Search for ttH production at high-p_T with the ATLAS detector

The associated production of the **Higgs boson with a pair of top/anti-top quarks** (ttH) is the only process providing **direct access to the measurement of the Yukawa coupling** between the Higgs boson and the top quark. The aim of this analysis is the measurement of the **cross section** of the process. The presented results exploit the data collected during the **2015** and **2016** by the ATLAS experiment during the LHC collisions at a center-of-mass energy of **13 TeV. It is the first time that a boosted category** is considered in a ttH ATLAS analysis.

Boosted topology

- A particle is generally defined "boosted" if its p_T is more than twice its resonant mass: **top quark p_T > 350 GeV** and **Higgs boson p_T > 250 GeV**;
- most of the decay products are collimated within a ΔR < 1.0 (Fig.1).

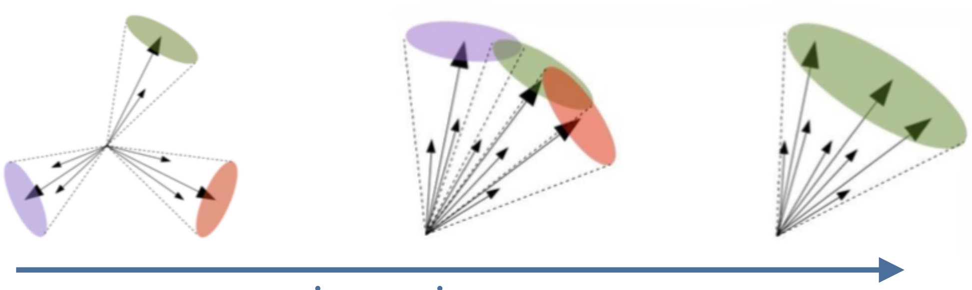

Fig.1: topology of a three-body decay increasing the decaying particle p_T.

- The ability to resolve the individual hadronic decay products using the standard R=0.4 narrow-cone jet algorithms starts degrading;
- **tagging** (for top quark and Higgs boson) and **re-clustering techniques** have been tested for the boosted ttH analysis.

Re-clustering technique

Problem

Traditionally only a few choices of radius parameter R are used for all analyses, because **every jet configuration must be calibrated**.

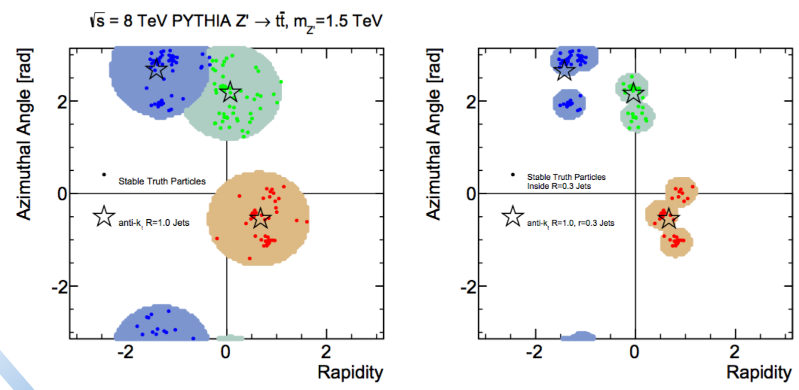

Fig.2: Standard large-R jet reconstruction algorithm (left), re-clustering algorithm (right).

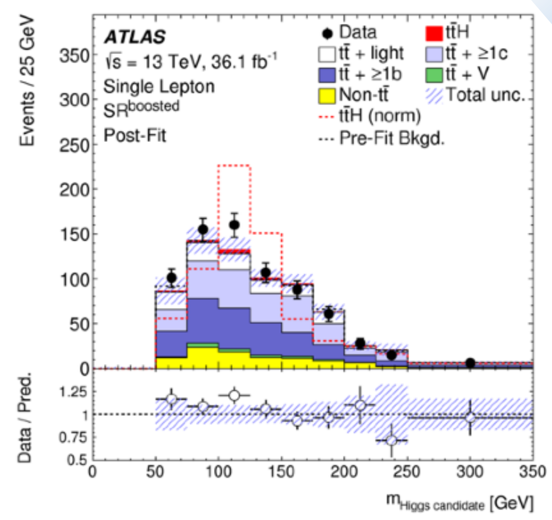

Fig.3: Higgs candidate mass distribution, reconstructed by re-clustering technique.

RE-CLUSTERING

- Allows a broader class of algorithms and jet radius parameters to be used by analyses;
- **no additional calibrations required**;
- **anti-k_T small-R jets (R=0.4) re-clustered into large-R jets** (R = 1.0, p_T > 200 GeV, |η| < 2, m > 50 GeV) in this analysis (Fig.2).

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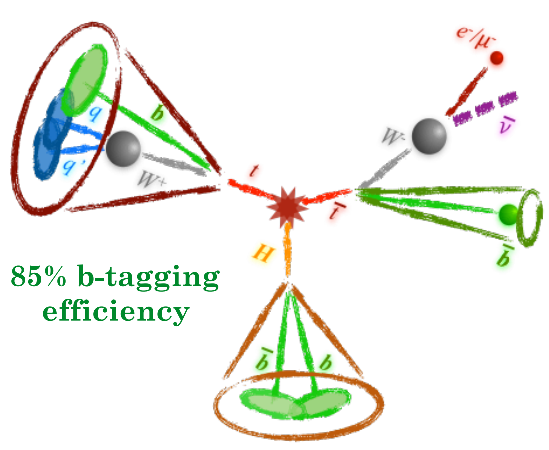
Boosted signal region selection

- Exactly **one charged lepton (e or μ)**;
- **one Higgs candidate:** one reclustered jet (p_T > 200 GeV) with two b-tagged small-R sub-jets;
- **one Top candidate:** one reclustered jet (p_T > 250 GeV) with one b-tagged small-R sub-jet and one non-b-tagged sub-jet;
- **one b-tagged jet** outside the two reclustered jets.



85% b-tagging efficiency

Process	Pre-fit Yield
tt+ light	180 ± 120
tt+ ≥1c	168 ± 70
tt+ ≥1b	236 ± 89
tt+V	16 ± 3
non-tt	104 ± 30
ttH	16 ± 2
data	740

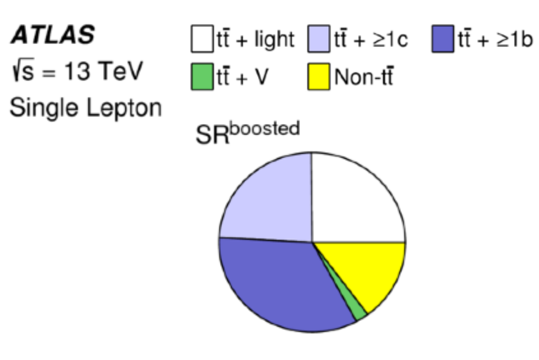


Fig.4: pre-fit background composition of the boosted SR.

Analysis strategy

- **Signal identification:** MVA (BDT, Fig.5) using event kinematics and topology, b-tagging information:
  - identification of very low signal over a very large background;
- **combination with the resolved channel:**
  - single-lepton
  - di-lepton
- **signal extraction:** BDT distribution (Fig.6) into a combined fit.

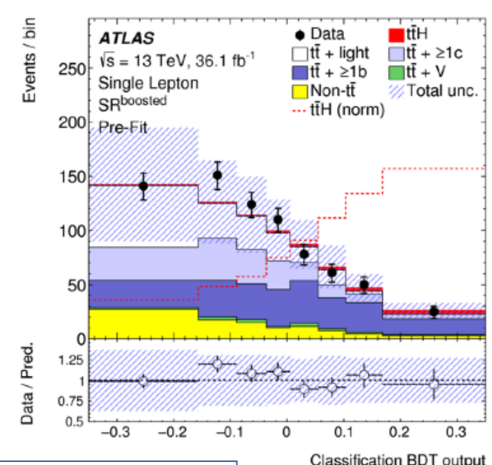


Fig.5: data/MC comparison for the BDT discriminant, before the combined dilepton and single-lepton fit to the data.

$$\mathcal{L}(\mu,\theta) = \underbrace{\mathcal{L}_{poisson}(N_{data}}_{\text{observed data events}}|\underbrace{(\mu s(\theta)+b(\theta))}_{\text{expected signal and background events, adjusted according to the corresponding systematics uncertainty}}) \times \underbrace{\mathcal{L}_{gauss}(\theta)}_{\text{modelling of systematics: }\theta\text{ nuisance parameters}}$$

Aim of this analysis: estimation of the ttH signal strength μ and its 95% CL upper limit

$$\mu_{t\bar{t}H} = \frac{\sigma(t\bar{t}H)_{obs}}{\sigma(t\bar{t}H)_{SM}}$$

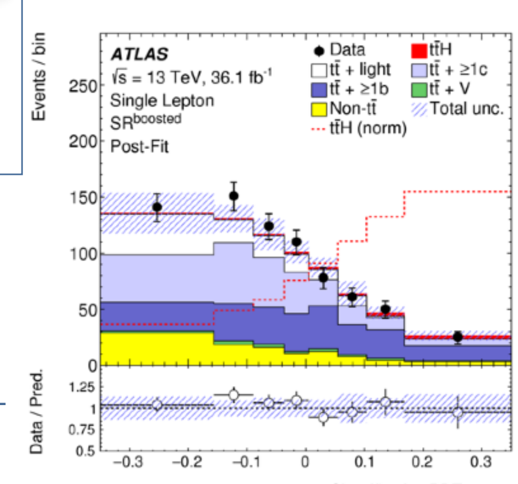


Fig.6: data/MC comparison for the BDT discriminant, after the combined dilepton and single-lepton fit to the data.

Backgrounds and systematics

- Main background: **tt+HF jets**, estimated from MC and constrained by dedicated control regions;
- **experimental and theoretical uncertainties on both signal and background** have been considered;
- b-tagging and JES: main sources of experimental uncertainty.

Uncertainty source	$\Delta\mu$	
$tt + \geq 1b$ modeling	+0.46	−0.46
Background-model stat. unc.	+0.29	−0.31
b-tagging efficiency and mis-tag rates	+0.16	−0.16
Jet energy scale and resolution	+0.14	−0.14
$t\bar{t}H$ modeling	+0.22	−0.05
$t\bar{t} + \geq 1c$ modeling	+0.09	−0.11
JVT, pileup modeling	+0.03	−0.05
Other background modeling	+0.08	−0.08
$t\bar{t}$ + light modeling	+0.06	−0.03
Luminosity	+0.03	−0.02
Light lepton (e,μ) id., isolation, trigger	+0.03	−0.04
Total systematic uncertainty	+0.57	−0.54
$t\bar{t} + \geq 1b$ normalization	+0.09	−0.10
$t\bar{t} + \geq 1c$ normalization	+0.02	−0.03
Intrinsic statistical uncertainty	+0.21	−0.20
Total statistical uncertainty	+0.29	−0.29
Total uncertainty	+0.64	−0.61

Fig.7: Breakdown of the contributions to the uncertainties in μ. The contribution of the different sources of uncertainty is evaluated after the fit.

- **tt+b-jets and tt+c-jets modelling uncertainties (Fig.7)** have the largest impact;
- corresponding **normalisation factors left free** into the fit.

Combined results from the resolved and boosted categories

- **Motivation** for adding the boosted category to it:
  1. fewer **combinatorial background**;
  2. easier **system reconstruction**;
  3. testing **new methods for the future**, to increase sensitivity in the high-p_T regime.
- Sensitivity limited by systematics;
- an improved modelling of tt+≥1b background will be crucial for future efforts.

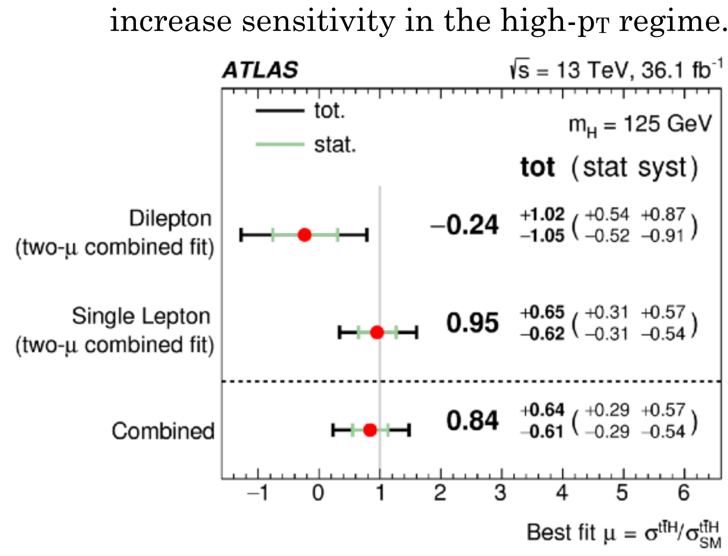


Fig.8: Signal strength determined for the single-lepton (resolved+boosted), di-lepton and their combination.

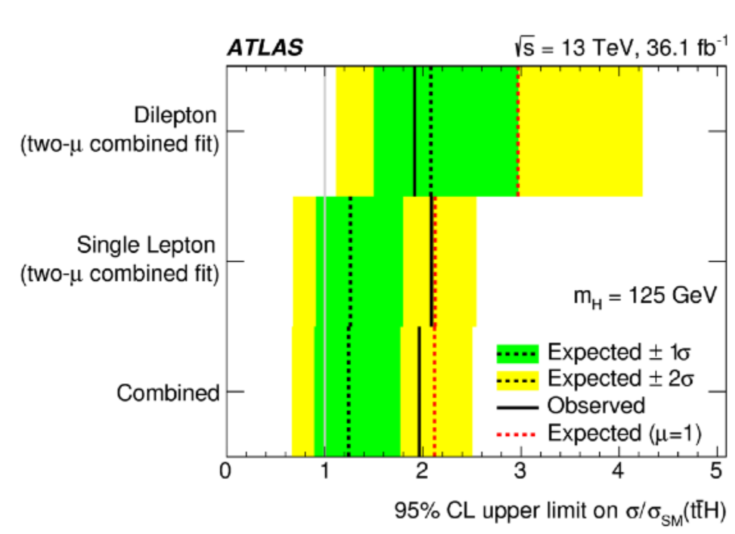


Fig.9: 95%CL limits on the signal strength for the single-lepton (resolved+boosted), di-lepton and their combination.

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