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# Distinguishing VBF from gluon-gluon fusion

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## In collaboration with:

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arXiv: 1506.01016

# H+jets in gluon-gluon fusion

- NLO study of the dominant Higgs production channel in association with up to 3 jets

Motivated by:

- GGF is large irreducible background to Higgs production in VBF
- Precise knowledge of GGF-channel crucial to estimate contamination in VBF sample
- When applying vetoes to jets
  - H+jets cross section needed to estimate uncertainties in efficiencies

Possible thanks to important developments which lead to previous computations of H+2, 3 jets at NLO [v. Deurzen et al.; Cullen et al.]

- Higher rank extension/ Samurai / Ninja / Golem95 / GoSam-2.0

[Cullen, v. Deurzen, Greiner, Heinrich, Mastrolia, Mirabella, Ossola, Peraro, Schlenk, v. Soden-Fraunhofen, Tramontano]

# Calculational setup

- Amplitudes computed with GoSam+Sherpa and BLHA
  - Virtual amplitudes: GoSam with Ninja [Mastrolia, Mirabella, Peraro; v. Deurzen et al.; Peraro]
  - Tree amplitudes and integration: Sherpa with Comix [Gleisberg, Höche]

- Phenomenological analysis via generation of ROOT Ntuple files:
  - Events for: H+1 jet / H+2 jets / H+3 jets ⟶ **~ 4 TB**

✓ Available both for 8 and 13 TeV

✓ For kt/anti-kt algorithm and R=0.1, … , 1.0

✓ Allow for fast analysis, change of **scale, pdf, cuts, jet-tagging**

# Calculational setup

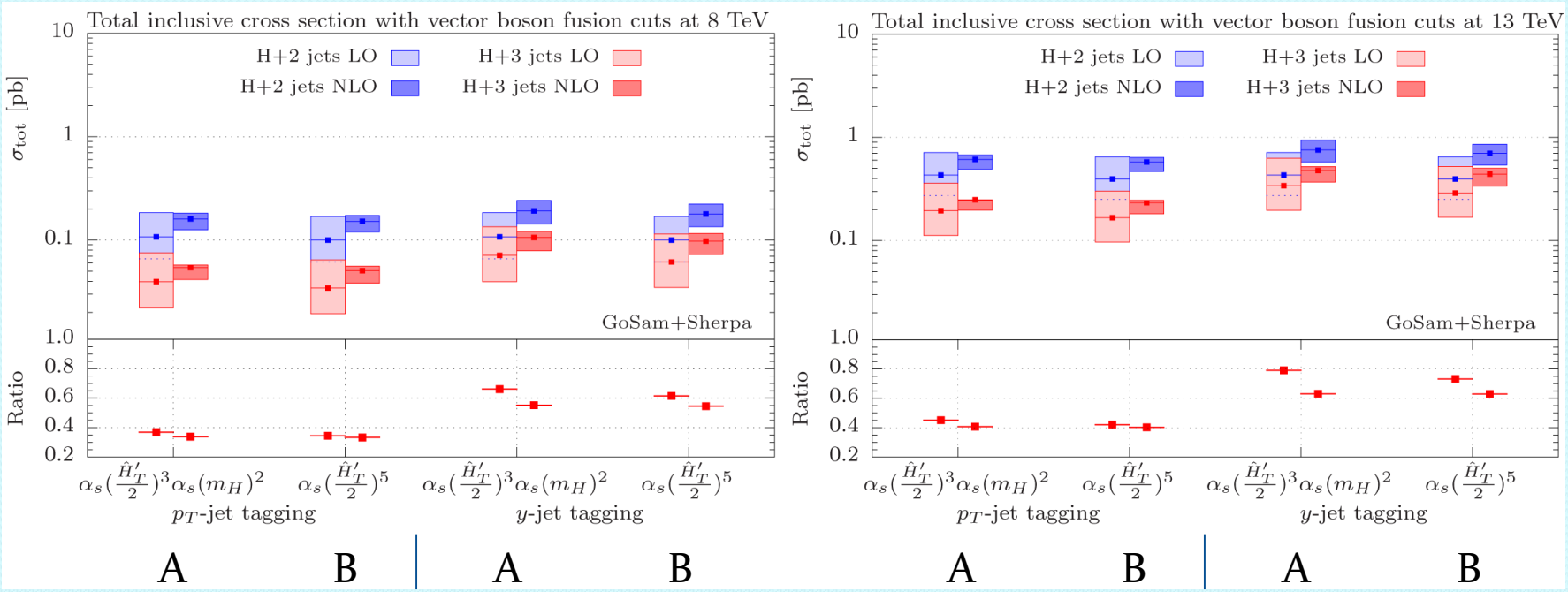
- Setup and cuts
  - 3 scale choices: $\mu_F = \mu_R = \frac{\hat{H}'_T}{2} = \frac{1}{2}\left(\sqrt{m_{\rm H}^2 + p_{T,\rm H}^2} + \sum_i |p_{T,i}|\right)$

    A: $\alpha_{\rm s}\left(x \cdot \frac{\hat{H}'_T}{2}\right)^3 \alpha_{\rm s}\left(x \cdot m_{\rm H}\right)^2$

    B: $\alpha_{\rm s}\left(x \cdot \frac{\hat{H}'_T}{2}\right)^5$ Default

    C: $\alpha_{\rm s}\left(x \cdot m_{\rm H}\right)^5$
  - PDFs: CT10nlo
  - **Baseline cuts:** anti-kt with $p_T > 30\ \text{GeV}, \quad |\eta| < 4.4$
  - **Additional VBF cuts**: $m_{j_1 j_2} > 400\ \text{GeV}, \quad |\Delta y_{j_1, j_2}| > 2.8$

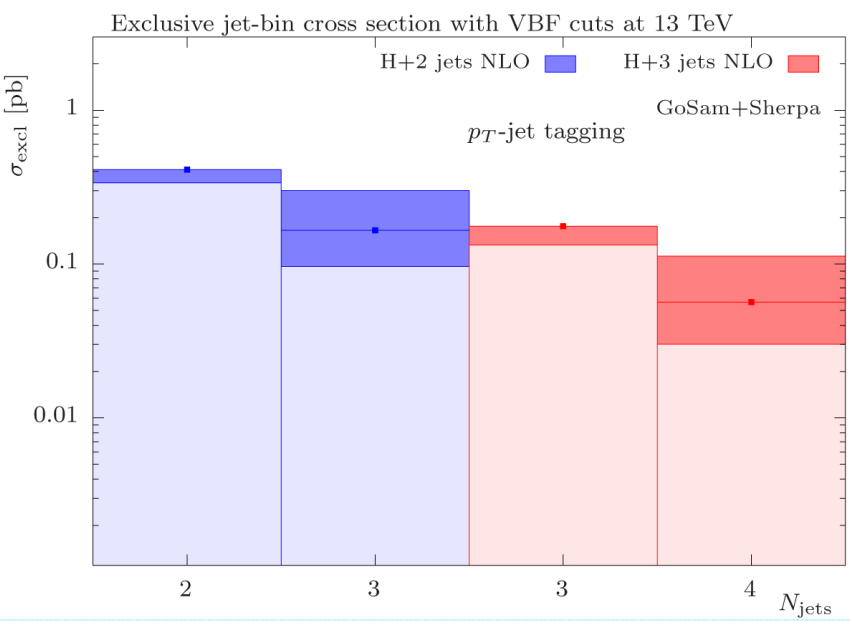
# VBF cut results: Total XS

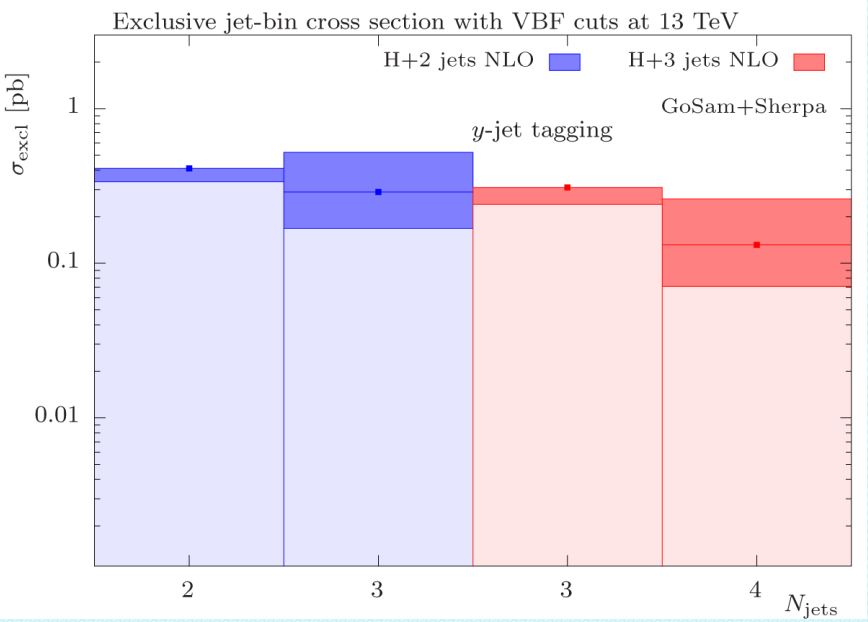



- Energy, scale and jet-tagging method dependence:
  - For $p_T$-tagging inclusive H+3j/H+2j ratios similar at LO & NLO
  - y-tagging increases H+3j contribution

$p_T$-tagging: consider 2 leading pt jets
y-tagging: consider 2 most forward/backward jets

# VBF cut results: Exclusive jet bins




- VBF cuts enhance real radiation contribution
  - y-tagging increases the realtive importance even more
- larger portion of total XS described with LO accuracy

➢ H+3 NLO for accurate 3 jet prediction and exclusive H+2j XS

# VBF cut results: distributions

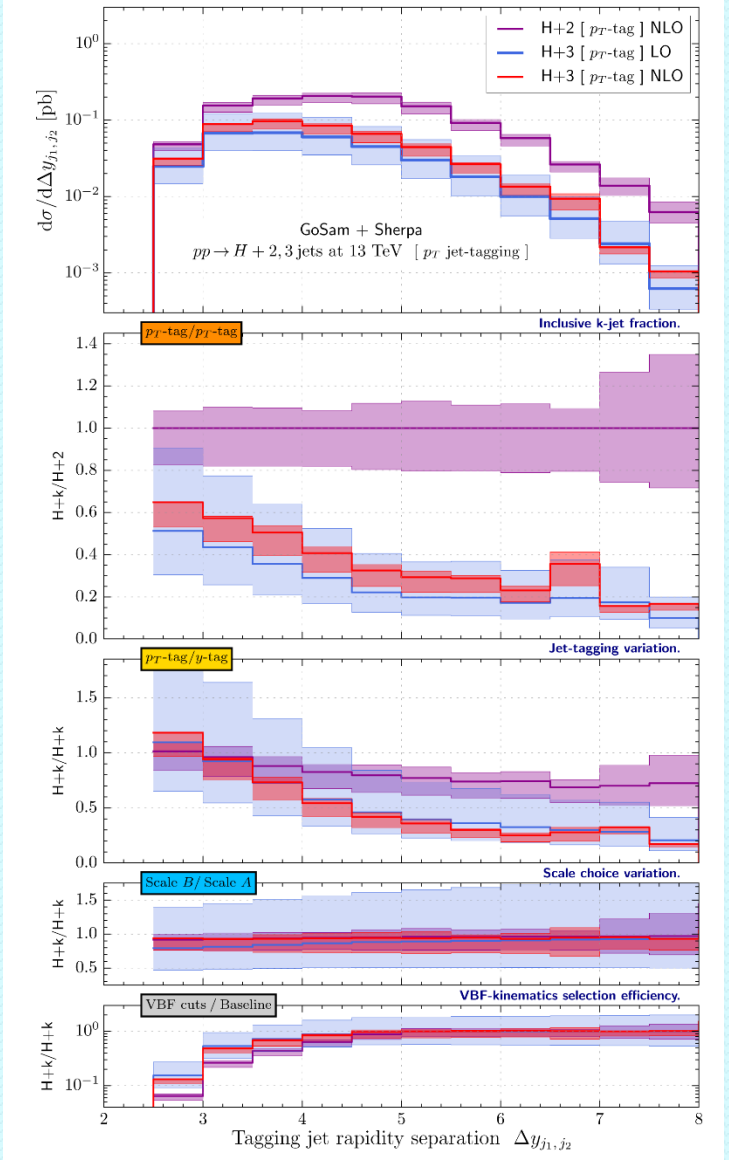
- Experimentally discrimination of VBF compatibles events from GGF typically done via BDTs
  - Relevant observables are:

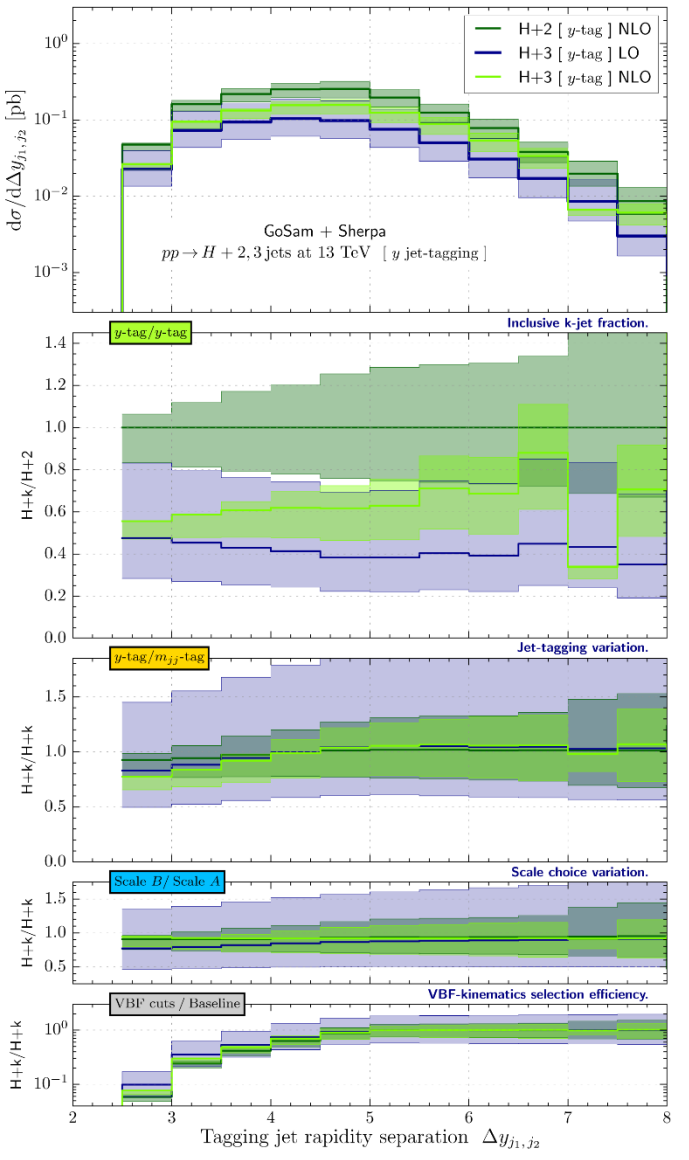
$$m_{j_1,j_2},\ \Delta y_{j_1,j_2},\ p_{T,j_1},\ p_{T,j_2},\ \Delta\phi_{\mathrm{H},j_1j_2},\ldots$$

  - Analyse contribution of H+2j and H+3j at 13 TeV for $p_T$-tagging, y-tagging and $m_{jj}$-tagging

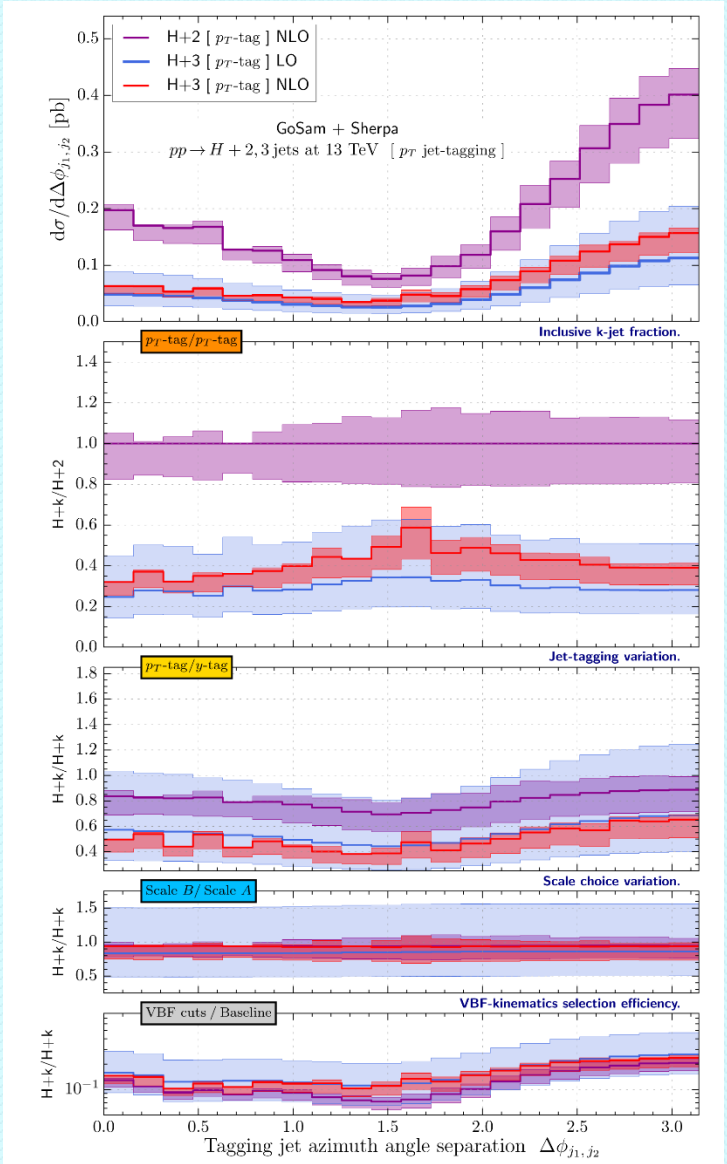
    (8 TeV analysis can be done with available Ntuples set).

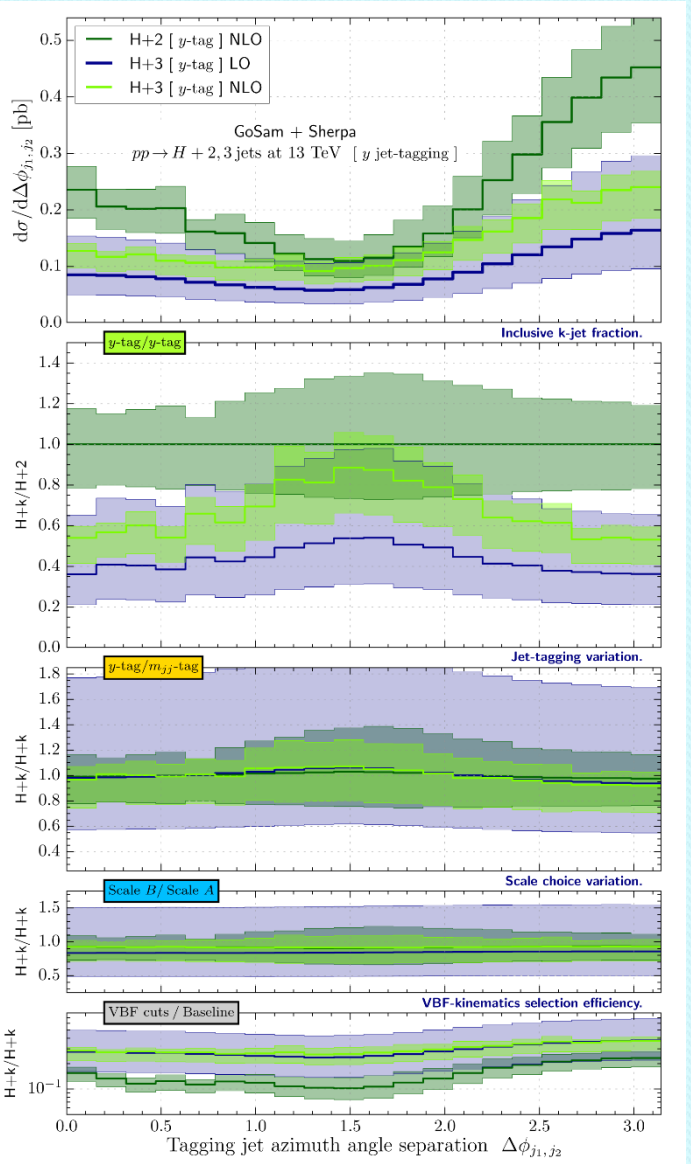
# VBF cut results: $\Delta y_{j_1,j_2}$



# VBF cut results: $\Delta\phi_{j_1,j_2}$



# Conclusions & Outlook

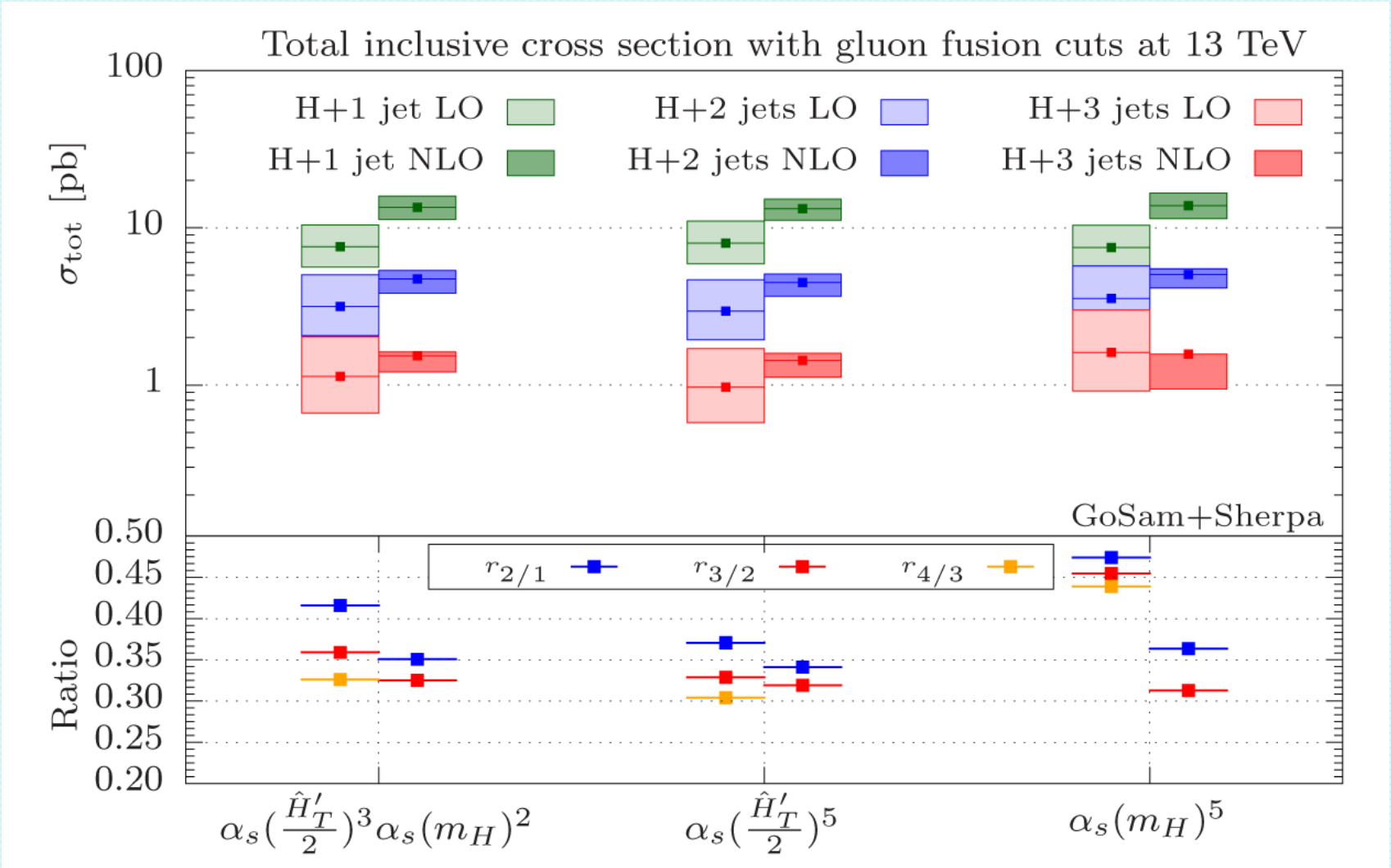
- H + up to 3 jets @ NLO in gluon-gluon fusion
  - Parton level results available in terms of ROOT NTuples
  - Baseline cuts allow for interesting studies of QCD in GGF
  - NLO corrections relevant both for GGF and for VBF:
    - Reduction of uncertainties / modification of shapes
  - Only a small subset of the analysed observables shown here, more results can be found in arXiv: 1506.01016

➢ Work in progress

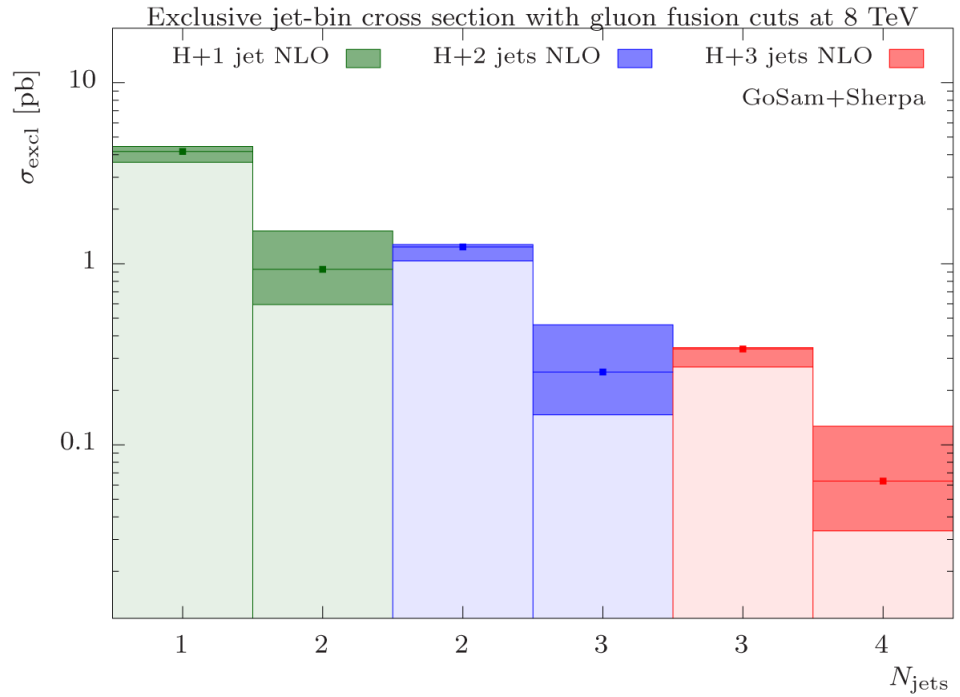
  - ➢ Release code and NTuples files
  - ➢ Merging of multiplicities at NLO and matching to parton shower
  - ➢ Ongoing LH2015 study to compare with other predictions

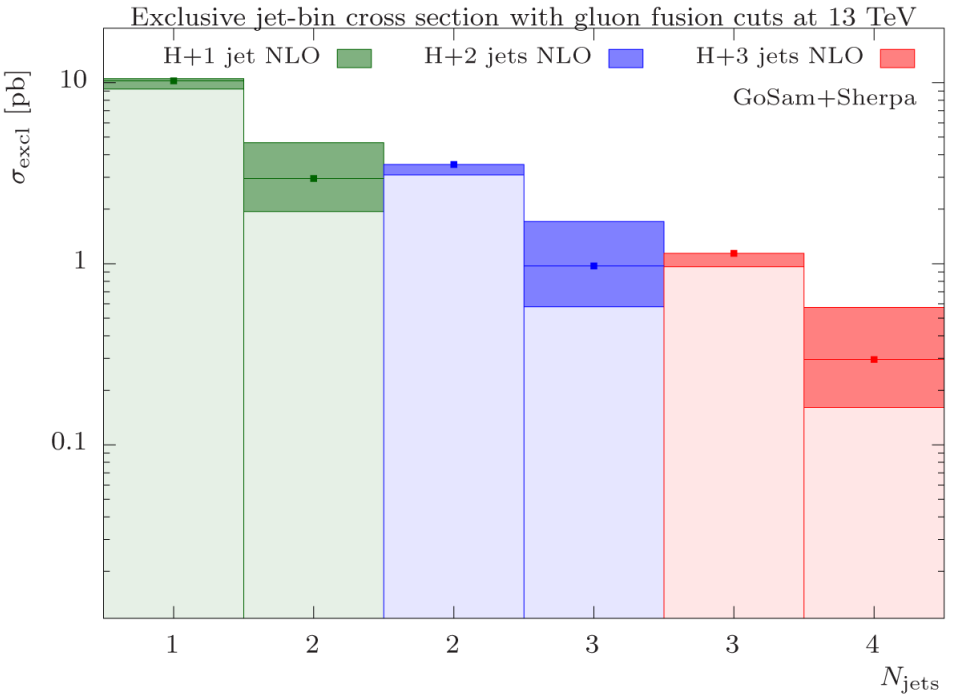
# Backup slide

# GGF total cross section



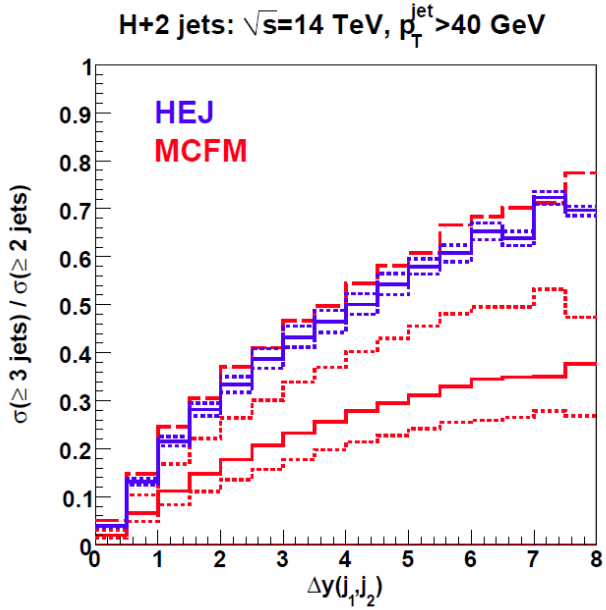
# GGF exclusive jet bins



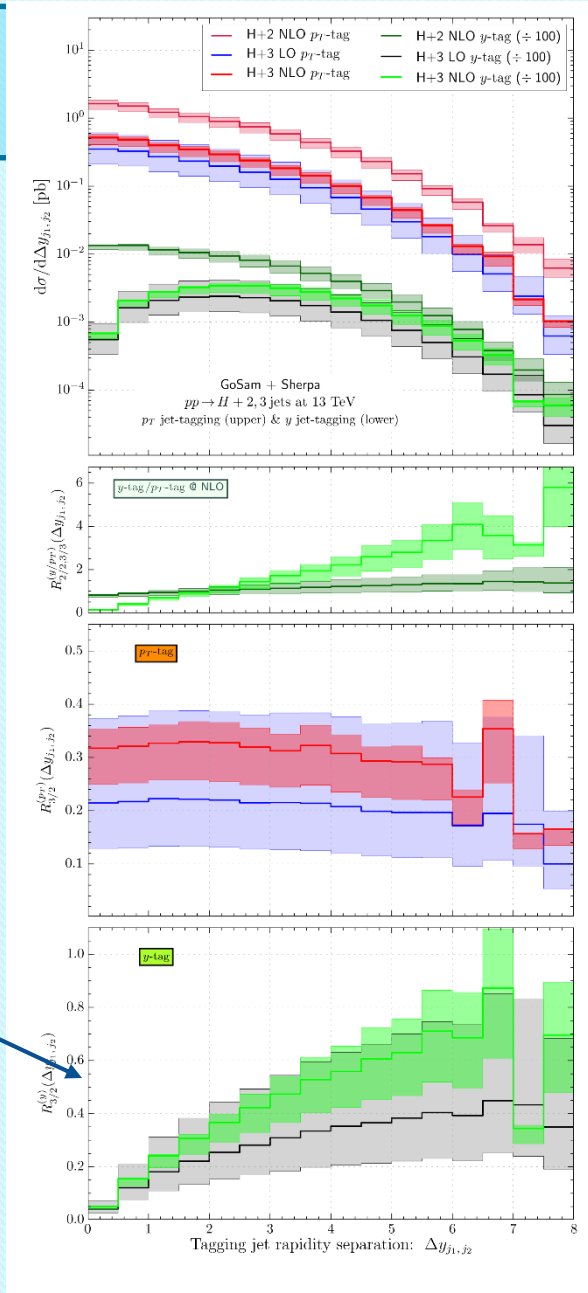
# GGF results: $\Delta y_{j_1,j_2}$

- y-tagging also to investigate universal QCD properties in high-energy limit
  - How much can NLO computation describe high-energy effects




[Andersen, Smillie] [Campbell, Ellis, Williams]

[Report of the Snowmass 2013 energy frontier QCD working group, 1310.5189 ]



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