T 72: Flavour Physics IV

Time: Thursday 16:15–18:15 Location: KH 01.011

T 72.1 Thu 16:15 KH 01.011

Early Studies on rare $B_s^0 \to \mu^+\mu^-$ decays and related control modes in Run 3 at the LHCb experiment — Johannes Albrecht, •Lukas Bertsch, Mick Mulder, Katharina Popp, and Jan Wagner — TU Dortmund University, Germany

Rare $B^0_{(s)} \to \mu^+\mu^-$ decays provide a sensitive test of the Standard Model owing to their exceptional suppression, clean experimental signature, and precise theoretical predictions. Searches for these decays have been conducted since the start of the LHCb experiment, accomplishing the observation of $B_s^0 \to \mu^+\mu^-$ in 2014, together with the CMS collaboration. However, the more strongly suppressed B^0 meson counterpart of the decay has not yet been measured with statistical significance, due to interfering backgrounds and limited data. Much larger datasets collected during Run 3 of the LHC provide a clear opportunity to find evidence for the $B^0 \to \mu^+\mu^-$ decay, but also pose new challenges due to the busy collision environment. Therefore, early studies on the new dataset are performed in this work, providing a first implementation of required analysis tools and verifying the analysis procedure on Run 3 data. Based on $11\,\text{fb}^{-1}$ of data recorded in 2024 and early 2025, branching fractions of control modes are measured following the signal-channel analysis strategy, and a preliminary estimate of the sensitivity to the $B^0 \to \mu^+\mu^-$ decay is obtained.

T 72.2 Thu 16:30 KH 01.011

Multivariate analysis of the rare decays $B^0_{(s)} \to \mu^+\mu^-$ in Run 3 at the LHCb experiment — Johannes Albrecht, Lukas Bertsch, Mick Mulder, •Katharina Popp, and Jan Peter Wagner — TU Dortmund University, Dortmund, Germany

Studies of the rare $B^0_{(s)} \to \mu^+\mu^-$ decays are core to the physics programme of the LHCb experiment, as they provide sensitivity to physics beyond the Standard Model. While the decay $B_s^0 \to \mu^+\mu^-$ has been observed in the previous analyses using data from Run 2 of the LHC, the process $B^0 \to \mu^+\mu^-$ is still to be observed. With the LHCb Upgrade I detector in Run 3, an upgraded strategy is required for the search for these processes. A major challenge arises from the amount of background events caused by random combinations of muons from b-hadron decays, which superimpose the signal processes. Thereby, a powerful tool for the suppression of combinatorial background is provided by considering the isolation of the final state muon tracks with respect to other tracks in the event. This aspect has already proven useful in previous analyses, where a combination of Boosted Decision Trees has been utilised. For the analysis with Run 3 data, the existing strategy for the suppression of combinatorial background is revisited and improvements are pursued, in order to enhance the signal significance of the decay $B^0 \to \mu^+\mu^-$.

T 72.3 Thu 16:45 KH 01.011

Transformer-based classification of $B_s^0 \to \tau^+\tau^-$ decays in $Z \to b\bar{b}$ events at the FCC-ee — •Alejandro Quiroga Trivino[1], Jan Kieseler[1], Markus Klute[1], Joscha Knolle[1], Anuar Sifuentes Name[1], Samuel Wyrowski[1], and Xunwu Zuo[2] — [1]Institute for Experimental Particle Physics (ETP), Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany — [2]Ecole polytechnique federale de Lausanne (EPFL), Lausanne, Switzerland

Experimental indications of potential deviations from lepton flavor universality have intensified interest in rare B meson decays involving tau leptons. Among these, the decay $B_s^0 \to \tau^+\tau^-$ remains largely unexplored experimentally due to its challenging final state and the limited sensitivity of current detectors. The high-statistics and low-background environment of electron-positron collisions at the Z pole that will be provided by the FCC-ee creates a unique opportunity to study this process with unprecedented precision. Leveraging these conditions, advanced machine-learning techniques can be brought to bear to enhance the separation between signal candidates and the overwhelming $Z \to b\bar{b}$ background. In this contribution, the application of a transformer model to separate between $Z \to b\bar{b}$ events with and without a $B_s^0 \to \tau^+\tau^-$ decay is discussed. The usage of different sets of input features, relying either on reconstructed hadronic tau lepton candidates or on tracks and neutral particles, are compared. The achieved background rejection paths the way towards the observation of this rare standard model process.

T 72.4 Thu 17:00 KH 01.011

Prospects for $B_s^0 \to \tau^+\tau^-$ searches in final states with six charged pions at the FCC-ee — •Anuar Sifuentes Name[1], Jan Kieseler[1], Markus Klute[1], Joscha Knolle[1], Alejandro Quiroga Trivino[1], Samuel Wyrowski[1], and Xunwu Zuo[2] — [1]Institute for Experimental Particle Physics (ETP), Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany — [2]Ecole polytechnique federale de Lausanne (EPFL), Lausanne, Switzerland

Recent results from the LHCb and Belle-II experiments have reported hints of lepton flavor universality (LFU) violation in rare B meson decays. One particularly interesting probe for this potential deviation from the standard model (SM) of particle physics is the measurement of the branching fraction of the rare decay $B_s^0 \to \tau^+\tau^-$, for which the expected LHCb sensitivity at the end of the HL-LHC era is several orders of magnitude away from the SM prediction. The future circular collider (FCC), operated with electron-positron collisions at the Z pole, will offer an experimentally clean environment to search for this decay. In this contribution, an analysis strategy is presented that targets the final state corresponding to the decay chain $B_s^0 \to \tau^+\tau^- \to 6\pi^{\pm}2\nu$. Through an optimized set of dedicated kinematic cuts and training of machine-learning discriminants, a sufficient separation between the signal and the background from other $Z \to b\bar{b}$ events is achieved to demonstrate the capability of the FCC to probe LFU in beyond-the-SM scenarios.

T 72.5 Thu 17:15 KH 01.011

FCC-ee Sensitivity Estimation to the Direct CP-Violating Decay-Rate Asymmetry $A_{CP}(D^0 \to \pi^0\pi^0)$ — •Willy Weber[1,2], Kevin Kröninger[1], Romain Madar[2], and Stéphane Monteil[2] — [1]TU Dortmund University, Department of Physics, Dortmund — [2]Université Clermont-Auvergne, Laboratoire de Physique de Clermont, Clermont-Ferrand

The Future Circular Collider (FCC-ee) is a proposed electron-positron collider designed to enable high-energy collisions. It is expected to produce $O(10^{12})$ $Z \to q\bar{q}$ events, significantly enhancing our ability to perform precision measurements of electroweak observables.

CP violation in D^0 decays to charged particles has been observed by LHCb. Our understanding of CP violation in the charm sector can be further improved by studying the decays into neutral particles. This presentation considers the potential for precise measurement of *CP* violation in $D^{*\pm} \to (D^0 \to \pi^0(\to \gamma\gamma) + \pi^0(\to \gamma\gamma))\pi^{\pm}$ decays at FCC-ee to complement the knowledge gathered by LHCb with charged modes. Monte Carlo samples, including a simulated detector response based on the IDEA detector concept, are used for this purpose. It is demonstrated that the FCC-ee will significantly improve the precision of the measurement of the *CP*-Violating decay-rate asymmetry $A_{CP}(D^0 \to \pi^0\pi^0)$. Furthermore, the necessary detector requirements for this future measurement are investigated.

T 72.6 Thu 17:30 KH 01.011

Branching fraction measurements of the rare decays $B^0_{(s)} \to \pi^+\pi^-\mu^+\mu^-$ at LHCb — Johannes Albrecht[1], Thomas Blake[2], Mick Mulder[1], Janina Nicolini[3], and •Jan Peter Wagner[1] — [1]TU Dortmund University, Dortmund, Germany — [2]University of Warwick, Coventry, United Kingdom — [3]CERN, Geneva, Switzerland

Rare flavour-changing neutral-current decays with $b \to q\ell^+\ell^-$ quark transitions ($q = s, d$) provide powerful probes of the Standard Model and are central to the LHCb physics programme. Owing to the smaller CKM matrix elements, $b \to d\ell^+\ell^-$ decays are further suppressed relative to $b \to s\ell^+\ell^-$ processes, making them particularly challenging to observe. Using Run 1 data, the LHCb collaboration observed the decay $B_s^0 \to \pi^+\pi^-\mu^+\mu^-$ with a significance of $7.2\,\sigma$, while evidence for the analogous decay $B^0 \to \pi^+\pi^-\mu^+\mu^-$ was reported with a significance of $4.8\,\sigma$.

This contribution reports the current status of the branching-fraction measurements of $B^0_{(s)} \to \pi^+\pi^-\mu^+\mu^-$ decays using the full $9\,\text{fb}^{-1}$ data sample recorded by LHCb in Runs 1 and 2 of the LHC. First studies based on Run 3 data are also presented, providing an outlook on the improved sensitivity and future prospects for measurements of rare $b \to d\ell^+\ell^-$ and $b \to s\ell^+\ell^-$ decays with the upgraded LHCb detector.

T 72.7 Thu 17:45 KH 01.011

Measurement of the Energy Dependence of Strong Isospin Violation in $\Upsilon(4S)$ Decays — •Lena Nowatzki, Thomas Kuhr, and Thomas Lück — Ludwig-Maximilians-Universität München (LMU), München, Germany

Precise measurements of B meson branching fractions are essential both for testing Standard Model predictions and for many measurements that rely on accurate modeling of data composition in flavor-physics analyses. At Belle II, B mesons are produced via the process $e^+e^- \to \Upsilon(4S) \to B\bar{B}$. The total number of such events can be determined with high precision, yet using this quantity for B meson branching fraction measurements requires knowledge of the production fractions of neutral and charged B meson pairs in $\Upsilon(4S)$ decays, respectively f_{00} and $f_{\pm}$. Although strong isospin symmetry predicts equal production rates, recent theoretical studies indicate a possible energy dependence of the ratio $f_{\pm}/f_{00}$, motivating an experimental investigation.

In this analysis, we aim to measure the energy dependence of the $\Upsilon(4S)$ decay fractions using Belle II data. We employ two different approaches. The first relies on direct B meson energy measurements using the channels $B^+ \to J/\psi K^+$ and $B^0 \to J/\psi K^0_S$. The second includes a multivariate classifier based on event-level observables to distinguish between neutral and charged $B\bar{B}$ pair production. This talk will present the current status and an outlook on future developments of this analysis.

T 72.8 Thu 18:00 KH 01.011

Analysis of Rare Charm Three-Body Decays using LHCb Run 3 data — Dominik Mitzel, Carolina da silva Bolognani, and •Christopher Breitfeld — TU Dortmund University, Dortmund, Germany

Flavor-changing neutral currents in the charm sector provide a sensitive testing ground for the Standard Model. Certain observables, such as *CP* and forward-backward asymmetries are highly suppressed and their measurements therefore constitute null tests. Dominated by non-perturbative long-distance contributions, these decays are also challenging to study theoretically. It is thus essential not only to perform null-test measurements but also to provide experimental information on the resonant structure.

Using data collected with the upgraded LHCb detector during Run 3 of the LHC, the rare decays $D^+_{(s)} \to \pi^+\mu^+\mu^-$ and $\Lambda_c^+ \to p\mu^+\mu^-$ are studied. The analysis aims to measure the *CP* and the forward-backward asymmetry in bins of the dimuon mass, and to perform an amplitude analysis to disentangle the interference of intermediate resonances.

In this talk, an introduction and the general analysis strategy are presented.