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The upgrade of the Belle II Vertex Detector: Thermomechanical characterization of prototype ladders and system integration.

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The Belle II experiment is planning an all-pixel upgrade of the vertex detector around 2029-2030, aiming to be more performant in terms of tracking efficiency and more robust against the machine background expected at higher luminosity.
The design of the new Vertex Detector (VTX) is based on five barrel-shaped layers spanning from 14 to 140 mm in radius, equipped with the depleted MAPS chip named OBELIX supported by a light support structure.

The two inner layers (iVTX) feature the "all-silicon ladder"concept, with a material budget less than 0.2% X/X_0 per layer.
Four contiguous OBELIX chip blocks are diced out of the production wafers to build a mechanical standalone 12 cm long sensitive ladder. A post-processing step deposits metal strips on redistribution layers (RDL) to interconnect the sensors along this ladder.
The back side of the sensor regions can then be thinned down to 50 μm.
The first demonstrator, based on a silicon wafer processed with dummy heater structures in place of the sensors, allows to characterize the electrical, mechanical and thermal performance of the inner ladder prototype. The specific power dissipated on the periphery of the chip is almost one order of magnitude greater than on the area covered by the matrix. Thermal simulations and measurements on a dedicated thermal bench facility have been performed to evaluate an effective low mass cooling system to evacuate the average power of 200 mW/cm2, considering the maximum operational temperature of the chip, with a thermal gradient still acceptable in terms of threshold dispersion. Several options are now being explored with air cooling only or combination of air cooling with thin pipes for liquid cooling at the edge of the silicon ladder.

A more traditional approach has been adopted for the ladders of the three outer layers (oVTX), which extensions along the beam axis reach 70 cm. We are also exploring the engineering and performance aspects of the 4 layer option. Their design has been optimized in order to have ladders occupying a limited radial space. By accumulating four layers over 7 cm towards large radii, the efficiency in the Ks reconstruction can be preserved or improved. The high stiffness of the ladders is obtained by sandwiching rohacell with two carbon fiber sheets in an omega-shaped structure. An additional thin carbon fiber layer integrating a pipe for the circulation of a coolant liquid serves as a cold plate in direct thermal contact with a raw of sensors. These chips are electrically connected by aluminum flex circuits, for powering and data output. The material budget of each oVTX layer is expected to be less than 0.45% X/X_0.
Results from the mechanical and thermal characterization of the prototype ladders will be reported.

Auteurs principaux: BAUDOT, Jerome (IPHC); M. BETTARINI, STEFANO (University of Pisa and INFN)

Orateur: BAUDOT, Jerome (IPHC)

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