Study of W' -> μ ν at 14 TeV for CMS high-eta upgrade with GEM (GE1/1)

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OUTLINE

- CMS Detector at LHC
- Muon System
- LHC Upgrade
- GEM (Gas Electron Multiplier)
- W'-> μ ν (GEN-SIM-RECO)
- Analysis Cut
- Some Kinematics of W'-> μ ν (GEN and RECO Level)
- Tag and Probe Method
- Conclusion

CMS Detector

- The Compact Muon Solenoid (CMS) experiment is one of two large general-purpose particle physics detectors built on the Large Hadron Collider (LHC) at CERN in Switzerland and France.

- **The main goals of the experiment are:**

✓ to explore physics at the TeV scale.

✓ to study the properties of the recently found Higgs boson.

✓ to look for evidence of physics beyond the standard model, such as supersymmetry, or extra dimensions.

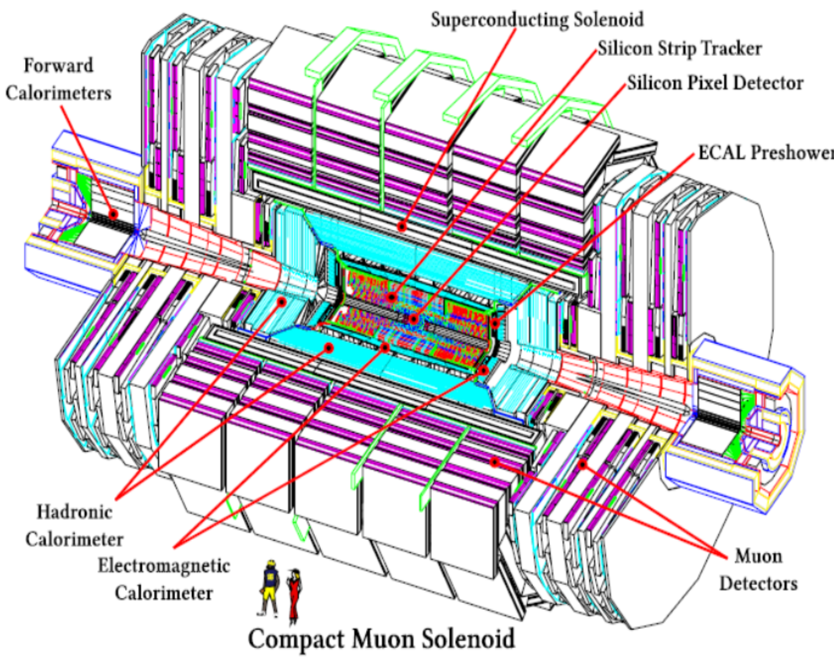
- It contains subsystems which are designed to measure the energy and momentum of photons, electrons, muons, and other products of the collisions.

✓ Tracker

✓ Electromagnetic Calorimeter (ECAL)

✓ Hadronic Calorimeter (HCAL)

✓ Muon System



Muon System

- The muon system, designed to identify muons correctly and reconstruct their momenta and detecting muons is one of CMS's most important tasks.

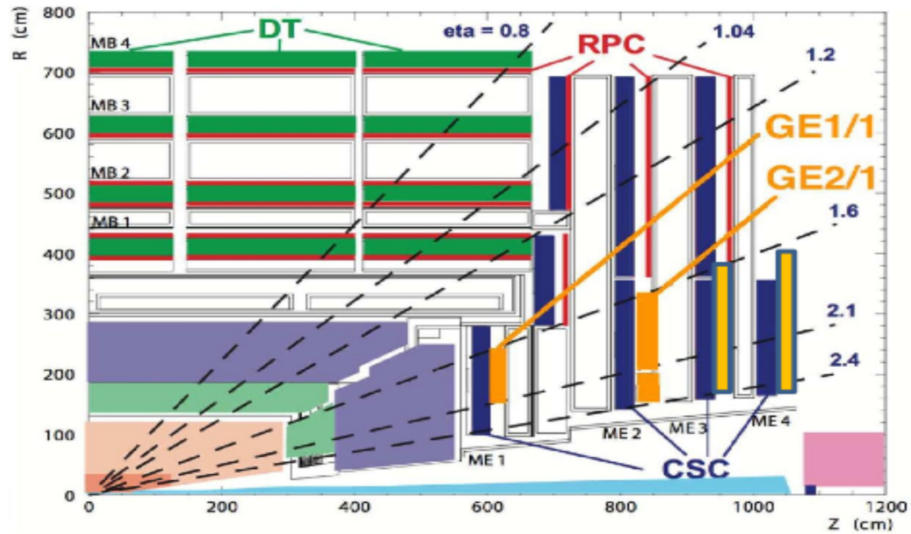
- The CMS muon system consists of three detectors interleaved with iron return yoke plates:

✓ **Drift Tubes (DT)** in the barrel region ($|\eta|<1.2$).

✓ **Cathode Strip Chambers (CSC)** in the endcap region ($0.9<|\eta|<2.4$).

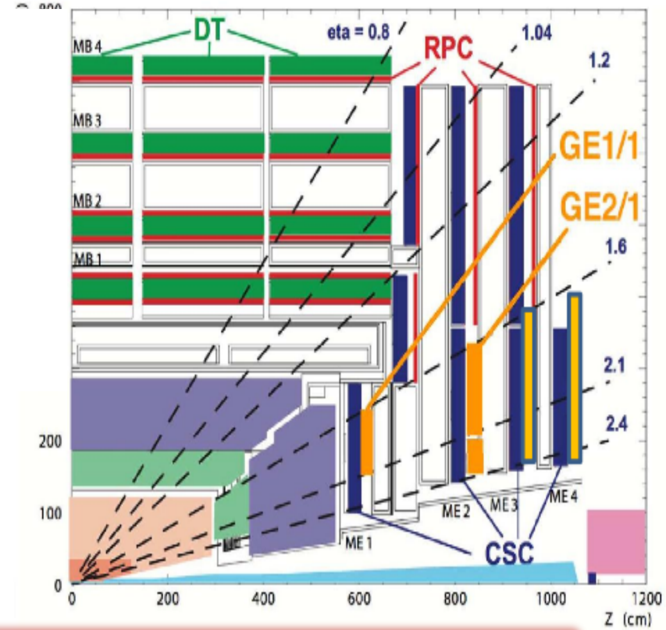
✓ **Resistive Plate Chambers (RPC)** in both the barrel and endcap regions ($|\eta|<1.6$).

- The Drift Tubes and the Cathode Strip Chambers are used for muon tracking while the Resistive Plate Chambers used for muon triggering.



LHC Upgrade

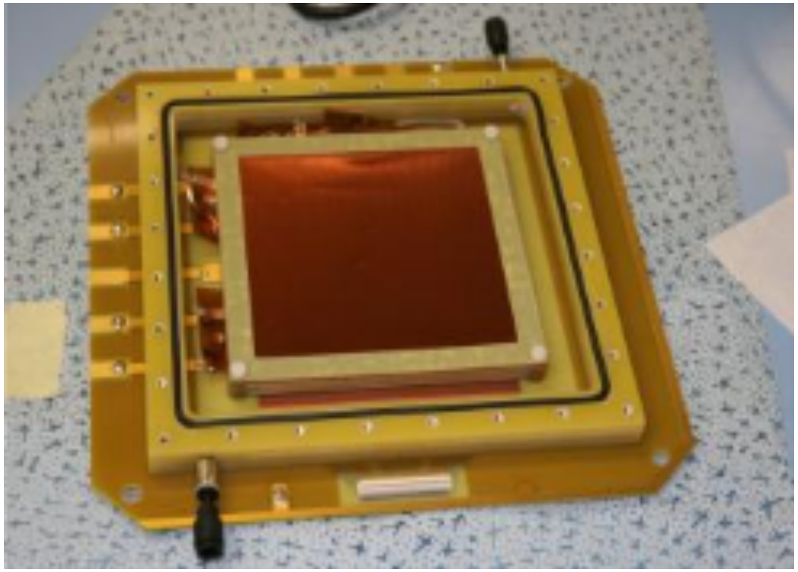
- 2010-2012 : 7-8 TeV (L = $6 \times 10^{33}\ cm^{-2}s^{-1}$)
- 2013-2014 : Long Shutdown 1 (LS1)
- 201 -2016 : 14 TeV (L = $10^{34}\ cm^{-2}s^{-1}$)
- 2017-2018 : LS2
- 2018-2020 : 14 TeV at high luminosity (L = $2 \times 10^{34}\ cm^{-2}s^{-1}$)
- >2020 - … : 14 TeV at high luminosity (L > $2 \times 10^{34}\ cm^{-2}s^{-1}$)

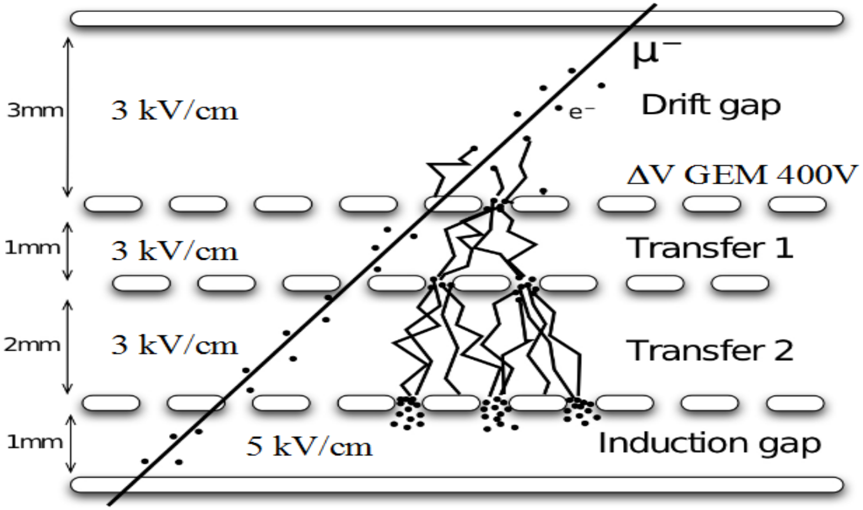


- It is planned to install GEM in the high-eta region (1.6<η<2.1) in the upgrade of the CMS muon system in the second long shutdown (LS2).
- Including GEM (GE1/1) might be helpful in improving the acceptance of the detector and the muon resolution on each search with muons.
- CMS is optimized not only for SM searches, but also for new physics searches, especially the searches with muons.
- Interested in search of W'->μν channel.

GEM (Gas Electron Multiplier)

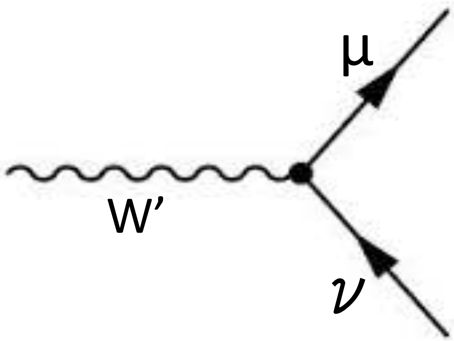
- The Gas Electron Multiplier (GEM) is a type of gaseous ionization detector used in nuclear and particle physics and radiation detection.
- GEM is constructed of 50-70 μm thick Kapton foil clad in copper on both sides with a regular pattern of densely spaced holes, an electric field is formed which focuses inside the holes where it is strong enough for gas amplification.
- When a single electron entering any hole will create an avalanche containing 100-1000 electrons.
- then electron enter second GEM to provide an additional stage of amplification.





W’-> μ ν (GEN-SIM-RECO)

- **CMSSW release:** CMSSW_6_2_0_SLHC5
- **GlobalTag :** “auto:upgrade2019”
  CMSSW automatically choose globaltag = DES19_62_V8::All
  and geometry [which include GEM]
- **Samples:** Signal samples with GEM (PU0)
  (W’ mass 3000, 6000 GeV)
- **Need to check out packages listed here:**
  https://twiki.cern.ch/twiki/bin/view/MPGD/GemSimulationsInstructionsCMSSW
- **Physics Objects:** to reconstruct high-mass resonances (W’)
  reco::Muon
  reco::PFMET



Analysis Cut

Selection criteria (based on AN2012_423 and Muon POG)

✓ **good primary vertex**

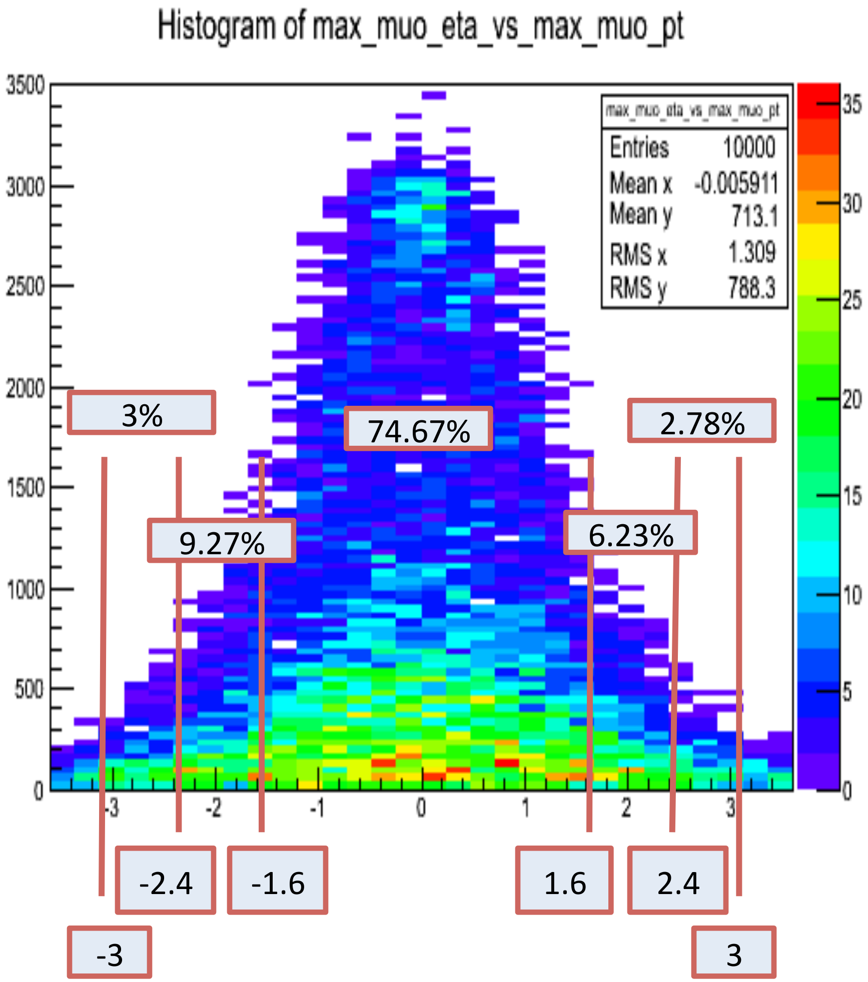
(!isFake && ndof > 4 && abs(z) <= 24 && position.Rho <= 2)

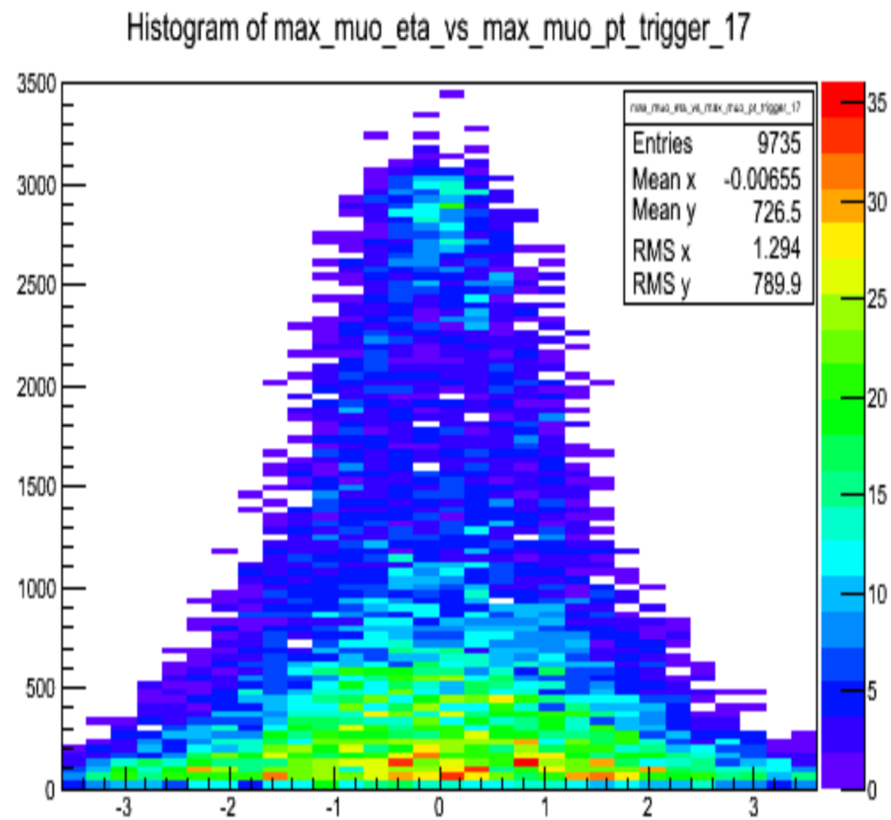
✓ **High pT Muons**

- (muon->isGlobalMuon()) && (muon->isTrackerMuon())
- (muon->globalTrack()->hitPattern().numberOfValidMuonHits() > 0)
- (muon->globalTrack()->hitPattern().numberOfValidPixelHits() > 0)
- (muon->globalTrack()->hitPattern().trackerLayersWithMeasurement() > 5)
- (muon->numberOfMatchedStations() > 1)
- (dxy < 0.2) (transverse impact parameter)
- (dz < 0.5) (longitudinal impact parameter)

Some Kinematic dist. of W'-> μ ν (GEN Level)

For W' Mass 6000 GeV

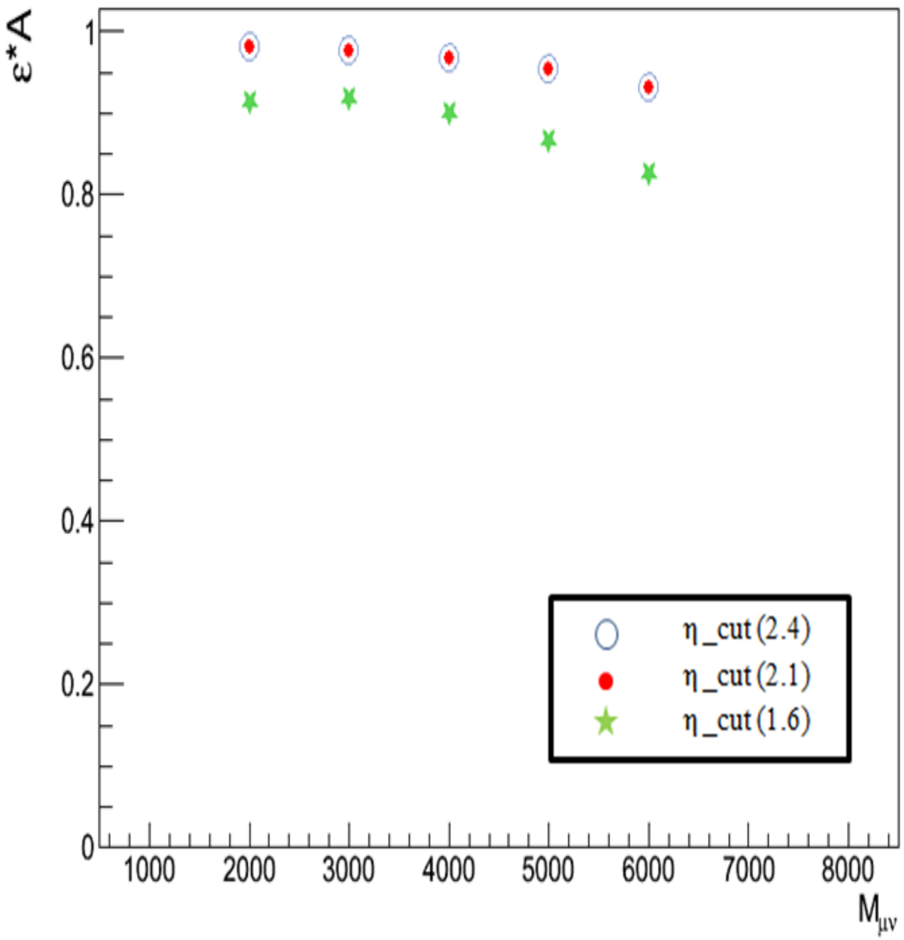




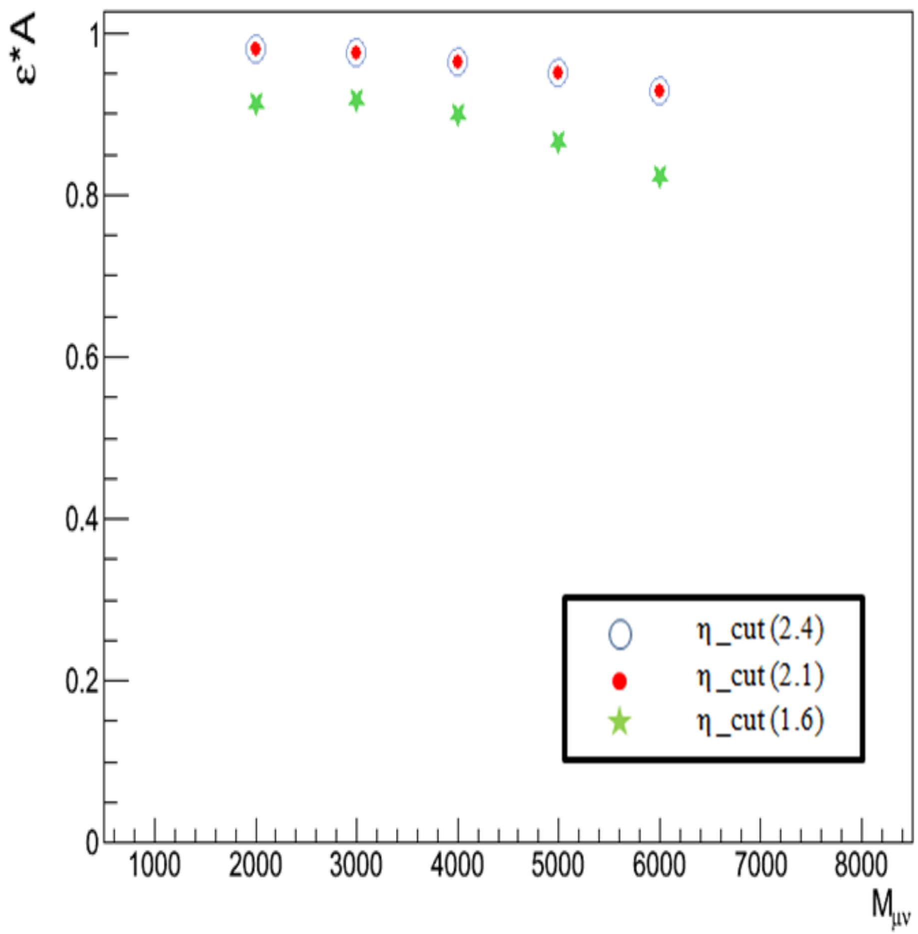
Trigger Efficiency 0.9735

Some Kinematic dist. of W'-> μ ν (GEN Level)

Mass VS Eff*Acc (Trigger 17)

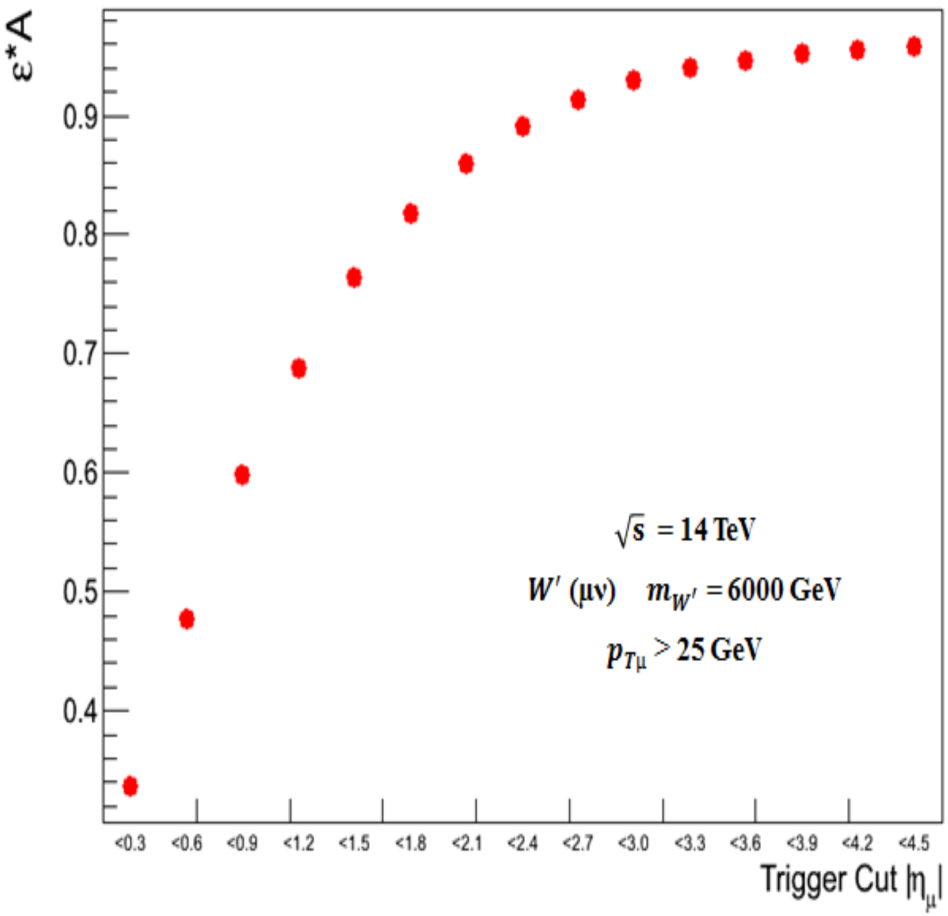


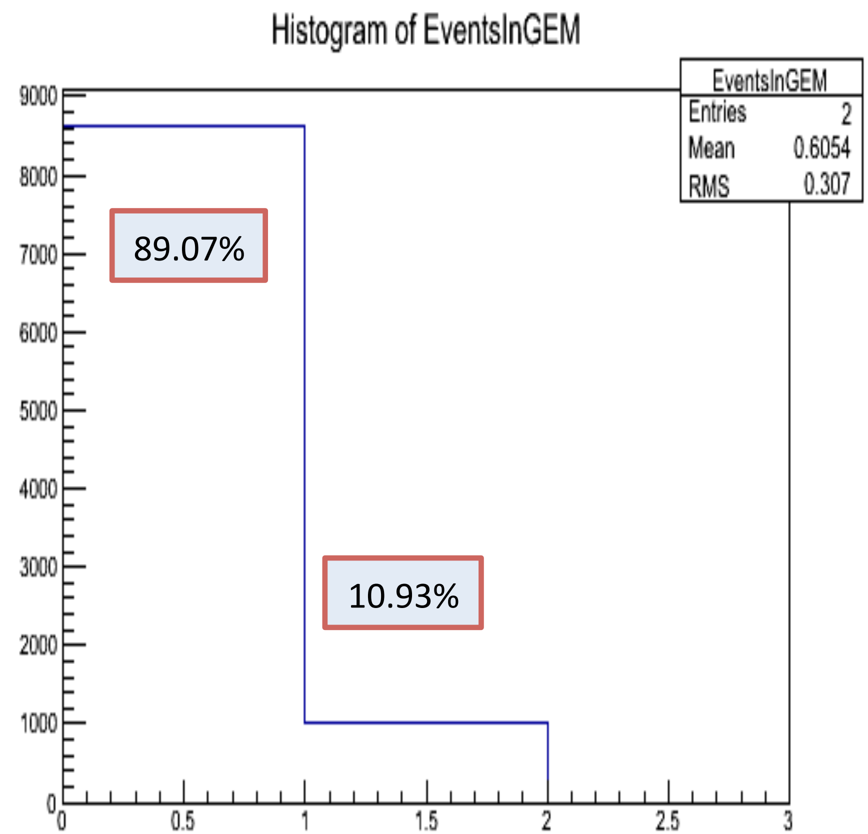
Mass VS Eff*Acc (Trigger 21)



Some Kinematic dist. of W'-> μ ν (GEN Level)

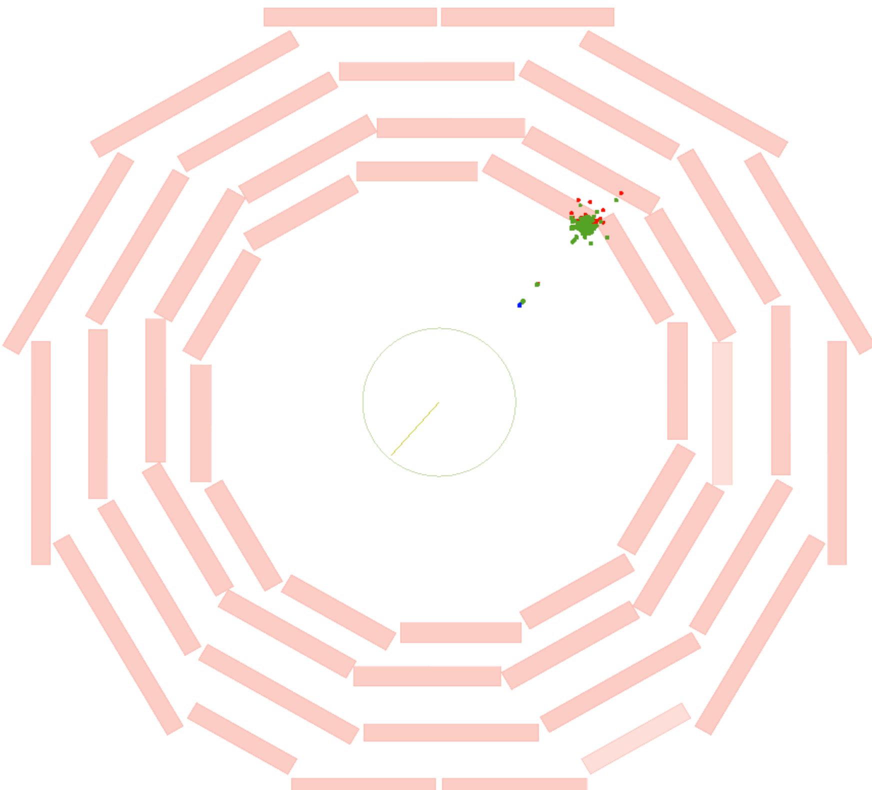
Eta VS Eff*Acc

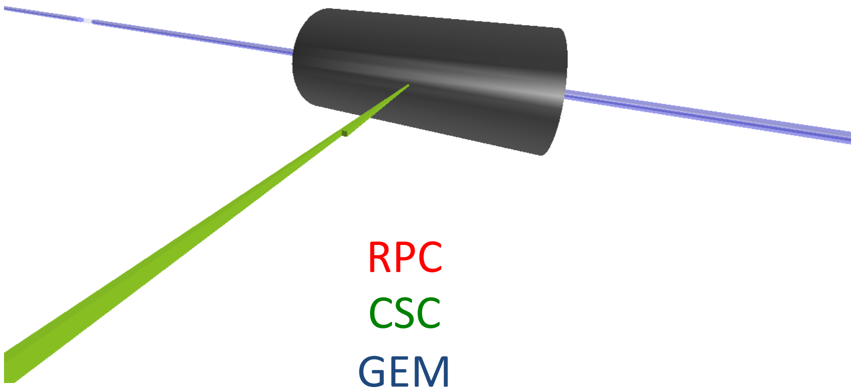




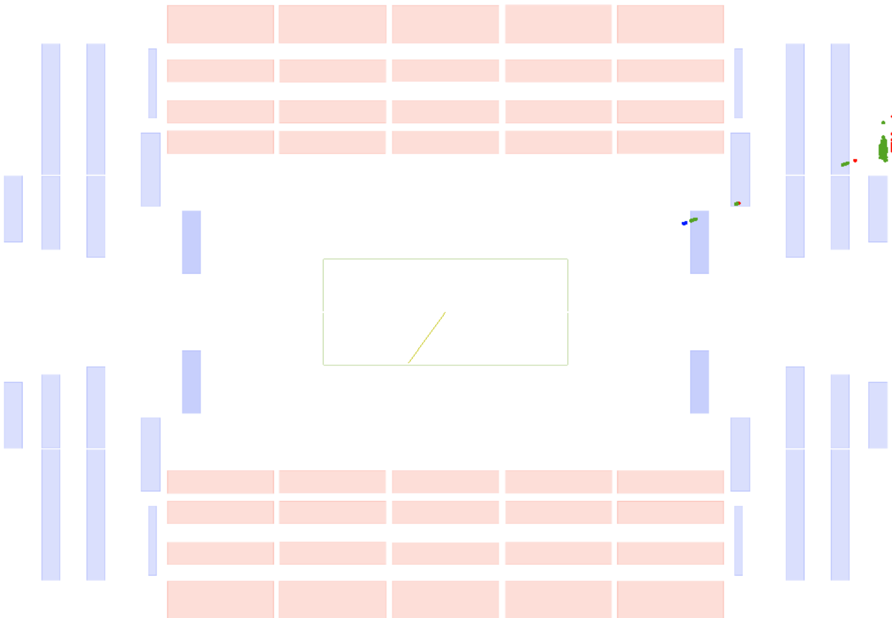
W' mass = 6000 GeV
1.6 < η < 2.1
muHitGEM = 1093
zeroHitGEM = 8907

Event Display





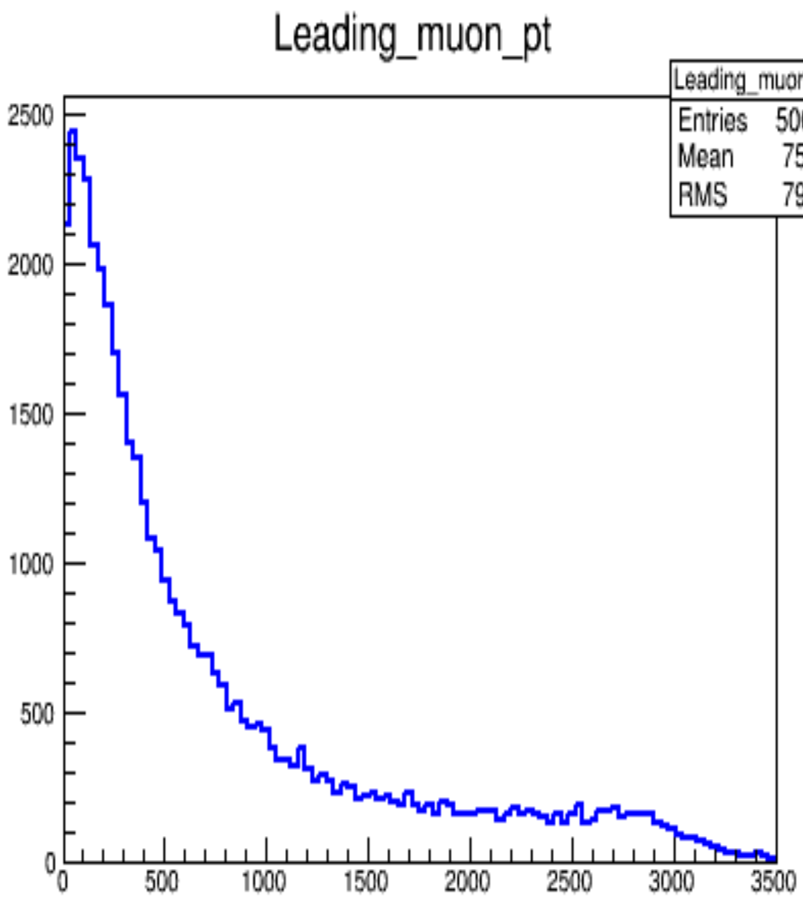
RPC
CSC
GEM
MET_true

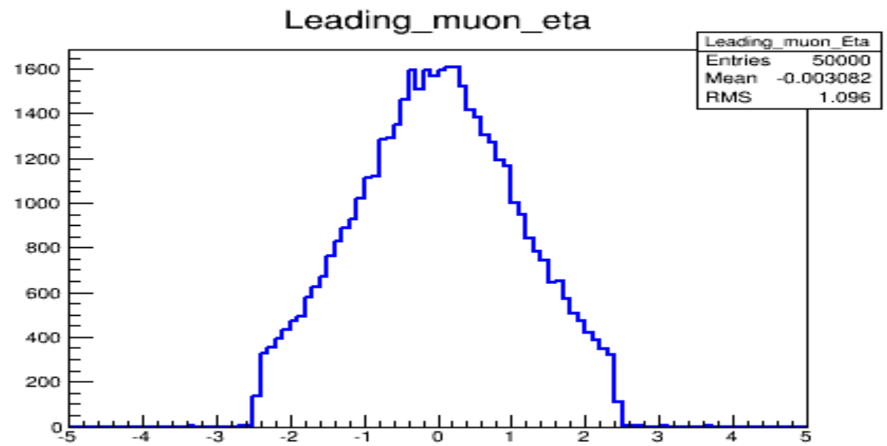


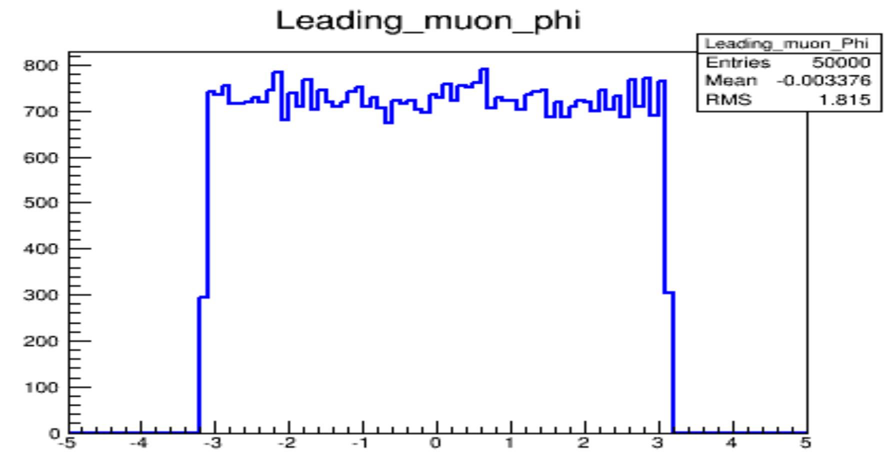
W' Mass = 6000 GeV
Muon pT = 1116 GeV
Eta = 1.633
Phi = 0.894

Some Kinematic dist. of W'-> μ ν (RECO Level)

Leading Muon Pt
(Without selection)



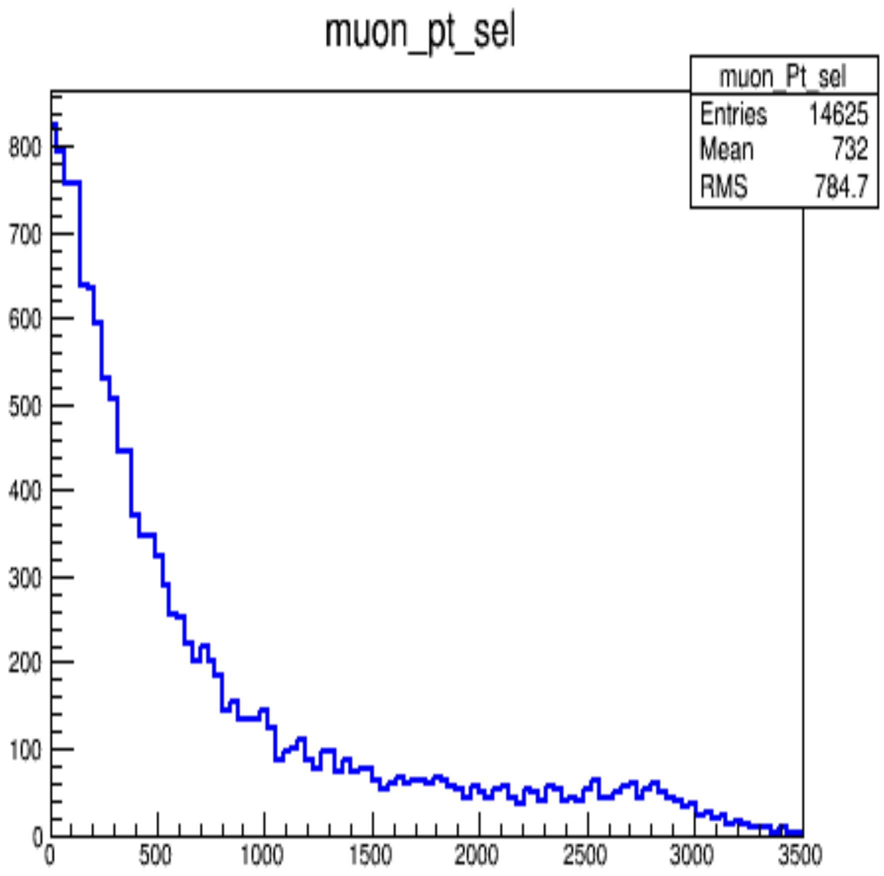


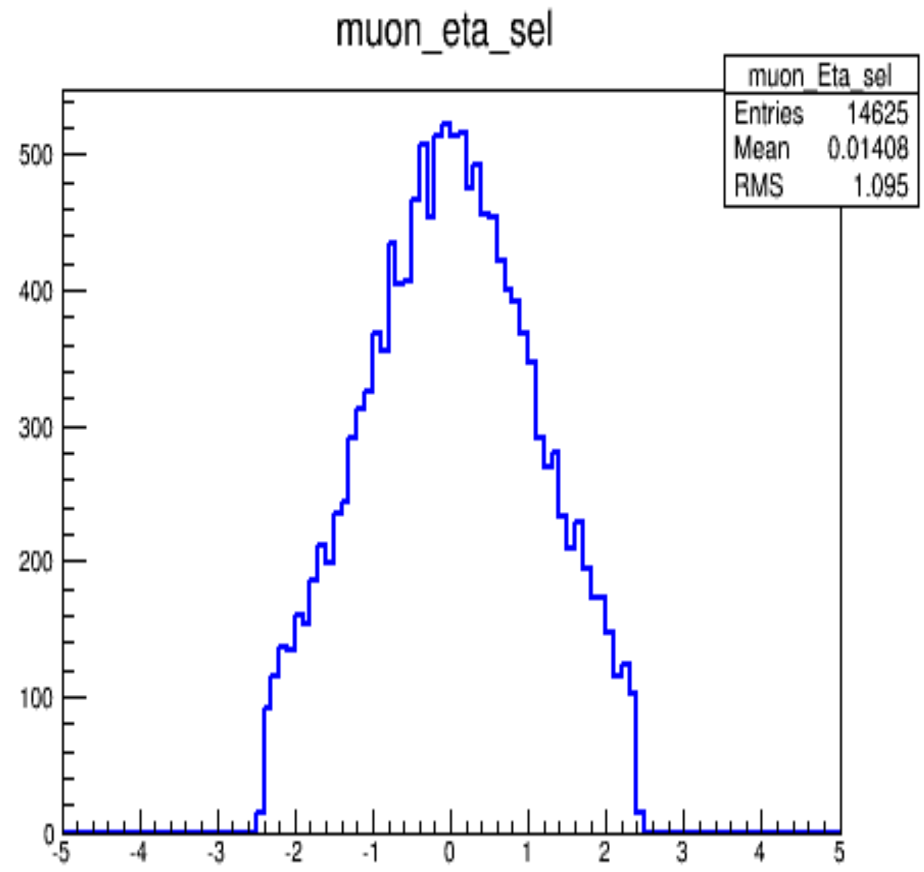


Leading Muon Eta & Muon Phi
(Without selection)

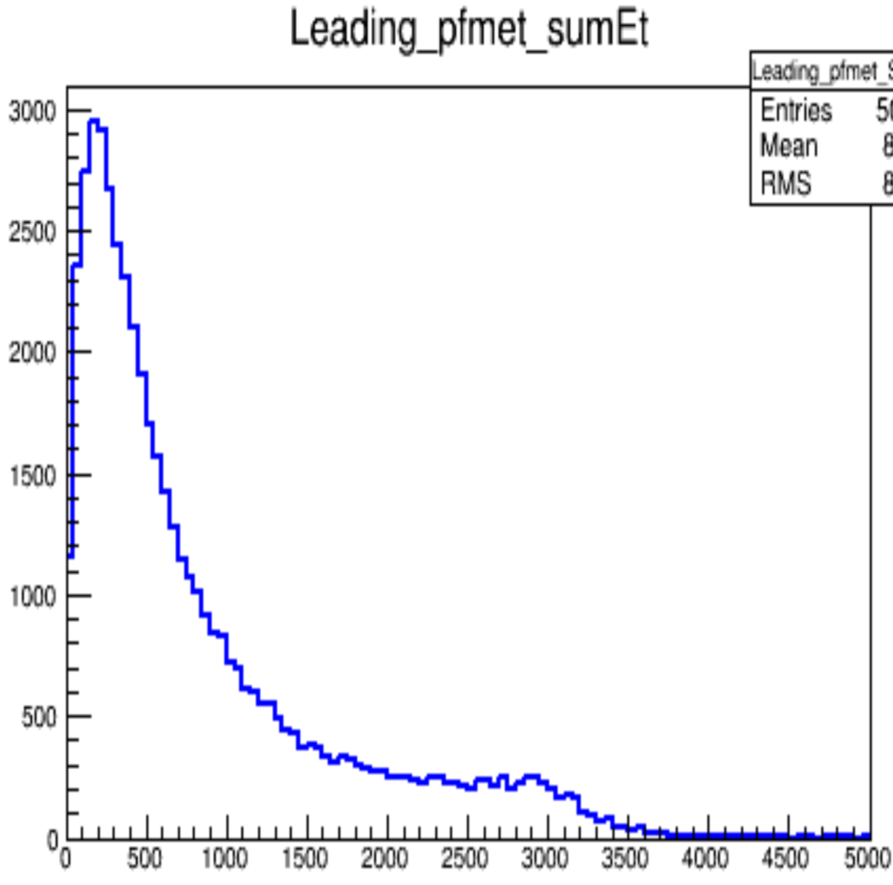
Some Kinematic dist. of W'-> μ ν (RECO Level)

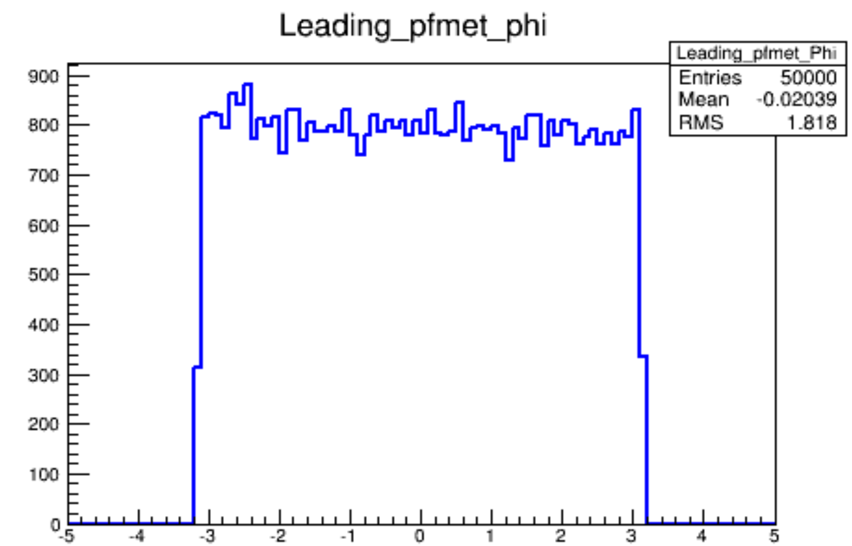
Muon Pt & Muon Eta
(After selection criteria)

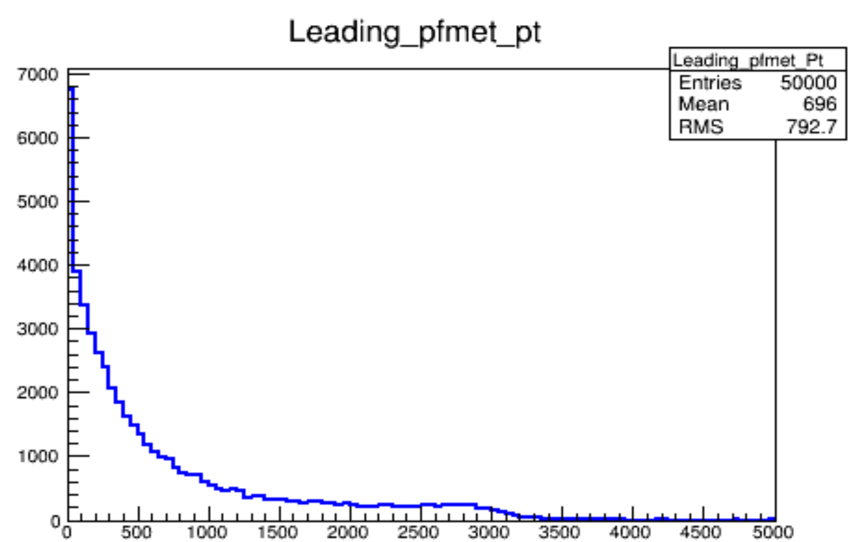




Some Kinematic dist. of W'-> μ ν (RECO Level)

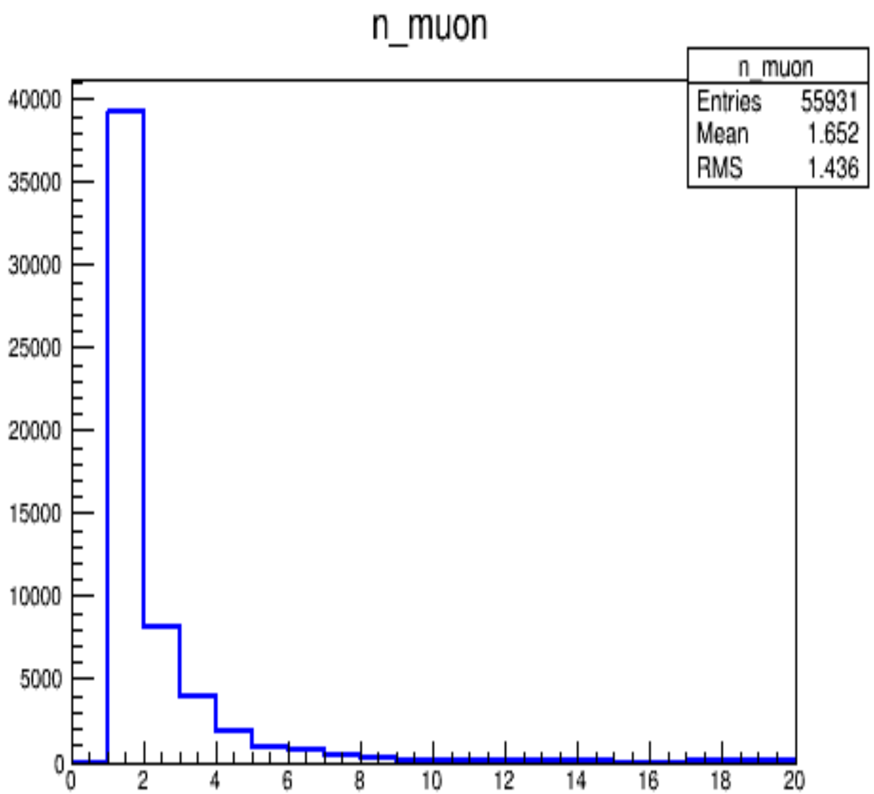




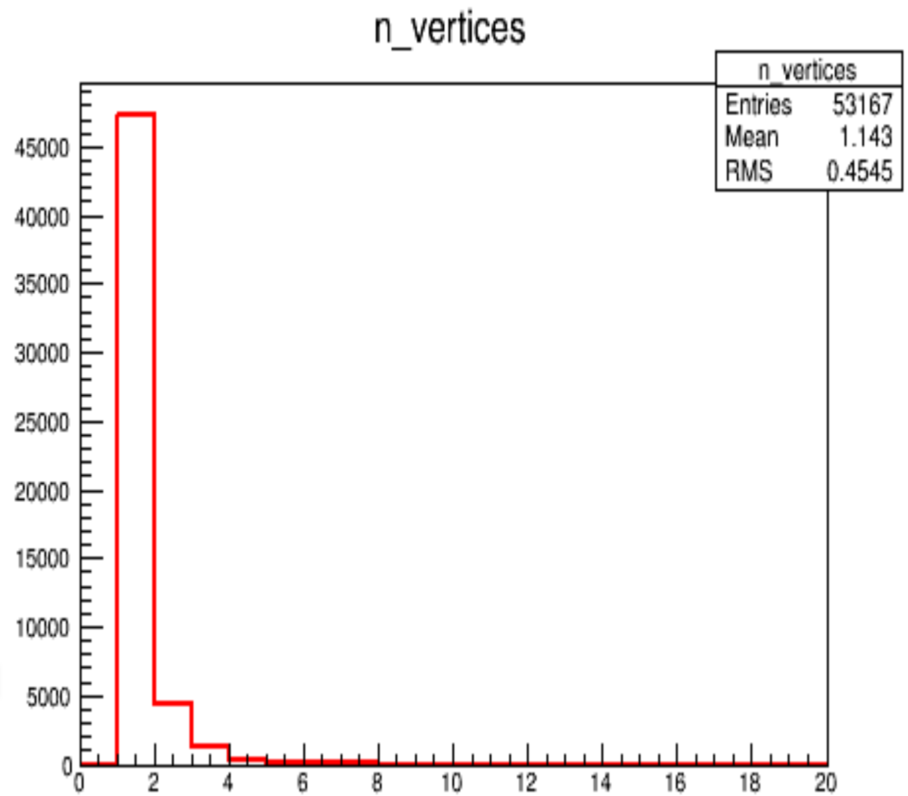


Leading pfmet
(sumEt & phi & pt)

Some Kinematic dist. of W'-> μ ν (RECO Level)



Number of reco Muons per event
(Without selection)



Number of reconstructed vertices
(Without selection)

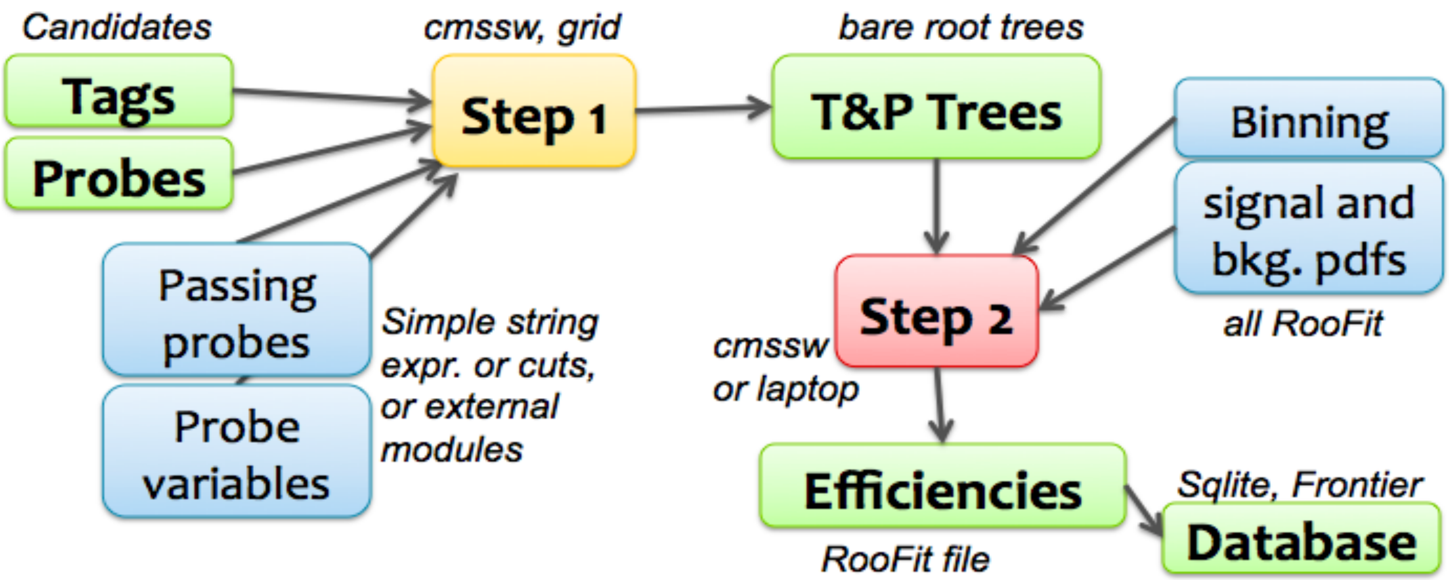
Tag and Probe Method

Tag and Probe Overview

- Tag and probe is a data driven technique used to calculate efficiency of identification, isolation or trigger.
- In order to calculate the efficiency one needs a mass resonance (i.e. J/psi, upsilon or Z).
- The Tag has very tight selection criteria and a very low fake rate.
- The Probe has looser criteria.
- The Passing Probe has tighter criteria than the probe, but not tighter than the Tag.

Tag and Probe Method

Tag and Probe Workflow



Make TnP Trees

- By combining tags and probes into TnP pairs
- Centrally produced

Analyze TnP Trees

- by defining the binnings and num and denom definitions.
- Make the efficiency plots.

Tag and Probe Method (2)

Tag and Probe Exercise for HZZ4l

- **CMSSW release:** CMSSW_5_3_7
- **Need packages listed here:** https://twiki.cern.ch/twiki/bin/viewauth/CMS/SWGuideCMSDataAnalysisSchoolHZZ4lSearchExercise
- **Copy Files:**

  /afs/cern.ch/user/p/piet/public/CMSDAS2013/tnp/
- **Input File:** tnpZ_run2012A_13Jul2012_withEAIso_DAS.root
- **Configuration Files :**

  TnP_Muon_Z_DATA_53A_Loose2012_from_Tracks_pt_abseta.py

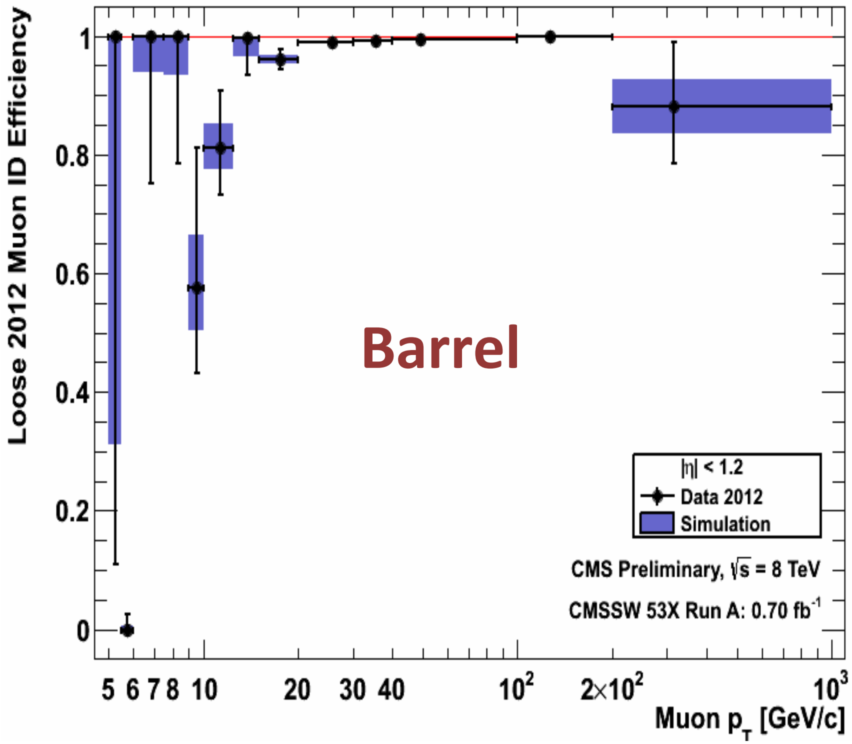
  TnP_Muon_Z_MC_53A_Loose2012_from_Tracks_pt_abseta.py
- **Output Files:**

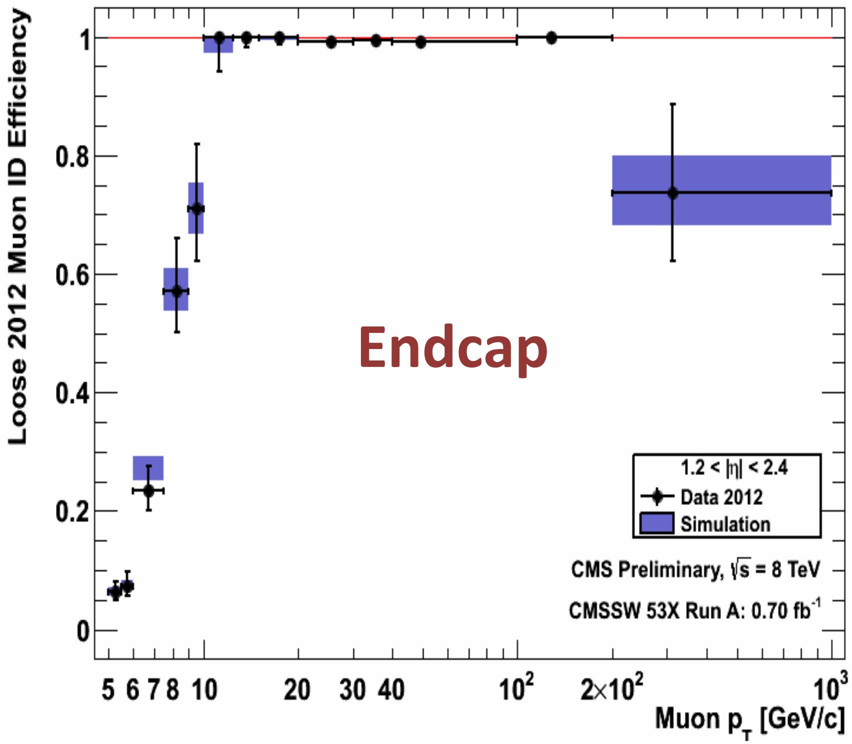
  TnP_Muon_Z_DATA_53A_Loose2012_from_Tracks_pt_abseta.root

  TnP_Muon_Z_MC_53A_Loose2012_from_Tracks_pt_abseta.root
- **Run:** root.exe -b -l -q MuonID_PT.C+

Tag and Probe Method (3)

Loose 2012 Muon ID





- Understanding MET variables, how to clean MET, and how to select W events.
- Produce new TnP trees rely on W events.
- Make the efficiency plots.

Conclusion

- A GEM Detector System is used for an Upgrade of the CMS Muon Endcaps covering the pseudorapidity range of $1.6 < \eta < 2.1$.
- GEM would be helpful with
  - ✓ improved eta coverage
  - ✓ better muon resolution
  - ✓ better muon isolation for high occupancy environment

➢ Next Step

- Complete the analysis code for W'-> μ ν with GEM in the RECO level.
- Produce new TnP trees rely on W events.
- Make the efficiency plots.


THANK YOU