NtupleProducer: Algorithm Calculations

code set 7

July 15, 2025

Overview of the Algorithm

- Module processes events to fill a ROOT TTree.
- Inputs: reconstructed muons, PF candidates, vertices, pile-up info, and generator-level particles.
- Main logic in `analyze()`:
  - Loop over reco muons.
  - Match each to a generator-level particle.
  - Extract kinematics (p_T, η, ϕ).
  - Classify using status flags (e.g., prompt, signal, pileup).
  - Save results into vectors for output.

Physics Quantities and Classification

Kinematics:

$$p_T = \sqrt{p_x^2 + p_y^2}, \quad \eta = -\ln\left(\tan\frac{\theta}{2}\right), \quad \phi = \arctan 2(p_y, p_x)$$

Generator Flags:

- `isPrompt`, `fromHardProcess`, `isLastCopy` from status flags.
- Define:

  $\text{isPileup} = \neg\text{isPrompt} \wedge \neg\text{fromHardProcess},$

  $\text{isSignal} = \text{isPrompt} \wedge \text{fromHardProcess} \wedge |\text{pdgId}| = 13 \wedge \text{status} = 1$

- Photon ancestry check: `hasPhotonMother()` walks up the decay chain for PDG ID 22.

Computation and Storage

- Reco and gen muon quantities are stored as vectors:

  `evt_.mu_pt`p_T, `evt_.mu_eta`η, $\cdots$

  `evt_.gen_mu_pt`, `evt_.gen_mu_status`, `evt_.gen_mu_isSignal`, ...

- All filled vectors are flushed to the output TTree per event: `tree_->Fill()`.
- Runtime scales linearly with number of muons: $\mathcal{O}(N_\mu)$.

Datasets Used for GGToMuMu

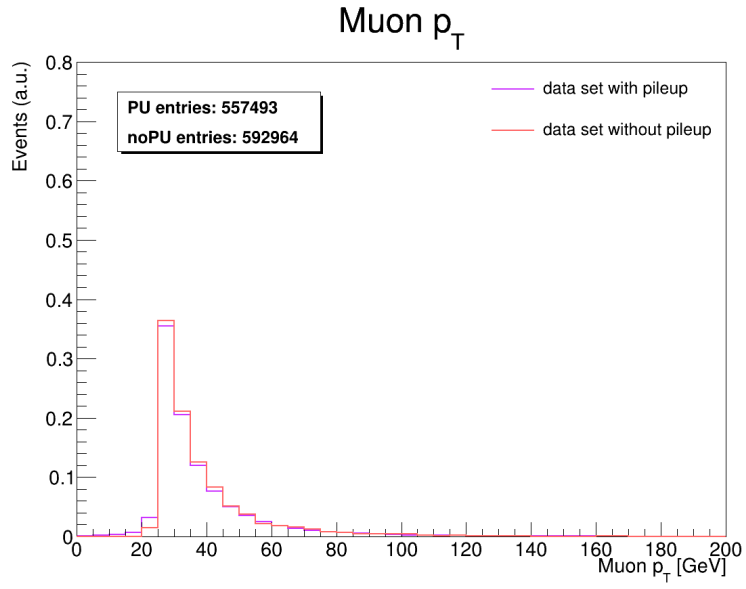
Category 1 – NoPU Sample (v3):

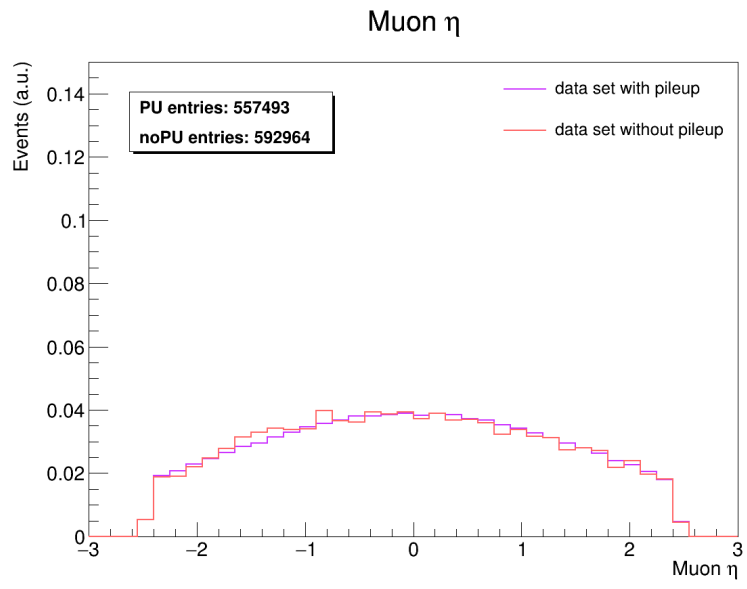
- GGToMuMu_PT-25_El-El_13p6TeV_lpair
- MiniAODSIM, NoPU, Run3Summer22EEMiniAODv3
- CMSSW version: 124X_mcRun3_2022_realistic_postEE_v1-v4

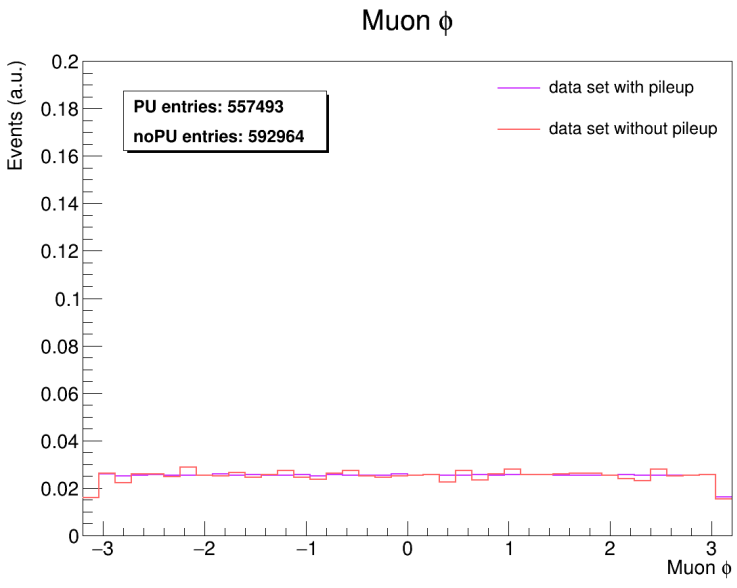
Category 2 – PU Sample (v4):

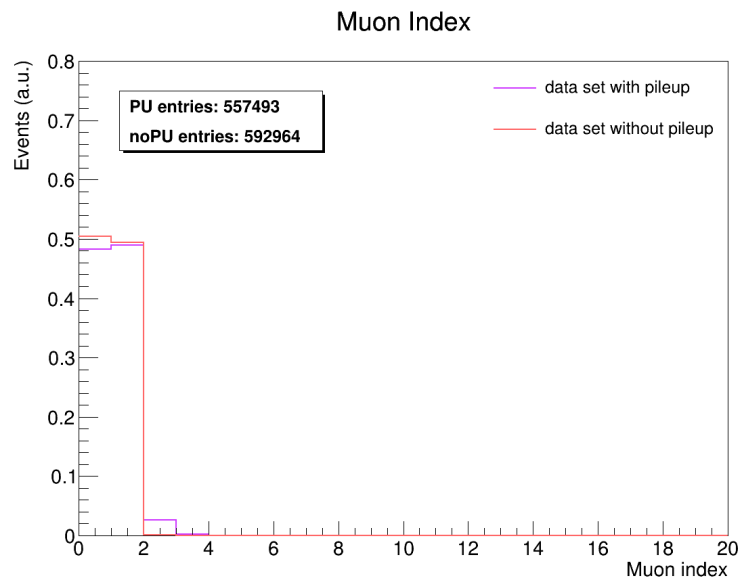
- GGToMuMu_PT-25_El-El_13p6TeV_superchic
- MiniAODSIM, Run3Summer22EEMiniAODv4
- CMSSW version: 130X_mcRun3_2022_realistic_postEE_v6-v2

Plots 1 (GG)

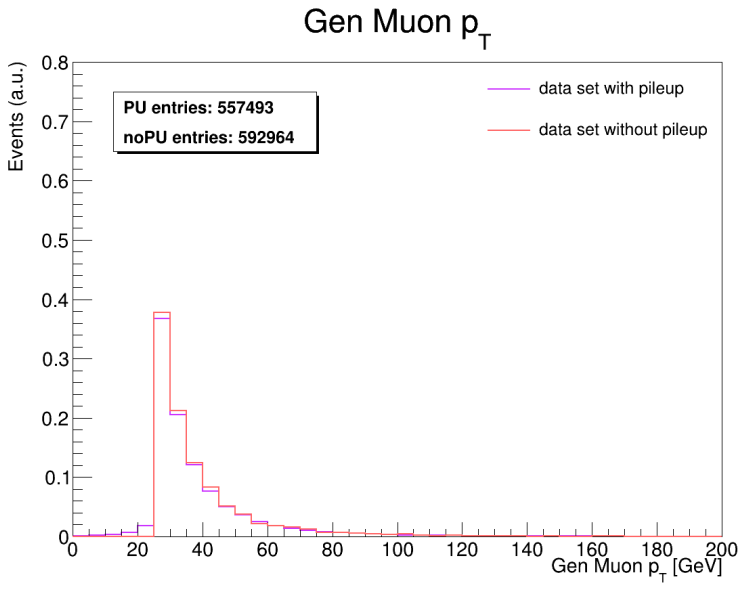

Muon p_T
Events (a.u.)
PU entries: 557493
noPU entries: 592964
data set with pileup
data set without pileup
Muon p_T [GeV]

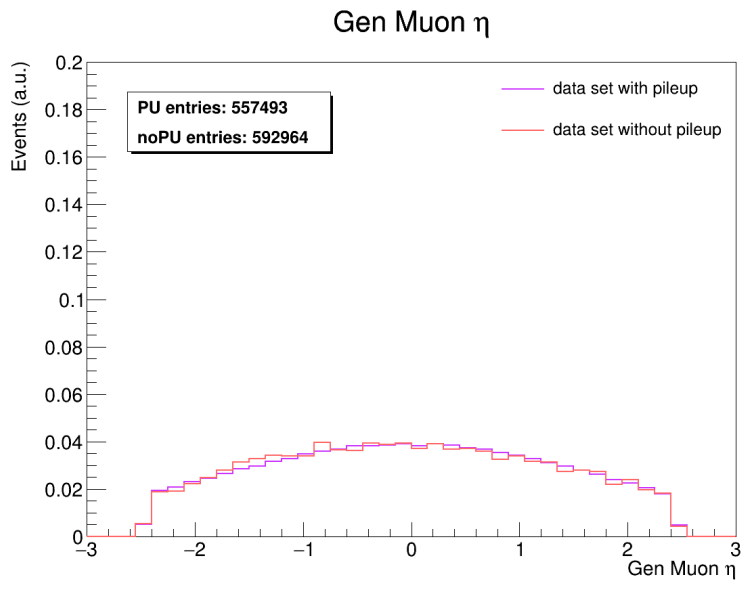

Muon η
Events (a.u.)
PU entries: 557493
noPU entries: 592964
data set with pileup
data set without pileup
Muon η

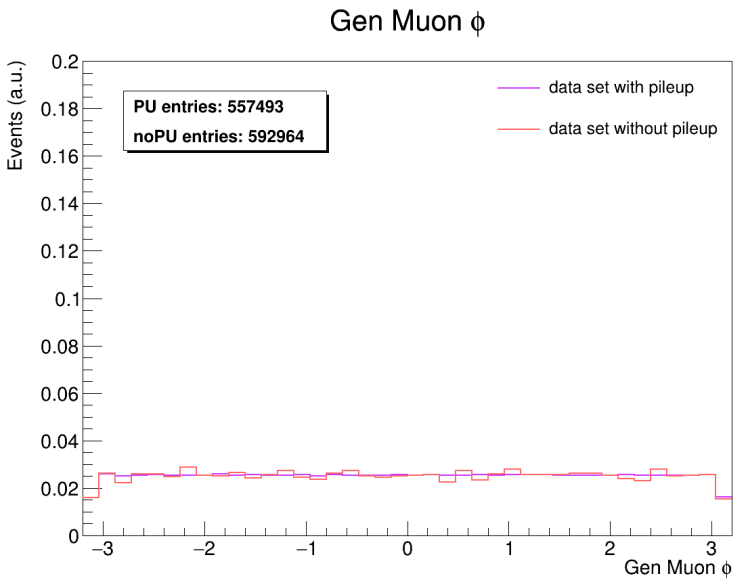

Muon ϕ
Events (a.u.)
PU entries: 557493
noPU entries: 592964
data set with pileup
data set without pileup
Muon ϕ

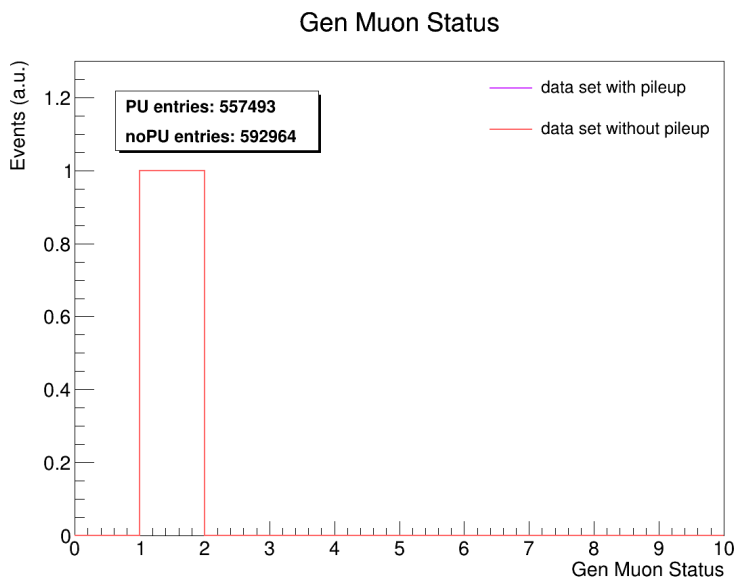

Muon Index
Events (a.u.)
PU entries: 557493
noPU entries: 592964
data set with pileup
data set without pileup
Muon index

Plots 2 (GG)

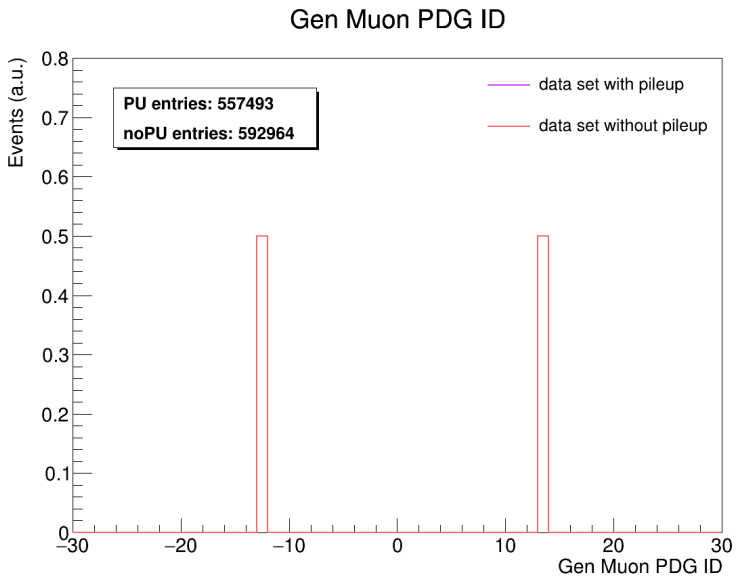

Gen Muon p_T
PU entries: 557493
noPU entries: 592964
data set with pileup
data set without pileup
Events (a.u.)
Gen Muon p_T [GeV]

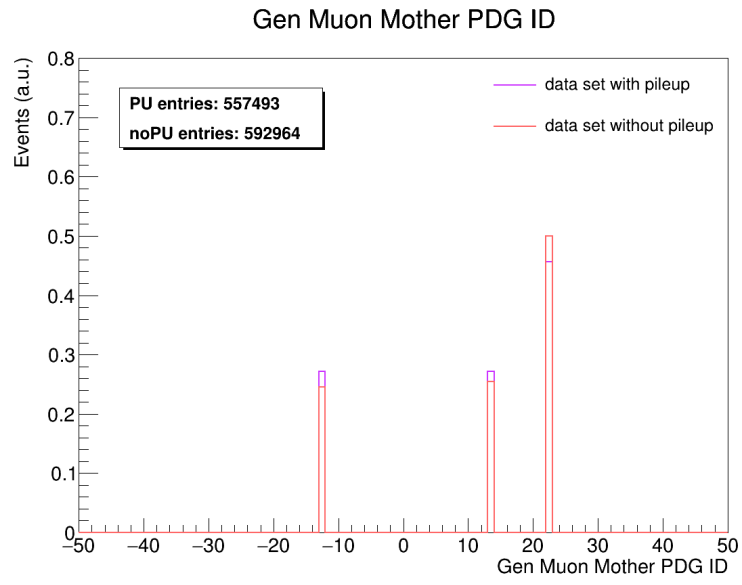

Gen Muon η
PU entries: 557493
noPU entries: 592964
data set with pileup
data set without pileup
Events (a.u.)
Gen Muon η

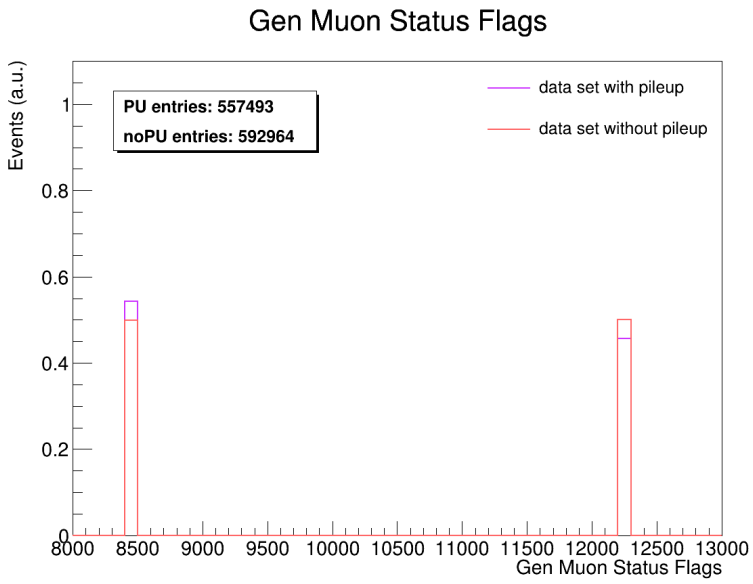

Gen Muon ϕ
PU entries: 557493
noPU entries: 592964
data set with pileup
data set without pileup
Events (a.u.)
Gen Muon ϕ

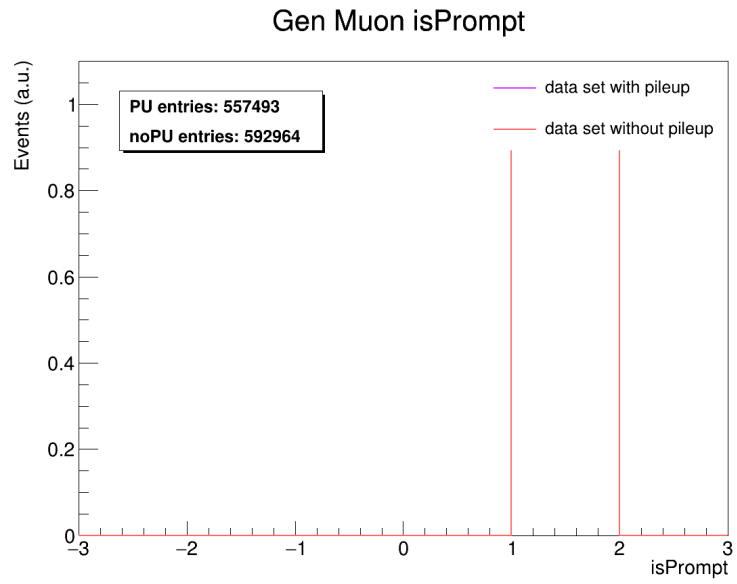

Gen Muon Status
PU entries: 557493
noPU entries: 592964
data set with pileup
data set without pileup
Events (a.u.)
Gen Muon Status

Plots 3 (GG)

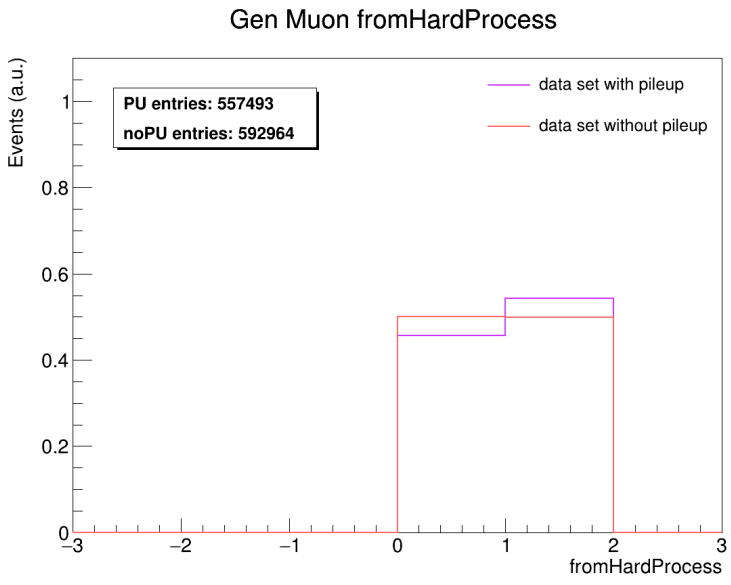

Gen Muon PDG ID
PU entries: 557493
noPU entries: 592964
data set with pileup
data set without pileup
Events (a.u.)
Gen Muon PDG ID

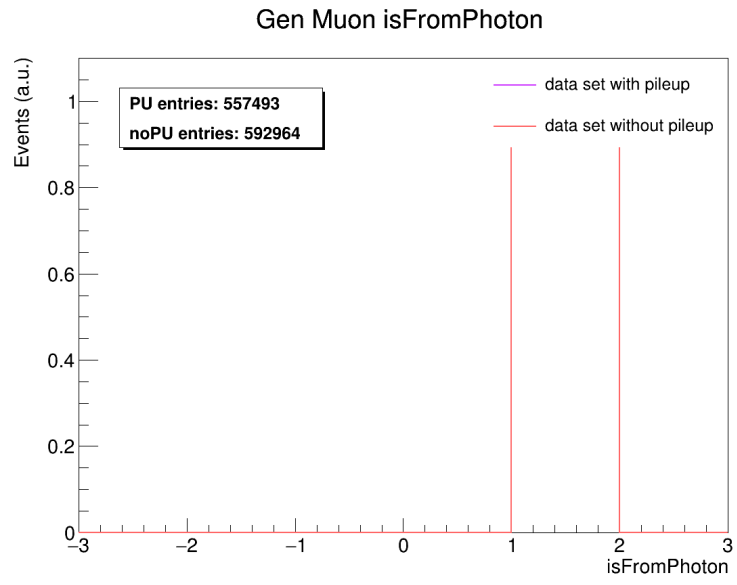

Gen Muon Mother PDG ID
PU entries: 557493
noPU entries: 592964
data set with pileup
data set without pileup
Events (a.u.)
Gen Muon Mother PDG ID

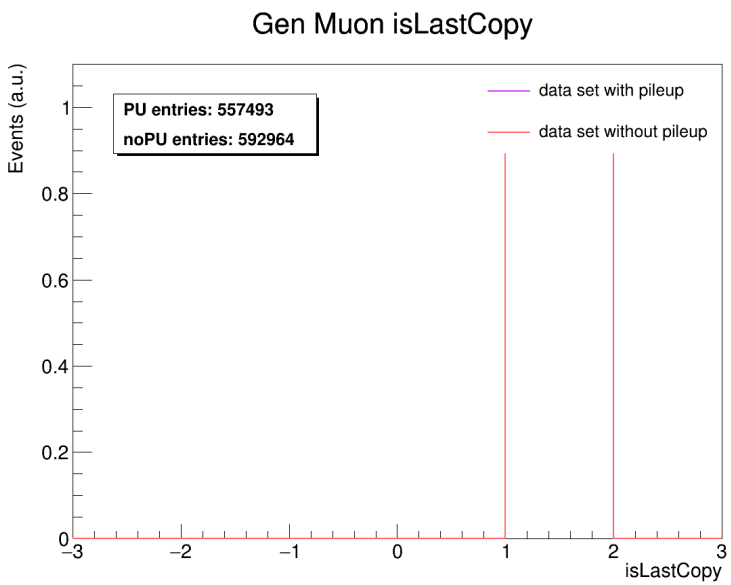

Gen Muon Status Flags
PU entries: 557493
noPU entries: 592964
data set with pileup
data set without pileup
Events (a.u.)
Gen Muon Status Flags

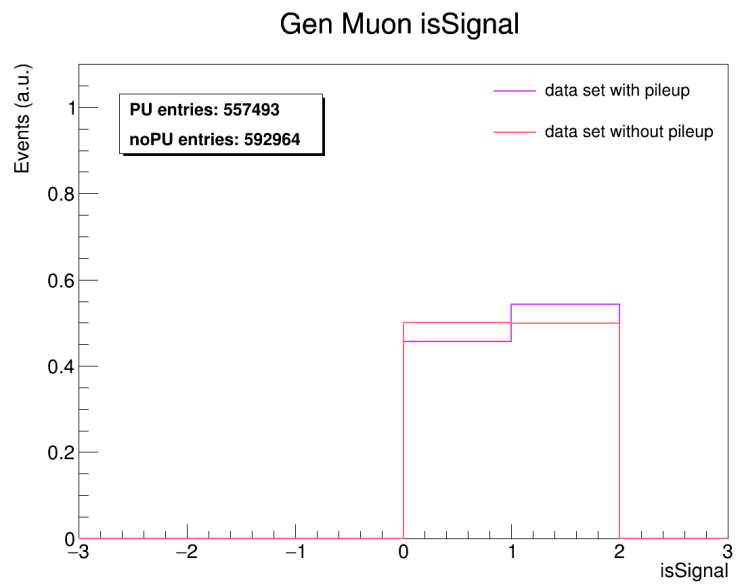

Gen Muon isPrompt
PU entries: 557493
noPU entries: 592964
data set with pileup
data set without pileup
Events (a.u.)
isPrompt

Plots 4 (GG)

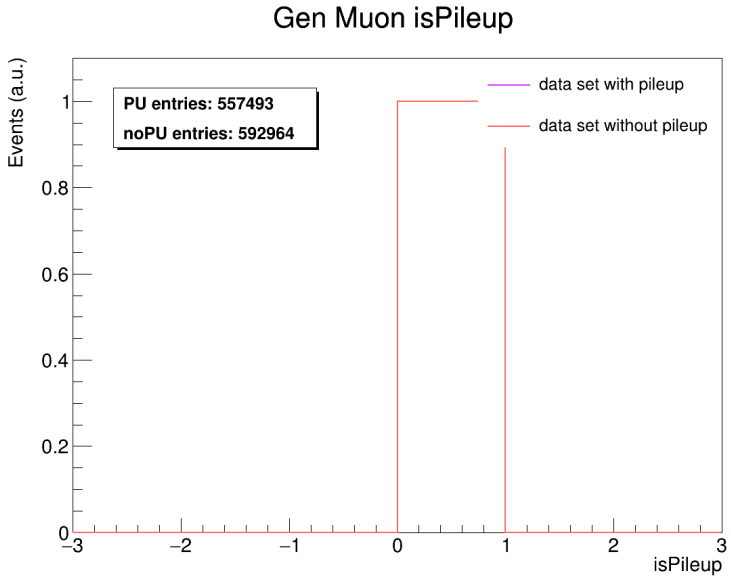

Gen Muon fromHardProcess
PU entries: 557493
noPU entries: 592964
data set with pileup
data set without pileup
Events (a.u.)
fromHardProcess

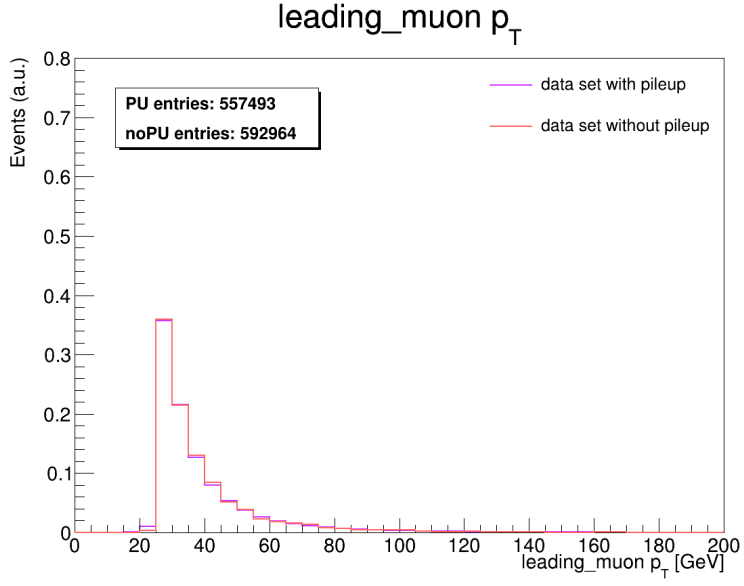

Gen Muon isFromPhoton
PU entries: 557493
noPU entries: 592964
data set with pileup
data set without pileup
Events (a.u.)
isFromPhoton

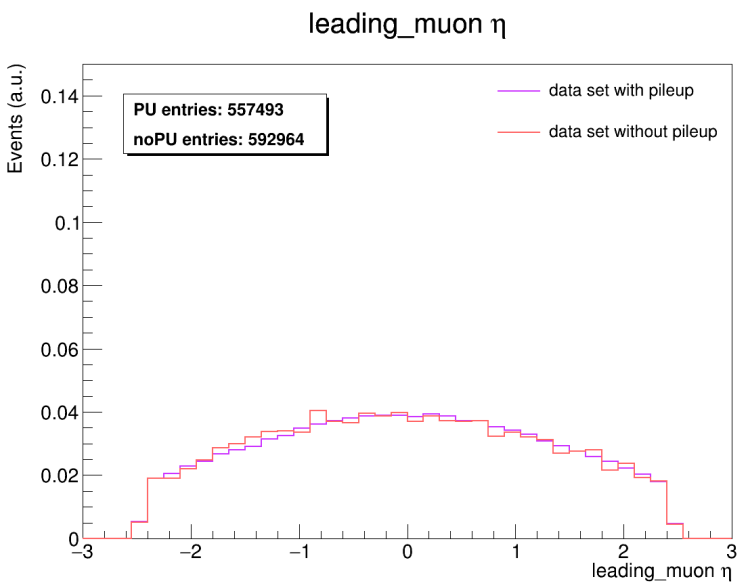

Gen Muon isLastCopy
PU entries: 557493
noPU entries: 592964
data set with pileup
data set without pileup
Events (a.u.)
isLastCopy

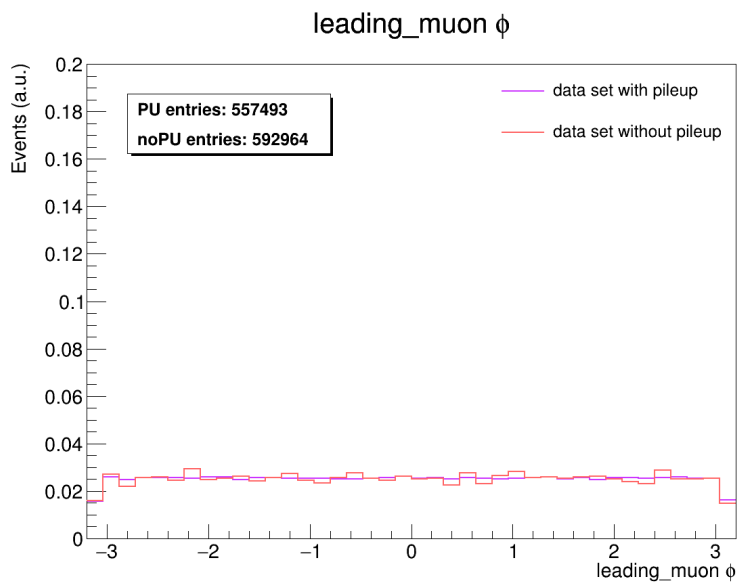

Gen Muon isSignal
PU entries: 557493
noPU entries: 592964
data set with pileup
data set without pileup
Events (a.u.)
isSignal

Plots 5 (GG)

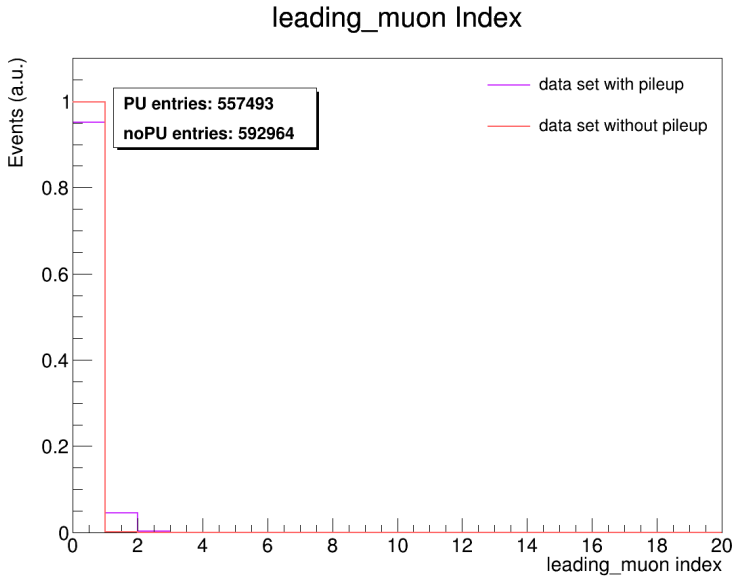

Gen Muon isPileup
PU entries: 557493
noPU entries: 592964
data set with pileup
data set without pileup
Events (a.u.)
isPileup

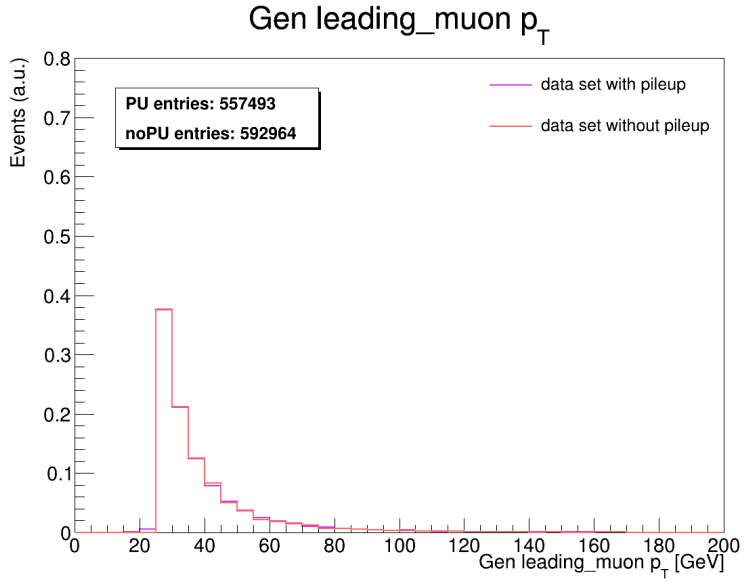

leading_muon p_T
PU entries: 557493
noPU entries: 592964
data set with pileup
data set without pileup
Events (a.u.)
leading_muon p_T [GeV]

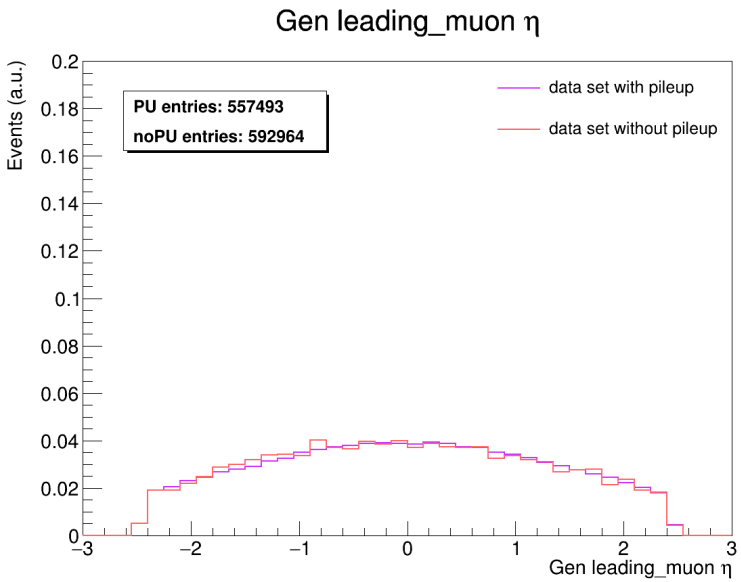

leading_muon η
PU entries: 557493
noPU entries: 592964
data set with pileup
data set without pileup
Events (a.u.)
leading_muon η

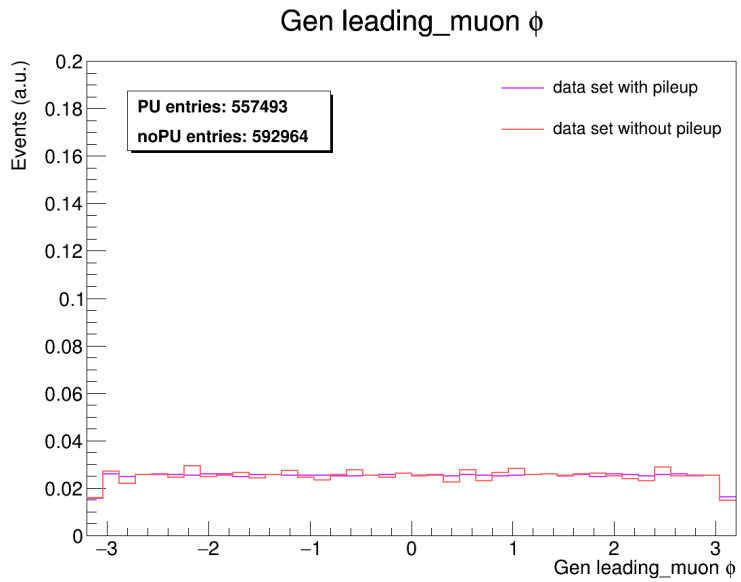

leading_muon ϕ
PU entries: 557493
noPU entries: 592964
data set with pileup
data set without pileup
Events (a.u.)
leading_muon ϕ

Plots 6 (GG)

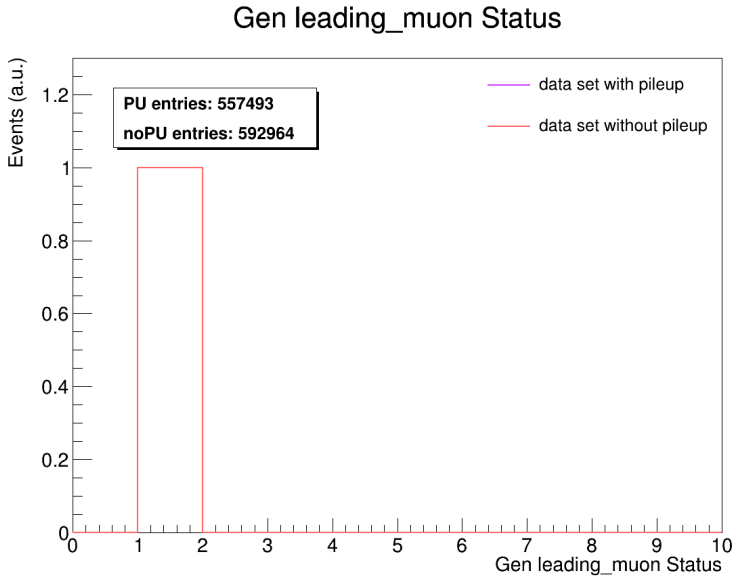

leading_muon Index
Events (a.u.)
PU entries: 557493
noPU entries: 592964
data set with pileup
data set without pileup
leading_muon index

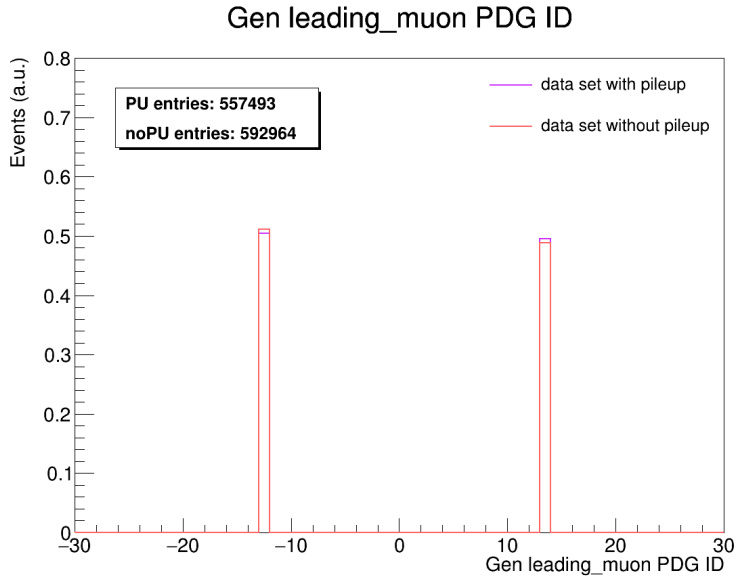

Gen leading_muon p_T
Events (a.u.)
PU entries: 557493
noPU entries: 592964
data set with pileup
data set without pileup
Gen leading_muon p_T [GeV]

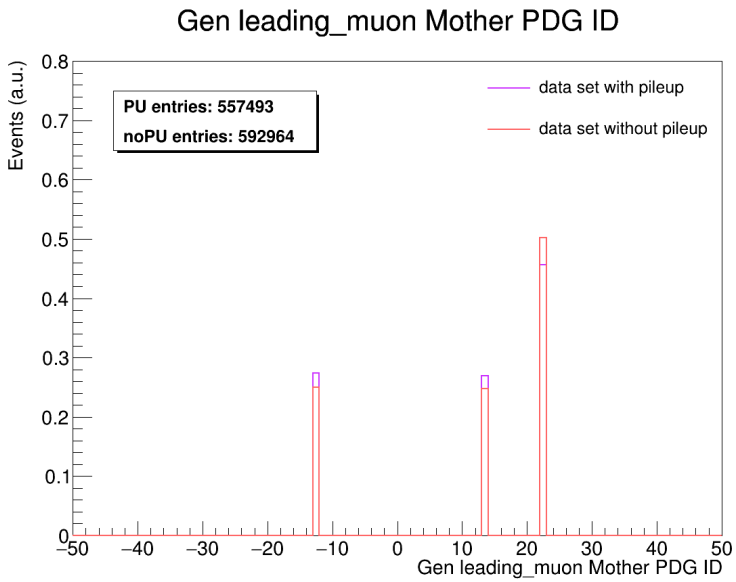

Gen leading_muon η
Events (a.u.)
PU entries: 557493
noPU entries: 592964
data set with pileup
data set without pileup
Gen leading_muon η

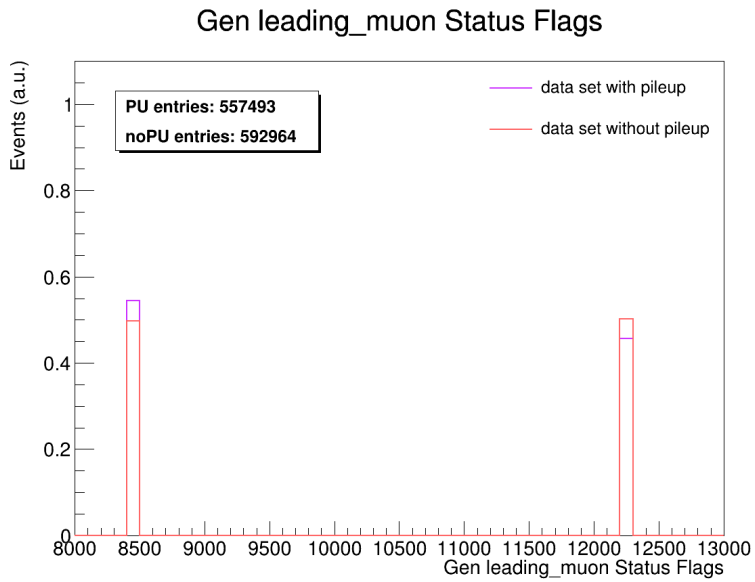

Gen leading_muon ϕ
Events (a.u.)
PU entries: 557493
noPU entries: 592964
data set with pileup
data set without pileup
Gen leading_muon ϕ

Plots 7 (GG)


Gen leading_muon Status
PU entries: 557493
noPU entries: 592964
data set with pileup
data set without pileup
Events (a.u.)
Gen leading_muon Status

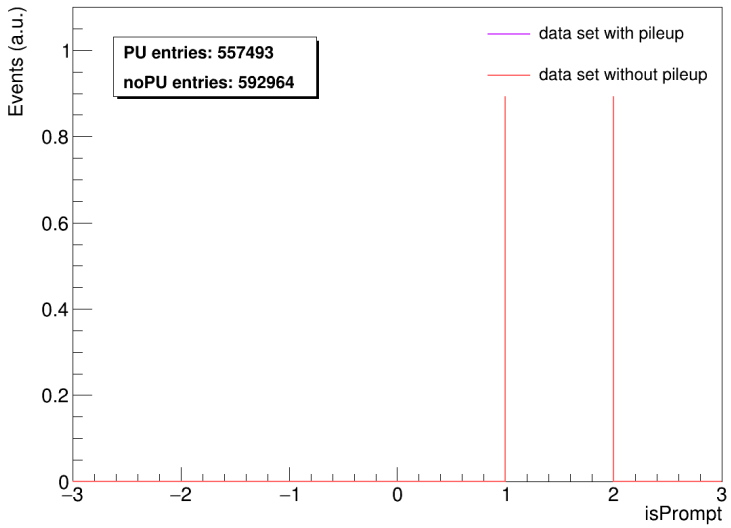

Gen leading_muon PDG ID
PU entries: 557493
noPU entries: 592964
data set with pileup
data set without pileup
Events (a.u.)
Gen leading_muon PDG ID


Gen leading_muon Mother PDG ID
PU entries: 557493
noPU entries: 592964
data set with pileup
data set without pileup
Events (a.u.)
Gen leading_muon Mother PDG ID

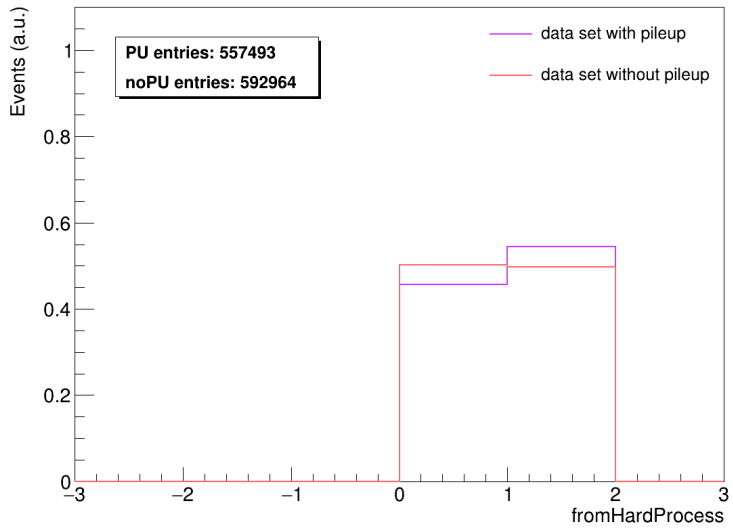

Gen leading_muon Status Flags
PU entries: 557493
noPU entries: 592964
data set with pileup
data set without pileup
Events (a.u.)
Gen leading_muon Status Flags

Plots 8 (GG)

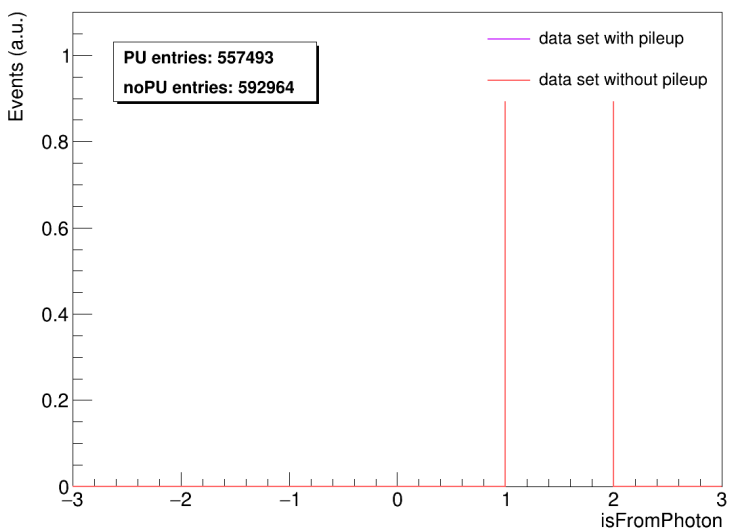
Gen Leading Muon isPrompt



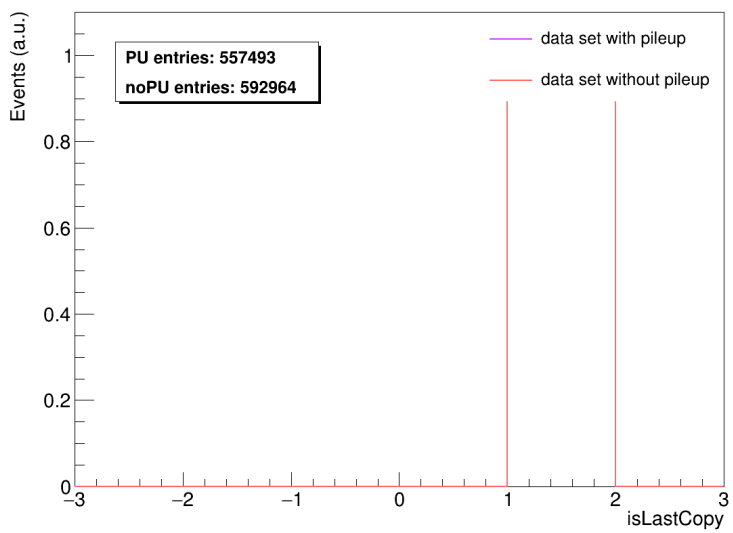
Gen Leading Muon fromHardProcess



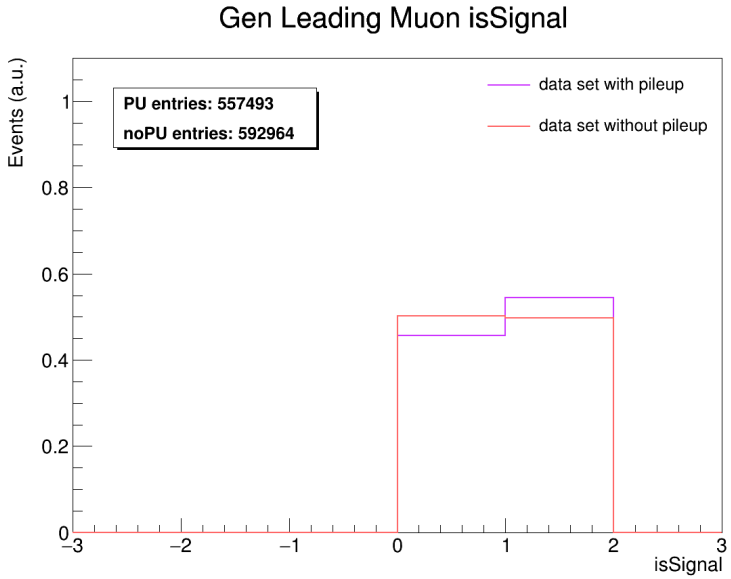
Gen Leading Muon isFromPhoton

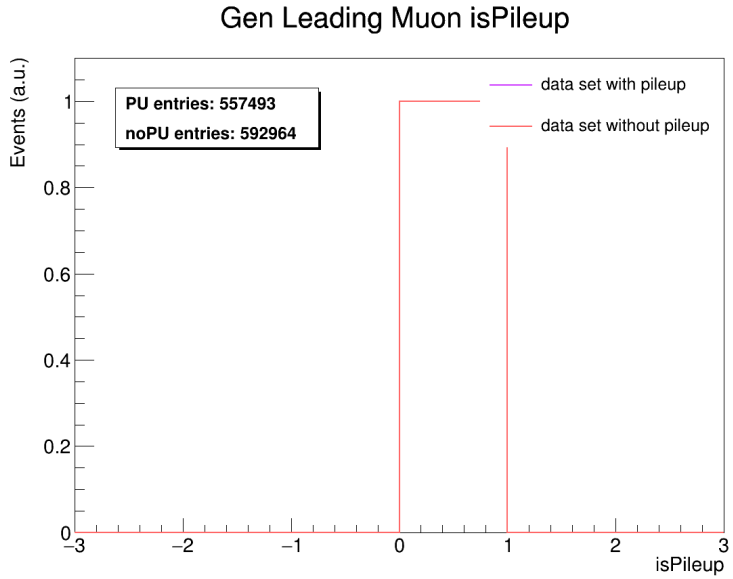


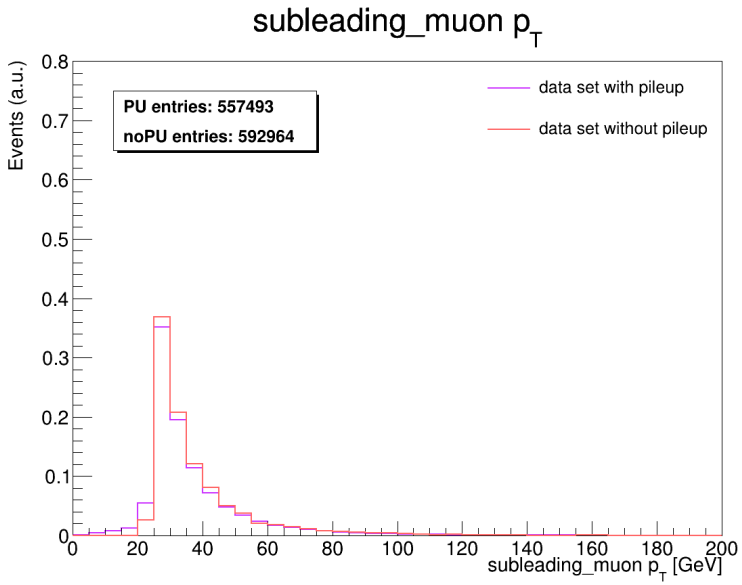
Gen Leading Muon isLastCopy

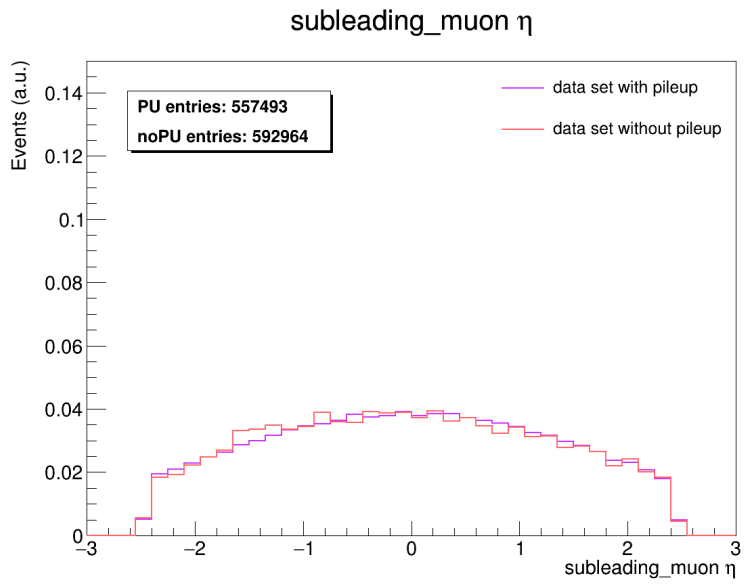


Plots 9 (GG)

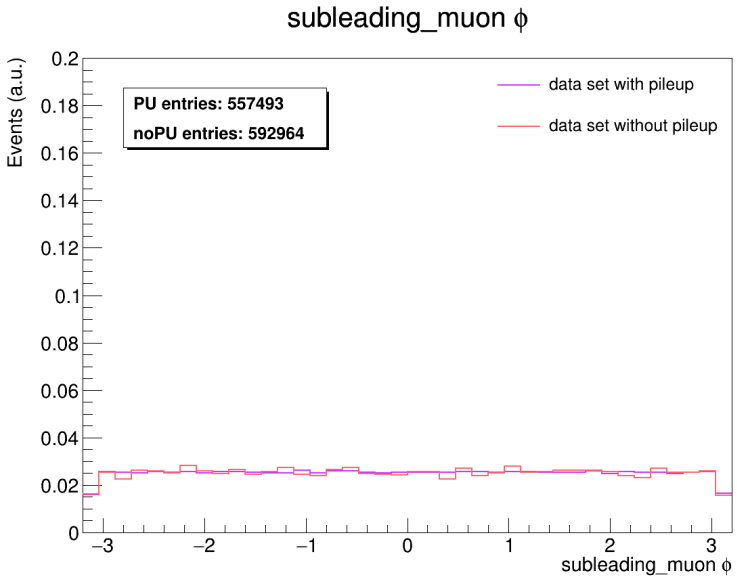

Gen Leading Muon isSignal
PU entries: 557493
noPU entries: 592964
data set with pileup
data set without pileup
Events (a.u.)
isSignal

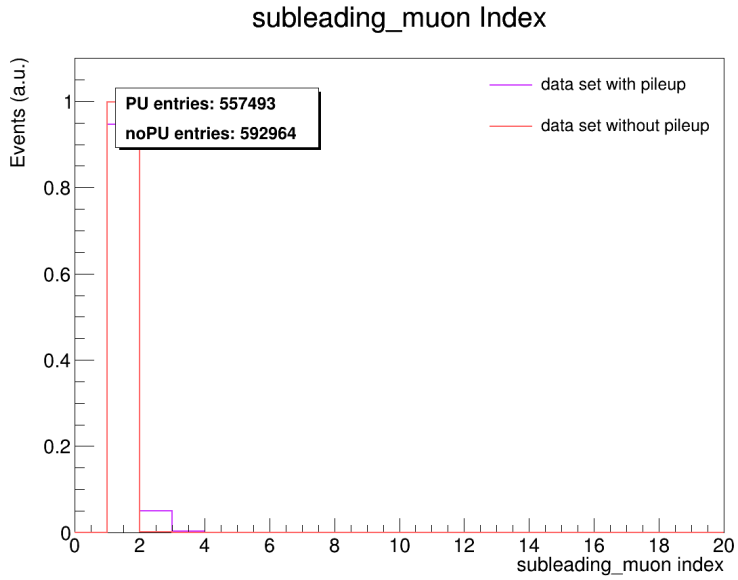

Gen Leading Muon isPileup
PU entries: 557493
noPU entries: 592964
data set with pileup
data set without pileup
Events (a.u.)
isPileup

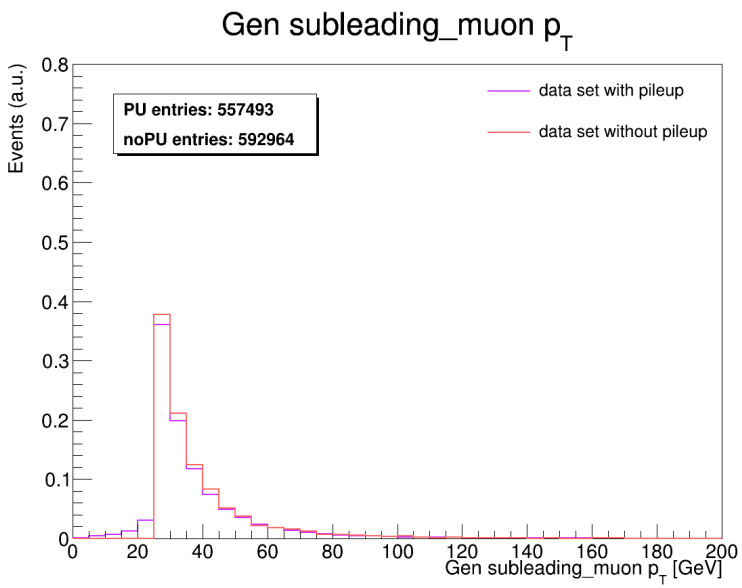

subleading_muon p_T
PU entries: 557493
noPU entries: 592964
data set with pileup
data set without pileup
Events (a.u.)
subleading_muon p_T [GeV]

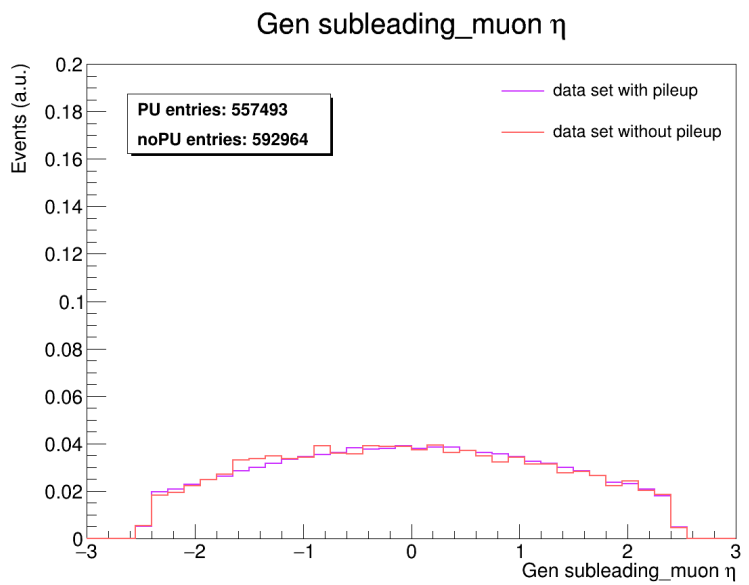

subleading_muon η
PU entries: 557493
noPU entries: 592964
data set with pileup
data set without pileup
Events (a.u.)
subleading_muon η

Plots 10 (GG)

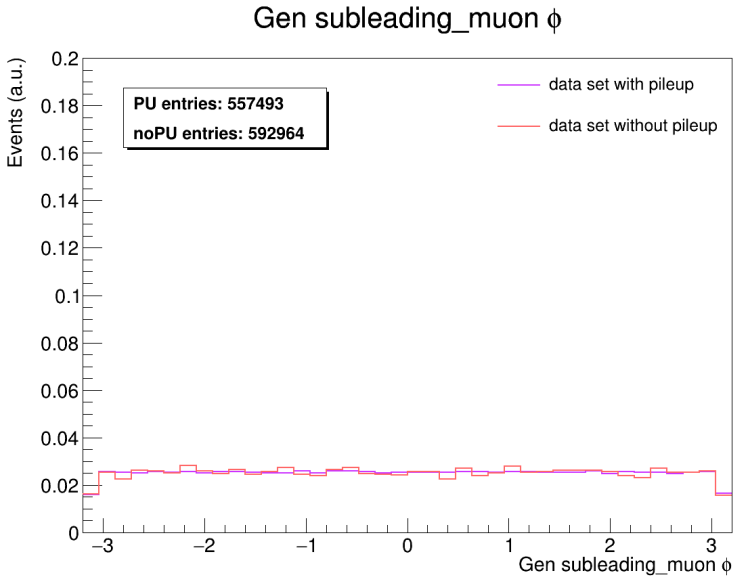

subleading_muon ϕ
PU entries: 557493
noPU entries: 592964
data set with pileup
data set without pileup
Events (a.u.)
subleading_muon ϕ

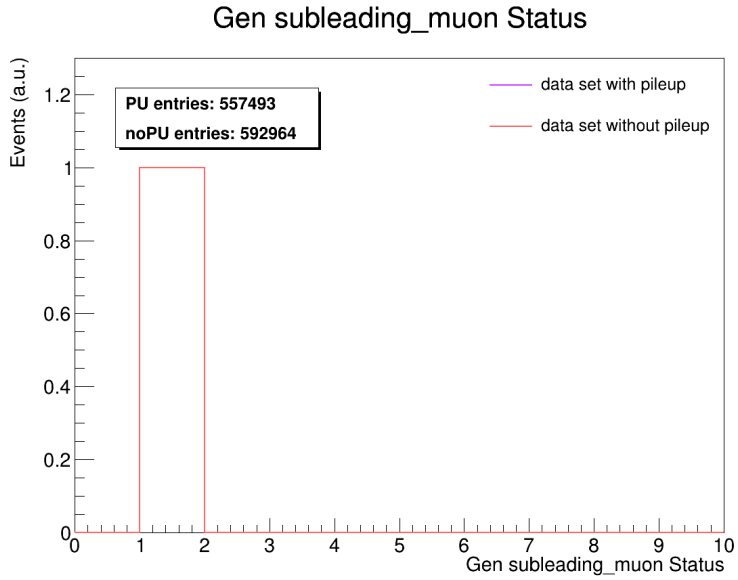

subleading_muon Index
PU entries: 557493
noPU entries: 592964
data set with pileup
data set without pileup
Events (a.u.)
subleading_muon index

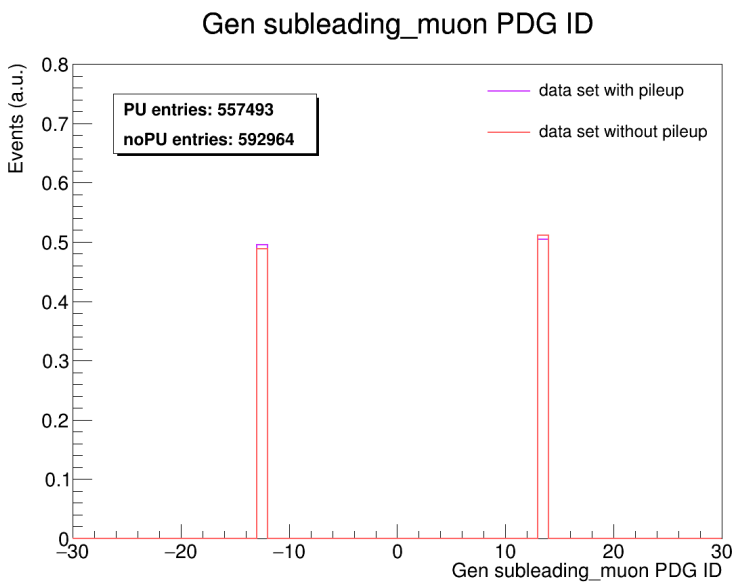

Gen subleading_muon p_T
PU entries: 557493
noPU entries: 592964
data set with pileup
data set without pileup
Events (a.u.)
Gen subleading_muon p_T [GeV]

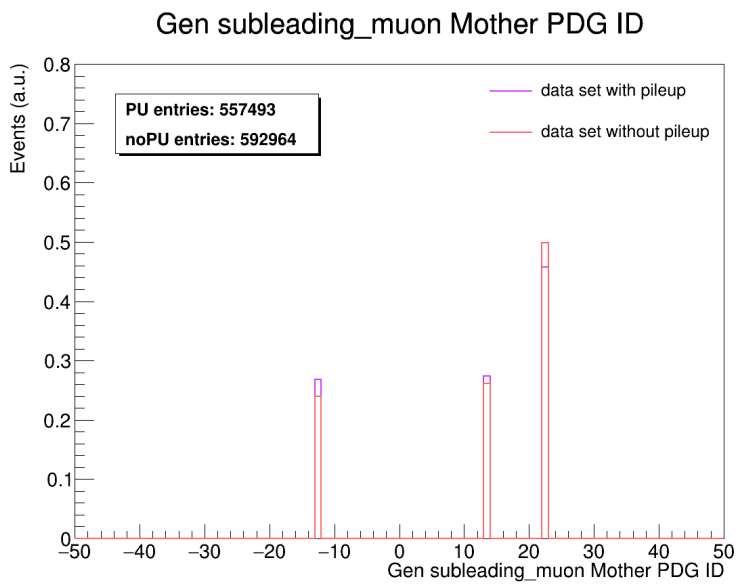

Gen subleading_muon η
PU entries: 557493
noPU entries: 592964
data set with pileup
data set without pileup
Events (a.u.)
Gen subleading_muon η

Plots 11 (GG)

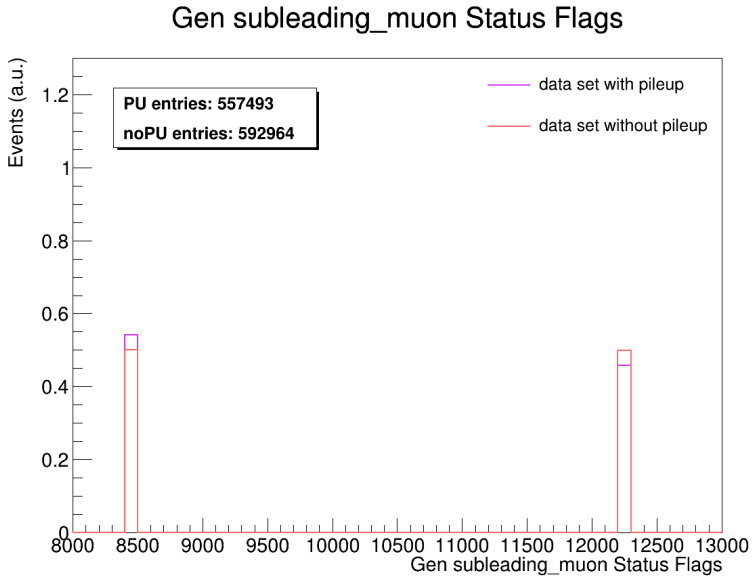

Gen subleading_muon ϕ
PU entries: 557493
noPU entries: 592964
data set with pileup
data set without pileup
Events (a.u.)
Gen subleading_muon ϕ

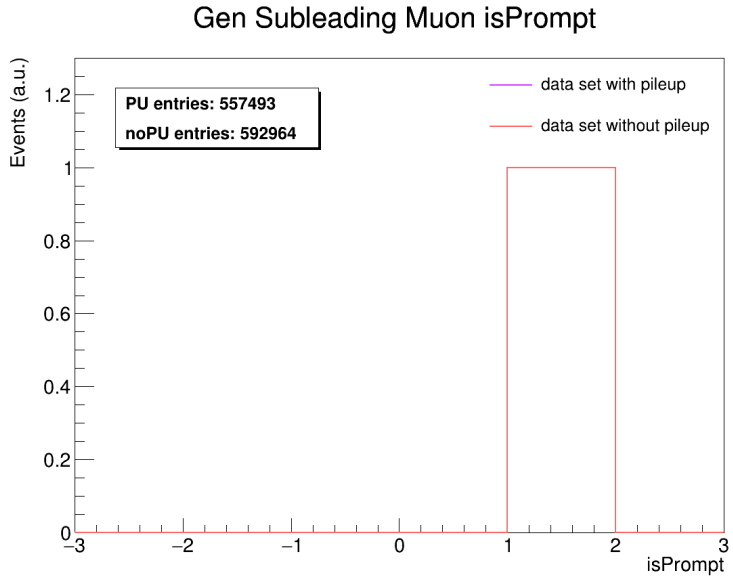

Gen subleading_muon Status
PU entries: 557493
noPU entries: 592964
data set with pileup
data set without pileup
Events (a.u.)
Gen subleading_muon Status

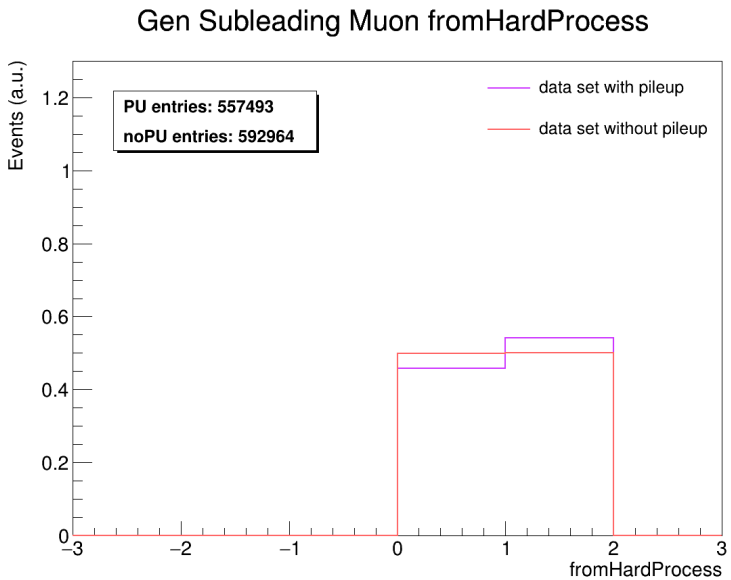

Gen subleading_muon PDG ID
PU entries: 557493
noPU entries: 592964
data set with pileup
data set without pileup
Events (a.u.)
Gen subleading_muon PDG ID

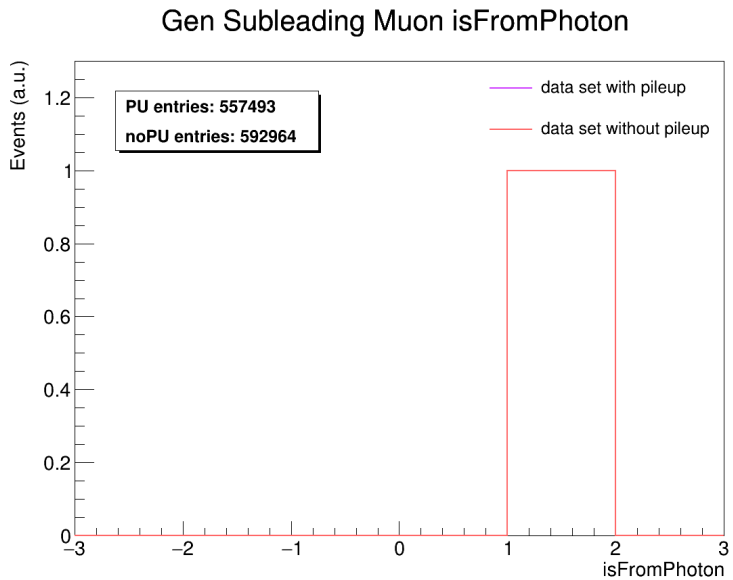

Gen subleading_muon Mother PDG ID
PU entries: 557493
noPU entries: 592964
data set with pileup
data set without pileup
Events (a.u.)
Gen subleading_muon Mother PDG ID

Plots 12 (GG)

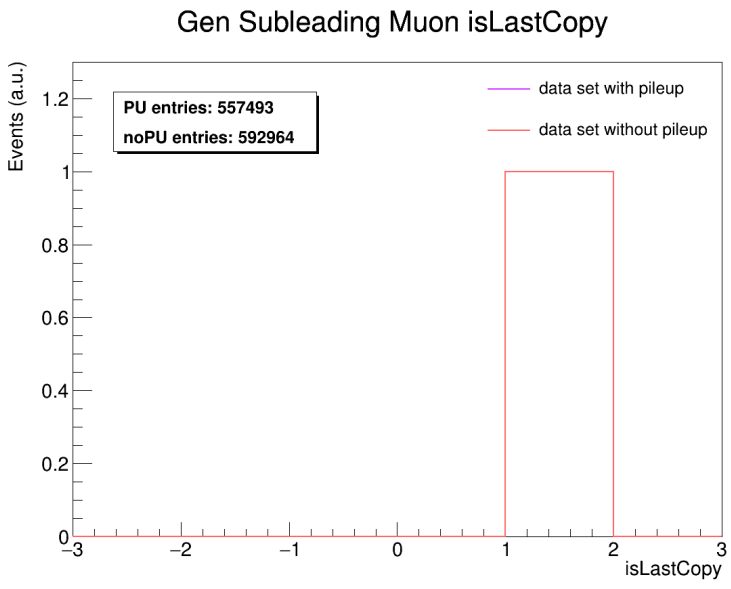

Gen subleading_muon Status Flags
PU entries: 557493
noPU entries: 592964
data set with pileup
data set without pileup
Events (a.u.)
Gen subleading_muon Status Flags

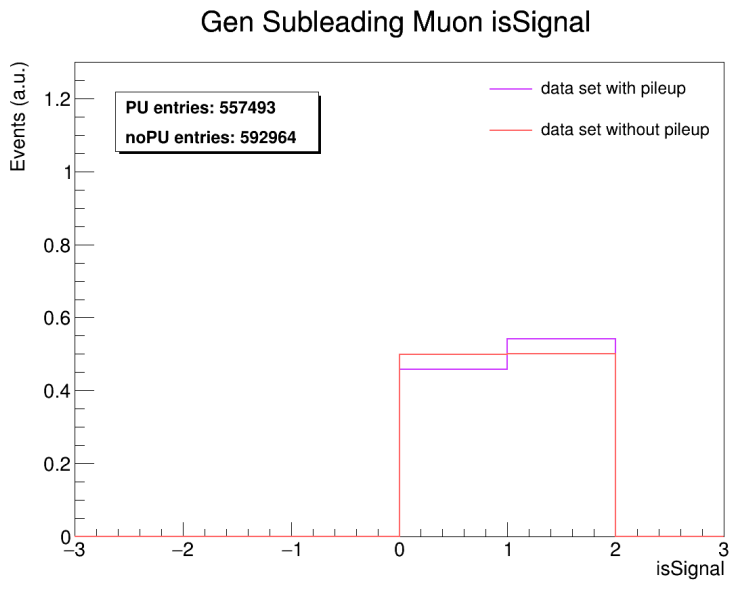

Gen Subleading Muon isPrompt
PU entries: 557493
noPU entries: 592964
data set with pileup
data set without pileup
Events (a.u.)
isPrompt

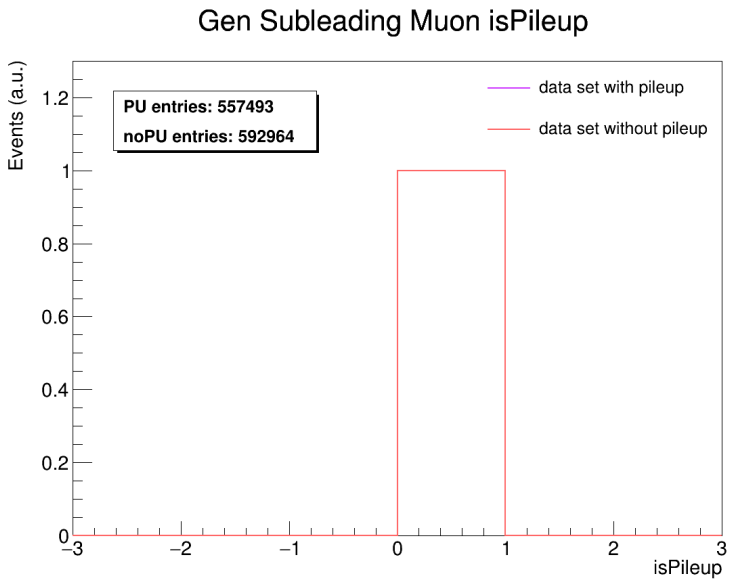

Gen Subleading Muon fromHardProcess
PU entries: 557493
noPU entries: 592964
data set with pileup
data set without pileup
Events (a.u.)
fromHardProcess


Gen Subleading Muon isFromPhoton
PU entries: 557493
noPU entries: 592964
data set with pileup
data set without pileup
Events (a.u.)
isFromPhoton

Plots 13 (GG)


Gen Subleading Muon isLastCopy
PU entries: 557493
noPU entries: 592964
data set with pileup
data set without pileup
Events (a.u.)
isLastCopy


Gen Subleading Muon isSignal
PU entries: 557493
noPU entries: 592964
data set with pileup
data set without pileup
Events (a.u.)
isSignal


Gen Subleading Muon isPileup
PU entries: 557493
noPU entries: 592964
data set with pileup
data set without pileup
Events (a.u.)
isPileup

Datasets Used for DYToMuMu

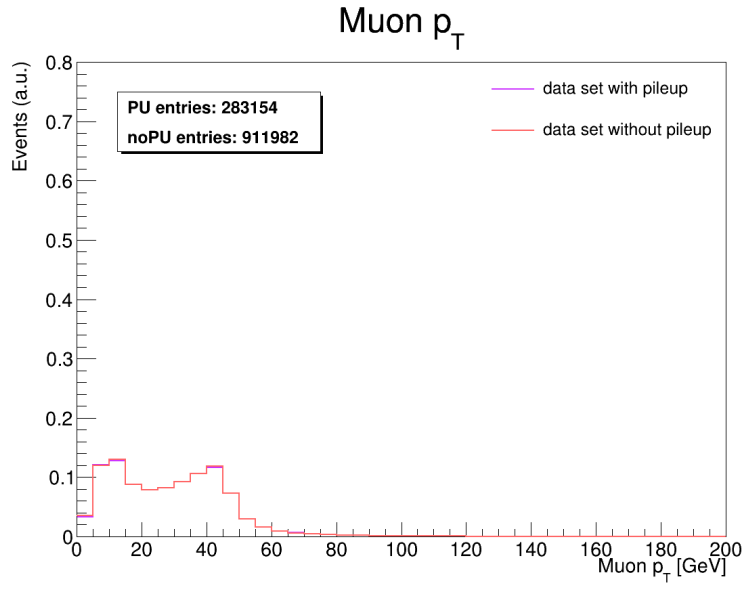
Category 1 – NoPU Sample (v9):

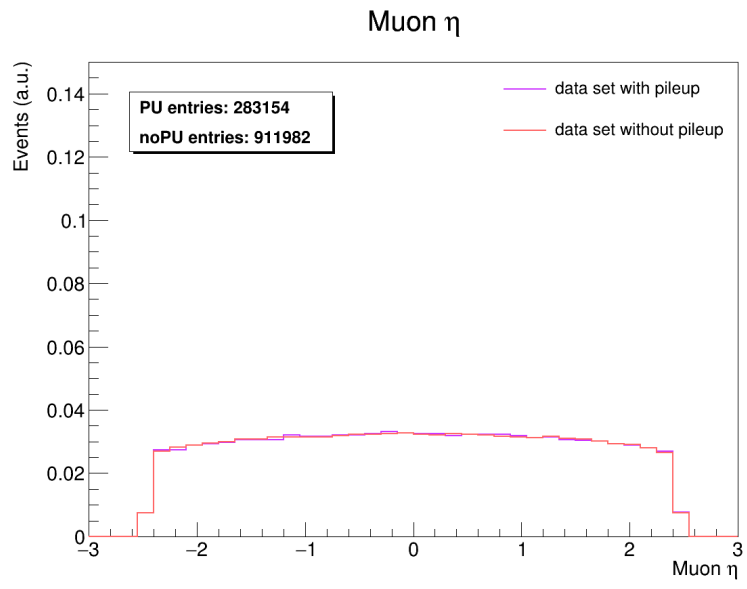
- DYToMuMu
- MiniAODSIM, NoPU, Run3Winter22EEMiniAODv3
- CMSSW version: 124X_mcRun3_2022_realistic_postEE_v1-v9

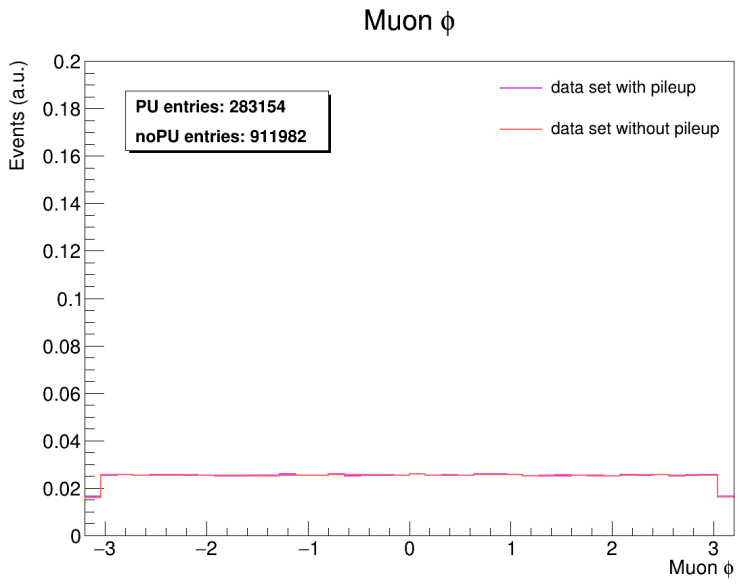
Category 2 – PU Sample (v9):

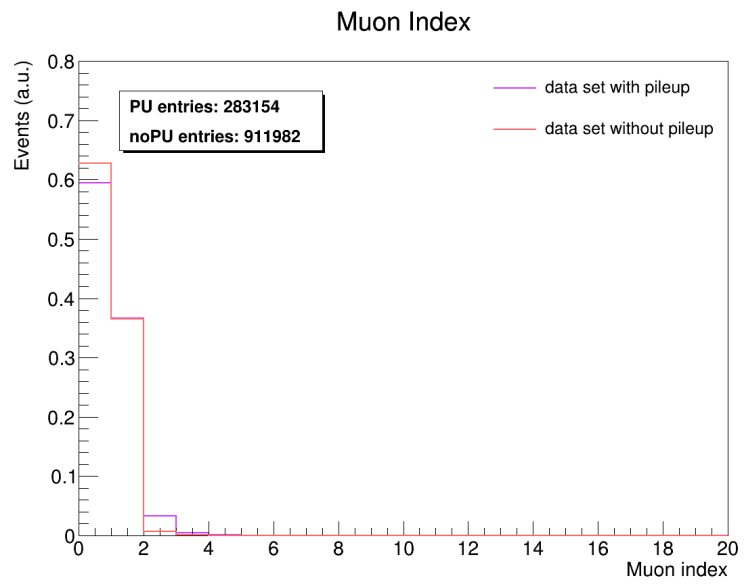
- DYToMuMu
- MiniAODSIM, Run3Winter22EEMiniAODv9
- CMSSW version: 130X_mcRun3_2022_realistic_postEE_v6-v2

Plots 1 (DY)

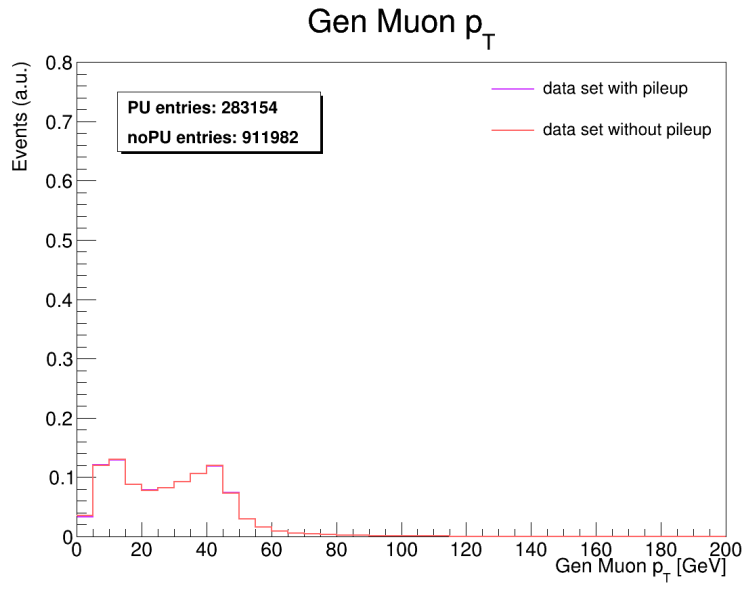

Muon p_T
PU entries: 283154
noPU entries: 911982
data set with pileup
data set without pileup
Events (a.u.)
Muon p_T [GeV]

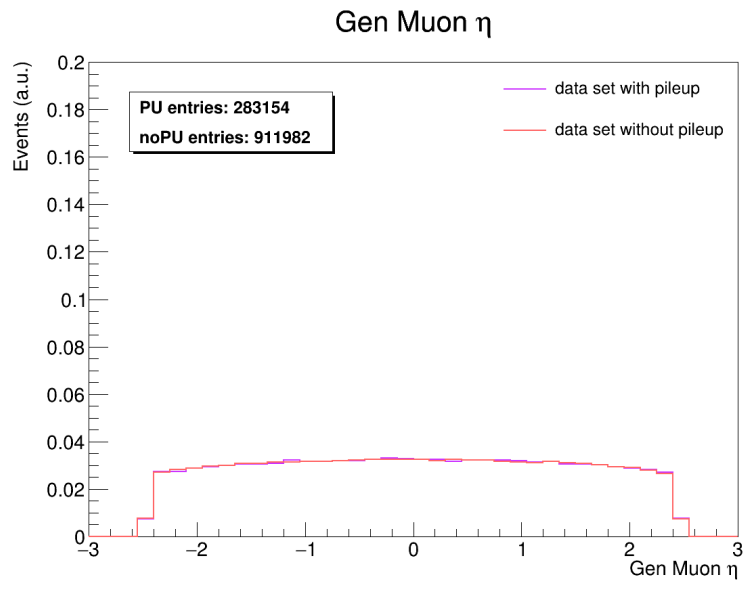

Muon η
PU entries: 283154
noPU entries: 911982
data set with pileup
data set without pileup
Events (a.u.)
Muon η

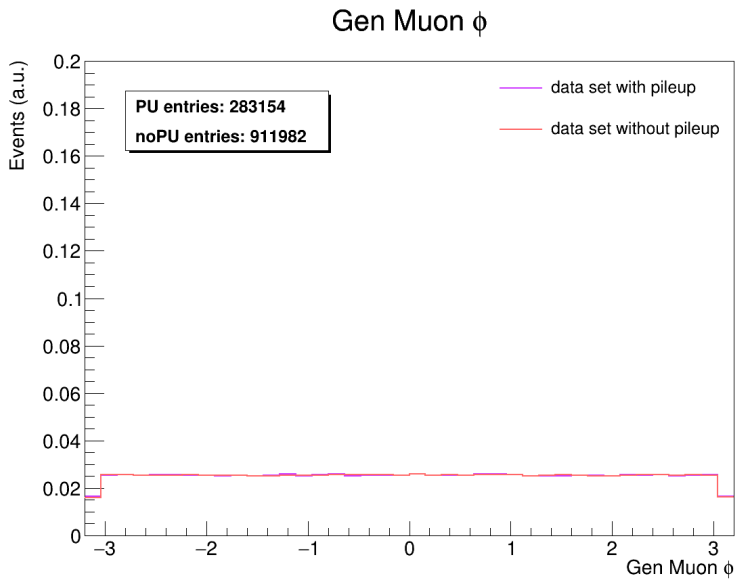

Muon ϕ
PU entries: 283154
noPU entries: 911982
data set with pileup
data set without pileup
Events (a.u.)
Muon ϕ

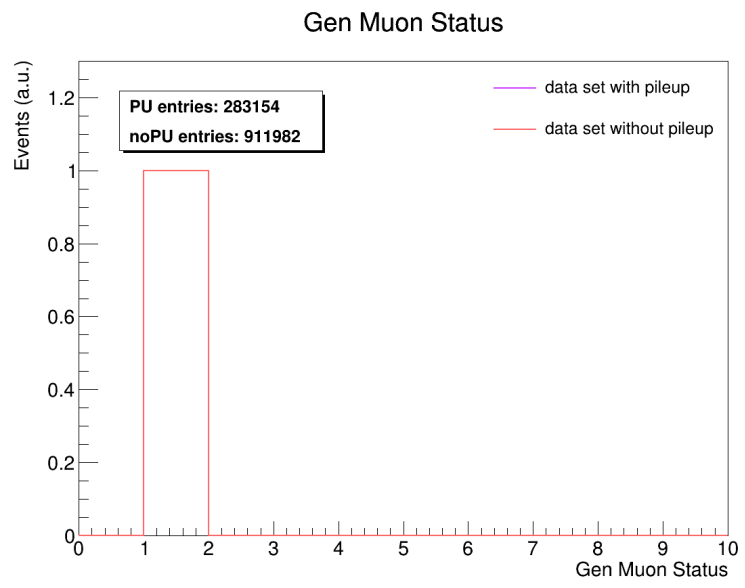

Muon Index
PU entries: 283154
noPU entries: 911982
data set with pileup
data set without pileup
Events (a.u.)
Muon index

Plots 2 (DY)

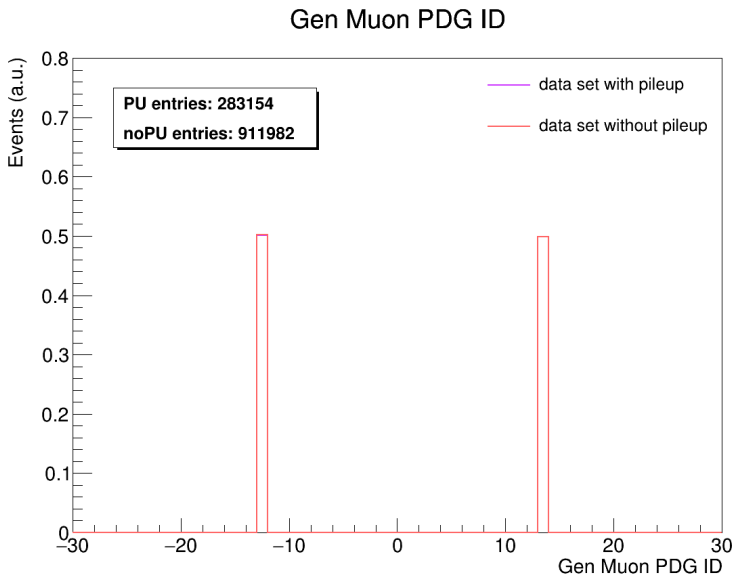

Gen Muon p_T
PU entries: 283154
noPU entries: 911982
data set with pileup
data set without pileup
Events (a.u.)
Gen Muon p_T [GeV]

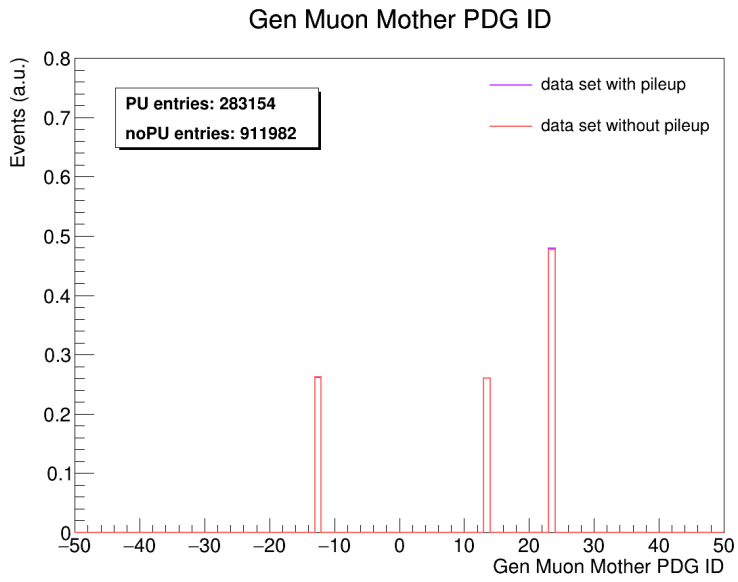

Gen Muon η
PU entries: 283154
noPU entries: 911982
data set with pileup
data set without pileup
Events (a.u.)
Gen Muon η

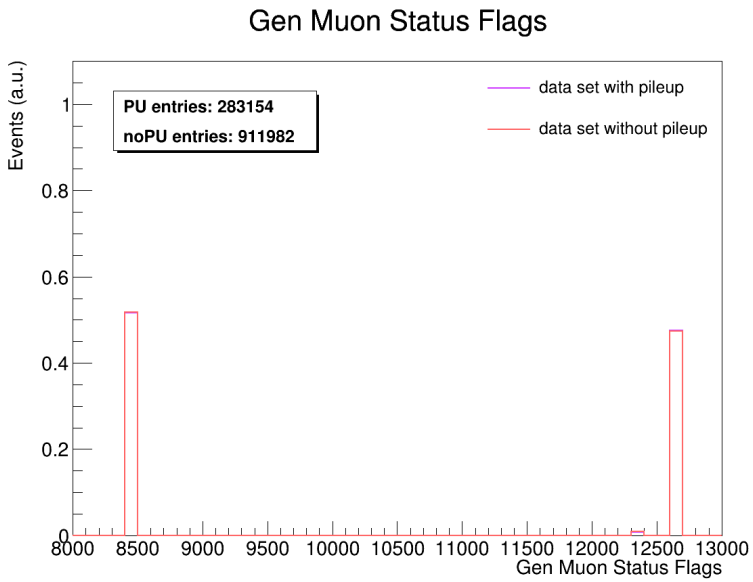

Gen Muon ϕ
PU entries: 283154
noPU entries: 911982
data set with pileup
data set without pileup
Events (a.u.)
Gen Muon ϕ

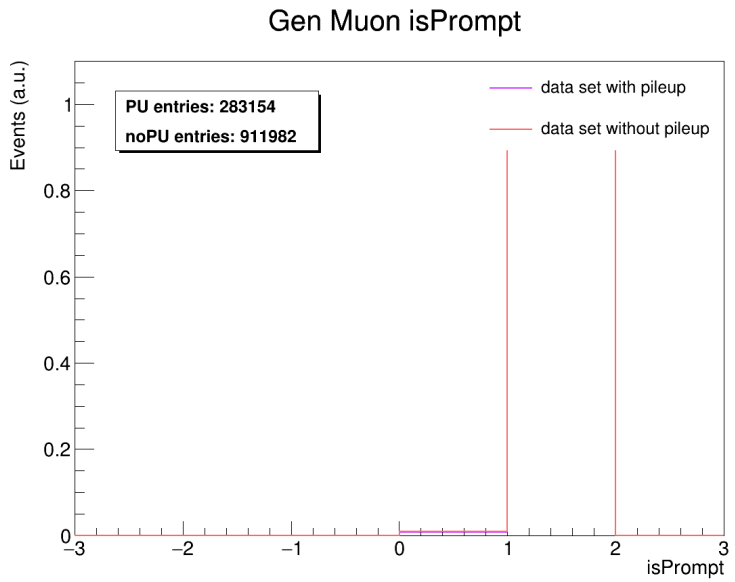

Gen Muon Status
PU entries: 283154
noPU entries: 911982
data set with pileup
data set without pileup
Events (a.u.)
Gen Muon Status

Plots 3 (DY)


Gen Muon PDG ID
PU entries: 283154
noPU entries: 911982
data set with pileup
data set without pileup
Events (a.u.)
Gen Muon PDG ID

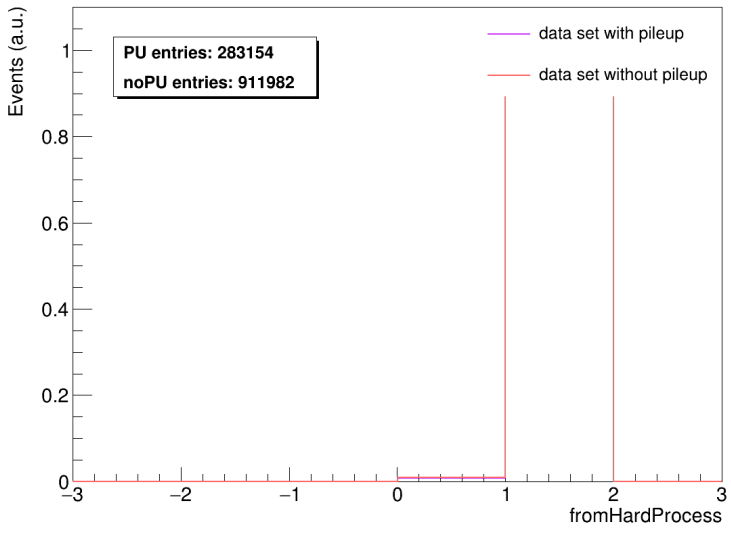

Gen Muon Mother PDG ID
PU entries: 283154
noPU entries: 911982
data set with pileup
data set without pileup
Events (a.u.)
Gen Muon Mother PDG ID


Gen Muon Status Flags
PU entries: 283154
noPU entries: 911982
data set with pileup
data set without pileup
Events (a.u.)
Gen Muon Status Flags

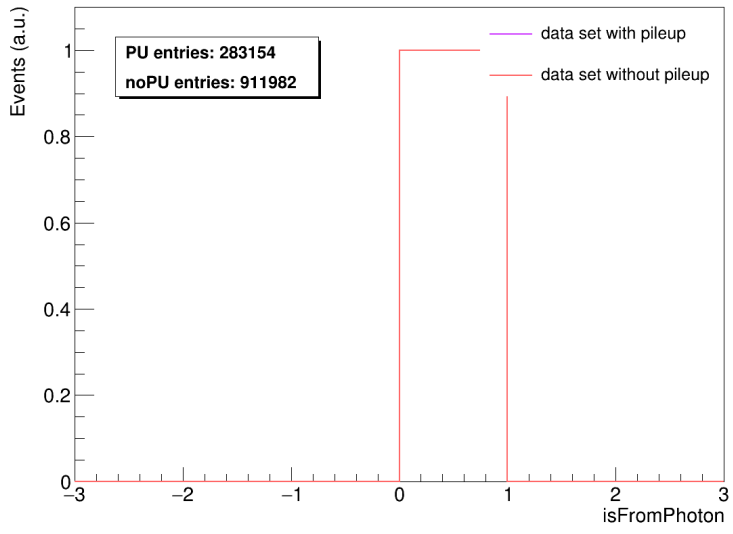

Gen Muon isPrompt
PU entries: 283154
noPU entries: 911982
data set with pileup
data set without pileup
Events (a.u.)
isPrompt

Plots 4 (DY)

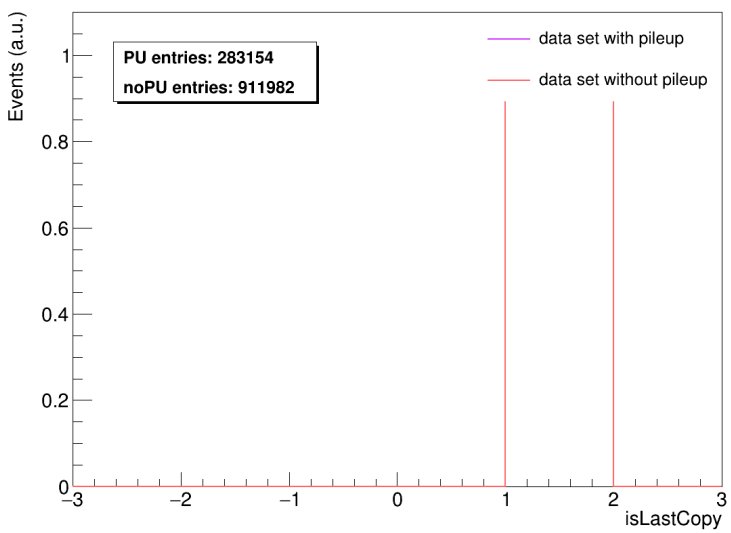
Gen Muon fromHardProcess



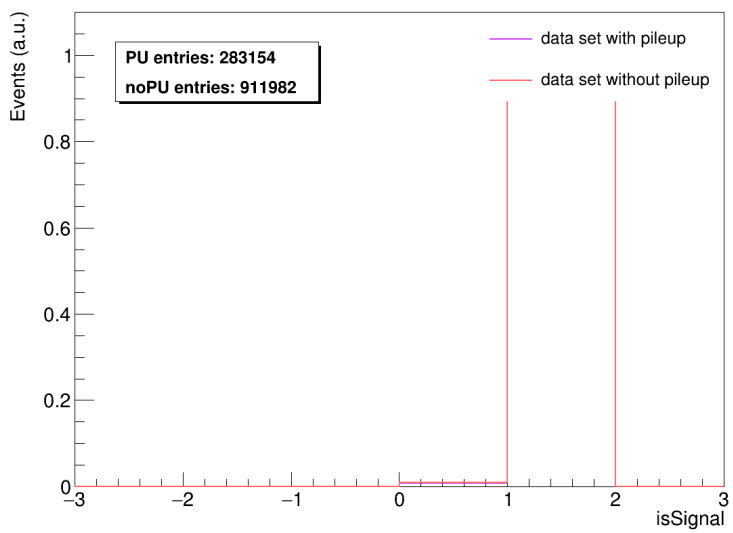
Gen Muon isFromPhoton



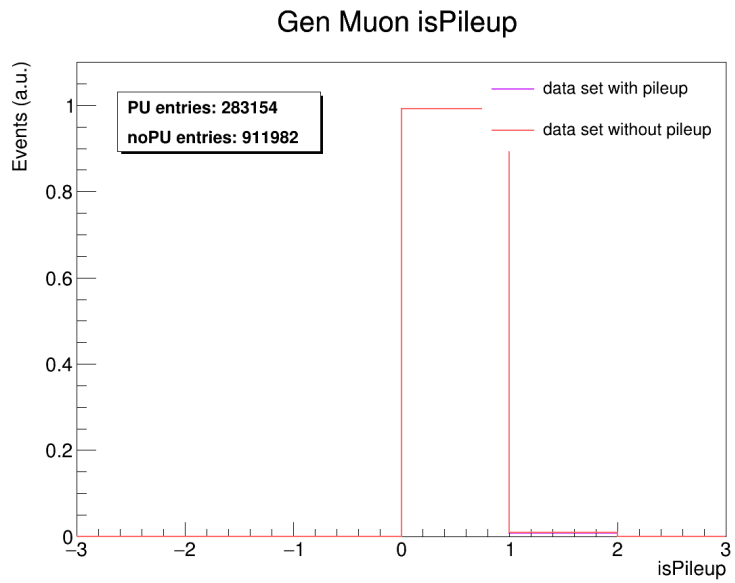
Gen Muon isLastCopy

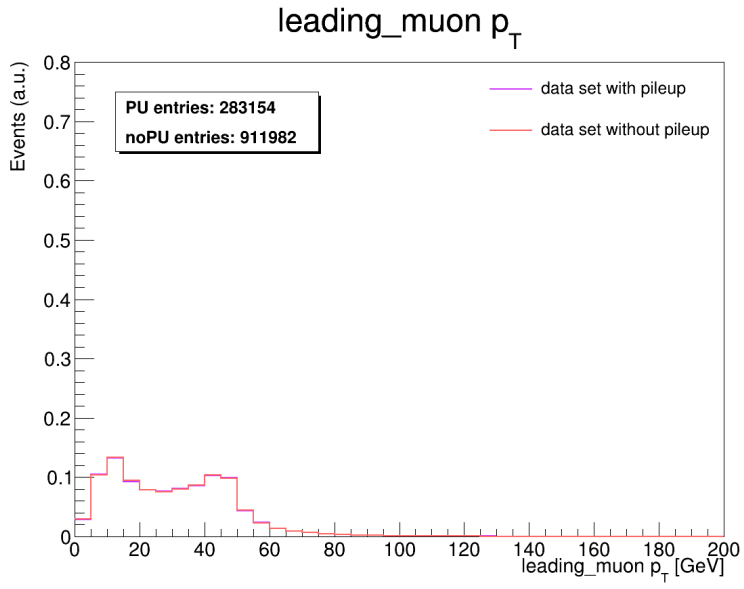


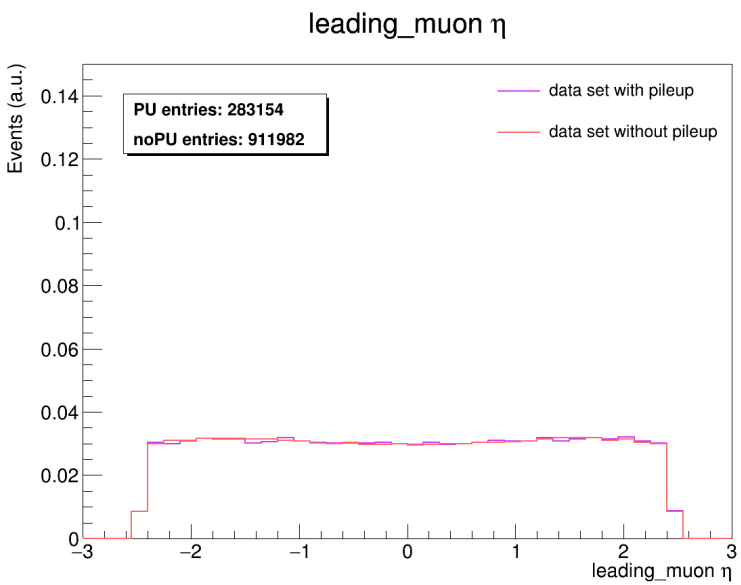
Gen Muon isSignal

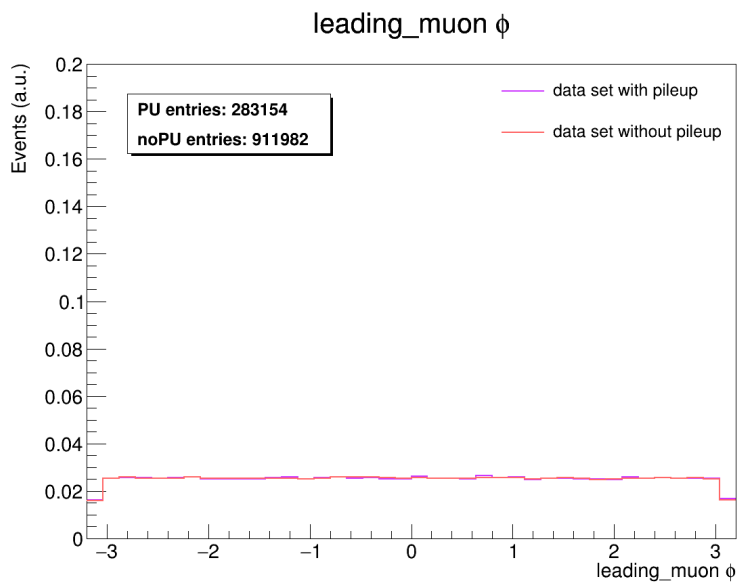


Plots 5 (DY)

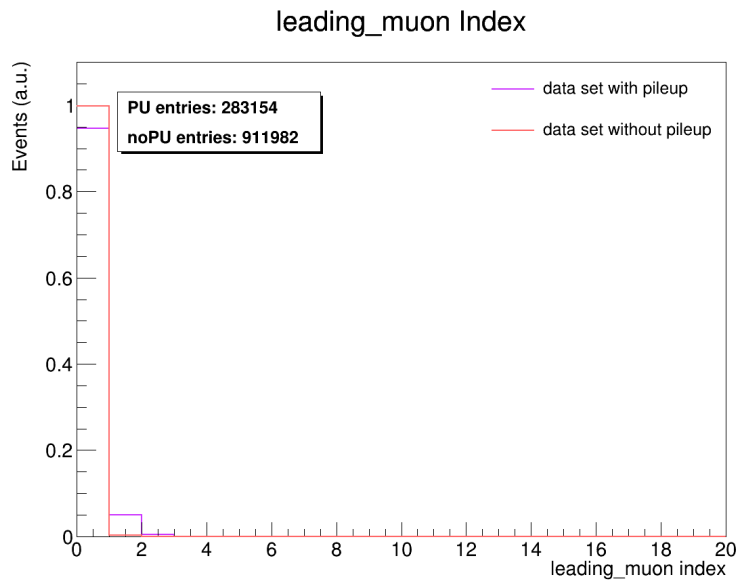

Gen Muon isPileup
PU entries: 283154
noPU entries: 911982
data set with pileup
data set without pileup
Events (a.u.)
isPileup

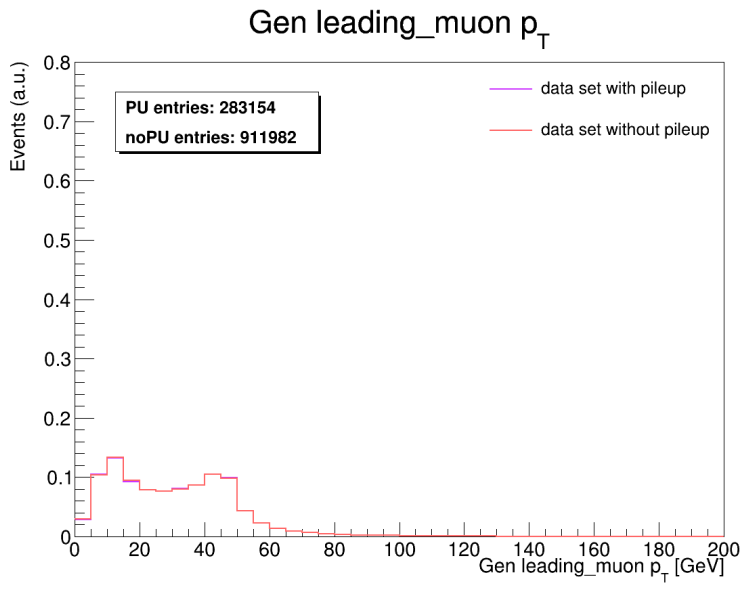

leading_muon p_T
PU entries: 283154
noPU entries: 911982
data set with pileup
data set without pileup
Events (a.u.)
leading_muon p_T [GeV]

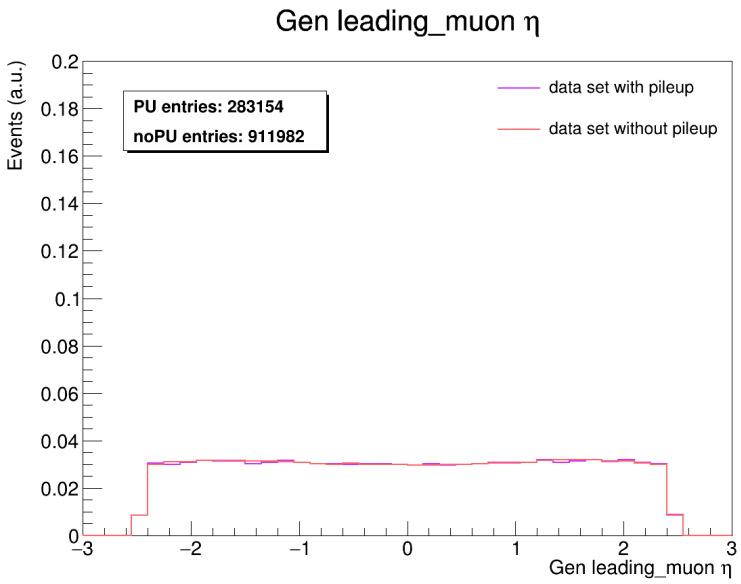

leading_muon η
PU entries: 283154
noPU entries: 911982
data set with pileup
data set without pileup
Events (a.u.)
leading_muon η

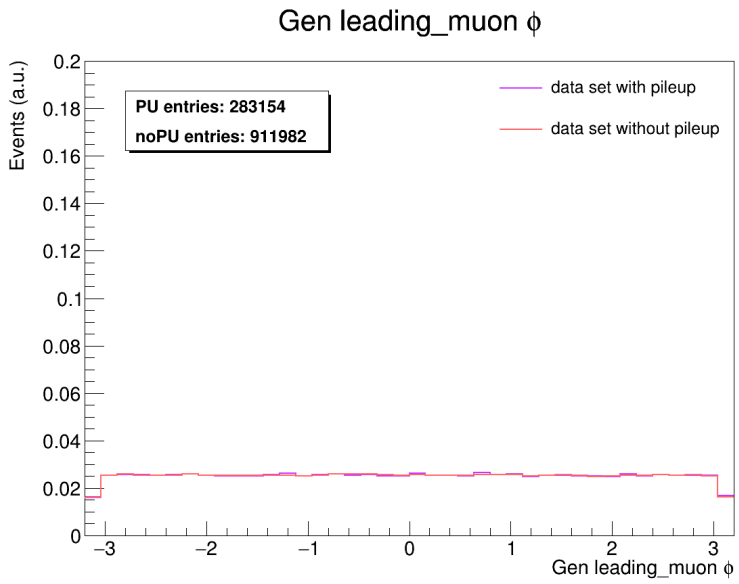

leading_muon ϕ
PU entries: 283154
noPU entries: 911982
data set with pileup
data set without pileup
Events (a.u.)
leading_muon ϕ

Plots 6 (DY)

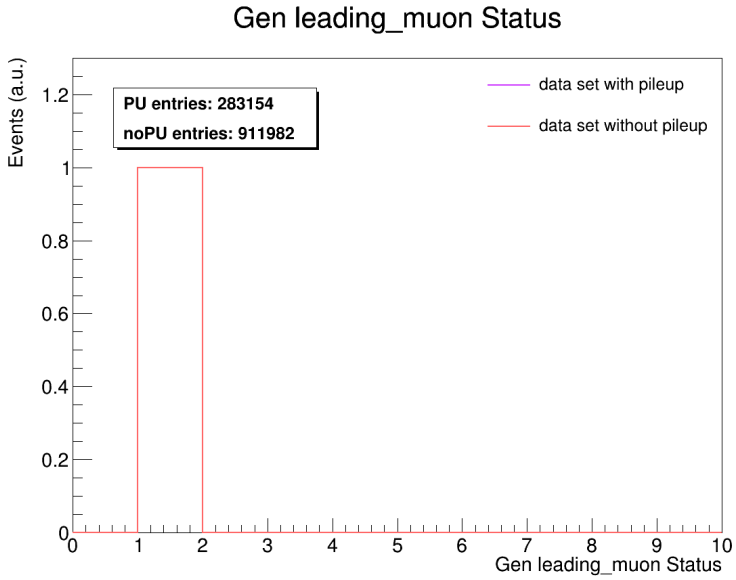

leading_muon Index
Events (a.u.)
PU entries: 283154
noPU entries: 911982
data set with pileup
data set without pileup
leading_muon index

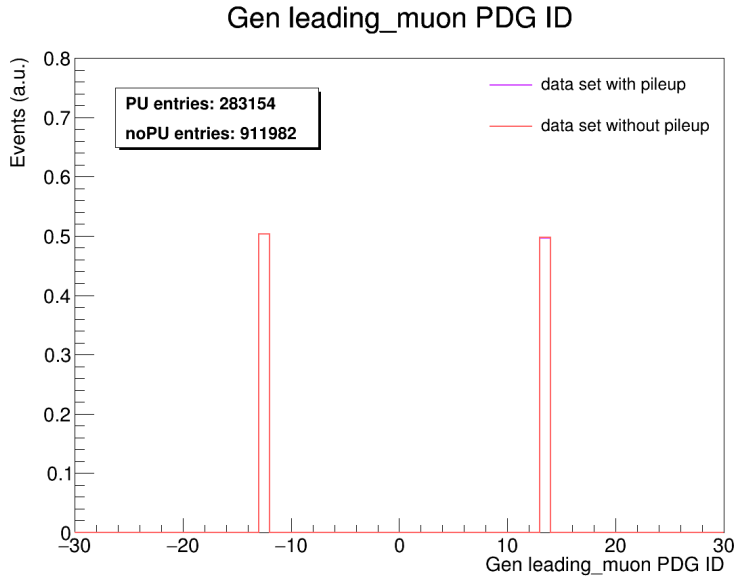

Gen leading_muon p_T
Events (a.u.)
PU entries: 283154
noPU entries: 911982
data set with pileup
data set without pileup
Gen leading_muon p_T [GeV]

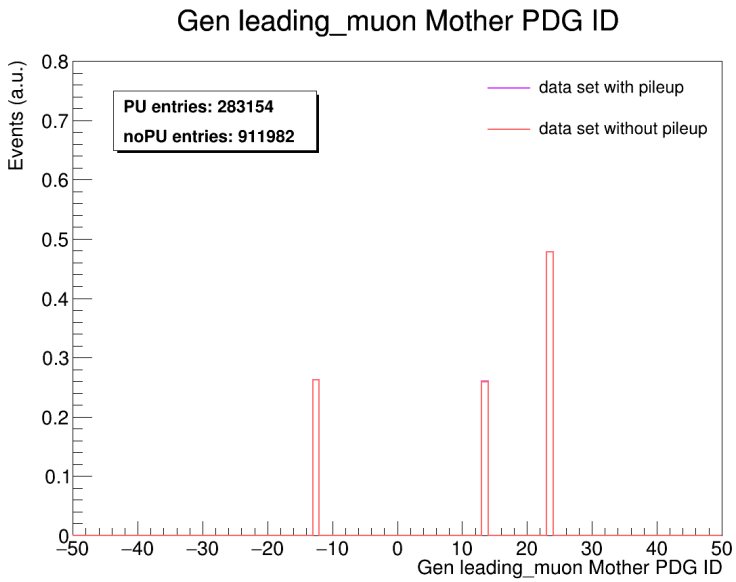

Gen leading_muon η
Events (a.u.)
PU entries: 283154
noPU entries: 911982
data set with pileup
data set without pileup
Gen leading_muon η

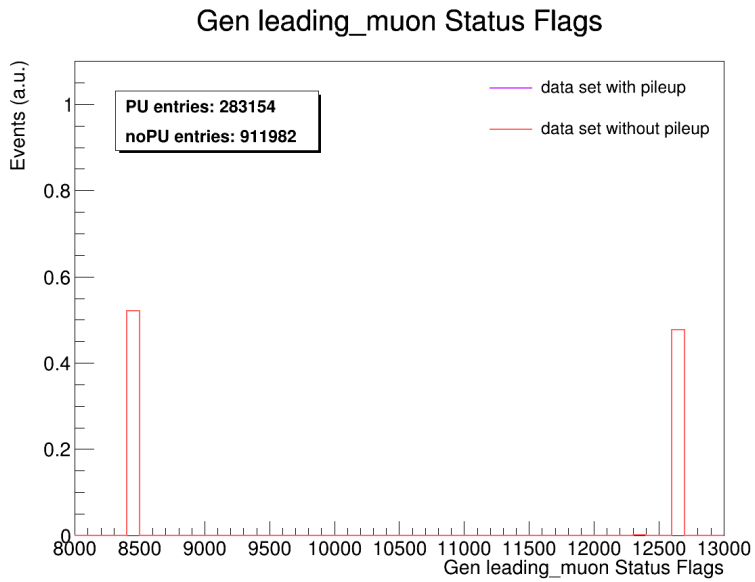

Gen leading_muon ϕ
Events (a.u.)
PU entries: 283154
noPU entries: 911982
data set with pileup
data set without pileup
Gen leading_muon ϕ

Plots 7 (DY)

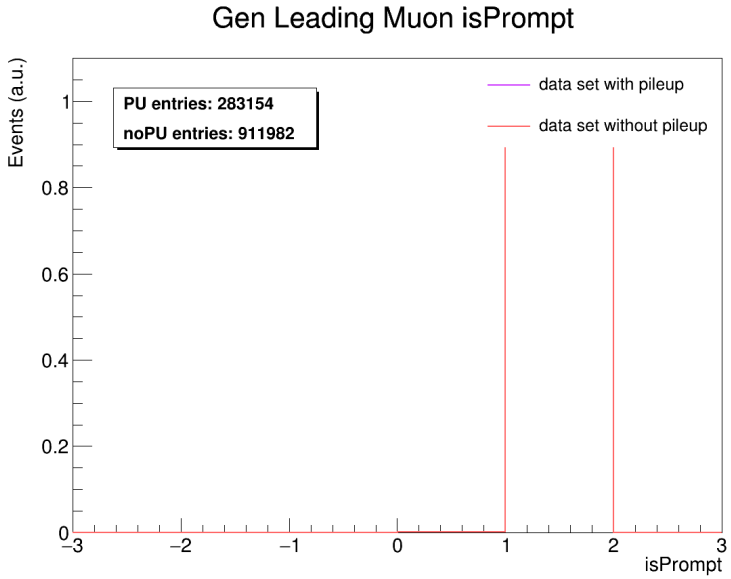

Gen leading_muon Status
PU entries: 283154
noPU entries: 911982
data set with pileup
data set without pileup
Events (a.u.)
Gen leading_muon Status

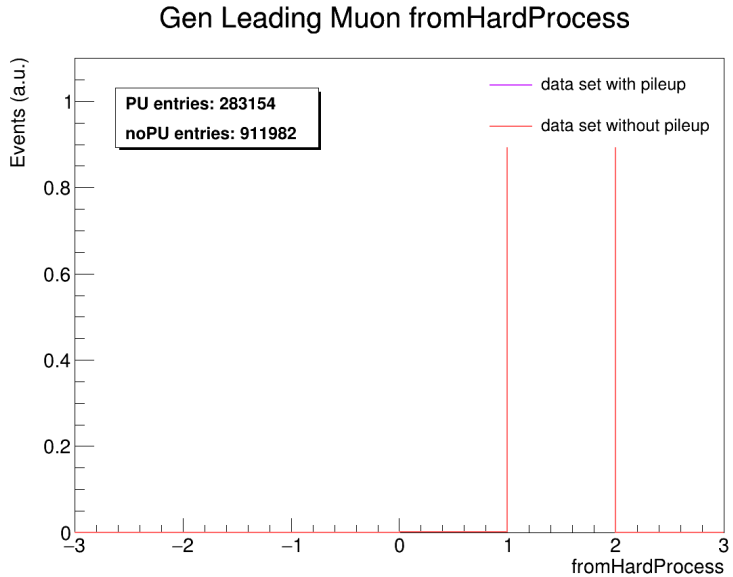

Gen leading_muon PDG ID
PU entries: 283154
noPU entries: 911982
data set with pileup
data set without pileup
Events (a.u.)
Gen leading_muon PDG ID

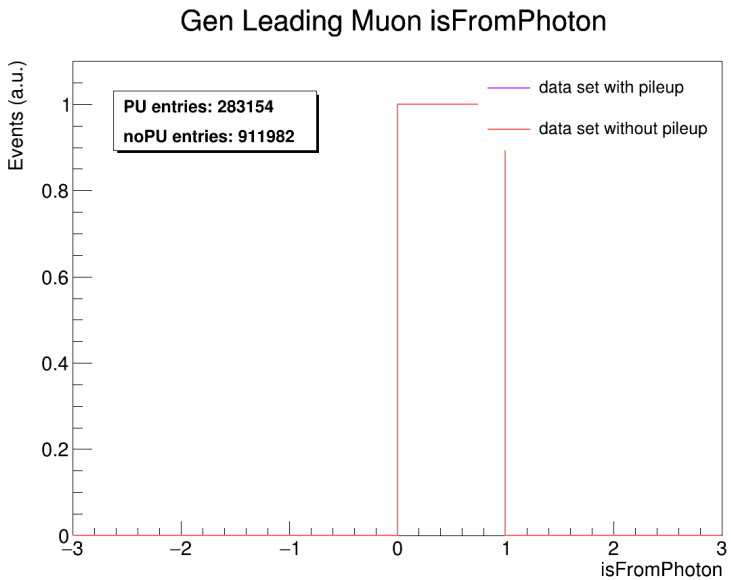

Gen leading_muon Mother PDG ID
PU entries: 283154
noPU entries: 911982
data set with pileup
data set without pileup
Events (a.u.)
Gen leading_muon Mother PDG ID

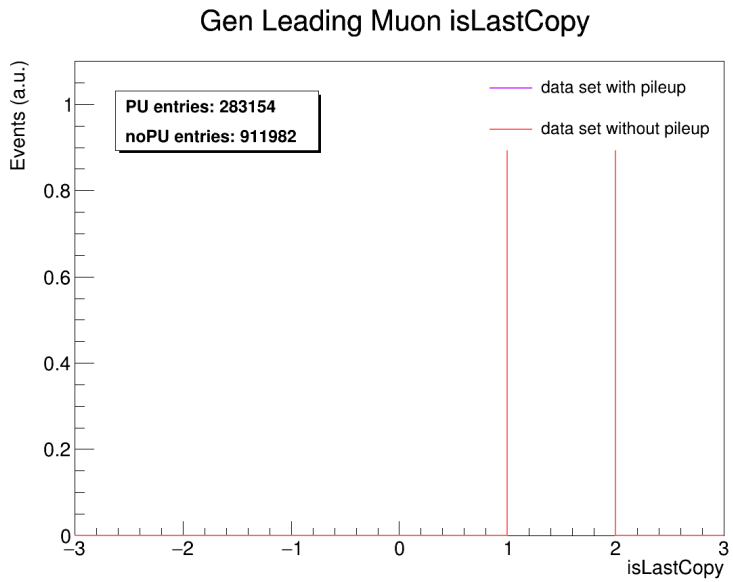

Gen leading_muon Status Flags
PU entries: 283154
noPU entries: 911982
data set with pileup
data set without pileup
Events (a.u.)
Gen leading_muon Status Flags

Plots 8 (DY)

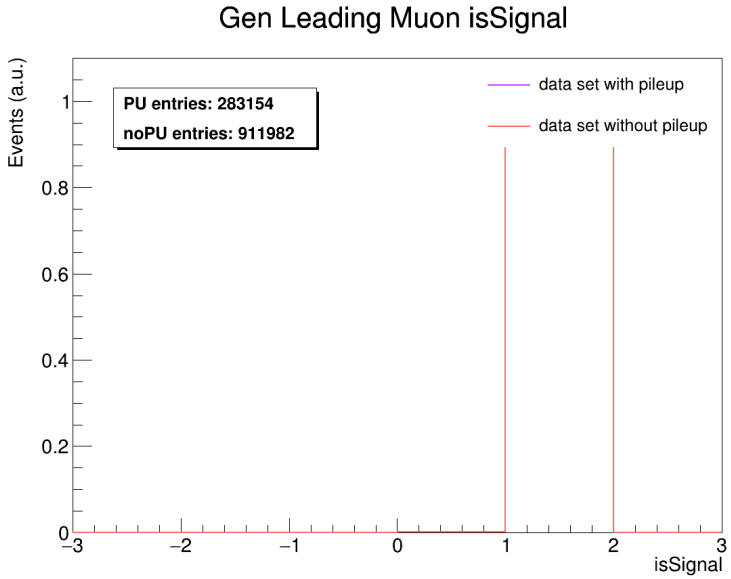

Gen Leading Muon isPrompt
PU entries: 283154
noPU entries: 911982
data set with pileup
data set without pileup
Events (a.u.)
isPrompt

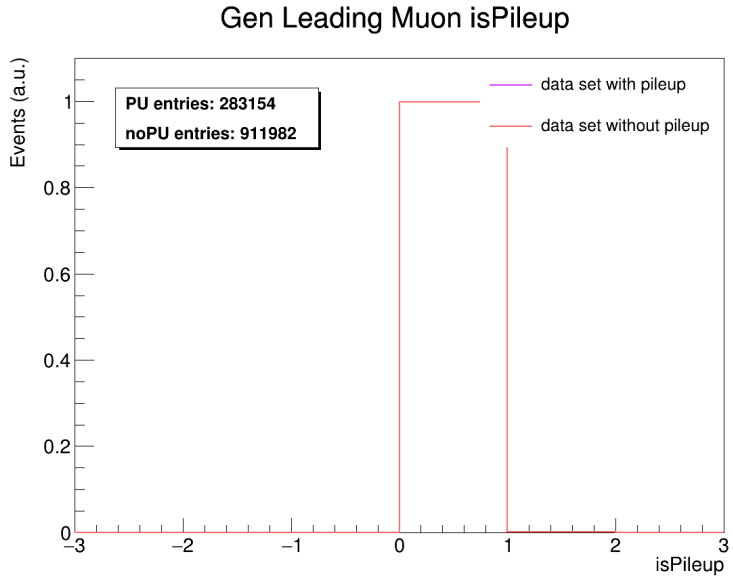

Gen Leading Muon fromHardProcess
PU entries: 283154
noPU entries: 911982
data set with pileup
data set without pileup
Events (a.u.)
fromHardProcess

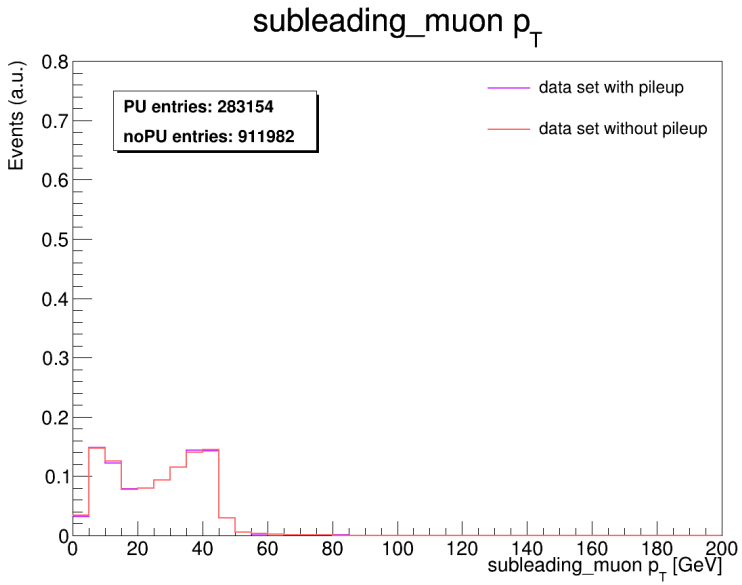

Gen Leading Muon isFromPhoton
PU entries: 283154
noPU entries: 911982
data set with pileup
data set without pileup
Events (a.u.)
isFromPhoton

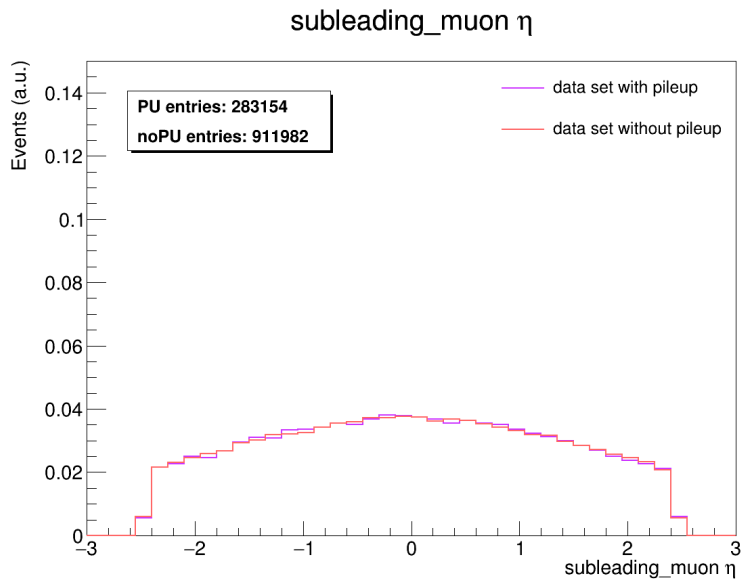

Gen Leading Muon isLastCopy
PU entries: 283154
noPU entries: 911982
data set with pileup
data set without pileup
Events (a.u.)
isLastCopy

Plots 9 (DY)

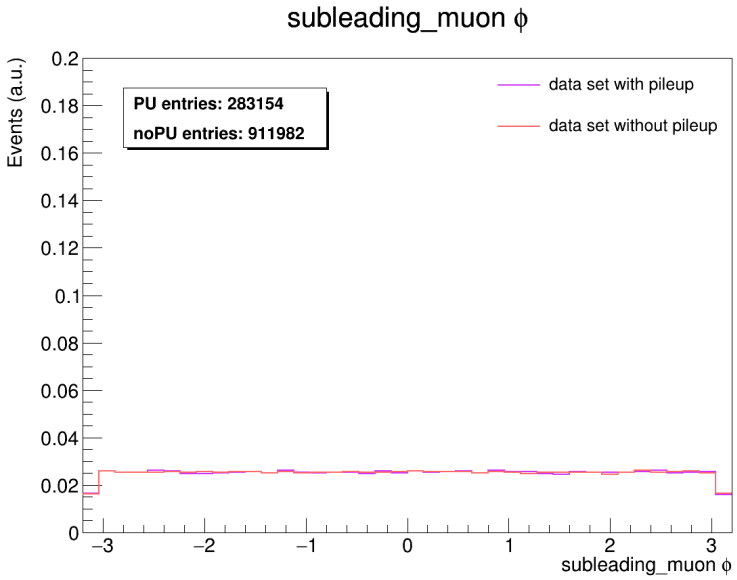

Gen Leading Muon isSignal
PU entries: 283154
noPU entries: 911982
data set with pileup
data set without pileup
Events (a.u.)
isSignal

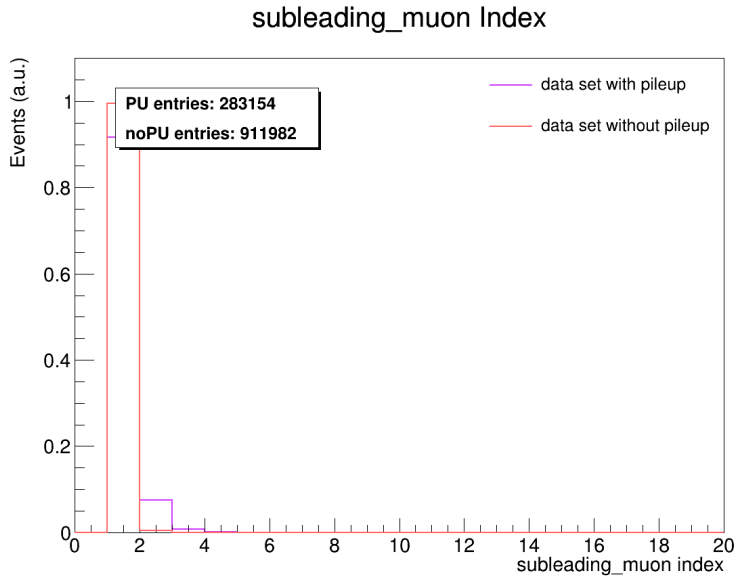

Gen Leading Muon isPileup
PU entries: 283154
noPU entries: 911982
data set with pileup
data set without pileup
Events (a.u.)
isPileup

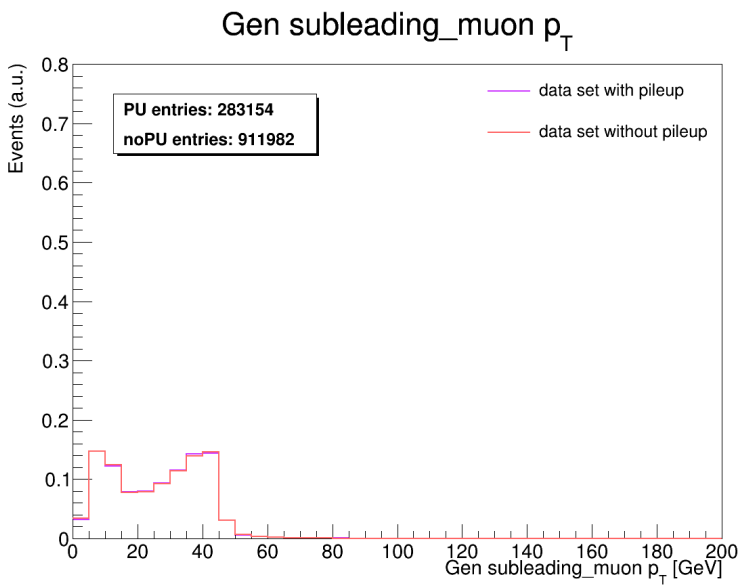

subleading_muon p_T
PU entries: 283154
noPU entries: 911982
data set with pileup
data set without pileup
Events (a.u.)
subleading_muon p_T [GeV]

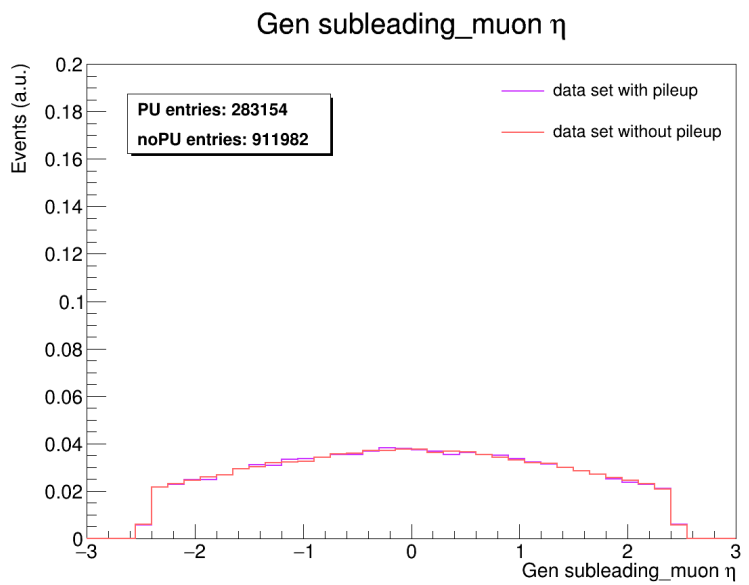

subleading_muon η
PU entries: 283154
noPU entries: 911982
data set with pileup
data set without pileup
Events (a.u.)
subleading_muon η

Plots 10 (DY)

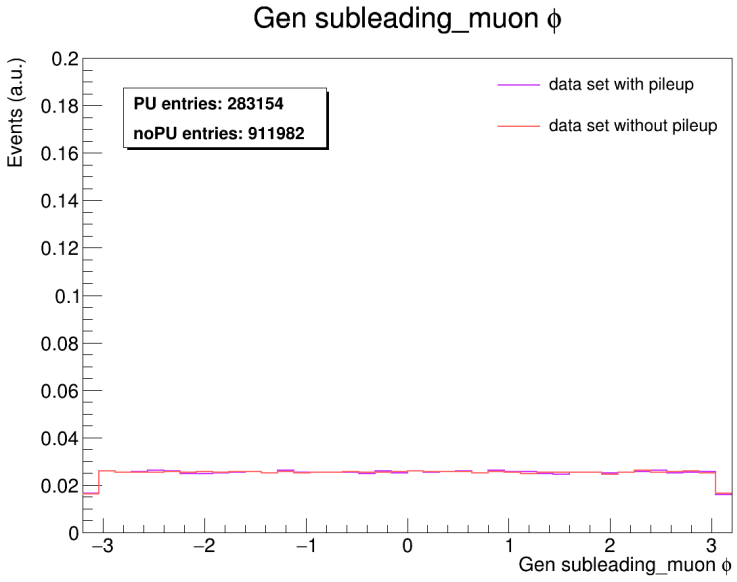

subleading_muon ϕ
PU entries: 283154
noPU entries: 911982
data set with pileup
data set without pileup
Events (a.u.)
subleading_muon ϕ

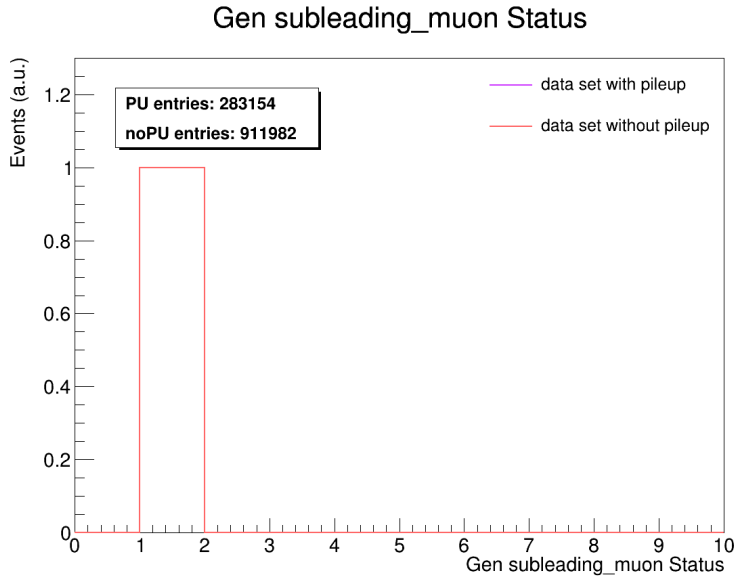

subleading_muon Index
PU entries: 283154
noPU entries: 911982
data set with pileup
data set without pileup
Events (a.u.)
subleading_muon index

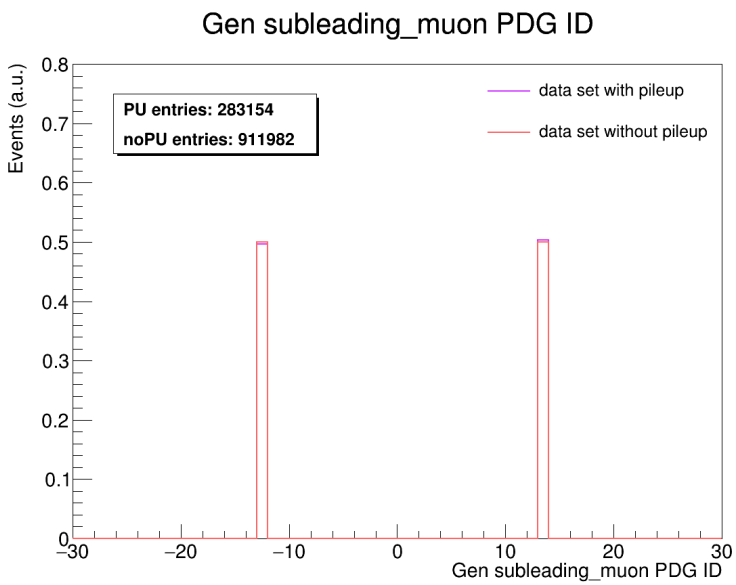

Gen subleading_muon p_T
PU entries: 283154
noPU entries: 911982
data set with pileup
data set without pileup
Events (a.u.)
Gen subleading_muon p_T [GeV]

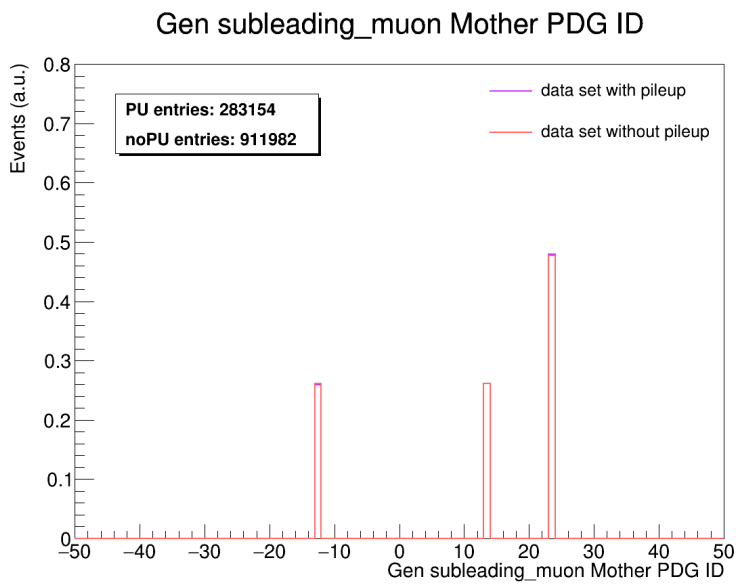

Gen subleading_muon η
PU entries: 283154
noPU entries: 911982
data set with pileup
data set without pileup
Events (a.u.)
Gen subleading_muon η

Plots 11 (DY)

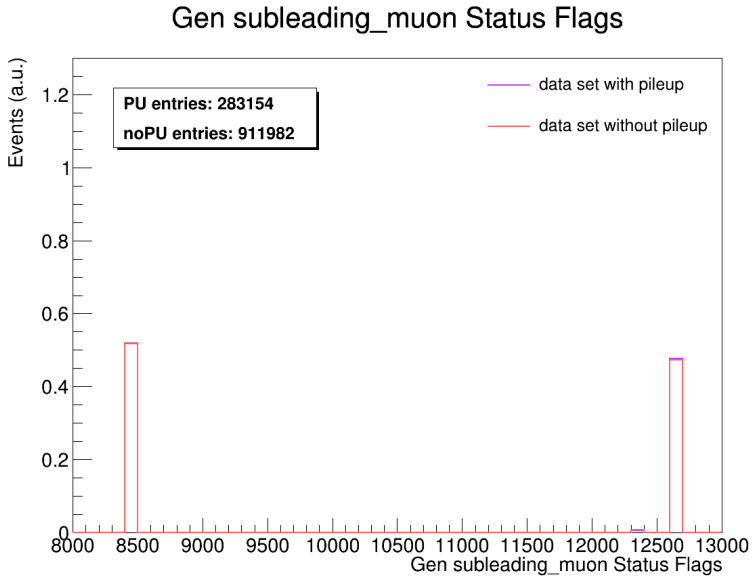

Gen subleading_muon ϕ
PU entries: 283154
noPU entries: 911982
data set with pileup
data set without pileup
Events (a.u.)
Gen subleading_muon ϕ

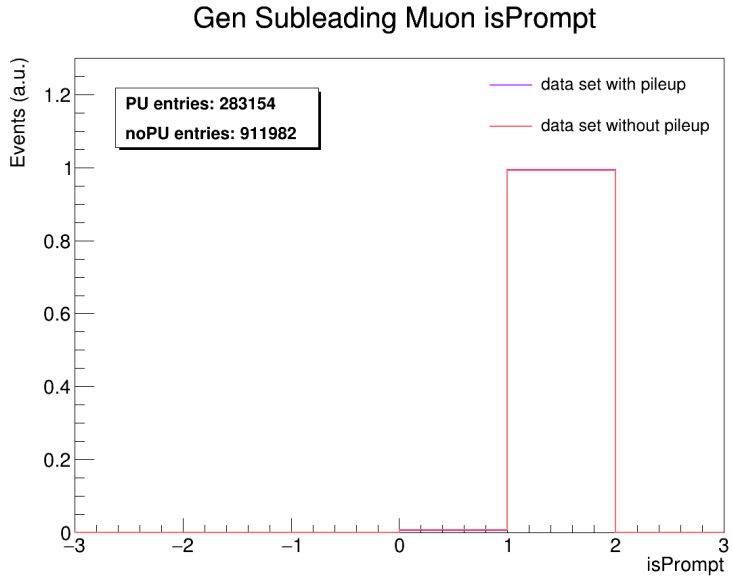

Gen subleading_muon Status
PU entries: 283154
noPU entries: 911982
data set with pileup
data set without pileup
Events (a.u.)
Gen subleading_muon Status

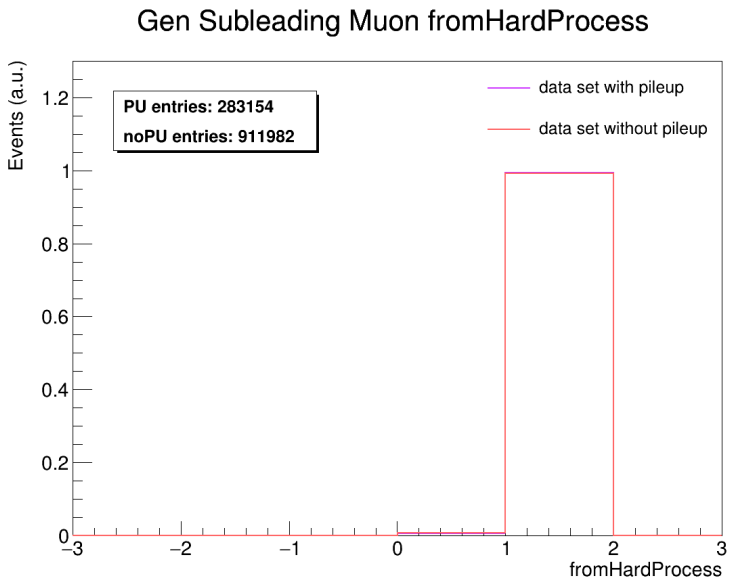

Gen subleading_muon PDG ID
PU entries: 283154
noPU entries: 911982
data set with pileup
data set without pileup
Events (a.u.)
Gen subleading_muon PDG ID

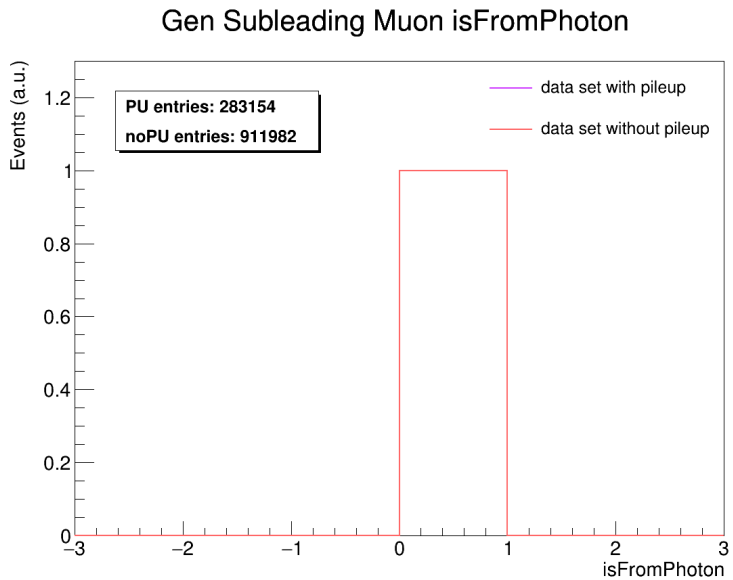

Gen subleading_muon Mother PDG ID
PU entries: 283154
noPU entries: 911982
data set with pileup
data set without pileup
Events (a.u.)
Gen subleading_muon Mother PDG ID

Plots 12 (DY)


Gen subleading_muon Status Flags
PU entries: 283154
noPU entries: 911982
data set with pileup
data set without pileup
Events (a.u.)
Gen subleading_muon Status Flags

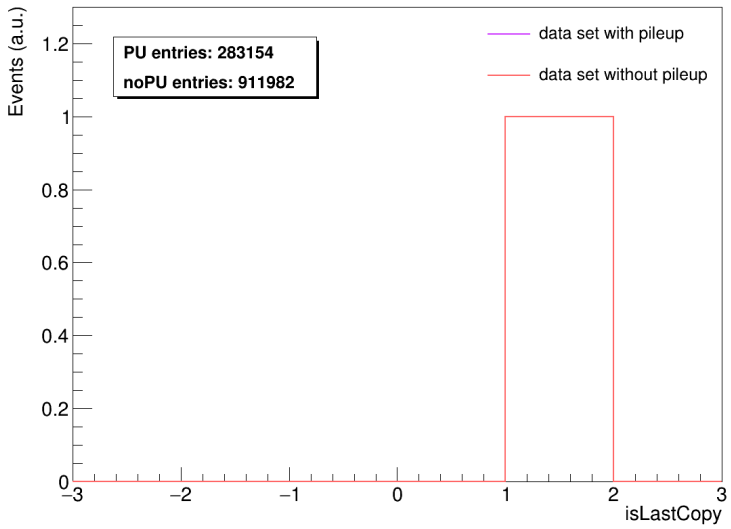

Gen Subleading Muon isPrompt
PU entries: 283154
noPU entries: 911982
data set with pileup
data set without pileup
Events (a.u.)
isPrompt


Gen Subleading Muon fromHardProcess
PU entries: 283154
noPU entries: 911982
data set with pileup
data set without pileup
Events (a.u.)
fromHardProcess

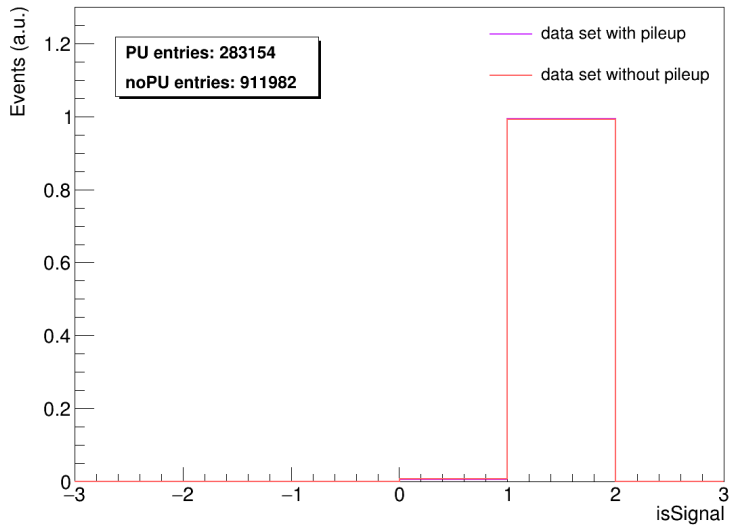

Gen Subleading Muon isFromPhoton
PU entries: 283154
noPU entries: 911982
data set with pileup
data set without pileup
Events (a.u.)
isFromPhoton

Plots 13 (DY)

Gen Subleading Muon isLastCopy



Gen Subleading Muon isSignal



Gen Subleading Muon isPileup