Proposal for a Test Beam Run at CERN SPS in November 2010

Experiment: DEPFET Active Pixel Sensors

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Introduction

DEPFET Active Pixels Sensors incorporate amplification in the active high-resistivity Silicon bulk. This offers interesting possibilities for applications in X-ray imaging and as a detector of minimum ionizing charged particles. A highly segmented DEPFET matrix can provide excellent performance as a vertex detector in collider experiments. DEPFET is a candidate technology for a future linear e^+e^- collider at the energy frontier and has been selected as the baseline for the vertex detector in the upgrade of the Belle experiment (Belle-II) at Tsukuba, Japan. For these applications, challenging granularity and read-out speed requirements must be met while keeping within a tight material and power budget. The specifications for such a device could be summarized as follows:

- single hit resolution better than 5 µm (ILC) / 15 µm (Belle-II)
- material budget less than 0.1-0.2 % X_0 per detector layer
- radiation tolerance to a level of 10^{12} n/cm^2
- frame time better than 100µs (ILC) / 20 µs (Belle-II)
- low power consumption

Detector Description

The DEPFET pixel detector integrates a transistor in every pixel cell of the sensor substrate. This leads to very small input capacitance and allows the charge collection in a fully depleted bulk. Thus, the DEPFET cell is expected to provide excellent S/N performance. A matrix of DEPFET cells yields the required spatial granularity. Pixel sizes of 20 x 20 µm^2 have been achieved.

A number of prototype DEPFET matrices from the PXD5 generation, with an area of 64 x 128 and 64 x 256 pixels, have been assembled into read-out modules. A zoomed photograph of such a read-out board is shown in figure 1.

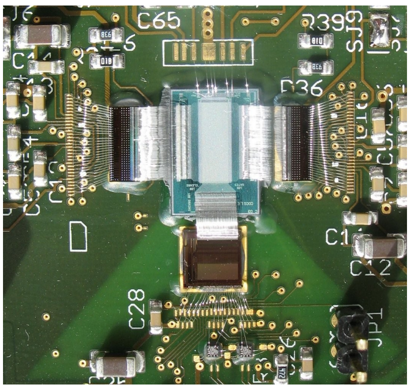

Illustration 1: Photograph of the S3B read-out system. The central device is the DEPFET matrix. It is surrounded by ancillary electronics, the CURO read-out chip and the Switchers that control the clear and read cycle.

Such DEPFET S3B modules have been submitted to exhaustive tests in several laboratories around the collaboration. The basic performance parameters are characterized in great detail using laser and source tests. A rich test beam program has been performed using this system. The S3B prototypes have been highly successful to prove the performance of the DEPFET principle. A brief overview is provided in the next section.

Recent test beam runs

In summer 2008 beam test measurements have been carried out at CERN SPS using pions of 120 GeV/c. During this test run DEPFET was the first fully integrated Detector Under Test (DUT) user of the EUDET telescope. The EUDET telescope provides up to six reference planes subdivided into two arms to allocate the DUT in between this two arms. Mechanical actuation helps to move the DEPFET DUT through the active area of the telescope. The reference plane sensors are based on Monolithic Active Pixel Sensors (MAPS) with 256 x 256 and a pitch of 30 µm (MimoTel)[1] (Fig.3).

A full integration of DEPFET DAQ during the CERN test beam season has been achieved. The event synchronization was ensured by the trigger-busy handshake of the EUDET TLU including the transmission of event numbers for each trigger. DEPFET and EUDET telescope Run Controls were synchronized with each other via TCP/IP and all controls such as configuration, start, and stop were done from the main EUDET Run Control PC. DEPFET data was sent to the EUDET PC via TCP/IP where they are merged with EUDET data and then written as one data stream into a file[2].

In summer 2009 beam test measurements have been carried out at CERN SPS using pions of 120 GeV/c. Again, the DEPFET collaboration used the MIMOTEL telescope offered by the EUDET project, as well as a telescope based on DEPFET devices.

These tests have firmly established the performance of the PXD5 prototypes. The signal to noise ratio of a typical DEPFET pixel detector with standard thickness (450 µm) is beyond 200. With a 20 x 20 μm^2 pixel size this leads to a spatial resolution of approximately 1 µm [3]. Several publications of test beam results are being prepared. They also form an important part of the Belle-II Technical Design Report [4]

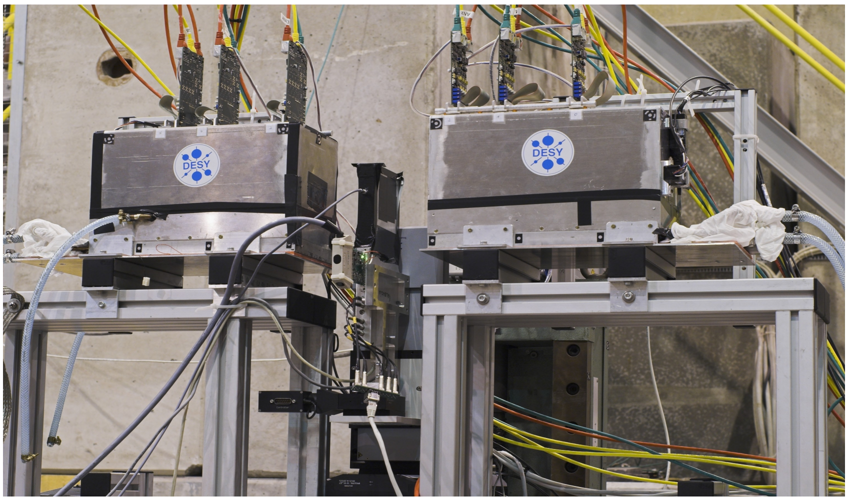

Fig.3: CERN SPS test beam setup.

Software

For the online monitoring of the data taking, the EUDET Data Quality Monitor (DQM), a tool that provides an online quality assessment of the data currently taken, was modified in order to process data from the DEPFET DUT[[5]].

EUTelescope software has been used to analyse DEPFET DUT data by several groups (Bonn, Göttingen, Valencia). The native DEPFET data raw format has been converted to the LCIO (Linear Collider Input/Output) format. The EUTelescope analysis has been extended to facilitate DEPFET specific data reduction steps (e.g. row wise common mode corrections).

New devices

The next generation of DEPFET devices, the PXD6 production, is expected to be delivered in autumn 2010. This generation has large-scale devices (5 x 1 cm^2) that are thinned to 50 µm (the nominal detector thickness for the Belle-II PXD is 75 µm). Thus, they represent two important steps in the DEPFET evolution.
In the development of the Belle-II vertex detector, several elements of the DEPFET read-out chain have been redesigned. Importantly, the CURO read-out chip is being phased out in favor of the DCD. Also the Switcher design has evolved.

Proposed test beam run with the EUDET telescope in November 2010

We propose a 1 week of test beam campaign with high energy pions at CERN SPS with the EUDET telescope as a reference system for high precision spatial resolution measurements. The goals will be:

- Read-out of a PXD6 DEPFET matrix. This will represent an important milestone, as it is the first test beam of thin DEPFET devices. The spatial resolution of this Device Under Test must be measured to good precision using the prediction of the EUDET telescope.
- Read-out of a DEPFET matrix using the DCD system. Full electrical characterization of the new read-out chain. The telescope must provide reference position mainly to be able to estimate the efficiency.
- Read-out of S3B modules built with DEPFET matrices with short gate length. These devices present a significantly higher quantum gain.

The feasibility of this aggressive program with several new components depends strongly on the timely availability of the PXD6 production. As there is relatively little experience with the new components, some time must be foreseen for basic cross-checks.

People and cost involved for the test beam campaign

People who will be present at CERN during the test beam are:

- Marcel Vos, tenure track at IFIC Valencia
- Sergei Furletov, postdoc at U. Bonn
- Julia Furletova, postdoc at U. Bonn

We would like to request funds for travel and 1 weeks stay for the above listed persons and for the material transport between Bonn and Geneva. The beam period begins on November 15th and ends on the November 21st. The preparations at CERN to set up the system will start several days ahead of the starting date, on November 10th.

[1] L.Reuen ``The DEPFET sensor as the first device under test using the EUDET JRA1 Telescope '', EUDET-Memo 2007-40
[2] J.Furletova, L.Reuen “JRA1 - The DEPFET sensor as the first fully integrated DUT in the EUDET pixel telescope: The PS test beam 2008”,Eudet-Memo-2008-33
[3] R. Richter, L. Andricek et. al. „Design and technology of DEPFET pixel sensors for linear collider applications“, Nucl. Instr. Meth. A511 (2003), 250-256
[4] Belle-II collaboration, Belle-II Technical Design Report
[5] J.Furletova, L.Reuen “JRA1 - The DEPFET sensor as the first fully integrated DUT in the EUDET pixel telescope: The SPS test beam 2008”,Eudet-Memo-2008-34