

Complex topologies, for example $pp \rightarrow WbW\bar{b}$.

“Precision measurements require us to understand effects beyond the factorization of $t\bar{t}$ production and decays”.

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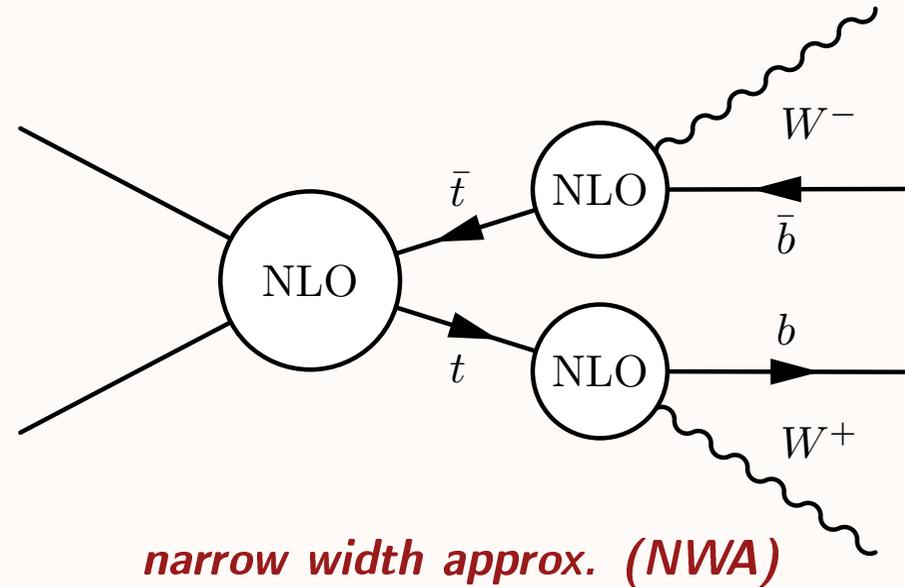
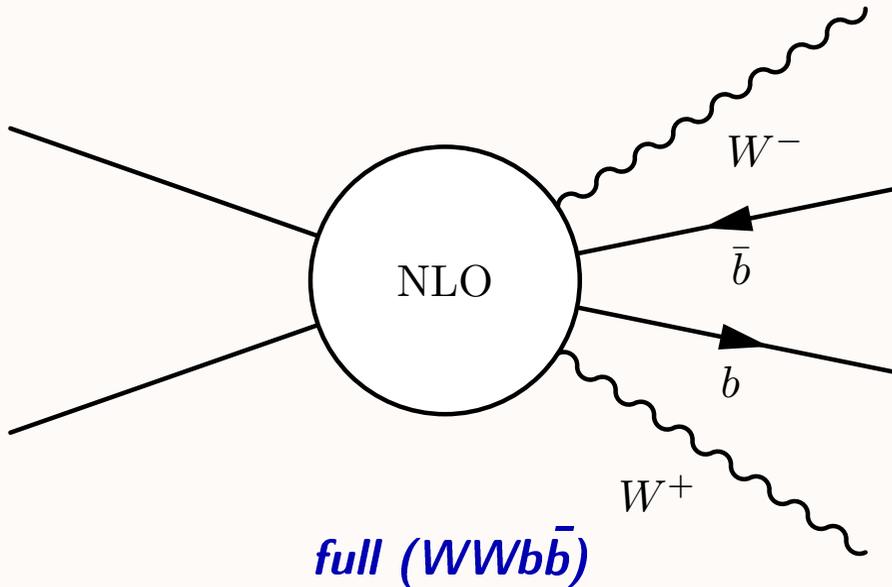
$pp \rightarrow WbW\bar{b}$ is the more realistic/physical final state
if one is interested in studies of $pp \rightarrow t\bar{t}$ production

~ quantum theoretical versus semi-classical treatment ~

- At the current & near-future precision of the experiments, we have to start worrying about offshell effects, non-factorizable corrections, b-mass dependence etc.
- As the “truth” objects are closely defined by the physics objects reconstructed in the detector, $WbW\bar{b}$ plus subsequent W decays gives a better description of the relevant truth object (stable-particle) final states.
- The operational definition of the top quarks, the pseudo-tops, and related observables can be directly compared to $W(\ell\nu)bW(\ell\bar{\nu})\bar{b}$ or even $\ell\ell\nu\bar{\nu}b\bar{b}$ predictions. Measurements can be done using fewer assumptions (no top quark reconstruction required etc).



Full calculation versus NWA

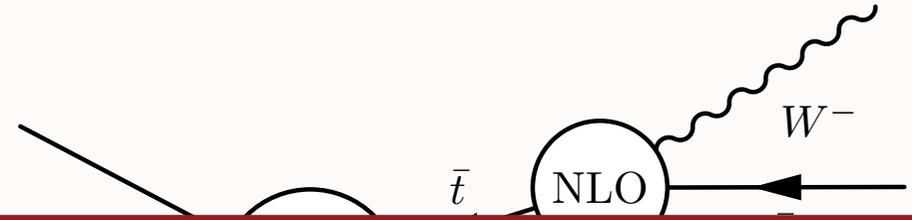
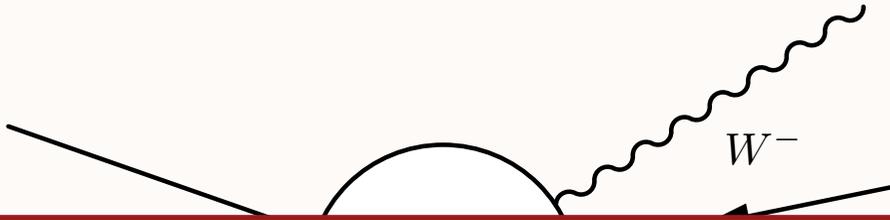


- full NLO description of the $WWb\bar{b}$ final state ($2 \rightarrow 4$ processes)
- accounts for non-resonant/non-factorizing contributions (quantum interferences)
- NLO effects in top quark decays
- Comparison between both calculations (in the $l\bar{l}$ channel) to investigate finite top-quark width effects.
 - No more than 1% deviations for inclusive cross sections (with experimental cuts).
 - Effects can be (significantly) larger in differential distributions.

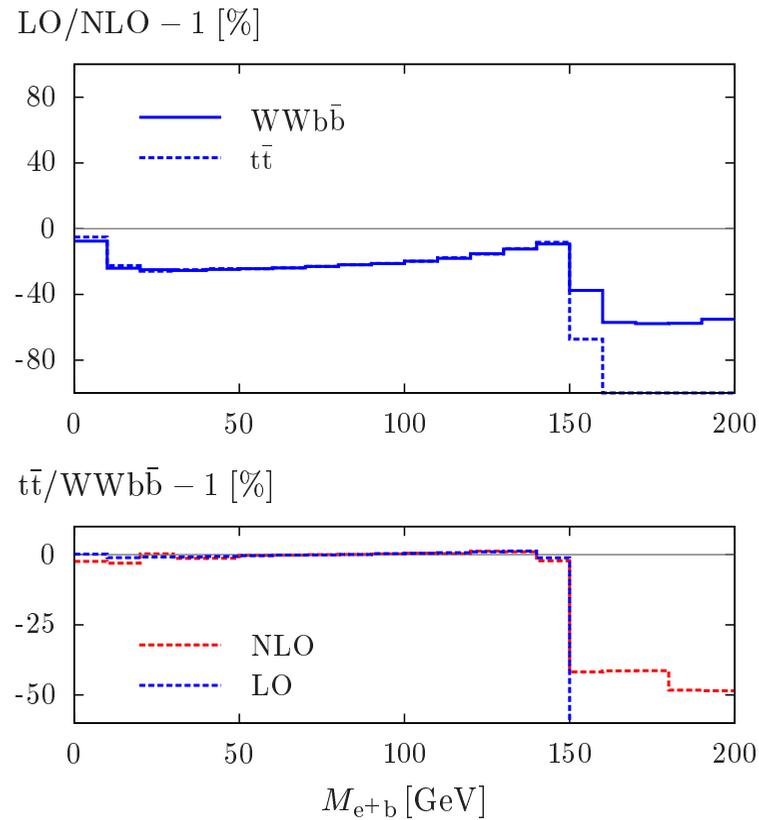
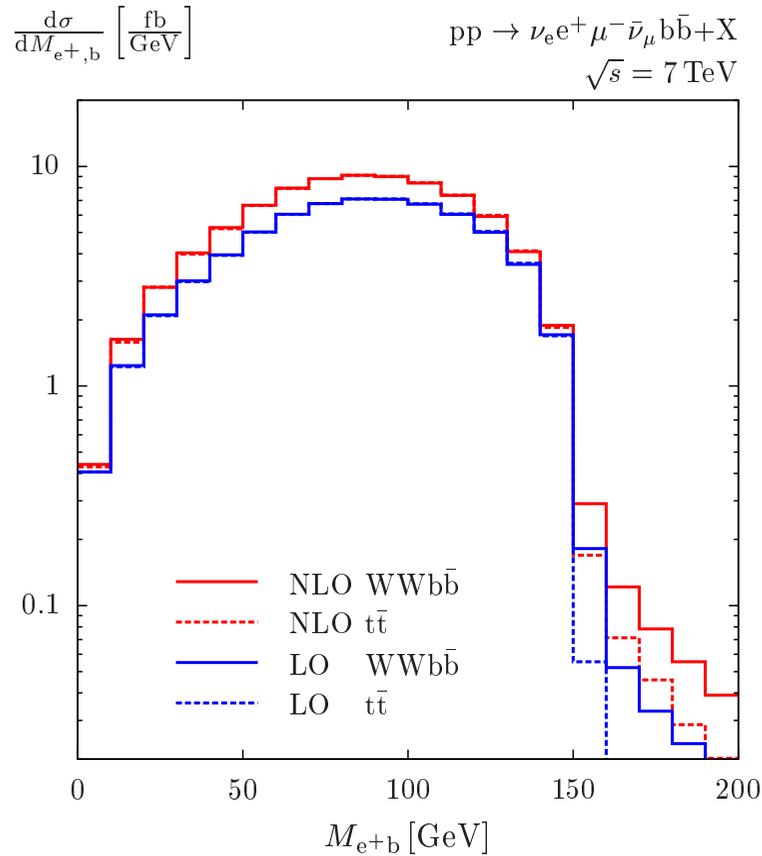
⇒ here exemplified by showing the invariant mass distribution of the $l\bar{b}$ system.



Full calculation versus NWA



[DENNER, DITTMAYER, KALLWEIT, POZZORINI, SCHULZE, LESHOUCHES2011, ARXIV:1203.6803]

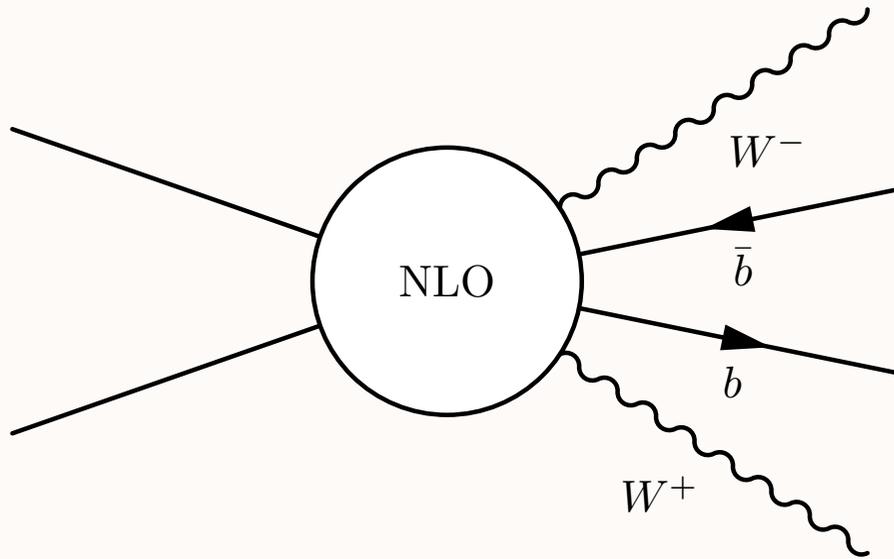


○ Effects can be (significantly) larger in differential distributions.

⇒ here exemplified by showing the invariant mass distribution of the lb system.

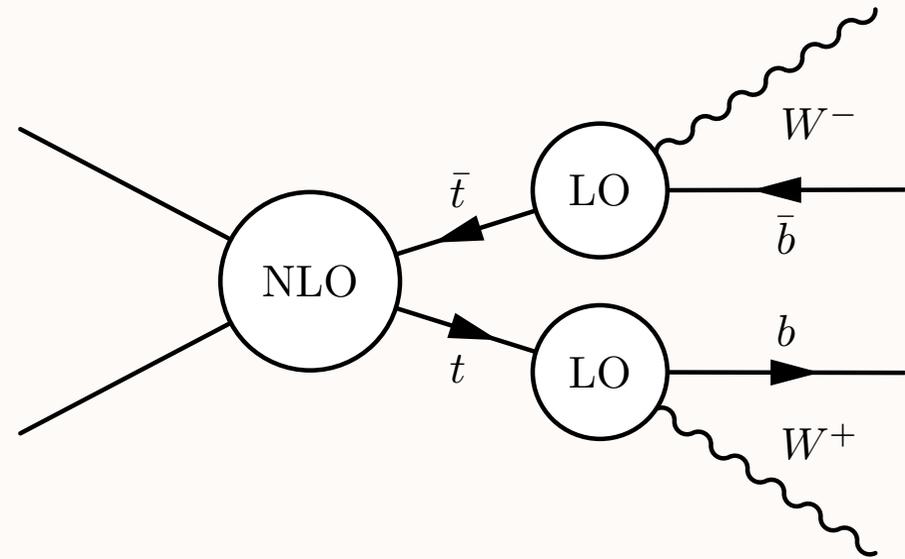


Full approach versus factorized treatment



full ($WWb\bar{b}$)

- full NLO description of the $WWb\bar{b}$ final state ($2 \rightarrow 4$ processes)
- accounts for non-resonant/non-factorizing contributions, includes NLO effects in top quark decays
- Calculations are used in pure parton level studies e.g. that of the $m_{l\bar{b}}$ distribution.



factorized ($t\bar{t}$)

- NLO $t\bar{t}$ production ($2 \rightarrow 2$ processes) with LO decays attached and spin correlations preserved
- standard description for the NLO core in NLO+PS matching

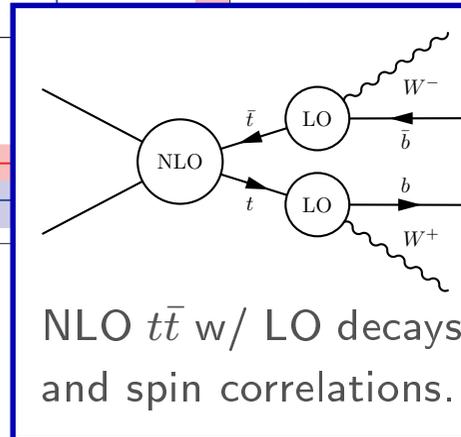
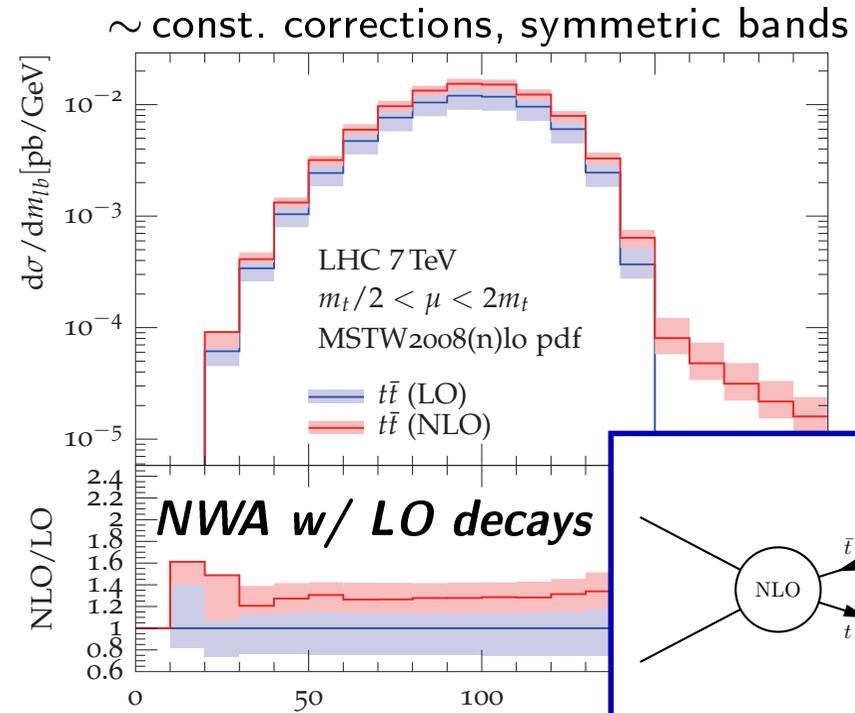
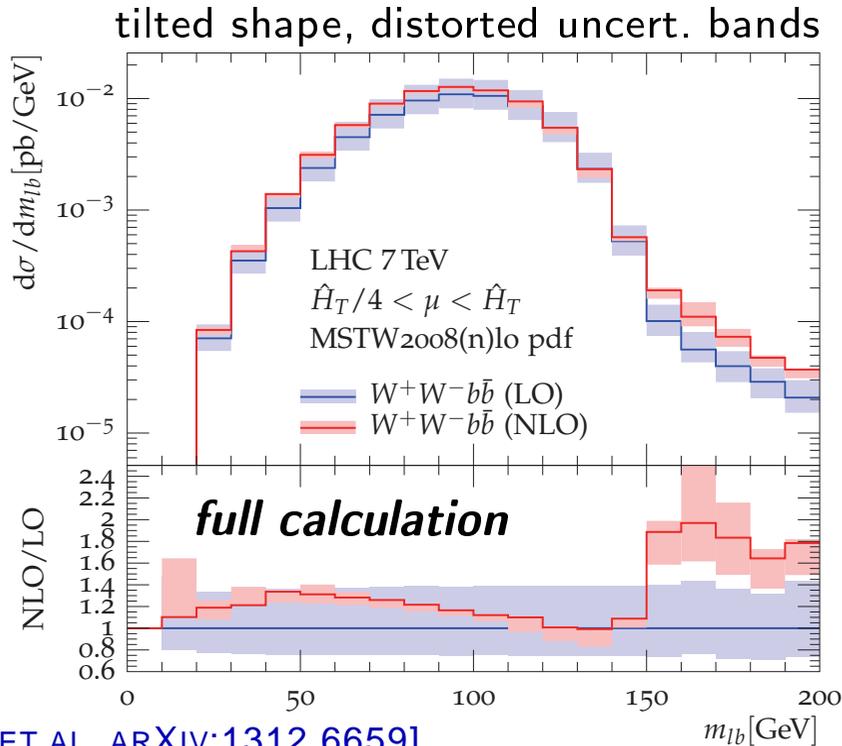
[HEINRICH, MAIER, NISIUS, SCHLENK, WINTER, ARXIV:1312.6659]



The m_{lb} distribution at NLO and scale variations

➔ *Parton-level NLO calculations for $W^+W^-b\bar{b}$ based on GoSam+Sherpa framework.*

(full & factorized calc., 5-flavour scheme, massless b-quarks, two resonant W decaying leptonically @ LO)



[HEINRICH ET AL, ARXIV:1312.6659]

- ▶ Important NLO corrections to the shape of m_{lb}
- ▶ Values of m_{lb} larger than $\sqrt{m_t^2 - m_W^2}$ are kinematically forbidden in narrow width approximation at LO

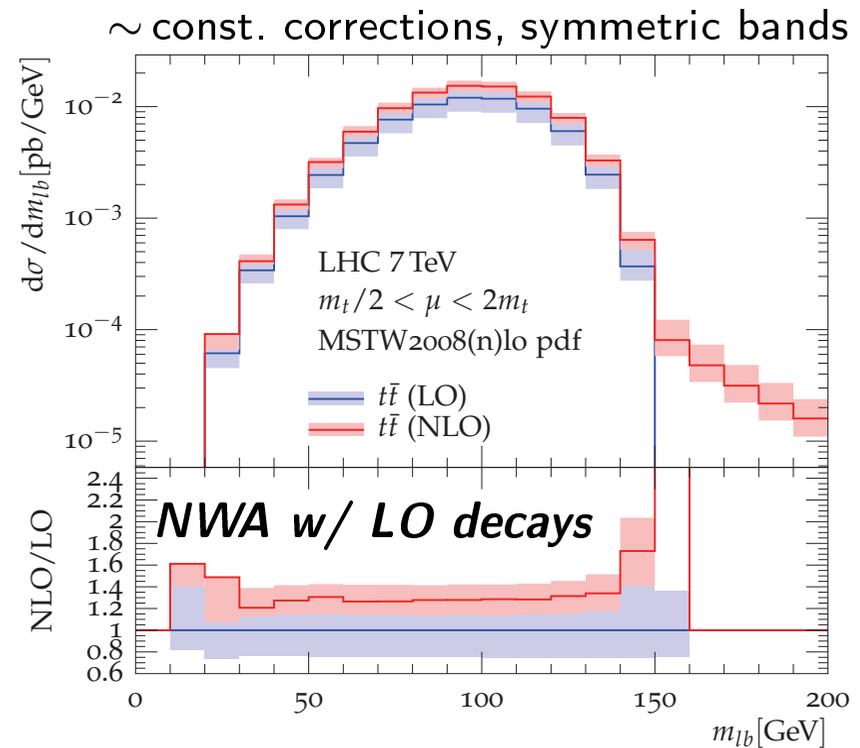
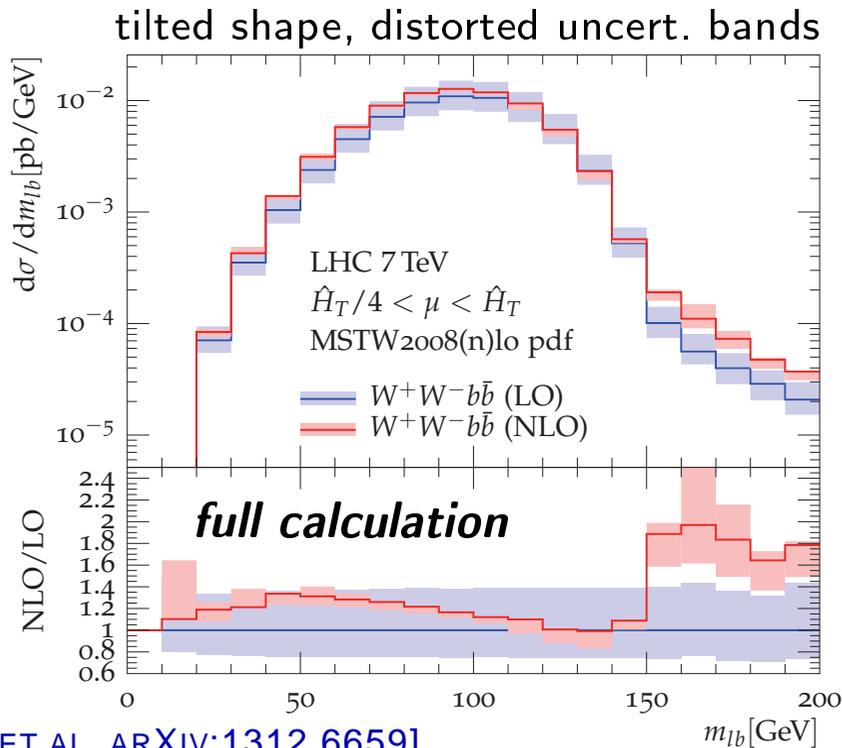
- follow ATLAS strategy: use charged-lepton b-jet pairing minimizing sum of both m_{lb} and average.



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Quick Summary.

Cutting edge parton-level calculations of NLO QCD corrections are available to describe more realistic, many-body final states! For $WWb\bar{b}$ production several modern NLO tools exist:

- MG5_aMCNLO, Frederix, arXiv:1311.4893 (b mass effects)
- OpenLoops+Sherpa, Cascioli et al, arXiv:1312.0546 (b mass effects)
 - GoSam+Sherpa, Heinrich et al, arXiv:1312.6659
 - Helac-NLO/PowHel, Garzelli et al, arXiv:1405.5859

Comparisons with NWA approaches & standard Monte Carlos help disentangle effects beyond the factorization and assess their relevance for phenomenology (on the inclusive level, the approximations work well, ...).

One example shown here concerning a system invariant mass:
Shape uncertainties from scale variations of the full NLO QCD corrections to $WWb\bar{b}$ production result in larger theory errors on the m_{lb} distribution than expected (-> impacting m_t measurements).

