



Feasibility Study of Measuring the Higgs Self-coupling Using the Muon Collider

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Apr 22nd, 2022



Implementing TauTagging module for anti-kt jets

- Efficiency formula from VLC_R05_inclusive tau-tagging module:
- The way MadGraph calling Delphes is really weird. It use the default card from either Template/Common or Template/LO. I hard code the modified card address into LO/bin/internal/run_delphes3 to make it work. It is also calling the wrong version of DelphesHepMC which need to be fix. Will wrote it into the script next week.

```
export LD_LIBRARY_PATH=$LD_LIBRARY_PATH:$ROOTSYS/lib
if [ ${file:-3} == ".gz" ]
then
  if [ ${file:-7} == ".hep.gz" ]
  then
    gunzip --stdout $file | $delphesdir/DelphesSTDHEP ../Cards/delphes_card.dat ${run}/${tag}_delphes_events.root
  else
    gunzip --stdout $file | $delphesdir/DelphesHepMC ../Cards/mucol.dat ${run}/${tag}_delphes_events.root
  fi
else
  if [ ${file:-4} == ".hep" ]
  then
    $delphesdir/DelphesSTDHEP ../Cards/delphes_card.dat ${run}/${tag}_delphes_events.root $file
  else
    $delphesdir/DelphesHepMC ../Cards/mucol.dat ${run}/${tag}_delphes_events.root $file
  fi
fi
echo $$ >> ../myprocid
```

```
#####
# Tau-Tagging module for anti-kt
#####

module TauTagging AKT_TauTagging_WP50_R05_inclusive {
  set ParticleInputArray Delphes/allParticles
  set PartonInputArray Delphes/partons
  set JetInputArray FastJetFinderAKt/AKTjets
  set DeltaR 0.5
  set TauPTMin 1.0
  set TauEtaMax 2.5
  add EfficiencyFormula {0} {0.02}
  add EfficiencyFormula {11} {0.001}
  add EfficiencyFormula {15} {
    (pt < 10) * (0.0) +
    (pt >=10) * (0.80)
  }
}
```



Ideas on $\mu^- \mu^+ \rightarrow \nu_\mu \bar{\nu}_\mu HH \rightarrow \nu_\mu \bar{\nu}_\mu b \bar{b} \tau \tau$

- Both hadronic decay $\nu_\mu \bar{\nu}_\mu b \bar{b} \tau_h \tau_h$, Branching ratio = 41%
- One hadronic decay, one leptonic decay $\nu_\mu \bar{\nu}_\mu b \bar{b} \tau_l \tau_h$, Branching ratio = 46%
- Both leptonic decay $\nu_\mu \bar{\nu}_\mu b \bar{b} \tau_l \tau_l$, Branching ratio = 13%

Start with both hadronic decay



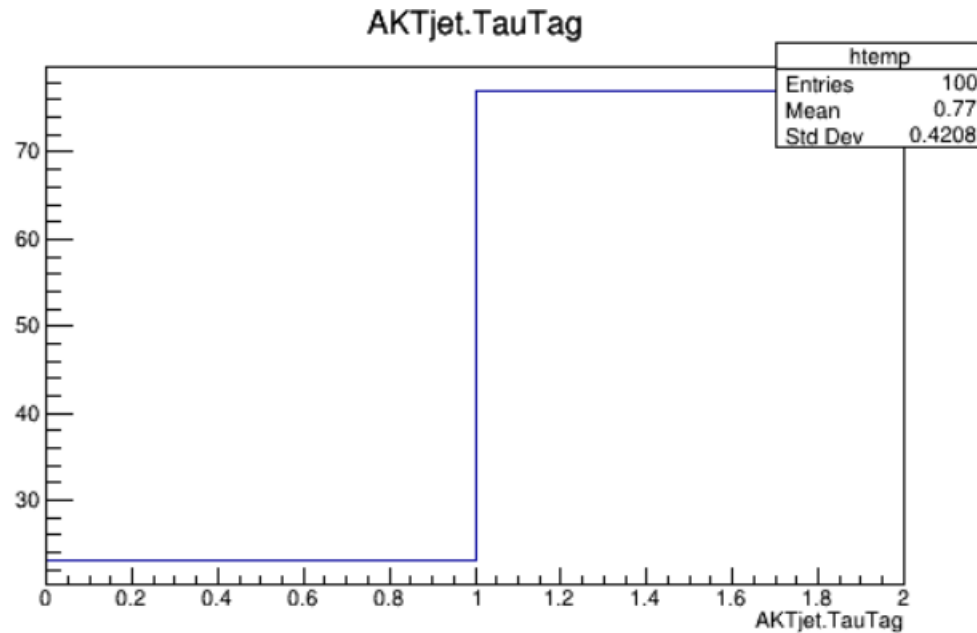
Ideas on $\mu^- \mu^+ \rightarrow \nu_\mu \bar{\nu}_\mu HH \rightarrow \nu_\mu \bar{\nu}_\mu b \bar{b} \tau_h \tau_h$

- Signal: $\mu^- \mu^+ \rightarrow \nu_\mu \bar{\nu}_\mu HH \rightarrow \nu_\mu \bar{\nu}_\mu b \bar{b} \tau_h \tau_h$
- Background:
 - $\mu^- \mu^+ \rightarrow \nu_\mu \bar{\nu}_\mu q \bar{q} \tau_h \tau_h, :$
 - $\mu^- \mu^+ \rightarrow \nu_\mu \bar{\nu}_\mu q \bar{q} H(\tau_h \tau_h).$
 - $\mu^- \mu^+ \rightarrow \nu_\mu \bar{\nu}_\mu Z(q \bar{q}) H(\tau_h \tau_h).$



Test with $H \rightarrow \tau \tau$ at 10 TeV

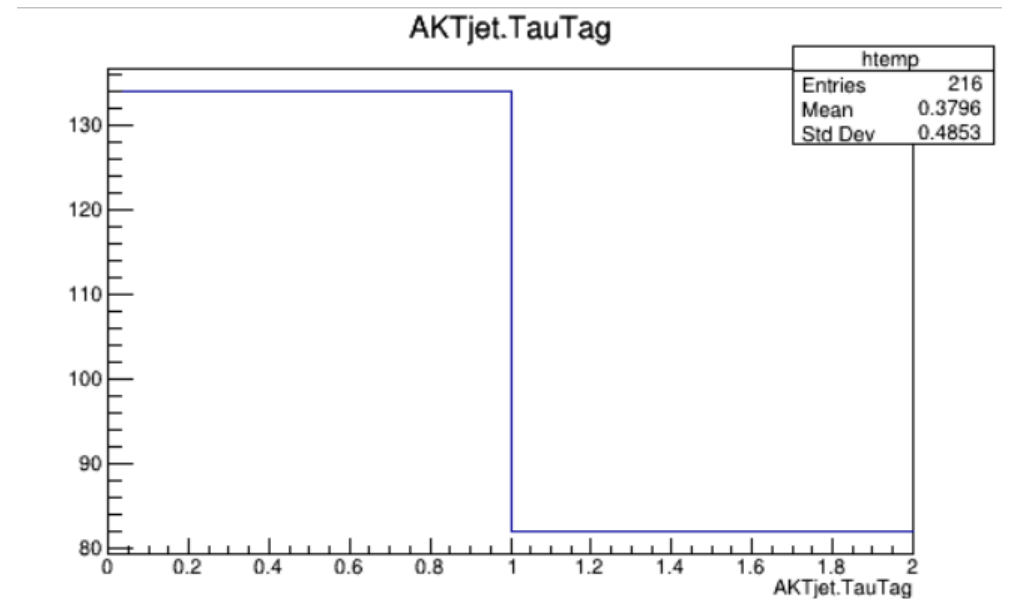
- Highly boosted Higgs produce two tau jet that merge into one:





Test with HH \rightarrow bbtatau at 10 TeV

- If tau jets doesn't merge by boosting, we expect $(13*2+46*3+41*4) = 328$ jets with 128 tau-tagged
- If tau jets merged as Higgs are boosted, we expect $(13*2+46*3+41*3) = 287$ jets with 87 tau-tagged
- It seems we should deal with $\tau_h\tau_h$ and $\tau_l\tau_h$ at the same time.

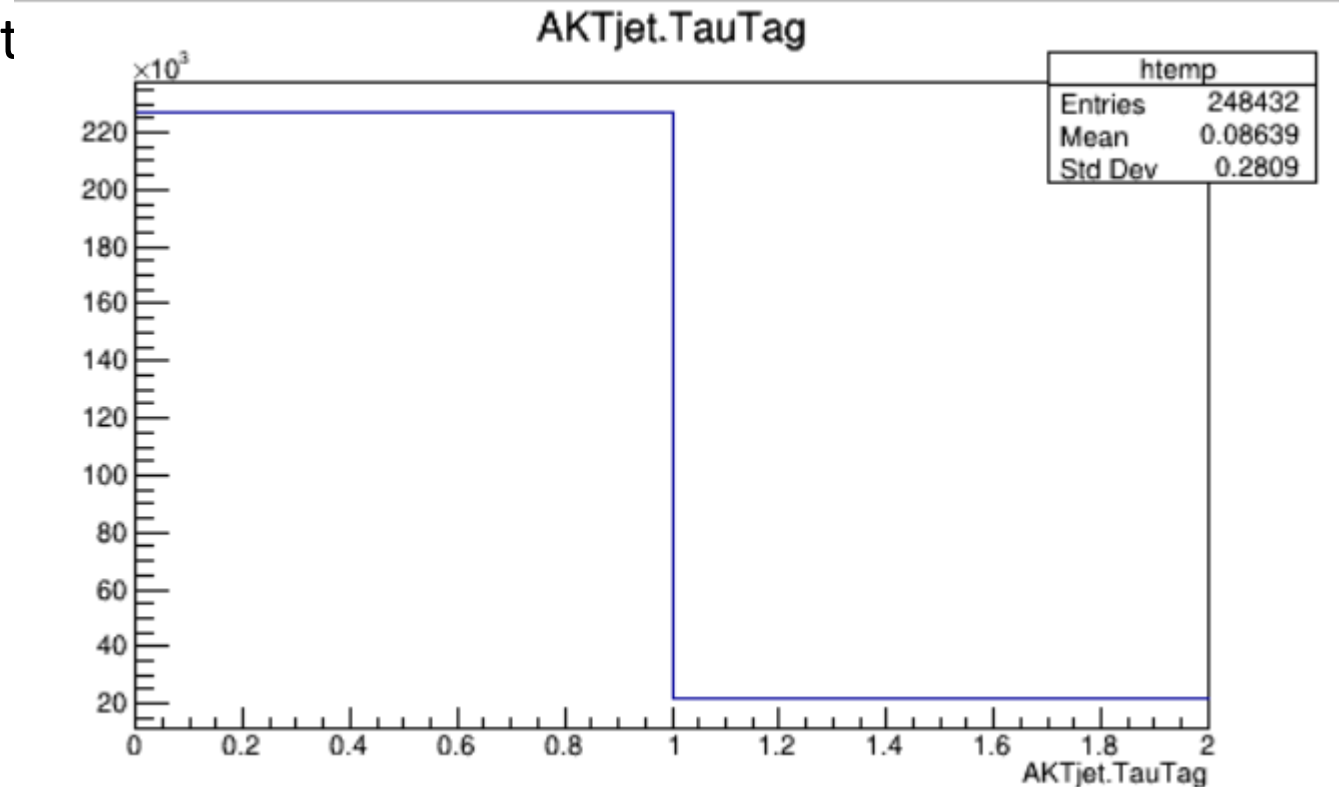




Generating 100k events of HH at 10 TeV

- Neglected boosted higgs effect
- $100000 * 7.3% * (46% + 2 * 41%)$
=9344

Too much jets are tau-tagged





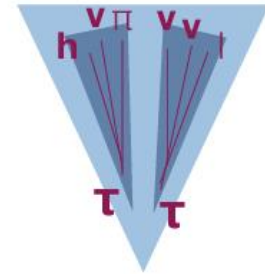
Other possibility from CMS Higgs-tagging

Using anti-kt_R02 and anti-kt_R10, requiring those R02 “sub jets” are inside the fat jet’s cone with both sub-jets tau-tagged

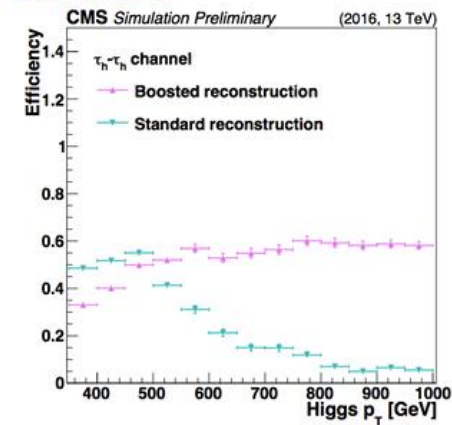
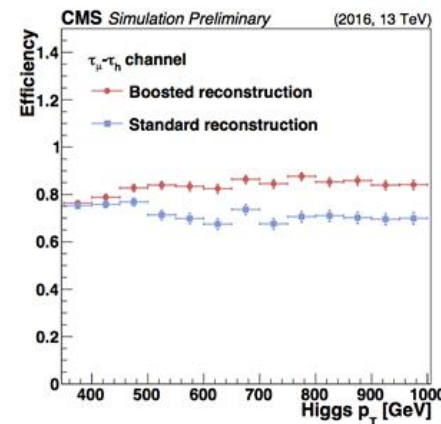
CMS, $h \rightarrow \tau\tau$



- High- p_T $h \rightarrow \tau\tau$ reconstruction is quite challenging
- New developments in Run II:
 - Requiring two sub-jets and then reconstruct the τ within each of them



CMS-DP-2016/038





Ideas on $\mu^- \mu^+ \rightarrow \nu_\mu \bar{\nu}_\mu HH \rightarrow \nu_\mu \bar{\nu}_\mu b \bar{b} \gamma \gamma$

- Signal: $\mu^- \mu^+ \rightarrow \nu_\mu \bar{\nu}_\mu HH \rightarrow \nu_\mu \bar{\nu}_\mu b \bar{b} \gamma \gamma$
 - Dominated by WW fusion mode, sub-dominate by Double Higgs-strahlung ZHH .
- Background:
 - $\mu^- \mu^+ \rightarrow \nu_\mu \bar{\nu}_\mu q \bar{q} \gamma \gamma, :$
 - $\mu^- \mu^+ \rightarrow \nu_\mu \bar{\nu}_\mu q \bar{q} H(\gamma \gamma)$.
 - $\mu^- \mu^+ \rightarrow \nu_\mu \bar{\nu}_\mu Z(q \bar{q}) H(\gamma \gamma)$.
 - Other $\nu_\mu \bar{\nu}_\mu q \bar{q} \gamma \gamma$ QCD process.
 - Other $\nu_\mu \bar{\nu}_\mu q \bar{q} \gamma \gamma$ QED process.



Bugs in the run MG on condor script

- Change random seed to be the first 8 digits of nanoseconds in order to avoid generate random seeds larger than $30081 * 30081$ which MadGraph could not handle.
- Delphes Card should be sent to both Common and LO. I don't fully understand how MadGraph called Delphes. But I am sure that sometimes it uses LO rather than Common.