

Preface

The workshop on ‘HERA and the LHC’ successfully brought together experimental and theory experts working on electron–proton and proton–proton collider physics. It offered a forum to discuss the impact of present and future measurements at HERA on the physics programme of the LHC. The workshop was launched with a meeting at CERN in March 2004 and its first phase was terminated with a summary meeting in April 2005 at DESY. The workshop was very timely with on the one hand HERA-II, expected to deliver more than 500 pb^{-1} per experiment by 2007, ramping up to full strength, and on the other hand three years before the first collisions at the LHC.

The following aims were defined as the charge to the workshop:

- To identify and prioritize those measurements to be made at HERA which have an impact on the physics reach of the LHC.
- To encourage and stimulate transfer of knowledge between the HERA and LHC communities and establish an ongoing interaction.
- To encourage and stimulate theory and phenomenological efforts related to the above goals.
- To examine and improve theoretical and experimental tools related to the above goals.
- To increase the quantitative understanding of the implication of HERA measurements on LHC physics.

Five working groups were formed to tackle the workshop charge. Results and progress were presented and discussed at six major meetings, held alternately at CERN and at DESY.

Working group one had a close look at the parton distribution functions (PDFs), their uncertainties and their impact on the LHC measurements. The potential experimental and theoretical accuracy with which various LHC processes such as Drell–Yan, the production of W’s, Z’s and dibosons, etc. can be predicted was studied. Cross-section calculations and differential distributions were documented and some of these processes are used as benchmark processes for PDF and other QCD uncertainty studies. In particular W and Z production at the LHC has been scrutinized in detail, since these processes will be important standard candles. It is even planned to use these for the luminosity determination at the LHC. The impact of PDFs on LHC measurements and the accuracy with which the PDFs can be extracted from current and forthcoming data, particular the HERA-II data, have been investigated, as well as the impact of higher order corrections, small- x and large- x resummations. Initial studies have been started to provide a combined data set on structure function measurements from the two experiments H1 and ZEUS. Arguments for running HERA at lower energies, to allow for the measurement of the longitudinal structure function, and with deuterons, have been brought forward.

The working group on multi-jet final states and energy flows studied processes in the perturbative and non-perturbative QCD region. One of the main issues of discussion during the workshop was the structure of the underlying event and of minimum-bias events. New models were completed and presented during the workshop, and new tunes on p–p data were discussed. A crucial test will be to check these generator tunes with e–p and γ –p data from HERA, and thus check their universality. Other important topics tackled by this working group concern the study of rapidity-gap events, multi-jet topologies and matrix-element parton-shower matching questions. The understanding of rapidity gaps and in particular their survival probability is of crucial importance to make reliable predictions for central exclusive processes at the LHC. HERA can make use of the virtuality of the photon to study in detail the onset of multiple interactions. Similarly HERA data, because of its handles on the event kinematics via the scattered electron, is an ideal laboratory to study multiple-scale QCD problems and improve our understanding in that area such that it can be applied with confidence to the LHC data. For example, the HERA data give strong indications that in order to get reliable and precise predictions, the use of unintegrated parton distributions will be necessary. The HERA data should be maximally exploited to extract those distributions.

The third group studied heavy flavours at HERA and the LHC. Heavy quark production, in particular at small momenta at the LHC, is likely to give new insight into low- x phenomena in general and saturation in particular. The possibilities for heavy quark measurements at LHC were investigated. The charm and bottom content of the proton are key measurements, and the anticipated precision achievable with HERA-II is very promising. Furthermore, heavy quark production in standard QCD processes may form an important background in searches for new physics at the LHC and has therefore to be kept as much as possible under control. Again, heavy quark production results from mostly multi-scale processes where topics similar to those discussed in working group two can be studied and tested. Important steps were taken for a better understanding of the heavy quark fragmentation functions, which are and will be measured at HERA. The uncertainties of the predicted heavy quark cross-section were studied systematically and benchmark cross-sections were presented, allowing a detailed comparison of different calculations.

Diffraction was the topic of working group four. A good fraction of the work in this group went into the understanding of the possibility of the exclusive central production of new particles such as the Higgs $pp \rightarrow p+H+p$ at the LHC. With measurable cross-sections, these events can then be used to pin down the CP properties of these new particles, via the azimuthal correlation of the two protons, and thus deliver an important added value to the LHC physics programme. The different theoretical approaches to calculate cross-sections for this channel have been confronted, and scrutinized. The Durham approach, though the one that gives the most conservative estimate of the event cross-section, namely in the order of a few femtobarns, has now been verified by independent groups. In this approach the generalized parton distributions play a key role. HERA can determine generalized parton distributions, especially via exclusive meson production. Other topics discussed in this group were the factorization breaking mechanisms and parton saturation. It appears that the present diffractive dijet production at HERA does not agree with a universal description of the factorization breaking, which is one of the mysteries in the present HERA data. Parton saturation is important for event rates and event shapes at the LHC, which will get large contributions of events at very low- x . Furthermore, the precise measurement of the diffractive structure functions is important for any calculation of the cross-section for inclusive diffractive reactions at the LHC. Additionally, this working group has really acted as a very useful forum to discuss the challenges of building and operating beam-line integrated detectors, such as Roman Pots, in a hadron storage ring. The experience gained at HERA was transferred in detail to the LHC groups which are planning for such detectors.

Finally, working group five on the Monte Carlo tools had very productive meetings on discussing and organizing the developments and tunings of Monte Carlo programs and tools in the light of the HERA–LHC connection. The group discussed the developments of the existing generators (e.g., PYTHIA, HERWIG) and new generators (e.g., SHERPA), or modifications of existing ones to include p – p scattering (e.g., RAPGAP, CASCADE). Many of the other studies like tuning to data, matrix-element and parton shower matching, etc., were done in common discussions with the other working groups. Validation frameworks have been compared and further developed, and should allow future comparisons with new and existing data to be facilitated.

In all it has been a very productive workshop, demonstrated by the content of these proceedings. Yet the ambitious programme set out from the start has not been fully completed: new questions and ideas arose in the course of this workshop, and the participants are eager to pursue these ideas. Also the synergy between the HERA and LHC communities, which has been built up during this workshop, should not evaporate. Therefore this initiative will continue and we look forward to further and new studies in the coming years, and the plan to hold a workshop once a year to provide the forum for communicating and discussion the new results.

We thank all the convenors for the excellent organization of their working groups and all participants for their work and enthusiasm and contribution to these proceedings.

We are grateful to the CERN and DESY directorates for the financial support of this workshop and for the hospitality which they extended to all the participants. We are grateful to D. Denise, A. Grabowski and S. Platz for their continuous help and support during all the meeting weeks. We would like to thank also B. Liebaug for the design of the poster for this first HERA–LHC workshop.

Hannes Jung and Albert De Roeck