The understanding of the Electroweak Symmetry Breaking after the discovery of a Higgs-like boson with the ATLAS detector

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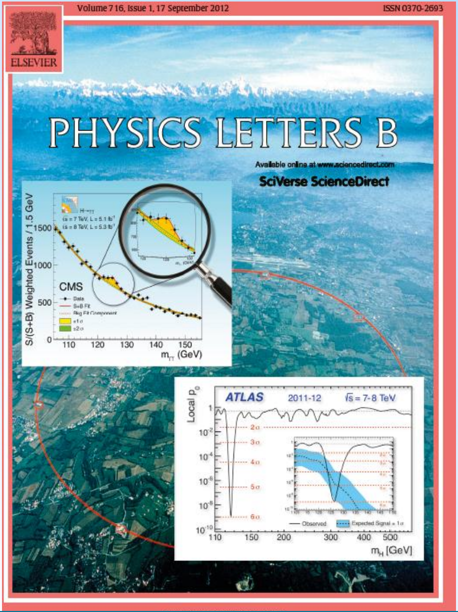
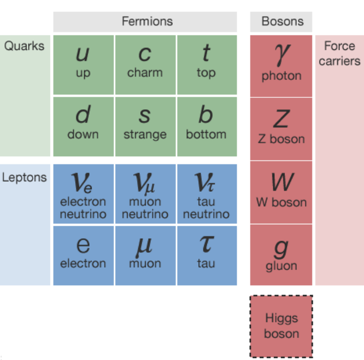
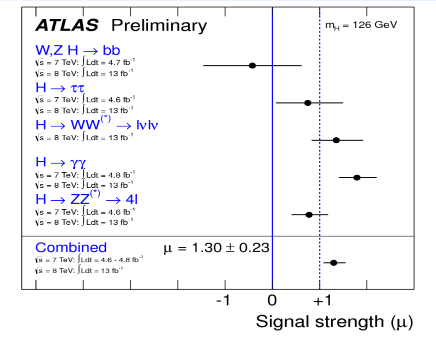


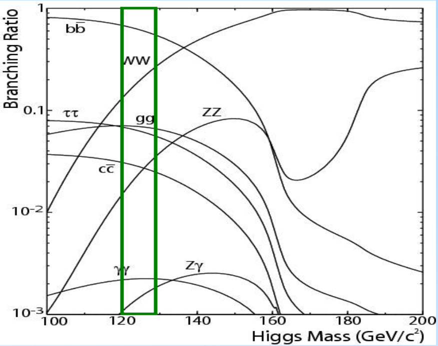
Historic milestone for the particle physics community in 2012.



Combined search of the SM Higgs Boson

Most updated results (before Moriond 2013) on the combined measurements of the new Higgs-like boson by ATLAS. Similar picture by CMS.





The entire LHC dataset needs to be digested and a new era of precise measurements just began. As of today,

- NO DIRECT EVIDENCE OF THE HIGGS BOSON COUPLING TO FERMIONS;
- MANY BSM SCENARIOS STILL TO BE TACKLED.

Outline

1. Higgs to *bb*
   a. Overview of the public results
   b. *b*-Jet reconstruction and calibration
   c. Trigger strategies
   d. *ttH* production cross section in the all-hadronic final state
2. Higgs exotics decay
   a. Overview of the benchmark model
   b. Trigger and reconstruction strategies
   c. Analysis and goal of the measurement
3. Conclusions

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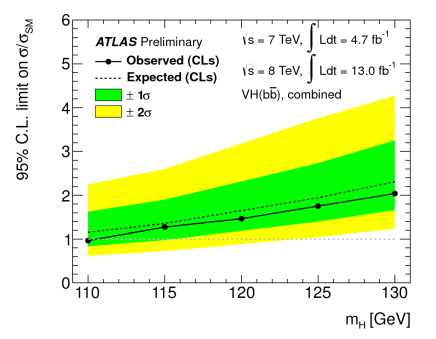
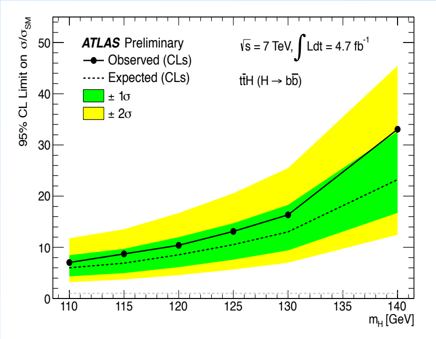
Higgs coupling to fermions



Combination of $WH \to bb$ and $ZH \to bb$ in the channels with 0, 1 or 2 leptons.



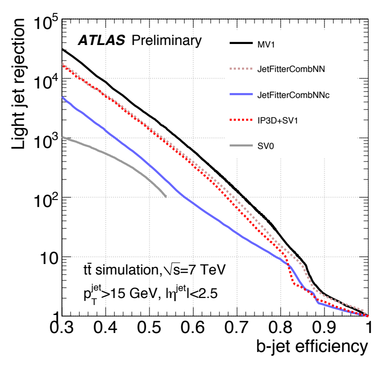
Semi-leptonic $ttH \to bb$.

The all-hadronic $ttH \to bb$ is entering into the game. Essential contribution to eventually discover the Higgs produced in association with tt and to study the top-Higgs Yukawa coupling.

b-Tagging

Crucial ingredient for $H \to bb$ searches. Class of algorithms to identify jets from the hadronization of b quarks exploiting physical properties

1. semi-leptonic decays of B-hadrons ($\mathcal{BR}(b \to \ell X) \approx 11\%$, $\mathcal{BR}(b \to c \to \ell X) \approx 10\%$) and its relatively larger transverse momentum distribution with respect to the jet axis
   $\Longrightarrow$ soft lepton tagging
2. lifetime of B-hadrons relatively long ($\tau_b \approx 1.6$ ps, $c\tau_b \approx 450\mu$m and flight path lenght $\langle l \rangle = \beta\gamma c\tau \approx 5$ mm)
   $\Longrightarrow$ spatial tagging, based on impact parameters and secondary vertices



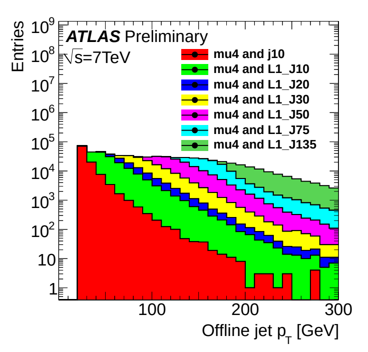
b-tagging calibration

Tracking details notoriously hard to simulate. Analyses relying on *b*-tagging techniques need to correct the data/MC discrepancy of tagging rate.

b-Tagging calibration based on reconstructing event topologies with *b*-jets without using any (or uncorrelated) *b*-tagging information. Two class of methods based on a sample with muons inside jets or *tt* candidates.

For the first class of methods, a set of triggers requiring a geometrical matching between a muon and a jet was deployed online.

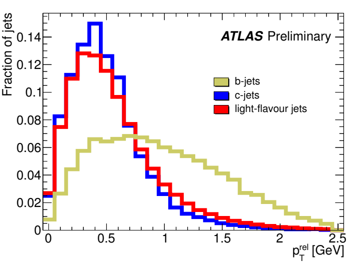
Different jet thresholds to cover the entire jet p_T spectrum while keeping the total bandwidth fixed and limited to few Hz.

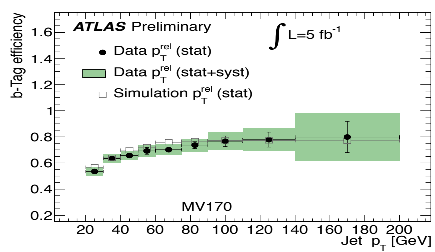


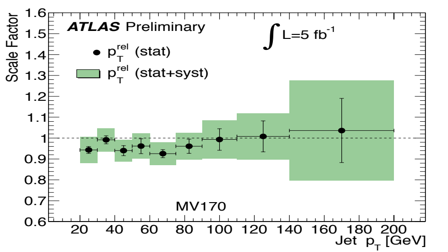
b-Tagging calibration using p_T^{rel}

Basic idea:

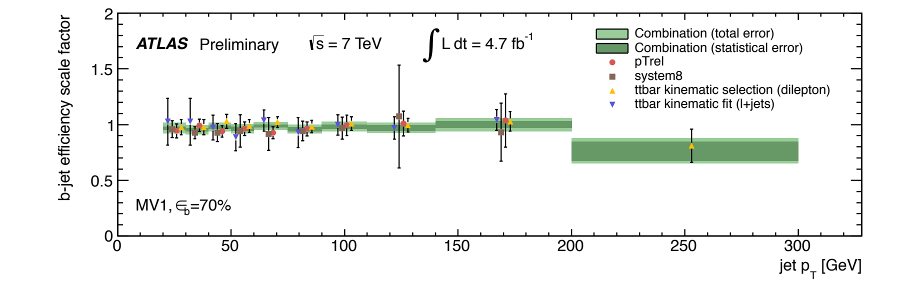
1. use p_T^{rel} (momentum of the muon transverse to the combined muon+jet axis) templates for *b*- *c*- and light-flavour jets;
2. fit the p_T^{rel} distribution on data;
3. obtain the fraction of *b*-jets before and after a *b*-tag requirement and extract the *b*-tagging efficiency.







b-Tagging calibration result



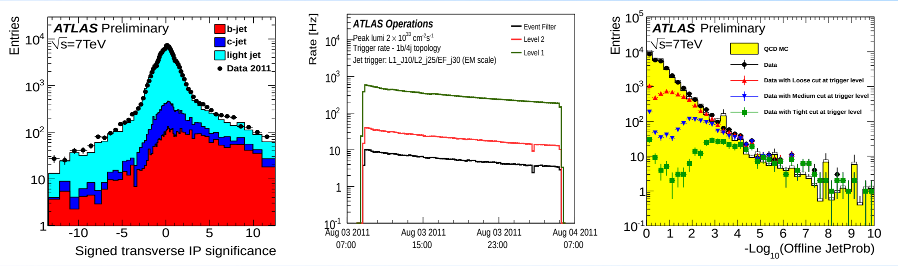
The data/MC discrepancy of tagging rates is corrected applying per-jet scale factor to simulation. Scale factors are obtained combining the results from all the *b*-tagging calibration methods

b-Jet triggers

The baseline triggers for $H \to bb$ are based on single lepton or MET objects.

The *b*-jet triggers extend the ATLAS physics potential selecting event with lower jet thresholds and enriched in *b*-jets.

As an example, *b*-jet triggers are used for the all-hadronic ttH cross section measurement and are promising triggers for the $ZH \to bb$ with 0 leptons channel after LS1.



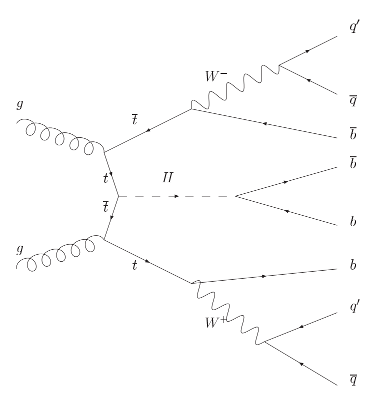
All-hadronic *ttH* cross section analysis

The top-Higgs Yukawa coupling is the only coupling directly measurable and allows probing for new physics contribution in the *ggH* and $\gamma\gamma H$ vertices.

Challenges:

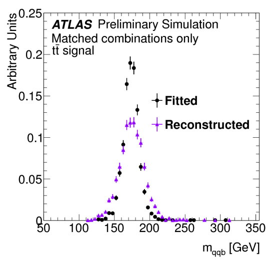
- very busy events with large combinatorial background and hard to reconstruct kinematically
- lower production cross section compared to the other Higgs production modes
- all-hadronic decay channel has the largest branching ratio but suffers from the huge multi-jet background

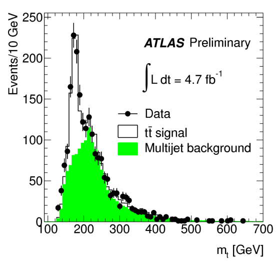
Redirect the knowledge acquired in the all-hadronic *tt* cross section measurement for the *ttH* analysis.



From all-hadronic *tt* to all-hadronic *ttH*

Similar signal topology with different jet multiplicity. Overwhelmed by QCD multi-jets. Very different production cross section ($\sigma(tt)/\sigma(ttH) \sim 2000$ at $\sqrt{s} = 7$ TeV).
tt measurement dominated by systematics (total uncertainty 35%, uncertainty on background modeling 4%) [CONF-NOTE-2012-031].





Kinematic fit based on a likelihood approach

Fully data-driven estimate of the background

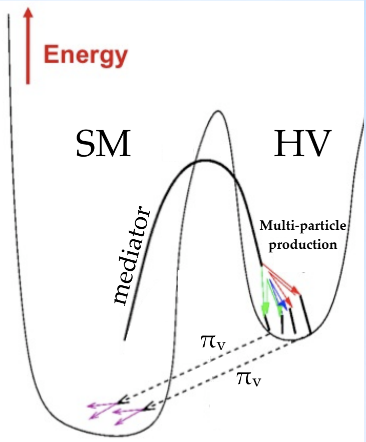
Goal:

- Same sensitivity of the semi-leptonic *ttH* analysis
- Sensitivity for σ_{SM} combining the *ttH* analyses with the full 2011-2012 dataset

Outline

Invisible Higgs decays

The understanding of the nature of the Higgs-like particle includes studying an invisibly decaying Higgs boson with a $\mathcal{BR}$ down to $\simeq 10\%$ to explore BSM contributions.



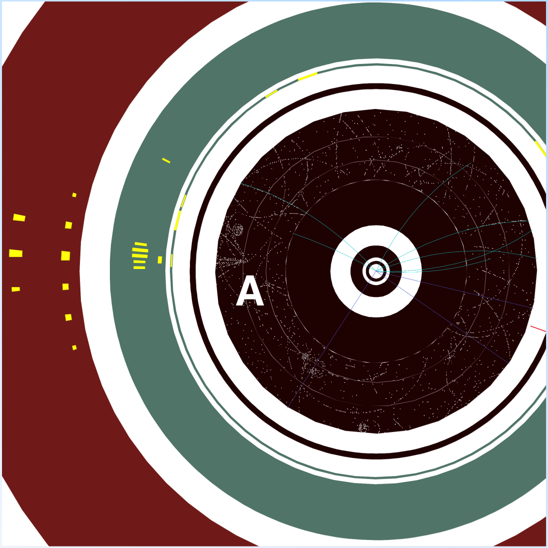
Models requiring non-standard analysis strategies and difficult final states need special care since possible signals are difficult to extract from the available data.

The Hidden Valley (HV) models are a general class of models which predict new long-lived, weakly-interacting particles.

HV and SM particles communicate through a mediator particle (Higgs).

The lightest HV particle, π_v, is stable in the HV sector and consequently can decay back to SM particles with long lifetimes.

[References here and here]



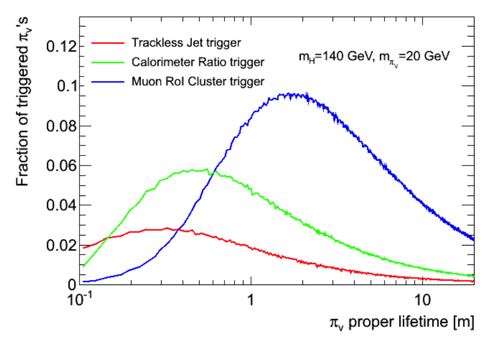
Simulated $H \to \pi_v \pi_v$ with one π_v decay in the TRT

Signature-driven triggers

Events with long-lived, neutral particles present many challenges at the trigger and reconstruction level. Standard ATLAS triggers (and the detector itself) are designed to select physics originating at or near the interaction point.

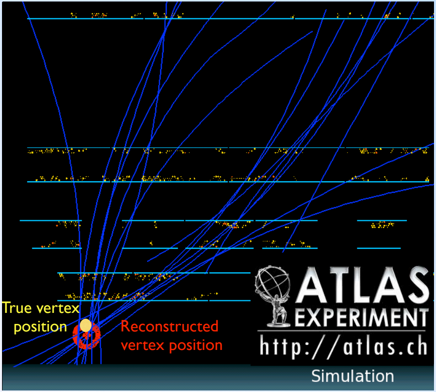
Three signature-driven triggers have been designed and deployed.
Each trigger is dedicated for a particular region of the ATLAS detector.

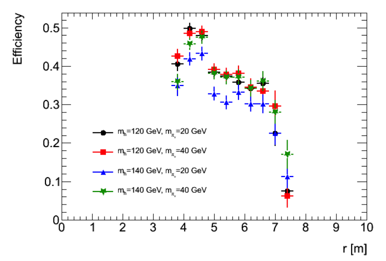
The expected number of triggered events is obtained

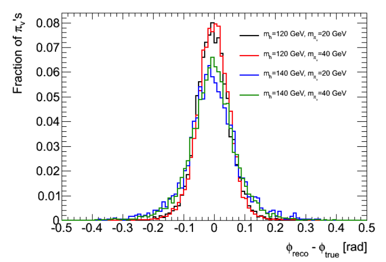


Detector region	Key feature	Trigger name
from SCT to ECal	Jet with track isolation	Trackless Jet trigger
HCal	Isolated jet with very low EM fraction	Calorimeter Ratio trigger
MS	Isolated cluster of muon RoIs	Muon RoI Cluster trigger

Standalone MS vertex routine







Vertices in the MS are reconstructed with a resolution of 20/32 cm in z/r.

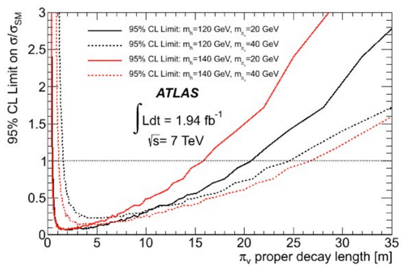
Analysis strategy

Search for two back-to-back π_v's. Focusing on decays in the ID or MS.

Main improvements compared to the 2011 published result: factor of 10 more luminosity and inclusion of decays in the ID exploiting new tuning of the tracking and vertexing in the ID.

Background estimation fully data-driven considering contributions from cosmic rays, punch-through jets and beam background.

New decay scenarios and theoretical interpretations are also being considered.



[1203.1303]

Expect to greatly extend the exclusion region in lifetime for a wider range of Higgs boson and π_v masses. Focus at $m_H = 126$ GeV looking at $\mathcal{BR}$ down to 10%.

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Conclusions

Exciting times in particle physics.

A new era of precise measurements began with the discovery of the Higgs-like particle announced in July 2012.

Probing the nature of the new Higgs-like particle looking at the coupling to fermions and to contributions beyond the SM is crucial.

In particular:

- No evidence of a Higgs-like particle in the *bb* decay channel. The *ttH* production channel allows to add sensitivity in the search while also looking at the top-Higgs Yukawa coupling for possible new physics contribution. The all-hadronic decay channel is particularly challenging and requires sophisticated trigger strategies.
- Partial exotics decay of the new Higgs-like particle is a possibility. Looking at very displaced decays is a not-excluded BSM scenario which requires ad-hoc trigger and reconstruction techniques.