Treatment of $p_T(gg \rightarrow H)$ in CMS

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Use of p_T in the CMS Higgs analysis

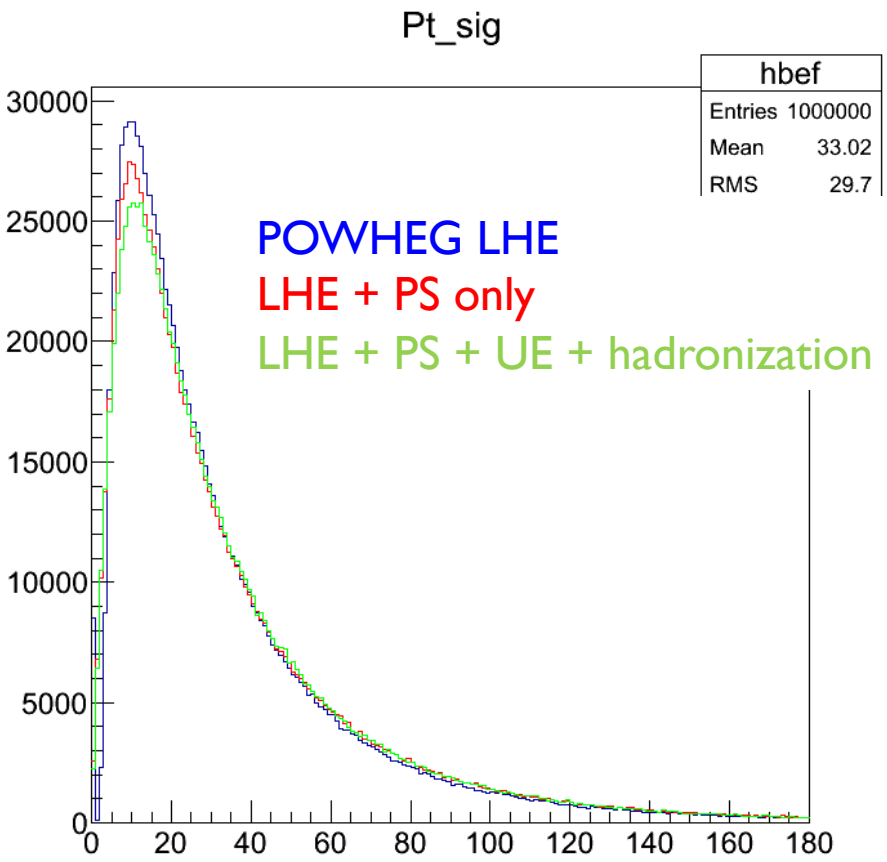
- Important use of p_T in only in the H → ZZ → 4l channel analysis (search performed in $100 < m_{4l} < 1000$ GeV)
  - For events where there are less than 2 jets reconstructed, use to discriminate ggH from VBF and VH production
  - Improves uncertainty on μ (3-dimensional analysis)
  - Maybe use for a primordial differential cross-section measurement (but event yield very small)
- Other channels do not have enough events, or not clean enough, for accurate use of p_T
  - Use same theoretical description as ZZ for acceptance estimation ($\gamma\gamma$) or use older MC and reweight (WW, $\tau\tau$)

MC choices for gg → H

- Close-to-latest POWHEG (Feb 2013)
  - Including heavy-quark mass effects
    - Latest b and t masses (top mass from Moriond 2013 CDF update)
  - hfact tuning (hfact = $m_H/1.2$) to reproduce NNLO+NNLL spectrum
  - Use of propagator scheme (CPS) for mass lineshape, with EW corrections on
    - Mass window (range = $m_H \pm$ masswindow $\cdot \Gamma_H$) for sampling Higgs virtuality had to be tuned by hand to avoid errors in the program about hitting the high limit

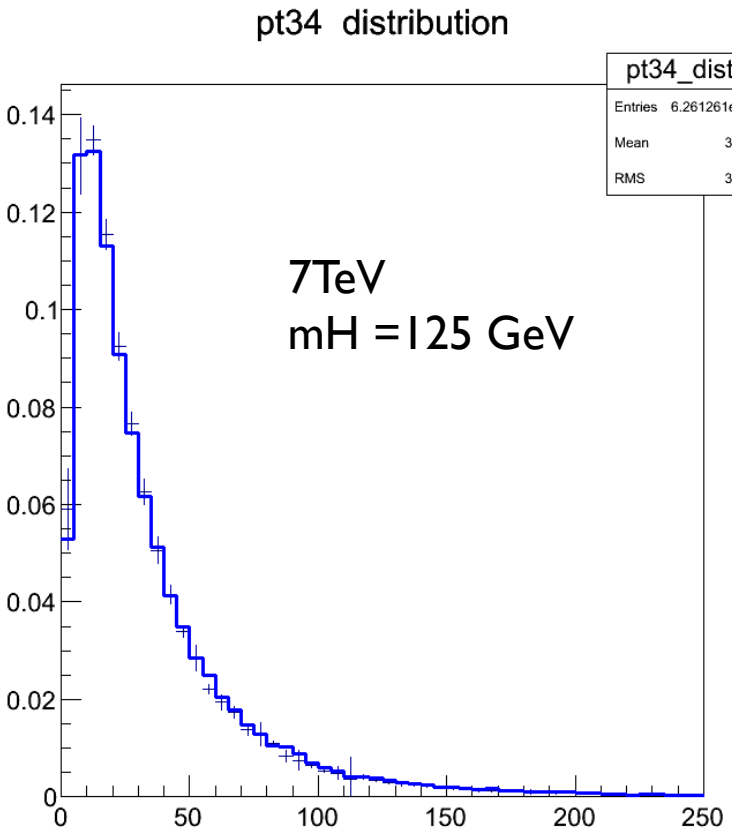
Verifying NNLO+NNLL tuning

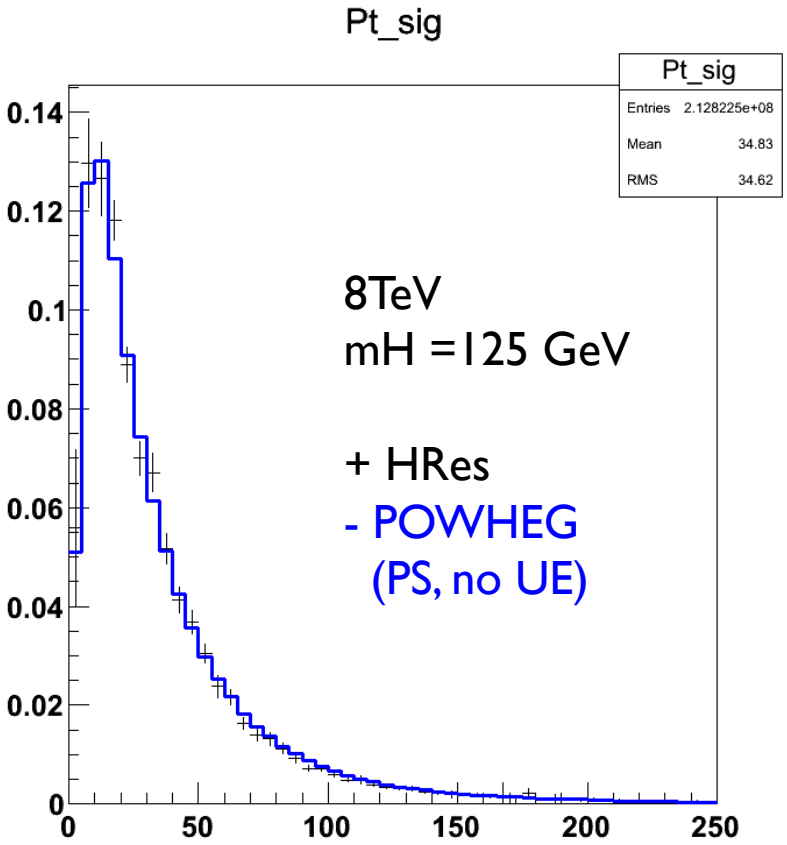
- Several spectra generated to verify correct reweighting, with:
  - HRes for m_H <= 400 GeV
  - HqT 2.0 above (HRes not available)
- Following recommendations of YR2 comparison was done with NLO spectra:
  - with no HQ effects
  - after parton-shower only performed by PYTHIA



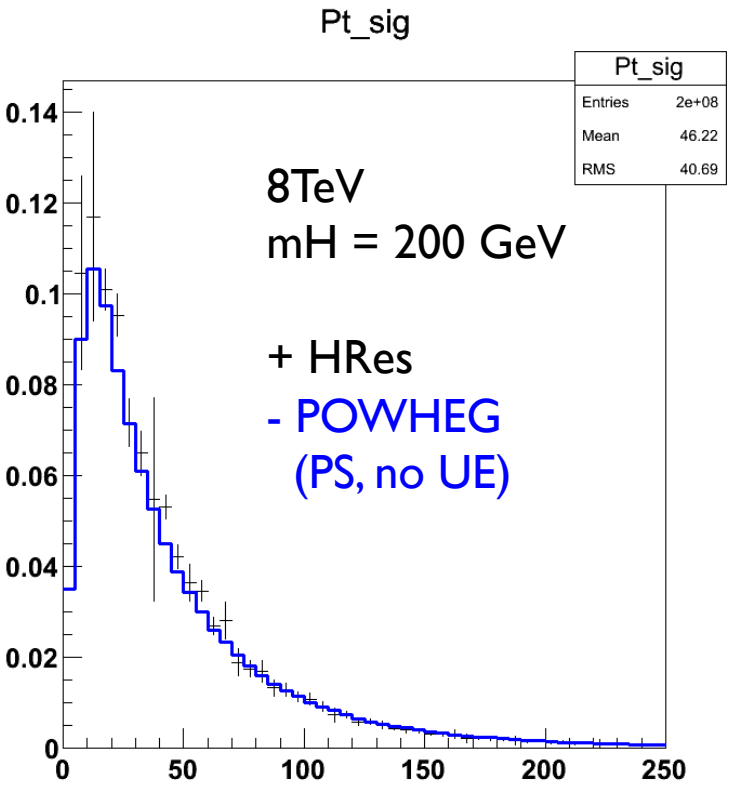
NNLO tuning: low mass

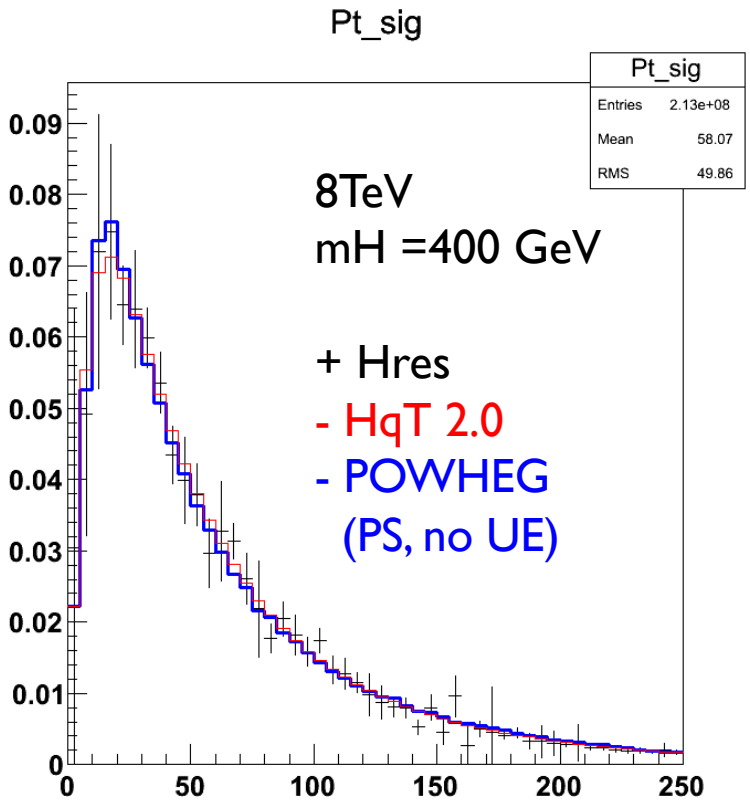
- Agreement with HRes is excellent at low mass for both 7 and 8 TeV





NNLO tuning: intermediate mass

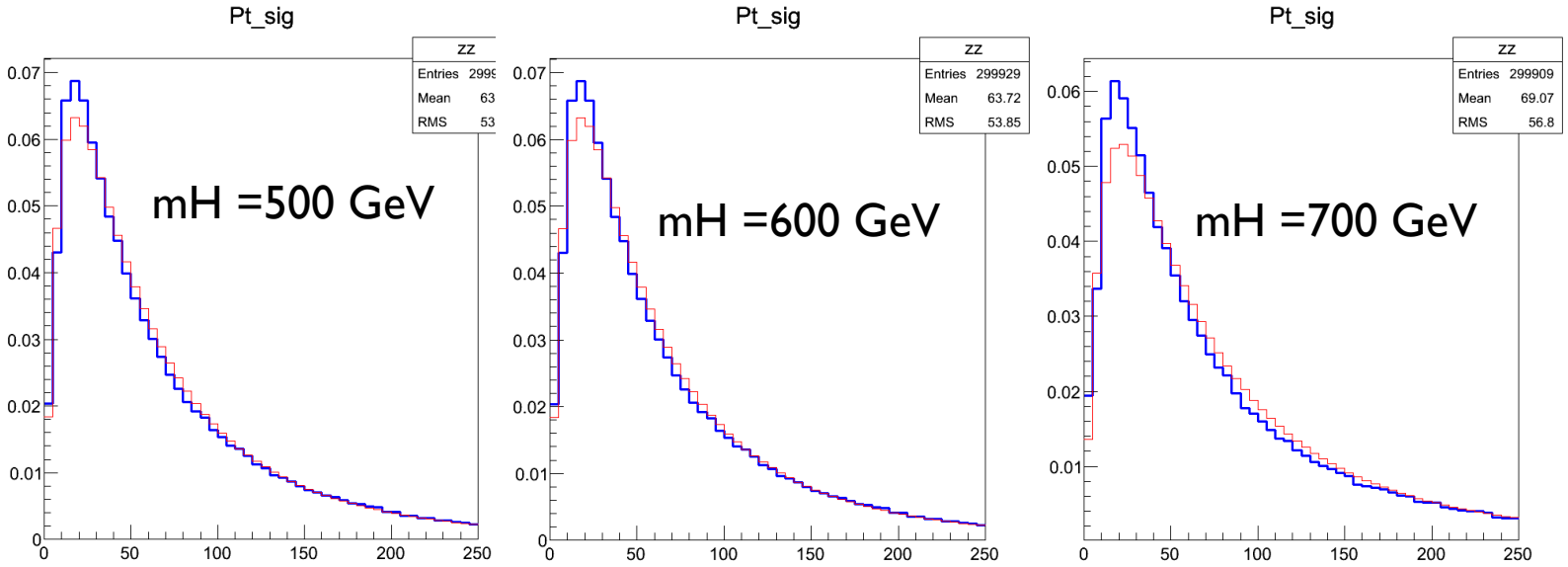


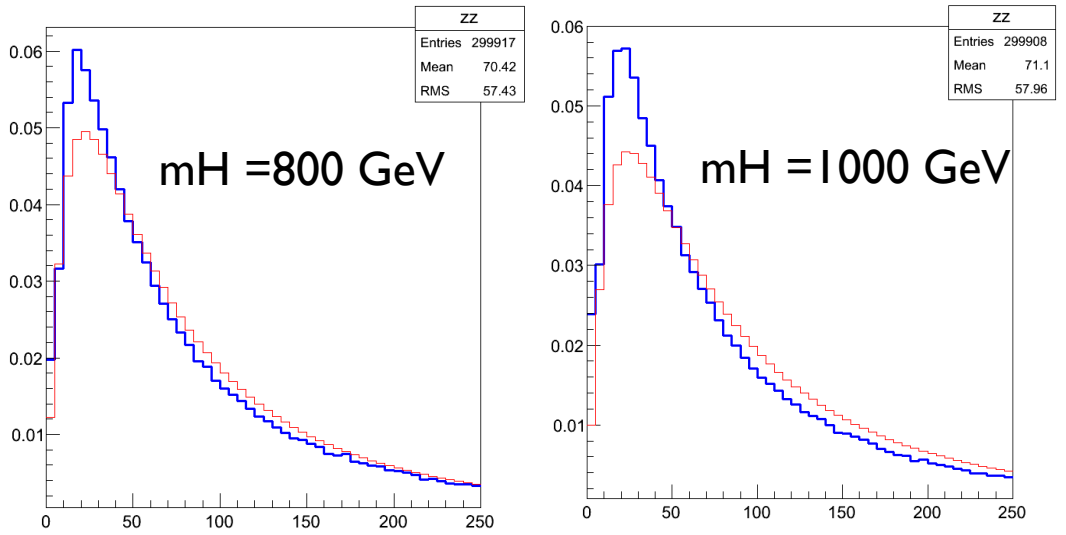


NNLO tuning: high mass

8TeV

- HqT 2.0
- POWHEG (PS, no UE)

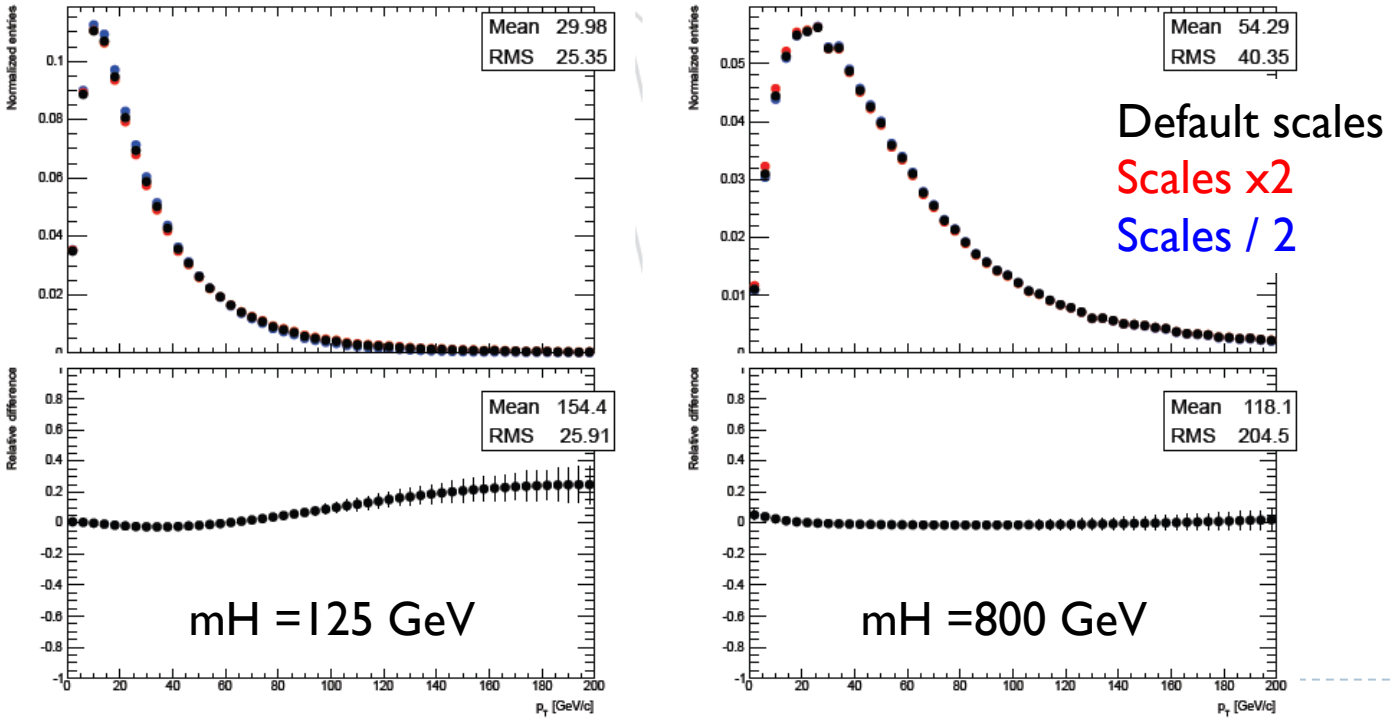




- MC reweighting needed for $m_H > 400$ GeV

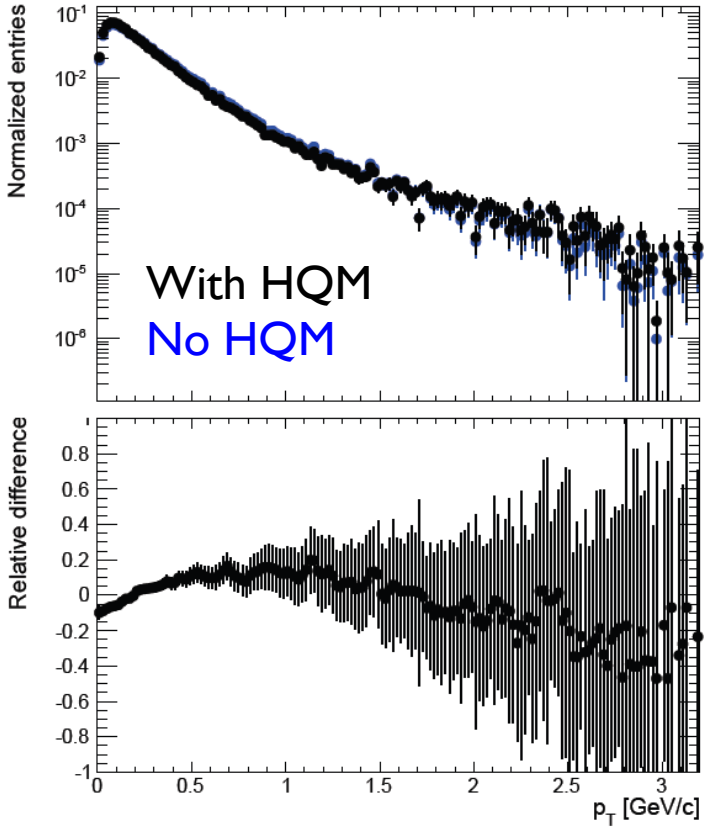
Scale systematics

- Easy to include
  - Re-run HRes with halved and doubled QCD scales (Res, Ren, Fact) and evaluate effect on spectrum
  - Up to 20% effect at low mass, almost negligible at high mass



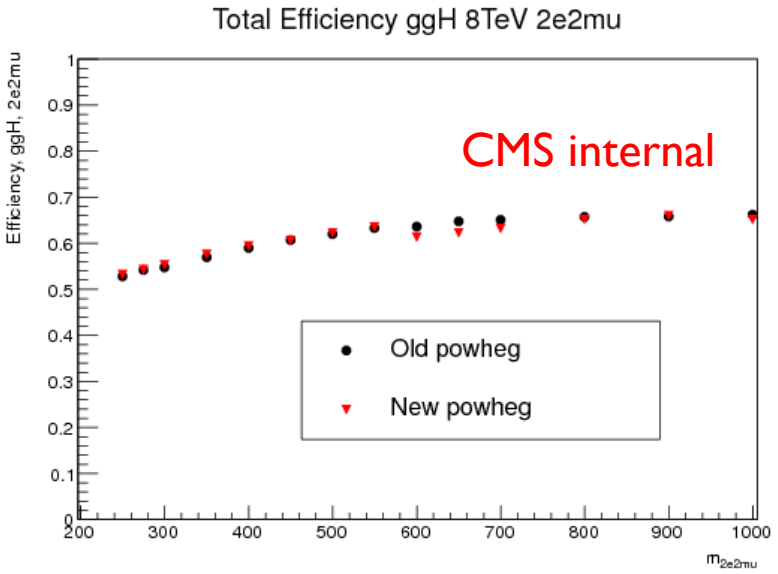
Finite heavy quark masses - PDFs

- Finite top (and bottom) mass effects as described by POWHEG
  - Quite large effect (up to 15%)
  - For the moment use b and t mass uncertainties to establish systematics ← 1-2%, too small?
  - Comparison with other generator?
    - Unfortunately no productions with MC@NLO done in CMS
    - Suggestions?
- Other PDF sets tested (CT10, MSTW2008, NNPDF2.1)
  - Effect also negligible compared to resummation



Mass window issue?

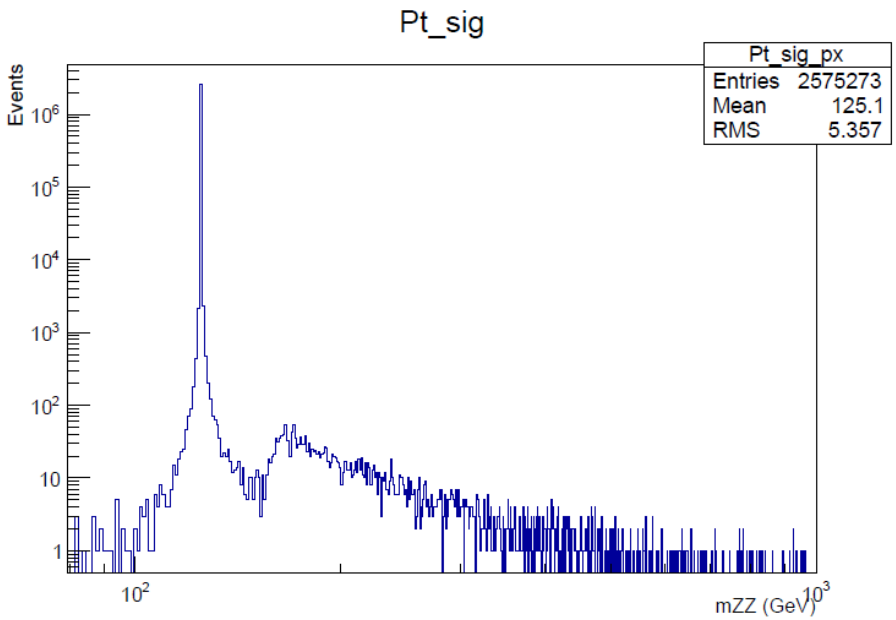
- Mass window (range = $m_H \pm$ masswindow $\cdot \Gamma_H$) for sampling Higgs virtuality → set a default value of 10
- At high mass it had to be tuned by hand to avoid errors in the program about hitting the high limit
- Examples:
  - 500 GeV: $0.5 < m_H < 1180$ GeV
  - 550 GeV: $0.5 < m_H < 1480$ GeV
  - 600 GeV: $0.5 < m_H < 1707$ GeV
  - 650 GeV: $0.5 < m_H < 1756$ GeV
  - 700 GeV: $0.5 < m_H < 1780$ GeV
  - 800 GeV: $0.5 < m_H < 1955$ GeV
  - …



- Caused strange "drop" in detector acceptance (had to be smoothed), not well understood

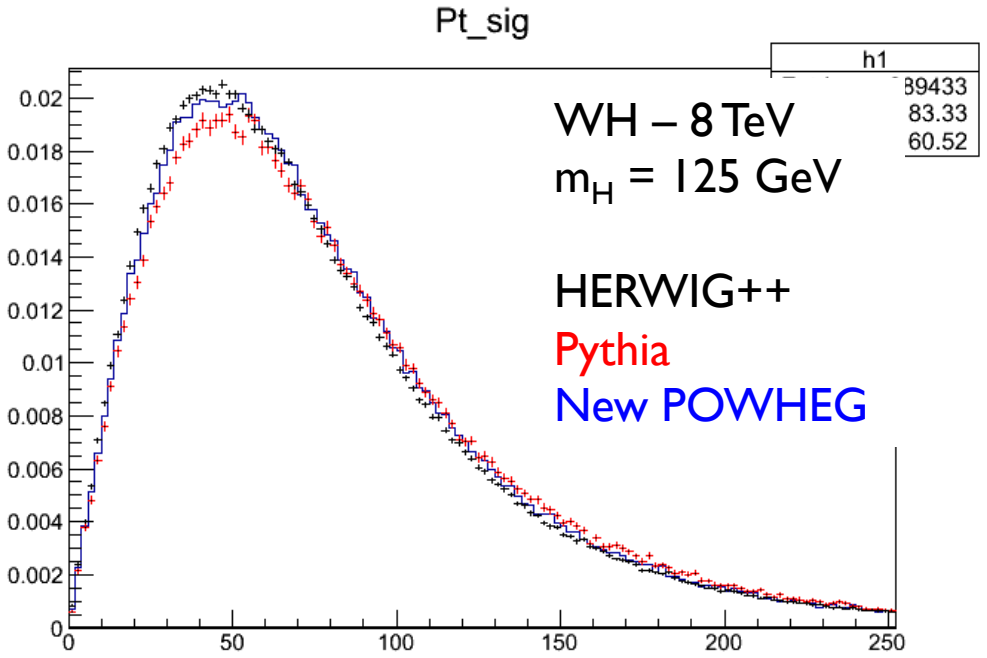
Mass window issue?

- Mass window (range = $m_H \pm$ masswindow $\cdot \Gamma_H$) for sampling Higgs virtuality → set a default value of 10
- At low mass always kept this value → are we losing a fraction of the cross-section?
- Tested very large mass window:
  - For mH = 125 GeV, 99.83% of the cross-section in the peak
  - According to Kauer-Passarino the effect could be larger when considering the ZZ final state…



On VBF and VH p_T

- For VBF use POWHEG p_T spectrum
  - Vary PDFs and scales
- VH was not available in POWHEG until recently
  - For the moment use Pythia or ThePEG/ HERWIG++ and use the difference in spectrum as systematics
  - Plan to move to same treatment as VBF (vary PDFs and scales) → no big change expected



Conclusions

- Most sophisticated studies on p_T in CMS come from ZZ → 4l Higgs analysis
  - Used to discriminate ggH, VBF/VH and background in a large m_{ZZ} search range (100-1000 GeV)
- Use POWHEG to describe signal spectrum
  - NNLO tuning works up to mH ~ 400 GeV, reweighting needed for larger masses
  - Finite HQ masses used ← uncertainty derived from HQ mass uncertainties, too optimistic?
  - Using complex-pole scheme with EW corrections, strange efficiency drop at 600 GeV not very well understood
    - Effect of Higgs virtuality ranges (only thing set by hand)?