

ITK进展汇报

钱小辉
20260623

4th DRD8 collaboration meeting

线上报告: Triangular carbon fiber beam for CEPC-ITK

- 变形问题: 加载曲线和卸载曲线不重合, 蠕变问题, 有人认为是裂开了细小裂纹
- 平面度问题: 芯片要求平面度高, 我们有没有测过平面度

Eric Anderssen: Lawrence Berkeley National Laboratory (LBNL), Berkeley, CA, USA

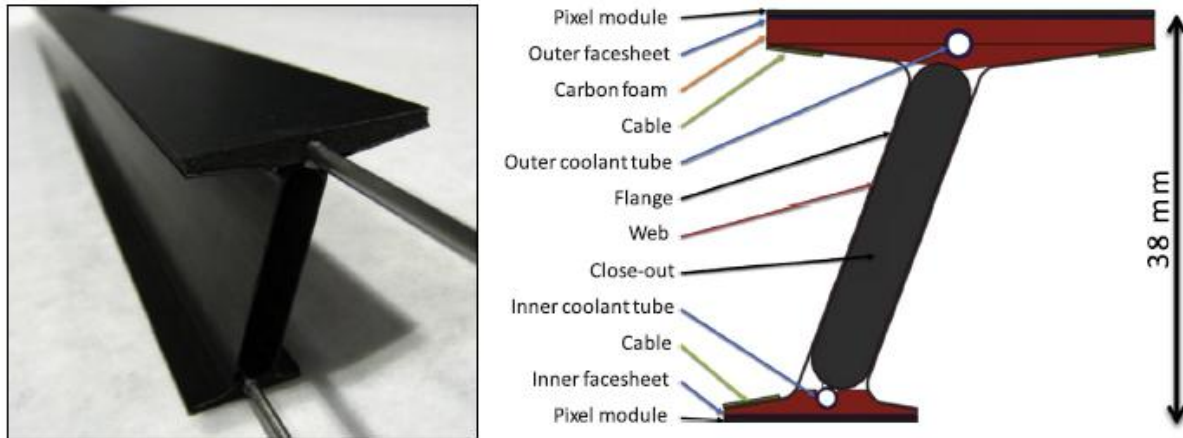


Fig. 1. 1 m long I-beam mechanical prototype (left) and cross-sectional structural layout (right).

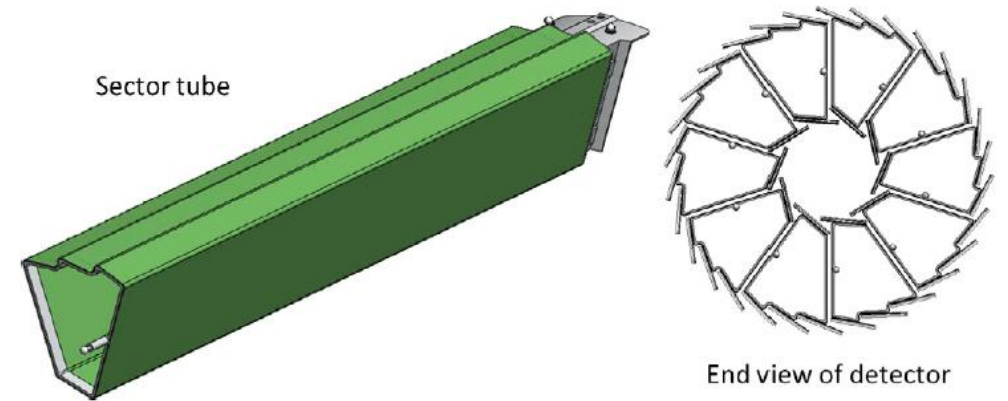


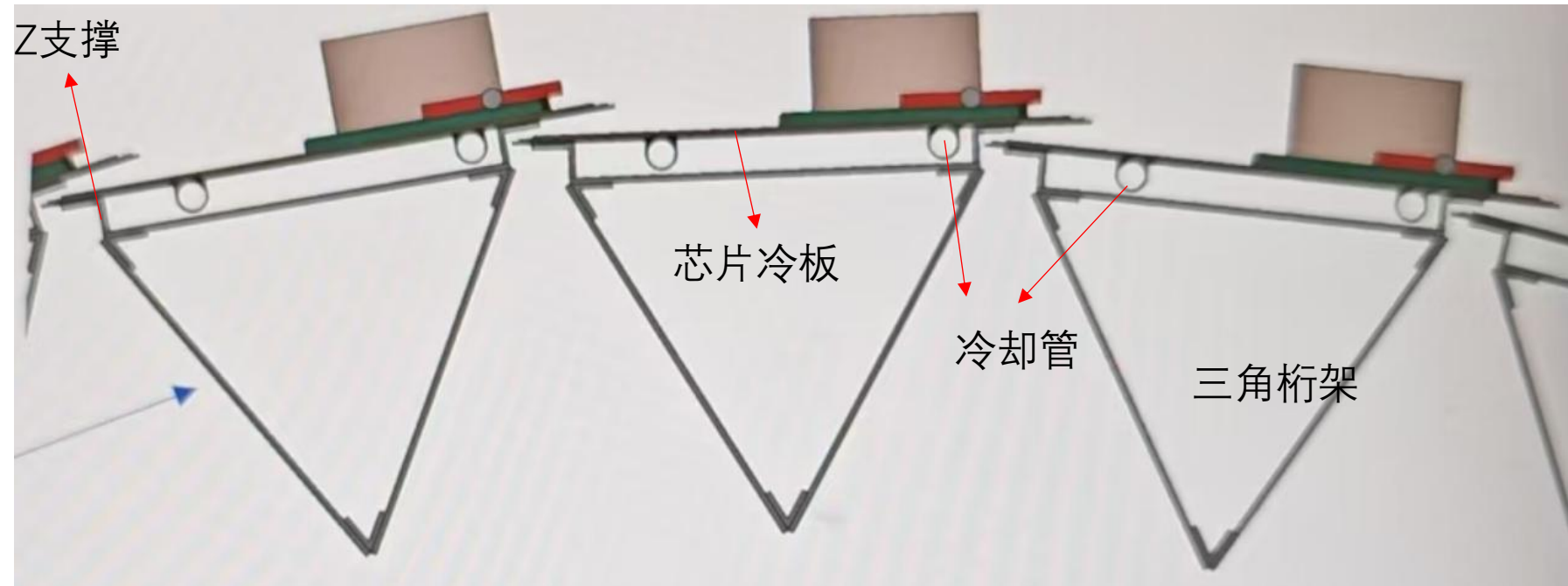
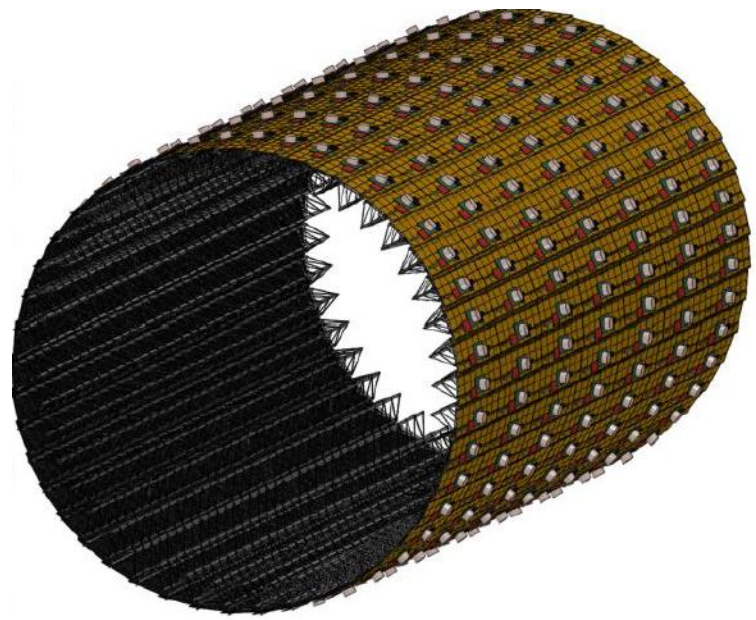
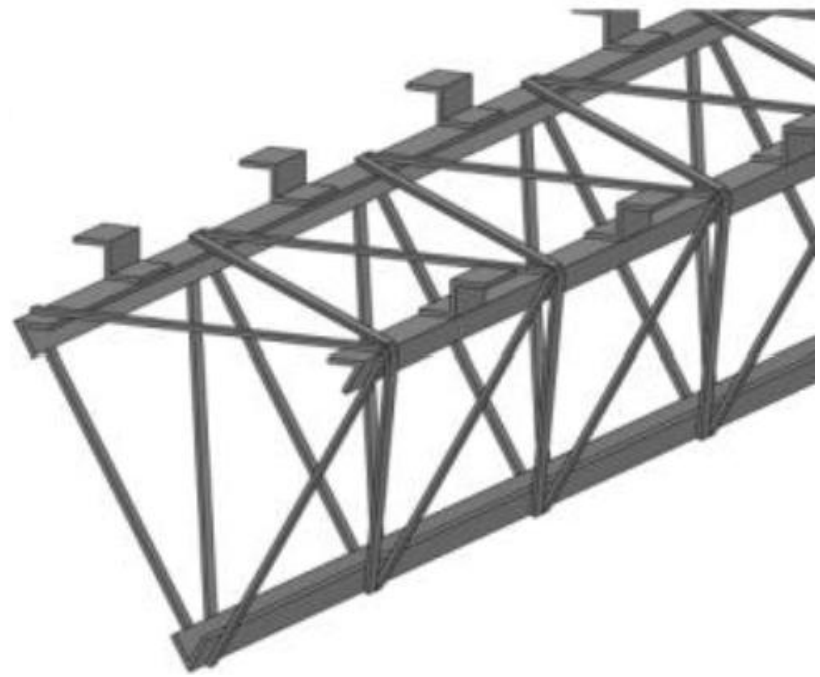
Fig. 2. Sector tube shape and end view of the detector showing the ladder positions on the sector.

Novel fabrication techniques for low-mass composite structures in silicon particle detectors

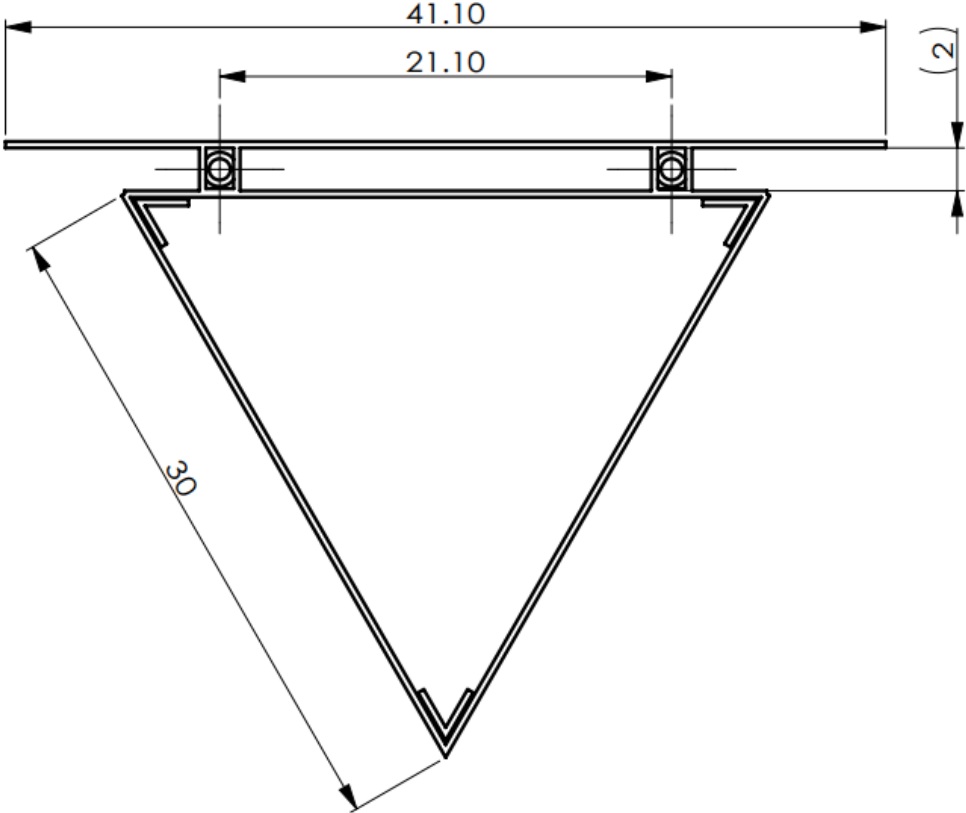
The STAR MAPS-based PiXeL detector

TDR桁架结构

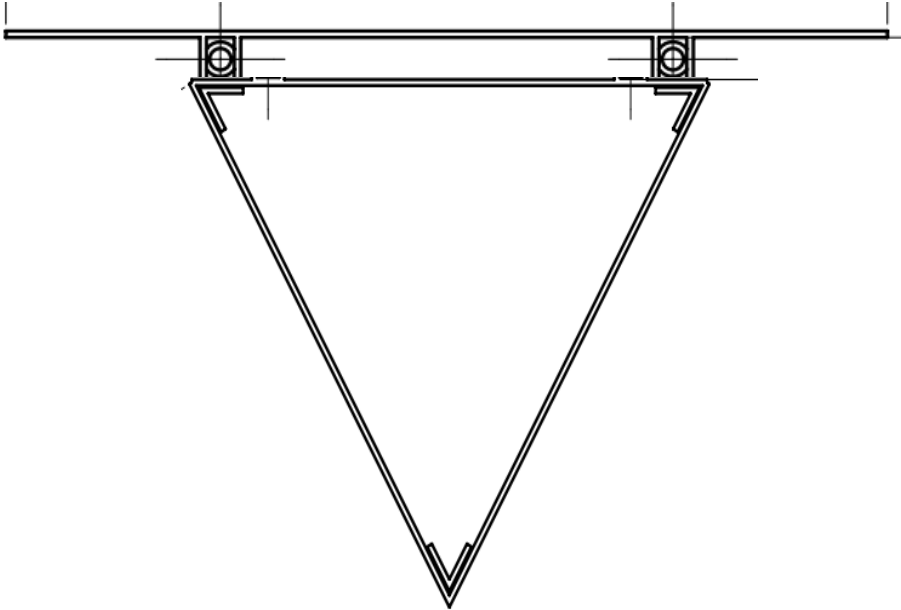
- 冷板采用Z支撑,
- 刚度弱, 变形比较大



实验桁架结构

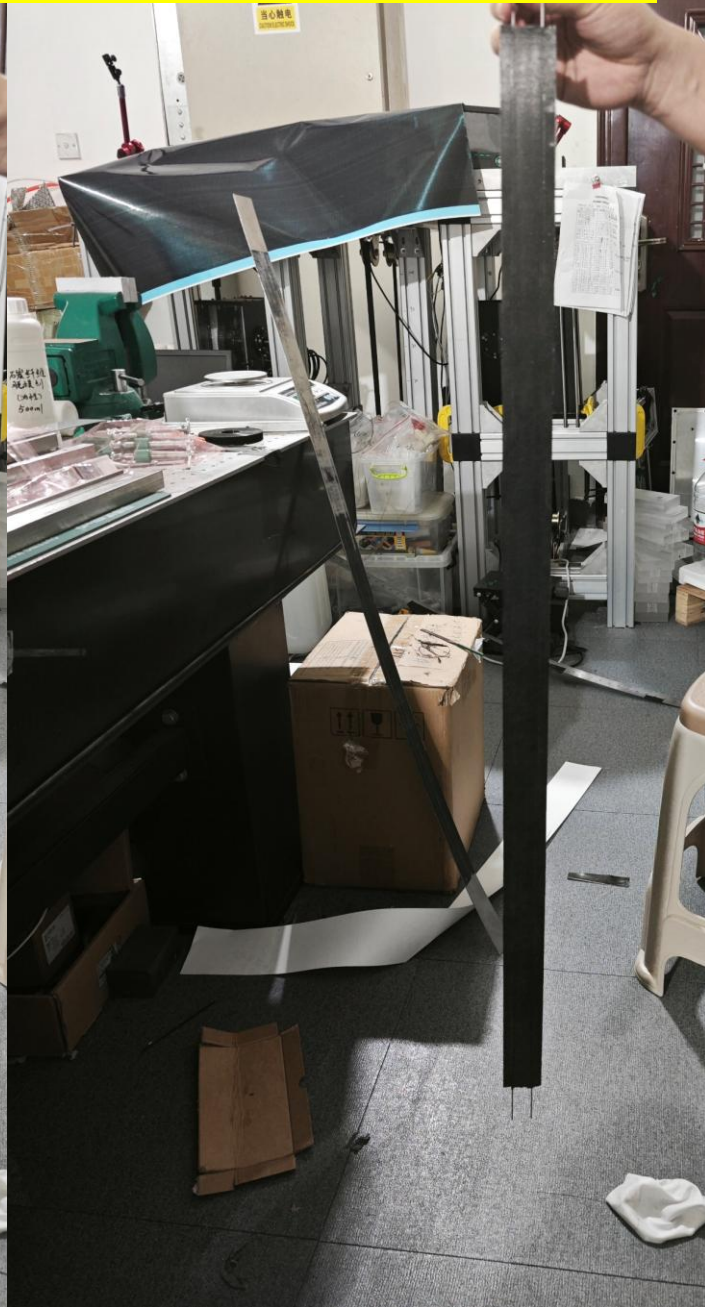


现在结构



未来结构?

First cold plate
Bended for the thermal coefficient difference between materials

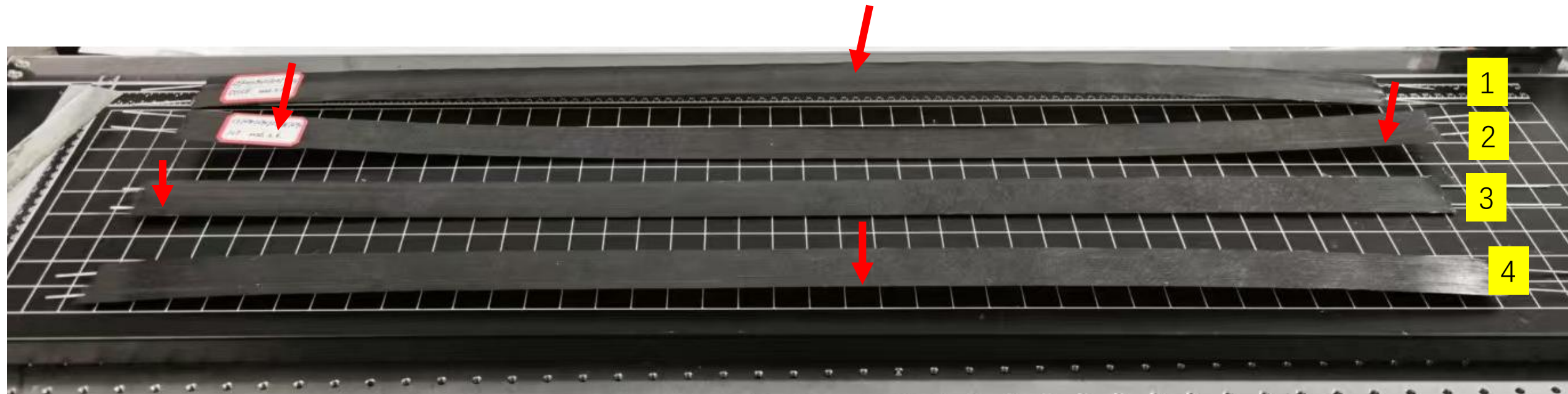


Cold plate manufacturing test of different direction

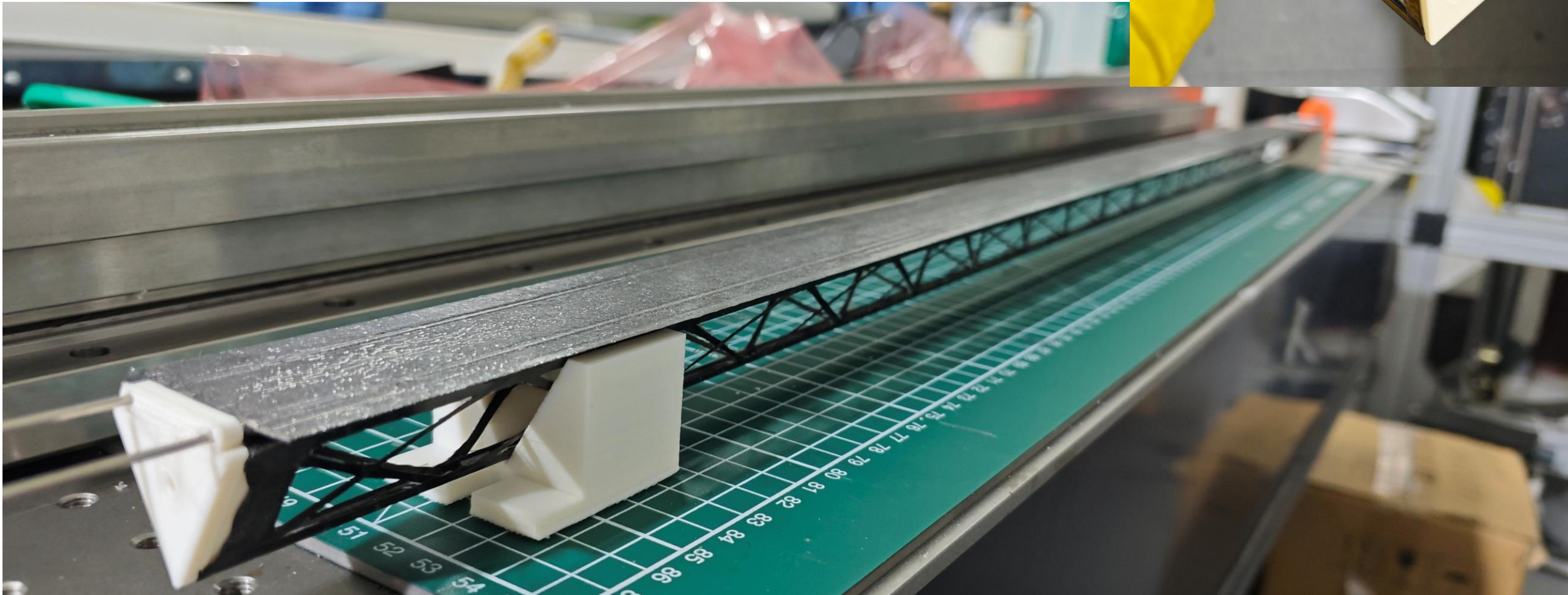
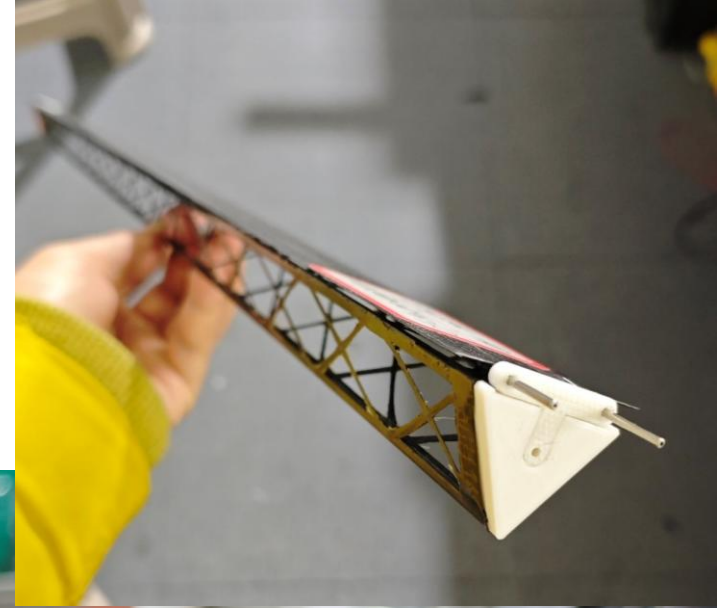
□ Optimizing Layer to reduce the bending deformation of cold plate

1. Carbon fiber direction: 0/0/90/0,
2. Carbon fiber direction: 90/90/90/90, without Graphene film
3. Carbon fiber direction: 0/90/90/90, without Graphene film
4. Carbon fiber direction: 90/90/0/90, without Graphene film

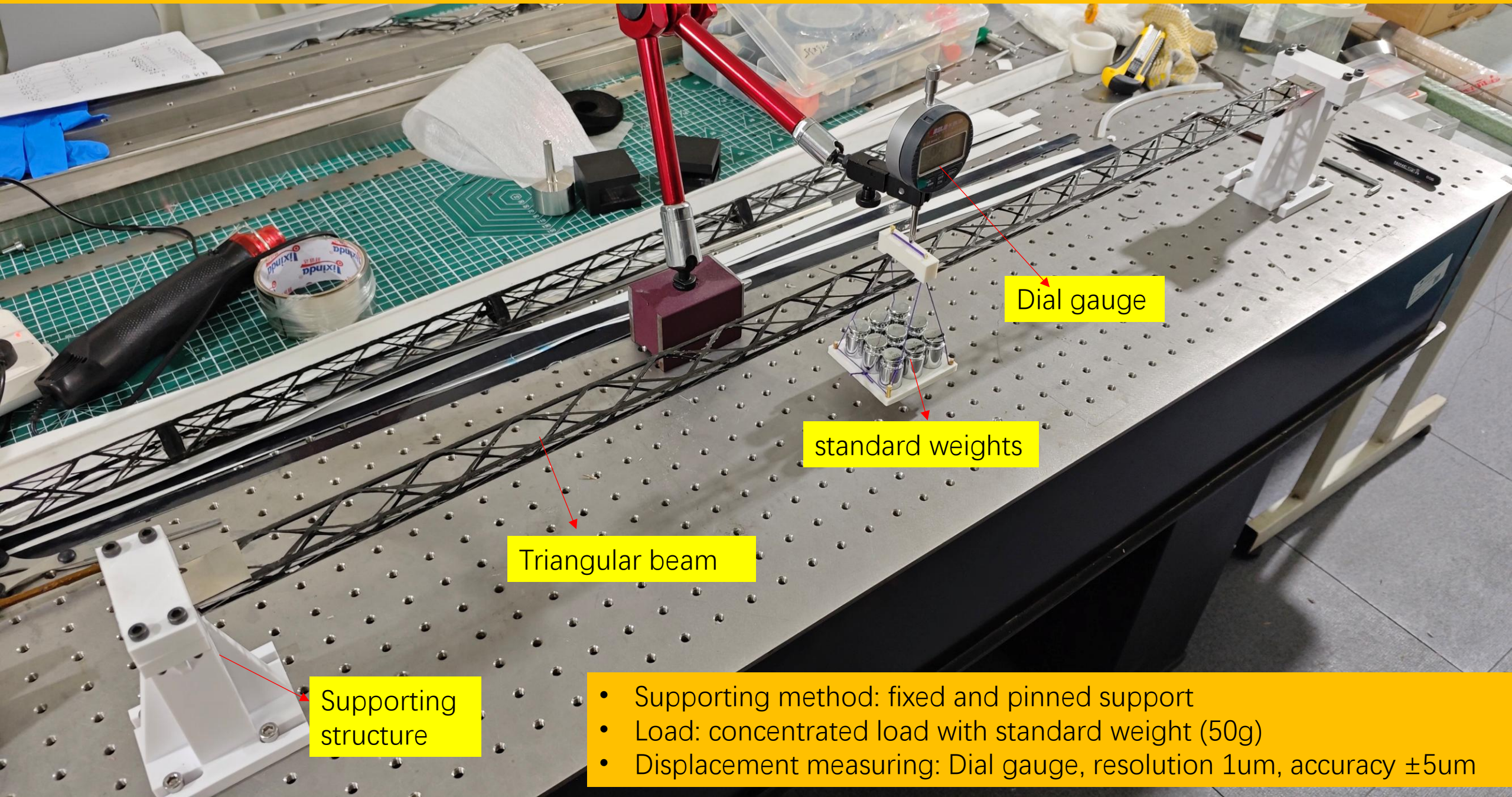
□ Good quality of the thickness consistency: $0.28 \pm 0.02 \text{mm}$



Assembly of cold plate and triangular beam



Static mechanical test of triangular beam



Dial gauge

standard weights

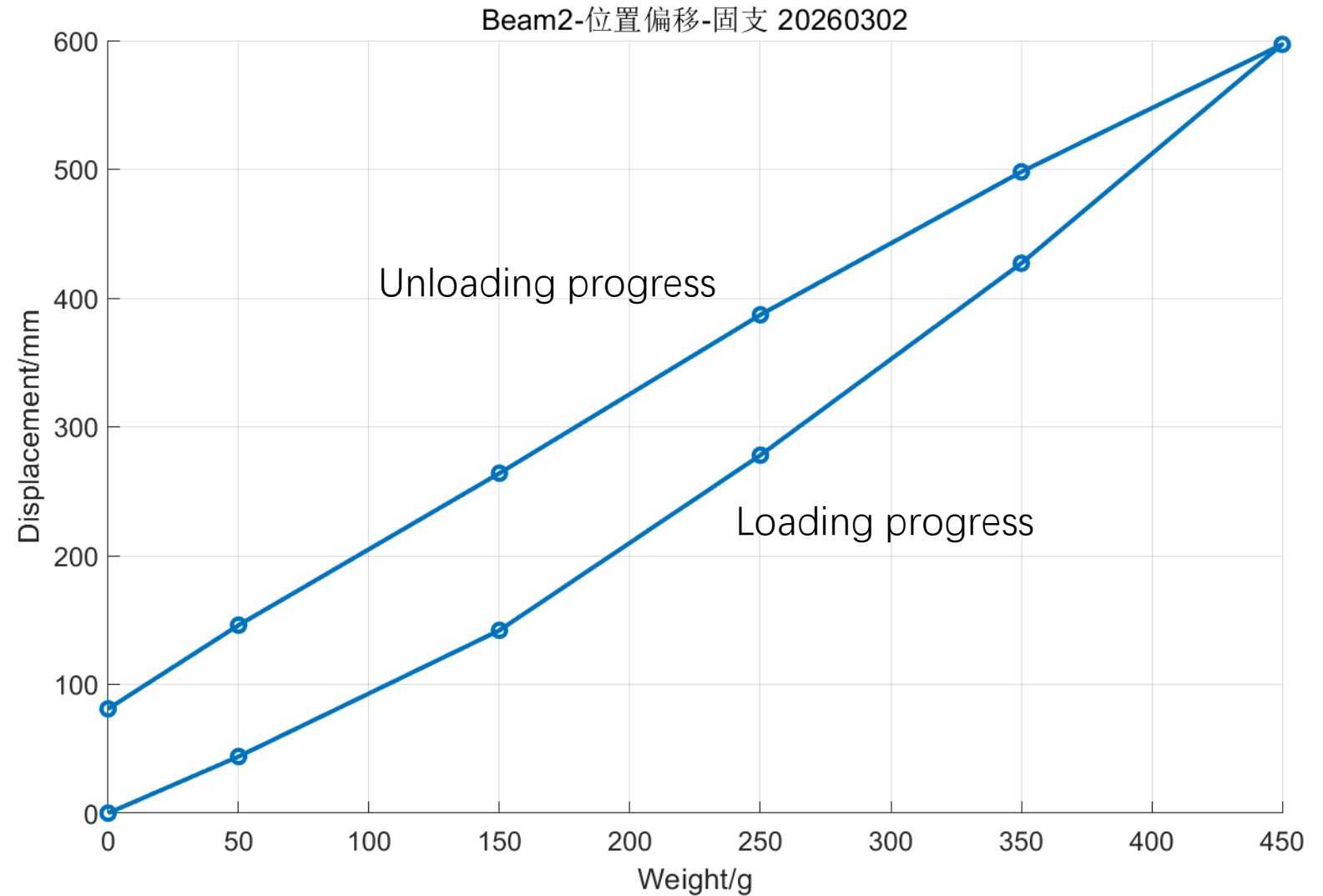
Triangular beam

Supporting structure

- Supporting method: fixed and pinned support
- Load: concentrated load with standard weight (50g)
- Displacement measuring: Dial gauge, resolution 1 μ m, accuracy $\pm 5\mu$ m

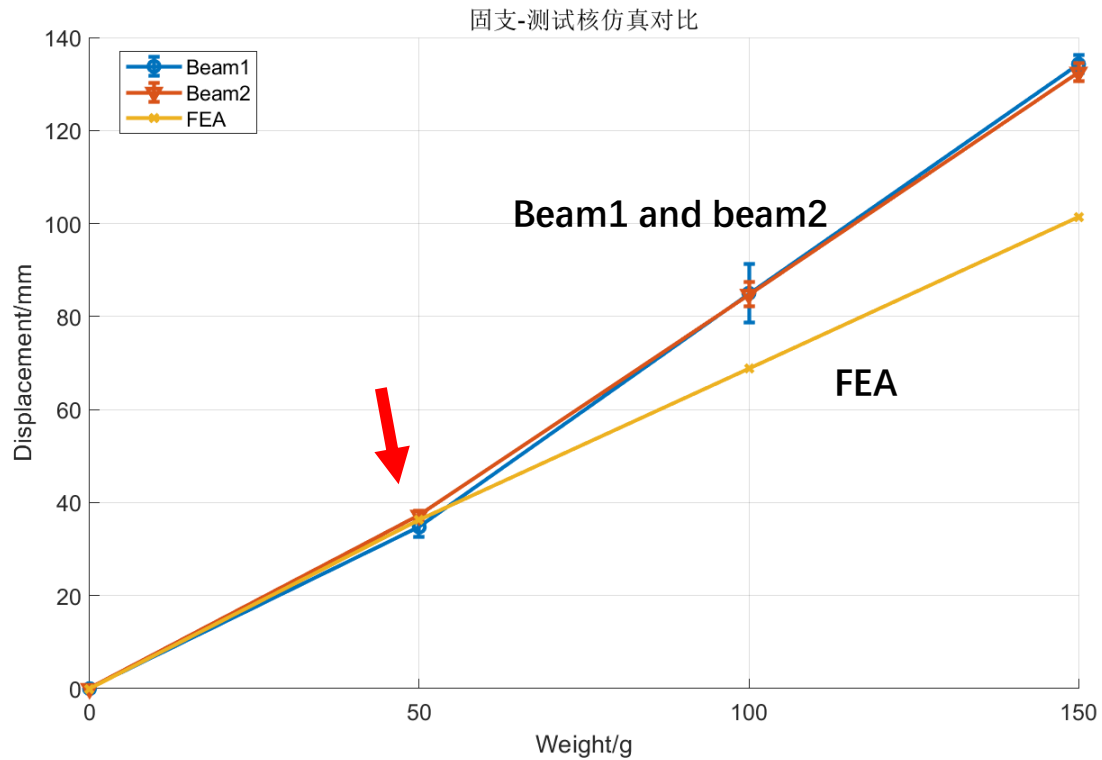
Beam-fixed supporting

- Load: 0~450g
- Loading and unloading curves are not matched together
- Displacement is not linear with the load increasing
- Creeping is obvious under high load

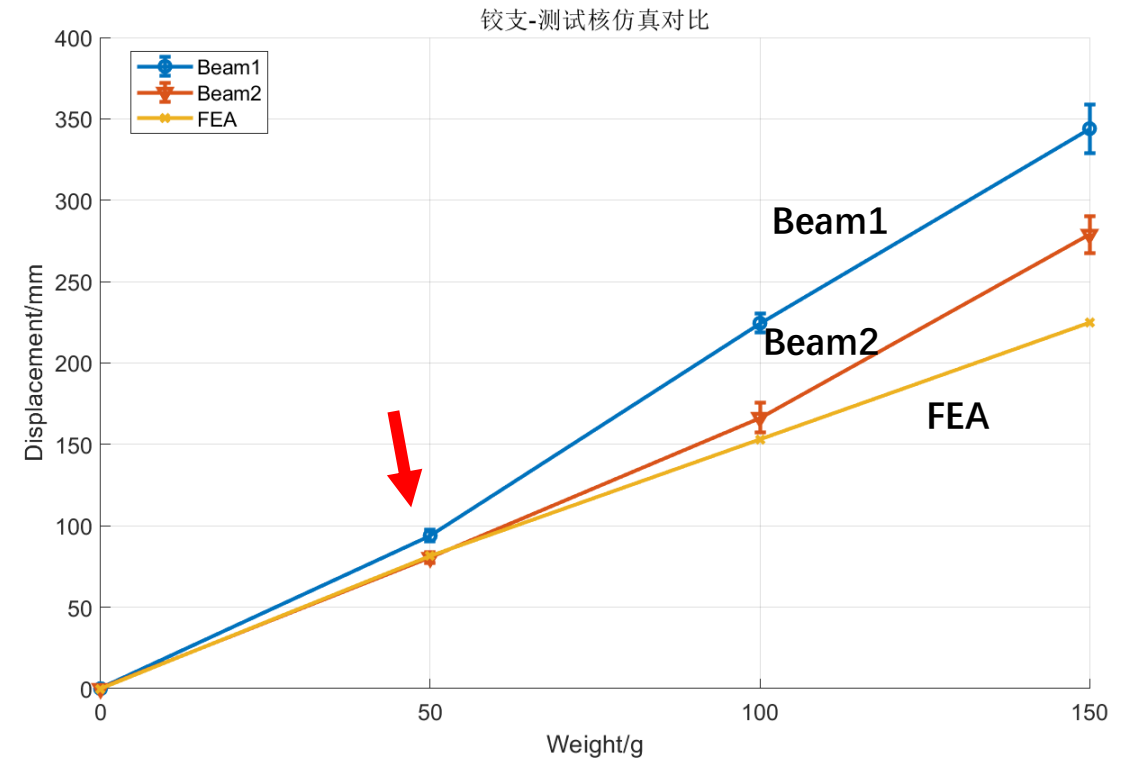


Compare between FEA of test result

- Under 50g load, the result can be matched very well between FEA and test results.
- The two beams deformation almost the same under the fixed boundary condition
- Under pinned boundary condition, Beam1(weight 13.9g) deformation is larger than beam2'(weight 15.1g)



Comparison under fixed boundary condition



Comparison under pinned boundary condition

未来计划

- 测三角桁架蠕变特性
- 测冷板和桁架组装后的平面度：0.1mm~0.3mm（百微米）
 - 难以确定模具影响
- 400mm长度碳纤维三角桁架：制作了二个三角桁架用于冷却研究（加速器常正泽）

- 准备做500mm长度冷板，采购钛管（壁厚0.2mm）



ITK支撑架设计

- 问题:
- ✓ ITK需要外延~1.4m固定在TPC端面板上, 变形大、增加支撑质量
- ✓ 切利科夫探测器安装干涉
- 改进: 固定在TPC内筒上

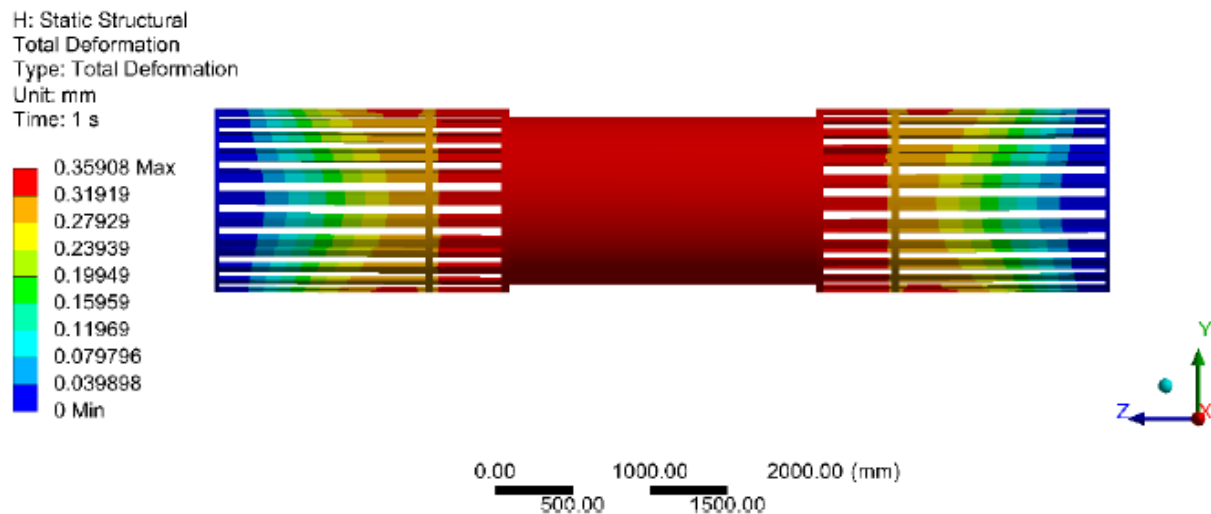
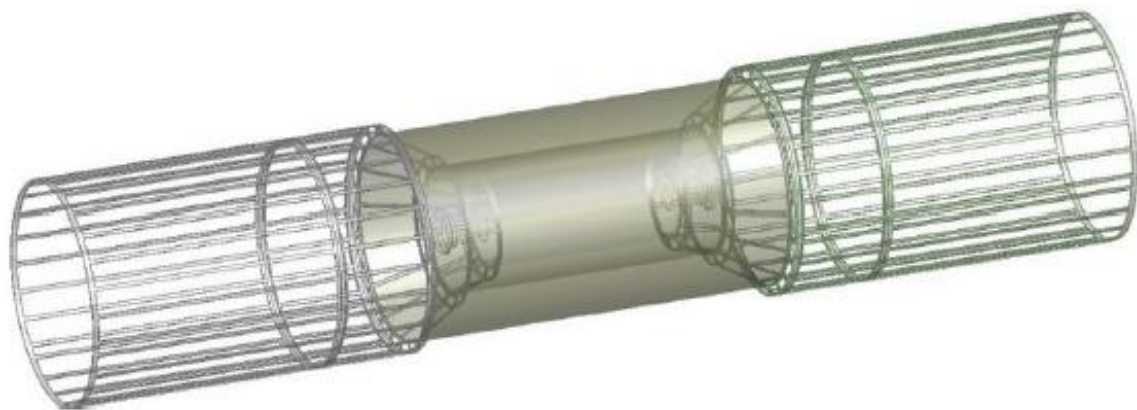


图 3.25 ITK 连接架两端固支变形仿真结果

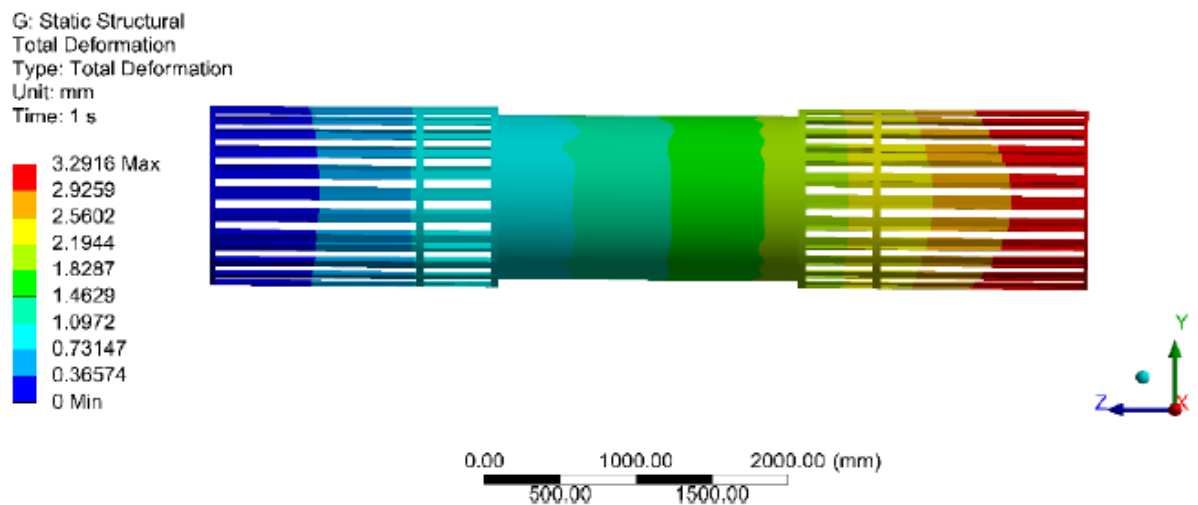
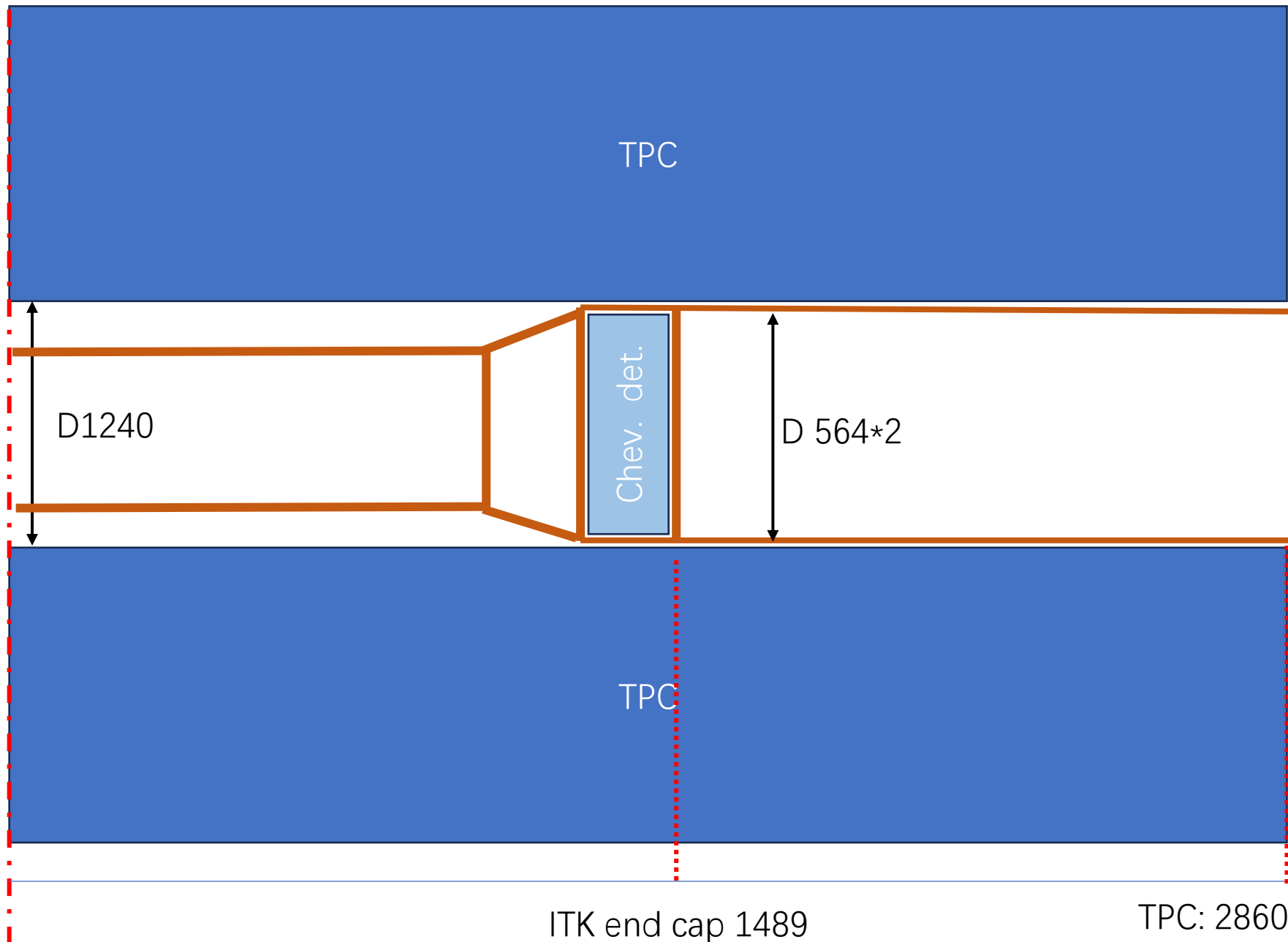


图 3.26 ITK 连接架一端固支变形仿真结果

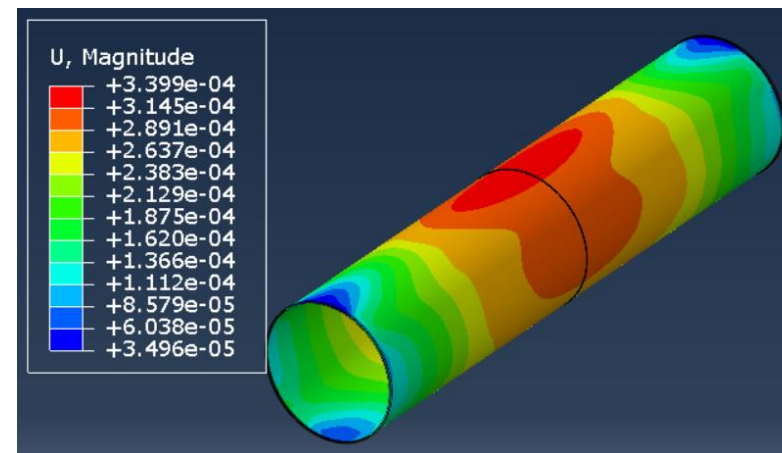
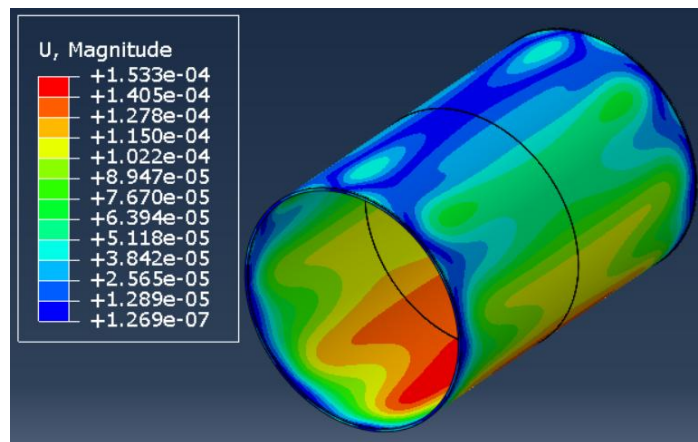
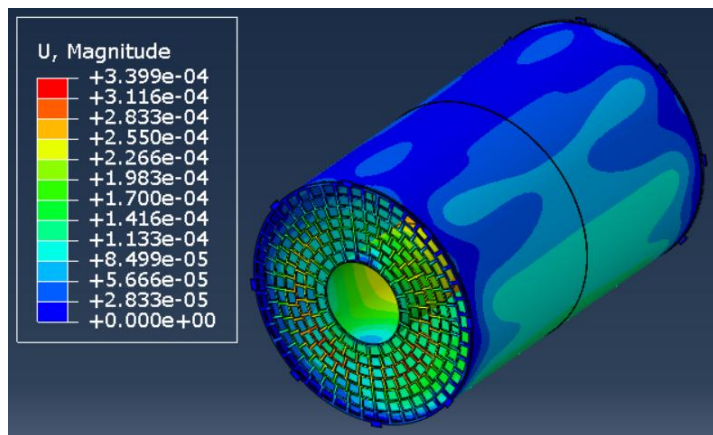
未考虑切利科夫探测器荷载

TPC内筒其他探测器荷载

- 总荷载
 - ITK:80kg
 - Vertex+beam pipe:10kg
 - Che: 30kg*2
- 单边荷载:
 - $(80+10)/2+30=75\text{kg}$
 - 按照单边85kg进行计算

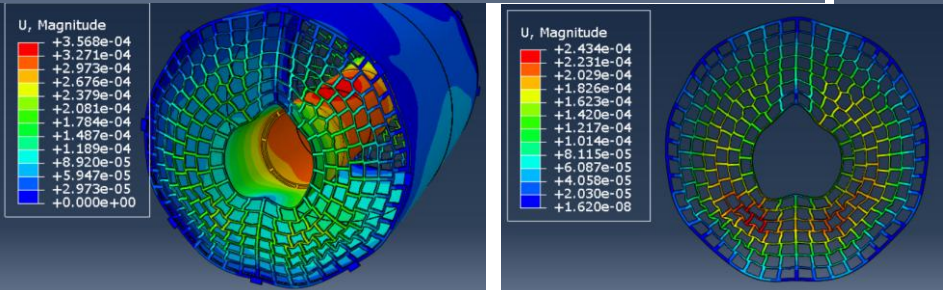
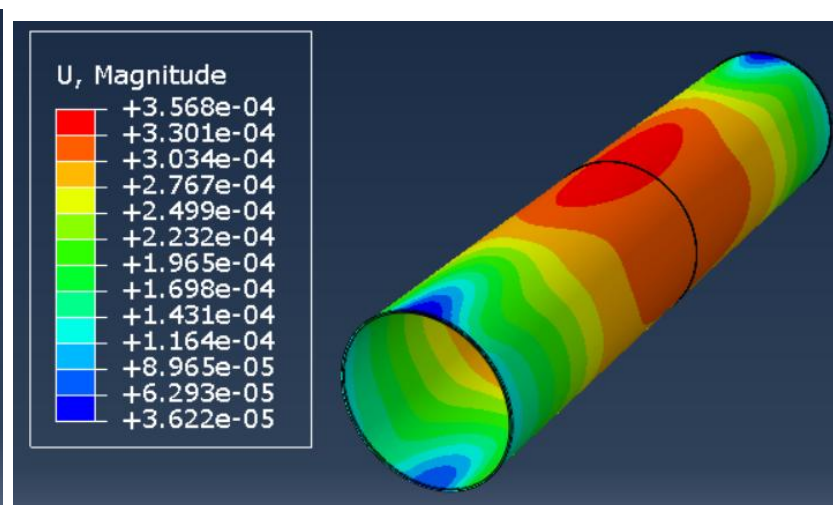
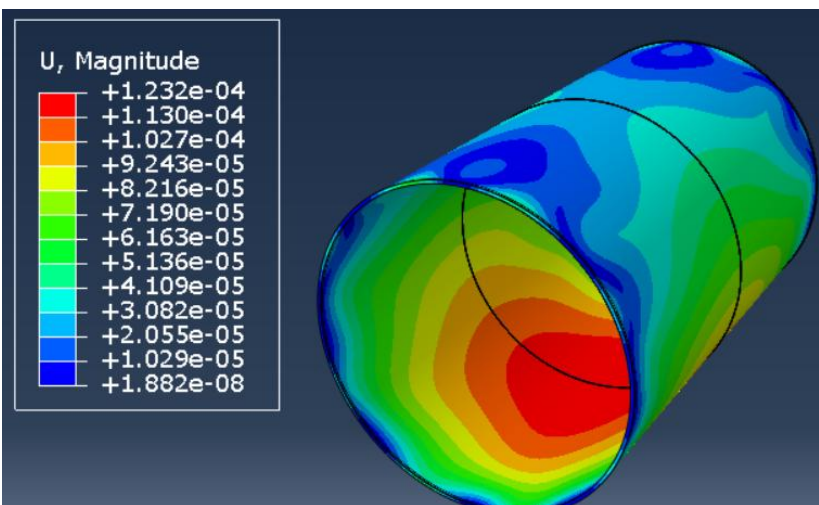
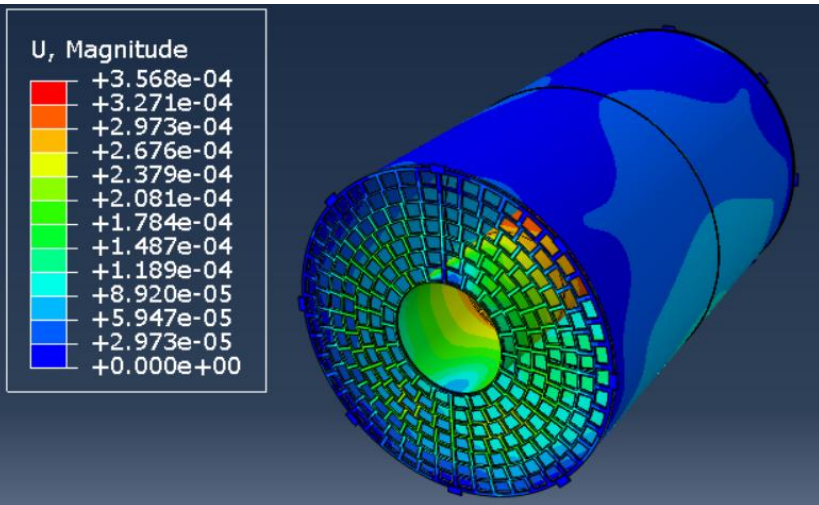


内筒厚度3mm(桶和端板绑定约束)



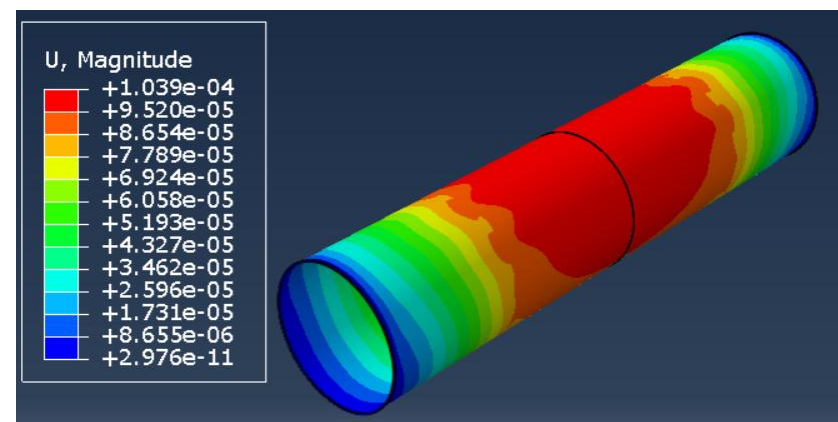
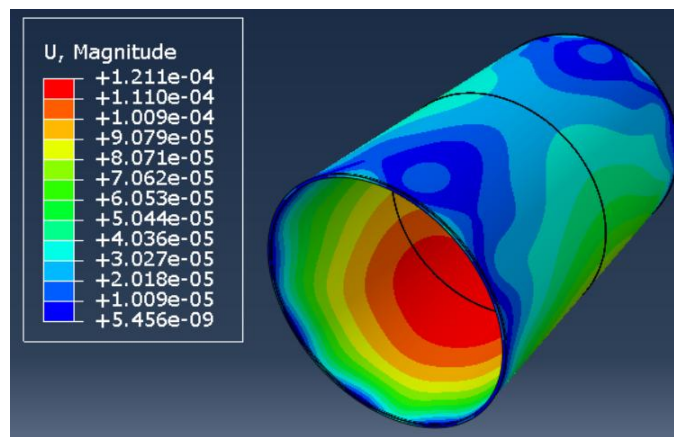
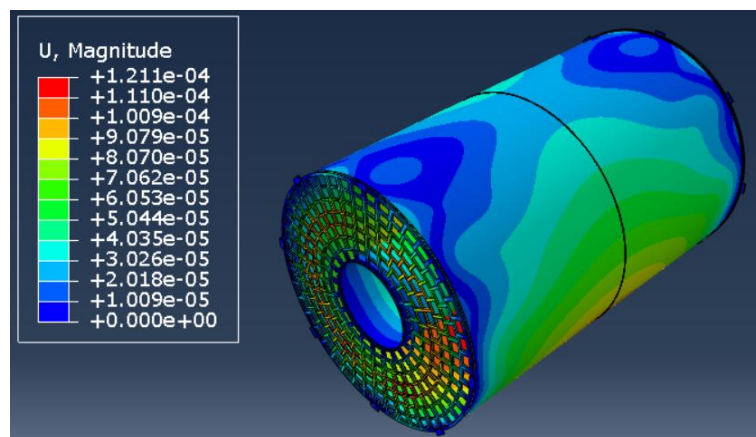
外筒固定：内筒变形0.34mm

内筒厚度6mm(桶和端板绑定约束)



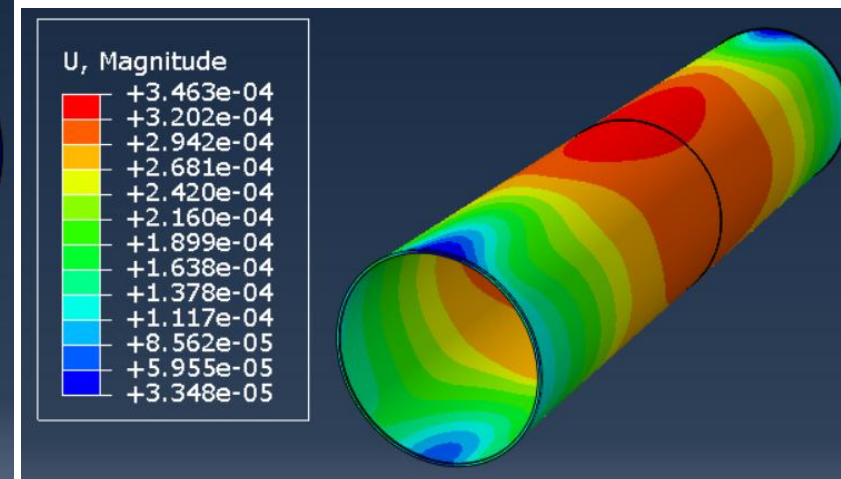
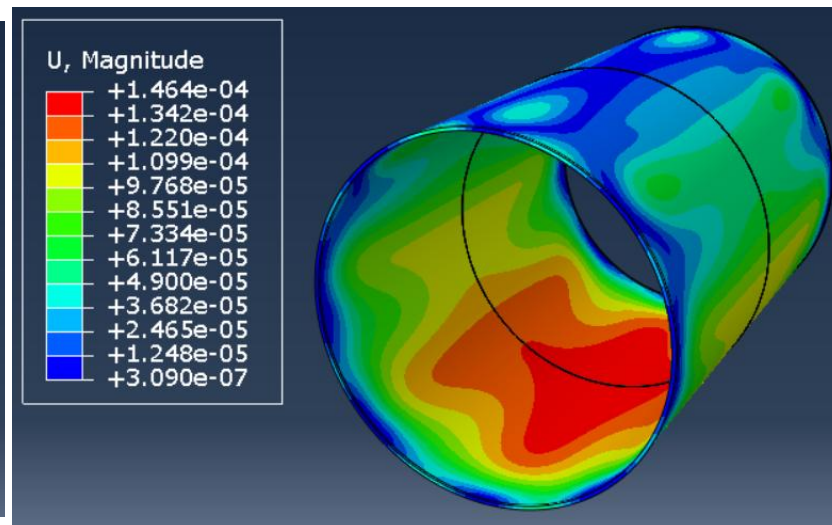
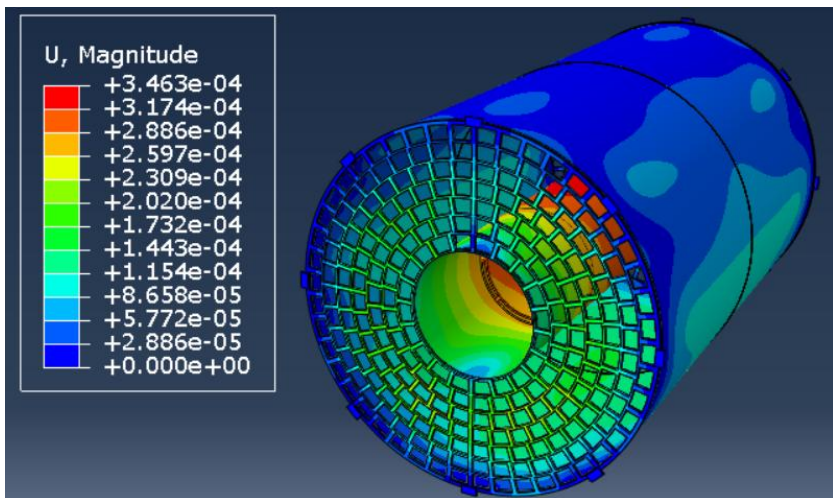
外筒固定：内筒变形0.36mm

内外筒固定：内筒变形0.10mm

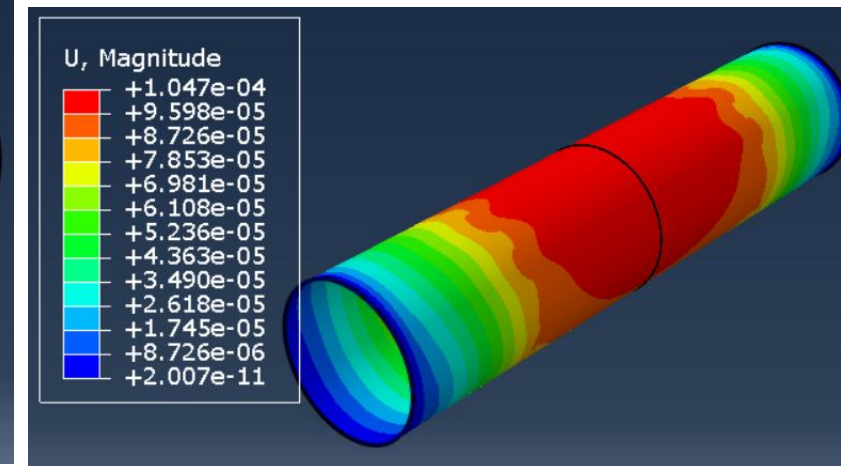
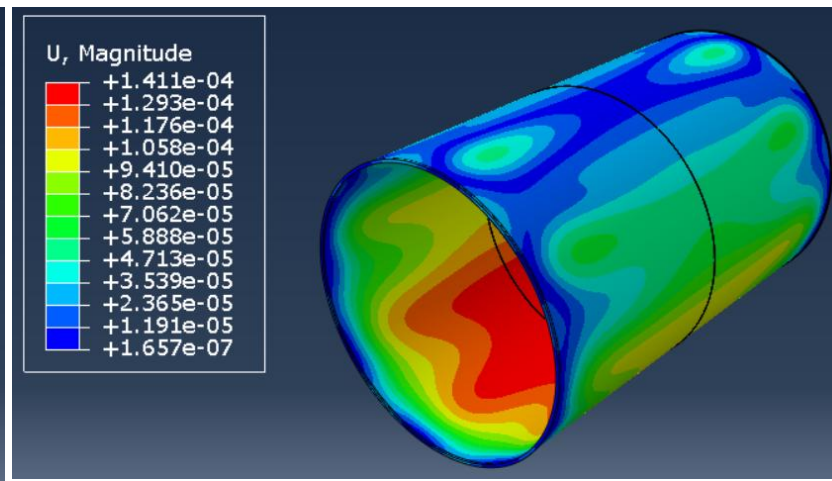
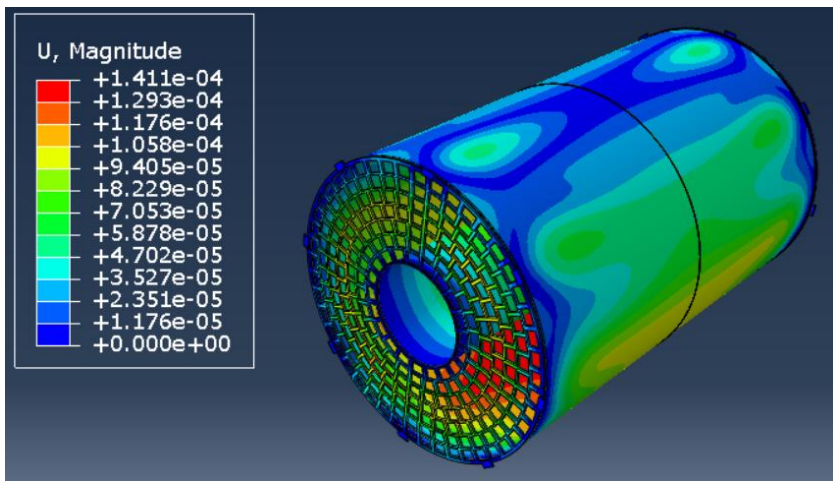


内筒厚度10mm (桶和端板绑定约束)

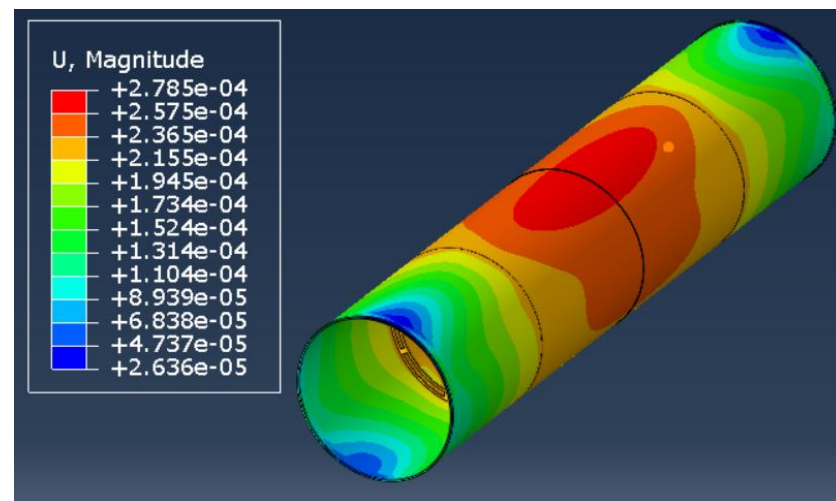
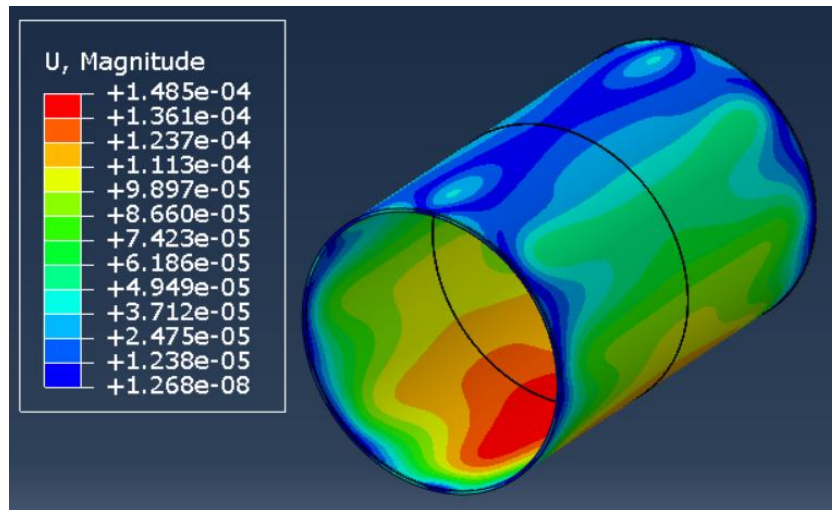
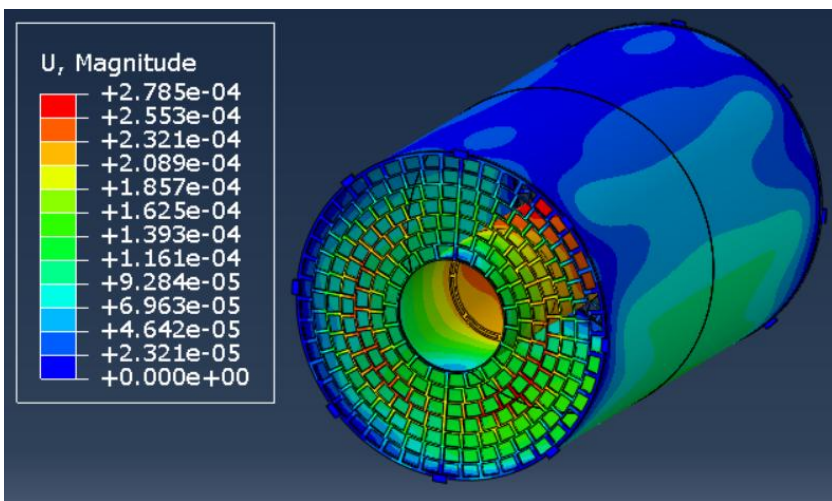
外筒固定：内筒变形0.35mm



内外筒固定：内筒变形0.10mm

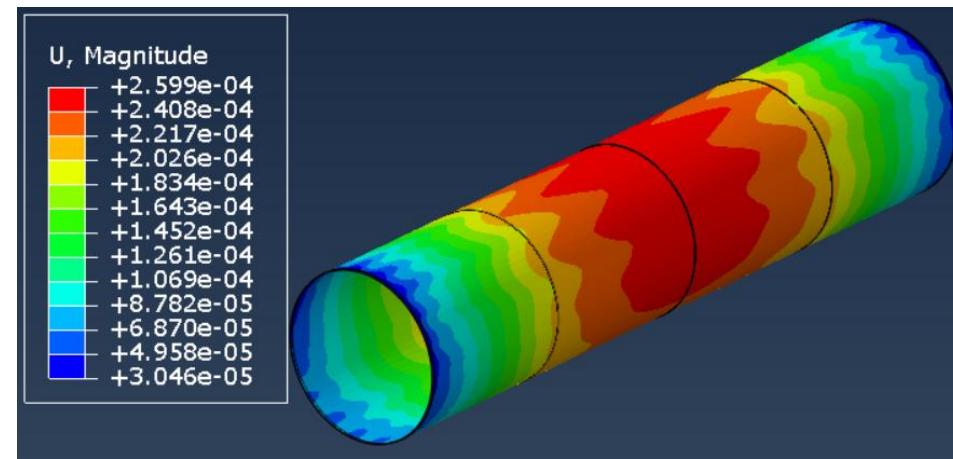
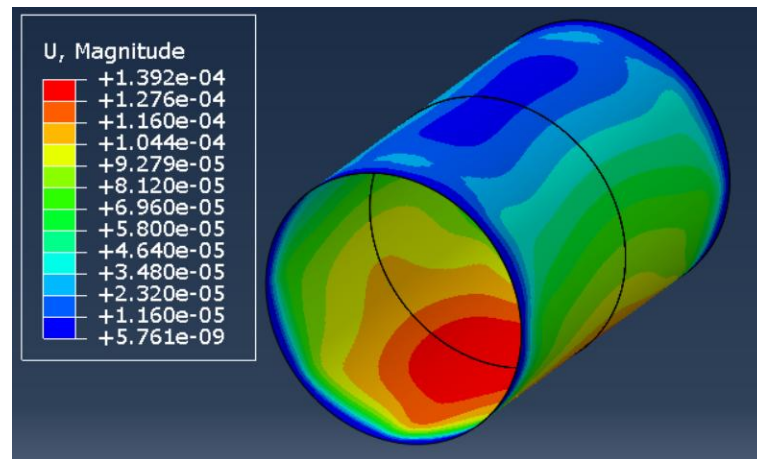
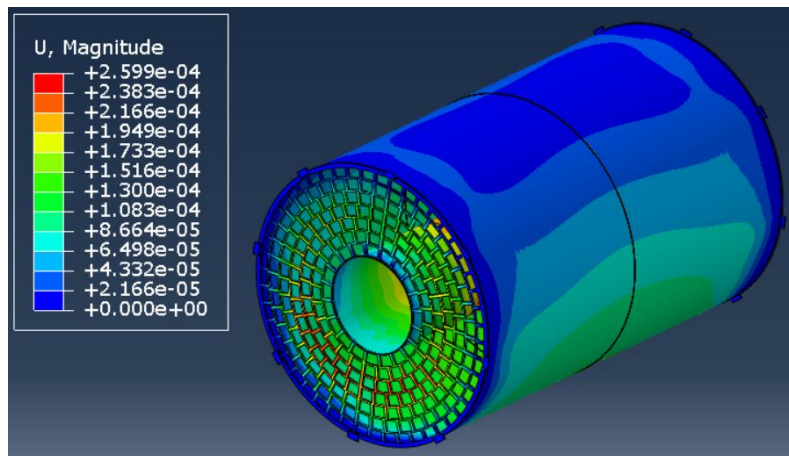


内筒厚度6mm (桶和端板为一个部件)



外筒固定：内筒变形0.28mm

内筒厚度3mm (桶和端板为一个部件)



外筒固定：内筒变形0.26mm

总结

表格：TPC 内筒最大变形

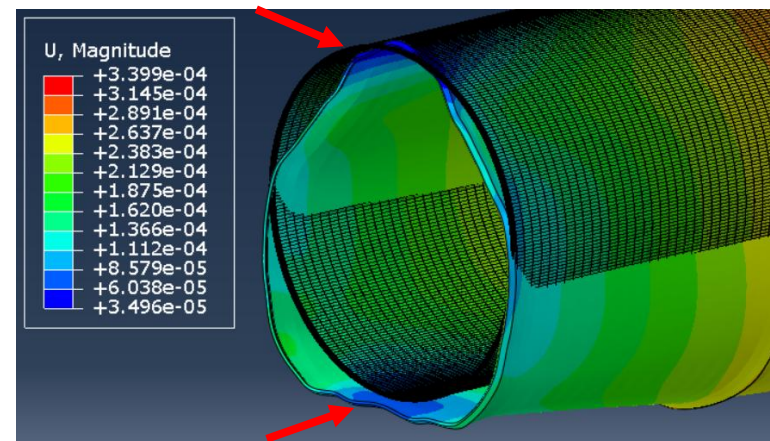
内筒厚度		3mm	6mm	10mm
外筒固定，内筒变形/mm	绑定约束	0.34	0.36	0.35
	一个部件	0.26	0.28	-
内外筒固定，内筒变形/mm		0.10	-	0.10
内筒蜂窝板质量/kg		0.96	1.93	3.22

碳纤维密度按照 1600kg/m^3 计算，厚度 0.2mm ，重量 3.53kg 。

芳纶密度按照 1450kg/m^3 计算，厚度 0.1mm ，重量 1.62kg

注：不同模型之间由于网格差异，有限元计算结果可能会有 0.0Xmm 的差异

- 内筒厚度改变对变形影响较小
- 内筒受到ITK弯矩作用，导致端面板(厚度 25mm)产生变形
- ITK独立固定在TPC端面板是否会产生相应弯矩作用，和安装方式有关，水平塞入安装可以消除弯矩作用？
- 安装方式对ITK变形有利，同时能够减少支撑质量，但对TPC不太有利，筒壁变形变大



内筒变形前后对比（放大1000倍）