DEPFET detector R&D

Introduction

The DEPFET collaboration pursues the development of active pixel detectors based on a fully depleted high-resistivity silicon wafer with an integrated Field Effect Transistor for signal amplification. The operation principle was extensively proven on small-scale prototypes.

The collaboration is making rapid progress - fueled by the election of DEPFET for the Belle II detector - towards a full-blown detector system including solutions for services and supports. A full-scale, 75 micron thin Belle II ladder was successfully submitted to a test in a beam of charged at DESY in January 2014. In the near future we hope to characterize the performance of ILC-design prototypes with pixels of 20 x 20 micron squared.

Important experience is furthermore gained with the thermal and mechanical properties of ultra-thin ladders. Measurents on thin ladders under a realistic load, including pulsed powering according to the ILC beam structure, prove the excellent mechanical properties of the all-silicon ladder. A complete mock-up for the innermost disks is under construction.

DEPFET for the ILC

DEPFET active pixel sensors are one of most mature candidates for the ILC vertex detector and the innermost disks of the forward tracker. The performance of a DEPFET-based vertex detector for the ILC is evaluated in a recent publication:

The DEPFET collaboration, "DEPFET active pixel detectors for a future linear e+e- collider", IEEE Trans. Nucl. Sc. 60, 2, 2 (2013).

Currently, the construction of the Belle II vertex detector is the main focus of the collaboration. The requirements of the Belle II vertex detector are similar to those of the ILC, and more stringent in some aspects. The Belle II construction project therefore has considerable synergy with developments for a future linear collider. The LC-specific effort is focused on the development of small-pixel devices and the design of a forward vertex detector. We envisage that after the installation of the Belle II detector (2016) the balance between both projects is restored.

The concept of a DEPFET active pixel detector for vertex detection at collider experiments was initiated in the linear collider community (for TESLA). The election of DEPFET technology for the Belle II detector therefore represents an important spin-off of linear collider detector R&D. DEPFET detectors are furtermore used for X-ray imaging at the XFEL. Future space missions envisage the use of DEPFET sensors. Their use in electron microscopy is being studied.

The DEPFET Collaboration

The DEPFET collaboration consists of nearly 100 members from 13 institutes. For a complete list, see:
http://www.hll.mpg.de/twiki/bin/view/DEPFET/CollaborationList
The DEPFET collaboration has designated a contact for the LC community (Marcel Vos, IFIC Valencia).

The implication of the institutes in specific areas of detector R&D (following roughly the work packages defined by the collaboration) is as follows:

Thin self-supporting “all-silicon” sensors:
The sensors are produced in-house at the HalbLeiterLabor (semiconductor laboratory) of the Max Planck Gesellschaft (MPG) in Munich, Germany.
The mechanical properties of thin ladders in a realistic environment are studied in detail by DESY Hamburg (that houses the Belle II mock-up) and IFIC Valencia (that focuses on LC-specific studies).

Cooling:
The DEPFET cooling concept for Belle II relies on two-phase CO2 cooling for the end-of-ladder. The sensor is cooled moreover with a forced flow of cold gas. The CO2 cooling plant is developed by KEK, while the design for the cooling block/support structure is performed at MPG. KIT in Karlsruhe has led the thermal performance work package.
A novel cooling strategy for future applications based on mico-channels in the sensors is being evaluated in collaboration between MPG, U. Bonn and IFIC Valencia. Solutions for monitoring of environmental parameters are developed at IFCA in Santander.

Read-out and steering ASIC production:
The operation of a DEPFET detector requires ancillary electronics in the form of a read-out ASIC (the Drain Current Digitizer), a steering ASICs (SWITCHER) and on-detector ASICs for digital data processing (DHP). These ASICs are developed at U. Heidelberg, U. Bonn and U. Barcelona.

Data Acquisition & Trigger:
The development of off-detector electronics to process the data from the Belle II vertex II detector is led by U. Giessen.

Characterization of prototypes, laboratory and beam tests:
This work package has contributions from nearly all institutes involved in the DEPFET collaboration. Overall coordination is in the hands of MPG, while the beam tests are coordinated by U. Bonn and U. Goettingen.