Status Report

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

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Motivation

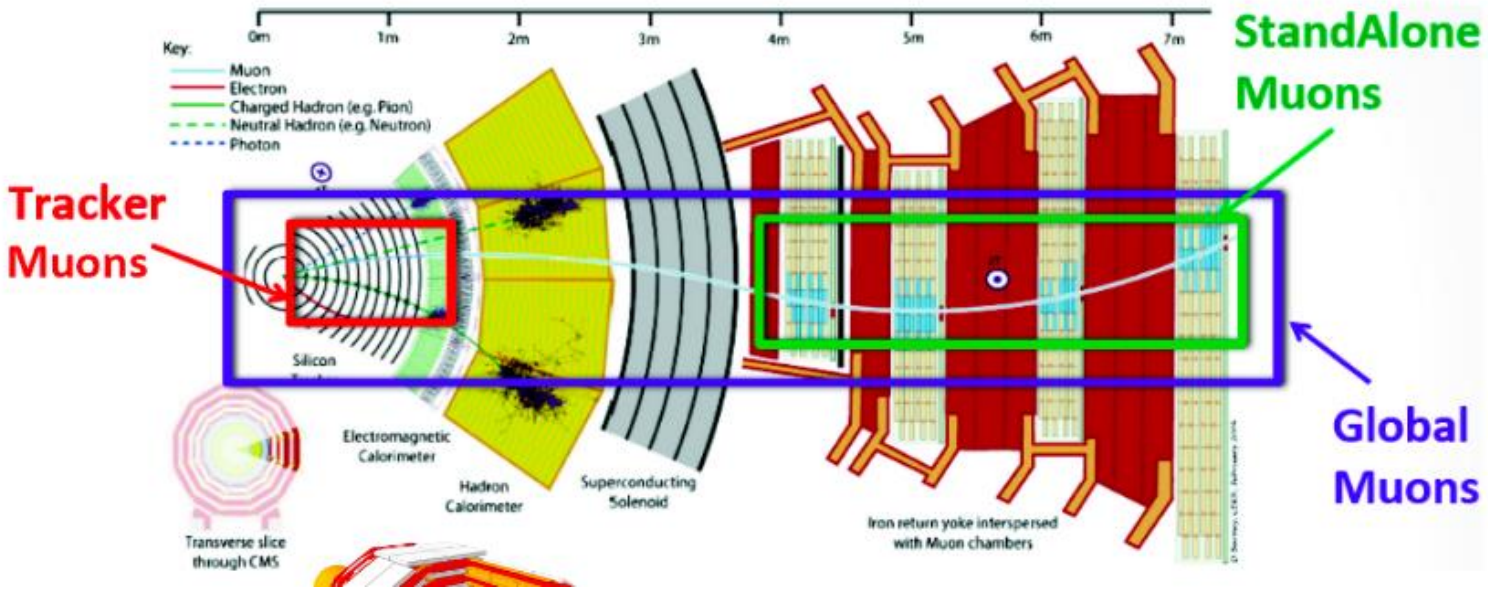
- ✓ Simple validation on recent CMS Run3 data collected from 2022 to 2024.
- ✓ Reconstructed Z boson mass with a muon pair is good indicator of muon performance.
- ✓ In this study, reconstruction of Z boson with different muon IDs are compared.

Muon Objects

Tracker Muon
Good resolution with low p_T region.

Stand Alone Muon
Dedicated detectors for muon.
GEM, RPC, CSC..

Extrapolate!



Global Muon
Combined from tracker muon and stand alone muon.

Particle Flow Muon (PF Muon)

- PF algorithm leverage all information of sub-detectors (including CAL).
- General muon object for physics analysis stored in MINIAOD, NANOAOD.

Muon Objects

RPC Muon

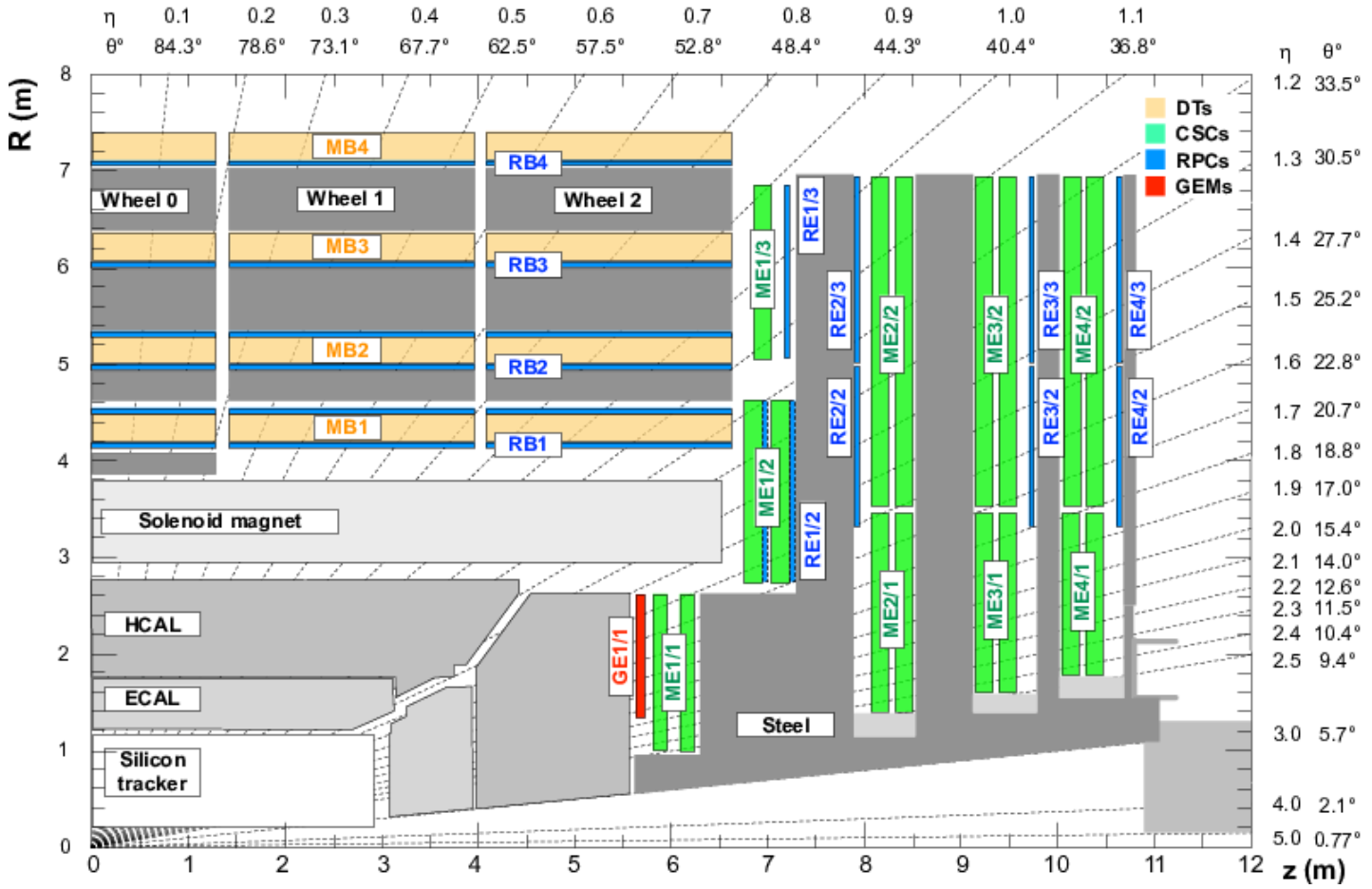
Resistive Plate Chamber(RPC)

- Fast time resolution ~ nano sec.

GEM Muon

Gas Electron Multiplier(GEM)

- Cover endcap region
- Additional position and direction information in endcap



Dataset and MC

Run3 data at $\sqrt{s} = 13.6\,TeV$ and MC sample.

DATA(2022)	LHC Delivered (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/Run2022G-PromptReco-v1/AOD	3.6185	3.2748	3.0828
total	14.4296	13.0298	**11.0604**

***Lumimask :** *Cert_Collisions2022_355100_362760_Golden.json*

***HLT Trigger :** HLT_IsoMu24_v

Drell Yan MC sample (# *72,909,628 events*)

/DYto2L-2Jets_MLL-50_TuneCP5_13p6TeV_amcatnloFXFX-pythia8/Run3Summer22DRPremix-124X_mcRun3_2022_realistic_v12-v4/AODSIM

Event Selection

Muon Definition

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

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

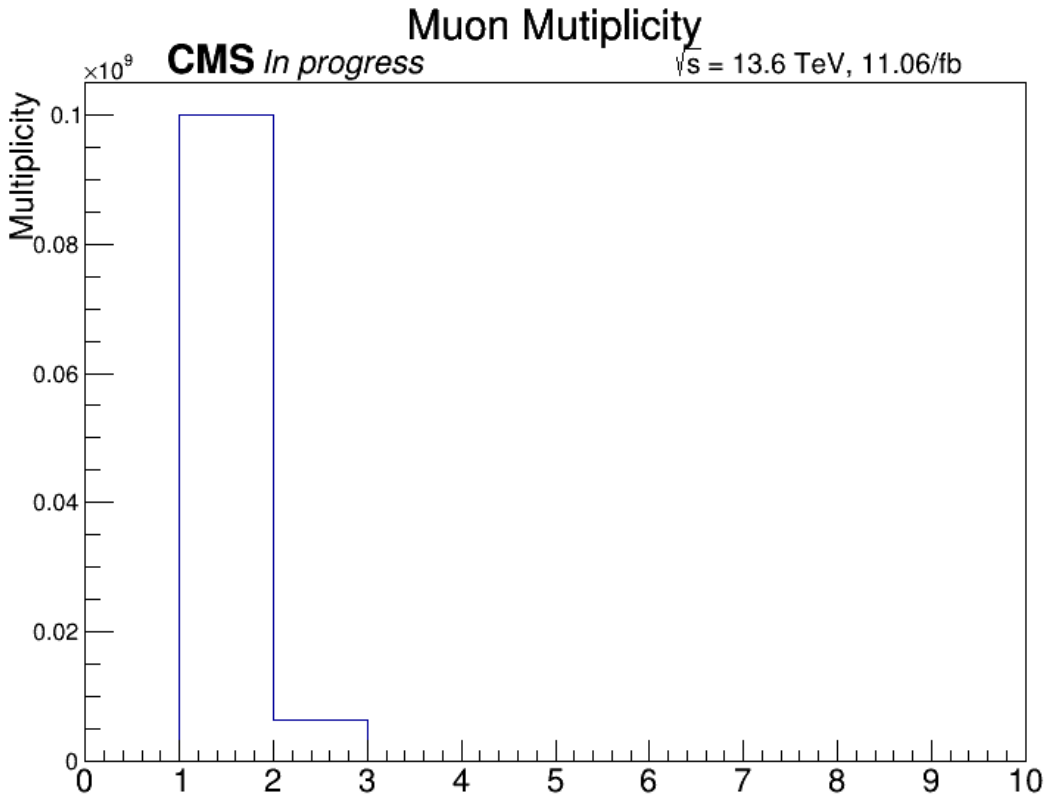
Event selection

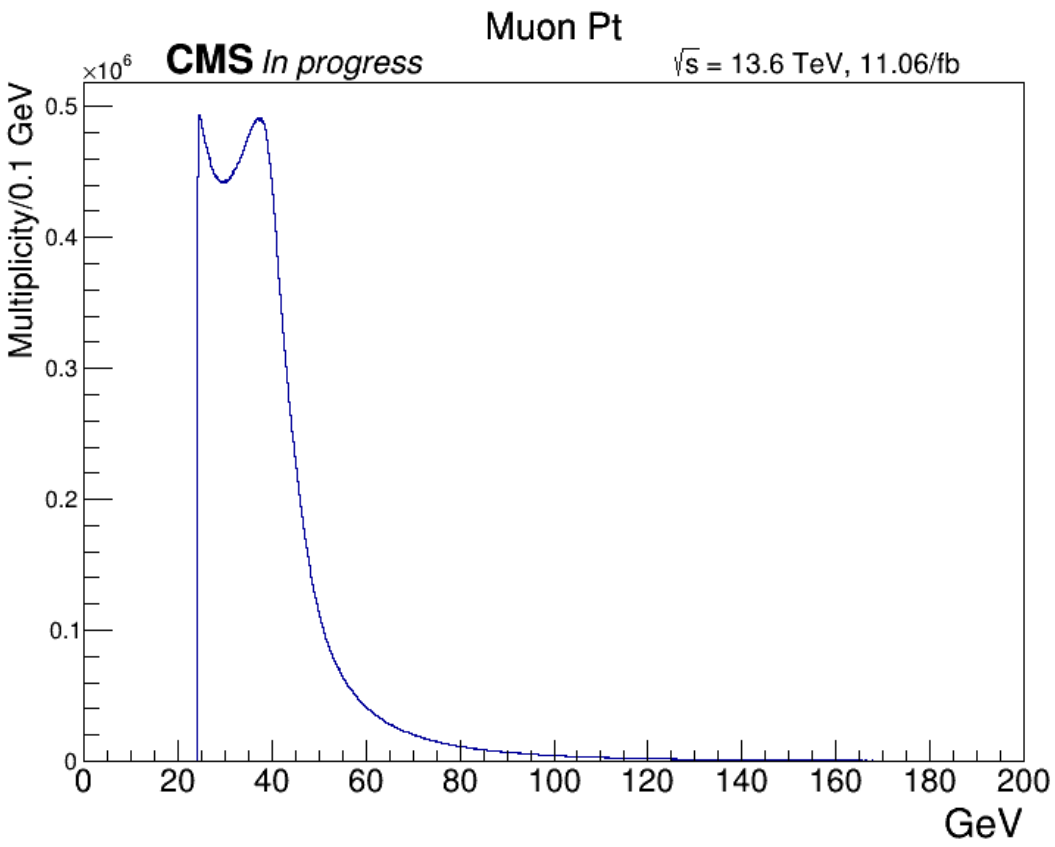
✓ S1. Events with number of muons ≥ 2

✓ S2. Events with z distance of two muons $|dz_{\mu\mu}| < 0.5$

✓ S3. Opposite electric charge of two leptons

Distribution of muons





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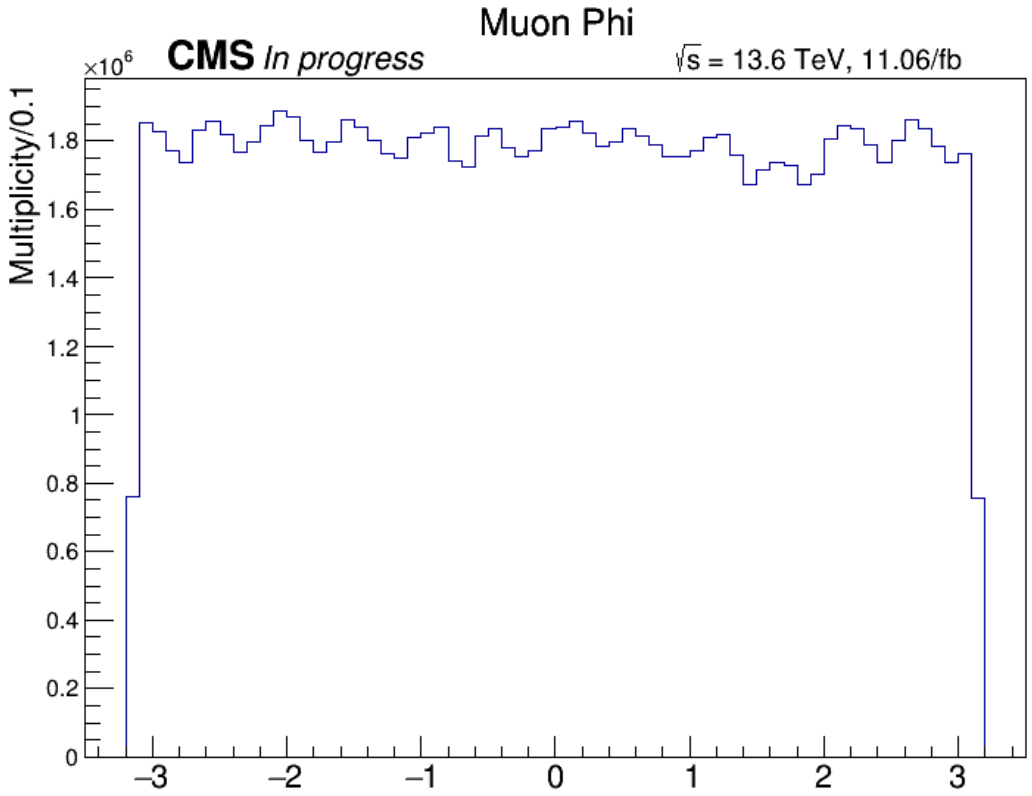

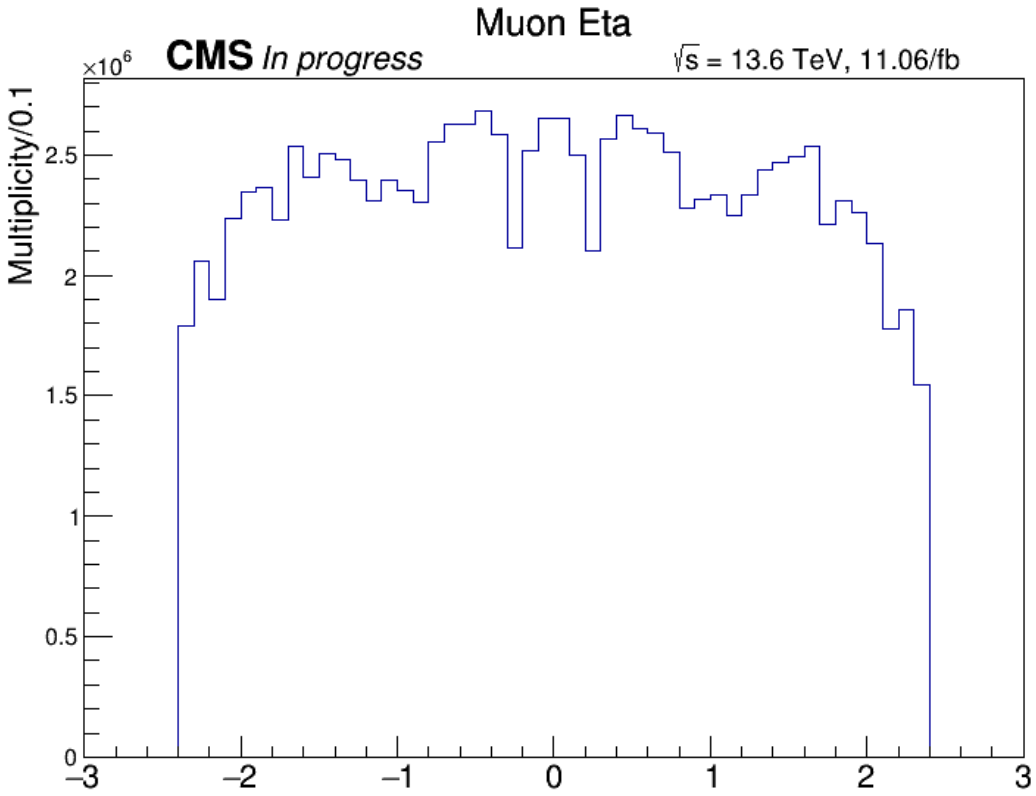

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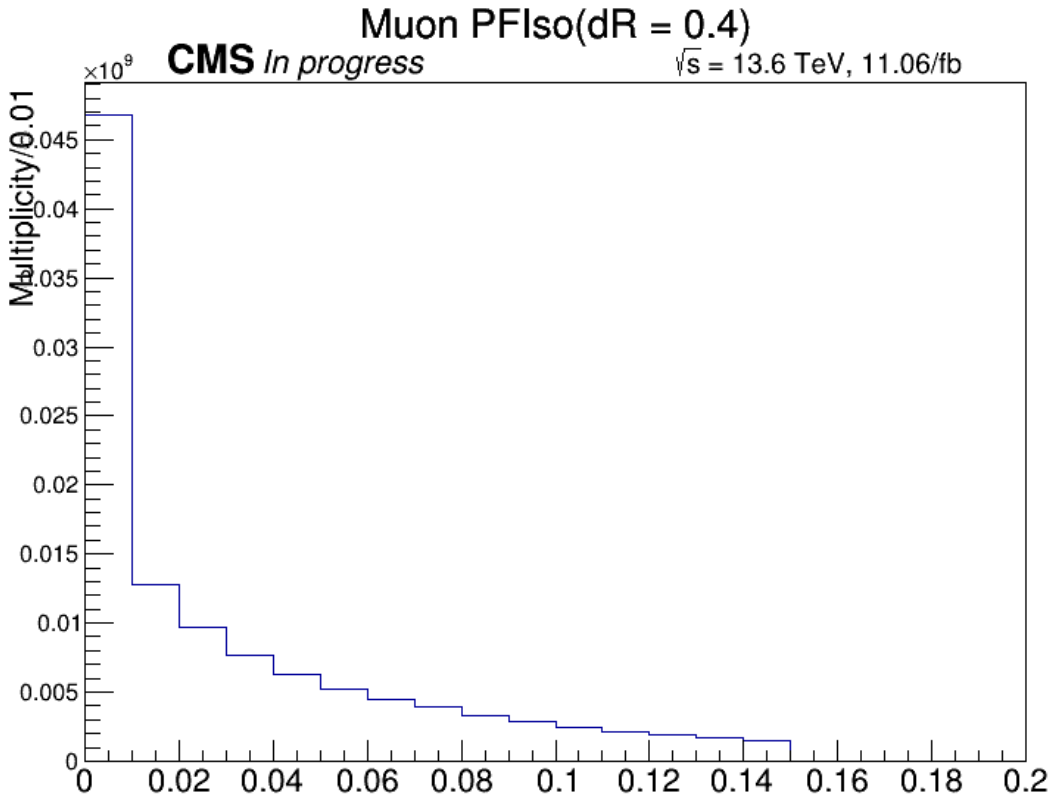
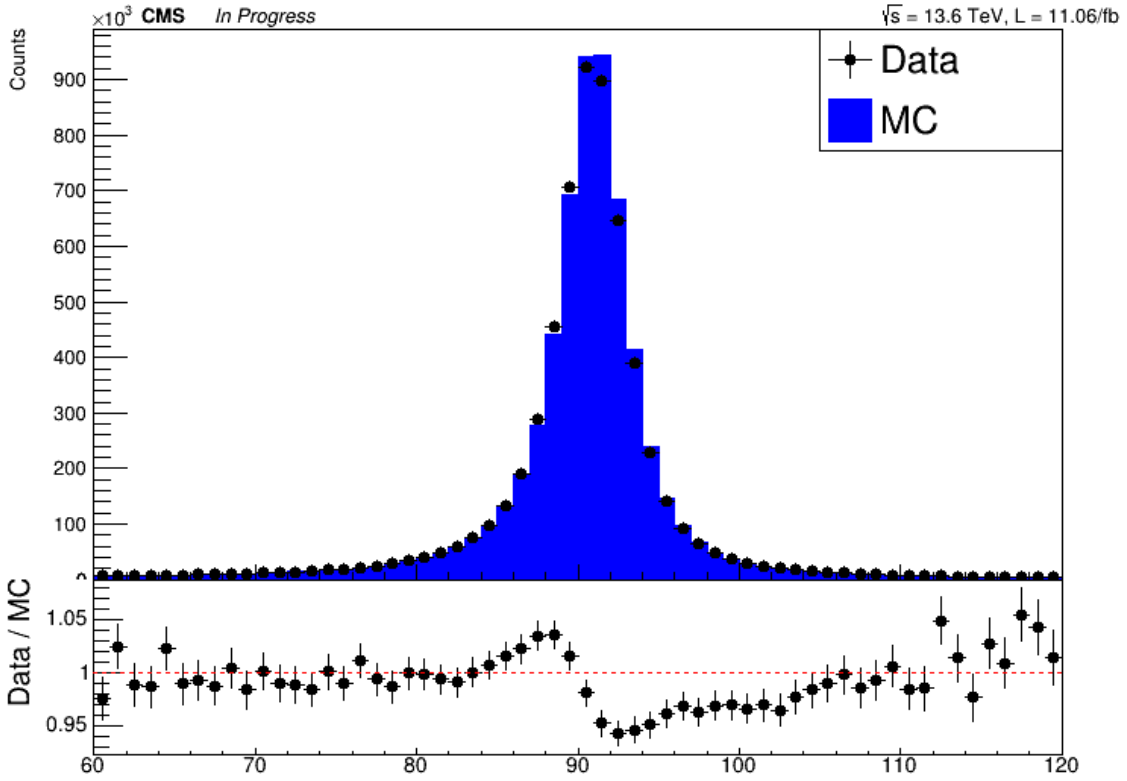
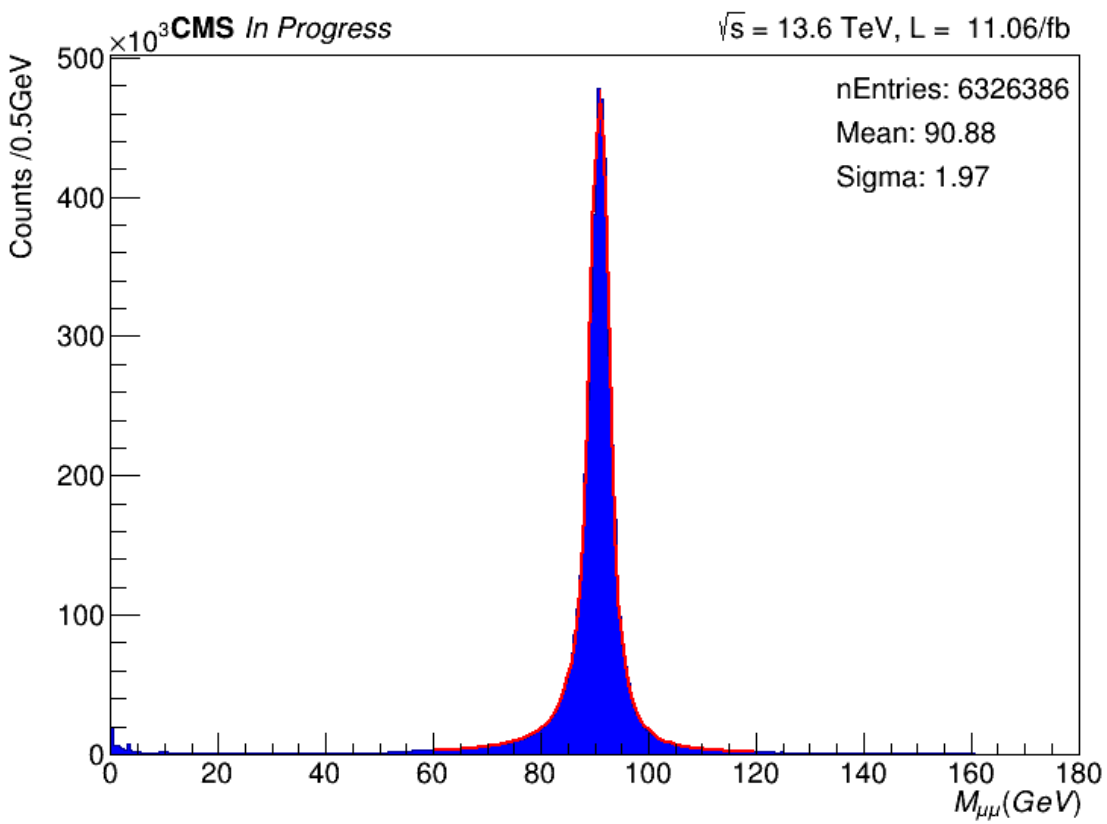


Result

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





Event Selection with the other muon objects

Muon Definition

- *RPCMuon*
- $p_T > 24GeV \ + |\eta| < 2.4$
- Tight ID + Tight PF Isolation ($Iso_{PF}^{Rel} < 0.15$)

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

Event selection

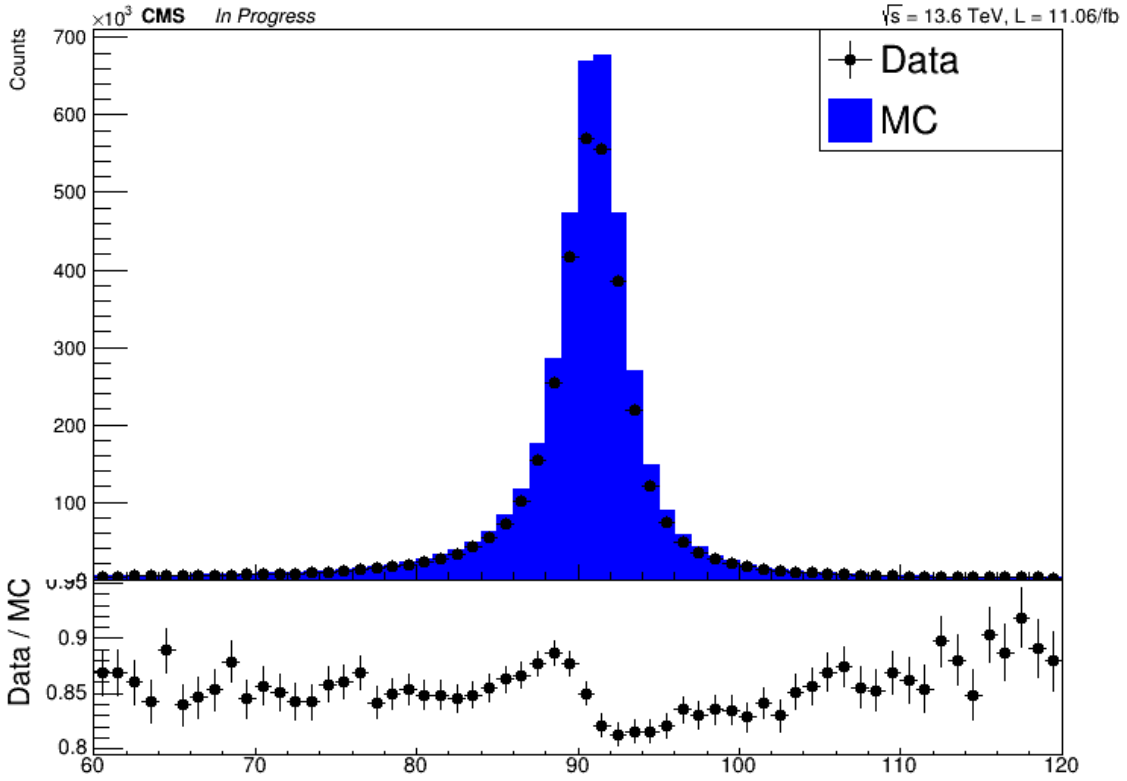
✓ S1. Events with number of muons ≥ 2

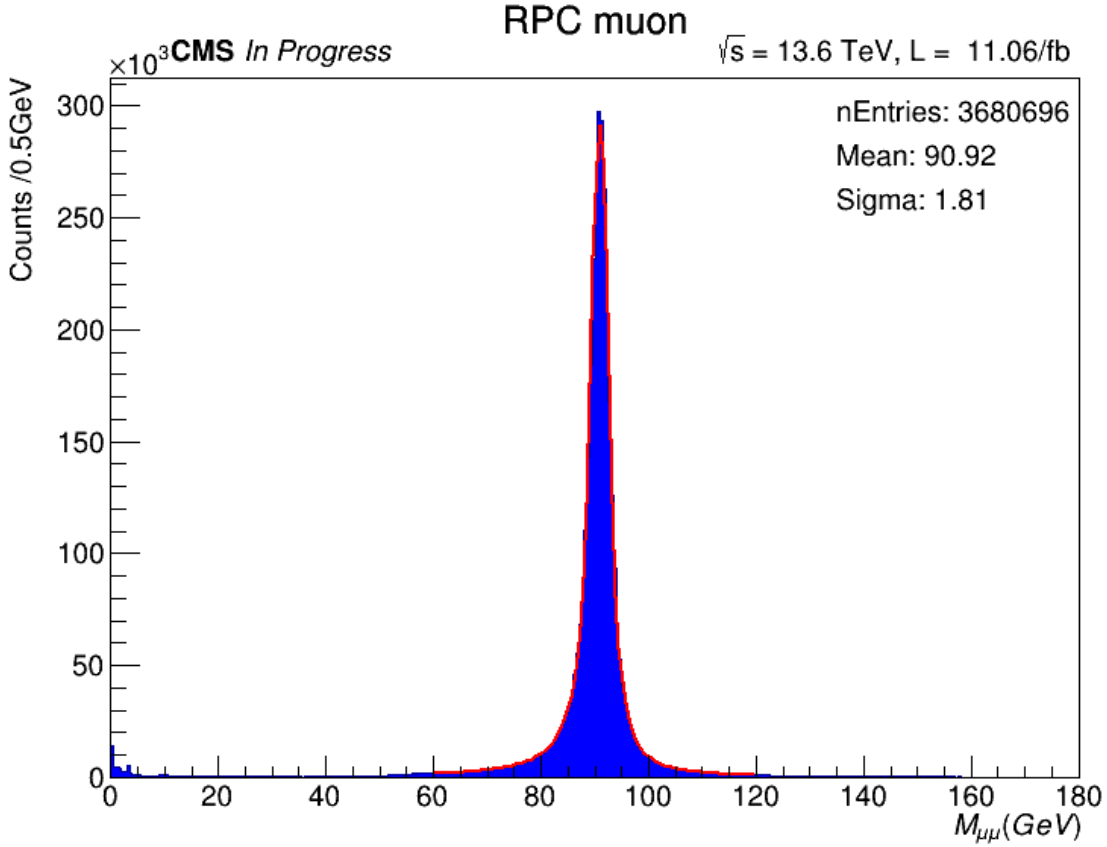
✓ S2. Events with z distance of two muons $|dz_{\mu\mu}| < 0.5$

✓ S3. Opposite electric charge of two leptons

Result – RPC Muon

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





RPC Muon Efficiency - Tag and Probe

Tag Muon Condition

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

Probe Muon Condition

- $p_T > 15GeV \ + |\eta| < 2.4$
- RecoMuon

Passing Probe Condition

- Probe Muon Condition + RPCMuon

Tag and Probe Muon Pair

- Opposite Charge + $dz_{\mu\mu} < 0.5$

Efficiency Definition

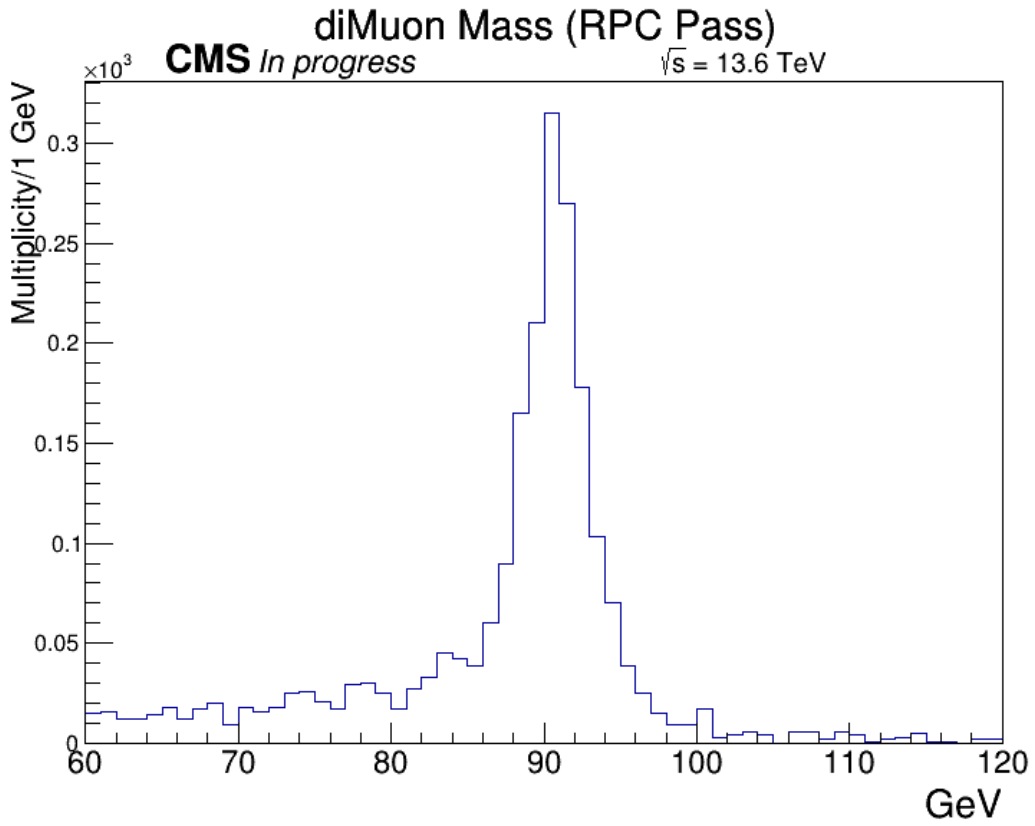
$$\epsilon = \frac{N_{passing\ probe}}{N_{passing\ probe} + N_{failing\ probe}}$$

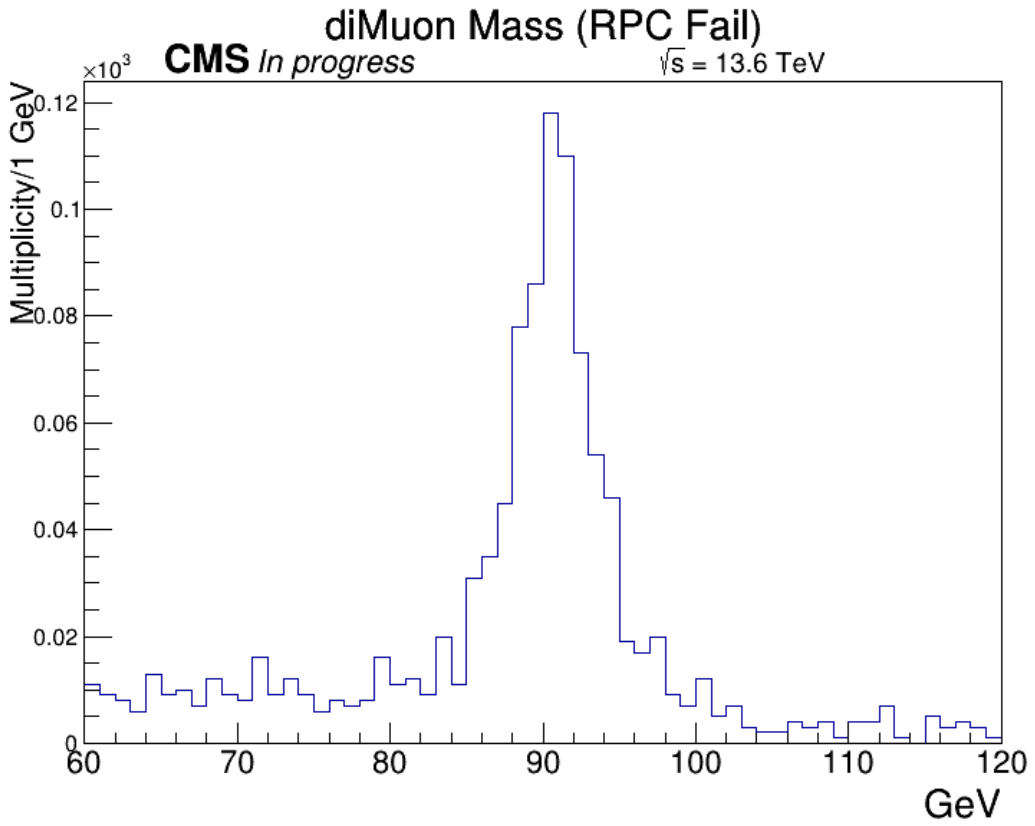
mass window : [60,120]

Scale Factor For RPC Muon

$$SF_{RPC} = \frac{\epsilon_{Data}}{\epsilon_{MC}}$$

RPC Muon Efficiency - Tag and Probe





- just for test data (parts of Run2022C, # of Events: 359548)
- Pass : 2270, Fail : 1197, ϵ = 0.6574

Summary and plans

- In the Run3 data, we checked how the z->mumu reconstruction is done for each muon object and compared it to MC.
- We can see some difference between RPC muons compared to MC.
- To Complement the difference, we need to calculate efficiency for RPC muons
- Using the Tag and Probe method, we will find the scale factor required when using RPC muon data.
- In addition to the currently used Run 22C,D,G data, we will analyze all currently released data.

Summary and plans

- studying and tuning for Z mass distribution difference between data and MC
- Divide tag selection conditions into sections(for pt, eta and iso)
- To calculate SF, running same analysis code for all data and MC

Backup

Datasets of the Run3

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

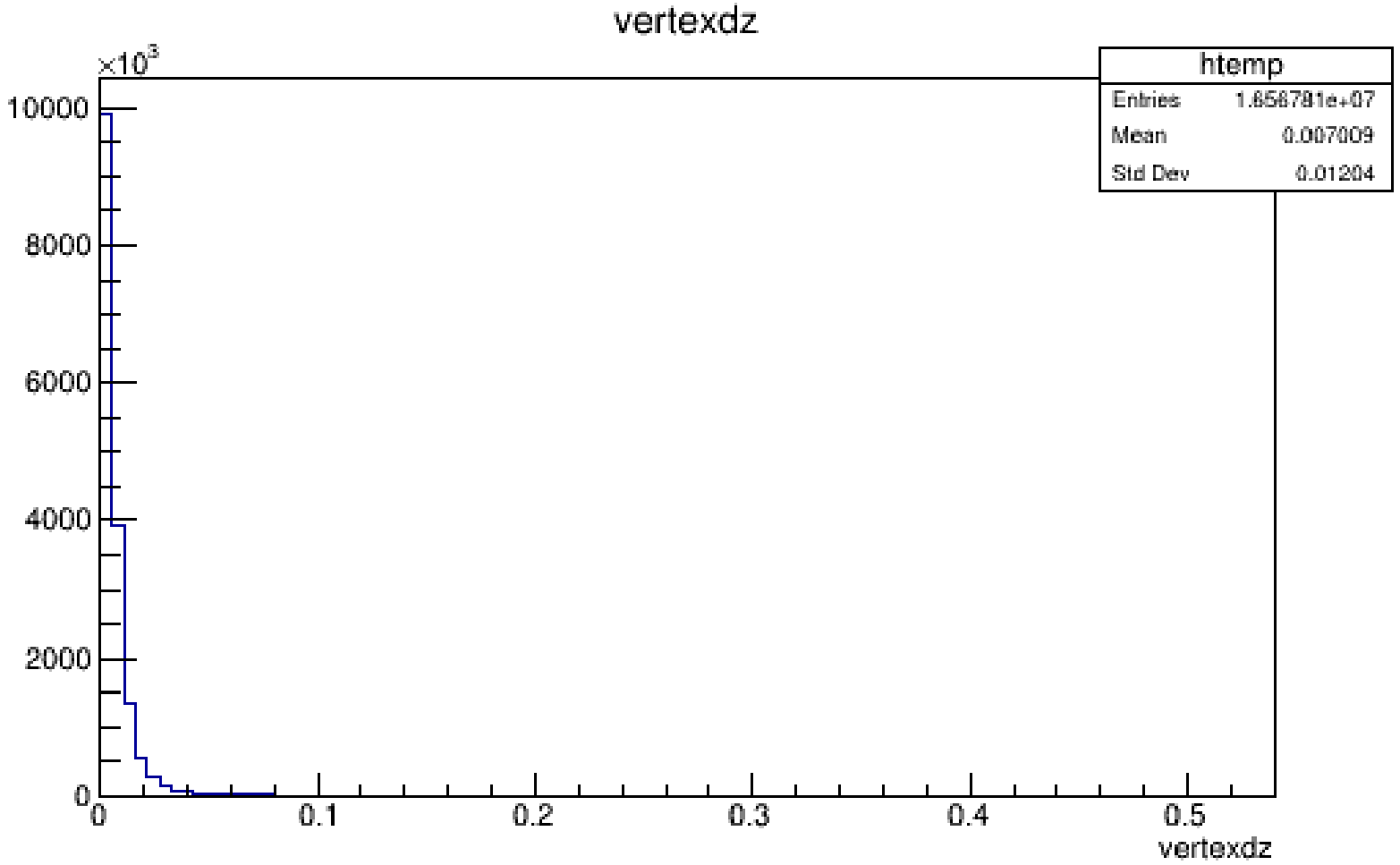
/DYto2L-2Jets_MLL-50_TuneCP5_13p6TeV_amcatnloFXFX-pythia8/Run3Summer22DRPremix-124X_mcRun3_2022_realistic_v12-v4/AODSIM

NEvents : 72909628

Muon Tight ID

- global muon and PF muon.
- $\chi^2/_{ndof}$ of the global muon track fit < 10
- At least one muon chamber hit included in the global-muon track fit
- Muon segments in at least two muon stations. (Implies that the muon is also an arbitrated tracker muon)
- Its tracker track has transverse impact parameter $d_{xy} < 2\ mm$ w.r.t. the primary vertex.
- The longitudinal distance of the tracker track wrt. the primary vertex is d_z < 5 mm
- Number of pixel hits > 0
- Cut on number of tracker layers with hits >5

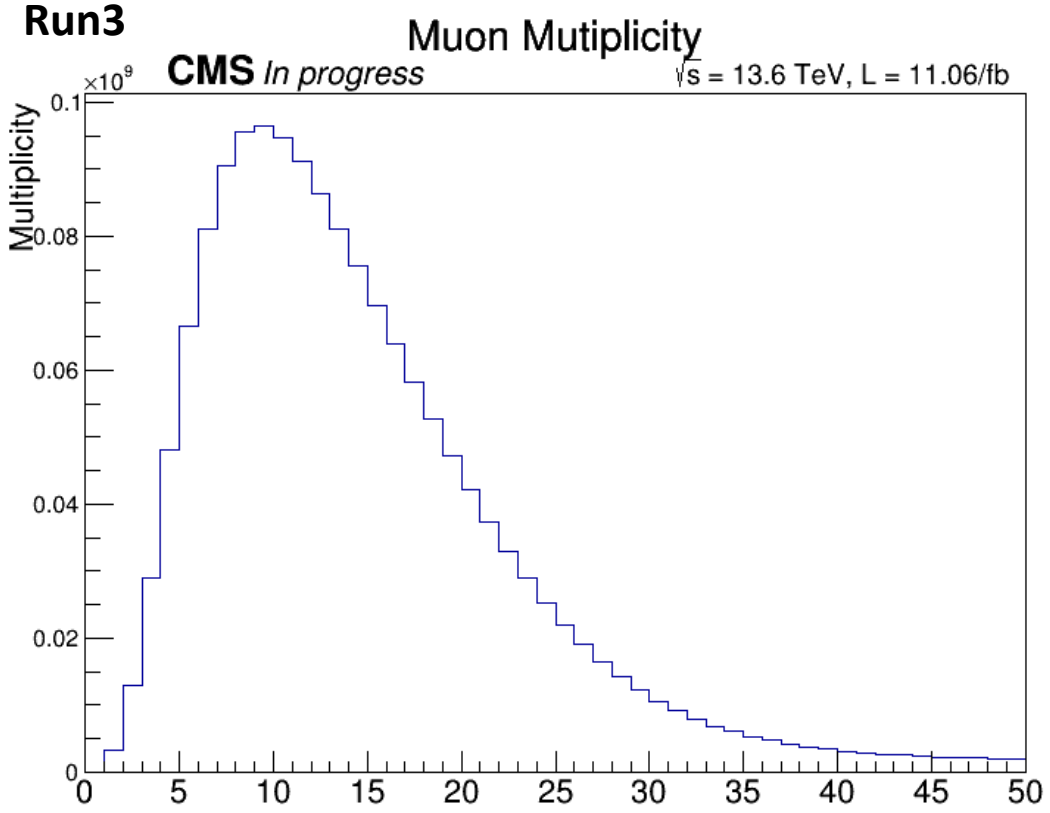
$dz_{\mu\mu}$ distribution of Muon



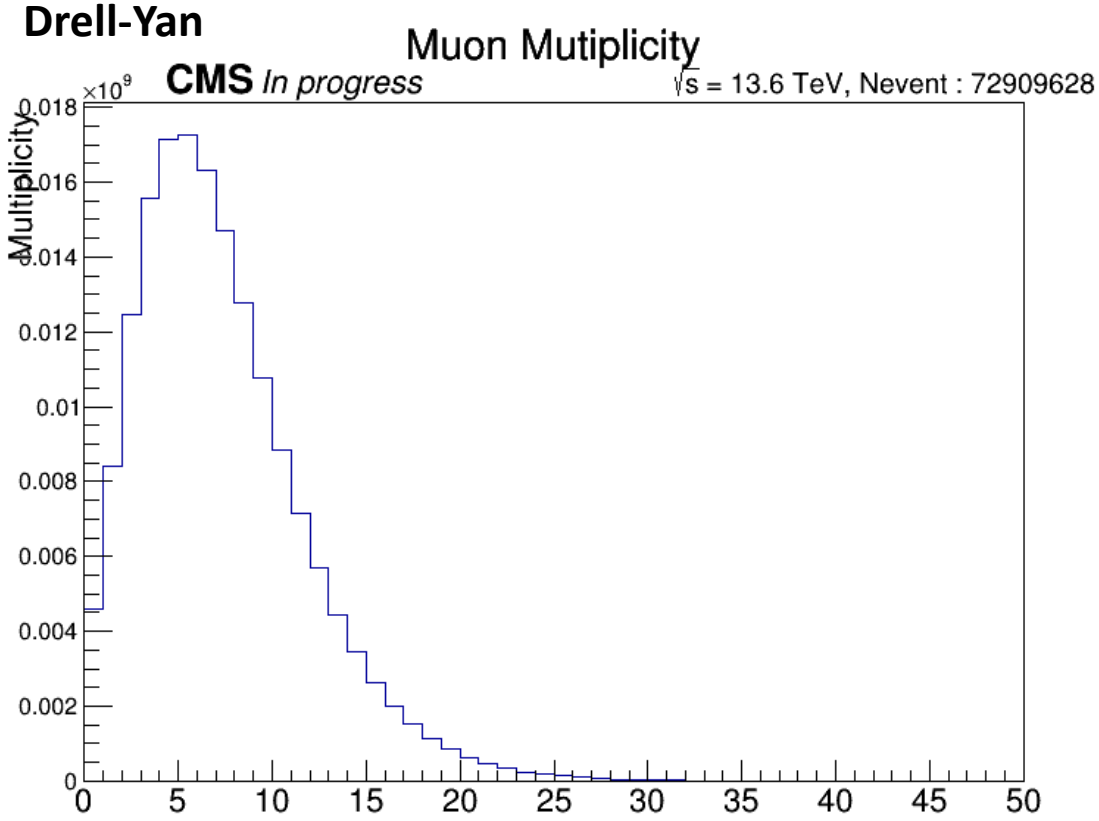
Data / MC comparison

Without any selection on muon object.

Run3



Drell-Yan



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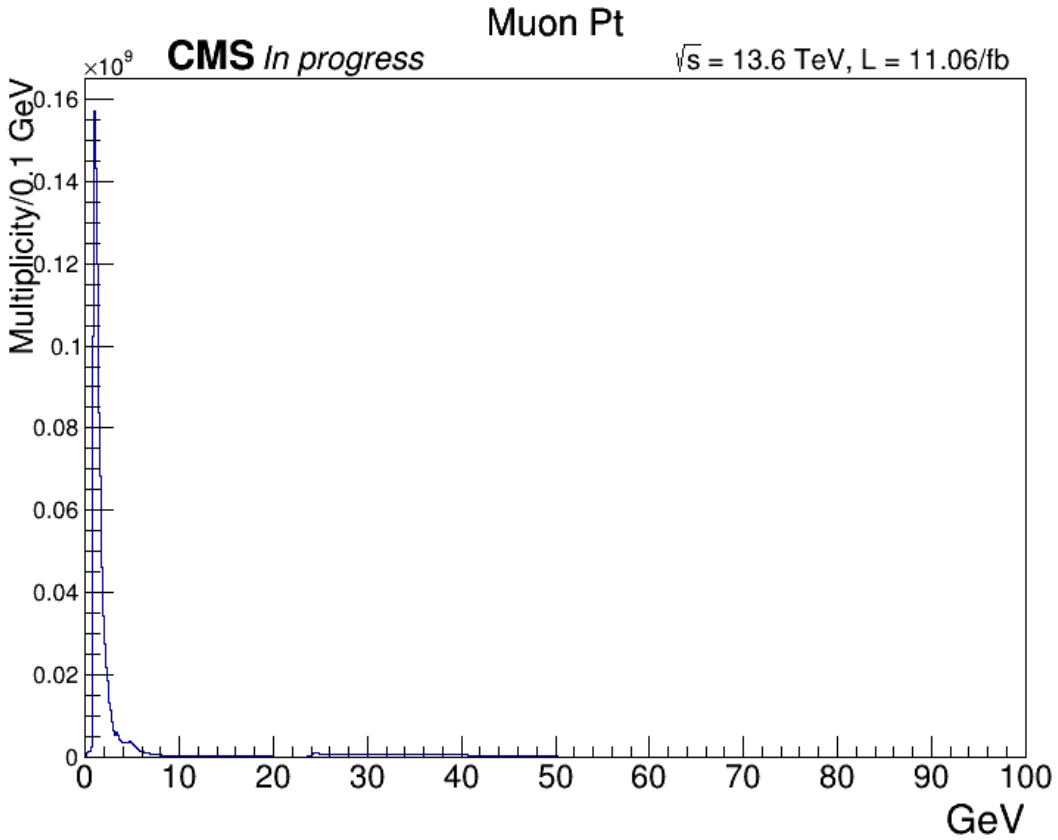

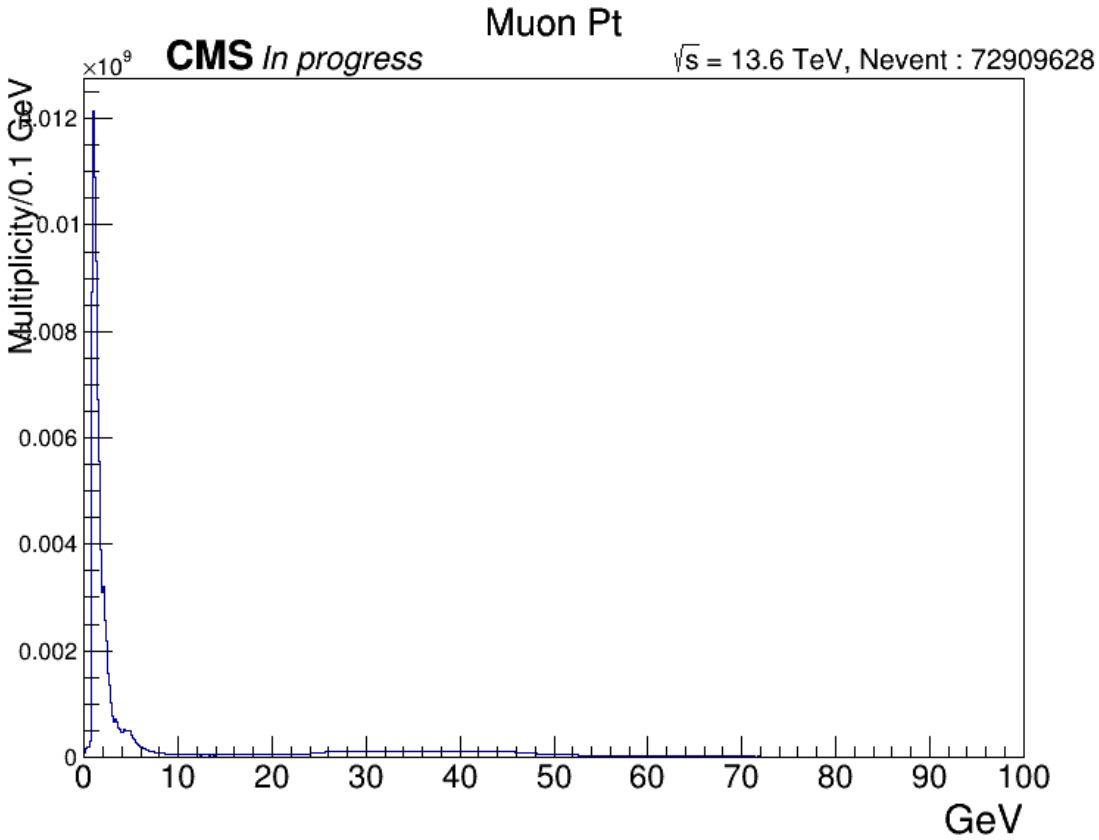

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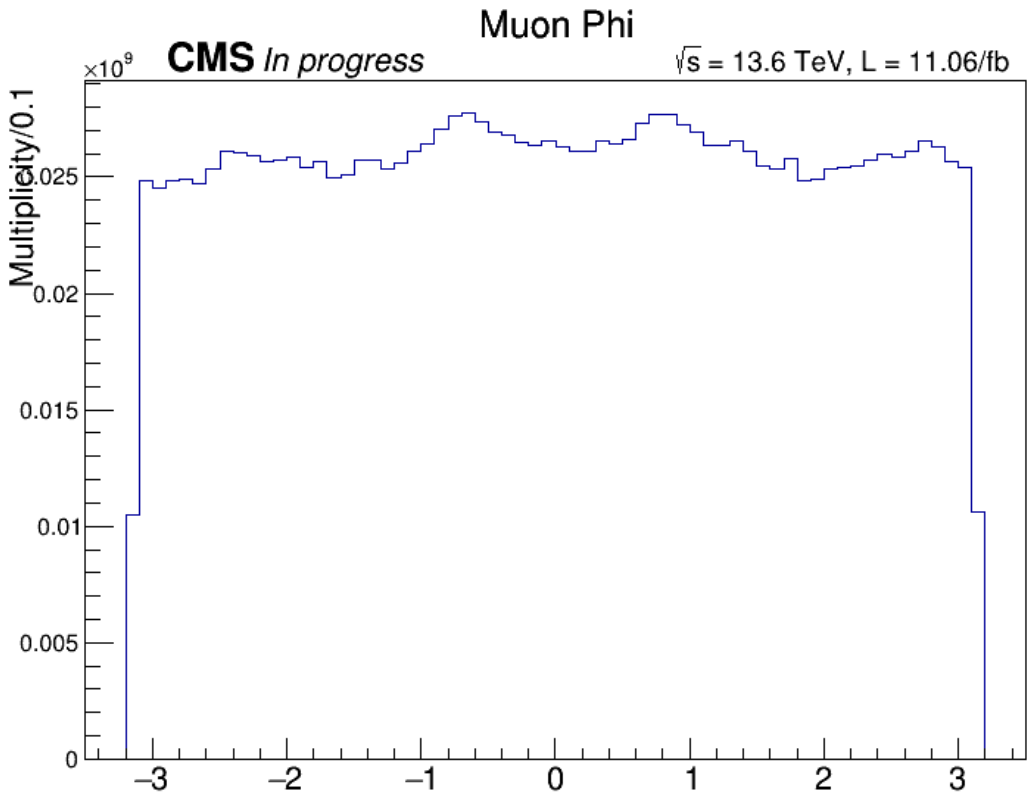

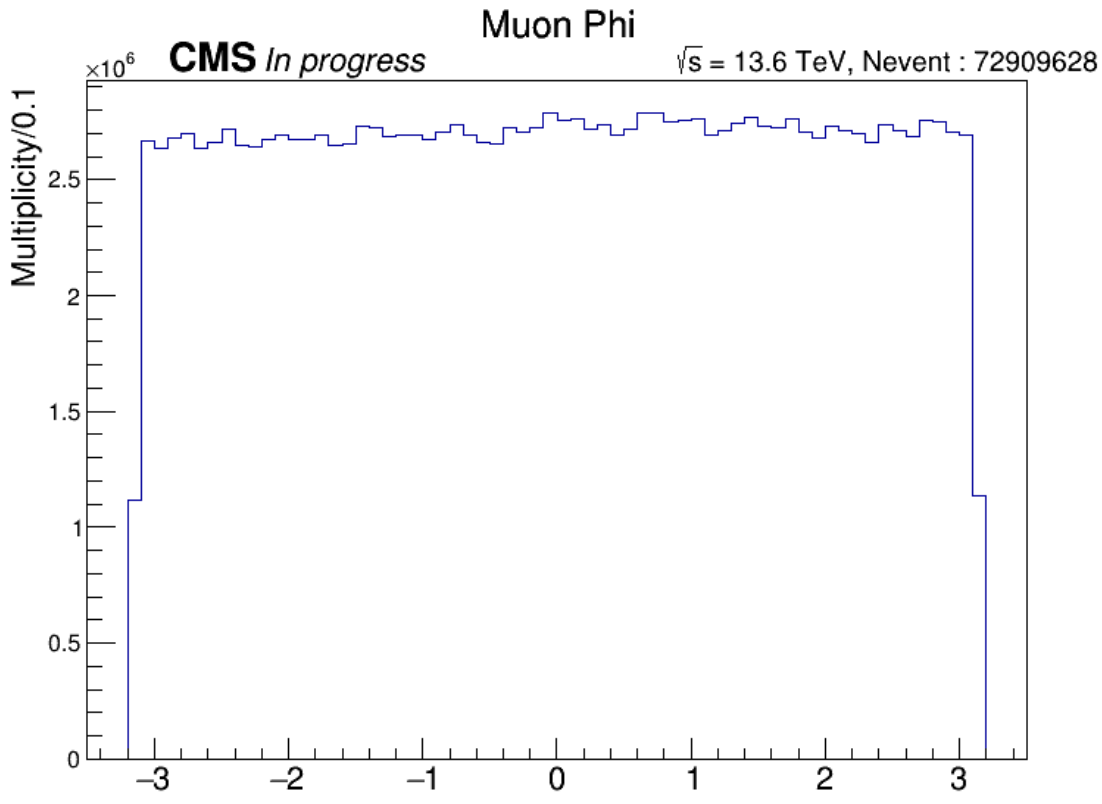

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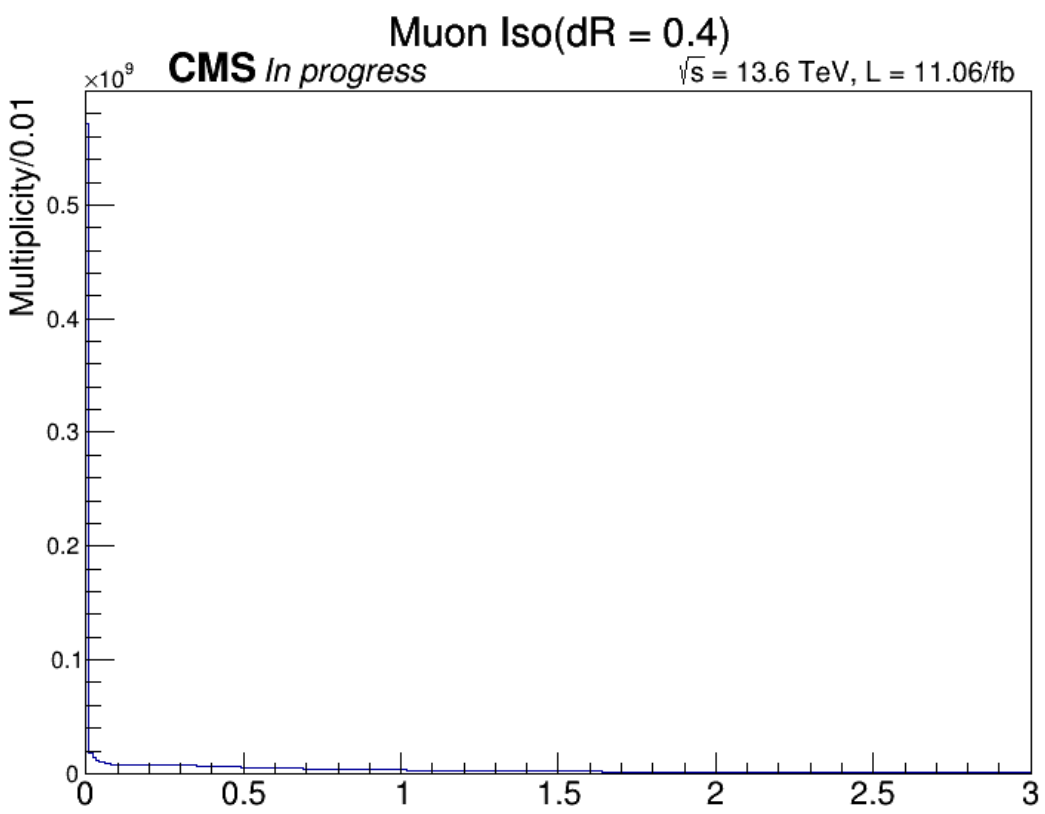

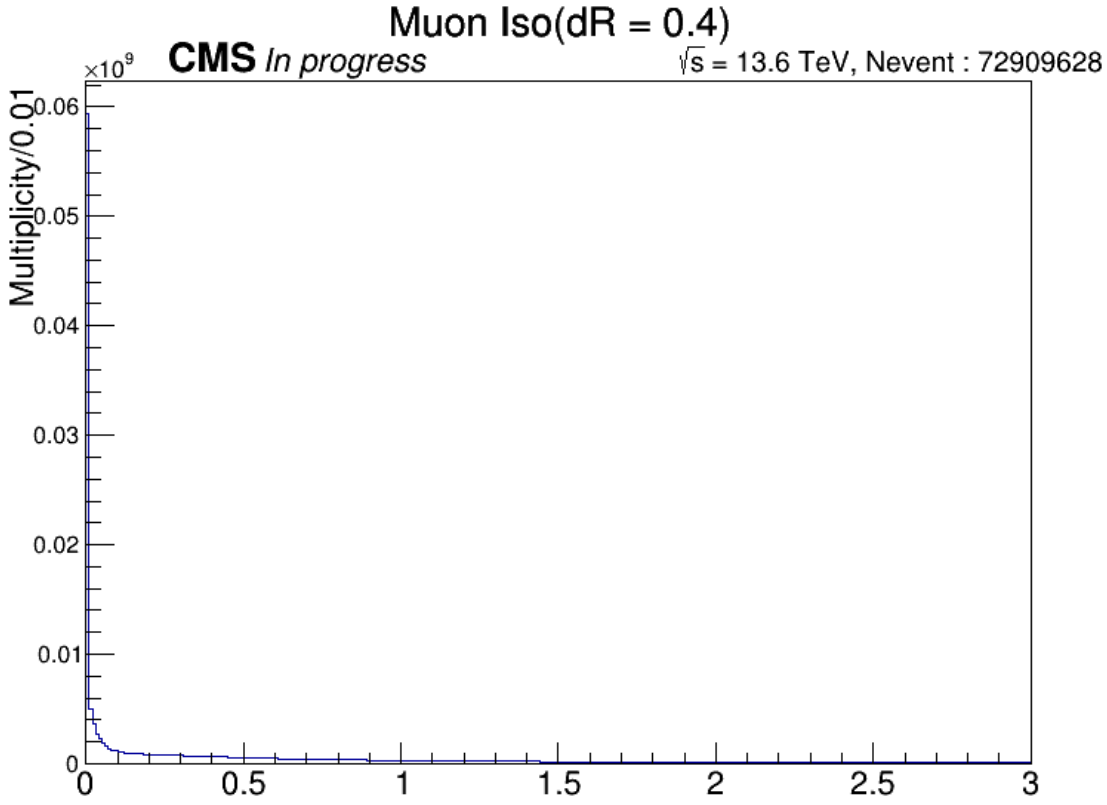

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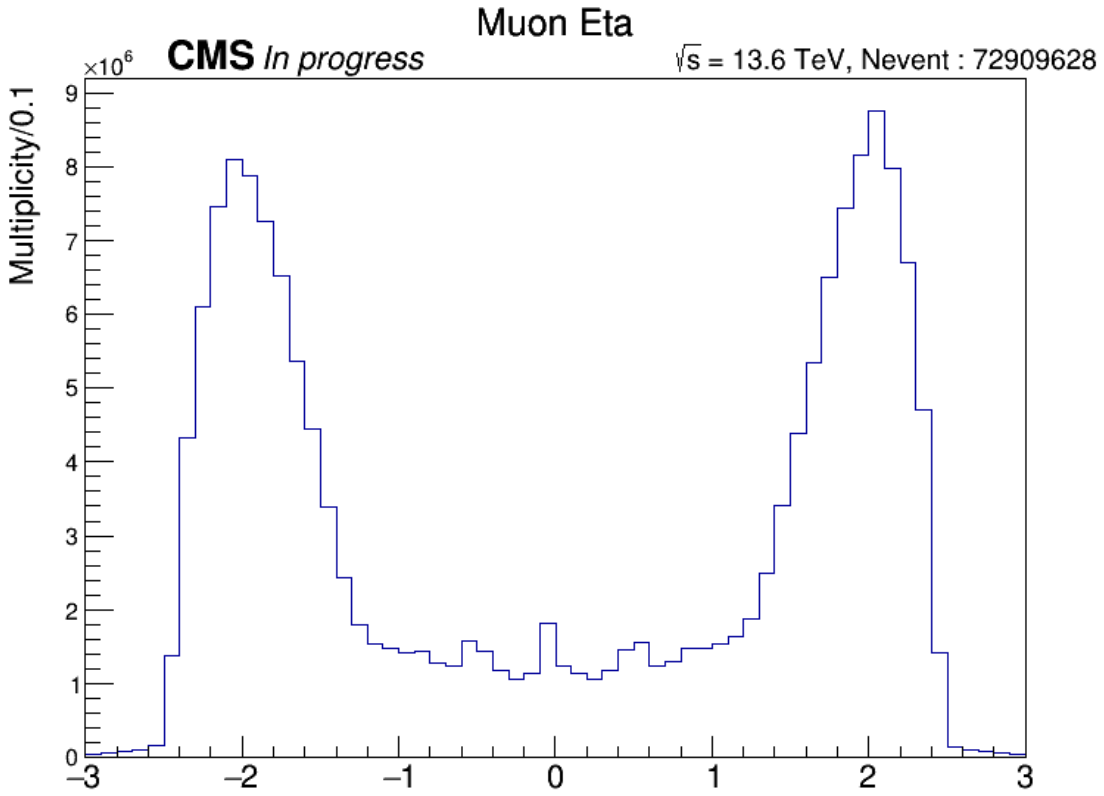

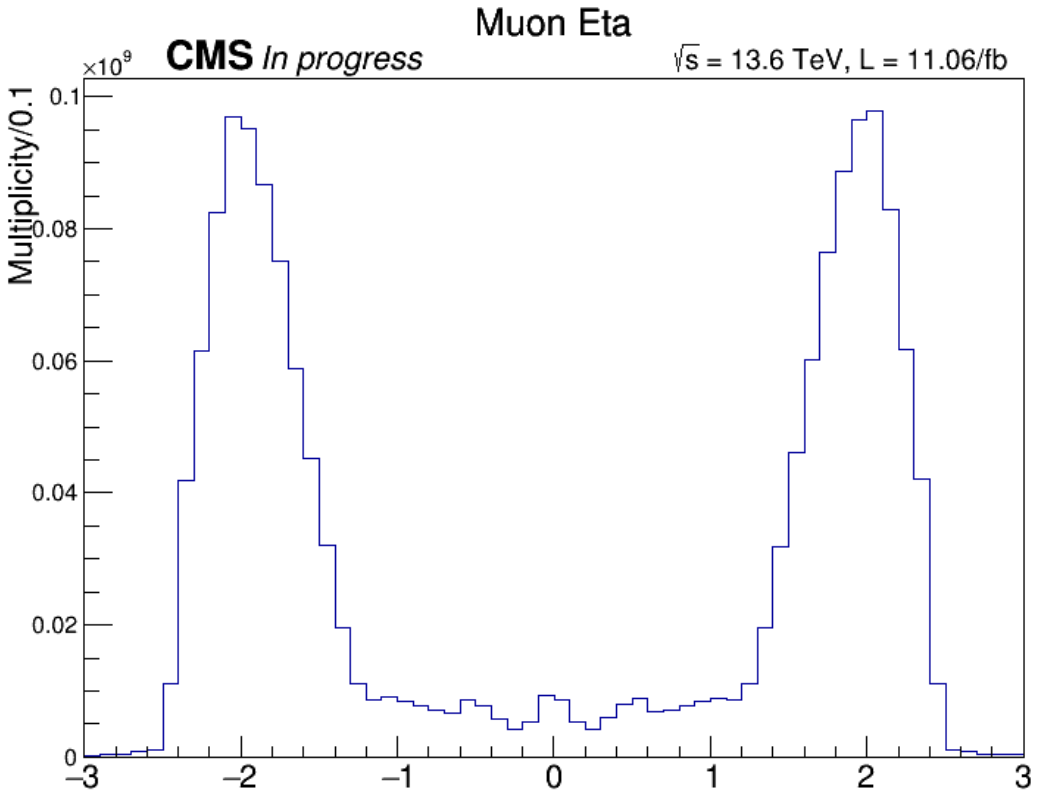

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