Study of the Sensitivity of the ATLAS Experiment to Constrain the Higgs Coupling to b-quarks

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1. Aim & Motivation

Aim

- Make a experimentally verifiable prediction about how precisely the $hb\bar{b}\gamma$ coupling can be measured in the ATLAS detector at $\sqrt{s} = 14$ TeV with a given integrated luminosity

Why Should We Care?

- In light of the relatively recent Higgs Boson discovery, it is an exciting time to look for new physics in this sector
- Beyond SM physics may modify the Higgs vertices, which in turn may lead to observable consequences of SM deviation in the decay channel of these vertices
- Interesting to consider the $hb\bar{b}\gamma$ vertex, this has not been looked at before

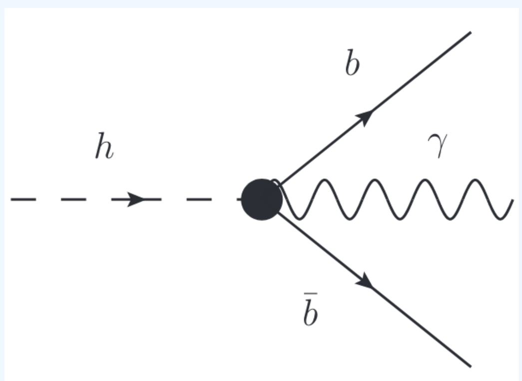
2. Higgs-Bottom Anamolous Coupling

Parametrization of the Interaction

- Adopt model-independent approach, parameterise anomalous $hb\bar{b}\gamma$ in terms of Wilson coefficients
- The $hb\bar{b}\gamma$ vertex is of the form

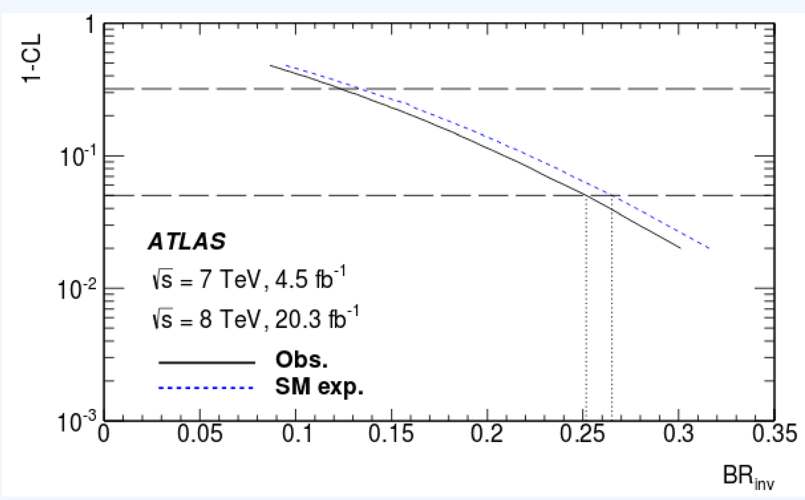
$$L_{hb\bar{b}\gamma} = \frac{1}{\Lambda^2} F^{\mu\nu} \bar{b} \sigma_{\mu\nu} (d_1 + i d_2 \gamma_5) b h$$

- If d1 and d2 are non-zero this would represent CP violation in the Higgs sector (diagram taken from arXiv:1702.06003)



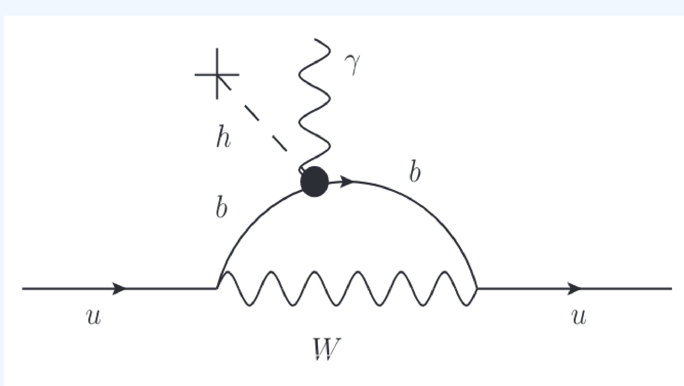
Constraints on Coefficients from LHC data

- No dedicated search for $H \to b\bar{b}\gamma$ has been reported
- Global fits of LHC data yield upper limit of 23% on any non standard branching ratio (BR) of the Higgs at 95% confidence level (upper limit seen in graph, arXiv:1509.00672)
- Apply this limit to $BR(h \to b\bar{b}\gamma)$ which bounds the coefficients to $|d_1|, |d_2| \leq 5$



Constraints on Coefficients from EDMs

- d_2 could be constrained from neutron electric dipole moment (nEDM) measurements
- In the EDM diagram, the smallness of the $|V_{ub}|^2$ results in a suppressed nEDM contribution
- Therefore the constraint on d_2 is much more relaxed compared to LHC constraint (diagram taken from arXiv:1702.06003)



3. Simulation of Signal/Background Samples

Software

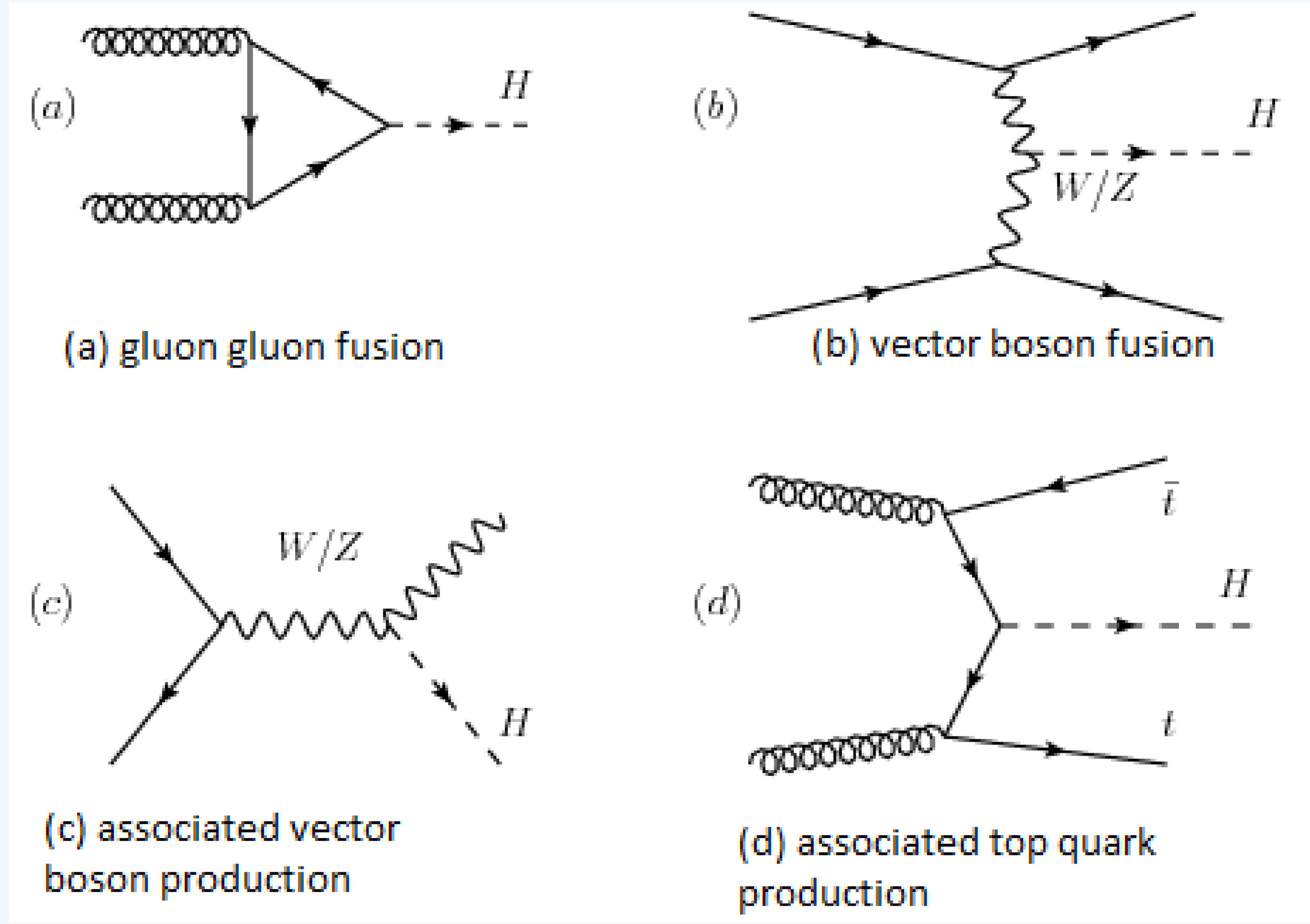
Performing an ATLAS analysis which involves:

1. Generating BSM Lagrangian (with constrained coupling parameters) via FeynRules.
2. Using MadGraph5 to generate events for the ATLAS analysis
3. Using PYTHIA for subsequent decay, showering and hadronization of the parton level events
4. Using Delphes3 for detector simulation

4. Preliminary ATLAS Analysis

Higgs Production Channel

Four different Higgs production channels can be considered (diagram taken from arXiv:1211.701):



(a) gluon gluon fusion
(b) vector boson fusion
(c) associated vector boson production
(d) associated top quark production

Which Production Channel to Use?

- (b) is a viable option, however it has a significantly lower cross section than (a) and background rejection not as good as in (c) (arXiv:hep-ph/0105325 & arXiv:hep-ph/0609075)
- (d) has a much smaller cross-section than the other channels and is not effective for studies like this one (`https://twiki.cern.ch/twiki/bin/view/LHCPhysics/HiggsEuropeanStrategy`)
- (c) has been done already for this effective vertex $hb\bar{b}\gamma$ by Dwivedi et al 2017 (arXiv:1702.06003)
- (a) is the most dominant production channel and therefore could be potentially useful (see Table I).

Process	$\sqrt{s} = 14$ TeV			
	σ (pb)	**NEV** (L=1000 fb^{-1})		
		Cut "**E0**" $P_{T\gamma} \geq 20$ GeV	Cut "**E1**" $P_{T\gamma} \geq 60$ $P_{Tj_1} \geq 40$ GeV $P_{Tj_2} \geq 20$ GeV	"**E1**" like cut $N_j \geq 2$ $1 \leq N_b \leq 2$ $N_\gamma \geq 1, E_{T\gamma} \geq 20$ GeV $N_\ell \geq 2$,opposite sign e, μ
$pp \to h \to b\bar{b}\gamma$ $(d_1 = d_2 = 5)$	1.8	1.6×10^6	2.6×10^5	-
$pp \to b\bar{b}\gamma$	1.9×10^4	1.3×10^8	1.7×10^6	-
$pp \to b\bar{b}j$	1.5×10^7	7.6×10^8	6.0×10^6	-
$pp \to Zh, h \to b\bar{b}\gamma$ $(d_1 = d_2 = 5)$	3.6×10^{-4}	-	-	83
$pp \to Zh\gamma$	2.0×10^{-4}	-	-	17
$pp \to t\bar{t}\gamma$	0.12	-	-	5214
$pp \to \ell^+\ell^- b\bar{b}\gamma$	0.43	-	-	3149
$pp \to \ell^+\ell^- jj\gamma$	1.45	-	-	5355
$S/\sqrt{B}$	-	54	93	0.7

TABLE I: Cross sections for the signal for both gluon gluon fusion and associated Z boson production, corresponds to $d_1 = d_2 = 5$ and all the SM backgrounds channels are shown in pb along with number of expected events (**NEV**) after each of the cuts. Signal and background numbers for associated production taken from arXiv:1702.06003

Gluon Gluon Fusion Channel

- As can be seen in Table I, the $\frac{S}{\sqrt{B}}$ is much better for gluon gluon fusion than associated Z production
- In the gluon gluon fusion channel, we will be able to reject much of the background due to the high P_T photon radiating from the effective $hb\bar{b}\gamma$ vertex

5. Conclusion & Next Steps

- Gluon gluon fusion chosen as production channel
- Determine other important backgrounds to gluon gluon fusion (apart from $pp \to b\bar{b}\gamma$ and $pp \to b\bar{b}j$)
- Optimize selection cuts for best $S/\sqrt{B}$
- Estimate ATLAS sensibility to anomalous couplings for L=300 fb^{-1} and L=3000 fb^{-1}