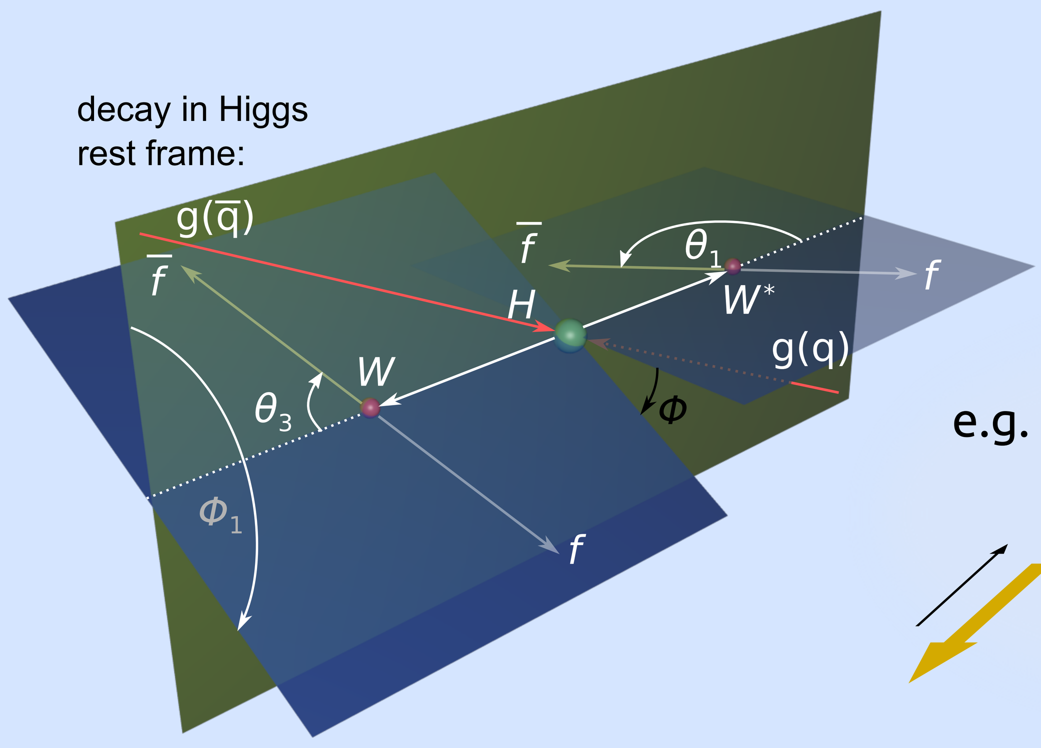
LHCC Poster Session - CERN, 5 March 2014

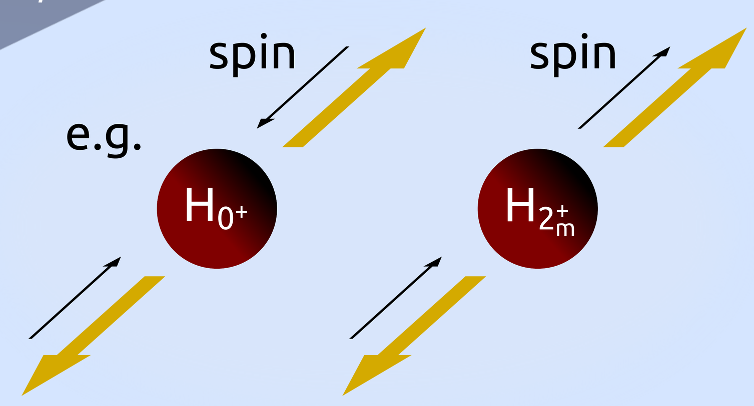
Spin and parity determination in H → WW with the ATLAS detector

Motivation and basic approach - from theory prediction to measurement

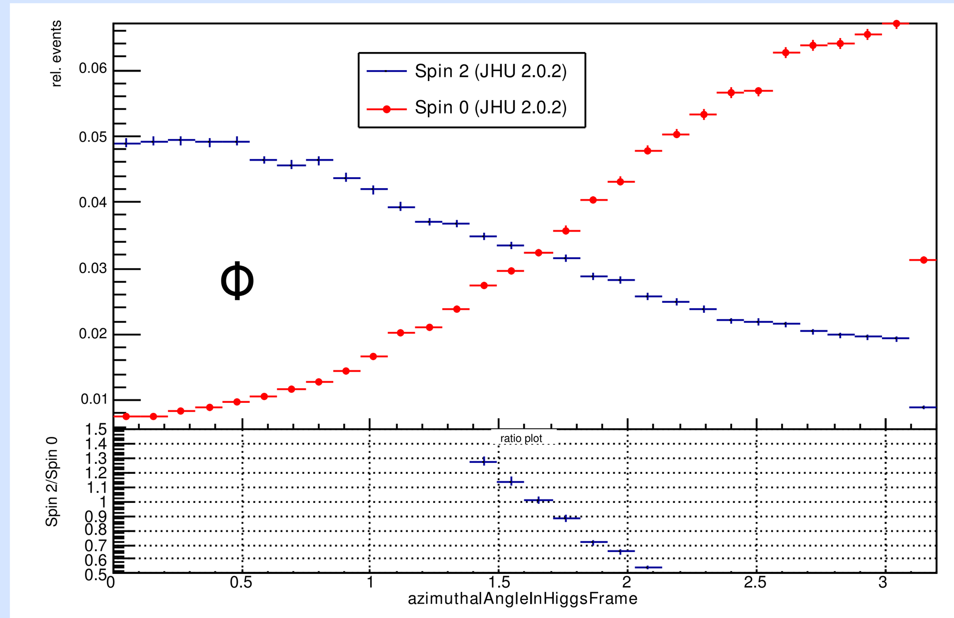
Motivation: check if the discovered Higgs particle has SM properties or not
- probe different spin models, i.e. 0^+ vs. 2^+ for different production modes (relative *gg/q$\bar{q}$* fractions)
- probe different parity models for spin 0, i.e. 0^+ vs. 0^-
- search for CP violation in the Higgs sector



process considered:
H → WW* → ℓνℓν
(only e/μ for the current analysis)



MC prediction for Φ angle in Higgs rest frame, JHU generator; comparing SM Higgs and spin 2^+ model



Starting point (see scheme): 5 Cabibbo-Maksymowicz variables (3 angles θ_1, θ_3, Φ and 2 invariant masses m_W, m_{W^*}) fully describe decay in Higgs rest frame, would be predestined for testing different models via shape differences

Difficulty: reconstruction of 2 neutrinos in final state not possible

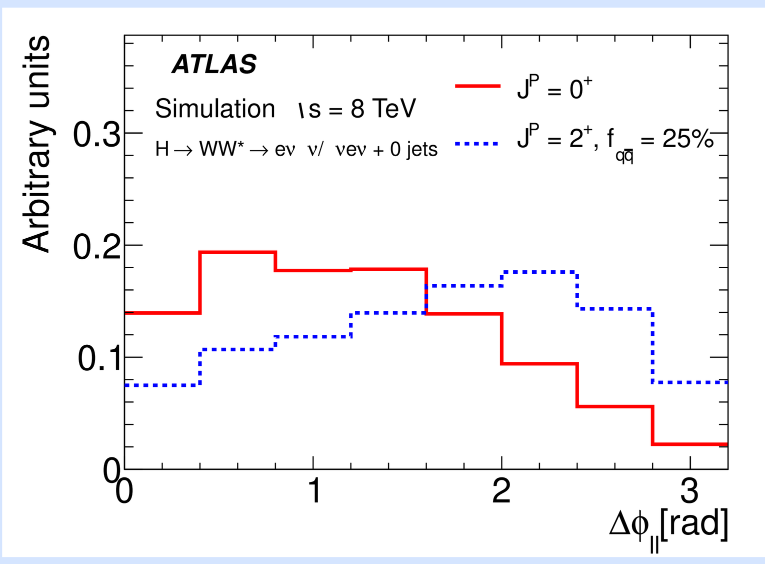
⇒ find variables sensitive to spin/parity in the lab frame + test ways to partly reconstruct the Higgs rest frame

Analysis strategy

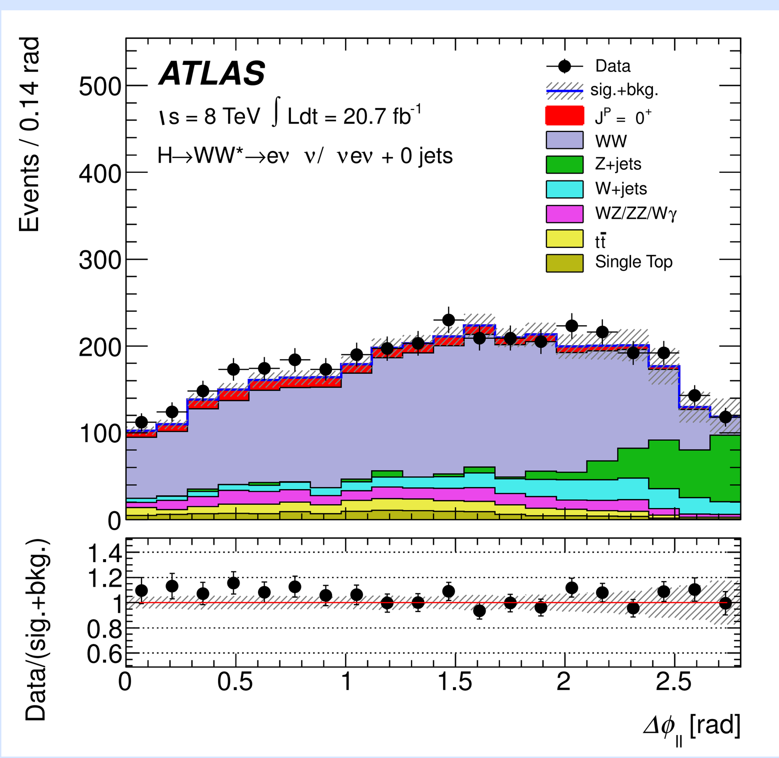
Search for observables sensitive to different spin/parity properties for 0^-, $1^+/^-$, 2^+

⇒ loosen cuts w.r.t H → WW coupling analysis to increase acceptance for all models and preserve shape variations

⇒ pick separating variables, e.g.:



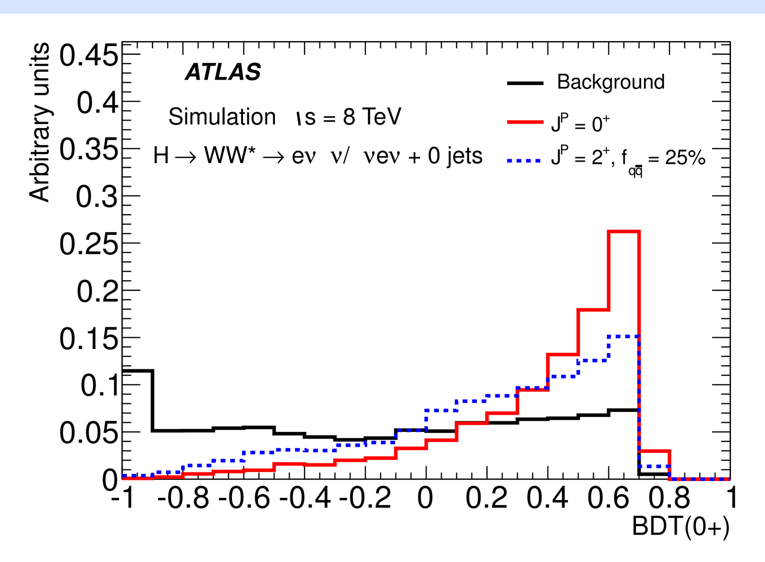
$\Delta\varphi_{ll}$ distribution showing data and MC, normalized to SM expectation with 0+ signal hypothesis including statistical, experimental and theoretical uncertainties:



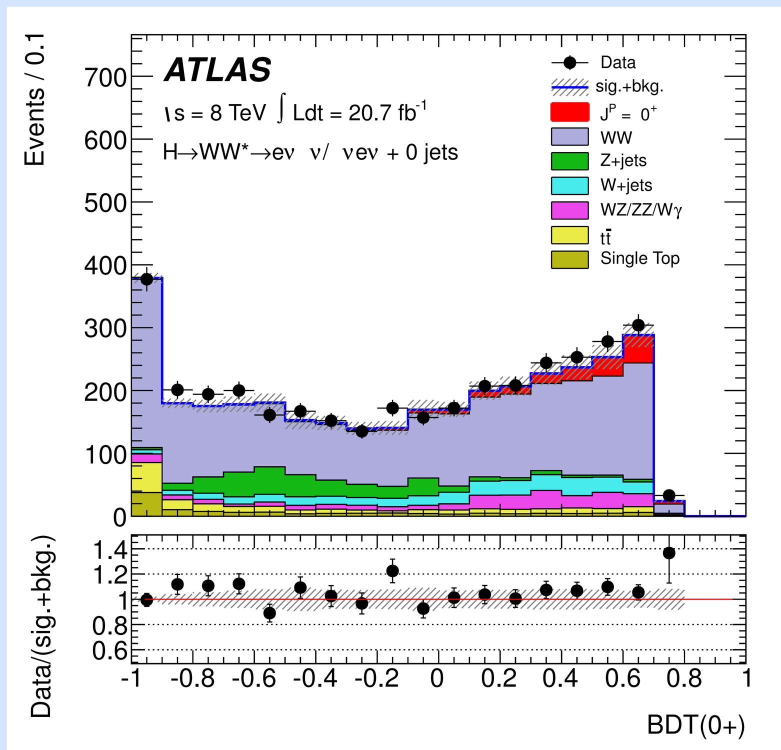
Backgrounds: diboson, Z/γ*+ jets, $t\bar{t}$ and single top, W + jets

use 2 BDTs to combine sensitive variables:
- train each spin hypothesis vs. backgrounds
- BDT inputs: $m_{\ell\ell}, p_{\mathrm{T}}^{\ell\ell}, \Delta\phi_{\ell\ell}, m_{\mathrm{T}}$ (m_T to suppress top/WW bkg)

BDT_0 (0^+ vs. bkg) is particularly sensitive to $0^+/2^+$ differences:

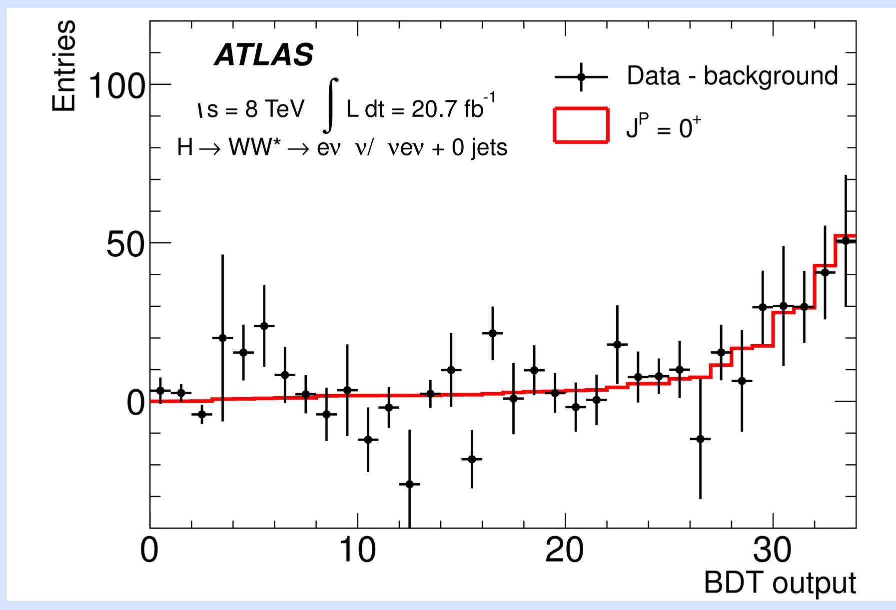


BDT results

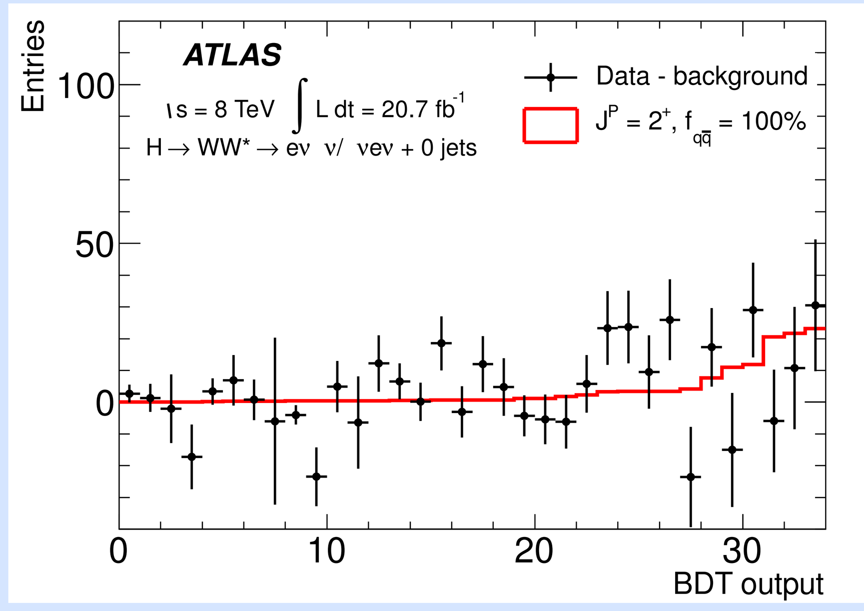


BDT_0 output in signal region w. SM cross section

Hypothesis test: remap both BDTs to 1D distribution and perform 1D fit for both models;



2 plots below: ex. BDT fit results (best fit values for background and signal normalization, 100 % q$\bar{q}$)

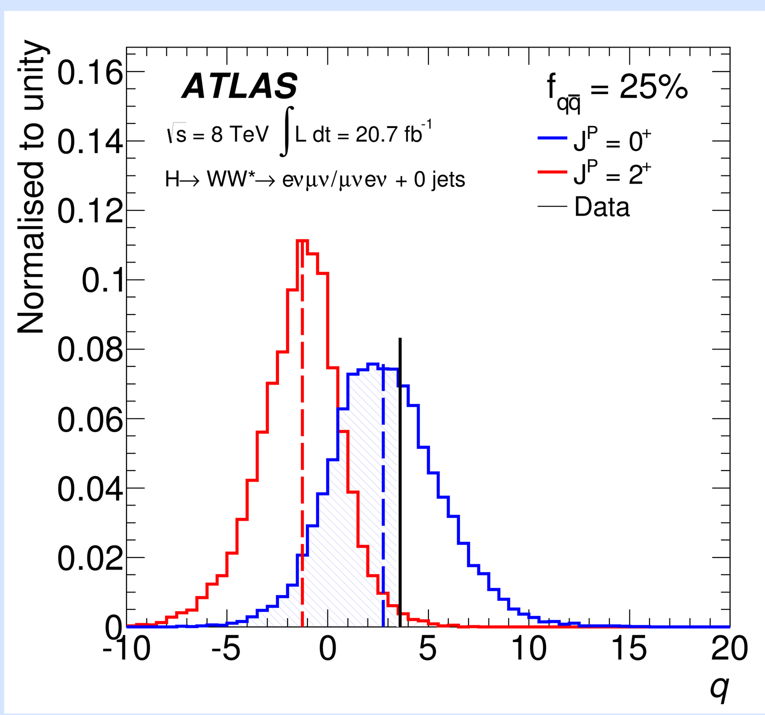


Statistical methodology

- fit binned likelihood $\mathcal{L}(\epsilon, \theta)$ with $\epsilon \triangleq 0^+$ fraction ($\epsilon = 0 \Rightarrow 2^+$ case)
- θ: nuisance parameters, signal strength μ fitted in data
- test statistic for agreement w. respective hypotheses:

$$q = \log \frac{\mathcal{L}(H_{0+})}{\mathcal{L}(H_{2^+_m})}$$

- nominator and denominator maximized over all nuisance par.
- distribution from pseudo exp.:



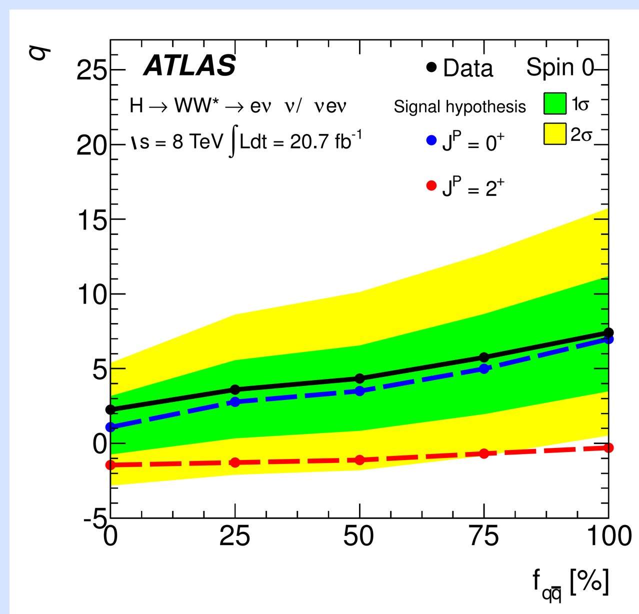
likelihood distributions from pseudo experimens; p-vals ≙ shaded areas

H → WW* and combined results

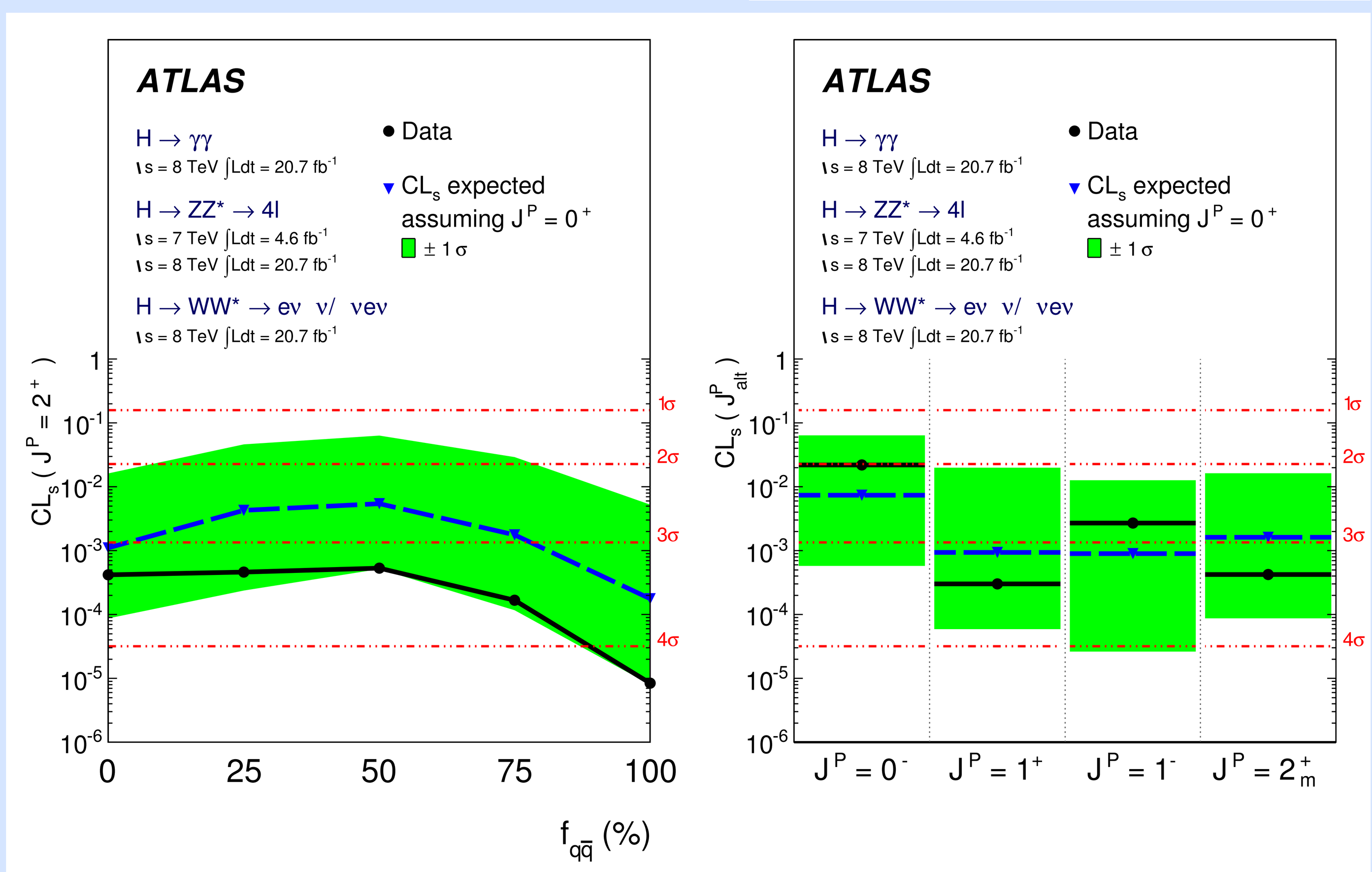
right plot: observed values of the test statistic for 5 different production modes comparing $J^P = 0^+$ vs. 2^+ for H → WW with up to 2σ exclusion (for the 100% q$\bar{q}$ fraction mode) in favour of a 0^+ hypothesis

Results combining all contributing channels:
- data is compatible with 0^+ (SM) hypothesis
- all tested hypotheses are excluded

(see comb. paper, Phys. Lett. B 726 (2013))



combined results from all channels: (all 5 q$\bar{q}$ test points, 4 different spin/parity models) showing respective significance of exclusion/ agreement w.SM Higgs



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ATLAS EXPERIMENT