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

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Summer plan

- Maybe GRE and PhyGRE prep in the last month of summer

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

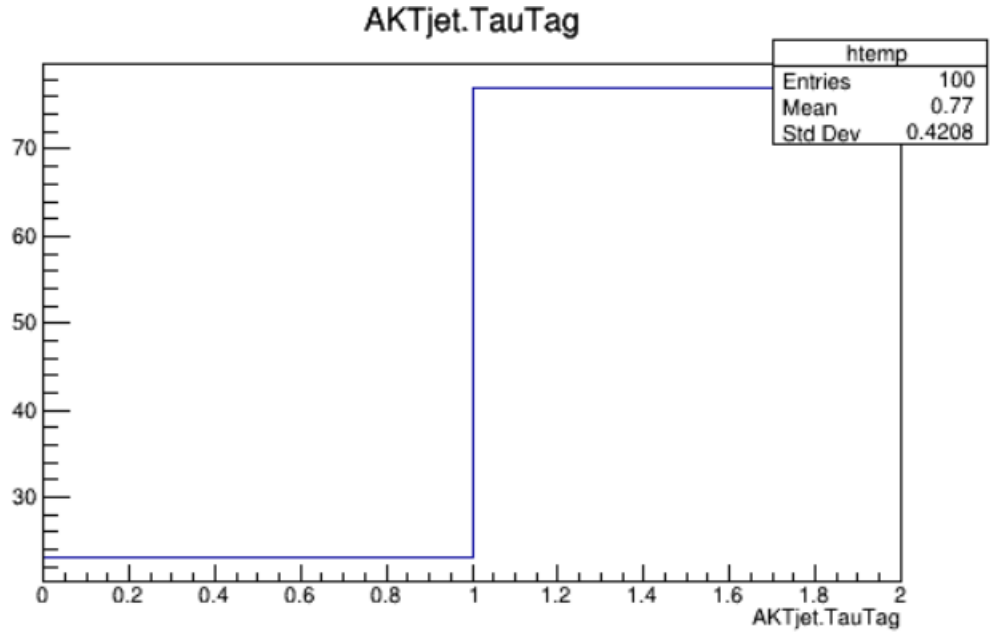
Implementing TauTagging module for anti-kt jets

- No general mis-tag rate: drop from ~20000 to ~16500

```
#############################################################
# Anti-KT jets Tau-Tagging Module
#############################################################
module TauTagging AKT_TauTagging_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}
 add EfficiencyFormula {11} {0.001}
 add EfficiencyFormula {15} {
 (pt < 10) * (0.0) +
 (pt >=10) * (0.80)
 }
 }
```

Test with H -> tau tau at 10 TeV

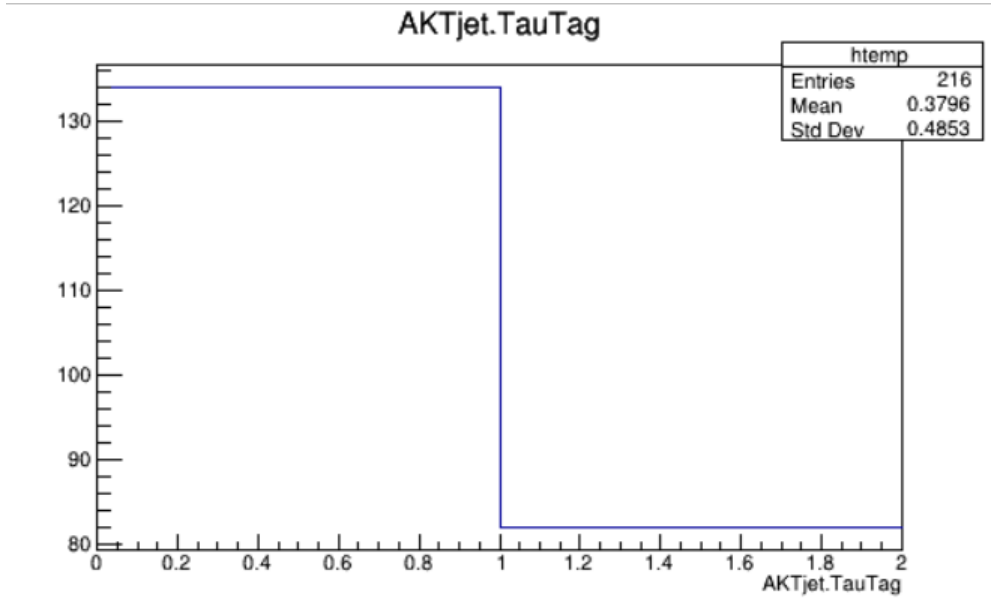
- Highly boosted Higgs produce two tau jet that merge into one:



Test with HH -> bbtautau at 10 TeV

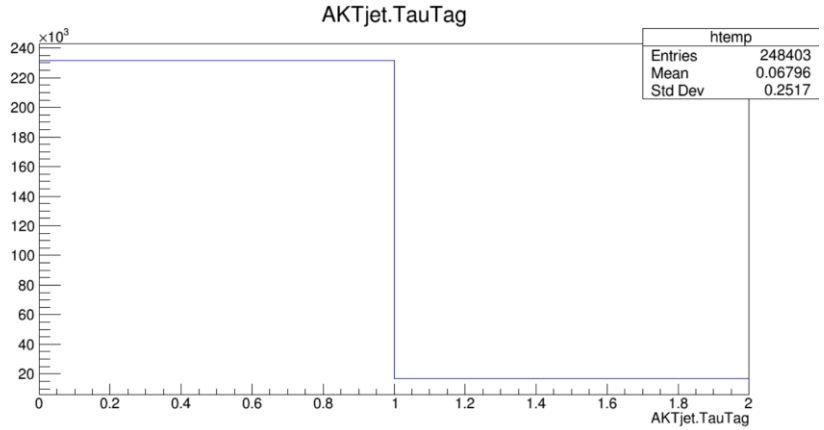
- If tau jets doesn't merge by boosting, we expect (13*2+46*3+41*4) =328 jets with 128 tau-tagged
- If tau jets merged as Higgs are boosted, we expect (13*2+46*3+41*3)=287 jets with 87 tau-tagged
- It seems we should deal with $\tau_h\tau_h$ and $\tau_l\tau_h$ at the same time.

216/328*128=84, boost effect?



Generating 100k events of HH at 10 TeV

- Neglected boosted higgs effect
- Wrong calculation last time:
  - 100000*7.3%*(46%+2*41%)=9344 X
- Correct calculation: Very close to what we have !
  - 100000*{ [(2*6.28%)-(6.28% * 6.28%)] * (46%+41%*2) +(6.28% * 6.28%)*(46%+41%*2)*2}=16581
- Green part for the percentage that only one of the Higgs decays to two tau
- Blue part for the expected tau-tagged jet from one Higgs decays to two tau
- Purple part for the percentage that both Higgs decays to two tau



Next step:

- Run 100k events specficy HH to bbtautau, compare with no specification in order to see whether it is one or two tau-tagged jets for the case which both tau decays hadronically.

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

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