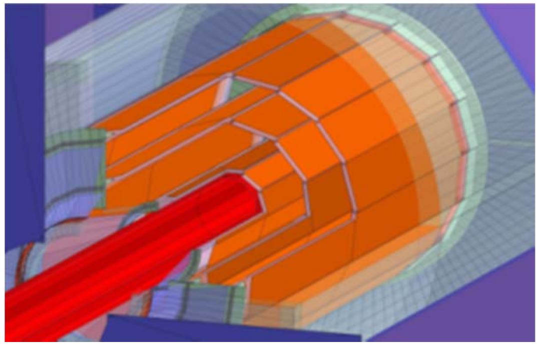
Mechanical Design Status of Silicon Vertex Detector Prototype

Jinyu Fu, Gang Li, Zhaoru Zhang, Mingyi Dong, Zhijun Liang, 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 ℃

* **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.

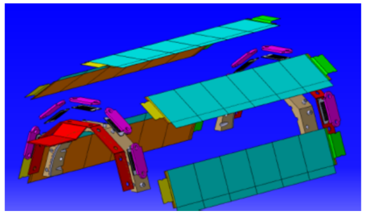
Challenges

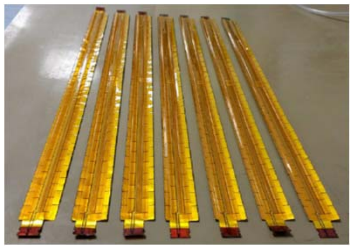
Material budget: 0.15% X/X_0 (radiation length) for each single sensor layer.

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

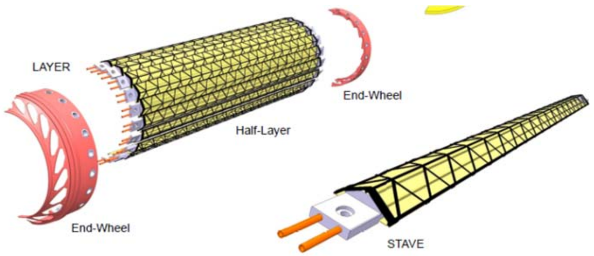




Mock-up ladders made of tape heaters

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

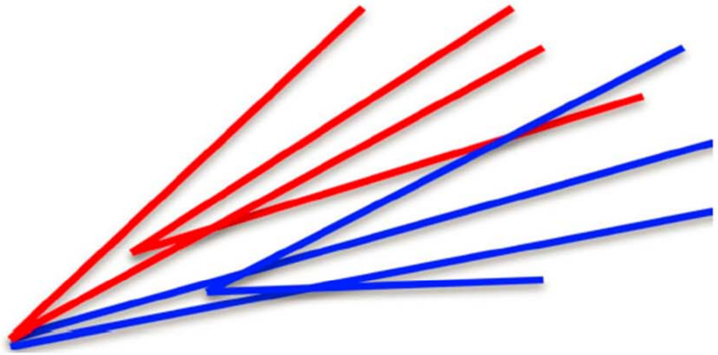


These two experiments both have pixel sensors on one side of the support. Our Material budget requirement is between them and closer to Mu3e, but the positon stability is higher than it.

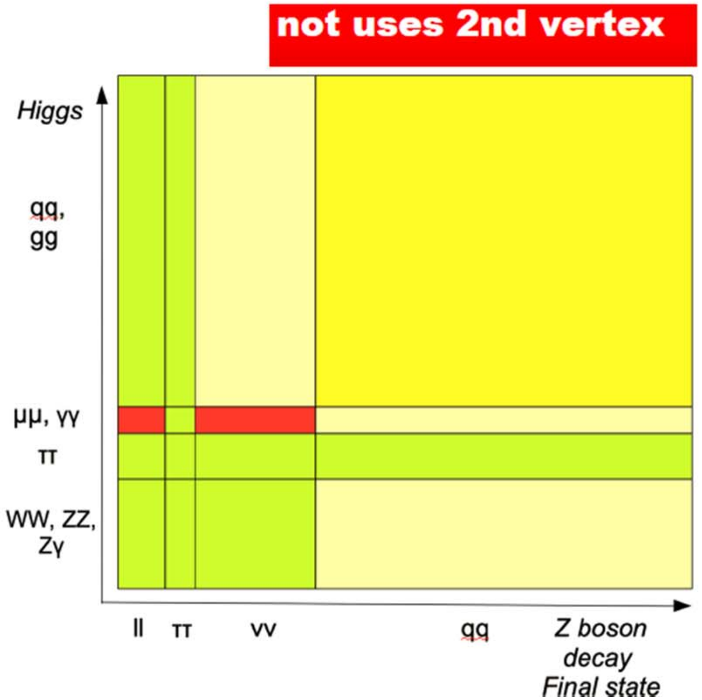
Layout Optimization

- 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

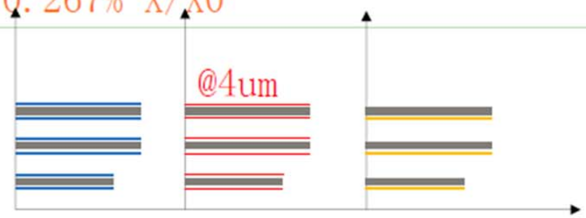


Layout Optimization

-by Zhaoru

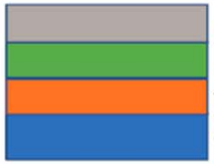
Basic Comparison

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



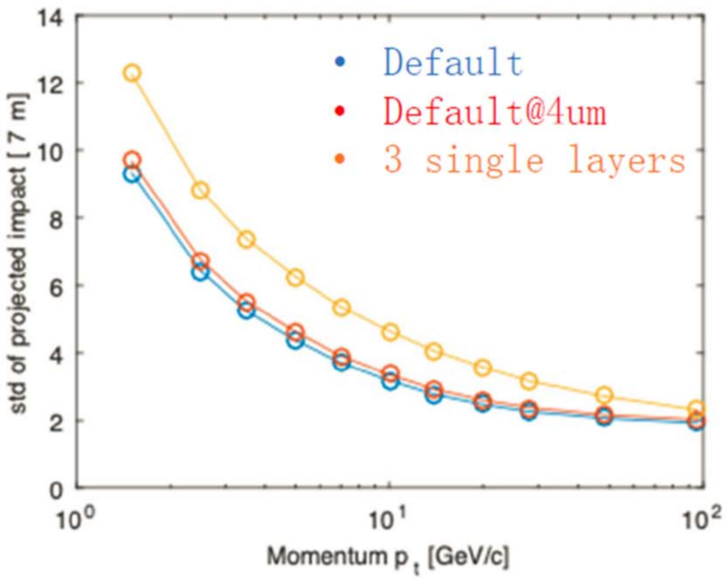
	R (mm)	$\|z\|$ (mm)	$\|\cos\theta\|$	σ (μm)
Layer 1	16	62.5	0.97	2.8
Layer 2	18	62.5	0.96	6
Layer 3	37	125.0	0.96	4
Layer 4	39	125.0	0.95	4
Layer 5	58	125.0	0.91	4
Layer 6	60	125.0	0.90	4

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

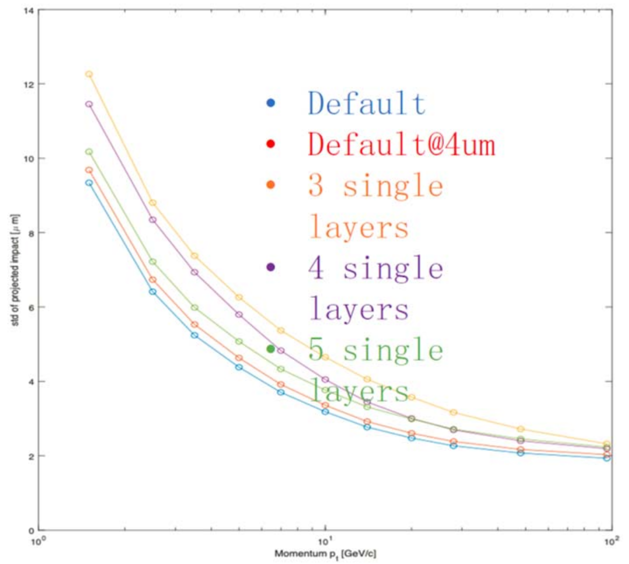


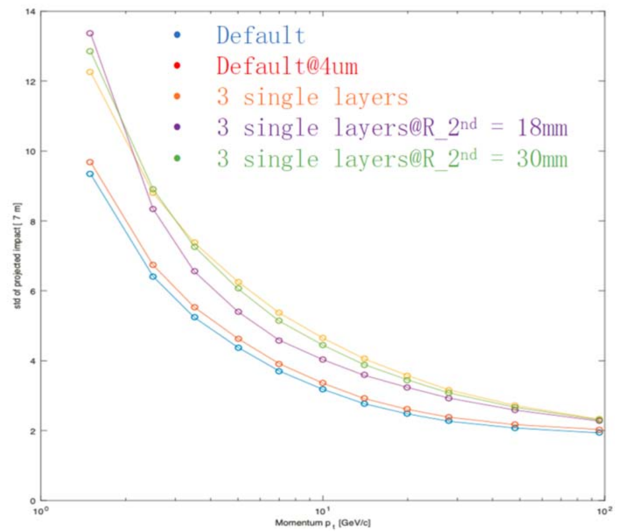
Layout Optimization

- 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 .

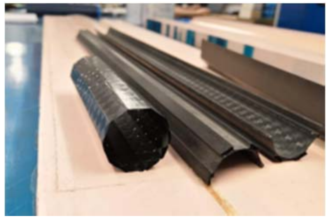
Oxford

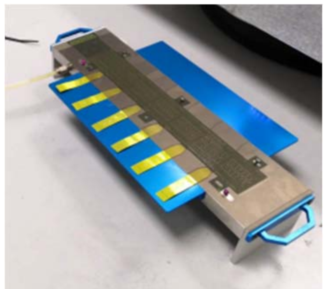
Mu3e ladder, Atlas barrel strip stave prototype.

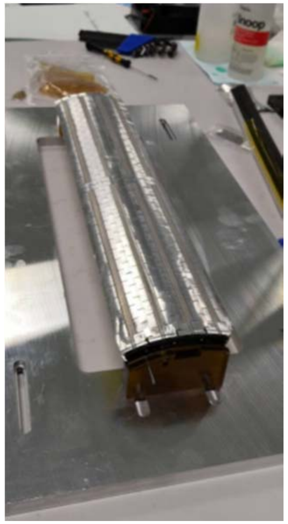
Thanks Daniela, Ian, Kirk Richard, Chris, Georg, Stephanie

Liverpool

Module of Alice' s OB tracker, Mu3e unit assembly





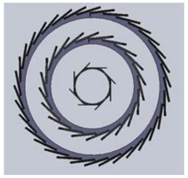


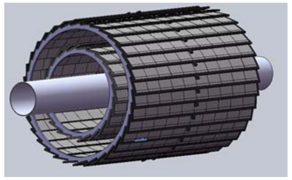
Thanks Yanyan, Tim, Peter, Joost

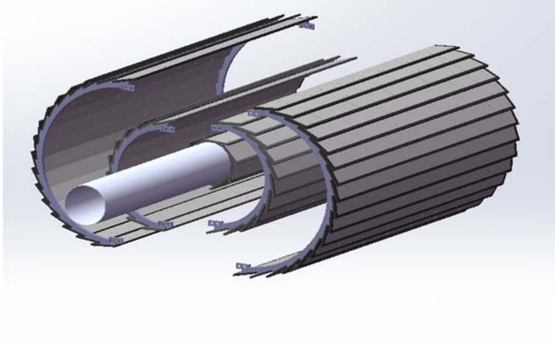
Conceptual Support Design of the SVXD

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

Vertex layout





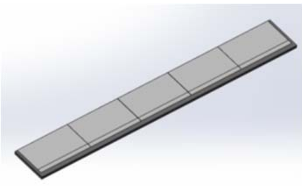


Local support

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

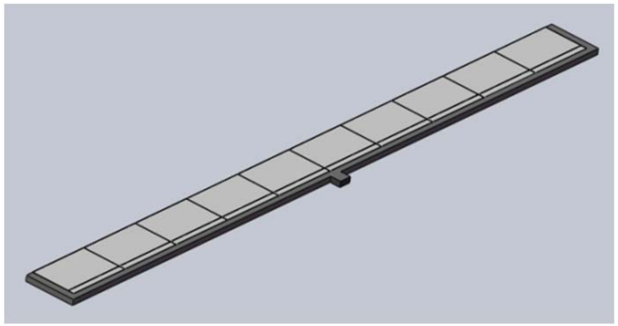
Ladder: mechanical structure + chips + FPC

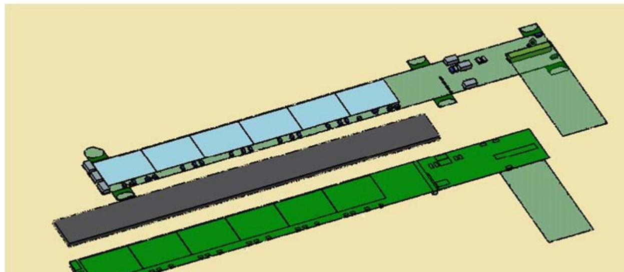
Ladder of inner layer:
10 chips total including both sides



0.1mm gap between chips

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





Double sided ladder concept – by Mingyi

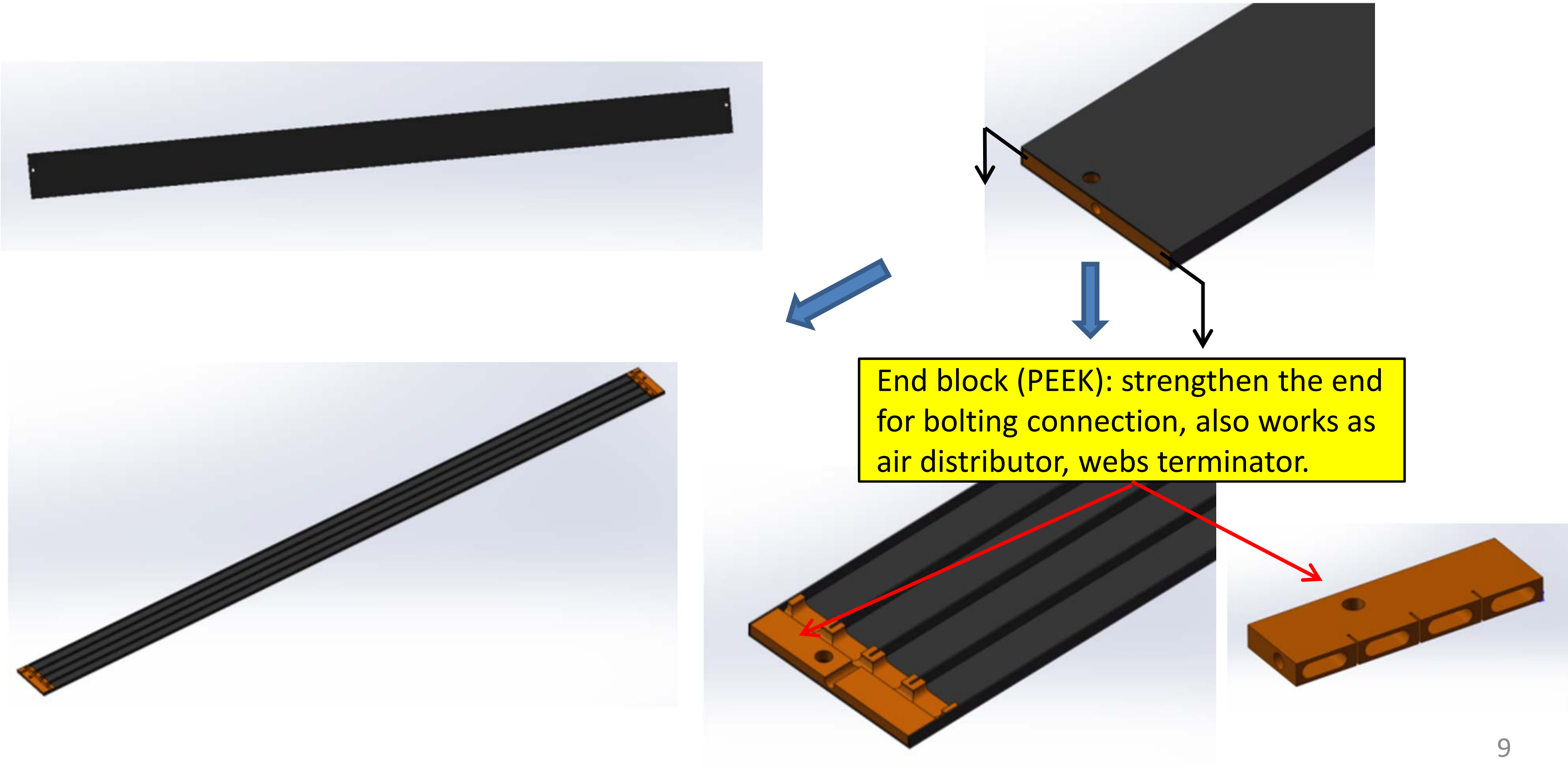
Ladder Mechanical Structure

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).

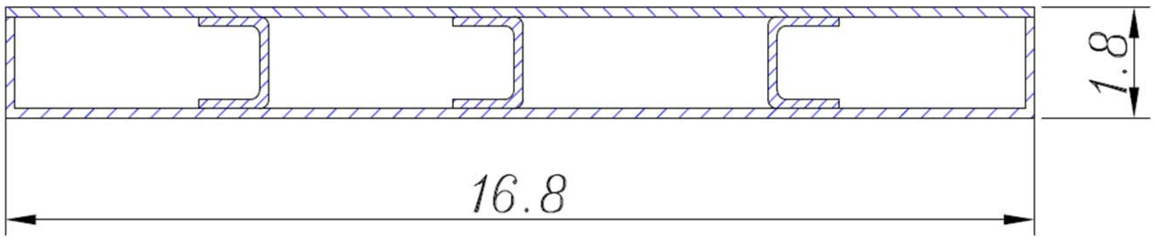
Channels inside the local support: to increase stiffness with less material, also work as a backup for air cooling from inside of the support.



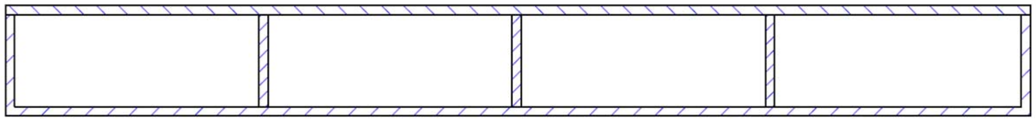
Ladder Mechanical Structure

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

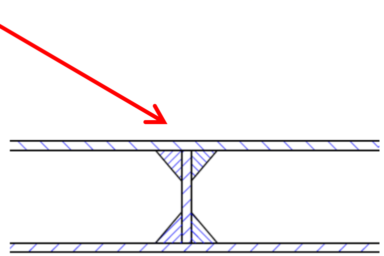
Option 1



Option 2

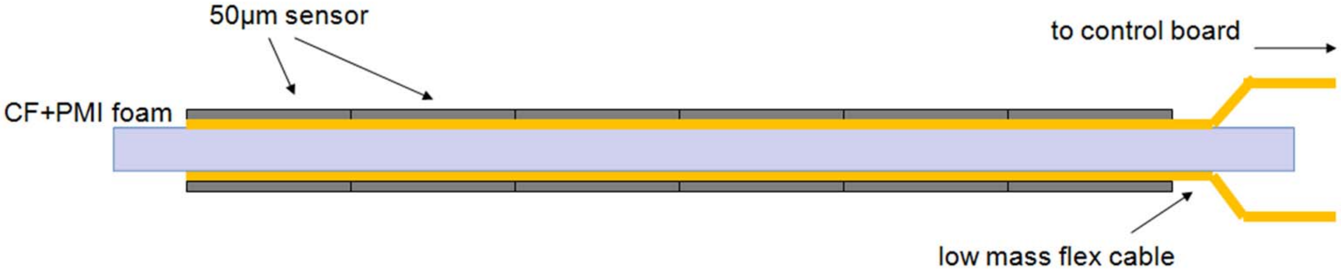


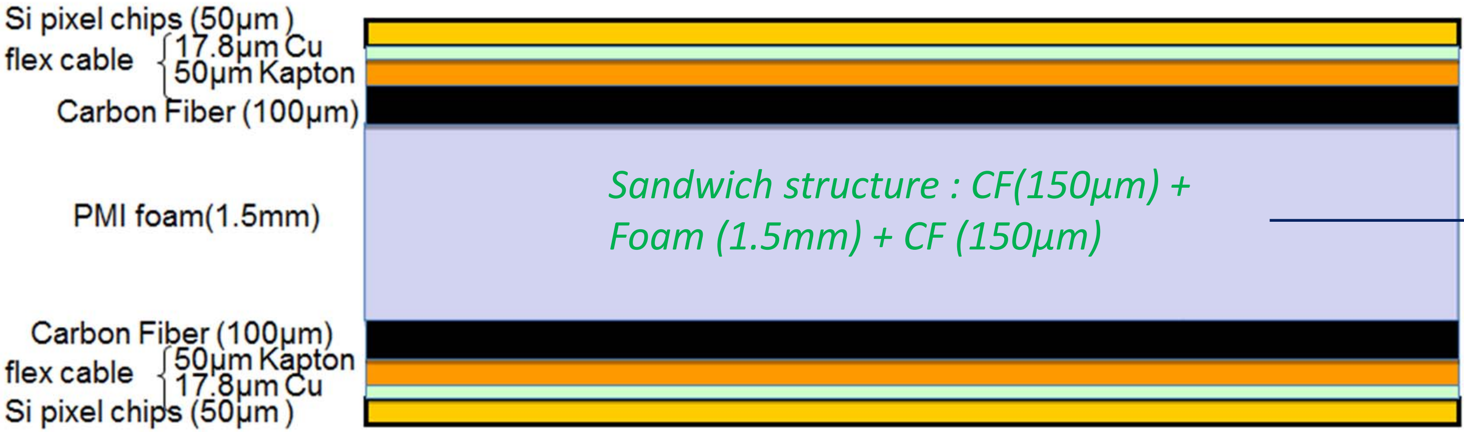
Option 3



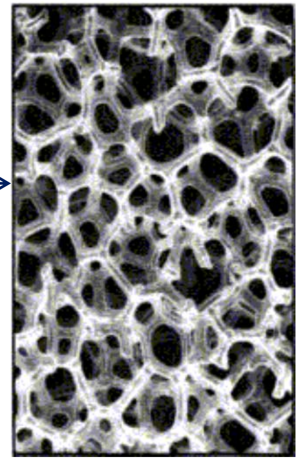
Ladder Mechanical Structure

- Mingyi's proposal





Optional foam with different material for optimization.

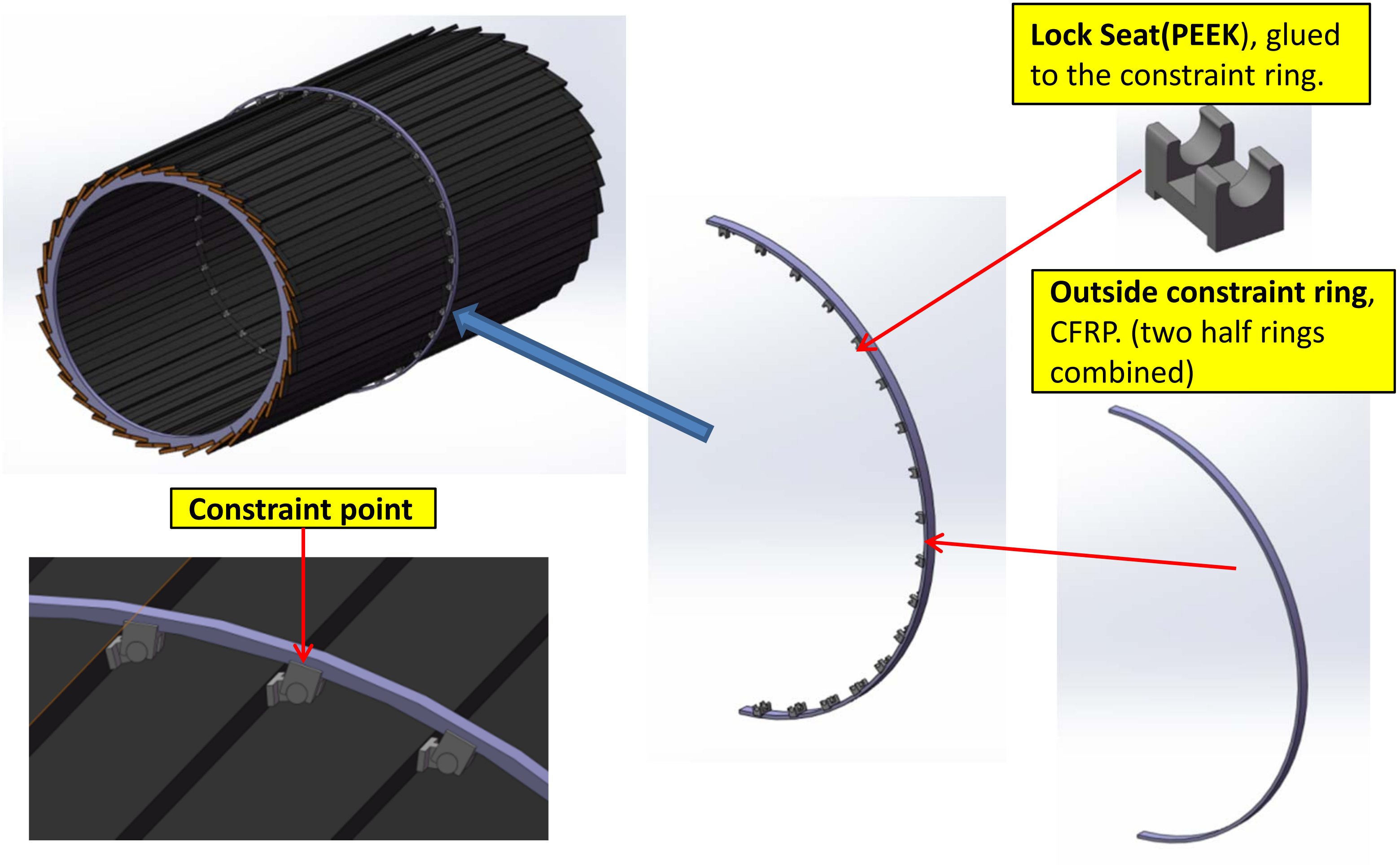


- Material budget: 0.53% X_0 (flex cable with copper traces)
- Reduce to 0.35% X_0 if using aluminum traces.

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

To Increase Stability of Ladder

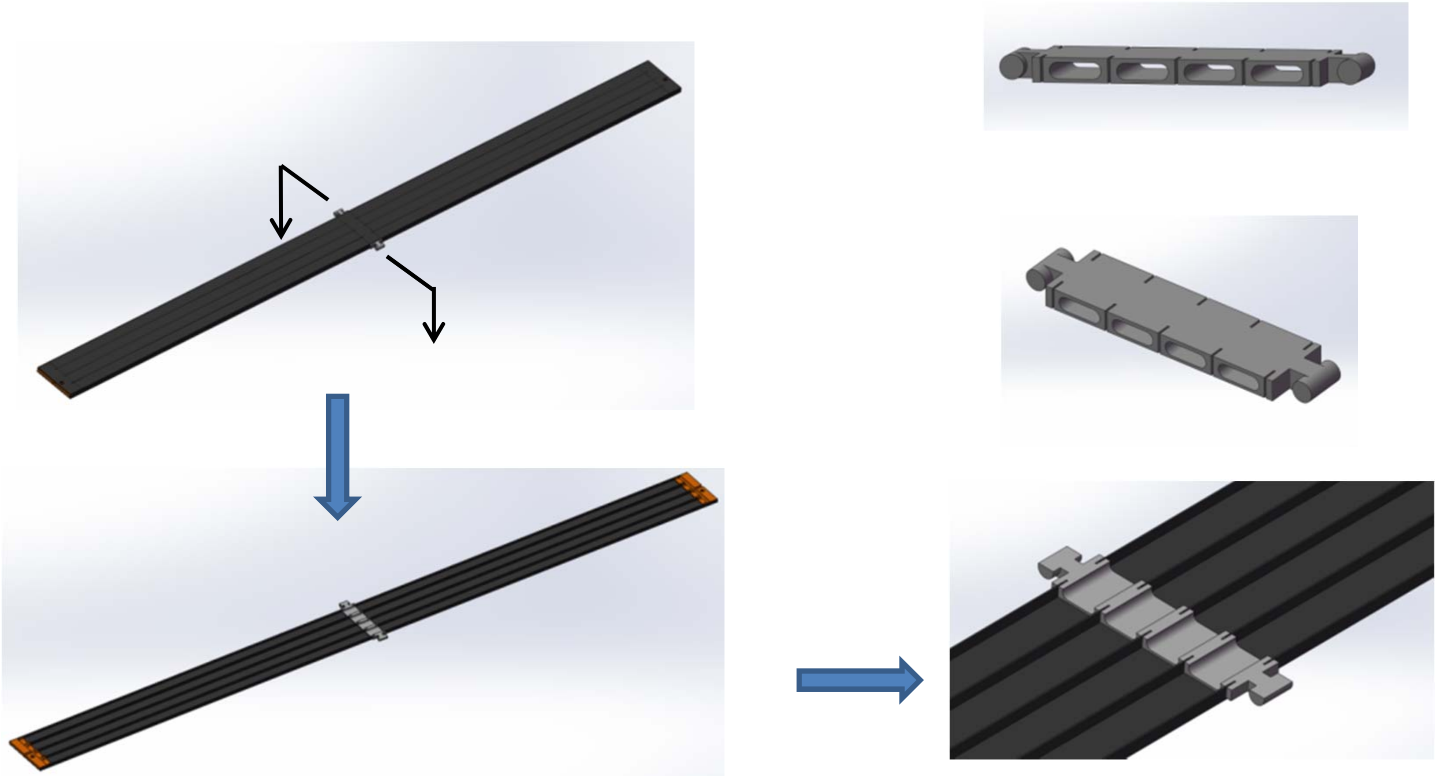
Link each ladder(directly on ladder mechanical structure) in middle to a constraint ring from outside of the barrel. Depends on further analysis or test, if needed, ladders can also be linked to an inside constraint ring. Here just show the outside linking structure which currently is just a backup design.



To Increase Stability of Ladder

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

Middle embedded connector (CF 3D printed for prototype): to generally constraint the ladder at middle, also works as air distributor and web connector locally inside the mechanical structure.

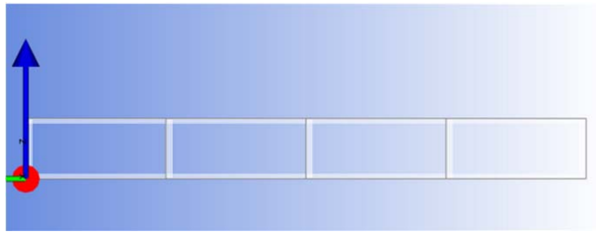


CFRP Laminates Design and FEA

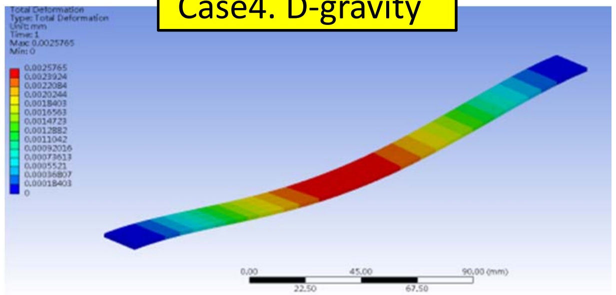
Static FEA analysis of combinations of different laminate layouts of surface and web and ladder mechanical structure with or without webs have been done. Result show the best combination is: ladder mechanical structure with webs , surface 3 layer（0 90 0）， web 3 layer（90 0 90）.

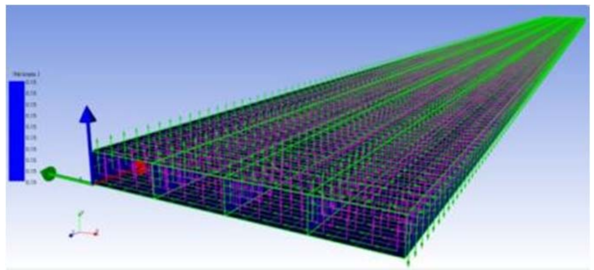
FEA Result Summary

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



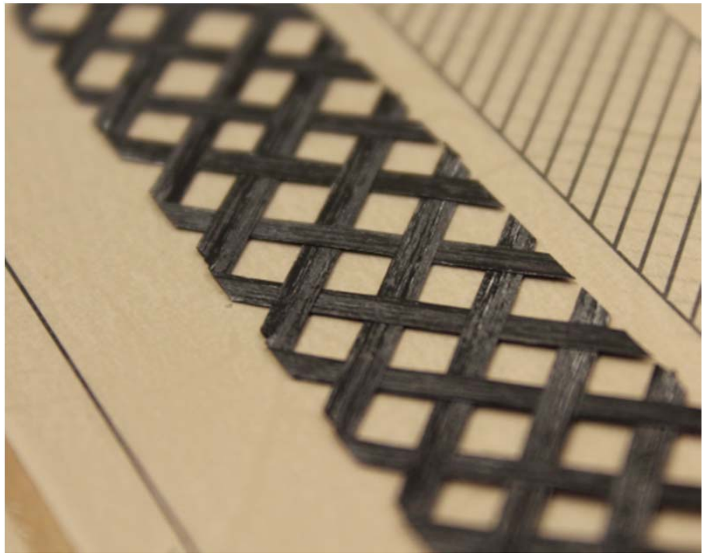


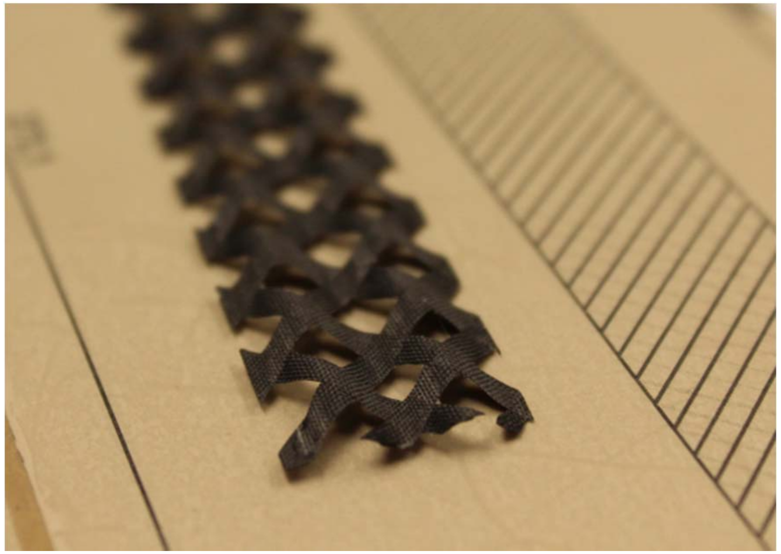
Prototype Part from Liverpool

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.*



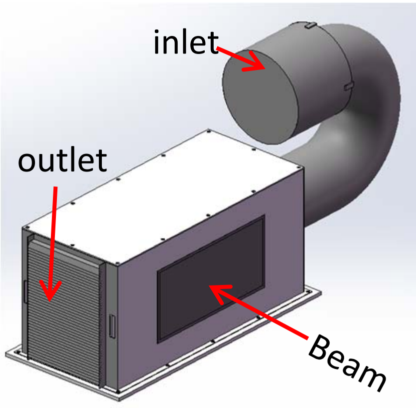


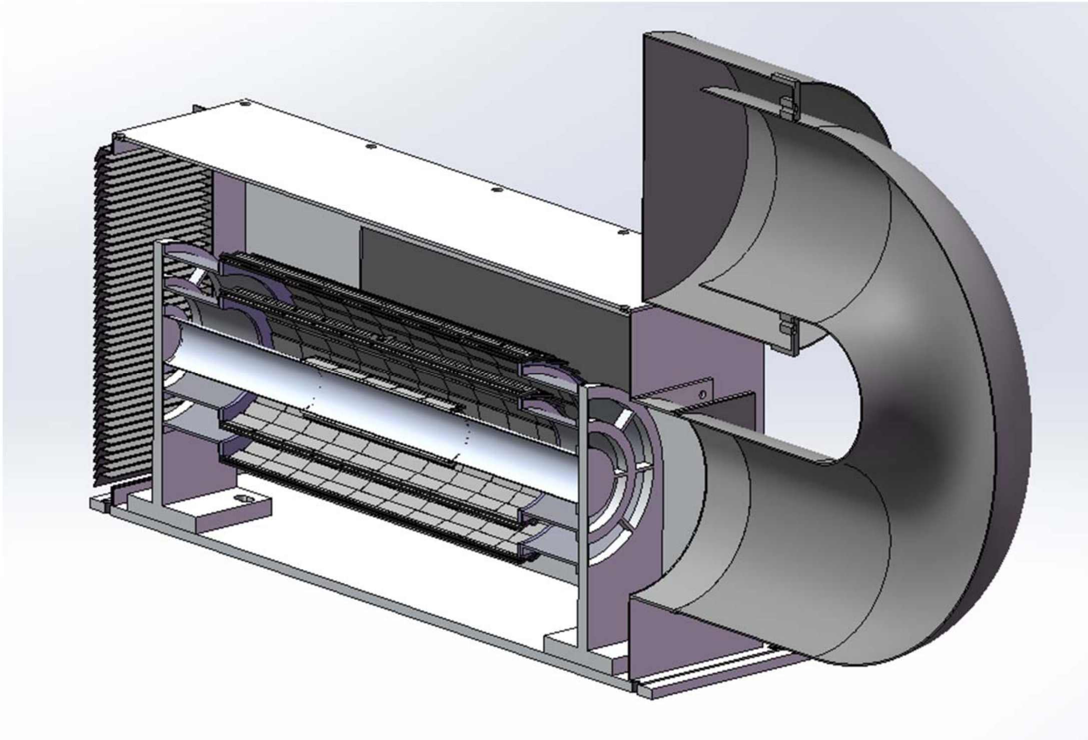
Beam test: detector supporting and cooling box

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

- Optimization of the structure design and more FEA analysis of material and structure.
- Investigate the: material, curing equipment, testing equipment, manufactures.
- Work on interface between SVXD and beam pipe with Quan Ji.

By the end of this year:

- ➢ 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

Backup

总体设计布局及边界：（1/2对称剖面图）

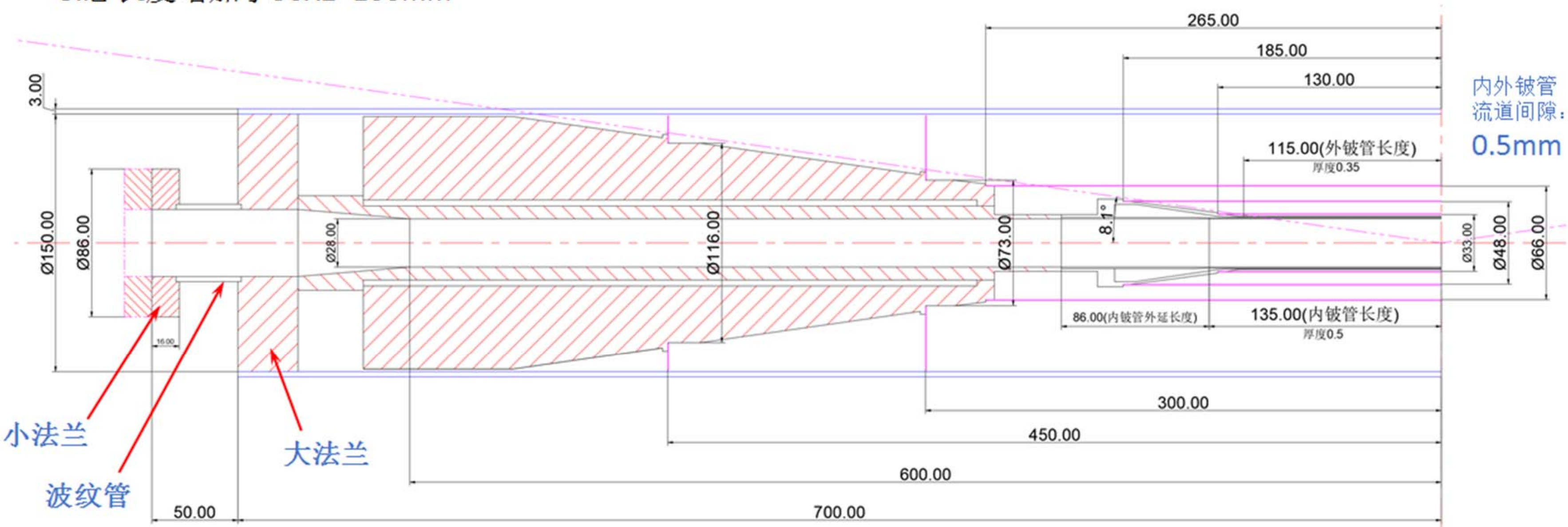
-by Quan Ji

方案改动部分:(与20190404比)

1.顶点探测器增加了端部垂直探测方式，圆周方向的三层探测分布更为紧凑

2.与加速器的对接法兰，由单一的不对称法兰变成大小组合、刚柔组合的法兰设计

3.总长度增加了50X2=100mm



对接法兰设计说明：

由大、小法兰和波纹管组成，既能保证束流管安装时的自身刚性，又能适应加速器的对接要求