MPGD-ECT

Updates on Assembly R&D and Cooling

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Istituto Nazionale di Fisica Nucleare

Outline

- Cooling
- Alternative assembly schemes
- Production tooling

Alternative Assembly Schemes

First results from the R&D

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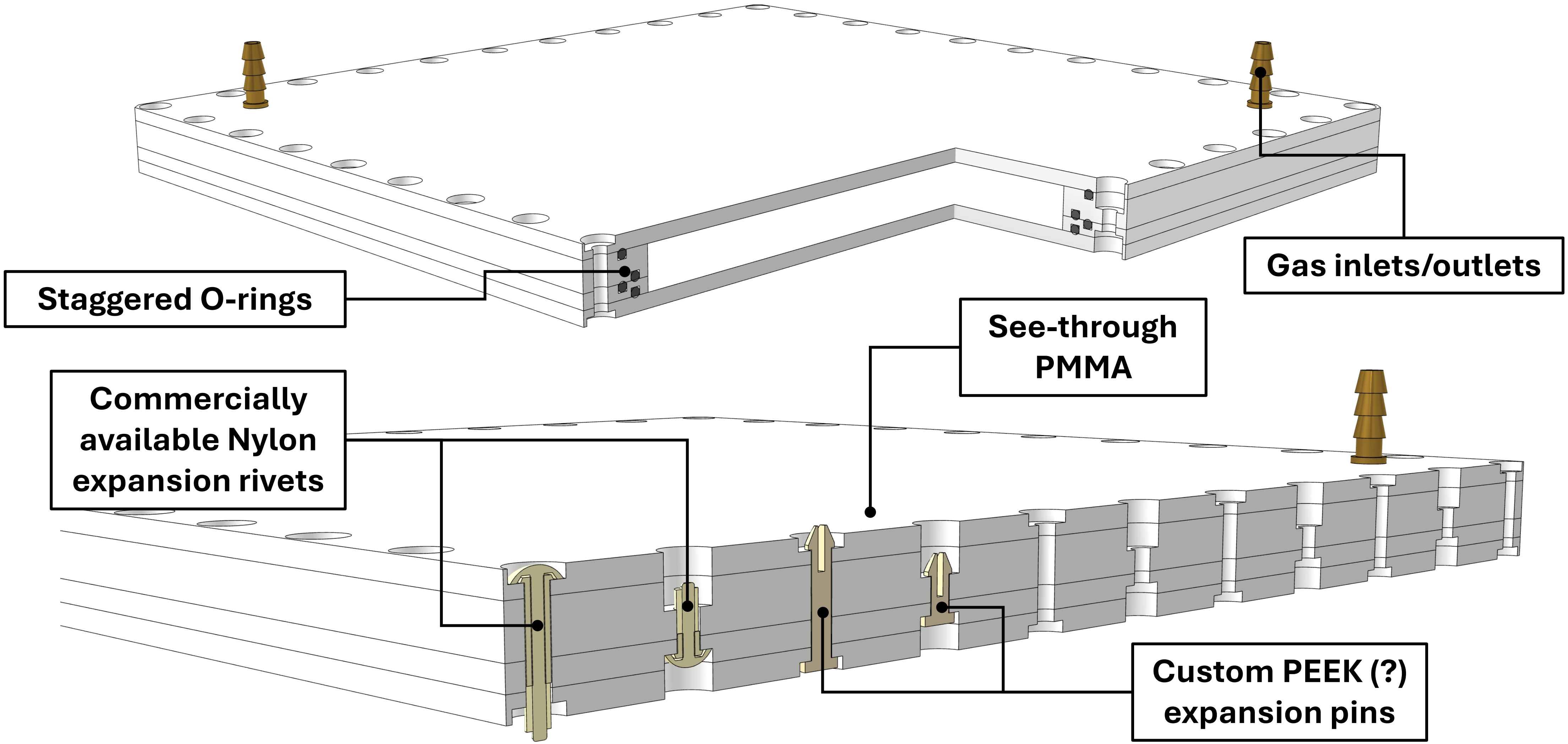
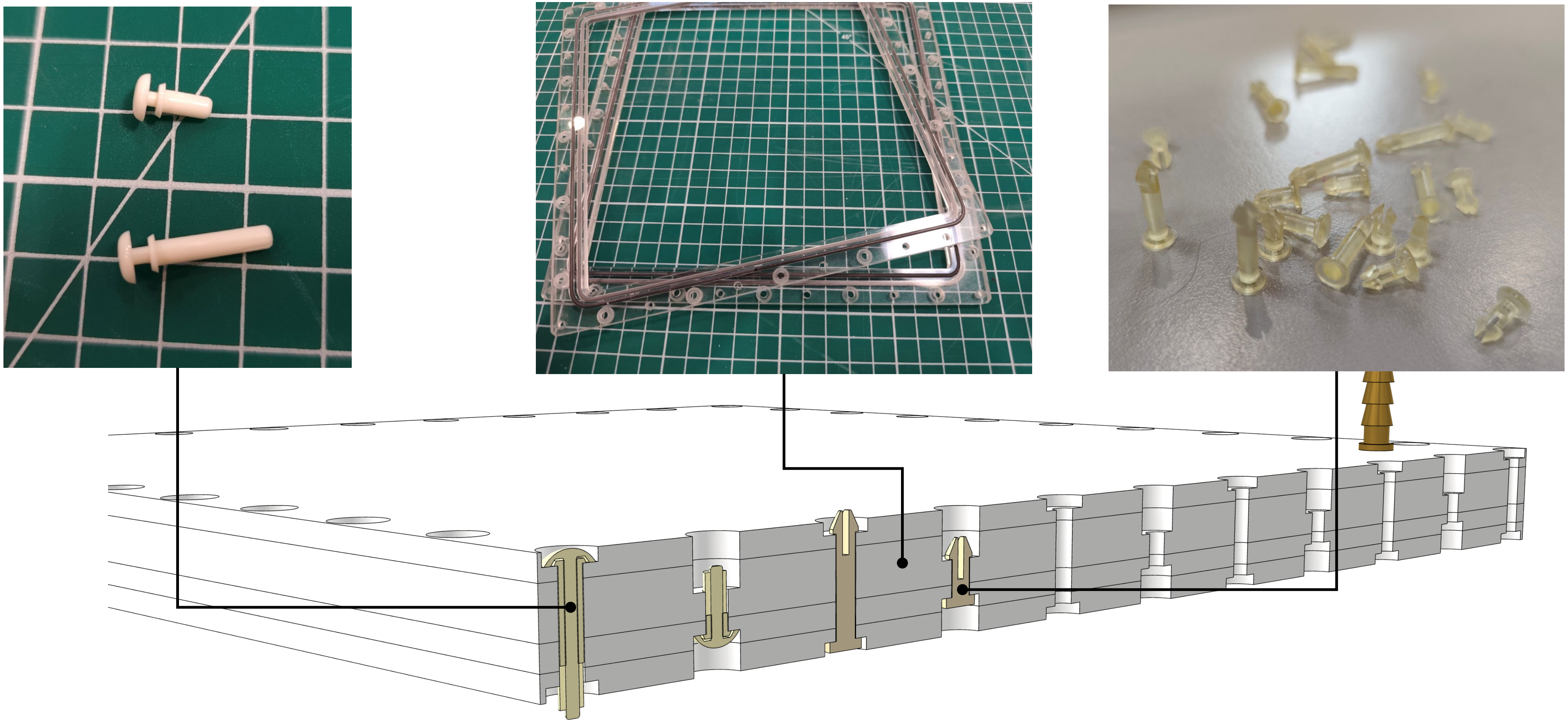
Metal Free Assembly Demonstrator



Procurement

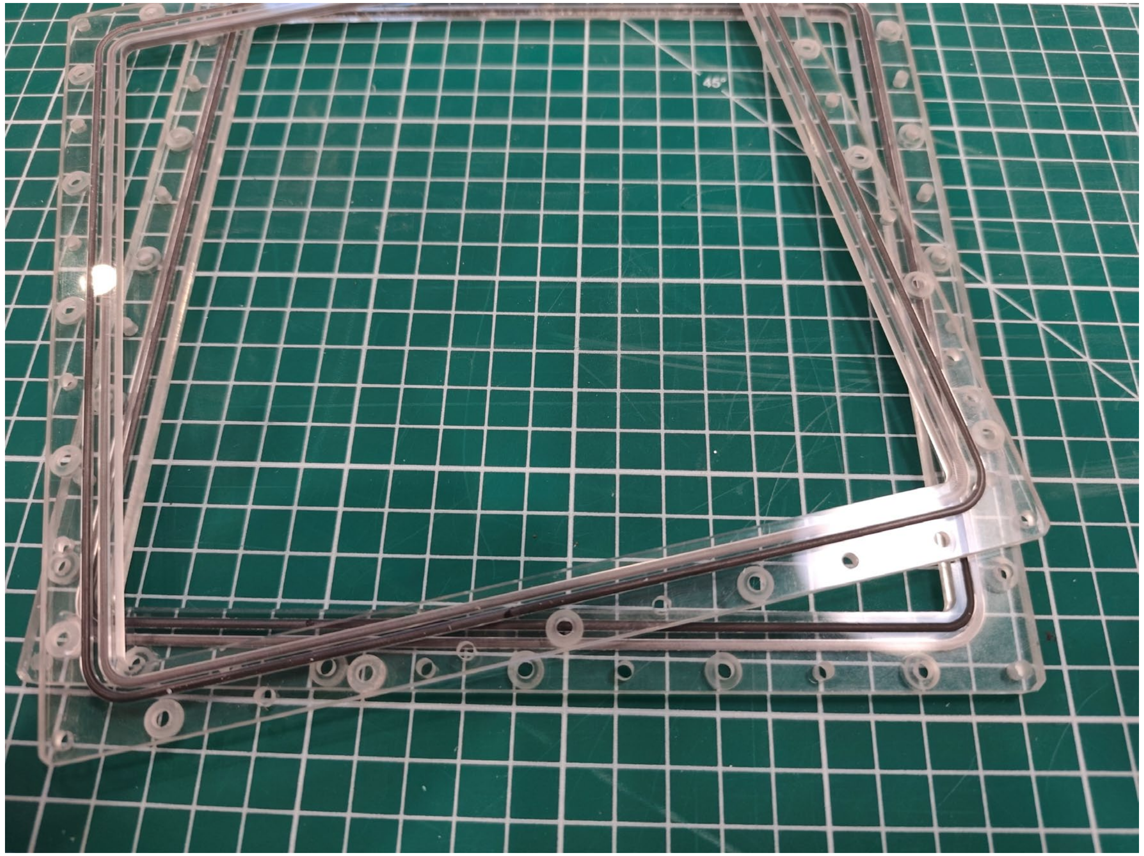


Mock-up Production

Mock-up parts manufactured internally from PMMA (Plexiglas)

Large variations in the thickness of the raw PMMA slabs → O-ring grooves out of tolerance

O-rings made of Ø2 mm, 75 Shore A, FKM (Viton) O-ring cord, glued with Loctite 406



Custom Pin Prototyping / 1

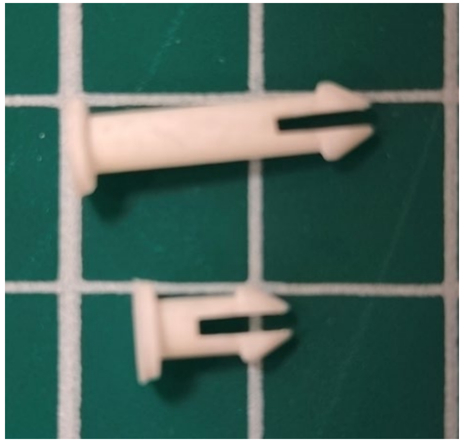
Formlabs © Clear Resin V5

Material Properties	METRIC [1]		
	Green	Post-Cured for 5 min at ambient temperature [2]	Post-Cured for 15 min at 60 °C [3]
Tensile Properties	METRIC [1]		
Ultimate Tensile Strength	46 MPa	51 MPa	60 MPa
Tensile Modulus	2200 MPa	2575 MPa	2750 MPa
Elongation at Break	13%	10%	8%
Flexural Properties	METRIC [1]		
Flexural Strength	82 MPa	91 MPa	103 MPa
Flexural Modulus	2000 MPa	2450 MPa	2750 MPa
Impact Properties	METRIC [1]		
Notched Izod	31 J/m	29 J/m	
Thermal Properties	METRIC [1]		
Heat Deflection Temp. @ 1.8 MPa	54 °C		57 °C
Heat Deflection Temp. @ 0.45 MPa	61 °C		69 °C

Custom Pin Prototyping / 2

Formlabs © Rigid 10K Resin - Glass filled

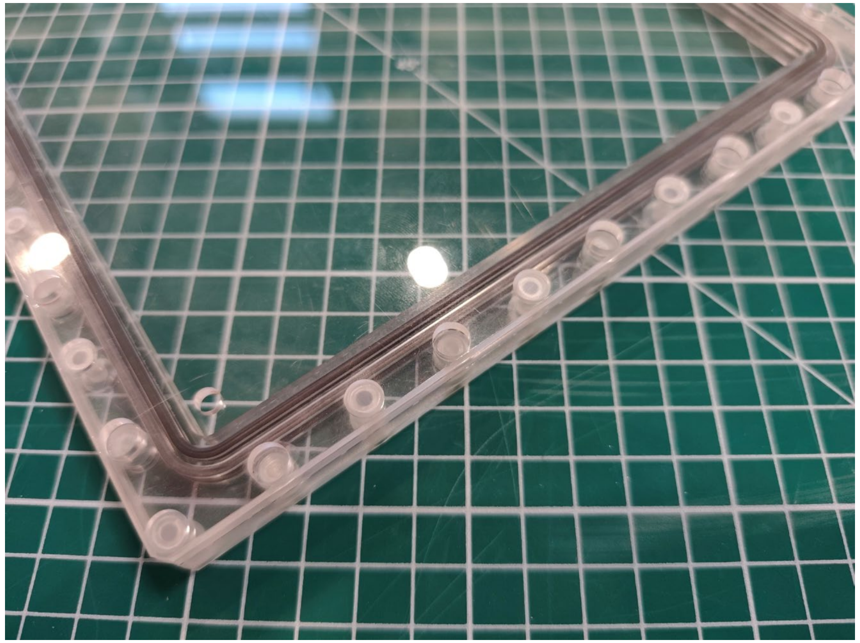
Before tip compression



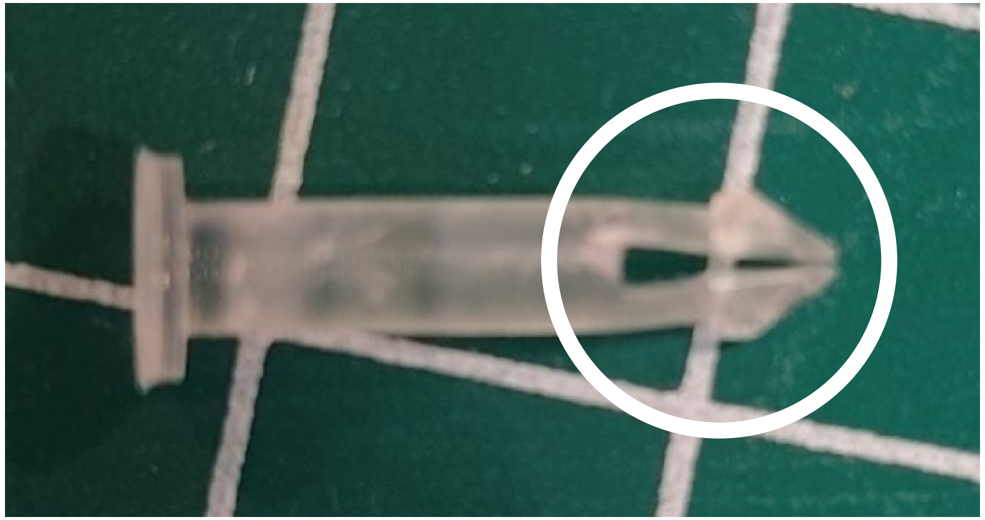
After tip compression

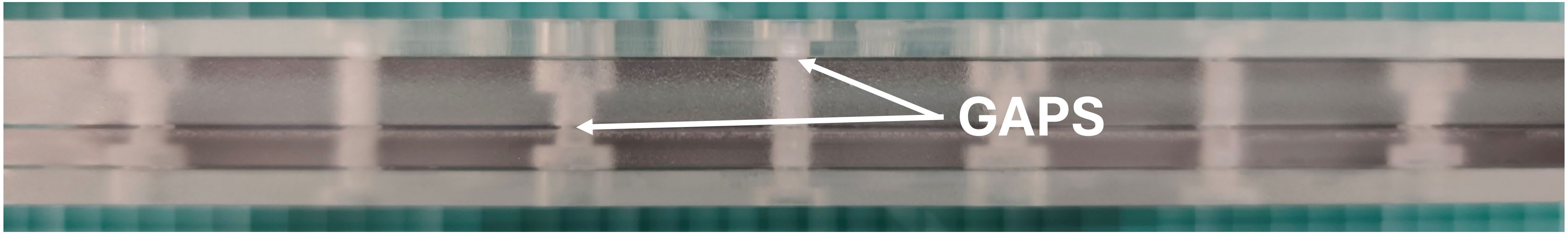
Material Properties	METRIC			
	Green	**Post-Cured** for 60 min at 70 °C[1]	**Post-Cured** for 60 min at 70 °C and 125 min at 90 °C[2]	**Post-Cured** for 60 min at 70 °C and Media Blasted
Tensile Properties	METRIC			
Ultimate Tensile Strength	55 MPa	65 MPa	53 MPa	88 MPa
Tensile Modulus	7.5 GPa	10 GPa		11 GPa
Elongation at Break	2%	1%		1.7%
Flexural Properties	METRIC			
Flexural Strength	84 MPa	126 MPa	103 MPa	158 MPa
Flexural Modulus	6 GPa	9 GPa	10 GPa	9.9 GPa
Impact Properties	METRIC			
Notched Izod	16 J/m	16 J/m	18 J/m	20 J/m
Unnotched Izod	41 J/m	47 J/m	41 J/m	130 J/m
Thermal Properties	METRIC			
Heat Deflection Temp. @ 0.45 MPa	65 °C	163 °C	218 °C	238 °C
Heat Deflection Temp. @ 1.8 MPa	56 °C	82 °C	110 °C	92 °C
Thermal Expansion, 0-150 °C	48 μm/m/°C	47 μm/m/°C	46 μm/m/°C	41 μm/m/°C

Custom Pin Test

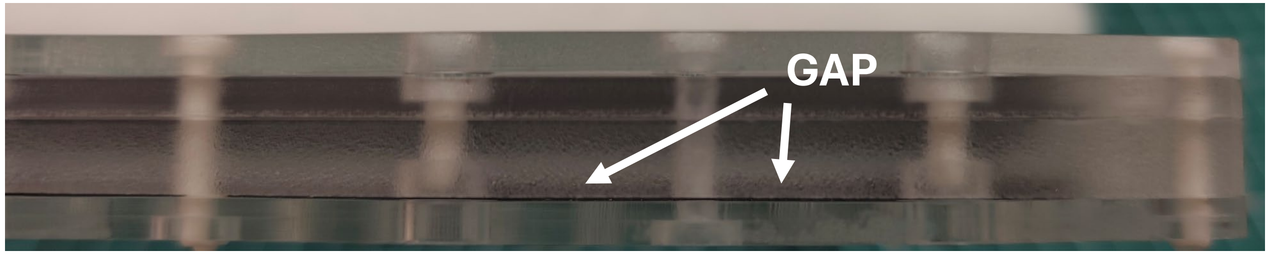


Plastic Deformation → the resin is not suitable

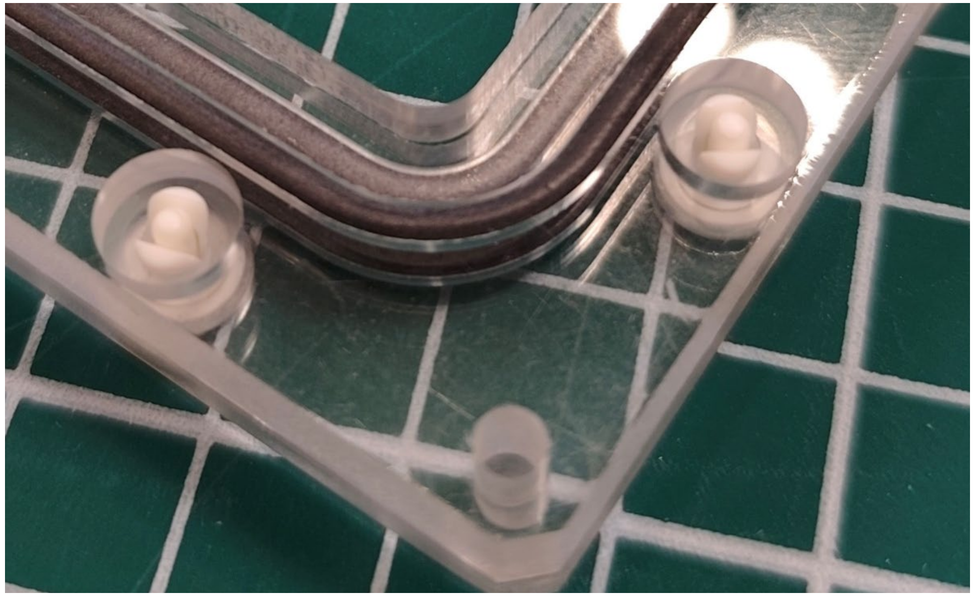




Commercial Expansion Rivet Test



Missing Rivet



Roadmap Toward Technology Adoption

Commercial Rivets

- Gas leakage test (NEXT)
- FR4 mock-up production
- GEM tensioning test
- Gas leakage test 2
- Thermal stress test
- Vibration resistance test
- Radiation hardness test (?)

Custom Pins

- New materials/manufacturing methods (NEXT)
- Pin design optimization
- FR4 mock-up production
- Production sample run
- GEM tensioning test
- Gas leakage test 2
- Thermal stress test
- Vibration resistance test
- Radiation hardness test (!)

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Cooling

Heatsink Design and Thermal Simulation

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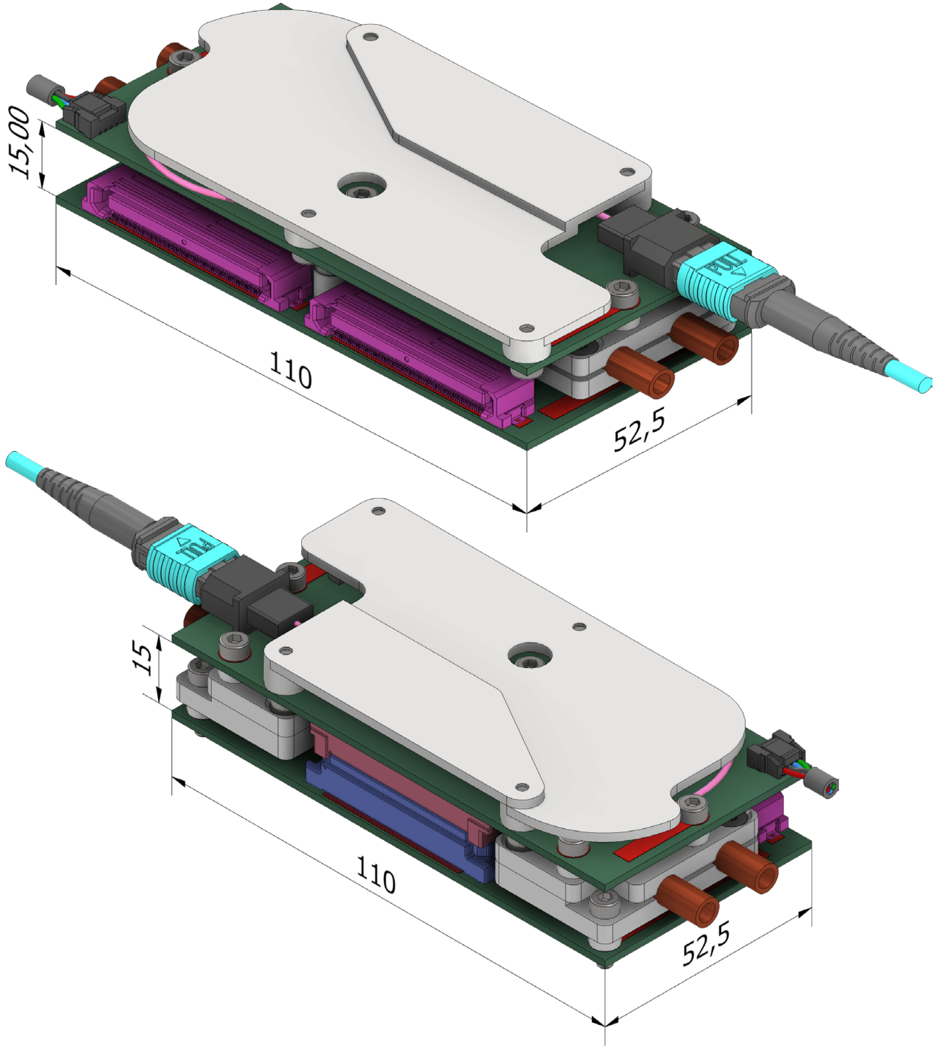
Front End Board Conceptual Design

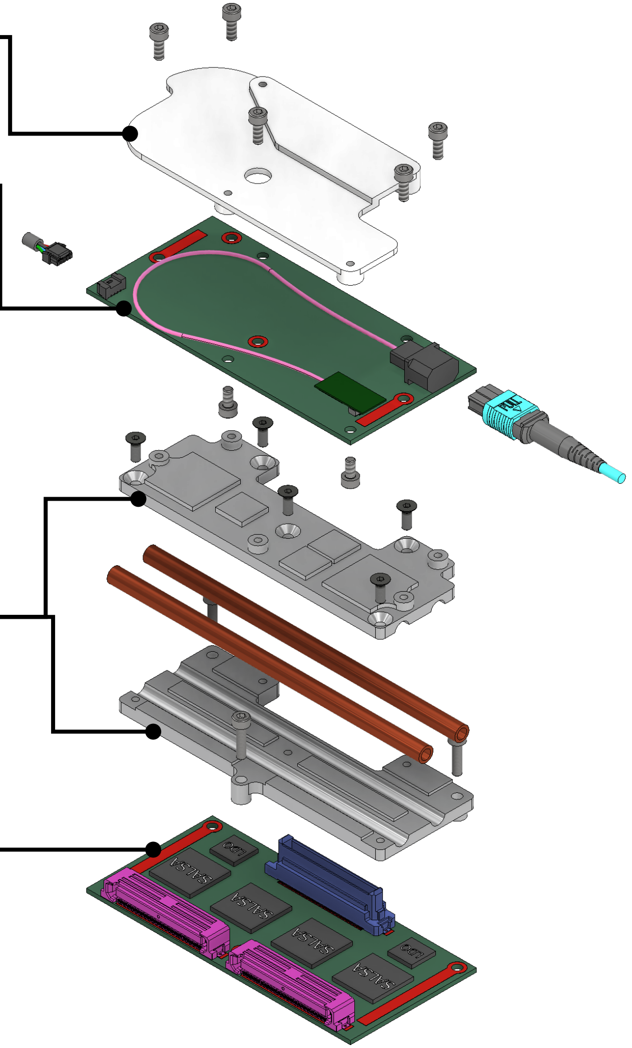


3D printed **pigtail guard**

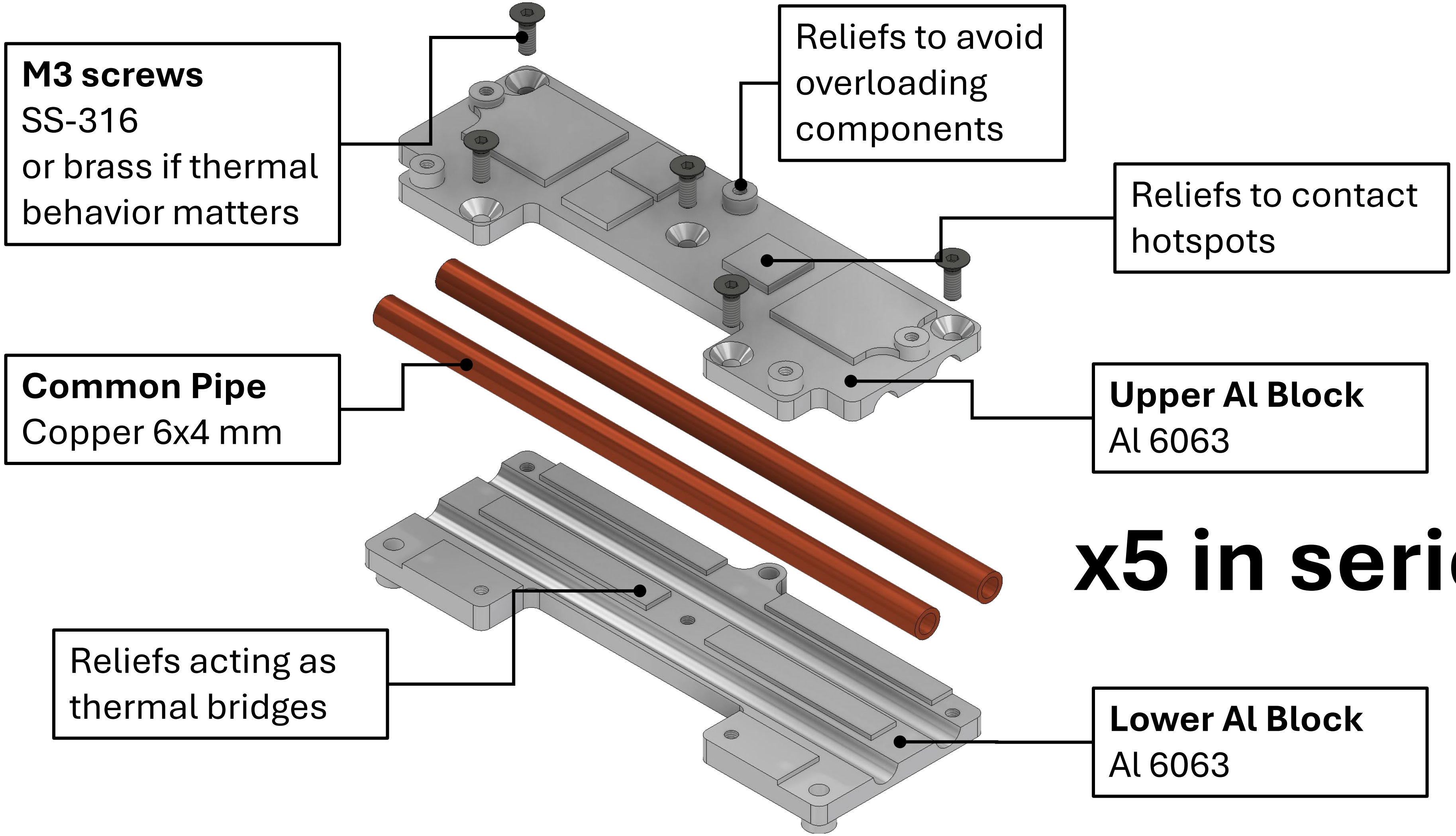
FE2 (COM/PWR)
1x vTRX+
1x lpGBT
2x DC/DC Conv.
2x LDO
1x HRS FX20-140P
1x MT-MPO Conn.

Aluminum heatsink clamped on **copper pipe**

FE1 (DAQ)
4x SALSA ASICs
2x LDO
3x HRS FX20-140P



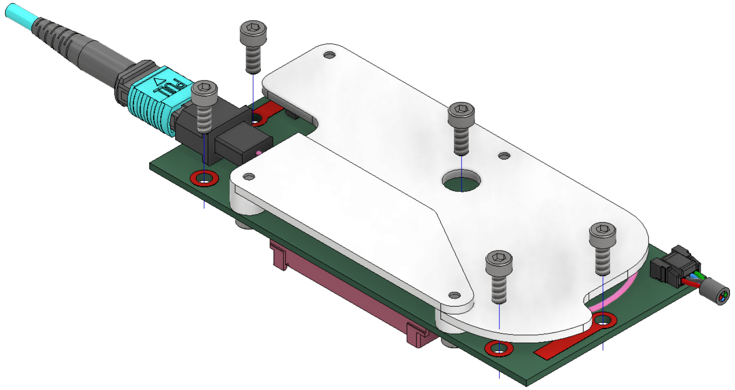
Heatsink Conceptual Design



x5 in series

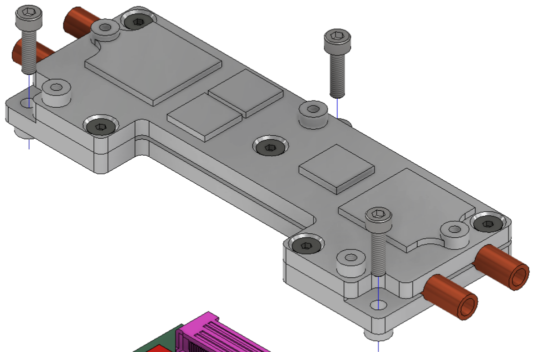
FEB Installation Procedure

3.



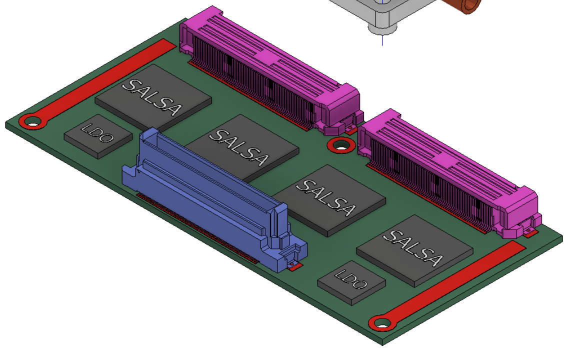
Connect FE2 to FE1 via FX20 BTB connector and screw to heatsink

2.



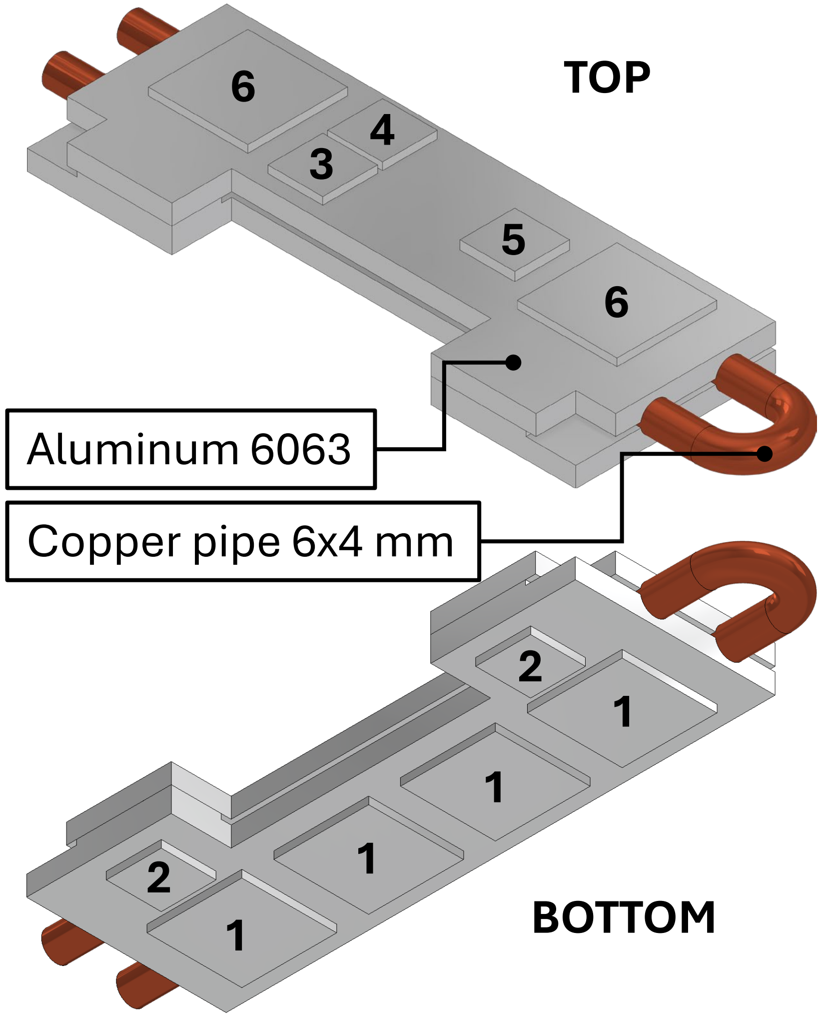
Position heatsink (entire chain) and screw in place

1.



Connect FE1 to detector R/O via FX20 Connectors

Materials and Thermal Load



Number	Component	Thermal Load (per individual component)	Heatsink Pad size	Component size
1	SALSA	1800 mW	19x19	17x17
2	LDO SALSA	900 mW	11x11	10x10
3	LDO lpGBT	200 mW	11x11	10x10
4	LDO VTRx+	875 mW	11x11	10x10
5	lpGBT	600 mW	11x11	9x9
6	DC/DC Converter	2500 mW	20x20	20x20
	TOTAL	**15675 mW**		

The VTRx+ is not actively cooled
It should output around 175 mW

Goals and Simulation Parameters

Target Parameters (Performance Goals)	Value, values or range
Operating Temperature Range (SALSA)	25 - 35 °C
Temperature Stability (SALSA)	± 3 °C peak to peak

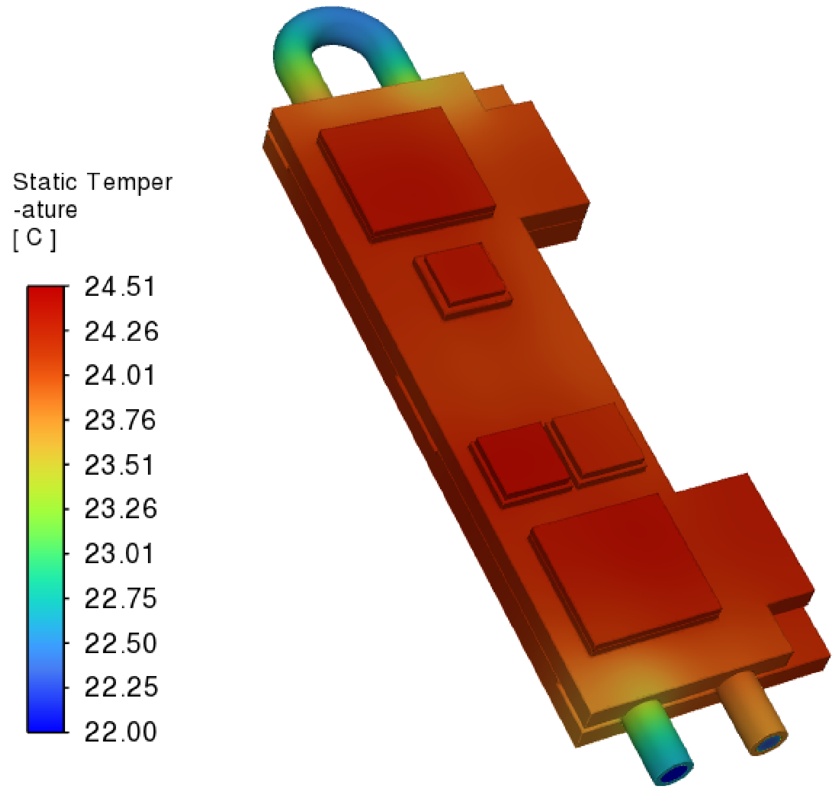
Simulation Parameters	Value, values or range
Ambient Temperature	23°C → 40°C
Water inlet temperature	22°C, 19°C (if needed)
Water flow rate	0.5 liters / min

Ambient Temperature might be affected by SVT air cooling and by hot air being trapped within the faraday cage (in the absence of forced circulation)

To be safe the cooling solution should work in a wide range of environmental temperatures

Results – Ambient Temperature 23 °C

Temperature distribution



Air heat transfer coefficient 5 W/(m² °C)

Simulation work by Girish Gowda

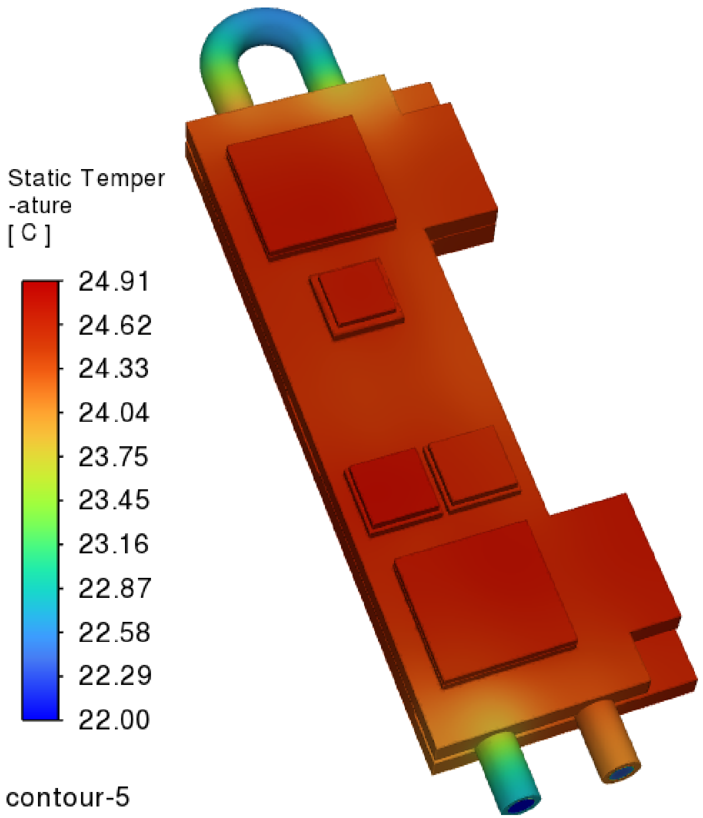
Analytical Calculation		
Number of FEB	1	
Single FEB Heat	15.675	W
Ambient Temperature	23	°C
Inlet Water Temperature	22	°C
Water Flow rate	0.5	l/min
Cp	4181	J/(kg °C)
m	0.0083	kg/s
m	0.0083	l/s
m	8.33	ml/s
Tube diameter	4	mm
dT	0.45	°C
Velocity	0.663	m/s
Re	2772	Transition Flow

CFD Calculation		
m	0.007975	kg/s
Cp	4181	J/(kg °C)
Ambient Temperature	23	°C
Inlet Water Temperature	22	°C
dT	0.47	°C
Velocity	0.663	m/s
Single FEB heat	15.675	W
Air Heat Transfer Coefficient	5	W/(m² °C)
Pressure drop	720	Pa

Heat Load		
Analytical calculation	15.675	W
CFD calculation	15.675	W
Heat loss to ambient	0.08	W

Results – Ambient Temperature 40 °C / 1

Temperature distribution



Air heat transfer coefficient 10 W/(m^2 °C)

Simulation work by Girish Gowda

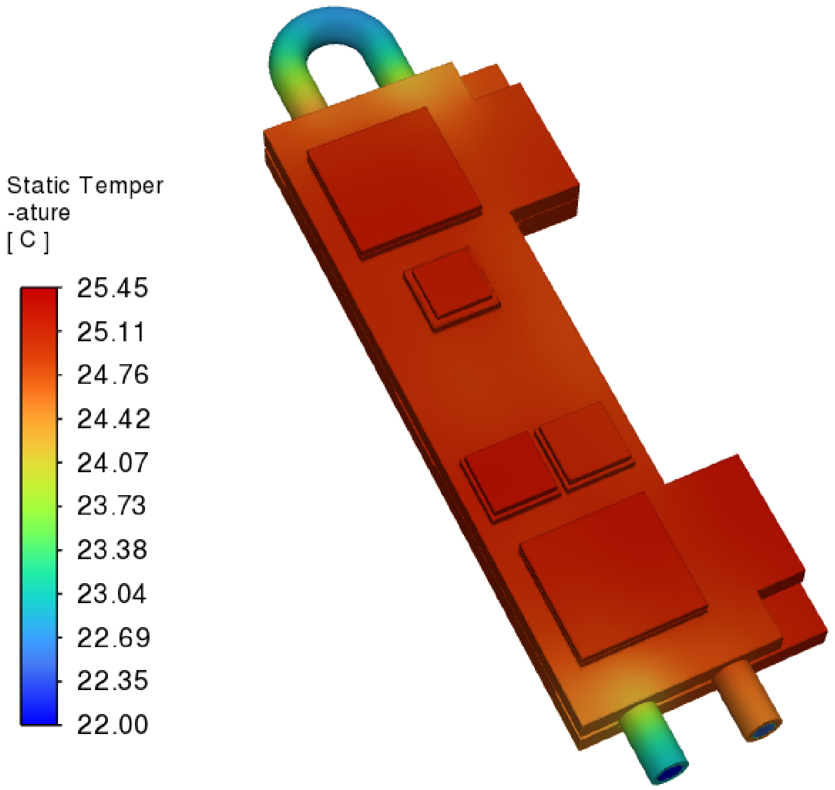
Analytical Calculation		
Number of FEB	1	
Single FEB Heat	15.675	W
Ambient Temperature	40	°C
Inlet Water Temperature	22	°C
Water Flow rate	0.5	l/min
Cp	4181	J/(kg °C)
m	0.0083	kg/s
m	0.0083	l/s
m	8.33	ml/s
Tube diameter	4	mm
dT	0.45	°C
Velocity	0.663	m/s
Re	2772	Transition Flow

CFD Calculation		
m	0.007975	kg/s
Cp	4181	J/(kg °C)
Ambient Temperature	40	°C
Inlet Water Temperature	22	°C
dT	0.546	°C
Velocity	0.663	m/s
Single FEB heat	15.675	W
Air Heat Transfer Coefficient	10	W/(m^2 °C)
Pressure drop	713	Pa

Heat Load		
Analytical calculation	15.675	W
CFD calculation	15.675	W
Heat gain from ambient	2.5	W

Results – Ambient Temperature 40 °C / 2

Temperature distribution



Air heat transfer coefficient 25 W/(m² °C)

Simulation work by Girish Gowda

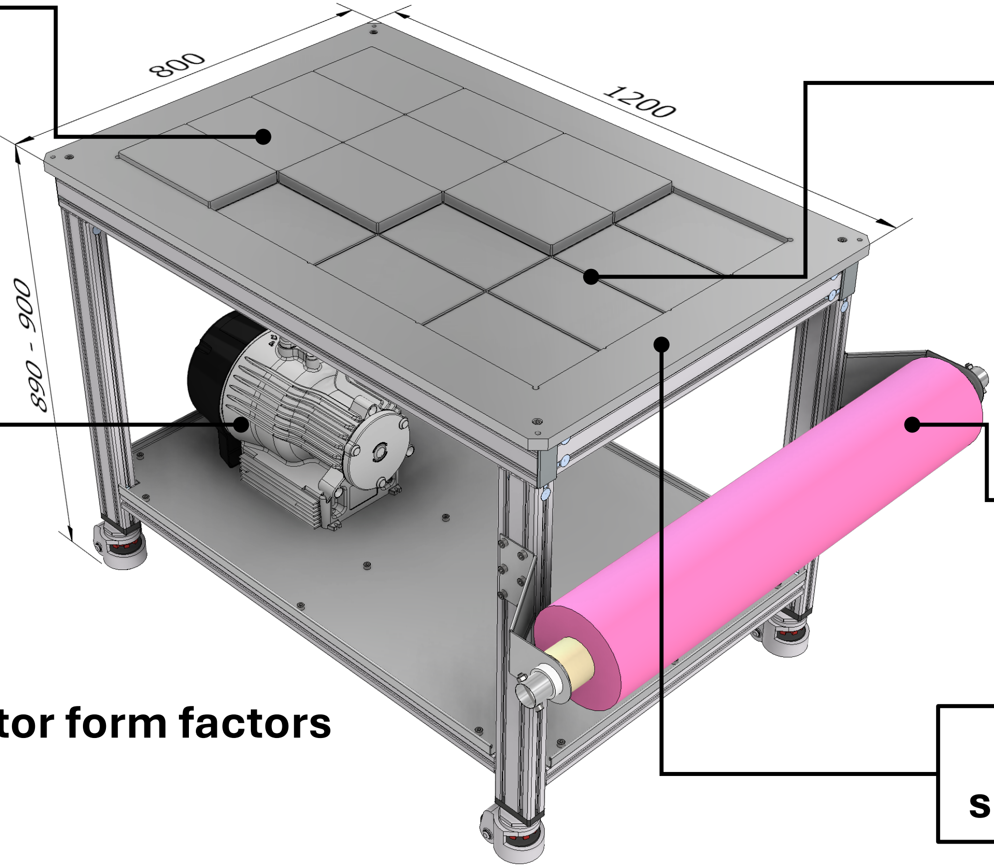
Analytical Calculation		
Number of FEB	1	
Single FEB Heat	15.675	W
Ambient Temperature	40	°C
Inlet Water Temperature	22	°C
Water Flow rate	0.5	l/min
Cp	4181	J/(kg °C)
m	0.0083	kg/s
m	0.0083	l/s
m	8.33	ml/s
Tube diameter	4	mm
dT	0.45	°C
Velocity	0.663	m/s
Re	2772	Transition Flow

CFD Calculation		
m	0.007975	kg/s
Cp	4181	J/(kg °C)
Ambient Temperature	40	°C
Inlet Water Temperature	22	°C
dT	0.65	°C
Velocity	0.663	m/s
Single FEB heat	15.675	W
Air Heat Transfer Coefficient	25	W/(m² °C)
Pressure drop	713	Pa

Heat Load		
Analytical calculation	15.675	W
CFD calculation	15.675	W
Heat gain from ambient	6.2	W

Production Tooling

Configurable Gluing/Assembly Gig



1000 x 600 mm^2 working area
→ suitable for **multiple detector form factors**

No. 16 **250 x 150 mm^2 tiles**
→ reference pin holes **can be machined in-house**

Final Remarks

- **Alternative assembly schemes** based on commercially available **nylon expansion rivets** look **promising, more work is needed** before the procedure can be greenlit
- **Prototyping** custom expansion pins **in-house proved harder** than initially envisioned
- The **heatsinks' design was modified** to simplify FEB installation
- First results from **thermal simulations** with 1 FEB **are reassuring**, simulations of 5 FEB in series will follow
- We **started working on the production tooling** to secure funding
- We are trying to design **tools suitable to different detector geometries** to keep costs in check

Thanks for your attention!!

And many thanks to **Girish Gowda** from the ECT group
for his invaluable support with cooling simulations