Precision measurements of the Top Higgs Yukawa Coupling1 TeV

T. Price & T. Tanabe

International Large Detector

txp@hep.ph.bham.ac.uk

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Overview

Input Variables I

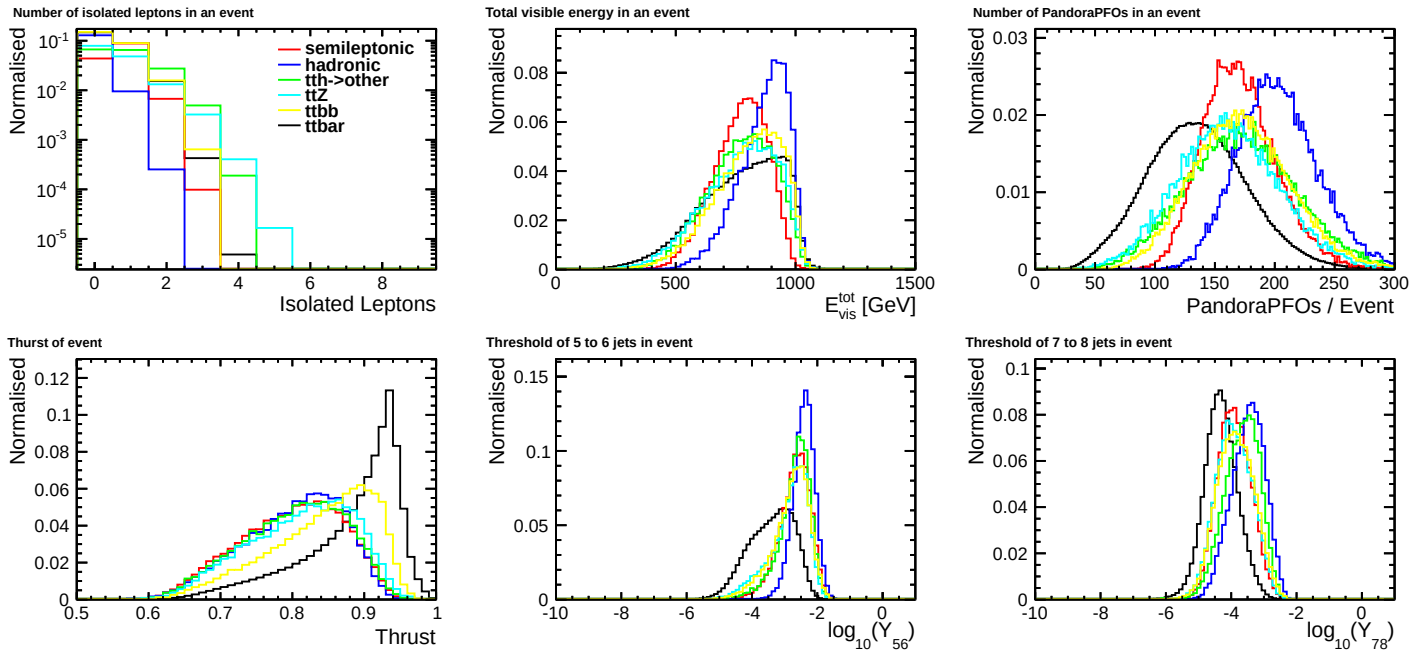

Figure: Normalised histograms of the number of identified isolated leptons (top left), total visible energy (top middle), number of PandoraPFOs (top right), thrust (bottom left), and the jet parameters (bottom) within the events for the semileptonic (red) and hadronic (blue) modes alongside the backgrounds.

Input Variables II

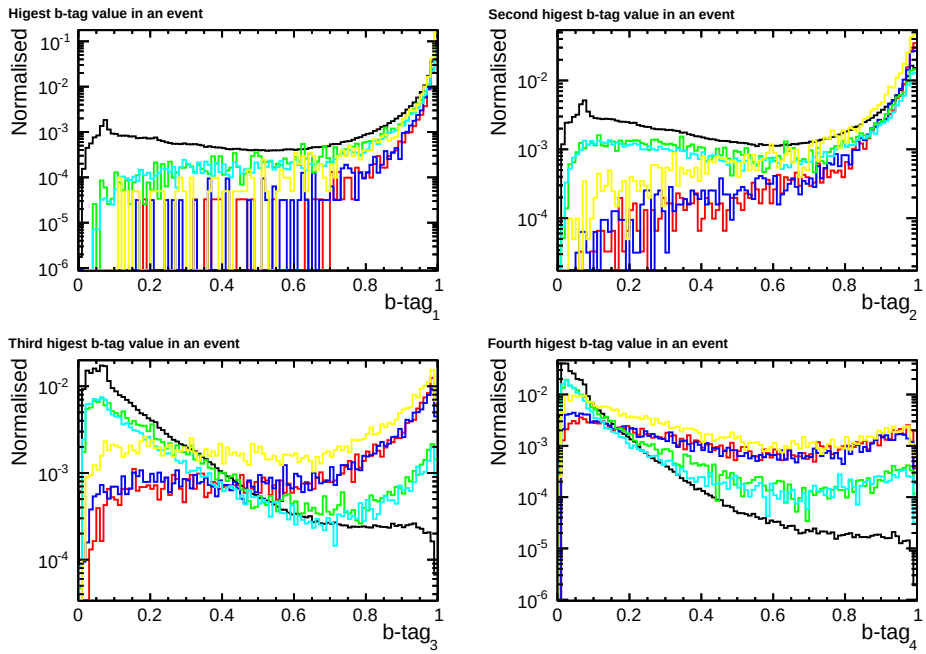

Figure: Normalised histograms for the response of the b-tagging from LCFIPlus for the highest ranked jet in an event (top left), second highest (top right), third highest (bottom left), and fourth highest (bottom right) for the semileptonic (red) and hadronic (blue) signal modes and all backgrounds.

Input Variables III

Reconstructed Masses

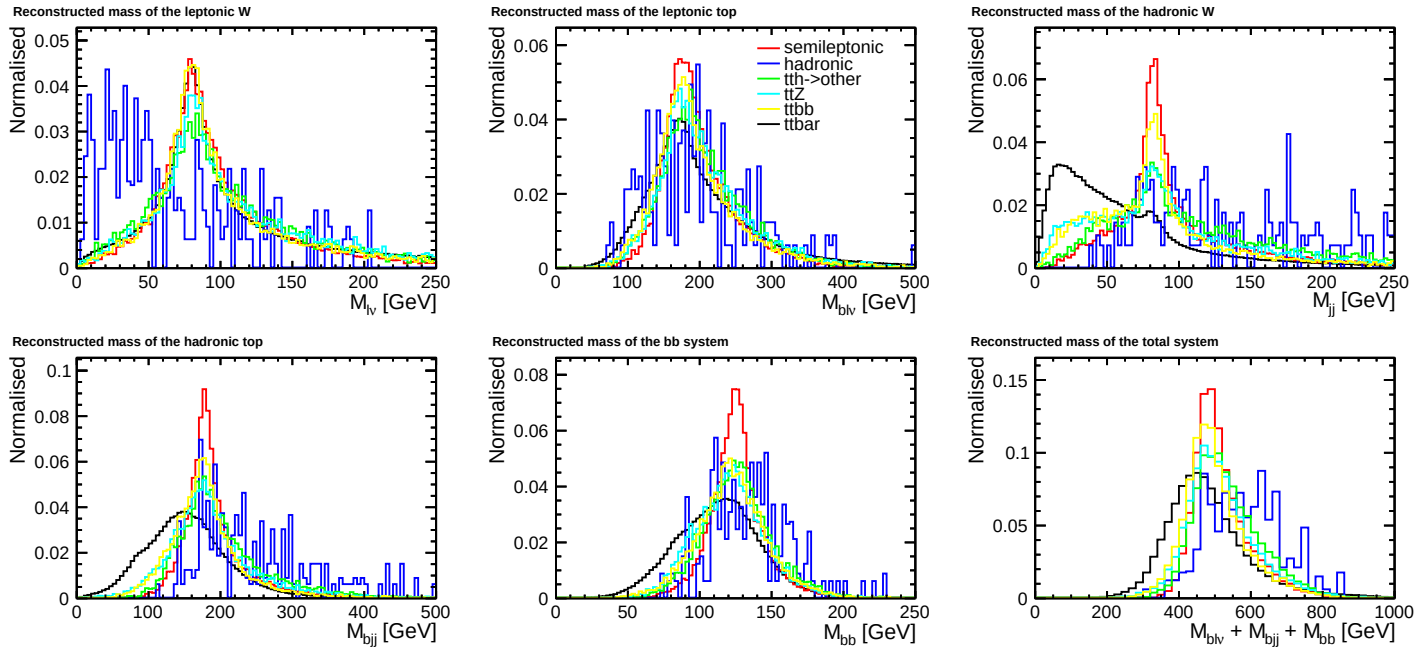

Figure: The reconstructed masses of the leptonic W boson (top left), leptonic top quark (top middle), hadronic W boson (top right), hadronic top quark (bottom left), Higgs boson (bottom middle) and total mass (bottom right) when there is exactly one identified isolated lepton in the event.

Input Variables IV

Reconstructed Masses

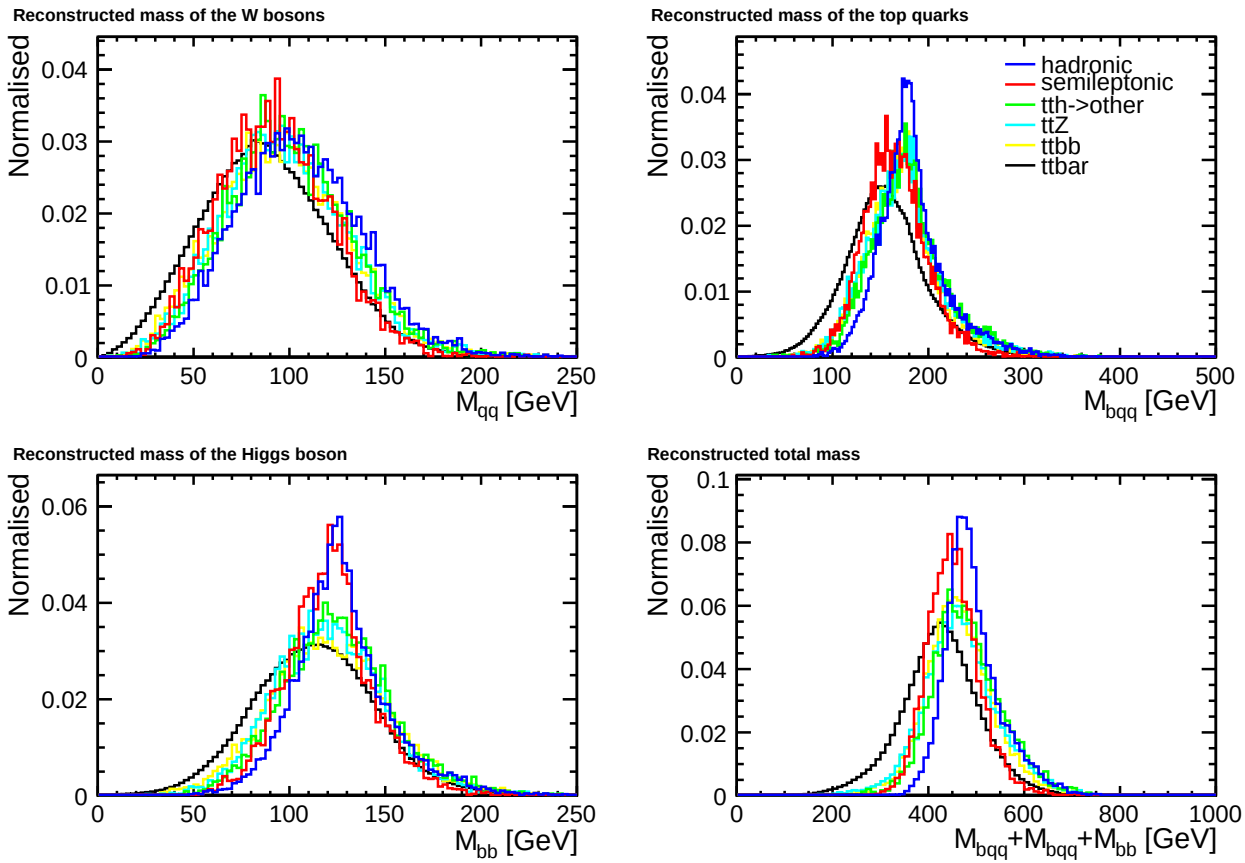

Figure: The reconstructed masses of the W boson (top left), top quark (top right), Higgs boson (bottom left) and total mass (bottom right) when there are no identified isolated leptons.

Cut Based Analysis

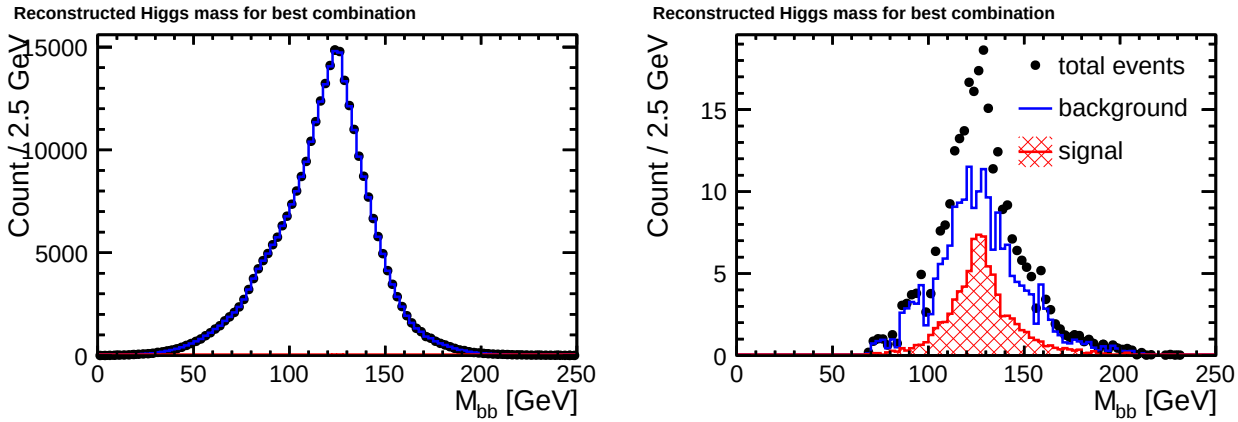

Figure: The reconstructed Higgs boson mass for the optimal combination of jets in the semileptonic decay mode for all events (left) and only the events which pass all of the cuts (right).

	Efficiency	Purity	Significance
Semileptonic	15.1%	30.6%	5.40
Hadronic	39.1%	20.3%	7.20

Table: Summary of efficiencies, purities, and significances.

Combined: Sig = 9.01, stat err = 5.8%

TMVA

Trained two TMVA's split by the number of isolated leptons. Input variables as outlined earlier.

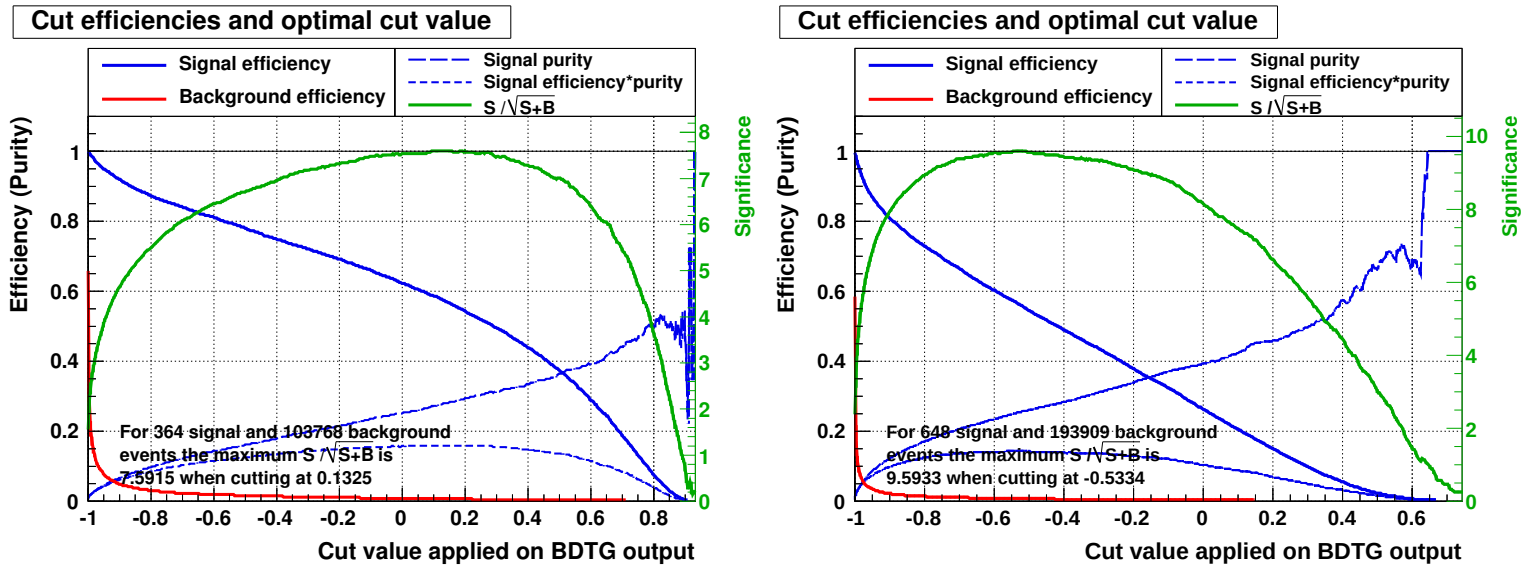

Figure: The response of the multivariate analysis for the semileptonic (left) and hadronic (right) decay modes.

TMVA

Background breakdown

Cut	lept	semi	had	other	$t\bar{t}Z$	$t\bar{t}b\bar{b}$	$t\bar{t}$	$\frac{S}{\sqrt{S+B}}$
Total Events	151.4	628.7	652.7	1046.1	5332.4	1434.5	308800.9	1.11
Semi>0.1325	18.7	208.0	2.1	10.1	126.1	125.4	261.2	7.59
Had>-0.5334	0.3	65.5	365.6	25.0	260.5	222.6	513.6	9.59

Table: The number of events passed each cut in the TMVA analysis for the semileptonic and hadronic channels.

	Efficiency	Purity	Significance
Semileptonic	33.3%	28.0%	7.59
Hadronic	56.0%	25.2%	9.59

Table: Summary of efficiencies, purities, and significances.

Combined: Sig = 12.23, stat err = 4.3%

TMVA

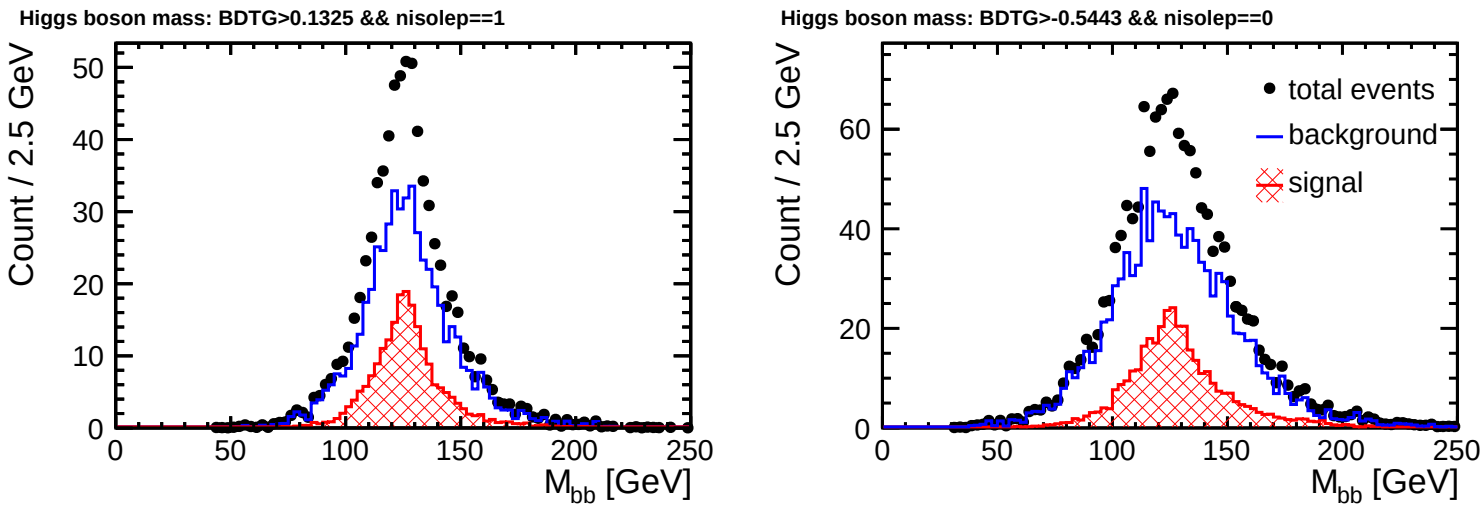

Figure: Reconstructed masses for the Higgs boson candidate after applying a cut on the multivariate classifier for the semileptonic (left) and hadronic (right) decay modes.

TMVA

Discriminating Power

Excluded Cut	Optimal BDTG	N_{sig}	N_{bg}	ϵ_{sig}	ρ_{sig}^{sample}	$\frac{S}{\sqrt{S+B}}$
E_{vis}	0.1073	208.9	576.7	0.57	0.27	7.45
PandoraPFOs	0.2176	193.8	466.5	0.53	0.29	7.54
Thrust	0.1254	200.3	569.7	0.55	0.26	7.22
$\log_{10}(Y_{45})$	0.2608	185.9	422.4	0.51	0.31	7.54
$\log_{10}(Y_{56})$	0.1369	207.1	540.2	0.57	0.28	7.57
b-tag$_1$	0.2403	190.7	444.6	0.53	0.30	7.57
b-tag$_2$	0.1988	197.5	486.2	0.54	0.29	7.55
b-tag$_3$	0.1116	184.5	494.0	0.51	0.27	7.08
b-tag$_4$	0.1204	207.4	564.8	0.57	0.27	7.46
χ^2	0.2510	189.3	434.1	0.52	0.30	7.58
$M_{l\nu}$	0.2346	192.0	448.3	0.53	0.30	7.59
$M_{bl\nu}$	0.2048	196.7	483.1	0.54	0.29	7.55
M_{jj}	0.1886	200.0	496.2	0.55	0.29	7.55
M_{bjj}	0.2405	191.1	446.8	0.53	0.30	7.57
M_{bb}	0.2082	195.7	484.0	0.54	0.29	7.51
$\cos(\theta_{hel})$	-0.0221	229.1	697.4	0.63	0.25	7.53

Table: Response of the TMVA training when one variable was excluded from the training process.

TMVA

Higgs Excluded

Higgs dependance removed from reconstruction and TMVA to use M_{bb} as final discriminant.

Cut	lept	semi	had	other	$t\bar{t}Z$	$t\bar{t}b\bar{b}$	$t\bar{t}$	$\frac{S}{\sqrt{S+B}}$
Total Events	151.4	628.7	652.7	1046.1	5332.4	1434.5	308800.9	1.11
BDTG	17.2	210.2	2.3	10.9	125.9	126.0	278.4	7.57
$M_{b\bar{b}}$ >45	17.2	209.3	2.3	10.8	124.1	120.7	269.1	7.62

Table: Number of events expected when the Higgs boson mass was removed from the jet optimisation and TMVA training for all events, the number passed the BDTG cut, and the numbers passed cuts on the mass distributions.

TMVA

Higgs Excluded

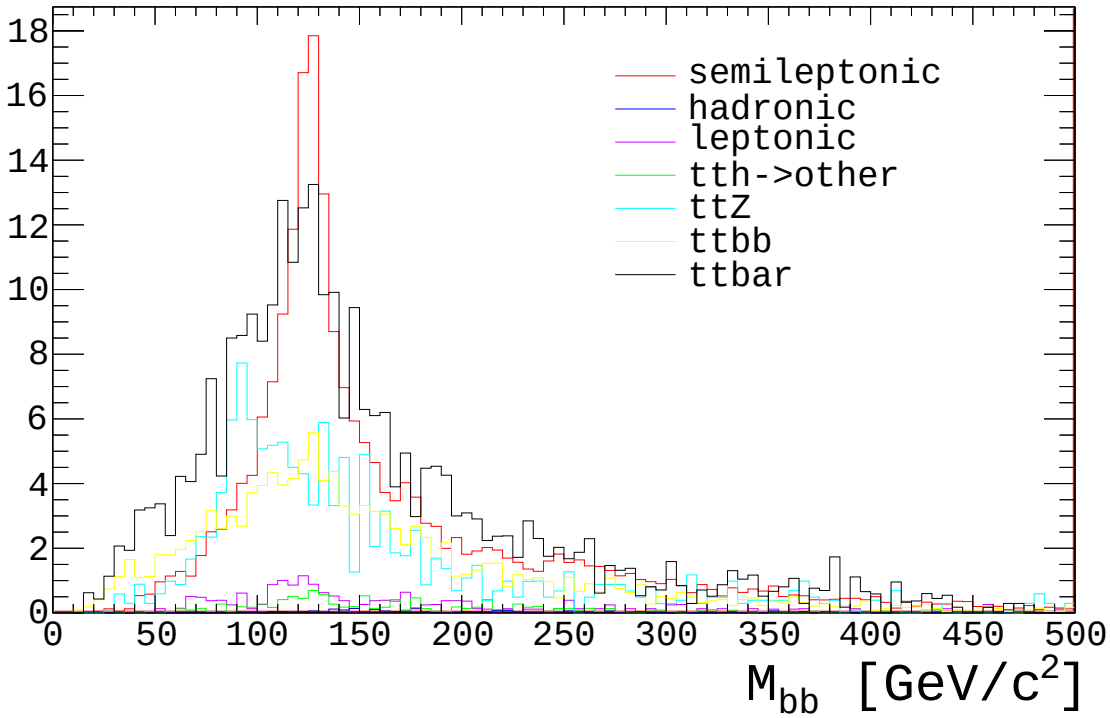

Figure: The reconstructed mass of the $b\bar{b}$ system with the Higgs mass constraint removed for events with one isolate lepton and passing the BDTG for the TMVA trained without the Higgs boson constraints.

Current Status

Current Status

- Note reviewed as "DBD Ready"
- Updated note sent to reviewers again
- Updated results in DBD

To Do

- Write thesis
- Submit note to DESY. Could it also go on the arXiv?
- Combine results with SiD and publish
- Consider systematics

Conclusions

Results

- Semileptonic results: 6.9% (9.6%) [TMVA (Cut based)]
- Hadronic results: 5.4% (7.2%) [TMVA (Cut based)] T. Tanabe
- Combined results: 4.3% for TMVA analysis

Thank You!

- Thank you to Roman and Akimasa for reviewing the note.
- Huge thank you to Mikael for updating the DBD section

Cut Based Analysis

Cut Flow -Semileptonic

Cut	lept	semi	had	other	$t\bar{t}Z$	$t\bar{t}b\bar{b}$	$t\bar{t}$	$\frac{S}{\sqrt{S+B}}$
Total Events	151.4	628.7	652.7	1046.1	5332.4	1434.5	308800.9	1.11
N_{isolep}=1	74.6	363.5	5.0	371.8	1581.5	439.9	101295.2	1.13
610< E_{vis} <1000	49.6	338.5	4.7	312.7	1228.9	373.8	75507.1	1.21
nPFOs>154	15.0	235.0	4.1	195.0	589.0	194.5	12605.9	2.00
Thrust<0.88	12.5	205.6	3.7	168.9	492.6	140.0	6092.3	2.44
$\log_{10}(Y_{45})$ >-2.25	7.7	151.3	3.2	108.5	295.2	91.0	2067.2	2.90
$\log_{10}(Y_{56})$ >-3.35	6.9	145.1	3.2	106.2	277.6	86.0	1836.1	2.92
b-tag$_3$ >0.67	5.5	102.1	1.6	5.7	59.4	56.0	137.2	5.33
χ^2 <450	5.3	100.0	1.4	5.2	56.8	53.7	126.0	5.36
364< M_{Tot} <808	5.2	99.7	1.4	5.2	56.5	53.5	124.7	5.36
98< M_H <234	4.6	95.1	1.2	4.7	46.1	48.6	109.9	5.40

Table: The number of events passed each cut when the cut values are optimised to select the semileptonic signal with maximum significance. The $t\bar{t}H \rightarrow$other is the background where the Higgs boson does not decay to a $b\bar{b}$ pair.

Cut Based Analysis

Cut Flow - Hadronic

Cut	lept	semi	had	other	$t\bar{t}Z$	$t\bar{t}b\bar{b}$	$t\bar{t}$	$\frac{S}{\sqrt{S+B}}$
Total Events	151.4	628.7	652.7	1046.1	5332.4	1434.5	308800.9	1.11
N_{isolep}=0	20.9	261.2	647.9	556.7	3226.1	932.5	188911.4	1.47
E_{vis}¿ 650	9.8	221.0	636.2	497.5	2743.5	849.3	157389.6	1.58
Thrust<0.87	8.1	187.8	577.6	440.1	2219.7	540.9	46916.1	2.56
$\log_{10}(Y_{78})$ >-4	3.7	143.6	549.5	415.5	1926.6	474.6	27472.1	3.12
b-tag$_4$ >0.38	1.9	81.0	275.0	17.6	230.0	209.6	680.6	7.11
$\cos(\theta_{hel})$ <0.9	1.6	73.8	263.7	16.5	215.9	189.2	584.9	7.19
M_t >120	1.5	68.9	255.4	15.6	207.8	178.5	530.93	7.20

Table: The number of events passed each cut when the cut values are optimised to select the hadronic signal with maximum significance. The $t\bar{t}H \rightarrow$other is the background where the Higgs boson does not decay to a $b\bar{b}$ pair.