Application for Transnational Access to the DESY Testbeam and usage of the EUDET telescope

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The Cherwell program is a focused R&D program aimed at the development of pixel sensors for future particle physics vertexing and tracking with in-pixel data processing with emphasis on Linear Colliders. The goal is to implement the full data processing for an array of pixels onto the monolithic active pixel itself. Here one can think of: hit finding, digitization, clustering and hit position reconstruction. The first step towards this is the study of the FORTIS. The FORTIS is the first 4T monolithic active pixel sensor developed for particle physics.
We are planning a one week beam test using the EUDET telescope in March 2010 to test our basic devices and ask for EUDET support. We request travel support for 5 people for 9 days to come to DESY and take the data.

1 Scientific Background

As particle physics colliders reach higher energies and luminosities, finely segmented pixel detectors will be needed for vertexing and tracking.

1.1 Vertexing

The function of a vertex detector is to provide precision spatial measurements of tracks close to the primary interaction vertex without introducing too much material. The innermost layer is placed as close as possible to the interaction vertex (typically $\sim$1 cm). To distinguish the tracks from displaced vertices the resolution needs to be a few microns, implying a pixel size of 20 μm or smaller and analogue readout. Some form of time-stamping is required to get the occupancy per time-slice below $\sim$1% as required for pattern recognition. The material per measurement layer is a crucial parameter if multiple scattering is not to spoil the measurement of track angles. Thin layers of silicon plus supports can be realised with a material budget of

$\sim$0.1% radiation lengths (X_0) provided the required power can be restricted to sufficiently low levels so that liquid cooling is not required.
Monolithic silicon technology is one of the few proven techniques for realising thin, low power consumption sensors with the small pixel sizes required.

1.2 Tracking

The function of a tracking detector is to provide sufficient granularity and measurement precision to be able to find and reconstruct all charged particles, again without introducing too much material and to provide a precise measurement of the curvature. Achieving the required momentum resolution requires an rϕ precision of $\sim$15 μm. Pattern recognition for track reconstruction demands the detector occupancy to be less than 1%.

1.3 Cherwell sensor

The first Cherwell sensor is currently being designed. It will be realised using the 4T imaging technology which has recently become available to us and will provide better noise performance than previous 3T architectures. It provides efficient charge collection and storage with low power. The readout will be realised as a conventional rolling shutter, with the columns subdivided to give the required time slicing. It is an important question for our R&D programme to determine whether this approach using a pinned photodiode will provide full detection efficiency for minimum-ionising particles (MIPs) with compact clusters and adequate precision. This could be more challenging with the larger pixels ($\sim$25-50 μm) needed for tracking. The readout and memory buffers will be distributed over the pixel area with no dead space using the deep p-well INMAPS technology. These sensors will be known as the Cherwell family. A schematic picture of the Cherwell concept can be found in figure 1. The time-stamp resolution will be adjustable from the full 1 ms in the barrel down to 0.1 ms in the very forward region. Power dissipation even in the forward region is expected to be compatible with gas cooling.

2 FORTIS

At the moment we have the first 4T sensor, the FORTIS, in hand. This is a technical study sensor for the 4T architecture performance. The FORTIS' sensor area of 512×448 pixels was divided into twelve different sections. These differ in pixel size, diode size, in-pixel active area shape and in-pixel source follower transistor size.

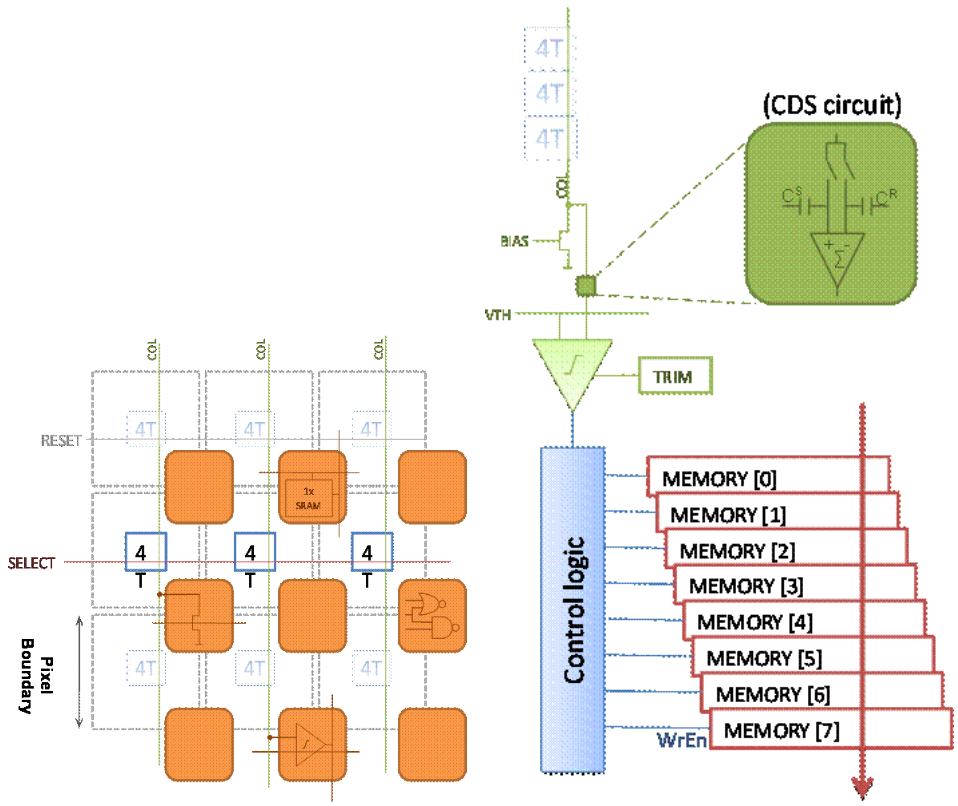

Figure 1: *Schematic drawing of the Cherwell concept.*

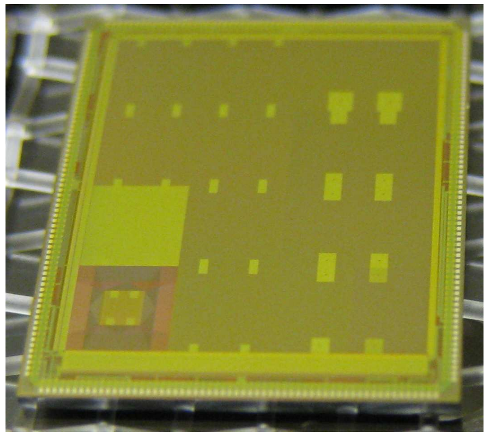

Figure 2: *Photograph of the FORTIS.*

By varying the diode area, the effects of a larger diode could be observed. Larger diodes have a larger diode capacitance, which means that more charge can be collected. The size of the diode also affects the cross talk between pixels in an array. The larger the diode, the less the amount of cross talk as the diode area to pixel area ratio is greater. The experimental shape of the active area which contains the four transistors present in the 4T pixel should reduce the capacitance and hence increase the conversion gain of the pixel. The in-pixel transistor size determines the noise. Therefore multiple transistors were implemented.
The FORTIS was produced in three variations. Some have a high resistivity epitaxial layer. This should result in faster and more complete charge collection. Another batch has deep p-well islands, which might change the charge collection properties of the sensor. This needs to be studied in detail as the readout electronics for Cherwell will be implemented in these deep p-well islands. A picture of the FORTIS can be found in figure 2.

The FORTIS has been tested in a particle beam at CERN. Unfortunately, a bug in the firmware ment that is impossible to match the telescope information with the FORTIS information. This bug has been fixed now. A successful beam test is an essential component of these tests.

3 Beam test request

FORTIS has been granted 1 week of beam time at the DESY beam test facility starting Thursday the 18th of March 2010. We request usage of the EUDET telescope. The telescope is needed to provide precision tracks. We also request travel support for 5 people for 9 days to come to DESY and take the data.

The total estimated cost for this beam test are 3350 Euro. This is calculated based on staying in the DESY hostel and a per diem of 25 Euros.