

# CMS Torino Status and long-term plans In support of European Strategy for PP

*Stefano Argirò for CMS  
Torino, 17/10/2024*



# CMS Torino Business Card

**Largest Italian CMS group** with 43 members, 25 staff

Several responsibilities (in 2025: 3xLevel1, 16xLevel2, 23xLevel3)

Involvement in top-level CMS management (2 System Managers)

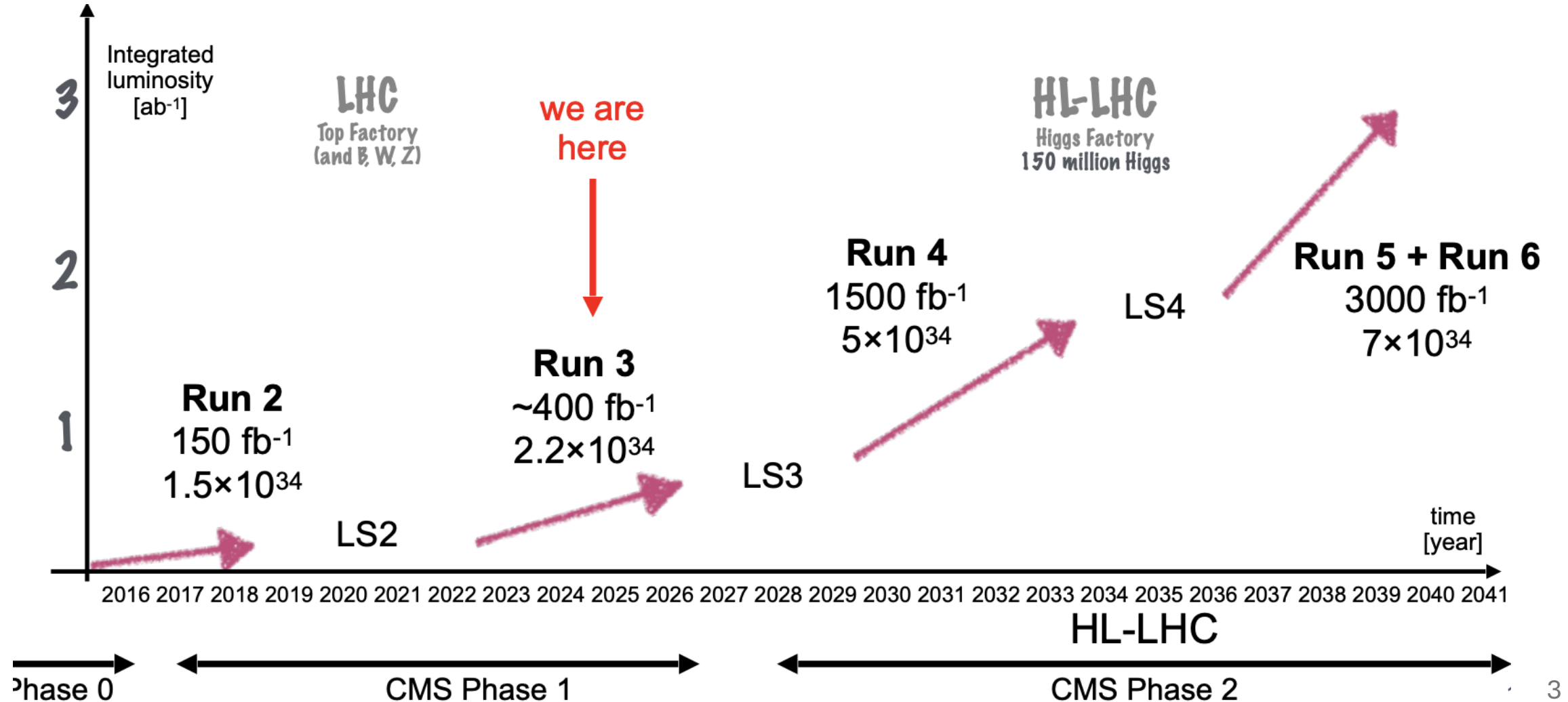
INFN RAs (TK, MTD. Ex PPS, ECAL)

6 sub-systems

Prominent roles in Higgs physics, SM physics, B physics, forward physics

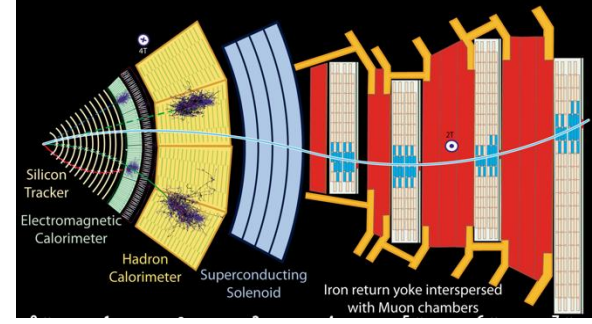


# LHC and HL-LHC Plans

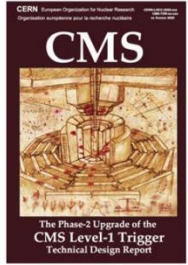




# Hardware



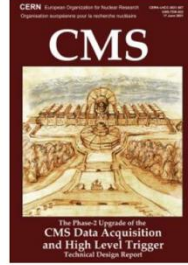
## Our Future Unprecedented Beauty - A Bold Upgrade



### L1-Trigger

<https://cds.cern.ch/record/2714892>

- Tracks in L1-Trigger at 40 MHz
- Particle Flow selection
- 750 kHz L1 output
- 40 MHz data scouting



### DAQ & High-Level Trigger

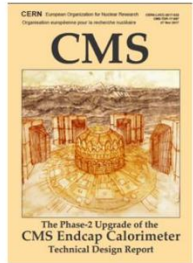
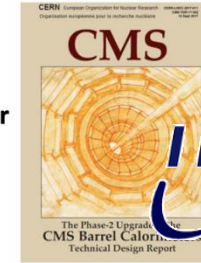
<https://cds.cern.ch/record/2759072>

- Full optical readout
- Heterogenous architecture
- 60 TB/s event network
- 7.5 kHz HLT output

### Barrel Calorimeters

<https://cds.cern.ch/record/2283187>

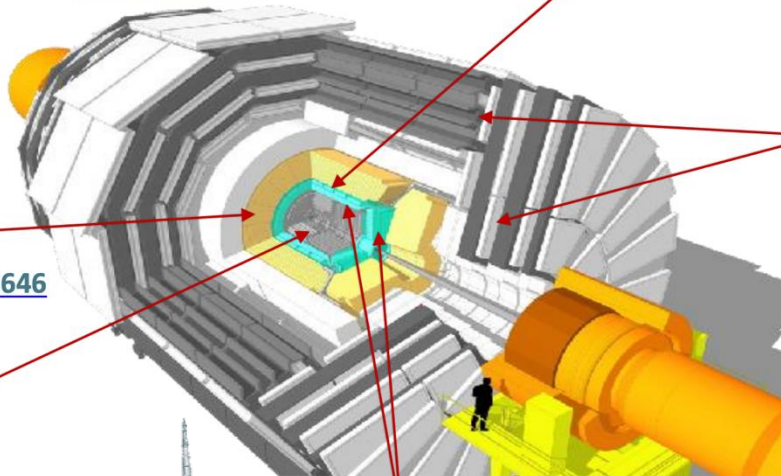
- ECAL single crystal granularity at L1 trigger with precise timing for e/γ at 30 GeV
- ECAL and HCAL new Back-End boards



### Calorimeter Endcap

<https://cds.cern.ch/record/2293646>

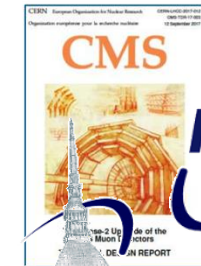
- 3D showers and precise timing
- Si, Scint+SiPM in Pb/W-SS



### Muon systems

<https://cds.cern.ch/record/2283189>

- DT & CSC new FE/BE readout
- RPC back-end electronics
- New GEM/RPC  $1.6 < \eta < 2.4$
- Extended coverage to  $\eta \approx 3$



### Tracker

<https://cds.cern.ch/record/2272264>

- Si-Strip and Pixels increased granularity
- Design for tracking in L1-Trigger
- Extended coverage to  $\eta \approx 3.8$



### MIP Timing Detector

<https://cds.cern.ch/record/2667167>

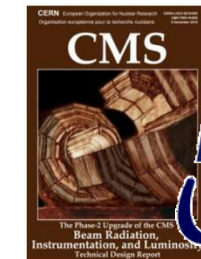
Precision timing with:

- Barrel layer: Crystals + SiPMs
- Endcap layer: Low Gain Avalanche Diodes

### Beam Radiation Instr. and Luminosity

<http://cds.cern.ch/record/2759074>

- Beam abort & timing
- Beam-induced background
- Bunch-by-bunch luminosity: 1% offline, 2% online
- Neutron and mixed-field radiation monitors



→ PPS EOI link



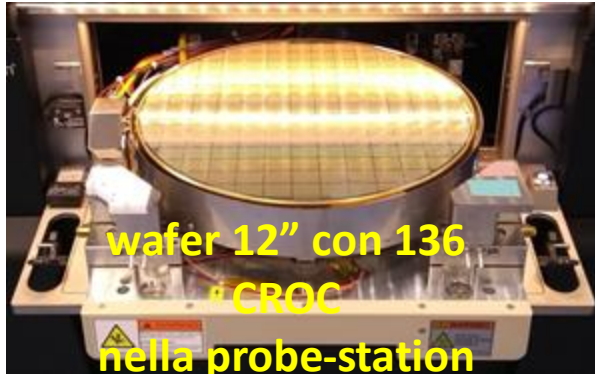
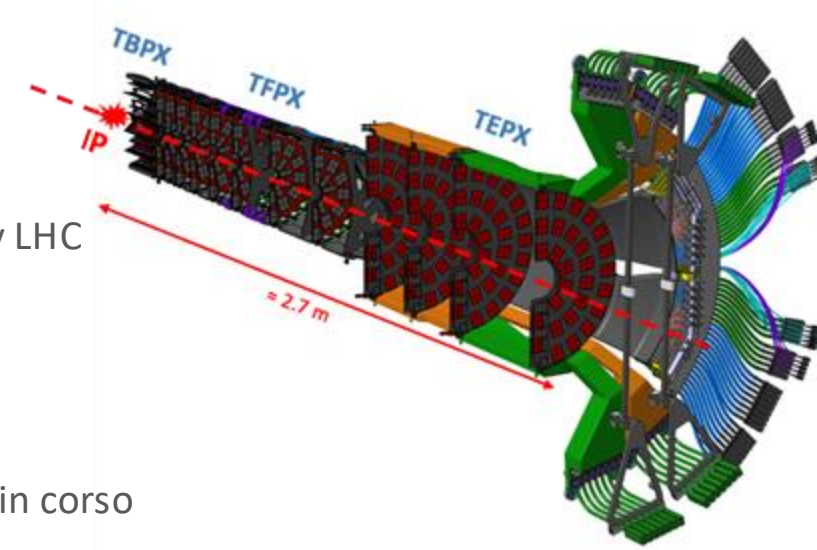


# CMS TO Tracker

Attività sul rivelatore di vertice a pixel (**Inner Tracker**) per l'upgrade di CMS per High-Luminosity LHC

Ruolo di Torino:

- **sviluppo** del **chip** di readout (CROC) in tecnologia **CMOS 65 nm** - conclusa
- **centro** per **wafer-level test** del CROC (150-200 wafer - 50% della produzione) - in corso
- **progettazione** (con Pisa) di **meccanica** e **servizi** (cooling e flange) del **barrel pixel** (TBPX) - in corso
- **unico centro** di **integrazione** del **barrel pixel** (TBPX) - 2025-2027
- **coordinamento** degli **studi** su **layout** e **performance** - in corso

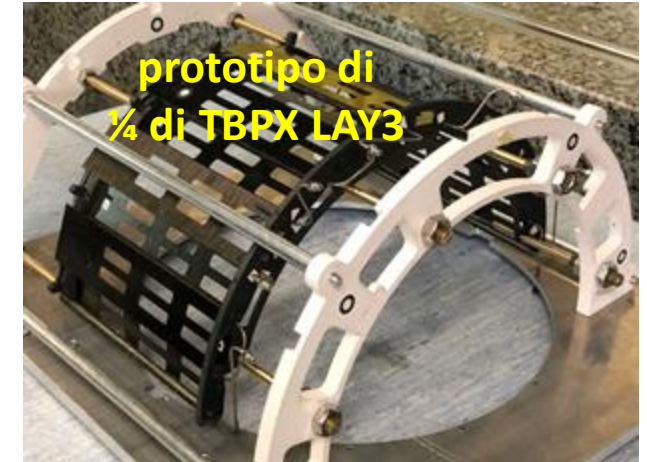


wafer 12" con 136  
# CROC  
nella probe-station  
semi-automatica



sistema di cooling  
MARTA  
CO<sub>2</sub> bi-fase

scatola per test di un layer  
durante integrazione



prototipo di  
¼ di TBPX LAY3

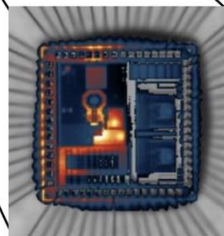
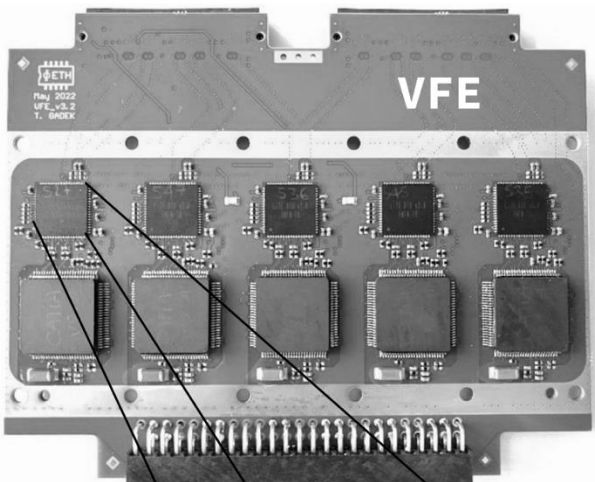
Attività svolta presso il Laboratorio Tecnologico di Strada delle Cacce

È disponibile un diffrattometro a raggi-X per irraggiamenti di ASIC ( $1 \text{ Grad in SiO}_2 = 4 \text{ gg/mm}^2$ ) e caratterizzazione sensori con luce di fluorescenza ( $K_\alpha$ : 5-25 keV)

# CMS TO ECAL Barrel

Development, production, test of LiTE-DTU ASIC  
(chief Eng. Mazza)

2x 160 MHz ADC, 12 bit. Data conditioning,  
compression, transmission @ 1.28 Gb/s. 61200  
channels.



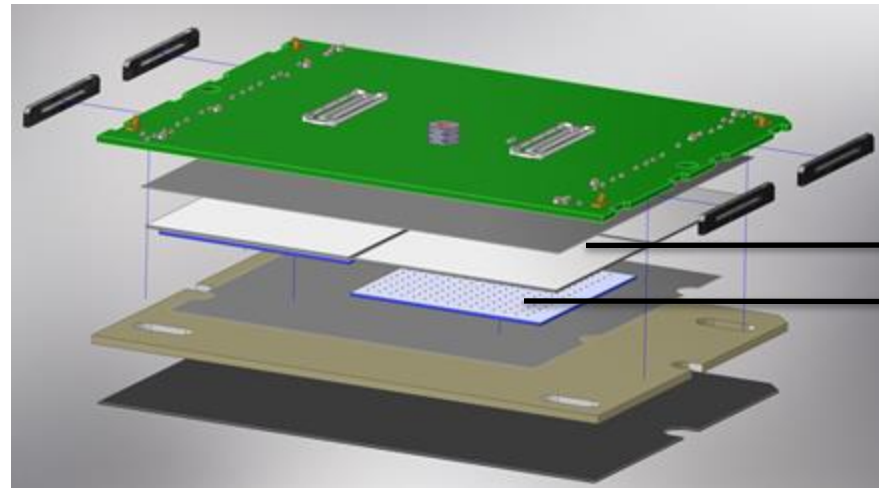
LiTE DTU





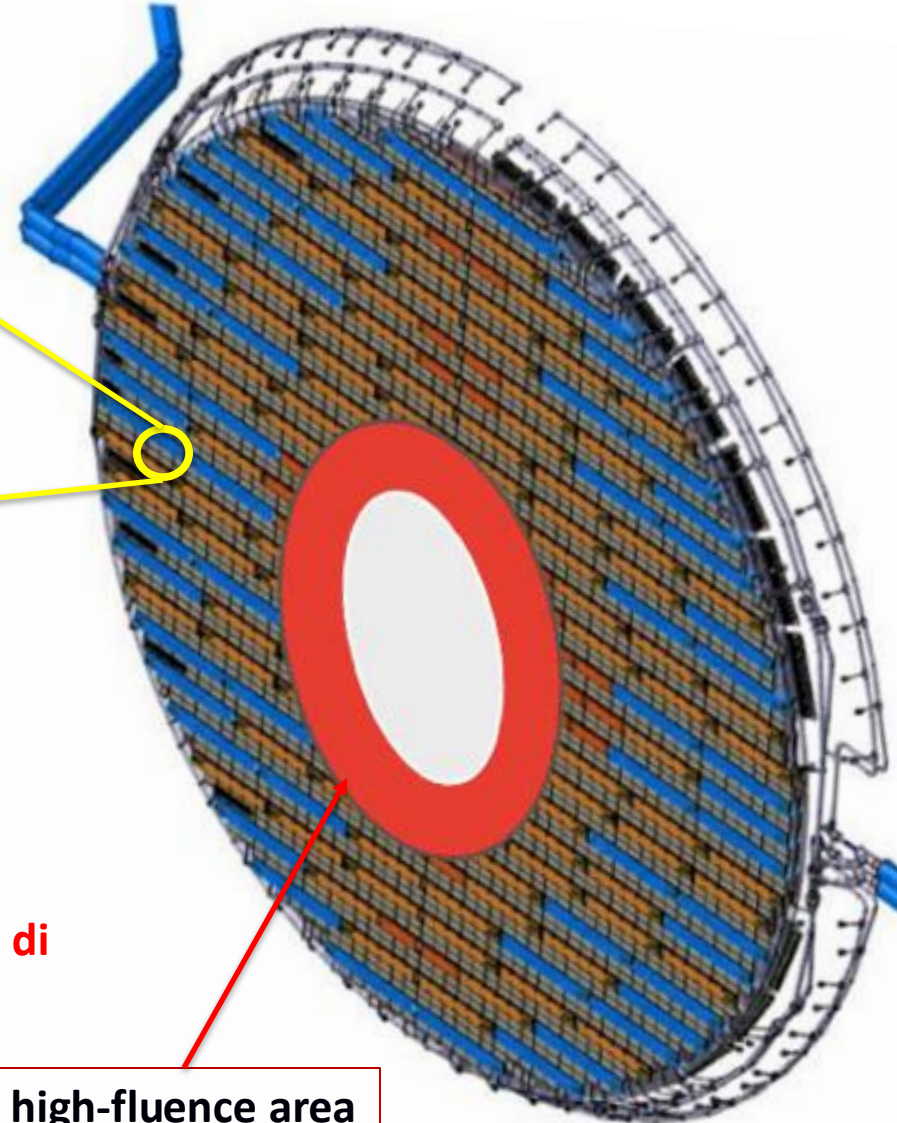
# CMS TO - Endcap Timing Layer

## ETL MODULE



ETROC

LGAD



Il gruppo di **Torino** è coinvolto nello **sviluppo del sensore** ( $\sim 14 \text{ m}^2$  di LGADs), nell'**assemblaggio dei moduli** e nel **software di ricostruzione**

- **Responsabile del disegno e della produzione dei sensori LGAD (inclusa QA/QC)**
- **Sito di assemblaggio dei moduli (2000 moduli da fare), ora in fase di allestimento**

high-fluence area  
( $>1\text{E}15 \text{ n}_{\text{eq}}/\text{cm}^2$ )





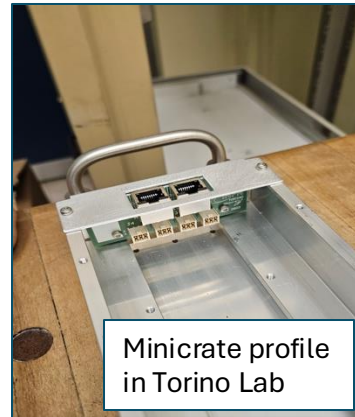
# CMS Muon Drift Tube Upgrade for HL-LHC (Phase 2 Upgrade) Minicrates Assembly at INFN Torino

## Status of production of Minicrates components:

- Production of Minicrate profiles are proceeding on schedule
- OBDT boards in production
- Minicrate cables production on schedule
- Test stands for Minicrate Assembly Sites ready



First assembled Minicrate at CERN



Minicrate profile in Torino Lab



Shelf for Minicrates stocking in Torino Lab



TestBox and OBDT under test in Torino Lab. First tests performed successfully

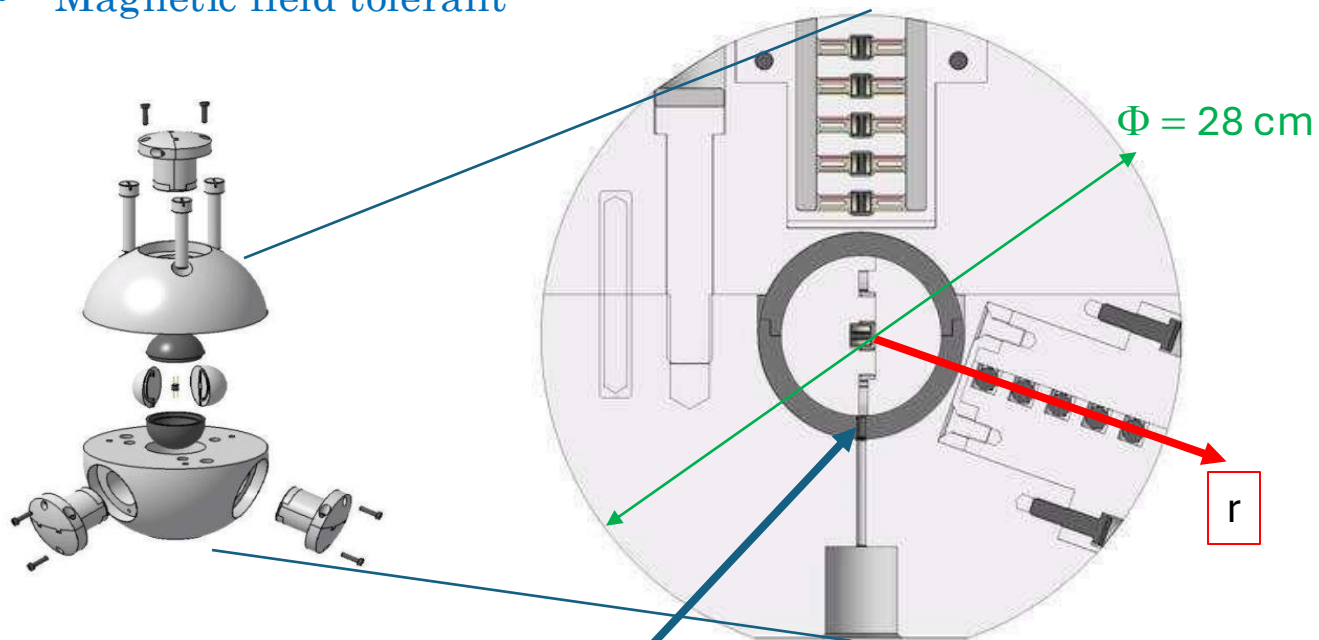
## The Torino DT Laboratory is ready for the Minicrates assembly.

- **20 % of Minicrates to be assembled in Torino (50 Minicrates)**
- **Preparation of the Assembly Site (Q3 2024-Q1 2025):** tools for the assembly and commissioning , logistic organisation for Minicrates handling
- **Assembly Phase:** Need a dedicated person-power during all the assembly period **Q4 2024 – Q1 2026 (estimation of 1,5 year for assembly)**



INFN-LNF & INFN-Torino

- Insensitive to gamma and ch hadrons
- Single exposure: from meV to GeV
- Radiation-Hard (CMS Cavern)
- Magnetic field tolerant

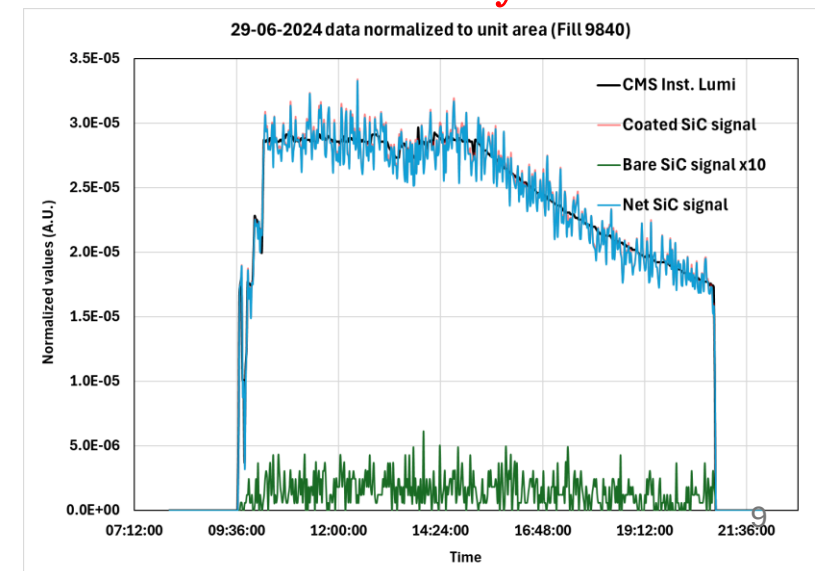


HDPE moderator with a one-cm lead insert for high-Energy

42 SiC detectors arranged in Tetrahedral Geometry at different  $r$  along four axis



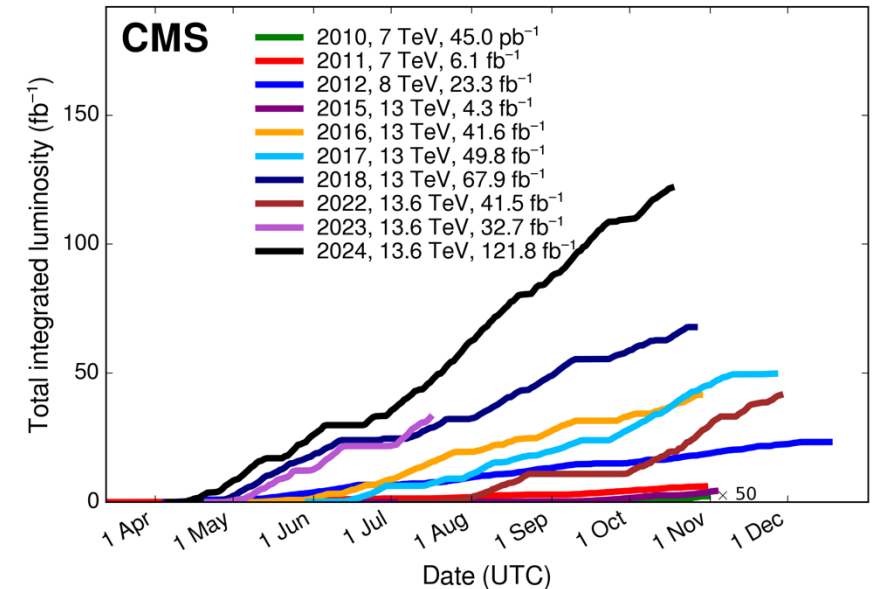
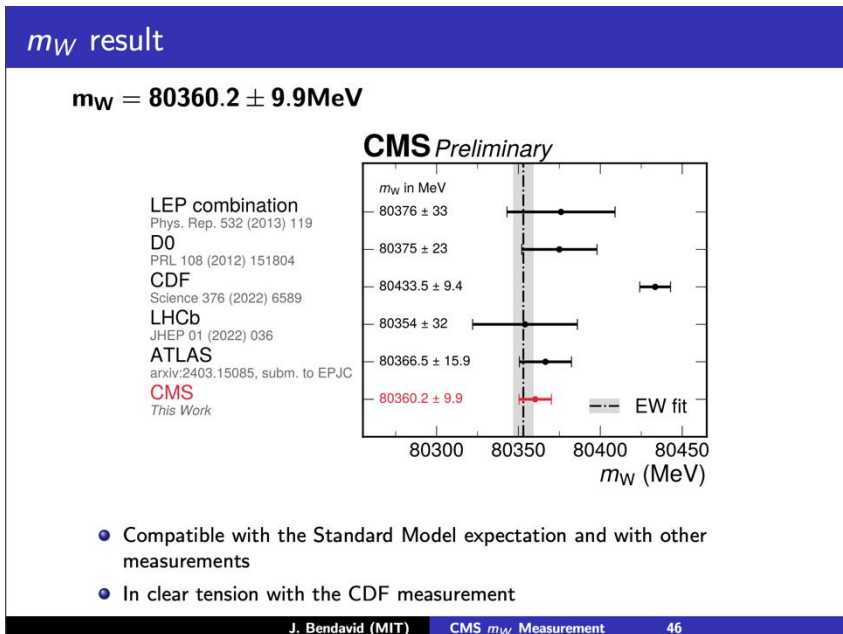
Single Channel test configuration (june 2024) shows good linearity bw neutron response and instantaneous luminosity





# Data taking & Physics

- LHCC : [CMS status report](#)



Record Luminosity in 2024

Other recent results:

[Higgs cross sections](#) and EFT interpretations

[Quantum entanglement](#) in  $t\bar{t}$

[Searches at the TeV scale](#) in 4l

[Heavy Ion physics](#): QGP Jets, gamma + jet, light-by-light

## Precision SM Physics

The **Run3 physics program** includes:

Intensity and precision frontier: **Higgs and EW** program

**Flavor**: top physics + data streams for b, c, and  $\tau$  (-> scouting, parking,..)

**Heavy ion**: PbPb and pPb LHC runs

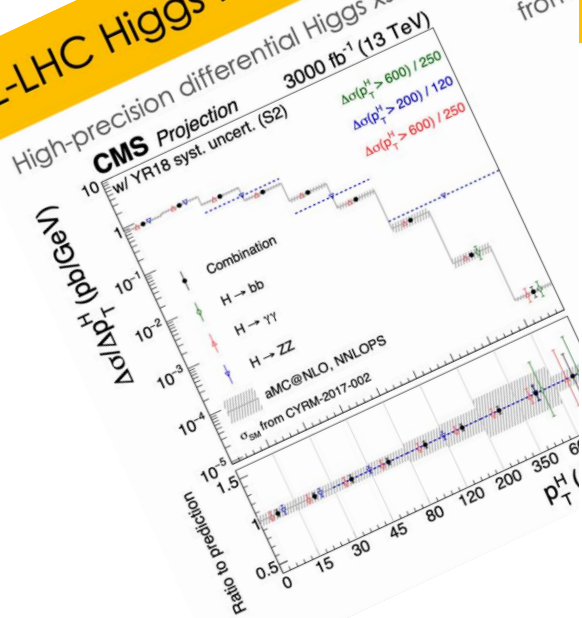
**Photon collider**: ultra-peripheral HI collisions + proton tagging in pp runs, ...

**Technology**: reconstruction on GPUs, real-time analysis, AI applications

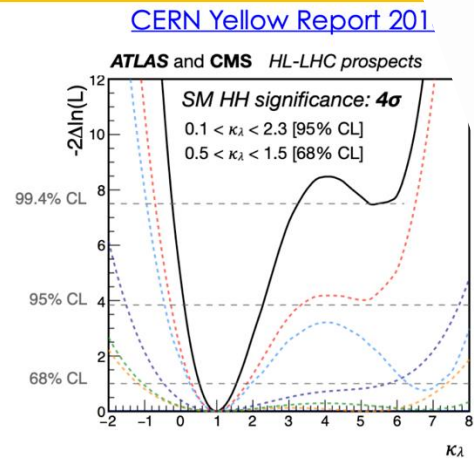


# HL-LHC physics program

## HL-LHC Higgs Production

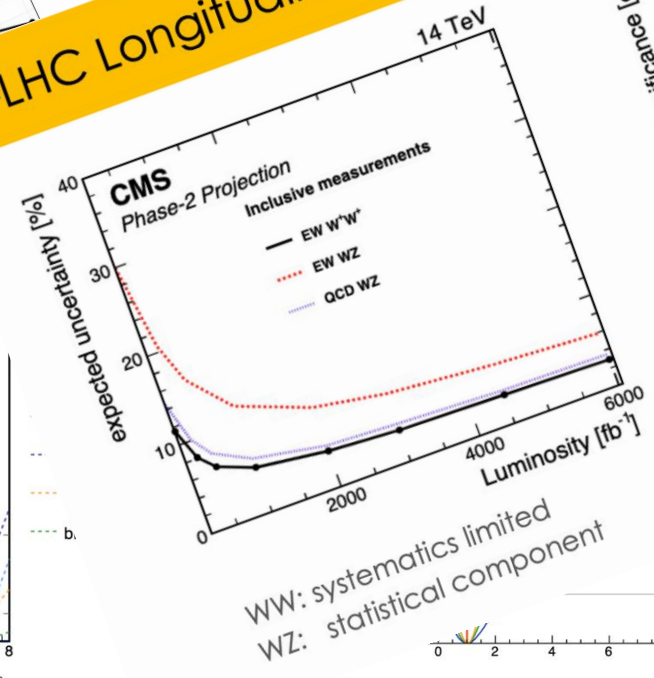


## HL-LHC Di-Higgs Production

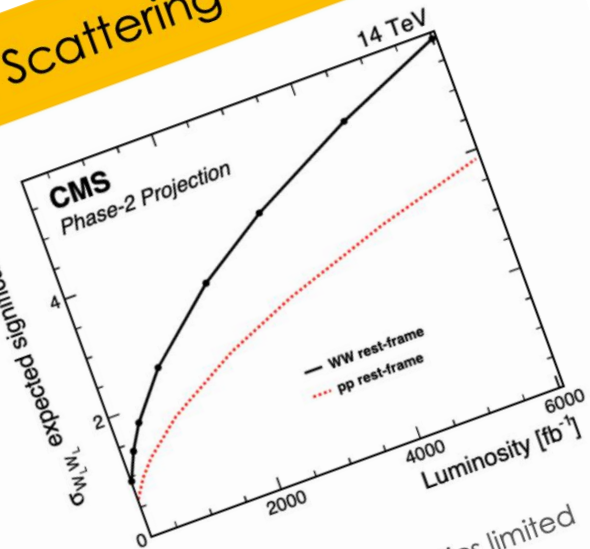


2018 (based on 2016 only)  
 expect for ATLAS+CMS combined:  
 $4\sigma$  signal significance and 50% precision

## HL-LHC Longitudinal Vector Boson Scattering



Today:  
 full Run 2 combination (no Run 3 yet):  
 same precision by CMS alone



W<sub>L</sub>W<sub>L</sub> remains statistics limited

CMS+ ATLAS  
 will submit a  
 30-pages  
 report for ESPP





Aula Magna "Tullio Regge"

Dipartimento di Fisica

Via Pietro Giuria 1

# CMS ITALIA

Workshop annuale della collaborazione

TORINO, 18-20 ottobre 2023

## Conclusions

How can we contribute to laying down the future strategy ... ?

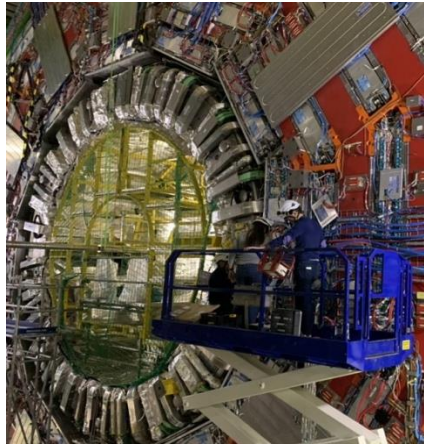


@martatornago 2023

# Extras

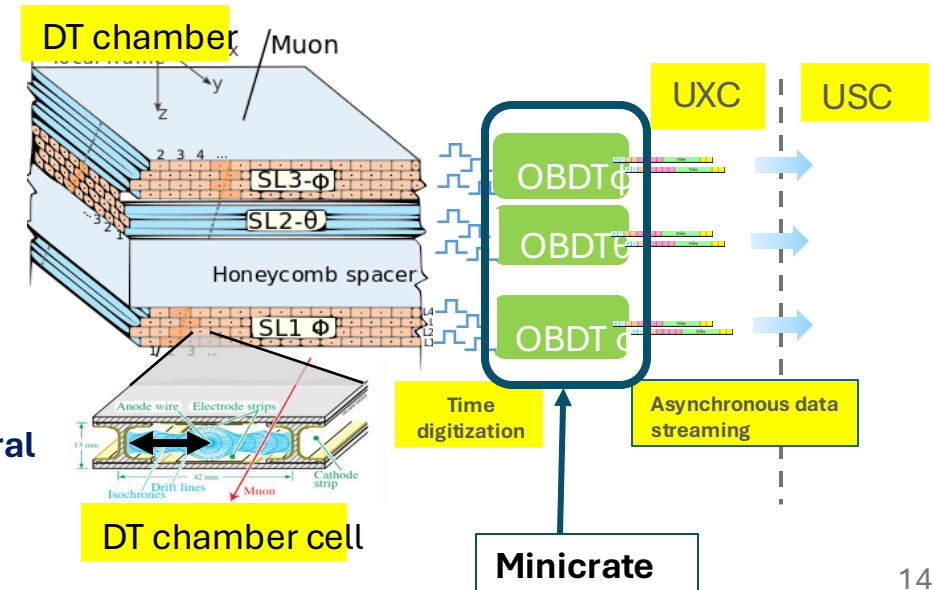


# CMS Muon Drift Tube Upgrade for HL-LHC (Phase 2 Upgrade) Minicrates Assembly at INFN Torino



- **250 CMS DT gas chambers** instrument the barrel region of the return yoke providing excellent Muon identification, reconstruction and trigger over > 40% of CMS volume.
- **INFN is the major participant of DT since CMS construction. It counts >40% of FTE of DT community.**
- **In HL-LHC:** chambers remain, but full electronics system is replaced to match the CMS operating conditions. Electronics has been redesigned with a new architecture with the goal to move the offline reconstruction precision and methods to the back-end electronics and L1 HW trigger.
- In the Frontend system, the On Board DT (OBDT) electronics digitizes the times coming from the chambers with a precision of 0,8 nsec.

- **~1000 OBDT boards are equipped with the FPGAs in the DT chambers, 80% have been designed and being produced by INFN.**
- **OBDTs are assembled in Aluminum frames (New Minicrates)** which act as thermal interface and as mechanical and electro-magnetic shield.
- **All Minicrates should be at CERN before installation access is allowed by CMS at the beginning of 2026.**
- **INFN has led upgrade program since conception with several responsibilities position within the organigram.**
- **INFN committed to 40% of the DT Upgrade CORE cost (5.6 MCHF).**







# CMS Muon Drift Tube Upgrade for HL-LHC (Phase 2 Upgrade)

## Sistema DSS MONSA

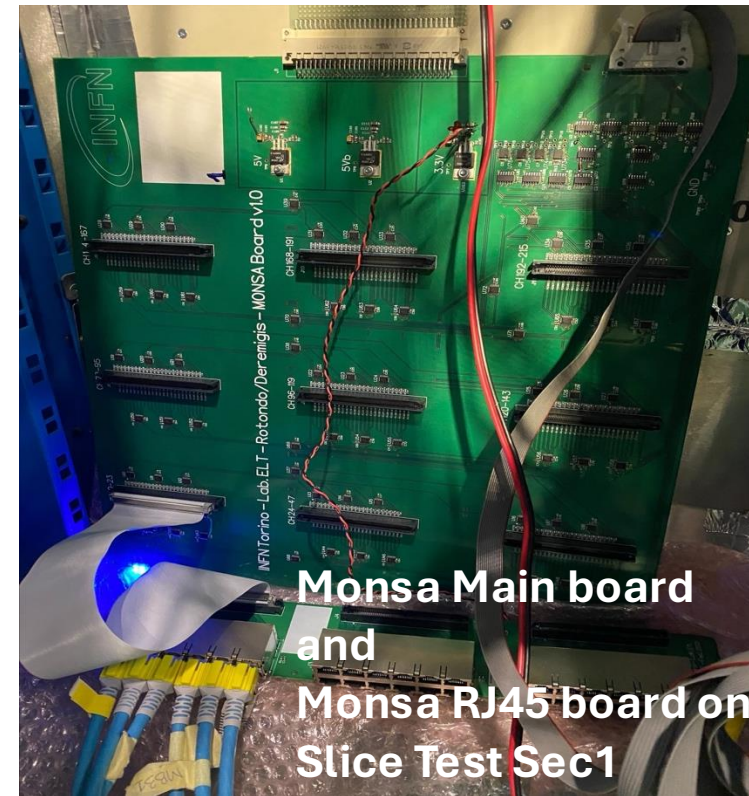
### Automatic hardware interlock for OBDT alarms

- Monitoring of OBDT status
- Connection to CMS DT DCS (Detector Control System)
- Prototype board ready and tested with OBDTs
- Installation in SX5 . Prototype DSS backend system also in place
- Control and Monitoring software developed
- Monsa v2 prototype by the summer and full production could start at the end of the year

### Control and Monitoring Software



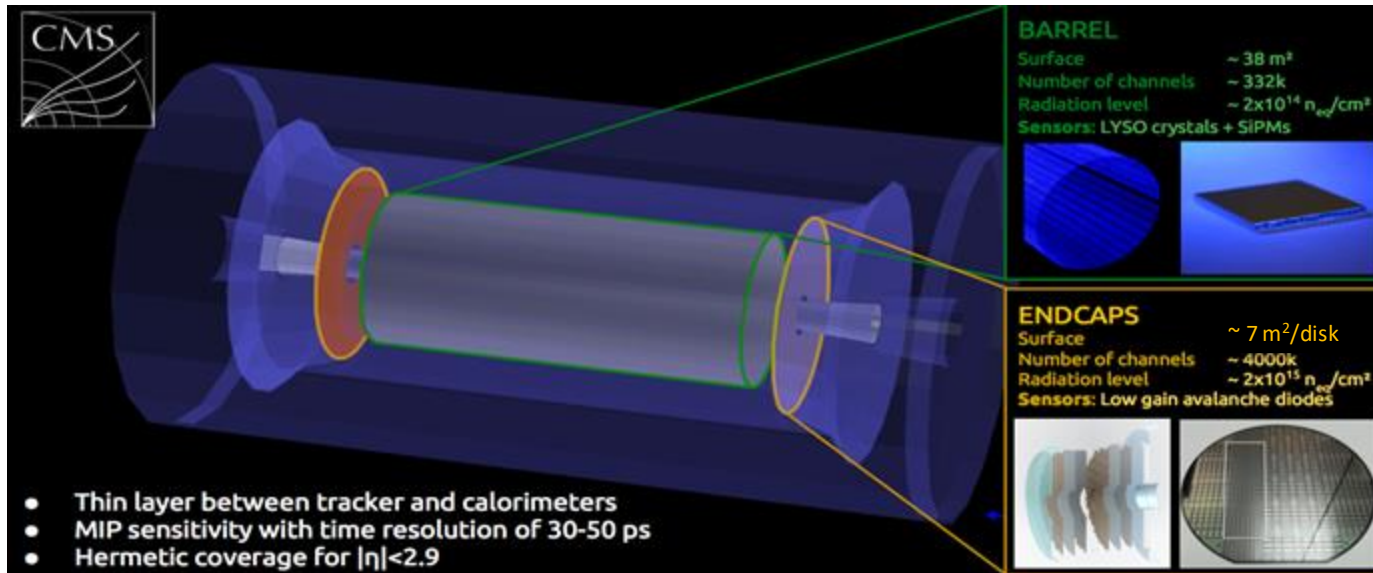
Installed and tested in the Sector 1 slice test  
**Functionalities verified on Monsa on the Sect1 Slice Test**



**Monsa Main board and Monsa RJ45 board on Slice Test Sec1**



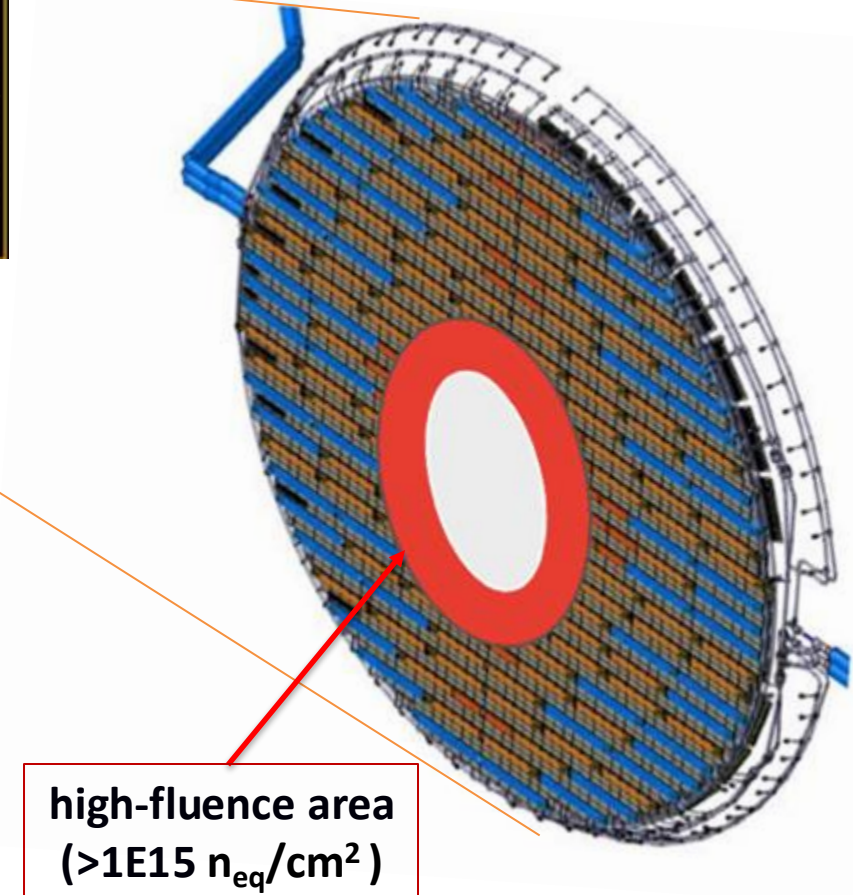
# CMS - Endcap Timing Layer



MTD: **rivelatore di CMS-Fase2** per misurare il tempo di passaggio di tutte le particelle cariche.

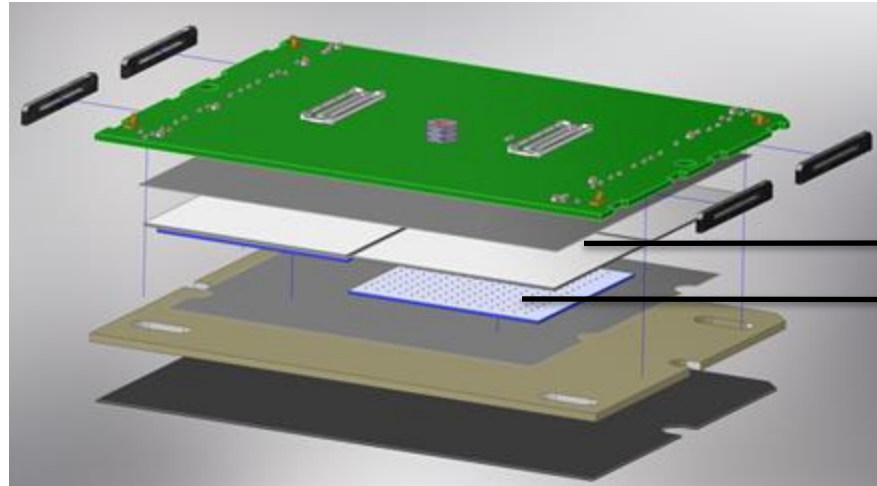
Il gruppo di **Torino** è coinvolto **nell'endcap (ETL – 2 dischi per parte)**.

- Si sta preparando la review dei sensori LGAD per procedere (in Settembre) alla gara per l'acquisto di tutta la fornitura ( $\sim 33.000$  sensori).
- I test del chip di lettura (ETROC) sono in fase di completamento.
- Sono in corso "system test" di parte della catena di lettura del rivelatore (sempre più prossimi a quella finale).
- Si stanno ottimizzando i disegni di moduli e di tutta la parte meccanica.
- Si stanno ottimizzando le varie procedure di assemblaggio e validazione.



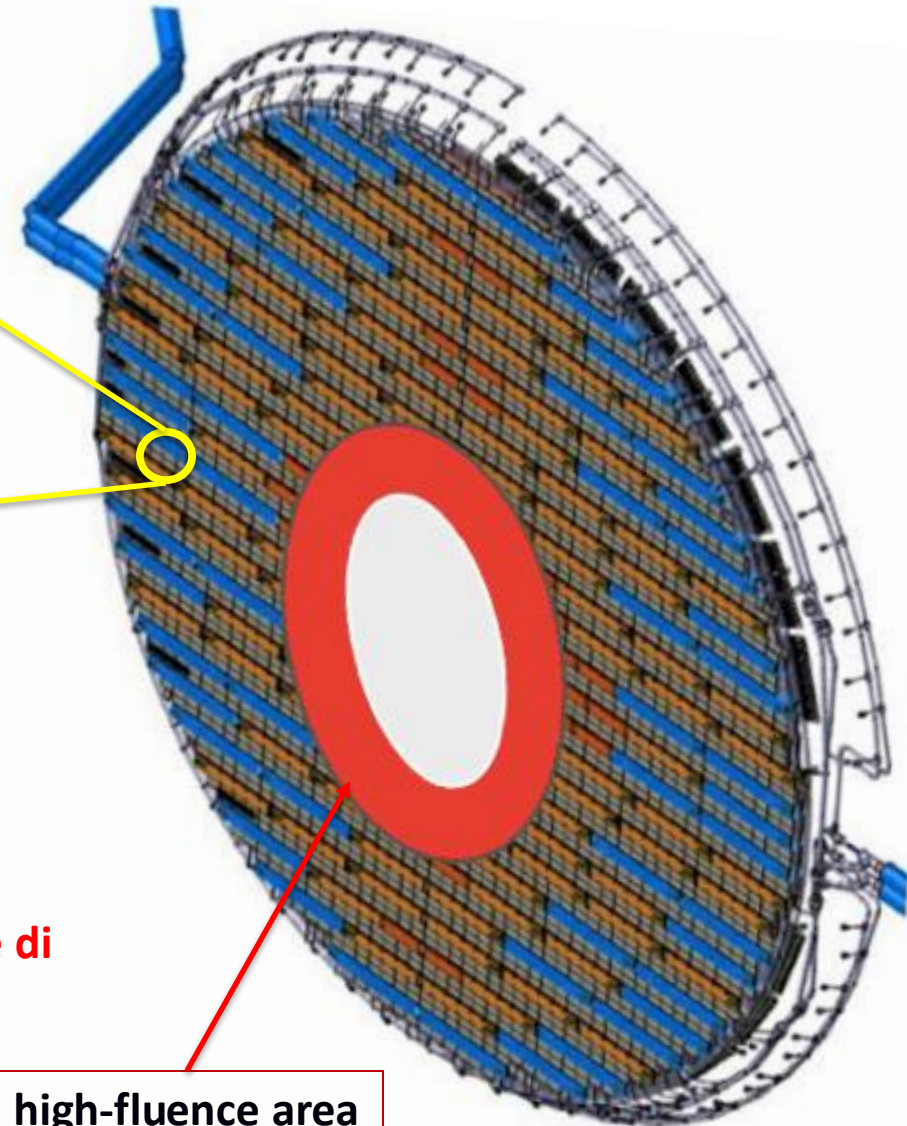
# CMS - Endcap Timing Layer (2)

## ETL MODULE



ETROC

LGAD



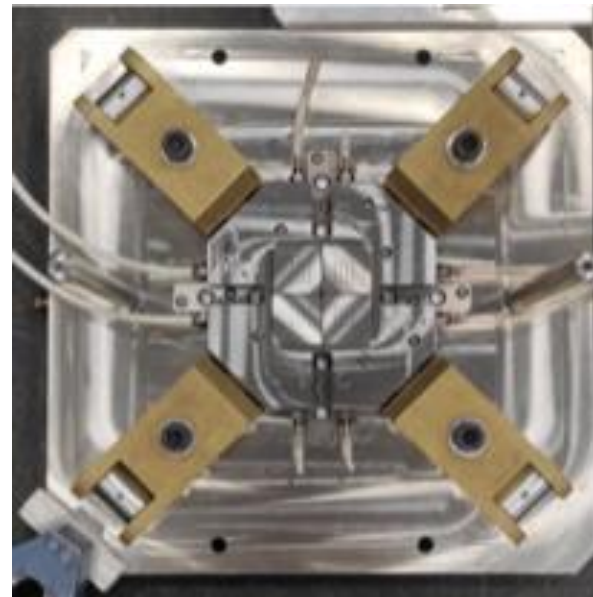
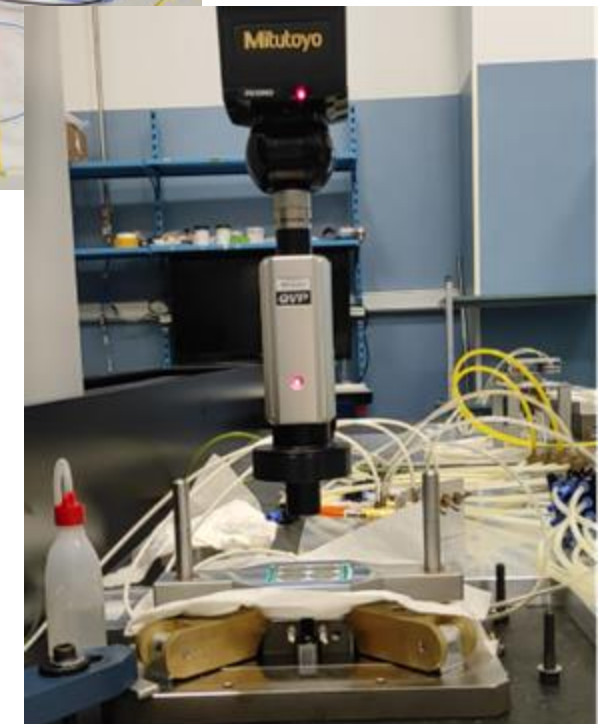
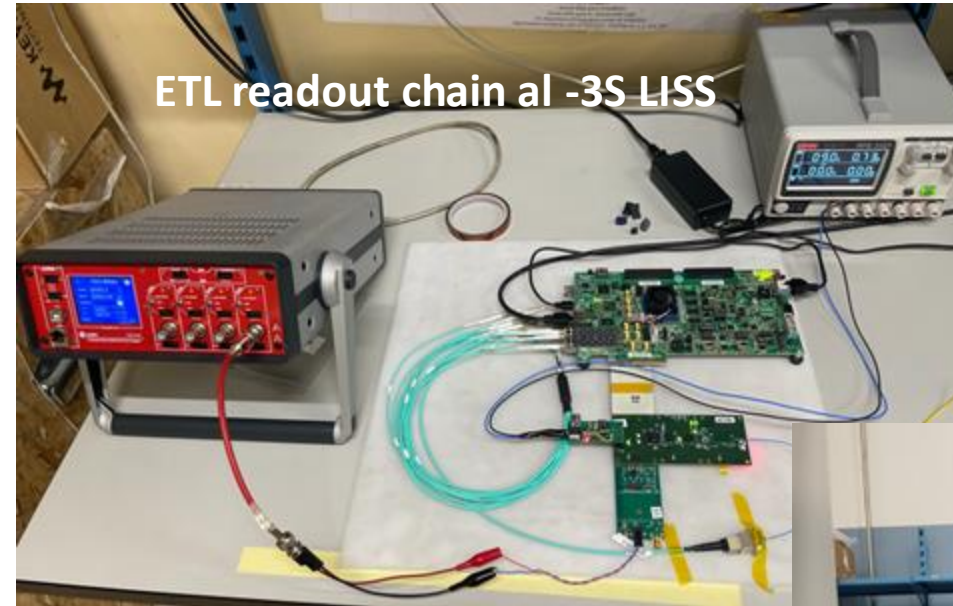
high-fluence area  
( $>1E15 n_{eq}/cm^2$ )

Il gruppo di **Torino** è coinvolto nello **sviluppo del sensore** ( $\sim 14 m^2$  di LGADs), nell'**assemblaggio dei moduli** e nel **software di ricostruzione**

- **Responsabile del disegno e della produzione dei sensori LGAD (inclusa QA/QC)**
- **Sito di assemblaggio dei moduli (2000 moduli da fare), ora in fase di allestimento**



# Qualche foto!

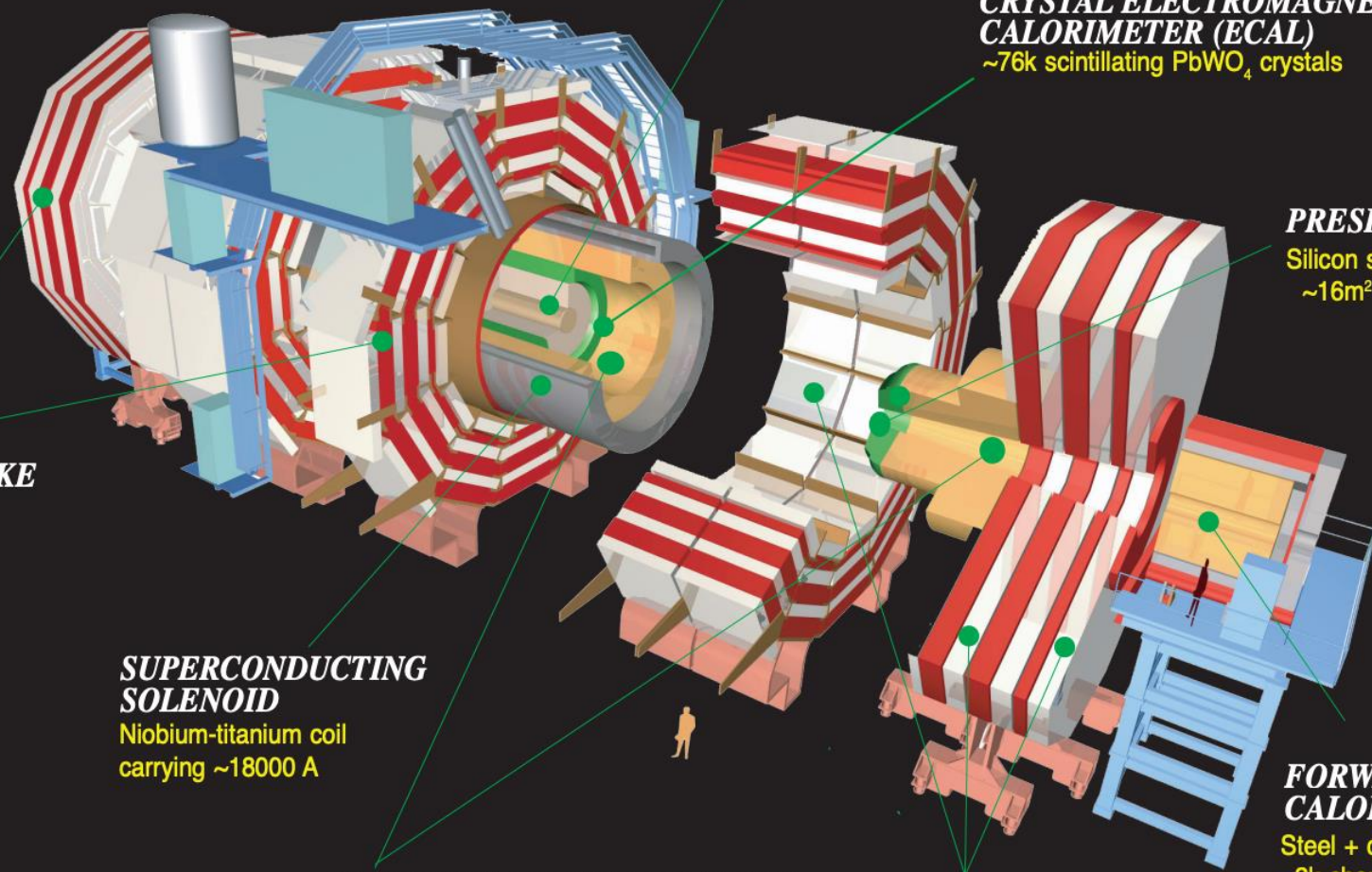


Misura dei  
moduli prodotti

prototipo jig per  
assemblaggio di precisione  
del modulo di ETL  
(progetto P. Mereu/M. Nenni)

# CMS Detector

Pixels  
Tracker  
ECAL  
HCAL  
Solenoid  
Steel Yoke  
Muons



**SILICON TRACKER**  
Pixels ( $100 \times 150 \mu\text{m}^2$ )  
~1m<sup>2</sup> ~66M channels  
Microstrips (80-180 $\mu\text{m}$ )  
~200m<sup>2</sup> ~9.6M channels

**CRYSTAL ELECTROMAGNETIC CALORIMETER (ECAL)**  
~76k scintillating PbWO<sub>4</sub> crystals

**PRESHOWER**  
Silicon strips  
~16m<sup>2</sup> ~137k channels

**STEEL RETURN YOKE**  
~13000 tonnes

**SUPERCONDUCTING SOLENOID**  
Niobium-titanium coil  
carrying ~18000 A

**FORWARD CALORIMETER**  
Steel + quartz fibres  
~2k channels

**HADRON CALORIMETER (HCAL)**  
Brass + plastic scintillator  
~7k channels

**MUON CHAMBERS**  
Barrel: 250 Drift Tube & 480 Resistive Plate Chambers  
Endcaps: 473 Cathode Strip & 432 Resistive Plate Chambers

Total weight : 14000 tonnes  
Overall diameter : 15.0 m  
Overall length : 28.7 m  
Magnetic field : 3.8 T



