VBF Theoretical Systematics

Yaquan Fang (IHEP), Jin Wang(USYD), Yu Zhang (IHEP)

Theoretical systematics in VBF analysis

- Higher-order perturbative correction uncertainty for ggF
  - missing higher-order perturbative corrections to the ggF prediction
- Modelling uncertainties of the $\Delta\eta^*$
  - Powheg+Pythia8 shape of the $\Delta\eta^*$ variable different with MCFM
  - reweight function using truth jet distribution (MCFM/nominal)
- Modelling uncertainties of $\Delta\varphi_{jj}$
  - Powheg+Pythia8 shape of $\Delta\varphi_{jj}$ different with the prediction from Sherpa
  - reweight function using truth $\Delta\varphi_{jj}$ (Sherpa/nominal)
- Underlying event uncertainty
  - comparing the samples with the multi-parton interaction (MPI) and without any MPI
  - reweight function using truth $\Delta\varphi_{\gamma\gamma,jj}$ (no-MPI/nominal)

ggF Higher-order perturbative correction uncertainty

- Vary the scale between mH=2 to 2mH to evaluate the uncertainty
  - use Stewart-Tackmann method
    - differential cross section covariance matrix in 29 bins of $\Delta\varphi_{\gamma\gamma,jj}$ generated using MCFM at NLO
      - uncert_i*corr(i,j)*uncert_j gives uncertainty
    - the covariance between the total cross section, the exclusive 2 jet cross section (= the cumulant), and the inclusive 3 jet cross section (= the inverted cumulant) are fully determined
  - the cumulant uncertainties are translated into differential uncertainties in $\Delta\varphi_{\gamma\gamma,jj}$
    - $\Delta\varphi_{\gamma\gamma,jj}$ is binned up for > 2.94 to avoid the highest uncertainty and negative cross section
  - need to find the$\Delta\varphi_{\gamma\gamma,jj}$ region with current BDT cuts
    - find the effective 95% rectangular cuts of the final BDT selection to see in what region of phase space it is homing in

Output of Florian's code


```
int main() {
  Str config="uncertainty_input/ggF_dphi_theory_ATLASjetsel_mjj400_DeltaEta28.config";
  ScaleUncertainty_ggF_2jets ggF_theory(config);
  ScaleUncertainty_ggF_2jets ggF_theory28(config);
  ScaleUncertainty_ggF_2jets ggF_theory295(config);

  ggF_theory.DrawVariable();

  // now calculate the theory uncertainty for an inclusive selection
  TString fn="macro/PowhegPythia8_ggF_mH125.root";
  TFile *inf = TFile::Open(fn);
  if (inf==NULL||inf->IsZombie()) { cout<<"Cannot open "<<fn<<endl; abort(); }
  TTree *tree = (TTree*)inf->Get("EvtTree");
  if (tree==NULL) { cout<<"Cannot access EvtTree in "<<fn<<endl; abort(); }

  // SIGNED dphi
  Float_t dphi_H_jj=0, Mjj=0, DelEta_jj=0; double pi=TMath::Pi();
  tree->SetBranchAddress("DelPhi_ggjj", &dphi_H_jj);
  tree->SetBranchAddress("Mjj", &Mjj);
  tree->SetBranchAddress("DelEta_jj", &DelEta_jj);
  int Nevts=tree->GetEntries();
  printf("\nWill loop over %d ggF+2jet Pythia events and calculate uncertainty\n",Nevts);

  vector<double> all, cut_at_28, cut_at_25, cut_at_26, cut_at_295;
  for (int ievt=0;ievt<Nevts;++ievt) {
    tree->GetEntry(ievt);
    double pi_minus_dphi=pi-fabs(dphi_H_jj);
    all.push_back(pi_minus_dphi);

    ggF_theory.AddEventBeforeCuts(pi_minus_dphi);
    ggF_theory28.AddEventBeforeCuts(pi_minus_dphi);
    ggF_theory295.AddEventBeforeCuts(pi_minus_dphi);

    if (Mjj<400) continue;
    if (fabs(DelEta_jj)<2.8) continue;

    if (fabs(dphi_H_jj)>2.6) ggF_theory.AddEventAfterCuts(pi_minus_dphi);
    if (fabs(dphi_H_jj)>2.8) ggF_theory28.AddEventAfterCuts(pi_minus_dphi);
    if (fabs(dphi_H_jj)>2.95) ggF_theory295.AddEventAfterCuts(pi_minus_dphi);

  }
  printf("Done looping!\n\n");
```

```
=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=-=
Info in <TCanvas::Print>: pdf file DeltaPhi_Hjj.pdf has been created

Created plot of DeltaPhi_{H,jj} and saved as DeltaPhi_Hjj.pdf

Will loop over 19174 ggF+2jet Pythia events and calculate uncertainty
Done looping!

  Theory uncertainty without any cuts: 21.036%
  Theory uncertainty for DeltaPhi(H,jj)>2.6: 28.798%
  Theory uncertainty for DeltaPhi(H,jj)>2.8: 42.237%
  Theory uncertainty for DeltaPhi(H,jj)>2.95: 74.983%

Done.
```

Suggestions for early VBF theoretical uncertainties

- Get uncertainties for $\Delta\eta^*$, $\Delta\varphi_{jj}$ and underlying event using corresponding 8TeV reweighting functions
  - maybe update with 13TeV MCFM, Sherpa and no-MPI samples when available

- Using Florian's code and $\Delta\varphi_{\gamma\gamma,jj}$ region in 13TeV MVA for estimation of higher-order perturbative correction uncertainty for ggF
  - re-evaluate using 13TeV covariance matrix and 13TeV Powheg+Pythia samples in future