Study of the quantum interference between singly and doubly resonant top-quark production in the $WbWb$ phase-space with the ATLAS detector

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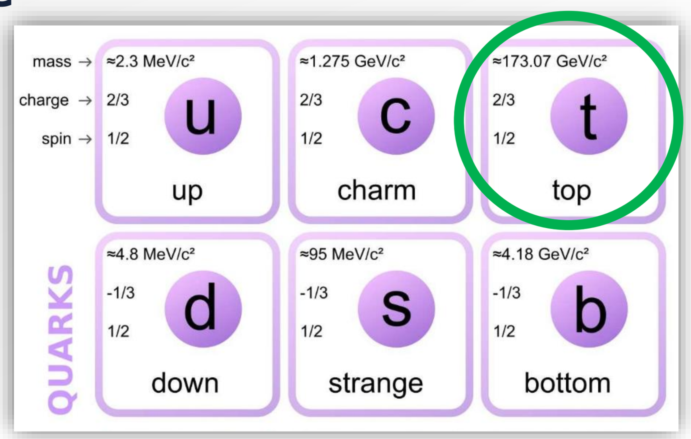
Introduction

The **top quark** is the heaviest known elementary particle of the Standard Model. It allows to explore physics processes inaccessible otherwise:

- One of them is the **quantum interference** between singly (NLO tW with an extra b-quark) and doubly (LO $t\bar{t}$) resonant top quark production, which can lead to identical $WbWb$ final-states [1]. **My research** activity is focused on the measurement of the particle-level differential cross-section of the $WbWb$ production in the dilepton channel.



The **measurement** is performed using the full ATLAS Run-2 dataset from proton-proton collisions at the LHC ($\sqrt{s} = 13$ TeV and L = 139 fb^{-1}). The cross-section is measured as a function of the most interference-sensitive variable: $m_{bl}^{minimax}$.

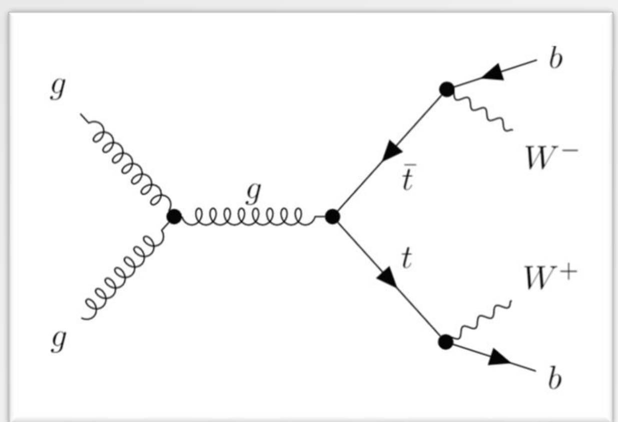
Results are compared to different prediction schemes: Diagram Removal (DR) and Diagram Subtraction (DS), which are used to model in a different way the quantum interference description.

This measurement could be compared to many predictions and can be used to define a better systematic uncertainty linked to the interference, with respect to the previous measurement.

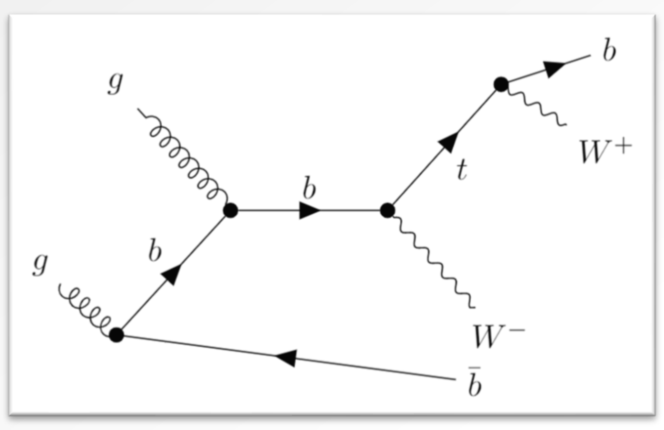
Process production

Quantum interference between:

(LO) $gg \to t\bar{t} \to WbWb$ (NLO) $gb \to tWb \to WbWb$



Doubly resonant (LO)



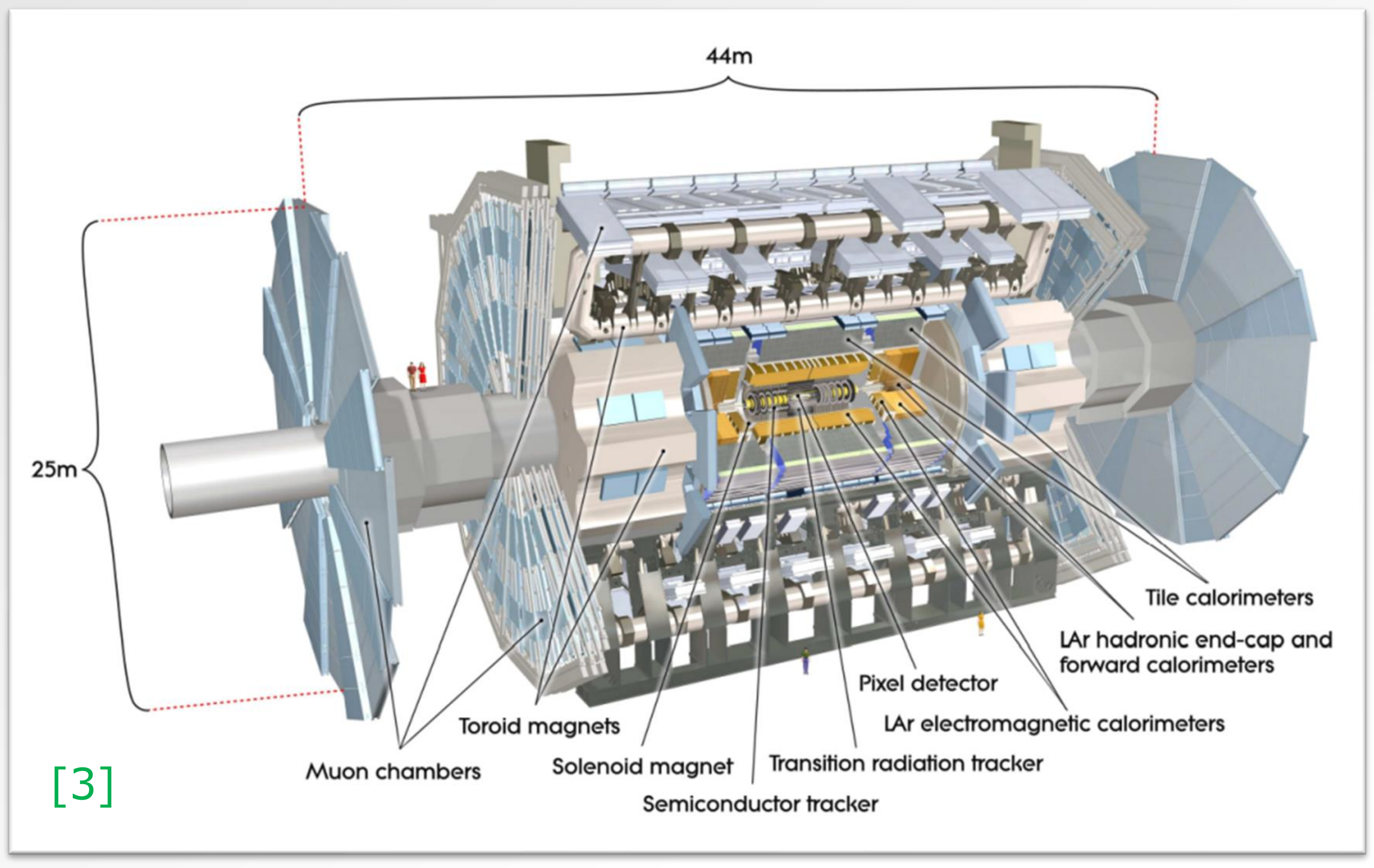
Singly resonant (NLO)

$$\alpha + \beta \to t + W + b \Longrightarrow \mathcal{A}_{\alpha\beta} = \mathcal{A}_{\alpha\beta}^{(Wt)} + \mathcal{A}_{\alpha\beta}^{(t\bar{t})}$$

[2]

$$\sigma_{WbWb} \propto \left|\mathcal{A}_{\alpha\beta}\right|^2 = \left|\mathcal{A}_{\alpha\beta}^{(Wt)}\right|^2 + 2\mathcal{R}e\left\{\mathcal{A}_{\alpha\beta}^{(Wt)}\mathcal{A}_{\alpha\beta}^{(t\bar{t})}\right\} + \left|\mathcal{A}_{\alpha\beta}^{(t\bar{t})}\right|^2$$

The ATLAS detector



[3]

Event selection

Dilepton *Opposite-Sign* (OS) and *different-flavour* final-state ($e\mu$, $e\tau$ and $\tau\mu$):

$$pp \to WbWb \to \nu_{l,1} l_1^- b_1 \bar{\nu}_{l,2} l_2^+ \bar{b}_2$$

Requirements

- $N_{jets} \geq 2$ and $N_{b-jets} = 2$
- $p_T^{\text{lepton}} > 28\ GeV$, $p_T^{\text{jets}} >$ 25 GeV and $|\eta| < 2.5$

Samples

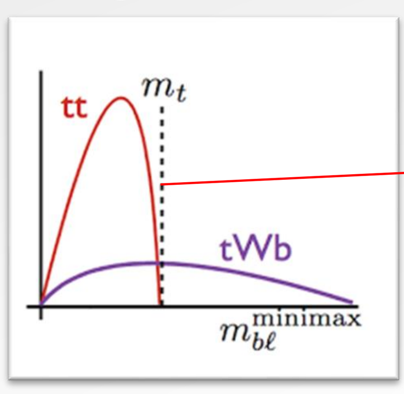
- **Signal**: $t\bar{t}$ + tW
- **Backgrounds**: $t\bar{t}V$, fake leptons, diboson production, Z + jets

The m_{bl}^{minimax} variable

$$m_{bl}^{\text{minimax}} \equiv \min\{\max(m_{b_1 l_1}, m_{b_2 l_2}), \max(m_{b_1 l_2}, m_{b_2 l_1})\}$$

bl coming from t: on-shell $\Longrightarrow$ two m_{bl} below the top mass bound

bl coming from Wb: off-shell $\Longrightarrow$ a single m_{bl} below the top mass bound



$m_{bl}^{\text{minimax}} > m_{top}$

contribution of two on-shell top final-state is suppressed suppressed and interference becomes large

Unfolding procedure

Unfolding is used to correct data for finite resolution and limited geometrical acceptance of the detector. It can be applied to several analyses for cross-section extractions. Final cross-sections are extracted through an **iterative Bayesian unfolding** method, using this equation [4]:

$$\frac{d\sigma^{\text{fid}}}{dX^i} \equiv \frac{1}{\mathcal{L}\cdot\Delta X^i}\cdot\frac{1}{\epsilon^i}\cdot\sum_j M^{-1}\cdot f_{\text{acc}}^j\cdot\left(N_{\text{obs}}^j - N_{\text{bkg}}^j\right) \Longrightarrow \frac{d\sigma^{\text{norm}}}{dX^i} = \frac{1}{\sigma^{\text{fid}}}\frac{d\sigma^{\text{fid}}}{dX^i}$$

Binning has been provided through **binning optimization** procedures (with additional resolution studies) and **closure tests** to ensure their stability

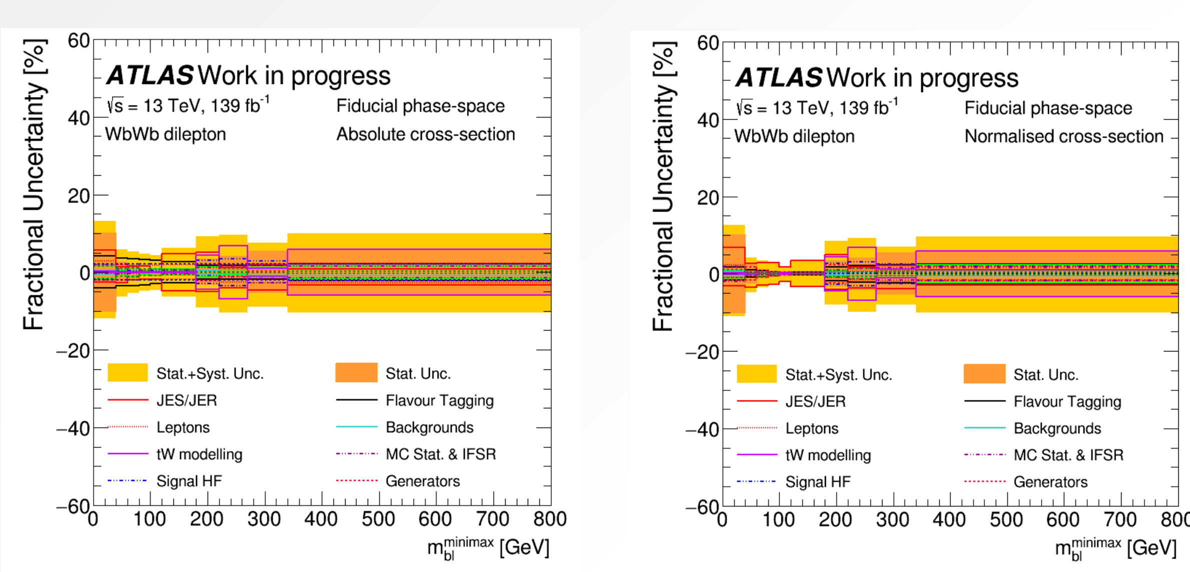
Systematic uncertainties

Evaluated by:

- Unfolding the varied MC detector-level spectra with nominal corrections
- Compare the unfolded result with the particle-level distribution of the generator

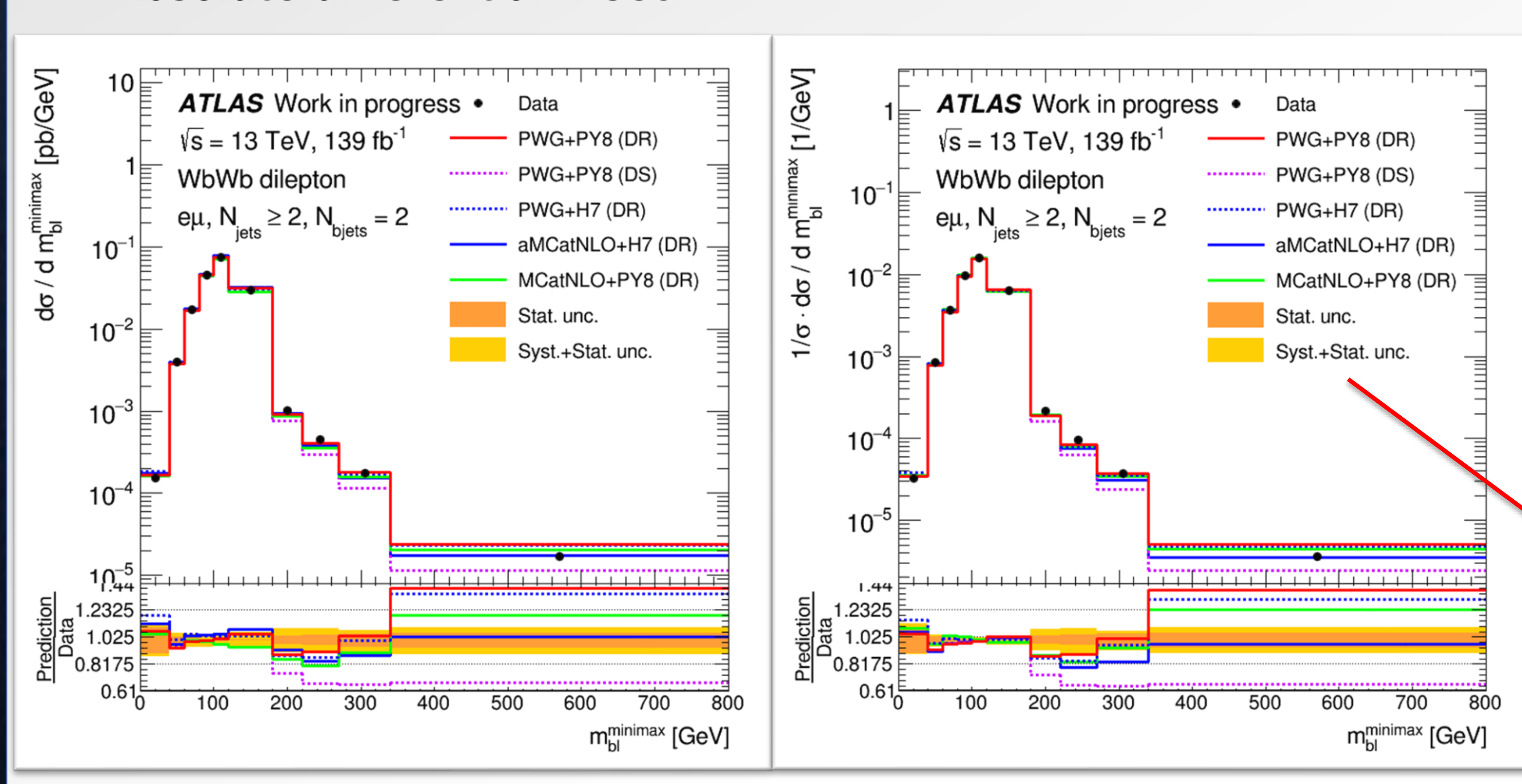
List of considered systematics:

1. Detector-related: lepton reconstruction efficiency, JVT, b-tagging, pileup reweighting,…
2. Signal modelling: choice of removal scheme, finite sample statistics of MC generators, …
3. Background modelling: systematics related to the various background processes



Differential cross-sections results

Absolute differential x-sec Normalized differential x-sec



Bibliography

[1] The ATLAS Collaboration In: *Phys. Rev. Lett.* 121.15 (2018), p.152002.

[2] Stefano Frixione et al. In: *Journal of High Energy Physics* (2008), p. 029.

[3] The ATLAS collaboration. In: *JINST* **3** S08003 (2008).

[4] Biondi, Silvia. In: *EPJ Web Conf.* 137 (2017), p. 11002.

Among each DR and DS model, the **aMCatNLO+H7 (DR)** seems to be best one so far for the $WbWb$ interference cross-section modelling

Conclusions and future steps

- In general, DR predictions seem to better describe the interference region
- Aiming to a measurement of the x-sec with half the uncertainty with respect to the previous one [1]
- Full $WbWb$ general cross-section measurement, independent from the quantum interference
- Possible top mass extraction in $WbWb$ phase-space
- Search for toponium resonance formation in $WbWb$ phase-space

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