Beyond CMOS sensors, submicron pixels for the vertex detector

N.T. Fourches (CEA-Saclay, Universite Paris-Saclay), Charles Renard, (CNRS-C2N, Universite Paris-Saclay), A. Barbier (CEA-IRAMIS, Universite Paris-Saclay)

ABSTRACT: We propose to develop a submicron position sensitive vertex detector for the future linear colliders experiments. Present vertex-pixels detector installed at the hadron collider suffer from a low position resolution, although improved from their predecessors. The objective of vertex detectors is to enable the accurate secondary vertex determination that is crucial for b-tagging [1] [2] in the case of high transverse momentum (pT) events. The heavy quark events are characterized by a relatively high lifetime that induce a secondary vertex, distinct from the interaction point [3]. For an accurate track reconstruction we want to improve point to point resolution well below the 5 micrometer limit. In the framework of ILD we propose to develop a pixel detector based on the DoTPiX structure, and establish a working collaboration with other institutes in the High Energy Physics domain to enlarge our present working collaboration.

Why do we need to improve point-to-point resolution?

Accurate track reconstruction with a vertex detector is possible using a small pitch detector, which in the case of ILC can reduce the multiplicity (a pixel hit several times). This is crucial for the ILD where the readout of the detector is only made after several bunches. With this in mind, with a track fit, displaced secondary vertices can be evaluated (using an impact parameter technique to select the right track) and the full decay of particle analysis can be done, using all necessary jets. In addition, isolated tracks can be tagged in order to reduce fake events.The vertex detectors implemented in the LHC experiment are based on a pixel hybrid principle. The constraints on these experiments being due to the high particle rates. These induces a large ionizing dose in the detector material supplemented by a Non-Ionizing-Energy-Loss that damages the detector material and the electronic readout. Special techniques have been used to circumvent these effects with the use of hardened processes [4] and adequately doped Silicon pixel structures [5]. With the LHC having a high luminosity with a beam crossing time of 15-20 ns, using a triggered readout the constraint is a fast ROC (readout chip). The on pixel electronics has to be elaborate to get the information of all the pixels hits output when triggered. With the technologies available in the late nineties and the early 2000,s, this has excluded small pitch pixel detectors as even with tens' of microns pitch pixel detectors the number of channels (pixels) is of the order of tens of millions in the inner vertex detector.

- The constraints are different for the ILC where reconstructions that are more accurate are the objective. The advantages of much improved resolution vertex detectors will simply be a good secondary vertex reconstruction with an accuracy of 0.5 micrometers or in time at the speed of light of 1.6 fs. This cannot be matched by a timing procedure, which can only estimate the position of the interaction point in the beam-crossing zone. This zone will be reduced for the ILC compared with the LHC. Additionally short-lived particles can be tagged at this stage.
- The detectors close to the primary interaction point can detect charged particles with a low mass that can escape the tracker, this being the effect of the magnetic field on particles with a low mass [6] [7]. In this case charged. Tagging such particles can be established with a good vertex detector) [8]. They induce disappearing tracks. The energy of these long-lived particles cannot be determined easily as they escape calorimetry. The only possibility besides using Time Of Flight which is difficult is to add some extra layers to the vertex to match they trajectory.
- The operation of a vertex detector in a trigger-free mode means that many bunch crossing will be recorded (pile up) in the detector before being output and reset. This makes the use of very small pixels necessary to avoid multiple hits in a single pixel. The pitch has to be reduced to match these requirements, only a full monolithic pixel can be used for this purpose.
- The reconstruction of tracks neat the IP with relatively low pT with will easier with a pixel detector with an aspect ratio (height/width) large enough. Hence, a small pitch (< 1 micrometer) with a height up to of 10 micrometers (sensitive zone) opens up such possibility.

The solution proposed and how to develop it, the choice monolithic pixel.

A pixel design was proposed in [9] [10]. We have made the necessary simulations to assess the functionality of the proposed device. The next step is to find out what is the adequate process, which is required to obtain the functionality and reach some required specifications. Some work about the physics that can be investigated using this pixel detector is required too. We would like that researchers interested in such investigation join to form a collaboration. On our side the organization for the development of the pixel process comprises a three institutes all belonging to the Paris-Saclay University (CEA-IRFU, CEA-IRAMIS, CNRS-C2N), the latter focusing in nano-sciences having excellent technological equipment. We would welcome any member of an institution, academic or not for either contribution in the technologic or physics aspects of the project.

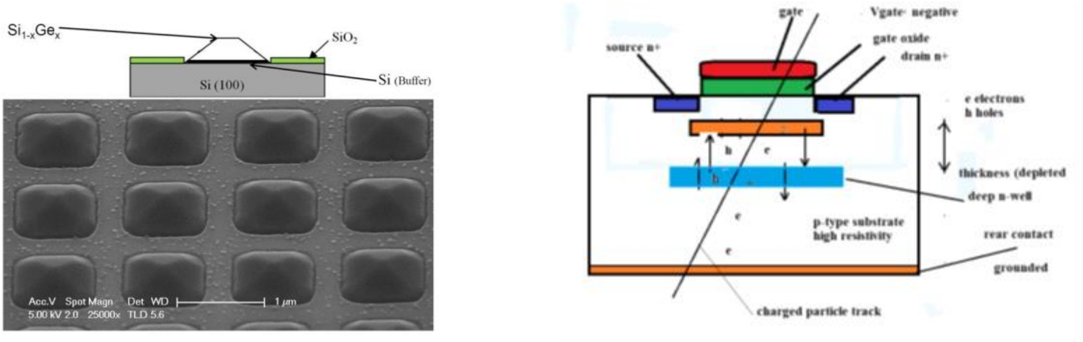

Fig. 1: Left, epitaxial layer of SiGe grown selectively on silicon. Right, structure of the single transistor device proposed. In orange between the deep n-well and the gate oxide, the SiGe layer p-doped (buried gate).

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