Direct constraint on the $H \to c\bar{c}$ coupling at ATLAS

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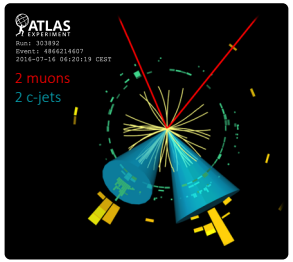
1. Motivation

- Coupling of Higgs field to fermions is a potential source of their masses
- Interaction only observed for the 3rd generation of fermions
- H → $c\bar{c}$ is the experimentally most promising and direct probe of Higgs boson coupling to 2nd generation of quarks
- Standard Model Higgs Yukawa coupling to charm quarks is small

($y_c = \sqrt{2}\, m_c(\mu=m_H)/v \simeq \sqrt{2}\, 0.6\ \text{GeV}/246\ \text{GeV} \simeq 3 \times 10^{-3} \simeq 0.2 \times y_b$)

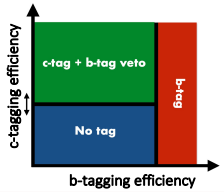
- Susceptible to significant modifications in some new physics scenarios (e.g. 2HDM models)
- VH (V = W/Z) production with leptonic V decays offers clear signature in detector and background suppression – 0, 1 and 2 lepton (L) analysis channels



2. Event Selection

Tagging Procedure

- c-tag with b-veto on two Higgs boson candidate jets: two highest transverse momentum (pT) jets
- b-veto on additional jets
- Efficiencies: c-jets (27%), b-jets (8.3%), light-jets (1.6%)



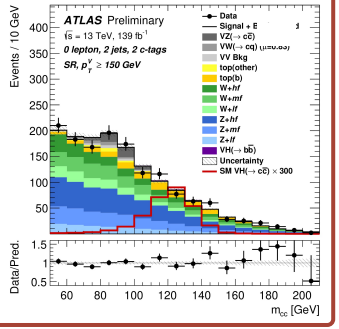
Using Full Run 2 dataset

Signal Regions (SRs)

Phase-space split in:

- c-tag categories
- jet multiplicity
- p_T^V regimes (p_T^V is the transverse momentum of associated vector boson produced)

Dedicated control regions to constraint **V+jets** and **top** backgrounds

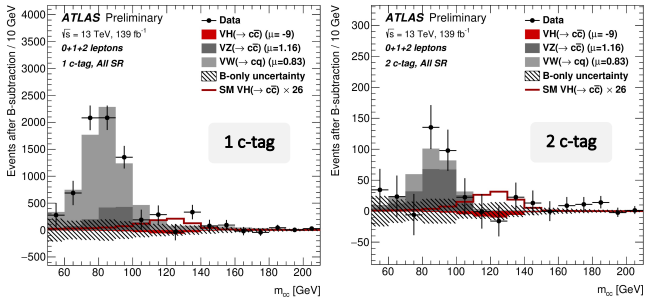


3. Fit Results

- Simultaneous binned likelihood fit to m_{cc} distributions, measuring following signal strengths:
  - VH (H → $c\bar{c}$): $\mu = -9 \pm 15$
  - VZ (Z → $c\bar{c}$): $\mu = 1.16 + 0.50 - 0.46$
  - VW (W → cq), q = s, d: $\mu = 0.83 + 0.25 - 0.23$
- Signal strength defined as ratio of respective observed and expected cross section x BR

Significance	Expected	Observed
VW(cq)	4.6σ	3.8σ
VZ(cc)	2.2σ	2.6σ

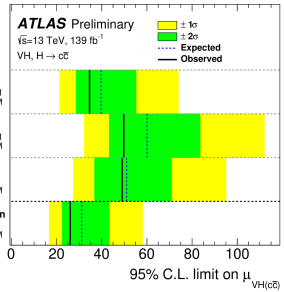
Background Subtracted Mass Spectrum



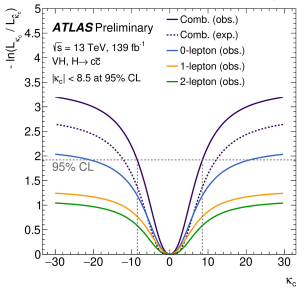
4. Run 2 Limit on μ_{VHcc} and κ_c Interpretation

- Parametrisation of $\mu(\kappa_c)$ includes effects on the Higgs width: $\mu_{VH(c\bar{c})} = \dfrac{\kappa_c^2}{1 + B^{SM}_{H\to c\bar{c}}(\kappa_c^2 - 1)}$
- Limits obtained using a modified frequentist CLs method
- Limits for individual channels from fit with VH(cc) signal strength decorrelated in channels

95% CL Limit on μ_{VHcc}



Profile likelihood scans on κ_c



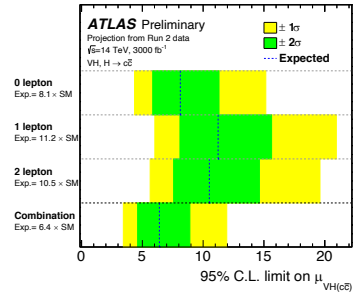
Observed μ_{VHcc} limit of 26 × SM @ 95% CL
Current world's best limit

Observed constraint of $|\kappa_c| \leq 8.5$ at 95% CL
First direct limit on $|\kappa_c|$ from H → cc decays

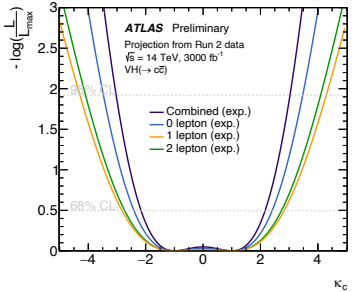
5. HL-LHC Extrapolation

- Extrapolation of Run 2 analysis to HL-LHC scenario ($\sqrt{s} = 14$ TeV, 3000 fb^{-1})
- Flavour tagging (except light-jets in VH (H → $c\bar{c}$)), theory and background uncertainties scaled by 1/2
- Leading uncertainties on results from Z+jets modelling and flavour tagging

95% CL Limit on μ_{VHcc}



Profile likelihood scans on κ_c



Expected μ_{VHcc} limit of 6 × SM @ 95% CL

Expected constraint of $|\kappa_c| \leq 3.0$ at 95% CL

References: Run 2 plots and results from ATLAS-CONF-2021-021; HL-LHC extrapolations from ATL-PHYS-PUB-2021-039

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