Development of the MTD Control and Safety Systems at CMS

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on behalf of MTD group
many thanks to Wassef and the whole central DCS team

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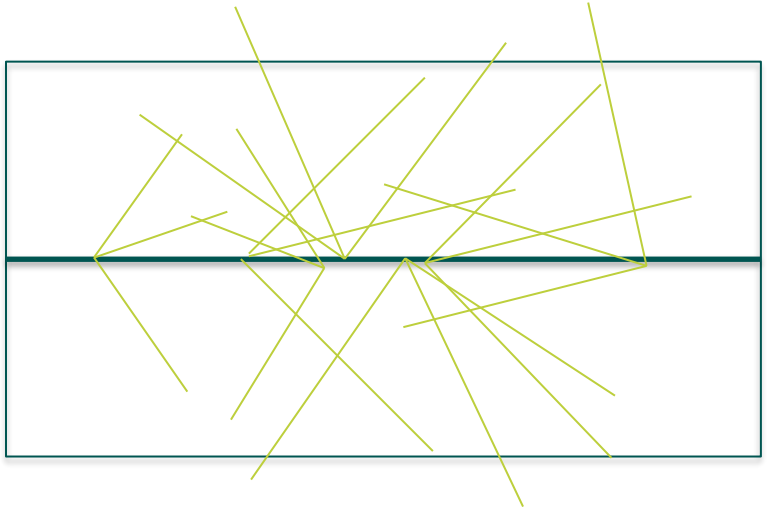
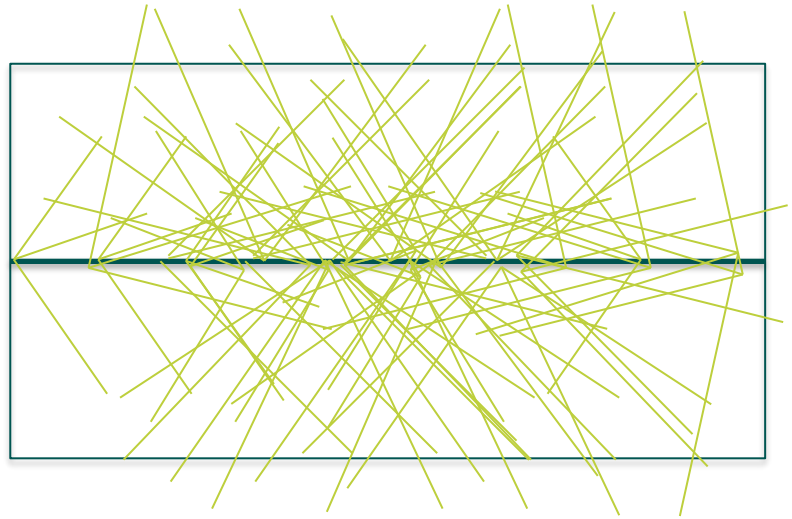
Increased luminosity poses challenges

- The high-luminosity Large Hadron Collider (HL-LHC) upgrade will provide the LHC experiments with a 5-fold increase in the instantaneous luminosity
- Particle reconstruction and identification will be challenging due to the abundance of simultaneous primary interactions



~20 – 40
primary
interactions



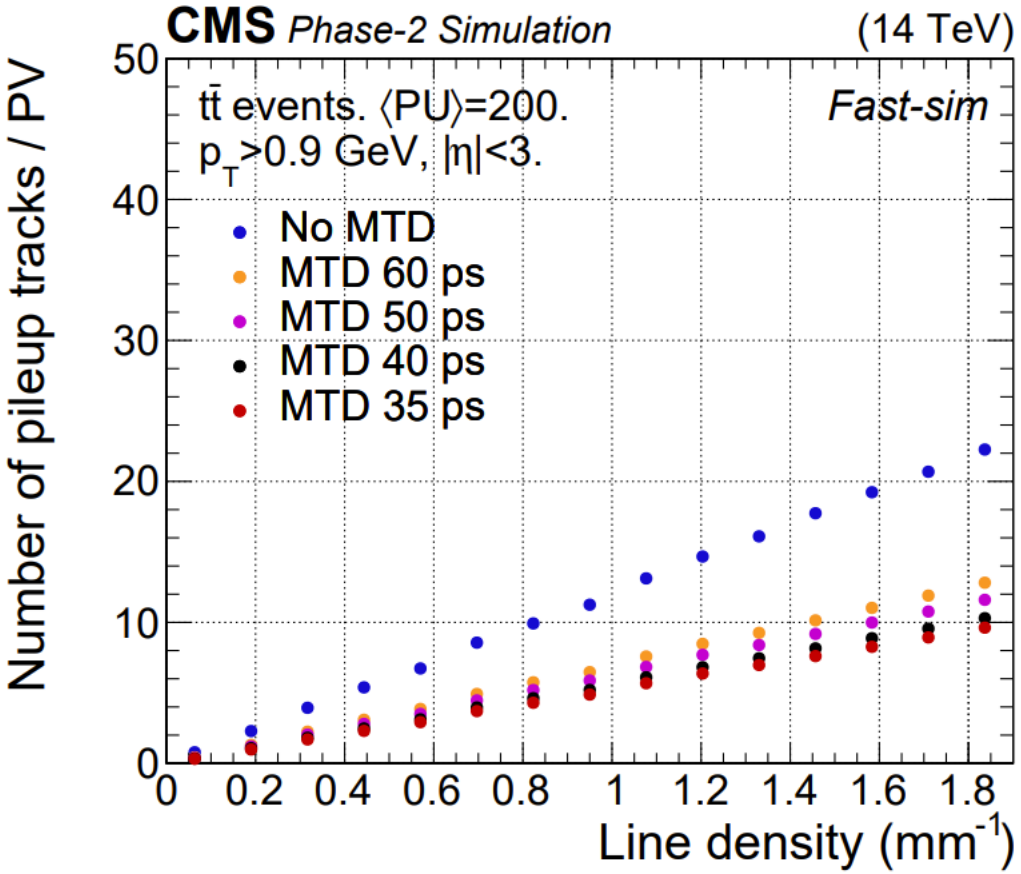
~140 – 200
primary
interactions

A superhero for untangling pileup

- The interaction region at CMS extends longitudinally covering an RMS collision time of 180-200 ps

- The addition of track-timing information with 35 - 70 ps precision reduces the wrong associations by more than a factor of two

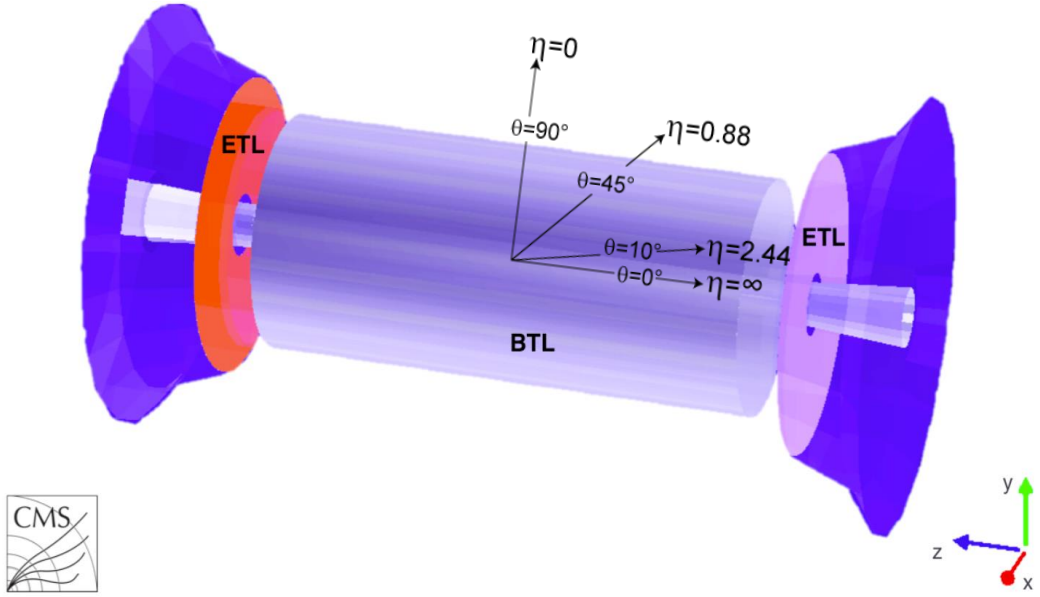
- The timing upgrade of the CMS detector will improve the particle-flow performance at high pileup to a level comparable to the current CMS detector



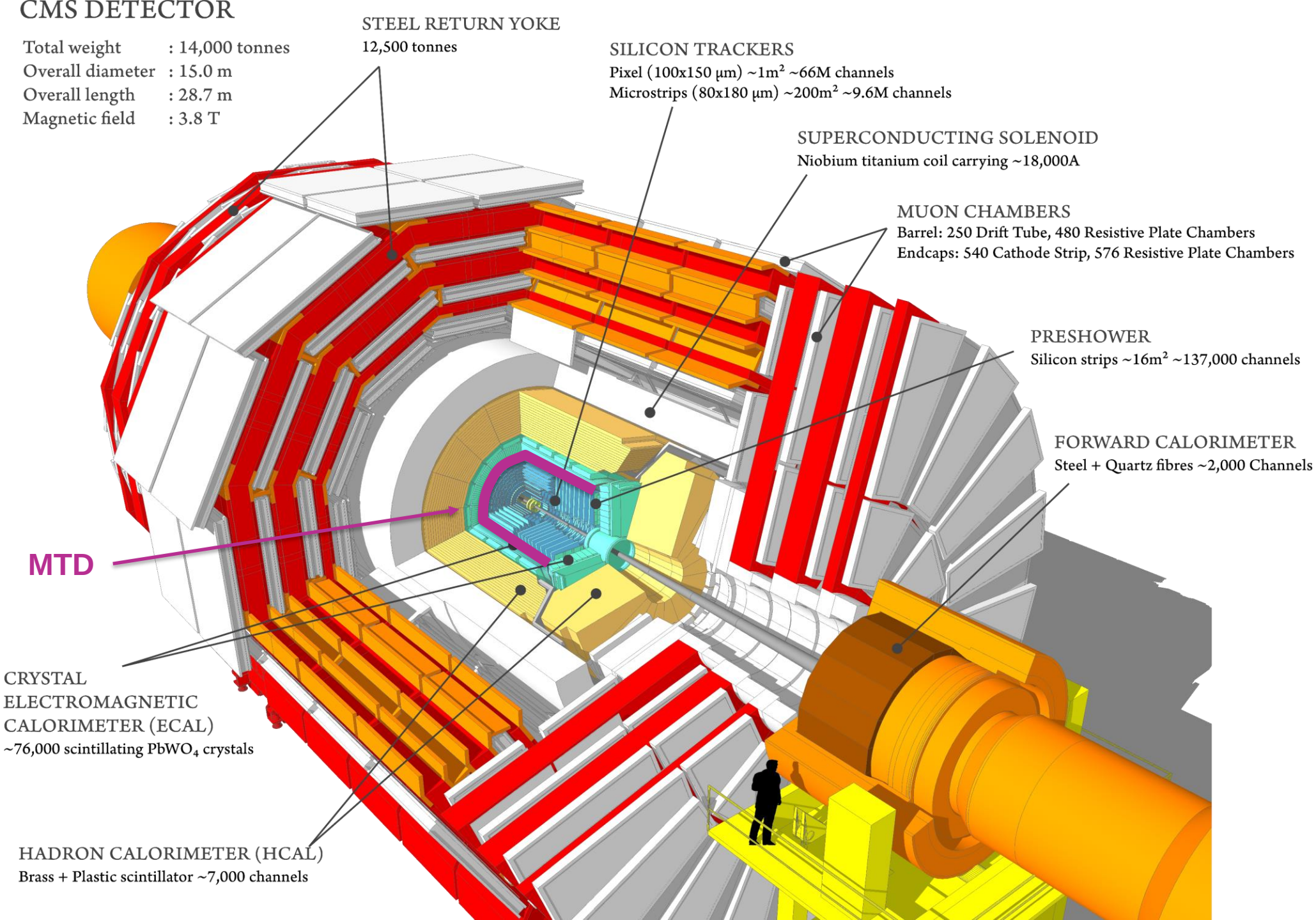
TDR: A MIP Timing Detector for the CMS Phase-2 Upgrade

Schematic representation of MTD

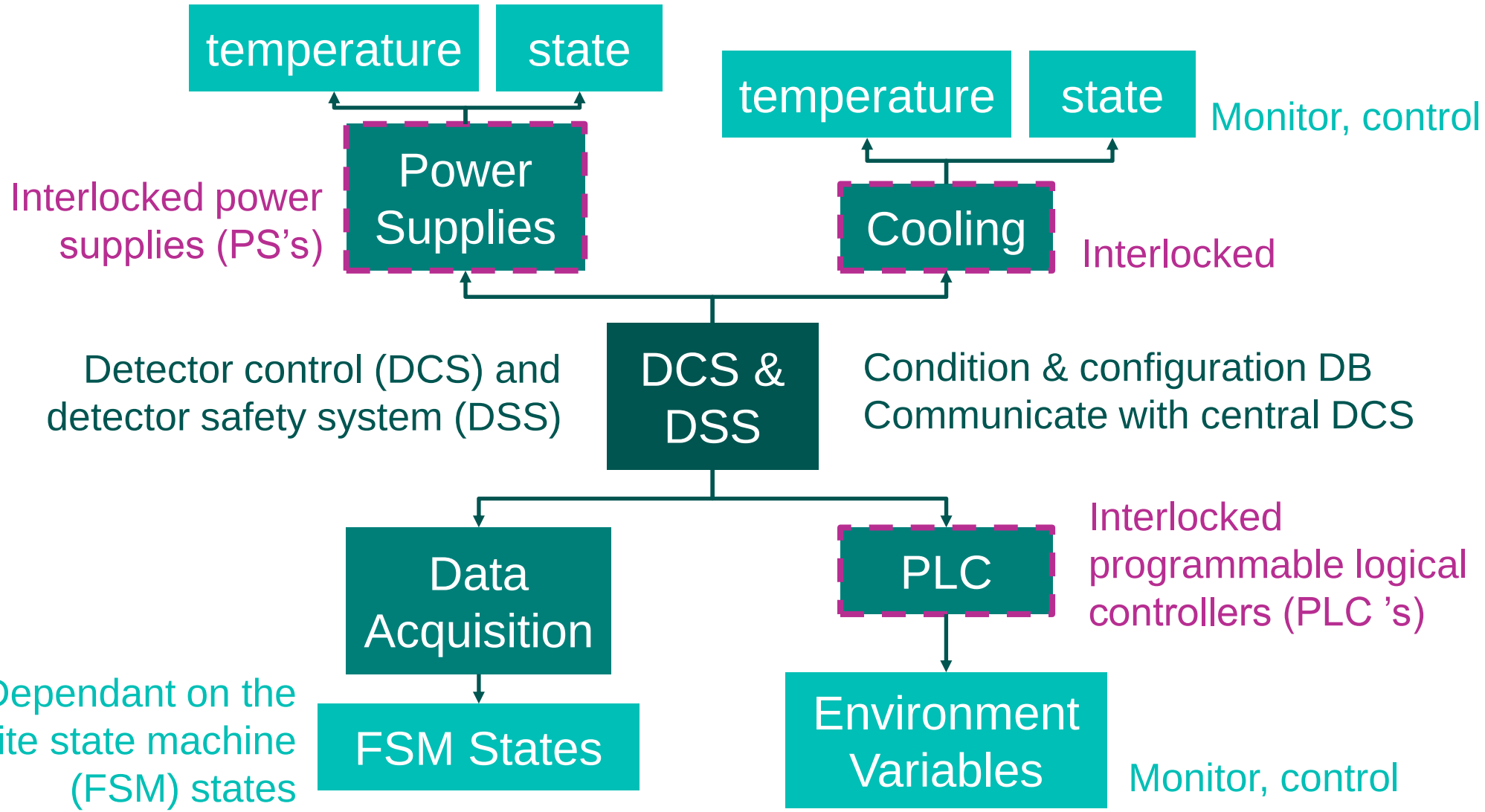
- **M**inimum ionizing particle **T**iming **D**etector (MTD) consists of a barrel timing layer (BTL) and two endcap timing layers (ETL)
- MTD identifies charged hadrons up to a few GeV in p_T **based on time-of-flight**



TDR: A MIP Timing Detector for the CMS Phase-2 Upgrade


CMS DETECTOR
Total weight : 14,000 tonnes
Overall diameter : 15.0 m
Overall length : 28.7 m
Magnetic field : 3.8 T
STEEL RETURN YOKE
12,500 tonnes
SILICON TRACKERS
Pixel (100x150 μm) ~1m² ~66M channels
Microstrips (80x180 μm) ~200m² ~9.6M channels
SUPERCONDUCTING SOLENOID
Niobium titanium coil carrying ~18,000A
MUON CHAMBERS
Barrel: 250 Drift Tube, 480 Resistive Plate Chambers
Endcaps: 540 Cathode Strip, 576 Resistive Plate Chambers
PRESHOWER
Silicon strips ~16m² ~137,000 channels
FORWARD CALORIMETER
Steel + Quartz fibres ~2,000 Channels
MTD
CRYSTAL ELECTROMAGNETIC CALORIMETER (ECAL)
~76,000 scintillating $PbWO_4$ crystals
HADRON CALORIMETER (HCAL)
Brass + Plastic scintillator ~7,000 channels

A typical architecture of DCS



WinCC OA = a tool to build DCS

WinCC OA has capabilities for:

- Device Description
  - Data Points, and Data Point elements
- Device Access
  - OPC, ProfiBus, Drivers
- Alarm Handling
  - Generation, Masking, etc
- Alarm Display, Filtering, Summarising
- Archiving, Trending, Logging
- User Interface Builder
- Access Control

Additional CERN-written

- JCOP framework
- Finite State Machine (FSM)
  - Abstract representation of the detector, what state is it in:
    - Data taking/ Standby/ Error
    - What triggers it to move from one of these states to another?
  - Same states for all experiment

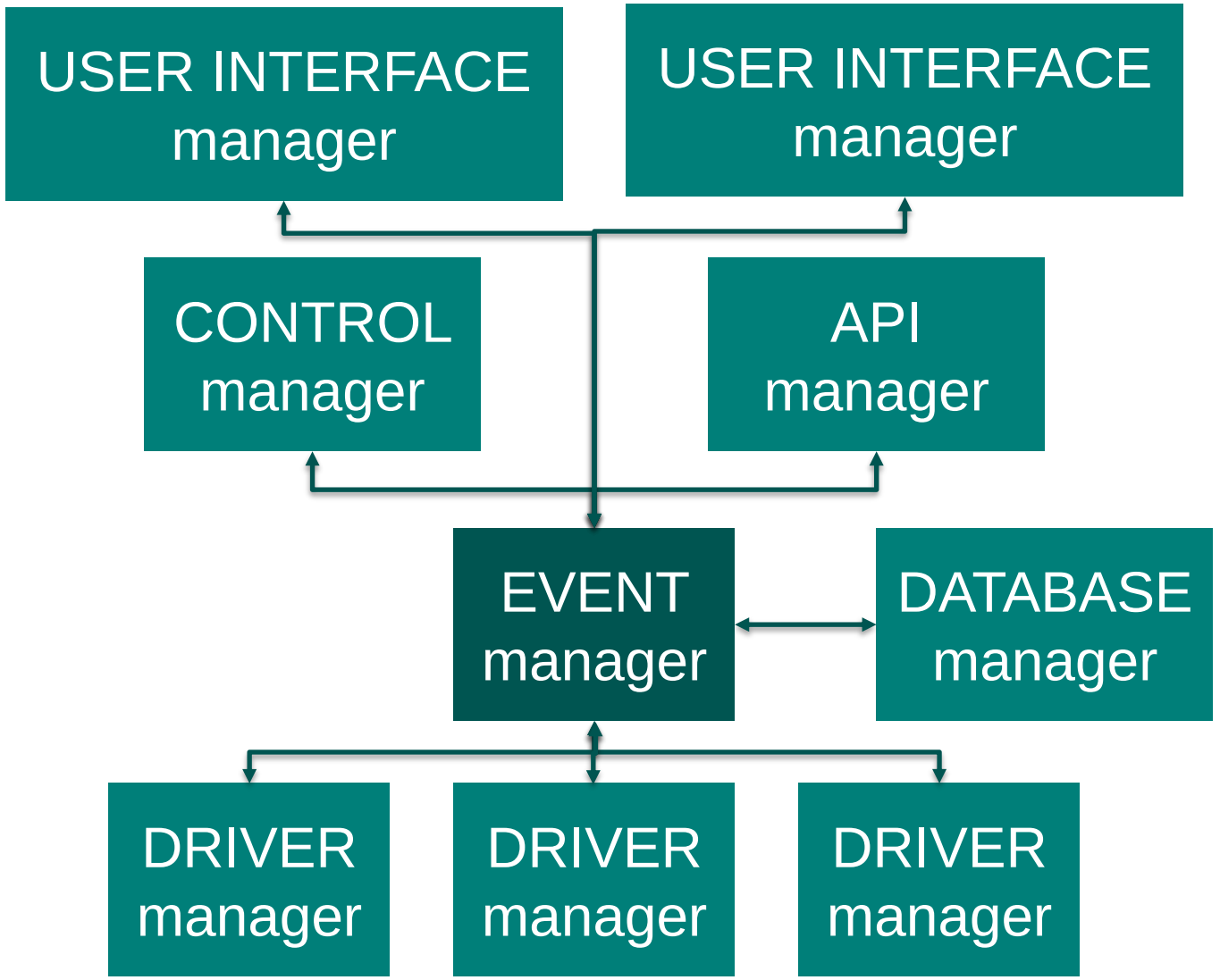
Event driven data exchange via managers

User interface layer

Processing layer

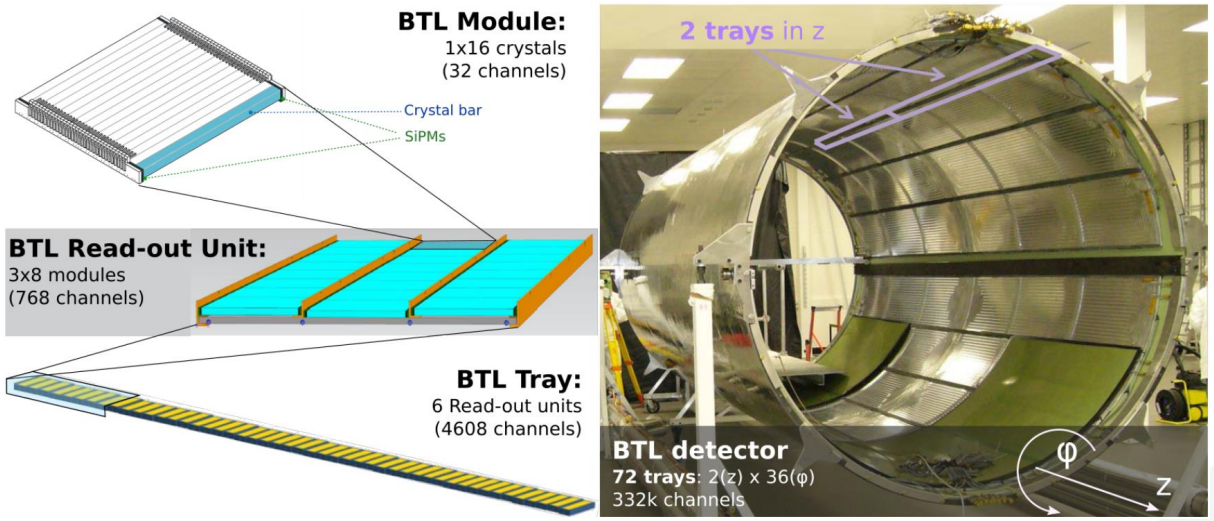
Communication and memory layer

Driver layer



CMS MTD TIF DCS

- Currently working on initial prototype tests in tracker integration facility (TIF)
- The DCS development is divided into three stages:



TDR: A MIP Timing Detector for the CMS Phase-2 Upgrade

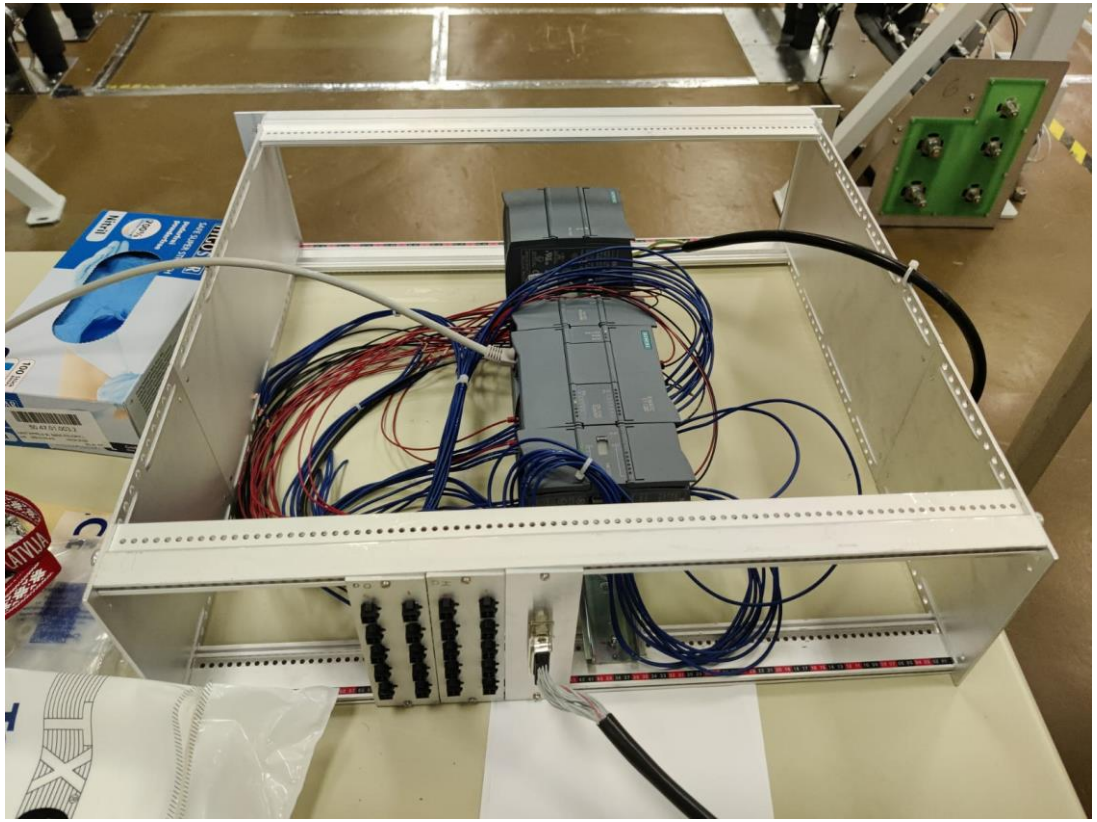
Initial prototype for tests

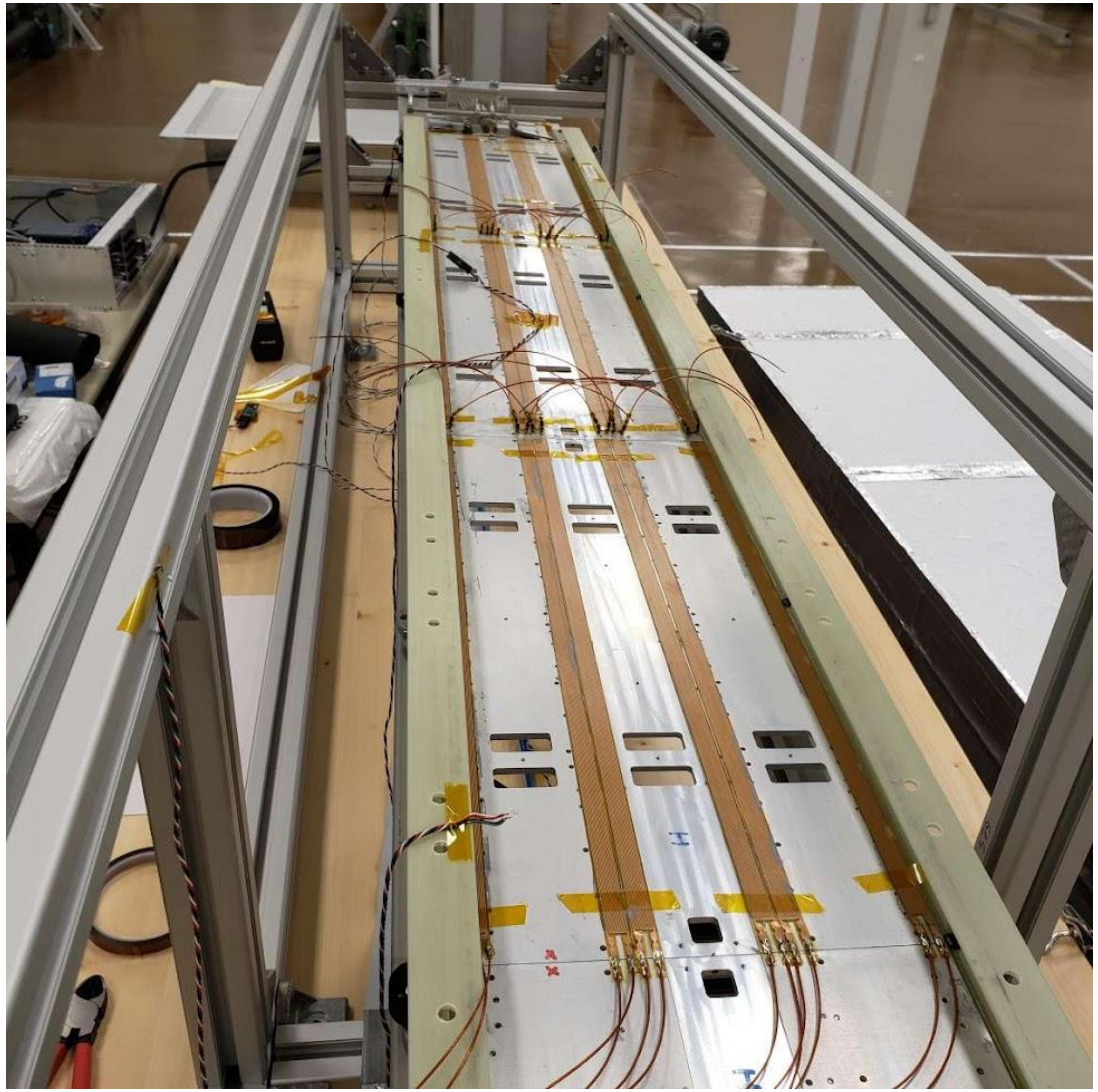
Single tray prototype

Full tray model

Initial prototype for tests

- Cooling tests (CO_2 flow)
- Heating tests (simulating modules and chips)





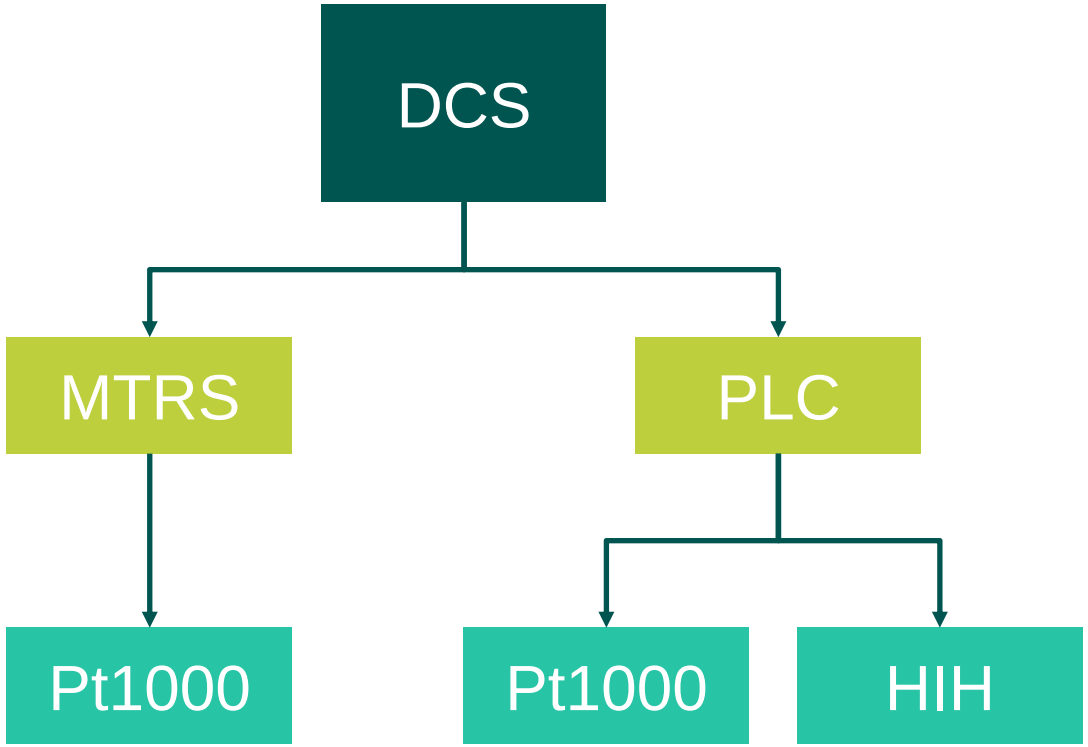
DCS for the initial prototype

MTRS – massive temperature readout system
PLC – programmable logical controller

Condition & configuration DB

Monitoring

Archiving



for temperature and humidity readouts

Initial interface panels

MTRS main pannel

MTRS CARD READOUT

cms_mtdtf_dcs_1:MTRS/MTD_TIF_33

19.45	19.48	19.52	19.43
19.48	19.57	19.36	19.40
19.60	19.56	19.42	19.33
19.54	19.43	20.43	19.64
19.54	19.55	19.59	19.41
19.41	19.47	19.36	19.56

cms_mtdtf_dcs_1:MTRS/MTD_TIF_34

-999.00	-999.00	-999.00	-999.00
-999.00	-999.00	-999.00	-999.00
-999.00	-999.00	-999.00	-999.00
-999.00	-999.00	-999.00	-999.00
-999.00	-999.00	-999.00	-999.00
-999.00	-999.00	-999.00	-999.00

Close

cms_mtdtf_dcs_1:MTRS/MTD_TIF_33/Chip_1/Channel_0

Data Point Information

chip, channel: 1 | 0
DP alias:
DP description: Seventh RTD
DP name: cms_mtdtf_dcs_1:MTRS/MTD_TIF_33/Chip_1/Ch

Readings

Value: 19.48 °C — Plot..
State: OK

Value Limits

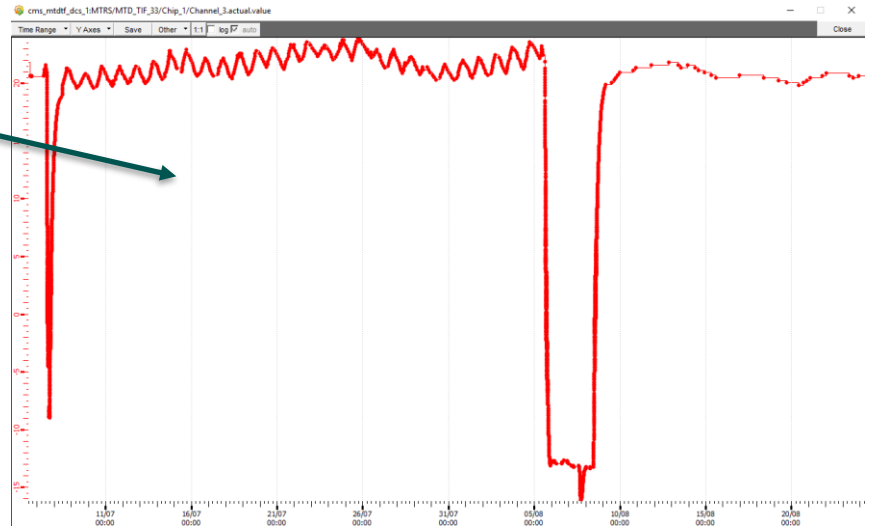
Upper limit: 0 — Disabled
Lower limit: 0 °C — Disabled

Detailed Information

Parameter	Value	Warnings
Dcs out of Limit	OK	
Dcs upper Limit enabled	Disabled	
Dcs upper Limit value	0	
Dcs lower Limit enabled	Disabled	
Dcs lower Limit value	0	
Dcs channelNum	0	
Dcs chipNum	1	
Model		Empty string
Raw complex ID	000000000000000	
Raw value	0100110111101000	
User Defined		Empty string
Last Updated	18/09/22 00:48:22	

Disable sensor

Close



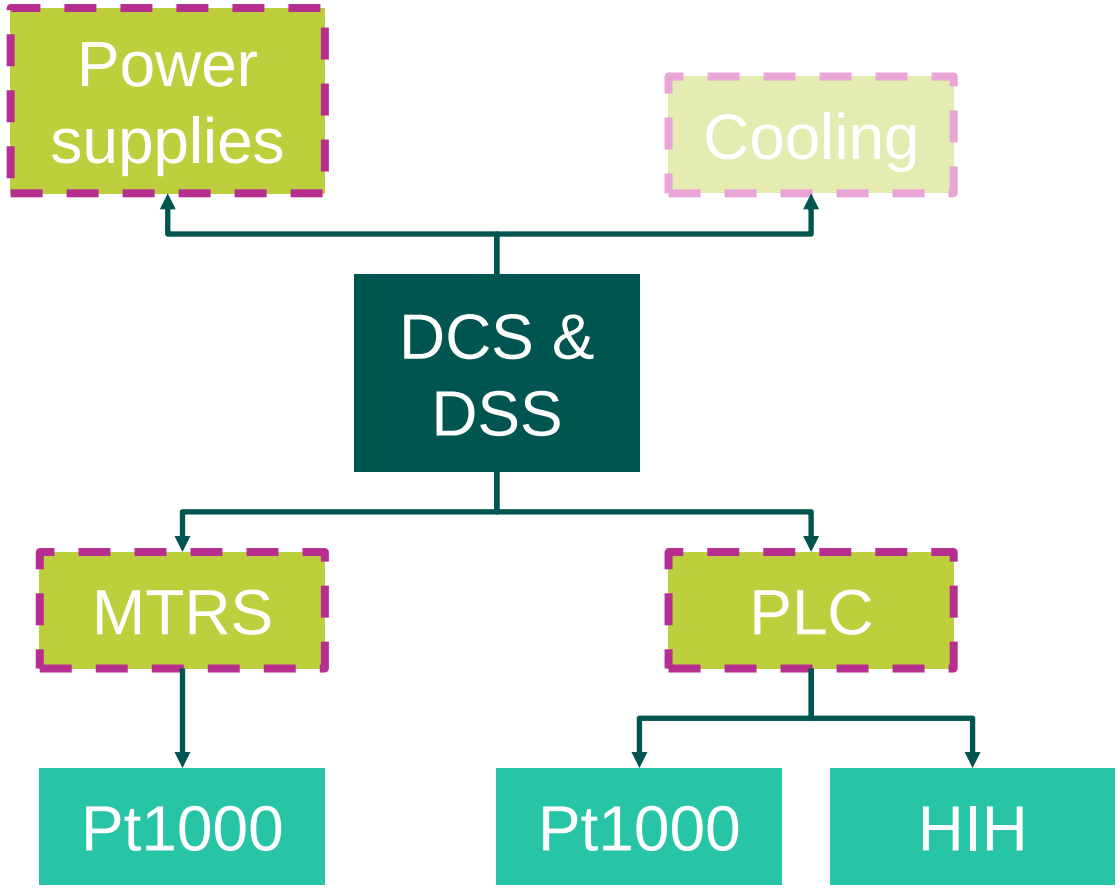
DCS in near future

Condition & configuration DB DAQ

Monitoring & controlling

Archiving

Interlocked



Summary

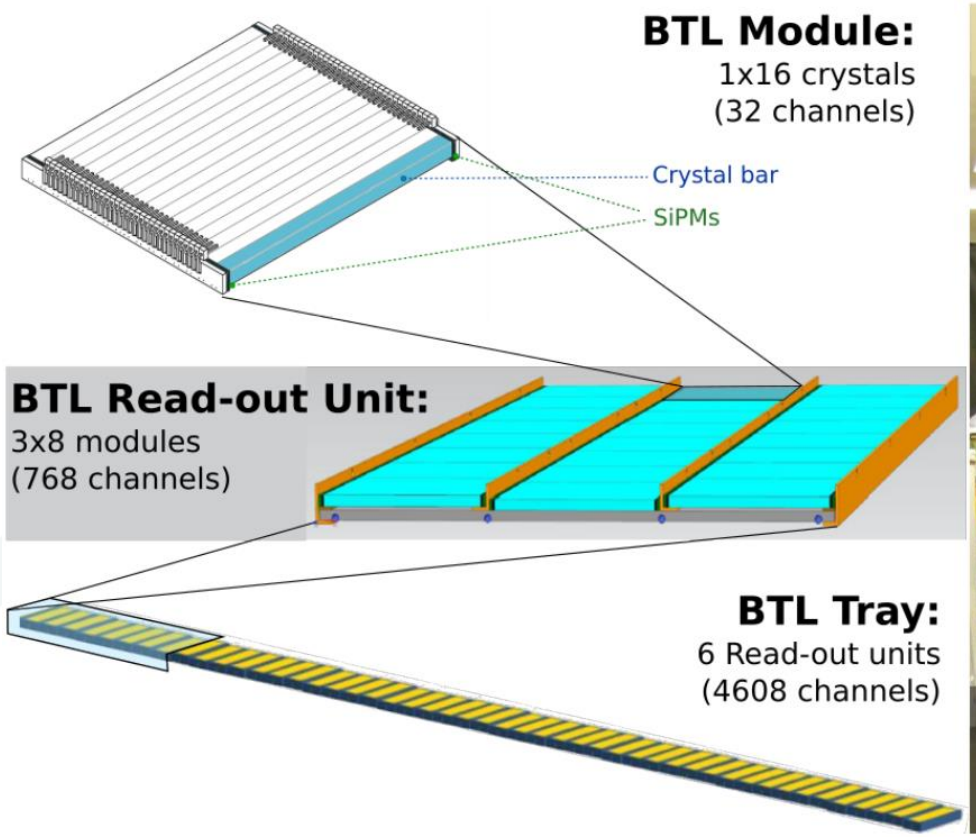
- The HL-LHC upgrade will provide the CMS experiment with a 5-fold increase in the instantaneous luminosity
- Up to a 5-fold increase in the number of p-p collisions per bunch crossing are expected in Run 4 compared to Runs 1-3
- A new subsystem, the MTD will be built to help untangle the collision data
- DCS and DSS systems are being developed to ensure safe operation of the detector
- The initial prototype has been developed and the work towards the development of a full DCS/DSS prototype is on-going

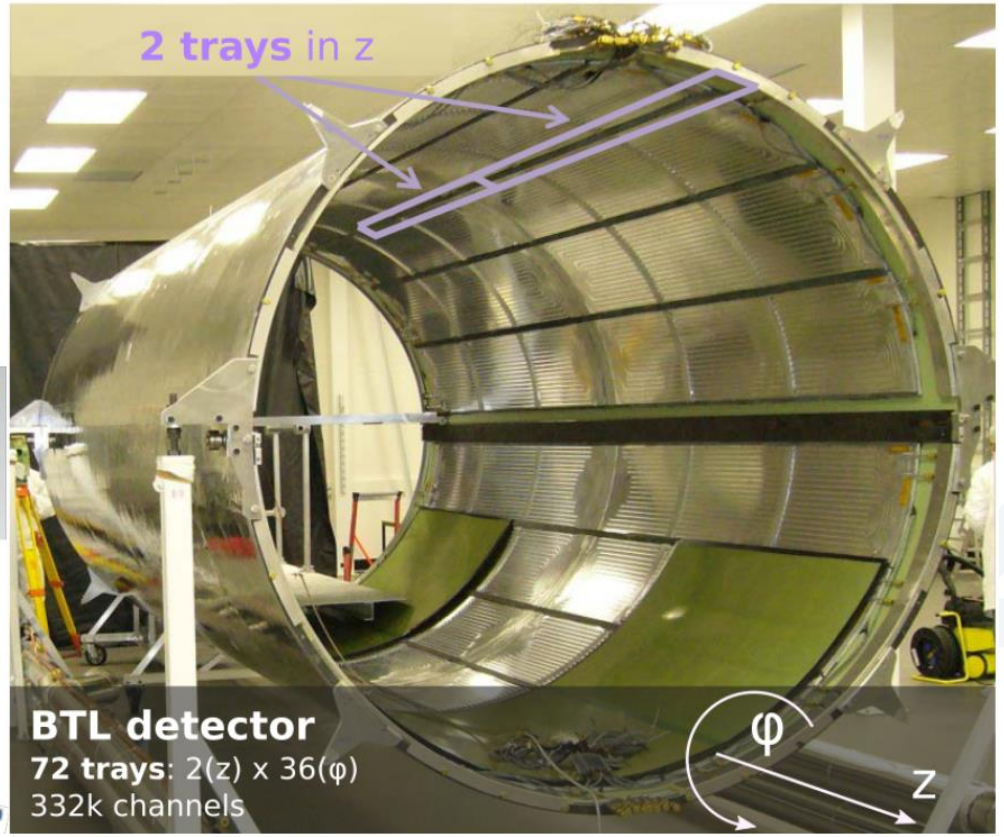
Questions?

backup

The Compact Muon Solenoid (CMS) experiment at the Large Hadron Collider (LHC) will undergo extensive upgrades during the long-shutdown 3 (LS3) scheduled for 2026-28. One of the most prominent aspects of the upgrade will be the introduction of a **new detector sub-system**, the MIP Timing Detector (MTD), situated between the outer tracker and the electromagnetic calorimeter. The MTD is a timing layer, which **aims to provide a charge-track time resolution on the order of tens of picoseconds**. As with all detector systems at CMS, the MTD will be controlled and monitored using detector control and detector safety systems (**DCS and DSS**). DCS and DSS are one-of-a-kind purpose-built prototype software systems, constructed using the WinCC OA software package.

CMS MTD TIF DCS DSS





The proposed solution is a new detector

- Minimum ionizing particle Timing Detector (MTD) is a new detector planned for **CMS** during the **High Luminosity LHC** (HL-LHC) era:
  - timing information for MIPs
    - 30 – 40 ps at the beginning of HL-LHC operation
    - 50 – 60 ps by the end of HL-LHC operations
  - identifies charged hadrons up to a few GeV in p_{T} **based on time-of-flight**
  - improves the particle-flow reconstruction
    - Improving e^-, e^+, p, γ, τ, μ, jet, and p_{T}^{miss} reconstruction