Development of the new vertex detector of the Belle II experiment for search of physics beyond the Standard Model

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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 $B^0 \to K_{\rm res}\,\gamma$. However, this decay proceeds via a quantum loop where the appearance of yet unknown particles might change the photon polarisation and lead to an observable CP violation effect. The Belle II group [1] at IPHC is investigating such processes. We published a recent measurement [2] with the current data set recorded by the Belle II experiment at the SuperKEKB e^+e^- collider located in Japan. In the coming years, SuperKEKB will considerably increase the luminosity beyond its current world record of $0.5 \times 10^{35}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$. The rise of the luminosity will generate a hit rate — mostly from beam induced background — exceeding the capability of the current vertex detector. An upgraded vertex detector (VTX) [3] is in development and will be installed in 2032. However, the OBELIX monolithic CMOS pixel sensors equipping the VTX should be ready well before this date.
The proposed thesis topic is twofold, including a instrumental part to strongly contribute to the development of the OBELIX sensor, and a second part to participate in the on-going data analysis within the IPHC group.

The main task will be the characterisation of the first sensor version, OBELIX-1. Especially, these tests will culminate with experiments conducted on beam at KEK, Tsukuba, in December 2026 and later on in 2027 at DESY, Hambourg. The VTX is the first vertex detector of a new generation based on fast CMOS pixel sensors, providing time resolution in the nanosecond range. This performance is critical to separate beam-background from elementary-collision particles. This work will hence mostly focus on the validation of the timing performance of OBELIX-1. It will also extend to the validation of the exploitation of the OBELIX fast information to the trigger logic of Belle II.
The second and final version of the sensor, OBELIX-2, should be fabricated around 2028. The results from the characterisation of OBELIX-1 will play a crucial role in optimising the final sensor design. After the fabrication of OBELIX-2, validation of the final performance will conclude the experimental characterisation.

In parallel to the instrument work, the PhD student will continue the physics analysis work conducted on the $B^0 \to K_{\rm res}\,\gamma$ decay and its charge conjugate. The latter provides key information to disentangle the CP eigenstate from the non-eigenstates in the complex landscape of the various channels leading to the $K_{\rm res} \to K\pi^+\pi^-$ final states. This study is paramount to interpret properly the CP violation measurement in terms of non Standard-Model physics.

This PhD work also entails contributions to the general operation of the Belle II experiment in Japan and reporting results regularly at collaboration meetings.

[1] Belle II group at IPHC web page : https://iphc.cnrs.fr/la-recherche/drs-recherches-subatomiques/belle-ii.
[2] Measurement of time-dependent CP asymmetries in $B^0 \to K^0_{\rm S}\,\pi^+\pi^-\gamma$ decays at Belle and Belle II, arXiv :2510.01331 [hep-ex] 2025, https://doi.org/10.48550/arXiv.2510.01331.
[3] The DMAPS upgrade of the Belle II Vertex Detector, NIM **A 1072** (2024) 170164, https://doi.org/10.1016/j.nima.2024.170164.