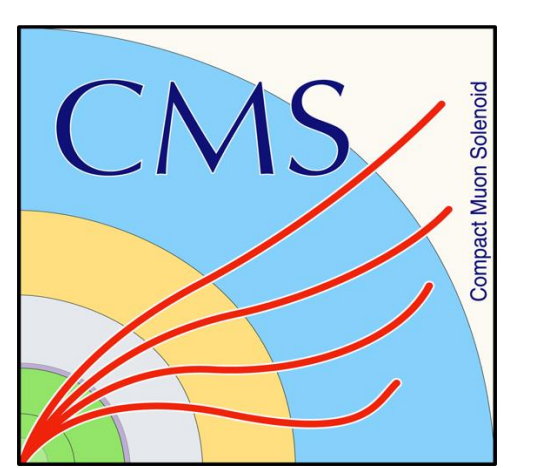


Data transmission performance and characterization of TEPX disk of Phase-2 CMS Inner Tracker

Filip Bilandžija (Universität Zürich) on behalf of the CMS Tracker Group

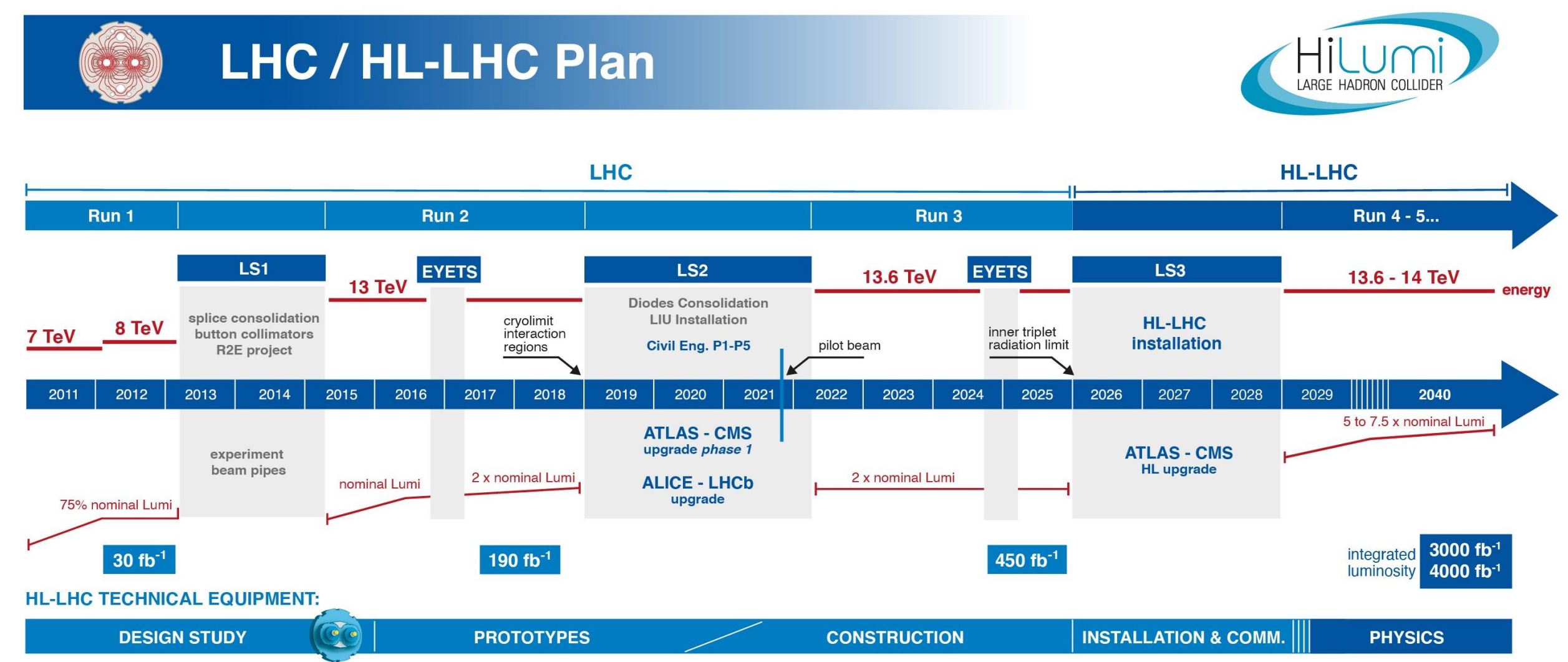


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The High-Luminosity LHC and Phase-2 Upgrade

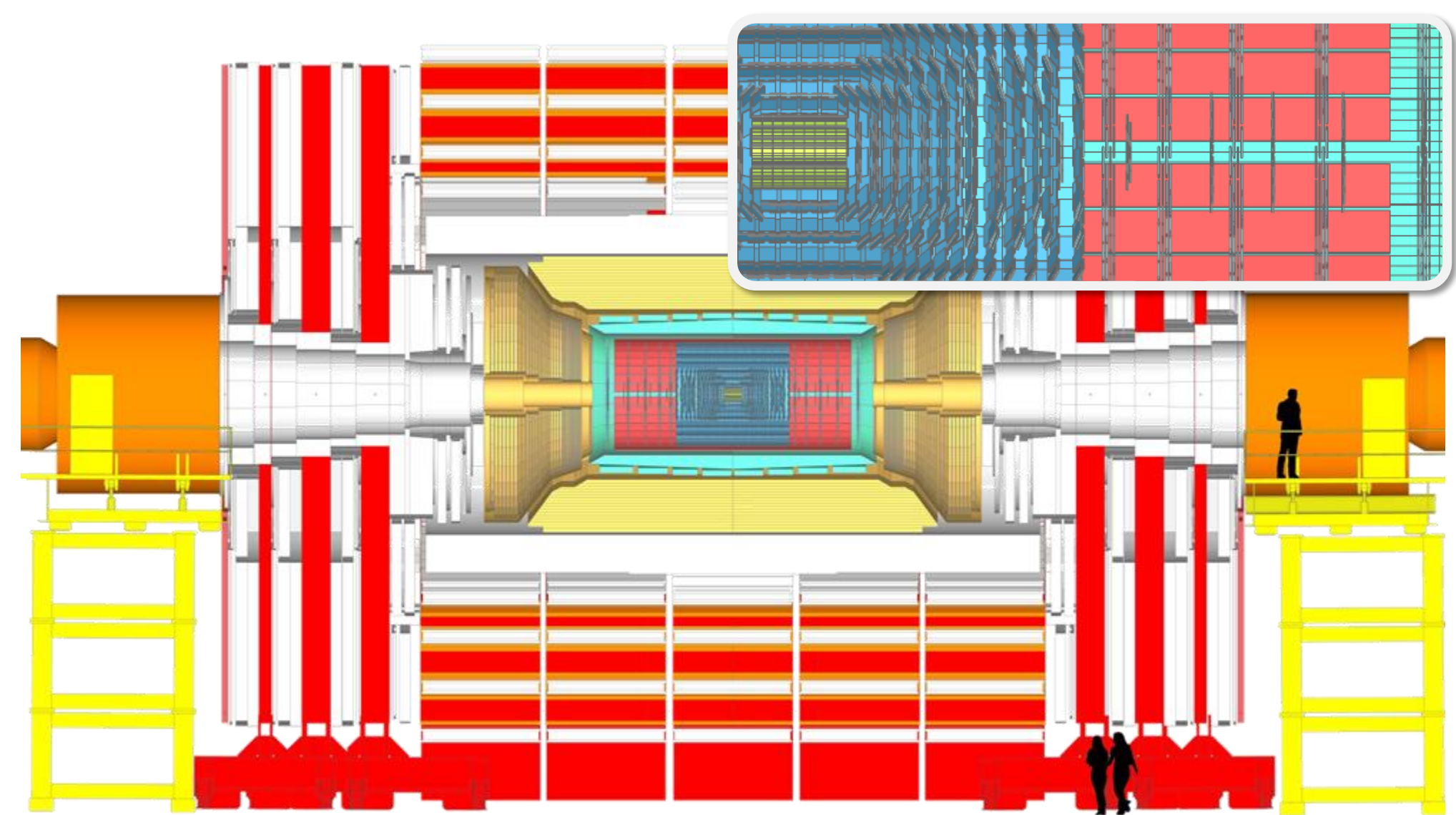
During the Long-Shutdown 3, LHC will be upgraded and enter its High-Luminosity era, allowing LHC experiments to increase their collected statistics, enabling more precise measurements and the potential to observe rare processes.



Up to 7.5x Up to 4000 fb⁻¹ Up to 200

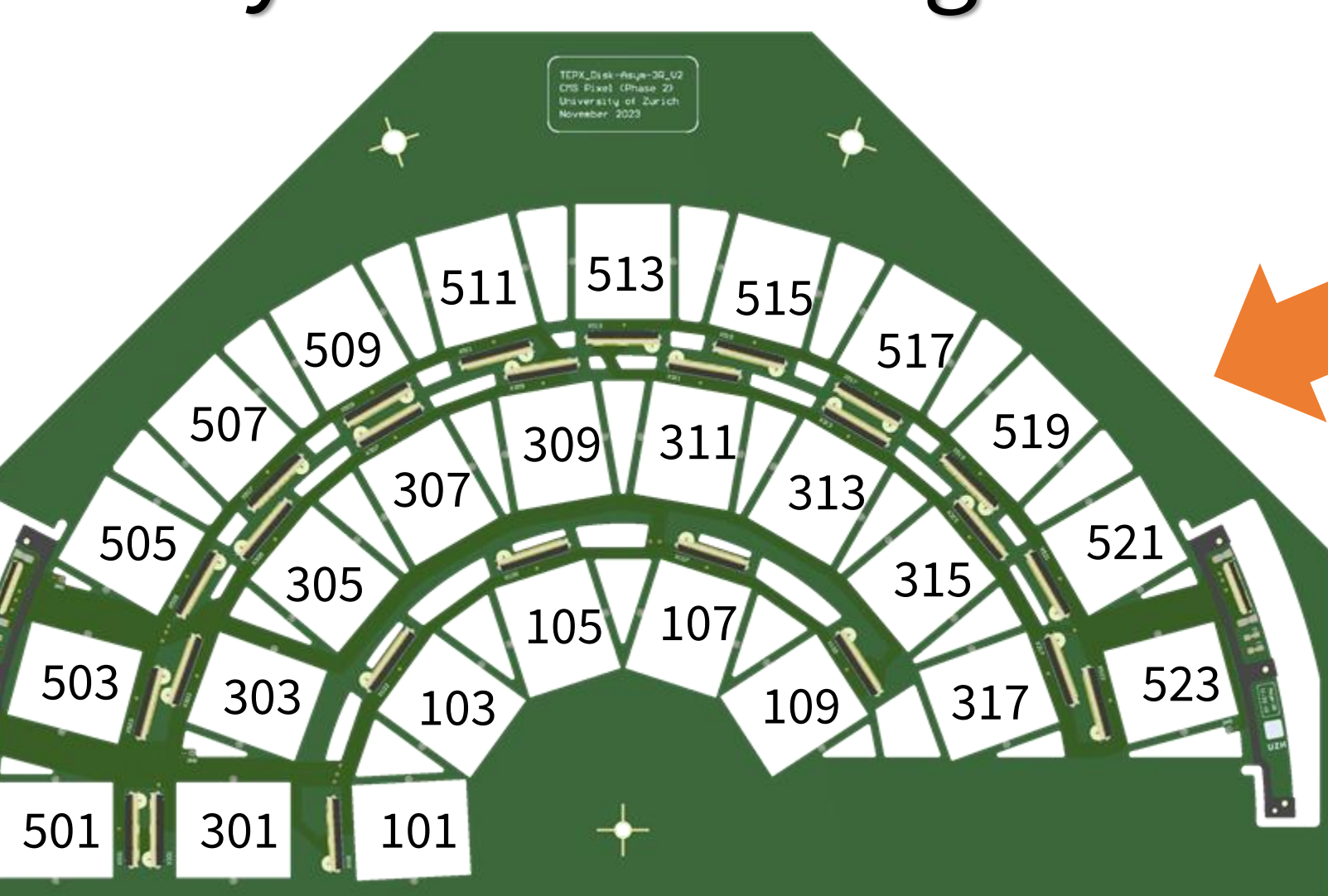
instantaneous luminosity compared to Run II target (2 × 10³⁴ cm⁻²s⁻¹) of integrated luminosity during the projects lifetime to be collected by CMS and ATLAS each additional pp collisions within the same or adjacent bunch crossing

CMS Phase-2 Tracker System and the Tracker Endcap PiXel Detector (TEPX)

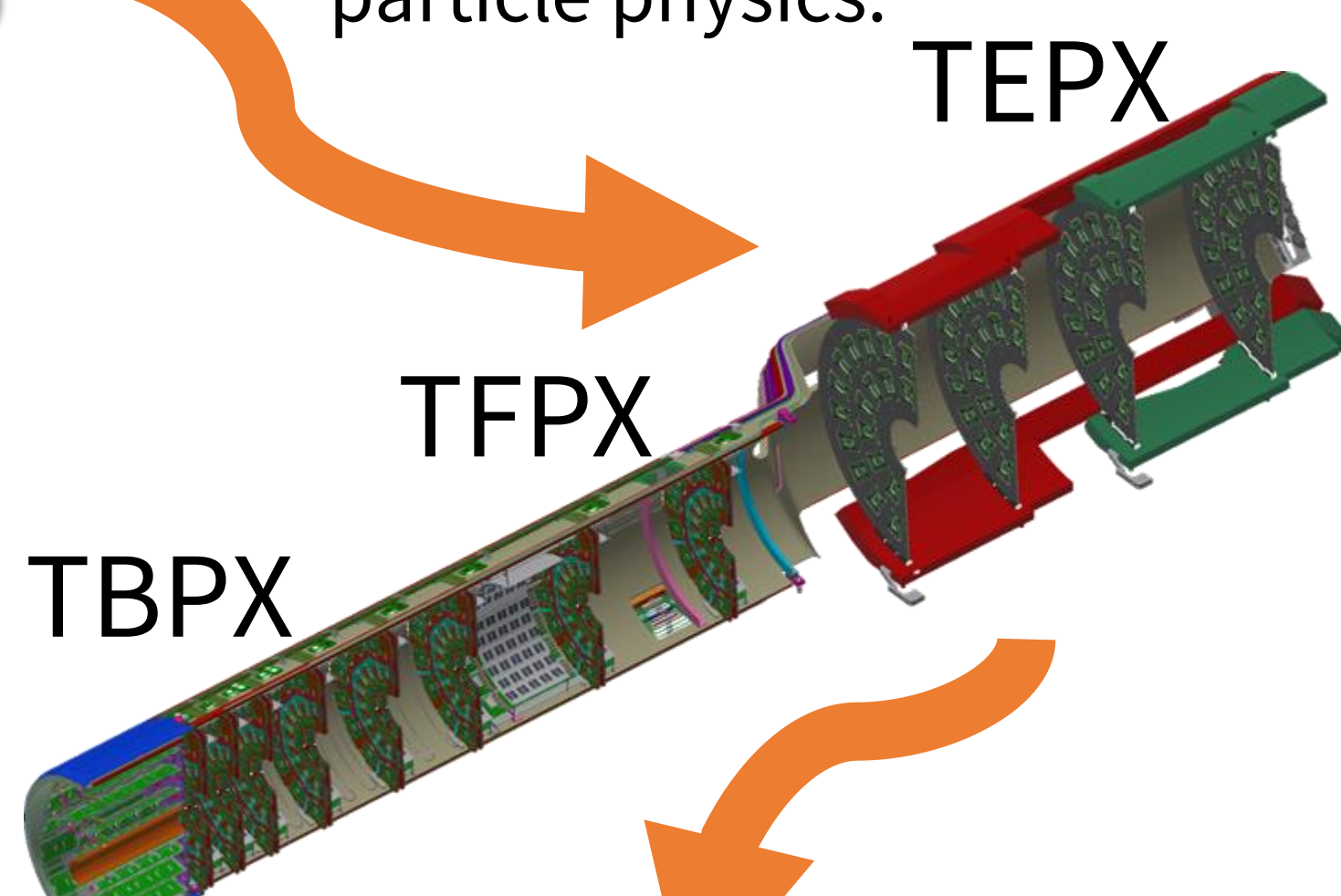


- Increased radiation tolerance
- Increased granularity
- Extended forward coverage up to $|\eta| \sim 4$

Asymmetric 3-ring PCB



In order to cope with increased data rates and overall more challenging operational conditions expected in the HL-LHC era, CMS will undergo an upgrade known as Phase-2 Upgrade, with its inner tracker system completely replaced, continuing its role in pushing the frontiers of particle physics.

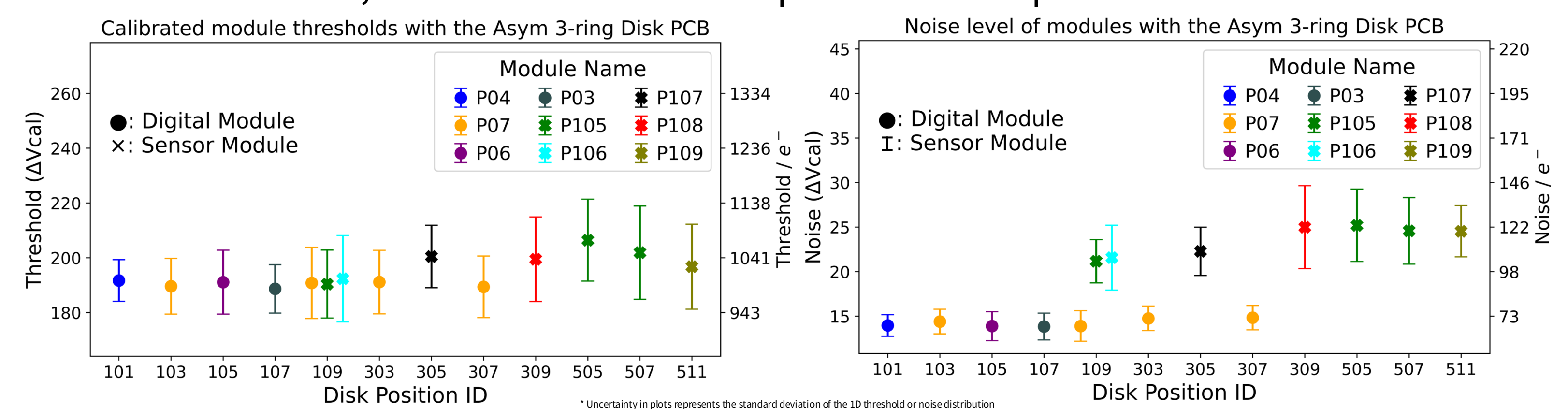


CMS Phase-2 Inner Tracker Upgrade

	Phase 1	Phase 2
➤ Mechanics	4 layers + 6 disks	➔ 4 layers + 24 disks
➤ Active Si area	2 m ²	➔ 5 m ²
➤ Channels	124M	➔ 2000M
➤ Pixel size	150 × 100 μm ²	➔ 100 × 25 μm ²
➤ Radiation tolerance	300 Mrad	➔ 1.2 Grad

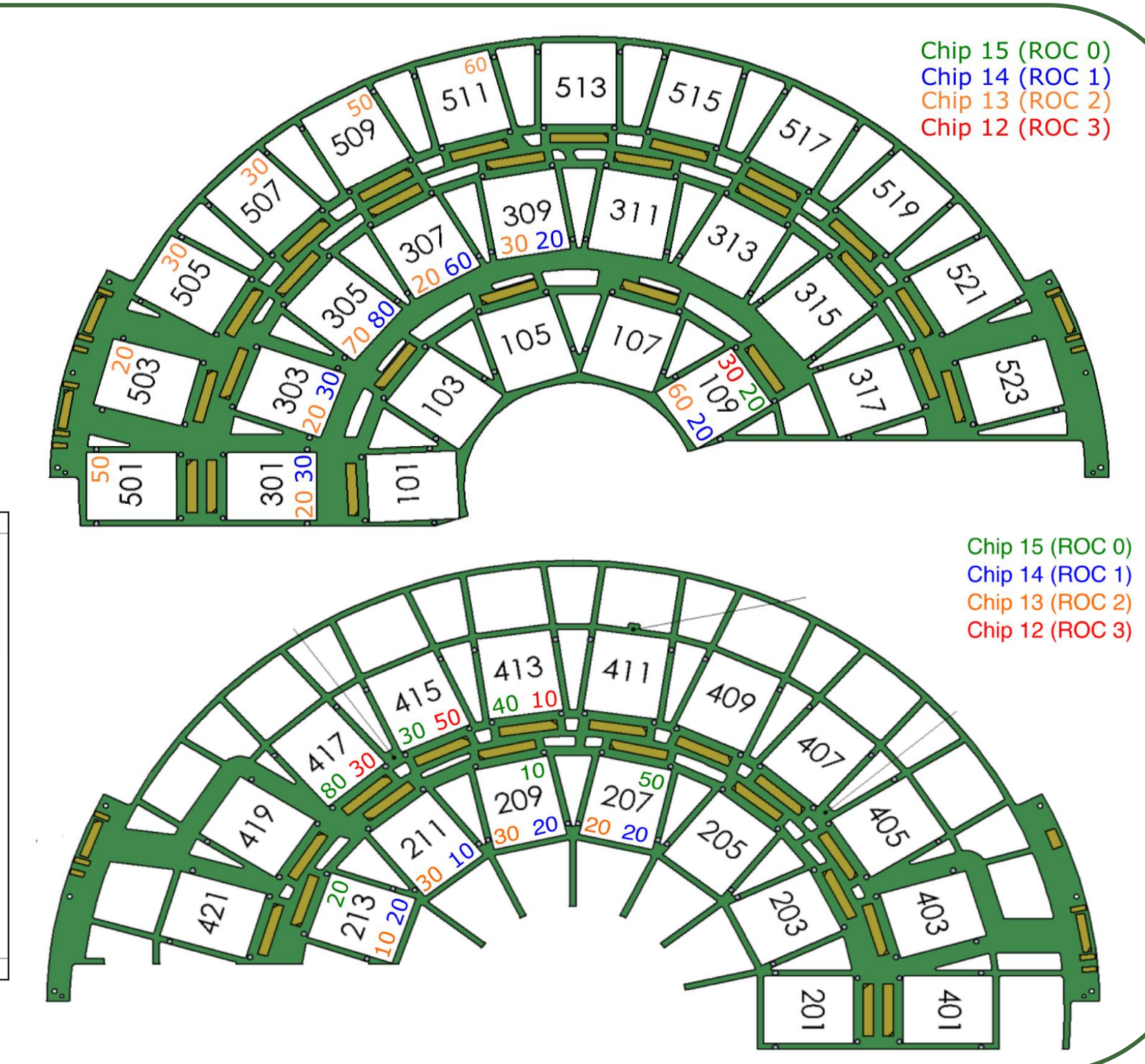
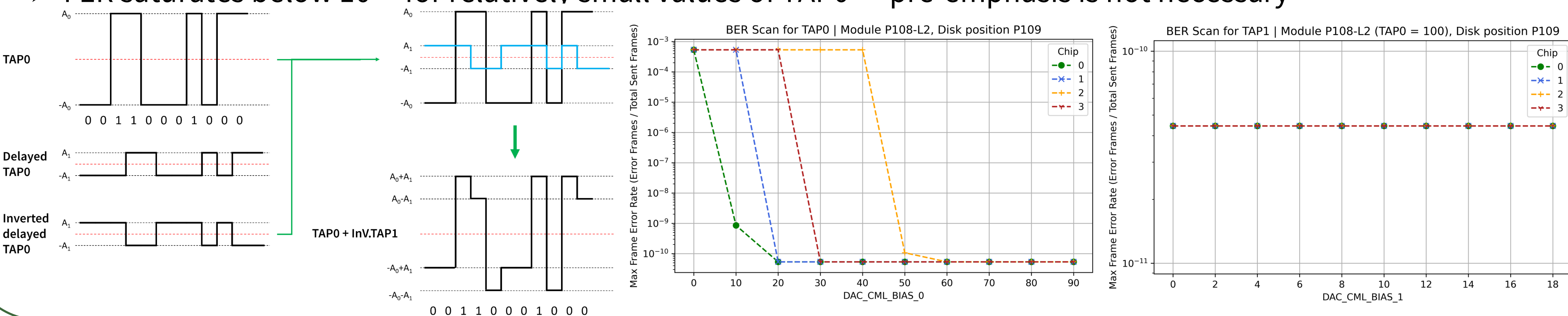
Disk PCB Validation

- 4-layer Polyimide PCB with Epoxy adhesive, 446μm thickness
- 4 different layouts: asymmetric/symmetric 2-ring/3-ring disk PCB
- Module test results with serial power distribution on disk consistent with standalone module operation
- Consistent, low noise level across positions compared to calibrated threshold



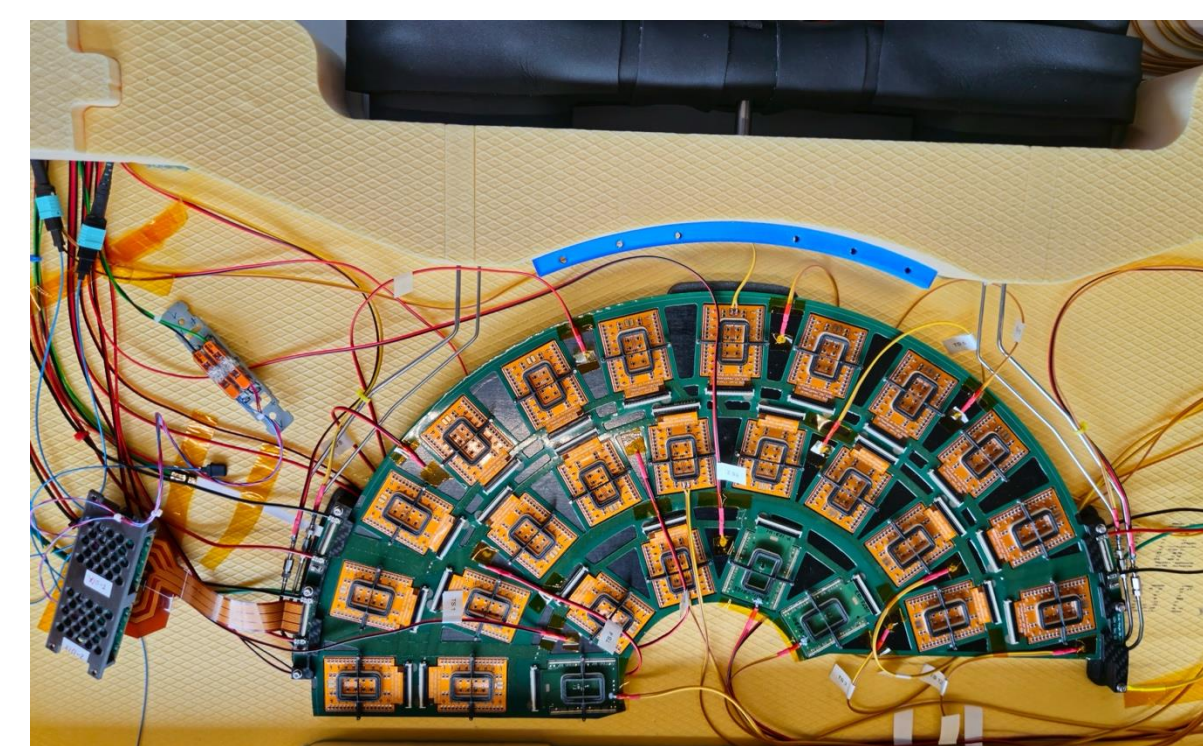
Disk PCB Bit Error Rate

- 4 current mode logic differential output drivers with programmable pre-emphasis
- Each driver can provide pre-emphasis with 3 current mode switches (TAPs)
- FER = number of error frames received / total number of frames transmitted (frame = 32 bits)
- FER saturates below 10⁻¹⁰ for relatively small values of TAP0 → pre-emphasis is not necessary



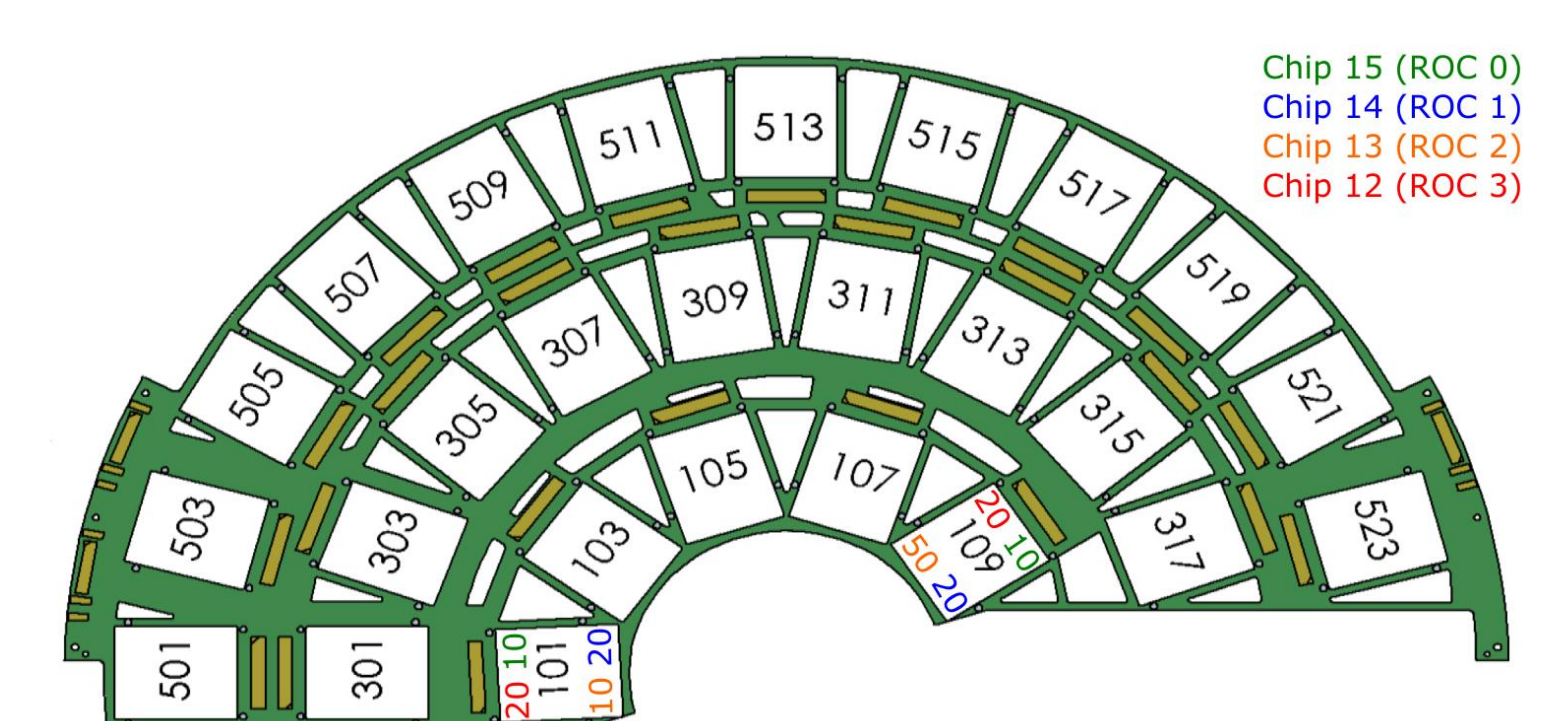
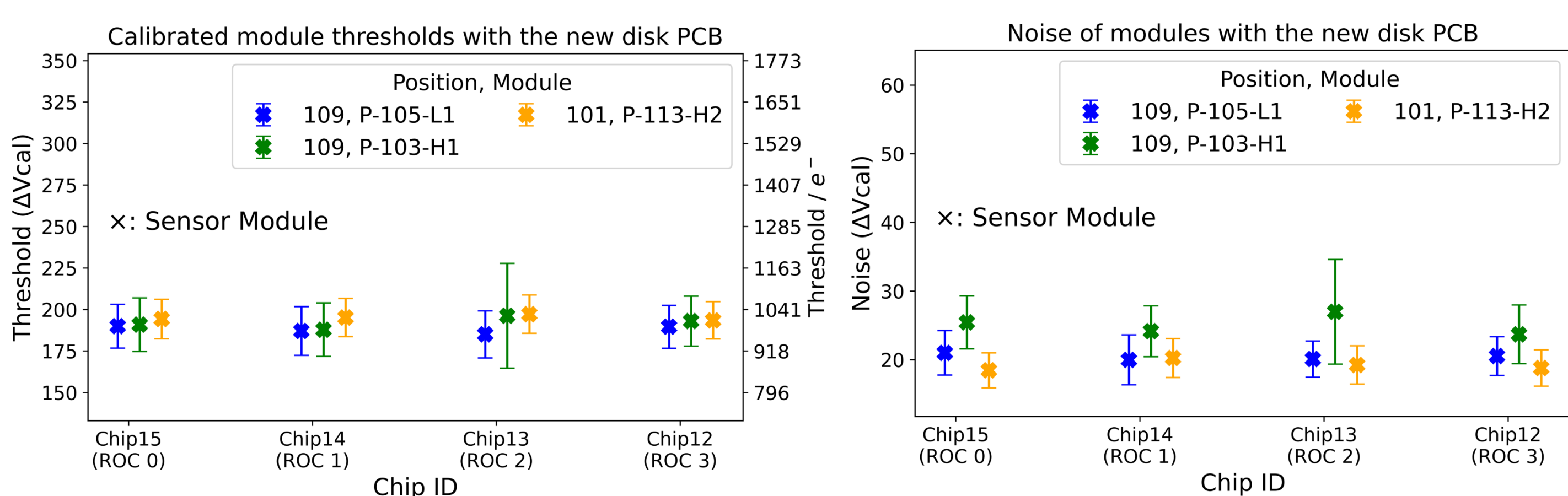
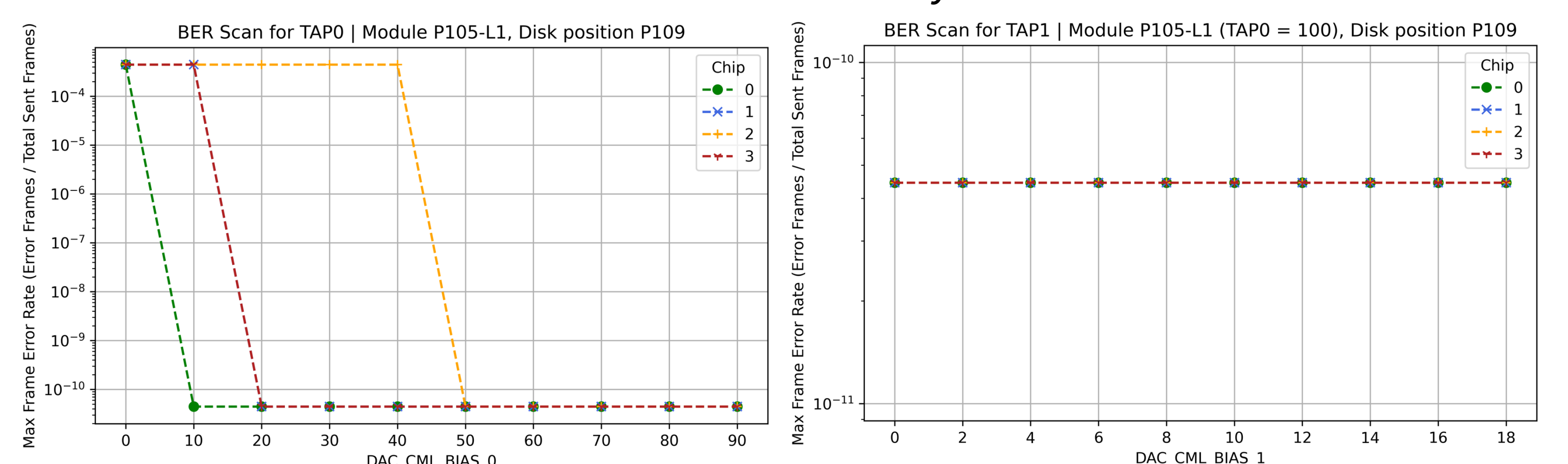
Disk Prototype Validation

- Prototype with Ti tubes
- Cooled with CO₂ to -30°C
- Ring 1 populated with sensor modules
- Ring 2/3/4/5 populated with heater modules



Disk Prototype Bit Error Rate

- Tested with fully powered frontal PCB (under thermal load of 300W)
- FER still saturates below 10⁻¹⁰ for relatively small values of TAP0



References

CMS Collaboration, *The Phase-2 Upgrade of the CMS Tracker*, CERN-LHCC-2017-009, CMS-TDR-014 (2017)
RD53 Collaboration, *RD53B Chip Manual*, CERN-RD53-PUB-19-002 (2019)