Tools and Monte Carlo Working Group Report

Convenors:

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Les Houches workshop, June 9, 2015

✦ Apologies for overlap with other summary talks and omissions!

TTBAR+JETS COMPARISON

- With the statistical accuracy reached at the LHC, **top pair production is a new benchmark process**
- Currently, already a lot of efforts being made within the experimental communities to assess systematic uncertainties in MC modelling.
  - For example, for the top mass, one of the dominant uncertainties is the modelling of radiation
  - The top pT spectrum is badly modelled
- Also ttbar+jets is the dominant background to ttbar+Higgs production, and the dominant uncertainty

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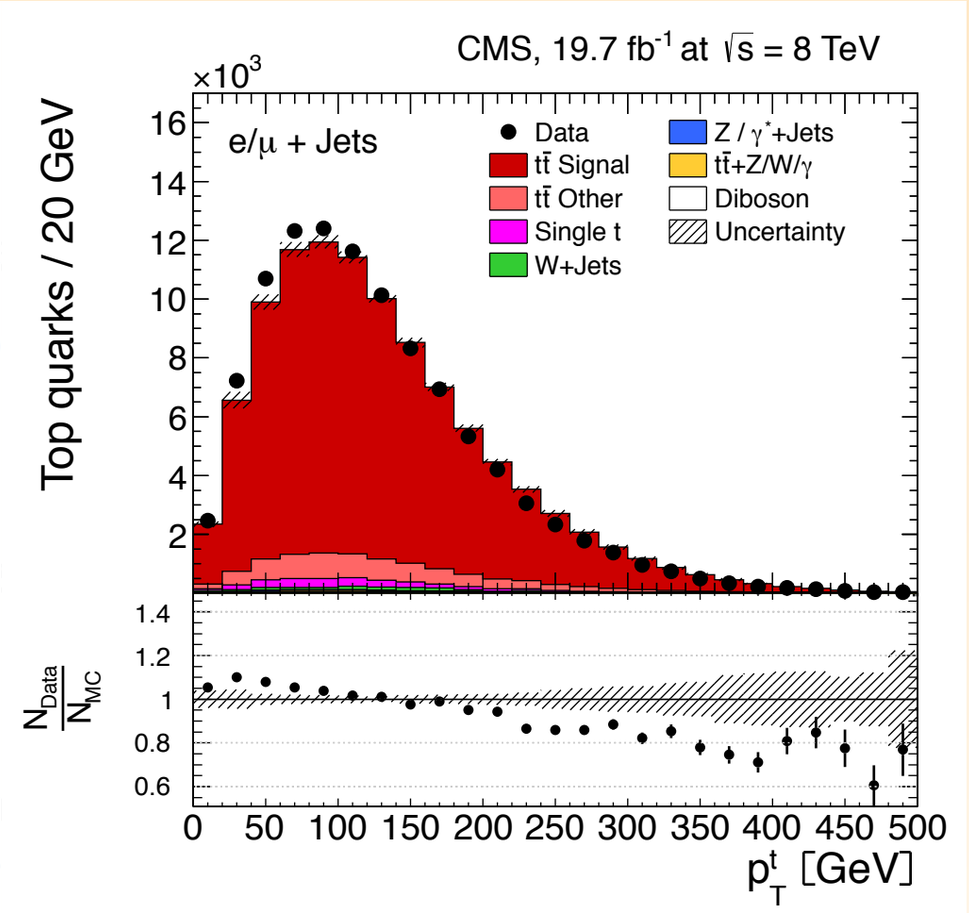


TTBAR+JETS COMPARISON

- Agreement has been made on the generator setup and observables to study; analysis routine is being written
  - On June 15 there will be a ttH/tH subgroup of LHCHXSWG meeting dedicated to MC validation/simulations within ATLAS & CMS
  - Probably after that, we can finalize the analysis and start making the predictions
- Extensive list of simulation programs and methods, MadGraph5_aMC@NLO, Sherpa, OpenLoops, MEPS@NLO, Herwig++, Pythia8, UNLOPS, FxFx merging, POWHEG, …
- CMS has agreed that we can use some of their event samples to perform this analysis. ATLAS hasn't agreed just yet…

Observables:

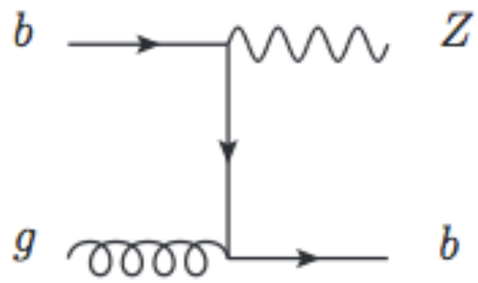
- pT(top)
- pT(ttbar)
- pT(ttbar+jet)
- m(t,tbar)
- m(top)
- DeltaPhi(l1,l2)
- DeltaPhi(lj1,lj2)
- m(b1,b2)
- # of jets
- # of b-jets
- # of light jets
- pT(j1), pT(j2), pT(j3), pT(j4)
- pT(b1), pT(b2), pT(b3), pT(b4)
- pT(lj1), pT(lj2), pT(lj3), pT(lj4)
- asymmetries:
  - lepton
  - ttbar
- Gap fraction: Q0, inclusive in Delta y
- tt+jets as background to ttH. Input from the

LesHouches2015, wiki

5-flavour vs 4-flavour in Z+b(b)

Emerging pattern:

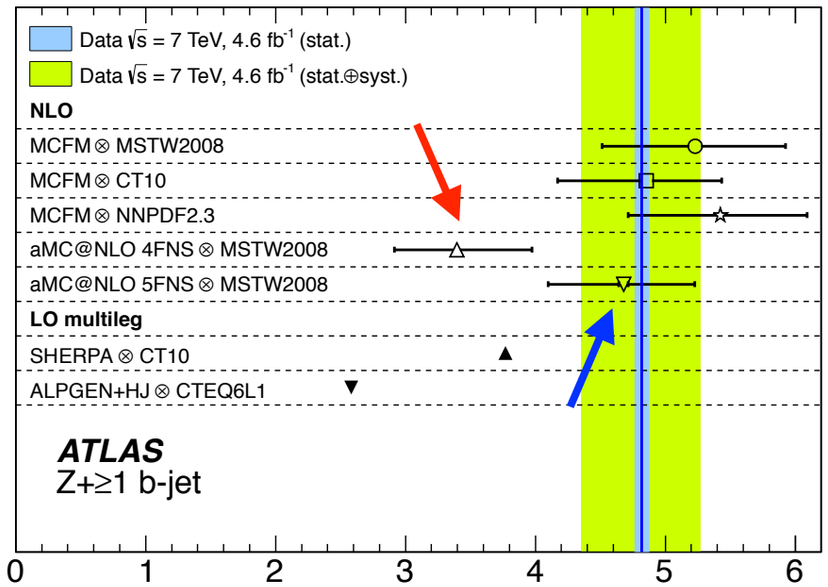
- 5-flavour is better for Z+1b
- 4-flavour is better for Z+2b

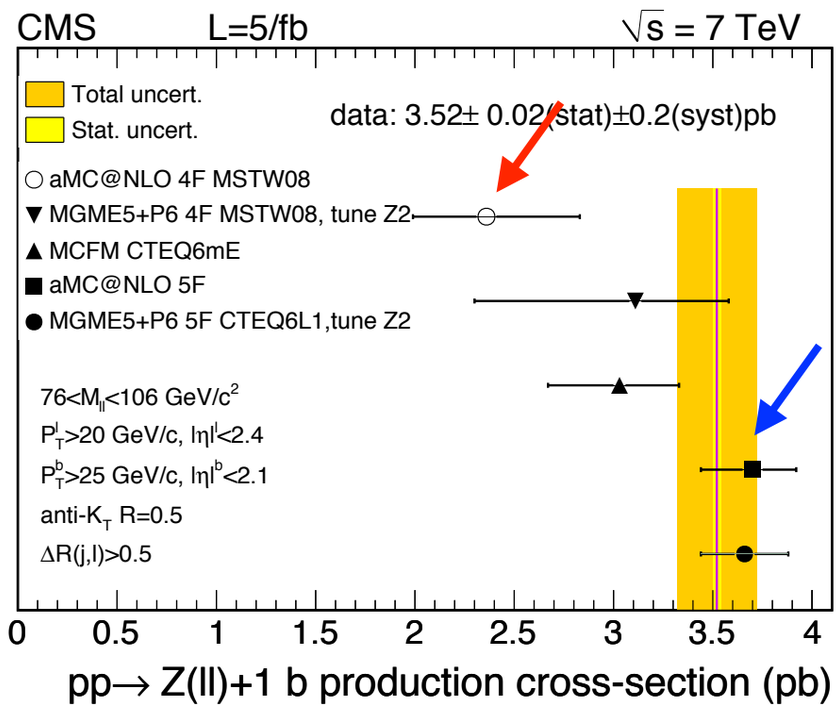


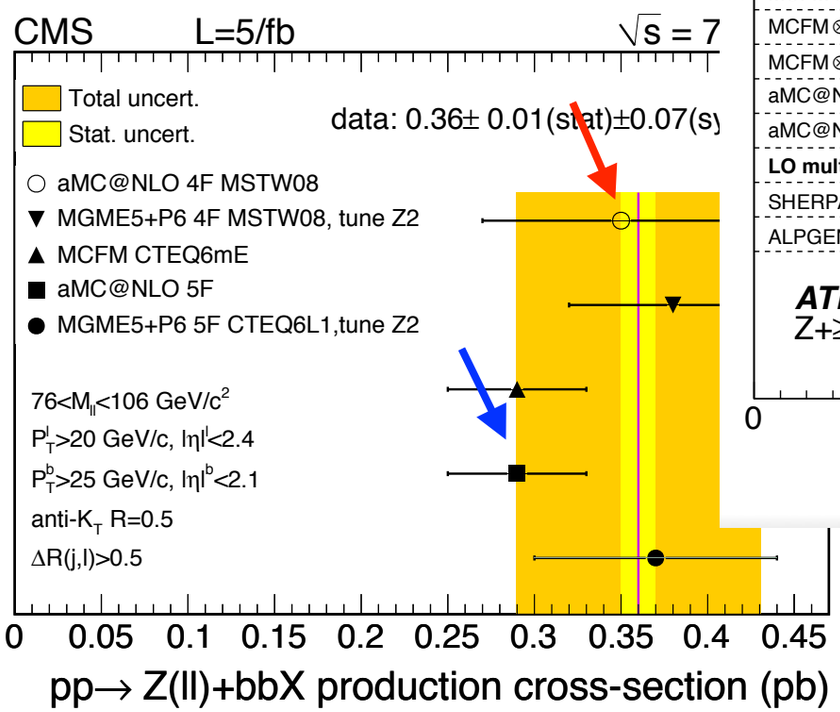
at least for aMC@NLO…

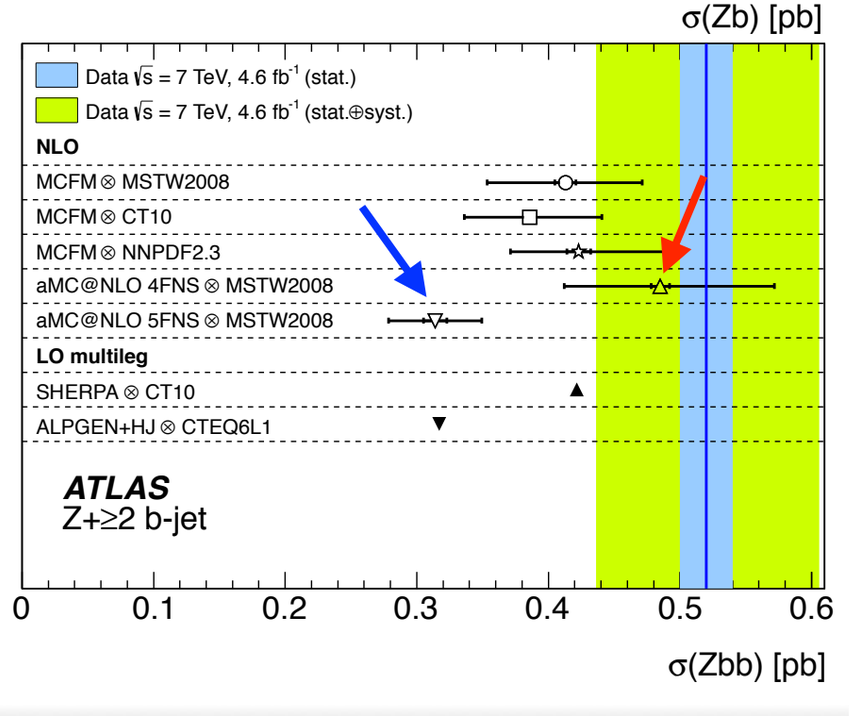
Somewhat reasonable but is it fully understood?

What must be used to evaluate background e.g. for ZH?









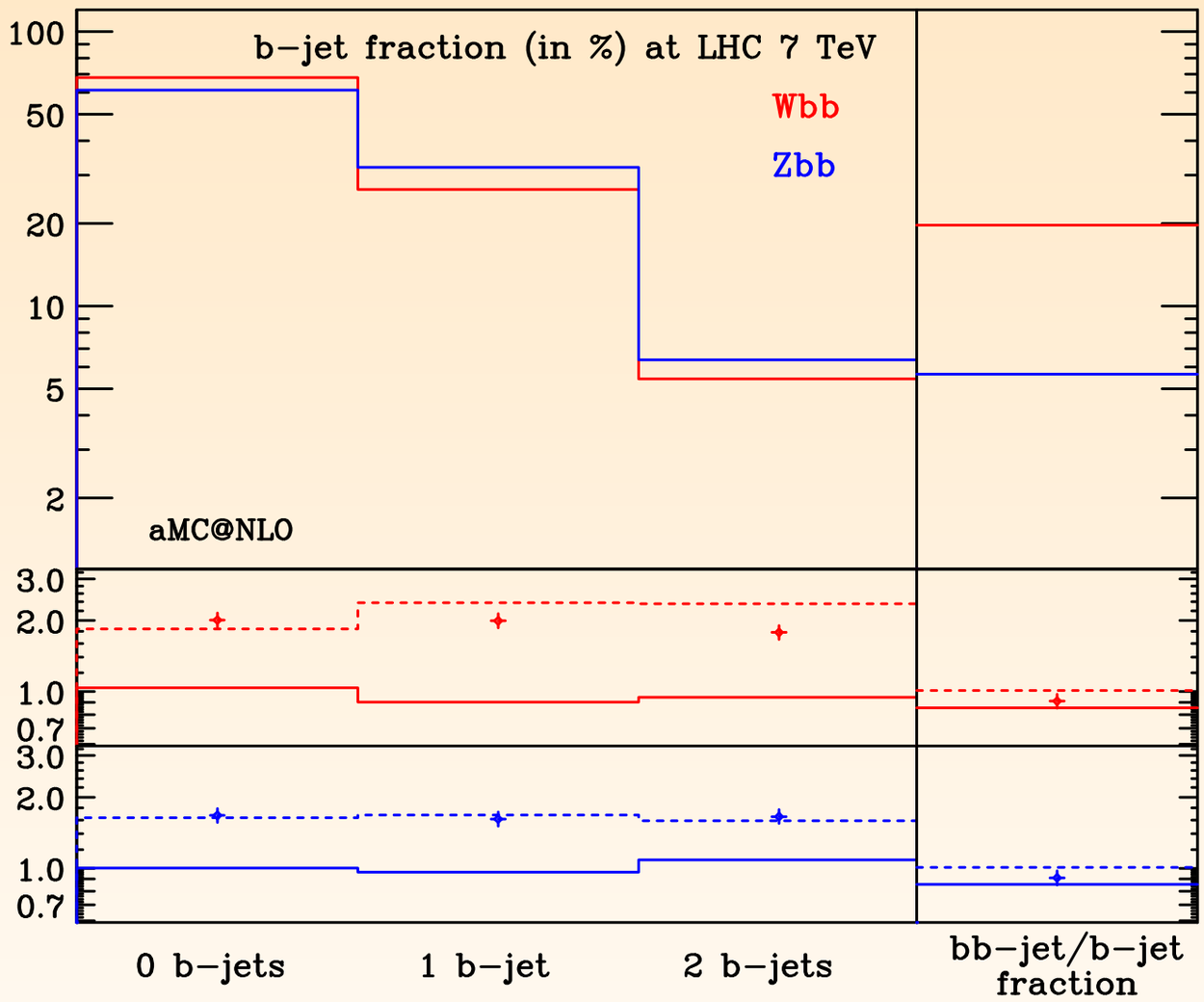
4/5 FLAVOUR SCHEMES

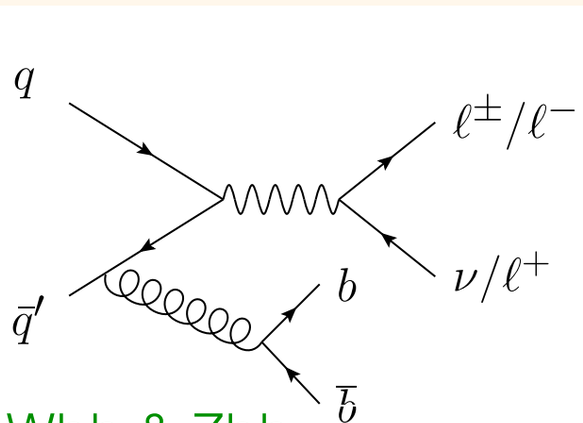
- Idea: perform a careful study on the differences between 4F and 5F scheme calculations
  - Study both Zb(b) and Wb(b). Important differences in kinematics! (see next slide)
  - Both at particle level (after hadronisation) and parton level (before or after shower)
  - Predictions from Powheg (Wbb 4F only), Sherpa, and MG5_aMC will be generated… others are still welcome
- Interest by Gavin Hesketh, Vitaliano Ciulli, RF, Marek Schoenherr, Paolo Francavilla, Gionata Luisoni, Davide Napoletano, Carlo Pandini, Frank Krauss …

BB-JETS IN 4 FLAVOUR

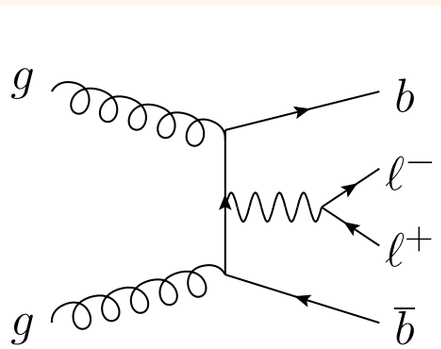
- Fraction of events containing 0, 1 and 2 b-jets for Wbb and Zbb processes in the 4-flavour scheme, at NLO+PS accuracy
- Important differences due to different kinematic structures
- Not obvious if shower approach (which resums large logs), or fixed order (which take mass effects correctly into account) is the better description

RF et al., 2011





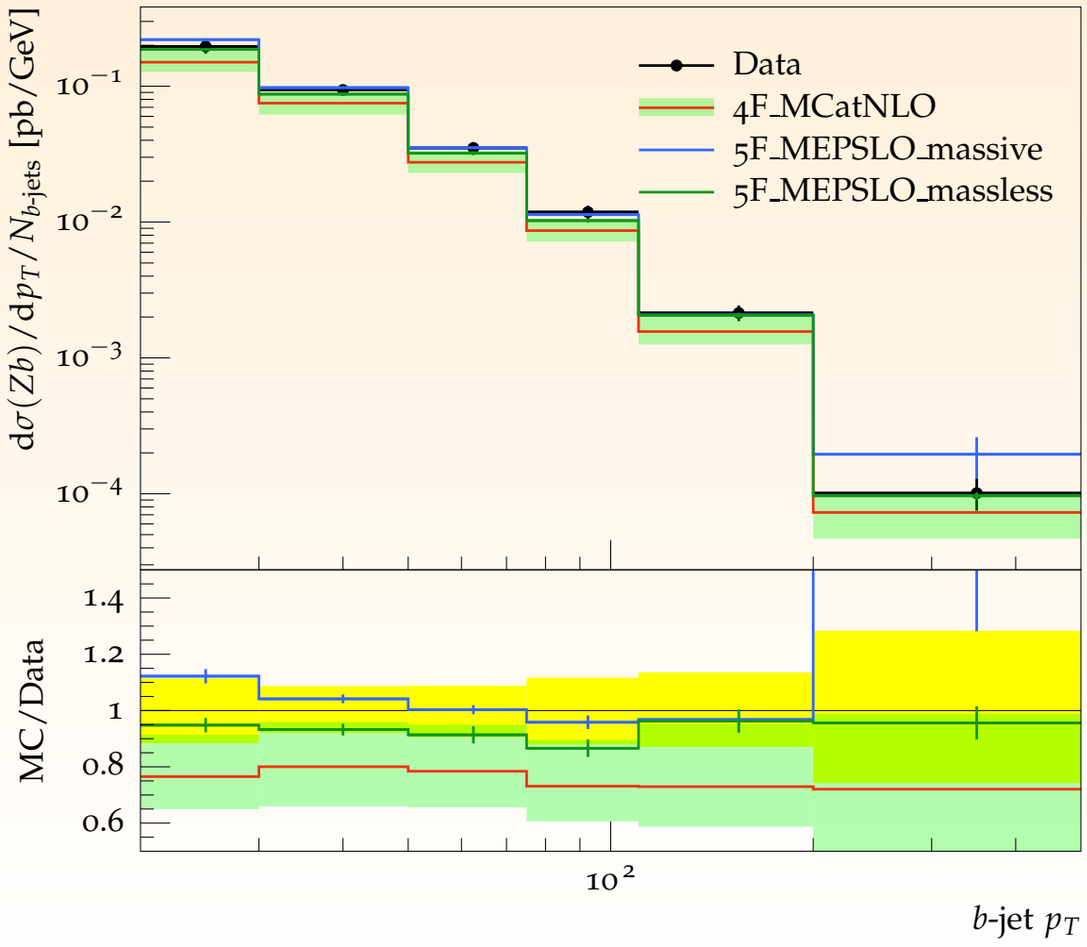
Wbb & Zbb

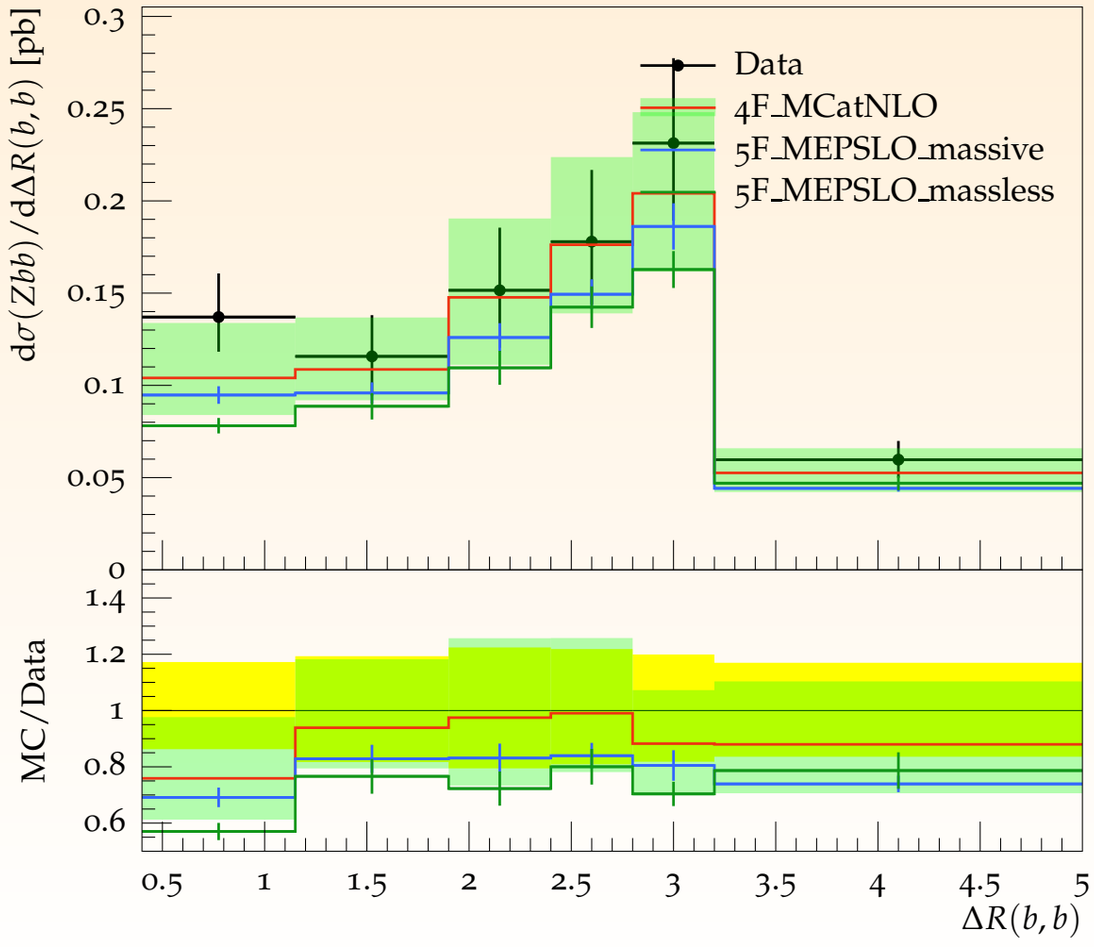


only Zbb

First results

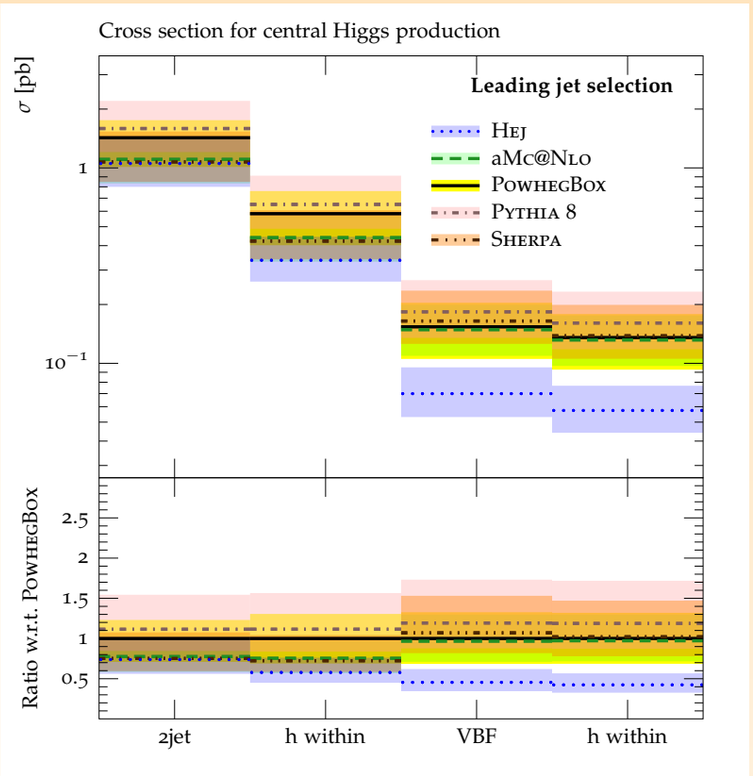
- First results look promising: pT(b-jet) is well-modelled; no significant differences in shape for 5F and 4F
- All predictions agree with each other also at small DeltaR(b,b): no sign for the need of resummation or inclusion of mass effects
  - although maybe undershooting the data a bit there
- Thanks to Davide Napoletano for the plots

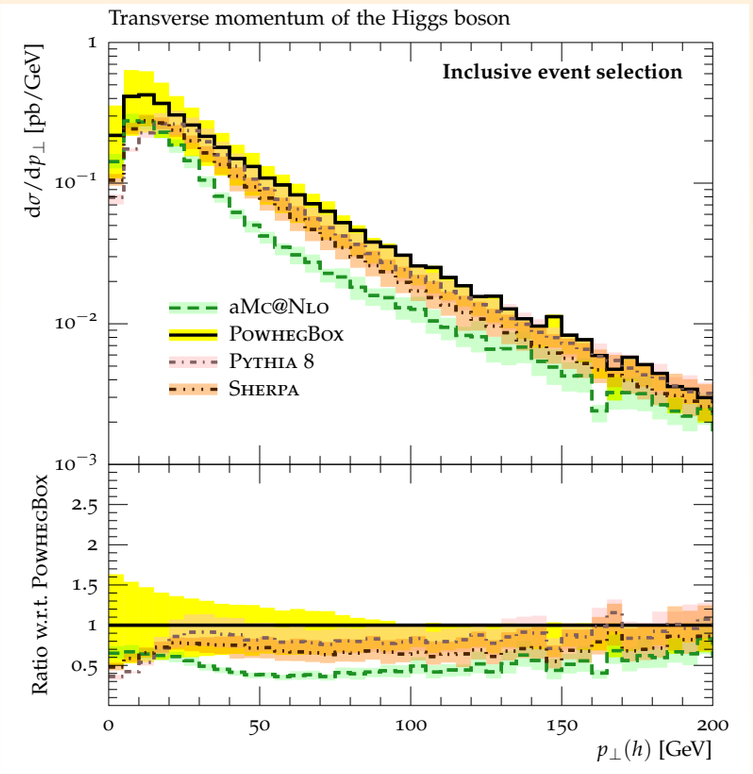




Les Houches, 2013

Higgs+jets



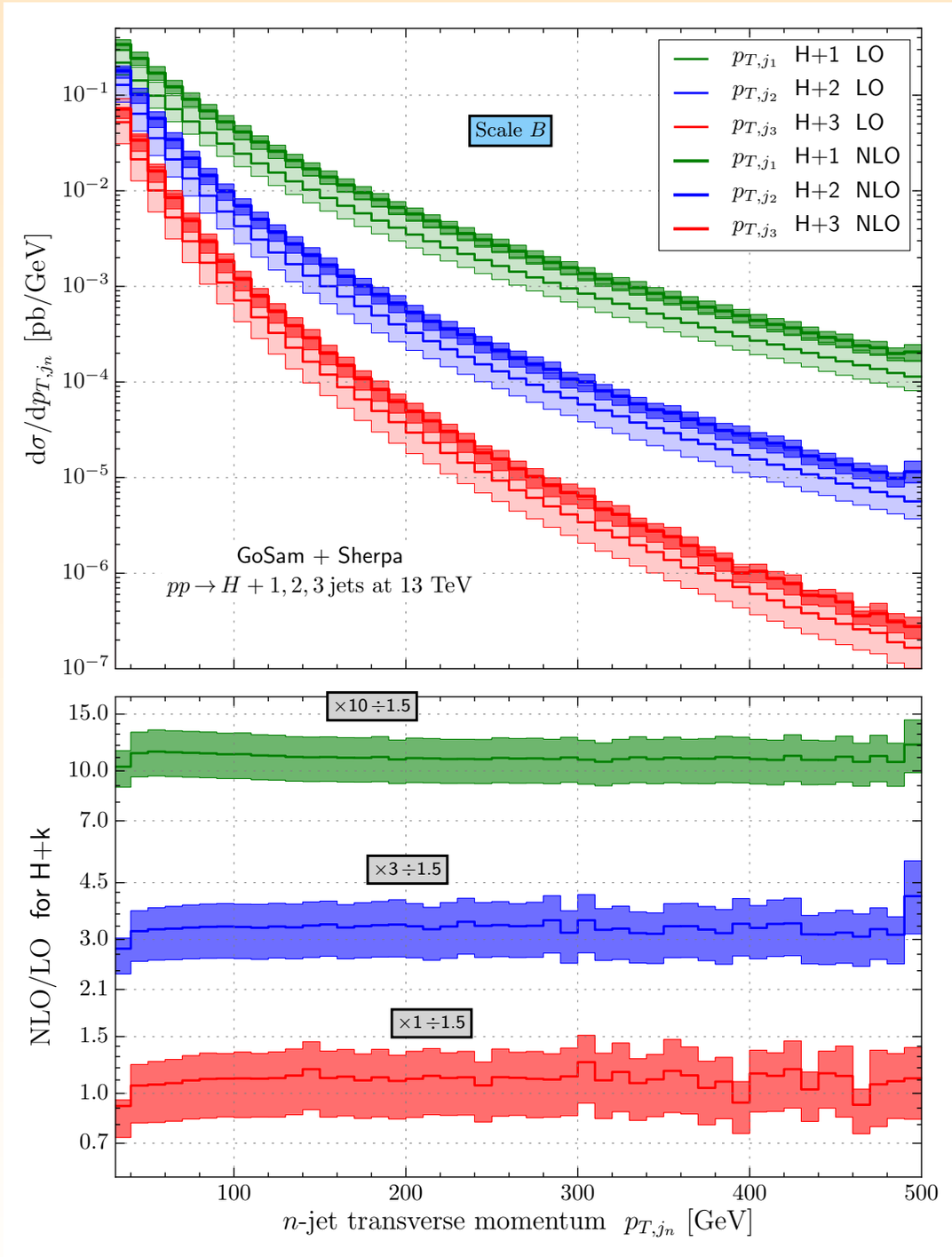


- At last Les Houches, a comparative study for Higgs (+jets) has been made at the NLO+PS level, including merging for various multiplicities
- In general, good agreement has been found between the various codes
- Missing in previous comparison is to compare to higher order calculation with/without (analytic) resummation
- Common project with SM group

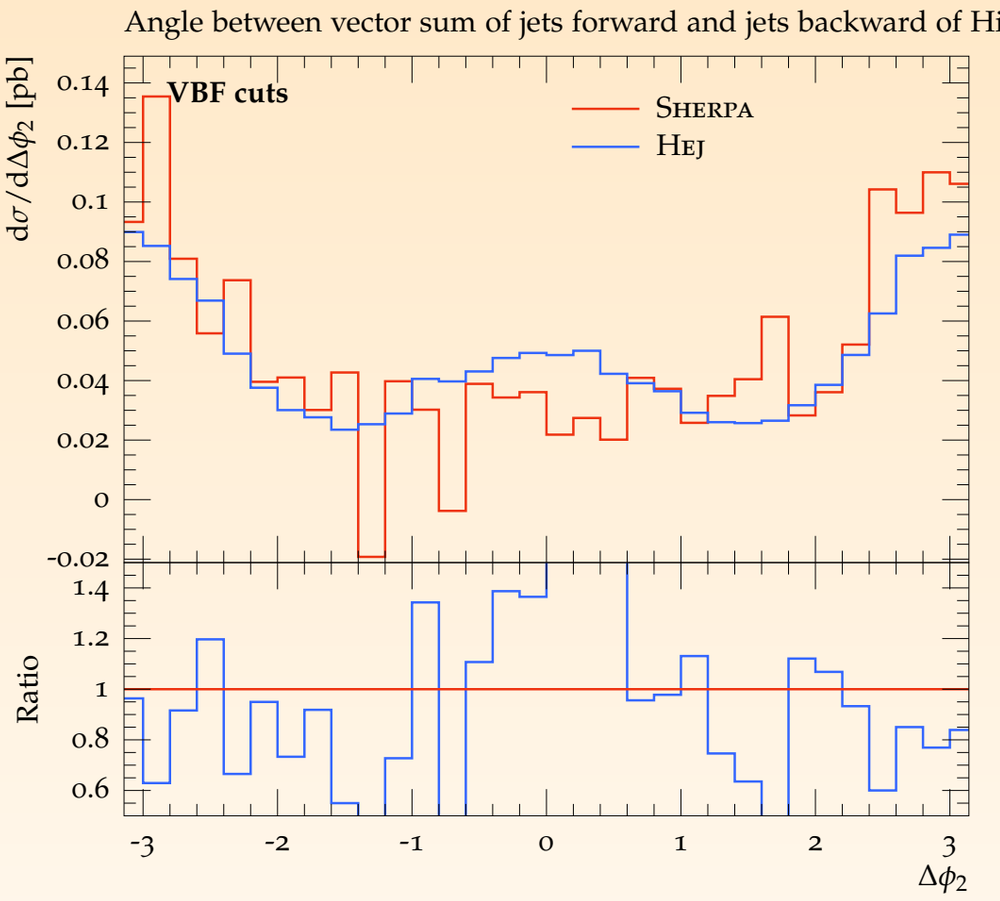
Higgs+jets

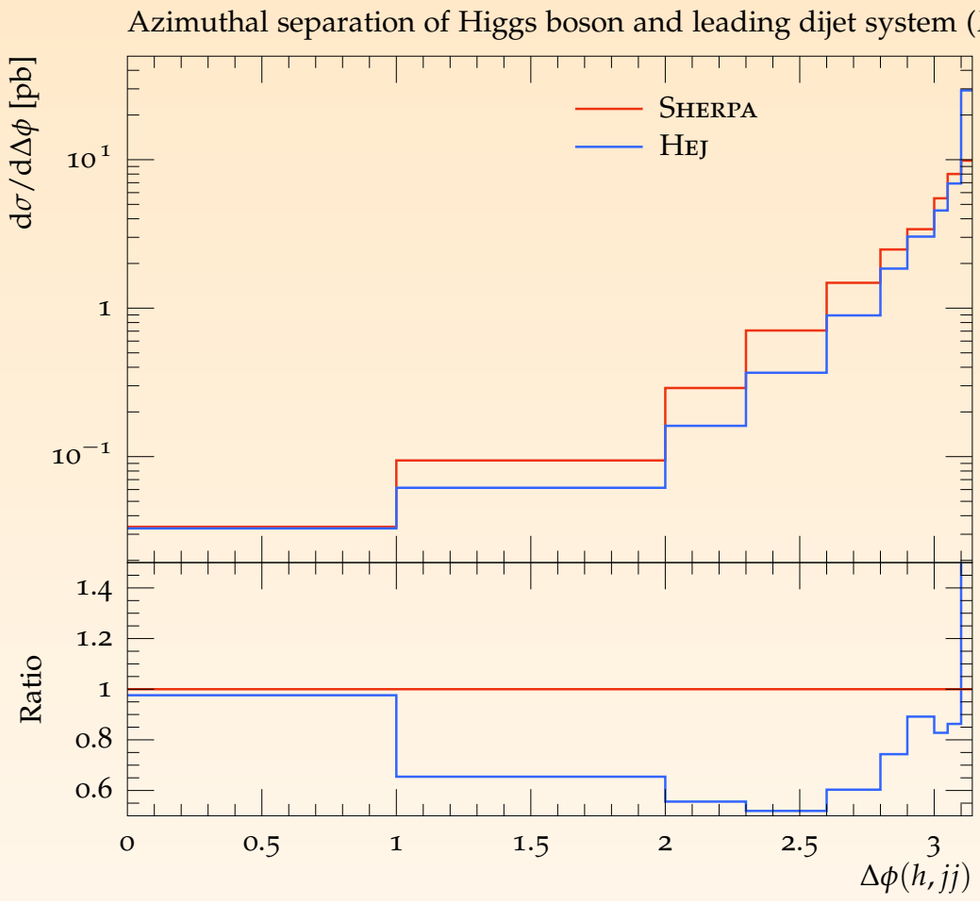
- In the recent years, great improvements have been made in analytic computations
- For example, NNLO for H+j known, NLO H+3j, jet-veto including NNLL resummation, …
- For non-trivial observables it is not obvious which ones can be decently described by fixed order calculations

Greiner et al., 2015



First results





- First results for Sherpa with MEPS@NLO and HEJ
  - still low statistics and very preliminary

Overview.

Uncertainties in Shower and matching to matrix elements

[Simon Plätzer & Marek Schönherr on behalf of the shower uncertainties group]

What we're really after are **event generator uncertainties.**

A very complex and highly non-trivial exercise.
Attempted two years ago, and failed due to complexity.

Need to start somewhere to get a full understanding.
Will look at **perturbative part first**, then go further ahead.

Disclaimer: Work is just starting.

Shower Uncertainties

Goodness of Approximation

$\longleftrightarrow$ Resummation Region

Accessible Phase Space

Scales

Evolution Variable

$\mu_{\{Q,F,R\}}$

Subleading (?) Effects

- Kinematics
- Finite terms
- Colour
- Spin
- ...

Uncertainties in one Algorithm $\longleftrightarrow$ (X-check) Different Algorithms

Uncertainties in one Algorithm $\rightarrow$ Matching to improve

Shower & Matching Uncertainties.

Use available shower algorithms to cross-validate uncertainty prescriptions.
Unique setting as opposed to check-order-by-order in fixed order corrections.

Uncertainty precriptions are algorithm specific and should be decided by each generator.

1) Start with LO+PS as matching may hide important details.
2) Add in matching/merging and check that uncertainties are improved in the regions where we expect an improvement.
3) Look at higher jet multiplicity: Do we recover LO+PS uncertainties?
4) Cross-validate versus analytic resummation where available.

[Thanks to Frank Tackmann for providing results.]

Look at a small set of representative observables:
e^+e^- event shapes, colour singlet $p_\perp$ spectra in inclusive jet bins, maybe Z plus jet.

Irreducible Background Subtraction: To do or not to do ?

Jon Butterworth, Vitaliano Ciulli, Paolo Francavilla, Frank Krauss, Carlo Pandini, Luca Parrozzi, …

The problem…

- Even in fiducial cross-section measurements, more than one "process" may contribute to the same final state
- Subtraction is entirely theory-based, even if there are control regions
- Often contributions are subtracted before unfolding, so cannot be undone/redone if theory improves
- Can we do better?

Well, ATLAS did…

- W+b jets measurement … with and without single-top subtraction
- Size of contribution vs pT of b-jet
- Effect on systematics varies with kinematic region, but go from 16% before subtraction to 54% after, due to theory uncertainty in top radiation

arXiv:1302.2929 (JHEP)

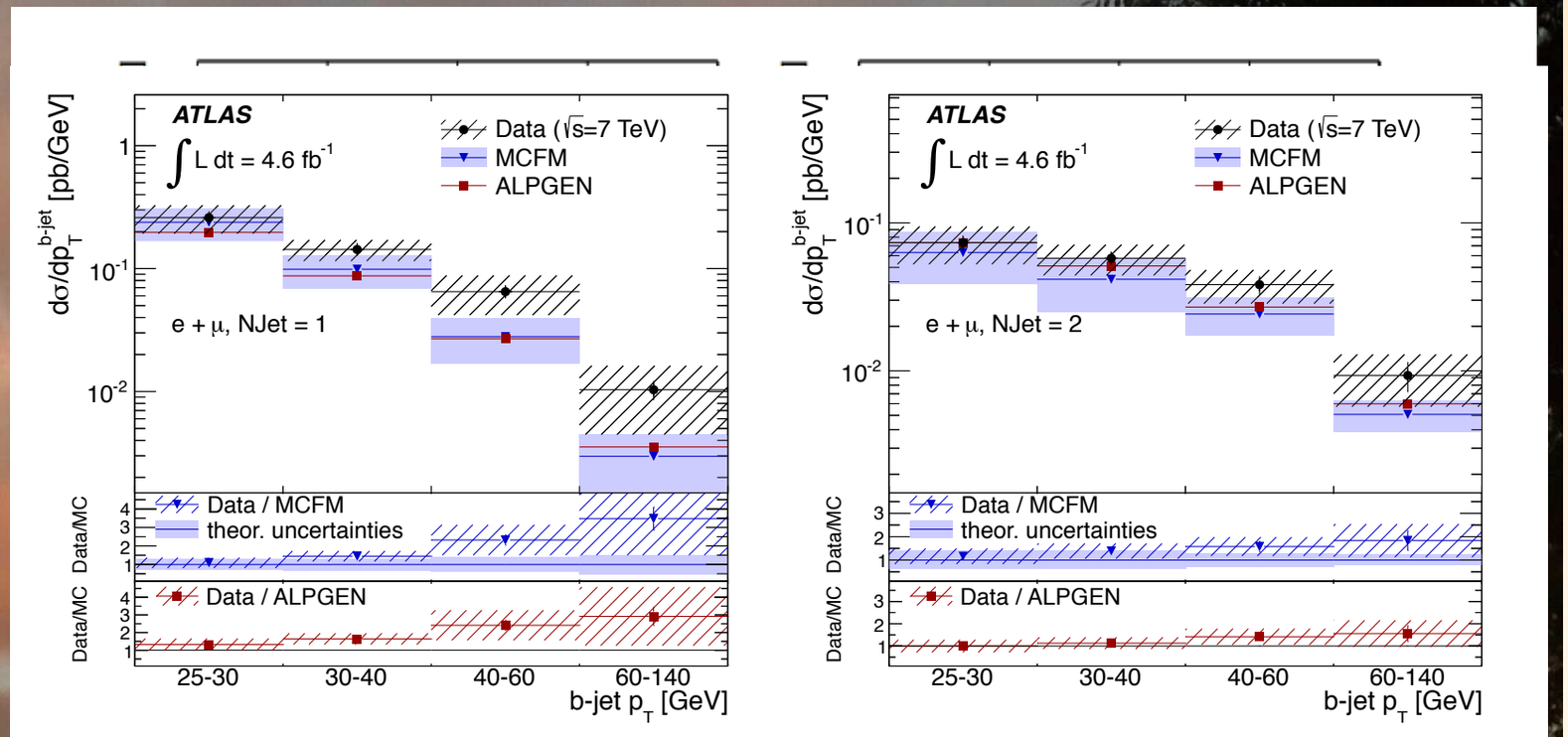


Figure 8. Measured differential $W+b$-jets cross-sections with the statistical plus systematic uncertainties as a function of $p_{\mathrm{T}}^{b\text{-jet}}$ in the 1-jet (left) and 2-jet (right) fiducial regions, obtained by combining the muon and electron channel results. The measurements are compared to the MCFM predictions and to the ALPGEN predictions interfaced to HERWIG and JIMMY and scaled by the NNLO inclusive W normalization factor. The ratios between measured and predicted cross-sections are also shown.

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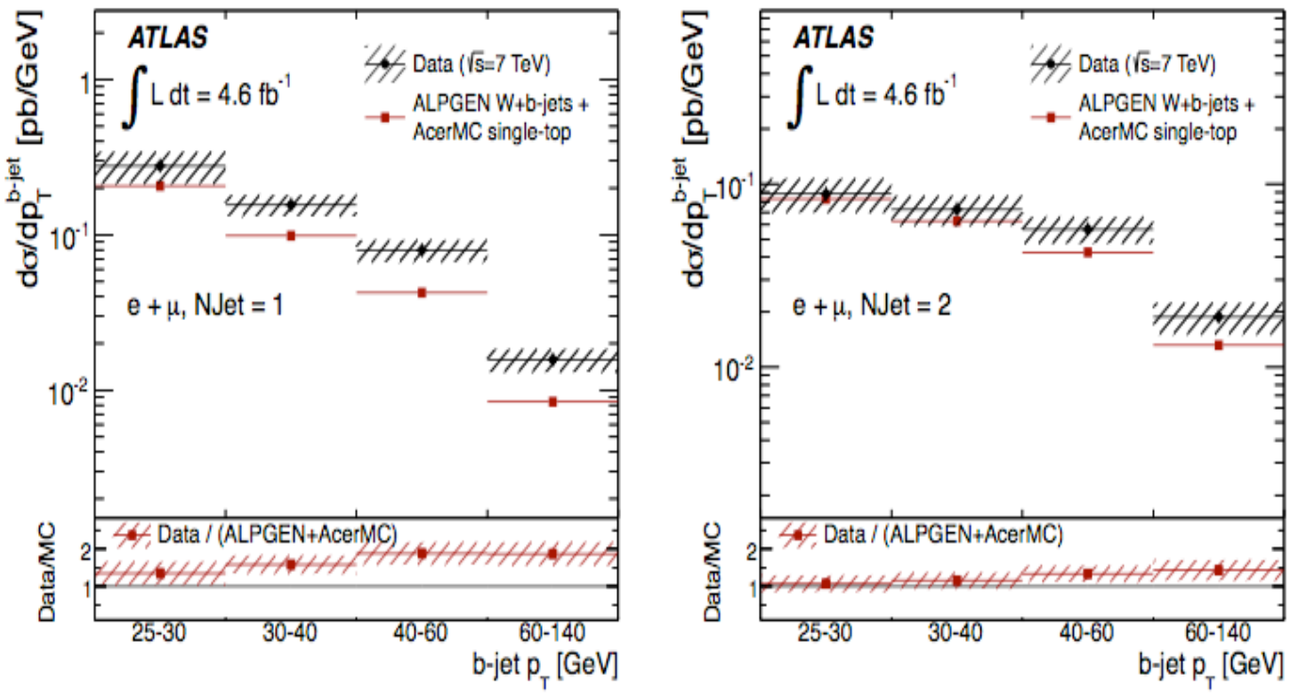


Figure 9. Measured differential $W+b$-jets cross-section without single-top subtraction as a function of $p_{\mathrm{T}}^{b\text{-jet}}$ in the 1-jet (left) and 2-jet (right) samples, obtained by combining the electron and muon channels. The measurements are compared to the $W+b$-jets plus single-top predictions obtained using ALPGEN interfaced to HERWIG and JIMMY and scaled by the NNLO inclusive W normalization factor plus ACERMC interfaced to PYTHIA and scaled to the NLO single-top cross-section. The ratios between measured and predicted cross-sections are also shown.

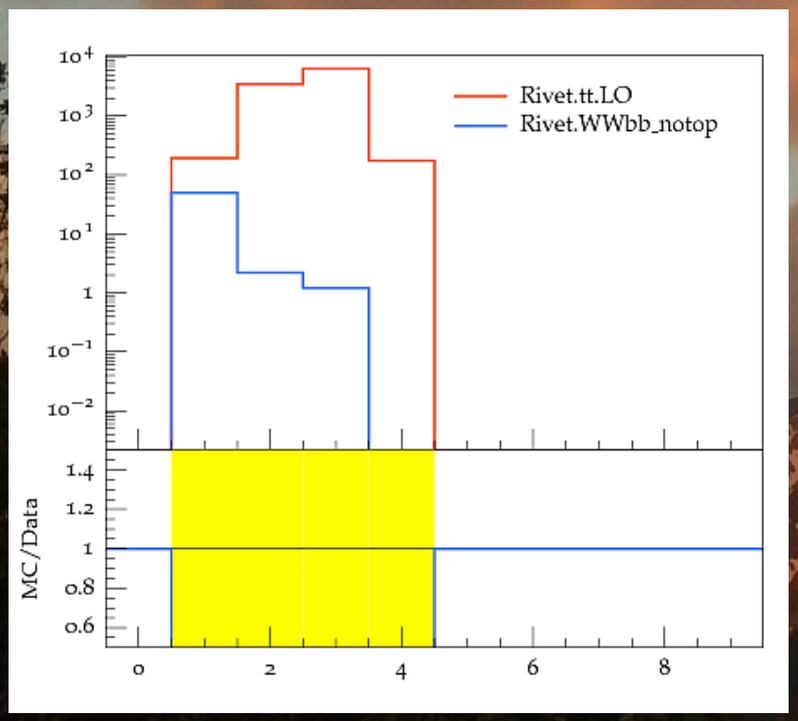
The project…

- Choose the final state with two leptonic W's and two b-jets as a demonstration
- Consider on- and off-shell top contributions, WW+bb diagrams without top, and WWjj diagrams when the b-jets are too far forward to be tagged.
- Generation with Sherpa
- Rivet analysis

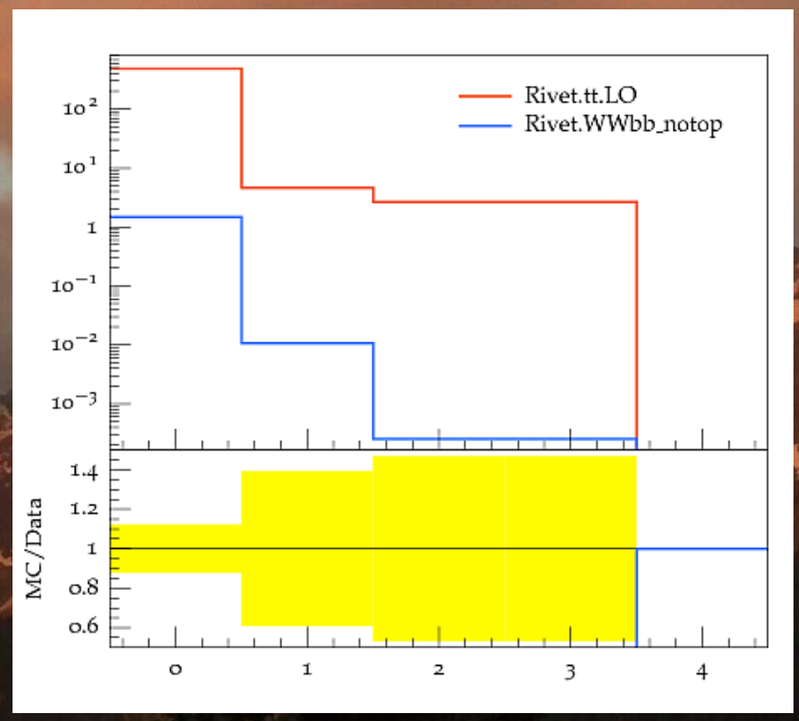
The project…

- First plots, still trouble-shooting, but demonstrates that indeed diagrams both with & without top contribute in the interesting kinematic regions
- Plan to study this and compare impact of theory uncertainties on future subtracted and unsubtracted measurments

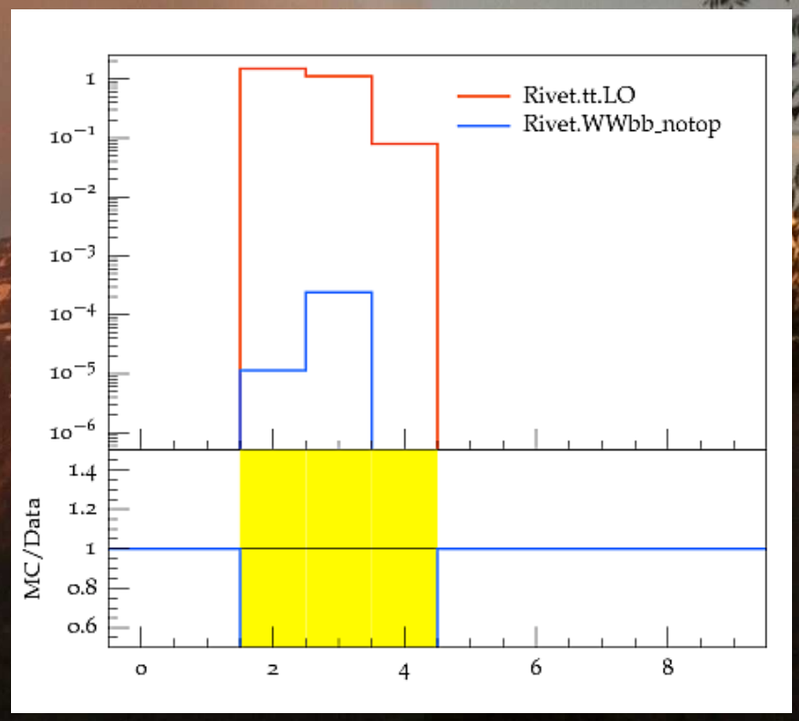
N-Jets after WW cuts



VBF cut flow



N-Jets after VBF cuts



Thanks to the organisers for the wonderful workshop!