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Measurement of the spin and parity of the new boson observed at 125 GeV in the $H \to ZZ^* \to 4\ell$ search at ATLAS

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Summary. — Most recent results on spin-parity (J^P) measurement of the new particle observed in the Higgs boson search in the $H \to ZZ^* \to 4\ell$ decay channel are presented. The J^P state of this boson is probed exploiting two complementary multivariate analysis techniques (using matrix element description of the process or a Boosted Decision Tree discriminant). Results, based on about 25 fb^{-1} collected in pp collisions at $\sqrt{s} = 7$ and 8 TeV, show how the 0^+ state is favoured against specific 0^-, 2^+, 2^- and spin 1 hypotheses.

PACS 14.80.Bn – Standard-model Higgs bosons.
PACS 14.80.Ec – Other neutral Higgs bosons.

This analysis is based on about 25 fb^{-1} collected in pp collisions at $\sqrt{s} = 7$ and 8 TeV with the ATLAS detector at the LHC. Events are selected within the search for the decay $H \to ZZ^* \to 4\ell$, as described in ref. [1], with the additional requirement on the reconstructed four-lepton invariant mass to be $115 < m_{4\ell} < 130$ GeV.

Different signal J^P hypotheses lead to different angular and di-lepton mass distributions [2]; a discriminant can be built to exploit the full final state information to differentiate among them and between them and the background. Results are shown for a discriminant defined as $J^P\text{-MELA}(0^+, J^P) = p(\text{data}|0^+)/[p(\text{data}|0^+) + p(\text{data}|J^P)]$, where $p(\text{data}|X)$ is the likelihood of the observed data sample given a signal J^P hypothesis, which incorporates matrix-element description of final state kinematics corrected for acceptance and selection effects.

Events are separated in two mass regions, $121 < m_{4\ell} < 127$ GeV and $115 < m_{4\ell} < 121$ GeV $\cup$ $127 < m_{4\ell} < 130$ GeV, to enhance signal to background separation. A total of 43 events is observed, with 16 events expected from background only; observed local significance for a boson mass of 125.5 GeV is 6.6 standard deviations.

Hypothesis testing is performed using the CL_s method. The log-likelihod ratio with profiled nuisance parameters is used as a test statistics, whose distribution is obtained from many simulated experiments, as shown in fig. 1 right.

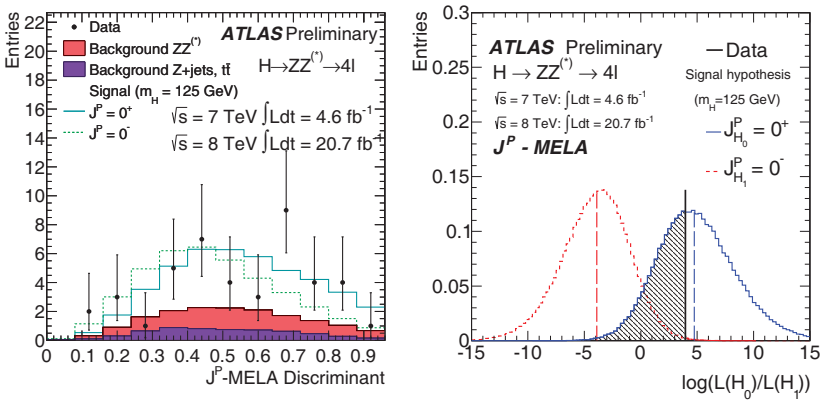

Fig. 1. – Distributions of J^P-MELA$(0^+, 0^-)$ (left) and corresponding test statistics (right) [1].

Specific $J^P = 0^-, 1^+, 1^-, 2^+_m$ and 2^- models are tested, as defined in ref. [2]; the 2^+_m state is tested for a fraction of gg fusion relative to $q\bar{q}$ annihilation production mechanisms varying between 0 and 100%. Discriminant shapes are obtained from full-simulation Monte Carlo samples (signal, ZZ^* background) or data-driven control regions ($Z + bb/Z + jj/t\bar{t}$). Systematic uncertainties on signal and background yields ($\sim$ 20% for signal, 7% for ZZ^*, 30% for reducible backgrounds), relative normalisation of the two mass bins due to resolution and to Higgs boson mass uncertainty ($< 10\%$) as well as the related discriminant shape uncertainties are taken into account.

Results show that observed data are compatible with the Standard Model (SM) 0^+ expectation. Tested 0^-, 1^+ and 1^- hypotheses are excluded against the SM one at more than 96.9% CL (expected $> 99.7\%$). Expected exclusion in the 2^+_m case is 87% CL, independent on the production mechanism.

REFERENCES

[1] ATLAS-CONF-2013-013.
[2] Bolognesi S. *et al.*, arXiv:1208.4018.