Totem Experiment
Status Report

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(on behalf of the TOTEM collaboration)

135st LHCC open session

Outline

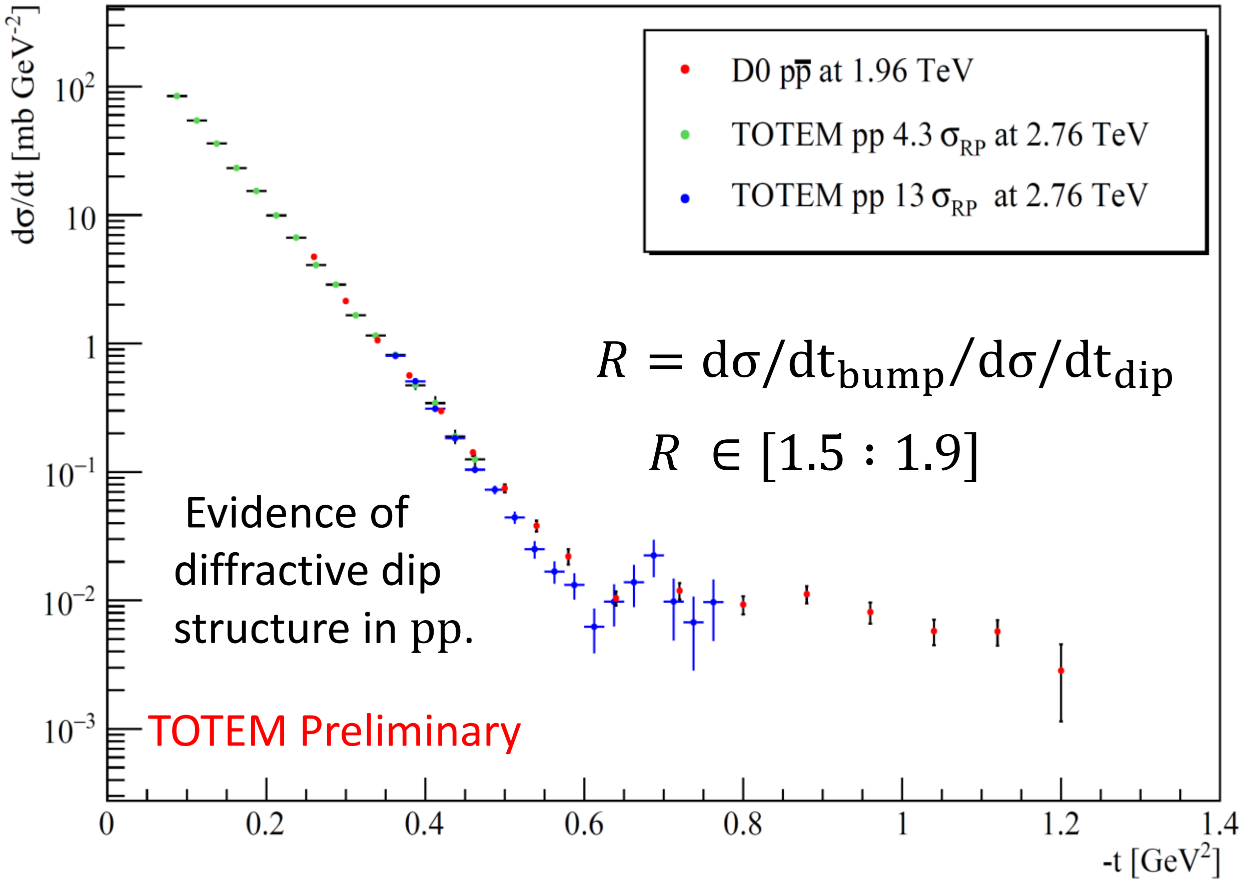
Analysis updates:
- 2.76 TeV differential cross section
- 13 TeV σ_{tot} and ρ

Special run (13 TeV, β^{*}= 90 m, 2018) :
- physics goals
- commissioning and operation
- trigger strategy
- preliminary performance of the forward detectors

900 GeV run

2.76 TeV analysis

Elastic differential cross-section: pp @ 2.76 TeV and p$\bar{p}$ @ 1.96 TeV



Durham model *(PLB 784 (2018) 192)* predictions for R:

Model/collision type	No-Odderon pp & p$\bar{p}$	Odderon pp	Odderon p$\bar{p}$
$\sqrt{s}$ = 1.96 TeV	1.42	1.78	1.20
$\sqrt{s}$ = 2.76 TeV	1.47	1.82	1.25

Odderon pp model by Nicolescu predicts (preliminary) R ~ 1.5 @ 2.76 TeV [arXiv:1808.08580v1]

Physics goal is to probe differences of pp and p$\bar{p}$ differential cross section at the TeV energy scale .

Joint working group with D0 collaboration.

Given the preliminary central value by TOTEM at 2.76 TeV (R ~ 1.7 for pp) and the recent Levy expansion results by [arXiv:1807.02897] at 1.96 TeV (R ~ 1.0 for p$\bar{p}$), the data clearly disfavour the Pomeron-only predictions and favour the predictions with the Odderon. Additional parameters/variables/observables characterizing the dip/bump region are going to emphasize the difference between pp and p$\bar{p}$ even more significantly (excluding the predictions by the Pomeron-only model).

13 TeV analysis

Reminder: The TOTEM σ_{tot} and ρ @ 13 TeV more compatible with Odderon models than no-Odderon ones.

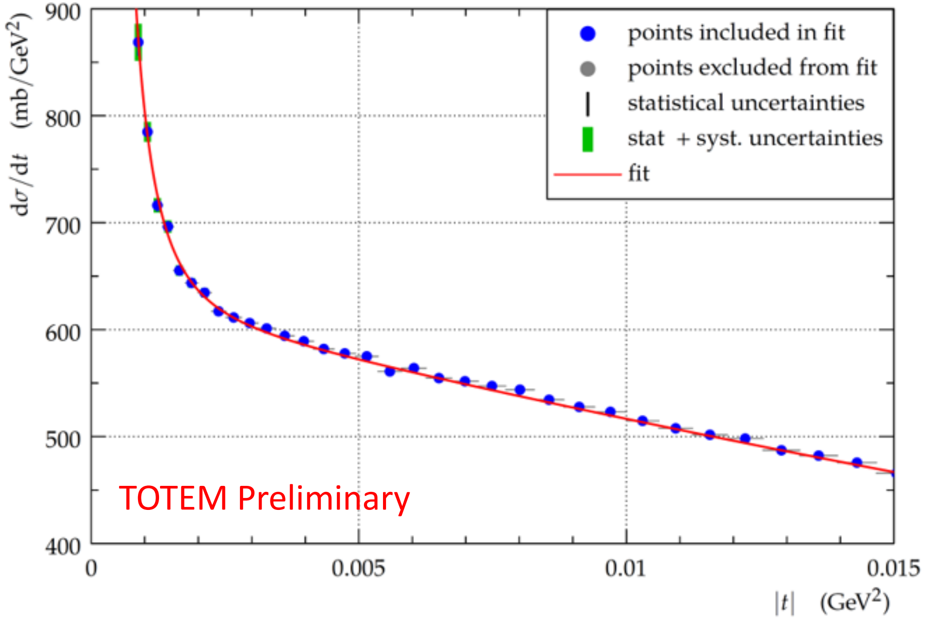
Analysis goal: compute σ_{tot} and ρ from β^*= 2.5 km data using QED normalization method to verify the results of luminosity independent method [CERN-EP-2017-321, CERN-EP-2017-335].

Three approaches (all using Coulomb-nuclear interference):

1. normalization fixed using β^*= 90m data from lumi-independent method.
2. partial QED normalization with a χ^2 term corresponding to the lumi-independent result .
3. full QED normalization.

Preliminary uncertainties

	ρ	σ_{tot} (mb)
CERN-EP-2017-321	—	110.6 ± 3.4
CERN-EP-2017-335	0.09 ± 0.01	—
approach 1: norm. fixed	0.09 ± 0.01	111.8 ± 3.0
approach 2: norm. constrained	0.09 ± 0.01	111.3 ± 3.0
approach 3: norm. free	0.09 ± 0.01	108.3 ± 4.0



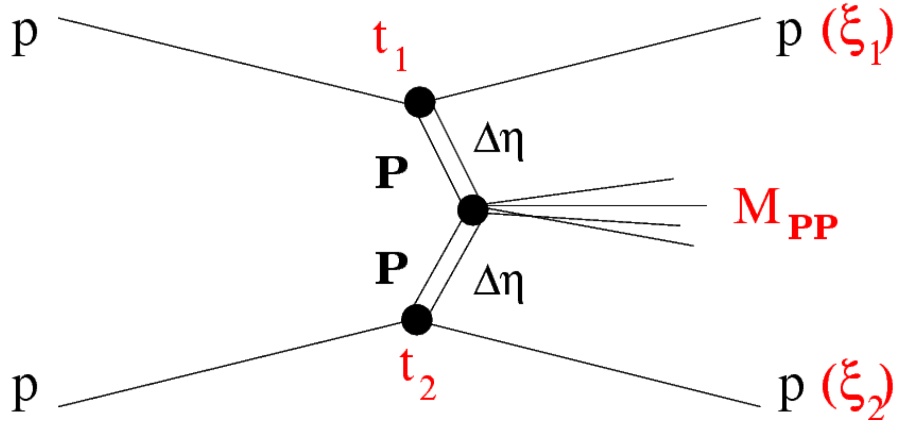
All σ_{tot} and ρ results consistent within uncertainties.

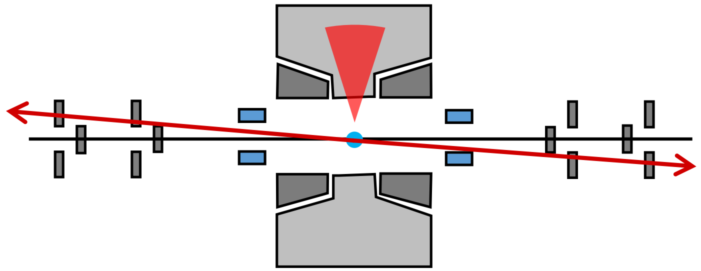
σ_{tot} results 110.6 ± 3.4 mb and 108.3 ± 4.0 mb obtained with fully independent methods and disjoint data sets: should be averaged and should lead to smaller uncertainty (~ 109.5 ± 2.5 mb) .

Special β^*= 90 m run

Main physics goal:

- Studies of glueball candidates
- Low mass spectroscopy ($\pi\pi$, KK, $\rho\rho$):
  - Spin
  - Decay modes
  - Branching ratios





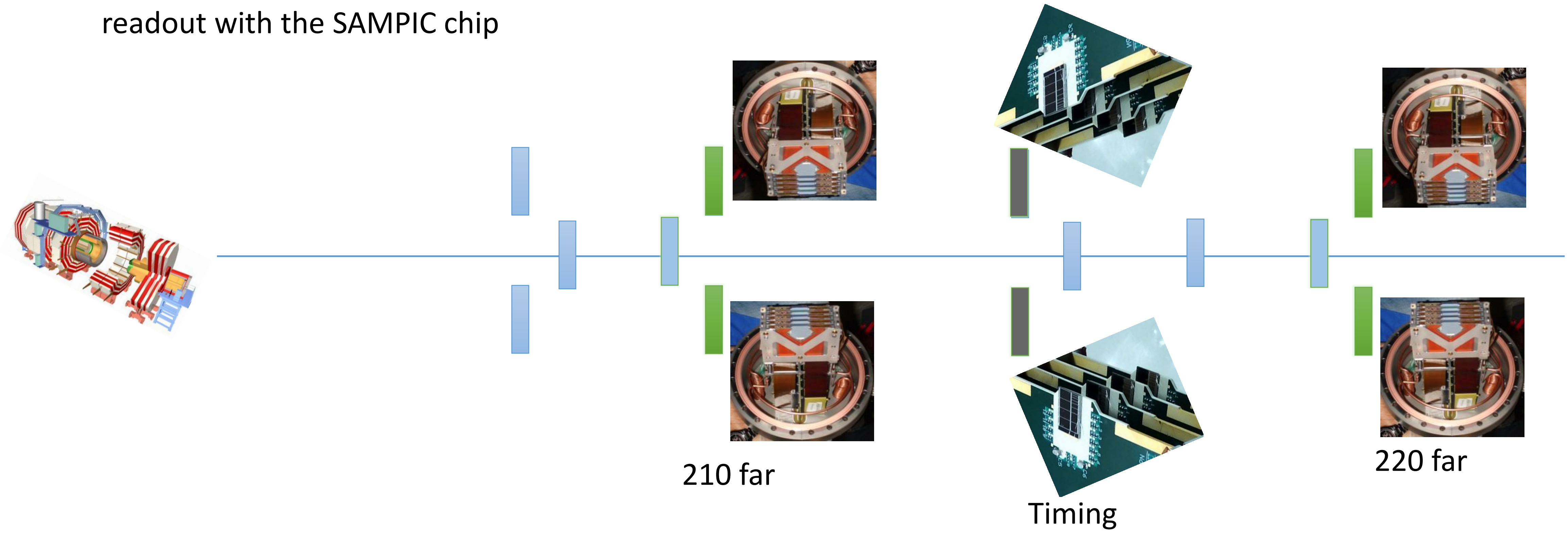
Comparison/prediction from forward (TOTEM) to central (CMS) system: M_{PP}, $p_{T,z}$, longitudinal vertex coordinate, …

CMS-TOTEM collected ~0.4 pb^{-1} of low-PU (μ=0.06-0.13) data at 13 TeV in 2015
Need to increase the statistics

Forward detector layout

On each arm:

- 4 tracking RP equipped with TOTEM strip detectors (210 and 220 m from the IP)
- 2 timing RP equipped with UFSD and readout with the SAMPIC chip



Commissioning and operation

Timing system commissioning:

- Installation of new UFSD timing detectors and readout electronics (YETS1, completed during TS1)
- DAQ integration (ready in April 2018)
- Commissioning of UFSD during the low-beta alignment run and LHC rump-up fills (RP inserted and low radiation damage to the sensors)

Trigger commissioning (CMS and TOTEM):

- New TOTEM trigger with «antielastic» trigger (more later)
- CMS Special menu based on TOTEM RP triggers (L1) and track selections in central Pixel (HLT)

Reconstruction:

- Special track reconstruction in central tracker
- Timing Detector reconstruction

<u>90 m operations</u>

Alignment on June 24:

- All systems validated.
- Detector and trigger fine tuning performed.

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

- All machine luminosity rump-up step completed
- All detectors and systems worked as expected

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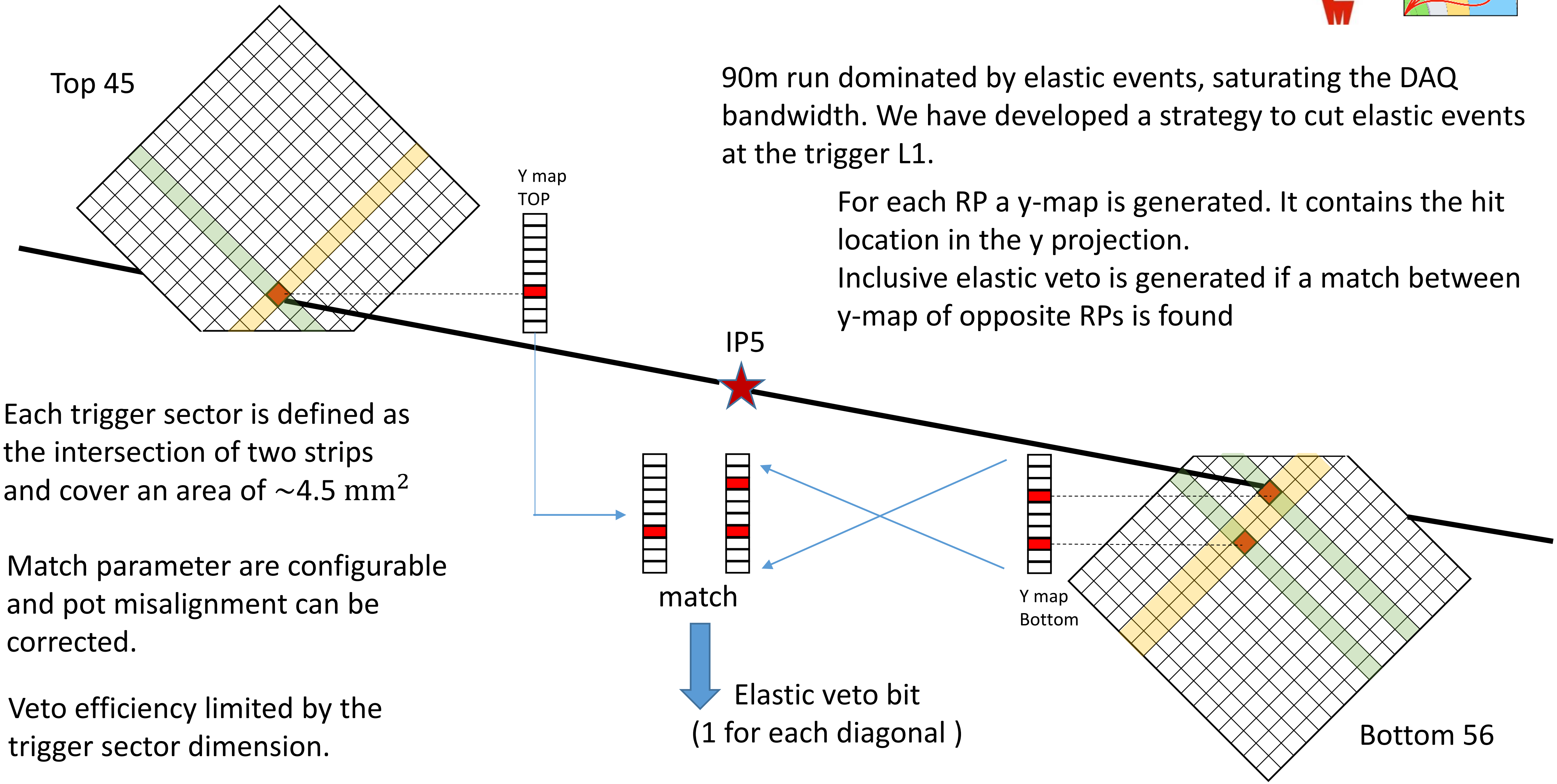
Recorded luminosity $\sim 5.6\ \mathrm{pb}^{-1}$.
10 times the 2015 statistics!!

L1 trigger: elastic veto

90m run dominated by elastic events, saturating the DAQ bandwidth. We have developed a strategy to cut elastic events at the trigger L1.

For each RP a y-map is generated. It contains the hit location in the y projection.
Inclusive elastic veto is generated if a match between y-map of opposite RPs is found



Each trigger sector is defined as the intersection of two strips and cover an area of $\sim 4.5\ \mathrm{mm}^2$

Match parameter are configurable and pot misalignment can be corrected.

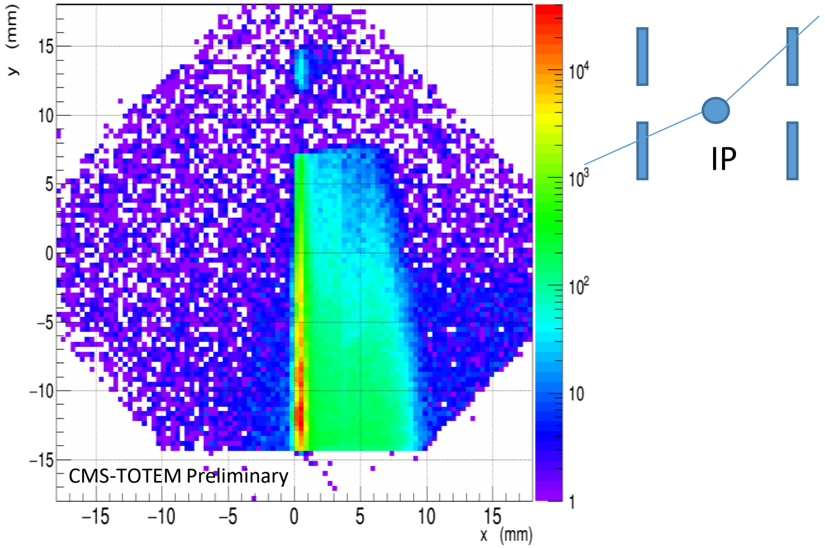
Veto efficiency limited by the trigger sector dimension.

Trigger selection

Data have been divided in 4 data streams based on different trigger selection:

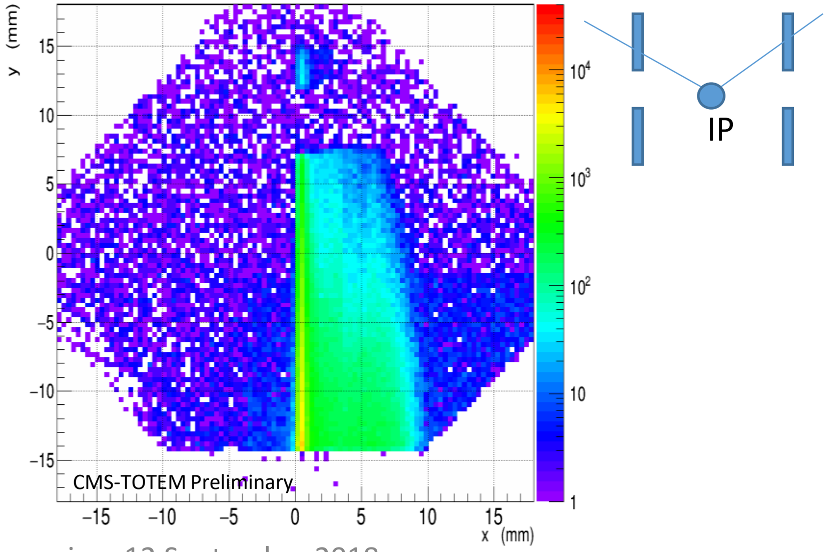
- Inclusive double arm (control sample)
- Exclusive diagonal non-elastic
- Exclusive Top-Top/Bottom-Bottom
- Elastic (control sample)

Exclusive diagonal non-elastic



Reduction of elastic scattering ~50%

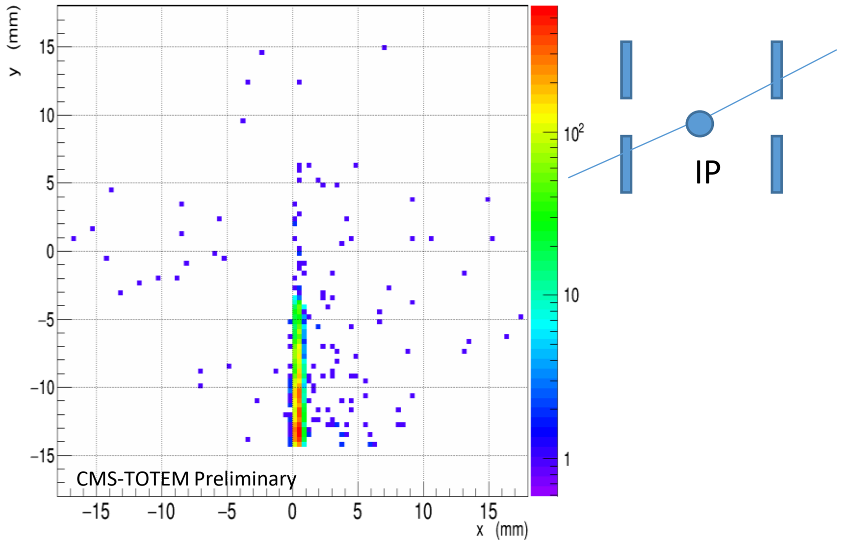
ExclusiveTop-Top/Bottom-Bottom



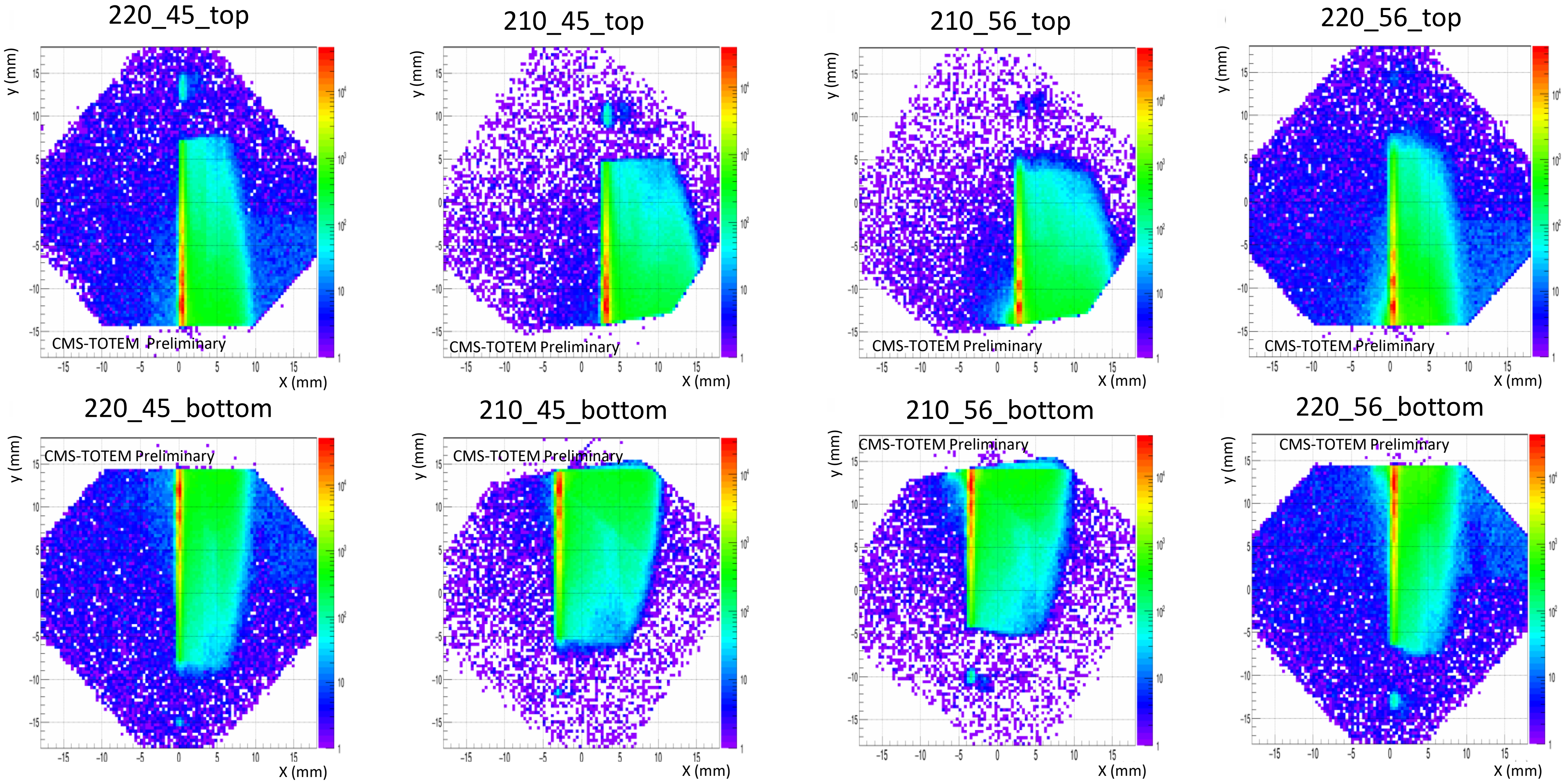
Adding exclusivity cut and requiring low track multiplicity we further reduced the overall rate of a factor ~5

Very clean data sample!

Elastic (control sample)



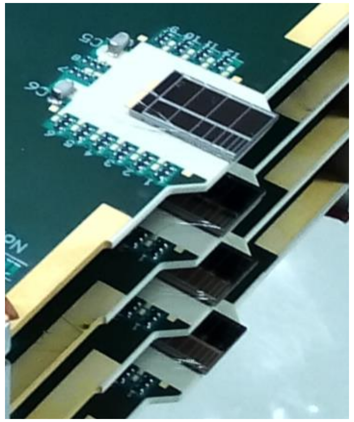
Strip hit maps

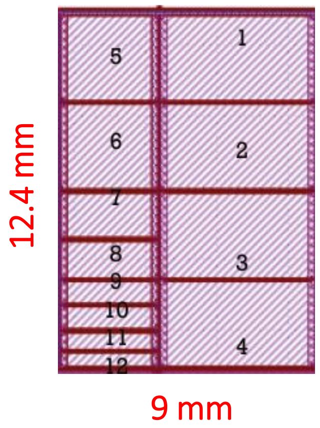


The RP located at 210m are tilted by 8°. Data from DQM, no offline RP alignment

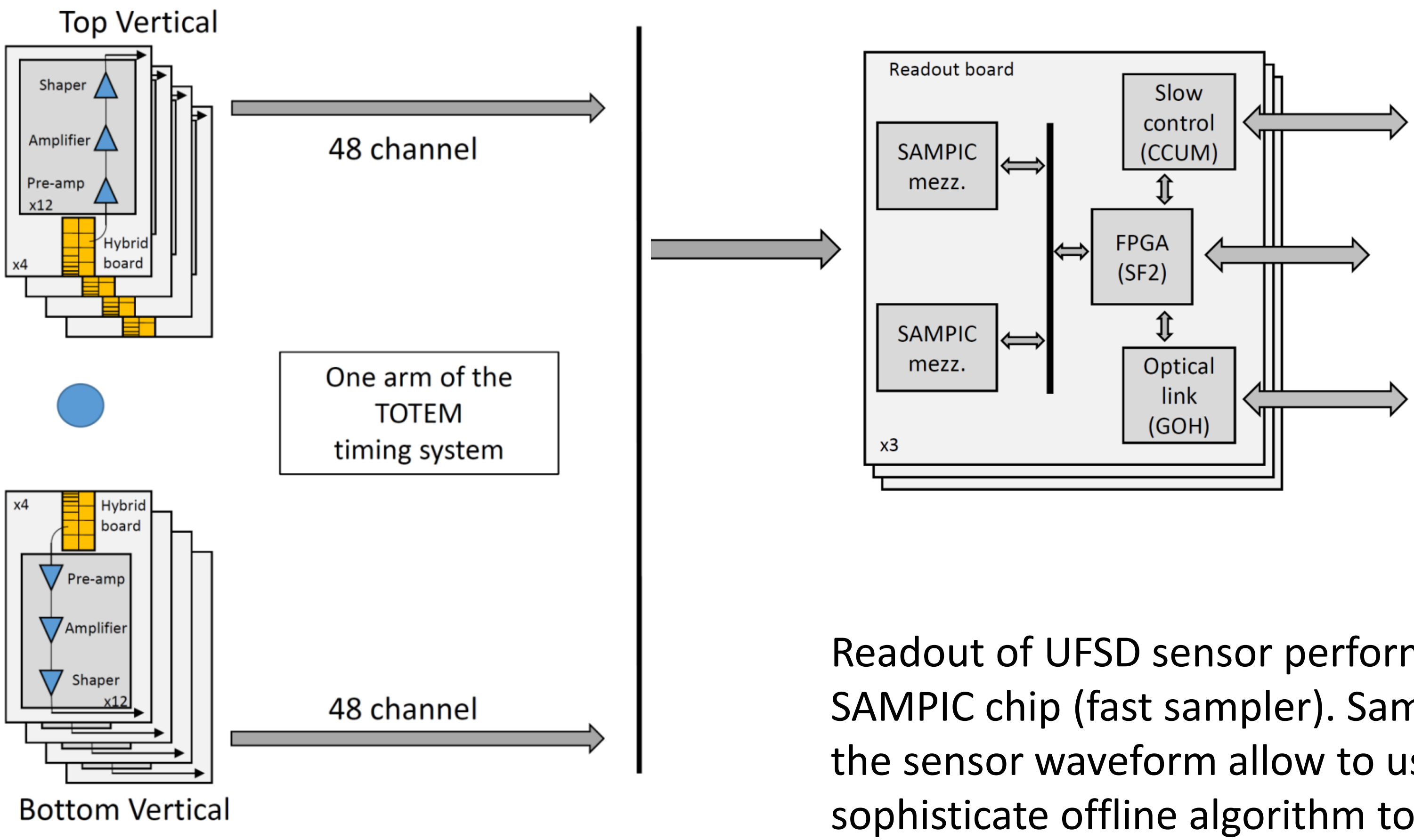
Hits displaced on the right side represent proton with significant momentum loss ξ.

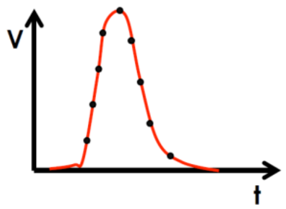
Vertical timing system





Each UFSD sensor is divided in 12 channels, with optimized geometry.



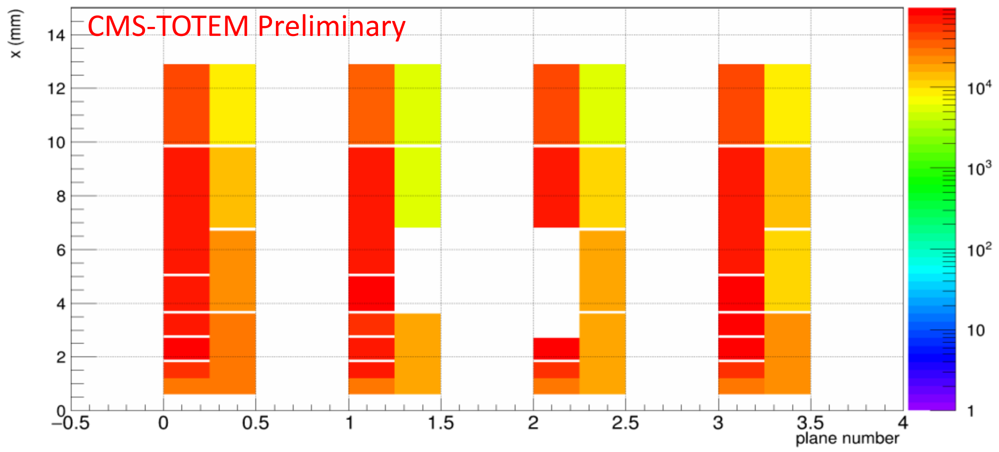


Each vertical timing RP hosts four timing sensors

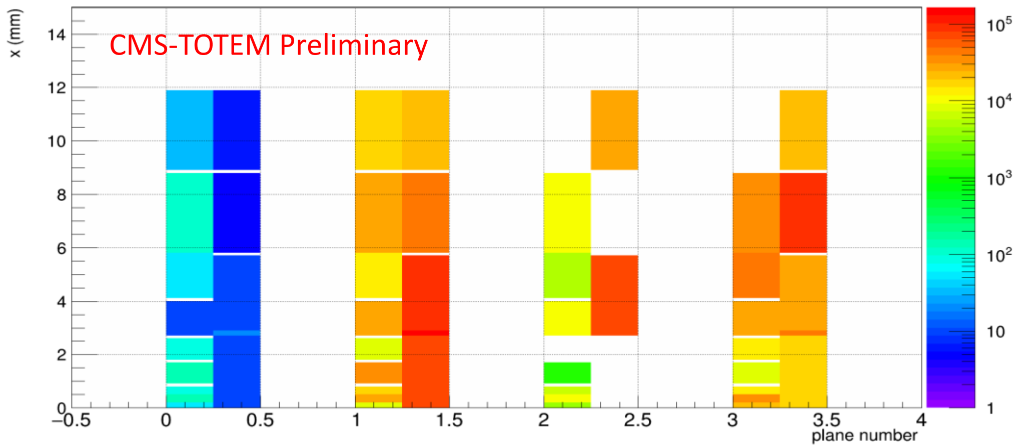
Readout of UFSD sensor performed by the SAMPIC chip (fast sampler). Sampling of the sensor waveform allow to use sophisticate offline algorithm to calibrate and reconstruct the proton time of arrival.

Sensor hit map

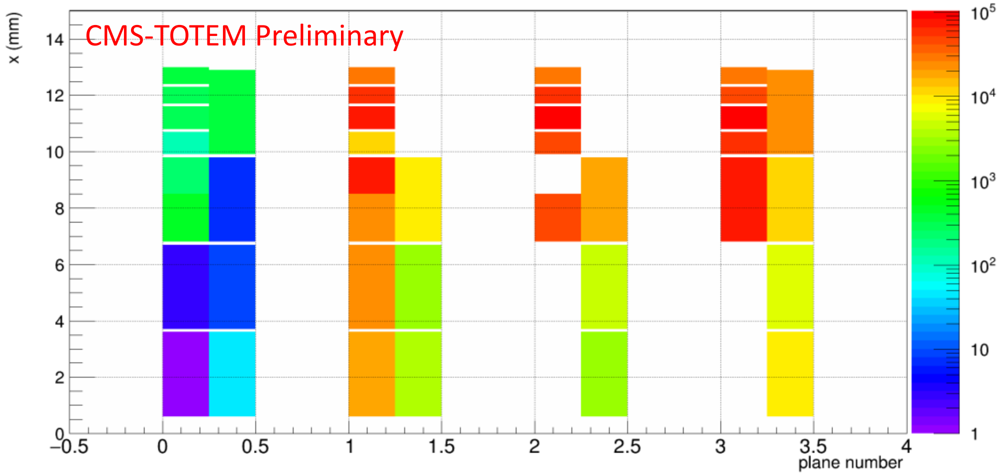
Timing RP 45 Top



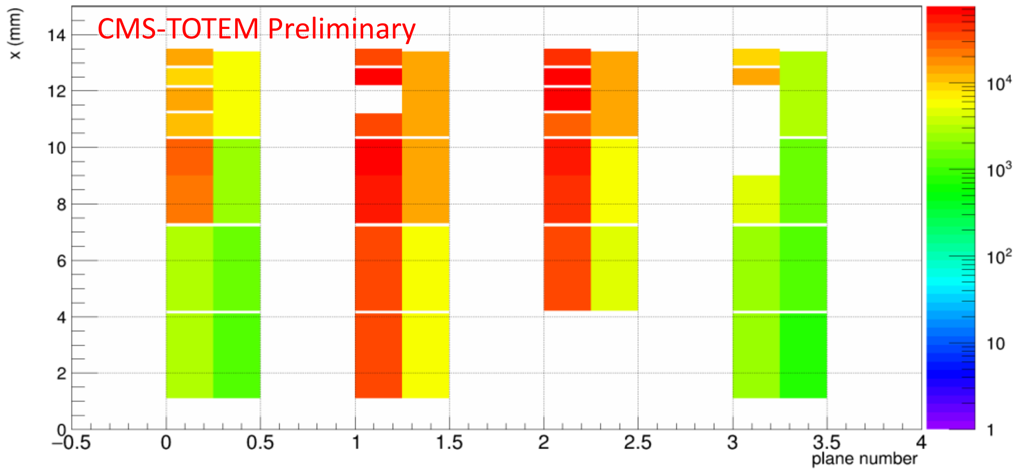
Timing RP 56 Top



Timing RP 45 Bottom

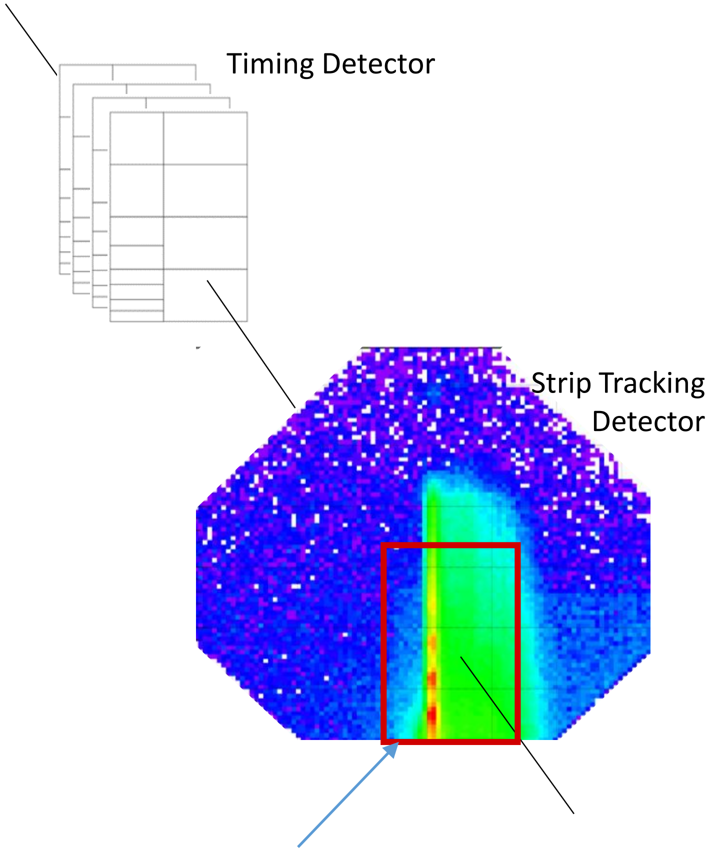


Timing RP 56 Bottom



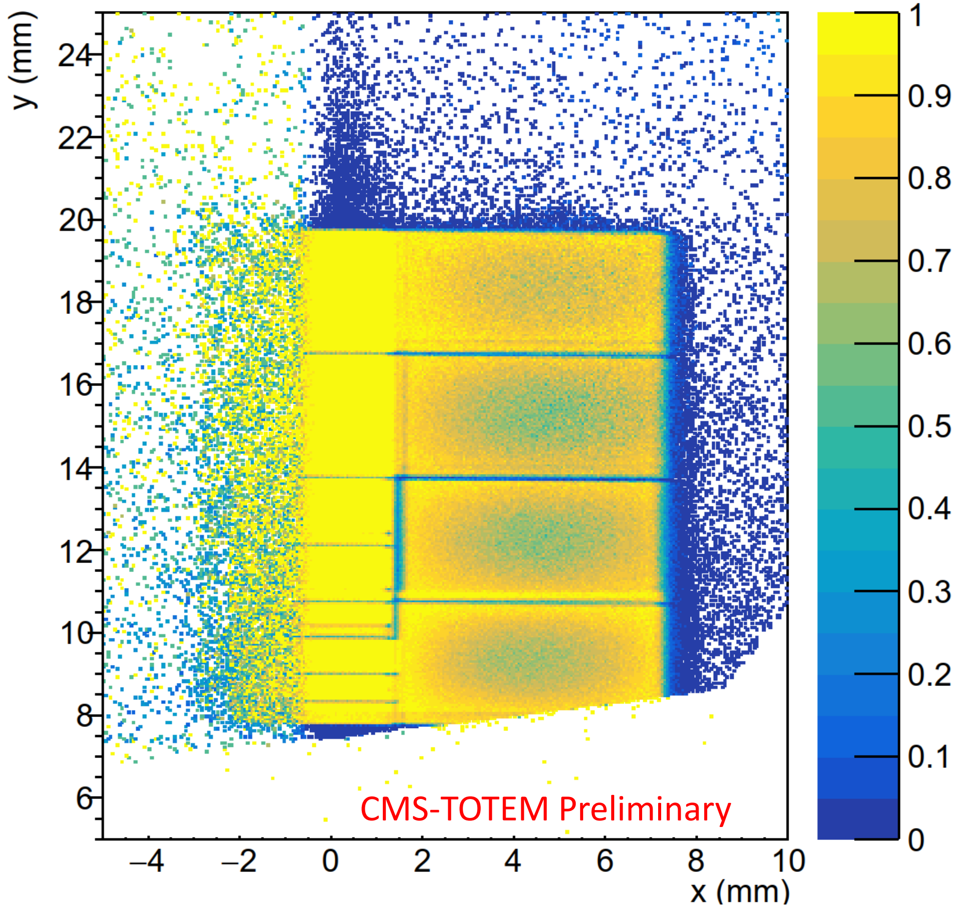
Data collected during the special run (1452 bunch fill)

Detector efficiency



Projection of the area covered by the UFSD sensors

Efficiency map 45 Top



Sample selected by requiring one track in the tracking RP and extrapolating its impact point in the timing detector.

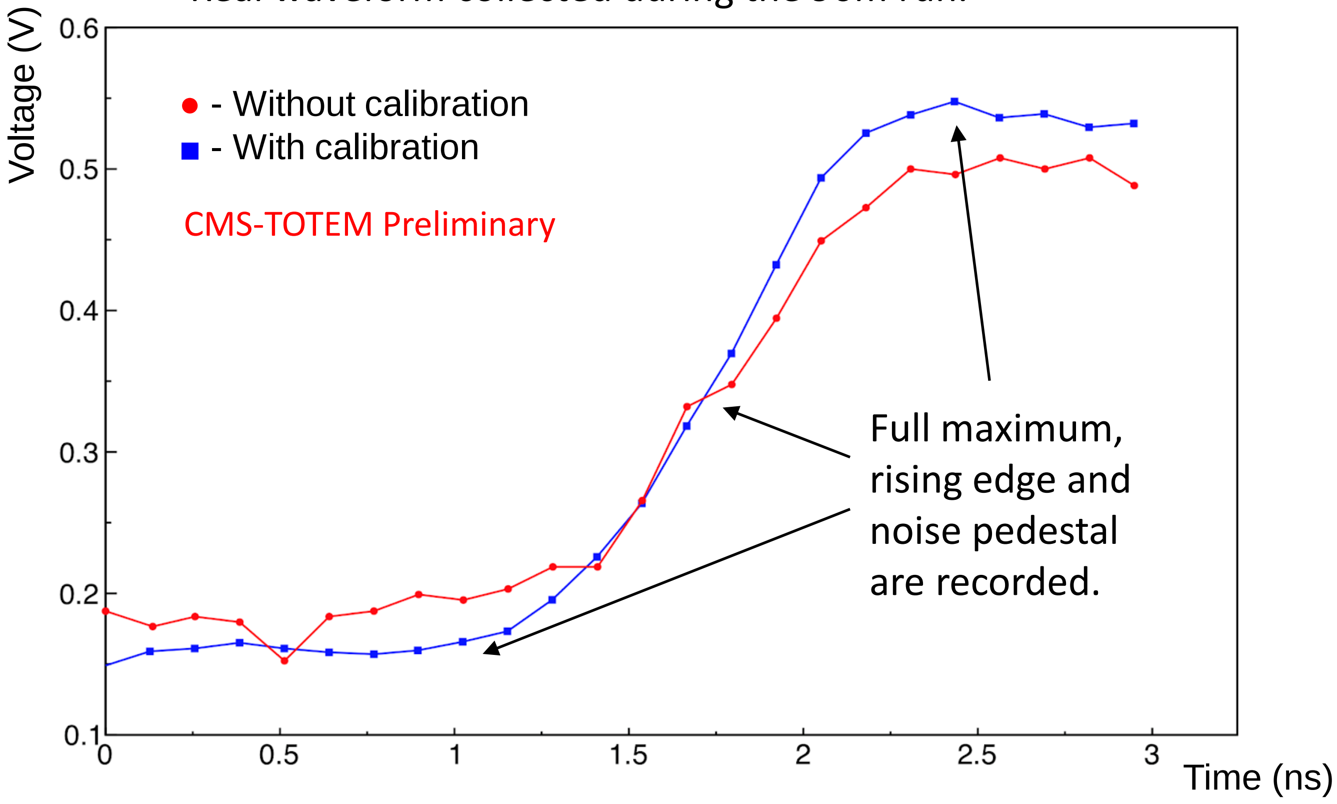
Detector is considered efficient if there is a timing track in the region pointed by the tracker.

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)

Very good quality of the collected waveform.

Real waveform collected during the 90m run.



To center all waveforms in the acquisition windows fine latency tuning is needed:

- ✓ Detector coarse latency adjusted with a precision of ~ 8.3 ns.
- ✓ SAMPIC fine latencies adjusted with a precision of ~ 300 ps.

Calibration of the waveforms is ongoing. A different calibration curve to applied not only to each channel, but also for each sample.

Chip calibrations performed before installation, will be repeated after TS2 for cross-check. The calibration will greatly improve the final time resolution

900 GeV run

Three test campaigns performed within November 2017 and May 2018:

- optics commissioning very successful.
- time from fill dump to data taking with new fill within 20 minutes (no ramp, no de-squeeze).
- high backgrounds.

Despite the high background TOTEM would be able to perform the foreseen measurement: possibility to reach t_{min}~$7\text{x}10^{-4}\ \text{GeV}^2$, a new record of penetration in the CNI region.

Machine effort to improve collimation scheme ongoing. New tests foreseen soon.
TOTEM readiness for a 900 GeV run in 2018.

Conclusions

Analysis of the 2.76 TeV data shows evidence of diffractive dip structure in pp.
The R parameter is incompatible with the no-odderon models.

σ_{tot} and ρ obtained with 13 TeV (β^*= 2.5 km) data analysis, using QED normalization, are fully compatible with previous luminosity-independent TOTEM results, that favours Odderon models over no-Odderon models.

Special run (13 TeV, β^*= 90 m) took place in July:

- 10 times the 2015 statistics collected.
- very clean sample of data .
- all detectors and subsystem performed well.
- preliminary results show good quality of the acquired data.

We would like to thank the machine and the CMS experiment for the great support provided during the preparation and the conduct of the special run.

TOTEM readiness for 900 GeV run in 2018.