Status of ttH analysis: 8-jet mode

Tomohiko Tanabe
ICEPP, The University of Tokyo

ILD Analysis/Software Meeting
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Introduction

3. $e^+e^- \to t\bar{t}h^0$ at $E_{\rm CM} = 1$ TeV, where h^0 is a Standard Model Higgs boson of mass 120 GeV, in the final state $h^0 \to b\bar{b}$. The reaction involves final states with 8 jets and final states with 6 jets, one lepton, and missing energy. The goal is to measure the Higgs boson Yukawa coupling to $t\bar{t}$.

- The task is to evaluate the precision of the top Yukawa coupling at √s = 1 TeV
- **Higgs boson mass has been changed to 125 GeV in light of LHC data.**
  - BR(H→bb) = 57.8%
- There are three decay modes depending on the W decay:
  - ttH → 4 jet + 2 lepton mode
    - BR(tt → blvblv) = 11% -- not analyzed
  - **ttH → 6 jet + lepton mode**
    - BR(tt → bqqblv) = 45% for l=e,μ,τ (29% for l=e,μ)
  - **ttH → 8 jet mode**
    - BR(tt → bqqbqq) = 44%

Tomohiko Tanabe (tomohiko@icepp.s.u-tokyo.ac.jp)

Data Samples

id	name	pol	xsec	ngen	weight
106427	Pttbb-all-all	eL.pR	3.429300	3600	0.276249
106428	Pttbb-all-all	eR.pL	1.517400	1600	0.275029
106429	Pttz-all-all	eL.pR	14.020600	13829	0.294018
106430	Pttz-all-all	eR.pL	4.367100	4400	0.287832
106451	Ptth-6q-hbb	eL.pR	1.552750	3025	0.148859
106452	Ptth-6q-hbb	eR.pL	0.698000	1361	0.148729
106453	Ptth-6q-hnonbb	eL.pR	1.133670	1749	0.187973
106454	Ptth-6q-hnonbb	eR.pL	0.509620	787	0.187789
106455	Ptth-ln4q-hbb	eL.pR	1.495560	2914	0.148837
106456	Ptth-ln4q-hbb	eR.pL	0.672430	1311	0.148745
106457	Ptth-ln4q-hnonbb	eL.pR	1.091920	1684	0.188038
106458	Ptth-ln4q-hnonbb	eR.pL	0.490940	758	0.187827
35786	P6f_yyveev	eL.pL	0.753694	10000	0.015828
35787	P6f_yyveev	eL.pR	14.262567	14263	0.289991
35788	P6f_yyveev	eR.pL	3.191048	10000	0.092540
35789	P6f_yyveev	eR.pR	0.759213	9999	0.015945
35790	P6f_yyvelv	eL.pL	1.434391	10000	0.030122
35791	P6f_yyvelv	eL.pR	22.876428	22873	0.290043
35792	P6f_yyvelv	eR.pL	6.272190	10000	0.181894
35794	P6f_yyveyx	eL.pL	4.121621	9999	0.086563
35795	P6f_yyveyx	eL.pR	67.534318	67525	0.290040
35796	P6f_yyveyx	eR.pL	18.645337	18644	0.290021
35799	P6f_yyvlev	eL.pR	22.875149	22871	0.290053
35800	P6f_yyvlev	eR.pL	6.264408	9998	0.181704
35801	P6f_yyvlev	eR.pR	1.427611	10000	0.029980
35803	P6f_yyvllv	eL.pR	41.275472	41270	0.290038
35804	P6f_yyvllv	eR.pL	12.598244	12597	0.290029
35807	P6f_yyvlyx	eL.pR	115.979040	115968	0.290028
35808	P6f_yyvlyx	eR.pL	37.306473	37301	0.290043
35811	P6f_yyxyev	eL.pR	68.502191	68493	0.290039
35812	P6f_yyxyev	eR.pL	18.659270	18658	0.290020
35813	P6f_yyxyev	eR.pR	4.163067	10000	0.087424
35815	P6f_yyxylv	eL.pR	116.426720	116408	0.290047
35816	P6f_yyxylv	eR.pL	37.321082	37317	0.290032
35819	P6f_yyuyyu	eL.pR	84.595962	84588	0.290027
35820	P6f_yyuyyu	eR.pL	27.500471	27497	0.290037
35823	P6f_yyuyyc	eL.pR	84.581774	17762	1.380966
35824	P6f_yyuyyc	eR.pL	27.508546	27504	0.290048
35827	P6f_yycyyu	eL.pR	84.426452	84412	0.290050
35828	P6f_yycyyu	eR.pL	27.483992	27478	0.290063
35831	P6f_yycyyc	eL.pR	84.975908	84964	0.290041
35832	P6f_yycyyc	eR.pL	27.584594	27582	0.290027

Signal

Assumed luminosity is 1 ab^{-1}, split equally between two polarizations:

- 0.5 ab^{-1} for (−0.8, +0.2)
- 0.5 ab^{-1} for (+0.8, −0.2)
- Weights are computed by summing the two polarizations

We have sufficient statistics for most processes.

Jan has kindly generated the missing samples, **thank you!**

- To be included in December update

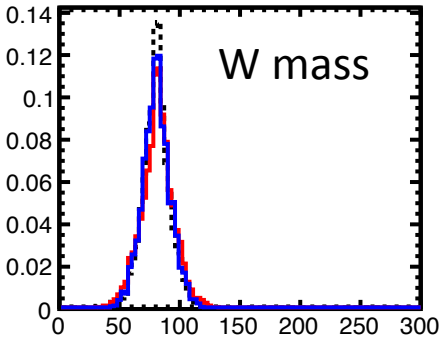
Tomohiko Tanabe (tomohiko@icepp.s.u-tokyo.ac.jp)

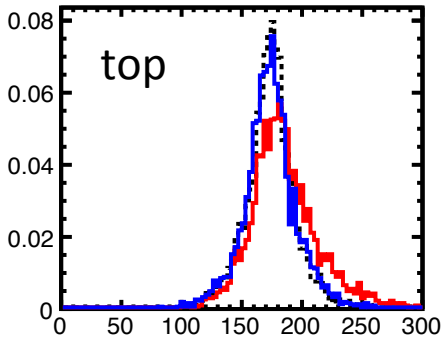
Analysis Flow

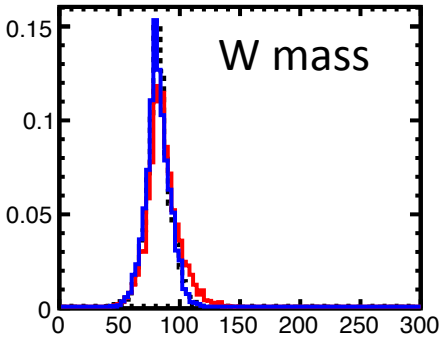
- Start with standard reconstruction samples
- Removal of γγ→hadrons
- Isolated lepton selection
- Event selection based on:
  - b-tagging
  - jet combination mass
  - etc
- Two analyses:
  - Cut-based
  - TMVA (Boosted Decision Trees)

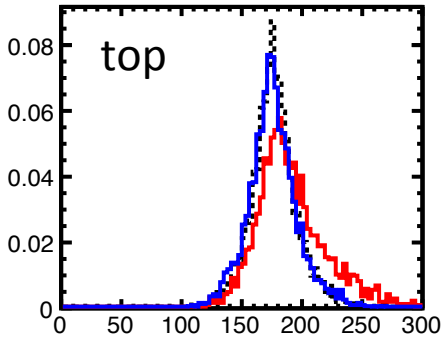
Tomohiko Tanabe (tomohiko@icepp.s.u-tokyo.ac.jp)

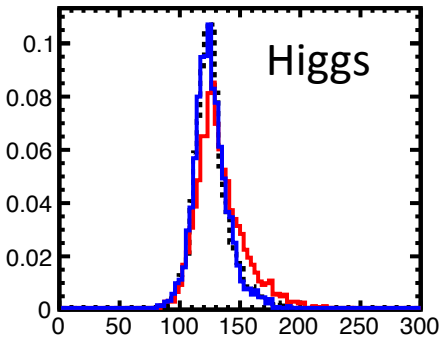
Removal of γγ→hadrons











Black (dotted):
Durham w/o γγ→hadrons

Red:
Durham w/ γγ→hadrons

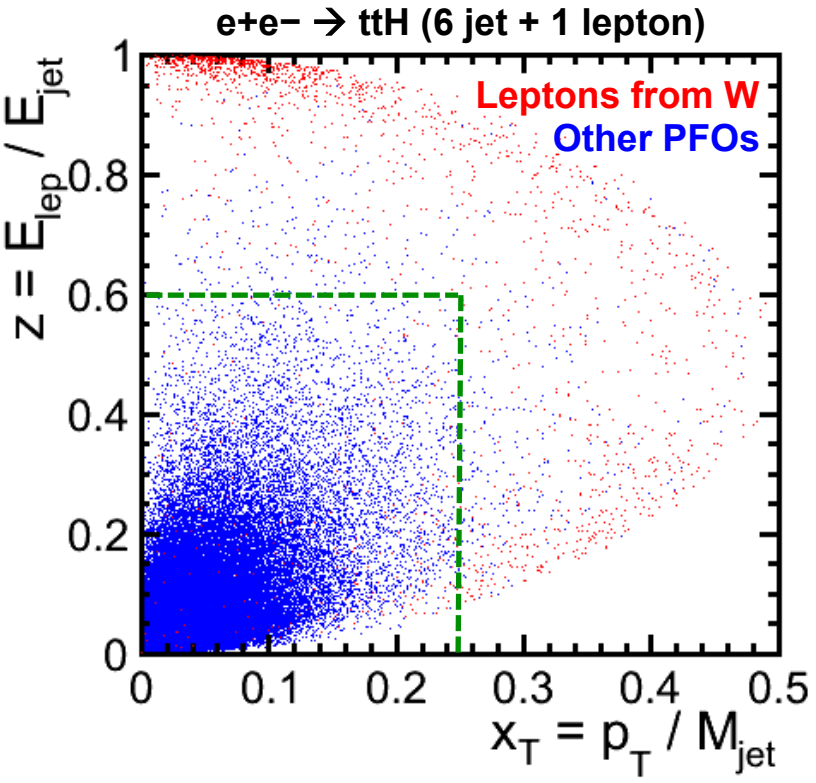
Blue:
Durham w/ γγ→hadrons after removing PFOs with cosθ>0.94

→ **Mass resolution is successfully recovered.**
(PFOs are mostly central for ttH process.)

Consistency with 6 jet + lepton analysis (which uses kT algorithm) could be an advantage – this will be checked for December update.

Tomohiko Tanabe (tomohiko@icepp.s.u-tokyo.ac.jp)

Isolated Lepton Finding



Hard isolated leptons coming from W decay

- Useful discriminant for separating 6 jet + lepton mode / 8 jet mode

Selection based on:

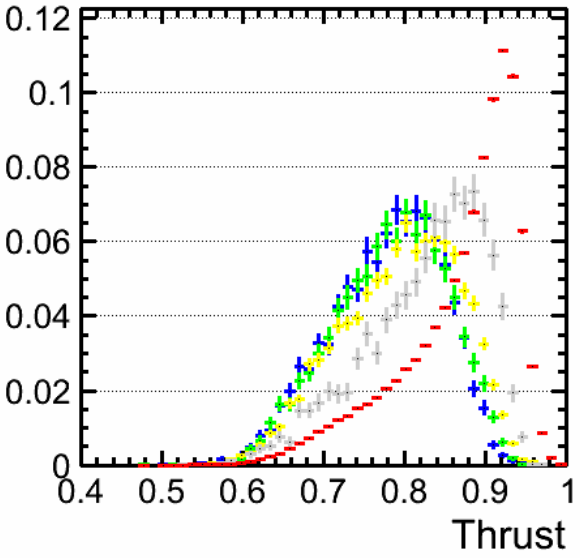
- Lepton ID based on calorimeter energies
  - reduces fake leptons
- Impact parameter significance
  - reduces contamination from bottom and tau decays
- Jet-based discriminants (**"LAL Lepton Finder"**)
  - good for isolation

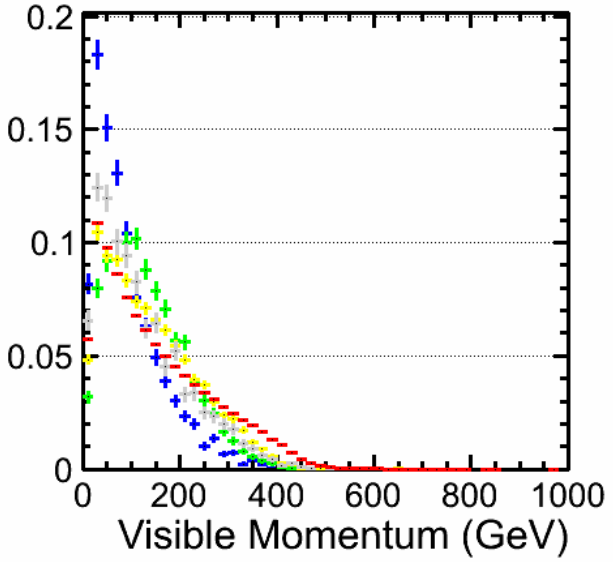
	Efficiency	Composition			
		W→e,μ	W→τ→e,μ	Other e,μ	Fake e,μ
Electrons	82%	95%	2.8%	1.3%	0.9%
Muons	89%	97%	2.0%	0.9%	0.1%

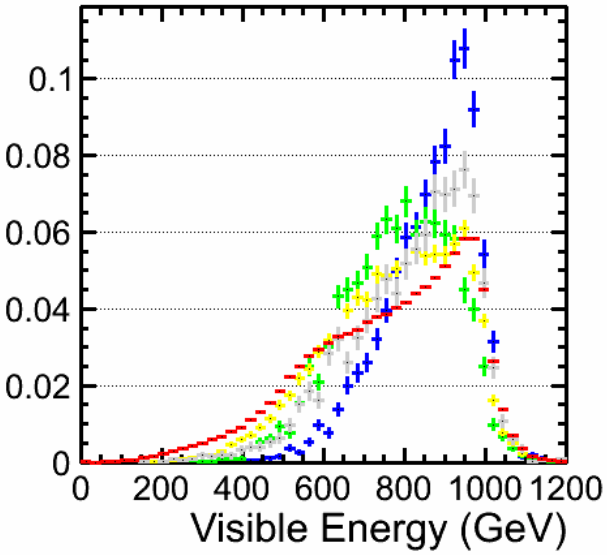
(n.b. Large statistical errors on composition fake rates)

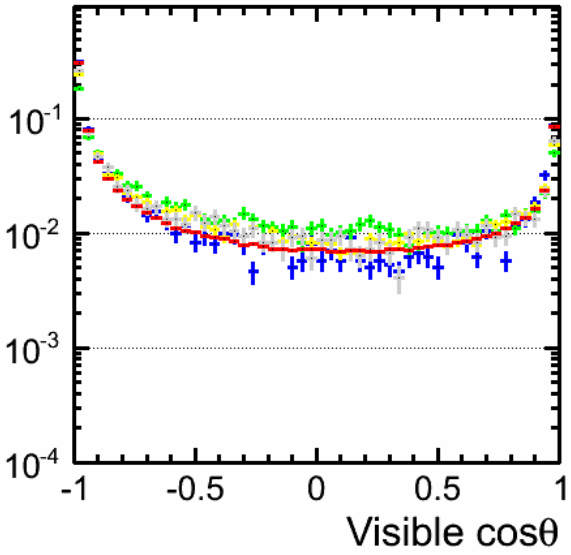
Variables (1)

ttH 8 jet
ttH other
ttZ
ttbb
tt





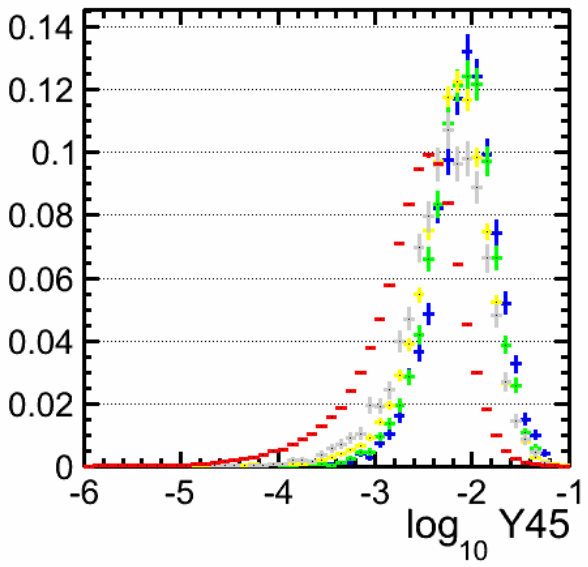


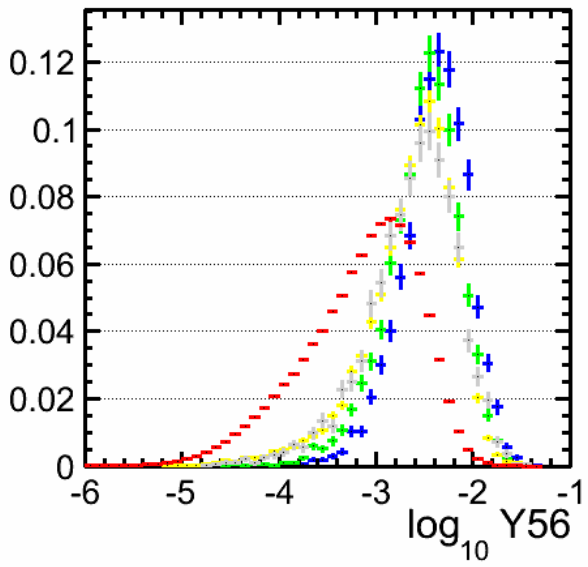


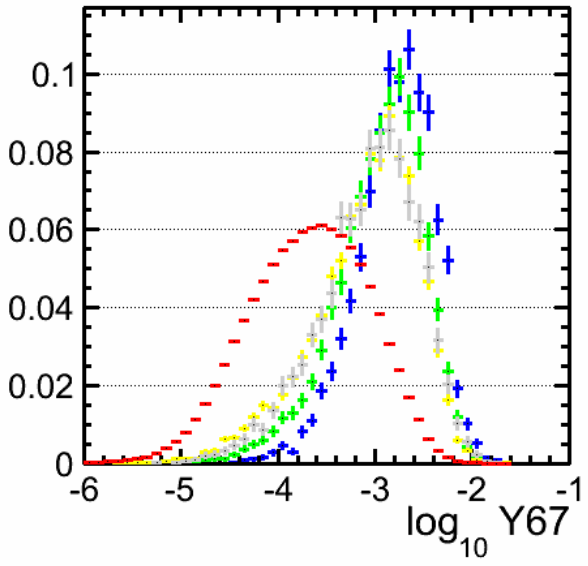
Tomohiko Tanabe (tomohiko@icepp.s.u-tokyo.ac.jp)

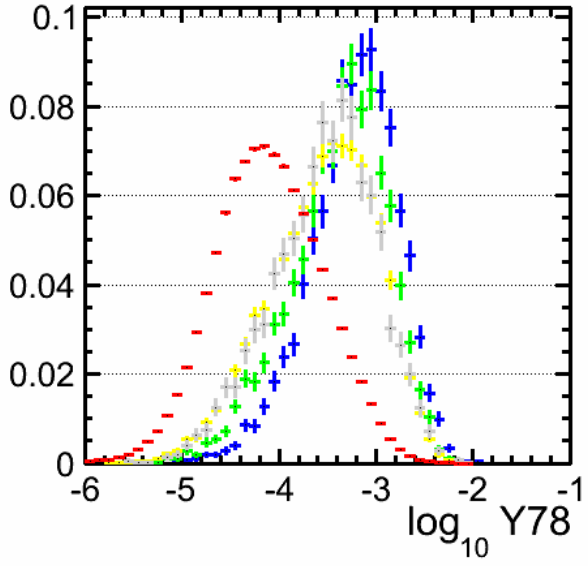
Variables (2)

ttH 8 jet
ttH other
ttZ
ttbb
tt



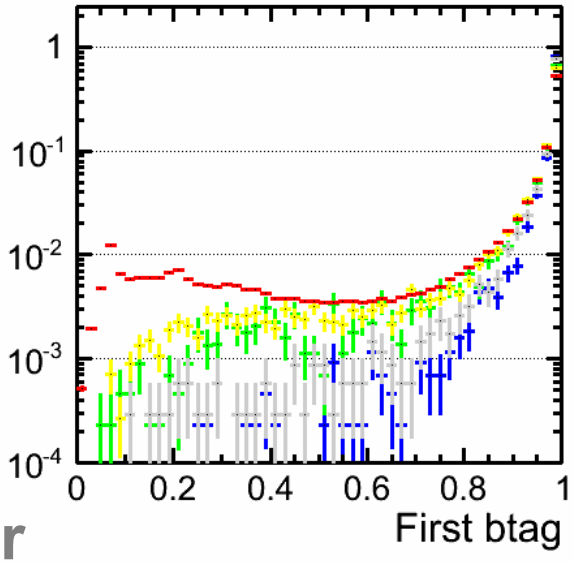


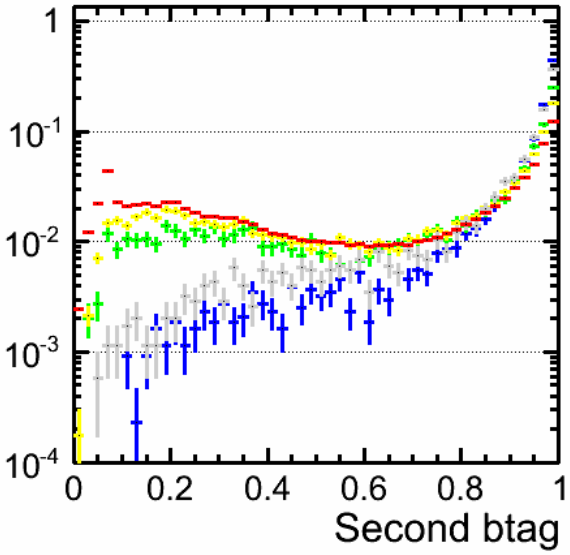


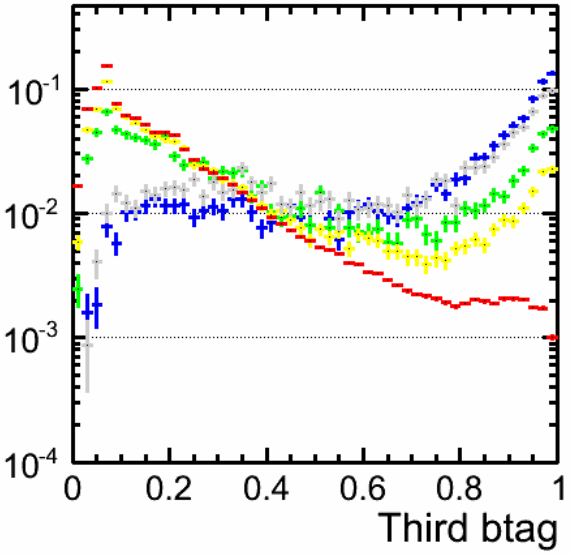


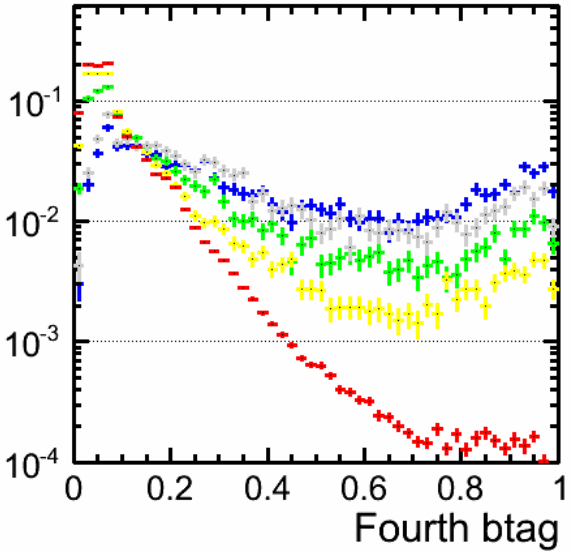
Variables (3)

ttH 8 jet
ttH other
ttZ
ttbb
tt





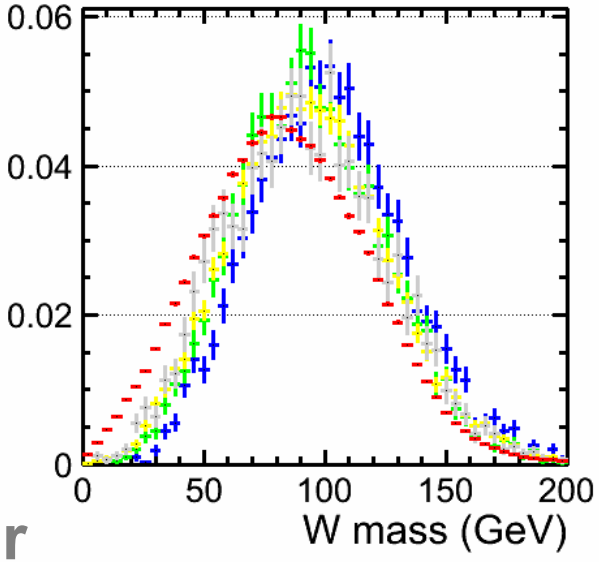


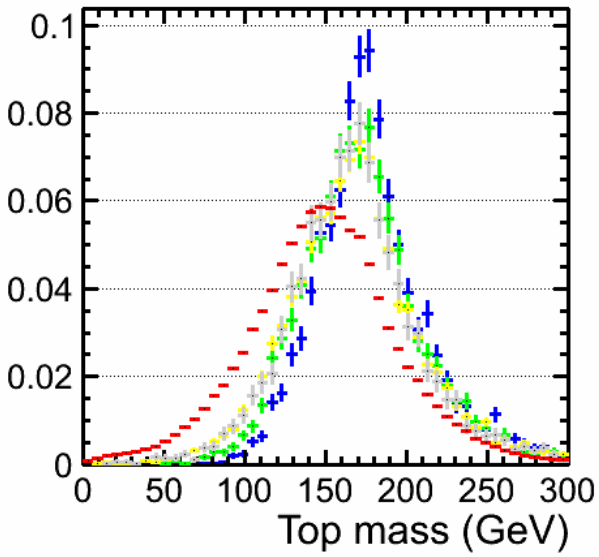


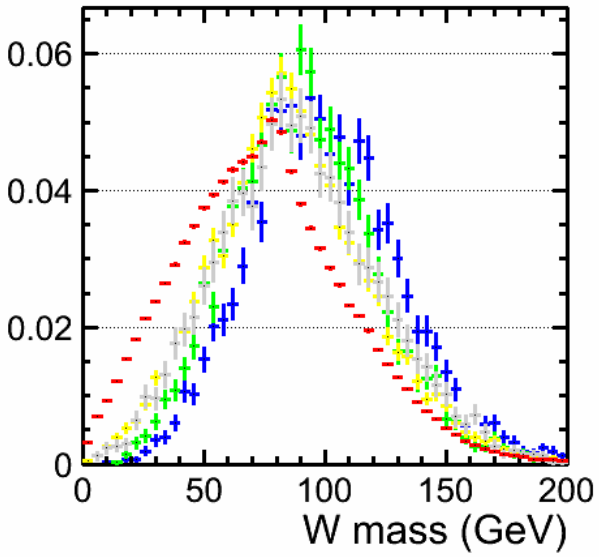
Tomohiko Tanabe (tomohiko@icepp.s.u-tokyo.ac.jp)

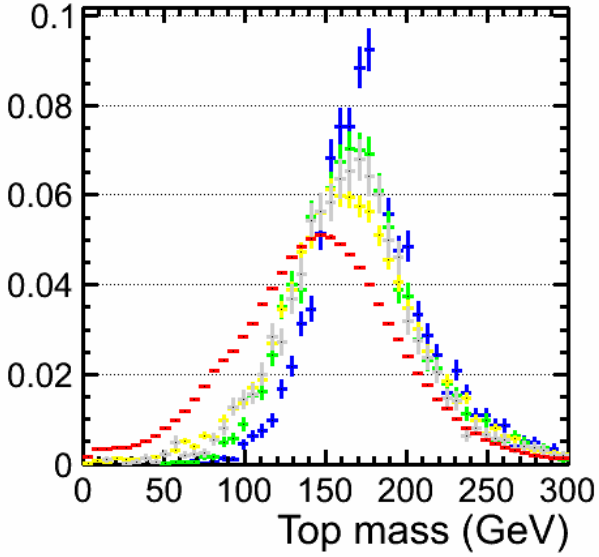
Variables (4)

ttH 8 jet
ttH other
ttZ
ttbb
tt



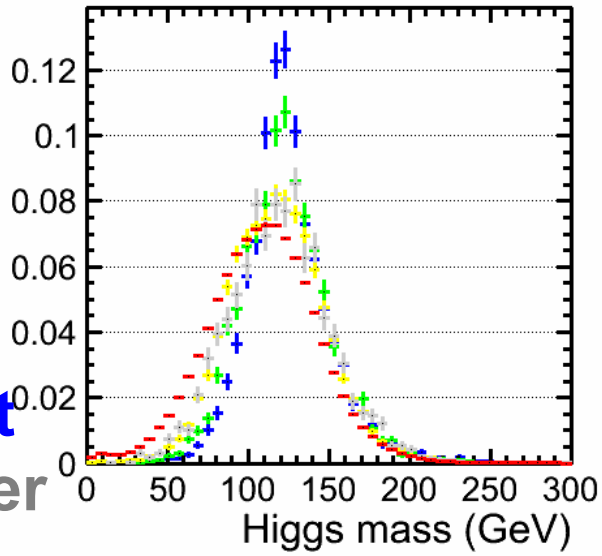


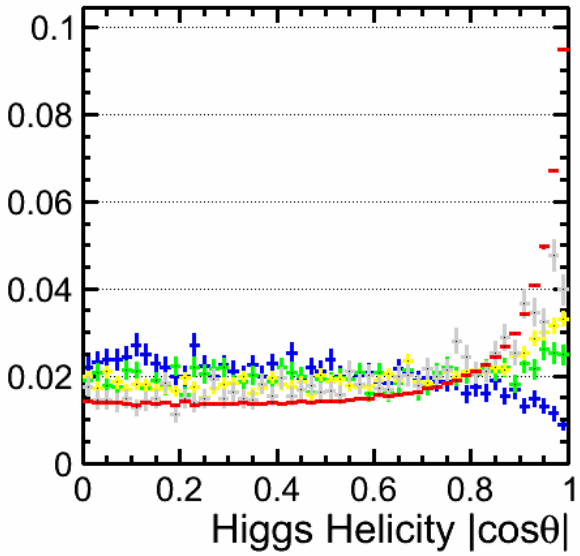




Tomohiko Tanabe (tomohiko@icepp.s.u-tokyo.ac.jp)

Variables (5)





ttH 8 jet
ttH other
ttZ
ttbb
tt

Jet combination based on chi-squared method as described by Tony, jets with 4 lowest b-tags selected for W reconstruction.

Tomohiko Tanabe (tomohiko@icepp.s.u-tokyo.ac.jp)

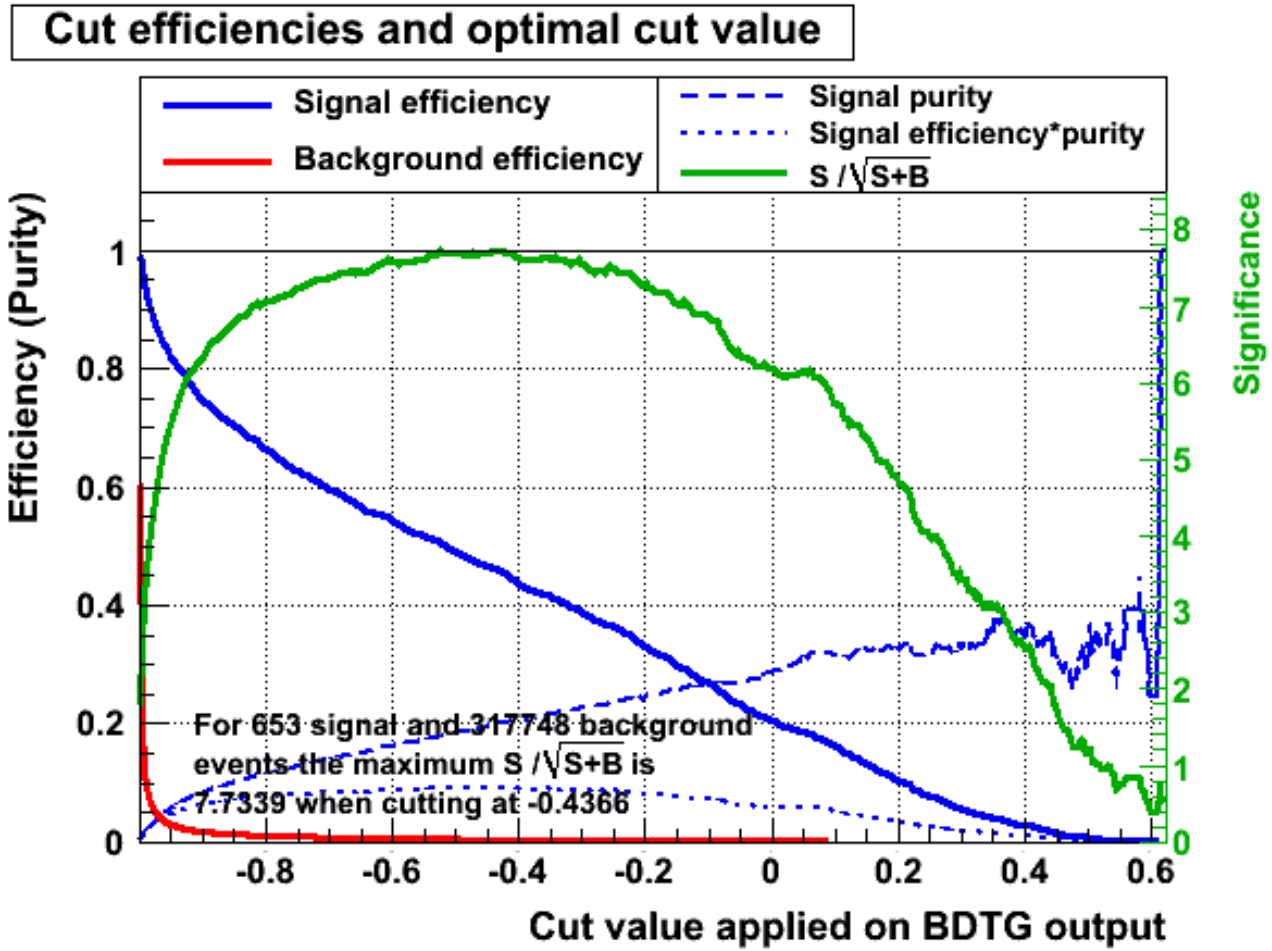
Cut-based Analysis

	ttH-8J	ttH-other	ttZ	ttbb	tt	Sig
No Cuts	652.75	1564.28	5317.80	1434.53	309431.06	1.16
#iso=0	646.94	832.77	3293.87	955.08	195149.36	1.44
Evis>650	616.14	687.47	2559.01	808.03	139433.45	1.62
Thru<0.87	568.96	610.03	2120.20	526.38	42112.57	2.65
Y87>0.0001	538.60	547.47	1852.99	462.92	26173.68	3.13
btag3>0.38	250.91	86.63	200.86	187.04	496.79	7.18
H_hel<0.9	240.04	76.34	186.80	167.46	430.00	7.24

Cut-based analysis result (8 jet mode only):
Statistical significance = 7.2 sigma (**preliminary**)

Multivariate Analysis

- Use TMVA Boosted Decision Trees with Gradient boost
- All 18 variables (shown earlier) were used



TMVA analysis result (8 jet mode only):
Statistical significance = 7.7 sigma (**preliminary**)

Systematic Uncertainties

- Systematic uncertainties: cannot discuss in detail for DBD, but will be studied for eventual publication (with SiD)
- Topics to be considered (in no particular order)
  - Background normalization
  - Jet energy scale
  - Luminosity spectrum
  - B-tagging efficiency
  - Lepton isolation criteria
  - Lepton ID performance

Tomohiko Tanabe (tomohiko@icepp.s.u-tokyo.ac.jp)

Summary

- Preliminary result of top Yukawa 8 jet mode now available
  - Cut-based analysis: **7.2 sigma**
  - TMVA-based analysis: **7.7 sigma**
- Tony obtains (6 jet + lepton mode):
  - Cut-based analysis: **6.6 sigma**
  - TMVA-based analysis: **6.7 sigma**
- **Combined: 10.2 sigma, 4.9% precision in $\Delta y_t/y_t$ (TMVA)**

- DBD Benchmark Section to be updated
  - I will revise the text tonight…
- Include refinements for final update
  - Various optimizations
    - Include kinematic fits?
  - Systematics?

Tomohiko Tanabe (tomohiko@icepp.s.u-tokyo.ac.jp)