# Operation and performance of the new detectors in the CMS-TOTEM Precision Proton Spectrometer in 2017


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## General Concept

- **Precise measurement of the scattered protons** from IP5 (CMS) in the **very forward region** at high luminosity**.**
- **Protons with small momentum loss** *($\xi = \Delta p/p$ between 2 and 10%)* propagate through the LHC lattice and are detected in the Roman Pots (RP).
- **Different Sensors Technologies**: **tracking detectors** (3D pixel and micro-strips) and **timing detectors** (artificial single-crystal diamonds – scCVD and *Ultra-Fast Silicon Detectors - UFSD*) have been installed into ***Roman Pots*** (RP).

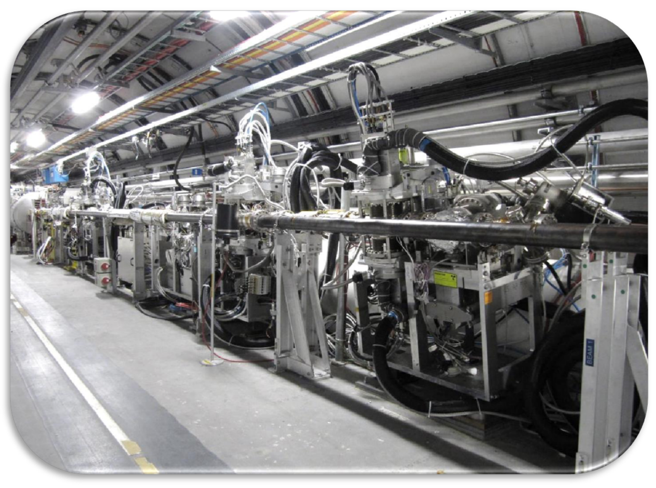

**Figure 1:** CT-PPS at LHC.

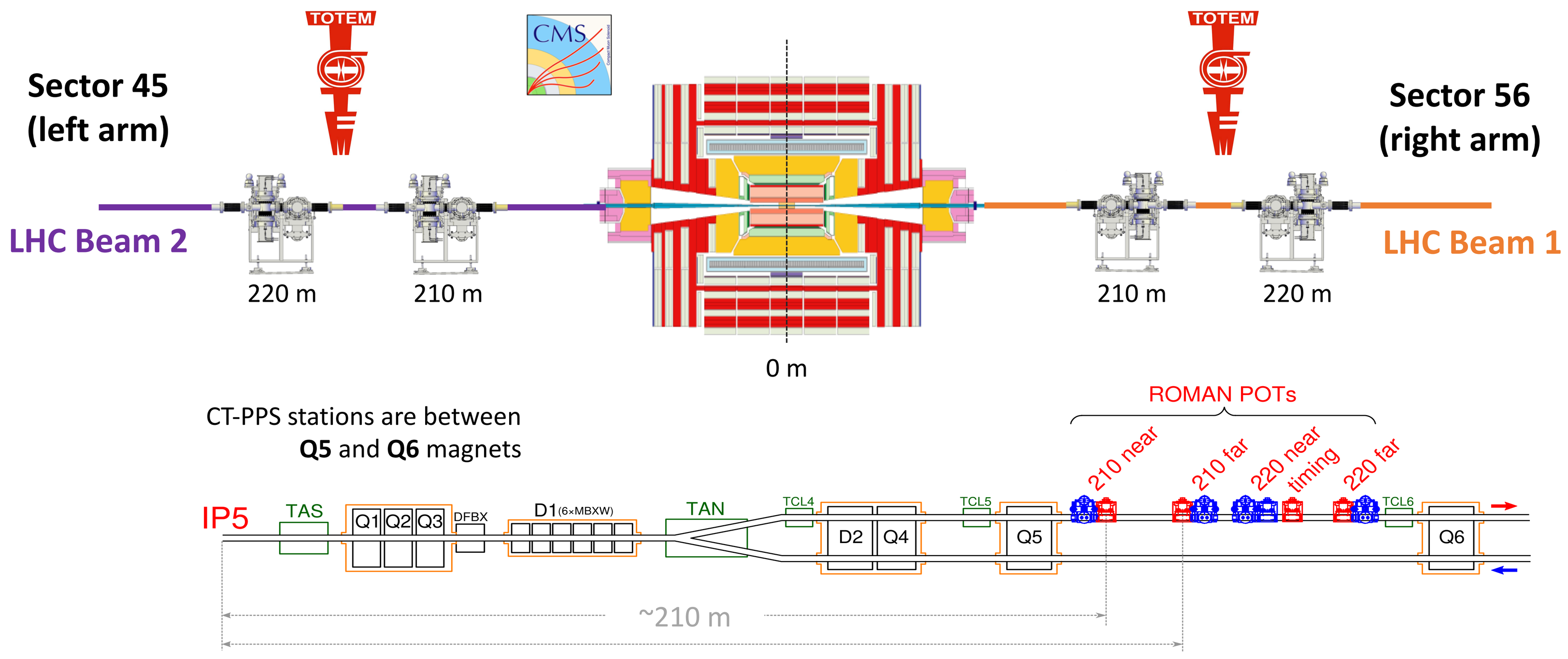


**Figure 2:** Scheme of CT-PPS. Stations are placed around 210 and 220 m from CMS to detect scattered protons (top). Roman pots are installed between quadrupoles Q5 and Q6 and between collimators TCL5 and TCL6 (bottom).

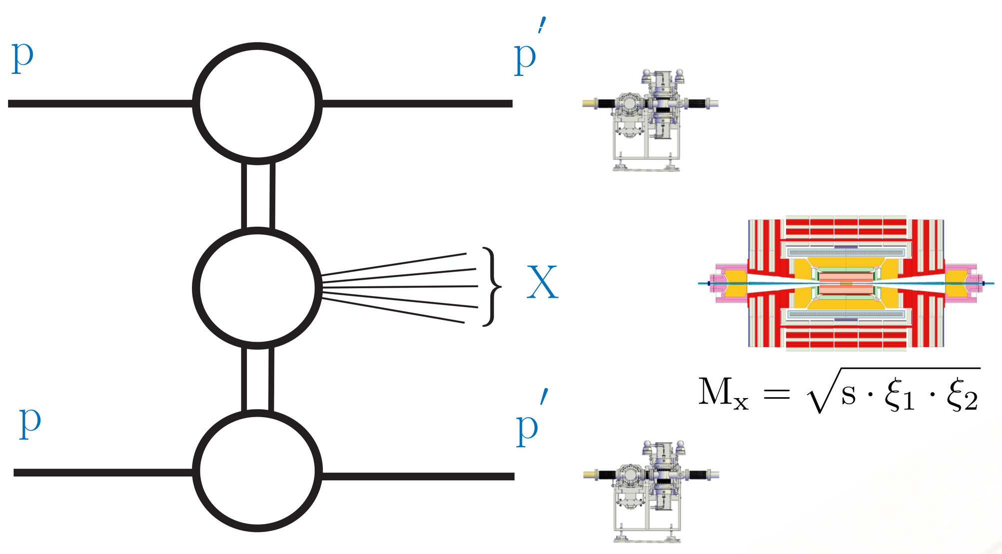


**Figure 3:** CT-PPS measures central exclusive production (CEP).

**Why** **timing detectors?** **For pile-up rejection** and CEP vertex identification.
**tracking detectors?** **For measuring protons *kinematics*** (*Δp/p* and *square of the four-momentum transfer*).

- **Physics Motivation:** CT-PPS aims to explore different physics subjects using LHC as a **gluon-gluon collider** (central exclusive hard production), as a **photon-photon collider** (measuring exclusive electroweak processes and possible Anomalous Quartic Gauge Couplings) or explore processes **beyond the standard model,** taking advantage of the clean experimental signature of central exclusive production (CEP).

## Detector Technologies

### scCVD (Artificial Diamonds) Detector

- 4 sensors with 4.5 x 4.5 mm$^2$ and different profile pads per plane;
- Radiation hardness: lifetime close to 5x10$^{15}$ p/cm$^2$;
- Resolution per sector: around 55 ps (2017);
- Readout: NINO & High Precision TDC chips (HPTDC).

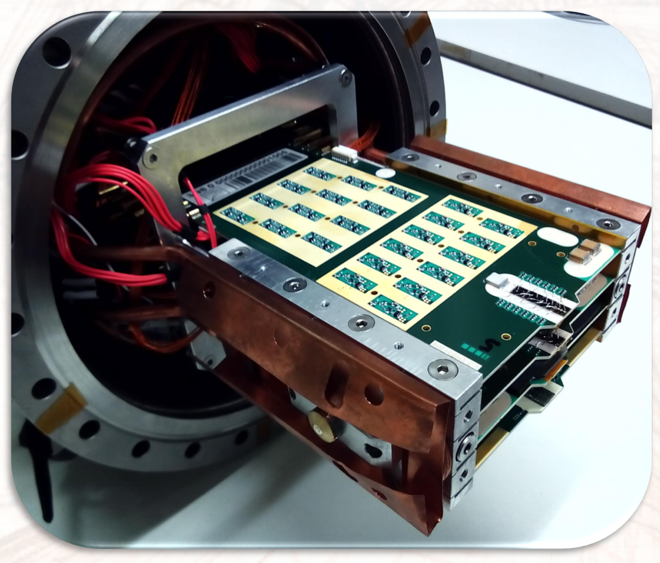

**Figure 4:** Diamond detector package.

### 3D Pixel Detector

- Radiation hardness: lifetime up to an integrated flux of 5x10$^{15}$ p/ cm$^2$;
- Small insensitive area at the edge of the sensor towards the beam;
- High granularity: pixels with 100 x 150 $\mu m^2$;
- Planes tilted by ~18$^0$ to improve resolution ($\sigma_x$ ~15 $\mu m$ and $\sigma_y$ ~30 $\mu m$);
- Readout: CMS Phase I Pixel (TBM & ROC).

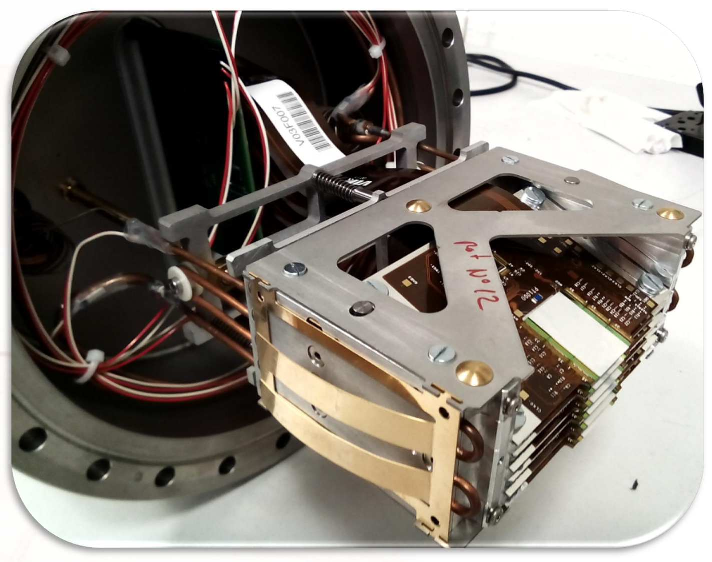

**Figure 5:** 3D pixels detector package.

## Performance in 2017

### Timing System Hit Map

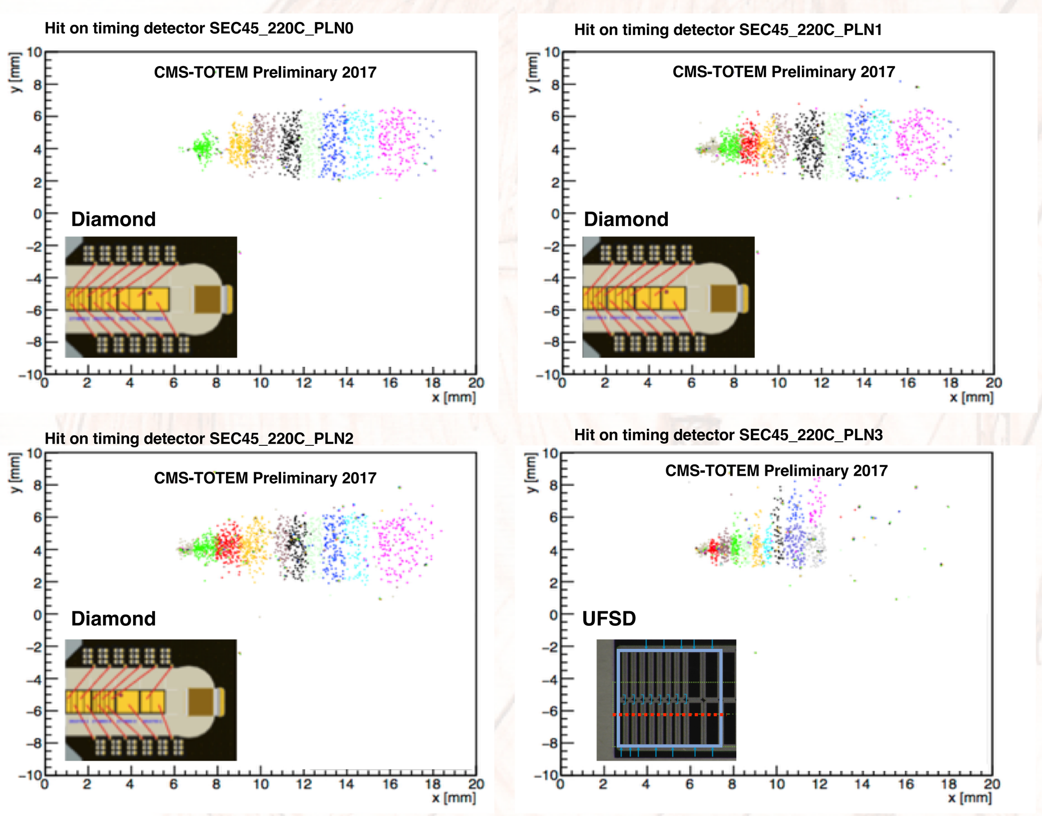


**Figure 6:** Track impact points when requiring coincidence with timing detectors planes. Each color corresponds to a single channel. In 2017, timing detector packages were composed of three planes of diamonds and one plane of Ultra-Fast silicon detectors (UFSD).

### 3D Pixel Resolution

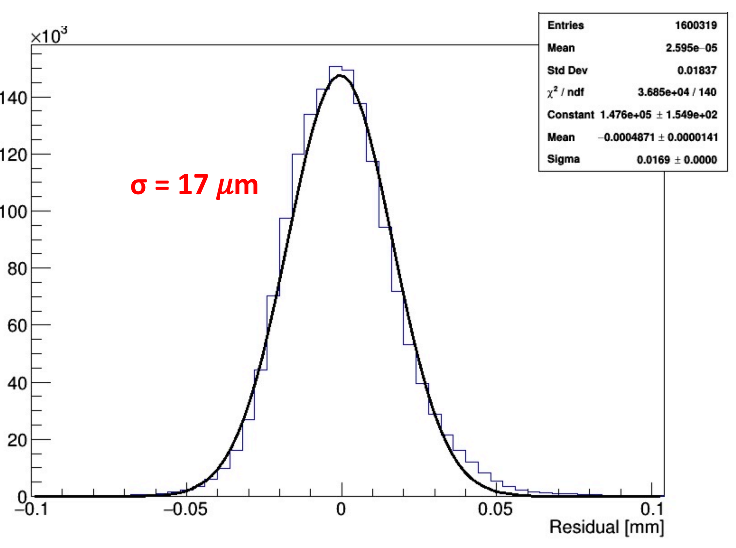


**Figure 8:** Hit residuals for single planes are evaluated with respect to the local track reconstructed in the pixel RP. Residuals are consistent with those obtained at the beam tests. The pixel tracker works as expected.

### 3D Pixel Track Reconstruction

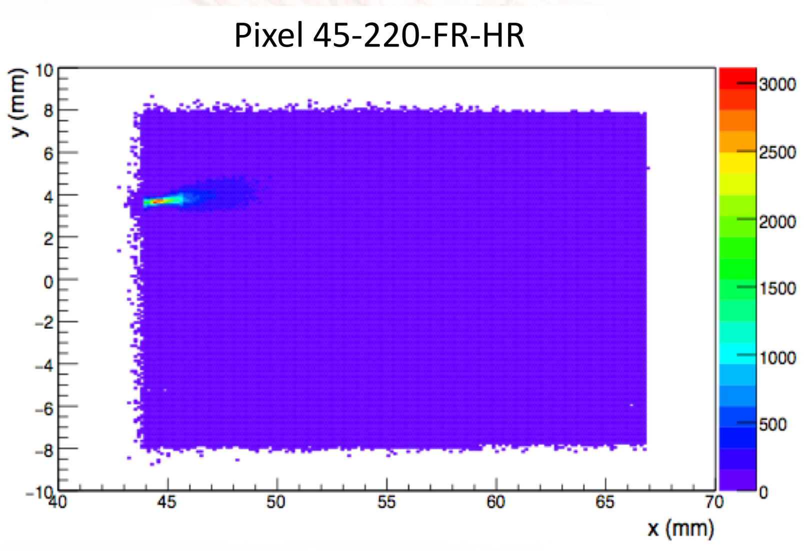


**Figure 10:** Track impact points reconstructed from the 3D pixel detector package (sector 45). The track is reconstructed requiring at least activity in 3 planes (similar to sector 56).

### Timing Resolution

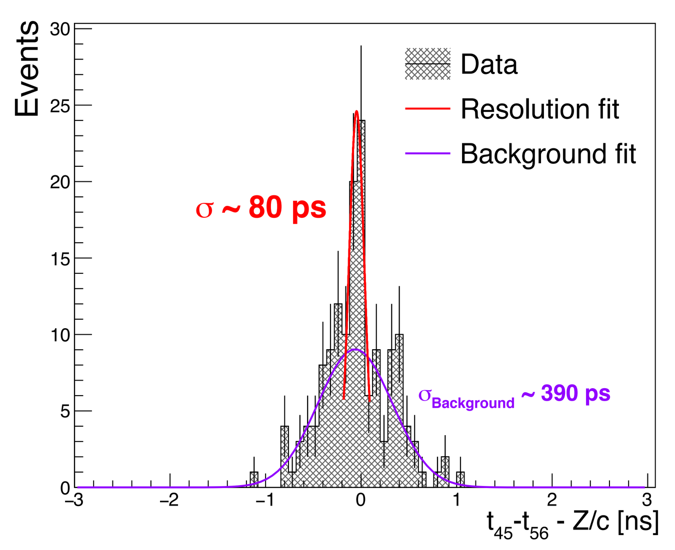


**Figure 7:** Timing resolution measured in low pile-up runs with two protons (one per arm) detected. The variable $t_{45(56)}$ is the proton time of arrival measured per arm (45 and 56 respectively), ***Z*** is the longitudinal position of the CMS vertex and **c** the speed of the light. The resulting distribution is fitted with the sum of two *gaussians*, one with 80 ps width, corresponding to signal events, and the other with 390 ps width, attributed to the background (single dissociation, pileup and beam halo protons). The resolution (σ) around 80 ps is compatible with a time precision of 55 ps per sector.

### Local timing tracks Vs. Local 3D Pixel Tracks

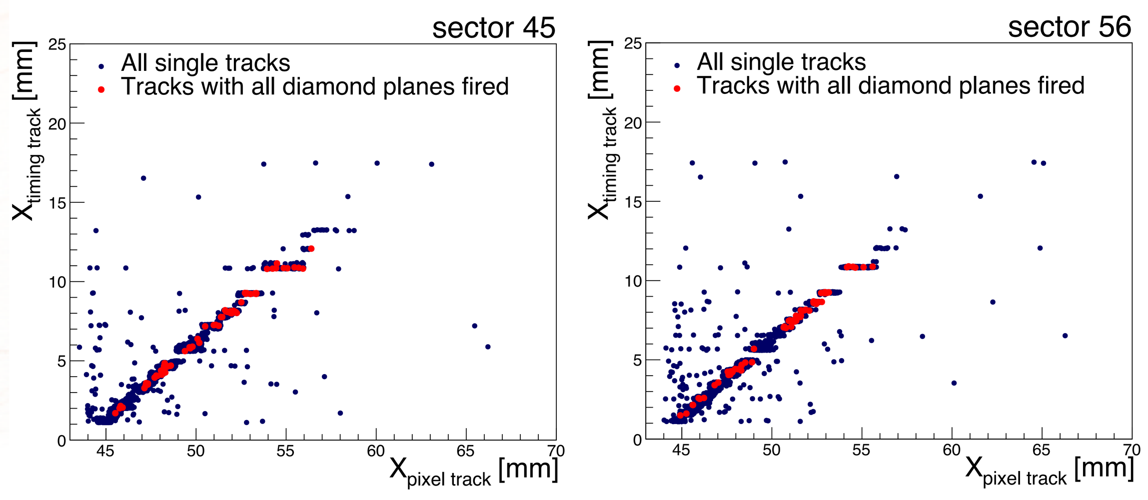


**Figure 9:** Correlation between horizontal track impact point positions reconstructed with the pixel and the timing detectors. Blue points show all events with a single track in each arm reconstructed in the pixels, red points represent a subsample in which all timing detectors planes were fired.

### 3D Pixel Occupancy

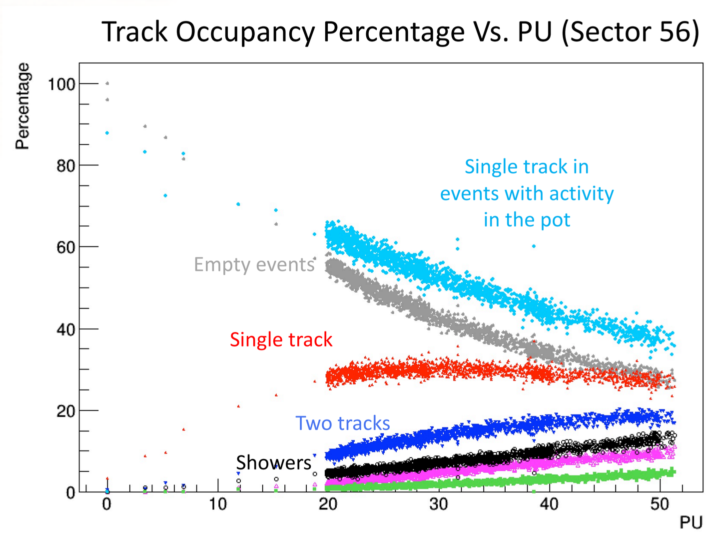


**Figure 11:** The number of tracks reconstructed by the pixel detector shows a clear correlation with the number of pile-up (PU) events. Percentage of showers (5 and more tracks, black points) reaches 10% at the highest luminosity.