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IHEP Framework Tutorial

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Scope of the code

Main goals

- Create a generic, highly customisable and easily configurable framework.
- Highly parallelisable to exploit Condor cluster

Inputs

- TNT/BOOM BSM framework trees,
  - This is, strictly, customisable, but in general it's built around the BSM trees
- Cut and object definitions

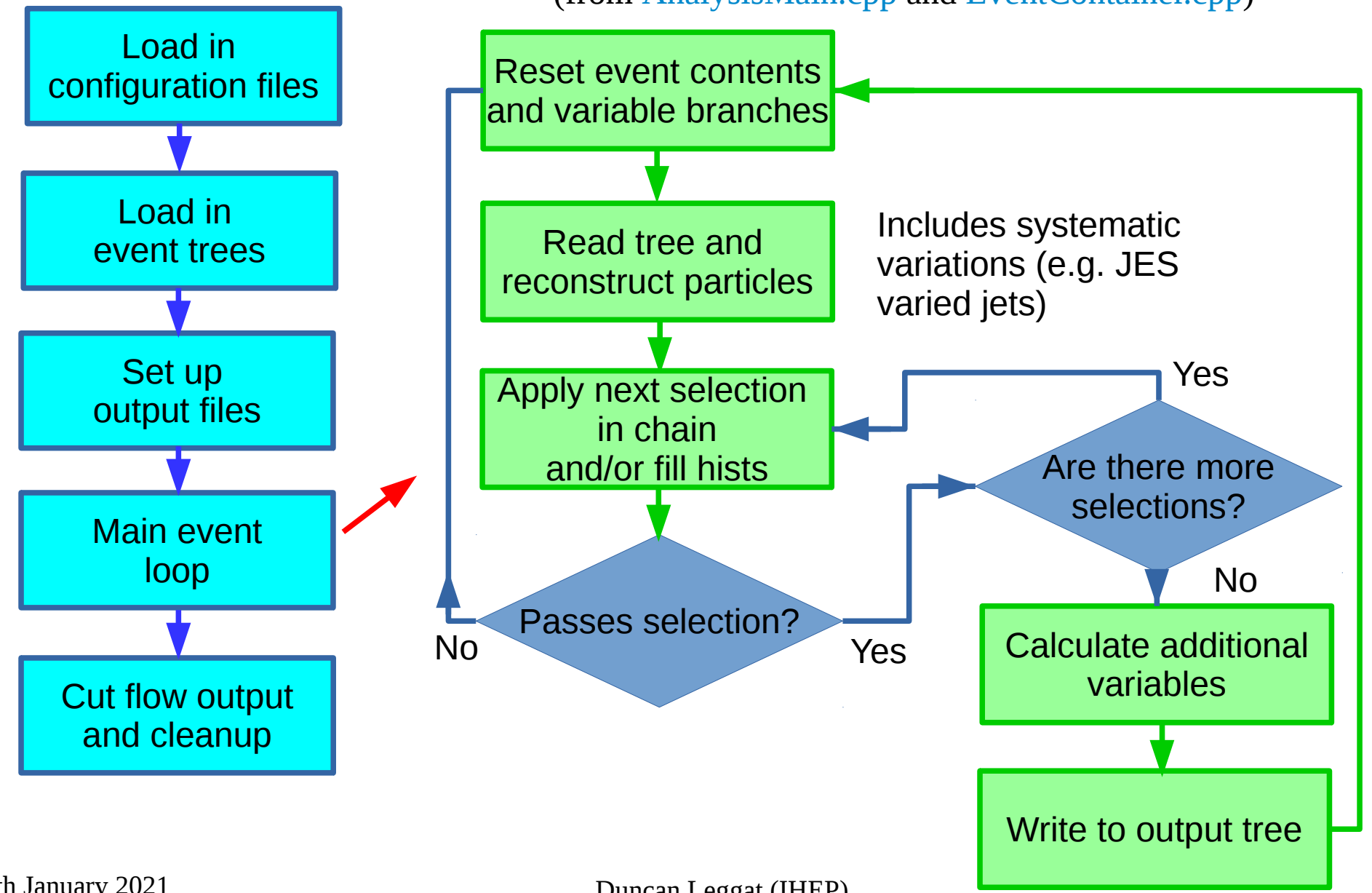
Action on trees

- Extract particles and apply all necessary/relevant corrections
- Apply customisable selection requirements
- Plot customisable histograms
- Calculate systematic uncertainties

Outputs

- Skimmed output tree (including additional variables)
- Histogram files

Flow of the code



Github frontpage

leggat / **tWIHEPFramework**

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master | 5 branches | 0 tags | Go to file | Add file | Code

leggat Moving the fill branches command so that it doesn't break weighting `016678f` 5 days ago | **267** commits

SingleTopRootAnalysis	Merge pull request #4 from leggat/nonStableJESChanges	2 months ago
bin/Wt	Setting up skim version of the code	2 months ago
config	Updating git ignores to clean up repository	2 months ago
macros/wt-channel/LP/config	Updating git ignores to clean up repository	2 months ago
src	Moving the fill branches command so that it doesn't break weighting	5 days ago
tmva	Merge pull request #4 from leggat/nonStableJESChanges	2 months ago
utils	Merge pull request #4 from leggat/nonStableJESChanges	2 months ago
.gitignore	Updating git ignores to clean up repository	2 months ago
Makefile	Setting up skim version of the code	2 months ago
README.md	Updating documentation	5 years ago
SingleTop.Wt.LP.mm1+j.muonMSS...	added main config file	5 years ago
newTest.sh	Update the test file	2 months ago

About

tW code based on IHEP framework

Readme

Releases

No releases published
Create a new release

Packages

No packages published
Publish your first package

Languages

C++ 85.3% | Python 12.5% | C 1.6% | Other 0.6%

Framework front page: https://github.com/leggat/tWIHEPFramework

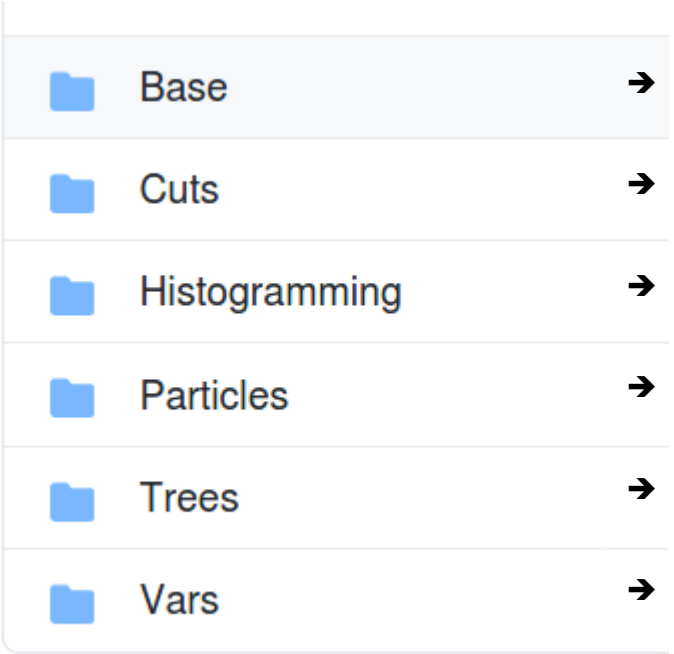
What's in each folder?

SingleTopRootAnalysis	→ Headers for all classes
bin/Wt	→ Analysis executables
config	→ Configuration files
macros/wt-channel/L…	→ Object and cut definitions
src	→ Source code for all classes
tmva	→ TMVA code
utils	→ Utilities
.gitignore	→ Git ignore file
Makefile	→ Make file
README.md	
SingleTop.Wt.LP.m…	
newTest.sh	→ Example to run Wt_generic.x

Key:
Main code
Configurations
tW-related code

Main code sub-directories

Main code directories found in SingleTopRootAnalysis (headers) and src (source)



- Base → Classes that govern the central running of the code
- Cuts → Event selections
- Histogramming → Classes for the production of histograms
- Particles → Definition of particles
- Trees → Event tree (makeclass output)
- Vars → Additional variables to store in output tree

Example executable

A bunch of pre-amble, but the important bit starts at l.225

Two main vectors to be customised:

Cut list mystudy.AddCut()

- Includes selection requirements and histogramming classes,
- Performed sequentially on each event until the event passes or fails a cut.

Additional variable list mystudy.AddVars()

- Add additional variables to the output skim tree,
- Performed to all events that pass selection.

```
225  ////////////////////////////////////////////////////////////////////////////
226  // Add Cuts and Histograms applicable to Fast and Full Analyses
227  ////////////////////////////////////////////////////////////////////////////
228  // ******** Cuts and Histograms applied to all studies ********
229
230  mystudy.AddCut(new EventWeight(particlesObj,mystudy.GetTotalMCatNLOEvents(), mcStr, doPileup, dobWeight, useLeptonSFs, usebTagR
231
232  mystudy.AddCut(new HistogrammingMuon(particlesObj,"All"));  // make the muon plots, hopefully.
233  mystudy.AddCut(new HistogrammingMuon(particlesObj,"Tight",useInvertedIsolation));  // make the muon plots, hopefully.
234  mystudy.AddCut(new HistogrammingMuon(particlesObj,"Veto"));  // make the muon plots, hopefully.
235  mystudy.AddCut(new HistogrammingMuon(particlesObj,"UnIsolated"));  // make the muon plots, hopefully.
236  mystudy.AddCut(new CutPrimaryVertex(particlesObj));
237  mystudy.AddCut(new CutTriggerSelection(particlesObj, whichtrig));
238
239  mystudy.AddCut(new HistogrammingMET(particlesObj));
240  //mystudy.AddCut(new CutElectronTighterPt(particlesObj, "Tight"));
241  mystudy.AddCut(new CutMuonN(particlesObj, leptonTypeToSelect));     //require that lepton to be isolated, central, high pt
242
243  mystudy.AddCut(new CutMuonN(particlesObj, "Veto"));     //require that lepton to be isolated, central, high pt
244
245
246
247  mystudy.AddCut(new CutElectronN(particlesObj, leptonTypeToSelect)); //require that lepton to be isolated, central, high pt
248  mystudy.AddCut(new CutElectronN(particlesObj, "Veto")); //require that lepton to be isolated, central, high pt
249
250  mystudy.AddCut(new HistogrammingElectron(particlesObj,leptonTypeToSelect,useInvertedIsolation));  // make the muon plots, hopef
251  mystudy.AddCut(new HistogrammingElectron(particlesObj,"Veto"));  // make the muon plots, hopefully.
252
253  mystudy.AddCut(new HistogrammingMET(particlesObj));
254  mystudy.AddCut(new HistogrammingMtW(particlesObj,useInvertedIsolation));
255
256  mystudy.AddCut(new HistogrammingMuon(particlesObj,leptonTypeToSelect));  // make the muon plots, hopefully.
257
258  //mystudy.AddCut(new CutMuonTighterPt(particlesObj, "Tight")); //require that new Pt cut for leading and subleading muon
259  //if (isemu){
260  //  mystudy.AddCut(new CutEMuOverlap(particlesObj));
261  //}
262  //mystudy.AddCut(new CutJetPt1(particlesObj));
263  mystudy.AddCut(new CutJetN(particlesObj,nJets));
```

Link: https://github.com/leggat/tWIHEPFramework/blob/master/bin/Wt/Wt_generic.cpp

Example cut class

Each cut contains;

- BookHistogram()
  - Book histograms to fill when running cut
  - Also defines the value of the cut
- Apply()
  - Applies the cut to each event
  - Fill histograms
  - Returns true if pass, false if fail cut

Added into analysis executable

```
/*****************************************************************************
 * CutMissingEt.hpp                                                          *
 *                                                                           *
 * Cuts on Missing Et                                                        *
 *                                                                           *
 * Derived from HistoCut which is in turn derived from BaseCut               *
 *                                                                           *
 * Public Member Functions of CutMissingEt class                             *
 *    CutMissingEt()                    -- Parameterized Constructor         *
 *    ~CutMissingEt()                   -- Destructor                        *
 *    BookHistogram()                   -- Book histograms                   *
 *    Apply()                           -- Apply cuts and fill histograms    *
 *    GetCutName()                      -- Returns "CutMissingEt"            *
 *                                                                           *
 * Private Data Members of CutMissingEt                                      *
 *    myTH1F* _hMissingEtBefore         -- Hist of MissingEt before cuts     *
 *    myTH1F* _hMissingEtAfter          -- Hist of MissingEt after cuts      *
 *    Int_t _missingEtMin;              -- Minimum Missing Et                *
 *    Int_t _missingEtMin;              -- Minimum Missing Et                *
 *                                                                           *
 * History                                                                   *
 *      15 Dec 2006 - Created by P. Ryan                                     *
 *****************************************************************************/
```

```
236   ıystudy.AddCut(new CutPrimaryVertex(particlesObj));
237   ıystudy.AddCut(new CutTriggerSelection(particlesObj, whichtrig));
```

https://github.com/leggat/tWIHEPFramework/blob/master/src/Cuts/Other/CutMissingEt.cpp

Example histogram class

Histogram classes are treated as cuts but always return true

```
/*****************************************************************************
 * HistogrammingMET.hpp                                                      *
 *                                                                           *
 * Books and fills histograms                                                *
 * Used for events passing cuts applied in other classes                     *
 *                                                                           *
 * Derived from HistoCut which is in turn derived from BaseCut               *
 *                                                                           *
 * Public Member Functions of AnalysisMain class                             *
 *    HistogrammingMET()              -- Parameterized Constructor           *
 *    ~HistogrammingMET()             -- Destructor                          *
 *    BookHistogram()                   -- Book histograms                   *
 *    Apply()                           -- Fill histograms only (No Cuts)    *
 *    GetCutName()                      -- Returns "HistogrammingMET"        *
 *                                                                           *
 * Private Data Members of this class                                        *
 *  - histograms of MET                                                      *
 *                                                                           *
 * History                                                                   *
 *      14 Nov 2006 - Created by R. Schwienhorst for ATLAS                   *
 *      20 Nov 2006 - Modified by Bernard Pope                               *
 *      21 Mar 2007 - RS: Fill from event container, add sumET, mex, mey     *
 *****************************************************************************/
```

Added into executable in the cut flow list chain:

```
    mystudy.AddCut(new HistogrammingMET(particlesObj));
    mystudy.AddCut(new HistogrammingMtW(particlesObj,useInvertedIsolation));
    mystudy.AddCut(new HistogrammingJetAngular(particlesObj,useInvertedIsolation));
    mystudy.AddCut(new HistogrammingJet(particlesObj));
    mystudy.AddCut(new HistogrammingNPvtx(particlesObj));
```

Link: https://github.com/leggat/tWIHEPFramework/blob/master/src/Histogramming/Recon/HistogrammingMET.cpp

Example of additional variable class

Adds additional variables to the output tree

- Variables are defined in the constructor
  - float, int, vectors of floats and ints are currently supported types
- Filled in the FillBranches() method

Included in analysis executable in the additional variable chain:

```
289    mystudy.AddVars(new JESBDTVars());
290    mystudy.AddVars(new WeightVars(useIterFitbTag));
291    mystudy.AddVars(new ChannelFlag());
```

Additional variable definition

```
15  WeightVars::WeightVars(Bool_t useIterFit){
16    _floatVars["EventWeight"] = 0.;
17    _floatVars["bWeight"] = 0.;
18    _floatVars["puWeight"] = 0.;
19    _floatVars["lepSF"] = 0.;
20    _floatVars["trigSF"] = 0.;
```

Now the output tree contains additional branches named after these strings

Variable filling

```
39  void WeightVars::FillBranches(EventContainer * evtObj){
40
41    //Fill the nominal event weight variables
42    _floatVars["EventWeight"] = evtObj->GetOutputEventWeight();
43    _floatVars["bWeight"] = evtObj->GetEventbTagReshape();
44    _floatVars["puWeight"] = evtObj->GetEventPileupWeight();
45    _floatVars["lepSF"] = evtObj->GetEventLepSFWeight();
46    _floatVars["trigSF"] = evtObj->GetEventTrigSFWeight();
```

Link: https://github.com/leggat/tWIHEPFramework/blob/master/src/Vars/WeightVars.cpp

Running the code

Once we've written our main analysis and cut/histogram/variable classes we need to compile the code

- Most technical bit: edit Makefile to run over your specific code

Now we are ready to run the analysis:

bin/myAnalysis.x -config config/overall/myAnalysis.config -inlist config/files/myAnalysisFiles.list -skimfile skimFileOutput/mySkim.root -hfile histFileOutput/myHists.root [additional options]

Necessary parts of execution command:

- Analysis executable
- -config <config> – contains links to further configuration files
- -inlist <inlist> – a list of files to run over
- -skimfile <skimFile> – what to call the output skim tree (optional)
- -hfile <hfile> – histogram file destination (optional)
- Additional opts – Defined in analysis executable and AnalysisMain.cpp

Commands can also be run on Condor cluster

- Utility classes to help with this are available in the utils folder

Main Configuration File

Important information that the analysis needs

All configuration files are united into one common TEnv area accessible to the analysis code.

Each item is stored in a map locatable by its unique string identifier (e.g. Include.CutsFile)

```
1  ##############################################################################
2  #
3  # Configuration file for the single top analysis.
4  #
5  # Modifications:
6  ##############################################################################
7  #
8  #
9  # Set the debug level: the higher, the more printout
10 DebugLevel: 10
11 #
12 # Mass set to MC value for this study.
13 # If we are optimizing for some top mass, set that mass here:
14 TopMass: 172.5
15 #
16 #
17 # Read in a file listing cuts we want to make (electron channel):
18 #Include.CutsFile: macros/wt-channel/LP/config/cuts/SingleTopCuts.Wt.DiElectron.onePlusJets.cuts
19 Include.CutsFile: macros/wt-channel/LP/config/cuts/SingleTopCuts.Wt.ElectronMuon.onePlusJets.cuts
20 #
21 #
22 # Read in a file listing the event weight:
23 Include.WeightsFile: config/weights/MCInformation.weights
24 #
25 #
26 # Read in a file listing the object ID definitions:
27 Include.ObjectIDFile: macros/wt-channel/LP/config/objects/SingleTopObjects.Wt.LP.noshift.config
28 #
29 # Output file with topological variables
30 Topology.SkimFile: topovars.root
31 #
32 #
33 # Events files
34 Include.MCTotEventNumberFile: config/weights/MCInformation.weights
35 #
36 #
37 # pile up vtx reweighting
38 #Include.pileUpReWeightingFile: config/weights/SingleTopWeights.PileUpReWeight.156.weights
39 #
40 #
41 #muonID SFs
42 Include.MuonIDSFsFile: config/weights/muon/MuonID_all.root
```

The cut values to use in the analysis

Information of weights of MC samples

Physics objects defintions

Root file containing pt/eta dependent muon ID SF information

Example for tW analysis:
https://github.com/leggat/tWIHEPFramework/blob/master/config/overall/SingleTop.Wt.LP.mm1%2Bj.muonMSSmeardown.config

Examples of cut and object definition files

- Cut definitions are read in by the cut classes
- Object definitions are read by the particle classes

```
#------------------------------------------------------------
# Jets
#------------------------------------------------------------
ObjectID.Jet.MinPt: 30.0
ObjectID.Jet.MaxEta: 2.4
ObjectID.BJet.MaxEta: 2.4
ObjectID.BJet.MinPt: 30.
#ObjectID.BJet.BTagCut: 0.5426  #Loose CSVv2 WP
ObjectID.BJet.BTagCut: 0.8484 #Medium CSVv2 WP
#ObjectID.BJet.BTagCut: 0.9535 #Tight CSVv2 WP
ObjectID.BJet.InverseTag: 0.6 # For QCD region possibly
ObjectID.Jet.ElectronDeltaRMin: 0.3
ObjectID.Jet.LepCleanR: 0.4

#ObjectID.Jet.ElectronDeltaRMin: 0.2
##ObjectID.Jet.ElectronDeltaRMin: 0.0

ObjectID.Vertex.Ndof: 4.
ObjectID.Vertex.Z: 24.
ObjectID.Vertex.Dxy: 2.
```

https://github.com/leggat/tWIHEPFramework/blob/master/macros/wt-channel/LP/config/objects/SingleTopObjects.Wt.LP.noshift.config

```
#####################################################################
#
# SingleTopCuts.Wt.ElectronMuon.onePlusJets.cuts
#
#####################################################################

# ############ Trigger Cuts ##############
# Trigger cuts implemented within the trigger cut classes (for now)

################ Electron Cuts ########################
# Number of Electrons
Cut.Electron.Tight.Number.Min:  0
Cut.Electron.Tight.Number.Max:  0
Cut.Electron.Tight.LeadingPt:  26
Cut.Electron.Tight.SubLeadingPt:  20
################ Veto Electron Cuts ########################
# Number of Electrons
Cut.Electron.Veto.Number.Min:  0
Cut.Electron.Veto.Number.Max:  0
################ Muon Cuts ########################
# Number of  Muons
Cut.Muon.Tight.Number.Min:  1
Cut.Muon.Tight.Number.Max:  1
Cut.Muon.Tight.LeadingPt:  26
Cut.Muon.Tight.SubLeadingPt:  20
################ UnIsolated Muon Cuts ########################
# Number of  Muons
Cut.Muon.UnIsolated.Number.Min:  1
Cut.Muon.UnIsolated.Number.Max:  1
Cut.Muon.UnIsolated.LeadingPt:  26
Cut.Muon.UnIsolated.SubLeadingPt:  20
################ Veto Muon Cuts ########################
# Number of Veto Muons
Cut.Muon.Veto.Number.Min:  1
Cut.Muon.Veto.Number.Max:  1
# ############ Jet Cuts ############################
# Jet multiplicity cuts
Cut.Jet.Number.Min:  2
Cut.Jet.Number.Max:  4
Cut.Jet.Pt.1.Min:  30
Cut.Jet.Pt.1.Max: 999
```

https://github.com/leggat/tWIHEPFramework/blob/master/macros/wt-channel/LP/config/cuts/SingleTopCuts.Wt.ElectronMuon.onePlusJets.cuts

File list and MC weighting

An example file list file:

```
Name: tW_top_nfh
Number: 500026_1
/publicfs/cms/data/TopQuark/cms13TeV/tWlJetSamples/mc/updatedEleJets/ST_tW_top_5f_NoFullyHadronicDecays_13TeV-powheg_TuneCUETP8M1/crab_tW_top_NFHext1updatedEleJets/180508_153925/0000/OutTree_5.root
/publicfs/cms/data/TopQuark/cms13TeV/tWlJetSamples/mc/updatedEleJets/ST_tW_top_5f_NoFullyHadronicDecays_13TeV-powheg_TuneCUETP8M1/crab_tW_top_NFHext1updatedEleJets/180508_153925/0000/OutTree_6.root
/publicfs/cms/data/TopQuark/cms13TeV/tWlJetSamples/mc/updatedEleJets/ST_tW_top_5f_NoFullyHadronicDecays_13TeV-powheg_TuneCUETP8M1/crab_tW_top_NFHext1updatedEleJets/180508_153925/0000/OutTree_12.root
/publicfs/cms/data/TopQuark/cms13TeV/tWlJetSamples/mc/updatedEleJets/ST_tW_top_5f_NoFullyHadronicDecays_13TeV-powheg_TuneCUETP8M1/crab_tW_top_NFHext1updatedEleJets/180508_153925/0000/OutTree_31.root
/publicfs/cms/data/TopQuark/cms13TeV/tWlJetSamples/mc/updatedEleJets/ST_tW_top_5f_NoFullyHadronicDecays_13TeV-powheg_TuneCUETP8M1/crab_tW_top_NFHext1updatedEleJets/180508_153925/0000/OutTree_7.root
/publicfs/cms/data/TopQuark/cms13TeV/tWlJetSamples/mc/updatedEleJets/ST_tW_top_5f_NoFullyHadronicDecays_13TeV-powheg_TuneCUETP8M1/crab_tW_top_NFHext1updatedEleJets/180508_153925/0000/OutTree_25.root
/publicfs/cms/data/TopQuark/cms13TeV/tWlJetSamples/mc/updatedEleJets/ST_tW_top_5f_NoFullyHadronicDecays_13TeV-powheg_TuneCUETP8M1/crab_tW_top_NFHext1updatedEleJets/180508_153925/0000/OutTree_2.root
/publicfs/cms/data/TopQuark/cms13TeV/tWlJetSamples/mc/updatedEleJets/ST_tW_top_5f_NoFullyHadronicDecays_13TeV-powheg_TuneCUETP8M1/crab_tW_top_NFHext1updatedEleJets/180508_153925/0000/OutTree_20.root
/publicfs/cms/data/TopQuark/cms13TeV/tWlJetSamples/mc/updatedEleJets/ST_tW_top_5f_NoFullyHadronicDecays_13TeV-powheg_TuneCUETP8M1/crab_tW_top_NFHext1updatedEleJets/180508_153925/0000/OutTree_23.root
/publicfs/cms/data/TopQuark/cms13TeV/tWlJetSamples/mc/updatedEleJets/ST_tW_top_5f_NoFullyHadronicDecays_13TeV-powheg_TuneCUETP8M1/crab_tW_top_NFHext1updatedEleJets/180508_153925/0000/OutTree_29.root
```

'Number' corresponds to a specific number in the config/weights/MCInformation.weights file:

Weight.Source.Number: <cross section>
Events.Source.Number: <nEvents in sample>

Plausible that additional settings could be added into this file (i.e. different configuration for run years?) but not included as of now.

```
#500026 = not fully hadronic tW
Weight.Source.500026: 19.559
Events.Source.500026: 11345619

#500027 = not fully hadronic tW_antitop
Weight.Source.500027: 19.559
Events.Source.500027: 11408144

#500028 = w+0jets
Weight.Source.500028: 49670.0
Events.Source.500028: 98083988
```

Cut flow output

At completion the framework outputs a cut flow of the processed trees

- A cut class can be linked the cut flow using

  GetCutFlowTable()->AddCutToFlow(cutName)

- And filled using:

  GetCutFlowTable()->[Pass|Fail]Cut(cutName)

<CutFlowJetTable> GlobalCutFlow result:

Cut Name	0 jet	1 jet	2 jet	3 jet	4 jet	5 jet	6 jet	7 jet	8+jet	total
PV	25768	131334	259142	255591	146440	60764	21016	6409	2425	908889
MuonTrigger	7631	38972	69302	60413	30588	11769	3971	1132	398	224176
TightMuon.Number.Min	7388	36856	63229	51601	24027	8765	2840	791	255	195752
TightMuon.Number.Max	6515	35026	67179	59566	30298	11686	3952	1125	395	215742
TightMuon.Number.All	6272	32910	61106	50754	23737	8682	2821	784	252	187318
VetoMuon.Number.Min	6272	32910	61106	50754	23737	8682	2821	784	252	187318
VetoMuon.Number.Max	5218	26438	49180	39900	17709	6006	1884	495	145	146975
VetoMuon.Number.All	5218	26438	49180	39900	17709	6006	1884	495	145	146975
TightElectron.Number.Min	5218	26438	49180	39900	17709	6006	1884	495	145	146975
TightElectron.Number.Max	5042	25907	48927	39810	17682	6002	1883	495	145	145893
TightElectron.Number.All	5042	25907	48927	39810	17682	6002	1883	495	145	145893
VetoElectron.Number.Min	5042	25907	48927	39810	17682	6002	1883	495	145	145893
VetoElectron.Number.Max	4809	22908	40990	32616	13686	4395	1313	348	80	121145
VetoElectron.Number.All	4809	22908	40990	32616	13686	4395	1313	348	80	121145
Jet.Number.Min	0	1266	40990	32616	13686	4395	1313	348	80	94694
Jet.Number.Max	4809	22908	40990	32616	13686	488	5	0	0	115502
Jet.Number.All	0	1266	40990	32616	13686	488	5	0	0	89051

<CutFlowTable> GlobalCutFlow result:

Cut Name	exposed		pass		cut
	count	yield	count	yield	
PV	925904	56240.1	908889	55383.7	Primary Vertex Cut
MuonTrigger	908889	55383.7	224176	13516.1	Muon Trigger
TightMuon.Number.Min	224176	13516.1	195752	11769.5	Tight Muon : N >= 1
TightMuon.Number.Max	224176	13516.1	215742	13024.7	Tight Muon : N <= 1
TightMuon.Number.All	224176	13516.1	187318	11278.1	Tight Muon : 1 <= N <= 1
VetoMuon.Number.Min	187318	11278.1	187318	11278.1	Veto Muon : N >= 1
VetoMuon.Number.Max	187318	11278.1	146975	9003.72	Veto Muon : N <= 1
VetoMuon.Number.All	187318	11278.1	146975	9003.72	Veto Muon : 1 <= N <= 1
TightElectron.Number.Min	146975	9003.72	146975	9003.72	Tight Electron : N >= 0
TightElectron.Number.Max	146975	9003.72	145893	8944.91	Tight Electron : N <= 0
TightElectron.Number.All	146975	9003.72	145893	8944.91	Tight Electron : 0 <= N <= 0
VetoElectron.Number.Min	145893	8944.91	145893	8944.91	Veto Electron : N >= 0
VetoElectron.Number.Max	145893	8944.91	121145	7418.47	Veto Electron : N <= 0
VetoElectron.Number.All	145893	8944.91	121145	7418.47	Veto Electron : 0 <= N <= 0
Jet.Number.Min	121145	7418.47	94694	5779.79	Jet : N >=2
Jet.Number.Max	121145	7418.47	115502	7076.55	Jet : N <= 4
Jet.Number.All	121145	7418.47	89051	5437.87	Jet : 2 <= N <= 4

Output histogram file

Example of output histogram file