ATLAS & CMS measurements of jets and heavy flavour produced in association with a W or Z boson

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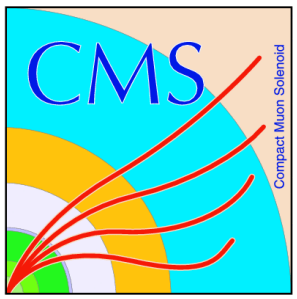


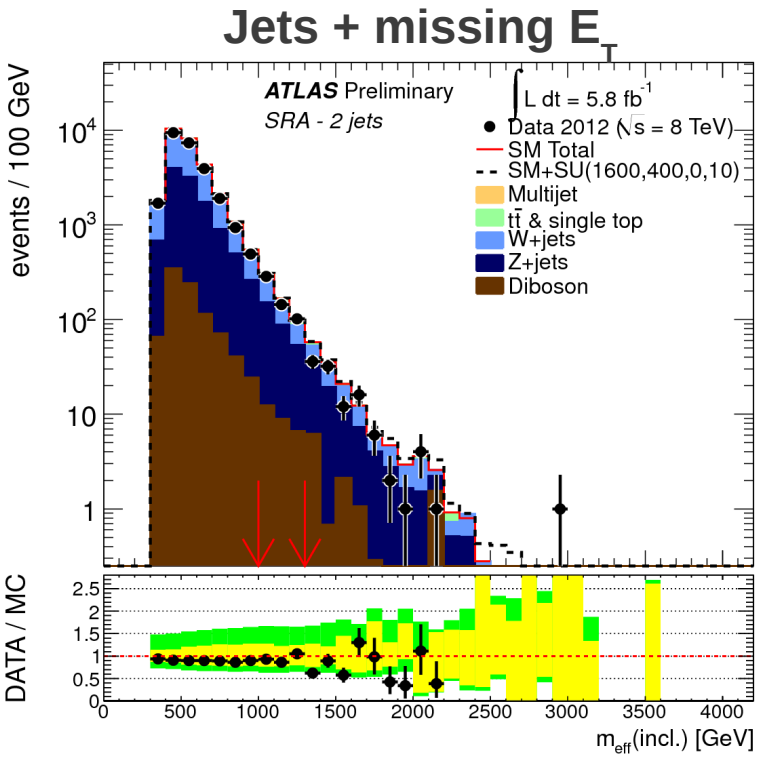
GDR Terascale - 14/05/2013

W/Z+jets measurements

- Highlights of the most recent measurements
  - This talk is not a complete summary, only some of the results based on the 2011 dataset are presented here
  - References to all the measurements can be found at the end of the talk
- Z + light jets
  - Studies of many observables
    - e.g., angular variables, event shapes
  - Studies in various phase space regions
    - e.g., boosted objects, forward jets (including electroweak production)
- W + 1 or 2 b jets

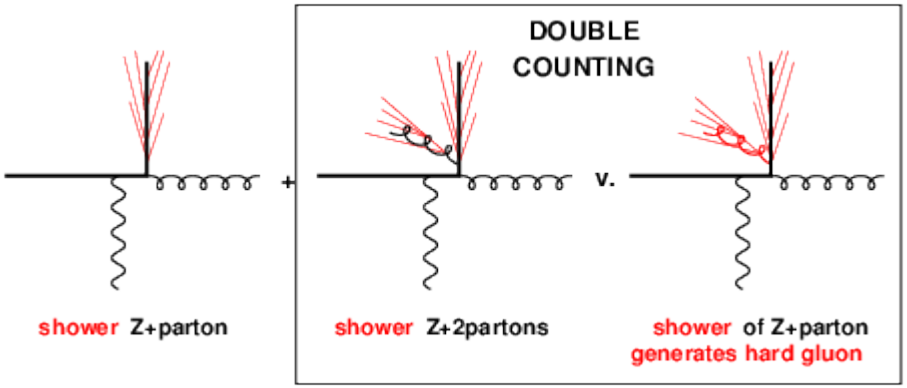
Motivations

- W/Z + jets events are background to many measurements and searches:
  - ↳ e.g., Higgs, SUSY
  - ↳ Specific regions are selected where generators have never been tested
  - ↳ Jet vetoes or categories based on jet multiplicity are often used to improve S/B
    - – It is therefore important to understand the scaling of jet multiplicity
- Improving Monte-Carlo generators
- Testing pQCD
- Probing the content of the proton (I won't talk much about this here)
  - ↳ Strange content (poorly constrained)
  - ↳ Heavy flavour content

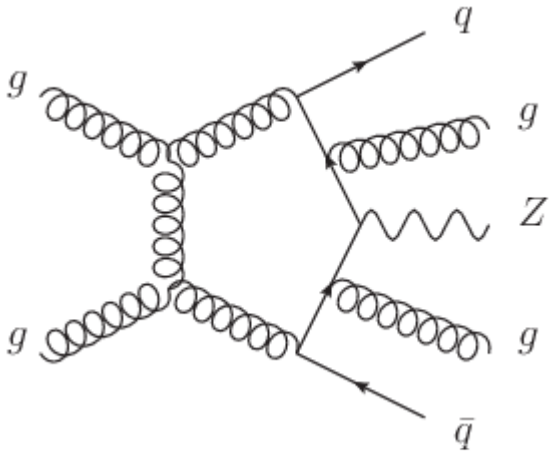


Available predictions

- Event generators (fully exclusive):
  - ↳ Leading order (LO) matrix element (ME) + parton shower (PS)
    - – Pythia, Herwig
  - ↳ Tree level multiparton ME (up to 5 partons) + PS merging
    - – Alpgen, Sherpa, Madgraph
  - ↳ NLOPS (NLO matching)
    - – Powheg, MC@NLO
  - ↳ MENLOPS
    - – Sherpa

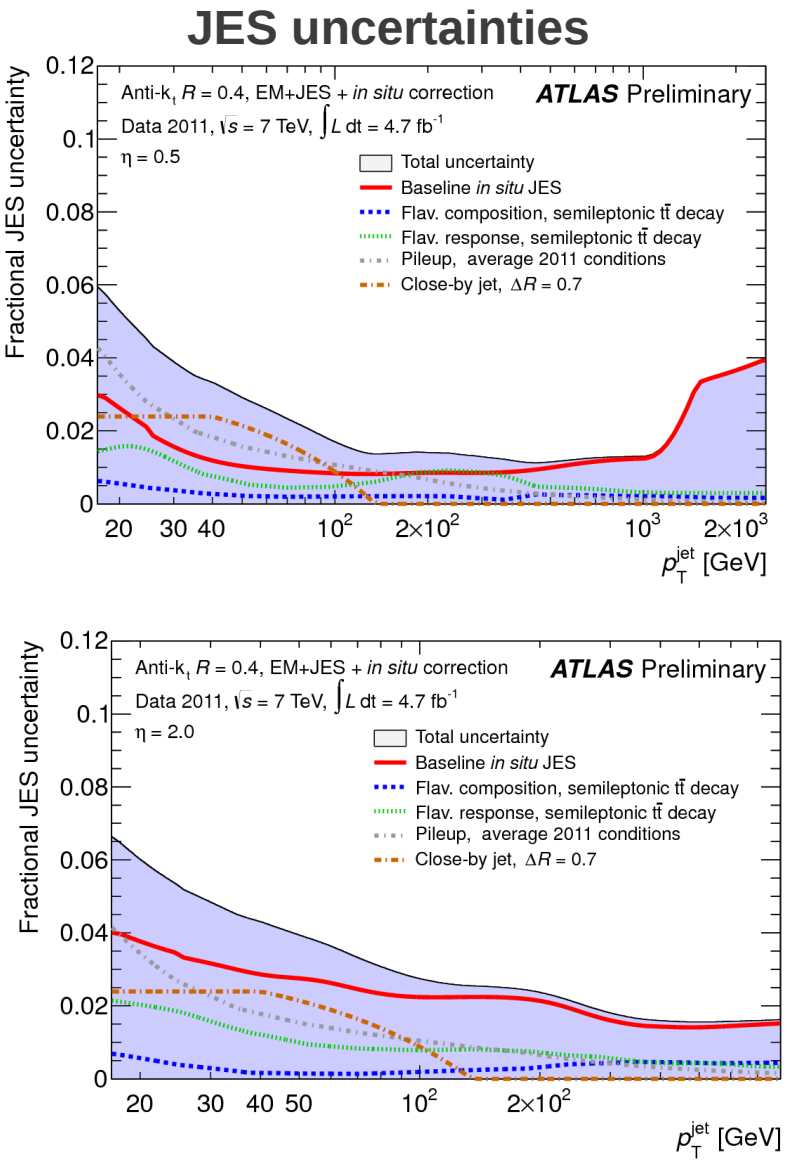


- Fixed order pQCD calculation (at NLO):
  - ↳ Parton level: needs to be corrected for soft QCD effects (UE, hadronization)
    - – MCFM
    - – BlackHat+Sherpa → W(Z) + up to 5(4) partons



Main experimental uncertainties

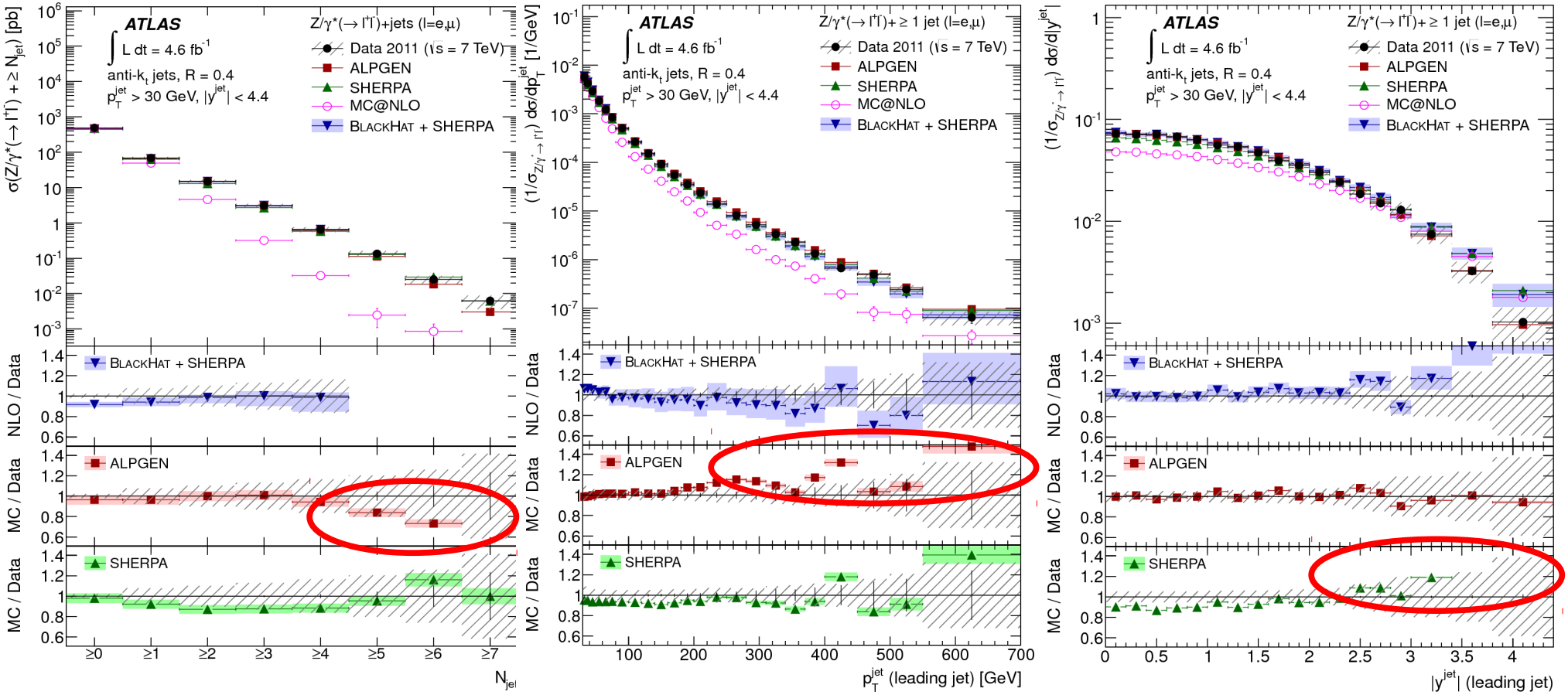
- Jet energy scale (JES)
  - ↳ Determined using simulation & in situ measurements
  - ↳ Uncertainties from
    - In situ measurements, pile-up, close-by jets, flavour response and composition (quark, gluon, HF)
  - ↳ Large uncertainties at low p_T
    - Region important e.g. for jet counting/veto
  - ↳ Also larger uncertainties in the forward region
    - Important for electroweak production
- Jet energy resolution
- b-tagging efficiency (for measurements involving b-jets)



Z+jets

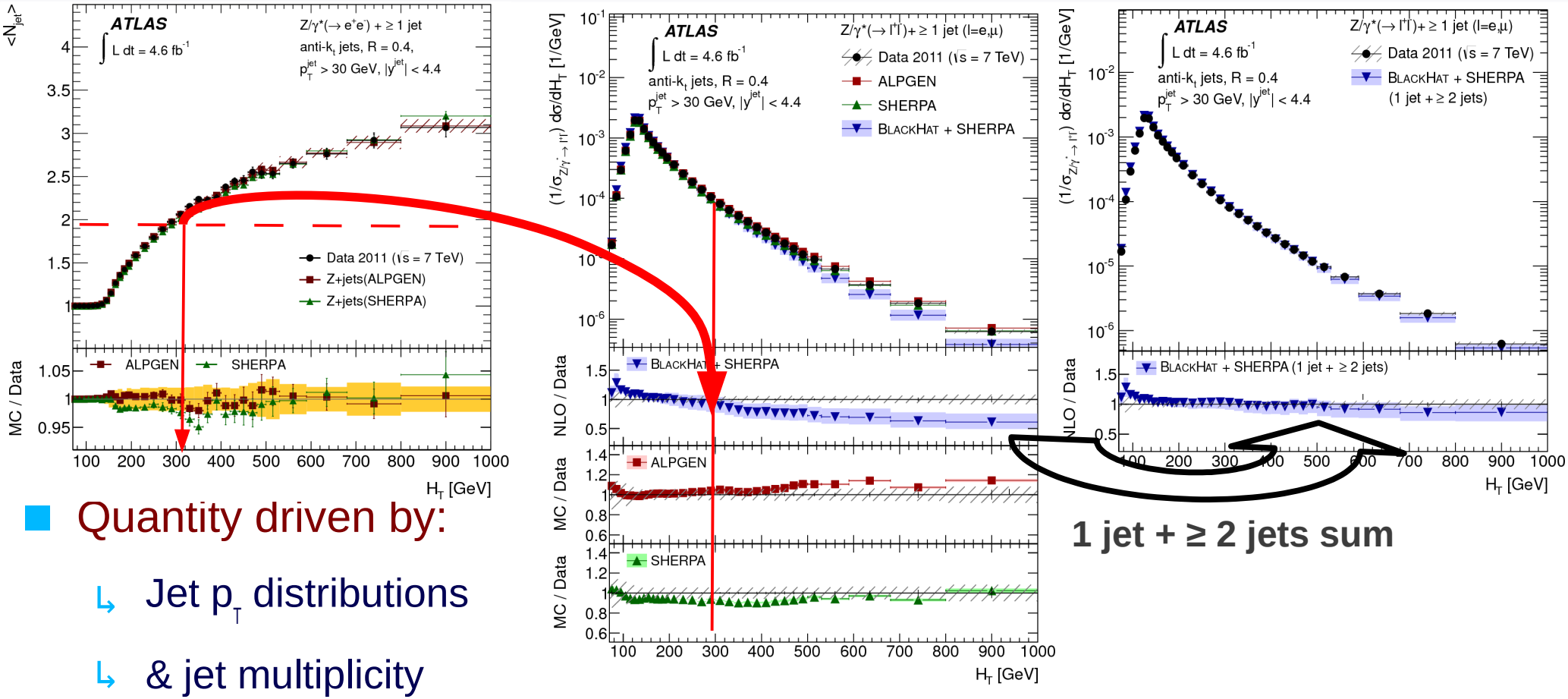
arXiv:1304.7098

- Large jet multiplicity (≥ 7 jets)
  - ↳ Limits of ME+PS generators are reached (e.g., Alpgen generates up to 5 partons with ME, higher multiplicities come from parton shower)
- Large jet (and Z) p_T, for which both missing higher order QCD and EWK contributions can become large
- Forward jets → background to VBF Higgs



Z+jets, inclusive p_T sum (H_T)

arXiv:1304.7098



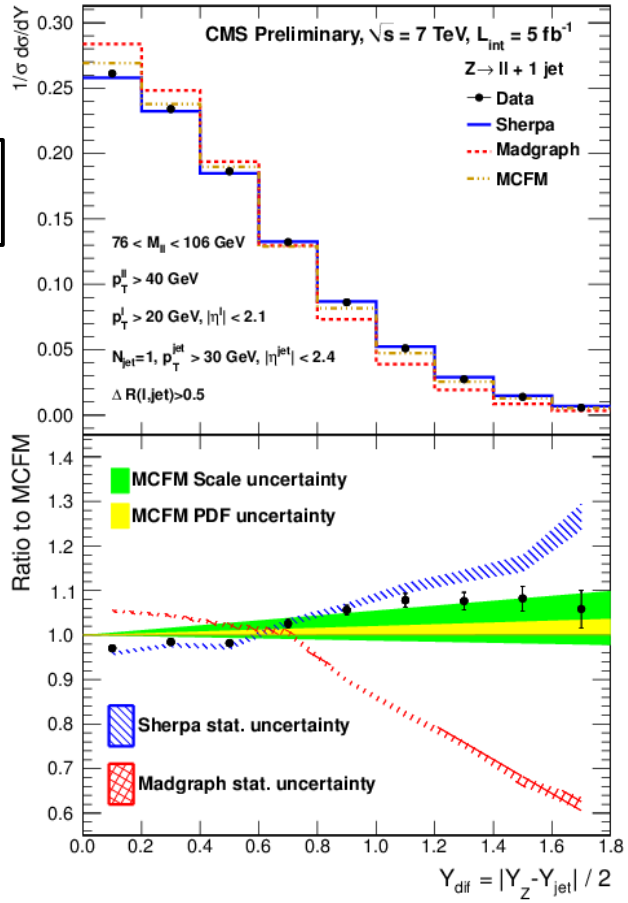
1 jet + ≥ 2 jets sum

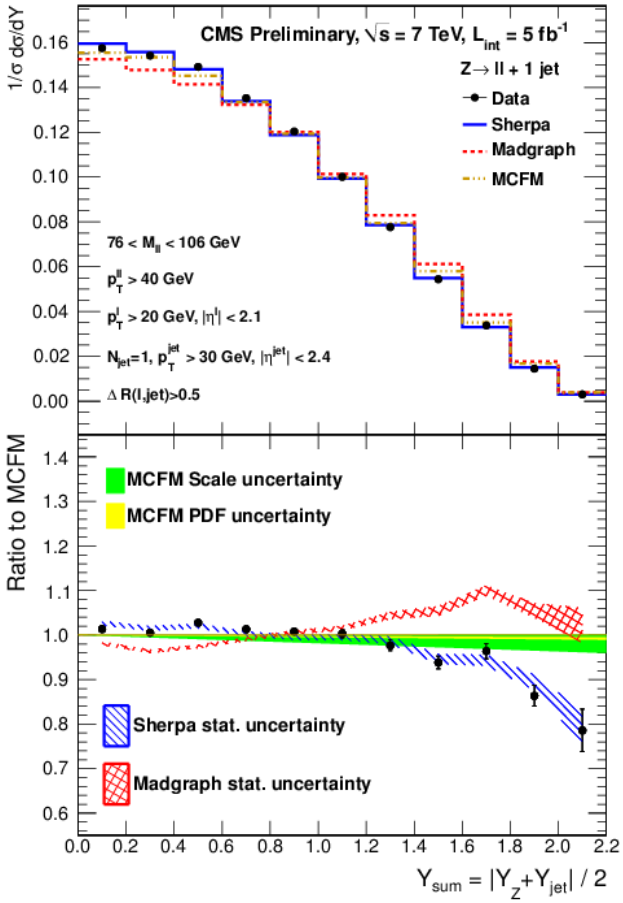
- Quantity driven by:
  - ↳ Jet p_T distributions
  - ↳ & jet multiplicity
- Important for searches (e.g., Meff = Σp_T + MET in SUSY searches)
- BlackHat+Sherpa fails to describe the high H_T regime
  - ↳ Due to missing contributions from events with 3 or more partons
  - ↳ Can be cured by performing a sum of exclusive 1 jet + ≥ 2 jets predictions

Z+1 single jet, rapidity distributions

- Transformed Z and jet rapidities into 2 quantities
  - ↳ $|Y_Z - Y_{jet}|/2$ and $|Y_Z + Y_{jet}|/2$
- Clear differences between Sherpa and Madgraph
  - ↳ Attributed to differences in the merging procedure (CKKW vs MLM)
  - ↳ Sherpa (CKKW) tends to reproduce the data better

$|Y_Z - Y_{jet}|/2$





$|Y_Z + Y_{jet}|/2$

Z+jets, event shapes

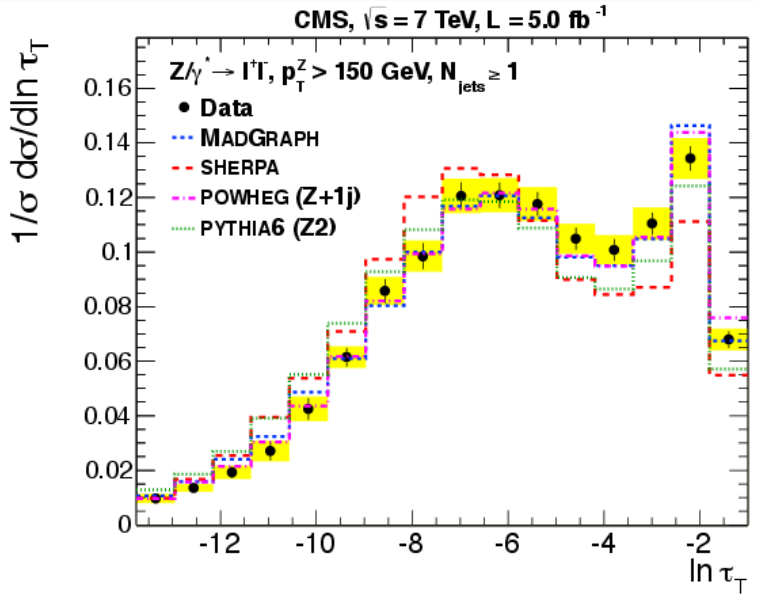
arXiv:1301.1646

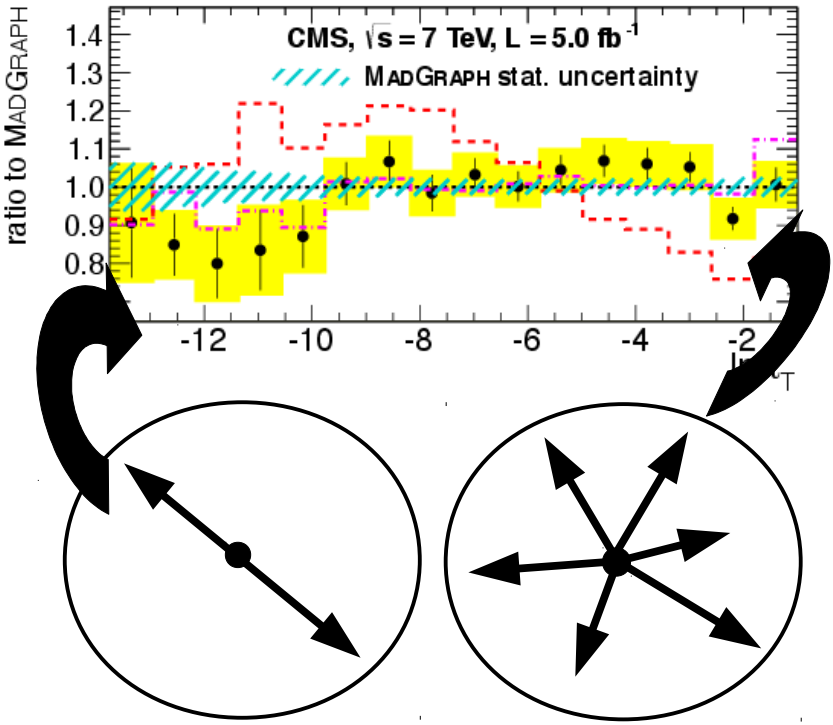
- Topological structure of Z+jets events is probed using the transverse thrust variable:

$$\tau_T = 1 - max_{\vec{n}_\tau} \frac{\sum |\vec{p_{T,i}} \cdot \vec{n}_\tau|}{\sum p_{T,i}}$$

  - ↳ Most sensitive to 2-jet and 3-jet topologies
  - ↳ Less sensitive to large jet multiplicities

- Measurement performed for events with a boosted Z ($p_T(Z) > 150$ GeV)
  - ↳ More jets → more spherical events
  - ↳ Too small values predicted by Pythia and Sherpa
    - – Too large proportion of back-to-back Z + 1 jet events
  - ↳ Good agreement of Powheg Z + 1 jet and Madgraph with the data





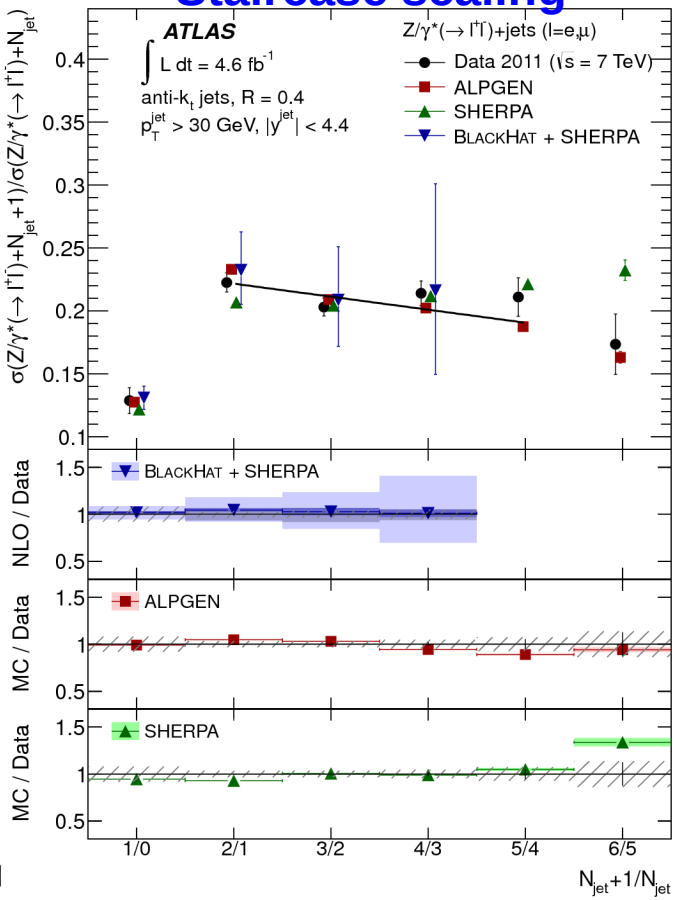
Z+jets, exclusive jet multiplicity scaling

arXiv:1304.7098

- Scaling patterns can be probed at different energy scales
  - ↳ Democratic jet selection: Staircase scaling
  - ↳ Large scale separation: Poisson scaling (Abelian limit of QCD)
- Evolution compatible with theoretical expectations

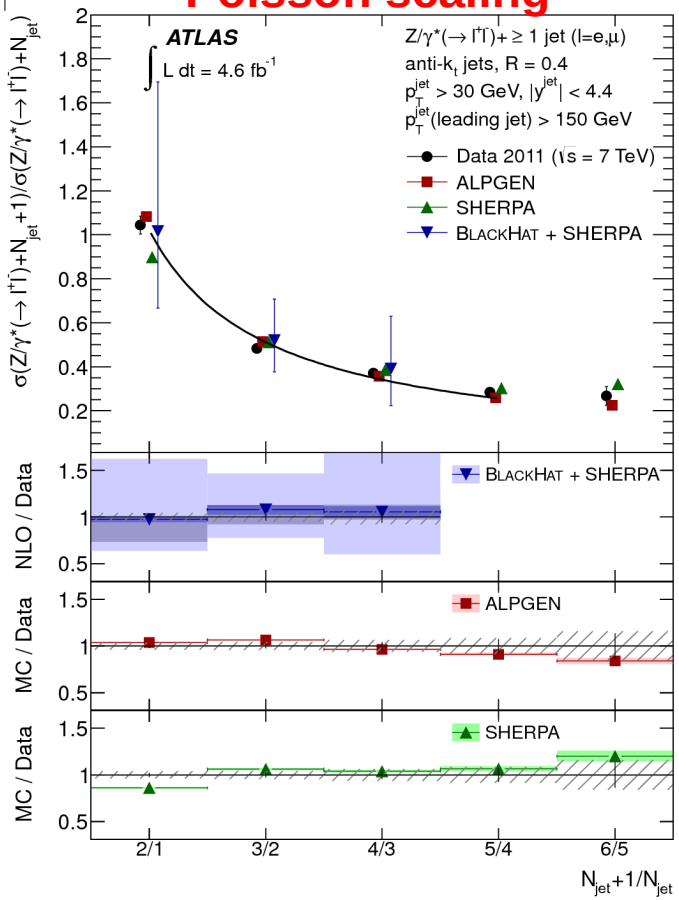
p_T(leading jet) > 30 GeV

Staircase scaling



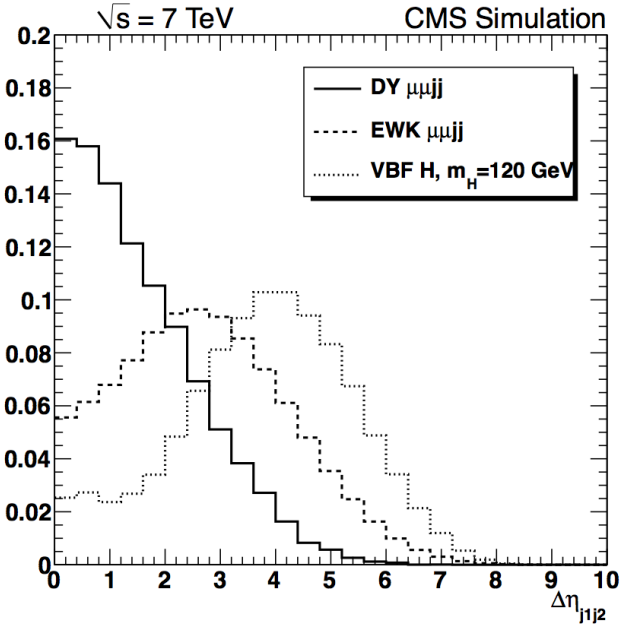
p_T(leading jet) > 150 GeV

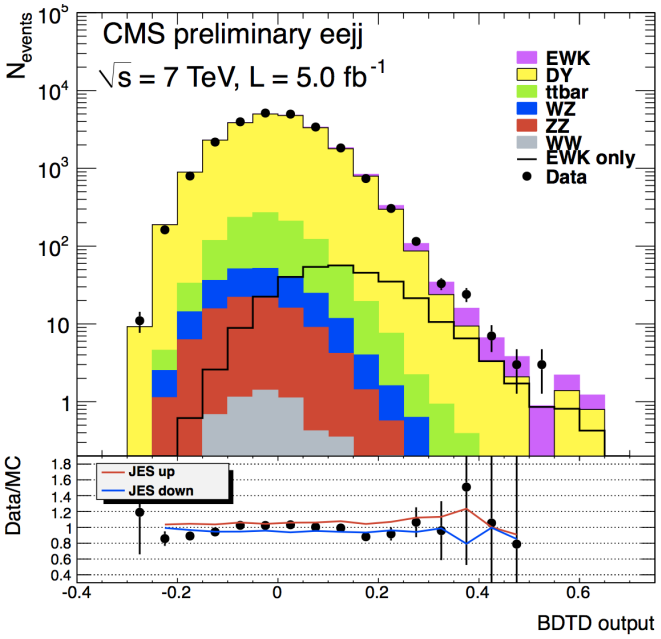
Poisson scaling



Z+jets, electroweak production

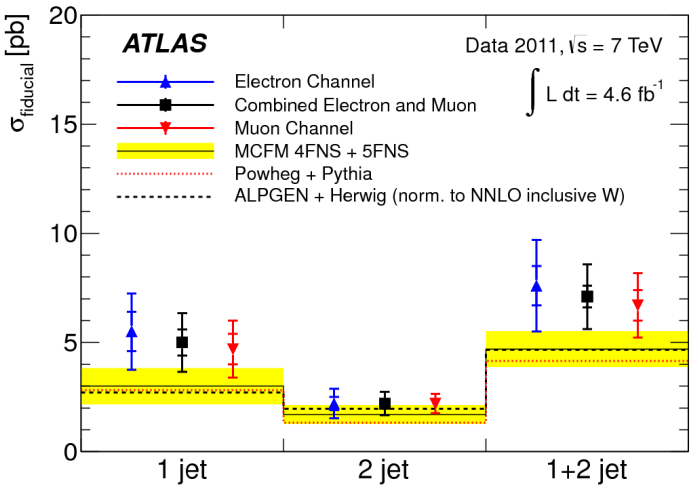
- Events containing a Z and two forward-backward jets
  - ↳ Probe for anomalous triple gauge boson couplings
  - ↳ Background to VBF Higgs signal
- Capability to extract a process compatible in cross-section and topologically with the SM Higgs produced by VBF
- Use of a quark-gluon likelihood discriminator
  - ↳ Signal jets are exclusively initiated by quarks
- Signal extracted using a BDT
  - ↳ Makes use of jets p_T, Δη(leading jets), dijet mass,...
- Measured cross section in agreement with NLO cross section
  - ↳ 154±24(stat)±46(exp)±27(th)±3(lumi) fb vs 166 fb

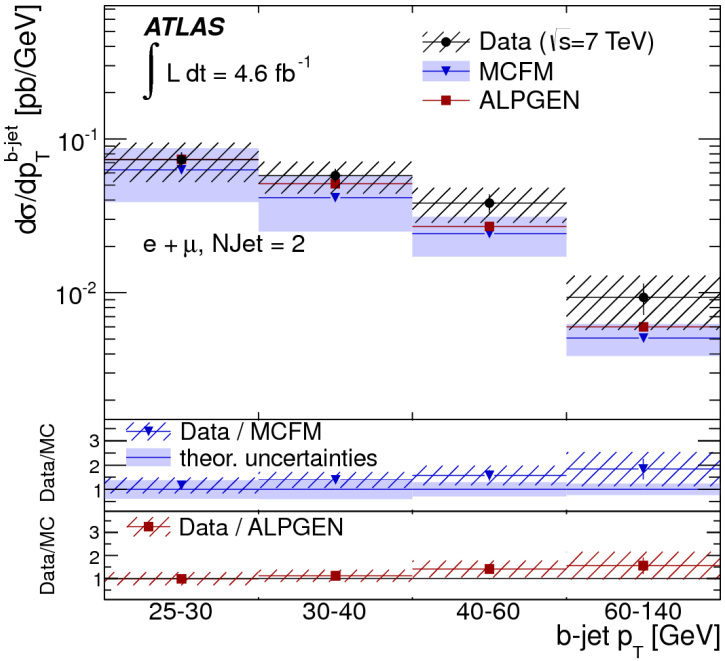




arXiv:1302.2929

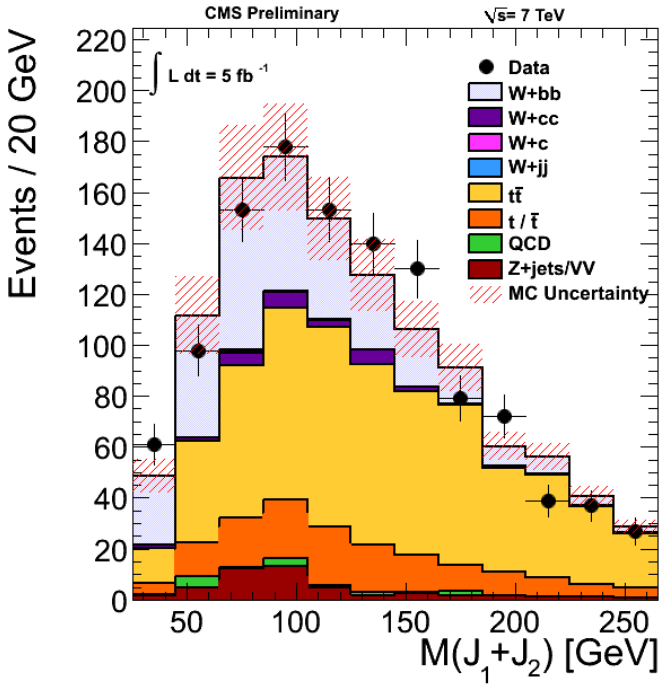
- Background to the Higgs associated production WH(→bb)
  - ↳ Important for the study of couplings to fermions
- Test predictions using different flavour number schemes
  - ↳ Including or not b-quarks in the initial state
- 1 jet and 2 jet final states are studied
- Measurements also done differentially
  - ↳ Function of the b-jet p_T
- Everything is consistent within 1.5 σ with NLO predictions

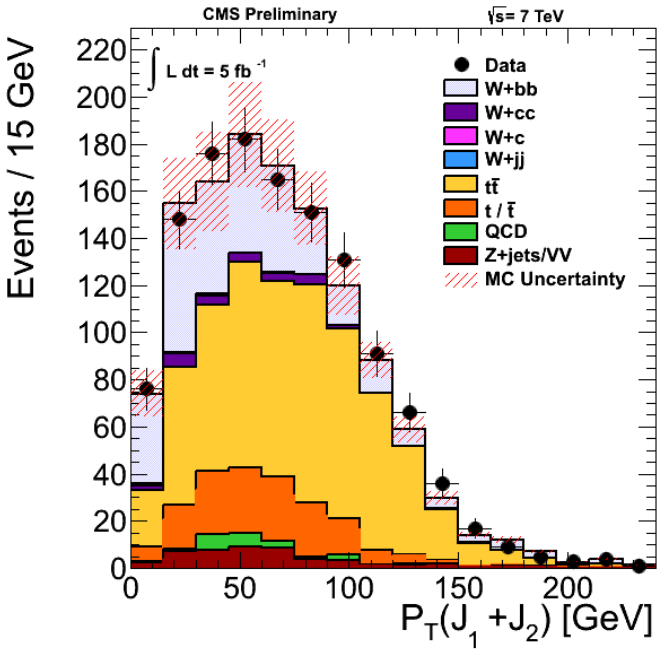




W+bb

- Events with exactly 2 jets passing b-tagging requirement
- Same physical interests as W+b
- But suffers from more tt background compared to W+b
  - ↳ Constrained by simultaneous fits in signal and control regions
- Measured cross section in agreement with SM prediction
- W+bb kinematic also studied
  - ↳ Dijet system mass, dijet p_T, etc.





Summary & Conclusion

- Many analyses based on the 2011 dataset have been performed (more in the pipeline), which extended significantly the probed phase space of W/Z + jets events
  - ↳ Growing list of observables since 2010
  - ↳ Events with boosted objects, forward jets, ...
  - ↳ Electroweak production
- Enable testing of predictions based on very recent tools (huge progress made recently)
  - ↳ Measurements will serve to improve them
- Precision measurements of W/Z+heavy flavour, including differential cross sections
- Data recorded in 2012 still to be analysed
  - ↳ Statistically limited results (e.g., very high jet or Z p_T) could be improved
  - ↳ We can also expect a reduction of the systematics (in particular for the JES)

List of results

- CMS
  - http://arxiv.org/abs/1110.3226
  - http://arxiv.org/abs/1204.1643
  - https://cdsweb.cern.ch/record/1428117
  - http://arxiv.org/abs/1301.1646
  - https://cdsweb.cern.ch/record/1524190
  - https://cdsweb.cern.ch/record/1525727
  - https://cdsweb.cern.ch/record/1528578
  - http://cdsweb.cern.ch/record/1493475

List of results

- ATLAS
  - http://arxiv.org/abs/1108.4908
  - http://arxiv.org/abs/1109.1470
  - http://arxiv.org/abs/1109.1403
  - http://arxiv.org/abs/1201.1276
  - http://arxiv.org/abs/1302.2929
  - http://arxiv.org/abs/1304.7098