Zwischenbericht (Sachbericht)

Förderinstrument:	**Sondermaßnahmen**
Impulsfonds-Förderkennzeichen	SO-072
Projekttitel	Determination of the proton structure using deep inelastic scattering and proton-proton collisions
Federführende/r Wissenschaftler/in	Dr. Katerina Lipka
Helmholtz-Zentrum	DESY
Berichtszeitraum (=Kalenderjahr)	01/2012-12/2012

Hinweis:
Sondermaßnahmen sind Einzelförderungen außerhalb von Ausschreibungen zur Sicherung herausragender Exzellenz. Ziele, Arbeitsprogramm, Finanzplan etc. sind individuell im jeweiligen Antrag beschrieben. Dieses Muster ist nicht für alle Projekte ideal. Bitte machen Sie nach Möglichkeit Angaben zu allen nachfolgenden Punkten; wo dies nicht möglich ist, geben Sie es bitte explizit an.

1) Fortschritt des im Antrag beschriebenen Arbeitsprogramms

Berichten Sie kurz und allgemeinverständlich über die wesentlichen Ergebnisse. Waren Abweichungen vom Arbeitsprogramm notwendig?

The project follows the original working plan with several important extensions, leading to formation of new (or strengthening the already existing) collaborations between DESY and German Universities, as well as institutions outside Germany.
Group members contribute significantly to the main Standard-Model analyses in both ATLAS and CMS experiments, having strong impact on precise determination of the proton structure. The work on experimental analyses within the CMS collaboration is strongly connected to the work of the young investigator group HGF-NG-401.

In addition, the group members contribute to the QCD global analysis of the parton distribution functions (PDFs) of the proton together with the CTEQ collaboration via common work with Southern Methodist University in Dallas, USA. An agreement on close collaboration and exchange program between DESY and the SMU is in preparation.

A new collaboration with the theory group of the University of Hamburg is established and the work on top-quark phenomenology has started.

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 in significant increase of the LHC discovery potential through increased precision of understanding of the Standard Model. As a part of this activity, the group is contributing to the project “Inclusive and Semi-Inclusive Constraints on the Parton Distributions at the LHC and the Study of Hard Processes” within HGF Alliance “Physics at the Terascale” that was launched in 2013.

In the following, detailed activities within the project are presented, separated into experimental and theory parts.

- **Experiment-Related Analyses on Determination of the Proton Structure**

The open-source programm HERAFitter represents a framework for the determination of the fundamental QCD parameters and detailed study the proton structure. HERAFitter platform provides the basis for confronting the experimental data with different theory approaches in the computation of observables such as cross-sections in deep inelastic scattering and hadron-hadron collisions. This program allows for direct study of the impact of new data on proton structure using a coherent treatment of the experimental uncertainties and theory predictions. Originally developed by the H1 and ZEUS collaborations and used for determination of the HERAPDFs sets, HERAFitter has been extended since 2011 to include the data from the LHC experiments and further different phenomenological approaches. The SO-072 members are co-conveners of the HERAFitter working group and contribute significantly to code development and support. The program is used for all QCD analyses, discussed in the following.

The SO-072 members play leading role in organisation of physics forums at the LHC, devoted to extraction of the fundamental QCD parameters and the proton PDFs. The forums provide a scope for coherent analyses of the precise measurements at ATLAS and CMS with the impact on proton structure and determination of PDFs. The PDF forum in ATLAS experiment exists since 2011. The corresponding working group was initiated within the CMS experiment by the SO-072 members and is meanwhile well established. In particular, the LHC measurements of W-boson production, Drell-Yan and top-quark-pair production are addressed, since these are of crucial importance to constrain the light-quark and gluon content of the proton.

After the first determination [1] of strange quark density in the proton obtained by the ATLAS collaboration using 2010 W and Z inclusive data using HERAFitter, PDF sensitivity studies for high-mass Drell-Yan events using LHC data collected in 2011 were performed. The QCD analysis involving comparison of the measurement to Standard Model predictions were performed in the HERAFitter framework, accounting for all provided correlated uncertainties. The results were presented at the Hadron Collider Physics Symposium in 2012 [2]. The most recent measurement of the W-boson asymmetry, based on the data collected by the CMS collaboration in 2011 and corresponding to an integrated luminosity of 4.7 inverse femtobarn, are used in the QCD analysis, providing new constraints on the distribution of the strange quark in the proton. Results will be published in 2013. In addition, sensitivity studies to the gluon distributions using measurements of the ATLAS inclusive jet cross section at 2.76 TeV and comparison to the inclusive jet cross section at 7 TeV were performed. Results were presented at numerous international conferences are expected to be published in 2013 [3].

Predictions of top-quark-pair production cross sections at next-to-next-to-leading order (NNLO) in the QCD strong coupling constant, are interfaced to HERAFitter, allowing us for the first time, to use precision measurements of top-quark production at the LHC in the QCD analysis.

For the first time, inclusive top-pair cross-sections are used to determine the QCD strong coupling constant [4]. This measurement by the CMS collaboration probes very high scales and is of competitive precision with the world average value. Furthermore, this is the first determination of the strong coupling obtained by using NNLO theory predictions at hadron colliders. This analysis has entered the publication procedure.

- **Phenomenological Studies**

In close collaboration with the University of Hamburg, a calculation of the differential cross sections for top-quark pair production at the LHC and Tevatron is ongoing. The theory prediction incorporates the threshold re-summation formalism up to next-to-next-to-leading

logarithmic accuracy (NNLL) and takes advantage of results obtained in Soft-Collinear Effective Theory (SCET). This work is highly important to compare state-of-the-art QCD theory with current and forthcoming LHC data. The theory calculation, implemented in a computer code will be part of an open-source program, which will be interfaced to HERAFitter. The publication is expected in 2013.

Heavy-quark treatment is crucial for the correct determination of the DIS structure functions and it is of key importance for extracting PDFs from experimental data.
In close collaboration with CTEQ collaboration, the work on the implementation of the General Mass Variable Flavour Number (GMVFN) scheme S-ACOT-χ at NNLO in the strong coupling constant for the heavy-quark treatment in the structure functions of the proton in HERAFitter program is progressing.
In close collaboration with the CTEQ-TEA (Tung et al.) collaboration, the work on CT10 NNLO PDFs has been accomplished. The SO-072 member is one of the main authors of the corresponding publication [5].

The work on the development of the ResBos resummation program is ongoing. ResBos is a tool for QCD predictions for lepton angular distribution in inclusive production of Z-bosons, photons and W-bosons at hadron colliders. It is based on the Collins-Soper-Sterman formalism for the re-summation of large logarithmic contributions in the transverse momentum distribution (p_T-re-summation) of the vector boson, and it includes a computation at NLO and approximated NNLO plus re-summed contributions up to NNLL. This work is done in collaboration with Prof. P. Nadolsky (SMU USA) and Prof. C.-P. Yuan (Michigan State Univ., MI USA). The SO-072 member is one of the leading authors of the corresponding paper [6] and is leading author of a forthcoming publication, planned for early 2013, in which new ResBos predictions for the re-summed cross sections will be presented. Results are planned to be included into HERAFitter in order to analyze the impact of the LHC data on W and Z-boson production in QCD analysis.

The publication of the combined data on charm-quark production at HERA was the major achievement of the HGF-NG-401 group (see the corresponding report). Based on this data, several analyses are performed by the members HGF-NG-401 and SO-072 to determine the pole and the running mass of the charm quark. These analyses are made in collaboration with the ABM and CTEQ collaborations. The unique comprehensive analysis [8] is performed in close collaboration with the ABM group and charm mass is determined at NLO and approximate NNLO taking into account the full dependence of the phase-space corrections to the measurement on theory parameters. This result is published in 2012 and enters the updated world average charm mass in Particle Data Group Review in 2013. The follow-up global QCD analysis represents the simultaneous determination of charm quark mass and PDFs with a thorough study of correlations of charm mass, PDFs and the strong coupling constant.
Also, in the framework of CTEQ collaboration, the extraction of the mass of the charm quark within the global QCD analysis is ongoing. The SO-072 member is one the main authors of a forthcoming paper describing this study. The publication is expected in spring 2013.

2) **Meilensteine**
Welche wichtigen Meilensteine konnten im Berichtsjahr erreicht werden?

Since its first public release of HERAFitter QCD fit platform in September 2011 on HEPFORGE http://herafitter.hepforge.org/, the program appeared in two updated versions, which can be accessed at www.herafitter.org (latest release in March 2013).
The HERAFitter platform was used at ATLAS for determination of the strange quark density of the proton, the publication appeared in 2012.
The final QCD analysis of inclusive H1 HERA measurements is published.
The combination and the QCD analysis of charm data of HERA is published.

The determination of charm quark mass at NLO and NNLO in ABM scheme is published. PDF forum within the ATLAS and CMS experiment is initiated and well established. Many coherent analyses of proton structure using the LHC data are launched.

3) **Finanz-/Zeitplan**
Können Sie Finanz- und Zeitplan einhalten oder sind Anpassungen notwendig?

As mentioned in the annual report 2011, the official start of the project and the related funding was shifted to 01.01.2012. The funding in 2011 was rebooked to 2012. Two announced positions for ATLAS and CMS are filled.

4) **Strategischer Mehrwert**
Welchen strategischen Mehrwert für die Helmholtz-Gemeinschaft hat das Vorhaben bisher erreicht oder inwieweit ist er absehbar?

The project joins the work of the QCD analysis experts at DESY into a coherent, highly visible activity in the LHC physics programme. The project makes the essential contribution for preserving the unique expertise in study of proton structure at DESY and makes up the roadmap for the ideal transition of the HERA legacy to the LHC, by joining efforts of experimentalists at HERA, ATLAS and CMS and the theorists at DESY and elsewhere.

5) **Nachhaltigkeit**
Inwieweit ist Nachhaltigkeit des Vorhabens bereits abzusehen oder eine Weiterführung nach Auslaufen der Förderung geplant?

The project is timely and provides the platform for most important analyses in Standard Model and beyond at the LHC over the whole running period, becoming particular importance for the 13 TeV and 14 TeV running. The steeply rising interest in the project from the German and external groups and institutes supports the importance of the topic and its long-term perspectives. The original plan of the scientists involved in the project, as stated in the original proposal, was the application for the virtual institute, an instrument, which would officially join the activities, originated from the project SO-072. Since the call for virtual institutes in 2012 was stopped by the HGF, the prolongation of the activities in the project beyond 2015 is of the key importance in order to assure successful accomplishment of started analyses and the corresponding publications and establishing the leading role of DESY in related activities at the LHC.

6) **Drittmittel**
Wurden Drittmittel eingeworben? Wenn ja, von wem und in welcher Höhe?

Together with Universities Freiburg, Hamburg, Mainz and Karlsruhe Institute of Technology, DESY assured participation in the project “Inclusive and Semi-Inclusive Constraints on the Parton Distributions at the LHC and the Study of Hard Processes” within HGF Alliance “Physics at the Terascale”. In 2013, an application for a DFG Forschergruppe, in collaboration with Universities of Bonn, Hamburg, Karlsruhe and Mainz is planned.

7) **Patentanmeldungen**
Wurden Patente angemeldet bzw. erteilter? Ggf. wie viele?

8) **Publikationen**
Im Zwischenbericht bitte nur die wichtigsten bzw. Anzahl aufführen (peer reviewed, andere)

[1] ATLAS Collaboration, "Determination of the strange quark density of the proton from ATLAS measurements of the W->l nu and Z->ll cross sections", submitted to Physical Review Letters, http://arxiv.org/abs/1203.4051

[2] ATLAS Collaboration, ATLAS-CONF-2012-159 '*Measurement of the high-mass Drell-Yan differential cross-section in pp collisions at √s = 7 TeV with the ATLAS detector*'

[3] ATLAS Collaboration, ATL-CONF-2012-128, *Measurement of the inclusive jet cross section in pp collisions at √s = 2.76 TeV and comparison to the inclusive jet cross section at √s = 7 TeV using the ATLAS detector.*

[4] CMS Collaboration, CMS-PAS-12-022, *First Determination of the Strong Coupling Constant from the top-pair cross-section.*

[5] J. Gao, M. Guzzi et al, [arXiv:1302.6246], *The CT10 NNLO Global Analysis of QCD*.

[6] V. Guzey, M. Guzzi et al., Eur.Phys.J. A49 (2013) 35, [arXiv:1212.5344], *Massive neutral gauge boson production as a probe of nuclear modifications of parton distributions at the LHC*.

[7] 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 MS-bar scheme using charm production data from deep inelastic scattering at HERA*

[8] S. Alekhin, J. Bluemlein, K. Daum, K. Lipka, S. Moch, Phys.Lett. B 720 (2013) 172-176 [arXv:1212.2355], *Precise charm-quark mass from deep-inelastic scattering*