tW production in $t\bar{t}$ phase space

Tomáš Ježo

SFB TRR 257
Institute for Theoretical Physics, KIT

In collaboration with S. Ferrario Ravasio, M. Mangano, P. Nason

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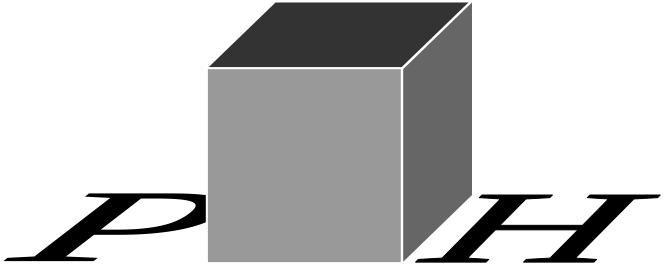


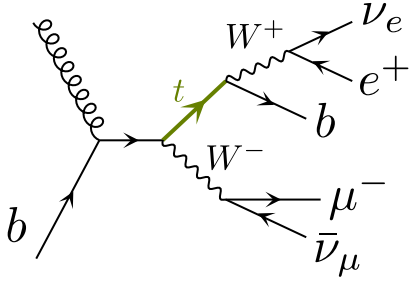
Outline

- Interplay of tW and $t\bar{t}$ production
  - 5FNS NLO tW production and its interference with $t\bar{t}$
  - Unified description for tW & $t\bar{t}$ in 4FNS
- NLOPS event generators for tW and $t\bar{t}$ in `POWHEG BOX`
  - tW: `ST_wtch` NLO tW with Diag. Removal (DR) and Diag. Subtraction (DS)
  - $t\bar{t}$: `hvq` NLO $t\bar{t}$
  - $tW + t\bar{t}$:
    - `ttb_NLO_dec`: NLO $t\bar{t}$, tW added through LO reweighting
    - `b_bbar_4l`: $t\bar{t}$, tW and tW-$t\bar{t}$ interference at NLO
- Compare predictions for observables with two b jets: $m(W^+W^-j_bj_b)$, $m(l^+l^-j_bj_b)$, $\Delta y(l^+j_b, l^-j_b)$

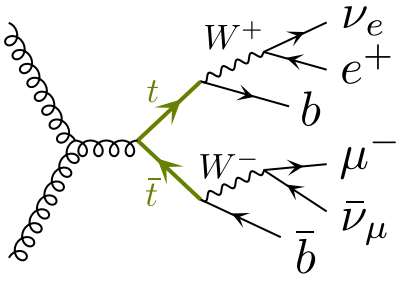
Interplay of tW and $t\bar{t}$ production

5FNS

tW associated production @ LO



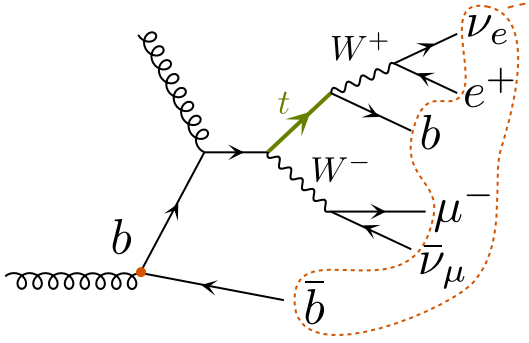
$t\bar{t}$ production @ LO



Interplay of tW and $t\bar{t}$ production

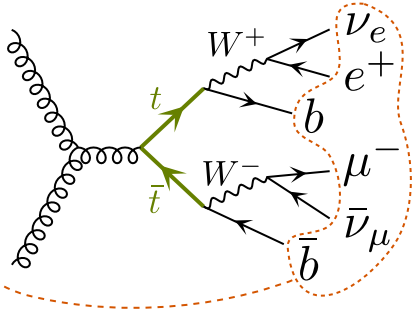
5FNS

tW associated production @ NLO



same final state!

$t\bar{t}$ production @ LO

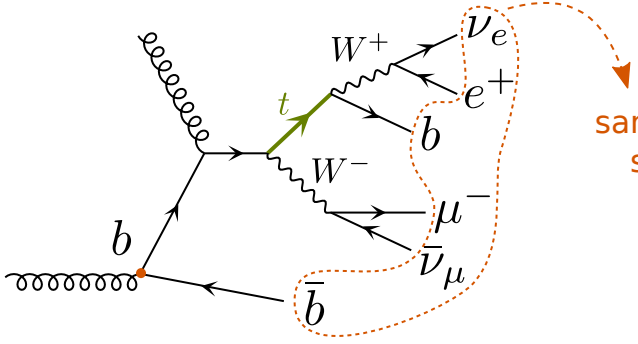


- tW and $t\bar{t}$ interfere!

Interplay of tW and $t\bar{t}$ production

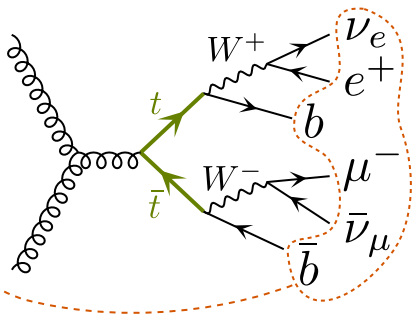
5FNS

tW associated production @ NLO



same final state!

$t\bar{t}$ production @ LO



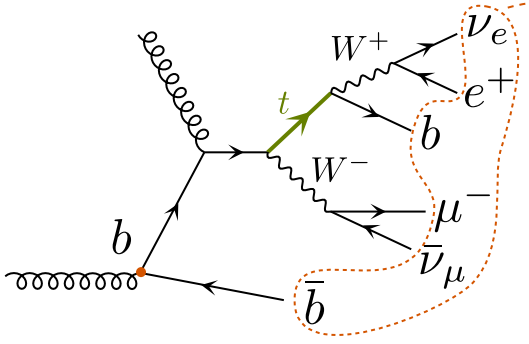
- tW and $t\bar{t}$ interfere!
  - Problems for tW:
    - Perturbative convergence of tW "spoiled" ($\sigma_{tW} \sim 0.1\sigma_{t\bar{t}}$)
    - $t\bar{t}$ removed using: Diag. Removal (DR) or Diag. Subtraction (DS)

$$\mathcal{M} = \mathcal{M}^{tW} + \mathcal{M}^{t\bar{t}} \qquad \mathcal{R}^{\mathrm{DR}} = \frac{|\mathcal{M}^{tW}|^2}{2s} \qquad \mathcal{R}^{\mathrm{DS}} = \frac{|\mathcal{M}^{tW}+\mathcal{M}^{t\bar{t}}|^2 - \mathcal{C}}{2s} \qquad \mathcal{C} = \frac{(m_t\Gamma_t)^2}{((k_b+k_W)^2-m_t^2)^2+(m_t\Gamma_t)^2}|\mathcal{M}^{t\bar{t}}|$$

Interplay of tW and $t\bar{t}$ production

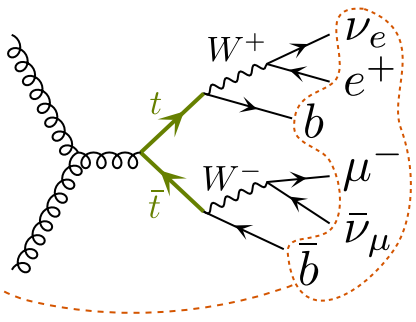
5FNS

tW associated production @ NLO



same final state!

$t\bar{t}$ production @ LO

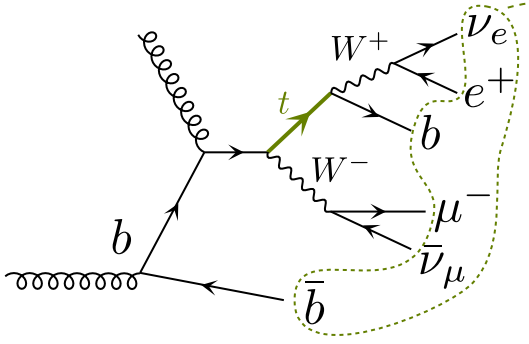


- tW and $t\bar{t}$ interfere!
  - Problems for $t\bar{t}$:
    - tW and tW-$t\bar{t}$ interference irreducible background to $t\bar{t}$

Interplay of tW and $t\bar{t}$ production

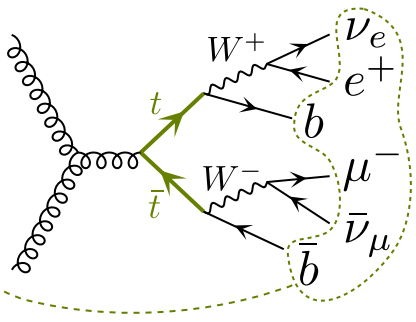
4FNS

tW associated production @ LO



same final state!

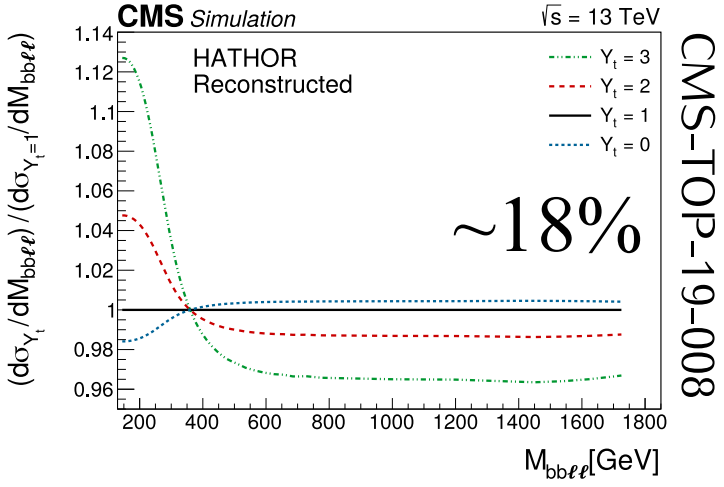
$t\bar{t}$ production @ LO

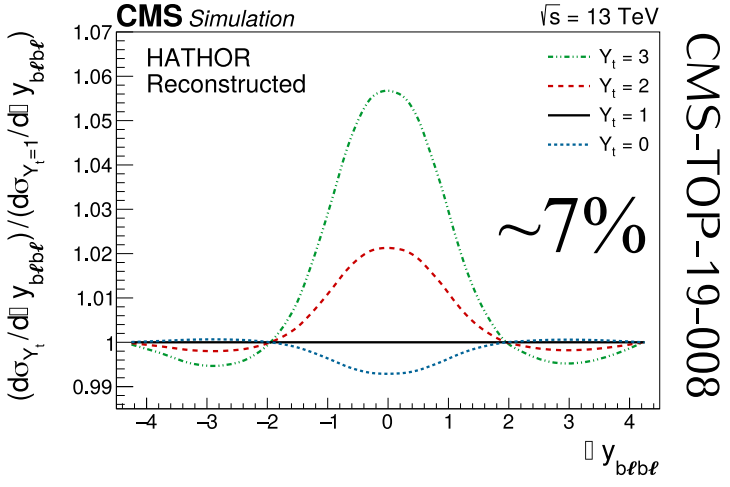


- tW and $t\bar{t}$ interfere!
  - Solution: tW and $t\bar{t}$ included simultaneously using $W^+W^-b\bar{b}$ amplitudes in 4FNS

Event generator available: `b_bbar_4l`.

Goal





- We want to compare the sizes of two effects:
  - shape effects of Y_t variations
  - shape effects of non-resonant, interference and finite-width effects
    - non-resonant: tW and other non-resonant contributions
    - interference: $t\bar{t} - tW$ interference
    - finite width: top width effects in $t\bar{t}$ topologies

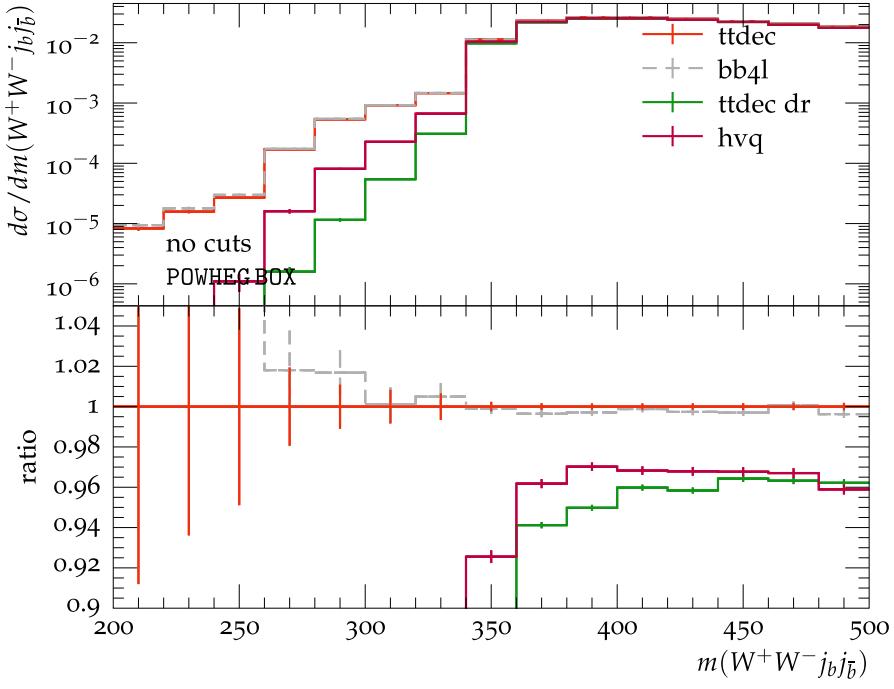
Event generators

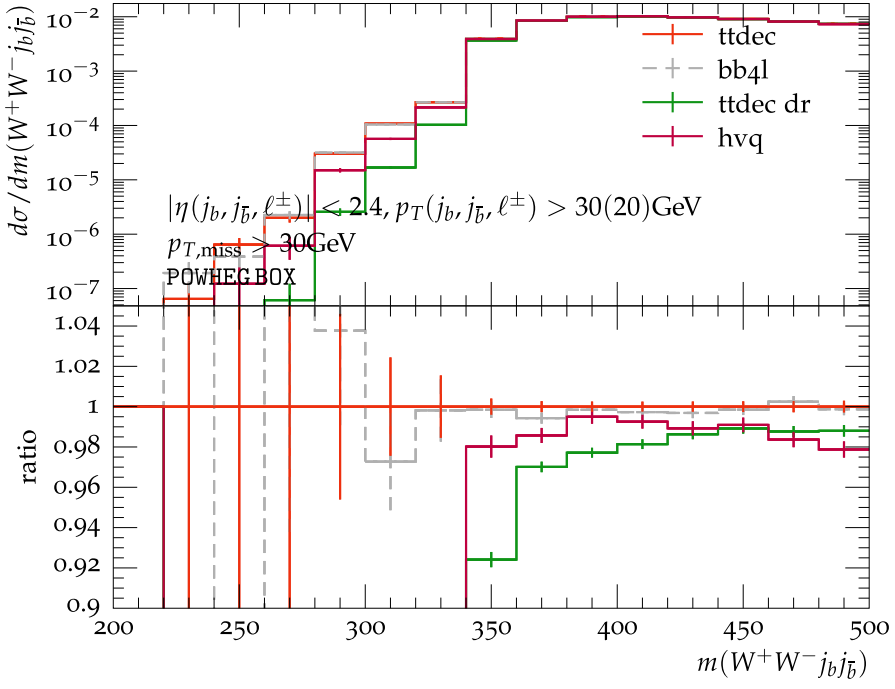
- `ST_wtch` (wtch DS, wtch DR): NLO tW production, LO t and W decay
  - $t\bar{t}$ removed with Diag. Removal (DR) or Diag. Subtraction (DS)
  - at FO LO only one j_b
- `hvq` (hvq): NLO $t\bar{t}$ production, LO t decay
- `hvq+ST_wtch` (hvq+wtch DS, hvq+wtch DR):
  - sums $t\bar{t}$ and tW, tW–$t\bar{t}$ interference?
- `ttb_NLO_dec`: NLO $t\bar{t}$ production, NLO t decay
  - includes tW and tW–$t\bar{t}$ interference at LO (through reweighting) (ttdec)
  - tW and tW–$t\bar{t}$ can be switched off (ttdec dr)
- `b_bbar_4l` (bb4l): NLO $t\bar{t}$ production, NLO t decay
  - includes tW and tW–$t\bar{t}$ interference at NLO (exact)

Setup

- 13 TeV pp collider
- NNPDF31_nlo_as_0118
- $m_t = 172.5$ GeV, $m_b = 4.75$ GeV
- $\mu_r = \mu_f = m_t$, 7-pt variations
- Event selection:
  - leptons
    - one e^+ and one μ^-
    - $|\eta| < 2.4, p_T > 30/20$ GeV
    - $p_T^{\text{miss}} > 30$ GeV
  - b-jets
    - j_b: anti-k_T R=0.4, $\geq 1b$ parton
    - $|\eta| < 2.4, p_T > 30$GeV
- Reconstruction: $\ell - \nu$ and $\ell - j_b$ paired based on MC truth
- SMC settings: `Pythia 8.244`, hadronization=off, mpi=off, QEDshower=off, MEC=yes, PowhegHooks=yes

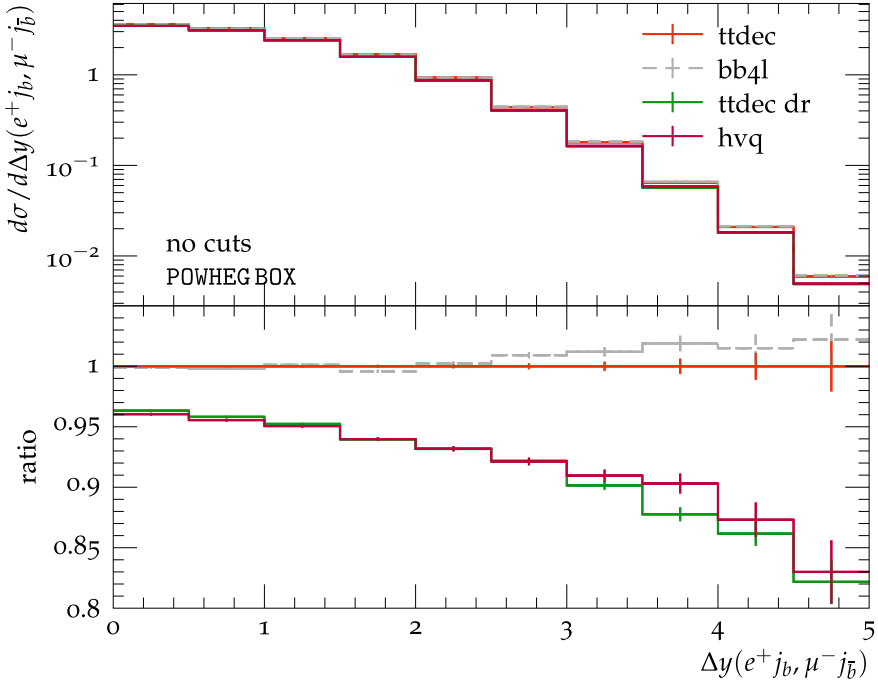
$m(W^+W^-j_b j_{\bar{b}})$ at LO

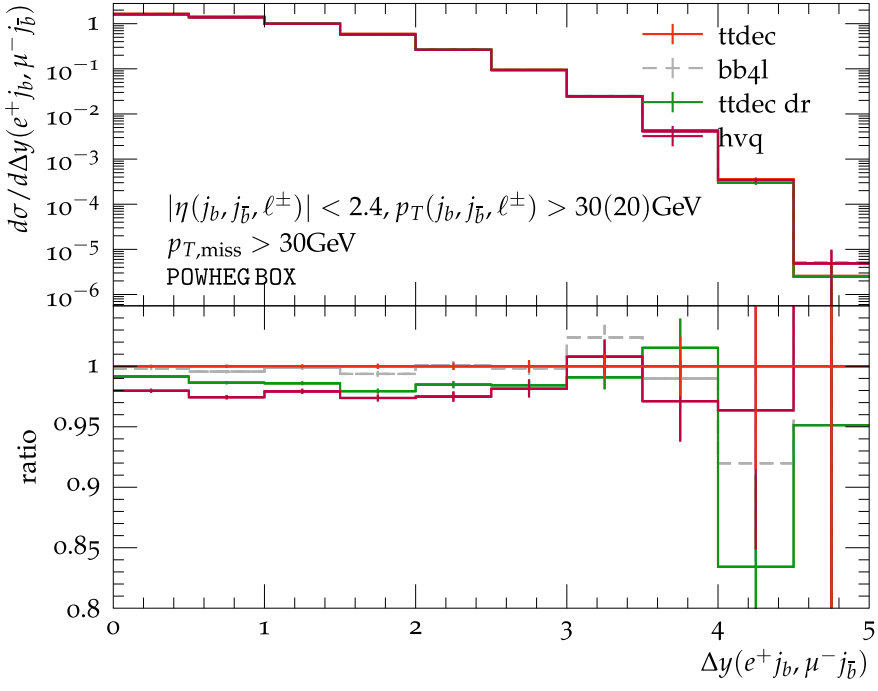




- no cuts
  - ~ 3 – 4% σ_t difference
  - reduction grows towards lower tail
- cuts
  - ~ 1 – 2% σ_t difference
  - shape agreement improves

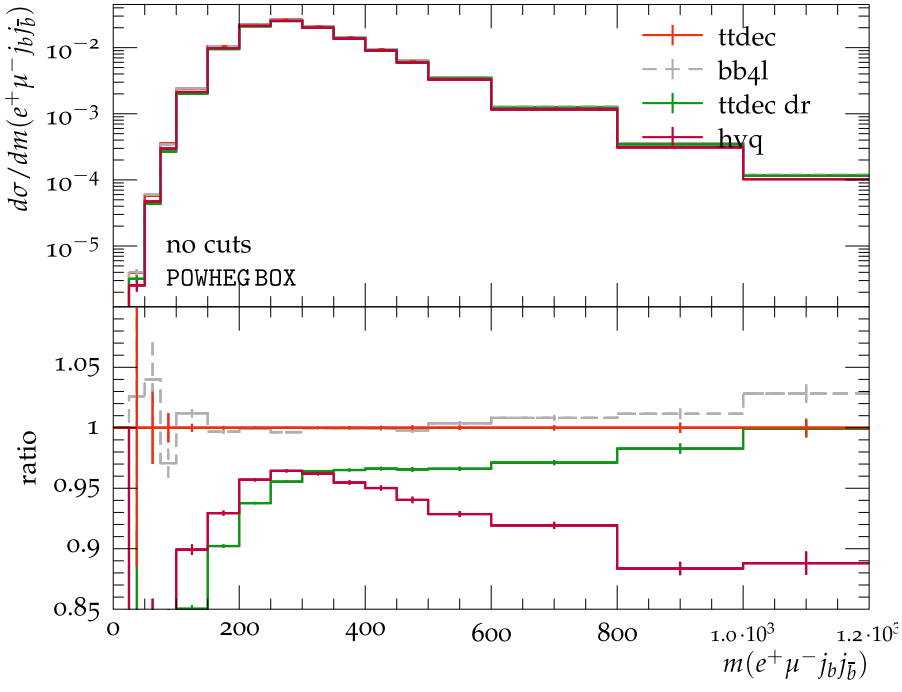
$\Delta y(e^+ j_b, \mu^- j_{\bar{b}})$ at LO

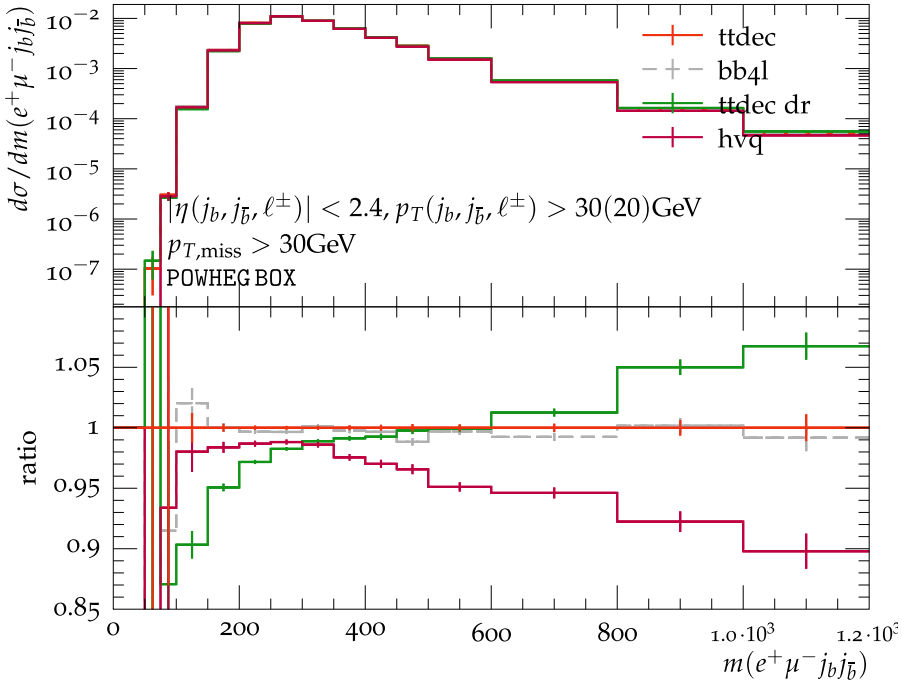




- no cuts
  - ~ 10% shape effect
- cuts
  - shapes agree extremely well

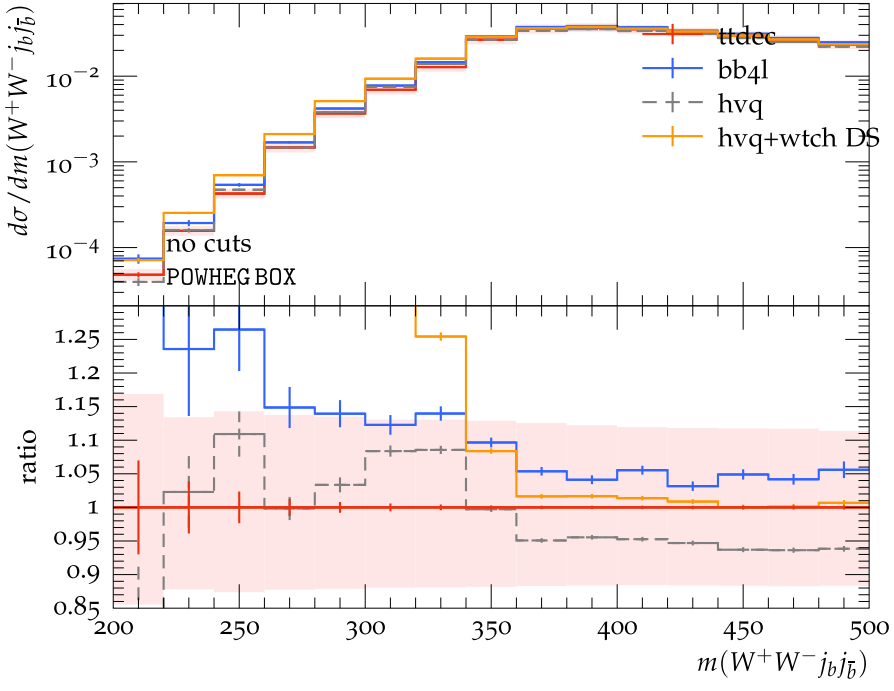
$m(e^+\mu^- j_b j_{\bar{b}})$ at LO

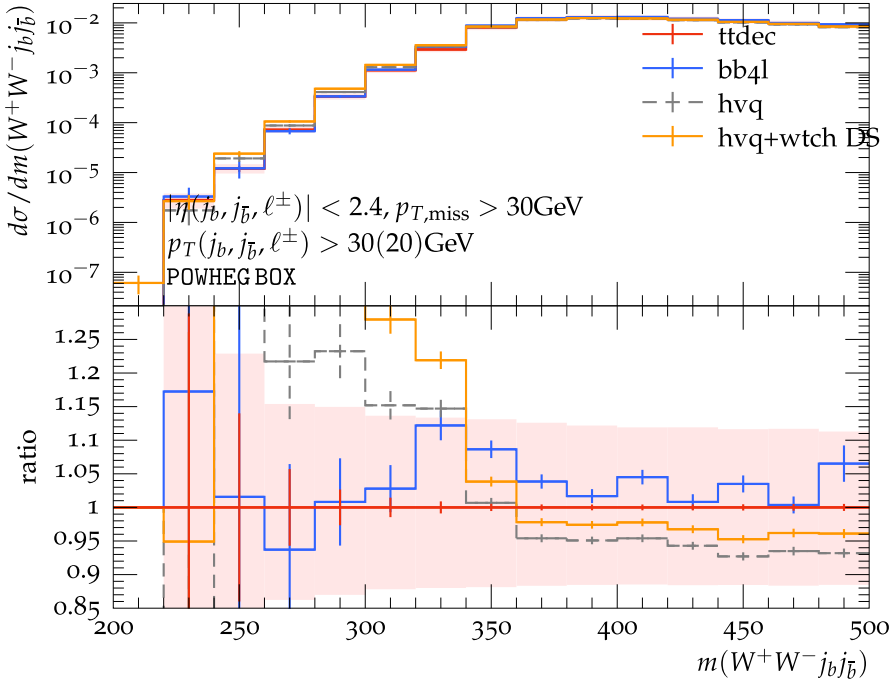




- missing tW and $tW - t\bar{t}$ interference: ~ 10% shape effect
- different implementations of finite-width effects differ appreciably
- fiducial cuts improve the agreement in the low tail

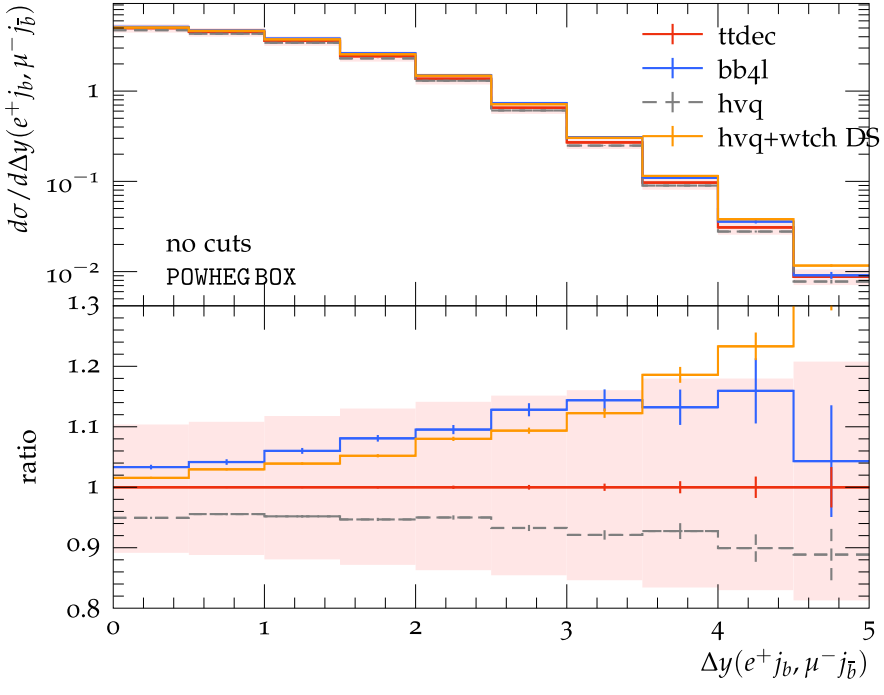
$m(W^+W^-j_b j_{\bar{b}})$ at NLOPS

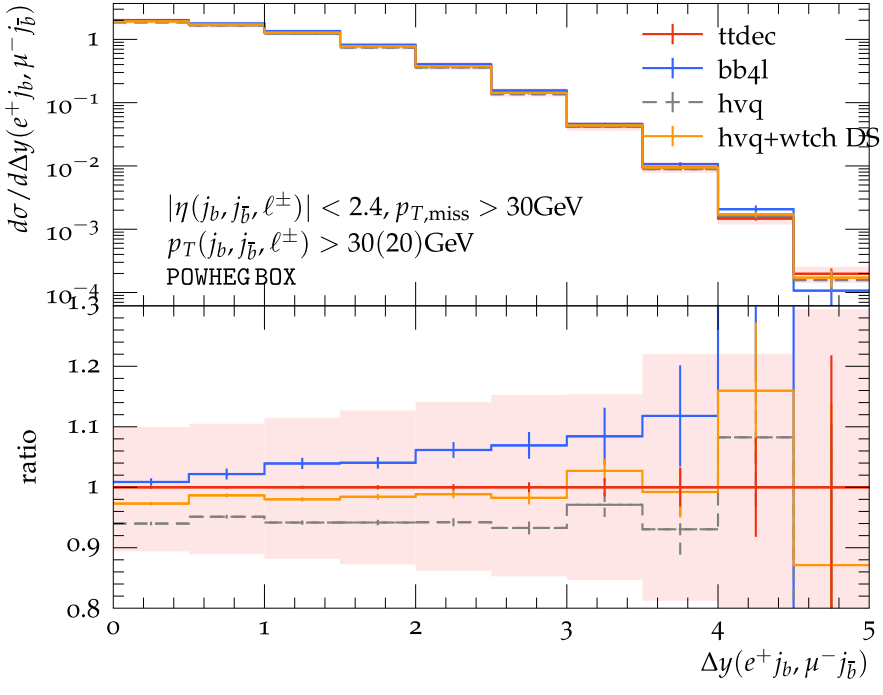




- below threshold the agreement improves considerably @NLOPS
- above threshold shapes agree very well, ~ 1 – 2% shape effects
- cuts don't have the same effect as at LO

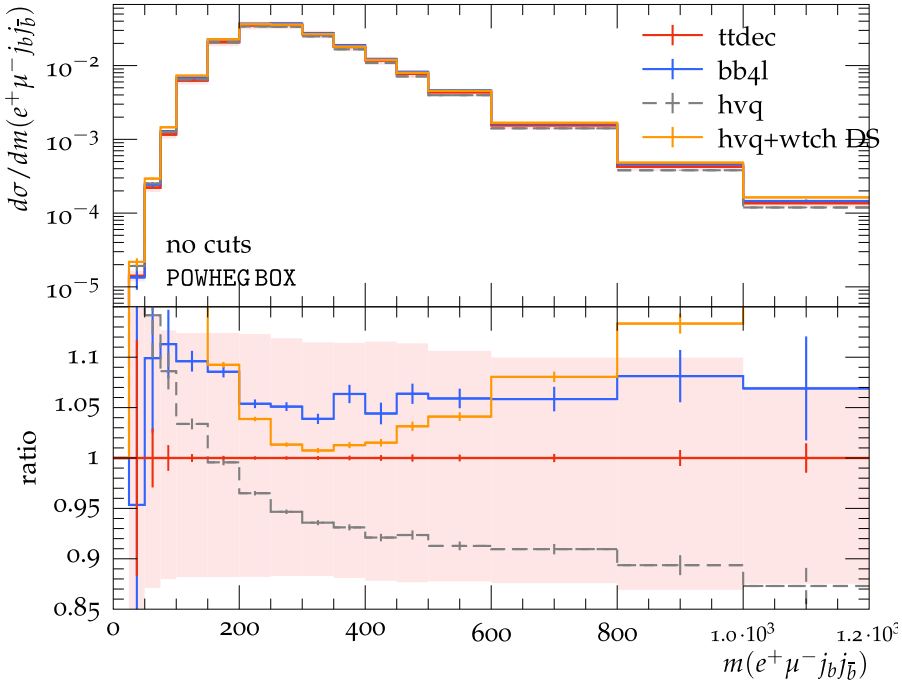
$\Delta y(e^+ j_b, \mu^- j_{\bar{b}})$ at NLOPS

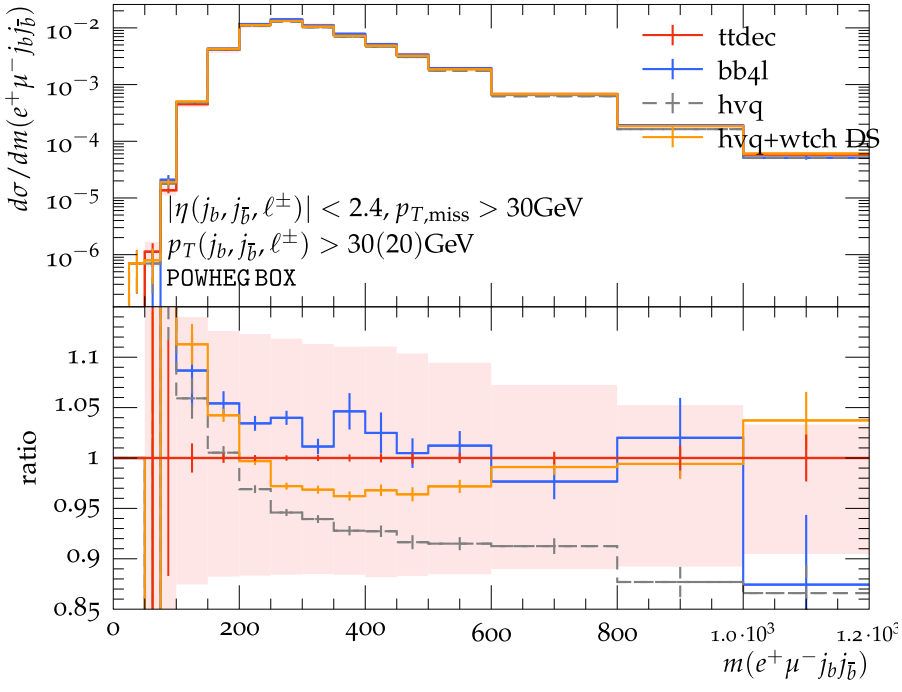




- missing NLO corrections to tW and $tW - t\bar{t}$ ~ 15% shape effect (bb4l vs ttdec)
- interference modelling difference (bb4l vs hvq+wtch DS)
  - subdominant without cuts
  - dominant ~ 5 – 10% shape effect with cuts

$m(e^+\mu^- j_b j_{\bar{b}})$ at NLOPS





- difference in $tW - t\bar{t}$ modelling ~ 10% shape effect (bb4l vs. hvq+wtch)
- NLO corrections to tW and $tW - t\bar{t}$ rather flat (bbl4 vs. ttdec)

Summary

- in LO comparisons we observe:
  - tW contribution important, induces shape effects of ~ 15%
    - we mostly know how to include it: by adding wtch to hvq or using ttdec and bb4l
    - fiducial cuts make it nearly irrelevant in $\Delta y(e^+ j_b, \mu^- j_{\bar{b}})$ but not in $m(e^+\mu^- j_b j_{\bar{b}})$
  - finite-width effects in resonant production important in $m(e^+\mu^- j_b j_{\bar{b}})$
    - ttdec offers more sophisticated treatment than hvq
- NLO comparisons suggest:
  - consistent inclusion of $tW - t\bar{t}$ effects at LO may be more important for these two observables than the inclusion of NLO corrections to tW and $tW - t\bar{t}$
  - ttdec seems more suited for this study than hvq+wtch
- all of these effects (and more) included in bb4l, we recommend you use it