Hirschegg 2024 - Strong interaction physics of heavy flavors

Report of Contributions

https://indico.gsi.de/e/18061

Contribution ID: **44** Type: **Invited talk**

Quarkonia spectral function and thermal static quark-antiquark potential from Lattice QCD

Friday, January 19, 2024 9:50 AM (50 minutes)

Quarkonia, the bound states of heavy quark-antiquark pairs, have proven to be crucial probes for studying quark-gluon plasma. The color screening properties of the QGP weaken the interaction between quark-antiquark pairs, leading to the suppression of quarkonia yields within the QGP. We present some preliminary results on the fate of quarkonia bound states in the QGP by performing spectral reconstruction from lattice correlators. The spectral function is reconstructed by combining the vacuum part, which is valid at large energy, with the one obtained from the thermal potential near the threshold. We observe that this spectral function effectively describes the lattice data. Our findings indicate that the thermal interaction shifts the bound state mass and results in a significantly larger thermal width. In the charmonium system, the width is much larger than in the bottomonium system.

Presenter: ALI, Sajid

Contribution ID: **45** Type: **Invited talk**

Charm and beauty production in Pb-Pb collisins at the LHC and the statistical hadronization model

Friday, January 19, 2024 11:10 AM (50 minutes)

I will review the broad aspects of quarkonium production at the LHC and compare to the statistical hadronization model predictions. The focus will be on pT-integrated yields and will include open-charm hadrons and also comparisons to other approaches.

Presenter: ANDRONIC, Anton (Universitaet Muenster)

Contribution ID: **46** Type: **Invited talk**

Studying the interaction between charm and light-flavor mesons

Tuesday, January 16, 2024 9:00 AM (50 minutes)

In the last years, several exotic states were observed in the charm sector; such particles cannot be interpreted as regular baryons or mesons and are thought to be either quark bags or molecular states. To unveil their nature, it is crucial to experimentally constrain the strong force that governs the interaction between the charm hadrons and other hadrons, for instance, via the measurement of the scattering parameters. However, the available experimental knowledge of these interactions is very poor: so far, only the D-proton system was investigated. In this contribution, the studies of the strong nuclear force in the charm sector are extended, focusing on the interactions between open-charm and light-flavor mesons. The measurement of the final-state strong interaction is achieved with a femtoscopic study of high-multiplicity proton-proton collisions at sqrt(s) = 13 TeV, collected by the ALICE Collaboration.

Presenter: BATTISTINI, Daniel

Contribution ID: **47** Type: **Invited talk**

XYZ exotics with Effective Field Theory

Tuesday, January 16, 2024 4:45 PM (50 minutes)

On the basis of scales separation, we construct a general nonrelativistic effective field theory treatment for exotics XYZ states called BOEFT. Scale factorization introduces systematicity and simplicity allowing model independent predictions. The dynamics contained in the nonperturbative low energy correlators is addressed with new and tailored lattice QCD computational tools. We will show how the BOEFT is suitable to describe exotics states ranging from hybrids to tetraquarks and pentaquarks and report some applications.

Presenter: BRAMBILLA, nora (tum)

Contribution ID: **48** Type: **Invited talk**

Title: Hadronization of heavy-quarks: from elementary processes to heavy-ion collisions

Tuesday, January 16, 2024 11:10 AM (50 minutes)

The formation of hadrons is a fundamental process in nature that can be investigated at particle colliders. This seminar focuses on the investigation of hadronization processes, particularly those involving heavy quarks, in various collision systems ranging from e+e− to proton–proton (pp) and nucleus–nucleus (AA) collisions. In recent years, the paradigm that heavy-quark hadronisation should be universal and proceed similarly in e+e− and hadronic collisions was severely questioned by the observation that charm and beauty baryon production relative to that of mesons is larger in hadronic than in e+e− collisions. The seminar aims to provide insights through a combination of the most relevant and recent experimental results and theoretical modeling. Perspective for future measurements and phenomenological modeling, that will shed light on the current open question will also be discussed.

Presenter: Dr DUBLA, Andrea (GSI Helmholtzzentrum für Schwerionenforschung GmbH(GSI))

Contribution ID: **49** Type: **Invited talk**

Transport coefficients for heavy quarks and quarkonia

Friday, January 19, 2024 9:00 AM (50 minutes)

In this talk I concentrate on two very important coefficients in the open-quantum system description of quarkonium in media, namely the mass shift \gamma and the width \kappa. I illustrate recent developments related to the differences in the definitions pertaining to heavy quarkonia and to isolated heavy quark and I discuss their impact on perturbative, lattice and holographic determinations.

Presenter: GHIGLIERI, Jacopo (SUBATECH, Nantes)

Contribution ID: **50** Type: **Invited talk**

Recent results from BESIII

Monday, January 15, 2024 5:35 PM (50 minutes)

A ‘second charm revolution’ was sparked with the discovery of new ‘XYZ’ states, such as the X(3872) or the Y(4260) by the B factories Belle and BABAR, which do not fit into the conventional picture of quark-antiquark bound systems. Recently, a number of further, non-conventional bound states have been seen by various experiments in several different production channels. In this talk, I will concentrate on some of the more exotic bound states recently discovered at BESIII, and show some of the connections between them being made, both in the charmonium and the light quark sector.

Presenter: GRADL, Wolfgang (Institut für Kernphysik, Johannes Gutenberg-Universität Mainz)

Contribution ID: **51** Type: **Invited talk**

Rescattering of charmed hadrons in the late-stage of heavy ion collisions

Tuesday, January 16, 2024 9:50 AM (50 minutes)

Presenter: HIRAYAMA, Renan (FIAS)

Contribution ID: **52** Type: **Invited talk**

Volume dependence of quantum bound states and resonances

Thursday, January 18, 2024 9:00 AM (50 minutes)

Simulating quantum systems in a finite volume is a powerful theoretical tool for extracting information about them. The observation that the real-world properties of states are encoded in how their energy levels change with the size of the volume gives rise to a versatile approach that has applications in nuclear physics, hadron physics, and is also relevant for simulations of cold atomic systems. This talk will give an overview of recent progress that has been achieved regarding finite-volume relations for states that correspond to isolated energy levels in infinite volume. In particular, it will discuss the volume dependence of charged-particle bound states and show how the "complex scaling" method can be used to study resonances in finite volume.

Presenter: KOENIG, Sebastian (NC State University)

Contribution ID: **53** Type: **Invited talk**

XYZ states at Belle and Belle II

Thursday, January 18, 2024 4:45 PM (50 minutes)

This talk will focus on X(3872) and other multiquark candidate states observed in B meson decays and focus on results from Belle and Belle II. The results will be put into perspective by comparing to states observed at other experiments. Implications of the observed spectroscopical pattern will be discussed and conclusions for the underlying potential will be drawn. Unresolved puzzles and future key measurements will be adressed.

Presenter: LANGE, Jens Sören (Universität Giessen, II. Physikalisches Institut)

Contribution ID: **54** Type: **Invited talk**

Resonant multi-hadron systems in (in-)finite volume

Thursday, January 18, 2024 10:50 AM (50 minutes)

The quest of unraveling the nature of excited hadrons necessarily involves determination of universal (reaction independent) parameters of these states. Such determinations require input, either from experiment or theory. The challenge in answering these questions from theory arises from the very structure of the theory of strong interaction —QCD. Lattice gauge theory is the only tool available to us to tackle the non-perturbative dynamics of QCD encoded in the determined finite-volume interaction spectra. Many insights have been gained on resonant two-body systems in the past by studying such spectra. Now – with the advent of the three-body finite-volume methods – advances are being made towards more complex systems. This progress will be discussed in the talk, including theoretical developments and applications to phenomenologically interesting systems.

Presenter: MAI, Maxim

Contribution ID: **55** Type: **Invited talk**

Heavy-flavor hadrons at LHCb

Thursday, January 18, 2024 5:35 PM (50 minutes)

The presentation will provide a review of the latest discoveries in heavy-flavor hadron spectroscopy at LHCb, particularly focusing on exotic multiquark states.
Key updates will include the recent evidence for a J/ψK0S structure in B0 decays, the groundbreaking observation of the first doubly charged tetraquark,
and insights from the ongoing search for pentaquarks in prompt production within proton-proton collisions.
These studies will highlight the evolving landscape of heavy-flavor spectroscopy and persistent LHCb's effort in unveiling these novel phenomena.

Presenter: MIKHASENKO, Mikhail (ORIGINS Excellence Cluster, Munich, Germany)

Contribution ID: **56** Type: **Invited talk**

Doubly-charm tetraquark, its quark mass dependence and left-hand cut

Wednesday, January 17, 2024 10:50 AM (50 minutes)

I will review lattice QCD results on the doubly charm tetraquark and discuss the observed dependence on the masses of light and charm quarks. The DD* scattering amplitude at larger-than physical pion masses has a so-called left-hand cut that opens slightly below threshold due to pion exchange. I plan to discuss also how to incorporate the effects of this cut on the analysis of the scattering amplitude using effective field theory approach.

Presenter: PRELOVSEK, Sasa (University of Ljubljana/Regensburg)

Contribution ID: **57** Type: **Invited talk**

Multiquark states: recent results in charm-strange and bottomonium spectroscopy

Monday, January 15, 2024 4:45 PM (50 minutes)

Understanding the line shape of the cs and double-cs states, and searching for new resonances, are topics of great interest. Recent results in hadron spectroscopy are going to be presented. This talk covers in particular the most recent achievements by using the complete Belle and Belle II data sets in the analyses of the continuum, ISR, and gamma-gamma processes. Future perspectives by hunting hexaquarks and the scan-energy results in the bottomonium sector are also given. A panorama of the achievements and a comparison with other experiments is also provided.

Presenter: PRENCIPE, Elisabetta (JLU - University of Giessen)

Contribution ID: **58** Type: **Invited talk**

The formalism to study the Tcc from lattice QCD

Wednesday, January 17, 2024 4:45 PM (50 minutes)

In this talk, I discuss progress developing and applying the relativistic field-theoretic three-particle finite-volume scattering formalism to systems of nondegenerate mesons. In particular, I focus on the recently developed formalism for $DD\pi$ systems in the charm C = 2 sector. This includes the isospin-0 channel, in which the recently discovered doubly-charmed tetraquark $T_{cc}(3875)^+$ is expected to manifest as a pole in the $DD\pi \to DD\pi$ scattering amplitude. The formalism presented here can also be applied to lattice QCD settings in which the D^* is bound and, in particular, remains valid below the left-hand cut in DD^* scattering, thus resolving an issue in previous analyses of lattice-determined finite-volume energies.

Presenter: ROMERO-LOPEZ, Fernando (MIT)

Contribution ID: **59** Type: **Invited talk**

Three-particle decays on the lattice

Wednesday, January 17, 2024 5:35 PM (50 minutes)

A brief overview of the derivation of the manifestly relativistic-invariant expression for the Lellouch-Lüscher factor in three-particle decays is given. Furthermore, the framework has been explicitly applied to the decay process of a kaon into three (non-identical) pions at leading order. The role of the three-particle force is investigated in detail.

Presenter: RUSETSKY, Akaki (HISKP, UNi Bonn)

Contribution ID: **60** Type: **Invited talk**

Heavy flavour spectroscopy from lattice QCD

Tuesday, January 16, 2024 5:35 PM (50 minutes)

The charm and bottom meson sectors offer a rich arena in which to study strong interaction physics. I will describe recent lattice calculations in heavy
meson spectroscopy and radiative transitions and offer some perspectives for
future study.

Presenter: RYAN, Sinead

Contribution ID: **62** Type: **Invited talk**

Heavy exotic mesons from lattice QCD

Wednesday, January 17, 2024 9:00 AM (50 minutes)

I discuss the basic principle as well as typical problems, when computing masses of hadrons, in particular heavy exotic mesons, with lattice QCD. I also present selected recent lattice QCD results for heavy exotic mesons. I focus on tetraquarks composed of two heavy anti-bottom quarks and two lighter quarks.

Presenter: WAGNER, Marc (Johann Wolfgang Goethe-Universität Frankfurt am Main)

Contribution ID: **63** Type: **Invited talk**

Heavy quark production and the initial stages: progress and open questions

Monday, January 15, 2024 10:50 AM (50 minutes)

The initial stages of ultra-relativistic nucleus-nucleus collisions are not well constrained. In particular, the number of initially produced heavy-quark pairs, part of any initial conditions required for modeling, is not well known. When the heavy-quark pair production in nucleus-nucleus collisions is estimated based on an extrapolation from proton-proton collision measurements, this is mainly driven by the lack of our knowledge of the gluon densities at low longitudinal momentum fraction of the nucleus.

In this presentation, I will give an experimentally-driven overview of the significant progress of our knowledge on these gluons via inclusive heavy-quark production in proton-nucleus and exclusive gamma-nucleus collisions at the LHC. I will point out the conceptual caveats related to both types of measurements in view of their interpretation as initial state constraints of nucleus-nucleus collisions. In this context, I will mention their potential beyond density constraints and the role of these measurements for an open question in hadron structure physics, the quest for gluon saturation. I will argue that, firstly, we see the emergence of a coherent picture of strong gluon depletion in the nucleus compared to the proton and that, secondly, experimental and theoretical progress is under way to solidify and quantify better this picture.

Finally, I will comment on charm production during the preequilibrium stage in ultra-relativistic heavy-ion collisions, the phase between the initial hard scatterings and the phase described by viscous hydrodynamics. This production contribution is usually coined ´thermal´ production. It is non-negligible, but suffers from large theoretical uncertainties. Nonetheless, it can provide us experimental information on the preequilibrium stage and hence the thermalisation process in heavy-ion collisions, if precise measurements of total charm production and precise calculations are conducted.

Presenter: WINN, Michael (Physikalisches Institut Heidelberg)

Contribution ID: **64** Type: **Contributed talk**

Properties of heavy-flavour Four-Quark states from Functional Methods

Wednesday, January 17, 2024 11:40 AM (30 minutes)

Since the experimental discovery of the first tetraquarks in 2003, there has been a lot of excitement around this topic from the theoretical as well as the experimental side. To study the properties of these four-quark states we employ hadronic bound state equations, i.e., Faddeev or Bethe-Salpeter equations. In this talk we will present our results for the mass spectra and internal structure of heavy-light hidden-flavour four-quark states in the charmonium and bottomonium sector.

Presenter: HOFFER, Joshua (University Gießen)

Contribution ID: **65** Type: **Contributed talk**

Tetraquarks with two b-quarks

Wednesday, January 17, 2024 9:50 AM (30 minutes)

In this talk I will discuss our investigations into the proposed, deeply-bound, T_{bb} and T_{bbs} tetraquark states. For our most-recent determination the focus will be on the influence of the lattice NRQCD b-quark tuning and furthermore outlining the pertinent systematics in our final mass determinations. I will then illustrate our ongoing efforts to further reduce these systematics, primarily by moving away from lattice NRQCD.

Presenter: HUDSPITH, Renwick

Contribution ID: **66** Type: **Contributed talk**

Time-like Baryon Form Factors

Wednesday, January 17, 2024 6:35 PM (30 minutes)

Inspired by the recent precise data, we perform model-independently an isospin decomposition of the timelike octet baryons electromagnetic form factors. As noted in our previous work, the relative magnitude of isoscalar and isovector component is determined with the input of data on various isospin channels. Herein we further assert that their relative phase can be constraint by the phase difference of oscillatory modulation of effective form factors between isospin channels. The framework is extended to analyze the data of differential cross sections and applied to the form factors of nucleon and hyperons with detail and isospin non-conservation of charmonium decay into baryon-anti-baryon as well. We address that isospin analysis is meaningful when the isospin broken scale is compared to or smaller than the uncertainties of data

Presenter: LENSKE, Horst (JLU Giesen)

Contribution ID: **67** Type: **Contributed talk**

Bottomonium suppression from the 3-loop QCD potential

Monday, January 15, 2024 11:40 AM (30 minutes)

We present results for bottomonium suppression in the QGP based on pNRQCD and the open quantum system framework. We solve the corresponding Lindblad equation for the quarkonium density matrix to obtain results for the nuclear modification factor. We extend previous studies by including the three-loop potential from pNRQCD for the singlet and octet into the simulation pipeline. We find good agreement with the experimental data by using values for the transport coefficients that we extract from lattice measurements of the in medium width and thermal mass shift.

Presenter: MAGORSCH, Tom

Contribution ID: **68** Type: **Contributed talk**

Elastic nucleon-pion scattering at $m_\pi = 200$ MeV from lattice QCD

Thursday, January 18, 2024 9:50 AM (30 minutes)

Elastic nucleon-pion scattering amplitudes are computed using lattice QCD on a single ensemble of gauge field configurations with $N_\mathrm{f} = 2 + 1$ dynamical quark flavors and $m_\pi = 200$ MeV. The s-wave scattering lengths with both total isospins $I = 1/2$ and $I = 3/2$ are inferred from the finite-volume spectrum below the inelastic threshold together with the $I = 3/2$ p-wave containing the $\Delta(1232)$ resonance. The amplitudes are well-described by the effective range expansion with parameters constrained by fits to the finite-volume energy levels, enabling a determination of the $I = 3/2$ scattering length with statistical errors below 5\%, while the $I = 1/2$ scattering length is somewhat less precisely evaluated. Systematic errors due to excited states and the influence of higher partial waves are controlled, providing a step toward future computations down to physical light quark masses with multiple lattice spacings and volumes.

Presenter: SKINNER, Sarah

Contribution ID: **70** Type: **Contributed talk**

On the two-pole nature of the Λ(1405) from lattice QCD

Thursday, January 18, 2024 11:40 AM (30 minutes)

This talk presents results of the first coupled-channel meson-baryon Σπ – N $\bar{K}$ computation from lattice QCD
in the Λ(1405) region. Correlation functions were calculated using a single ensemble with a pion mass mπ = 200
MeV and kaon mass mK = 487 MeV, including single- and multi-hadron operators and the finite-volume energy
spectra were extracted. The Lüscher method was employed to study scattering amplitudes based on these finite-
volume energies. The final results showed agreement with the two-pole picture after parametrizing the two-channel
K-matrix. These poles correspond to a virtual bound state below Σπ threshold and a resonance pole below the
N $\bar{K}$ threshold.

Presenter: CID MORA, Barbara Alexandra (GSI Helmholtzzentrum für Schwerionenforschung GmbH(GSI))

Contribution ID: **71** Type: **Invited talk**

Charmonia as probe of deconfinement

Monday, January 15, 2024 9:00 AM (50 minutes)

This talk will review the prospect to use heavy flavor hadron yields and spectra as probes of deconfinement. It will also review the approach using the statistical hadronization model, the SHMc, to describe heavy flavor observables. the necessary input, i.e. the open charm cross section and the knowledge about thermalization of charm in the QGP will be presented. A few results of the SHMc will be shown, a more comprehensive review of all results will be given in the talk by A. Andronic.

Presenter: STACHEL, Johanna (Ruprecht-Karls-Universität Heidelberg(U_HD_PHYS))

Contribution ID: **72** Type: **Contributed talk**

Medium effects on Y yields in p–Pb and Pb–Pb collisions

Monday, January 15, 2024 9:50 AM (30 minutes)

The respective contributions of cold-matter and hot-medium effects to the suppression of Y(1S) and Y(2S) mesons in p-Pb collisions at energies reached at the Large Hadron Collider (LHC) are investigated. Whereas known alterations of the parton density functions in the lead nucleus and coherent parton energy loss account for the leading fraction of the modifications in cold nuclear matter (CNM), the hot-medium (quark-gluon plasma, QGP) effects turn out to be relevant in spite of the small initial spatial extent of the quark-gluon droplet. Transverse-momentum-, rapidity-, and centrality-dependent theoretical results for the Y(1S) suppression in p-Pb collisions at a center-of-mass energy of √ s_NN = 8.16 TeV are compared with recent LHCb and ALICE data from the Large Hadron Collider (LHC). Both cold-matter and hot-medium effects are needed to account for the data, lending support to a transient QGP formation in small systems. The initial central temperature of the quark-gluon-droplet in p-Pb at √ s_NN =8.16 TeV is found to be T_0=460 MeV. The results for the asymmetric p-Pb system are compared to the hot-medium effects on Y-suppression in symmetric Pb-Pb-collisions at LHC energies, where the spatially extended fireball is mostly responsible for the dissociation of quarkonia, and cold-matter effects are less relevant. Here our hot-medium model yields excellent agreement with CMS data at 2.76 and 5.02 TeV, a comparison with recent Au-Au data from STAR is shown.

Presenter: WOLSCHIN, Georg (U Heidelberg)

Contribution ID: **73** Type: **Invited talk**

Comparative Study of Quarkonium Transport in Hot QCD Matter

Friday, January 19, 2024 4:45 PM (50 minutes)

This talk summarizes the efforts of the EMMI Rapid Reaction Task Force on "Suppression and (re)generation of quarkonium in heavy-ion collisions at the LHC", centered around their 2019 and 2022 meetings. It provides a review of theoretical approaches, and semi-classical and quantum approaches for the dynamical evolution of quarkonia in the quark-gluon plasma as probed in high-energy heavy-ion collisions. Key ingredients of the transport models are reminded, such as reaction rates, binding energies, and nuclear modification factors. A diagnostic assessment of the various results is attempted and coupled with an outlook to the future

Presenter: GOSSIAUX, Pol-Bernard (IMT Atlantique, Nantes, France)

Contribution ID: **74** Type: **Invited talk**

TBA

Presenter: ESCOBEDO ESPINOSA, Miguel Angel (Instituto Galego de Física de Altas Enerxías)