TB2S Ladder Assembly and Qualification for the CMS Outer Tracker System

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On behalf of the CMS Tracker Group

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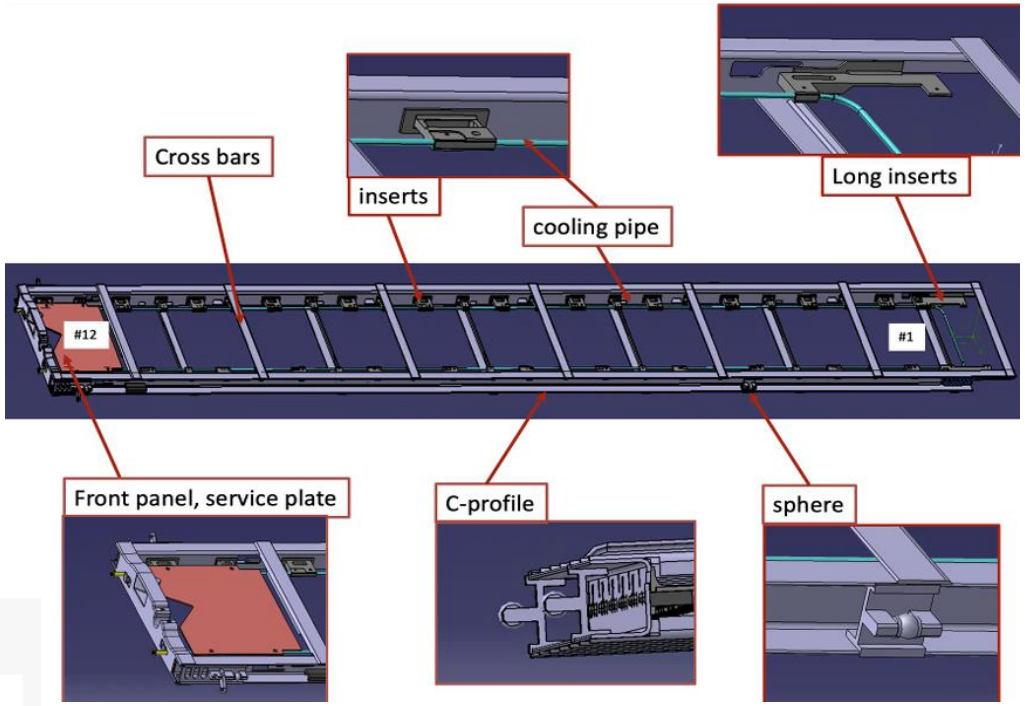
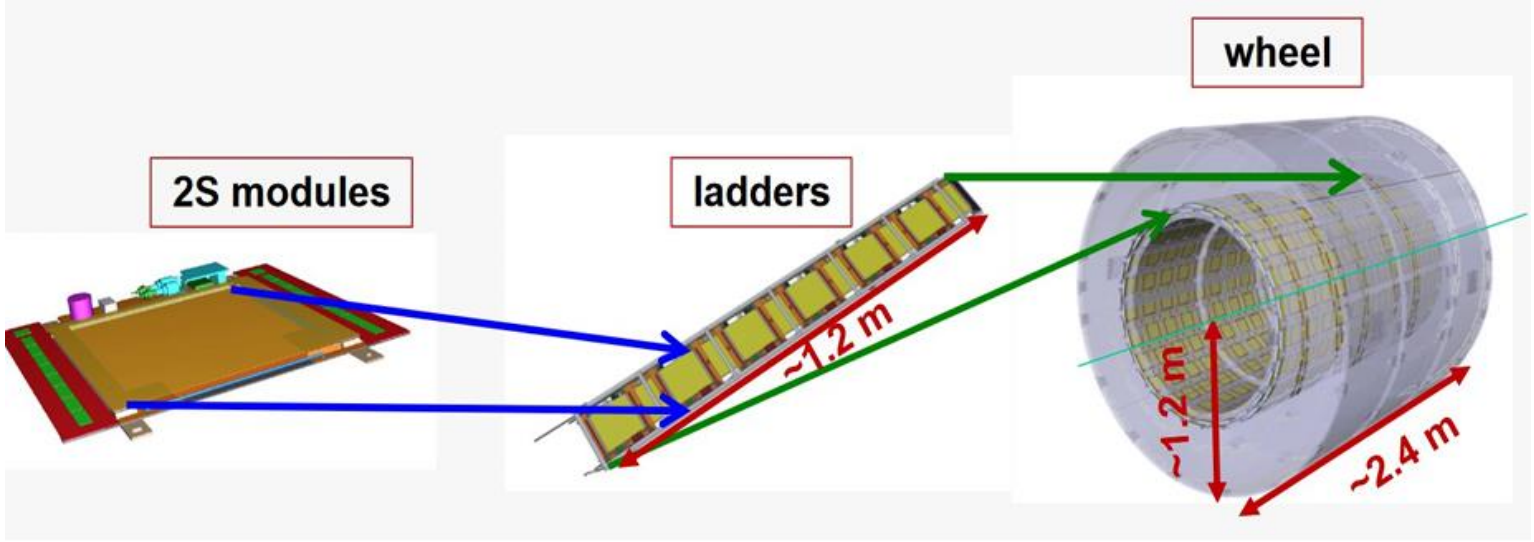
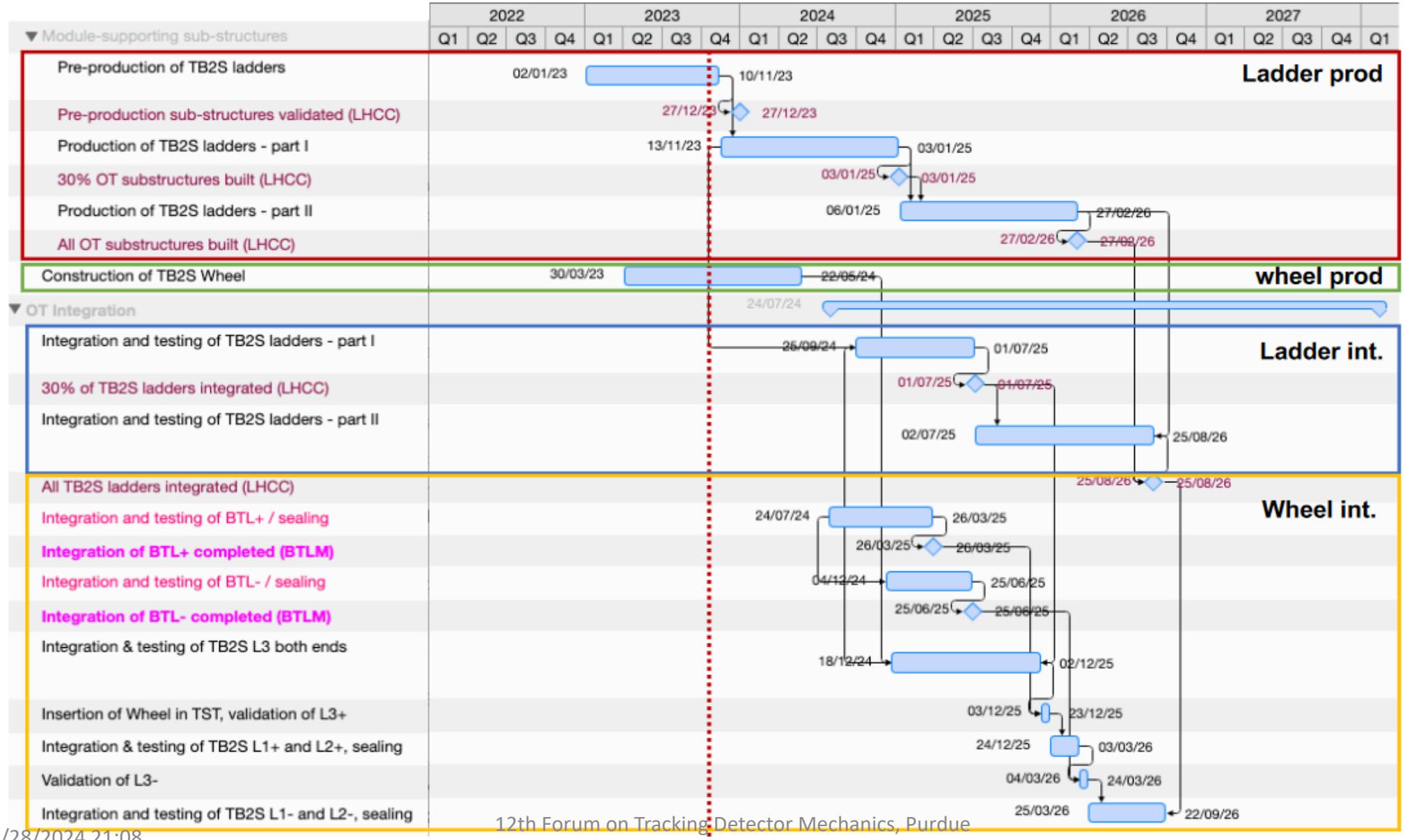
TB2S ladder project overview

- There are total 372 ladders (+10% spare) in the TB2S wheel
- The ladders are placed in 3 layers, positioned at r-distances of about 687, 850 and 1083 mm for layers 1, 2 and 3 respectively.
- 12 2S silicon modules could be installed per ladder





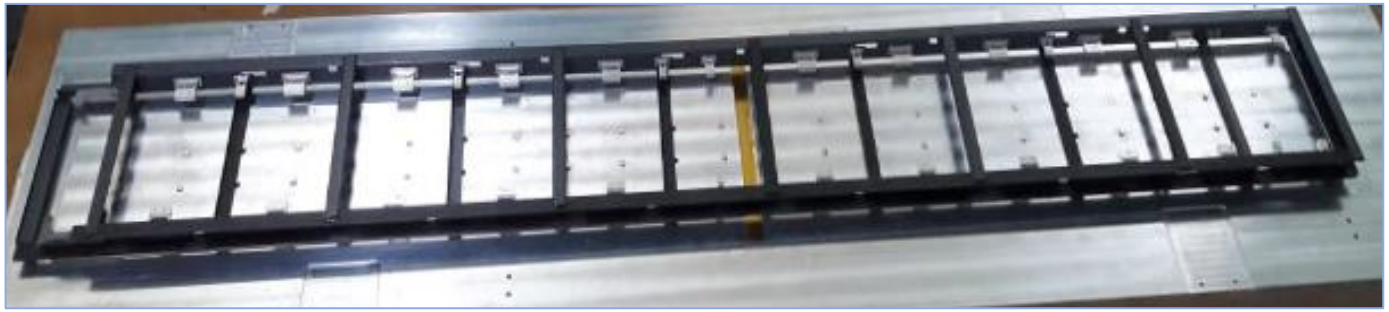
TB2S ladder production schedule



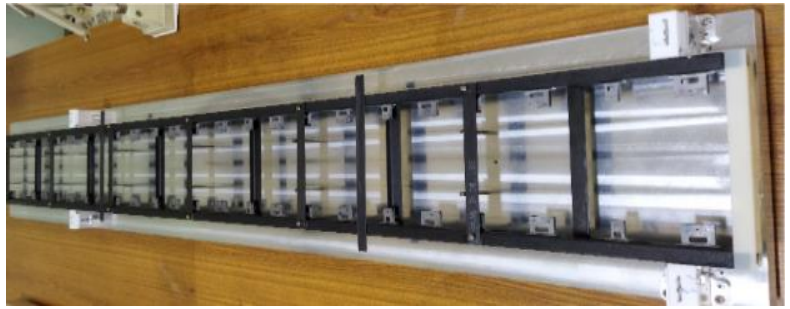
TB2S ladder project prototyping

- **Three ladder prototypes were designed, fabricated and assembled successfully at NCP**
- **Jigs and inserts fabricated in NEW-II and water jet cutting in a private company in Lahore**

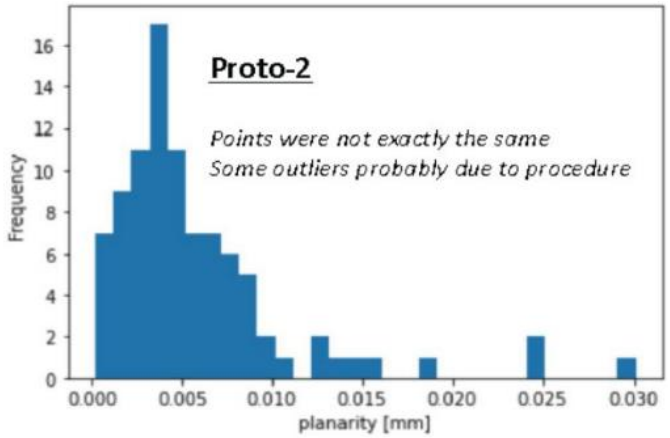
1st Prototype Ladder – Proof of Concept sent to CERN in April 2019

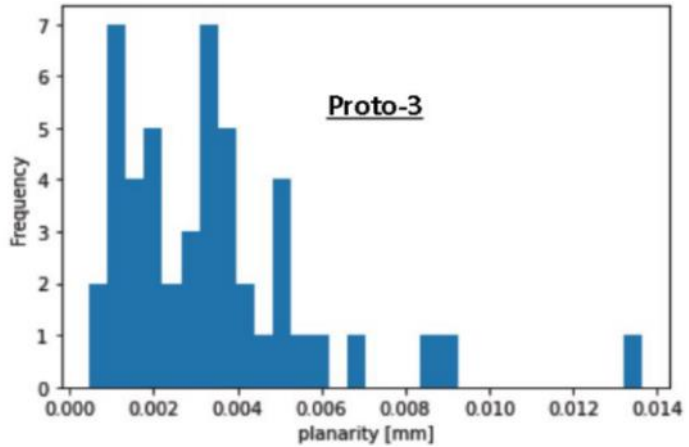


2nd Prototype Ladder – planarity < 30 microns, Sent to CERN in August 2020, validated and tested at CERN/Strasbourg, well appreciated

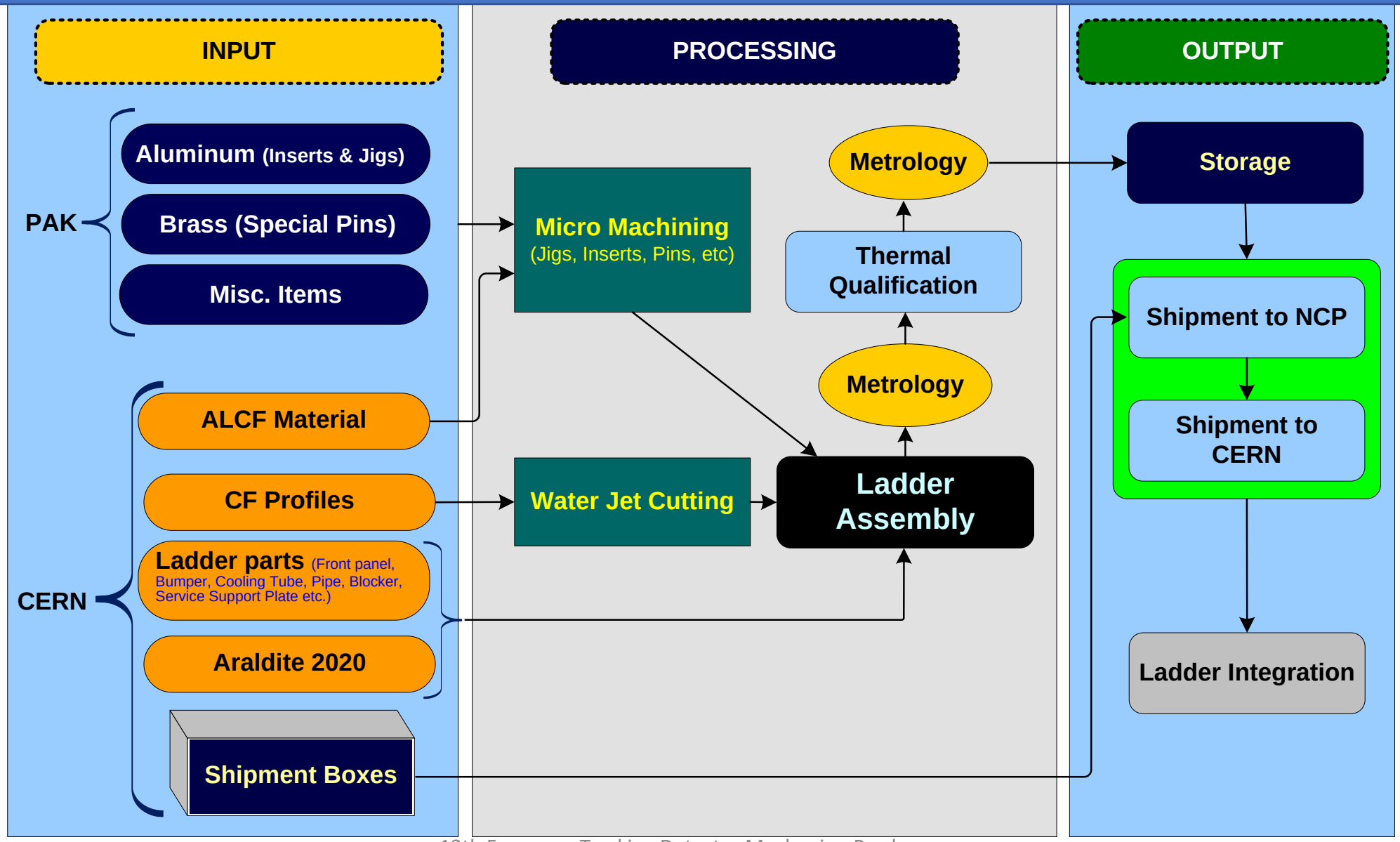


3rd Prototype Ladder – planarity < 14 microns) shipped to CERN on 14 October, 2021, Tested for performance at CERN/Strasbourg, well appreciated!

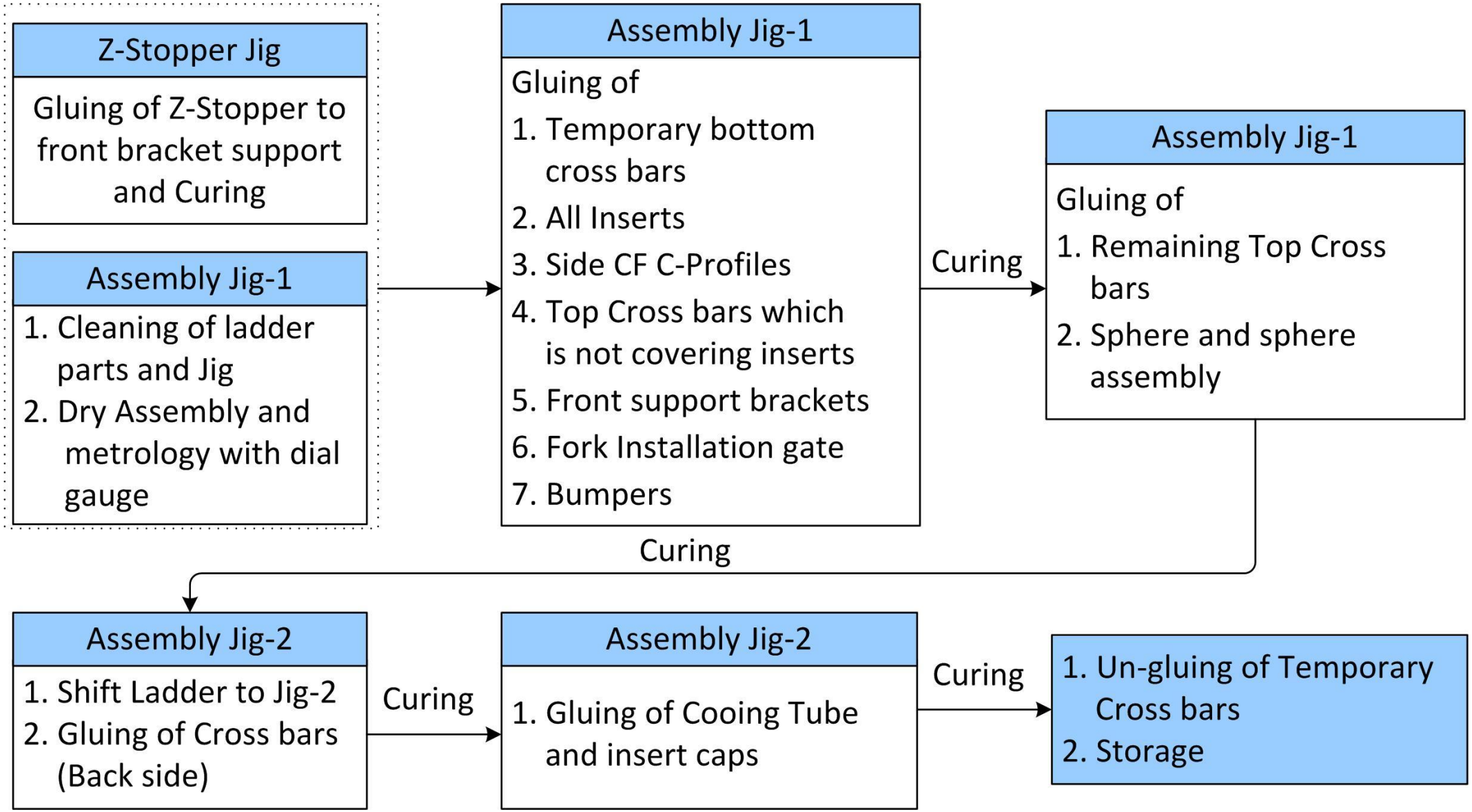




Ladder production flow



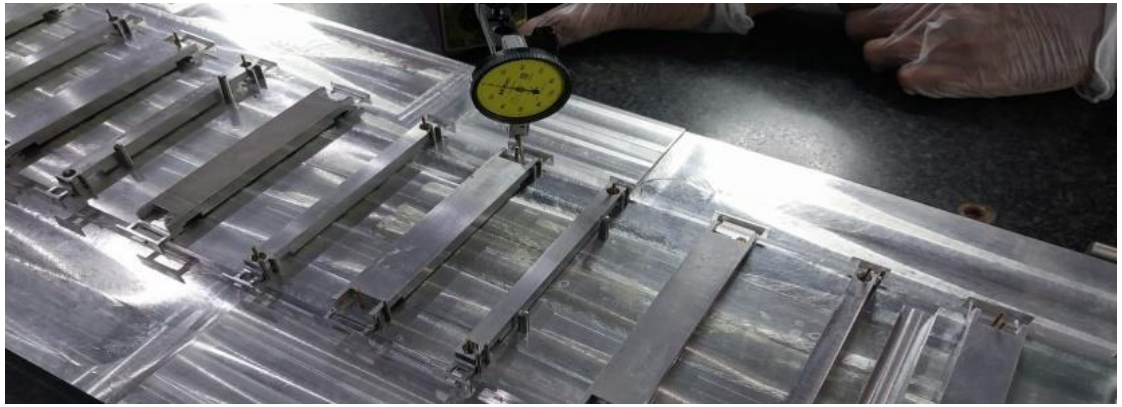
Ladder assembly sequence

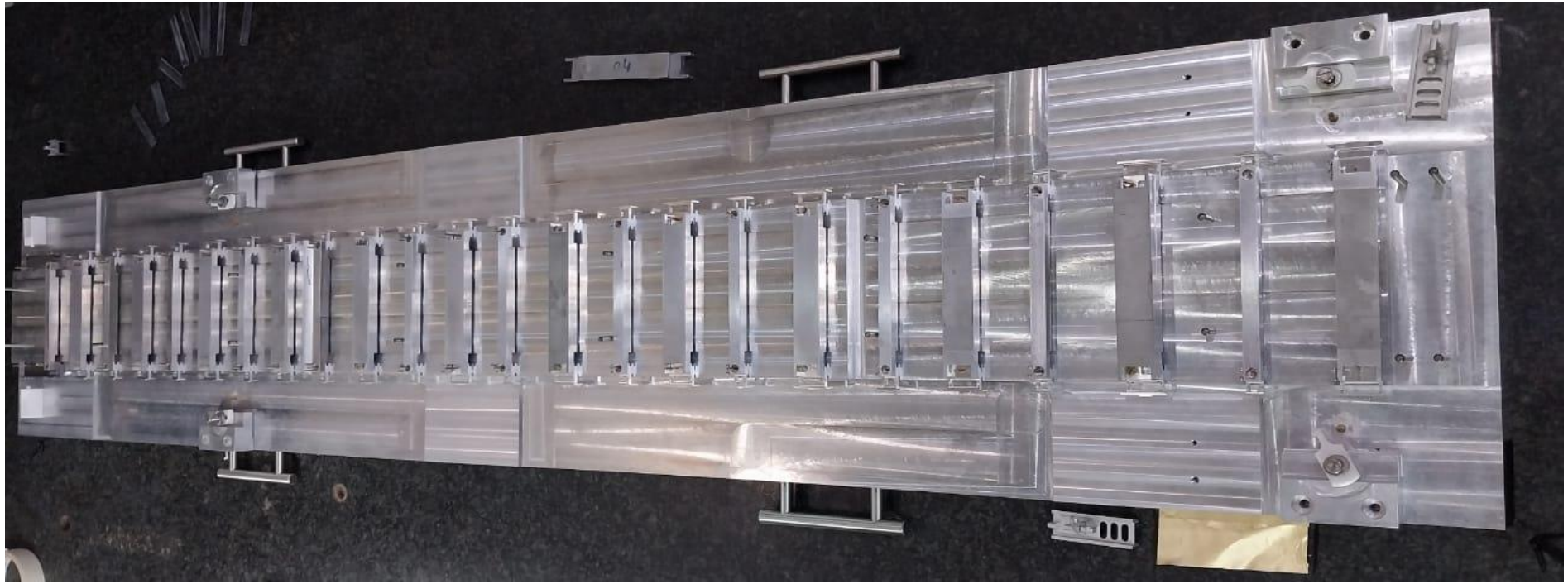


TB2S ladder production phases

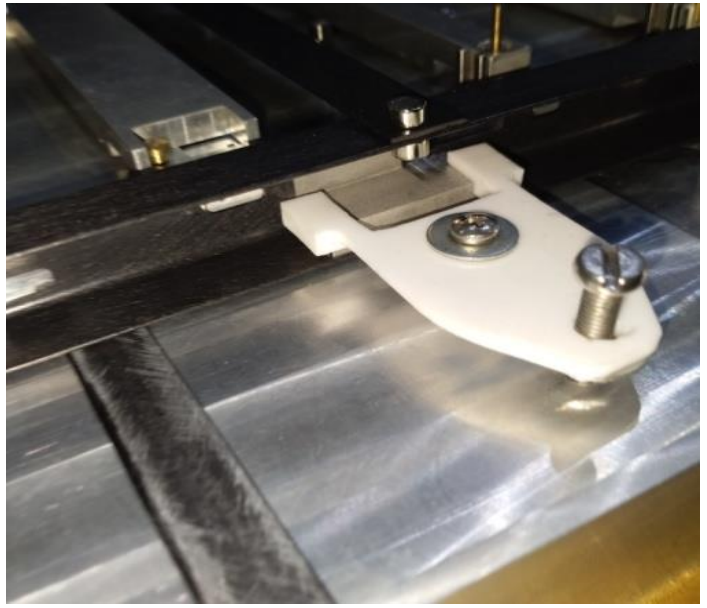
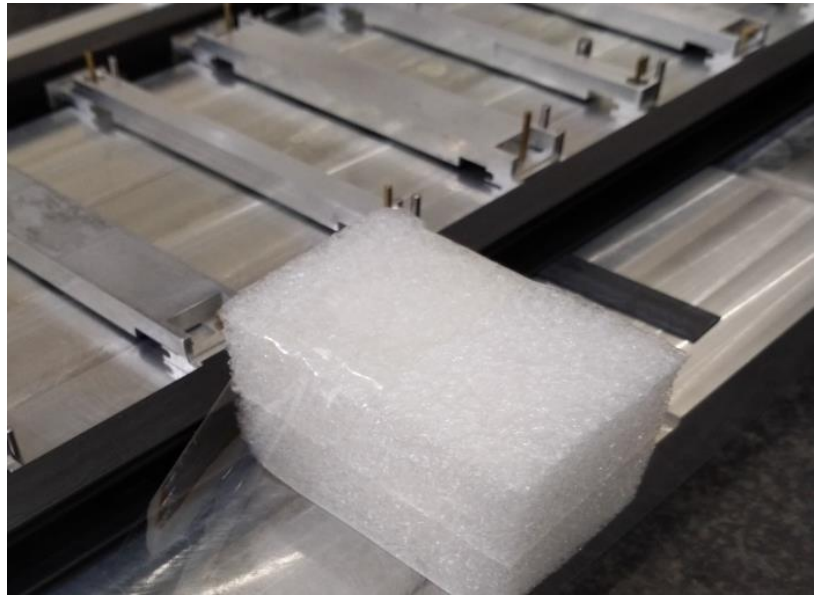
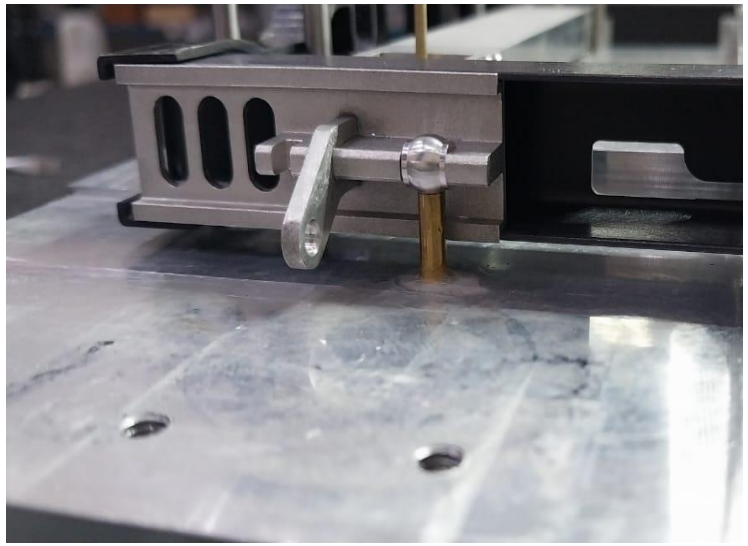
Ser. no.	Phases	Quantity	Timeline
1	Pre-production	5 +1 (Z-ve) and 5+1 (Z+ve) Ladder Assemblies	9 months
2	Production Series -1	120 Ladder Assemblies	14 months
3	Production Series -2	280 Ladder Assemblies	19 months

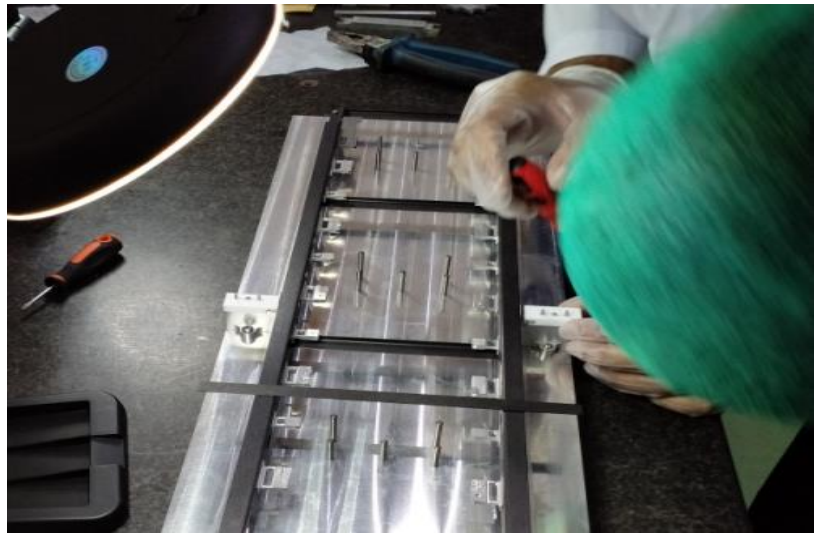
Pre-production: ladder dry assembly



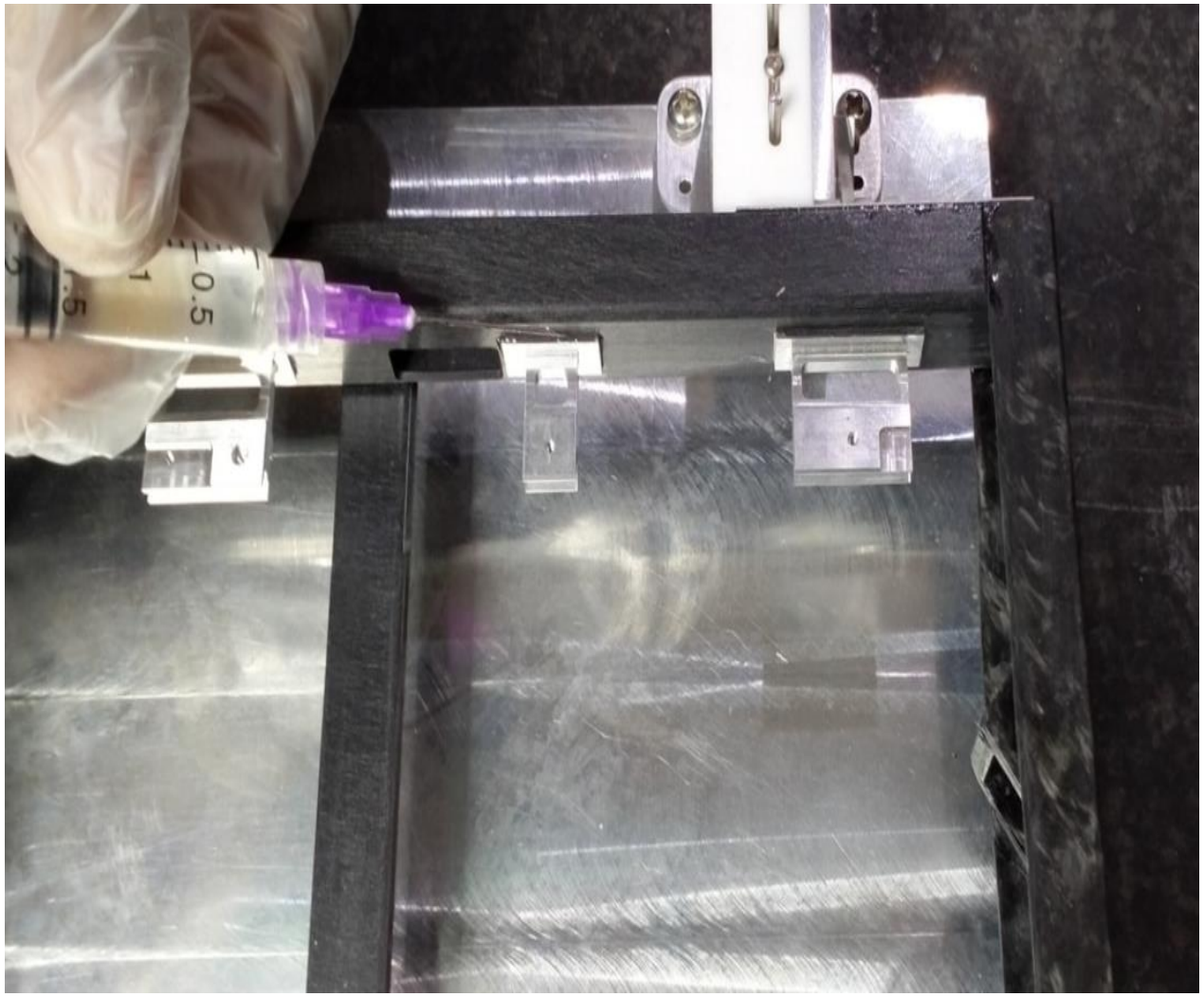


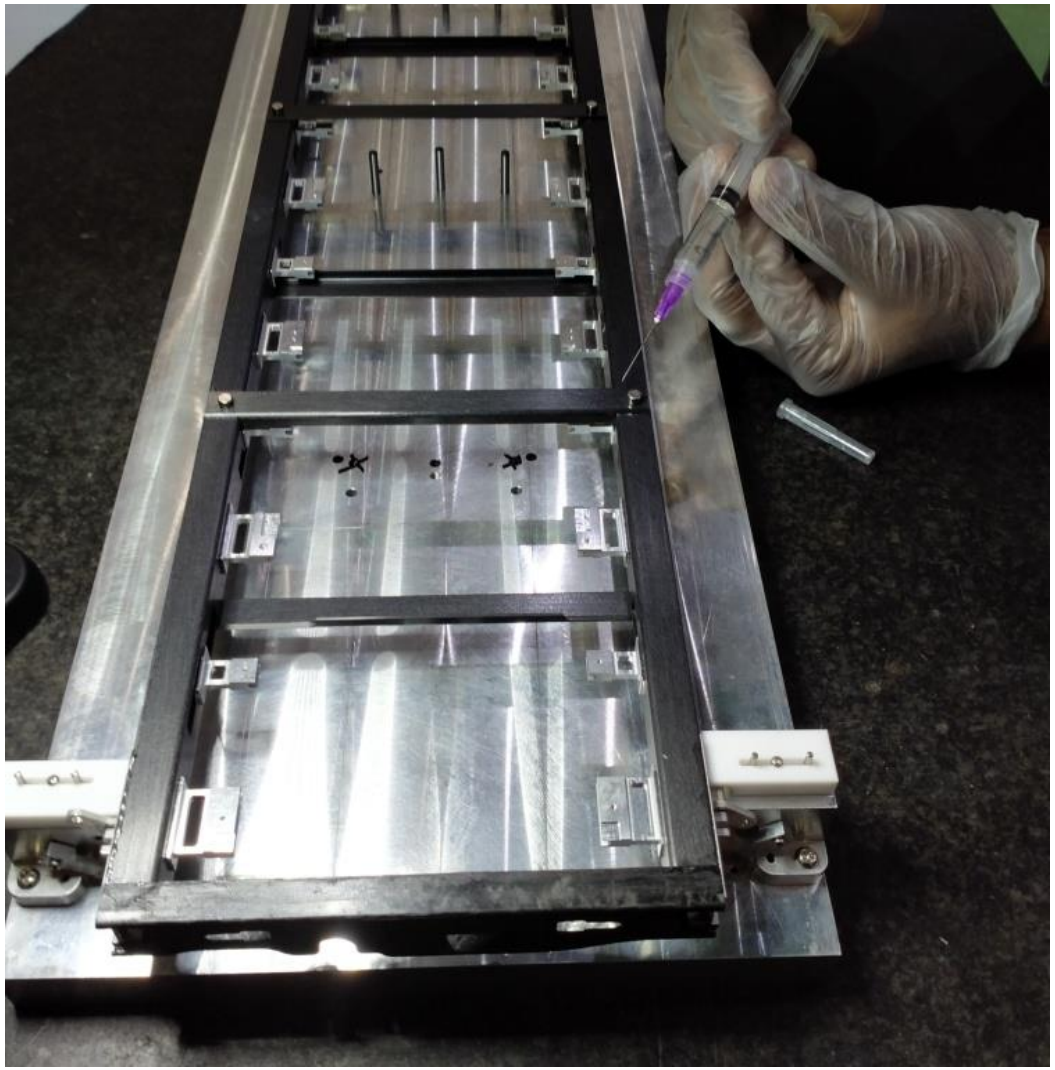
Pre-production: Application of supports & clamps

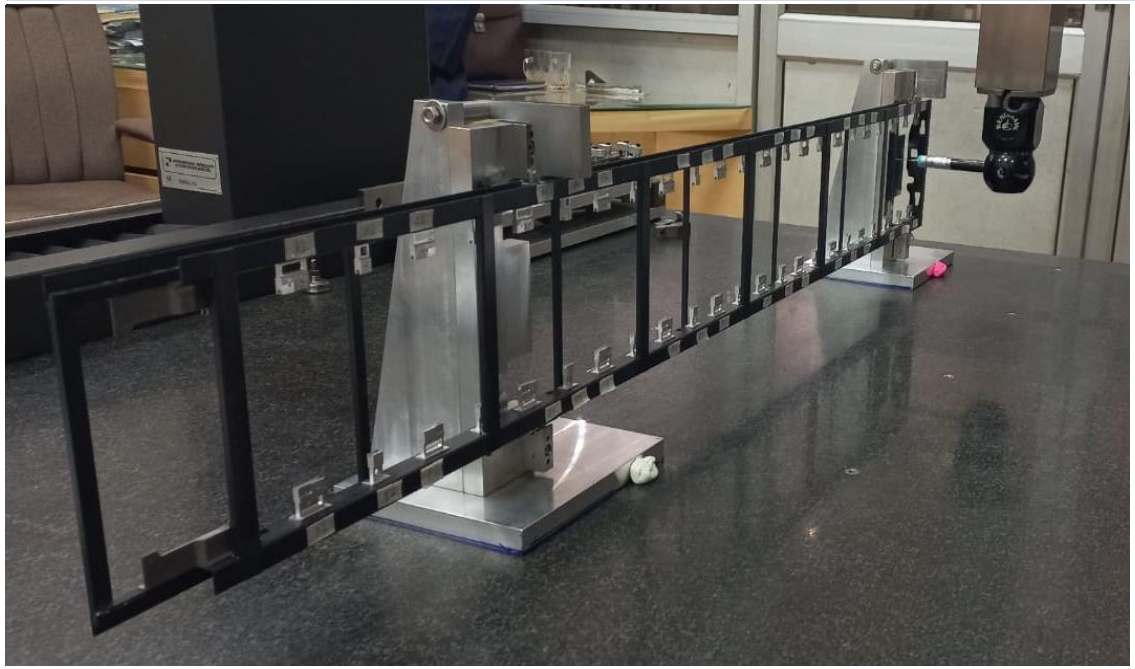


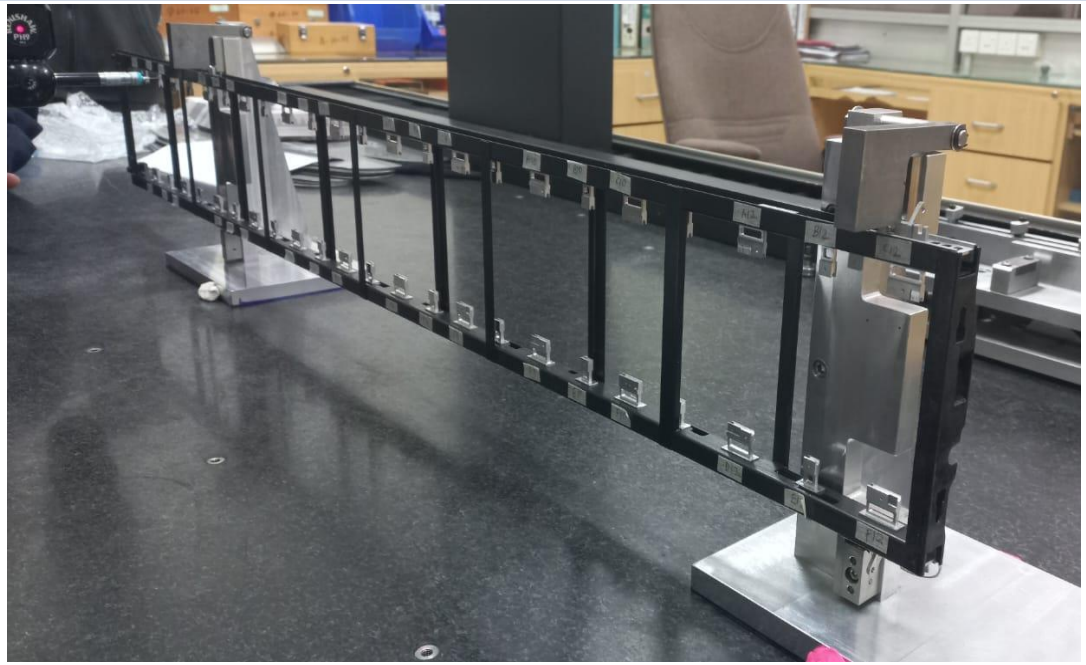
Pre-production: Gluing of cross bars and inserts



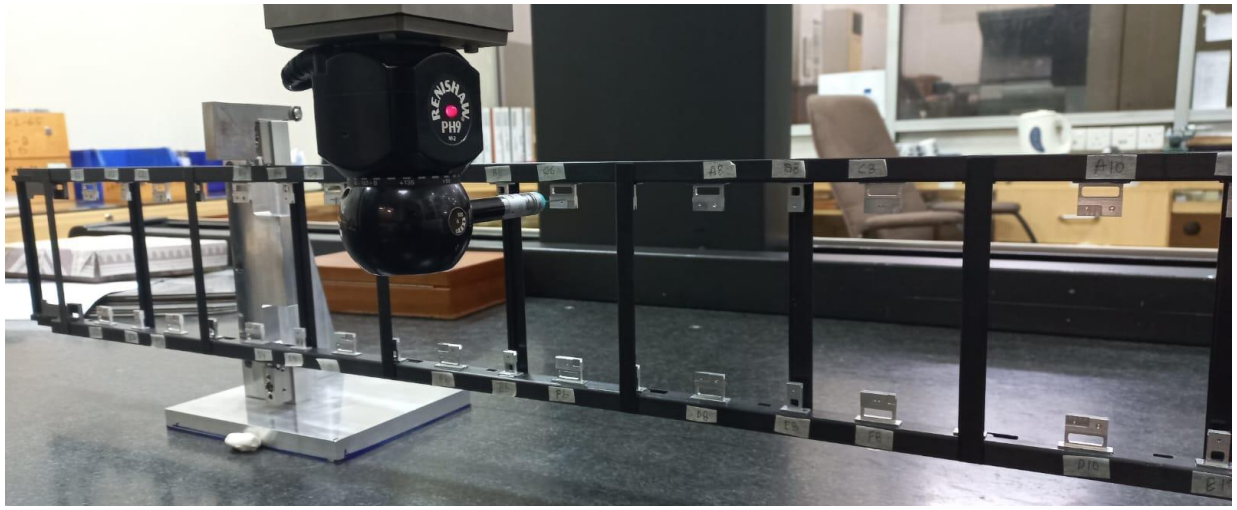


Pre-Production: Metrology at CMM (dedicated setup)

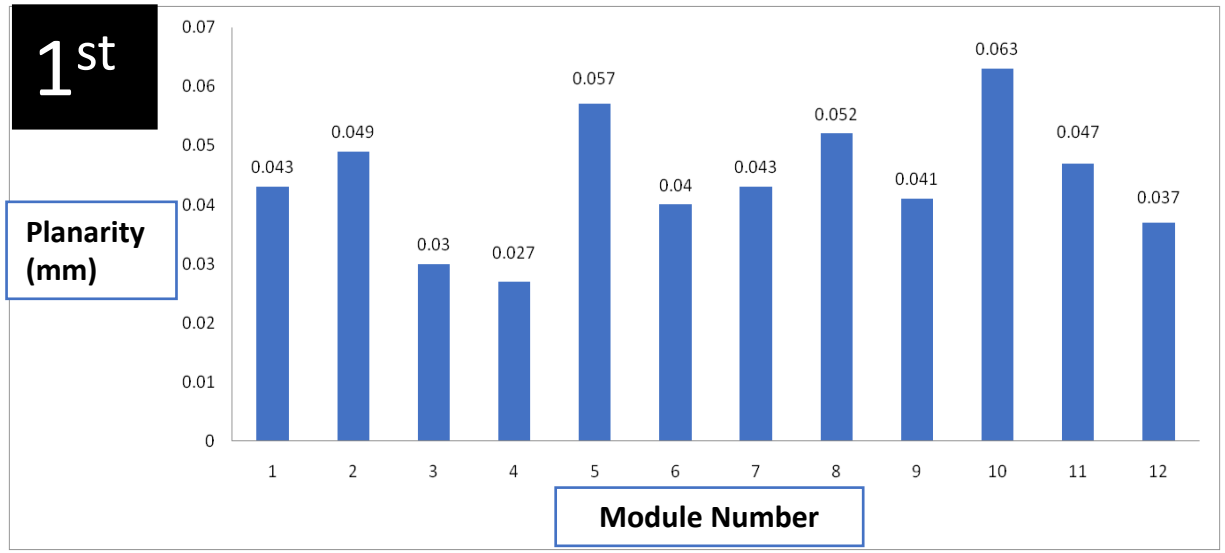


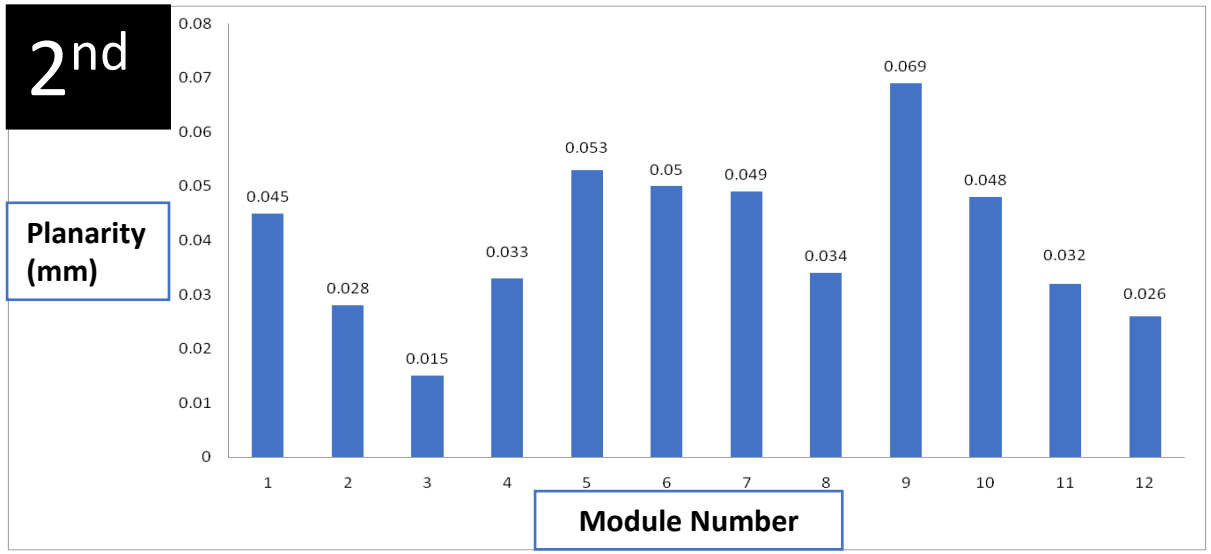


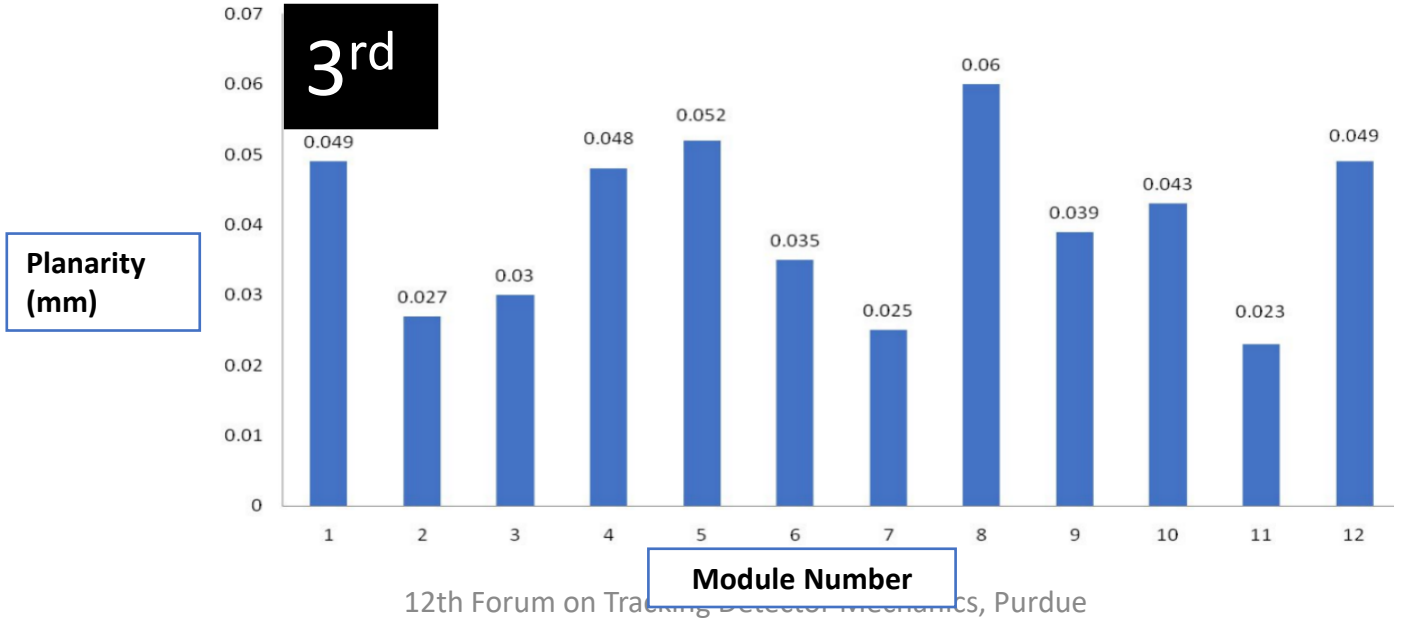
- The dedicated metrology setup is prepared
- It has already been utilized to perform metrology on the three pre-production ladders.



Planarity of pre-production ladders

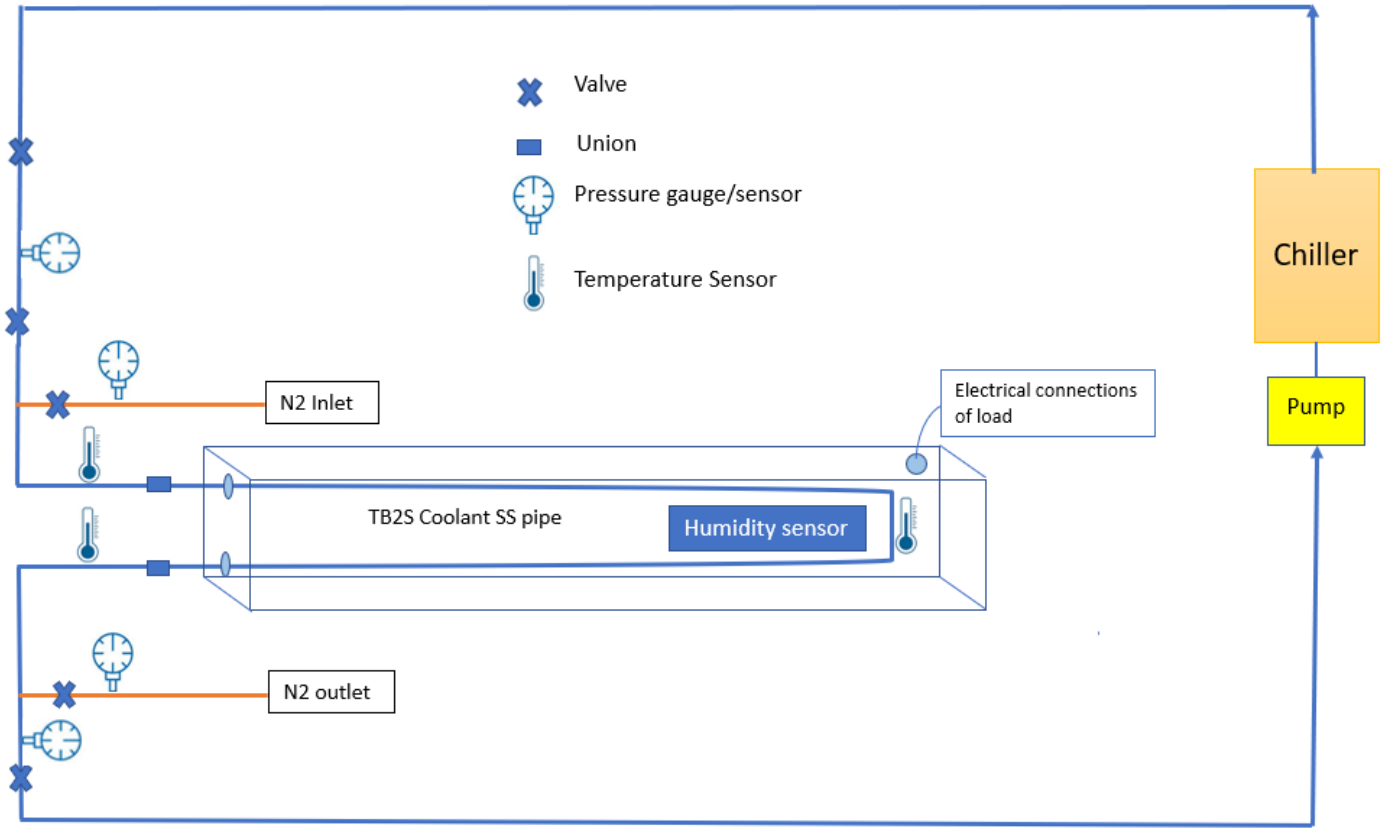






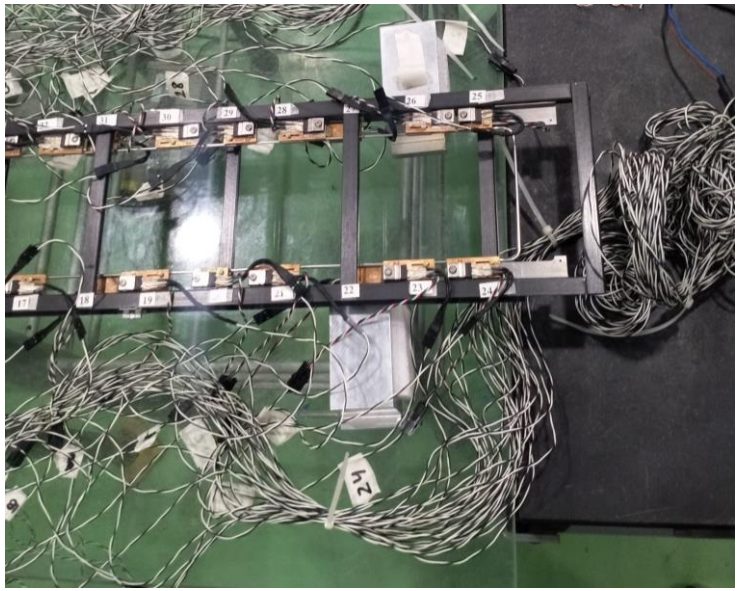
Thermal qualification setup

- A specialized thermal qualification setup has been built at NCP and relocated to the company premises.
- A comprehensive thermal qualification procedure document has been drafted.
- To study the thermal performance of the ladder, equivalent twelve 2S modules load is applied by using heating elements

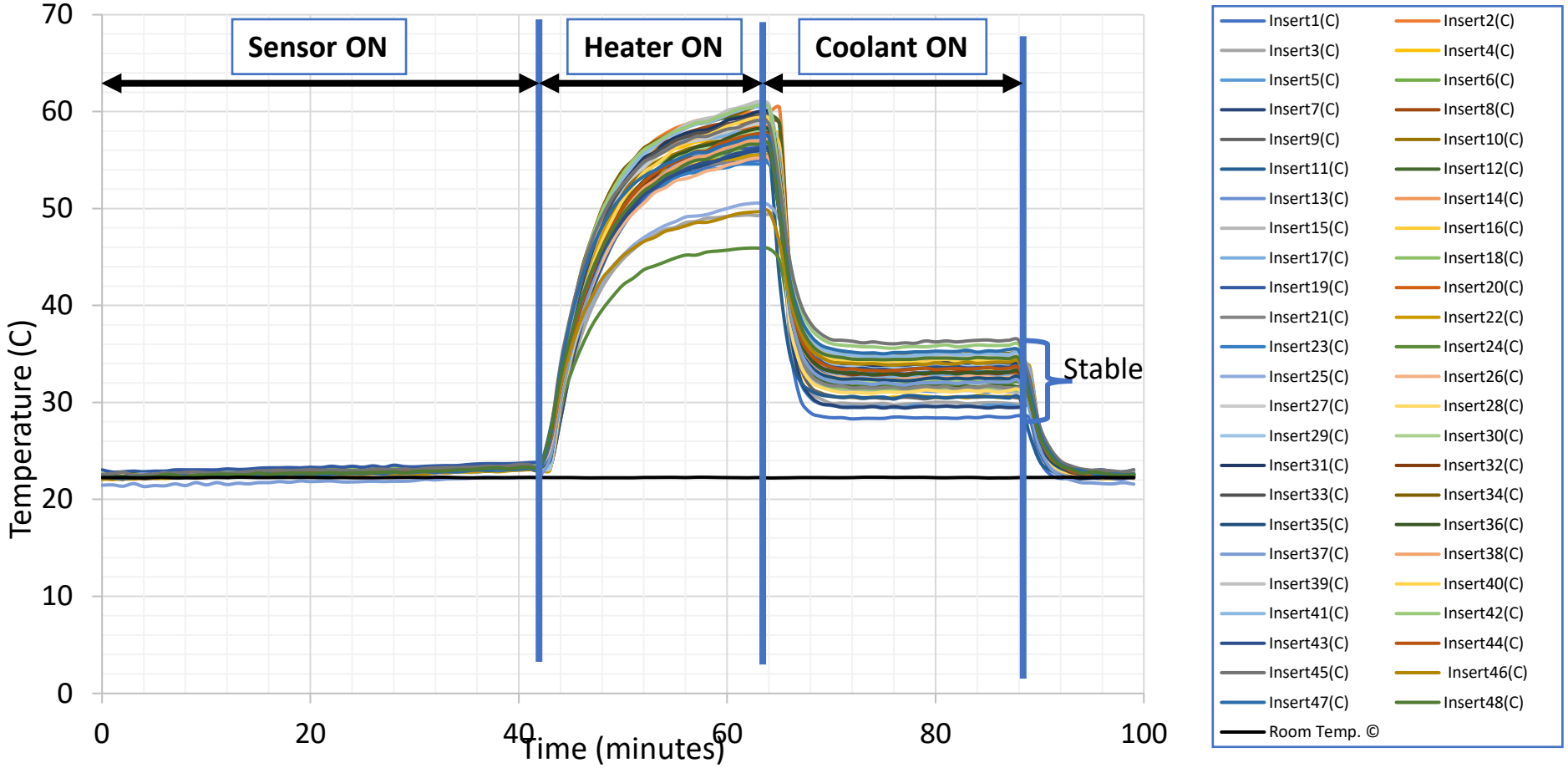


Thermal qualification of the pre-production ladder

- Forty-eight heating elements have been affixed to the ladder, dissipating approximately 0.8 Watts of heat at each point (Thanks to Duccio Abbaneo for providing thermal cubes). The thermal response is monitored and recorded at each point.
- **Three pre-production** ladders have successfully undergone thermal qualification.

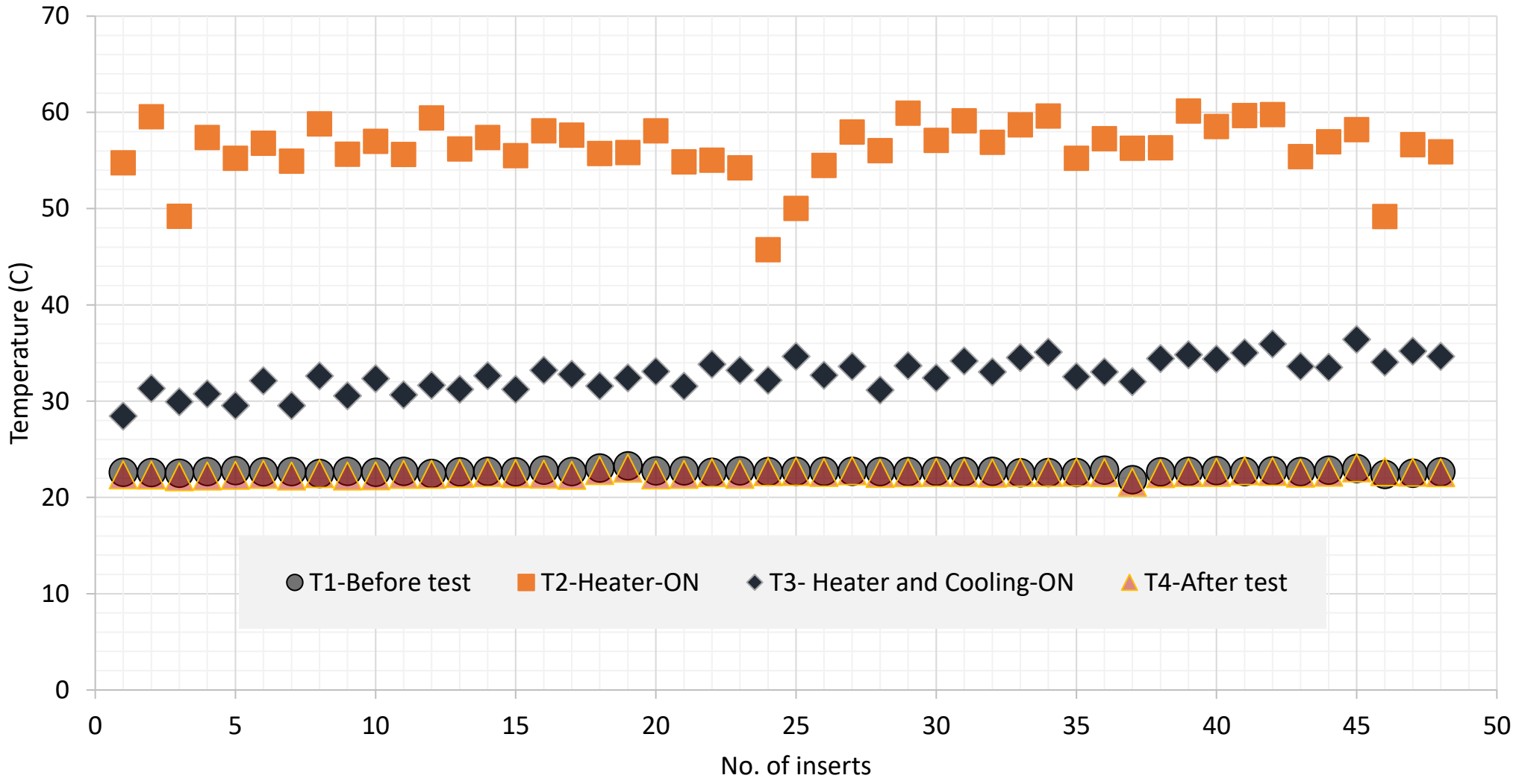


Thermal qualification results of 1st pre-production ladder



Nice first ladder, no visible issues, all contacts are functioning as expected.

Thermal qualification results of 1st pre-production ladder



Pre-production ladders

Three Z-Ve ladders have shipped to CERN

First pre-production ladder shipped to CERN on Jan. 10, 2024

2nd and 3rd pre-production ladder shipped to CERN on 16 May 2024

Pre-production ladders status

- Three Z-ve pre-production ladders were shipped to CERN after undergoing metrology and thermal qualification tests.
- Following the initial results from the first pre-production ladder (regarding sphere placement position), the CERN team proposed modifications to the Z-ve jig design.
- As a result, pre-production has been put on HOLD.
- Ladder pre-production will recommence once the drawings are finalized and got green signal from CERN.
- Nevertheless, ladder parts are currently in production to expedite the process and adhere to project timelines.

Z-ve pre-production updates

Activity	Ladder no. 1	Ladder no. 2	Ladder no. 3	Ladder no. 4	Ladder no. 5	Ladder no. 6 spares
Parts Machining	✔	✔	✔	✔	✔	✔
Assembly	✔	✔	✔	O.H	O.H	N/A
Cooling Pipe Installation	✔	✔	✔	-	-	N/A
Metrology w/o Cooling Pipe	✔	✔	✔	-	-	N/A
Metrology with Cooling Pipe	✔	✔	✔	-	-	N/A
Thermal Test	✔	✔	✔	-	-	N/A

Legend: ✔ = Done, O.H=On Hold, N/A= Not applicable

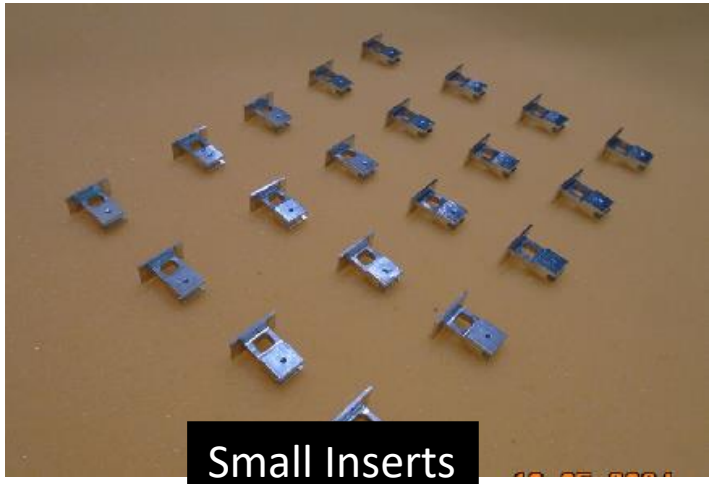
Z+ve pre-production updates

Activity	Ladder no. 1	Ladder no. 2	Ladder no. 3	Ladder no. 4	Ladder no. 5	Ladder no. 6 spares
Small inserts	✔	✔	✔	✔	✔	✔
Special inserts	✔	✔	✔	✔	✔	✔
Large Inserts	Drawings under finalization					
CF Profile						
Assembly Jig						
Assembly	After parts and drawing availability					N/A

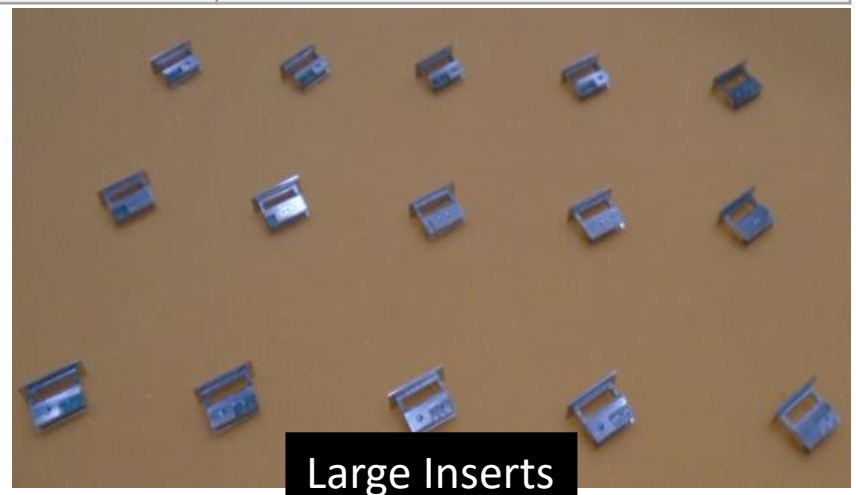
Legend: ✔ = Done, N/A= Not applicable

Ladder parts manufacturing updates

Ser. no.	Description	Qty Completed	For Ladders
1	Small Inserts	1150	**52**
2	Special Insert (2 types)	65	**32**
3	Large Z-ve Insert (23 types)	1315	**55**
4	Cooling cap long	700	**27**
5	Cooling cap short	800	**36**
6	CF profiles (Z-ve)	12	**6**


Small Inserts


Special Inserts


Large Inserts

Summary

- **Three prototypes were assembled and qualified before transitioning to the pre-production phase.**
- **Pre-production for the Z-ve is progressing well.**
  - ✓ Three pre-production ladders have been assembled.
  - ✓ Metrology and thermal qualification tests have been conducted.
  - ✓ The ladders have already been sent to CERN.
- **Production of the more ladders is on HOLD, due to modification in the Z-ve jig design**
- **Finalization of the Z+ve jig and ladder design is underway.**