Interference study for VBF Higgs using Phantom and Madgraph

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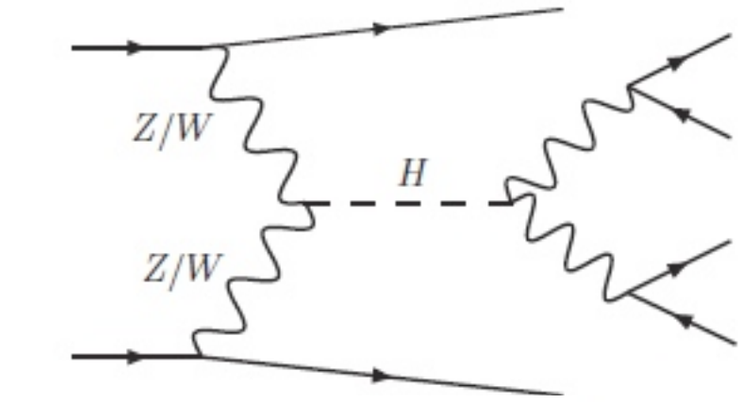
Introduction

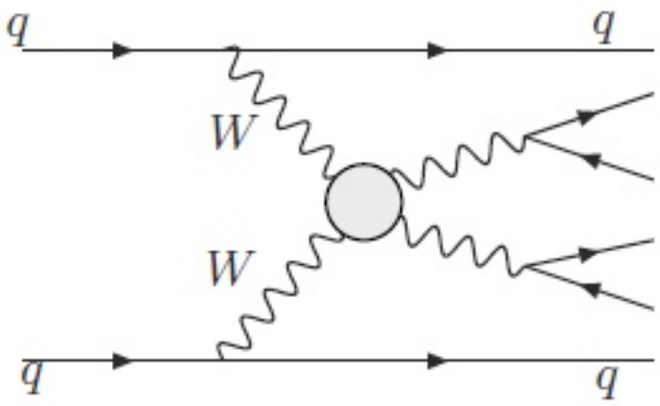
- When mH > 400 GeV, signal width is large and interference is significant
- Heavy Higgs search in ZZ->2l2nu channel (CMS-PAS-HIG-13-014)
  - Interference of ggH with gg->ZZ was included, computed using gg2VV (N. Kauer), by reweighting signal to signal+interference
    - Nothing was done for interference in VBF. A conservative error was assigned.
- Try to repeat similar procedure: to compute interference using some MC (e.g. Phantom), to get (S+I)/S weights

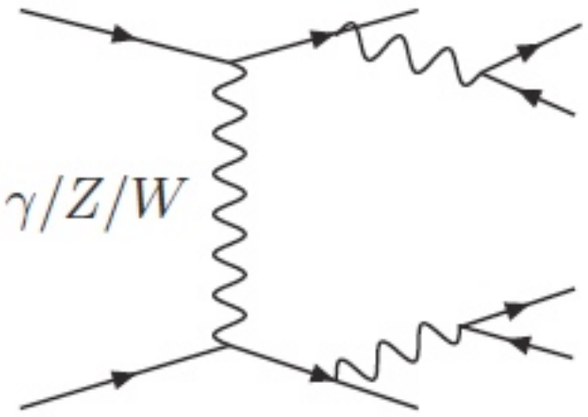
Interference in VBF channel

Signal



Background



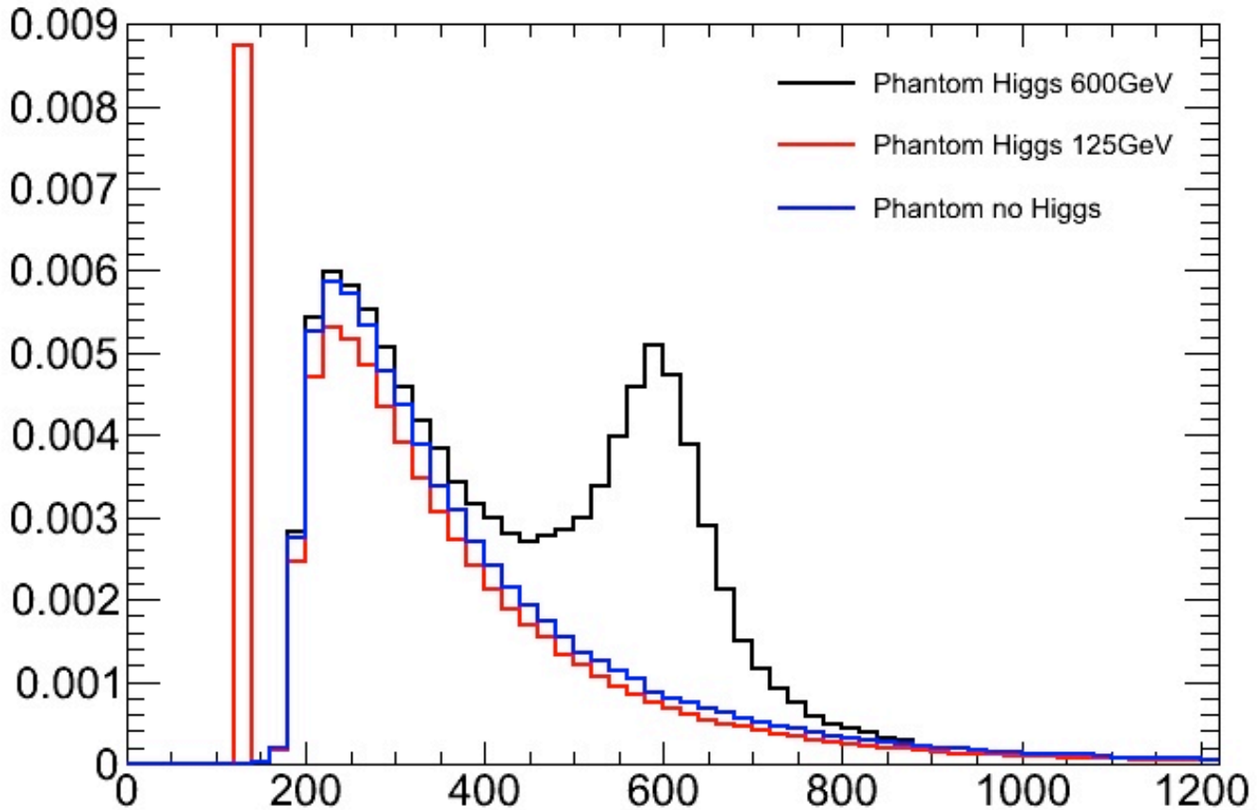


+ ...

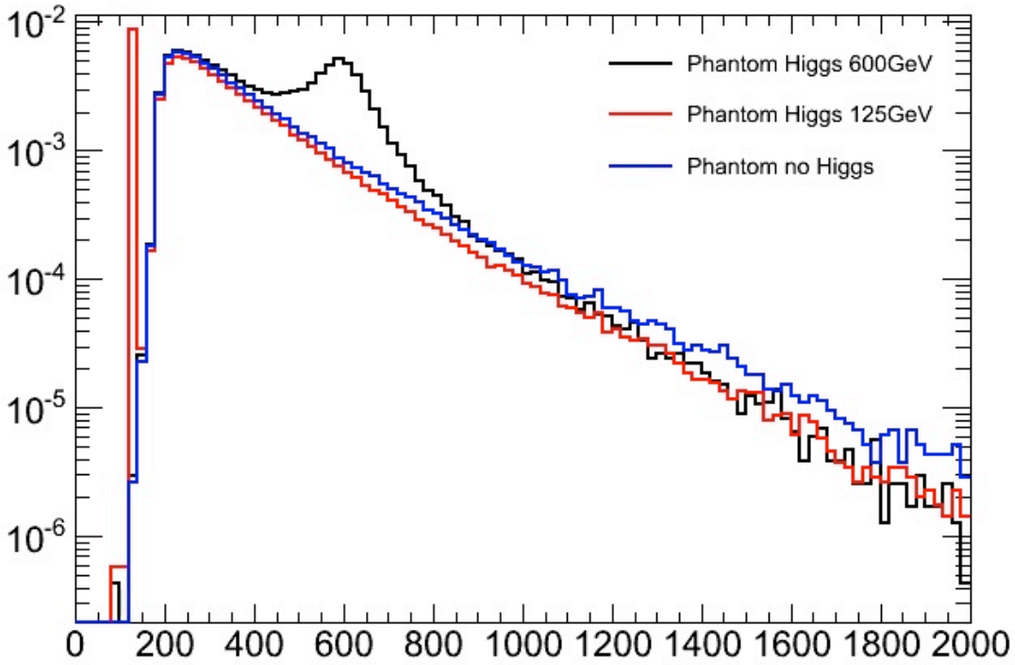
- Phantom includes all these (Signal+Bkgd+Interference)
  - Need to subtract background contribution
- Madgraph generates signal-only

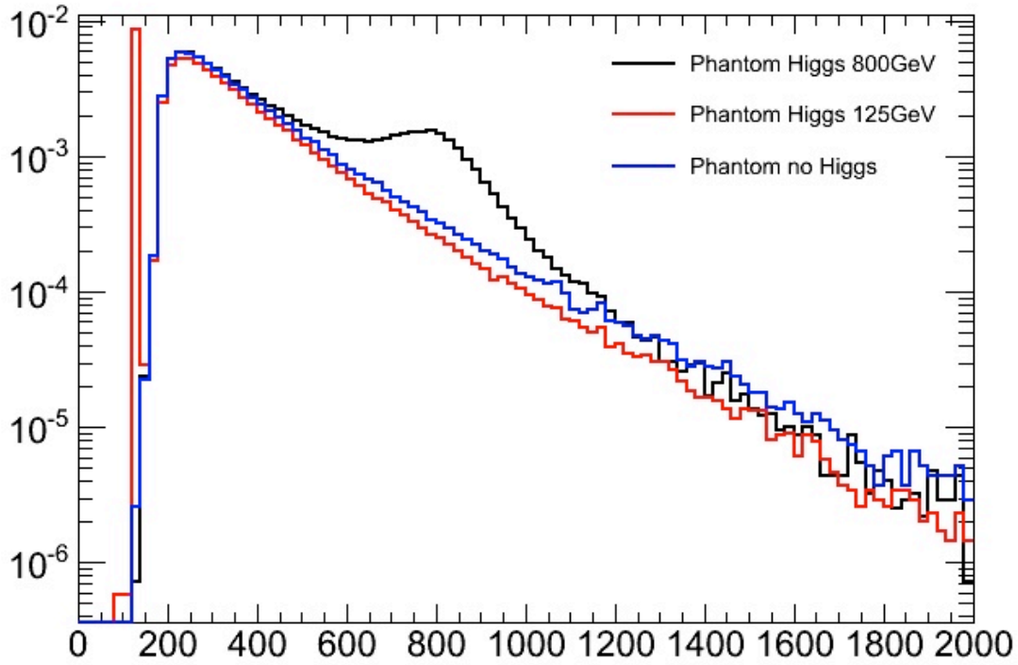
Step1: to subtract background from Phantom

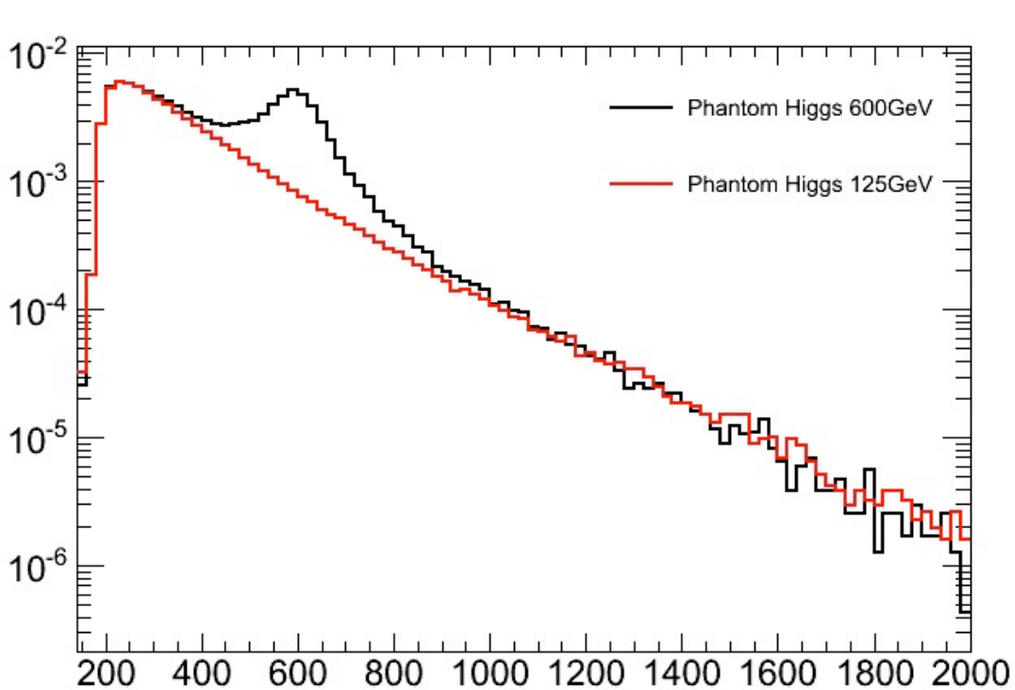
To find a shape well modeling background-only

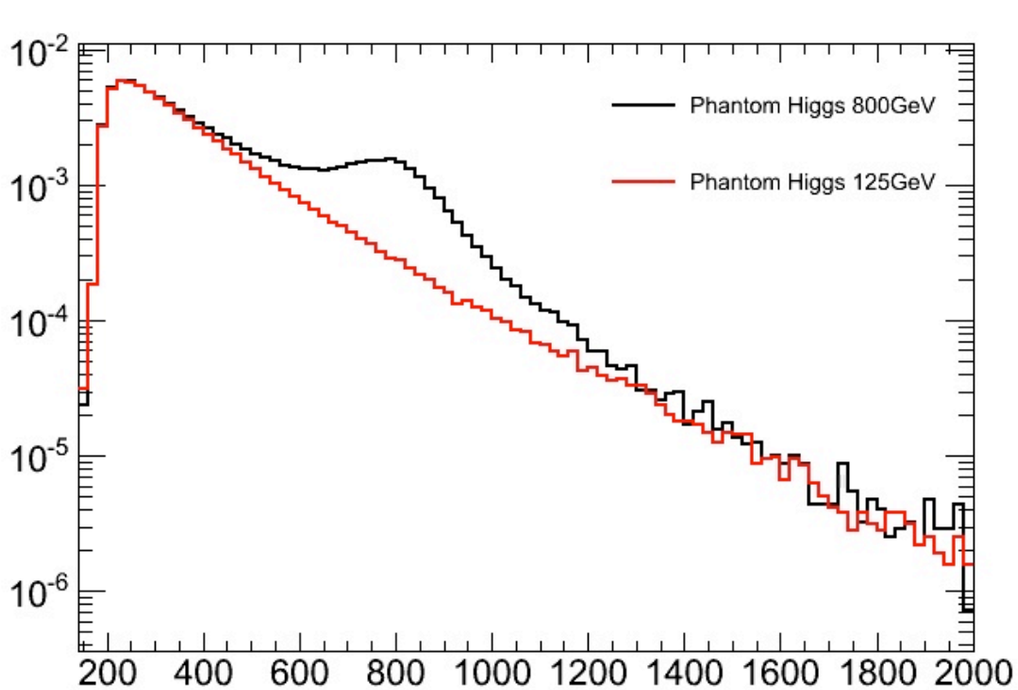


Phantom generations with
(a) heavy Higgs, (b) light Higgs, (c) no Higgs



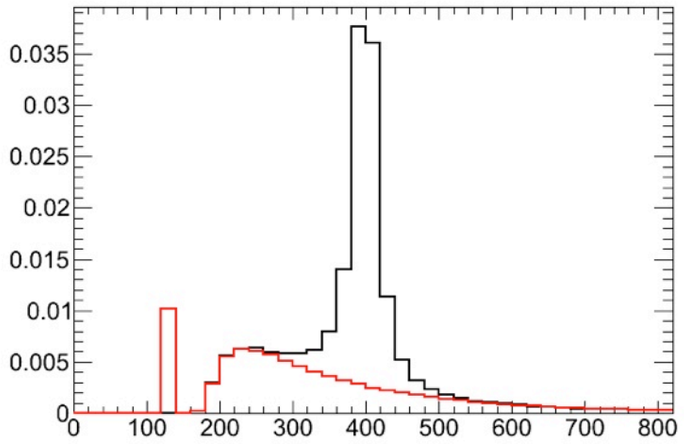


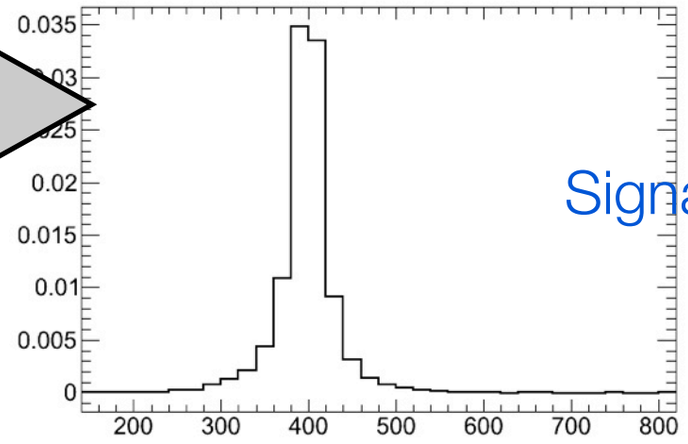




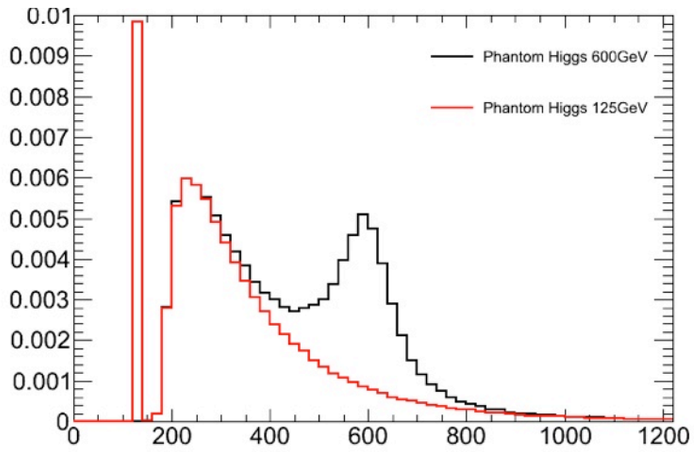
The red lines are scaled up in the bottom 2 plots,
and well model background shape

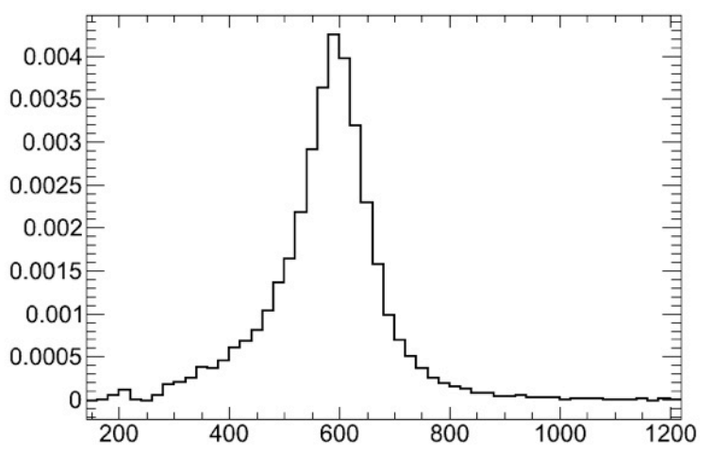
No Higgs scenario violates unitarity at very high mass; should not be used.
Light Higgs scenario is slightly below the other two (reason unknown), but it should be safe to rescale it and use it as background shape.

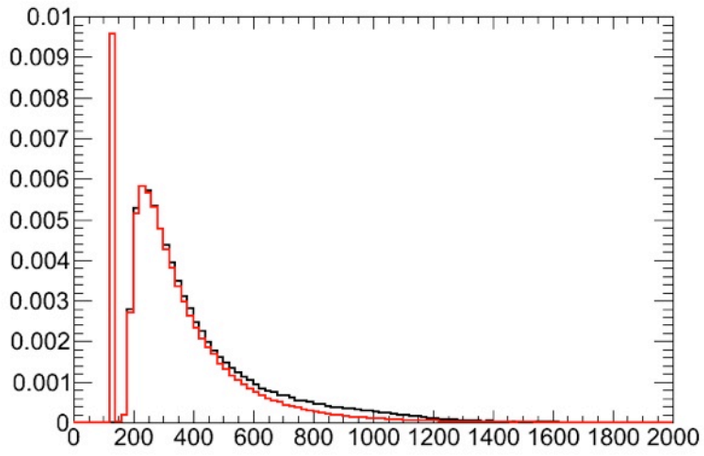


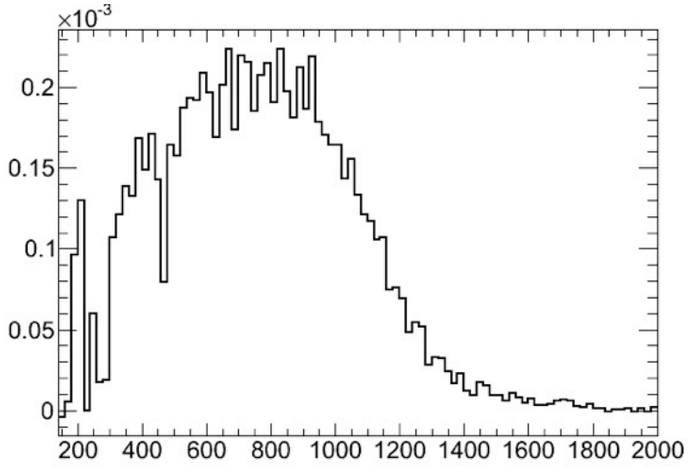


Signal+Interference







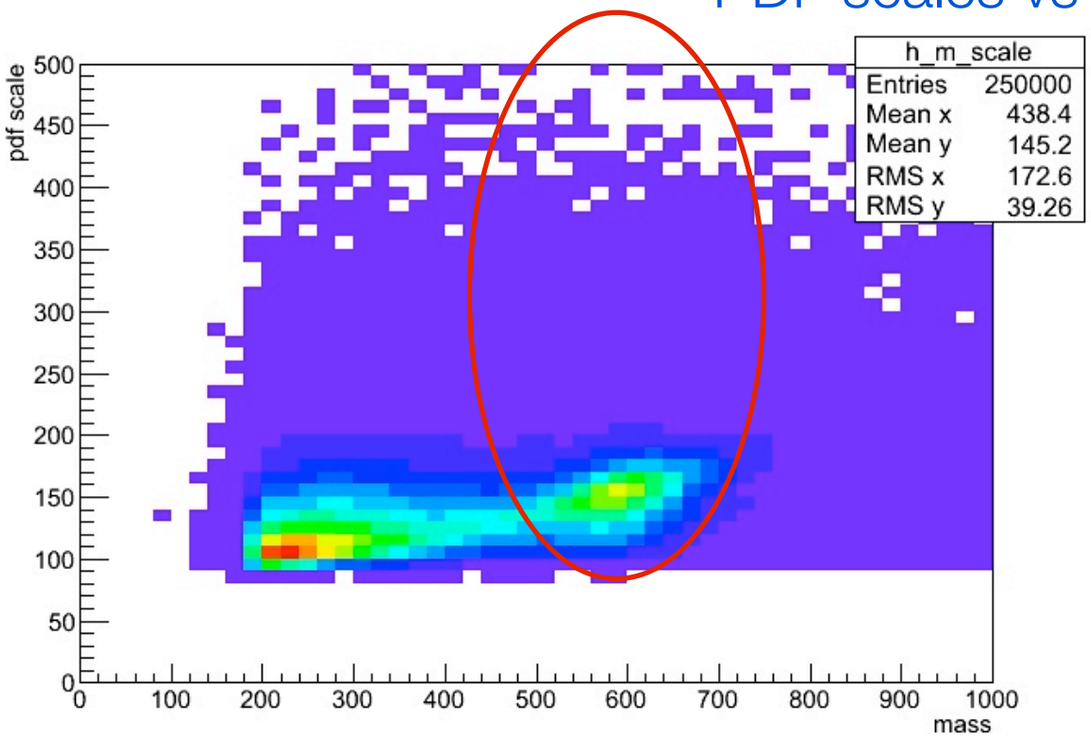


Step 2: to compare Phantom to Madgraph

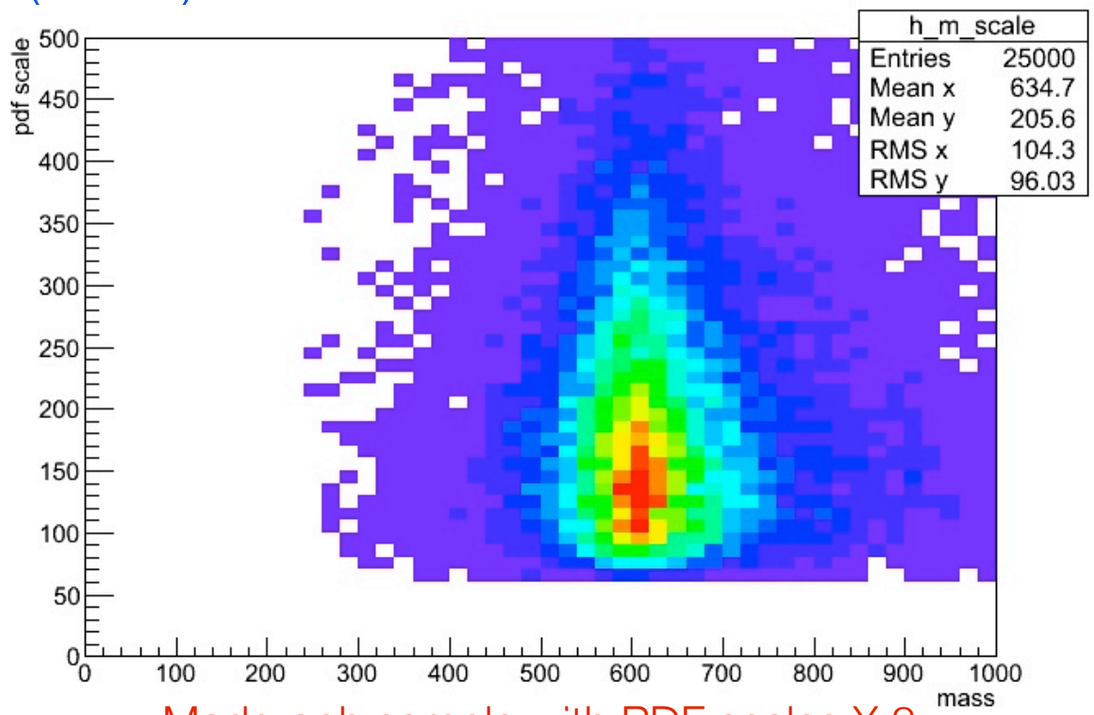
The point is to make sure configurations in the two generations as close as possible.

Both Phantom and Madgraph compute PDF scales event-by-event, but in different ways.

PDF scales vs M(2l2nu)



Phantom sample with 600GeV Higgs

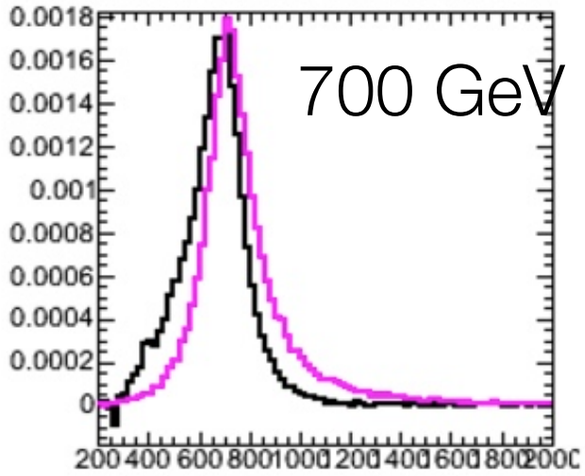


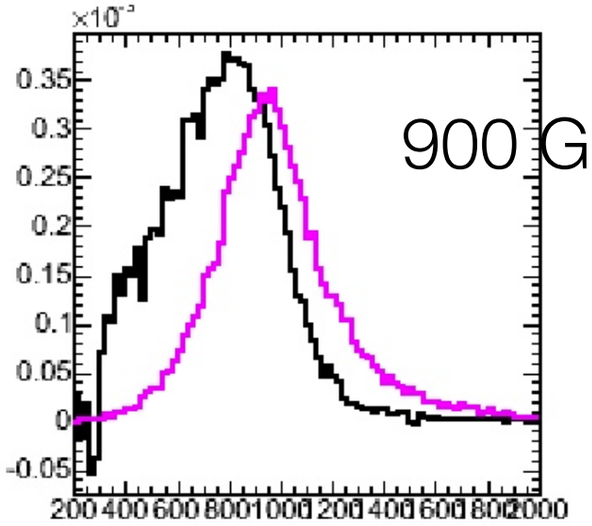
Madgraph sample with PDF scales X 2

If the default scales in Madgraph generation multiplied by a factor of 2, they match well with scales of signal-region events in Phantom on average

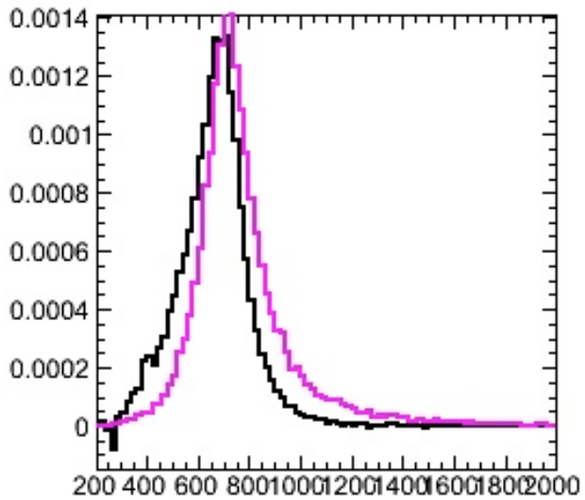
Recompute PDFs using x and flavor of the two incoming partons;
Reweight samples to fixed scales (mH)

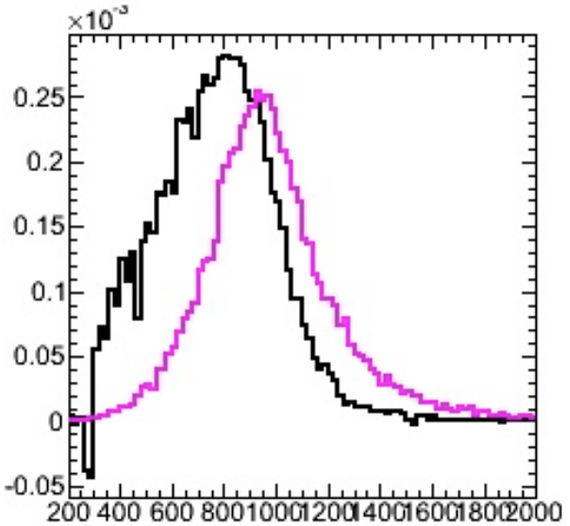
Before



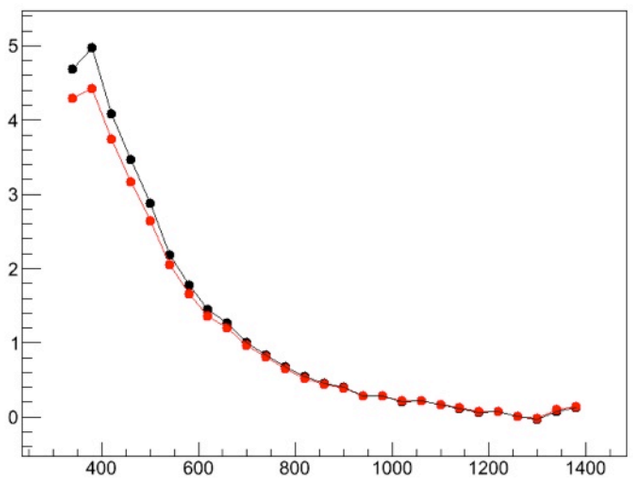


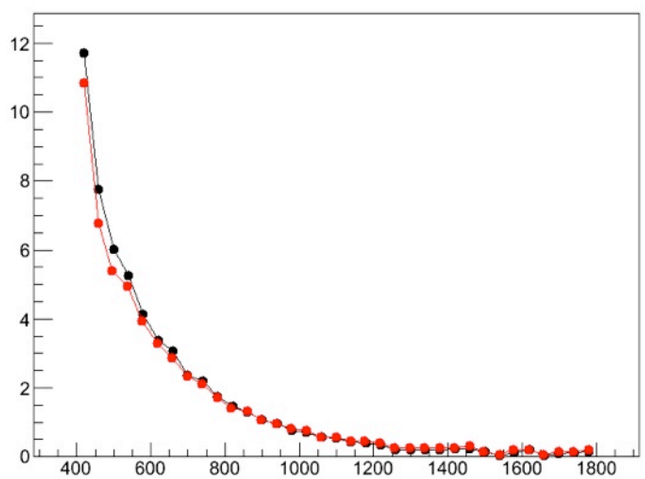
After PDF reweighting

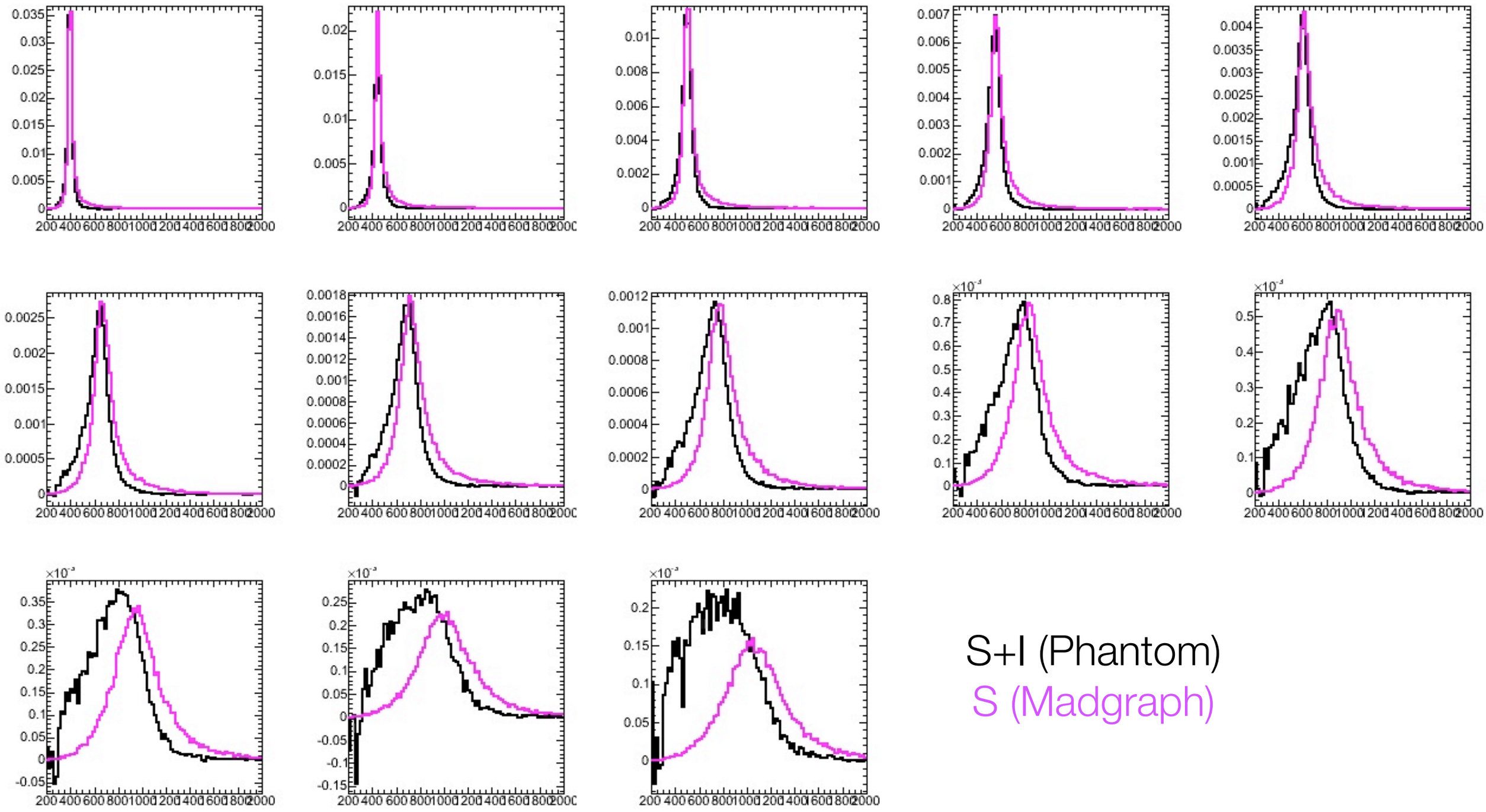




Weights: (S+I)/S







S+I (Phantom)
S (Madgraph)

1) The effect of interference are on normalization and also on shape.
2) It is a destruction for high mass end and enhancement for low mass region.
3) The effect is larger for higher mass signal.
All the above are consistent with what we have seen in ggH study.

Summary

- The Signal-background interference for VBF Higgs is studied using Phantom and Madgraph
  - To goal is to get (Signal+Interference)/Signal weights
- The results look reasonable, and consistent with previous study on ggH
- Different PDF scale choices are tested and little effect is found
- Suggestion is welcome on how to assign an uncertainty on this procedure
- Need a “sign-off” from experts before we implement it in our analysis

Backup

- 2j2e2vm is used, i.e. no WW contribution
    - Previous ggH experience: WW is an order smaller than ZZ after Z mass window cut
- Gen-level selections:
    - pT _e > 20, |eta_e|< 2.5, M_ee > 50
    - pT_j > 30, |eta_j| < 5
    - MissingET > 40
    - deltaEta_jj > 2, M_jj > 200

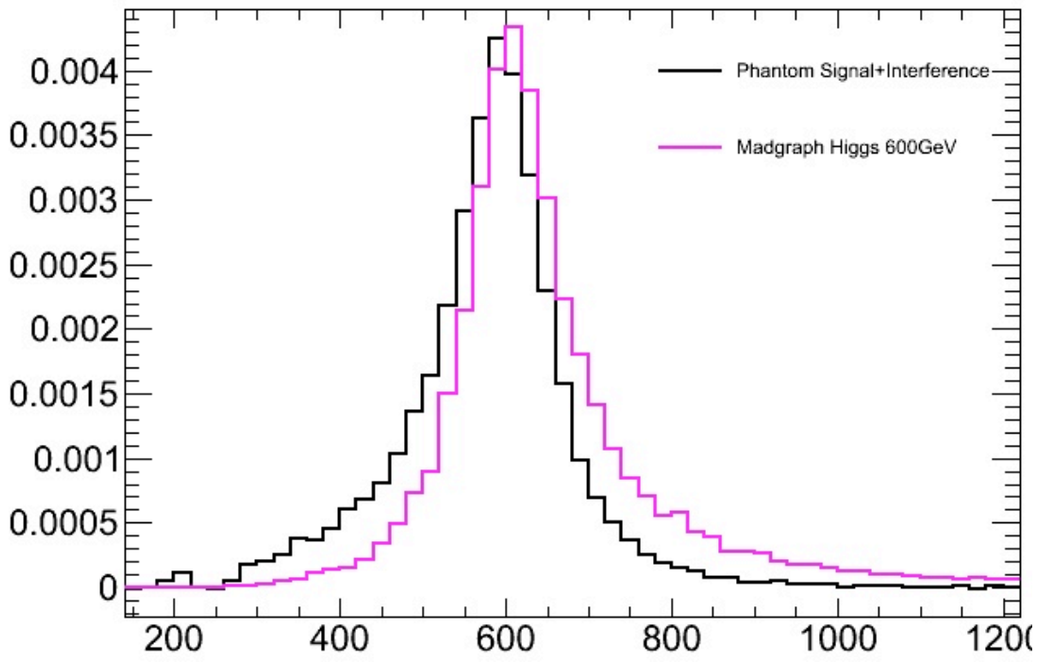
There was a concern from the Phantom author

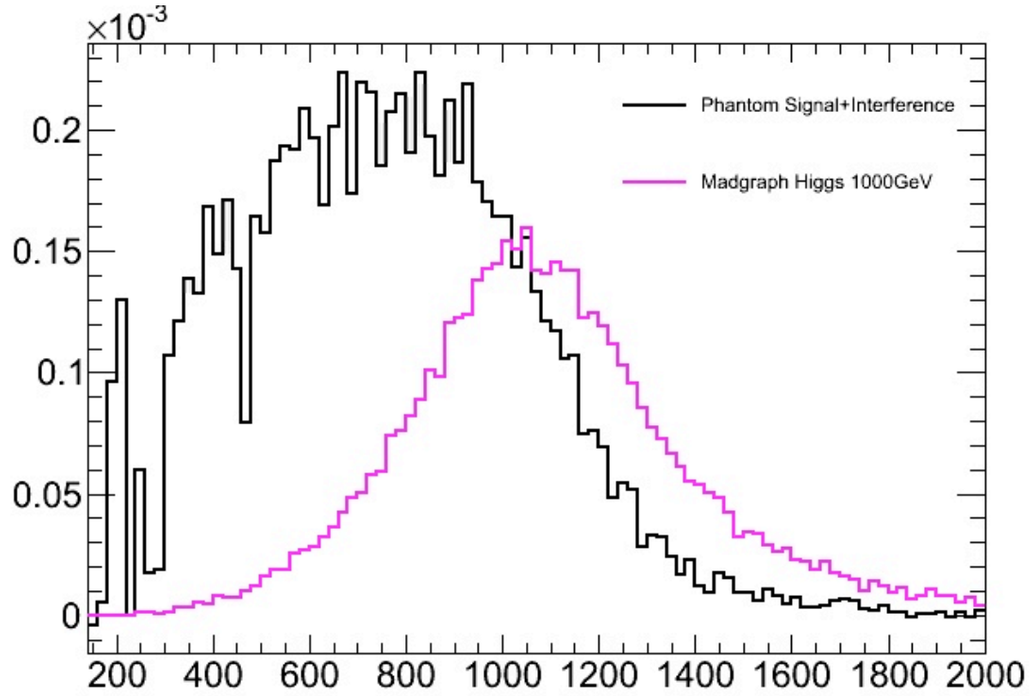
Better to use same scales event-by-event in Phantom and Madgraph

The contribution of one event to the total cross section is proportional to PDF(1)*PDF(2)

```
weight = LHAPDF::xfx (x[0], referenceScale, flavour[0]) * LHAPDF::xfx (x[1], referenceScale, flavour[1]) /
         (LHAPDF::xfx (x[0], scale, flavour[0]) * LHAPDF::xfx (x[1], scale, flavour[1])) ;
```

Recompute PDFs using x and flavor of the two incoming partons;
Reweight a sample to any new scales (now fixed at mH)





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