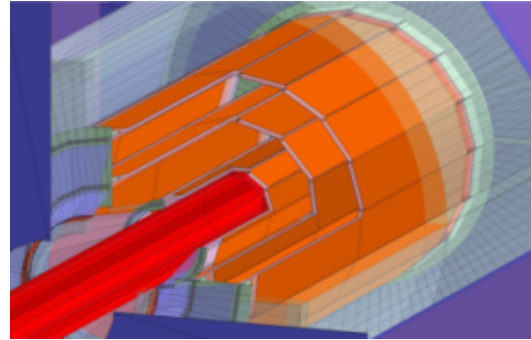# Mechanical Design Status of Silicon Vertex Detector Prototype

Jinyu Fu, Gang Li, Zhaoru Zhang, Mingyi Dong,
Zhijun Liang(梁志均), Joao Guimaraes da Costa

IHEP

Layout of CEPC Silicon Vertex Detector

	R (mm)	|z| (mm)	Current z in total
Layer 1	16	62.5	130.6 mm
Layer 2	18	62.5	
Layer 3	37	125.0	263.1 mm
Layer 4	39	125.0	
Layer 5	58	125.0	263.1 mm
Layer 6	60	125.0	

6 layer of sensors (3 layer barrels, each has sensors mounted double sides)

* Working temperature range: 20-50 °C

* Power dissipation:
   Final goal: ≤ 50 mW/cm2. (air cooling)
   Current (short term) goal: ≤ 200 mW/cm2. (air cooling)

* Single point resolution: currently in CDR range from 2.8-6 μm, eventually we aim for only one type of pixel sensor with single point resolution of 3-5 μm.

Challenges

**Material budget**: 0.15% X/X_0 (radiation length) for each single sensor layer.

Position stability: (caused by any vibration) should be better than the sensor's single point resolution which is within 3-5 µm.

　All challenges to the design mainly come from these two key requirements, which requires the development of ultra light material with high stiffness besides the feasible structure design. We currently use carbon fiber composite materials to make the main structures .
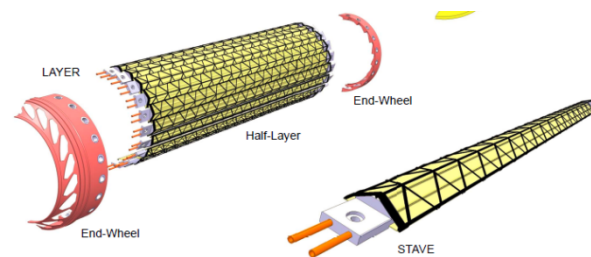
Mu3e
0.1% X/X_0
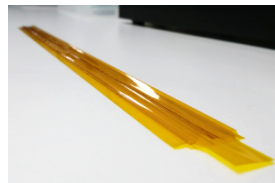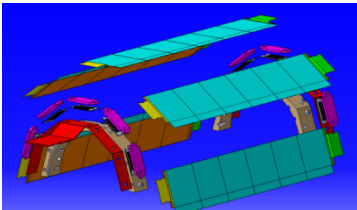
Mock-up ladders made of tape heaters
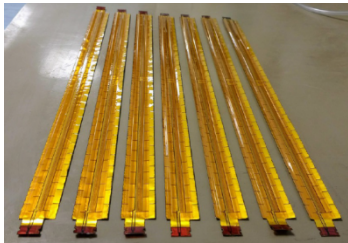
Made of aluminium-polyimide laminate (25 µm thickness each), laser structured meander for heating and temperature measurement.
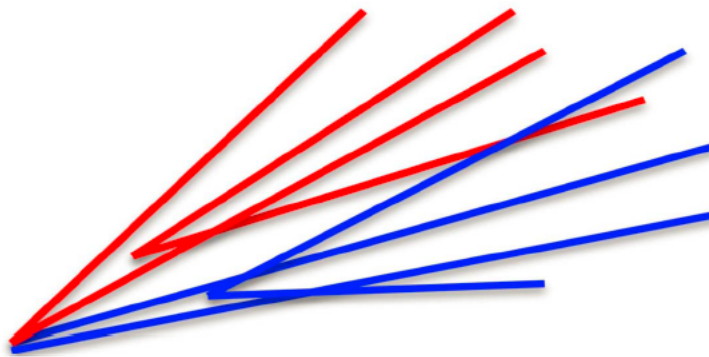
Alice ITS Upgrade
0.3% X/X_0

These two experiments both have pixel sensors on one side of the support. Our Material budget requirement is between them and closer to Mu3e, but the positon stability is higher than it.
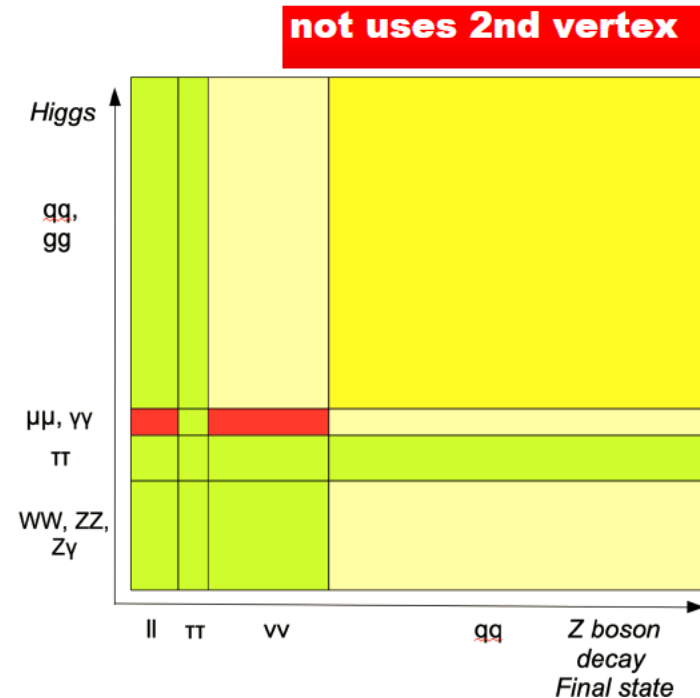
Layout Optimization
- by Gang

- **Jet flavor/tau tagging is important for CEPC physics study, ~70% of Z, W, and H decay products are jets**
- **Mainly determined by the vertex displacement**
- **VXD essential to measure the vertex displacement**
- **Fast/full simulation tools used to optimize layout**
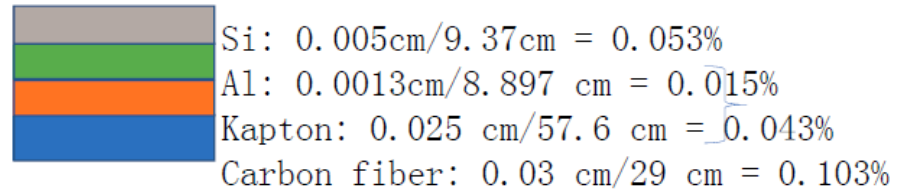

Vertex displacement

not uses 2nd vertex

Higgs: qq, gg / μμ, γγ / ττ / WW, ZZ, Zγ

Z boson decay Final state: ll, ττ, νν, qq

Layout Optimization

-by Zhaoru

Basic Comparison

- Default
- Default@4um
- 3 single-layers + 4 um + supporting 0.267% X/X0

@4um

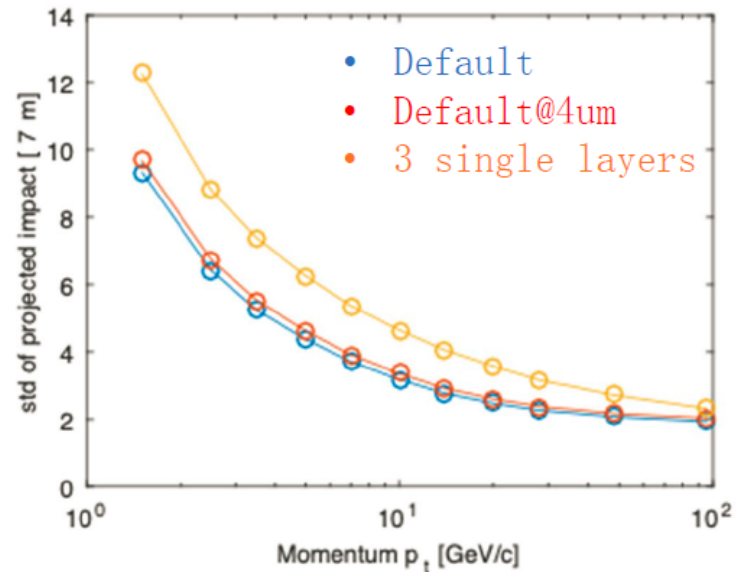|	R (mm)	$|z|$ (mm)	$|\cos\theta|$	$\sigma(\mu m)$
Layer 1	16	62.5	0.97	2.8
Layer 2	18	62.5	0.96	6
Layer 3	37	125.0	0.96	4
Layer 4	39	125.0	0.95	4
Layer 5	58	125.0	0.91	4
Layer 6	60	125.0	0.90	4

0.267% WITH OVERLAP

Si: 0.005cm/9.37cm = 0.053%
Al: 0.0013cm/8.897 cm = 0.015%
Kapton: 0.025 cm/57.6 cm = 0.043%
Carbon fiber: 0.03 cm/29 cm = 0.103%
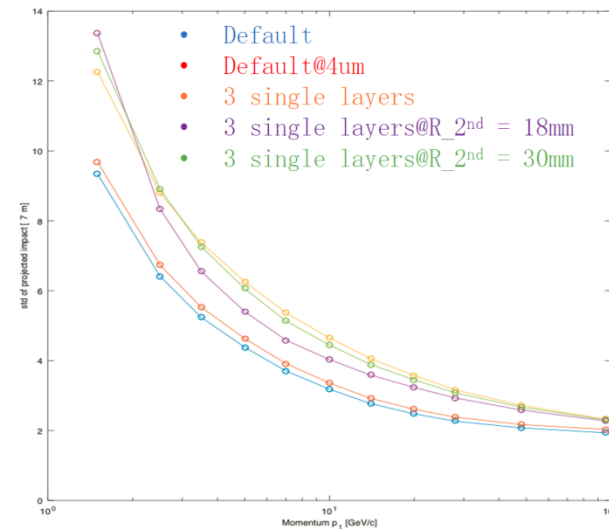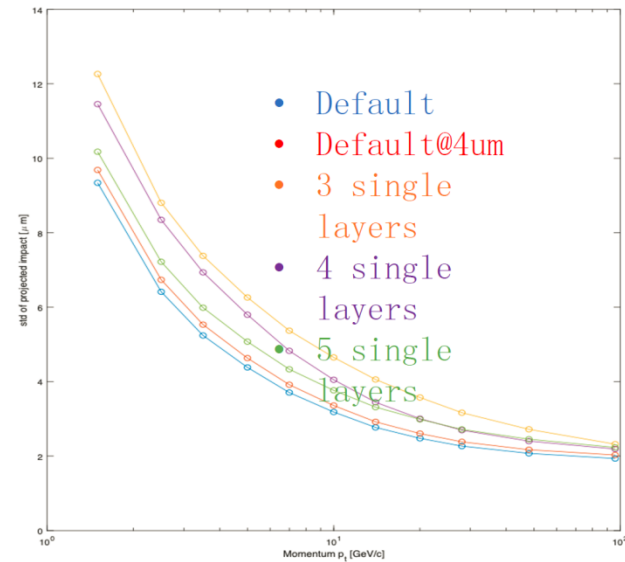
1. Overlap
2. Carbon fiber C structure

- Default
- Default@4um
- 3 single layers

Layout Optimization

- Various layouts were tested

- Some discrepancies need to be understood: multi-scattering, R_2nd, number of layers, …

- To be validated with TkLayout and full simulation.

Recent Collaboration Activity

From late February to late March this year, visited Oxford and Liverpool, learned a lots about silicon detectors .
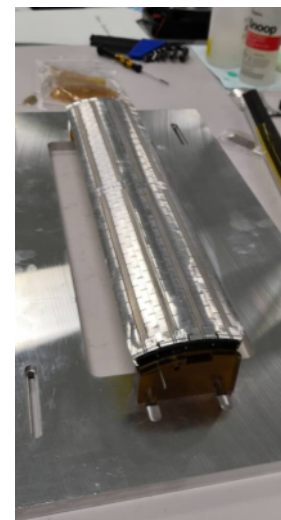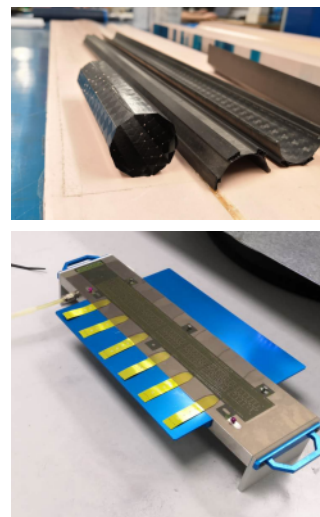
Oxford

Mu3e ladder, Atlas barrel strip stave prototype.

Thanks Daniela, Ian, Kirk Richard, Chris, Georg, Stephanie

Liverpool
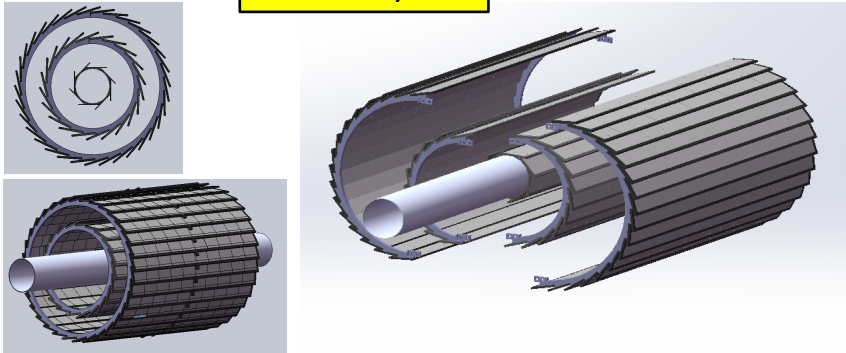
Module of Alice′s OB tracker, Mu3e unit assembly

Thanks Yanyan, Tim, Peter, Joost

Conceptual Support Design of the SVXD

Sensor chip : 14.8 x 25.6 x 0.05 mm (2 mm wide margin at one side for wire bonding)
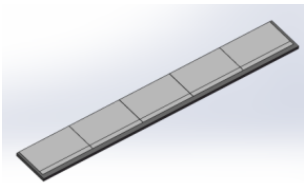
Vertex layout

Local support

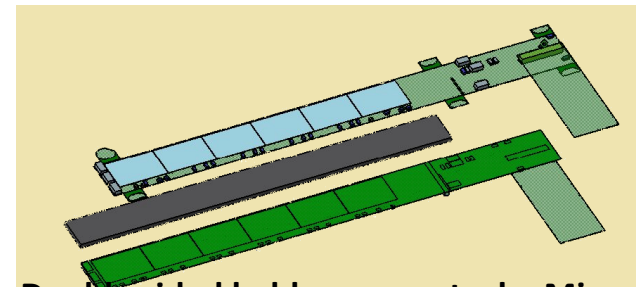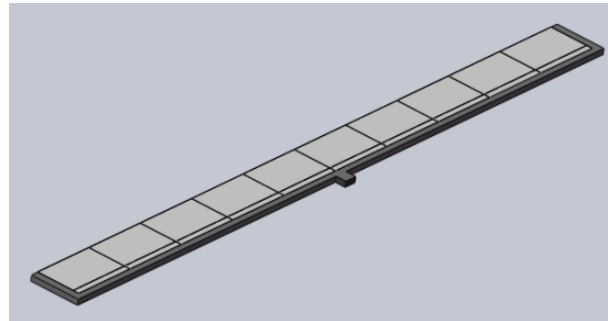End Ring (CFRP): fix the end of local support by bolting connection.

Ladder: mechanical structure + chips + FPC

Ladder of inner layer:
10 chips total including both sides

Ladder of outer two layers:
20 chips total including both sides

0.1mm gap between chips

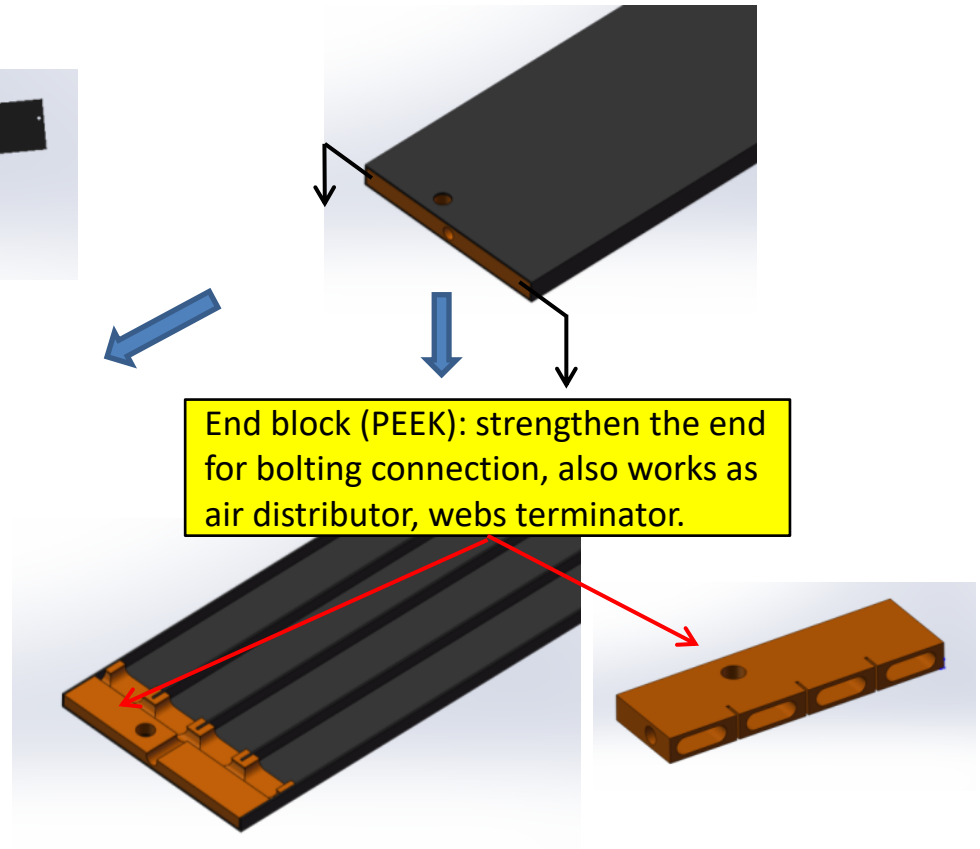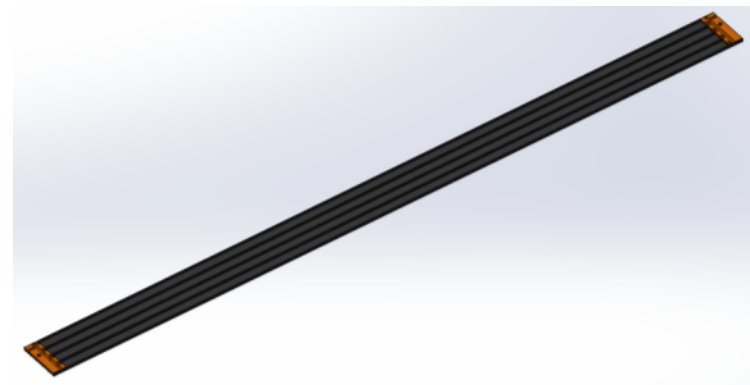**Double sided ladder concept – by Mingyi**

Ladder Mechanical Structure

Size: 263.1 x 16.8 x 1.8 mm (L x W x H), for outer and middle barrels.

130.6 x 16.8 x 1.8 mm for inner barrel. W is 2 mm wider than sensor.

Material: Carbon fiber in thickness of 0.15 mm (3 layers 0-90-0).

Channels inside the local support: to increase stiffness with less material, also work as a backup for air cooling from inside of the support.

End block (PEEK): strengthen the end for bolting connection, also works as air distributor, webs terminator.
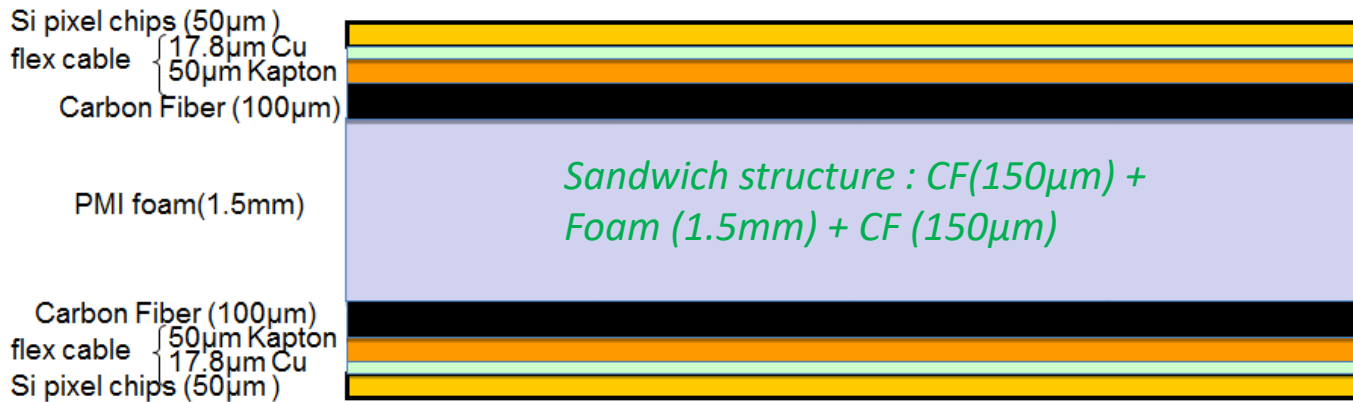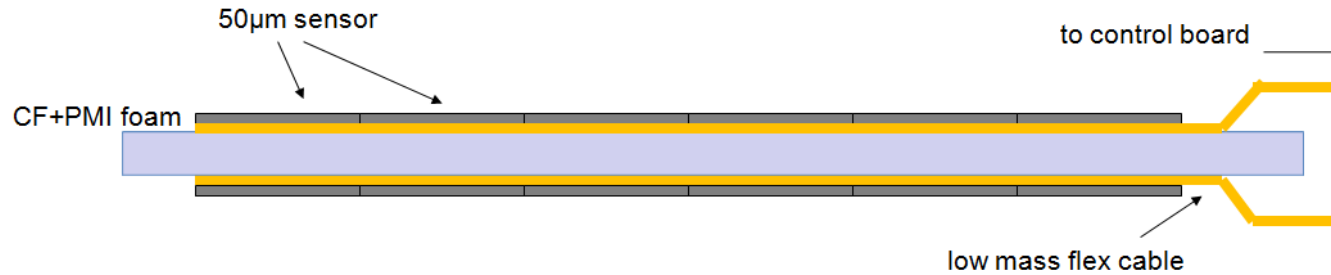
Ladder Mechanical Structure

To glue webs inside the local support, few options are considered
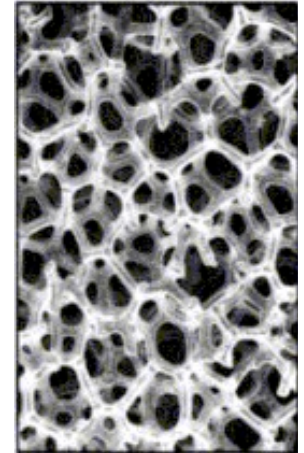(cross-sectional view of local support):
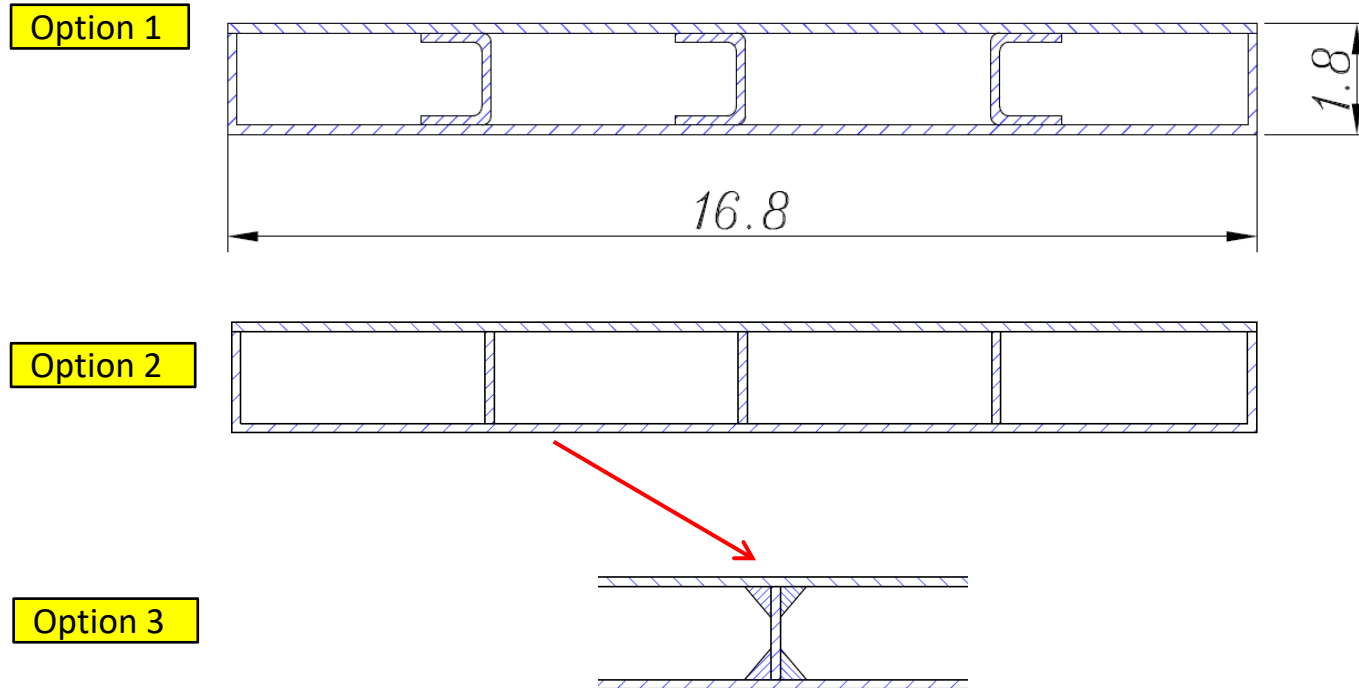
Ladder Mechanical Structure

- Mingyi's proposal

50μm sensor

to control board

CF+PMI foam

low mass flex cable

Optional foam with different material for optimization.

Si pixel chips (50μm)
flex cable { 17.8μm Cu / 50μm Kapton
Carbon Fiber (100μm)

PMI foam(1.5mm)

Carbon Fiber (100μm)
flex cable { 50μm Kapton / 17.8μm Cu
Si pixel chips (50μm)

*Sandwich structure : CF(150μm) + Foam (1.5mm) + CF (150μm)*

- Material budget: 0.53% X_0 (flex cable with copper traces)

- Reduce to 0.35% X_0 if using aluminum traces.

It can be reduced to 0.48% X0 with copper traces (0.29% X0 with aluminum trace) after optimization.

To Increase Stability of Ladder

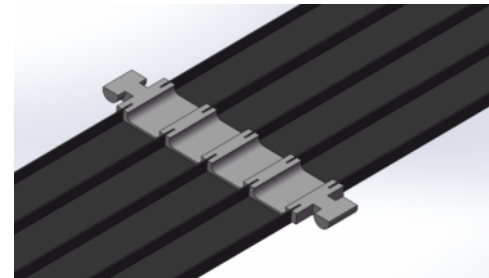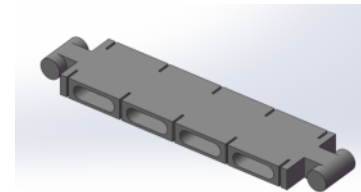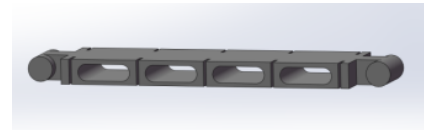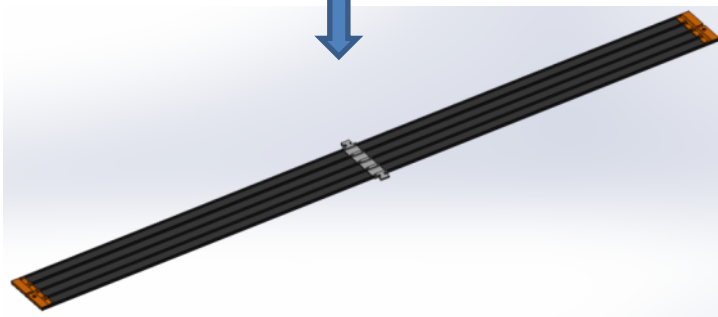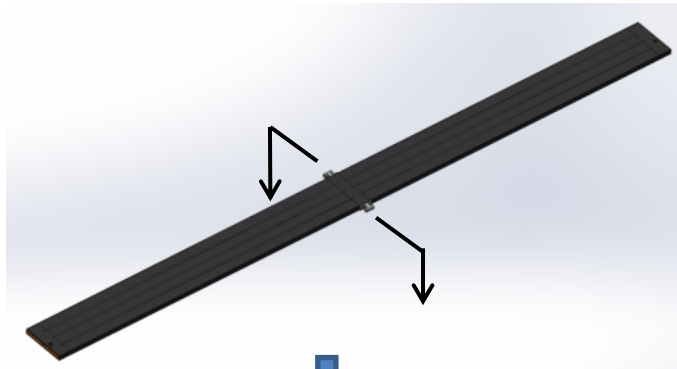Link each ladder(directly on ladder mechanical structure) in middle to a constraint ring from outside of the barrel. Depends on further analysis or test, if needed, ladders can also be linked to an inside constraint ring. Here just show the outside linking structure which currently is just a backup design.

Lock Seat(PEEK), glued to the constraint ring.

Outside constraint ring, CFRP. (two half rings combined)

Constraint point
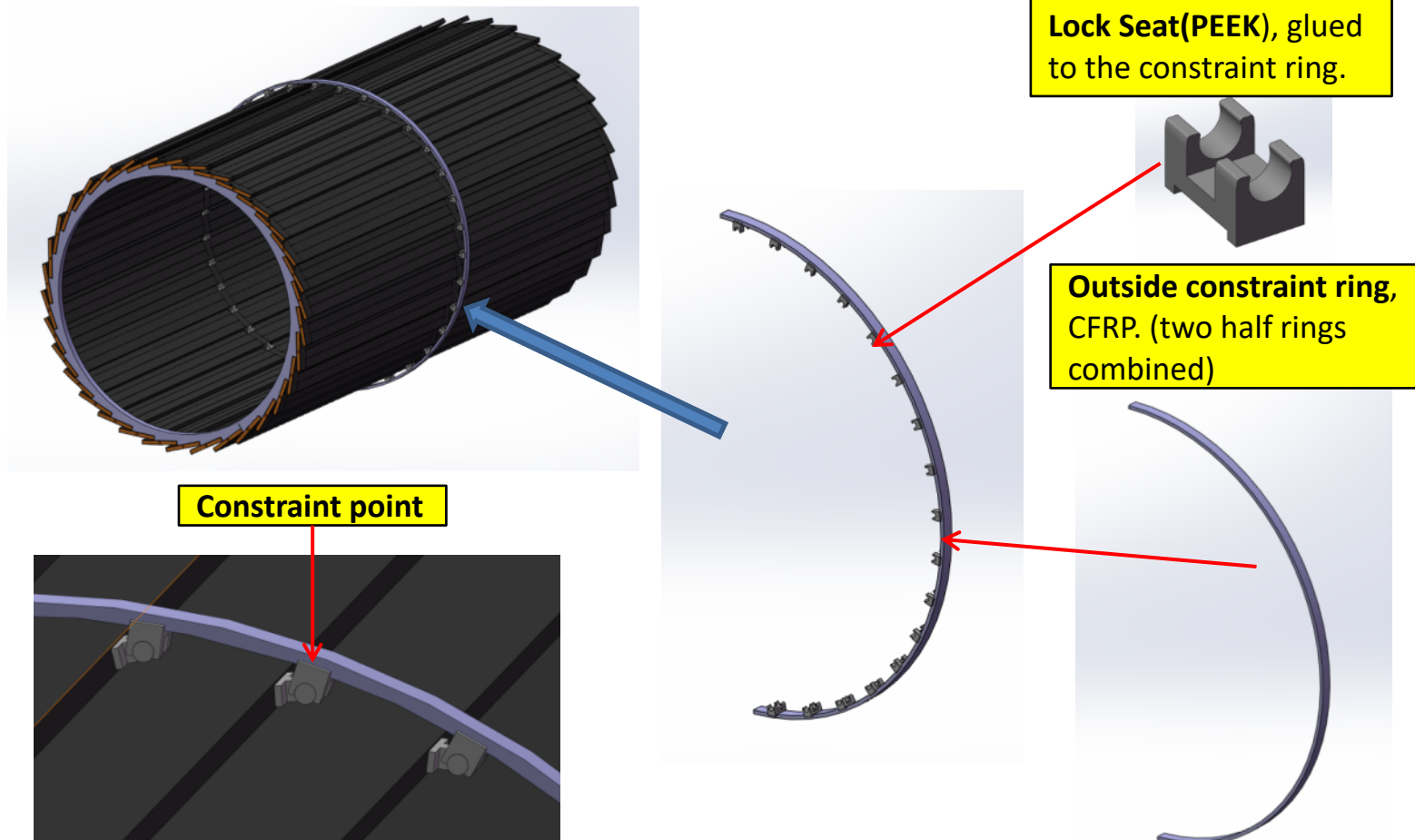
To Increase Stability of Ladder

To mate with the lock seat on the constraint rings, a connector is embedded inside the ladder mechanical structure.

CFRP Laminates Design and FEA

Static FEA analysis of combinations of different laminate layouts of surface and web and ladder support with or without webs have been done. Result show the best combination is: ladder support with webs , surface 3 layer （0 90 0）， web 3 layer （90 0 90）.

| N. case	Layers Surface	Layers Web	Weight (g)	D (μm) Gravity	D（μm） Full load
1	3(0 90 0)	3(0 90 0)	2.36	4.392	4.949
2	3(0 90 0)	NO	2.03	7.091	
3	3(0 90 0)	4(0 90 90 0)	2.54	2.577	5.049
4	3(0 90 0)	3(90 0 90)	2.36	2.555	5.18
5	4(0 90 90 0)	4(0 90 90 0)	3.14	3.296	5.835
6	4(0 90 90 0)	NO	2.7	3.952	7.478
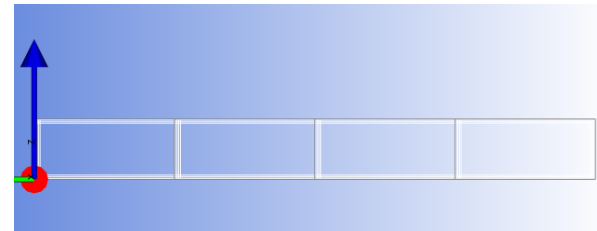
Case4. D-gravity
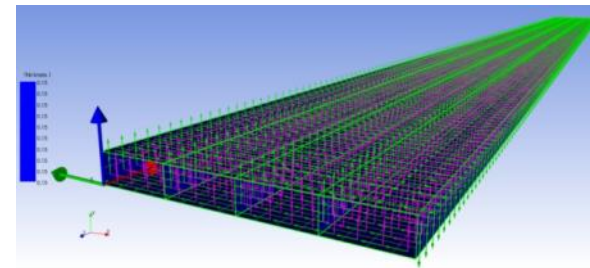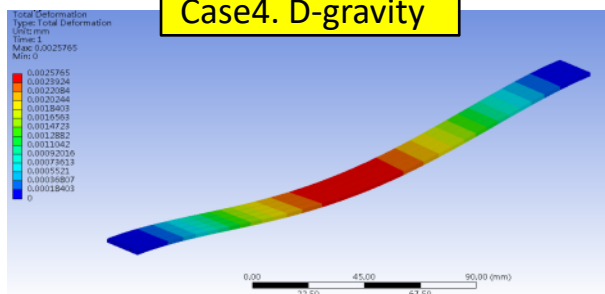
Prototype Part from Liverpool

Recently, Liverpool provided a different option for the ladder structure reinforcement.
 To optimize the inside reinforced structure, we need:
- *more work on structure optimization*
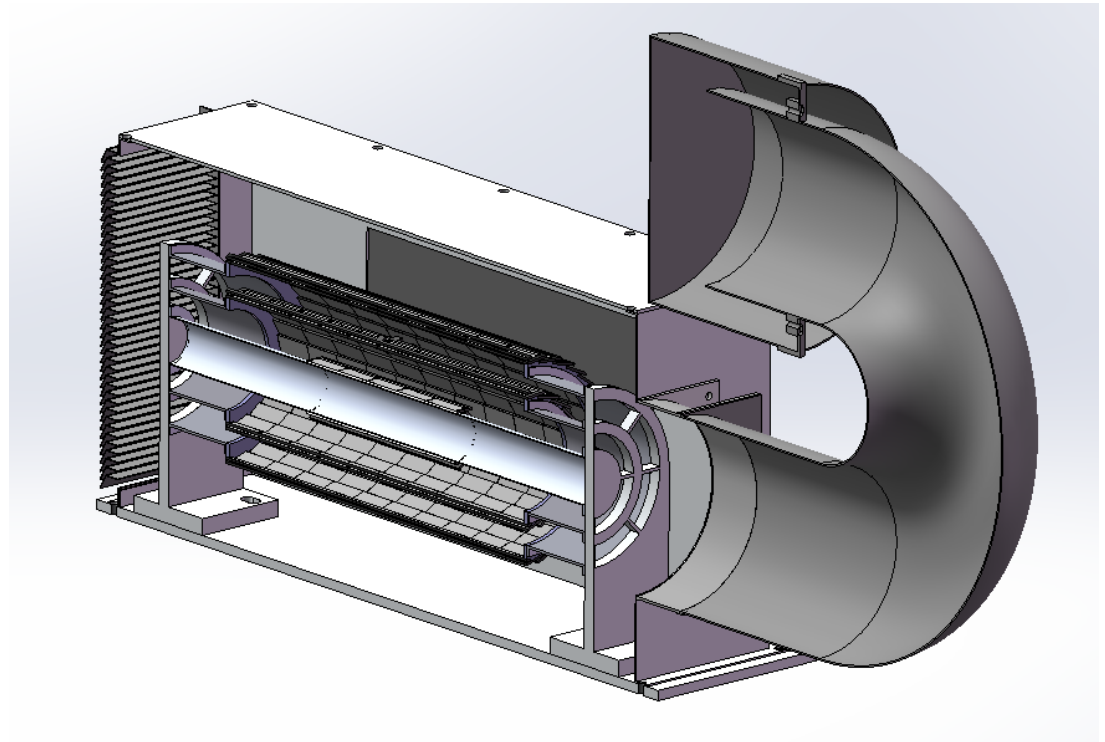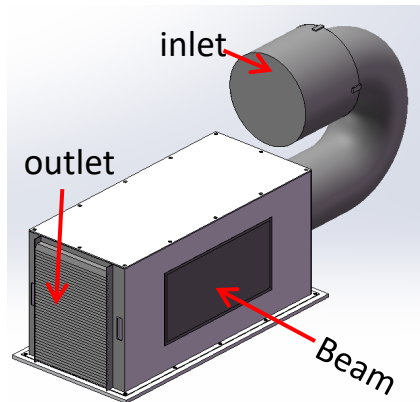- *produce samples*
- *test for evaluation.*
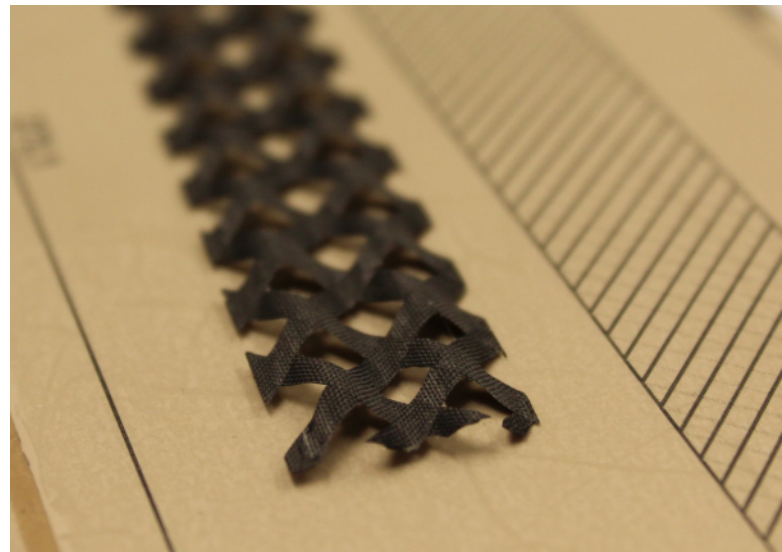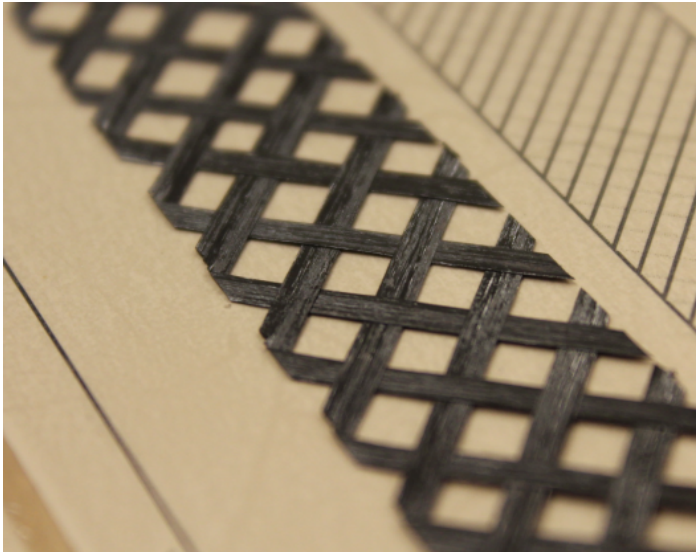
Beam test: detector supporting and cooling box

The box is air cooled and light tight.
Application:

- Assembly of the support structure of SVXD prototype and testing。
- Final beam line testing SVXD

Short Term Plan

By the end of this year:

- Optimization of the structure design and more FEA analysis of material and structure.

- Investigate the: material, curing equipment, testing equipment, manufactures.

➢ Composite material sample procurement and performance test.

➢ Trial-manufacture of composite laminates and performance test.

● Fast/full simulation will be continued for layout optimization and expected to be finished by the end of this year.

Thanks