Update on the top Yukawa coupling measurement at 1.4 TeV CLIC

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on behalf of the CLICdp collaboration

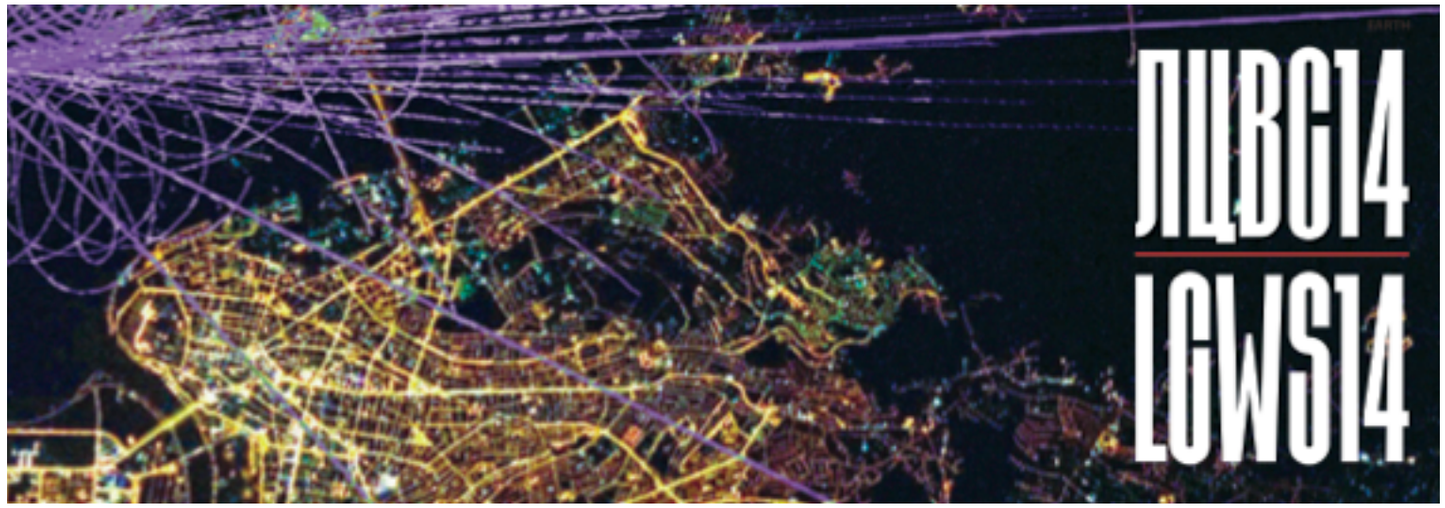
Outline

Recap of original analysis

- **As seen at LCWS13**
- **Documentation published: CLICdp-Note-2014-001**

First look at analysis of non-ttbar (+X) backgrounds

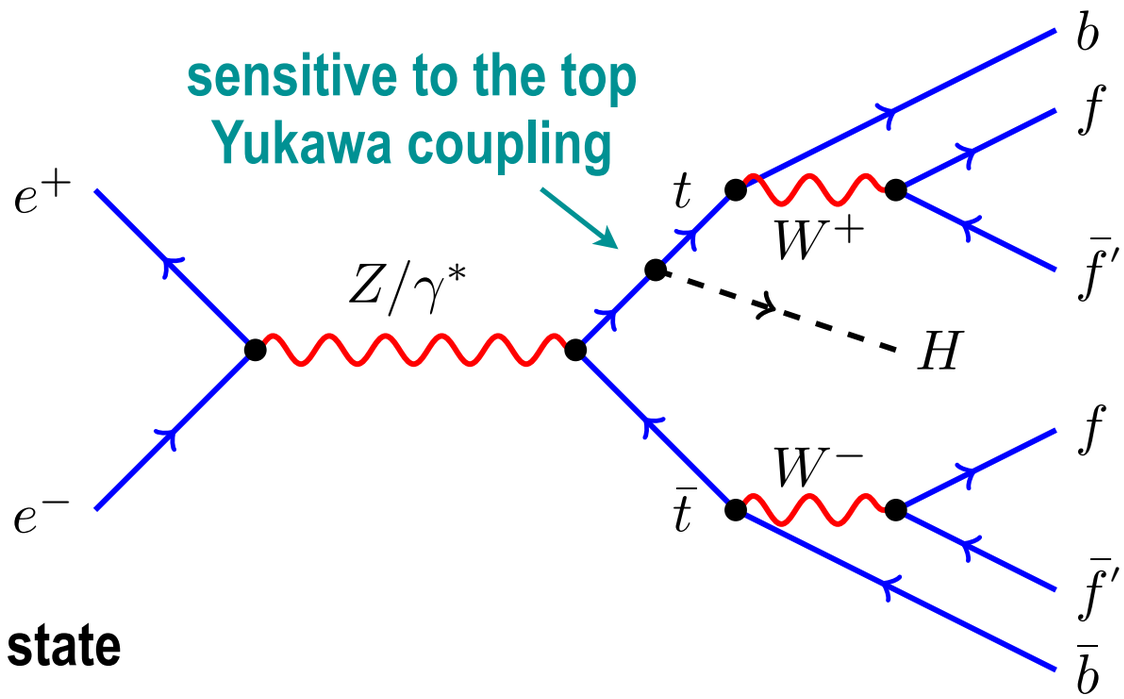
- **New for LCWS14**
- **High cross section processes**
- **Fewer particles in the final state**
- **Impact on original measurement quantified**
- **Documentation under preparation**



Top Yukawa coupling at 1.4 TeV

Goal

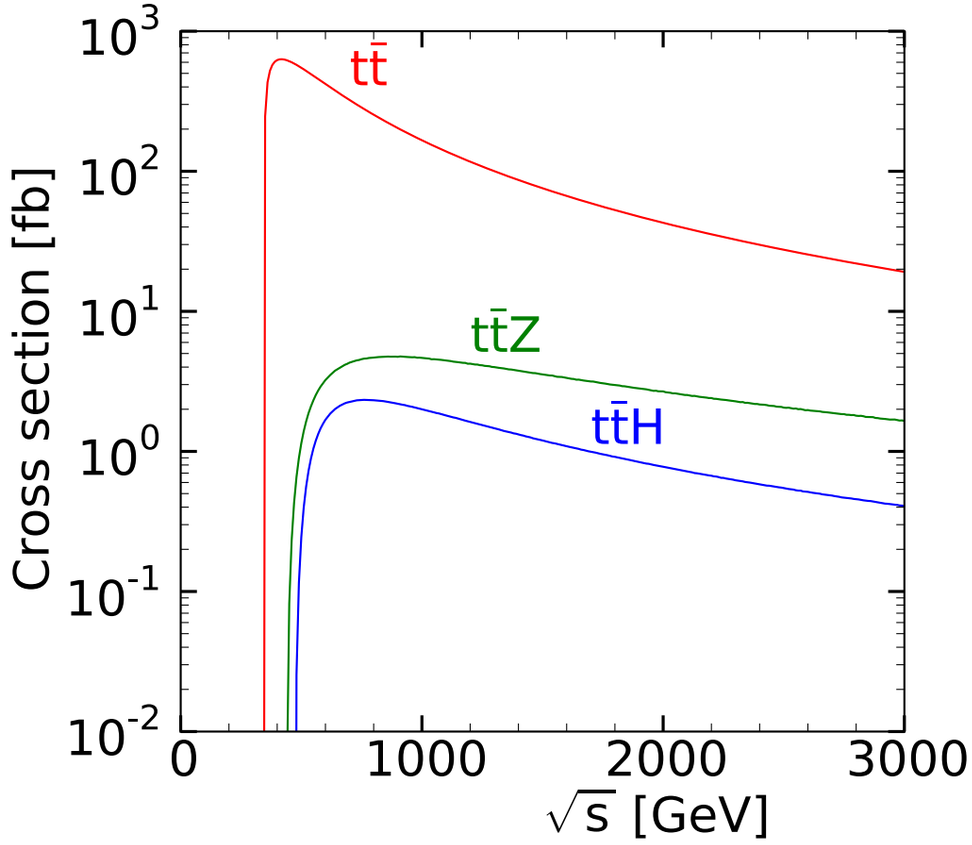
Determine the precision with which we can measure the top Yukawa coupling



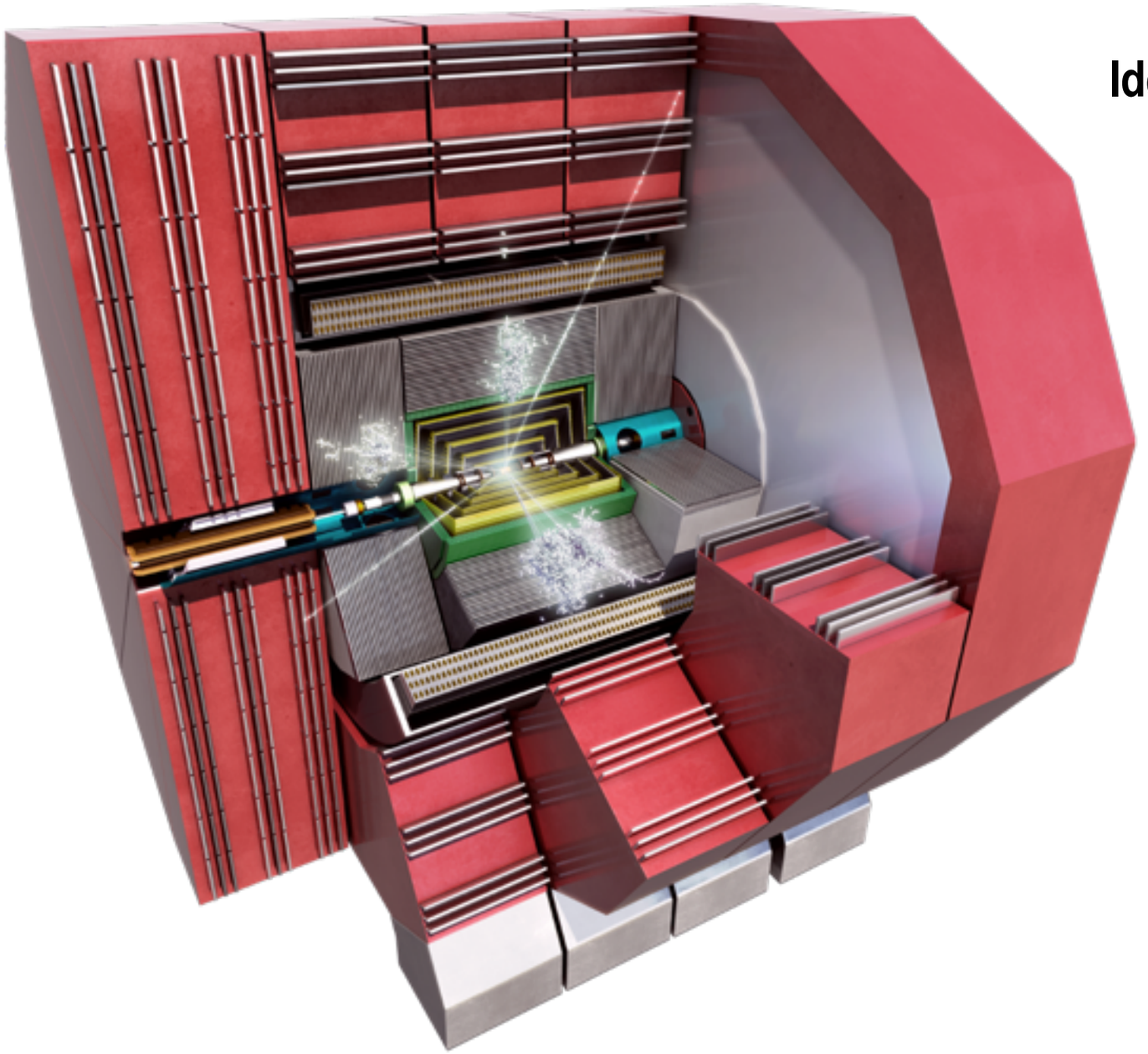
- **Using the decay H→bb: eight fermion final state (including 4 b-jets)**
- **Two channels are analysed:**
  1. **Fully hadronic channel: eight jets**
  2. **Semi-leptonic channel: six jets + lepton + nu**

Why 1.4 TeV (in comparison to 1 TeV)?

- **Further from ttH maximum cross section**
- **But much reduced tt background**



Detector benchmarking



ttH event in CLIC detector
H→bb, both tops decay leptonically

Ideal process to benchmark detector performance:

- High multiplicity final state (reconstruction, background rejection)
- Jet reconstruction (calorimeter, particle flow software)
- Missing energy (coverage)
- Lepton identification (tracker, muon system, isolation, calorimeter)
- Flavour-tagging (vertex detector)

Original event samples

	Process	Cross section (fb)	Events in 1.5 ab^{-1}	Simulation weight
Signal ttH	$t\bar{t}H$, 6 jet, $H \to b\bar{b}$	0.431	647	0.03
	$t\bar{t}H$, 4 jet, $H \to b\bar{b}$	0.415	623	0.03
Other ttH	$t\bar{t}H$, 2 jet, $H \to b\bar{b}$	0.100	150	0.006
	$t\bar{t}H$, 6 jet, $H \not\to b\bar{b}$	0.315	473	0.02
	$t\bar{t}H$, 4 jet, $H \not\to b\bar{b}$	0.303	455	0.02
	$t\bar{t}H$, 2 jet, $H \not\to b\bar{b}$	0.073	110	0.004
tt-based background	$t\bar{t}b\bar{b}$, 6 jet	0.549	824	0.03
	$t\bar{t}b\bar{b}$, 4 jet	0.529	794	0.03
	$t\bar{t}b\bar{b}$, 2 jet	0.127	191	0.008
	$t\bar{t}Z$, 6 jet	1.895	2,843	0.1
	$t\bar{t}Z$, 4 jet	1.825	2,738	0.1
	$t\bar{t}Z$, 2 jet	0.439	659	0.03
	$t\bar{t}$	135.8	203,700	1.5

Number of jets refers to the tt decay only

Analysis method

1) Lepton finding

2) Jet clustering

3) Flavour tagging

- 4 b jets!

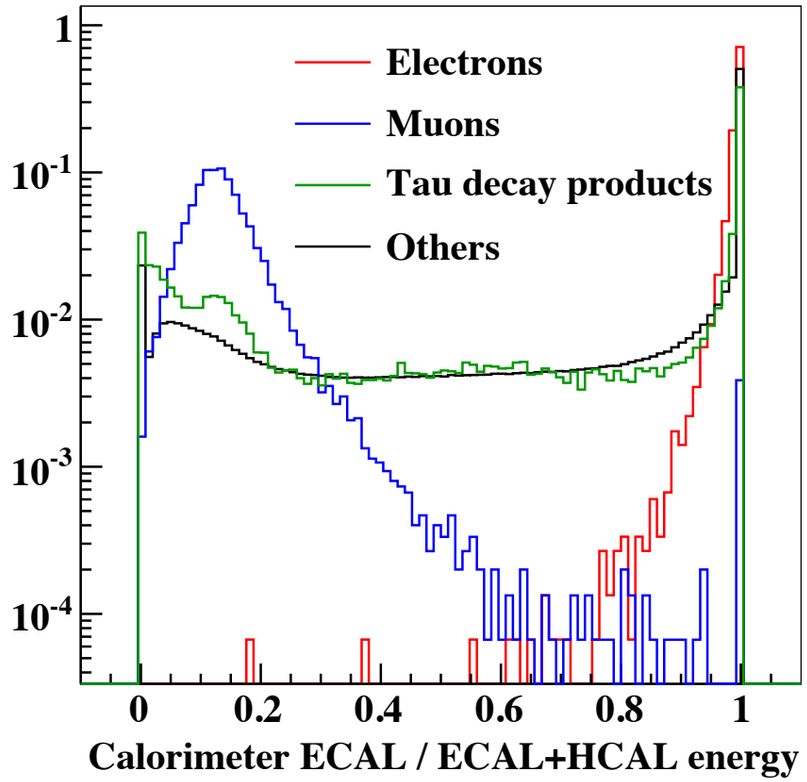
4) Jet grouping

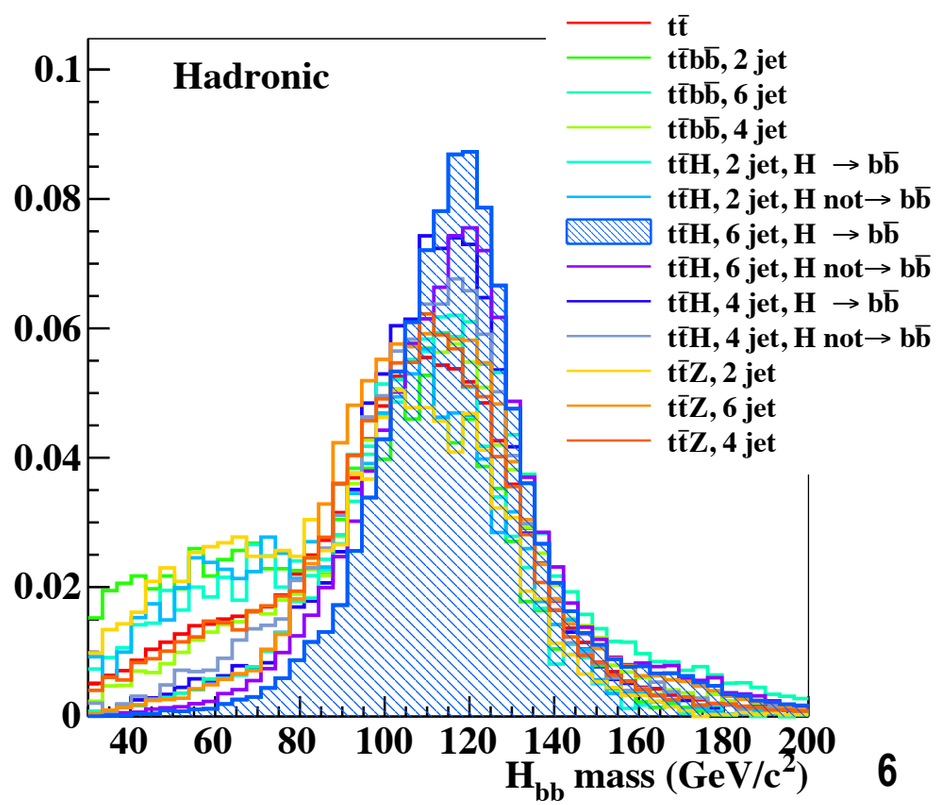
- Choose permutation with smallest χ^2:

$$\chi^2 = \frac{(M_{12} - M_W)^2}{\sigma_W^2} + \frac{(M_{123} - M_t)^2}{\sigma_t^2} + \frac{(M_{45} - M_h)^2}{\sigma_h^2}$$

5) MVA selection on discriminating variables

6) Channel combination and compensation for Higgsstrahlung





Original result

Semi-leptonic channel

- Significance: 8.36 σ
- Precision on ttH: 12.0%

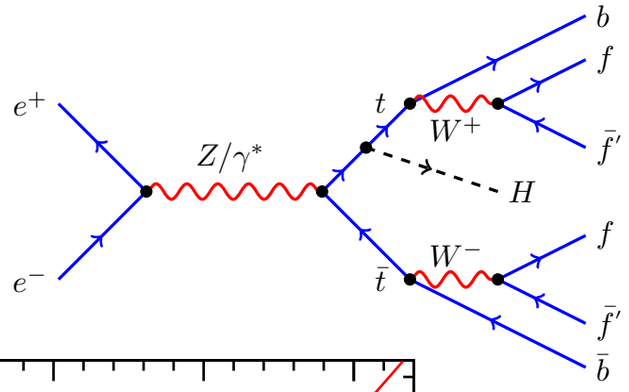
Hadronic channel

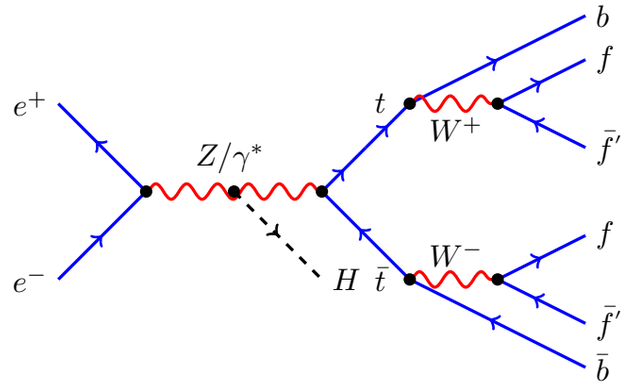
- Significance: 9.17 σ
- Precision on ttH: 10.9%

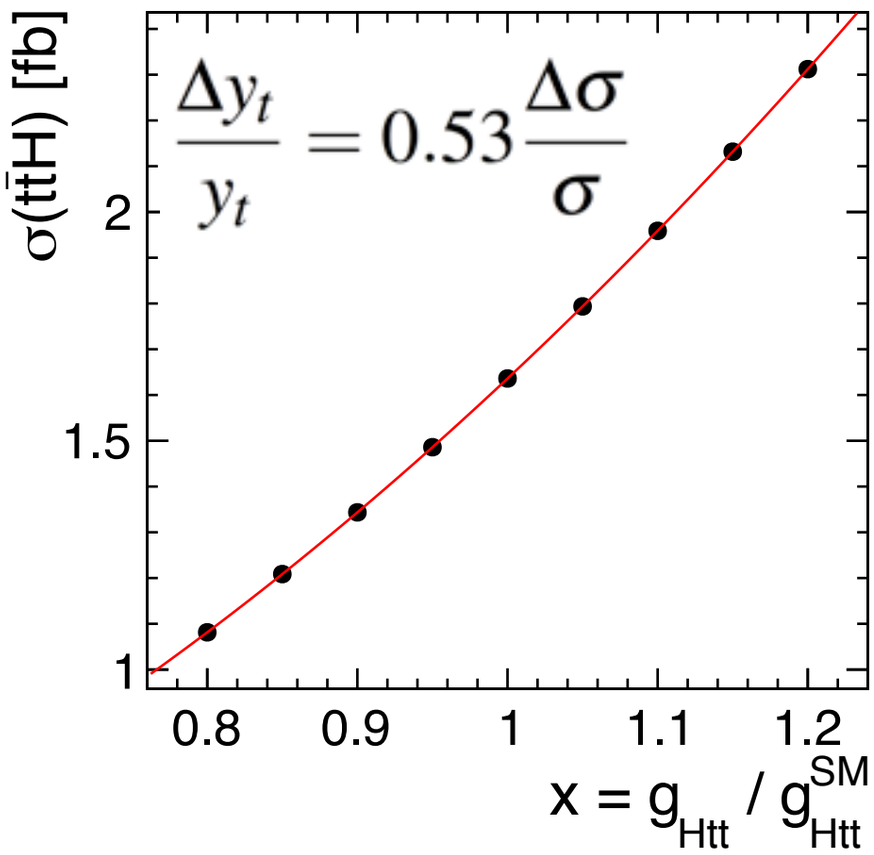
Combined result

- Significance: 12.35 σ
- Precision on ttH: 8.1%

Compensation for Higgsstrahlung (not sensitive to the top Yukawa coupling):







The CLIC_SiD detector

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operating at a future e^+e^- linear collider with centre of mass energy 1.4 TeV

-

with a recorded dataset of 1.5 ab^{-1}

-

could measure the top Yukawa coupling with a precision of 4.27%

would be < 4% inc. polarisation

New for LCWS14

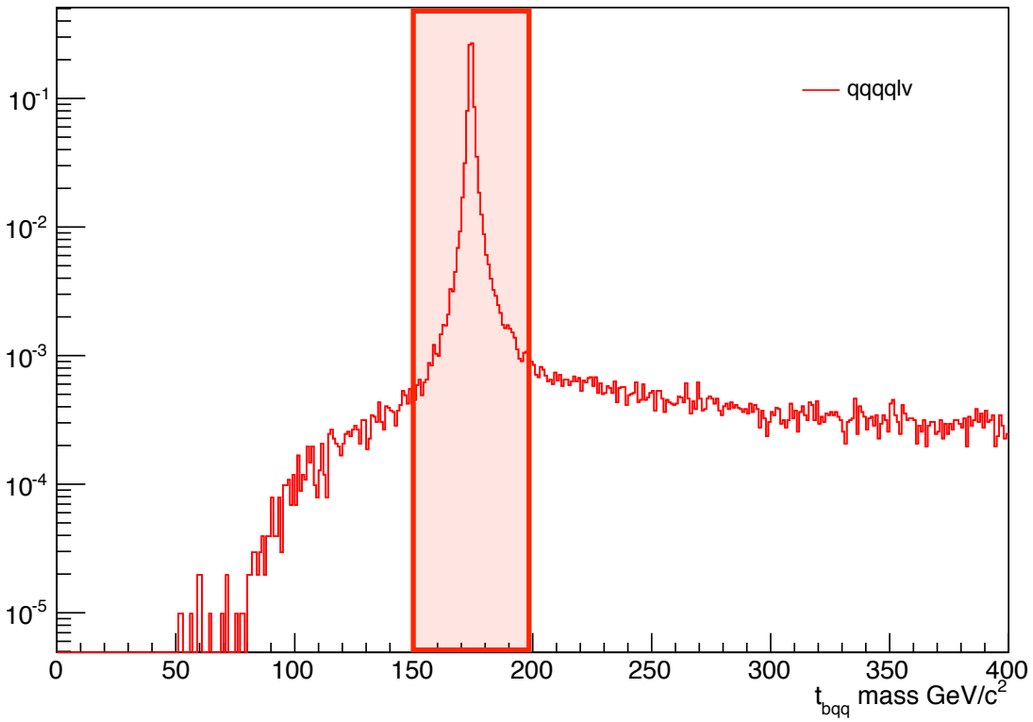
Additional backgrounds

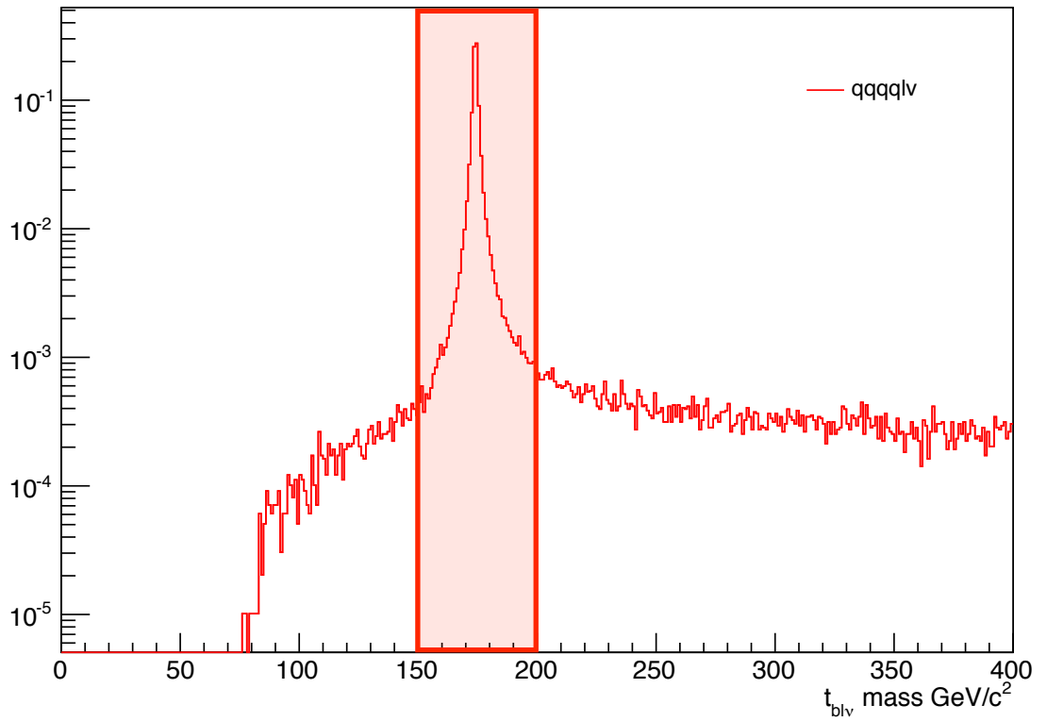
Take into account four additional final states, covering non-ttbar(+X) backgrounds

Process	Cross section (fb)	Events in 1.5 ab^{-1}	Sample weight
qqqq	1326	1.989×10^6	8.11
qqqqvv	24.7	37050	0.17
qqqqlv	115.3	172950	1.22
qqqqll	71.7	107550	0.65

- qqqq sample mostly WW production
- qqqqlv sample contains many ttbar events, which are removed
  - (separate sample already considered in original analysis)
- Strategy:
  - reconstruct as 6 or 8 jets depending on number of leptons found
  - apply existing BDT and see what happens

Removal of ttbar from qqqqlv





- Veto if 150 < t_1_mass < 200 AND 150 < t_2_mass < 200
- This removes 60% of the qqqqlv sample

Process	Cross section (fb)	Events in 1.5 ab^{-1}
qqqq	1326	1.989×10^6
qqqqvv	24.7	37050
qqqqlv	115.3	~~172950~~ 68338
qqqqll	71.7	107550

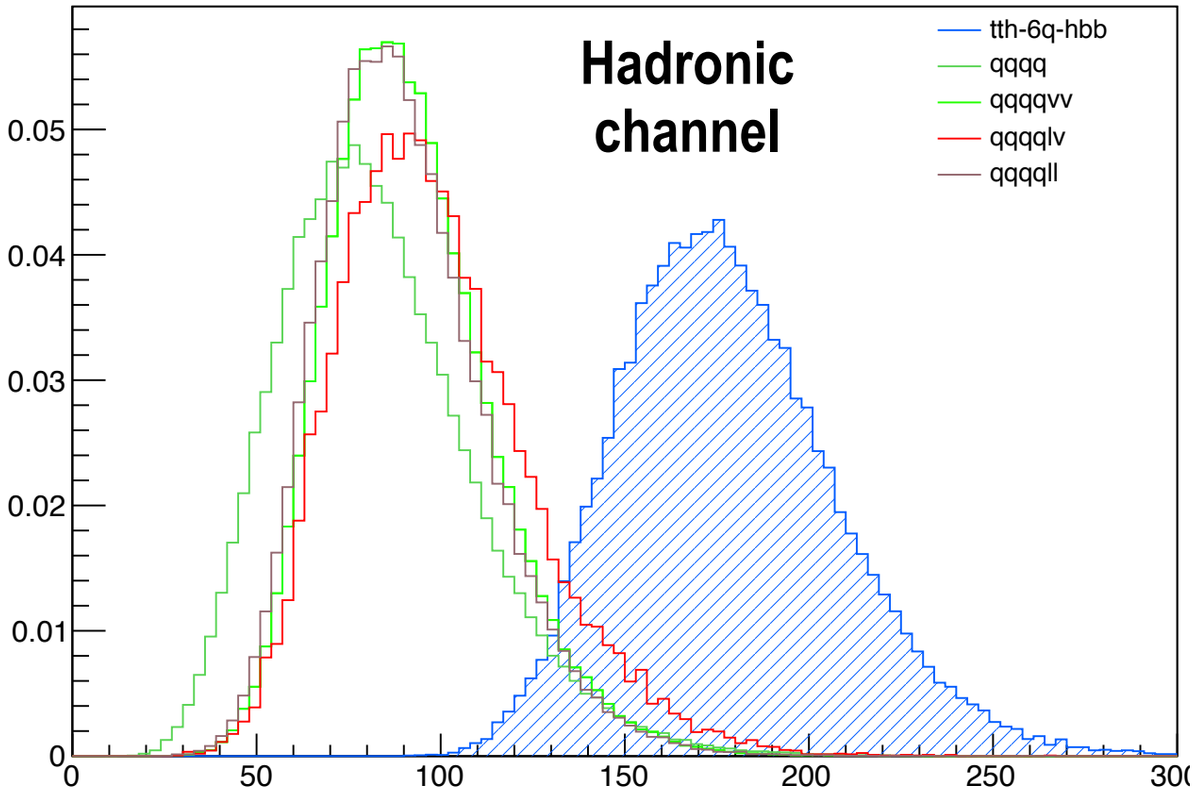
Performance of existing lepton selection

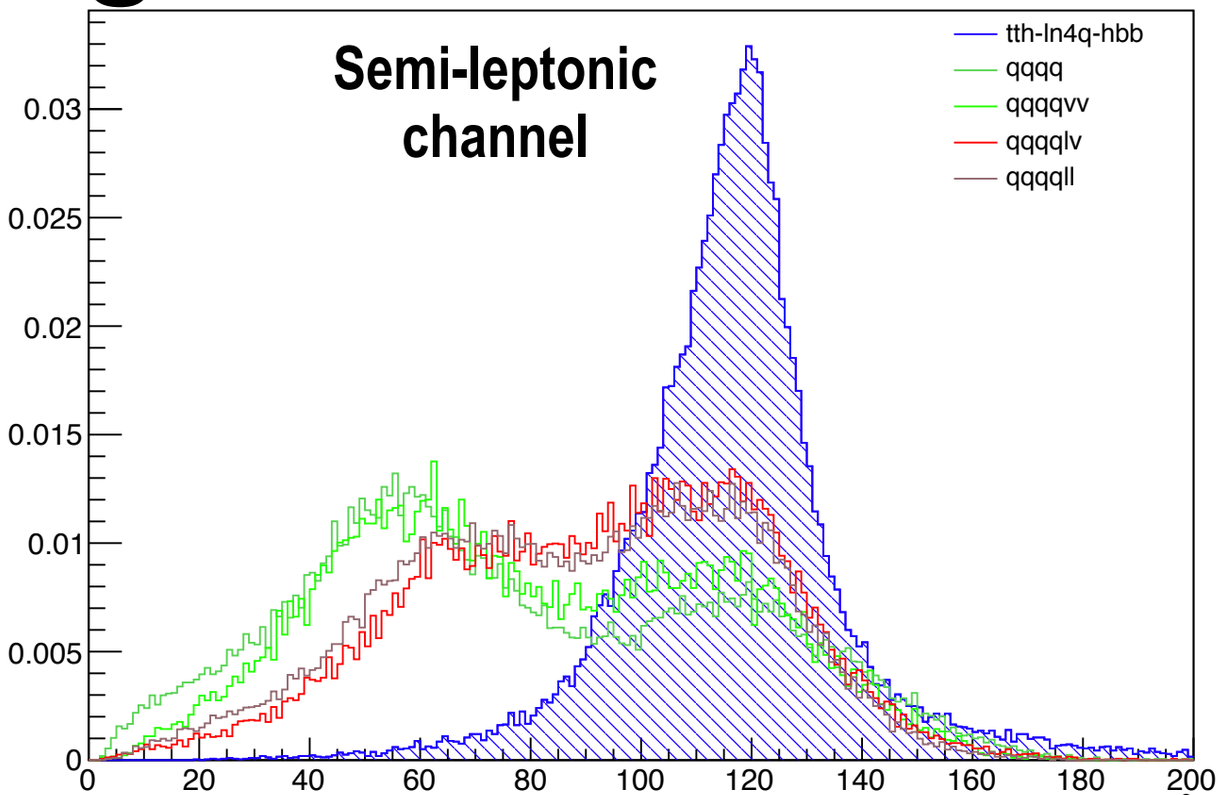
Process	Events in 1.5 ab^{-1}	Events with 0 leptons	Events with 1 lepton
qqqq	1.989 x 10^6	1.637 x 10^6 (82%)	301343 (15%)
qqqqvv	37050	33760 (91%)	3021 (8%)
qqqqlv	68338	24812 (36%)	38893 (57%)
qqqqll	107550	50865 (47%)	37668 (35%)
		1.782 x 10^6	380925

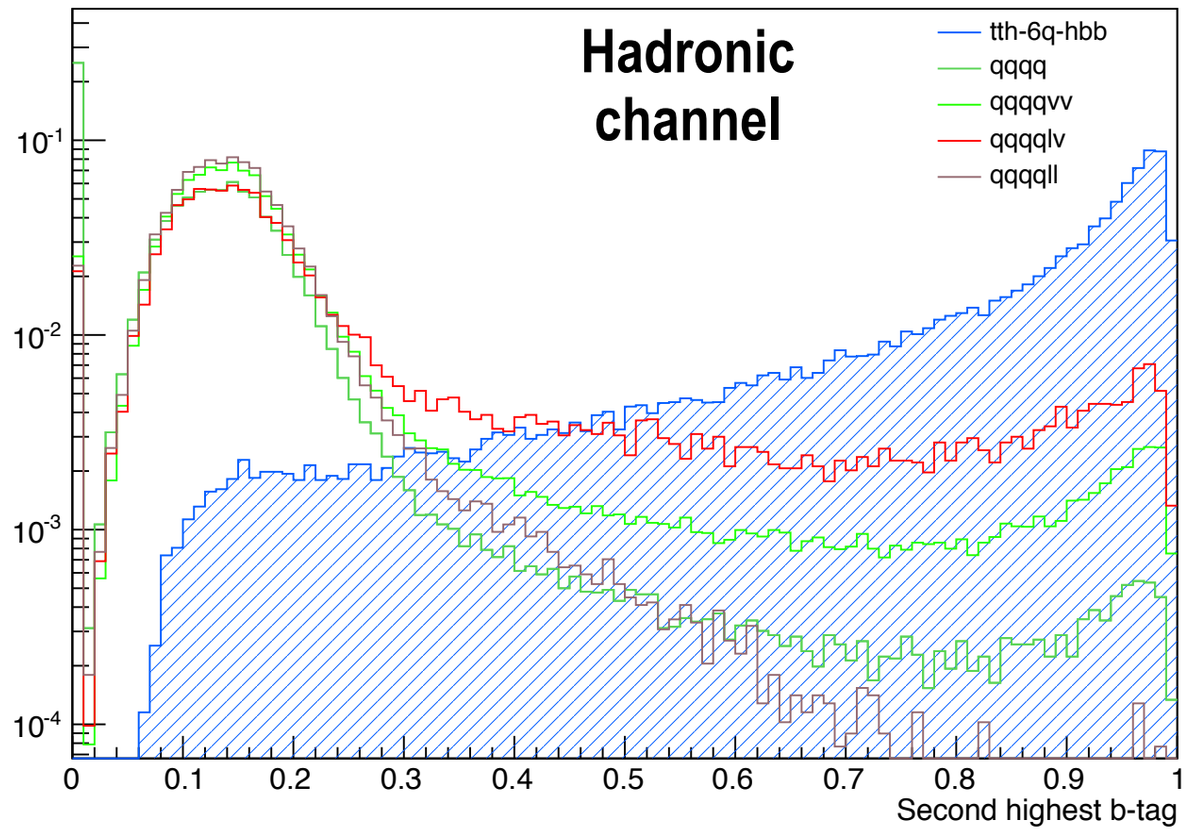
ZZ fusion events

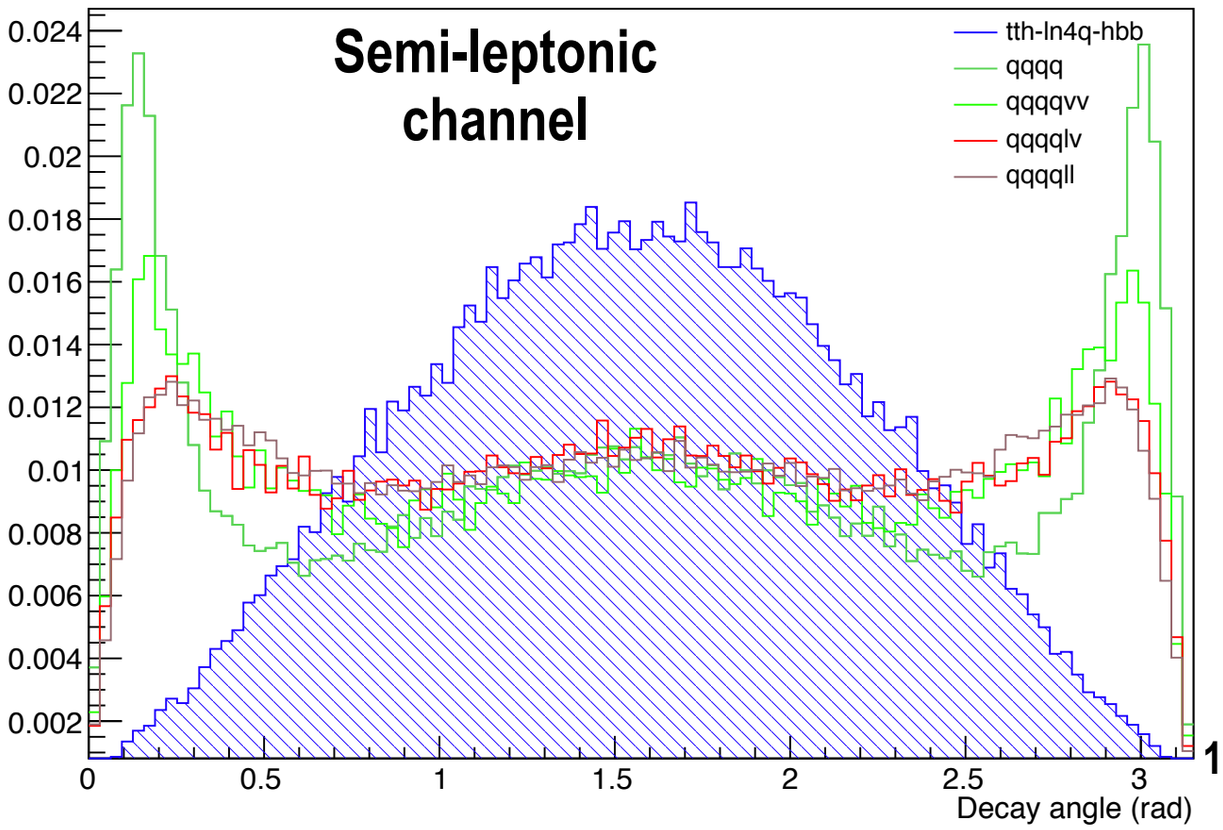
Leptons are beam particles after radiation of photon/Z boson. Hence very forward direction.

Discriminating variables

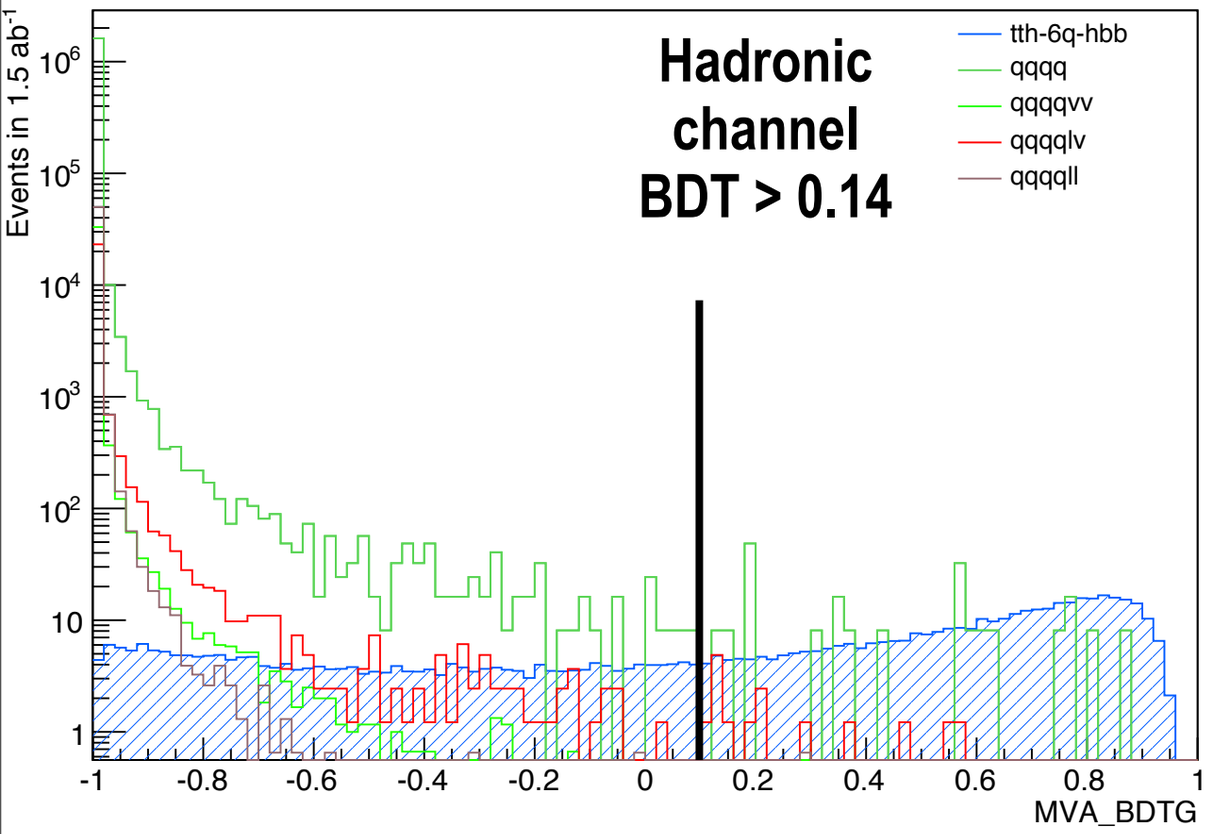


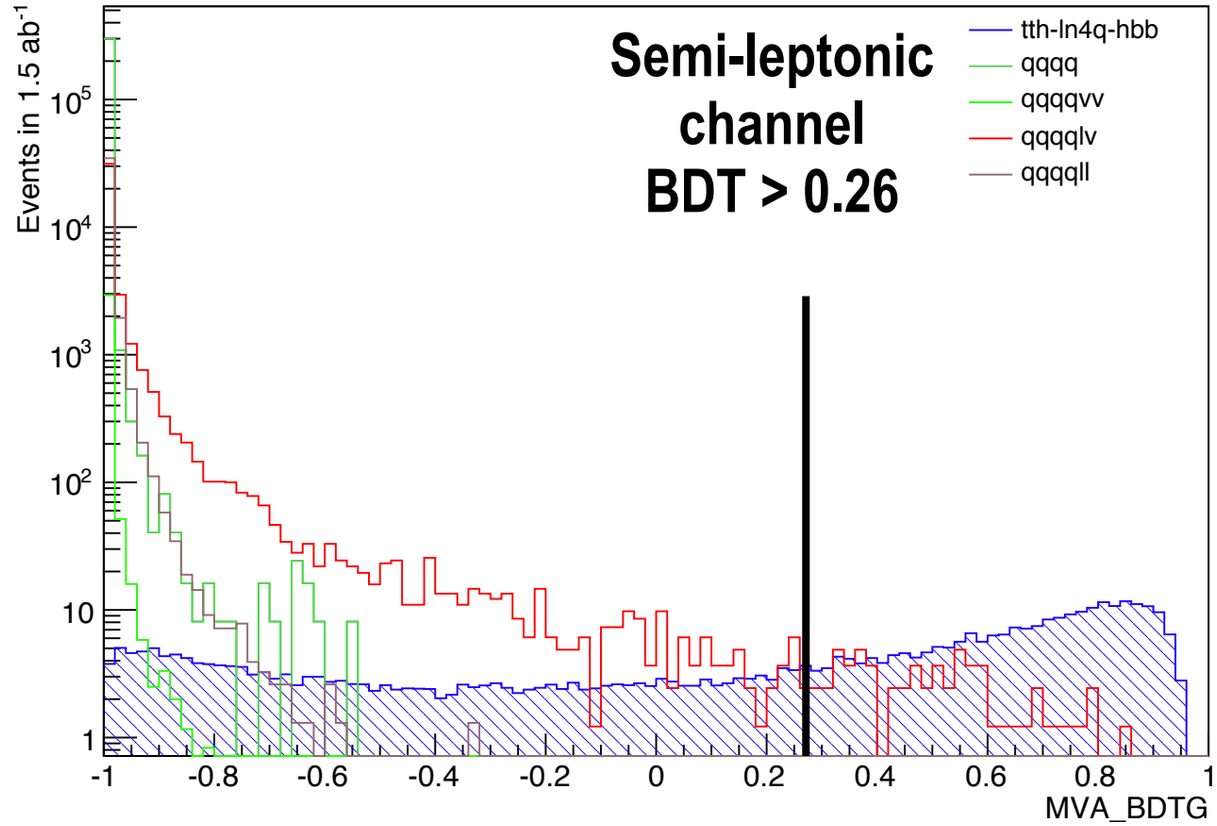






Performance of existing BDT





Process	Events with 0 leptons...	... which pass hadronic BDT	Events with 1 lepton...	... which pass semi-leptonic BDT
qqqq	1.637×10^6	195	301343	0
qqqqvv	33760	1.2	3021	0
qqqqlv	24812	11	38893	70
qqqqll	50865	1	37668	0
	1.782×10^6	208	380925	70

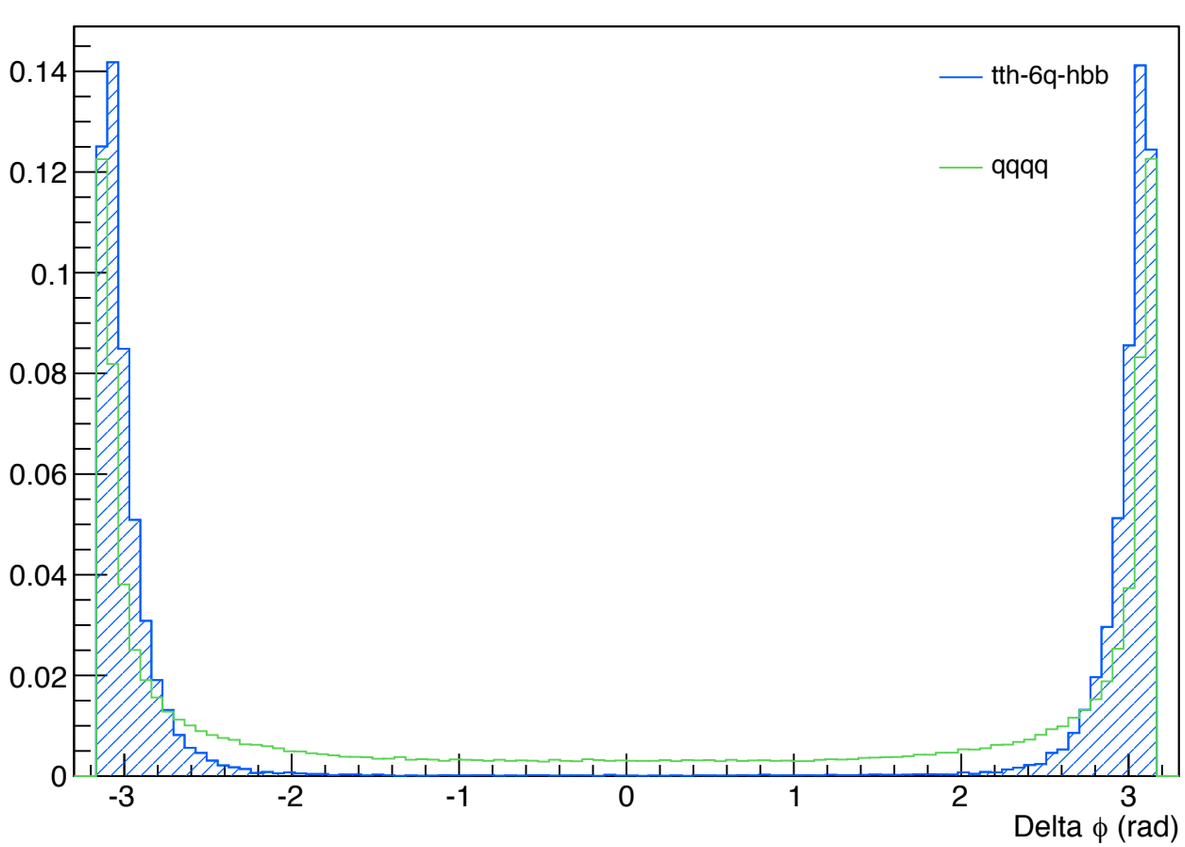
Impact on original measurement

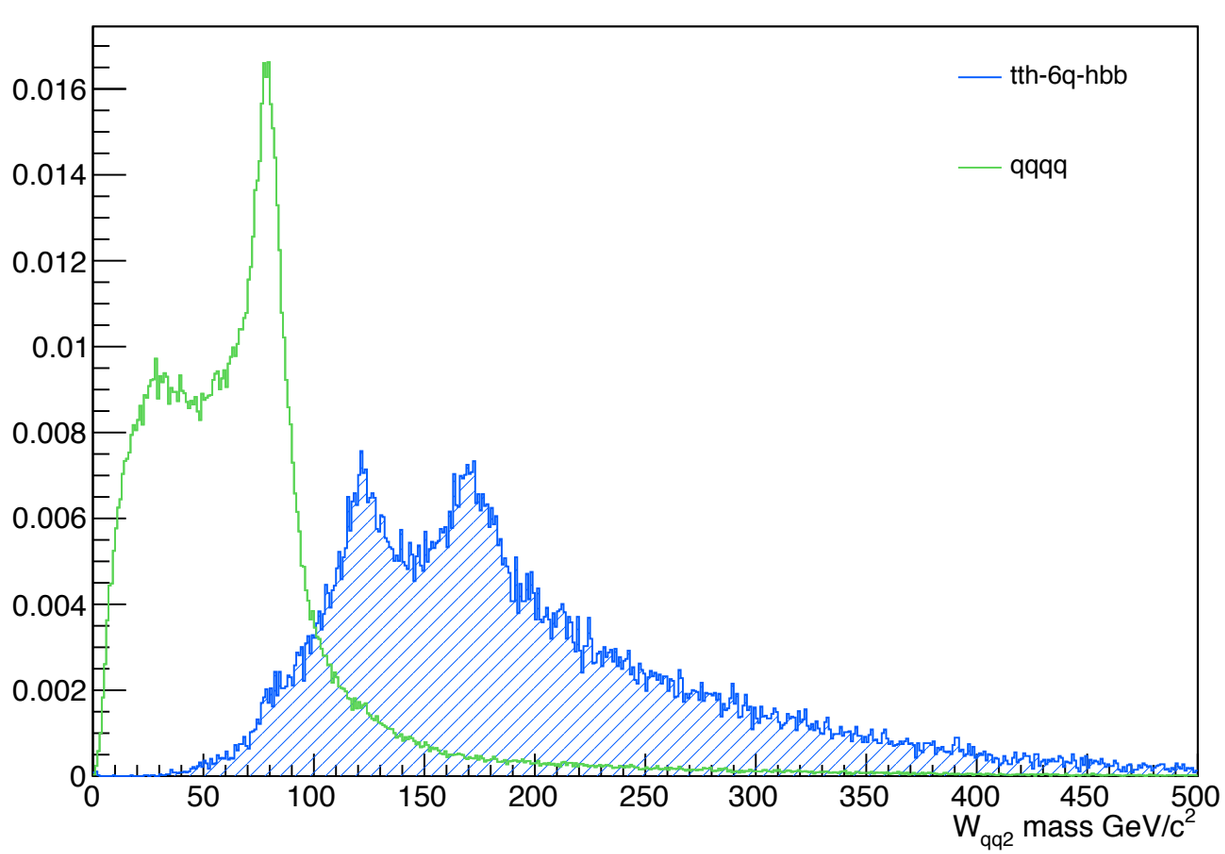
- Hadronic channel
  - Number of background events: 2305 (previously 2097)
  - Uncertainty on cross-section $\Delta\sigma/\sigma$: 11.4% (previously 10.9%)
- Semi-leptonic channel
  - Number of background events: 985 (previously 915)
  - Uncertainty on cross-section $\Delta\sigma/\sigma$: 12.3% (previously 12.0%)
- Combined:
  - Uncertainty on cross-section $\Delta\sigma/\sigma$: 8.4% (previously 8.1%)
  - Uncertainty on coupling $\Delta g_{ttH} / g_{ttH}$: 4.5% (previously 4.3%)

Existing selection does adequate job of removing non-ttbar (+X) backgrounds

Ideas for future improvements

- Reducing the qqqq background in the hadronic channel would be the priority
  - Cluster into 4 jets and reconstruct WW
  - Look for discriminating variables:
    - delta phi
    - W mass





Summary

- Non ttbar (+X) backgrounds were considered for the first time in the ttH analysis
- The existing lepton selection and BDT do an adequate job of removing them
- The uncertainty on the top Yukawa coupling measurement at 1.4 TeV changes from:

$\Delta g_{ttH}/g_{ttH} = 4.3\%$ ⇒ $\Delta g_{ttH}/g_{ttH} = 4.5\%$

- To be compared with ILC analyses at 1 TeV:
  - ILD $\Delta g_{ttH}/g_{ttH} = 4.3\%$ (LC-REP-2013-004)
  - SiD $\Delta g_{ttH}/g_{ttH} = 4.5\%$ (arXiv:1307.7644)
- Future improvements could be made by using discriminating variables based on reconstructing events as 4 jets

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Thanks for your attention!

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