T 73: Flavour Physics IV

Time: Thursday 16:15–18:30 Location: VG 1.103

T 73.1 Thu 16:15 VG 1.103

Quantum Entanglement of neutral B-mesons at the Y(5s) decay — •Adrian Liese — Max-Planck-Institut, Garching

We investigate the decay channel $\Upsilon(5s) \to B^0\bar{B}^{0*}$ and its subsequent decay into $B^0\bar{B}^0$. This B-meson pair is supposed to be produced in an $J^{PC} = 1^{-+}$ entangled state which is different from a neutral B-meson pair coming from the $\Upsilon(4s)$ where $J^{PC} = 1^{--}$. The different C-symmetry changes the entanglement and subsequently the probability density. The Belle I data for the $\Upsilon(5s)$ offers the unique ability to measure $\bar{t} = t_1 + t_2$ and $\Delta t = t_2 - t_1$ individually, which is not possible for Belle II data of the $\Upsilon(4s)$. The new probabilities were calculated as functions of $\bar{t}$ and Δt and compared to the C=-1 entanglement as well as the disentangled system.

T 73.2 Thu 16:30 VG 1.103

Event separation at the $\Upsilon(5s)$ for entanglement studies — •Kilian Brückner — Max Planck Institut for Physics Garching

Upcoming analyses aim to study the quantum coherence (entanglement) of the $B^0/\overline{B^0}$ system at the $\Upsilon(5s)$ resonance. Doing this effectively requires the knowledge of how the $\Upsilon(5s)$ decayed, since the different decay channels have different entanglement properties. In this analysis the $B^0/\overline{B^0}$ system is reconstructed and later separated into the $B^0/\overline{B^0}$, $B^{0*}/\overline{B^{0*}}$ and $B^{0*}/\overline{B^0}$ decay channels. The separation is done mainly using the variables ΔE, which describes the difference between the beam energy and B-Meson energy, as well as M_{bc}, which describes the beam-energy-constrained mass. Since the Belle II Experiment has thus far not collected any data exactly on resonance of the $\Upsilon(5s)$, Belle I data is used for this analysis.

T 73.3 Thu 16:45 VG 1.103

Entanglement studies with Belle $\Upsilon(5S)$ data — •Vanessa Geier — Max-Planck-Institute for Physics Garching

Compared to the $\Upsilon(4S)$ the $\Upsilon(5S)$ can decay in excited B^0 giving rise to $B^{0(*)}/\ \bar{B}^{0(*)}$ states with different quantum numbers. Directly after the decay of the $\Upsilon(5S)$ the $B^{0(*)}/\ \bar{B}^{0(*)}$ pairs are supposed to be in the $J^{PC} = 1^{--}$ state. After the transition of the excited state into the $B^0/\ \bar{B}^0$ state via photon emission, the $B^0/\ \bar{B}^0$ pairs are supposed to be in the states $J^{PC} = 1^{-+}$. Depending on the C parity the $B^{0(*)}/\ \bar{B}^{0(*)}$ can be in a symmetric or antisymmetric wave function leading to different time evolutions of the entangled states. Possibly the gamma transition of the excited state can also disrupt the entanglement. We will study these effects using $\Upsilon(5S)$ data collected by the Belle experiment. The Analysis includes the reconstruction of the signal $B^{0(*)}$ mesons as well as the tag-side reconstruction through the decay chain $B^0 \to D^-(\to K^+\pi^-\pi^-)\pi^+$. In addition the resulting $B^0/\ \bar{B}^0$ mesons need to be separated with the help of M_{bc} and ΔE variables. Reconstruction and selection efficiencies will be studied with MC events. Then the time evolution of the B-mesons will be investigated to study possible (dis)entanglement properties of the produced $B^0/\ \bar{B}^0$ meson pairs.

T 73.4 Thu 17:00 VG 1.103

Analysis of Rare $B^0_{(s)} \to \mu^+\mu^-$ Decays using Run 3 LHCb Data — Johannes Albrecht[1], Lukas Bertsch[1], Claudiu Cotirlan[2], Joel Mainusch[1], Biljana Mitreska[1], and •Jan Peter Wagner[1] — [1]TU Dortmund University, Dortmund, Germany — [2]University of Manchester, Manchester, England

In 2024, the LHCb experiment recorded an integrated luminosity of more than $9\,\text{fb}^{-1}$ of proton-proton collisions which is larger than the samples recorded during the combined LHC data-taking periods Run 1 and Run 2. A key measurement of the LHCb collaboration are the branching fraction measurements of the statistically limited rare $B^0_{(s)} \to \mu^+\mu^-$ decays. In this contribution studies on normalisation and control channels are presented using 2024 LHCb data and simulation. These include detector performance studies and studies comparing 2024 measurements with the already published Run 2 results.

T 73.5 Thu 17:15 VG 1.103

Studies of extended selection methods for the rare decays $B^0_{s,d} \to \mu^+\mu^-$ at the LHCb experiment — Johannes Albrecht, Maik Becker, Quentin Führing, and •Katharina Popp — TU Dortmund University, Dortmund, Germany

Studies of the rare decays $B^0_{s,d} \to \mu^+\mu^-$ are core to the physics programme of the LHCb experiment as they provide sensitivity to new physics. For effective suppression of combinatorial background and improvement of signal significance, extended selection strategies in the analysis of the rare decays $B^0_{s,d} \to \mu^+\mu^-$ at the LHCb experiment are investigated. Information from the existing Flavour Tagging algorithms, as well as from the underlying tracks of the event, is taken into account in the classification of signal and background candidates. MC-simulated signal samples as well as LHCb sideband data from 2018 are used, assuming that the data contains only combinatorial background. The data is recorded during LHC Run 2 at a centre-of-mass energy of 13 TeV in proton-proton collisions and corresponding to an integrated luminosity of $2.19\,\text{fb}^{-1}$. The multivariate selection method developed in previous analyses used as a baseline and mistag probabilities of the existing Flavour Tagging algorithms are included. A neural network is trained analogously to the previously used multivariate approach and shows an improvement in the classification. In addition, a DeepSet neural network is trained with the original variables and information about the underlying event. This contribution discusses the effect of the different classification algorithms and input information on the performance of the classification.

T 73.6 Thu 17:30 VG 1.103

Measurement of the branching ratio and q^2-spectrum of $B \to D^{**}\ell\nu$ decays at Belle II — •Eylul Uenlue, Thomas Lueck, and Thomas Kuhr — Ludwig-Maximilians-Universitaet Muenchen

There is currently some tension between the measured value of $R(D^*) = \mathcal{B}(B \to D^*\tau\nu_\tau)/\mathcal{B}(B \to D^*\ell\nu_\ell)$ and the Standard Model prediction, hinting at lepton universality violation. Semileptonic B meson decays to D^{**} mesons are background to the $R(D^*)$ measurement, where D^{**} denotes the orbitally excited P-wave charm mesons: $D_1(2420)$, $D_2^*(2460)$, $D_0^*(2300)$, and $D_1'(2430)$. These decays are not well understood, and there have been discrepancies between past measurements of their yields made by BaBar and Belle. Hence, improving understanding of these decays decreases an important systematic uncertainty on $R(D^*)$ measurements.

The aim of the present study is to use simulation and data from the Belle II experiment to study these decays, in particular to determine the q^2 spectrum, which is a key input for theory.

We reconstruct one of the B mesons from the $\Upsilon(4S) \to BB$ decay in the signal channel, $B \to D^{**}(D^*\pi)\ell\nu$. The other B meson is reconstructed in various hadronic modes using the Full Event Interpretation algorithm, which provides a tag B sample with well known kinematics. The signal yield is determined by a maximum likelihood fit to the mass difference $M(D^*\pi) - M(D^*)$. The resulting q^2 spectrum is fitted by a differential decay rate model after correcting for detector resolution effects. The current status of the analysis will be presented including results on simulation and some sources of systematic uncertainty.

T 73.7 Thu 17:45 VG 1.103

Measurement of angular coefficients of $\bar{B} \to D^*\ell\bar{\nu}_\ell$ using Belle II data — Florian Bernlochner[1], Markus Prim[1], Michael Hedges[2], and •Maximilian Hoverath[1] — [1]Physikalisches Institut der Rheinischen Friedrich-Wilhelms-Universiät Bonn — [2]Fermi National Accelerator Laboratory

A precise determination of the CKM matrix element V_{cb} is essential for understanding quark-flavor transitions within the Standard Model (SM). In addition to measuring V_{cb}, semileptonic decays provide a valuable opportunity to probe lepton-flavor universality (LFU), a fundamental feature of the SM that predicts universal gauge couplings for leptons. Any observed deviation from LFU would indicate the presence of physics beyond the SM. In this work, we analyze the exclusive semileptonic decay $\bar{B} \to D^*\ell\bar{\nu}_\ell$ using hadronic tagging and Belle II data to determine the angular coefficients. These coefficients allow for the determination of V_{cb} and the associated form factors, which parameterize the hadronic interaction in the decay. Additionally, we test LFU by measuring asymmetries between the electron and muon channels. Using helicity angles $\cos\theta_\ell$, $\cos\theta_V$, χ, and the hadronic recoil parameter w, we fully describe the kinematics of the decay product by reconstructing the angular coefficients in bins of w. We subtract the background in a model-independent way by fitting the missing mass

squared and correct the measured distributions for migration and selection effects.

T 73.8 Thu 18:00 VG 1.103

Improving $R(D^{(*)})$ with hadronic FEI and leptonic tau decays with Belle II Run 1 data. — •Agrim Aggarwal, Florian Bernlochner, Markus Prim, Felix Metzner, and Ilias Ilias Tsaklidis — Physikalisches Institut der Rheinischen Friedrich-Wilhelms-Universität Bonn, Bonn, Germany

An important postulate of the Standard Model, which has been challenged by experimental measurements, is the assumption that all leptons couple identically to the electroweak gauge bosons. In this work, the expected precision of ratios $R(D^*) = \mathcal{B}(B \to D^{(*)}\tau\bar{\nu}_\tau)/\mathcal{B}(B \to D^{(*)}\ell\bar{\nu}_\ell)$ are studied, a crucial test of lepton flavour universality, at Belle II. The Long Shutdown Run 1 (LS1) data at Belle II which corresponds to the total integrated luminosity of 365 fb^{-1} is used. A technique known as hadronic tagging is employed to fully reconstruct one of the $\mathcal{B}$ mesons and furthermore the leptonic decays of τ lepton is considered. The ratios of interest are extracted using a two-dimensional binned maximum likelihood fit with a revised signal extraction strategy, implemented via pyhf, that enables a conceptually safer treatment of the systematic uncertainties handled using the package SysVar developed in Bonn.

T 73.9 Thu 18:15 VG 1.103

Measurement of the efficiency and the partial branching fraction in a B Meson to X_c inclusive semileptonic Decay for the different q^2 (squared momentum transfer) with Belle II data — •Rajeshwari Roy, Munira Khan, Florian Bernlochner, and Markus Prim — Physikalische Institut der Rheinische Friedrich-Wilhelms- Universität Bonn, Nussallee 12, 53115, Bonn

The study of B-meson decays into charmed hadronic states (X_c) accompanied by a lepton and neutrino ($B \to X_c\ell\nu$) provides crucial insights into the dynamics of weak interactions and the structure of the Standard Model. This project focuses on the measurement of the partial branching fraction for $B \to X_c\ell\nu$ for different kinematic regions defined by cuts on the squared momentum transfer, q^2. A detailed event selection strategy is employed, leveraging kinematic constraints (moments: q^2, M_X) The use of multivariate techniques distinguishes the signal events from the backgrounds, such as continuum events and non-charmed semileptonic decays. The plots and fit results are generated using pyhf, a robust framework for statistical modeling and systematic uncertainty evaluation.The efficiency of identifying these decays is determined using simulated datasets and is given by the ratio of the number of reconstructed events to the number of generated events. Further, the partial branching fractions are determined for different q^2 thresholds, providing a refined understanding of semileptonic decay dynamics.