BR($h \to \tau^+\tau^-$) Study Status: 500 GeV $q\bar{q}h$ Study

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Current Results of 250 GeV Analysis

250 GeV 250 fb^{-1}	$q\bar{q}h$	e^+e^-h	$\mu^+\mu^-h$	$\nu\bar{\nu}h$
$\frac{\Delta(\sigma \times \mathrm{BR})}{(\sigma \times \mathrm{BR})}$	3.4%	14.4%	11.3%	32.4%

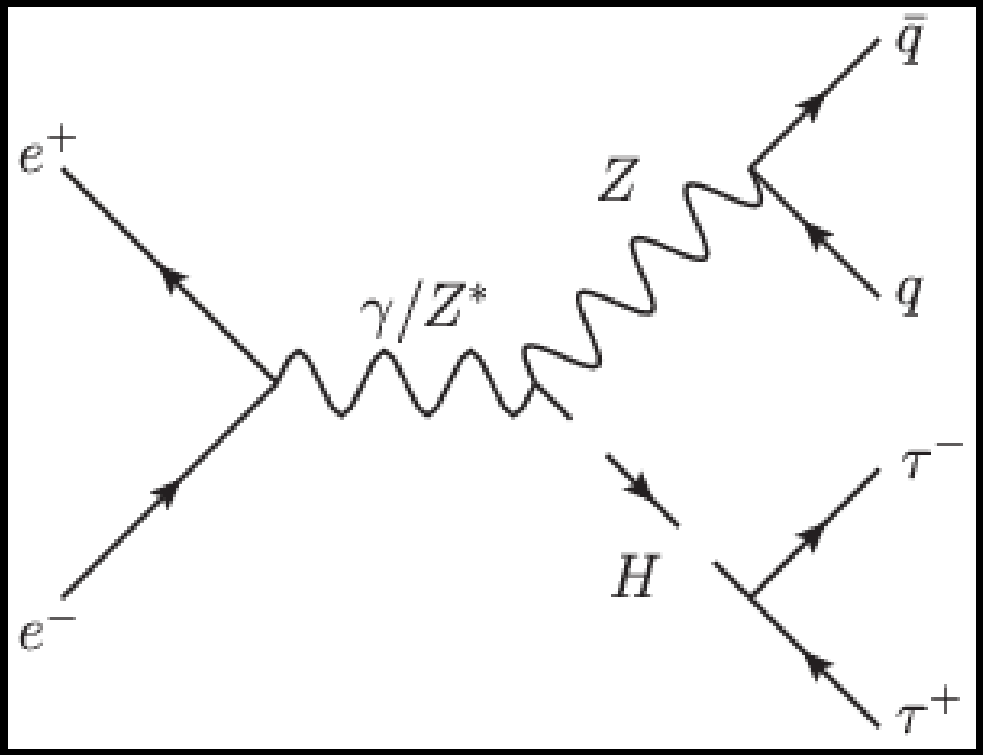
performed Cut-based and TMVA both with using samples with proper tau polarization
TMVA: optimized input variables/training parameters

Next: 500 GeV analysis with proper tau pol. samples, starts from qqh mode

Signal & Background at 500 GeV qqh

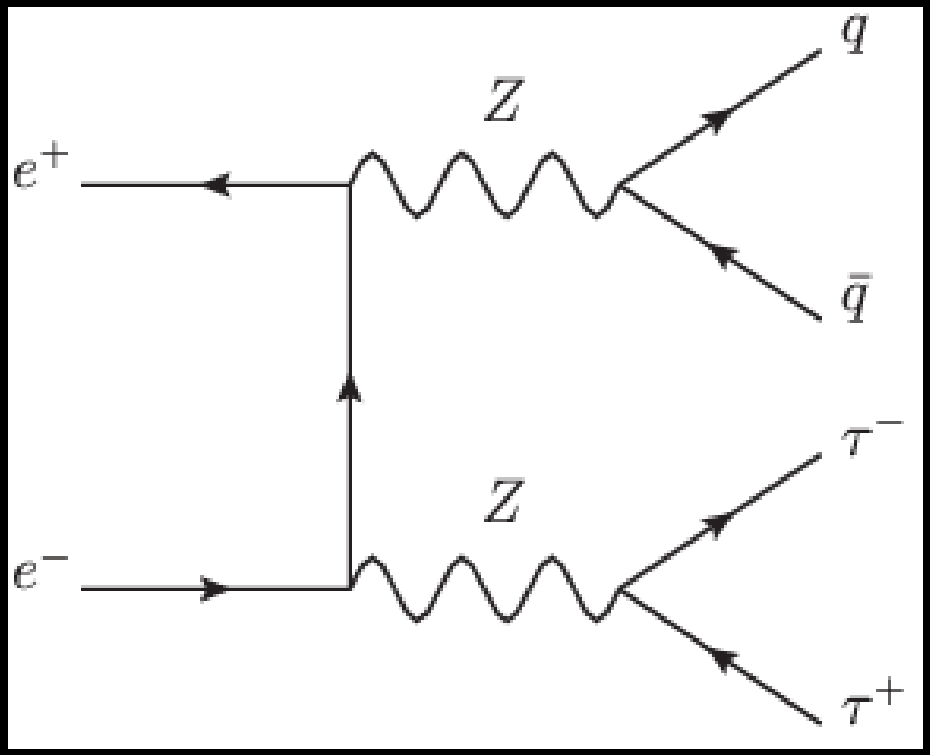
Signal

$e^+e^- \to Zh \to q\bar{q}\tau^+\tau^-$



Main background

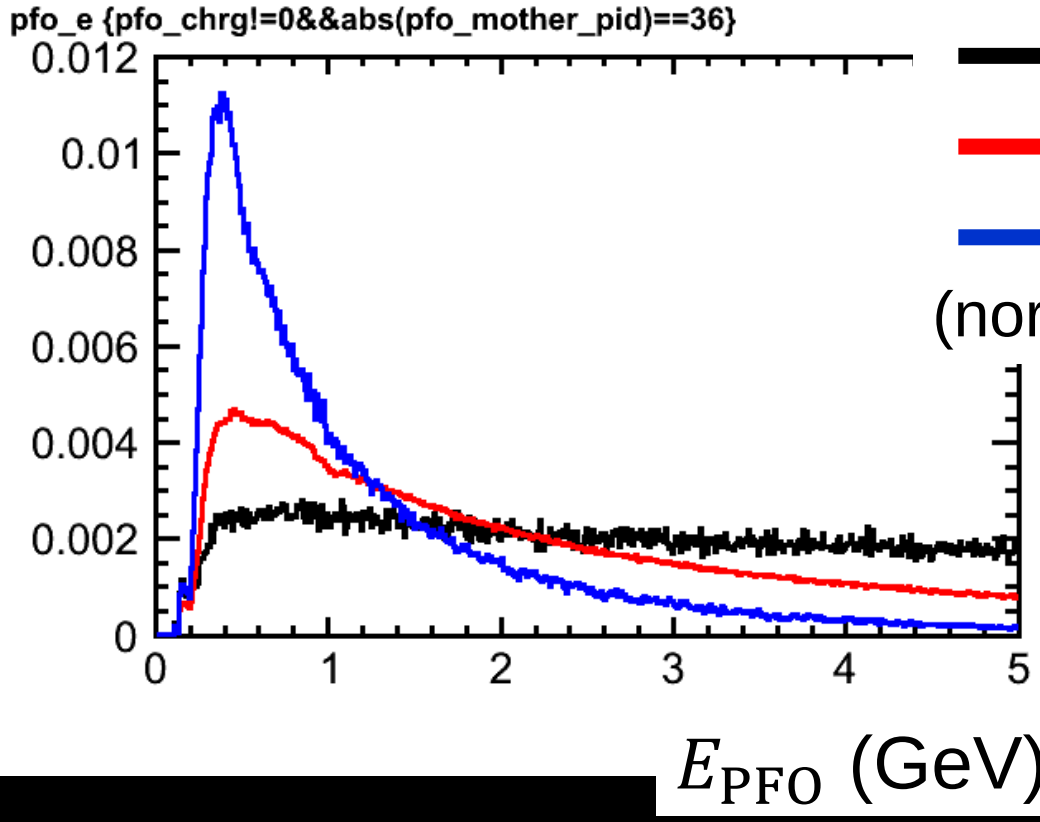
$e^+e^- \to ZZ \to q\bar{q}\tau^+\tau^-$



Event Reconstruction

- Previous analysis
  1. kT clustering 4-jet ← - this will erase some of physics signal object - how to optimize?
  2. tau finder
  3. Durham 2-jet
- This time I'm trying
  1. tau finder ← need optimization: not reconstructing overlay
  2. kT clustering 2-jet ← easy optimization with using Z mass
  3. Durham 2-jet

An example of Tau Finder Optimization



parent is Higgs = tau

parent is Z

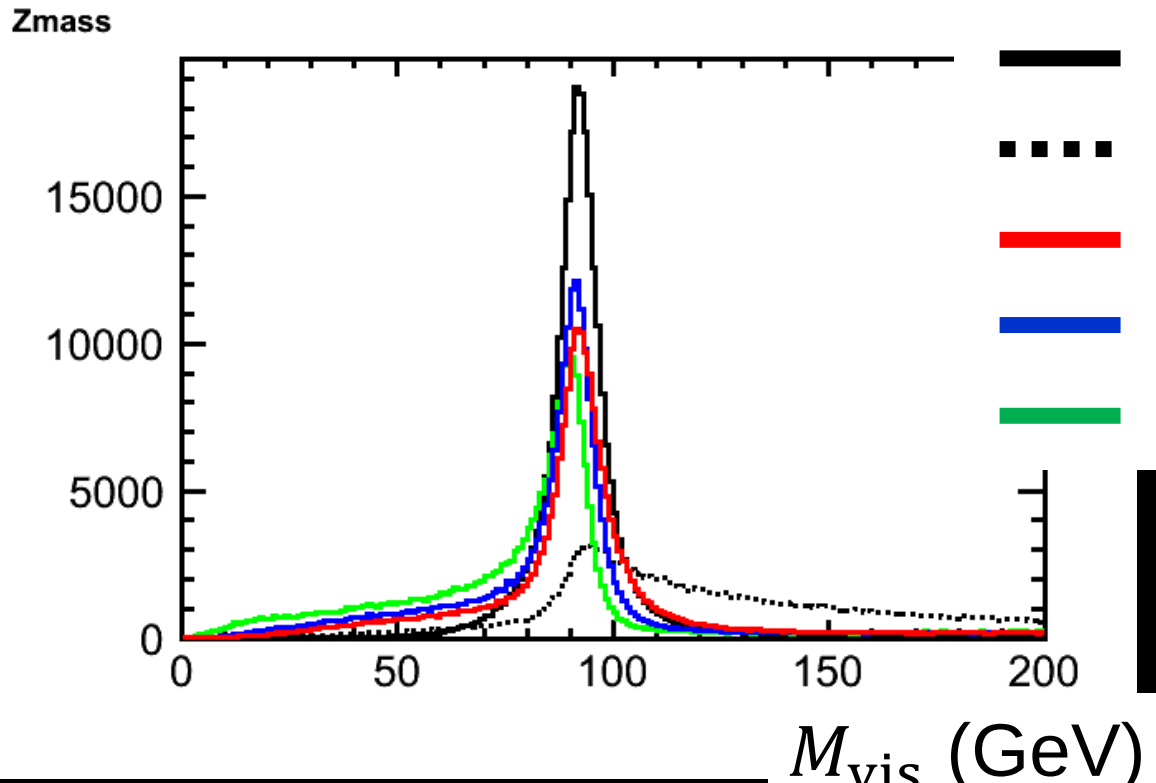
parent is overlay

(normalized to 1)

selecting charged PFO as a seed for tau clustering

I set $E_{\mathrm{PFO}} > 2$ GeV for seed of tau clustering.
Low energy particles are almost from overlay.

Optimizing kT clustering



Plot of the visible mass after tau selection.
(M_Z) = (M_{vis} after tau selection) for ideal, but contaminated by overlay objects.
I checked R = 0.5 - 1.4 (every 0.1), **R = 0.9** was best.

Cut-based Analysis

Cut 0 (pre-cuts): # of q = 2, # of $\tau^{+(-)}$ = 1
Cut 0.5 (basic cuts):
8 <= # of tracks <= 70, $140 < E_{\mathrm{vis}} < 580$, $110 < M_{\mathrm{vis}} < 575$,
$P_t > 60$, thrust < 0.99, $E_{\tau\tau} < 320$, $M_{\tau\tau} < 300$, $\cos\theta_{\tau\tau} < 0.65$,
$50 < E_Z < 395$, $10 < M_Z < 375$, $30 < E_{\mathrm{col}} < 450$, $5 < M_{\mathrm{col}} < 360$
Cut 1: # of tracks <= 67
Cut 2: $P_t(\mathrm{all}) > 5$
Cut 3: thrust < 0.94
Cut 4: $|\cos\theta_{\mathrm{thrustaxis}}| < 0.86$
Cut 5: $|\cos\theta_{\mathrm{miss}}| < 0.99$
Cut 6: $\cos\theta_{\tau\tau} < 0.56$
Cut 7: $\log_{10}|d_0\mathrm{sig}(\tau^+)| + \log_{10}|d_0\mathrm{sig}(\tau^-)| > -0.3$
Cut 8: $\log_{10}|z_0\mathrm{sig}(\tau^+)| + \log_{10}|z_0\mathrm{sig}(\tau^-)| > 0.3$
Cut 9: $E_Z > 190$
Cut 10: $70 < M_Z < 110$
Cut 11: $110 < M_{\mathrm{col}} < 140$ ← cut for collinear approximation: most important in this analysis

Cut Table and Results

表 1　500 GeV $q\bar{q}h$ Cut-based 解析の cut table。eX は $\times 10^X$ を表す。

	qqh $h \to \tau\tau$	qqh $h \not\to \tau\tau$	$\nu\nu h$ $\ell\ell h$	2f	4f	5f	6f	aa_2f	aa_4f	sig.
None	2131	3.260e4	9.397e4	1.320e7	1.598e7	6.895e4	5.888e5	9.829e8	1.041e5	0.0669
pre	1014	691.4	5223	8.181e5	6.224e5	6440	2.886e4	1.583e6	9619	0.578
basic	998.9	357.7	2631	5.919e4	1.781e5	3956	2.042e4	2.567e4	2273	1.84
# tracks	998.6	353.8	2628	5.916e4	1.780e5	3947	2.005e4	2.567e4	2270	1.84
P_t(all)	991.5	299.4	1972	3.636e4	1.375e5	3059	1.886e4	2.219e4	1695	2.10
thrust	978.8	297.3	1955	2.138e4	7.974e4	2999	1.881e4	1.220e4	1653	2.62
$\theta_{\mathrm{thrustaxis}}$	883.2	273.8	1458	1.082e4	3.628e4	1388	1.476e4	4056	668.4	3.32
θ_{miss}	875.6	259.9	1330	9066	3.273e4	1245	1.444e4	3863	543.0	3.45
$\theta_{\tau\tau}$	872.5	232.9	874.9	8425	3.038e4	1216	1.404e4	3818	521.6	3.55
$d_0$sig	849.4	173.8	584.7	5861	2.028e4	726.0	9900	1586	334.0	4.23
$z_0$sig	784.9	109.1	230.2	3533	9256	165.6	5241	159.7	80.55	5.61
E_Z	697.8	86.72	155.6	2073	4542	36.28	2461	14.83	15.93	6.95
M_Z	610.5	19.13	34.03	176.3	1836	11.20	181.7	5.207	7.968	11.4
M_{colapp}	515.2	3.047	4.187	2.634	116.9	1.718	15.21	0	0	20.1

remained N_{sig} = 515.2, N_{bkg} = 143.7

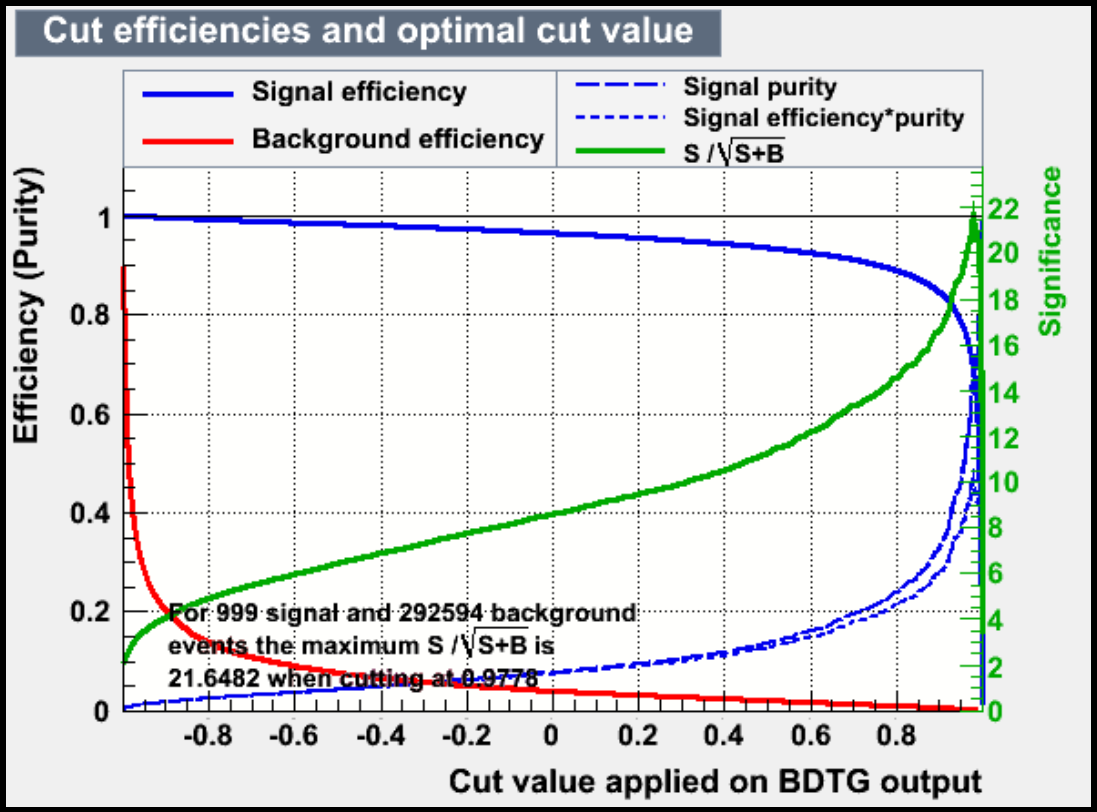
$$\frac{S}{\sqrt{S+B}} = \mathbf{20.1\sigma} \leftrightarrow \frac{\Delta(\sigma \times \mathrm{BR})}{(\sigma \times \mathrm{BR})} = \mathbf{5.0\%}$$

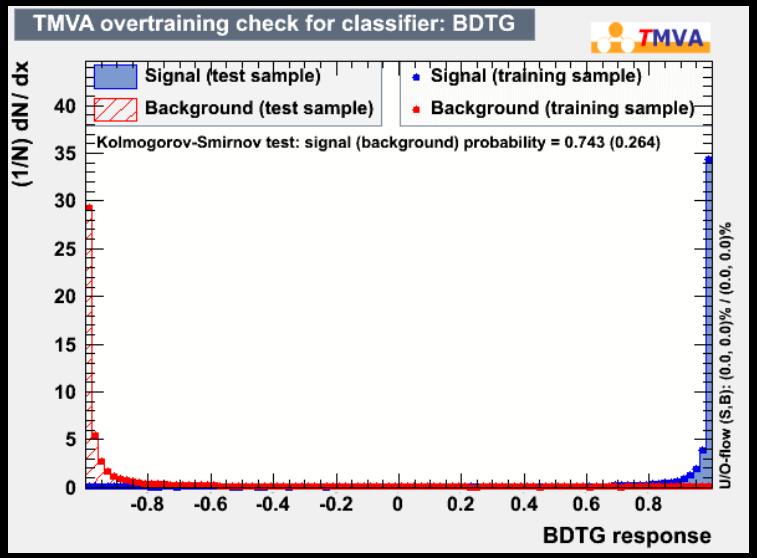
not so changed than previous (4.9%)

TMVA (BDTG) Analysis

- 14 variables
  - E_{vis}、P_t、 $P_t(\mathrm{all})$
  - M_Z、 E_Z、$\cos\theta_{q\bar{q}}$、$\cos\theta_Z$
  - $M_{\tau\tau}$、$\cos\theta_{\tau\tau}$、$\cos\theta_{\mathrm{acop}}$、$d_0$sig、$z_0$sig
  - M_{col}、E_{col}
- Training parameters
  - nCuts = 45, Shrinkage = 0.20, MaxDepth = 3, NTrees = 300, nEventsMin = 250

BDTG Results





$N_{sig} = 695.1$, $N_{bkg} = 335.8$

$$\frac{S}{\sqrt{S+B}} = 21.6\sigma \leftrightarrow \frac{\Delta(\sigma \times \mathrm{BR})}{(\sigma \times \mathrm{BR})} = 4.6\%$$

Summary and Plans

500 GeV, 500 fb^{-1} $q\bar{q}h$ mode	**Cut-based**	**TMVA (BDTG)**
$\frac{\Delta(\sigma \times \mathrm{BR})}{(\sigma \times \mathrm{BR})}$	5.0%	**4.6%**

Next:

- tau finder study
  --- current eff. = 49.8% for tau+ and tau- reco.
  --- tau+(tau-) reco. eff. = 70.6%(70.6%)
- Analysis of other signal process
  --- $\nu\bar{\nu}h$, e^+e^-h, $\mu^+\mu^-h$ ($\nu\bar{\nu}h$ just started)
  --- need to get final results before JPS (Mar./21 - 24)