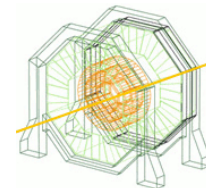
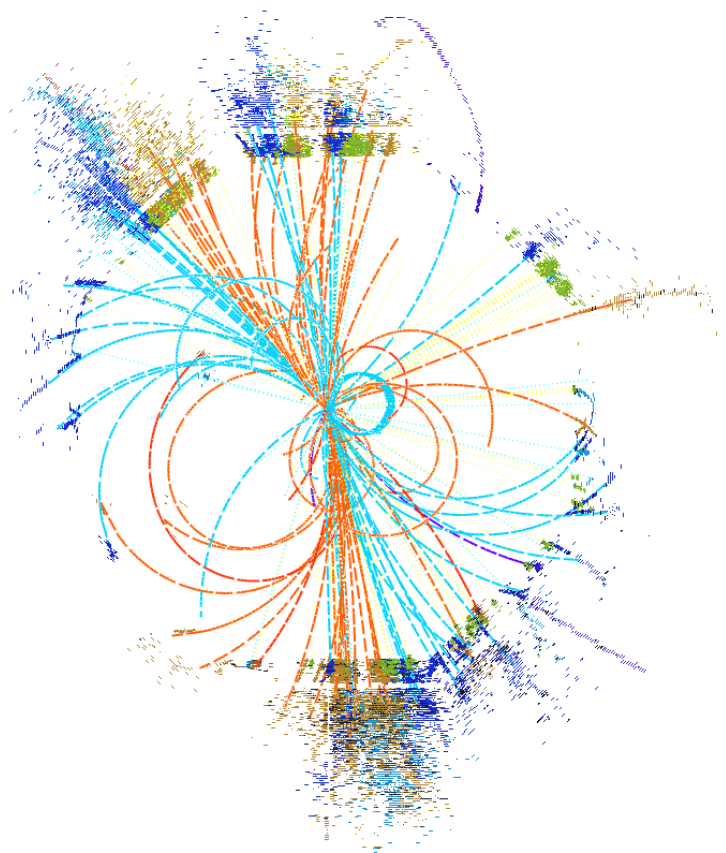




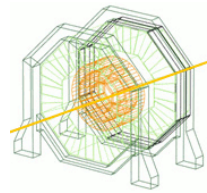
Measurement of the top Yukawa coupling at $\sqrt{s} = 1$ TeV using the SiD detector



Philipp Roloff
(CERN)



Joint ILD/SiD analysis meeting, 18/01/2013



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, $Y_{5 \rightarrow 6}$,

number isolated leptons, number of PFOs, missing transverse momentum, visible energy

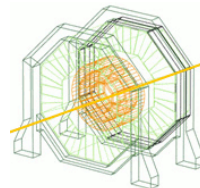
→ 13 variables

Input variables for the 8-jet final state:

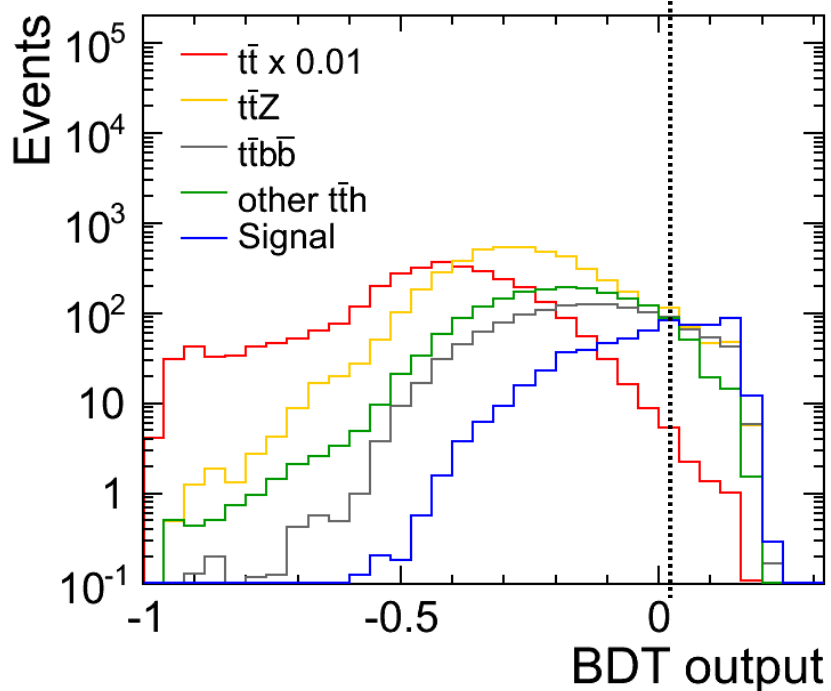
M_{12} , M_{123} , M_{45} , M_{456} , M_{78} , four highest b-tags values, Thrust, $Y_{7 \rightarrow 8}$,

number isolated leptons, number of PFOs, missing transverse momentum, visible energy

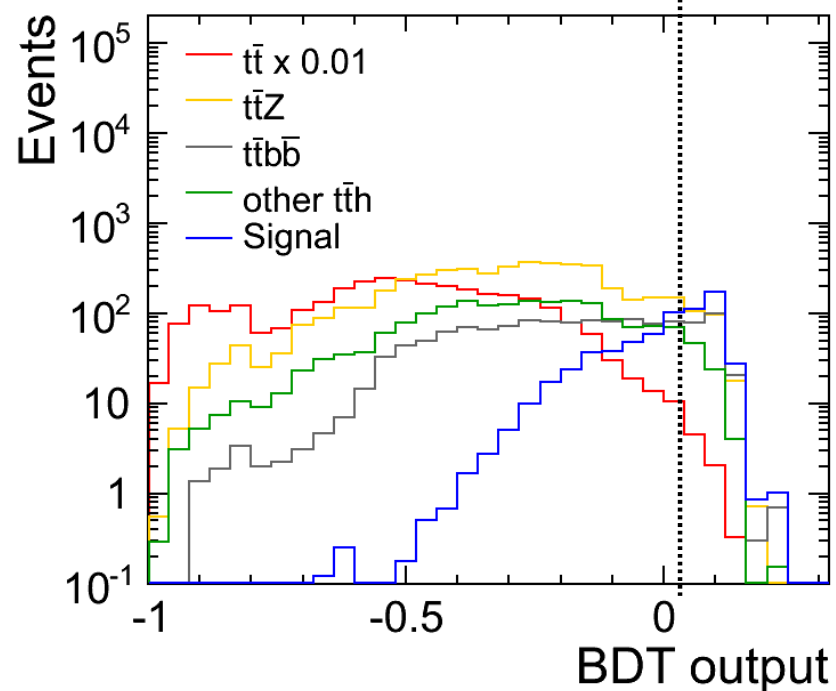
→ 15 variables



6 jets: BDT > 0.0266



8 jets: BDT > 0.0363



Using cut on BDT output with best $S / (S + B)^{1/2}$

$$\Delta\sigma / \sigma = 13.6\% \rightarrow \Delta y_t / y \approx 7.1\%$$

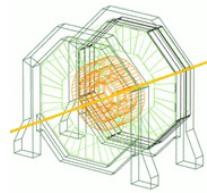
$$\Delta\sigma / \sigma = 12.3\% \rightarrow \Delta y_t / y \approx 6.4\%$$

Combined: $\Delta y_t / y \approx 4.8\%$

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



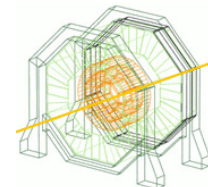
Results with 1 ab^{-1} with $P(e) = -0.8$ and $P(p) = +0.2$



6 jets: $\Delta y_t / y \approx 6.3\%$ (7.1% for default polarisations)

8 jets: $\Delta y_t / y \approx 5.8\%$ (6.4% for default polarisations)

Combined: $\Delta y_t / y \approx 4.3\%$ (4.8% for default polarisations)



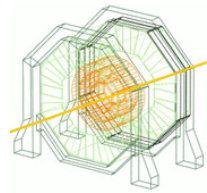
- **Preselection:** For 6 jets only accept events with one isolated lepton, for 8 jets only accept events without isolated lepton (like ILD analyses).
- Boosted decision trees retrained using the preselected signal and background samples.

6 jets: $\Delta y_t / y \approx 7.4\%$ (7.1% for default analysis)

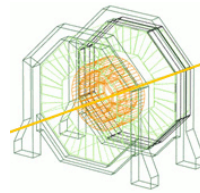
8 jets: $\Delta y_t / y \approx 6.4\%$ (6.4% for default analysis)

Combined: $\Delta y_t / y \approx 4.8\%$ (as for default analysis)

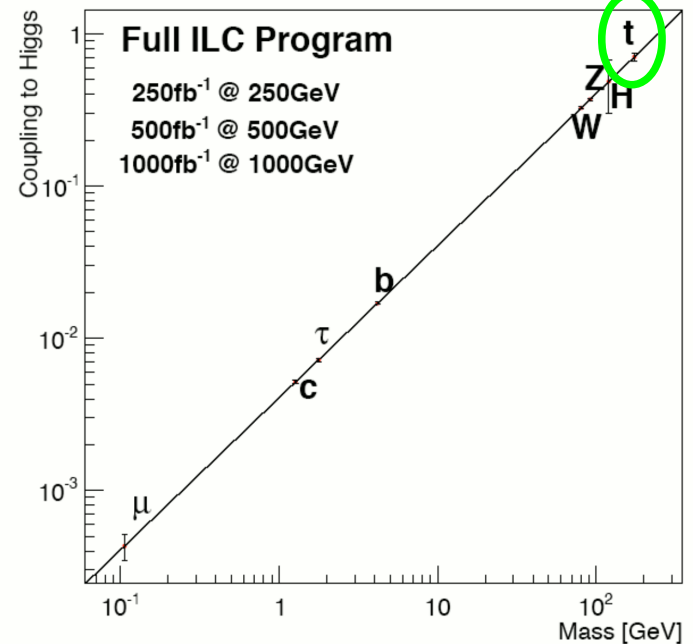
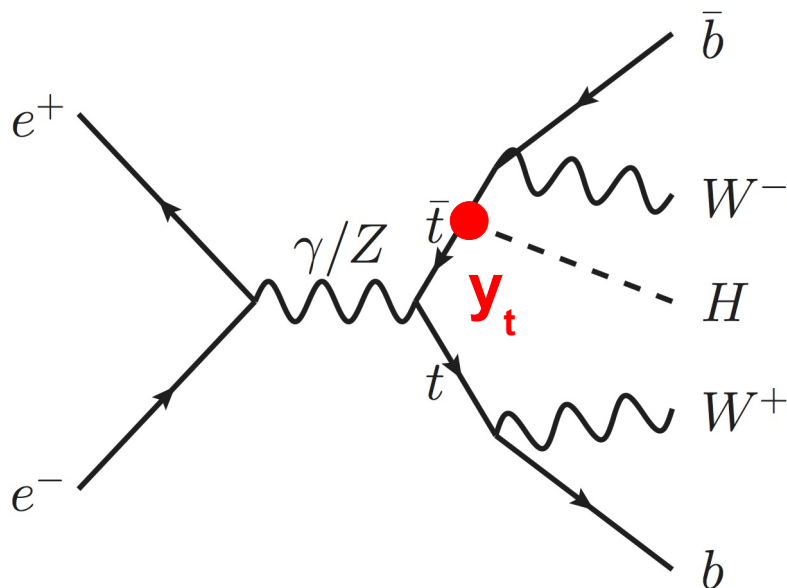
→ **Results (almost) unchanged**



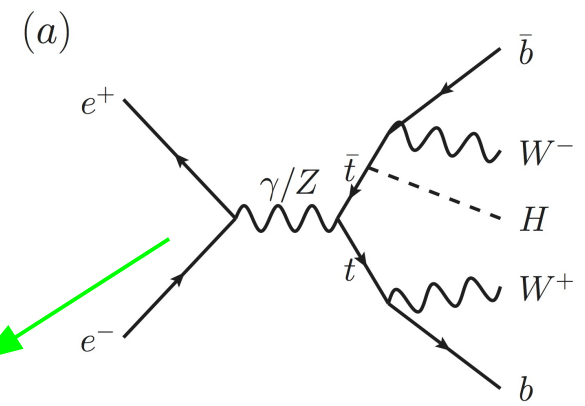
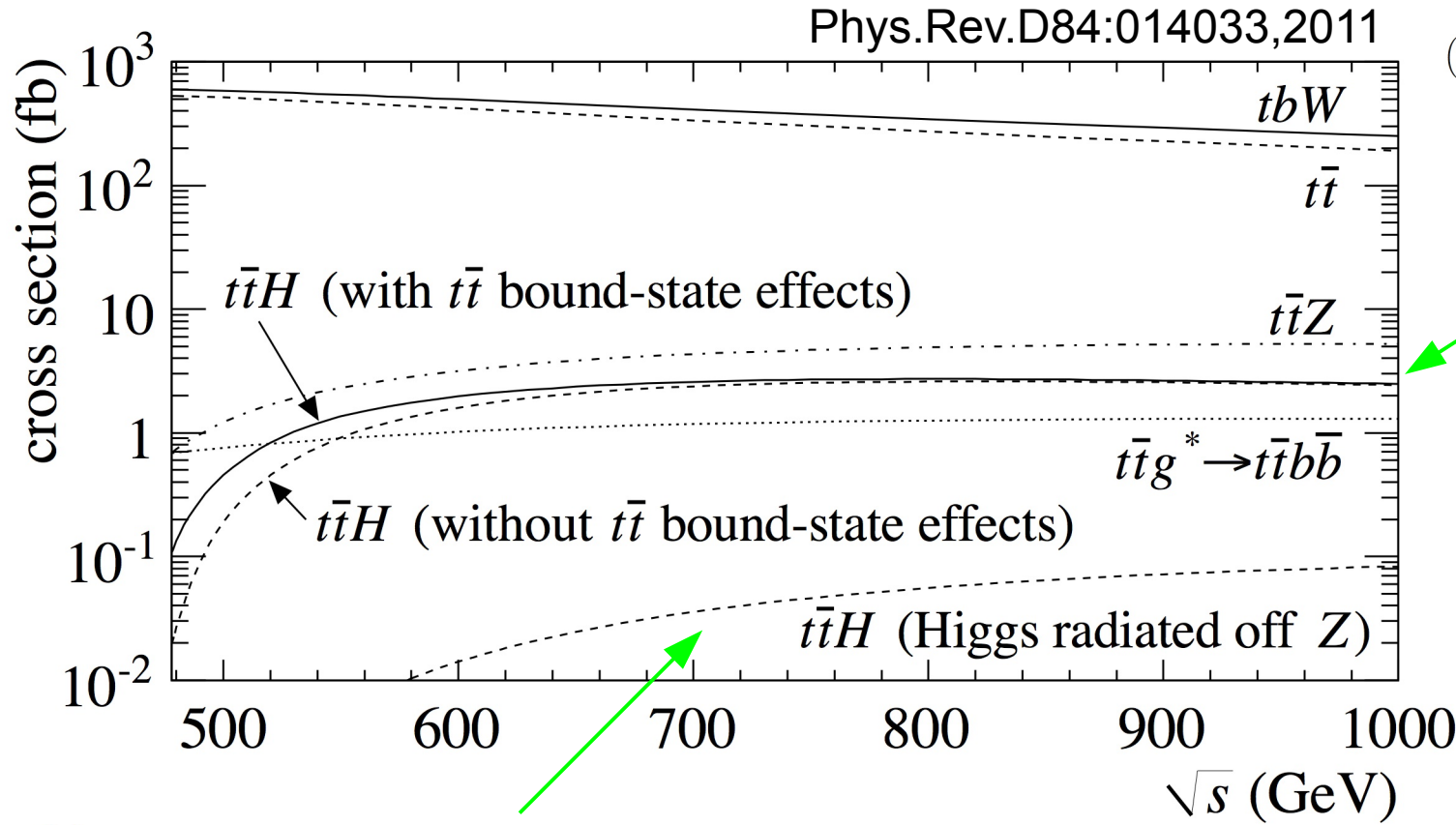
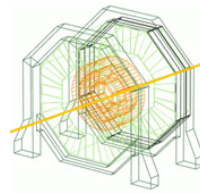
Backup



- Detector benchmarking processes for the DBD
- **Final states:**
 - “6 jets”: $t(\rightarrow qqb)\bar{t}(\rightarrow lv\bar{b})H(\rightarrow b\bar{b})$, $m_H = 125 \text{ GeV}$
 - “8 jets”: $t(\rightarrow qqb)\bar{t}(\rightarrow qq\bar{b})H(\rightarrow b\bar{b})$, $m_H = 125 \text{ GeV}$
- **Motivation:** Cross section for $t\bar{t}H$ production is directly sensitive to the top Yukawa coupling, y_t :

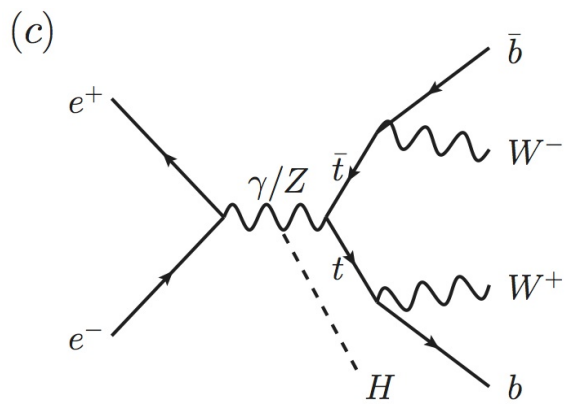


Cross sections



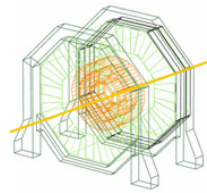
At 1 TeV:

- $\sigma \approx 2.2$ fb
- $t\bar{t}$ bound-state effects can be neglected



Higgs radiated off Z:

- $\sigma \approx 0.08$ fb
- **Not sensitive to y_t**



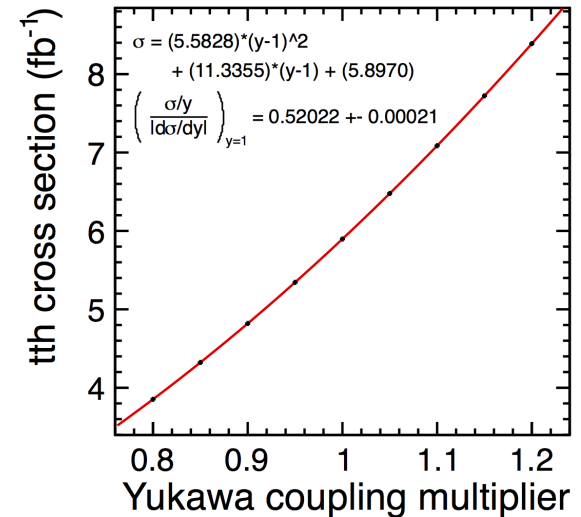
- Without Higgsstrahlung:

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

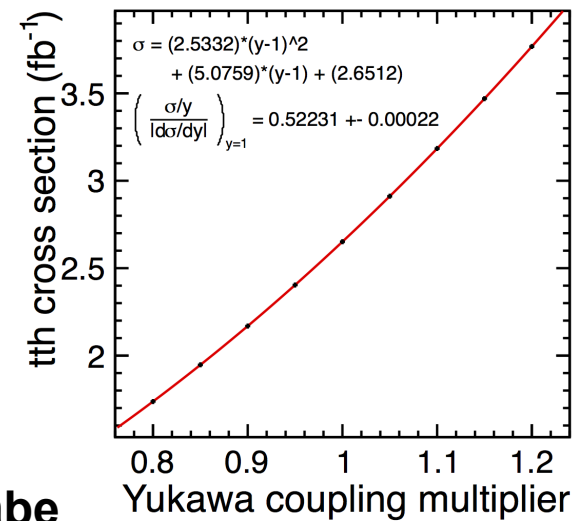
- 4% correction for $m_H = 125$ GeV:

$$\frac{\Delta y_t}{y_t} = 0.52 \frac{\Delta \sigma}{\sigma}$$

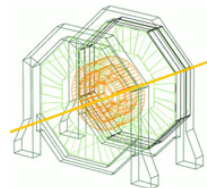
$m_H=125$ GeV, $\sqrt{s}=1$ TeV, $\text{epol}=-1.0$, $\text{ppol}=+1.0$



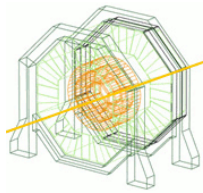
$m_H=125$ GeV, $\sqrt{s}=1$ TeV, $\text{epol}=+1.0$, $\text{ppol}=-1.0$



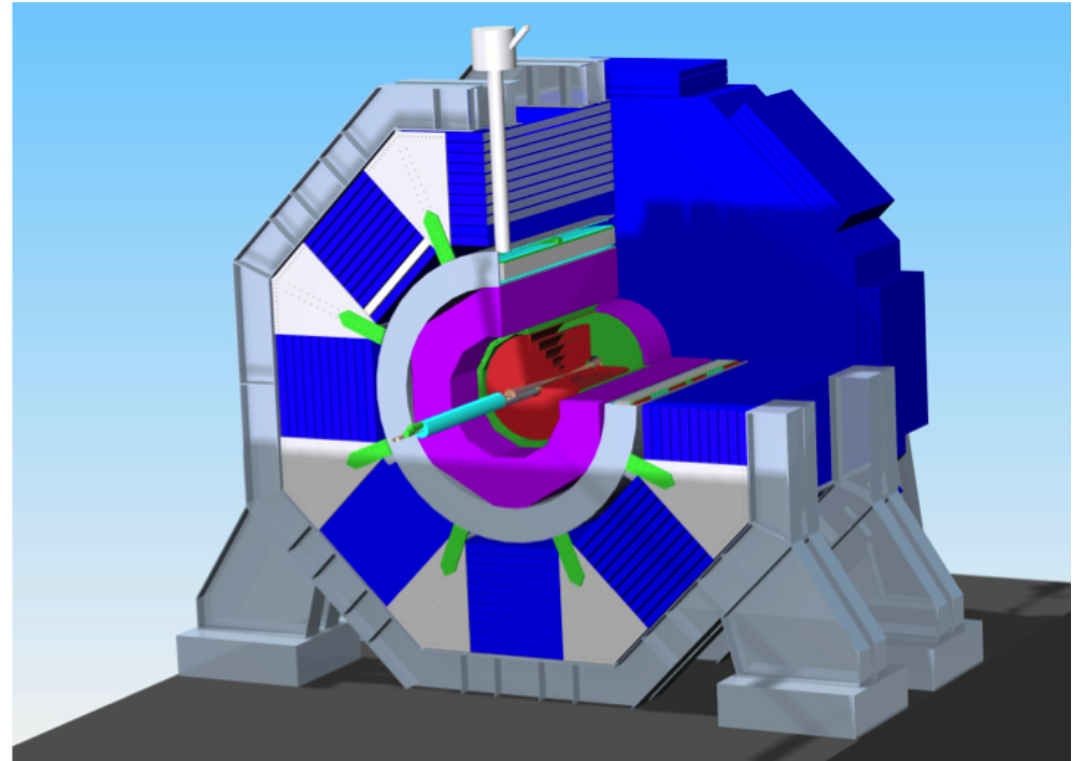
Tomohiko Tanabe



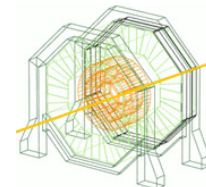
Final state	P(e) [%]	P(p) [%]	N(events)	N(L = 1 ab ⁻¹)
$t\bar{t}(\rightarrow lv4q)b\bar{b}$	+80	-20	20000	421
	-80	+20	20000	846
$t\bar{t}(\rightarrow 6q)Z$	+80	-20	20000	1328
	-80	+20	20000	3483
$t\bar{t}(\rightarrow 6q)b\bar{b}$	+80	-20	20000	436
	-80	+20	20000	874
$t\bar{t}(\rightarrow lv4q)Z$	+80	-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



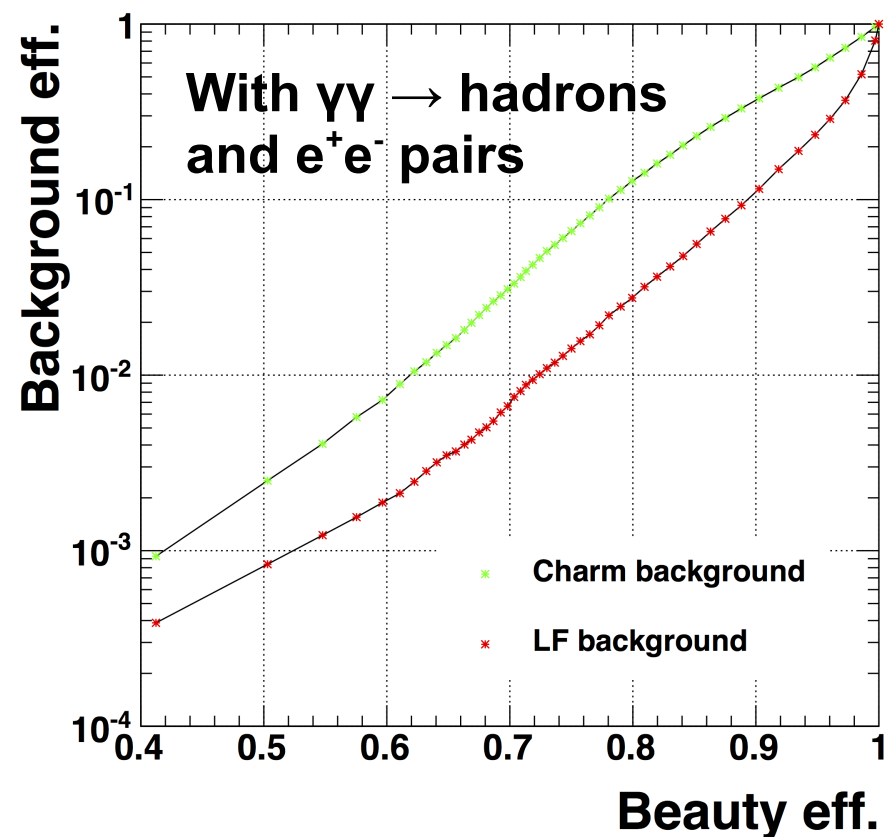
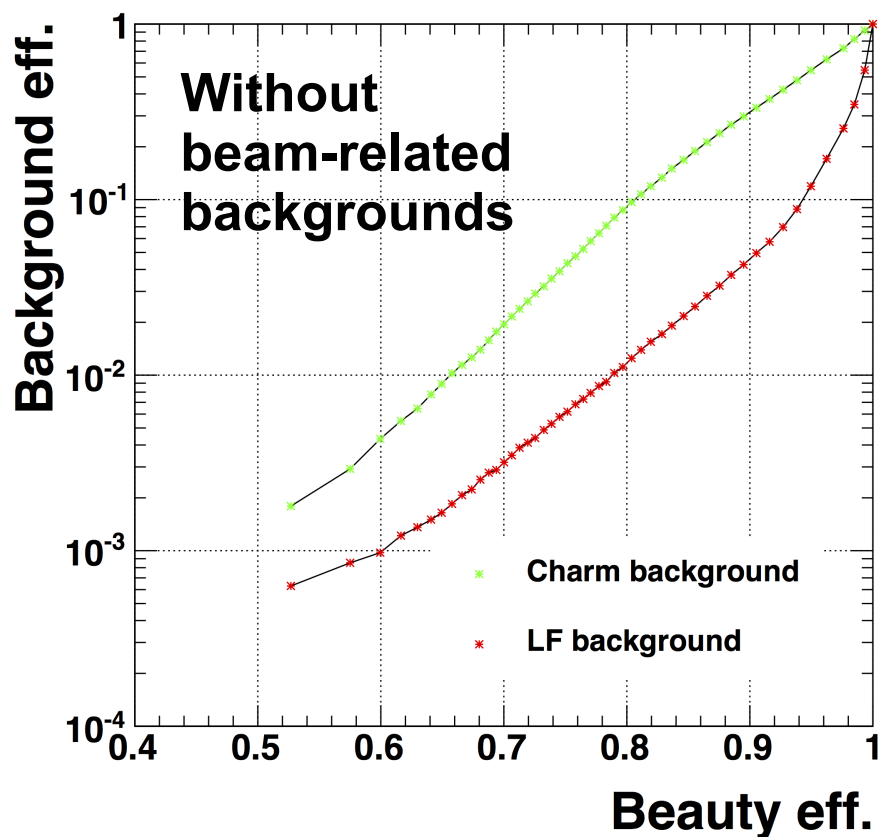
- Full simulation of the sidloi3 detector (used for DBD benchmark studies)
- The physics events were overlaid with beam-related backgrounds corresponding to 1 BX:
 - incoherent pairs (450.000 particles)
 - $4.1 \mu\text{y} \rightarrow$ hadrons interactions
- PandoraPFA for particle flow reconstruction



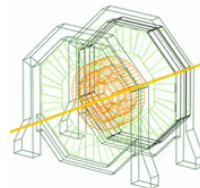
Beauty-jet tagging



- Based on the LCFIPlus package
- Cuts adjusted for the SiD detector geometry
- Trained using bbbbbb, cccccc, qqqqqq at 1 TeV



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



Kinematic Cuts:

- $\cos(\Theta_{\text{cone}}) > 0.99$
- $E_{\text{track}} > 15 \text{ GeV}$
- $E_{\text{cone}} < (3.0 \cdot E_{\text{lepton}})^{1/2}$

PID:

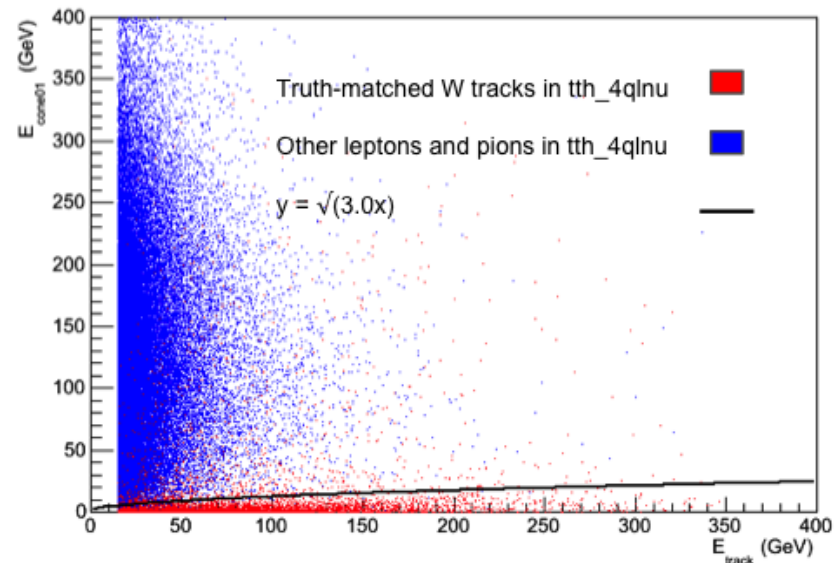
- **Electrons:**

$$0.95 < E^{\text{ECal}} / E^{\text{HCal}} < 1 \quad 0.85 < E / p < 1.15$$

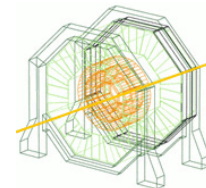
- **Muons:**

$$0.03 < E^{\text{ECal}} / E^{\text{HCal}} < 0.2 \quad 0.0 < E / p < 0.4$$

$$0 < d_0 < 0.02 \text{ mm} \quad 0 < z_0 < 0.1 \text{ mm} \quad 0 < d_0(3D) < 0.1 \text{ mm}$$



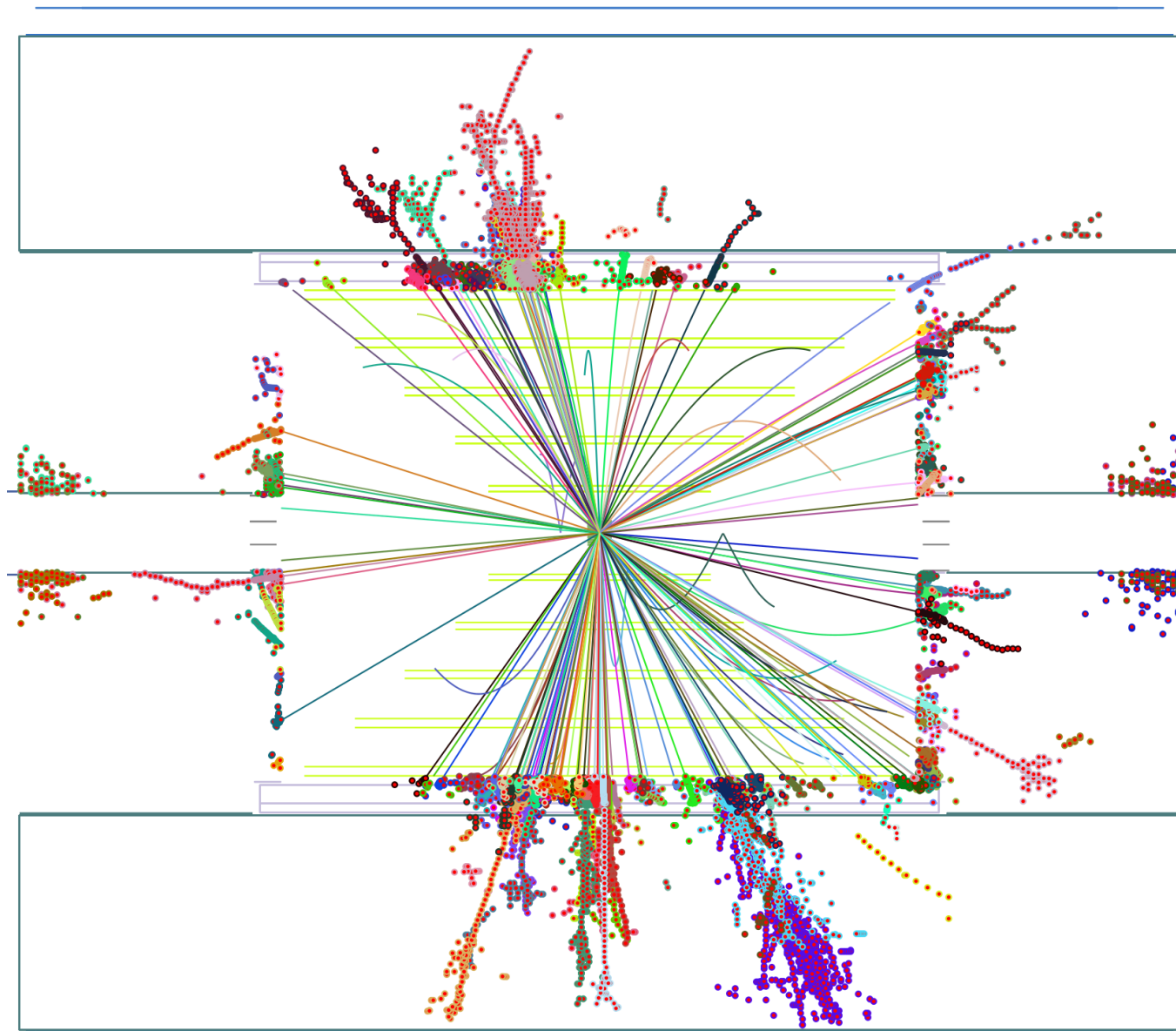
Jan Strube



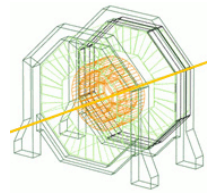
1.) Remove all PFOs with:

- $p_T < 500 \text{ MeV}$
- $\Theta < 20^\circ$
- $\Theta > 160^\circ$

2.) Remove identified isolated leptons from PFO list



8jet signal event



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

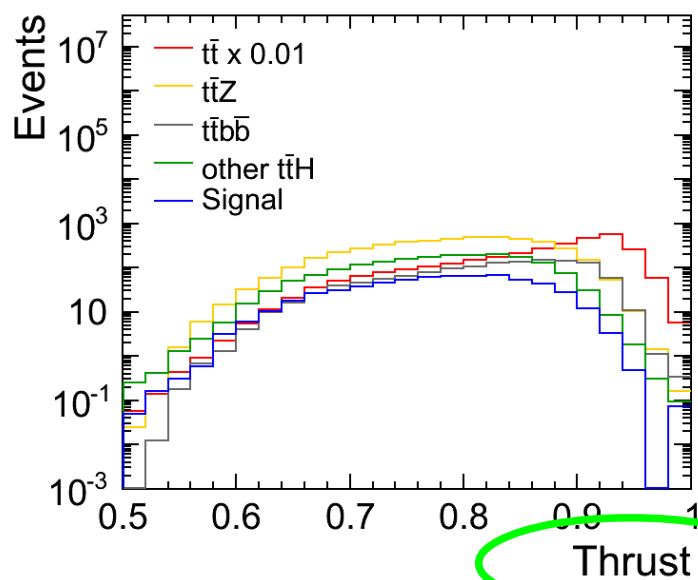
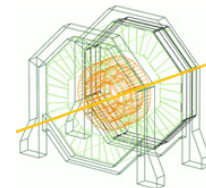
5.) Group jets into W^\pm , H and top pairs by minimising:

$$\text{6jets: } \frac{(M_{12} - M_{W^\pm})^2}{\sigma_{W^\pm}^2} + \frac{(M_{123} - M_t)^2}{\sigma_t^2} + \frac{(M_{45} - M_H)^2}{\sigma_H^2}$$

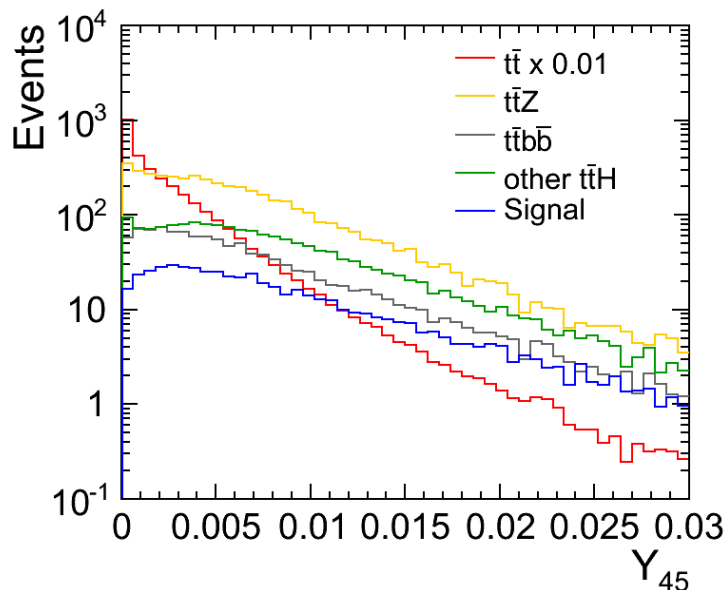
8jets:

$$\frac{(M_{12} - M_{W^\pm})^2}{\sigma_{W^\pm}^2} + \frac{(M_{123} - M_t)^2}{\sigma_t^2} + \frac{(M_{45} - M_{W^\pm})^2}{\sigma_{W^\pm}^2} + \frac{(M_{456} - M_t)^2}{\sigma_t^2} + \frac{(M_{78} - M_H)^2}{\sigma_H^2}$$

6 jets: selection variables I

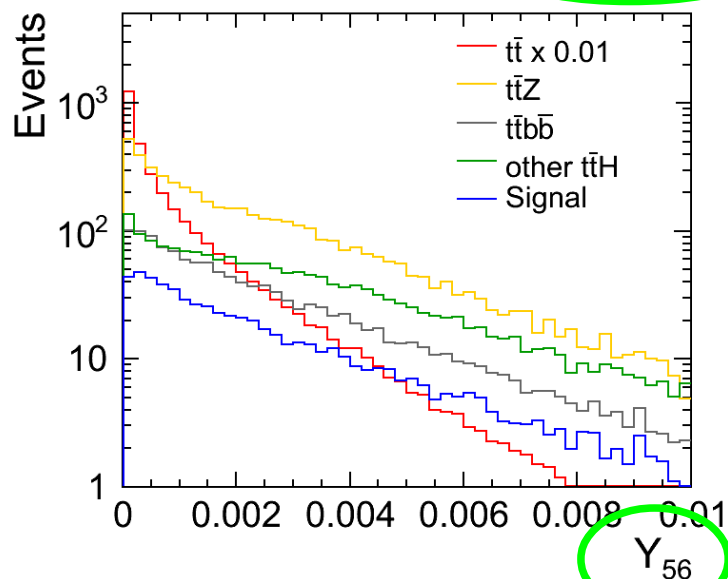


Thrust

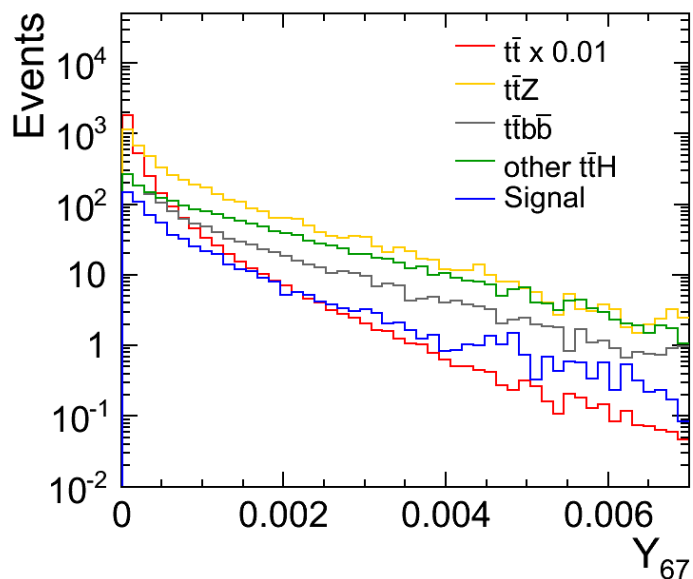


- $t\bar{t}$ background scaled by 0.01

- $Y_{5 \rightarrow 6}$ used instead of $Y_{4 \rightarrow 5}$ or $Y_{6 \rightarrow 7}$

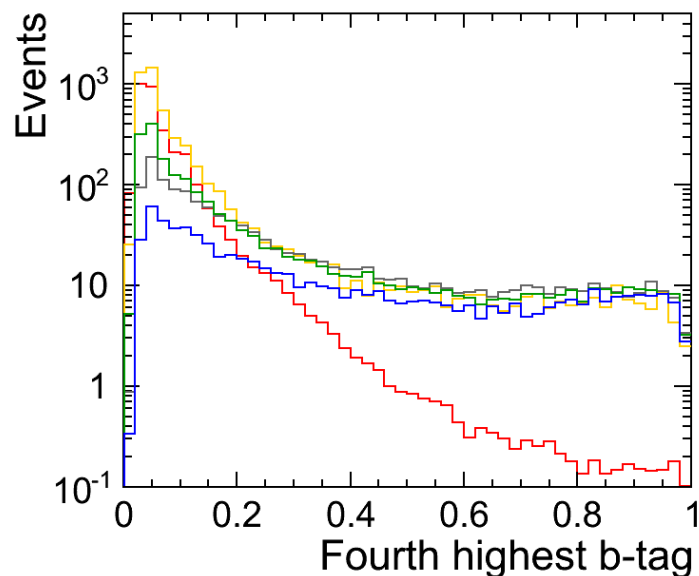
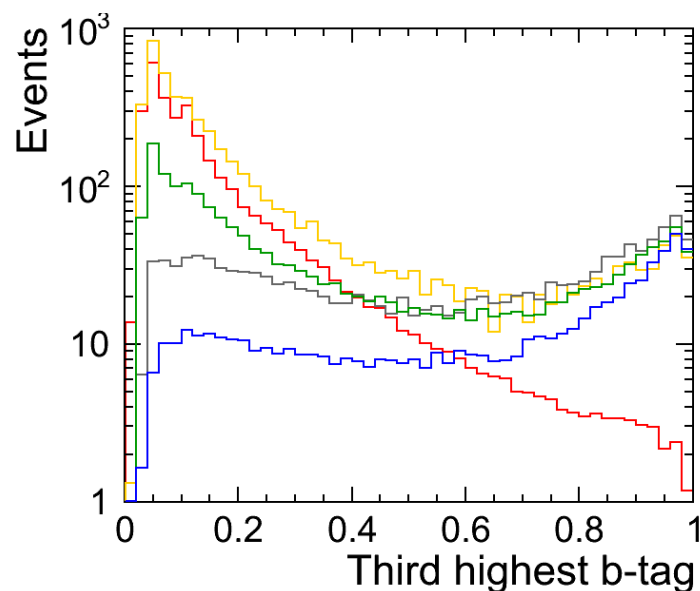
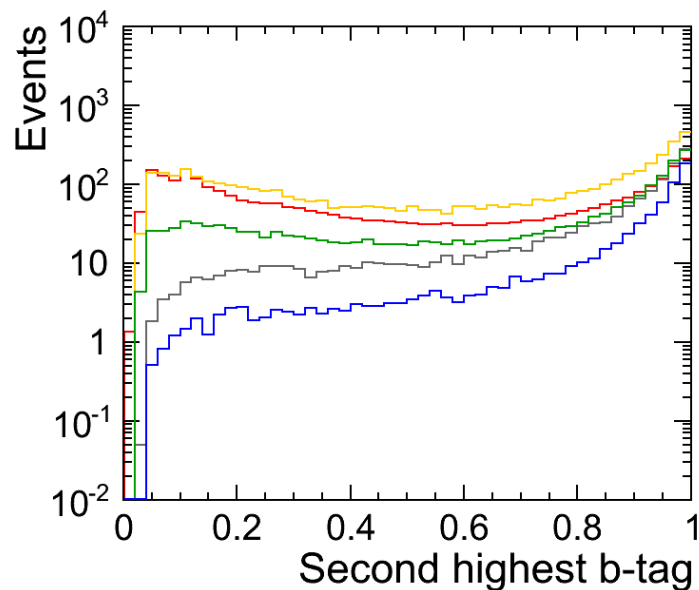
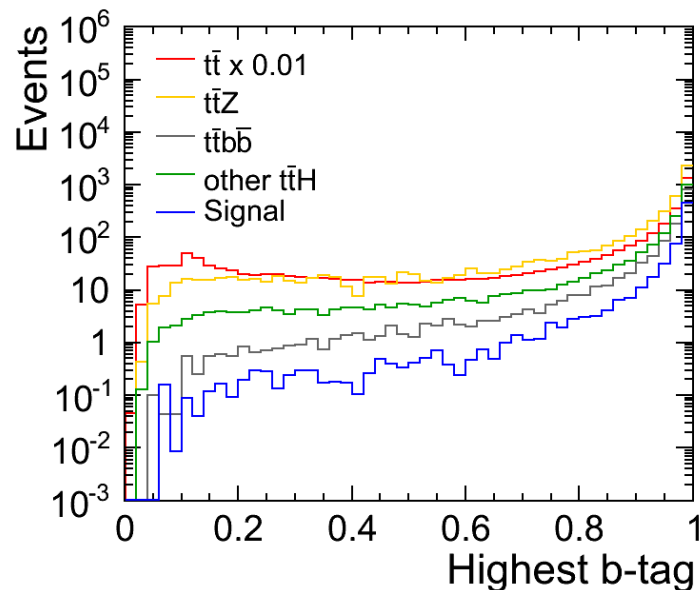
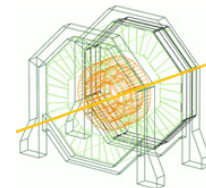


Y_{56}



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

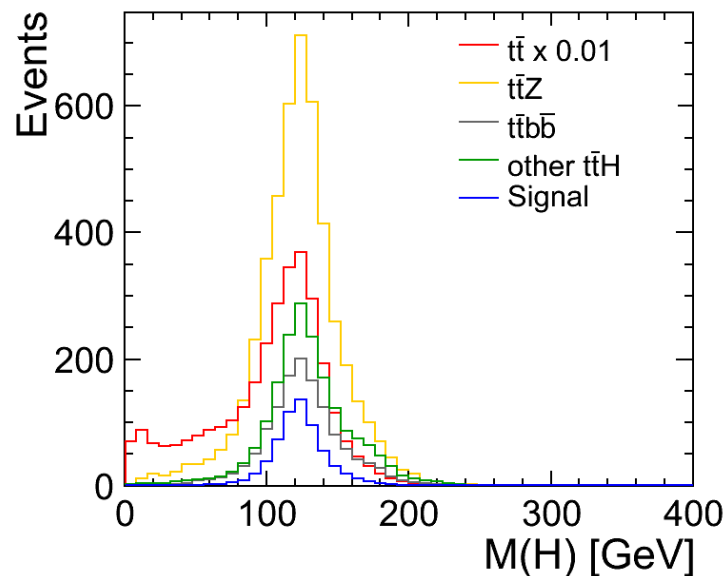
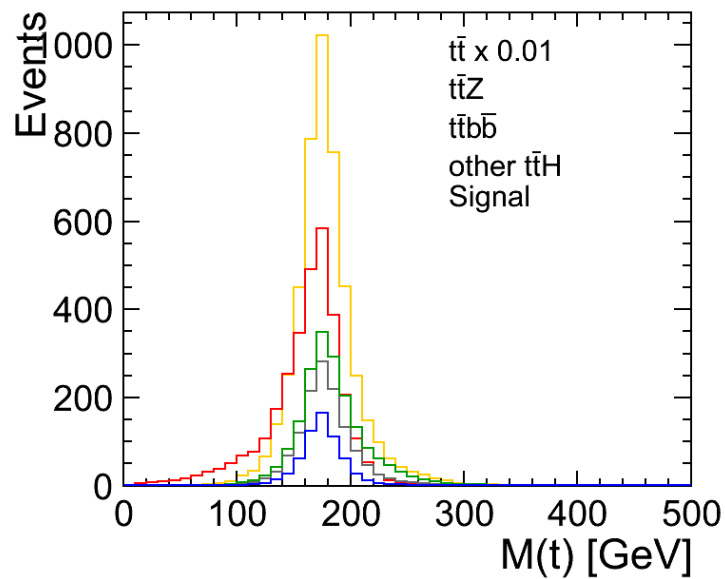
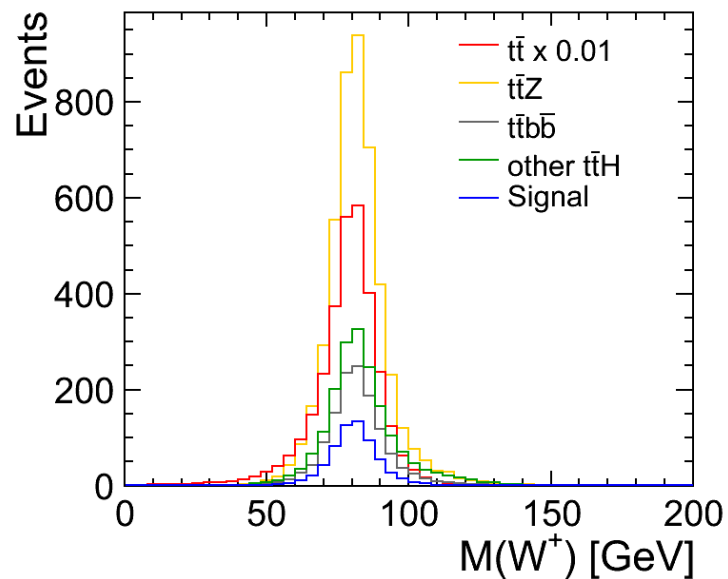
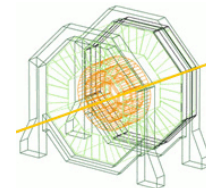
6 jets: b-tag values



- $t\bar{t}$ background scaled by 0.01
- Signal has 4 b-jets, part of the background samples contain only 2 b-jets

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

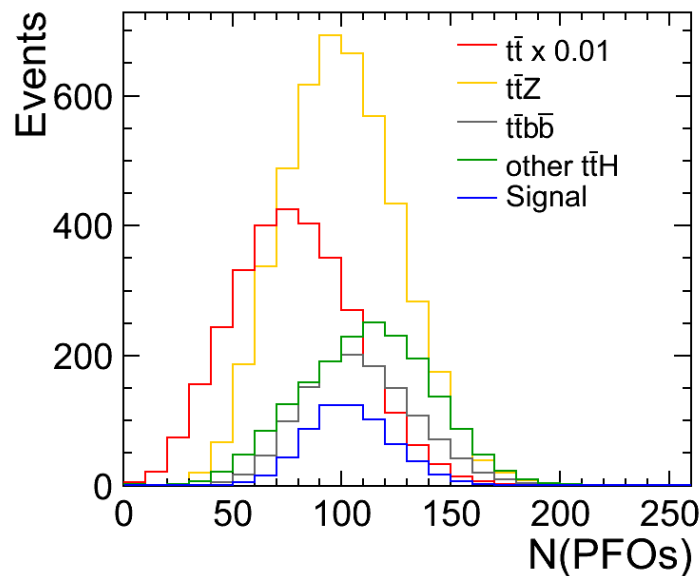
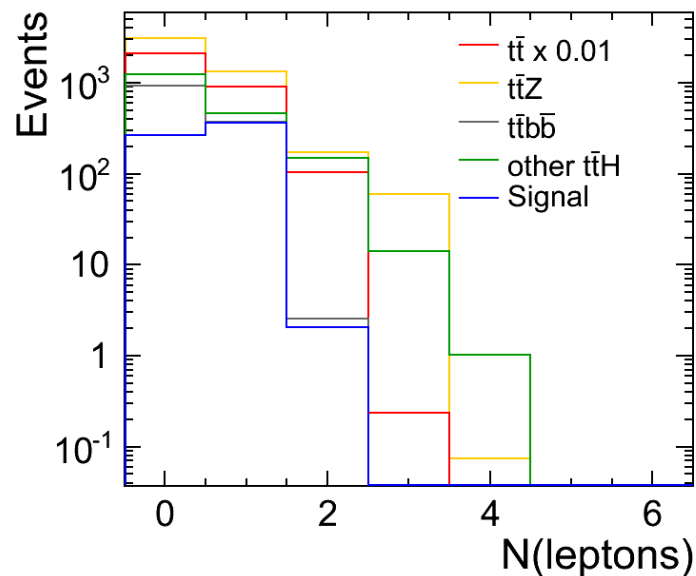
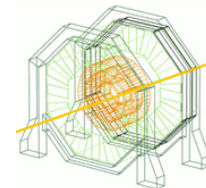
6 jets: W^+ /top/Higgs masses



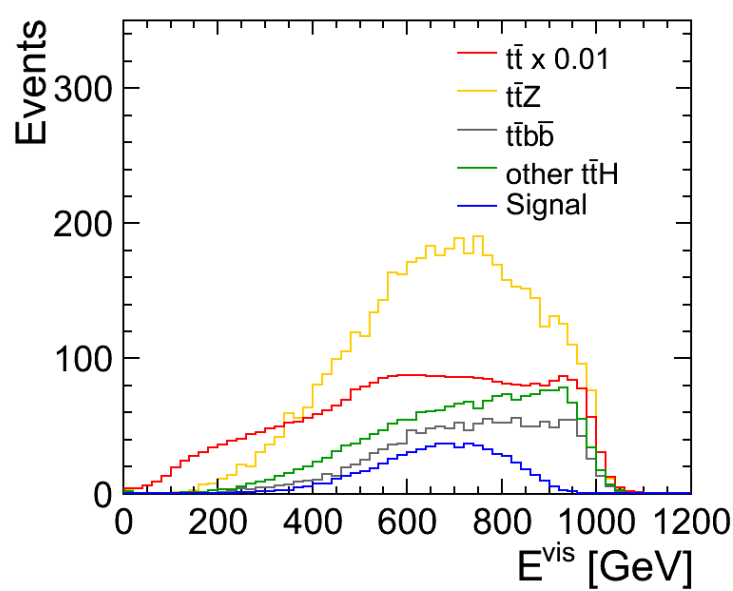
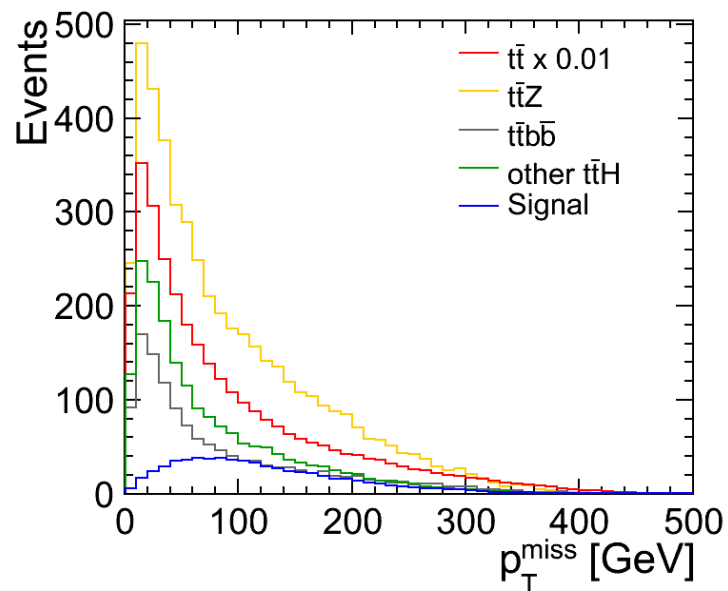
- $t\bar{t}$ background scaled by 0.01
- The background distributions are broader than the signal peaks

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

6 jets: new variables

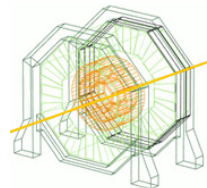


- $t\bar{t}$ background scaled by 0.01

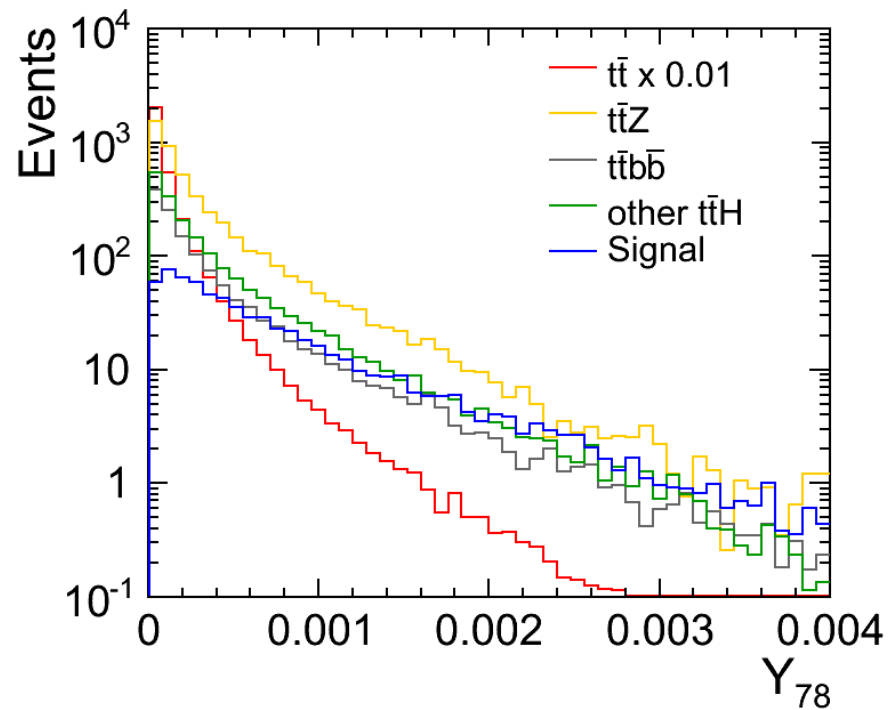
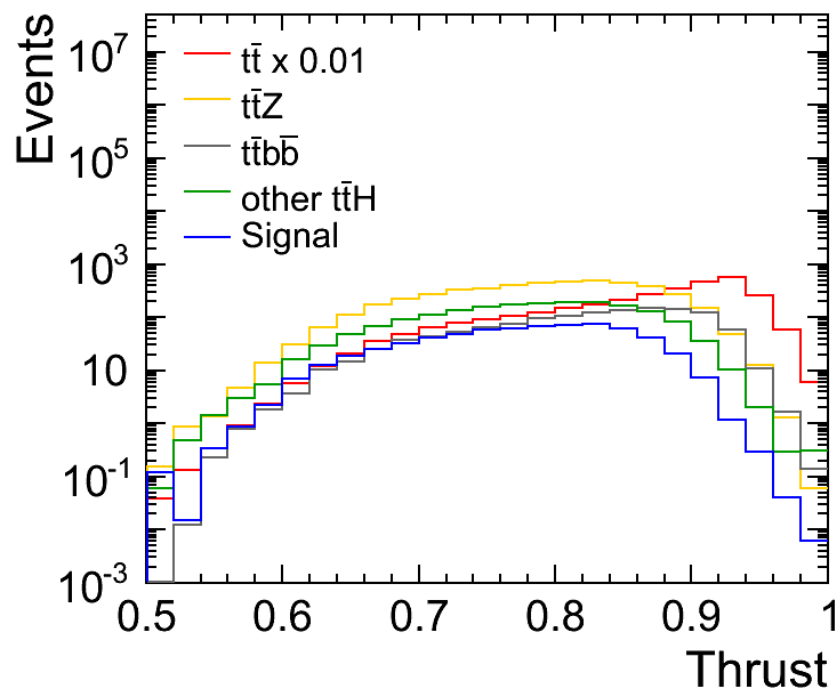


$$L_{\text{int}} = 1 \text{ ab}^{-1}$$

8 jets: selection variables I

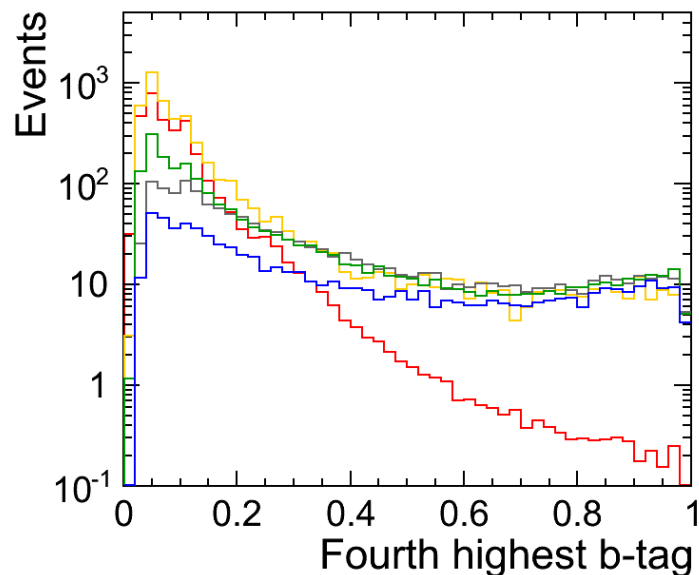
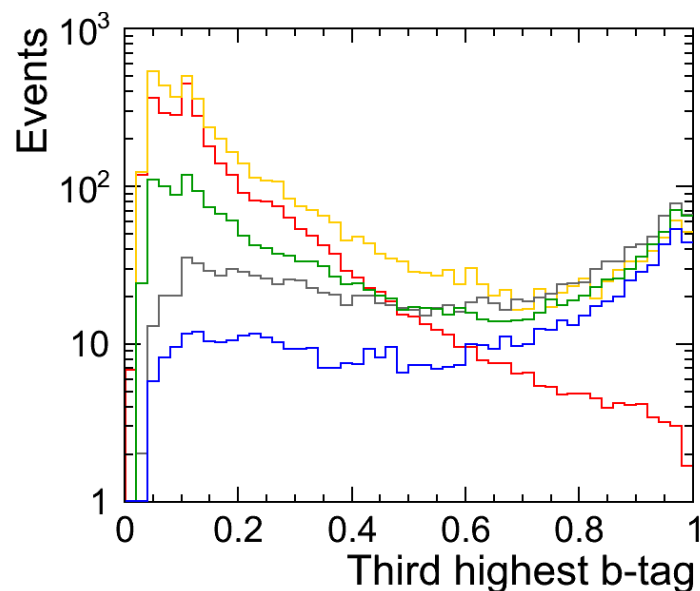
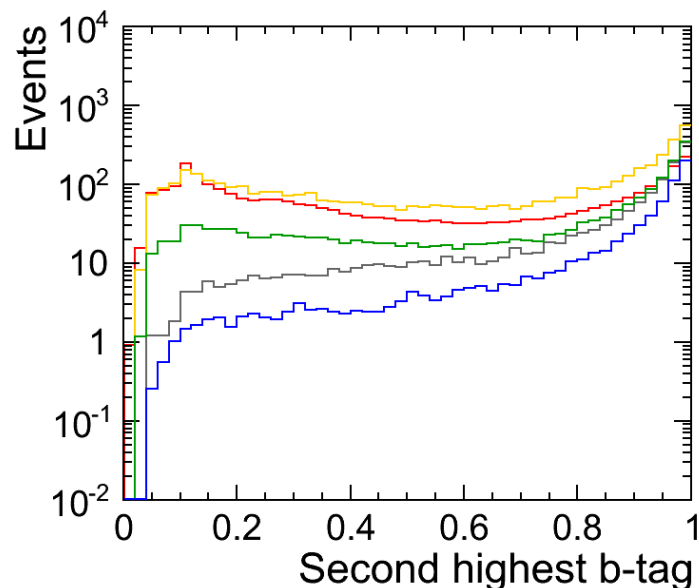
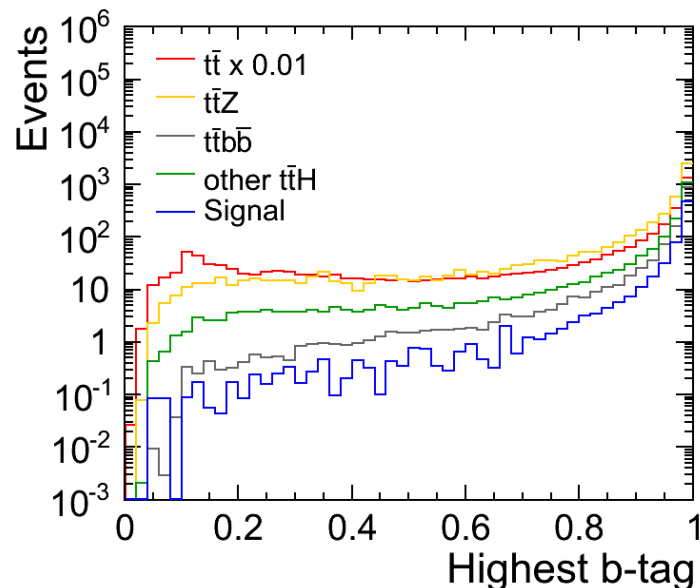
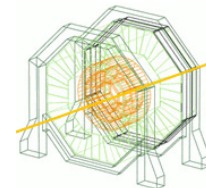


- $t\bar{t}$ background scaled by 0.01



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

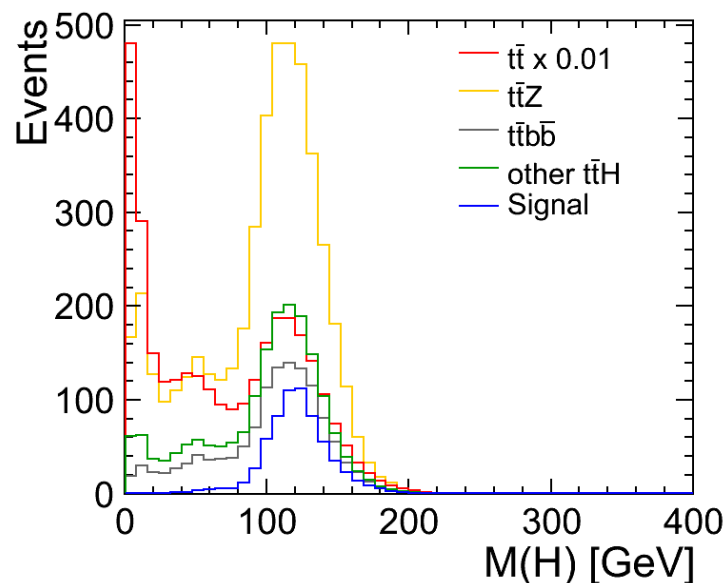
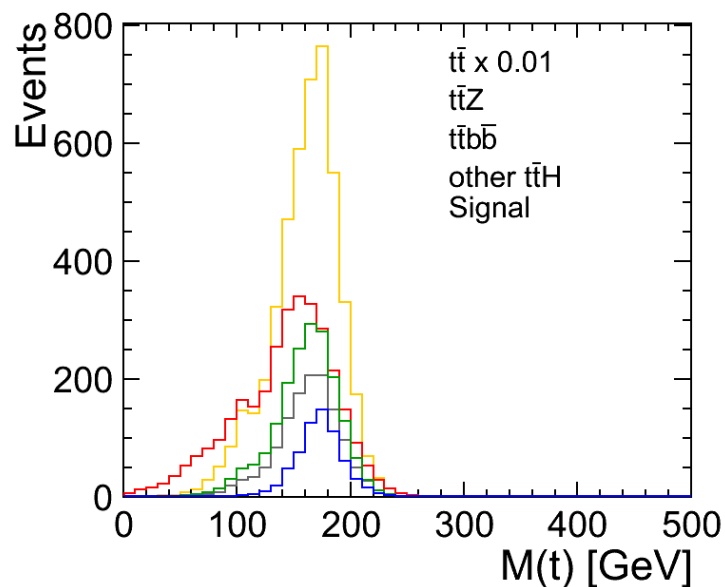
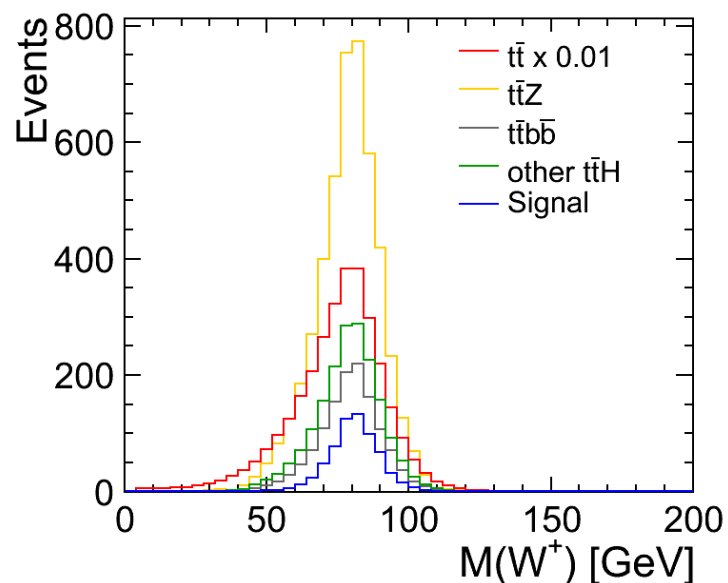
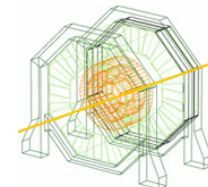
8 jets: b-tag values



- $t\bar{t}$ background scaled by 0.01
- **Signal has 4 b-jets, part of the background samples contain only 2 b-jets**

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

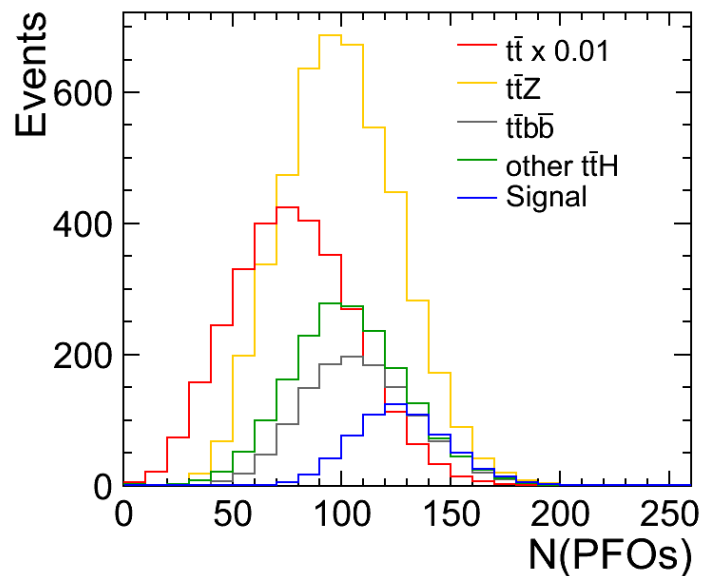
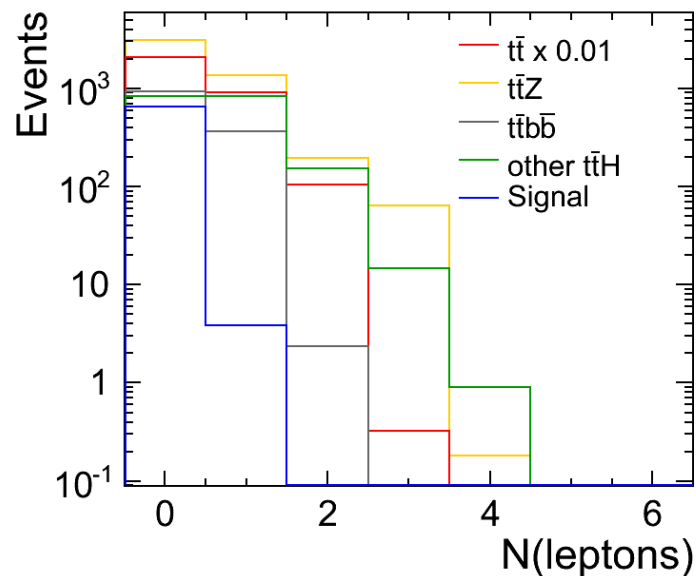
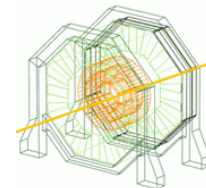
8 jets: W^+ /top/Higgs masses



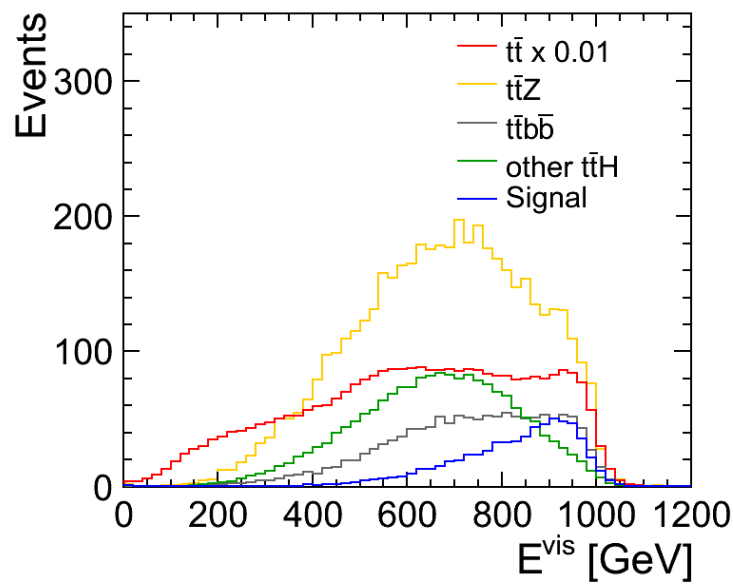
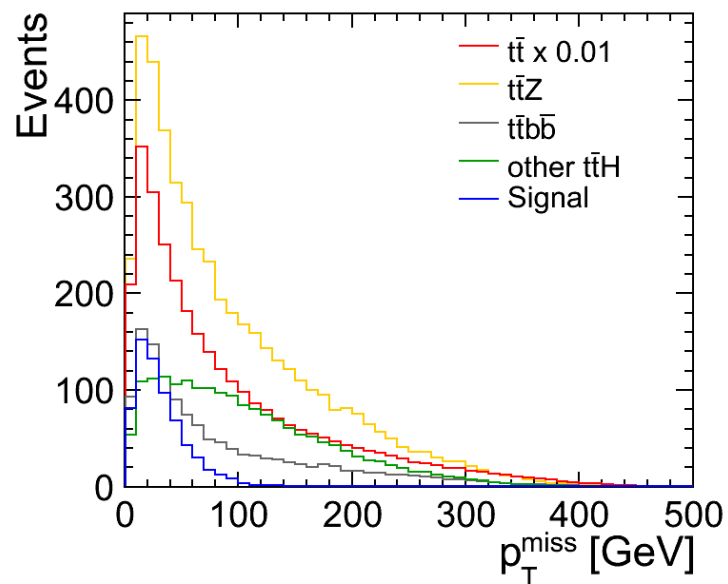
- $t\bar{t}$ background scaled by 0.01
- The background distributions are broader than the signal peaks

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

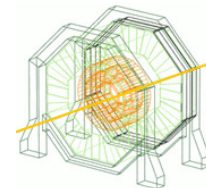
8 jets: new variables



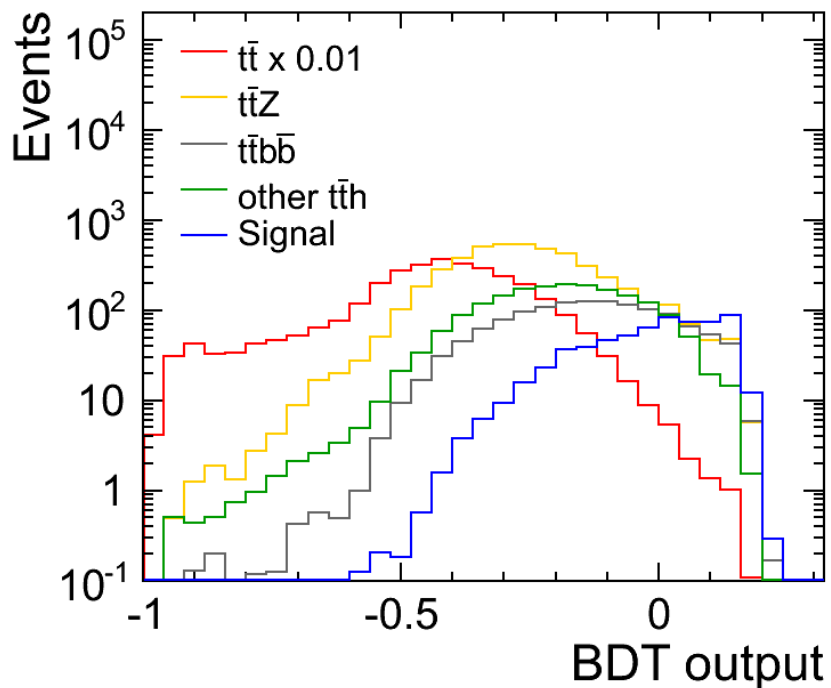
- $t\bar{t}$ background scaled by 0.01



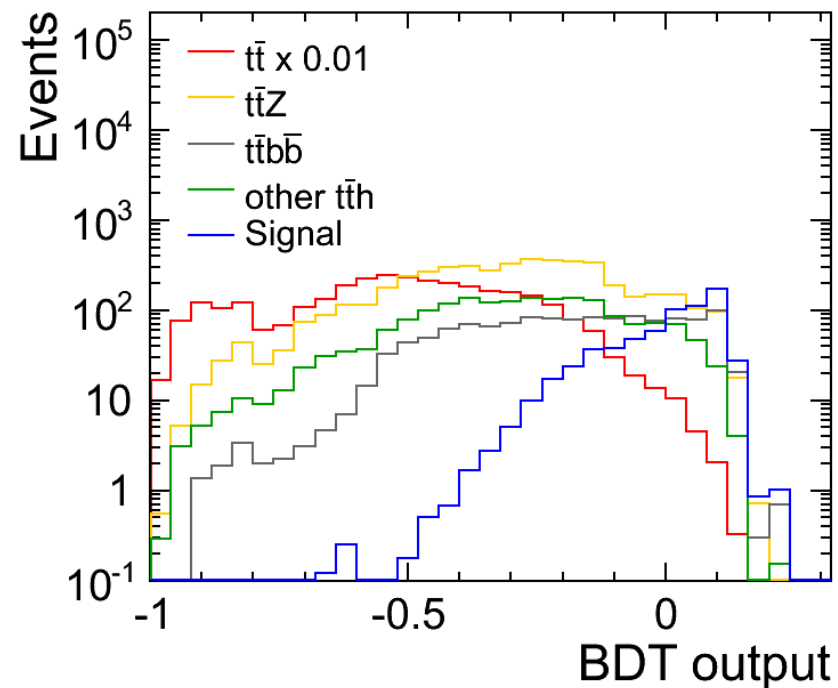
$$L_{\text{int}} = 1 \text{ ab}^{-1}$$



6 jets:

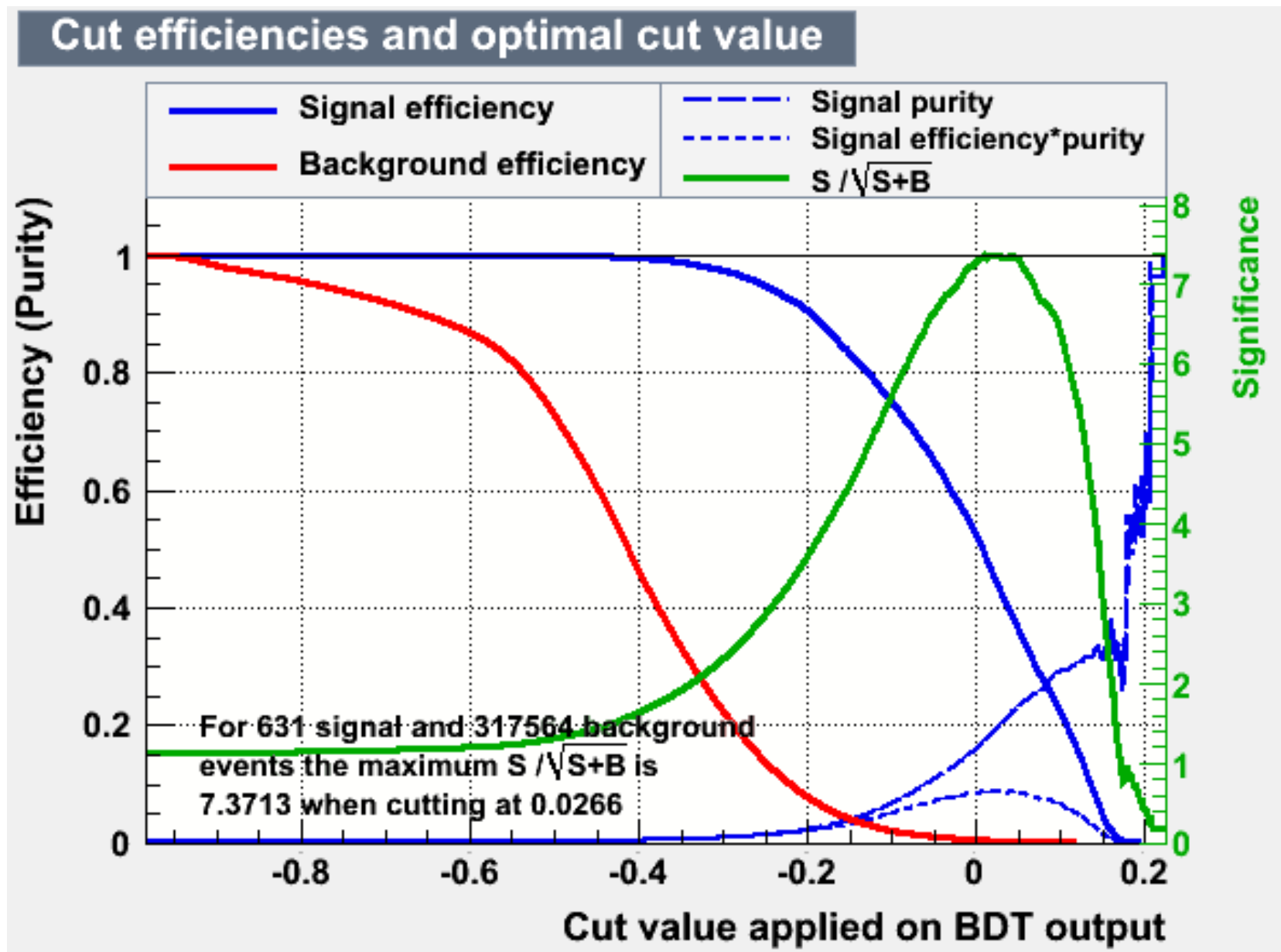
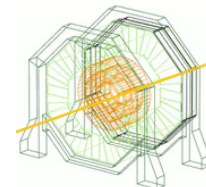


8 jets:

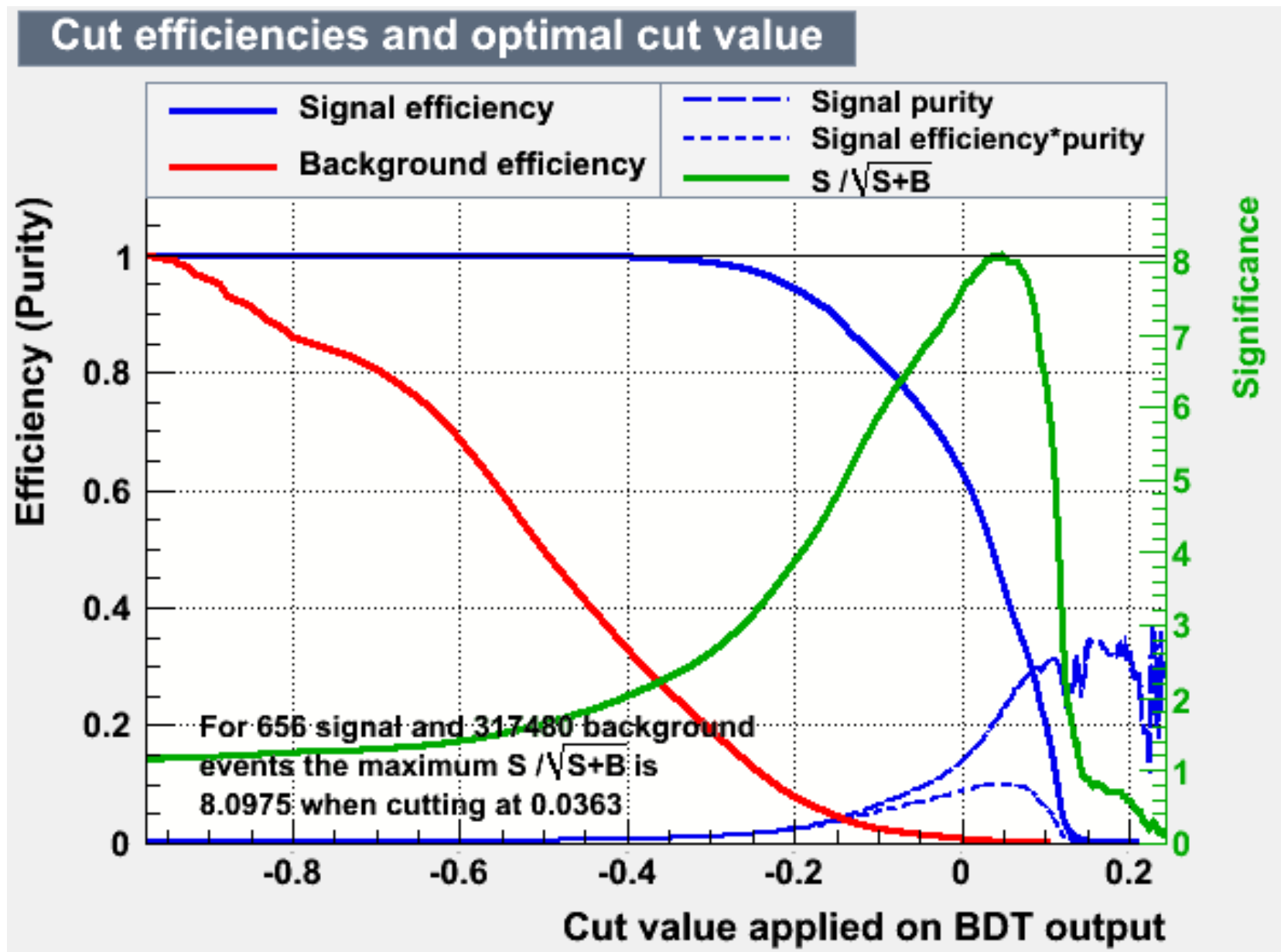
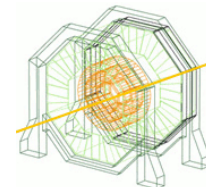


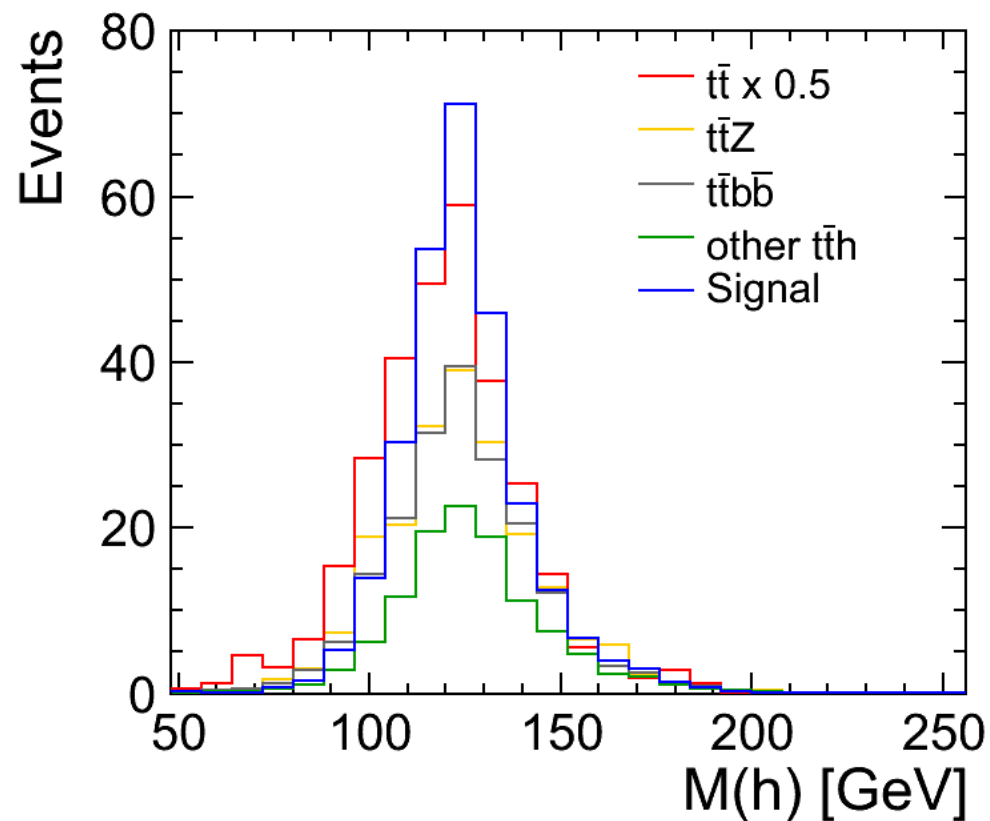
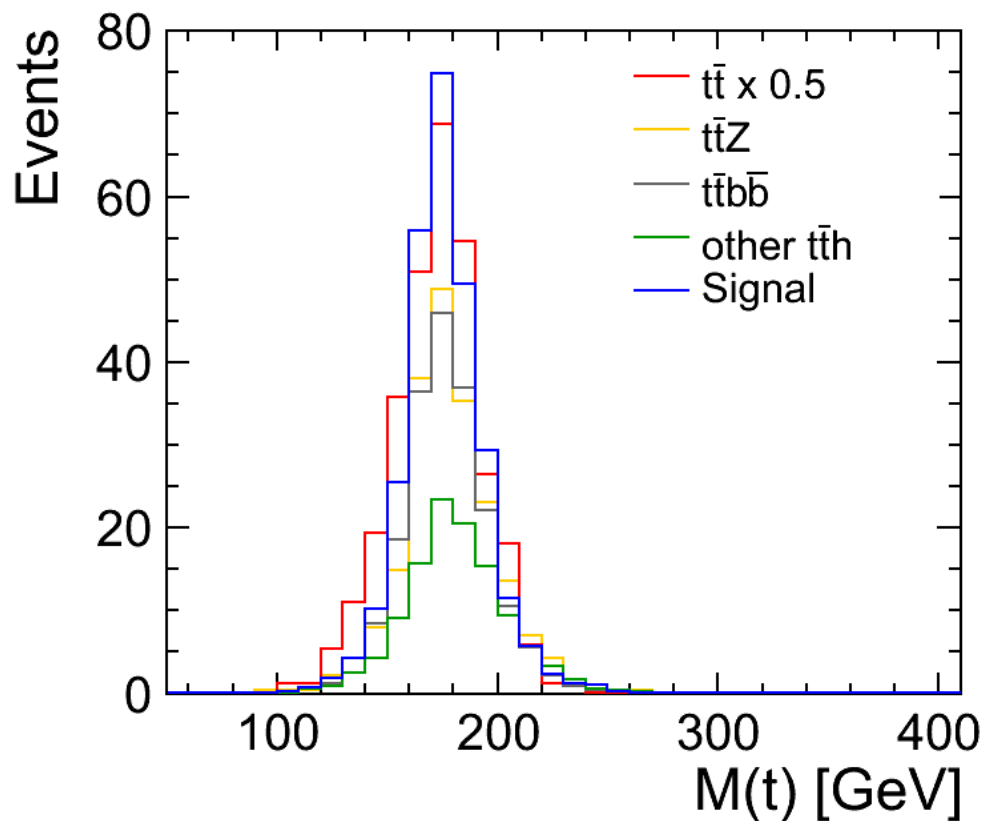
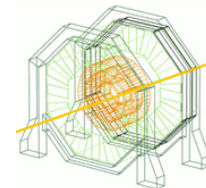
$$L_{\text{int}} = 1 \text{ ab}^{-1}$$

Significance: 6 jets



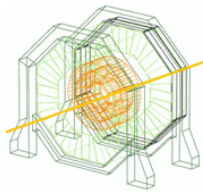
Significance: 8 jets





These figures are shown in the DBD

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



- 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 4.8% on the top Yukawa coupling can be achieved for 0.5 ab^{-1} with $P(e) = -0.8$, $P(p) = +0.2$ and 0.5 ab^{-1} with $P(e) = +0.8$, $P(p) = -0.2$
- **Ideas for further improvement (for publication):**
 - Try kinematic fitting
 - Include tau-leptons for final state with 6 jets?