

Mid Term Report

Type of the project	<b>Helmholtz-(Hochschul-)Nachwuchsgruppen</b>
Support Number	HGF-VH-NG-401
Topic	Physics of gluons and heavy quarks from HERA to the LHC: Precision measurement of the gluon density at HERA and its application for cross section measurements at the LHC
Scientist in charge	Katerina Lipka
Helmholtz Center:	DESY
University Partner	Hamburg, Mainz, Wuppertal
Reference period	05/2008 until 04/2013

The topics addressed in the project are the precision measurement of the charm contribution to the proton structure function at HERA, phenomenology of charm quark production in deep inelastic electron-proton scattering, and the measurement of the top quark mass at the LHC. Correspondingly, the activities in the group are divided in 3 working packages. In the following, the progress for each of the working packages is summarised.

**Progress on the working plan of the proposal**

Precision measurement of the charm contribution  $F_2^c$  to the inclusive proton structure function  $F_2$ .

The aim of this part of the project is to access the gluon density in the proton directly, via precision measurements of the cross section of events involving charm quarks, produced in the boson-gluon fusion process. Charm quarks are tagged via charm- containing  $D^*$  mesons. Precisely measured cross section of  $D^*$  meson production in the deep inelastic scattering at H1 experiment are extrapolated using perturbative QCD calculations to obtain  $F_2^c$ . These measurements will be used in the global QCD fits to the HERA data to determine the most precise parton density functions (PDFs) of the proton. As indicated in the proposal, this part will be the main focus of the group activities until 2011. In this context the following progress was made in this subject.

- For the first time the  $D^*$  production cross section was measured [1] at H1 at high photon virtualities  $Q^2 > 100 \text{ GeV}^2$ .
- Charm contribution to the proton structure function,  $F_2^c$  was determined [2] using the  $D^*$  production cross sections in the wide range of the photon virtuality  $Q^2$  at H1. The experimental precision of this measurement will further improve after the H1 data reprocessing in summer 2009. Studies of the hadronic final state and charm fragmentation into  $D^*$  mesons are ongoing.
- Measurements of  $F_2^c$  using different charm tagging methods (measurement of  $D^*$  cross sections and charm lifetime tag) from the H1 experiment have been combined. This combination implies a sophisticated fit of the experimental data taking into account the correlations of the systematic uncertainties between the data points of a single measurement and systematic sources of different measurements. With this

method the yet most precise charm contribution  $F_2^c$  to the proton structure function at HERA is determined [3].

- The work on the combination of  $F_2^c$  measurements of H1 and ZEUS collaborations is ongoing. The preliminary result this combination is planned for summer 2009.

In the past, in the precise determination of the charm contribution to the proton structure function both experimental and theory uncertainties played similar role. With recent improvements of the experimental systematics the theoretical uncertainty starts to dominate. The enhancement of the dialog between experimentalists and theorists is the issue of the crucial importance, as addressed in the proposal. In the framework of the project the following experiment-theory workshops and meetings have been organized:

- 07-08 August 2008, experimental-theory workshop on charm physics at HERA
- 01-05 September 2008, working week with the author of NLO calculation HVQDIS for heavy quark production in DIS J. Smith (Stony Brook)
- 04 December 2008, "Heavy quarks in 3 loops", invited Seminar by J. Bluemlein (DESY Zeuthen)

Many experts in experiment and theory of heavy quarks participated in these workshops, which have been very productive.

#### Phenomenology of charm production in DIS at HERA

In collaboration with the THEP group of the Johannes-Gutenberg University of Mainz, the group participates in the development of the theoretical models of charm production at HERA at next-to-leading order (NLO) of perturbative QCD. The program HVQDIS is being worked on. This package is used for the extrapolation of the  $D^*$  cross sections to obtain  $F_2^c$  in the full phase space. The charm quarks are produced in LO and NLO and are further fragmented via a phenomenological model into charmed hadrons. The finite masses of these hadrons affect the production phase space and therefore the normalization and shape of the predicted production cross section. These effects have been yet not included into the HVQDIS package. The influence of the hadron masses is studied and the dependence of the hadron production cross section on the definition of the fragmentation parameter at LO and NLO is investigated.

#### Top quark physics at CMS

One of the aims of the project is the precision measurement of the top quark mass with the CMS detector at the LHC. The mass of the top quark will be identified in di-leptonic decays via the long lifetime of B-hadrons. The measurement relies on the precise spatial information provided by the silicon tracker and the efficient identification of the b-quarks.

The crucial issue for the analysis is the reconstruction of the secondary vertices. The group has overtaken the responsibility, within the CMS b-tagging Physics Objects Group, for the development of secondary vertex validation tool. This instrument is necessary to evaluate performance of the secondary vertex reconstruction and corresponding b-tagging algorithms. In collaboration with the University of Illinois the necessary software was developed by the group and integrated into the CMS software framework. The validation of the secondary vertex using the developed software is ongoing.

The development of the analysis framework for the reconstruction of top-quarks in di-leptonic decays has started.

## Achieved milestones

- Measurement of the  $D^*$  production cross section at high  $Q^2$  in deep inelastic scattering at H1 experiment
- Determination of the charm contribution to the proton structure function  $F_2$  using the measurement of  $D^*$  cross section at H1 experiment.
- Combination of the charm tagging methods to obtain the yet most precise measurement of  $F_2^c$  at H1 experiment
- Implementation of the hadron mass effects at LO and NLO into the HVQDIS program
- Development and implementation of the vertex validation package into the CMS software

## Adherence to the time and financial plans.

Personell: the group consists of the group leader and the following members

Post-Docs:

- Dr. Maria Aldaya Martin (started 01.10.2008)
- Dr. Kadeer Alimuijang (started 01.06.2008)

Ph.D. Students:

- Ms. Ewelina Kosior (started 01.09.2008)
- Mr. Boris Pokorny (started 01.07.2008)
- Mr. Martin Brinkmann (started 01.02.2007) is associated Ph.D. student, supervised by the Group Leader and working on the project related topic.

The progress of the activities is in agreement with the agenda of the project. The status of the personal expenses follows the original financial plan of the proposal with corrections for the later employment of the personell with respect to the start of the project.

## Investments

Investments of the group is in accordance to the proposal, including the computing equipment of the group with 2 powerful working group servers, 3 PCs in the group office and the laptops for 3 group members.

## Additional (travel) expenses

Additional expenses include the charge for the announcements of the job openings in the group and the travel expenses of the group members and invited scientists for the organized workshops. These expenses correspond to the financial plan with corrections for the later employment of the personell with respect to the start of the project.

## Publications, Talks

- [1] M. Brinkmann, K. Lipka, H1 Preliminary-08-074 "Measurement of  $D^*$  cross sections at high  $Q^2$  at H1 experiment."
- [2] K. Lipka, H1 Preliminary-08-172 "Determination of  $F_2^c$  from the measured  $D^*$  cross-sections at H1 using the NLO pQCD."
- [3] K. Lipka, H1 Preliminary-08-174 "Extraction of  $F_2^c$  using the combination of charm tagging methods at H1."
- [4] K. Lipka for H1 and ZEUS Collaborations "Measurement of  $F_2^c$  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).
- [5] M. Brinkmann, "Heavy quark physics at HERA", International Conference on Particles and Nuclei (PANIC08) 9-14 November 2008, Eilat, Israel.
- [6] M. Brinkmann, "Measurement of  $F_2^c$  at high  $Q^2$  at H1" Spring Meeting of German Physics Society, 09.03.2009