Improving theoretical predictions for general collider observables

GRADUIERTENKOLLEG Masse-Spektrum-Symmetrie

TECHNISCHE UNIVERSITÄT DRESDEN

Motivation

As the LHC has ended its first years of operation, taking large sets of data at both 7 and 8 TeV, theoretical predictions of hadronic final states with as small uncertainties as possible are of prime importance for a large variety of processes. To this end a consistent combination of the available next-to-leading order calculations and the resummation provided by parton showers is paramount: it not only offers an improved description of the partonic short-distance interaction but also allows its connection to the non-perturbative description of long-distance interaction in an event, such as the formation of primordial hadrons and their decay into stable particles. For such a combination, denoted NLOPS, to be useful in a general purpose Monte-Carlo event generator, it of course needs to be formulated observable independently.
Further, the tremendous energy available at the LHC necessitates not only the accurate description of single-multiplicity events, but of whole event classes, e.g. the production of a W or Z boson in association with any number of jets. For such multiscale processes higher-order matrix themselves are not sufficient to reach the level of accuracy aimed for, but instead also the inherent hierarchy of the scales involved has to be resummed. Well known methods with LO accuracy, collectively called MEPS, therefore have to be extended to NLO. They then merge NLOPS calculations of successive jet multiplicities into an inclusive description.

Methods

In order to match any resummed calculation to a fixed-order expression, terms included in both ansatzes have to be identified and treated consistently. To this end two methods have appeared in the literature: MC@NLO and POWHEG, collectively denoted NLOPS. Both have been implemented in a process independent way [3,6] within the SHERPA Monte-Carlo event generator framework [2]. Further, in [6] it was shown that both methods are formally identical differing only in their choice of resummation kernels beyond their claimed accuracy.
Both methods can now be combined with well known MEPS methods, e.g. CKKW, to include a better description of higher jet multiplicities in an inclusive sample. This so-called MENLOPS [4,11] method describes the inclusive process at NLO accuracy while additional emission are described at LO accuracy. Hierarchies of scales are resummed wrt. the inclusive process.
These methods have been (re)formulated and implemented within the course of my PhD thesis and form the basis of the MEPS@NLO method [10,11]: the systematic elevation of the accuracy of the description of higher jet multiplicities to NLO by merging NLOPS matched calculations of the individual contributions in an extension of the CKKW method. It is thus able to describe both the inclusive process and its association with any number of jets at NLO accuracy, while at the same time resumming hierarchies of scales with the parton shower's accuracy wrt. the inclusive process, allowing a consistent assertion of its associated uncertainties [3,4,6,8,10,11,12].

Applications

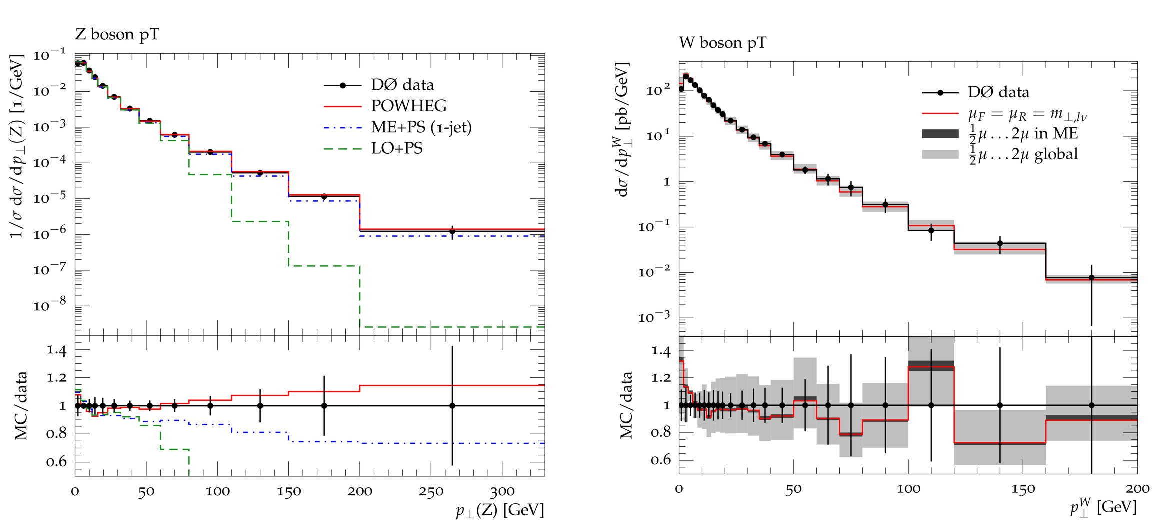

FIG. 1: Transverse momenta of the lepton pair in $p\bar{p}\to\ell\ell$ (left) and the lepton neutrino pair in $p\bar{p}\to\ell\nu$ (right) at the Tevatron compared to DØ data.

With the methods outlined above a number of important results have been obtained both within my PhD thesis and, building upon this work, thereafter. Fig. 1 shows exemplary results of such a calculation of the transverse momentum of a W or Z boson at the Tevatron and its associated uncertainties [3,4]. Similarly, more refined methods have been applied to the case of dijet production, enabling a full assessment of all associated perturbative and non-perturbative uncertainties of an NLOPS calculation [12]. In Fig. 2 these uncertainties are evaluated for the inclusive jet multiplicity and the three-jet-over-two-jet ratio.

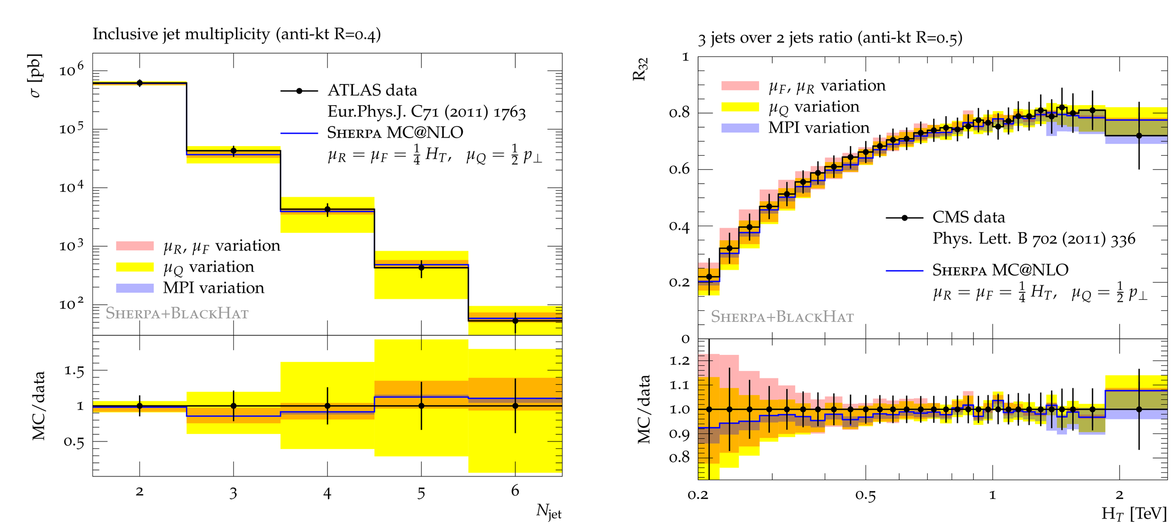

FIG. 2: Inclusive jet multiplicity (left) and three-jet-to-two-jet ratio (right) in inclusive jet production at the LHC compared to ATLAS and CMS data.

Fig. 3 then presents a calculation of the transverse momenta of the two hardest jets in W-boson production with the MEPS@NLO method, compared to data taken by the ATLAS collaboration, [10]. Therein, the $pp\to W+0,1,2$ jet(s) processes have been calculated at NLO accuracy, while the $pp\to W+3,4$ jets exhibit LO accuracy only. This is contrasted with a calculation using the MENLOPS method. The uncertainties due to the truncation of the perturbative series are shown as orange and blue bands, respectively. It can be seen that both the theoretical accuracy and data description are improved when including higher-order

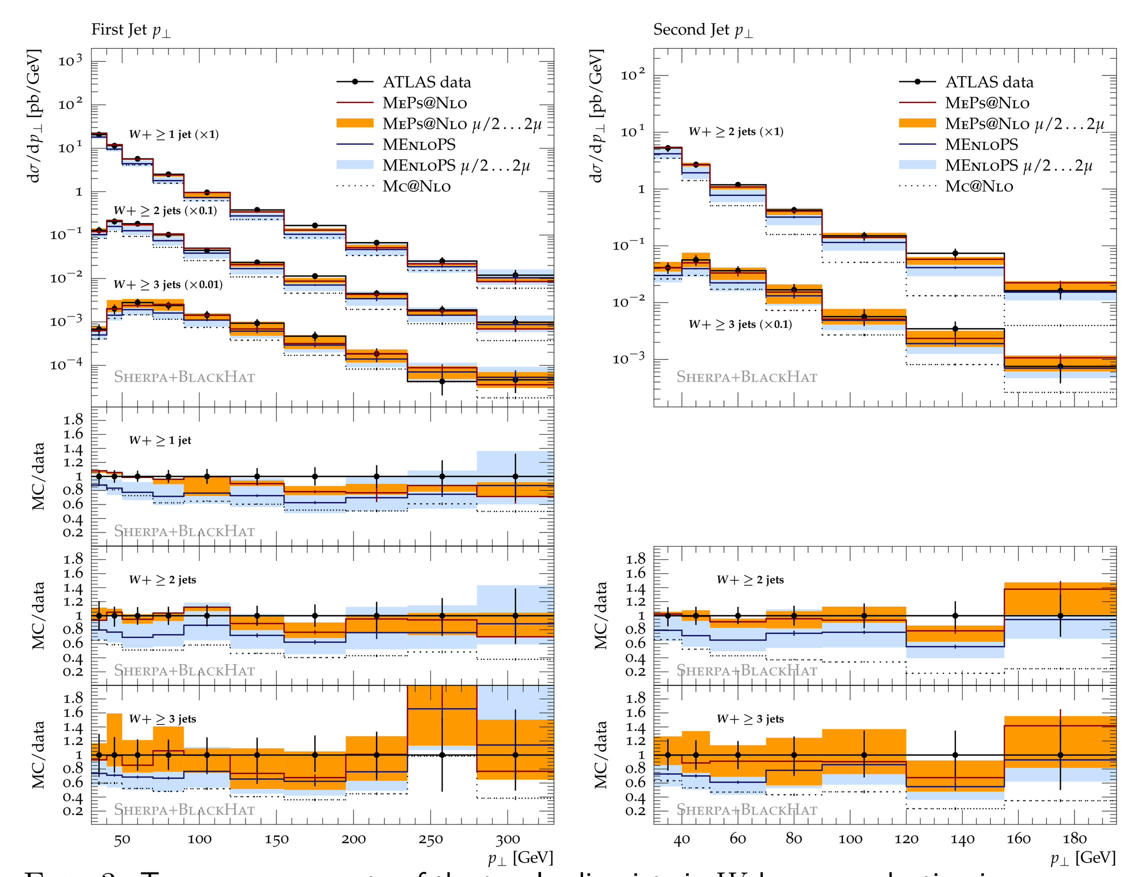

FIG. 3: Transverse momenta of the two leading jets in W-boson production in association with at least one, two, or three jets at the LHC.

matrix elements for multijet processes, as is the case for both observables in events with a W-boson in association with at least one or two jets.

Publications

1. M. Schönherr and F. Krauss, "Soft Photon Radiation in Particle Decays in SHERPA", JHEP12(2008)018, `arXiv:0810.5071`
2. T. Gleisberg et.al, "Event generation with SHERPA-1.1", JHEP02(2009)007, `arXiv:0811.4622`
3. S. Höche, F. Krauss, M. Schönherr, F. Siegert, "Automating the POWHEG method in SHERPA", JHEP04(2011)024, `arXiv:1008.5399`
4. S. Höche, F. Krauss, M. Schönherr, F. Siegert, "NLO matrix elements and truncated showers.", JHEP08(2011)123, `arXiv:1009.1127`
5. F. Bernlochner and M. Schönherr, "Comparing different ansatzes to describe electroweak radiative corrections to exclusive semileptonic B meson decays into (pseudo)scalar final state mesons using Monte-Carlo techniques", `arXiv:1010.5997`
6. S. Höche, F. Krauss, M. Schönherr, F. Siegert, "A critical appraisal of NLO+PS matching methods", JHEP09(2012)049, `arXiv:1111.1220`
7. S. Dittmaier et.al., "Handbook of LHC Higgs Cross Sections: 2. Differential Distributions", `arXiv:1201.3084`
8. S. Höche, F. Krauss, M. Schönherr, F. Siegert, "$W+n$-jet predictions at the Large Hadron Collider at next-to-leading order matched with a parton shower", to appear in PRL, `arXiv:1201.5882`
9. J. Alcaraz Maestre et.al., "The SM and NLO Multileg and SM MC Working Groups: Summary Report", `arXiv:1203.6803`
10. S. Höche, F. Krauss, M. Schönherr, F. Siegert, "QCD matrix elements + parton showers: The NLO case", submitted to JHEP, `arXiv:1208.2815`
11. T. Gehrmann, S. Höche, F. Krauss, M. Schönherr, F. Siegert, "NLO QCD matrix elements + parton showers in $e^+e\to$ hadrons", to appear in JHEP, `arXiv:1207.5031`
12. S. Höche, M. Schönherr, "Uncertainties in NLO + parton shower matched simulations of inclusive jet and dijet production", Phys.Rev.D86(2012)094042, `arXiv:1208.2815`

Selected Talks

- "Softe Photonemission und QED-Korrekturen höherer Ordnung", DPG Frühjahrstagung, Freiburg, 04.03.2008
- "Heavy Quark Production with SHERPA", 3rd Top Workshop, Grenoble, 24.10.2008 (invited talk)
- "SHERPA: Overview", YETI 2009, Durham, 12.01.2009 (invited talk)
- "SHERPA Status Report", "Towards NLO Event Generation with SHERPA", DPG Frühjahrstagung, München, 09.03.2009
- "Hadron Level Event Generation with NLO Accuracy with SHERPA", DPG Frühjahrstagung, Bonn, 16.03.2010
- "Systematic Uncertainties in SHERPA-1.2.2", V+jets Workshop, Durham, 09.09.2010 (invited talk)
- "Automation of the POWHEG Method and Consistent Combination with CKKW Merging", Annual Workshop of the Helmholtz Alliance, Dresden, 02.12.2010
- "Automating the POWHEG and MENLOPS Approches in SHERPA", DPG Frühjahrstagung, Karlsruhe, 31.03.2011
- "Automation of the POWHEG and MENLOPS approches in SHERPA", Les Houches, 03.06.2011
- "Recent Progress in Matching and Merging", QCD@LHC, St. Andrews, 23.08.2011 (invited talk)

Profit from the GK

- enabled participation in important workshops, conferences and schools (incl. GK courses)
- enabled collaboration/exchange of knowledge between theorists and experimentalists (e.g. [5])
- set the basis for successful start of scientific/postdoctoral work

Contact Details and further Information

PhD student: Marek Schönherr
PhD advisors: Dominik Stöckinger, Heiko Lacker

Website: `http://www.ippp.dur.ac.uk/ mschoenherr`
Email: `marek.schoenherr@durham.ac.uk`

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DRESDEN concept

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