



Contribution ID: 88

Type: Poster

Readout concept of the future Belle II Vertex Detector

Thursday 9 October 2025 18:40 (20 minutes)

For a proposed upgrade of the Belle II experiment an R&D program has been established to develop a new vertex detector (VTX) made from a single type of depleted active monolithic pixel detector named OBELIX. The chip will provide two LVDS data links with a transmission speed of about 339 MHz. To read out the OBELIX data it is foreseen to utilize optical links based on the lpGBT chip and the VTRx+ transceiver module, both developed at CERN. We will present a first concept of the VTX readout system and discuss its technical requirements.

Summary (500 words)

The Belle II experiment at the SuperKEKB e+e-collider in Tsukuba, Japan, holds the world luminosity record of $5.1 \times 10^{34} \text{ cm}^{-2} \text{ s}^{-1}$ and aims to push up to $6 \times 10^{35} \text{ cm}^{-2} \text{ s}^{-1}$. In such a luminosity range a hit rate of up to 120 MHz/cm² and harsh beam background are expected.

An intensive R&D program has been established to develop a new vertex detector (VTX) entirely made from a single type of depleted monolithic pixel detectors (DMAPS), named OBELIX, as a replacement of the Belle II vertex detector (VXD).

The OBELIX sensor is derived from TJ-Monopix2, originally developed for the ATLAS experiment, which is studied in lab experiments and beam tests to establish its performance and provide valuable inputs for the design of OBELIX. It will feature a pixel matrix of 896x464 pixels of 33x33 μm^2 size. The hit data will be read out over a single LVDS output, while another LVDS output can provide trigger information with low latency. The SuperKEKB machine runs at an RF of 508.887 MHz, and OBELIX receives a clock of $\text{RF}/3 = 169.629 \text{ MHz}$. The LVDS outputs deliver data at double rate, i.e. 339.258 MHz. $\text{RF}/12$ would be 42.407 MHz which is clearly out of specs for the lpGBT (39.41 MHz). Therefore, intense testing of lpGBT chips from several wafers is ongoing to determine the actual limits. So far, measurement results look promising, and we see a limited dependence on VDD as well as on the production wafer from which the chips originated. In the near future, we plan to measure the temperature dependence and the behavior after irradiation.

The baseline plan is to equip each detector ladder at the end with one lpGBT chip plus one VTRx+ transceiver, placed onto the same flex PCB as the OBELIX chips. In case it turns out that this is not viable, an alternative would be to put lpGBT and VTRx+ on a separate board. In that case, we might aggregate two (or even four) ladders, each with its own lpGBT, onto one VTRx+, which features four up-links and one down-link that would then be received by the master lpGBT. Such a configuration with two or four up-links is used by several LHC experiments and therefore known to work.

In this contribution, we will present the overall layout of the VTX readout system, the design of the OBELIX chip and results from the tests on lpGBT and VTRx+ at frequencies that are out of specs.

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Session Classification: Poster 2

Track Classification: System Design, Description and Operation