Report from WG1/Off-shell Subgroup

Experimental Summary

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The 8th Workshop of LHC Higgs Cross Section Working Group, 22 Jan 2015

Overview

- Run-1 overview
  - Off-shell Higgs couplings
  - The total width interpretation
- Run-2 preview
  - Analysis in VBF channels
  - Anomalous couplings constraints (High dimensional operators)
  - EFT based analyses

Run-1 Overview

CMS: Phys. Lett. B 736 (2014) 64
ATLAS: http://cds.cern.ch/record/1740973

Main Theoretical Treatment

	ATLAS	CMS
gg→H*→VV	LO: gg2VV and MCFM m(H*) dependent NNLO k-factors	
gg→VV gg→H*→VV/gg→VV	LO: gg2VV and MCFM	
	- result as a function of the unknown gg→ZZ k-factor - Studied Sherpa+OpenLoops 0+1 Jet Merged - 30% on interference	H*→VV k-factor, with 10%σ (later revised to be ~30% for interference by M. Bonvini et al)
qq→VV	Powheg NLO, EWK correction	
	NNLO correction m(vv) from M. Grazzini	
VBF (H*) VV	Madgraph LO (Xchecked with Phantom)	Phantom LO (Xchecked with Madgraph)

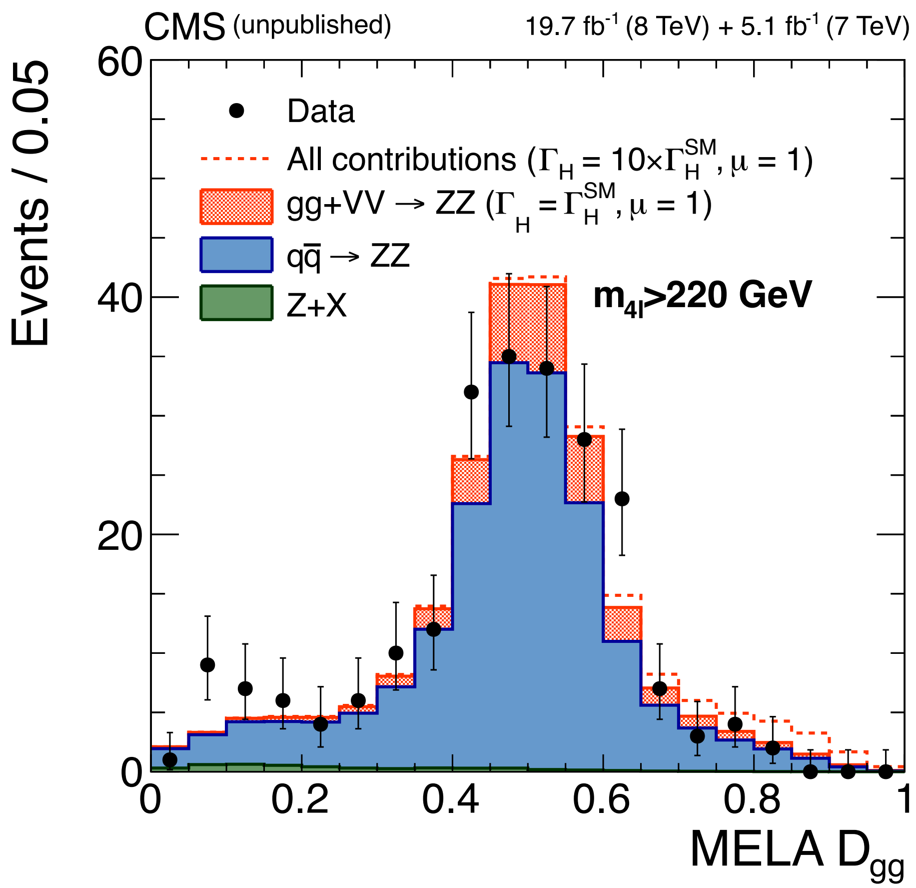
- Main limitation is the LO gg→VV background and its interference with H signal
- Small inconvenience: VBF H VV process can not be generated on its own
    - Scaled from other processes such as VBF (B), S+B+I(SM), and S+B+I (with 10 times SM width)

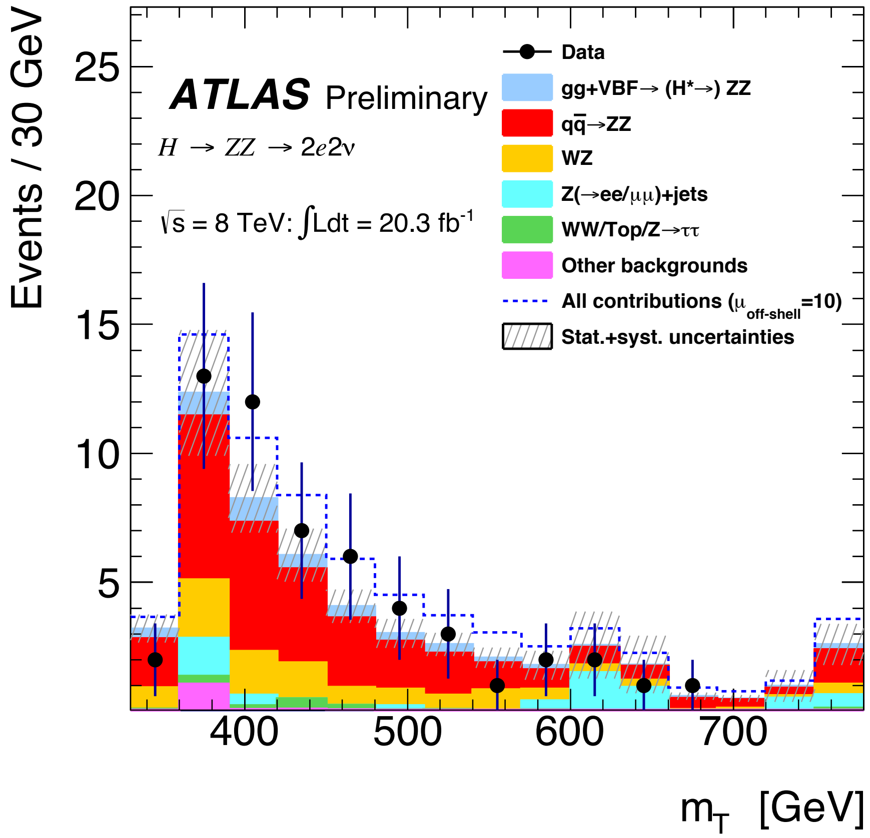
Overview of the Analysis

- Both ATLAS/CMS explored ZZ high mass region in 4l and 2l2ν channels
    - For the 4l channel, both explored the kinematics using matrix element methods
    - For the 2l2ν, both use the transverse mass (with different definitions) as the key variable
- ATLAS focuses on the off-shell signal strength

$$\frac{\sigma^{gg\to H^*\to ZZ}_{\text{off-shell}}}{\sigma^{gg\to H^*\to ZZ}_{\text{off-shell, SM}}} = \mu_{\text{off-shell}} = \kappa^2_{g,\text{off-shell}} \cdot \kappa^2_{V,\text{off-shell}}$$

    - 95% C.L. U.L. ~ 5 - 9.
- Both CMS and ATLAS put a constraint on the total width of the Higgs boson
    - Assumes SM off-shell/on-shell coupling ratio in a combined fit for the on-shell/off-shell regions
    - 95% C.L. upper limit for Run-1 is ~ 20-35 MeV





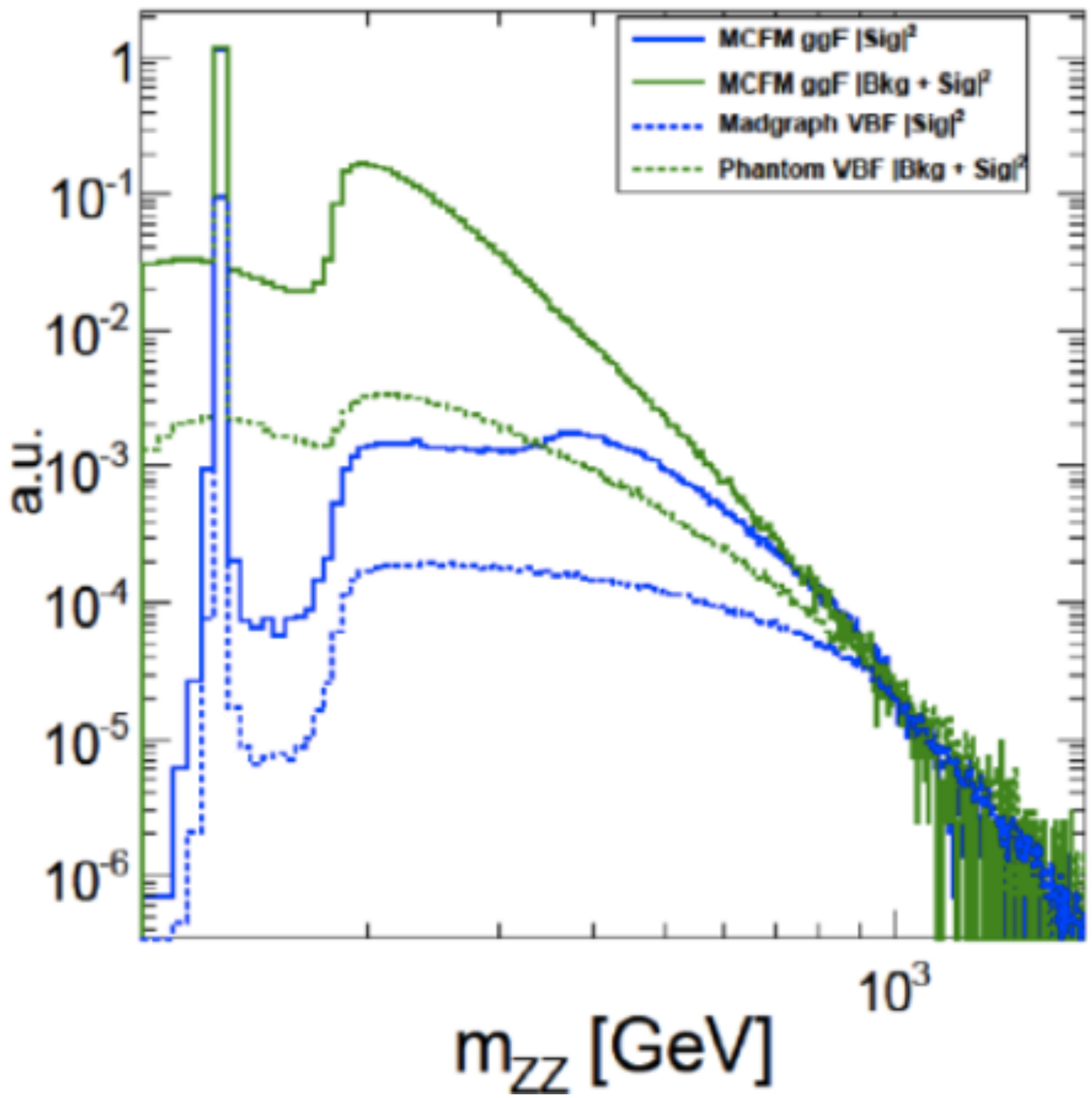
Run-2 Preview

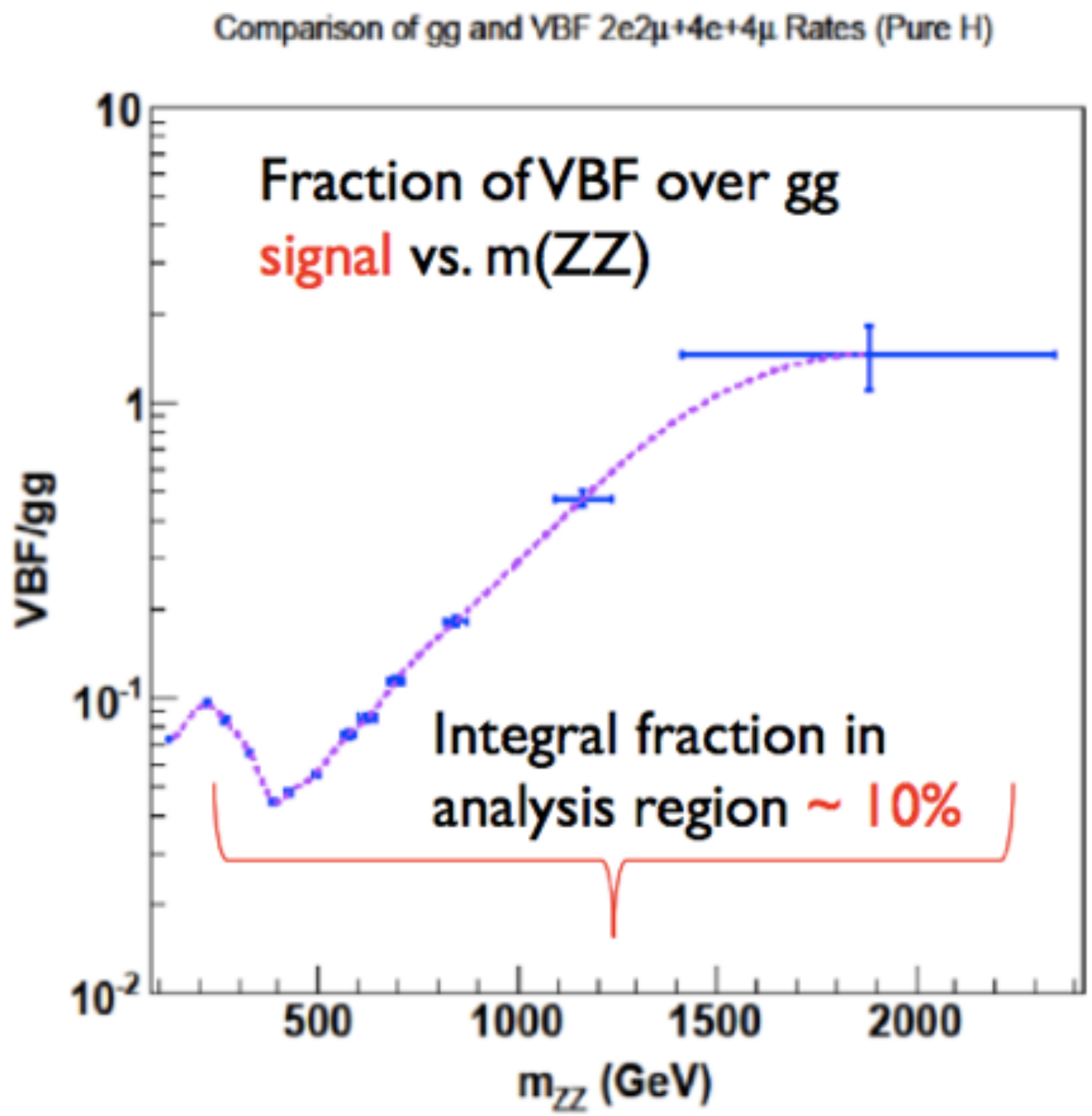
General Remarks

- In general we would need to keep probing new physics through the high mVV region
- Focus on the off-shell coupling constraints with the EFT based analyses
  - However it would not be trivial as the number of non-SM operators will be large
    - Perhaps some kind of prioritising is needed
- Total width assumptions/limitations need to be more carefully evaluated
- VBF channel serves an interesting probe with high signal-to-background ratio

Analysis in the VBF Channel

- With tree-level LO couplings, VBF is less sensitive to new physics effects compared to ggF
- VBF contributes ~ 10% on average, increasingly larger in the high mass region
  - Marco Zaro: VBF NLO QCD corrections are quite flat as function of the mVV





CMS R. Covarelli, I. Anderson and U. Sarica

https://indico.cern.ch/event/313725/session/2/contribution/34/0/material/slides/0.pdf

Anomalous gg→ZZ (HD) Couplings

- Off-shell events are sensitive to HD operators
  - Enhancement in the high mass, leading to more stringent limit on the total width if present
- Amplitude approach from MCFM and JHUGen

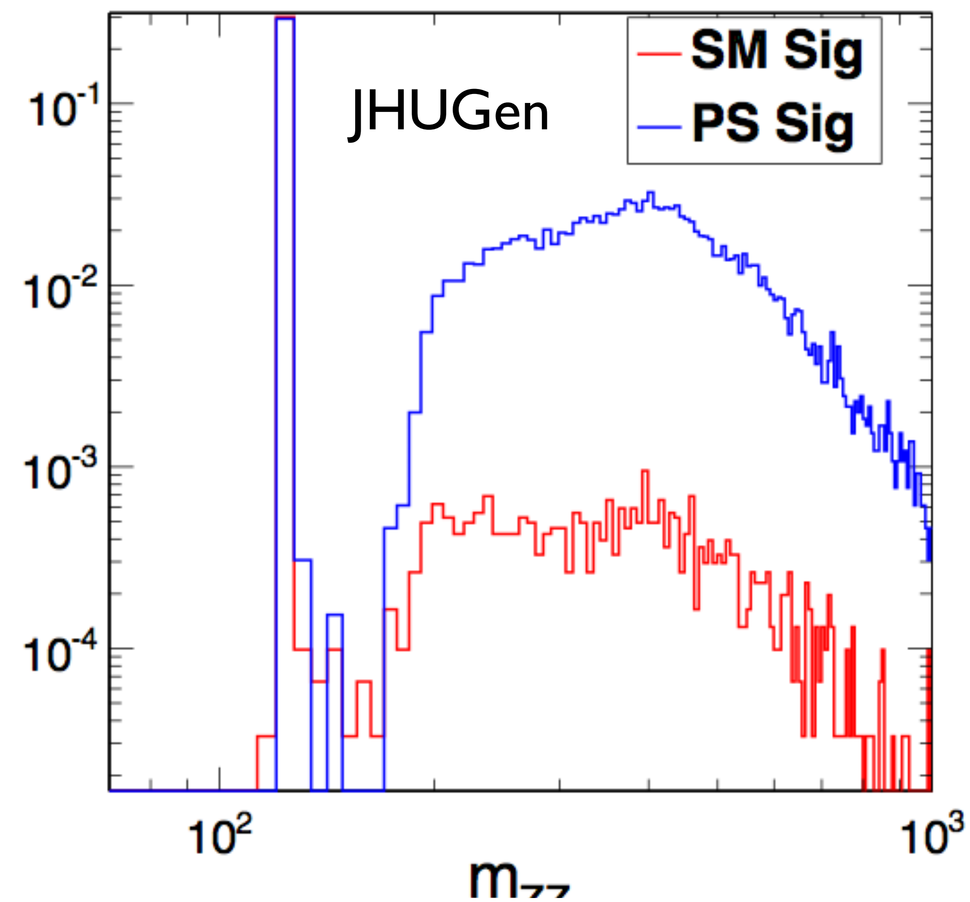
$$A(X_{J=0} \to Z_1 Z_2) \sim v^{-1} \left[a_1 - e^{i\phi_{\Lambda 1}} \frac{q_1^2 + q_2^2}{\Lambda_1^2} - \right] m_Z^2 \epsilon_1^* \epsilon_2^* + a_2 f_{\mu\nu}^* f^{*,\mu\nu} + a_3 f_{\mu\nu}^* \tilde{f}^{*,\mu\nu}$$

  - http://www.pha.jhu.edu/spin/
  - JHUGen version ≥4.8.1, released 31.10.2014
    - JHUGen also allows matrix element calculation analysis (MELA)
    - full S+B+I is included in gg→ZZ
- EFT approach as in 1403.4951

$$\mathcal{L} \supset \sum_{i=1}^{5} \kappa_i \mathcal{O}_i = -\kappa_1 \frac{M_Z^2}{v} X Z_\mu Z^\mu - \frac{\kappa_2}{2v} X F_{\mu\nu} F^{\mu\nu} - \frac{\kappa_3}{2v} X F_{\mu\nu} \tilde{F}^{\mu\nu} \quad (13)$$

$$+ \frac{\kappa_4 M_Z^2}{M_X^2 v} \Box X Z_\mu Z^\mu + \frac{2\kappa_5}{v} X Z_\mu \Box Z^\mu. \quad (14)$$

I. Anderson1, U. Sarica1, M. Schulze



Cross Section for 2e2μ Final State without Cuts