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Material from the ATLAS TOPQ-2020-02 analysis (Measurement of the $t\bar{t}$ production cross-section in the lepton+jets channel at $\sqrt{s} = 13$ TeV with the ATLAS experiment)

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RAMP

GEFÖRDERT VOM
Bundesministerium
für Bildung
und Forschung

FSP ATLAS
Erforschung von
Universum und Materie

ATLAS
EXPERIMENT

The Analysis

Introduction

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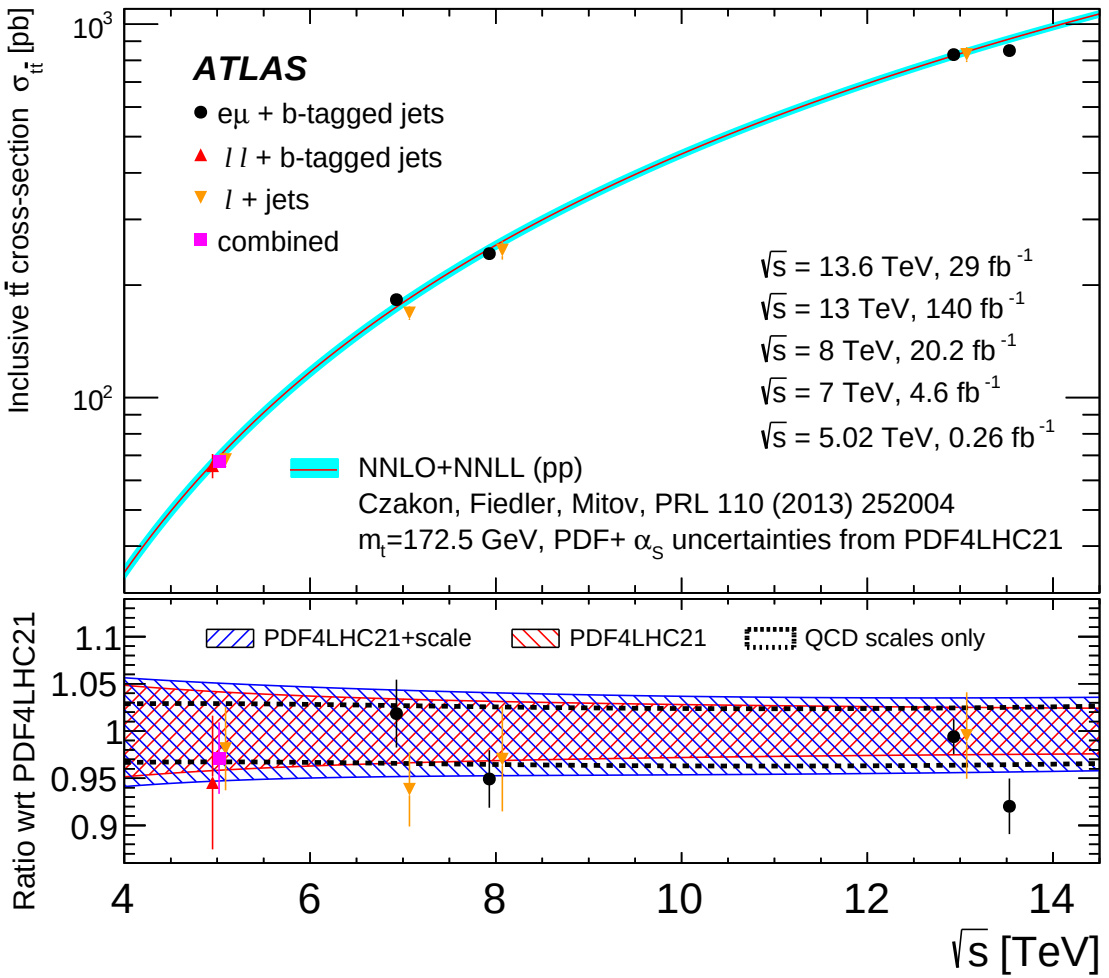
Why Top Quarks?

- it is the heaviest particle known so far
- $t\bar{t}$ cross-section provides very precise probe of SM

This Analysis:

- full run 2 dataset
- expect ~115M $t\bar{t}$ pairs
- ℓ+jets channel, final state: $\ell\nu q\bar{q}'b\bar{b}$
- inclusive and fiducial measurement
- profile likelihood fit to data



The Analysis

Event Selection

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Detector Level

- $= 1$ lepton, $p_T > 25$ (27; 28) GeV for 2015 (2016; 2017/18) data
- ≥ 4 jets, $p_T > 25$ GeV
- 1 or 2 b-jets
- $E_{\mathrm{T}}^{\mathrm{miss}} > 30$ GeV, $m_{\mathrm{T}}^{W} > 30$ GeV (e+jets)
- $E_{\mathrm{T}}^{\mathrm{miss}} + m_{\mathrm{T}}^{W} > 60$ GeV (μ+jets)

Particle Level

- $= 1$ lepton, $p_T > 25$ GeV
- ≥ 4 jets, $p_T > 25$ GeV
- 1 or 2 b-jets (ghost-matched)

- 3 orthogonal signal regions (SRs)
  - SR1: ≥ 4 jets, $= 1$ b-jet $\rightarrow$ fewer b-jets, higher background-fraction
  - SR2: $= 4$ jets, $= 2$ b-jets $\rightarrow$ expected signature, different bkg than SR1
  - SR3: ≥ 5 jets, $= 2$ b-jets $\rightarrow$ $t\bar{t}$ events with extra radiation

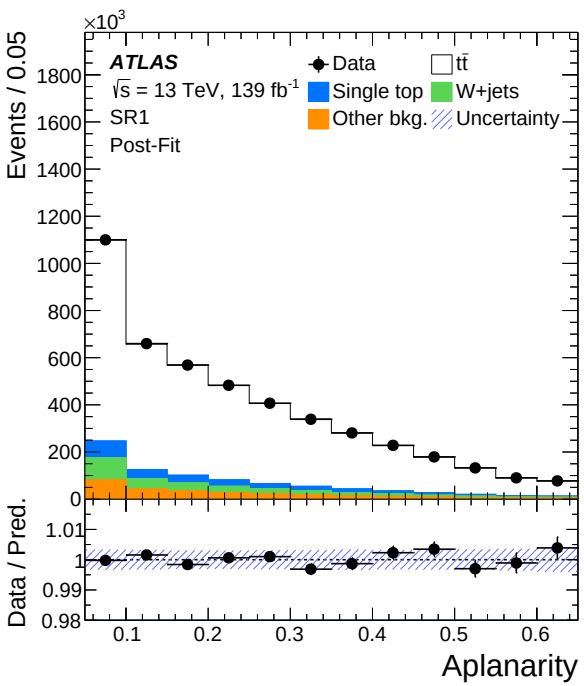
	SR1	SR2	SR3
$t\bar{t}$	3 630 000 ± 210 000	990 000 ± 90 000	980 000 ± 100 000
W+jets	350 000 ± 160 000	24 000 ± 10 000	17 000 ± 9000
Single top	255 000 ± 31 000	52 000 ± 7000	37 000 ± 8000
Z+jets & diboson	80 000 ± 40 000	8000 ± 4000	5800 ± 3000
$t\bar{t}X$	15 600 ± 2100	2110 ± 290	7200 ± 1000
Multijet	210 000 ± 80 000	28 000 ± 10 000	22 000 ± 8000
Total prediction	4 540 000 ± 310 000	1 110 000 ± 100 000	1 070 000 ± 100 000
Data	4 540 886	1 100 558	1 103 317

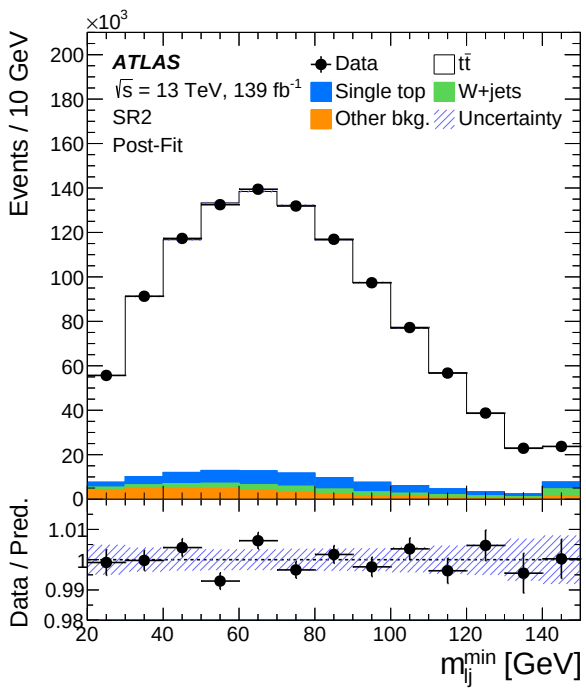
$\Rightarrow$ high $t\bar{t}$ purity

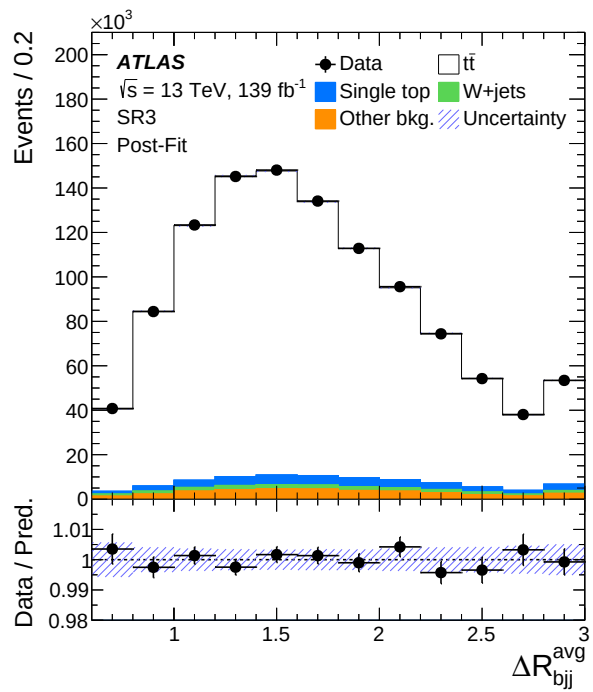
The Analysis

The Fit

- simultaneous profile-likelihood fit in all regions
- each region uses a different observable:
  - SR1: Aplanarity $A = \frac{3}{2}\lambda_3$, λ_3 smallest eigenvalue of sphericity tensor, analogously to previous $t\bar{t}$ cross-section measurements
  - SR2: minimum lepton-jet mass m_{lj}^{min}, calculated over all lepton-jet pairs
  - SR3: $\Delta R_{bjj}^{\text{avg}}$, bjj system with highest p_T for the 4-momentum vector sum likely from top decay, average distance between the objects







The Analysis

Cross-Sections

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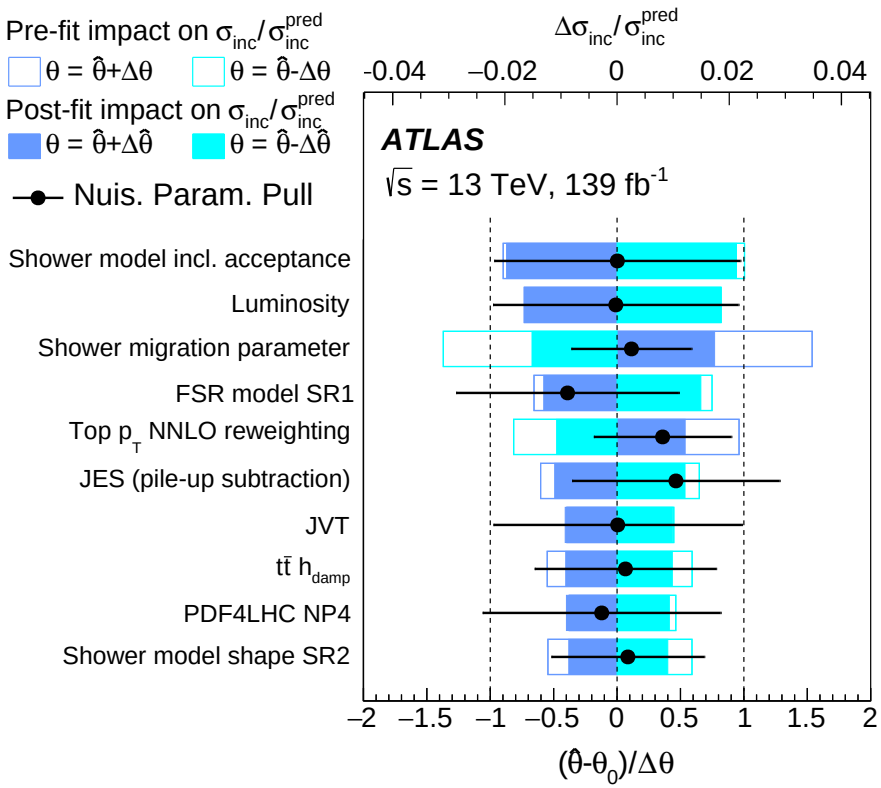
Fiducial Cross-Section:

- defined as $\sigma_{\text{fid}} = A_{\text{fid}} \times \sigma_{\text{inc}}$
- using fiducial acceptance A_{fid}
- based on particle level selection
- alternative signal samples scaled to same fiducial cross-section

Generator set-up	A_{fid} [%]	$\frac{A_{\text{fid}}^{\text{alt}} - A_{\text{fid}}^{\text{nom}}}{A_{\text{fid}}^{\text{nom}}}$ [%]
POWHEG+PYTHIA nominal	13.50	0.00
POWHEG+PYTHIA top-quark p_{T} reweighted	13.40	−0.75
$\mu_{\text{R}}^{\text{FSR}} \times 2$	13.58	1.29
$\mu_{\text{R}}^{\text{FSR}} \times 0.5$	13.18	−1.64
$\mu_{\text{R}} \times 2$	13.37	−0.25
$\mu_{\text{R}} \times 0.5$	13.45	0.38
$\mu_{\text{F}} \times 2$	13.38	−0.15
$\mu_{\text{F}} \times 0.5$	13.43	0.17
Var3cUp	13.46	0.41
Var3cDown	13.35	−0.38
$h_{\text{damp}} \times 2$	13.57	1.21
POWHEG+HERWIG	13.44	0.31
PDF4LHC15 variations		0.47
Total		$^{+1.9}_{-2.2}$



Results:

$$\sigma_{\text{fid}} = 110.7 \pm 4.8 \text{ pb}$$

$$\sigma_{\text{fid}}^{\text{ext}} = 820 \pm 40 \text{ pb}$$

$$\sigma_{\text{inc}} = 830 \pm 38 \text{ pb}$$

Available Material

Overview

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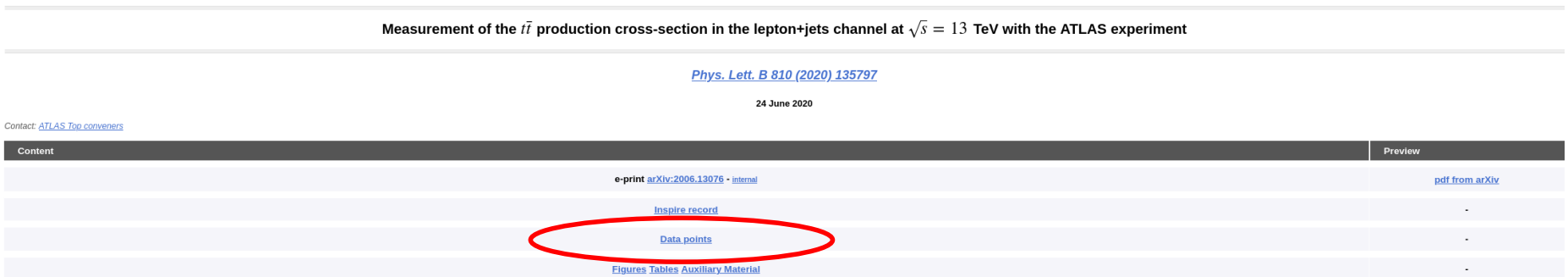
Material includes:

- the full likelihoods of the inclusive and fiducial fits
- tabulated datapoints of all plots
- exact definition of fiducial event selection

Where to find it?

- links to hepdata either in the agenda or the paper's Cern page ($\rightarrow$ Data points)



Measurement of the $t\bar{t}$ production cross-section in the lepton+jets channel at $\sqrt{s} = 13$ TeV with the ATLAS experiment

Phys. Lett. B 810 (2020) 135797

24 June 2020

Contact: ATLAS Top conveners

Content	Preview
e-print arXiv:2006.13076 - internal	pdf from arXiv
Inspire record	-
Data points	-
Figures Tables Auxiliary Material	-

Available Material

Closer Look

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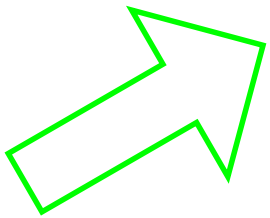
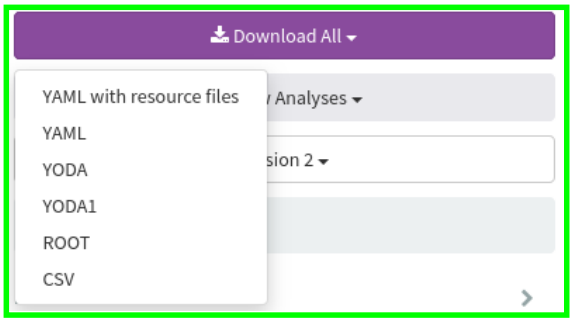
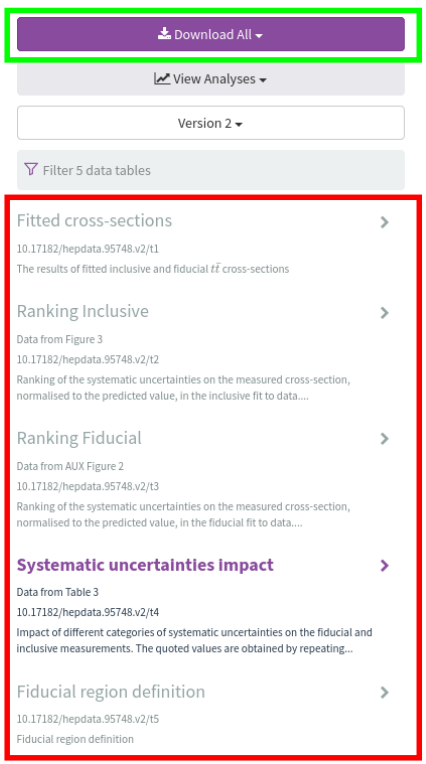




Available formats



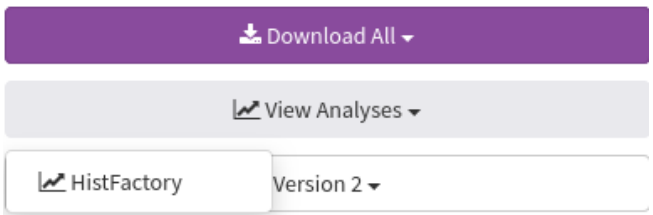
Available datapoints

SQRT(S)	13 TeV	
Category	**Relative uncertainty in percentages for the fiducial result**	**Relative uncertainty in percentages for the inclusive result**
$t\bar{t}$ shower/hadronisation	2.8	2.9
$t\bar{t}$ scale variations	2.2	2.7
h_{damp}	1.5	1.1
MC background modelling	1.8	2.0
Multijet background	0.8	0.6
Jet reconstruction	2.5	2.6
Luminosity	1.7	1.7
Flavour tagging	1.2	1.3
E_T^{miss} + pile-up	0.3	0.3
Muon reconstruction	0.6	0.5
Electron reconstruction	0.7	0.6
Simulation stat. uncertainty	0.6	0.7

Preview

Available Material

Likelihoods



- selecting "View Analyses"→"HistFactory" gives access to full inclusive and fiducial likelihood
- using JSON format as described in ATL-PHYS-PUB-2019-029

- likelihoods are readable with pyhf, python package for histogram-based analyses
- based on HistFactory, independent of ROOT
- documentation/tutorial available here

pyhf
∂ifferentiable
$\mathscr{L}$ikelihoods

Available Material

Likelihoods - Usecases

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- validation/replication
  - analysis can be repeated by other groups to check analysis results/validate analysis code
- re-interpretation
  - individual samples for any process can be replaced by updated/modified samples, e.g. for EFT studies
  - uncertainties can be modified too
  - example: "Staying on Top of SMEFT-Likelihood Analyses", 2312.12502, RAMP talk next week
- combination
  - define combined likelihood based on available workspaces
  - caveat: exact definitions of nuisance parameters can be unclear/differ between measurements

Limitations:

- does not apply to all analyses, only those using profile likelihood fits
- pyhf doesn't currently work with reparameterisations, e.g. for asymmetry measurements

Summary

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Analysis:

- measurement of inclusive and fiducial $t\bar{t}$ cross-section with run 2 data

$$\sigma_{\text{inc}} = 830 \quad \pm 38 \ \text{pb}$$
$$\sigma_{\text{fid}} = 110.7 \pm 4.8 \ \text{pb}$$

Material:

- data points of plots in the paper
- exact definition of fiducial region
- full likelihoods for inclusive and fiducial

Tools/Documentation:

- workspace format: ATL-PHYS-PUB-2019-029
- pyhf documentation: here
- next weeks seminar: here

back-up