Mechanical design of the VTXD prototype

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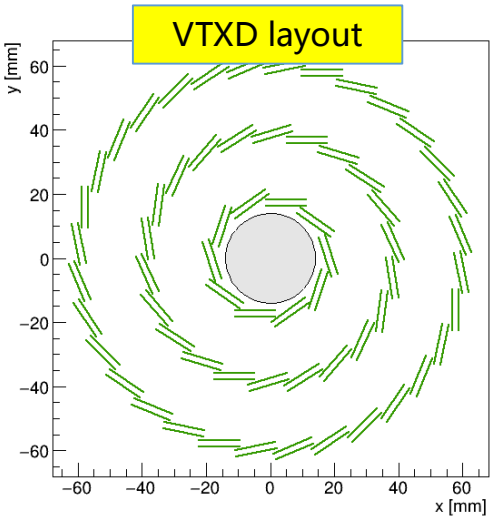
The VTXD layout

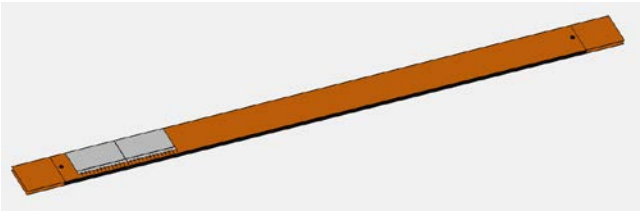
Design parameters of the vertex detector

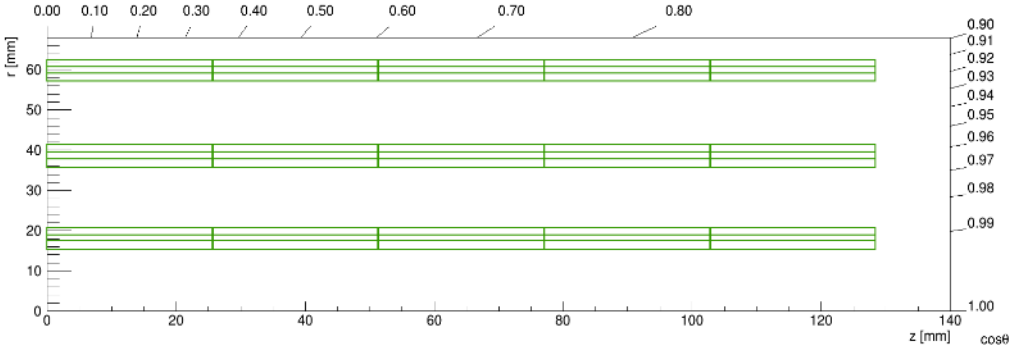
	R (mm)	|z| (mm)	Number of ladders	Number of chips
Layer 1	16	125.0	10	200
Layer 2	18	125.0		
Layer 3	37	125.0	22	440
Layer 4	39	125.0		
Layer 5	58	125.0	32	640
Layer 6	60	125.0		

VTXD layout



The double-sided ladder



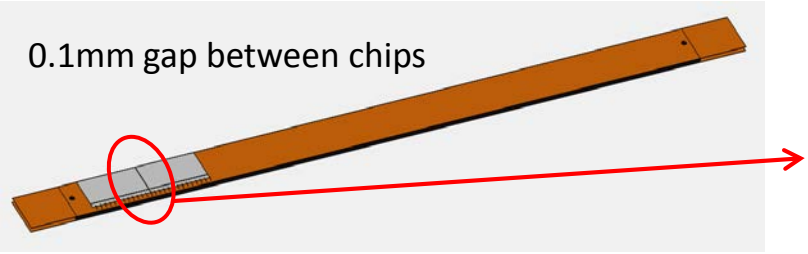


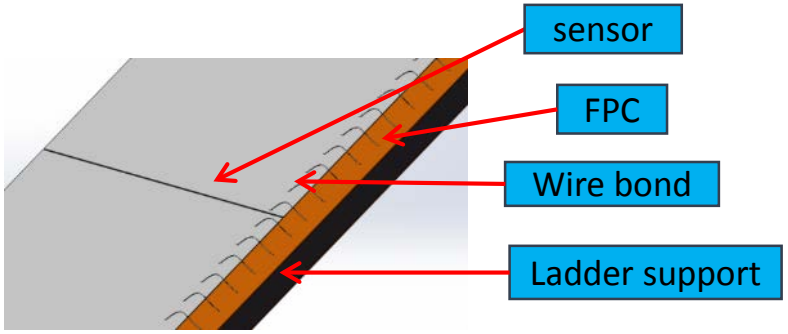
Ladder and Barrels

Sensor chip : 16.8* x 25.6 mm (2* mm margin at one side for wire bonding)

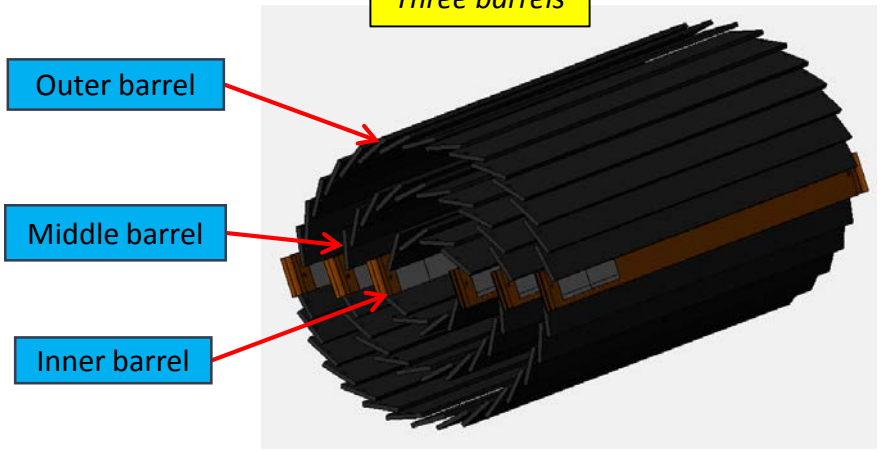
Ladder: support + sensors + FPCs, sensors and FPCs on doubled sides of the ladder.

The double sided Ladder (17.4 *x 272.9 mm)

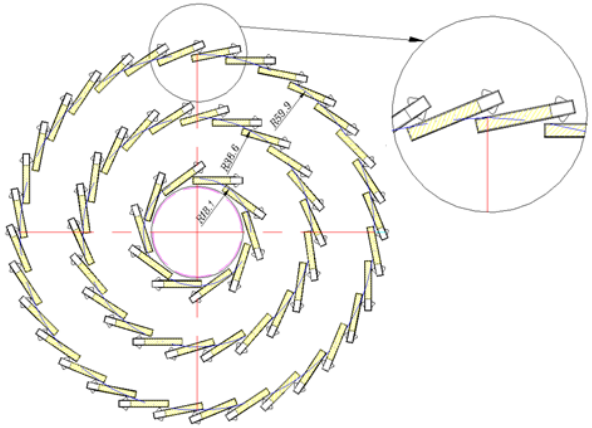




Three barrels



Overlapped area



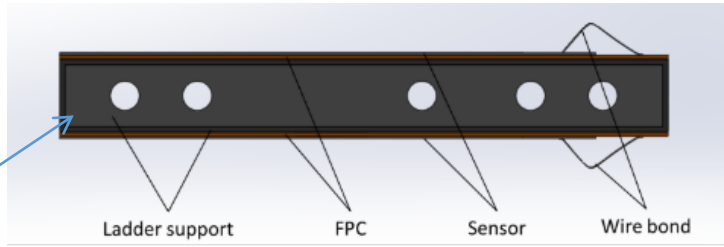
Ladder Support

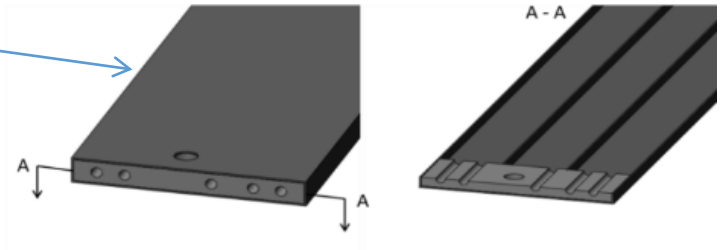
With the FEA assistance, compared different optional design, optimized and finalized the details of the official design (including layers of plies design).

Material: CFRP.

Size: 272.9 x 17.4 x 2 mm (L x W x H).

ladder support structure

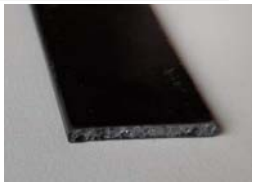




FEA results of static deformation of ladder support

Laminate thickness	Weight of the support tube (gram)	Deformation (μm)		
		Ladder (under self-weight)	Ladder support (under full load)	Ladder support (under self-weight)
120 μm	2.0	4.9	6.8	2.5

Fabrication process validation

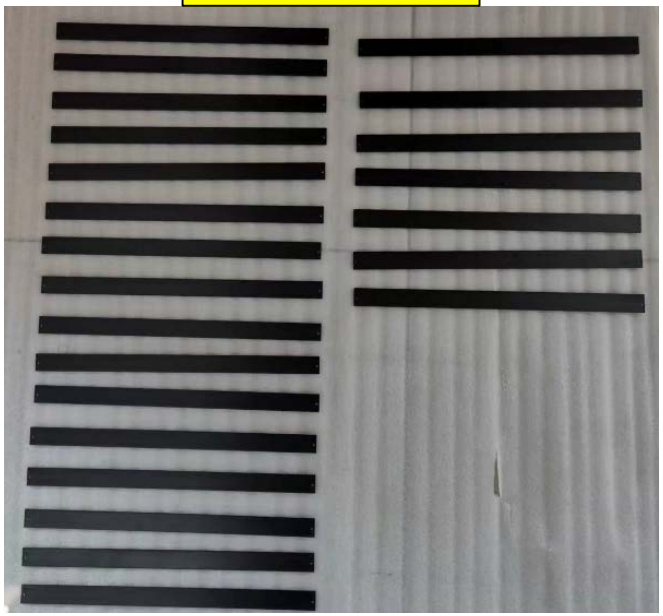


Aiming to reduce material, the CFRP laminate has to be very thin and the fabrication is very challenging.

Ladder Support

By fabrication process validation test, the best we can realize is that to control the thickness of the CFRP laminate down to 0.12mm, this significantly reduced material.

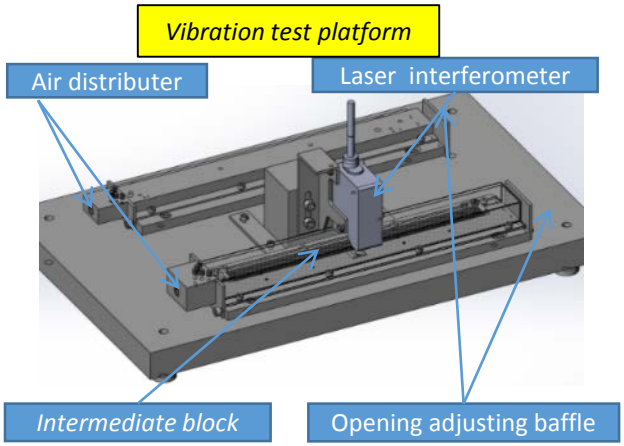
Ladder support



For the prototype, the CFRP laminate is slightly thicker than the previous fabrication test.
Due to COVID pandemic, a new company that can make it before beam test was chosen to make the ladder support.

Ladder support test

Platforms were designed for static and vibration test of the ladder support.

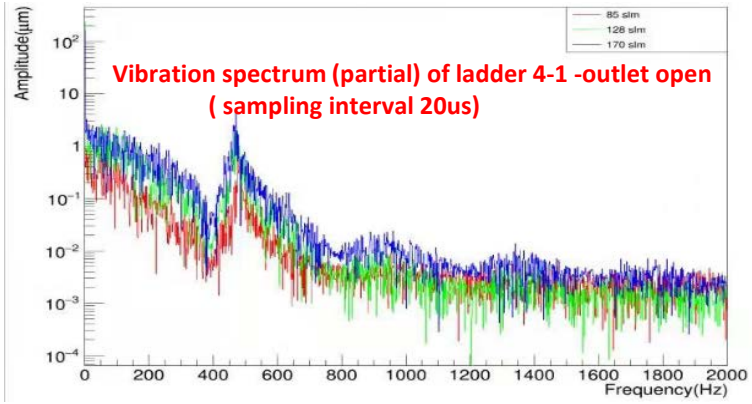


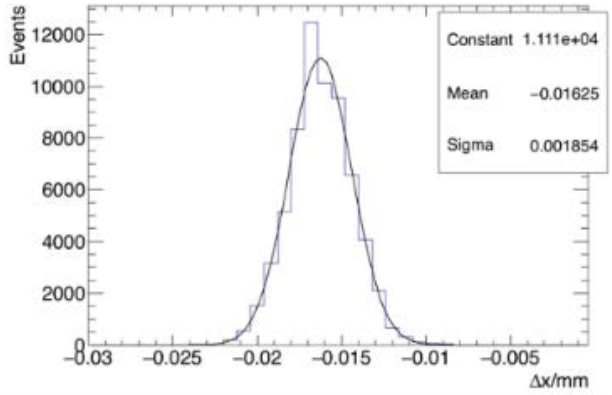
For this design a patent was authorized:

一种超轻梁的振幅测量装置
专利号：ZL202110576983.3
2022年4月授权

Vibration test result:

The max vibration amplitude is much smaller than 5 μm (detector resolution).



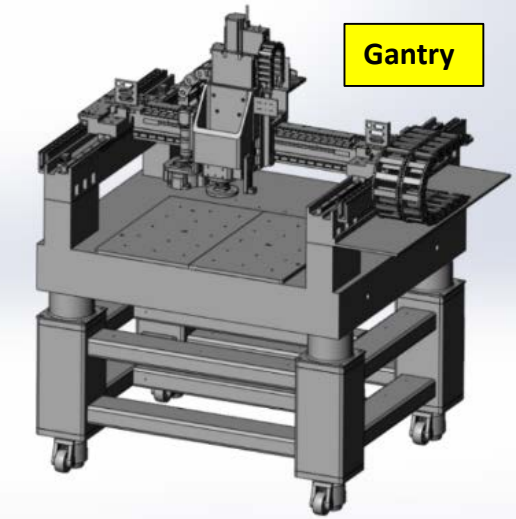


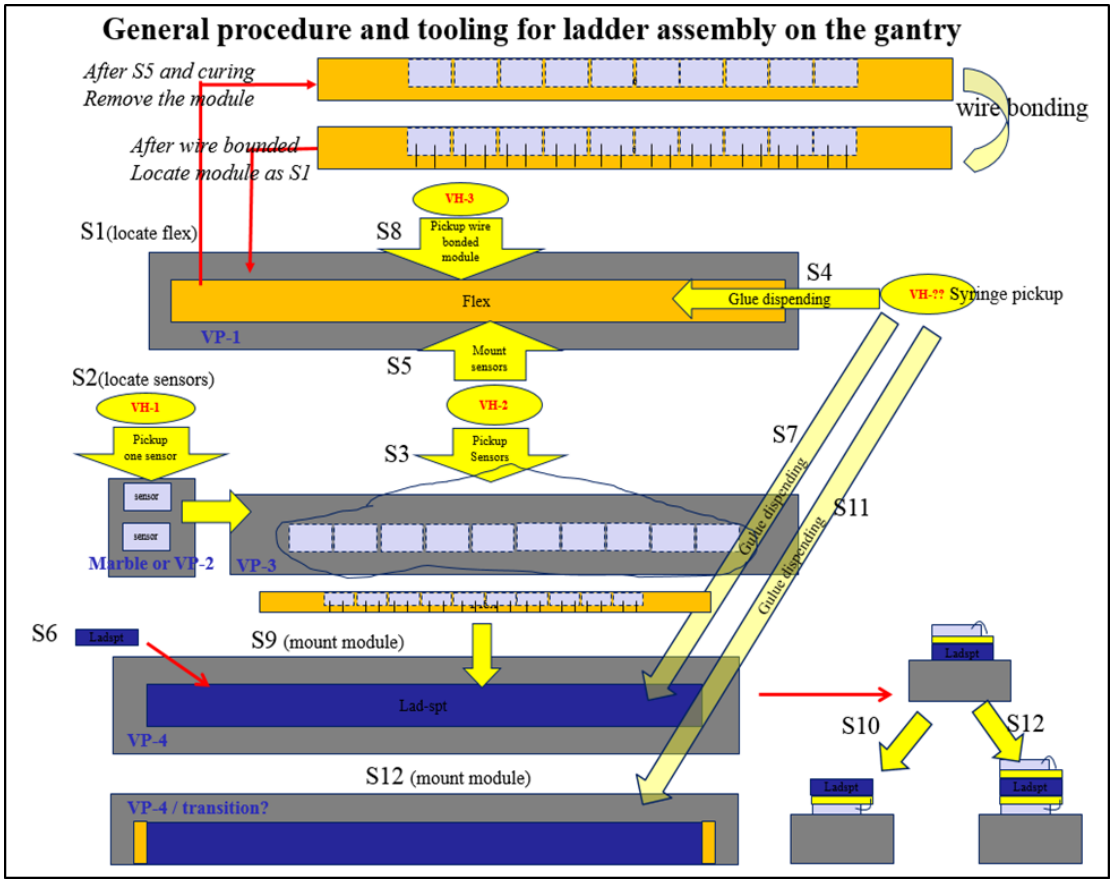
Verified the ladder support is rigid enough under estimated air flow rate.

Tooling design for ladder assembly on the gantry

To assemble the double-sided ladder is a complex and delicate work, no experience.

- Assembly scheme and procedures were fully considered.
- Tooling for specific process were designed.



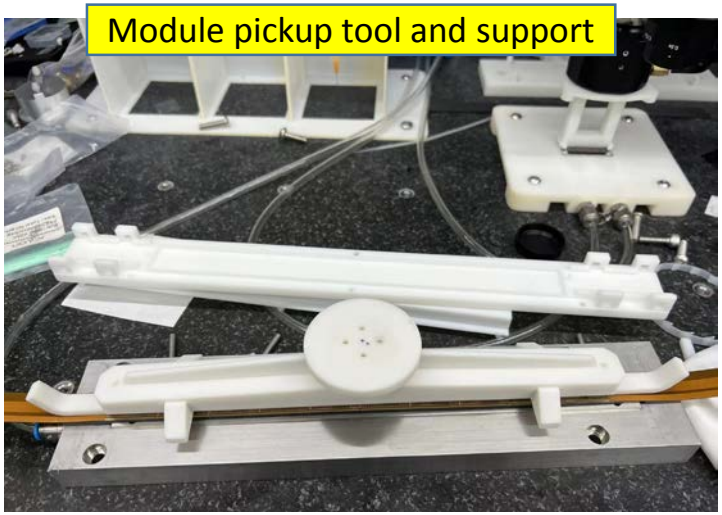


Tooling design for ladder assembly on the gantry

Sensor pickup tool

Vacuum plate for flex and CFRP support fixation

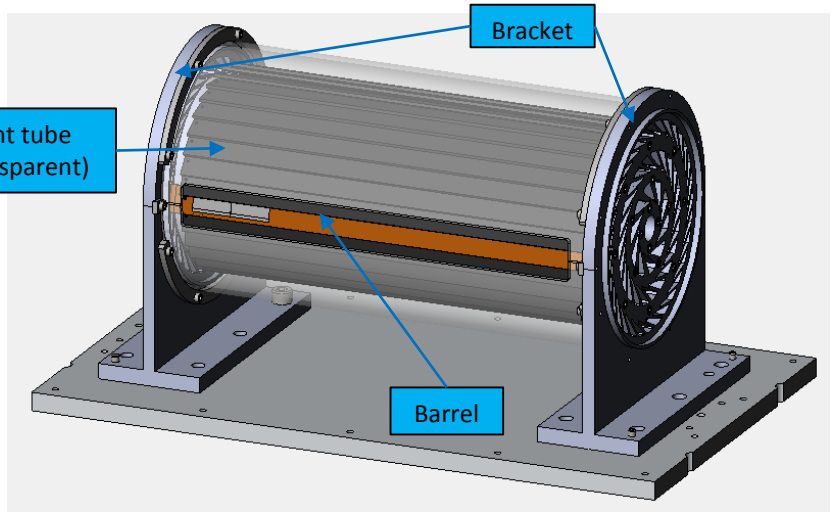
Module pickup tool and support



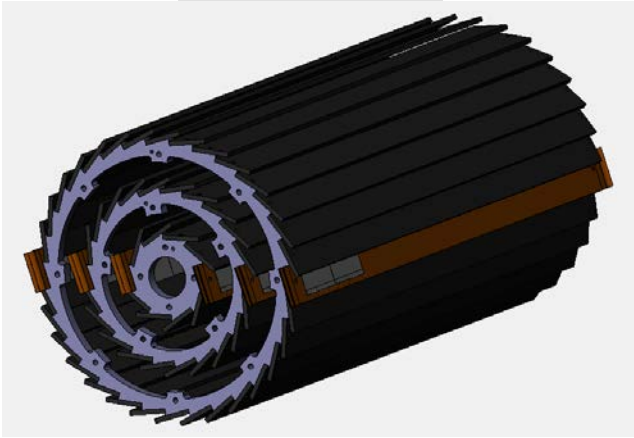
Vacuum chuck for sensors array

Module fixation and protection components

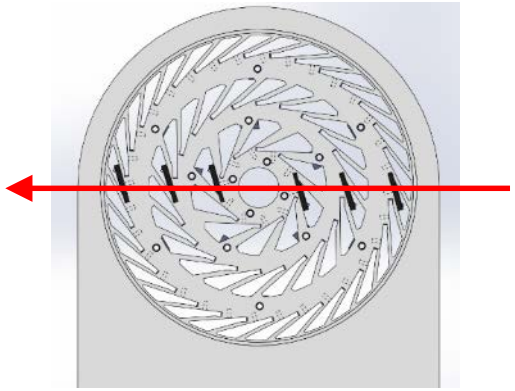
Main structure of the VTXD prototype



Prototype barrels

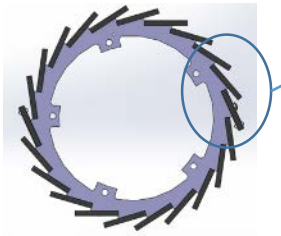


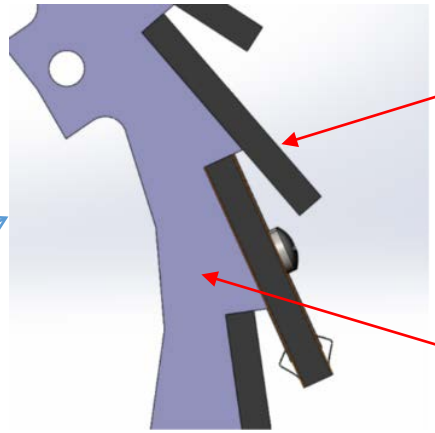
For prototype beam test: 6 ladders are mounted on one line, others are bare CFRP ladder support.

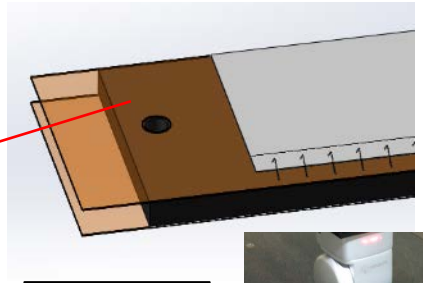


Ladder fixation on barrel

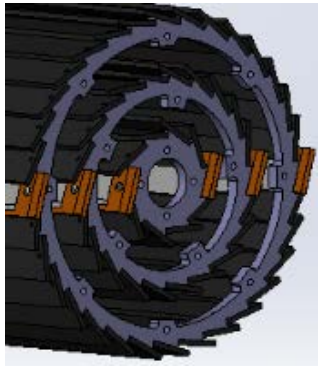
Sides constraint/alignment + screw tighten

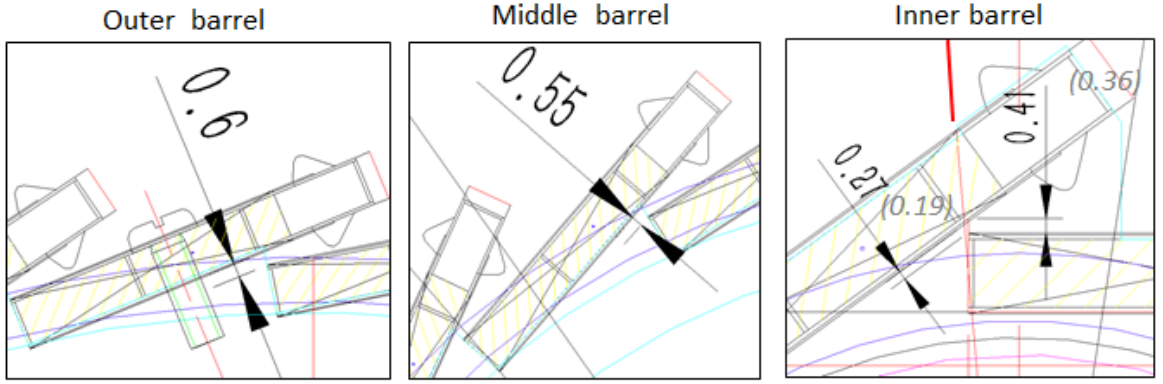






Side ring

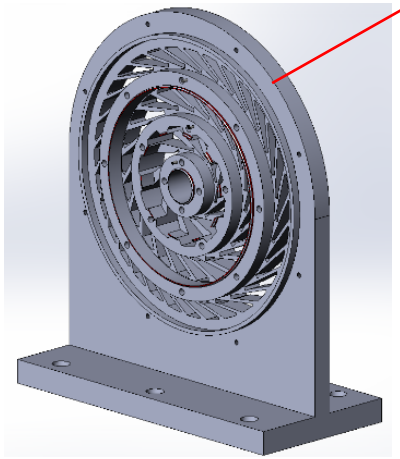


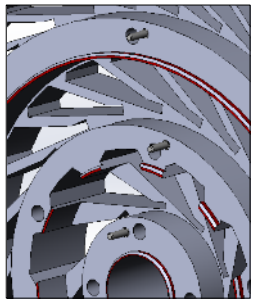


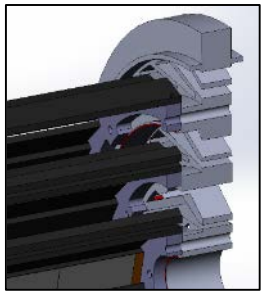
Very high precision is required for the CFRP support and barrel support.

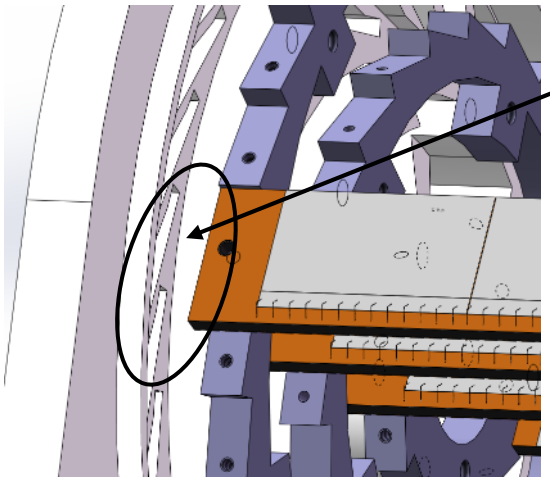
Barrels fixation on the brackets

Barrels (side ring) are located on the main bracket by: ring + pin

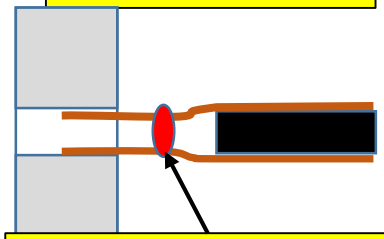






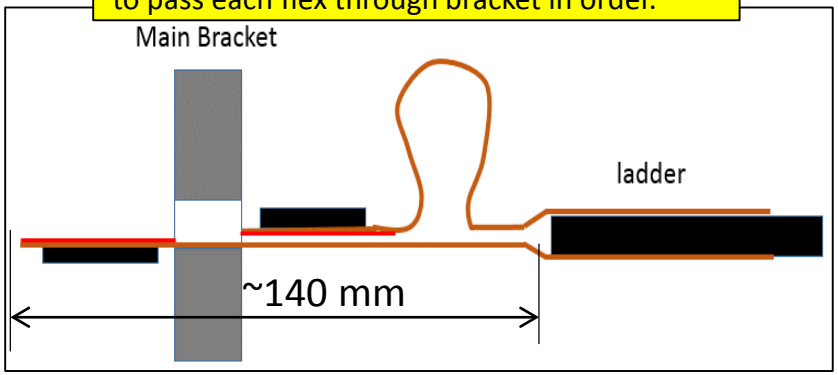


The convex ring provide a transition region for flex routing.

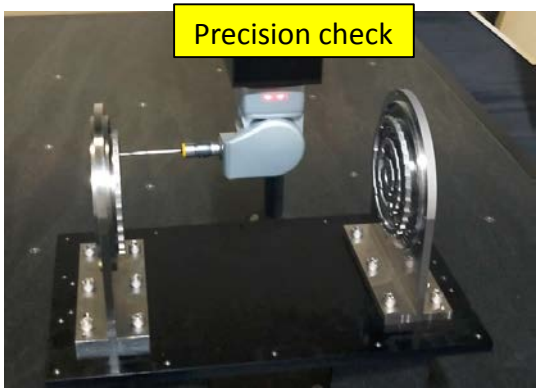


Glue adjacent flex to enable routing and for protection.

Extended length outer the ladder is required to pass each flex through bracket in order.



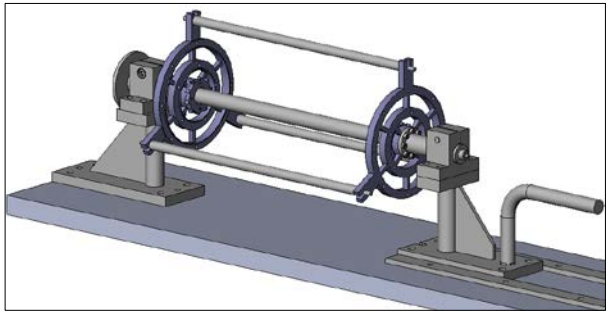
Precision check

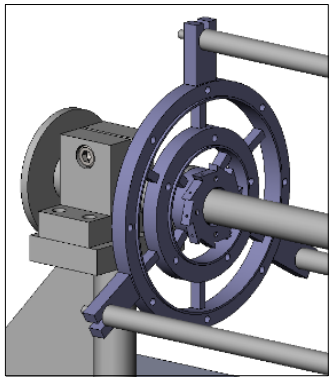


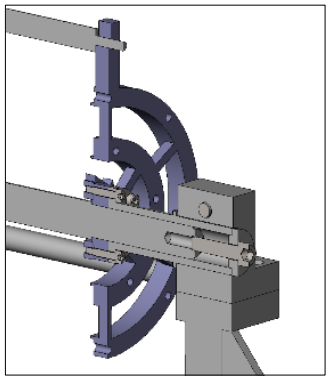
The metal material used for the support brackets and side rings of the prototype is not necessary for the detector, it is only for the beam testing and transportation.

Tooling design for VTXD assembly

Barrel assembly tooling





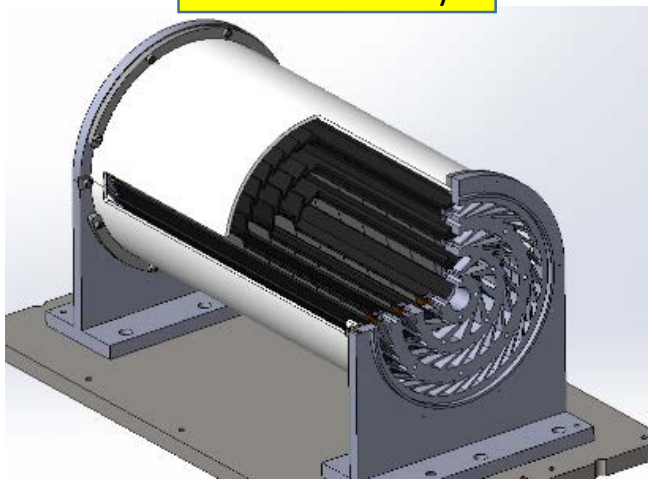


Middle barrel assembling

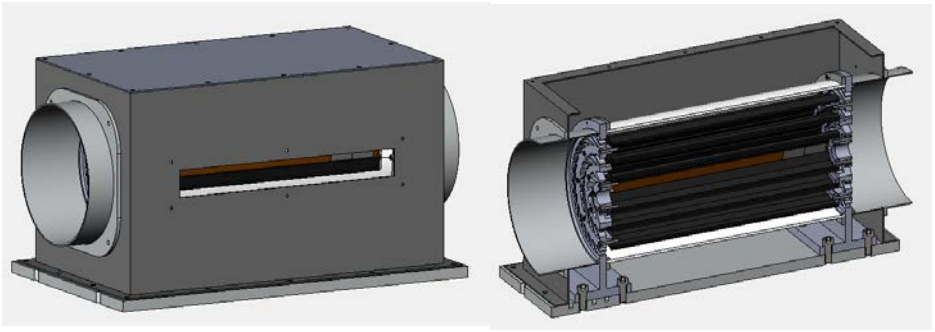
Outer barrel assembling

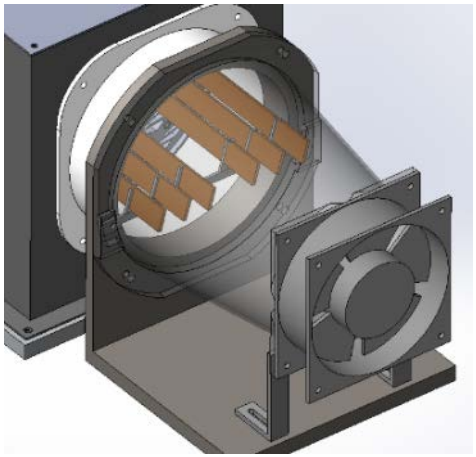
General structure of the VTXD prototype

VTXD assembly

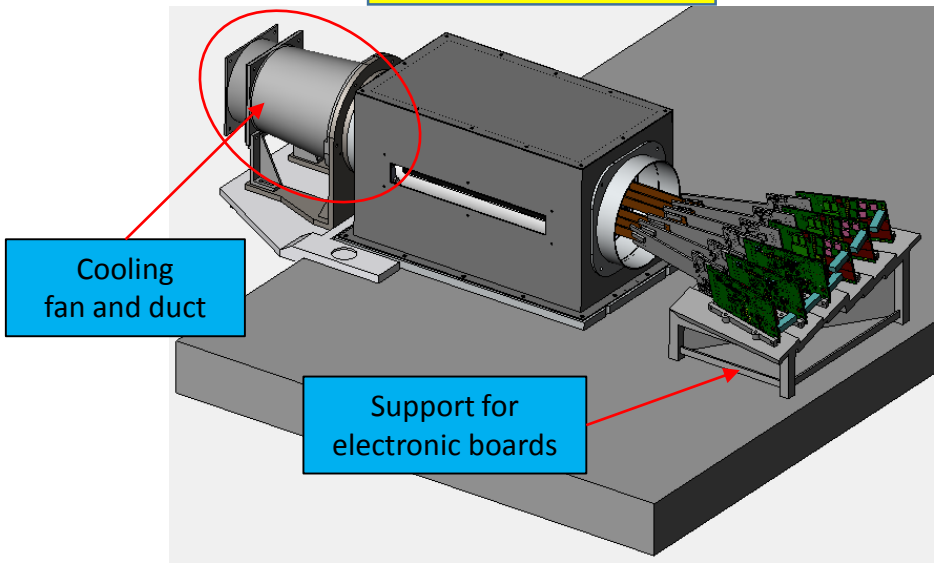


VTXD box (vent, protection, vibration-isolated)





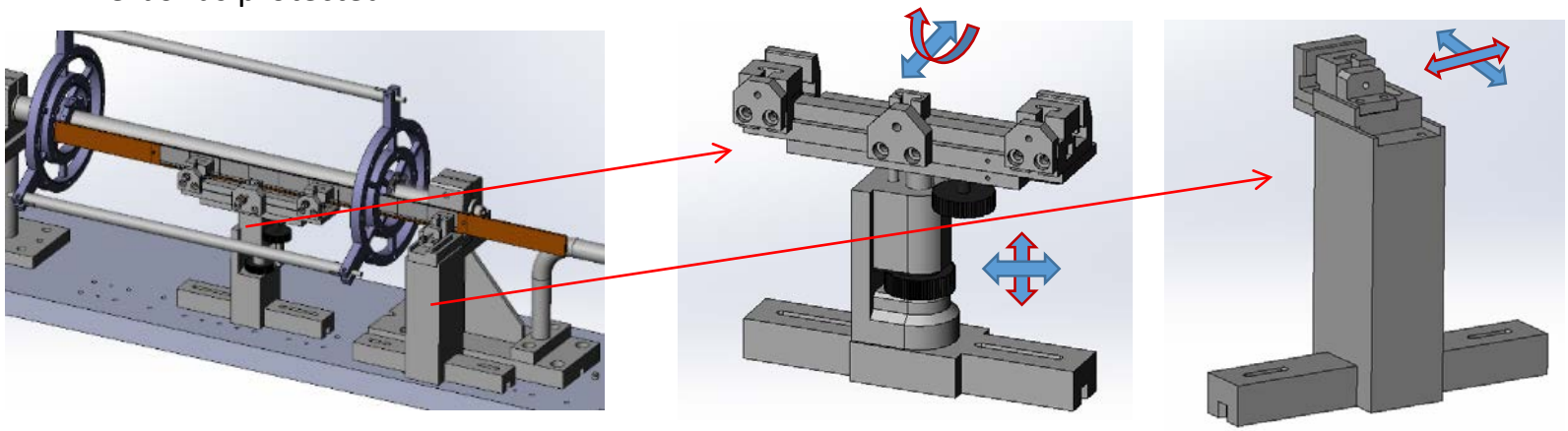
Peripheral structure



Tooling design for ladder loading

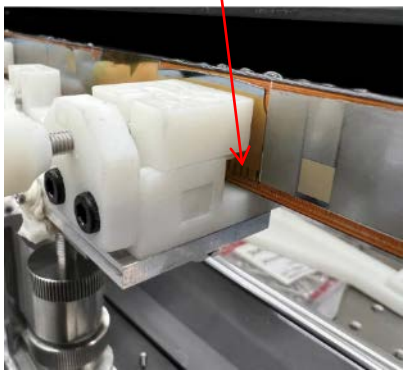
Jigs were designed and used for ladder installation on barrel.

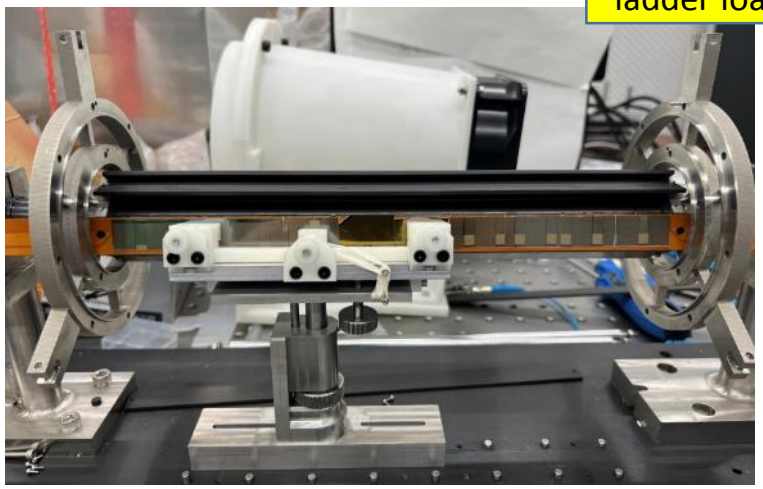
- Allow ladders to move in 3 axial directions and rotate along the longitudinal direction
- Wire-bonds protected

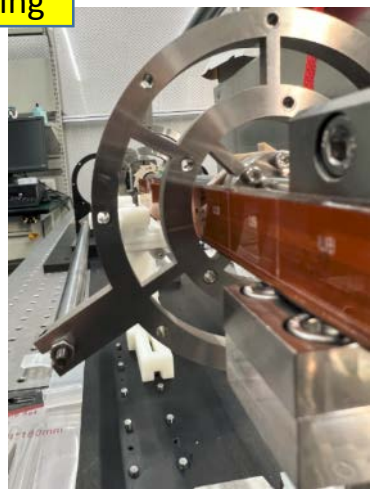


ladder loading

Wire-bond

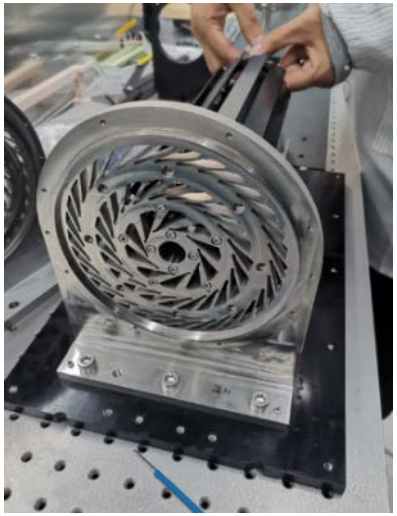


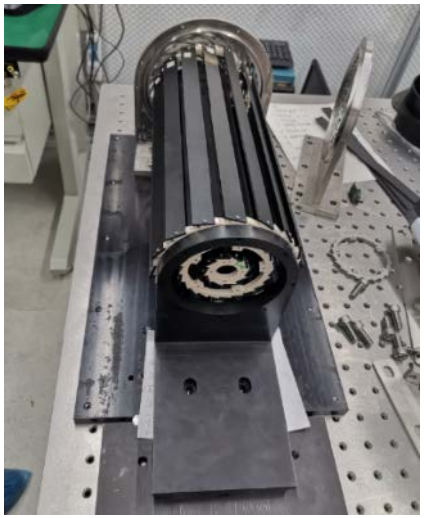


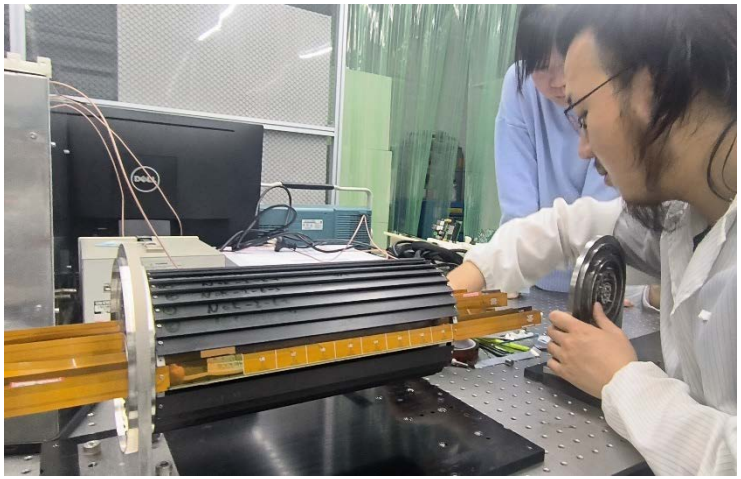


Prototype - barrels installation

The installation proceeded very smooth, all three barrels aligned with and fitted to the main brackets very well.

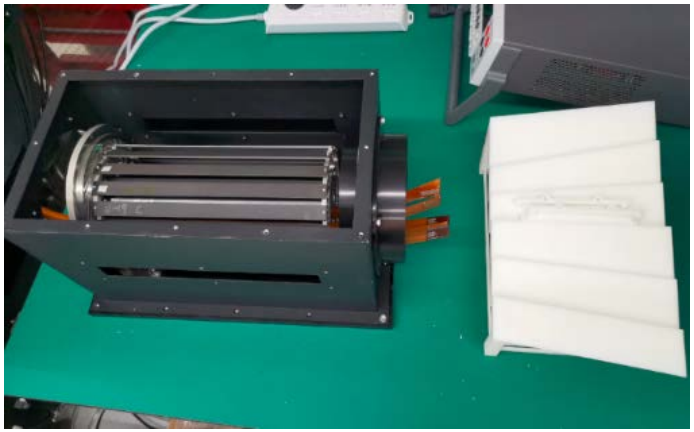


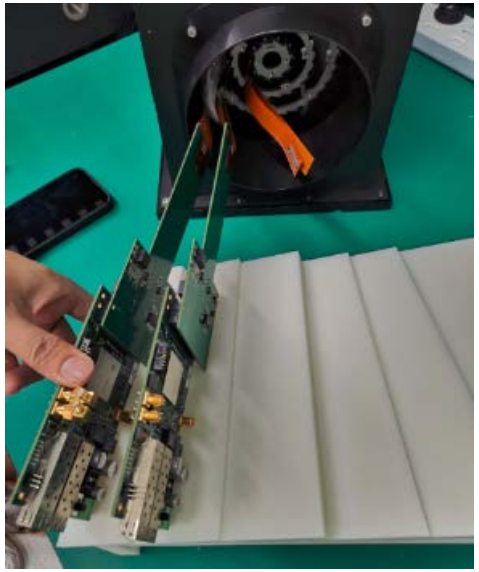




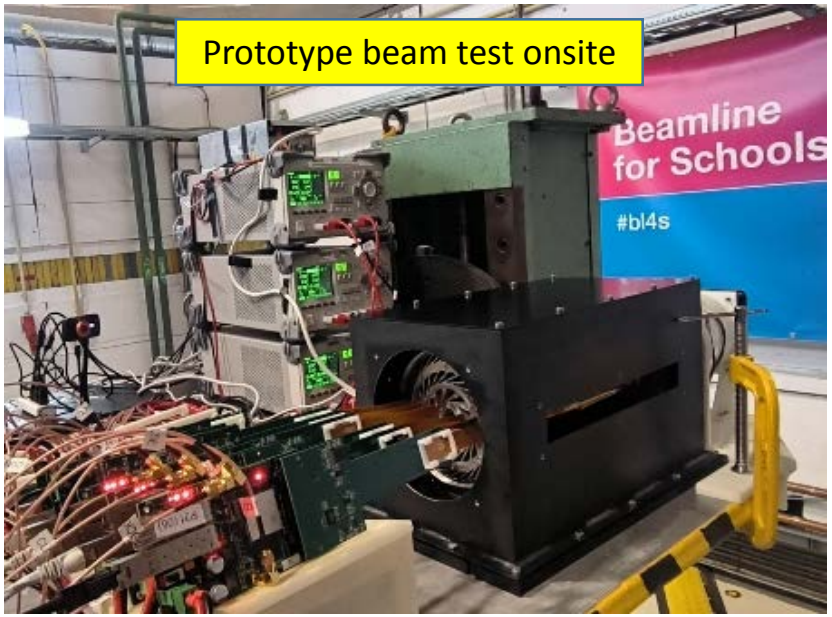
Prototype - general

VTXD box





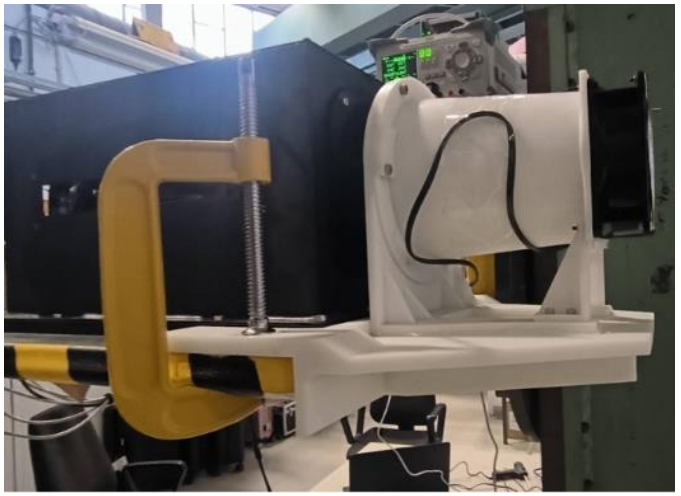
Prototype beam test onsite



Prototype cooling

The cooling for prototype were designed based on the power dissipation (61 mW/cm^2) of sensor:

- air cooling (fan selected)
- ventilation and cooling duct design
- cooling simulation



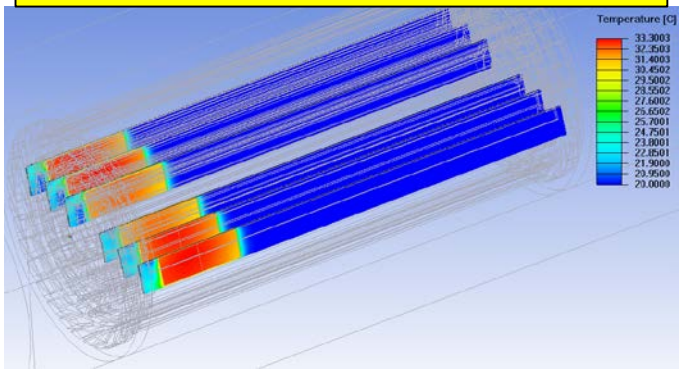
Temperature of the chips was monitored during the beam test. Verified:

- ➢ reasonable cooling design (real temperature is within the simulation)
- ➢ good vibration isolation - Vibration induced by cooling does not affect the detector resolution, due to the non-contact independent assembly design.

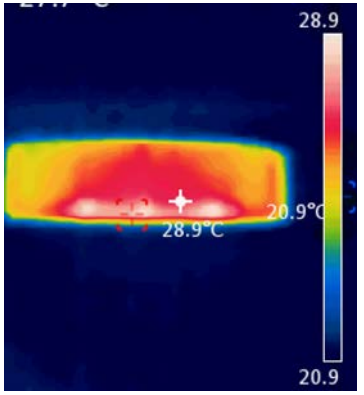
A patent was authorized:

一种探测器气冷测试装置
专利号：ZL202121144759.9
2022年8月授权

Prototype cooling simulation：Max 33.3 ℃



Chip temperature under cooling during beam test: Max 28.9 ℃



Summary

- The ultralight ladder support was designed, which contribute to lower the material of the VTXD.
- The general VTXD prototype structure and tooling have been fabricated and assembled.
- Dedicate tooling was designed for ladder assembly and testing.
- Necessary test and the final beam test proved the mechanical design of the VTXD prototype meet the physical requirements (low mass & high rigidity, cooling, vibration isolation)
- Achievements:
  - two patents authorized
  - one article published in RDTM