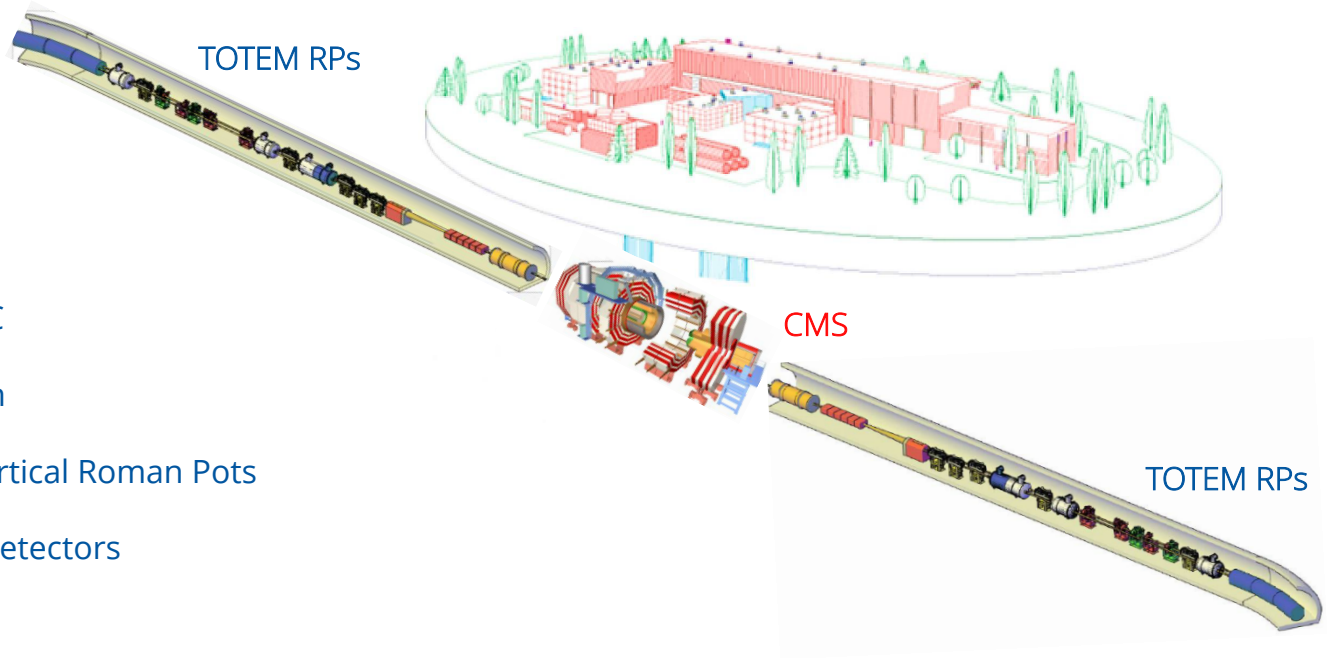
Totem Timing detector: SAMPIC and UFSD at the LHC

Nicola Minafra on behalf of the TOTEM Collaboration

WORKSHOP ON PICO-SECOND TIMING DETECTORS
FOR PHYSICS AND APPLICATIONS

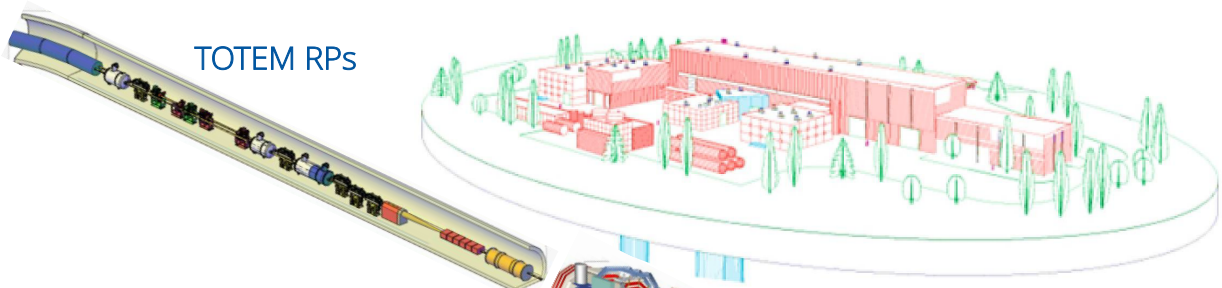
16-18 May 2018 Torino

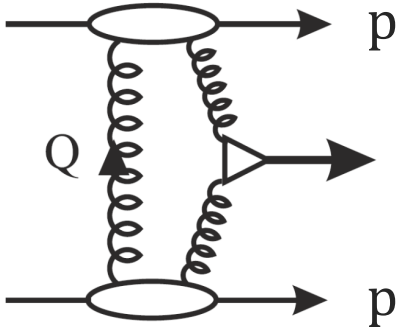
The TOTEM Experiment at the LHC



- Central Diffraction at LHC
- Totem Roman Pot system
- Timing detector in the vertical Roman Pots
    - Ultra Fast Silicon Detectors
    - SAMPIC
- Commissioning: LHC preliminary results

Central Diffraction at LHC





$p_1(\xi_1)$

X

CMS

Central system

$p_2(\xi_2)$

Leading proton detected by TOTEM

TOTEM

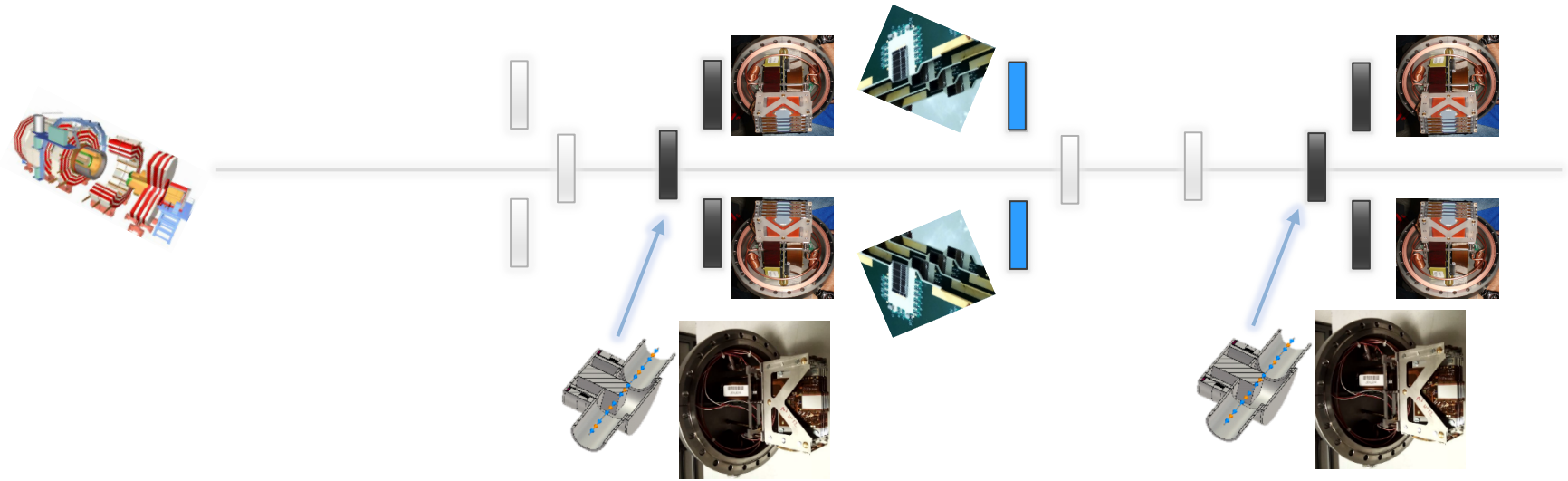
The TOTEM Roman Pot system

High β^* runs

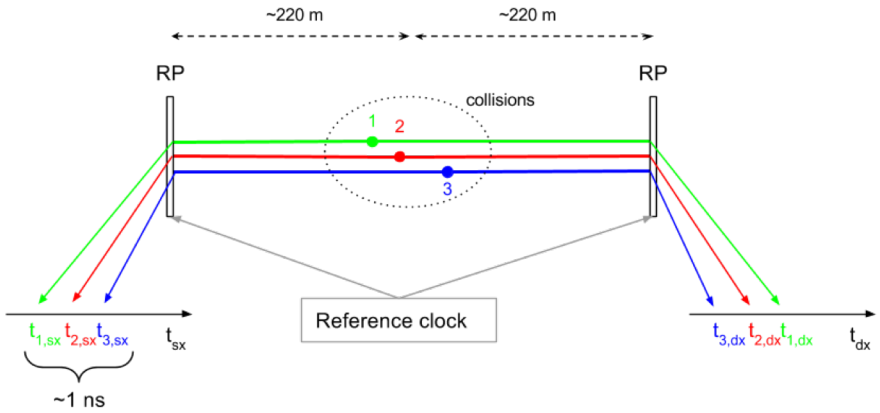
Expected after TS1 (July)

- 6 Vertical RPs
  - 4 Tracking (strip)
  - 2 Timing (UFSD)
- 2 Horizontal RPs (only alignment)
  - Tracking (pixel)

PER ARM

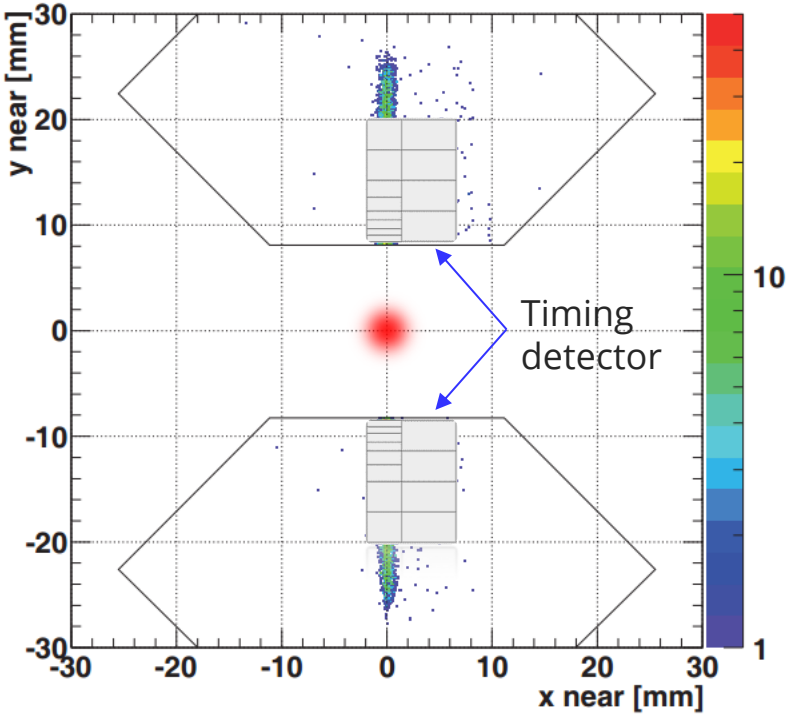


The TOTEM Timing Detector



To associate the detected protons to the correct vertex, when there are multiple interactions per bunch crossing (pile-up) it is possible to measure the time difference between the arrival instants.

With a time resolution of 50 ps ($|Z_{CMS} - Z_{RP}| < 2$ cm) the impurity of the selected events equal to 5% (instead of 22% without the timing information).



$\sqrt{s} = 7\ TeV$, $\beta^* = 90$ m

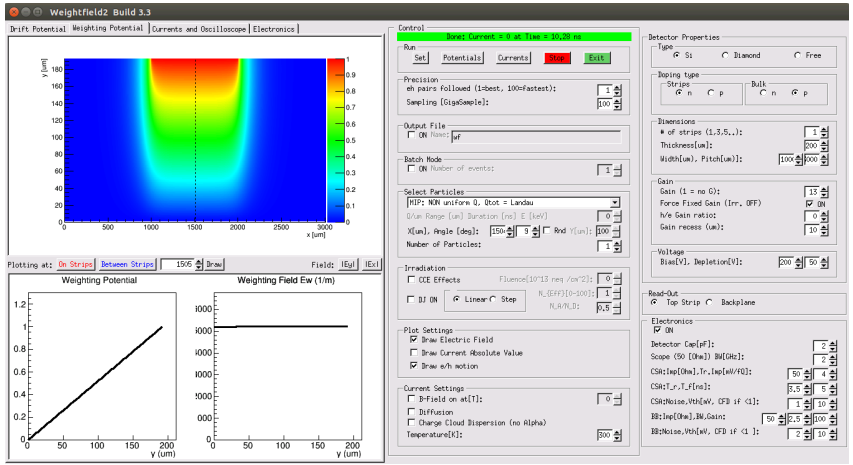
Ultra Fast Silicon Detectors (LGADs)

Ultra Fast Silicon Detectors (UFSD) are Low Gain Avalanche Detectors optimized for timing measurements employing a thin multiplication layer to increase the output signal at the passage of a particle of a factor ~10.

The signal generated at the passage of a MIP by a 50 μm UfSD can be simulated using Weightfield2*.

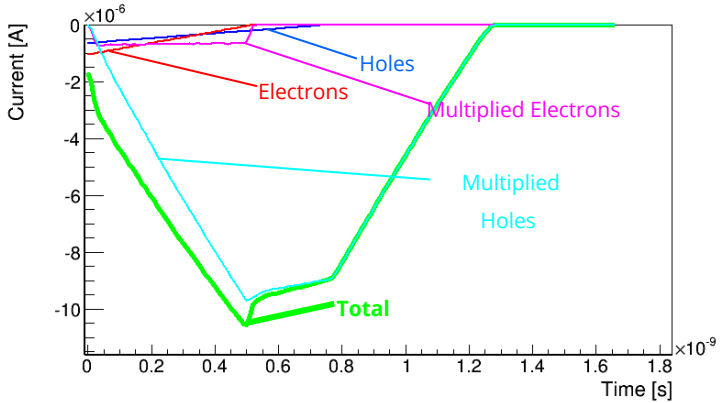
arXiv:1608.08681

Timing capabilities of Ultra-Fast Silicon Detector



The signal is "amplified" by a gain layer inside the sensor itself, but the leading edge is slower and depends on the charge that is collected by the gain layer

Time precision: as good as **30 ps**...

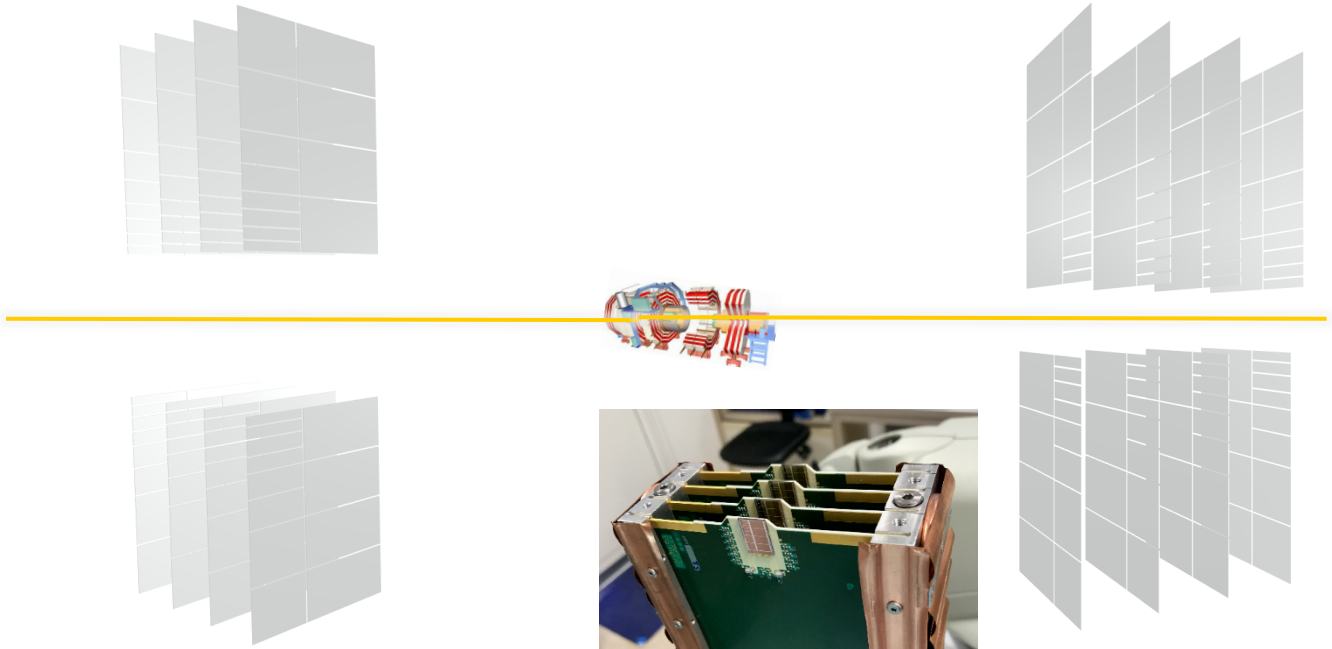


50 μm UfSD at 200V with a gain 15

*: http://personalpages.to.infn.it/~cartigli/Weightfield2/Main.html

Geometry of the detectors

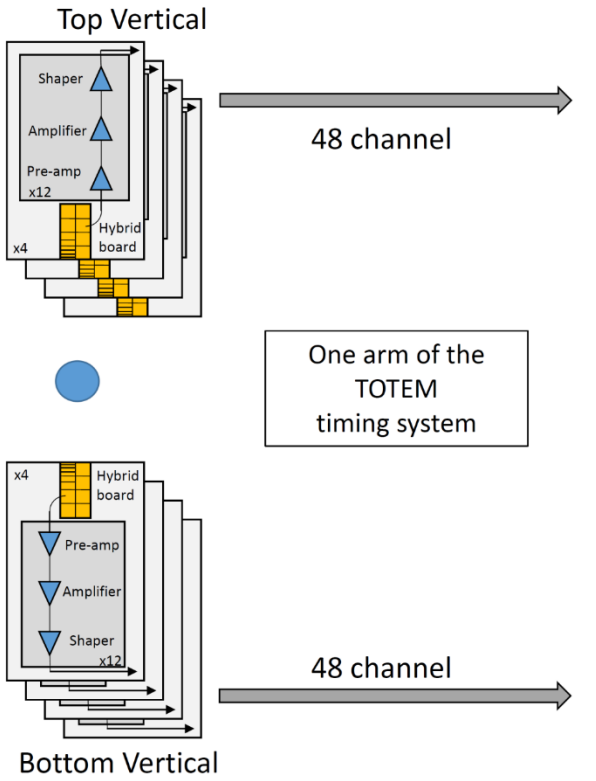
Ch 7: 3.5 x 3.1 mm^2	Ch 8: 5.5 x 3.1 mm^2
Ch 6: 3.5 x 3.1 mm^2	Ch 9: 5.5 x 3.1 mm^2
Ch 5: 3.5 x 1.7 mm^2	Ch 10: 5.5 x 3.1 mm^2
Ch 4: 3.5 x 1.4 mm^2	
Ch 3: 3.5 x 0.9 mm^2	Ch 11: 5.5 x 3.1 mm^2
Ch 2: 3.5 x 0.9 mm^2	
Ch 1: 3.5 x 0.7 mm^2	
Ch 0: 3.5 x 0.6 mm^2	

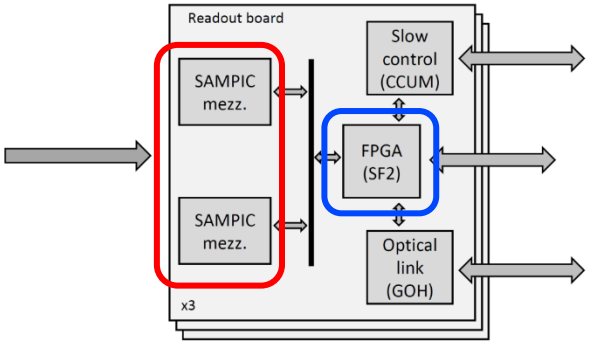


- 12 channels per plane
- 4 planes per package
- 2 packages per arm (top and bottom)

- Time precision better than 50 ps per plane

Read-out chain

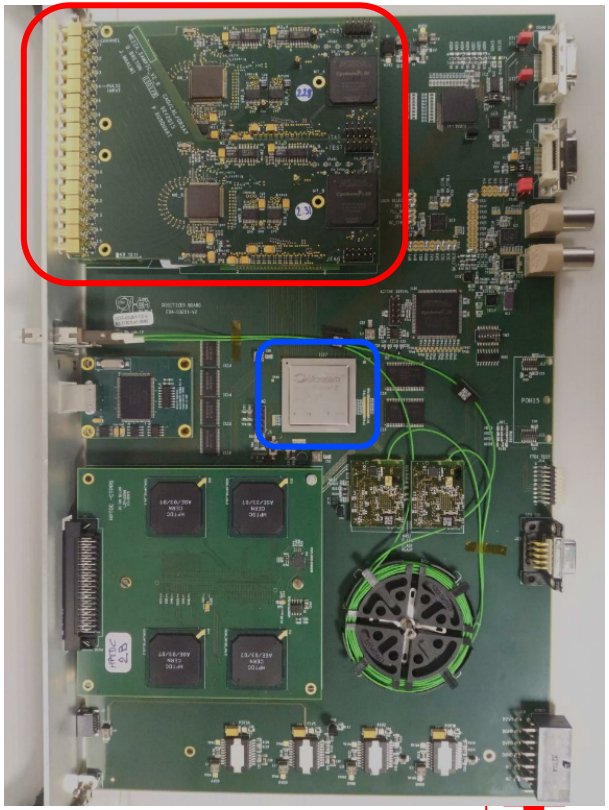




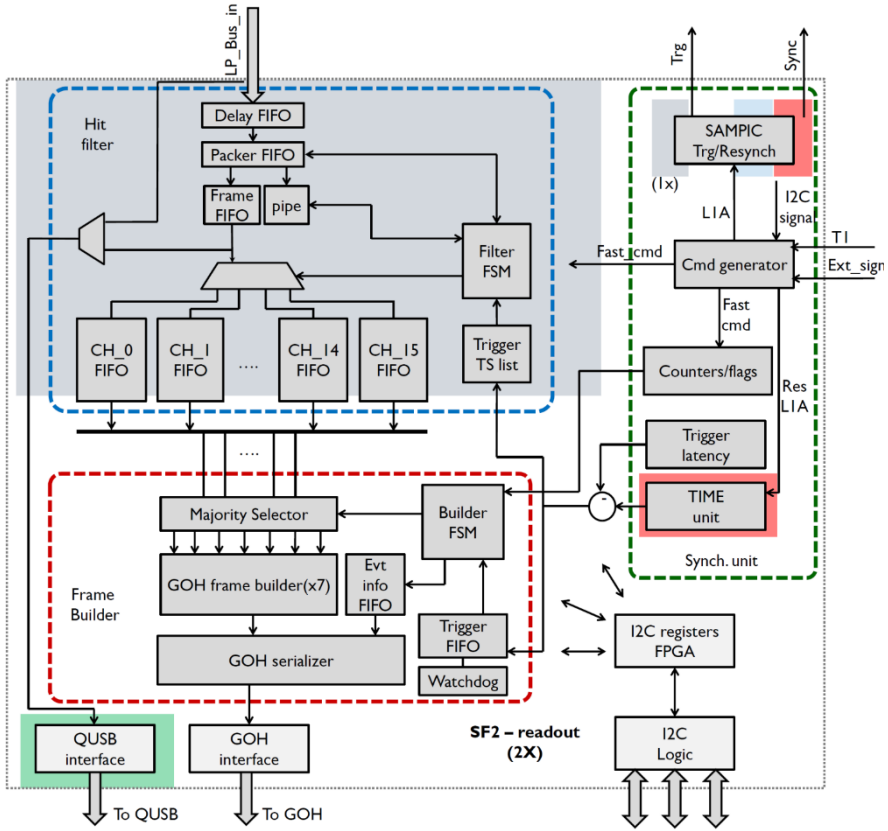
SAMPIC

- 16 channels/chip
- Up to 64 samples/hit @ 10 GSa/s
- 1.5 GHz bandwidth
- 8-11 bit resolution
- 0.2-1.6 μs channel dead time

Trigger matching and frame building done in the Digitizer Board



Frame Building in the FPGA

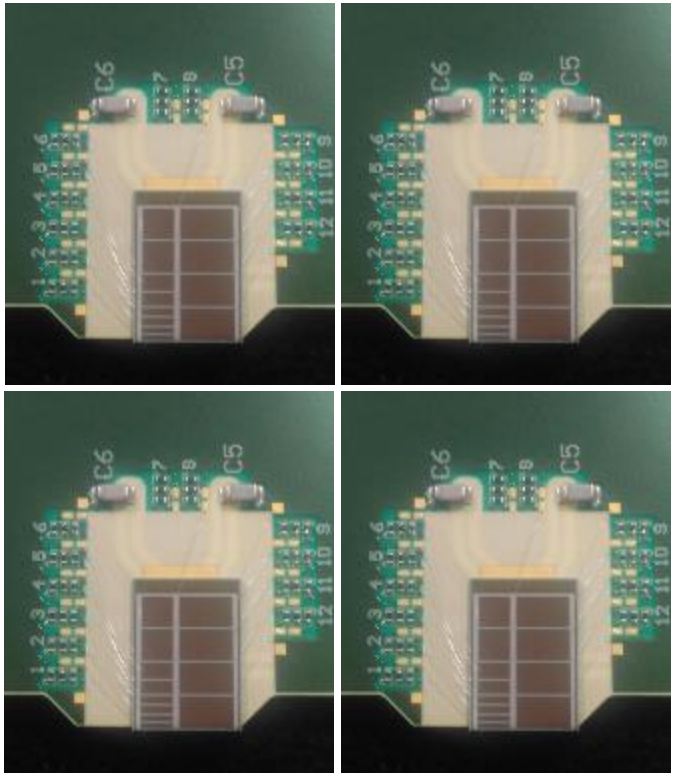


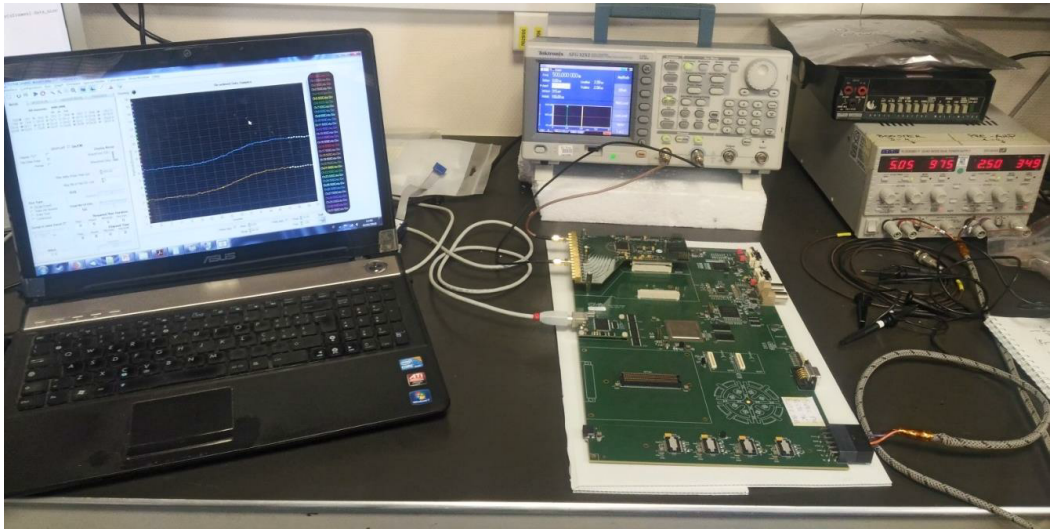
Frame Filtering:

- Delay of incoming frames
- Check frame integrity (header, trailer, …)
- Timestamp reconstruction and matching with trigger list
- Event rejected or send to channel FIFO
- USB readout available

- Trigger latency ~ 6 us
- 1 Frame for each trigger
- Max frame size ~ 350 B
- Trigger rate up to 100kHz

Test in the lab



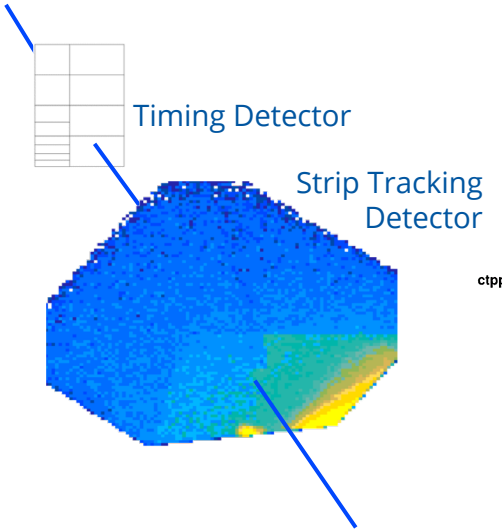


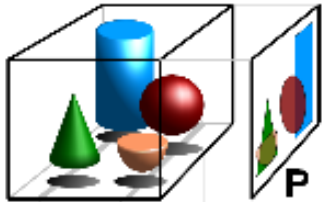
UFSDs were tested (IV, noise, Sr90, …)

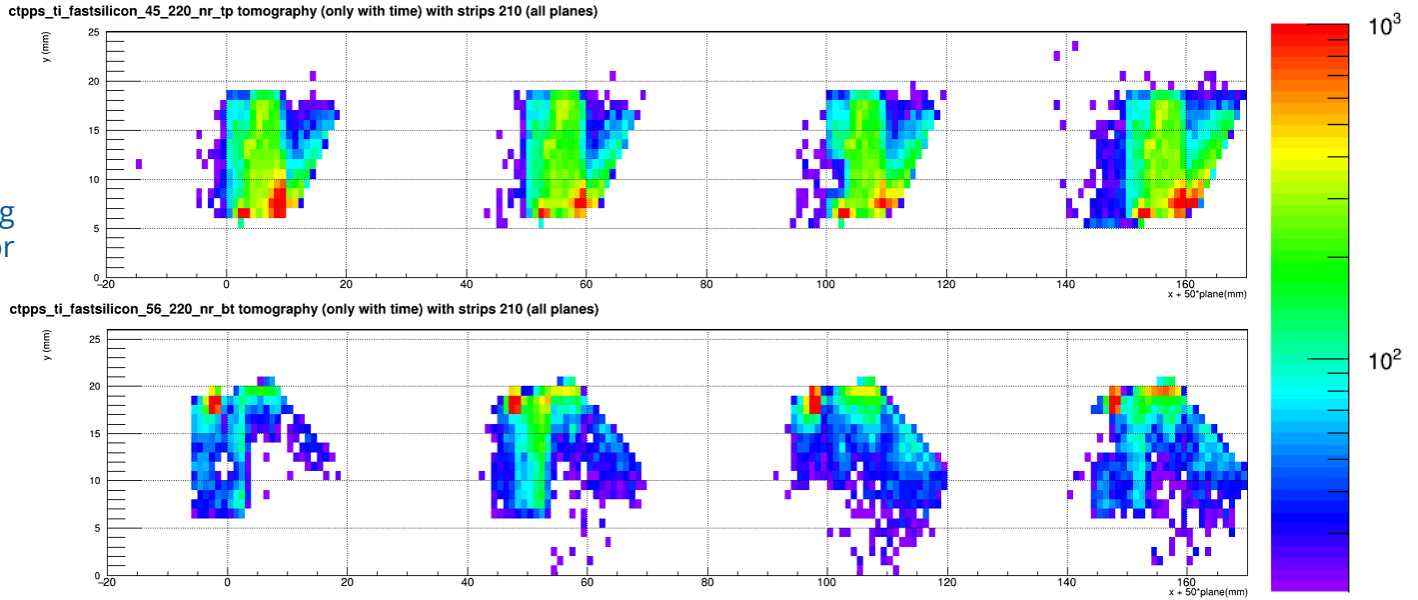
SAMPIC and firmware were tested in the lab thanks to the possibility to configure and read the Digitizer Board using USB.

Preliminary results from LHC tests

Tomography



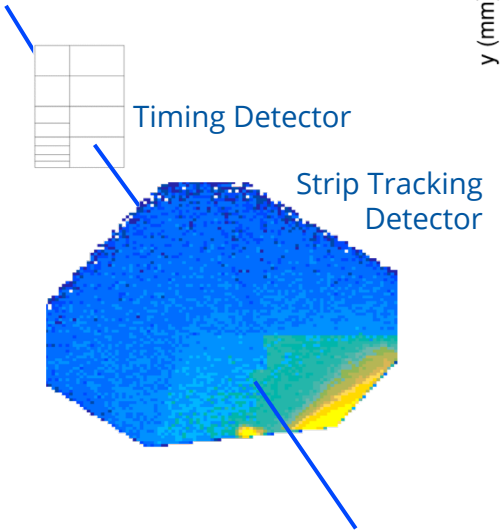


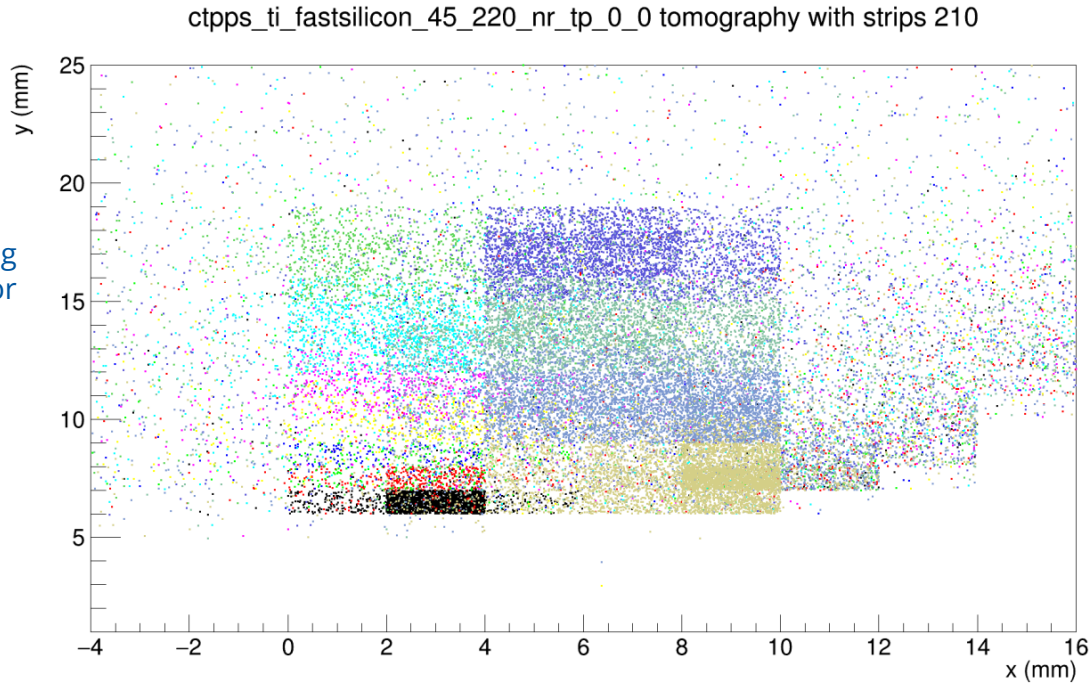


Tomography is imaging by sections or sectioning, through the use of any kind of penetrating wave.
en.wikipedia.org/wiki/Tomography

Preliminary results from LHC tests

Tomography





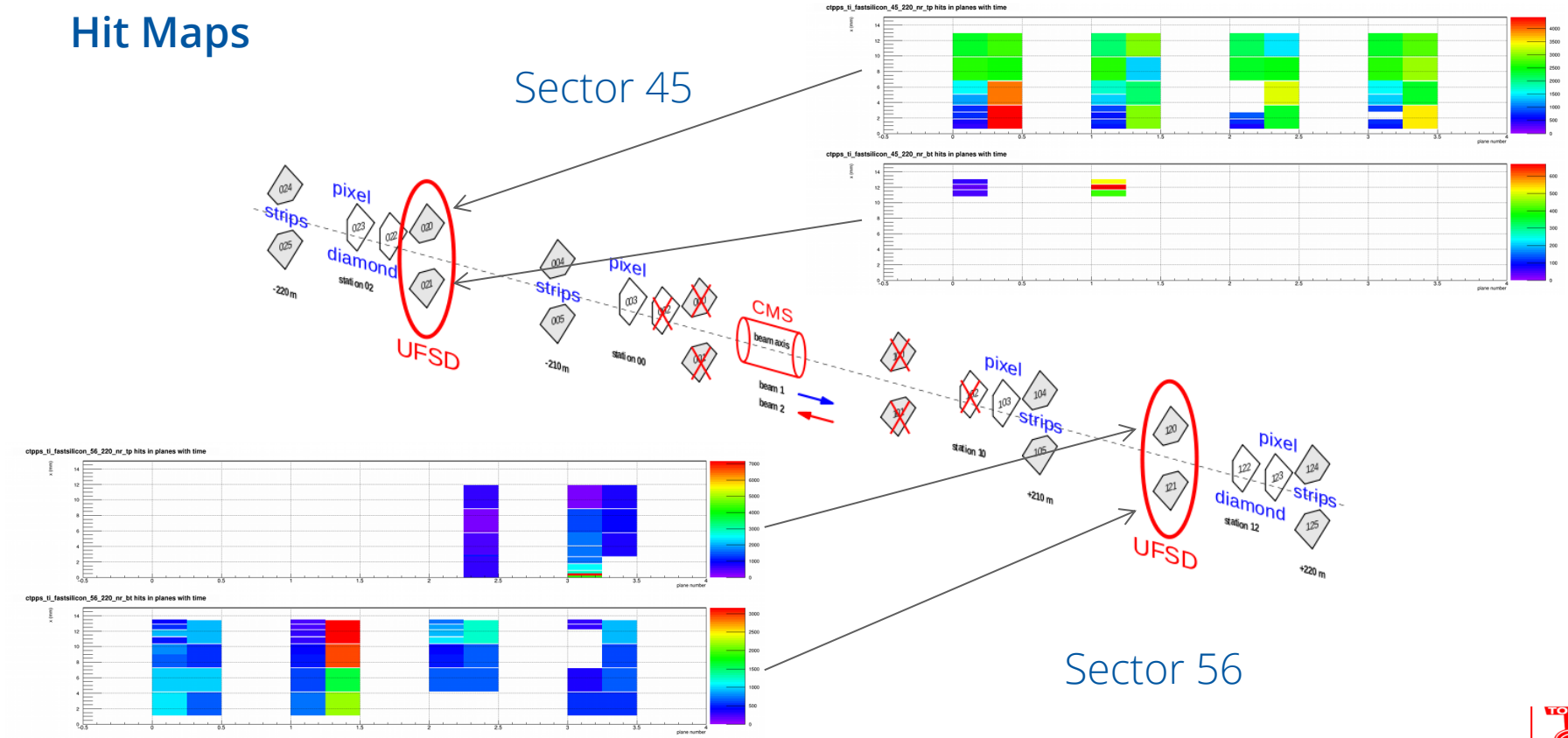
Ch 7 Ch 8
Ch 6 Ch 9
Ch 5 Ch 10
Ch 4
Ch 3
Ch 2 Ch 11
Ch 1
Ch 0

Very low statistics....

... just enough to double check the mapping!

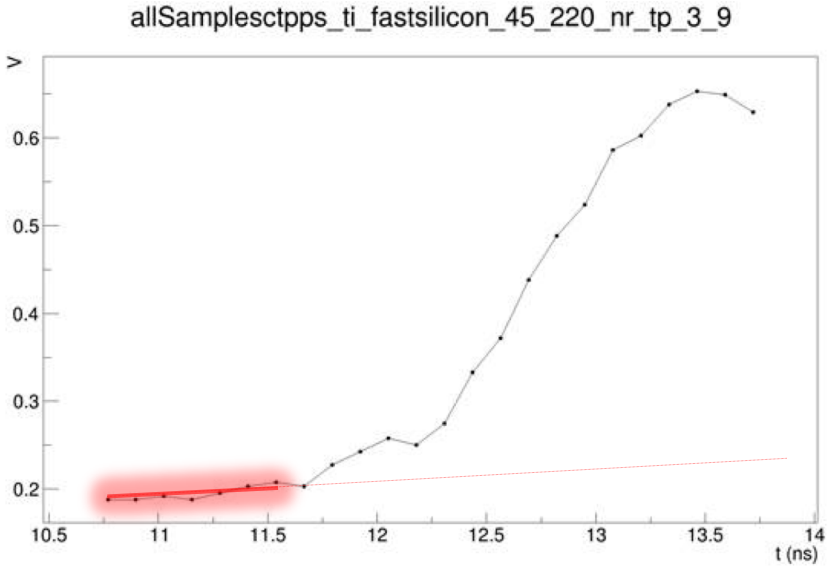
Preliminary results from LHC tests

Hit Maps



Only 2/3 of channels connected!

Time of Arrival measurement



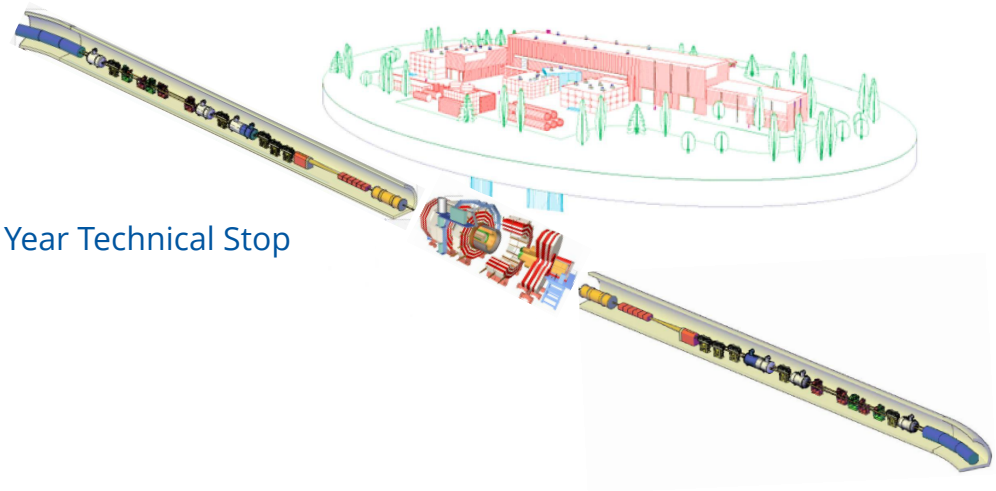
- Baseline: linear fit on the first baselinePoints
- Baseline is subtracted

- If max < saturationLimit
- Smoothing: sinc convolution using (smoothingPoints points) low pass filter with frequency lowPassFrequency
- Constant Fraction Discriminator, using cfdFraction and hysteresis

ADC and INL calibrations to be done…

Other algorithms tested, better performance with CFD

Conclusions



- Detector packages installed and tested during End of Year Technical Stop
- 2/3 of channels connected to the CMS DAQ
- Detector hardware tested and installed in the RPs
- Firmware developed and tested
- Software developed and included in CMS official framework
- Optimization and characterization in progress....

... physics coming with dedicated run at end of June...

... stay tuned!

totem.web.cern.ch