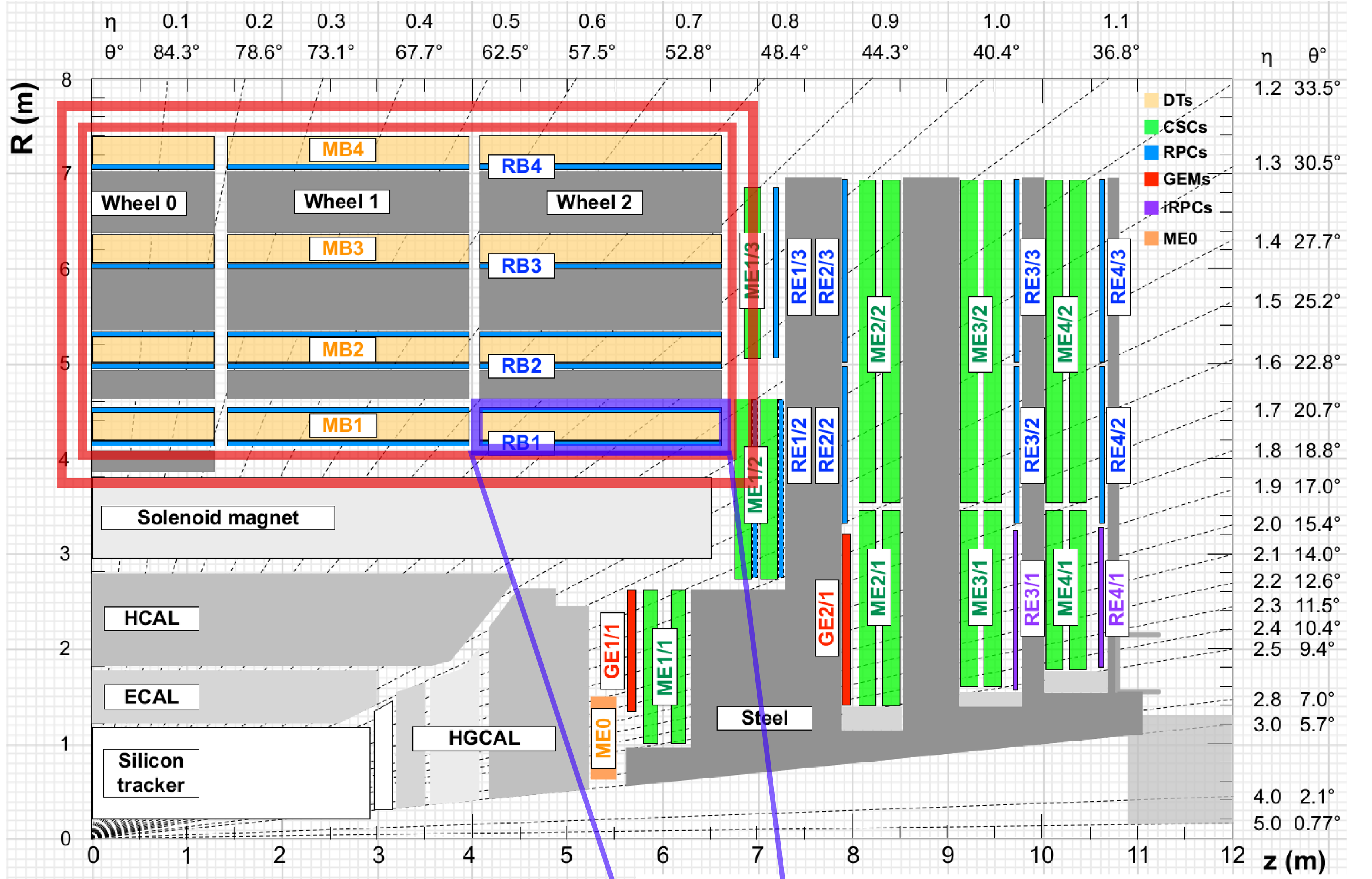
# A muon tracking algorithm for Level 1 trigger in the CMS barrel muon chambers during HL-LHC

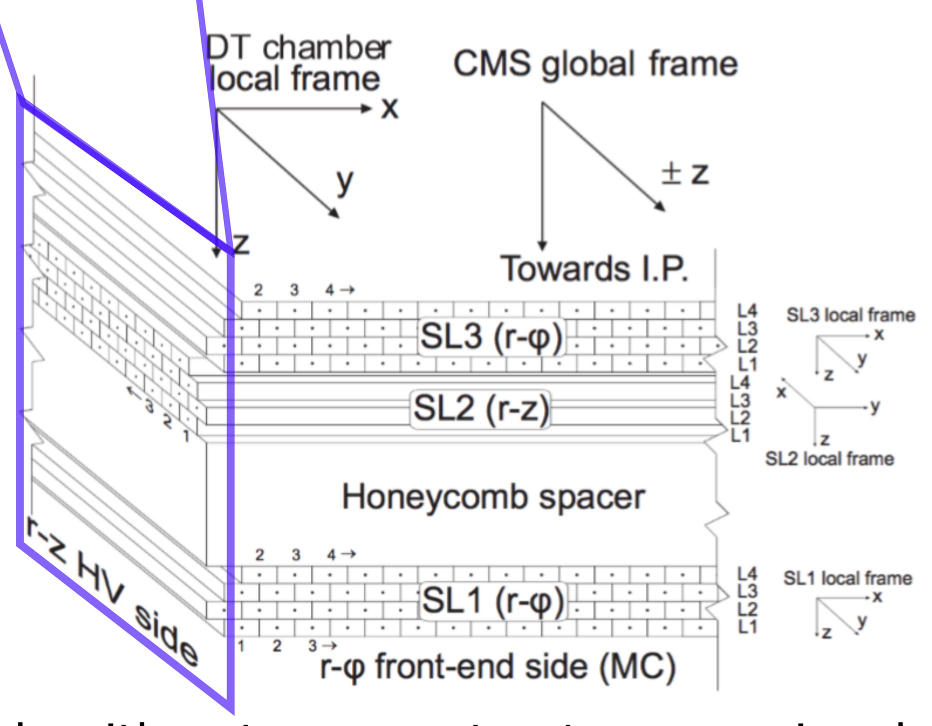
Víctor Rodríguez Bouza and Carlos Francisco Erice Cid on behalf of the CMS Muon Group
partially funded by the Ministerio de Universidades de España (FPU grant)
and by the Ministerio de Ciencia e Innovación de España (FPI grant)

Universidad de Oviedo
Universidá d'Uviéu
University of Oviedo
ICTEA

## High Luminosity challenges in the DT chambers




The barrel muon system is key in the high quality identification of muons in the CMS detector. Composed of Drift Tubes (DTs) surrounded by 1 or 2 sets of Resistive Plate Chambers (RPCs).




Focusing on the DTs: multiple stations (MB), each one divided in 8 to 12 layers of tubes (cells) organized in 2 to 3 "Superlayers".

Our aim is to provide a robust algorithm to reconstruct muon signals inside a station at the L1 trigger level [0]. The running conditions of the HL-LHC (higher instantaneous luminosity) introduce several challenges:

- Higher cell occupancy (more muons).

- More radiation in the whole detector implies a possible introduction of detector degradation/ageing [1].

## The analytic approach at a glance

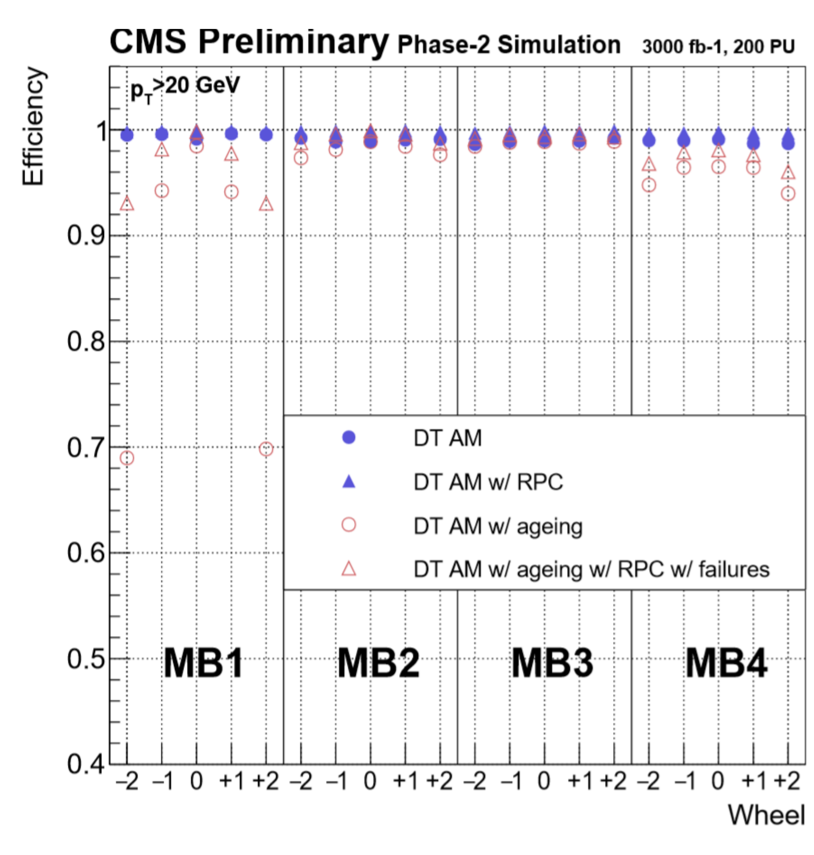
An analytic approach in 3 steps is introduced for the DT system:

1) **Grouping**: group together fired cells that are consistent with the passing of a muon through a single superlayer.
Each superlayer is examined thoroughly to look for hits that are closeby in adjacent layers, forming a compatible straight-line distribution.

2) **Fitting**: extract the (muon) track parameters from the groups obtained in the previous step :
-Bunch crossing: obtained from the mean measurement of timings inside each single fired cell in the group.
-Track parameters (position, slope): obtained with analytic formulae derived from a chi-square fit to an straight line.

3) **Correlation**: look for compatible measurements between different superlayers and recompute track parameters with the greater lever arm. Optionally, also correlate with RPC clusters and update time/position information accordingly.

## Performance projections into the HL-LHC




Triggering efficiencies computed on top of reconstructed segments with/without correlating with the RPC clusters and in different detector degradation cases.

Results show near perfect efficiency (>99%) for the "ideal" detector state.

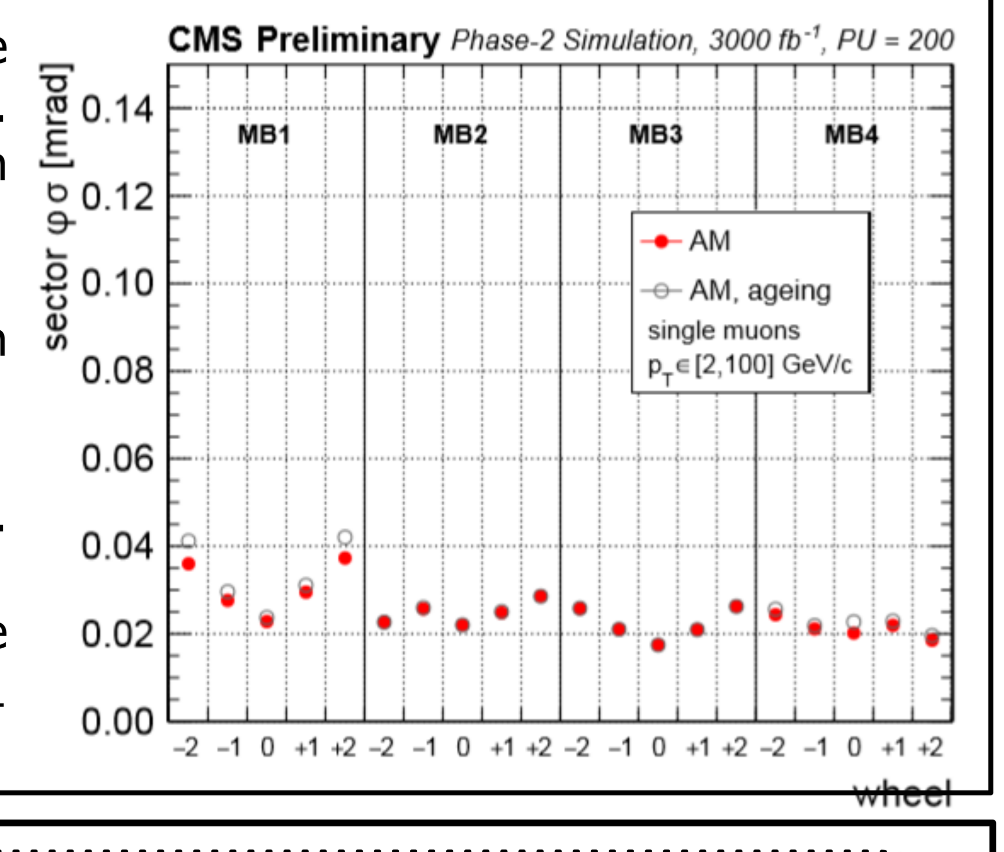
Including the RPC information into the correlation reduces the effect of DT ageing effects which are near negligible in most of the regions except for the first station (suffers the most radiation).

Spatial resolution estimated to be at the cents of miliradian level. Around ~6 times better than Run II algorithm resolution.

Performance kept even in high activity environments (PU~200).

Little effect from detector ageing.

Similarly good resolutions are obtained for the muon slope (~1 mrad) and time estimate (~2 ns).




## Possible future improvements

Current algorithm already close to *perfect* efficiency and providing very good resolution in the track parameters. Analytical formulae are incredibly robust for the spatial measurements. However it requires testing a high number of grouping combinations. Can we make it even faster by reducing those with alternative grouping strategies?
A possible path ahead lies in performing the grouping step using information from the whole station to produce **correlated groups** and then use the same fitting strategy (do steps 1 and 3 simultaneously).
Approach: search for a robust and quick grouping recognition technique.

## Option 1: The Transformation approach

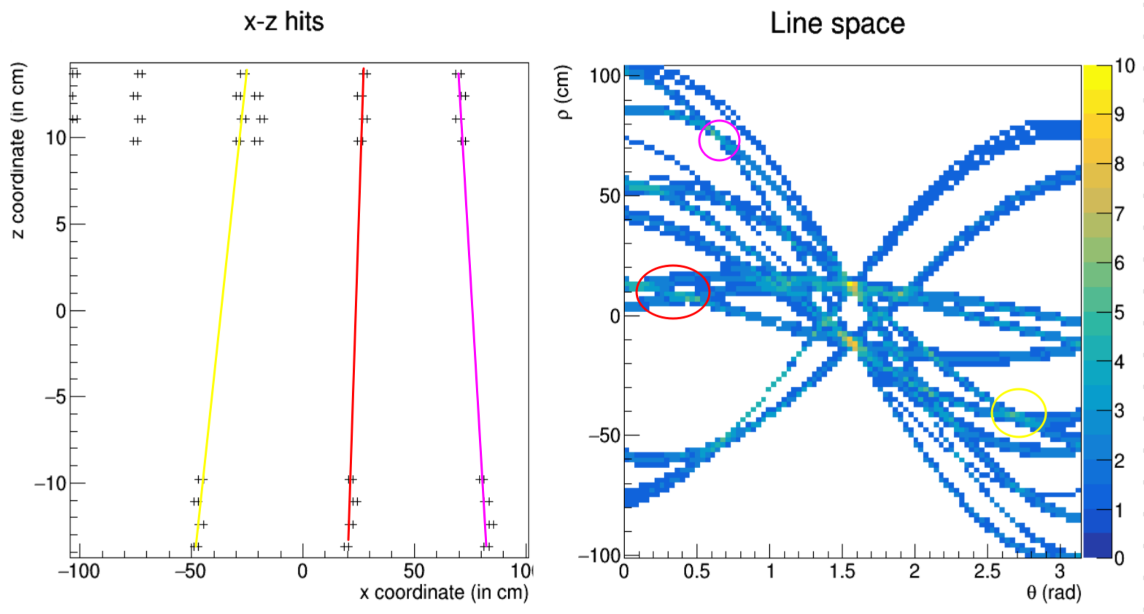
Use the **Hough Transform** procedure to build the *line space* in a DT station.

In the Line space:

-Trajectories (lines) → points

- Cells (points) → lines

Multiple lines in line space → several fired cells lie in a straight line → The fired cells are group candidates.



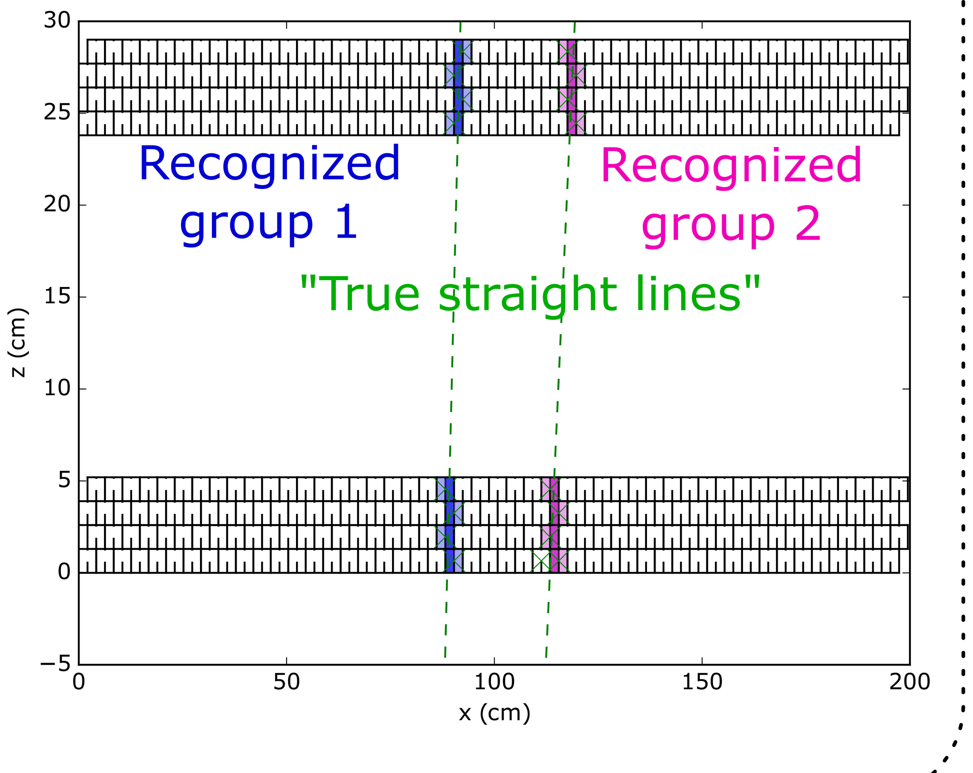

The problem is reduced to the search for maximums in the 2D line space.

## Option 2: The Pattern approach

Use a set of precomputed patterns that represent all possible straight lines going through the detector with coarse granularity.

Grouping candidates can be selected by comparison of observed set of fired cells with the straight line patterns.

Profit from the various symmetries of the system (translation, reflection, etc.) to reduce pattern multiplicity.




[0] CMS Collaboration, "The Phase-2 Upgrade of the CMS Level-1 Trigger", CERN-LHCC-2020-004/CMS-TDR-021 (https://cds.cern.ch/record/2283189)
[1] CMS Collaboration, "Results of DT Longevity Studies", CMS-DP-2019-018 (https://cds.cern.ch/record/2682229/)

Eigth annual conference on LHC Physics (LHCp), 25-29 May 2020, Online