BR($h \to \tau^+\tau^-$) Study Status

Shin-ichi Kawada
Hiroshima University

Status

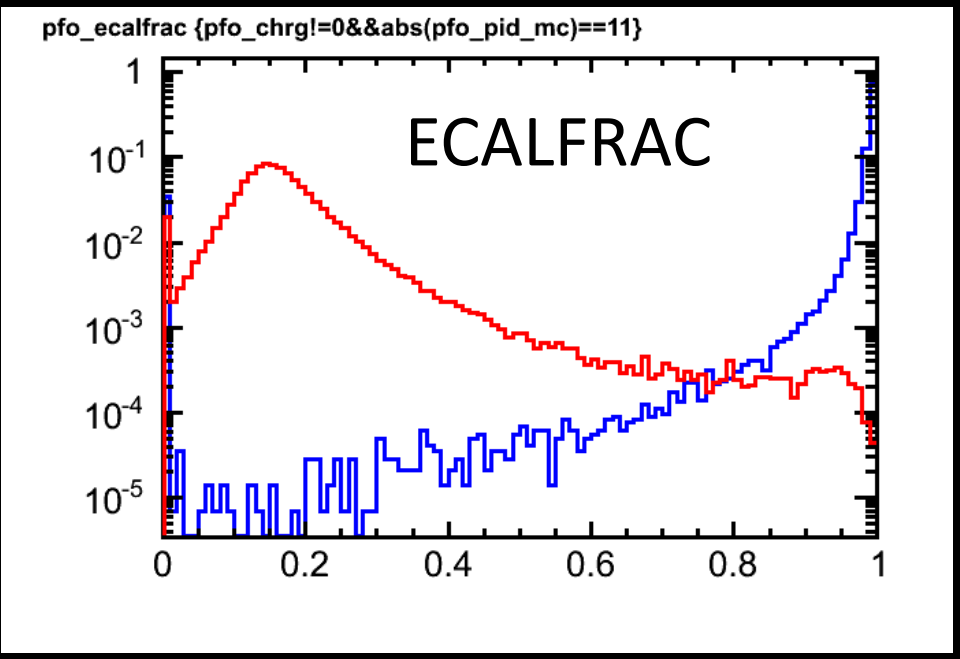
- Now: working on 500 GeV e^+e^-h and $\mu^+\mu^-h$ with proper tau polarization samples

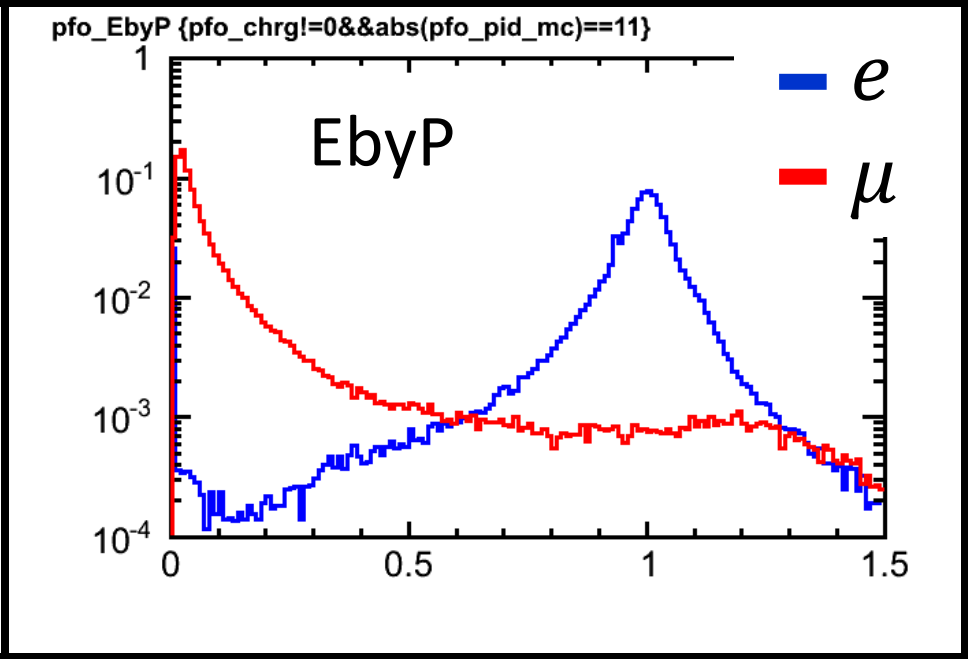
Event Reconstruction

- Lepton finder and tau finder for $\nu\bar{\nu}h$ & $\ell^+\ell^-h$
  - Previous: kT-4, then lepton finder, then tau finder. But kT will discards some of physics signal object.

Lepton Finding

using ECALFRAC = $\frac{E_{\mathrm{ECAL}}}{E_{\mathrm{ECAL}}+E_{\mathrm{HCAL}}}$ and EbyP = $\frac{E_{\mathrm{ECAL}}+E_{\mathrm{HCAL}}}{P_{\mathrm{track}}}$

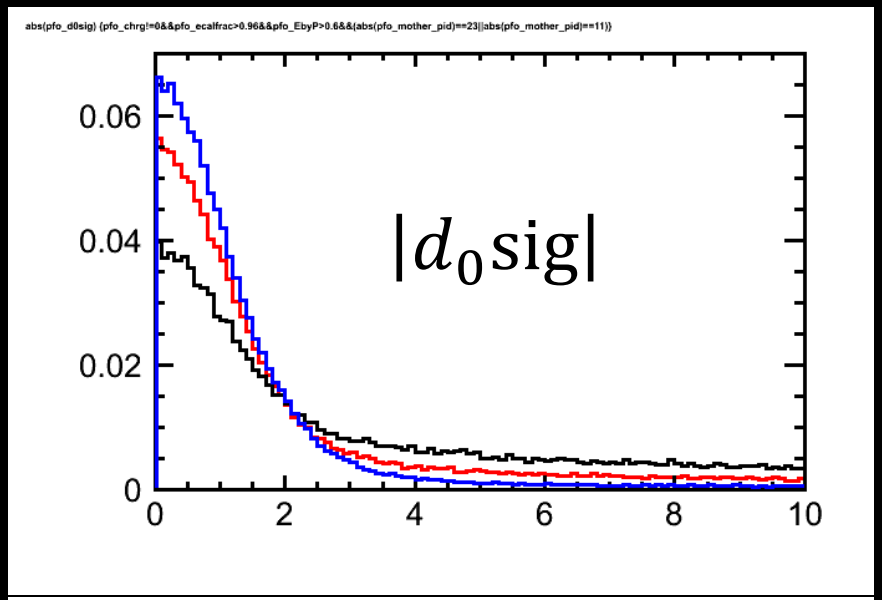


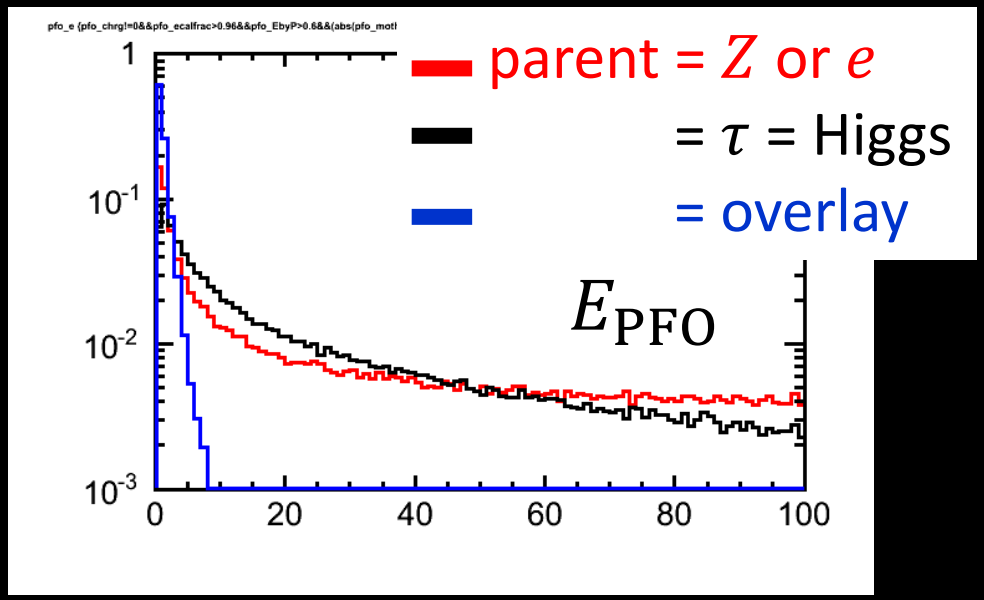


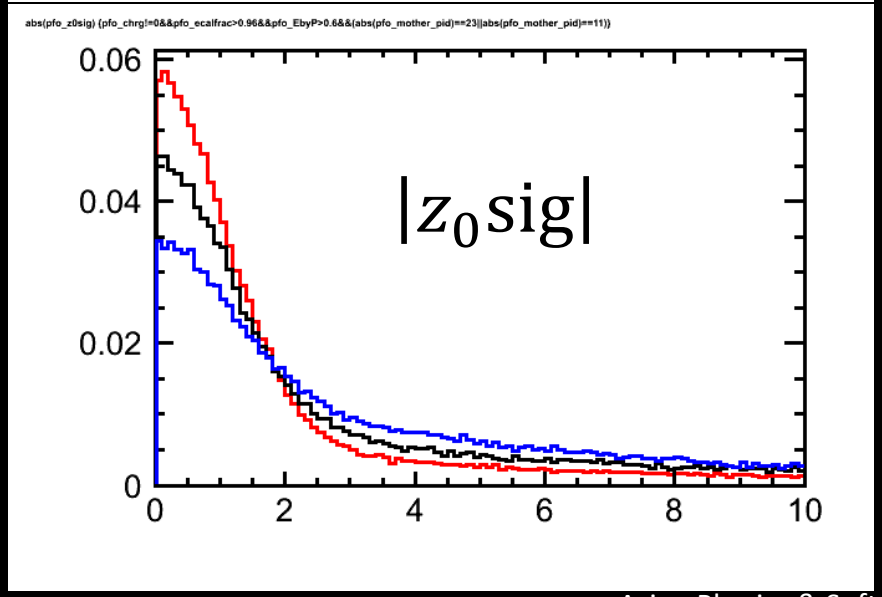
e-ID: ECALFRAC > 0.96 && EbyP > 0.6

μ-ID: ECALFRAC < 0.6 && EbyP < 0.6

Lepton Selecting (e-ID)



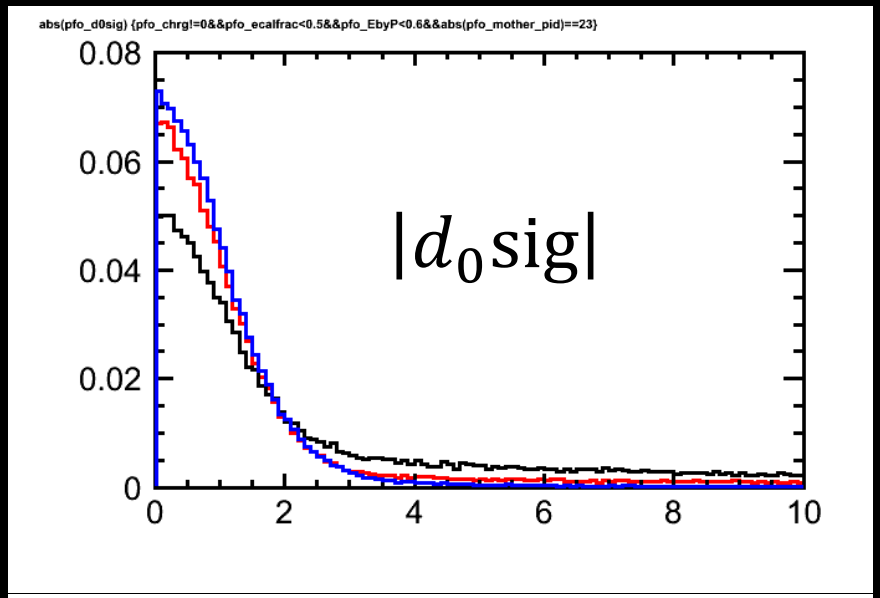


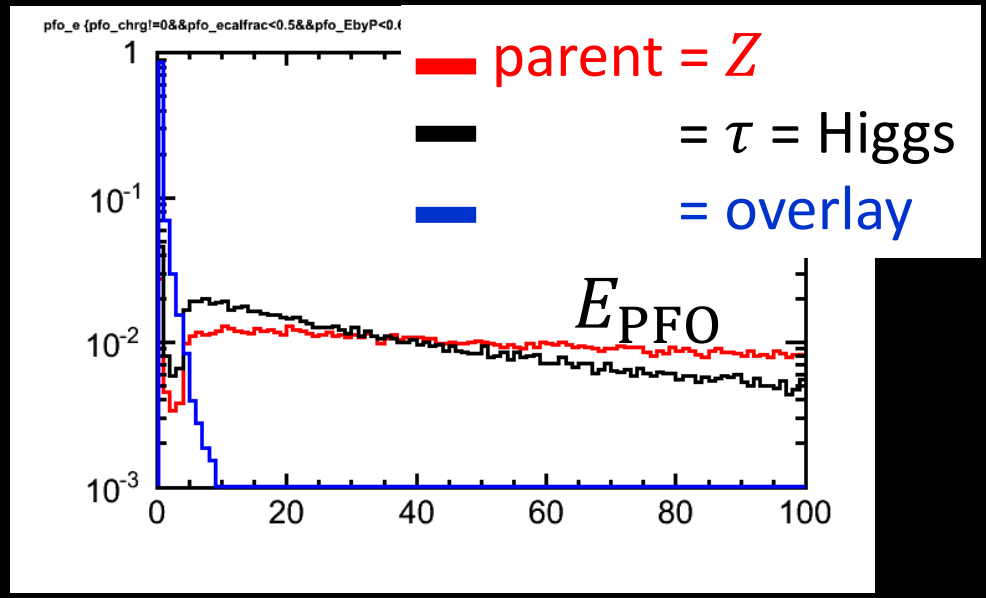


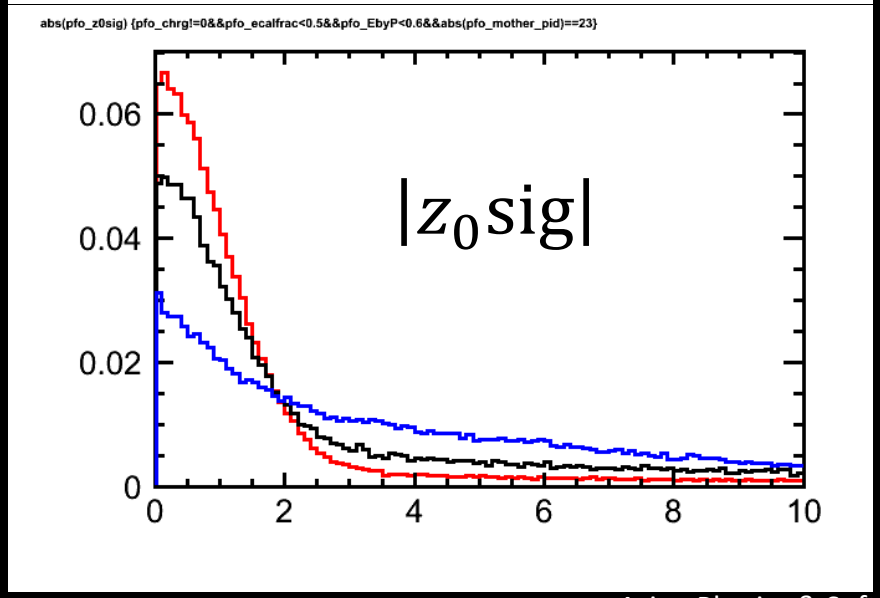
required:

$$|d_0\mathrm{sig}| < 2, |z_0\mathrm{sig}| < 2,$$
$$E_{\mathrm{PFO}} > 10$$

Lepton Selecting (μ-ID)







required:

$$|d_0\mathrm{sig}| < 2, |z_0\mathrm{sig}| < 2,$$
$$E_{\mathrm{PFO}} > 25$$

500 GeV e^+e^-h

Cut-based Analysis: Cut Flow

Cut 0 (pre-cuts): flag = 1 (e type), # of $\tau^{+(-)} \geq 1$, # of tracks <= 12
Cut 0.5 (basic cuts):
$150 < E_{\mathrm{vis}} < 585$, $110 < M_{\mathrm{vis}} < 580$, $P_t > 55$,
$90 < E_{ee} < 425$, $M_{ee} < 415$, $M_{\tau\tau} < 260$
Cut 1: $P_t > 215$
Cut 2: $P_t(\mathrm{all}) > 15$
Cut 3: thrust < 0.92
Cut 4: $M_{ee} > 50$
Cut 5: $\cos\theta_{ee} > 0.57$
Cut 6: $E_{\tau\tau} > 100$
Cut 7: $M_{\tau\tau} < 125$
Cut 8: $\cos\theta_{\tau\tau} < 0.69$
Cut 9: $\cos\theta_{\mathrm{acop}} < 0.99$
Cut 10: $\log_{10}|d_0\mathrm{sig}(\tau^+)| + \log_{10}|d_0\mathrm{sig}(\tau^-)| > 0.4$

Cut Table & Results

表 1　$e^+e^- \to e^+e^-h$ 500 GeV 解析のカットテーブル。eX は $\times 10^X$ を表す。

	e^+e^-h signal	e^+e^-h other	$\mu^+\mu^-h$	$\tau^+\tau^-h$	$q\bar{q}h$ $\nu\bar{\nu}h$	2f	4f	5f	6f	aa_2f	aa_4f	sig.
none	358.6	5097	1724	1724	1.198e5	1.320e7	1.598e7	6.895e4	5.888e5	9.829e8	1.041e5	0.0113
pre	113.3	65.65	0.859	2.955	57.59	2.524e5	1.351e5	1366	506.0	4.642e5	2181	0.122
basic	112.5	64.29	0.578	2.034	9.773	2.054e5	7.943e4	920.8	420.3	2.968e5	722.3	0.147
P_t	64.09	35.92	0.574	0.603	0.053	2.646e4	1.137e4	262.4	141.2	4.337e4	98.65	0.224
P_t(all)	58.07	33.03	0.295	0.601	0.053	2828	6453	202.3	133.3	3.592e4	58.07	0.272
thrust	51.15	28.65	0.002	0.042	0.044	1841	2336	162.7	119.2	1.246e4	50.52	0.392
M_{ee}	50.84	28.28	0.002	0.004	0.027	1770	2266	153.0	112.2	1.218e4	46.73	0.395
$\cos\theta_{ee}$	18.88	8.608	0	0	0	24.37	90.48	1.342	3.315	310.0	1.905	0.881
$E_{\tau\tau}$	14.13	4.854	0	0	0	0	27.88	1.174	3.315	277.0	1.905	0.778
$M_{\tau\tau}$	12.92	4.837	0	0	0	0	22.06	0	1.836	45.69	0	1.38
$\cos\theta_{\tau\tau}$	12.73	1.257	0	0	0	0	9.576	0	1.836	45.69	0	1.51
$\cos\theta_{\rm acop}$	12.62	1.257	0	0	0	0	3.286	0	1.836	43.05	0	1.6
$d_0$sig	11.50	0.035	0	0	0	0	0.376	0	0.067	0	0	3.32

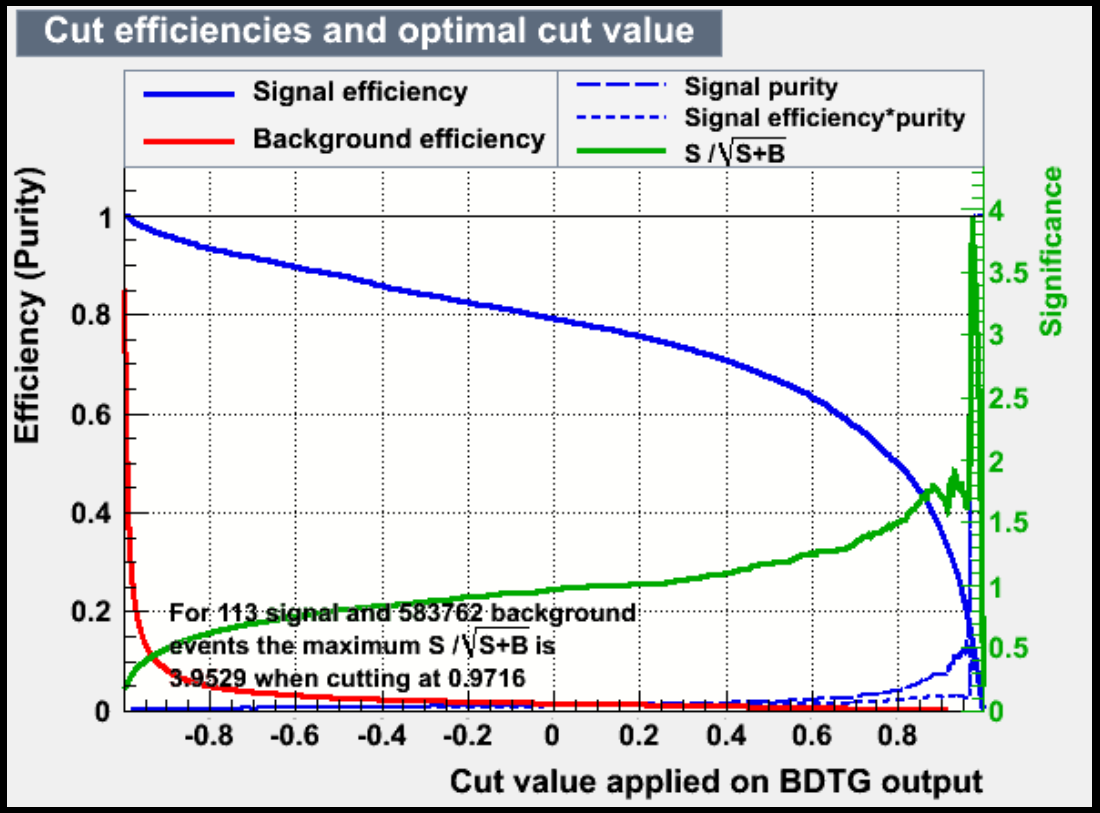
remained N_{sig} = 11.50, N_{bkg} = 0.48

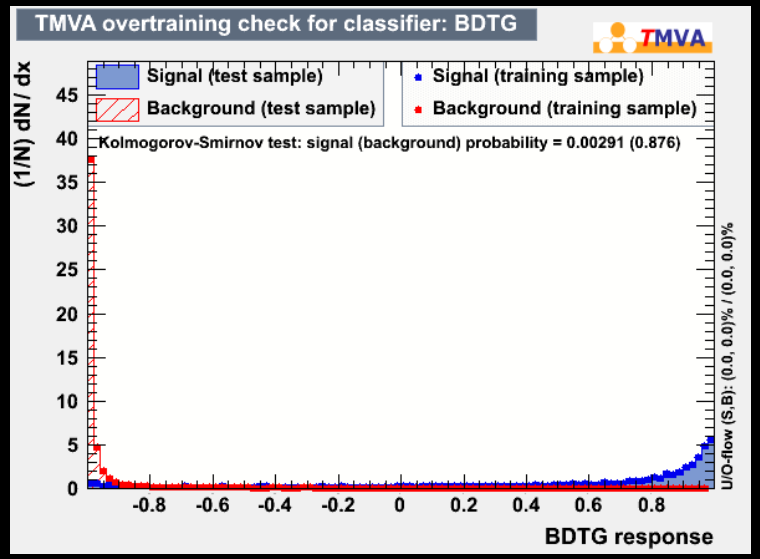
$$\frac{S}{\sqrt{S+B}} = \mathbf{3.32\sigma} \leftrightarrow \frac{\Delta(\sigma \times \mathrm{BR})}{(\sigma \times \mathrm{BR})} = \mathbf{30.1\%}$$

TMVA (BDTG) Analysis

- 10 input variables
  - E_{vis}, P_t
  - $M_{ee}, E_{ee}, \cos\theta_{ee}$
  - $M_{\tau\tau}, \cos\theta_{\tau\tau}, \cos\theta_{\mathrm{acop}}, \log_{10}|d_0\mathrm{sig}(\tau^+)| + \log_{10}|d_0\mathrm{sig}(\tau^-)|,$ $\log_{10}|z_0\mathrm{sig}(\tau^+)| + \log_{10}|z_0\mathrm{sig}(\tau^-)|$
- Training parameters
  - nCuts = 60, Shrinkage = 0.11, MaxDepth = 3, NTrees = 400, nEventsMin = 100

Results





$KS_{sig} = 0.00291$

$KS_{bkg} = 0.876$

(OVERTRAINING)

$N_{sig} = 15.660$, $N_{bkg} = 0.035$

$$\frac{S}{\sqrt{S+B}} = \mathbf{3.95\sigma} \leftrightarrow \frac{\Delta(\sigma \times \mathrm{BR})}{(\sigma \times \mathrm{BR})} = \mathbf{25.2\%}$$

500 GeV $\mu^+\mu^-h$

Cut-based Analysis: Cut Flow

Cut 0 (pre-cuts): flag = 2 (μ type), # of $\tau^{+(-)} \geq 1$, # of tracks <= 12
Cut 0.5 (basic cuts):
$160 < E_{\mathrm{vis}} < 570$, $110 < M_{\mathrm{vis}} < 560$, $P_t > 80$,
$80 < E_{\mu\mu} < 300$, $15 < M_{\mu\mu} < 250$, $M_{\tau\tau} < 175$, $M_{\mathrm{recoil}} > 60$
Cut 1: $M_{\mathrm{vis}} < 500$
Cut 2: $P_t > 200$
Cut 3: $P_t(\mathrm{all}) > 25$
Cut 4: thrust < 0.94
Cut 5: $|\cos\theta_{\mathrm{miss}}| < 0.94$
Cut 6: $E_{\mu\mu} > 215$
Cut 7: $M_{\mu\mu} < 105$
Cut 8: $M_{\tau\tau} > 35$
Cut 9: $\cos\theta_{\tau\tau} < 0.56$

Cut Table & Results

表 2　$e^+e^- \to \mu^+\mu^- h$ 500 GeV 解析のカットテーブル。eX は $\times 10^X$ を表す。

	$\mu^+\mu^- h$ signal	$\mu^+\mu^- h$ other	$e^+e^- h$	$\tau^+\tau^- h$	$q\bar{q}h$ $\nu\bar{\nu}h$	2f	4f	5f	6f	aa_2f	aa_4f	sig.
none	105.7	1618	5455	1724	1.198e5	1.320e7	1.598e7	6.895e4	5.888e5	9.829e8	1.041e5	0.00332
pre	57.93	30.61	7.713	1.477	41.64	1.795e5	6.656e4	425.9	301.8	1.515e5	718.3	0.0917
basic	57.33	28.63	2.486	1.199	12.83	2.675e4	1.684e4	217.1	202.7	1.022e4	177.1	0.246
$M_{\rm vis}$	56.48	26.69	1.609	1.199	12.83	2.103e4	1.381e4	208.7	202.6	9314	167.3	0.267
P_t	50.47	21.79	0.941	0.603	0.425	4169	2446	51.17	88.82	2826	25.59	0.513
P_t(all)	45.74	19.68	0.321	0.594	0.425	72.31	1378	42.06	72.28	1817	9.839	0.778
thrust	44.75	18.56	0.321	0.594	0.425	39.37	1055	40.72	69.79	850.0	8.855	0.970
$\theta_{\rm miss}$	44.12	18.54	0.321	0.594	0.425	39.00	1027	39.32	67.99	836.0	7.871	0.967
$E_{\mu\mu}$	37.17	14.69	0.006	0.276	0	39.00	824.5	2.559	14.06	146.6	1.968	1.13
$M_{\mu\mu}$	35.81	13.56	0.006	0	0	32.18	186.9	0	5.275	0	0	2.16
$M_{\tau\tau}$	28.42	3.917	0.006	0	0	0	19.89	0	3.455	0	0	3.81
$\cos\theta_{\tau\tau}$	28.26	2.161	0	0	0	0	0.358	0	1.586	0	0	4.97

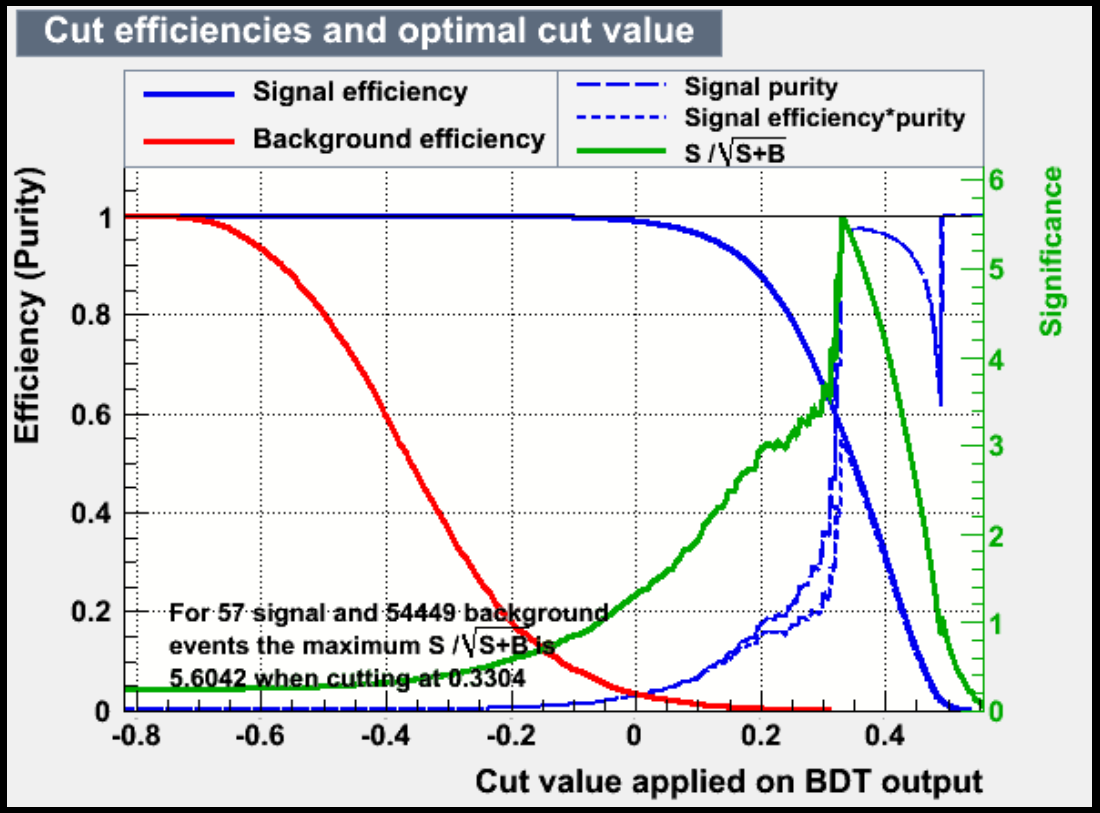
remained N_{sig} = 28.26, N_{bkg} = 4.11

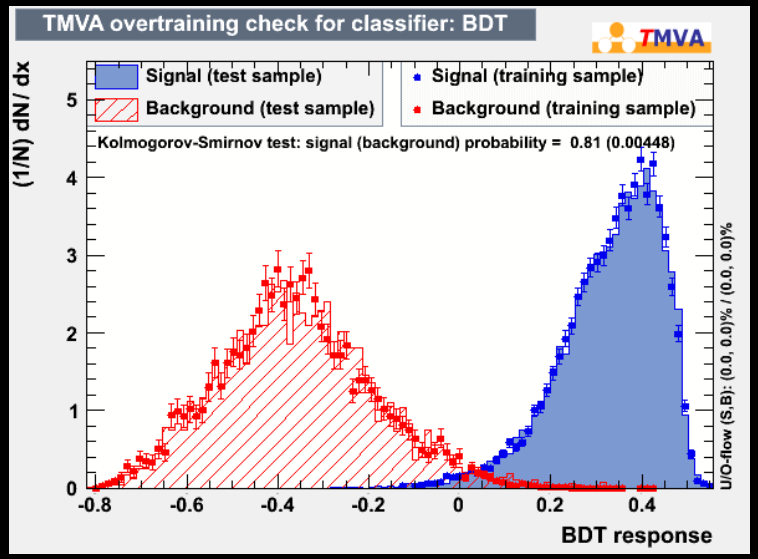
$$\frac{S}{\sqrt{S+B}} = \mathbf{4.97\sigma} \leftrightarrow \frac{\Delta(\sigma \times \mathrm{BR})}{(\sigma \times \mathrm{BR})} = \mathbf{20.1\%}$$

TMVA (BDT) Analysis

- 10 input variables
  - M_{vis}, E_{vis}, P_t, thrust
  - $M_{\mu\mu}$, $E_{\mu\mu}$
  - $M_{\tau\tau}$, $\cos\theta_{\tau\tau}$,
    $\log_{10}|d_0\mathrm{sig}(\tau^+)| + \log_{10}|d_0\mathrm{sig}(\tau^-)|$,
    $\log_{10}|z_0\mathrm{sig}(\tau^+)| + \log_{10}|z_0\mathrm{sig}(\tau^-)|$
- Training parameters
  - nCuts = 50, MaxDepth = 3, NTrees = 350, nEventsMin = 20

Results





$KS_{sig} = 0.810$

$KS_{bkg} = 0.00448$

(OVERTRAINING)

$N_{sig} = 32.29$, $N_{bkg} = 0.91$

$$\frac{S}{\sqrt{S+B}} = \mathbf{5.60\sigma} \leftrightarrow \frac{\Delta(\sigma \times \mathrm{BR})}{(\sigma \times \mathrm{BR})} = \mathbf{17.8\%}$$

Summary & Next

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%

500 GeV, 500 fb^{-1}	$q\bar{q}h$	e^+e^-h	$\mu^+\mu^-h$	$\nu\bar{\nu}h$
$\frac{\Delta(\sigma \times \mathrm{BR})}{(\sigma \times \mathrm{BR})}$	4.6%	25.2%	17.8%	6.9%

Next:

- some additional study in analysis
- separation of Zh and WW-fusion in 500 GeV $\nu\bar{\nu}h$