EPS HEP 2013 - Stockholm, 18-24 July 2013

The new Higgs particle in the $H \to ZZ^* \to 4l$ searches with the ATLAS detector

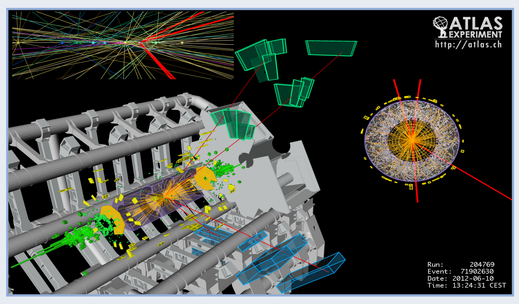
Abstract

This poster presents results and measurements of the properties of the newly observed Higgs particle in the decay channel $H \to ZZ^{(*)} \to l^+l^-l'^+l'^-$, where $l, l' = e$ or μ. The analysis is based on 4.6 fb^{-1} and 20.7 fb^{-1} of proton-proton collisions at 7 TeV and 8 TeV, respectively, recorded with the ATLAS detector at the LHC. An excess of events over background is observed at $m_H = 124.3$ GeV with a significance of 6.6 standard deviations. The mass is measured to be $m_H = 124.3^{+0.6}_{-0.5}$ (stat) $^{+0.5}_{-0.3}$ (syst) GeV and the signal strength at this mass is found to be $\mu = 1.7^{+0.5}_{-0.4}$.

A spin-parity analysis is also performed: the Higgs-like boson is found to be compatible with the Standard Model (SM) expectation of 0^+, when compared pair-wise with 0^-, 1^+, 1^-, 2^+ and 2^- [1].

Event Selection

- $p_{T_{1,2,3,4}} > 20, 15, 10, 7/6$ (e/μ) GeV
- $50 < m_{12} < 106$ GeV
- $115 > m_{34} > 12$ to 50 GeV (depending on m_{4l})
- resolution improved (12-19%): applied FSR correction and on-shell Z mass constraint



Signal properties:

- $\sigma \times BR \sim 2.5$ fb (@ m_H=125 GeV)
- high purity (S/B$\sim$1.6 @ m_H=125 GeV)
- narrow peak: width around 2 GeV at 125 GeV (dominated by experimental resolution)

Background Estimate

Irreducible Background

The irreducible ZZ* background is estimated using MC simulation nomalised to the theoretical cross section. It constitutes **70% of the whole background** and the rejection is done through kinematic cuts, e.g. m_{34}. Data and Monte Carlo are compared in different regions of m_{4l}.

Reducible Background

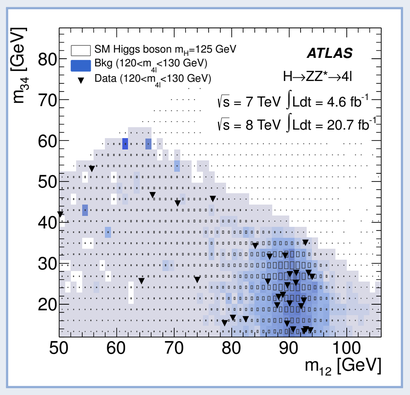
Composed of Zbb, Z+jets and $t\bar{t}$ and estimated from 'background-enriched' *control regions* in data:

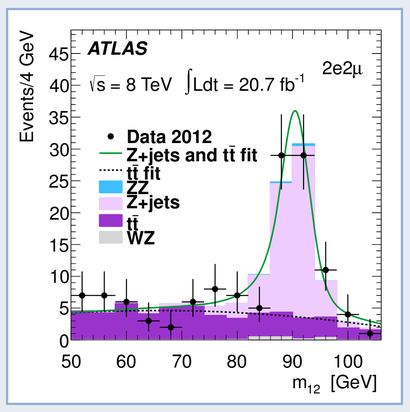
- **No isolation requirements on the subleading pair**
- $ll + \mu\mu$: leptons fails the impact parameter significance requirement (*to **enhance the Zbb and $t\bar{t}$ contribution***)
- $ll + ee$: fake, conversions, heavy q decays; relaxed electron identification (*to **enhance the Z+jet contribution***)

Expected and observed events

Window of 5 GeV around 125 GeV

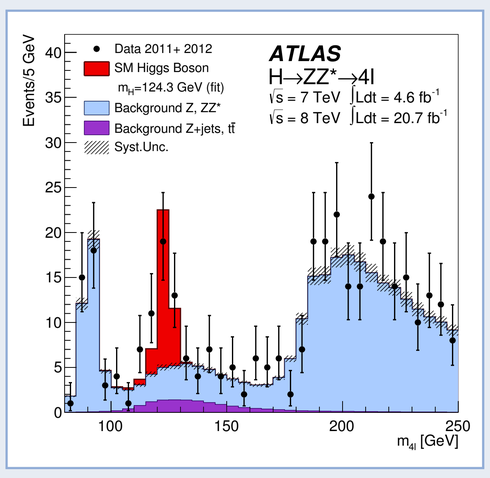
signal	ZZ*	Z+jets+$t\bar{t}$	data
15.9 $\pm$ 2.1	7.4 $\pm$ 0.4	3.74 $\pm$ 0.93	32

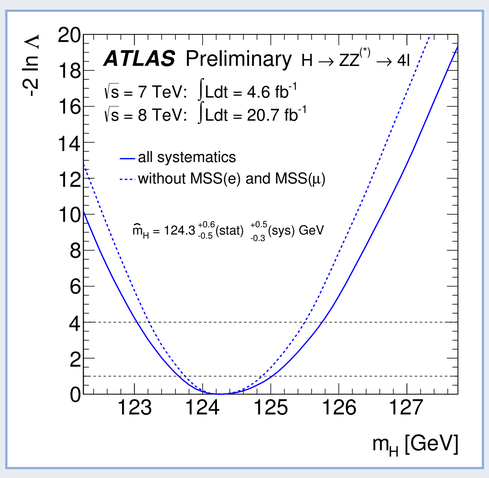




Mass Measurement

4-lepton invariant mass for the selected candidates compared to the background expectation signal expectation for the $m_H = 125$ GeV hypothesis is also shown.





The **measured mass** is $m_H = 124.3^{+0.6}_{-0.5}$ (stat) $^{+0.5}_{-0.3}$ (syst) GeV

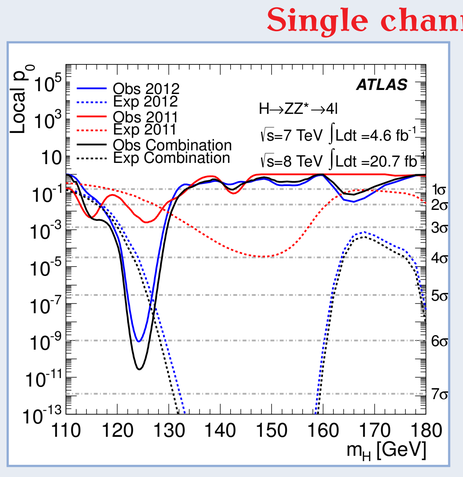
Signal strength

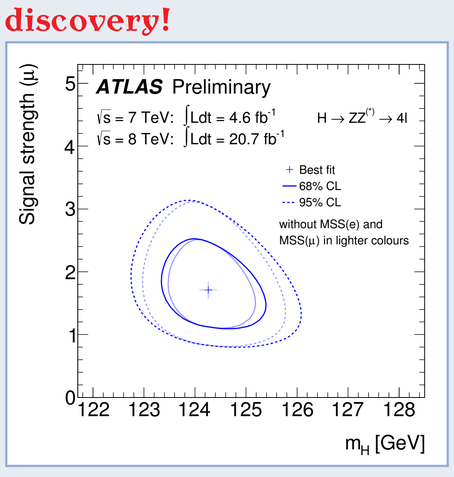
Maximum deviation from background-only expectation observed for $m_H = 124.3$ GeV:

Local p0-value: 2.7×10^{-11} or **6.6 σ**

Expected from SM Higgs: $\sim$ **4.4 σ**

Single channel discovery!





Signal strength at the best fit value for m_H (124.3 GeV) is $\mu = 1.7^{+0.5}_{-0.4}$.

Spin-Parity Measurement

Spin and parity can be measured using:

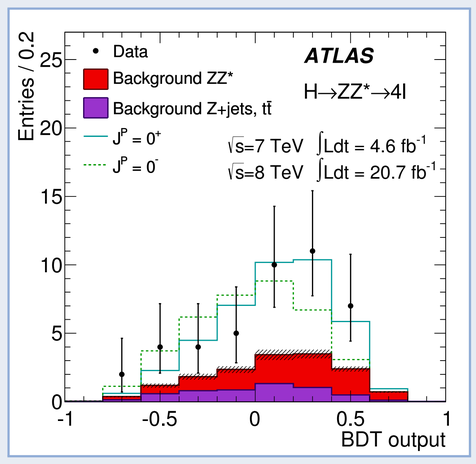
- m_{12} and m_{34}
- $\theta_1, \theta_2 \to$ decay angles of negative leptons
- $\phi \to$ angle between the Z_1 and Z_2 decay planes
- $\phi_1 \to Z_1$ decay plane angle
- $\theta^* \to Z_1$ production angle

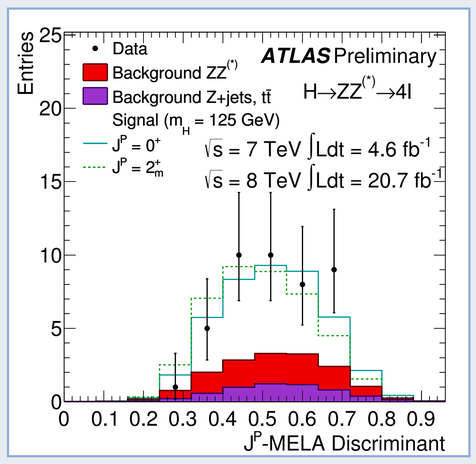
Two Multivariate techniques:

- *Boosted Decision Tree* (**BDT**)
- *Matrix-Element Likelihood-Analysis* (**JP-MELA**)

Expected discrimination between 0^+ and other hypotheses:

0^-	1^+	1^-	2^-	2^+_m
$> 2.5\,\sigma$				$\sim 1.5\,\sigma$





The **observed CL$_s$ exclusion** confidence levels for 0^-, 1^+, 1^- and 2^+_m hypotheses are 97.8% (99.6%), 99.8% (99.4%), 94.4% (96.4%), and 83.2% (81.8%), respectively, in favour of 0^+ for the BDT (JP-MELA).

Standard Model (0^+) hypothesis favoured!

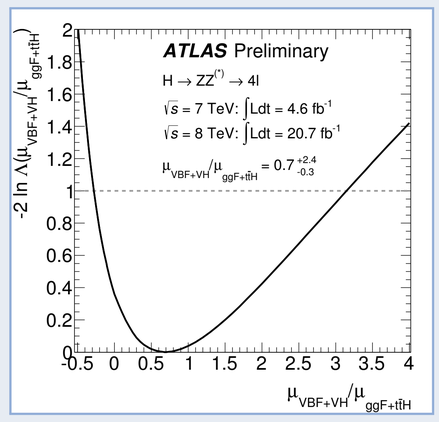
Event categorization

Categories are exclusive!

VBF-like: selection cuts + $N_{jet} \geq 2$, $|\eta_{j_1} - \eta_{j_2}| > 2$ and $m_{j_1,j_2} > 350$ GeV

VH-like: selection cuts + additional lepton p_T >8 GeV

ggf-like: selection cuts



In m_{4l} 115-130 GeV

1 VBF candidate @ 123.5 GeV

SM Higgs boson expectation 0.71 ± 0.10

Distinguishing couplings to vector bosons or fermions

$\mu_{VBF+VH}/\mu_{ggF+ttH} = 0.7^{+2.4}_{-0.3}$

Conclusions

- The **observation** of the Higgs particle is **fully confirmed** [2]
- **Single channel discovery** $\to$ 6.6 standard deviations
- **Preference for Standard Model (0^+) hypothesis** [3]

References

[1] *Measurements of the properties of the Higgs-like boson in the four lepton decay channel with the ATLAS detector using 25 fb^{-1} of proton-proton collision data* (**ATLAS-CONF-2013-013**)

[2] *Observation of a new particle in the search for the Standard Model Higgs boson with the ATLAS detector at the LHC* (**Phys. Lett. B 716 (2012) 1-29**).

[3] *Evidence for the spin-0 nature of the Higgs boson using ATLAS data* (**arXiv:1307.1432 [hep-ex]**)

[4] *Measurements of Higgs boson production and couplings in diboson final states with the ATLAS detector at the LHC* (**arXiv:1307.1427 [hep-ex]**).

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