ttH experimental overview

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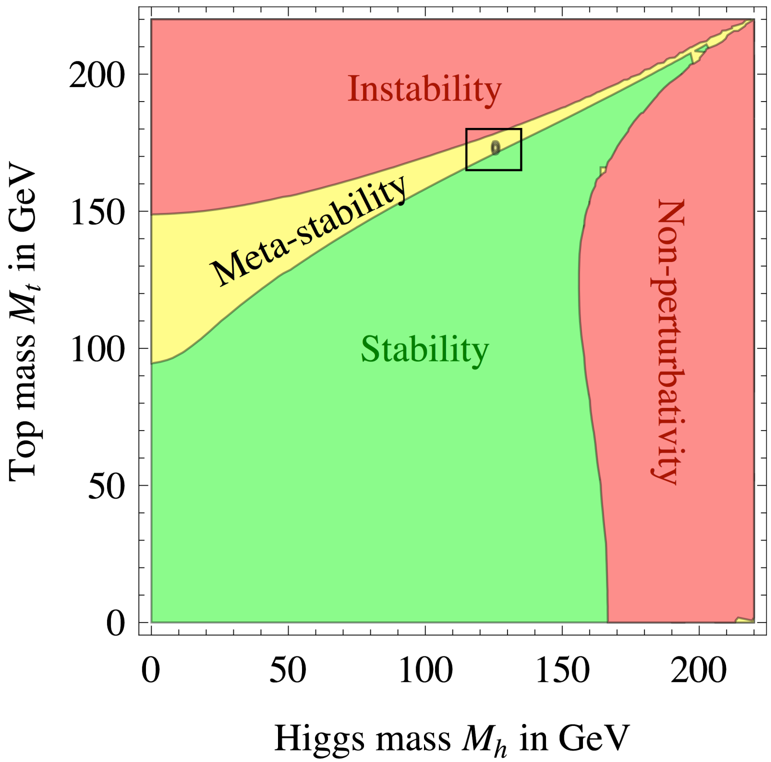
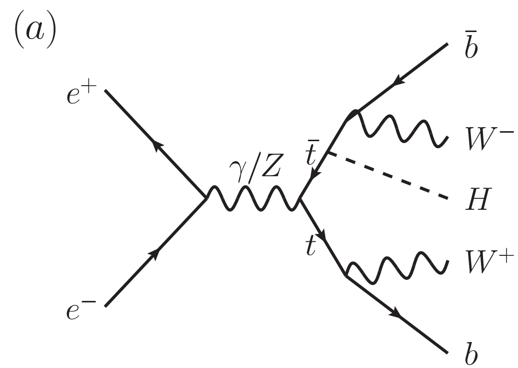
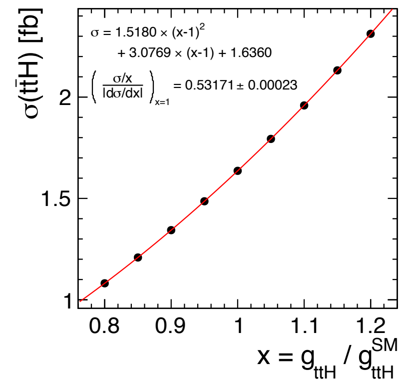
Pacific Northwest National Laboratory

LCWS2015, Whistler, BC

Introduction







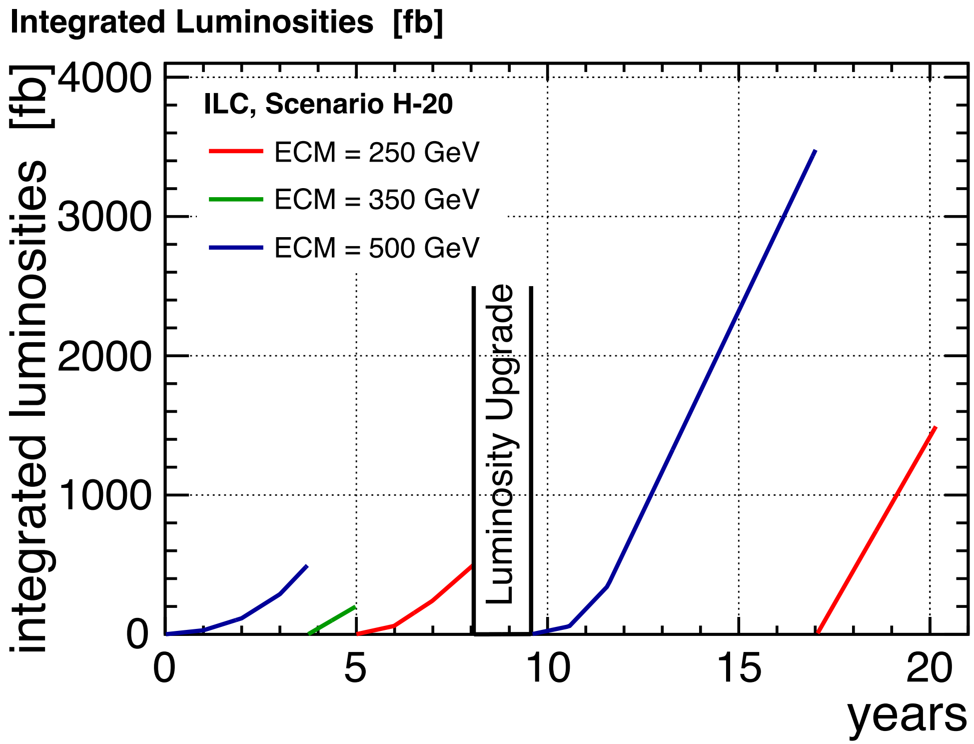
Search channel for the ttH coupling in direct production at all energies
-- 4 b-jets
-- (4-)6-8 jets

Vacuum stability depends on the value of the top mass

Simulate dependence of ttH cross section on top Yukawa coupling. Different from 0.5 mainly due to Higgsstrahlung

ILC Operating Scenarios

- First measurement happens at 500 GeV!
- 350 GeV can use input to improve the top threshold measurement
  - Top Yukawa coupling known at time of the scan
- I will use energy ordering for this talk



Experimental Conditions

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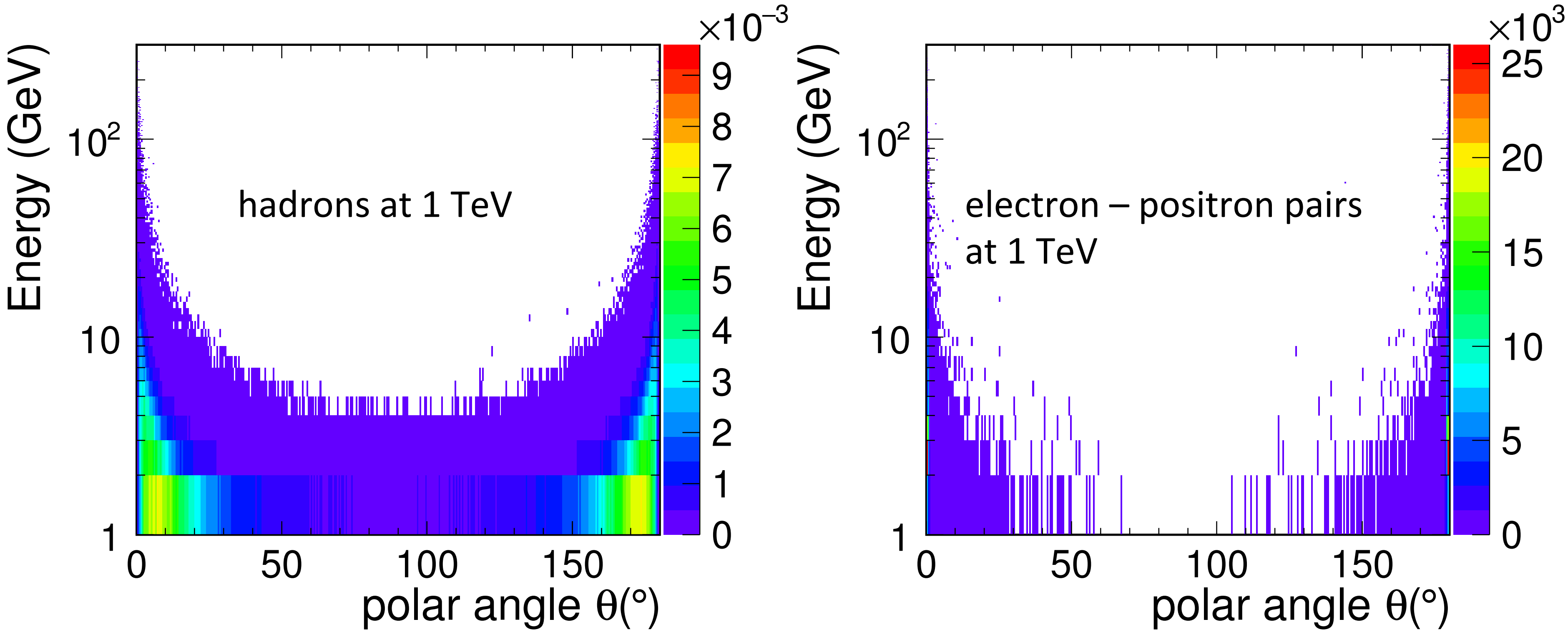


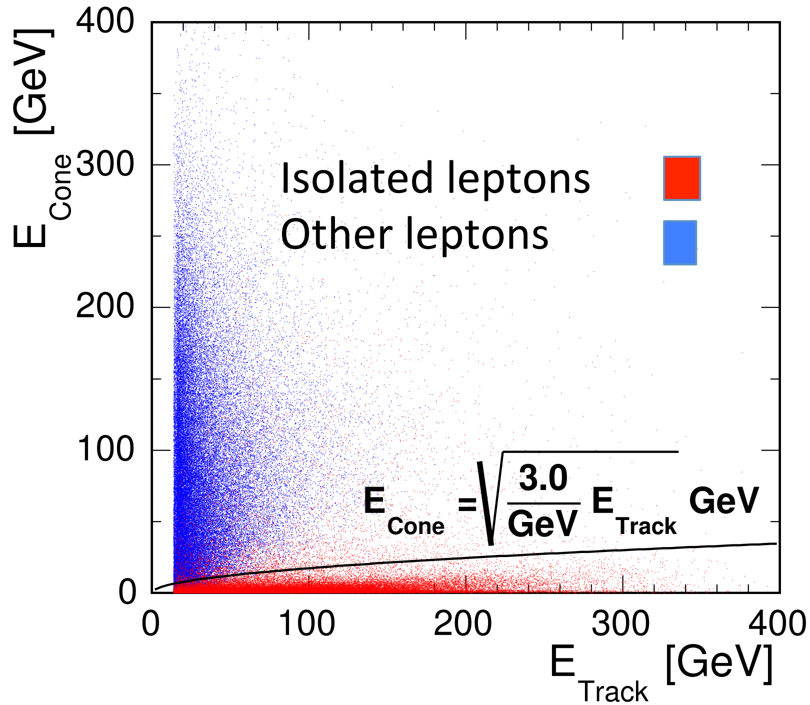
Present at all energies, both, at CLIC and at ILC.
All measurements use strategies to mitigate these background processes

Isolated Lepton Finding

Two main strategies

- Isolated Lepton Finding: Calorimeter activity in cone around lepton (PID from PandoraPFA, or from ratio of calorimeter contributions)
  - Remove leptons from event before jet clustering

- Jet-based lepton finding: Include the leptons from the matrix element when forcing the event into N jets
  - Apply some cuts on the jet to identify it as an isolated lepton



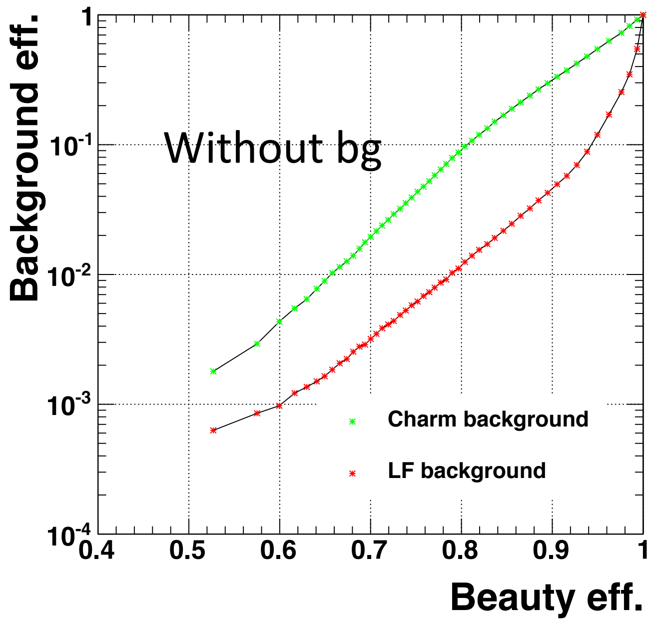
Distribution of isolated leptons (red) from W decays in semi-leptonic ttH events and leptons in jets (blue)

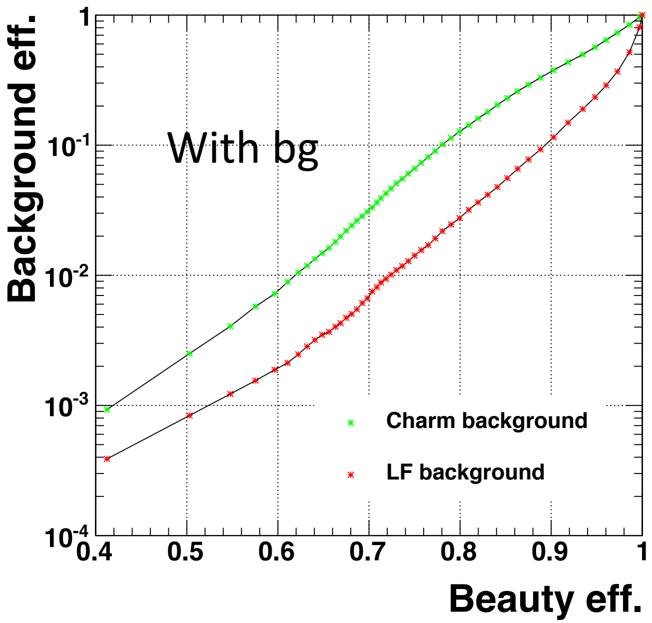
Jet Finding

- Fastjet algorithms:
  - Force event into known number of jets taking into account isolated leptons
- Durham (used in all analyses as final step):
  - Sensitive to background processes (worse at higher energies)
  - Jet mass increases with background
  - Forward region picks up more background
- Anti-kt (used to remove background):
  - Hadron-collider kt algorithm: Beam Jets(!)
  - Picks up background in forward region as beam jet (could overlap with signal)
  - Uses eta rather than cosTheta
- Valencia
  - Weds the cosTheta distance with a beam jet
  - Reasonable background rejection and jet size rather independent of angle

Flavor Tagging

- Common to all analyses: LCFIPlus
- Finds Vertices in all tracks before jet finding.
- ZVTop vertex finder
- Boosted decision trees, trained separately at each energy
  - Energy-dependent background rejection

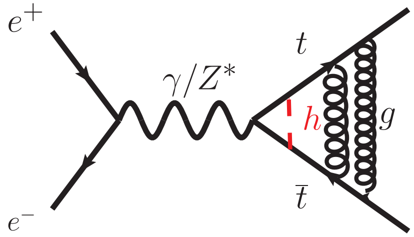


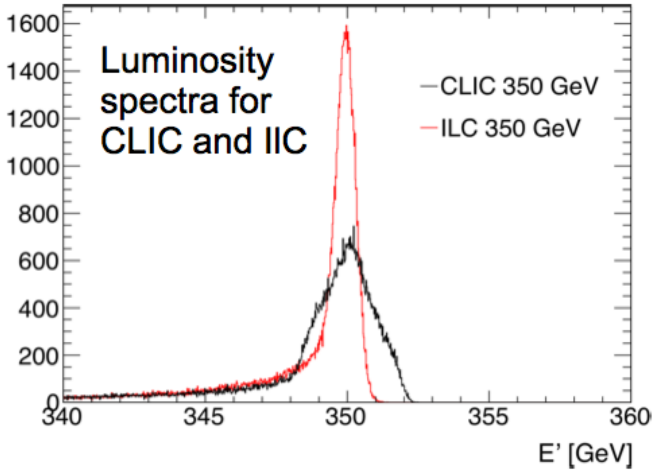


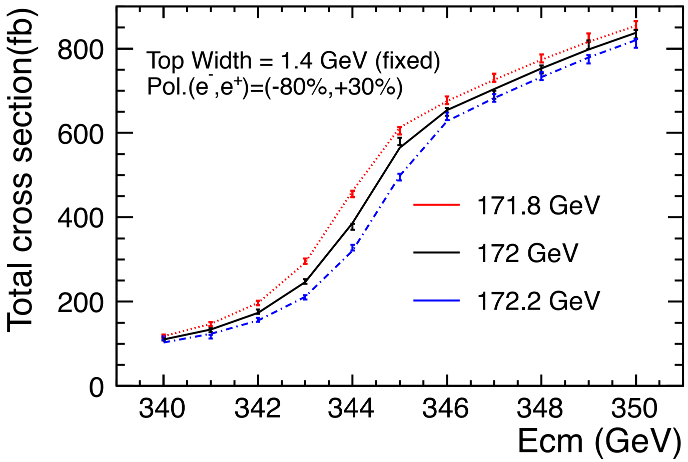
top Yukawa at 350 GeV

Horiguchi et al.
arXiv:hep-ex/1310.0563

- Measure the top Yukawa coupling in a threshold scan
- Higher order corrections to the top pair production cross section are sensitive to the top Yukawa coupling
- 11 point threshold scan (340 – 350 GeV), 10 / fb, 2 polarization states, 220 / fb total
- 9% effect on cross section
- 4.2% statistical uncertainty







PS Top quark mass

Top Yukawa at 500 GeV

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- Sudo (ALCW15)

$$S/\sqrt{S+B}$$

(P_{e^-},P_{e^+})	(-0.8,+0.3)		(+0.8,-0.3)	
Lumi. (fb^{-1})	500	1600	500	1600
8 jets	2.17	3.89	1.40	2.53
lν + 6 jets	2.00	3.58	1.29	2.32
2l2ν + 4 jets	1.02	1.83	0.72	1.31

Preliminary

Details in next talk

Top Yukawa at 550 GeV

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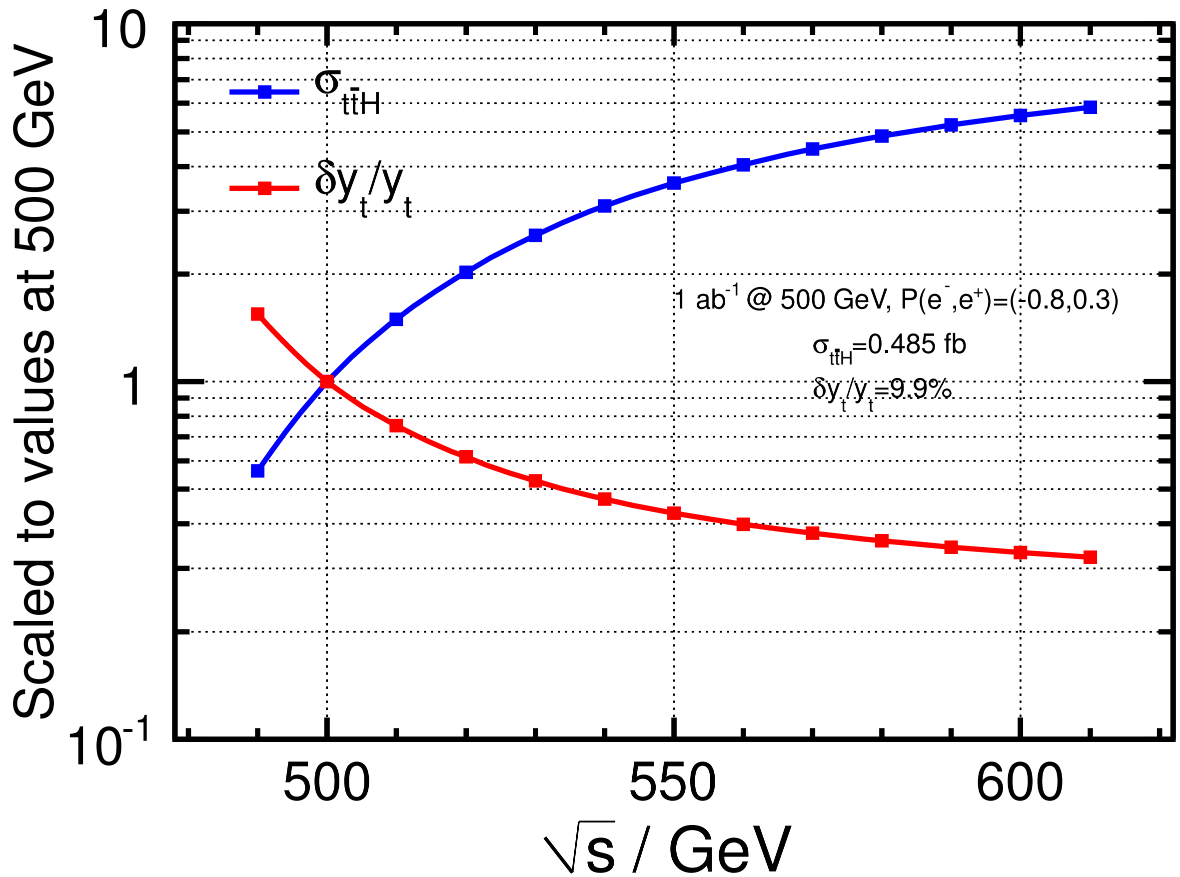
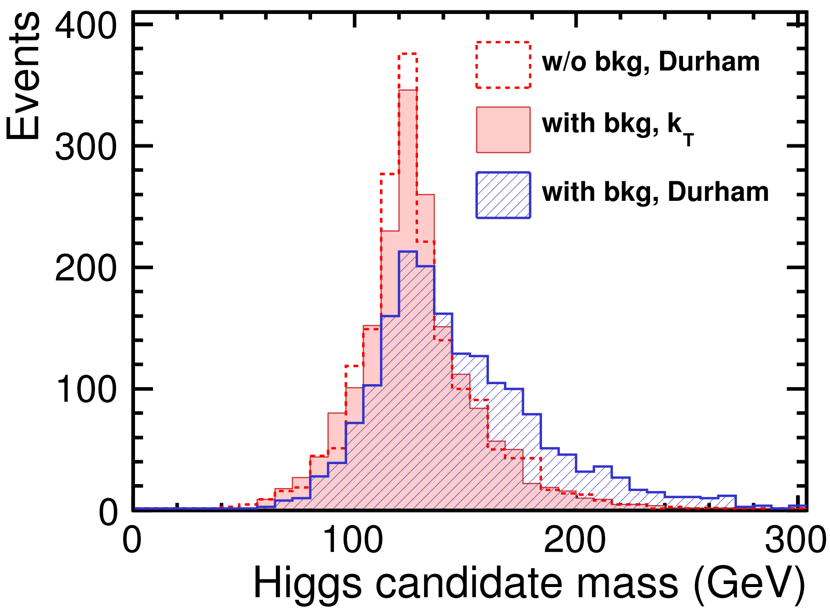
ILC is now 10% longer. If cryomodules perform to spec, 10% higher initial energy

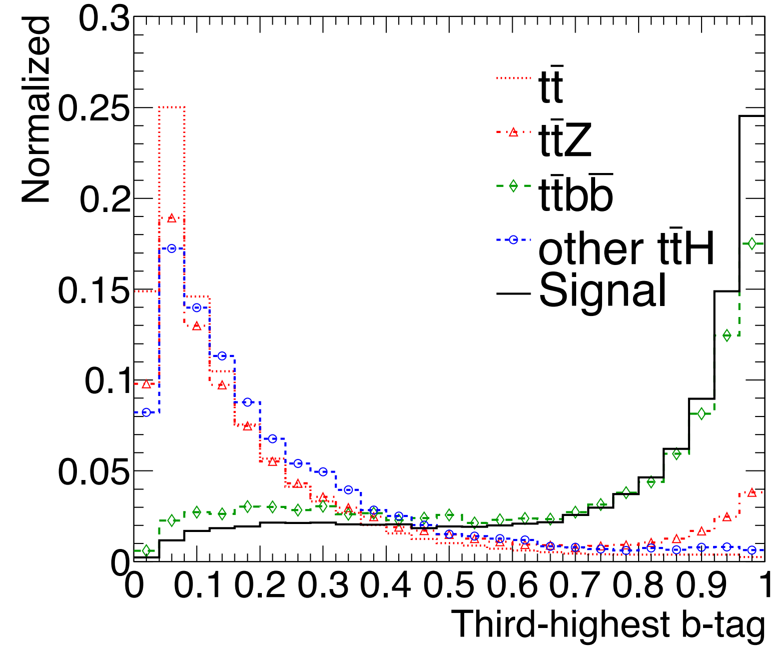
Leads to more than 3-fold increase in cross section

> 2 times better measurement



Top Yukawa at 1 TeV Price, et al. arXiv:1409.7157





Strategy:

Isolated lepton finding

Jet reconstruction in the 6- or 8- jet signature

Incl. flavor tagging

Boosted decision trees

$$\chi^2_{8\text{ jets}} = \frac{(M_{12} - M_W)^2}{\sigma_W^2} + \frac{(M_{123} - M_t)^2}{\sigma_t^2} + \frac{(M_{45} - M_W)^2}{\sigma_W^2} + \frac{(M_{456} - M_t)^2}{\sigma_t^2} + \frac{(M_{78} - M_H)^2}{\sigma_H^2}, \quad (1)$$

Signal Extraction at 1 TeV

- Reconstruct Signal in both, 6-jet and 8-jet signature
- Take into account signal cross-feed

Table 2 Number of selected events for the different final states assuming an integrated luminosity of 1 ab^{-1}. The values obtained for the six- and eight-jets final state selections are shown separately.

Detector		ILD		SiD	
Sample	Before cuts	After Cuts			
		6 jets	8 jets	6 jets	8 jets
$t\bar{t}H$ 6 jets	628.7	208.0	65.5	191.6	57.4
$t\bar{t}H$ 8 jets	652.7	2.1	365.6	1.6	299.4
$t\bar{t}H \to$ other	1197.5	28.8	25.3	33.0	16.6
$t\bar{t}Z$	5332.4	126.1	260.5	105.6	187.1
$t\bar{t}b\bar{b}$	1434.5	125.4	222.6	100.1	180.7
$t\bar{t}$	308800.9	261.2	513.6	232.0	381.6
y_t statistical uncertainty		6.9%	5.4%	7.0%	5.8%
combined		4.3%		4.5%	

Error on g(ttH) in 1 ab^{-1} @ 1 TeV

Extapolated estimate for total ILC program ~2%

Top Yukawa at 1.4 TeV

CLICdp-Note-2014-001 CLICdp-Note-2015-001

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- CLIC 1.4 TeV, 1.5 ab^{-1}
- Same basic strategy as ILC 1 TeV analysis
  - Added dedicated tau reconstruction, 2-jet reconstruction

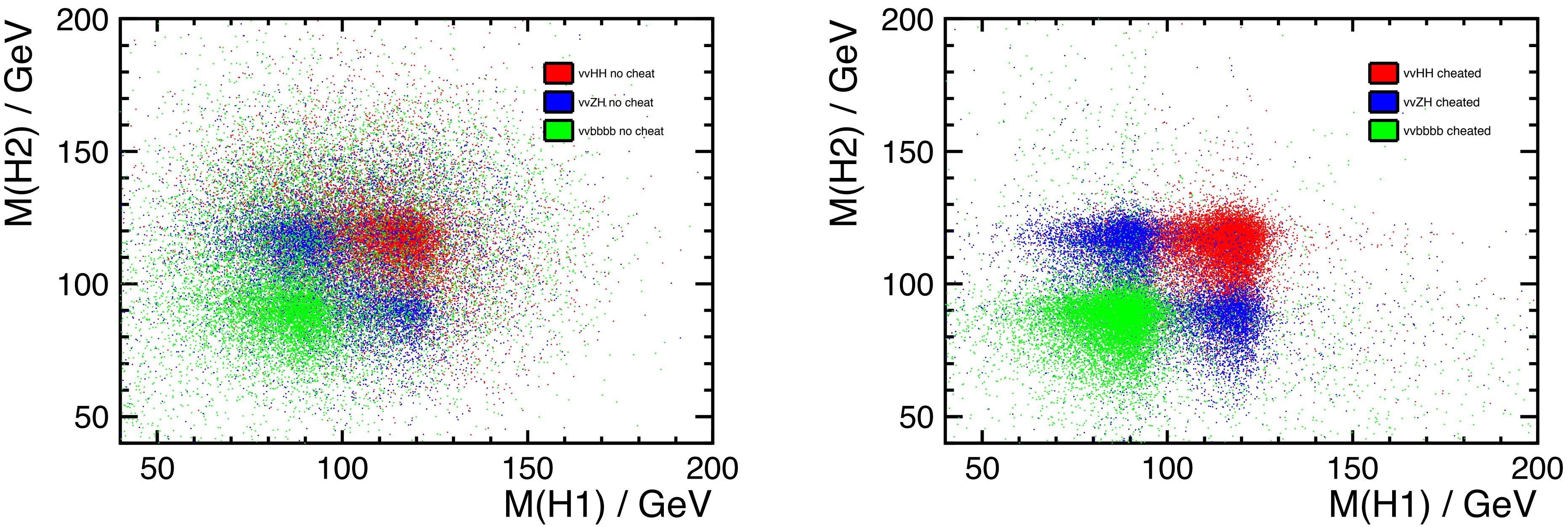
Table 4: Selection efficiency for each event sample. Column 1 shows the simulated process. Column 2 shows the expected number of events in 1.5 ab^{-1}. Column 3 shows the number of events in which 0 leptons were found. Column 4 shows the number (and percent) of these '0 lepton' events which pass the BDT trained for the hadronic channel. Column 5 shows the number of events in which 1 lepton was found. Column 6 shows the number (and percent) of these '1 lepton' events which pass the BDT trained for the semi-leptonic channel. The number of jets refers to the $t\bar{t}$ decay only.

Process	Evt in 1.5 ab^{-1}	Evt with 0 leptons	Evt pass Had BDT		Evt with 1 lepton	Evt pass SL BDT	
$t\bar{t}H$, 6 jet, $H \to b\bar{b}$	647	593	357	(60.2%)	49	9	(18.8%)
$t\bar{t}H$, 4 jet, $H \to b\bar{b}$	623	178	62	(35.1%)	420	233	(55.3%)
$t\bar{t}H$, 2 jet, $H \to b\bar{b}$	150	13	1	(10.7%)	61	20	(32.5%)
$t\bar{t}H$, 6 jet, $H \not\to b\bar{b}$	473	306	38	(12.3%)	127	8	(6.52%)
$t\bar{t}H$, 4 jet, $H \not\to b\bar{b}$	455	89	5	(5.81%)	246	19	(7.82%)
$t\bar{t}H$, 2 jet, $H \not\to b\bar{b}$	110	6	0	(1.52%)	33	1	(3.66%)
$t\bar{t}b\bar{b}$, 6 jet	824	737	287	(38.9%)	80	8	(9.75%)
$t\bar{t}b\bar{b}$, 4 jet	794	222	44	(19.6%)	533	175	(32.9%)
$t\bar{t}b\bar{b}$, 2 jet	191	16	1	(8.71%)	78	14	(18.1%)
$t\bar{t}Z$, 6 jet	2,843	2,335	316	(13.5%)	322	12	(3.68%)
$t\bar{t}Z$, 4 jet	2,738	711	49	(6.86%)	1,678	170	(10.2%)
$t\bar{t}Z$, 2 jet	659	54	1	(2.03%)	248	13	(5.23%)
$t\bar{t}$	203,700	111,020	1,399	(1.26%)	77,110	523	(0.68%)

Final number: 4.43% error on g(ttH)

Outlook

- Room for improvement



Example from ZHH analysis: realistic reco (left) vs. perfect reconstruction (right) (including perfect jet reco:) 20% improvement

Current development: Jet clustering for EW states

Jet substructure not used

Personal estimate for achievable precision of top Yukawa precision at a Linear Collider: <2%