SPiDeR: Request for SPS beam time in 2010

The SPiDeR Collaboration

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1 Introduction

The SPiDeR (Silicon Pixel Detector R&D) collaboration [1] consists of five UK institutes[1] studying monolithic CMOS pixel sensors for future colliders, in particular high energy lepton colliders (ILC and CLIC).

The collaboration is studying both fundamental technologies for future detector sensors and also novel applications of CMOS sensors. These could be applied both to tracking and calorimetry. In particular, the collaboration is currently doing preliminary tests towards a digital electromagnetic calorimeter (DECAL) and is exploring pixels with four-transistor ("4T") structures for particle physics. The DECAL would be a new approach to EM calorimetry where the initial electron or photon energy is estimated by counting particles rather than from the deposited energy. The collaboration aims to provide a proof-of-principle of the DECAL technique over the next three years. This DECAL work is being undertaken as part of the CALICE collaboration [2]. The 4T structure is a new approach to monolithic pixels coming from the imaging area, which has a very low-noise performance. A prototype sensor has been produced and shows very promising performance but requires further testing with beam. The aim is to explore this low-noise design further in upcoming sensor productions.

Further information about the SPiDeR collaboration and its aims can be found in a recent DESY PRC submission [3]. The DECAL technique and status is summarised in the CALICE submission to the same meeting [4].

2 The SPiDeR sensors

There are two sensors which the collaboration would like to test in beam in 2010, namely the "Fortis" and "TPAC" sensors. Both sensors are around $1 \times 1\,\mathrm{cm}^2$ in size.

The tracking-like sensor, Fortis [5] , is based on a 4T pixel circuit design, which is expected to give very low noise and high efficiency for MIPs. It was designed as a test sensor, implementing several possible design technologies, and so has 14 different pixel designs within each sensor. The pixel sizes vary from 15 to 45 μm. In addition, the sensors were fabricated both with and without deep p-well implants [6] and using both standard and high-resistivity substrates. This means there are multiple variants which should be tested to understand the sensor fully and this will require significant beam time.

The TPAC (Tera-Pixel Active Calorimeter) sensor is a study sensor for the DECAL application. This has a uniform array of $50 \times 50\,\mu\mathrm{m}^2$ pixels with a readout architecture compatible with an ILC beam timing structure. While this $1 \times 1\,\mathrm{cm}^2$ sensor is too small to contain a full EM shower, it can be used to study the shower core densities which dominate the EM resolution and set the pixel size requirement for a realistic DECAL. Such measurements of high energy EM shower densities at the sub-millimetre level have not previously been performed. These measurements would help to constrain significantly the sensor design for the large-scale DECAL sensor which SPiDeR intends to design and fabricate within the next two years. First measurements of the shower densities will be done with a low energy electron beam at DESY in March 2010.

[1] University of Birmingham, Bristol University, Imperial College London, University of Oxford, and Rutherford Appleton Laboratory

3 SPS request

The collaboration estimates that two weeks in the SPS test beam would allow a thorough test of all variants of the Fortis sensor and give sufficient statistics for the TPAC shower density studies. Both detectors require an external tracking telescope and so will need to have the EUDET telescope available. The DAQ system has been tested and found to run at around 100 Hz. This implies a total data rate of up to 1000 events per spill and the estimates below are based on that figure.

One Fortis sensor at a time will be mounted between the planes of the EUDET telescope. These tests need high energy (120 GeV) pions to minimise scattering and so give the most accurate interpolation from the telescope to the sensor. Each sensor variant will be exposed for around one day to get sufficient statistics for all the pixel designs within the sensor, so these measurements will take much of the first week. The pions are also useful for MIP calibration of the TPAC sensors, which will be mounted downstream with no converter material, so acting as a second tracking system.

Following the Fortis studies, then the TPAC response to electron showers will be measured. Varying amounts of tungsten converter material will be added in front of the sensors to get measurements of the shower density as a function of material depth. The previous DESY beam test will give information on showers in the 1 to 6 GeV range, so the CERN beam test will be used to extend this range dramatically. Ideally, 6 GeV data would also be taken at CERN to provide a cross-check although 10 or even 20 GeV would be sufficient if reasonable electron rates at lower energies are not feasible. The beam energy would be scanned from this lowest point up to around 100 GeV. The EUDET telescope is needed to provide an accurate shower centre; this is essential as the core density falls rapidly on the scale of 1 mm so that the centre needs to be known more accurately than this. With an estimate of around 1M events being needed, for each combination of converter thickness and energy point, to accurately measure the shower core, then at least eight days will be needed to acquire the total dataset.

References

[1] `https://www.spider.ac.uk`.

[2] `https://twiki.cern.ch/twiki/bin/view/CALICE/WebHome`.

[3] The SPiDeR Collaboration, "DESY PRC Report", Oct 2009, `http://www.hep.ph.imperial.ac.uk/calice/official/091105prc/spider.pdf`

[4] The CALICE Collaboration, "Report to the DESY PRC", Oct 2009, `https://twiki.cern.ch/twiki/pub/CALICE/CaliceCollaboration/CALICE_PRC09.pdf`.

[5] R. Coath *et al.*, "Advanced Pixel Architectures for Scientific Image Sensors", presented at TWEPP '09, Paris, France, September 2009 and to be published in the proceedings thereof.

[6] J. A. Ballin *et al.*, "Monolithic Active Pixel Sensors (MAPS) in a quadruple well technology for nearly 100% fill factor and full CMOS pixels,", Sensors **8** (2008) 5336.