GRADUIERTENKOLLEG
Masse-Spektrum-Symmetrie

Measurement of the Underlying Event with ATLAS

Motivation

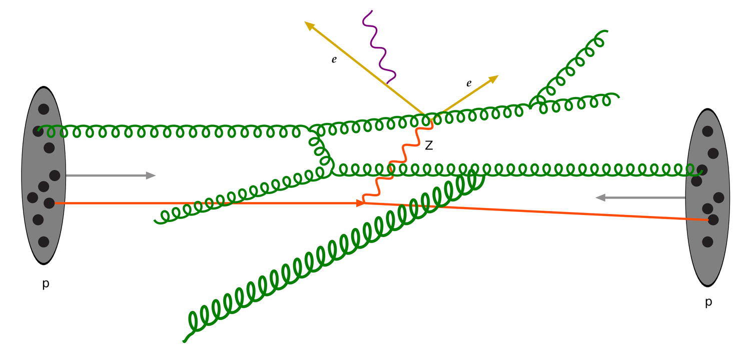
One of the dominant backgrounds at the LHC (Large Hadron Collider) at CERN are effects of the so-called Underlying Event (UE). This background is composed of various QCD (Quantum Chromo Dynamics) effects, is non-reducible and contributes by varying degree to all measurements at hadron-hadron colliders such as the LHC. The situation is being complicated by the fact that these QCD interactions are happening at comparably low scales where the coupling constant, α_S, is large and hence perturbation theory is not applicable anymore. This leads to the necessity to model these effects with Monte Carlo (MC) generators. Modelling, however, introduces a large number of phenomenological parameters that need to be adjusted to data to give a realistic description of data. This process is commonly known as "tuning" of MC generators to which I contributed significantly [1–8] during the process of my thesis. Tuning relies on specialised measurements that are sensitive to effects of the Underlying Event of which several have been performed at the LHC and the Tevatron. This projects aims to measure the UE measurement in way that is very different to previous measurements that are always sensitive to several effects.

This measurement

We try to separate and neglect contributions from the main interaction (Z boson production) from the remaining event activity, namely Multiple Parton Interactions (MPI) that are parton-parton interactions happening in addition to the interaction of interest in the same proton-proton collision. We measure track-based event-shapes, e.g. transverse Thrust

$$T = \sum_{i=1}^{N_{\mathrm{trk}}} \frac{|\vec{p}_{\perp,i} \cdot \vec{n}_T|}{p_\perp}$$

in $Z \to e^+e^-$ events where after removal of the leptons and a requirement on a low value of $p_\perp(Z)$, the remaining event activity should come from MPI. Tracks are measured in the Inner Detector of ATLAS and electron energies in the electromagnetic calorimeter (ECAL).



Pile-up correction

We choose to analyse ATLAS data from the data taking period of 2011 with a total number of 250.000 recorded $Z \to ee$ events. The number of simultaneous proton-proton interactions has an approximately stable mean for that dataset of $\langle\mu\rangle = 5$. However, the contributions of pile-up to our measurement are significant which is why we came up with a data-driven method to correct for tracks coming from additional proton-proton interactions. The method relies on the HBOM [9] approach of repeated application of the contamination one would like to correct the measured observable for. The actual correction is then achieved by parameterisation of observables as function of how often a contamination has been applied and by back-extrapolation to the non-contaminated distribution (see Fig. 1). The method can deal with many different observables and tests based on MC simulation show closure within $\mathcal{O}(1\cdots2\%)$ for the majority of bins of most observables (Fig. 2).

Figure 1: HBOM correction procedure for transverse Thrust. The red line, D_1, shows the to be corrected and D_0 the corrected distribution obtained by back-extrapolation. Lines labeled as $D_{2\ldots7}$ are obtained by recursively adding pile-up.

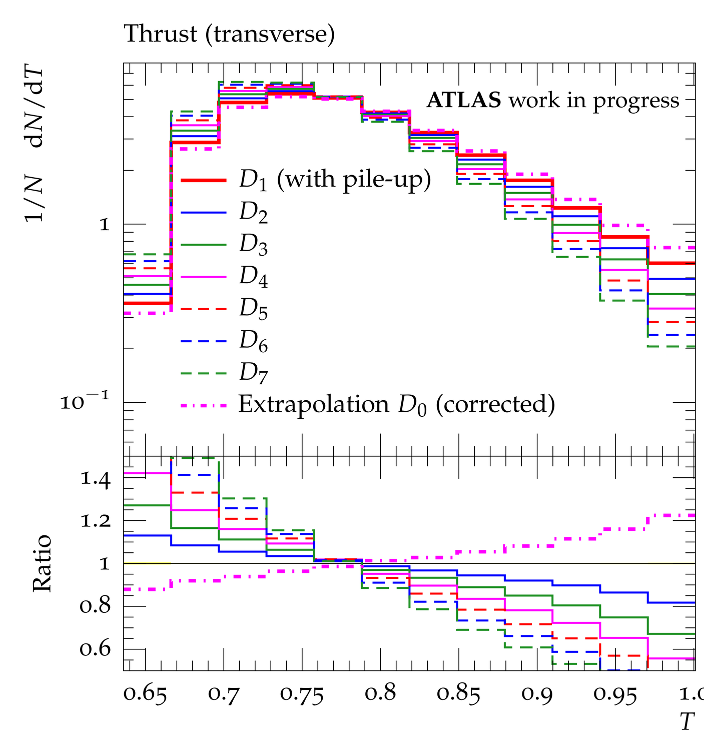
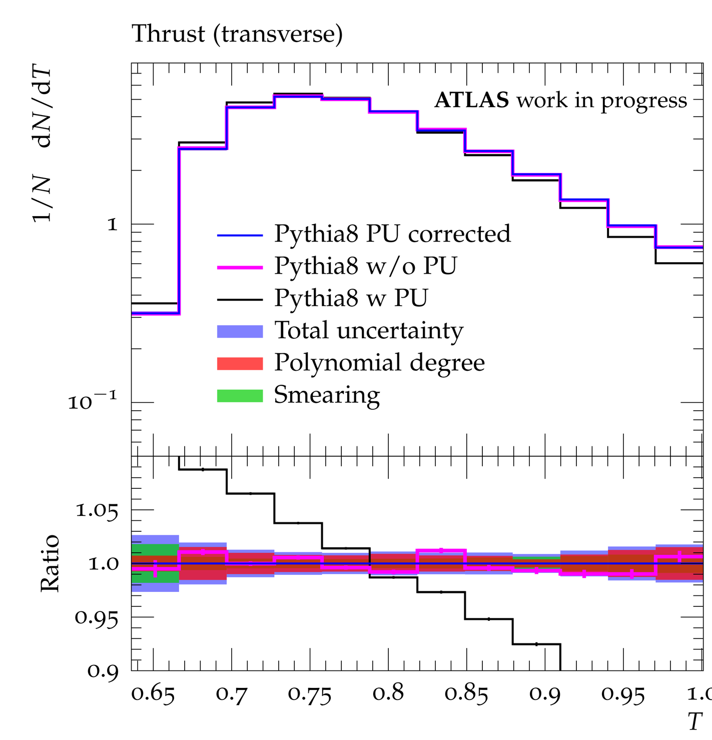


Figure 2: MC-based closure test (magenta coloured line) of pile-up correction and breakdown of systematic uncertainties for transverse Thrust. Comparison of Pythia8 sample with PU but corrected for PU with HBOM, and the same Pythia8 sample w/o PU shows closure of $\mathcal{O}(1..2\%)$ for most bins.



Unfolded distributions

The unfolding of detector effects is performed using a BAYESian method implemented in the Imagiro [10] package. The unfolding is done in several phase-spaces of $p_\perp(Z)$ allowing to probe regions very sensitive to MPI ($p_\perp(Z) < 6$ GeV, Fig. 3) and e.g. the fully inclusive phase-space where also contributions of recoil jets enter (Fig. 4). A comparison of the data points of both distributions shows that in the absence of a recoil jet the events tend to be more spherical (more entries of small values of T in Fig. 3). The comparison with generator level MC distributions shows that current models fail to describe event-shape data. Hence these distributions should be very helpful in improving the models of the Underlying Event by means of tuning.

Figure 3: Unfolded transverse Thrust distribution for ATLAS 2011 data in phase-space $p_\perp(Z) < 6$ GeV and comparison with generator level MC showing that current MPI models fail to describe the data.

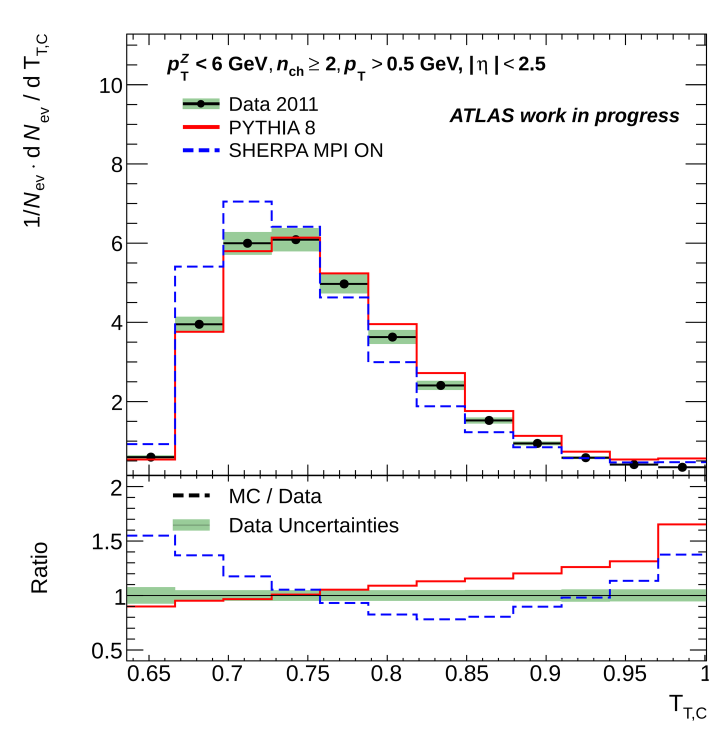
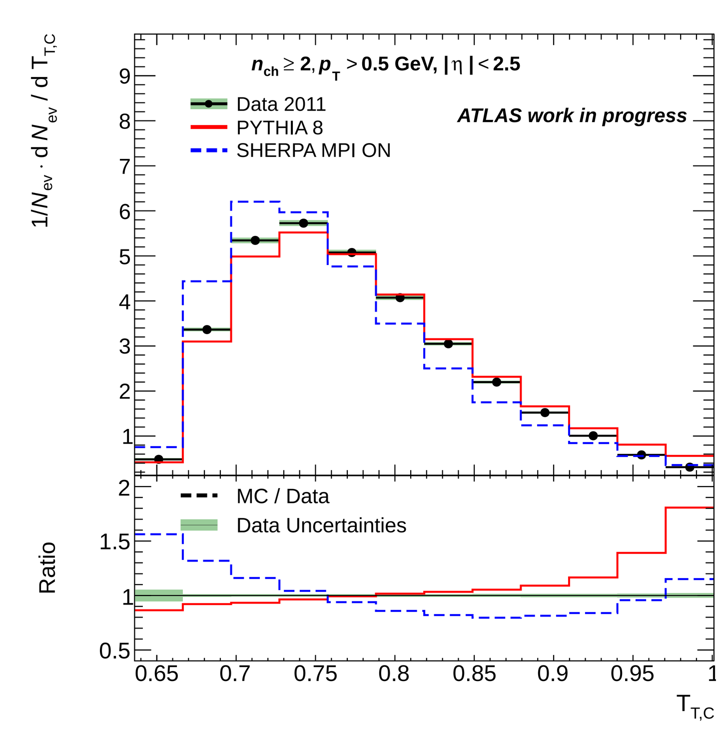


Figure 4: Unfolded transverse Thrust distribution for ATLAS 2011 data in fully inclusive $p_\perp(Z)$ phase-space and comparison with generator level MC showing that current MPI models fail to describe the data.



Publications and references

[1] Andy Buckley, Hendrik Hoeth, Heiko Lacker, Holger Schulz, and Jan Eike von Seggern. Systematic event generator tuning for the LHC. *Eur.Phys.J.*, C65:331–357, 2010.

[2] First tuning of herwig/jimmy to atlas data. Technical Report ATL-PHYS-PUB-2010-014, CERN, Geneva, Oct 2010.

[3] New atlas event generator tunes to 2010 data. Technical Report ATL-PHYS-PUB-2011-008, CERN, Geneva, Apr 2011.

[4] A Buckley, D Kar, P Loch, and J Monk. Summary of atlas pythia 8 tunes. Technical Report ATL-COM-PHYS-2012-738, CERN, Geneva, Jun 2012.

[5] H. Schulz and P.Z. Skands. Energy Scaling of Minimum-Bias Tunes. *Eur.Phys.J.*, C71:1644, 2011.

[6] Andy Buckley, Hendrik Hoeth, Heiko Lacker, James Monk, Holger Schulz, et al. New developments in event generator tuning techniques. *PoS*, ACAT2010:079, 2010.

[7] J.M. Butterworth, F. Maltoni, F. Moortgat, P. Richardson, S. Schumann, et al. The Tools and Monte Carlo working group Summary Report. 2010.

[8] J. Alcaraz Maestre et al. The SM and NLO Multileg and SM MC Working Groups: Summary Report. 2012.

[9] James W. Monk and Cristina Oropeza-Barrera. The HBOM Method for Unfolding Detector Effects. 2011.

[10] Benjamin Wynne. Imagiro: an implementation of bayesian iterative unfolding for high energy physics. 2012.

[11] Siegfried Bethke, Andre H. Hoang, Stefan Kluth, Jochen Schieck, Iain W. Stewart, et al. Workshop on Precision Measurements of α_s. 2011.

[12] B. Alessandro, D. Bergman, M. Bongi, A. Bunyatyan, L. Cazon, et al. Hadron-Hadron and Cosmic-Ray Interactions at multi-TeV Energies. 2011.

Selected Talks

- ACAT 2010, Jaipur [6]
- DIS 2011, Newport News
- Workshop on Precision Measurements of α_s, Munich 2011 [11]
- Hadron-Hadron and Cosmic-Ray Interactions at multi-TeV Energies, Trento 2011 [12]

Collaboration

- Collaboration with and theoretical guidance from Dr. Frank Krauss (IPPP, Durham, UK)

Profit from the GK

- Regular block-courses
- Financial support for attending conferences (e.g. DIS2011, Newport News, VA)

Contact Details and further Information

PhD student: Holger Schulz, hschulz@cern.ch
PhD advisors: Prof. Dr. Heiko Lacker, Jun. Prof. Dr. Arno Straessner

January 13, 2013

Supported by DFG Deutsche Forschungsgemeinschaft