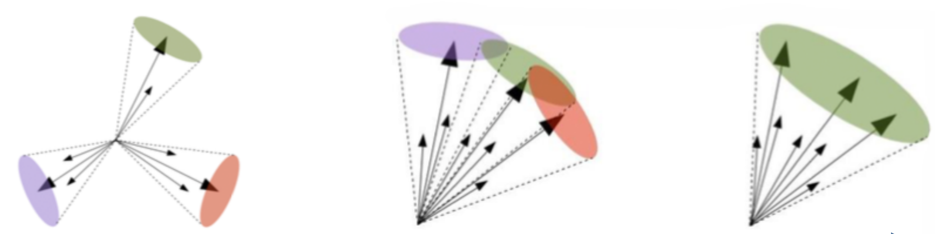
Search for the ttH production in high-p_T regimes with the ATLAS detector

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 **signal strength** of the process. The study of this channel is fundamental, since the results obtained by the previous data-taking have not the necessary statistical significance to confirm the existence of the ttH production. **For the first time a boosted category** has been studied in the ttH channel.

Boosted topology

- A particle is generally defined "boosted" if its p_T is more than twice its resonant mass: **top quark with p_T > 350 GeV** and **Higgs boson with p_T > 250 GeV**;
- Most of the decay products are collimated within a $\Delta R < 1.0$ (Fig.1);
- The decay products are developed in a **single hadronic jet with radius R up to 1.0** (large-R jet).



increasing p_T

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 narrow-cone jet algorithms starts degrading;
- **Trimmed large-R jets** (tagging top quark and Higgs boson) and **re-clustering techniques** have been tested for the boosted ttH analysis.

Re-clustering technique

Traditionally only a few choices of radius parameter R are used for all analyses, because **every jet configuration must be calibrated** to account unmeasured energy deposits and other experimental effects.

Given d_{ij} (between particles 4-vectors), d_{iB} (between particle and beam 4-vectors), recursively combine sub-jets until there are none left (Fig.2).

- use metrics $\mathbf{d_{ij} = \min(p_{Ti}^{2n}, p_{Tj}^{2n}) R^2_{ij}/R^2}$;
- if $\boldsymbol{i \neq B}$, sub-jet $\boldsymbol{i}$ and $\boldsymbol{j}$ are combined into one sub-jet (sum of the original two 4-vectors);
- if $\boldsymbol{i = B}$, sub-jet $\boldsymbol{i}$ declared as a jet and removed from the list of sub-jets.

- Allows a much broader class of algorithms and jet radius parameters to be selected by analyses;
- **no additional calibrations required** for different re-clustered jet radius;
- **anti-k_T jets (R=0.4) used to re-cluster the large-R jets** (R = 1.0, 200 < p_T < 1500 GeV, $|\eta|$ < 2, m < 50 GeV) in this analysis.

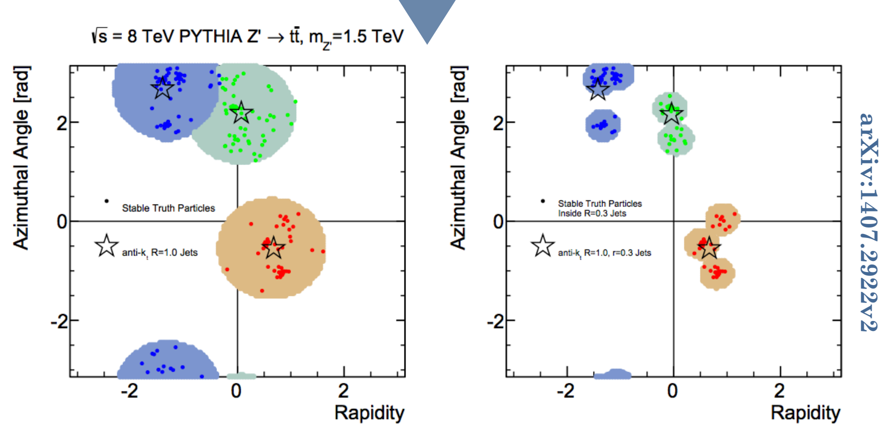
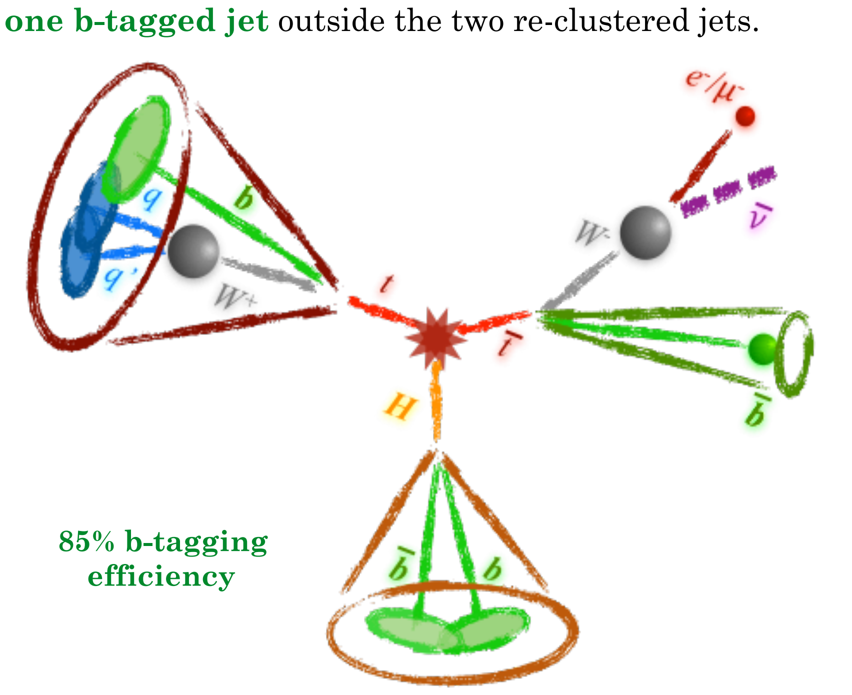


Fig.2: Standard reconstruction algorithm (left), re-clustering algorithm (right).

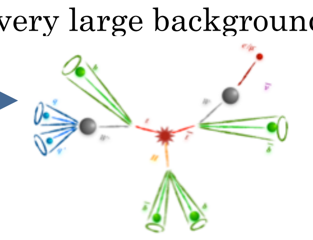
Description of the signal region selection

- exactly **one lepton**;
- **one Higgs candidate:** one re-clustered jet (p_T > 200 GeV) with two associated b-tagged jets:
  - ➡ η and ϕ comparison between sub-jet and small-R jet
- **one Top candidate:** one re-clustered jet (p_T > 250 GeV) with one associated b-tagged jet and one non-b-tagged jet:
  - ➡ removing the Higgs tagged reclustered jet from the collection, before searching for the Top candidate
- **one b-tagged jet** outside the two re-clustered jets.



Analysis strategy

- **Event selection:** single lepton;
- **Signal identification:** MVA (BDT, Fig.3) 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



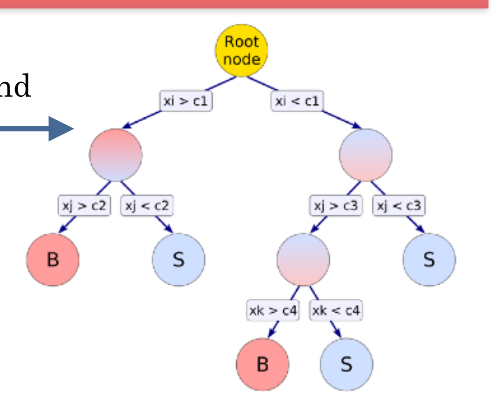


Fig.3: depiction of a BDT, with different cuts (c_1, c_2, c_3, c_4) on variables (x_i, x_j).

- **Signal extraction:** BDT distribution into a combined fit, using a Likelihood function to determine the best value of the signal strength.

$$\mathcal{L}(\mu,\theta) = \mathcal{L}_{poisson}(N_{data} | (\mu s(\theta) + b(\theta)) \times \mathcal{L}_{gauss}(\theta)$$

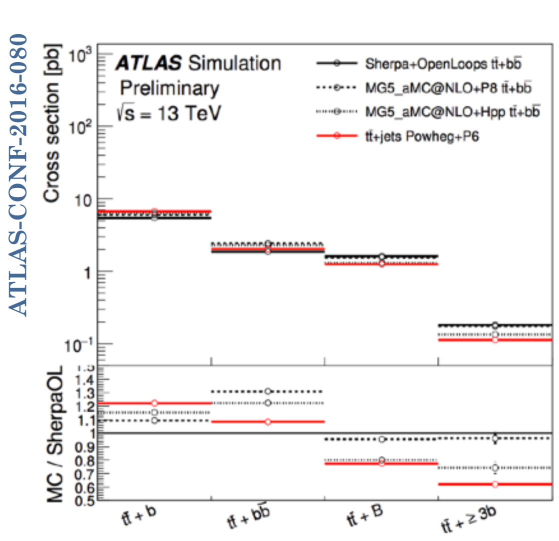
observed data events | expected signal (s) and background (b) events, adjusted according to the corresponding systematics uncertainty | modelling of systematics: θ nuisance parameters

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

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

Systematic uncertainties

- Systematic uncertainties have been estimated for all the backgrounds considered via both **MC and data driven techniques**;
- modelling of **both signal and some background processes** has been considered;
- **tt modelling** is the most important source of instability, especially for the tt+b-jets production process (Fig.4).



- **tt+b-jets** and **tt+c-jets** have the highest disagreement between different generators;
- corresponding **normalisation factors left free** into the fit procedure.

Fig.4: tt+b-jets events for different simulations, compared to the nominal one (PP6), for different additional jets origin and numbers.

Combined results from the resolved and boosted categories

With more luminosity, corresponding to 36.1 fb^{-1}, the boosted category will be an interesting addition to the results of the resolved channel (Fig.5 and Fig.6, obtained using 13.2 fb^{-1}).

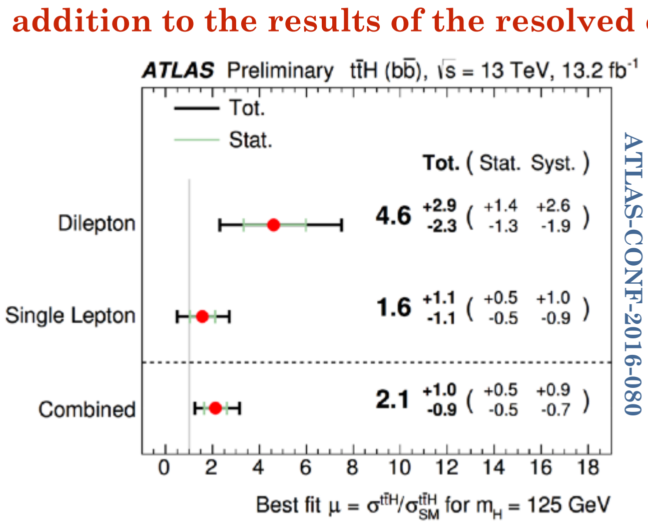


Fig.5: Signal strength determined for the single-lepton (resolved), di-lepton and their combination.

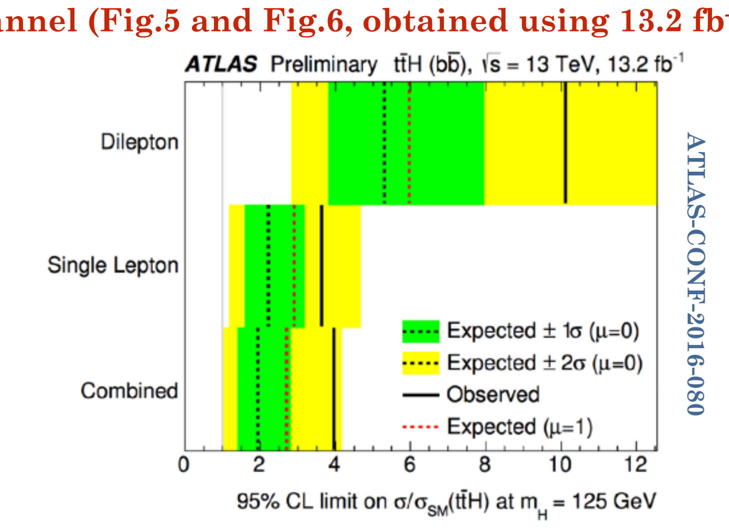


Fig.6: 95%CL limits on the signal strength for the single-lepton (resolved+boosted), di-lepton and their combination.

- **Motivation** for adding the boosted category to the resolved channel:
  1. fewer **combinatorial background**;
  2. easier **system reconstruction** thanks to the re-clustered techniques;
  3. testing **new methods for the future**, measuring the Higgs p_T in ttH events (useful for differential cross-section analysis).

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Venezia, EPS 2017