

# Ladder Mechanics Studies for the CECF Vertex Prototype

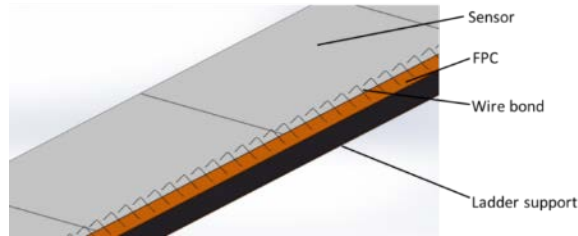
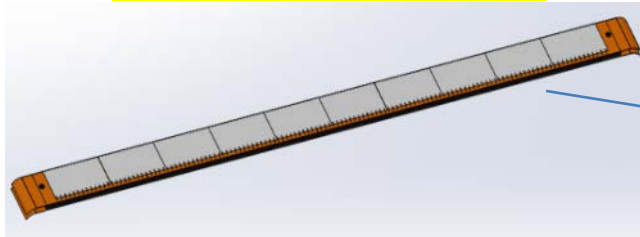
Jinyu Fu

2021-9-22

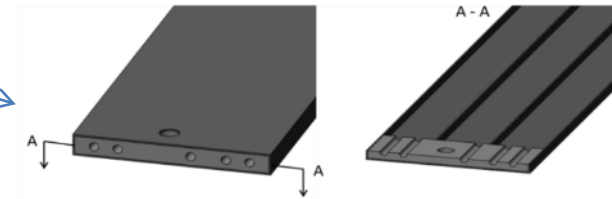
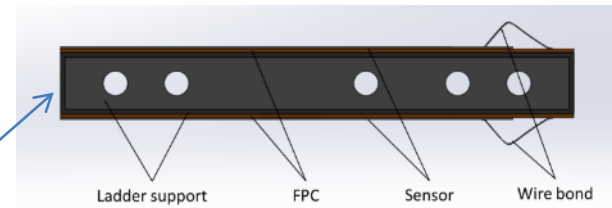
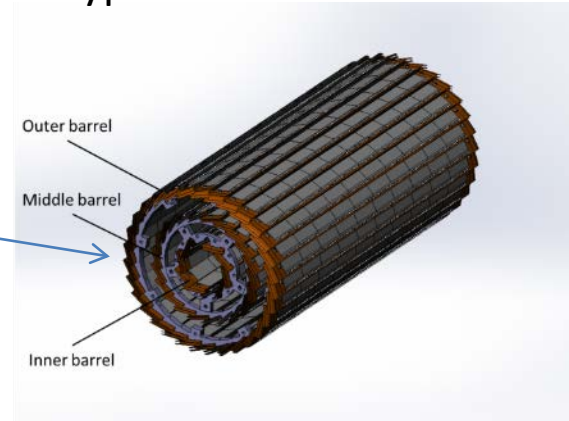
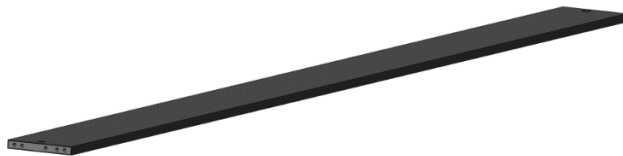
# Ladder and its support structure

Driven by the material budget requirement of 0.15% radiation length of one sensitive layer of the silicon vertex detector, the ladder support structure mainly made of carbon fiber composites were designed and have been prototyped.

The double sided ladder



ladder support structure



# Ladder support prototype

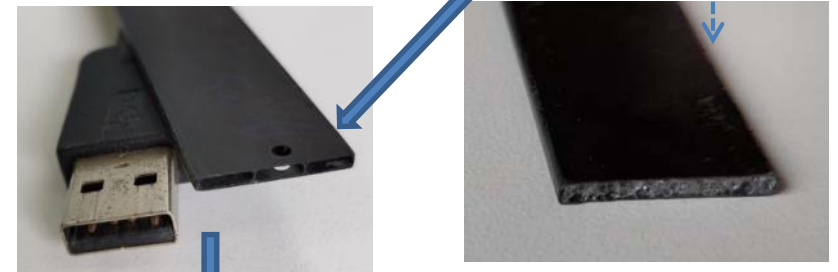
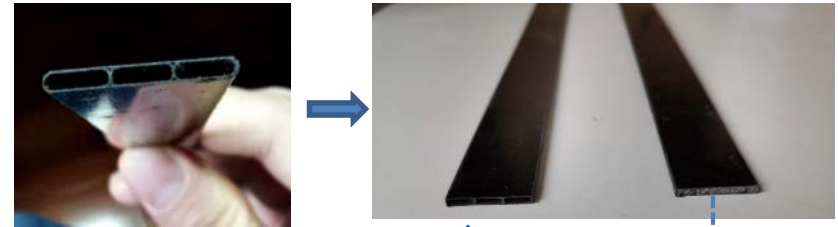
- **Manufacture process validation:**  
short beam - trial materials - full length/required material.
- **Ladder support prototypes for testing:**  
Full size:  $16.8 \times 2 \times 273$  mm.  
High modulus CFRP, 120 - 150  $\mu\text{m}$  thick.  
4 pieces as listed below:

Ladder support	Thickness ( $\mu\text{m}$ )	Weight (g)
4-1	120	2.83/(2.5)
4-2	120	3.23/(2.5)
5-1	150	2.83/(3.0)
5-2	150	3.26/(3.0)

## Vibration Test and Purpose:

To verify the stiffness of the ladder support, amplitude induced by air cooling should be less than spatial resolution of the CEPC VTX requirement.

Different ladder support samples



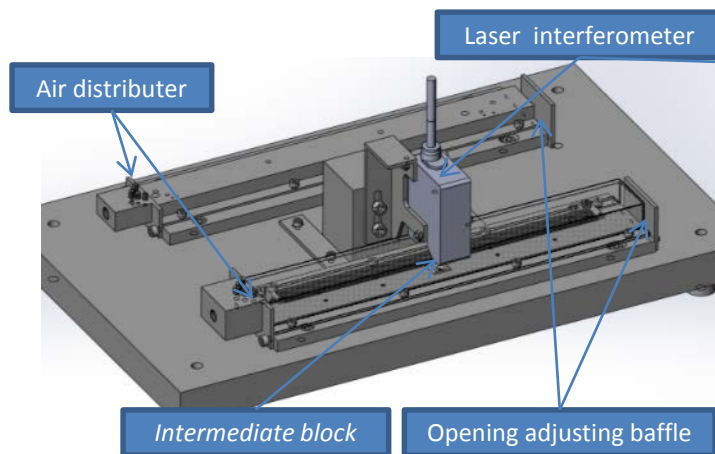
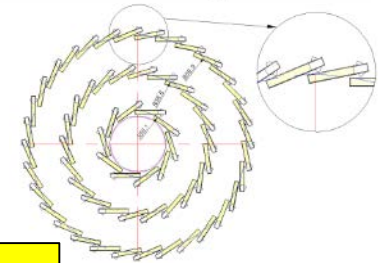
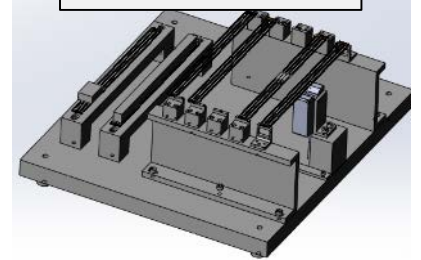
Latest ladder support samples



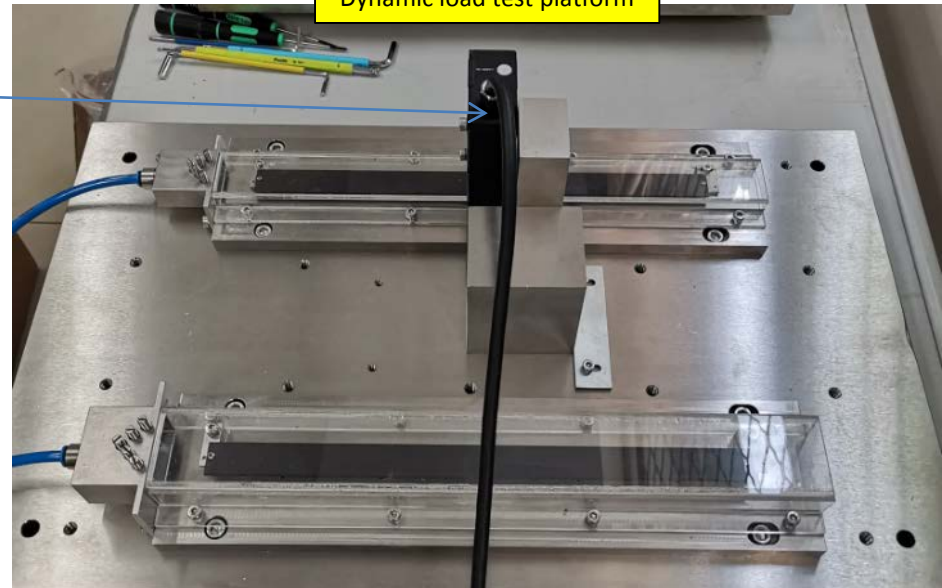
# Test platforms of ladder/ladder-support

- *Static (different support and load cases)*
- *Vibration and cooling + pressed air (different cases)*
  - Two air channels with different section sizes.
  - Ladder ladder horizontally fixed in channel by two L shaped blocks.
  - Gaps within small/big channel in top and bottom sides of the ladder support is 3 mm/9 mm.
  - One laser interferometer - non contact measurement

Static load test platform

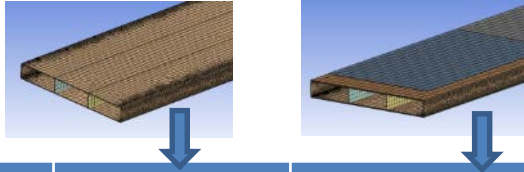


Dynamic load test platform



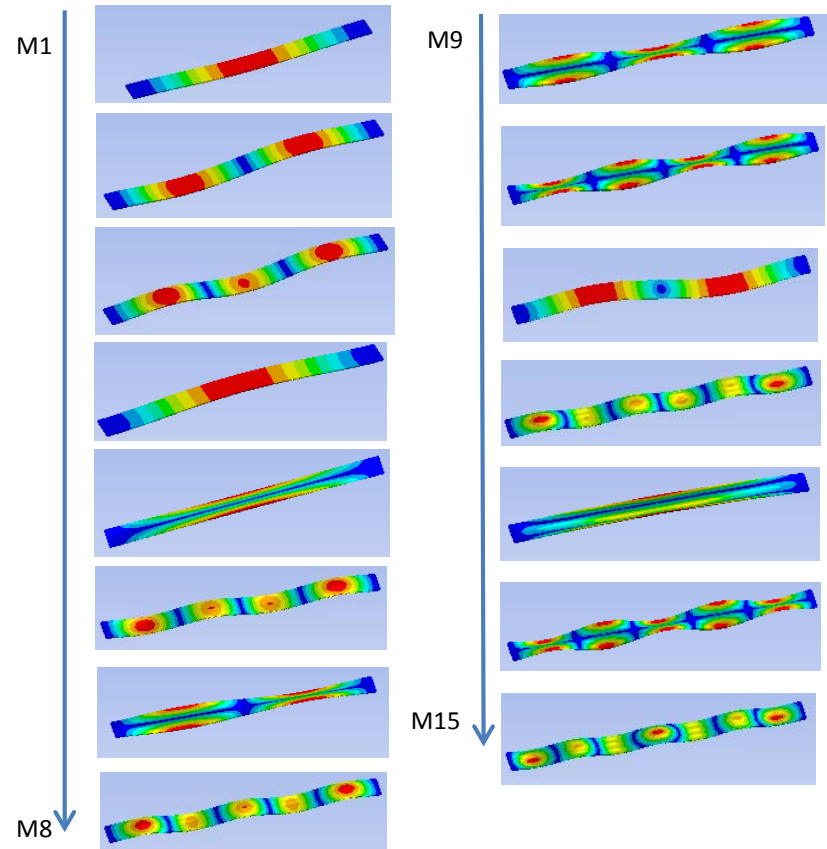
# Modal analysis of ladder support

- Natural frequency of the ladder support and ladder (two ends fixed)



mode	Ladder support Freq.(Hz)	Ladder Freq.(Hz)
1	309.98	234.54
2	837.48	629.48
3	1593.7	1188.4
4	1793.2	1252.3
5	2238	1753.6
6	2532.3	1866.7
7	3351.8	2624.5
8	3603	2678.9
9	4000.6	3166.9
10	4624.7	3336.2
11	4743.6	3446.2
12	4753.3	3591.6
13	5180.3	4095.7
14	5366.8	4261.1
15	5946.5	4719.6

- Mode shapes of ladder support



# Test of the ladder support prototype

- updated pressure and flow control devices
  - digital flow meter
  - air filter and pressure reducing valve
- temperature monitor (thermal couple)



# Preliminary results of the vibration test

## 1-Ladder support in the small channel.

- The measuring point set to the center of the top surface of ladder support
- Air speed of 2.5 m/s is the predicted speed that can cool the ladder with sensor power dissipation of 50 mW/cm<sup>2</sup> lower than 30 Celsius degree.
- *Sampling interval 1ms*

Vibration test results ( $\mu\text{m}$ )-*will be updated*

Flow	Outlet	4-1	4-2	5-1	5-2
60.5 SLM ( $\sim 5\text{m/s}$ ) With pins	open	0.4	0.3	0.2	0.3
	20% open	0.4	0.3	0.2	0.3
60.5 SLM ( $\sim 5\text{m/s}$ ) Without pins	open	0.6	0.5	0.7	0.5
	20% open	0.6	1.4	0.5	0.5
<b>30.25 SLM</b> ( $\sim 2.5\text{m/s}$ ) <b>Without pins</b>	<b>open</b>	-	<b>0.1</b>	-	-
	<b>20% open</b>	-	<b>0.2</b>	-	-

*The listed values are the **peak to peak** values very roughly picked from the measured curves. The results is being further processed. The Max vibration amplitude (very conservatively) is less than **half** of the listed value. All of which are less than the CEPC VTX spatial resolution of 3  $\mu\text{m}$ .*

# Preliminary results of the vibration test

## 2-Ladder support in the big channel.

- the measuring point set to the center of the top surface of ladder support
- Air speed of 2 m/s is the predicted speed that can cool the ladder with sensor power dissipation of 50 mW/cm<sup>2</sup> lower than 30 Celsius degree.
- Different sampling intervals

Vibration test results ( $\mu\text{m}$ )- *will be updated*

Flow	Outlet	4-1 (20us/100us)	4-2 (20us)	5-1 (20us)	5-2 (20us)
V1=85 SLM ( $\sim 2$ m/s)	open	3.2/2.5	2.5	4.5	3.7
	20% open	4/ 2.3	2.3	2.5	3.9
V2=128 SLM ( $\sim 3$ m/s)	open	8/ 4.7	7.9	11	7
	20% open	12.7/4.7	9	9	8
V3=171 SLM ( $\sim 4$ m/s)	open	-/ 6.5	11	10	8.9
	20% open	15.6/6.3	11.4	13.5	10

*The listed values are the **peak to peak** values very roughly picked from the measured curves. The results is being further processed. The Max vibration amplitude (very conservatively) is less than **half** of the listed value, which of the top two rows are less than the spatial resolution of 3  $\mu\text{m}$  of the CEPC VTX.*

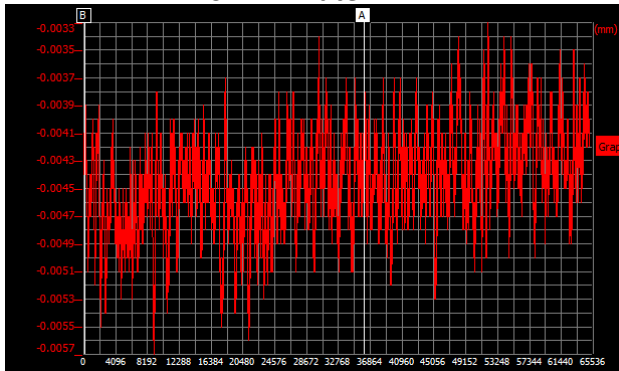


# Data processing and analysis

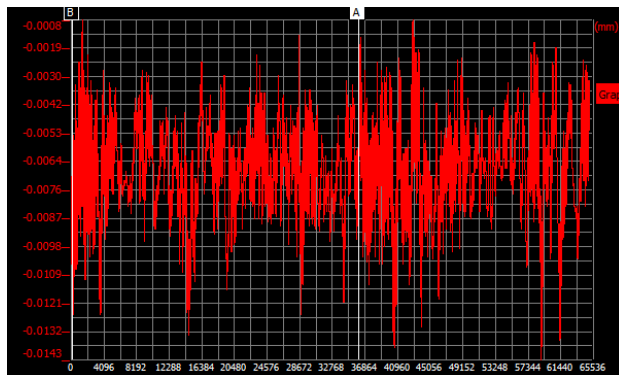
## The laser interferometer

- Sampling interval ranges 1ms -20  $\mu$ s
- The Max number of samples 65000

The sampling interval is 1 ms (1k Hz)  
for 1 minute



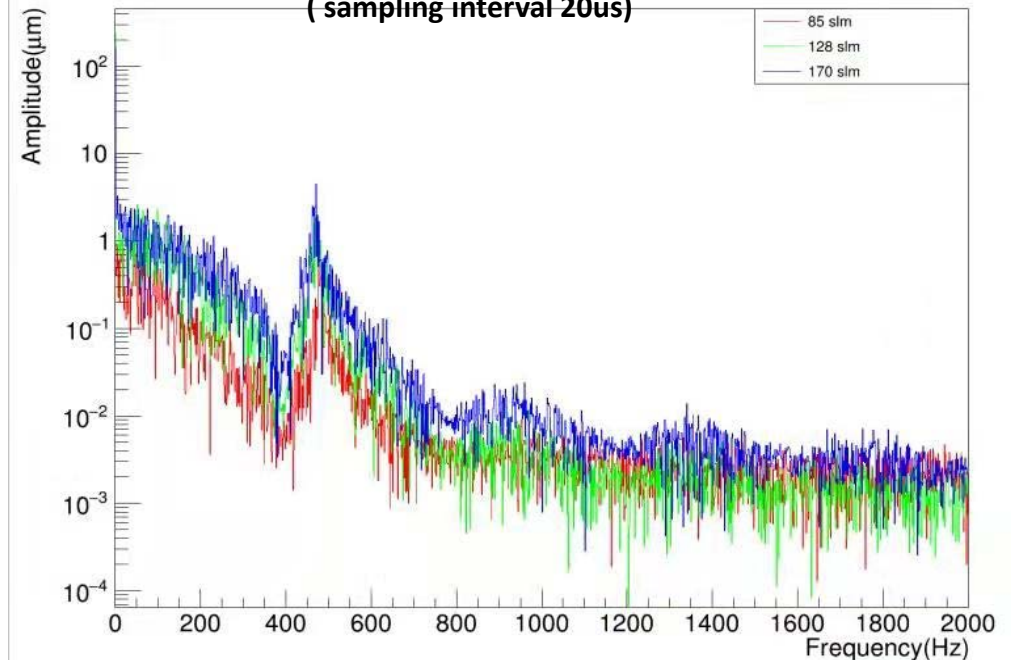
The sampling interval is 20  $\mu$ s (50k Hz)  
for 1.3 second



## 2. The data is being processed:

- FFT to get the vibration spectrum (*sample as below*)
- *statistic analysis of the amplitude (Gaussian distribution)*

Vibration spectrum (partial) of ladder 4-1 -outlet open  
( sampling interval 20us)



A few resonant peaks were confirmed at frequencies below 2000 Hz.

# Summary

- Preliminary test was done and results were obtained.
- 120 um thick CFRP ladder support verified to be feasible according to the preliminary results of current stage.
- Further analysis of the results is being processed.
- Enlightenment from the preliminary results analysis:
  - Adjust the sampling frequency and test the small channel again.
  - Add extended data storage hardware and prolong the continuous sampling time with high-frequency.

## NEXT

- Continue testing the ladder support prototypes
  - testing of other setup (of the test platform).
  - with multiple measuring point (adder laser interferometer/change location)
- Vibration test of dummy
- Cooling test of dummy ladder