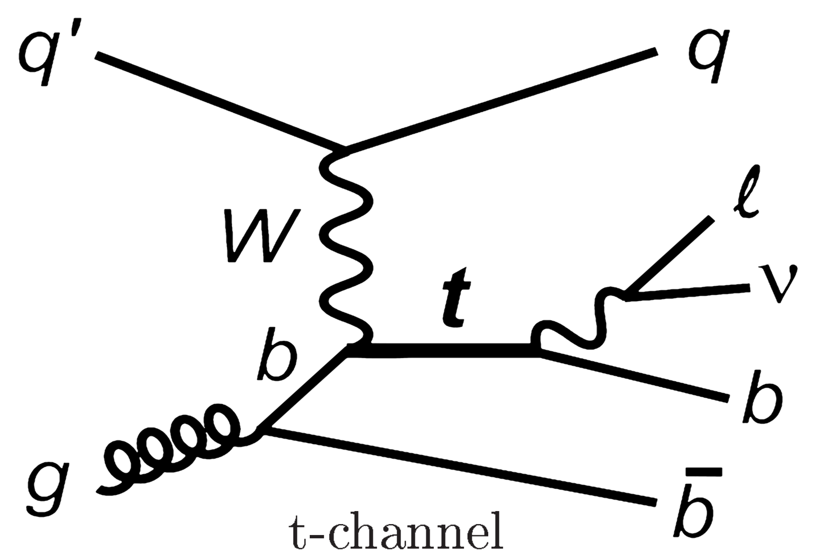
# Measurement of top quark polarization in t-channel single-top production

Andres Tiko (University of Tartu and National Institute of Chemical Physics and Biophysics)
on behalf of the CMS Collaboration
andres.tiko@cern.ch

## 1. Top Quark Polarization




t-channel

Signal phase space:

- 1 isolated muon or electron
- Missing transverse energy, $\not{E}_{\mathrm{T}}$, from W-boson decay
- One central b-tagged jet from top decay
- One light jet
- Reject events from QCD by cuts on $\not{E}_{\mathrm{T}}(e)$ and $m_{\mathrm{T}}(\mu)$

- In Standard Model (SM) t-channel single-top production, top quarks are ≈ 100% polarized through the V-A coupling structure of the involved electroweak interactions.
- Top quark decays before forming hadrons, causing its decay products to retain memory of its spin orientation.
- In this analysis [1], we use spin asymmetry $A_l$ to measure polarization $P_t$:

$$A_l \equiv \frac{1}{2} \cdot P_t \cdot \alpha_l \quad = \frac{N(\uparrow) - N(\downarrow)}{N(\uparrow) + N(\downarrow)} .$$

(Spin analyzing power $\alpha_l = 1$ in SM for leptons)

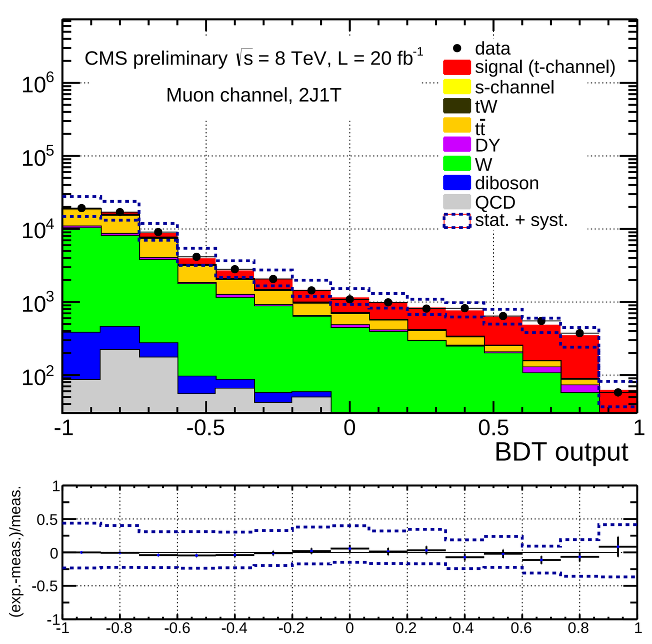
- Angular distribution ($\theta_l$) of lepton from top quark decay is

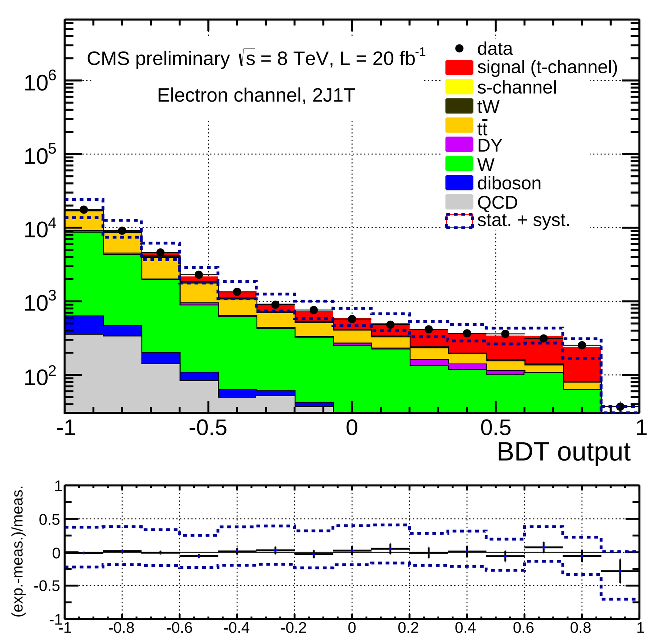
$$\frac{d\Gamma}{d\cos\theta_l} = \frac{\Gamma}{2}(1 + P_t \alpha_l \cos\theta_l) \equiv \Gamma(\frac{1}{2} + A_l \cos\theta_l) ,$$

- We study polarization by slope of $\cos\theta_l^*$ distribution, $\boldsymbol{\cos\theta_l^* = \angle}$**(charged lepton, light jet)** - light quark recoiling against the single top quark tends to have a direction parallel to the spin direction of the top quark at the production vertex
- New physics models may alter the coupling structure, consequently affecting the top quark polarization.

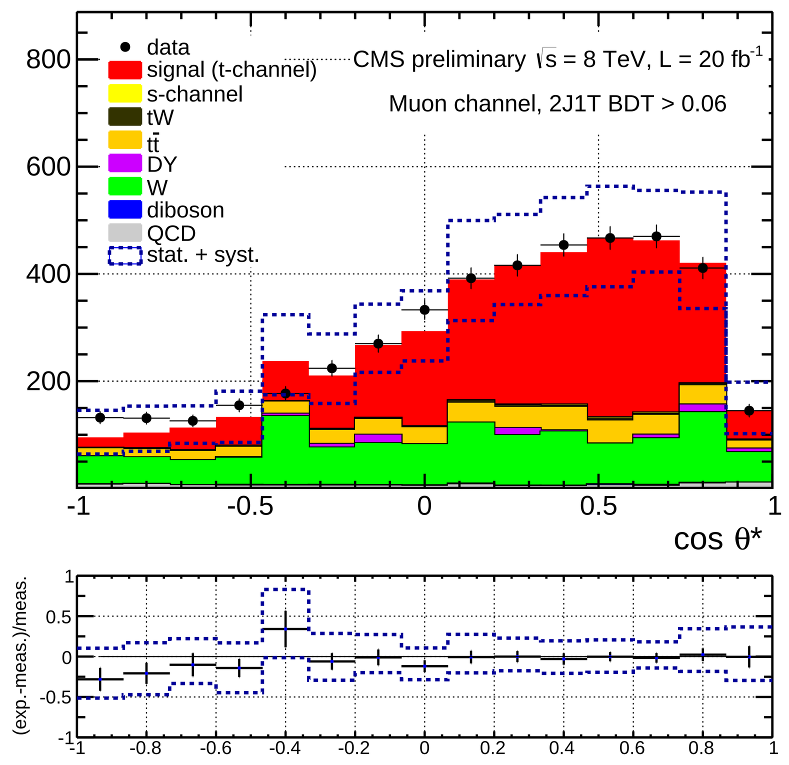
## 2. Signal Extraction

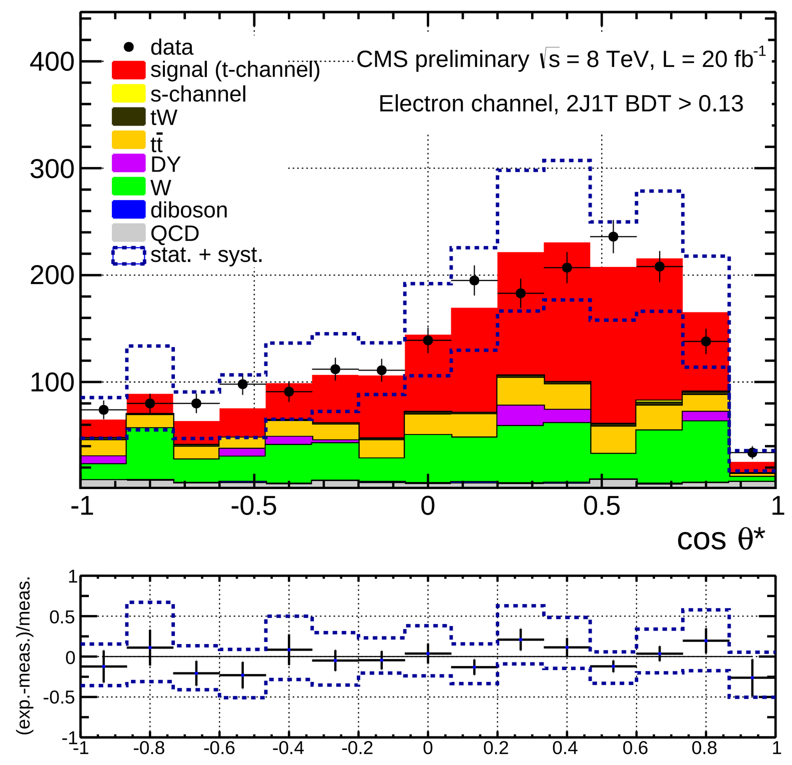
- Multivariate analysis (BDT) used for signal and background separation
- Signal and background yields extracted by a maximum-likelihood fit to BDT distribution
- Shapes for the fit taken from Monte Carlo simulation except for QCD multijet category, which is estimated from data.



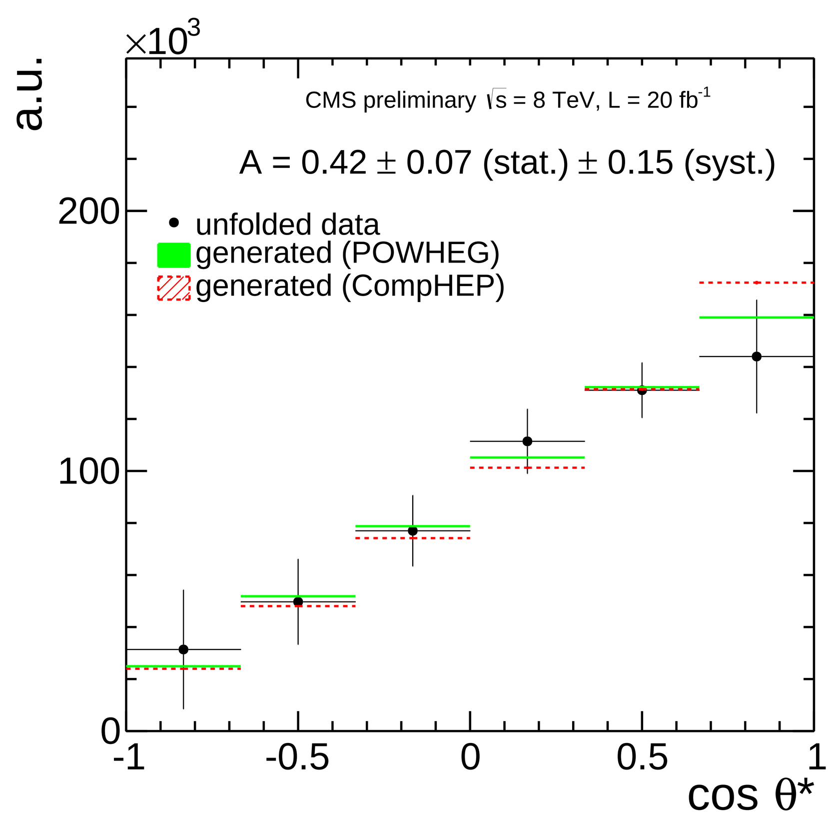

- Signal purity is further enhanced by performing a cut on the BDT value, giving us the following distributions of $\cos\theta_l^*$

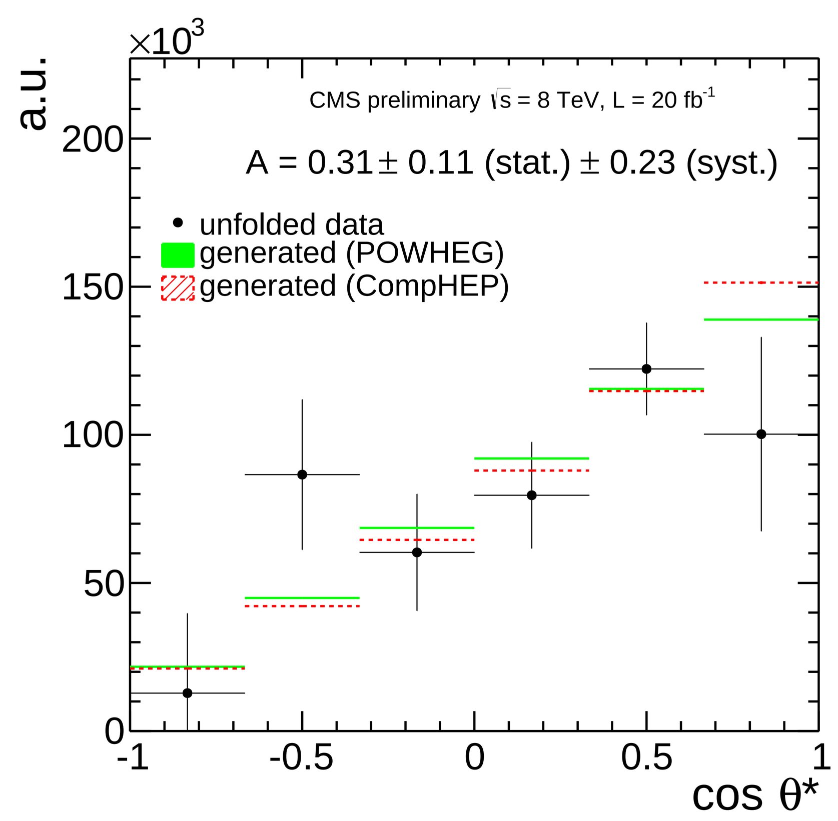



## 3. Unfolding

Reconstructed distributions are corrected for background contributions, migration effects and selection efficiency by unfolding.




We measure the asymmetry $A_l$ from the difference between forward- and backward- going leptons in the top rest frame, after unfolding:

$$A_l = \frac{N(\cos\theta^*_{unfolded} > 0) - N(\cos\theta^*_{unfolded} < 0)}{N(\cos\theta^*_{unfolded} > 0) + N(\cos\theta^*_{unfolded} < 0)} .$$

## 4. Results

We measure:

$$A_l^{\mu} = 0.42 \pm 0.07(stat.) \pm 0.15(syst.)$$
$$A_l^{e} = 0.31 \pm 0.11(stat.) \pm 0.23(syst.)$$

Systematic uncertainties are estimated by repeating the background estimation and unfolding with systematically varied templates.

The two channels are statistically compatible with the expected SM value of 0.4317 predicted with POWHEG.

We combine the two channels with the BLUE technique, obtaining

$$\boldsymbol{A_l = 0.41 \pm 0.06(stat.) \pm 0.16(syst.)}$$
$$\boldsymbol{= 0.41 \pm 0.17 .}$$

This corresponds to a polarization of

$$\boldsymbol{P_t = 0.82 \pm 0.34.}$$

| Uncertainty source | $\delta A_l^{\mu}$ | $\delta A_l^{e}$ |
|---|---|---|
| generator | 0.025 | 0.009 |
| $Q^2$ scale $t$-channel | 0.024 | 0.055 |
| $Q^2$ scale, tt̄ | 0.015 | 0.005 |
| $Q^2$ scale, W+jets | 0.036 | 0.038 |
| top quark mass | 0.058 | 0.042 |
| W+jets shape | 0.016 | 0.007 |
| W+jets flavour | 0.005 | 0.008 |
| top $p_T$, tt̄ | 0.010 | 0.025 |
| matching, tt̄ | 0.028 | 0.052 |
| matching, W+jets | 0.025 | 0.038 |
| PDF | 0.013 | 0.014 |
| JES | 0.074 | 0.074 |
| JER | 0.016 | 0.179 |
| unclustered $\not{E}_{\mathrm{T}}$ | 0.013 | 0.006 |
| lepton ID and isolation | 0.001 | 0.002 |
| lepton trigger | 0.001 | 0.002 |
| pileup | 0.015 | 0.002 |
| b tagging | 0.007 | 0.009 |
| mistagging | 0.001 | 0.003 |
| lepton weight | 0.001 | 0.009 |
| anti-isolation range of QCD | 0.010 | 0.053 |
| QCD fraction | 0.092 | 0.028 |
| background fractions | 0.007 | 0.018 |
| unfolding bias | 0.002 | 0.003 |
| total systematics | 0.15 | 0.23 |
| statistical | 0.07 | 0.11 |
| total | 0.17 | 0.26 |

## Acknowledgements

This work was supported by Estonian Science Foundation grant ETF8499, Estonian Research Council grant MTT59 and partially supported by graduate school "Functional materials and technologies" receiving funding from the European Social Fund under project 1.2.0401.09-0079 in Estonia.

## References

[1] CMS Collaboration, "Measurement of top quark polarization in t-channel single-top production," Tech. Rep. CMS-PAS-TOP-13-001, CERN, Geneva, 2013.