# Top Mass Determination Using New NLO+PS Generators

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In collaboration with:
*S. Ferrario Ravasio, P. Nason and C. Oleari*



Universität Zürich[UZH]

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  - Methods based on the top reconstruction from its decay products
- New NLO+PS generators based on POWHEG method
  - Top-pair generators including top decay at different levels of precision
- Motivation and Goal
  - Experimental precision reaching unprecedented level
  - Critically assess the modelling uncertainity
- Disclaimer
  - Sneak-peak into our recent progress
  - Results very preliminary ⇒ conclusions possibly premature

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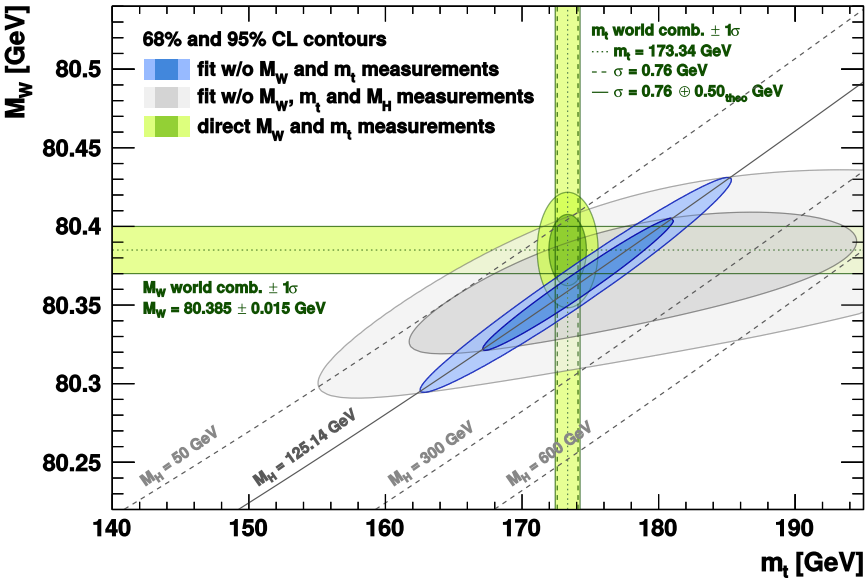
- Accurate knowledge of $m_T$ useful for
  - Precision tests of the SM
    - $m_H$, $m_W$ and $m_T$ correlated




Global fit to electroweak precision observables [arXiv:1407.3792]

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- Accurate knowledge of $m_T$ useful for
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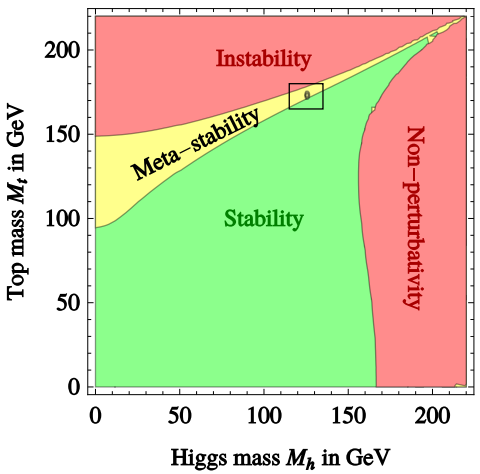
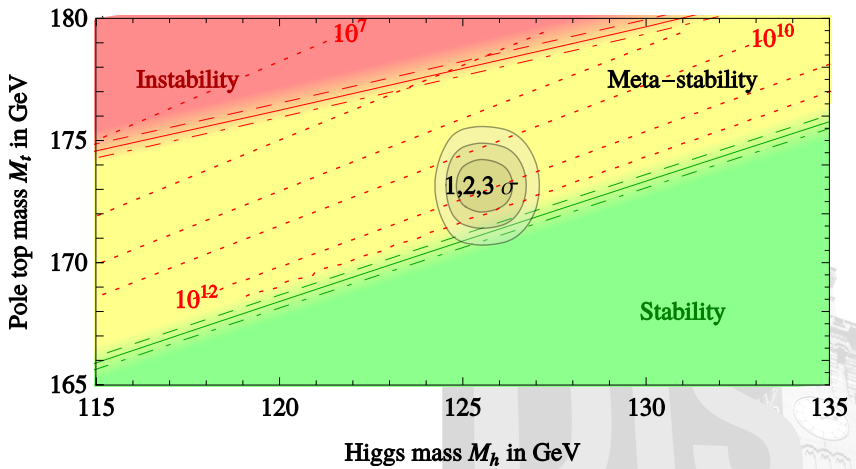
  - Addressing the issue of vacuum stability
    - Current values of $m_H$ and $m_t$ suggest the vacuum is metastable

[arXiv:1205.6497]



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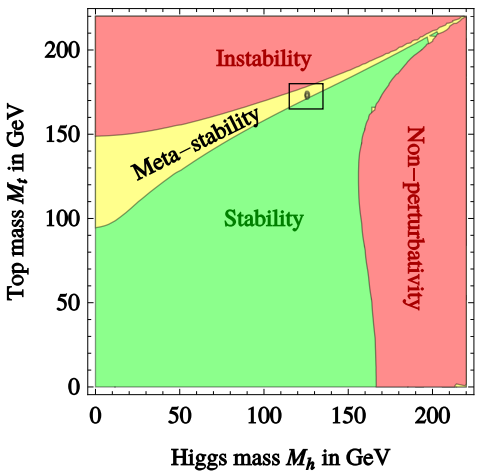


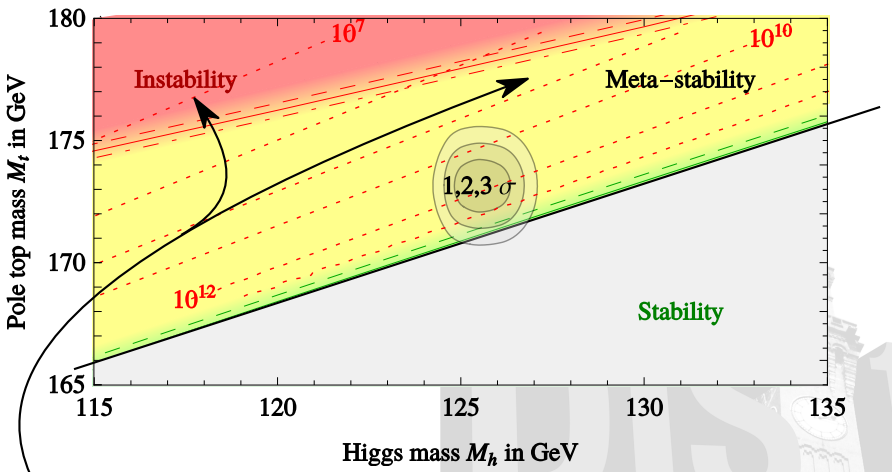


Higgs quartic coupling $\lambda_H$ runs to negative values at Planck scale

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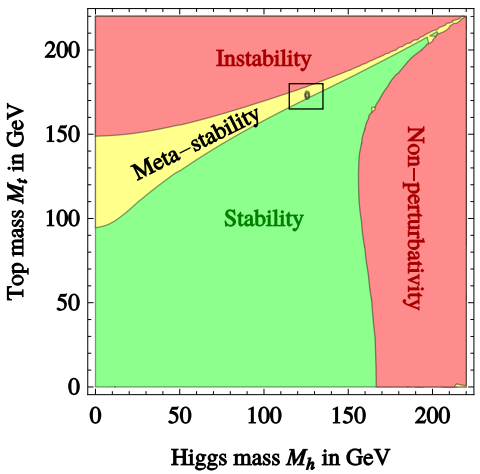
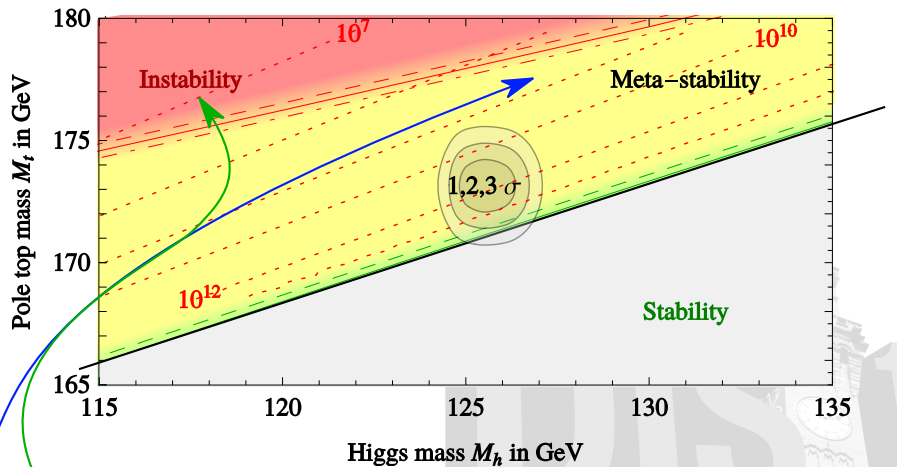



The vaccum life-time is long enough

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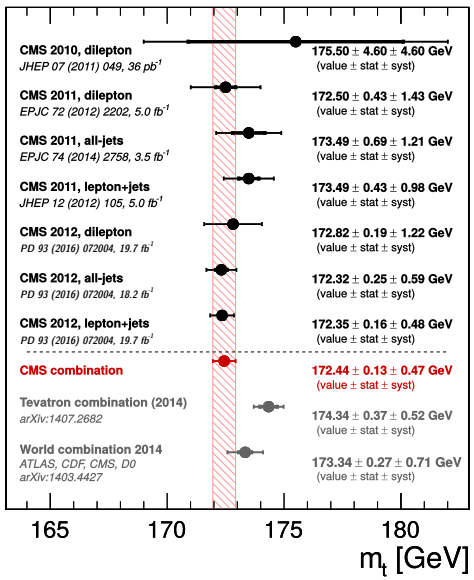


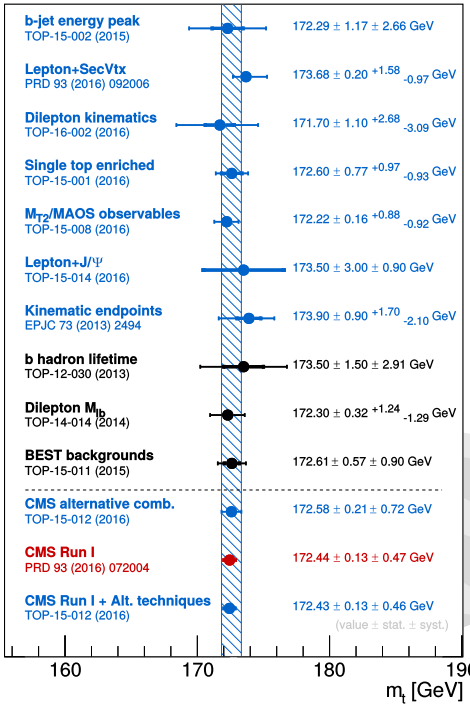

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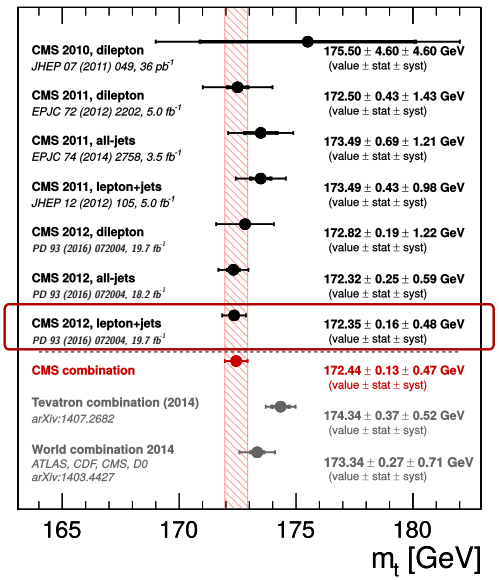


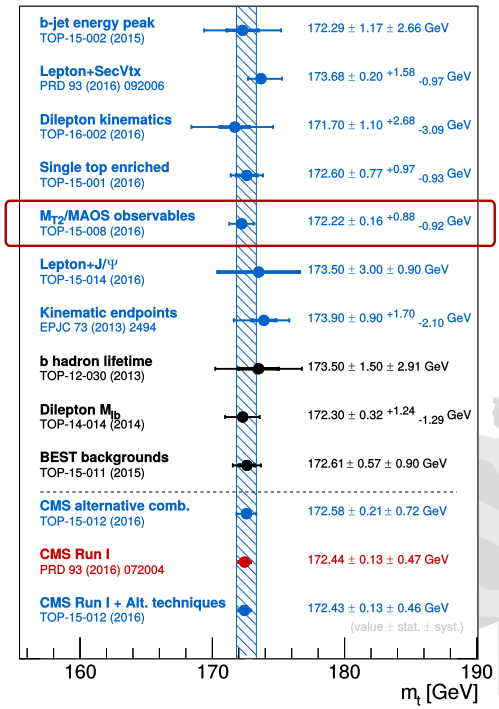

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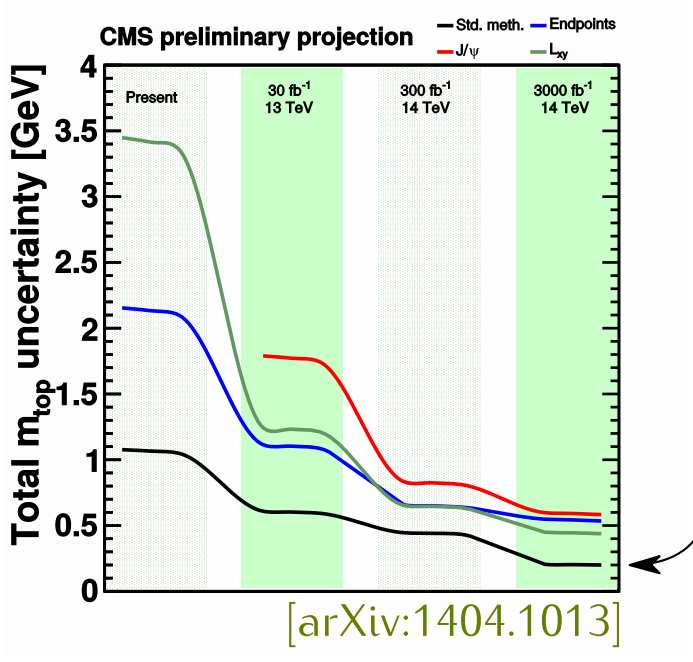


0.2 GeV?

# $m_T$: summary

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- $m_T$ measurement at the LHC
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  - $m_T$ determinted by a fit to a template
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*precise and accurate

UZH

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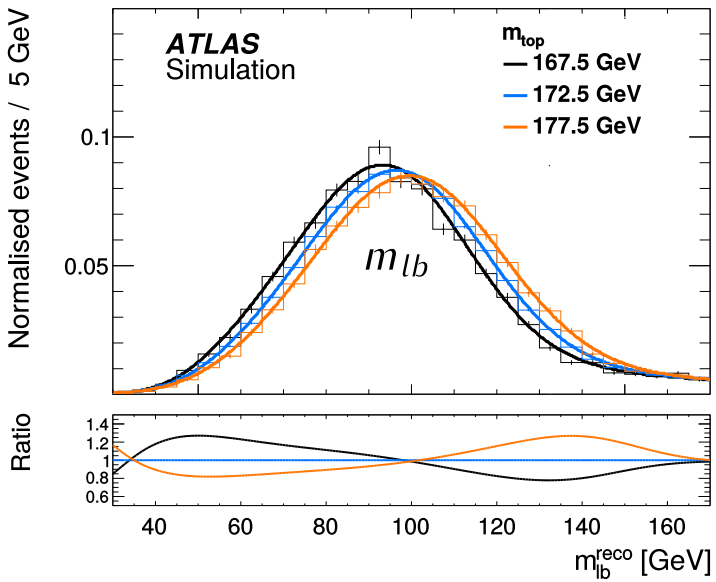


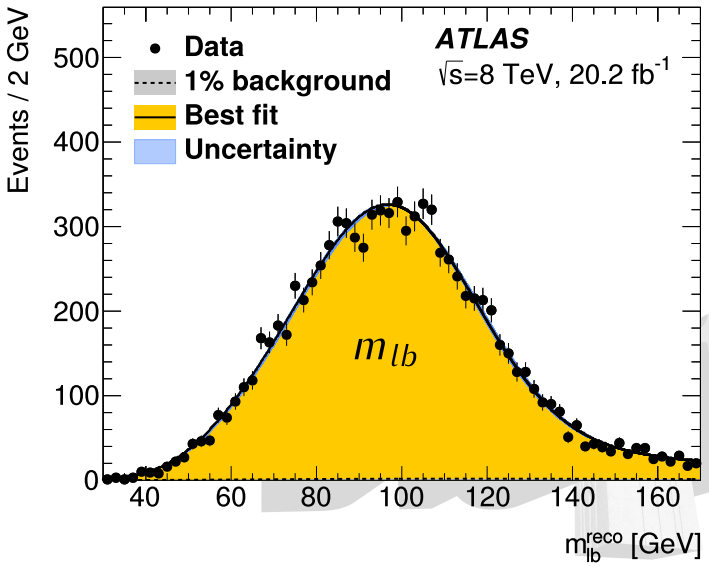

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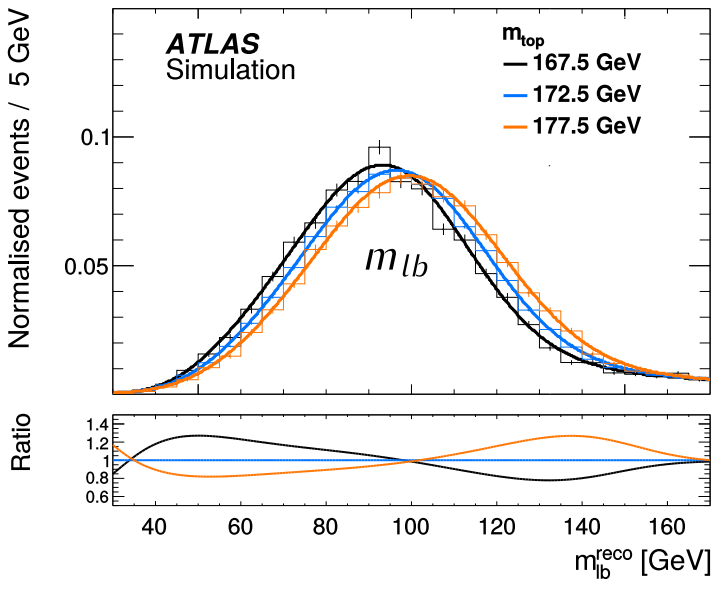
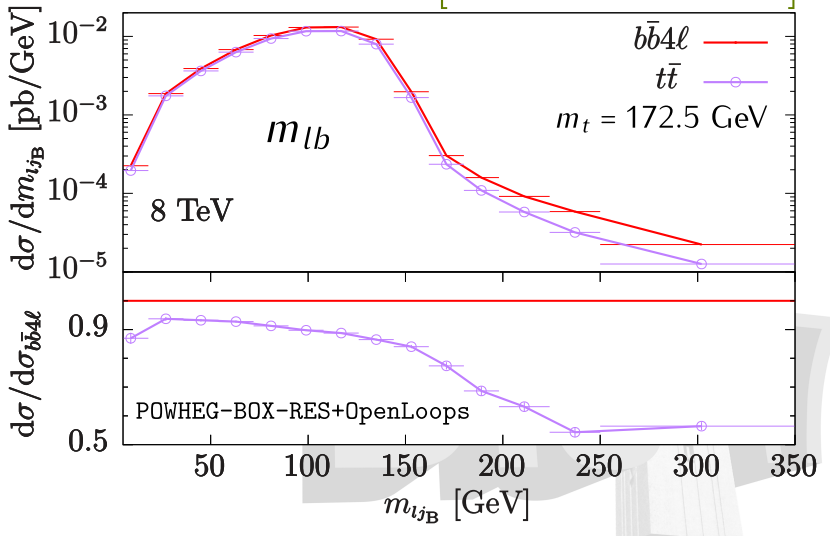



[arXiv:1607.04538]



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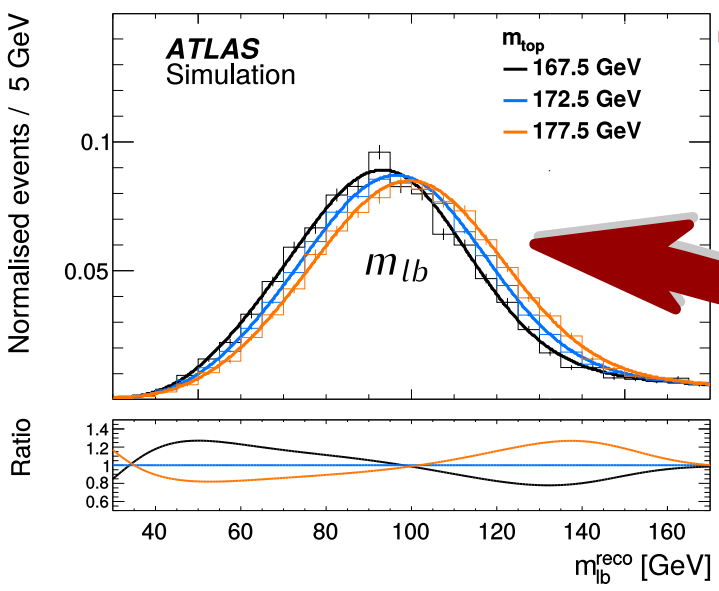


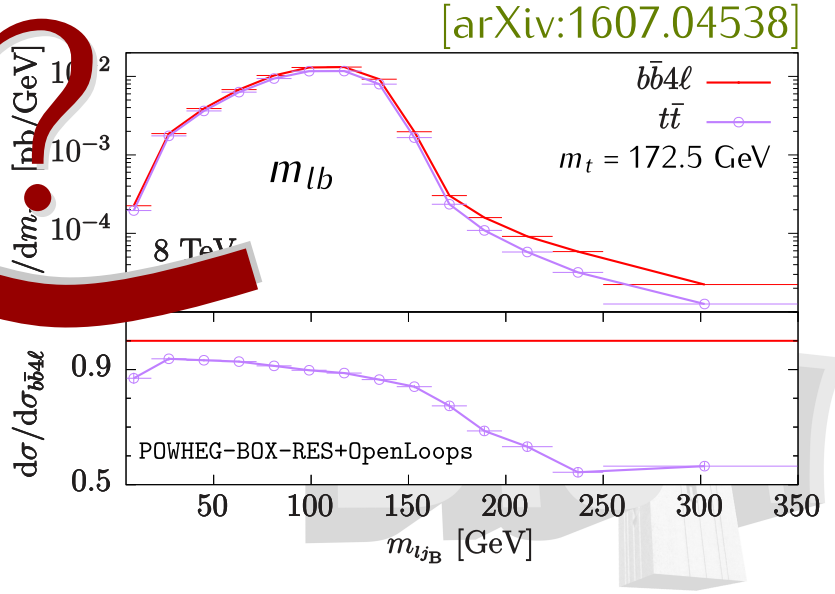

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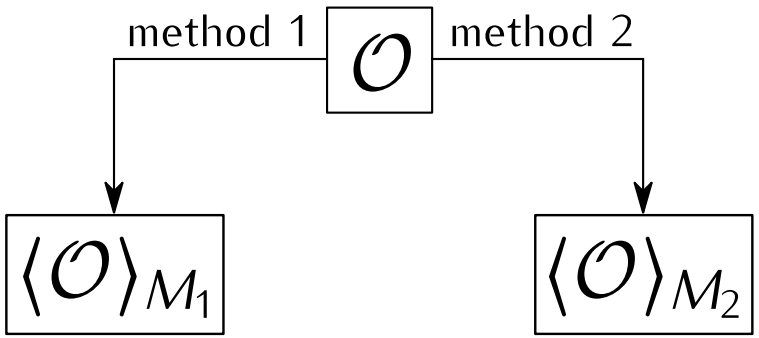


$$\langle\mathcal{O}\rangle_{M_1} - \langle\mathcal{O}\rangle_{M_2}$$

- $\mathcal{O}$ ...
  - $m_l b$
  - $b$-jet energy spectrum
  - etc.
- method ...
  - order in perturbation theory
  - Shower Monte Carlo
  - etc.

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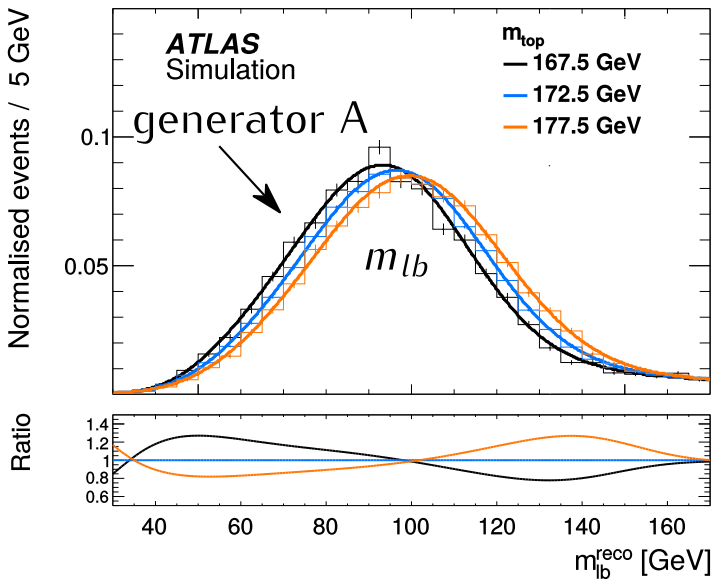


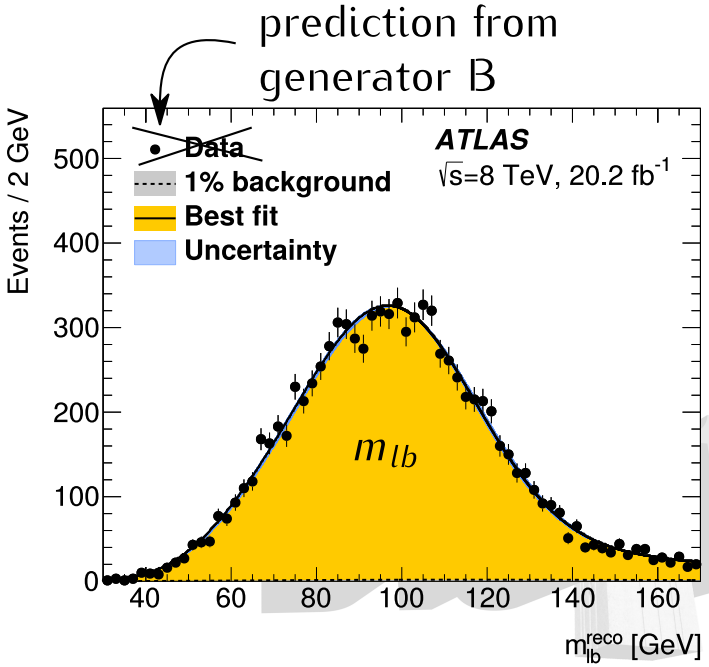

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- We look at:
  - Three generators implementing an increasingly precise treatment of $t\bar{t}$ production and decay in leptonic channel
  - SMCs: Pythia8.2 [Sjöstrand et al. 2014], Herwig7.0 [Bellm et al. 2015]
  - Observables:
    - Invariant mass of the $W$ – $b$-jet system
    - Shape of lepton spectrum [Kawabata et al. 2014]
    - Mellin moments of lepton spectra [Frixione et al. 2014]
    - $b$-jet energy spectrum [Agashe et al. 2016]

# $t\bar{t}$ NLO+PS generators

- `POWHEG-BOX/hvq` [Frixione, Nason, Ridolfi, 2007]
  - $t\bar{t}$ production at NLO
  - No NLO corrections in decays (radiation from $b$ only by PS)
  - Spin correlations and off shell effects approximate
- `POWHEG-BOX/ttb_NLO_dec` [Campbell, Ellis, Nason, Re, 2014]
  - $t\bar{t}$ production at NLO
  - Includes NLO corrections in decays
  - Exact spin correlations and LO exact off shell effects
  - No interference of radiation from production and decay
- `POWHEG-BOX-RES/bb4l` [TJ, Lindert, Nason, Oleari, Pozzorini, 2016]
  - $pp \to \ell^+ \nu_\ell \, l^- \bar{\nu}_l \, b \, \bar{b}$ production at NLO
  - Exact spin correlations* and exact off shell effects
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POWHEG-BOX-V2 $t\bar{t}$

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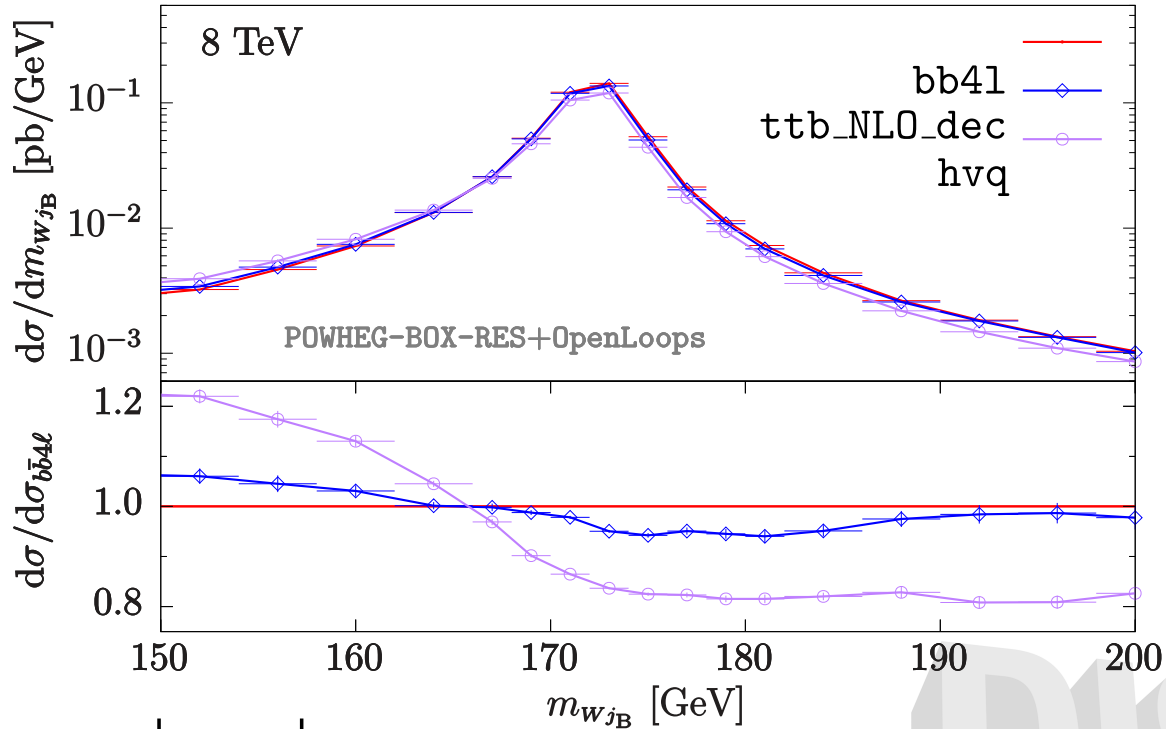
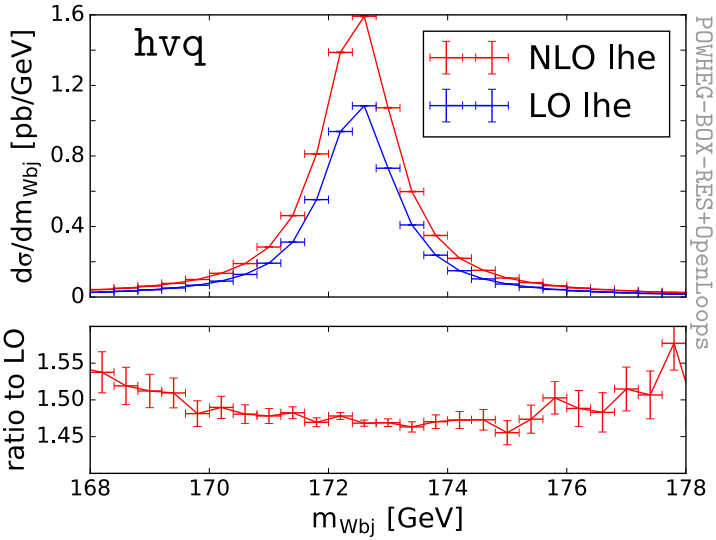
# $m_{Wb_j}$

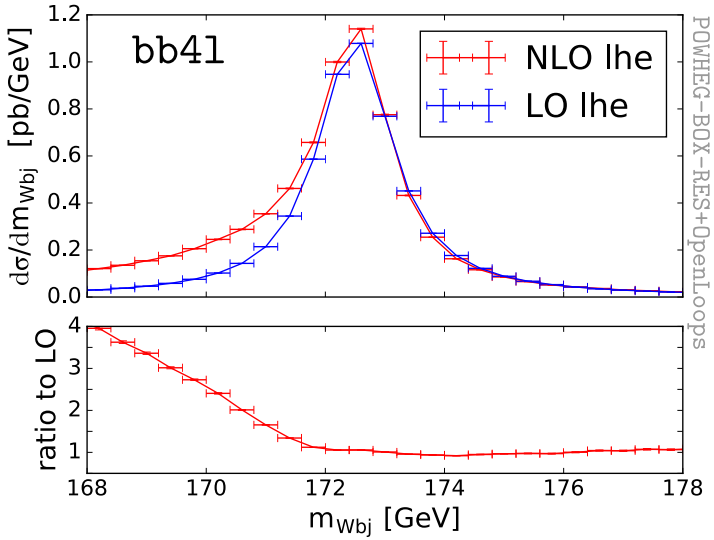
[TJ, Lindert, Nason, Oleari, Pozzorini, 2016]




- Where we observed:
  - Reasonable agreement between `bb4l` and `ttb_NLO_dec`
  - Considerable difference between `bb4l` and `hvq`

# $m_{Wb_j}$

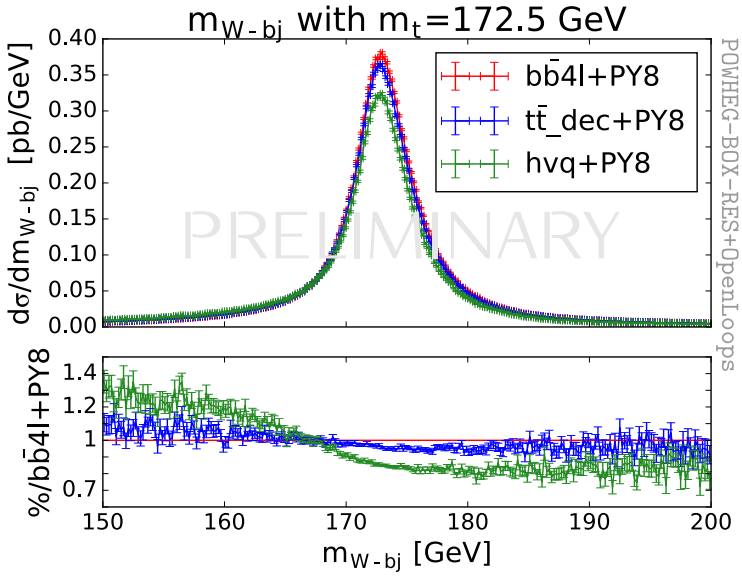


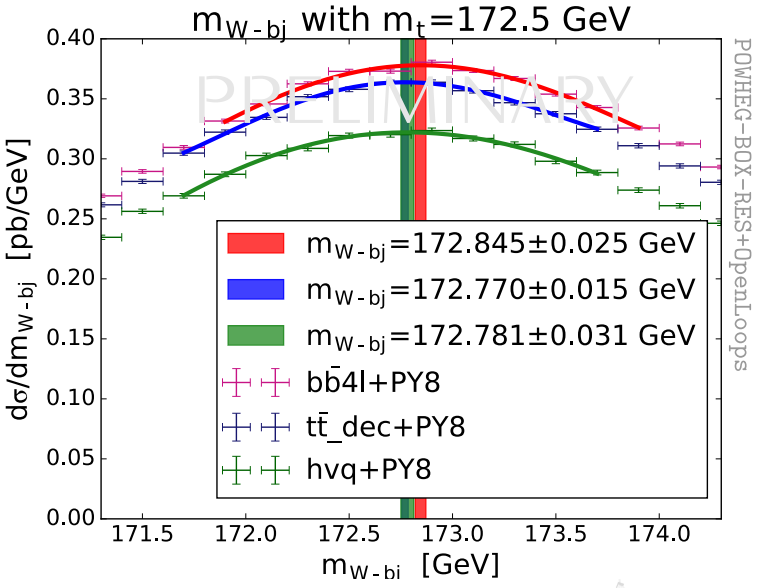




- $k$-factor in `hvq` mostly flat
- In `bb4l`, $k$-factor in low mass tail very large
  - Caused by energy loss in $b$-jet due to radiation outside the cone

* lhe = includes sudakov suppressed hardest emission(s) but no shower

# $m_{Wb_j}$: NLO+PS dependence




- Shower brings the two predictions closer together
- There's a shape difference, but is the peak shifted?
  - Polynomial fit of the invariant mass distribution reveals a peak shift of ~ 0.1 GeV

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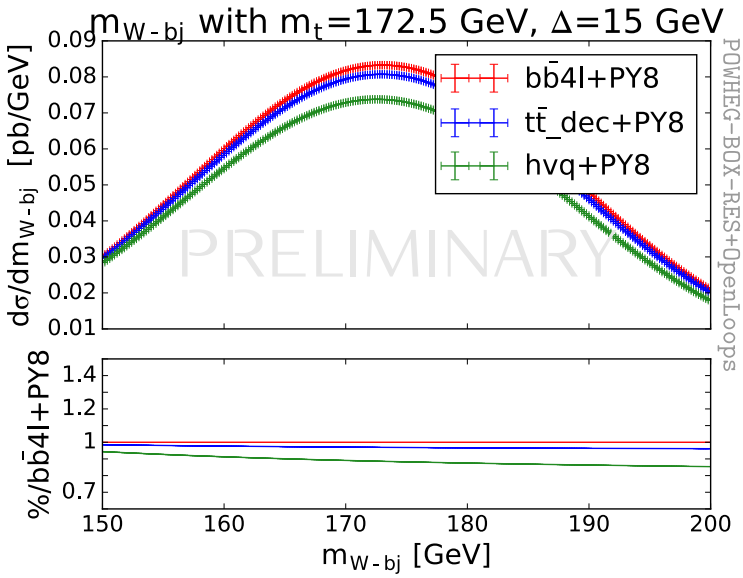
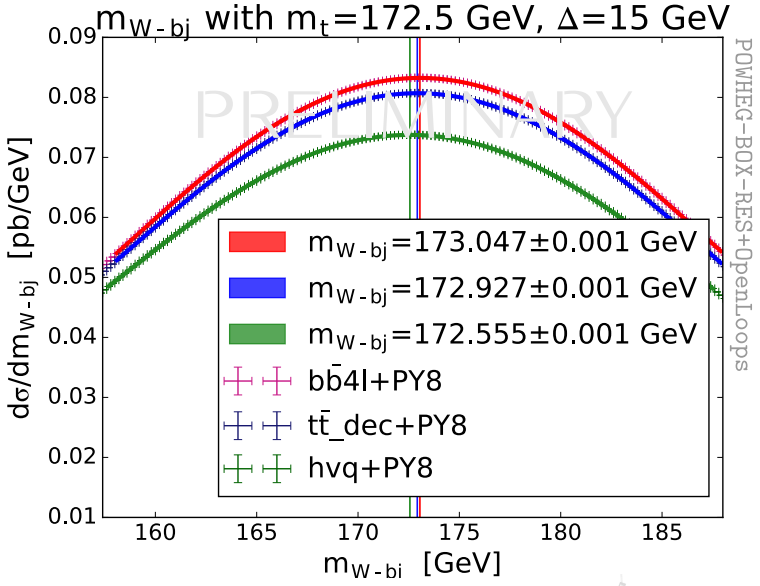


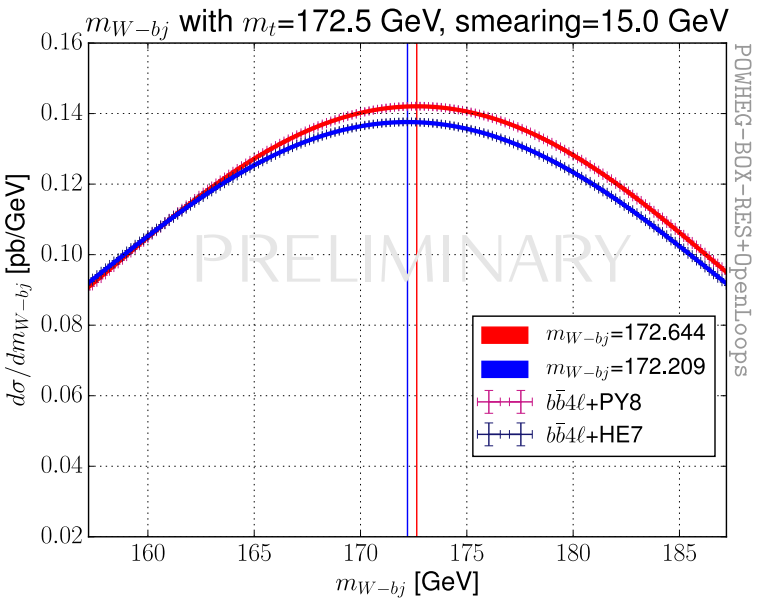



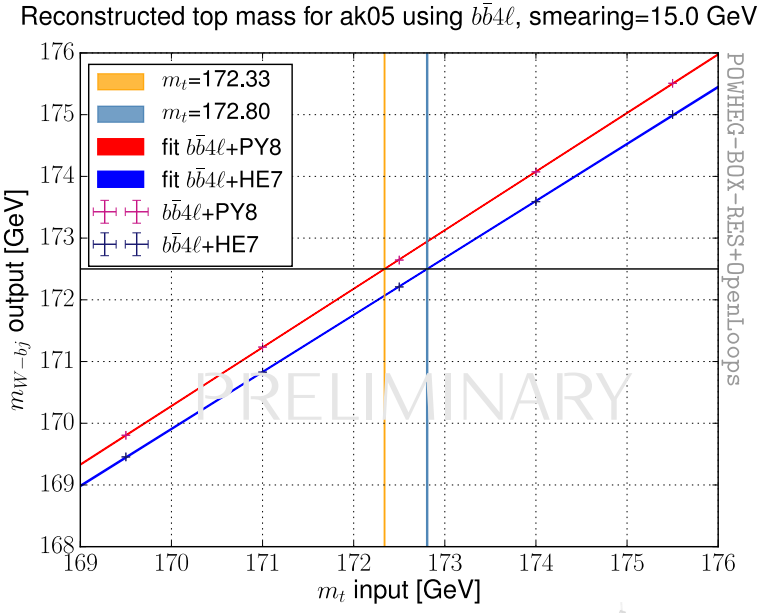

- Repeat the exercise with distributions smeared with a gaussian weight

$$f(x) = N \int dx' f(x') \exp\left[-\frac{(x-x')^2}{2\Delta^2}\right]$$

  - Polynomial fit now reveals a peak shift of ~ 0.5 GeV

# $m_{Wb_j}$: SMC dependence

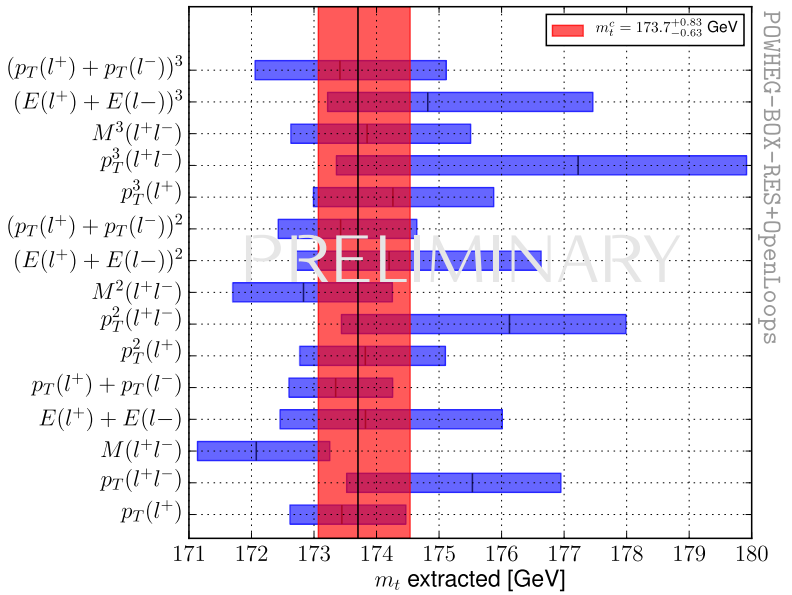



- Left: polynomial fit reveals a peak shift of ~ 0.5 GeV
- Right:
  - Dependence of the fitted peak position as a function of input top mass
  - We observe a fairly constant peak shift

# Leptonic observables

$m_t$ using $hvq$ as theoretical sample and $b\bar{b}4\ell$+PY8 with $m_t$=172.5 GeV as data




- Proposed in [Frixione et al. 2014]
- Pseudo data generated using `bb4l`
- Input mass $m_t = 172.5$ GeV
- Mass extracted using `hvq`
- Output mass $m_t = 173.7^{+0.83}_{-0.63}$ GeV
- Uncertainties from scale, pdf and shower variations

# Summary

- Are our tools precise enough?
  - The precision of $m_t$ determination is reaching unprecedented levels
  - Recent development on NLO+PS $t\bar{t}$ front suggests that radiative corrections in decays are rather important
  - Is it necessary to use better tools in order to determine $m_t$ accurately?

- Perhaps.
  - Radiative corrections in decay distort the shapes of many observables
  - They do not seem to affect the position of the peak in an ideal detector
  - Averaging over the ±15 GeV window induces a peak shift of 0.5 GeV

- It may be necessary to review our point of view on modelling uncertainity.