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The Origami Chip-on-Sensor Concept for Low-Mass Readout of Double-Sided Silicon Detectors

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Modern front-end amplifiers for silicon strip detectors offer fast shaping but consequently are susceptible to input capacitance which is the main contribution to the noise figure. Hence, the amplifier must be close to the sensor which is not an issue at LHC, but a major concern at material budget sensitive experiments such as Belle or the ILC detector.
We present a design of a silicon detector module with double-sided readout where thinned front-end chips are aligned on one side of the sensor which allows efficient cooling using just a single, thin aluminum pipe. The connection to the other sensor side is established by thin kapton circuits wrapped around the edge - hence the nickname origami.

Summary

The current Belle Silicon Vertex Detector (SVD) at the high-luminosity KEK-B accelerator pushes the limits in terms of occupancy. The sensors are read out with the low-noise, but slow-shaping (Tp˜800ns) VA1TA front-end chip, and due to the large background, track finding becomes increasingly difficult as the occupancy exceeds the 10% level in the innermost layer. At increasing trigger rate, another issue is dead time which occurs since the VA1TA has no pipeline and thus is blind during the readout which takes about 25µs.

Already for several years, there are plans to upgrade the Belle SVD and these have evolved from replacing the innermost layer only to an entirely new and significantly larger subdetector for the Super-Belle experiment. Coming from CMS, we proposed their front-end chip, the APV25, as it perfectly meets the requirements of Belle: It has a shaping time of just 50ns and an analog pipeline of 192 cells in order to avoid any dead time.

However, this fast shaping inevitably comes along with higher noise figures for both the constant term and the capacitance slope. Hence, one has to take great care to minimize the load capacitance presented at the inputs of the front-end amplifiers. The Belle SVD has a limited angular coverage (17° to 150° azimuth) and currently is read out from the sides, which implies long flex fanouts. For the innermost layer, which is composed of only two sensors per ladder, this concept also works with the APV25. However, capacitance will not allow that scheme for outer layers. In comparison to the LHC, KEK-B is a low-energy machine (3.5GeV for positrons and 8GeV for electrons) and thus material budget is a critical issue for the vertex resolution, which is a key parameter at Belle. Consequently, one has to minimize material as far as possible, which will also be a critical point for the International Linear Collider (ILC).

This was the motivation to develop a chip-on-sensor concept for double-sided readout with lowest possible material budget, yet including cooling for the front-end chips, and minimum noise figure, which means smallest possible load capacitance. We achieve this goal by
* using a thin kapton "hybrid" placed on the sensor but separated by a Rohacell (styrofoam) layer
* thinning the APV25 chips to 100µm (or less)
* using a single thin aluminum pipe for water cooling
* connecting the sensor strips to the APV25 inputs by thin kapton circuits

All APV25 chips are aligned on the hybrid such that they can be cooled by a single aluminum pipe. The central chips are connected to the strips on the same side using a kapton fanout, where the outer APVs are attached to flex circuits which will be wrapped around the sensor edges and connected to the strips on the other side.

We already successfully demonstrated the chip-on-sensor concept for one sensor side with a prototype module in 2006, achieving excellent signal-to-noise in beam tests. In summer 2008, we will build an origami module as described above and by the time of the TWEPP workshop, we will already have source measurement results. A beam test will follow later this year.

We prefer a poster presentation which will include not only photos, drawings and results of the origami module, but also a 3D mechanical model attached to the poster.

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