



Ratios of W+jets to Z+jets cross sections to probe QCD at SLHC



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Introduction and motivation

Studying QCD at the SLHC

- + What new can we learn at the SLHC?
 - Higher luminosity → Higher jets kinematic
 - ⇒ More parton radiation
 - ⇒ Higher jet multiplicity
 - ⇒ Different PDF regime
 - ⇒ Heavy flavor contribution
 - Effects enhance if CME reach 33 TeV
 - New calculations to be testes
 - + New physics discovery at hadron collider in energy frontier regime require a good understanding of the strong interaction
 - Precise background predictions means better sensitivity to new physics
 - Very good understanding of SM contribution give confidence in a eventual discovery
- ⇒ **Need for precision**

Studying QCD at SLHC (II)

- + Particularly interesting to probe QCD with events involving vector bosons?
 - W/Z can be well understood (lepton efficiencies, backgrounds, etc.)
 - Very powerful for jet calibration and study of other detector effects
 - Look at quark jets rather than gluon jets, at least for the leading jets.
 - Study quark radiation
 - Abundantly produced and easier to trigger on with lepton trigger
 - Can go to low jet p_T threshold than dijet events
- + Complementary between inclusive and exclusive jet observables
 - Inclusive $\frac{d^2\sigma}{dMdy}$ to study PDF
 - W/Z P_T sensitive to soft/collinear QCD radiation;
 - W/Z+jets sensitive to hard QCD radiation and heavy flavor
- + Important backgrounds to numerous new physics signatures

W/Z+jets at the LHC

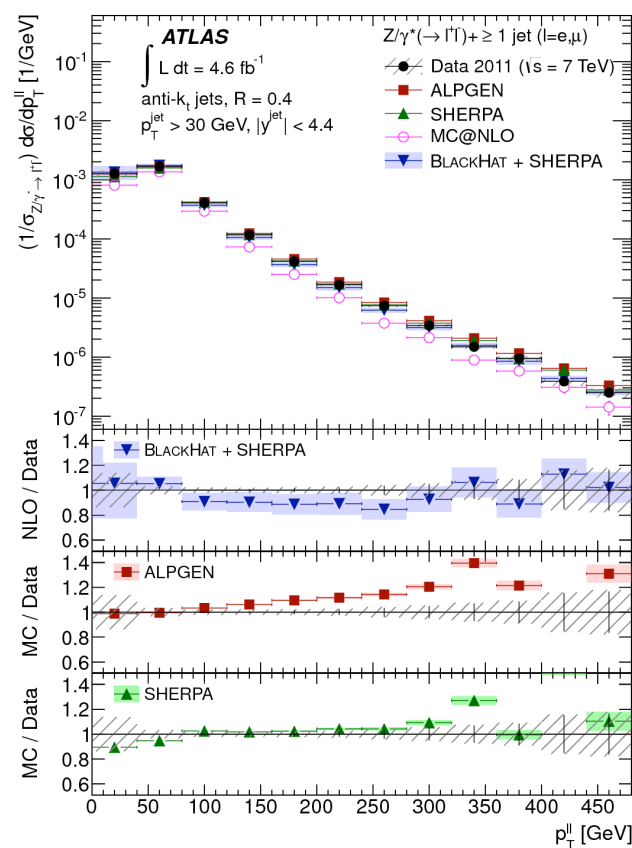
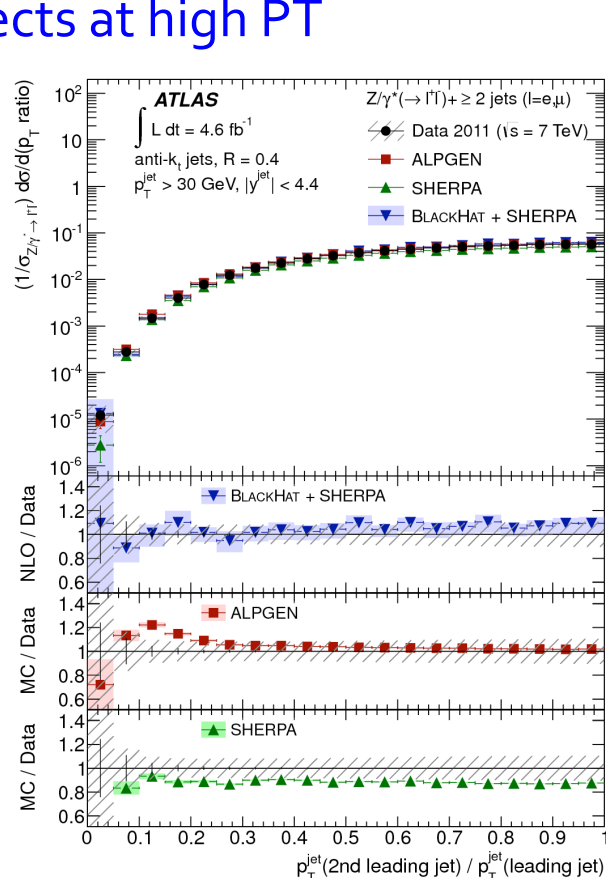
arXiv:1304.7098

+ Strong expertise in W/Z+jets studies is being developed

➤ Probe NLO effects in regions where new physics is expected

➤ Interesting effects at high PT

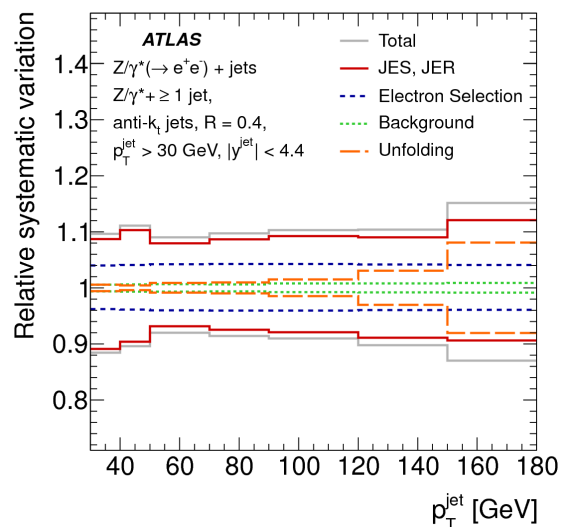
- Large k-factors
- Important HO QCD/EWK corrections
- High multiplicity from hard radiation
- Test of matching



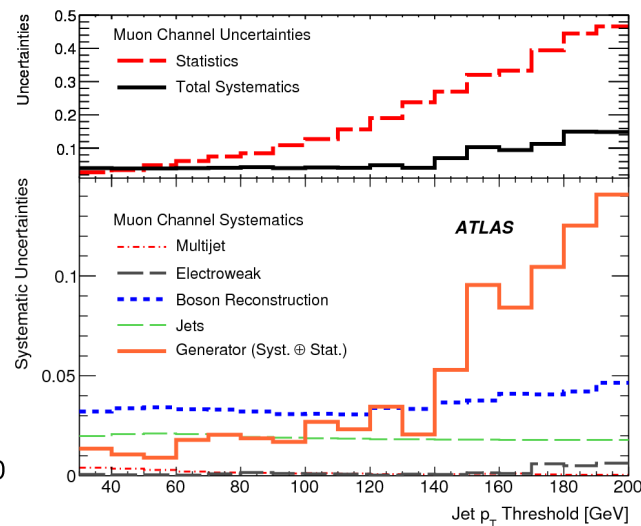
Systematic uncertainties

- + Systematic uncertainty often at similar level than NLO theory uncertainty for W/Z+jets measurements
 - Dominated by Jet energy scale uncertainty
 - Statistical uncertainty important in a some part of the spectrum probed
- + Systematic substantially reduced in the case of ratios
 - Dominated by lepton rather than jet systematics and prediction almost insensitive to PDF uncertainties

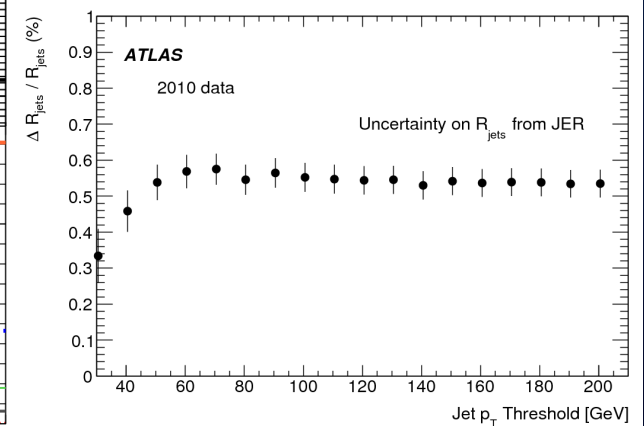
Z+jets (2010 data)



W+jets/Z+jets (2010 data)



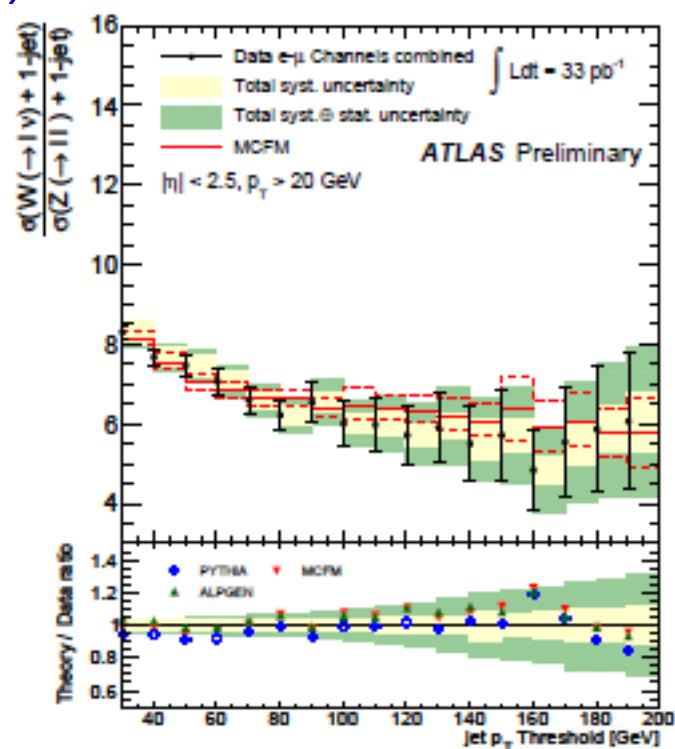
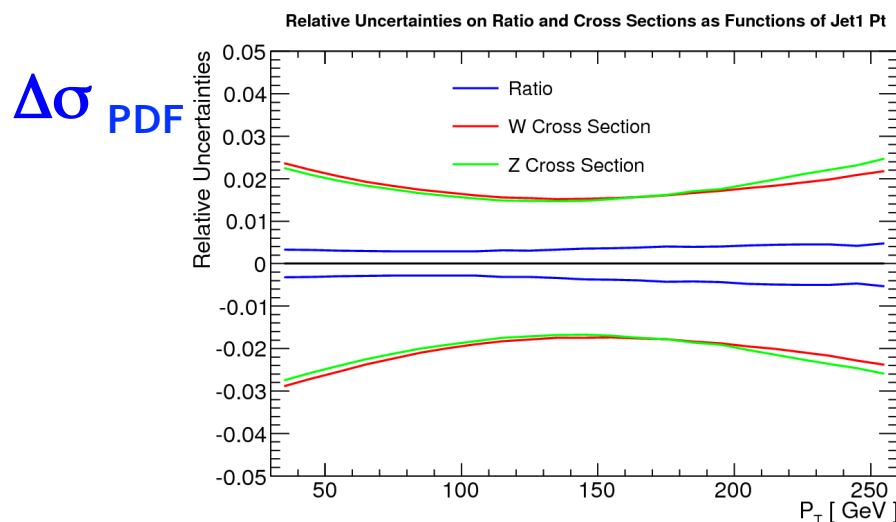
Level of cancellation of Jet effects in R_{jets}



R_{jets}

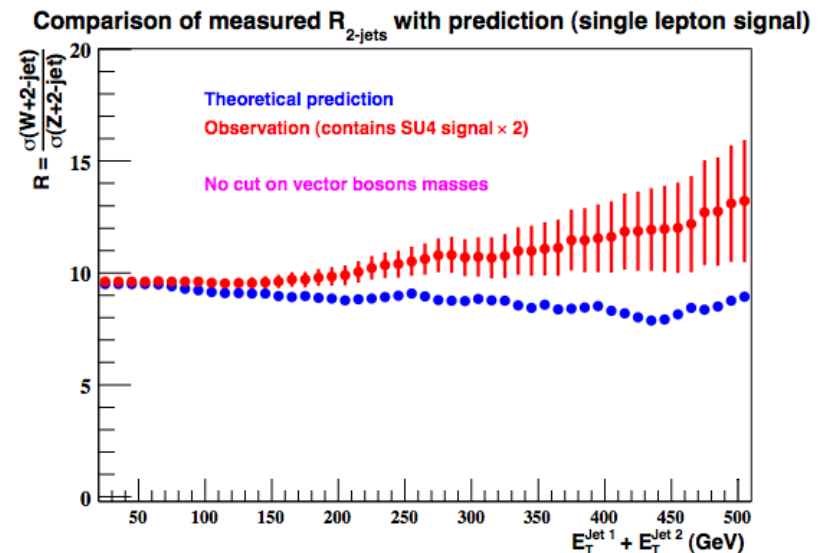
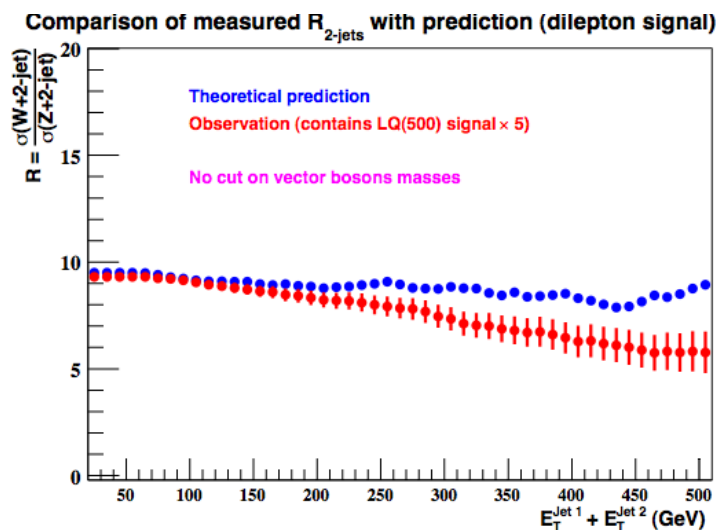
Phys. Lett. B708 (2012) 221-240

- + The ratio of W+jets to Z+jets cross section retains some sensitivity to higher order hard emission effects on some observable, and very little dependence on some others
 - high precision and very little dependence on non-perturbative effects (PDF, fragmentation, underlying events)
 - Exclusive jet selection enhance impact of hard radiation for QCD studies
 - **Robust against pile-up!!!**



Extra motivations

- + W+jets/Zjets is used in data-driven background estimate to jets +E_{miss} events
 - Precise measurement = precise background predictions
- + The ratio can even be directly used for new physics searches in jets +leptons final state



I want to redo this study with 14 SLHC 14 and 33 TeV samples

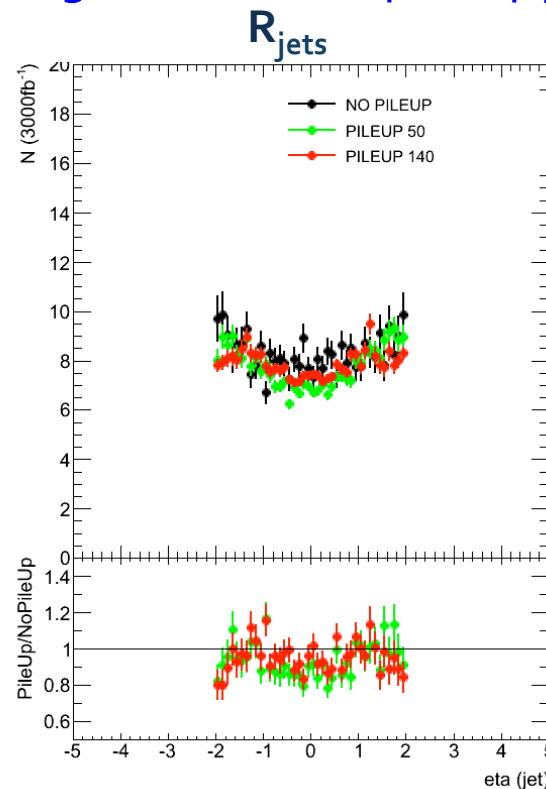
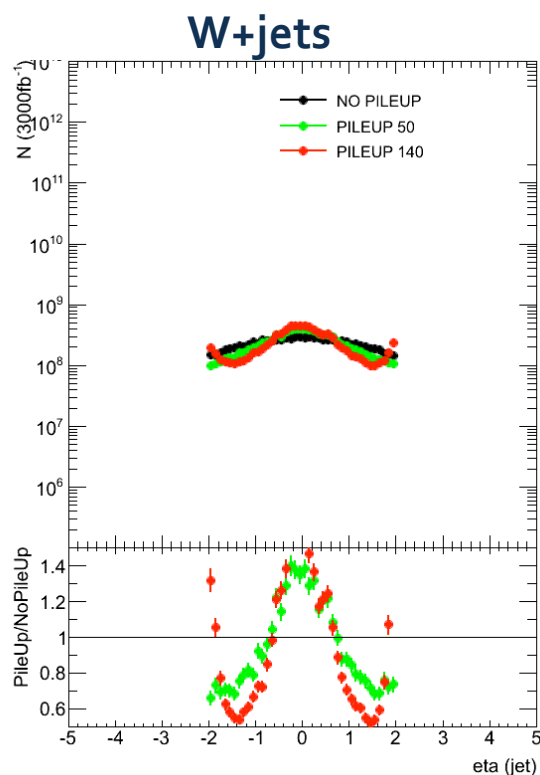
Objectives of the studies

- + QCD precision measurement must be unfolded
 - Uncertainties due to pile-up can be large
 - Affect JES, the biggest systematics on W+jets and Z+jets
 - Large migration
 - Hard to control jet multiplicity
 - Jet and b-jet reconstruction efficiency???
- + Want to check how R_{jets} is sensitive to pile-up effects
 - Compare the ratio of various observables for various pile-up expectations and quantify the size of the effects
 - Compare with absolute W+jets and Z+jets cross sections
 - Choose lepton selections which minimize sensitivity to pile-up while hopefully suppressing multijet background
 - Particularly difficult for MET
 - Eventually (...) also look at Wb/Zb , $Z\nu\nu+\text{jets}/Zl+\text{jets}$ and new physics

A few **very** preliminary plots

Pile-up effect on the ratio (I)

- + Pile-up effects are largely reduced in the ratio
 - Small difference between 50 and 140 pile-up scenario
 - Not the full pile-up effect is an uncertainty, but only a fraction of it
 - For more forward jets, larger number of pile-up jets

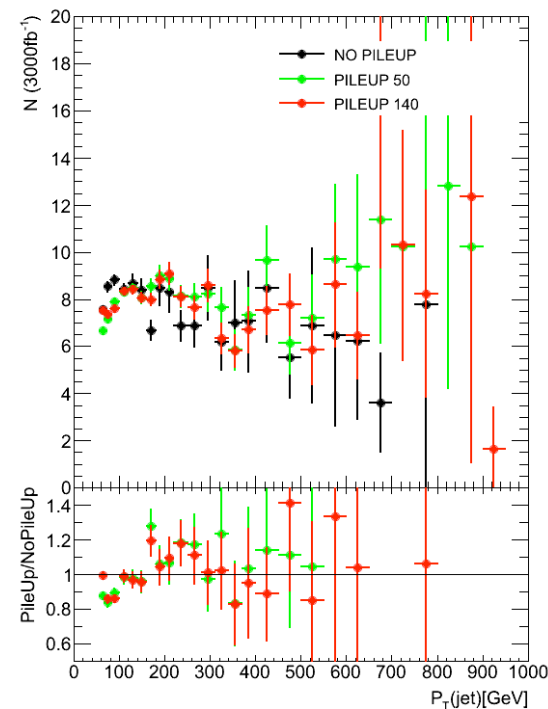
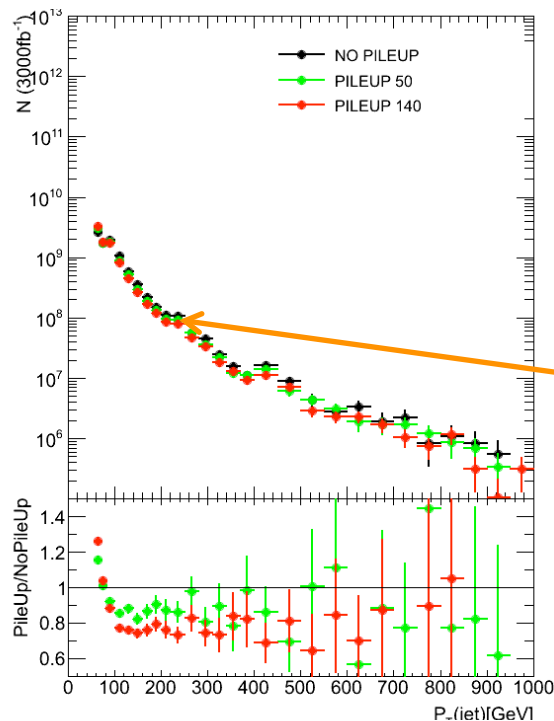


Use Pythia samples
with Delphes 3.0.9
at 13 TeV

Would like to
update to latest
samples, and also
run at 33 teV

Pile-up effect on the ratio (II)

- + Sensitivity to pile-up varies with measured observables
 - But always get significantly reduced in ratio
 - Very crucial to control what is different between W and Z
 - Lepton-jet overlap removal can't be a simple cone removal if high pile-up
 - Lepton efficiency assumed fully corrected here



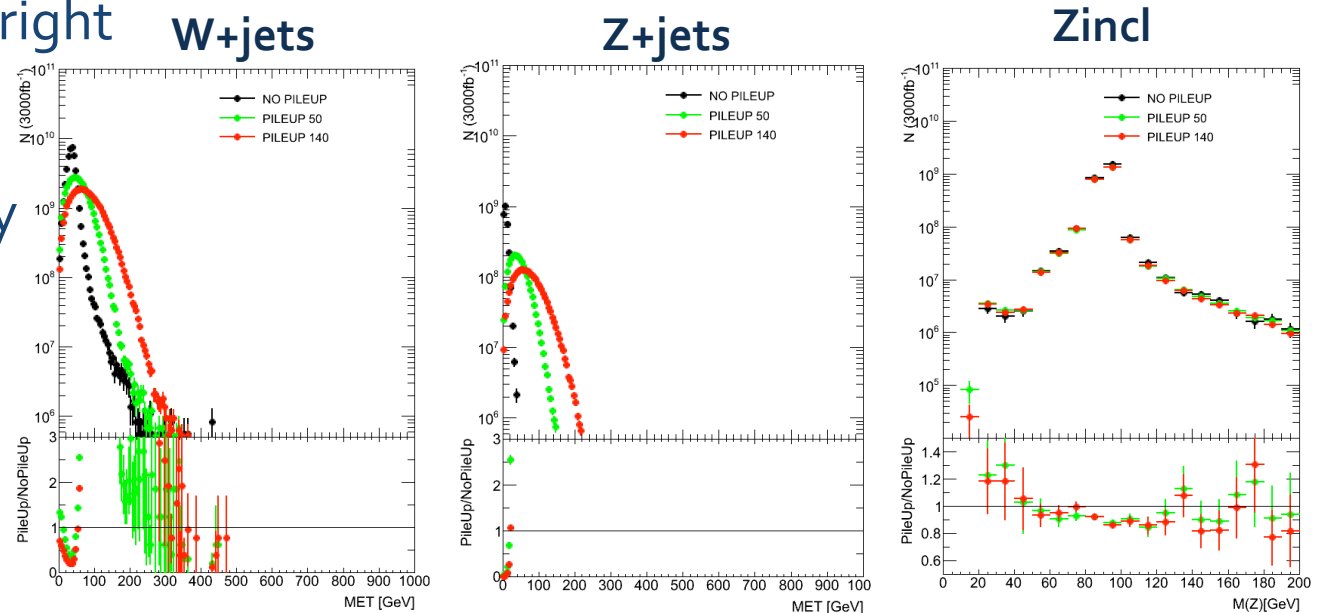
$$E_T^{\text{miss}}$$

- + Missing transverse selections very powerful to reduce QCD multijet background to W+jets events
 - Largest source of difference between W+jets and Z+jets

- + Low E_T^{miss} cut lead to high acceptance, so small effect in the ratio, but fake E_{Tmiss} in QCD event will be high too

- + Need to find the right balance...

- + Lepton efficiently also affected by pile-up



Conclusion

- + Sensitivity to new physics and parameter values require precise QCD predictions
- + LHC data provided and will continue to give serious test of QCD from an extensive set of measurements, but all must be investigated again when new energy regime is being probed
- + Ratios of W+jets and Z+jets differential cross section are very robust against systematic uncertainties and significantly less sensitive to pile-up than absolute cross section measurement
 - Can be used for precision QCD measurement
 - Central to data-driven background to jets+E_{miss} events
 - Can be used for robust new physics searches
- + Still preliminary studies, but would like to contribute to white paper
 - Solve a few technical issues, but code is in place, things work!
 - Need to determine how to select W and Z
 - Optimize ratio measurements
 - Possibly investigate new physics sensitivity and other ratios