The role of the RPCs in the CMS Level-1 Trigger Clustering at CMSSW during Phase-2

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CMS Phase-2 Muon System

High-Luminosity LHC (HL-LHC):

- PileUp (PU) from 50 to 140-200
- Centre of mass energy 14 TeV
- Instantaneous Luminosity from 2.2 x 10^{34} to 5-7.5 x 10^{34} cm^{-2} s^{-1}

Muon upgrade in Barrel(B) and Endcaps(E) :

- Cathode Strip Chambers (**CSC** in E) **UPGRADE(electronics)**
- Drift Tubes (**DT** in B) **UPGRADE(electronics)**
- Resistive Plate chambers (**RPC**/**iRPC** in B/E) **UPGRADE**
- Gas Electron Multipliers (**GEM** in E) **NEW**

RPC Link System upgrade:

- Improve timing resolution for existing RPCs ($|\eta|<1.9$)
- Replace all off-chamber electronics
- Intrinsic time resolution of RPC system is 1.5 ns

iRPC Project:

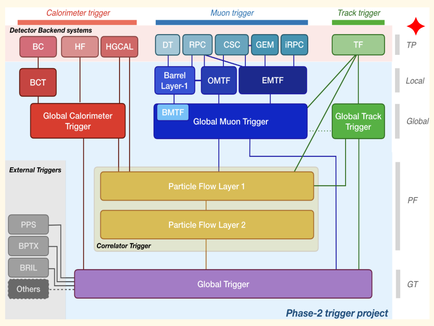
- High particle rate & high PU environment in HL-LHC
- Installation of new RPCs

Improved RPC (**iRPC**) added to 2 outer stations of the CMS endcap in the $1.8 < |\eta| < 2.4$ region (intrinsic time resolution of 0.5 ns)

Phase-2 Level 1 Muon Trigger

High-Luminosity LHC requirements:

- acceptance rate 750 kHz
- latency budget 12.5 μs
- new muon subdetectors
- improved electronic boards

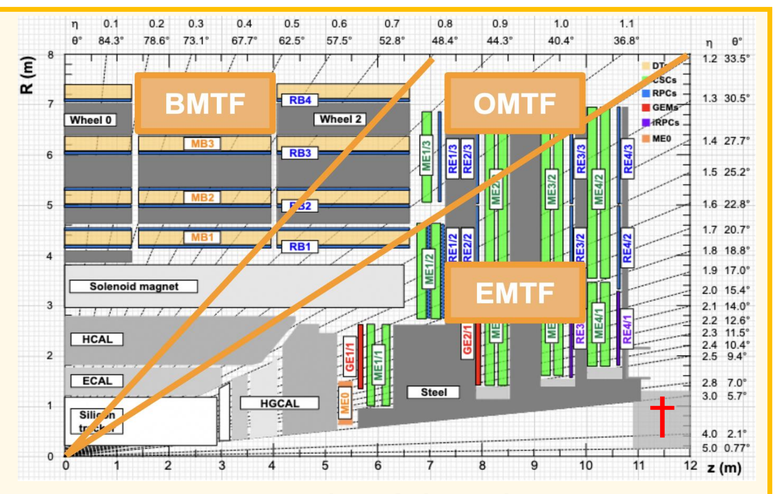


Muon trigger structure:

- Barrel Muon track finder (**BMTF**)
- Overlap Muon Track Finder (**OMTF**)
- Endcap Muon Track Tinder (**EMTF**)

Muon candidates and stubs are sent to the Global Muon Trigger (GMT) by EMTF/OMTF, while BMTF Layer-1 sends stubs.
GMT is tasked with:

- sorting in terms of p_T & quality,
- removing duplicates and
- generating track-matched muons & L1 tracks matched to muon stubs



EMTF++ = Upgrade of the Phase-1 EMTF, which operates in the $1.2 < |\eta| < 2.4$ region

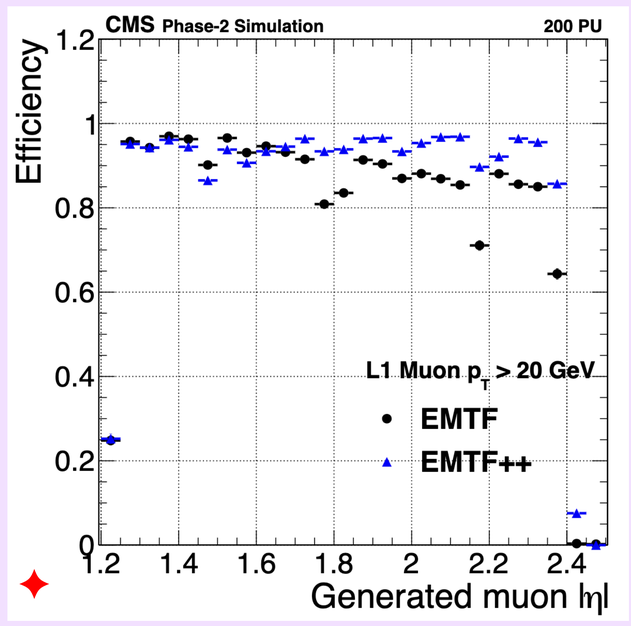
Endcap Muon Track Finder ++ (EMTF++) ✦

Functionality:

- **Pattern recognition:** finds hits in the 4 (or more) muon stations
- **Track building:** matches hits to a track, resolves ambiguities by building the straightest track
- **p_T assignment**: determines the track p_T through a Neural Network

39 features in a feedforward NN with 3 hidden layers (50, 30, 20 nodes respectively).
Batch normalization is applied to all layers.

hits → **Pattern Recognition** → **Track Building** → **p_T Assignment** → tracks



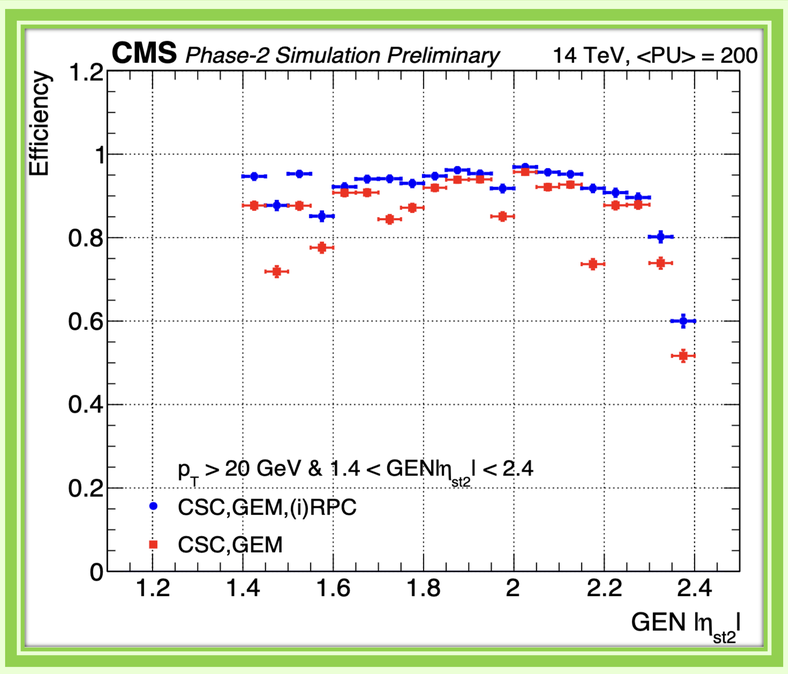
(i)RPC contribution

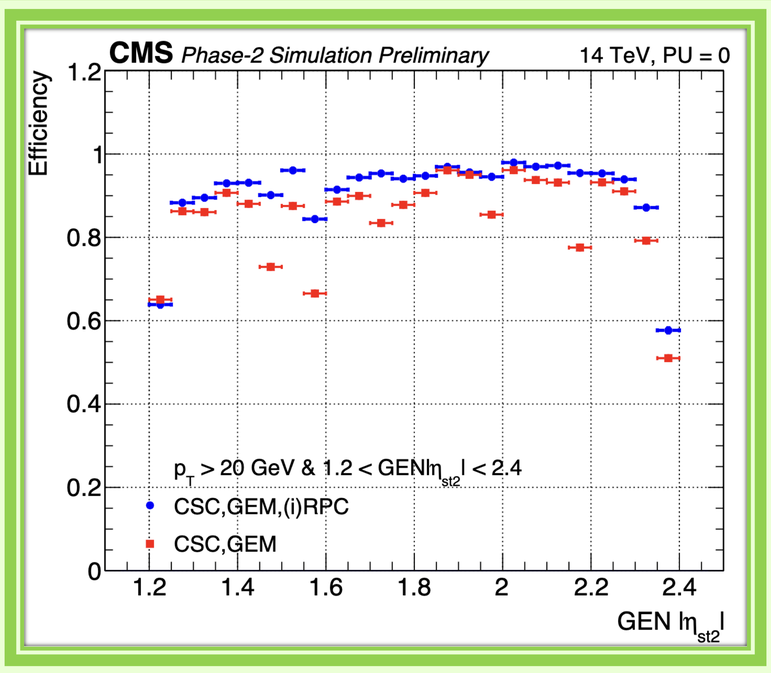
Efficiency definition:

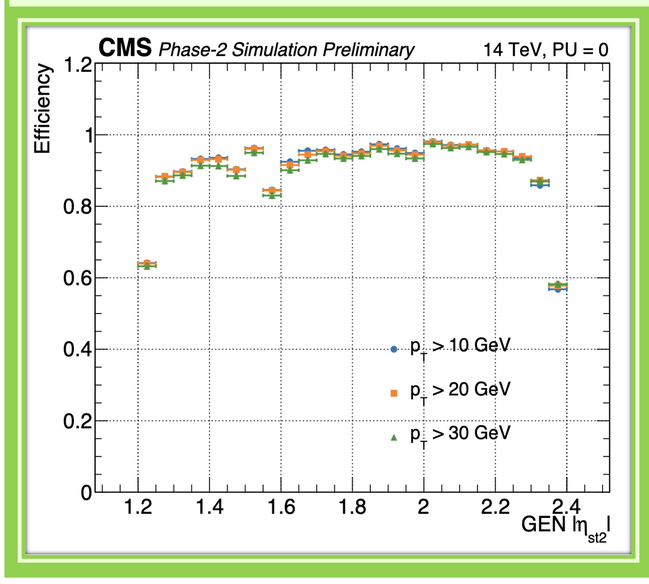
Numerator:
- $dR(\mu_{Gen}, track) < 0.1$ matching
- L1 Muon p_T > 10,20,30 GeV threshold
- 1 station 1 hit + 2 other station hits
- $1.2\ (1.4) < GEN|\eta|_{st2} < 2.4$ for PU 0(200)

Denominator:
- GEN p_T> 14,24,34 (16,26,36) GeV for plots to the right (below)
- $1.2 < GEN|\eta|_{st2} < 2.4$

Below, the efficiencies of the algorithm for the sample containing (i)RPC information.
The performance is stable when going to higher p_T cuts.







Efficiencies demonstrating the contribution to the EMTF++ algorithm of both RPC and iRPC; these plots show how inefficiencies due to geometry of the other subsystems are recovered by the addition of (i)RPC. The algorithm at this stage is not optimized to account for the absence of subdetector systems.

Next steps:
- Adding timing information from (i)RPC to the NN
- Studying new physics models (e.g. Long Lived Particles)

References:
- CMS Collaboration, "The Phase-2 Upgrade of the CMS Muon Detectors", CERN-LHCC-2017-012, CMS-TDR-016, 12 September 2017 †
- CMS Collaboration, "The Phase-2 Upgrade of the CMS Level-1 Trigger", CERN-LHCC-2020-004, CMS-TDR-021, 10 March 2020 ✦