TOTEM hardware status

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(on behalf of the TOTEM collaboration)

LHC Working Group on Forward Physics and Diffraction
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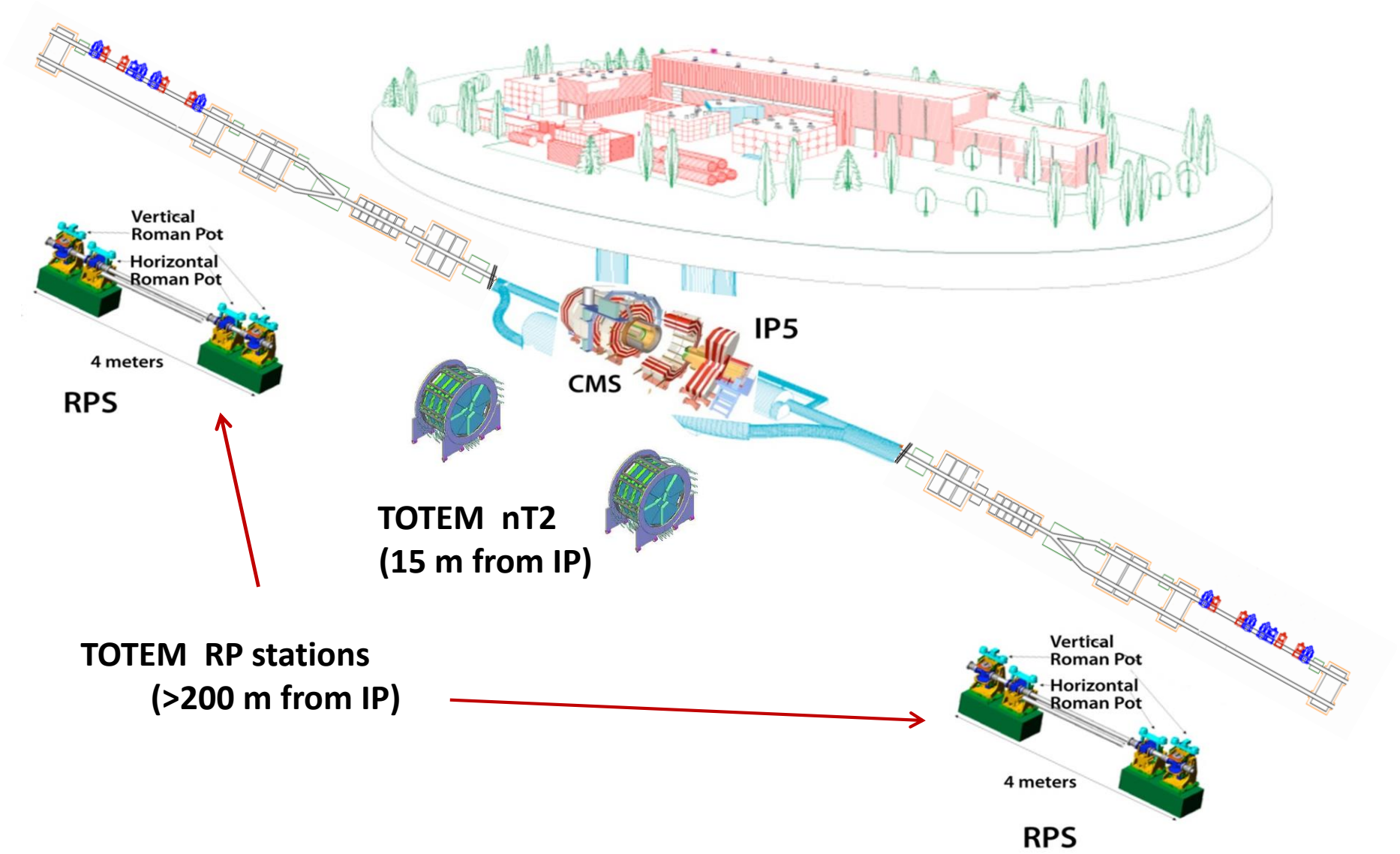
OUTLINE:

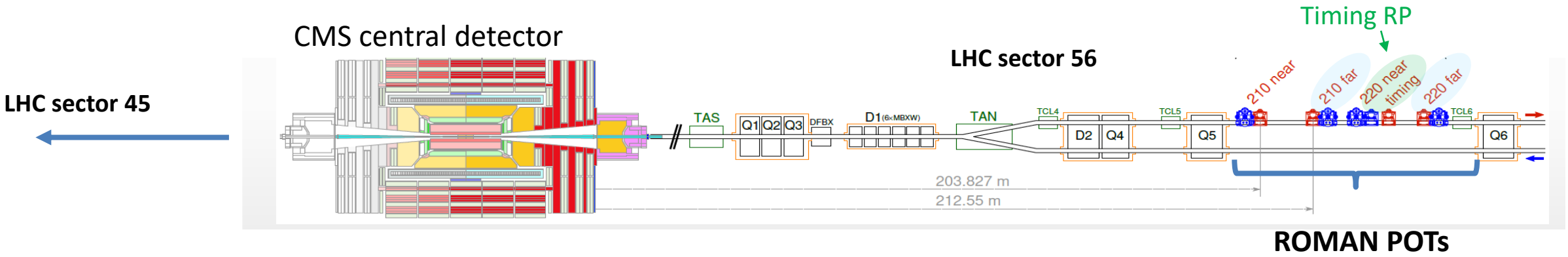
- RP status
- The new TOTEM T2 detector
- SAMPIC readout for timing detectors

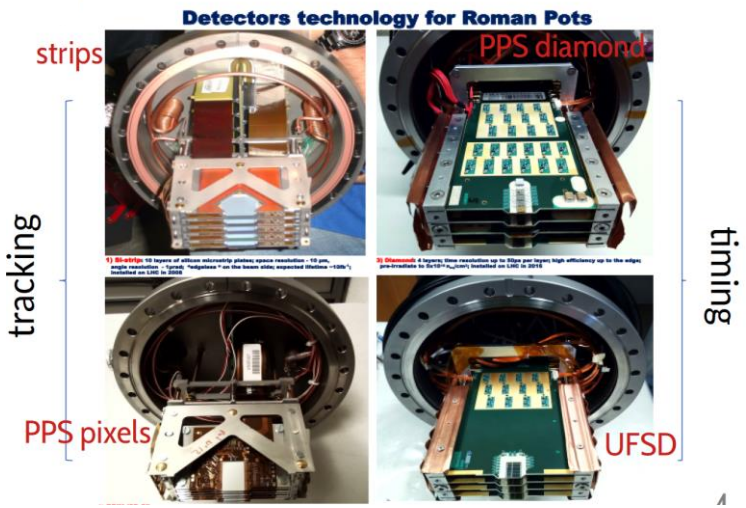
IP5 layout


Vertical
Roman Pot
Horizontal
Roman Pot
4 meters
RPS
IP5
CMS
TOTEM nT2
(15 m from IP)
TOTEM RP stations
(>200 m from IP)
Vertical
Roman Pot
Horizontal
Roman Pot
4 meters
RPS

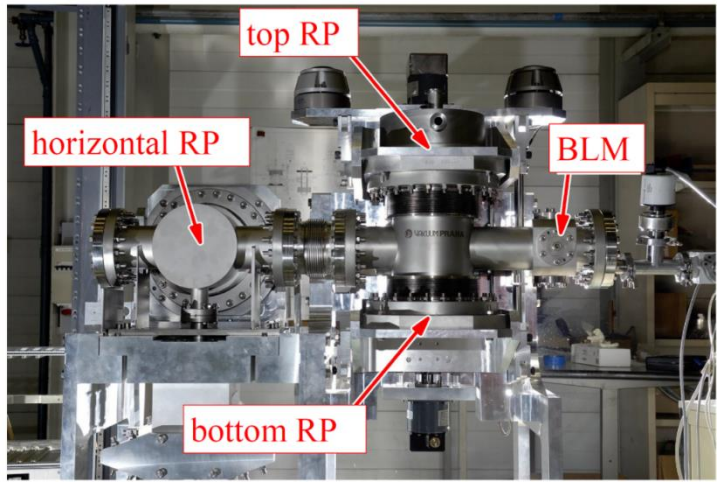
Roman Pots layout

Symmetric experimental setup w.r.t. the interaction point



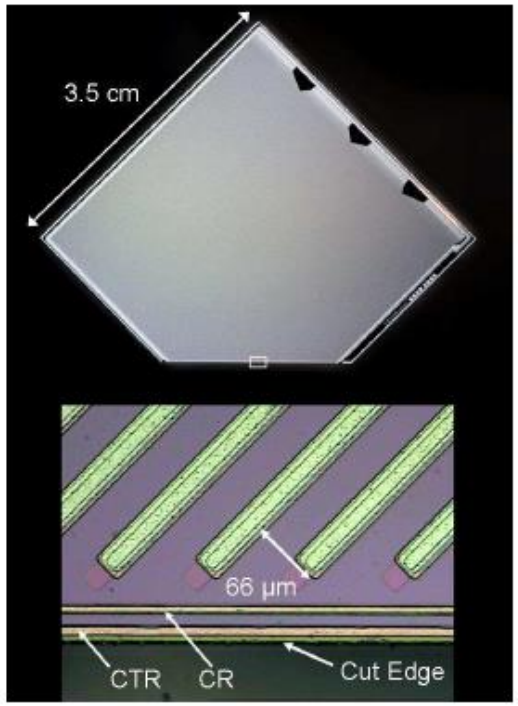


- ✓ Several technologies hosted in RPs during Run 2, for both timing and tracking. Used by TOTEM and CMS (PPS)



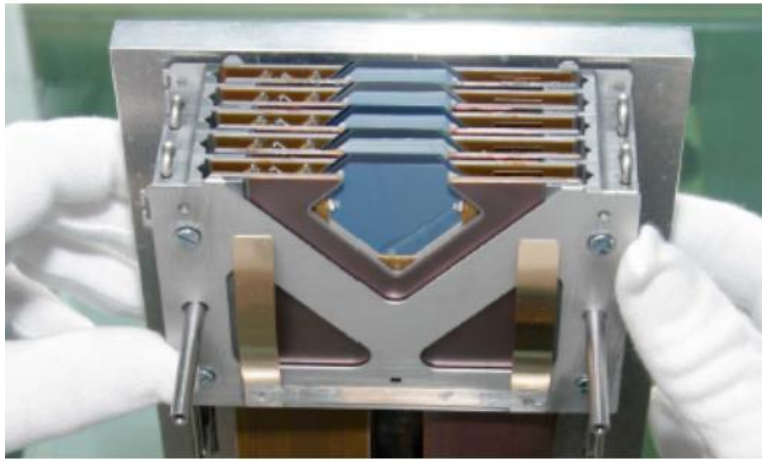
RP: Vacuum vessel entering the beam pipe, can be equipped with many types of detectors. Hosted detectors brought to few mm from LHC beam centre.

Silicon strips detectors

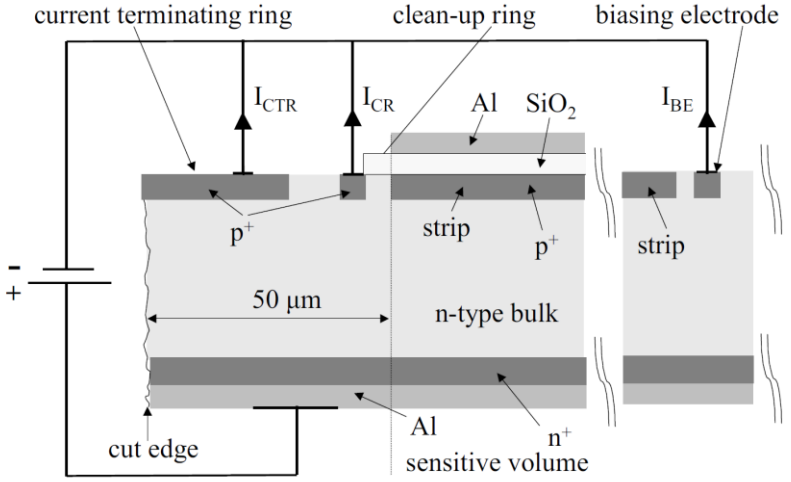


10 planes of micro-strip silicon detectors:

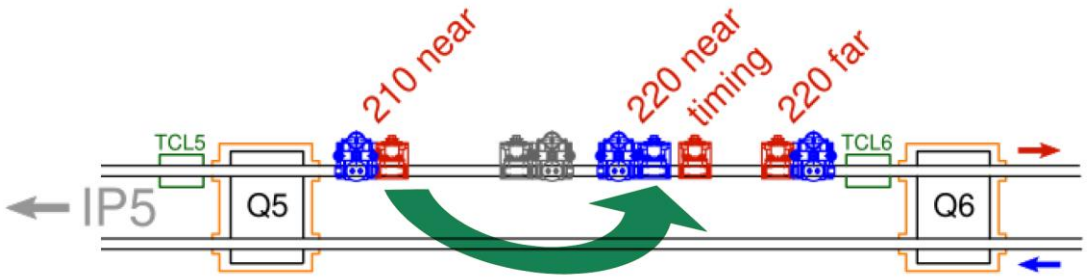
- 512 strips per plane: 66 µm pitch, 300 µm thickness, 20 µm resolution
- 45° strip orientation, mounted in back to back configuration, for a total of 5 position measurements per package
- Edgeless technology with current terminating structure. Reduction of edge inactive area to 50 µm depth
- Digital readout without charge info provided by VFAT2 chipHit track reconstruction using TOTEM algorithms, integrated in CMSSW in 2016



TOTEM strips were also used in PPS in standard high-luminosity fills in 2016 and 2017.



RP LS2 activity



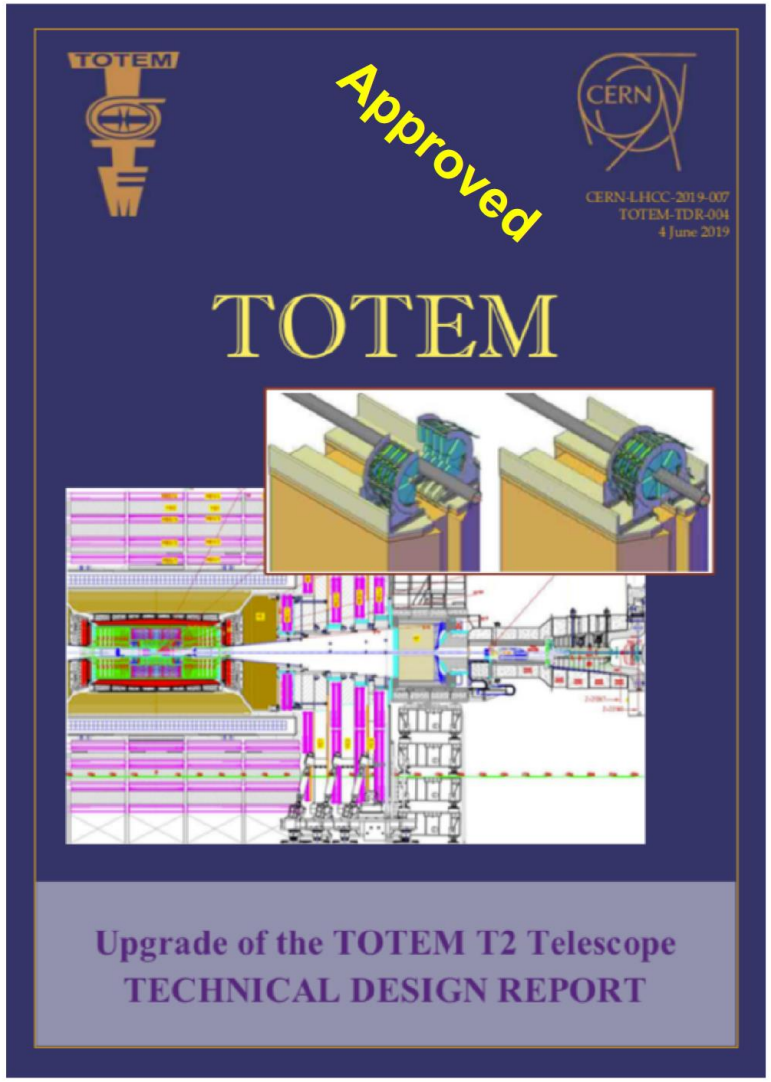
- Roman Pot (RP) infrastructure ready: RP210 <near> horizontal RP (high-lumi qualified) relocated to RP220 <near> horizontal RP position to double the number of PPS timing diamond stations.

- CMS has requested **3mm-beamline downshift**: implied breaking RP vacuum, mechanical movement of all RP units and safety checks;

- **Laser metrology** of the RP spectrometer area is **planned to be done** in the **beginning of the next year by EN-SMM** group;

- RP **movement system commissioning ongoing** (*software* and *firmware*): upgrade of the PXI low-level motor control system (more robust components);

New T2 telescope (nT2)



Physics goal for nT2: measurement of the inelastic event rate for the extraction of total pp cross section at 14 TeV with the luminosity-independent method.

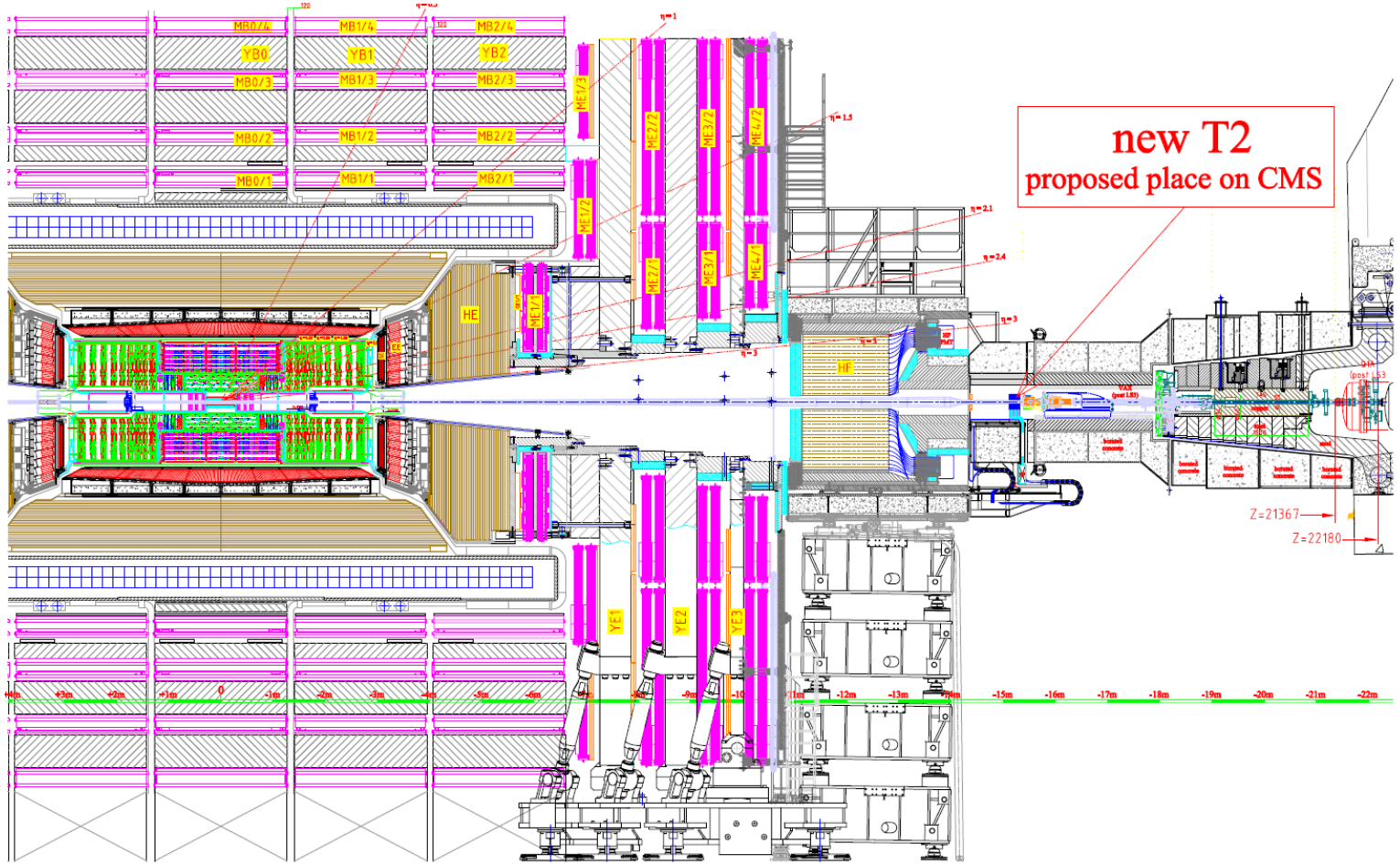
$$\sigma_{tot} = \frac{16\pi}{1+\rho^2} \frac{\left.\frac{dN_{el}}{dt}\right|_{t=0}}{N_{el}+N_{inel}}$$

Designed to detect particles in the high-η region ($5.3 < \eta < 6.5$)

→ > 90 % efficiency in the detection of inelastic events at 14 TeV. Coverage of CMS Tracker+HF only 80-85%.

TDR for nT2 submitted to LHCC on June
- ✓ Endorsed by LHCC in September
- ✓ Approved by Research Board in September

nT2 location



nT2 mounted with sliding supports on the CASTOR tables on each side of CMS

Installation/removal will require access to the CASTOR table :

- switching off the CMS magnet
- removal of Collar shield
- opening of the thin section of the CMS Rotating Shielding

Can be installed during an LHC Technical Stop (few days)

Radiation hardness

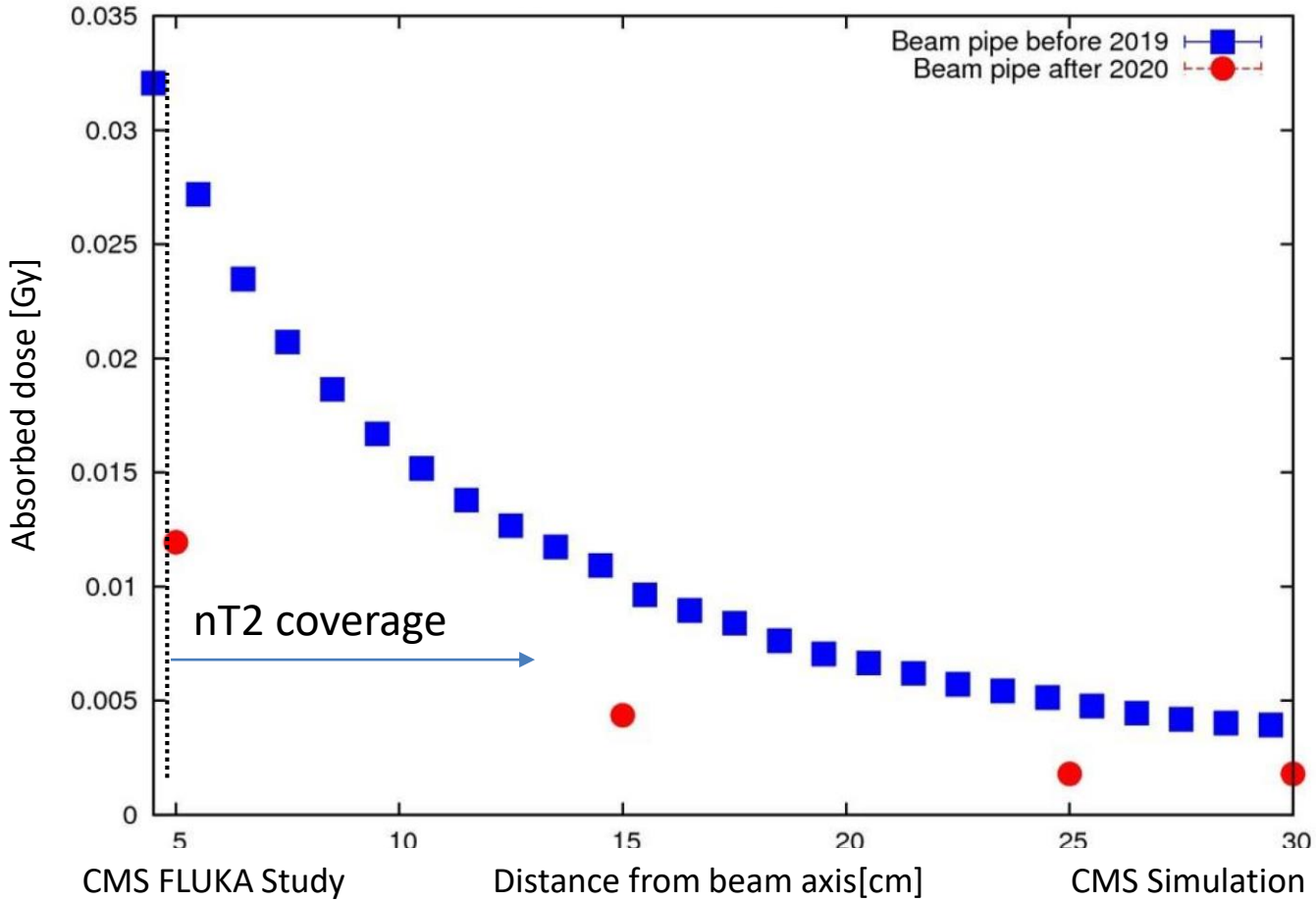
FLUKA study of radiation doses in nT2 location (z=15 m) done in collaboration with CMS-BRIL for 2.6 nb^{-1} integrated luminosity (value expected for the special run):

- Absorbed dose quite small during special Run
- The detector must be installed just before the data taking to avoid radiation damage during LHC standard fills

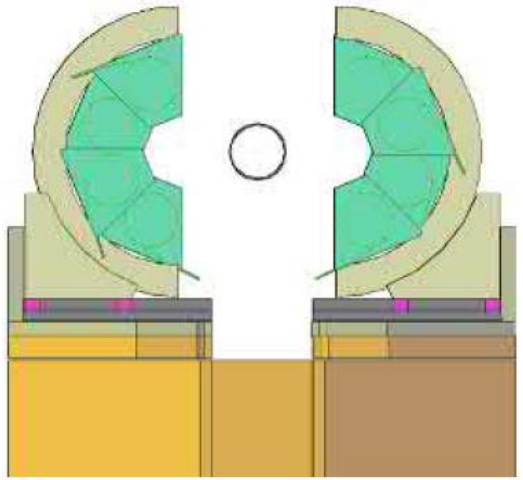
- Passive sensors in near beam region
- Fast installation of the sensors needed (1-2 days!)
- Electronics located outside Collar shield for easy access and radiation protection

Scintillators readout by WLS + optical fibres.

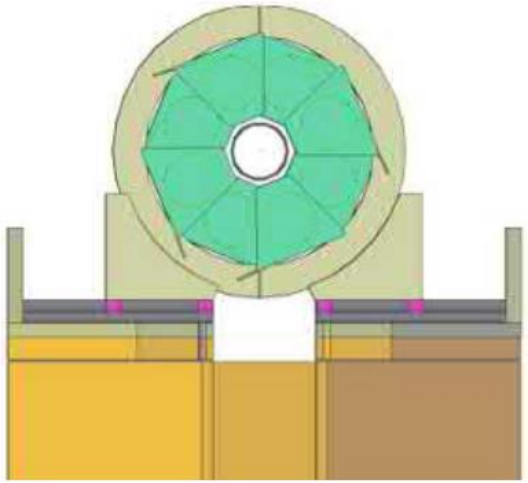
CMS p-p collisions at 7 TeV per beam, 2.6 nb^{-1}



Detector geometry



Installation removal position

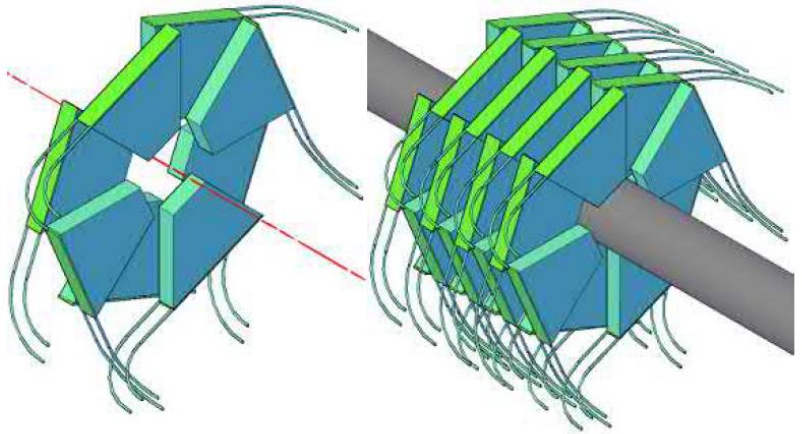


Run configuration

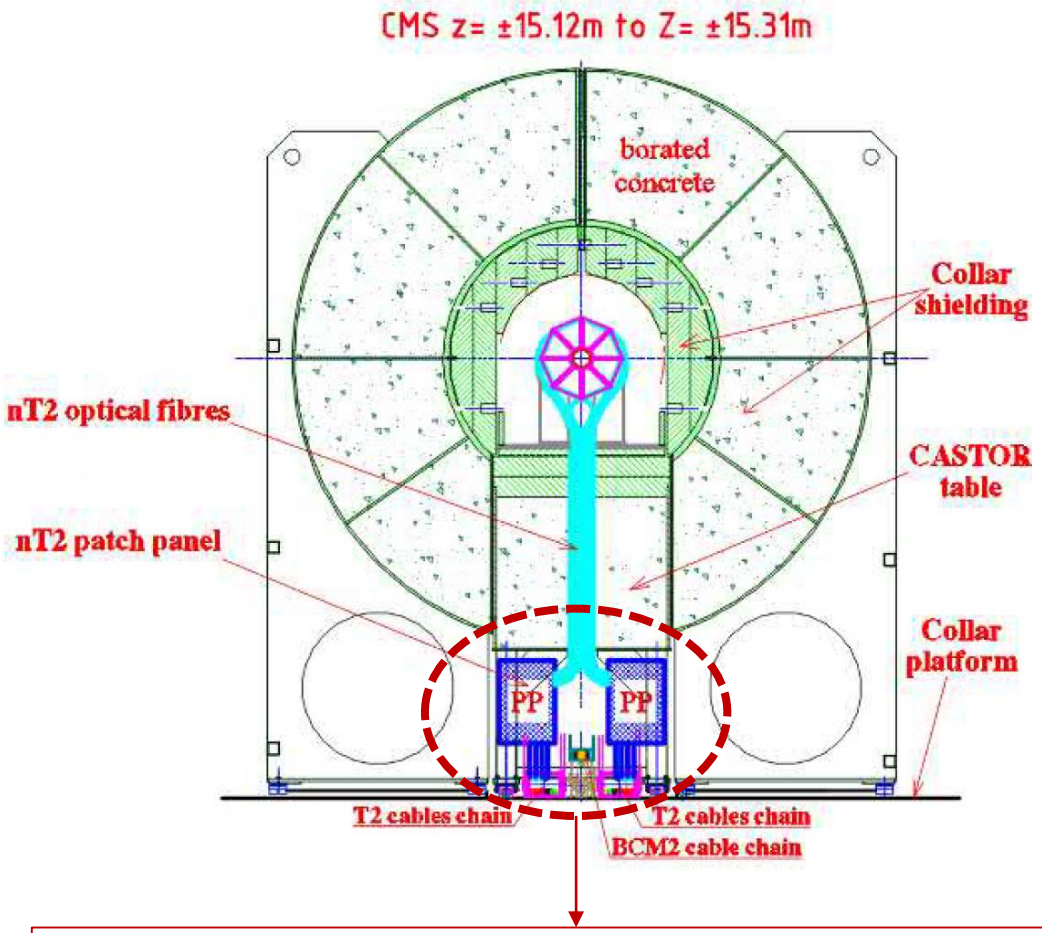
- Four planes of segmented plastic scintillator counters
- Each plane made up of eight counters with small overlaps

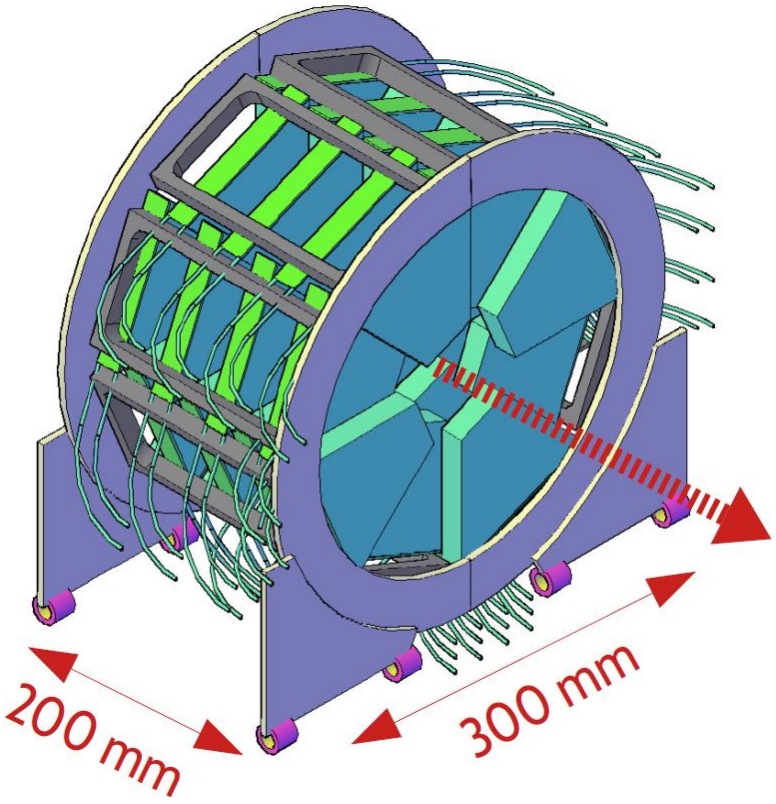
- Inner diameter 90mm, outer diameter 600mm
- Overall weight for 1 quarters about 5 Kg (scintillators + aluminium frame)

Each sector divided in 2 independent quarters to facilitate installation/removal procedure (like for the old T2)



Detector geometry





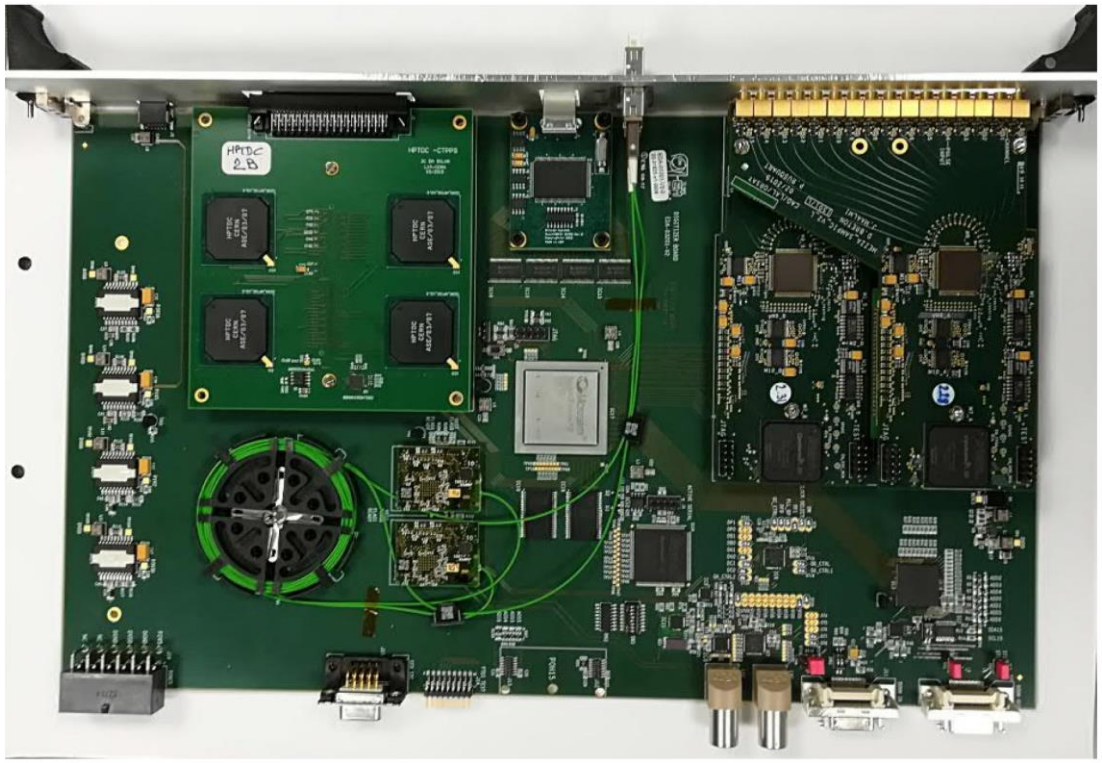
Electronics can be installed well in advance for commissioning!

Handbag-size detector

Readout & trigger

Readout will be based on the CMS/TOTEM Digitizer board:

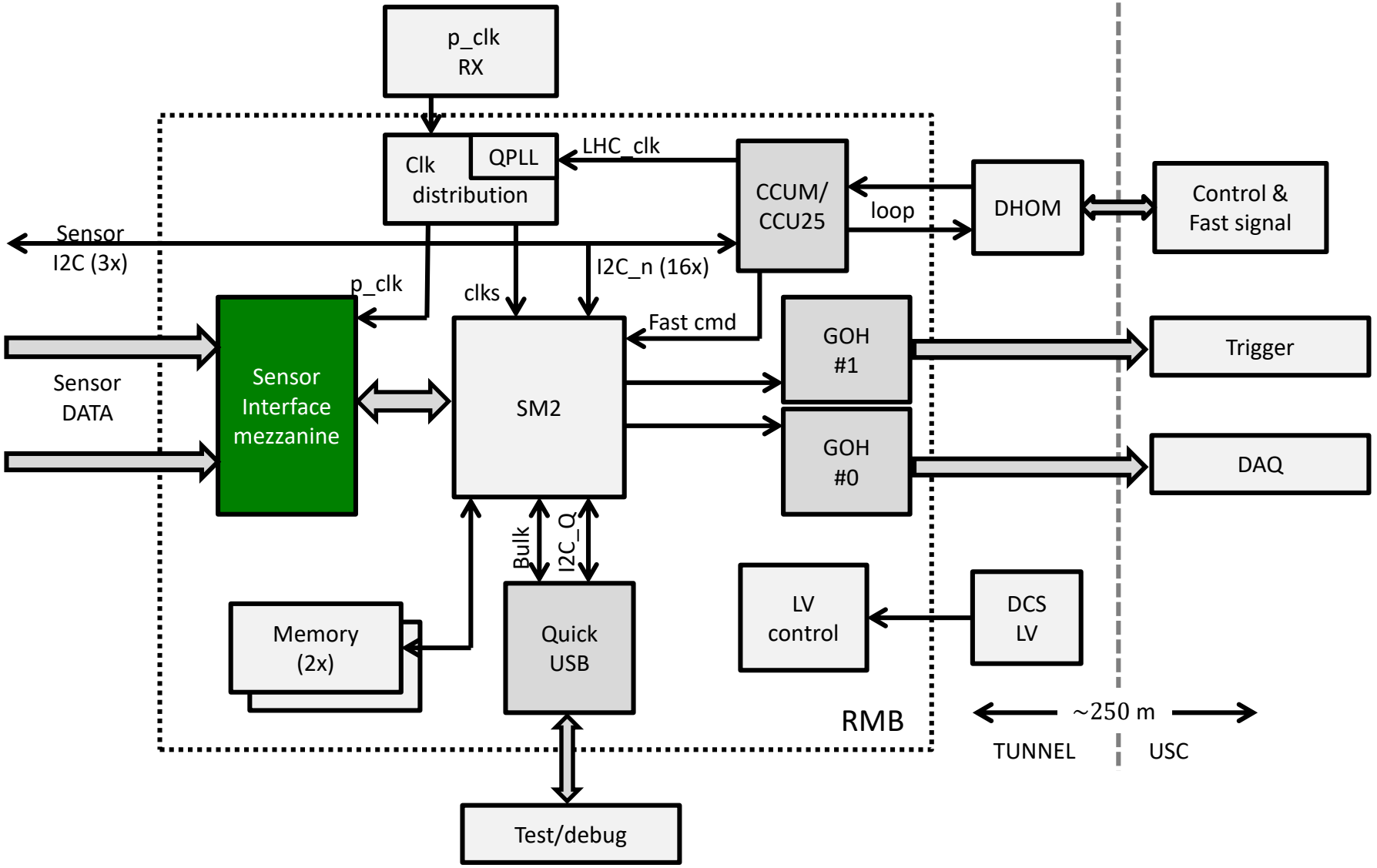
- General purpose readout and control board
- Application specific mezzanines can be designed
- Radiation tolerant design. Main FPGA from Microsemi (SmartFusion2)



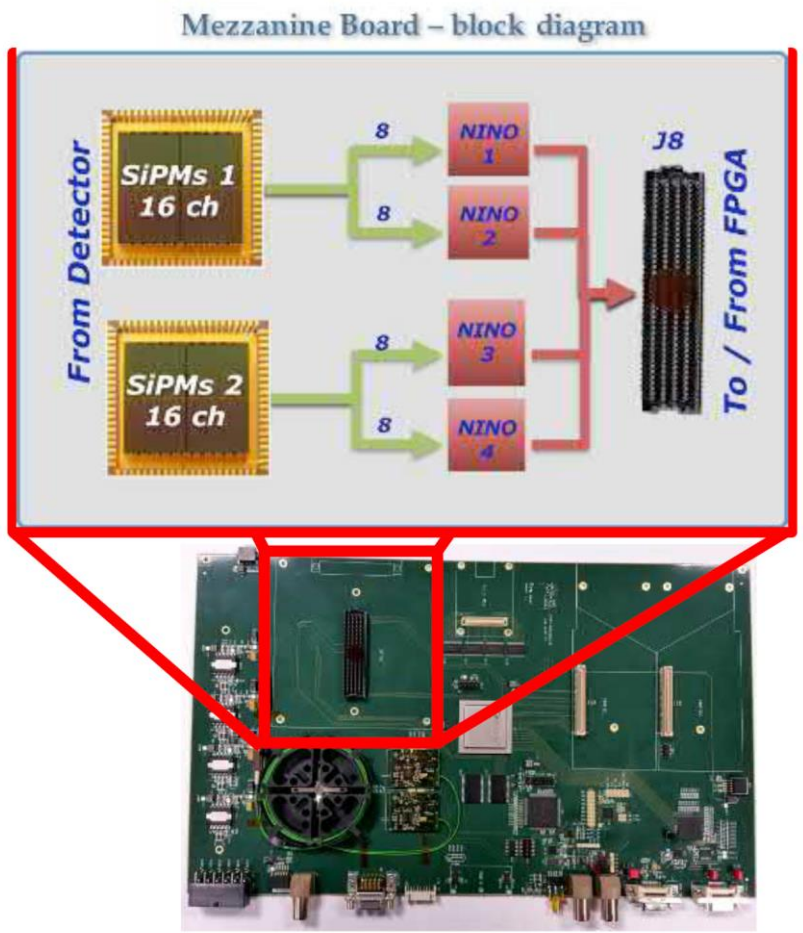
During Run2 the *Digitizer board* has been used from TOTEM/PPS timing detectors:

- transparent under CMS environment (slow control, configuration and readout);
- *Software* and *firmware* adapted from timing detectors;
- Fully tested

Readout & trigger scheme

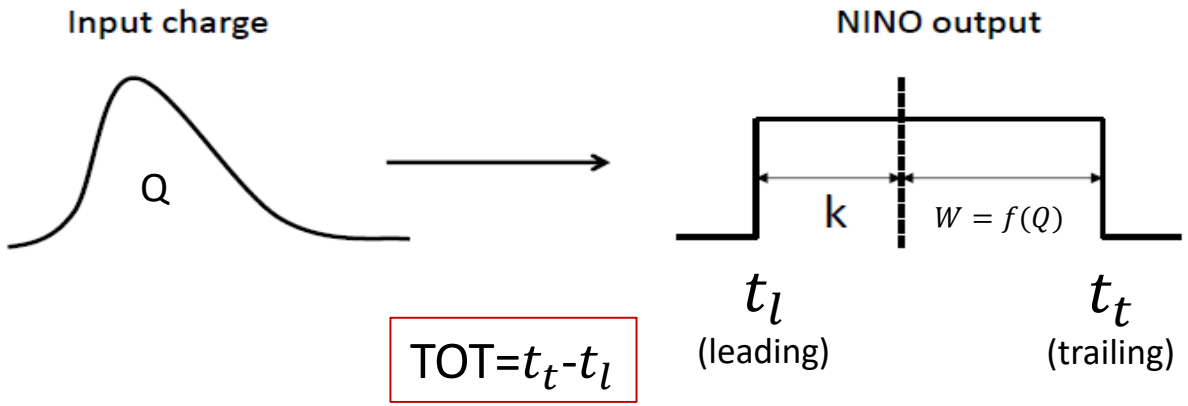


Readout & trigger



Readout and trigger:

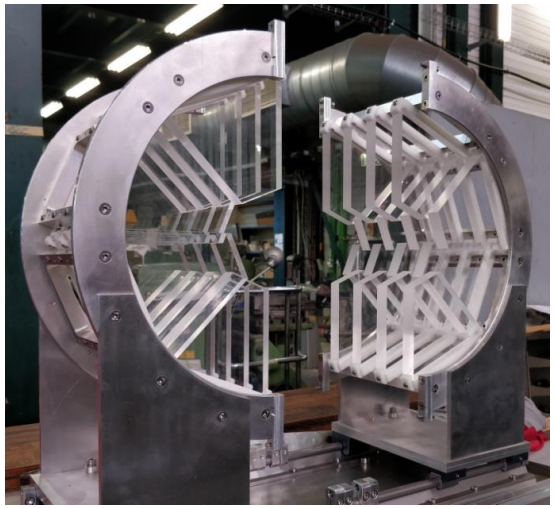
- **2 optical GOL link:** one for data and one for trigger.
- The new T2 will be **readout by SiPMs** collecting the light from the scintillator tiles;
- Candidate for final production: Hamamatsu MPPC S13361-6050, 4x4 SiPM matrix
- Each MPPC can readout a full nT2 quarter
- Discrimination with NINO chip (in use in PPS timing system)



nT2 status

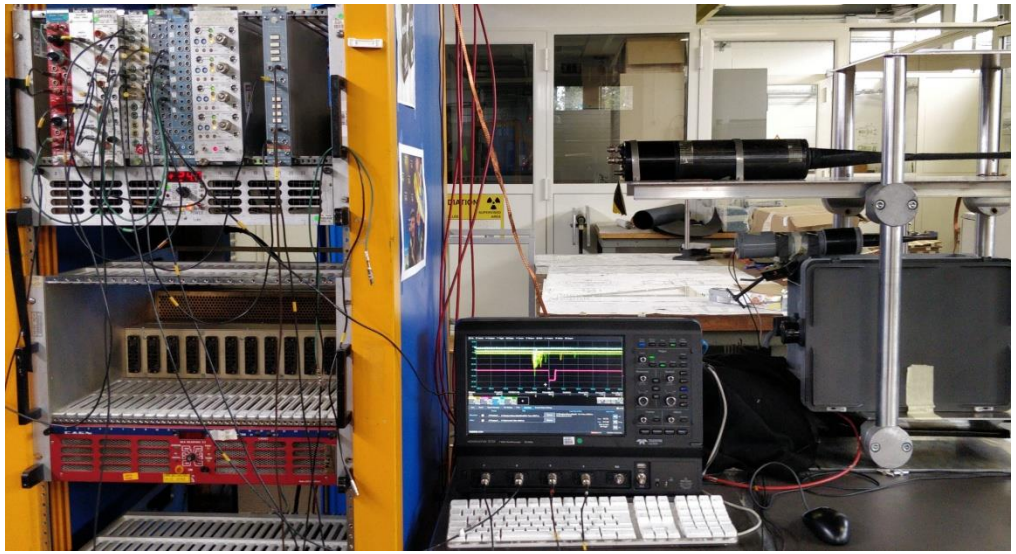
Mechanical design:

Mock-up ready to test
- integration
- detector assembly and disassembly
- fiber and service paths



Electronics:

- Digitizer board under production
- Readout mezzanine under design
- Firmware/software under development

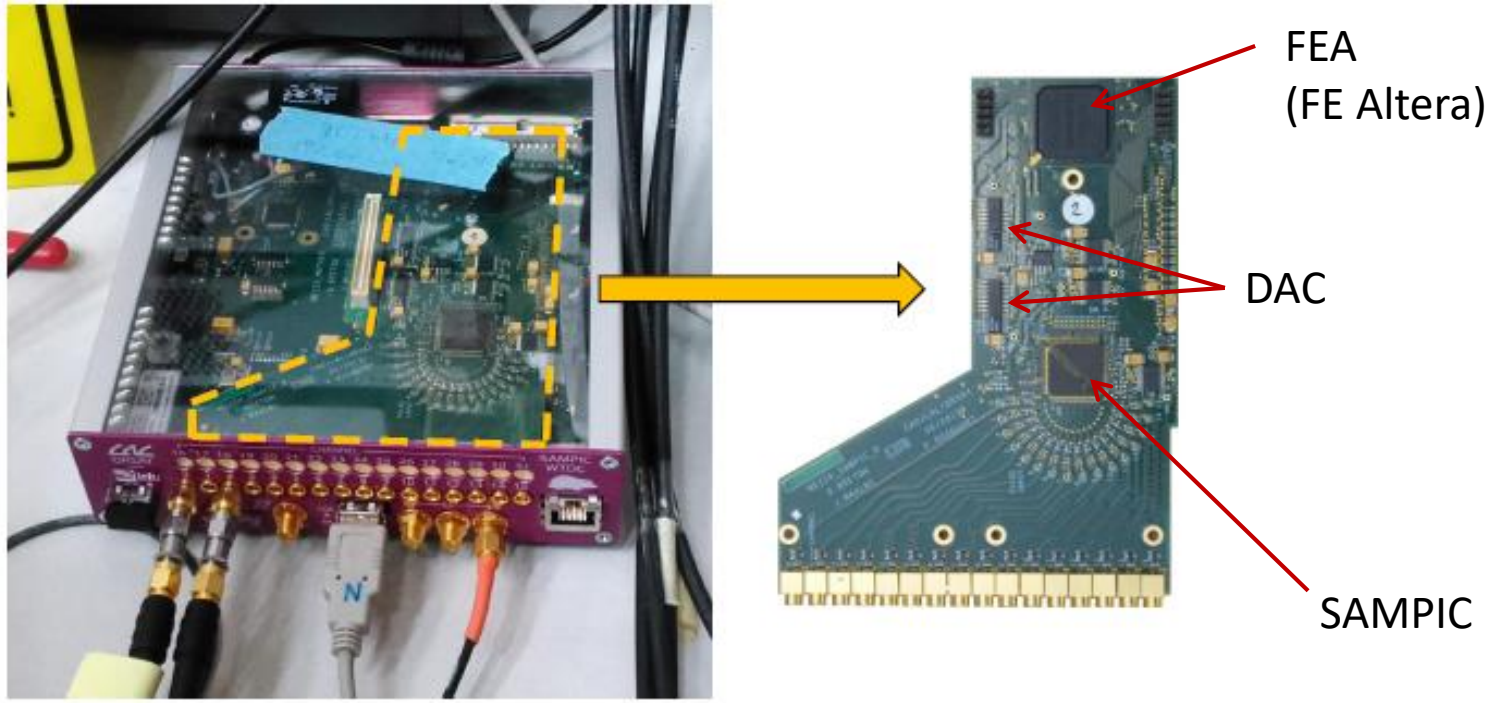


Scintillators and light collection:

- Several light collection configuration tested with cosmic ray.
- In 2020 test beam to asses final configuration and start mass production

SAMPIC readout

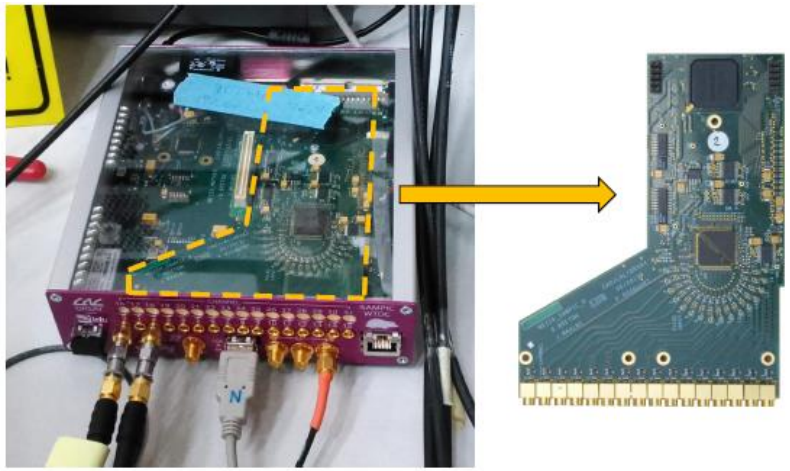
Readout of TOTEM timing sensors during the special CMS-TOTEM data taking in 2018 was successfully performed with the SAMPIC chip (fast sampler).

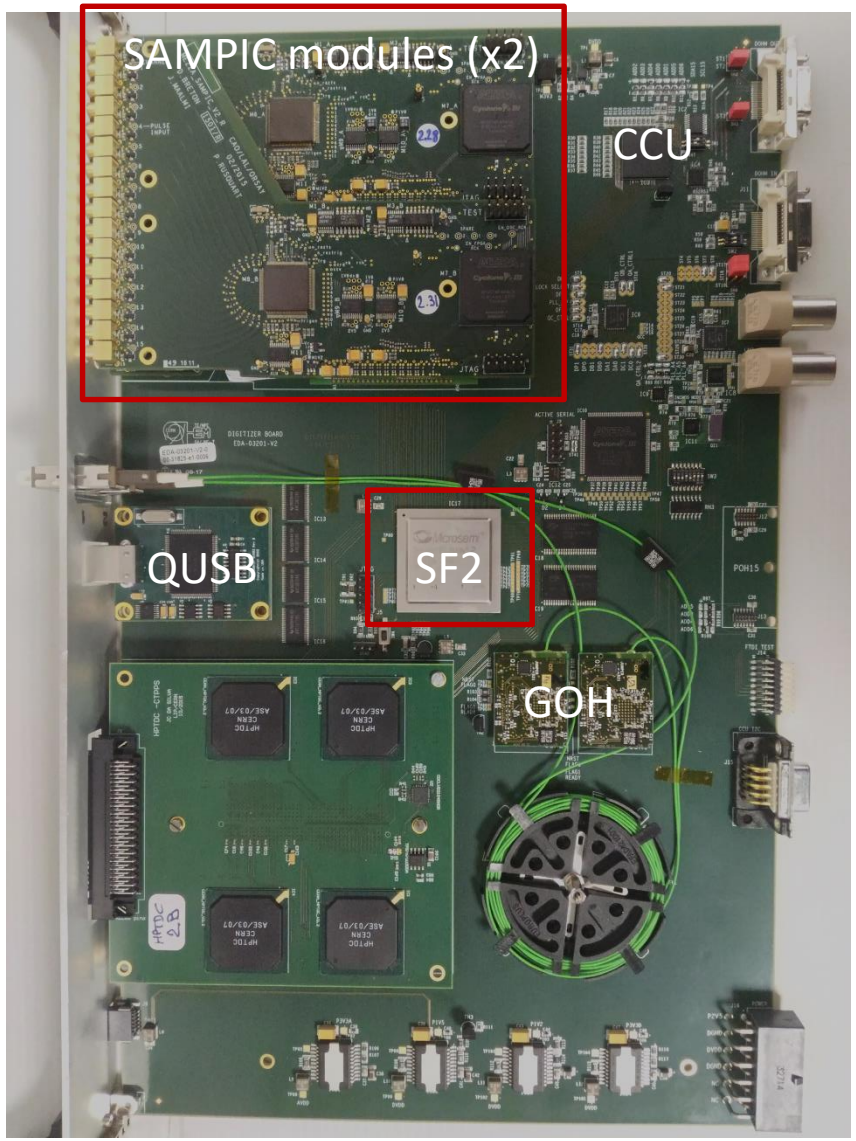


- 16 channel/chip
- Up to 64 sample/hit @ 10 GSa/s
- 1.5 GHz bandwidth
- 8-11 bit resolution
- 0.25-1.6 µs channel dead time

- Self trigger (2ns max latency on central)
- No event building
- Each sampled signal sent out

SAMPIC integration



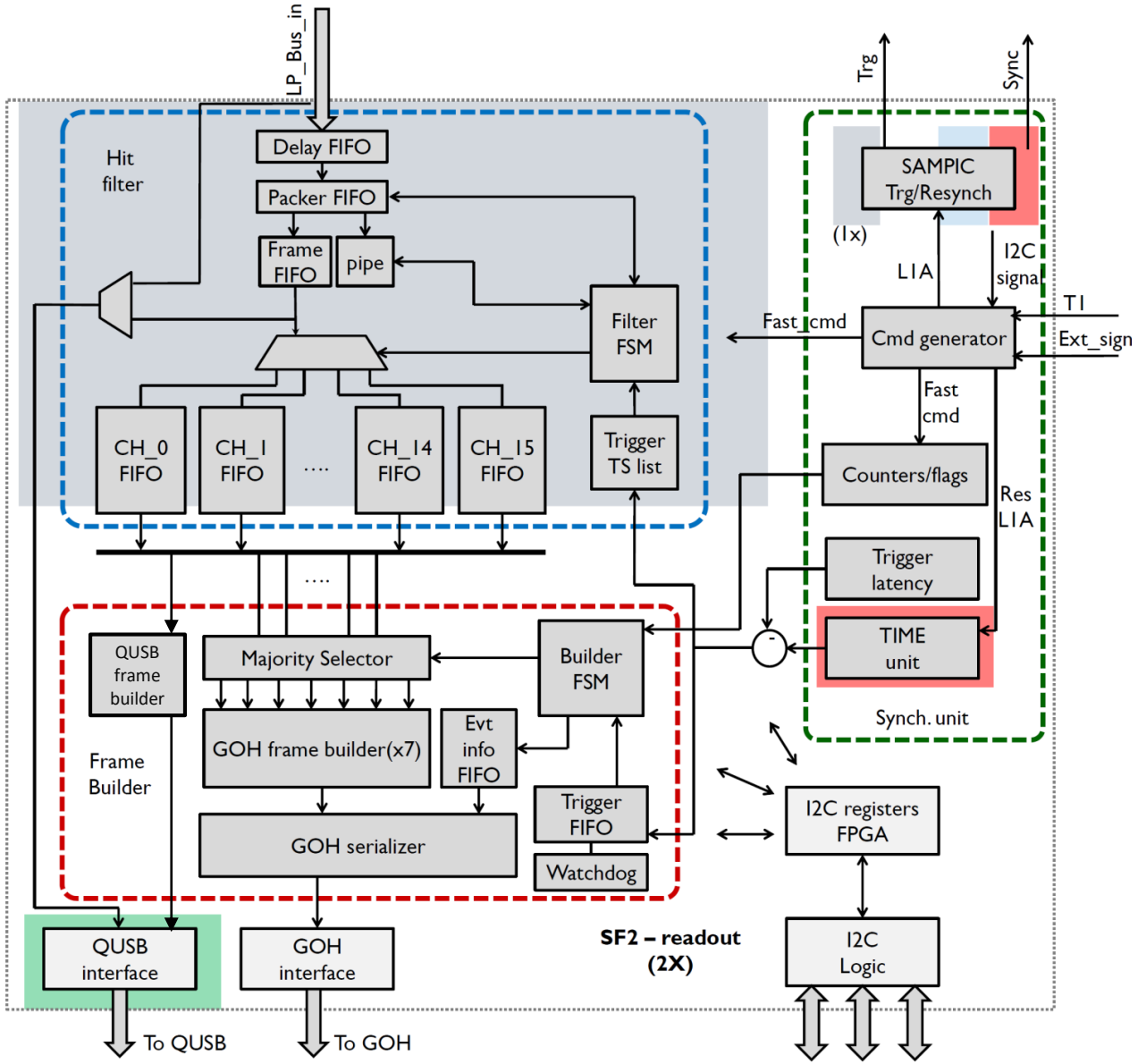


Special needs for the SAMPIC for data taking in CMS/TOTEM:

- Chip configuration with I²C
- Readout with optical link (GOL chip)
- Compatibility with the high precision clock distribution
- USB interface for debugging and test beam

Digitizer board

SAMPIC Readout firmware

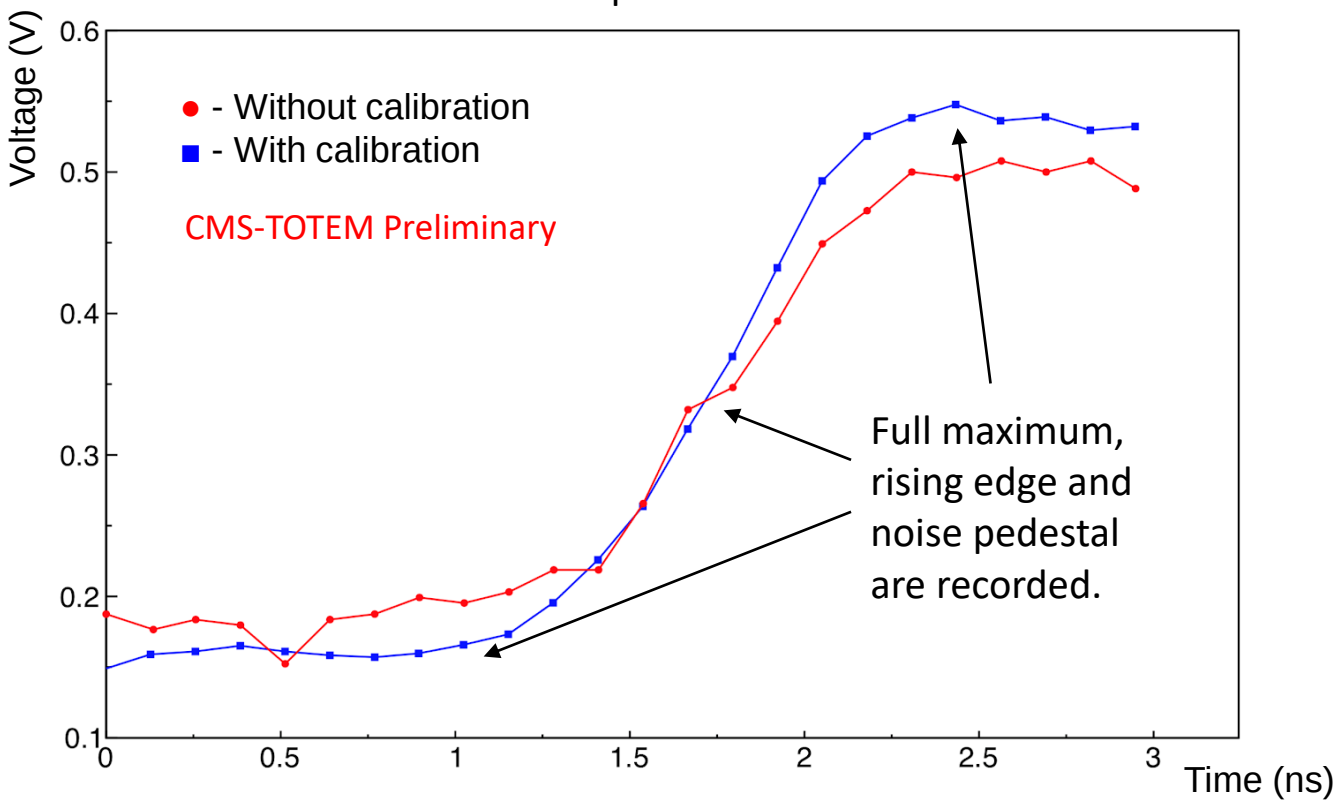


- Data packet reception from SAMPIC (1 packet/hit)
- Data packet sanity check
- Fast command decoding and event timestamp generation
- Raw hit selection based on triggered event list
- Event building
- Data compression
- Interface to optical transceiver / USB

Waveform quality

SAMPIC chip was operated at 7.8 Gsa/s, with 8 bit voltage resolution. 24 samples were collected for each waveform (recording window of ~3.1 ns)

Example of waveform

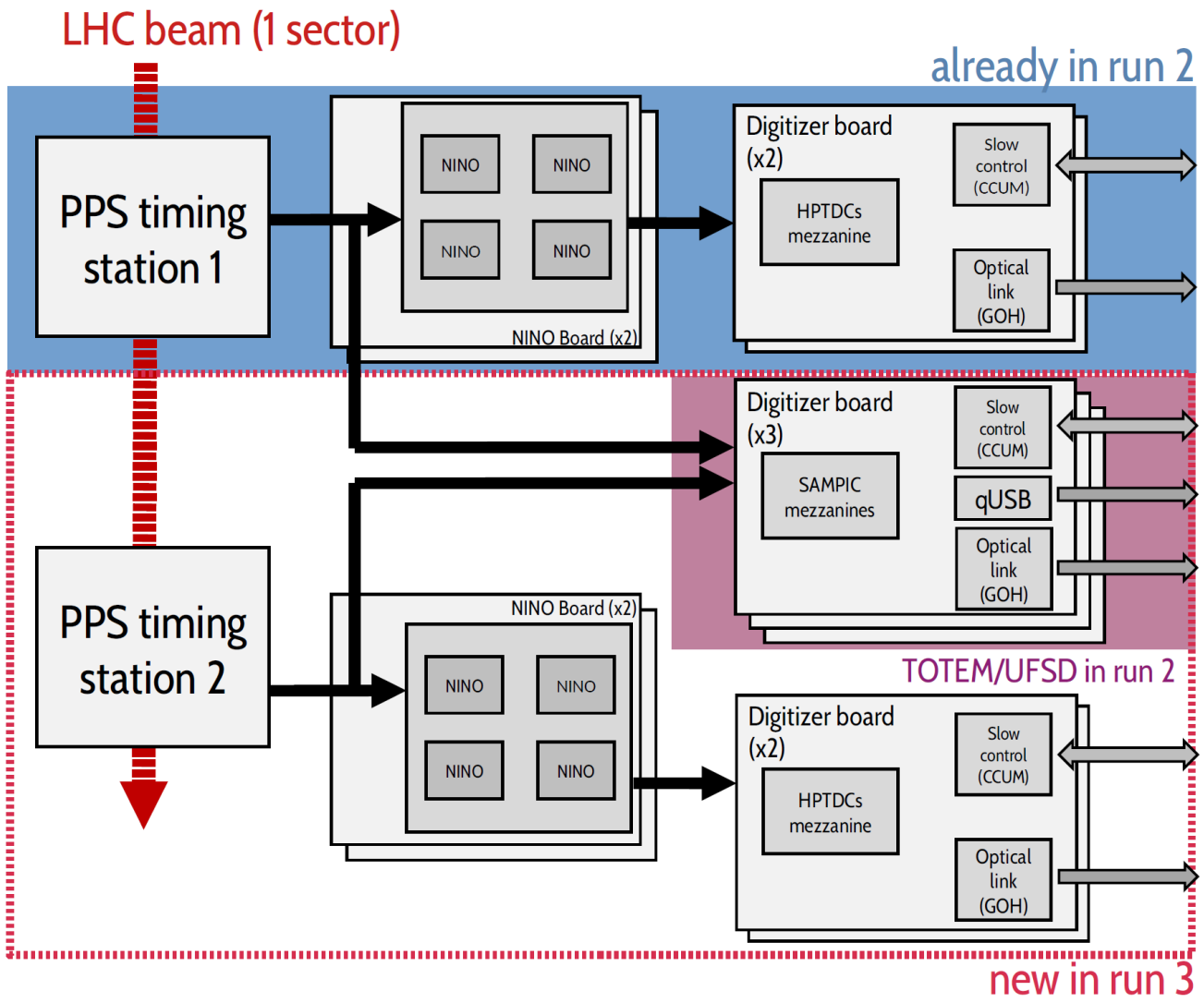


Special run successfully performed in 6 intense days (2-7 July 2018):

- SAMPIC readout worked without issues for the full period.
- Integration in CMS (DAQ, control, DQM) completed
- Very good quality of the collected waveform

Will be used in Run3 for PPS timing sensors for commissioning and sensor monitoring (cannot sustain hit rate at nominal LHC luminosity).

SAMPIC in PPS



- Improvement of calibration quality
- Fast feedback from settings modification
- Monitor of sensor performance (disentangled from digitization stages)
- Parallel readout -> No impact on regular data acquisition

Will operate during luminosity rump fills or on a programmable sub-set of bunches during full luminosity fills

Conclusions

- TOTEM will perform pp cross section measurements at 14 TeV during LHC Run3
- RP beamline relocation and levelling done, will be followed by laser metrology in January 2020.
- New T2 forward telescope has been approved. Many parallel activities ongoing (and on schedule): mechanics, electronics and detectors.
- SAMPIC readout, developed by TOTEM for the 2018 special Run, will be used un Run3 as a parallel readout system to monitor and calibrate the timing detectors of PPS.