Francesca Dordei

Curriculum Vitae

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Personal

Born **February 7, 1987**, *Cagliari (Italy)*.
Nationality **Italian**.

Languages

Italian **Native**
English **Fluent**
German **Basic**

Education

02/2011–today **PhD student and Member of the Heidelberg Graduate School of Fundamental Physics**, *Ruprecht-Karls-Universität*, Heidelberg.
Thesis under the supervision of Prof. Dr. Stephanie Hansmann-Menzemer within the LHCb group of the Physikalisches Institut in Heidelberg.
- Thesis topic: *Lifetime measurements of beauty hadrons at the LHCb experiment*.

Expected date of defense: April, 2015. Main activities are listed in *Research activities*.

09/2008–09/2010 **Master degree in Physics, "Laurea Specialistica"**, *Università degli studi di Cagliari*, Grade: 110/110 cum laude.
Thesis under the supervision of Prof. Biagio Saitta and Dr. Francesco Dettori within the LHCb group of Cagliari.
- Thesis topic: *Production of charmed baryons at $\sqrt{s} = 7$ TeV*.

09/2005–07/2008 **Bachelor degree in Physics, "Laurea Triennale"**, *Università degli studi di Cagliari*, Grade: 110/110 cum laude.
Thesis under the supervision of Prof. Biagio Saitta within the LHCb group of Cagliari.
- Thesis topic: *Kinematic techniques for the identification of rare decays of B^0_s mesons at the LHCb experiment*.

Scholarships and Memberships

02/2011–today **International Max Planck Research School for Precision Tests of Fundamental Symmetries (IMPRS-PTFS)**, *Max-Planck–Institut*, Heidelberg.

Publications with significant contributions

02/2015 **Precision measurement of CP violation in $B^0_s \to J/\psi K^+K^-$ decays**, *DOI: 10.1103/PhysRevLett.114.041801 [1]*.

02/2014 **Measurements of the B^+, B^0, B^0_s meson and Λ^0_b baryon lifetimes**, *DOI: 10.1007/JHEP04(2014)114 [2]*.

06/2013 **Measurement of CP violation and the B^0_s meson decay width difference with $B^0_s \to J/\psi K^+K^-$ and $B^0_s \to J/\psi\pi^+\pi^-$**, *DOI: 10.1103/PhysRevD.87.112010 [3]*.

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

Conference Talks & Posters

09/2014 **8th International Workshop on the CKM Unitarity Triangle**, *Vienna*, Austria.
Talk in parallel session: *Lifetime measurements in B decays at LHCb.*

07/2014 **International Max Planck Research School seminars**, *Heidelberg*, Germany.
Talk: *Measurements of b-flavoured hadron lifetimes at LHCb.*

03/2014 **Rencontres des Moriond EW 2014**, *La Thuile*, Italy.
Plenary talk: *CP violation in the $B^0_{(s)}$ system.*

03/2014 **DPG (German Physics Society) Spring Meeting 2014**, *Mainz*, Germany.
Talk in parallel session: *Measurement of different b-hadron lifetimes, lifetime ratios and $\Delta\Gamma_d/\Gamma_d$ at LHCb.*

09/2013 **Weak Interactions and Neutrinos**, *Natal*, Brazil.
Talk in parallel session: *Measurement of ϕ_s at LHCb.*

04/2013 **IFAE 2013, Incontri di fisica delle alte energie**, *Cagliari*, Italy.
Poster: *Lifetime measurements of b-hadrons using the exclusive decays $b \to J/\psi\mu^+\mu^-$ at LHCb.*

09/2012 **7th International Workshop on the CKM Unitarity Triangle**, *Cincinnati*, Ohio.
Talk in parallel session: *Measurements of B lifetimes at LHCb.*

Tasks in the LHCb Collaboration

since 02/2011 **Data Quality piquet**.

03/2012–05/2014 **Data stripping contact person for the LHCb B2cc working group**.

Teaching experience

03/2009–09/2009 **Tutor for bachelor courses for physics students**, *Università degli studi di Cagliari*.
Mechanics, Thermodynamics and Electromagnetism.

03/2012–03/2014 **Tutor for Advanced Physics Lab course for students**, *Ruprecht-Karls-Universität*, Heidelberg.

03/2012–09/2012 **Supervision of two bachelor students**, *Ruprecht-Karls-Universität*, Heidelberg.

Research schools

since 02/2011 **Biannual Physics Graduate Days**, *Heidelberg*, Germany.
Lecture week on different physics topics.

since 02/2011 **Annual German B-physics workshop**, *Neckarzimmern*, Germany.
Lectures about theoretical and experimental flavour physics.

07/2011 **Trans-European School of High Energy Physics**, *Alushta, Crimea*, Ukraine.
Talk: *Λ_c production cross-section measurement in pp collisions at $\sqrt{s} = 7$ TeV in 2010 data at the LHCb experiment.*

10/2012 **Asia-Europe-Pacific School of High-Energy Physics**, *Fukuoka*, Japan.
Poster: *Measurements of B lifetimes at LHCb.*

Research activities in LHCb

After a visit to the different CERN experiments at the end of my second year of University, I was so fascinated by the physics programme and the complexity of the various detectors that I decided to join the LHCb group of Cagliari in 2008 for a small research project, documented in my Bachelor thesis. My task was to implement a simplified version of a kinematic fit for the reconstruction of a decay and the effect of momentum and pointing constraints was tested on a simulated sample of $B_s^0 \to \mu^+\mu^-$ events. The topic of my Master thesis (April - September 2010), that I performed again within the LHCb group of Cagliari, was the measurement of the production cross-section of Λ_c baryons and the determination of the $\overline{\Lambda}_c/\Lambda_c$ ratio using the first data recorded in 2010 by the LHCb detector. In February 2011 I joined the LHCb group of the Physikalisches Institut in Heidelberg as a PhD student. During my PhD I was involved in several analyses, covering a broad spectrum of physics subjects, including cross-section, lifetime and CP-violation measurements where I invested a lot of time in understanding the reconstruction software. I had the opportunity to present these results at several international conferences, notably at the 2014 Rencontres de Moriond and at the Workshop on the CKM Unitarity Triangle in 2011 and again in 2014 (this is one of the major conferences in the field of heavy flavour). I served as a *stripping contact* in the physics working group dedicated to the analysis of b-hadron decays to two c quarks (B2cc). The stripping contact is responsible for developing and testing selection requirements specific for each decay of interest, with the aim of selecting relevant events that are subsequently processed by individual users. This served as a fantastic window to gain insights into the wide range of physics analyses performed within the B2cc group. In the following, I give a brief overview of the main analyses I performed during my PhD.

- **Prompt Λ_c production in pp collisions at $\sqrt{s}$=7 TeV**

At the beginning of my PhD, I completed my Master's thesis project on the determination of the Λ_c production cross-section in pp collisions at $\sqrt{s} = 7$ TeV in minimum bias events taken in 2010. The measurement of a production cross-section is an important input to Monte Carlo generators, especially because of the unique geometrical acceptance of the LHCb detector. I was the main author of this analysis, developing the entire study, from the event selection to the fit used to determine the result. This analysis was published together with the production cross-sections of other hadrons containing a c quark [4].

- **Measurament of the CP-violating phase ϕ_s in $B_s^0 \to J/\psi\phi$ decays**

Afterwards, I moved to one of the LHCb flagship analyses, the measurement of the CP-violating phase ϕ_s in $B_s^0 \to J/\psi\phi$ events, using 2011 data. This phase, which arises from the interference between the amplitudes of B_s^0 mesons decaying directly and those decaying after oscillation to $\overline{B}_s^0$, is precisely predicted in the Standard Model (SM). Therefore, a measurement of a value different from the predicted one would provide an indication for processes that are not included in the SM. In order to gain confidence with the analysis, my first task was to produce several toy studies to check the feasibility and the gain in sensitivity of a per-event decay-time resolution. At the same time, I determined the effect of production and tagging asymmetries and of direct CP violation in mixing and/or decay on the parameters of interest, which at the time of the study were not explicitly included in the fit. This allowed me to become familiar with the rather complex fitting algorithm and to develop crucial tools to determine the future steps of the analysis.

- **Measurements of the B^+, B^0, B_s^0 meson and Λ_b^0 baryon lifetimes**

The most notable part of my PhD work is my involvement in the measurement of the lifetime of different hadrons containing a b quark, namely B^+, B^0, B_s^0 and Λ_b^0 [2]. These measurements are extremely helpful towards validating the Heavy Quark Expansion (HQE) model, reinforcing the reliability of other HQE predictions, which are used to test the validity of the SM. I was one of the main authors of this analysis and the contact author during the review process. From an experimental point of view, there are several effects which have to be controlled when performing these measurements at LHCb. Particularly insidious are the acceptance effects that depend on the b-hadron decay time, which can be introduced at any stage of the reconstruction, trigger and selection. While lifetime measurements relative to a reference mode have the advantage that many effects and systematic uncertainties cancel in the ratio, they are limited by the irreducible systematic uncertainty due to the lifetime precision of the reference mode. Thus, to reach a small systematic uncertainty in all modes, absolute measurements have been performed. This implied a comprehensive study of the b-hadron decay-time acceptance. The observation of a drop in the acceptance at long decay times has been a long-standing puzzle within the LHCb collaboration before my deep and detailed analysis of this effect. I identified around 10 steps in the trigger and off-line selection, track-reconstruction in the vertex detector (VELO) and primary vertex reconstruction that contributed to this acceptance. The main contribution, which causes a bias of almost 15 fs, originates from the decay-time dependent efficiency to reconstruct particle tracks in the vertex detector. I developed a tag and probe technique to measure this efficiency directly in data to completely remove this effect. This study was technically very challenging and required performing several times a private reprocessing of the entire dataset with modified algorithms. To identify the true source of the bias inside the VELO algorithm I profited from the experience of my colleagues from the Heidelberg group, who are heavily involved in tracking studies. Moreover, the detailed understanding of the source of the effect which is related to the VELO detector geometry, its alignment and the way this is exploited in the pattern recognition algorithm had a crucial impact on the design of the vertex detector for the upgrade. A successful correction for all these effects is essential to demonstrate a good understanding of the LHCb detector and it is of outmost importance for other lifetime-related analyses. All the results obtained, aside from the Λ_b^0 lifetime, represent the most precise measurements of b-hadron lifetimes, with a total uncertainty of only 5 fs for the B^+ lifetime.

- Measurement of ϕ_s, Γ_s and $\Delta\Gamma_s$ in $B_s^0 \to J/\psi\phi$ decays

The same techniques developed to obtain the aforementioned lifetimes were used to determine the bias introduced by the decay-time acceptance on the measurement of the average decay width, Γ_s. This parameter is extracted from a fit to the angular and decay-time distributions of $B_s^0 \to J/\psi\phi$ events, together with the CP-violating phase, ϕ_s. I determined the decay-time acceptance correction for the data collected in 2011 together with the same authors of the lifetime measurements paper. The usage of the techniques developed for the lifetime measurements allowed us to reduce the systematic uncertainty on Γ_s from 11 ns^{-1} to 6 ns^{-1} [3].
For the analysis of the whole 3 fb^{-1} data set taken in 2011 and 2012, I further refined the decay-time acceptance correction for Γ_s, this time working completely on my own. I made the important observation that the decay-time acceptance also causes a bias on $\Delta\Gamma_s$, the decay width difference in the B_s^0 system. The parameters ϕ_s and $\Delta\Gamma_s$ are very closely related and the interpretation of one makes only sense if the other one is measured simultaneously as well. Thus, an unbiased and precise determination of $\Delta\Gamma_s$ is crucial to put severe constraints on New Physics in the $\phi_s - \Delta\Gamma_s$ plane. Thanks to this refined analysis, the systematic uncertainty on Γ_s has been reduced to 1.5 ns^{-1}. Despite the introduction of the new correction, the systematic uncertainty on $\Delta\Gamma_s$ did not increase. This work resulted in the world's best measurement of ϕ_s, Γ_s and $\Delta\Gamma_s$ [1].

Statement of research interests

In the last few years, LHCb has recorded data of excellent quality in running conditions that are very encouraging for the future, playing a key role in the search of processes beyond the Standard Model (SM). However, it seems all measurements performed so far have been found to be consistent with SM predictions. Even if the precision of these measurements was greatly increased, there is still room for New Physics (NP). The next years of data taking will be crucial to reduce the Run-I uncertainties for the key LHCb measurements and increase the sensitivity to NP. Some of the well-known flagship analyses, such as the measurement of the CP-violating phase ϕ_s in $B^0_s \to J/\psi\phi$ decays, require a large integrated luminosity to significantly increase the sensitivity. However, there are other studies, also of great interest, which can be performed with the already existing or more modest data samples, like the measurement of the decay width difference in the B^0 system, $\Delta\Gamma_d$, and the effective lifetime in the $B^0_s \to \mu^+\mu^-$ channel. If I was to receive a CERN fellowship, I would like to focus on these two measurements where I could fully exploit the knowledge I gained in the determination of the decay-time acceptance and lifetime measurements. Moreover, especially for the reconstruction trigger strategy, the data collected in the next years will be a test bench for the coming detector upgrade based on a full 40 MHz readout.

One of the largest discrepancies with the SM reported during the last years is the like-sign dimuon asymmetry measured by the DØ collaboration in $p\overline{p}$ collisions at Fermilab [5]. The DØ measurement differs from the SM prediction [6] at the level of 3 σ. The LHCb collaboration recently measured the semileptonic asymmetry separately in B^0_s and B^0 decays. These new measurements agree well with the SM, but at the same time can not exclude the DØ result. Clearly, more precise measurements of these observables would be welcome. With more data, an improved event selection and a refined analysis technique the LHCb experiment might be able to reach the theoretical precision. Before collecting enough data to do it, a measurement of the decay width difference $\Delta\Gamma_d$ could help to shed light on this intriguing anomaly. Indeed, part of this tension could be related to an anomalous enhancement of $\Delta\Gamma_d$ [7], which could receive sizable NP effects. Contrary to $\Delta\Gamma_s$, the decay-width difference in the B^0 system is considerably less constrained from an experimental point of view. From the ratio of the effective lifetime measurements of B^0 mesons decaying to a flavour-specific final state, like $J/\psi K^*(892)^0$, and those decaying to a CP eigenstate final state, like $J/\psi K^0_S$, it is possible to derive a measurement of the quantity $\Delta\Gamma_d/\Gamma_d$. During my PhD, I demonstrated the feasibility of this measurement using the data collected at the LHCb experiment in 2011. If I was to receive a CERN fellowship, an exciting task will be to perform this measurement exploiting the full data set collected by the LHCb detector in 2011 and 2012. Including the data from the first year of Run-II data-taking should be enough to produce the world's best measurement of this quantity, with a total estimated uncertainty of ~ 1.3 %. This would imply evaluating the decay-time acceptance using the 2015 data and would require a deep investigation due to the significant changes in the data taking conditions. Due to the 25 ns bunch spacing and the higher center-of-mass energy, the detector occupancy will be higher and the track reconstruction algorithms will have to deal with harsh conditions and a higher number of fake tracks. The whole collaboration will benefit from this study, which is crucial to prove a good control of the track reconstruction and to determine the decay-time acceptance correction for the Γ_s and $\Delta\Gamma_s$ measurements.

Precise measurements of very rare decays could provide an insight on the presence of particles not included in the SM that enter in loop or in box diagrams. An example of this kind of decay is $B^0_s \to \mu^+\mu^-$, which in the SM has a very low branching fraction due to the values of the CKM matrix elements, the GIM mechanism and the helicity suppression. However, NP models can enhance it significantly. The combined analysis of data from CMS and LHCb establishes conclusively the existence of this decay [8], with a branching fraction consistent with the SM prediction [9]. Since the theory predictions of the branching fraction are theoretically limited, the relative measurement of $B^0 \to \mu^+\mu^-$ and $B_s^0 \to \mu^+\mu^-$ cross-sections will become an interesting probe of the SM. However, the measurement of the branching fraction is not the only interesting physics result that can be extracted. In particular, the measurement of the $B_s^0 \to \mu^+\mu^-$ effective lifetime, $\tau_{\mu^+\mu^-}$, is a theoretically clean probe for NP scenarios which could reveal large NP effects even if the branching fraction agrees with the SM [9]. If I was to receive a CERN fellowship I could also use my experience to determine the $B_s^0 \to \mu^+\mu^-$ effective lifetime. The effective lifetime is the time expectation value of the untagged rate and is obtained in practice by fitting a single exponential function to the B_s^0 untagged decay-time distribution. Thus, it is experimentally feasible since it is possible to use the same sample of untagged events used for the branching fraction measurement, i.e. without distinguishing between events originating from a B_s^0 or a $\overline{B}_s^0$ meson. My expertise would be valuable to develop the strategy to perform the measurement, especially for the fit strategy in order to deal with the low statistics that will be available. The uncertainty on this measurement is expected to be $\sim 23\%$ using Run-I data and $\sim 14\%$ using Run-II data. The measurement of the $B_s^0 \to \mu^+\mu^-$ effective lifetime also provides a crucial ingredient to link the experimental value of the $B_s^0 \to \mu^+\mu^-$ branching fraction to the theoretical prediction. They differ due to a non negligible value of $\Delta\Gamma_s$ and if this effect is not corrected, for instance using the information coming from the effective lifetime, it can lead to a systematic uncertainty as large as 10% on the branching fraction. So far, these effects have only partially been included and their determination will be crucial now that we are approaching the era of precise measurements using $B_s^0 \to \mu^+\mu^-$ decays.

In the next years LHCb will face new challenges. In addition to the analysis effort to further increase the precision on key observables, it is essential to ensure a smooth restart of the experiment after the end of LS1. Moreover, LHCb has a challenging upgrade program to which I would like to contribute. Based on my experience on the reconstruction software, I will contribute to the trigger reconstruction sequence. About 90% of the time in the HLT sequence is spent in track reconstruction and fitting and thus my detailed understanding of the pattern recognition algorithms will be very beneficial to optimize the trigger strategy in Run-II, which will be at the same time the testing workbench for the Upgrade running scenario. Additionally, to get as much data as possible through the hadron trigger is especially important for charm analyses, due to the high charm data rate that will represent the real challenge for the trigger in Run-II.

I believe my credentials are well-matched to the requirements of a CERN Fellow candidate. I am excited about the opportunity to work for an extended period with the people at CERN and I am determined to play an important role in the search for NP. I believe that the knowledge gained during my PhD, my active involvement in many and very diverse areas and my enthusiasm to contribute to key measurements in flavour physics equip me well for the challenges ahead.

References

[1] R. Aaij *et al.*, "Precision measurement of CP violation in $B_s^0 \to J/\psi K^+K^-$ decays," *Phys. Rev. Lett.*, vol. 114, p. 041801, 2015.

[2] R. Aaij *et al.*, "Measurements of the B^+, B^0, B_s^0 meson and Λ_b^0 baryon lifetimes," *JHEP*, vol. 1404, p. 114, 2014.

[3] R. Aaij *et al.*, "Measurement of CP violation and the B_s^0 meson decay width difference with $B_s^0 \to J/\psi K^+K^-$ and $B_s^0 \to J/\psi \pi^+\pi^-$," *Phys. Rev.*, vol. D87, no. 11, p. 112010, 2013.

[4] R. Aaij *et al.*, "Prompt charm production in pp collisions at $\sqrt{s} = 7$ TeV," *Nucl. Phys.*, vol. B871, pp. 1–20, 2013.

[5] V. M. Abazov *et al.*, "Study of CP-violating charge asymmetries of single muons and like-sign dimuons in pp collisions," *Phys. Rev.*, vol. D89, no. 1, p. 012002, 2014.

[6] A. Lenz and U. Nierste, "Numerical Updates of Lifetimes and Mixing Parameters of B Mesons," *arXiv/hep-ph 1102.4274*, 2011.

[7] G. Borissov and B. Hoeneisen, "Understanding the like-sign dimuon charge asymmetry in $p\bar{p}$ collisions," *Phys. Rev.*, vol. D87, no. 7, p. 074020, 2013.

[8] V. Khachatryan *et al.*, "Observation of the rare $B_s^0 \to \mu^+\mu^-$ decay from the combined analysis of CMS and LHCb data," *arXiv/hep-ex 1411.4413*, 2014.

[9] K. De Bruyn, R. Fleischer, R. Knegjens, P. Koppenburg, M. Merk, *et al.*, "Probing New Physics via the $B_s^0 \to \mu^+\mu^-$ Effective Lifetime," *Phys. Rev. Lett.*, vol. 109, p. 041801, 2012.