ggF STXS Uncertainties

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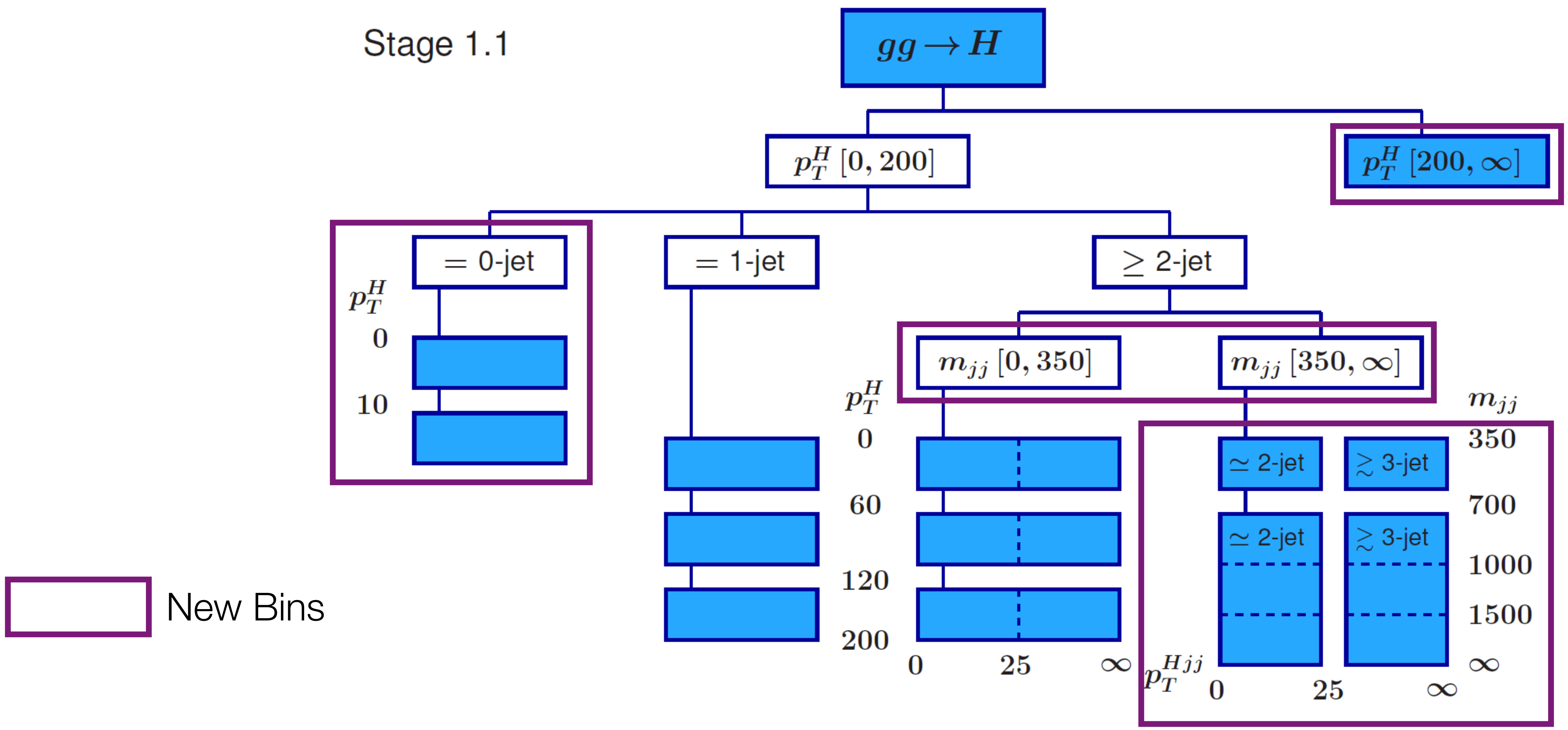
Introduction

- With the STXS 1.1 scheme, new bins are defined
  - Uncertainty scheme for stage 1: Link (2017 scheme)
  - The corresponding systematic scheme needs to be updated
- 2 Parts to the talk:
  - Proposed systematic for the **0-jet p_T bins**
  - **First look** at the new bins for >= 2 jets



p_T Shape Variation

- Used **standalone** Powheg and Pythia to generate ggF events
  - POWHEG HJ MINLO process with NNLOPS reweighing
- Analysis results using **Rivet** STXS code (Git Link)
  - Small updates to use Rivet 3.0 for easier LHE3 weight handling

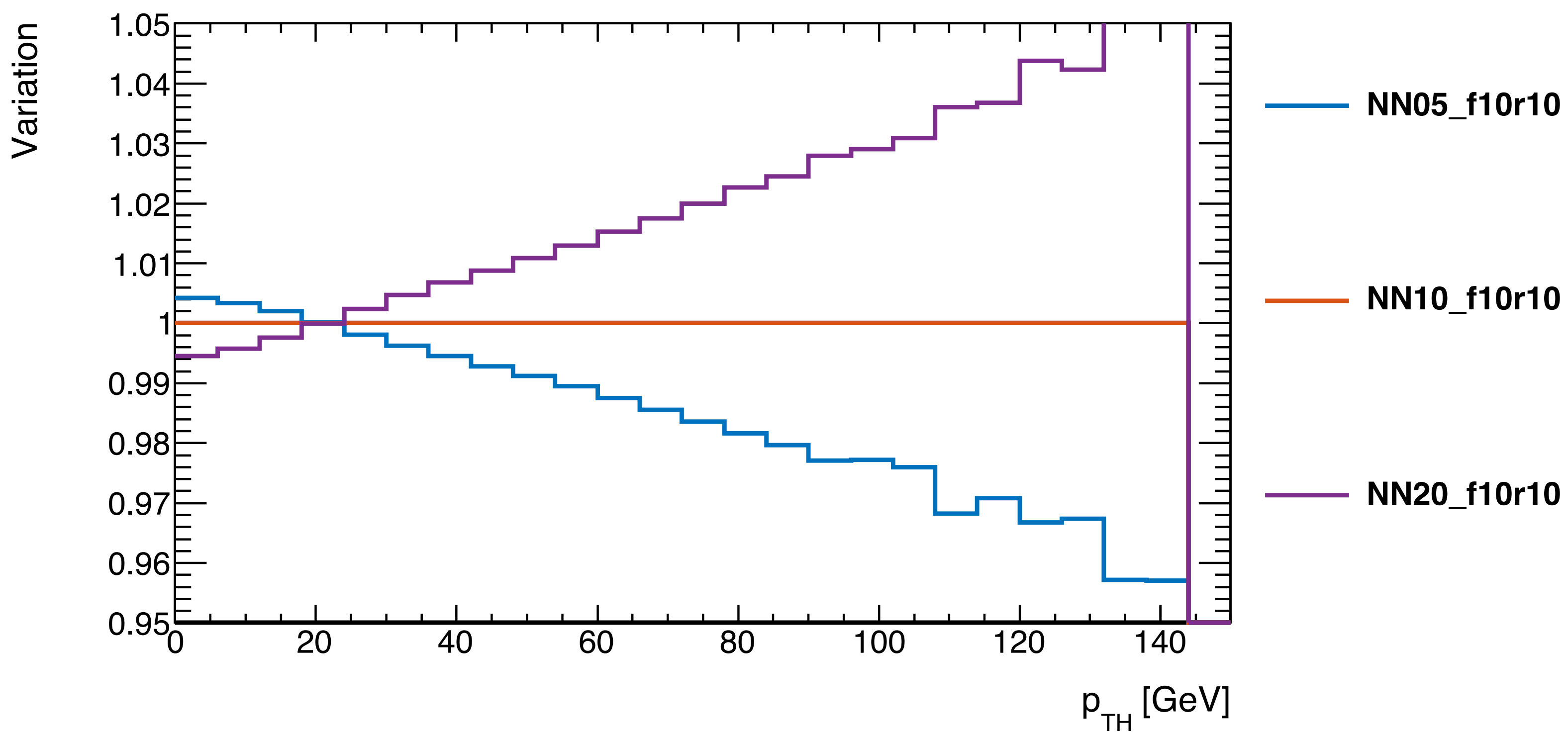
- To derive p_T shape variation
  - **Vary** all internal scales and take the one with the largest impact
  - **3 scales:**
    - HNNLO NNLOPS scales
    - muR/muF scales for Powheg

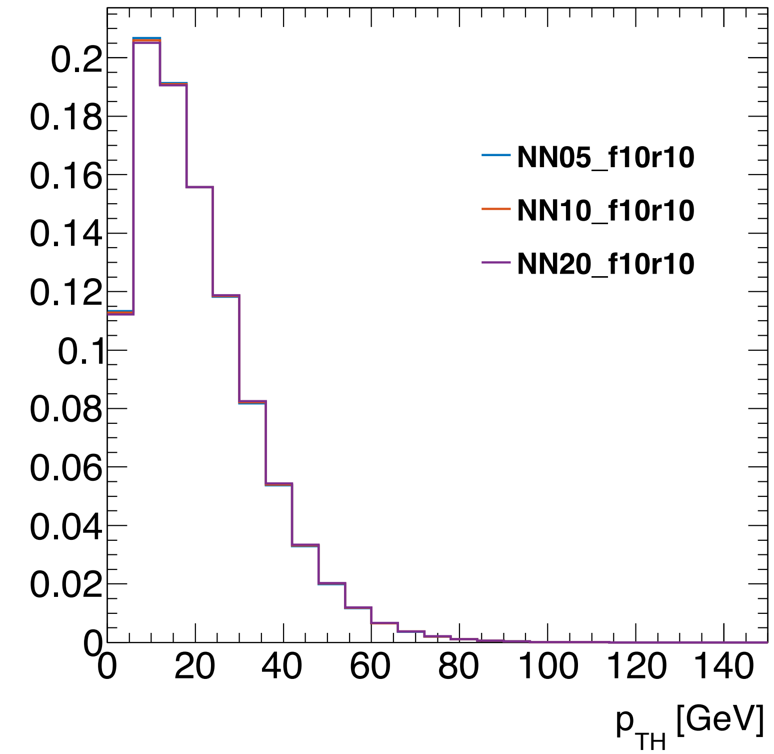
- We want **pure** shape uncertainty on the pT - normalize all histograms in $N_J = 0$ before comparing distributions
  - Other parameters in the systematic scheme **cover** overall normalization and N_J migrations uncertainties

0Jet - p_T Distribution

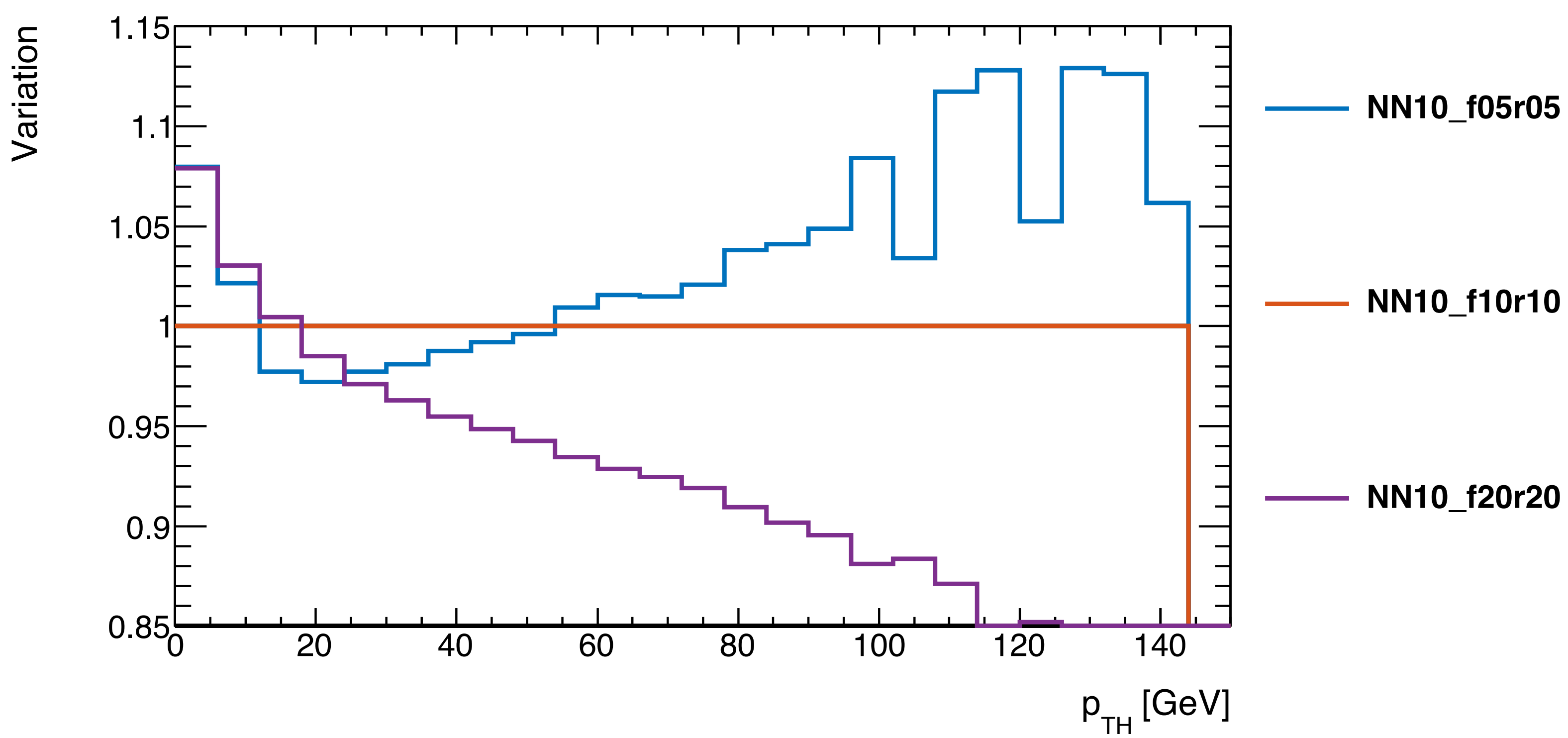
Legend map: NNxx_fyyrzz
xx = HNNLO scale
yy = muF scale
zz = muR scale

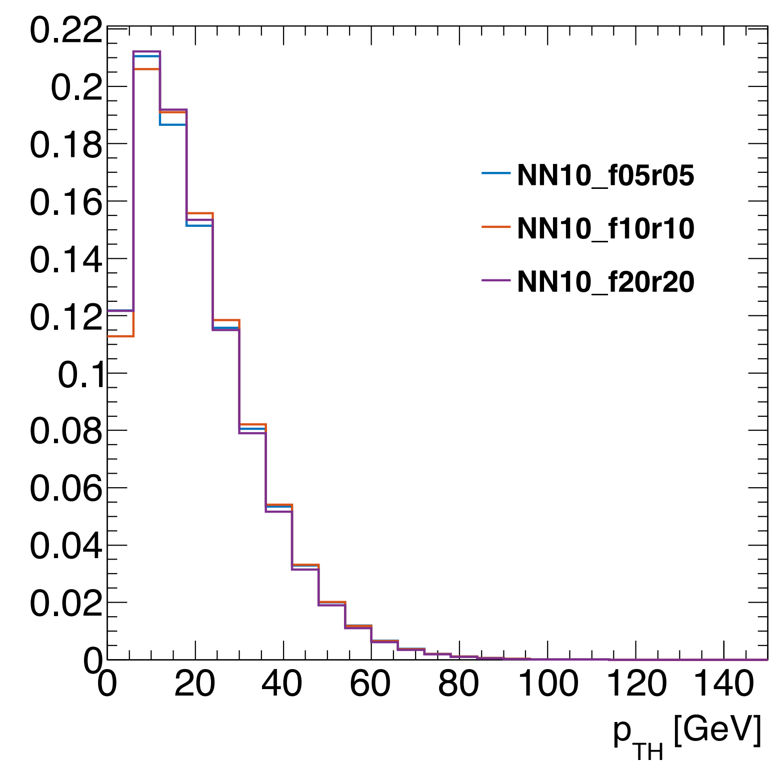
Vary HNNLO NNLO scale, muR,muF at Nominal





Vary muR=muF scale, HNNLO at Nominal scale



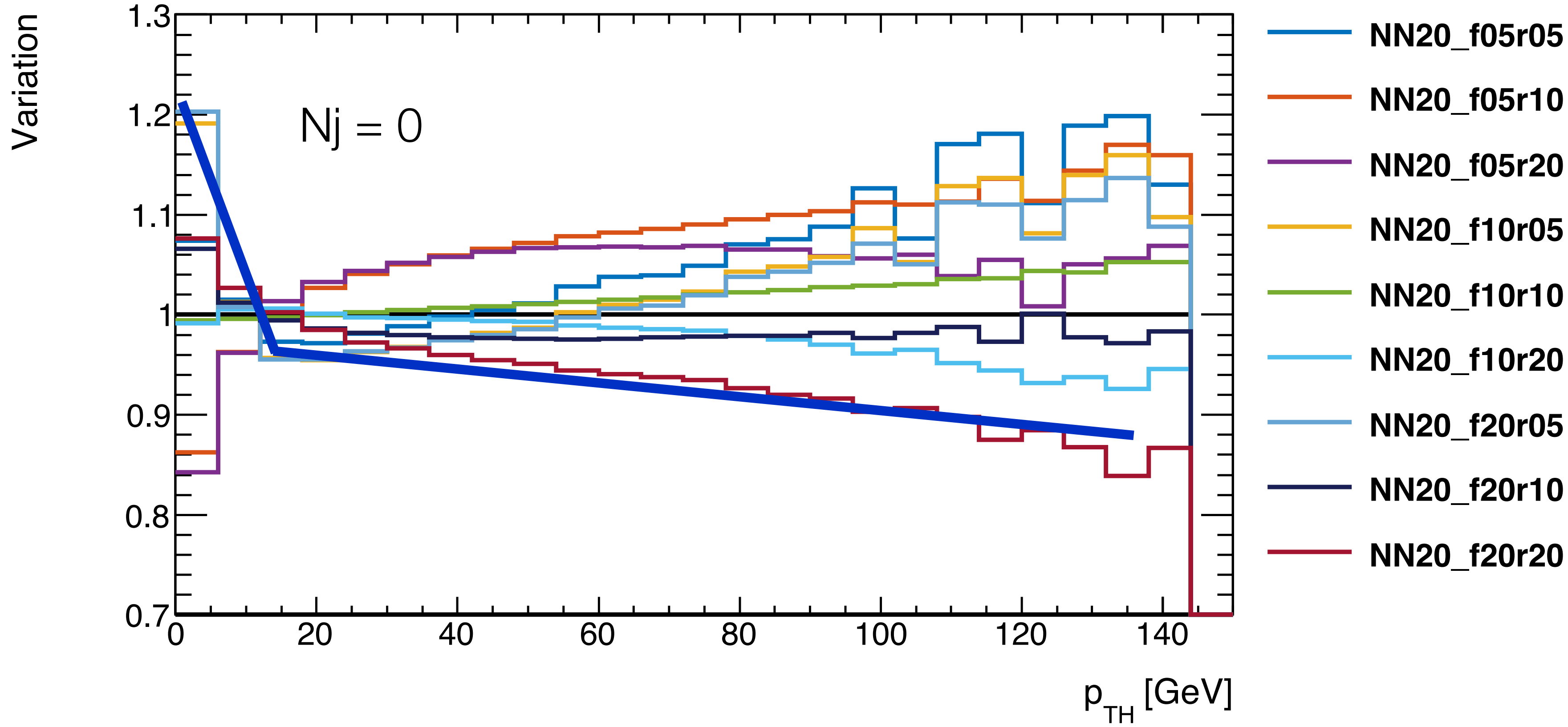


p_T Shape Variation

Legend map: NNxx_fyyrzz
xx = HNNLO scale
yy = muF scale
zz = muR scale

- All scale variations considered and plots are in the backup
- Proposed systematic - interpolate with pT to get the overall shape change impact

Blue line - New sys for p_T in 0J



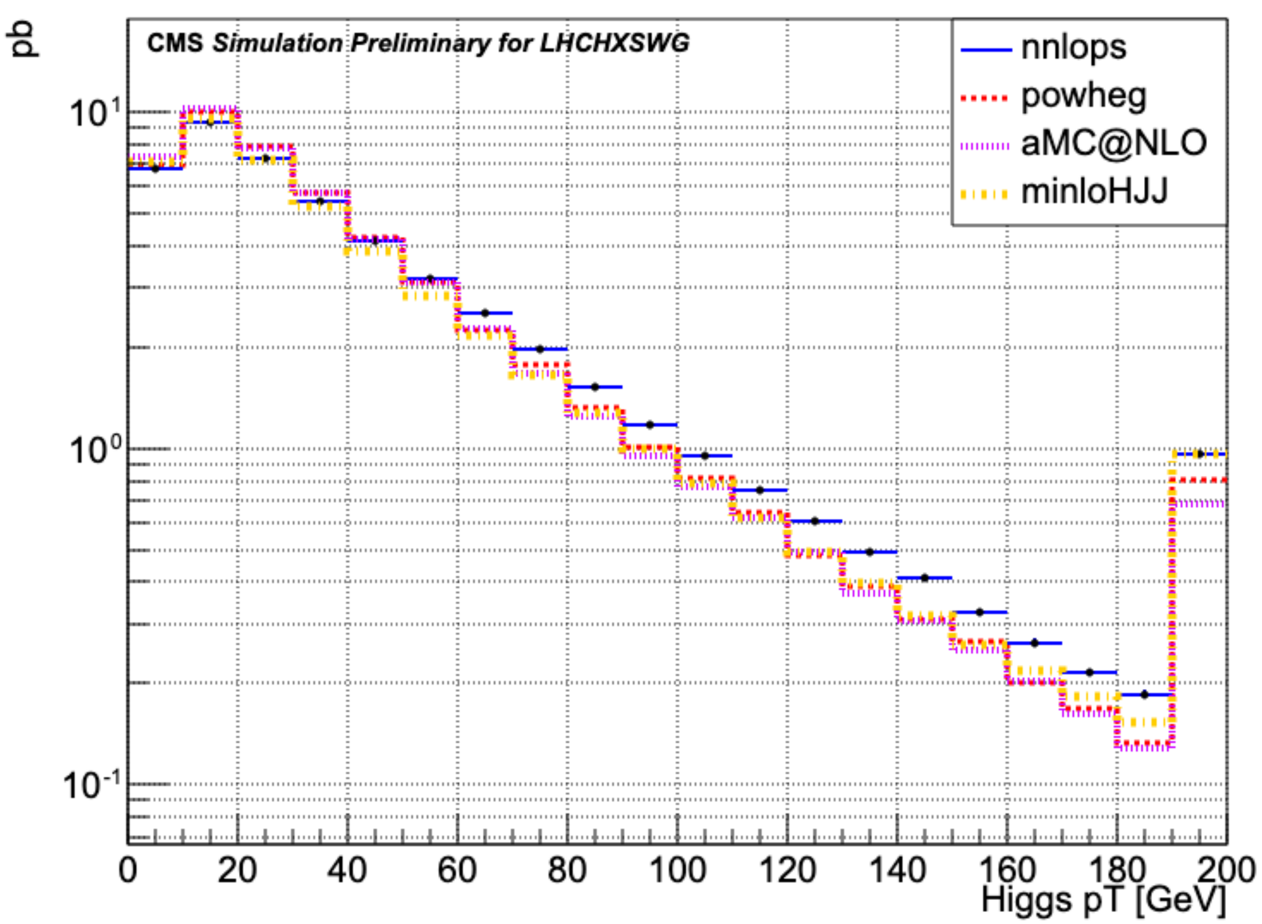
Impact of systematics on XS in 0J-p_T STXS bin

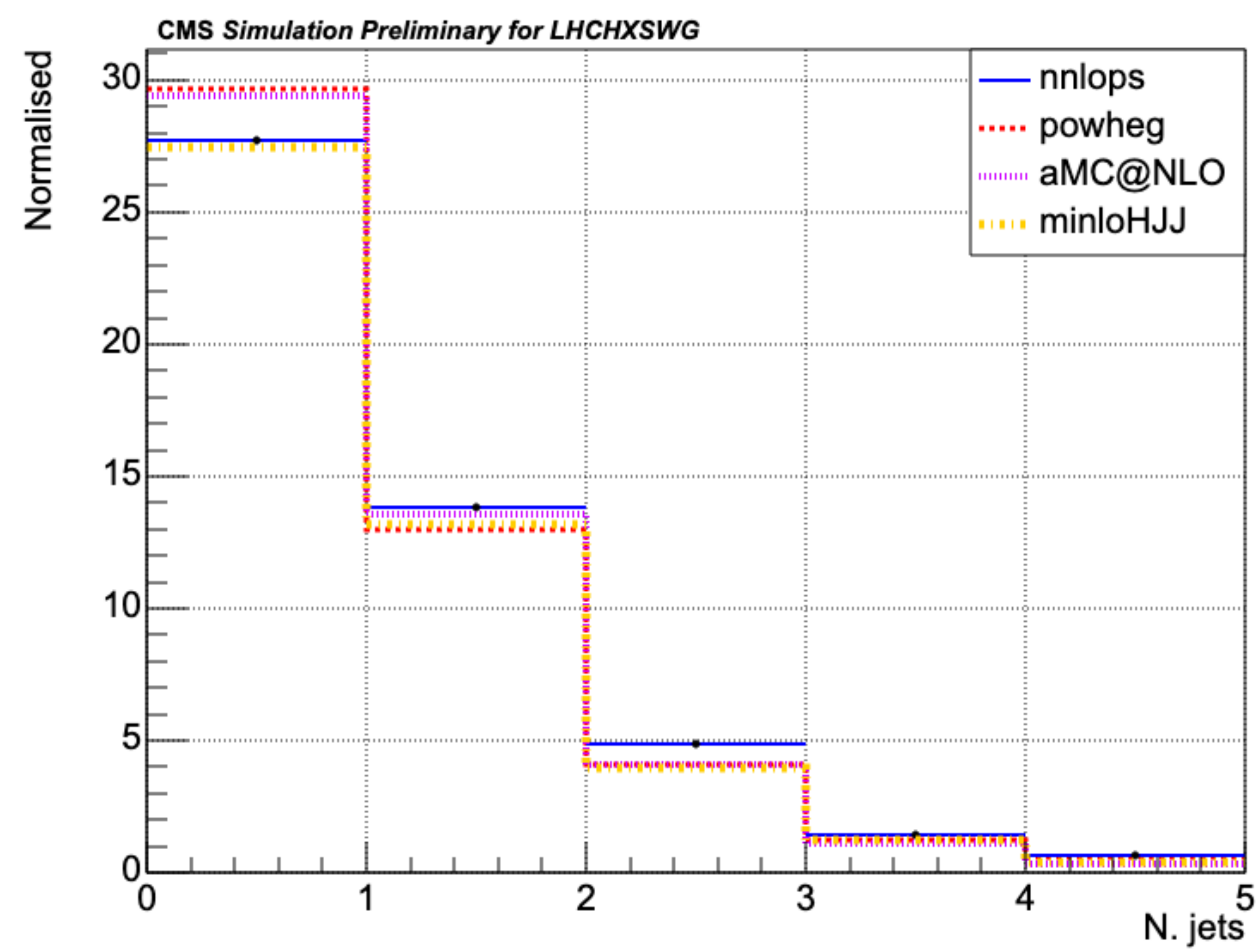
	Total XS (pb)	ΔXS - p_T^{10} (Proposed)	ΔXS - Overall Norm (Current)	ΔXS - $N_j^{0\to1}$ (Current)
p_T < 10 GeV	6.64	0.74pb / 11.2%	0.25pb / 3.8%	0.27pb / 4.1%
p_T > 10 GeV	20.65	-0.74pb / -3.6%	0.78pb / 3.8%	0.85pb / 4.1%

Generator Comparison

- **Complementary** study on deriving systematics using the approach outlined @ Link
  - Using CMS software and generator setup
  - Variation of the POWHEG renormalization and factorization scale
  - Systematic modelled a **step** function
- Additional **comparison** with MC@NLO or POWHEG HJJ for >=2 jet

All generators normalized to N3LO
HJJ normalized to its own XS

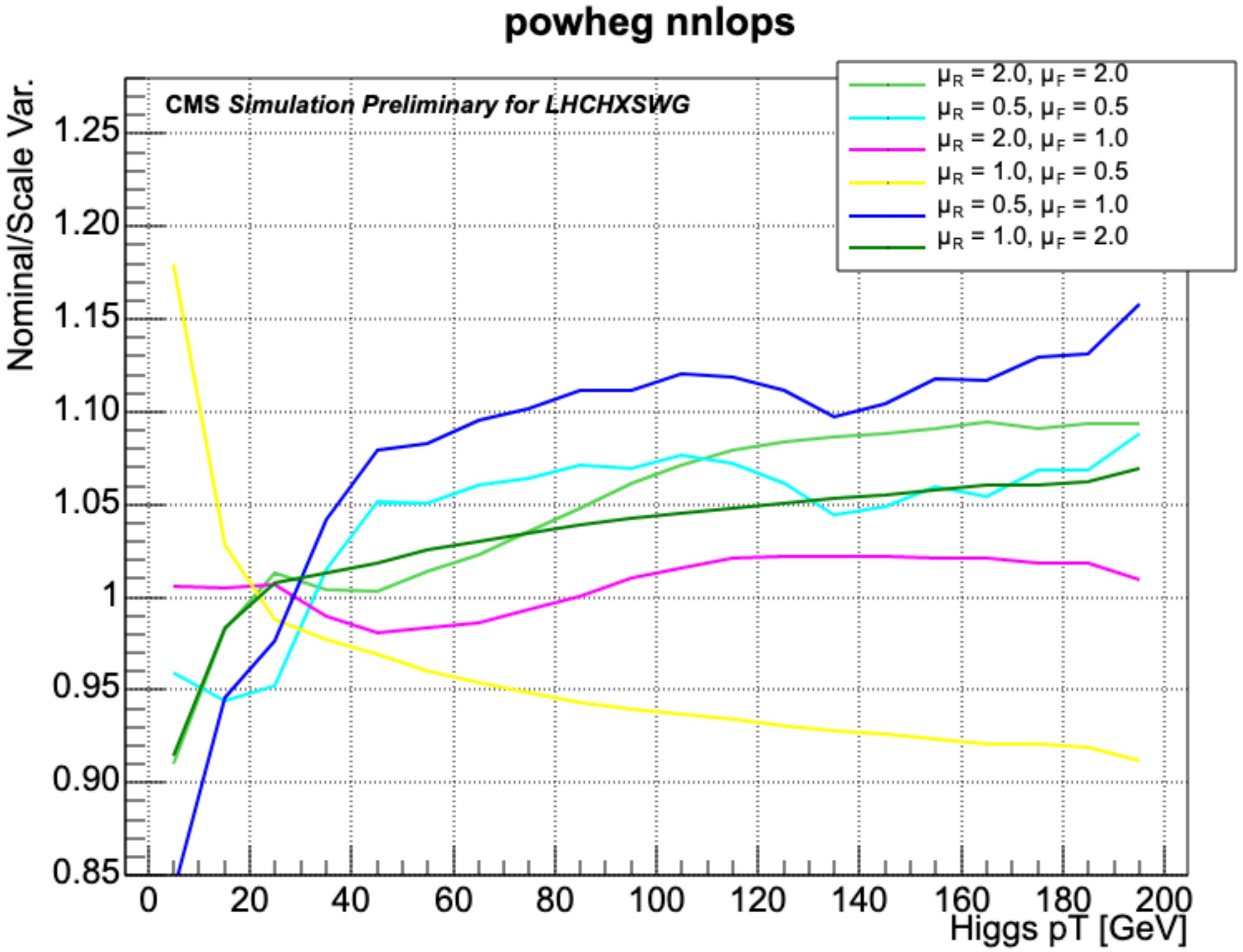


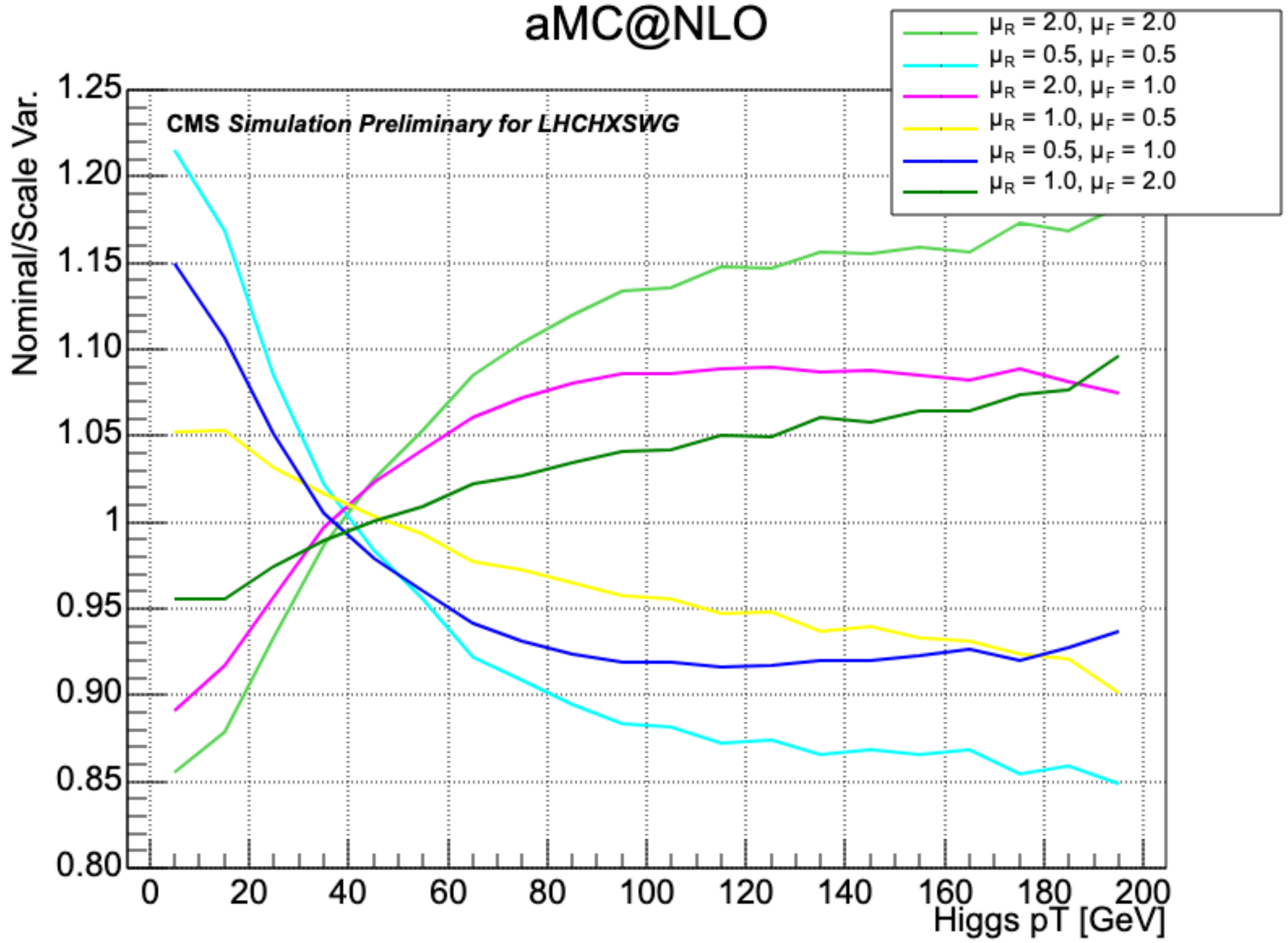


Inclusive p_T spectrum

Generator Comparison

- Scale variation roughly **consistent** across different generators

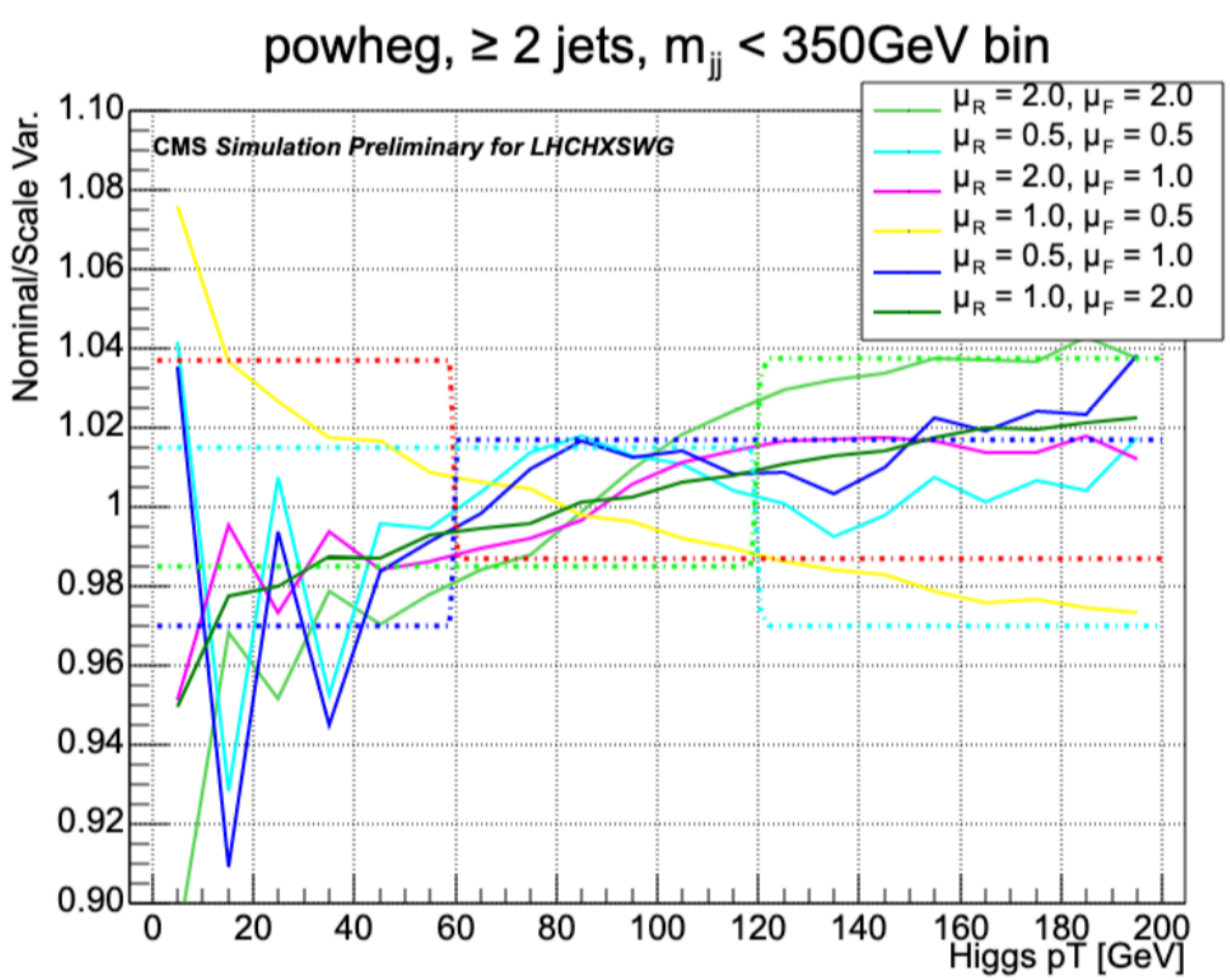


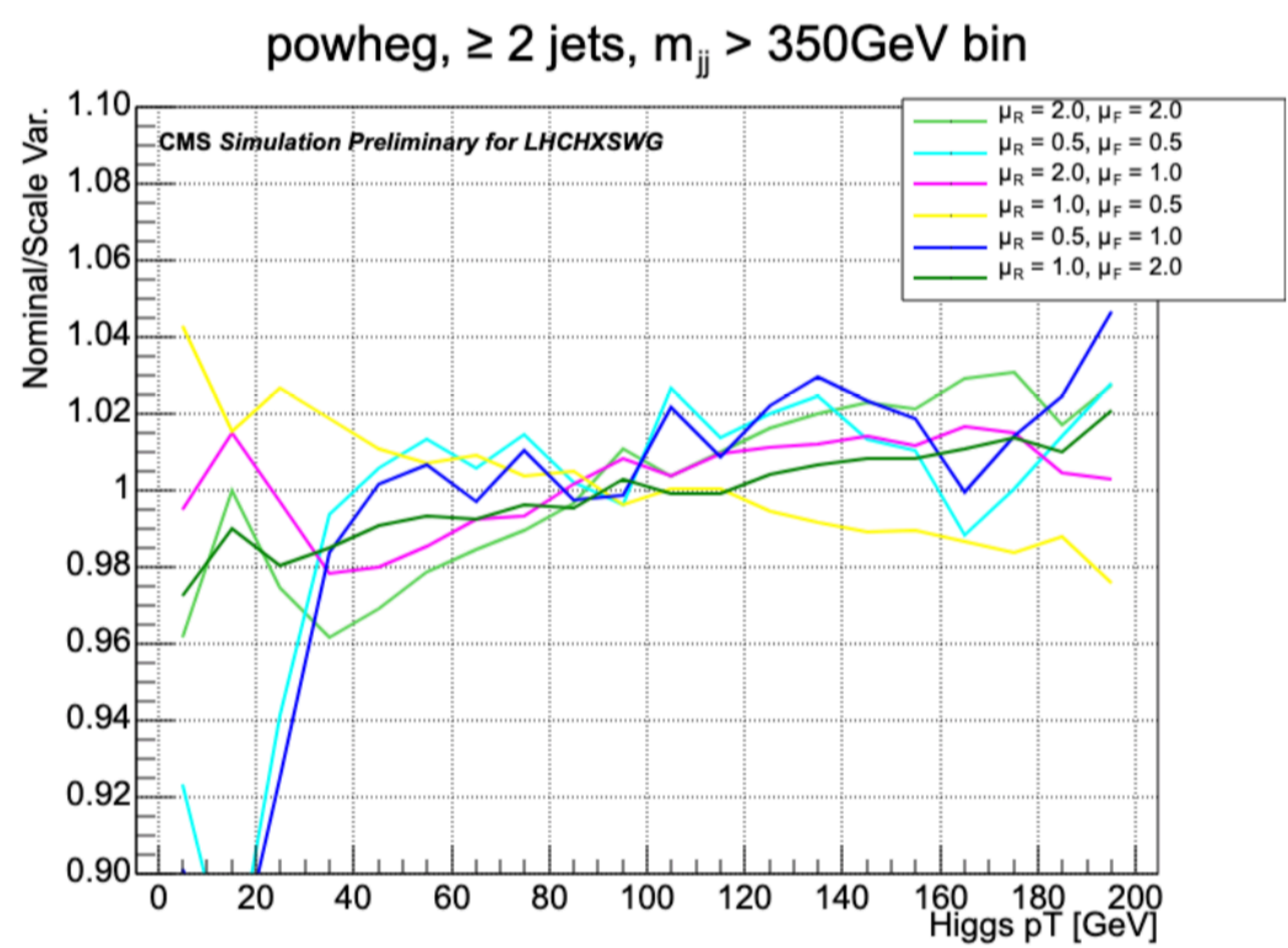


Inclusive p_T spectrum

pT Shape and Generator studies

- Scale variation for >=2-jets topology need to be derived with H+2j process at NLO - HJJ MiNLO or mc@NLO - First look with POWHEG
- 60, 120 GeV bin p_T **shape** variation for two m_{JJ} bins
- **Note**: mJJ > 350 GeV is further split according to mJJ and not pTH - initial look
- In the **Stage 1 scheme**, combine >=2-jets p_T and specific VBF topology systematics





dotted line = uncertainty bands across pT boundary

Conclusion

- New bins introduced within the ggF Stage 1.1 STXS scheme
    - New uncertainties to **encode** shape along the pT spectrum
- Proposed a p_T-dependent uncertainties for the **0-jet pT bins**
    - **Based** on scale variations computed using POWHEG with NNLOPS reweighing
    - ~0.74pb impact in each bin with a split at 10 GeV (11%/-3.5%)

- Scale variations from different generators look consistent
    - **First look** at the new bins for >= 2 jets
    - For **short** term, use generators with H+2j at NLO
    - For **long** term, higher order calculations

Backup

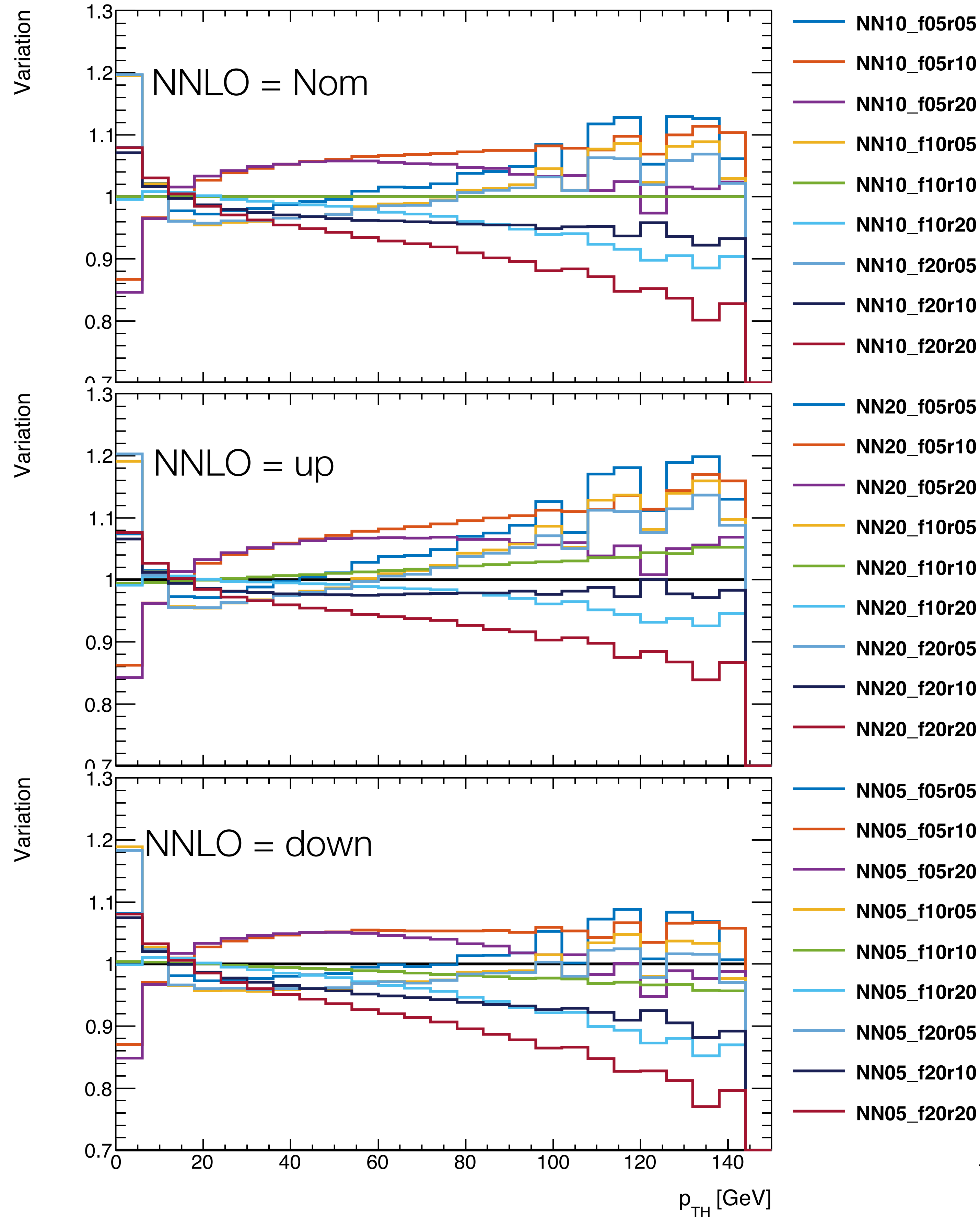
Setup for NNLOPS generation

- POWHEG - r3652 - small updates to allow for larger number of sys variations
  - HJ process - r3652
    - Increased ncall1, itmx1, ncall2, itmx2, foldcsi, foldy, foldphi, nubound to improve grid integration
  - PDF4LHC used as default, derived new NNLOPS Reweighing with this setup
  - Flattened abs(weight) > 100 - know issue of large weights number of events per jobs is small - 10k per job for current setup
  - 1.93M event in total
- Pythia versions 8.243
  - Setting from Example main31 used
- Rivet 3.0 - for improved LHE3 weight handling

Scale variations for nJ = 0

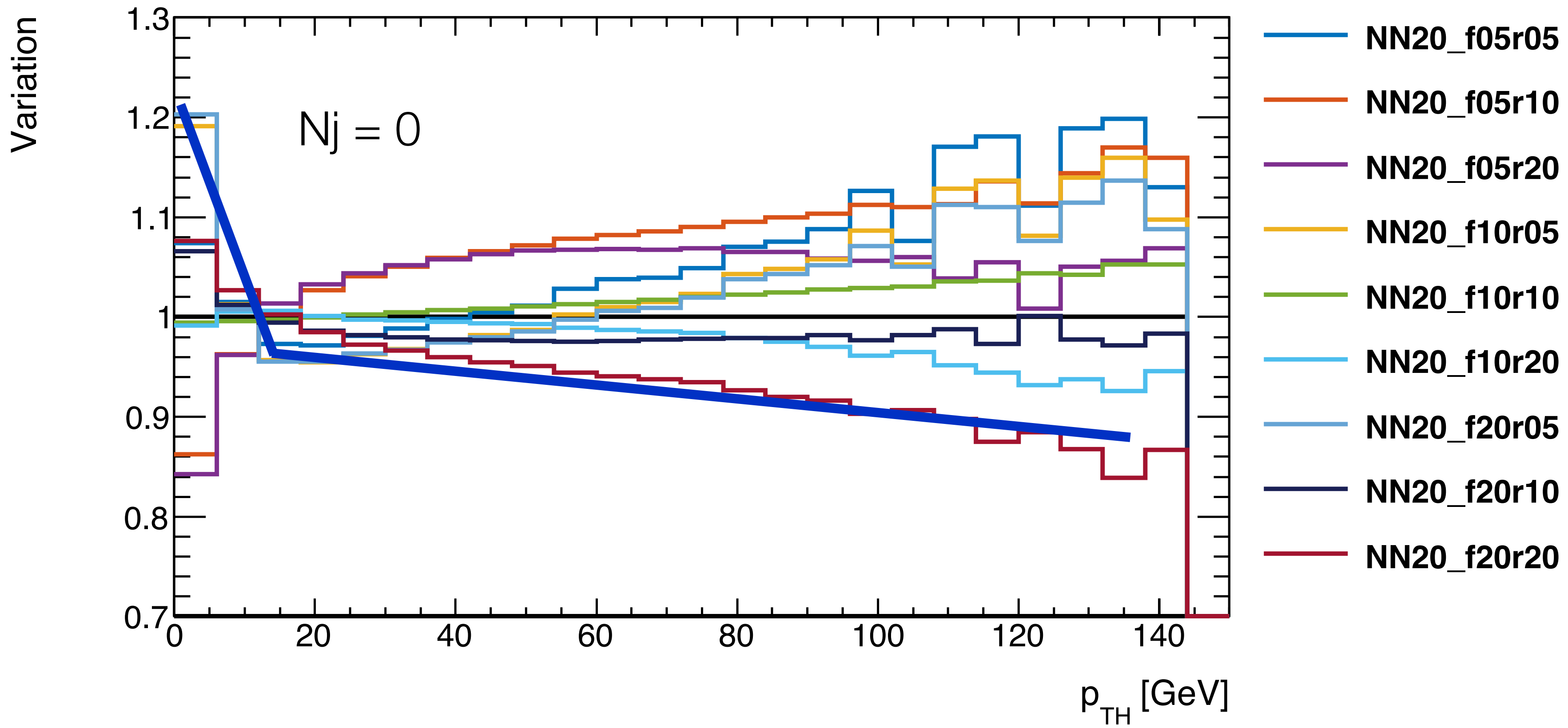
Largest impact comes
from varying all 3 scales up or down

Legend map: NNxx_fyyrzz
xx = HNNLO scale
yy = muF scale
zz = muR scale



p_T migration

Legend map: NNxx_fyyrzz
xx = HNNLO scale
yy = muF scale
zz = muR scale



Blue line is linear interpolation between the following points

pT [GeV]	Systematics Scale factor
0	1.2175
15	0.96
140	0.895

POWHEG Run card

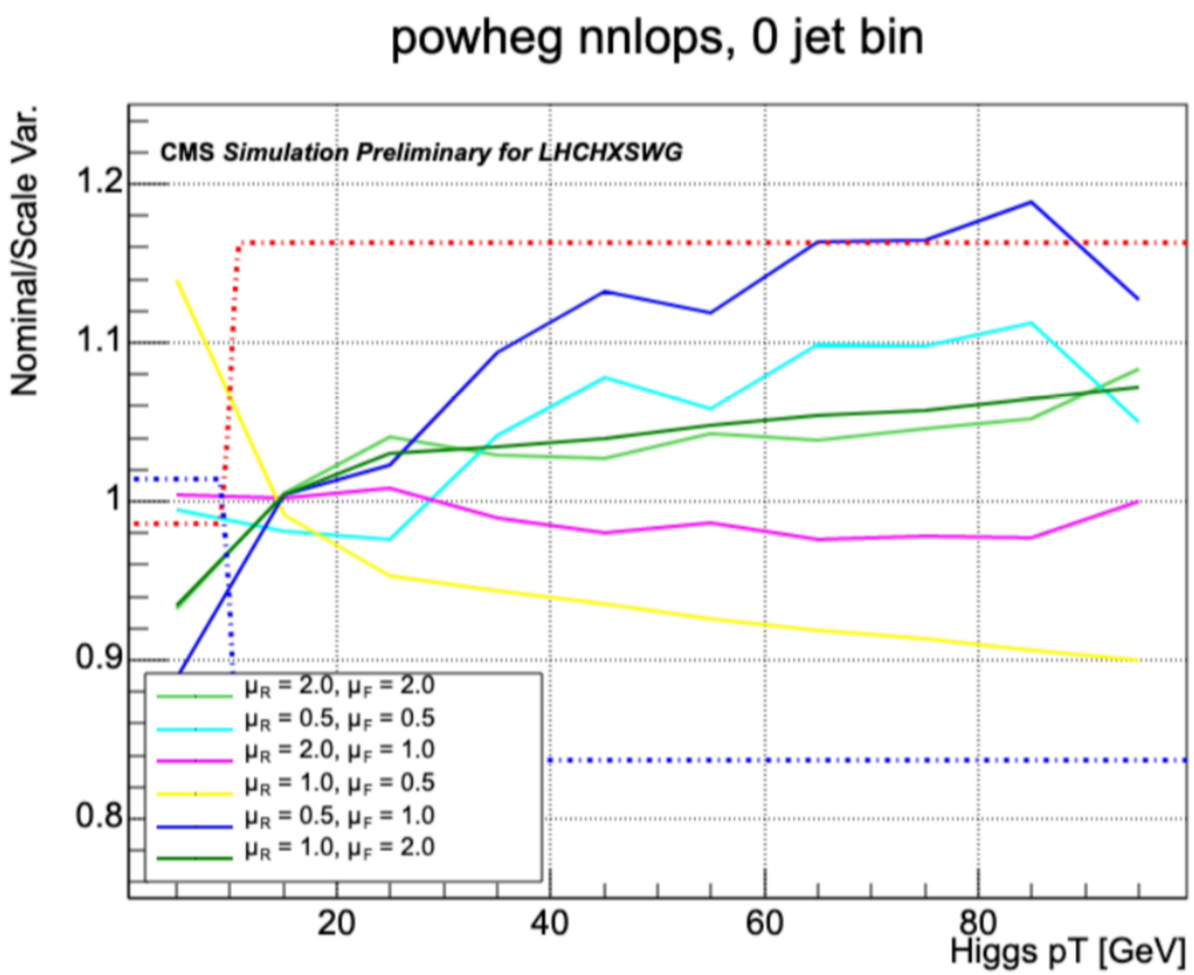
```
numevts 10000      ! number of events to be generated
ih1   1            ! hadron 1 (1 for protons, -1 for antiprotons)
ih2   1            ! hadron 2 (1 for protons, -1 for antiprotons)
ebeam1 6500d0      ! energy of beam 1
ebeam2 6500d0      ! energy of beam 2

hmass 125.0
hwidth 0.00407

hdecaywidth 0       ! If equals to 1 read total decay width from HDECAY sm.br2 file
                    ! if 0 the hwidth value is used

bwcutoff 1000       ! how many W widths below and above the Higgs mass are included

! To be set only if using LHA pdfs
lhans1   91400     ! pdf set for hadron 1 (LHA numbering)
lhans2   91400     ! pdf set for hadron 2 (LHA numbering)
! To be set only if using internal mlm pdf
ndns1 131          ! pdf set for hadron 1 (mlm numbering)
ndns2 131          ! pdf set for hadron 2 (mlm numbering)
! To be set only if using different pdf sets for the two incoming hadrons
! QCDLambda5  0.25 ! for not equal pdf sets
! Parameters to allow or not the use of stored data
use-old-grid    1 ! if 1 use old grid if file pwggrids.dat is present (<> 1 regenerate)
use-old-ubound  1 ! if 1 use norm of upper bounding function stored in pwgubound.dat, if
present; <> 1 regenerate

#higgsfixedwidth 1 ! (default 0), If 1 uses standard, fixed width Breit-Wigner
                  ! formula, if 0 it uses the running width Breit-Wigner
#bornsuppfact 1 ! (default 1), If 1 the Born suppression factor is included.
               ! Weighted events are generated. If 0 no suppression
               ! factor is included, and events are unweighted. A
               ! generation cut bornktmin>0 must be supplied in this case.
#ckkwscalup 1 ! (default 1), If 1 compute the scalup scale for subsequent
             ! shower using the smallest kt in the final state;
             ! If 0, use the standard POWHEG BOX scalup

#runningscales 1  ! (default 0), if 0 use hmass as central
                  ! factorization and renormalization scale;
                  ! if 1 use the Ht/2
ncall1   150000   ! number of calls for initializing the integration gri
itmx1    5        ! number of iterations for initializing the integration grid
ncall2   80000   ! number of calls for computing the integral and finding upper bound
itmx2    5        ! number of iterations for computing the integral and finding upper bound
fastbtlbound 1    ! (default 0) if 1 use fast btilde bound
storemintupb 1    ! store calls for grids
foldcsi   5       ! number of folds on csi integration
foldy     5       ! number of folds on  y  integration
foldphi   2       ! number of folds on phi integration
nubound 20000    ! number of bbarra calls to setup norm of upper bounding function
maxseeds 10000
```

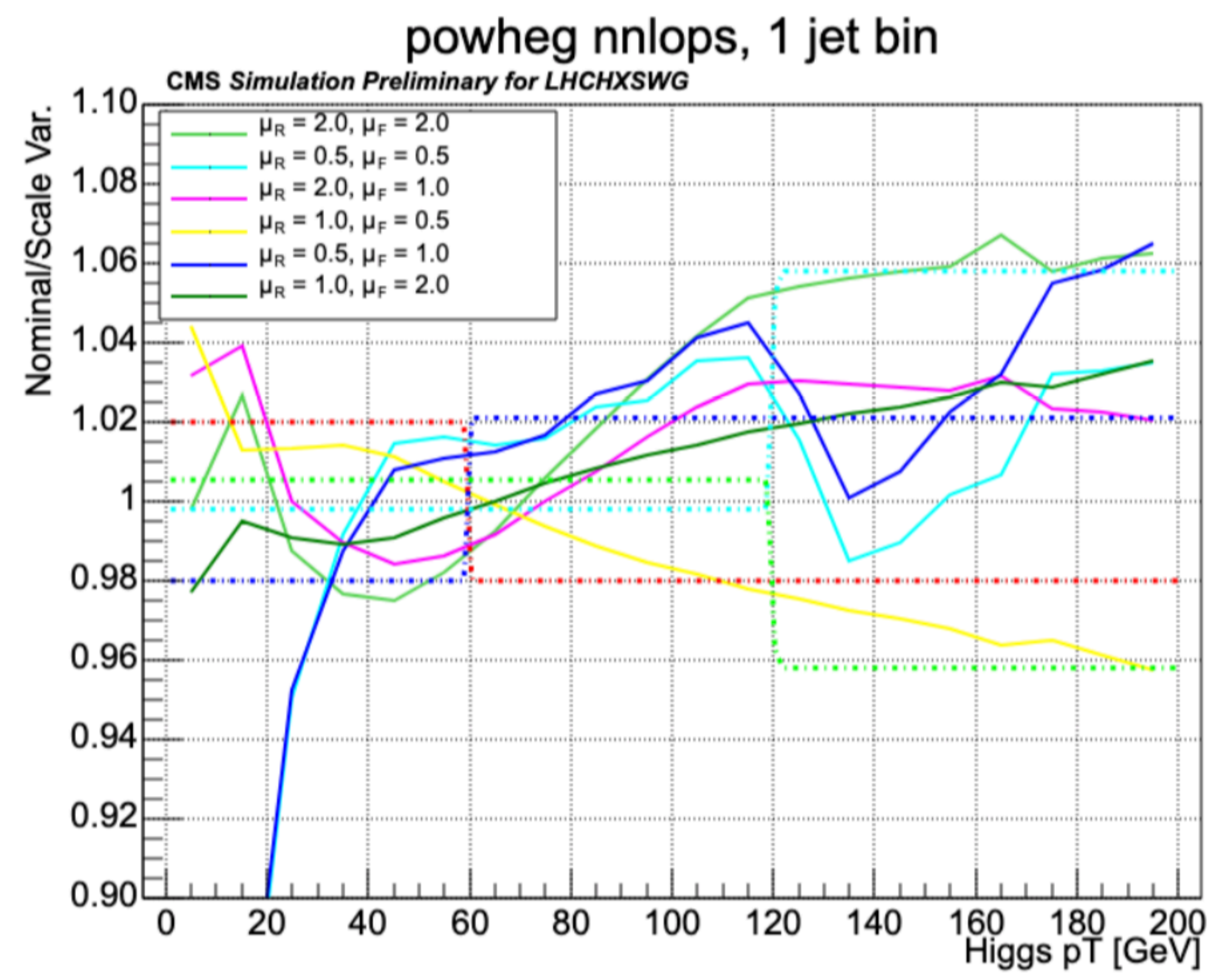
```
! OPTIONAL PARAMETERS
testplots  1       ! (default 0, do not) do NLO and PWHG distributions
#withnegweights 1  ! (1 default) If 1 output negative weighted events.
                   ! If 0 descard them
# bornonly   1     ! (default 0) if 1 do Born only
renscfact  1d0   ! (default 1d0) ren scale factor: muren  = muref * renscfact
facscfact  1d0   ! (default 1d0) fac scale factor: mufact = muref * facscfact
bornktmin 0.26    ! Minimum transverse momentum of the Higgs at the underlying Born level
#nohad 1           ! no hadronization and U.E. in pythia
storeinfo_rwgt 1   ! store info to allow for reweighting
flg_debug      1   ! store extra event info for debugging
#ckkwscalup 0      ! (default 0) Do not use the CKKW scalup, use the normal Powheg one.
minlo 1            ! default 0, set to 1 to use minlo
factsc2min 2       ! at this value the factorization scale is frozen (neede with minlo)
sudscalevar 1      ! (default 1) scale variation also in Sudakov form factors in minlo
#iseed    12       ! initialize random number sequence
#rand1     3       ! initialize random number sequence
#rand2    -1       ! initialize random number sequence
manyseeds 1
parallelstage 4
xgriditeration 1


#smartsig 0

# variables for including quark mass effects
#quarkmasseffects 1   ! Include quark mass effects
#topmass 172.5d0      ! top quark mass (172.5 in HNNLO-patches/mdata.f)
#bottommass 3.38d0    ! bottom quark mass in MSbar at MH
#bmass_in_minlo 1     ! Include quark mass effects in Sudakov exponent
#bmass_sud_approx 0   ! Kind of approximation for inclusion of mass effects in Minlo Sudakov exponent
                      ! 2 is Keith's approximate formula

rwl_file '-'
<initrwgt>
<weightgroup name='MiNLO'>
<weight id='mtinf'>  default </weight>
<weight id='mt'>  quarkmasseffects=1 topmass=172.5d0 </weight>
<weight id='mtmb'>  quarkmasseffects=1 topmass=172.5d0 bottommass=3.38d0 </weight>
<weight id='mtmb-bminlo'>  quarkmasseffects=1 topmass=172.5d0 bottommass=3.38d0 bmass_in_minlo=1 </weight>
<weight id='10505'>  renscfact=0.5d0 facscfact=0.5d0 </weight>
<weight id='11005'>  renscfact=1.0d0 facscfact=0.5d0 </weight>
<weight id='12005'>  renscfact=2.0d0 facscfact=0.5d0 </weight>
<weight id='10510'>  renscfact=0.5d0 facscfact=1.0d0 </weight>
<weight id='11010'>  renscfact=1.0d0 facscfact=1.0d0 </weight>
<weight id='12010'>  renscfact=2.0d0 facscfact=1.0d0 </weight>
<weight id='10520'>  renscfact=0.5d0 facscfact=2.0d0 </weight>
<weight id='11020'>  renscfact=1.0d0 facscfact=2.0d0 </weight>
<weight id='12020'>  renscfact=2.0d0 facscfact=2.0d0 </weight>
</initrwgt>
```

NNLOPS Card

```
# a line beginning with 'lhfile' followed by the name of the event file
lhfile pwgevents-0192.lhe

# uncomment the following if you want a compress les-houches file output.
#compress_lhe
# uncomment the following if you want the long format for the weights.
rwl_format_rwgt

# weights present in the lhfile: 'mtinf', 'mt', 'mtmb', 'mtmb-bminlo'
# a line with: 'nnlofiles'
# followed by a quoted label and the name of a HNNLO output file.
# In the following the 3 ouput refer to mt=infinity approx,
# finite mt, and finite mt and mb

nnlofiles
'nn-mtinf' H1250-CM13-PDF4LHC30-APX0-HH.top
'nn-mtmb' H1250_CM13_PDF4LHC30-APX2-HH.top
'nn-up' H1250_CM13_PDF4LHC30-APX2-11.top
'nn-down' H1250_CM13_PDF4LHC30-APX2-QQ.top

<initrwgt>
<weightgroup name='nnl'>
<weight id='nnlops-mtinf'> combine 'nn-mtinf' and 'mtinf' </weight>
<weight id='nnlops-mtmb'> combine 'nn-mtmb' and 'mtmb' </weight>
<weight id='nnlops-mtmb-bminlo'> combines 'nn-mtmb' and 'mtmb-bminlo' </weight>
<weight id='nnlops-NN10-r05f05'> combine 'nn-mtmb' and '10505' </weight>
<weight id='nnlops-NN10-r10f05'> combine 'nn-mtmb' and '11005' </weight>
<weight id='nnlops-NN10-r20f05'> combine 'nn-mtmb' and '12005' </weight>
<weight id='nnlops-NN10-r05f10'> combine 'nn-mtmb' and '10510' </weight>
<weight id='nnlops-NN10-r10f10'> combine 'nn-mtmb' and '11010' </weight>
<weight id='nnlops-NN10-r20f10'> combine 'nn-mtmb' and '12010' </weight>
<weight id='nnlops-NN10-r05f20'> combine 'nn-mtmb' and '10520' </weight>
<weight id='nnlops-NN10-r10f20'> combine 'nn-mtmb' and '11020' </weight>
<weight id='nnlops-NN10-r20f20'> combine 'nn-mtmb' and '12020' </weight>
<weight id='nnlops-NN05-r05f05'> combine 'nn-down' and '10505' </weight>
<weight id='nnlops-NN05-r10f05'> combine 'nn-down' and '11005' </weight>
<weight id='nnlops-NN05-r20f05'> combine 'nn-down' and '12005' </weight>
<weight id='nnlops-NN05-r05f10'> combine 'nn-down' and '10510' </weight>
<weight id='nnlops-NN05-r10f10'> combine 'nn-down' and '11010' </weight>
<weight id='nnlops-NN05-r20f10'> combine 'nn-down' and '12010' </weight>
<weight id='nnlops-NN05-r05f20'> combine 'nn-down' and '10520' </weight>
<weight id='nnlops-NN05-r10f20'> combine 'nn-down' and '11020' </weight>
<weight id='nnlops-NN05-r20f20'> combine 'nn-down' and '12020' </weight>
<weight id='nnlops-NN20-r05f05'> combine 'nn-up' and '10505' </weight>
<weight id='nnlops-NN20-r10f05'> combine 'nn-up' and '11005' </weight>
<weight id='nnlops-NN20-r20f05'> combine 'nn-up' and '12005' </weight>
<weight id='nnlops-NN20-r05f10'> combine 'nn-up' and '10510' </weight>
<weight id='nnlops-NN20-r10f10'> combine 'nn-up' and '11010' </weight>
<weight id='nnlops-NN20-r20f10'> combine 'nn-up' and '12010' </weight>
<weight id='nnlops-NN20-r05f20'> combine 'nn-up' and '10520' </weight>
<weight id='nnlops-NN20-r10f20'> combine 'nn-up' and '11020' </weight>
<weight id='nnlops-NN20-r20f20'> combine 'nn-up' and '12020' </weight>
</weightgroup>
</initrwgt>
```

pT systematics





Stage 1.1 systematics

ASSIGNED UNCERTAINTIES FOR STXS 1.1 INTERPRETATION

STXS	10 GeV	60 GeV	120 GeV	VBF 2 jets	VBF 3 jets
0jet	16%, 5%	-	-	-	-
1jet	-	2%, 2%	1%, 5%	-	-
>=2jets	-	5%, 1.9%	2%, 5%	20 %	30 %

Preliminary values: come from scale variations shown in previous slides. Total uncertainty is the envelope of the uncertainties on all the nuisances.