# WG1 ggF report

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HXSWG meeting

# Gluon fusion sections in Yellow Report 4

- Main focus on the $N^3LO$ inclusive cross section
  - Not focus of this presentation
- Contributions from different groups:
  - Predictions for ggF jet binning
    + including jet bin correlations
  - Predictions of Higgs boson $p_T$
  - Leading jet $p_T$ (@NNLO)
- Comparison of “benchmark predictions”: key distributions of Higgs gluon fusion
  - Both analytical and MC predictions included

# Benchmark comparison from YR4

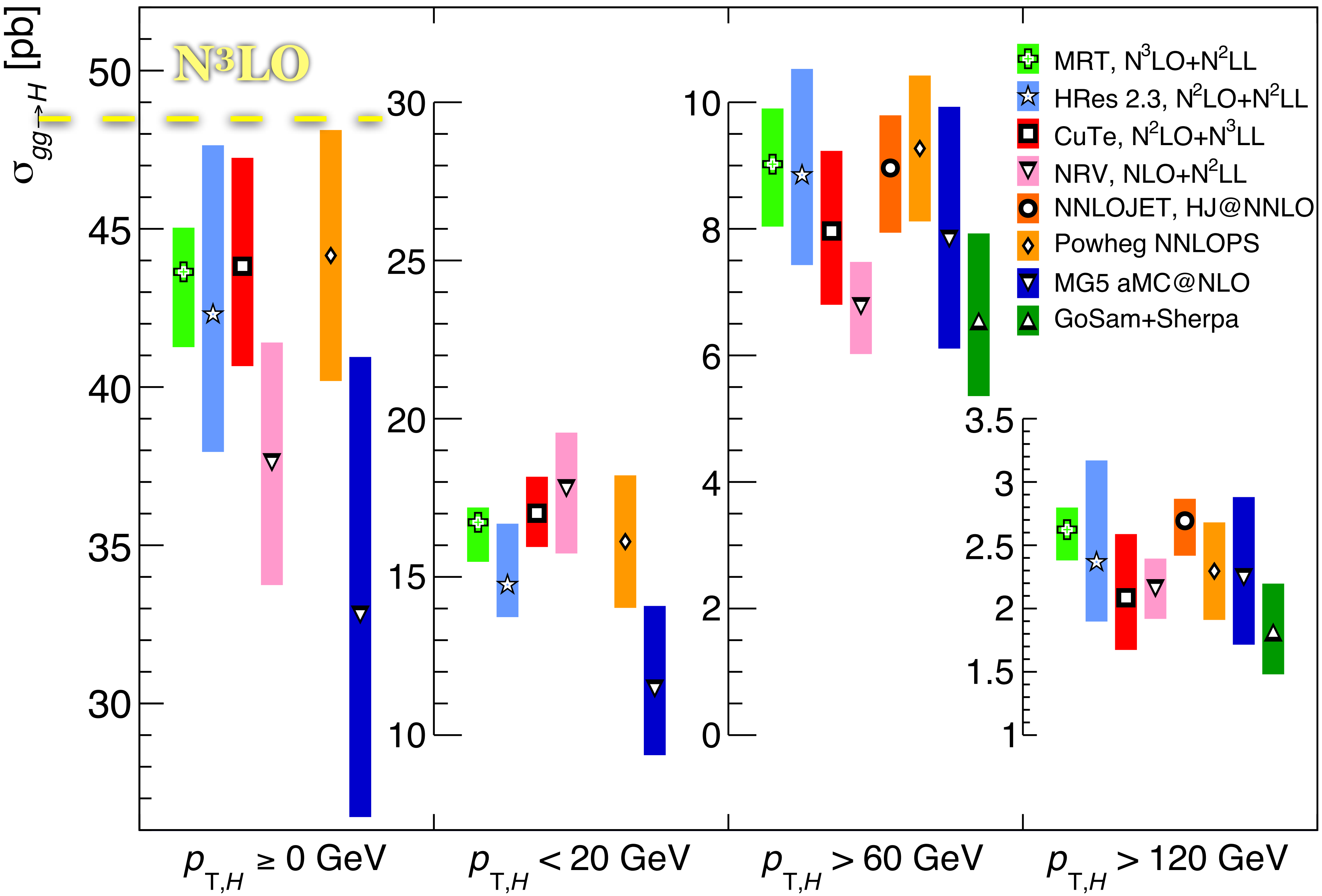
- In **Run-1** ATLAS and CMS used Powheg (0-jet@NLO) as default MC generator for inclusive ggF production (several other generators used for cross-checks, e.g. of 2-jet region)
  - Normalization from YR3 (dF-G, NNLO+NNLL, $\mu = m_H$), $k$-factor ~= 1.5
  - First jet at LO, second jet from parton shower, hence imperfect modelling of jet activity and Higgs boson transverse momentum → **Applied reweighing** to match kinematic distribution from state-of-the-art predictions, namely $p_{TH}$ from HRes 2.3 (dynamic scale) and $N_{jets}$ from higher order calculations
- For Run-2 we hope we can avoid reweighing
- Benchmarking predictions important for several reasons, one of them to see how well modern MC generators hold up against analytical predictions

| MC generators (hadron level) | |
|---|---|
| Powheg NNLOPS | inclusive NNLO, 1j@NLO |
| aMC@NLO MG5 | NLO-merged 0,1,2j @NLO |

* Powheg NNLOPS likely baseline generator for inclusive ggF by ATLAS+CMS for next round of analyses

| Parton level predictions | |
|---|---|
| HRes | NNLO+NNLL |
| CuTe | NNLO+$N^3$LL |
| NRV | NLO+NNLL |
| MRT | $N^3$LO+$N^2$LL |
| NNLOJET | HJ@NNLO |
| BFGLP | HJ@NNLO |
| STWZ,BL | NNLL'+$NNLO_0$ |
| JVE | $N^3$LO + jet veto |
| GoSam+Sherpa | 1,2,**3J** @ NLO |

# Benchmark comparison from YR4, $p_{T,H}$




- Different approaches used
- No prediction use EW correction. Many include quark masses. Need to keep in mind when comparing with N3LO:

$$
\begin{aligned}
48.58\,\text{pb} =\; & (+32.9\%) && (\text{LO, rEFT}) \\
& (+42.9\%) && (\text{NLO, rEFT}) \\
& (-4.2\%) && ((t,b,c),\ \text{exact NLO}) \\
& (+19.7\%) && (\text{NNLO, rEFT}) \\
& (+0.7\%) && (\text{NNLO, } 1/m_t) \\
& (+4.9\%) && (\text{EW, QCD-EW}) \\
& (+3.1\%) && (\text{N}^3\text{LO, rEFT})
\end{aligned}
$$

~10%

**inclusive cross section**

- In general, good agreement between most predictions
- Powheg NNLOPS does well (no need for reweighing)

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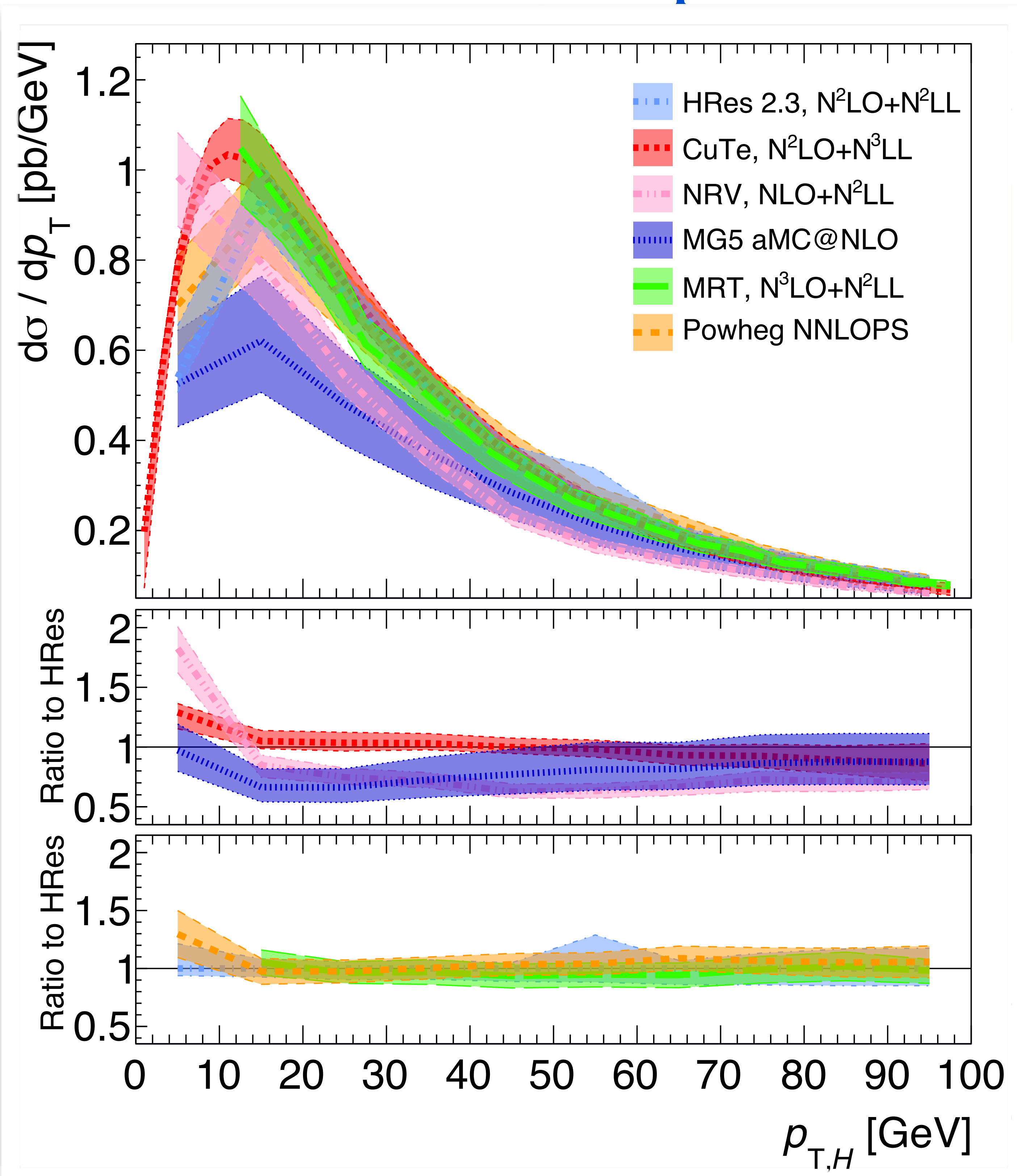


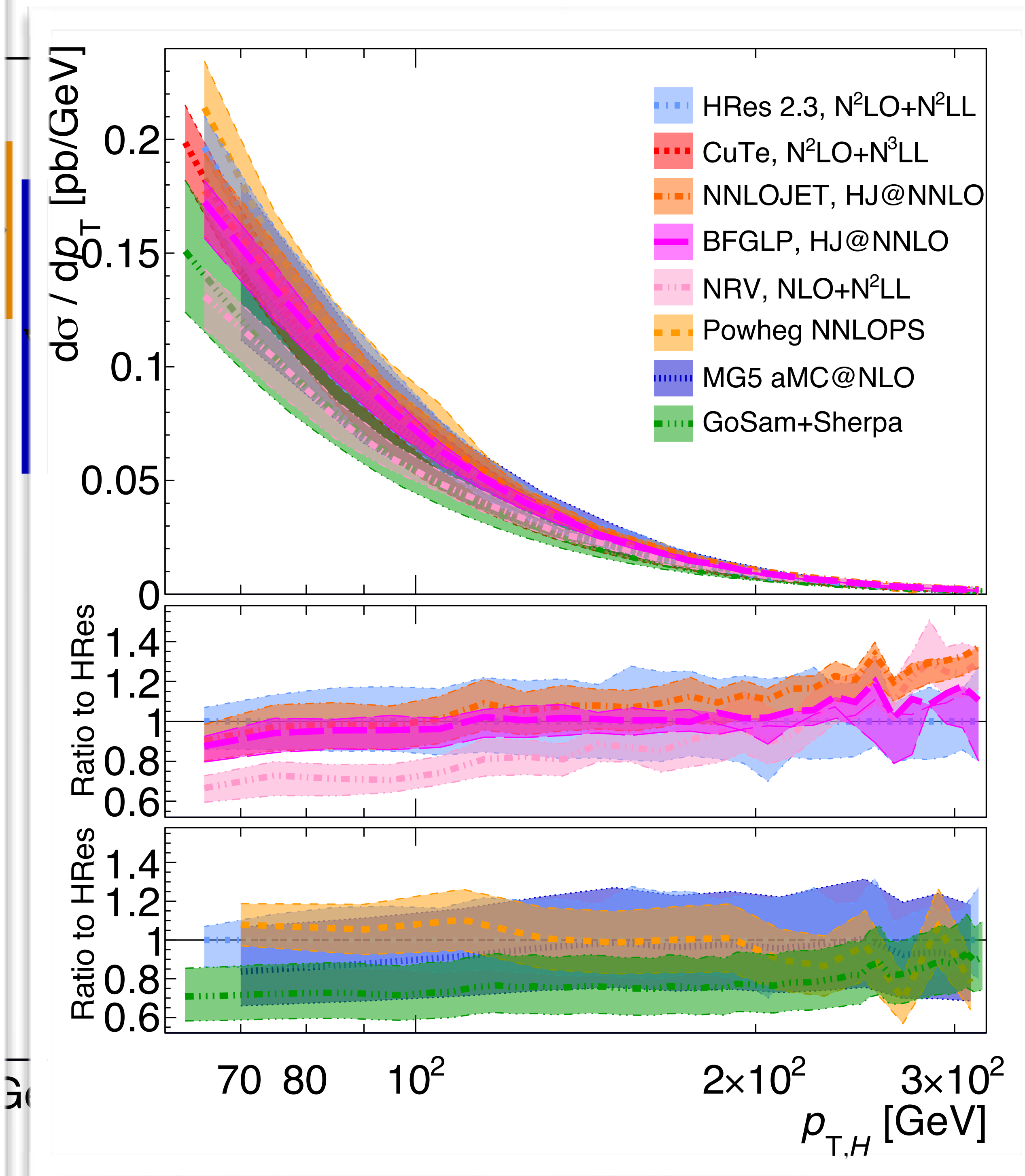


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cross section

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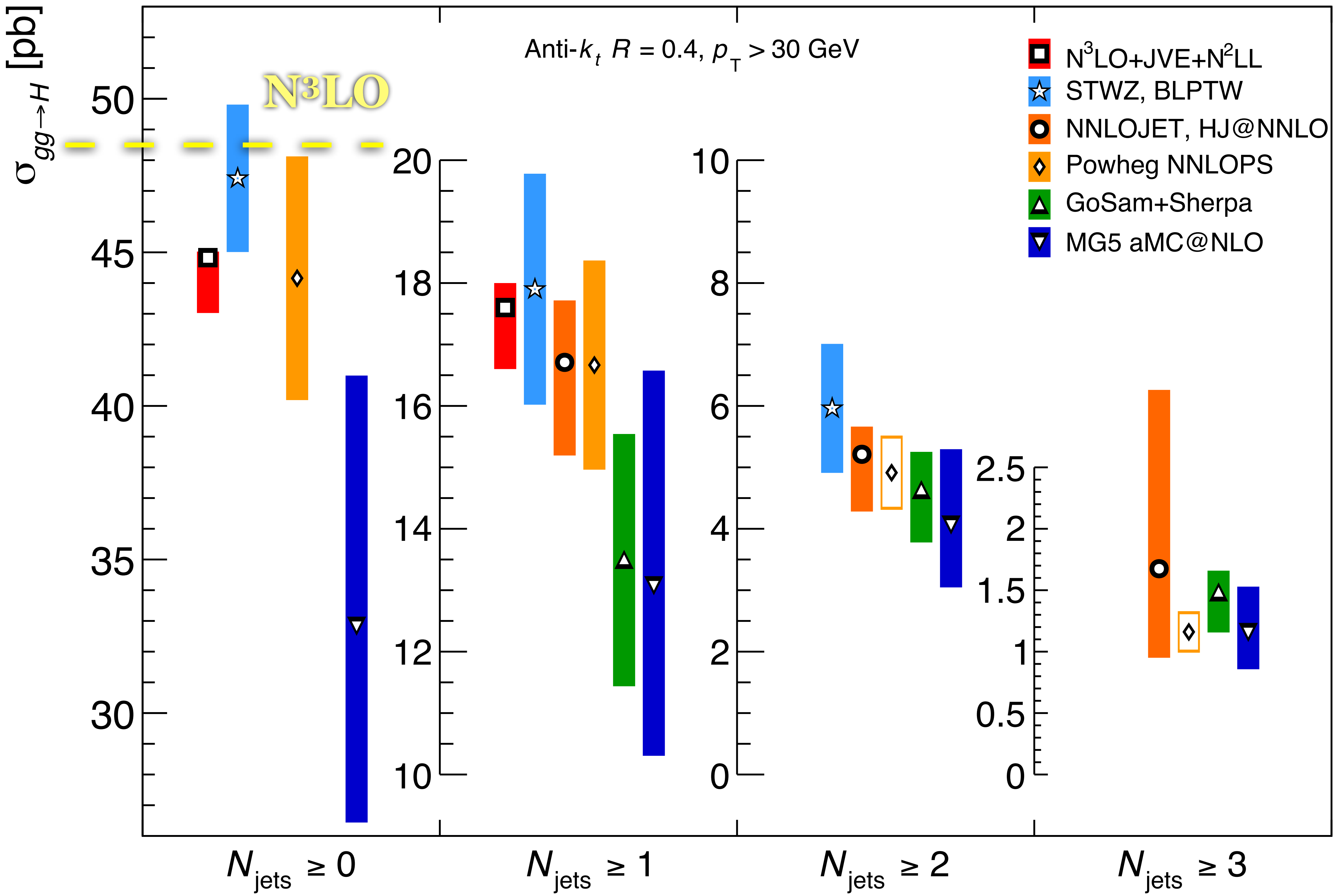
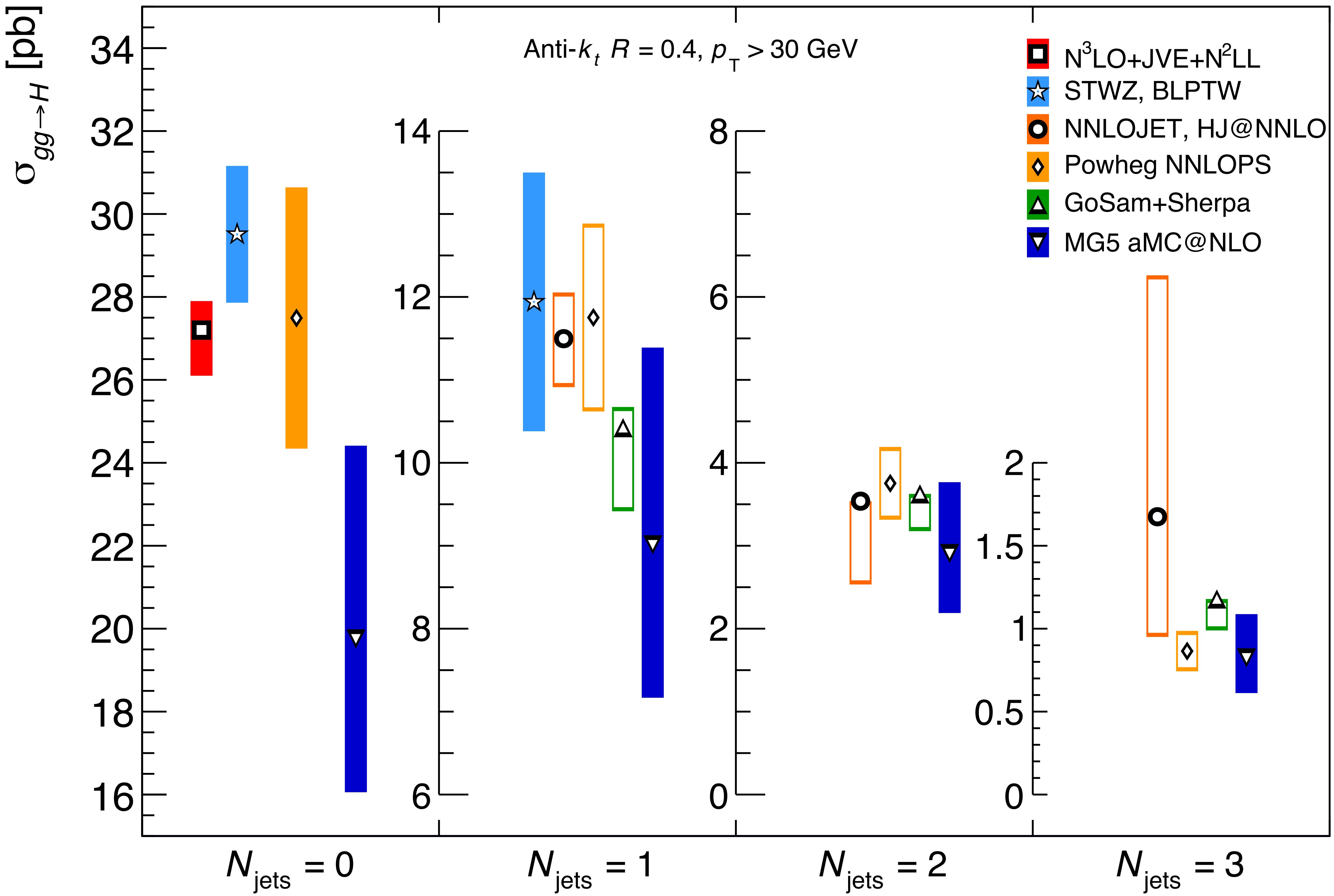
# Benchmark comparison from YR4, $N_{\text{jets}}$




**inclusive jet bins**

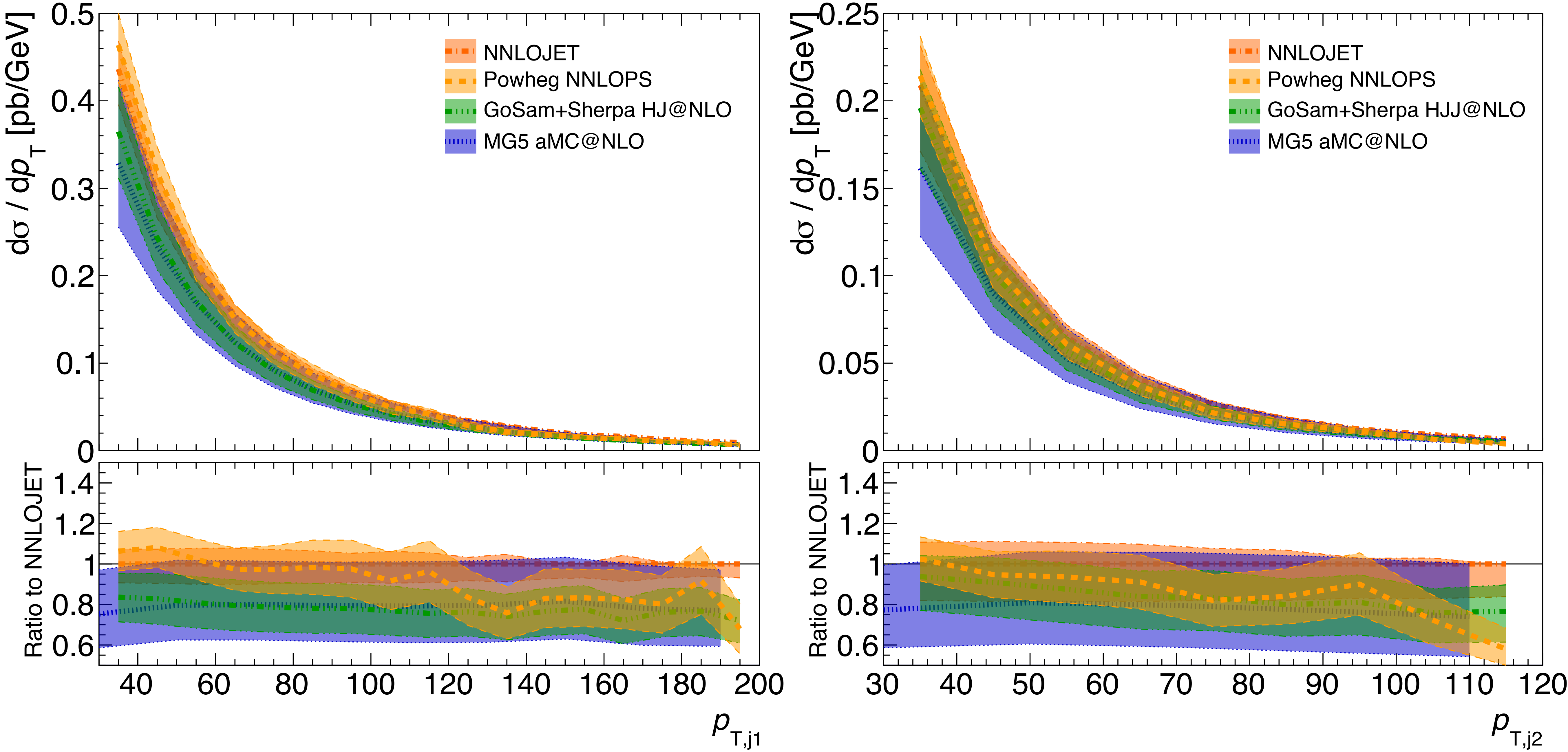
# Benchmark comparison from YR4, $N_{\text{jets}}$



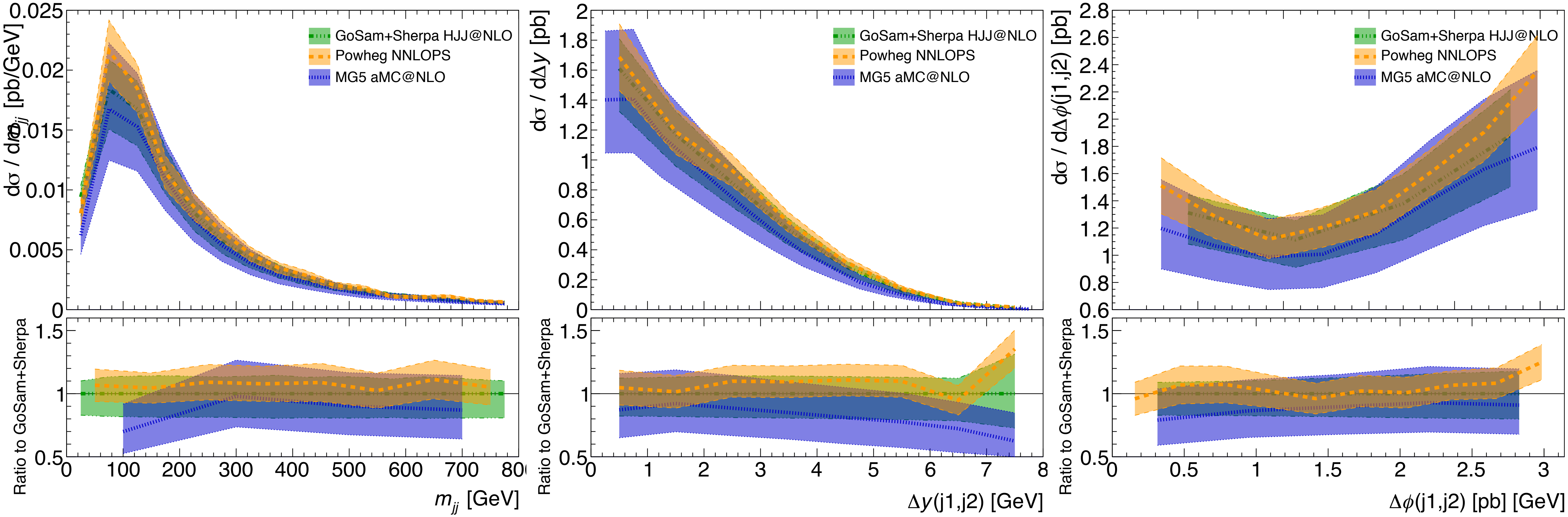

**exclusive jet bins**

*Several predictions do not consider the jet veto in uncertainty estimation (open boxes)*

# Benchmark comparison from YR4, jet $p_T$



# Benchmark comparison from YR4, VBF region




| Prediction | $m_{jj} > 400$ GeV, $\Delta y_{jj} > 2.8$ no jet3 veto | $m_{jj} > 400$ GeV, $\Delta y_{jj} > 2.8$ $p_{T,j3} < 30$ GeV | $m_{jj} > 600$ GeV, $\Delta y_{jj} > 4.0$ no jet3 veto | $m_{jj} > 600$ GeV, $\Delta y_{jj} > 4.0$ $p_{T,j3} < 30$ GeV |
|---|---|---|---|---|
| POWHEG NNLOPS | $653^{+86}_{-86}$ fb | $435^{+54}_{-54}$ fb | $283^{+36}_{-36}$ fb | $198^{+24}_{-24}$ fb |
| aMCNLO MG5 | $512^{+152}_{-133}$ fb | $329^{+92}_{-84}$ fb | $214^{+62}_{-57}$ fb | $142^{+39}_{-37}$ fb |
| GOSAM+SHERPA HJJ@NLO | $610^{+74}_{-120}$ fb | $435^{+0}_{-70}$ fb | $268^{+32}_{-55}$ fb | $195^{+0}_{-31}$ fb |
| POWHEG NNLOPS, $k = 1.05$ | $683^{+90}_{-90}$ fb | $455^{+57}_{-57}$ fb | $296^{+38}_{-38}$ fb | $207^{+25}_{-25}$ fb |
| aMCNLO MG5, $k = 1.41$ | $721^{+214}_{-188}$ fb | $463^{+129}_{-118}$ fb | $302^{+87}_{-80}$ fb | $200^{+55}_{-52}$ fb |

# Current focus of the ggF group

*Desired from the experimental side:*

1. MC predictions with accurate central values
   → Wish to avoid reweighing kinematic distributions (as was done in Run-1)

2. Theoretical uncertainties (**QCD** in particular)
   a. ggF **jet bins**
   b. **Higgs $p_T$**
   c. ggF with **VBF topology** ("VBF contamination")
   d. Need to assess all the above ***simultaneously***, in a combined fit
      → QCD uncertainties split into independent (Hessian) components, such that they can be treated as "nuisance parameters".

3. Agreement on valid procedure(s), including technical implementation

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*In YR4*

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*Partially in YR4*

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   c. ggF with **VBF topology** ("VBF contamination")
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3. Agreement on valid procedure(s), including technical implementation

*To be further discussed in dedicated meeting.*
*(See doodle later)*

# Jet bin uncertainties and correlation

- The "main" Higgs (coupling) results are extracted in combined fits using multiple Higgs decay channels and several kinematic regions simultaneously
  - ➡ We don't just need the SM ggF uncertainty in a kinematic region, but also uncertainty correlation between different bins
  - ➡ In experimental analyses, this is typically achieved by splitting the total uncertainty into independent (Hessian) components(/sources) treated with an associated nuisance parameter in the fit
- Nice section in YR4 discusses this:
  *General treatment of theory uncertainties between kinematic bins*
- Two contributions also touch on this topic:
  - JVE @ N3LO, providing uncertainty for 0⟷1 jet migration: 0 and ≥1 jet bins
  - STWZ, BLPTW, providing uncertainties for the 0, 1 and ≥2 jet bins

| $p_T^{\rm cut} = 30$ GeV | $\sigma$/pb | $\Delta_\mu$ | $\Delta_\varphi$ | $\Delta_{\rm cut}^{0/1}$ | $\Delta_{\rm cut}^{1/2}$ | total pert. unc. |
|---|---|---|---|---|---|---|
| $\sigma_{\geq 0}$ | $47.41 \pm 2.40$ | 4.6% | 2.0% | - | - | 5.1% |
| $\sigma_0$ | $29.51 \pm 1.65$ | 3.8% | 0.1% | 4.1% | - | 5.6% |
| $\sigma_{\geq 1}$ | $17.90 \pm 1.88$ | 6.0% | 5.2% | 6.8% | - | 10.5% |
| $\sigma_1$ | $11.94 \pm 1.58$ | 5.5% | 4.8% | 8.4% | 7.2% | 13.2% |
| $\sigma_{\geq 2}$ | $5.96 \pm 1.05$ | 7.1% | 6.1% | 3.6% | 14.5% | 17.6% |

*QCD uncertainty split into 4 independent sources*

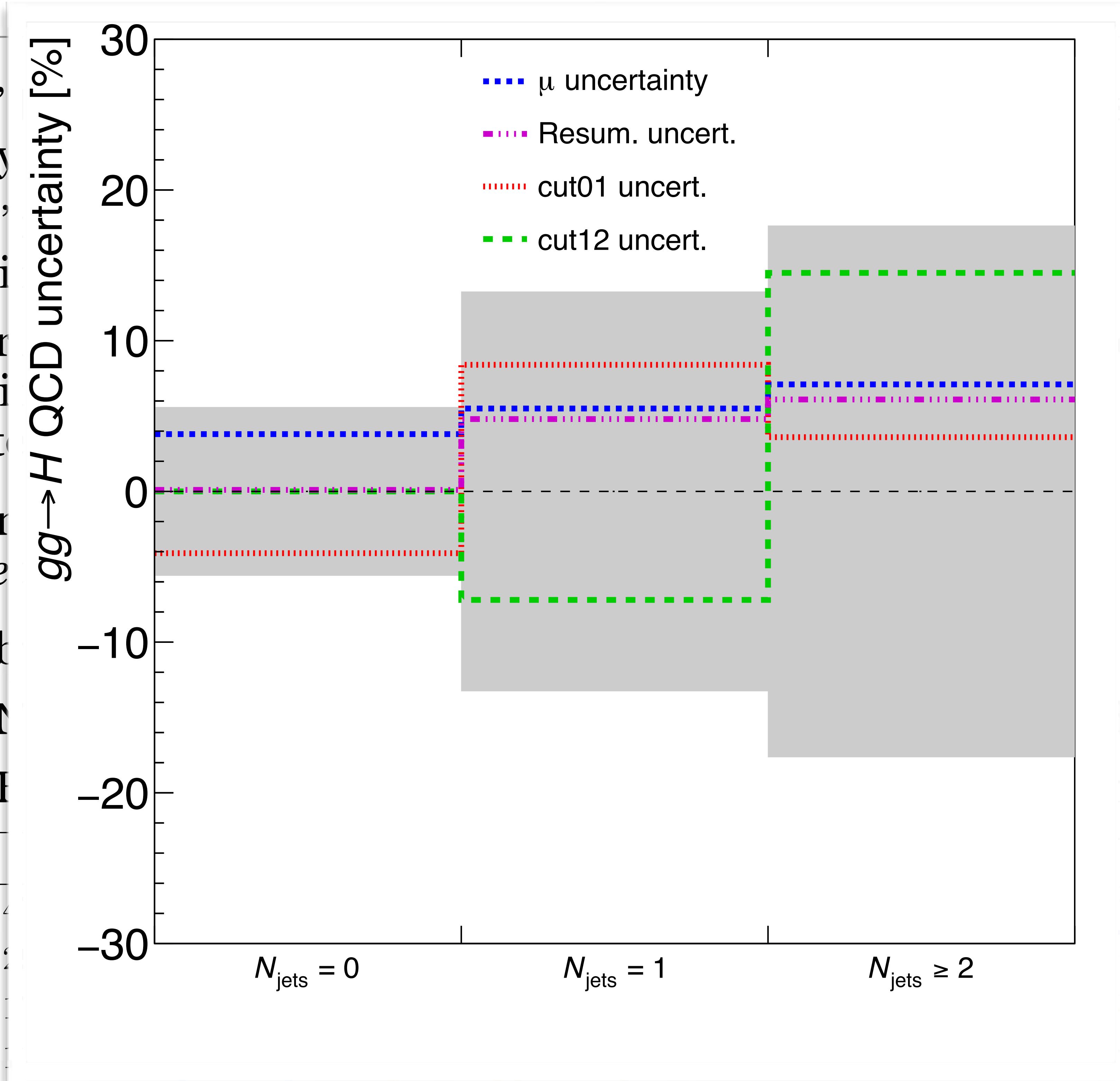
*normalization*

*resummation*

*0⟷1 jet migration*

*1⟷2 jet migration*

# Jet bin uncertainties and correlation




- The "main" … ing multiple Higgs decay…
  - ➡ We don' … but also uncertai…
  - ➡ In exper… total uncertai… eated with an associat…
- Nice sectio… *General tre…*
- Two contri…
  - JVE @ … ≥1 jet bins
  - STWZ, … s

| $p_T^{cut} = 30$ GeV | | | | | | |
|---|---|---|---|---|---|---|
| $\sigma_{\geq 0}$ | | | | | | |
| $\sigma_0$ | | | | | | |
| $\sigma_{\geq 1}$ | | | | | | |
| $\sigma_1$ | | | | | | |
| $\sigma_{\geq 2}$ | 5.96±1.05 | 7.1% | 6.1% | 3.6% | 14.5% | 17.6% |

*…inty split into 4 … sources*

*…on*

*…n*

*…ration*

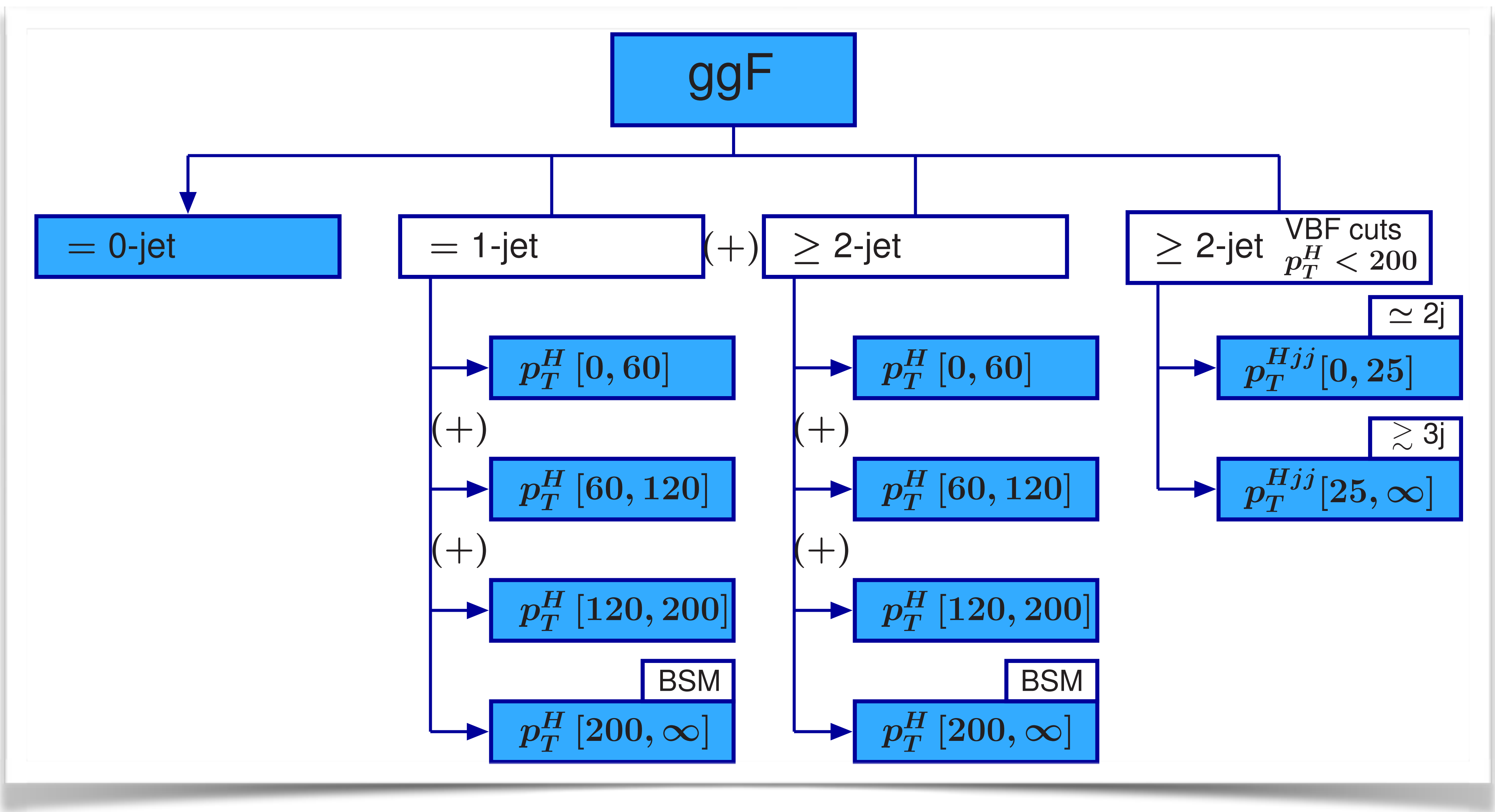
*1⟷2 jet migration*

# Requests from ATLAS+CMS 1/2

**Simplified template cross sections (STXS)**

1. Can the ggF subgroup provide theory uncertainties for the "stage 1" binning of the STXS? (see picture below)
   *Note: pT,$N_{jets}$ uncertainty correlations becomes particularly important here!*

2. Benchmarks from precision calculation of these cross sections also desired for comparison with MC predictions (normalized to the N³LO inclusive cross section)



# Requests from ATLAS+CMS 2/2

1. **Uncertainties in VBF-like regions** are becoming more relevant, could there be recommendations with the latest updates?

2. Several analyses use MVA discriminate to separate VBF from ggF, starting from all events with (at least) 2 jets. → need to assess **uncertainty** on both normalization and shape of such a **MVA discriminant**

*To be discussed further in dedicated meeting.*

*Also note: In YR3 there is recommendation, with an associated code, to evaluate uncertainty of the ggF prediction.*

# WG1 ggF meeting, to discuss ggF predictions (jets, $p_{TH}$, VBF region) and in particular QCD uncertainties

## WG1 ggF: H+jets, pT,H and VBF predictions and uncertainties

Poll initiated by Dag Gillberg | 2 | 0 | 3 days ago

Where: CERN

Meeting discussing predictions and in particular uncertainties and correlations for Higgs ggF. This includes jet bin uncertainties, and uncertainties on the Higgs pT and jet pT spectra, and uncertainties in kinematic regions with VBF topology. The technical approach to implement these uncertainties in an experimental analysis will also be discussed.

Table view

Time zone: Zurich change

| | November 2016 Tue 1 | Tue 15 | Thu 17 | Fri 18 | Tue 22 | Thu 24 | Fri 25 |
|---|---|---|---|---|---|---|---|
| **2 participants** | 2:00 PM – 5:00 PM | 2:00 PM – 5:00 PM | 2:00 PM – 5:00 PM | 2:00 PM – 5:00 PM | 2:00 PM – 5:00 PM | 2:00 PM – 5:00 PM | 2:00 PM – 5:00 PM |

**Please fill in doodle if you wish to attend:**
**http://doodle.com/poll/xbcnrxbrf5ux6pxh**

*Backup*

# Benchmark comparison from YR4, jet $p_T$