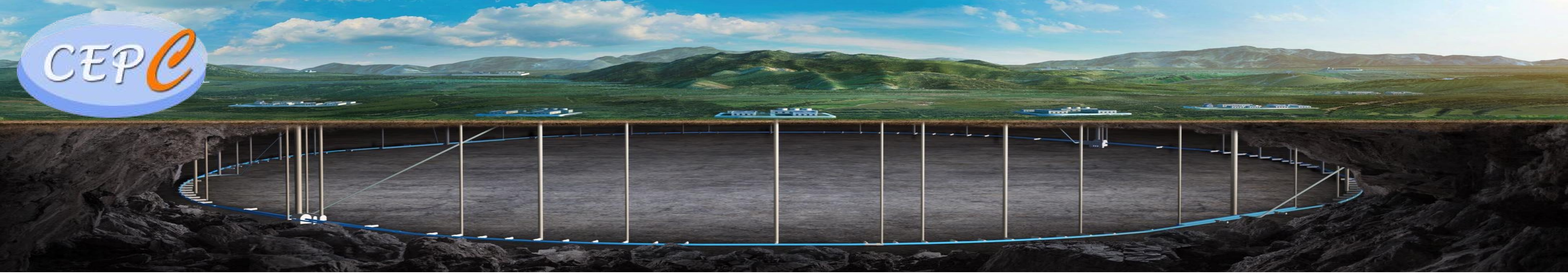

Mechanical Design for the silicon tracker

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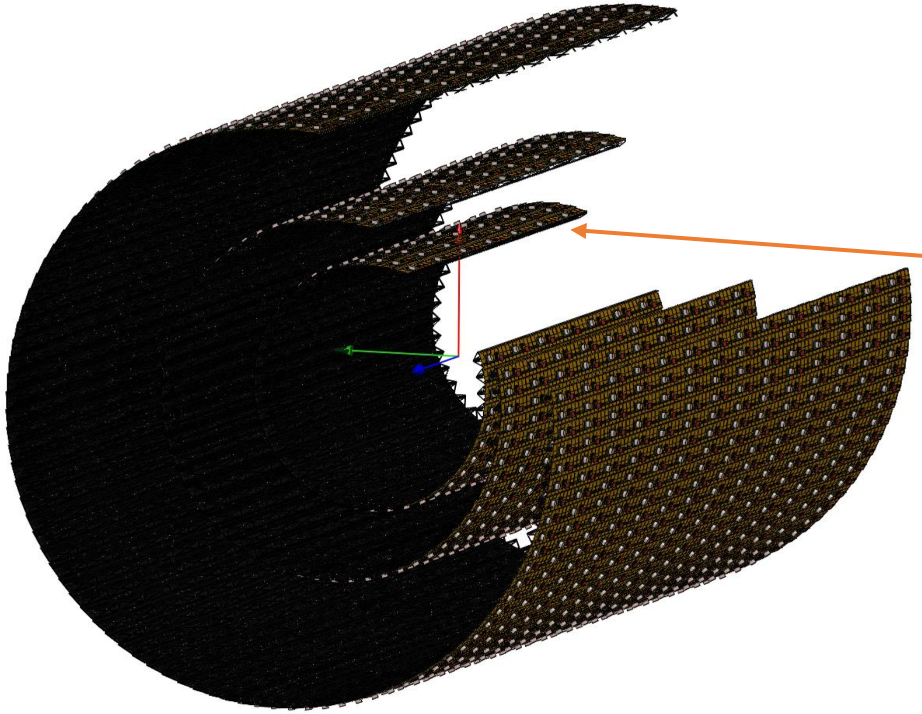
2025 02 15

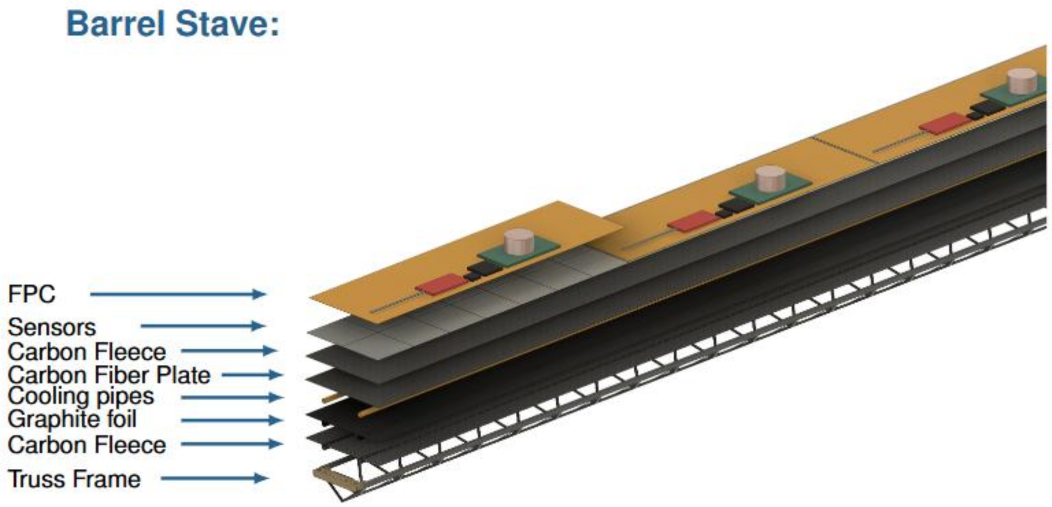
中国科学院高能物理研究所
Institute of High Energy Physics
Chinese Academy of Sciences

Outline

- Mechanical and cooling design for the ITK and OTK

5.3.4.1 ITK barrel local support





- Estimation of ITK stave material contributions

Estimation of ITK stave material contributions

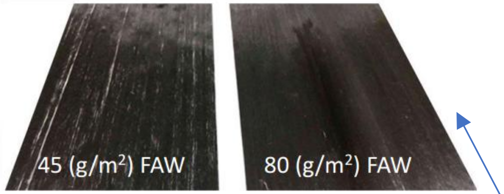
Functional unit	Component	Material	Thickness [μm]	X_0 [cm]	Radiation Length [% X_0]
Sensor Module	FPC metal layers	Aluminium	100	8.896	0.112
	FPC Insulating layers	Polyimide	100	28.41	0.035
	Sensor	Silicon	150	9.369	0.160
	Glue		100	44.37	0.023
	Other electronics				0.050
Cooling Plate	Carbon fleece layers	Carbon fleece	40	106.80	0.004
	Carbon fiber plate	Carbon fiber	150	26.08	0.057
	Cooling tube wall	Polyimide	64	28.41	0.013
	Carbon fluid	Water		35.76	0.105
	Graphite foil	Graphite	30	26.56	0.011
	Glue	Cyanate ester resin	100	44.37	0.023
Truss Frame	Carbon rowing				0.080
Total					0.673

5.3.4.1.1 Materials

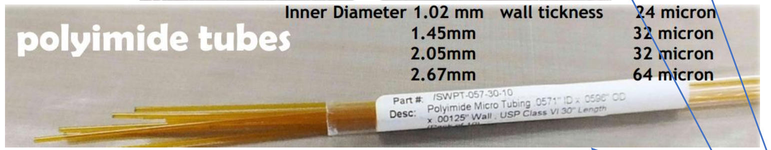
Filling layer, enhanced heat conduction

Carbon Unidirectional Prepreg

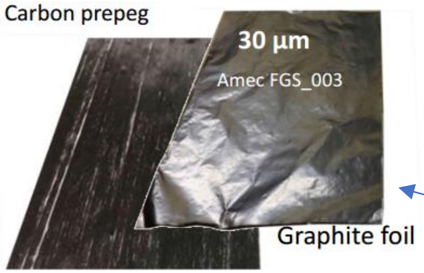
Heat dissipation, maintaining chip temperature stability



Cooling fluid circulating passage

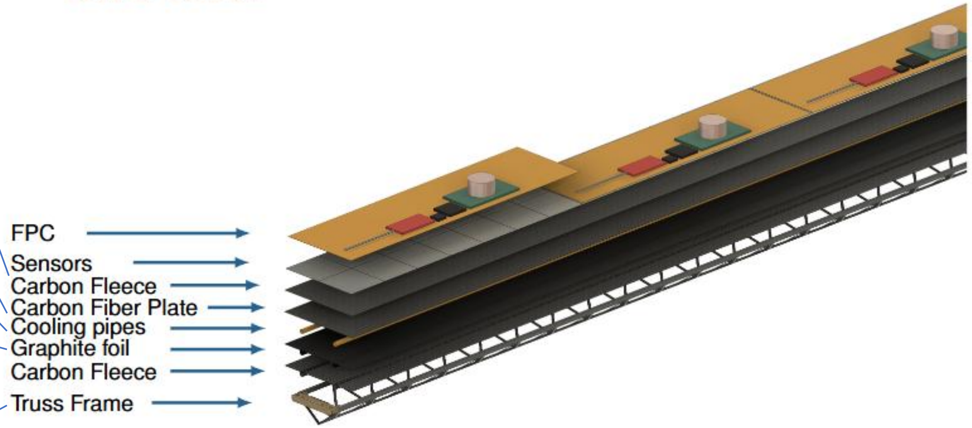


Enhance heat transfer between cold plate and cooling tube

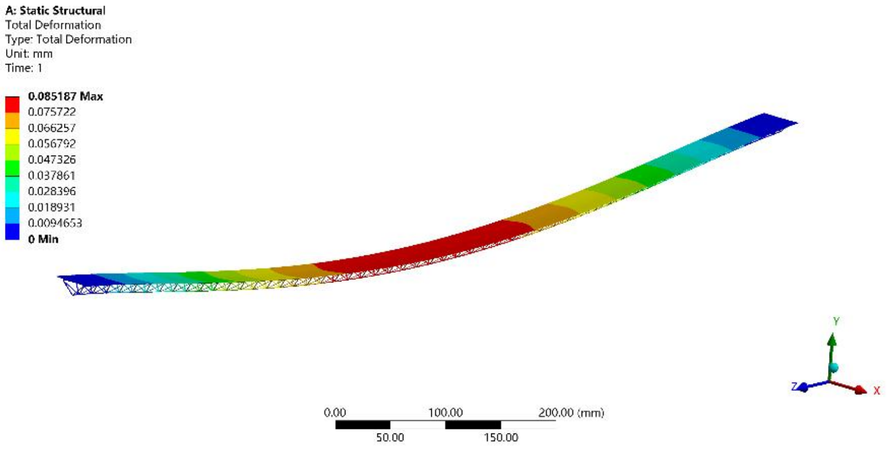


Support, provide structural rigidity

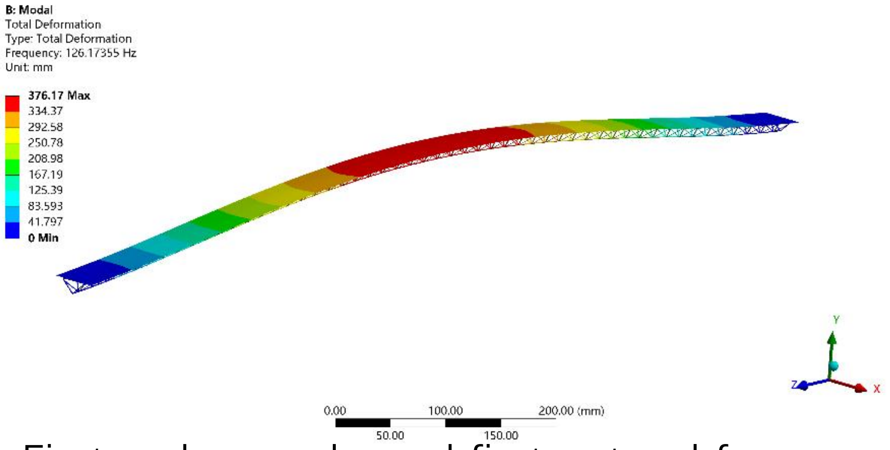
Barrel Stave:



5.3.4.1.2 Structural characterisition



ITKB1 stave deformation



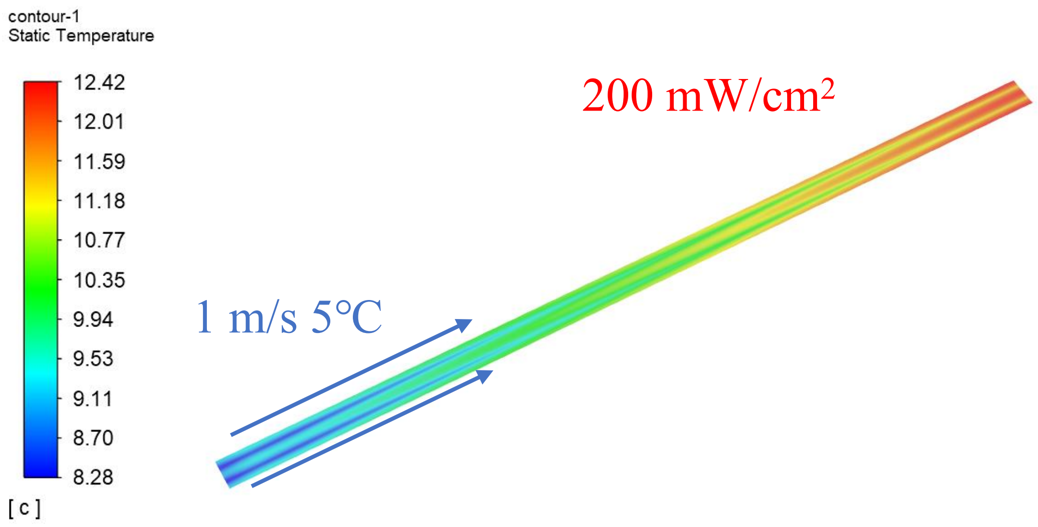
First order mode and first natural frequency

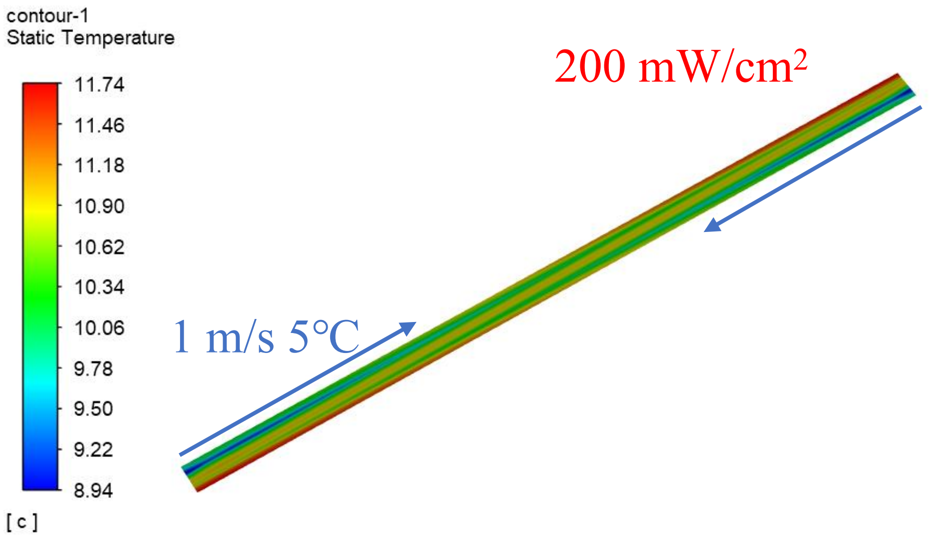
ITK Stave	ITKB1	ITKB2	ITKB3
Stave length [mm]	**987**	1410	1974
Maximum sag [μm]	85	289	896
First natural frequency [Hz]	126	69	34

5.3.4.1.3 Thermal characterisition

- The heat generated by ITK sensors with a magnitude of 200 mW/cm². The cooling design should achieve the following:

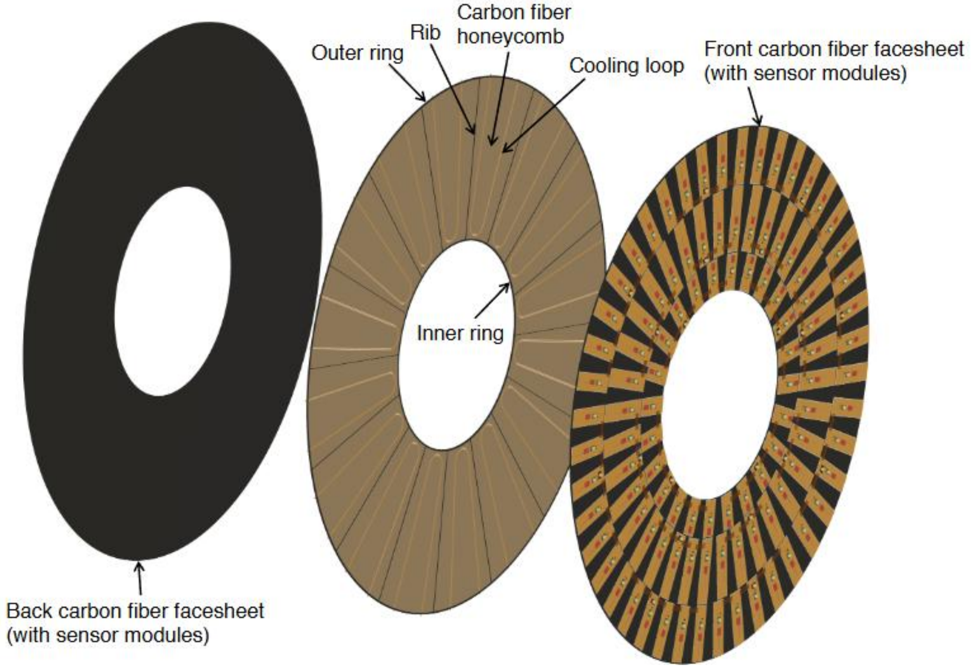
- The overall sensor operating temperature <30°C.
- The temperature uniformity across a single sensor <5°C.





The temperature gradient along the 987 mm length of the stave can be controlled within 5°C. The water cooling meets the detector's requirements.

5.3.4.2 Endcap local support for HV-CMOS pixel detector



- Estimation of ITK HV-CMOS pixel endcap material contributions

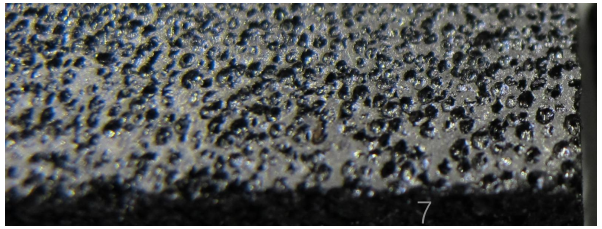
Estimation of ITK HV-CMOS pixel endcap material contributions

Functional unit	Component	Material	Thickness [μm]	X_0 [cm]	Radiation Length [% X_0]
Sensor Module	FPC metal layers	Aluminium	50	8.896	0.056
	FPC Insulating layers	Polyimide	100	28.41	0.035
	Sensor	Silicon	150	9.369	0.160
	Glue		100	44.37	0.023
	Other electronics				0.050
Structure	Carbon fiber facesheet	Carbon fiber	150	26.08	0.057
	Cooling tube wall	Titanium		3.560	XXX
	Cooling fluid	Water		35.76	XXX
	Graphite foam+Honeycomb	Allcomp+Carbon fiber	2000	186	0.108
	Carbon fiber facesheet	Carbon fiber	150	26.08	0.057
	Glue	Cyanate ester resin	200	44.37	0.045
Total					0.591+XXX

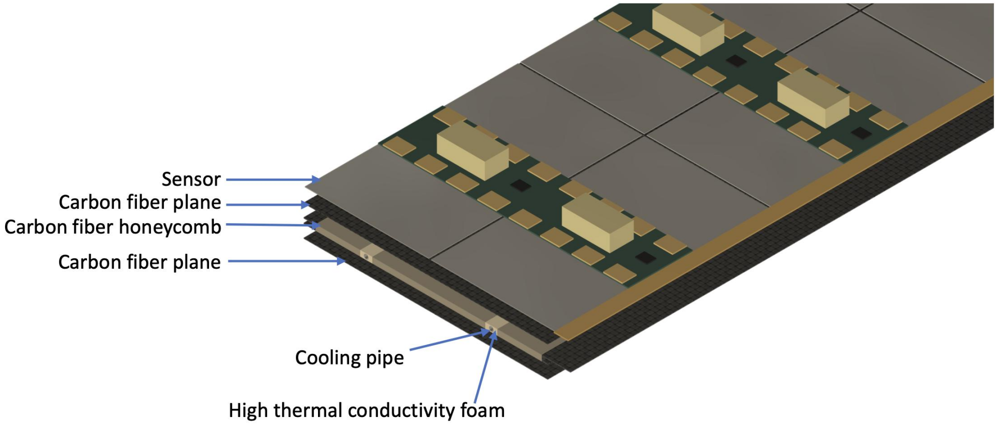
- Additional new materials (the same with OTK) :

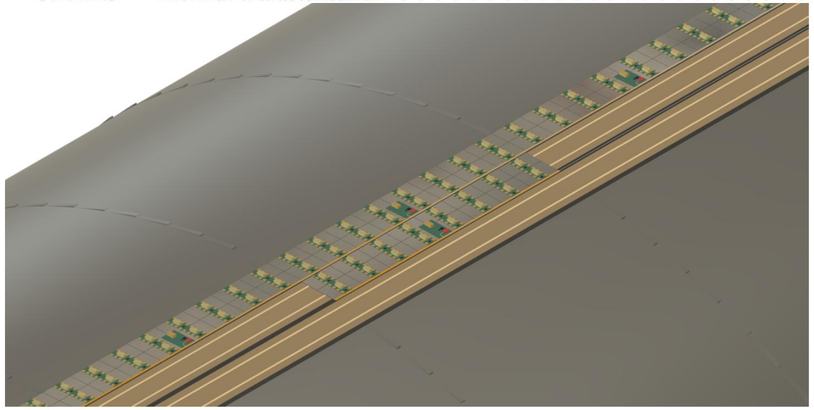
Honeycomb（light weight high strength）

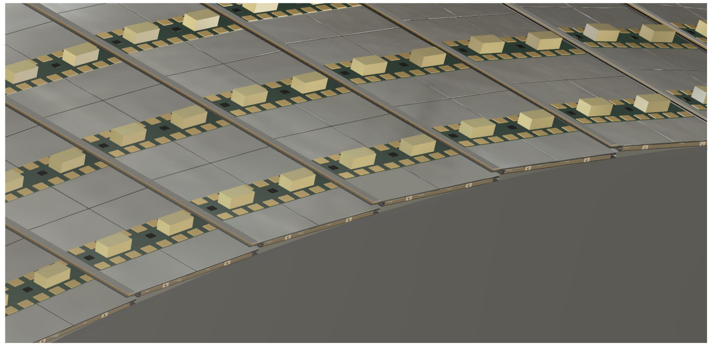
filled with poco foam（Light weight and high thermal conductivity）



5.4.4.1 OTK barrel local support





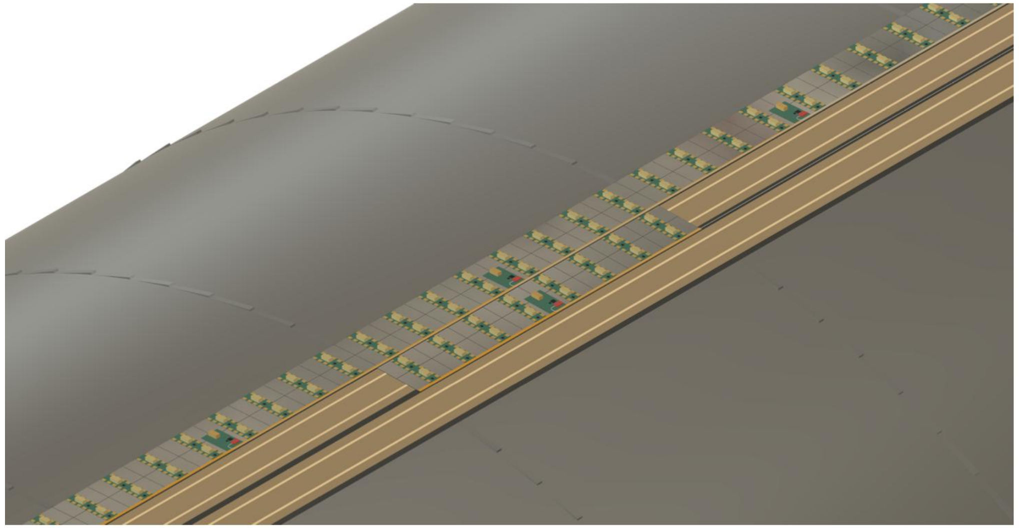


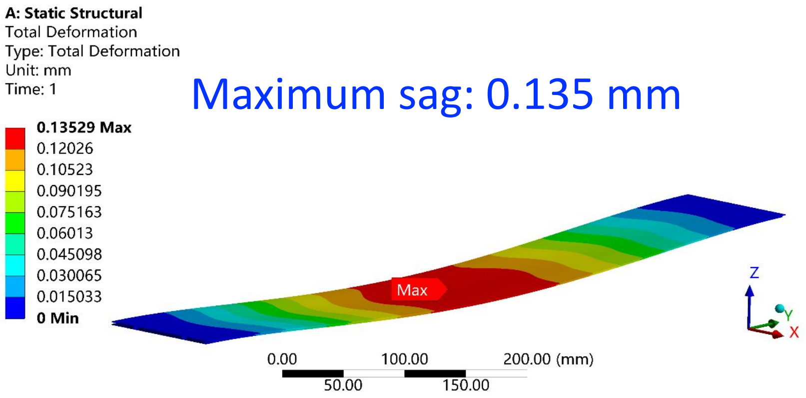
- Estimation of OTK stave material contributions

Estimation of OTK stave material contributions

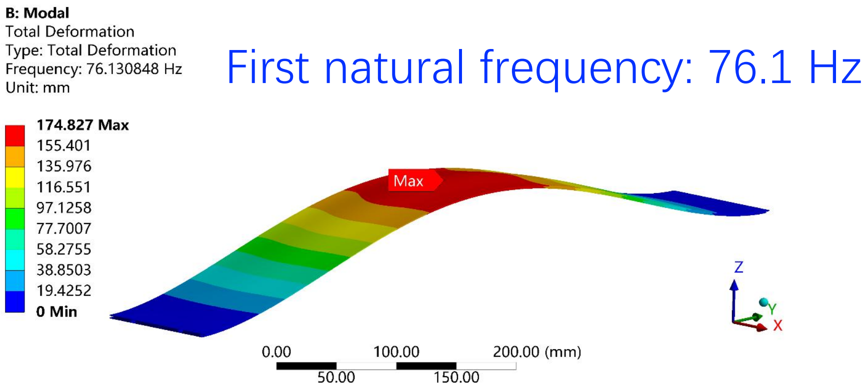
Functional unit	Component	Material	Thickness [μm]	X_0 [cm]	Radiation Length [% X_0]
Sensor Module	PCB metal layers	Cu		1.436	0.200
	PCB Insulating layers	Polyimide		28.41	0.070
	Sensor	Silicon	300	9.369	0.320
	Glue		100	44.37	0.023
	Other electronics				0.100
Structure	Carbon fiber facesheet	Carbon fiber	300	26.08	0.115
	Cooling tube wall	Titanium		3.560	0.169
	Cooling fluid	Water		35.76	0.105
	Graphite foam+Honeycomb	Allcomp+Carbon fiber	6000	186	0.322
	Carbon fiber facesheet	Carbon fiber	300	26.08	0.115
	Glue	Cyanate ester resin	200	44.37	0.045
Total					1.584

5.4.1.1.2 Structural characterisition



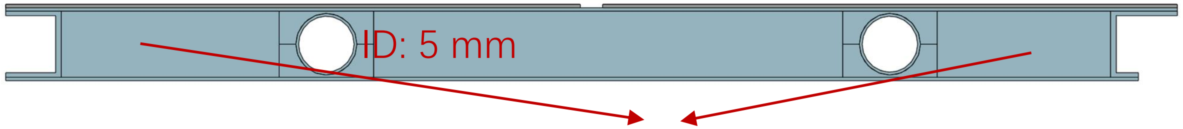


OTK stave deformation（719.6mm）

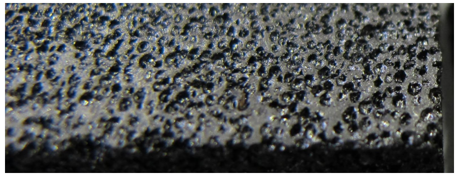


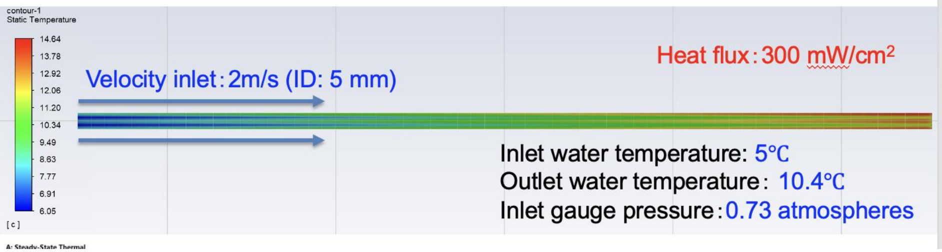
First order mode and first natural frequency（719.6mm）

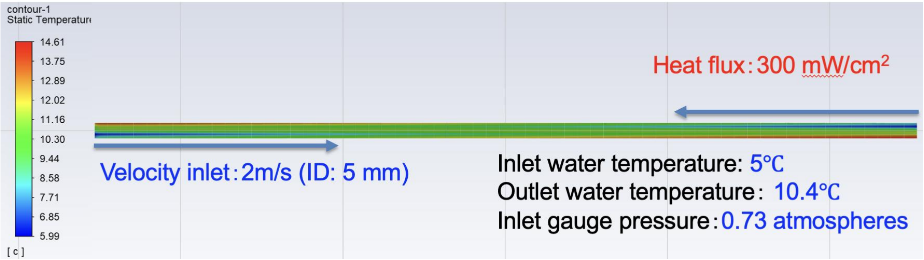
5.4.4.1.3 Thermal characterisition



Honeycomb filled with poco foam to increase thermal conductivity





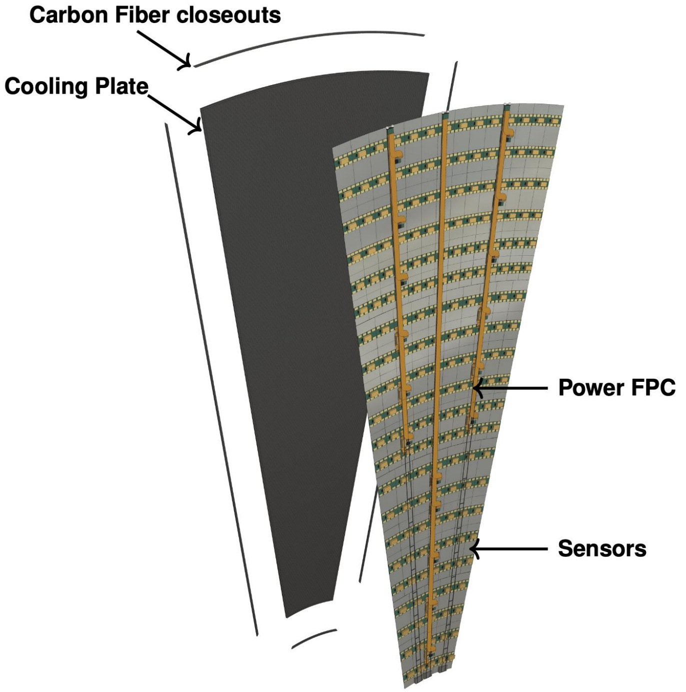


Using a 5 ℃ and 2 m/s water inlet (ID: 5 mm), the maximum temperature difference across one sensor is <2.9 ℃ for inlet from one end and <4 ℃ for inlet from two ends.

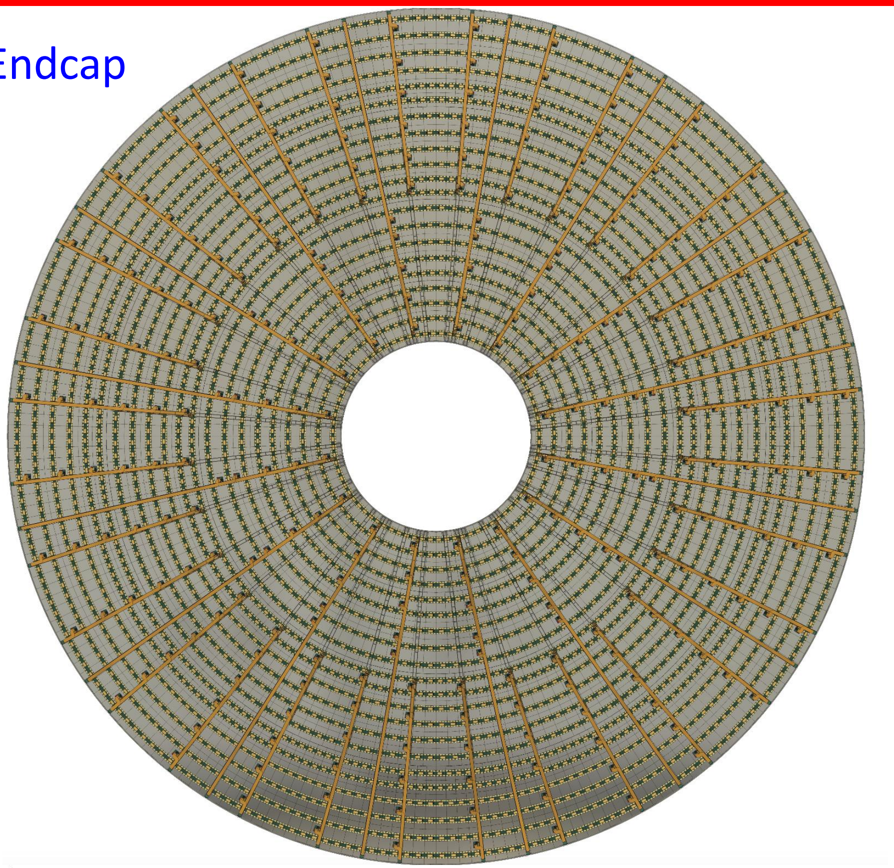
Water cooling can meet the thermal requirements for the OTK over ~6 m stave length.

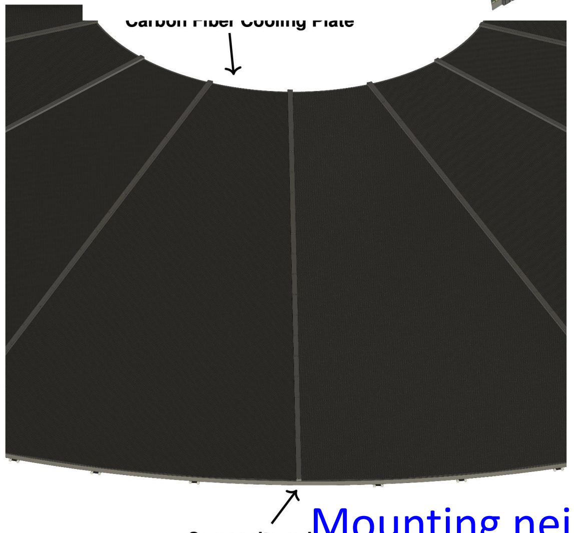
5.4.4.2.2 Structural characterisition

OTK endcap 1/16 sector

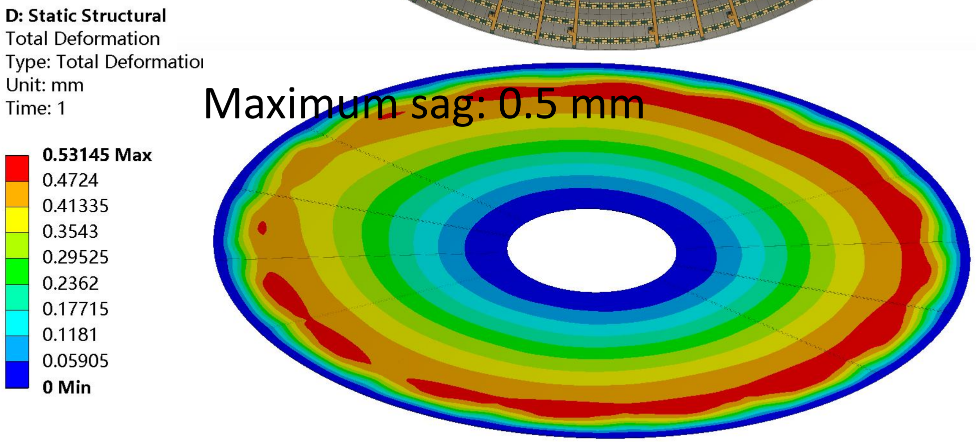


OTK Endcap



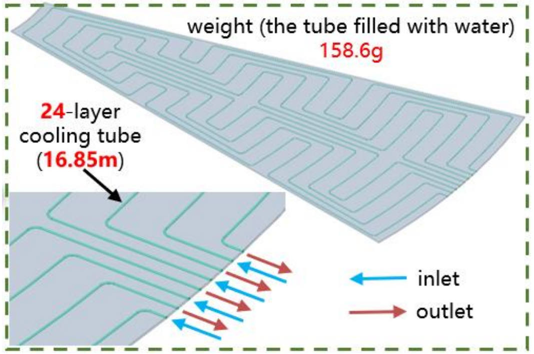


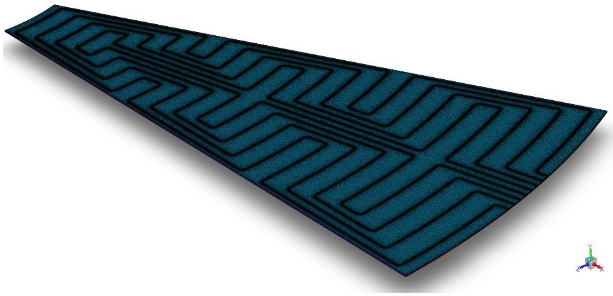
Mounting neighboring 1/16 sectors

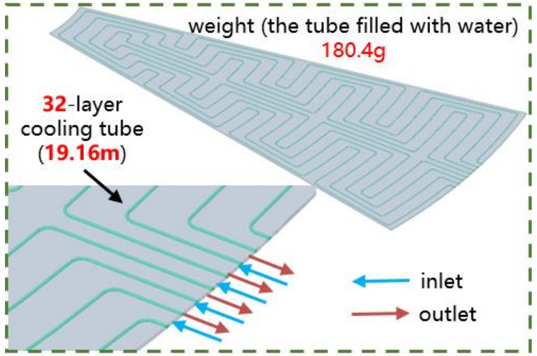


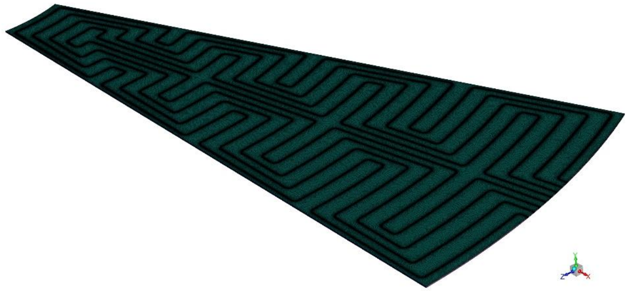
Maximum sag: 0.5 mm

5.4.4.2.3 Thermal characterisition







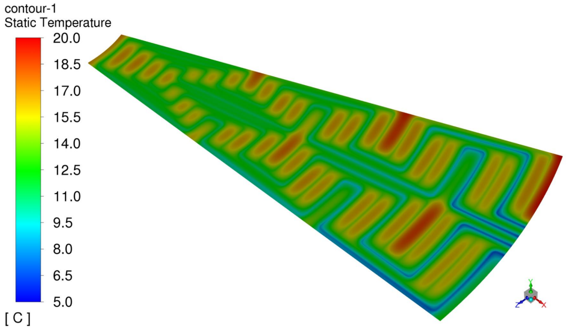


- ✓ The mesh generation is performed for two different cooling tube arrangements, and numerical solutions are obtained using the finite volume method.
- ✓ The cooling performance of both arrangements is analyzed and compared.

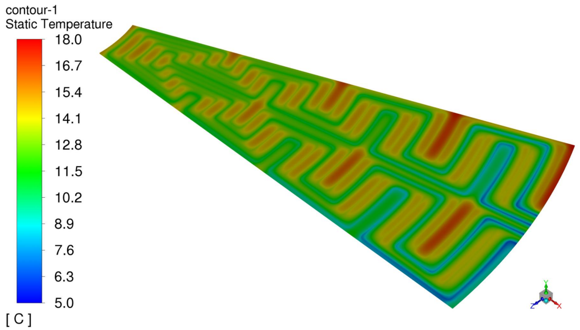
- Cooling tube diameter: 2.6 mm
- Water inlet velocity: 2.5m/s

Continuous optimization is ongoing!

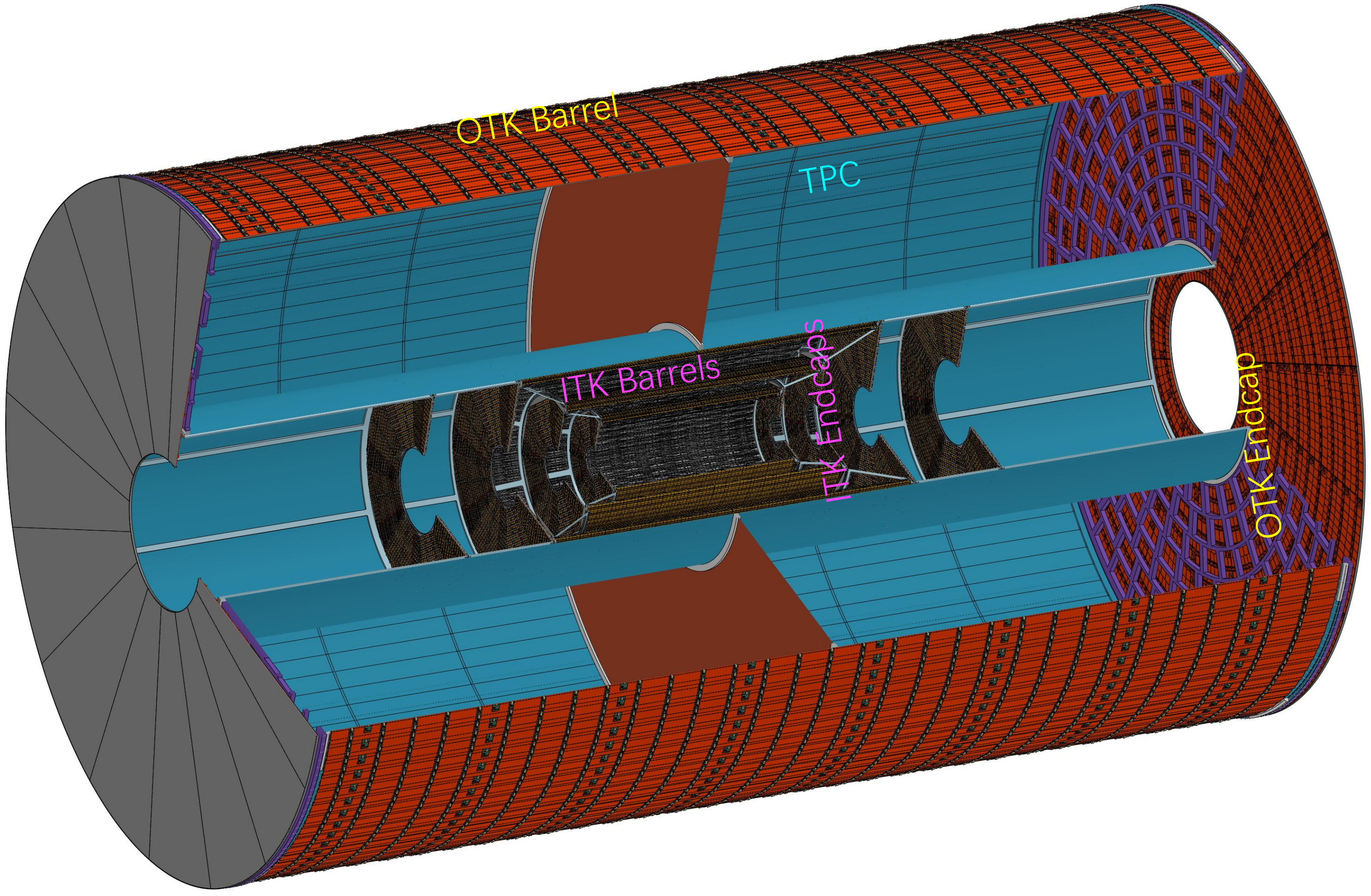
Xuehong Wu, Yong Liu, … (郑州轻工业大学)



24-layer cooling tube



32-layer cooling tube


OTK Barrel
TPC
ITK Barrels
ITK Endcaps
OTK Endcap

Thank you！