

# Measurement of the energy asymmetry in $t\bar{t}b\bar{b} + \text{jet}$ events

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# Top-quark decay modes

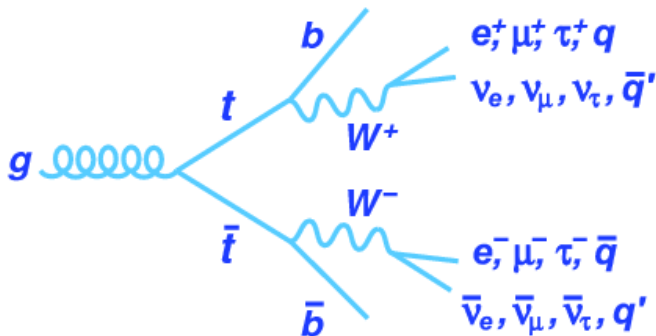
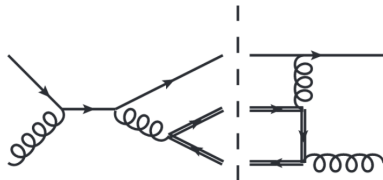


Figure: Possible decay topologies of top-quark pairs.

→ only look at semileptonic events



- induced at NLO QCD in  $t\bar{t}j$ -events, not yet seen
- enhanced in quark-gluon initial states, not present in gluon-gluon fusion
- relies on jet kinematics
- boost in  $t\bar{t}j$  rest frame  $\rightarrow \Delta E$  and  $\theta_j$  defined there

$$A_E(\theta_j) = \frac{\sigma_{t\bar{t}j}(\theta_j, \Delta E > 0) - \sigma_{t\bar{t}j}(\theta_j, \Delta E < 0)}{\sigma_{t\bar{t}j}(\theta_j, \Delta E > 0) + \sigma_{t\bar{t}j}(\theta_j, \Delta E < 0)}$$

# Shape of asymmetry

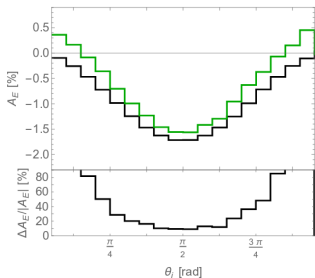


Figure: Theoretically predicted asymmetry on truth level by taking jet with  $p_T > 100$  GeV and  $|y_j| < 2.5$  [arXiv:1608.00574].

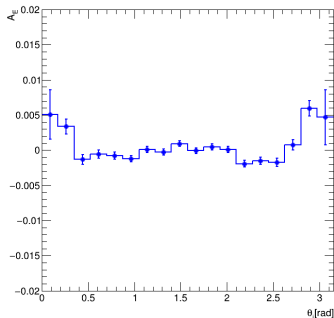


Figure: Determined asymmetry on truth level by taking jet with  $p_T > 100$  GeV and  $|y_j| < 2.5$ .

→ asymmetry not reproduced in ATLAS-Powheg-MC-sample

- $t\bar{t}$  MC-simulation with ATLAS-detector
- taken jet with  $p_T > 100 \text{ GeV}$  and  $|y_j| < 2.5$  for truth
- event with reconstruction
  - event selection lepton  $e/\mu$ , 5 jets, b-tag

- eight ways to find additional jet for nominal
  - ① klfitter with jet not matched to any quarks with and without boost
  - ② klfitter with first jet with and without boost
  - ③ reconstruction with jet not matched to any quarks with and without boost
  - ④ reconstruction with first jet with and without boost

- done reweighting according to  $w = 1 - a(\theta_j)\Delta E_{truth}$

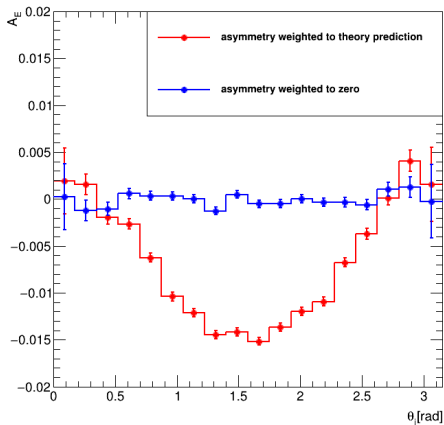


Figure: Determined asymmetry on truth level by reweighting according to the theoretical predictions and zero.

# Significance test

- compare histograms weighted to theoretical predictions and zero by  $\chi^2$ -test
- just taken statistical uncertainties into account

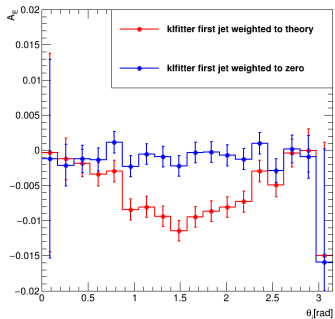


Figure: Plot to see difference between klfitter first jet with boost weighted to theory and zero.



# Significance test for asymmetry

- $\mathcal{L}_{int} = 290 \text{ fb}^{-1}$

| <b>taken values</b>                     | $\sigma$ |
|---|----------|
| klfitter with jet not matched           | 0.67     |
| klfitter with jet not matched and boost | 2.45     |
| klfitter with first jet                 | 1.96     |
| klfitter with first jet and boost       | 13.67    |
| reco with jet not matched               | 0.44     |
| reco with jet not matched and boost     | 1.79     |
| reco with first jet                     | 1.53     |
| reco with first jet and boost           | 9.35     |

**Table:** Significance test to determine asymmetry for klfitter and reco-values with different ways to look for additional jet.

# Best significance

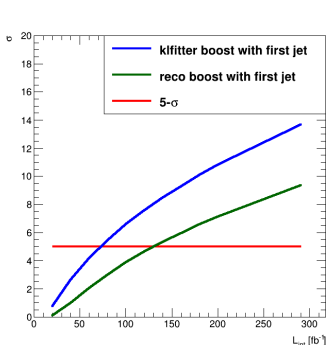


Figure: Plotted best significance for asymmetry with klfitter with first jet and boost and also reco with first jet and boost.

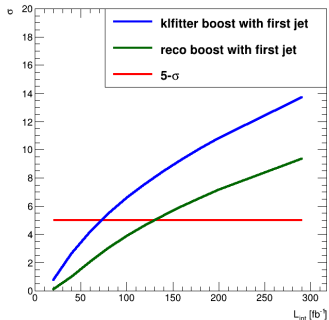


Figure: Plotted best significance for optimised asymmetry with klfitter with first jet and boost and also reco with first jet and boost.

- energy asymmetry: higher-order QCD effect in  $t\bar{t}$  production
- not reproduced in current ATLAS simulation → re-weighting required
- studied also some systematic uncertainties → so far smaller than statistical ones
- measurement with full Run-II dataset promising

$$A_E^{opt}(\theta_j) = \frac{\sigma_A(\theta_j, y_{t\bar{t}j} > 0) + \sigma_A(\pi - \theta_j, y_{t\bar{t}j} < 0)}{\sigma_S(\theta_j, y_{t\bar{t}j} > 0) + \sigma_S(\pi - \theta_j, y_{t\bar{t}j} < 0)}$$

with

$$\sigma_{S,A}(\theta_j) = \sigma_{t\bar{t}j}(\theta_j, \Delta E > 0) \pm \sigma_{t\bar{t}j}(\theta_j, \Delta E < 0)$$

# Backup: Correlation between $\Delta E_{truth}$ and $\Delta E_{reco}$

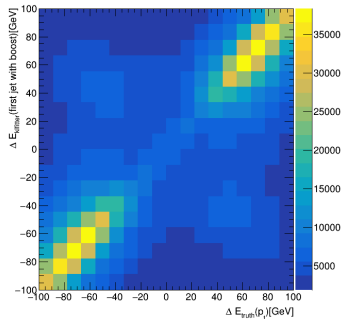


Figure: Correlation between  $\Delta E_{truth}$  and  $\Delta E_{klfitter}$ .

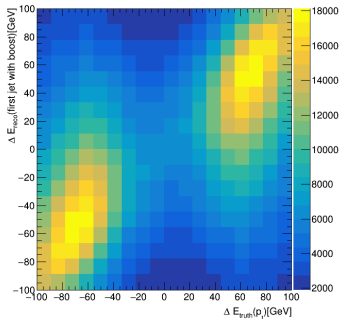


Figure: Correlation between  $\Delta E_{truth}$  and  $\Delta E_{reco}$ .

# Backup: Correlation between $\theta_j^{truth}$ and $\theta_j^{reco}$

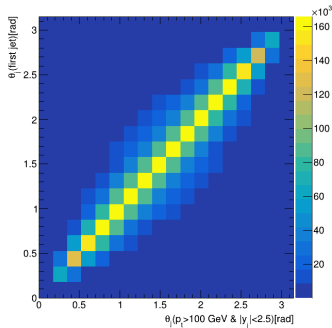


Figure: Correlation between  $\theta_j^{truth}$  and  $\theta_j^{klfitter}$ .

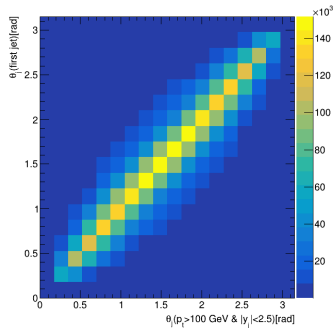


Figure: Correlation between  $\theta_j^{truth}$  and  $\theta_j^{reco}$ .

# Backup: Correlation between $y_{t\bar{t}j}^{truth}$ and $y_{t\bar{t}j}^{reco}$

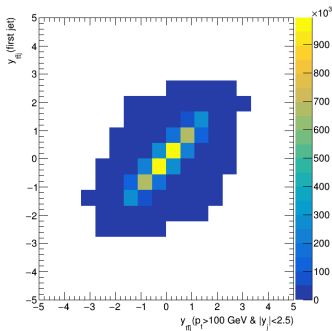


Figure: Correlation between  $y_{t\bar{t}j}^{truth}$  and  $y_{t\bar{t}j}^{klfitter}$ .

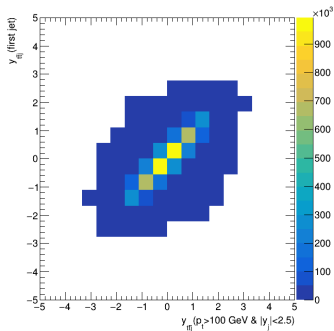


Figure: Correlation between  $y_{t\bar{t}j}^{truth}$  and  $y_{t\bar{t}j}^{reco}$ .