Search for CP violation beyond the Standard Model in the decay $B^0 \longrightarrow K_{res}\gamma$ with the Belle II experiment

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Due to the axial-vector structure of the weak interaction, as described in the Standard Model of particle physics, no CP violation effect is expected in the decay $B^0 \longrightarrow K_{res}\,\gamma$. However, this decay proceeds via a quantum loop where the appearance of yet unknown particles might change the photon polarisation and lead to observable CP violation effects [1]. The CP parameters of this neutral B radiative decay are therefore very sensitive to new physics beyond the Standard Model.

The Belle II group [3] at IPHC is currently preparing the measurement of the CP parameters in $B^0 \longrightarrow K_{res}\,\gamma \longrightarrow K^0_S\,\pi^+\,\pi^-\,\gamma$ decays, based on a time-dependent CP asymmetry analysis. For the first time the method based on a Dalitz analysis suggested in [2] is applied with the goal to better constrain the Wilson coefficients appearing in the effective Lagrangian describing physics beyond the Standard Model. However, constraining these Wilson coefficients will require additional studies to understand hadronic effects in the B meson radiative decay to a kaonic resonant or non-resonant system.

The work is based on the data acquired by the Belle II experiment between 2019 and 2022 from the energy-asymmetric $e^+\,e^-$ collisions produced by SuperKEKB, located at Tsukuba, Japan. These data correspond to an integrated luminosity of about 500 fb^{-1}. Belle II will continue accumulating data at a faster pace since SuperKEKB will step up its already world-record instantaneous luminosity from 2024 on. An integrated luminosity of a few ab^{-1} is expected in the coming year.

This thesis topic proposes to first complete this novel CP violation measurement with a study of the kaonic structure of $B^+ \longrightarrow K_{res}\,\gamma \longrightarrow K^+\,\pi^-\,\pi^+\,\gamma$ decays. Modelling the line shape of the later final state will allow to extract the hadronic parameters needed to constrain the Wilson coefficients describing new physics.
In parallel, the wealth of additional data will be used to make a second measurement of potential CP violation effects in the $B^0 \longrightarrow K^0_S\,\pi^+\,\pi^-\,\gamma$ channel with improved sensitivities.

In order to prepare for the highest ever targeted instantaneous luminosity of the SuperKEKB collider, $6\text{x}10^{35}\ cm^{-2}s^{-1}$, the Belle II experiment will be upgraded around 2027, notably the silicon vertex detector. The IPHC group is a strong proponent of this upgrade, using the monolithic active pixel sensor technology developed in house. The new detector will not only enhance Belle II performance but will also become the fastest and most radiation-tolerant instrument of its kind around the world.
An additional topic for the thesis is to participate to the developments for this upgraded vertex detector. Various activities will be possible from the characterisation of the pixel sensors to the design of specific particle trajectory reconstruction algorithms exploiting the features of the new instrument.

Besides focusing on the thesis goals, the PhD student will also contribute to the general operation of the Belle II experiment in Japan and will report on their work regularly at collaboration meetings.

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[2] S. Akar, *et al.*, J. High Energ. Phys. 9 (2019) 34, https://arxiv.org/abs/1802.09433.
[3] Belle II group at IPHC web page:
https://iphc.cnrs.fr/la-recherche/drs-recherches-subatomiques/belle-ii
[4] M. Babeluk, *et al.*, Nucl. Instrum. Meth. A1048 (2023) 168015,
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