IT service cylinder design and prototyping

- *Composite Manufacturing & Simulation Center*
- *Inner tracker region*
- *Service Cylinder*
- *A few slides on IT support tube*
- *Conclusions*

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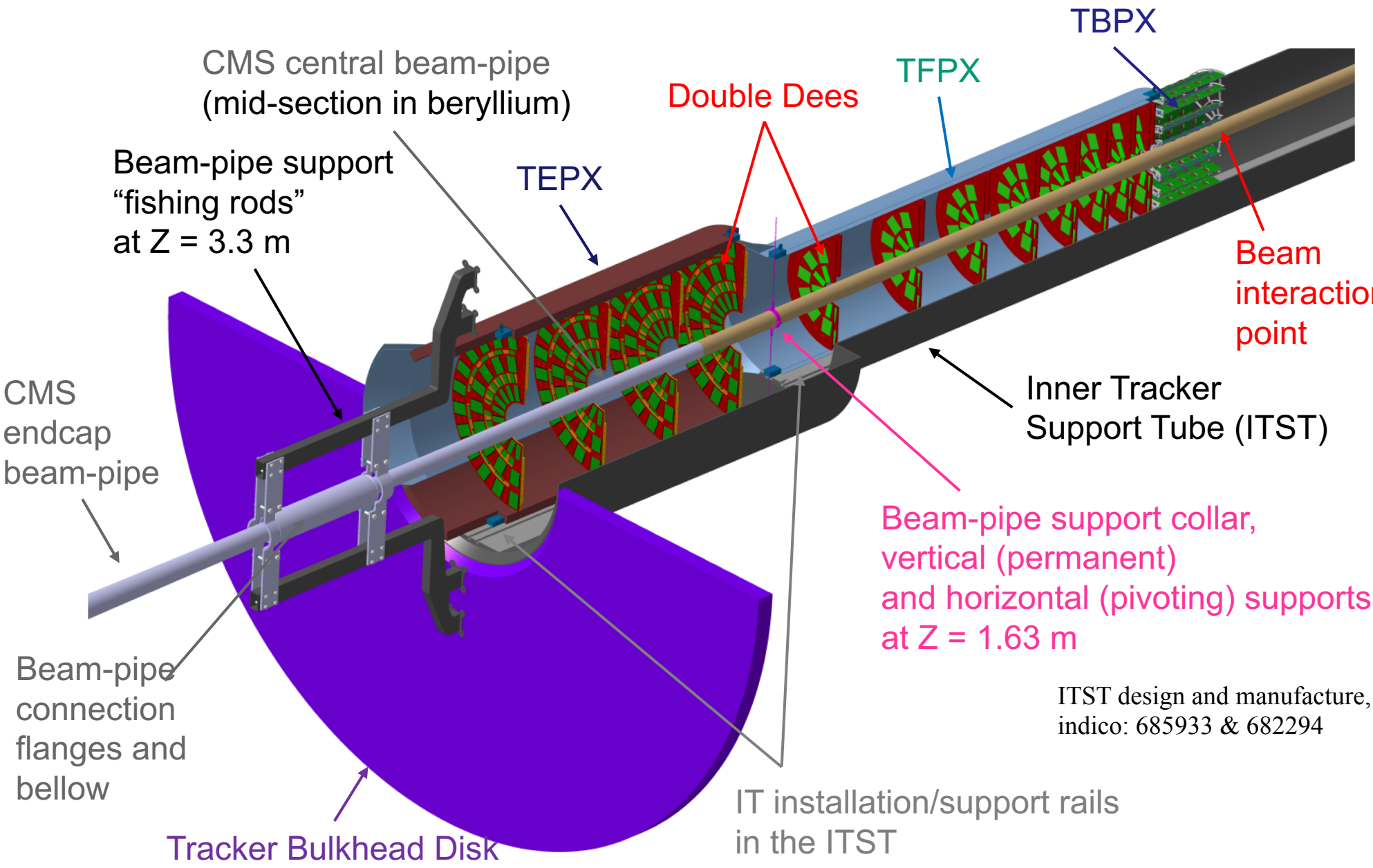
Zixin Ziong (Eng. UG), Sushrut Karmarkar (CMSC phd), Byron Pipes (CMSC Director)

PURDUE UNIVERSITY

Composites Manufacturing & Simulation Center

June 15th , 2018

Inner Tracker region



ITST design and manufacture,
indico: 685933 & 682294

IT mechanics working group

- Combined/Merged with IT modules meeting: bi-weekly Tuesday, 4:30 pm.
- Mechanical and thermal performance of the support structures (dee's, ladders and cylinder) and relevant interface materials
- Purdue focus on material choices and R&D to improve on those, includes FEAs, thermal conductivities
- Closely working with Cornell, UC Davies

Purdue CMSC / Service cylinder

Completed in summer 2016:

- Composite manufacturing & simulation center, CMSC
- Aeronautics, Chemical E, Materials E, Aviation Tech, Computer graphics
- Highly qualified full-time staff
- 32,000ft^2 building with 13,000ft^2 dedicated to composite manufacturing

Main Equipment relevant for the Cylinder effort:

→ 2 large pressurized ovens (both around 6 feet or less)
→ 1 larger oven with vacuum hook-ups (probably 8-10 feet of usable space)
→ Larger ovens accessible with an industry partner in the area
→ Large areas/labs for layups
→ Maximum pressure is 85 psi / 5.9 bar

Purdue CMSC / Service cylinder

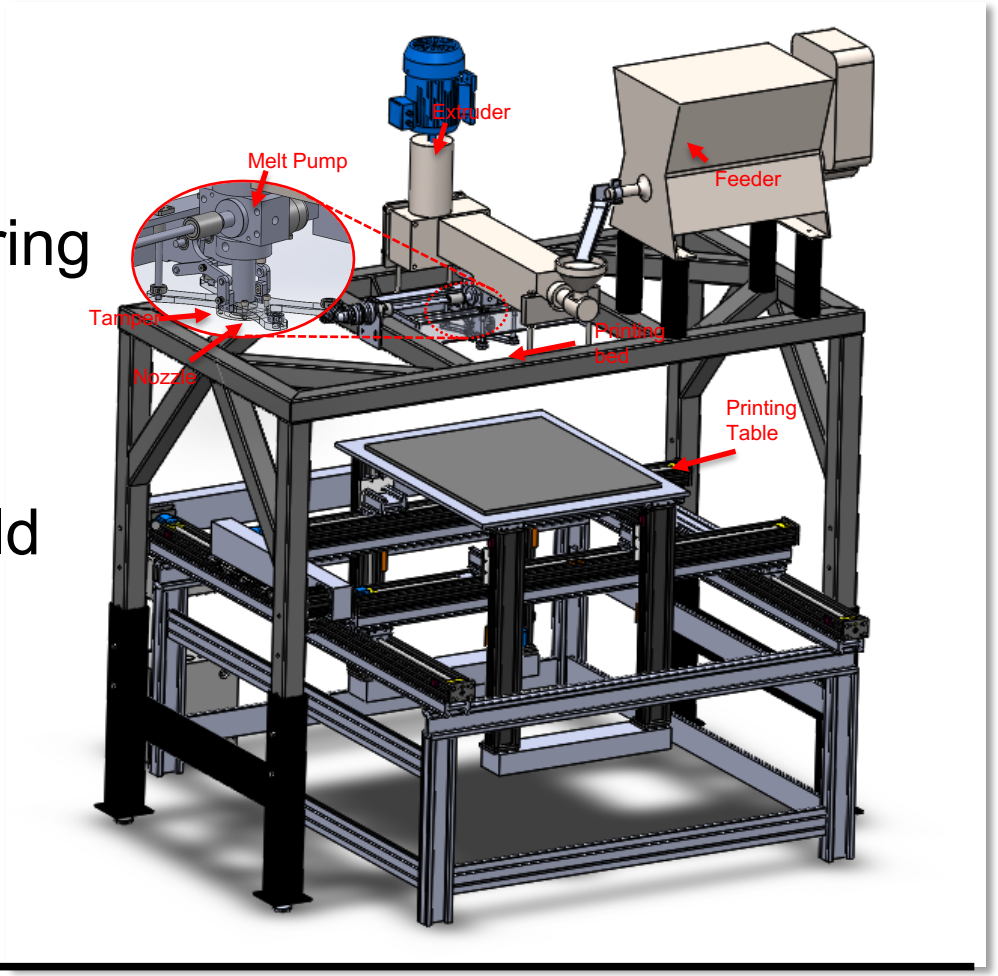
- → Established a close collaboration between PSDL-CMSC
- → A graduate student from the engineering school associated with the project
- → Long-term interest of the CMSC on our project/research

EDAM – Purdue CAMRI

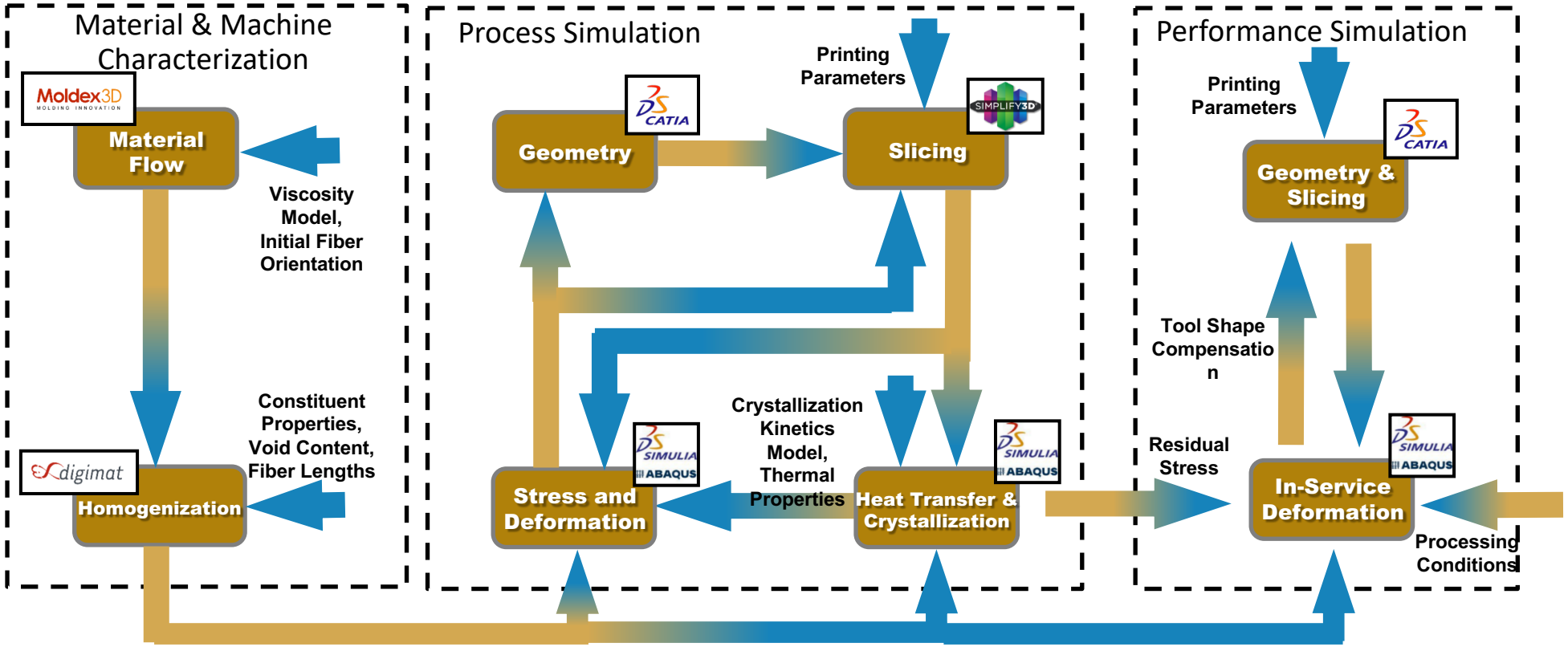
- Custom developed at Purdue
- Print volume of 20”x20”x20”
- Precise flow-rate control through melt pump
- Tamper for material compaction
- Equipped with sensors for monitoring process
- Max throughput 10 lb/hr
- No CTE miss match between mold and layup material

→ Higher accuracy & better tolerances

CAMRI
Composites Additive Manufacturing Research Instrument

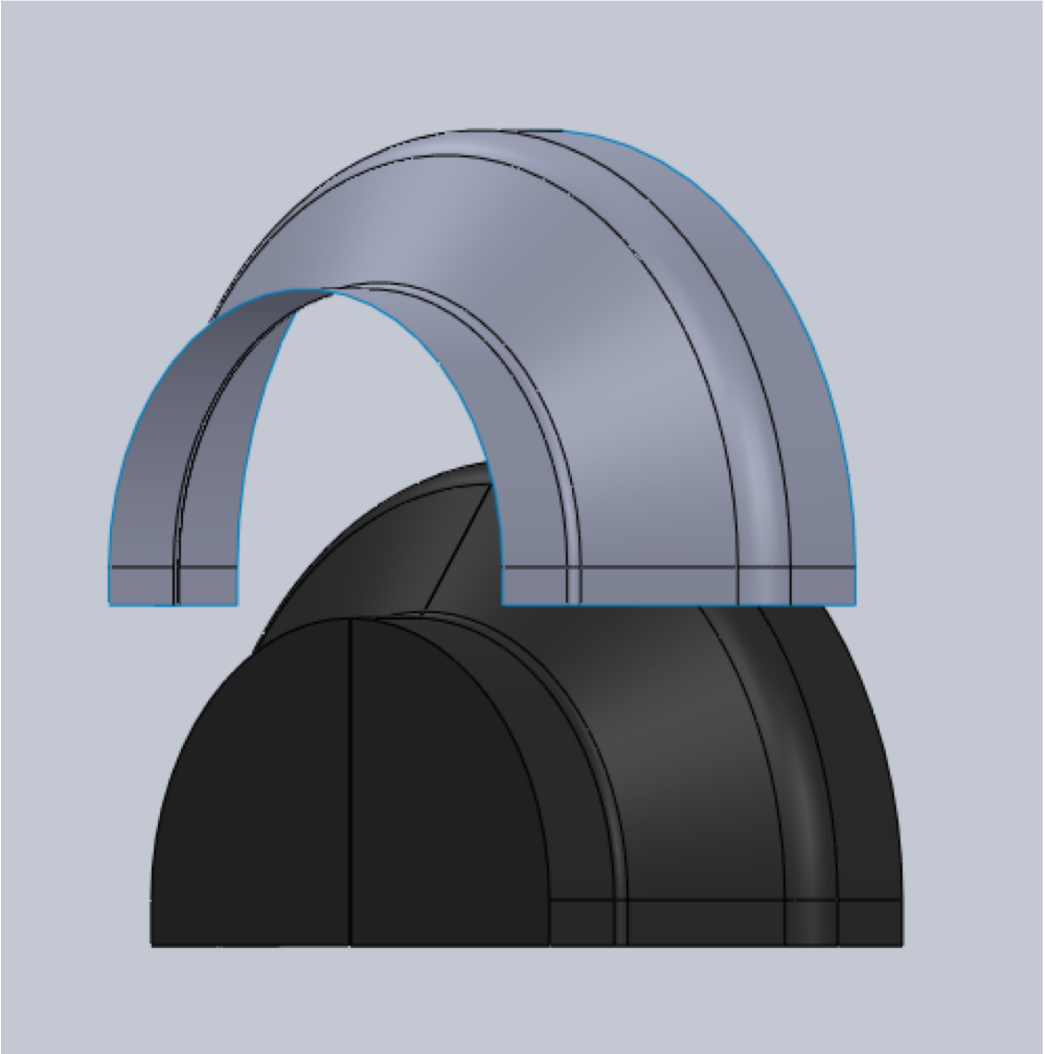


Process and Performance simulation



Two part mold and layup

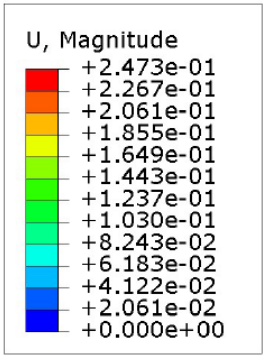
- Mold printed in two half's and bonded using RenLam 4017 epoxy based adhesive
- Laminate to be used for prototype – IM7/8552 unidirectional thermoset pre-preg.
- Material properties used from literature to simulate deformation in the part[1]



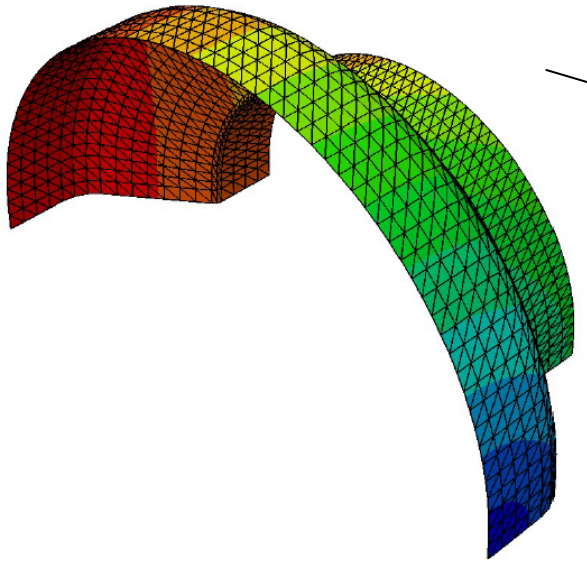
[1] http://www.niar.wichita.edu/coe/ncamp_documents/Hexcel%208552/CAM-RP-2009-015%20Rev%20A%20April%2022%202011%20Hexcel%208552%20IM7%20Uni%20Data%20Report.pdf

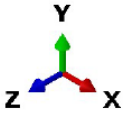
Tool/Mold compensation

- Deformation analysis due to thermal stresses (abaqus)
- The deformation was compensated in the tool geometry



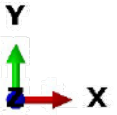
Scale in mm

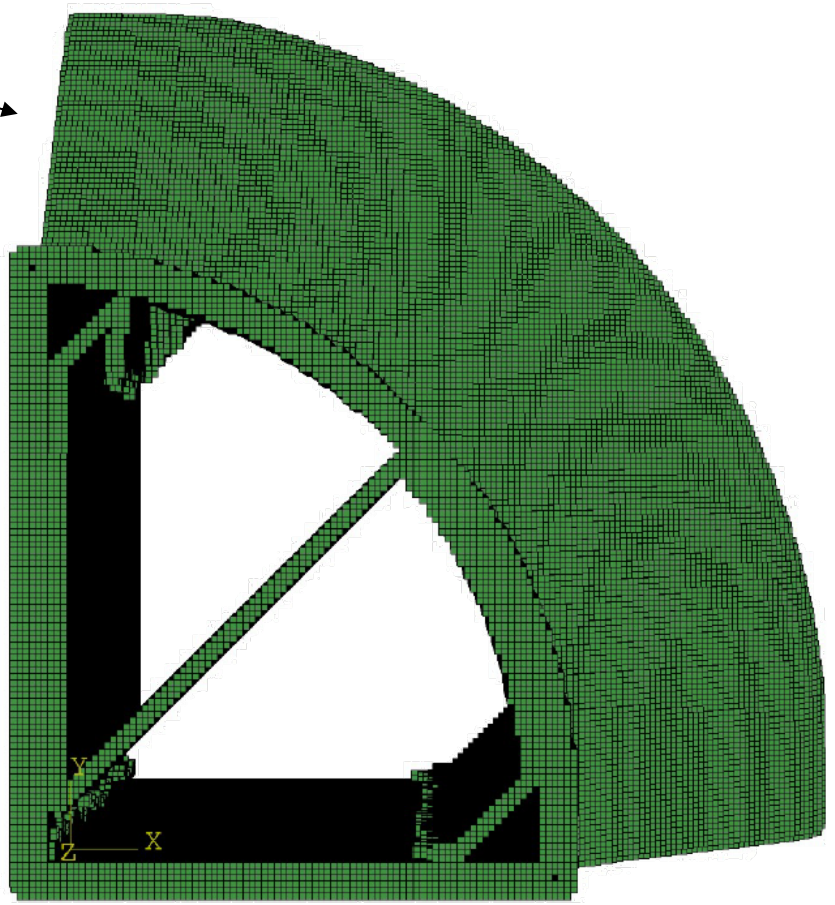




ODB: ThermalDef1.odb Abaqus/Standard 3DEXPERIENCE R2017x

Step: Step-1
Increment 1: Step Time = 1.000
Primary Var: U, Magnitude
Deformed Var: U Deformation Scale Factor: +2.327e+02





3D mold printing process

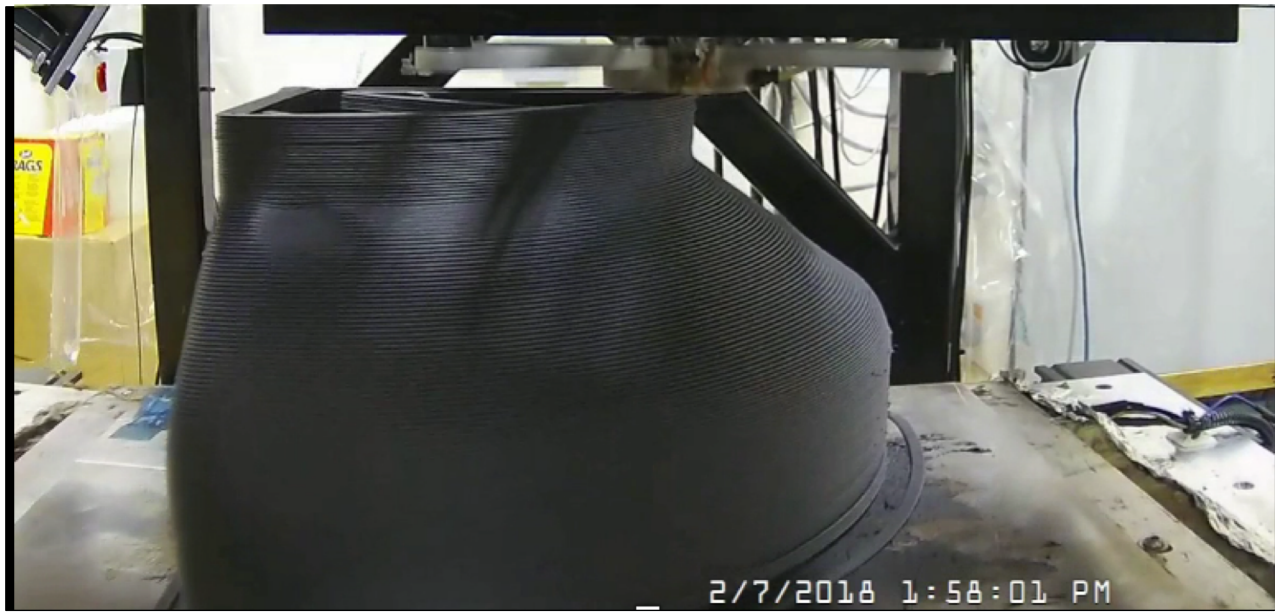
Collaborating with Composite Manufacturing & Simulation Center at Purdue

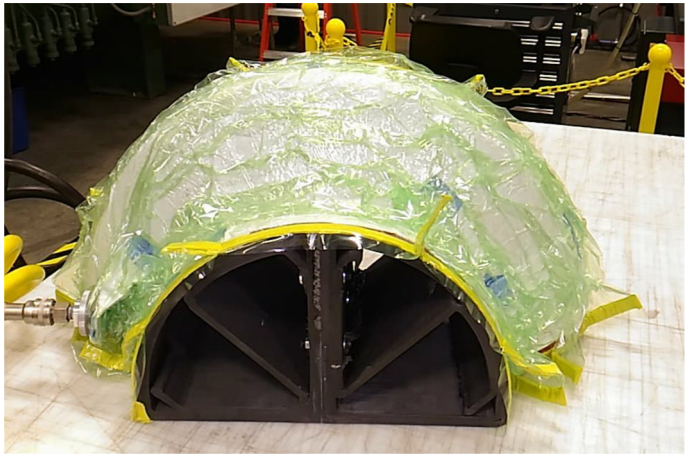
→ Carbon Fiber laminates widely used in industry, Center partners with Aeronautics, Car

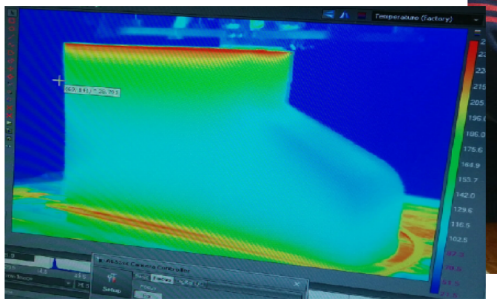
→ Large 3+3m long carbon fiber based support cylinders

→ FEAs to optimize material budget, stiffness, deformation

→ Accurate simulation of 3D-printed molds used for layup

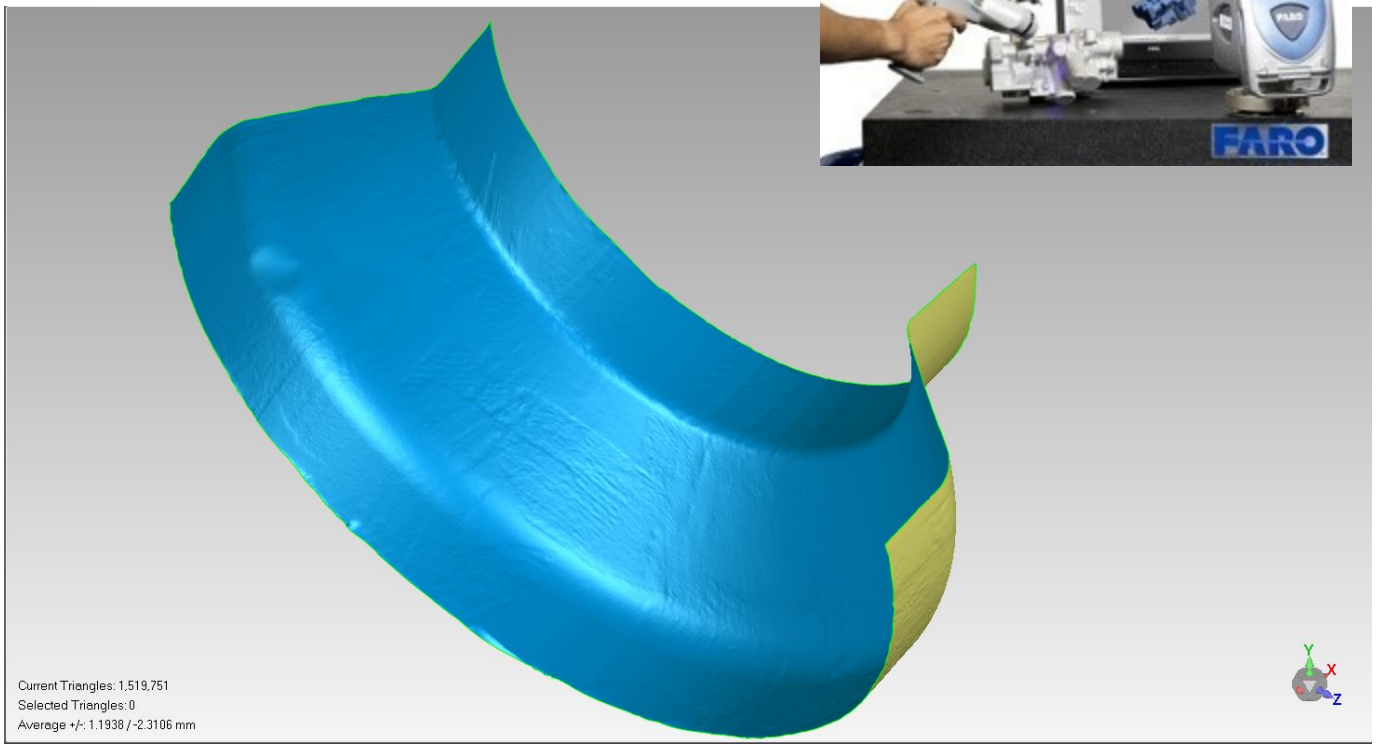






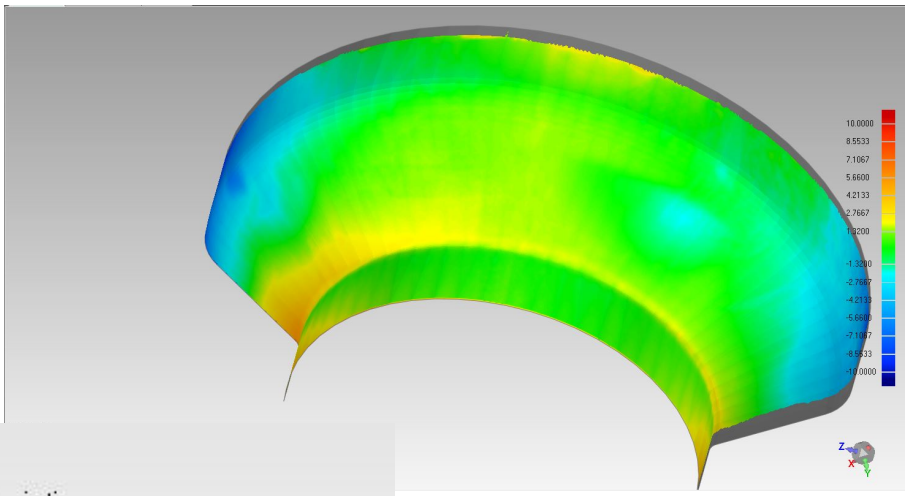
1st prototypes of "step section"

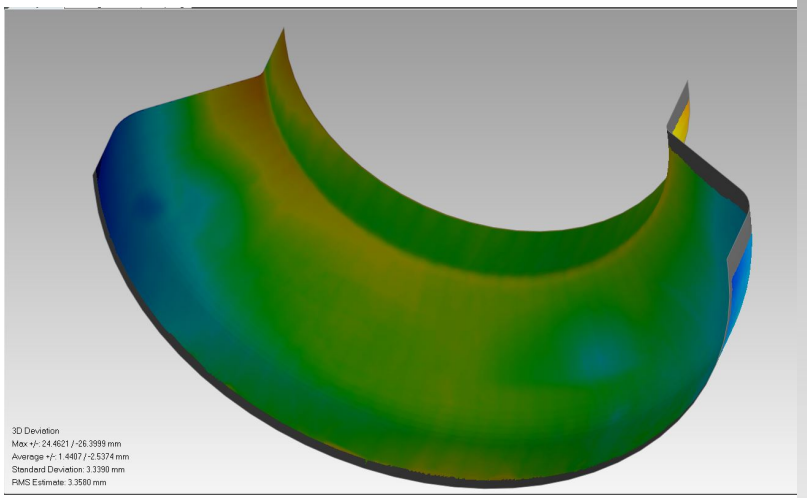
- Scanned surface needs to be corrected for imperfections.
- Using a FARO Scanning Arm and support software CAM2Measure 10.6
- Post processing done in Geomagic 2015

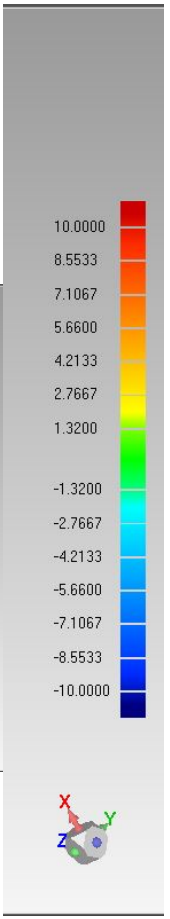


Comparisons to CAD & tool

- Edges show largest deviations, these are unsupported in the prototypes, not the case in CAD
- Average deviation large: 1.4mm, caused by cracks in the mold, reasons understood & addressed in 2nd prototype





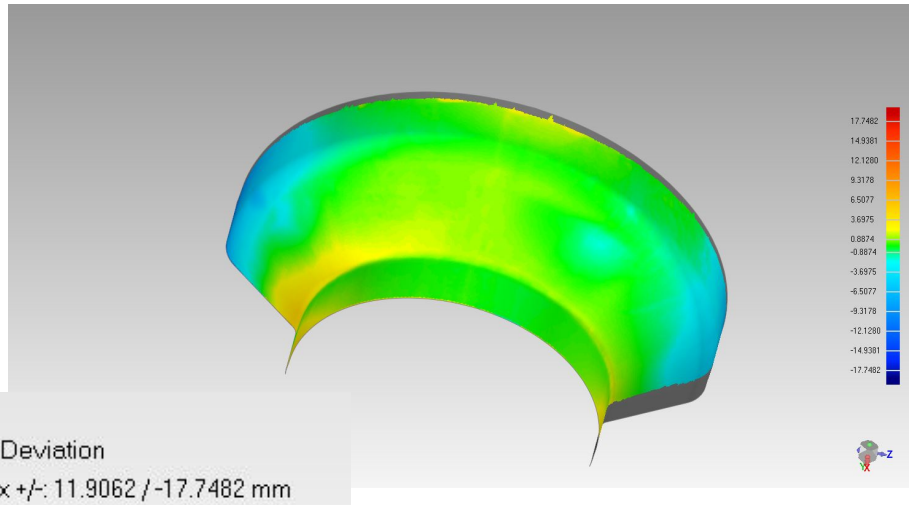


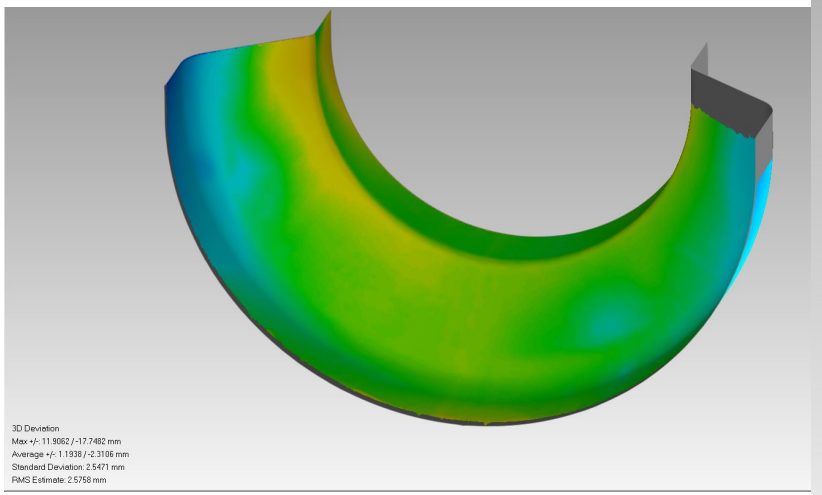
3D Deviation
Max +/-: 24.4621 / -26.3999 mm
Average +/-: 1.4407 / -2.5374 mm
Standard Deviation: 3.3390 mm
RMS Estimate: 3.3580 mm

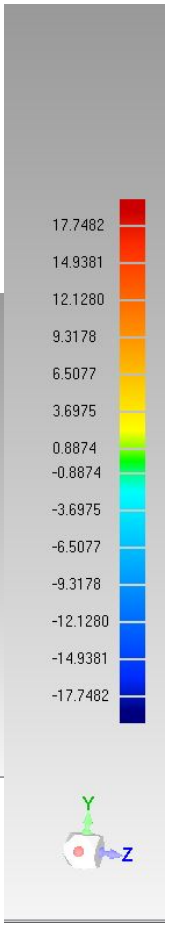
Measurements in mm. The color spectrum is same for both images.

Comparisons to CAD & tool

- Edges show largest deviations, these are unsupported in the prototypes, not the case in CAD
- Average deviation smaller: 1.1mm, caused by cracks in the mold, reasons understood & addressed in 2nd prototype





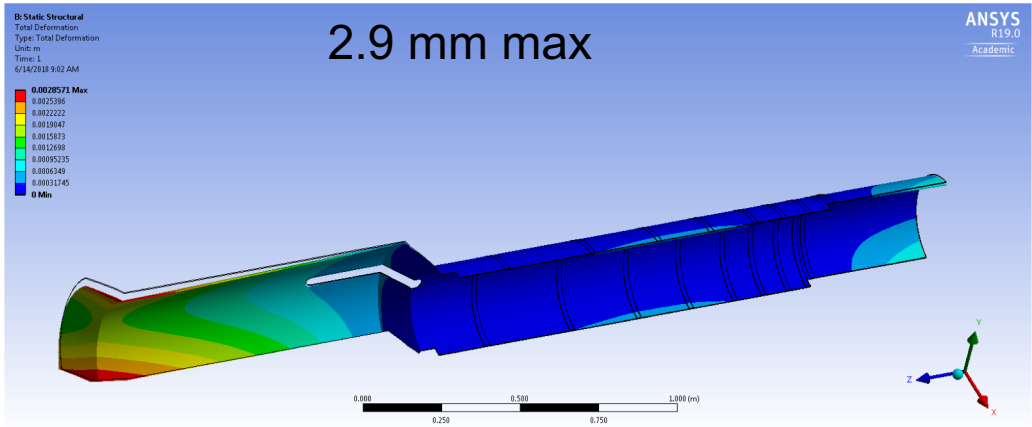


Measurements in mm. The color spectrum is same for both images.

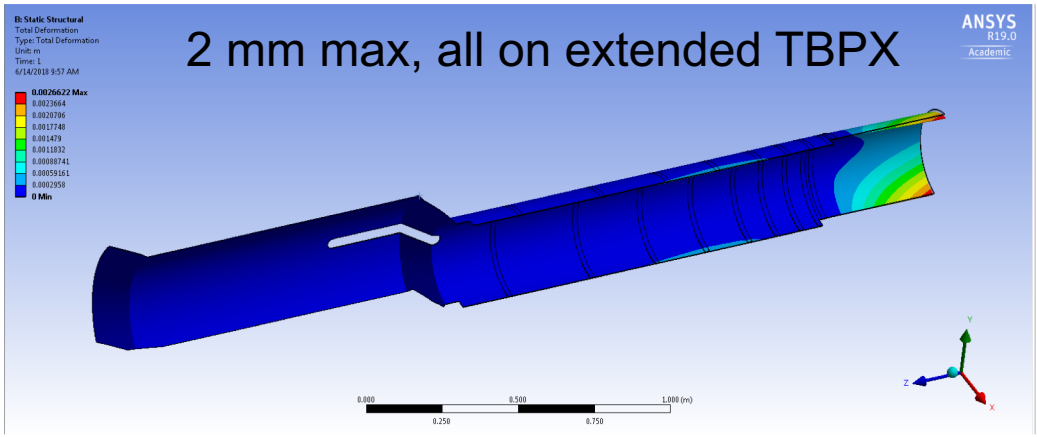
2nd prototype: full scale + realistic FEA

- Addressing shortcomings of 1st prototype
  - Thicker walls
  - Unique reference system to transfer to milling stage
  - Enlarged printing volume, no quarter sections anymore

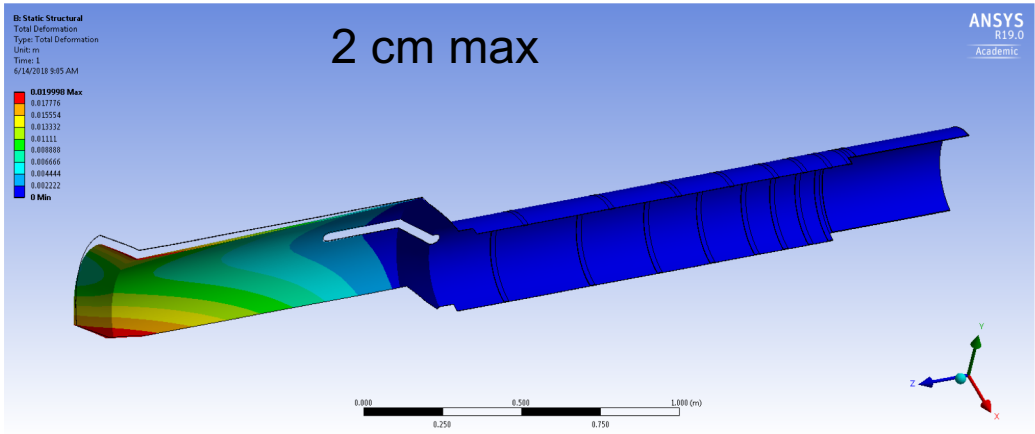
3mm thick CF laminate, 4 wheels, mass of 5kg per double-dee, no mass for services



3mm thick CF laminate, 8 wheels, mass of 5kg per double-dee, no mass for services

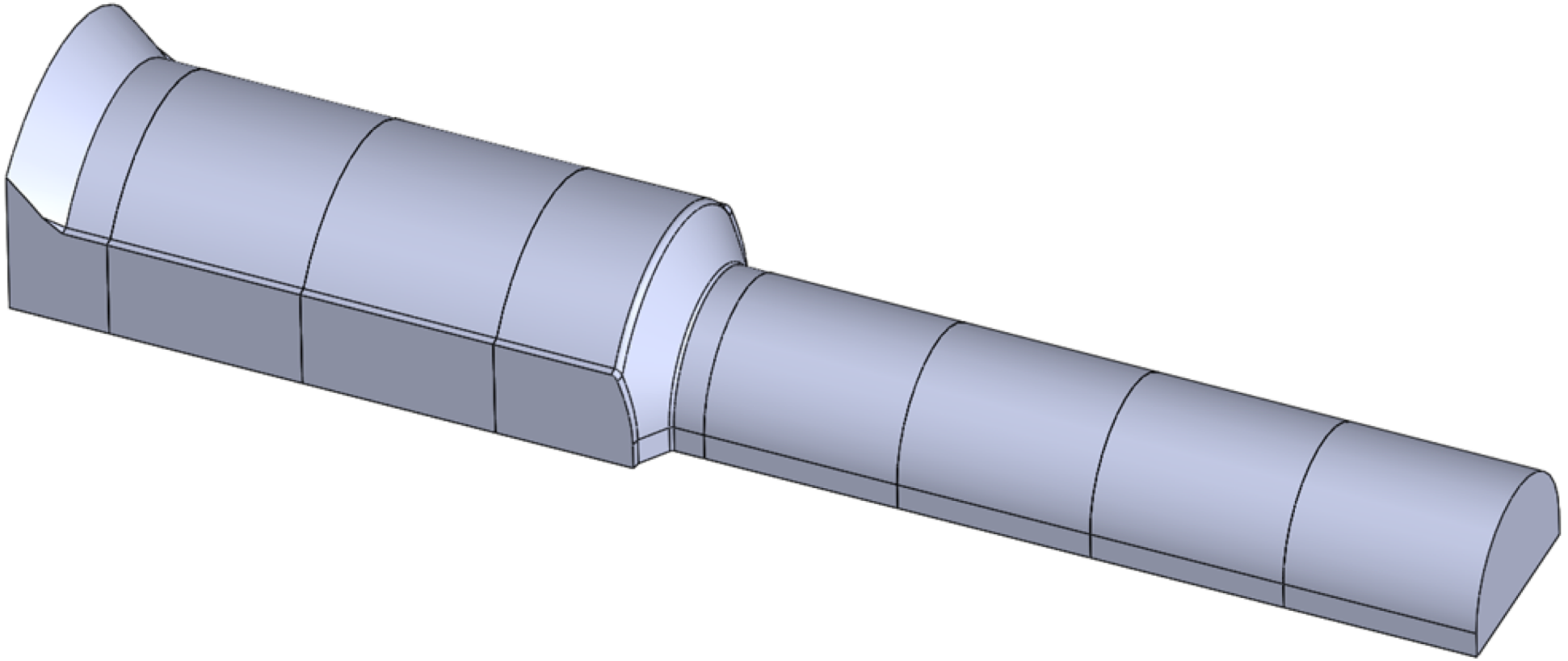


1mm thick CF laminate, 4 wheels, mass of 5kg per double-dee, no mass for services



2nd prototype: full scale + realistic FEA

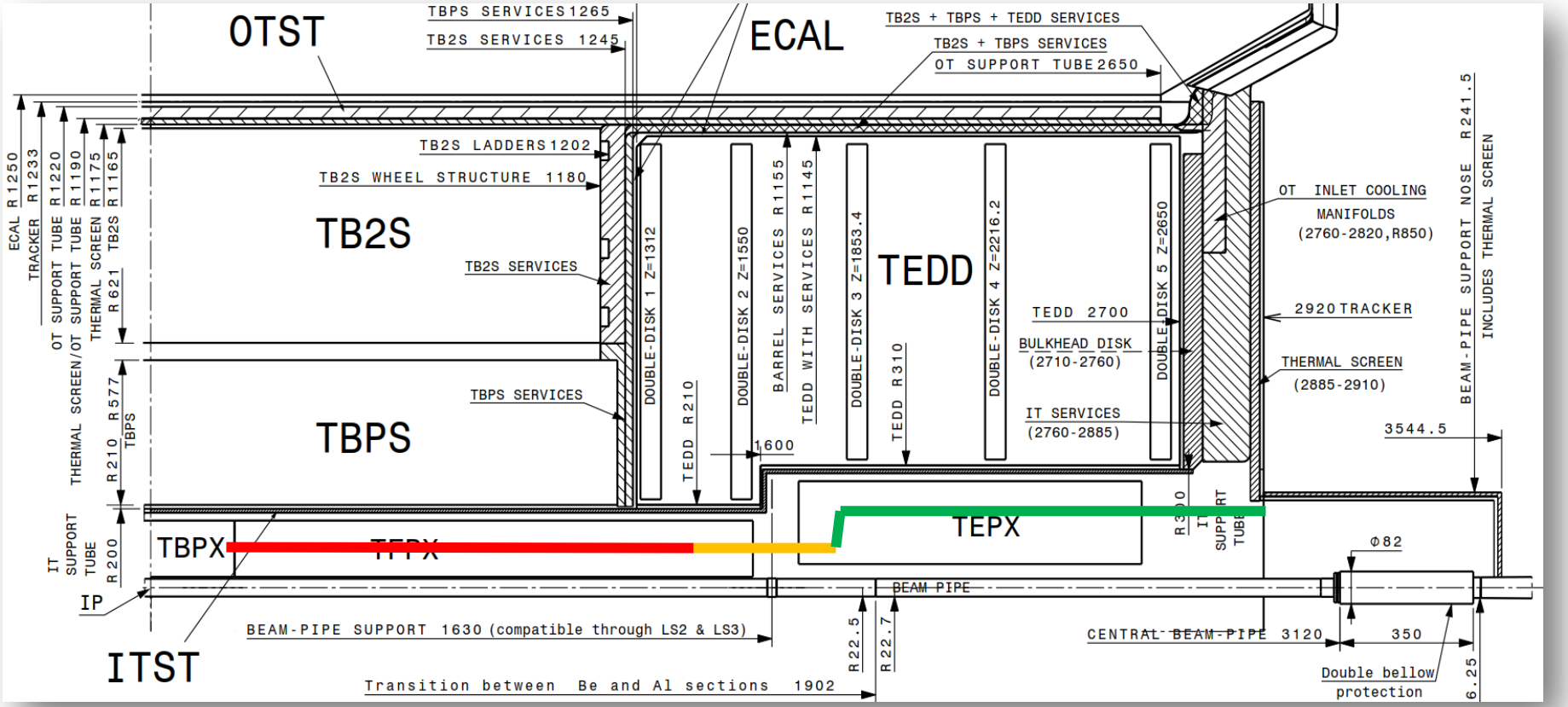
- Currently using AS4 for prototyping, “cheap”
- Service Cylinder CF choice under investigation…thermal shielding, grounding (co-cured mesh), thermal conductivity
- 8 individual mold pieces, epoxied together and milled



A few slides on IT support tube

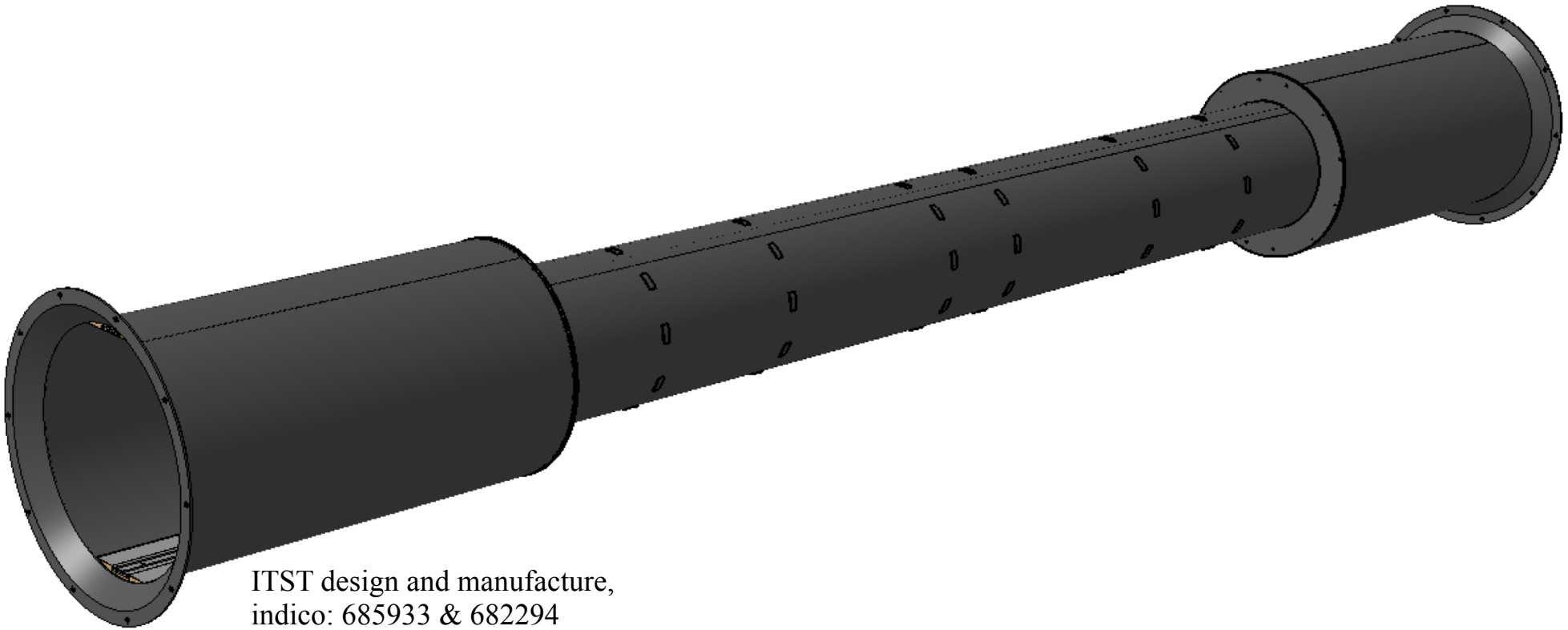
ITST design and manufacture,
indico: 685933 & 682294

→ Design/Slide credit: Antti Onella
→ Composed of: Central section, integral part of the TBPS
→ Currently: No transition sections, longer Central
→ 2 End sections, attached to transition sections & to bulkheads after TEDD instal.
→ Supports the IT and provides humidity sealing between the OT and the IT volumes.



Conceptual design of IT support tube

- Currently using AS4 for prototyping, “cheap”
- Even “cheaper” production method for mold
- Planning for 1st prototype of central section during summer



ITST design and manufacture,
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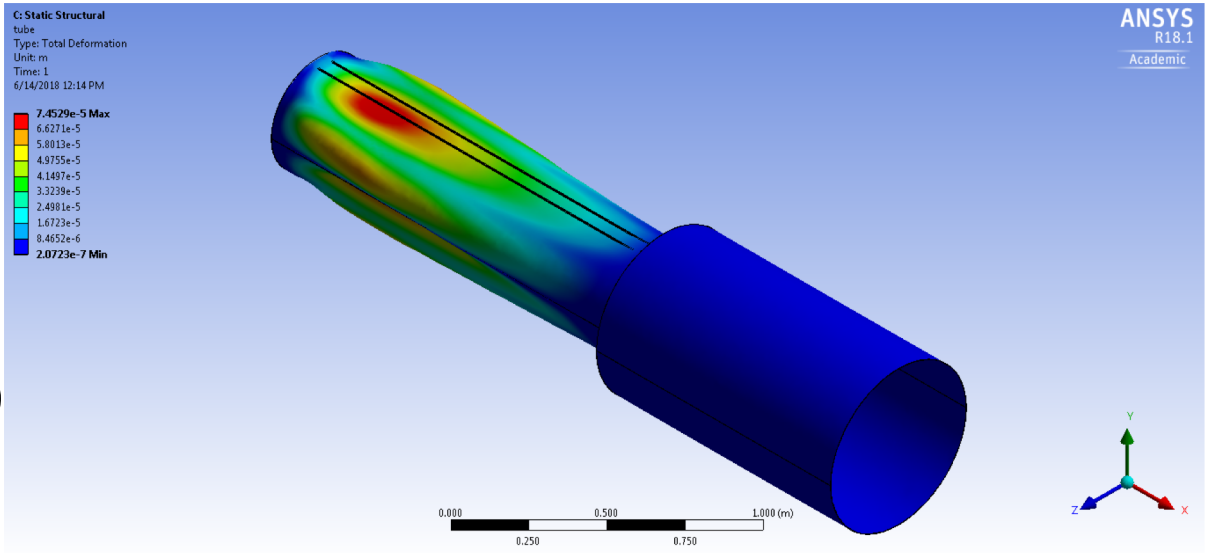
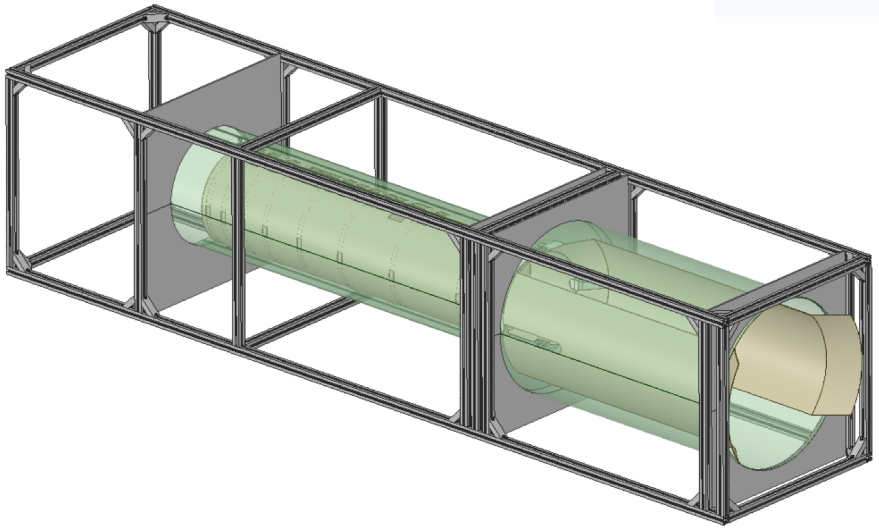
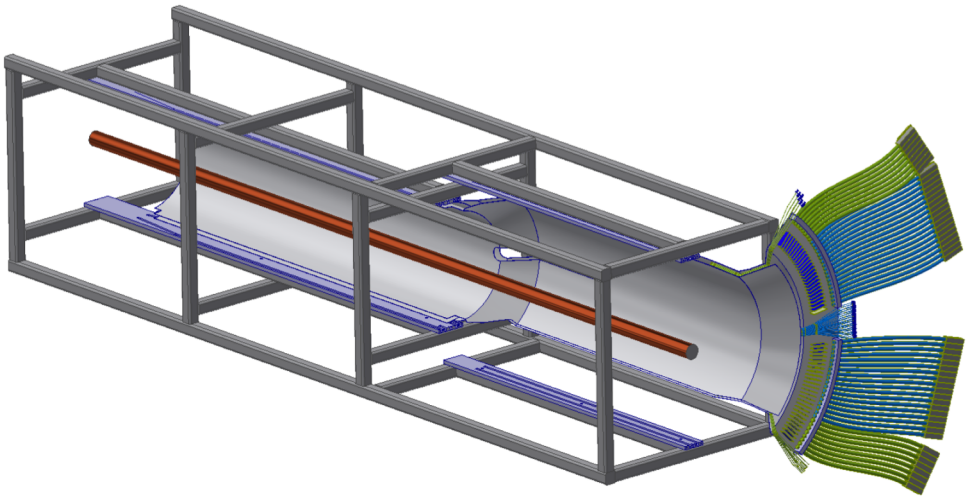
In-house "Insertion" test

- Tube from 1.5mm CF laminate, deformation due to TFPX only
- Very preliminary
- Support mock-up by Purdue (left)
- Support mock-up by UC Davis (John Conway, rts)

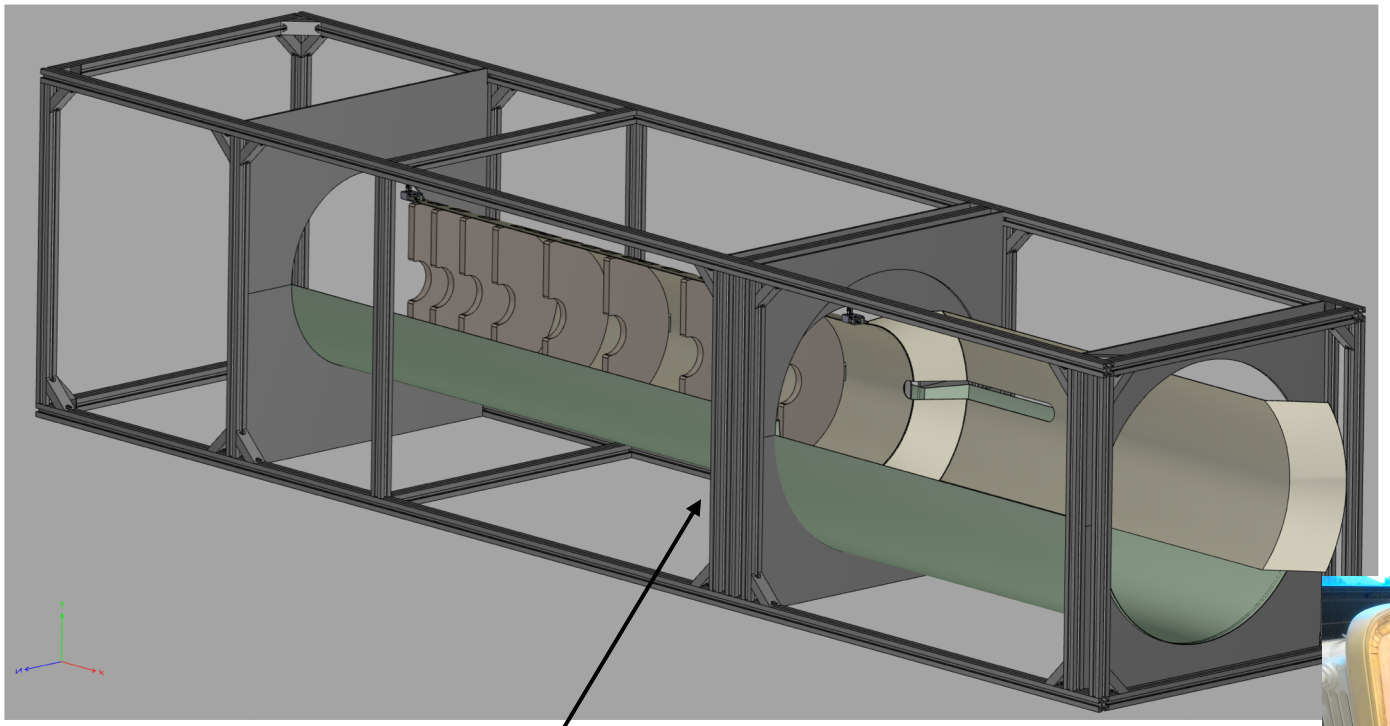


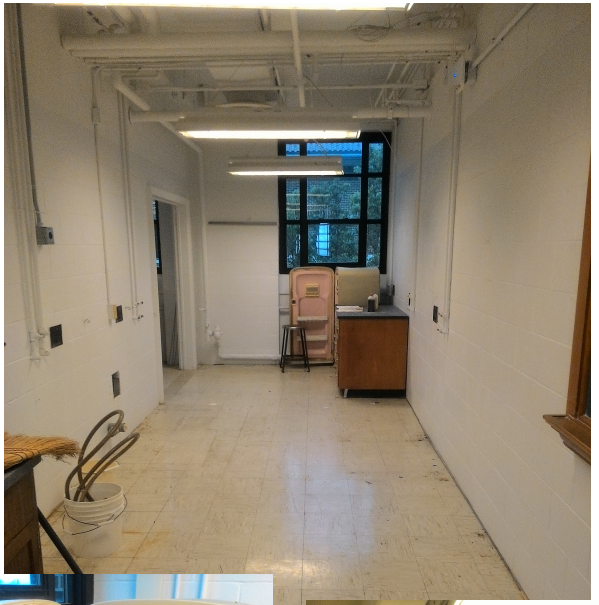




In-house "Insertion" test

- Cleaned out some space, to setup both service cylinder & ITST
- T-style slotted Al-frame for support, alignment, reference frame

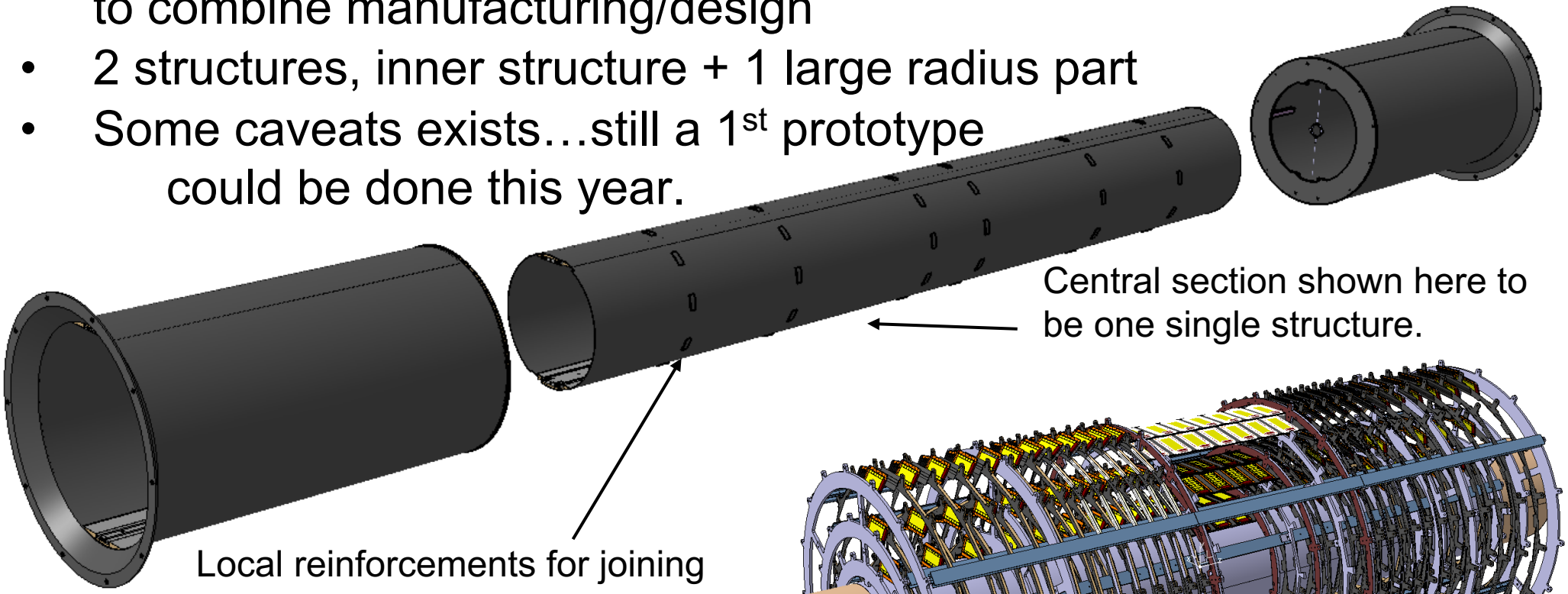




- 1st simple CAD design for supporting t-slotted frame
- Allows reference frame, tolerance measurements
- Can add simple mock-up for services
- Ensures good product
- Closely work with UC Davies

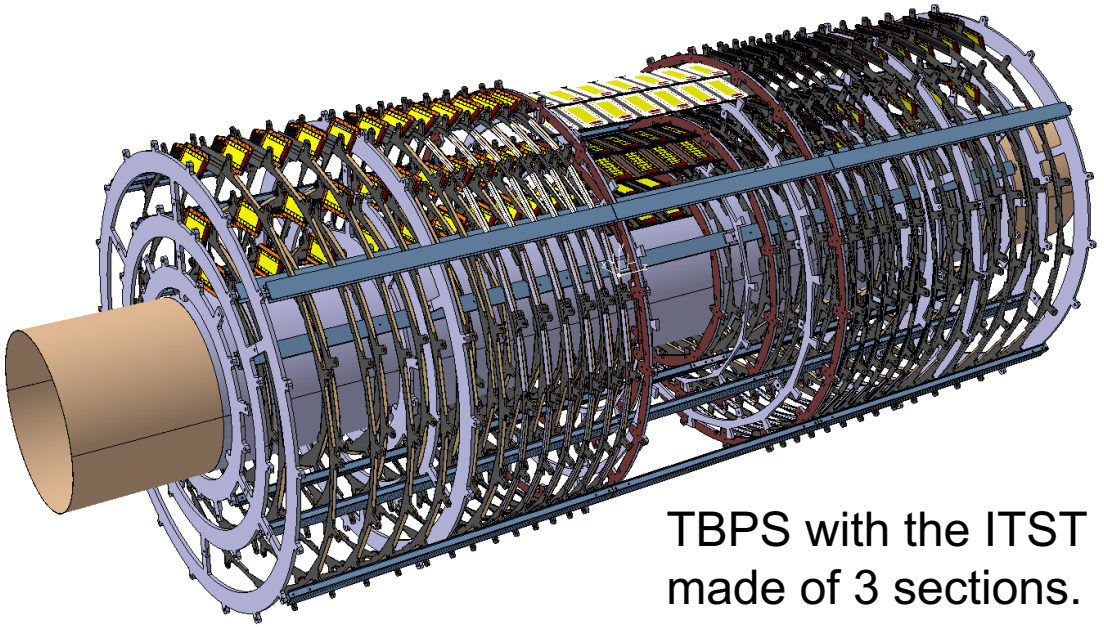
Conceptual design of the ITST

- On track for a 1st prototype of the ITST at Purdue, very sensible to combine manufacturing/design
- 2 structures, inner structure + 1 large radius part
- Some caveats exists…still a 1st prototype could be done this year.



Central section shown here to be one single structure.

Local reinforcements for joining the ITST and the TBPS



TBPS with the ITST made of 3 sections.

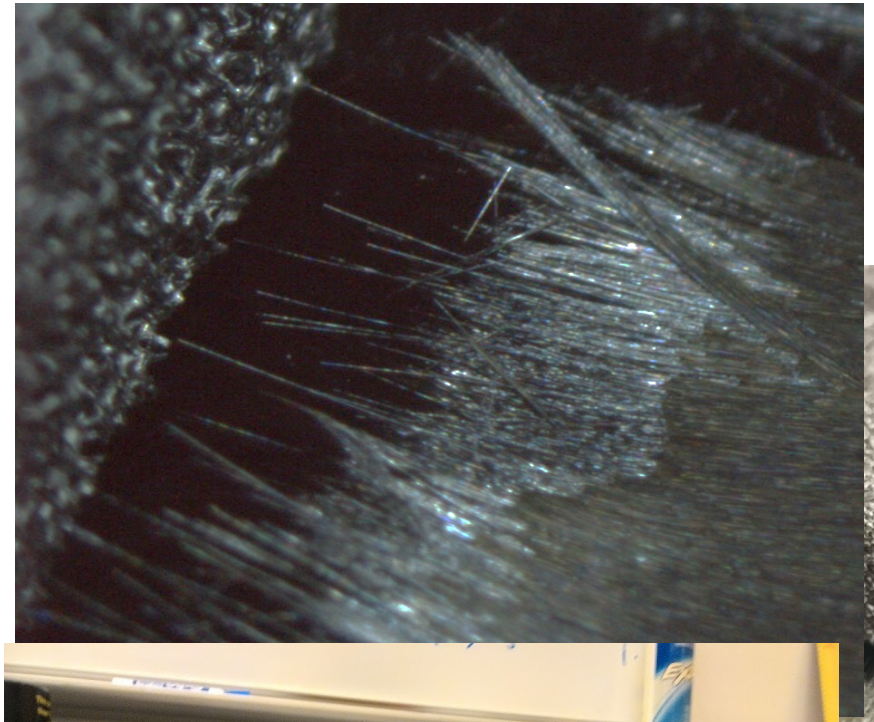
ITST design and manufacture, indico: 685933 & 682294

Conclusions…

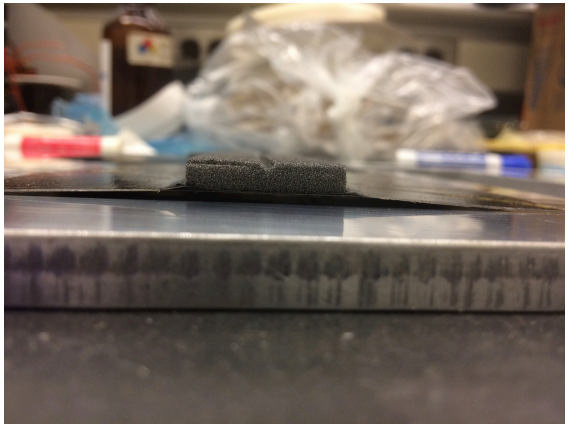
- Prototyping of the service cylinder is progressing
  - Many lessons learned from 1st prototype of step section
  - Now on track for full scale prototype, print starts in coming weeks
  - Established collaboration with CMSC
- Straight section prototypes ready before summer
  - Mechanical and thermal FEA's currently developed for stresses due to temperature profile
  - CMSC "worries" about mechanical stability given the constrains we provide
- ITST prototyping (…and design) is a potential very sensible addition to the Purdue-CMSC ongoing effort
  - Caveats exists…

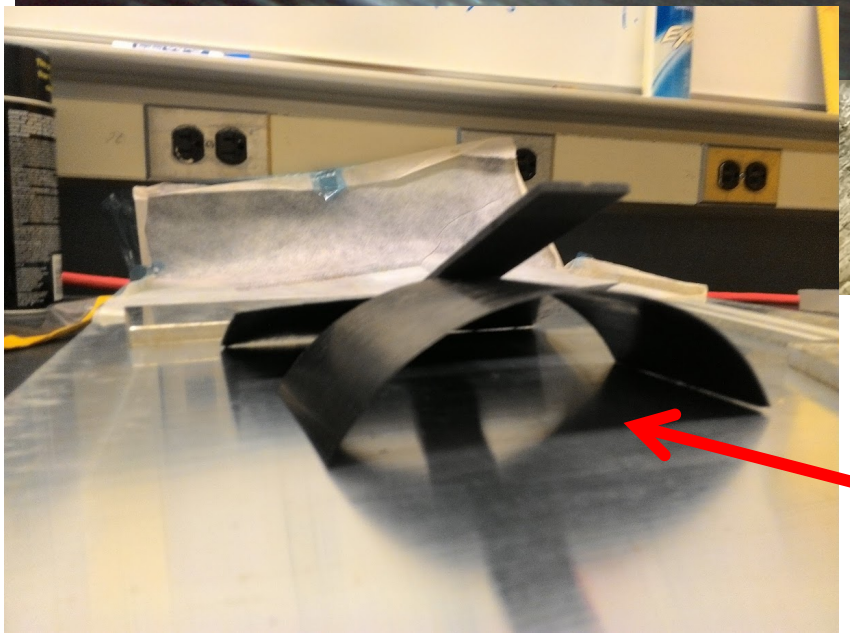
Backup

CF production: lessons learned…

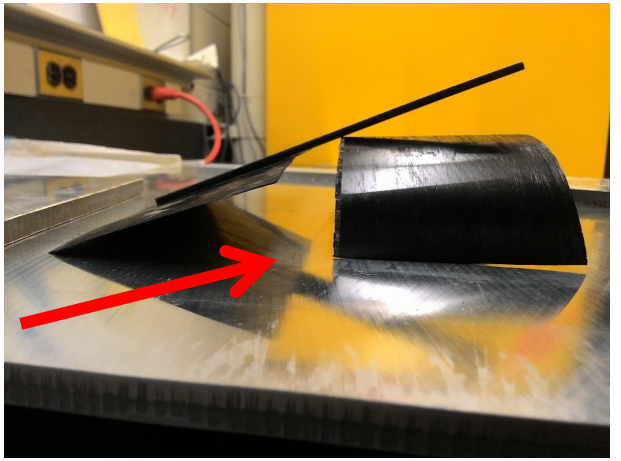


- Co-curing requires exact molds to avoid broken fibers (cause bad TC and bad contact to pixel modules





- Ply orientation **really matters**



Envelope of the ITST

To allocate space for the detectors the ITST is made thin.
It does not have a thick 'sandwich' wall.

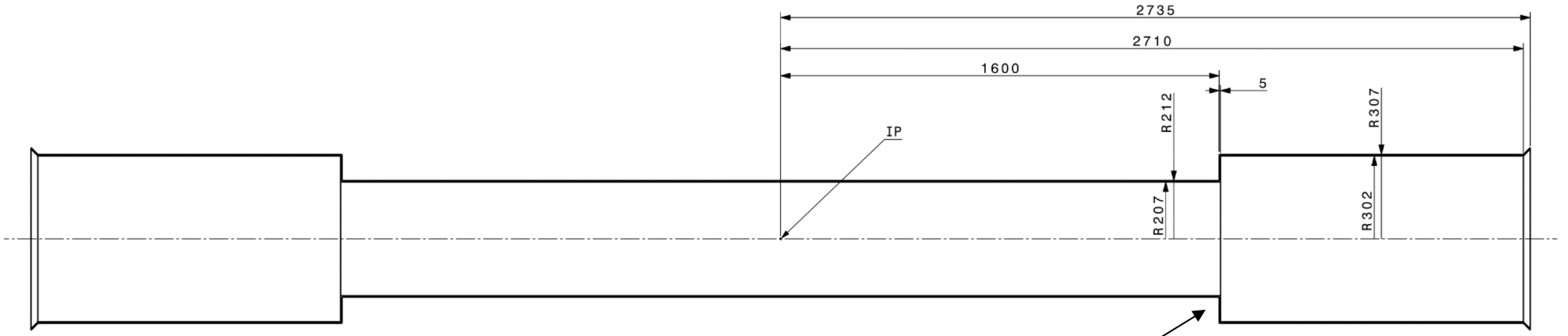
The geometry shown here is the envelope for the ITST, not its nominal dimensions.

The ITST is to fit within this envelope, taking into account manufacturing and assembly tolerances and deformations under load.

To fit within that envelope the ITST wall-thickness needs to be 2-3 mm. Additional elements (ribs) in radial direction are needed to reinforce the ITST.

In the central section by the TBPS structures.

In the end sections by flanges in the diameter change and in the Bulkhead Disk connection.



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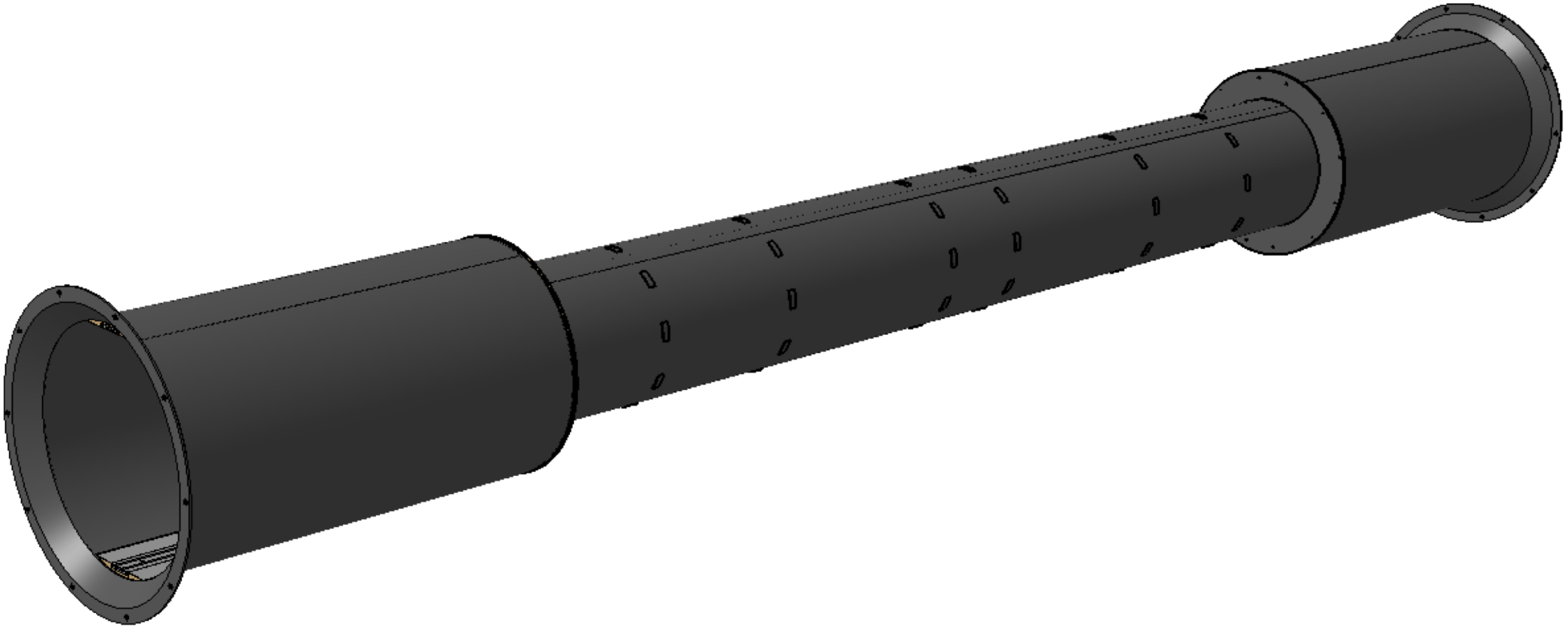
N.B. the transition does not need to be with right angle. A more shallow angle may be preferred.

Conceptual design of the ITST

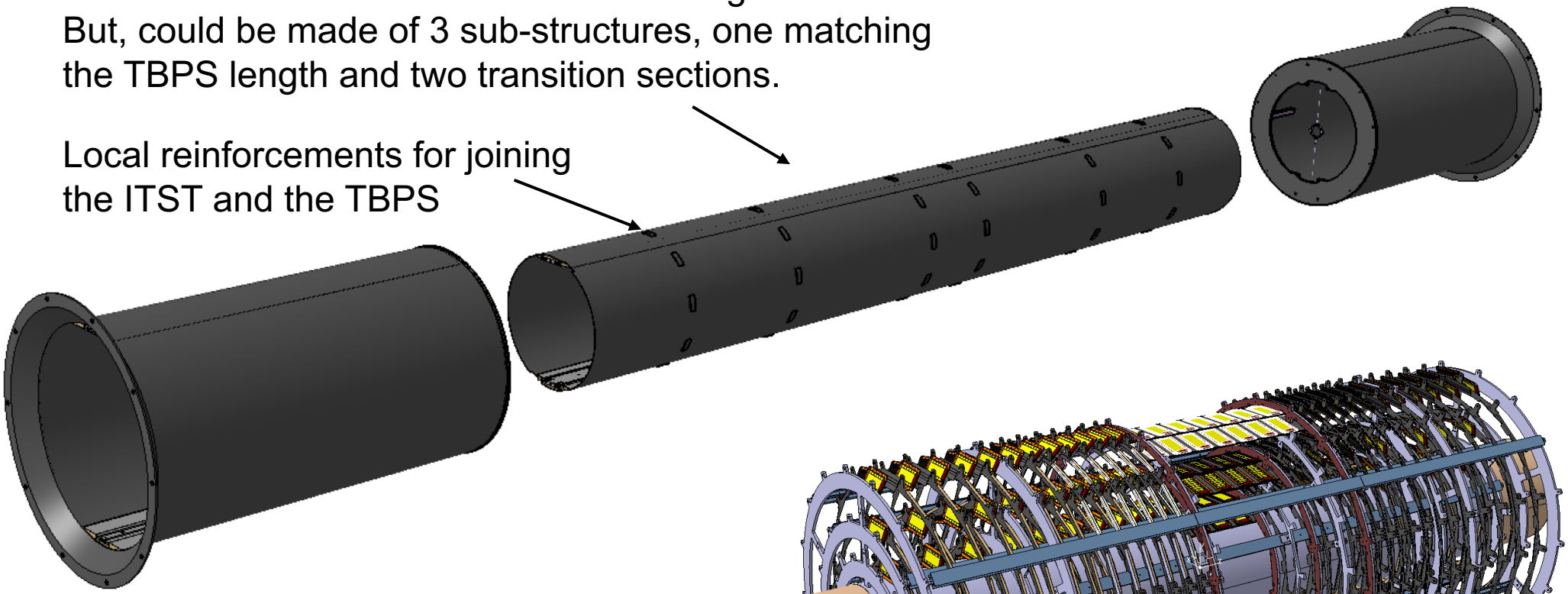


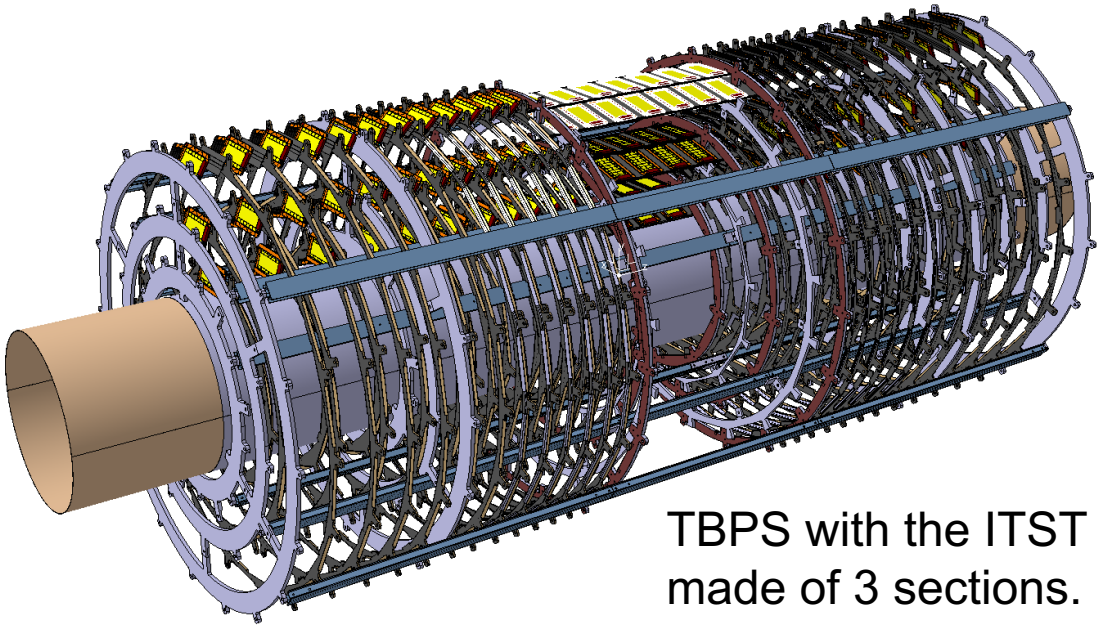
ITST design and manufacture,
indico: 685933 & 682294

Conceptual design of the ITST

Central section shown here to be one single structure.
But, could be made of 3 sub-structures, one matching the TBPS length and two transition sections.

Local reinforcements for joining the ITST and the TBPS





TBPS with the ITST made of 3 sections.