Closure test for REPOLO using VBFNLO

Max-Planck-Institut für Physik
(Werner-Heisenberg-Institut)

Interference effect in the VBF signature

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Rikard Sandström

Max Planck Institut für Physik

Introduction
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Introduction

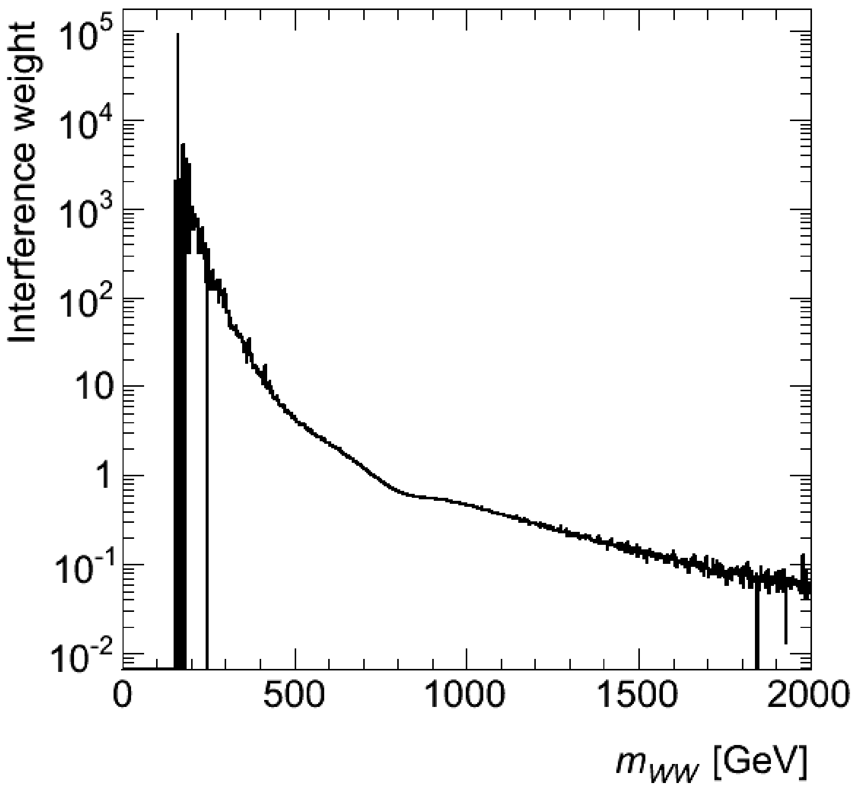
- ATLAS is using POWHEG samples for describing heavy Higgs bosons
  - Uses Complex Pole Scheme and parameters from CERN Higgs Cross Section group
- To include the effect of the interference between $H \rightarrow WW$ and the WW continuum from box diagrams we are using REPOLO (REweight POwheg at Leading Order)
  - It is a tool from the same developers as VBFNLO
  - Special thanks to Michael Rauch and Franziska Schissler!

http://www.itp.kit.edu/~vbfnloweb/wiki/doku.phpid=external:heavyhiggs:overview

Inputs and necessary variables

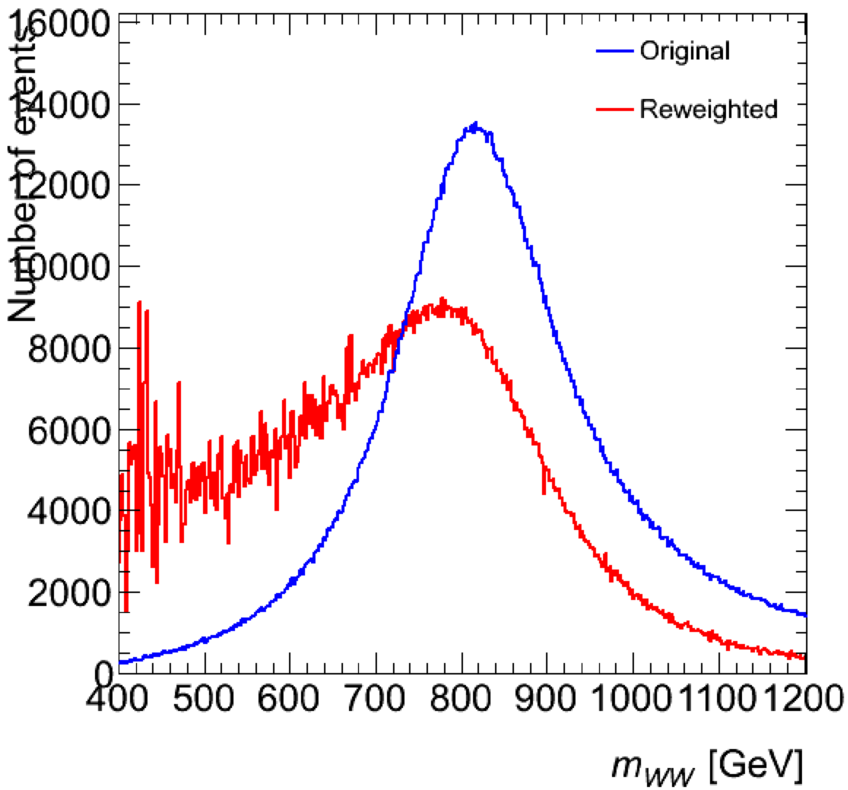
- REPOLO reads Les Houches Event files as default input
  - ATLAS stores 12 M LHE events per VBF mass point, so there is little problem with statistics
- The ATLAS Higgs analysis are using D3PD, which is a derived physics data, where only some of the MC truth information is kept from the original LHE file
- Ideally, we should be able to run REPOLO using the truth information kept on the D3PD, but the missing variables makes this impossible
- We *could* try to identify the LHE events that corresponds to the events that are accepted by the analysis, and only run REPOLO on that subset, then use that interference weight in the downstream analysis
  - This would be a way to "repair" the events, but it is technically and computationally challenging
- Instead, another idea was explored:

Simplified use by utilizing look-up tables



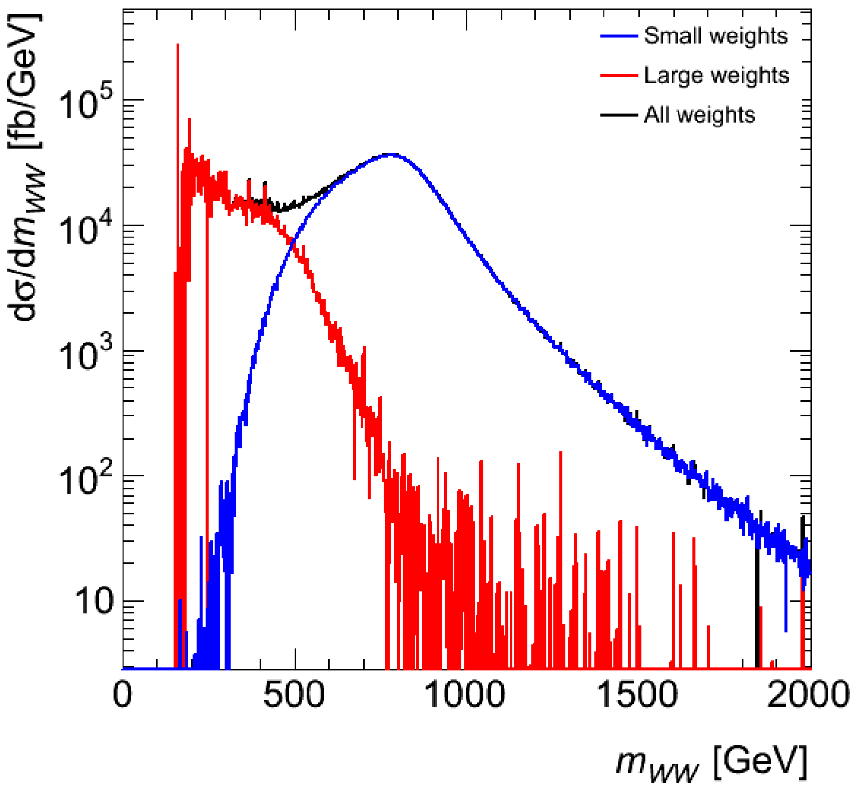
- Idea:
  - Create a mapping for the average weight as a function of a small set of variables that characterize the event by using the large number of POWHEG events in LHE format
  - Since the reconstructed mass is our discriminating variable in the search for new bosons, we characterized events only by m_{WW}.
    - As such, it can be represented as a 1D histogram
- The ratio of weighted m_{WW} distribution to unweighted distribution is used as a look-up table to map events to their average interference weight given their m_{WW} value

Large event weights



- We have 12 M event generator Higgs bosons per mass point
  - This is more than enough statistics
- However REPOLO weights are sometimes huge, producing spikes in the plot on the left
  - This gives a "statistical uncertainty" on the mapping S → SI
- By rerunning multiple times on these rare events, we can replace the large weight with the average of the calculated weights for such events
  - More details in backup

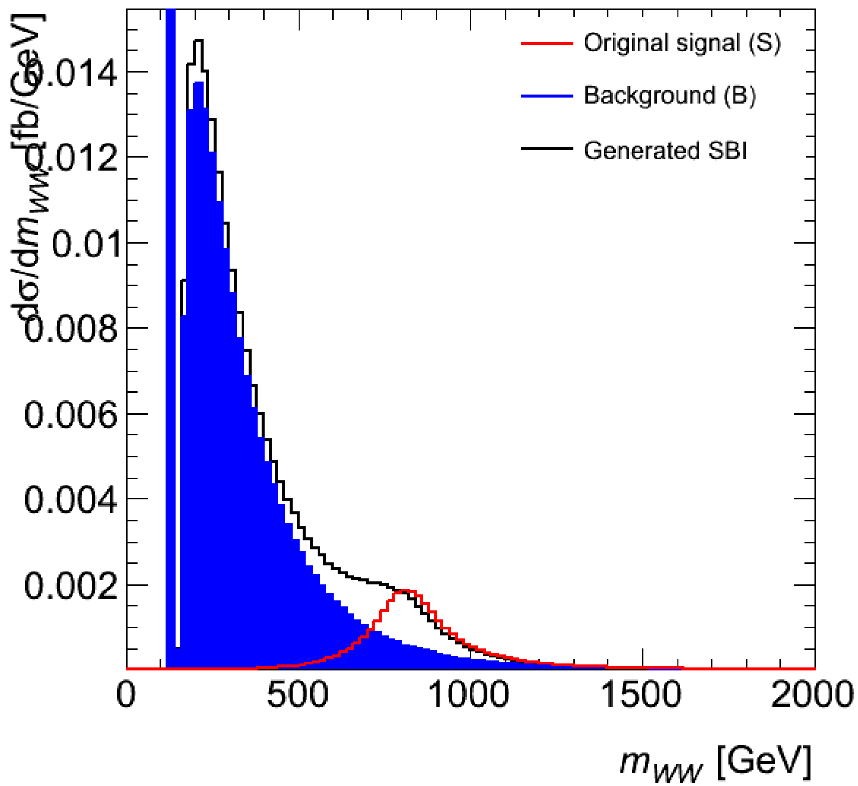
Example of weight splitting, 800 GeV



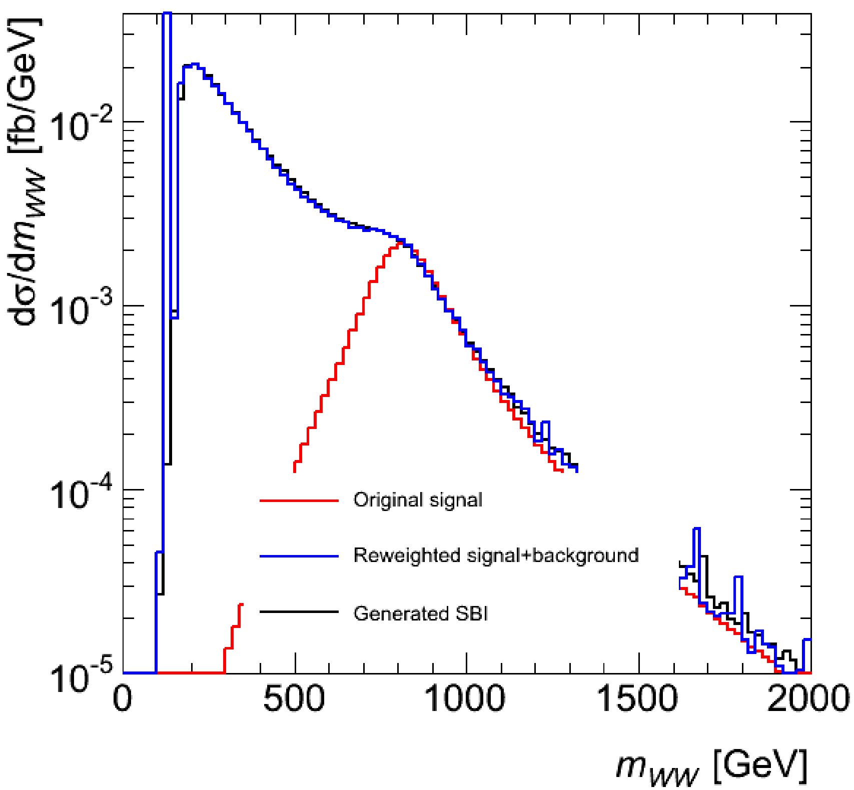
- Blue are events with |w|<10, used as they are without any special treatment
- Red are events with |w|>10, rerun 20 times with different random seed, and using average weight to fill the histogram
- Black is the sum of all events
- The final distribution is much smoother than the original distribution

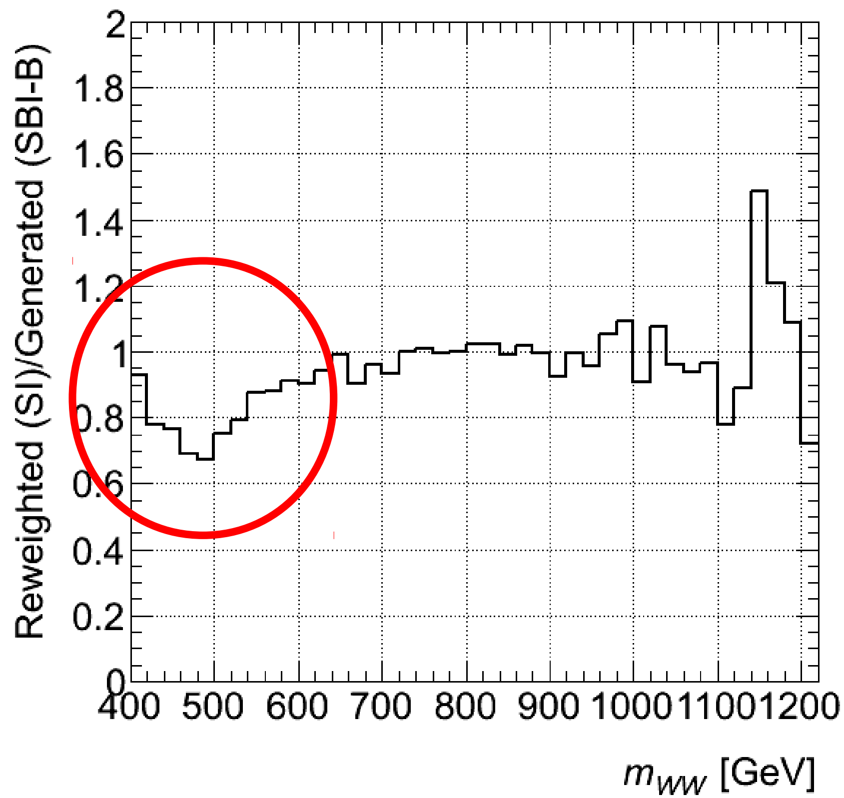
Closure test with VBFNLO

- The look-up table method is a simplification, and it is important to study if the results thus obtained are accurate enough for our needs
- There could also be imperfections in how well REPOLO can reweight to include the interference term
- By comparing directly generated VBFNLO samples which include Signal+Background+Interference with VBFNLO signal only samples we can study if we obtain the same result after weighting with REPOLO
  - S = Signal only (here 800)
  - SBI = Signal (here 800) + Background + Interference
  - B = Signal (125) + Background + Interference → Only background remains m_{WW}>200 GeV



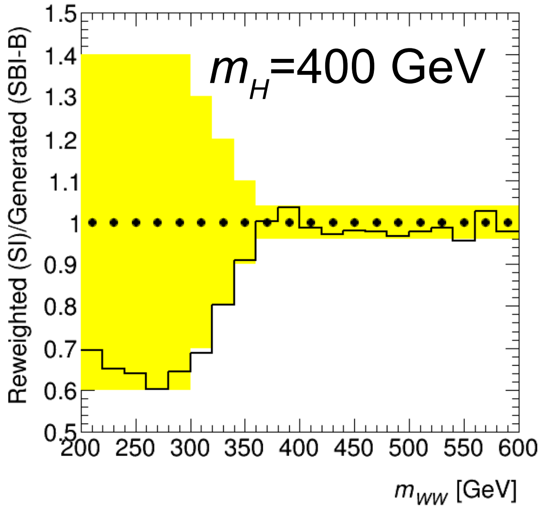
Closure test, 800 GeV

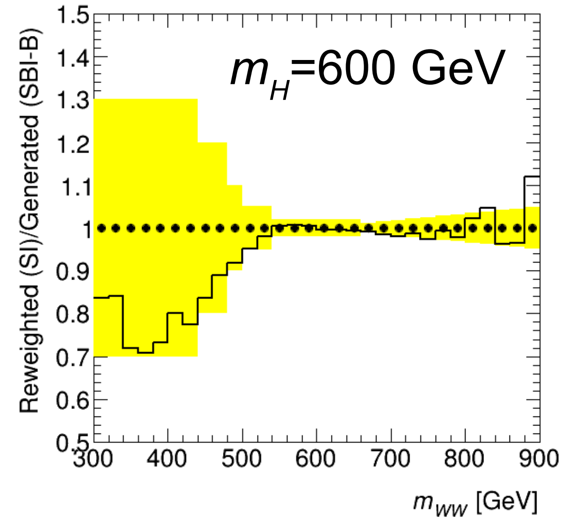


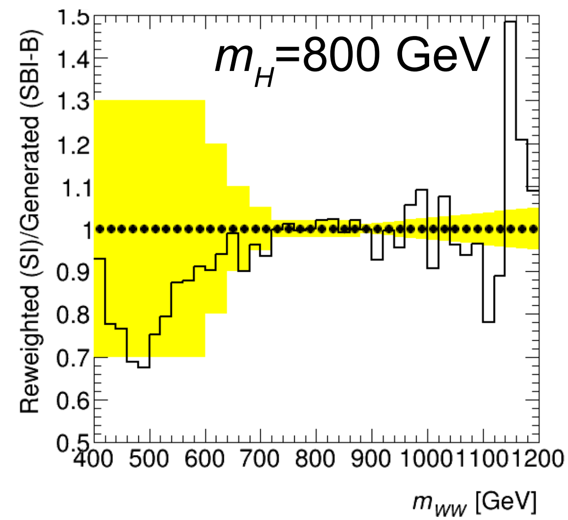


- Since we include interference effect in the search for signal, the background is subtracted from both numerator and denominator
- Good closure at m_{WW}~m_H
- Significant systematic underestimate of constructive interference for m_{WW}<<m_H
- Fluctuations at m_{WW}>1 TeV would need more reiterations to reduce

Systematic from this method







- The large non-closure for mWW<<mH is present at all mass points
  - This method infers a systematic uncertainty that needs to be accounted for
  - Proposed uncertainty depends only on m_H and m_{WW} and is shown in the backup slides
- This is *not* a theory uncertainty on the interference

Proposed systematic to assign

Summary

- REPOLO was used to reweight signal only samples to also include interference effects in the signal shape
- Due to technical limitations (ATLAS file format, computational requirements etc) a simplified method using look-up tables were explored, mapping $weight(m_H, m_{WW})$ from average REPOLO weights
  - ...which have good closure wrt VBFNLO, with the exception in the region $m_{WW} << m_H$
- The systematics from the non-closure seems large at glance, but only rare events in the tails will be assigned the larger systematic uncertainty

Additional material

The function


```
float getVBFInterferenceUncertainty(double mH, double mWW) {
  float unc = 0;
  if (mH<600) {
    if (mWW<0.75*mH) unc = 0.4;
    else if (mWW<0.8*mH) unc = 0.3;
    else if (mWW<0.85*mH) unc = 0.2;
    else if (mWW<0.9*mH) unc = 0.1;
    else unc = 0.04;
  } else {
    if (mWW<0.75*mH) unc = 0.3;
    else if (mWW<0.8*mH) unc = 0.2;
    else if (mWW<0.85*mH) unc = 0.1;
    else if (mWW<0.9*mH) unc = 0.05;
    else if (mWW>1.1*mH) unc = (mWW/mH-1.)*0.1;
    else unc = 0.02;
  }
  return unc;
};
```