

Charm is better than beauty: Searching for the Higgs coupling to charm quarks





LHCP Poster session, 10.06.21 Marko Stamenkovic on behalf of the ATLAS collaboration marko.stamenkovic@cern.ch



Theory: fermions acquire mass through interaction with Higgs field → Do all particles get their mass through Brout-Englert-Higgs mechanism?

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Motivation

[ATLAS-CONF-2021-021]



Direct search for Higgs coupling to 2nd generation of quarks: $H \rightarrow cc$



Charm tagging and analysis strategy

Charm tagging:

Is the jet initiated by a c-hadron?

Machine learning algorithm based on mass and lifetime of heavy hadrons for identification of c-jets

Strategy: c-tagging + b-tag veto

	c-tagging+b-veto efficiency	b-to eff
c-jets	27%	
b-jets	8%	7
light-jets	1.6%	0

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Categorisation: 1 and 2 c-tag Orthogonality with VH(bb)





- $\mu_{VH(cc)} = -9 + 15 15$
- $\mu_{VZ(cc)} = 1.16 + 0.50 0.46 \rightarrow validation of the 2 c-tag category$
- → Result in agreement with the Standard Model prediction

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Fitted signal strength of VH(cc), VZ(cc) and VW(cq) from profile likelihood fit

• $\mu_{VW(cq)} = 0.83 + 0.25 - 0.23 \rightarrow validation of the 1 c-tag category$





Result and interpretation



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Best limit on VH(cc) Most stringent direct constraint on Kc Measurement of $W \rightarrow cq$ and $Z \rightarrow cc$ using c-tagging





Back up



Tagging c-jets is challenging

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• Lifetime and mass of c-hadrons in between b-hadron and light hadrons measured in detector • Use Machine Learning to distinguish signal = c-jets from background = b-jets and light-jets



Charm tagging calibrations



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Analysis strategy: how do I reconstruct my Higgs?

VHcc categorisation:

- 2 c-tag + b-veto
- 1 c-tag + b-veto

VHbb categorisation:

• 2 b-tag

Orthogonality with VHbb: • Always < 2 b-tagged jets

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Categorisation of events with 2 jets







Analysis strategy: how do I reconstruct my Higgs?

VHcc categorisation:

- 2 c-tag + b-veto
- 1 c-tag + b-veto
- Additional **b-veto** on 3+jets

VHbb categorisation:

• 2 b-tag

Orthogonality with VHbb: • Always < 2 b-tagged jets

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Categorisation of events with 3 jets





Sensitivity timeline of VHcc





Kc interpretations



Kc interpretation: quantity possible deviations from the SM

- Parametrise signal strength as a function of coupling enhancement Kc
- Assume Ki = 1 for other fermions and bosons
- Only sensitive to Kc if μ < 35 due to Higgs width in parametrisation
- Direct constraint: |Kc| < 8.5 @ 95% CL (<12.4 @ 95%CL expected)
 - Only sensitive to Kc through combination of 0-, 1 and 2-lepton

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deviations from the SM

ction of coupling enhancement Kc Id bosons

Higgs width in parametrisation
 % CL (<12.4 @ 95%CL expected)
 bination of 0-, 1 and 2-lepton



Breakdown of uncertainties

- Similar statistical and systematic uncertainties
- Dominant systematic uncertainties:
 - Background modelling: V+jets and ttbar
 - Simulation statistics
 - Truth flavour tagging

Breakdown of uncertainties

	Source of uncertainty		$\mu_{VH(c\bar{c})}$	$\mu_{VW(cq)}$	$\mu_{VZ(c\bar{c})}$
	Total		15.3	0.24	0.48
	Statistical		10.0	0.11	0.32
	Systematics		11.5	0.21	0.36
	Statistical uncertainties				
-	Data statistics only		7.8	0.05	0.23
	Floating normalisation	S	5.1	0.09	0.22
_	Theoretical and modell	ing uncertainties			
	$VH(\rightarrow c\bar{c})$		2.1	< 0.01	0.01
	Z+jets		7.0	0.05	0.17
	Top-quark		3.9	0.13	0.09
	W+jets		3.0	0.05	0.11
	Diboson		1.0	0.09	0.12
	$VH(\rightarrow bb)$		0.8	< 0.01	0.01
	Multi-Jet		1.0	0.03	0.02
	Simulation statistics		4.2	0.09	0.13
	Experimental uncertain	nties			
	Jets		2.8	0.06	0.13
	Leptons		0.5	0.01	0.01
	$E_{ m T}^{ m miss}$		0.2	0.01	0.01
	Pile-up and luminosity		0.3	0.01	0.01
	Flavour tagging	<i>c</i> -jets	1.6	0.05	0.16
		<i>b</i> -jets	1.1	0.01	0.03
		light-jets	0.4	0.01	0.06
		au-jets	0.3	0.01	0.04
	Truth-flavour tagging	ΔR correction	3.3	0.03	0.10
_		Residual non-closure	1.7	0.03	0.10









Background composition plots: postfit 0-lepton





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Background composition plots: postfit 1-lepton





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3 jets



Background composition plots: postfit 2-lepton



2 jets

≥3 jets

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2 jets

≥3 jets



Results: signal strength

VH(cc) POI



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VZ(cc) and VW(cq) POI



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Postfit distributions: 1-lepton 2 jets 3 jets



1 c-tag

2 c-tag

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Postfit distributions: 2-lepton

pTV > 150 GeV 3+ jets 2 jets





