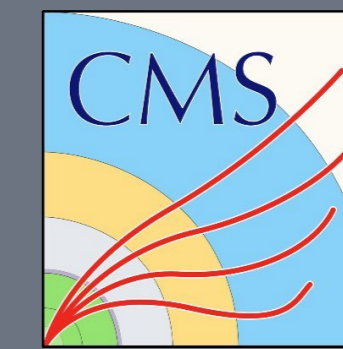


Services Design for the CMS Phase-II Outer Tracker Endcaps

Izzeddin Suat Donertas on behalf of the Tracker group of the CMS collaboration

suat.donertas@uclouvain.be

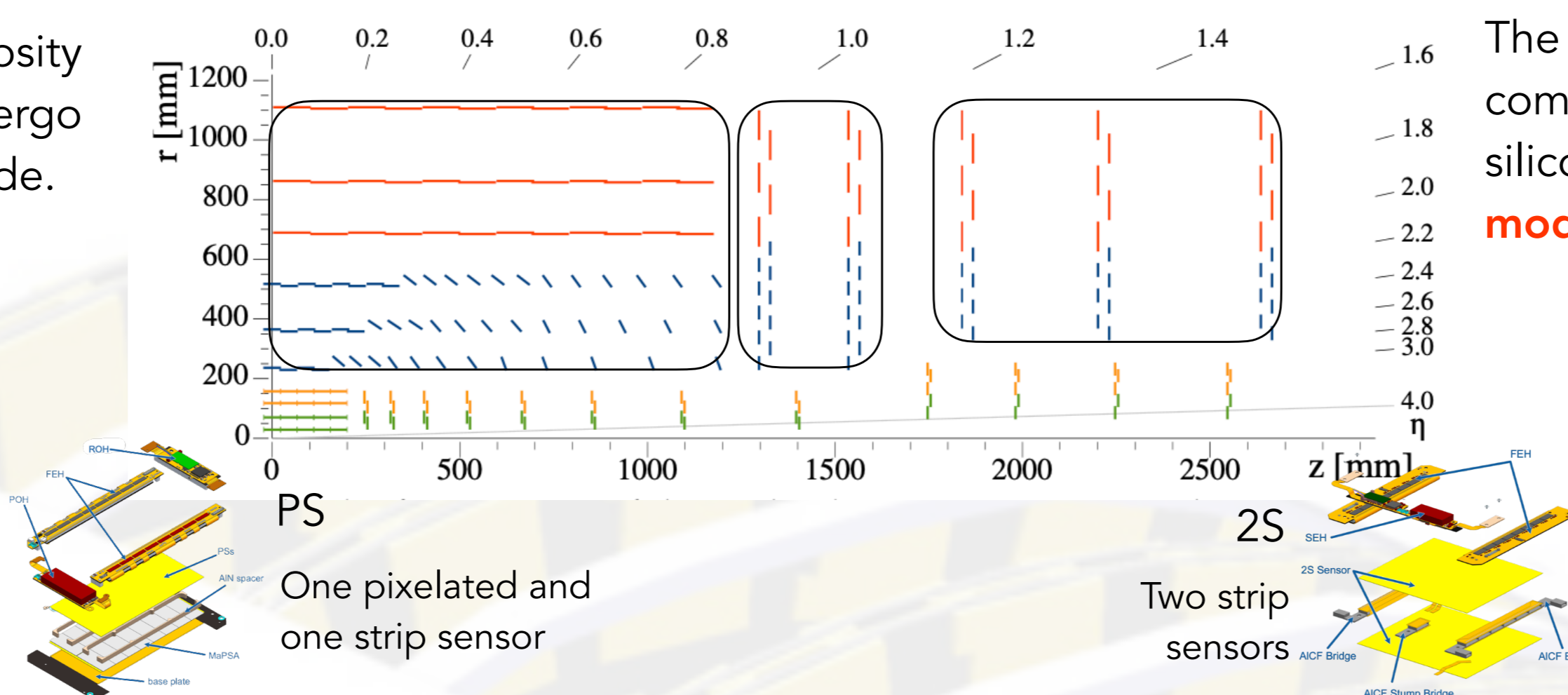


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CMS Phase-II Outer Tracker

The experimental conditions of High Luminosity LHC (HL-LHC) motivates the CMS to undergo series of upgrades called the Phase-II Upgrade.

- Radiation tolerance
- Increased granularity
- Improved two-track separation
- Reduced material in the tracker volume
- Contribution to the L1 Trigger
- Extended tracker acceptance

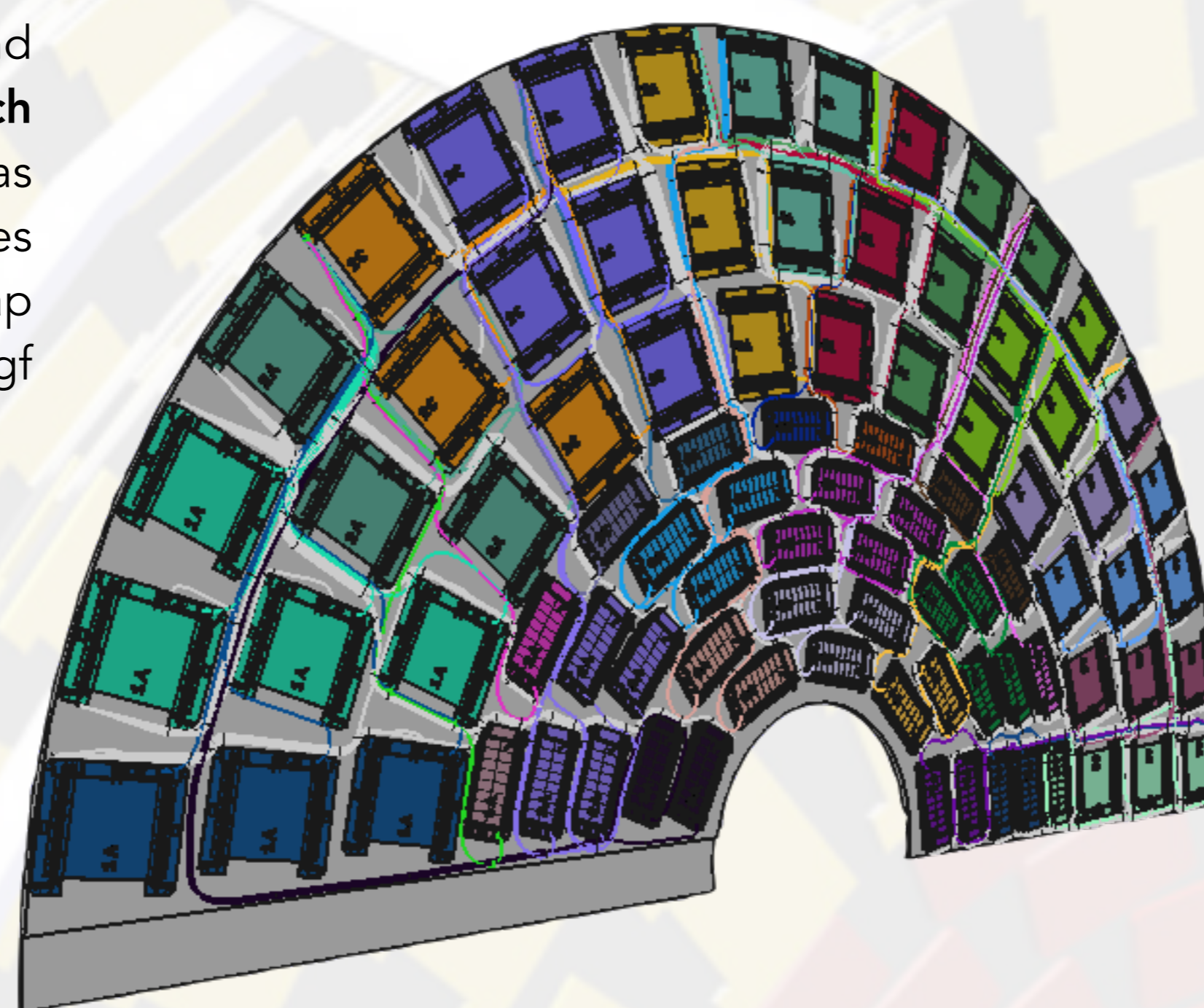
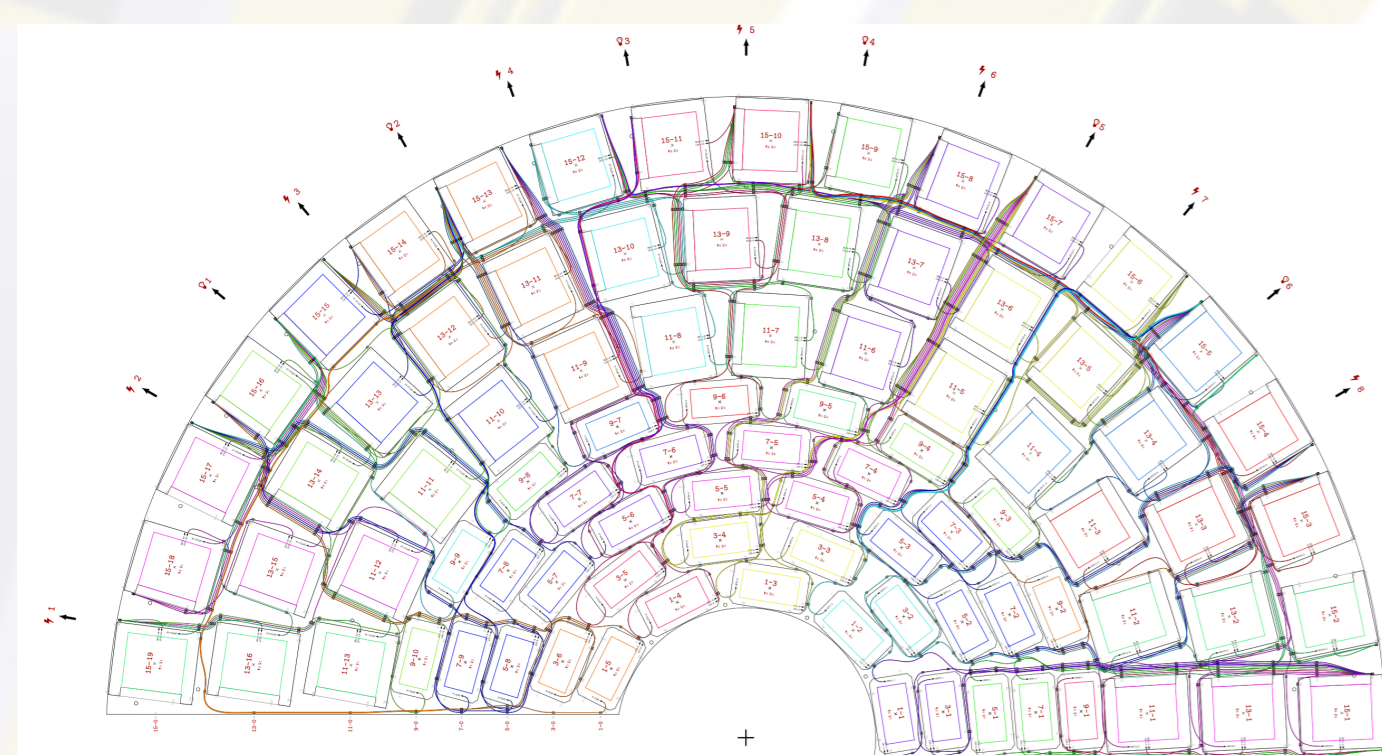


The Phase-II outer tracker design that was realised is composed of a barrel and an endcap, both consisting of silicon detector modules of two types; **PS modules** and **2S modules**. This surrounds the inner tracker.

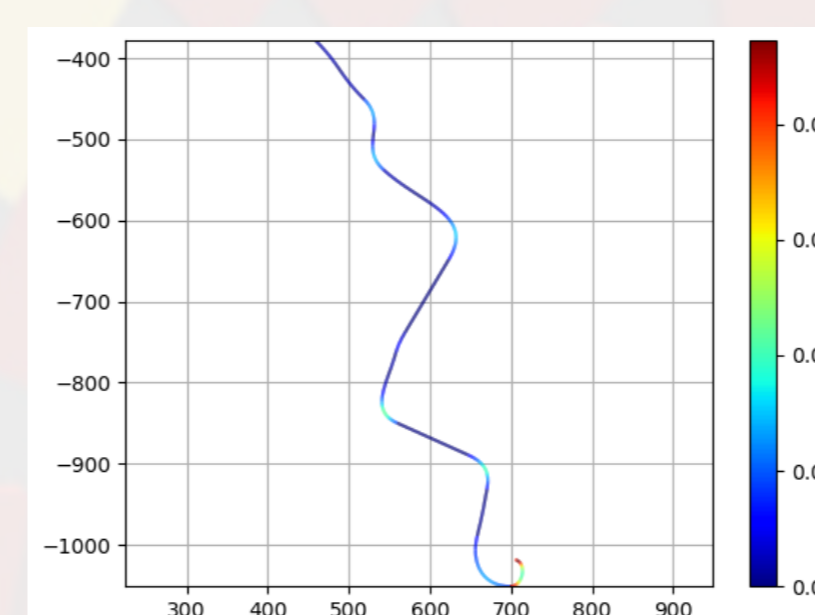
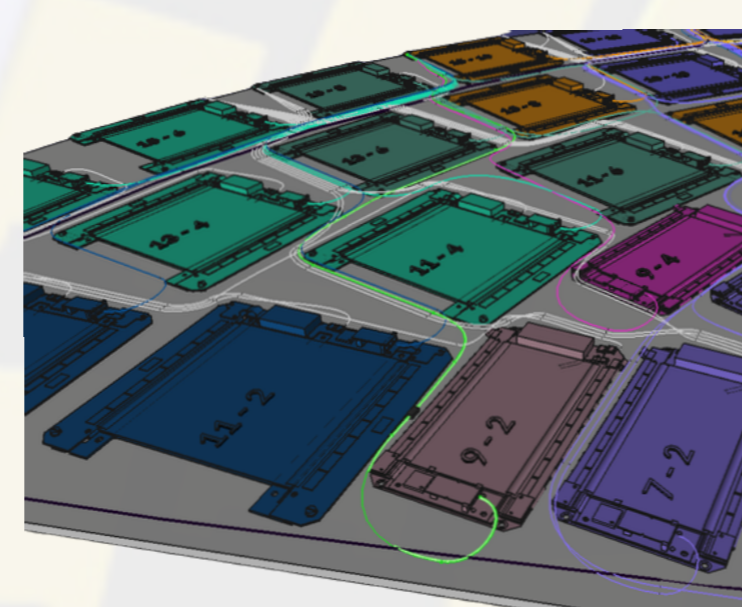
The building block of the new endcaps are the half disk objects carrying the detector modules; **Dees**. The dees are hosting the transverse services belonging to the modules along with the cooling elements. Two Dees make up a disk and five double-disks make up a full endcap; **TEDD**.

Dee Services (Transverse Services)

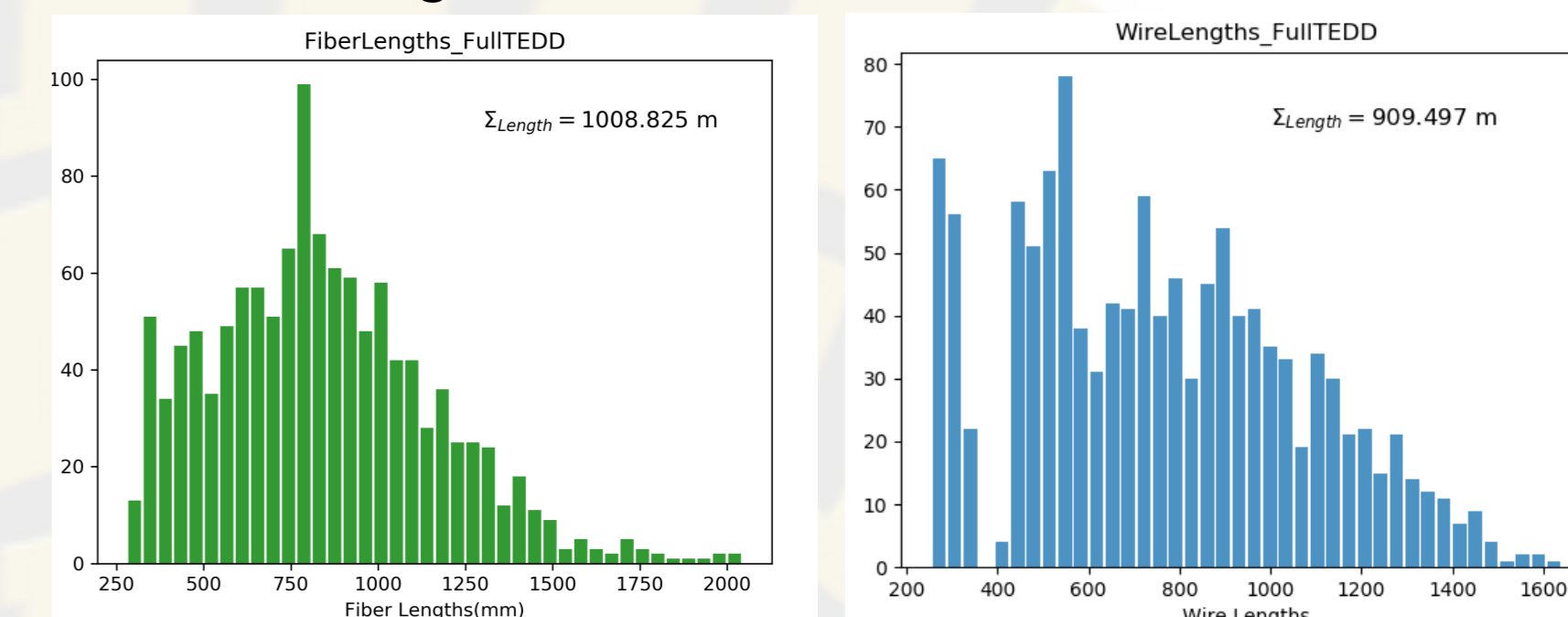
Hosting the 2S and PS detector modules, Dees are populated with the transverse services of optics and electrics to be routed from the modules until the **patch panels (PPOs)** located at the Dee periphery. The routing has been obtained in two steps. First, the tracing of the services was laid out according to the predefined logical map using LaTeX with a user-defined library built on the tikz/pgf package. This allows to script the routing easily.



Curvature checks



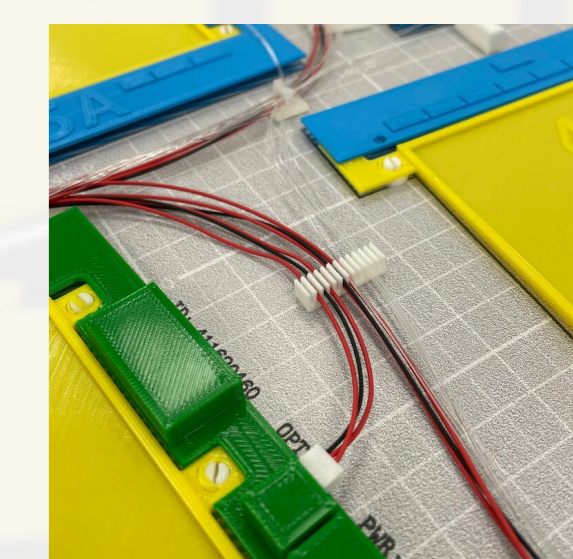
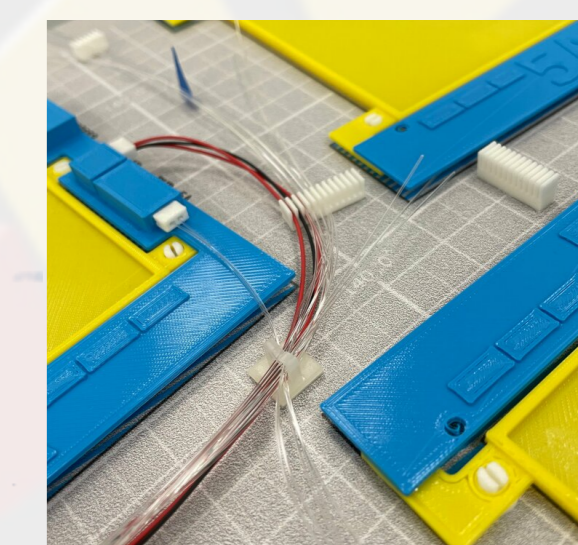
Total length measurement for one full TEDD



Validation of the design

Dedicated studies have been performed on a dee mockup in order to validate the routing and to compare various options for cable holders.

Dee mockup



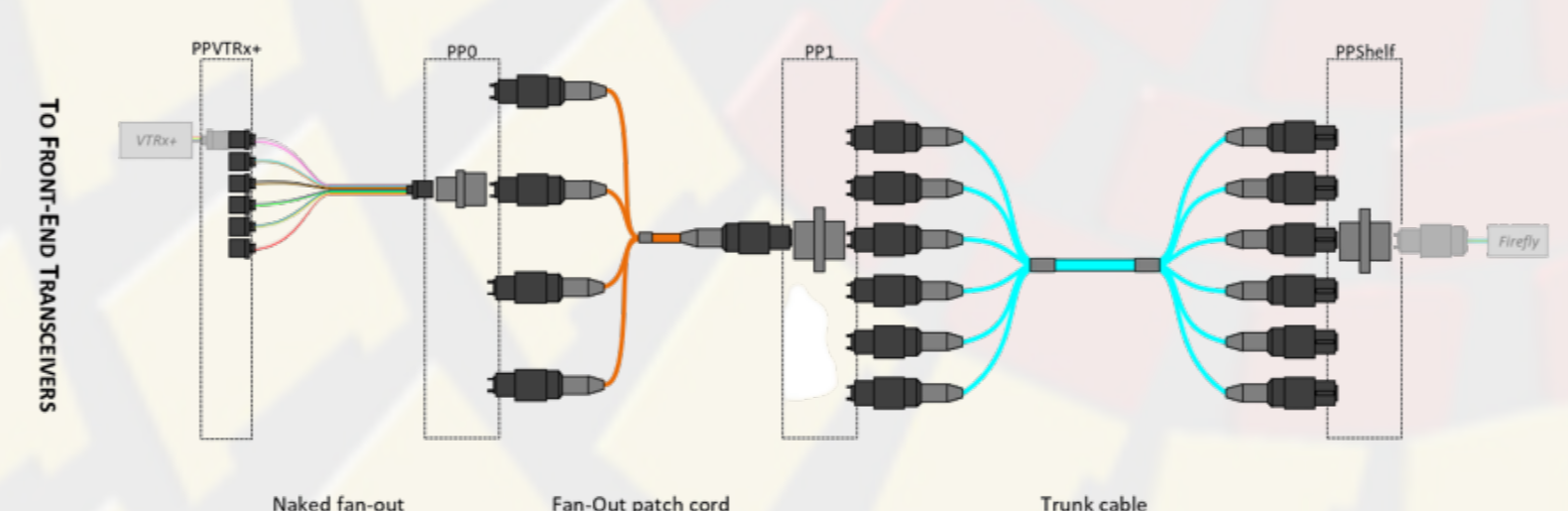
Second, FreeCAD (complemented with dedicated python-based macros) was used to perform the 3D visualisation of the cabling along with its analysis:

- The curvature measurements of the fiber bendings
- The length measurements of the fibers and wires
- The length measurements/checks of the pigtails

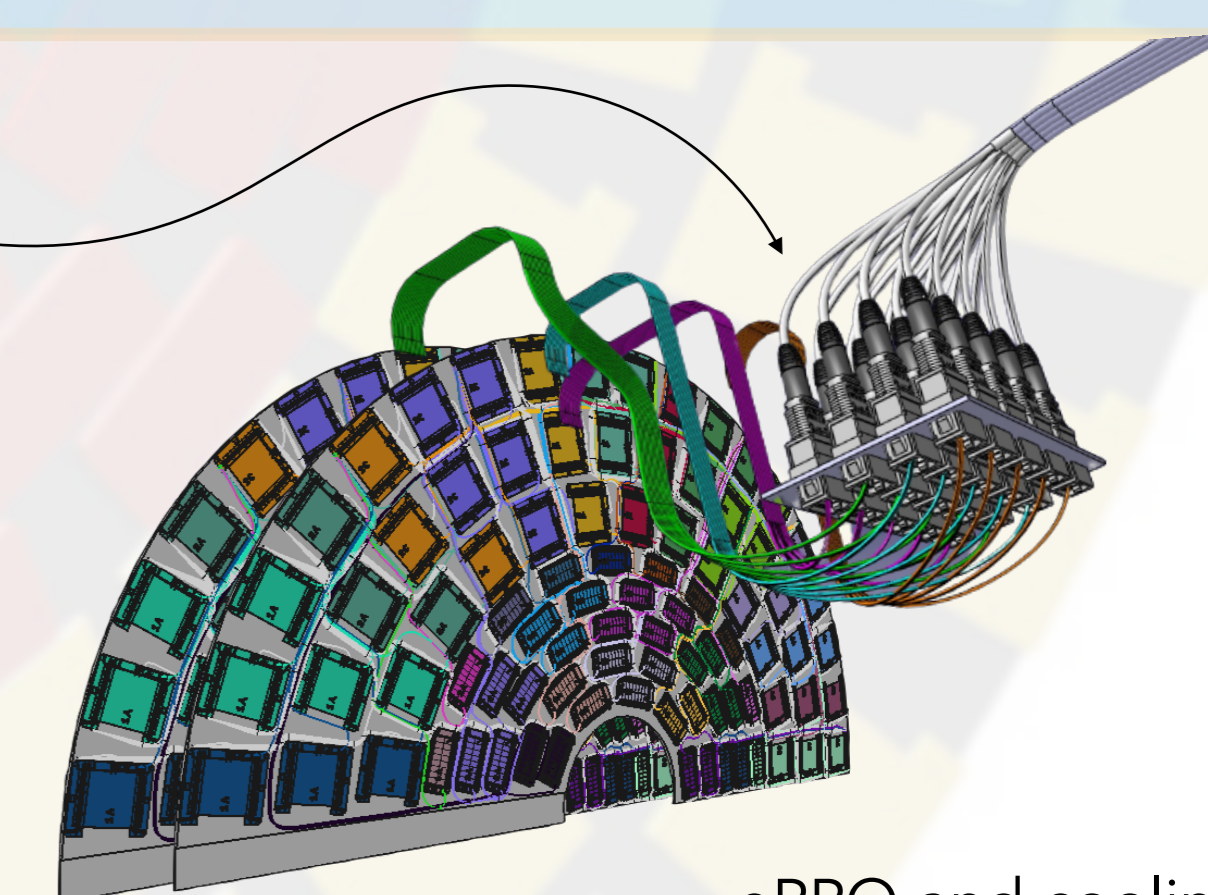
Longitudinal Services

The transition to longitudinal services starts from PPOs at the Dee periphery. They run longitudinally on the outer side of the TEDD volume and enter dedicated service channels in the bulkhead region, connecting the **PPOs** to the **PP1s** outside the TEDD volume.

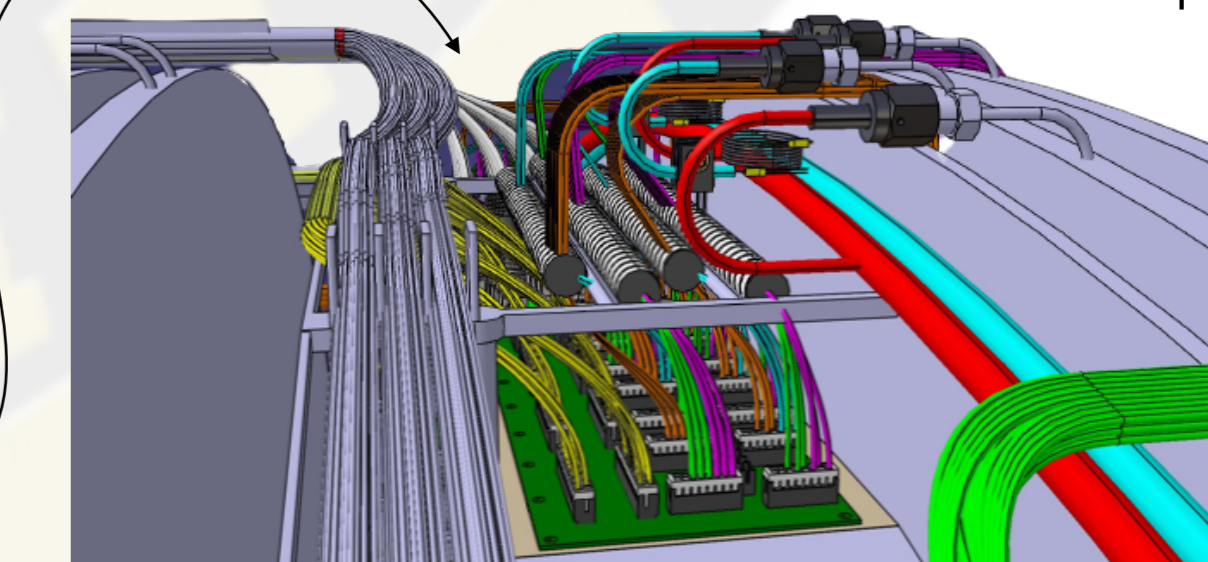
In the case of optical fibers, the longitudinal sections consist of the rugged fanouts which are connected to the optical PPO (**oPPO**) via four MTP connectors. The four branches are quickly merged into one single fiber ribbon that runs towards the service channel.



In the case of power cables, these are multi-service cables regrouping LV and HV from two dees to form power groups, as well as one temperature sensor and one preheater. The electrical PPO (**ePPO**) exists in two variants, with either three or four power groups.



ePPO and cooling manifold concept



Summary

The services design for the end caps of the phase-2 tracker for HL-LHC is being finalized.

- Detailed studies based on CAD software and custom codes allowed to develop a concept that meets all the requirements and constrains of the challenging environment.
- Validation of the transverse services with actual fiber and wire samples and module dummies is being carried on with full-scale mockups.
- Dedicated studies are also targeting the PPO region and the longitudinal services, both with more detailed CAD models and with dedicated mockups.

Acknowledgements

This work is supported by IISN Convention 4.4502.17. This project is being carried out in collaboration with IP2I, Lyon and DESY, Hamburg.

References

1. The Phase-2 Upgrade of the CMS Tracker, CMS Collaboration, CMS-TDR-014