Interference effects in the $H \to \gamma\gamma$ + 2 jets channel at the LHC

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HXSWG open meeting

CONICET

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- Signal-background interference in $H \rightarrow \gamma\gamma$ + 2 jets
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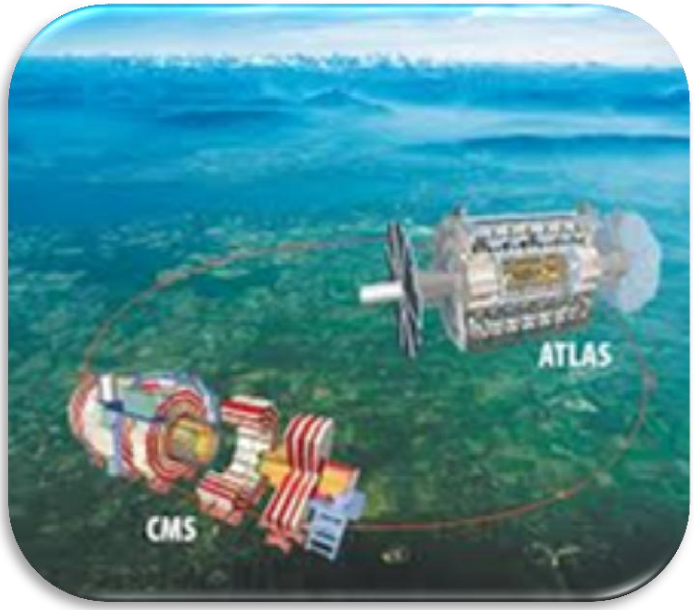
Motivation



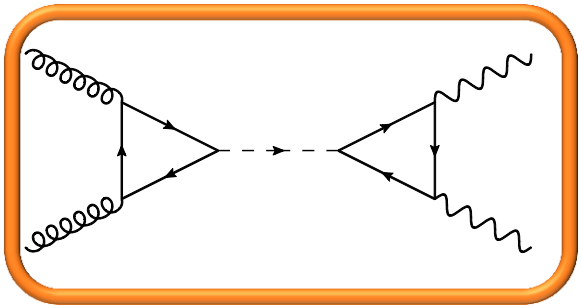
1 Signal-background interference

Shift in the diphoton invariant mass peak

2

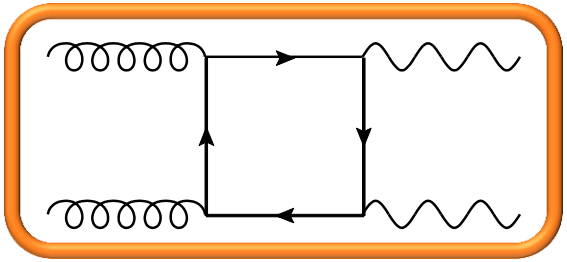
Shift is highly dependent on the Higgs Width → May allow for its measurement and/or bound

Inclusive case: gg ⇒ H ⇒ γγ



- 2-loop
- $\mathcal{O}(g_s^2)$

Interferes with…



- 1-loop
- $\mathcal{O}(g_s^2)$

gg ⇒ γγ continuum

After convolution with the broad experimental diphoton mass resolution
(highly antisymmetric nature of the interference terms is enhanced by the convolution)

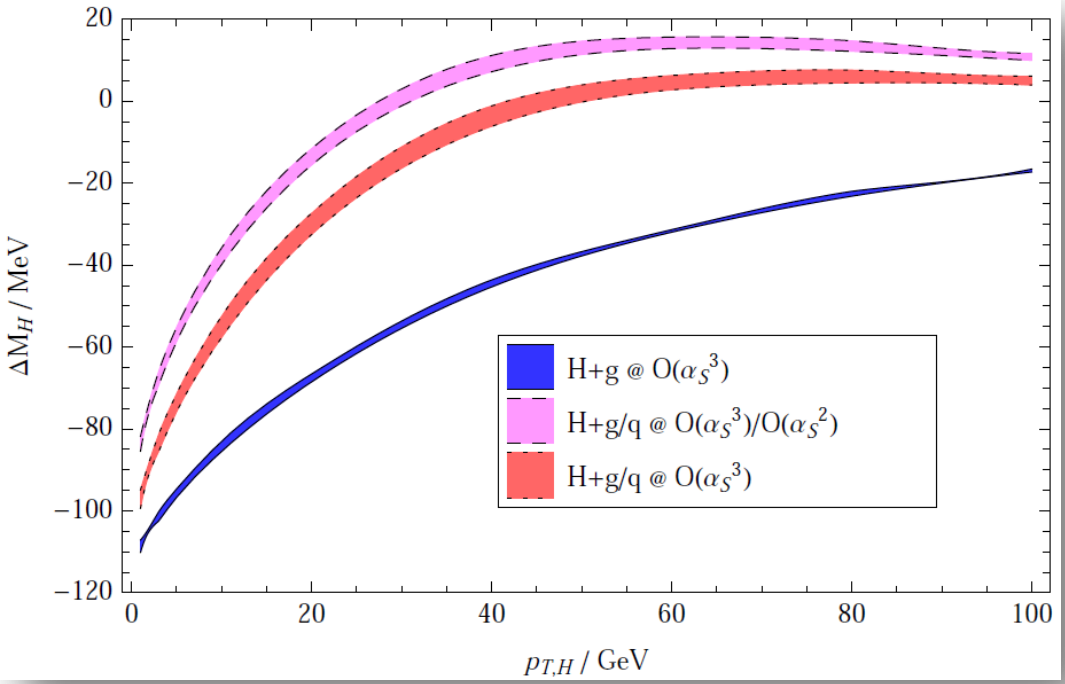
Shift in the diphoton mass peak towards lower invariant masses

LO: ~100 MeV

NLO: ~60-70 MeV

MASS SHIFT AT NLO AND WIDTH DEPENDANCE

- Shift depends on Γ_H ⇒ We can use it to bound its value
- Maintaining the Higgs signal constant ⇒ Shift proportional to $\sqrt{\Gamma_H}$
- Less model dependent than off-shell measurements



- Shift shows a strong dependance on pT_H

WHY LOOK AT $H \rightarrow \gamma\gamma$ + 2 jets

- We need another measurement of the Higgs mass to compare and extract the shift

- Resonance in the diphoton channel: $m_H^{\gamma\gamma} = 125.07 \pm 0.25\,(\text{stat}) \pm 0.14\,(\text{syst})\ \text{GeV}$

  In the ZZ* mode: $m_H^{ZZ^*} = 125.15 \pm 0.37\,(\text{stat}) \pm 0.15\,(\text{syst})\ \text{GeV}$

  Yielding a mass difference of: $m_H^{\gamma\gamma} - m_H^{ZZ^*} = -80 \pm 490\ \text{MeV}$

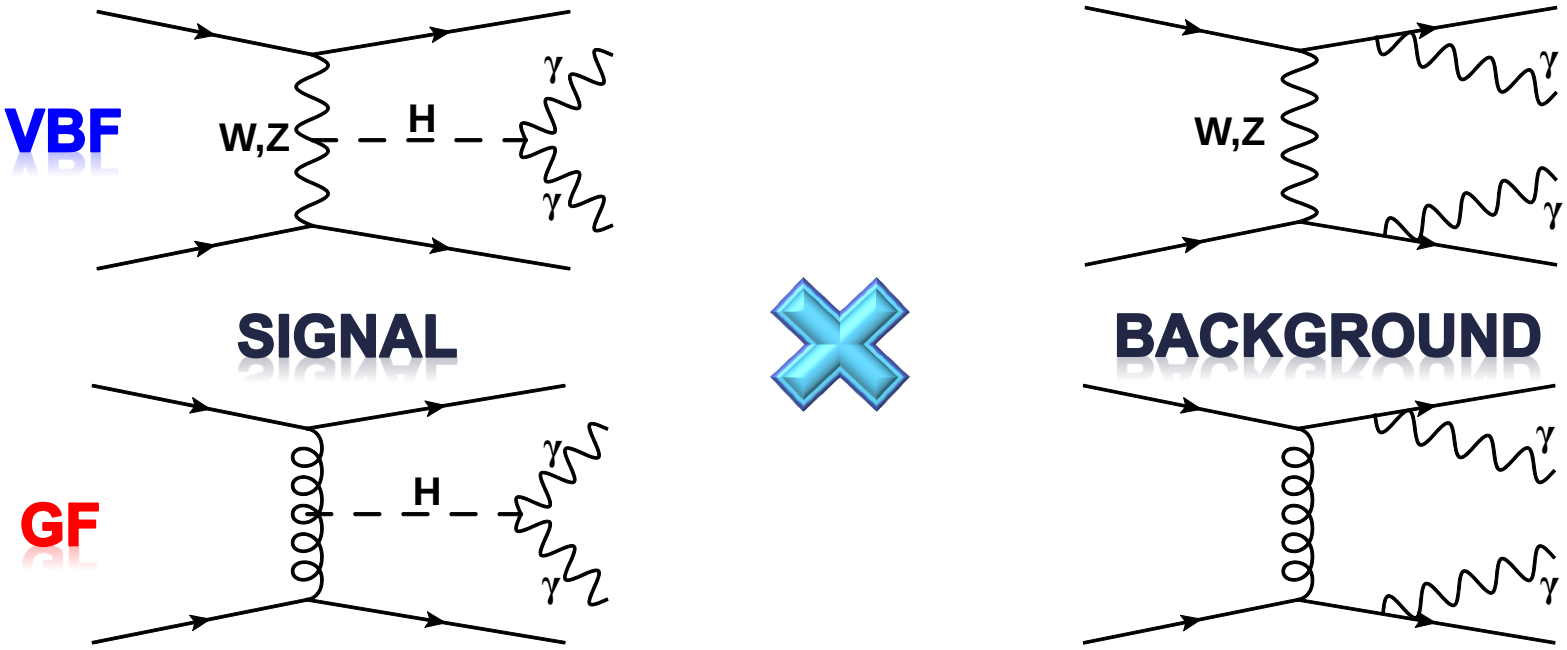
- Using a reference mass with photons ⇒ Reduced systematic uncertainties

Subsample of the inclusive GF $\gamma\gamma$ sample with non zero $p_{T,H}$

2 photons + 2 jets ⇒ Rare but low background, so reasonable statistical uncertainties on the possition of the mass peak

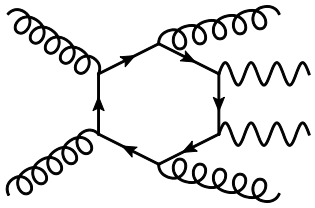
More robust theoretically than high-pT_H region in the inclusive pp → $\gamma\gamma$

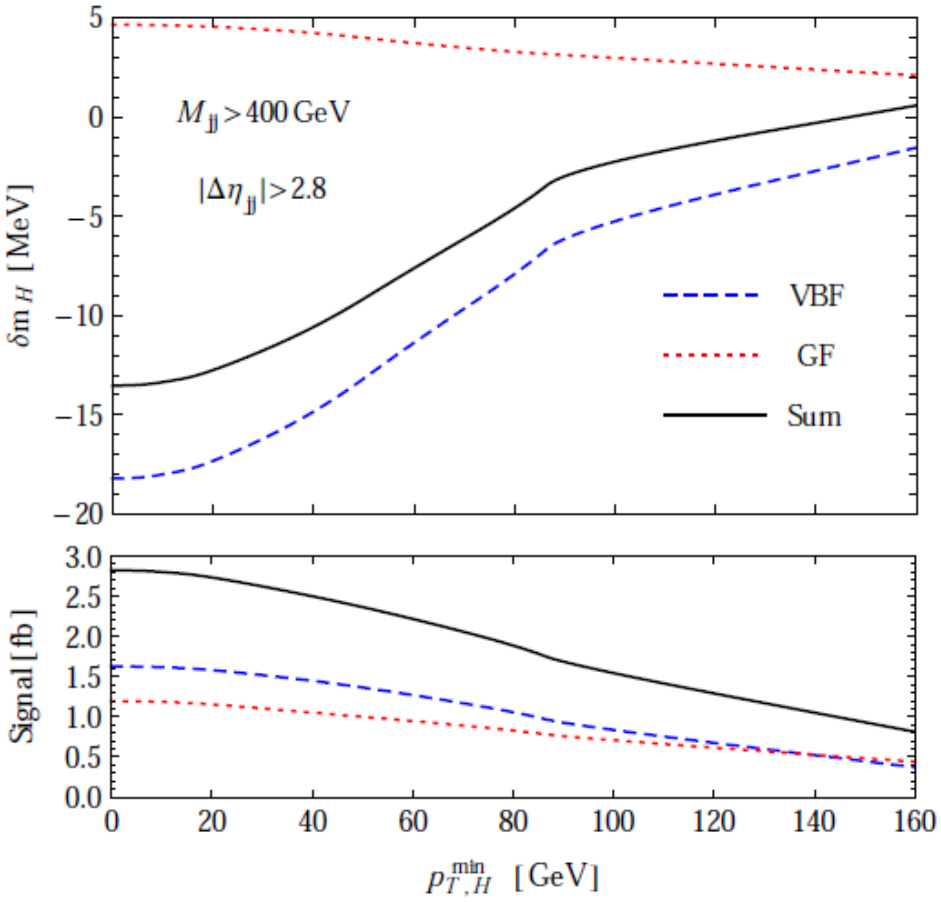
Mass shift in γγ + 2 jets



Two independent calculations:

- Analytic amplitudes obtained with the help of FeynArts, FeynCalc and FormCalc
  Interface with numeric phase-space integration via a custom Fortran code
- Events generated with SHERPA and COMIX used to compute tree level amplitudes, and cross checked with MADGRAPH5
- Gluon channel contribution (formally higher order) included
  It's matrix element was provided by the BlackHat library



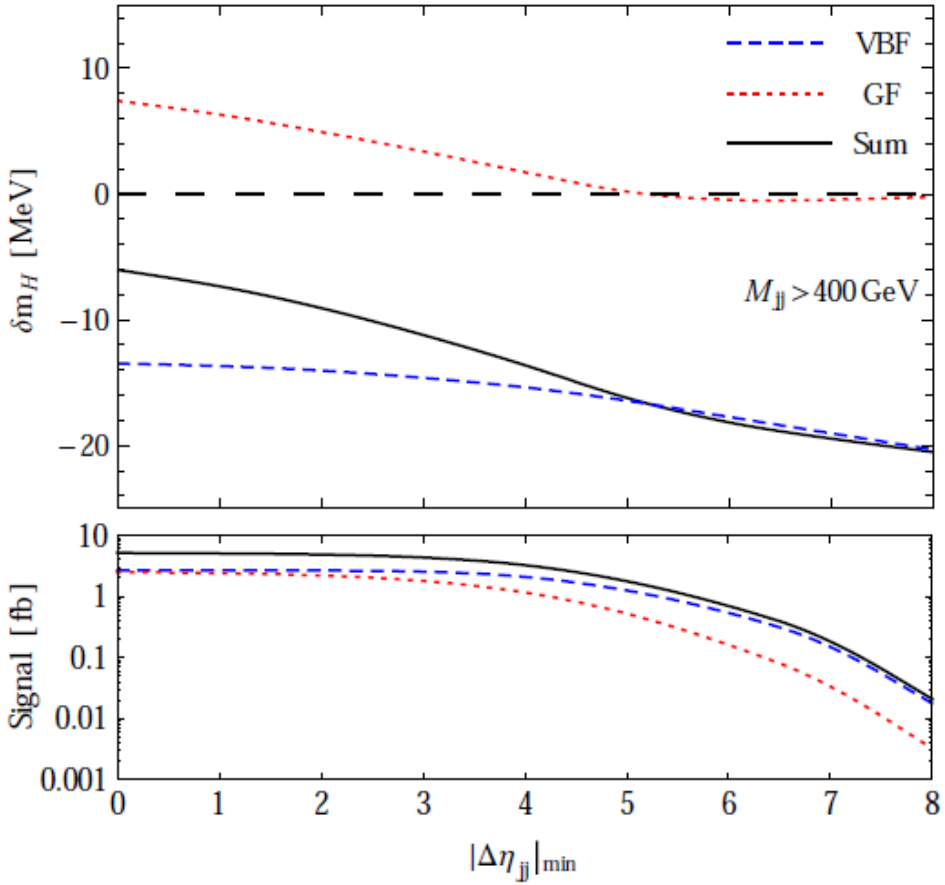


- Higher ptH ⇨ Smaller shift

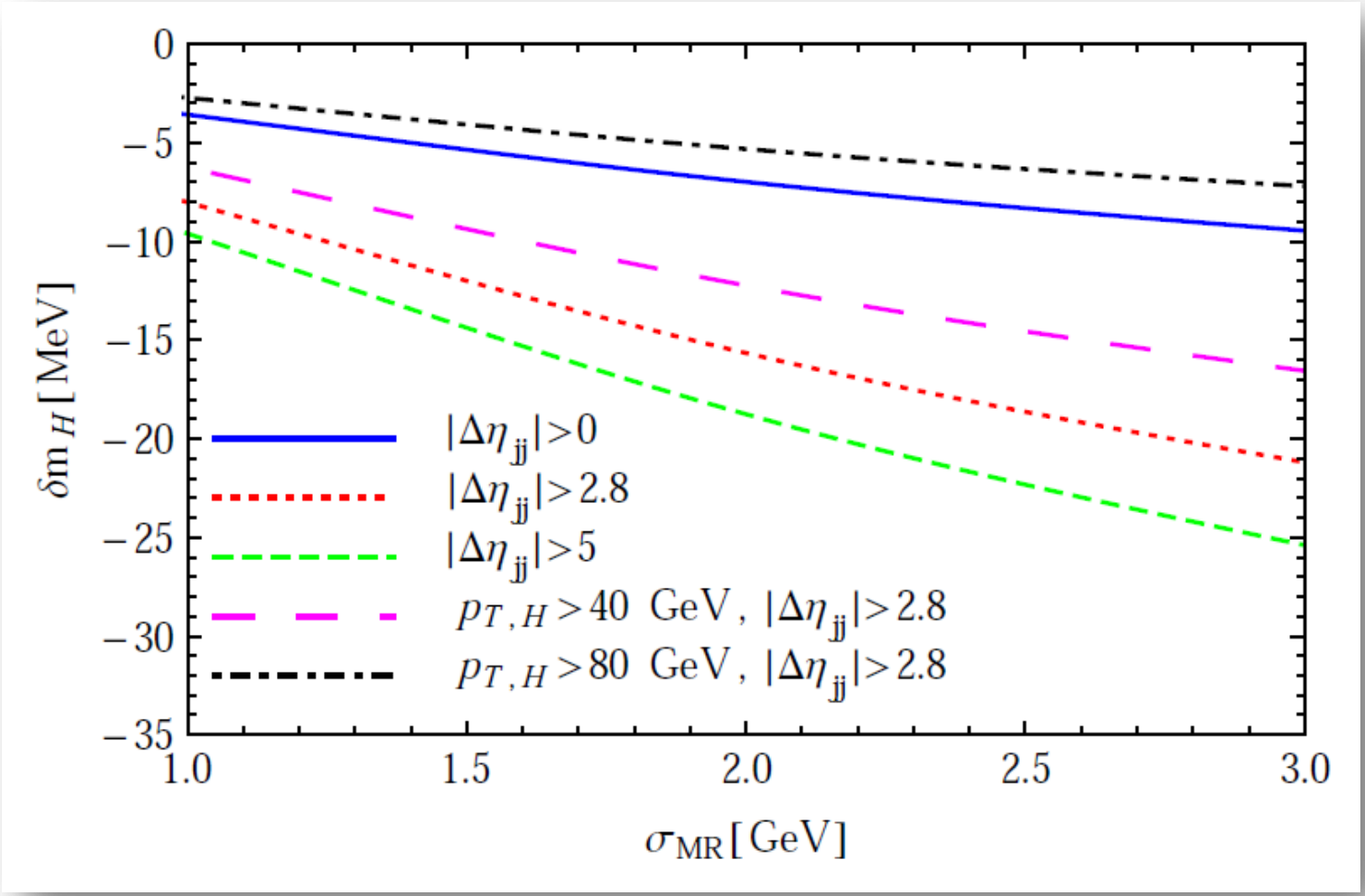
- Contributions have opposite sign

VBF Shifts towards lower masses

GF Shifts towards higher masses



Dependence of the mass shift on the width of the Gaussian used to simulate the experimental mass resolution of the detector



δm_H increases with σ_{MR} in a roughly linear way, for five different choices of cuts

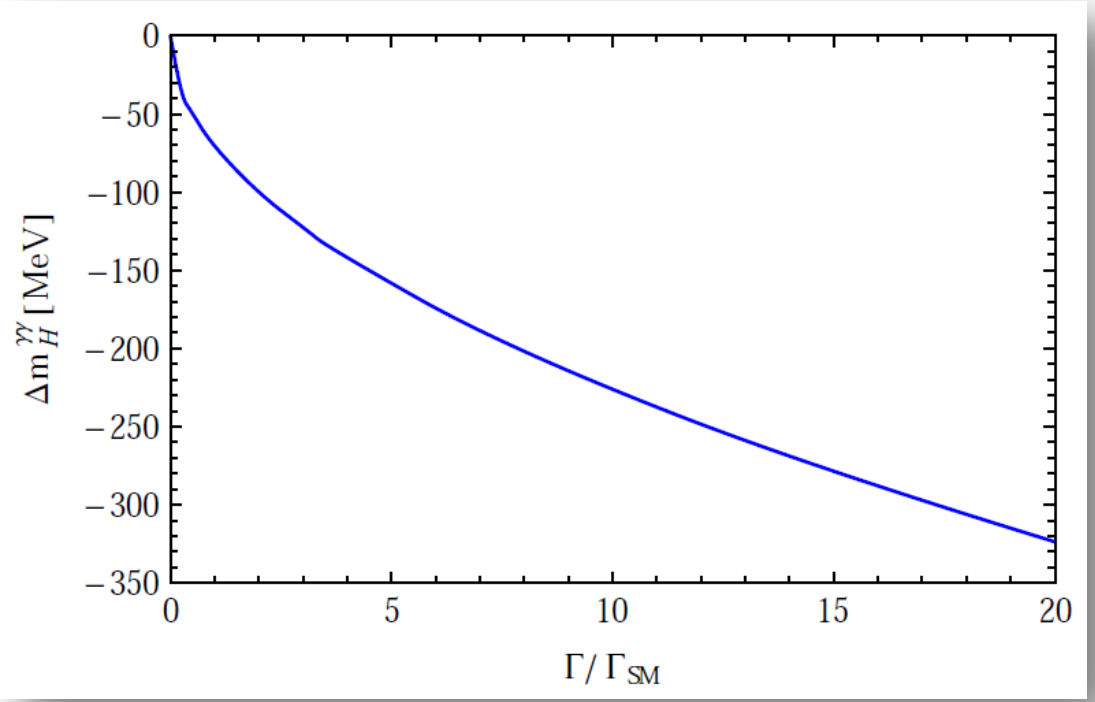
BOUNDING THE HIGGS WIDTH

- Much smaller shift than in inclusive case → Using only this for bounding the width is not so good
- Useful as a reference mass for experimental measurement of the mass difference:

$$\Delta m_H^{\gamma\gamma} \equiv \delta m_H^{\gamma\gamma,\,\mathrm{incl}} - \delta m_H^{\gamma\gamma,\,\mathrm{VBF}}$$

Higgs width is varied → its couplings must also be modified, to prevent the total cross section from suffering large variations

- Assume couplings of the Higgs with the top quark and massive weak bosons deviate from the SM predictions by real factors
- We adjust Γ to maintain the Higgs signal strength near the SM value.
- $\Delta m_H^{\gamma\gamma} \propto \sqrt{\Gamma/\Gamma_{SM}}$



Conclusions

- Signal-background interference leads to a shift in the diphoton inv mass peak
- The mass shift depends on the Higgs width, and can therefore be used to bound its value
- In the inclusive case the shift is O(50-100 MeV) for SM values
- Much smaller shifts for Higgs + 2 jets; VBF and GF with opposite signs
- Can be used as a control region against the inclusive case