Referee's Independent Report

Candidate: Oldřich Kepka
Degree: Doctor of Philosophy
Title of Thesis:
QCD and diffraction in the ATLAS Experiment at the LHC

The candidate has written an excellent thesis. It describes work on hard diffractive and exclusive processes in hadron-hadron scattering, with particular emphasis on both the physics and the ATLAS detector capability at the CERN Large Hadron Collider. The candidate has demonstrated a very high level of expertise in both theoretical and experimental analysis.

After some introductory remarks in the opening chapter, the thesis begins in Chapter 2 with a competent introduction of the Standard Model. The concept of diffractive scattering is introduced, and the theoretical foundation based on the Regge theory approach is nicely summarised. The whole field was given a boost in recent years by quantitative measurements of a hard component to diffractive scattering, originally through measurements of jet production in UA8 at CERN, but more recently through high-precision measurements of diffractive structure functions at HERA. This has led to new theoretical concepts, particularly the 'hard pomeron' and extensions of the standard QCD factorisation theorem. As for standard inclusive hard scattering, these ideas can be tested at the Tevatron. In particular, in hadron-hadron collisions soft interactions between the colliding hadrons can cause the rapidity gaps to be 'filled in' and indeed the resulting gap survival probabilities are in general quite small. There has been a lot of discussion of these survival probabilities in the recent literature (particularly on the concept of 'enhanced absorptive corrections', a reference to which could perhaps be added) with experimental data from the Tevatron providing a strong constraint on various models. All of these concepts are very clearly and comprehensively summarised in this chapter. Indeed this chapter could be worth publishing on its own as a very accessible review of the whole subject.

Chapter 3 is a self-contained yet comprehensive account of the LHC and the ATLAS detector. Each component of the detector is described, together with triggering and analysis strategies. The issue of multiple interactions per beam crossing, which is especially relevant for exclusive processes, is carefully addressed. The hardware discussion is then continued in Chapter 7, where explicit plans for forward proton detectors in the context of the Atlas Forward Physics programme are described in detail. It is shown how the standard candle $\gamma\gamma \rightarrow \mu\mu$ process could be used to align the various components of the detector.

In order to carry out the necessary simulations of diffractive processes at the LHC, it is necessary to have an appropriate event generator that contains the essential physics. In Chapter 4 the candidate describes his FPMC generator, which contains various options for treating the diffractive part of the process (based either on non-perturbative or semi-perturbative QCD approaches currently to be found in the literature) and also various 'hard scattering' final states. The generator also allows for processes which are mediated by photon-photon collisions. While these have so far not been relevant for studies at the Tevatron, they should be visible at the LHC and indeed form the basis for some interesting physics studies later in the thesis.

Chapter 5 discusses how the theoretical ideas and models for diffractive hard scattering processes can already be tested at the Tevatron, using the rapidity gap signature. The measured dijet cross section provides an excellent tool for distinguishing inclusive and exclusive production mechanisms, and indeed there is clear evidence for a significant contribution from the latter (Fig. 5.6 etc.). The fact that exclusive models (in particular those based on a perturbative approach) can well explain these data gives confidence for the corresponding LHC predictions. Although the dijet data has received the most attention, there are other more recent data on central exclusive production at the Tevatron, particularly regarding χ_c meson production [CDF Collaboration, Phys. Rev. Lett. 102, 242001 (2009)]. These data are also proving very useful in constraining the various models and perhaps mention could have be made of them.

I was particularly impressed by the very thorough theoretical and experimental analysis of the production of a pair of electroweak (W, Z) gauge bosons in photon-photon collisions at the LHC., the topic of Chapter 7. This can be used not only as a clean Standard Model benchmark process, but also as a way to search for anomalous gauge boson processes. Although much has been learned about anomalous (VVV) couplings at LEP and the Tevatron, the constraints on quartic (VVVV) couplings are much weaker. The $\gamma\gamma \to WW$, ZZ exclusive diffractive process at the LHC will provide a strong constraint on such couplings. In particular, significant limits can already be obtained in early LHC running. The work described in this chapter is highly original.

The bulk of the thesis is concerned with the scenario where far-forward protons are detected in special purpose detectors situated a long way from the interaction point, although it is acknowledged that the availability of such detectors is far from certain. Nevertheless experience at the Tevatron shows that much interesting 'exclusive' diffractive physics can be done using large rapidity gaps as a proxy for forward proton detection. This is the topic of Chapter 8, where new techniques for identifying rapidity gap events using the ATLAS calorimeters are described. This is a difficult challenge, since noise fluctuations in the calorimeter can 'fill in' the gaps.

Overall, the candidate has produced a very large amount of high-quality original research. The account of the work is everywhere written up in a professional manner, with good use of plots and diagrams and with appropriate citations. There are a small number of misprints and typographical errors which can be easily corrected and which do not detract from the quality of the research.

In summary, it is my strong opinion that the candidate deserves to pass his thesis defense and be awarded the PhD degree.

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