The CMS/TOTEM Upgrades

F. García

On behalf of the CMS and TOTEM Collaborations

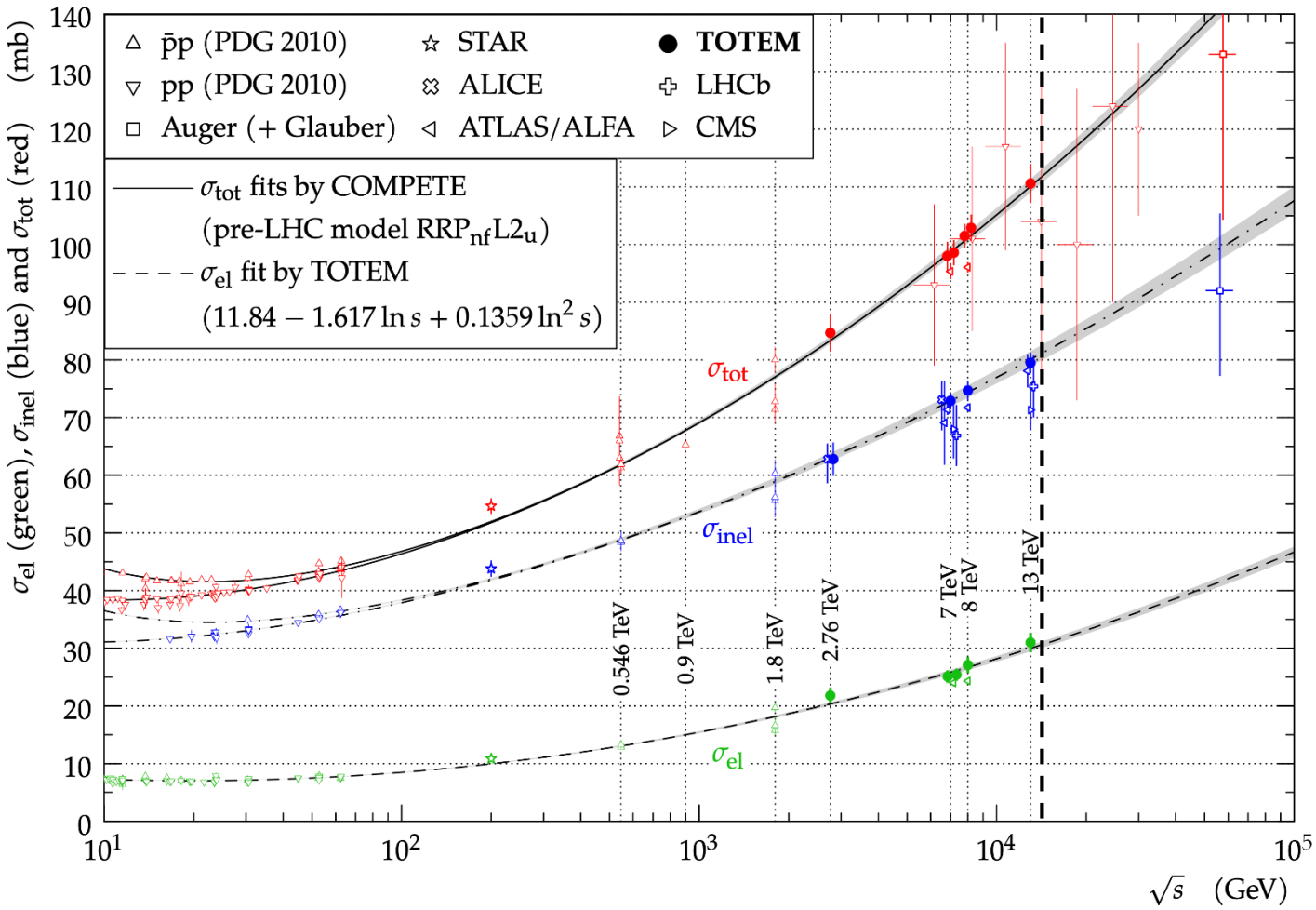
OUTLINE

- **TOTEM:**
  - Introduction and Experimental Apparatus
  - Detector Upgrade for the nT2 telescope
  - Installation, commissioning and running scenarios
- **The Precision Proton Spectrometer of CMS:**
  - Introduction and experimental apparatus
  - Operation in Run 2 and Upgrade for Run 3
- **R&D for the HL-LHC Roman Pot Upgrades for Run4 and on:**
  - The Phase-2 inner tracker project and TimeSpot Collaboration
  - The MIP Timing Detector (MTD) with LGADs

σ_{tot}, σ_{inel} and σ_{el} as a Function of $\sqrt{s}$

TOTEM FORWARD PHYSICS EXPERIMENT FOCUSES ON THE MEASUREMENTS OF:

- The total proton proton (pp) cross section,
- The ρ parameter,
- The elastic differential pp cross section in a wide range of |t|,
- Diffractive physics with CMS



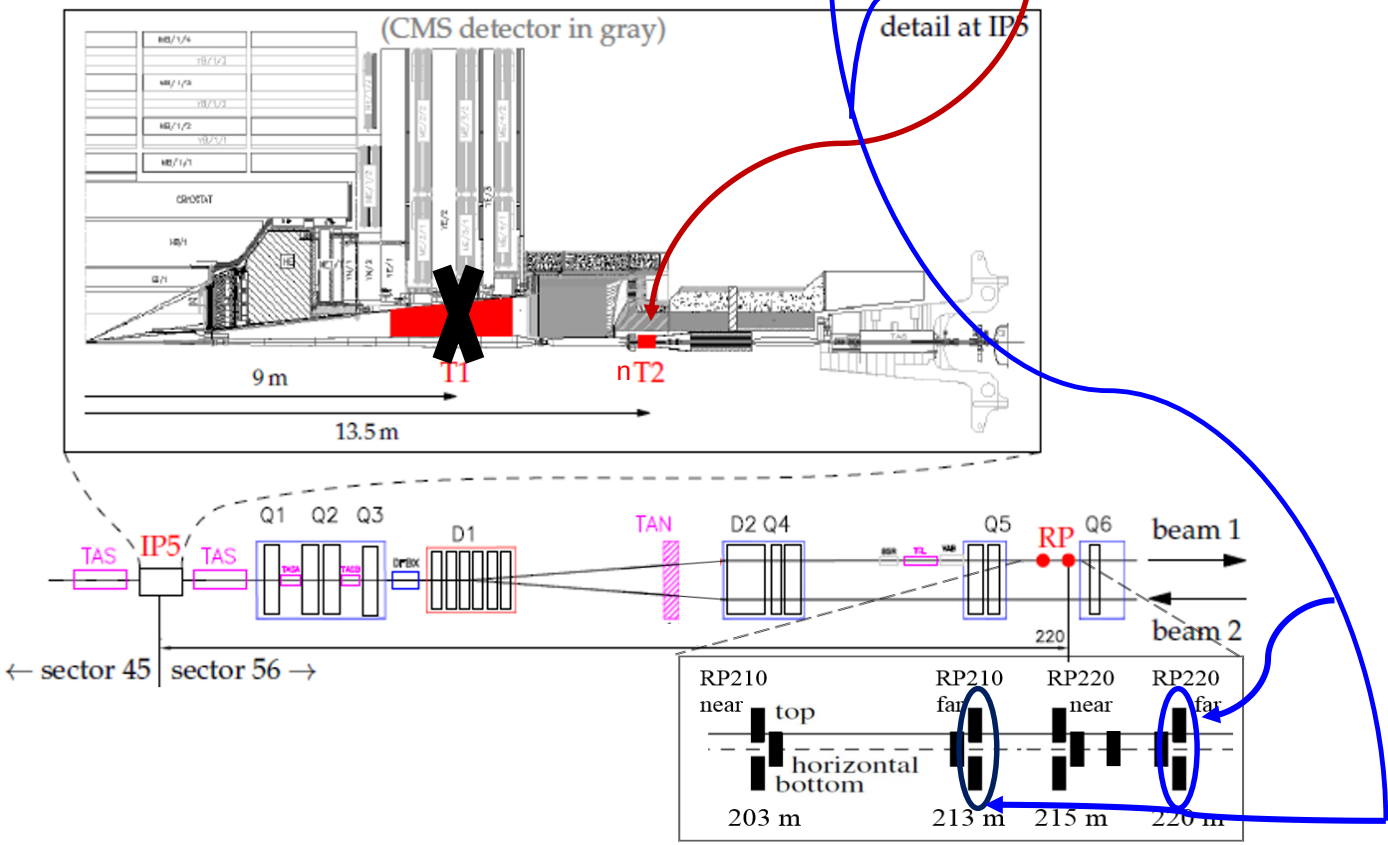
The total, elastic and inelastic cross-sections as measured at various LHC energies and below.

σ_{tot} Measurement at $\sqrt{s}$ = 13.6 TeV

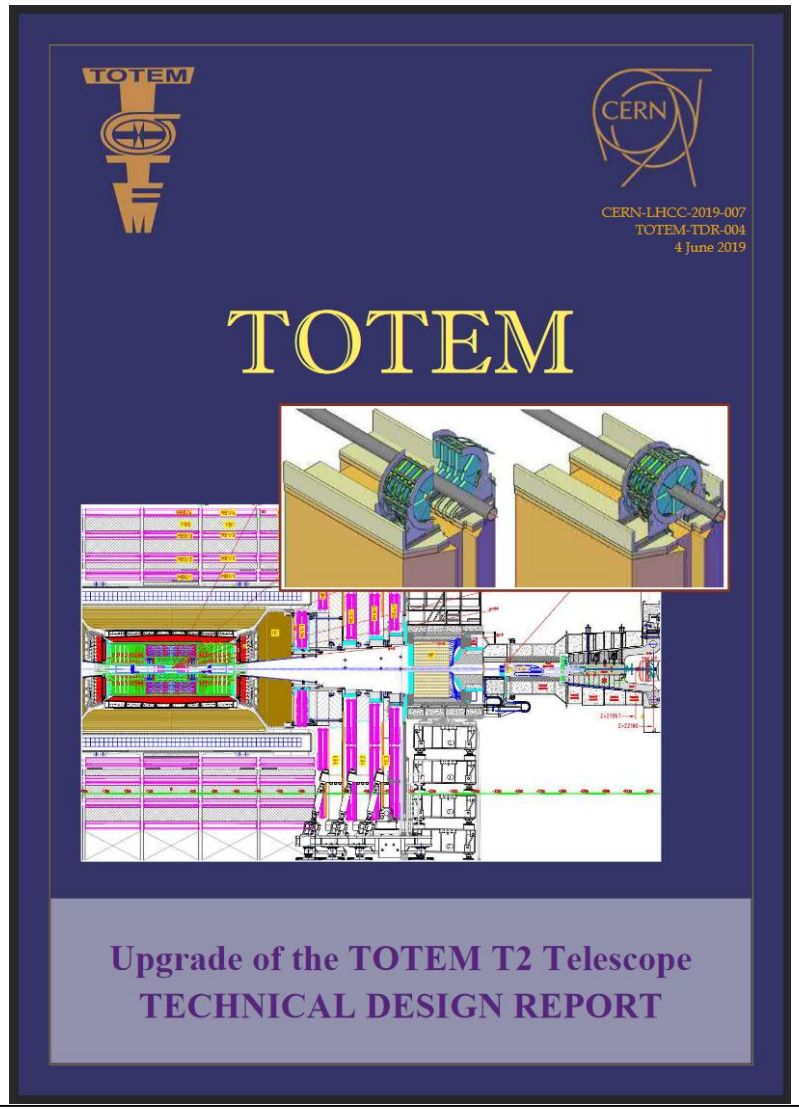
Luminosity independent method:

$$\sigma_{tot} = \frac{16\pi}{(1+\rho^2)} \frac{(dN_{el}/dt)_{t=0}}{(N_{el} + N_{inel})}$$

- Dedicated special β^* = 90 m run in 2023
- Old T2 not compatible with the LHC vacuum pipe installed in LS2 (for CMS HGCAL)

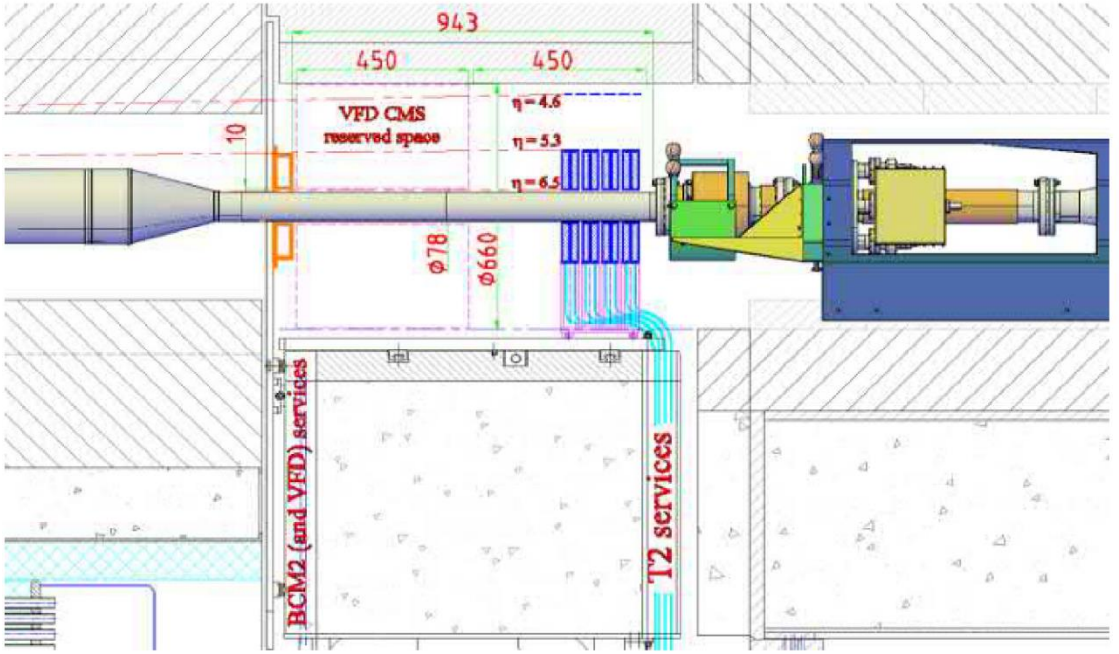


nT2 Telescope for Run 3



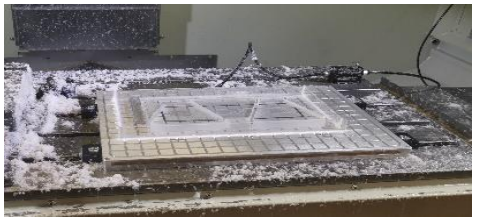
A new **plastic scintillitaion based** detector for the TOTEM experiment is designed to measure the rate of inelastic proton-proton events in low luminosity special runs dedicated to the measurement of the total cross section at the highest LHC energy.

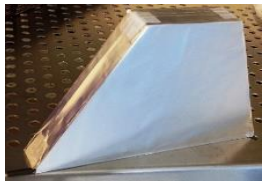
With a **pseudorapidity coverage of 5.3 < |η| < 6.5**, the new T2 will **detect more than 90 % of the inelastic events** at a center-of-mass energy of 13.6 TeV and thus allow a precise inelastic rate and total cross section measurement.

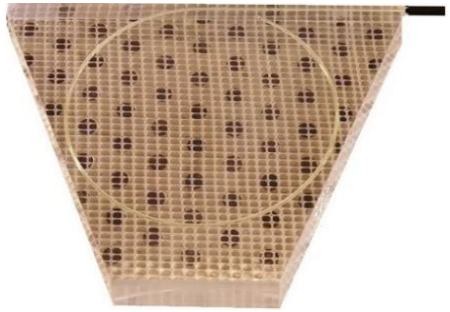


nT2 Installation, Commissioning and Running Scenarios

Process developed at HIP: mechanical workshop & clean rooms







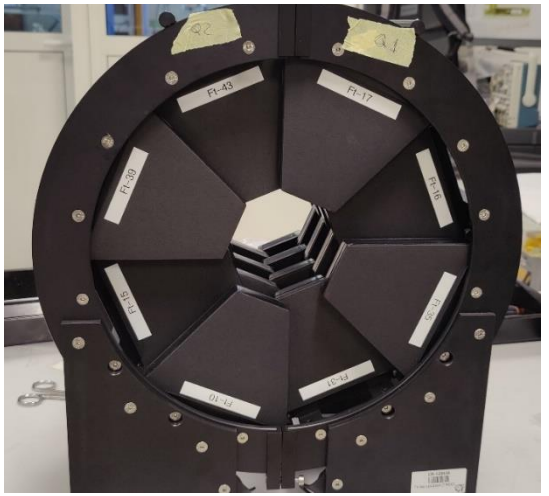
Final Tile structure and assembling

The Finnish Contribution to TOTEM experiment is very wide from the coordination of the physics program to the R&D of the different types of detectors currently in use, as for instance the production and operation of the T2 telescope and now with its upgrade.

The production of 80 tiles is finished at the Helsinki Institute of Physics. They are used to equip four quarters, which forms two telescopes.

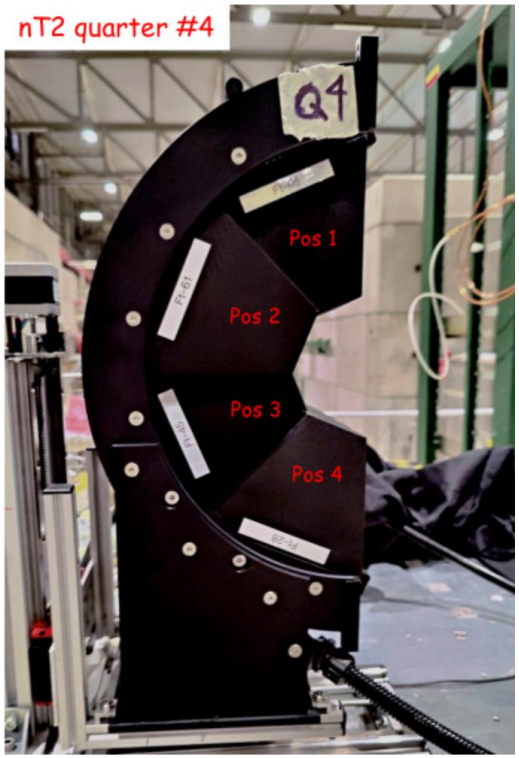
Set of tiles for all four quarters

nT2 telescope goes to the CMS - side



nT2 telescope goes to the CMS + side

nT2 Tiles Test Beam at the SPS in 2022



Test setup at the SPS – H8 line

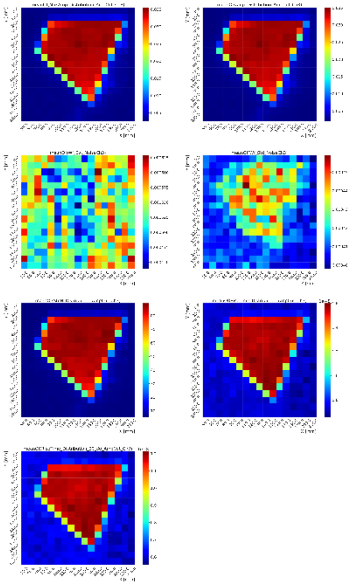
Test bench card for the photosensor

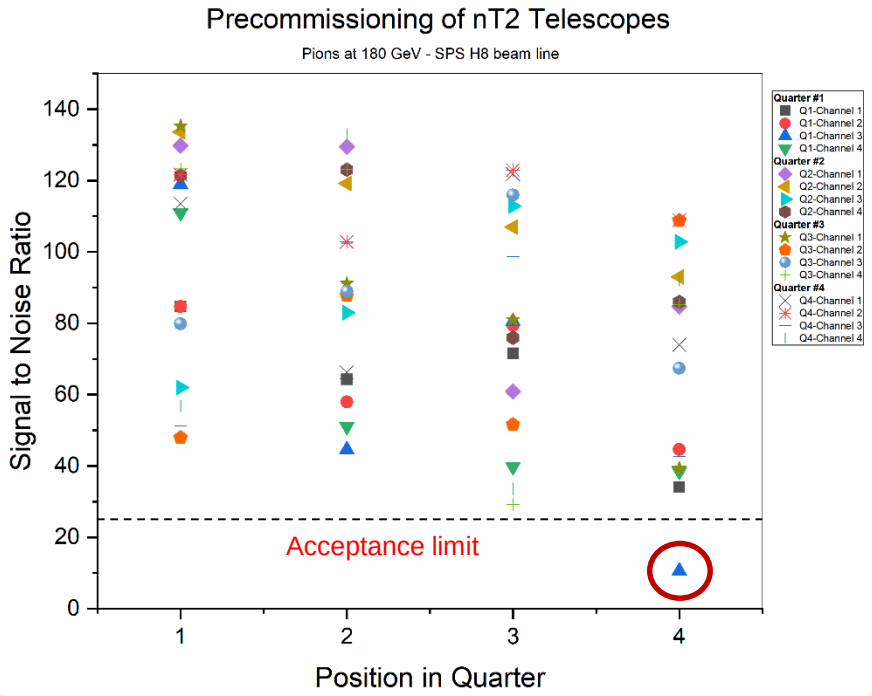
The tomography scans of the **Mean Amplitude, Noise, Signal to Noise ratio and Rise Time** for pions showed good uniformity for all four quarters.

- 2022 → Commissioning 1st quarter in May at SPS
- 2022 → Commissioning 2nd, 3rd and 4th quarters
- **2023** → New date for **the special run?**

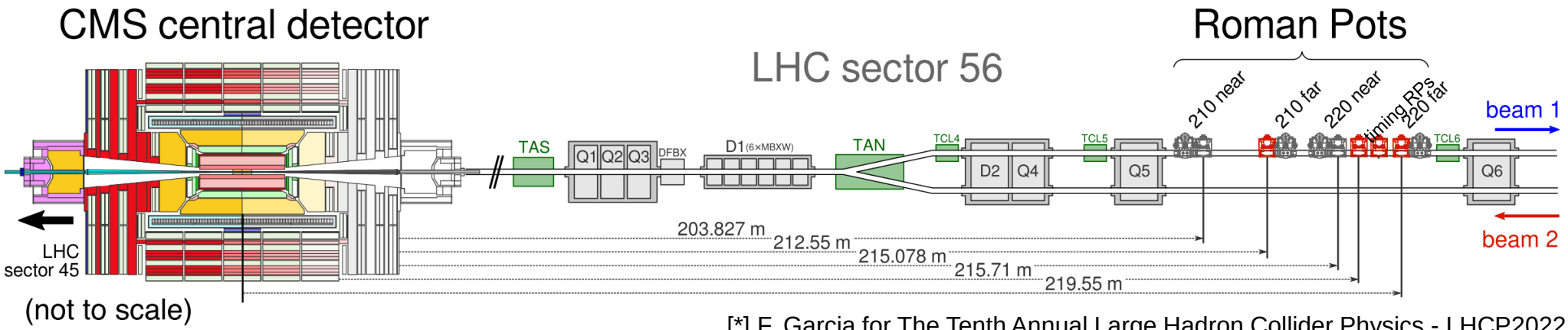
The photosensor used for the measurements was a Hamamatsu MPPC matrix array of 4 x 4 pixels. Operating at temperature around 30C and with a bias voltage of 54V

Tomography scans of Amplitude, Noise, Signal to Noise ratio and Rise time





The Precision Proton Spectrometer of CMS



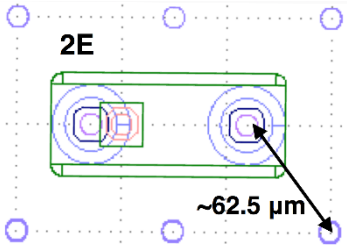
[*] F. Garcia for The Tenth Annual Large Hadron Collider Physics - LHCP2022

- **CT-PPS was a joint CMS-TOTEM** project to study **C**entral **E**xclusive **P**rocesses → Since 2018 is a CMS subdetector
- Detects intact protons surviving from the IP and driven by magnets within the beam pipe → Detector approach the beam at few millimetres
- With the Tracking Roman Pots stations used for measuring the proton kinematics using the LHC as spectrometer
- And with the Timing Roman Pots stations used to measure the proton time-of-flight to reduce the pile-up background by correlating the vertex with the one of the central system
- during Run 3 (2023-25) / Run 2 (2016-18)+2022 two tracking stations and **two**/one timing station
- Designed to operate continuously at standard LHC running conditions (**for Run2 PPS collected data up to an integrated luminosity of 100 fb^{-1}**)

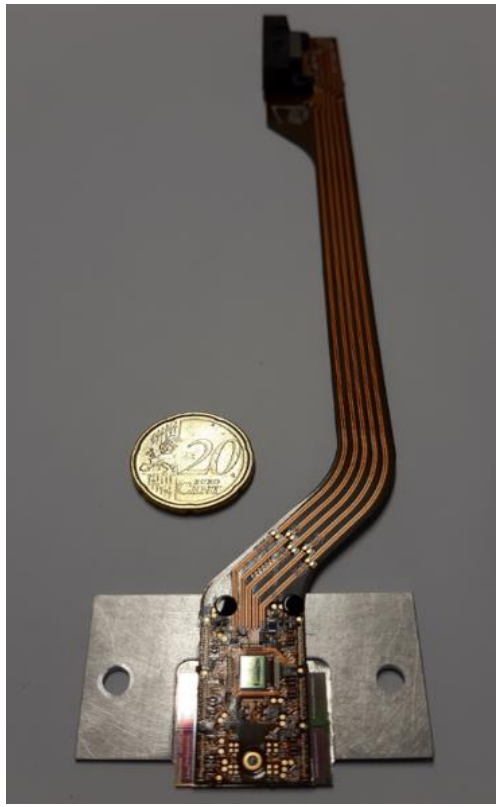
PPS - Roman Pots Upgraded for Tracking

New 3D Silicon Pixel detectors produced by FBK:

- Single side technology
- 2 x 2 sensor geometry
- 150 μm thick
- 2E electrode configuration



Pixel electrode configuration

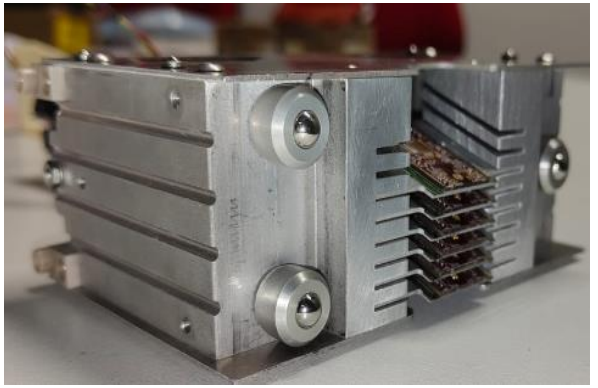


Flex cable with detector and electronics

ROC: PROC600 (same as for layer-1 of CMS pixel detector)

New flex circuit design (different look but similar to the one used in Run 2)

New detector package with internal moving system (12 positions spaced by 500 μm withstanding 50 fb^{-1} with minimal efficiency losses)

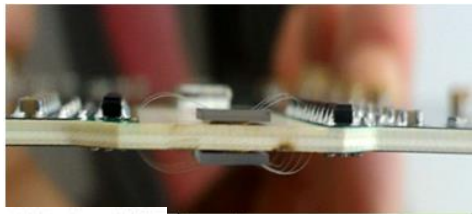


One pixel package equipped with six detector planes

[*] A. Solano for the Precision Proton Spectrometer of CMS: performance and upgrade – ICHEP2020

PPS - Roman Pots Upgraded for Timing

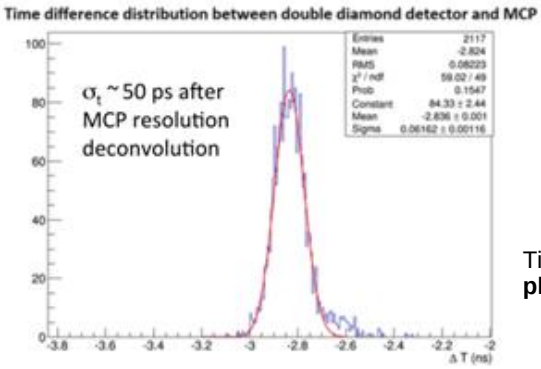
DD plane configuration (right)

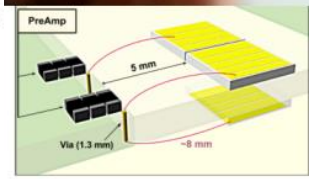


ScCVD diamond detectors:

- Four **Double Diamond (DD)** detectors per plane (4.5 mm x 4.5 mm) of 500 μm thick (detector configurations of 2 and 4 strips)
- Intrinsic radiation hardness withstanding an integrated radiation flux $5 \cdot 10^{15}$ p/cm^2
- Time resolution 50 ps per plane
- Amplification with TOTEM hybrids (remote control for low voltages)
- Readout by TOTEM boards (remote control of thresholds) for NINO chips plus HPTDC (calibration)

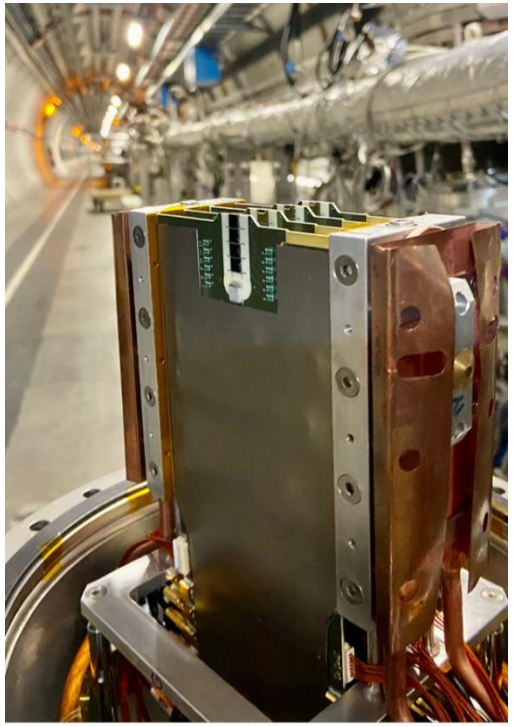
[*] M. Beretti et al., JINST 12 (2017) P03026





Time resolution for a **DD plane** (left)

RP in sector 56 at the LHC tunnel (right)



Lab test of High voltage stability under vacuum (bottom)

For Run 3:

- Two Roman pot already equipped with **double diamond** planes and installed at the LHC tunnel in sectors 45 and 56
- Two more additional stations to be installed during the EYETS 2022
- Ultimate resolution goal (< 30 ps) with the 7 – 8 planes on each sector

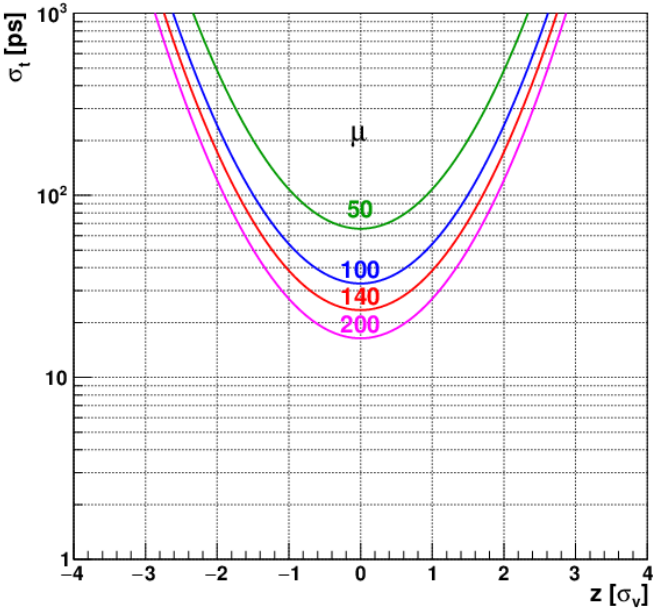
R&D for HL-LHC Roman Pot Upgrade for Run4 and on

Challenges:

- Increased of the pile-up multiplicity at the interaction point in the HL-LHC ($L \approx 7.5 \times 10^{34}$ cm^{-2} s^{-1}) . A factor of 3 - 4 higher than in Run2 and Run 3
- Timing requirements for combined PPS – MTD of about 15 ps

Synergies:

- For the tracking possible scenario a solution with the TimeSpot collaboration
- For the Timing possible combine collaborations:
  - The TimeSpot collaboration (some colleagues are working in PPS)
  - The Phase-2 Inner Tracker and the MIP Timing Detector (MTD) (lead by Prof. Panja Lukka)



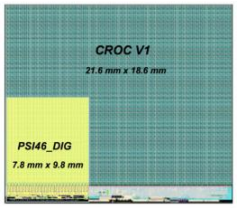
The CMS collaboration. The CMS Precision Proton Spectrometer at the HL-LHC -- Expression of Interest. arXiv:2103.02752.

Phase-2 Inner Tracker

- Hybrid pixel modules using new CROC ASIC.
- Smaller pixels for less occupancy.
- Planar n-in-p Si sensors baseline, rad hard 3D Si sensors for innermost layer.

Finnish contribution:

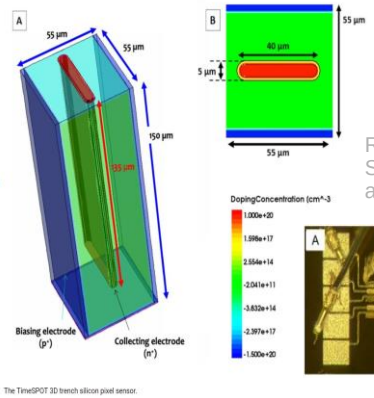
- Building, testing and calibrating 250 TEPX modules
- Produced successfully our first full digital module with CROCs
- Currently: setting up of TEPX readout electronics in Helsinki lab to develop QC software; constructing of cold box for QC of pixel modules.

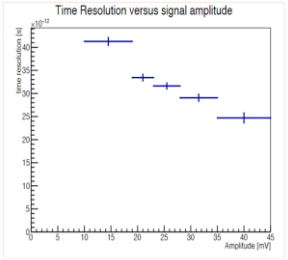


S. Orfanelli et al., JINST 17 C08003,2022

Courtesy of: E. Brucken

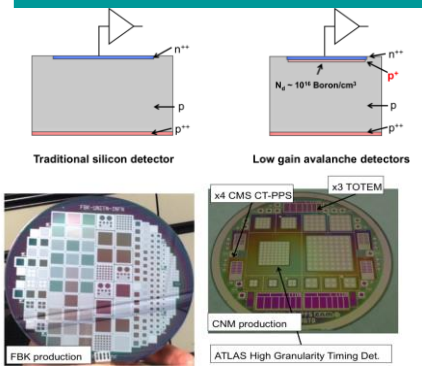
TimeSpot Detector





R. Mulargia et al., 15th Topical Seminar on Innovative Particle and Radiation Detector

Low Gain Avalanche Detector



CERN-LHCC-2017-027 ; LHCC-P-009. Technical proposal for a MIP timing detector in the CMS experiment Phase 2 upgrade

SUMMARY

- The scintillator based nT2 telescope of TOTEM will be installed for the total cross section measurements at 13.6 TeV during special run (~ 2023)

- The CMS Precision Proton Spectrometer has been upgraded for tracking and timing in continuous data taken during Run 3

- Looking for synergies in the R&D of suitable technologies to be used for the HL-LHC upgrade of the Roman Pots