Performance of Muons using Z boson events in Run3 at the CMS

권 우 연

Wooyeon Kwon

wkwon@cern.ch

Nov, 2024

Motivation

- CMS collects Run3 data from 2022 to 2024 at $\sqrt{s} = 13.6$ TeV
- We need to understand about Run 3 data
- CMS is specialist in detecting muons. CMS offers various muon objects.
- To understand about muon data we verify muon performance with muon objects
- Z boson mass reconstruction with $Z \rightarrow \mu\mu$ process is a good indicator of muon performance

Muon objects

Global Muon

Reconstructed muon with tracker track information inner trackers and standalone tracks with hits

Tracker Muon

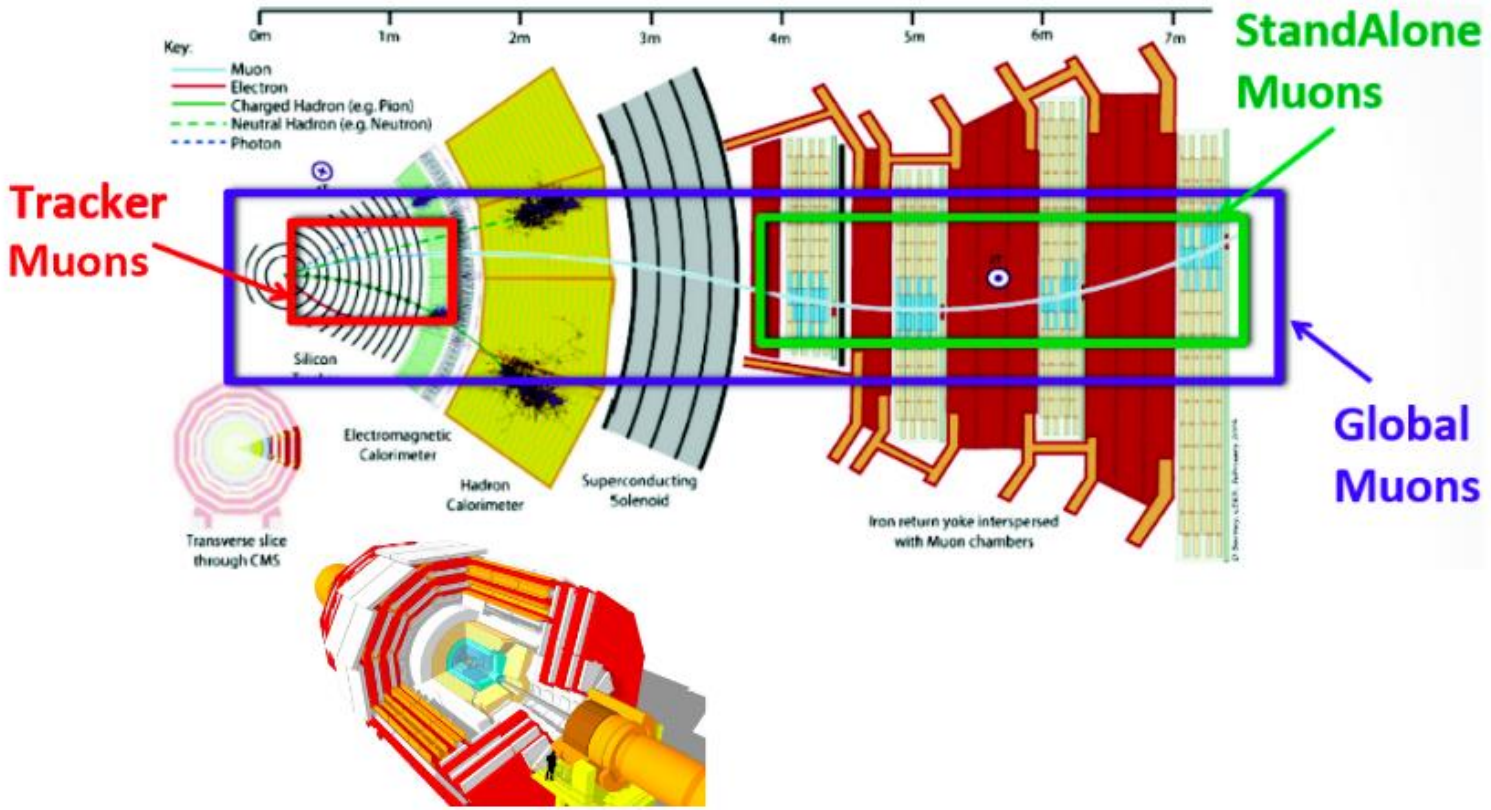
Reconstructed muon with tracker track

Stand Alone Muon

Reconstructed muon with tracks and hits information of muon detector in muon cha

PF Muon

Reconstructed Muon with Particle Flow(PF) Algorithm. This uses all information of detectors including calorimeter. generally used muon object in MINIAOD or NANOAOD data.



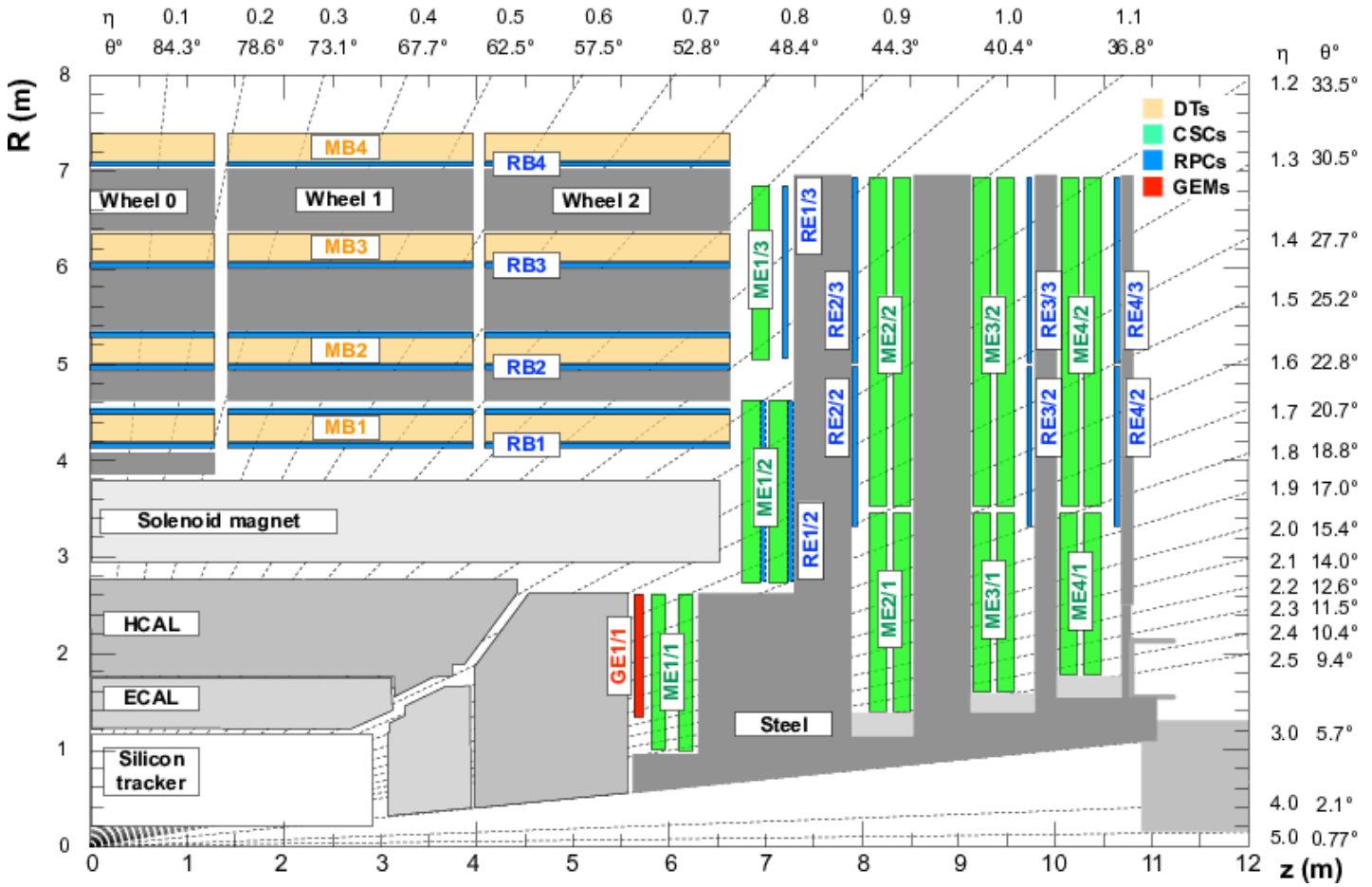
Muon objects

RPC Muon

Reconstructed Muon with Resistive Plate Chamber(RPC) information

GEM Muon

Reconstructed Muon with Gas Electron Multiplier(GEM) information



Datasets

DATA*

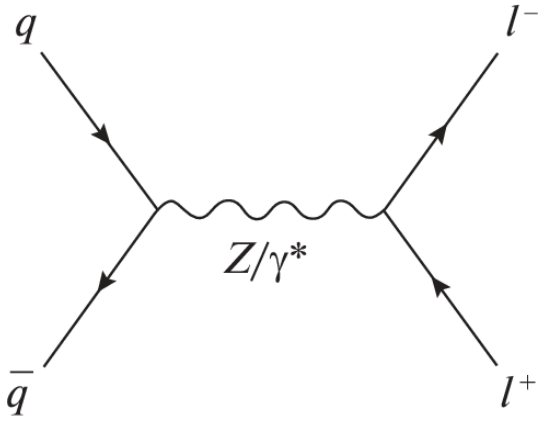
Run2022(C~G) : 34.652 fb-1

Run2023(B~D) : 27.862 fb -1

Run2024(B~G) : 58.06 fb -1

=> Total luminosity : **120.5741** $\boldsymbol{fb^{-1}}$

*Luminosity value with Golden Json



MC Simulation

Drell-Yan to 2 leptons with invariant mass > 50 GeV at 13.6TeV

Selection

HLT Trigger : HLT_IsoMu24_v

Muon selection

- globalMuon && (rpcMuon, standAloneMuon, pfMuon, or gemMuon)
- $p_T > 24GeV \ + |\eta| < 2.4$
- Tight ID + Tight PF Isolation($Iso_{PF}^{Rel} < 0.15$, dR = 0.4)

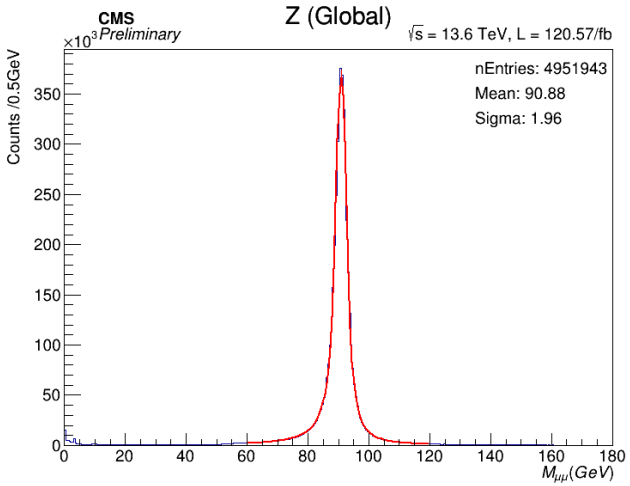
$^{*}\ Iso_{PF}^{Rel} = [\sum_{charged\ hadron} p_T + max(0,\ \sum_{neutral\ hadron} E_T + \sum_{photon} E_T\ -\ 0.5\ * \sum_{pileup} p_T)]\ /p_T^{\mu}$

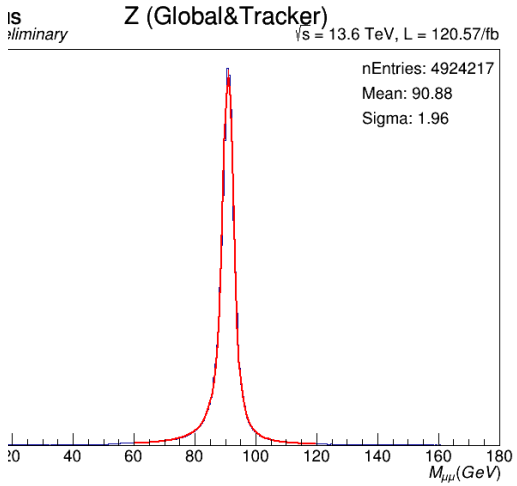
Event selection

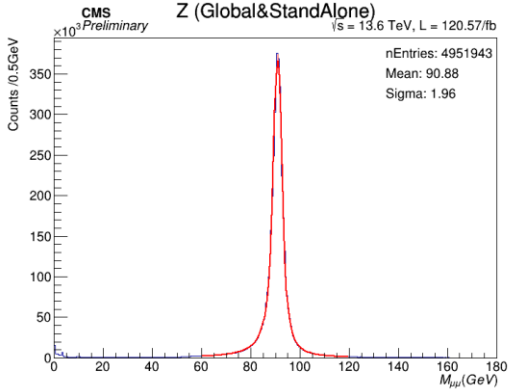
- select two muons with below condition
- $\left|dz_{\mu\mu}\right| < 0.5$
- opposite charge

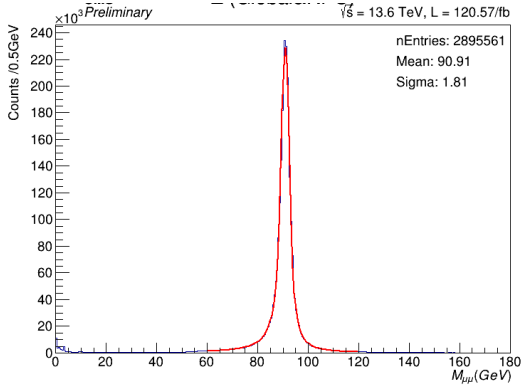
Z mass is reconstructed with a muon pair whose invariant mass is closest to 91.1876GeV

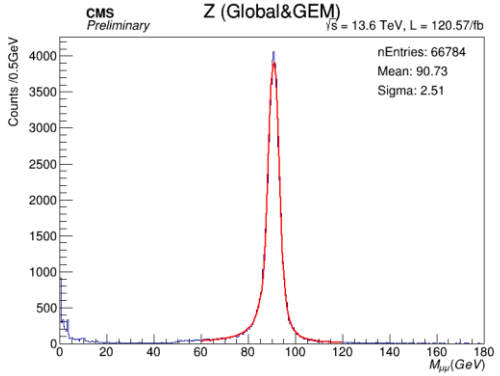
Data Result

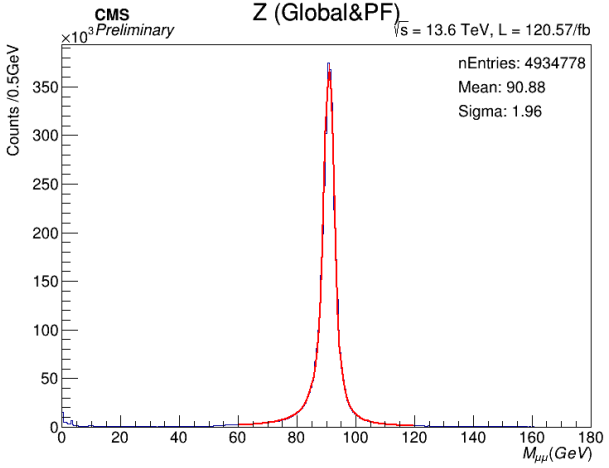






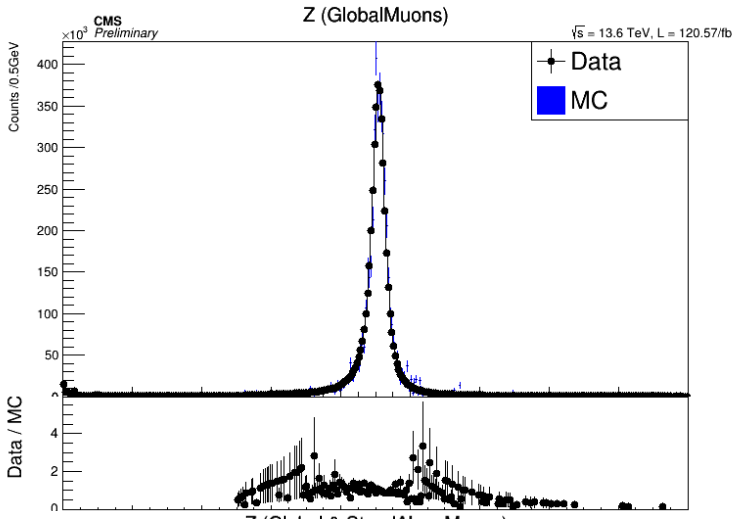


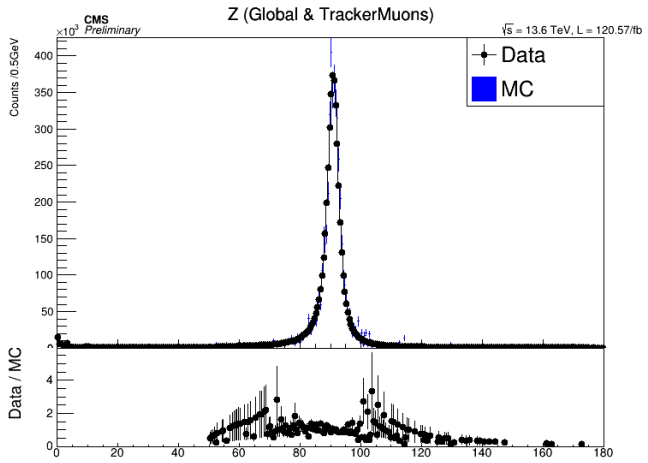


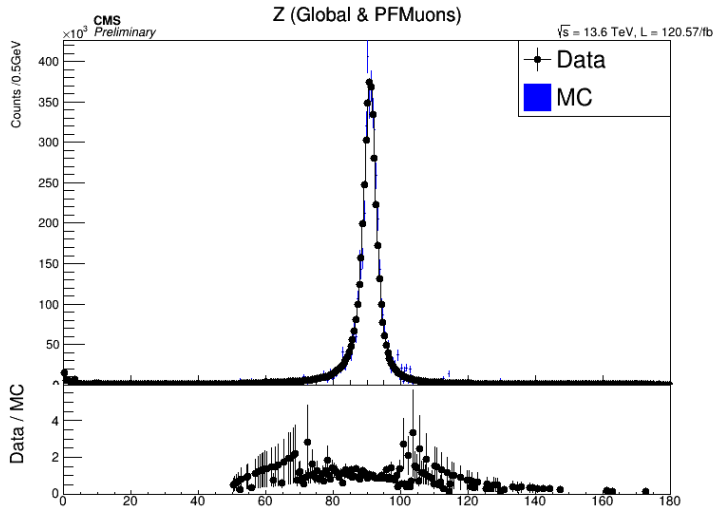


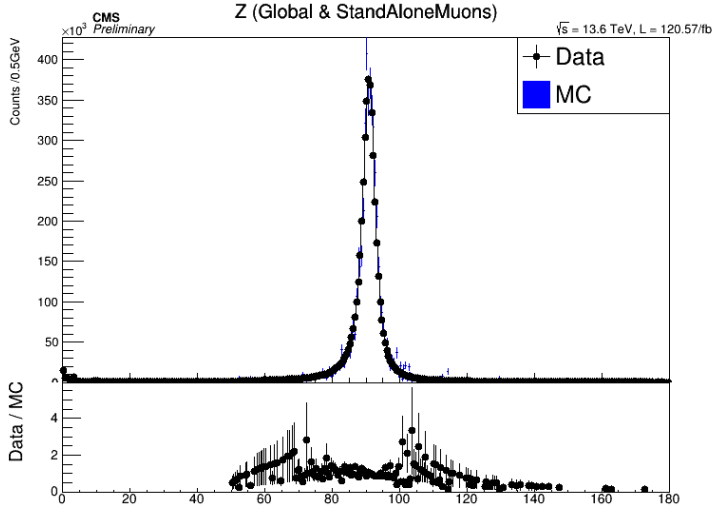
Data : /Muon/Run2022D-27Jun2023-v2/AOD, 13.6TeV, 3.0828 fb^{-1} , other data will be added soon

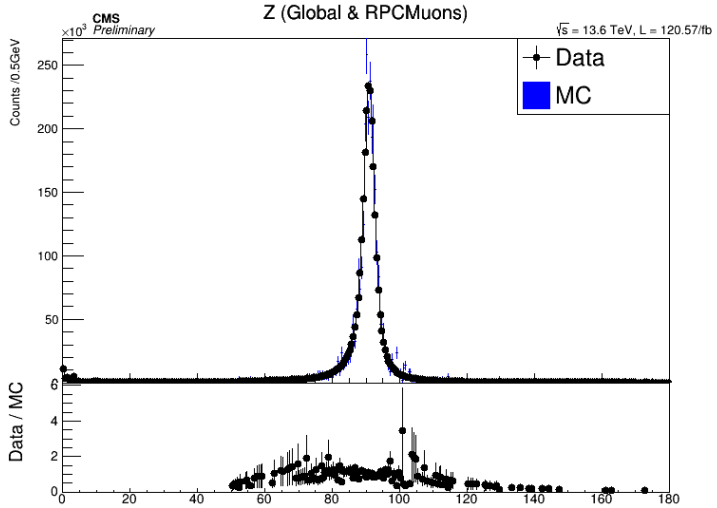
Data / MC

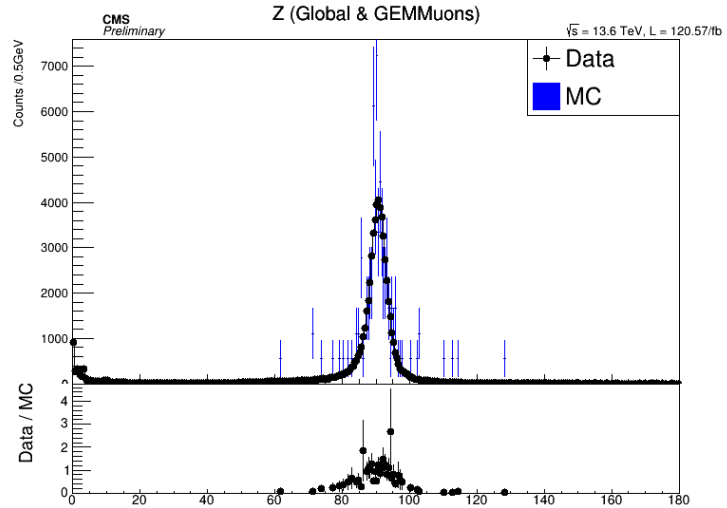












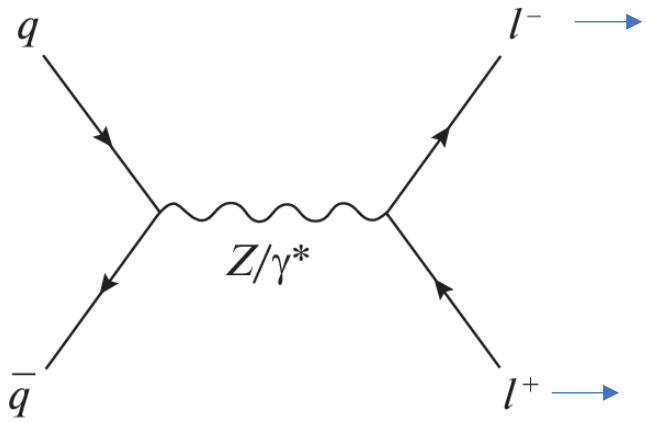
mix
_ex

data for another muon object will be added soon…

Tag and Probe Method

- Select tags and probes, and the probe is used to measure the efficiency of the trigger.
- We adopted this method with $Z \rightarrow \mu\mu$ process
- Tag muon : well identified and reliable muons. tight selection criteria applied.
- Probe muon : unbiased muon candidates. loose selection criteria applied
- Check whether probe muon passed triggers or conditions. And evaluate efficiency.
- high efficiency means probes are good objects

$$\epsilon\,(efficiency) = \frac{N_{probe\ muon\ passed\ trigger}}{N_{all\ probe\ muon}}$$



tag : reliable object

probe : is it really from that Z?

Tag and Probe Selection Criteria

HLT Trigger : HLT_IsoMu24_v

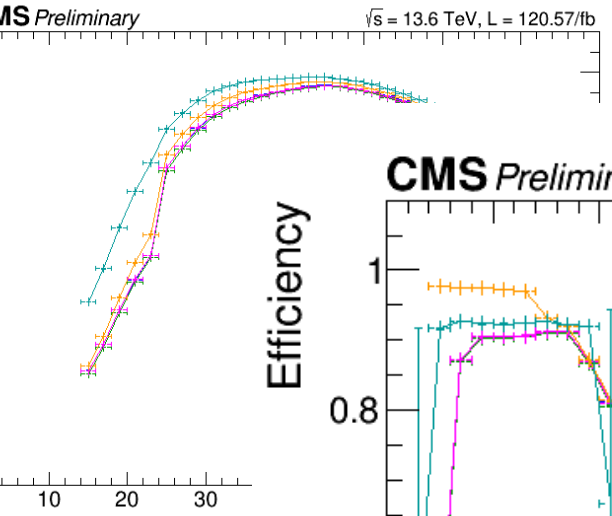
Tag Muon

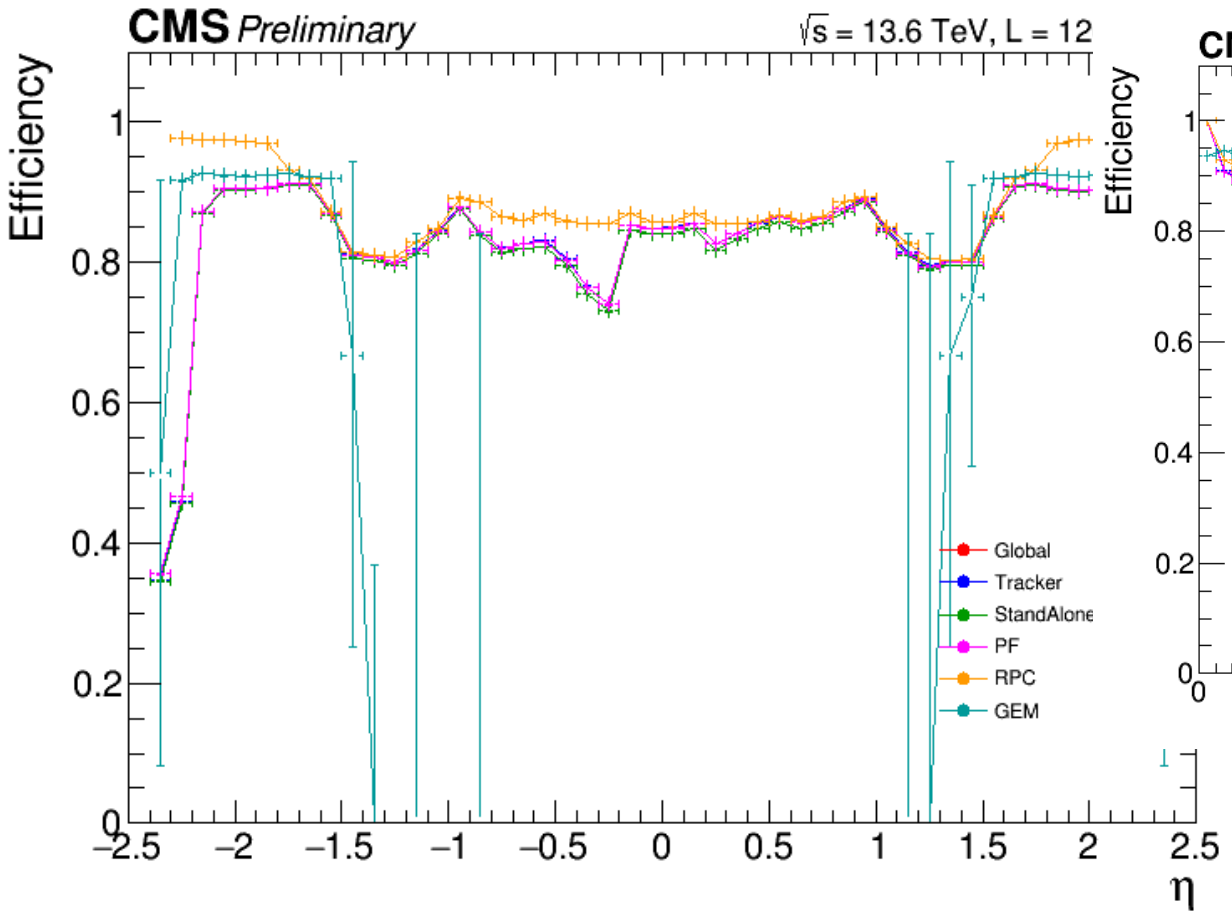
- globalMuon
- $p_T > 24GeV \ + |\eta| < 2.4$
- Tight ID + Tight PF Isolation($Iso_{PF}^{Rel} < 0.15$, dR = 0.4)

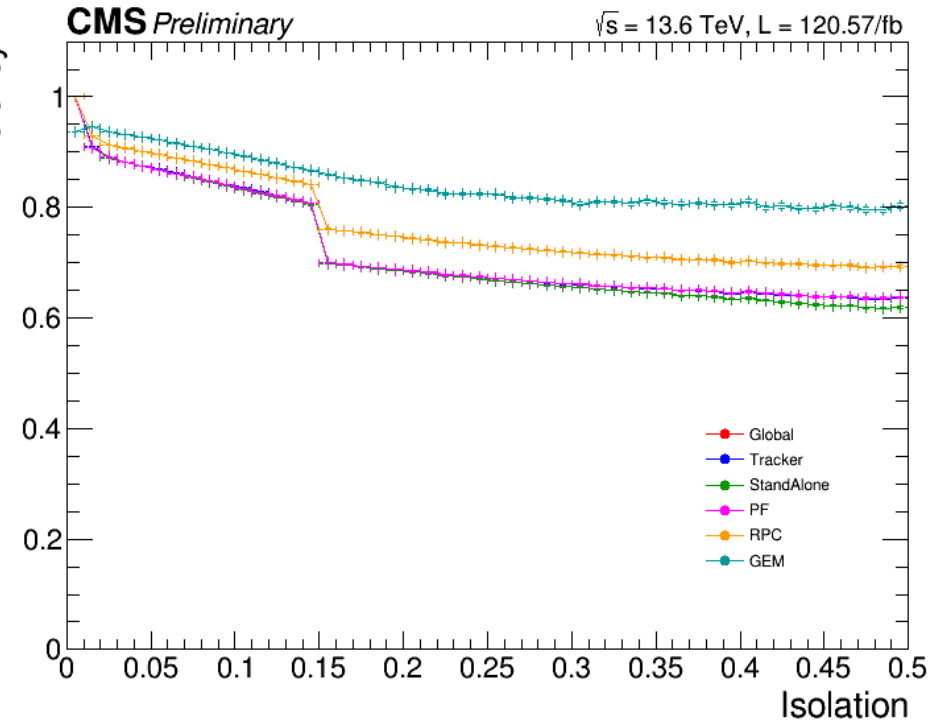
Probe Muon

- globalMuon && (rpcMuon, standAloneMuon, pfMuon, or gemMuon)
- $p_T > 15GeV \ + \ |\eta| < 2.4$
- $\left|dz_{\mu\mu}\right| < 0.5$ with tag muon
- opposite charge with tag muon
- invariant mass of tag and probe pair [60,120]

Efficiency


MS Preliminary
√s = 13.6 TeV, L = 120.57/fb
10
20
30


CMS Preliminary
√s = 13.6 TeV, L = 12
Efficiency
1
0.8
0.6
0.4
0.2
0
−2.5
−2
−1.5
−1
−0.5
0
0.5
1
1.5
2
2.5
η
Global
Tracker
StandAlone
PF
RPC
GEM


CMS Preliminary
√s = 13.6 TeV, L = 120.57/fb
Efficiency
1
0.8
0.6
0.4
0.2
0
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
Isolation
Global
Tracker
StandAlone
PF
RPC
GEM

Summary

- We have seen how the different muon objects provided by CMS affect the analysis.
- We checked the efficiency of muon objects through the Tag and Probe method.
- Using RPC muon and GEM muon information may be more beneficial in certain situations.

Back up

Datasets

DATA(2022)	Delivered by LHC(fb^{-1})	Recorded by CMS(fb^{-1})	Golden JSON(fb^{-1})
/Muon/Run2022C-27Jun2023-v1/AOD	7.0067	6.3777	5.0104
/Muon/Run2022D-27Jun2023-v2/AOD	3.8044	3.3773	2.9700
/Muon/Run2022E-27Jun2023-v1/AOD	6.7495	6.2649	5.8070
/Muon/Run2022F-PromptReco-v1/AOD	20.1584	18.6049	17.7819
/Muon/Run2022G-PromptReco-v1/AOD	3.6185	3.2748	3.0828
total	41.3375	37.8996	**34.6521**

DATA(2023)	Delivered by LHC(fb^{-1})	Recorded by CMS(fb^{-1})	Golden JSON(fb^{-1})
/Muon*/Run2023B-PromptReco-v1/AOD	1.267	1.134	0.617
/Muon*/Run2023C-PromptReco-v4/AOD	20.064	18.466	17.794
/Muon*/Run2023D-PromptReco-v2/AOD	10.761	9.897	9.451
total	32.094	29.504	**27.862**

DATA(2024)	Delivered by LHC(fb^{-1})	Recorded by CMS(fb^{-1})	Golden JSON(fb^{-1})
/Muon*/Run2024B-PromptReco-v1/AOD	0.742	0.656	0.13
/Muon*/Run2024C-PromptReco-v1/AOD	7.95	7.434	7.238
/Muon*/Run2024D-PromptReco-v1/AOD	8.899	8.301	7.957
/Muon*/Run2024E-PromptReco-v2/AOD	12.899	11.92	11.319
/Muon*/Run2024F-PromptReco-v1/AOD	30.786	28.433	25.79
/Muon*/Run2024G-PromptReco-v1/AOD	5.988	5.484	5.477
total	66.29	61.42	**58.06**

$\sqrt{s} = 13.6\ TeV$

Total luminosity with Golden JSON : **120.5741** fb^{-1}

lumimasks

Cert_Collisions2022_355100_362760_Golden.json

Cert_Collisions2023_366442_370790_Golden.json

Cert_Collisions2024_378981_385194_Golden.json

MC Simulation

/DYJetsToLL_M-50_TuneCP5_13p6TeV-madgraphMLM-pythia8/Run3Summer22DRPremix-124X_mcRun3_2022_realistic_v12-v2/AODSIM

/QCD_PT-15to7000_TuneCP5_Flat2022_13p6TeV_pythia8/Run3Summer22DRPremix-124X_mcRun3_2022_realistic_v12-v3/AODSIM

MC Truth Matching

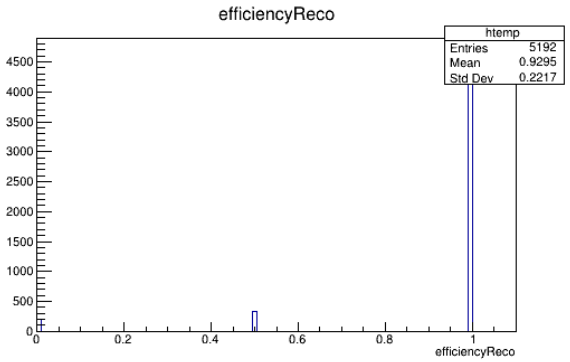
Muon object matching

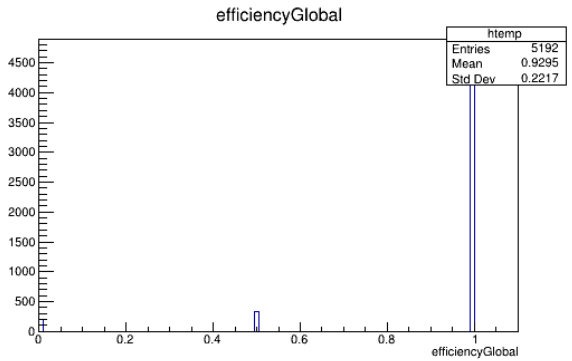
- ΔR matching (< 0.15)
  - $\Delta R = \sqrt{(\eta_{reco} - \eta_{gen})^2 + (\phi_{reco} - \phi_{gen})^2}$
- Charge matching
  - same sign charge
- PDG ID matching
  - genMuon.pdgId() == recoMuon.pdgId()

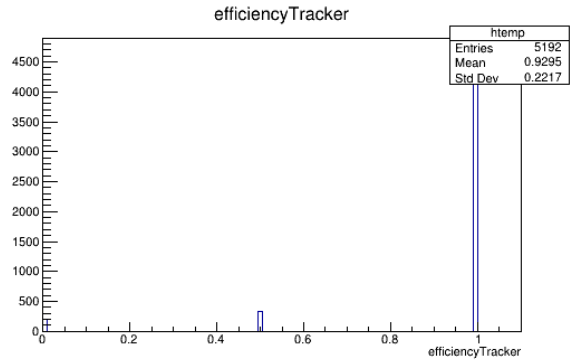
Muon Efficiency

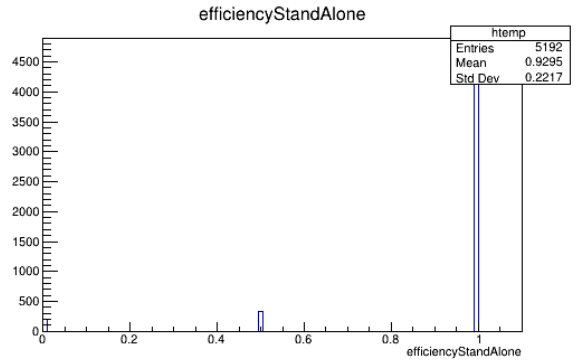
- muon Efficiency = N_{matched reco muon} / N_{gen muon}

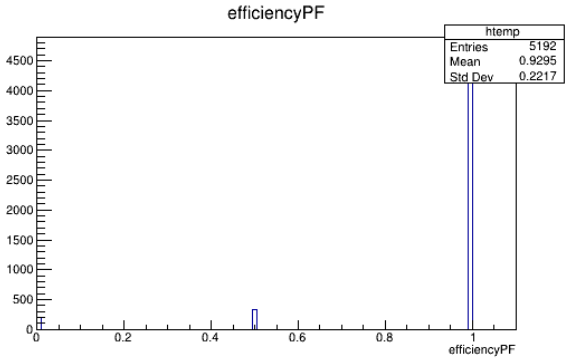
MC Result – Muon Efficiency

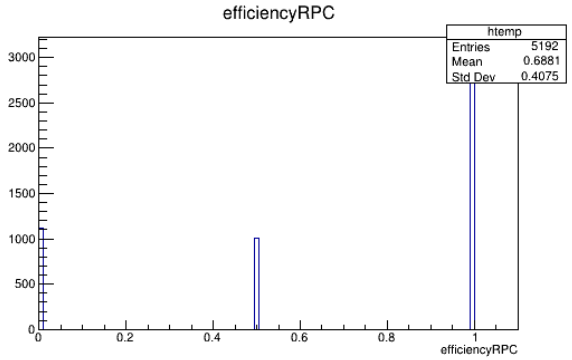


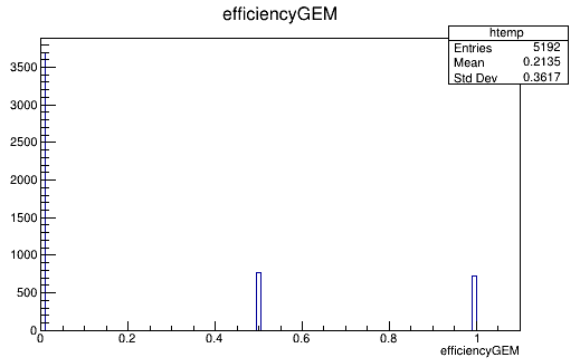












MC Data : /Run3Summer22DRPremix/DYto2L-2Jets_MLL-50_TuneCP5_13p6TeV_amcatnloFXFX-pythia8/AODSIM/124X_mcRun3_2022_realistic_v12_ext1-v1/00775a3b-7386-44ac-8ade-e3aafbdc0261, 00656c16-fb80-415d-b50b-15fbe6824f22, 0066b911-997b-4e7a-b322-442102f0a30e. other data will be added soon…

total events : 24188