Probing the Higgs-vector coupling with same-sign W bosons

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In collaboration with Roni Harnik and Felix Yu [arXiv:14XX.YYYY]

Motivation

- One goal going forward for current and future colliders is to test if the 125 [GeV] Higgs is the one of the SM.
- Goal of our project: does the 125 [GeV] Higgs couple to the W & Z in the way predicted by the SM.

Parametrization

- Higgs effective Lagrangian

$$\mathcal{L}_{\text{eff}} \supset c_V \frac{2m_W^2}{v} h W^{+\mu} W^-_\mu + c_V \frac{m_Z^2}{v} h Z^\mu Z_\mu + c_\gamma \frac{\alpha}{\pi v} h F_{\mu\nu} F^{\mu\nu} + c_{Z\!Z} \frac{\alpha}{\pi v} h Z^{\mu\nu} Z_{\mu\nu} + \cdots \tag{1}$$

  where, in the SM, $c_V = 1$.

- We have assumed in Eq. (1) that the custodial symmetry in the Higgs sector is preserved and so $c_W = c_Z = c_V$.

Our goal is to measure or, at least, bound c_V.

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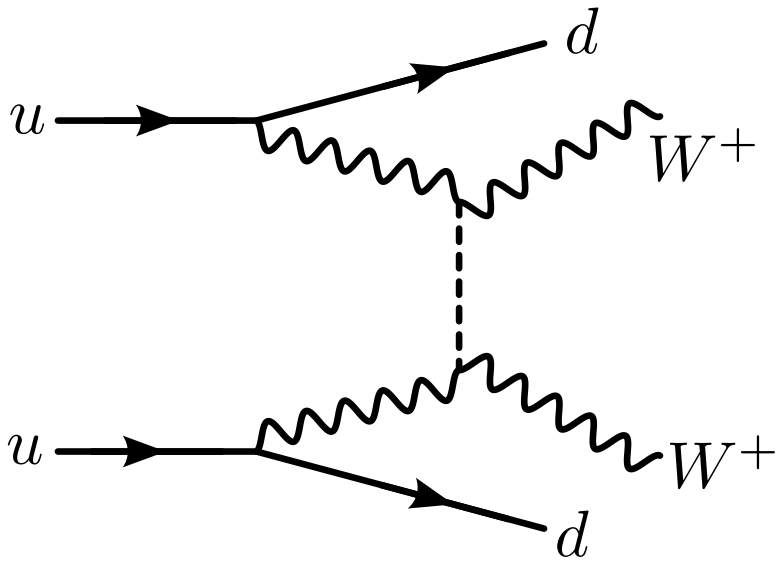
The same-sign W channel

- The Higgs mediated diagram



$$\sigma \propto g_V^4$$

where $g_V \equiv 2m_W/v$.

- The Higgs in the t/u-channel $\Rightarrow$ no dependence on Γ_h
- No Higgs couplings other than g_V enter.

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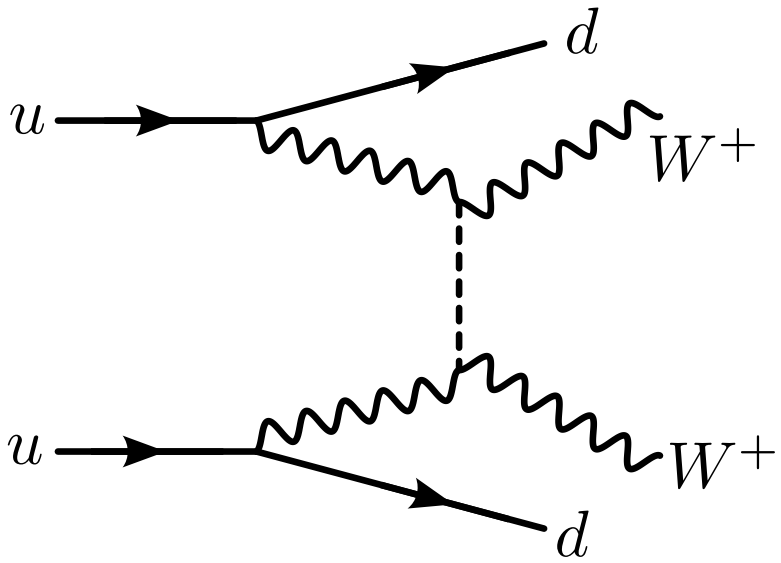

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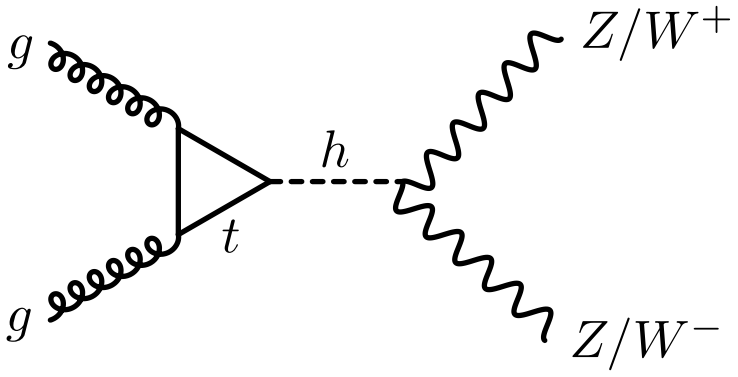
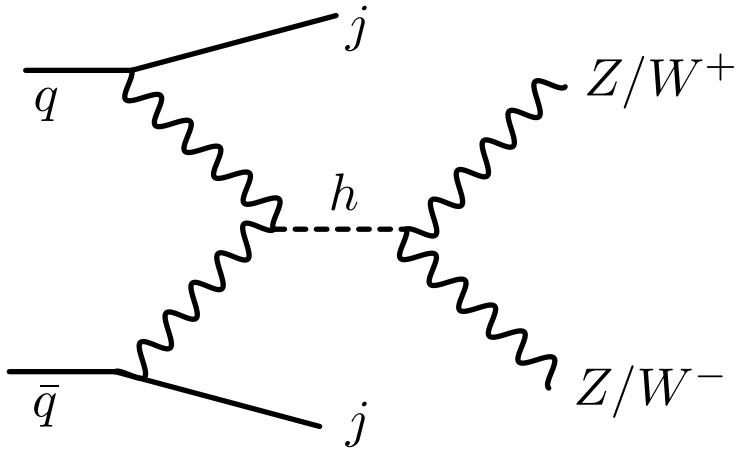
Compare with other channels



$$\sigma \propto \begin{cases} \dfrac{g_t^2\, g_V^2}{\Gamma_h^{\mathrm{TOT}}} & \text{on peak} \\ g_t^2\, g_V^2 & \text{off peak} \end{cases}$$



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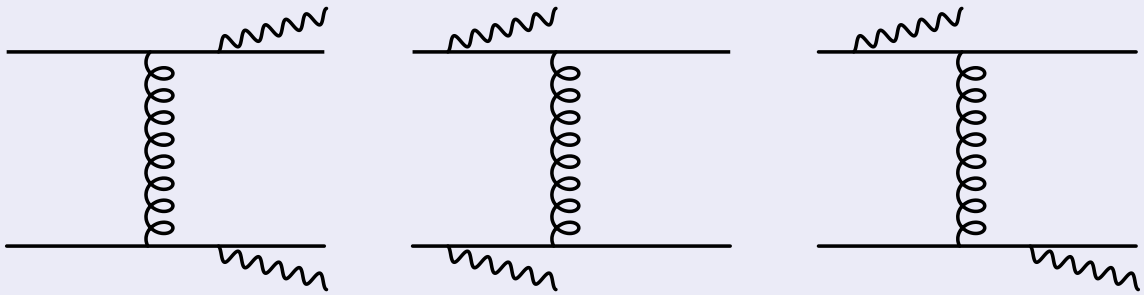
Either g_t enters (golden chan.) or suffer from large $t\bar{t}$ bkgd (VBF).

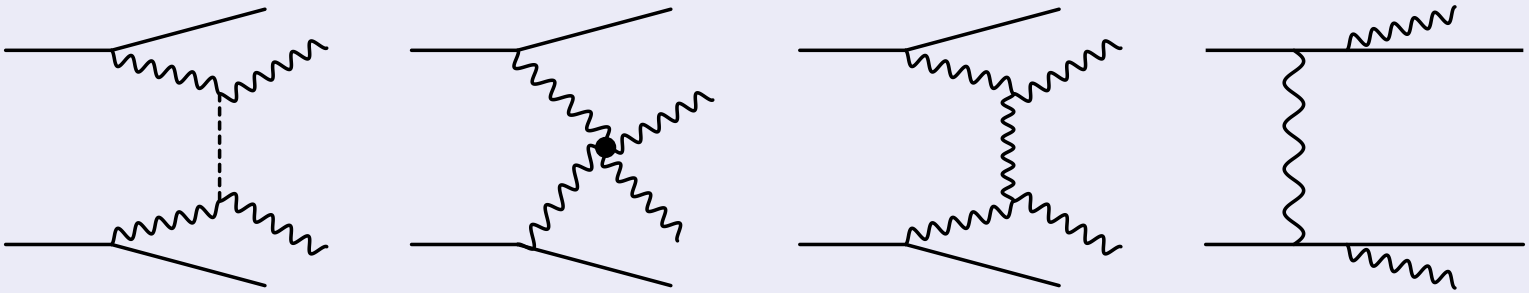
Main contributions

There are two classes of diagrams: strong and electroweak.

- Strong production (amplitude $\propto \alpha_W \alpha_S$)



- Electroweak production (amplitude $\propto \alpha_W^2$)



The same-sign W channel – summary

- Exploit the VBS process $\rightarrow$ isolate the hVV coupling since no other Higgs couplings enter the process.
- Tagging jets are predominantly forward $\rightarrow$ this gives a handle to cut strong contribution where jets are color-connected.
- Cutting on M_{jj} and $\Delta\eta_{jj}$ also reduces strong contribution.
- We further restrict to same sign W bosons (same sign lepton final state) to avoid $t\bar{t}$ background.

Lightening background review

- Atlas recently released the first evidence of this final state [ATLAS-CONF-2014-013]
- Doroba et al.: testing WW unitarity at LHC including use of same sign Ws. Considered Higgsless and SM cases as examples [arXiv:1201.2768].
- Freitas and Gainer: enhanced sensitivity through MEM [arXiv:1212.3598].
- Many more...

Extensive literature on unitarization of WW scattering. Our proposal is intricately tied to WW unitarization but we cast the problem in terms of a measurement or bound on c_V.

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Cuts

As a starting point, used Atlas [ATLAS-CONF-2014-013] cuts.

Pre-selection

Jets	Leptons
$\|\eta\| < 4.5$	$\|\eta\| < 2.5$
$p_T > 30$ GeV	$p_T > 25$ GeV
$\Delta R_{\ell j} > 0.3$	$\Delta R_{\ell\ell} > 0.3$
$m_{j_1 j_2} > 300$ GeV	$m_{\ell\ell} > 20$ GeV
	$E\!\!\!/_T > 40$ GeV

VBS (in addition)

$m_{j_1 j_2} > 500$ GeV
$\|\Delta y_{j_1 j_2}\| > 2.4$

Cross-sections*

$\ell \in \{e, \mu\}$	$\sqrt{s} = 8$ [TeV]		$\sqrt{s} = 14$ [TeV]	
	Pre	VBS	Pre	VBS
$W^+(\ell\nu)W^+(\ell\nu)jj$ strong	0.63	0.09	1.65	0.30
$W^-(\ell\nu)W^-(\ell\nu)jj$ strong	0.19	0.02	0.64	0.10
$W^+(\ell\nu)W^+(\ell\nu)jj$ electroweak	1.11	0.78	3.64	2.81
$W^-(\ell\nu)W^-(\ell\nu)jj$ electroweak	0.30	0.18	1.22	0.86
$\sum$ Events at 20 $[fb^{-1}]$	44.5	21.4	143	81.4
$\sum$ Events at 3 $[ab^{-1}]$	(6665)	(3210)	21425	12210

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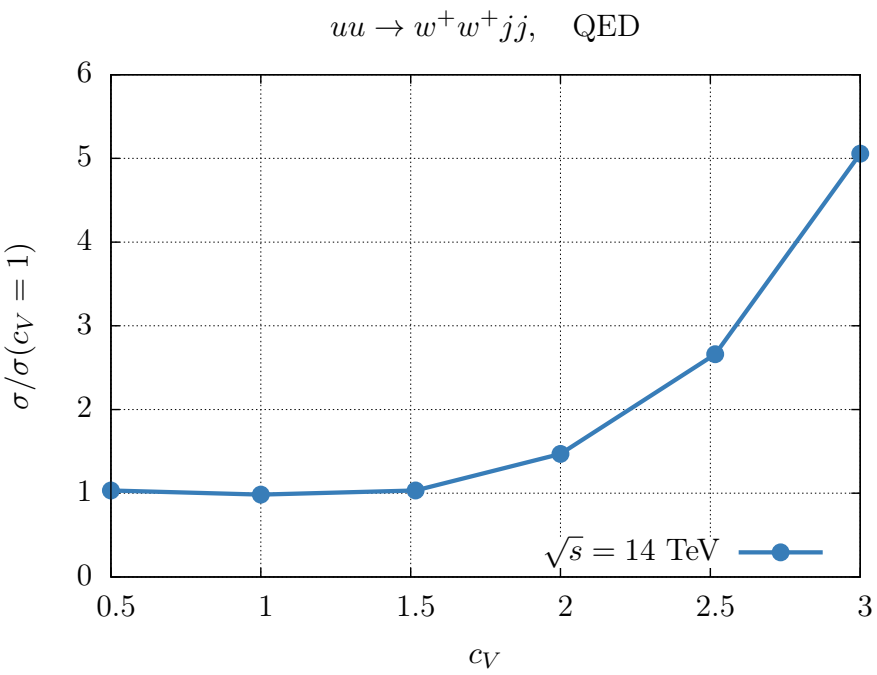
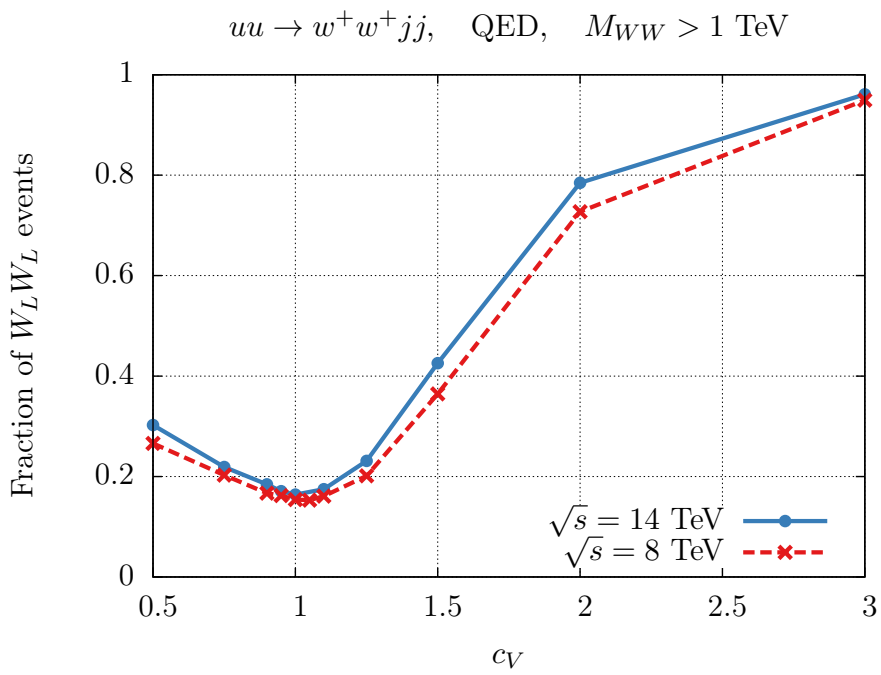
Sensitivity to c_V





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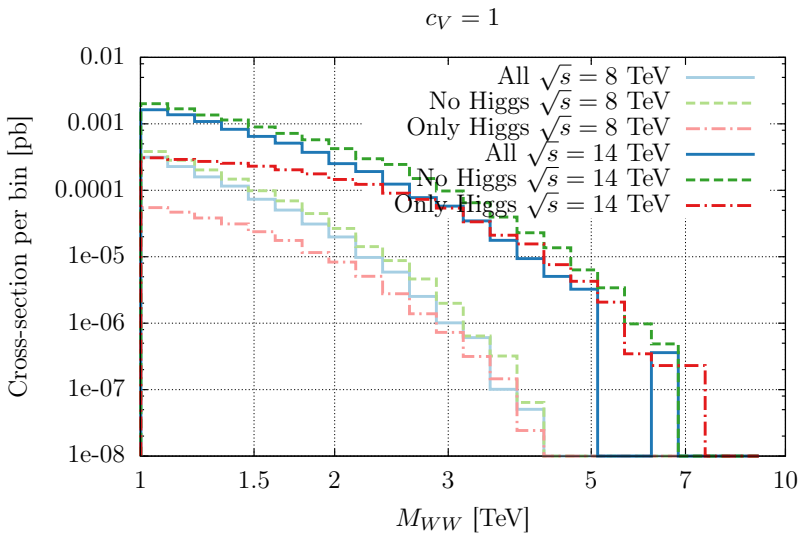
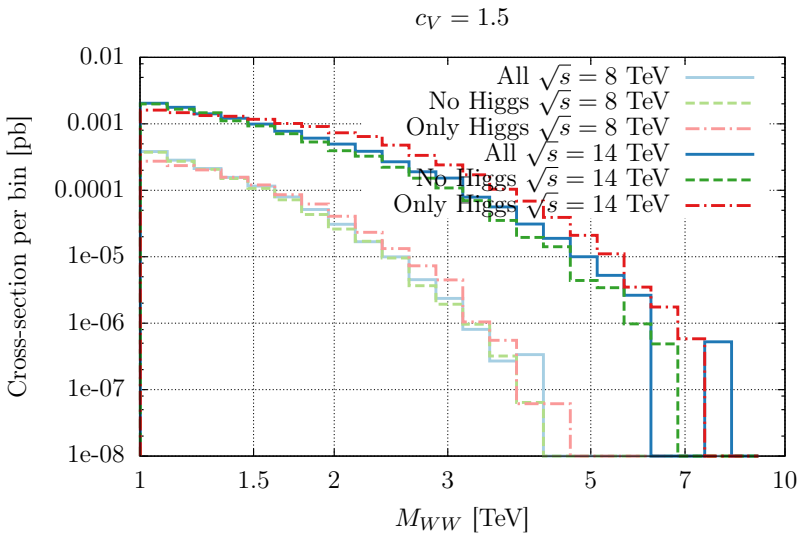
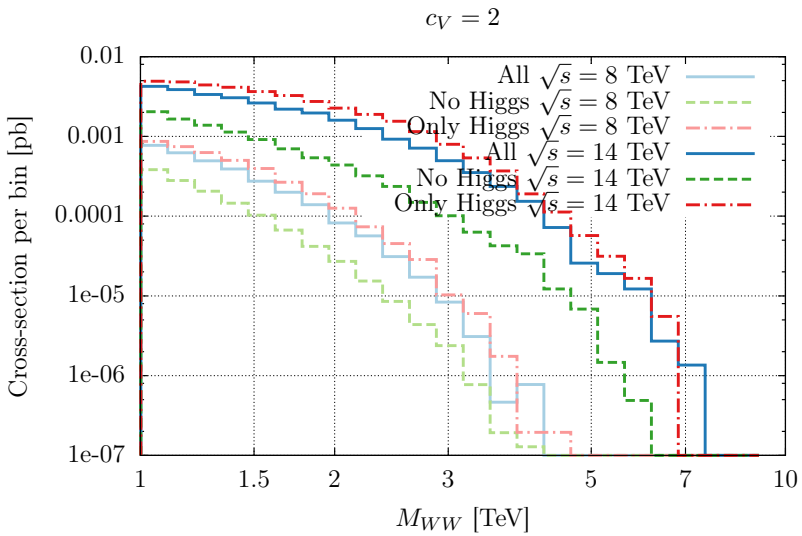
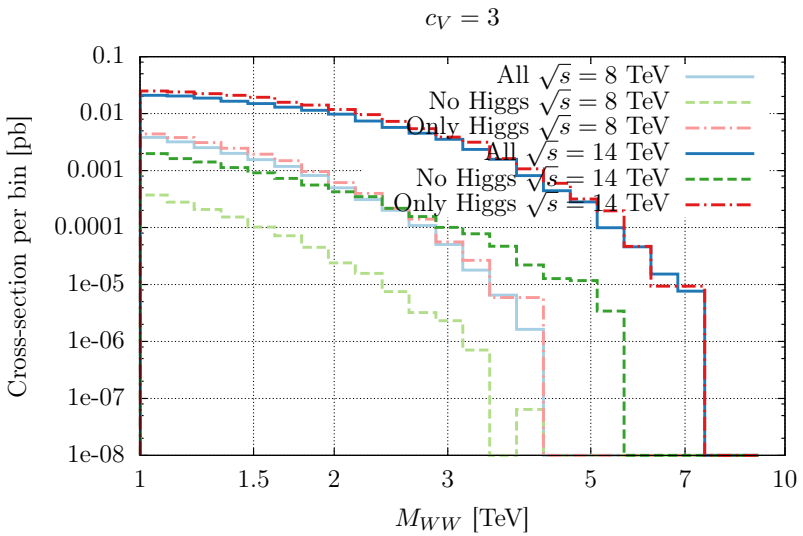


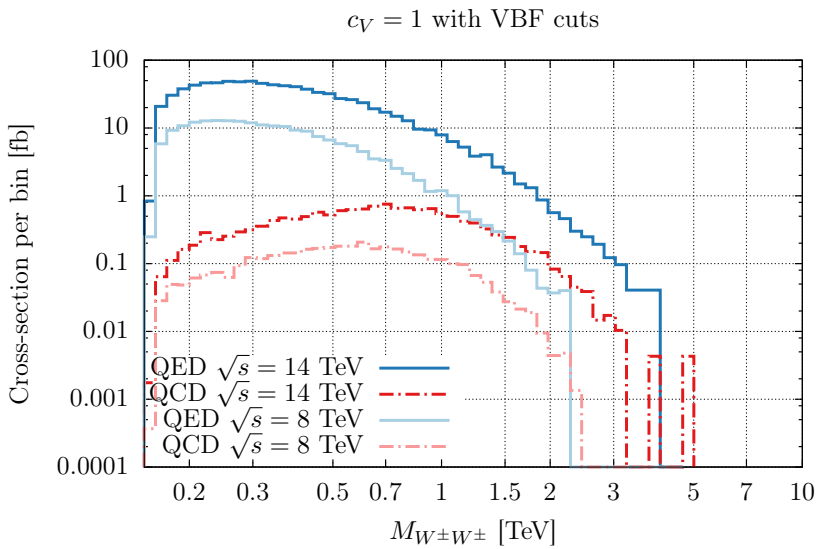


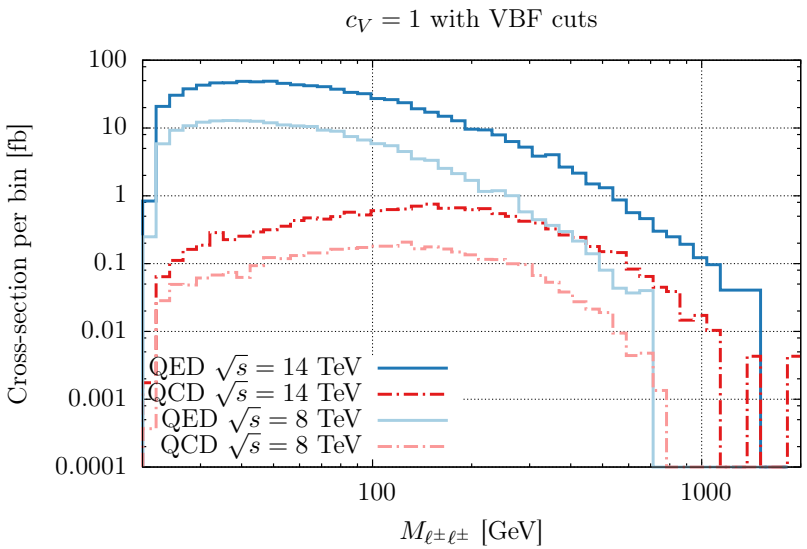




Sensitivity to c_V in $pp \to W^{\pm}W^{\pm}jj$

Full simulation chain `MG5v2` + `Pythia8` + `FastJet3`





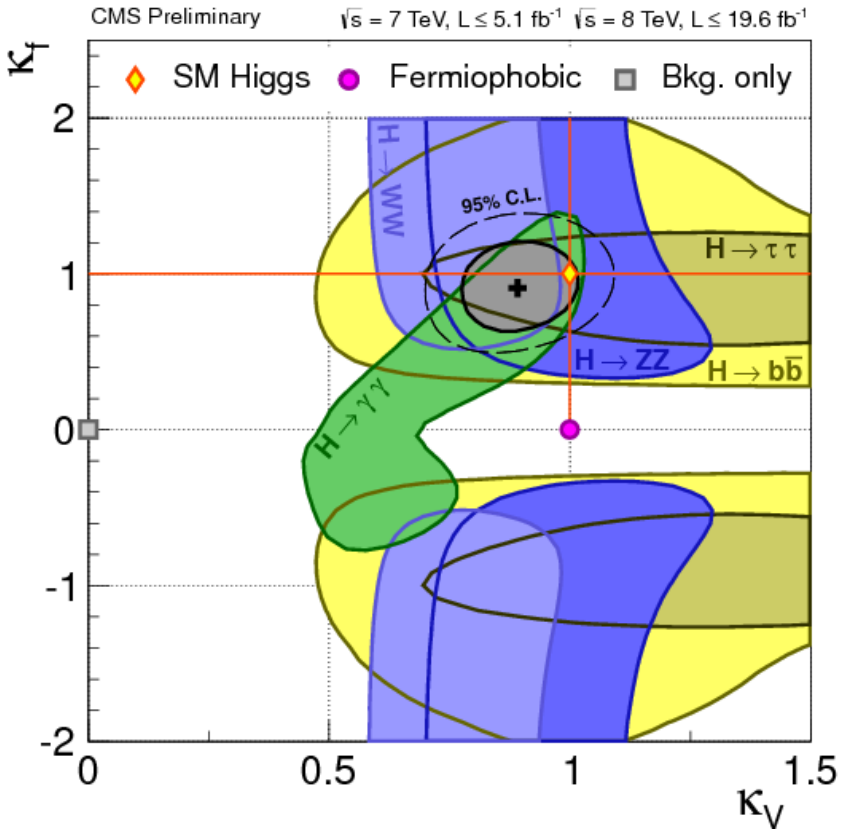
- In progress: find an optimal observable to isolate the events in the tail of M_{WW} distribution.
- E.g., consider obervables like m_{T2} to reconstruct M_{WW}.
- Ideally, find optimal observable sensitive to W helicity.

Conclusions

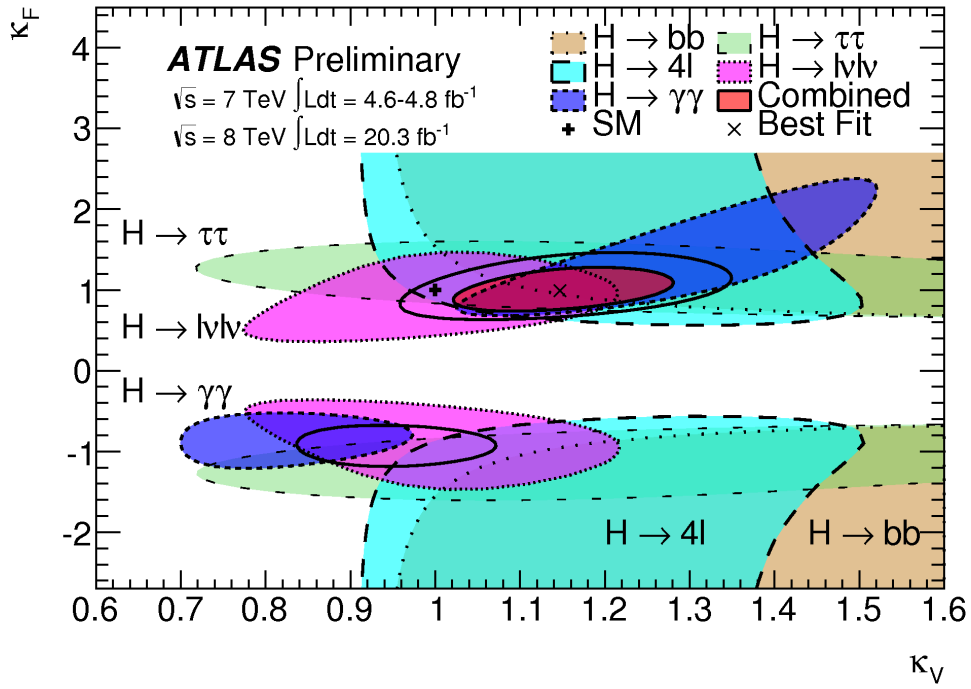
- We can, in principle, measure or bound c_V with same-sign W boson scattering.
- Need optimized kinematic observables to isolate the longitudinal Ws (work in progress).
- While this may not give the most stringent bound, it is an independent and direct measurement of c_V.

Backup Slides

Higgs coupling fits from Atlas & CMS



CMS-PAS-HIG-13-005



ATLAS-CONF-2014-009