Search for T'→ top+H in Dilepton OS Final State

Status Report

Di Wang

DESY& LYON Meeting, Sep. 14th, 2022

Baisc Cut Strategy

- **Focus on 1 signal process for now**
  - **T'->tH; t->Wb->qqb; H->WW->m+m-*vv* (1 lepton pair, 3 jets and at least 1 b jet)**

- **Basic cuts**
  - **Cuts for muons**
    - **Tight ID cut: Muon_tightId**
    - **Pt(mu) > 20GeV**
    - **|eta| < 2.4**
    - **Tight isolation cut: goodMuons_miniPFRelIso_all < 0.05**
    - **Significance cut: Muon_sip3d < 3**
  - **Cuts for jets**
    - **Tight jet ID cut: Jet_jetId: 6**
    - **Pt(jet) > 30GeV**
    - **|eta| < 2.5**
  - **Cuts for events**
    - **1 OS muon pair (2 muons)**
    - **At least 3 jets**
    - **At least 1 b jet**
      - **Loose b-tag jet: goodJets_btagDeepFlavB>0.049**

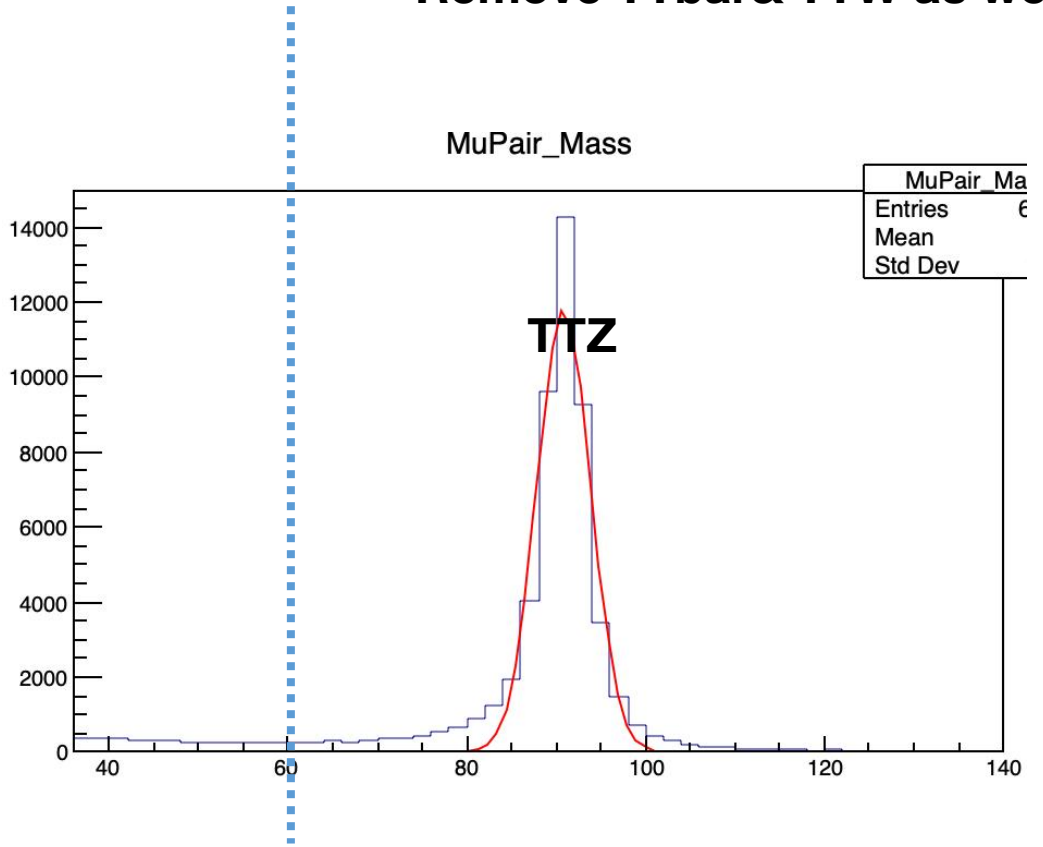
After Basic Selection

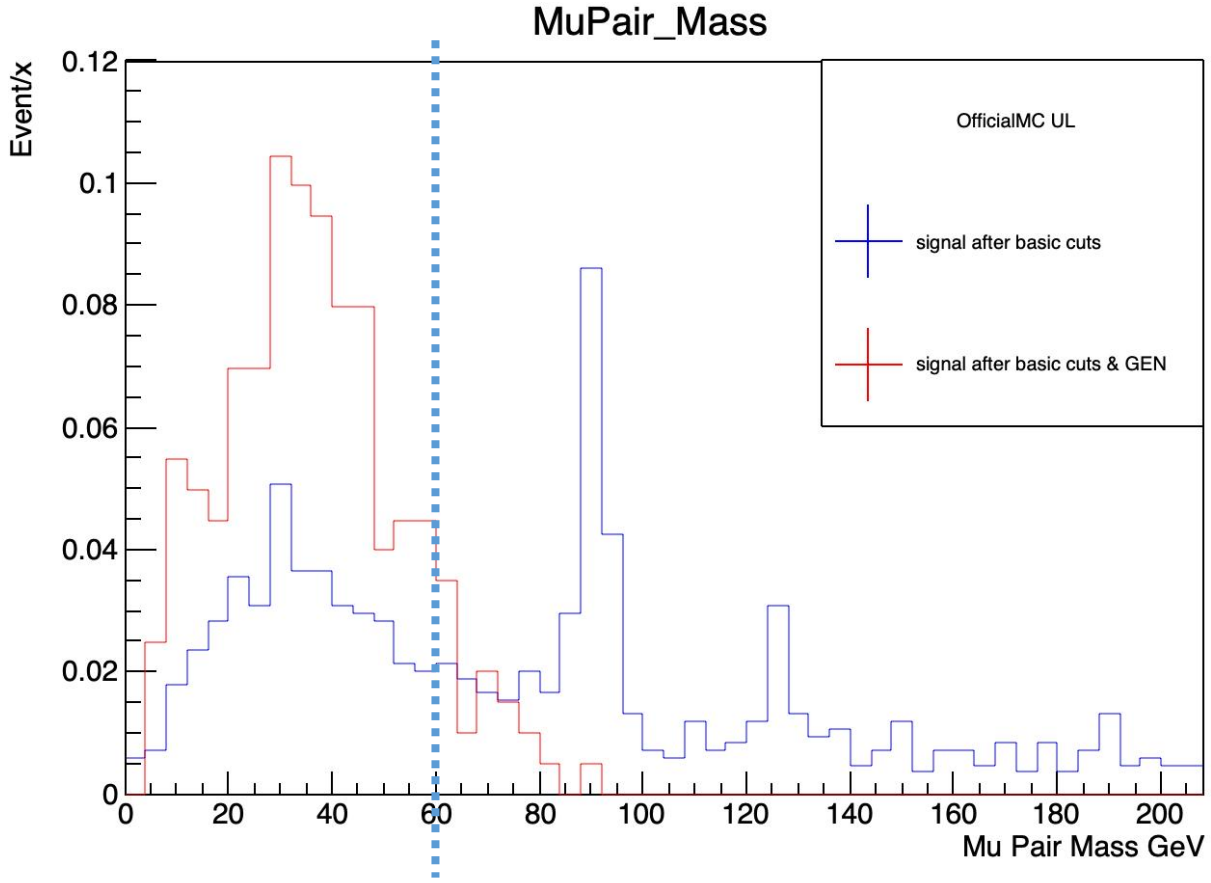
- **Signal: Basic cuts && GEN selection (H->W->mu)**
  - **2016, 2016apv, 2017& 2018 Official UL MC samples**
  - **Find 2.25 events (cross-section 89fb)**
- **Background: Basic cuts**
  - **Main background: TTbar, TTZ, TTH, TTW**
  - **Ignore background process which has < 5 events after cuts: WW, WW double scattering, WZ, WWW, WJets, DY, ZZ**

Cuts	N_signal (89fb)	N_signal GEN (89fb)	Signal ϵ	Signal Purity	N_TTbar (87315fb)	N_WW&WZ (12178 fb)	N_TTZ (770 fb)	N_TTH (271fb)	N_TTW (610.5 fb)	S(GEN)/B
Basic cuts	9.53	2.25	100%	24%	36878	75	883	205	182	0.006%

Cut0 : Mu Pair Mass < 60

- **Remove Z peak and Higgs peak in Muon pair mass distribution**
  - **Add mass window cut: Mu Pair Mass <60**
  - **Remove Z peak & Higgs peak from fake muons (tau)**
  - **Remove many TTZ**
  - **Remove TTbar& TTW as well :-)**





Cut0 : Mu Pair Mass < 60

- $\epsilon = N(\text{Gen \&\& Seclection})/N(\text{Gen})$
- Purity = $N(\text{Gen \&\& Seclection})/N(\text{Selection})$
  - Gen: H->W->mu

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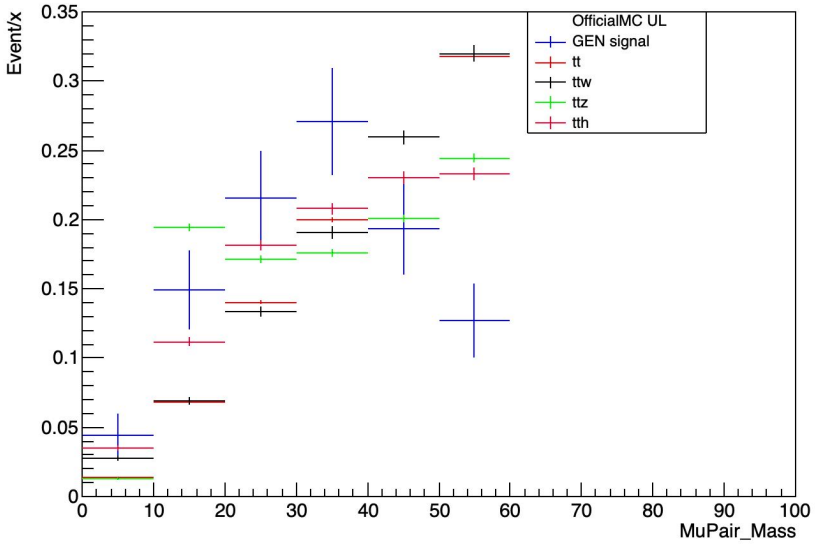
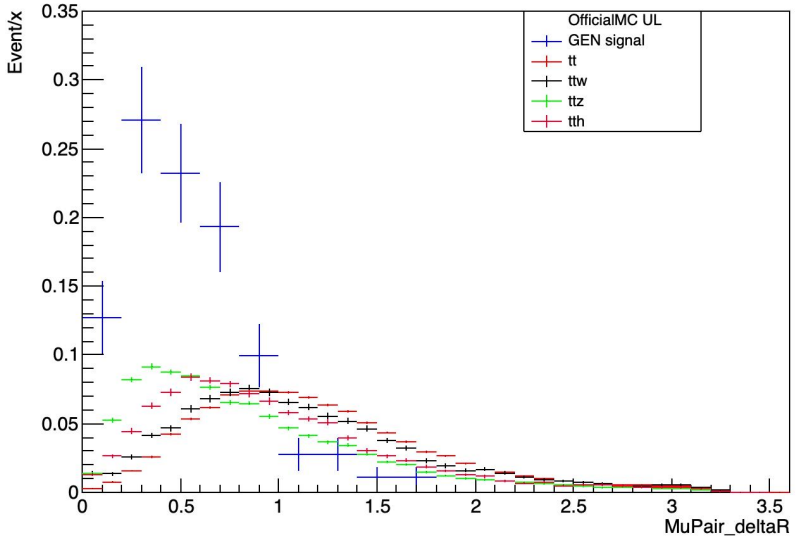
After Basic Cuts && Cut0

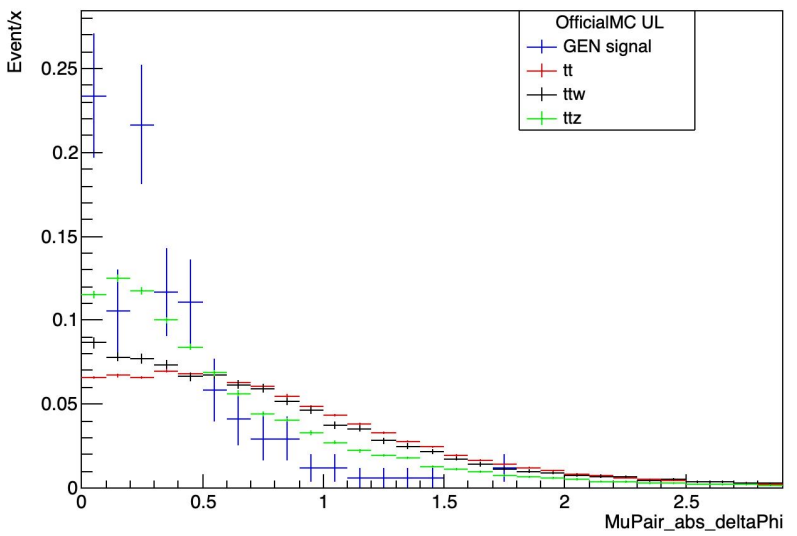
MuPair_Mass_GENWH



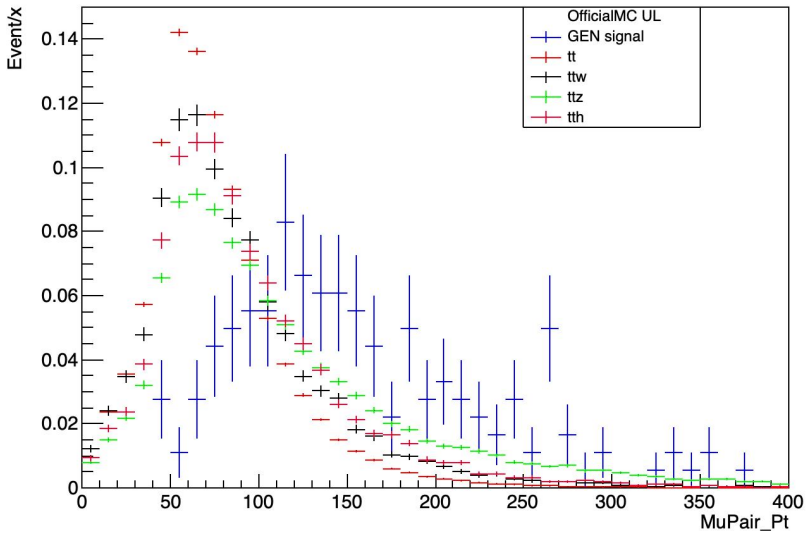
MuPair_deltaR_GEN_HW



MuPair_abs_deltaPhi_GEN_HW



MuPair_Pt_GEN_HW



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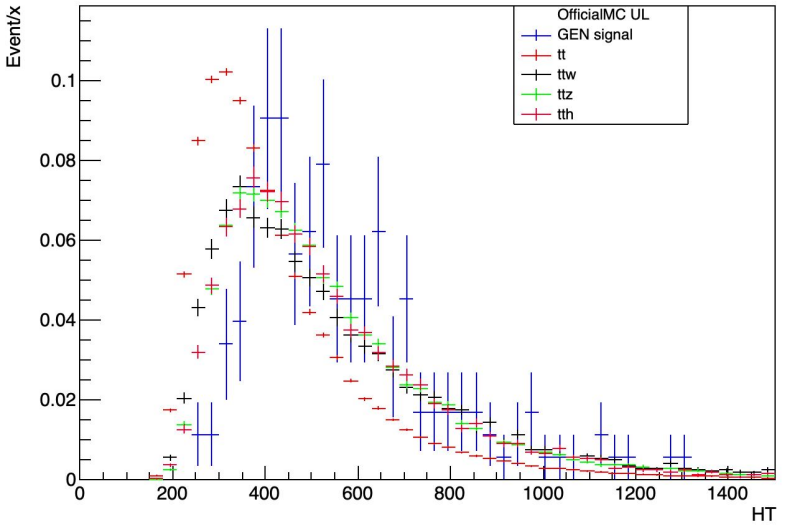

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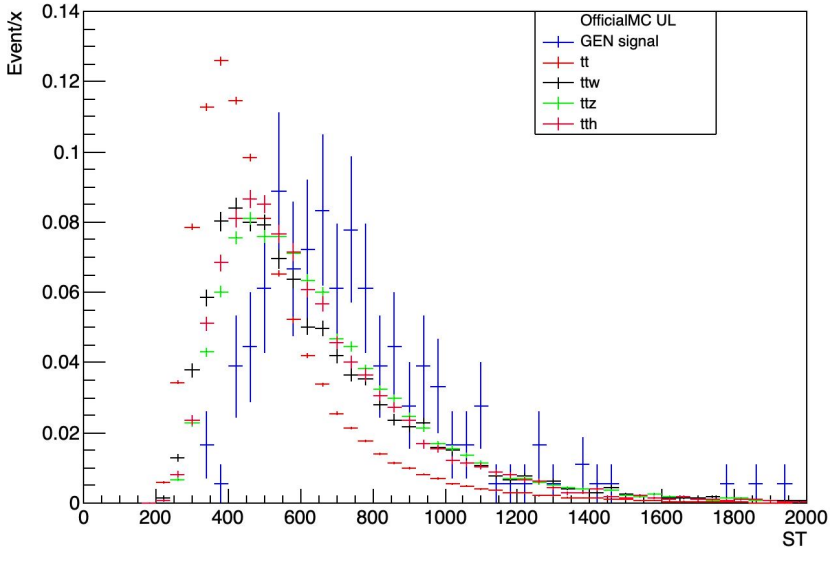
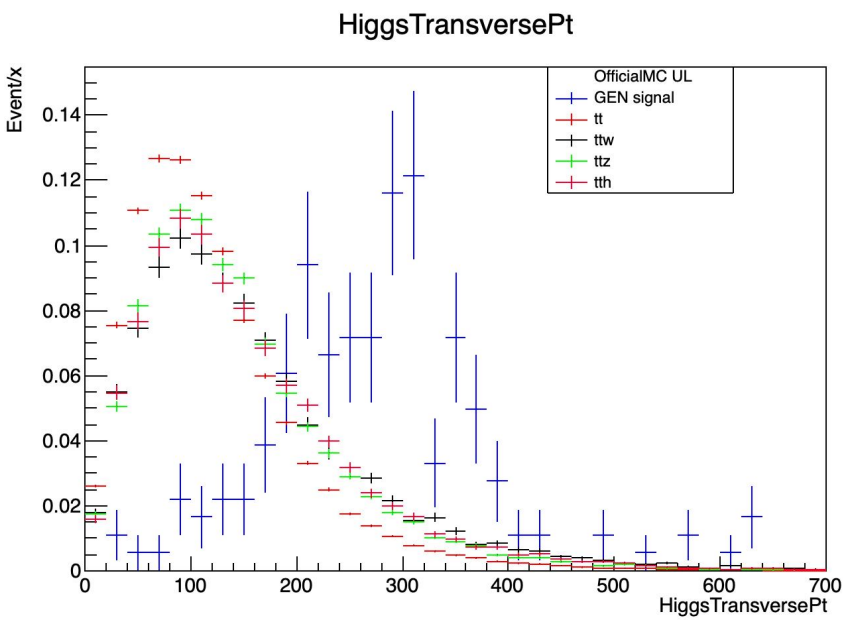
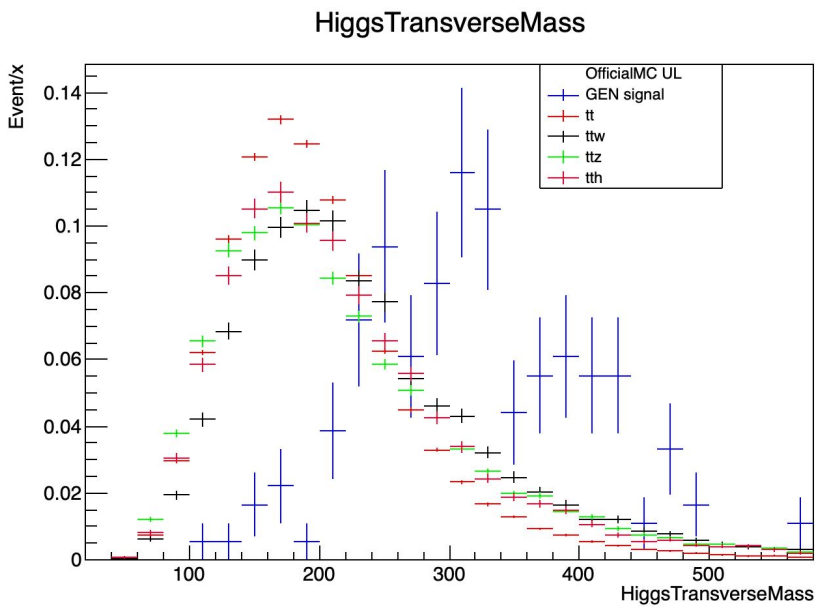
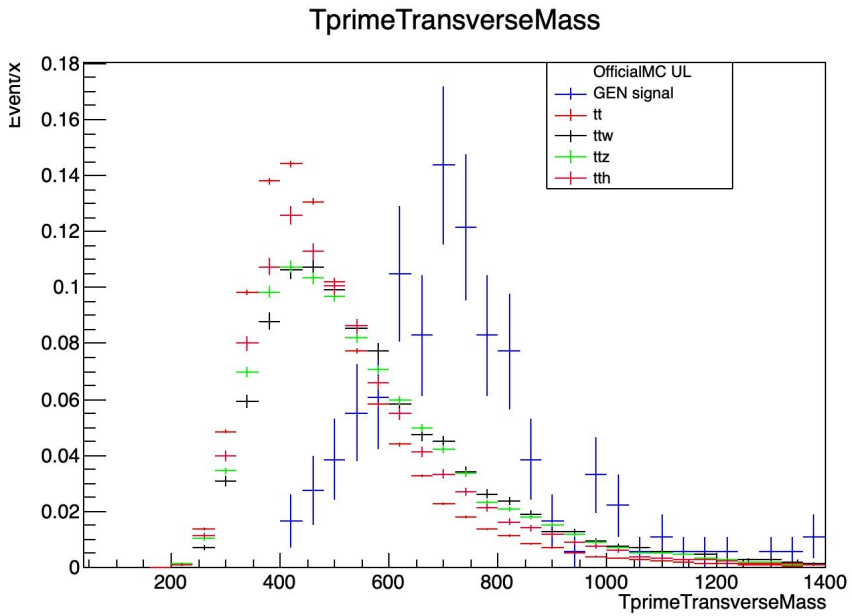


After Basic Cuts && Cut0

- **Higgs Tansverse Pt is a good variable to cut on**

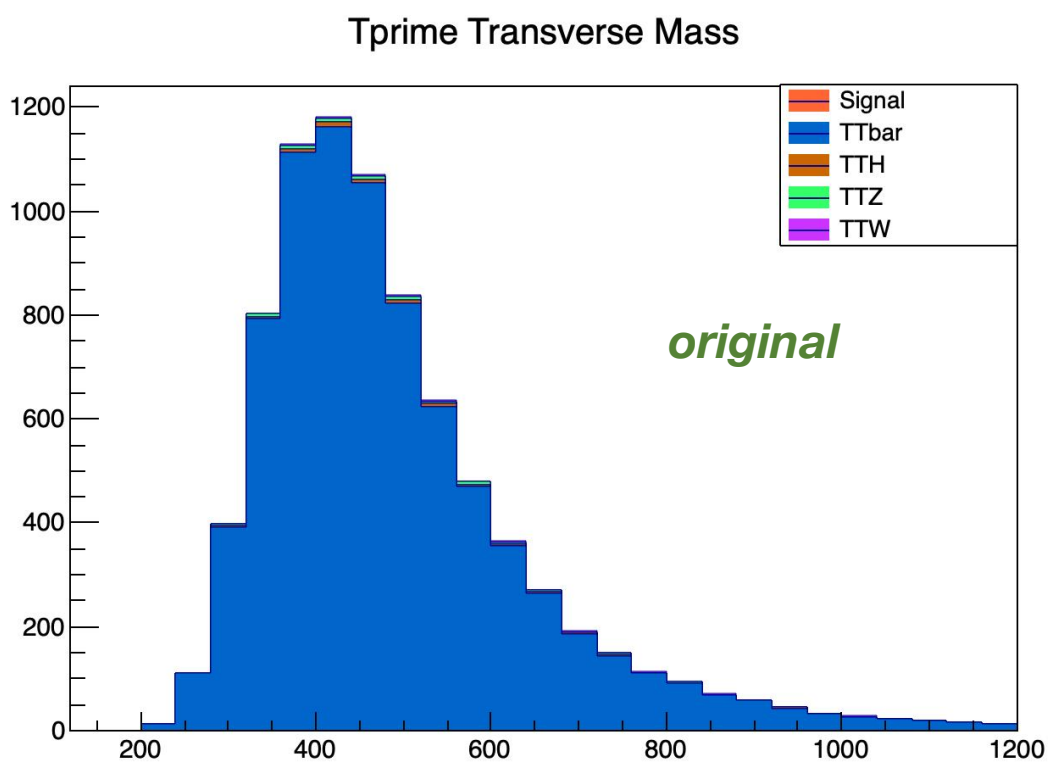


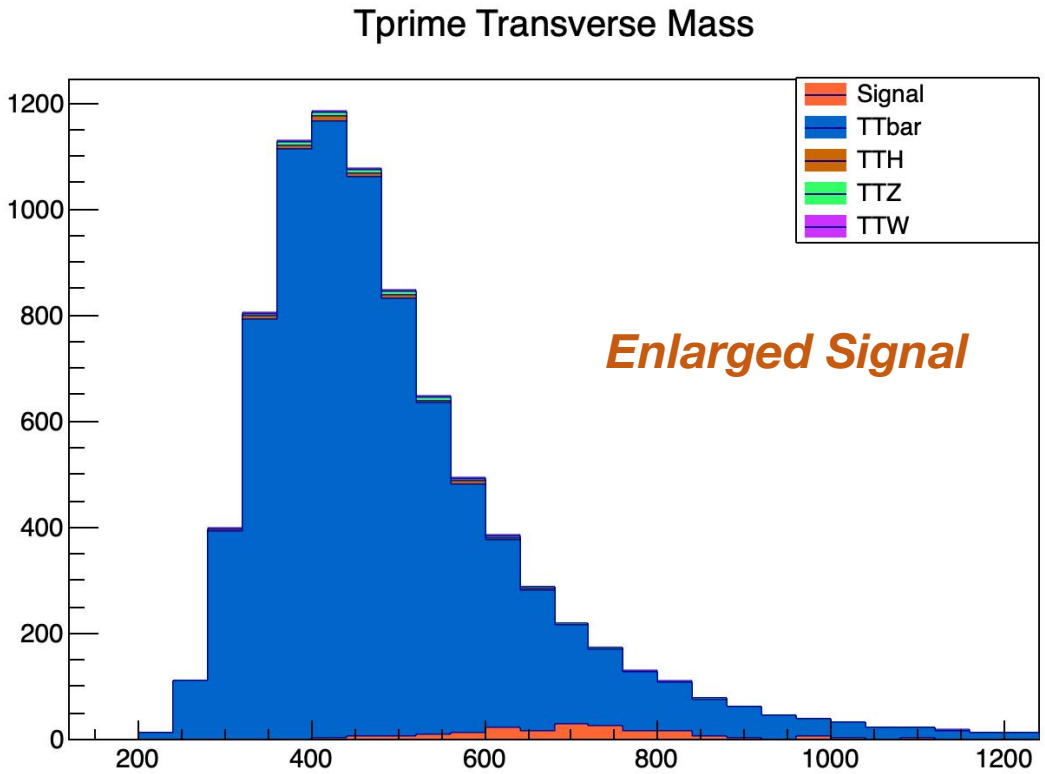




After Basic Cuts && Cut0

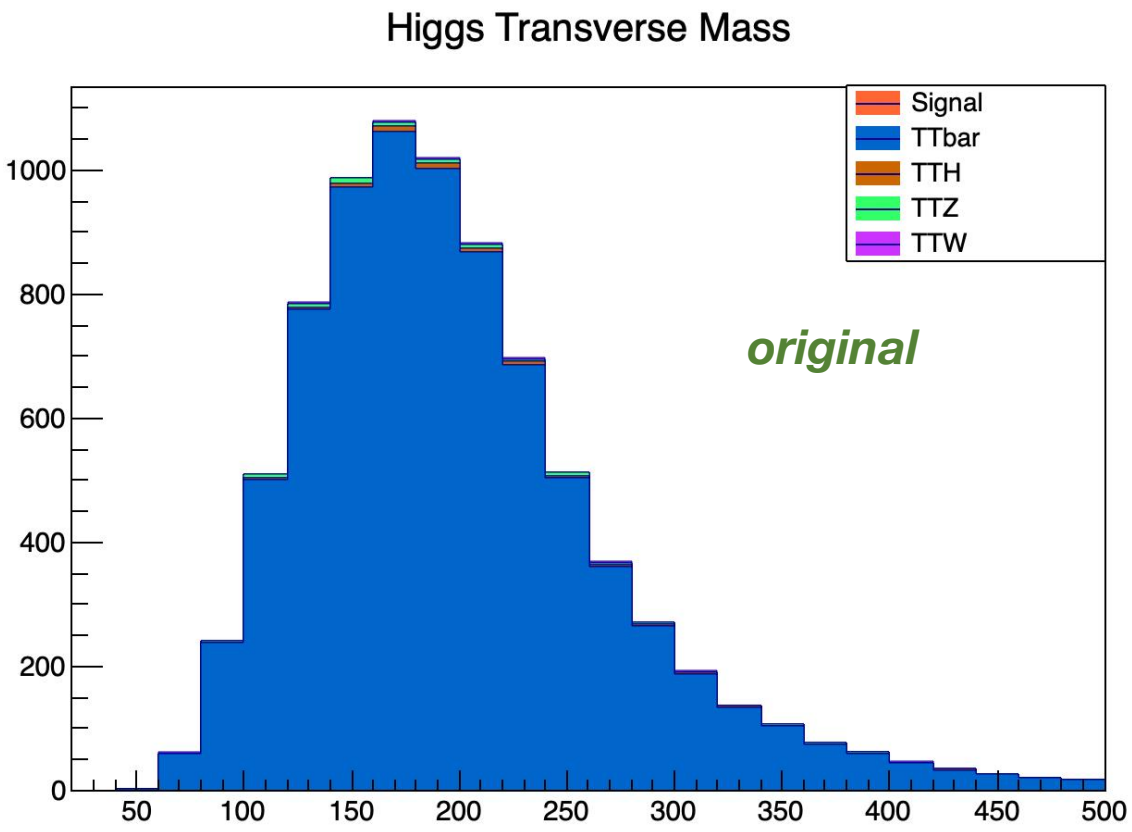
- **Stacked plot for Tprime Transverse Mass**
  - **Events number after scaling**
  - **Right plot: N_signal* 100**
    - **Just want to see the signal shape**

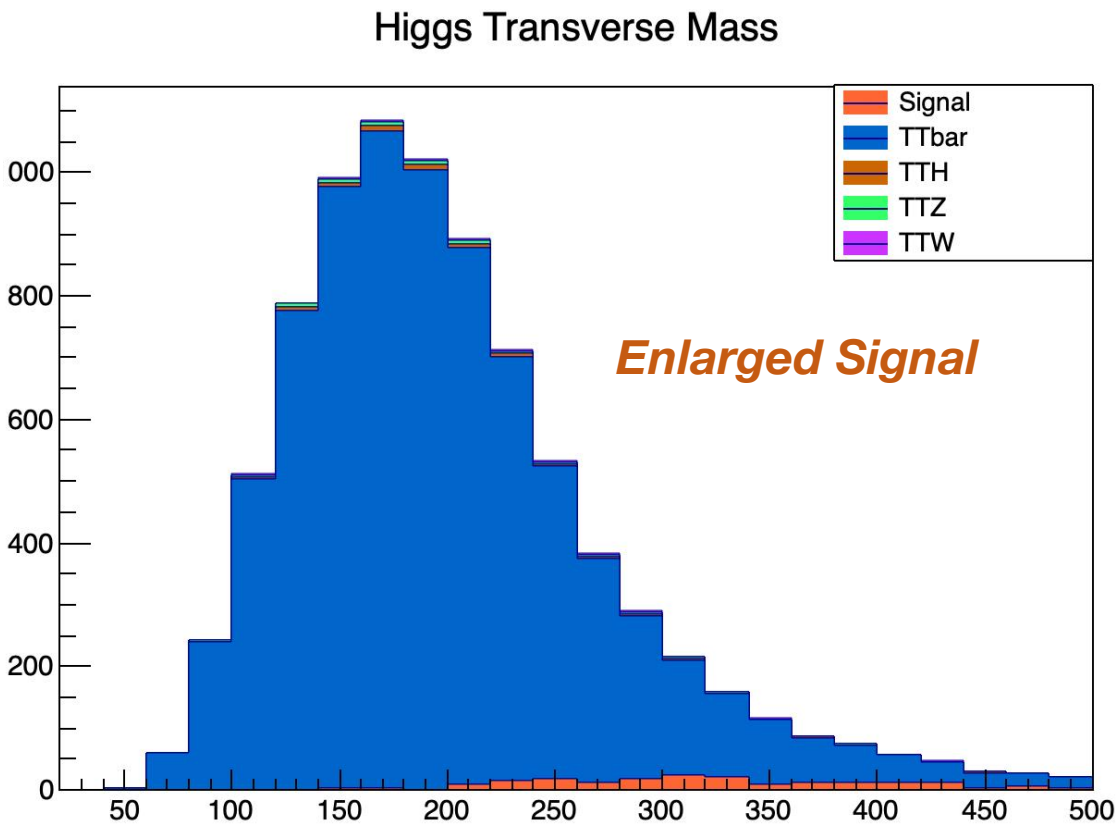




After Basic Cuts && Cut0

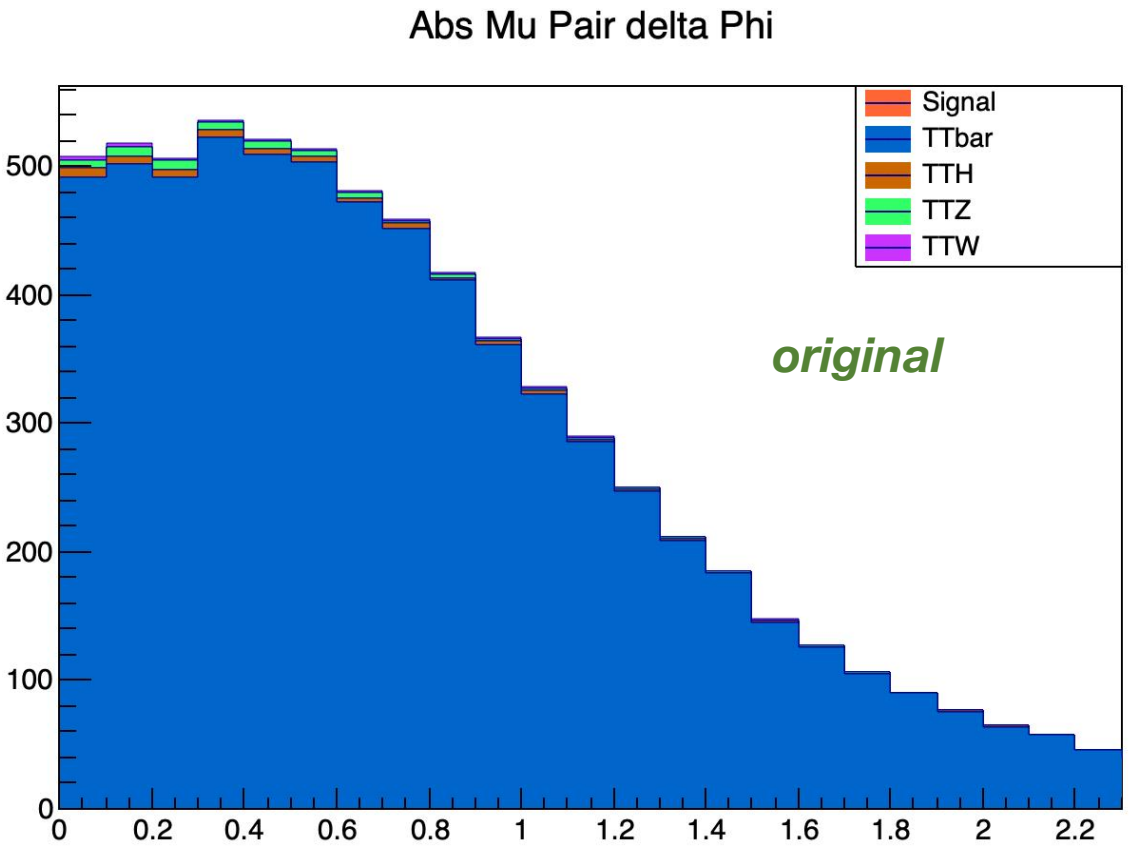
- **Stacked plot for Higgs Transverse Mass**
  - **Events number after scaling**
  - **Right plot: N_signal* 100**
    - **Just want to see the signal shape**

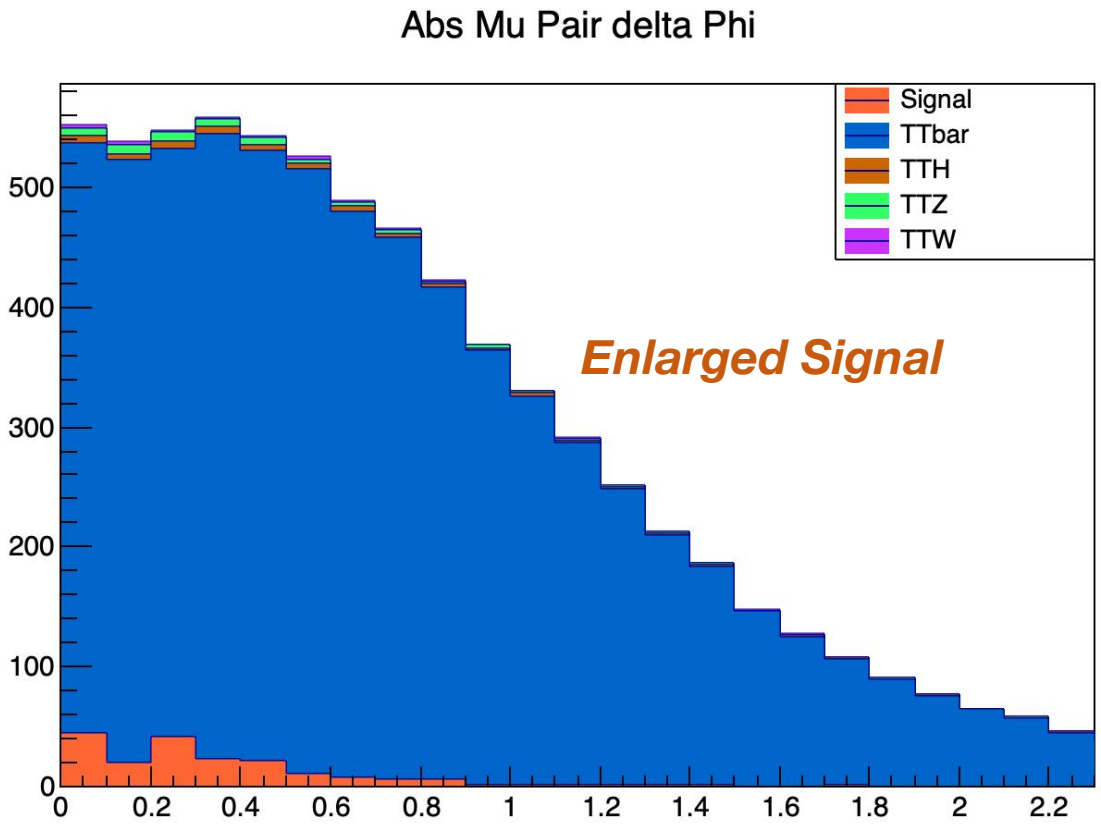




After Basic Cuts && Cut0

- **Stacked plot for absolute value of Mu Pair delta Phi**
  - **Events number after scaling**
  - **Right plot: N_signal* 100**
    - **Just want to see the signal shape**





Cut1: Chi2 Sorting Algorithm

- **Apply χ^2 sorting algorithm described in AN-21-140 (line 210- 231)**
  - **Reconstruct top->Wb->qqb with 3 good jets**
  - **Loop on all selected jets, select two jets, make a W candidate and evaluate the χ^2_W part**
  - **Loop on all selected b-tag jets, reject the jets used for the W candidate, select one b-tag jet and combine it with the W candidate and evaluate the χ^2_{top} part. The sum of χ^2_W and χ^2_{top} is then minimised**
  - **Cut on χ^2 ($\chi^2_W + \chi^2_{top}$)**

$$\chi^2_w = \frac{(M_W - M_{jj})^2}{\sigma^2_W}$$

$$\chi^2_{top} = \frac{(M_t - M_{bjj})^2}{\sigma^2_t}$$

$$\chi^2 = {\chi_w}^2 + {\chi_{top}}^2$$

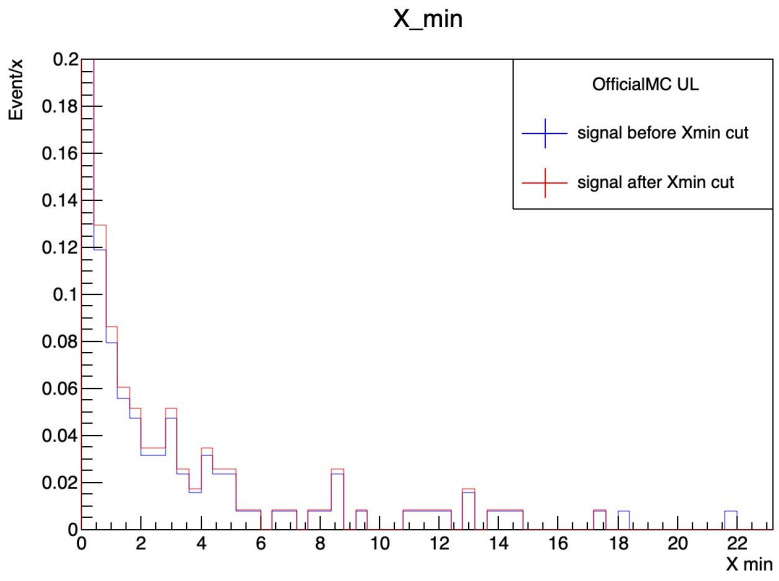
Table 1: Value of masses/σ used to build the χ^2 in the case of using the value from observed reconstructed masses in 2016, in 2017 UL and in 2018 UL.

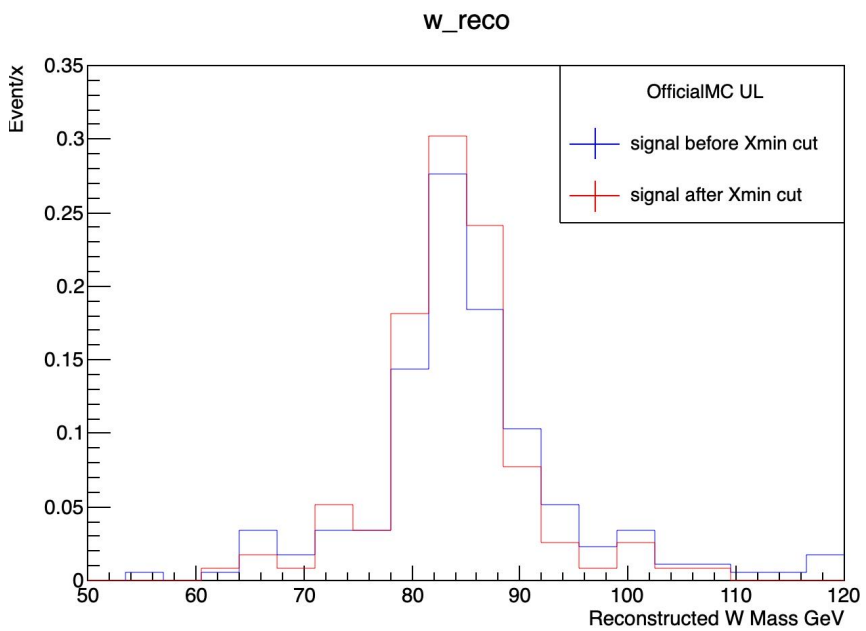
from AN-21-140

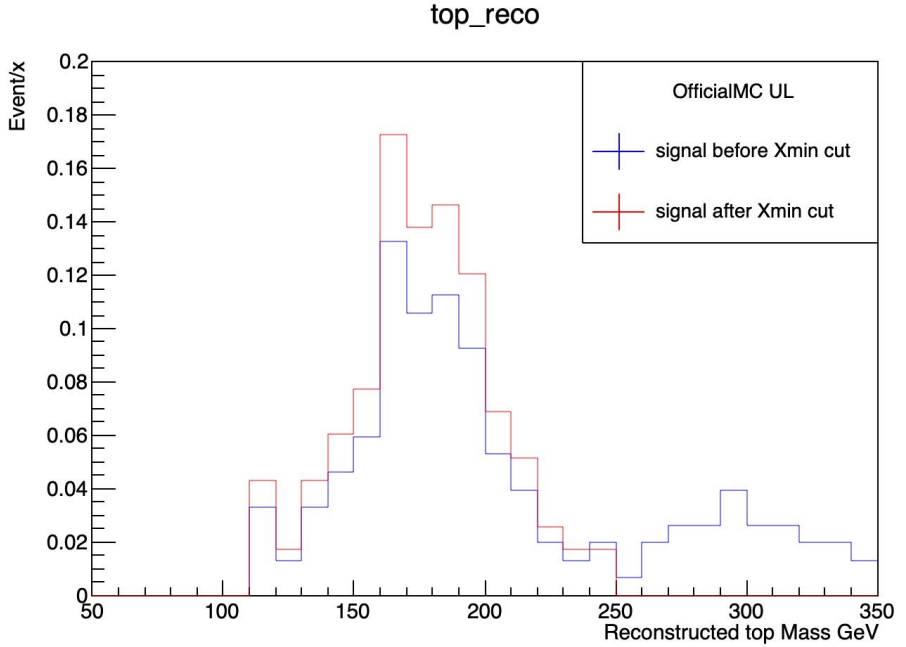
Particles	Reconstructed Masses			Reconstructed σ		
	2016	2017 UL	2018 UL	2016	2017 UL	2018 UL
M_Z	90.9 ± 0.4 GeV/c^2	89.2 ± 0.3 GeV/c^2	90.9 ± 0.3 GeV/c^2	11.4 ± 0.4 GeV/c^2	12.0 ± 0.3 GeV/c^2	11.3 ± 0.2 GeV/c^2
M_H	121.9 ± 1.1 GeV/c^2	118.9 ± 0.2 GeV/c^2	120.2 ± 0.3 GeV/c^2	13.5 ± 1.1 GeV/c^2	14.7 ± 0.2 GeV/c^2	14.3 ± 0.2 GeV/c^2
M_W	83.8 ± 0.8 GeV/c^2	82.5 ± 0.2 GeV/c^2	83.9 ± 0.2 GeV/c^2	10.9 ± 0.2 GeV/c^2	12.6 ± 0.2 GeV/c^2	10.8 ± 0.2 GeV/c^2
M_t	173.8 ± 1.3 GeV/c^2	172.8 ± 0.3 GeV/c^2	175.9 ± 0.4 GeV/c^2	16.0 ± 1.0 GeV/c^2	18.9 ± 0.3 GeV/c^2	17.2 ± 0.3 GeV/c^2

Chi2 Sorting Algorithm for Jets

- **Better W and top reconstruction after $\chi^2 < 18$**





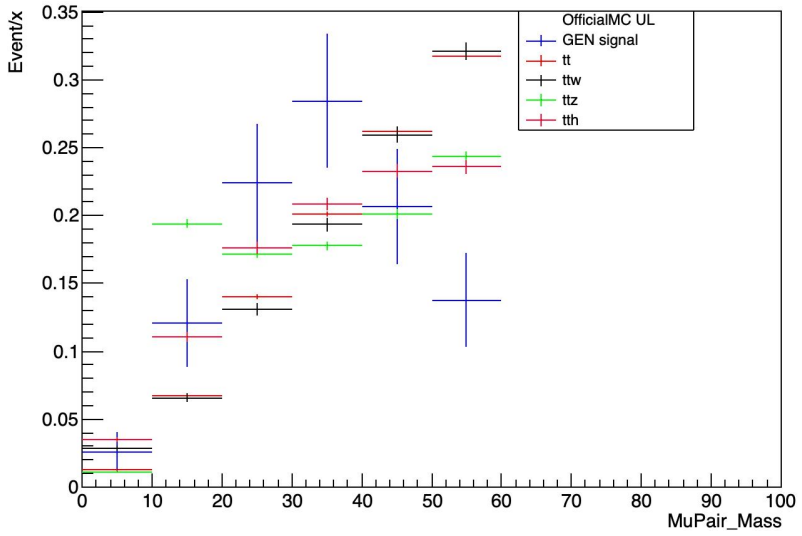


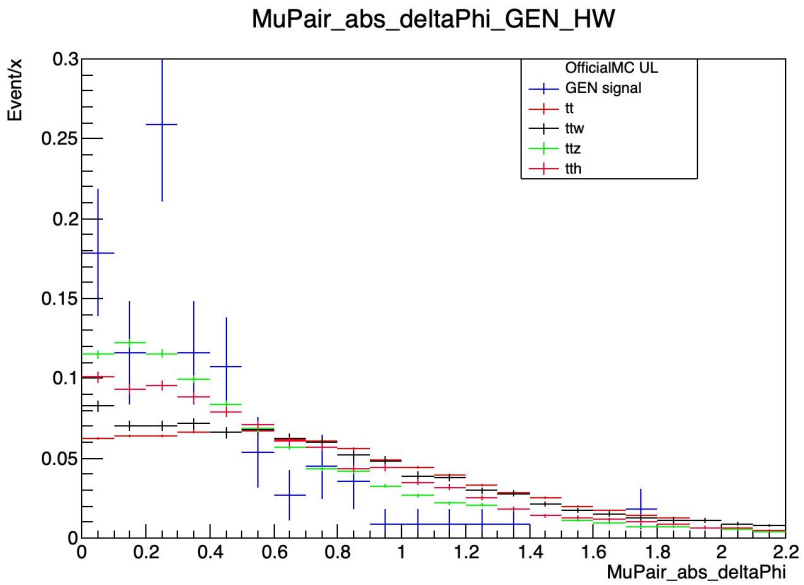
Cut1: Xmin < 18

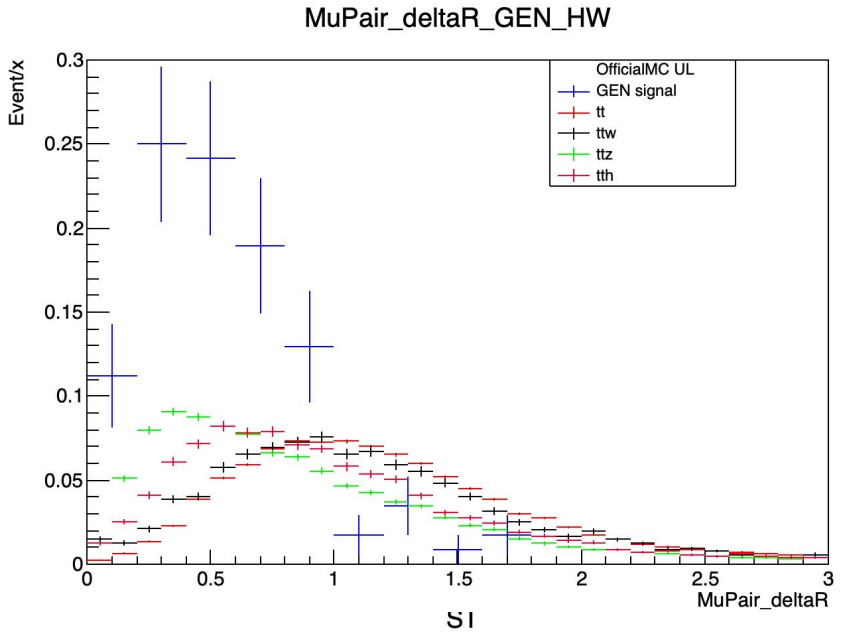
- **Cut1 is for better top reconstruction**
  - **Let's keep it even it casue S/B decrease**

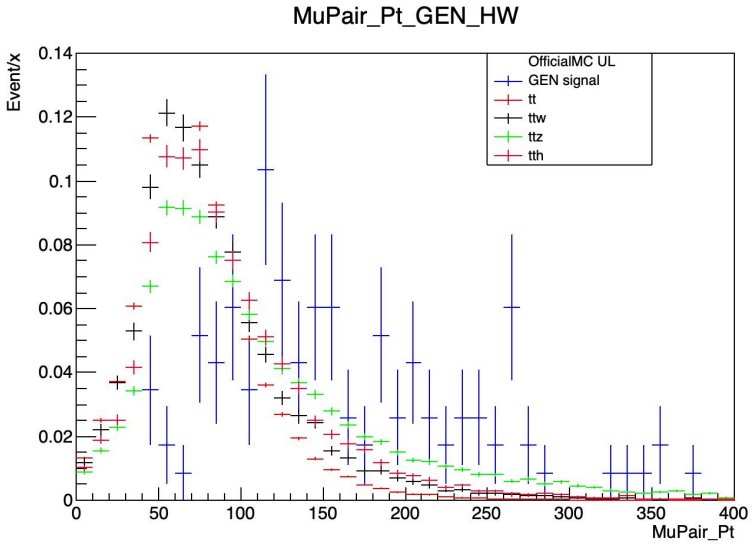
Cuts	N_signal (89fb)	N_signal GEN (89fb)	Signal ϵ	Signal Purity	N_TTbar (87315fb)	N_WW&WZ (12178 fb)	N_TTZ (770 fb)	N_TTH (271fb)	N_TTW (610.5 fb)	S(GEN)/B
Basic cuts	9.53	2.25	100%	24%	36878	75	883	205	182	0.006%
Basic cut && cut0	3.87	2.03	90%	52%	8076	1 (ignore it)	63	65	28	0.025%
Basic cut && cut0 && cut1	2.41	1.30	58%	54%	5735	-	46	50	20	0.022%

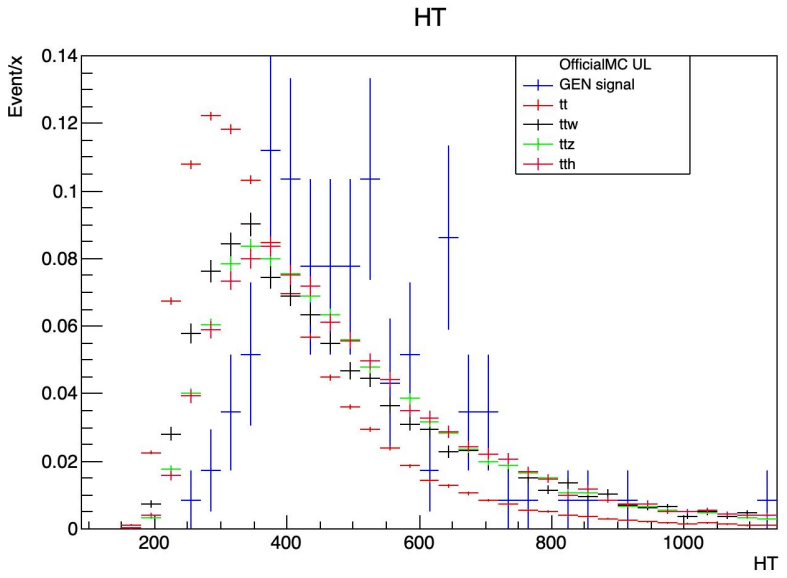
After Basic Cuts && Cut0 &&Cut1

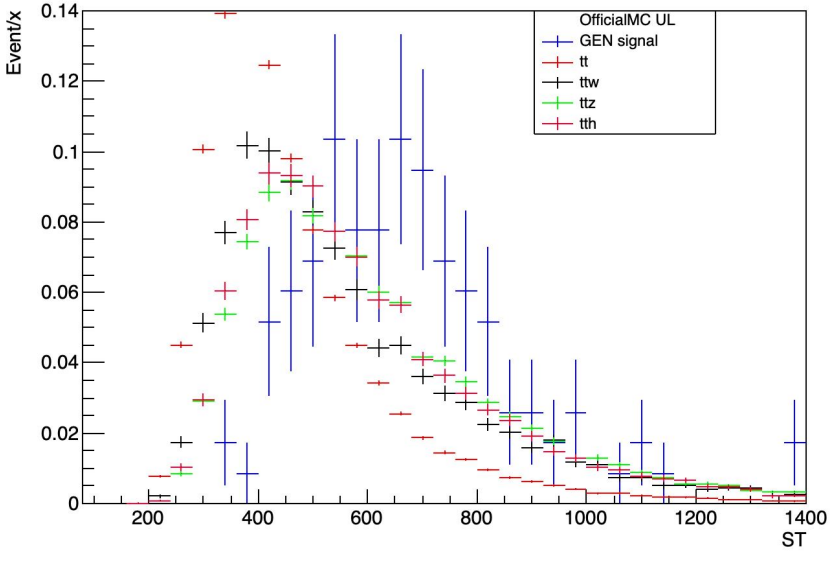




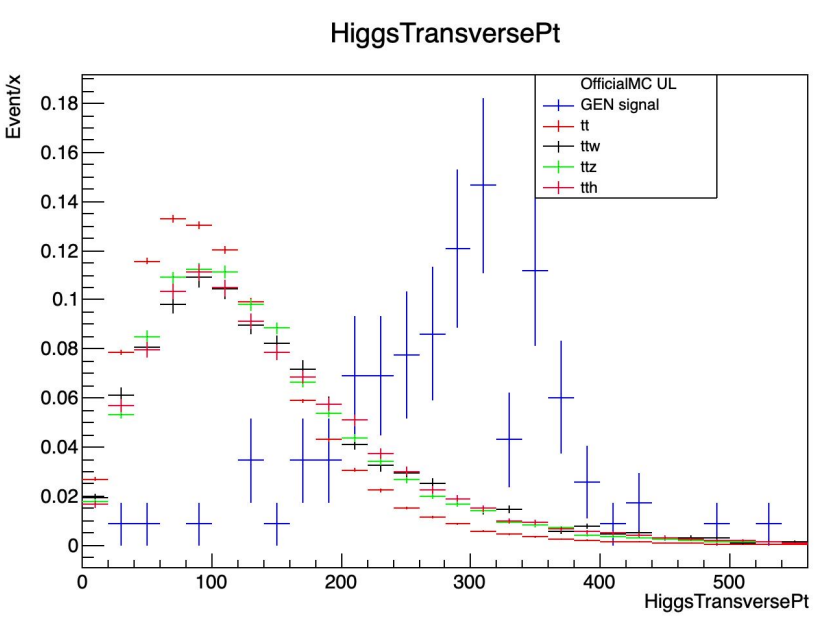


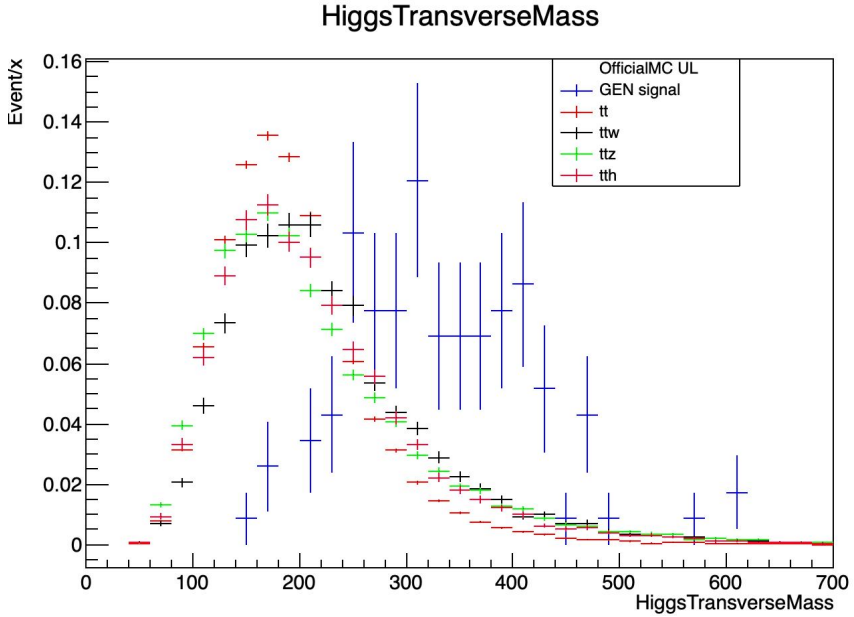


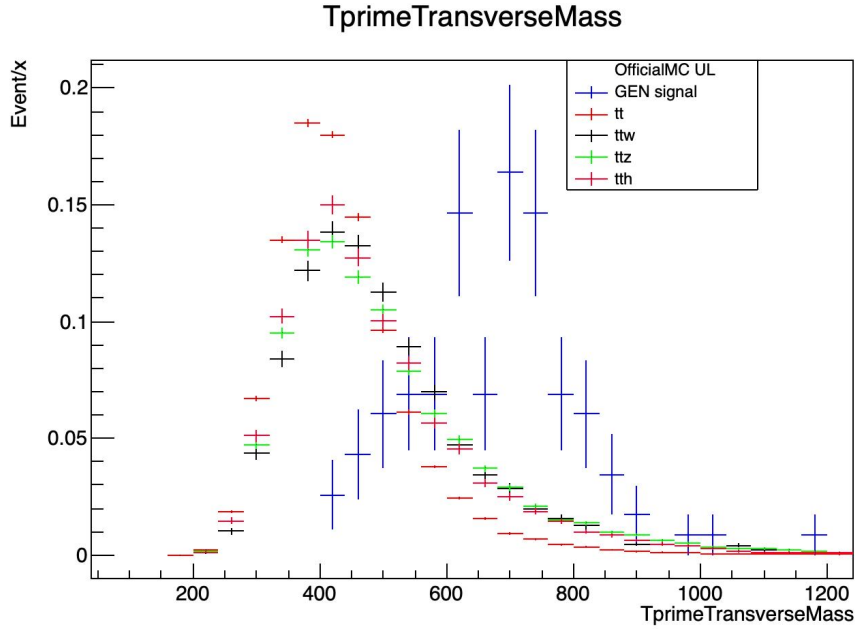




After Basic Cuts && Cut0 &&Cut1

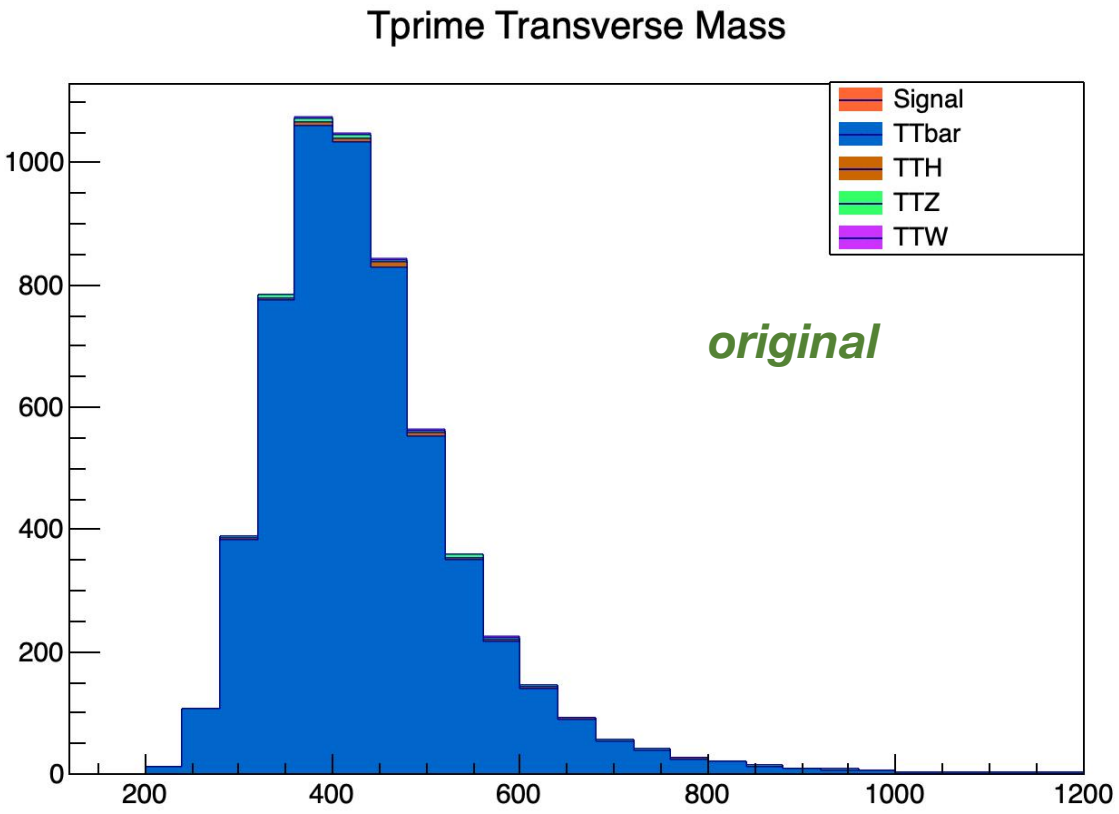


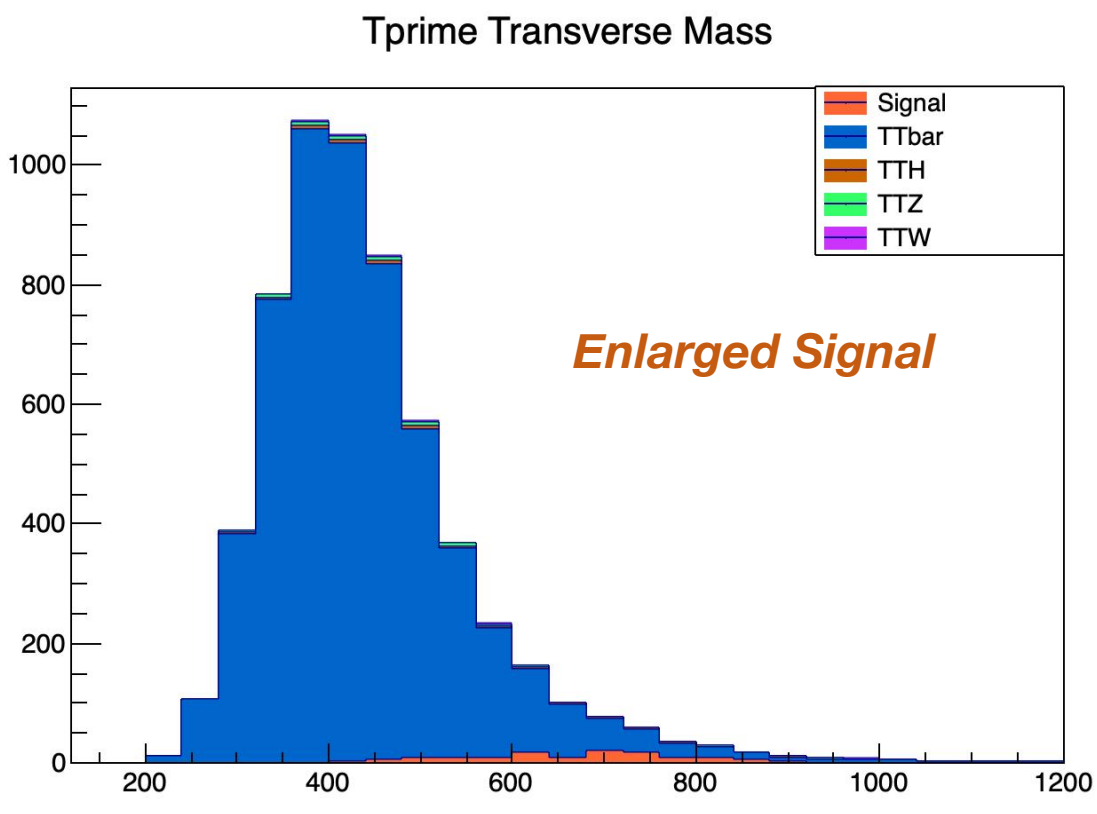




After Basic Cuts && Cut0

- **Stacked plot for Tprime Transverse Mass**
  - **Events number after scaling**
  - **Right plot: N_signal* 100**
    - **Just want to see the signal shape**





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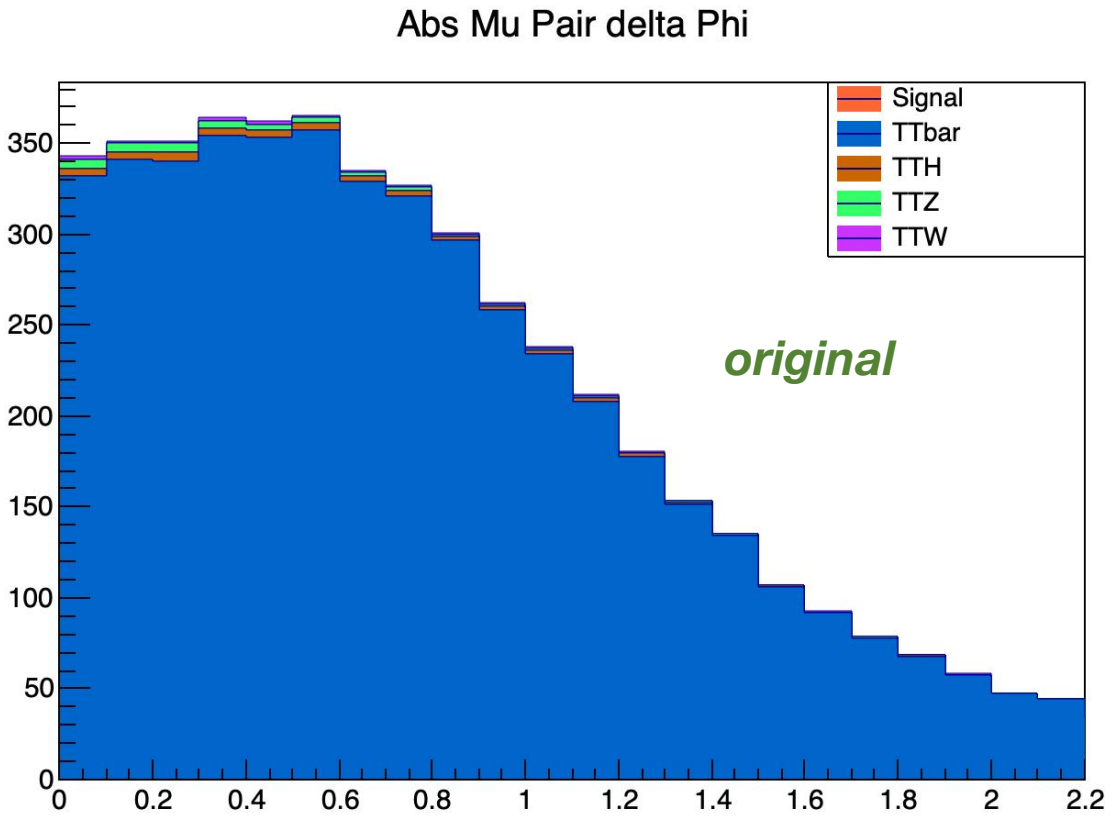
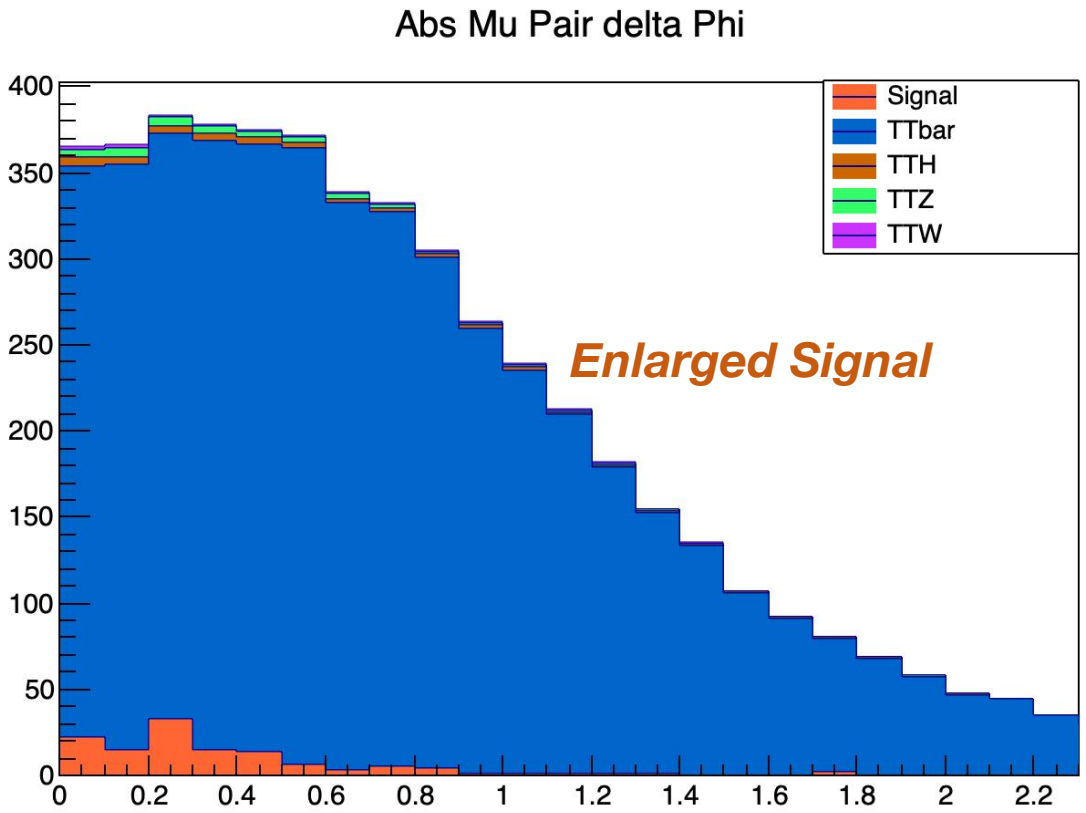
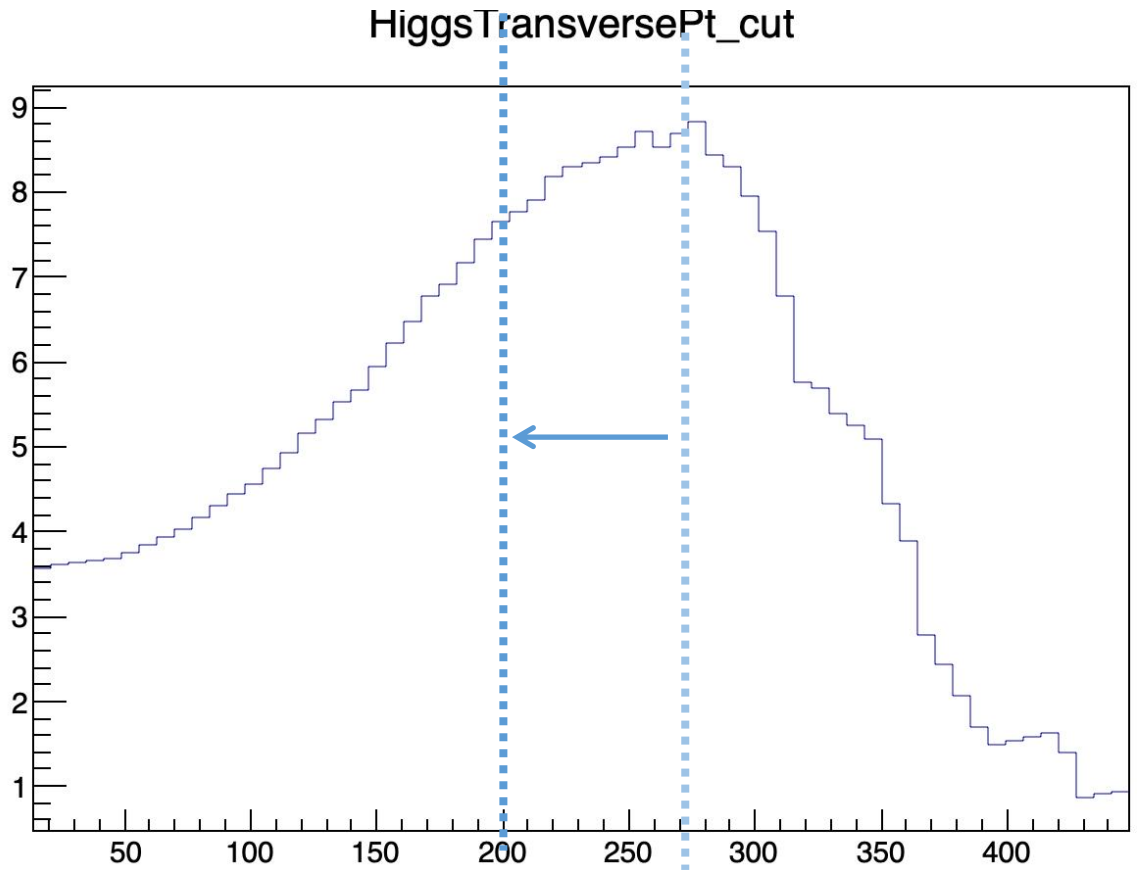




Cut2: Higgs Transverse pT > 200

- **Cut2: Higgs Transverse pt > 200 GeV**
  - **FOM = N_signal/(Sqrt(N_background+3/2))**
  - **Signal: 16 17 18 MC samples**
  - **Background: TTbar, ttW, ttZ, ttH (scaled)**
  - **Take 200GeV instead of 270GeV to improve fitting quality**



Cut2: Higgs Transverse pT > 200

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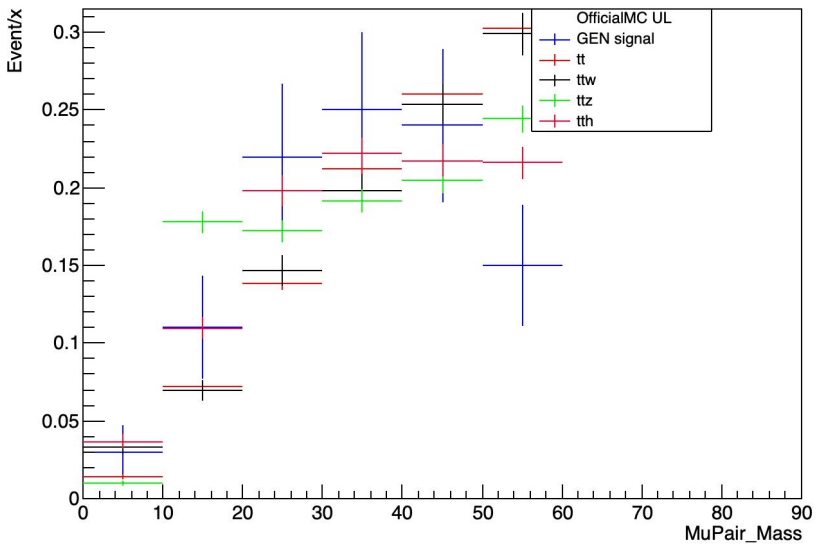
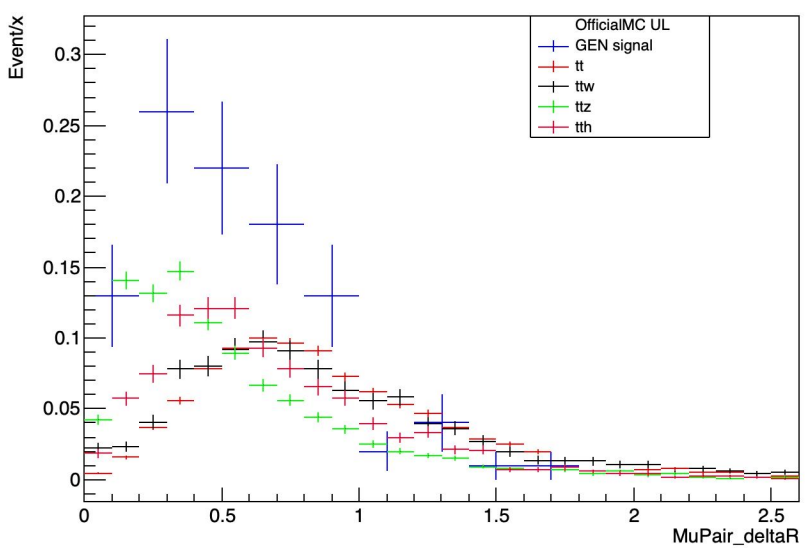
Basic cut && cut0 && cut1	2.41	1.30	58%	54%	5735	-	46	50	20	0.022%
Basic cut && cut0 && cut1 && cut2	1.64	1.12	50%	68%	661	-	9	11	4	0.164%

After Basic Cuts && Cut0 &&Cut1&& Cut2

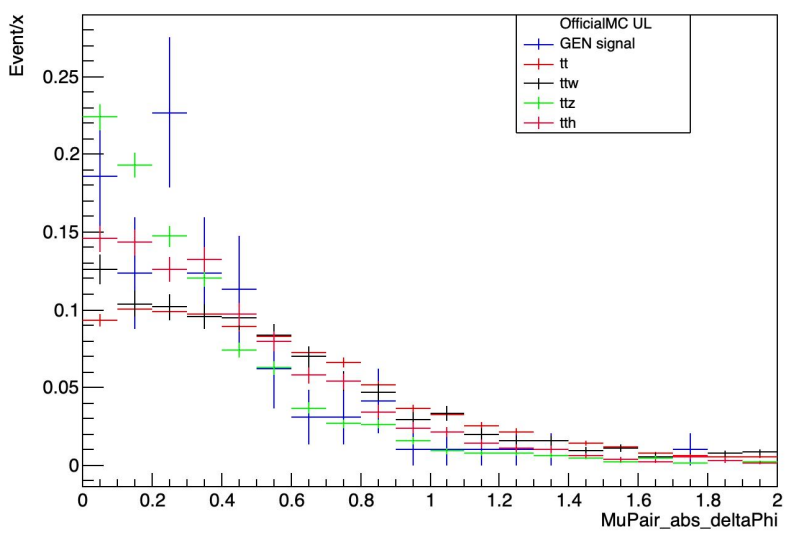
MuPair_Mass_GENWH



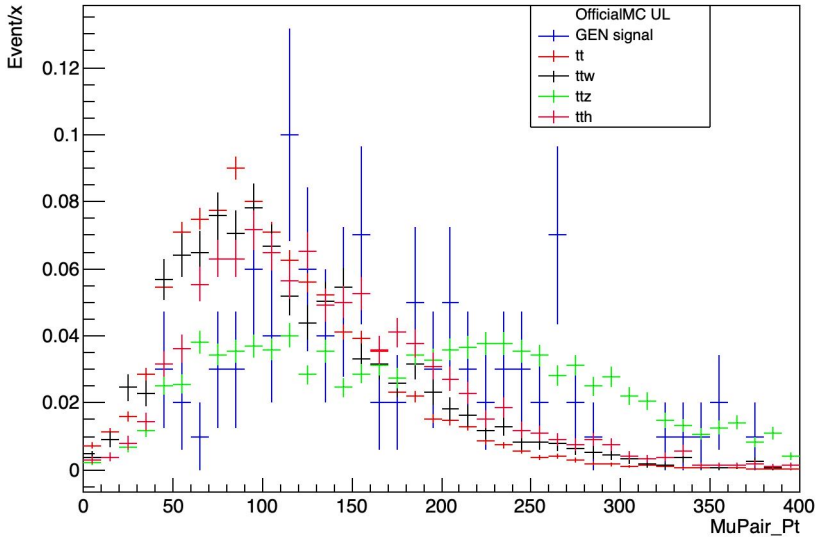
MuPair_deltaR_GEN_HW



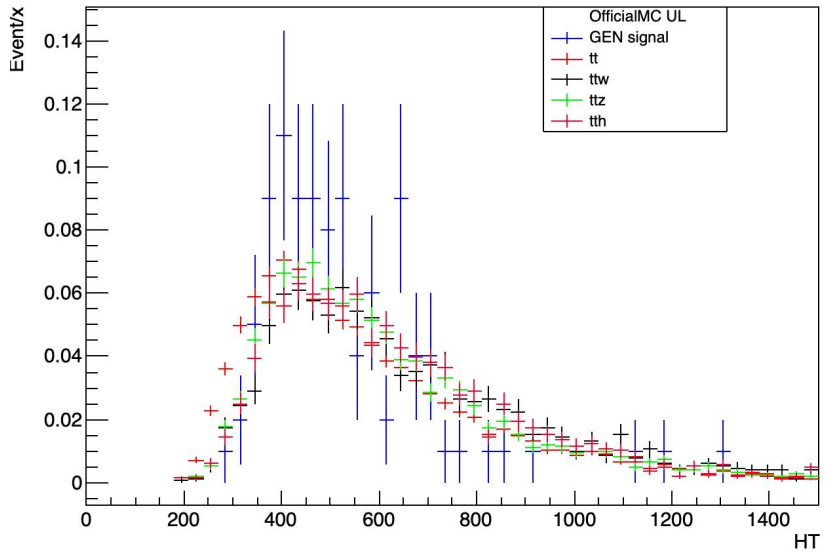
MuPair_abs_deltaPhi_GEN_HW



MuPair_Pt_GEN_HW



HT



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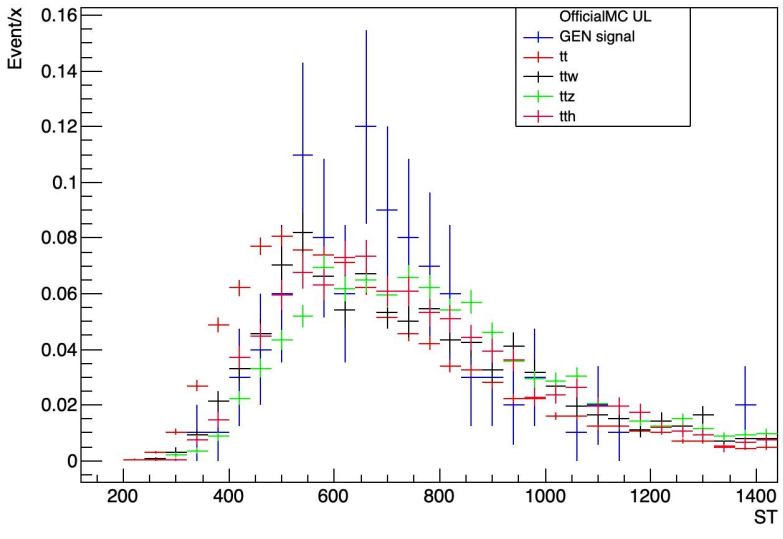
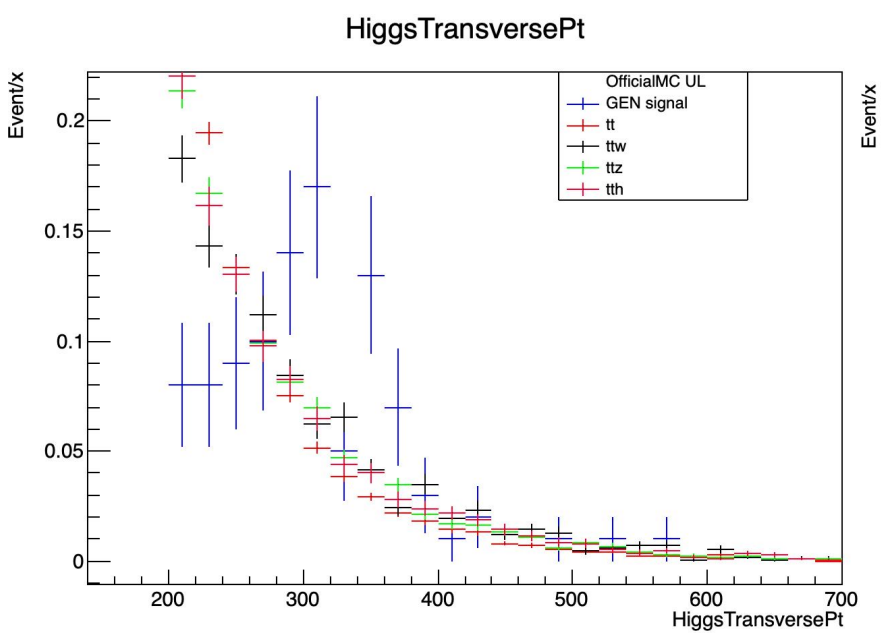
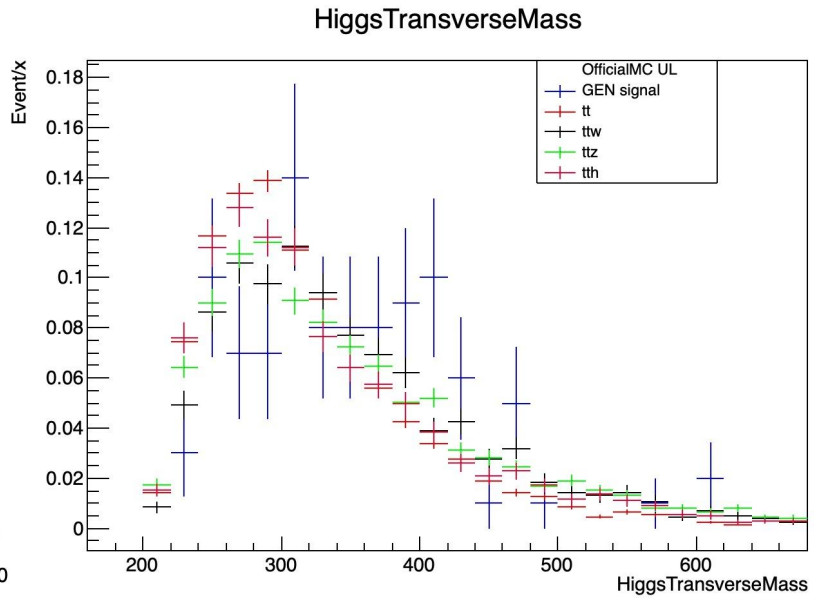
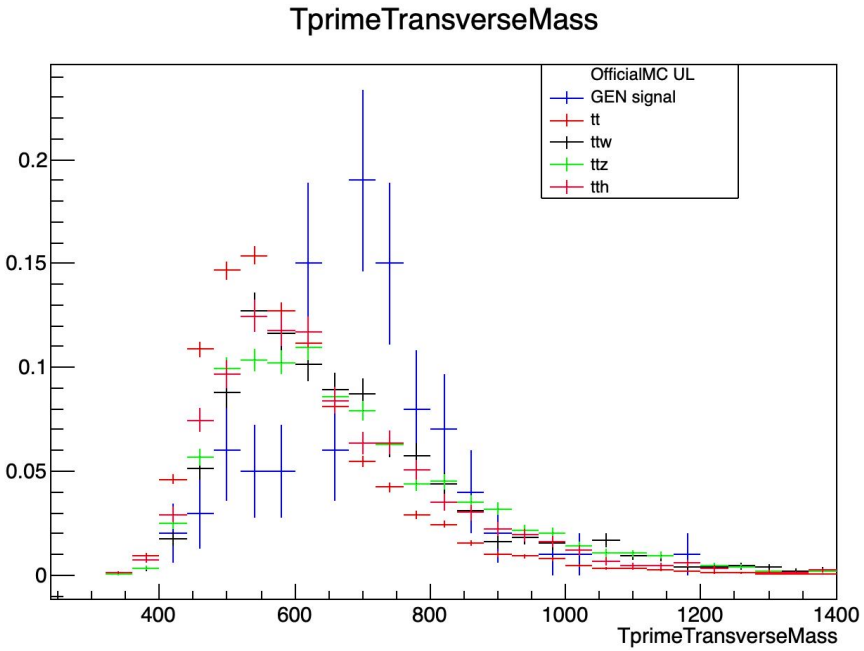


After Basic Cuts && Cut0 &&Cut1&& Cut2

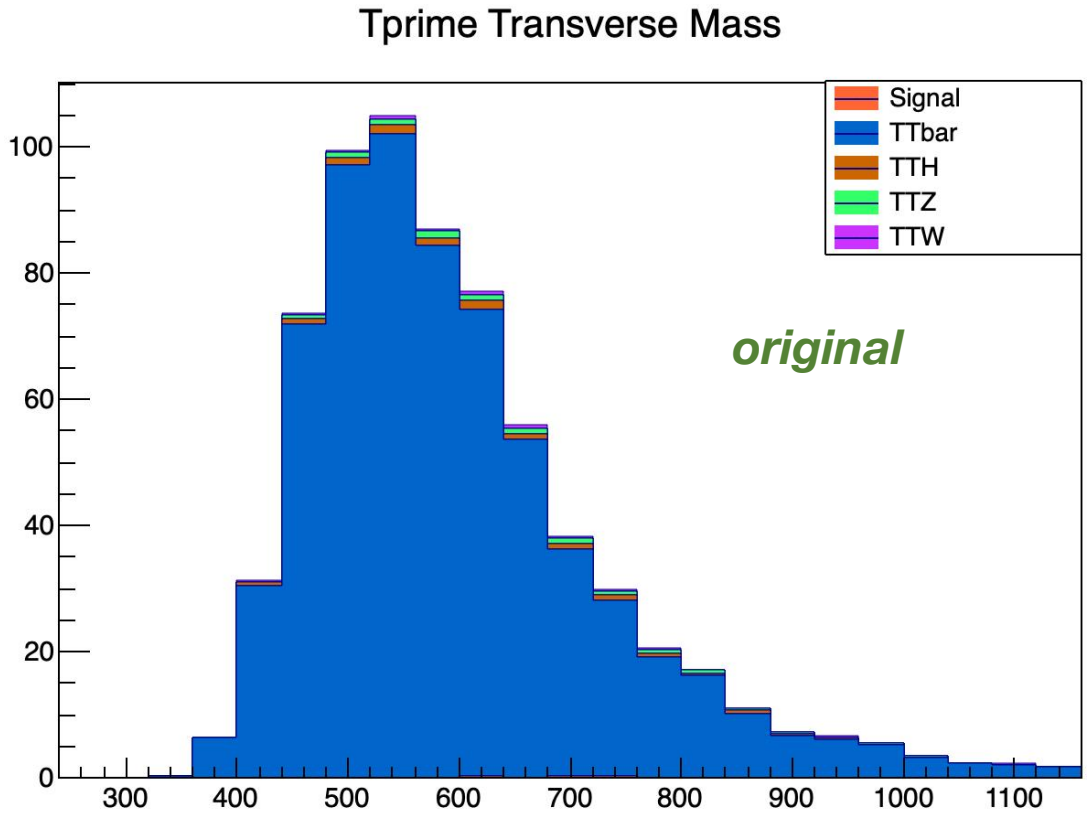


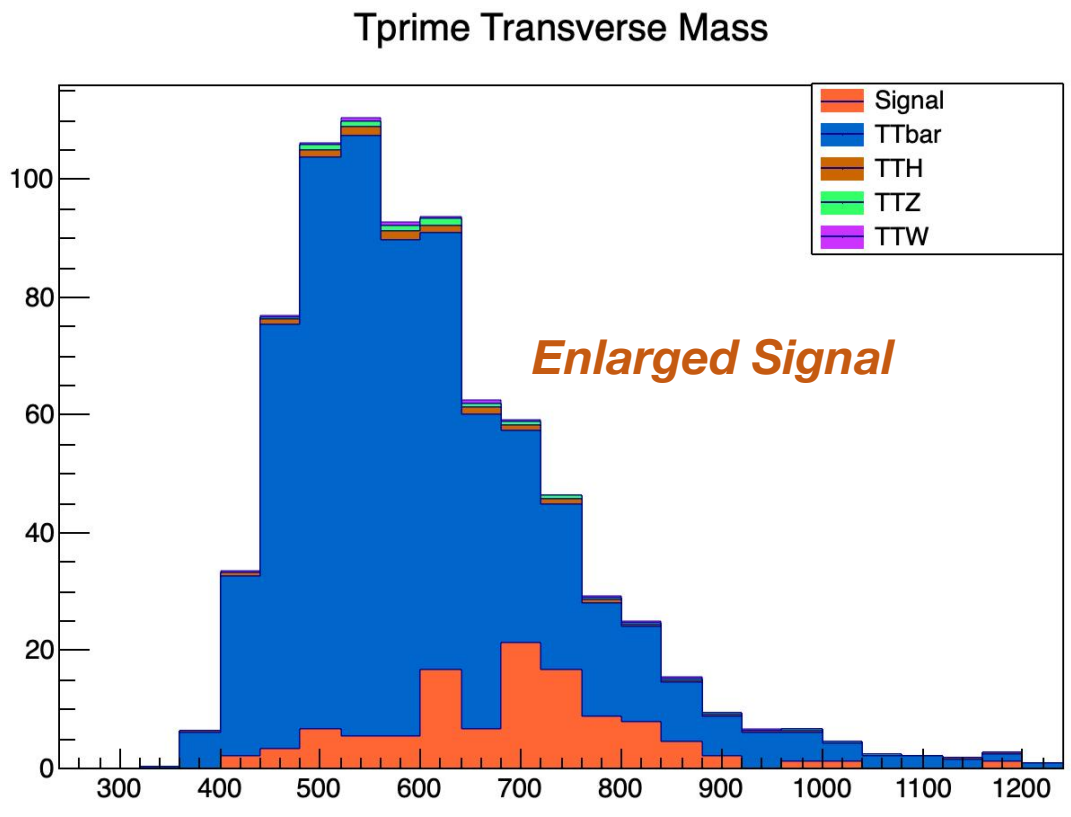




After Basic Cuts && Cut0 &&Cut1&& Cut2

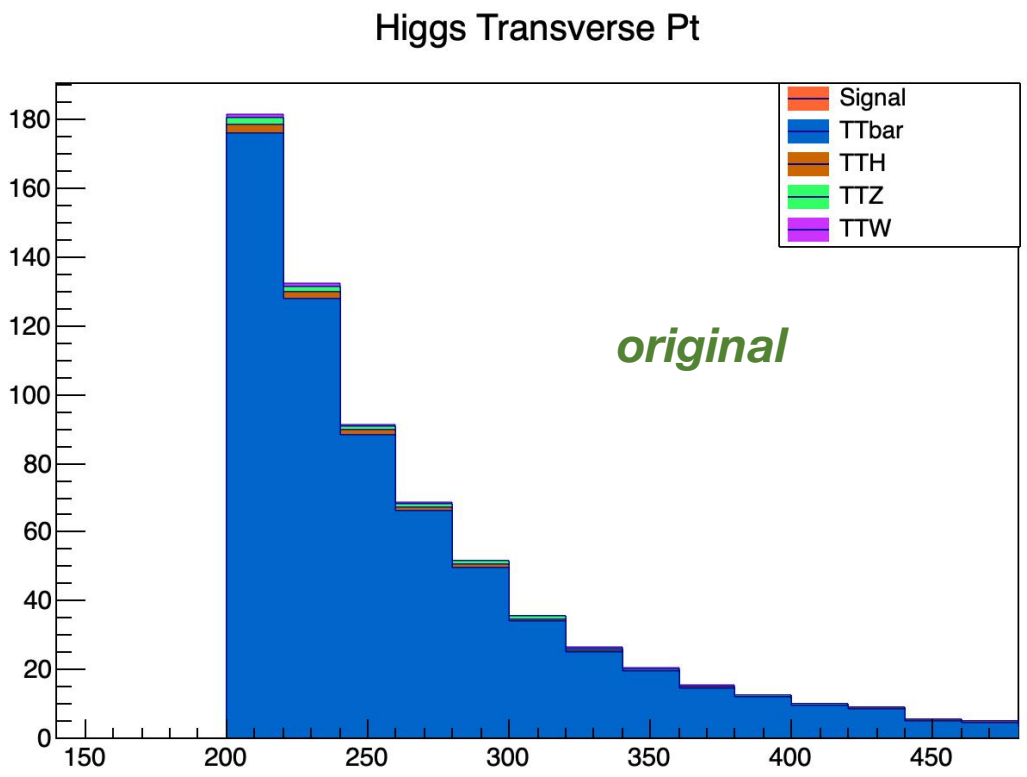
- **Stacked plot for Tprime Transverse Mass**
  - **Events number after scaling**
  - **Right plot: N_signal* 100**
    - **Just want to see the signal shape**
- **A good main variable?**

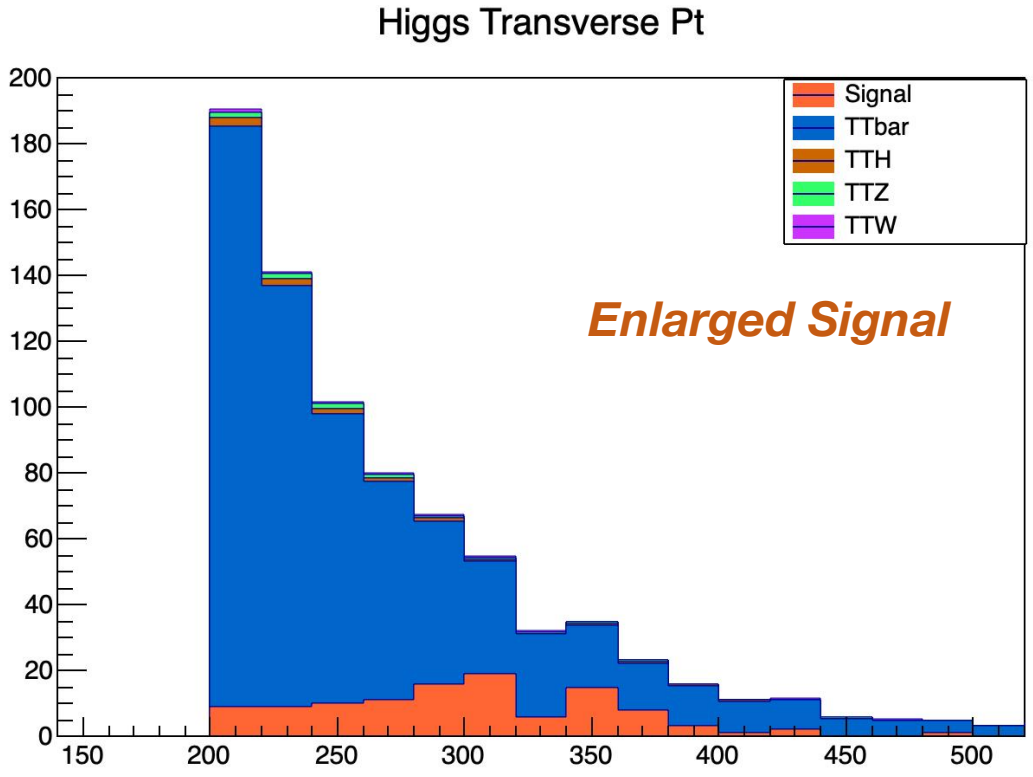




After Basic Cuts && Cut0 &&Cut1&& Cut2

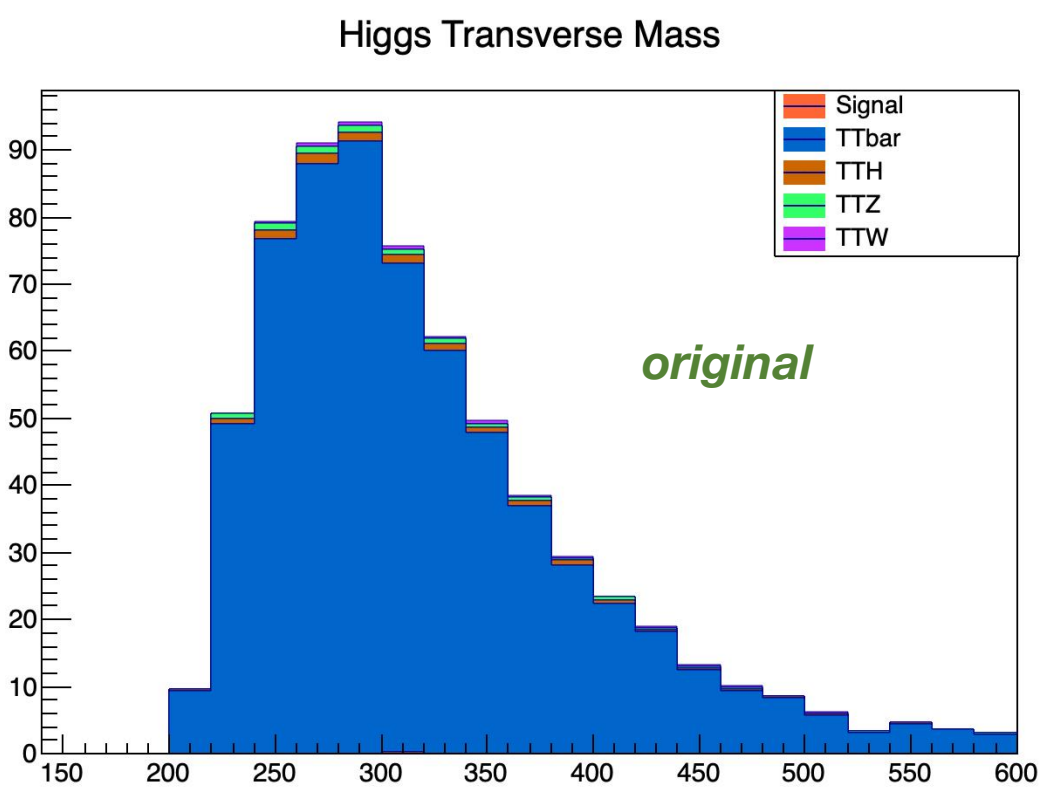
- **Stacked plot for Higgs Transverse Pt**
  - **Events number after scaling**
  - **Right plot: N_signal* 100**
    - **Just want to see the signal shape**
- **A good main variable?**
  - **Can we cut on main variables?**

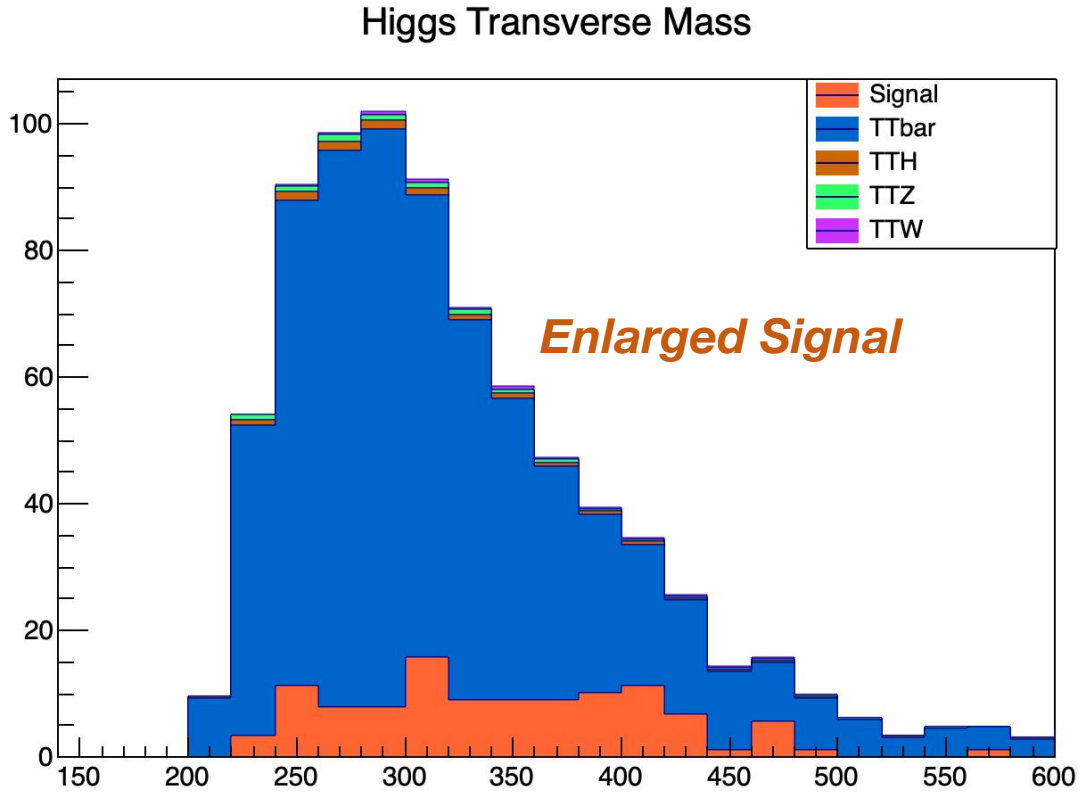




After Basic Cuts && Cut0 &&Cut1&& Cut2

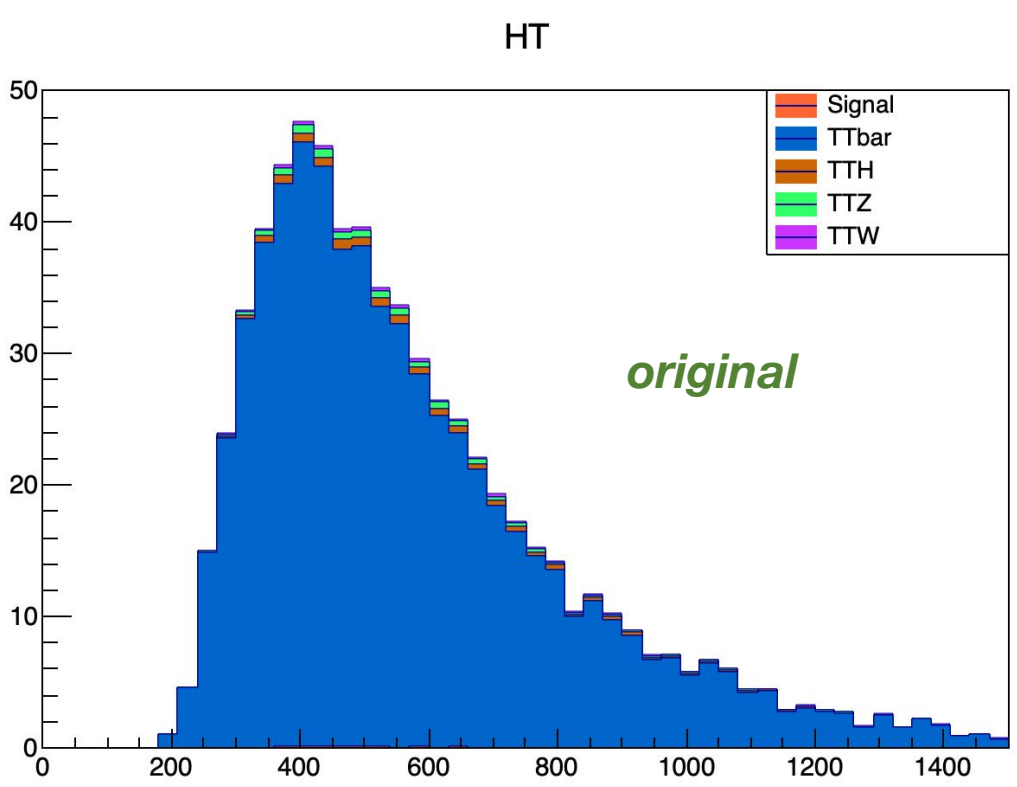
- **Stacked plot for Higgs Transverse Mass**
  - **Events number after scaling**
  - **Right plot: N_signal* 100**
    - **Just want to see the signal shape**

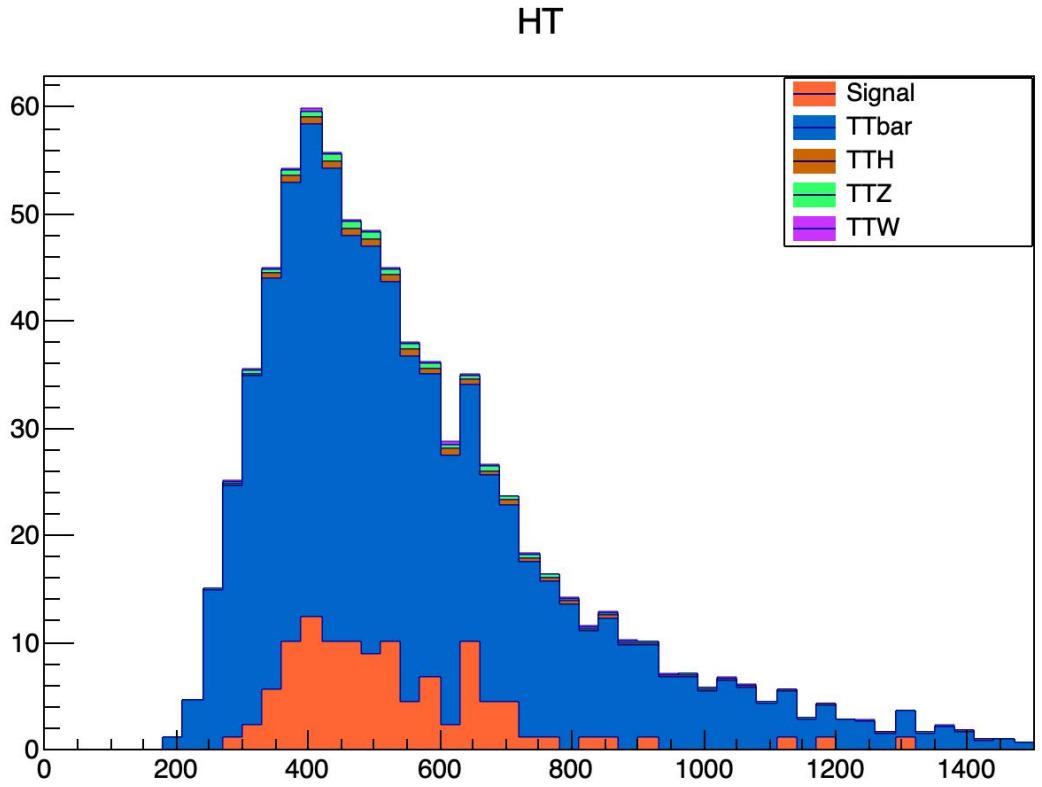




After Basic Cuts && Cut0 &&Cut1&& Cut2

- **Stacked plot for Higgs Transverse Mass**
  - **Events number after scaling**
  - **Right plot: N_signal* 100**
    - **Just want to see the signal shape**
- **A good main variable?**





Fly with HTCondor!

- **Analysis datasets within fly framework in HTCondor pool**
  - **Scripts are prepared for LPC server**
    - **Big bandwidth & less restrictions**
  - ***No long need to download nanoaod files to local machine!***
    - **Directly read root files from CMS das**
    - **Input: txt files contains nanoaod files name**
    - **VOMS certificate needed**
  - **Collect results at EOS space**
  - **Very effective for big MC samples (TTbar) ! && Save a lot of space!**

```
/store/mc/RunIIAutumn18NanoAOD/TprimeBToTH_M-700_LH_TuneCP5_PSweights_13TeV-madgraph_pythia8/NANOAODSIM/102X_upgrade2018_realistic_v15-v1/20000/474E140E-D6B8-8143-
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AE4B-83E3-42675828F48E.root
```

Input: 1 txt file

```
diwang@cmslpc147:/eos/uscms/store/user/diwang/VLQOutput$ls
TTLOS_Signal18_0.root          TTLOS_TTW18_29.root   TTLOS_TTZ18_16.root  TTLOS_TTZ18_42.root          TTLOS_WW18_26.root
TTLOS_Signal18_1.root          TTLOS_TTW18_3.root    TTLOS_TTZ18_17.root  TTLOS_TTZ18_43.root          TTLOS_WW18_3.root
TTLOS_Signal18_2.root          TTLOS_TTW18_30.root   TTLOS_TTZ18_18.root  TTLOS_TTZ18_44.root          TTLOS_WW18_4.root
TTLOS_Signal18_3.root          TTLOS_TTW18_31.root   TTLOS_TTZ18_19.root  TTLOS_TTZ18_45.root          TTLOS_WW18_5.root
TTLOS_Signal18_700_2_10.root   TTLOS_TTW18_32.root   TTLOS_TTZ18_2.root   TTLOS_TTZ18_46.root          TTLOS_WW18_6.root
TTLOS_Signal18_700_2_11.root   TTLOS_TTW18_33.root   TTLOS_TTZ18_20.root  TTLOS_TTZ18_47.root          TTLOS_WW18_7.root
TTLOS_Signal18_700_2_12.root   TTLOS_TTW18_34.root   TTLOS_TTZ18_21.root  TTLOS_TTZ18_48.root          TTLOS_WW18_8.root
TTLOS_TTW18_0.root             TTLOS_TTW18_35.root   TTLOS_TTZ18_22.root  TTLOS_TTZ18_49.root          TTLOS_WW18_9.root
TTLOS_TTW18_1.root             TTLOS_TTW18_36.root   TTLOS_TTZ18_23.root  TTLOS_TTZ18_5.root           TTLOS_WZ18_10.root
TTLOS_TTW18_10.root            TTLOS_TTW18_37.root   TTLOS_TTZ18_24.root  TTLOS_TTZ18_50.root          TTLOS_WZ18_11.root
TTLOS_TTW18_11.root            TTLOS_TTW18_38.root   TTLOS_TTZ18_25.root  TTLOS_TTZ18_51.root          TTLOS_WZ18_13.root
TTLOS_TTW18_12.root            TTLOS_TTW18_39.root   TTLOS_TTZ18_26.root  TTLOS_TTZ18_6.root           TTLOS_WZ18_14.root
TTLOS_TTW18_13.root            TTLOS_TTW18_4.root    TTLOS_TTZ18_27.root  TTLOS_TTZ18_7.root           TTLOS_WZ18_15.root
TTLOS_TTW18_14.root            TTLOS_TTW18_40.root   TTLOS_TTZ18_28.root  TTLOS_TTZ18_8.root           TTLOS_WZ18_2.root
TTLOS_TTW18_15.root            TTLOS_TTW18_41.root   TTLOS_TTZ18_29.root  TTLOS_TTZ18_9.root           TTLOS_WZ18_3.root
TTLOS_TTW18_16.root            TTLOS_TTW18_5.root    TTLOS_TTZ18_3.root   TTLOS_TTbar18_all_condor.root TTLOS_WZ18_4.root
TTLOS_TTW18_17.root            TTLOS_TTW18_6.root    TTLOS_TTZ18_30.root  TTLOS_WW18_0.root            TTLOS_WZ18_5.root
TTLOS_TTW18_18.root            TTLOS_TTW18_7.root    TTLOS_TTZ18_31.root  TTLOS_WW18_1.root            TTLOS_WZ18_6.root
TTLOS_TTW18_19.root            TTLOS_TTW18_8.root    TTLOS_TTZ18_32.root  TTLOS_WW18_10.root           TTLOS_WZ18_8.root
TTLOS_TTW18_2.root             TTLOS_TTW18_9.root    TTLOS_TTZ18_33.root  TTLOS_WW18_11.root           TTLOS_WZ18_all.root
TTLOS_TTW18_20.root            TTLOS_TTW18_all.root  TTLOS_TTZ18_34.root  TTLOS_WW18_12.root           TTZ18all.root
TTLOS_TTW18_21.root            TTLOS_TTZ18_0.root    TTLOS_TTZ18_35.root  TTLOS_WW18_13.root           WW18all.root
TTLOS_TTW18_22.root            TTLOS_TTZ18_1.root    TTLOS_TTZ18_36.root  TTLOS_WW18_14.root           WW18test.root
TTLOS_TTW18_23.root            TTLOS_TTZ18_10.root   TTLOS_TTZ18_37.root  TTLOS_WW18_15.root           allWW18.root
TTLOS_TTW18_24.root            TTLOS_TTZ18_11.root   TTLOS_TTZ18_38.root  TTLOS_WW18_16.root           oldTTLOS_Signal18_all.root
TTLOS_TTW18_25.root            TTLOS_TTZ18_12.root   TTLOS_TTZ18_39.root  TTLOS_WW18_18.root           signal.root
TTLOS_TTW18_26.root            TTLOS_TTZ18_13.root   TTLOS_TTZ18_4.root   TTLOS_WW18_19.root
TTLOS_TTW18_27.root            TTLOS_TTZ18_14.root   TTLOS_TTZ18_40.root  TTLOS_WW18_20.root
TTLOS_TTW18_28.root            TTLOS_TTZ18_15.root   TTLOS_TTZ18_41.root  TTLOS_WW18_24.root
```

Output: root files

Summary

- **Summary**
  - **Study cut strategy**
    - **basic cuts**
    - **Cut0: Mu Pair Mass <60**
    - **Cut1: χ^2 < 18**
    - **Cut2: Higgs Transverse pt > 200 GeV**
  - **Check multi background**
    - **TTbar, TTZ, TTH, TTW and others**
  - **Find potential main variables**

- **To do list**
  - **Study main variables**
  - **Try to apply neural network?**
  - **Look at other lepton OS channels**
    - **e+e-, e-mu+, e+mu-**