Western Norway University of Applied Sciences

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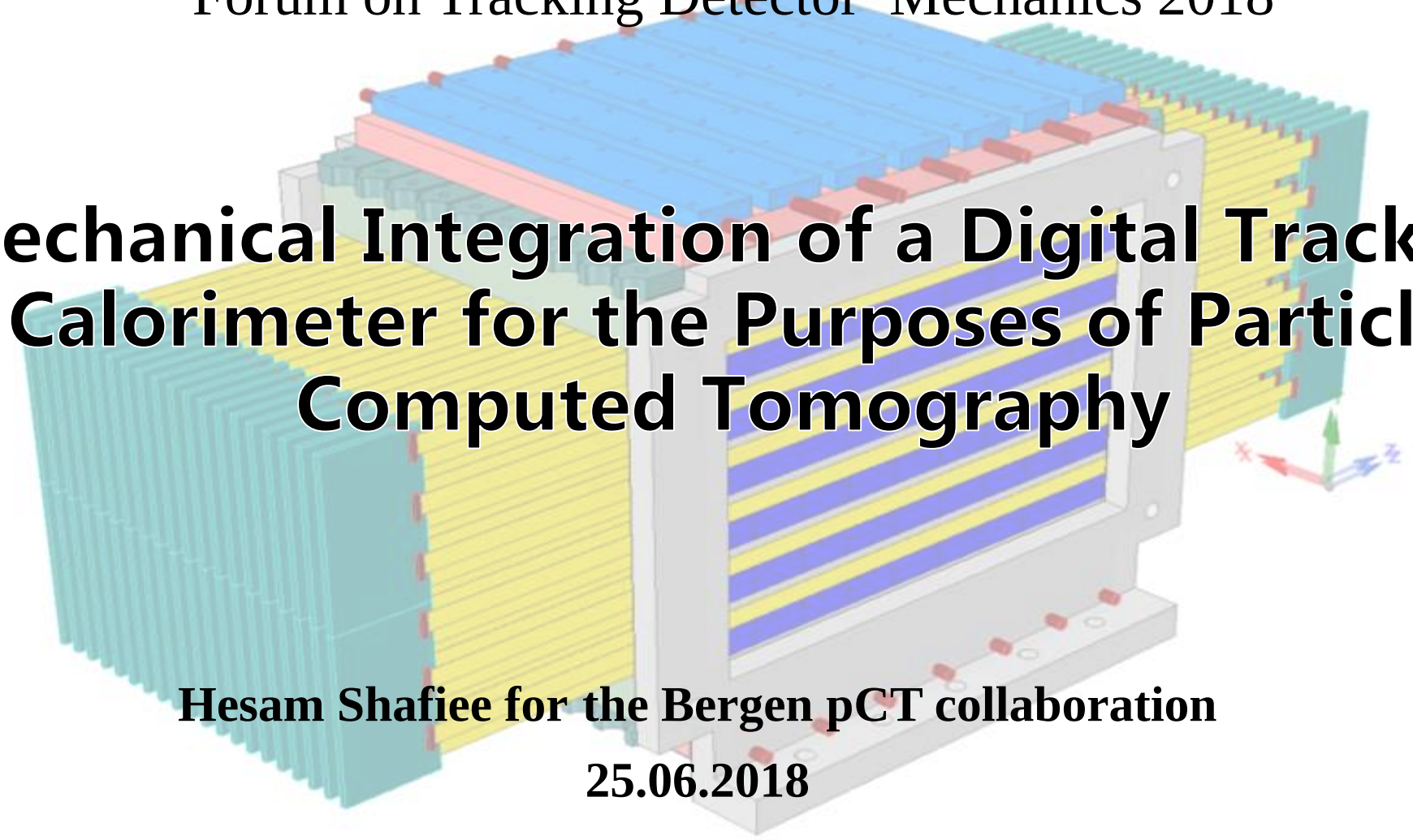
Haukeland University Hospital

University of Bergen

Forum on Tracking Detector Mechanics 2018

Mechanical Integration of a Digital Tracking Calorimeter for the Purposes of Particle Computed Tomography



Hesam Shafiee for the Bergen pCT collaboration

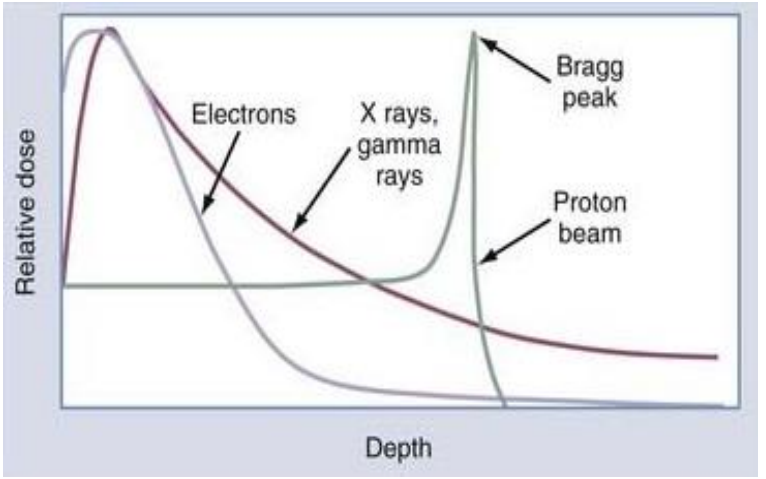
25.06.2018

Outlines:

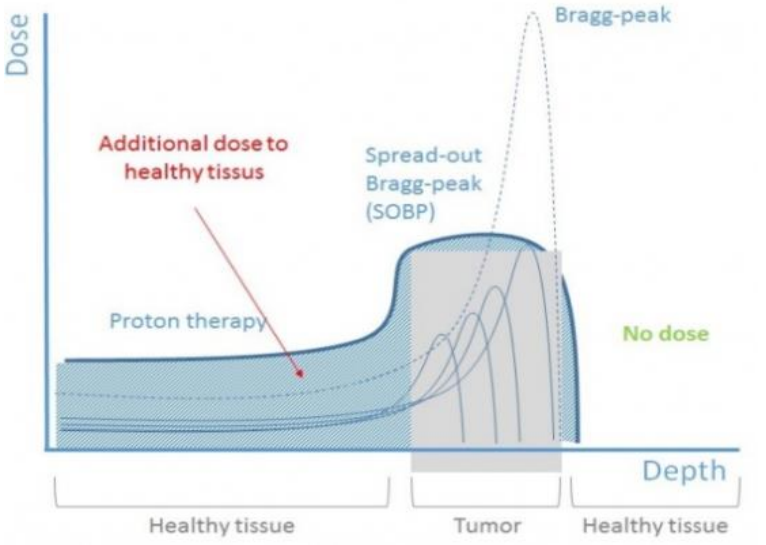
- ✓ Introduction
- ✓ DTC Mechanical Package challenges (Design Parameters)
- ✓ Stave assembly considerations
- ✓ Creating sensitive area for particle trajectory (One Slab)
- ✓ Full calorimeter structure
- ✓ Simulation results
- ✓ Tracker plates (Front Layer) structure
- ✓ Future Studies

Introduction:

- **Particle therapy:**
  - ✓ Novel method in cancer treatment; irradiation of cancerous tissue with protons and carbon ions
- **Why Proton CT**
  - ✓ Accuracy (Bragg peak)
  - ✓ Reducing uncertainties in Bragg peak location(from 1cm to < 1mm)
  - ✓ Direct measurement of stopping power instead of deriving it from a normal X-ray CT
  - ✓ Reduced dose to healthy tissue
  - ✓ Find proton energy after patient



(PHYS231, Roehrich D, 2017)



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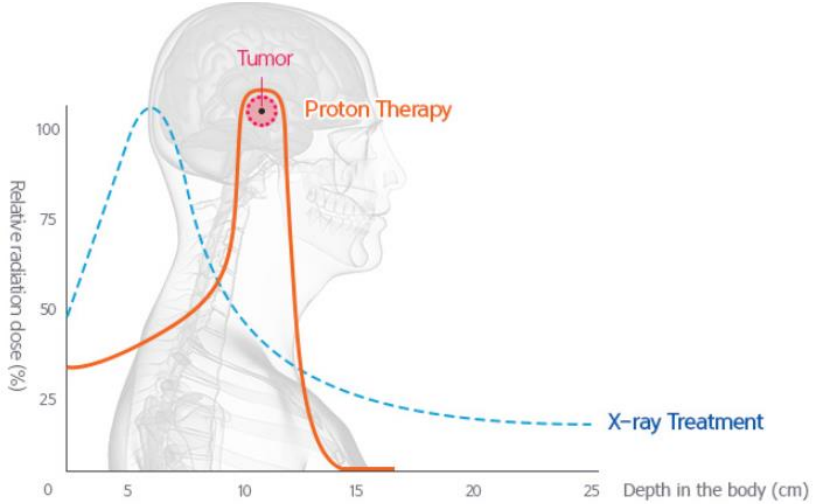
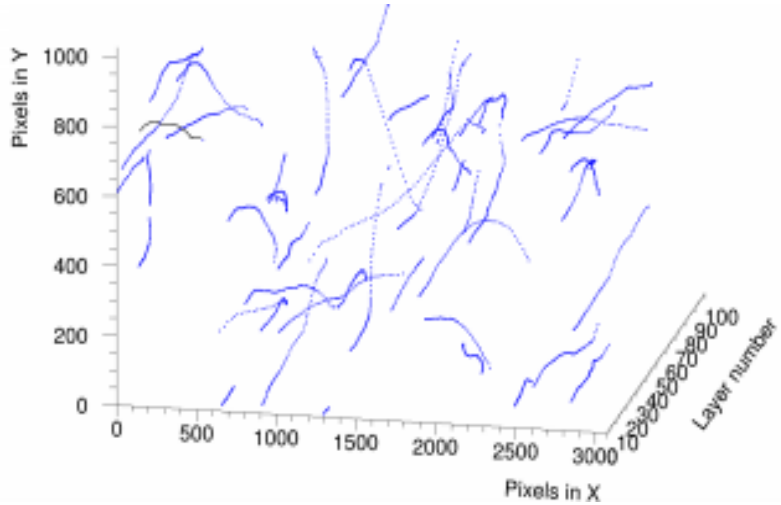


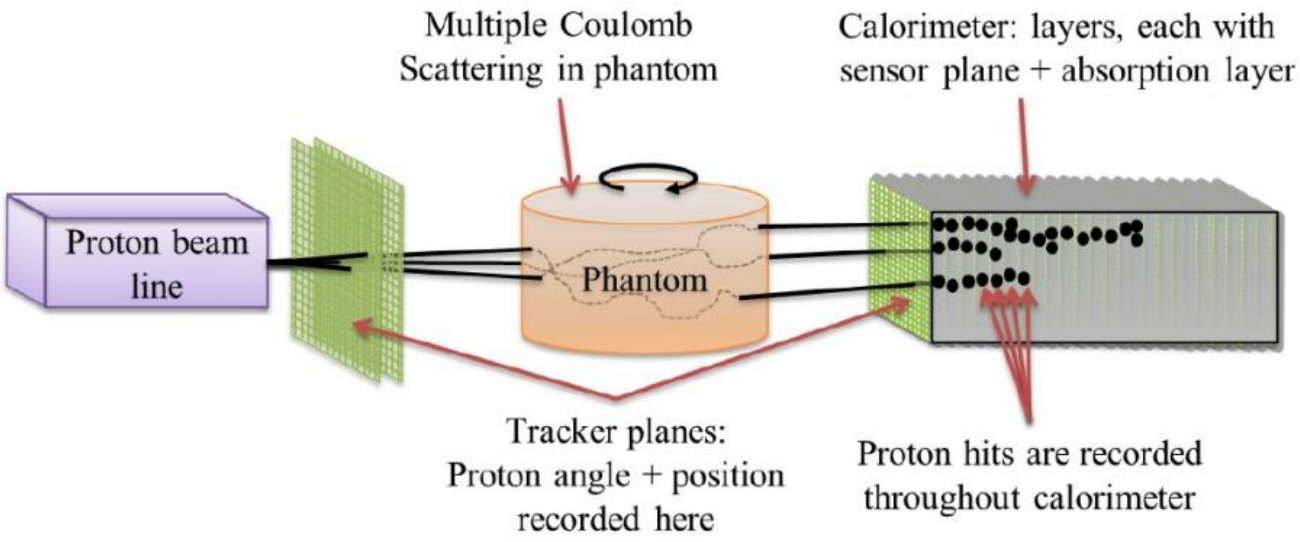
Samsung Medical Center
(http://www.samsunghospital.com)

Introduction:

- **Proton imaging**
  - ✓ Tracking proton beams : tracking individual protons through the detector
    - ➡ Estimating path of individual protons
  - ✓ Proton CT 3D image reconstruction by:
    - ➡ Finding proton vectors before / after patient
    - ➡ Finding proton energy before / after patient
    - ➡ Energy loss calculation
    - ➡ Repeating for different projections (phantom or device)



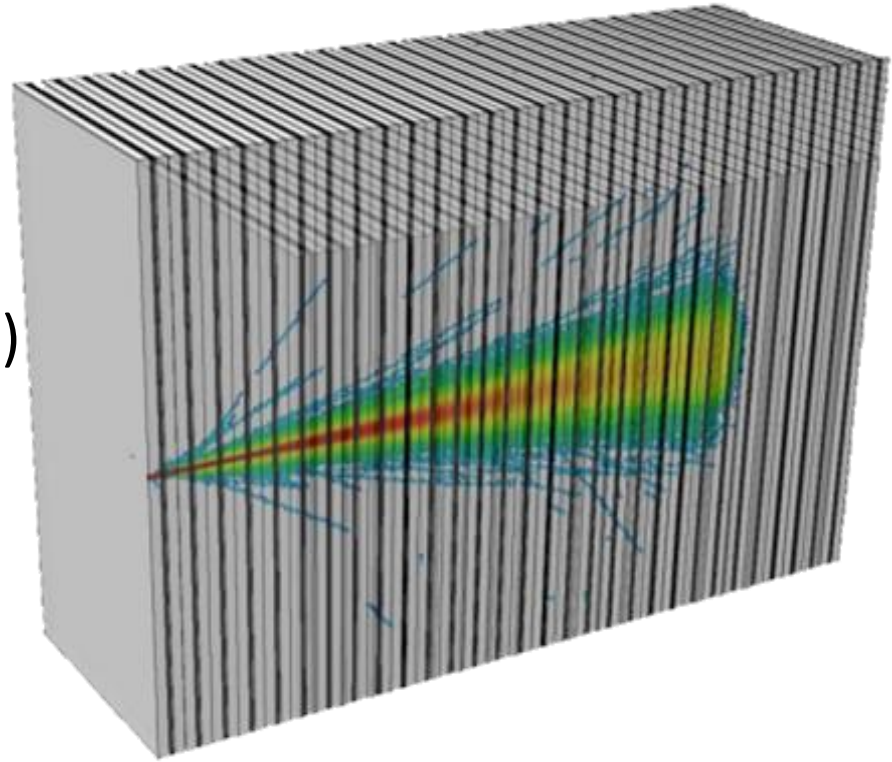
(Pettersen H.E.S., 2017)



(Pettersen H.E.S., 2017)

DTC Mechanical Package

- **Digital Tracking Calorimeter(Design parameters)**
  - ✓ Number of absorber layers and thickness
  - ✓ Material uniformity along proton trajectory
  - ✓ Mechanical stability
  - ✓ Fabrication & manufacturing aspect
  - ✓ Chip & readout electronics (mounting, sensitive area)
  - ✓ Bonding method
  - ✓ Heat transfer & Cooling
  - ✓ Mechanical deformation & errors



(Pettersen H.E.S., 2017)

Digital Tracking Calorimeter (DTC)

- **Number of absorber layers for stopping 230MeV protons**

Absorber thickness	Number of layers
2 mm	~63
3 mm	~45
4 mm	~35
5 mm	~29
6 mm	~25

- **Absorber thickness**
- **Material:**
  - ✓ Mechanical properties such as density, hardness, thermal capacity
  - ✓ Homogeneity
  - ✓ Ionization energy
  - ✓ Mechanica lintegrity, economy and clinical considerations

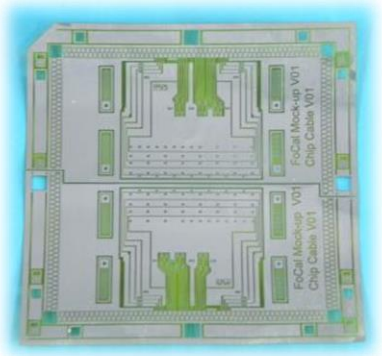


Figure from LTU

- **Material uniformity along proton trajectory**
  - ✓ Electrical connectors, wirings
  - ✓ Coolant channel
  - ✓ Support structure

Figure from ALICE ITS

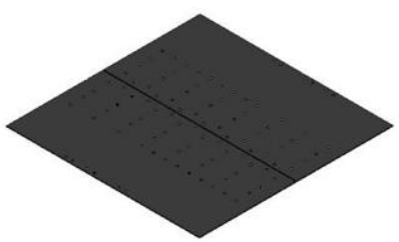
Digital Tracking Calorimeter (DTC)

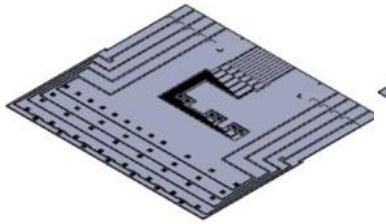
- **Mechanical Stability**
  - ✓ Solid & stiff structure
  - ✓ Assembly and maintenance reliability
  - ✓ No vibration
  - ✓ Production feasibility

- **Clinical considerations**
  - ✓ Working temperature range
  - ✓ No poisonous materials
  - ✓ Coolant leakage
  - ✓ Short circuit

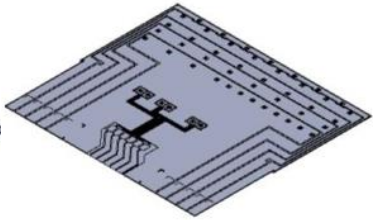
Digital Tracking Calorimeter (DTC)

- **Stave assembly of Chip & read-out electronics**
  - ✓ Chip size = 1.5cm x 3cm
  - ✓ Required sensitive area = 18cm x 27cm
  - ✓ Space for data readout strip
  - ✓ Cooling methods & coolant channel
  - ✓ Uniformity

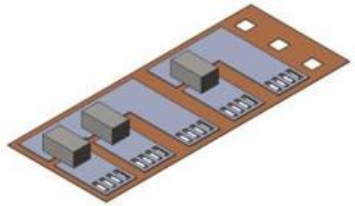




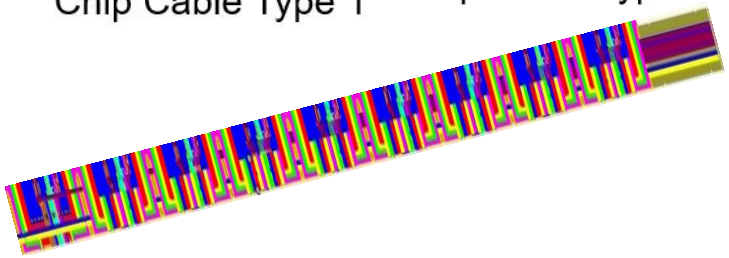
Chip Cable Type 1

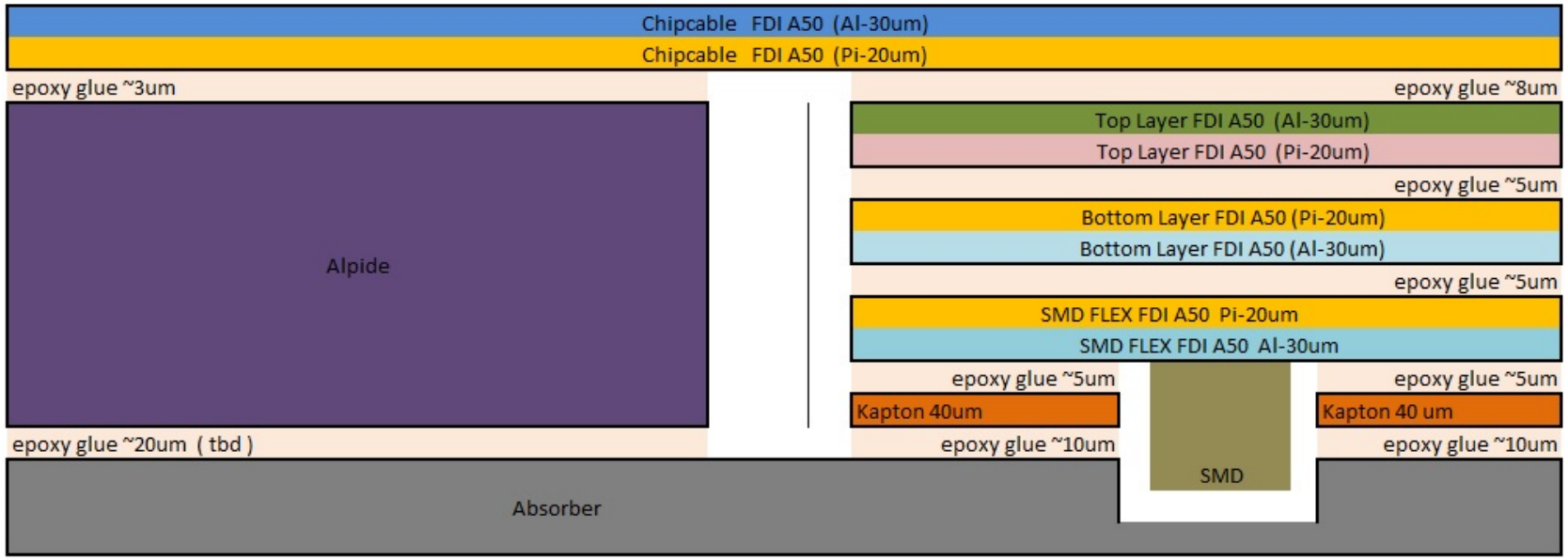


Chip Cable Type 2



SMD Flexmount





Figures from LTU: ''9 Alpide string'' & Nikhef '' Mock up of Focal slab''

Digital Tracking Calorimeter (DTC)

- **Bonding method**

  Mechanical Connection → Ultrasound welding

  Dielectric connection → Glue protection

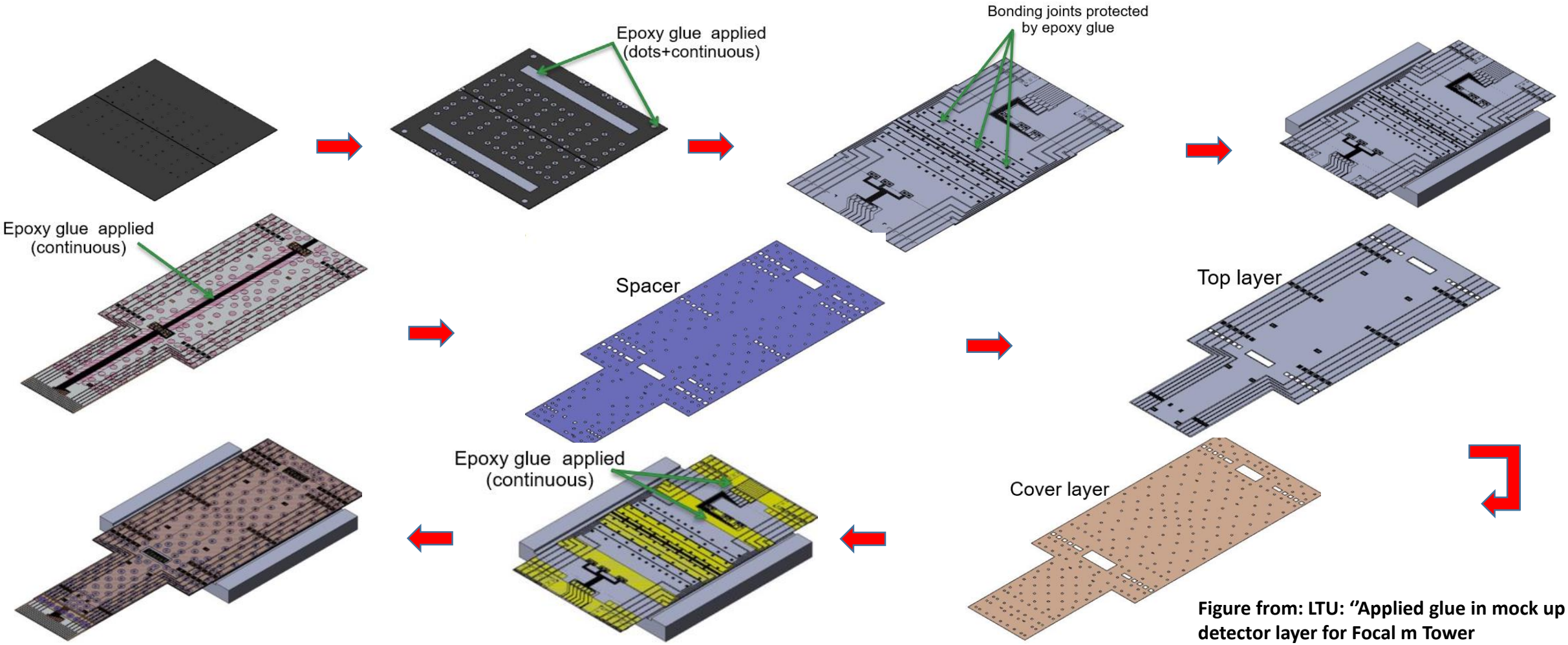


Figure from: LTU: ''Applied glue in mock up of detector layer for Focal m Tower

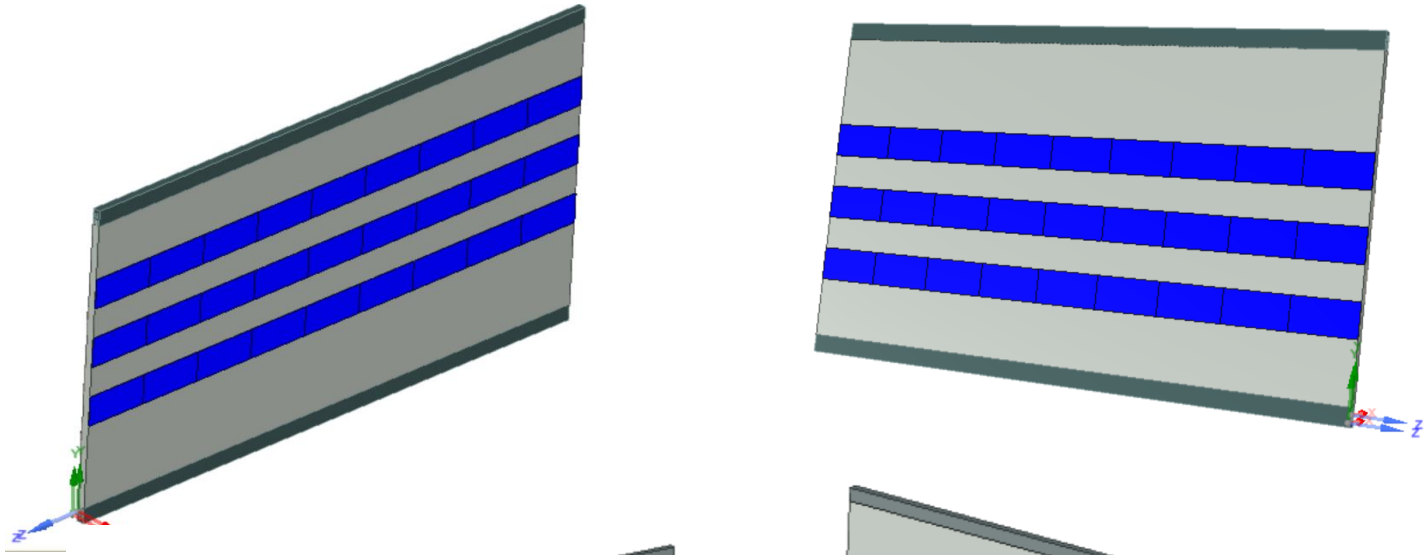
Digital Tracking Calorimeter (DTC)

- **Sensitive area (placement of chips)**

➡ 12 Rows, each with 9 chips side-by-side

Two Scenarios:

1)



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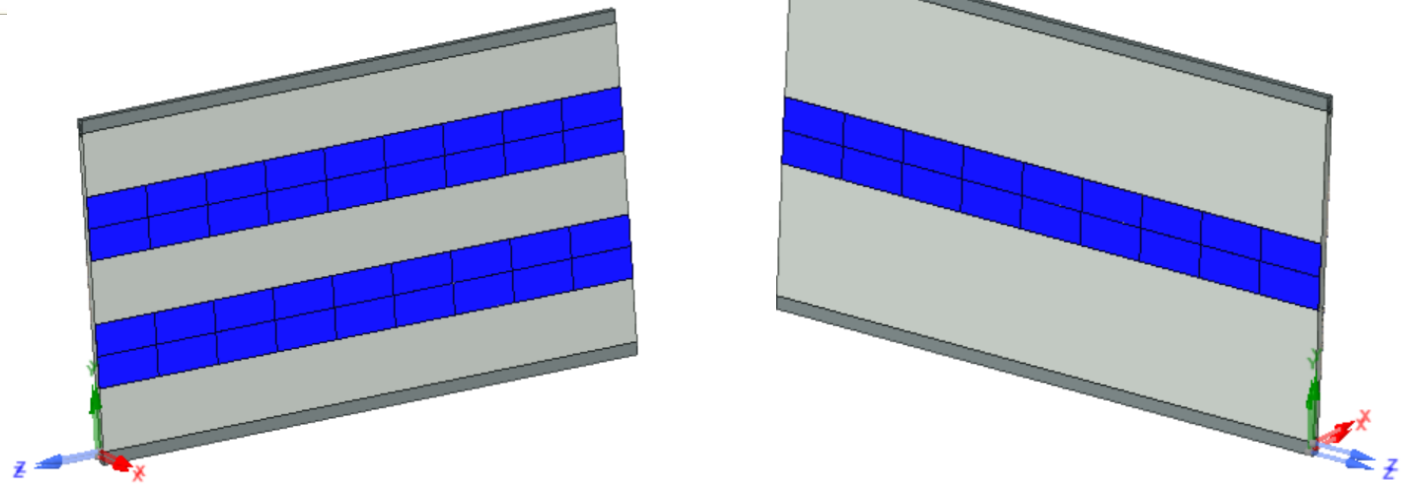
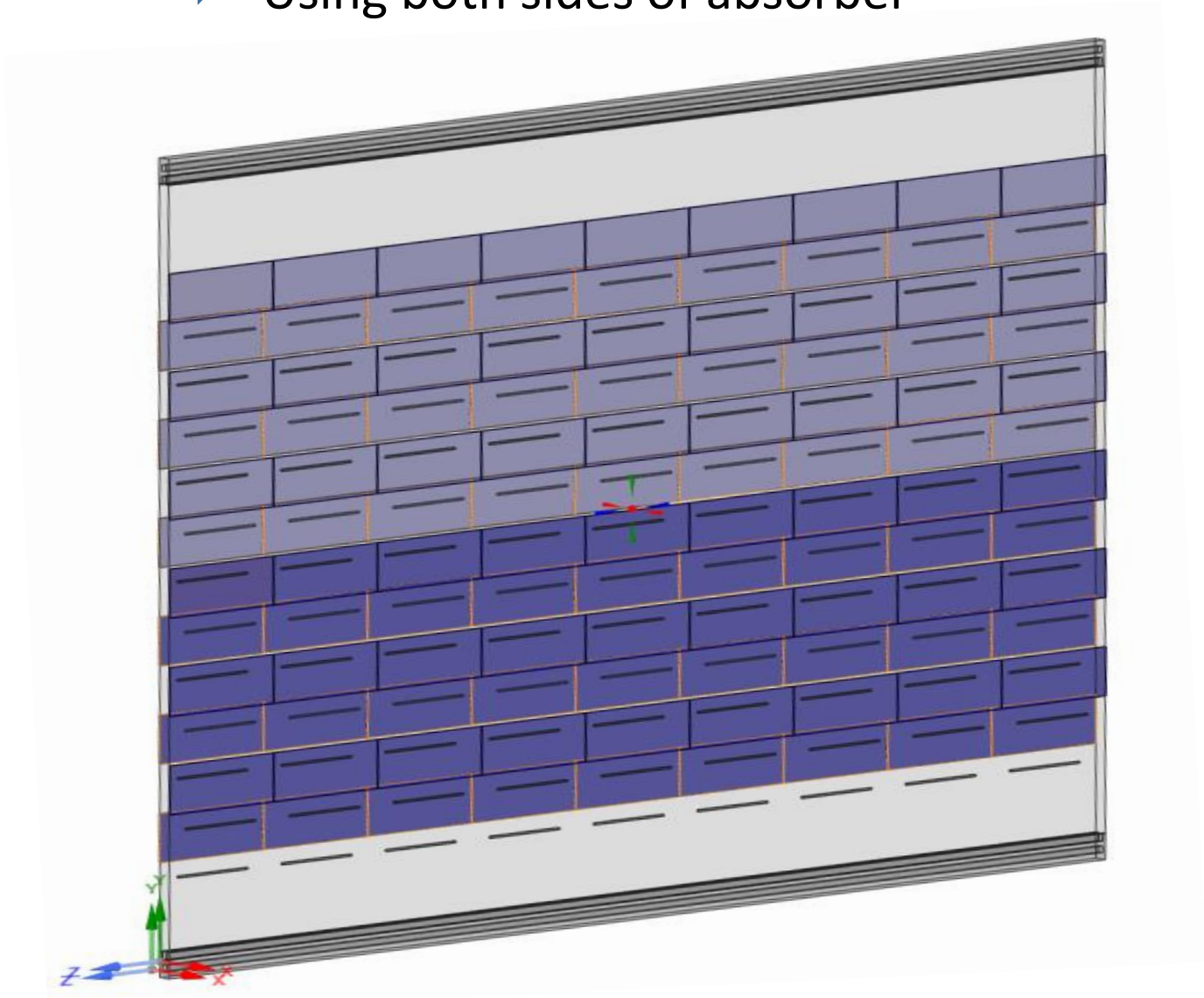
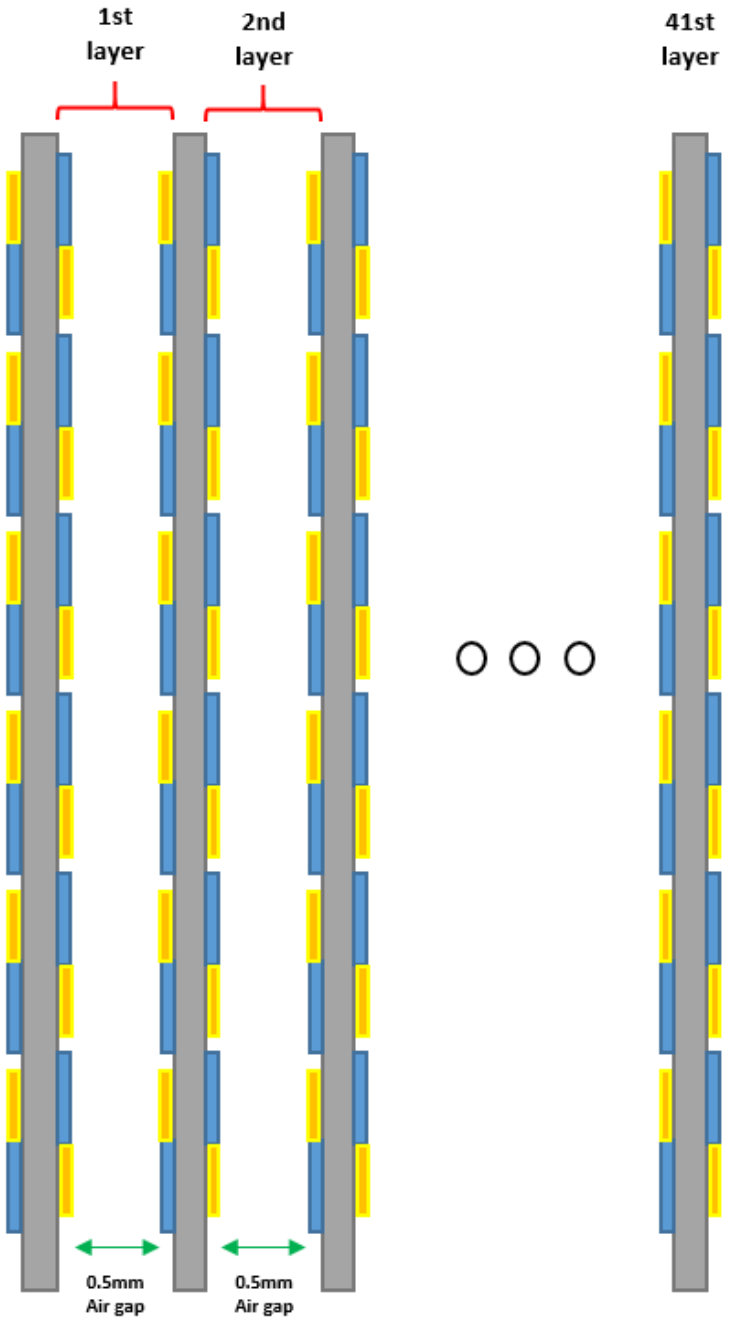


Digital Tracking Calorimeter (DTC)

- **Sensitive area (placement of chips):**
  - ➡ Temperature distribution (FEM study)
  - ➡ Using both sides of absorber





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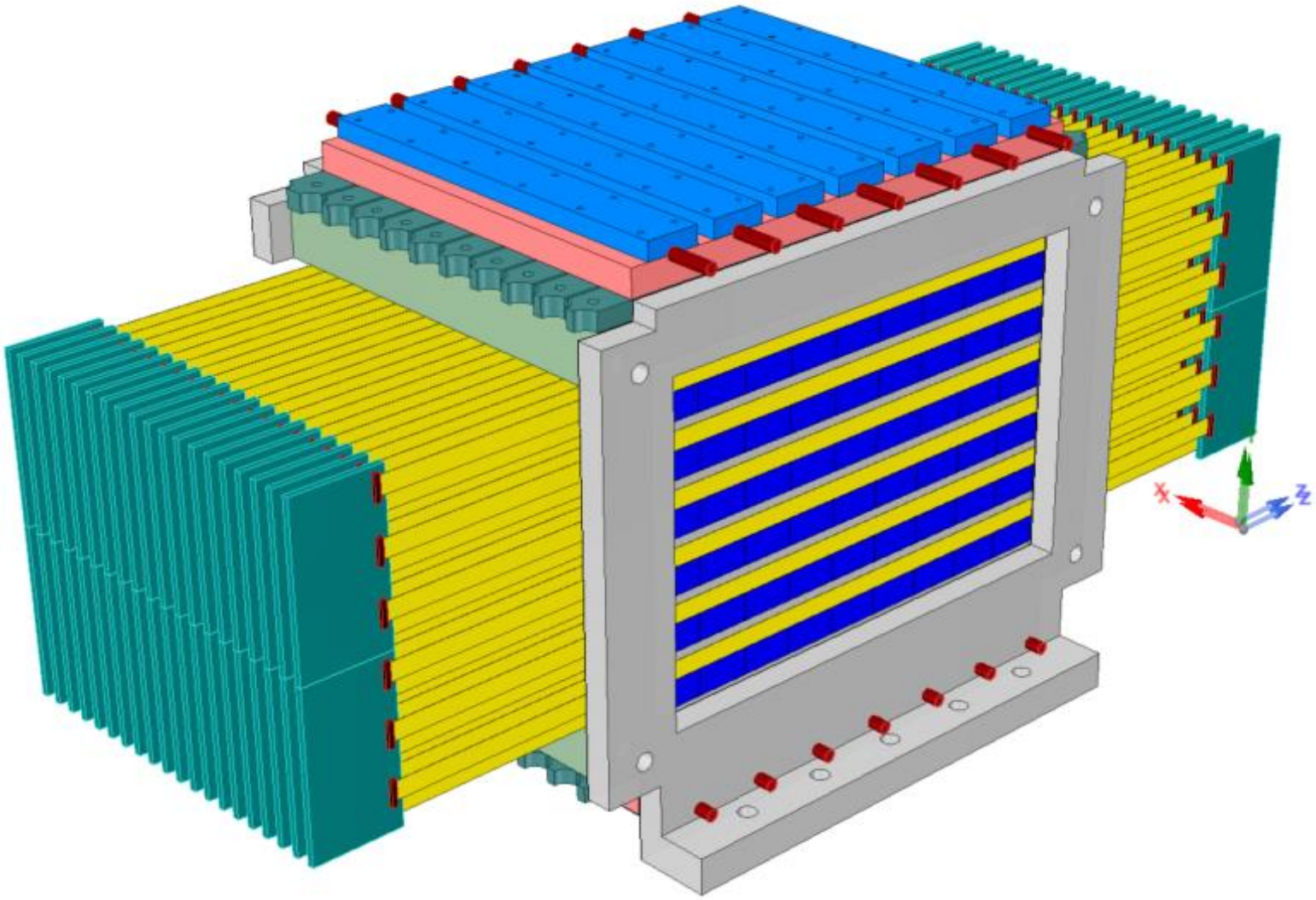
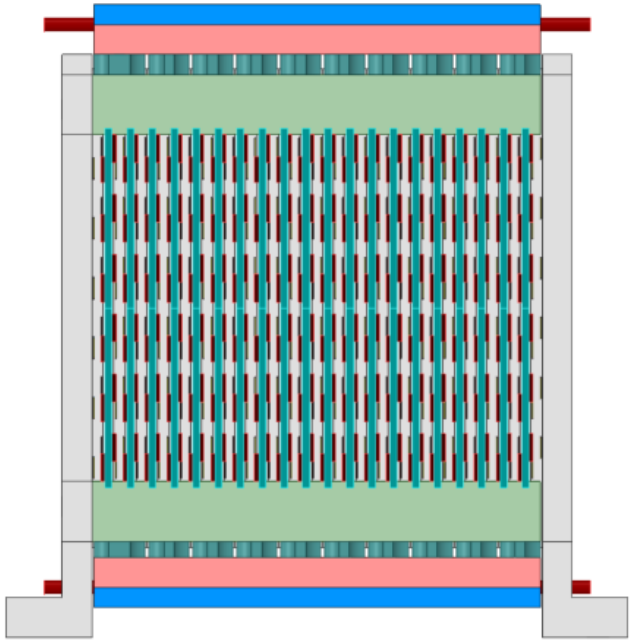
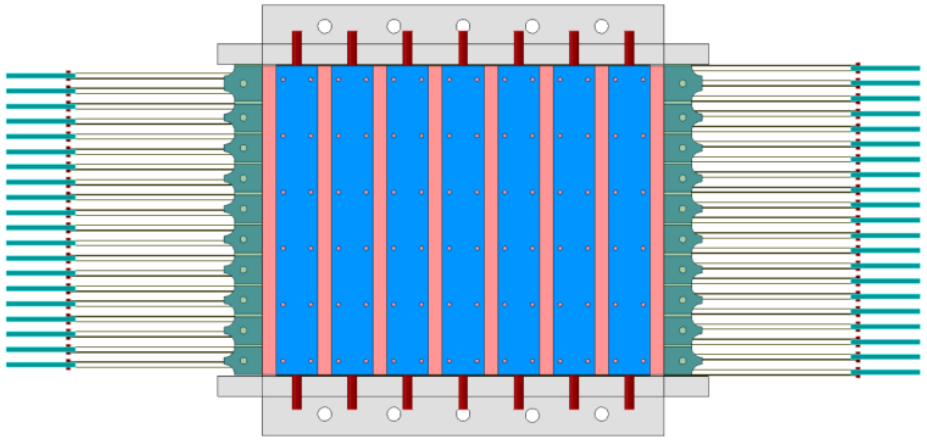
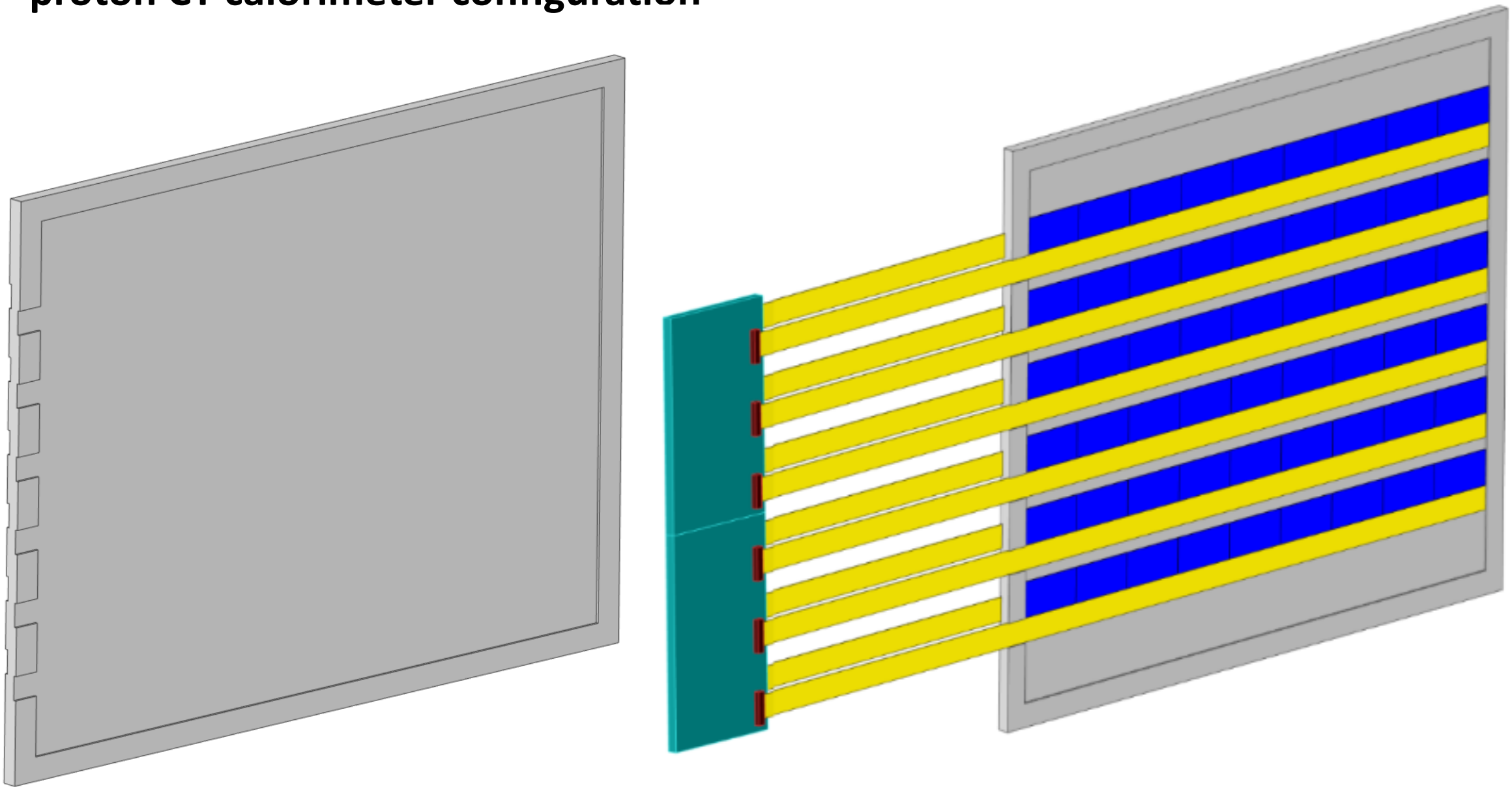






Digital Tracking Calorimeter (DTC)

- **proton CT calorimeter configuration**



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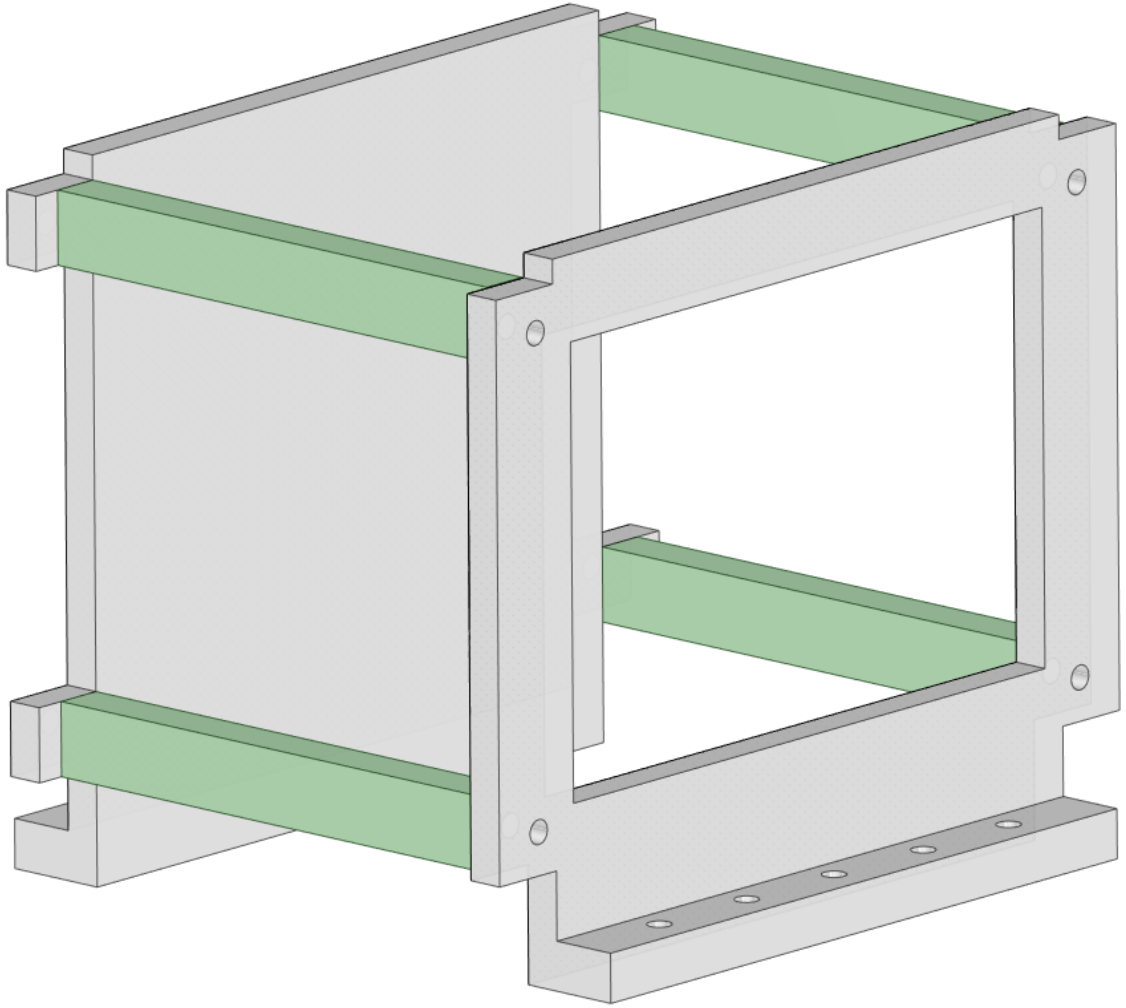

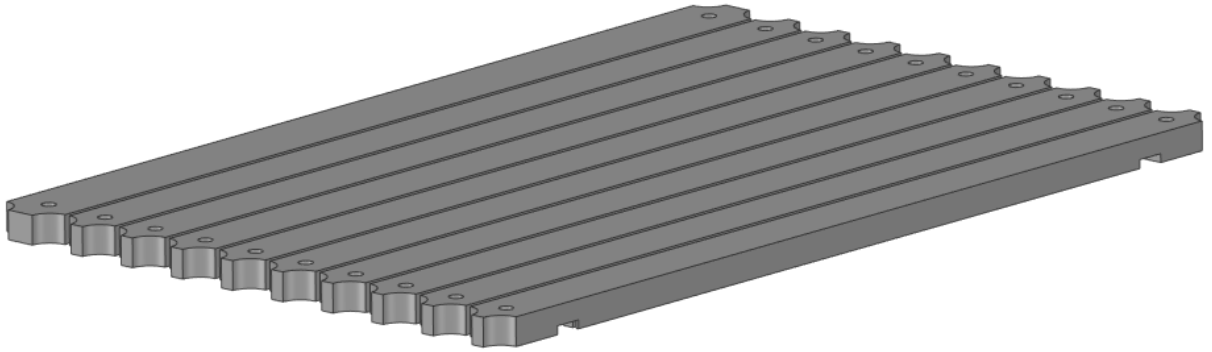

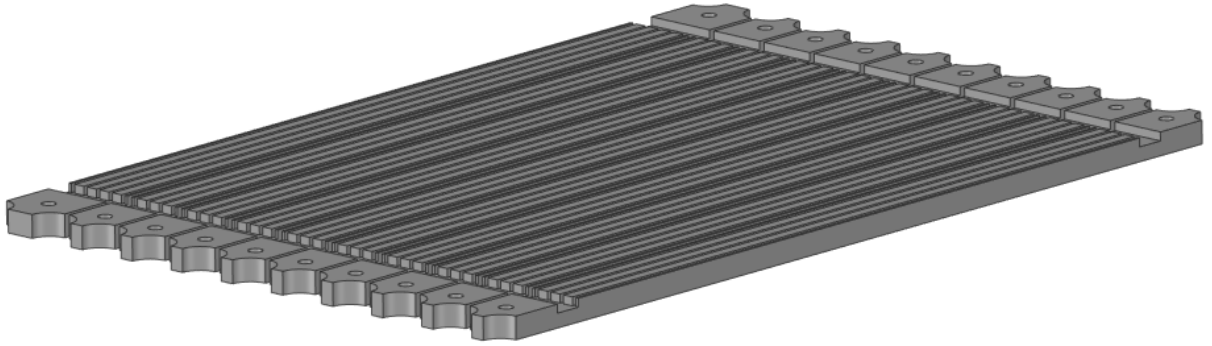

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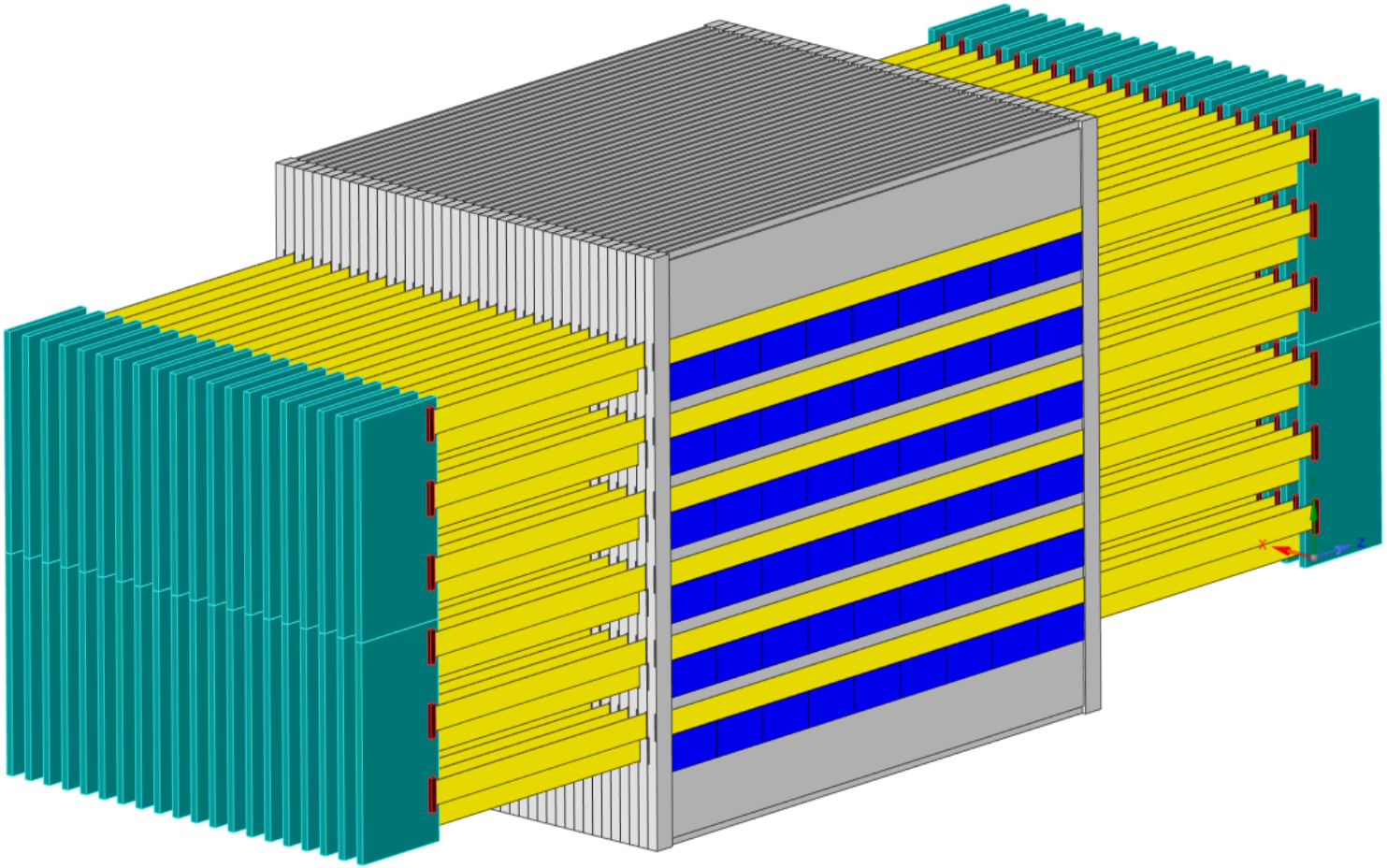
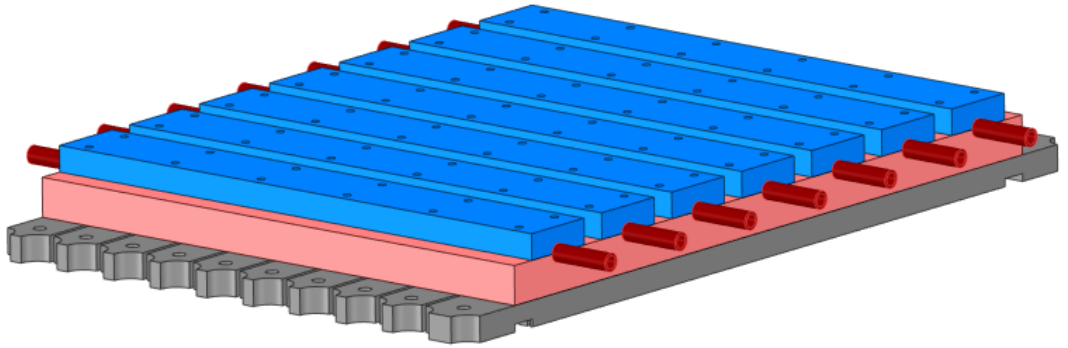
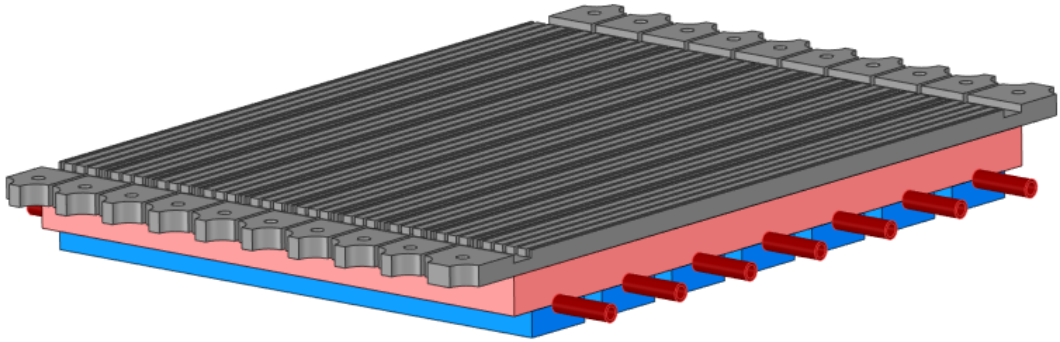


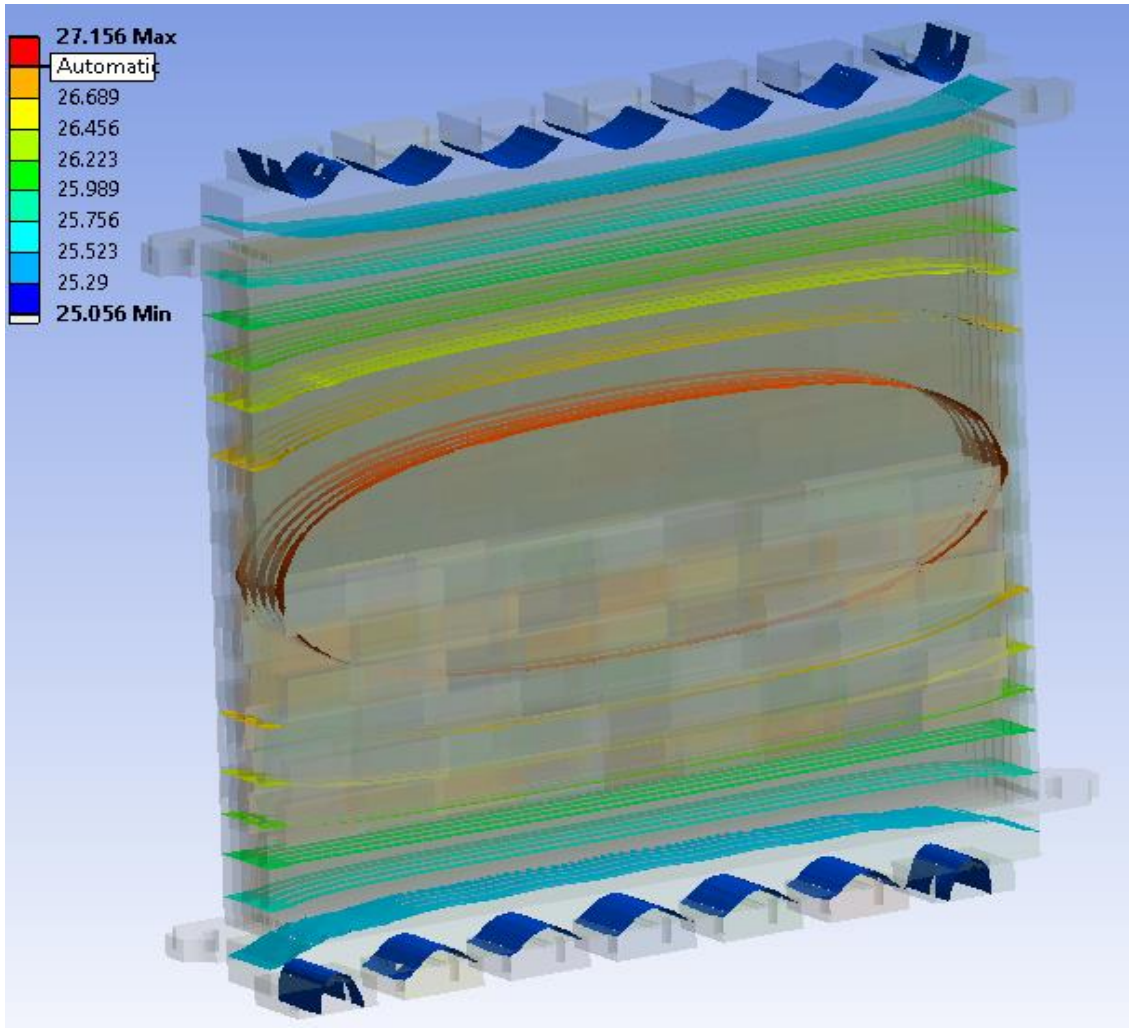




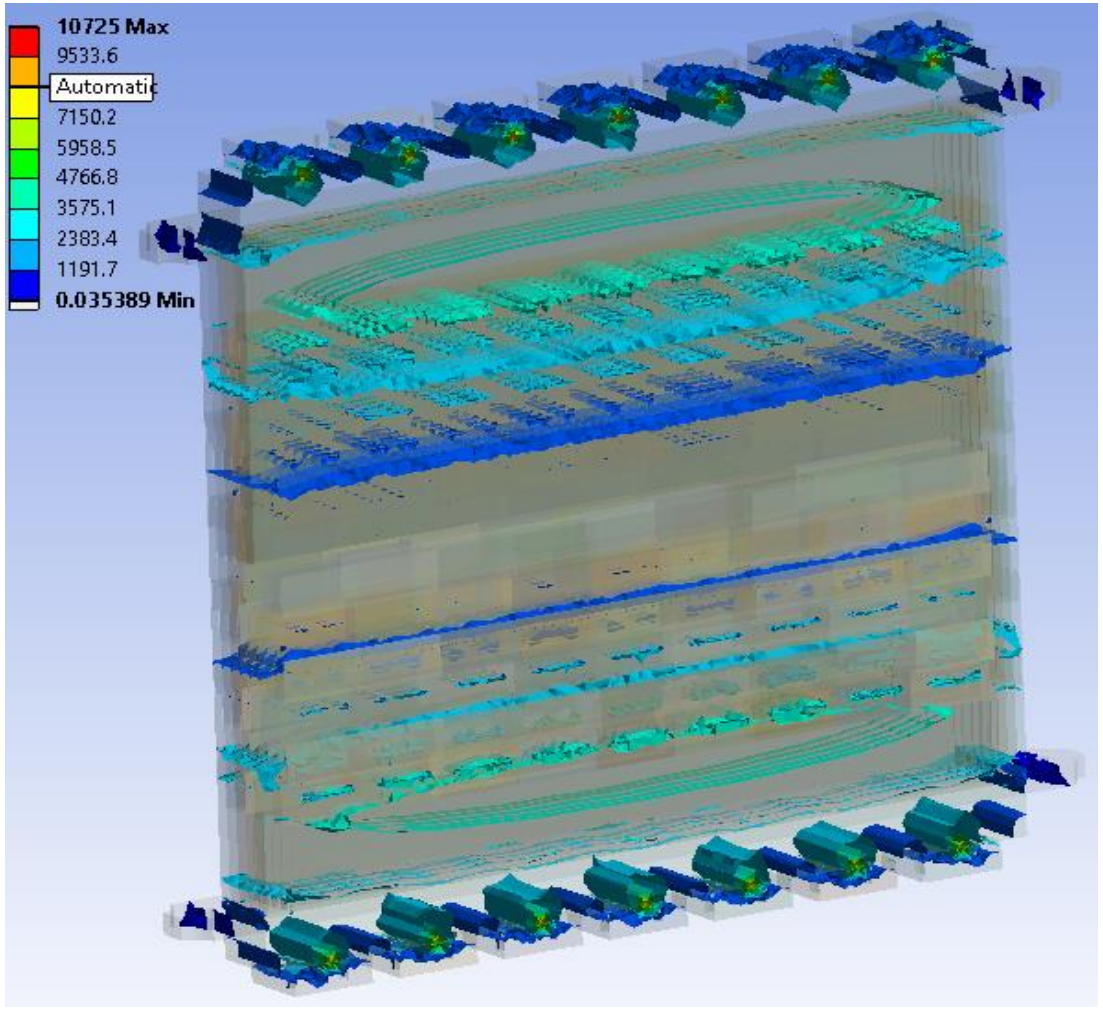
Digital Tracking Calorimeter (DTC)

- **Simulation result for 5 stack layers pack**
  - ➡ Free convection
  - ➡ 50 mW/Cm2 heat generation
  - ➡ Laminar water cooling(T=5°C, V=1m/s)
  - ➡ Ambient Temperature 22

Temperature distribution(C)
Max ~ 26.7°C



Heat Flux (W/m2)
Max ~ 14828 W/m2



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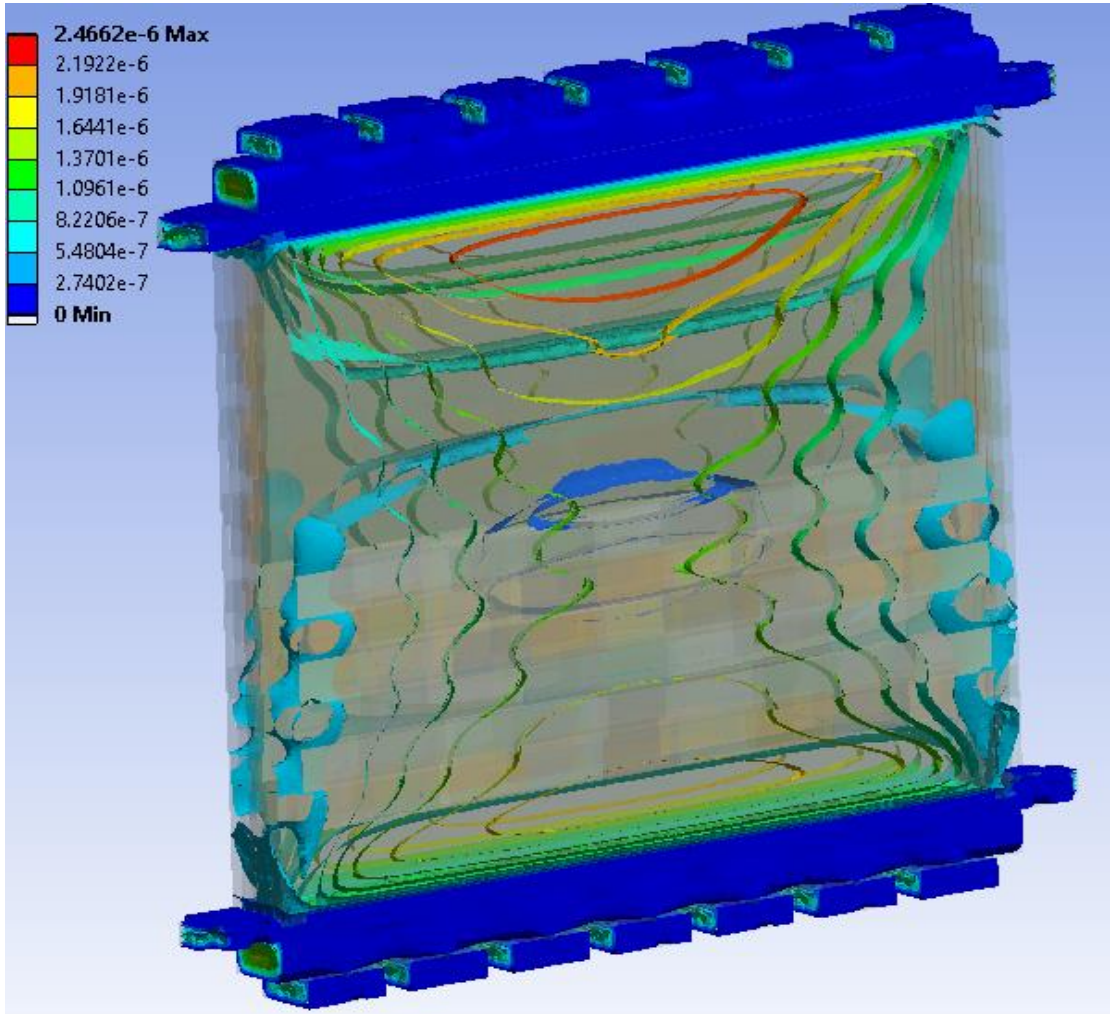
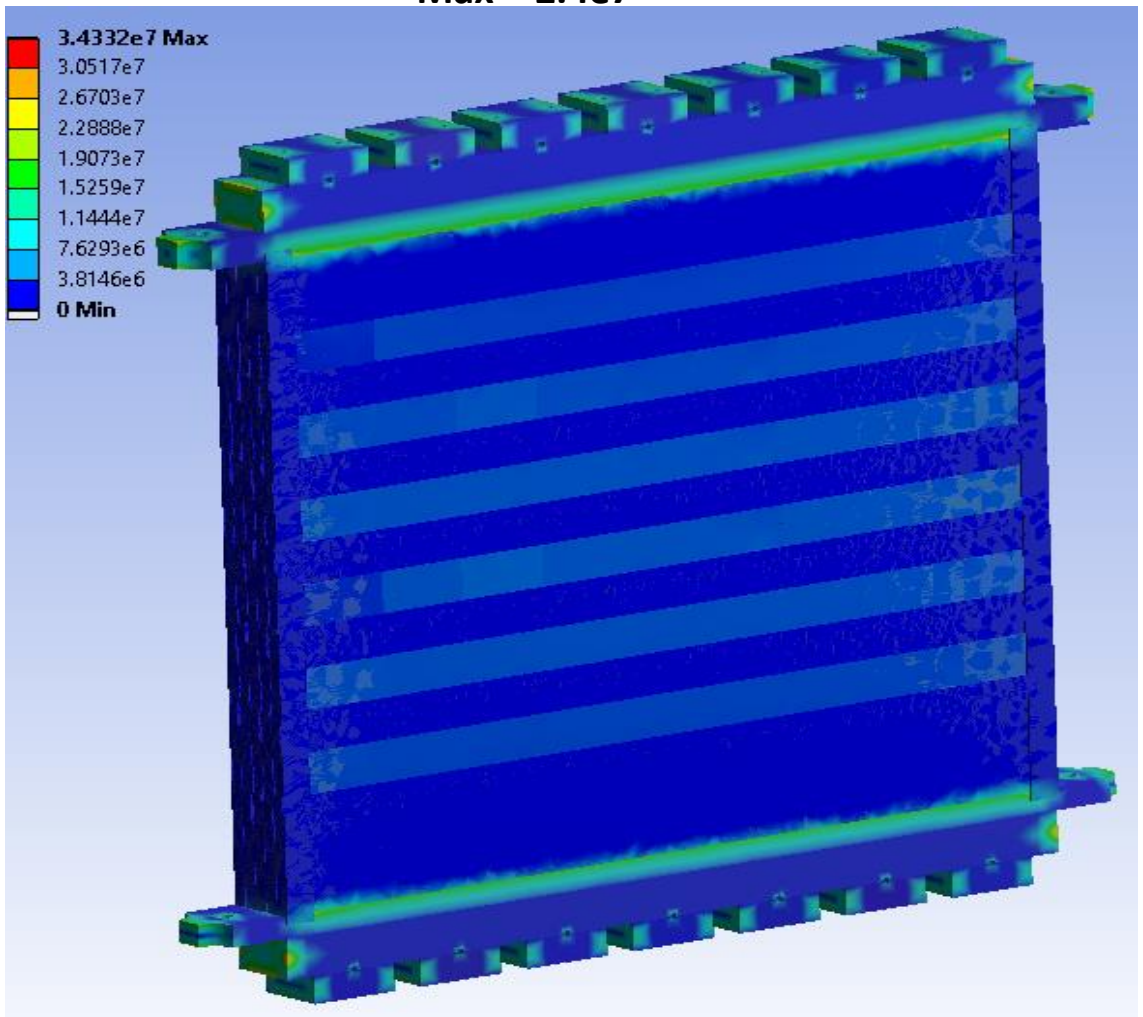
Total Deformation(m)
Max ~ 1.8e-6 m

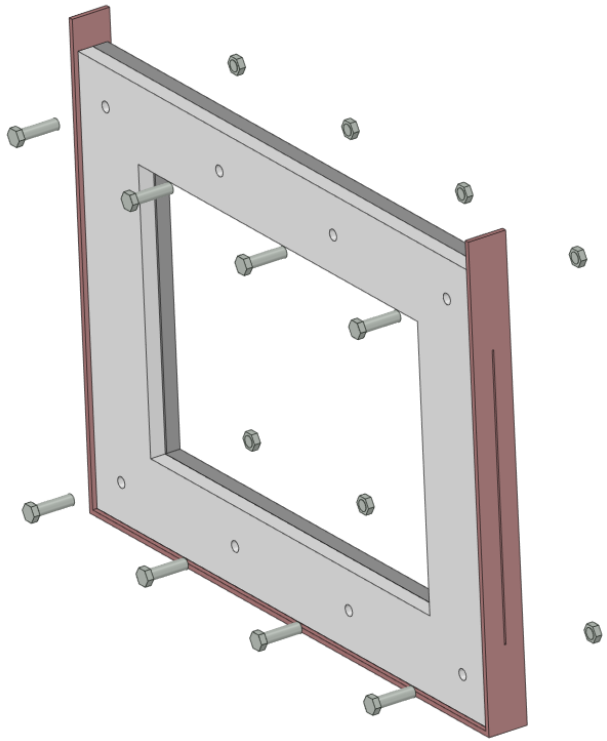


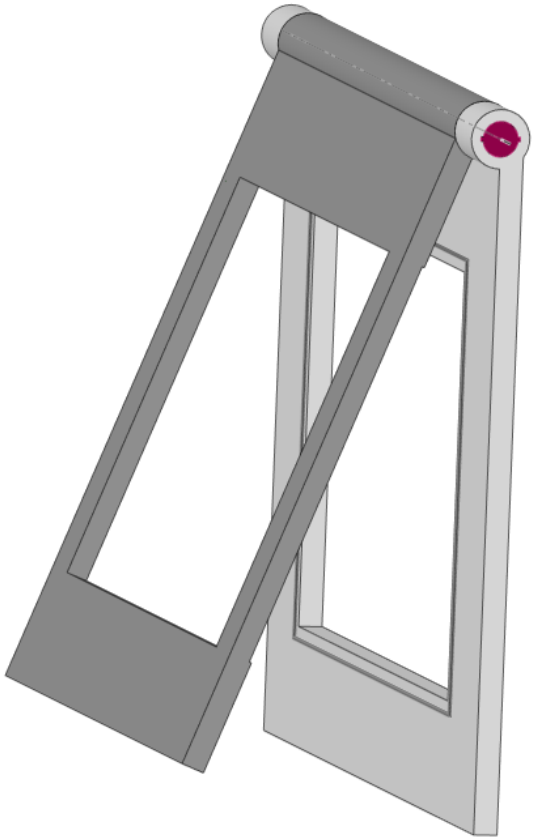
Equivalent Stress(Pa)
Max ~ 2.4e7

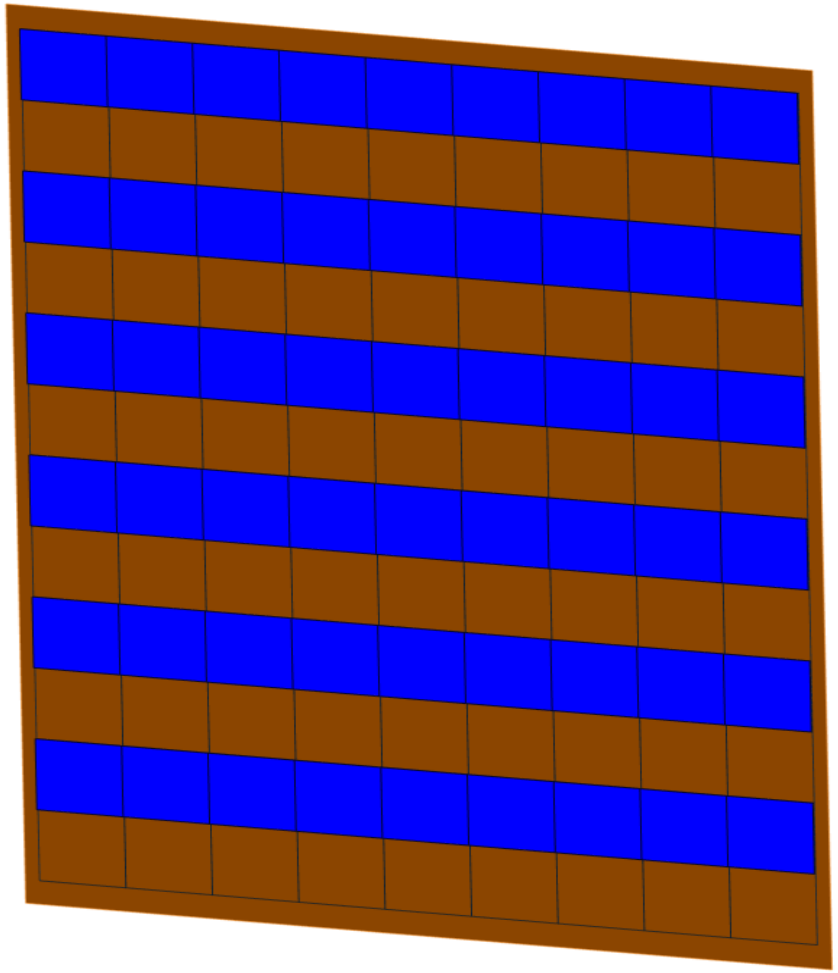


Digital Tracking Calorimeter (DTC)

- **Tracker Plates (Front layers)**
  - ➡ Minimize multiple scatering
  - ➡ Mechanical stiffness, stability, integrity
  - ➡ Assembely & fabrication challenge
  - ➡ Cooling challenge







Al Thikness=200 µm
Electronics = 253 µm
Total ~ = 0.5 mm

Digital Tracking Calorimeter (DTC)

Future Studies:

- Integrity & Reliability of front tracker layers:
  - Mechanical stability
  - Cooling
  - Protection

- Detectore Coolant study:
  - intensive heat transfer methods (Fluid Mechanics -CFD-)
  - Humidity & ventilation solution
  - Stave in plate heat transfer (Bonding, Thermal contact resistance)

- Data readout developement

- Sensitivity study of electronic layer arrangement

- Deformation analysis (Operational & accidental) and effect imaging accuracy

Thank You