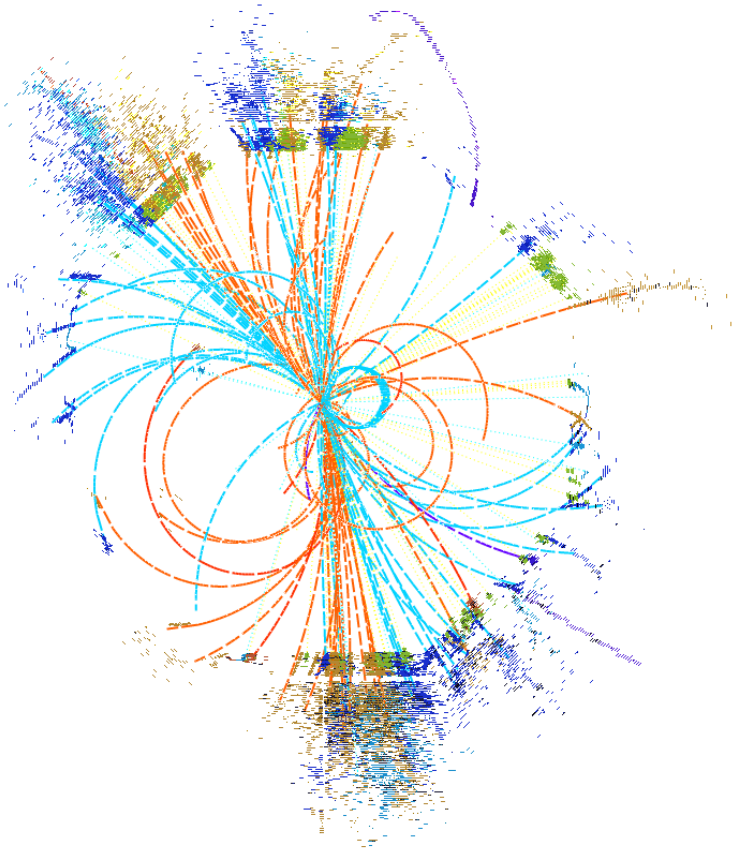
Measurement of the top Yukawa coupling at $\sqrt{s}$ = 1 TeV using the SiD detector

Philipp Roloff (CERN), **Jan Strube** (CERN)



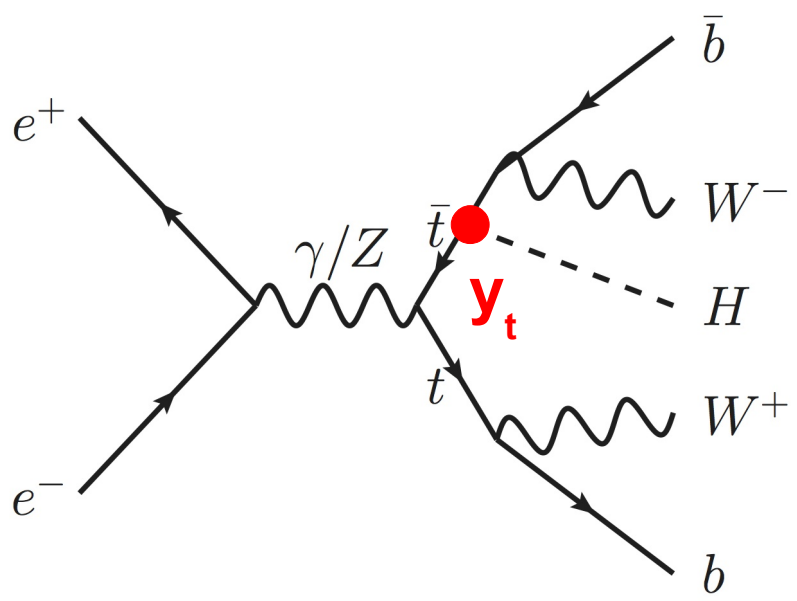
International Workshop on Future Linear Colliders,
University of Texas at Arlington, 24/10/2012

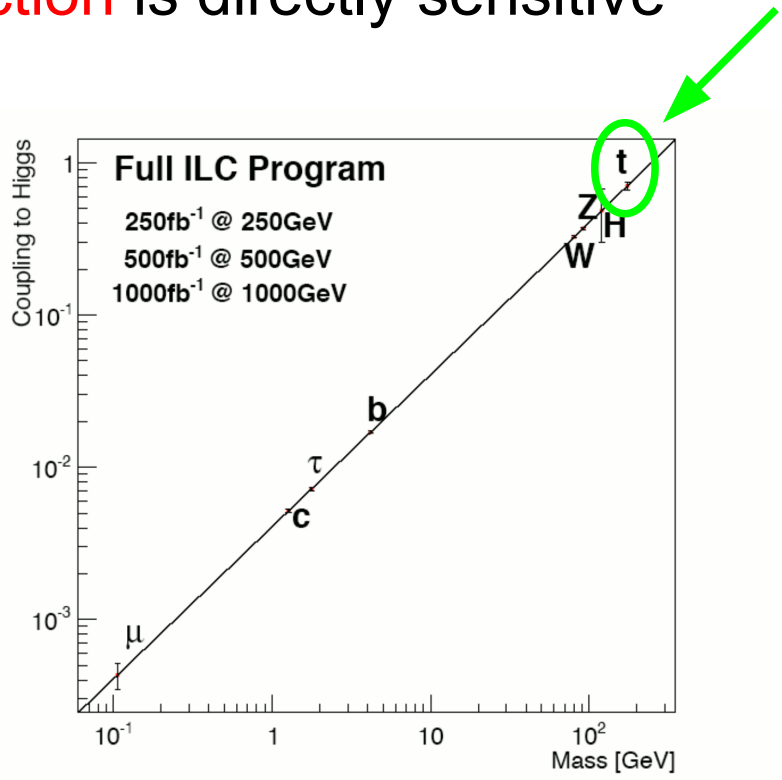
Introduction

- Detector benchmarking processes for the DBD

- **Final states:** - "6 jets": $t(\rightarrow qqb)\bar{t}(\rightarrow l\nu\bar{b})H(\rightarrow b\bar{b})$, m_H = 125 GeV
  - "8 jets": $t(\rightarrow qqb)\bar{t}(\rightarrow qq\bar{b})H(\rightarrow b\bar{b})$, m_H = 125 GeV

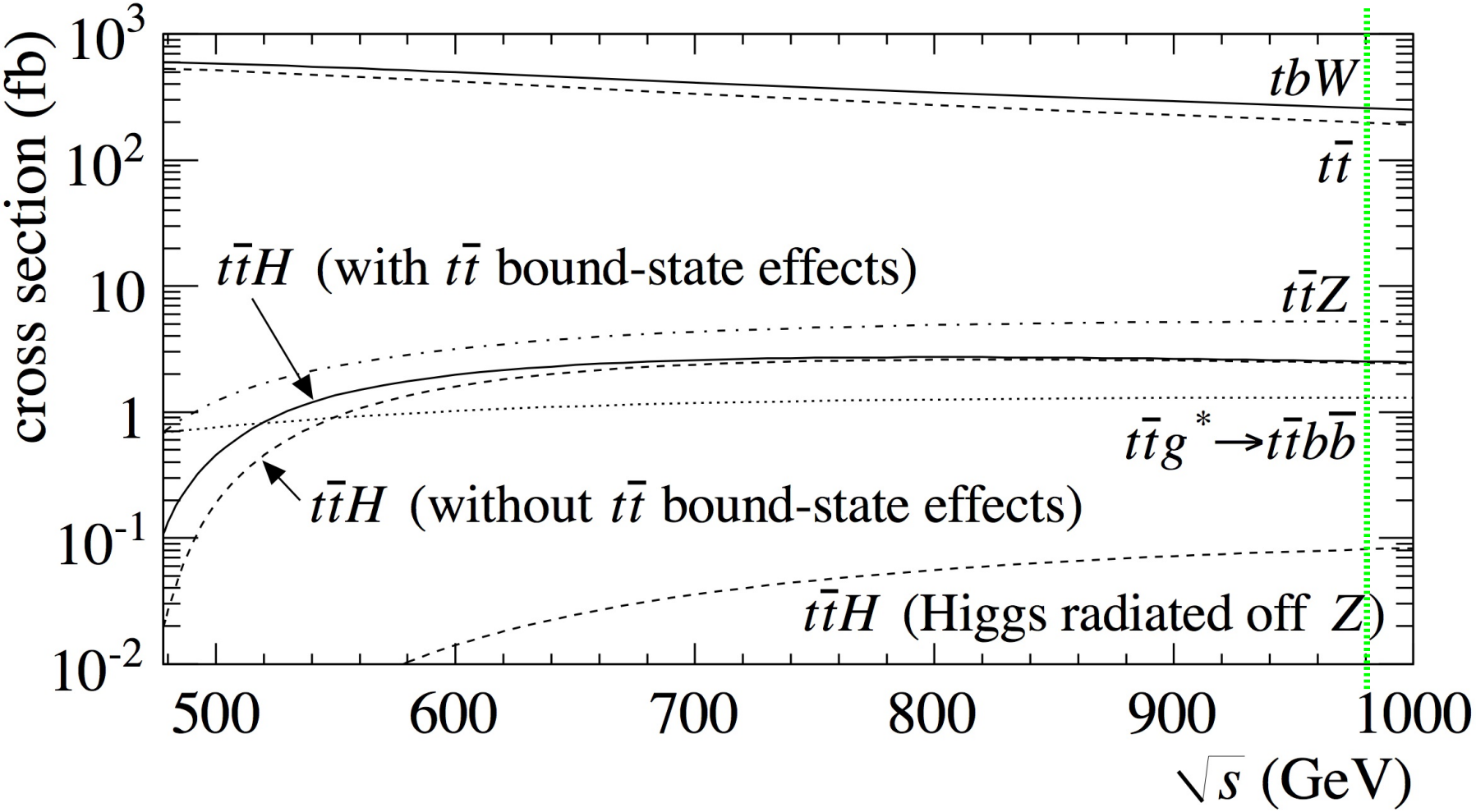
- **Motivation:** Cross section for $t\bar{t}H$ production is directly sensitive to the top Yukawa coupling, y_t:





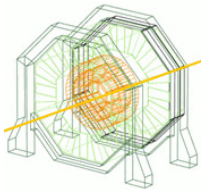
Cross sections

Phys.Rev.D84:014033,2011



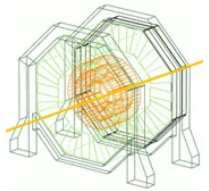
Unpolarised beams, m_H = 120 GeV

Monte Carlo samples

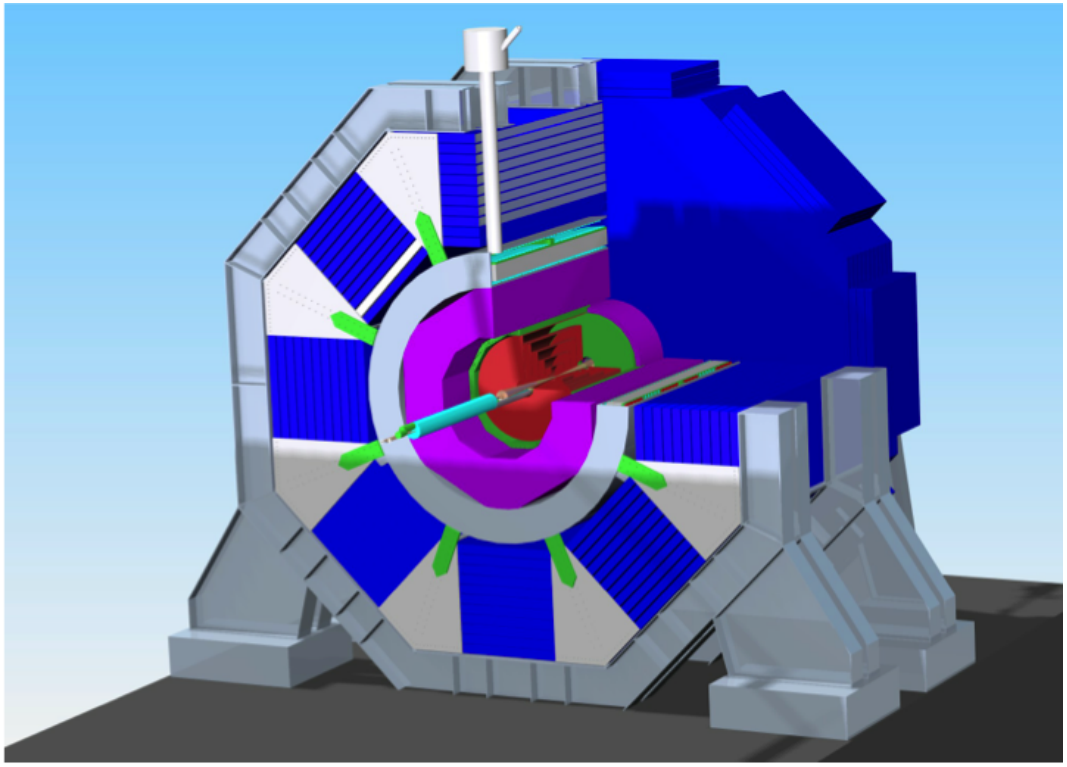


Final state	P(e) [%]	P(p) [%]	N(events)	N(L = 1 ab^{-1})
$t\bar{t}(\rightarrow lv4q)b\bar{b}$	+80	-20	20000	846
	-80	+20	20000	421
$t\bar{t}(\rightarrow 6q)Z$	+80	-20	20000	1328
	-80	+20	20000	3483
$t\bar{t}(\rightarrow 6q)b\bar{b}$	+80	-20	20000	436
	-80	+20	20000	874
$t\bar{t}(\rightarrow lv4q)Z$	+80	-20	20000	1277
	-80	+20	20000	3442
$t\bar{t}(\rightarrow 6q)H(\rightarrow b\bar{b})$	+80	-20	20000	439
	-80	+20	20000	866
$t\bar{t}(\rightarrow 6q)H(\text{not } b\bar{b})$	+80	-20	20000	321
	-80	+20	20000	634
$t\bar{t}(\rightarrow 2l2v2q)H(\rightarrow b\bar{b})$	+80	-20	20000	103
	-80	+20	20000	200
$t\bar{t}(\rightarrow 2l2v2q)H(\text{not } b\bar{b})$	+80	-20	20000	74
	-80	+20	20000	147
$t\bar{t}(\rightarrow lv4q)H(\rightarrow b\bar{b})$	+80	-20	20000	423
	-80	+20	20000	835
$t\bar{t}(\rightarrow lv4q)H(\text{not } b\bar{b})$	+80	-20	20000	307
	-80	+20	20000	608
$t\bar{t}$	+80	-20	566500	170198
	-80	+20	566500	449164

Event simulation



- Full simulation of the sidloi3 detector (used for DBD benchmark studies)



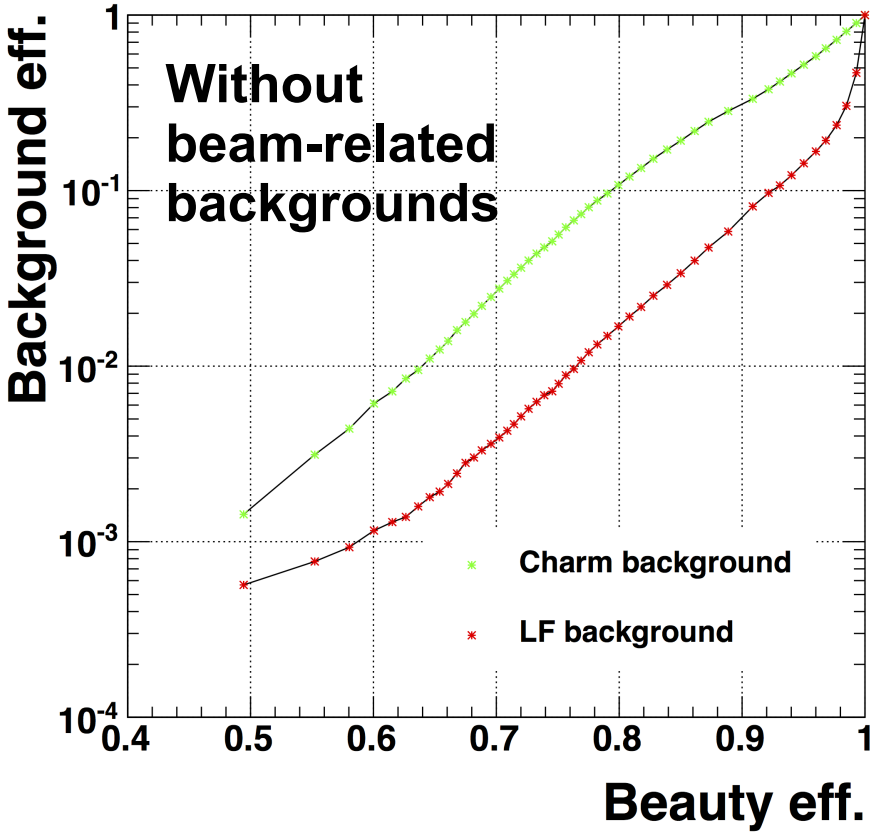
- **The physics events were overlaid with beam-related backgrounds corresponding to 1 BX:**

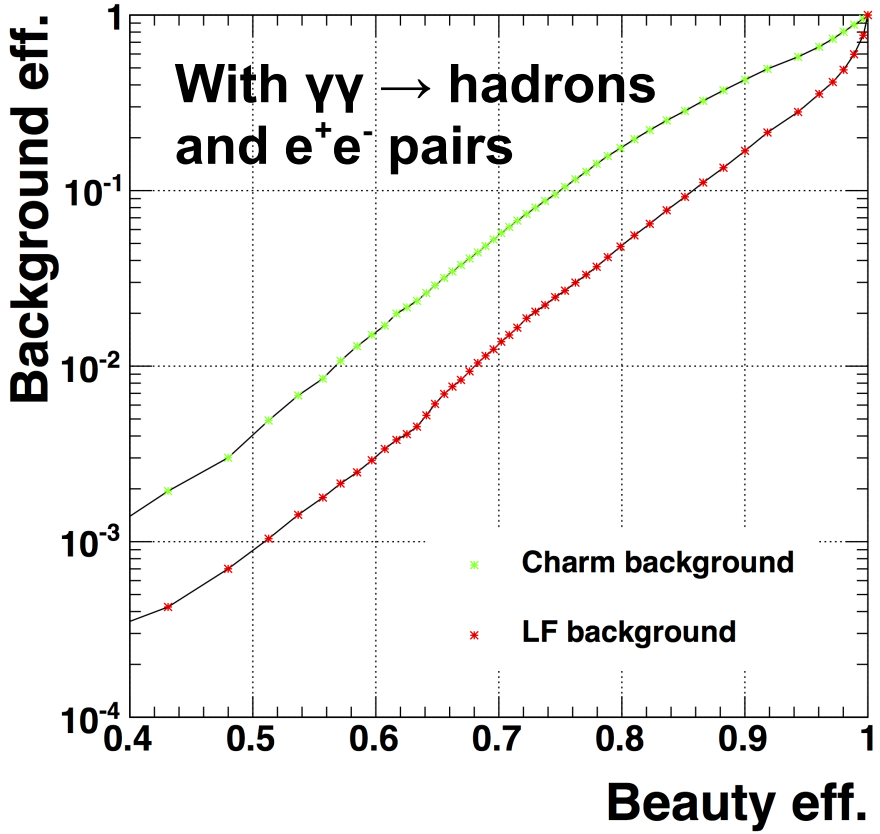
  - incoherent pairs (450.000 particles)
  - 4.1 $\gamma\gamma \rightarrow$ hadrons interactions

- PandoraPFA for particle flow reconstruction

Flavour tagging

- Based on the LCFIPlus package
- Cuts adjusted for the SiD detector geometry
- Trained using $Z \to b\bar{b}$, $c\bar{c}$, $q\bar{q}$





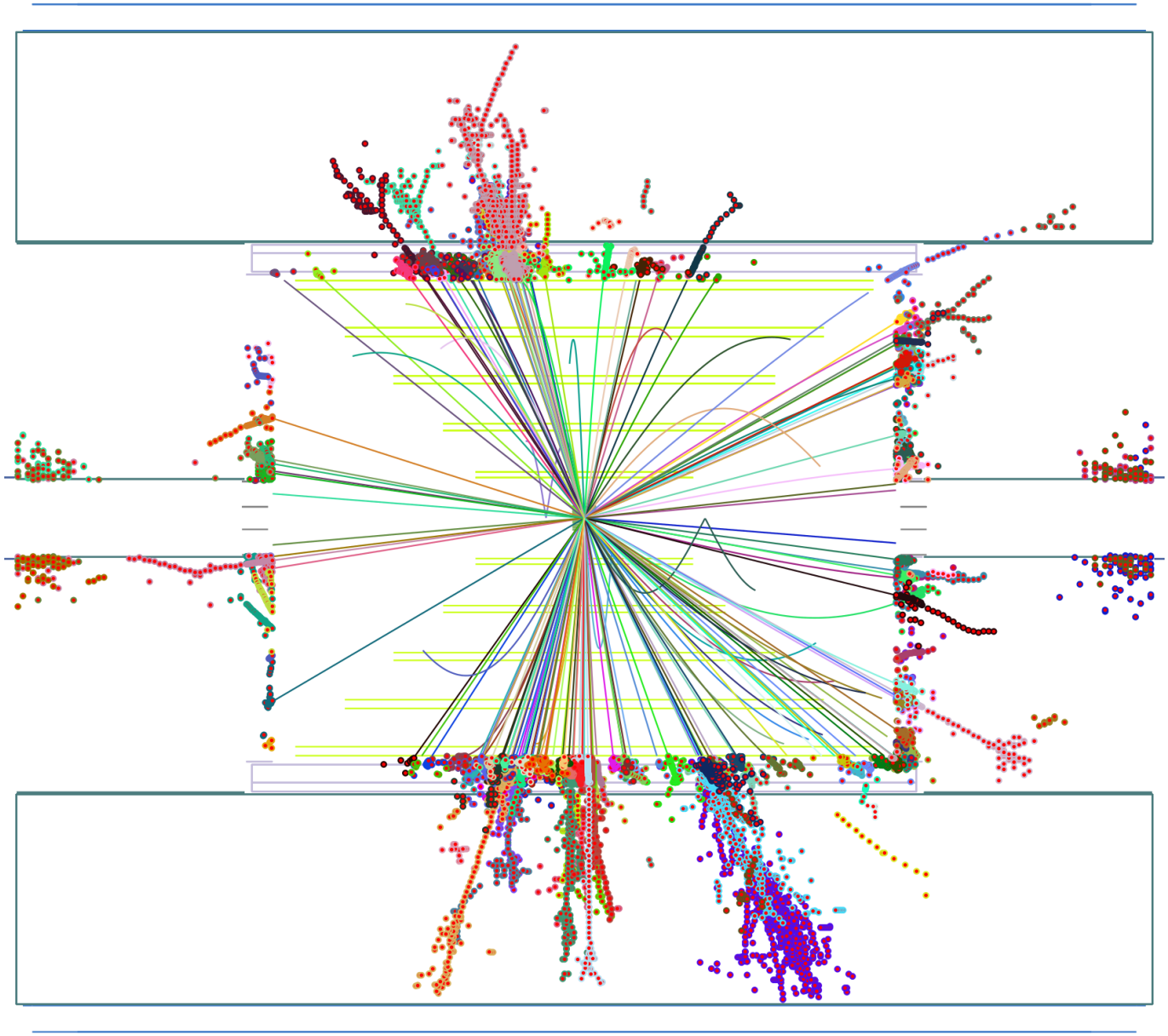
Test of the flavour tagging performance in $Z \to b\bar{b}$, $c\bar{c}$, $q\bar{q}$ events

Event reconstruction I

1.) Remove all PFOs with:

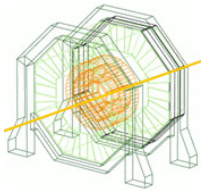
- p_T < 500 MeV
- Θ < 20°
- Θ > 160°

2.) Remove identified isolated leptons from PFO list



8jet signal event

Event reconstruction II



3.) Perform jet clustering using the Durham algorithm in the exclusive mode with 6 or 8 jets

4.) Obtain b-tag value for each jet using LCFIPlus

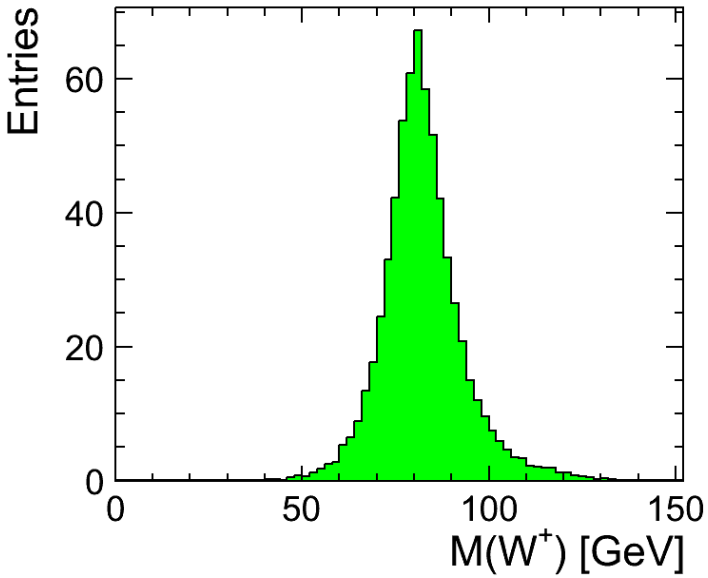
5.) Group jets into $W^{\pm}$, H and top pairs
by minimising:

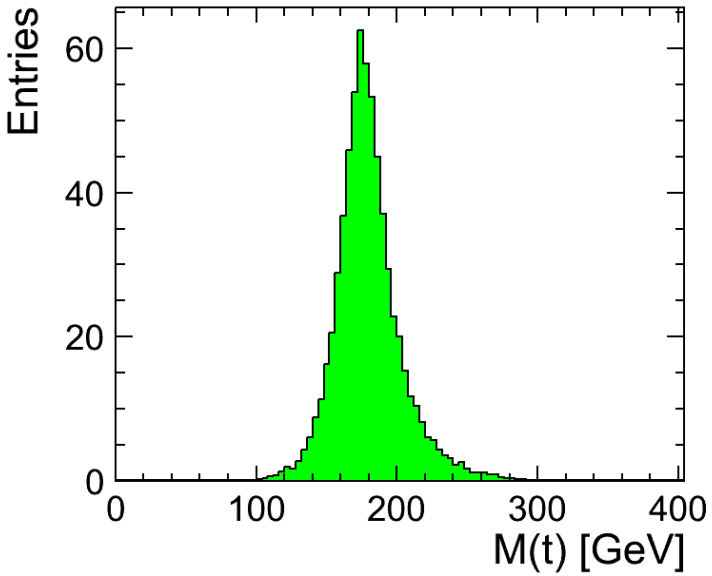
6jets: $$\frac{(M_{12}-M_{W^{\pm}})^2}{\sigma^2_{W^{\pm}}}+\frac{(M_{123}-M_t)^2}{\sigma^2_t}+\frac{(M_{45}-M_H)^2}{\sigma^2_H}$$

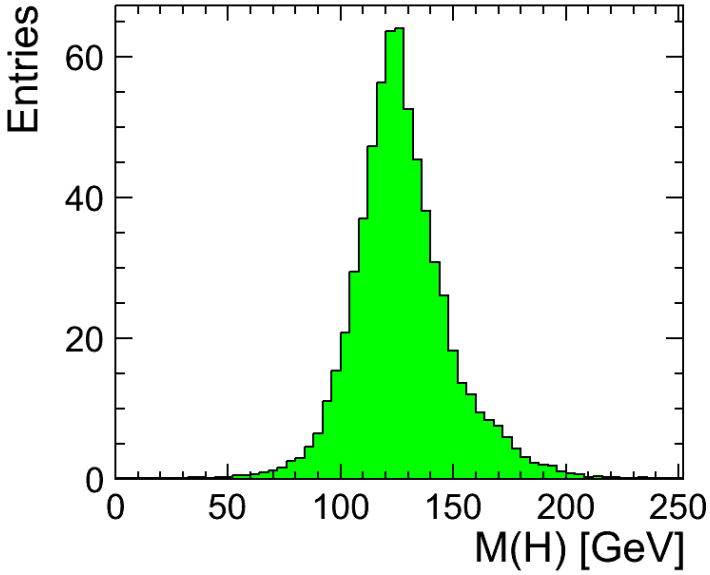
8jets:

$$\frac{(M_{12}-M_{W^{\pm}})^2}{\sigma^2_{W^{\pm}}}+\frac{(M_{123}-M_t)^2}{\sigma^2_t}+\frac{(M_{45}-M_{W^{\pm}})^2}{\sigma^2_{W^{\pm}}}+\frac{(M_{456}-M_t)^2}{\sigma^2_t}+\frac{(M_{78}-M_H)^2}{\sigma^2_H}$$

Jet reconstruction: 6 jets



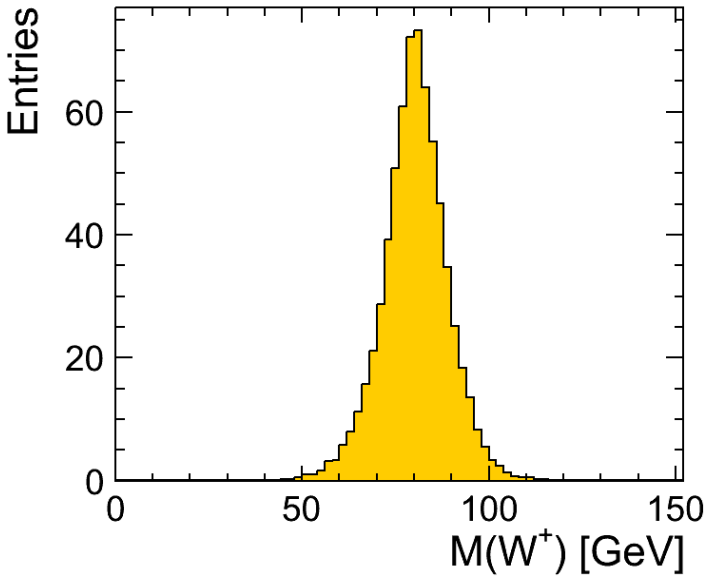


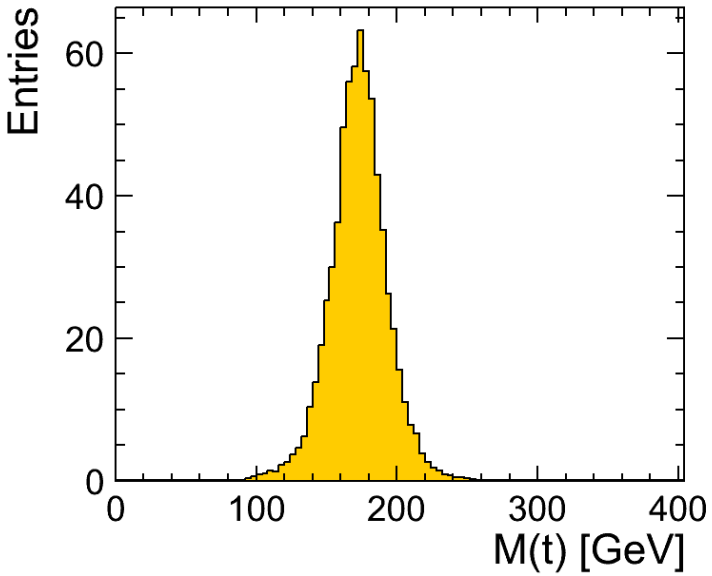


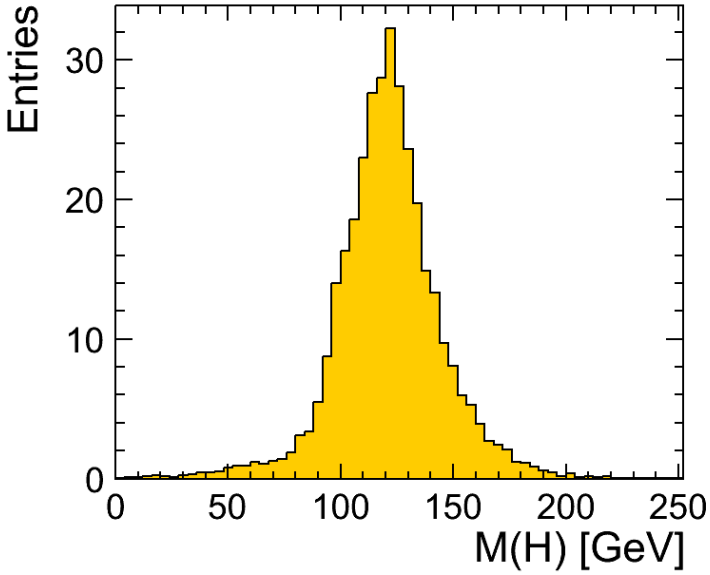
- With γγ → hadrons and e^+e^- pairs

- The hadronic final state with 6 jets is well reconstructed

Jet reconstruction: 8 jets



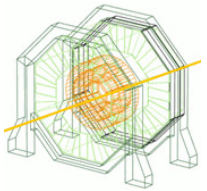




- With γγ → hadrons and e^+e^- pairs

- The hadronic final state with 8 jets is well reconstructed

Event selection

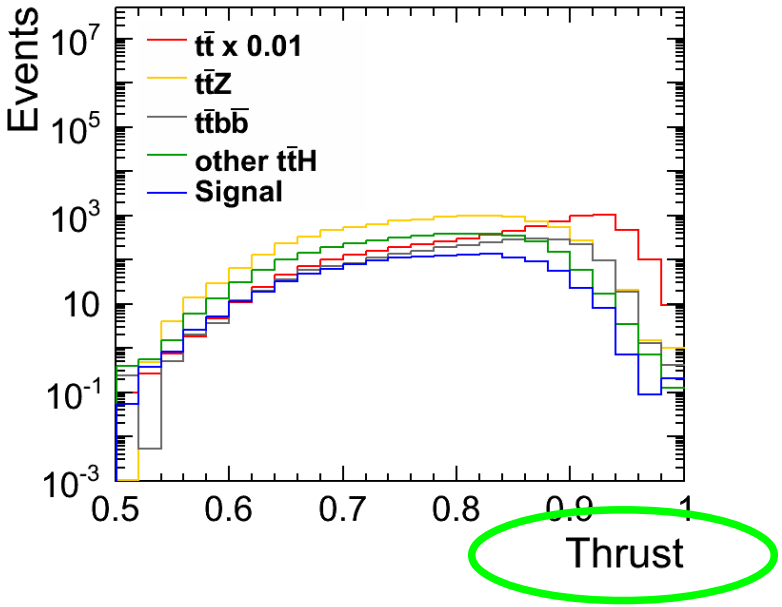


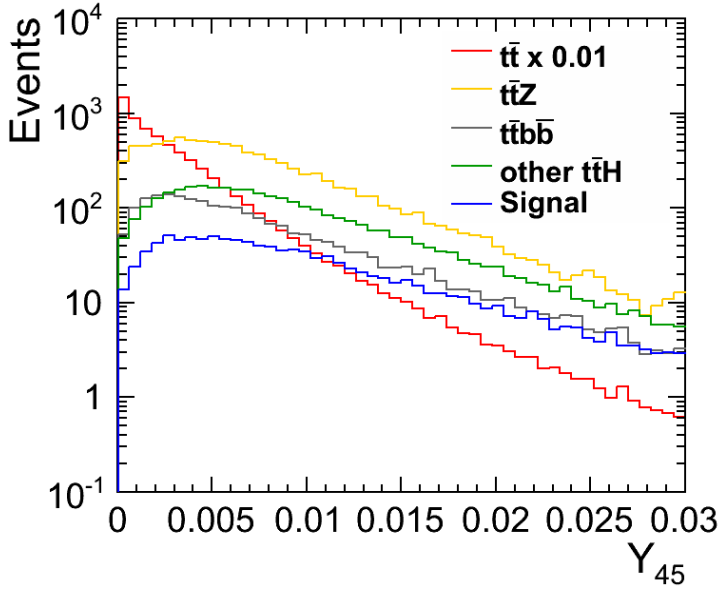
Signal events were selected using Boosted Decision Trees (BDTs) as implemented in TMVA.

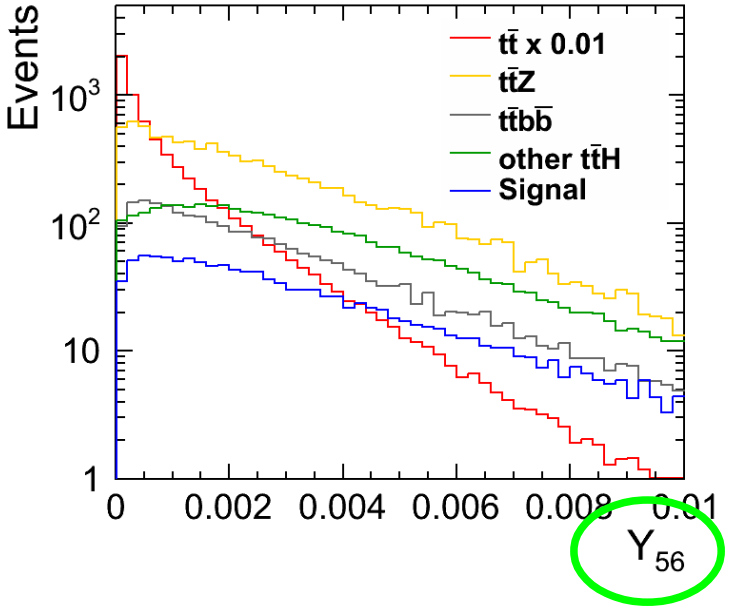
Input variables for the 6-jet final state:
M_{12}, M_{123}, M_{45}, four highest b-tags values, Thrust, $Y_{5\to6}$
$\longrightarrow$ 9 variables

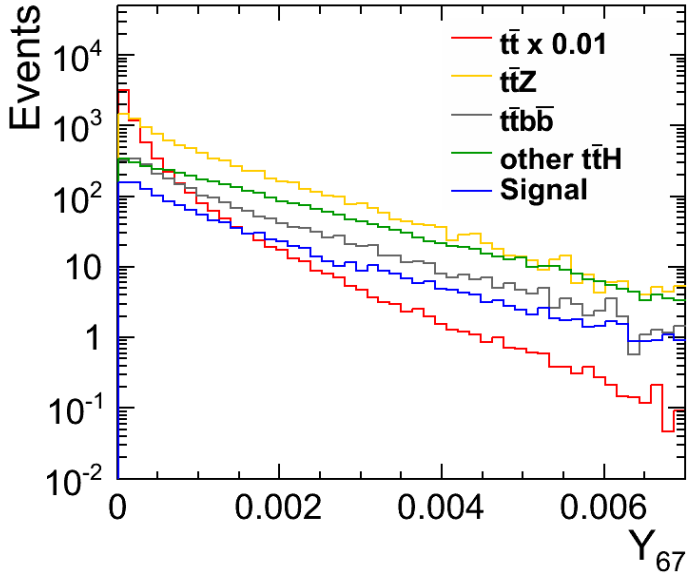
Input variables for the 8-jet final state:
M_{12}, M_{123}, M_{45}, M_{456}, M_{78}, four highest b-tags values, Thrust, $Y_{7\to8}$
$\longrightarrow$ 11 variables

6 jets: selection variables I





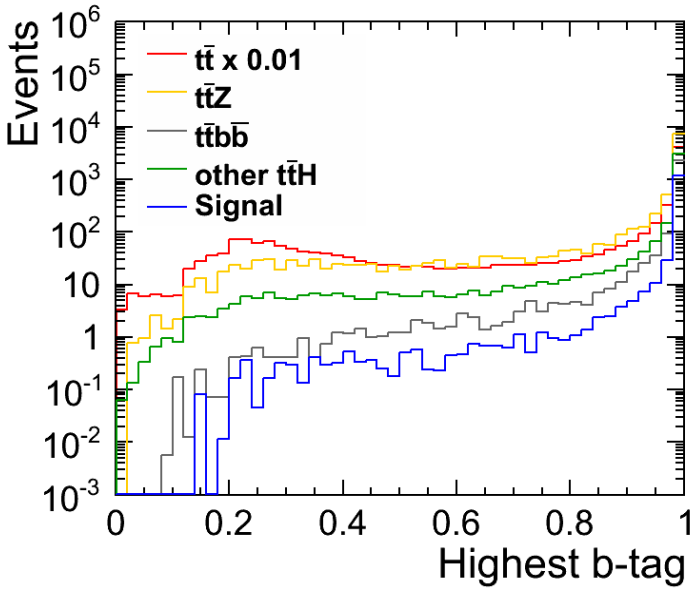


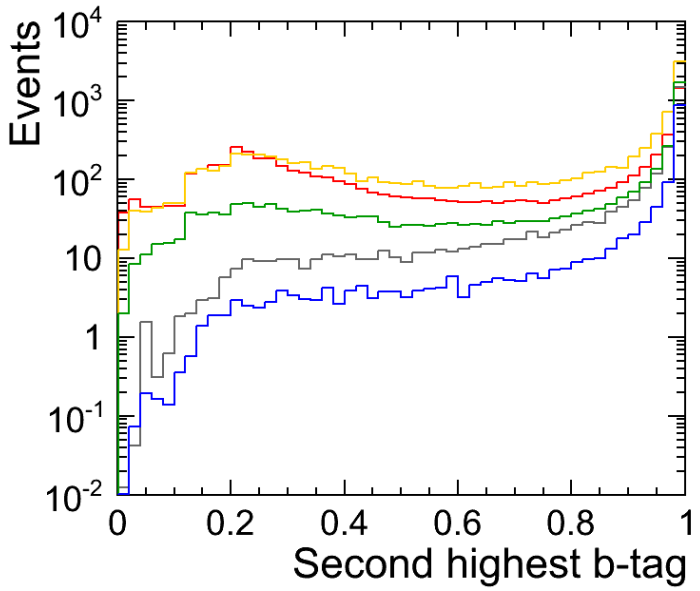


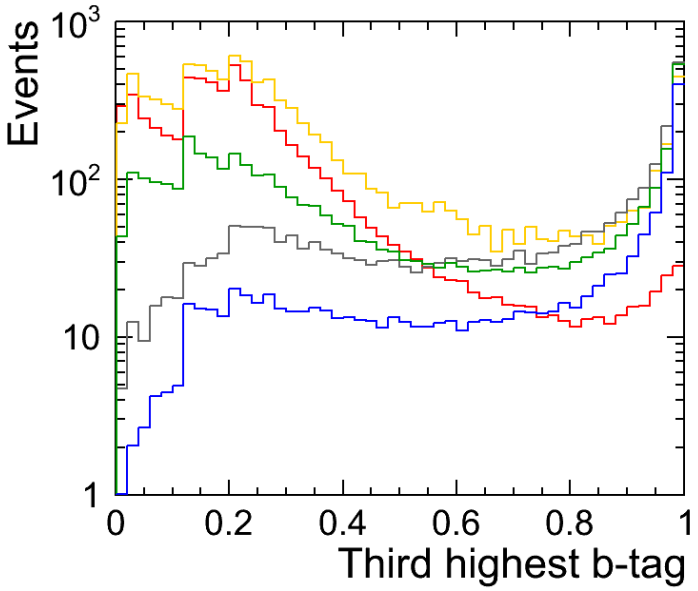
- $t\bar{t}$ background scaled by 0.01
- $Y_{5\to6}$ leads to better overall significance than $Y_{4\to5}$ or $Y_{6\to7}$

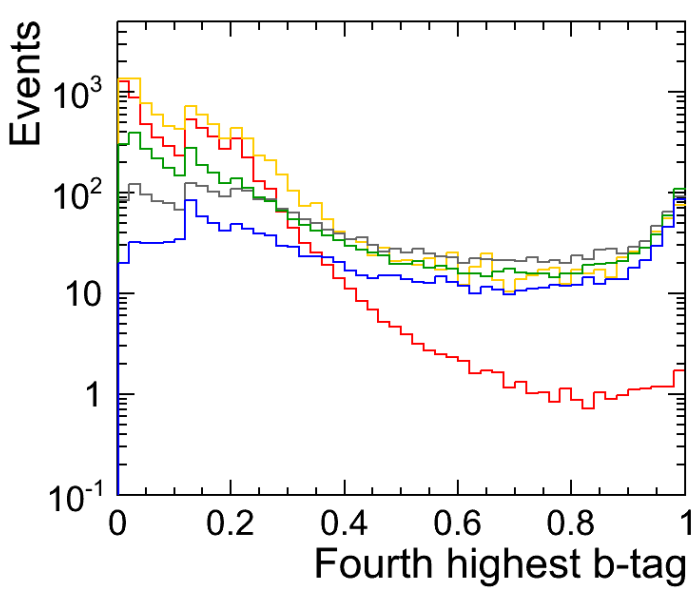
$L_{int} = 2\ ab^{-1}$

6 jets: b-tag values







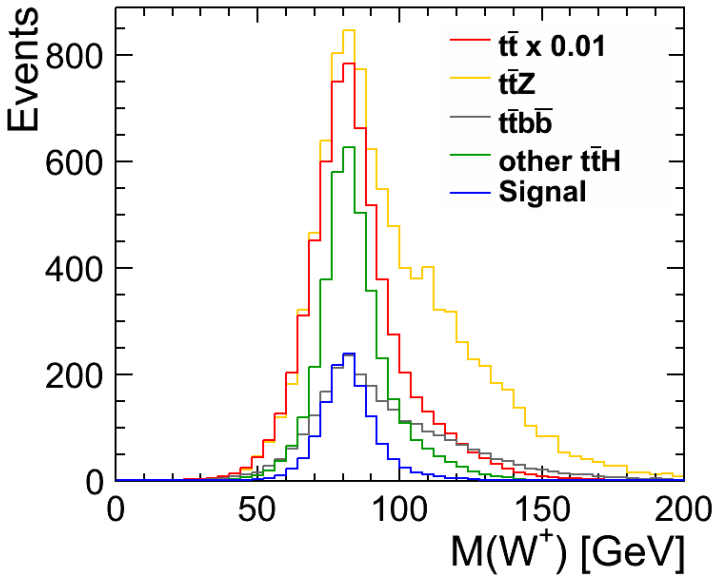


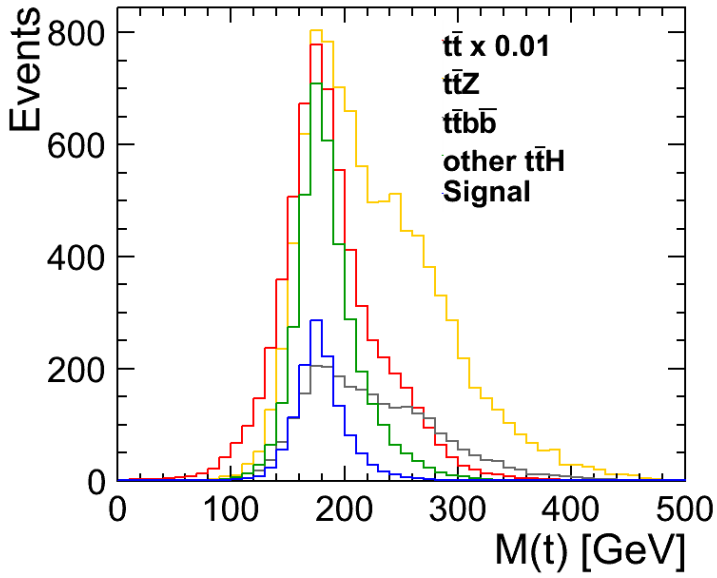
- $t\bar{t}$ background scaled by 0.01

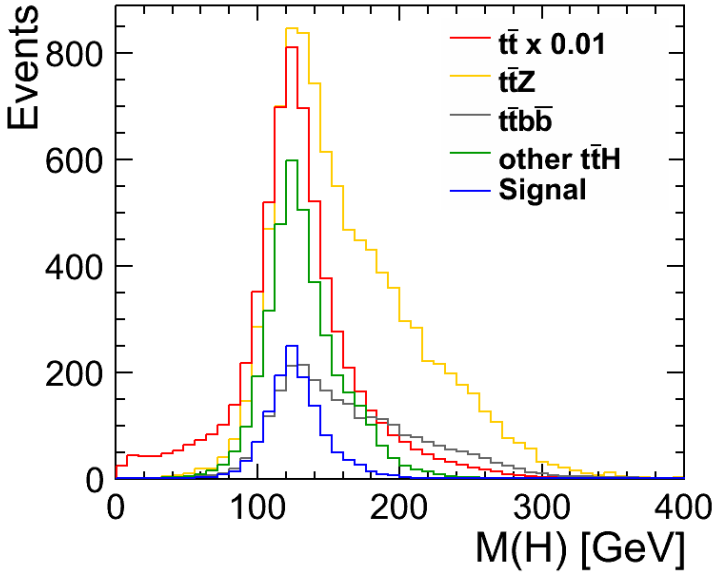
- Signal has 4 b-jets, part of the background samples contain only 2 b-jets

$L_{int} = 2\ ab^{-1}$

6 jets: W^+/top/Higgs masses



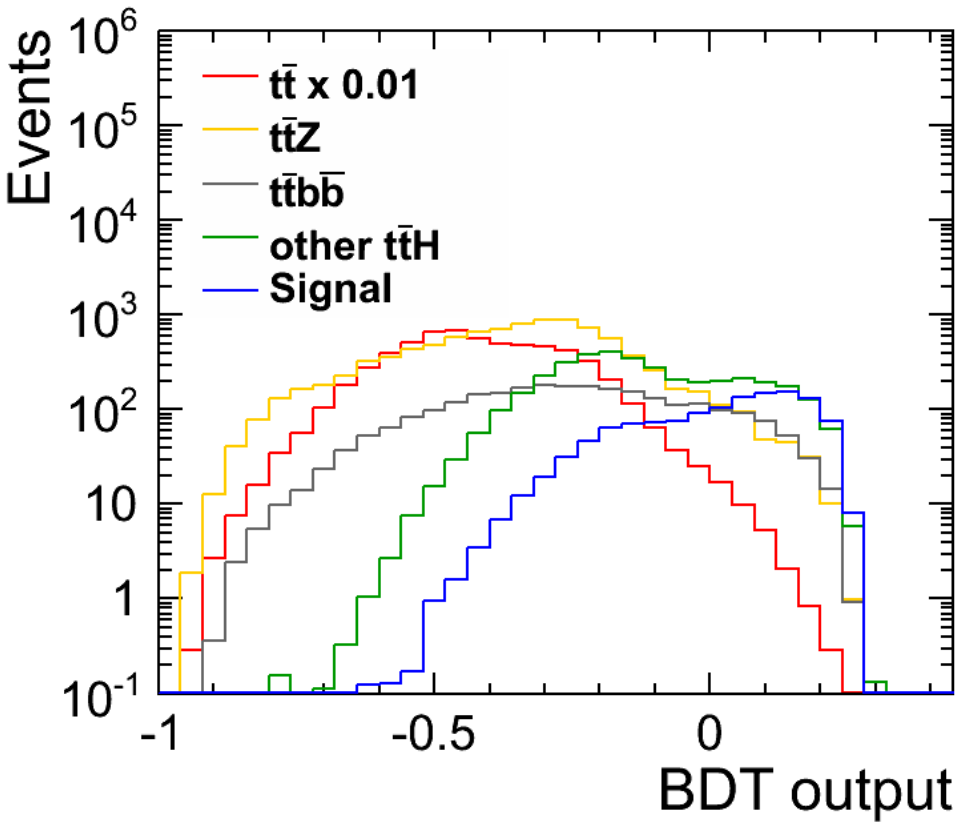


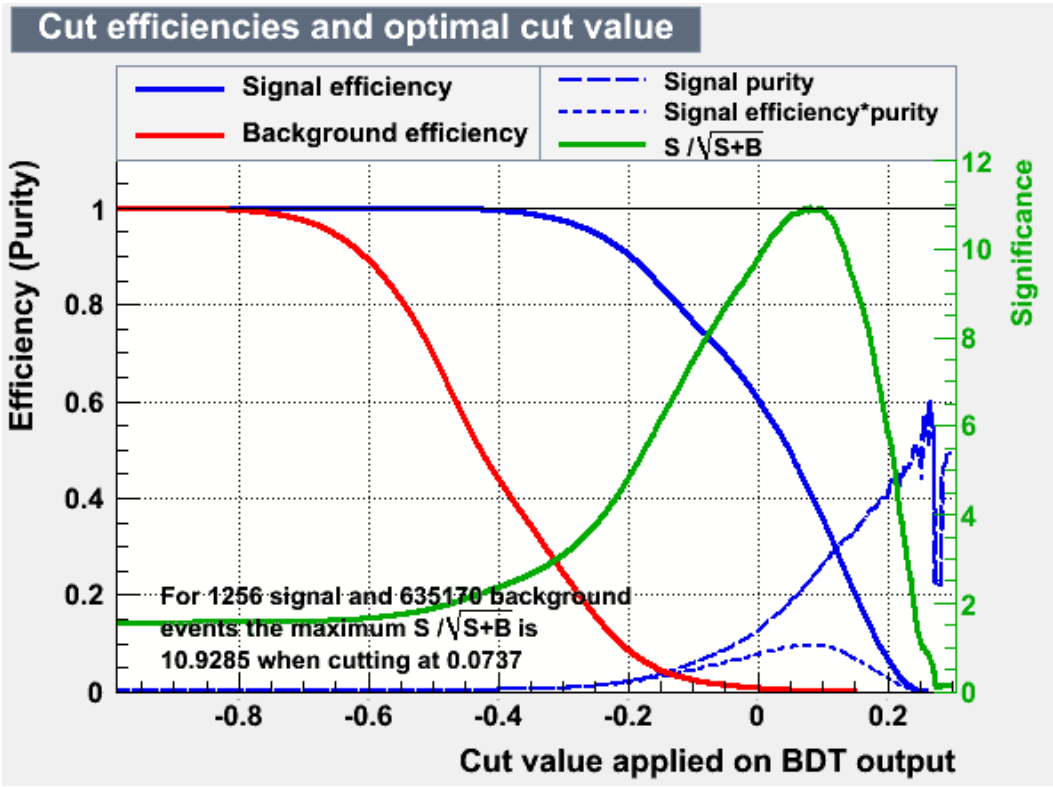


- $t\bar{t}$ background scaled by 0.01
- The background distributions are broader than the signal peaks

$L_{int} = 2\ ab^{-1}$

Results: 6 jets





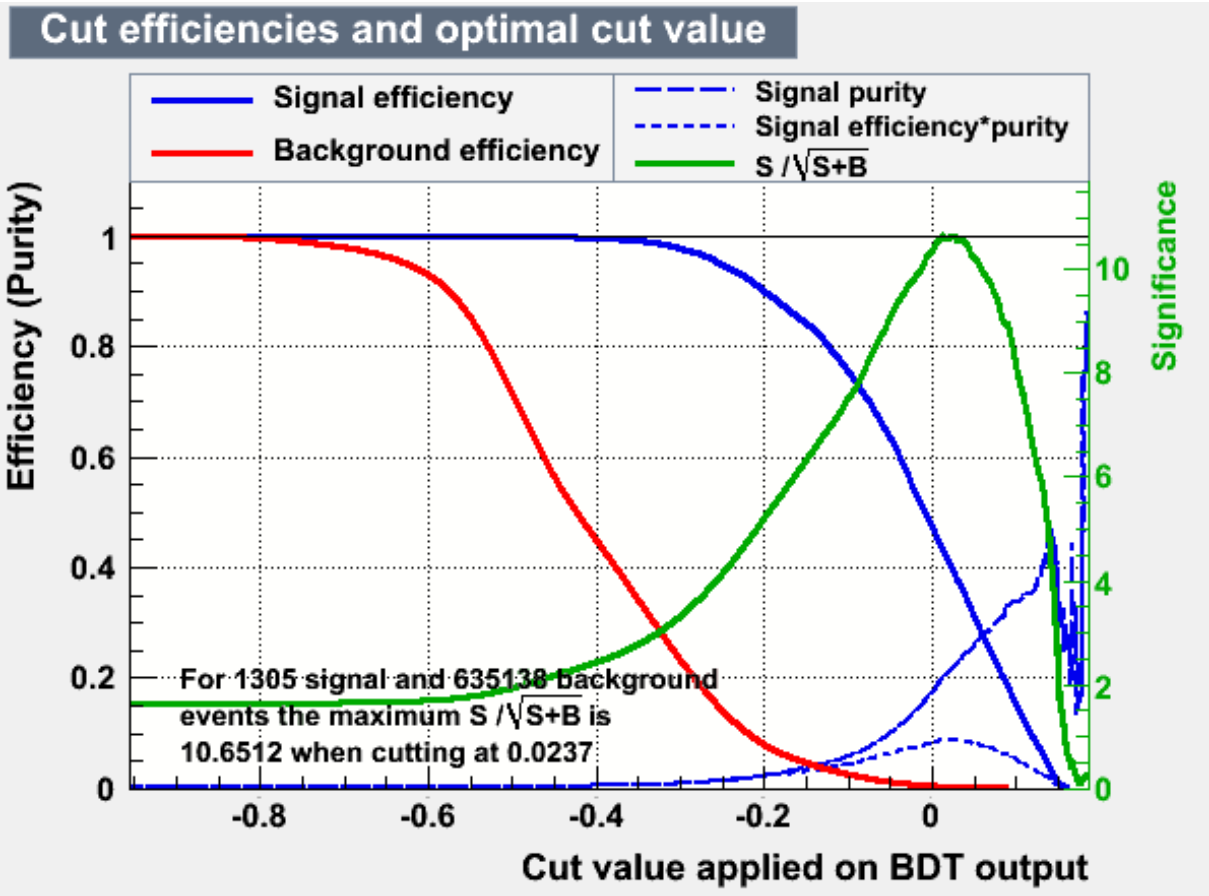
L_{int} = 2 ab^{-1} (1 ab^{-1} for each polarisation)

$$\frac{\Delta y_t}{y_t} = 0.5\,\frac{\Delta\sigma}{\sigma}$$

(small correction from Higgs radiation off Z neglected)

$\Delta\sigma / \sigma = 9.2\% \rightarrow \Delta y_t / y \approx 4.6\%$

Results: 8 jets



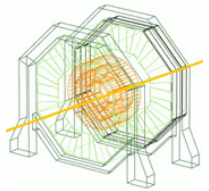
L_{int} = 2 ab^{-1}
(1 ab^{-1} for each polarisation)

$$\frac{\Delta y_t}{y_t} = 0.5 \frac{\Delta \sigma}{\sigma}$$

(small correction from Higgs radiation off Z neglected)

$\Delta\sigma / \sigma = 9.4\% \rightarrow \Delta y_t / y \approx 4.7\%$

Summary and conclusions



- The cross section for the $t\bar{t}H$ final state was extracted using two signal channels

- For a combination of both channels a precision of about 3% on the top Yukawa coupling can be achieved with the current analysis

- **Plans for further improvement:**

  - Use number of isolated leptons in the event selection
  - Try kinematic fitting
  - Try samples with more quarks in the final state for the training of the flavour tagging