Sascha Stahl

Personal

Birth **25th February 1985**, *Bad Kreuznach, Germany*.

Nationality **German**.

Education

School

08/1995–03/2004 **Secondary school**, *Lina-Hilger-Gymnasium*, Bad Kreuznach, Germany, Grade: 1.7 (good).

Social service

05/2004–02/2005 **Social service**, *Wohnungslosenhilfe kreuznacher diakonie*, Bad Kreuznach, Social service in a house for homeless people.

Studies and PhD

04/2005–06/2010 **Diploma in physics**, *Ruprecht-Karls Universität Heidelberg*, Heidelberg, Germany, Grade: sehr gut (very good).

08/2008–01/2009 **Erasmus Programme**, *Uppsala University*, Uppsala, Sweden, Exchange student in physics and internship with the Icecube experiment.
Topic: Finding Susy Dark Matter candidates with Icecube

05/2010 **Diploma thesis**, under the supervision of Prof. Dr. Stephanie Hansmann-Menzemer in the LHCb group of the Physikalisches Institut in Heidelberg.
Topic: Reconstruction of displaced tracks and measurement of K_s production rate in proton-proton collisions at $\sqrt{s} = 900$ GeV at the LHCb experiment

09/2010–today **PhD in physics**, *Ruprecht-Karls Universität Heidelberg*, Heidelberg.
Main activities are found below in section Research activities. Expected date of defense 11.06.2014.

09/2010–today **Member of Heidelberg Graduate School of Fundamental Physics**.

01/2012–02/2013 **Research stay at CERN**, Geneva.

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Scholarships

09/2010–02/2013 **International Max Planck Research School for Precision Tests of Fundamental Symmetries in Particle Physics, Nuclear Physics, Atomic Physics and Astroparticle Physics at the University of Heidelberg**, *Max-Planck–Institut für Kernphysik*, Heidelberg.

Teaching experience

2008-2011 **Tutor for undergraduate courses**, *Theoretical Mechanics, Theoretical Electrodynamics and Theoretical Quantum Dynamics*.

09/2013–02/2014 **Tutor for master course**, *Experimental Particle Physics*.

2010-2014 **Supervision of Bachelor and Summer Students**.

Research Schools

09/2010–today **Graduate School**, *Bi-annual Heidelberg Physics Graduate Days*, Heidelberg, Germany.

09/2010–today **Workshop**, *Annual German B Physics Workshop*, Neckarzimmern, Germany.

09/2011 **Summer School**, *The 2011 European School of High-Energy Physics*, Cheile Gradistei, Romania.

08/2012 **Summer School**, *2012 Joint Fermilab-CERN Hadron Collider Physics Summer School*, Fermilab, USA.

Talks

03/2010 **DPG Spring Meeting 2010 in Bonn**, *Talk in parallel session*, "Rekonstruktion der Spuren aus den K_s^0 Zerfällen und erste Signale auf Daten beim LHCb Experiment".

03/2010 **Rencontres des Moriond EW 2010**, *Talk in the Young Scientists Forum*, "Tracking performance in V0 reconstruction with first data at LHCb".

03/2012 **DPG Spring Meeting 2013 in Dresden**, *Talk in parallel session*, "Messung von CP-Asymmetrien im Charm-System mit semimyonischen B-Zerfällen bei LHCb".

03/2013 **Rencontres des Moriond QCD 2013**, "Properties of b and c hadrons at LHCb".

04/2013 **Institute Seminar**, *Physikalisches Institut Heidelberg*, "Measurement of CP violation in the Charm System".

Publications with significant personal contributions

09/2010 **Prompt K_S^0 production in pp collisions at $\sqrt{s}$ = 0.9 TeV**, *DOI: 10.1016/j.physletb.2010.08.055, [1]*.

12/2011 **Measurement of the $B_s^0 - \overline{B}_s^0$ oscillation frequency Δm_s in $B_s^0 \to D_s^-(3)\pi$ decays**, *DOI:10.1016/j.physletb.2012.02.031, [2]*.

12/2011 **Measurement of the CP-violating phase ϕ_s in the decay $B_s^0 \to J/\psi\phi$**, *DOI: 10.1103/PhysRevLett.108.101803, [3]*.

02/2013 **Prompt charm production in pp collisions at $\sqrt{s}$ = 7 TeV**, *DOI: 10.1016/j.nuclphysb.2013.02.010, [4]*.

03/2013 **Search for direct CP violation in $D^0 \to h^-h^+$ modes using semileptonic B decays**, *DOI: 10.1016/j.physletb.2013.04.061, [5]*.

Heidelberg, February 25, 2014

Brief overview of research activities in LHCb

My first contact with the LHCb experiment was an internship in the summer of 2007 in the LHCb group of the Heidelberg University under the supervision of Prof. Dr. Stephanie Hansmann-Menzemer. My task was to optimise the selection of $\Phi \to K^+K^-$ decays with a multivariate algorithm. The subject of my diploma thesis (May 2009 to June 2010) was a study of the tracking algorithms finalised to the measurement of the production cross-section of K^0_S mesons with the very first pp collision data. Since September 2010 I have been doing a PhD in physics; the expected day of the defense is the 11th June 2014. I was and I am still involved in several analyses, covering a broad spectrum of physics subjects, including cross-section, mixing and CP asymmetry measurements. Most notable is my involvement in the measurement of CP violation in neutral charm mesons. I am the main author of this analysis, which is the subject of my PhD thesis. I have also enjoyed taking an active role in the operation of the experiment, both as a shifter in the control room and as one of the experts in charge of the operation of the software trigger. I have invested a lot of work on the study of track reconstruction methods, with particular focus on their application to the LHCb software trigger. Due to my work I became one of the experts of our reconstruction software. Furthermore I am participating with major contributions to the reconstruction software for the upgrade of the LHCb tracking detectors.

Physics analyses within the LHCb experiment

During my diploma thesis and my PhD I worked on several analyses within the LHCb experiment.

Search for direct CP violation in $D^0 \to h^-h^+$ modes using semileptonic B decays

In November 2011 the LHCb experiment reported evidence of direct CP violation in the decay of charm mesons in the modes $D^0 \to K^-K^+$ and $D^0 \to \pi^-\pi^+$. This was a surprise as due to the hierarchy of the CKM matrix the predictions are generally close to zero. D^0 mesons are the only neutral-meson system consisting of up-type quarks. This makes them interesting for theories where new particles have different couplings to up-type quarks. The LHCb results sparked a big discussion among theorists and experimentalists. Theorists had to revisit their predictions. As the result was unexpected, it was important to perform a cross-check with an alternative analysis within the experiment, based on a differently selected sample of D^0 mesons. I am the main proponent of such an analysis, which is the topic of my PhD thesis. The final sensitivity to CP violation in the decay of charm mesons is $0.18\,\%$.

There are two ways to select high statistics samples of D^0 mesons in proton collisions. One uses direct production of charm quarks, which have a high rate but also a large background as there are only hadrons in the final state. My analysis selects charm mesons from semimuonic B decays. In this case the rate is lower, but one can take advantage of the distinct signature given by the muon plus two displaced vertices. The challenge of all asymmetry measurements at this level of precision is to disentangle the CP asymmetry from production and detection asymmetries, which are all of the order of a per mille to a per

cent. Controlling detection asymmetries requires a very good understanding of all detector components. The experimentally more robust number is the difference of the measured asymmetries in $D^0 \to K^-K^+$ and $D^0 \to \pi^-\pi^+$ decays as nuisance asymmetries cancel. I performed the measurement with the 2011 data [5] and could not confirm the evidence for CP violation. I showed my results at Rencontres des Moriond QCD 2013.
The next step of my work was to measure the individual asymmetries of $D^0 \to K^-K^+$ and $D^0 \to \pi^-\pi^+$ with the full data set. This requires a direct measurement of all production and detection asymmetries, which is experimentally very challenging. The main obstacle is the detection asymmetry of charged kaons in matter. I have developed and validated tools to measure this asymmetry. The same method to measure the kaon asymmetry is also used in the measurements of the CP-violating asymmetries in the mixing of B_d^0 and B_s^0 mesons. The measurement of CP violation in $D^0 \to K^-K^+$ and $D^0 \to \pi^-\pi^+$ decays is currently in the collaboration wide review and is the main focus of my PhD thesis. My work and my thesis cover almost every part of the analysis. The approval by the collaboration to publish a paper is expected in March 2014. The final sensitivity to CP violation in $D^0 \to K^-K^+$ decays is $0.18\,\%$, which is the world's best single measurement.

Measurement of K_s production rate in proton-proton collisions at $\sqrt{s} = 900$ GeV

The work that I did for my diploma thesis on the measurement of the production cross-section of K_S^0 mesons in proton-proton collisions at a centre-of-mass energy of 900 GeV was subject of the first LHCb publication. Due to the special conditions of the first data, the vertex detector was in a partially open position. I studied a tracking algorithm to be able to reconstruct charged particles with no hits in the vertex detector. I significantly improved the performance of the existing algorithm, i.e. by $5\,\%$ for low momentum tracks and $1.5\,\%$ for high momentum tracks. The largest part of the observed signal candidates in the first data has been reconstructed by this algorithm. My work also included optimizing the event selection and extracting the reconstruction efficiencies from simulated events. The work resulted in the first published paper of LHCb [1]. I was selected to present this analysis at the Young Scientists Forum at Recontres des Moriond EW 2010.

Measurement of the CP-violating phase ϕ_s in the decay $B_s^0 \to J/\psi\phi$

The Standard Model makes very precise predictions of the CP-violating phase ϕ_s in the decay $B_s^0 \to J/\psi\phi$. Thus a measurement of this phase is a crucial probe of the Standard Model and its extensions. I studied the decay time acceptance and the decay time resolution of these events, which provided a crucial input to a multi-dimensional fit in the decay time and angular observables that is needed to extract the phase ϕ_s. The analysis was published in [3].

Measurement of the $B_d^0-\overline{B}_d^0$ and $B_s^0-\overline{B}_s^0$ oscillation frequencies Δm_d and Δm_s

The first project during my PhD was to work on the measurement of the mixing frequencies of B_d^0 and B_s^0 mesons. One of the inputs to the flagship analysis measurement of the CP-violating phase ϕ_s in the decay $B_s^0 \to J/\psi\phi$ is the mixing frequency Δm_s of B_s^0 mesons. The measurement demonstrates the great decay time resolution and flavour tagging capabilities of the LHCb experiment. I calibrated the flavour tagging algorithms by measuring the mixing frequency Δm_d of B_d^0 mesons. At that time the analysis was the most precise measurement of the mixing frequency Δm_s of B_s^0 mesons [2].

Prompt charm production in pp collisions at $\sqrt{s} = 7$ TeV

The LHCb detector is fully instrumented in the forward region, which makes it unique among the LHC experiments. The measurement of production cross-sections is an important input to Monte Carlo generators. The LHCb experiment measured the prompt charm production in pp collisions at $\sqrt{s} = 7$ TeV in minimum bias events [4] taken in 2010. I worked on the measurement of the Λ_c baryon cross-section. I determined the reconstruction performance on simulated events and evaluated the systematic uncertainties due to the difference between data and simulation.

Tracking and Trigger

Since my diploma thesis I have developed a great expertise in the reconstruction of charged particles. I worked on tracking algorithms for the online reconstruction in the software trigger, where speed is very important, in the offline reconstruction and I worked on the tracking for simulation studies of the upgrade.

Upgrade of the LHCb tracking detectors

I set up the first fully functional tracking sequence for the simulations of the detector. Furthermore I was responsible for the reconstruction software of the upgrade simulations until May 2013. My work was essential to be able to make the first fundamental design choices for the upgrade of the LHCb detector.

Track reconstruction and its use in the trigger

During my stay at CERN from January 2012 to February 2013 I was heavily involved in the running of the software trigger. My main focus was the track reconstruction, which takes most of the time. Before the restart in 2012 I optimised the momentum dependent search windows in the track reconstruction to increase the efficiency and decrease the processing time. Furthermore I tuned the quality cuts of the reconstructed tracks such that the trigger stayed within its bandwith requirements. During data taking in 2012 I was involved in the operation of the software trigger. I took care of problems in the trigger and the tracking software and took many shifts. These included expert-on-call shifts, as well as shifts in the control room.

Tuning of the Downstream tracking algorithm

During my diploma thesis I studied the so-called Downstream tracking algorithm. This algorithm is designed to find the tracks of decay products of long-lived particles like K_S^0 mesons or Λ baryons. They often decay outside of LHCb's vertex detector. Thus, they leave only signals in a tracking station very close to the dipole magnet and the main tracking stations behind the magnetic field. I could significantly improve the performance of the existing algorithm by $5\,\%$ for low momentum tracks and $1.5\,\%$ for high momentum tracks. Furthermore, I tuned the algorithm for the taking of the first collision data in December 2009. The work is documented in an internal LHCb note and in my diploma thesis.

Statement of research interests

My focus over the last years has been the measurement of CP violation in the neutral charm system with a sample from semileptonic B decays. Thanks to the very precise measurements performed by LHCb and the wealth of interesting results, charm physics has gained a lot of attention in the last years. I measured the difference between two CP asymmetries in the decay channels $D^0 \to K^-K^+$ and $D^0 \to \pi^-\pi^+$, ΔA_{CP}, which is experimentally very robust [5] but also measured the individual asymmetries with the full data set with a precision of 0.18 %. Asymmetry measurements at this level are very challenging as several subtle effects in the event detection have to be controlled. The whole experiment gains through these analyses as they require a deep understanding of the detector. The crucial point of my analysis was to measure the interaction asymmetry of kaons in matter, which is about 1 %, with 0.12 % precision to extract CP asymmetries close to zero. In the future other asymmetry measurements will profit from my work as many final states include kaons. The analysis is currently in the collaboration wide review and is expected to be approved in March 2014. My work has shown that LHCb can perform precise CP asymmetry measurements with semileptonic B decays at the per mille level. The analysis also profited from the expertise in the event and track reconstruction that I have gained in the last years, becoming one of the LHCb tracking experts.
In the future I would like to focus on the analysis of semileptonic B decays to extract the CP-violating asymmetries in the mixing of B_d^0 and B_s^0 mesons. In this analysis I can combine the knowledge I gained in the mixing measurements with the measurement of very small asymmetries in the B system itself. Especially in the analysis of the asymmetry in B_d^0 decays, a mixing analysis has to be performed to discriminate the small detection and production asymmetries from the small CP violating asymmetry in mixing. Both are promising measurements as their theoretical values are very well predicted in the Standard Model. The theoretical predictions are $a_{sl}^d = -(4.1 \pm 0.6) \times 10^{-4}$ and $a_{sl}^s = (1.9 \pm 0.3) \times 10^{-5}$ [7]. The DØ collaboration has reported a 3σ deviation from the Standard Model [6] in these parameters. With more data, an improved event selection, online and offline, and refined analysis techniques the LHCb experiment might be able to reach the theoretical precision. This will make the measurements a good test of the Standard Model, not only to check deviations but also to test theoretical methods, like e.g. Heavy Quark Expansion [7]. A very interesting side product of the measurement will be the determination of the production asymmetry of B mesons in proton-proton collisions at the per mille level and below. This will help to better understand hadronization processes in proton-proton collisions better as predictions are not precise and theory needs more input from the experimental side [8]. All CP measurements in the B system at the LHC will profit from a better known B production asymmetry.

Planning and performing design studies for the upgrade is very important for the LHCb experiment and for the future of heavy flavour physics. I believe that with my expertise in track reconstruction I can contribute significantly to this common endeavour. However, at the same time we should not lose sight of urgent problems that will arise when starting up the detector in 2015.
It will be important to have experienced people, which can react quickly to the new challenges.

One specific example is the reduction of the spacing between the proton bunches from 50 to 25 ns. This will lead to a higher activity in the tracking detectors and thus requiring new tunings of the pattern recognition algorithms.
Due to the very flexible software trigger running at 1 MHz, the LHCb experiment has been able to constantly extend its physics programme. Track reconstruction is a vital part of the trigger as most time is spent there. In its second stage the trigger performs a full event reconstruction. One exciting task will be to optimise the track reconstruction to give the rest of the system, e.g. the particle identification system, more time to select the events which are needed for physics analyses and further improve the physics reach. Already in my diploma thesis and during my stay at CERN I studied ways to make a better use of the computing time in the software trigger.
Everything we will learn in the operation of the trigger system during Run 2, will also impact the upgrade plans of the experiment. The activity in the detector will be much higher after the upgrade. This will create much more stress on the track reconstruction and the trigger system. However, many ideas which are currently in development, like an earlier detector calibration or algorithms which are better optimized for parallelised computing, can already be tested in the next years.
I am looking forward to contributing to the new physics results that will challenge the Standard Model and I am looking forward to making the restart in 2015 and the upgrade of the detector a success. I feel that the hard work invested in the last few years has prepared me well for the challenges ahead.

Heidelberg, February 25, 2014

References

[1] R. Aaij et al. Prompt K_S^0 production in pp collisions at $\sqrt{s} = 0.9$ TeV. *Phys. Lett. B*, 693(arXiv:1008.3105. CERN-PH-EP-2010-027. LHCb-PAPER-2010-001):69–80. 24 p, Sep 2010.

[2] R. Aaij et al. Measurement of the $B_s^0 - \overline{B}_s^0$ oscillation frequency Δm_s in $B_s^0 \to D_s^-(3)\pi$ decays. *Phys. Lett. B*, 709(arXiv:1112.4311. LHCB-PAPER-2011-010. CERN-PH-EP-2011-194):177–184. 19 p, Dec 2011. Comments: 12 pages, 4 figures.

[3] R. Aaij et al. Measurement of the CP-violating phase ϕ_s in the decay $B_s^0 \to J/\psi\phi$. *Phys. Rev. Lett.*, 108(arXiv:1112.3183. CERN-PH-EP-2011-214. LHCB-PAPER-2011-021):101803. 9 p, Dec 2011.

[4] R. Aaij et al. Prompt charm production in pp collisions at $\sqrt{s} = 7$ TeV. *Nucl. Phys. B*, 871(arXiv:1302.2864. LHCB-PAPER-2012-041. CERN-PH-EP-2013-009):1–20. 27 p, Feb 2013.

[5] R. Aaij et al. Search for direct CP violation in $D^0 \to h^-h^+$ modes using semileptonic B decays. *Phys. Lett. B*, 723(arXiv:1303.2614. LHCB-PAPER-2013-003. CERN-PH-EP-2013-039):33–43. 21 p, Mar 2013.

[6] Victor Mukhamedovich Abazov et al. Study of CP-violating charge asymmetries of single muons and like-sign dimuons in p pbar collisions. *Phys.Rev.*, D89:012002, 2014.

[7] Alexander Lenz. Theoretical update of B-Mixing and Lifetimes. *arXiv*, 2012.

[8] E. Norrbin and T. Sjostrand. Production and hadronization of heavy quarks. *Eur.Phys.J.*, C17:137–161, 2000.