$t\bar{t}b\bar{b}$ 4F with Powheg+OpenLoops

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In collaboration with:
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Meeting of the LHC Higgs WG1
ttH/tH subgroup
July ~~5~~th
6

Universität
Zürich[UZH]

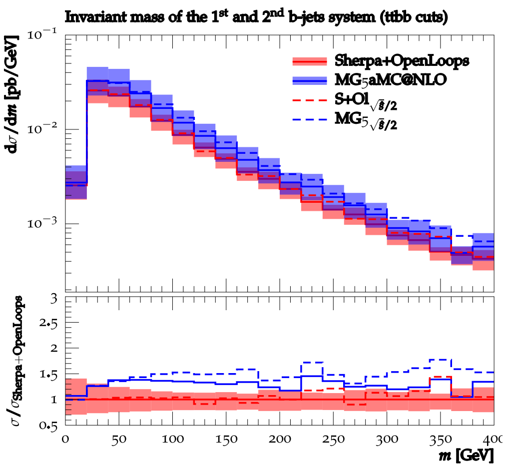
Outline and goal

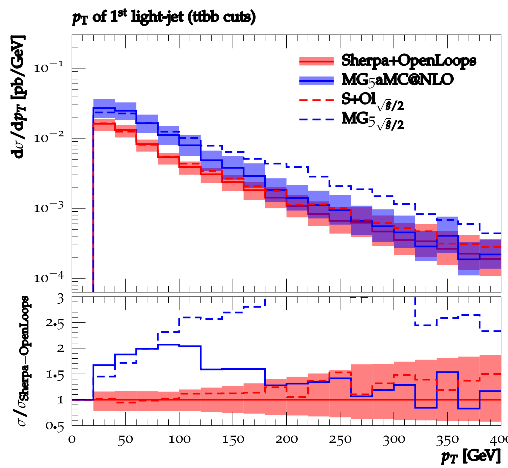
- We perform NLO+PS matching of $pp \to t\bar{t}b\bar{b}$ with the POWHEG method
  - Using 4 flavour number scheme
    - b-quark mass effects included
    - makes the full $t\bar{t}b$-jet phase space available
  - Employing the brand new `POWHEG BOX RES` [T.J., Nason 2015]
    - allows the choice of the most suitable FKS mapping
- Here I present a progress update
  - Comaprison against `Sherpa+OpenLoops` [Cascioli et al. 2013]
  - A study of `hdamp` dependence

Motivations

Dependence on resummation scale μ_Q

Stefano's talk





Nominal MG5_aMC and Sherpa+OpenLoops predictions in YR4

- MG5_aMC supports only* $\mu_Q = f(\xi)\sqrt{\hat{s}}$ $\Rightarrow$ smearing function restricted to $0.1 < f(\xi) < 0.25$ to mimic recommended $\mu_Q = H_T/2$ implemented in Sherpa

μ_Q variations enhance the discrepancy

- $\mu_Q = \sqrt{\hat{s}}/2$ in Sherpa to mimic MG5_aMC default choice $0.1 < f(\xi) < 1$
- strong μ_Q-sensitivity of MG5_aMC $\Rightarrow$ much more pronounced deviations

* Ongoing studies with new MG5 version supporting $\mu_Q = H_T/2$. See talk by C. Neu.

POWHEG BOX RES

- POWHEG BOX RES [T.J., Nason 2015]
  - Implements "resonance aware" NLO+PS matching providing the means of
    - choosing a FKS mapping appropriate to the matrix element
    - separating the calculation into regions in which the above is possible
  - Features a new interface with OpenLoops at a very advanced level of automation [T.J., Lindert, Nason, Oleari, Pozzorini 2016]
- Processes matched to PS using POWHEG BOX RES:
  - $pp \to \mu^+ \nu_\mu j_b j$
  - $pp \to \ell^+ \nu_\ell l^- \bar{\nu}_l b \bar{b}$
  - HV and HV+jet (QCD+EW)
- Improvements towards 4F $t\bar{t}b\bar{b}$ @ NLO+PS in POWHEG BOX RES[†]:
  - hdamp for massive final state emitters
  - Partial unweighting, Rivet interface, ...

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† RES features not used in the indended way

Setup

- LHC 13 TeV
- 4F scheme
- NNPDF30_nlo_as_0118_nf_4
- α_S from 4F PDFs
- $m_t = 172.5$ GeV, $m_b = 4.75$ GeV
- $\mu_r = \mu_f = \sqrt{0.5\sqrt{E_T^b E_T^{\bar{b}}}\sqrt{E_T^t E_T^{\bar{t}}}}$
- Top decay off, MPI off, Hadronization off, QED shower off
- `Sherpa`
  - $\mu_Q = H_T/2$
  - Default shower settings
- `POWHEG BOX RES`
  - `hdamp` $= 1.5 m_t$
  - Pythia 8.2 with `PowhegHooks`, A14 tune

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improves perturbative convergence

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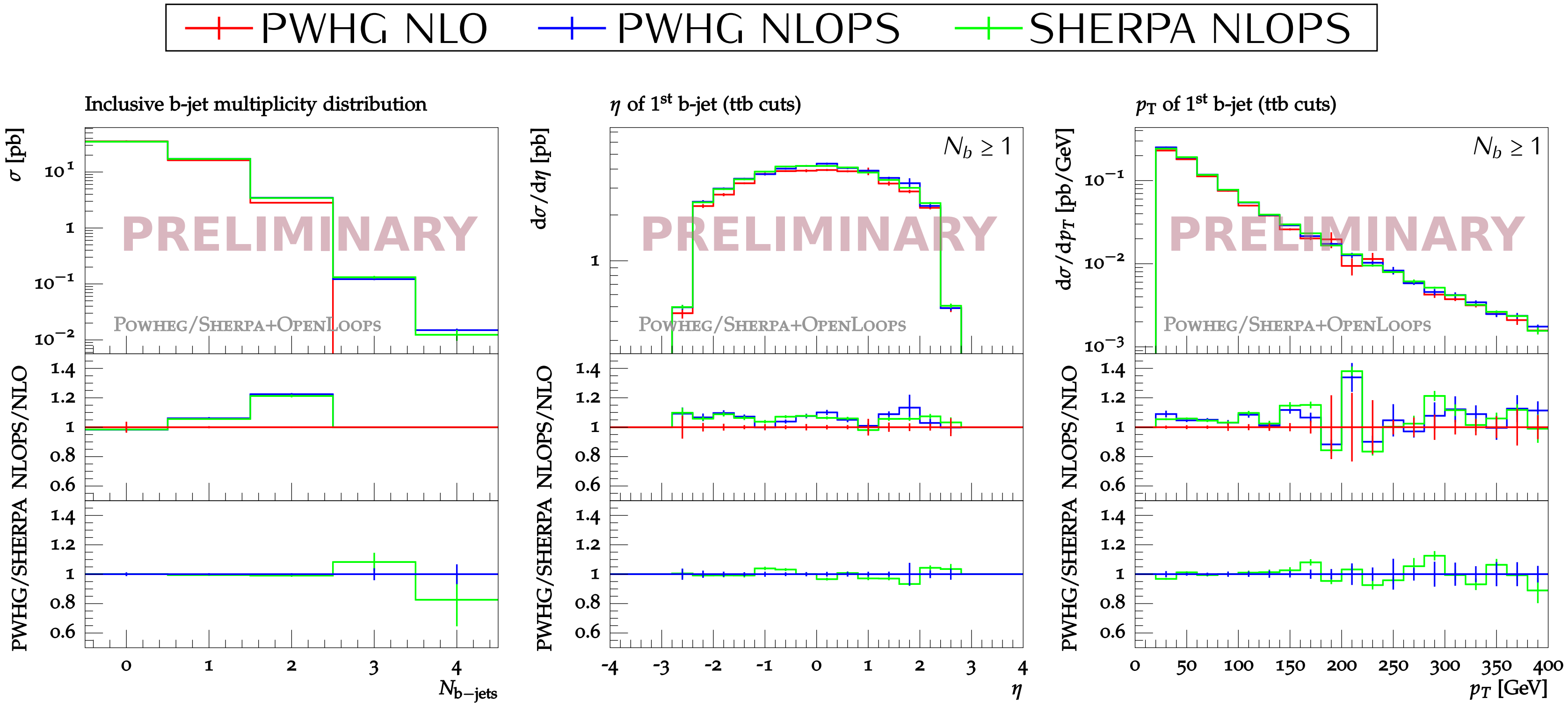
POWHEG BOX RES vs SHERPA



- Remarkable agreement for NLO accurate ttb observables
  - Agreement well under 5%; expected scale uncertainity ~20%
- Good agreement also in LOPS accurate bins 3 and 4 of $\sigma(N_{b\text{-jets}})$

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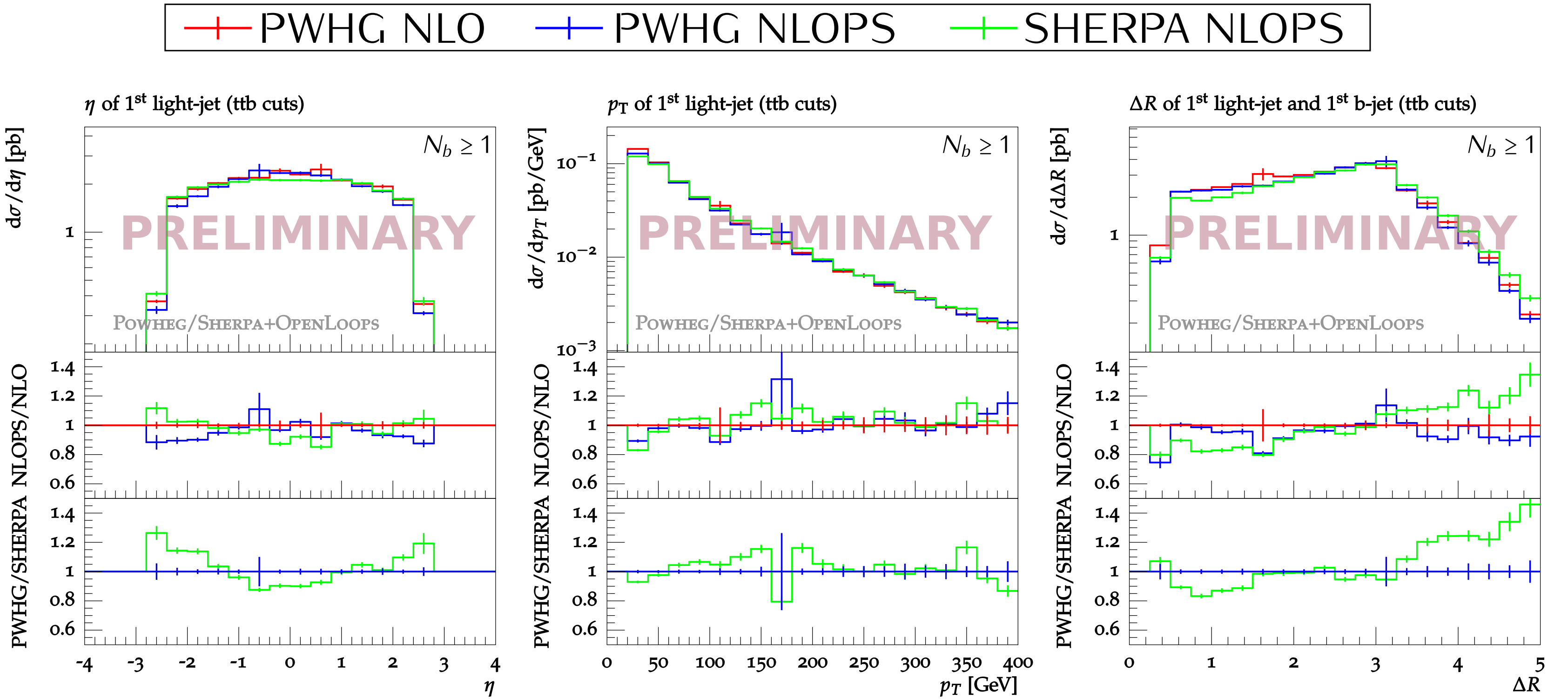

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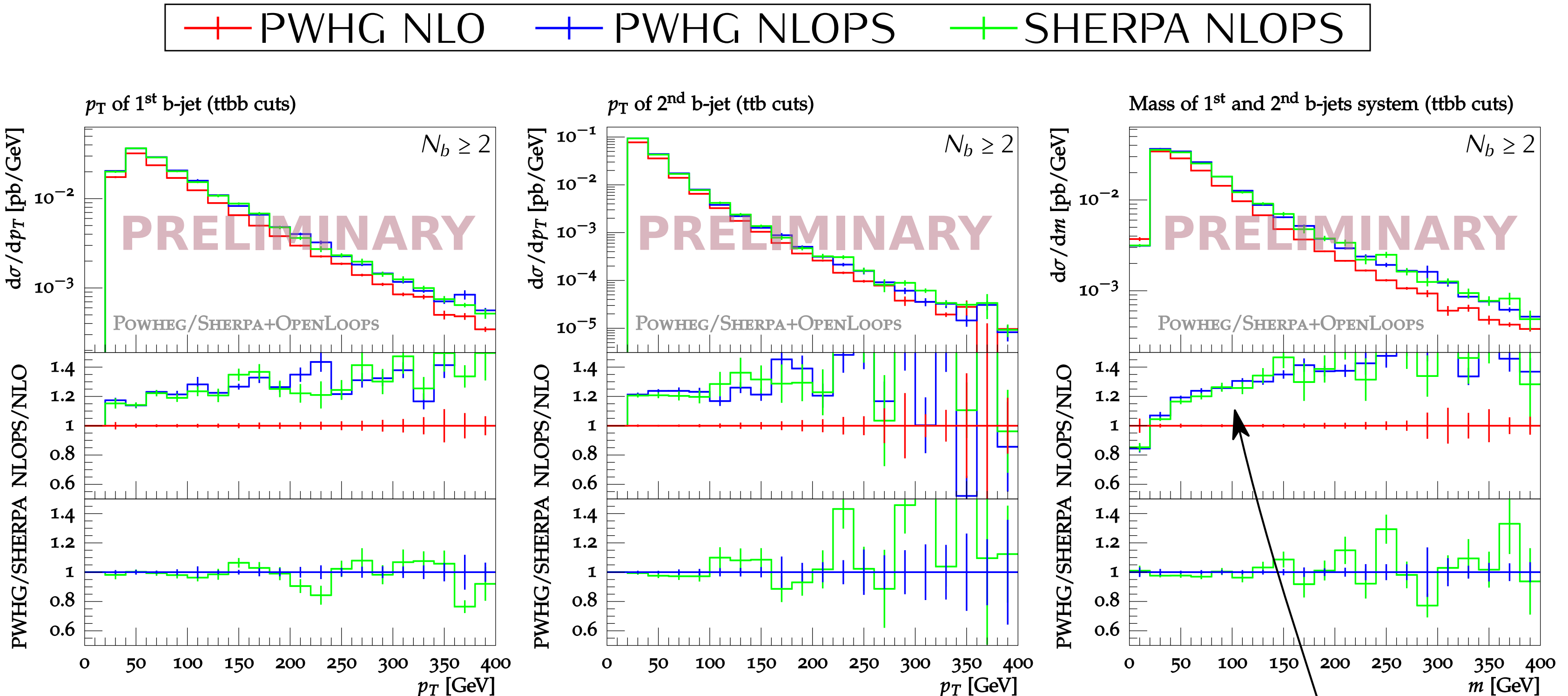

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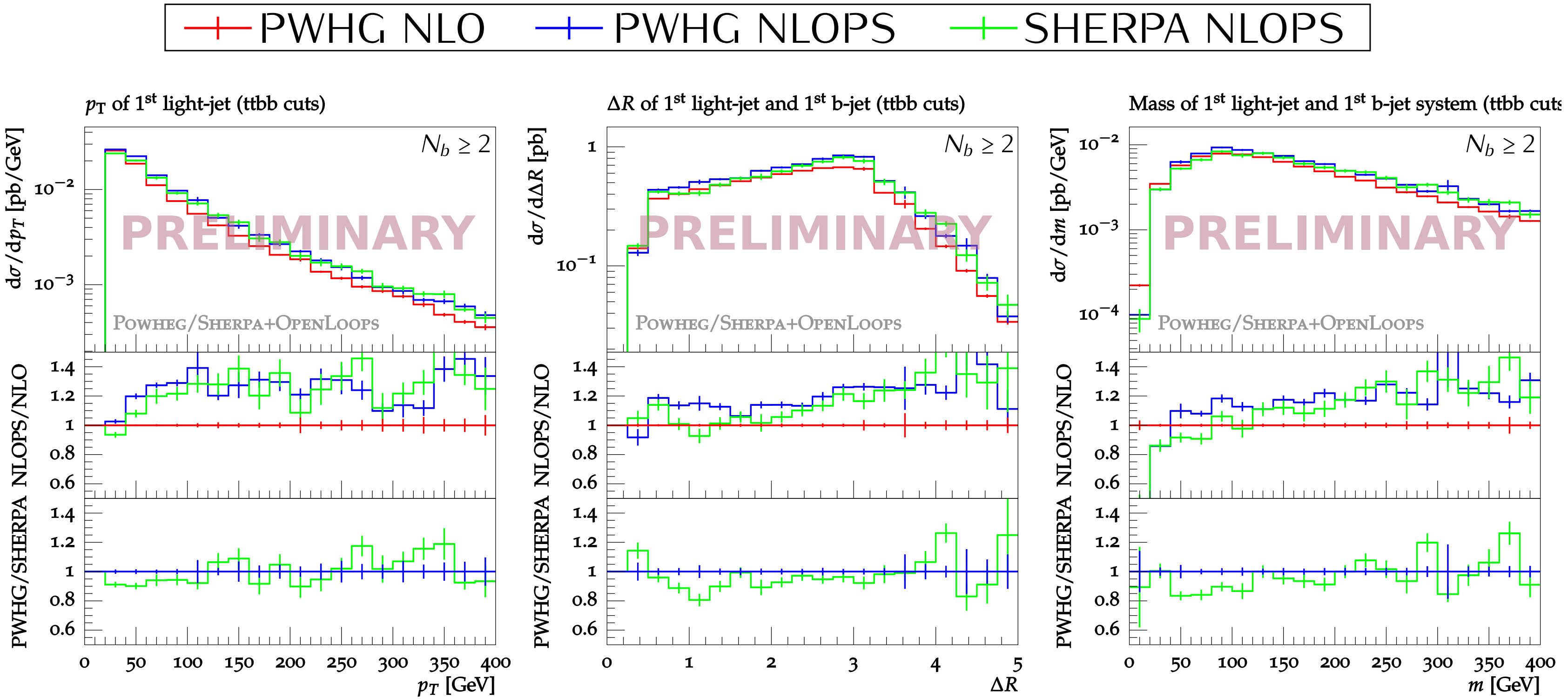

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`hdamp`

- POWHEG radiation formula:

$$\mathrm{d}\,\sigma = \overline{B}(\Phi_B)\,\mathrm{d}\,\Phi_B\left[\Delta(q_{\mathrm{cut}}) + \sum_\alpha \Delta(k_T^\alpha)\frac{R_\alpha^s(\Phi_\alpha(\Phi_B,\Phi_{\mathrm{rad}}))}{B(\Phi_B)}\,\mathrm{d}\,\Phi_{\mathrm{rad}}\right] + (R_\alpha^r \mathrm{contr.})$$

  - where $R_\alpha = R_\alpha^s + R_\alpha^r$
- Separation of the real contribution introduced to deal with "Born zeroes"
  - `if ( r0.gt.5*abs(rc+rs-rcs) ) then` ... R_α^r
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- More sophisticated separation introduced in the present form:

$$R_\alpha^s = R_\alpha F(k_T^2)\,, \qquad R_\alpha^r = R_\alpha\left[1 - F(k_T^2)\right]\,, \qquad F(k_T^2) = \frac{h^2}{k_T^2 + h^2}$$

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  maybe be thought of as an analogue to μ_Q in `MC@NLO`
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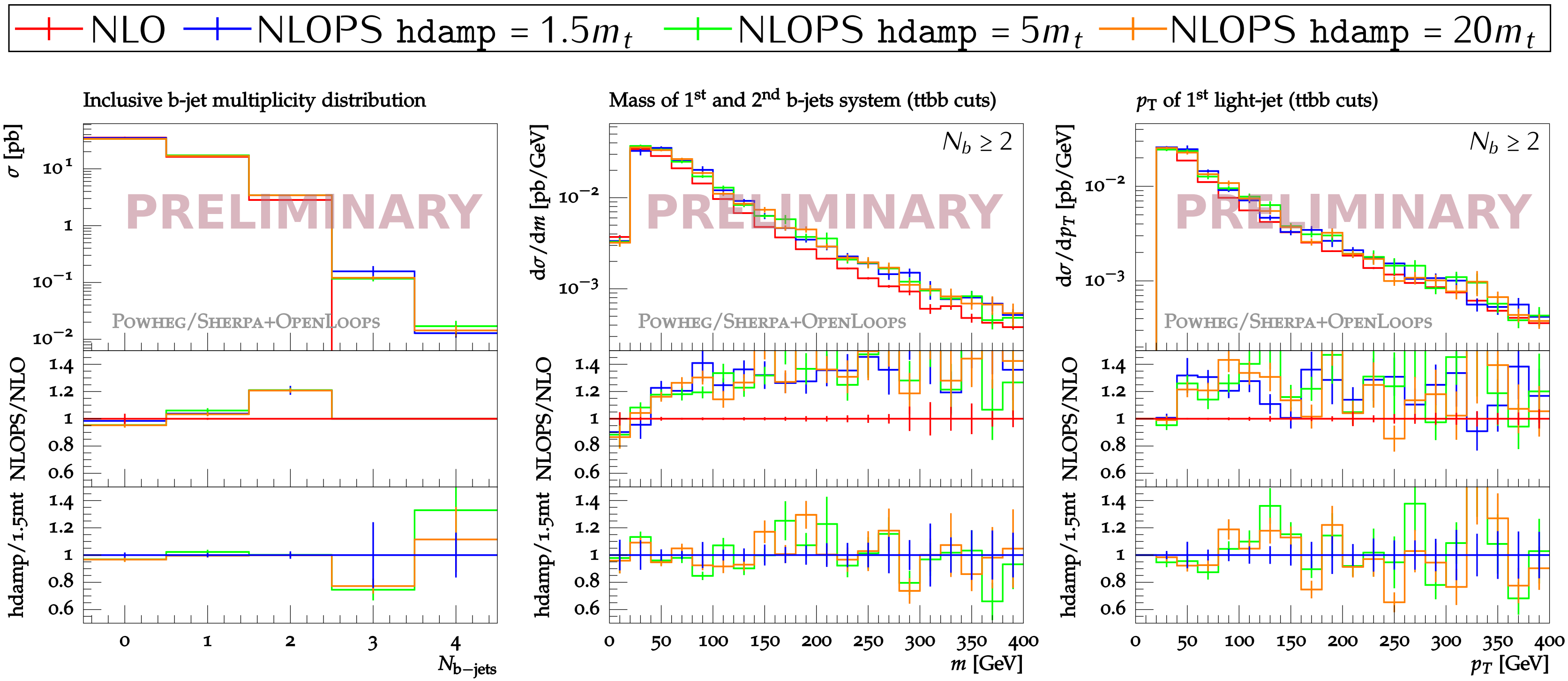
- In $t\bar{t}b\bar{b}$:
  - Default behaviour of `hdamp` needs modifying:
    - Default "`hdamp` applied only to IS" manifests convergence issues
    - We apply `hdamp` also to massive FS, with $\texttt{hdamp}_{\mathrm{IS}}$ and $\texttt{hdamp}_{\mathrm{FS}}$ independent
    - Further investigation underway
    - New `POWHEG BOX RES` features could be exploited for better understanding of the `hdamp` dependence

hdamp dependence



- hdamp applied also to final state massive emitters
- Both NLO and LOPS accurate observables very stable with respect to hdamp
  - Variations of at most 10% are observed

Summary

- Use POWHEG BOX RES framework to match 4F $t\bar{t}b\bar{b}$ at NLO QCD with PS
  - Matrix elements obtained from OpenLoops using the new OpenLoops+POWHEG BOX RES interface
  - The default hdamp behaviour extended in order to account for final state b-jets
  - Showered with Pythia8.2
- Compare our first results against Sherpa+OpenLoops
  - We observe a very good agreement
  - POWHEG BOX RES+OpenLoops confirms the “double splitting” enhancement
  - Comparison with YR benchmarks soon
- Study hdamp dependence
  - Predictions show very good stability with respect to hdamp variations
  - Further investigation under way

hdamp

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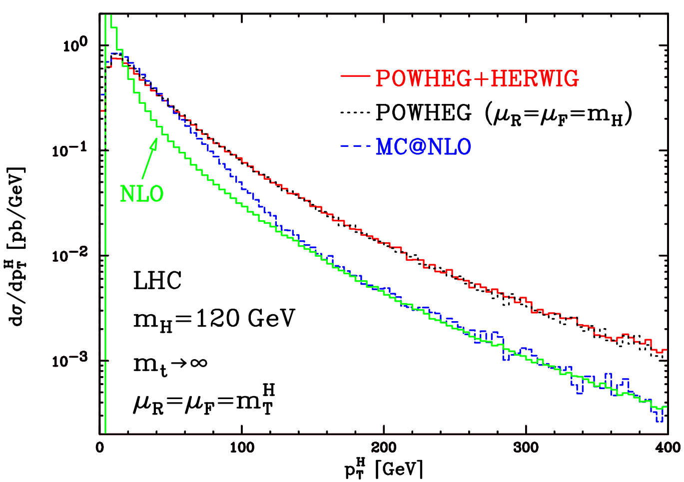
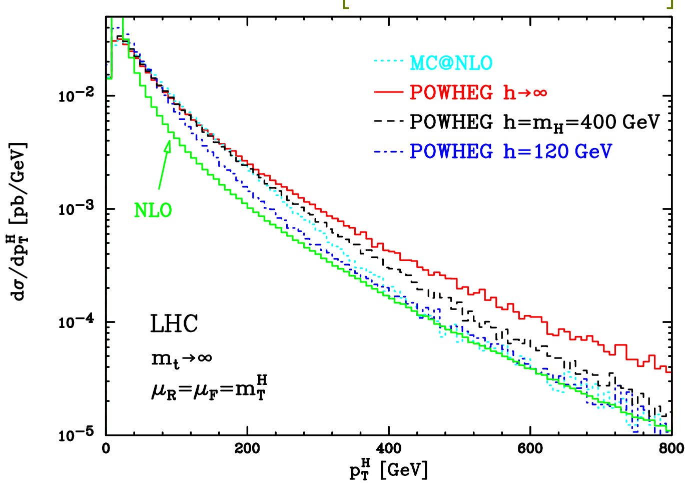
- In Higgs production:

[arXiv:0812.0578]





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