



Jet Muon Analysis



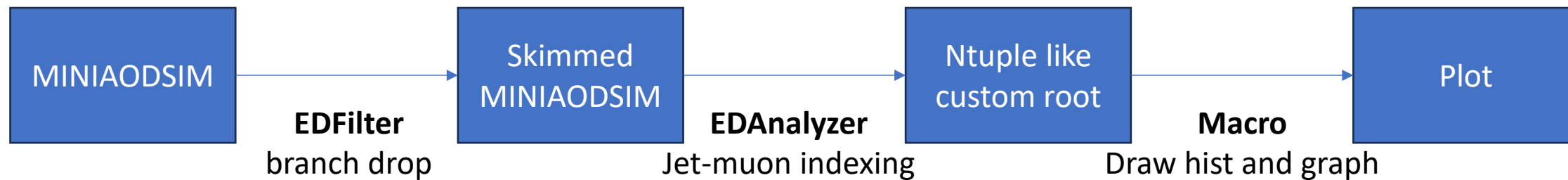
권 우 연

Wooyeon Kwon

wkwon@cern.ch

Apr 28, 2025

Purpose : Looking into the PFjet and the muons inside it. Comparing with gen level info.



Generator Object

- **genJet** : `slimmedGenJets`(*reconstructed gen jet with anti-kt $R=0.4$*)
- **genMuon** : `packedGenParticles`(*slimmed gen particle with $pdgID = \pm 13$ (muon)*)

Reconstructed Object

- **patJet** : `slimmedJetsPuppi(ak4PFPuppiJets)`

- **JetID** :

For AK4 PUPPI jets				
PF Jet ID	$ \eta \leq 2.6$	$2.6 < \eta \leq 2.7$	$2.7 < \eta \leq 3.0$	$3.0 < \eta \leq 5.0$
Neutral Hadron Fraction	< 0.99	< 0.90	< 0.99	-
Neutral EM Fraction	< 0.99	< 0.99	-	< 0.4
Number of Constituents	> 1	-	-	-
Charged Hadron Fraction	> 0.01	-	-	-
Charged Multiplicity	> 0	-	-	-
Number of Neutral Particles	-	-	-	≥ 2

- **Jet Selection** : $(p_t > 30 \text{ GeV} \ \&\& \ |\eta| \leq 2.5)$ or $(p_t > 50 \text{ GeV} \ \&\& \ 2.5 < |\eta| < 3.0)$
- **muon** : `packedPFCandidates(slimmed PFCandidates with pdgID =  $\pm 13$  (muon))`

MC era : Run3Summer22

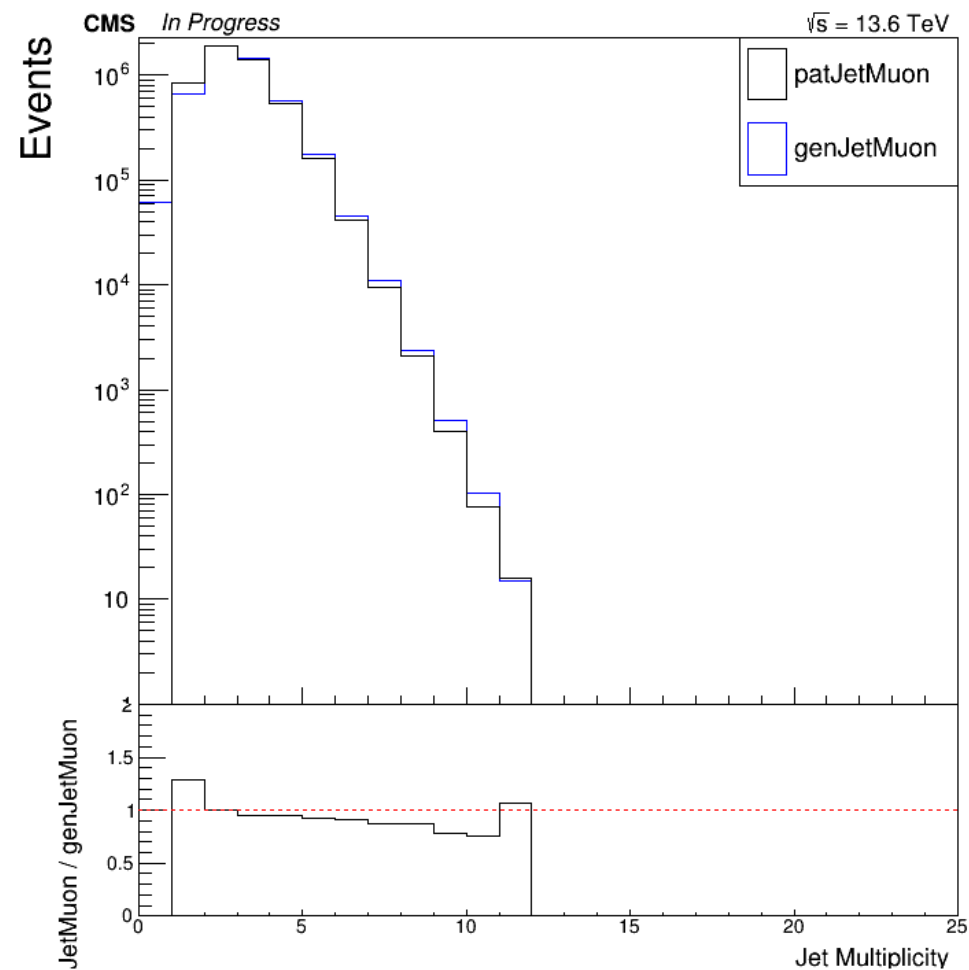
ttbar to semi leptonic : TTtoLNu2Q_TuneCP5_13p6TeV_powheg-pythia8

Event Selection

- Exact 1 prompt lepton
 - prompt lepton criteria
 - PAT electron
 - $p_t > 30 \text{ GeV}$
 - mva electron ID tight (egmGsfElectronIDs:mvaEleID-RunIIIWinter22-iso-V1-wp90)
 - $\text{mva_Isolated} > 0.9$ (Multivariate Analysis based isolation score)
 - PAT muon
 - $p_t > 24 \text{ GeV}$
 - muon Tight ID (Cut based ID Tight)
 - Tight PF Isolation ($\text{Iso}_{PF}^{Rel} < 0.15, R=0.4$)
- At least one jet which is $p_t > 30 \text{ GeV} \ \&\& \ |\eta| \leq 2.4$

Jet Multiplicity

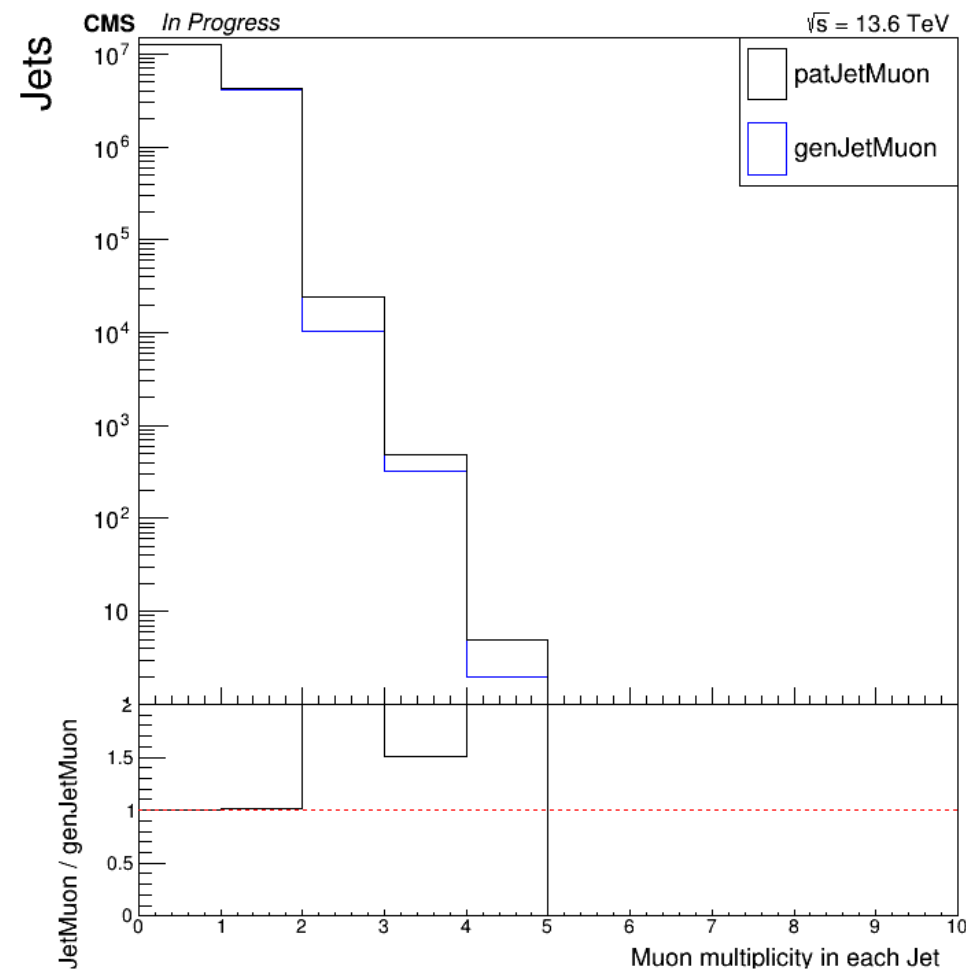
total number of events : 4,885,902



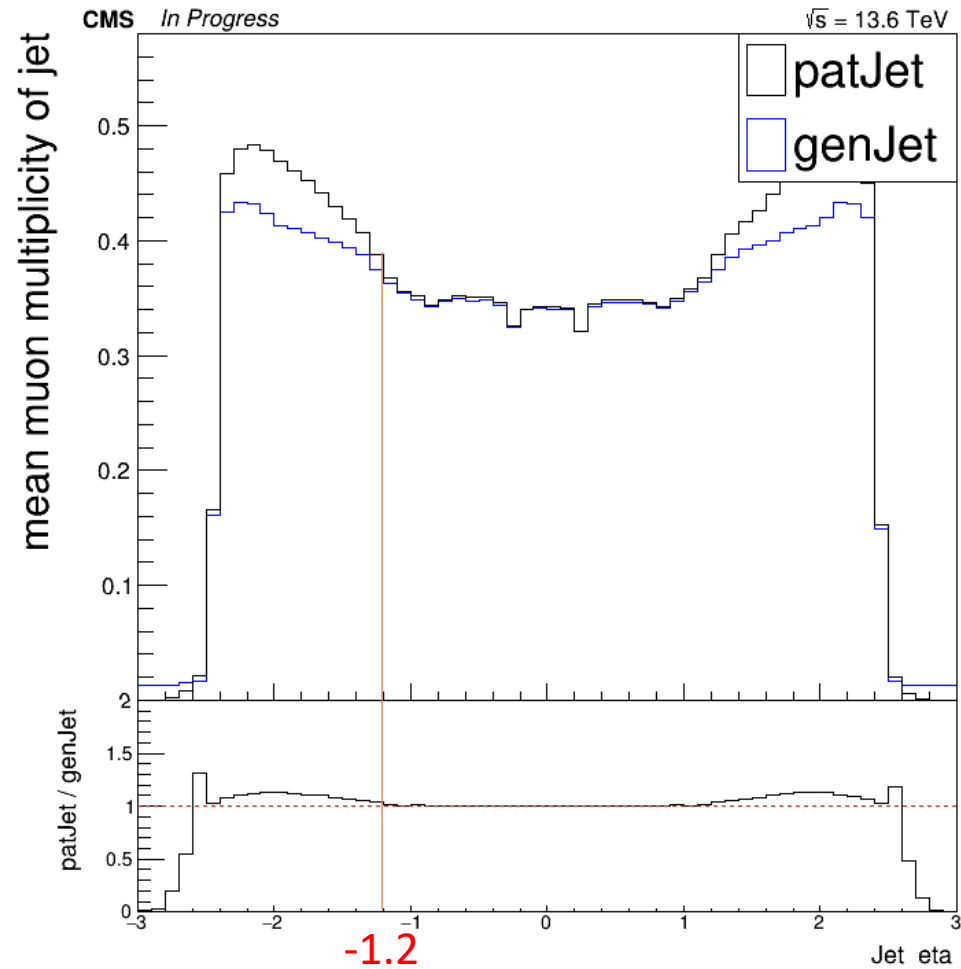
Muon multiplicity in each Jet

Total number of Jets : 11,904,565

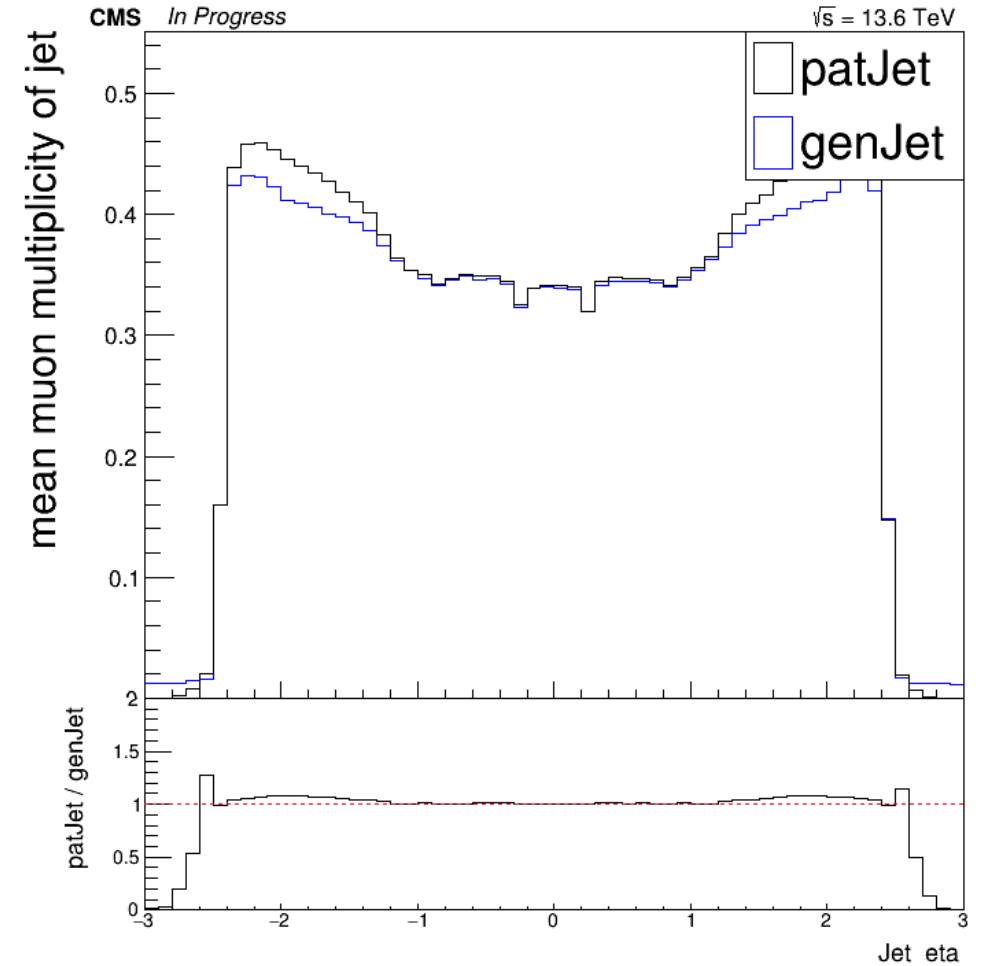
✕ Jet matching applied



average muon multiplicity in jet



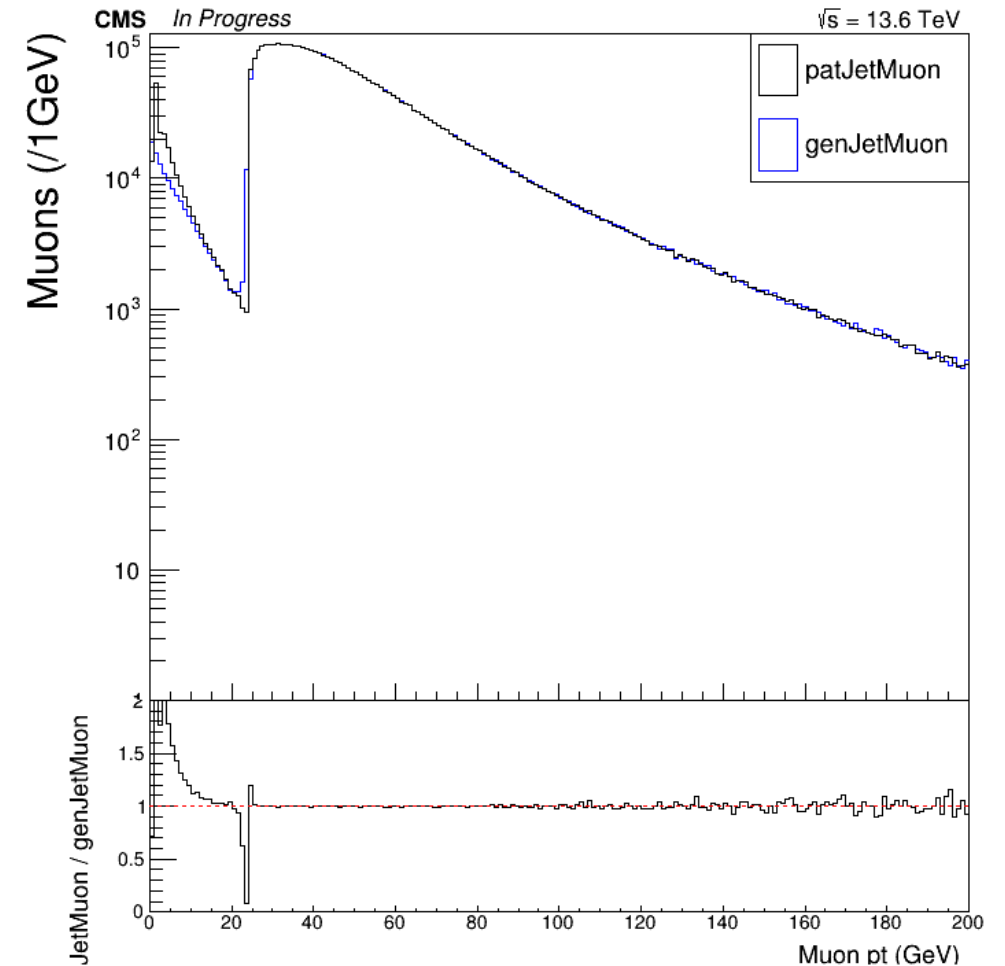
average muon multiplicity in jet (0 or 1 muon)



Muons pt in Jet

patJetMuon entries: 4,115,736

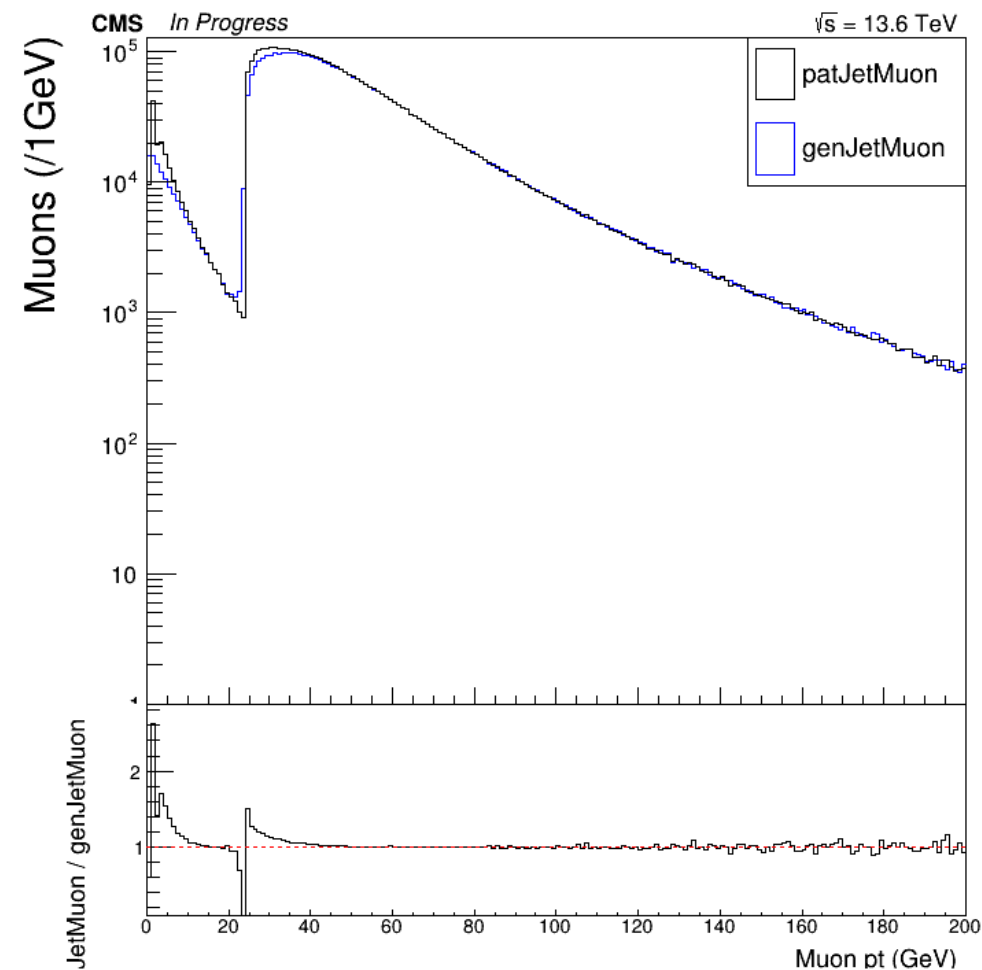
genJetMuon entries : 4,046,825



1st Leading Muons pt in Jet

patJetMuon entries: 4,092,466

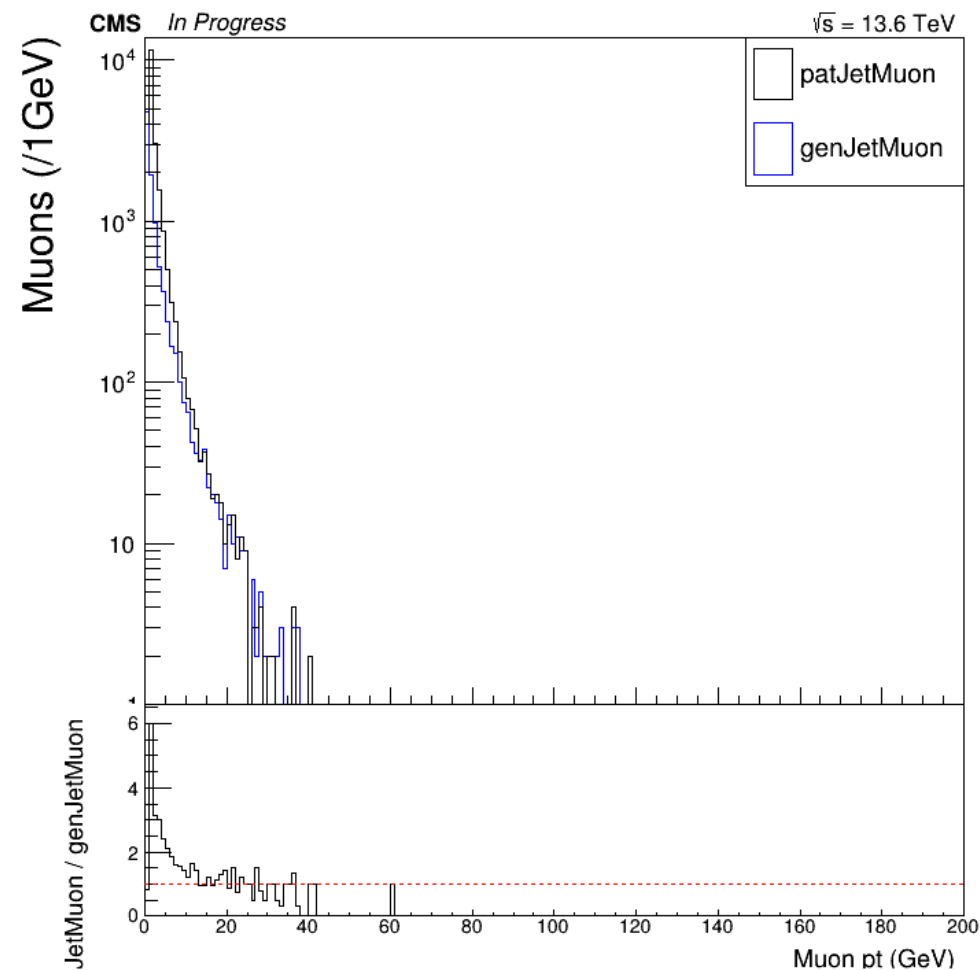
genJetMuon entries : 3,853,758



2nd Leading Muons pt in Jet

patJetMuon entries: 22,836

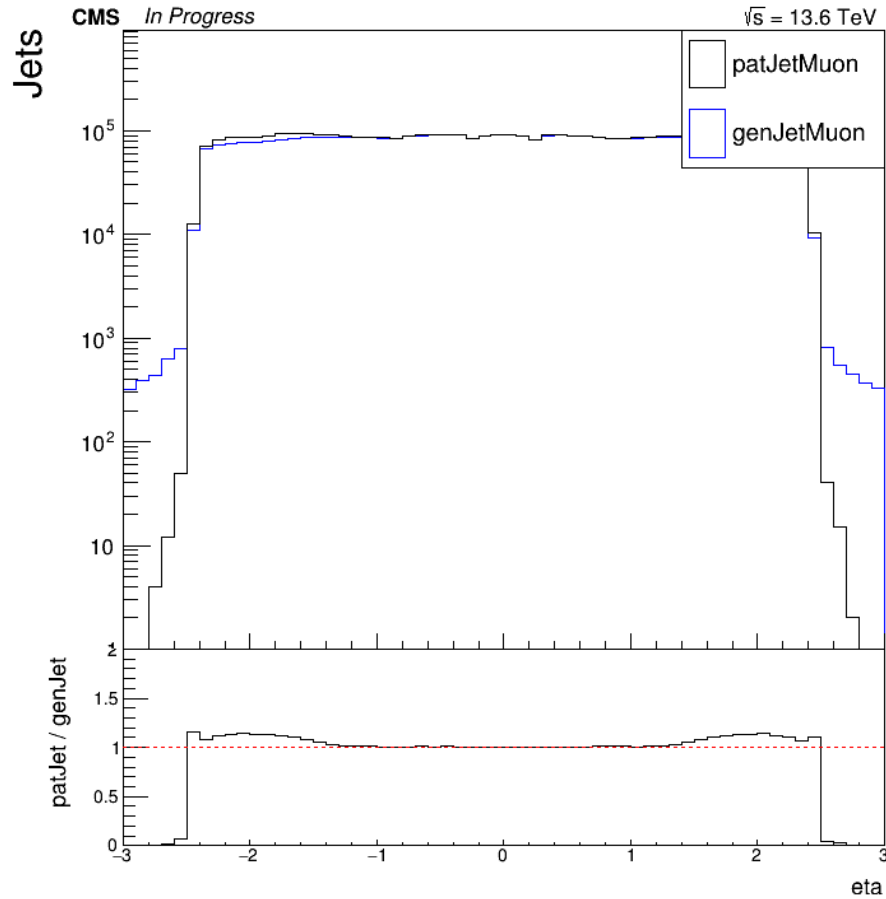
genJetMuon entries : 9,668



Matching Condition

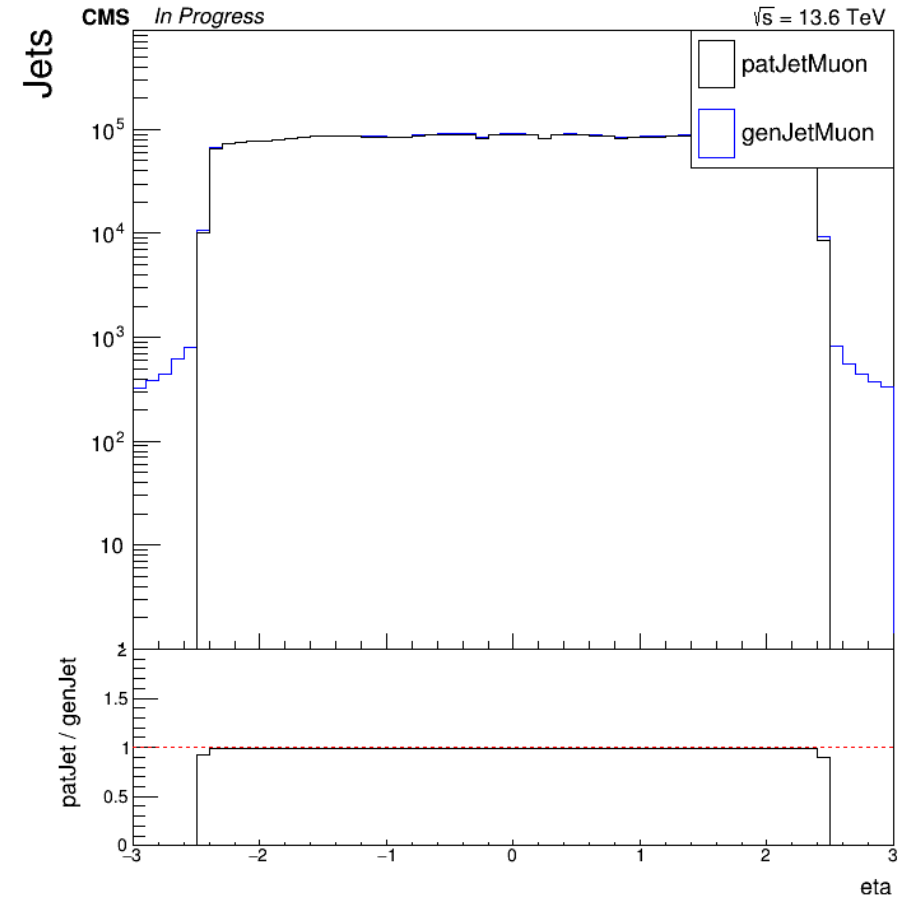
- same sign charge
- $dR < 0.3$
- $(\text{PFcandidate muon}_{\text{pt}} - \text{reco muon}_{\text{pt}}) / \text{reco muon}_{\text{pt}} < 0.5$

Muon jet with PFcandidate muon



#Jets : 4,247,138

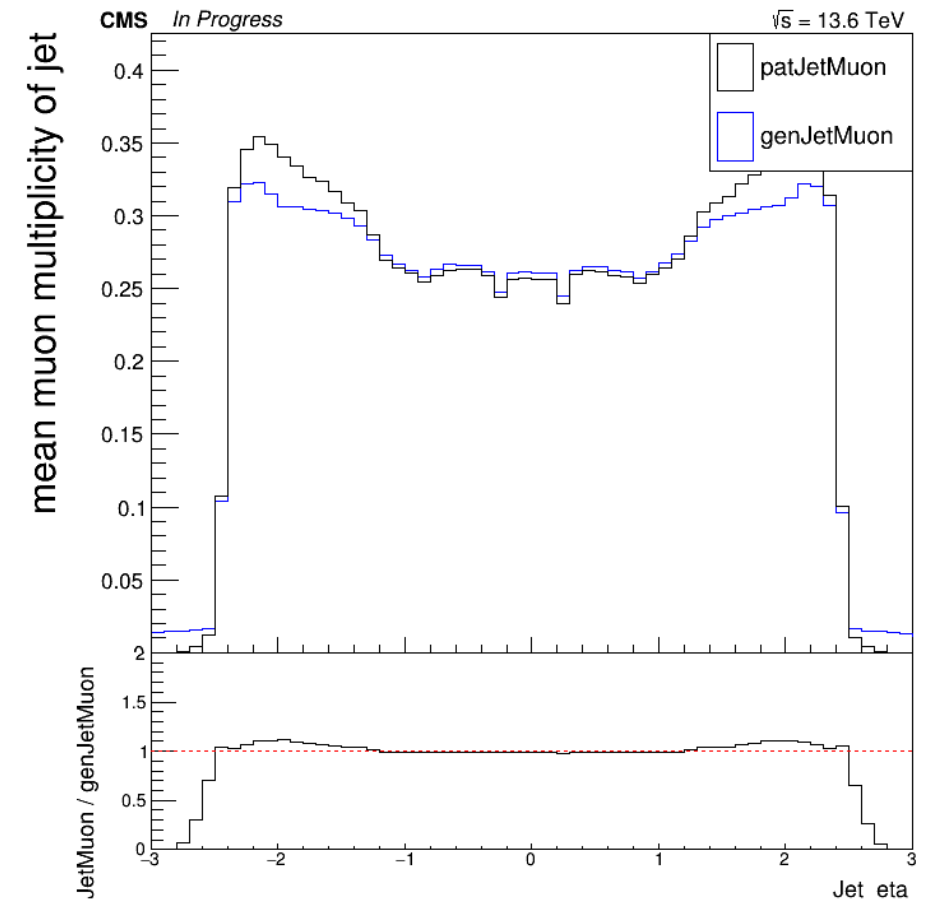
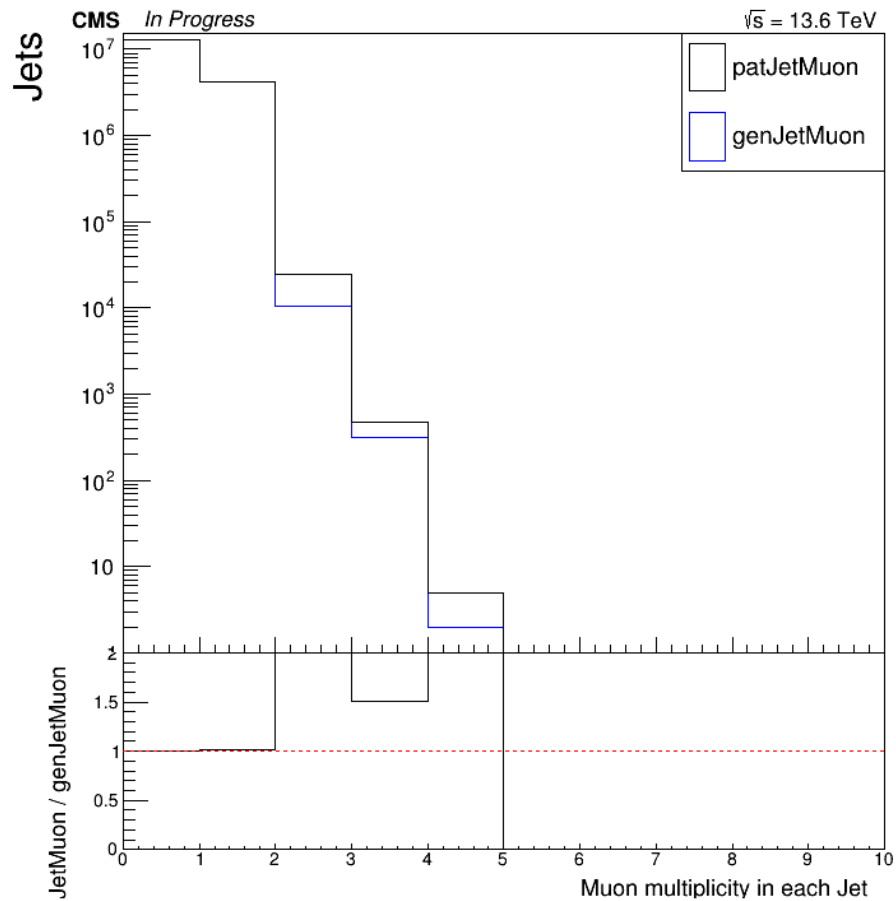
Muon jet with matched PFcandidate muon



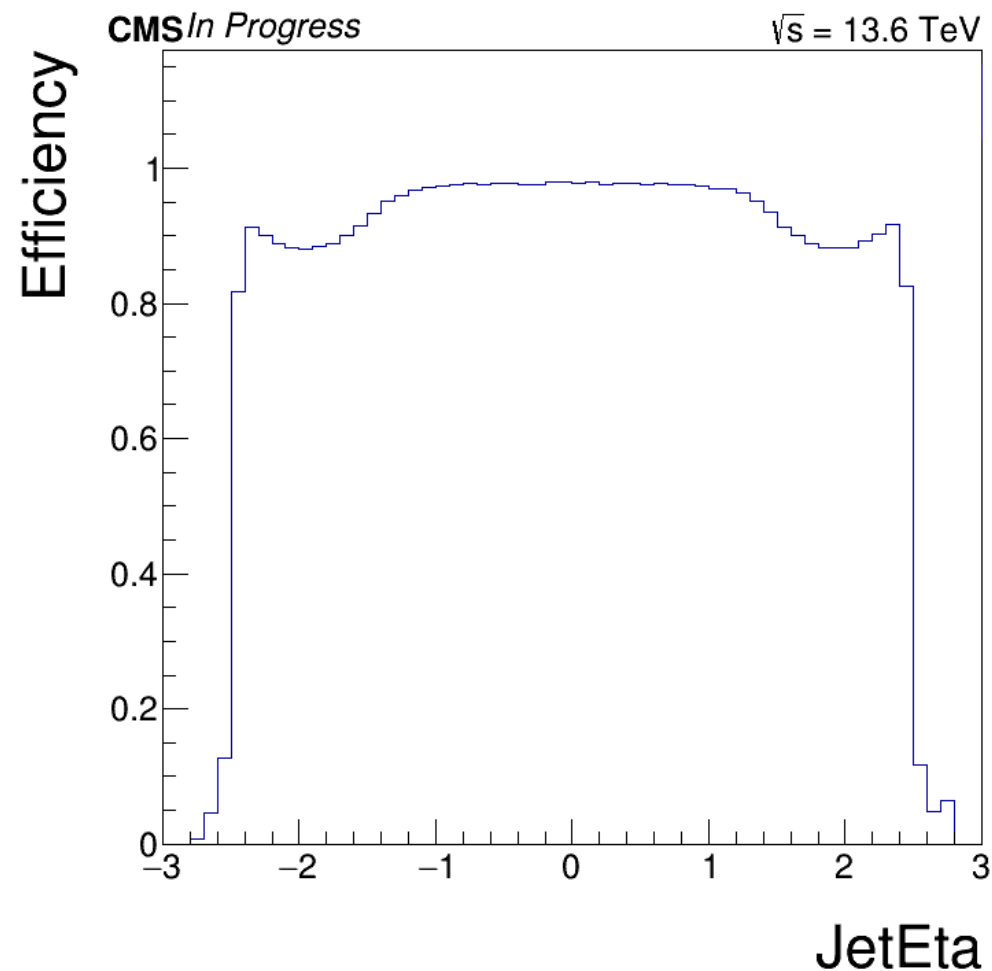
#Jets : 4,005,782

Muon multiplicity in each Jet

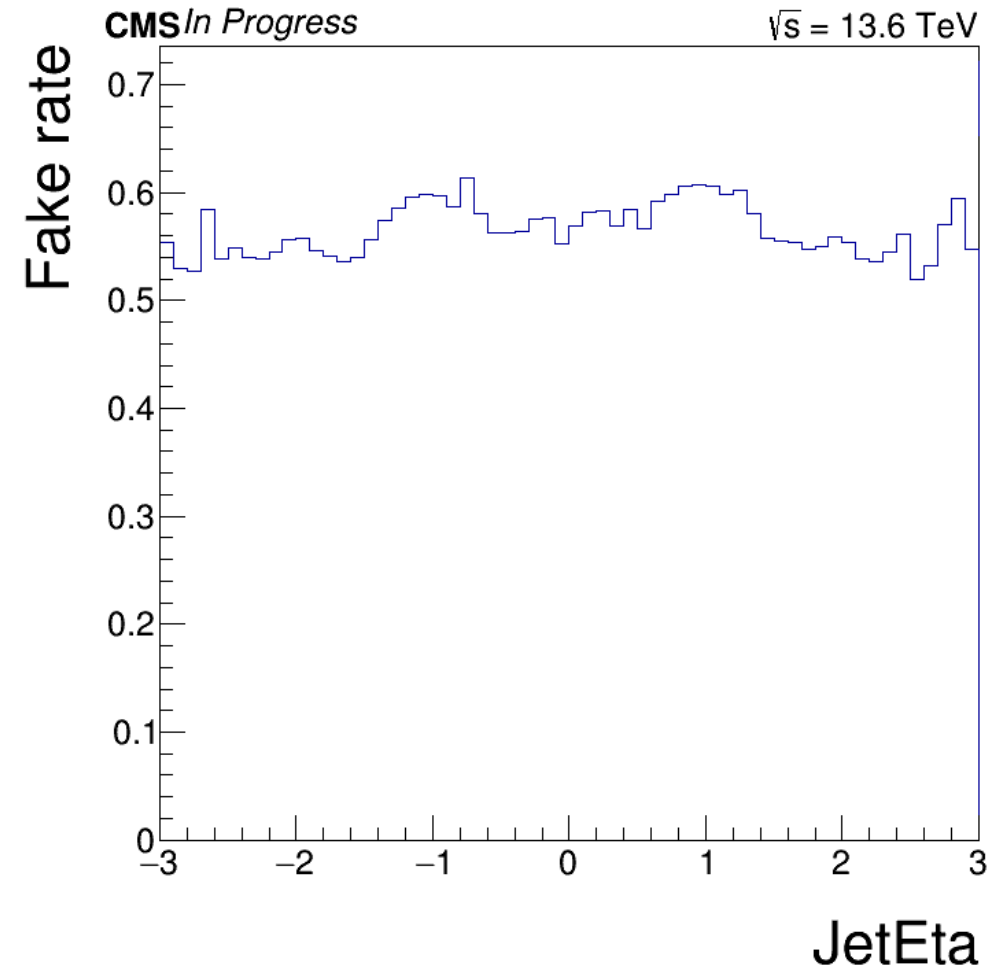
Total number of Jets : 17,101,314



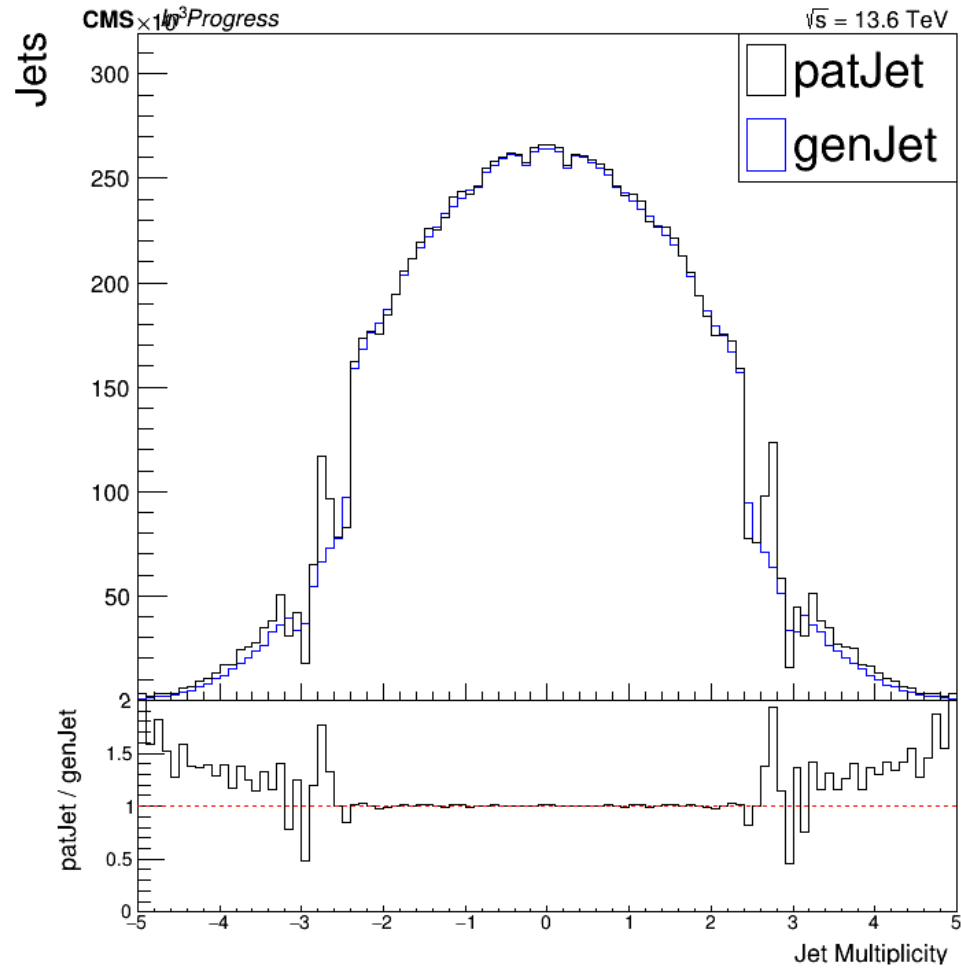
$$Efficiency = \frac{\#(SoftMuonID \ \&\& \ matched \ patMuon)}{\#genMuon}$$



$$FakeRate = \frac{\#(! (matched\ patMuon) \ \&\& \ SoftMuonID)}{\#(! (matched\ patMuon))}$$

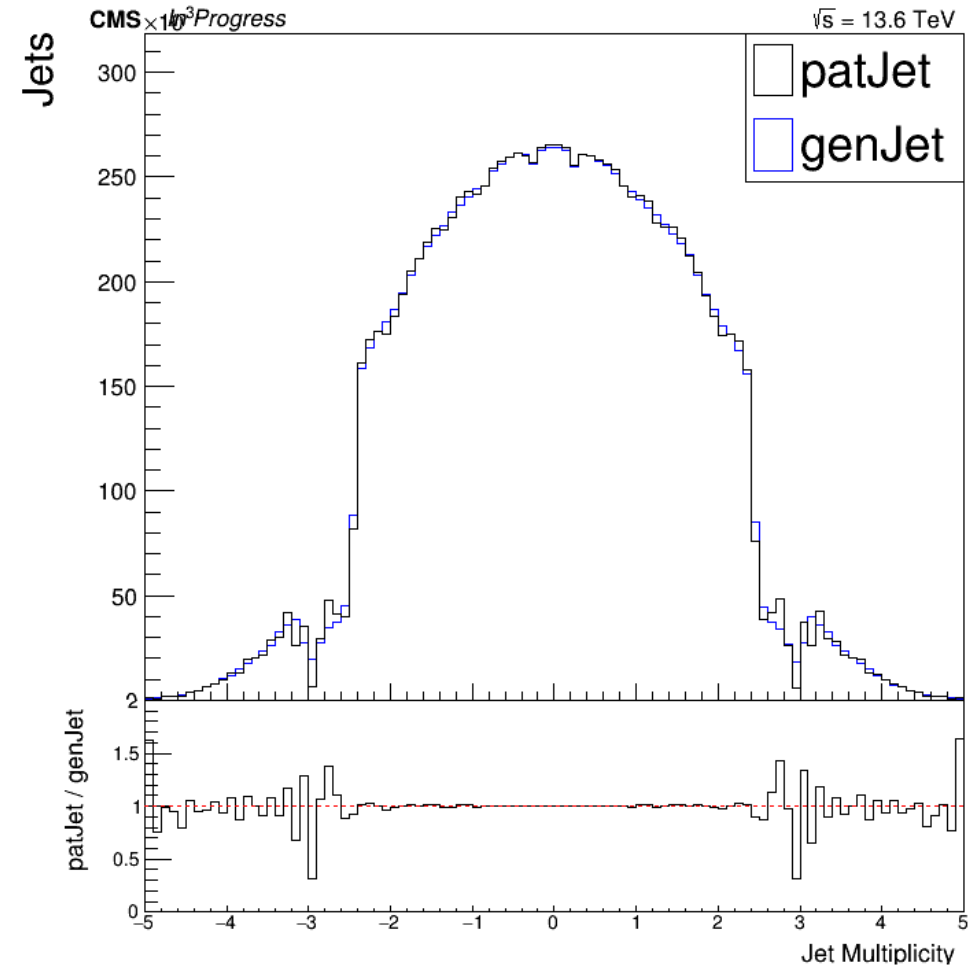


$pT_{Jet} > 30 \text{ GeV}$



#Jets : 12,216,318

$pT_{Jet} > 30 \text{ GeV}$ and $pT_{Jet} > 50 \text{ GeV}$ for $2.5 < |\eta| < 3.0$



#Jets : 11,555,300

[RunIII Nanov12/Nanov15] Data/MC disagreement in $2.5 < |\eta| < 3$

[Edit](#)

Open Issue created 5 months ago by **Anna Benecke**

This issue is there in order to collect material and ideas for the horns in $2.5 < |\eta| < 3$ that are more pronounced in MC than in data, and are present in Nanov12 and Nanov15 for 22-24.

We are having a first kick-off meeting to collect feedback and also to identify person power to work on this on the 18.11.24 [[indico](#)].

▼ [long-term] Where the spikes comes from:

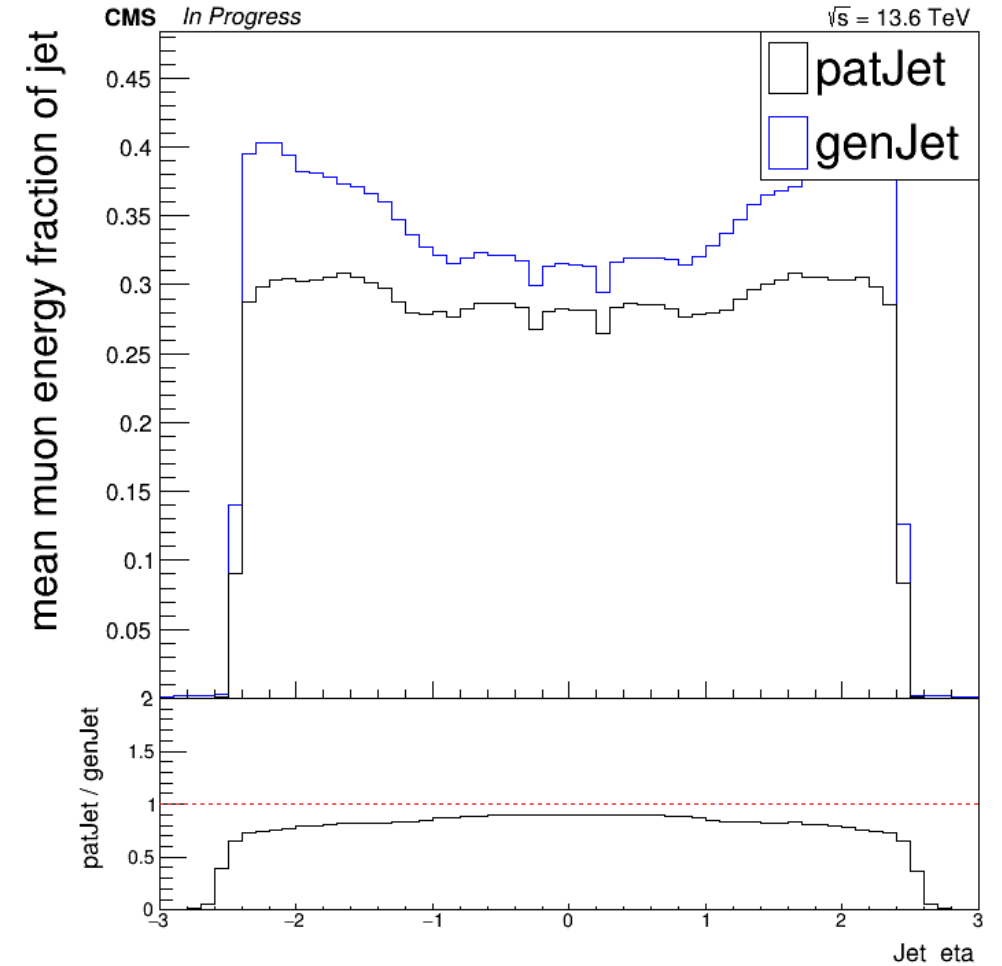
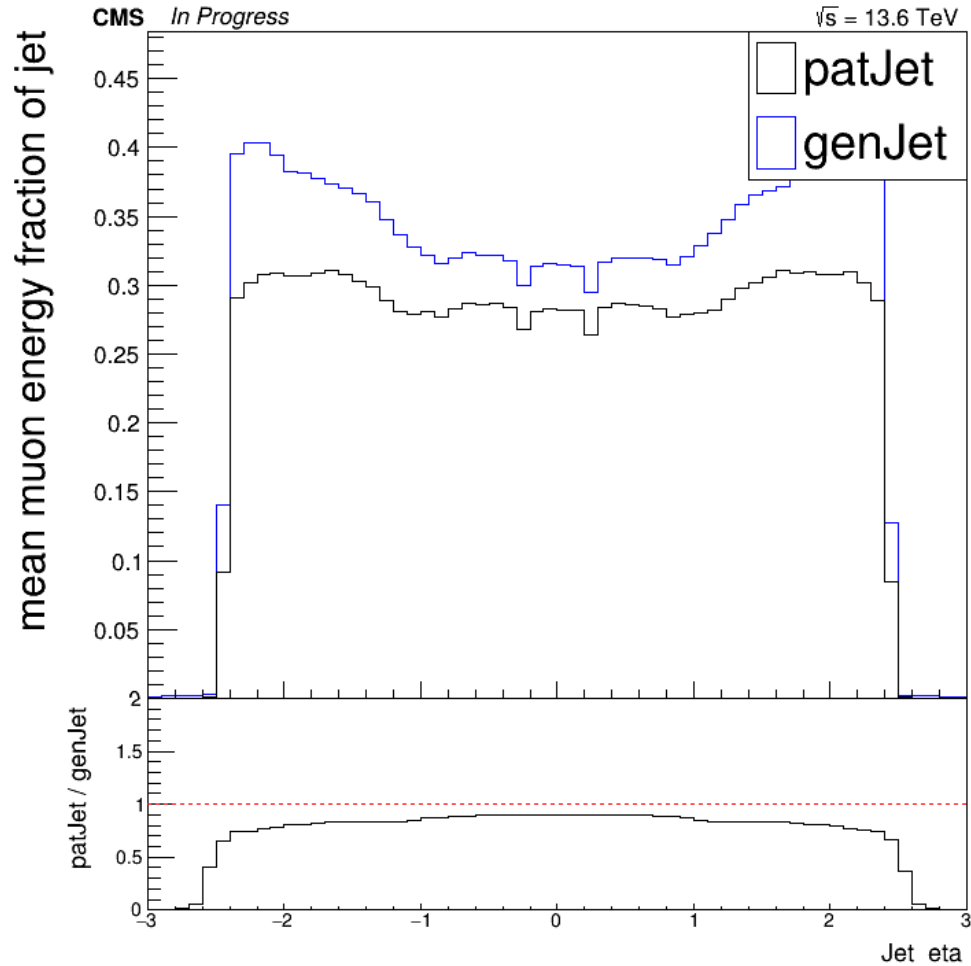
- The HCAL response in this eta region is too low and therefore the spikes are only seen in MC and not in data
- In addition, the HCAL noise thresholds are too low since the IsoTrack method might be impacted by PU/noise
- We plan to fix this with dedicated HE calibrations in 25 data taking
- Neutral hadrons show a more or less constant offset, however, charged hadron fraction (Tracker) shows a slope in p_T [[reference](#)]

<https://gitlab.cern.ch/cms-jetmet/coordination/coordination/-/issues/113>

May 12, 2025.

average muon energy fraction in jet

average muon energy fraction in jet (0 or 1 muon)



※ Object definition in miniAODSIM

(Type “module” : description)

gen level object

reco::GenJet "slimmedGenJets" : reconstructed gen jet with anti-kt $R=0.4$

reco::GenParticle "prunedGenParticles" : slimmed gen particle

pat::PackedGenParticle "packedGenParticles" : more slimmed gen particle than “prunedGenParticles”

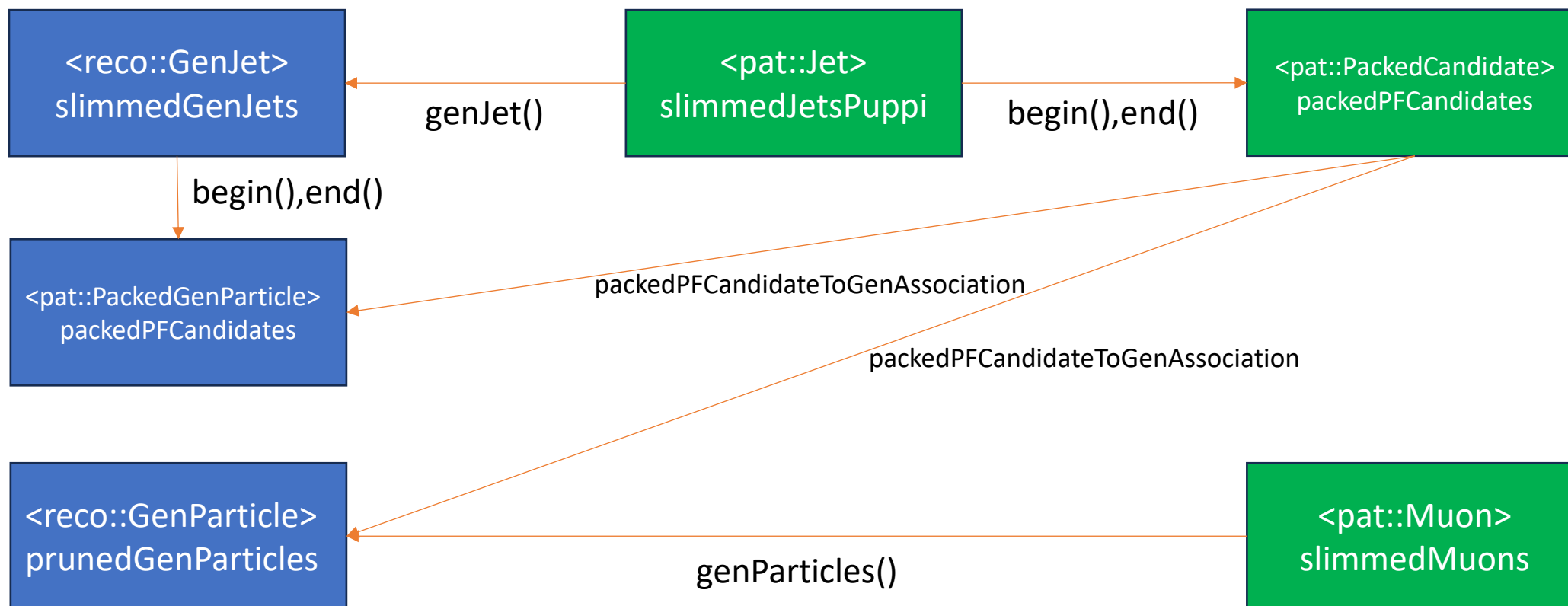
reco level object

pat::Jet "slimmedJetsPuppi" : ak4 PFJets Puppi

pat::Muon "slimmedMuons" : slimmed reco muon

pat::PackedCandidate "packedPFCandidates" : slimmed PFCandidates

miniAOD structure and its reference call methods



NanoAOD also use ak4PFPuppiJets

```
*.....*
*Br   248 :nJet      :
*      | Int_t slimmedJetsPuppi, i.e. ak4 PFJets Puppi with JECs applied, after basic selection (pt > 15)*
*Entries :      728 : Total Size=      3550 bytes File Size =      598 *
*Baskets :        1 : Basket Size=    32000 bytes Compression=    4.99 *
*.....*
*Br   249 :Jet_jetId : UChar_t Jet ID flag:
*      | bit2 is tight, bit3 is tightLepVeto
*Entries :      728 : Total Size=      6644 bytes File Size =     1239 *
*Baskets :        1 : Basket Size=    32000 bytes Compression=    4.87 *
*.....*
*Br   250 :Jet_nConstituents : UChar_t Number of particles in the jet
*Entries :      728 : Total Size=      6658 bytes File Size =     2455 *
*Baskets :        1 : Basket Size=    32000 bytes Compression=    2.46 *
*.....*
```

TWiki > [CMS Web](#) > [JetMET](#) > [JetMETAlgorithmsReconstruction](#) > [JetID](#) > [JetID13p6TeV \(2025-02-10, AnnaBenecke\)](#)

Jet Identification for the 13.6 TeV data

Contacts: [M.Kotsarini](#), [N.Saoulidou](#), [E.Tziaferi](#)

In the following tables, the JetID criteria for AK4PUPPI and AK4CHS jets are listed.

Please note: For AK8 jets, the corresponding (CHS or PUPPI) AK4 jet ID should be used.

Definition

of PFCandidate muon in PFJet

In Gen case also use PF-like definition.

```
namespace reco {
  class PFJet : public Jet {
  public:
    typedef reco::PFCandidatePtr ConstituentTypePtr;
    typedef reco::PFCandidateFwdPtr ConstituentTypeFwdPtr;

    struct Specific {
      Specific()
        : mChargedHadronEnergy(0),
          mNeutralHadronEnergy(0),
          mPhotonEnergy(0),
          mElectronEnergy(0),
          mMuonEnergy(0),
          mHFHadronEnergy(0),
          mHFEMEnergy(0),

          mChargedHadronMultiplicity(0),
          mNeutralHadronMultiplicity(0),
          mPhotonMultiplicity(0),
          mElectronMultiplicity(0),
          mMuonMultiplicity(0),

          // PF-like definitions
      {
        switch (std::abs(candidate->pdgId())) {
        case 11: //electron
          genJetSpecific->m_ChargedEmEnergy += e;
          ++(genJetSpecific->m_ChargedEmMultiplicity);
          break;
        case 13: // muon
          genJetSpecific->m_MuonEnergy += e;
          ++(genJetSpecific->m_MuonMultiplicity);
          break;
        }
      }
    };
  };
}
```

function

muonMultiplicity

Definitions Search

- ▼ DataFormats/JetReco/interface/GenJet.h


```
104 int muonMultiplicity() const { return m_specific.m_MuonMultipl
```
- ▼ DataFormats/JetReco/interface/JPTJet.h


```
100 int muonMultiplicity() const {
```
- ▼ DataFormats/JetReco/interface/PFJet.h


```
132 int muonMultiplicity() const { return m_specific.mMuonMultipli
```
- ▼ DataFormats/PatCandidates/interface/Jet.h


```
385 int muonMultiplicity() const;
```
- ▼ DataFormats/Scouting/interface/Run3ScoutingPFJet.h


```
99 int muonMultiplicity() const { return muonMultiplicity_; }
```
- ▼ DataFormats/Scouting/interface/ScoutingPFJet.h


```
100 int muonMultiplicity() const { return muonMultiplicity_; }
```