# Status of $\mathrm{BR}(h \to \tau^+\tau^-)$ Study

Shin-ichi Kawada
Hiroshima University

# Review of Current Numbers (1)

| 250 GeV 250 fb$^{-1}$ | $q\bar{q}h$ | $\nu\bar{\nu}h$ | $e^+e^-h$ | $\mu^+\mu^-h$ |
|---|---|---|---|---|
| $\frac{\Delta(\sigma \times \mathrm{BR})}{(\sigma \times \mathrm{BR})}$ | **3.4%** | 46.0% | 16.1% | 14.7% |
| Status | **DONE** | Extrapolation from $M_h$ = 120 GeV Cut-based only | | |

now working

# Review of Current Numbers (2)

| **500 GeV 500 fb$^{-1}$** | $q\bar{q}h$ | $\nu\bar{\nu}h$ | $e^+e^-h$ | $\mu^+\mu^-h$ |
|---|---|---|---|---|
| $\frac{\Delta(\sigma \times \mathrm{BR})}{(\sigma \times \mathrm{BR})}$ | 4.7% | 6.8% | 31.2% | 17.6% |
| Status | Mh = 125 GeV with TMVA<br>But wrong tau pol. | | | |

used buggy tau finder

separation $Zh$ and $WW$-fusion is needed

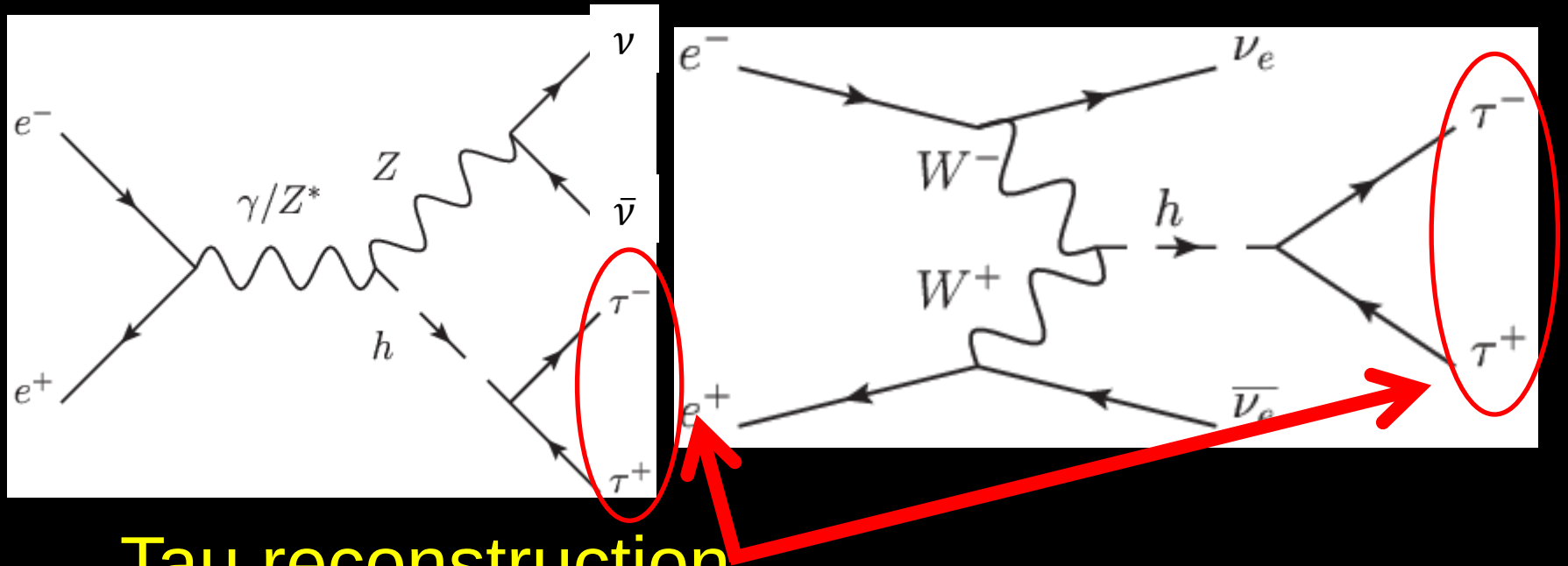
MC stat. was not enough

training parameter optimization is needed for all modes

# Today's topic: 250 GeV $\nu\bar{\nu}h$

- Second largest number of signal at 250 GeV, but background rejection is very difficult.
  - 2f: $\tau\tau$
  - 4f: $\nu\nu\tau\tau$ (irreducible), $\nu\nu\ell\ell$
  - aa_2f: $\gamma\gamma \to \tau\tau$, $\gamma\gamma \to \ell\ell$
- These background processes are like the irreducible processes because of neutrinos and initial photons.

# Event Reconstruction




Tau reconstruction

clustering based on tau mass

Most energetic $\tau^+$ and $\tau^-$ are combined as a Higgs boson

# Cut-based Analysis

Cut 0 (pre-cuts): # of $\tau^+(\tau^-) \geq 1$, # of tracks <= 6

Cut 0.5 (basic cuts): $5 < E_{\mathrm{vis}} < 150$, $5 < M_{\mathrm{vis}} < 135$,
$M_{\mathrm{inv}} > 75$, $P_t > 5$, thrust > 0.7,
$|\cos\theta_{\mathrm{miss}}| < 0.99$, (# of $E > 3$ tracks) >= 1,
(# of $P_t > 2$ tracks) >= 1

Cut 1: $M_{\mathrm{vis}} < 105$

Cut 2: $M_{\mathrm{inv}} > 120$

Cut 3: $P_t > 25$

Cut 4: thrust > 0.82

Cut 5: $|\cos\theta_{\mathrm{miss}}| < 0.94$

Cut 6: $M_{\tau\tau} > 10$

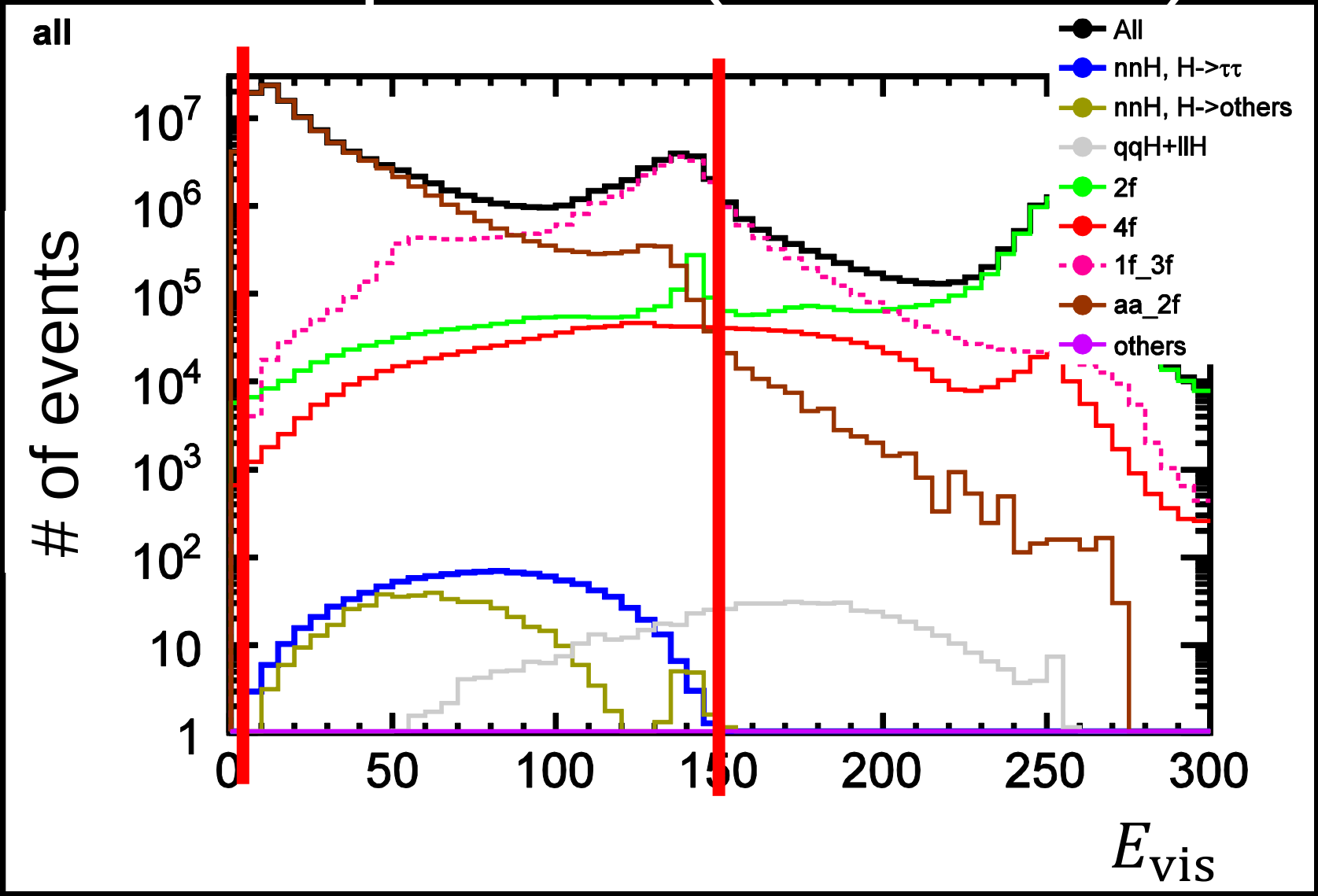
Cut 7: $-0.89 < \cos\theta_{\tau\tau} < -0.52$

Cut 8: $\cos\theta_{\mathrm{acop}} < 0.99$

Cut 9: $\log_{10}|\min d_0\mathrm{sig}| > 0.3$

pre-cuts: requiring signal topology
basic cuts: very loose cuts, but quite significant to suppress trivial process

# Example Plot (Basic Cuts)



# Example Plot (Final Discriminant)

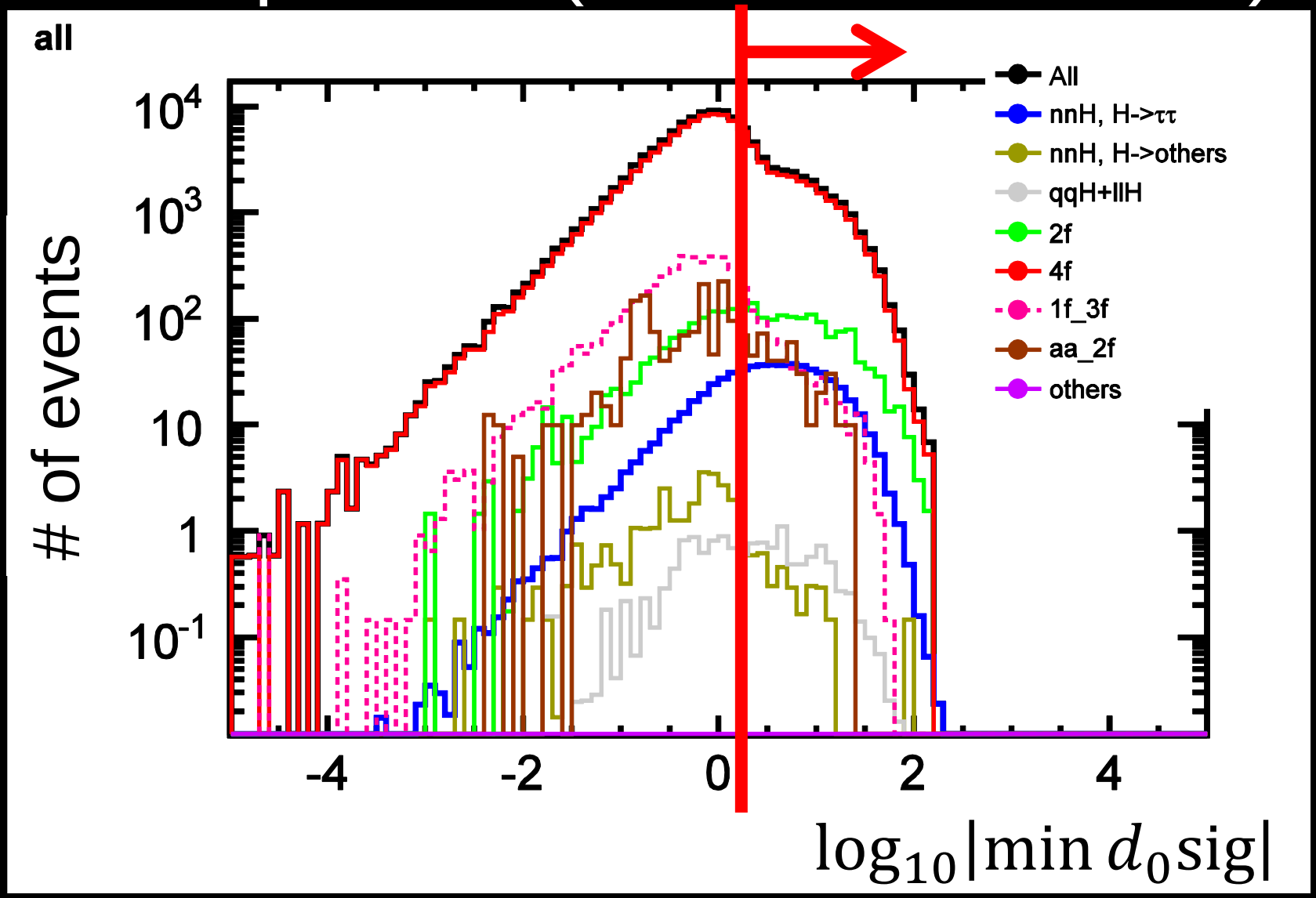


表 1　250 GeV $\nu\bar{\nu}h$ Cut-based 解析の cut table。eX は $\times 10^X$ を表す。

| | $\nu\bar{\nu}h$ $h \to \tau\tau$ | $\nu\bar{\nu}h$ $h \not\to \tau\tau$ | $q\bar{q}h$ $\ell\ell h$ | 2f | 4f | 1f_3f | aa_2f | sig. |
|---|---|---|---|---|---|---|---|---|
| None | 1212 | 1.817e4 | 6.043e4 | 2.863e7 | 1.021e7 | 2.305e8 | 1.634e8 | 0.0582 |
| pre-sel | 1093 | 465.6 | 594.8 | 7.005e6 | 1.226e6 | 2.768e7 | 1.062e8 | 0.0917 |
| basic | 1072 | 439.8 | 145.6 | 6.001e5 | 6.058e5 | 8.681e5 | 2.263e7 | 0.216 |
| $M_{\mathrm{vis}}$ | 990.6 | 429.0 | 69.57 | 4.834e5 | 4.607e5 | 8.029e5 | 2.262e7 | 0.201 |
| $M_{\mathrm{inv}}$ | 958.3 | 417.6 | 61.73 | 4.266e5 | 3.443e5 | 7.649e5 | 2.262e7 | 0.195 |
| $P_t$ | 866.1 | 368.5 | 60.36 | 3.391e5 | 3.141e5 | 9.862e4 | 1.904e5 | 0.892 |
| thrust | 856.9 | 282.6 | 35.79 | 2.635e5 | 2.642e5 | 7.605e4 | 1.748e5 | 0.970 |
| $\theta_{\mathrm{miss}}$ | 823.0 | 275.5 | 33.60 | 2.127e5 | 2.463e5 | 3.083e4 | 8.027e4 | 1.09 |
| $M_{\tau\tau}$ | 810.4 | 248.0 | 32.38 | 2.080e5 | 2.395e5 | 2.505e4 | 7.868e4 | 1.09 |
| $\theta_{\tau\tau}$ | 639.2 | 32.07 | 15.51 | 1.802e4 | 1.109e5 | 5443 | 1.311e4 | 1.66 |
| $\theta_{\mathrm{acop}}$ | 596.2 | 30.27 | 14.31 | 2314 | 1.045e5 | 4544 | 1793 | 1.77 |
| $d_0$sig | 378.3 | 3.314 | 6.980 | 1216 | 2.407e4 | 508.3 | 367.2 | 2.32 |

$2.32\sigma \leftrightarrow 43.1\%$

relatively ~7% better than previous analysis

# TMVA Analysis

- 13 parameters
  - $M_{\mathrm{vis}}$, $M_{\mathrm{inv}}$, $E_{\mathrm{vis}}$, $P_t$, thrust, $\cos\theta_{\mathrm{miss}}$, # of $E > 5$ tracks, # of $P_t > 5$ tracks, $M_{\tau\tau}$, $E_{\tau\tau}$, $\cos\theta_{\tau\tau}$, $\cos\theta_{\mathrm{acop}}$, $\log_{10}|\min d_0\mathrm{sig}|$
- used the file which applied pre-cuts and basic cuts
- tried BDT and BDTG in TMVA
  - still working, need time to optimize training parameters...
  - must be better than 43.1%, expecting ~30% level

# Results

| 250 GeV 250 fb$^{-1}$ | $q\bar{q}h$ | $\nu\bar{\nu}h$ | $e^+e^-h$ | $\mu^+\mu^-h$ |
|---|---|---|---|---|
| $\frac{\Delta(\sigma \times \mathrm{BR})}{(\sigma \times \mathrm{BR})}$ | **3.4%** | **43.1% Cut-based** | 16.1% | 14.7% |
| Status | **DONE** | **TMVA running (will be ~30%?)** | Extrapolation from $M_h$ = 120 GeV Cut-based only **NEXT WORKS** | |

# Additional Challenge

- Try to get Higgs mass with using an approximation.
- I tried collinear approximation like approximation.

# Collinear Approximation

- We assume following...
  1. visible tau decay products and invisible products are collinear
  2. there are no neutrinos except from tau decay
- In $\nu\bar{\nu}h$, we can't use this approximation due to additional neutrinos.

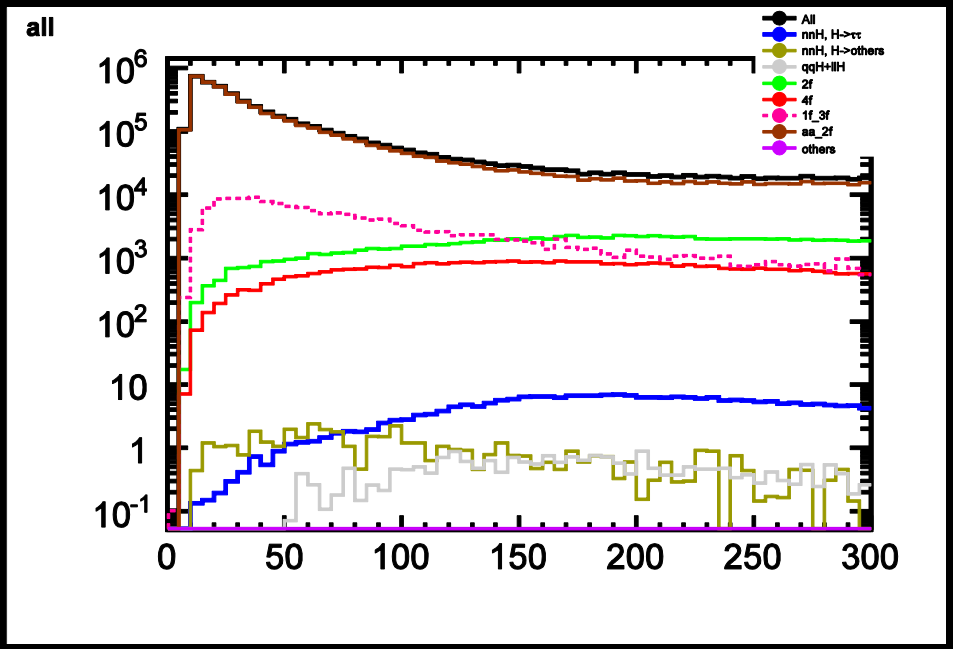
# Approximation This Time Tried

- I assume following...
  1. visible tau decay products and invisible products are collinear
  2. set the total invariant mass of decay products in 1. to tau mass (1.778 GeV)
  - I can get 4-momentum of neutrino(s) from tau decay by approximation.
- I applied this approximation to $\tau^+$ and $\tau^-$, and get Higgs mass(energy).

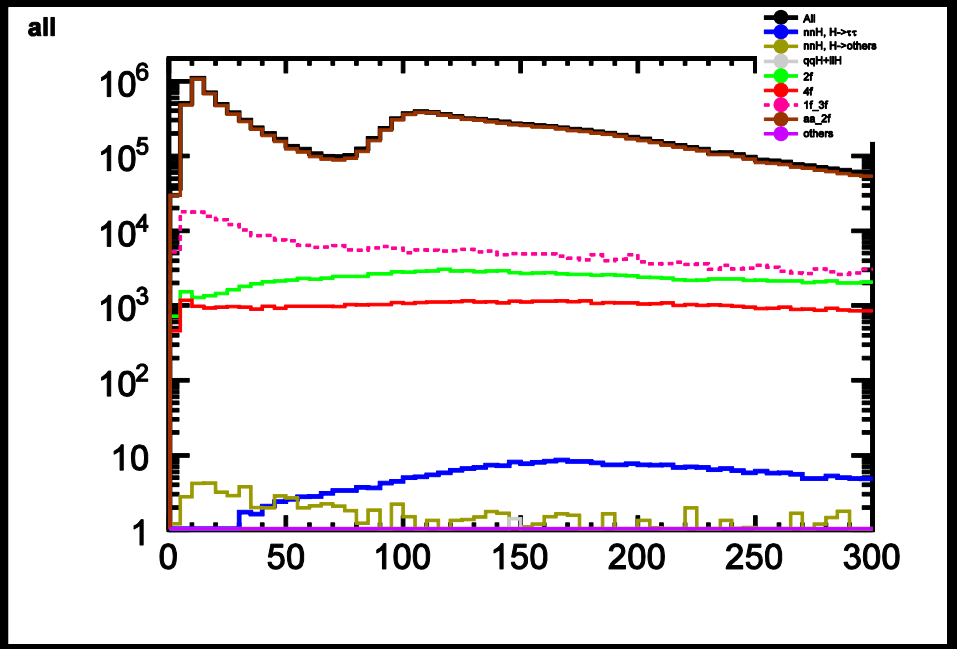
# Plots From Approximation

## after pre-cuts & basic cuts

$E_{\mathrm{app}}(E_h)$




$M_{\mathrm{app}}(M_h)$

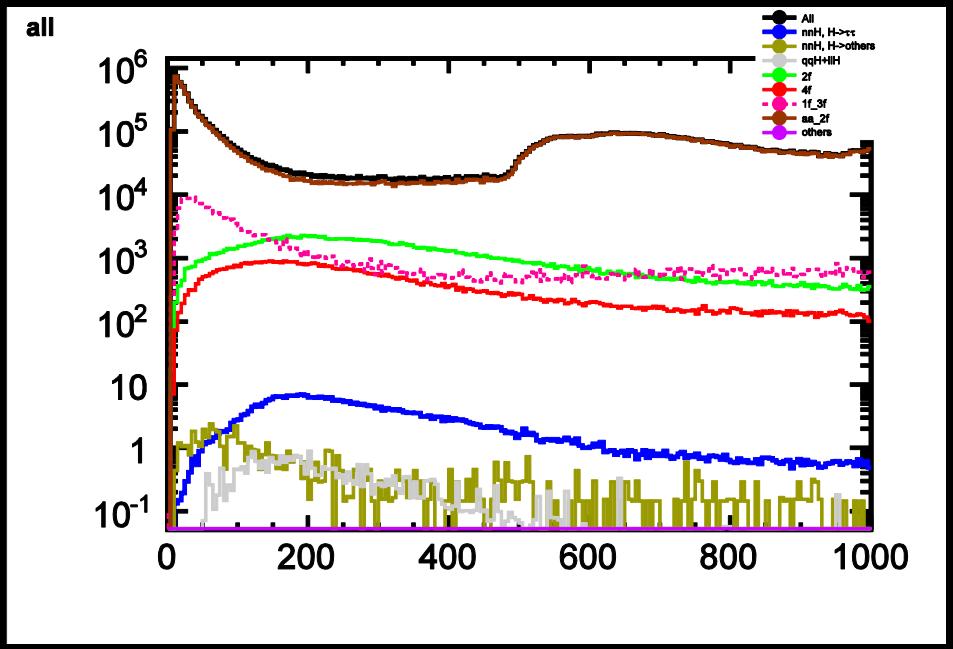


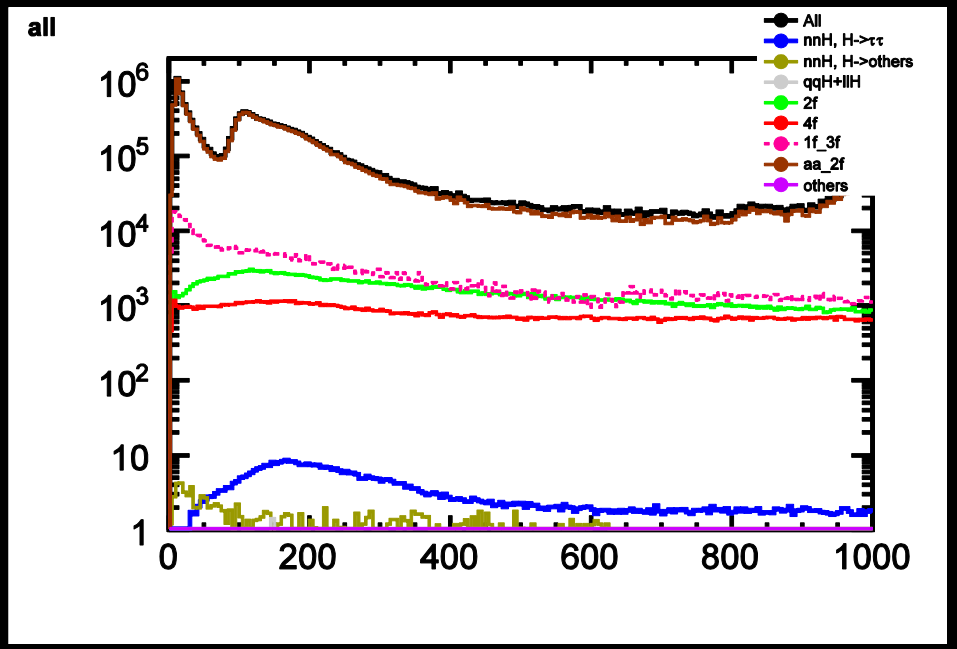

no peaks, long tails...

# Plots From Approximation

same plot but in wider range

$E_{\mathrm{app}}(E_h)$ $M_{\mathrm{app}}(M_h)$




applying cuts from higher region doesn't make sense


What a dirty distribution...

maybe need to check/develop in each tau decay mode to get better results in this approximation...

If possible, I want to use better approximation in 500 GeV $\nu\bar{\nu}h$... because it has the largest number of signal events.

# Summary

- The background rejection for $\nu\bar{\nu}h$ signal is very difficult due to lots of neutrinos and initial photons.
- Contribution of 250 GeV $\nu\bar{\nu}h$ looks small, expecting $\frac{\Delta(\sigma\times\mathrm{BR})}{(\sigma\times\mathrm{BR})}\sim 30\%$ level.
- First approximation trial gives me dirty things. If possible, I want to use better approximation especially in 500 GeV $\nu\bar{\nu}h$.
- Next: 250 GeV $\ell^+\ell^-h$, then 500 GeV