Progress status in hzz2l2nu analysis

Mostafa Mahdavikhorrami[1], Andrey Popov[1], Nicolas[1] Postiau, Ulascan Sarica[2], Pascal Vanlaer[1], Hanwen Wang[1,3], Sicheng Wang[2], Li Yuan[3]

[1]Universite Libre de Bruxelles,
[2]Univ. of California, Santa Barbara,
[3]Beihang University

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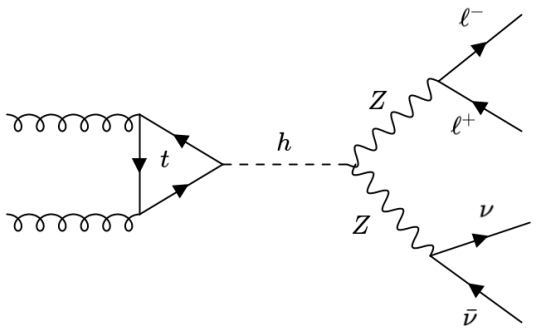
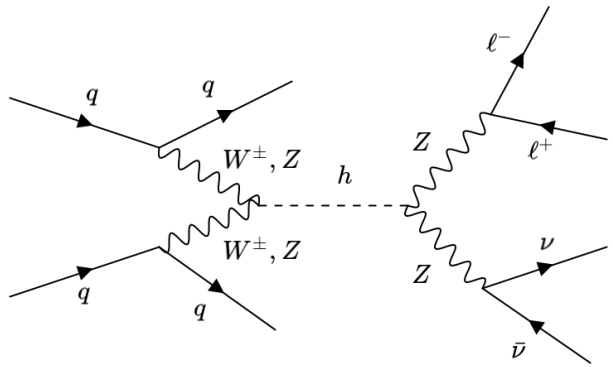
Analysis Goal

- In the hzz2l2nu group, our research goal is mainly focused on
  - Higgs decays width measurement,
  - The study of HVV anomalous couplings in the offshell to put strong constraints on HVV anomalous couplings and the Wilson coefficient of dimension-six operators.
- For this purpose the analysis has been focusing on GF/VBF Higgs production channels decaying to Z-boson pairs with $2l\ 2\nu$ final state.
- The analysis is based on Data collected by CMS experiment during LHC run 2 (2016-2018) at $\sqrt{s} = 13$ TeV and with integrated luminosity of around 140 fb^{-1}.



gF Higgs production



VBF Higgs production

Higgs width measurment

1) For a process such as $i \to \mathrm{H} \to f$ the differential cross section is:

$$\frac{\mathrm{d}\sigma_{i\to \mathrm{H}\to f}}{\mathrm{d}\mathrm{M}_f^2} \sim \frac{g_i^2 g_f^2}{\left(\mathrm{M}_f^2 - m_{\mathrm{H}}^2\right)^2 + m_{\mathrm{H}}^2 \Gamma_{\mathrm{H}}^2}$$

where $g_{i,f}$ are the Higgs boson couplings to initial and final states, Γ_{H} is the Higgs boson width and M_f is invariant mass of final states system.
By integrating over on-shell region (a small region around m_{H}) and over very off-shell region ($\mathrm{M}_f \gg m_{\mathrm{H}}$),

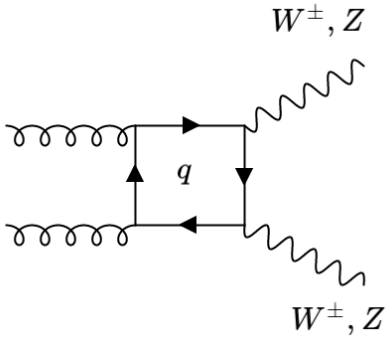
$$\sigma^{\text{on-shell}}_{i\to \mathrm{H}\to f} \sim \frac{g_i^2 g_f^2}{m_{\mathrm{H}}\Gamma_{\mathrm{H}}}$$

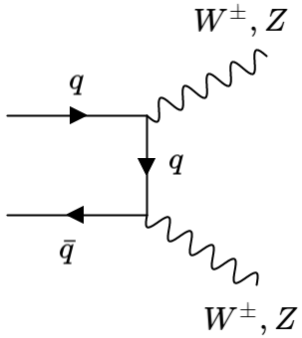
$$\sigma^{\text{off-shell}}_{i\to \mathrm{H}^*\to f} \sim \frac{g_i^2 g_f^2}{\mathrm{M}_f^2}$$

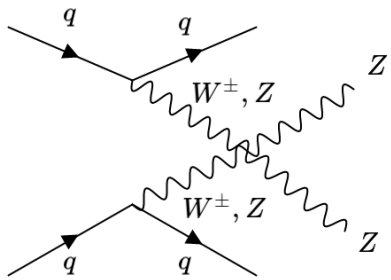
So, the measurement of relative productions in the both region, provides us direct information on Γ_{H}

Backgrounds

- Irreducibles:







- Reducibles:
  - Drell-Yan + Jets
  - $t\bar{t}$
  - Single top
  - WW
  - WZ
  - WWZ + WZZ + ZZZ

Selection cuts

Signal region selection cuts:

1) Selecting events having 2 final state charged leptons e, μ with $p_t \geq 25$ GeV (Lepton ID/Iso is applied)
2) Z mass window: $|\mathrm{M}_{\ell\ell} - \mathrm{M}_{\mathrm{Z}}| \leq 15$ GeV
3) $p_t^{\ell\ell} \geq 55$ GeV
4) MET ≥ 125 GeV
5) $|\Delta\phi(\ell\ell, \mathrm{MET})| \geq 1.0$
6) b veto
7) $|\Delta\phi(\mathrm{jets}, \mathrm{MET})| \geq 0.25$
8) $|\Delta\phi(\mathrm{jets} + \ell\ell, \mathrm{MET})| \geq 2.5$

One of my contribution was to optimize the selection cuts which ended up with modifying

- $|\Delta\phi(\ell\ell, \mathrm{MET})|$ cut from 1.5 to 1.0
- $|\Delta\phi(\mathrm{jets}, \mathrm{MET})|$ cut from 0.5 to 0.25
- Introducing a new cut for supressing Drell-Yan contributions much than before i.e. $|\Delta\phi(\mathrm{jets} + \ell\ell, \mathrm{MET})|$ cut.

Current status of the complete analysis

- The main pieces of the analysis such as CR estimation, MC corrections, Signal Modeling, systematic unc. and etc. are in the finilization stage.
- Using matrix-element (MELA) reweighting tool to simulate samples with different hypotheses.
- We are aiming to have the analysis approved for the winter conferences (Moriond 2021 in March next year).

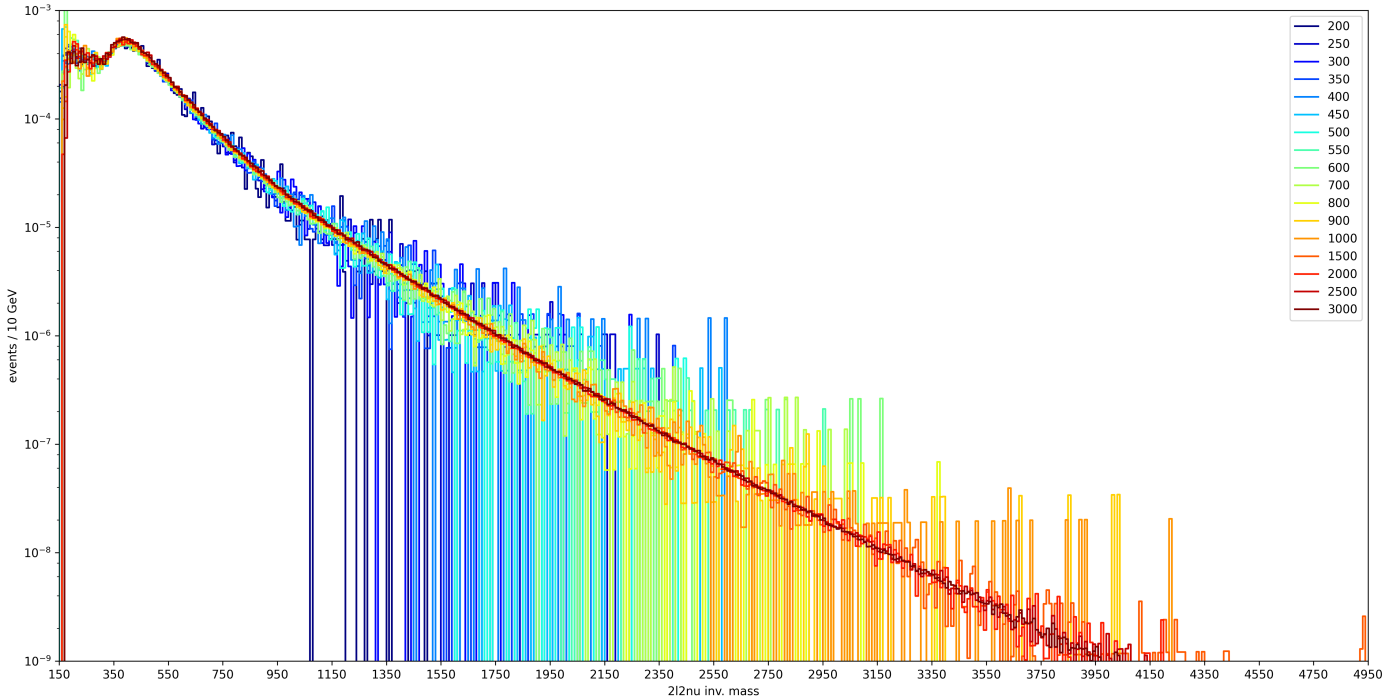
The Idea of MELA reweighting

- The main idea is to compute the Matrix Element probability density of the model of the sample we have (MEP_{sample})
- Compute the Matrix Element probability desity of the model we want (MEP_{target}) i.e. the target hypothesis
- Reweight the events in the sample we have by the MEP ratio i.e. $\frac{MEP_{target}}{MEP_{sample}}$
- This techniques allows us to create samples with different hypothesis such as SIG, BSI, BKG of SM and BSM without generating them explicitley
- Samples at different Higgs pole masses are needed to compensate the low statistics in tails
- The samples we are using are POWHEG samples at NLO QCD + LO EW with SM assumption (SM couplings of H to the SM particles).

POWHEG samples of GF Higgs production $\rightarrow ZZ \rightarrow 2\ell 2\nu$ process

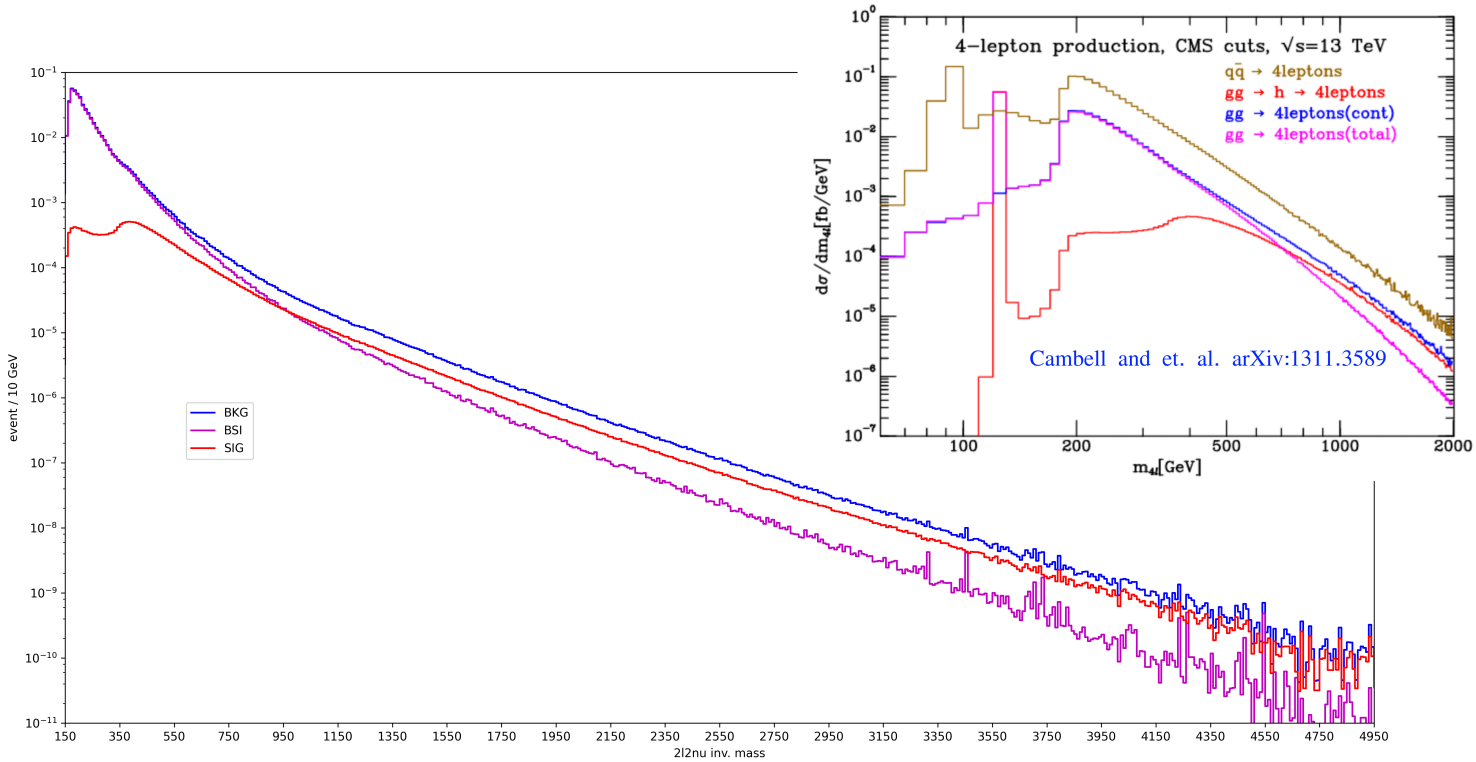
Higgs mass normalized distribution (out of box)

GF POWHEG sample after reweighitng



Signal hypotheisi, after applying computed MELA weights and normalization factors

POWHEG samples of GF Higgs production $\rightarrow ZZ \rightarrow 2\ell 2\nu$ process

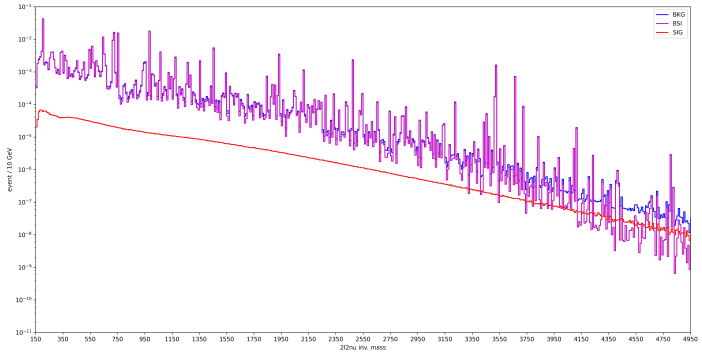


Combining samples for different hypotheses: Signal, BKG and BSI

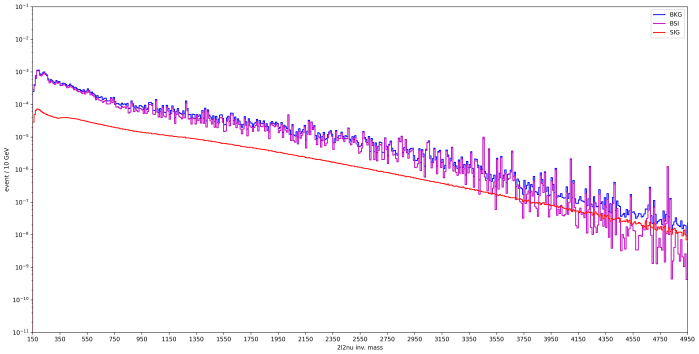
Current status/issues on MELA reweighitng

MELA reweighing results are very promising, however for VBF process, it's a bit challenging and we need to deal with some issues such as

- The outliers (very large weights) which have been resolved but some optimization may be needed.
- An unexpected shapeline at lower Higgs mass which is under investigation.



before removing very large weights



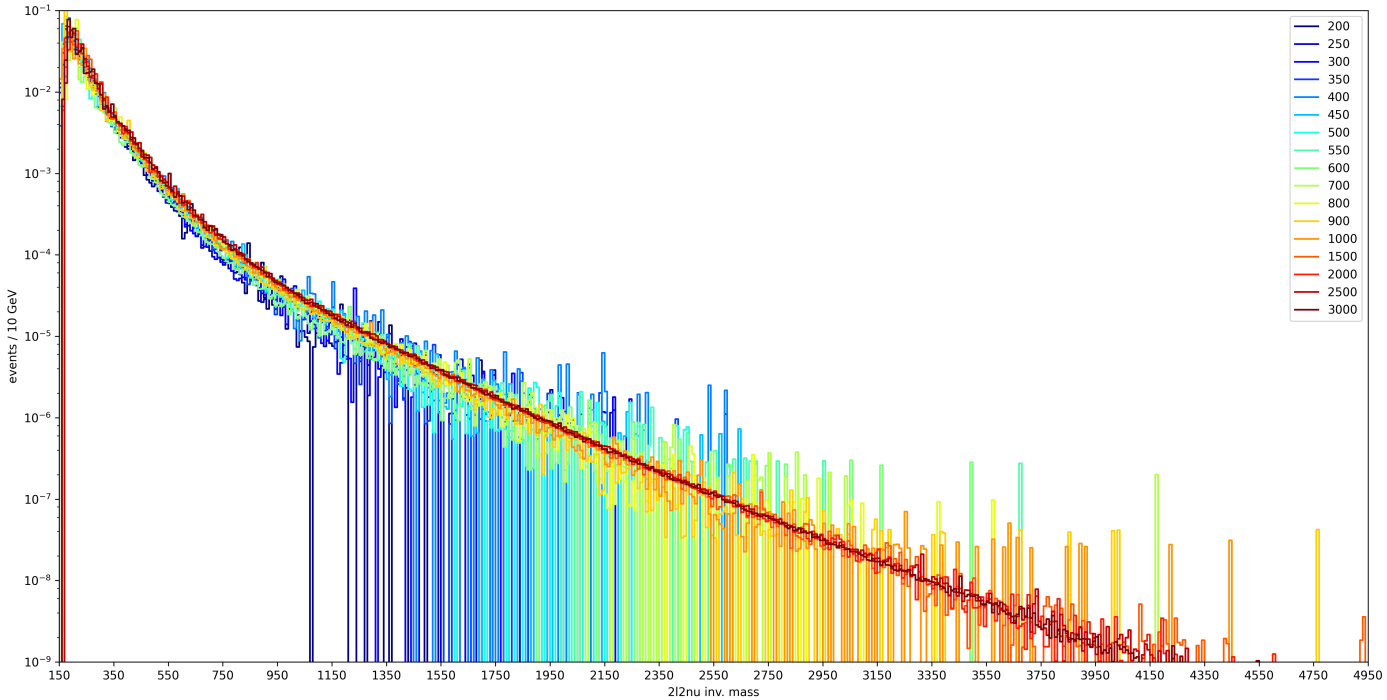
after removing very large weights

$$\text{VBF qq} \to H^* qq \to ZZqq \to 2\ell 2\nu qq$$

Near Future Plans

- Investigating and Resolving the issues in MELA reweightings
- Cross-checking the MELA reweighting technique w.r.t the similar sample at LO QCD such as MCFM samples for GF process and JHUGen samples for VBF.
- Studying observables such as m_T, MET, $p_t^{\ell\ell}$ and etc. in anomalous couplings samples obtained by MELA reweighting procedure.

Backup


events / 10 GeV
2l2nu inv. mass
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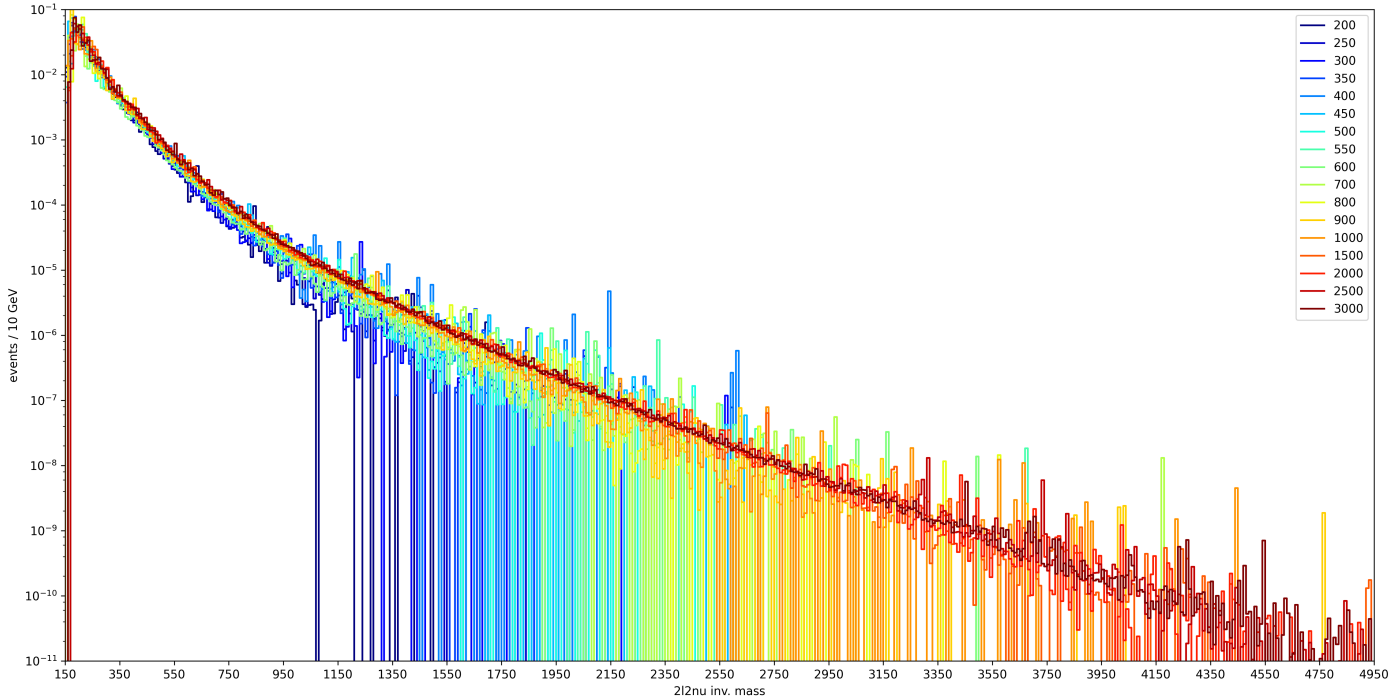
GF, BKG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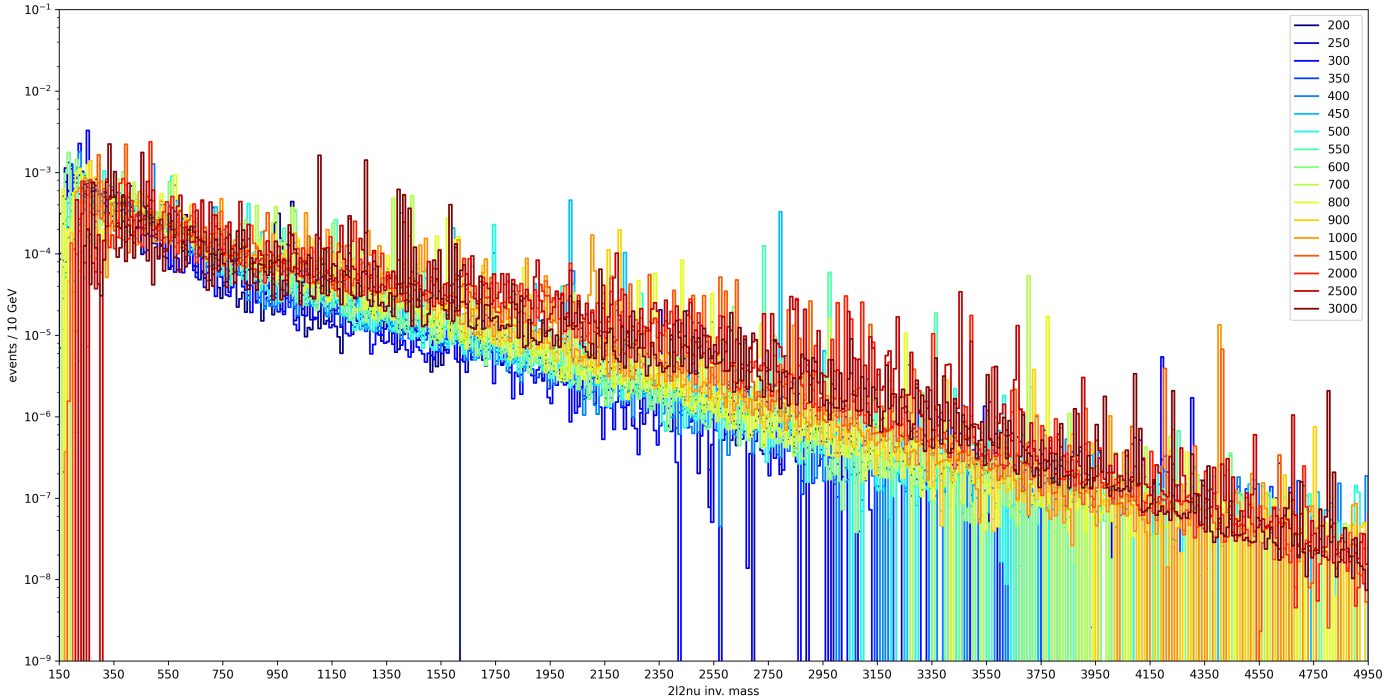
GF, BSI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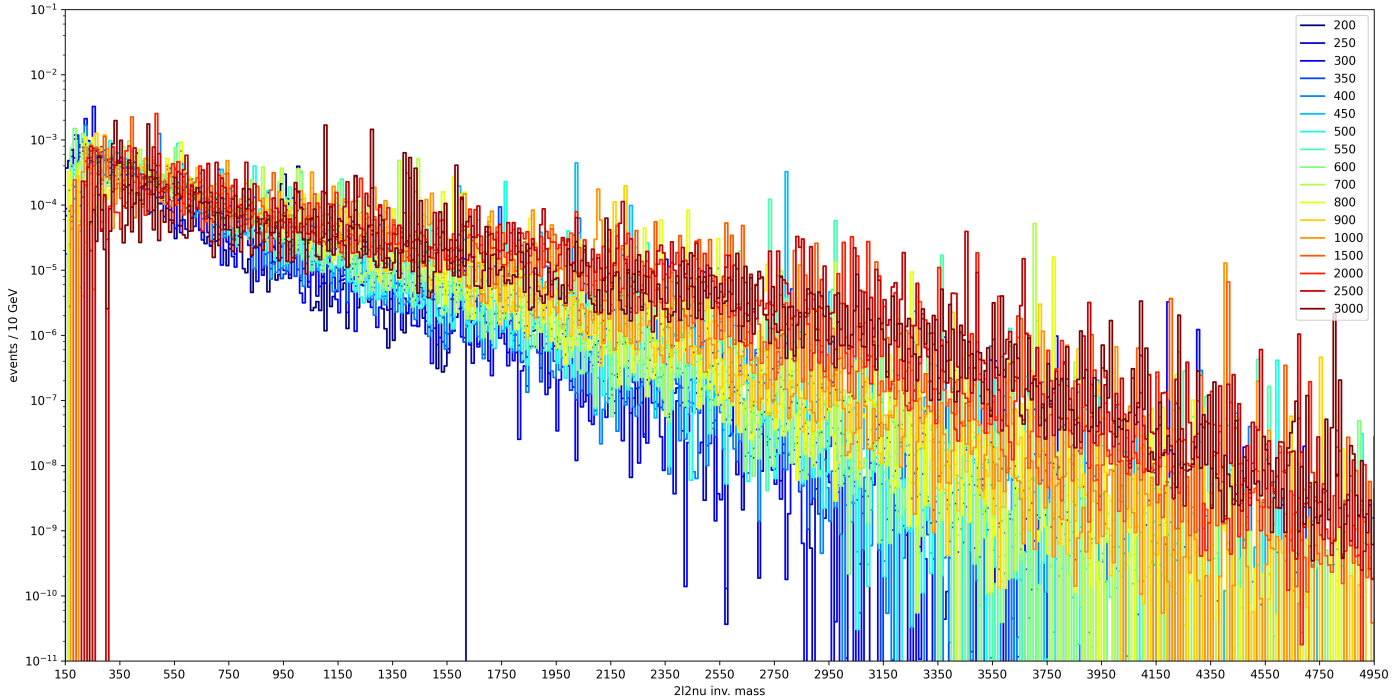
VBF, BKG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VBF, BSI