UNIVERSITY of ROCHESTER

Use of VBF MC for width determination

Roberto Covarelli (*University of Rochester*)

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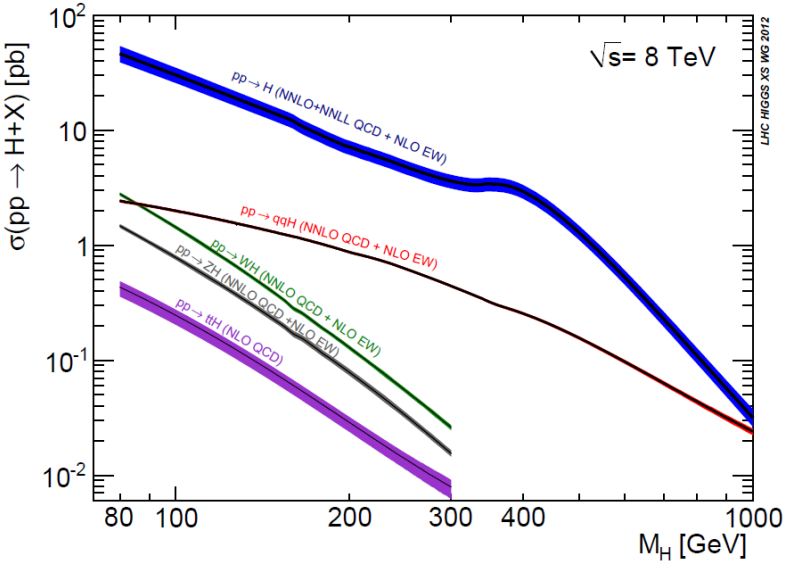
CMS width measurement

- Recent CMS paper (arXiv: 1405.3455) uses Caola-Melnikov's interpretation of Kauer-Passarino off-shell H calculations to constrain Higgs width
  - For gluon-gluon Higgs production, MC tools are quite advanced (gg2VV 3.1.5 and MCFM 6.7 giving results in excellent agreement)
  - Realized that VBF can give significant off-shell contribution (not considered in C&M paper)
  - (Naively?) inferred from $\sigma(M_H)$ that VH and ttH do not



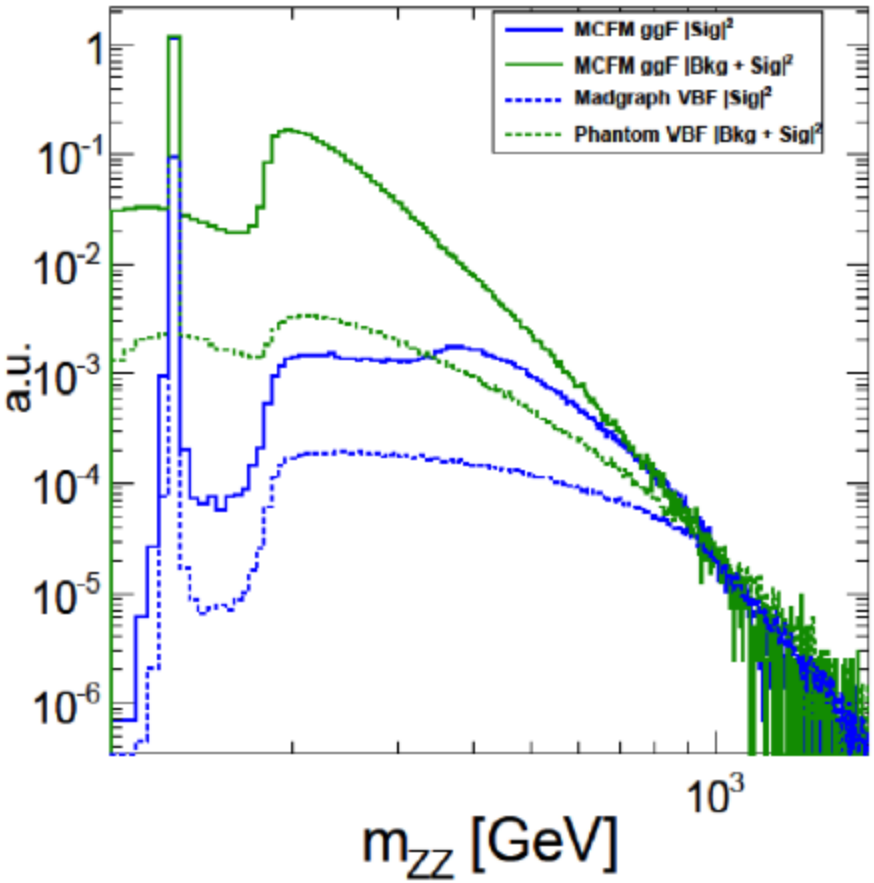
Generation of VBF MC

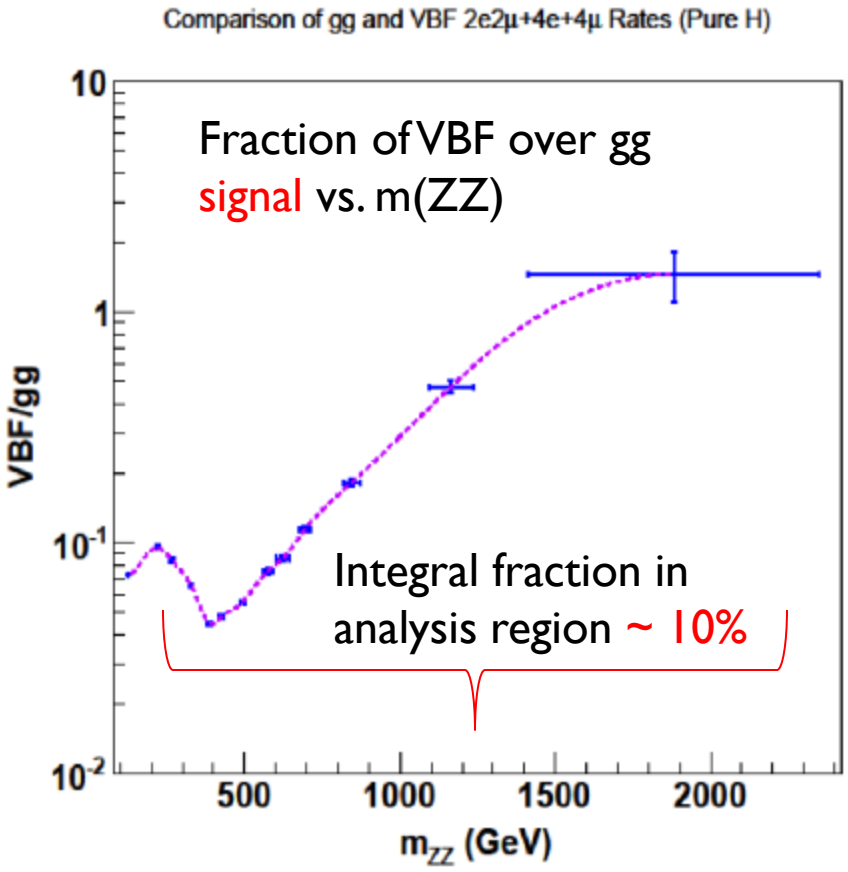
- Presence of off-shell tail in the VBF process verified in two generators with quite different working principles:

1. Madgraph 5.1.1
   - Can select a specific signal process (e.g. qq' → qq'H → qq' → ZZ → qq'4l), only that one is simulated
   - In its simplest version uses a fixed QCD scale (e.g. $m_H/2$)
2. Phantom 1.2.3
   - Generates all processes with a given initial and final state at order α_{EWK}^6 (e.g. qq' → qq'4l), means including:
     - VBF signal, background and interference process
     - Associated production (e.g. ZH, Z → ll, H → ZZ → 2lqq)
   - Has dynamical scales (i.e. ~ m_{ZZ})

Comparison with ggF (LO)

Plots by
I. Anderson – U. Sarica





- Note: in order to obtain "pure VBF" from PHANTOM, apply gen-level cut:
  - $m_{JJ} > 130$ GeV

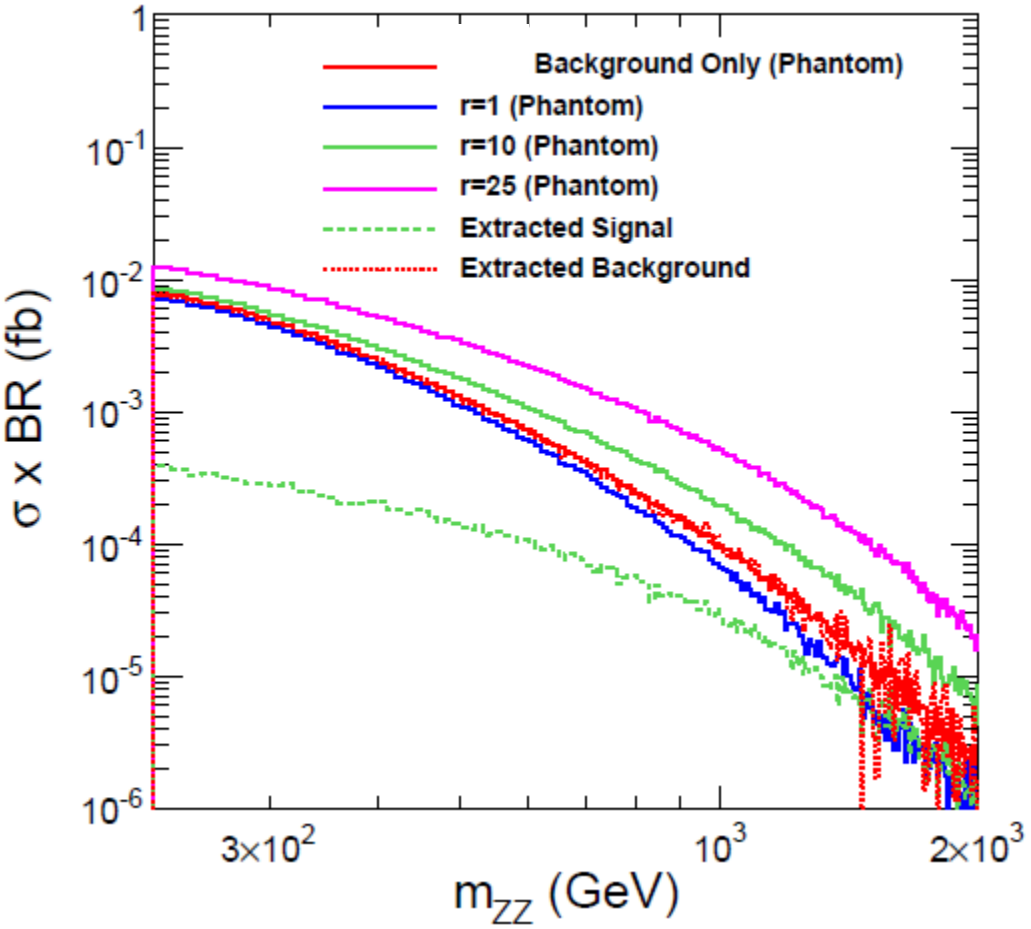
How to extract S, B, I

- Analysis needs template distributions of signal, background and interference terms:
  - $N_{tot} = \mu\,(\Gamma/\Gamma_0) \times S + \sqrt{\mu\,(\Gamma/\Gamma_0)} \times I + B$
- Not possible to generate single distributions with PHANTOM, use a workaround
  - PHANTOM now allows settings of BSM width and couplings
  - Generate three samples with Γ scaled by BSM factors (n = 1, 10, 25) while keeping $\mu = 1$, i.e. g are scaled by n^1/4
  - Solve matrix equation to obtain S, B, I in binned distributions

$$\begin{pmatrix} p_1 \\ p_{10} \\ p_{25} \end{pmatrix} = \begin{pmatrix} 1 & 1 & 1 \\ 10 & \sqrt{10} & 1 \\ 25 & 5 & 1 \end{pmatrix} \begin{pmatrix} S \\ I \\ B \end{pmatrix}$$

Result of the procedure

- Fully validated by comparing extracted B with PHANTOM run at unphysically high Higgs mass



Plot by
I. Anderson

Higher QCD orders

- NNLO/LO corrections to VBF process are small (5-6%) compared to ggF corrections (~250%)
  - In the analysis we decide to use a single k-factor, i.e. compute $k = \sigma_{YR}$ (on-peak) / σ_{LO}(on-peak) and apply a flat correction as a function of mZZ
  - Approximate independence of this correction on mZZ has been verified by M. Zaro
- Default QCD scale is mZZ/$\sqrt{2}$ in PHANTOM
  - Differs from default choices in gg2VV and MCFM of mZZ/2
  - Even if covered by systematic uncertainties ($\mu_{F,R}$ varied by factor 2 up and down) maybe we should agree on a common setting

Conclusions

- VBF treatment is an important part of the width measurement
  - Contributing by ~10% to the off-shell signal with much larger S/B ratio
  - In presence of high statistics, VBF-dedicated analysis may overcome inclusive analysis in sensitivity, with large suppression of qqbar → ZZ background
- Using PHANTOM for MC simulation
  - Can generate S+B+I at LO
  - Can scale SM width and couplings by arbitrary factors
  - Used a combination of BSM samples to extract S, B and I
  - Used a flat factor for NNLO/LO corrections