Development of the new vertex detector of the Belle II experiment

The Belle II experiment, located near Tokyo in Japan, is one of the few large international particle physics experiments designed to discover physics processes beyond the Standard Model of particle physics. Belle II has been operating since 2019 at the SuperKEKB collider, which targets the highest ever reached instantaneous luminosity of $6 \times 10^{35}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$ in order to collect several 10s billion $e^+e^- \to b\bar{b}, c\bar{c}, \tau\bar{\tau}$ processes over the next decade.
Currently, Belle II detector records data with a luminosity below $1 \times 10^{35}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$. An upgrade of its vertex detector (VTX) is required before ramping up the luminosity for two reasons. The rise of the beam induced background with the luminosity will generate a hit rate exceeding the capability of the current system. The current trigger logic cannot face efficiently this hit rate increase.
The new VTX will be equipped with the OBELIX monolithic CMOS pixel sensor developed at IPHC with collaborators in Europe and Japan. This new detector offers a space-time granularity allowing to match the high hit-rate expected at $6 \times 10^{35}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$ as well as the possibility to improve the trigger decision. The new VTX will not only enhance Belle II performance but will also become the fastest and most radiation-tolerant instrument of its kind around the world, announcing a new generation of instruments.

This internship proposes to address one of the critical open questions in the VTX development.
The first potential topic will study how the fast response of the OBELIX sensor can be exploited to contribute to the trigger of the Belle II experiment. OBELIX can indeed generate a hit map every $30\,\mathrm{ns}$, matching trigger decision time, but only with a degraded space-granularity, i.e. 4 to 16 segments instead of 500k pixels. Using simulated data and a fast algorithm based on look-up-tables, the study should conclude on the efficiency to reconstruct tracks and the corresponding amount of fake tracks, depending on the chosen number of segments and the correlation with the drift chamber information.
In the potential second topic, the study of the impact of the synchrotron background generated by the beam acceleration is proposed. Such background is present in any electron-positron collider and requires some shielding around the beam pipe. The increase of the material budget involved by this shielding limits the actual vertexing resolution of the instruments. The sensitive layer of monolithic CMOS pixel sensor is so thin $(30\,\mu\mathrm{m})$ that the detector should be quite tolerant to synchrotron radiation. Based on beam simulation and synchrotron interaction with silicon, the study should evaluate to which extent the gold coating can be thinned while maintaining a sustainable hit rate and the gain on the vertex resolution for physics performance.

The student will choose which topic they are mostly interested in. If the internship can exceed 4 months, a second part can include the first laboratory tests of the OBELIX-1 sensor.
This internship is connected with a PhD thesis proposal, combining the continuation of the work on the OBELIX-1 sensor and a physics analysis.

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