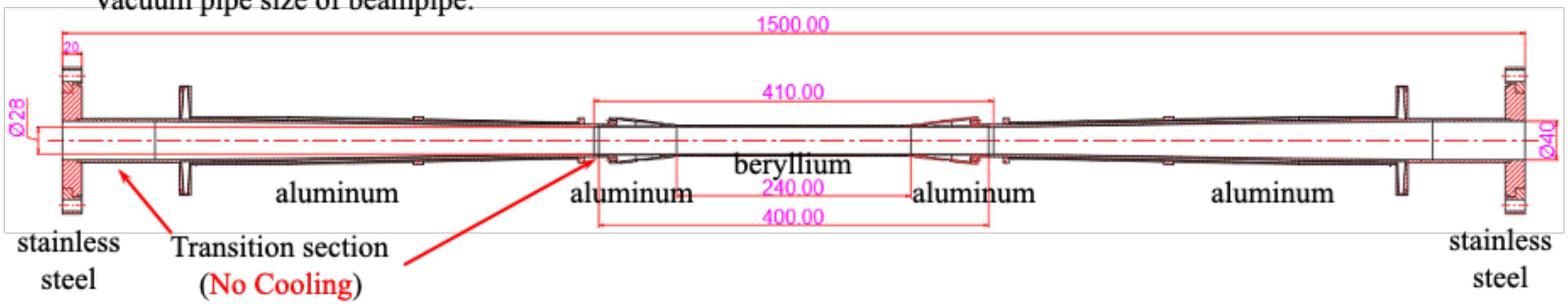
Background Type	Hit Density($cm^{-2} \cdot BX^{-1}$)	TID($krad \cdot yr^{-1}$)	1 MeV equivalent neutron fluence ($n_{eq} \cdot cm^{-2} \cdot yr^{-1}$)
Pair production	2.26	591.14	1.11×10^{12}
Synchrotron Radiation	0.026	15.65	
Radiative Bhabha	0.34	592.66	1.44×10^{12}
Beam Gas	0.9025	977.578	2.36×10^{12}
Beam Thermal Photon	0.32	318.12	0.75×10^{12}
Total	3.8485	2495.328	5.66×10^{12}

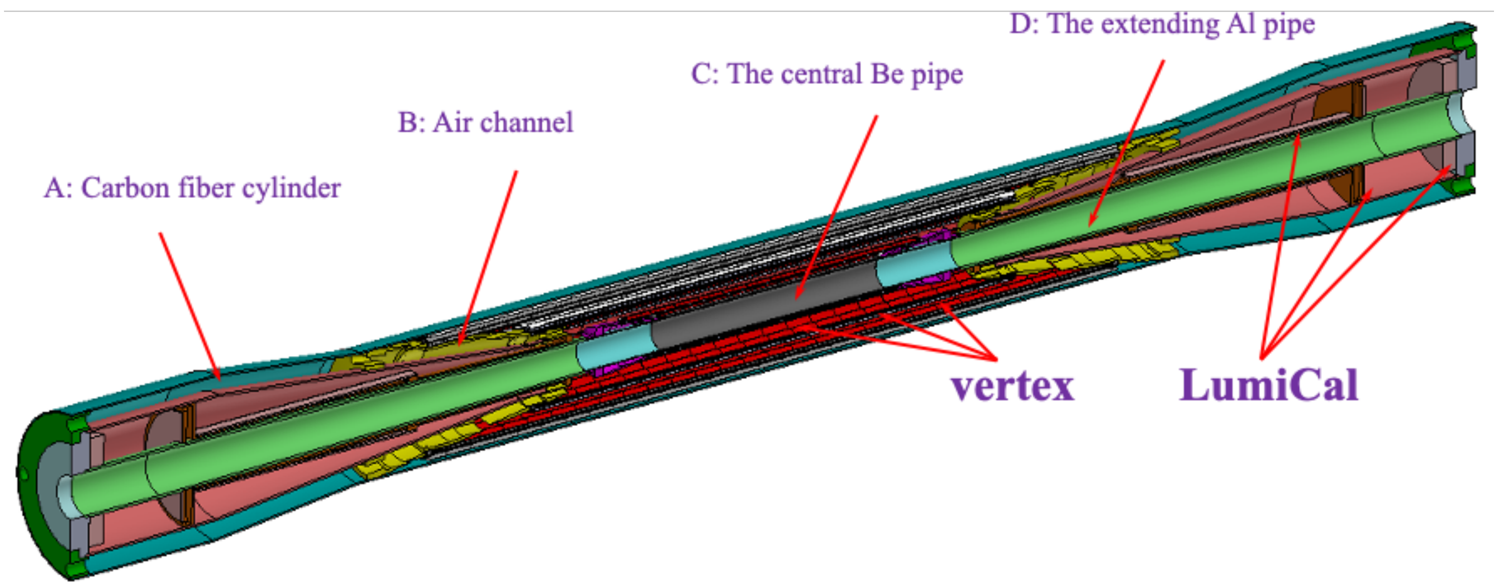
BEAMPIPE DESIGN

Q. Ji

2. Thermal-hydraulic estimation

Vacuum pipe size of beampipe:





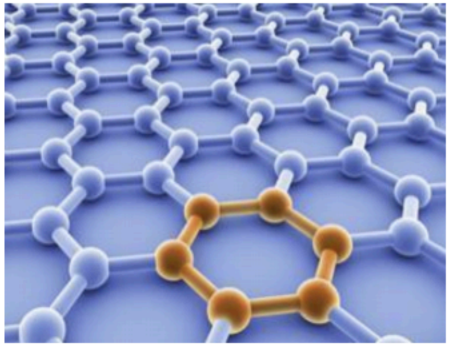
VERTEX DESIGN

Z. Liang

Thermal simulation

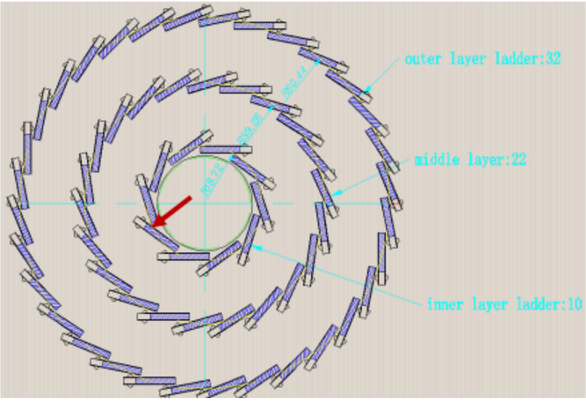
- Even using long barrel design with large Air flow
  - However, the temperature b layer of vertex detector is still high (>50 °C)
  - Too close to beampipe (limited air flow)
  - New idea about new material (Graphene) (Quan's talk)
    - Much High heat conductivity compared to Carbon fiber
  - What is Limitation in air velocity ?
    - Star HFT detector manage to provide 10m/s air flow)

Graphene



Thermal simulation (By Jinyu Fu)

Power dissipation (mW/cm2)	Temperature of beam pipe's surface (°C)	Inlet air temperature (°C)	Inlet air velocity (m/s)	Max temperature of inner barrel (°C)	Max temperature of middle barrel (°C)	Max temperature of outer barrel (°C)
50	*30*	*0*	*2*	57.1	29.1	26.9
50	*30*	*0*	*3*	54.5	24.3	22.9
50	*30*	*0*	*4*	52.3	21.3	19.9

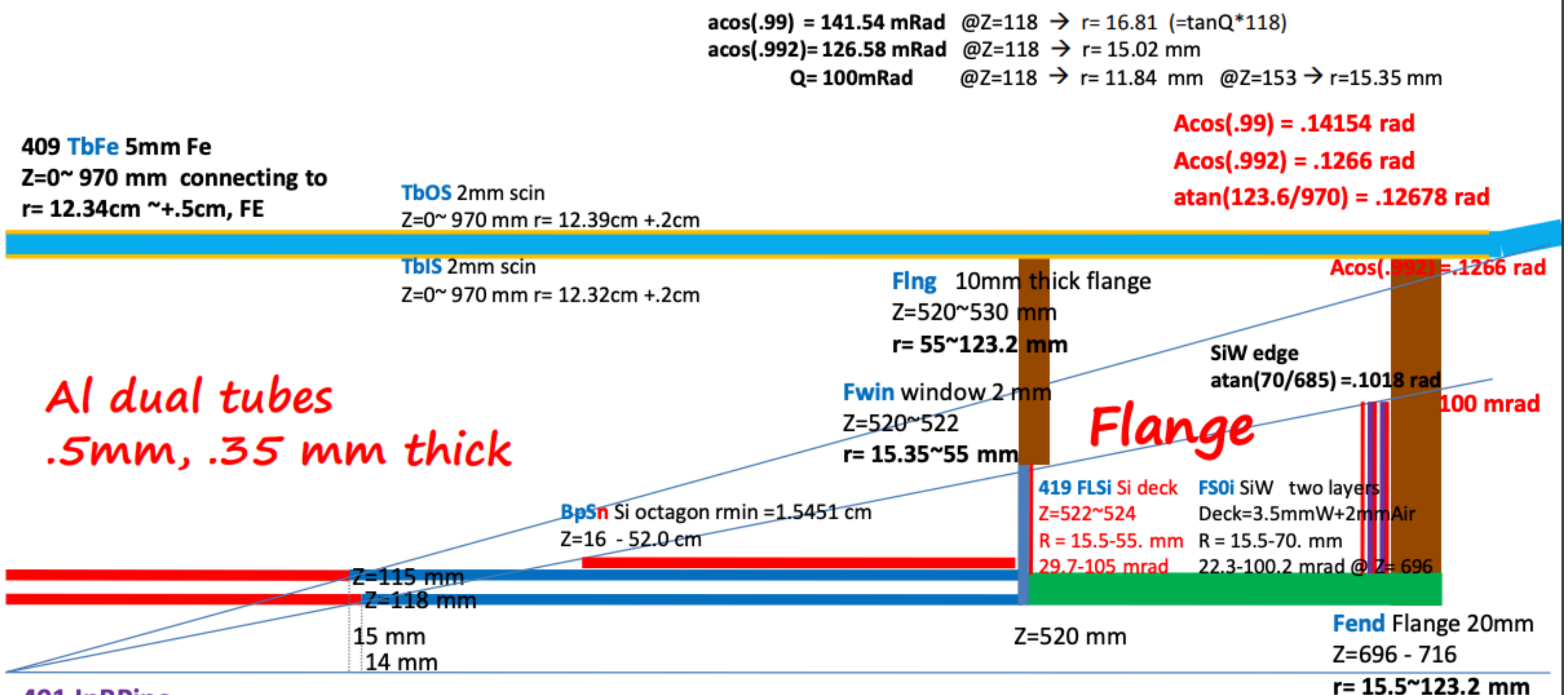


Power consumption: < 50 mW/cm^2 layer ,

temperature <30 °C

LumiCal Design

S. Hou



401 InBPipe

InBP Inner Be pipe
Z=0~118 mm,
inner diameter 28 mm 0.5mm thick

OuBP outer Be pipe
Z=0~115 mm
inner radius 28/2+1 mm 0.35mm thick

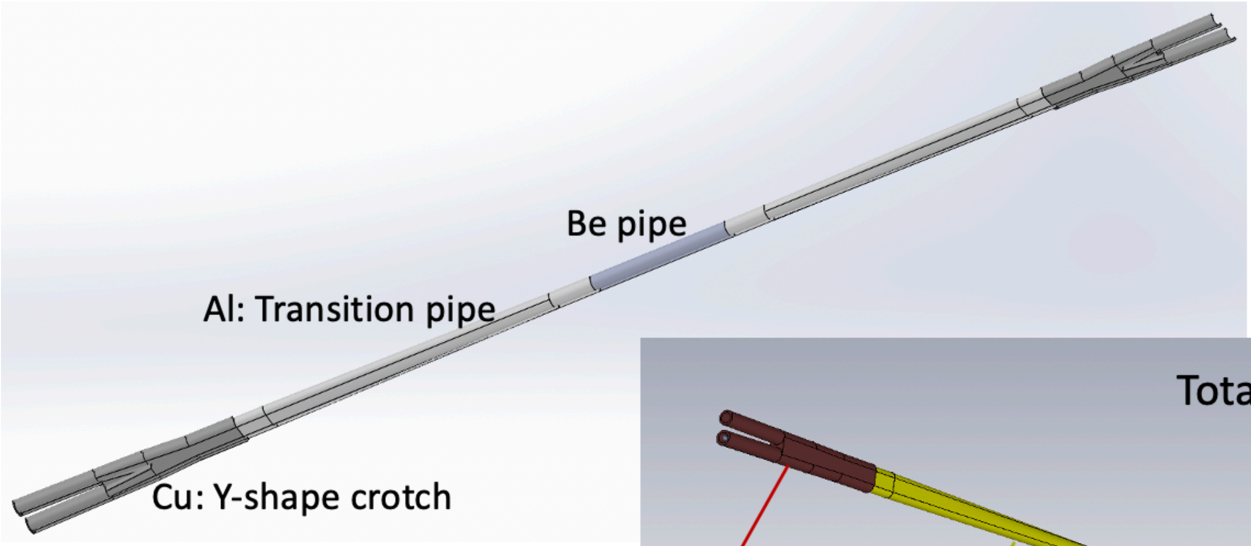
InAl Inner Al pipe
Z=118~500 mm,
inner diameter 28 mm 0.5mm thick

OuAl outer Al pipe
Z=0~115 mm
inner r=28/2+1 mm, 0.35 mm thick

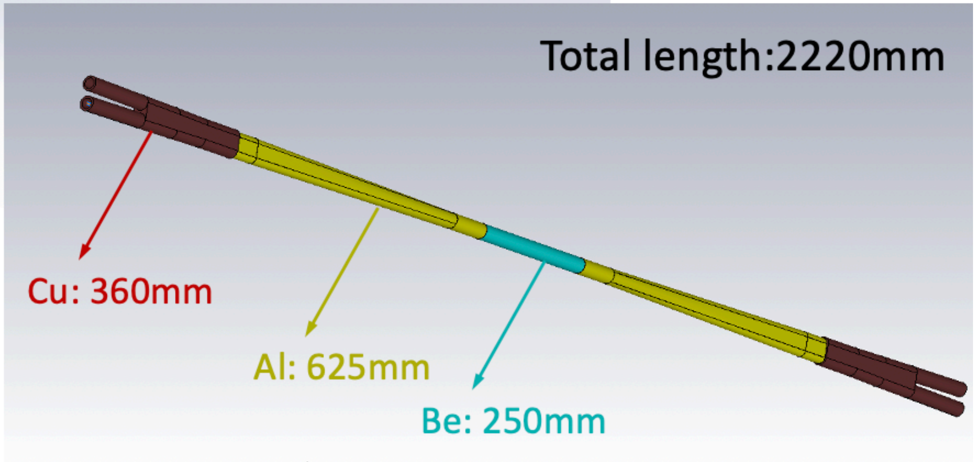
Fpip flange pipe 1.5 mm thick
Z= 522-716 mm
at Z=512 r= 14 – 15.5 mm

BEAMPIPE

- Beampipe design non-trivial (cooling, mechanical structure, coating material budget), direct impacts on physics performance
- ACTION: to re-visit the central beampipe radius



SQ Pipe



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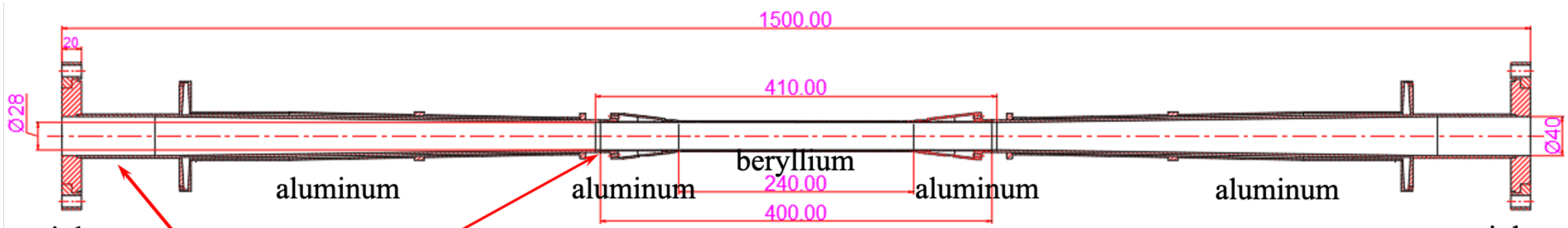
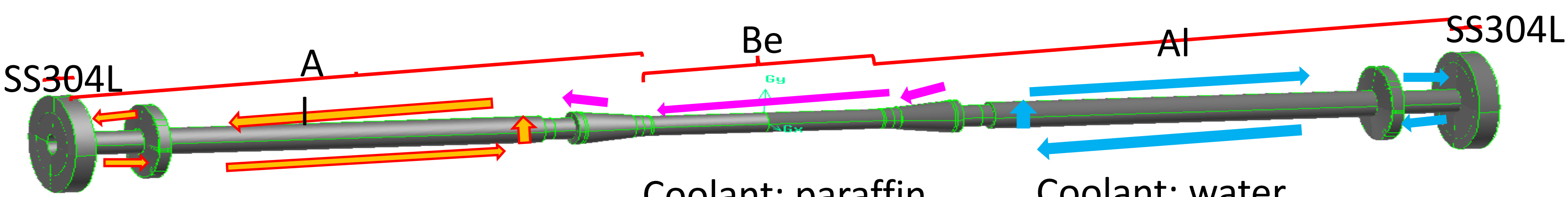
- Even higher HOM heat load for the high luminosity design

Latest Design

Please note we have never had a consistent beam pipe design between accelerator and detector.

Q. Ji



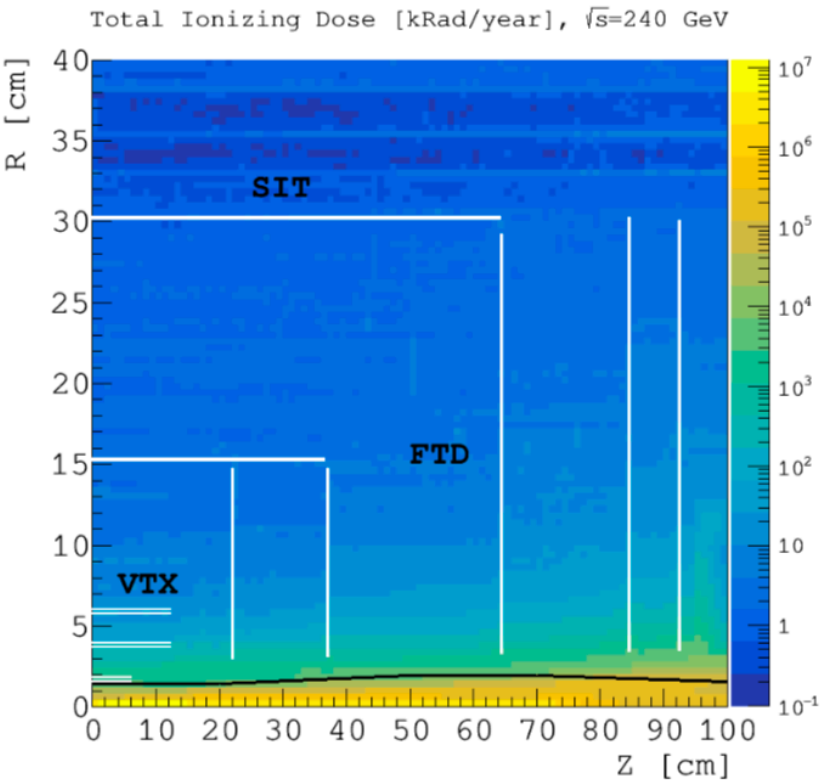


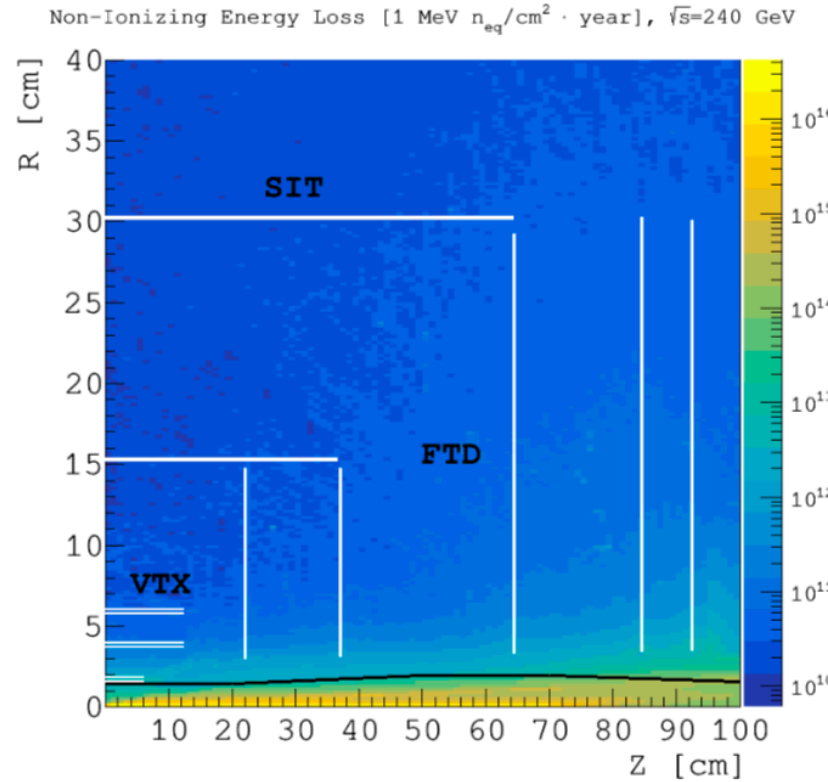
Coolant: water, 2 inlet,2 outlet	Coolant: paraffin, four inlet, four outlet	Coolant: water, 2 inlet,2 outlet
Inlet temperature: 23°C Inlet velocity: 2m/s	Inlet temperature: 23°C Inlet velocity: 0.6m/s	Inlet temperature: 23°C Inlet velocity: 2m/s

- Impacts of HOM heat load (+ from other sources) on beampipe design that will affect other components, e.g. Vertex and LumiCal

Radiation Backgrounds

H. Shi



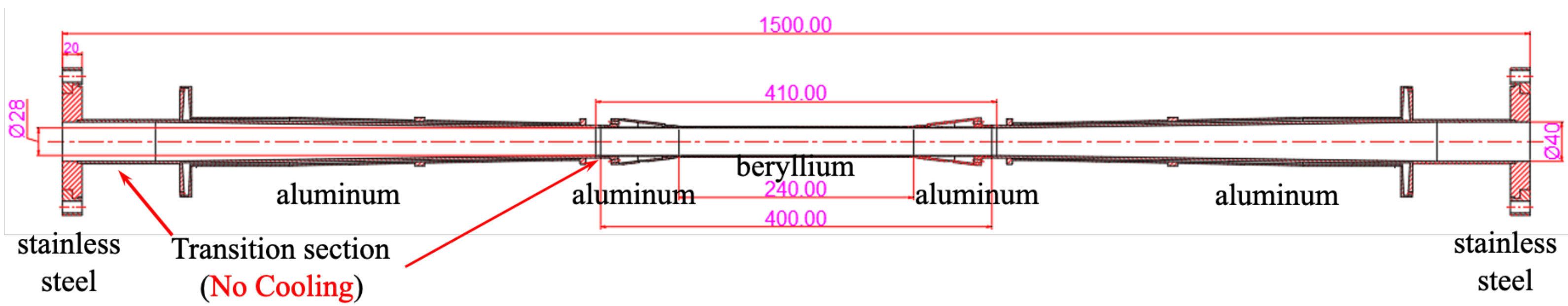


- Risky to push the beampipe/1st vertex detector layer too close to the interaction point, radiation damage

How to Converge on Beampipe Radius

- 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



SHORT TERM DELIVERABLES -- TO BE DISCUSSED

- A consistent design of the interaction region based on the CDR machine parameters in about two months
  - Head loads from HOM, synchrotron radiation, particle loss
  - Beampipe (central + forward) with cooing structures and interface to Vertex and LumiCal
  - Background levels (hit density, TID, NIEL) in sub-detectors (Vertex, Tracker, Calorimeter and LumiCal) + basic mitigation measures (collimators, masks, shielding, Au coating)
  - Superconducting magnets (compensating solenoid and quadrupoles) with optimized aperture size and protection
  - Detector solenoid and Yoke design
  - Supporting structure and install scheme
  - …

LONGER TERM PLAN – TO BE DISCUSSED

- Iterations of interaction region design to cope with/benefit from the higher luminosity machine design
  - To achieve consolidated designs before carrying out serious prototyping

- Requested to list critical topics, required/available manpower, funding – to be collected and further discussed