Quark gluon tag in HL-LHC Constituent-Based Tagger

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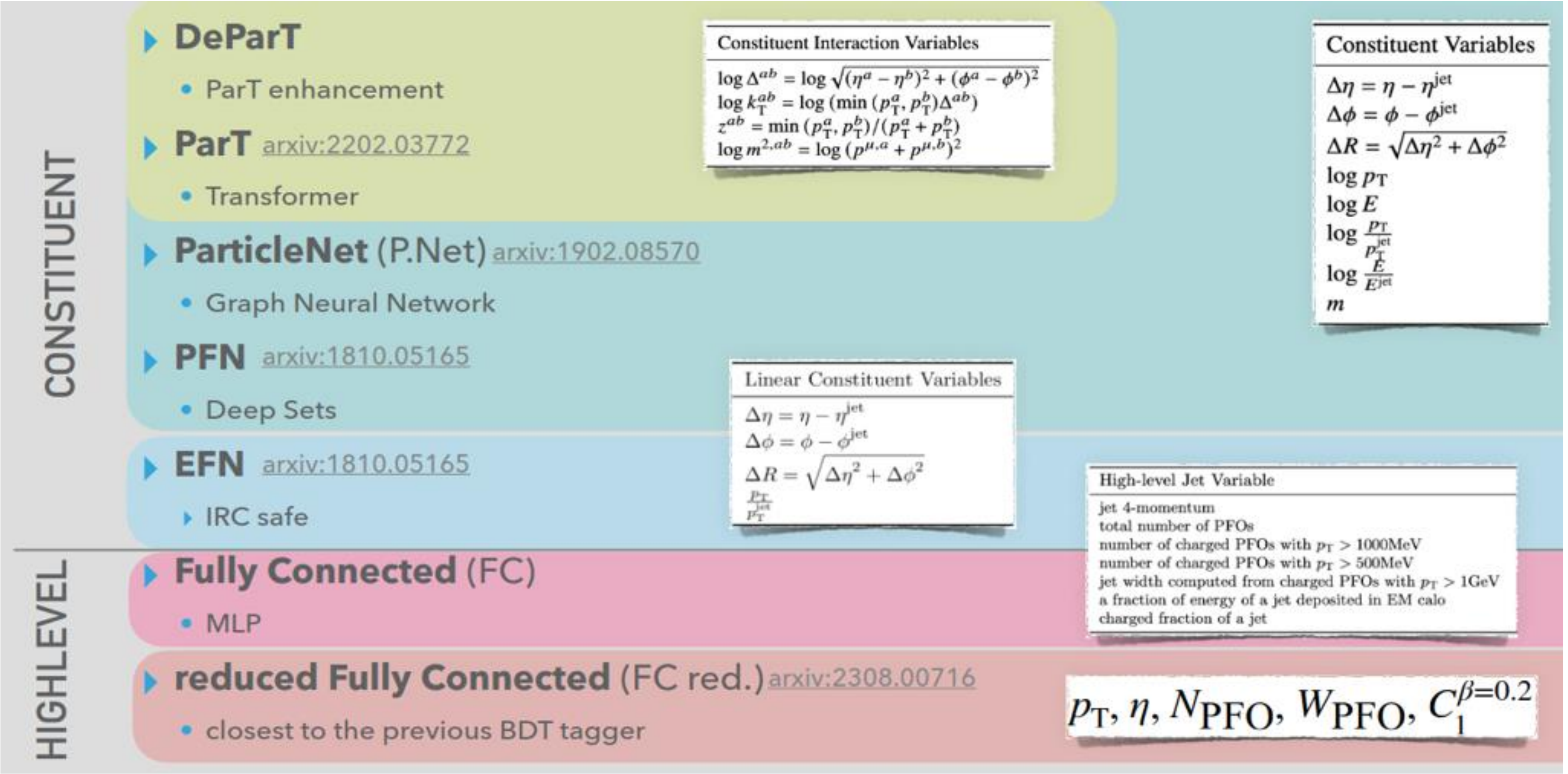
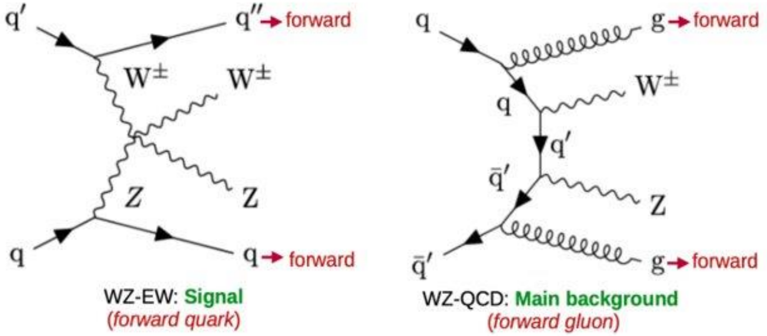
Jet tagging and scale factor meeting

cnrs LAPP Laboratoire d'Annecy-le-Vieux de Physique des Particules anr agence nationale de la recherche ATRAPP

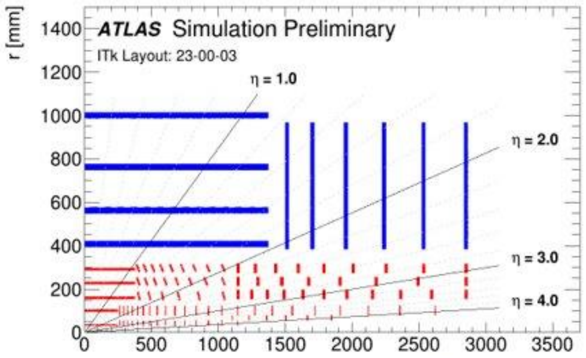
Outlook: quark gluon tag for HL-LHC

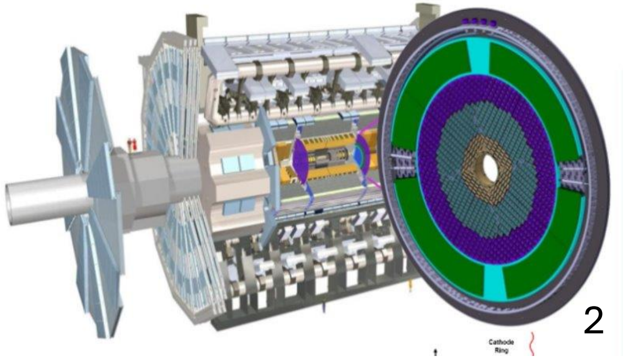
Constituents taggers :





Detector upgrades:





JET Definition and Samples

- **Jets** are reconstructed with the anti-kt with R = 0.4. PFlow jets no Calibrated
- **Cuts**: Only the two jets with the highest pT are keep it. pT > 20 GeV

- PFOs are a collection of **topo-clusters** formed from energy deposits in calorimeter cells and an algorithmic combination of charged-particle **tracks** with those topo-clusters (PFOs as constituents)
- Using official JETM2 production

- **Central Region**: Jets Pt > 20 GeV, Pt < 2.5TeV, |Jets y| < 2.5
- **Forward Region**: Jets Pt > 20 GeV, Pt < 500GeV, |Jets y| > 2.5 and |Jets y| < 4.0
- For training, only jets pt is flatten

- Samples used for training/validation/testing:
  - Dijets, VBF, ttbar(allhad).
  - **PU 0**: Jets for training: 8.6M central, 4M forward
  - **PU 60**: Only evaluation

Taggers from Run 2

Constituent-based

DeParT and ParT

Constituent Interaction Variables
$\log \Delta = \log \sqrt{(\eta^a - \eta^b)^2 + (\phi^a - \phi^b)^2}$
$\log k_\mathrm{T} = \log(\min(p_\mathrm{T}^a, p_\mathrm{T}^b)\Delta)$
$z = \min(p_\mathrm{T}^a, p_\mathrm{T}^b)/(p_\mathrm{T}^a + p_\mathrm{T}^b)$
$\log m^2 = \log(p^{\mu,a} + p^{\mu,b})^2$

Constituent Variables
$\Delta\eta = \eta - \eta^\mathrm{jet}$
$\Delta\phi = \phi - \phi^\mathrm{jet}$
$\Delta R = \sqrt{\Delta\eta^2 + \Delta\phi^2}$
$\log p_\mathrm{T}$
$\log E$
$\log \frac{p_\mathrm{T}}{p_\mathrm{T}^\mathrm{jet}}$
$\log \frac{E}{E^\mathrm{jet}}$
m

Highlevel variables

FC Network

Highway Network

EMFrac	+ Jet pT
Jet width	
TrackWidthPt1000	
NumChargedPFOWidthPt1000	
chf	

FC Crafted*

$$N_\mathrm{PF0} = \sum_{\mathrm{PFO}\in\mathrm{jet}}$$

+ Jet pT

$$C1^{\beta=0.2} = \frac{\sum_{i,j\in jet}^{i\neq j} p_{T,i} p_{T,j} (\Delta R_{i,j})^{\beta=0.2}}{(\sum_{i,j\in jet} p_T^{PFO})^2}$$

$$w^{PFO} = \frac{\sum_{\mathrm{PFO}\in\mathrm{jet}} p_T^{PFO} \cdot \Delta R_{PFO,jet}}{\sum_{\mathrm{PFO}\in\mathrm{jet}} p_T^{PFO}}$$

*FC crafted mimic Run 2 BDT tagger

Constituents defined by jets_y for HL-LHC

Constituent-based

DeParT and ParT

Constituent Interaction Variables
$\log\Delta = \log\sqrt{(y^a - y^b)^2 + (\phi^a - \phi^b)^2}$
$\log k_T = \log\left(\min\left(p_T^a, p_T^b\right)\Delta\right)$
$z = \min\left(p_T^a, p_T^b\right)/(p_T^a + p_T^b)$
$\log m^2 = \log\left(p^{\mu,a} + p^{\mu,b}\right)^2$

Constituent Variables
$\Delta y = y - y_{\text{jet}}$
$\Delta\phi = \phi - \phi_{\text{jet}}$
$\Delta R = \sqrt{\Delta y^2 + \Delta\phi^2}$
$\log p_T$
$\log E$
$\log\frac{p_T}{p_{T,\text{jet}}}$
$\log\frac{E}{E_{\text{jet}}}$
m

Highlevel variables

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*FC crafted mimic Run 2 BDT tagger

Evaluation. Central region.

Bins pT: (20, 60, 100, 150,500, 1000,2500) [GeV]

- Central region: jets_y < 2.5. Evaluation in jets_y: [0, 0.5 ,1.0, 1.5, 2.0, 2.5]

- For the central region at low pT , we don't see much improvement when using transform-based (low-level variable) taggers compared to NN-based (high-level variable) taggers.

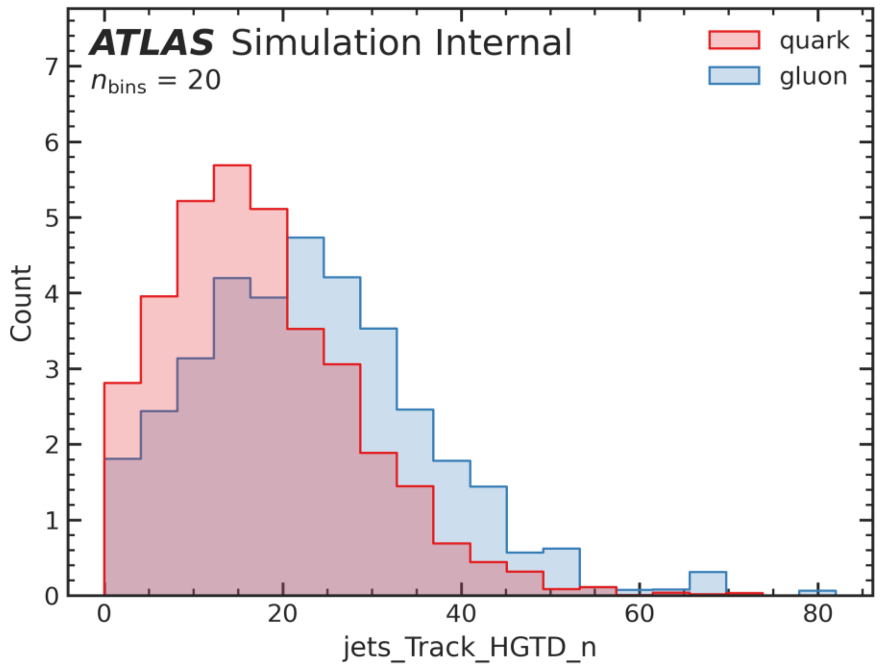
HGTD new variable: jets_Track_HGDT_n

```cpp
const std::vector<float>& times = track->auxdataConst< std::vector<float> >("HGTD_cluster_time");
for (float value : times) {
  if (value != -1.0f) {
    track_HGTD_num++;
  }
}

}
else {

  track_cluster_time_0.push_back(-2);
  track_cluster_time_1.push_back(-2);
  track_cluster_time_2.push_back(-2);
  track_cluster_time_3.push_back(-2);
}
```

HGTD has 4 clusters



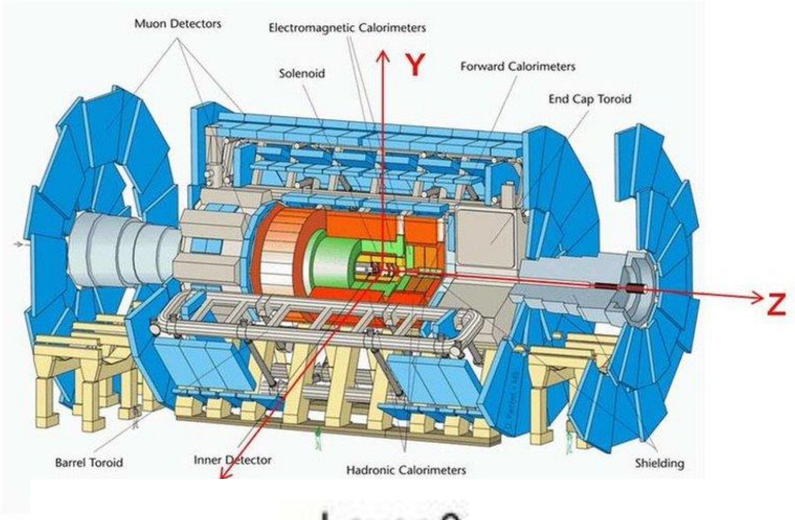
d	1
u	2
s	3
c	4
b	5
t	6
g	21

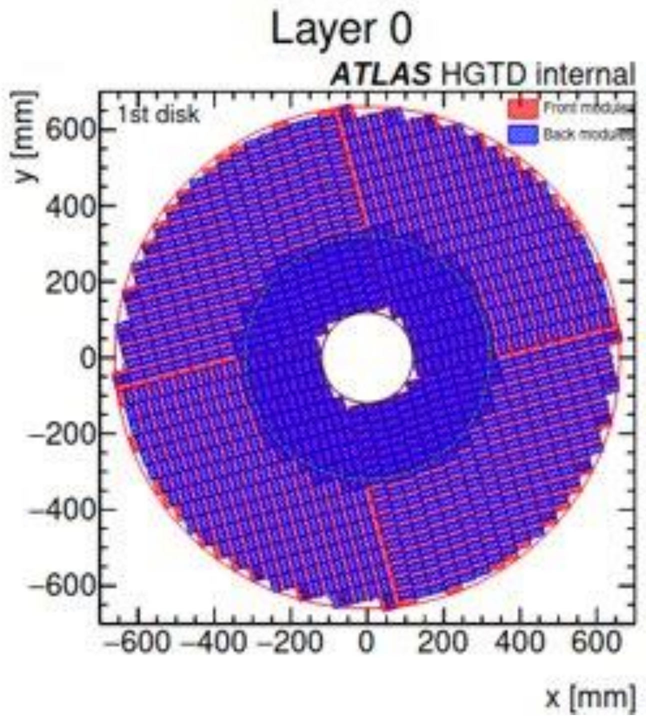
```
jets_PartonTruthLabelID { 3, 1 }
jets_Track_HGTD_cluster_time { {}, {}, {}, {}, {}, {}, {}, {}, {}, {}, {}, {}, {}, {}, {}, {}, { -0.0868788f, -1.00000f, -1.00
000f, -1.00000f }, { -0.0626068f, -0.133852f, -1.00000f, -1.00000f }, { -0.0399399f, -0.131161f, -0.0712185f, -0.201877f }, {
-1.00000f, -1.00000f, -1.00000f, -1.00000f }, { -1.00000f, -0.0767756f, -0.0902195f, -1.00000f }, { -0.104699f, -1.00000f, -0.
0932989f, -0.0751143f } }
jets_Track_HGTD_cluster_truth_class { {}, {}, {}, {}, {}, {}, {}, {}, {}, {}, {}, {}, {}, {}, {}, {}, { 4, -1, -1, -1 }, { 1,
1, -1, -1 }, { 1, 1, 1, 1 }, { -1, -1, -1, -1 }, { -1, 1, 1, -1 }, { 1, -1, 1, 1 } }
jets_Track_n { 16, 6 }
```

HGTD low level variable

$$\log \Delta_{x,y}^{HGTD} = \log \sqrt{(x^a - x^b)^2 + (y^a - y^b)^2}$$

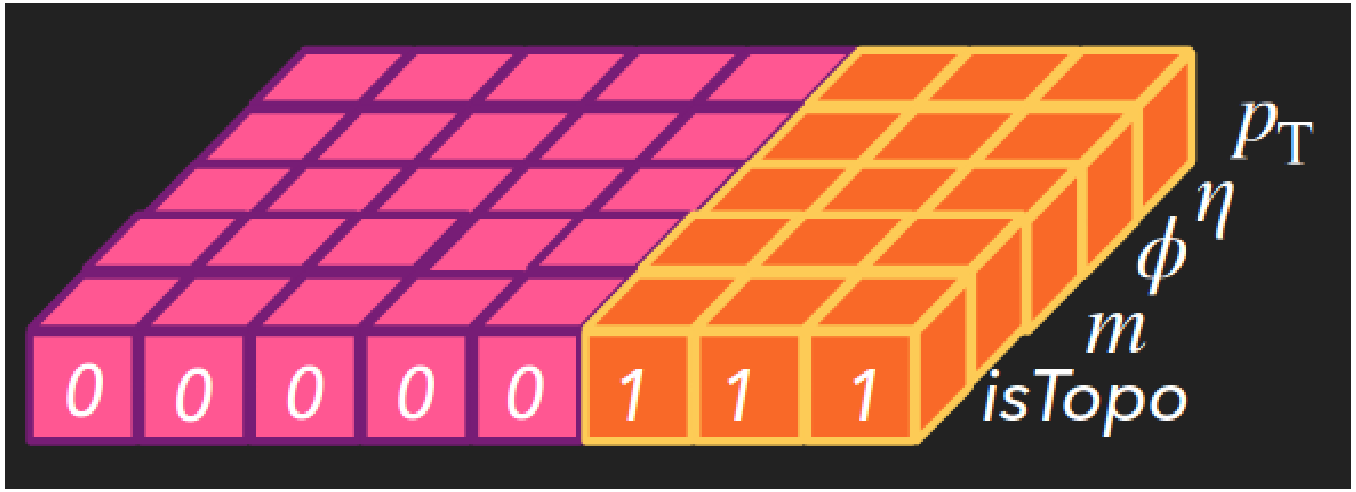
InDetTrackParticlesAuxDyn.HGTD_cluster_merged
InDetTrackParticlesAuxDyn.HGTD_cluster_raw_time
InDetTrackParticlesAuxDyn.HGTD_cluster_shadowed
InDetTrackParticlesAuxDyn.HGTD_cluster_time
InDetTrackParticlesAuxDyn.HGTD_cluster_truth_class
InDetTrackParticlesAuxDyn.HGTD_extension_chi2
InDetTrackParticlesAuxDyn.HGTD_extrap_x
InDetTrackParticlesAuxDyn.HGTD_extrap_y
InDetTrackParticlesAuxDyn.HGTD_has_extension
InDetTrackParticlesAuxDyn.HGTD_primary_expected





Input variables

- **PFOs are always used as input.**
- **For the forward region**, Topo Towers and Track information are included, along with the new HGTD variable.
- **For the central region**, Tracks are also added.
- These are concatenated with the PFOs, and an additional variable (isTopo or isTrack, depending on the object) is introduced. This approach follows the implementation by Samuel: slides



Constituent Interaction Variables
$\log \Delta = \log \sqrt{(y^a - y^b)^2 + (\phi^a - \phi^b)^2}$
$\log \Delta_{x,y}^{HGTD} = log\sqrt{(x^a - x^b)^2 + (y^a - y^b)^2}$
$\log k_T = \log\left(\min\left(p_T^a, p_T^b\right)\Delta\right)$
$z = \min\left(p_T^a, p_T^b\right) / (p_T^a + p_T^b)$
$\log m^2 = \log\left(p^{\mu,a} + p^{\mu,b}\right)^2$

Constituent Variables
$\Delta y = y - y_{\text{jet}}$
$\Delta\phi = \phi - \phi_{\text{jet}}$
$\Delta\phi^{HGTD} = \phi^{HGTD} - \phi_{\text{jet}}$
$\Delta R = \sqrt{\Delta y^2 + \Delta\phi^2}$
$\log p_T$
$\log E$
$\log \frac{p_T}{p_{T,\text{jet}}}$
$\log \frac{E}{E_{\text{jet}}}$
m

Evaluation. Forward region.

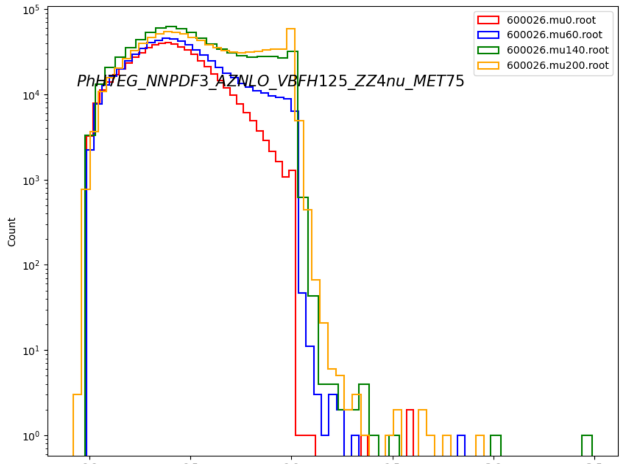
Bins split PT: (20, 60, 100,150, 500) [GeV]

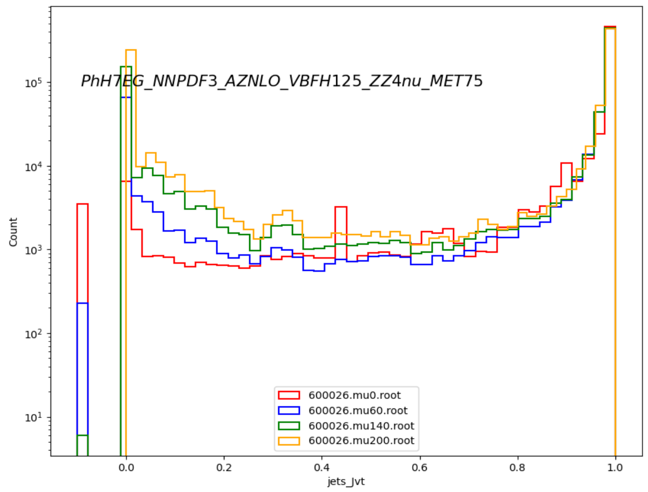
- Forward region: jets_y > 2.5. Evaluation in jets_y: [2.5, 3.0, 3.5, 4.0]

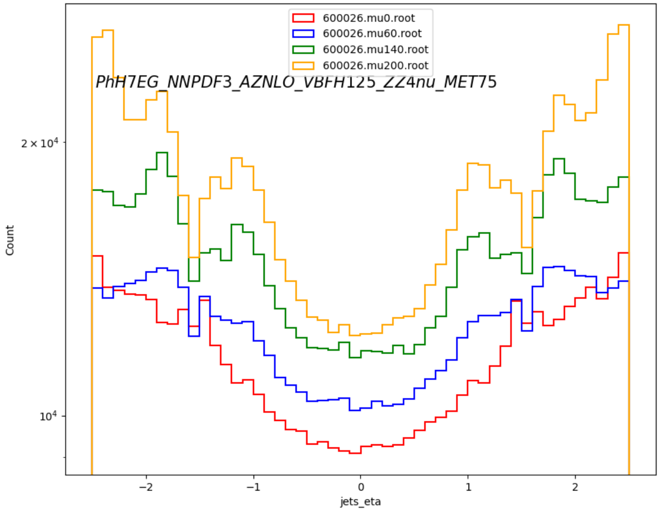
Pile-up studies

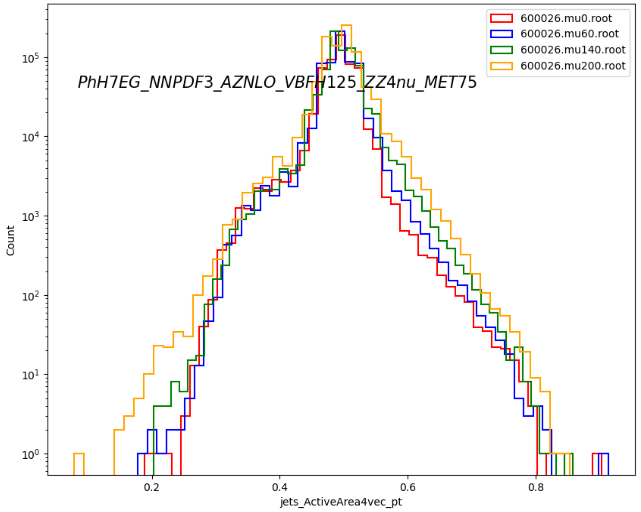
Test mu60

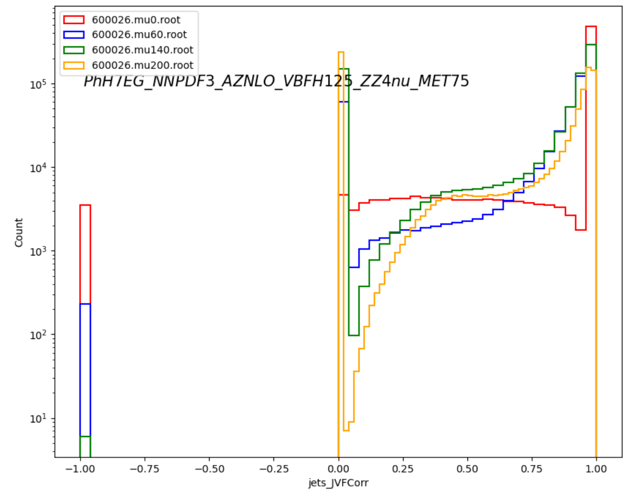
New input variables? Central region

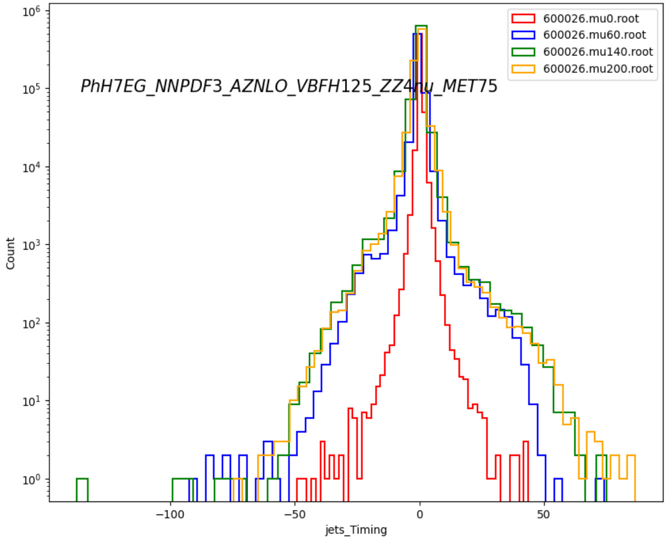




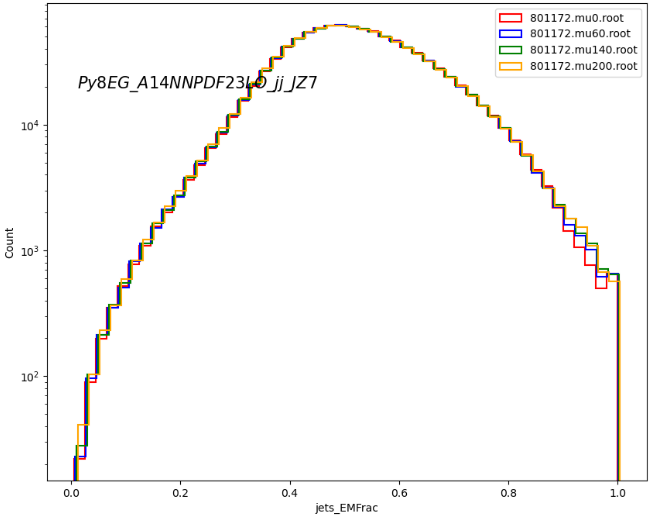


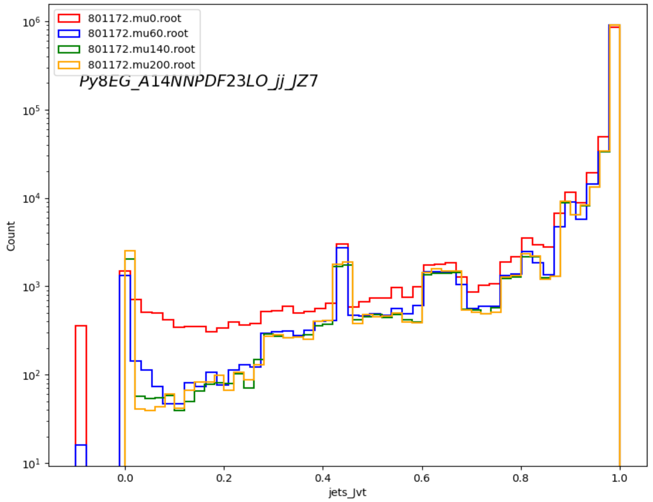


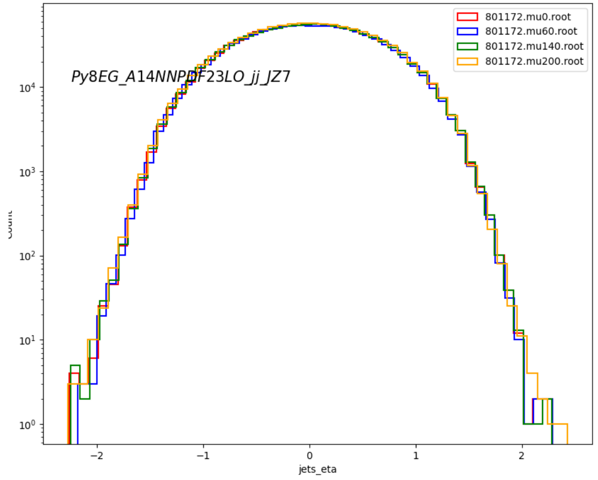


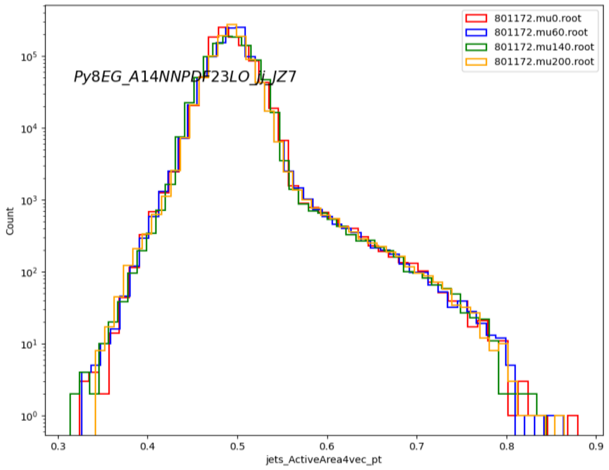


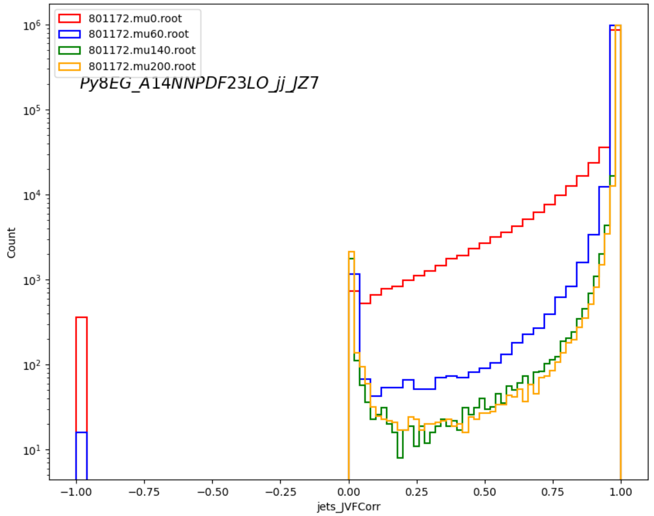
New input variables? Central region

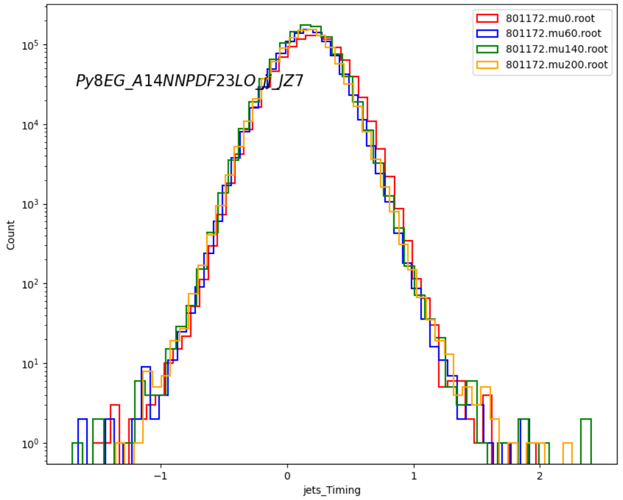




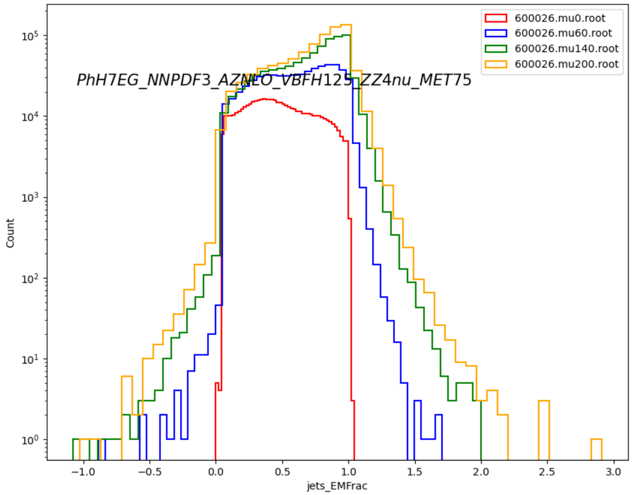


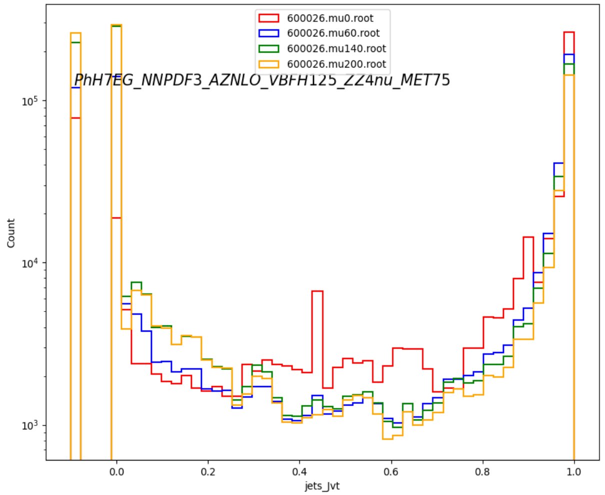


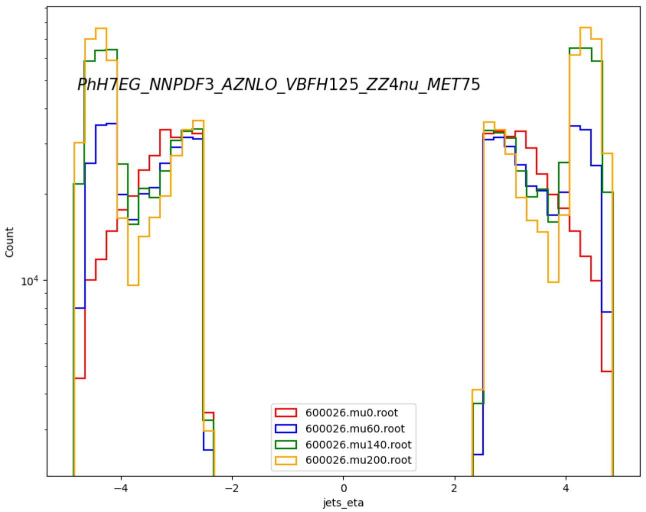


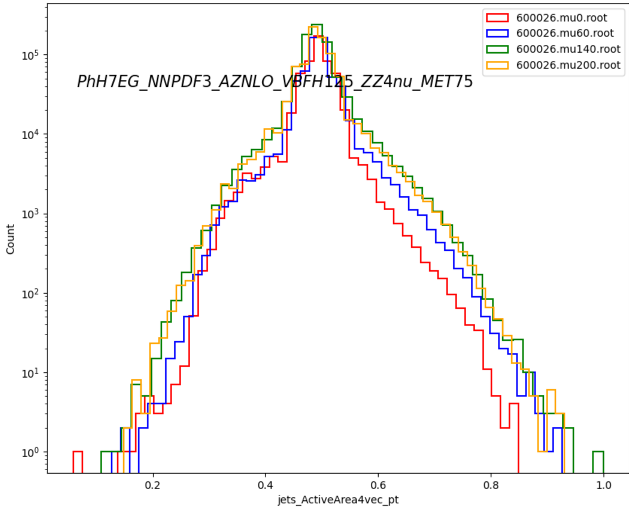


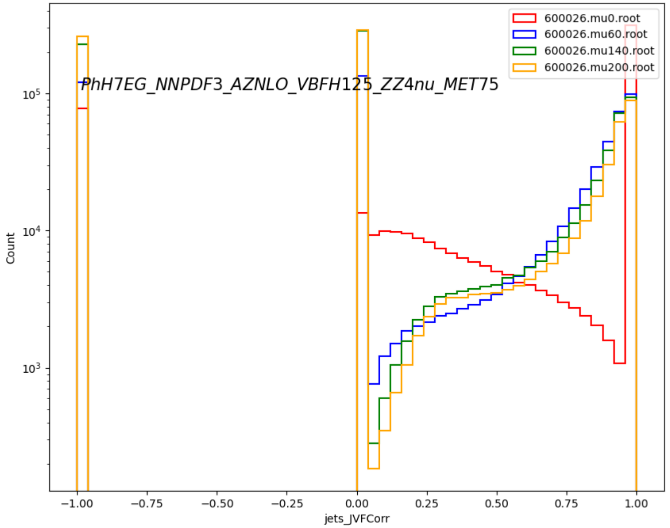
New input variables? Forward region

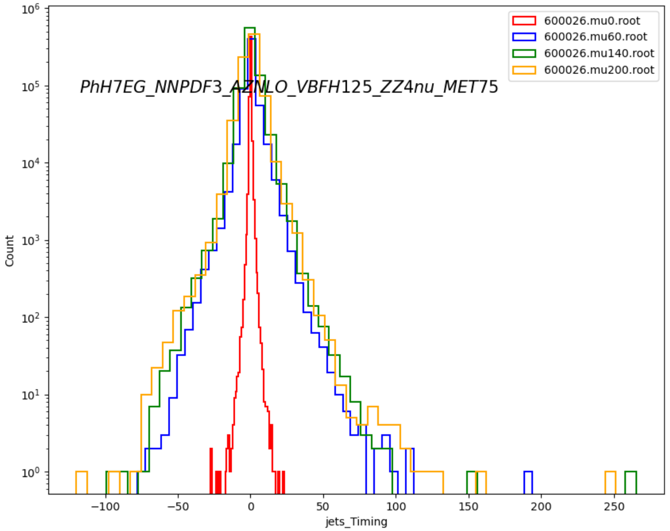




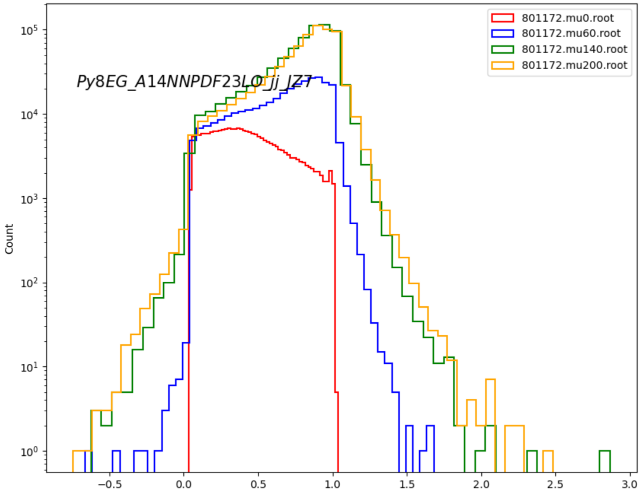


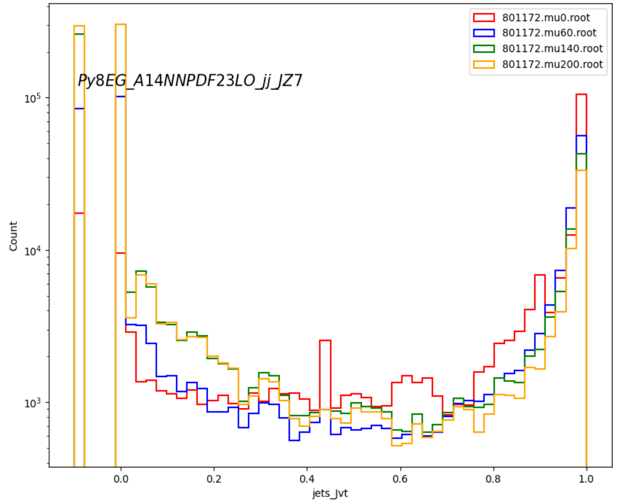


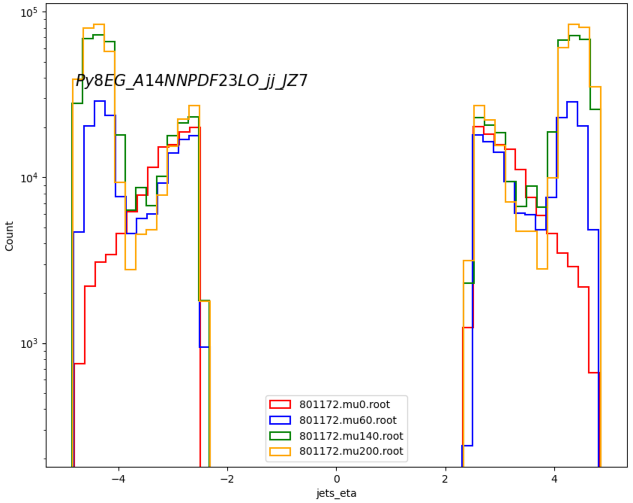


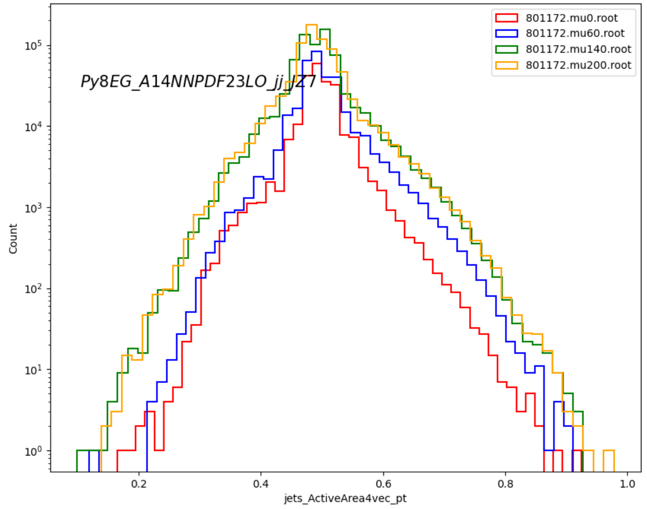


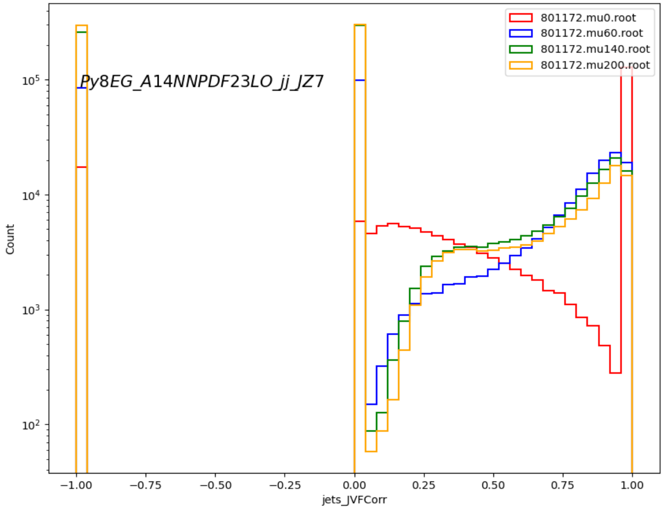
New input variables? Forward region

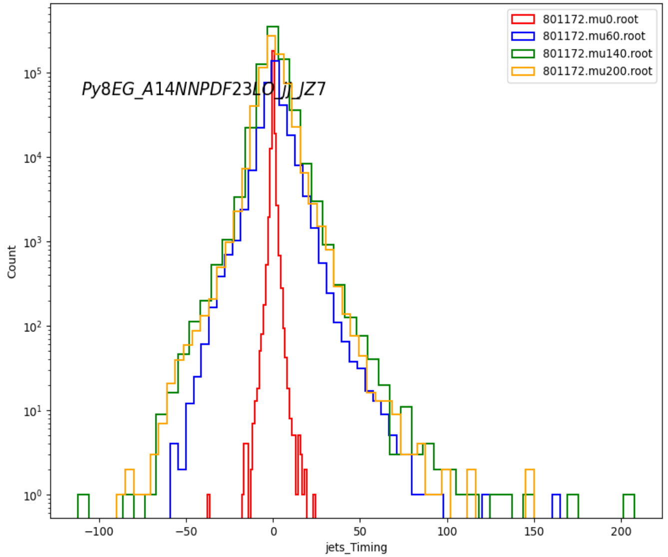




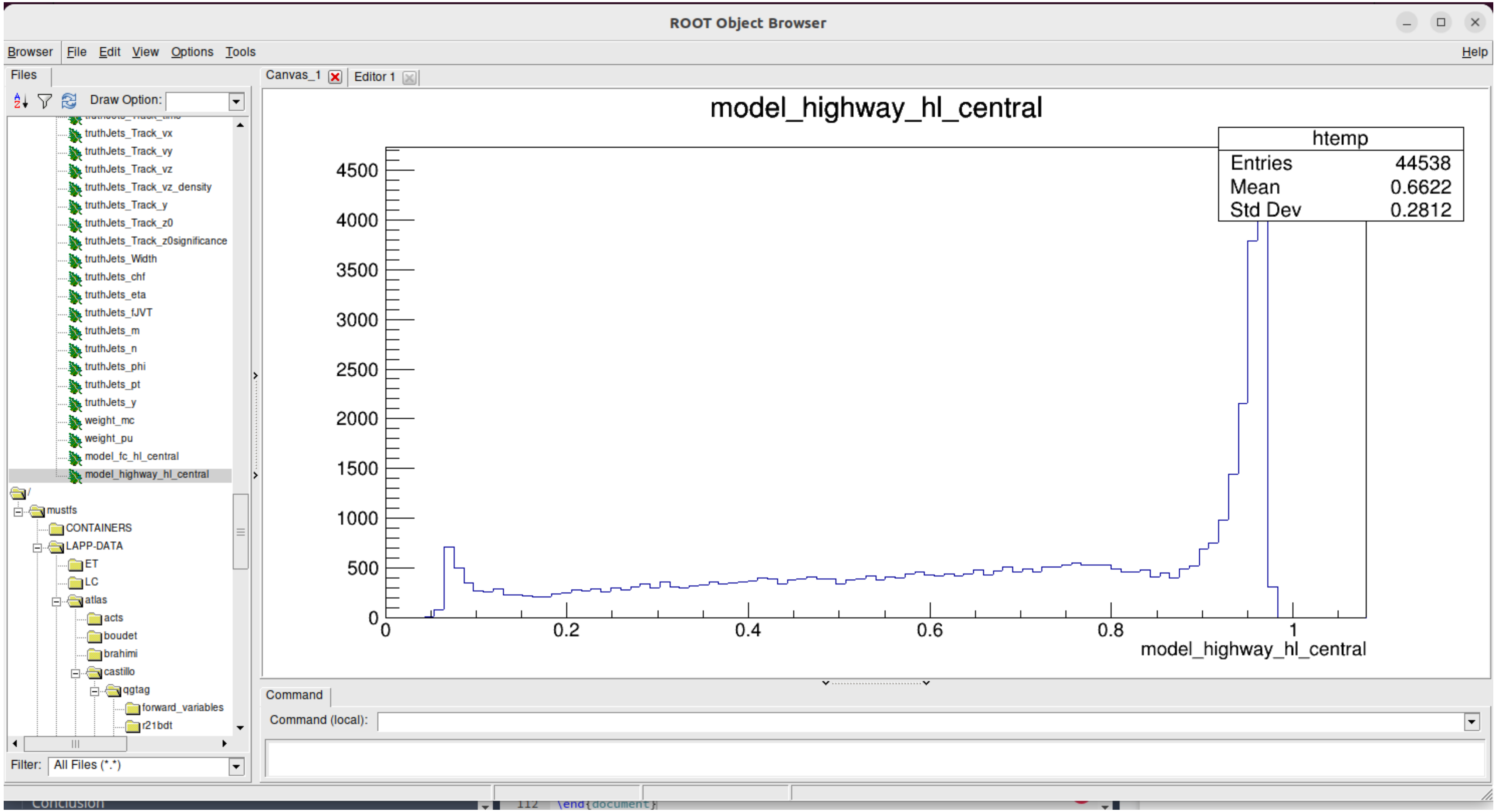








Scores in root files



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