EVIDENCE FOR S-CHANNEL SINGLE TOP-QUARK PRODUCTION IN pp-COLLISIONS AT $\sqrt{s} = 8$ TeV WITH THE ATLAS DETECTOR

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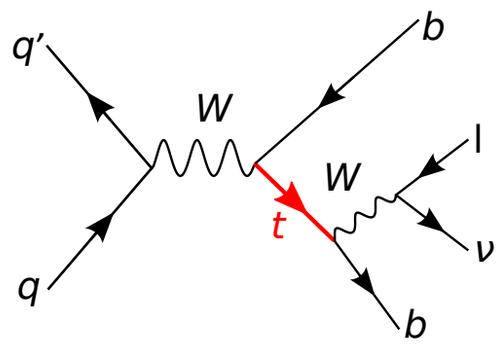
Electroweak top-quark production

The production of single top-quarks via electroweak interactions is rare compared to top-quark pair production via strong interactions. However, it is well suited for measurements of the Wtb coupling, the CKM matrix element V_{tb} and tests of possible new phenomena like FCNCs or heavy charged bosons. The s-channel mode is complementary to t-channel and Wt production but rarer. The interference between the s-channel and other modes is negligible.



s-channel single top

Previous Searches

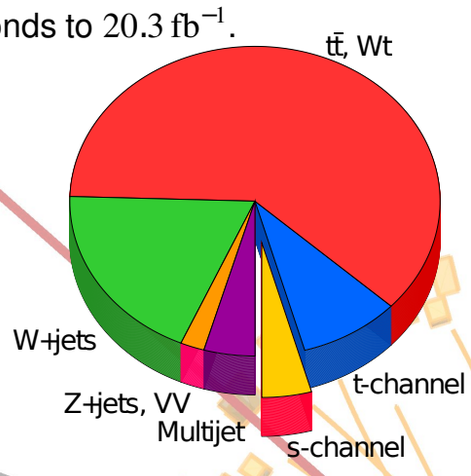
Almost 20 years after the discovery of the top-quark, CDF and D0 reported the observation of s-channel single top-quark production in 2014 [1]. At the LHC the relative rate of s-channel events is even smaller than it is at the Tevatron. In consequence, two previous searches at the LHC obtained only low signal significances, namely **0.7σ (CMS, 2013)** and **1.3σ (ATLAS, 2014)** [2,3].

Collider $\sqrt{s}$	Tevatron 1.96 TeV	LHC 8 TeV	LHC 13 TeV
$\frac{\sigma_{s-channel}}{\sigma_{t-channel}+\sigma_{t\bar{t}}}$ [%]	10.0	1.6	1.0

Collision Events

The analysed dataset consists of proton-proton collisions at a centre-of-mass energy of $\sqrt{s} = 8$ TeV. It was recorded with the ATLAS detector in 2012. The integrated luminosity corresponds to $20.3\ \text{fb}^{-1}$.
About 14 700 events are selected.
They contain

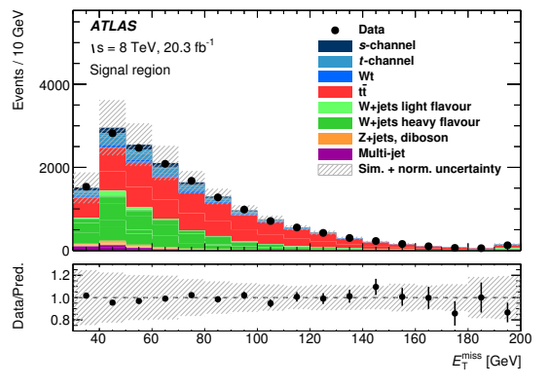
- One electron or muon
  $p_T > 30$ GeV, $|\eta| < 2.5$
- Two b-tagged jets
  $p_{T,1} > 40$ GeV, $p_{T,2} > 30$ GeV, $|\eta| < 2.5$
- Missing transverse momentum
  $E_T^{miss} > 35$ GeV, $m_T^W > 30$ GeV



In addition, there are two control regions enriched in W + jets and $t\bar{t}$-events, respectively. They mainly serve modelling validation purposes.

Modelling of Events

While most of the scattering processes are modelled by means of Monte Carlo event generators, contributions caused by mis-identified prompt charged leptons are estimated from data. Dedicated studies are used for this purpose. The description of the data by the resulting model is validated in the signal and control regions. The predictions agree with the data within the uncertainties.



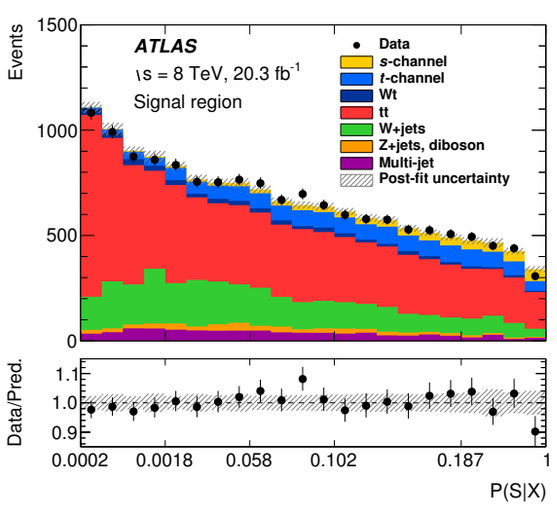
Matrix Element Method

The small signal contribution needs to be separated from the backgrounds in order to be able to detect it. For this purpose, probability densities of measured events X given different scattering processes H are computed approximately. In this context the hard scattering is described by perturbation theory at leading order. Higher order as well as detector effects are included as parametrizations known as transfer functions.

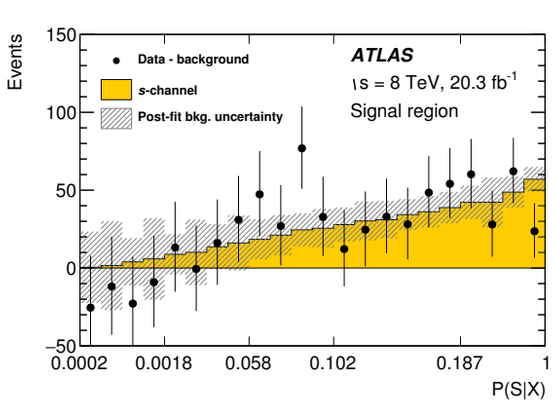
$$\mathcal{P}(X|H) = \text{⟨Feynman diagram⟩} \otimes \text{⟨detector⟩} \approx \int d\Phi \frac{1}{\sigma}\frac{d\sigma}{d\Phi} W(X|\Phi)$$

$$\approx \frac{1}{\sigma'} \sum_{p \in \{\text{permutations}\}} \int dx_1 dx_2 d\Phi \sum_{i,j} \frac{f_i(x_1) f_j(x_2)}{2 x_1 x_2 s} |\mathcal{M}_{ij}|^2 W_p(X|\Phi)$$

A comprehensive package for these Matrix Element Method computations has been developed. The resulting probability densities are combined into an approximate signal probability. This approach results in a significant separation of the s-channel signal from the backgrounds.

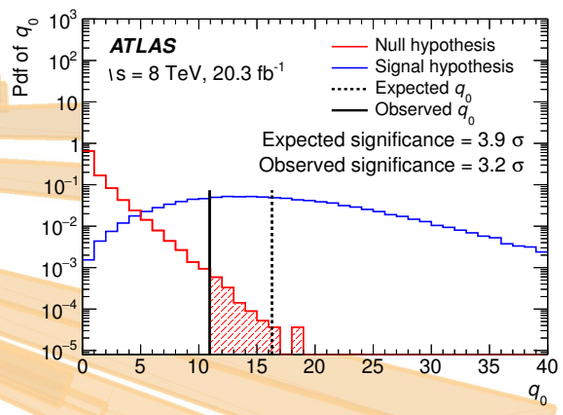


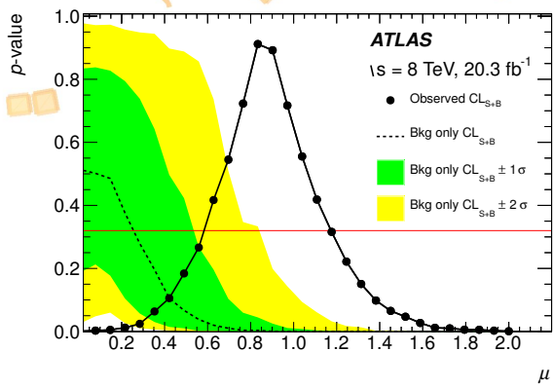
$$P(S|X) = \frac{P(S)\mathcal{P}(X|S)}{P(S)\mathcal{P}(X|S) + \sum_B P(B)\mathcal{P}(X|B)}$$



Results

A profile likelihood fit is performed using the discriminant $P(S|X)$ in the signal region and the lepton charge in the W + jets control region. The fit results in an **observed signal significance of 3.2 standard deviations**. This is the first evidence for s-channel single top-quark production in pp-collisions [4].





Source	$\frac{\Delta\sigma_s}{\sigma_s}$ [%]
Data statistics	16
MC statistics	12
Jet energy resolution	12
t-channel generator	11
Others	< 10 each
Total	34

Given the presence of the signal, its strength can be estimated. About 540 signal events are observed. The measured signal cross section is

$$\sigma_s = 4.8^{+1.8}_{-1.6}\ \text{pb}$$
$$= 0.86^{+0.31}_{-0.28} \cdot \sigma_s^{SM}.$$

The results agree with the standard model prediction. The overall uncertainty of 34% is dominated by the limited amount of data statistics.

References

[1] The CDF and D0 Collaborations, PRL 112:231803, 2014
[2] CMS Collaboration, CMS-PAS-TOP-13-009, 2013
[3] ATLAS Collaboration, PLB 740:118, 2015
[4] ATLAS Collaboration, arXiv:1511.05980, subm. to PLB

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