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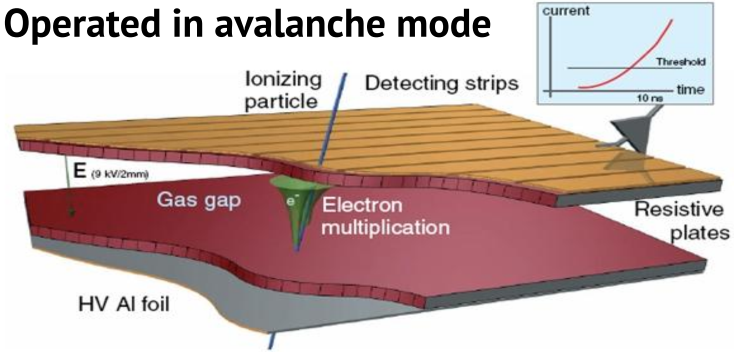
Colombia

September 9, 2024
https://indico.cern.ch/event/1354736/
XVII Conference on Resistive Plate Chambers and Related Detectors

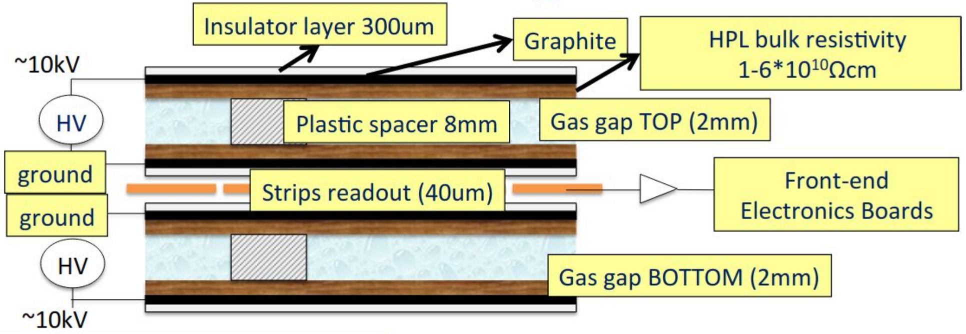
Novel ideas for CMS L1 trigger in HL-LHC using RPC ultimate timing performance

The Resistive-plate Chambers in CMS

Operated in avalanche mode

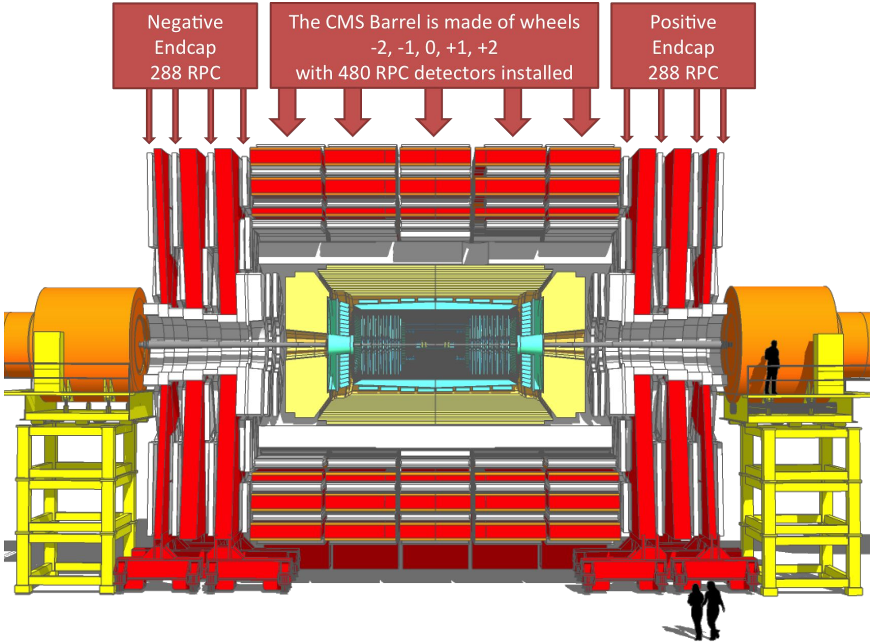


[CMS-OUTREACH-2018-05]



CMS Standard gas mixture:
95,2% $C_2H_2F_4$ (Freon)
4,5% iC_4H_{10} (Isobutane)
0,3% SF_6 (Sulphur Hexafluoride
Gas relative humidity 40%

[CMS-CR-2016-435, Fig 2]

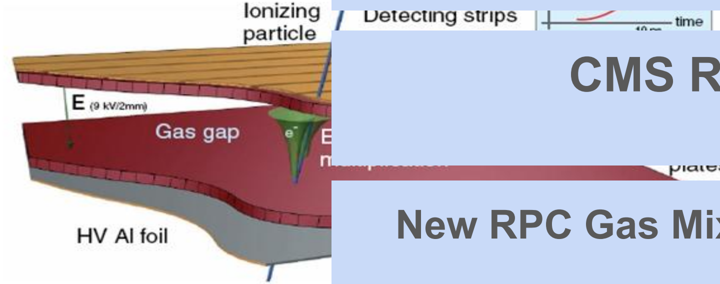


[CMS-CR-2016-435, Fig 4]

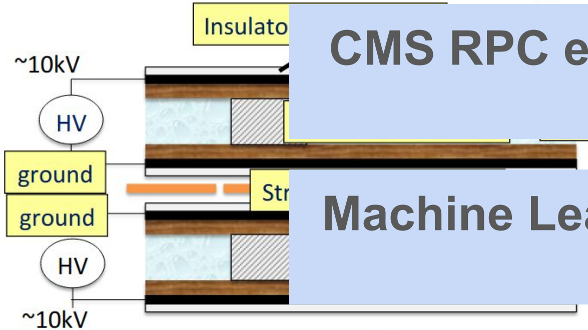
1056 RPCs in total
(present system)

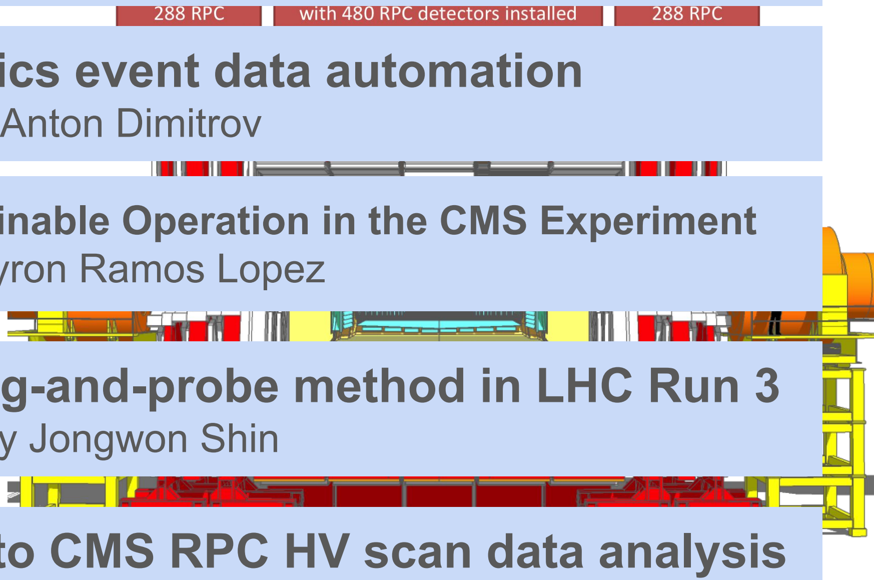
The Resistive-plate Chambers in CMS

Operated in avalanc



[CMS-OUTREACH-2018-05]





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CMS RPC performance and operation in LHC Run
Talk by Mariana Shopova

CMS RPC non-physics event data automation
Talk by Anton Dimitrov

New RPC Gas Mixtures for Sustainable Operation in the CMS Experiment
Talk by Dayron Ramos Lopez

CMS RPC efficiency using tag-and-probe method in LHC Run 3
Poster by Jongwon Shin

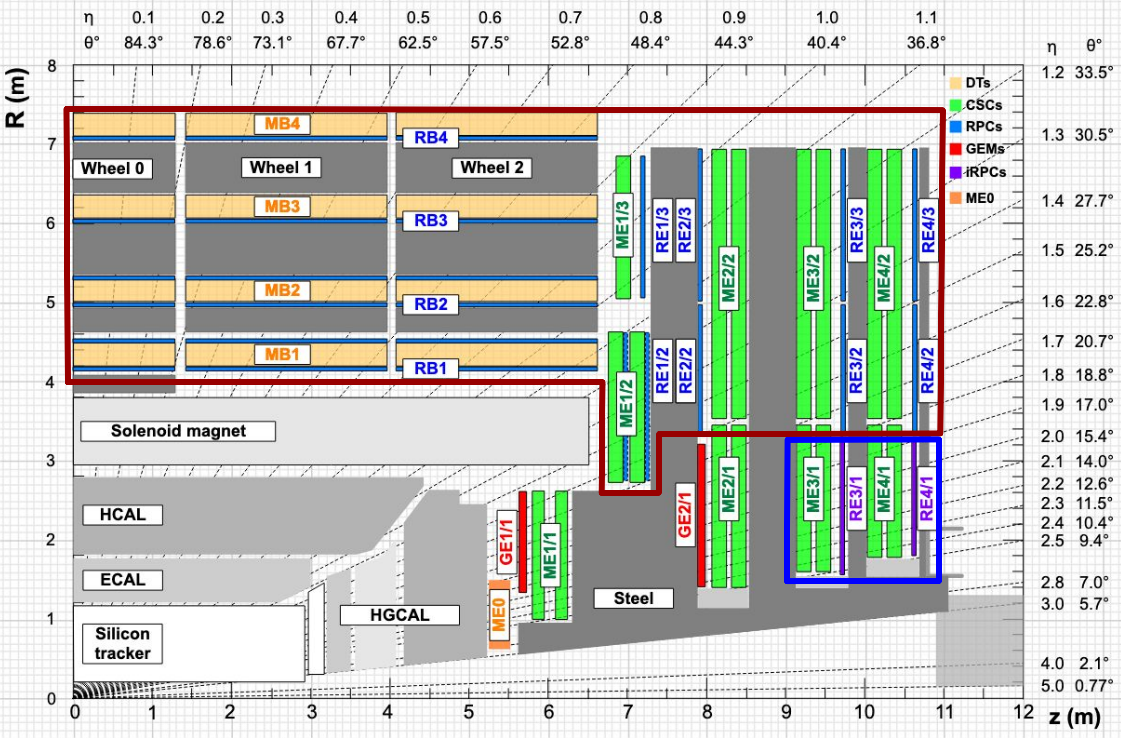
Machine Learning approach to CMS RPC HV scan data analysis
Poster by Mihaela Pencheva Pehlivanova

CMS RPC Background studies in LHC Run 2 and Run 3
Poster by Leonardo Favilla

CMS RPC Upgrade Project

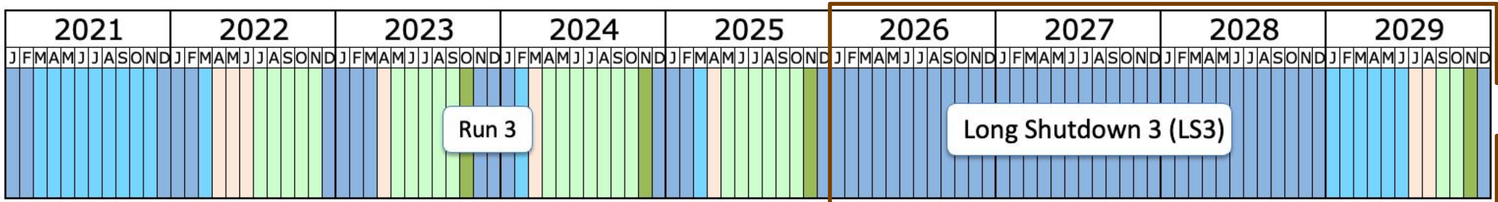
[CMS-TDR-016, Fig 1.4]

Link system upgrade for the existing RPC system |η|<1.9



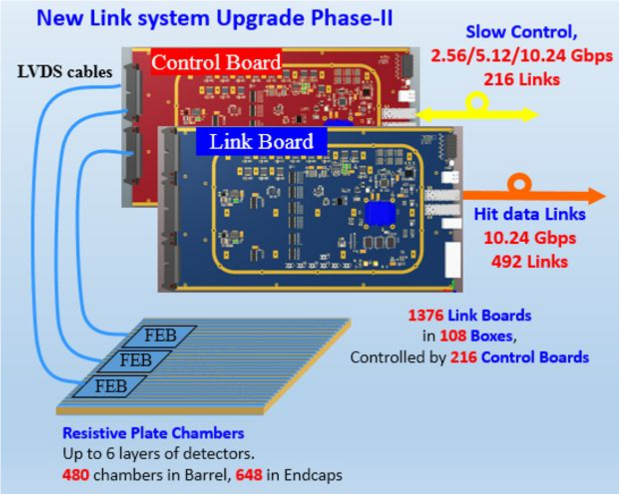
iRPC: extend the RPC coverage to |η|<2.4

[Longer term LHC schedule, June 2024]

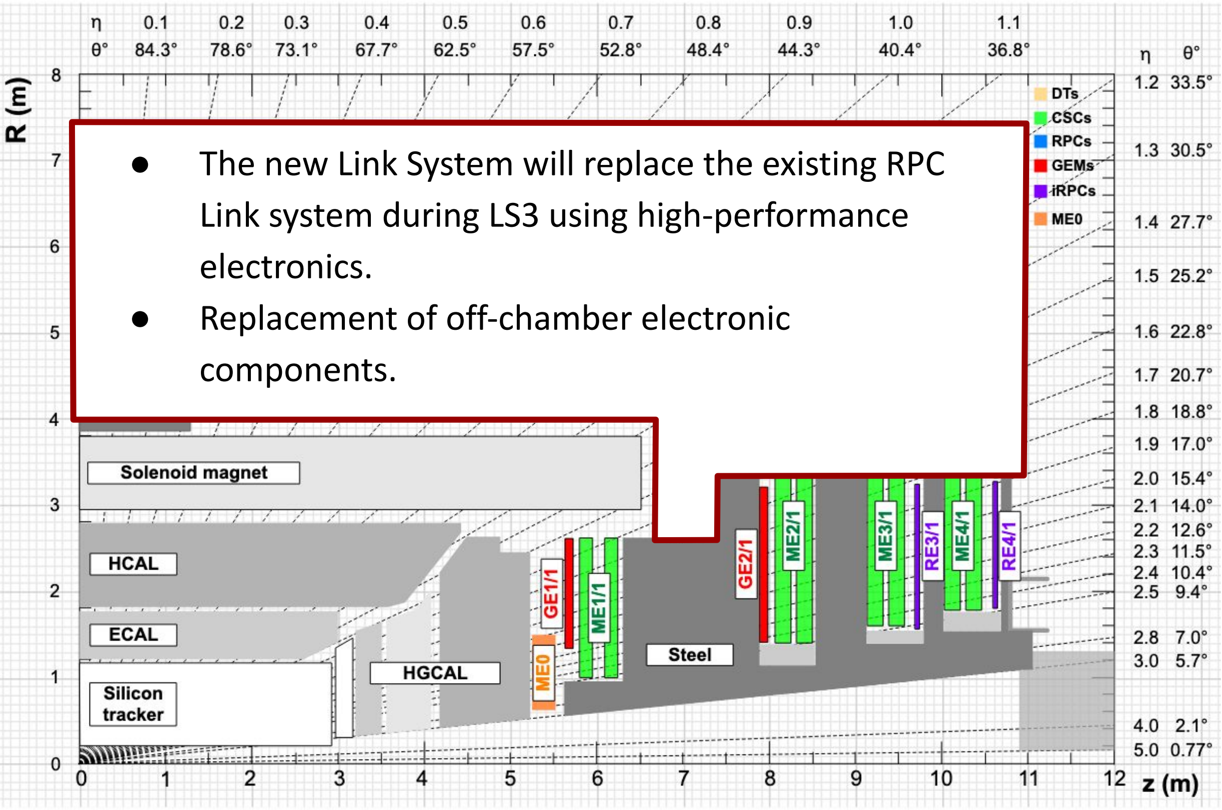


HL-LHC

CMS RPC Upgrade Project -> Link System



- The new Link System will replace the existing RPC Link system during LS3 using high-performance electronics.
- Replacement of off-chamber electronic components.

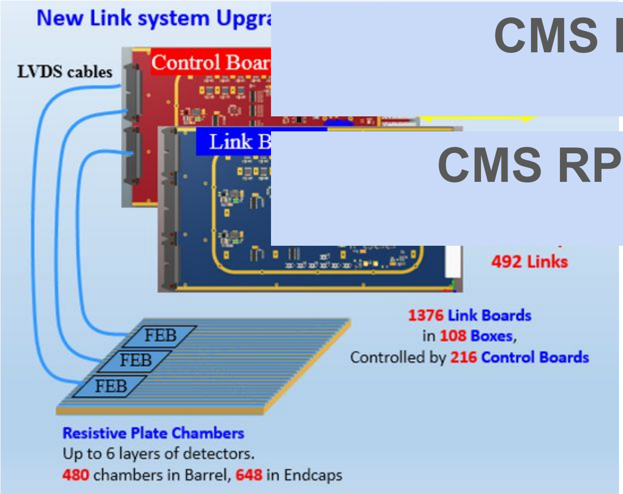


[CMS-TDR-016, Fig 1.4]

Key parameters:

- This will improve the time resolution from **25 ns to 1.56 ns.**
- Data transmission will be increased from **1.6 Gbps** to **10.24 Gbps.**

CMS RPC Upgrade Project -> Link System



CMS RPC Link System Tester and Quality Control

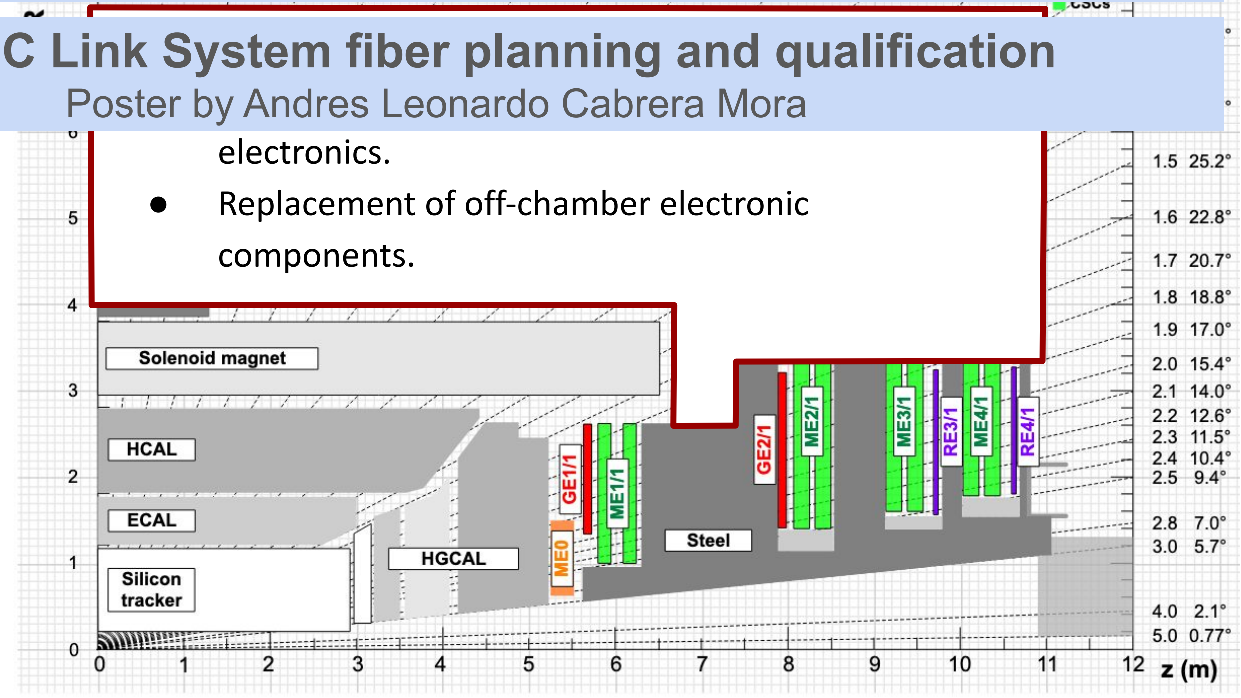
Poster by Fateme Esfandi

CMS RPC Link System fiber planning and qualification

Poster by Andres Leonardo Cabrera Mora

electronics.

- Replacement of off-chamber electronic components.



[CMS-TDR-016, Fig 1.4]

Key parameters:

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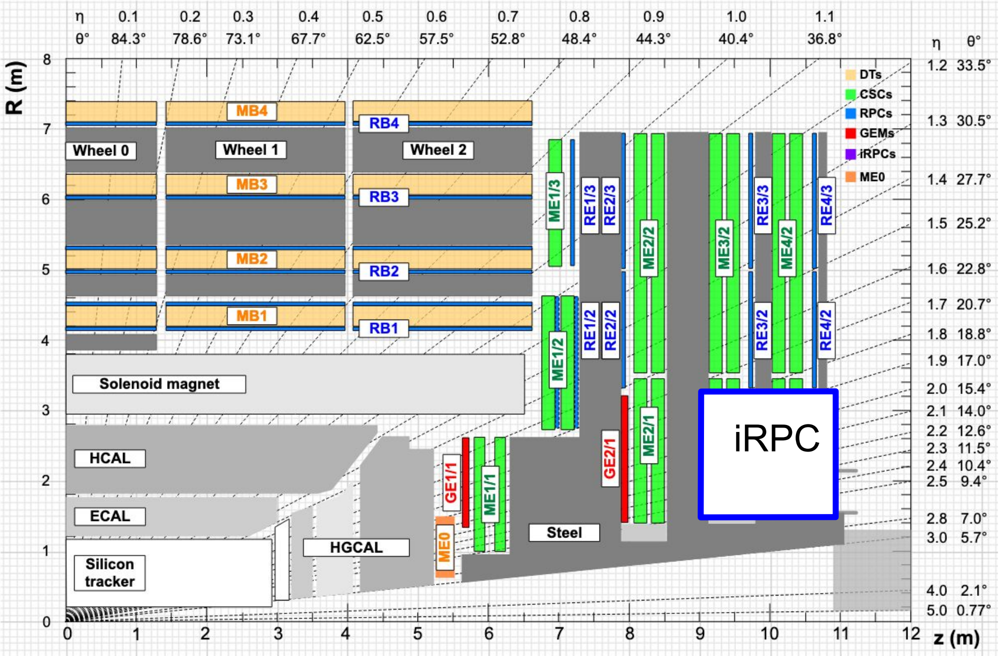
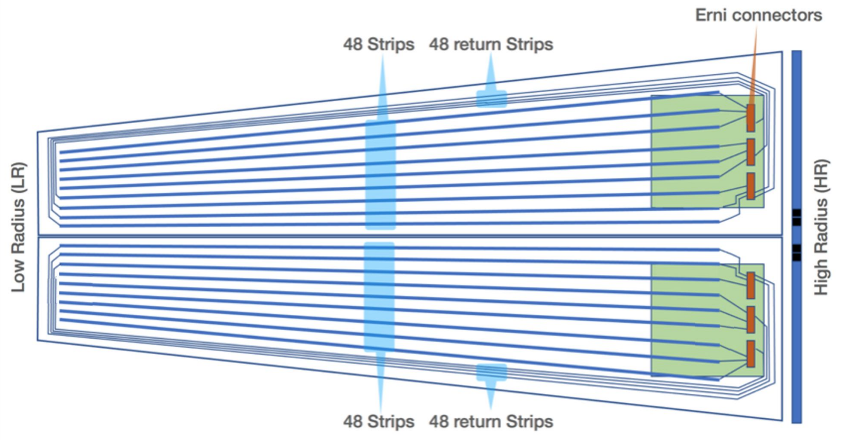
CMS RPC Upgrade Project -> iRPC

	RPC	iRPC
HPL thickness (mm)	2	**1.4**
Number of gas gaps	2	**2**
Gas gap thickness (mm)	2	**1.4**
Space resolution in η (cm)	20 - 28	**1.5**
Space resolution in φ (cm)	0.8 - 1.9	**0.3 - 0.6**
Intrinsic timing resolution (ns)	1.5	**0.5**

[CMS-TDR-016, Fig 1.4]





- Double readout in the strips high and low radius.
- Total 72 iRPC (20°) chambers
- 1.8< $|\eta|$ <2.4
- iRPC are able to sustain high expected rates of up to 2 kHz/cm2, with hit efficiency > 95%

CMS RPC

HPL thickness (mm)	2	1.4
Number of gas ga		
Gas gap thickness (mm)	2	1.4
Space resolution		
Space resolution		
Intrinsic timing resolution (ns)	1.5	0.5

Innovative Resistive Plate Chambers for the CMS Phase 2 Upgrade: Project Summary, Construction, and Quality Assurance
Talk by Jules Vandenbroeck

iRPC front-end board readout electronics
Talk by Maxime Gouzevitch

Use and application of the CMS RPC in future experiments
Talk by Ece Asilar

Performance and longevity of CO2 based mixtures in CMS Improved Resistive Plate Chambers in the HL-LHC environment
Talk by Joao Pinheiro

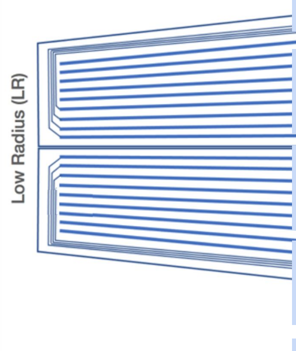
A novel solution for managing latency in the CMS iRPC backend: Check-Sort-Push
Poster by Weizhuo Diao

iRPC clustering algorithm and hit reconstruction
Poster by Mauricio Thiel

iRPC FEB cooling system
Poster by Otari Kemularia

Gas gaps and chambers quality control of improved resistive plate chambers (iRPC)
Poster by Mohammad Ahammad Ali

Preliminary aging studies of improved RPC gaps operated with HFO based mixtures
Poster by Zubayda Eve Kofi



CMS RPC L1 Trigger primitives in HL-LHC
Poster by Qingfeng Hou

HL-LHC Challenges

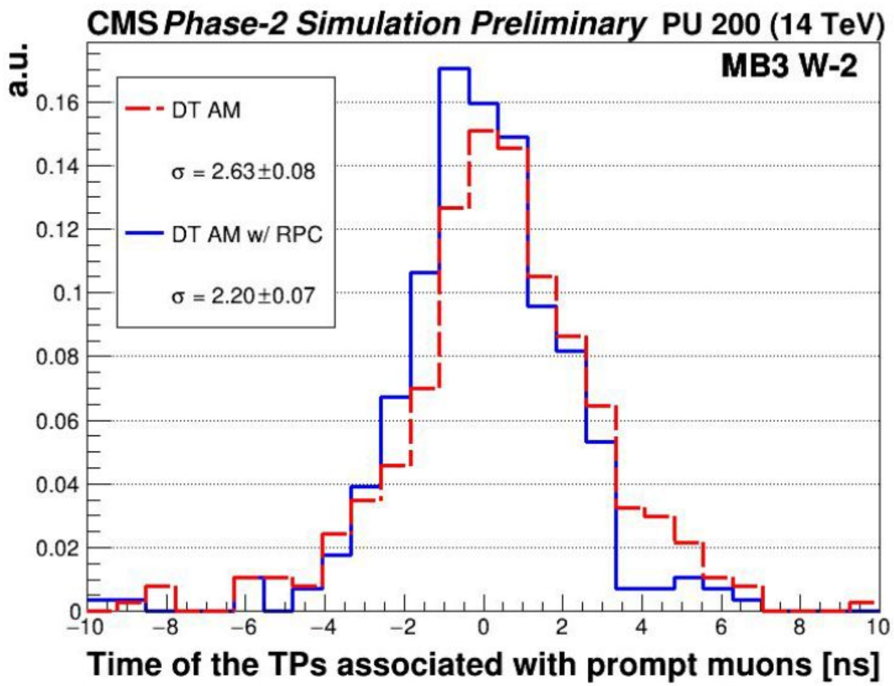
High particle rate and high pileup environment due to increased luminosity

- Maintain triggers at thresholds needed for sensitivity for physics:
  - Electroweak
  - Higgs
  - BSM
- To reject particles originating from pile-up vertices
- To maintain object reconstruction in the high-luminosity environment

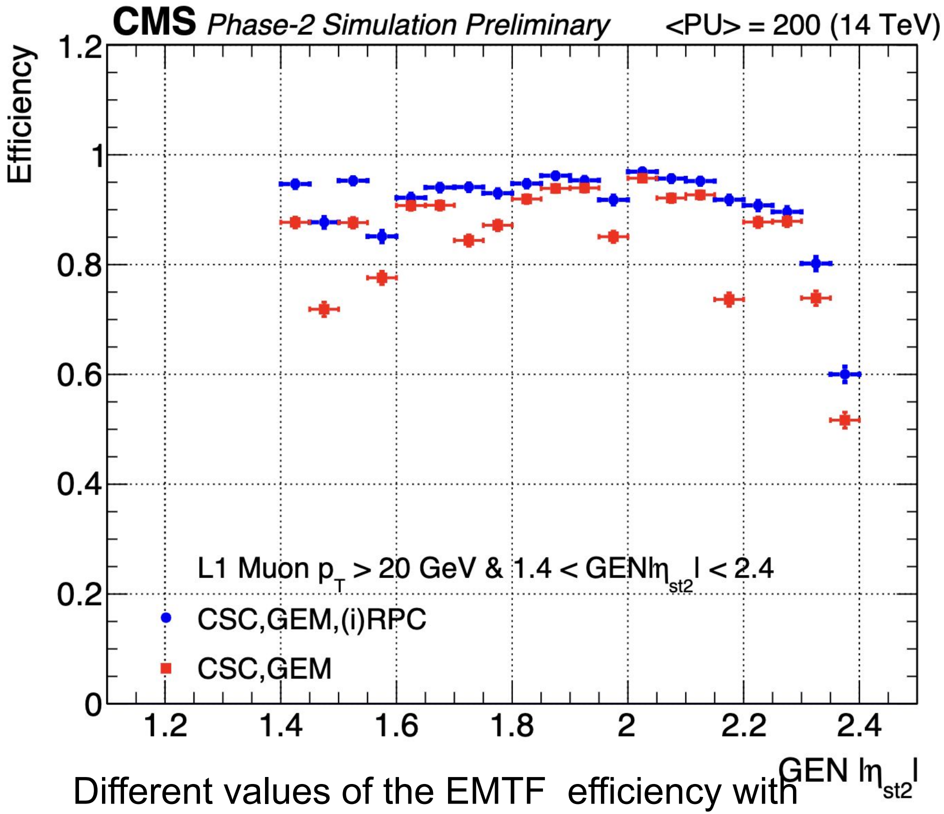
	LHC	**HL-LHC nominal**	**HL-LHC ultimate performance**
Instantaneous luminosity ($cm^{-2}s^{-1}$)	2×10^{34}	$\mathbf{5 \times 10^{34}}$	$\mathbf{7.5 \times 10^{34}}$
Integrated luminosity (fb^{-1})	300	**3000**	**4000**
Pile Up	50	**140**	**200**

	CMS Phase1	**CMS Phase 2**
L1 trigger (kHz)	100	**750**
L1 latency (μs)	3.6	**12.4**

Improvements in trigger for the CMS phase 2 with RPC

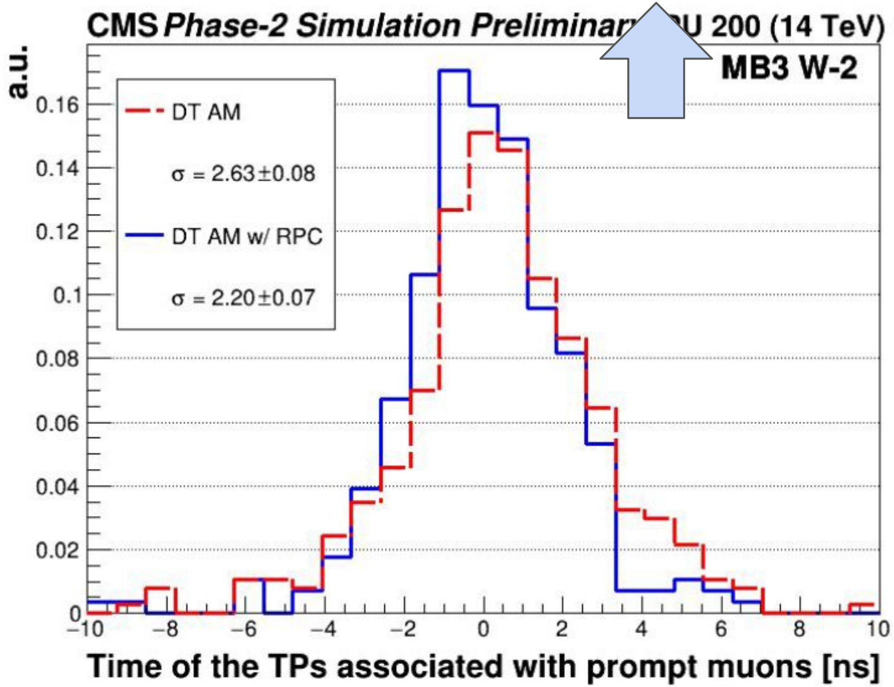


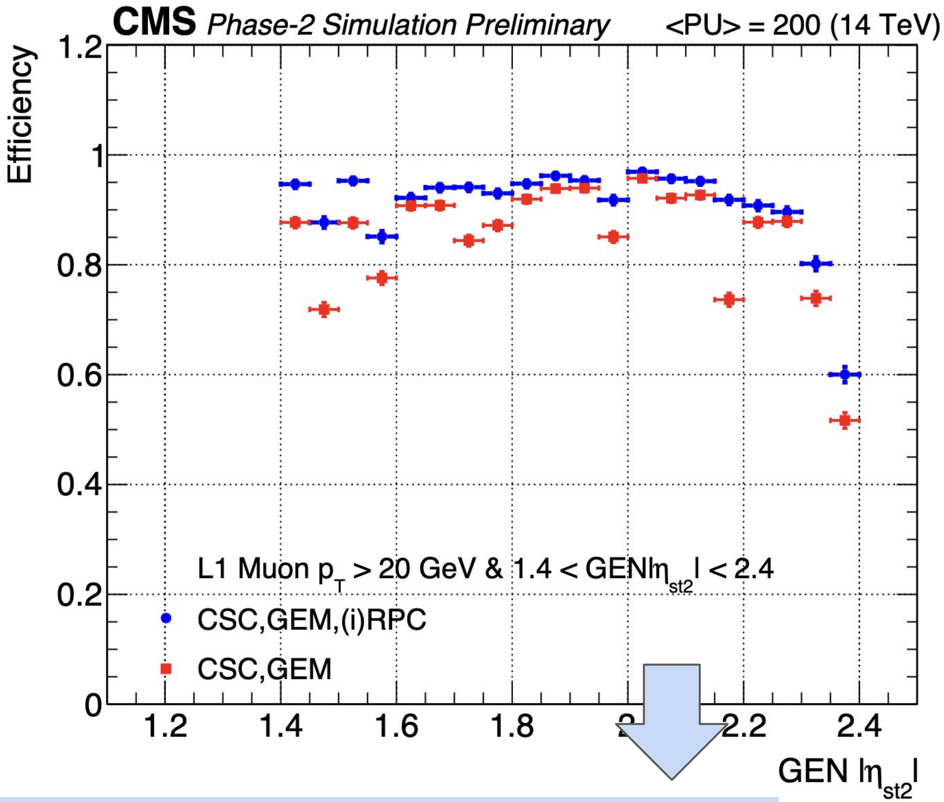
DT+RPC super-primitives has better resolution.



Different values of the EMTF efficiency with (blue) and without (red) the (i)RPC information added to the algorithm.

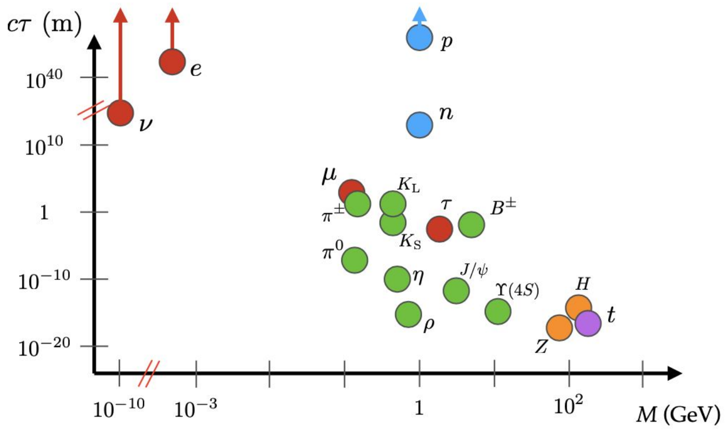
An extension to the Analytical Method clustering algorithm for BMTL1 benefitting from CMS RPC timing
Poster by Raphael Gomes De Souza





CMS RPC L1 Trigger clustering at CMSSW
Poster by Cristina Giordano

Long-lived particles (LLPs) -> Physics beyond the SM



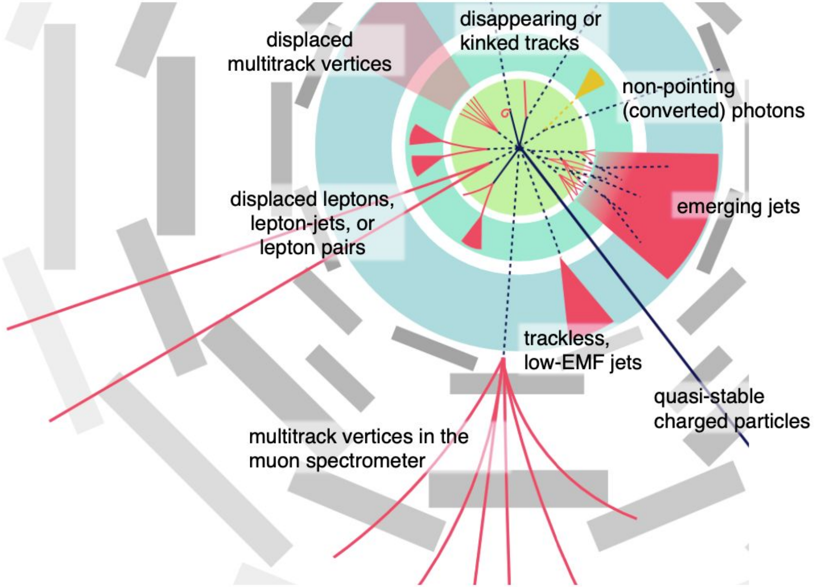
[J.Phys.G 47 (2020) 9, 090501, Fig 1.1]

$c\tau \gtrsim 10\ \mu\text{m}$ for BSM LLPs

Searches for long-lived particles are well motivated by various classes of extensions of the Standard Model:

- Minimal supersymmetric SM (MSSM)
- Neutral naturalness
- Hidden sector dark matter
- Breaking of symmetries motivated by cosmology, etc…

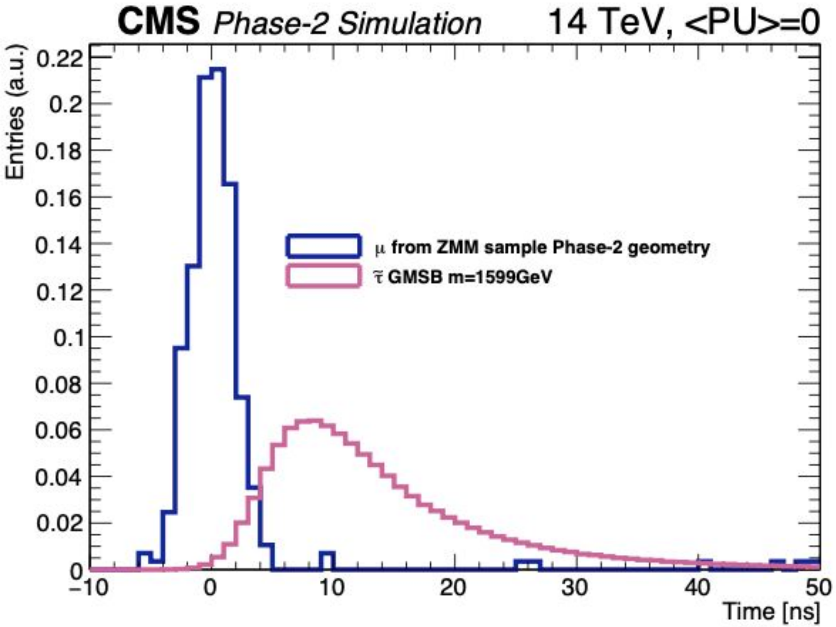
Standard reconstruction algorithms may reject events or objects containing LLPs.



[J.Phys.G 47 (2020) 9, 090501, Fig 1.2]

Often, the production cross section for such processes is expected to be very small. The HL-LHC will allow for the collection of much larger data sets needed to reach better sensitivity to such BSM scenarios.

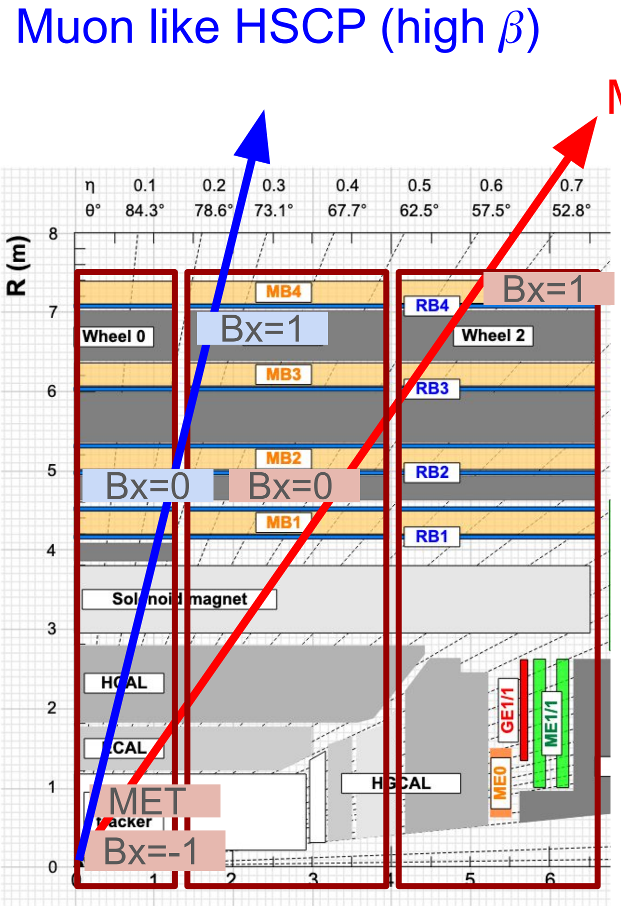
HSCP Trigger with RPC Detector Upgrade



[J.Phys.G 47 (2020) 9, 090501, Fig 5.10]

- Slow-moving particles will arrive with a delay depending on their speed.
- This time delay, measured by each RPC layer crossed by the HSCP, can be exploited in order to trigger on and reconstruct such particles.

Novel ideas for CMS L1 trigger in the Barrel

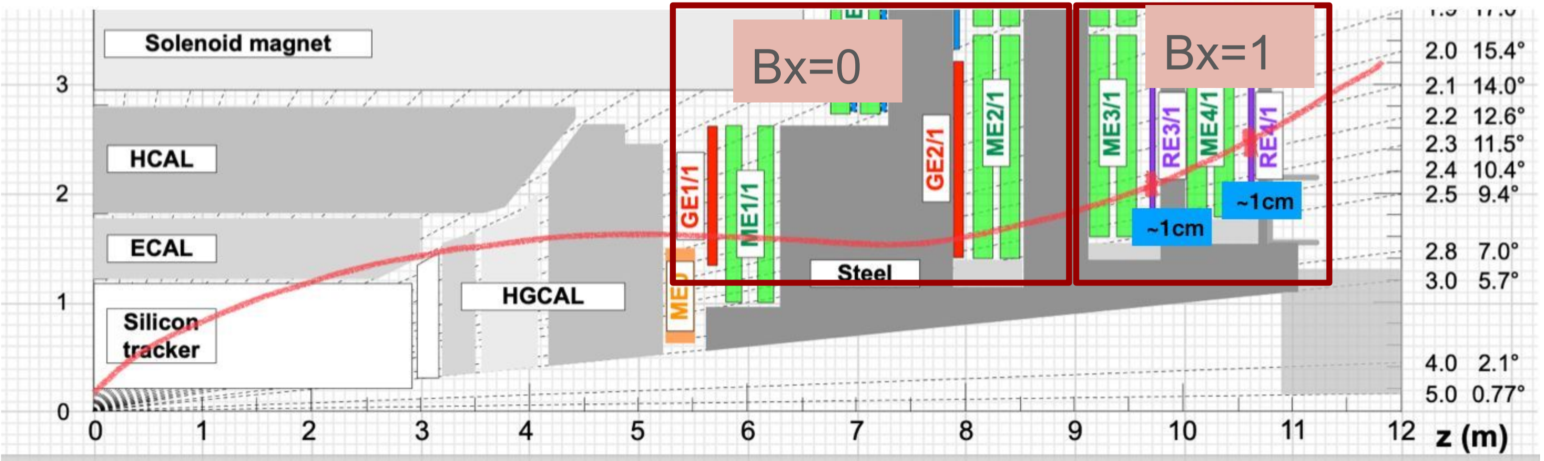


Time of Flight (ToF) to be able to distinguish different β!

Feasibility study is ongoing using 40 MHz L1 trigger scouting data

	Time to travel (ns)		Bx window (25 ns) for 7,4 meters
β (v/c)	1 meter	7,4 meters	
0,1	33,4	246,8	9
0,2	16,7	123,4	4
0,3	11,1	82,3	3
0,4	8,3	61,7	2
0,5	6,7	49,4	1
0,6	5,6	41,1	1
0,7	4,8	35,3	1
0,8	4,2	30,9	1
0,9	3,7	27,4	1
1	3,3	24,7	0

Novel ideas for CMS L1 trigger in the Endcaps



ToF can be used as a seed for a search of an HSCP particle in the previous Bx.

Conclusions

- **The RPC upgrade will allow to achieve a high trigger efficiency in the Phase 2 of the CMS experiment.**

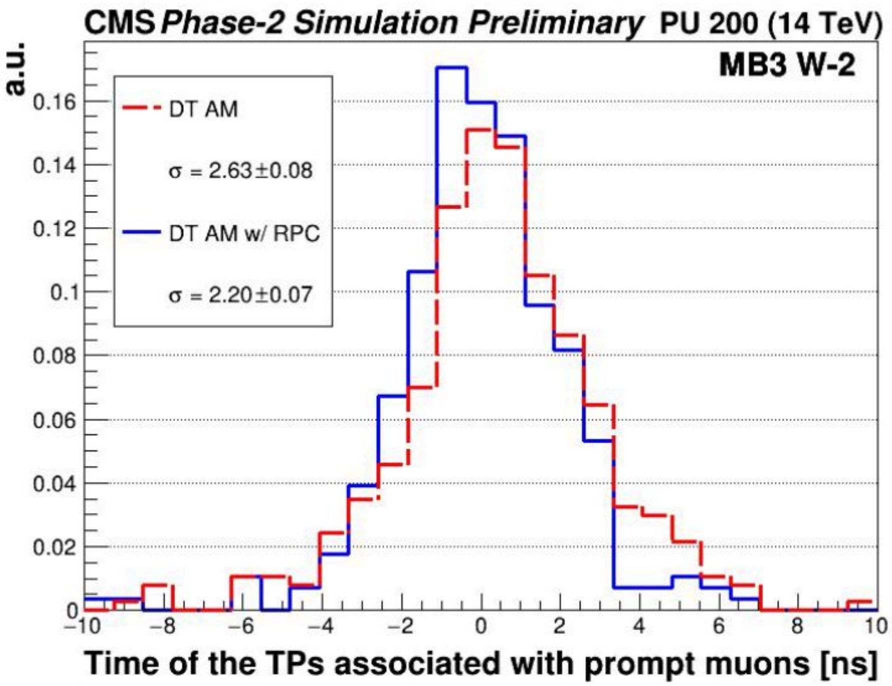
- **The additional hits in the new iRPC detectors, combined with the upgrade of the new link system will allow to improve L1 trigger algorithms to efficiently triggering on HSCP even in the harsh environment of the HL-LHC.**

Backup slides

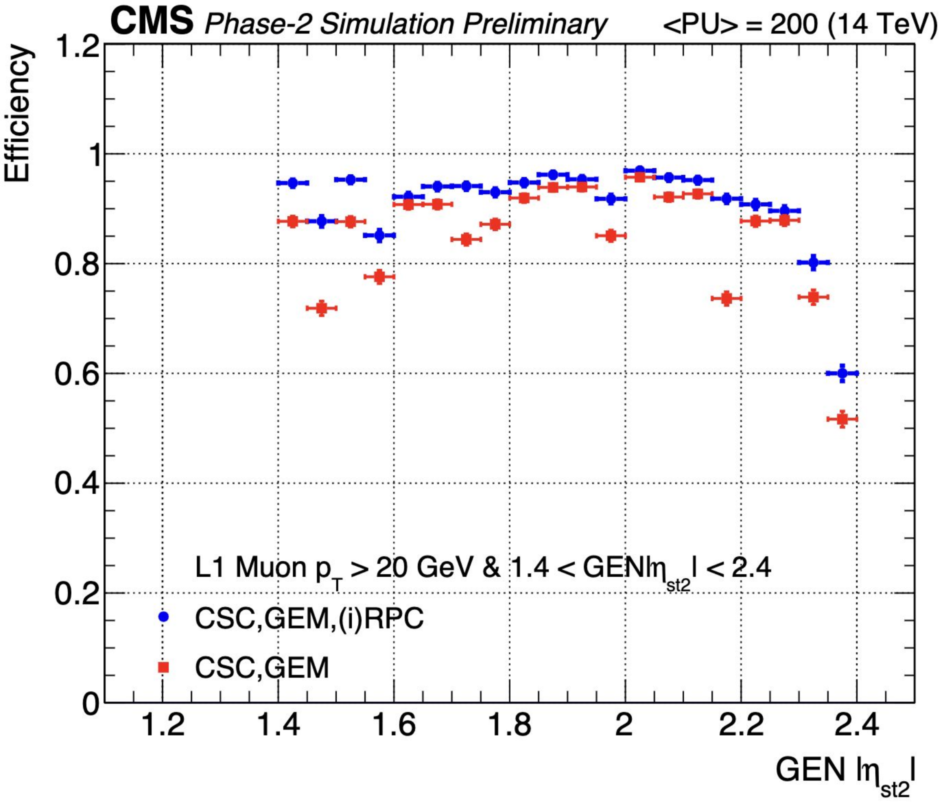
DT TPs: Time Resolution

Caption:

The timing distribution of the trigger primitives associated with a generated muon with DT Analytical Method (AM) and DT AM + RPC for the station 3 and wheel -2 (MB3 W-2). It is independent from the different sectors of a chamber. It shows that for the DT+RPC super-primitives, in blue, time distribution has better resolution, as you can notice in the standard deviation (σ) value.



Results for <PU>=200



Caption:

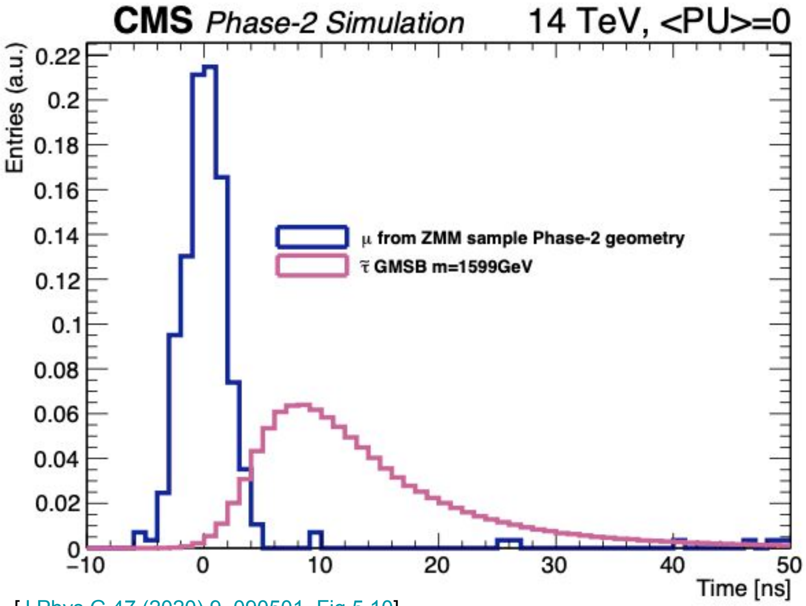
Plot showing the efficiency in bins of generated η.

The generated η is extrapolated to station 2 (st2).

The plot shows the different values of the EMTF efficiency with (blue circle) and without (red square) the (i)RPC information added to the algorithm for the case of a SingleMuon sample (50k events) generated with an average PileUp (<PU>) of 200. The algorithm was not optimized to account for the absence of the individual subsystems. This sample was produced with a flat p_T distribution between 0 and 200 GeV. The contribution of iRPC starts for |η| > 1.8, so that significant dips in efficiencies are seen around 2 and 2.2 for the case without the (i)RPC subsystem.

The increase in efficiency, compared to the PU=0 case, for the case without (i)RPC in the 1.55 < GEN|η_{st2} < 1.6 bin is due to the sample differences.

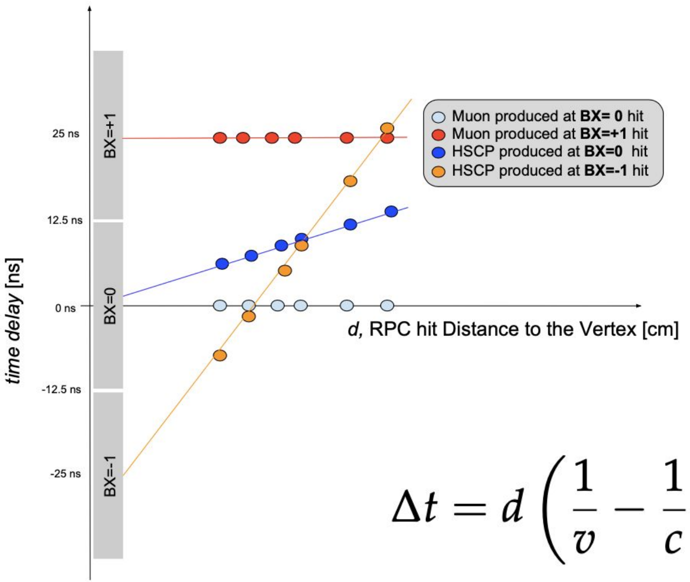
HSCP Trigger with RPC Detector Upgrade



[J.Phys.G 47 (2020) 9, 090501, Fig 5.10]

- Slow-moving particles will arrive with a delay depending on their speed.
- This time delay, measured by each RPC layer crossed by the HSCP, is exploited in order to trigger on and reconstruct such particles.

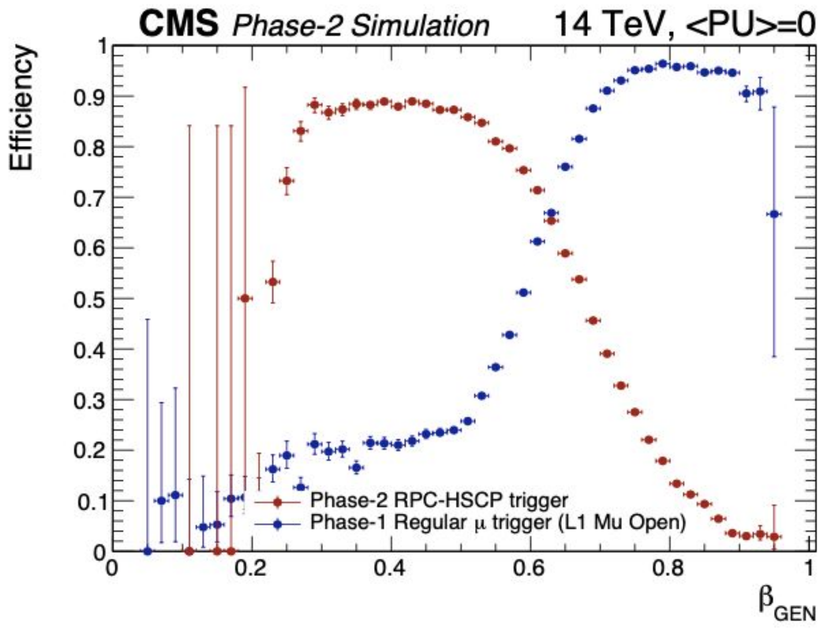
The speed of muon-like particles and the time (bunch crossing) of their origin will be computed with a fast algorithm to be implemented in the Level-1 trigger at the HL-LHC.



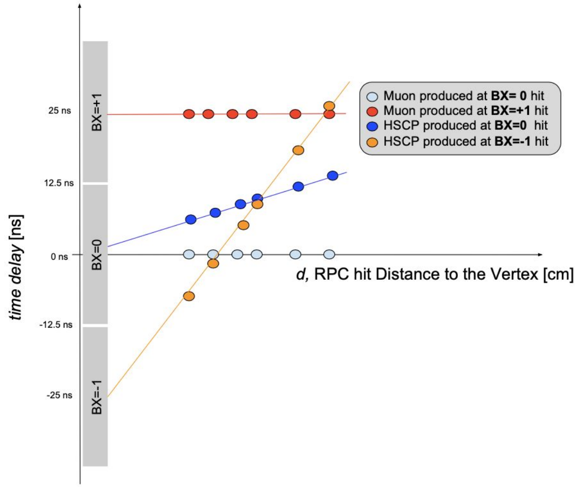
$$\Delta t = d\left(\frac{1}{v} - \frac{1}{c}\right)$$

The upgrade of the RPC system will allow the trigger and identification of slowly moving particles by measuring their time of flight to each RPC station with a resolution of O(1) ns.

HSCP Trigger with RPC Detector Upgrade



A particle-speed measurement resolution is shown for the case of 25 ns signal sampling time (Phase 1) and 1.56 ns sampling time provided with the upgraded RPC Link Board System



- The upgraded RPC Link Board System will allow for the triggering, at the correct bunch crossing, on possible HSCPs with velocities as low as β ~ 0.25.
- The current CMS-HSCP Phase 1 trigger performs well down to β ≈ 0.75.

- Possible improvements for this trigger proposal in the β measurement could be achieved by matching tracks in the track trigger to the HSCP muon trigger.