

HLT Efficiency measurement in 5 (2 b-tagged) jet

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Motivation

- Measuring HLT efficiency on 5 (2 b-tagged) jet HLT path for Run3 data taking and analysis

Strategy

- Target HLT path
 - HLT_PFHT400_FivePFJet_100_100_60_30_30_DoublePFBTagDeepJet_4p5_v2
 - HLT_PFHT400_FivePFJet_100_100_60_30_30_DoublePFBTagDeepCSV_4p5_v9
- Reference HLT path:
 - HLT_IsoMu24 ([CMSOMS](#))
- Target Sample
 - (Single)Muon Run2022{C,D,E,F} (PromptNanoAODv10) ([DAS](#))
 - With Cert_Collisions2022_355100_360491_Golden.json ([wget](#))
- Selections from baseline in $T' \rightarrow tH(bb)$ hadronic decay analysis ([AN](#))
 - HLT
 - $\text{nSel40Jets} \geq 6 \ \&\& \ \text{nSel80Jets} \geq 3 \ \&\& \ \text{nSelbJets (DeepJetM, DeepCSVM)} \geq *3$
 - $\text{nSel}\{X\}(b)\text{Jet}$: number of selected jet with $p_T > \{X = (30)40, 80\}$, $|\eta| < (2.5)4.5$, TightID
 - Working point between loose - medium offline
 - $\text{Jet1} > 170 \text{ GeV} \ \&\& \ \text{Jet2} > 130 \text{ GeV} \ \&\& \ \text{Jet3} > 80 \text{ GeV}$
 - $\text{HT} > 500 \text{ GeV}$
 - Minimum $\text{Chi2} < 15$
 - Invariant mass of 2nd Top $> 250 \text{ GeV}$
 - $\text{H_mass from Chi2} > 100 \text{ GeV}$

*Analysis is presented
in 3 different regions:
2M1L, 3M, 3T b-tagged jets

Measuring HLT Efficiency: Signal phase space

Trigger efficiency in data

- Efficiency =
$$\frac{\text{Events passing offline selection and reference HLT path AND signal HLT path}}{\text{Events passing offline selection and reference HLT path}}$$
- In orthogonal dataset: (Single)Muon

Efficiency

- (Single)Muon Run2022{C,D,E,F} dataset (512602923 events in total)
- With Medium working point used for 2018UL:
 - DeepJet M (> 0.2783), DeepCSV M (> 0.4168) ([twiki](#))
- Target HLT path
 - HLT_PFHT400_FivePFJet_100_100_60_30_30_DoublePFBTagDeepJet_4p5_v2
 - HLT_PFHT400_FivePFJet_100_100_60_30_30_DoublePFBTagDeepCSV_4p5_v9
- Reference HLT path
 - HLT_IsoMu24

HLT Path	DeepJet	DeepCSV
With Target Path	594	303 (RunF=3)
Only IsoMu Path	675	517 (RunF=195)
Efficiency (%)	88.0	93.4 (w/o RunF)

Removed
in RunF

Measuring HLT Efficiency: Signal phase space

Trigger efficiency in data

- Efficiency =
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Efficiency

- (Single)Muon Run2022{C,D,E,F} dataset (512602923 events in total)
- With Medium working point used for 2018UL:
 - DeepJet M (> 0.2783), DeepCSV M (> 0.4168) ([twiki](#))
- Split into meaningful era
 - Before TS1: Run < 359602 (split in RunE)
 - after TS1, pre HCAL calibration: 359602 < Run < RunF
 - after TS1, post HCAL calibration: RunF

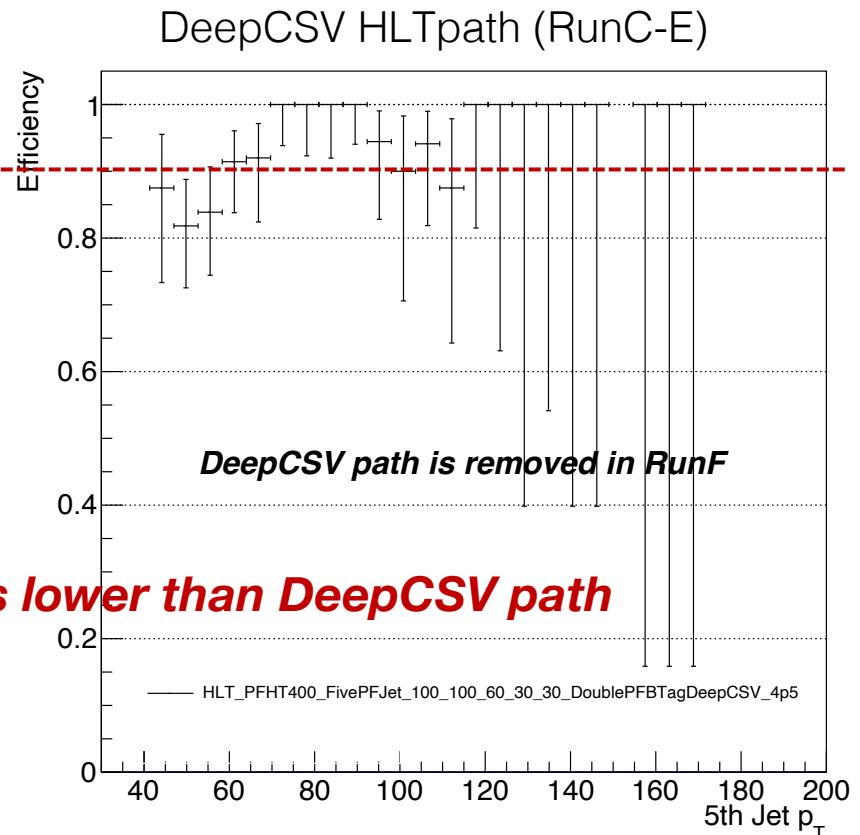
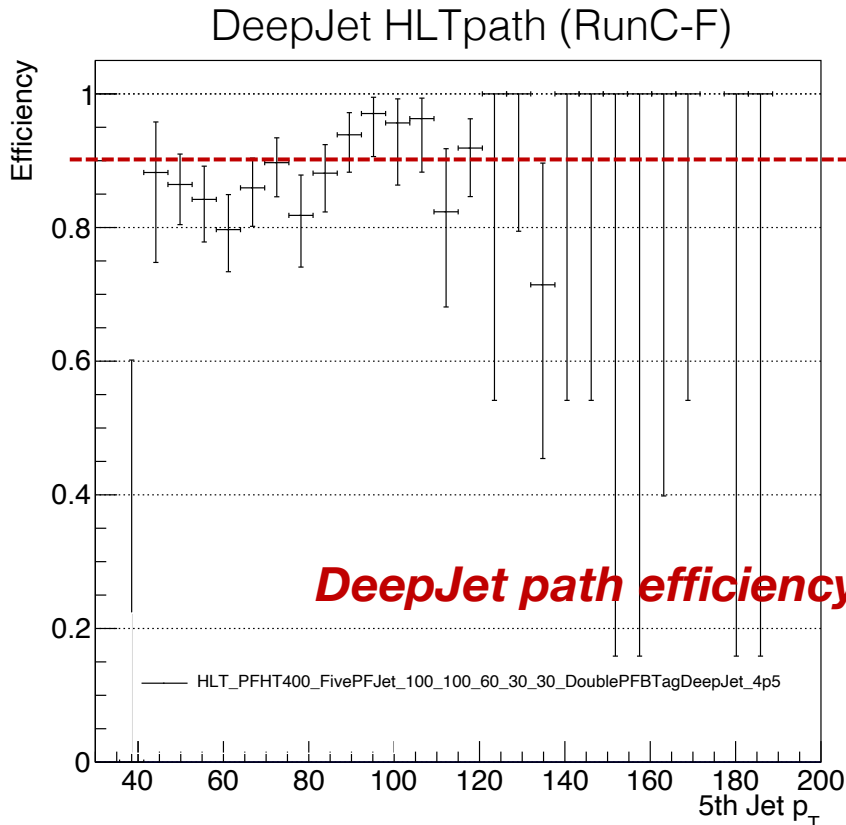
	Before TS1		after TS1, pre HCAL		after TS1, post HCAL	
HLT Path	DeepJet	DeepCSV	DeepJet	DeepCSV	DeepJet	DeepCSV
w/ Target Path	244	184	147	116	203	3
w/o Target Path	279	196	167	126	229	195
Efficiency (%)	87.4	93.9	88.0	92.1	88.6	1.54

Removed in RunF ↗

Turn-on Curve

TEfficiency on 5th leading jet

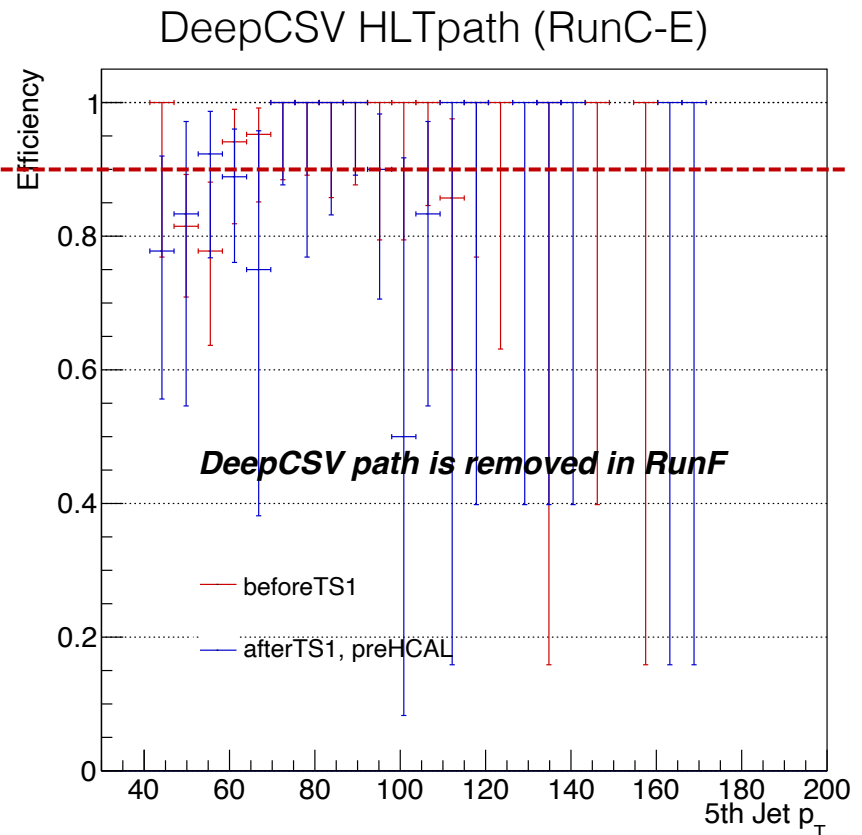
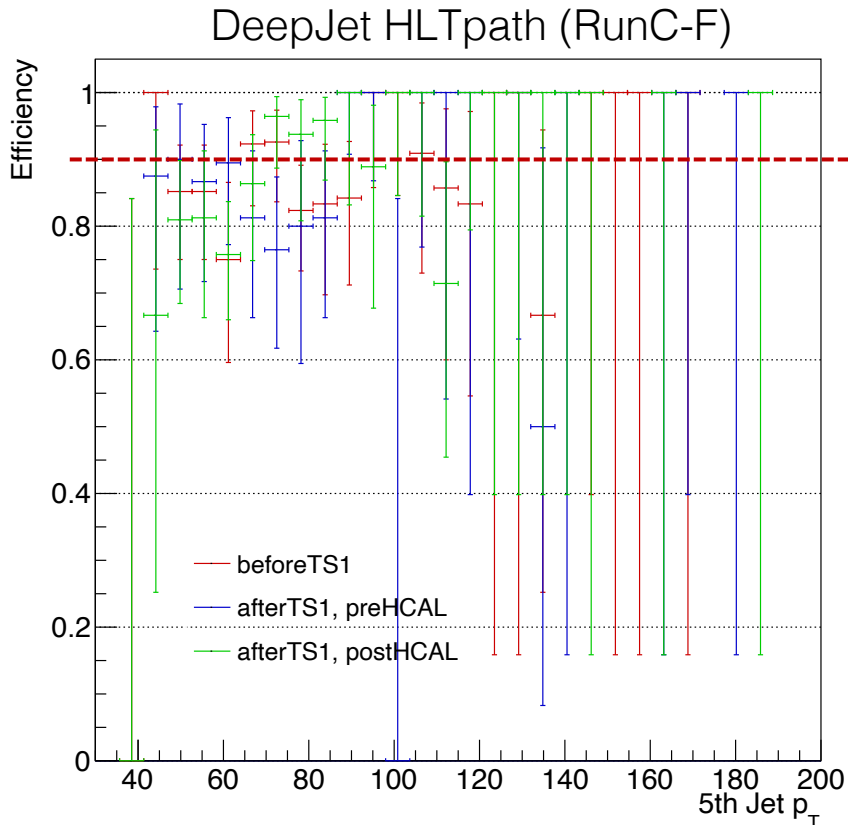
- With (Single)Muon Run2022{C,D,E,F} dataset (512602923 events in total)
- Target path:
 - HLT_PFHT400_FivePFJet_100_100_60_30_30_DoublePFBTagDeepJet_4p5_v2
 - HLT_PFHT400_FivePFJet_100_100_60_30_30_DoublePFBTagDeepCSV_4p5_v9
- HLT Efficiencies for all dataset



Turn-on Curve

TEfficiency on 5th leading jet

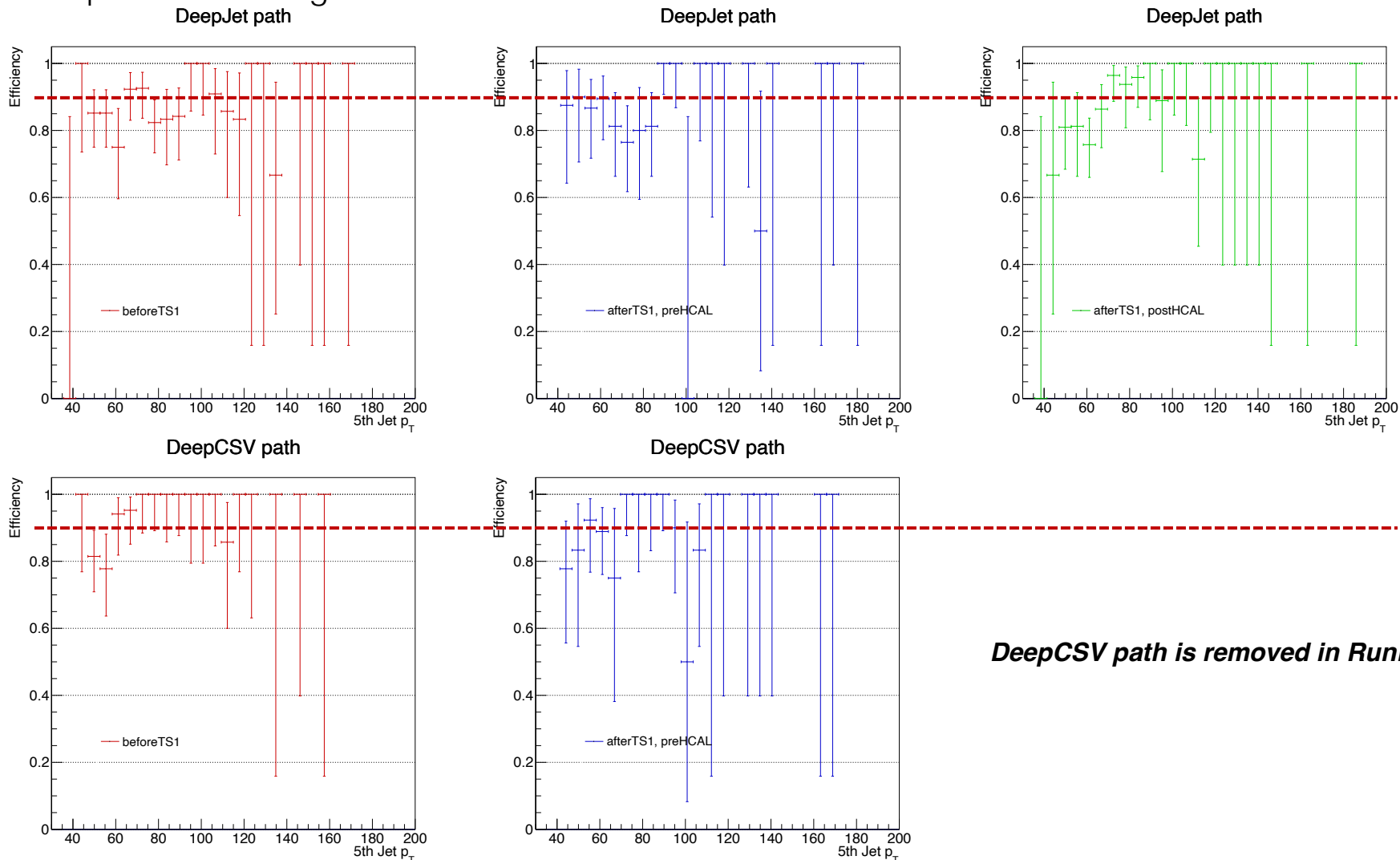
- With (Single)Muon Run2022{C,D,E,F} dataset (512602923 events in total)
- Target path:
 - HLT_PFHT400_FivePFJet_100_100_60_30_30_DoublePFBTagDeepJet_4p5_v2
 - HLT_PFHT400_FivePFJet_100_100_60_30_30_DoublePFBTagDeepCSV_4p5_v9
- Split into meaningful era



Turn-on Curve

TEfficiency on 5th leading jet

- Split into meaningful era



Measuring HLT Efficiency: QCD enriched

Efficiency

- With Looser selection

- HLT

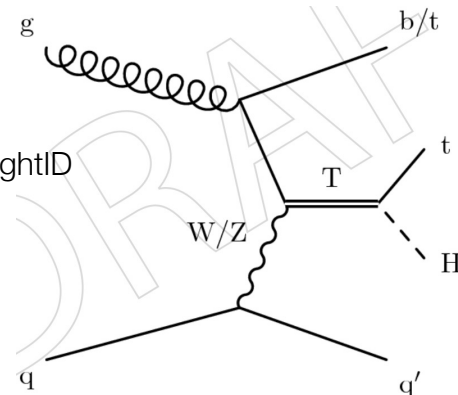
- $\text{nSel40Jets} \geq 6 \ \&\& \ \text{nSel80Jets} \geq 3 \ \&\& \ \text{nSelbJets (DeepJetM, DeepCSVM)} \geq 3$
 - $\text{nSel}\{X\}(\text{b})\text{Jet}$: number of selected jet with $p_T > \{X = (30)40, 80\}$, $|\eta| < (2.5)4.5$, TightID
 - Working point between loose - medium offline
- $\text{Jet1} > 170 \text{ GeV} \ \&\& \ \text{Jet2} > 130 \text{ GeV} \ \&\& \ \text{Jet3} > 80 \text{ GeV}$
- $\text{HT} > 500 \text{ GeV}$

— Minimum $\text{Chi2} < 15$

— Invariant mass of $2^{\text{nd}} \text{ Top} > 250 \text{ GeV}$

— $H_{\text{mass from Chi2}} > 100 \text{ GeV}$

→ Will have more QCD



- HLT Efficiencies for all dataset

HLT Path	DeepJet	DeepCSV
With Target Path	4917	2025 (RunF=27)
Only IsoMu Path	4535	3499 (RunF=1343)
Efficiency (%)	84.6	92.7 (w/o RunF)

- Split into meaningful era

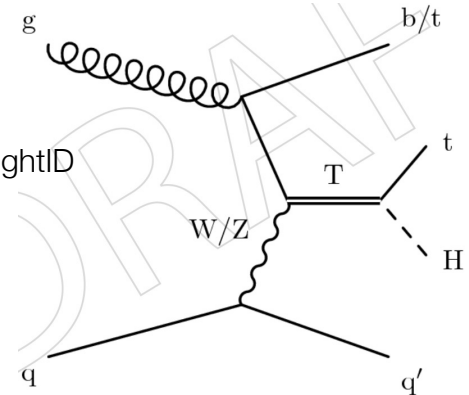
	Before TS1		after TS1, pre HCAL		after TS1, post HCAL	
HLT Path	DeepJet	DeepCSV	DeepJet	DeepCSV	DeepJet	DeepCSV
w/ Target Path	1348	1142	1030	856	1457	27
w/o Target Path	1659	1228	1177	928	1699	1343
Efficiency (%)	81.2	93.0	87.5	92.2	85.8	2.0

Measuring HLT Efficiency: ttbar region

Efficiency

- With Looser selection

- **HLT**
- $\text{nSel40Jets} \geq 6 \ \&\& \ \text{nSel80Jets} \geq 3 \ \&\& \ \text{nSelbJets (DeepJetM, DeepCSVM)} \geq 3$
 - $\text{nSel}\{X\}(\text{b})\text{Jet}$: number of selected jet with $p_T > \{X = (30)40, 80\}$, $|\eta| < (2.5)4.5$, TightID
 - Working point between loose - medium offline
- $\text{Jet1} > 170 \text{ GeV} \ \&\& \ \text{Jet2} > 130 \text{ GeV} \ \&\& \ \text{Jet3} > 80 \text{ GeV}$
- $\text{HT} > 500 \text{ GeV}$
- Minimum $\text{Chi2} < 15$
- **Invariant mass of 2nd Top < 350 GeV** → ttbar like
- $\text{H_mass from Chi2} > 100 \text{ GeV}$



- HLT Efficiencies for all dataset

HLT Path	DeepJet	DeepCSV
With Target Path	745	422 (RunF=6)
Only IsoMu Path	865	665 (RunF=223)
Efficiency (%)	86.1	94.1 (w/o RunF)

- Split into meaningful era

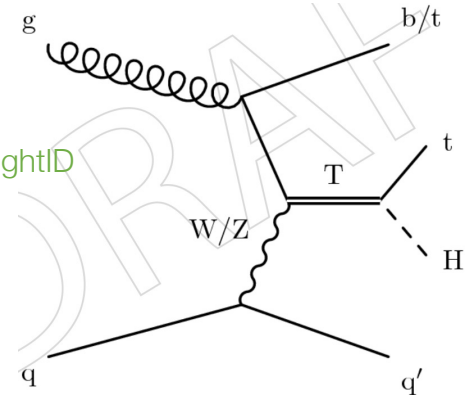
	Before TS1		after TS1, pre HCAL		after TS1, post HCAL	
HLT Path	DeepJet	DeepCSV	DeepJet	DeepCSV	DeepJet	DeepCSV
w/ Target Path	322	259	171	157	252	6
w/o Target Path	379	274	205	168	281	223
Efficiency (%)	85.0	95.5	83.4	93.4	89.7	2.69

Efficiency on DeepJet offline: Signal phase space

Efficiency

- With Looser selection

- **HLT**
- $\text{nSel40Jets} \geq 6 \ \&\& \ \text{nSel80Jets} \geq 3 \ \&\& \ \text{nSelbJets (DeepJetM)} \geq 3$
 - $\text{nSel}\{X\}(\text{b})\text{Jet}$: number of selected jet with $p_T > \{X = (30)40, 80\}$, $|\eta| < (2.5)4.5$, TightID
 - Working point between loose - medium offline
- $\text{Jet1} > 170 \text{ GeV} \ \&\& \ \text{Jet2} > 130 \text{ GeV} \ \&\& \ \text{Jet3} > 80 \text{ GeV}$
- $\text{HT} > 500 \text{ GeV}$
- Minimum $\text{Chi2} < 15$
- Invariant mass of 2nd Top $> 250 \text{ GeV}$
- $\text{H_mass from Chi2} > 100 \text{ GeV}$



- HLT Efficiencies for all dataset (w/o RunF for deepcsv path)

Options	DeepJet online DeepJet offline	DeepCSV online DeepCSV offline	DeepCSV online DeepJet offline
With Target Path	594	300	407
Only IsoMu Path	675	322	446
Efficiency (%)	88.0	93.4	91.2

- Split into meaningful era

Took values from previous study

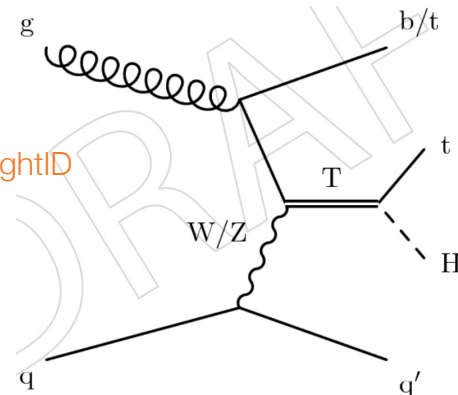
	Before TS1		after TS1, pre HCAL		after TS1, post HCAL	
Online HLT	DeepJet	DeepCSV	DeepJet	DeepCSV	DeepJet	DeepCSV
w/ Target Path	244	253	147	154	203	6
w/o Target Path	279	279	167	167	229	229
Efficiency (%)	87.4	90.7	88.0	92.2	88.6	2.6

Efficiency on DeepJet offline: QCD enriched

Efficiency

- With Looser selection

- **HLT**
- `nSel40Jets >= 6 && nSel80Jets >= 3 && nSelbJets (DeepJetM) >= 3`
 - `nSel{X}(b)Jet`: number of selected jet with $p_T > \{X = (30)40, 80\}$, $|\eta| < (2.5)4.5$, TightID
 - Working point between loose - medium offline
- `Jet1 > 170 GeV && Jet2 > 130 GeV && Jet3 > 80 GeV`
- `HT > 500 GeV`
- Minimum $\chi^2 < 15$
- Invariant mass of 2nd Top > 250 GeV
- `H_mass from  $\chi^2 > 100$  GeV`



- HLT Efficiencies for all dataset (w/o RunF for deepcsv path)

Options	DeepJet online DeepJet offline	DeepCSV online DeepCSV offline	DeepCSV online DeepJet offline
With Target Path	3835	1998	2574
Only IsoMu Path	4535	2156	2836
Efficiency (%)	84.6	92.7	90.8

- Split into meaningful era

Took values from previous study

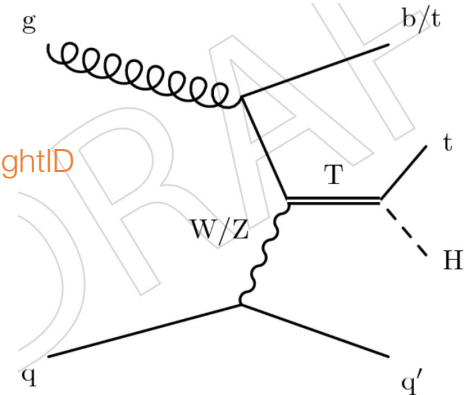
	Before TS1		after TS1, pre HCAL		after TS1, post HCAL	
Online HLT	DeepJet	DeepCSV	DeepJet	DeepCSV	DeepJet	DeepCSV
w/ Target Path	1348	1491	1030	1083	1457	35
w/o Target Path	1659	1659	1177	1177	1699	1699
Efficiency (%)	81.2	89.9	87.5	92.0	85.8	2.06

Efficiency on DeepJet offline: ttbar region

Efficiency

- With Looser selection

- **HLT**
- $\text{nSel40Jets} \geq 6 \ \&\& \ \text{nSel80Jets} \geq 3 \ \&\& \ \text{nSelbJets (DeepJetM)} \geq 3$
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- $\text{HT} > 500 \text{ GeV}$
- Minimum $\text{Chi2} < 15$
- Invariant mass of $2^{\text{nd}} < 350 \text{ GeV}$
- $\text{H_mass from Chi2} > 100 \text{ GeV}$



- HLT Efficiencies for all dataset (w/o RunF for deepcsv path)

Options	DeepJet online DeepJet offline	DeepCSV online DeepCSV offline	DeepCSV online DeepJet offline
With Target Path	745	416	524
Only IsoMu Path	865	442	584
Efficiency (%)	86.1	94.1	89.7

- Split into meaningful era

Took values from previous study

	Before TS1		after TS1, pre HCAL		after TS1, post HCAL	
Online HLT	DeepJet	DeepCSV	DeepJet	DeepCSV	DeepJet	DeepCSV
w/ Target Path	322	341	171	183	252	5
w/o Target Path	379	379	205	205	281	281
Efficiency (%)	85.0	90.0	83.4	89.3	89.7	1.78

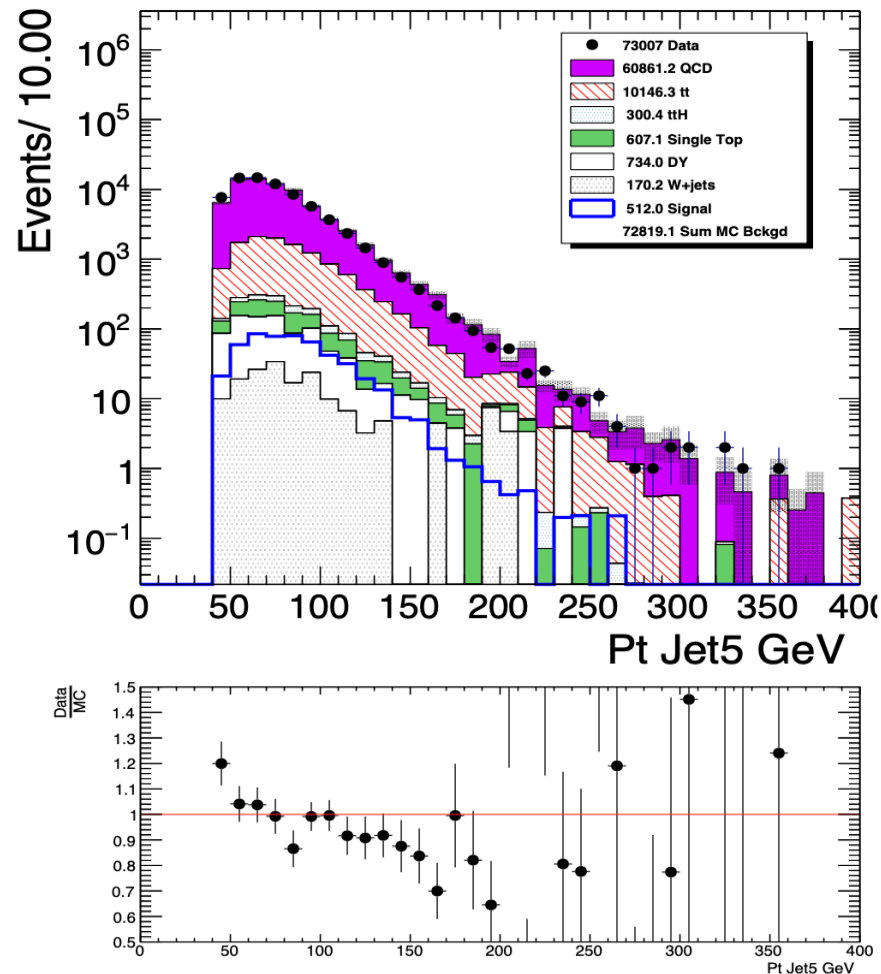
- Checked Efficiencies on 5 (2 b-tagged) jet HLT path in Run 3 dataset
 - HLT_PFHT400_FivePFJet_100_100_60_30_30_DoublePFBTagDeepJet_4p5
 - HLT_PFHT400_FivePFJet_100_100_60_30_30_DoublePFBTagDeepCSV_4p5
- DeepCSV path has 3 ~ 12 % higher efficiencies than DeepJet path
- [HIG](#) have seen similar behavior in DeepCSV vs DeepJet path
- It may affect on analysis using many jets including b-tagged jet

Thank you!

BACKUP

5th Leading Jet pT in T' hadronic analysis

pT of 5th leading jet (from [AN](#))



Signal is enriched in low pT region