NLO+PS $Wb\bar{b}$ and $Wb\bar{b}j$ at 100 TeV

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QCD, EW and tools at 100 TeV

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In collaboration with:

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Based on

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Introduction

- Wbb(j) production has interesting experimental and theoretical aspects:

  - Irreducible backgrounds to
    - H (H-> bb) W(j) production
    - Single top production

  - Theoretical aspects concerning the treatment of the b-quark mass: 4f scheme vs. 5f scheme

→ Here we present results for massive b-quarks

DISCLAIMER:
All results shown are very preliminary and with reduced statistics

Computational setup

- Computation performed within the POWHEG-BOX [Alioli, Oleari, Nason, Re]

- Processes publicly available in the POWHEG-BOX:

  - Wbb → massive b-quarks, approximate W boson decay [Oleari, Reina]

  - Wbb_dec
  - Wbbj

    → massive b-quarks, exact W boson decay into leptons [Oleari, Tramontano, GL]

  - Tree-level matrix elements via interface with MadGraph-4 [Stelzer, Long; Alwall et al.; Campbell, Ellis, Frederix, Oleari, Nason]

  - 1-loop matrix elements from BLHA interface with GoSam [Cullen, v. Deurzen, Greiner, Heinrich, Mastrolia, Mirabella, Ossola, Peraro, Schlenk, v. Soden-Fraunhofen, Tramontano, GL]

    -> reduction performed with Ninja, Samurai or Golem95
    [Mastrolia, Mirabella, Peraro] [Mastrolia, Ossola, Reiter, Tramontano] [Binoth, Cullen, Guillet, Heinrich, Kleinschmidt, Pilon]

    -> scalar loop integrals evaluated using OneLoop [v. Hameren]

Physical setup

- Runs were performed with the following setup:
  - Center-of-mass energies of 7, 14 and 100 TeV
  - b-quark mass: m_b = 4.75 GeV
  - PDF: MSTW2008nlo
  - CKM:

$$V_{\mathrm{CKM}} = \begin{array}{c} \\ u \\ c \\ t \end{array} \begin{array}{c} \begin{array}{ccc} d & s & b \end{array} \\ \begin{pmatrix} 0.97428 & 0.2253 & 0.00347 \\ 0.2252 & 0.97345 & 0.041 \\ 0.00862 & 0.0403 & 0.999152 \end{pmatrix} \end{array}$$

  - Jets: reconstructed with anti-k_T algorithm:
    - R = 0.7
    - $p_{T,min}$ = 1, [50, 100] GeV
    - $p_{T,min\ b\text{-}jet}$ = 0, [50] GeV

default values in black, variations in grey

  - Shower settings: PYTHIA 6.4.25 with AMBT1 tune [PYTUNE(340)]

[Sjöstrand, Mrenna, Skands]

Choice of scales

- Wbb:
  - renormalization and factorization scales set equal to

$$\mu_{\rm R} = \mu_{\rm F} = \mu \equiv \frac{E_B}{4} \quad \text{where} \quad E_B = \sqrt{\hat{s}} \quad \text{and} \quad \hat{s} = (p_{\rm W} + p_{\rm b} + p_{\bar{\rm b}})^2$$

- Wbbj:
  - renormalization and factorization scales set according to MiNLO, where we have the freedom to choose only the primary scale [Hamilton, Nason, Zanderighi]

→ if a clusterization happens: the primary scale is set equal to E_B
(the momenta $p_{\rm W}$, $p_{\rm b}$ and $p_{\bar{\rm b}}$ are now the ones of the primary process)

→ if no clusterization happens: consider the partonic center-of-mass energy of the event

⇨ This choice was shown to give good agreement between **Wbb** and **Wbbj+MiNLO** at 7 TeV in [1502.01213]

Wbb vs. **Wbbj+MiNLO**

- For processes where the lowest multiplicity consists of only one colorless final state object **V**, a modified MiNLO procedure allows to recover NLO accuracy for fully inclusive quantities from **Vj+MiNLO** (i.e when also **j** becomes soft or collinear).

  [Hamilton, Nason, Oleari, Zanderighi]

- Such a modification is not known for the case presented here. Nevertheless the NLO+PS **Wbbj+MiNLO** sample gives a finite cross section also when the additional jet is unresolved.

→ Interesting to compare the agreement between **Wbb** and **Wbbj+MiNLO** for observables with different degrees of inclusiveness.

Total cross section at NLO+PS with MiNLO

- No transverse momentum cut on b-quark jets:

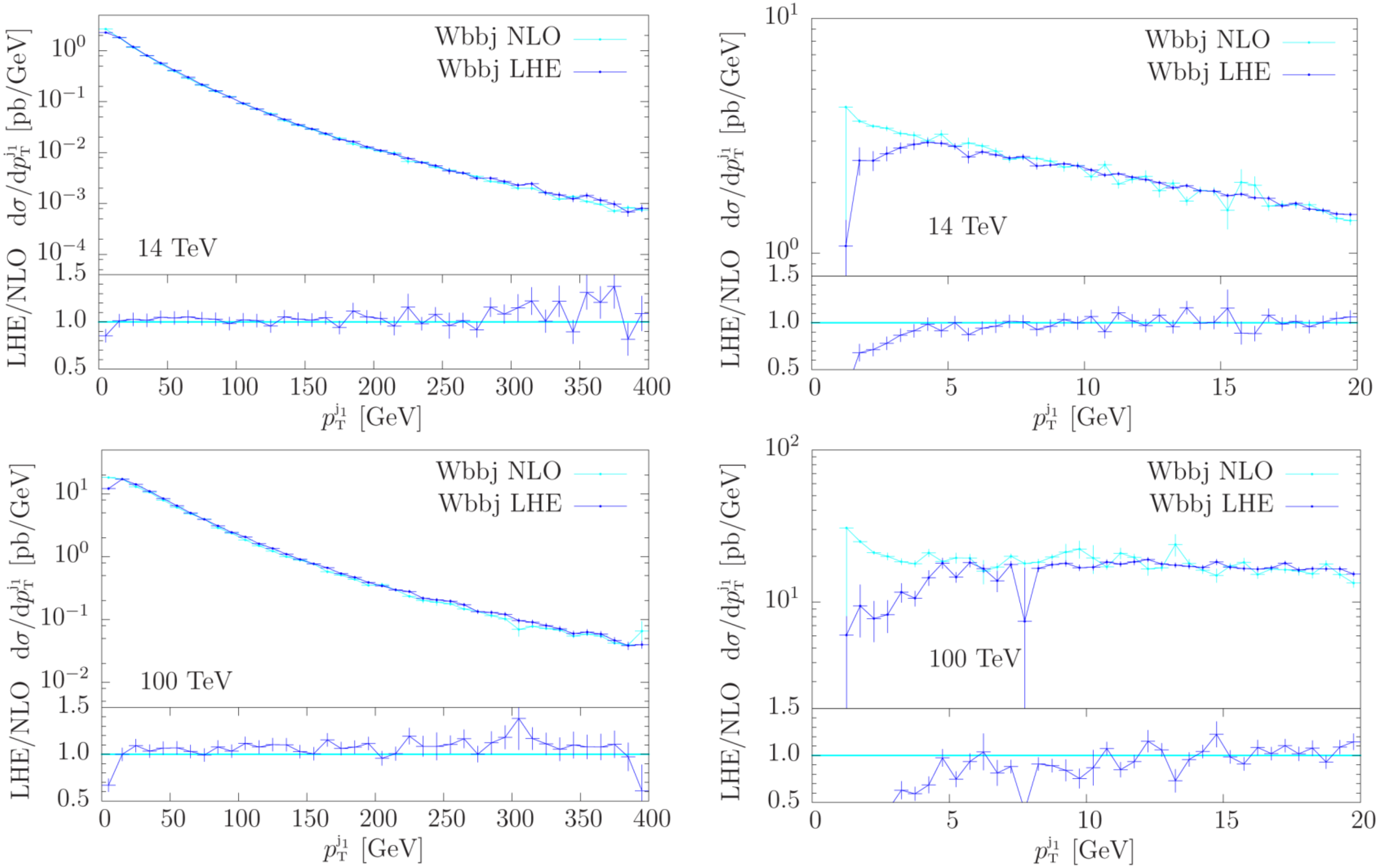
Process	14 TeV	100 TeV
Wbb	$67.0^{+13.9}_{-10.6}$ pb	738^{+167}_{-125} pb
Wbbj	$85.8^{+28.0}_{-19.3}$ pb	977^{+280}_{-201} pb

- For $p_T^b > 50\ \mathrm{GeV}$:

Process	14 TeV	100 TeV
Wbb	$0.96^{+0.18}_{-0.14}$ pb	$20.7^{+4.37}_{-3.32}$ pb
Wbbj	$1.30^{+0.19}_{-0.17}$ pb	$29.6^{+5.73}_{-4.83}$ pb

Wbbj: comparison NLO vs. LHE

- Comparison of NLO distributions with MiNLO and LH events where the first hard emission was generated with POWHEG



Wbbj: comparison NLO vs. LHE

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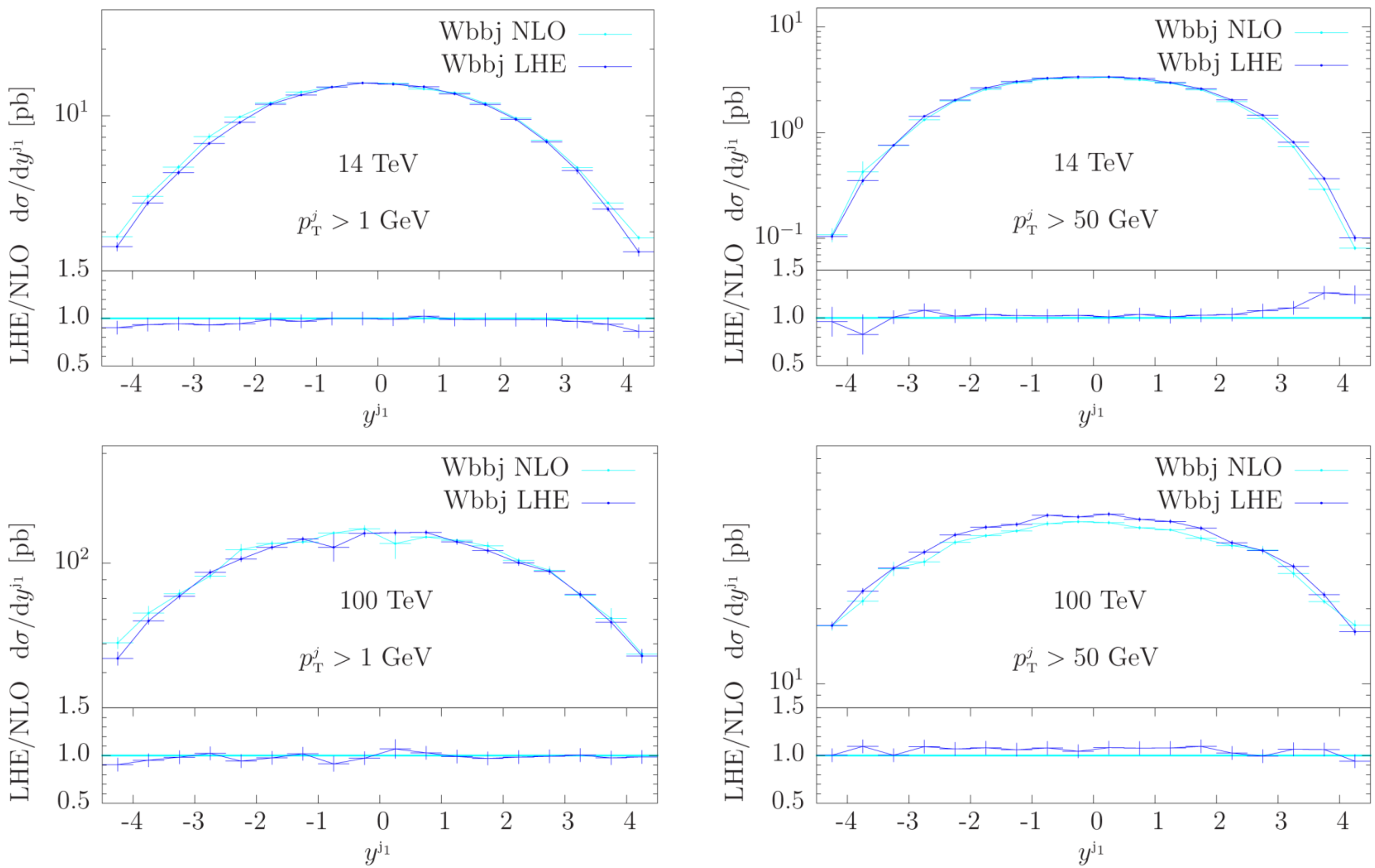

Wbbj: comparison NLO vs. LHE

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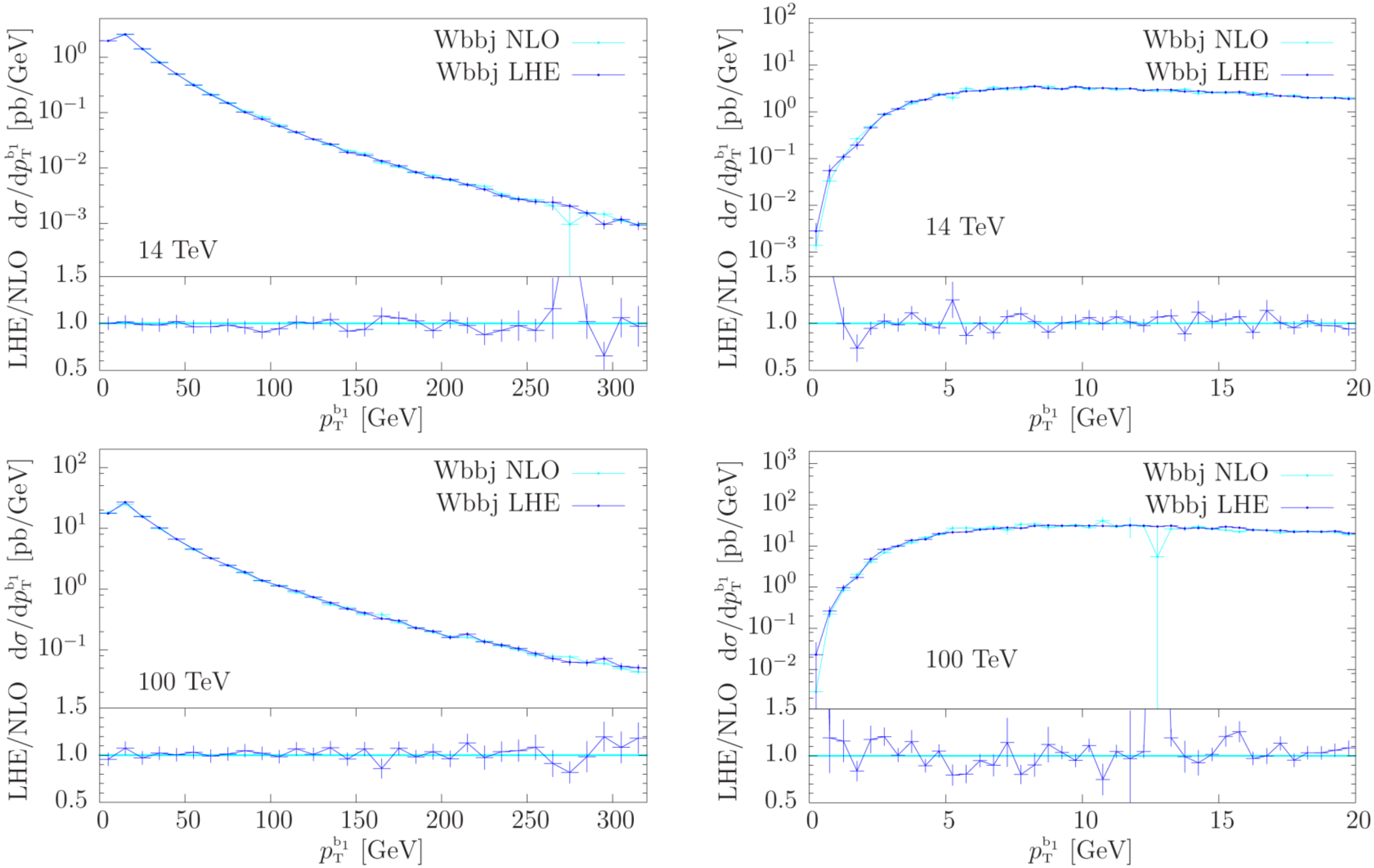

Wbbj: comparison NLO vs. LHE

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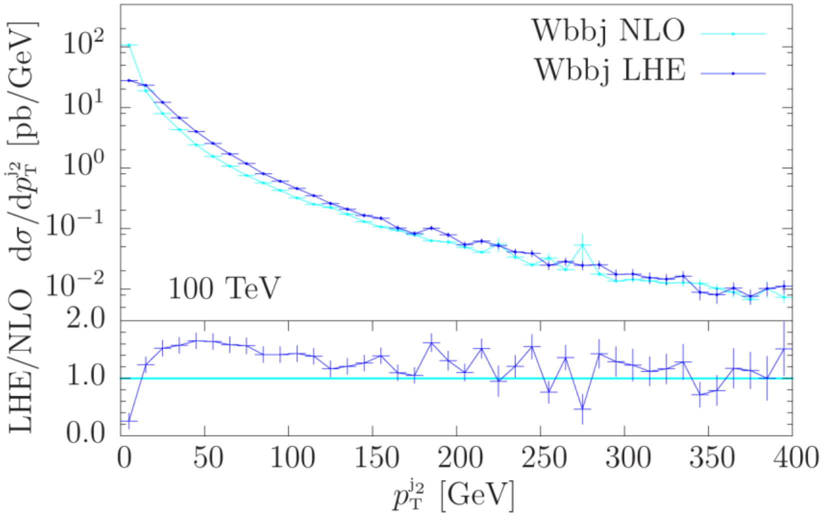
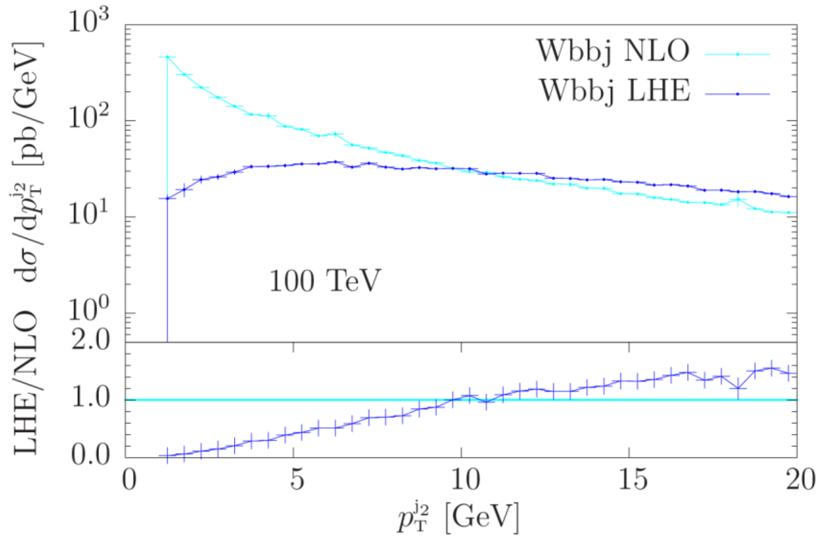




- Second hardest jet p_T is finite at LHE level thanks to the POWHEG Sudakov form factor.

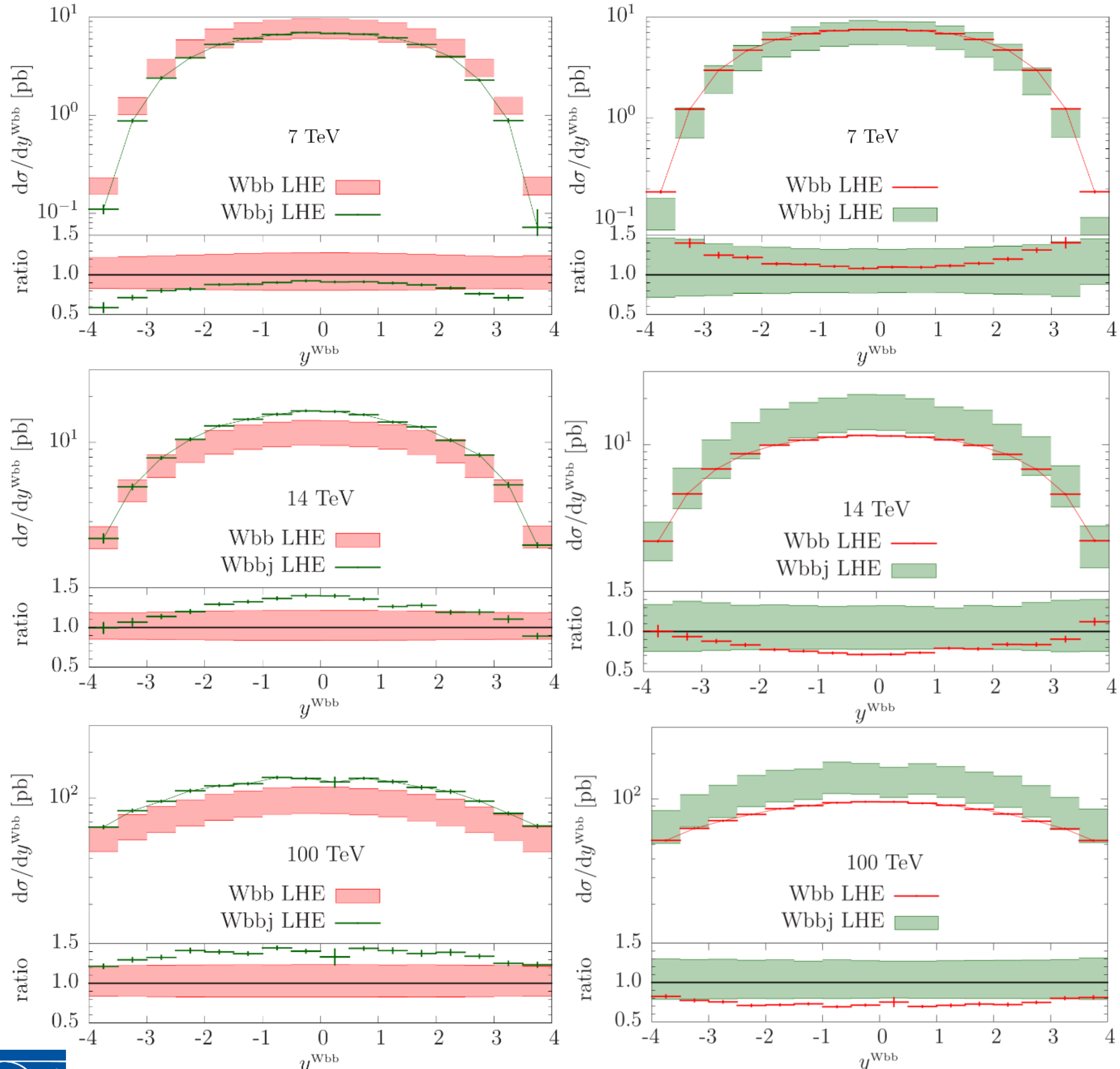
Wbb vs. **Wbbj+MiNLO**

- To investigate the level of agreement between **Wbb** and **Wbbj+MiNLO** perform comparison considering scale variation

→ Band for **Wbb** and **Wbbj+MiNLO** obtained by a 7 point variation of renormalization and factorization scale:

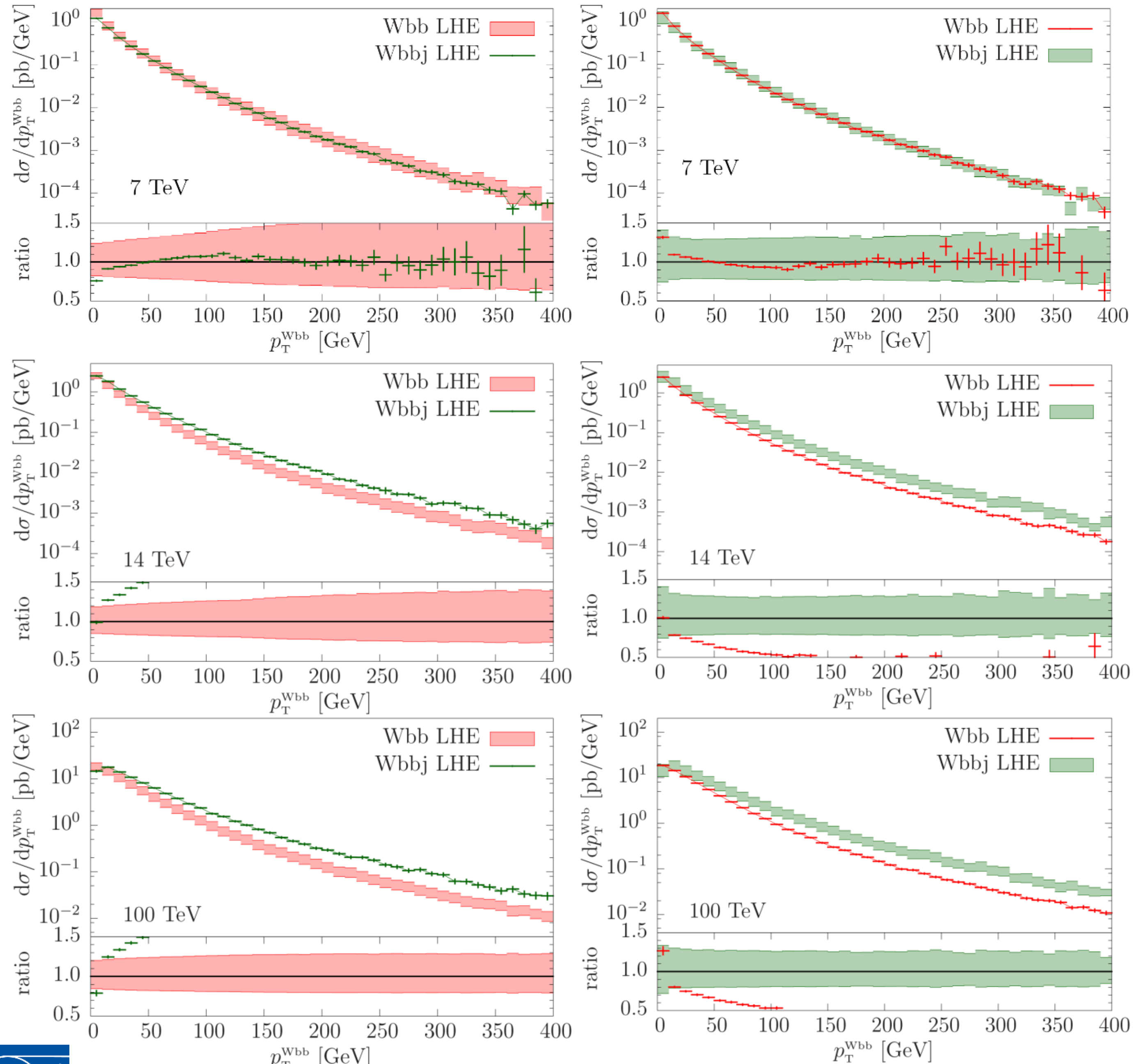
$$(K_{\mathrm{R}}, K_{\mathrm{F}}) = (0.5, 0.5), (0.5, 1), (1, 0.5), (1, 1), (2, 1), (1, 2), (2, 2)$$

and considering the envelope of the results for both **Wbb** and **Wbbj+MiNLO**



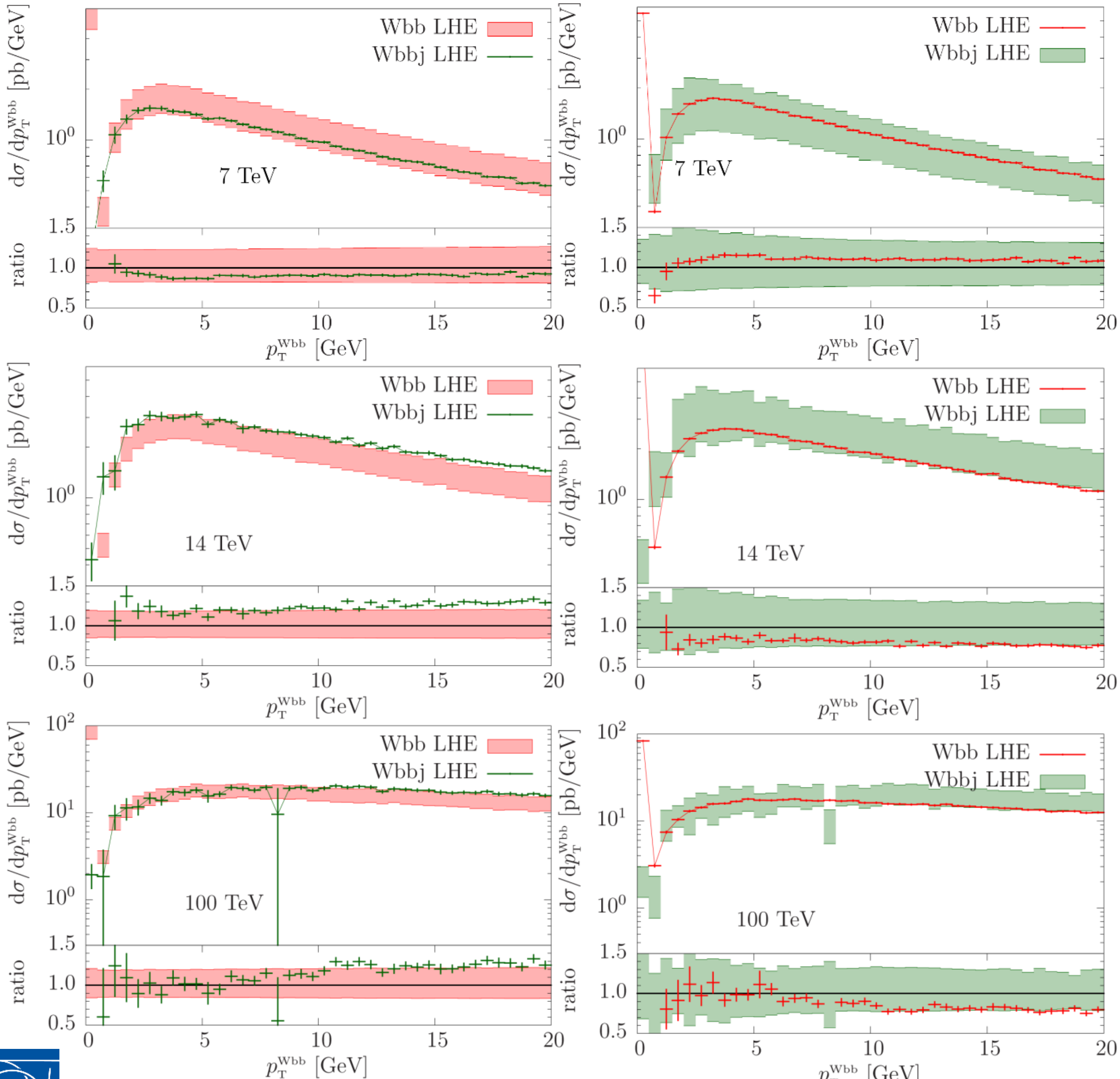
- y^{Wbb}:
  described at NLO by Wbb generator

Within the uncertainty band the agreement is reasonably good also for 14 and 100 TeV



- p_T^{Wbb} :
described only at LO by Wbb generator

- slight decrease in the uncertainty band when going from a LO (Wbb) to a NLO (Wbbj) prediction

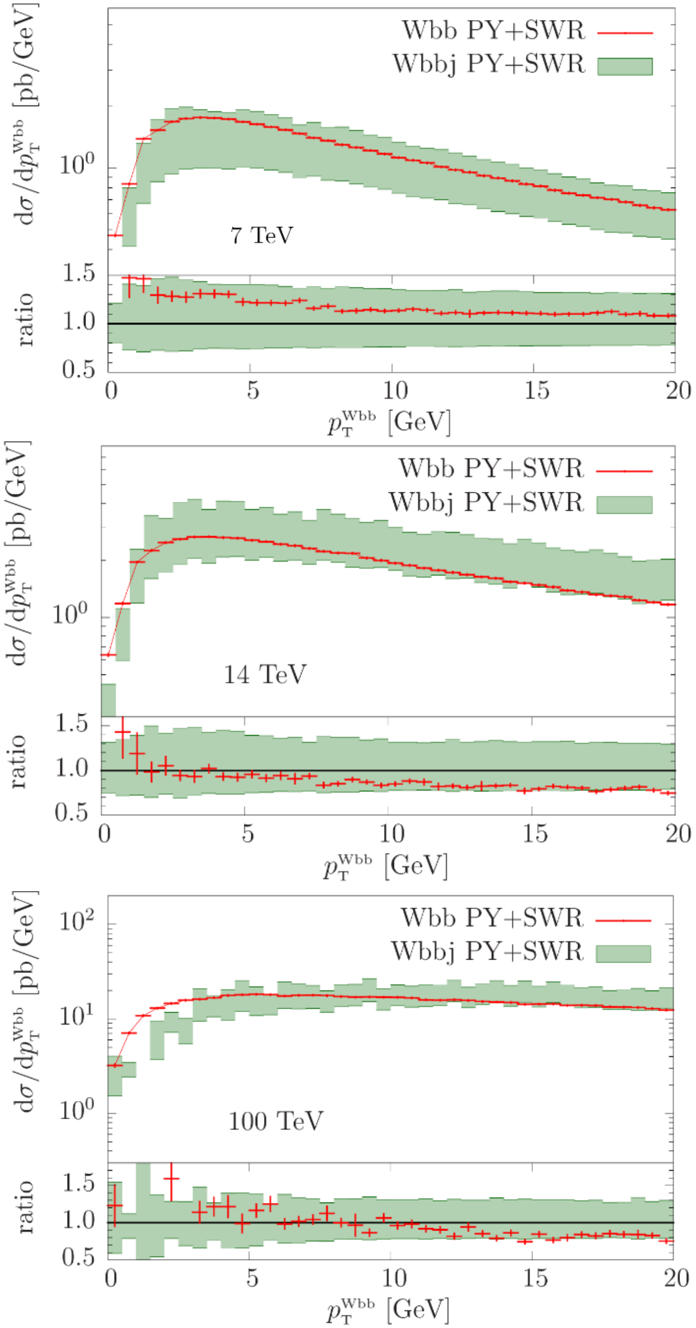


- p_T^{Wbb} :
  described only at LO by Wbb generator

In small p_T^{Wbb} region:

Wbb finite because of the POWHEG Sudakov form factor

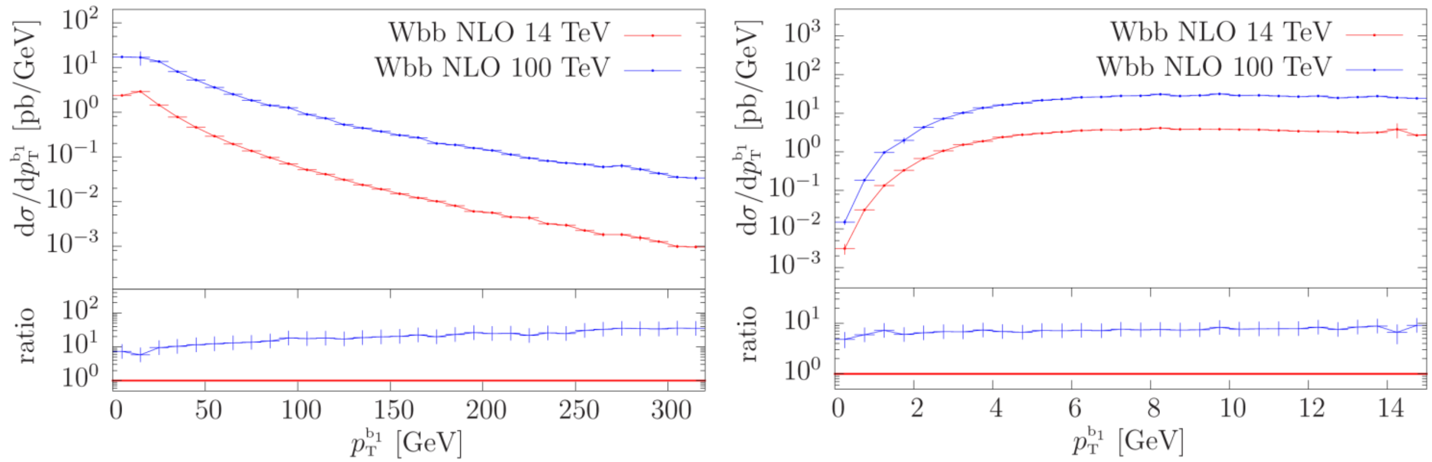
Wbbj+MiNLO finite because of MiNLO and POWHEG Sudakov for factor



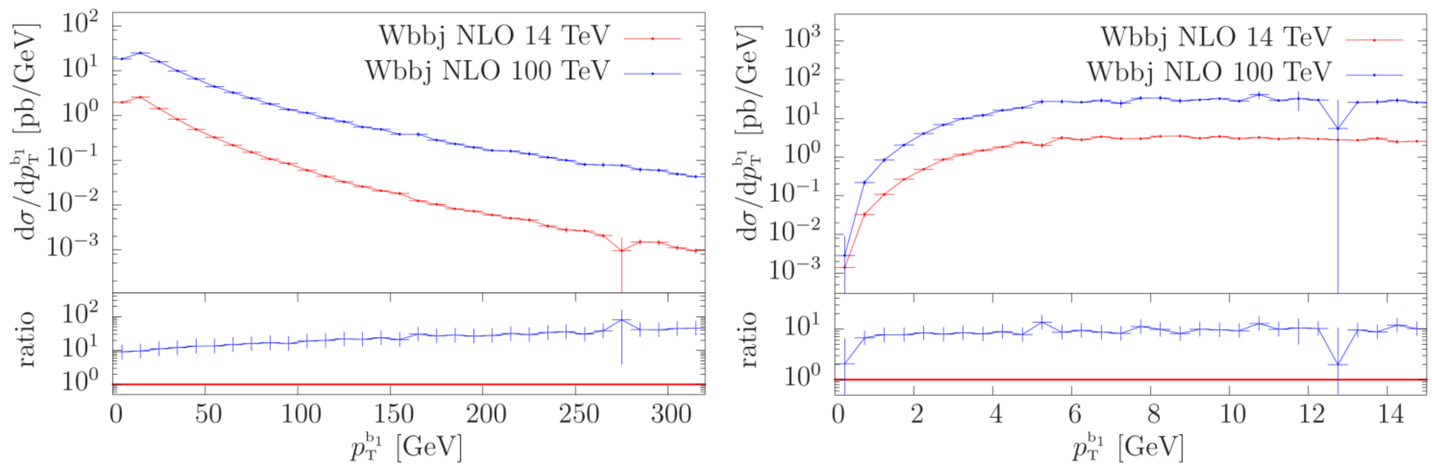
Finite contribution present in first p_T-bin for **Wbb** in LHE distribution due to events that have not radiated at the LHE level.
When full shower is performed these events are washed away.

14 vs. 100 TeV: direct comparison

- Leading b-quark transverse momentum:
  - Wbb:



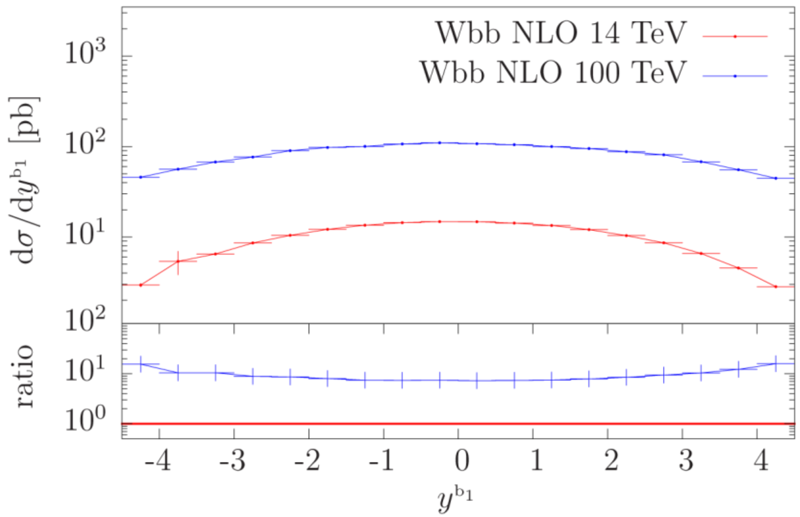
  - Wbbj:

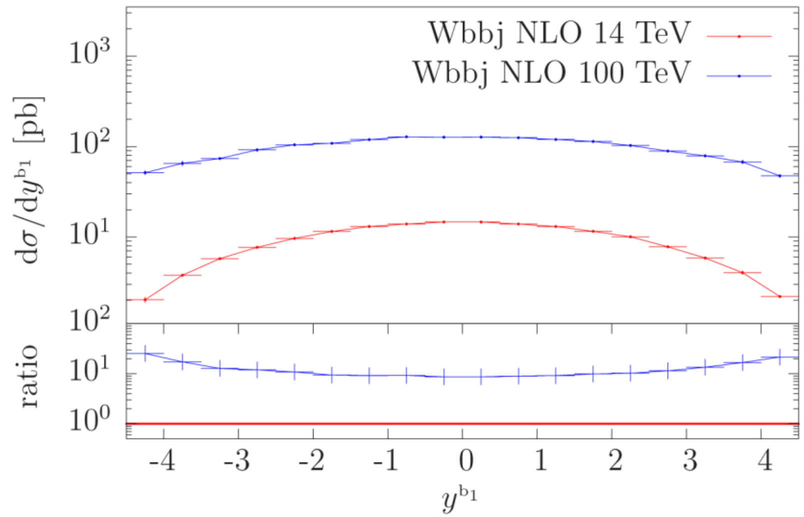


→ High p_T tail is increased by roughly the same amount in Wbb and Wbbj

14 vs. 100 TeV: direct comparison

- Leading b-quark rapidity:

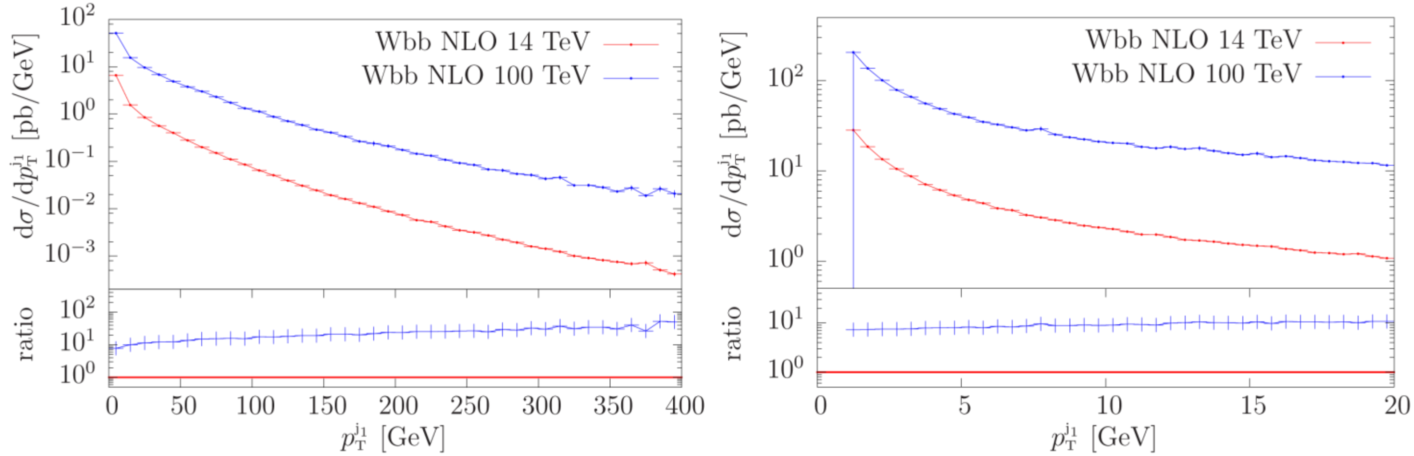




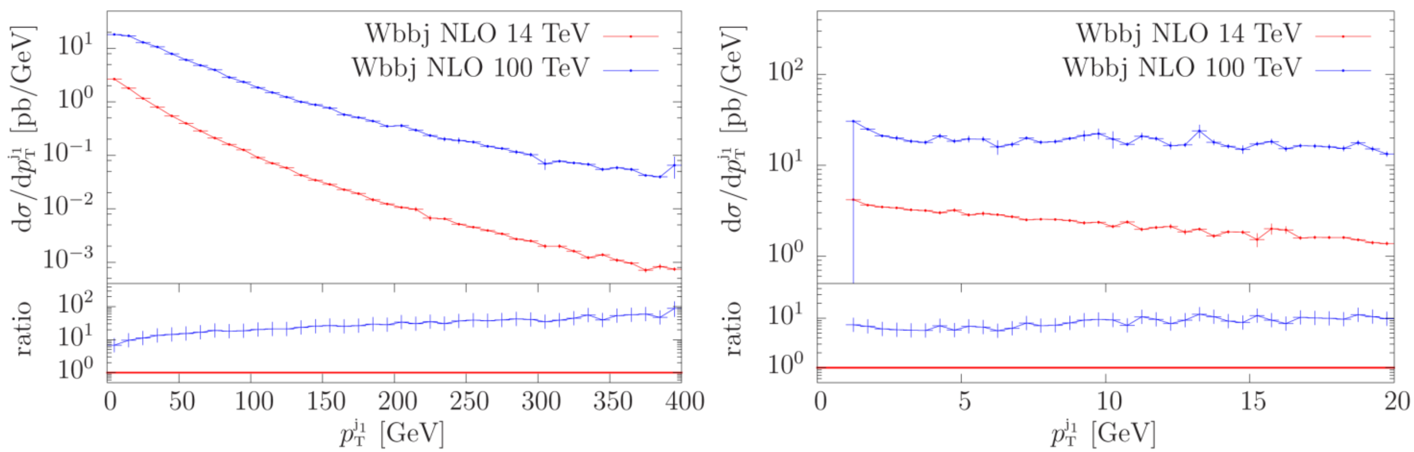
- Wbb-system produced at higher rapidities at 100 TeV
- **Wbb** and **Wbbj+MiNLO** have overall very similar behavior

14 vs. 100 TeV: direct comparison

- Hardest jet transverse momentum
  - Wbb:



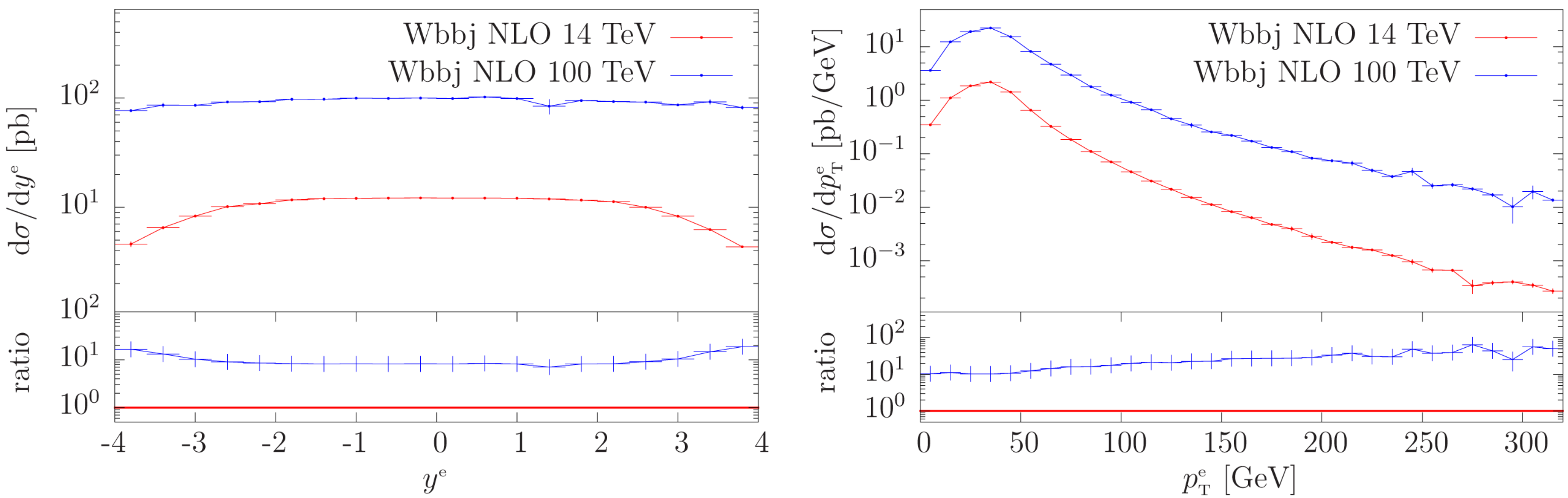
  - Wbbj:



  - Analogous ratio but at low p_T the predictions for Wbb are divergent

14 vs. 100 TeV: direct comparison

- Charged lepton distributions for Wbbj:



Conclusions

- Presented results at 7, 14 and 100 TeV for **Wbb** and **Wbbj** using in the POWHEG-BOX interfaced to GoSam featuring:
  - exact spin correlation for W decay into leptons implemented
  - possibility to apply MiNLO procedure to Wbbj

[ArXiv: 1502.01213]

- Codes can be downloaded from: http://powhegbox.mib.infn.it/

  (Processes names: Wbb_dec ; Wbbj)

- Preliminary comparison of 14 and 100 TeV results shows:
  - good agreement between **Wbb** and **Wbbj+MiNLO** predictions for inclusive observables
  - similar ratios between 14 and 100 TeV for **Wbb** and **Wbbj+MiNLO**
  - at 100 TeV final state particle are harder and more forward wrt 14 TeV

- But several other interesting things can still be studied..