

Schlussbericht

<b>Förderinstrument:</b>	<b>Helmholtz-Nachwuchsgruppen</b>
<b>Impulsfonds-Förderkennzeichen:</b>	VH-NG-401
<b>Projekttitle:</b>	Physics of gluons and heavy quarks from HERA to the LHC.
<b>Nachwuchsgruppenleiter/in:</b>	Katerina Lipka
<b>Helmholtz-Zentrum:</b>	DESY Hamburg
<b>Beteiligte Hochschule:</b>	Universities of Hamburg and Mainz
<b>Berichtszeitraum (Förderzeitraum):</b>	01.05.2008-30.06.2013

**1. Zusammenfassung (max. 1 DIN A4-Seite)**

*Stellen Sie kurz die wesentlichen Ergebnisse und Fortschritte gegenüber dem Stand des Wissens zum Zeitpunkt der Antragstellung dar und geben Sie einen Ausblick auf mögliche künftige Arbeiten sowie mögliche Anwendungen.*

Main achievements of the project encompass precision measurements of heavy quark production at HERA and the LHC and their implication for the extraction of fundamental parameters of quantum chromodynamics (QCD), like heavy quark masses and the strong coupling constant, and for the determination of parton distribution functions in the proton. The results achieved are of high relevance for the physics program at the LHC, since its discovery potential is limited by the precision of the standard model predictions and the knowledge of the proton structure. Several measurements in the project are novel and have not been performed before.

For the first time at the H1 experiment, the cross sections of D\*-mesons were measured at highest achievable energy scales,  $Q^2$  for such an analysis. These results were used among other measurements of charm quark production in the HERA combination of charm production cross-sections. For the first time, the combined charm measurements were included in the QCD analysis together with inclusive deep-inelastic cross sections to determine the parton distribution functions (PDFs) of the proton. The gluon universality was demonstrated and the mass of the charm quark was constrained, resulting in significant reduction of the associated PDF uncertainties and, in turn, improved accuracy on predictions for W- and Z-boson production at the LHC. The combination of the charm production measurements at HERA and their inclusion in the QCD analysis was one of the main aims of the proposal and was initiated and to large extent performed by the members of the group. The publication of the results of this unique analysis is among the most important milestones of the HERA physics program and a demonstration of the significant impact of the HERA data on the physics program at the LHC. In collaboration with the theory group of DESY Zeuthen and the University of Hamburg, the running mass of charm quark was determined to next-to-leading order (NLO) and approximate next-to-next-to leading order (NNLO) QCD and the results enter the world average estimate by the Particle Data Group (PDG) in 2013. This result is of general importance for fundamental research in particle physics, and in particular, for determination of proton PDFs.

The group pioneered the measurement of differential cross sections of top-quark production at the LHC and the determination of top-quark mass in pole-mass and running mass definition, using the inclusive cross-section measurement of top-quark pair production at the CMS experiment. For the first time, the top-pair cross-section measurements are used to determine the strong coupling constant of QCD. This measurement probes large energy scales and, in contrast to other measurements of strong coupling at hadron colliders, it

profits from small theoretical uncertainty, enabled by availability of the NNLO calculation. The group contributed significantly to the QCD analysis of jet production at HERA and the LHC, in particular through simultaneous determination of proton PDFs and the strong coupling constant. The group contributed to the development and the release of the HERAFitter analysis tool, which provides the experiments for the first time with a framework for QCD analysis of the experimental data and direct tests of different theory approaches. The group plays the leading role in organisation of physics forums at the LHC, devoted to the extraction of the fundamental QCD parameters and the proton PDFs.

In the context of QCD analyses of the LHC data, several questions related to theory and experiment were raised by the group, requiring a novel approach for a theory-experimental collaboration. A need for a common inter-experimental activity, in close collaboration with the theory groups, for determination of the proton structure using proton-lepton and proton-proton collisions was formulated in the proposal "Determination of the proton structure using deep inelastic scattering and proton-proton collisions", supported by the HGF special funding in 2012-2015 (SO-072). The group represents the origin and the core of the international, multi-institute network "Proton Structure Analyses in Hadronic Collisions", an initiative between theoretical and experimental groups, aiming for a significant increase of the LHC discovery potential through increased precision in the understanding of the Standard Model. In this framework, new collaborations with German universities were established or strengthened. The group is contributing to the project "Inclusive and Semi-Inclusive Constraints on Parton Distributions at the LHC and the Study of Hard Processes" within HGF Alliance "Physics at the Terascale" that was launched in 2013.

## **2. Arbeits- und Ergebnisbericht**

### **a) Ausgangslage (max. 1 DIN A4-Seite)**

By the start of the project in 2008, the Large Hadron Collider LHC at CERN was in the commissioning phase, aiming for the discovery and study of the Standard Model Higgs production and searches for the physics beyond the Standard Model in proton-proton collisions. The most probable channel for Higgs and top quark production at the LHC is the interaction between gluons of the colliding protons, the so-called gluon-gluon fusion. On the other hand, this process is also the main source of huge backgrounds. The success of the LHC effort in studying the Standard Model and its possible extensions demanded a correct description of the processes originating from gluon-gluon fusion. This made the precision of the gluon density distribution in the proton a key issue for LHC physics. The knowledge of the gluon density distribution in the proton is provided by electron-proton scattering experiments at HERA. In the end of the HERA running in 2007, upgrades in accelerator performance, detector hardware and the event reconstruction at the HERA experiments allowed for high precision measurements of the gluon density with additional constraints from photon-gluon fusion processes. Such measurements were not feasible before to the desired accuracy. The detailed study of the photon-gluon fusion process at HERA and a better determination of the gluon density in the proton through study of charm production by inclusion of high-precision charm measurements into the global QCD analysis, together with the study of the impact of the precise HERA data on accuracy of the prediction for the LHC processes was the major goal of the proposal.

In 2010, the proton beams were brought into collisions at the LHC reaching a centre of mass energy of 7 TeV. First evidence for Higgs-like particle was reported in 2011, when the LHC became also a top quark factory. The top quark plays a very special role in the description of the matter structure and interactions. Being the heaviest fundamental particle, it offers the unique possibility to study bare quark properties and to investigate Higgs couplings. Together with the Higgs-boson mass, the top-quark mass gives insights in the stability of the electroweak vacuum, connected to the ultimate fate of the universe. With the first data of the LHC available, the measurements of the top quark production cross section was planned

and the extraction of the top quark mass was envisaged.

The proposal took part in the interplay of both HERA experiments, theory, and the first analyses of the CMS experiment at LHC in the common effort of the understanding of the Standard Model of high-energy physics.

### **b) Darstellung der erzielten Ergebnisse (max. 4 DIN A4-Seiten)**

The topics addressed in the project are the precision measurement of the charm contribution to the proton structure function at HERA, the phenomenology of charm quark production in deep inelastic electron-proton scattering and the determination of charm quark mass, the measurement of the top quark cross section and mass at the LHC, as well as contribution to the detector upgrade programme of the CMS experiment. In the following, the activities of the group in these topics are briefly summarised. The experimental analyses are performed within the international collaborations H1 and ZEUS at HERA accelerator and the CMS experiment at the LHC.

#### **Role the charm production measurements in the determination of parton density functions at HERA and the impact on the cross section predictions for the LHC**

The major achievements of the project in this topic are: the combination and QCD analysis of charm quark cross-sections in deep-inelastic scattering; the determination of the charm quark mass; the study of the impact of HERA charm production measurements on the LHC physics. In the following, the achieved milestones are listed. The topics were initiated and the results were achieved with major or sole contribution of the group members.

##### Measurements of $D^*$ -meson production at HERA

Charm quarks cannot be directly measured. Instead, hadrons originating from charm quarks are identified (charm tagging). Different techniques are used experimentally to tag charm quarks – either through full reconstruction of charmed mesons, or exploiting long the lifetime of the heavy flavoured hadrons and the large mass of heavy quarks, expressed in the vertex displacement of tracks of final state particles. Of particular importance are the precision of the measurements and the fraction of covered kinematics plane, which ultimately determines the theoretical uncertainty.

The group contributed significantly to the measurements of the charm production cross sections at the H1 experiment via the reconstruction of  $D^*$  mesons at medium energy scale  $Q^2$  and performed for the first time the measurement of charm production cross section at high  $Q^2$  within H1. This is the most precise HERA measurement in this kinematics range. The analysis demonstrated, that the theoretical assumption of a massless charm quark in the proton is not applicable at HERA energies.

##### Combination and QCD analysis of charm cross sections and the impact for LHC physics.

The combination of different charm tagging methods at HERA was initiated and realized by the group. The charm-quark production cross-sections of 9 different measurements from the HERA experiments, H1 and ZEUS, were used, applying a consistent theory treatment to correct for the unmeasured phase space. The measurements were combined through a sophisticated statistical procedure, taking into account the correlations of all systematic uncertainties. As a result, the most precise charm quark cross sections in DIS are obtained. For the first time, the HERA measurements of charm production were included into the full QCD analysis of the HERA data, together with inclusive DIS cross sections. The uncertainties on the gluon, the charm and the light sea quark distributions are significantly reduced. Charm quark mass values in different theoretical approaches are determined. The impact of this study on the predictions for W- and Z- boson production at the LHC is investigated. It has been demonstrated, that the inclusion of the HERA charm cross section

measurements in the PDF fit reduces the uncertainty on the predictions for electroweak boson production at the LHC related to the theoretical treatment of charm quark from 7% to less than 2%.

#### Charm mass measurement

In close collaboration with the theory group (ABM) of DESY Zeuthen and the University of Hamburg, the running mass of the charm quark is determined, to next-to-next-to-leading order (NLO) and approximate next-to-next-to leading order (NNLO) perturbative QCD. For the first time, the charm quark mass value obtained from DIS data is included in the PDG estimate of the world average on the running charm quark mass. In addition, a simultaneous determination of the charm quark mass and the proton PDFs is performed.

#### Impact of jet data on the determination of proton PDFs and the strong coupling constant

The jet measurements provided by both H1 and ZEUS collaborations are included into the PDF fit together with preliminary combined H1 and ZEUS inclusive neutral current and charged current cross sections. By using the jet measurements, the correlations between the gluon density and the strong coupling constant has been significantly reduced. This analysis enabled the simultaneous determination of the parton density functions and the value of the strong coupling constant at the scale of Z-boson mass. The first measurements of inclusive jet production at the CMS experiment are included into the QCD analysis and a comprehensive study of the correlations of the experimental uncertainties is performed.

#### Accomplishment of the analysis of charge current cross sections at high $Q^2$ at HERA

The analysis of the deep-inelastic charged current scattering at HERA with longitudinal electron (positron) polarisation in HERA-II running period is has been accomplished. Results are published together with measurements of neutral current cross sections and NLO QCD analysis of the two data sets. This measurement is a major milestone in HERA physics programme and is the prerequisite for the final determination of the ultimate PDF set from HERA, the HERAPDF2.0.

#### HERA combination and the determination of HERAPDF

The data combination has highest priority in the physics programme of both the H1 and ZEUS collaborations. The group members took over leading positions in the combination activities of the HERA measurements and contribute significantly to the QCD analysis of the HERA data (HERAPDF). Also after the end of the project mandate, the responsibilities of the group members will remain until the full programme of the combination activities is finalised. In particular, the combination and the QCD analysis of the inclusive and semi-inclusive DIS cross sections, resulting in PDF set HERAPDF2.0 is envisaged end 2013/beginning 2014.

#### Tool development for determination of PDFs in hadron-induced interactions

The group contributed significantly to development of an open source framework HERAFitter for QCD analyses, which can be used for the determination of PDFs and fundamental QCD parameters like heavy quark masses and the strong coupling constant. The HERAFitter program provides a platform for experimentalists for studying the effect of different measurements on the PDFs even in an early stage of the analysis, using different theoretical schemes. HERAFitter is successfully used at the LHC. The development of HERAFitter has its origin in the HERAPDF group and is meanwhile supported by developers from the H1, ZEUS, ATLAS and CMS experiments and several QCD theory groups.

The first version of the HERAFitter has been made public in September 2011. The group contributes to the stable release of the code through the implementation and validation of different heavy flavour schemes, providing the interface to PDF libraries and to the theory calculations of top-quark pair production, implementation of the new data sets and documentation.

### Phenomenology of charm production in DIS at HERA

In collaboration with the THEP group of the Johannes-Gutenberg University of Mainz, the group participated in the development of the theoretical models of charm production at HERA at next-to-leading order (NLO) in perturbative QCD. These activities were supported by the Forschungszentrum des Landes Rheinland-Pfalz "Elementarkräfte und Mathematische Grundlagen". The H1 observation of differences in the  $D^*$ -meson fragmentation function observed in the charm threshold region with respect to the high energy regime was explained by the deficits in the definition of the fragmentation variable in the existing models.

### **Measurements of top quark production with the CMS experiment and CMS upgrade**

Within DESY CMS top-quark working group, the project group consolidated its strong position in the Top Physics Analysis Group of the CMS experiment and works together with the top quark group of the University of Hamburg. The achieved milestones are listed in the following.

### Measurements of top quark pair production at CMS

The very first differential measurement of the top-quark pair production at a centre-of-mass energy of 7 TeV at the LHC is performed. The top-quark pair production is identified via top-quark decays with 2 leptons (muons and electrons) in the final state. The cross sections are determined as a function of the kinematics of leptons, and top (anti-top) quarks. The measurement has been performed in close collaboration with the group of Hamburg University. The group made a major contribution to the publication of the results. The measurements of the differential cross sections at the centre-of-mass energy of 8 TeV is in the editorial procedure.

### Measurements of ratio of top-quark pair and Z-boson production

The measurement of the cross section ratio of top-quark pair production to Z-boson production is performed, using the decay channels with muons and electrons in the final state. The data set collected by the CMS experiment in 2011 is used. The advantage of the ratio measurement is its insensitivity to the luminosity uncertainties. Therefore it is used as an alternative method to determine the top-pair production cross section using the NNLO prediction of the Z-boson production. The obtained top-quark pair production cross section is in agreement with the SM predictions at approximate NNLO and with the earlier CMS result. The work on the measurement of the cross section ratios at 7 and 8 TeV is in the editorial procedure.

### Top-Quark Mass Measurement

The pole mass and running mass of the top quark was determined for the first time at the CMS experiment by comparing the top-quark pair production cross section measurement to different approximate NNLO predictions. This approach allows obtaining the top quark mass in an unambiguous definition, while the direct measurements so far always rely heavily on less-well defined top-quark masses from Monte Carlo simulations. The results are in very good agreement with similar measurements by the Tevatron experiments and by ATLAS. The publication of the results is in the editorial procedure.

### PDF-related studies using top-quark pair production at CMS

Top-pair production at the LHC probes the range of high proton momentum fractions  $x$  of the interacting partons. The PDFs in this  $x$ -range are poorly constrained so far by the HERA and Tevatron data. Therefore, top-pair production at the LHC can help constraining the gluon density at high  $x$ . Studies on PDF constraints from measured top-quark pair cross sections are performed. The program Hathor is implemented into the HERAFitter allowing for comparisons between data and predictions for the inclusive top-pair cross-section at NNLO. Studies of the PDF-dependence of differential cross section measurements using

NLO predictions are performed.

#### Determination of the strong coupling constant.

The determination of the strong coupling constant is performed by comparing the total top-pair cross section measured by CMS to predictions at NNLO using different available PDF sets. This is the first extraction of the strong coupling constant using top-quark measurements. It probes the strong coupling constant at high energies with remarkable experimental and theoretical precision. The publication of this analysis is in the editorial procedure. Comprehensive studies on the dependence of differential top-quark pair production cross-sections on top quark mass, the strong coupling constant and the PDFs are performed, using NLO predictions. The work on the simultaneous determination of these parameters is in progress.

#### Top production in association with jets in CMS.

The group is involved in the measurement of top-pair production in the two-lepton final state in association with additional jets. The normalised differential top-pair production cross-section as a function of the jet multiplicity is measured. The distribution of the fraction of events without additional jets above a certain transverse momentum threshold is also obtained. Preliminary results at 7 TeV are published. The publication containing these results and those in the lepton+jets channel is in preparation. Studies on jet-charge and jet-flavor identification using muons in jets for  $t\bar{t}$  event reconstruction are performed and the first CMS-internal estimate for the measurements of the top-quark mass using  $J/\psi$  candidates with the 7 TeV data is made.

#### Further top-quark physics related responsibilities within CMS

The group is acting as link between the Generator group and the Top Physics Analysis group within the CMS experiment, processing requests for simulations and testing their technical implementation for production as well as validating new Monte-Carlo event generators.

The group has overtaken responsibilities for coordinating the top-mass working group within the CMS experiment and for the combination of top quark pair production results from the CMS and ATLAS experiments. The latter activity is being carried out within the TOPLHC working group, which involves the top-quark physics groups from CMS, ATLAS and related theorists.

The group is also performing studies for CMS on the trigger and lepton identification and isolation efficiencies at center-of mass of 8 TeV for two-lepton final states. First results on early 2012 data are obtained for the cross-section measurement of top-pair production in the two-lepton channel. Currently, updated results using larger data samples are being used in several analyses of top-pair and single-top production, as well as in super-symmetric top searches.

#### Physics case simulation studies for the upgrade of pixel silicon tracker at CMS.

The upgrade of the CMS pixel detector will include the insertion of an additional layer of silicon detectors in the barrel and one additional disk in each endcap. This will improve in particular track reconstruction at smaller particle transverse momenta, resulting in significant increase of the b-tagging efficiency. Within the Super-LHC (SLHC) Tracker Simulation Group, and in collaboration with DESY CMS, the group performed physics simulation studies of the pixel detector. The tracking and b-tagging performance of the detector after the upgrade is investigated. Studies at the High-Level Trigger (HLT) level and in the full CMS track reconstruction are made. For this purpose, the existing tracking software had to be significantly modified in order to fully exploit the capabilities of the enhanced geometry. The improvement in tracking efficiency from 80% to over 90% and decrease of the fake rate by a factor of 2, both in the HLT tracking using the tracks in the pixel detector only and in the full CMS tracker is demonstrated. The developed software has been integrated into the

CMS software and became the official tracking algorithm for the upgrade projects. The HLT triggers based on b-tagging have been commissioned using the new tracking, resulting in a significant improvement in the b-tagging performance. The contribution is documented in the Technical Proposal and top-quark-related physics case analyses for the Technical Design Report (TDR).

**c) Ausblick auf zukünftige Arbeiten, Nachhaltigkeit (max. 2 DIN A4-Seiten)**

During the running of the project and based on the achieved results, several additional and related studies have been started, expanding significantly the physics programme of the original proposal.

The demonstrated sensitivity of the charm production cross-section measurements to the gluon and charm distribution in the proton enabled the determination of charm quark mass using DIS data. This particular study was not planned in the original proposal and represents a unique fundamental measurement, resulted from the joint effort of theory and experiment. Improvements of experimental measurements and theoretical calculations will further increase the precision of the charm quark mass measurement and the next publication of the updated result at NNLO is already planned in 2013.

The group members will further contribute to the upgrade of the CMS track detectors, in different upgrade phases, in this way strengthening the leading role of DESY in the LHC tracker upgrade program.

The contribution to the development of HERAFitter, establishing its usage in the LHC experiments and the organisation of the PDF forum within the CMS experiment are other spin-offs of the original proposal, which contribute to the QCD-related studies at the LHC. The development of the joined effort in theory and the LHC experiments in determination of parton distribution functions in the proton is the subject of the related project “Determination of the proton structure using deep inelastic scattering and proton-proton collisions”, launched in 2012 (HGF Kennzeichen S0-072).

The results achieved in the projects HGF-NG-401 and S0-072 are of particular relevance and will obtain greater importance over the next years. Nowadays, after the discovery of a Higgs boson at the LHC, the attention of the community shifts from observation of a signal towards precision measurements of the properties of this particle and searches for new physics. Establishing the Higgs-boson physics and the potential of the LHC for further discoveries, in particular at the high-energy runs at 13 and 14 TeV, depends severely on the precision of the Standard Model predictions. The latter is limited by the knowledge of the proton structure, yet unsolved phenomenological questions of the treatment of heavy quarks in QCD analyses, the accuracy of heavy quark masses and the strong coupling constant. Significant improvement in precision of these fundamental quantities can be achieved only in a joined effort of the experimental and theory groups, involved in the analysis and interpretation of LHC measurements, in particular sensitive to the proton structure and QCD parameters. This is the goal of the project “Proton Structure Analyses in Hadronic Collisions”, which encompasses different physics analyses at the LHC and other colliders, theory calculations and tool development. The idea of this long-term project originates and has been developed to large extent within the HGF-NG-401 project, with new collaborations with institutes in Germany and abroad established. In particular, close collaboration with the Universities of Hamburg, Mainz, Karlsruhe, Freiburg and Wuppertal is established within a common project “Inclusive and Semi-Inclusive Constraints on the Parton Distributions at the LHC and the Study of Hard Processes”, launched in 2013 within the Helmholtz Alliance “Physics at the Terascale”.

The results achieved in the mentioned activities are expected to play crucial role in the physics program at the LHC over its whole running period.

**d) Anwendungs-/Verwertungspotenzial (max. 2 DIN A4-Seiten)**

The results achieved in the scope of the project are of high relevance for the fundamental

research in high-energy physics and could be of interest for astro-particle physics, in particular for simulations of the cosmic ray interactions with the atmosphere, but of only limited interest for immediate applications in the industrial use.

### **3. Qualifikation des wissenschaftlichen Nachwuchses (max. 2 DIN A4-Seiten)**

*Beschreiben Sie die Struktur der Nachwuchsgruppe im Verlauf des Förderzeitraums und die wesentlichen Qualifikationserfolge (einschließlich Ihrer Person): Diplome, Promotionen, Habilitationen, Berufung/Juniorprofessur, Tenure Track, Preise etc., Besonderheiten und Ihre berufliche Planung nach Auslaufen der Förderung.*

The group was counted 6 postdocs (including the group leader) and 5 students. The post-docs involved in the project hold leading positions in physics analyses at HERA and the CMS experiment and gained significant visibility in their field of research.

*In the following, the qualification of the post-docs in the group is presented.*

After the positive evaluation in 2011, the group leader remains on the staff position at DESY and is the principle investigator (PI) in the project “Determination of the proton structure using deep inelastic scattering and proton-proton collisions” and one of the PIs for “Inclusive and Semi-Inclusive Constraints on the Parton Distributions at the LHC and the Study of Hard Processes”. The group leader holds the coordination position of HERA combination activities and PDF-related studies in the CMS experiment.

Dr. Maria Aldaya Martin accepted an offer for a position at the University of Hamburg and holds a coordination position in the LHC combination activities in top-quark physics. With the change of affiliation, Dr. Aldaya had to give up her position as convener of DESY-CMS top working group. Dr. Aldaya is highly qualified as a leader of a junior research group. With the support from DESY and the Universities of Hamburg and Karlsruhe, she is supported by DESY for the application for a HGF Young Investigator Group in 2013 with her project “Ultimate precision measurements and searches for new physics using top quarks at the CMS experiment at the LHC”.

The work of Dr. Alim Kadeer was supported by the Forschungszentrum des Landes Rheinland-Pfalz “Elementarkräfte und Mathematische Grundlagen”. After accomplishment of his first post-doc period, Dr. Kadeer left physics.

Dr. Krzysztof Nowak, during the 2 years of his work in the group, took over the responsibilities as a convener of the “Hadronic Final State” group of the H1 experiment and as a convener of the combination activities in HERA jet group. He accepted an offer for a post-doc position from the University of Oxford in November 2012.

Dr. Sebastian Naumann-Emme took over the responsibility as a convener of the Top Mass Working Group within the CMS Collaboration and also acts as the software coordinator of the CMS Top Group. Dr. Naumann-Emme is an outstanding young scientist, who qualified himself as a potential research group leader. DESY supports the application of Dr. Naumann-Emme for a Young Investigator Group in 2013 with his project “Top Images: ultimate-precision physics based on novel particle-detection and event-reconstruction techniques at a future lepton collider”.

Dr. Ringaile Placakyte plays a leading role in the HERAFitter project as one of the conveners and carries responsibility for the combination of the HERA inclusive data and the organisation of the PDF-related activities in the CMS experiment. Dr. Placakyte accepted the offer for a position within the DESY Analysis Center assuming preserving her responsibilities in PDF-related activities.

*The details of qualification of students are given below.*



Martin Brinkmann accomplished successfully his Ph.D. at the University of Hamburg with magna cum laude in 2010 and after a short-term employment as a post-doc in the group for finalisation of the analysis, accepted the offer of a post-doc position within the DESY Fellowship program.

Monica Dobre accomplished her Ph.D. in the University of Hamburg with cum laude in 2012 and accepted the offer for a staff position in the Bucharest University.

Jan Kieseler accomplished his Diploma thesis in the University of Hamburg in 2012 with honours, and was nominated by the CMS group of DESY for the Otto-Stern prize. In May 2012 he started his Ph.D. in the group with affiliation DESY/University of Hamburg. In spite of yet early stage of his professional experience, Jan Kieseler was asked to take the responsibilities of the generator contact person in the CMS top-quark working group.

Due to personal reasons, the Ph.D. student Boris Pokorny had to return to Chech Republic after few months of his studies in Germany. Due to family reasons, the Ph.D. student Ewelina Kosior quitted physics, left Germany and moved to France.

#### **4. Öffentlichkeitsarbeit**

*Welche Maßnahmen zur Öffentlichkeitsarbeit wurden ergriffen (z.B. Erfolgsberichte in den Medien, eigene Website)?*

The group is well represented in the community by about 15 public presentations per year by the group members at the international workshops, conferences and public seminars. The group has the website with the activities and major achieved results represented, together with the list of publications.

#### **5. Vernetzung**

*Wie hat sich die Vernetzung der Nachwuchsgruppe innerhalb des Helmholtz-Zentrums bzw. der Universität entwickelt? Wie zufrieden sind Sie mit der Zusammenarbeit mit dem Zentrum bzw. der Universität?*

The activities of the group are well embedded in the physics programme of the HERA and LHC groups at DESY. Close collaboration with DESY Zeuthen and the University of Hamburg is demonstrated by several common analyses and publications. The collaboration with other German universities is realized within the „Physics at the Terascale“ Alliance and strengthened through the common project „Inclusive and Semi-Inclusive Constraints on the Parton Distributions at the LHC and the Study of Hard Processes“. The group collaborates strongly with the global QCD analysis group CTEQ, resulting in a new collaboration between DESY and the Southern Methodist University in Dallas, with the agreement on common work being in preparation.

#### **6. Publikationen (Auflistung)**

*Artikel in Fachzeitschriften, Kongressbeiträge, Buchbeiträge; Studien- und Diplomarbeiten, Dissertationen, Habilitationen, Berichte, sonstige Publikationen*

##### **Publikationen:**

##### Major Journal publications

S. Alekhin, J. Bluemlein, K. Daum, K. Lipka, S. Moch, Phys. Lett. B720 (2013) 172-176, [arXv:1212.2355], „*Precise charm-quark mass from deep-inelastic scattering*“.

S. Alekhin, K. Daum, K. Lipka, S. Moch, Phys. Lett. B 718 (2012) 550 [arXiv:1209.0436] „*Determination of the charm-quark mass in the  $\overline{MS}$  scheme using charm production data from deep inelastic scattering at HERA*“.

[H1 and ZEUS Collaborations], Eur. Phys. J. C (2013) 73:2311 [arXiv:1211.1182] „Combination and QCD Analysis of Charm Production Cross Section Measurements in Deep-Inelastic ep Scattering at HERA“.

[CMS Collaboration] [arXiv:1211.2220], submitted to the EPJC, „Measurement of differential top-quark pair production cross sections in pp collisions at  $\sqrt{s} = 7$  TeV“.

[H1 Collaboration] JHEP 1209 (2012) 061 [arXiv:1206.7007], „Inclusive Deep Inelastic Scattering at High Q<sup>2</sup> with Longitudinally Polarised Lepton Beams at HERA“

[CMS Collaboration] Phys. Lett. B 692, 2 (2010) 83 „Measurement of the charge ratio of atmospheric muons with the CMS detector“

[H1 Collaboration] Phys. Lett. B 686, 91 (2010), „Measurement of the D\* Meson Production Cross Section and F<sub>2cc</sub> at High Q<sup>2</sup> in ep Scattering at HERA“.

[H1+ZEUS Collaborations] JHEP 1001:109 (2010), „Combined Measurement and QCD Analysis of the Inclusive ep Neutral and Charge Current Scattering Cross-Sections at HERA“.

Public results for H1, H1+ZEUS and CMS Collaborations  
(NB: based on the 25 Analysis Notes, not listed here)

[CMS-PAS-TOP-12-022] First Determination of the Strong Coupling Constant from the ttbar Cross Section.

[CMS-PAS-TOP-12-007] Measurement of the top-pair production cross section in the dilepton channel in pp collisions at center of mass energy of 8 TeV.

[CMS-PAS-TOP-11-013] Measurement of Top Quark Pair Differential Cross Sections at center-of mass energy of 7 TeV.

[CMS-PAS-TOP-11-008] Determination of the Top Quark Mass from the ttbar Cross section at center-of-mass energy of 7 TeV.

H1-Prelim-11-034/ZEUS-Prel-10-001 [HERA Combination Group], H1 and ZEUS Jet Data included in QCD Analysis and Determination of Strong Coupling Constant.

[CMS-AN-2010-028] Measurement of the Top-Quark Pair Production Cross Section in the Muon Electron Decay Channel at center-of-mass energy of 7 TeV.

[CMS-AN-10-428] Measurement of the Top-Quark Pair Production Cross Section in the Dimuon Decay Channel at center-of-mass energy of 7 TeV.

[CMS AN-10-429] Measurement of the Cross-Section Ratio of Top-Pair Production and Z Production in pp Collisions at center-of-mass energy of 7 TeV using the CMS Detector“.

H1-Prelim-10-143/ZEUS-Prel-10-019 [HERA Combination Group] QCD Analysis of HERA Charm Data and W/Z Predictions for the LHC.

H1-Prelim-10-045 [HERA Combination Group], QCD Analysis of HERA Data including Charm (PDF Fits)

H1prelim-09-171/ZEUS-prel-09-015 [HERA Combination Group] Combination of F<sub>2cc</sub> from DIS measurements at HERA

H1prelim-08-174 [H1 Collaboration] *Combination of  $F_{2cc}$  from  $D^*$  Measurement in DIS and inclusive measurement of displaced tracks at H1*

H1prelim-08-172 [H1 Collaboration] *Extraction of the Charm Contribution  $F_{2cc}$  to the Proton Structure Function from  $D^*$  Measurements in DIS at HERA*

H1prelim-08-074 [H1 Collaboration]  *$D^*$  production at high  $Q^2$  with the H1 detector.*

### Kongressbeiträge (alphabetische Reihenfolge)

- K. Alimujiang "General mass variable flavour number scheme in deep inelastic scattering", EMG Klausurtagung, 21.10.2009, Mainz
- M. Aldaya and H. Geenen, "Top Physics in CMS-D", plenary talk, FSP-CMS Annual Workshop, DESY-Hamburg, 23 - 35 September 2009
- M. Aldaya, "Status of CMS at DESY", talk at 70th PRC, Oct. 2010
- M. Aldaya, "The upgrade of the CMS pixel detector for LHC Phase 1", CMS CR-10-245, The International symposium XXX Physics in Collision (PIC2010), September 2010
- M. Aldaya, "*Recent Top Quark Physics Results from CMS*", XXVI Rencontres de Physique 4 von 7 de la vallee d'Aoste, 26 Feb - 3 Mar 2012, La Tuile (Italy)
- M. Aldaya, "*Highlights of CMS Physics Results at 7 TeV*", DESY seminar, 13-14 Dec2011, Hamburg-Zeuthen (Germany)
- M. Aldaya, "*Determination of the Top Quark Mass from the  $t\bar{t}$  Cross Section at 7 TeV*" (poster), Hadron Collider Physics Symposium, 14-18 Nov 2011, Paris (France), CR-2012-014
- M. Aldaya, "*Determination of the Top Quark Mass from the  $t\bar{t}$  Cross Section at 7 TeV*",(poster), 4th International Workshop on Top Quark Physics, 25-30 Sep 2011, Sant Feliu de Guixols (Spain), CR-2012-013
- M. Aldaya, "*Recent Results on Top Quark Physics at CMS*", 23rd Rencontres de Blois on Particle Physics and Cosmology, 29 May - 3 Jun 2011, Blois (France)
- M. Aldaya for the CMS Collaboration, "Measurement of Differential Top Quark Pair Production Cross Sections at 7 TeV with the CMS experiment", parallel talk at ICHEP2012: 36th International Conference on High Energy Physics, Melbourne (Australia)
- M.Aldaya, "Top quark physics results from the CMS experiment", plenary talk at 77. Jahrestagung der DPG und DPG-Fruehjahrstagung, Dresden (Germany)
- M. Aldaya for ATLAS and CMS experiments „Top Pair Production“, Standard Model at the LHC conference, Freiburg, April 2013.
- M. Brinkmann, "Heavy quark physics at HERA", International Conference on Particles and Nuclei (PANIC08) 9-14 November 2008, Eilat, Israel.
- M. Brinkmann, "Measurement of  $F_{2cc}$  at high  $Q^2$  at H1" Spring Meeting of German Physics Society, 09.03.2009
- M. Brinkmann, " $D^*$  production at high  $Q^2$  at H1 Experiment", XVII International Workshop on Deep-Inelastic Scattering and Related Subjects DIS 2009, 26-30 April 2009, Madrid
- M. Brinkmann, " $D^*$  and  $F_{c2}$  at high  $Q^2$  ", XVIII International Workshop on Deep-Inelastic Scattering and Related Subjects (DIS2010), April 2010, proceedings PoS(DIS 2010)149
- J. Kieseler, "*Measurement of the cross section ratio  $t\bar{t}/Z$  in the  $ee$  and  $\mu\mu$  final states at 7 TeV with the CMS experiment*", 5th Annual Workshop of the Helmholtz Alliance "Physics at the Terascale", 7-9 Dec 2011, Bonn (Germany)
- J. Kieseler, "*Measurement of the cross section ratio  $t\bar{t}/Z$  in the  $ee$  and  $\mu\mu$  final states at 7 TeV with the CMS experiment*", Spring Meeting of the German Physical Society (DPG 2012), 27 Feb - 2 Mar 2012, Göttingen (Germany)
- J. Kieseler for the CMS Collaboration, "Measurement of the  $t\bar{t}$  production cross

section in the dilepton channel in pp collisions at 8 TeV with the CMS experiment", poster at TOP2012: 5th International Workshop on Top Quark Physics, Winchester (United Kingdom)

- J. Kieseler, "Measurement of the Cross Section Ratio of  $Z/t\bar{t}$  (8 TeV) /  $Z/t\bar{t}$  (7 TeV) with the CMS Experiment", parallel talk at DPG 2013: 77. Jahrestagung der DPG und DPG-Fruehjahrstagung, Dresden (Germany)
- K. Lipka for H1 and ZEUS Collaborations „Measurement of  $F_2$  at HERA“ International experimental-theory workshop „New trends in HERA physics 2008“, Ringberg Castle, 5-10 Oktober 2008, Nuclear Physics B - Proceedings Supplements (NUPHBP-12943).
- K. Lipka, P. Thompson “Combination of  $F_2$  using vertex detector and  $D^*$  method at H1”, XVII International Workshop on Deep-Inelastic Scattering and Related Subjects DIS 2009, 26-30 April 2009, Madrid
- K. Lipka, "Charm and beauty of HERA" (for H1 and ZEUS), XXIèmes Rencontres de Blois “Windows on the Universe“, June 2009
- K. Lipka, "Measurement of  $F_2^{cc}$  and  $F_2^{bb}$  at H1", The 2009 Europhysics Conference on High Energy Physics 16-22 July 2009 Krakow, Poland
- K. Lipka, "Die Frage nach dem Leben, dem Universum und den ganzen Rest", eingeladener Vortrag, Tagung der Helmholtz-Gemeinschaft zur Chancengleichheit November 2009, Leipzig
- K. Lipka, "Combined Measurement of  $F_2^c$  at HERA" at PDF4LHC Workshop October 2009
- K. Lipka, “Physics of gluons and heavy quarks from HERA to the LHC”, eingeladener Vortrag, Frühjahrstagung der DPG, März 2010.
- K. Lipka, summary talk “Heavy flavours in DIS and hadron colliders: WG summary” XVIII International Workshop on Deep-Inelastic Scattering and Related Subjects (DIS2010), April 2010, proceedings PoS(DIS 2010)016
- K. Lipka, "Recent Combined Results of H1 and ZEUS", open session of the 69 DESY Physics Research Committee, April 2010
- K. Lipka, "Proton Structure Function Measurement at HERA", The International symposium XXX Physics in Collision (PIC2010), September 2010
- K. Lipka "Proton Structure Measurements at HERA", Particle Physics Seminar, University of Bonn, November 2010
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- K. Lipka, “Recent results from HERA and their impact for LHC”, Hadron Collider Physics Symposium 2011, Nov. 2011, Paris, proceedings <http://arxiv.org/abs/1201.4486>
- K. Lipka, “Proton structure from DIS and the impact of the LHC data”, invited talk, 5<sup>th</sup> Annual Workshop of the Helmholtz Alliance "Physics at the Terascale", Dec. 2011, Bonn
- K. Lipka "Proton structure from DIS and the impact of the LHC data", Graduiertenkolleg Seminar, University of Mainz, Mai 30 2012
- K. Lipka “Tatsaechlich ...Leben”, invited talk in Arbeitskreis Chancengleichheit der DPG 2013, March 2013, Dresden.
- K. Lipka for H1 and ZEUS experiments, “HERA Measurements for the LHC”, Standard Model at the LHC conference, April 2013, Freiburg
- K. Lipka “Highlights in Structure Function Measurements” summary talk, XXI. International Workshop on Deep-Inelastic Scattering and Related Subjects (DIS 2013), Marseille, France, April 2013
- S. Naumann-Emme, "Top-Quark Analyses in DCMS", summary talk, FSP-CMS Annual Meeting, Karlsruhe, Sept. 2011
- S. Naumann-Emme, "Top-Quark Measurements at the LHC", 3rd LC-Forum

Meeting, DESY Hamburg, Feb. 2012

- S. Naumann-Emme "Latest Constraints from Jet Measurements on Parton Distribution Functions and on the Strong Coupling Constant", Hadron Collider Physics Symposium 2012, Nov. 2012, Kyoto, conference report: <http://arxiv.org/abs/arXiv:1302.4652>
- S. Naumann-Emme, „Status of the DESY CMS Group“, presentation in the open session of DESY Physics Research Committee April 2013.
- K. Nowak, “Precise QCD measurements at HERA“, Lake Louise Winter Institute, Canada, February 2011
- K. Nowak, "QCD analysis with determination of strong coupling based on HERA inclusive and jet data", XIX International Workshop on Deep-Inelastic Scattering and Related Subjects (DIS 2011), 11-15 April 2011
- K. Nowak, "QCD measurements with jets and strong coupling determination at HERA", International Conference on the Structure and Interactions of the Photon and 19<sup>th</sup> International Workshop on Photon-Photon Collisions, 22-27 May 2011, Spa, Belgium
- K. Nowak, “Summary of the Hadronic Final State working group”, summary talk at XX International Workshop on Deep-Inelastic Scattering and Related Subjects (DIS 2012), 26-30 March 2012
- K. Nowak, "H1 recent results and the HERAFitter project", open session of the 73 DESY Physics Research Committee, April 2012
- R. Placakyte, summary talk "Parton densities from DIS and hadron colliders to LHC: WG summary", XVIII International Workshop on Deep-Inelastic Scattering and Related Subjects (DIS2010), April 2010, proceedings PoS(DIS 2010)013
- R. Placakyte, "Measurements of the proton structure in the electroweak regime at HERA" Low-x workshop, Kavala, Greece, June 2010
- R. Placakyte, "QCD analysis of combined H1 and ZEUS Fc2 data", QCD at the LHC workshop, Trento, Italy, September 2010
- R. Placakyte, "H1 Status Report", open session of the 70 DESY Physics Research Committee, October 2010
- R. Placakyte, "QCD Analysis of Combined HERA Fc2 Data and Impact from the LHC", Standard Model Benchmarks at the Tevatron and LHC, CTEQ Workshop, Fermilab, November 2010
- R. Placakyte, "HERA PDFs and the Impact for the LHC", invited talk at Enrico Fermi Institute lunch seminar (Chicago University) November 2010
- R. Placakyte, "QCD Analysis of Combined HERA Fc2 Data and Impact for the LHC" PDF4LHC meeting, DESY, November 2010
- R. Placakyte, "*Parton Distribution Functions, Uncertainties and Constraints*", DPG-Tagung, March 29 2011, Karlsruhe, invited talk
- R. Placakyte, "*QCD Analysis of the Combined H1 and ZEUS F2cc Data and the Impact on the Z, W Cross Section Predictions at the LHC*", Workshops on Deep-Inelastic Scattering and Related Subjects (DIS), April 2011
- R. Placakyte, "*Parton Distribution Functions*", XXXI Physics in Collision, Vancouver, Canada, Aug 28-1st Sep 2011; talk + proceedings (arXiv:1111.5452):
- R. Placakyte, "*HERAFitter project*", presentation on CMS General Weekly Meeting, 12.10.2011
- R. Placakyte, summary of the Structure functions working group in DIS2012, Bonn, 26-30 March 2012, Proceedings: [arxiv.org/pdf/1207.0353](http://arxiv.org/pdf/1207.0353)
- R. Placakyte, "HERAPDFs" in ICHEP 2012, Melbourne 4-11 July,
- R. Placakyte HERAFitter tutorial in QCD@LHC, 20th-24th August 2012 at Michigan State University [http://www.pa.msu.edu/~huston/qcd2012/QCD\\_LHC.html](http://www.pa.msu.edu/~huston/qcd2012/QCD_LHC.html)
- R. Placakyte for CMS experiment, “PDF studies at CMS”, PDF4LHC, CERN, 8 Oct 2012,
- R. Placakyte HERAFitter tutorial in "Proton Structure in the LHC Era" School of the

Analysis Center at DESY, October 2012

- R. Placakyte for H1 and ZEUS experiments, "Structure functions and PDF determination at HERA", XXVI Rencontres de Moriond QCD and High-Energy Interactions, Vallee d'Aoste, , La Tuile (Italy) March 2013.

In addition, K. Lipka, S. Naumann-Emme, K. Nowak and R. Placakyte participated in the organisation of the conferences on „Deep Inelastic Scattering“ in 2010, 2012, and 2013, were involved in the organisation of the schools and tutorials on PDF determination, HERAFitter and related subjects.

**Dissertationen:**

M. Brinkmann, *Measurement of the  $D^*$  Meson Production Cross Section and  $F_2^{cc}$  at High  $Q^2$  in  $ep$  Scattering at HERA*, University of Hamburg, April 2010, Ph. D. Thesis, DESY-THESIS-2010-016

J. Kieseler, *"Measurement of the Top-Antitop and  $Z^0$ -Boson production cross sections and their ratio in the dileptonic decay channels at center-of-mass energy of 7 TeV with the CMS Experiment"*, University of Hamburg, March 2012, Diploma Thesis, DESY-THESIS-2012-047

M. Dobre, *„Measurement of the  $D^*$  Meson Production Cross Section at Low and Medium  $Q^2$  with the H1 Detector at HERA“*, University of Hamburg, November 2012, Ph. D. Thesis, DESY-THESIS-2012-044