Search for anomalous tH couplings with $H \to \gamma\gamma$ at $\sqrt{s} = 13$ TeV

Jose Benitez[1], Javier Murillo[1], Cristina Oropeza[2], A. Giammanco[3]

[1]Universidad de Sonora
[2]Universidad Iberoamericana
[3]Université Catholique de Louvain

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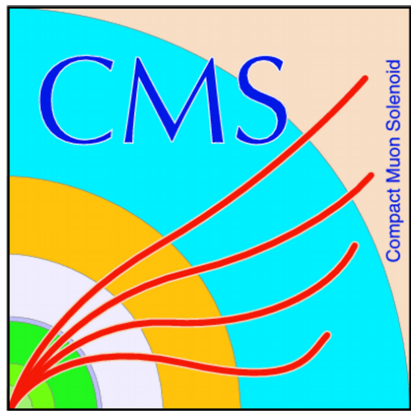
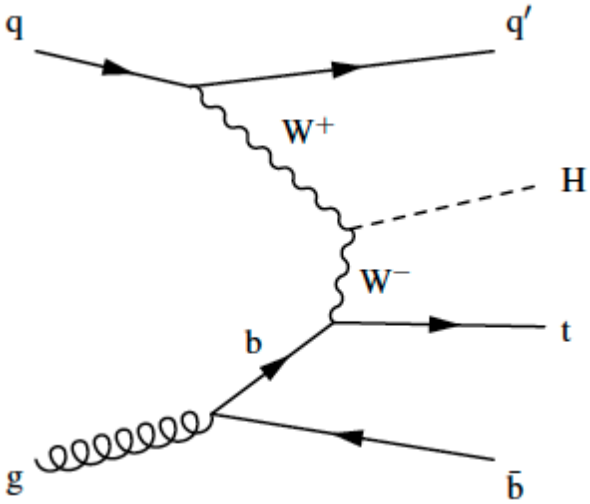
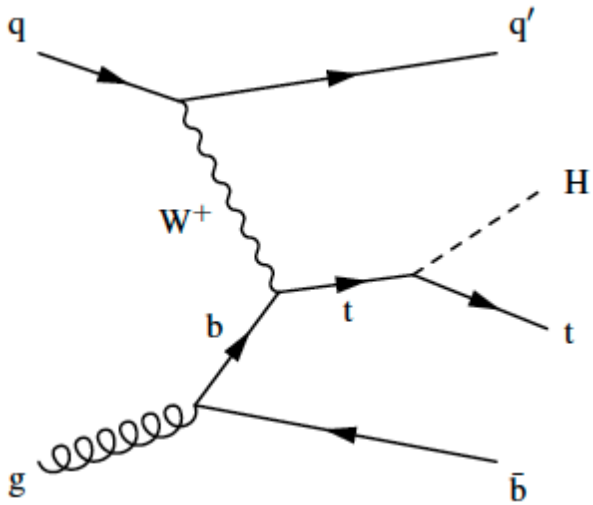


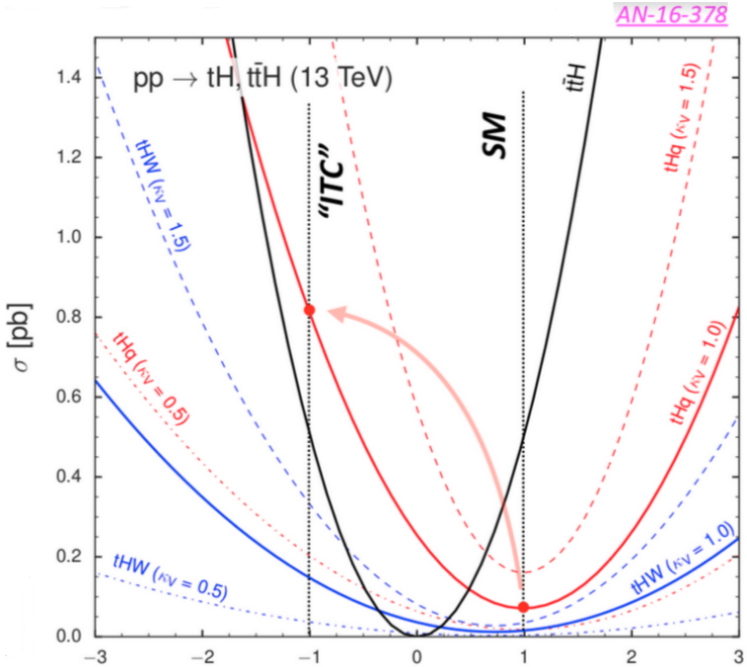
Overview

Search for anomalous tH couplings

- Interfering diagrams lead to large cross-section for inverted coupling scenario "ITC"

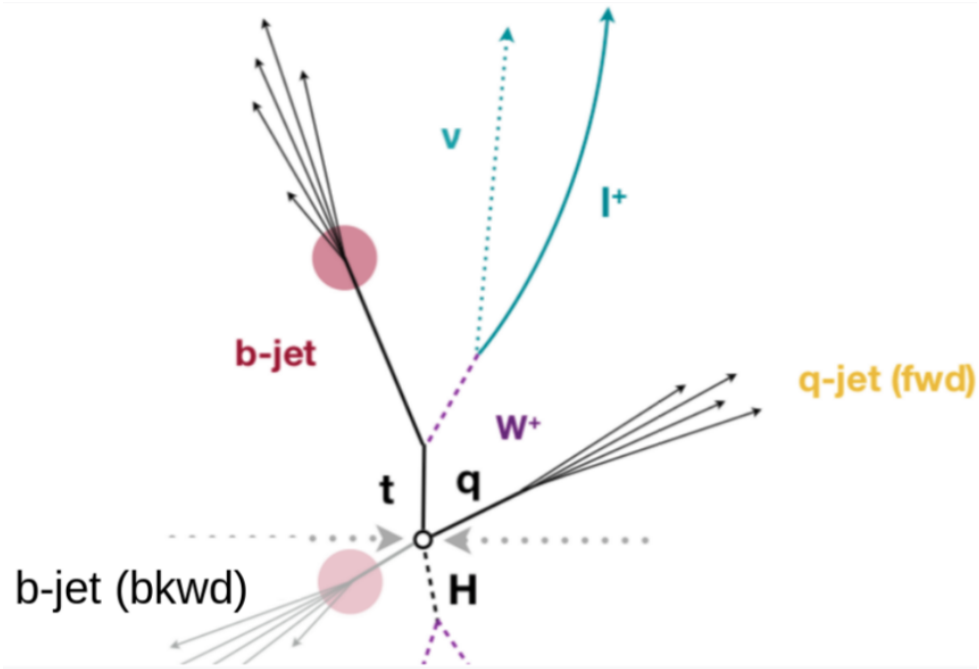






Signal topology

- Higgs events with additional signatures
  - top $\rightarrow$ W + b-jet
  - forward light jet
  - backward b-jet (soft)
- W can decay leptonically or hadronically, here we consider only leptonic decays



Previous results

- HIG-18-009 (arXiv:1811.09696)

  - 2016 combination: $b\bar{b}$, $\gamma\gamma$, multi-lep

  - Used only two Hgg categories:

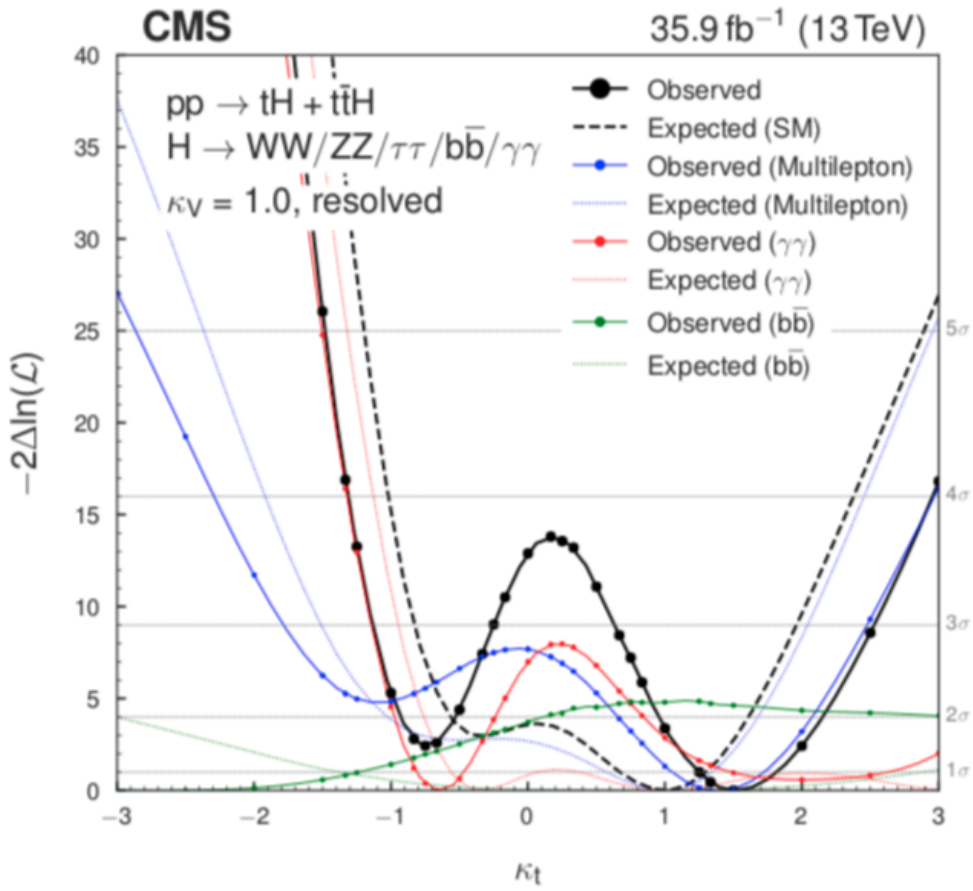
    tthLeptonic
    ttHHadronic

  - No dedicated tH category

  - $|k_t| = 0$ excluded at 3.5 sigma

  - ITC scenario only $\sim$ 1.5 sigma

  - Large improvements possible by adding new data and new categories



tHq tagger

- Very preliminary version of `THQLeptonic Tagger` has been integrated into flashgg framework using `cmsrel CMSSW_9_4_9` → latest release under support

  - Code adapted to previous flashgg version (8_0_26) was initially provided by Hamed Bakhshiansohi (DESY)

  - Original selection has not been modified

tHq tagger: selection requirements

Object selection:

- Photons
  - $|\eta|$ thresholds $\rightarrow |\eta| < 1.4442$ || $\eta \in [1.566, 2.5]$
  - Leading photon $\mathrm{p_T} > m_{\gamma\gamma} * 0.5$
  - Sub-leading photon $\mathrm{p_T} > m_{\gamma\gamma} * 0.25$
  - IDMVA $>$ -0.9
- Jets
  - $|\eta| < 4.7$
  - $\mathrm{p_T} > 30$ GeV
  - ΔR(leading photon, jet) > 0.4 & ΔR(sub-leading photon, jet) > 0.4
  - ΔR(lepton, jet) > 0.4
- Leptons
  - $p_T > 20$ GeV
  - Electron: $|\eta|$ thresholds $\rightarrow |\eta| < 1.4442$ || $|\eta| \in [1.566, 2.4]$,
  - Muon: $|\eta| < 2.4$ / Isolation cut: 0.15

tHq tagger: selection requirements

Event selection:

- Number of leptons

```
n_ele == 1 && n_muon == 0 || n_ele == 0 && n_muon == 1
(hasGoodElec && !hasGoodMuons || hasGoodMuons && !hasVetoElec)
```

- Number of jets

```
n_centraljets == 2 && n_fwdjets == 0 ||
n_centraljets == 2 && n_fwdjets == 1 ||
n_centraljets == 3 && n_fwdjets == 1
```

Samples

- We have produced `microAODs` with flashgg out of the following MiniAODs:

  thq sample → `/THQ_ctcvcp_HToGG_M125_13TeV-madgraph-pythia8_TuneCP5/RunIIFall17MiniAODv2-PU2017_12Apr2018_94X_mc2017_realistic_v14-v1/MINIAODSIM` (1623731 events)

- tth sample → ttHJetToGG_M125_13TeV_amcatnloFXFX_madspin_pythia8 (414189 events)

Preliminary yields

- Running over `THQ_ctcvcp_HToGG_M125_13TeV` $\sim$ most numbers consistent with 2016 results

TAG	Entries	ptg	only tagged	$\sim$2016
NoTag	822291	50.6%		
TTHLeptonicTag_0	37925	2.34%	4.73%	6.0%
TTHLeptonicTag_1	18023	1.11%	2.25%	
ZHLeptonicTag	87	0.00536%	0.0109%	0.0%
WHLeptonicTag	29387	1.81%	3.67%	3.6%
VHLeptonicLooseTag	13453	0.829%	1.68%	1.6%
TTHHadronicTag_0	31349	1.93%	3.91%	8.0%
TTHHadronicTag_1	46487	2.86%	5.8%	
TTHHadronicTag_2	76087	4.69%	9.49%	
VBFTag_0	9760	0.601%	1.22%	0.9%
VBFTag_1	3904	0.24%	0.487%	1.1%
VBFTag_2	12702	0.782%	1.58%	5.0%
VHMetTag	16905	1.04%	2.11%	2.8%
VHHadronicTag	23982	1.48%	2.99%	4.5%
UntaggedTag_0	24376	1.5%	3.04%	7.6%
UntaggedTag_1	142692	8.79%	17.8%	15.6%
UntaggedTag_2	175254	10.8%	21.9%	22.6%
UntaggedTag_3	139067	8.56%	17.4%	20.8%
TOTAL	1623731			

- Same sequence as `HIG-16-040`
- Additional sub-categories with respect 2016 results
- Priority in TagSorter file (Default arrangement)

```
flashggTTHLeptonicTag
flashggZHLeptonicTag
flashggWHLeptonicTag
flashggVHLeptonicLooseTag
flashggTTHHadronicTag
flashggVBFTag
flashggVHMetTag
flashggVHHadronicTag
flashggUntagged
```

- Running over THQ_ctcvcp_HToGG_M125_13TeV

TAG	Entries	ptg	only tagged
NoTag	821139	50.6%	
THQLeptonicTag	38926	2.4%	4.85%
TTHLeptonicTag_0	25185	1.55%	3.14%
TTHLeptonicTag_1	12195	0.751%	1.52%
ZHLeptonicTag	74	0.00456%	0.00922%
WHLeptonicTag	24156	1.49%	3.01%
VHLeptonicLooseTag	10843	0.668%	1.35%
TTHHadronicTag_0	31259	1.93%	3.89%
TTHHadronicTag_1	46350	2.85%	5.78%
TTHHadronicTag_2	75852	4.67%	9.45%
VBFTag_0	9610	0.592%	1.2%
VBFTag_1	3838	0.236%	0.478%
VBFTag_2	12456	0.767%	1.55%
VHMetTag	16276	1%	2.03%
VHHadronicTag	23765	1.46%	2.96%
UntaggedTag_0	24069	1.48%	3%
UntaggedTag_1	140500	8.65%	17.5%
UntaggedTag_2	171767	10.6%	21.4%
UntaggedTag_3	135471	8.34%	16.9%
TOTAL	1623731		

- Integrating THQLeptonicTag
- Priority in TagSorter file

```
flashggTHQLeptonicTag
flashggTTHLeptonicTag
flashggZHLeptonicTag
flashggWHLeptonicTag
flashggVHLeptonicLooseTag
flashggTTHHadronicTag
flashggVBFTag
flashggVHMetTag
flashggVHHadronicTag
flashggUntagged
```

- Running over ttHJetToGG_M125_13TeV

TAG	Entries	ptg	only tagged
NoTag	229916	55.5%	
THQLeptonicTag	9630	2.33%	5.23%
TTHLeptonicTag_0	19916	4.81%	10.8%
TTHLeptonicTag_1	7787	1.88%	4.23%
ZHLeptonicTag	194	0.0468%	0.105%
WHLeptonicTag	1837	0.444%	0.997%
VHLeptonicLooseTag	446	0.108%	0.242%
TTHHadronicTag_0	19561	4.72%	10.6%
TTHHadronicTag_1	21644	5.23%	11.7%
TTHHadronicTag_2	26217	6.33%	14.2%
VBFTag_0	486	0.117%	0.264%
VBFTag_1	129	0.0311%	0.07%
VBFTag_2	532	0.128%	0.289%
VHMetTag	2822	0.681%	1.53%
VHHadronicTag	1470	0.355%	0.798%
UntaggedTag_0	2373	0.573%	1.29%
UntaggedTag_1	15534	3.75%	8.43%
UntaggedTag_2	25520	6.16%	13.8%
UntaggedTag_3	28175	6.8%	15.3%
TOTAL	414189		

- Priority in TagSorter file

```
flashggTHQLeptonicTag
flashggTTHLeptonicTag
flashggZHLeptonicTag
flashggWHLeptonicTag
flashggVHLeptonicLooseTag
flashggTTHHadronicTag
flashggVBFTag
flashggVHMetTag
flashggVHHadronicTag
flashggUntagged
```

- Running over THQ_ctcvcp_HToGG_M125_13TeV ∼ swaping THQ and TTH leptonic tags

TAG	Entries	ptg	only tagged
NoTag	821139	50.6%	
THQLeptonicTag	20358	1.25%	2.54%
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flashggWHLeptonicTag
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flashggTTHHadronicTag
flashggVBFTag
flashggVHMetTag
flashggVHHadronicTag
flashggUntagged
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- Running over `ttHJetToGG_M125_13TeV` ∼ swaping thq and tth leptonic tags

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flashggVBFTag
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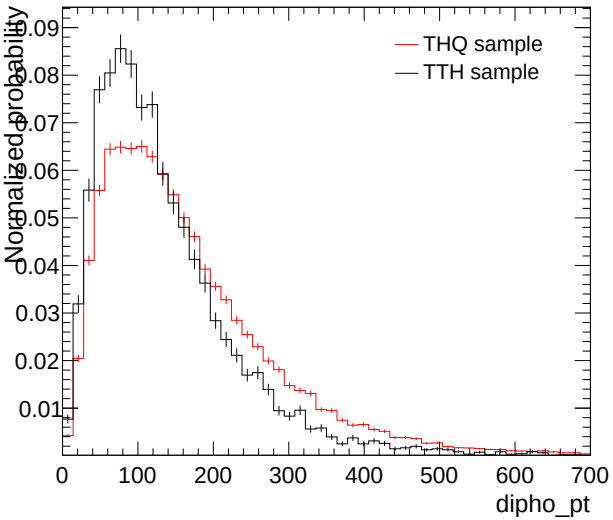
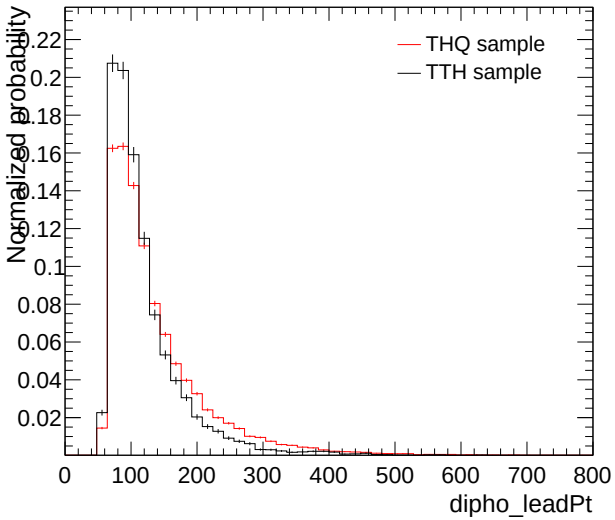
flashggVHHadronicTag
flashggUntagged
```

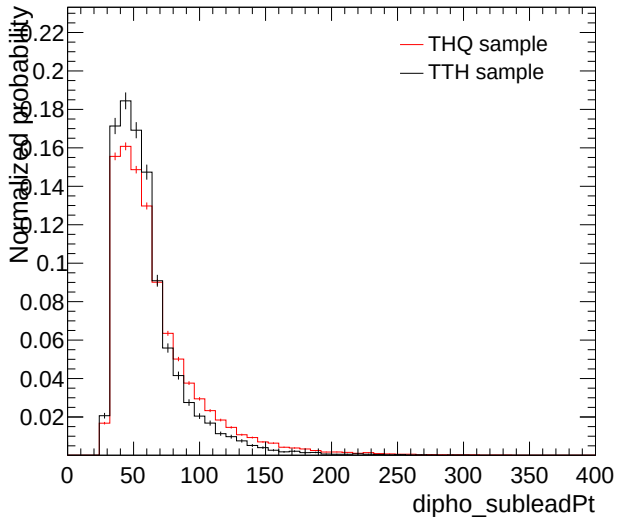
Preliminary plots from selected events with THQLeptonicTag

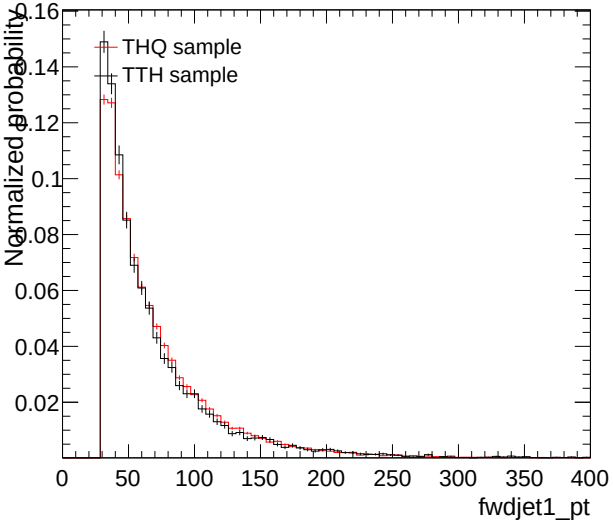
Selected events with THQLeptonicTag

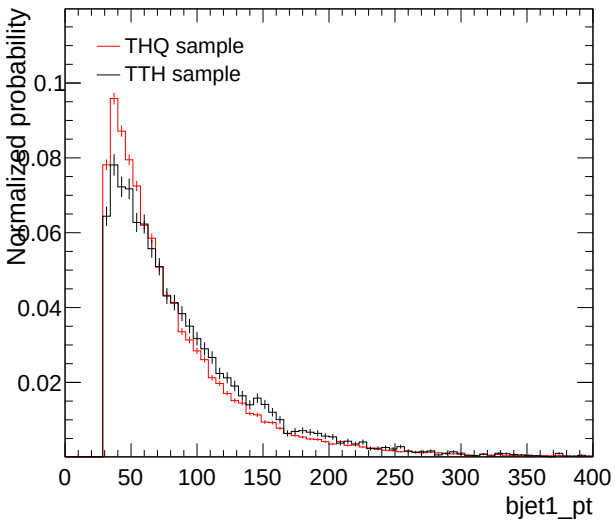
- Comparing tHQ and TTH signal samples

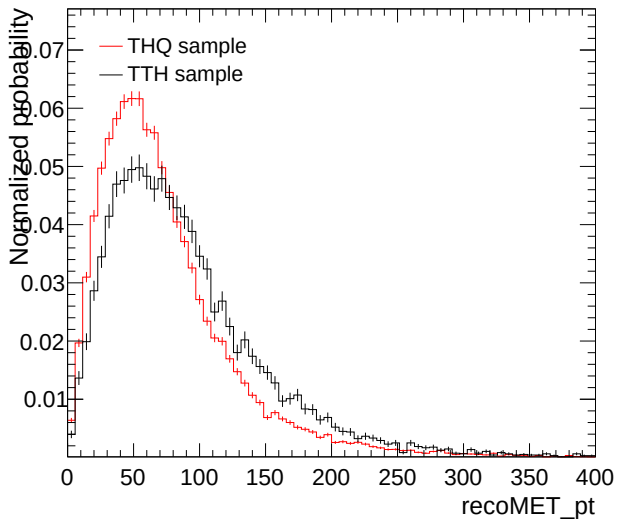






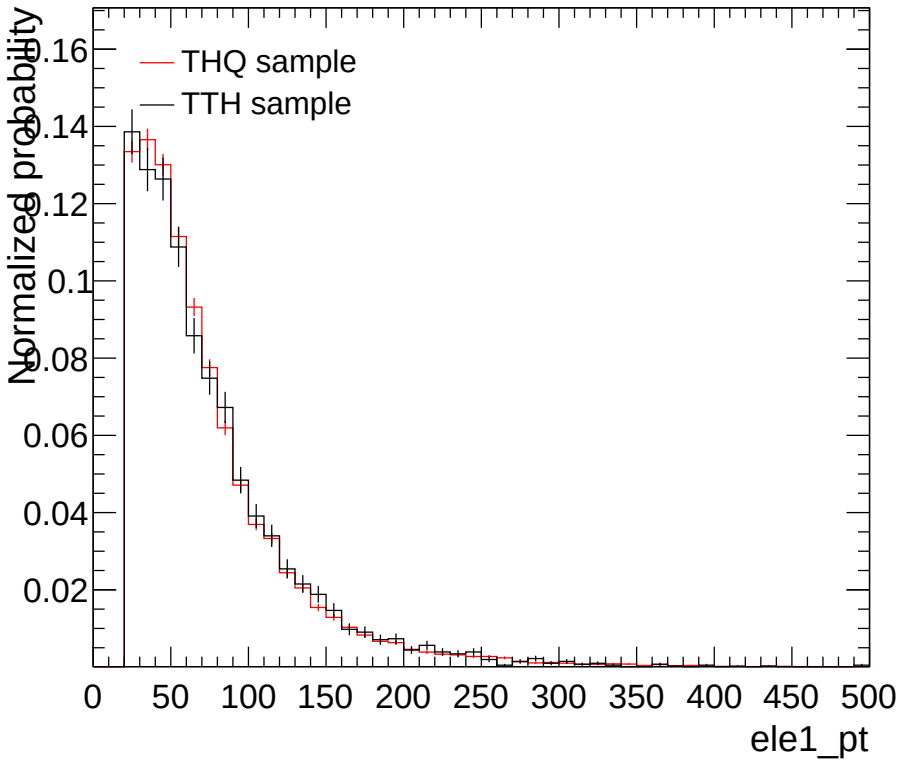


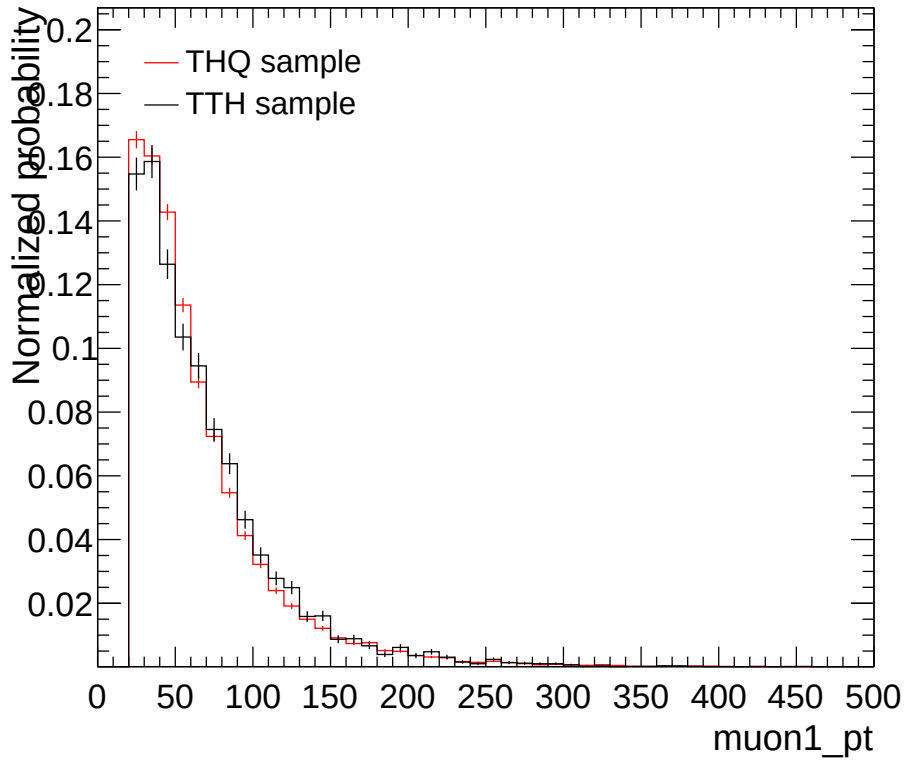




Selected events with THQLeptonicTag

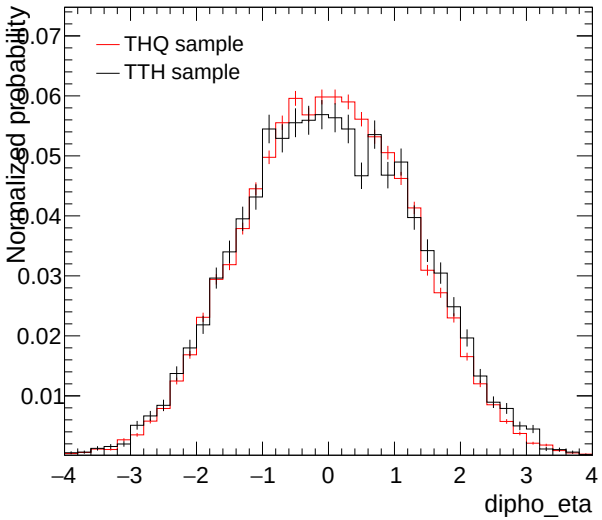
- Comparing tHQ and TTH signal samples

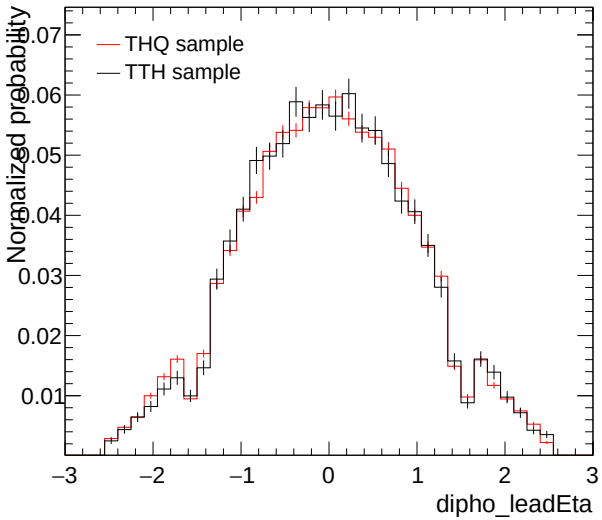


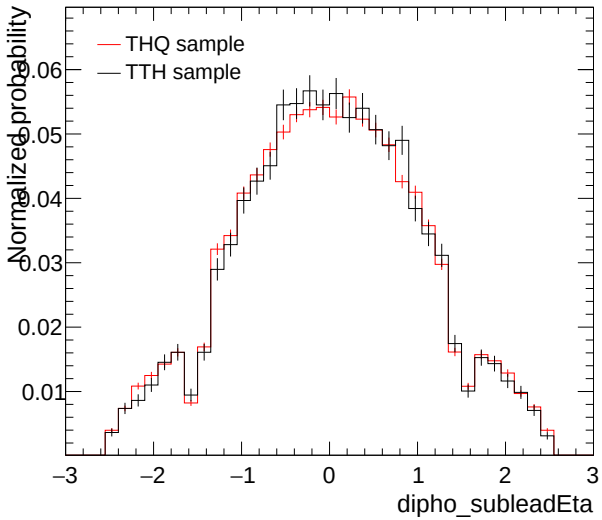


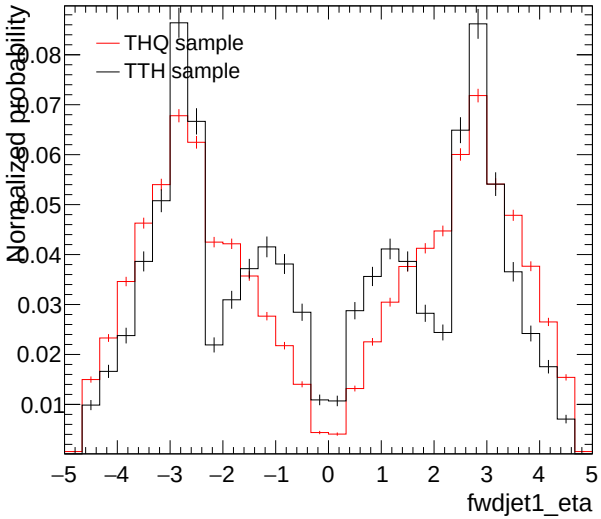
Selected events with THQLeptonicTag

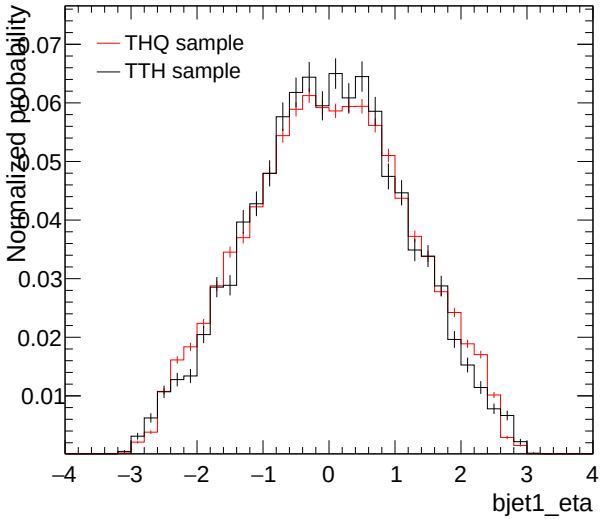
- Comparing tHQ and TTH signal samples

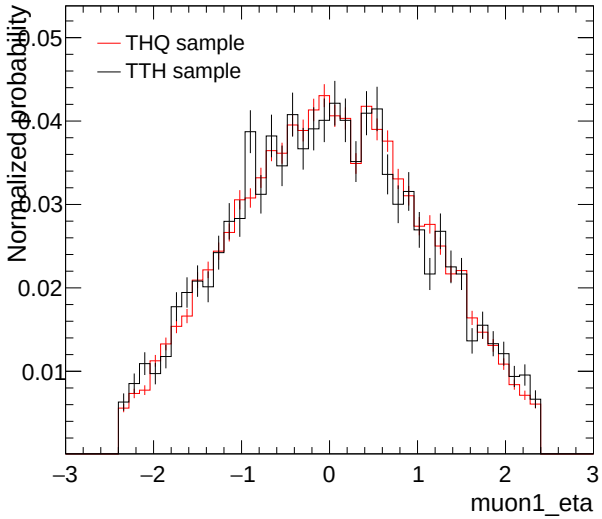












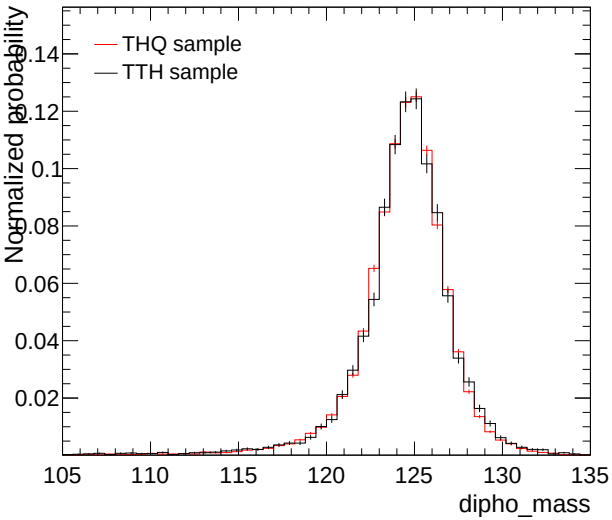
In progress

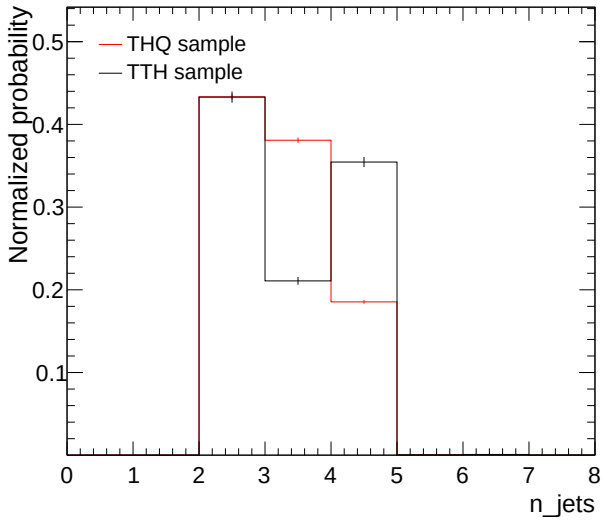
- Produce tHq M = 125 MicroAODs: 36 out of 38 microAODs already produced
- Have incorporated preliminary version of tHQ tagger into flashgg framework
- Optimize signal sensitivity

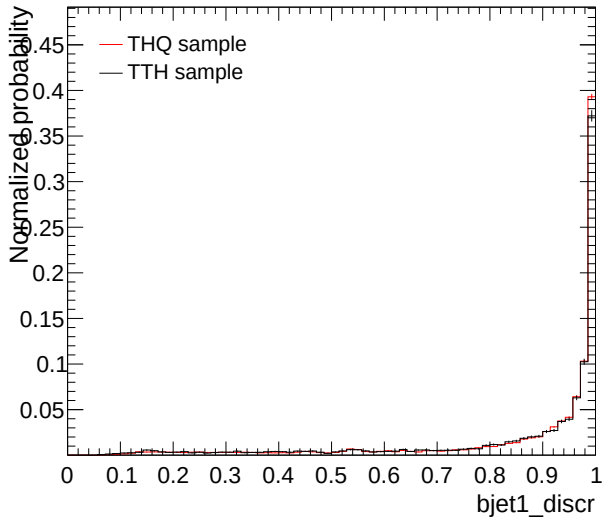
Backup

Selected events with THQLeptonicTag

- Comparing tHQ and TTH signal samples

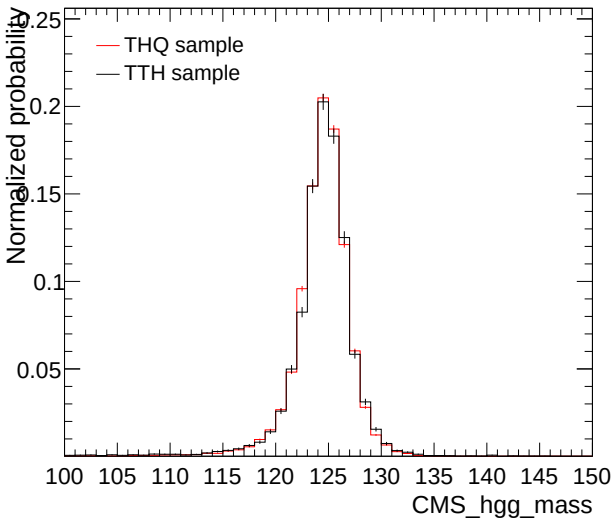


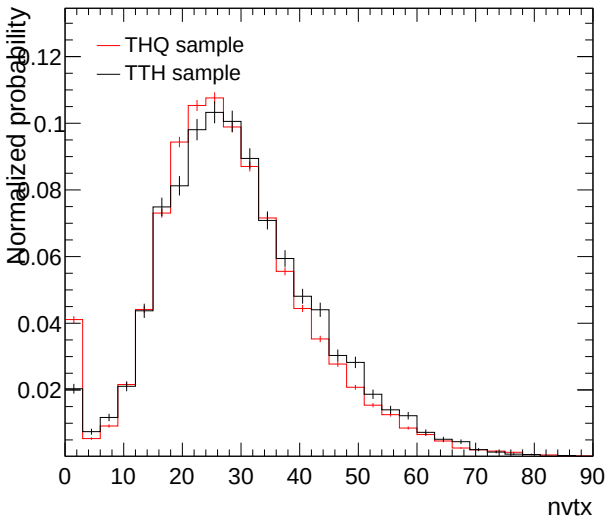


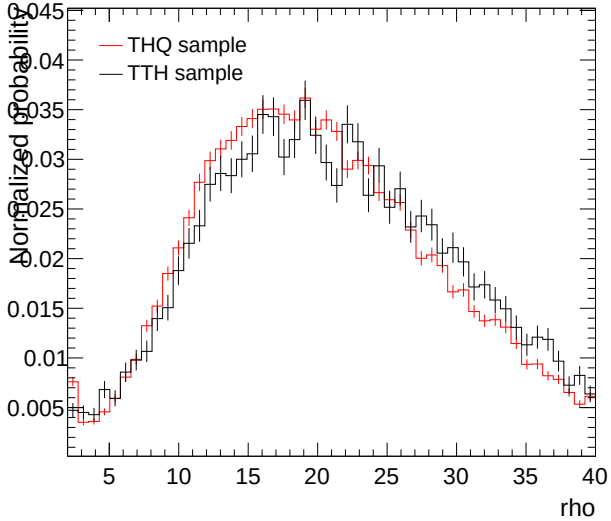


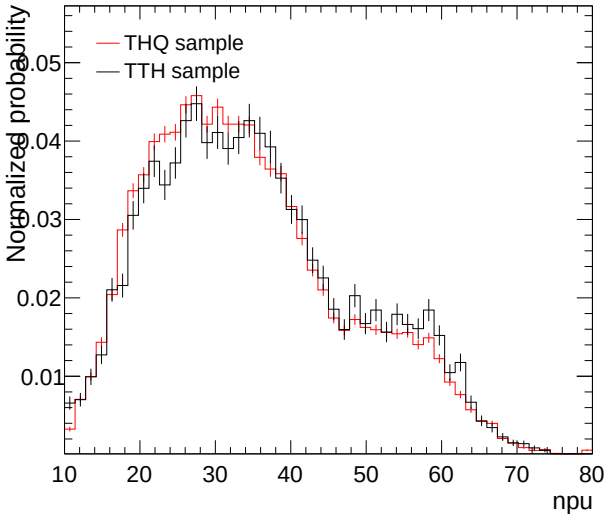
Selected events with THQLeptonicTag

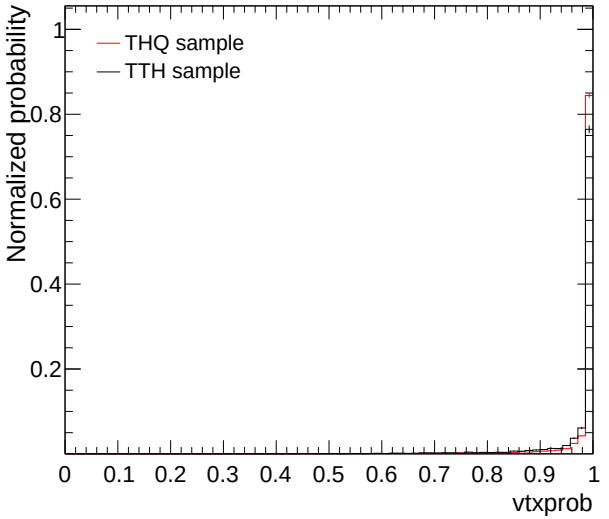
- Comparing tHQ and TTH signal samples

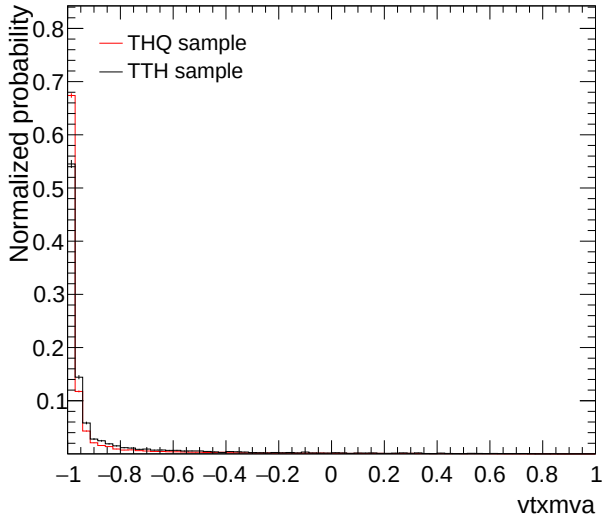






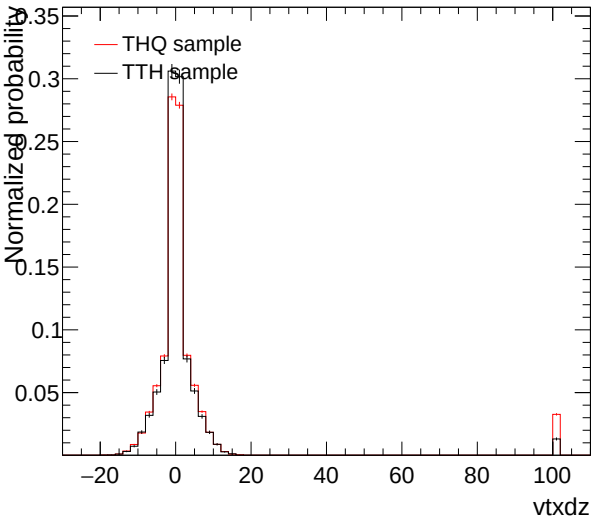


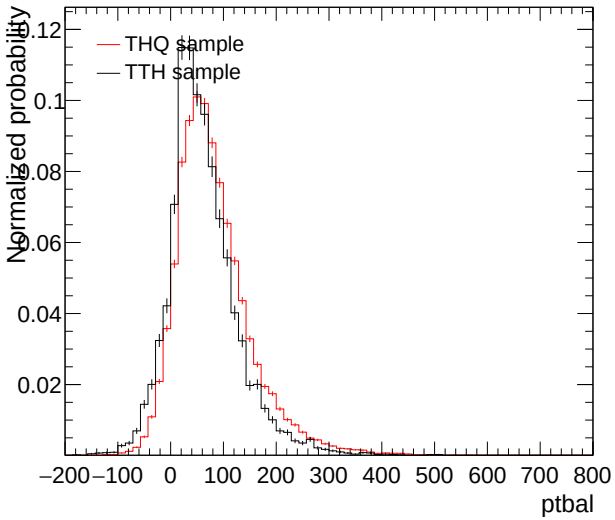


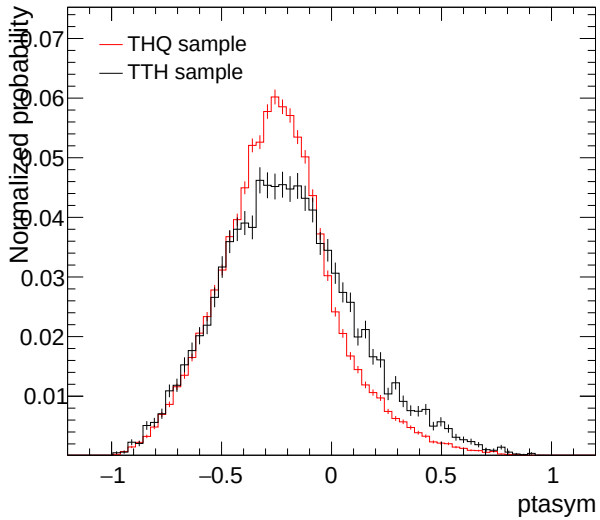


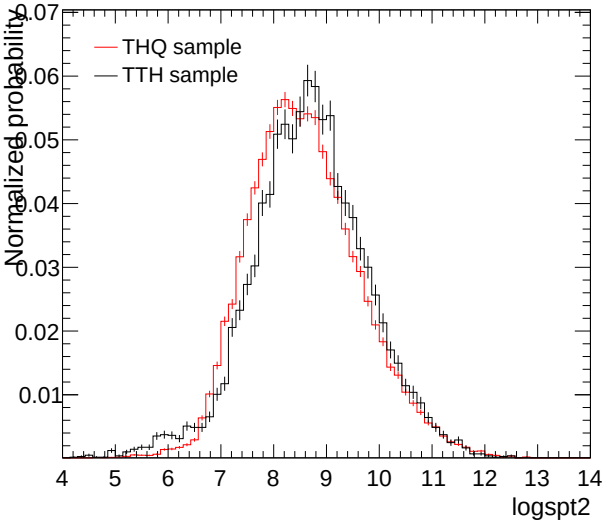
Selected events with THQLeptonicTag

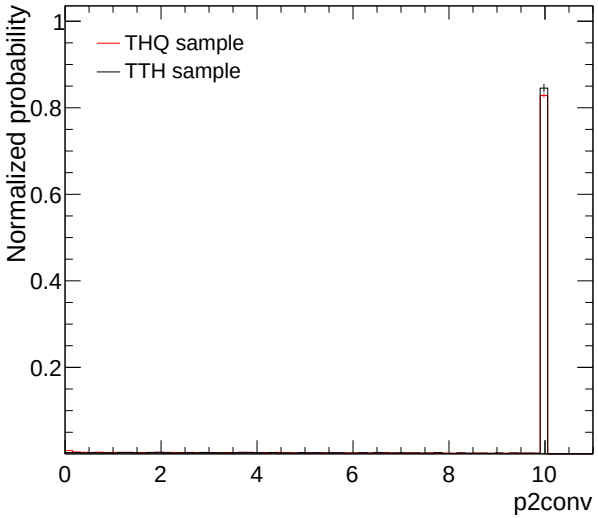
- Comparing tHQ and TTH signal samples

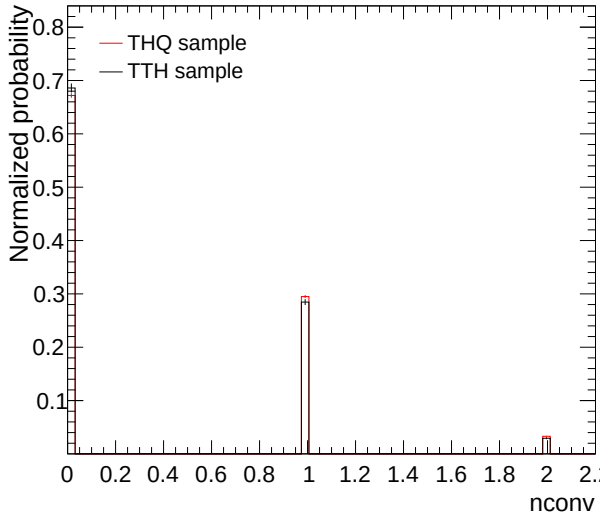






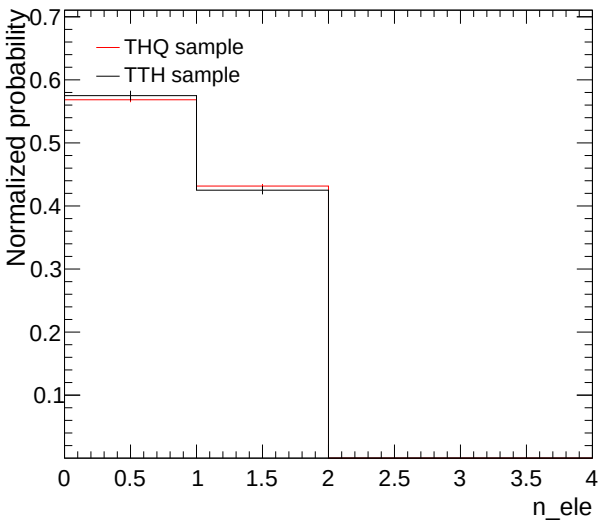


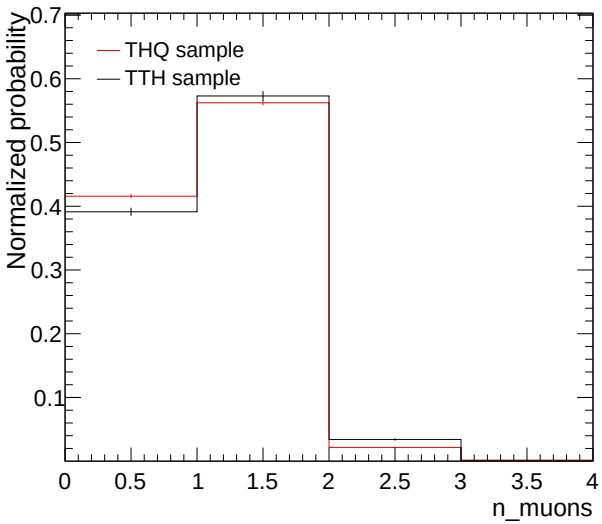




Selected events with THQLeptonicTag

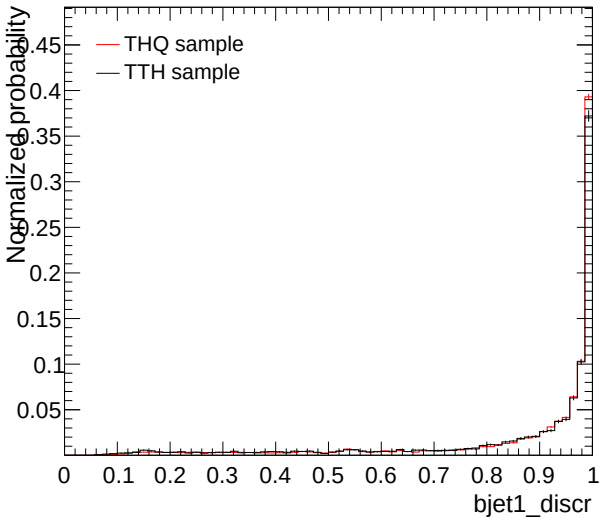
- Comparing tHQ and TTH signal samples

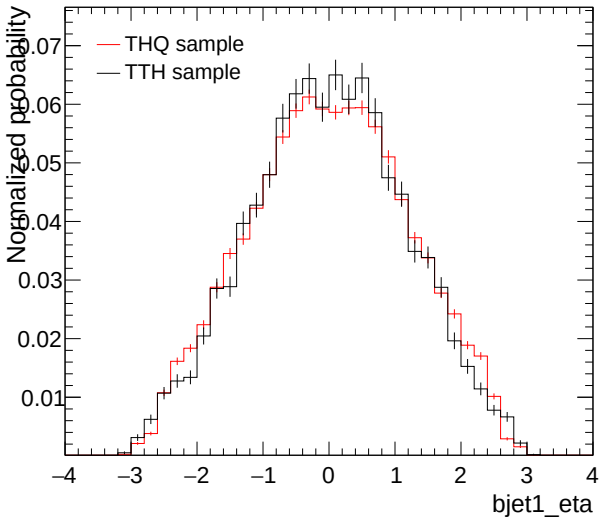


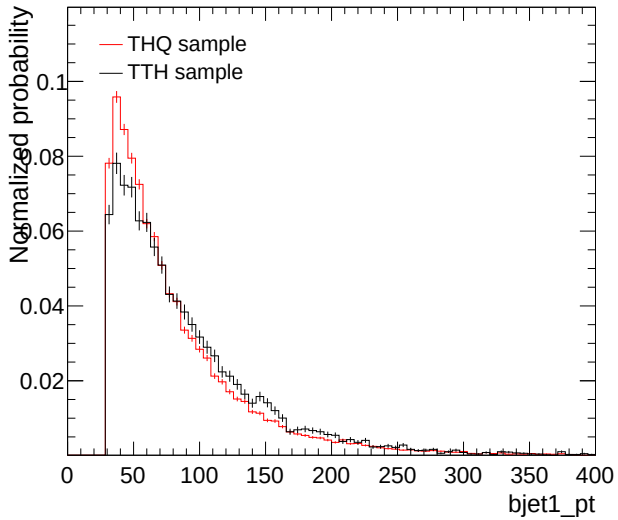


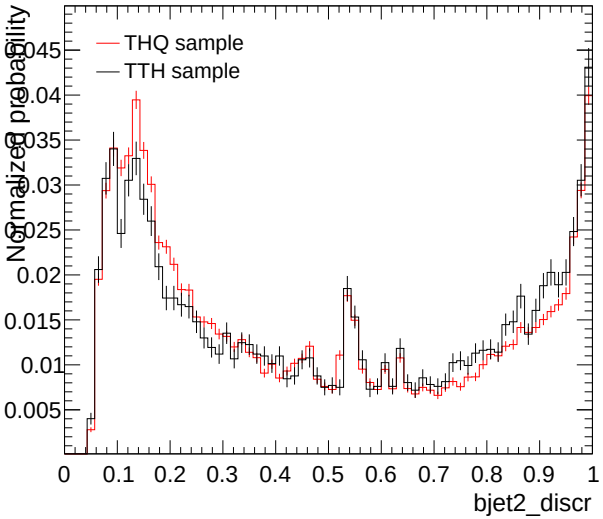
Selected events with THQLeptonicTag

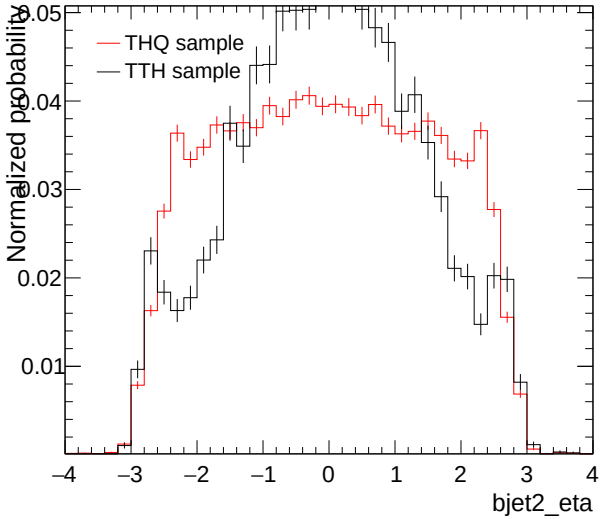
- Comparing tHQ and TTH signal samples

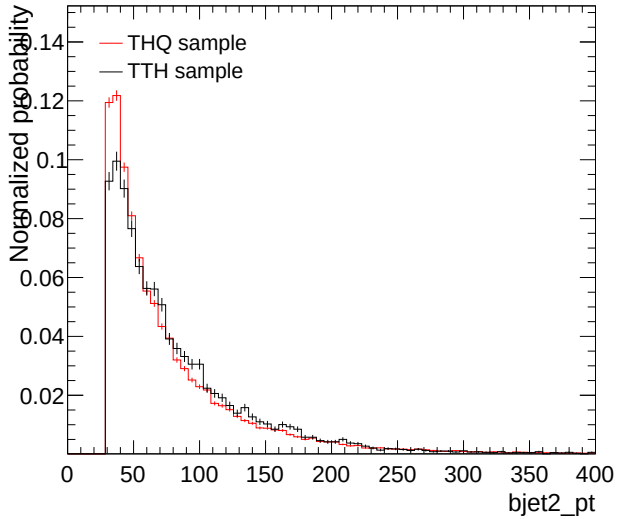






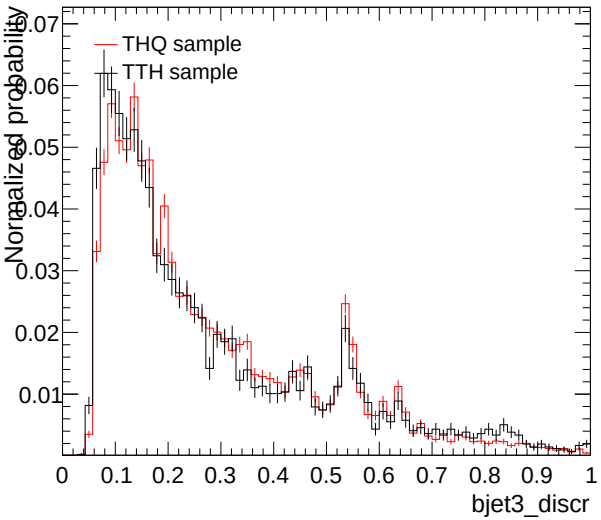


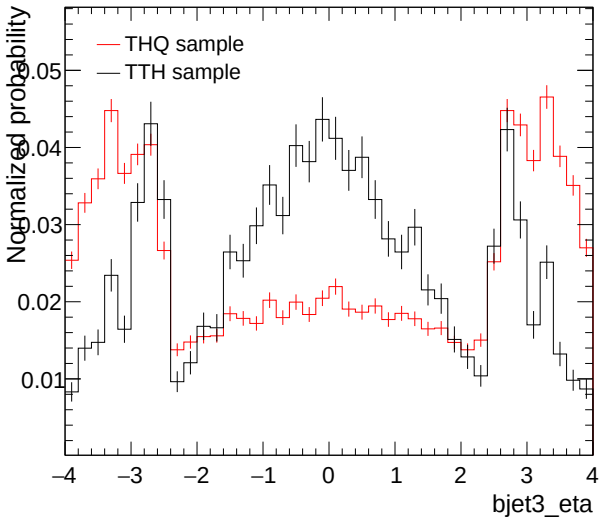


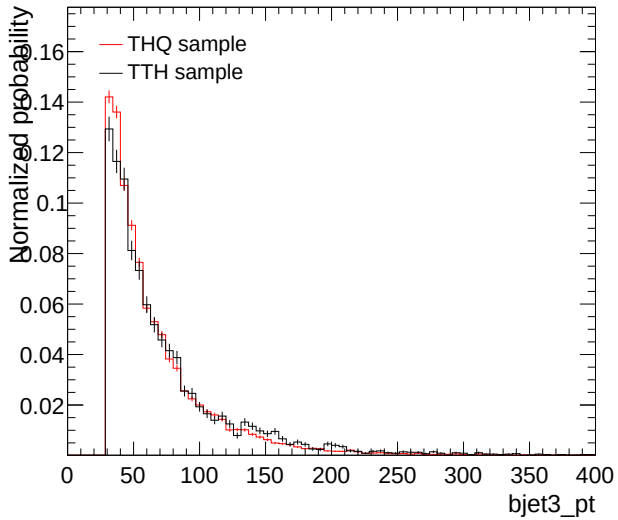


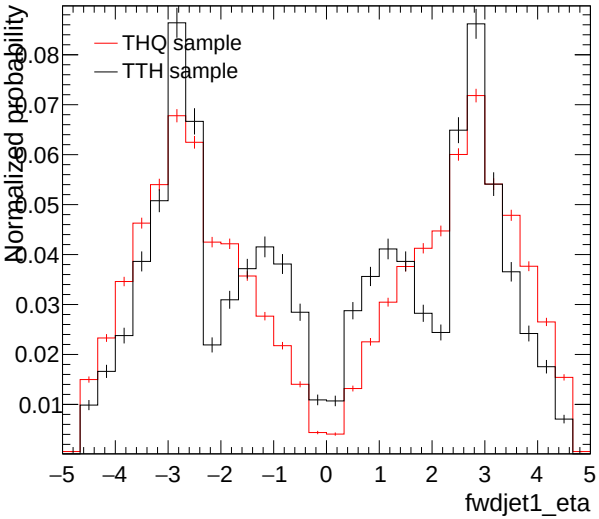
Selected events with THQLeptonicTag

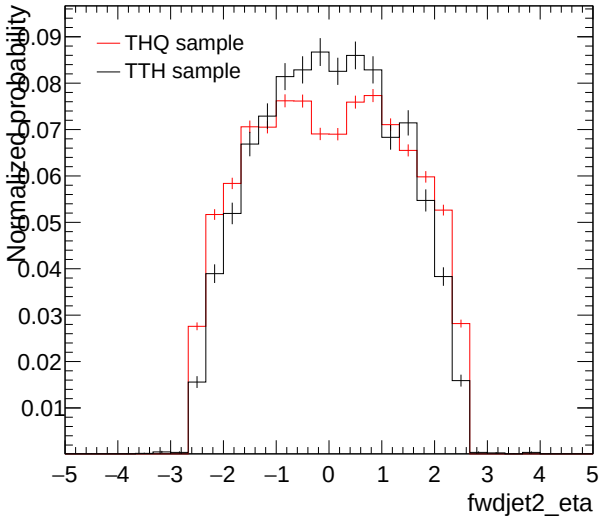
- Comparing tHQ and TTH signal samples

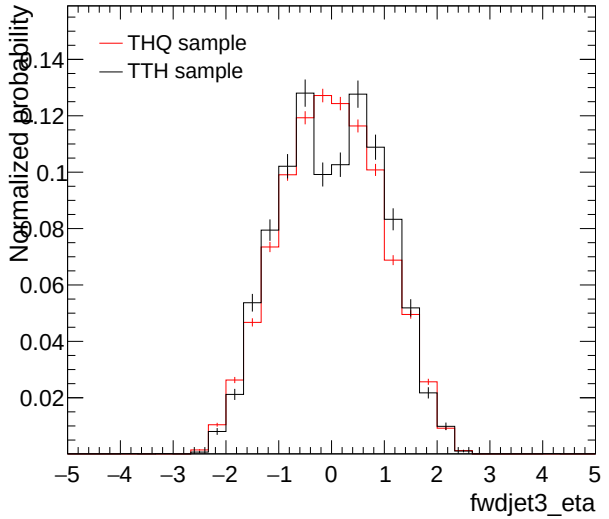






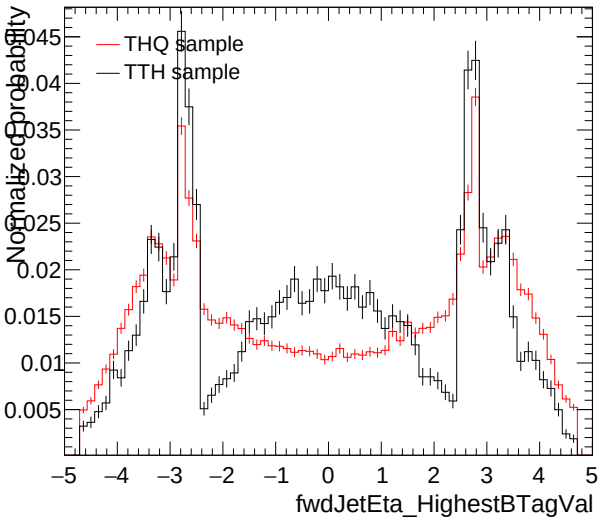


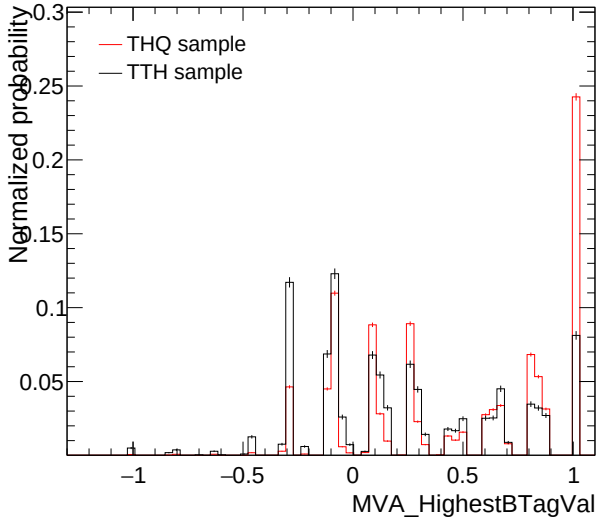


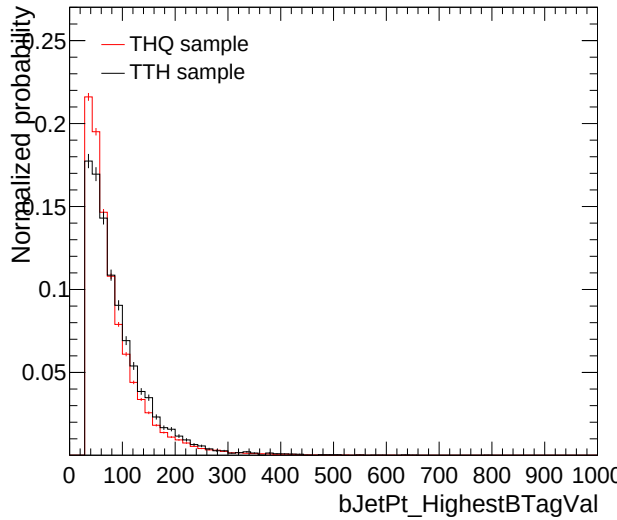


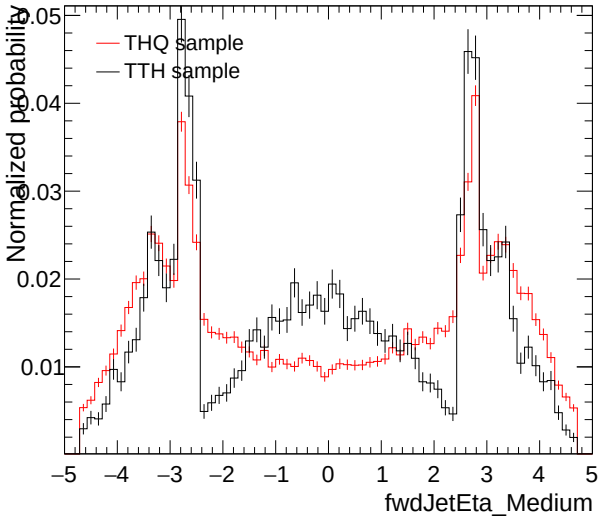
Selected events with THQLeptonicTag

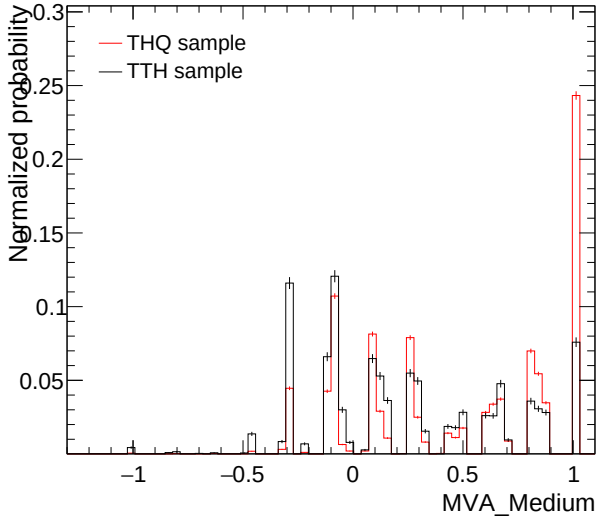
- Comparing tHQ and TTH signal samples

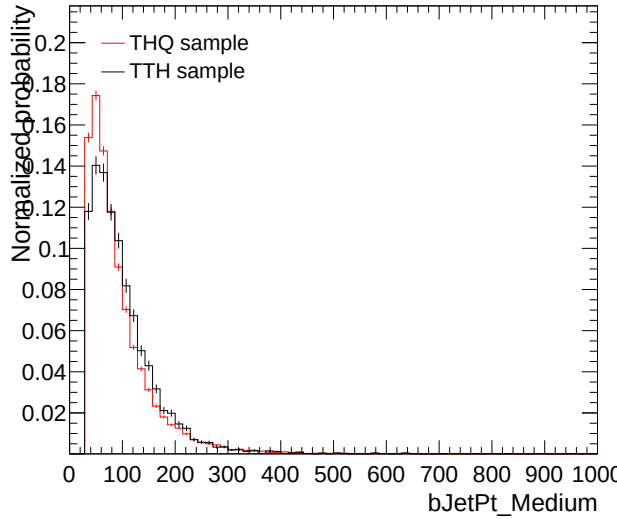






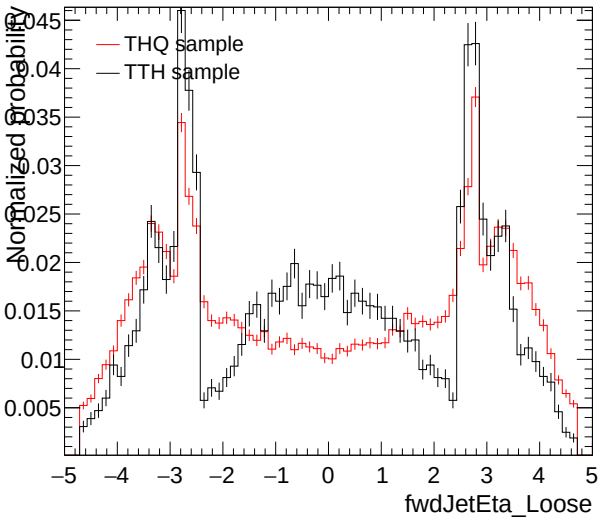


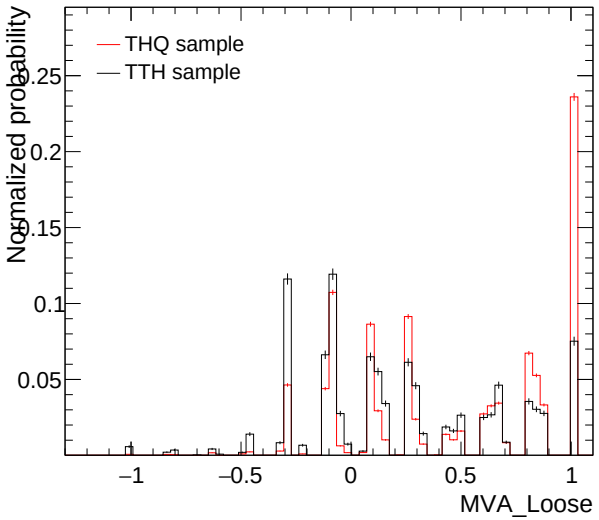


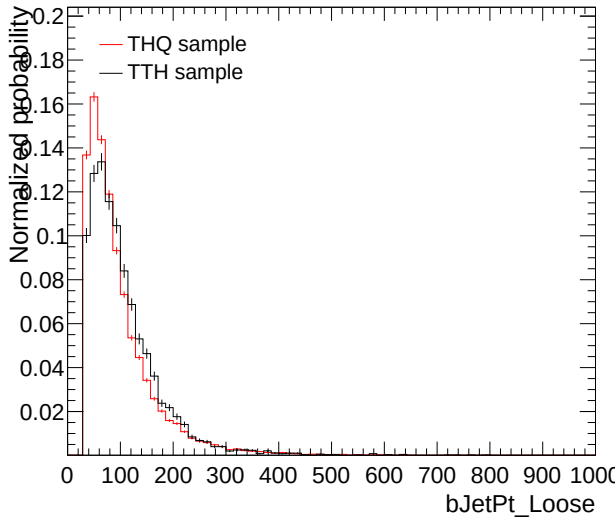


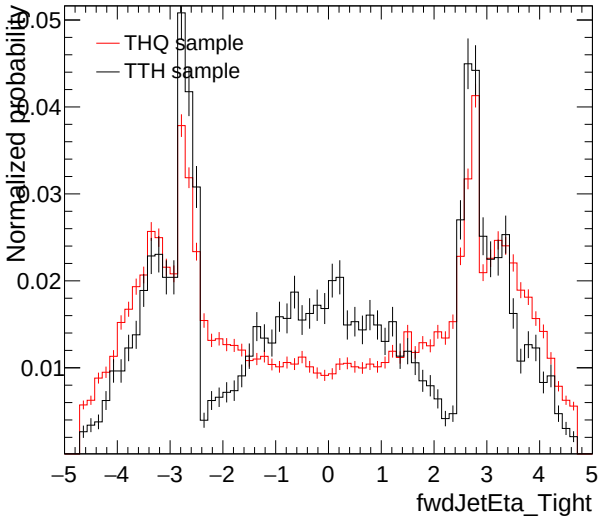
Selected events with THQLeptonicTag

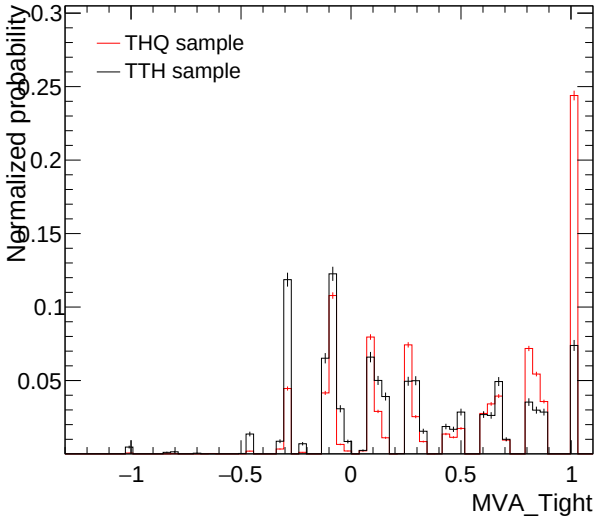
- Comparing tHQ and TTH signal samples

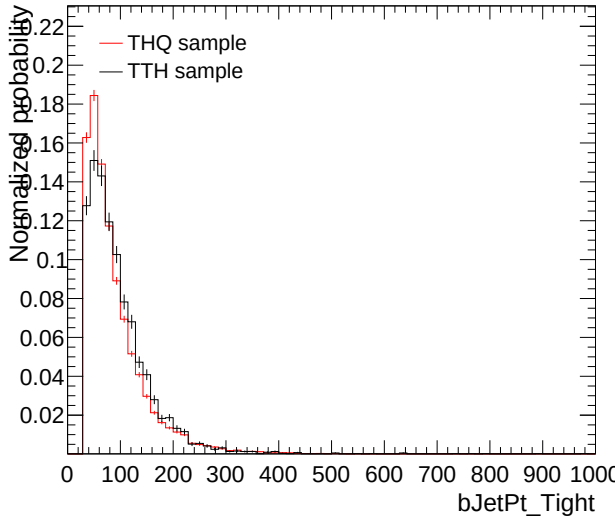












Selected events with THQLeptonicTag

- Comparing tHQ and TTH signal samples