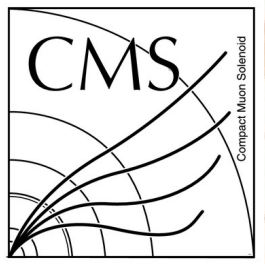
RPC Phase II Trigger Primitives and combination with DT/CSC

Brieuc François on behalf of RPC group
Hanyang University
Nov 29th, 2018



Outline

What is this talk about?

- Current RPC in Level-1 Trigger
- RPC Phase II Upgrade and Trigger Primitives
- RPC in Phase II MTF's
- RPC combined to other Trigger Primitives

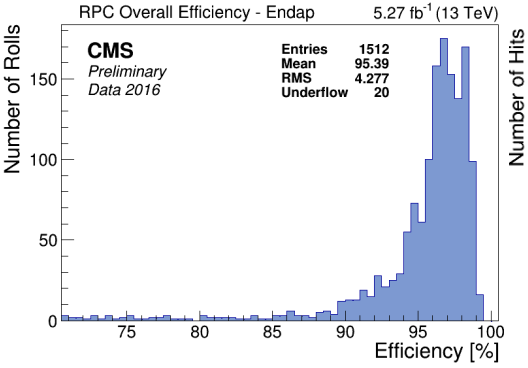
Ideas for future studies and thoughts on how to best use Upgraded RPC in Level-1

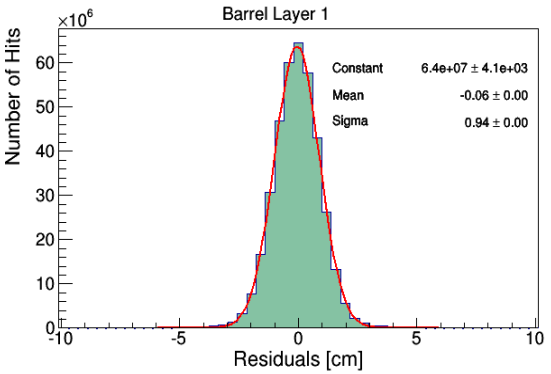
- **Open for discussion! What is most useful/promising, what is feasible or not...**

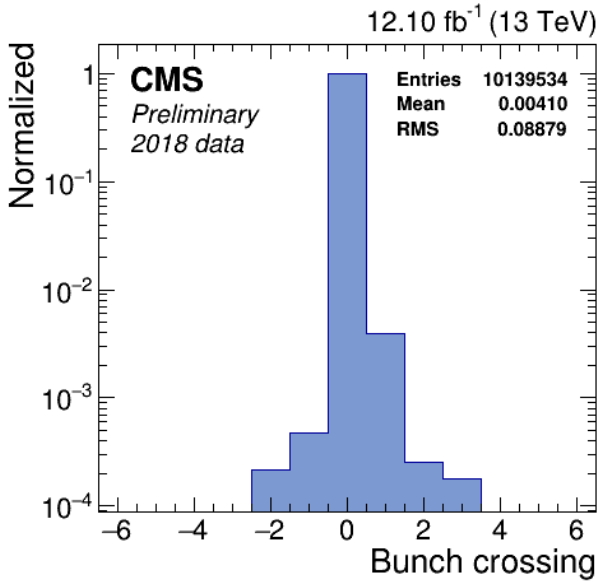
Current RPC in Level-1 Trigger

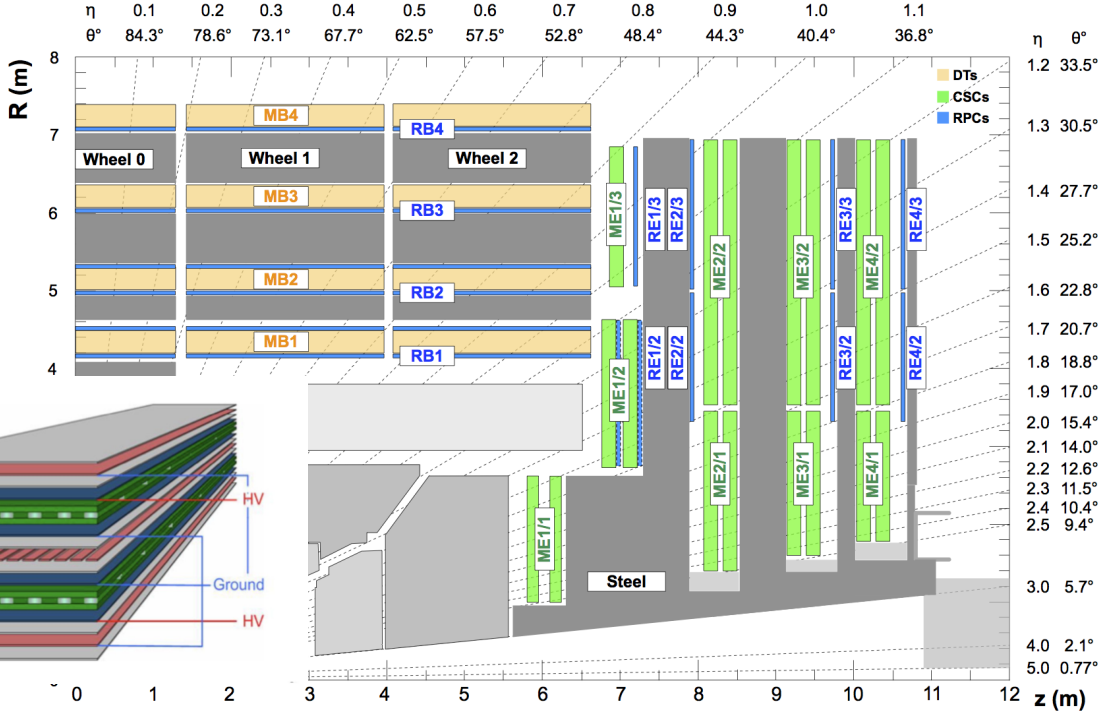
Current RPC Trigger Primitives

- RPC covers the three MTF's η regions
- 'Trigger Primitives' are clusters of strips
- Efficiency ~95%
- Provides φ measurement O(cm)
  - η depends on the strip length
- Very good intrinsic time resolution but 25 ns digitization



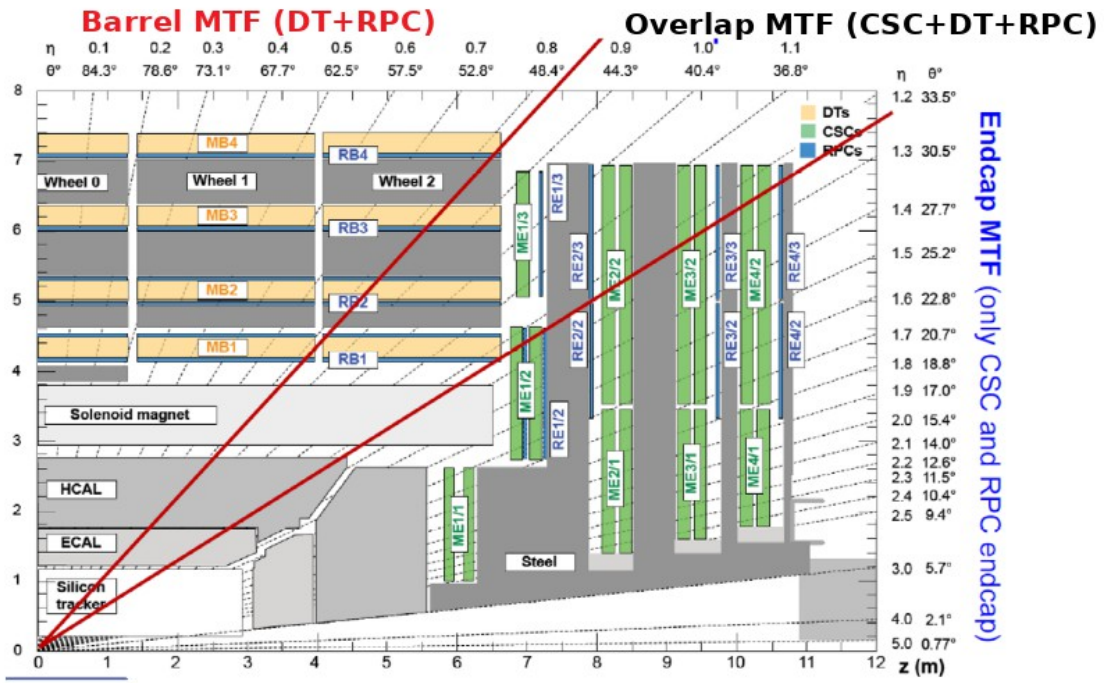


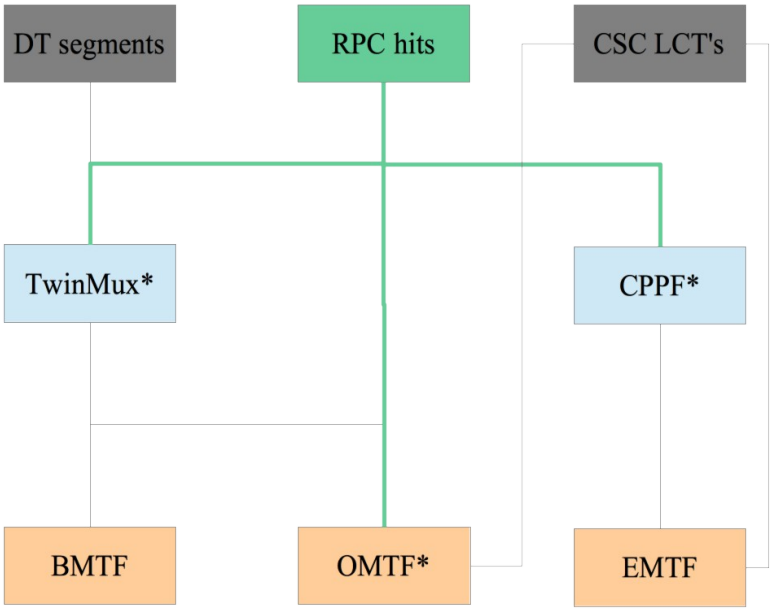




Current RPC contribution to L1T

- RPC contributes to the three Level-1 Muon Track Finders differently
  - BMTF ($|\eta| < 0.83$): assign bunch crossing of DT segments without 8 fired layers + build RPC only segments in MB1 and MB2
  - OMTF ($0.83 < |\eta| < 1.24$): the 8 RPC chambers (5 in barrel, 3 in end-cap) are used for position information
  - EMTF ($|\eta| > 1.24$): RPC hits are used in case of CSC segment absence

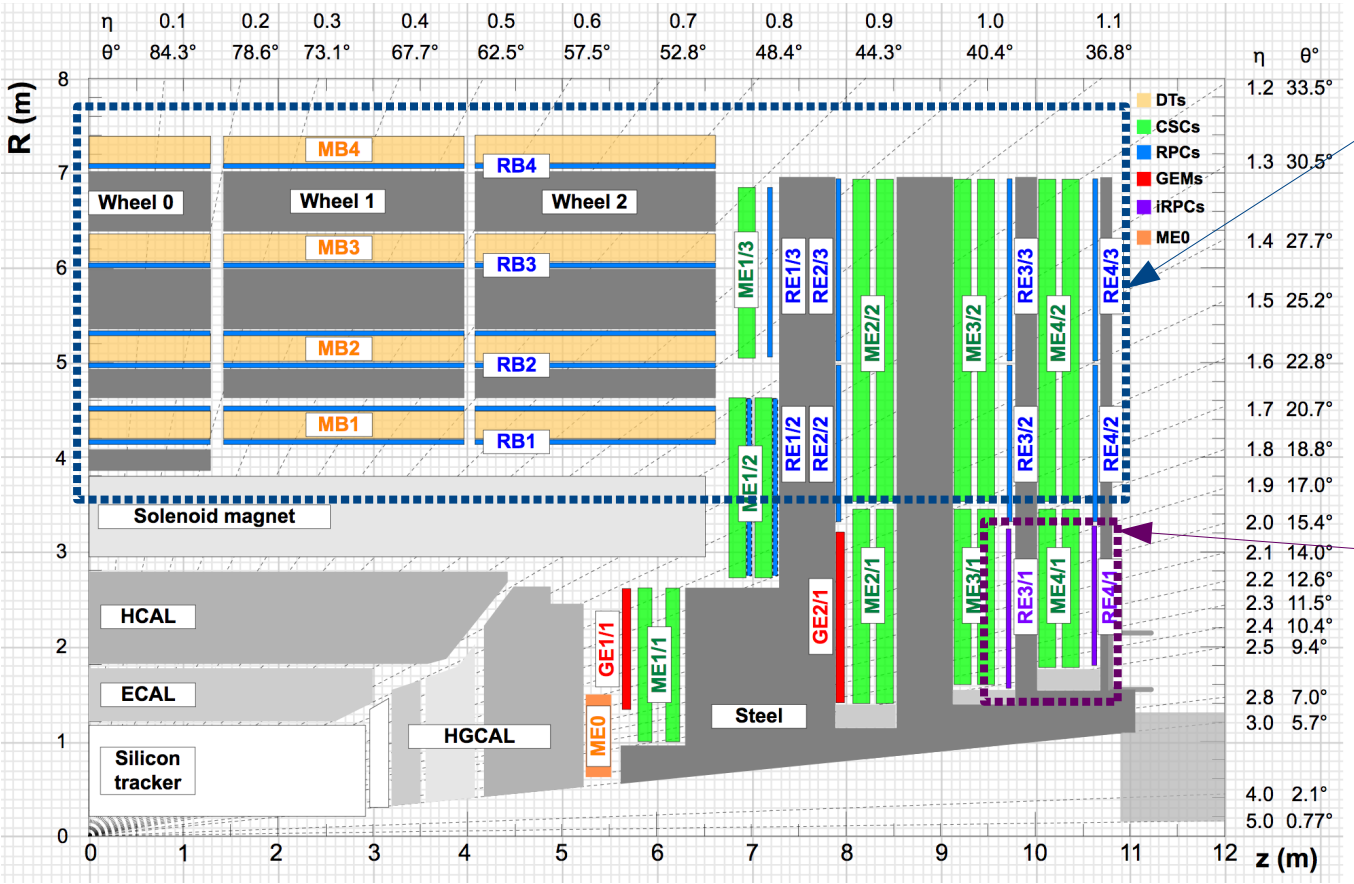




* Module with RPC hit clustering and cluster selection

RPC Phase II Upgrade and Trigger Primitives

RPC Phase II Upgrade



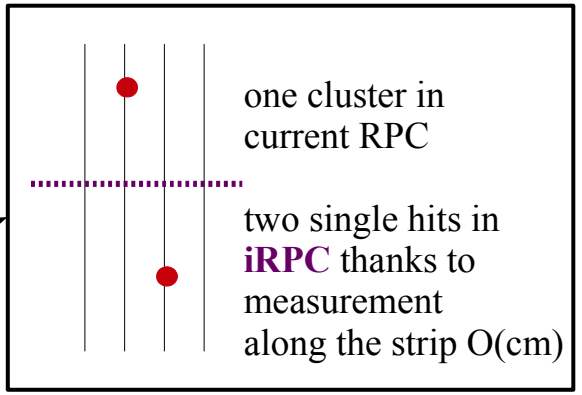
RPC Phase II Upgrade

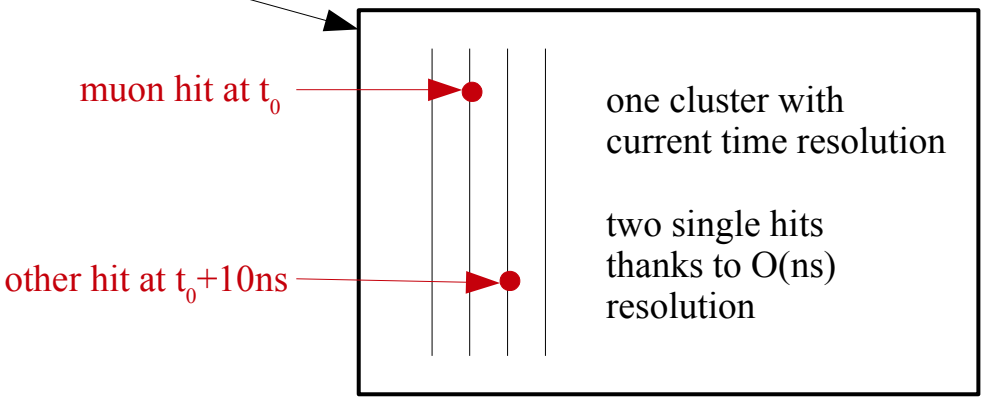
- Link System
  - Improved timing: 25 ns → ~1.5 ns
  - Extra smearing due to signal propagation along the strip
- Improved RPC (iRPC)
  - Extended η coverage with new RE3/1 and RE4/1 chambers
  - Better spatial resolution along the strip (~ 2cm)
  - Time resolution of 1.5 ns

RPC Phase II Trigger Primitives

Impact of the RPC Upgrade on its Trigger Primitives (TP)

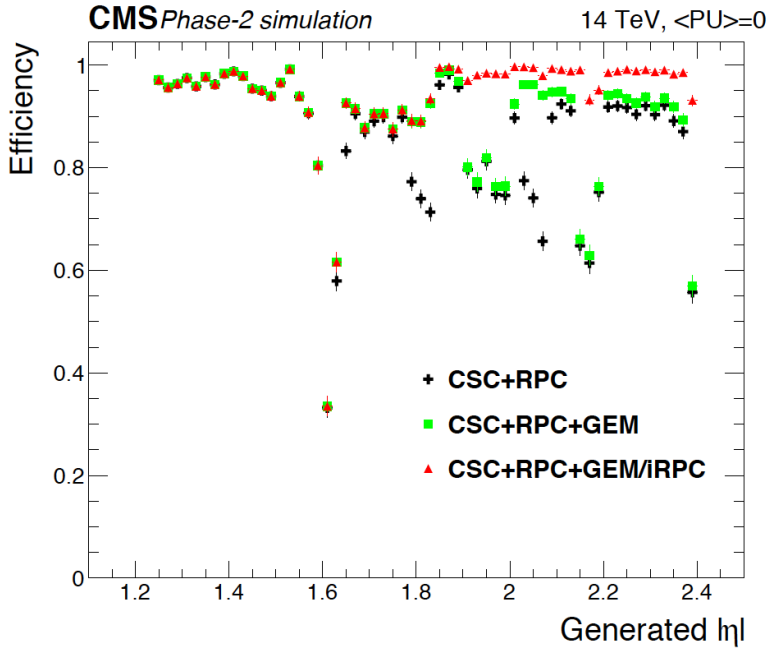
- TP φ resolution
  - TP position defined as the cluster center
  - Driven by the strip pitch and **cluster size**
  - Expect improvement from position along the strip in RE3/1 and RE4/1 (2D measurement in iRPC)
  - Expect improvement from better timing in full detector
  - Yet to be implemented and quantified





RPC in Phase II MTF's

RPC in Phase II MTF's



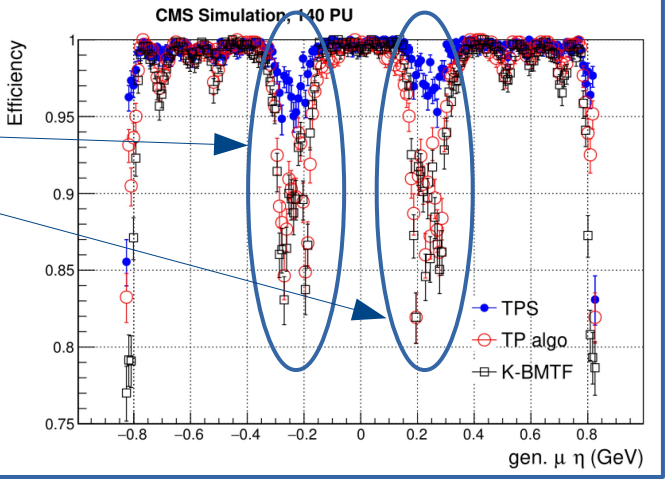
- EMTF
  - Extended η coverage from iRPC importantly improves efficiency for good quality muons
  - Further improvement expected from usage of timing and 2D measurement

- BMTF has currently no access to RPC single clusters
  - Could benefit from them, especially in cracks
  - Work to make them available for MC studies will start soon (maybe possible for run III as well!)
- OMTF already uses 'standalone' RPC clusters
  - Will benefit from better TP quality (true for all MTF)

Michalis Bachtis, David Hamilton

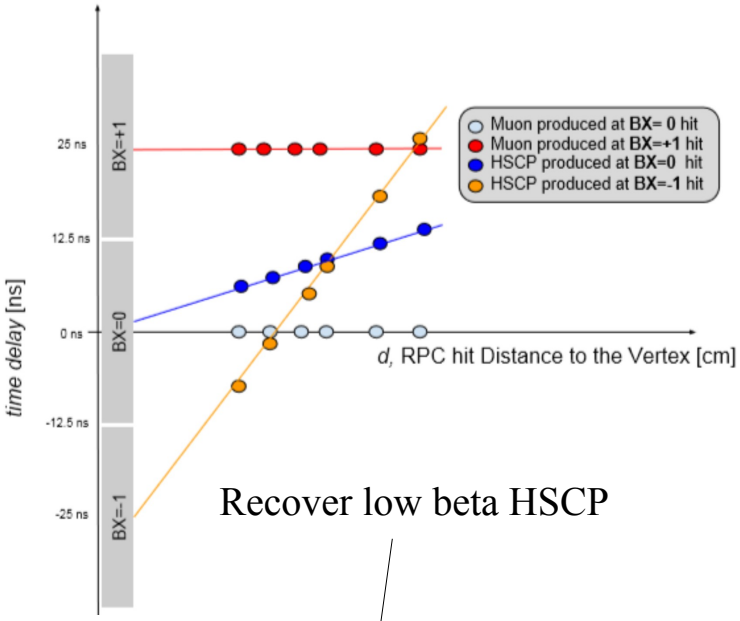
Phase-2 L1 Trigger Muon Algorithms Group Meeting (Nov 6th)

Blue: track + stub from TwinMux

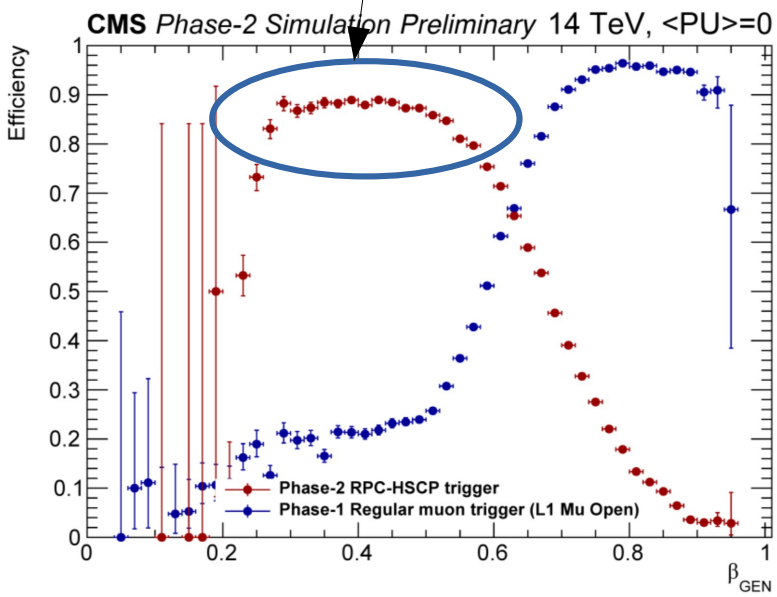


RPC in Phase II MTF's

- 'Slow muons': trigger based on time of flight
  - Algorithm needs to run on several consecutive BX's ($\beta = 0.2$ would require to have concurrent access to ~ 5 BX)
  - Need RPC sub-bx timing propagated in TP sent to MTF's
  - Need to send several BX's to DAQ at each L1Accept (~[-1, 5]) to allow offline analysis
  - Would require special procedure in iRPC η region (only two layers)
    - Additional timing info from tracker, GEM, CSC TP's?
  - More detail in John's talk tomorrow



Recover low beta HSCP



RPC in Phase II MTF's

Some (immature) **thoughts** about the possibilities from time resolution at L1

- 'Prompt muons': geometry based algorithms BUT
  - Spurious hits
    - Arrive in general at a different time then prompt muon hits and degrade p_T assignment
    - Their contribution could be diminished by applying a weighting procedure (or discarding them) based on the time arrival of associated RPC clusters
  - A first look without having to write new algorithms could be provided by the introduction of RPC time info in the input variables of EMTF++ DNN
- 'Displaced muons': could benefit from cluster time for models where the decay is delayed w.r.t. BX

RPC combined to other Trigger Primitives

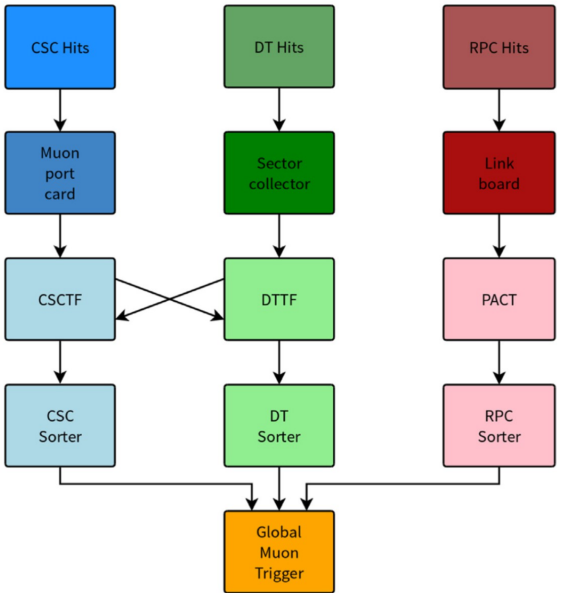
RPC combined to other TP

Possibilities offered by a new L1T architecture

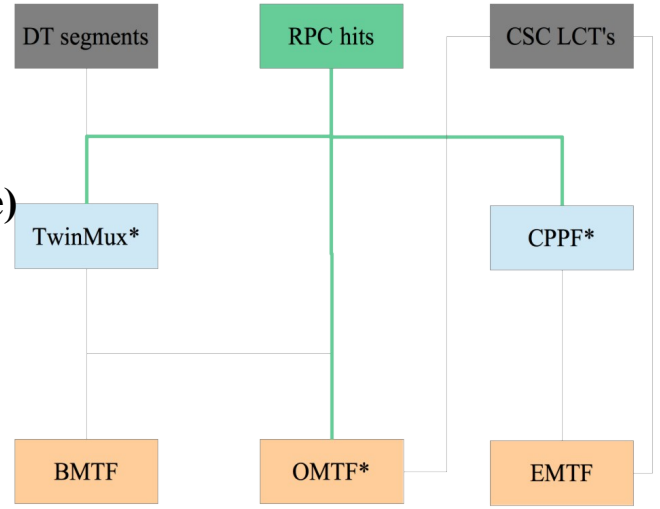
Combining detector information at early stages

- Can increase efficiency and lower rates
- Brings more flexibility and freedom to implement future ideas
- Allows to build more robust TP in view of aging

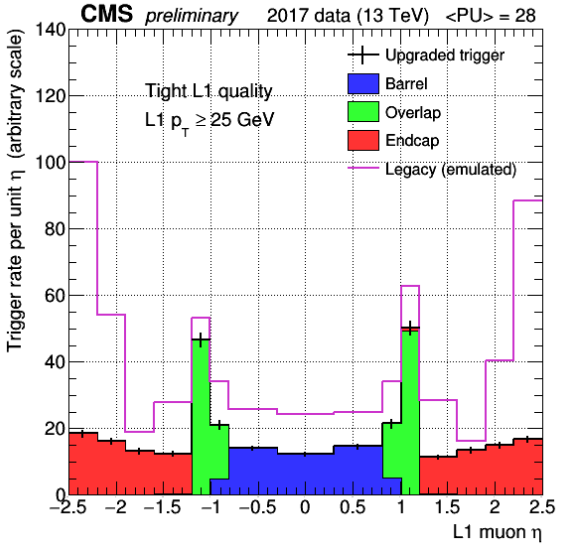
Run I Legacy Trigger

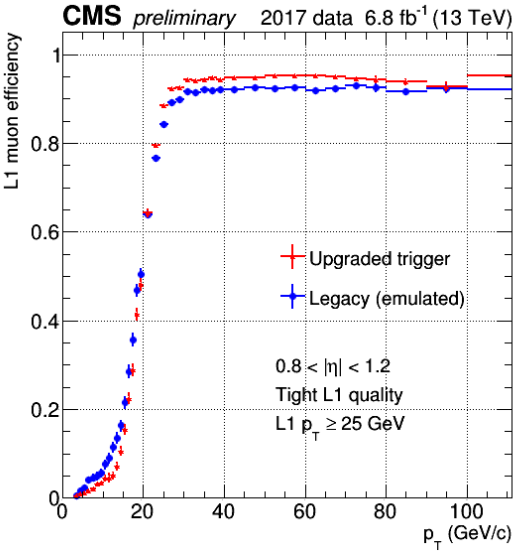


Run II Trigger (Phase I Upgrade)



* Module with RPC hit clustering and cluster selection

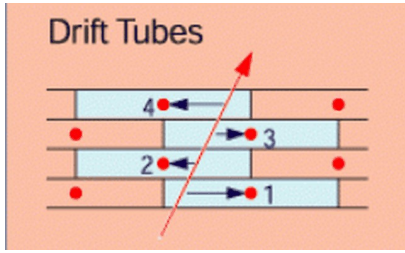




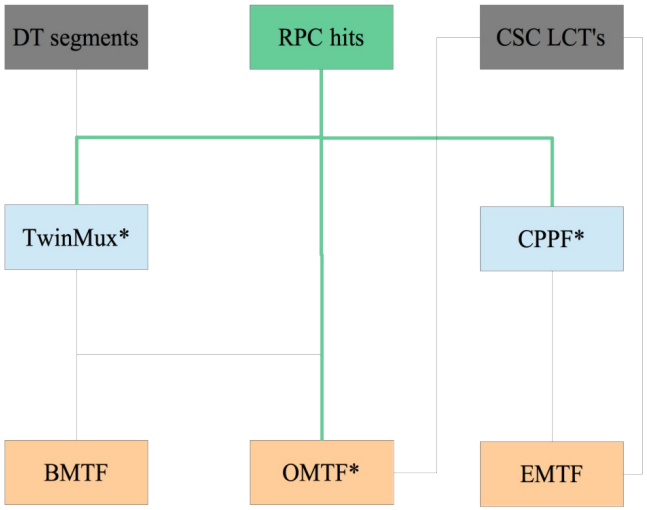
RPC combined to other TP

Possibilities offered by a new L1T architecture

- Combine RPC + DT
  - DT could profit from RPC time to improve segment quality with less layer fired → more robust against aging
  - RPC profit from precise DT position to minimize smearing of RPC timing due to time propagation along the strip → better HSCP trigger, better TP, …

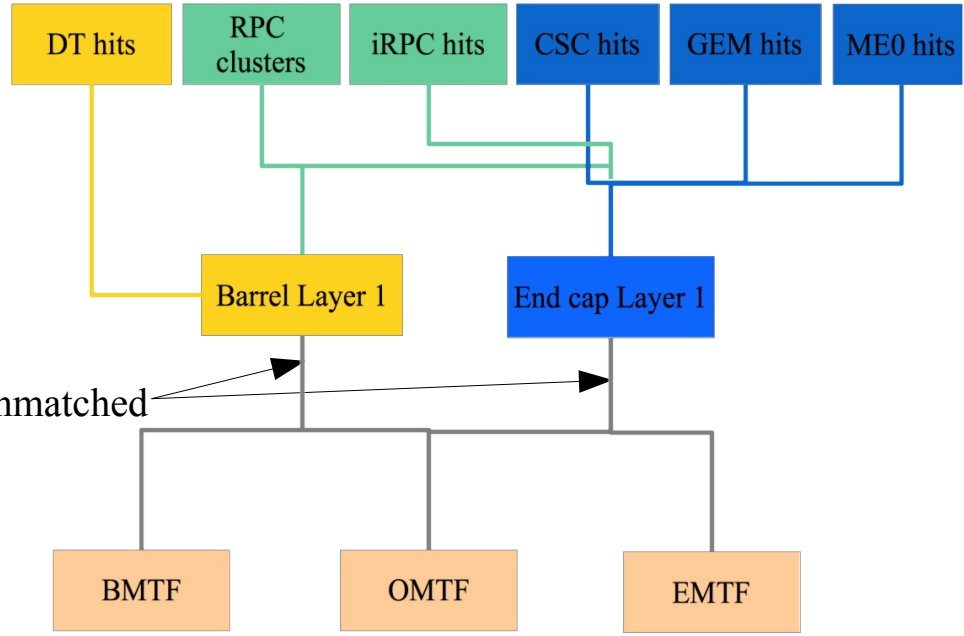


Phase I



* Module with RPC hit clustering and cluster selection

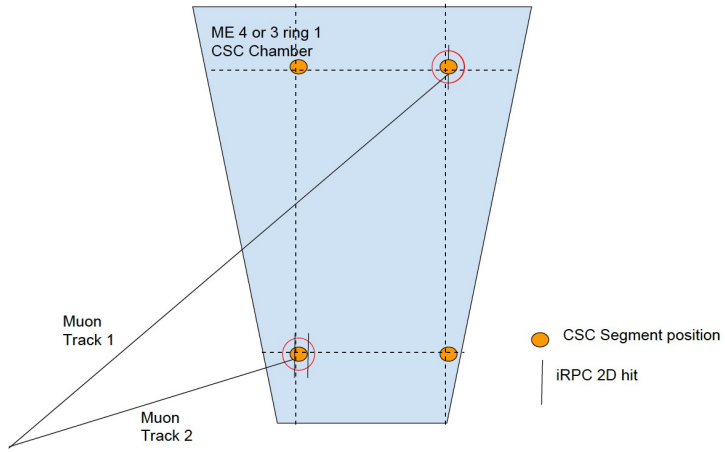
Possibility for Phase II (conceptual)



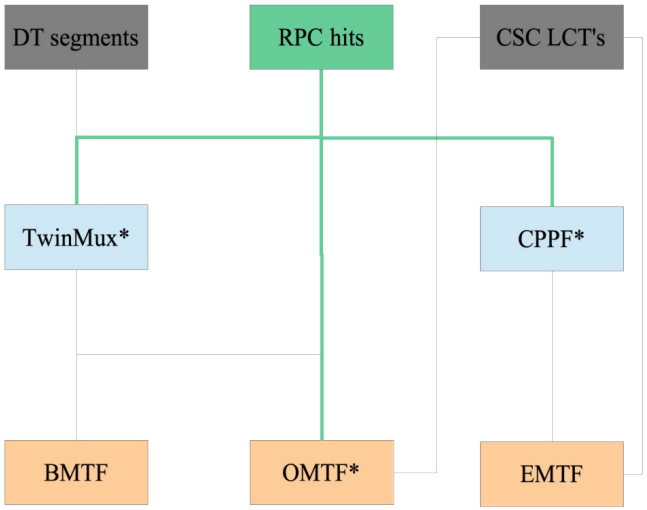
RPC combined to other TP

Possibilities offered by a new L1T architecture

- Build CSC segment already using RPC information (ME3/1 – ME4/1)
  - Could resolve ambiguities when two hits in the same chamber (boosted objects, spurious hits)
  - ~10% probability to have spurious segment at HL-LHC in ME3/1 – ME4/1
  - iRPC can resolve ambiguities in >99% → lower rate



Phase I



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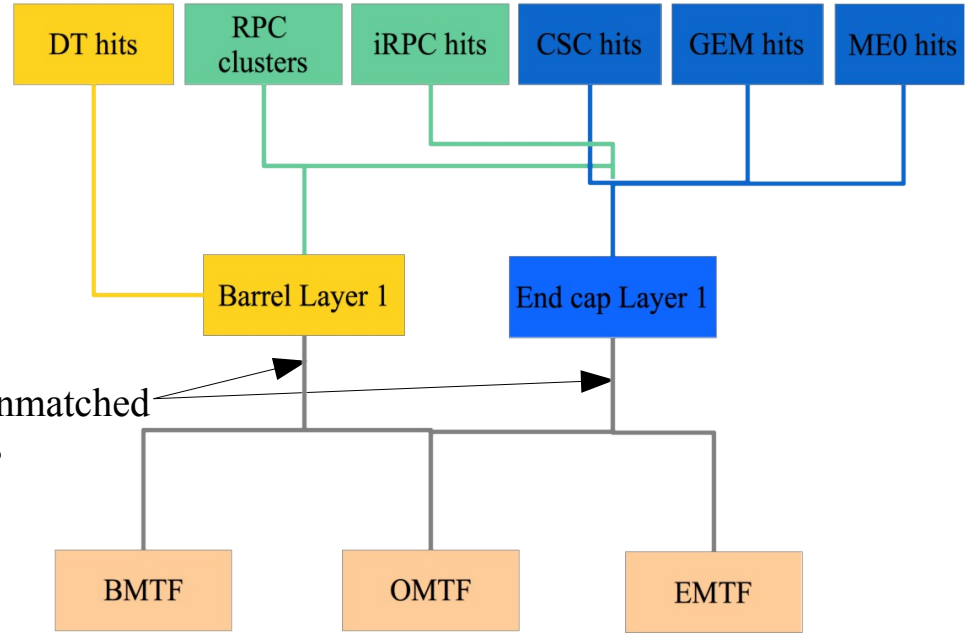
Possibility for Phase II (conceptual)

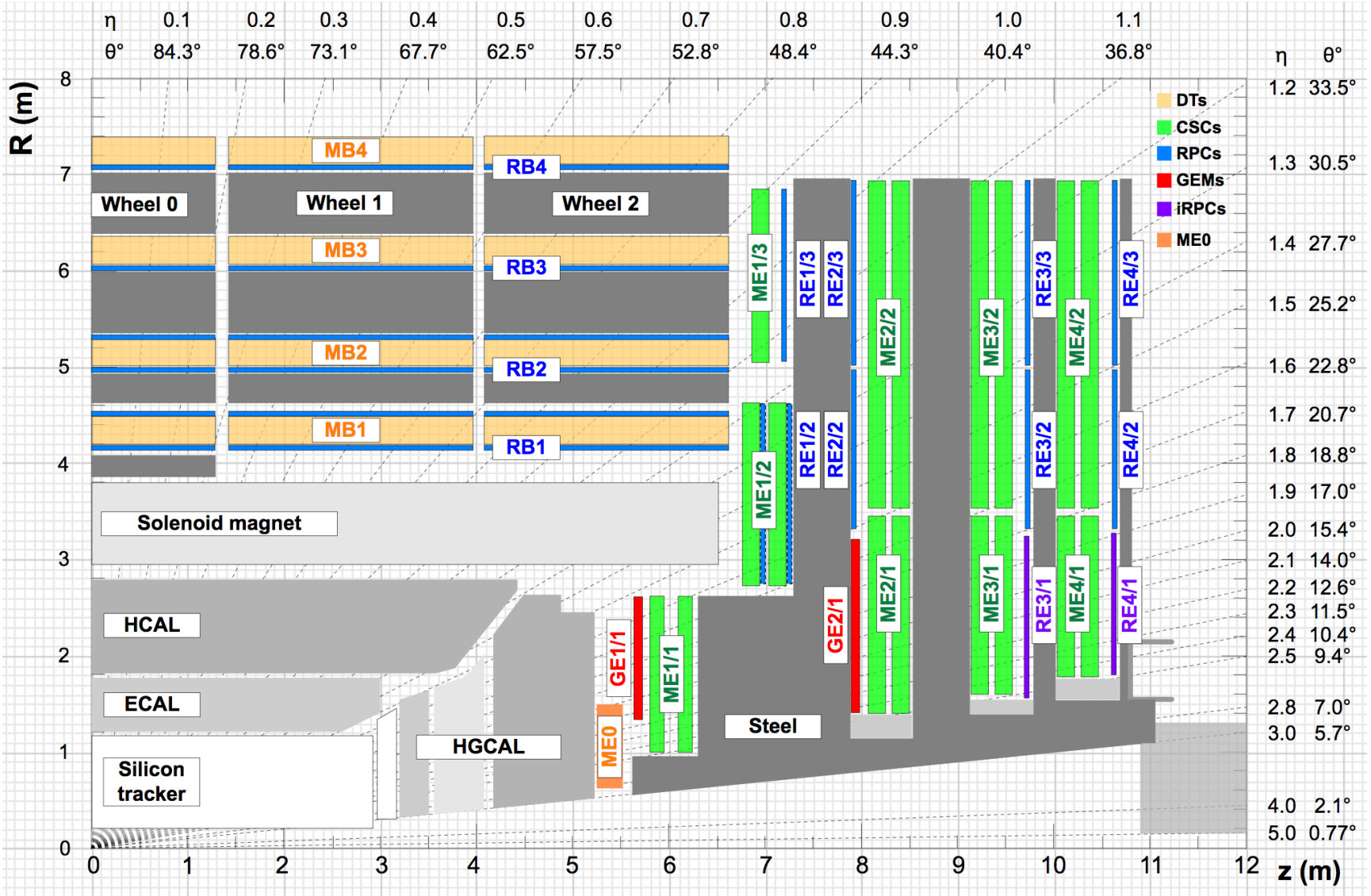


Summary

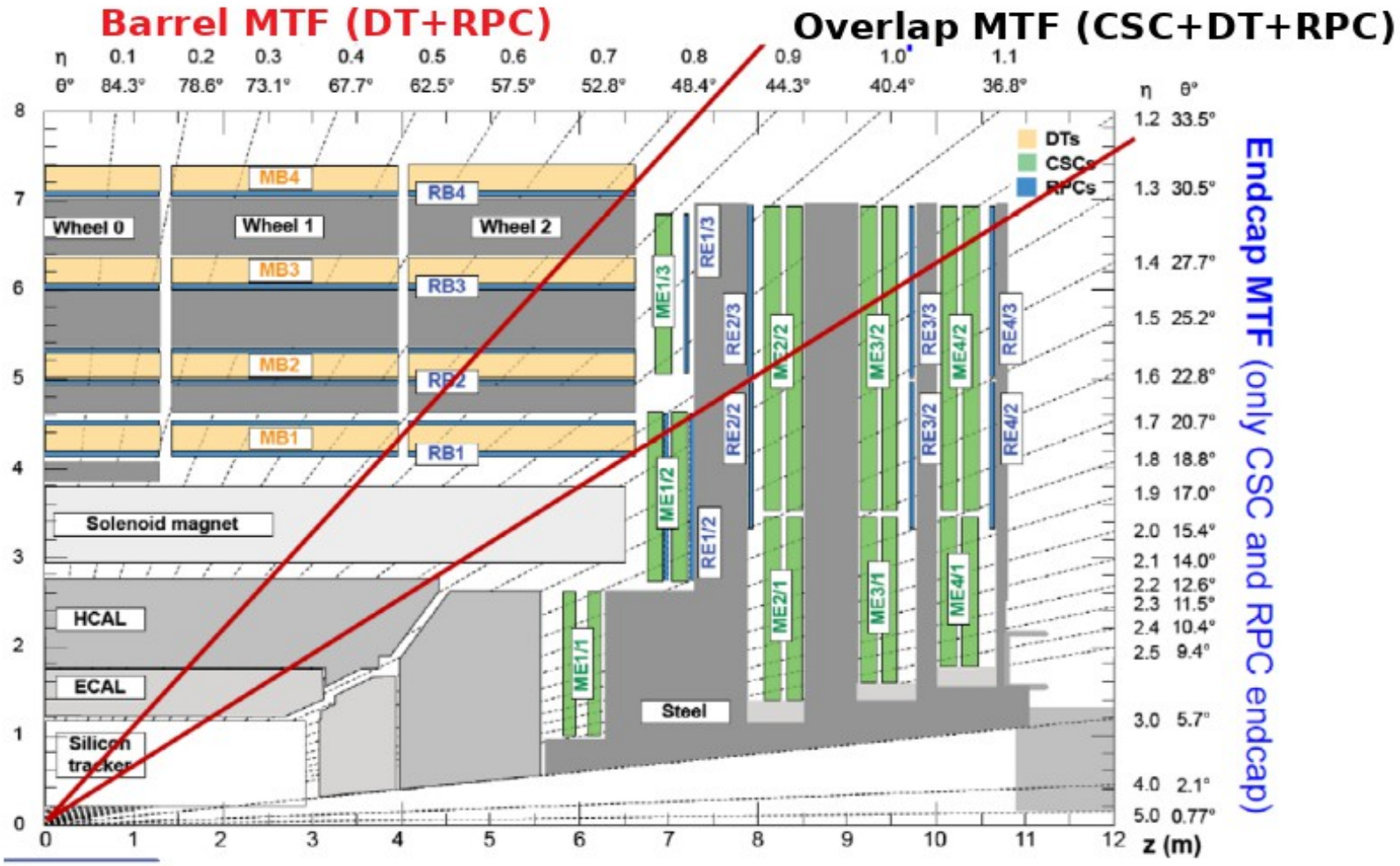
- CMS Muon System shows great redundancy and complementarity
- Usage of the complementarity in Level-1 Trigger has been greatly improved since the beginning of data-taking (Phase 0 → Phase I)
- Phase II Upgrade will bring yet new possibilities for complementarity, redundancy and for direct RPC contribution to Level-1 Trigger
  - Better RPC trigger primitives thanks to better timing and measurement along strip (iRPC)
  - Synergy between RPC and DT: higher DT segment quality and better RPC timing
  - Solve CSC LCT ambiguity in ME3/1 and ME4/1 when several hits in one chamber
  - Enhance RPC participation in MTF's thanks to the above points
    - + extended eta coverage
    - + usage of timing for slow muon algorithms (potentially also useful for displaced and prompt muons)
    - + propagating RPC clusters not matched to other TP to the Muon Track Finders (theoretically possible for run III)

Additional material

Muon System (including upgrade)

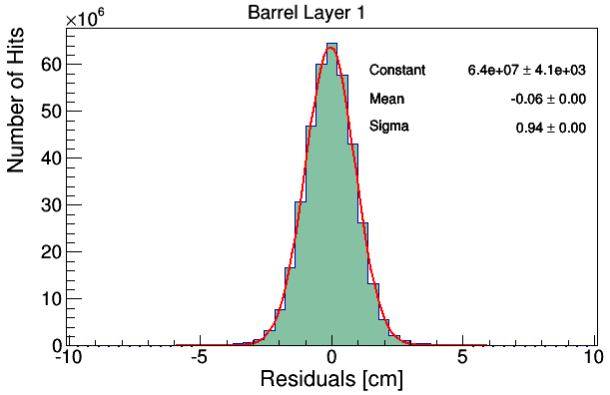


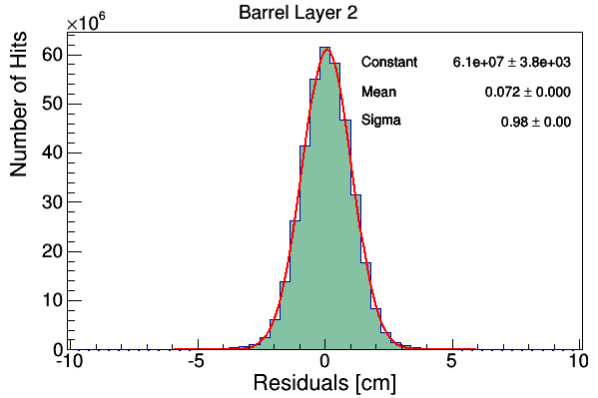
Muon Track Finders

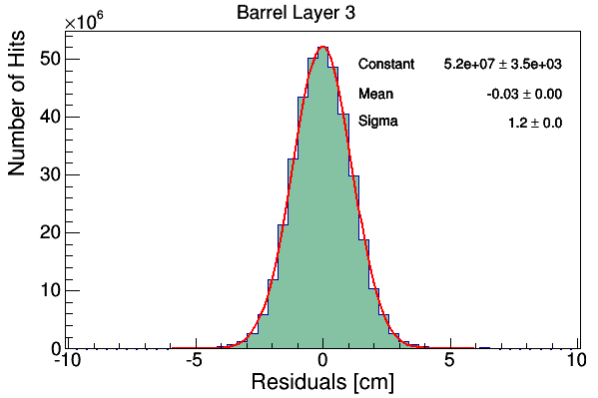


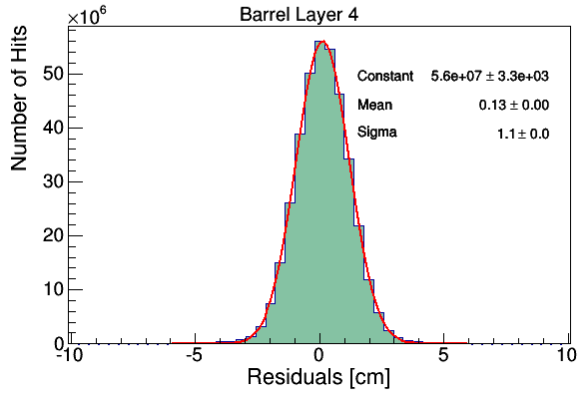
RPC phi resolution

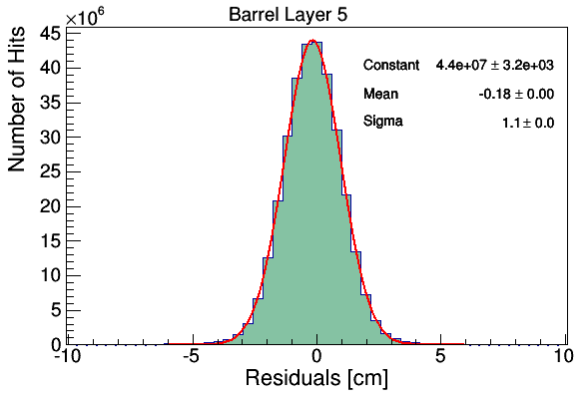
Residuals RPC Barrel **CMS** *Preliminary* 5.27 fb^{-1} (13 TeV, 2016)

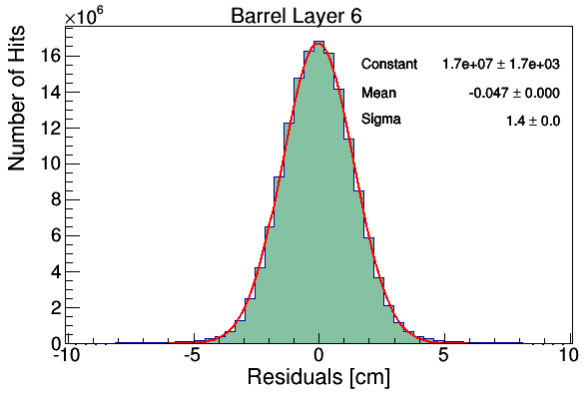






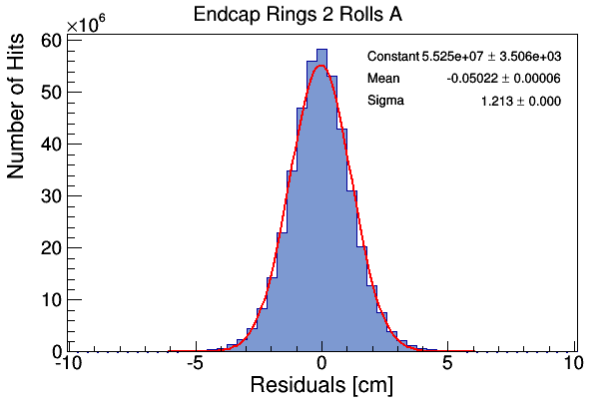


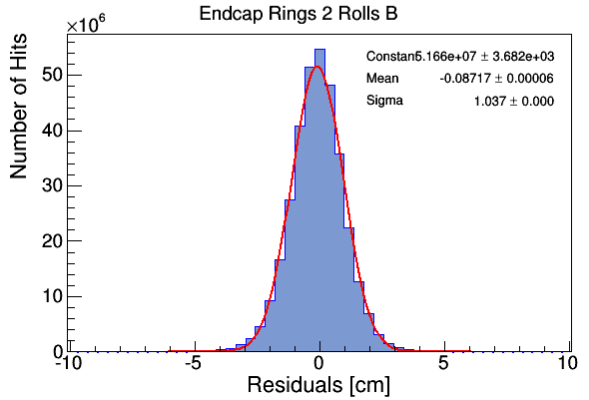


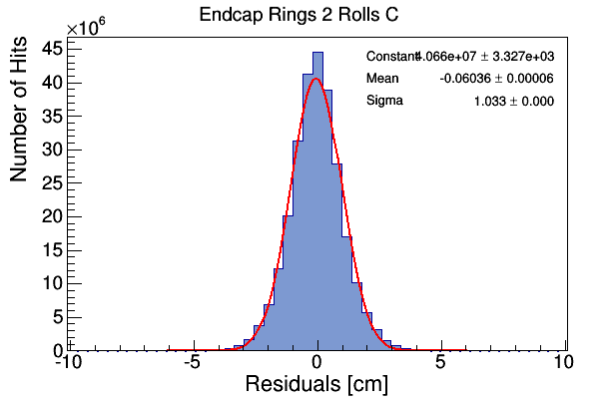


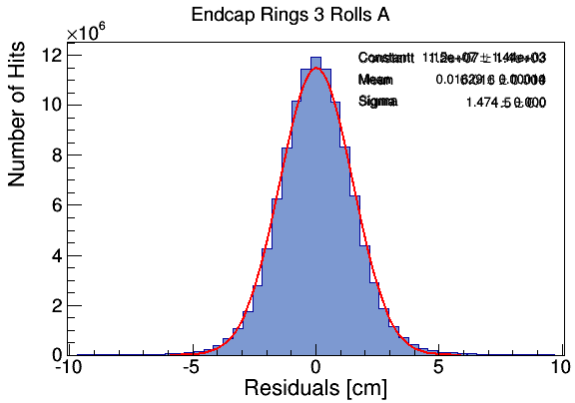
RPC phi resolution

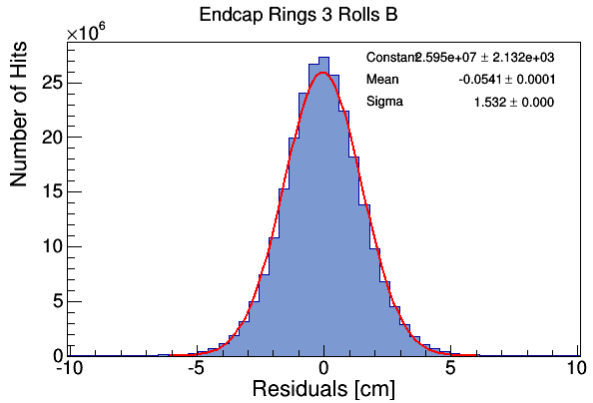
Residuals RPC Endcap **CMS** *Preliminary* 5.27 fb^{-1} (13 TeV, 2016)

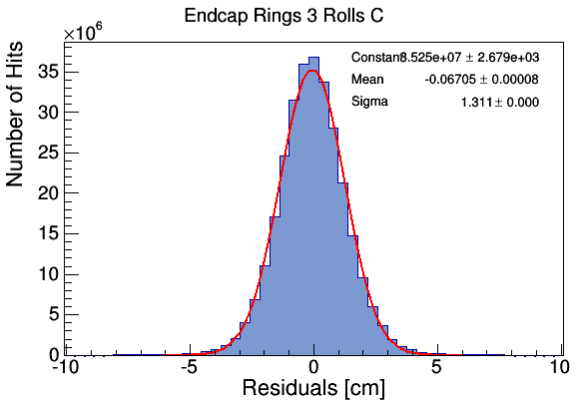




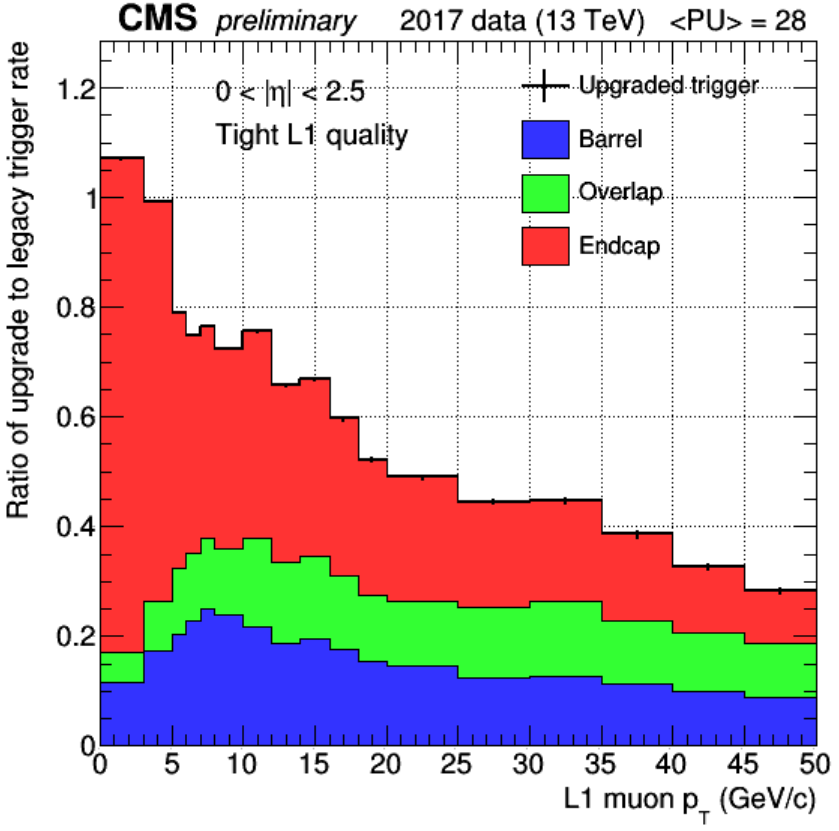




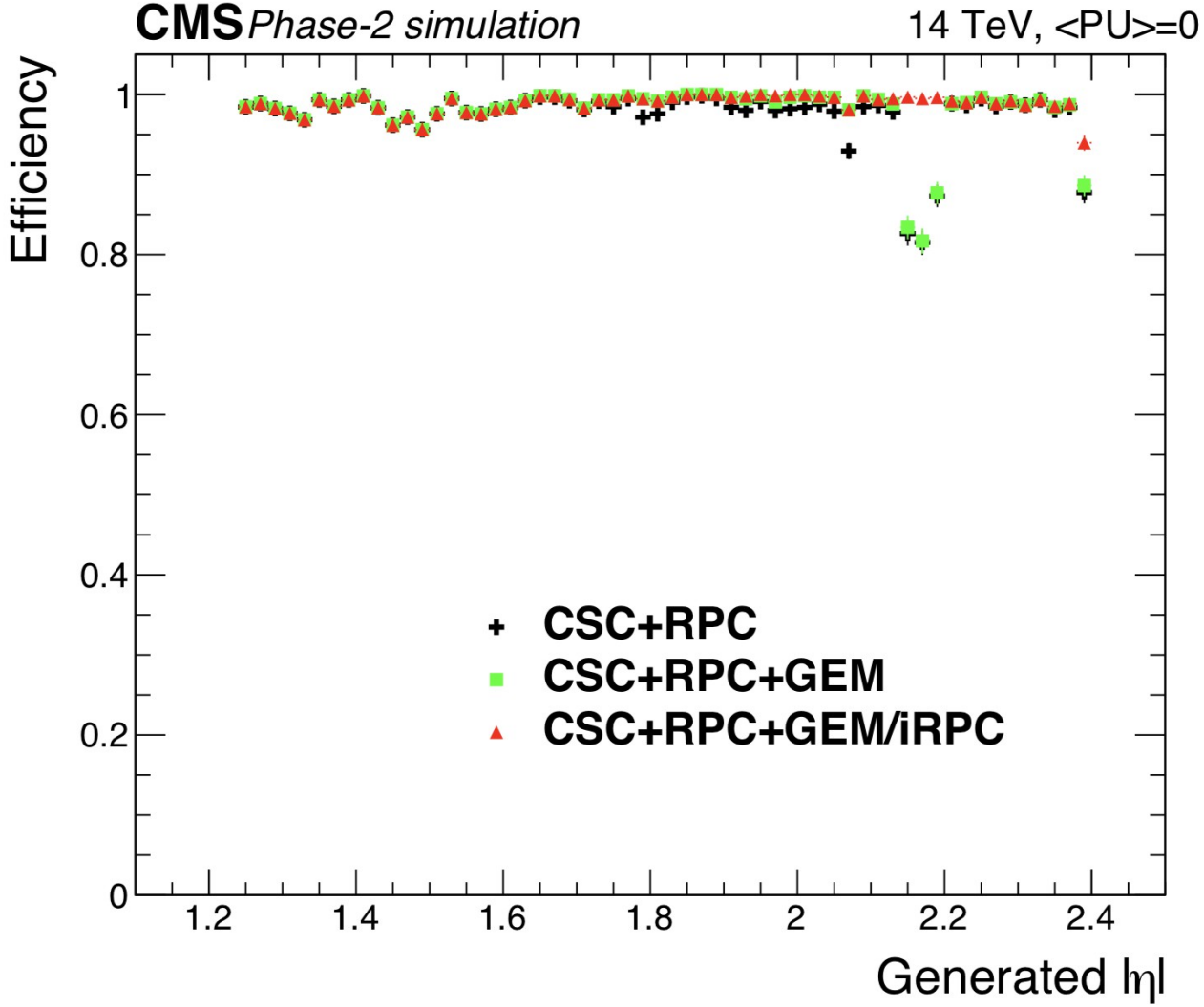




Phase I Muon Trigger Performances

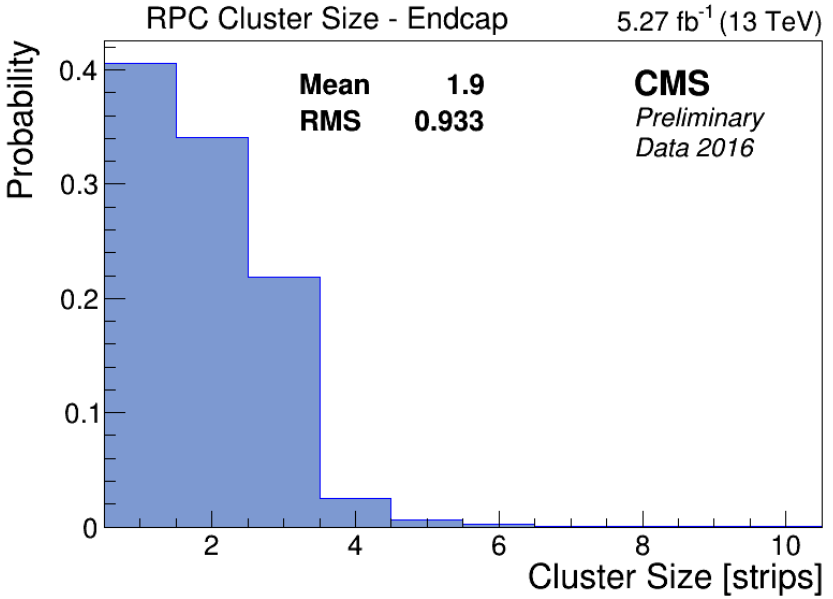


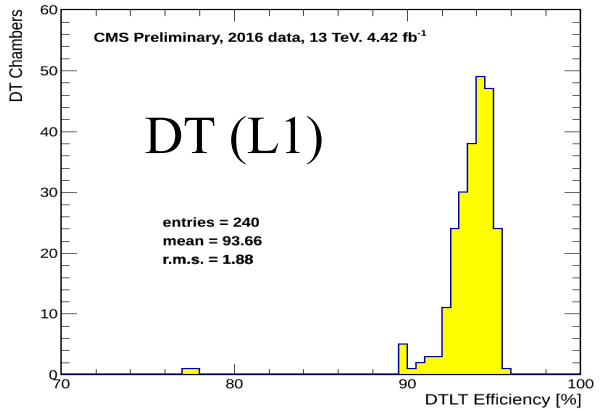
Phase II EMTF

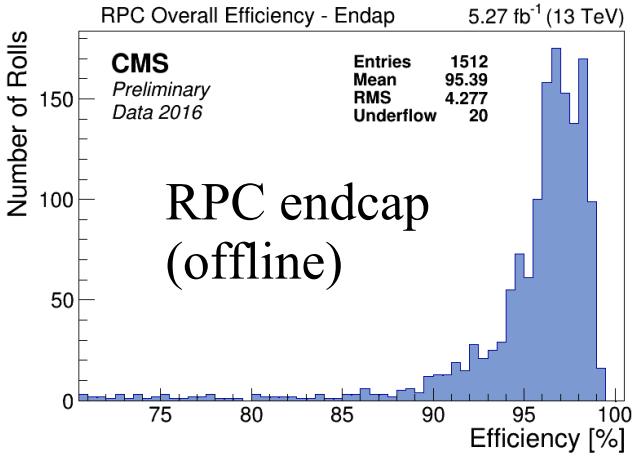


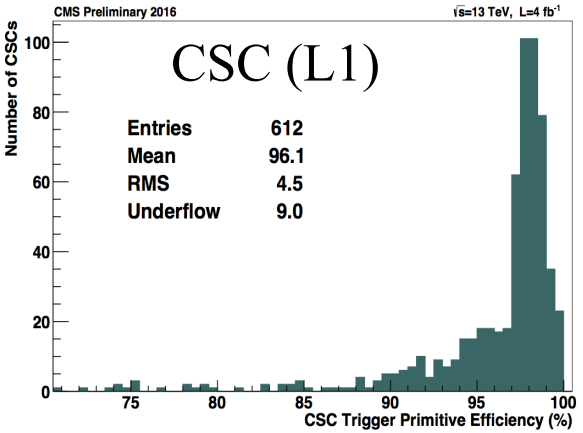
Muon System Performances

- Single hit spatial resolution (φ measurements) – depends on chamber, type of hit, etc
  - DT: Order of **hundreds of µm's**
  - CSC: Order of **hundred of µm**
  - RPC: Order of **cm**
- Timing information available at L1
  - **Bunch crossing granularity**
- Efficiency
  - **~93-96%** for all muon detectors at L1









Online data format proposal

		Cluster No. x					
Data frame format (bit)	Number of Clusters (1~10) (Maximum = 10)	Center of Cluster (1~96) or (97 ~192)	Cluster Width (8 strips)	Cluster sub-bx resolution(1~16)	LB Number	Partition Delay	EOD
173	4	8	3	4	2	2	1

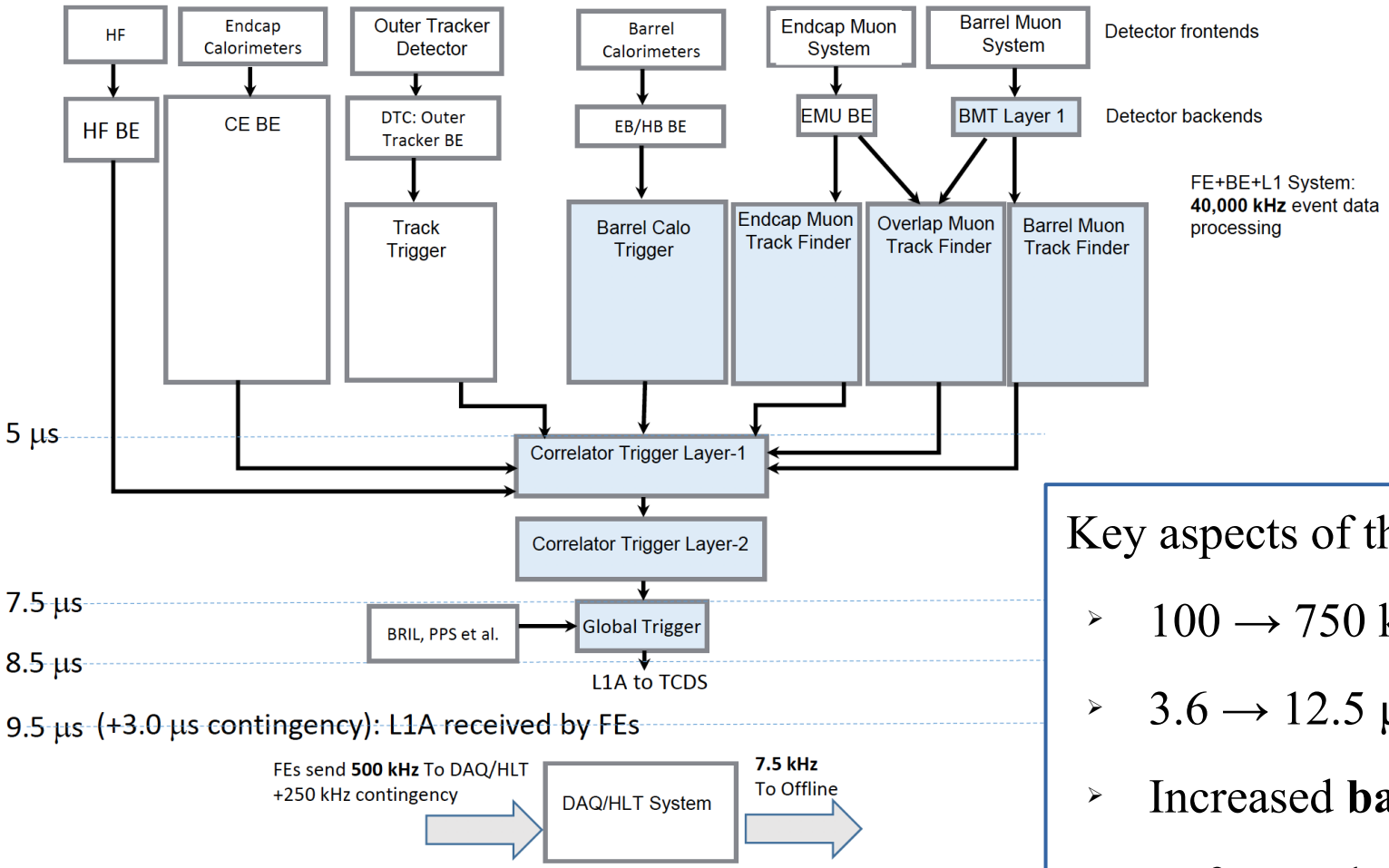
Timing Signeture (bit)
13

Total Bits
186

$$4 + \underbrace{(8 + 3 + 4 + 2) + \ldots + (8 + 3 + 4 + 2)}_{\text{Cluster No. 1} \quad \text{Cluster No. 10}} + 2 + 1 =$$

$$4 + 10 \times (8 + 3 + 4 + 2) + 2 + 1 = 173$$

Phase II Level-1 Trigger

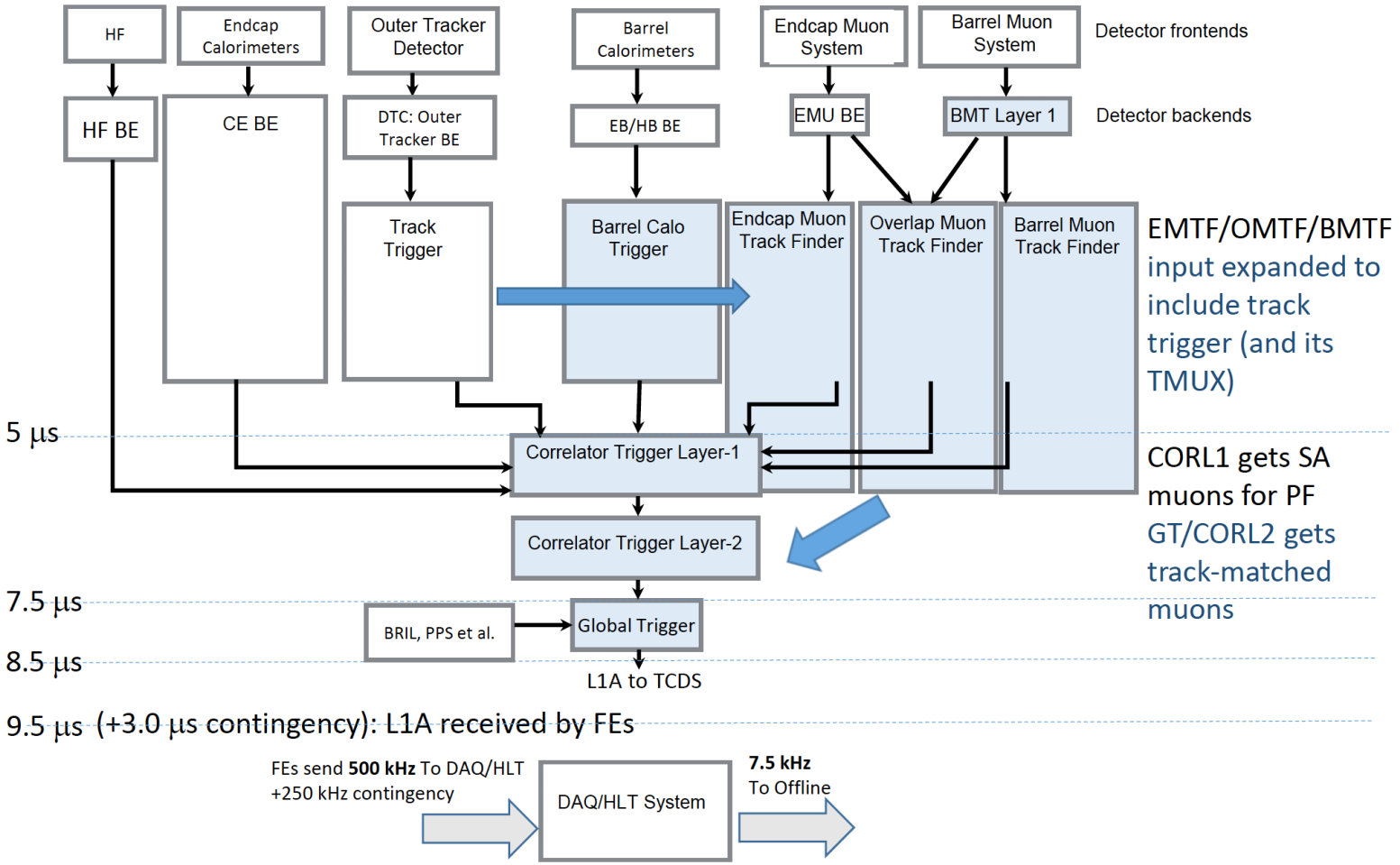


J. Berryhill at L1T Annual Review (Nov 13th)

Key aspects of the L1Trigger Upgrade

- 100 → 750 kHz **rate** to HLT
- 3.6 → 12.5 μs **latency**
- Increased **bandwidth**
- Refactored architecture
- Availability of tracking information!

Phase II Trigger



J. Berryhill at L1T Annual Review

Phase II Muon Track Finders

Jia Fu (L1T)

- EMTF++ (P_T assignment via DNN)
  - Higher plateau
  - Sharper turn-on
  - Flatter efficiency in η

	ME1/1	ME1/2	ME2	ME3	ME4	RE1	RE2	RE3	RE4	GE1/1	GE2/1	ME0
ϕ	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
θ	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
bend	✔	✔	✔	✔	✔							✔
F/R	✔	✔										✔
ring			✔	✔	✔							

+ pattern straightness
+ zone
+ median theta