# A study of CMS RPC trigger efficiencies using Data-Driven performance evaluation method at LHC

**Suman B. Beri[1], Marcello Maggi[2], Archana Sharma[1], Salvatore Alessandro Tupputi[3]**

**1: Panjab University, Chandigarh**

**2: Sezions INFN di Bari, Itly**

**3: Universit`a degli Studi di Bari, Itly**


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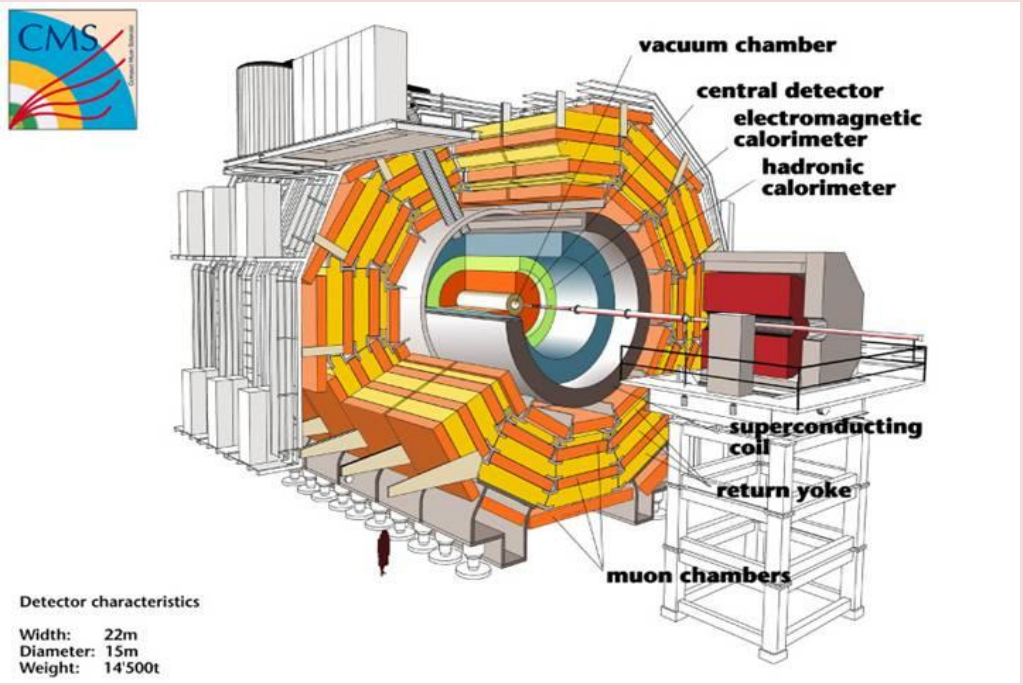
# Outline

- Introduction
  - Compact Muon Solenoid (CMS)
  - CMS muon system in trigger and reconstruction
- Motivation and method description
- Results
- Summary and perspectives

# Compact Muon Solenoid (CMS)

- In the LHC (Large Hadron Collider) accelerator proton beams will collide with energy up to 7-on-7 TeV and luminosity up to $10^{34}cm^{-2}s^{-1}$
- CMS is a general purpose detector designed to detect LHC collisions products and search for new physics signatures.




***LHC started successfully in this year and CMS has recorded 43.17 $pb^{-1}$ Integrated luminosity at 7TeV centre of mass energy***

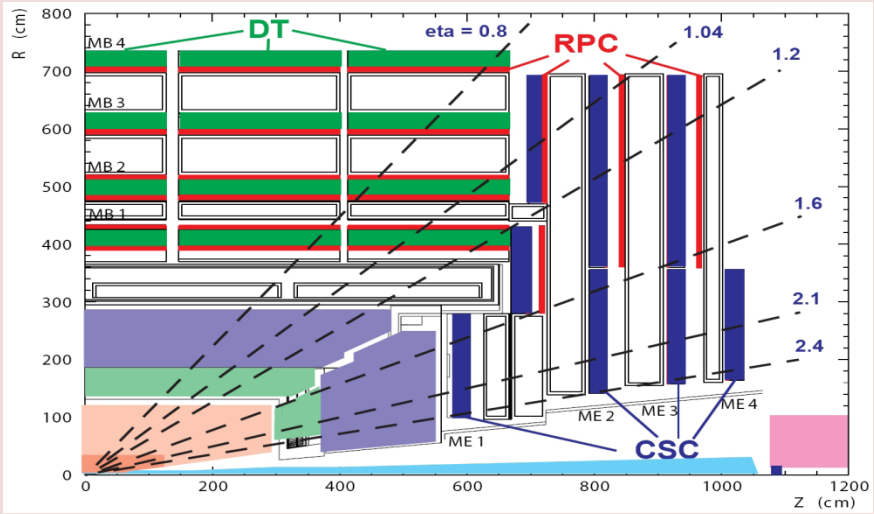
**Major Components of CMS Detector :**

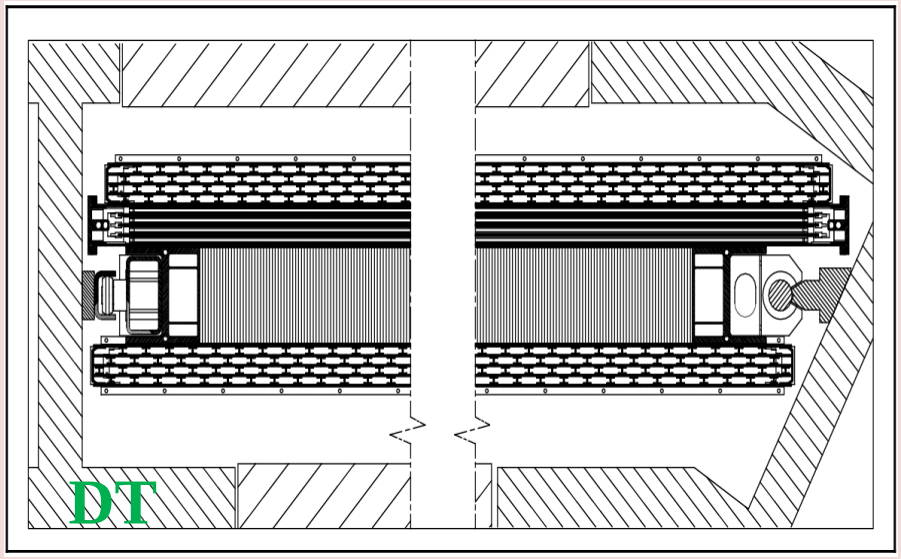
1)Central Tracker
2)Electromagnetic Calorimeter
3)Hadron Calorimeter
4)Superconductive Magnet
5)Muon System

**Events selection stages:**

1)Level 1 Trigger (L1)
customized electronics
decision in 3.2 μs
2)High Level Trigger (HLT)
reconstruction algorithms running on commercial computing farms

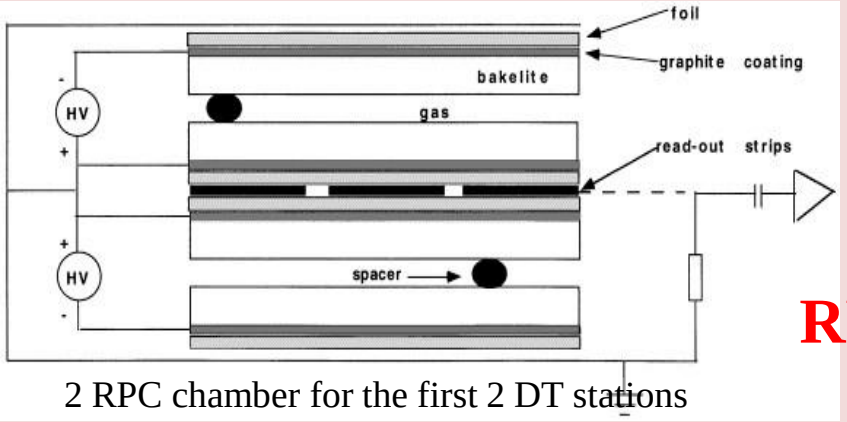
# CMS Muon System




**CMS detector specially optimized for muon measurement. The muon system is made of:**
Drift Tubes (DT) in barrel, Cathode Strips Chambers (CSC) in endcap upto η = 2.1 and RPC covering both barrel & endcap upto η = 1.6 (start-up).

3 Super Layer (2φ and 1θ) for the first 3 stations
2 Super Layer (2φ) for the last station
4 Layer for each Super Layer
~100 μm spatial resolution

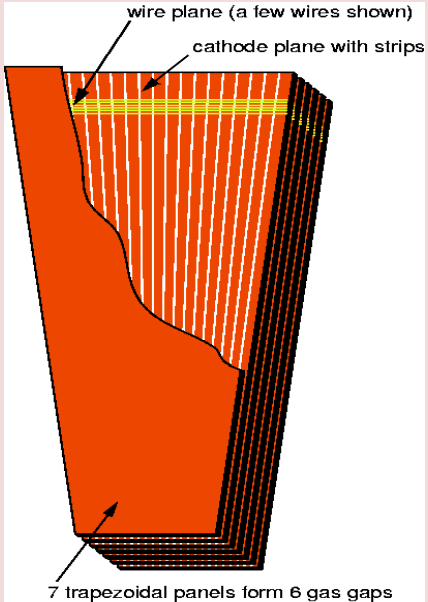



## RPC

2 RPC chamber for the first 2 DT stations
1 RPC chamber for the last 2 DT stations and for the CSC chamber till |η|<1.6
~ ns time resolution

## CSC

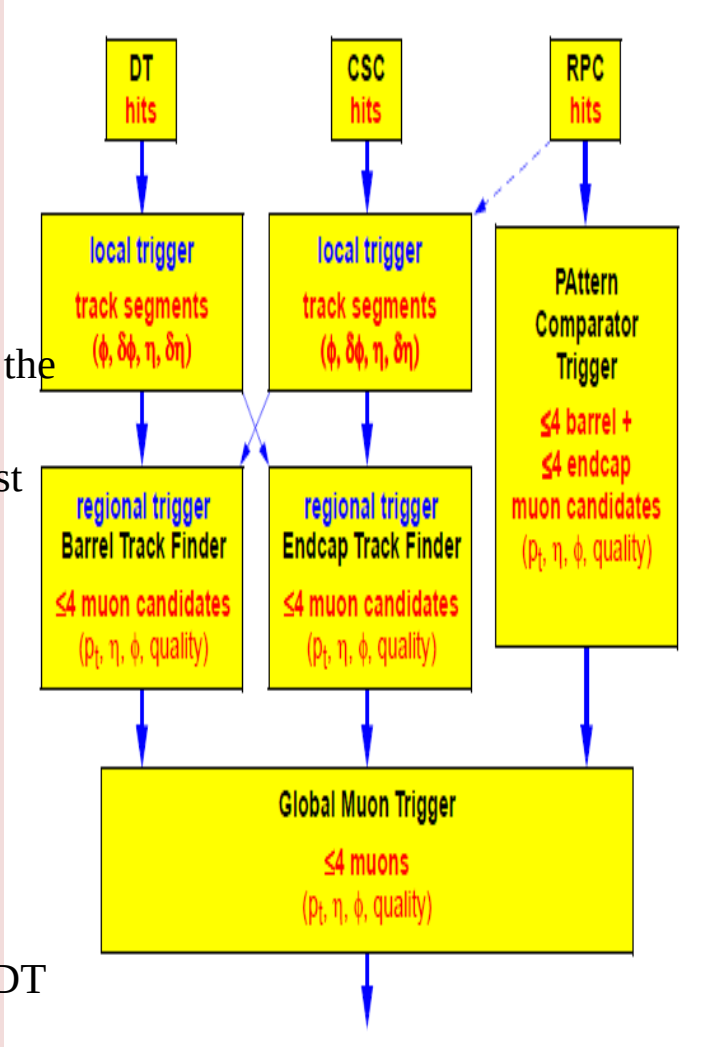
6 gaps (Layers) for each camber
1 wire plane and 1 cathode plane with strips
~100 μm spatial resolution



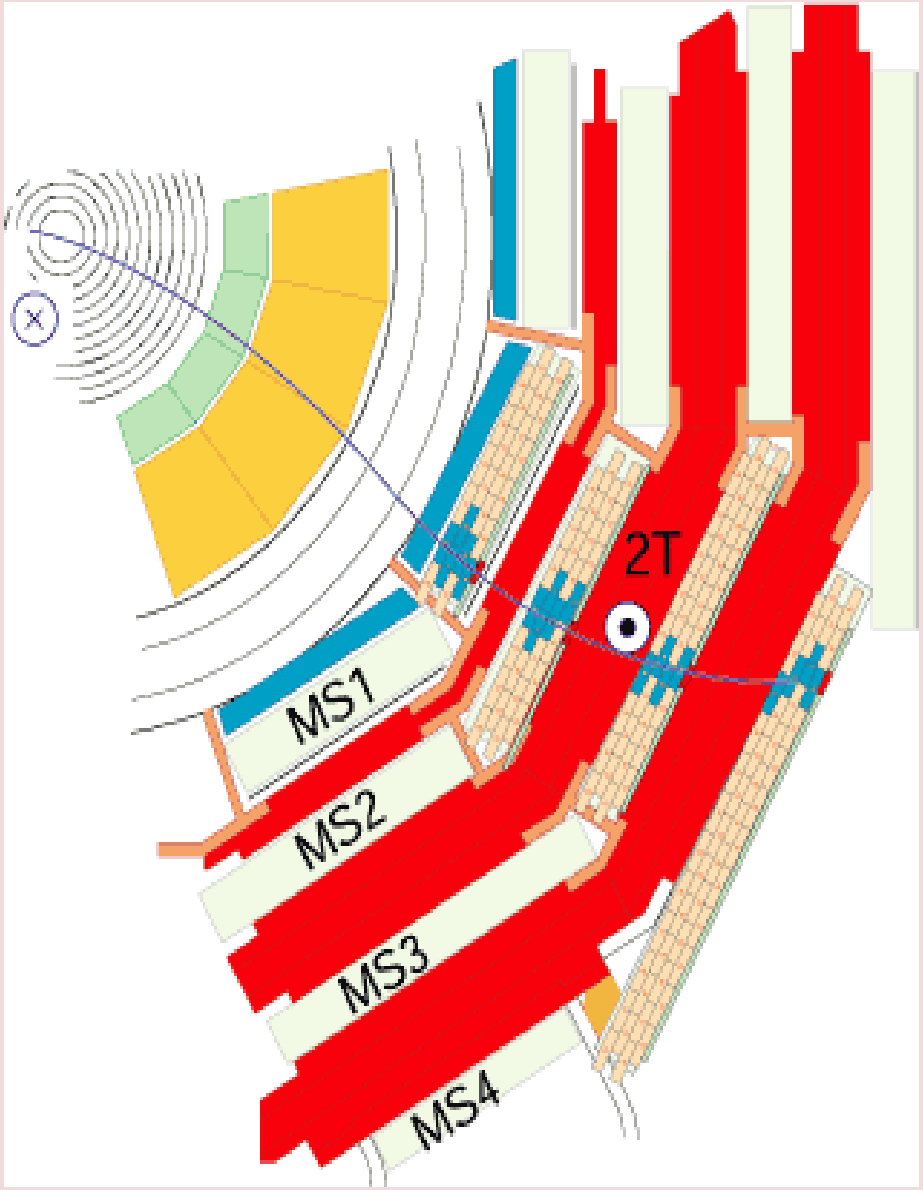
# CMS Muon Trigger

- Muon trigger processing is delivered in two different stages:
  - Regional Trigger (subdetector-wise) data processing
  - Global Muon Trigger algorithm processing (merging
  - information by the muon subdetectors)
- Regional Triggers:
  - DT & CSC provide up to four regional trigger candidates
  - RPC provide up to four regional trigger candidates both in the barrel and endcap regions
  - The candidates are selected according to highest $p_T$ and best measurement quality
- Global Muon Trigger (GMT) algorithm
  - Collects regional triggers information
  - The algorithm outputs GMT candidates seeking for good quality (regional) trigger candidates.
  - A GMT candidate can be the result of
    - Single detector measurement or…
    - Two complementary detectors measurements (RPC&DT or RPC&CSC)
  - Transmits up to 4 GMT candidates to L1 decision logic

**Muon Trigger Data Flow**



# Muon Tracks reconstruction in the muon stystem




Muon identification in CMS is accomplished with information from tracking systems and calorimeters (MIP and isolation bits).

In the muon system:

1.A seed from information at station level is created (point and direction)

2.Extrapolation of the seed to adjacent stations segments/hits (Kalman filter)

3.Application of different quality criteria ($\chi^2$, re-fit...)

4.The reconstructed object is called Stand-alone muon

Stand-alone reconstruction algorithm is employed both in on-line HLT stage (producing so-called L2 muons) and off-line reconstruction.

The L2 muon object keeps trace of the L1 muon object corresponding to the hits employed

# A Data Driven trigger performance evaluation method

- GMT algorithm keeps trace of the muon sub-system which provided the candidates measurement(s)
- **Such feature can be exploited for evaluating in a data-driven fashion the trigger performance of each muon sub-system**
  - By considering the trigger candidates provided by a given sub-detector using its complementary one as reference.
- Motivation
  - Such method is relevant in cross section calculation scenarios, for trigger efficiency evaluation unbiased by MC guesses

# Method implementation

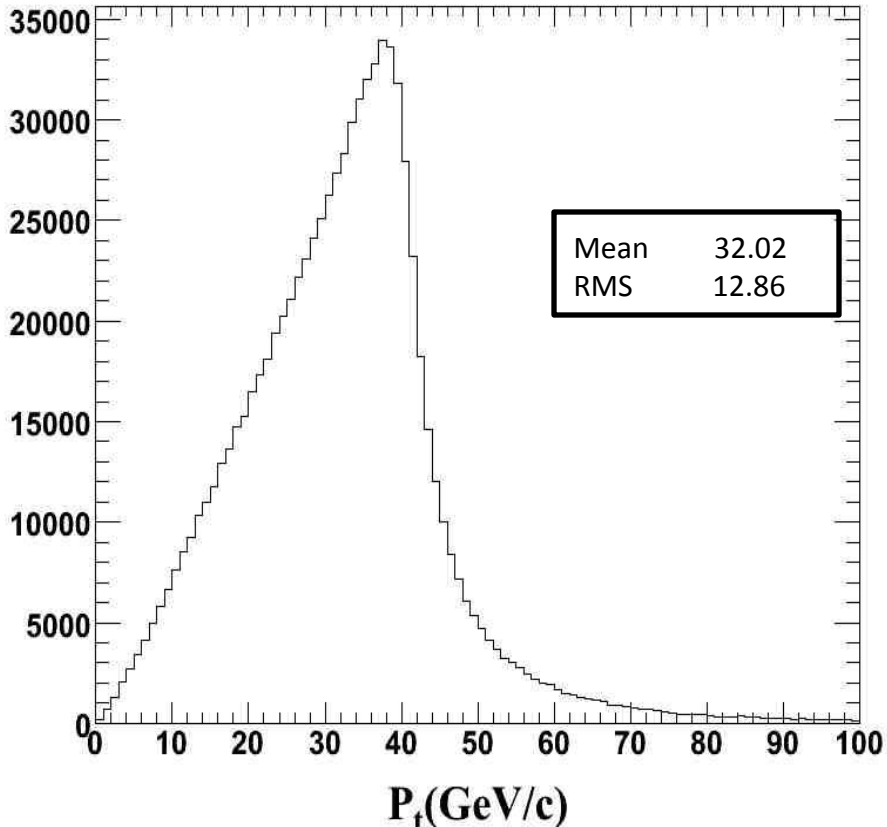
- For RPC trigger performance evaluation
  - **all the events with GMT candidates provided by the DT's in barrel or CSC's in endcaps are selected**
  - **amongst these, the number of events with candidates provided also by RPC is counted up.**
- **With such approach only RPC regional candidates good enough to be accepted by GMT are accounted for**
  - Thus the method measures the actual contribution of RPC system trigger to the L1 final decision
  - Furthermore GMT candidate is required to fulfill at least one L1 muon paths in the Global Trigger (GT) table.

# Analysis features and tasks

- Method validated with Monte Carlo:
  - Sample simulating $pp \rightarrow W+X \rightarrow \mu\nu+X$ process
  - High Transverse momentum (70-200 GeV/c) single muon events
  - Low Transverse momentum (0-10 GeV/c) single muon events
  - Pythia 6.
  - Detectors response simulation with GEANT4
    - RPC detectors efficiency plugged in the simulation is 95%.
- Results of data-driven method compared with a 'classic' MC-truth performance evaluation

**$p_T$ spectrum of muons from W → μν**

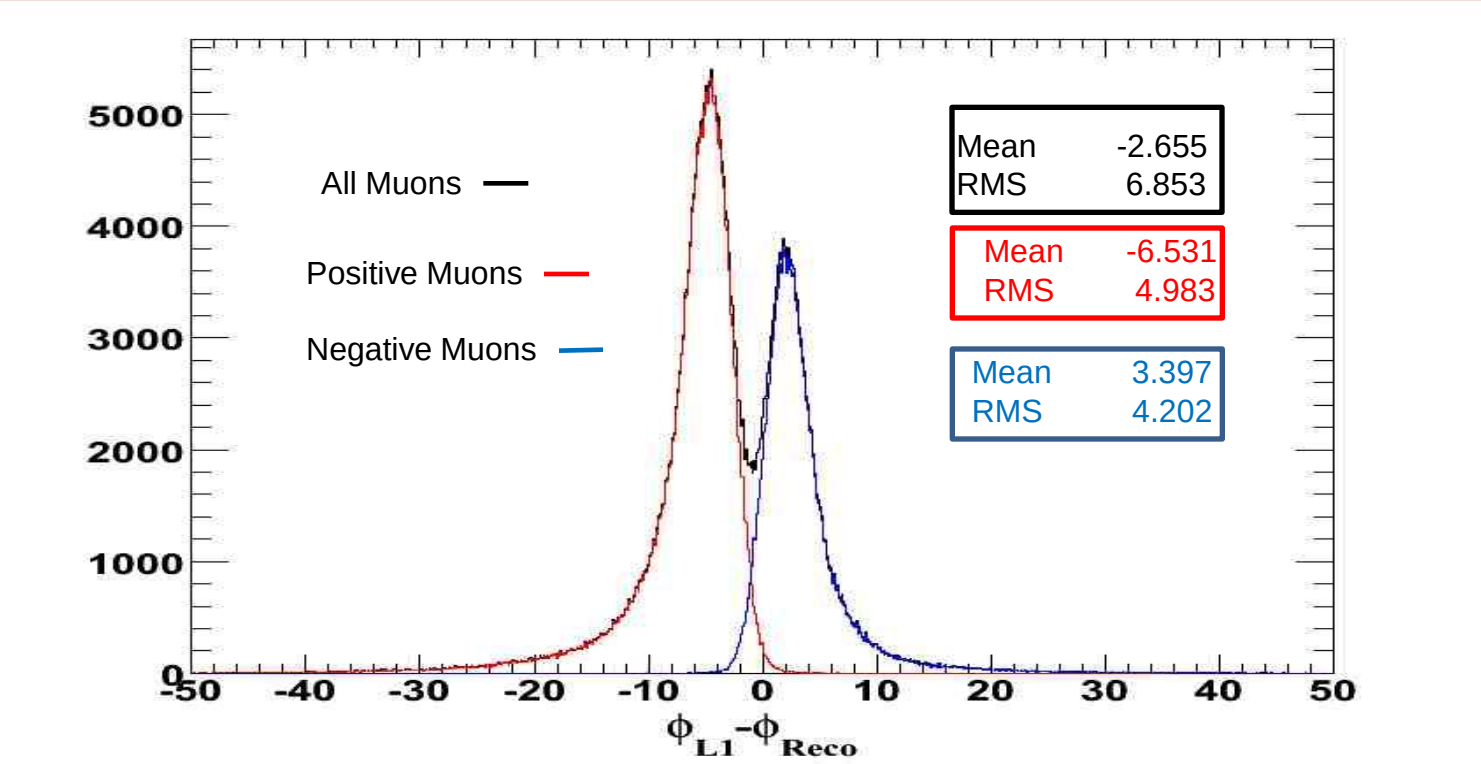
- Goal
  - **Achieve agreement between two methods**
  - **Flat efficiencies curves over $p_T$ range**



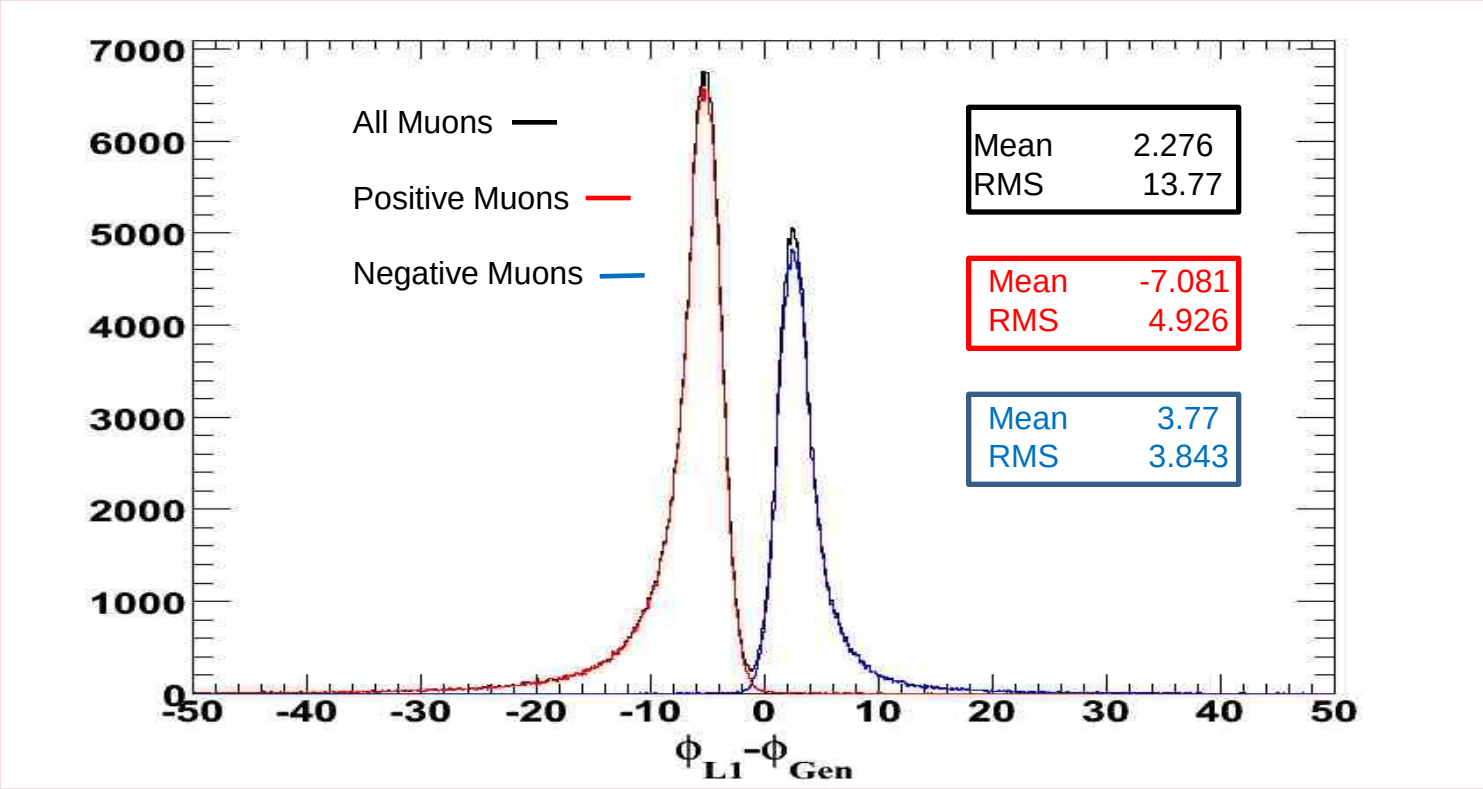
# Data-driven method

- Events with just one stand-alone muon are selected
- GMT candidate extracted from muon track seed information

**GMT residuals with respect to STAND-ALONE MUONS**



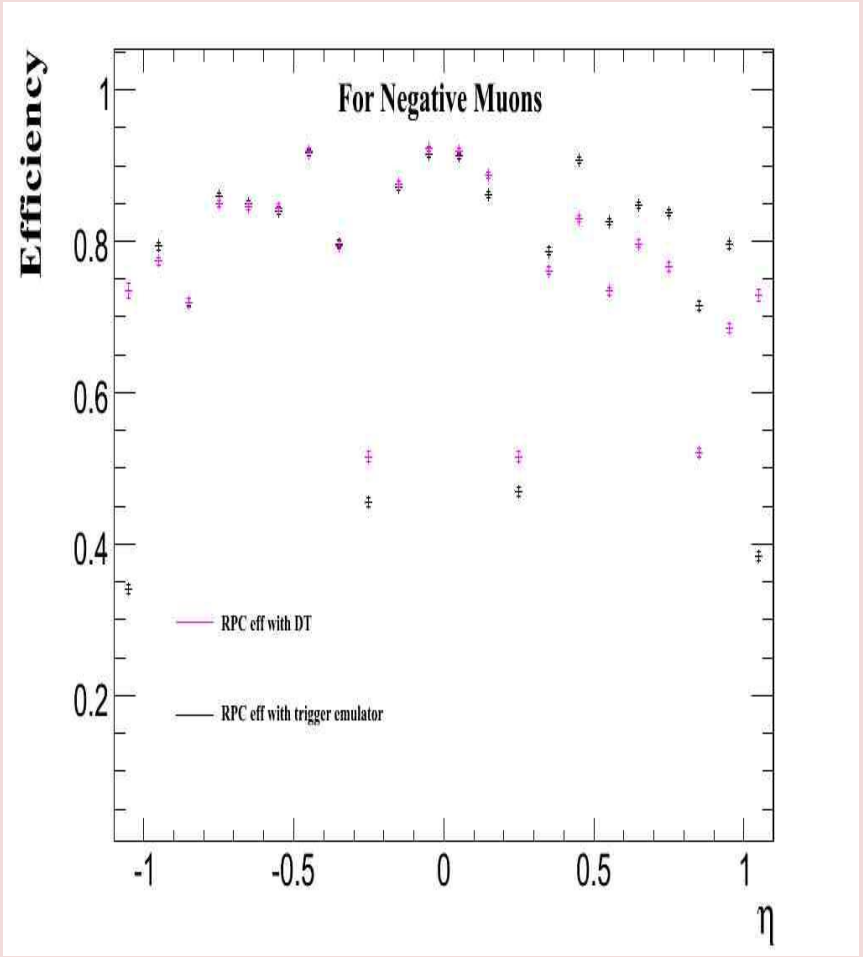
# MC-truth method

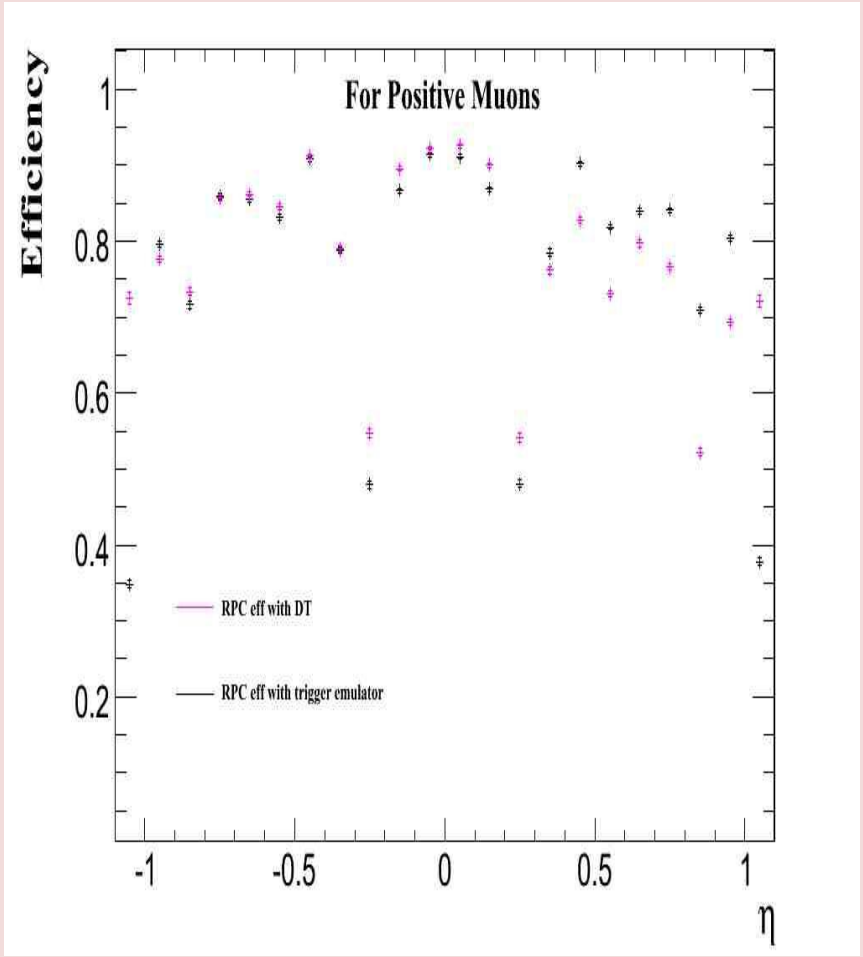



**GMT residuals with respect to GENERATED MUONS**

- Events with just one generated muon are selected
- The number of events with L1-accepted GMT candidates with RPC contribution is counted up

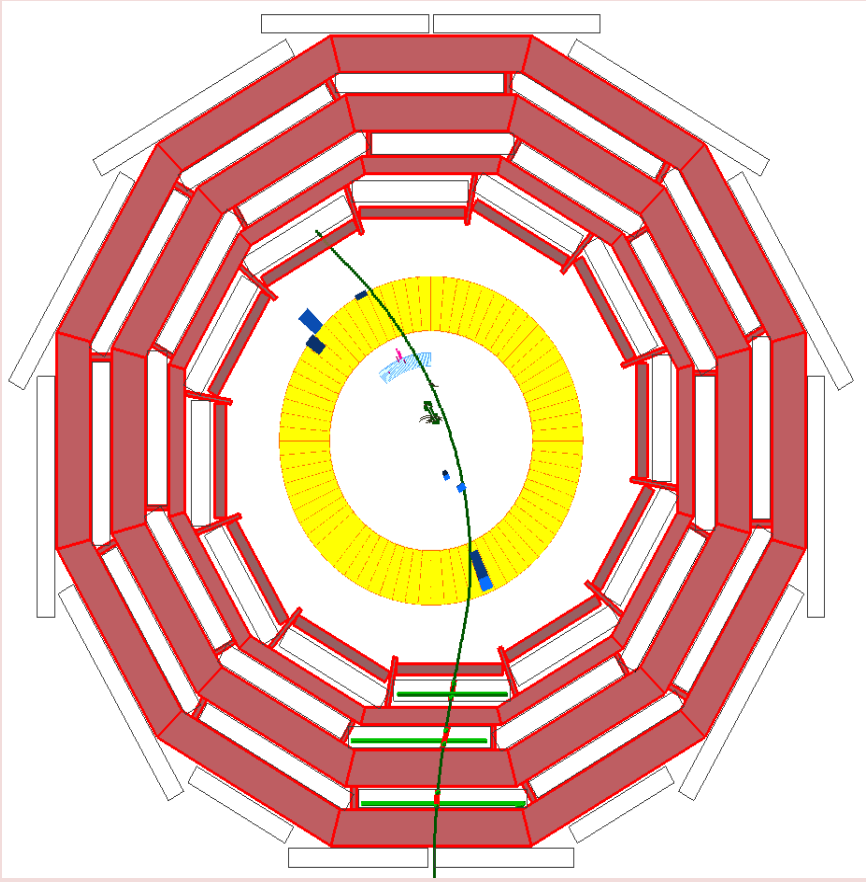
# RPC Trigger from GMT data-driven and MC-truth efficiencies (pseudorapidity)



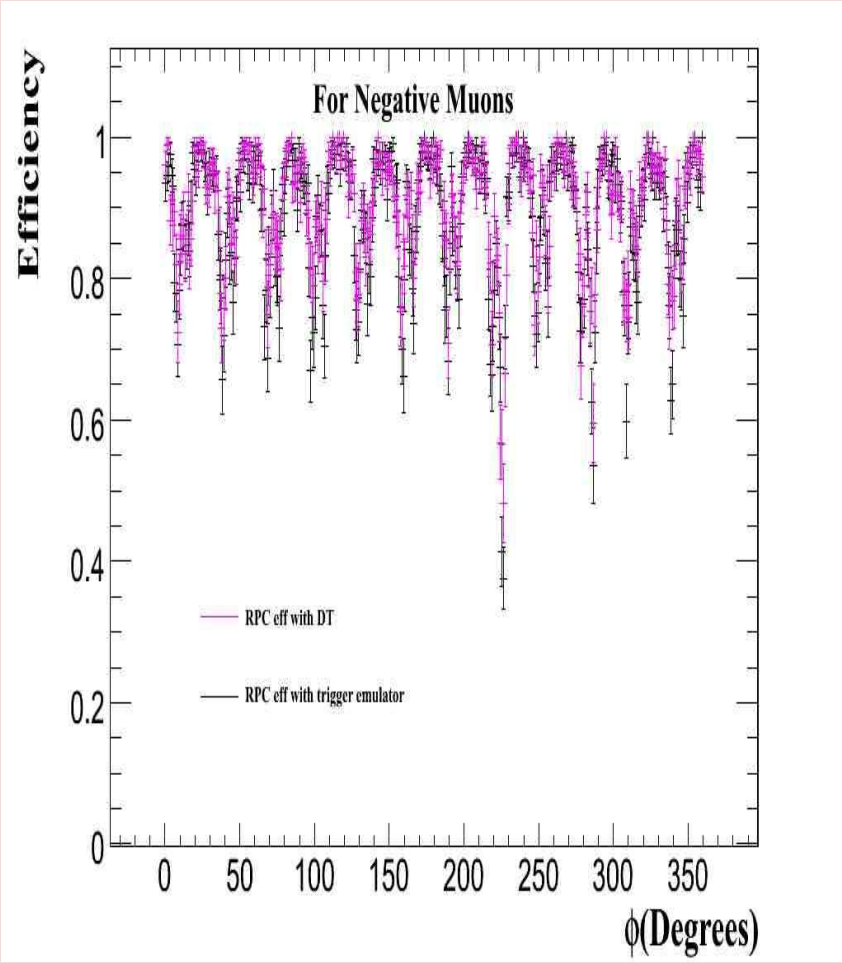



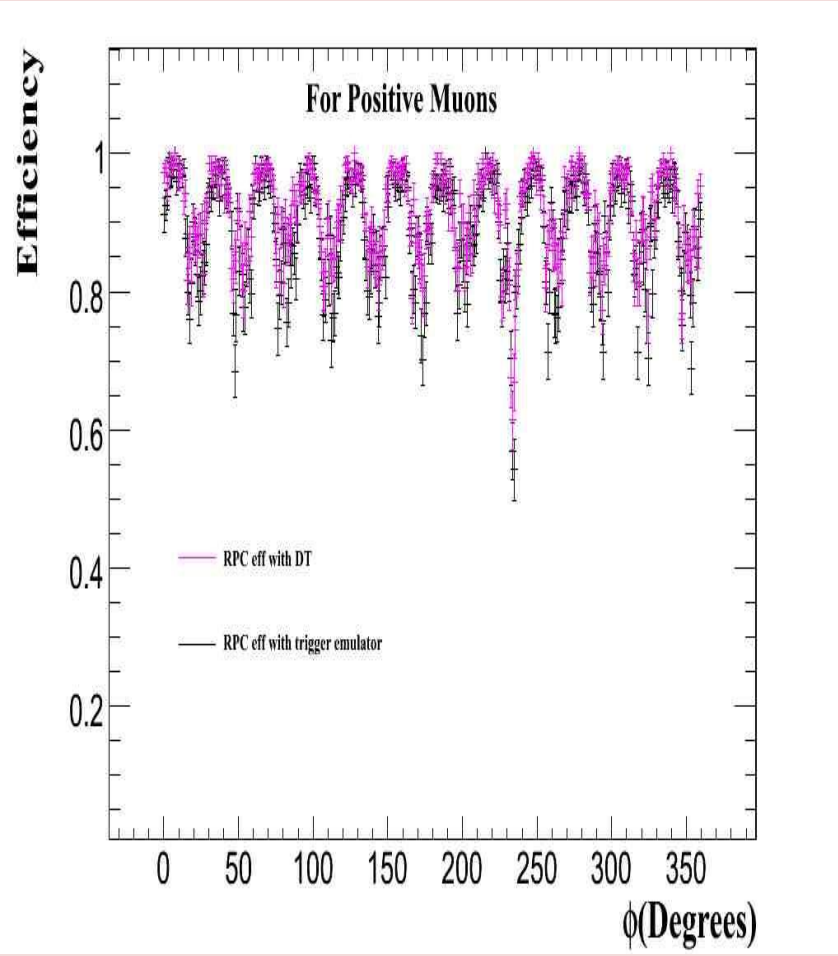
# Geometrical cuts

- Geometrical cracks along η (wheels transition) and between different sectors in φ are the source of mismatches
- GMT algorithm features in correspondence of such regions introduce a bias
- In order to study the goodness of the method
  - Removed the cracks along η between 5 wheels.
  - Rule out the φ cracks (periodic cut)
    - Two different sets of φ cuts depending on muon charge

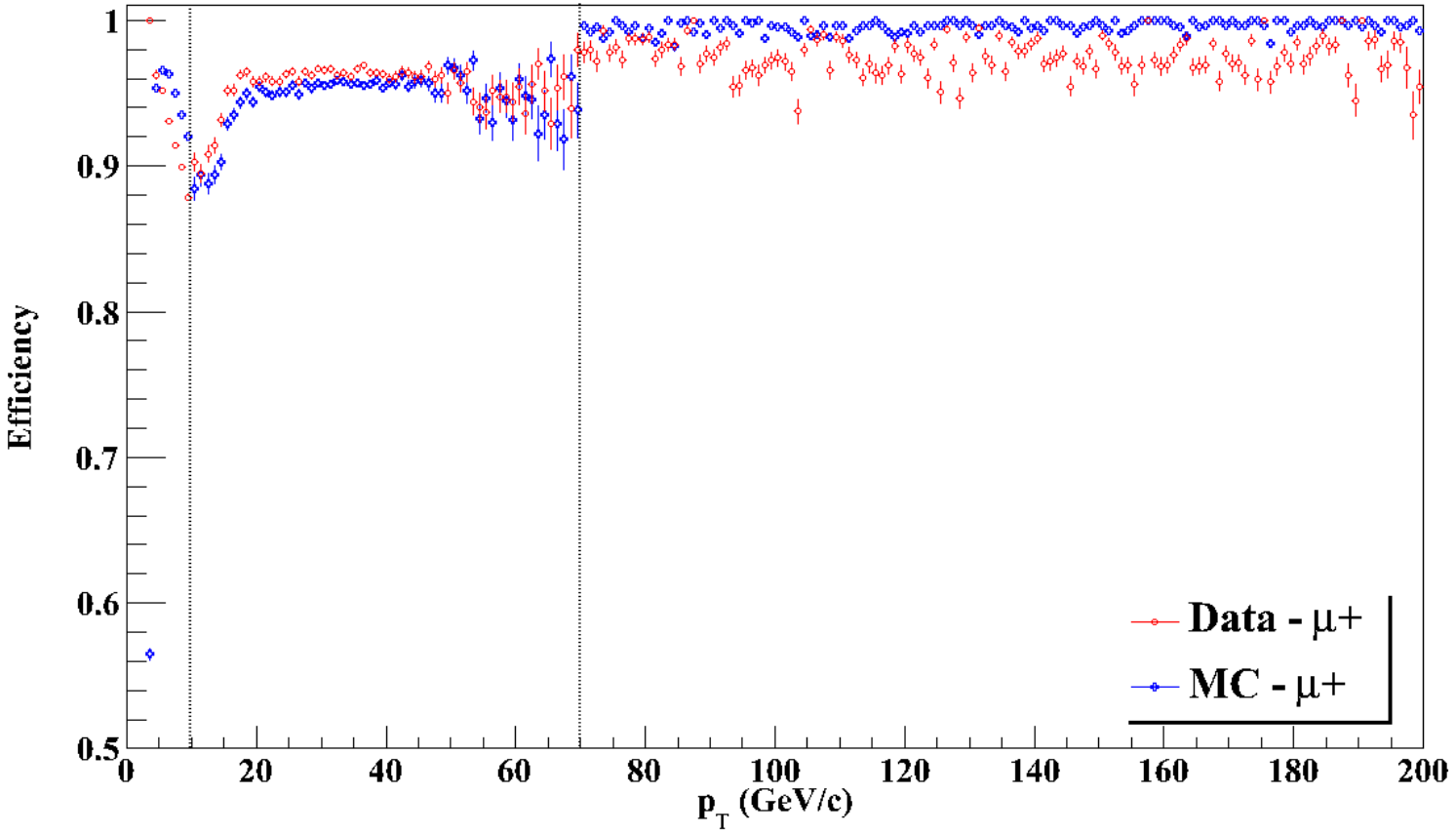


# RPC Trigger from GMT efficiencies in φ with |η|<0.2

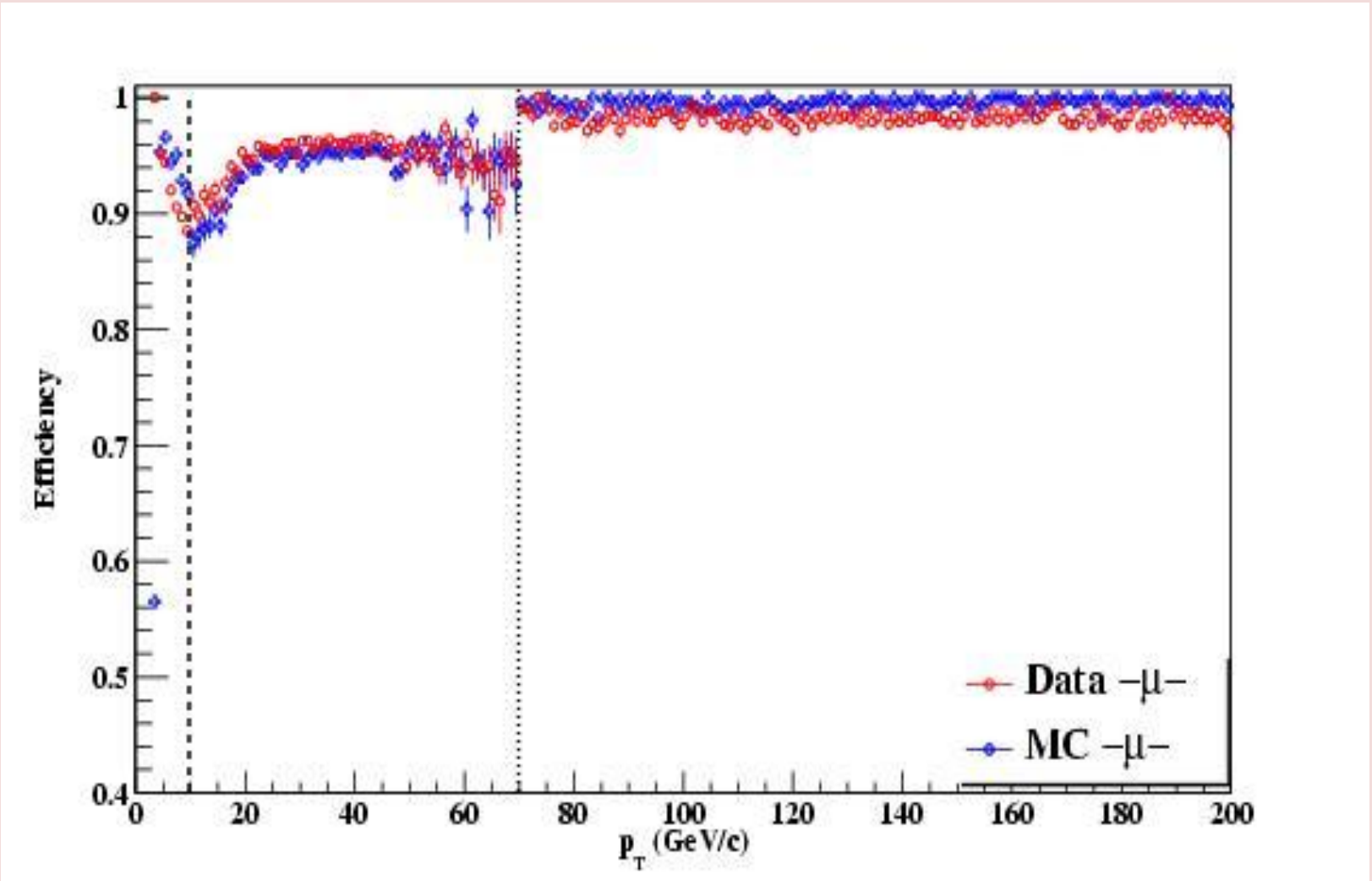


# Efficiency with respect to pt after applying all sets of cuts for overall pt range




***For positive muons***




***For negative muons***

# RPC system efficiencies for each sample obtained with the two methods

| pt range | MC-truth for $\mu^+$ | Data Driven MC for $\mu^+$ |
|---|---|---|
| 0-10 GeV/C | 88.9 ± 0.2 % | 93.5 ± 0.3% |
| 11-70 GeV/C | 94.6% ± 0.8% | 95.4 ± 0.8% |
| 71-200 GeV/C | 99.6% ± 0.13% | 98.3 ± 0.5% |

| pt range | MC-truth for $\mu^-$ | Data Driven MC for $\mu^-$ |
|---|---|---|
| 0-10 GeV/C | 88.9 ± 0.2% | 91.6 ± 0.2% |
| 11-70 GeV/C | 94.0 ± 1.1% | 94.9 ± 1.02% |
| 71-200 GeV/C | 99.5 ± 0.1% | 98.3 ± 0.5% |

# Summary and perspectives

- **Data-driven method measuring RPC trigger effectiveness in CMS muon framework**
  - **Fulfilling GMT and L1 requirements in trigger stage**
  - **Providing information employed in stand-alone reconstruction seeding**
- **η and φ cuts improve**
  - **the matching between the two curves**
  - **efficiencies.**
- **RPC Trigger efficiency curves after cuts show flat behavior with respect to transverse momentum.**
- The discrimination between differently charged muons yielded a clearer picture of detector behavior for low $p_T$ muons.
  - Different 'φ' ranges are affected by cracks
- **Work in progress…**
  - Use of method for other muon detectors as well and plugging it for physics oriented performance evaluation analysis
  - Delivery of the method for real data applications

***http://dx.doi.org/10.1016/j.nima.2010.09.065***

***THANKS***

# Backup Slides

- The method evaluates the trigger efficiencies as follows (the notations RPC/DT/CSC refer to GMT candidates detetctor contribution):

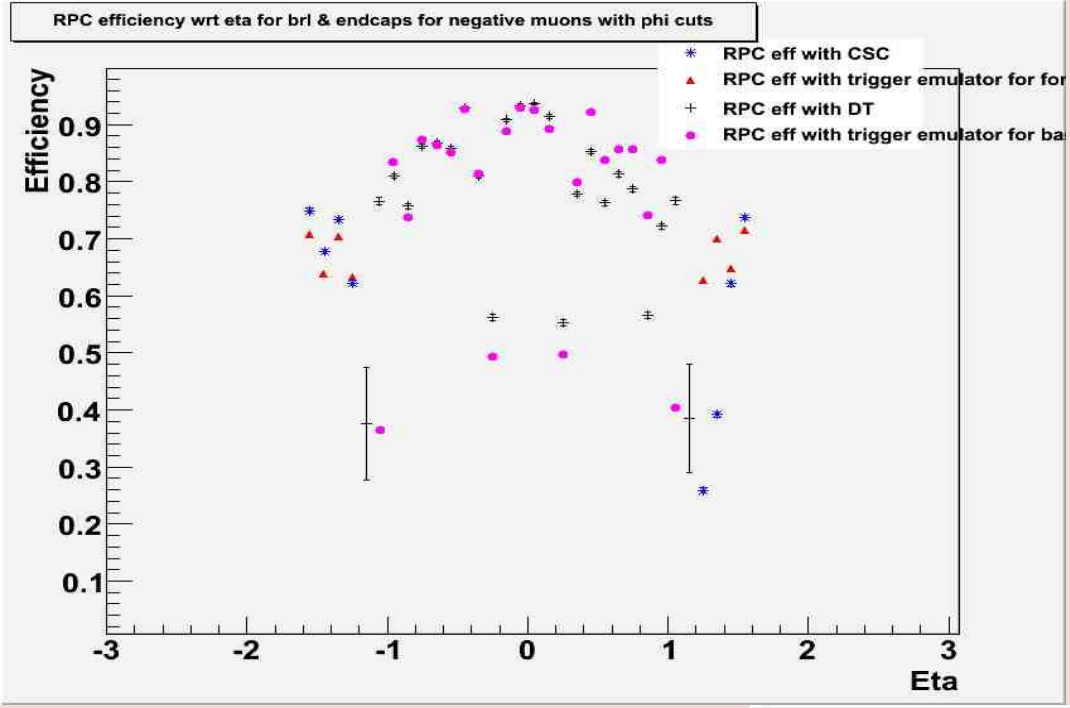
$$\varepsilon_{RPC\_Brl} = N_{ev}(DT \cap RPC_{Brl}) / N_{ev}(DT)$$

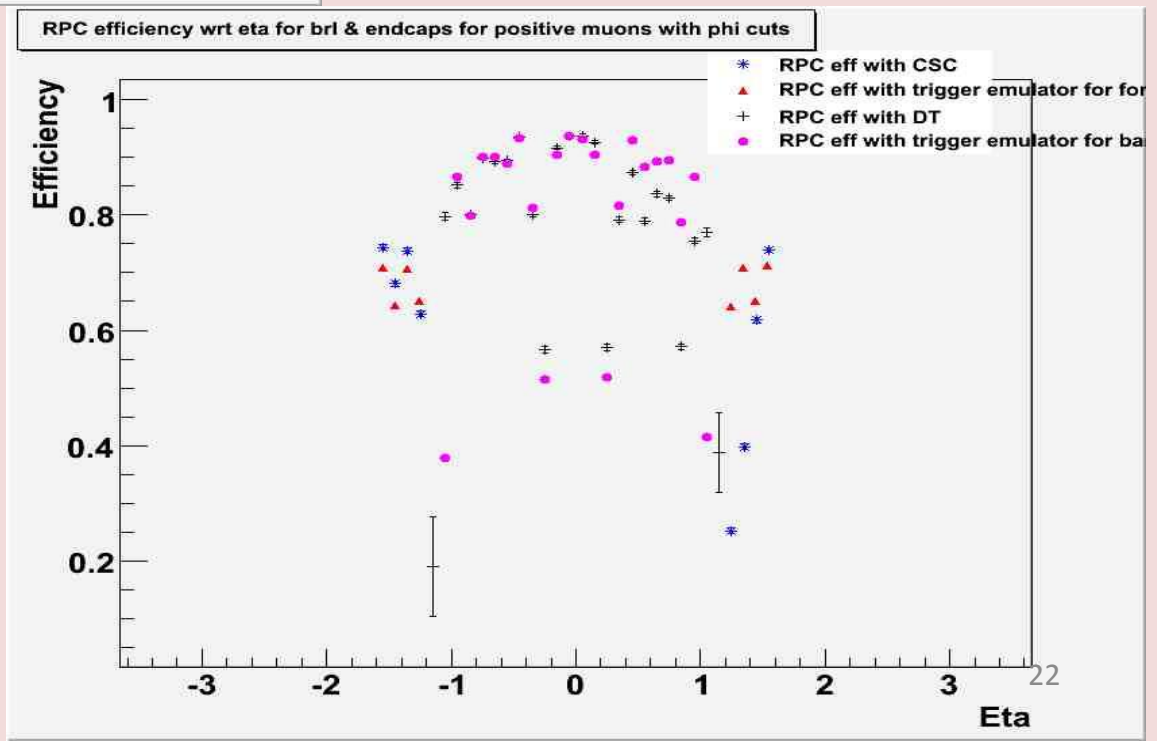
$$\varepsilon_{RPC\_Fwd} = N_{ev}(CSC \cap RPC_{Fwd}) / N_{ev}(CSC)$$

- Efficiency values drawn in such a way are compared with a “classic” Monte Carlo truth performance evaluation for each sub-system detector by counting the events in which GMT muon candidates are triggered by RPC detector with respect to the number of events yielded by generated muons.

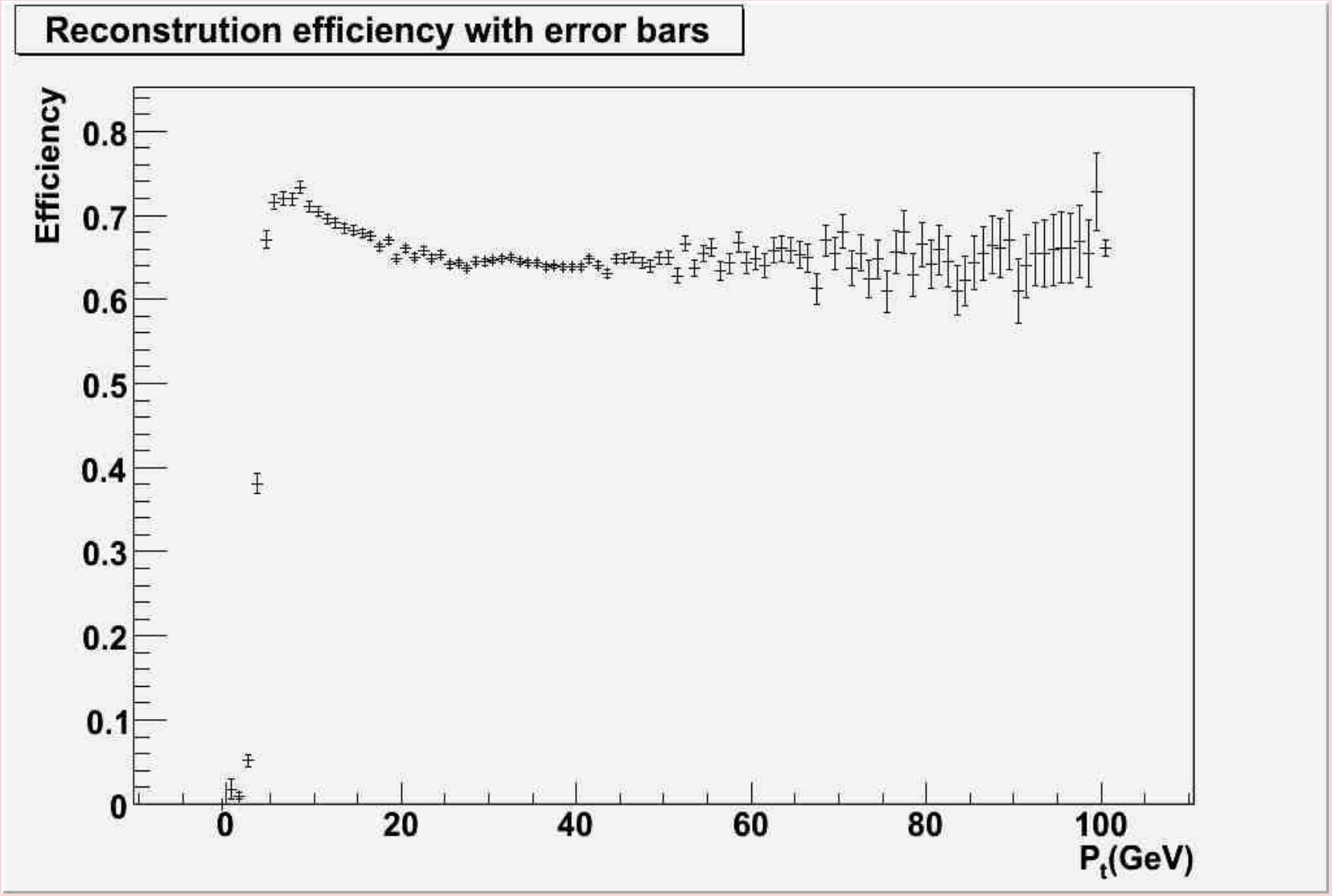
$$\varepsilon_{MC\_RPC} = N_{ev}(RPC) / N_{ev}(1\ GenMuon)$$

# Efficiency Plots with Phi cuts

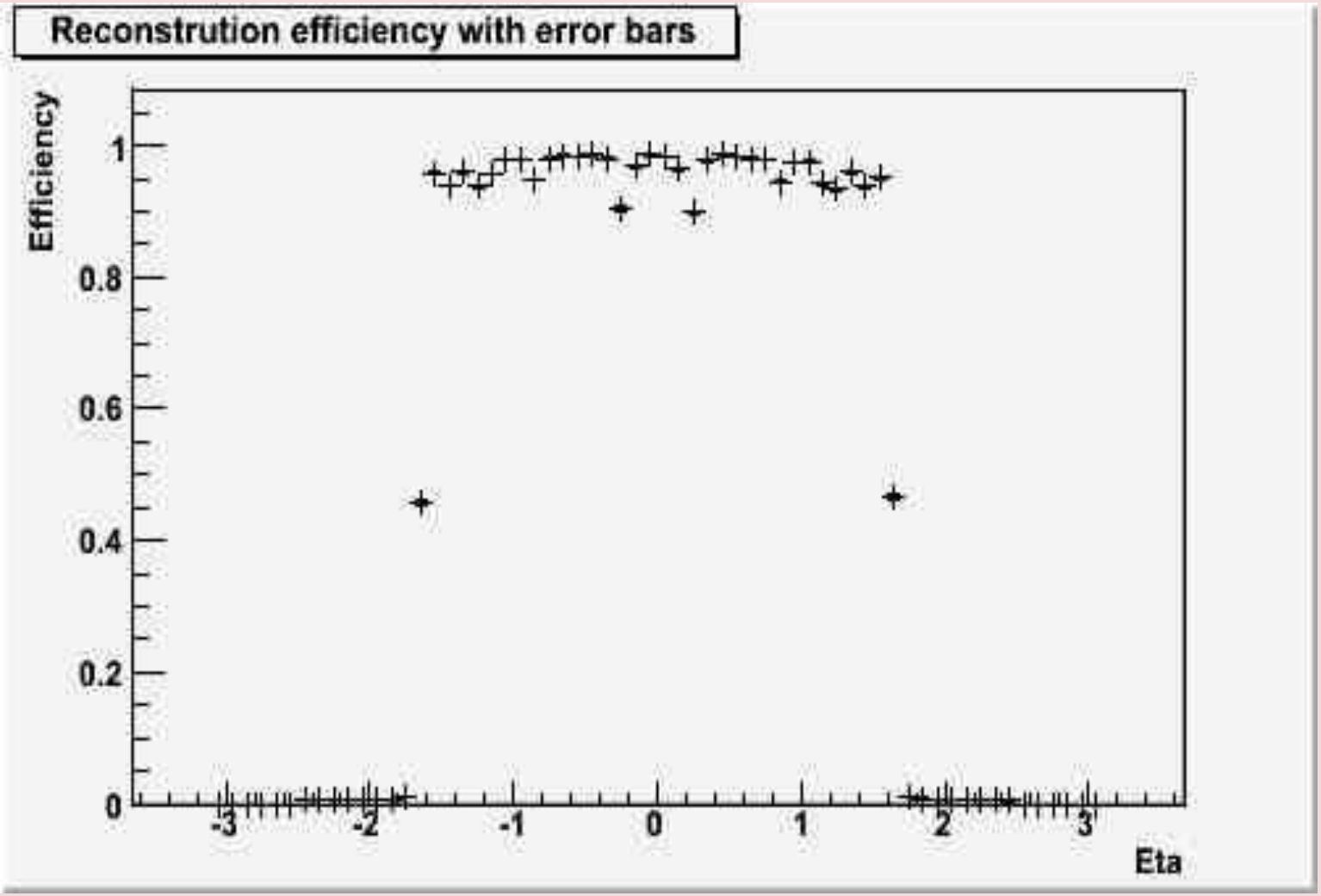


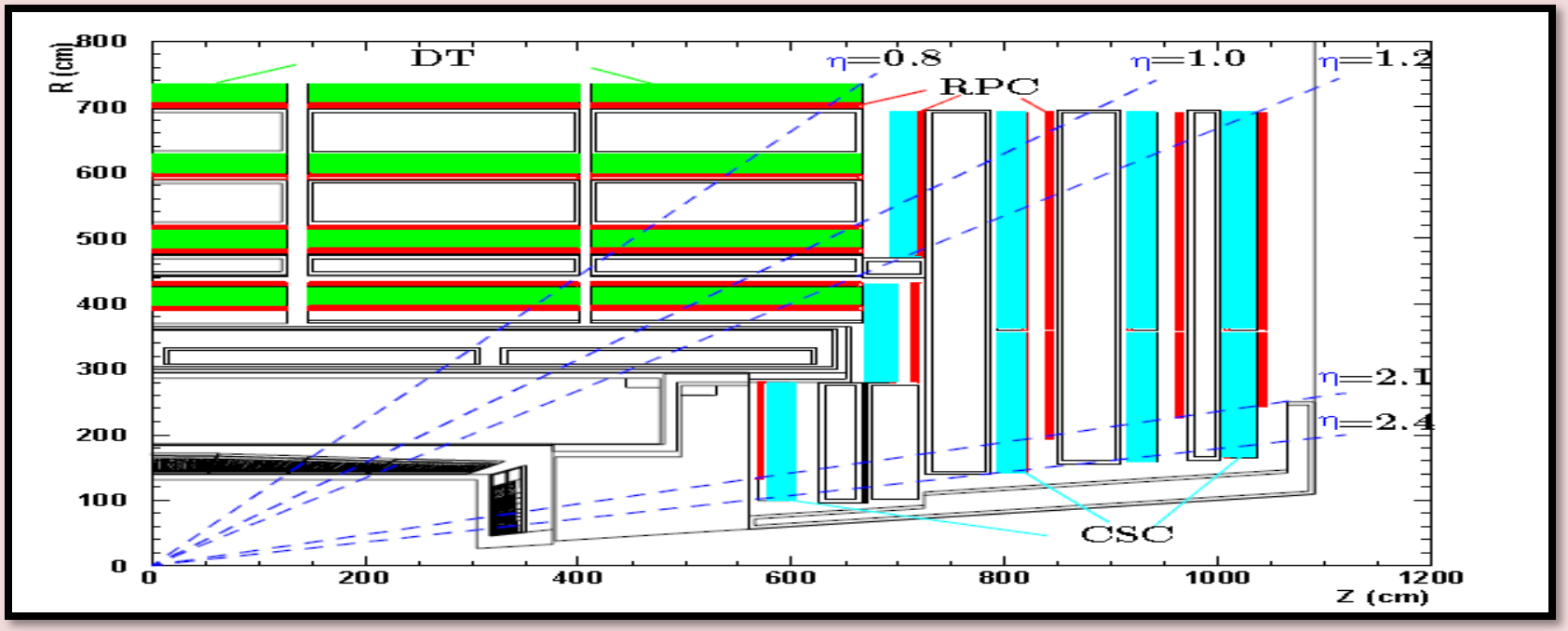
# Reconstruction efficiency w.r.t. Pt



# Reconstruction efficiency w.r.t. Eta



# CMS Muon Detector




## CMS detector specially optimized for muon measurement performed in muon system by :

DT trigger in barrel, CSC trigger in endcap upto η = 2.1 and RPC trigger covering both barrel & endcap upto η = 1.6 (start-up).

- Drift Tubes (DT) located outside magnetic coil in barrel region
- Cathode Strip Chambers (CSC) in endcap region
- Resistive Plate Chambers (RPC) in both barrel & endcap region