CALICE-UK Report to the STFC Oversight Committee

August 27, 2008

1 Introduction

A modified budget to support CALICE-UK for the rest of the current financial year has now been agreed with STFC. This has resulted in severe cuts with respect to our previously approved programme, although we have been able to maintain some effort in all workpackages (WP), albeit minimal in some cases. As would be expected, there has been a significant effect on the morale of the people involved, particularly those on non-permanent contracts. This has meant several PDRAs have decided to leave the project already which has had some effect on the WP timelines and scope.

Despite this, we believe we have a meaningful and achievable programme in the period up to the end of the grant in March 2009. The current status and plan to completion for each WP are outlined in each of the relevant Sections 3 to 7. The Gantt charts, milestones, financial and risk tables are supplied separately and some related points are discussed in Section 8.

2 General status of CALICE

The CALICE collaboration continues a major and successful programme of R&D into calorimetry for the ILC, directed towards the design of an ILC calorimeter optimised for both performance and cost. For the past few years, the main effort has been in testing "physics" prototypes, small sections of calorimeters used to compare data with simulation. Recently, the emphasis has started to move to the "technical" prototypes, which are realistic "ILC-like" modules used to test ideas for mechanical, electrical, etc., integration. Within CALICE, the latter work is supported significantly through the EUDET programme.

The collaboration has tested a silicon-tungsten (Si-W) electromagnetic calorimeter (ECAL) in beams at DESY in 2006, at CERN in both 2006 and 2007 and finally at FNAL in 2008. These tests covered a range of energies from 1 to 50 GeV and are now complete. For the next beam test run in September 2008 in FNAL, an alternative design, a scintillator-tungsten (Sc-W) ECAL, will be used. A quarter of this ECAL was run at DESY in 2006. The Sc-W physics prototype is now complete and the full ECAL will be exposed in September, allowing comparison of the two designs in a similar environment.

For most of the data taken so far, the scintillator-steel analogue hadron calorimeter (AHCAL) and tail catcher and muon tagger (TCMT) were also present. The AHCAL will take more data in the September run and then its data taking period will also be complete. It will replaced in future runs in 2009 by the RPC-steel digital hadron calorimeter (DHCAL). This will use the same mechanical structure as the AHCAL, again allowing direct a comparison of the two designs.

By mid 2009, the technical prototypes, similar to the calorimeter modules currently being considered in ILD and SiD, will be constructed. Testing of these will take place over the next two to three years and will mean that the CALICE collaboration will be well placed by 2012 to respond to whatever physics is revealed by the LHC.

The CALICE collaboration has continued to present a high profile at conferences. For example, CALICE members gave 12 talks at CALOR'08 in Pavia, and 18 talks at the ECFA ILC workshop in Warsaw.[1] Unfortunately, only six of these talks were given by UK members; unusually low because of limited travel funds and staff losses. We have 10 talks at the IEEE-NSS2008 symposium in Dresden. A CALICE-UK speaker gave the single CALICE summary talk at ICHEP'08.

3 WP1: Beam Test Programme

In the past two years, 2006 and 2007, the UK groups contributed strongly to the test beam running in CERN, providing a run coordinator, and were responsible for the DAQ system, monitoring and many aspects of data analysis. In addition one quarter of the shifts were run by CALICE-UK people.

In 2008 the CALICE test beam activity moved to FNAL, with two successful runs in May and July, involving the complete Si-W ECAL, the AHCAL and the TCMT. Because of the STFC funding cuts, and the recommendation of the OsC, UK involvement has been minimal, which has placed a heavy burden on our collaborators, especially those in the US, France and Germany.

However, as a result of the recent STFC consultation panel (PPCP), some funding for the continuation of WP1 has been secured. Unfortunately this was too late for us to participate in the May and July running, though we will support the September run, in which the Sc-W ECAL constructed by our Japanese and Korean colleagues will be tested. It is also unfortunate that most of the UK PDRAs have now left CALICE as a result of the funding crisis, with a consequent loss of expertise. Nevertheless, the restoration of our involvement in the test beam programme is welcome.

UK academics are still serving as the DAQ coordinator, and as the two Analysis and Physics coordinators for CALICE. However, because of losses of the PDRAs, our actual contribution to analysis work has been severely curtailed, and the bulk of our contribution is through our coordination rôles, trying to expedite analysis work, and organising conference talks, notes and papers.

3.1 Task 1.1: Support for beam tests

The DAQ was installed at the FNAL beam line and supported remotely from the UK throughout both the FNAL runs in May and July this year. Each period lasted for around four weeks. Since the calorimeters were virtually the same as used at CERN in 2007 there was little work required on the DAQ for this. However, some changes were needed to integrate to the FNAL beam line equipment and database readout. There were sufficient readout boards to maintain zero dead channels due to electronics throughout the two run periods. The FNAL spill timing structure has a relatively low duty cycle of 4 seconds every minute. This meant the DAQ buffer limit of 2000 events per spill was the limiting factor, giving an averaged rate of around 35 Hz. This was maintained effectively throughout both run periods, with over 85% uptime for the CALICE equipment.

Further changes to the DAQ to incorporate the Sc-W ECAL in September will be required. However, this should not prove too onerous thanks to experience gained with the quarter detector during its run at DESY in 2006, where the identical DAQ system was used.

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[1] https://twiki.cern.ch/twiki/bin/view/CALICE/CaliceConferenceTalks

More substantial work will be required when the DHCAL prototype replaces the AHCAL in 2009. As the support work is academic effort, this can be continued at a low level even after the end of the grant period.

3.2 Task 1.2: DESY test beam

The analysis of the electron test beam from DESY, recorded in May 2006, has largely paused now. Preliminary results on these data, which covered the energy range 1-6 GeV, have been documented and presented. However, we now have data in the same energy range from FNAL, with a now fully instrumented detector and better beam quality. The FNAL electron data also extend up to 20 GeV, permitting better overlap with the CERN data. It seems more likely therefore that we will use the FNAL data for publication. The DESY run was nevertheless immensely valuable, since it allowed the ECAL to be commissioned, and therefore to work with relatively little difficulty when it was taken to CERN.

3.3 Task 1.3: CERN test beam

Analysis of electron beam data in the Si-W ECAL, at energies from 6 to 50 GeV, has continued in the UK and France. A first publication, based largely on the 2006 data, has been published in JINST[2]. This paper, coordinated by a CALICE-UK physicist, focusses mainly on the technical performance and commissioning of the calorimeter. For example, in figure 1 shows the noise and gain for the 6480 cells of the prototype, indicating the uniformity of the detector. The studies have allowed a number of problematic issues to be identified which will need to be addressed in future designs:

- Capacitive coupling between the guard rings and the peripheral pads on the wafers, observed as a square structure of hits when a high energy shower core passes through a guard ring. This may be alleviated by segmentation of the guard ring.
- Sudden pedestal shifts affecting a whole PCB, believed to be caused by non-isolation of the PCB supply lines.
- Shifts of the pedestals of a wafer in which a high energy was deposited, suspected of being caused by an intermittent bad contact in the grounding.

The UK has also been significantly involved in the analysis of electron shower data from CERN. A recent CALICE Analysis Note[3] was prepared to provide approved results for presentation at conferences. After a few refinements to the event selection, and some added comparisons with Monte Carlo samples, this work will be ready to be submitted for publication. A couple of typical results are shown in figure 2, which indicates the linearity of the calorimeter response (better than 1%) and the energy resolution.

The analysis of the hadron data obviously relies in large part on the AHCAL and TCMT as well as the ECAL. Work here is concentrating on the 2007 CERN data, for which the complete AHCAL was first installed. The ultimate focus of this work is to discriminate between different hadronic shower models in GEANT4. Before this can be seriously attempted, however, it is essential that an absolutely secure understanding of the data be achieved, in order to avoid drawing premature false conclusions. The task of calibrating the hadron calorimeters has proved significantly more complex than the Si-W ECAL, and is still heavily occupying the DESY group. Part of the problem is understanding saturation effects associated with the SiPM photodetectors.

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[2] "Design and Electronics Commissioning of the Physics Prototype of a Si-W Electromagnetic Calorimeter for the International Linear Collider," J. Repond *et al.*, JINST 3 (2008) P08001, arxiv:0805.4833

[3] https://twiki.cern.ch/twiki/bin/edit/CALICE/SpeakersBureau/CAN-008.pdf

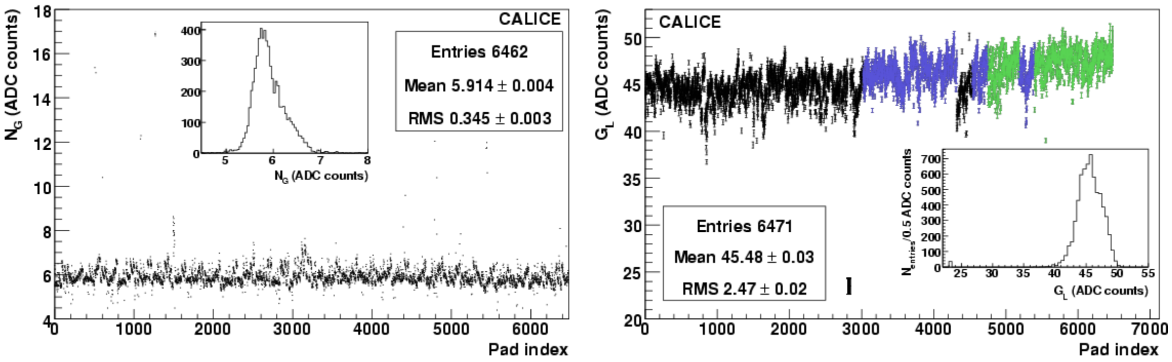

Figure 1: *Left: noise (i.e. r.m.s. of the pedestal) as a function of pad index; right: gain (i.e. ADC counts per MIP) determined using muon data as a function of pad index; the colours denoting different batches of silicon wafers.*

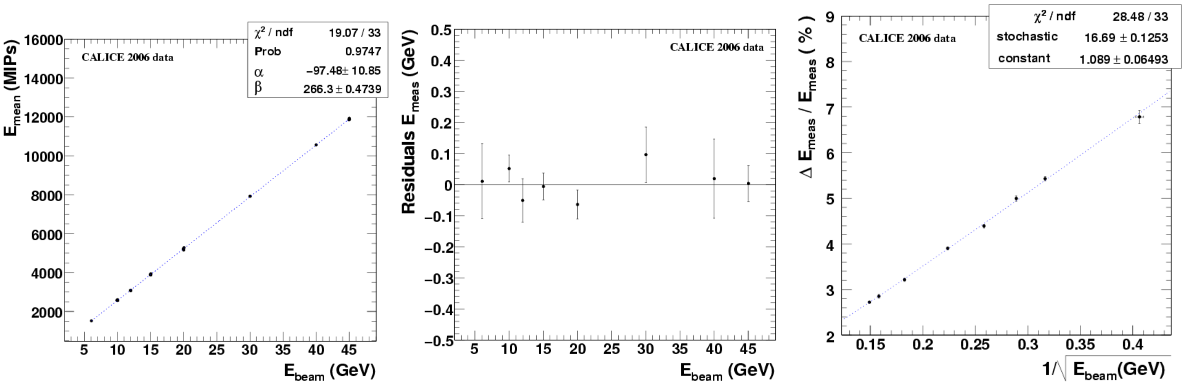

Figure 2: *Left: Energy response of the ECAL (in MIPS) as a function of electron beam energy; centre: residual deviations from linearity; right: energy resolution as a function of energy.*

Despite this, three analysis notes exploring the AHCAL data were produced[4] during May in order to approve new results for presentation at the summer 2008 conferences. These covered the three main areas of activity — muon response, electron response (very sensitive to saturation effects) and hadron response, including first comparisons with Monte Carlo simulation.

Some studies on hadron showers using the ECAL alone have been carried out in the UK by a first year graduate student. The ECAL itself is pretty well understood by now, and this study has shown that, even though hadronic showers are seldom contained in the ECAL, the data do have significant discriminating power, and will therefore complement the HCAL data. Members of CALICE-UK intend to pursue this further.

3.4 Task 1.4: FNAL test beam

In 2008, the centre of CALICE test beam activity moved to FNAL, with a particular focus on lower energy beams. The response of the calorimeters to low energy hadrons is of particular importance for the ILC (the average hadron energy is typically ~10 GeV, while higher energy showers obviously include many low energy hadrons). Higher energy data are also being recorded, to compare with CERN data, and to evaluate the long-term stability of the detectors.

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[4] https://twiki.cern.ch/twiki/bin/edit/CALICE/SpeakersBureau/CAN-009, CAN-010, CAN-011.

The Si-W ECAL, AHCAL and TCMT were all moved to FNAL in spring 2008, and successfully installed and commissioned. Two successful runs took place in May and July. The UK's involvement so far has been modest. We have continued to support the DAQ remotely. In addition the online monitoring code has been maintained until now, though this will have to be discontinued now owing to loss of staff.

In September 2008, the Si-W ECAL will be replaced by the Sc-W ECAL constructed by our Asian collaborators. This will be tested along with the AHCAL and TCMT, and will allow an interesting alternative technology to be evaluated. The UK will now be able to have some limited involvement in this run, though it seems unlikely that we will be able to participate significantly in the data analysis. Subsequently, the plan is to test DHCAL prototypes based on replacing the scintillator tiles of the AHCAL by RPCs (and possibly GEMs). These are important and very interesting tests, but given the timescale of the approved CALICE-UK programme, any UK participation will probably be limited to supporting the DAQ.

3.5 Plan to completion

The main aim will now be to concentrate on analysis of the existing data to get it to publication. There will be a small amount of effort for support of the future FNAL runs.

The available remaining effort is academic, some fractions of PDRAs and a graduate student. Of the PDRAs, two are funded part-time from the remaining CALICE-UK budget while one is on EUDET funding.

3.6 Milestones

The recent and future milestones are listed below.

3.6.1 Milestone ID27: "Present interim results at LCWS'07"

Achieved.

3.6.2 Milestone ID14: "Complete analysis of DESY data"

Achieved, in the sense that the analysis to date has been documented, presented at workshops. For publication they will probably be superseded by the FNAL data.

3.6.3 Milestone ID20: "Successful end of 2007 CERN test beam run"

Completed 22/08/07.

3.6.4 Milestone ID24: "Submit paper on electron results"

First paper accepted for publication. Second paper exists as an analysis note (i.e. the analysis is approved), but the paper still needs a little work before it is put through internal editorial and approval procedures. There will probably be further papers.

3.6.5 Milestone ID33: "Successful completion of FNAL test beam run"

The part of the program involving the Si-W ECAL and the AHCAL has gone well and is now complete for the former. The data are clearly usable. The Sc-W ECAL is still on schedule for operation in September. The timescale of the US-built DHCAL prototypes is still uncertain, and regrettably it seems unlikely that the UK will be able to participate.

3.6.6 Milestone ID37: "Submit paper on hadron results"

This will almost certainly turn into a series of papers. Papers have already appeared in conference proceedings. The UK is not the leader in these analyses (apart from the ECAL aspects) so the timescale for turning these into published papers is somewhat outside our control. The CALICE data will be a valuable resource, which our collaborators (and the UK groups, if we are allowed to) will surely continue to exploit well after 2009.

4 WP2: DAQ

4.1 Task 2.1: Readout of prototype VFE ASICs

Due to the revised programme, this task, which corresponds to Gantt chart items ID3 and ID4, has been terminated.

4.2 Task 2.2: Study of data paths over 1.5 m slab and manufacture of DIF

The full test-slab is now complete with various measurements made and recommendations given to the detector builders. This completes ID15 and ID16. Some examples of results found are: the jitter is generally low across the whole 1.68 m slab; the clock has been optimised for the particular configuration; and the cross-talk was a potential problem, but the layout of the electrical traces was optimised. The test-slab can now be used as a mock detector for validating our various hardware and links all the way down the DAQ chain.

Work has progressed on building the Detector Interface (DIF) card which serves as the detector-specific piece of electronics and links the detector and DAQ systems. A prototype of the ECAL DIF is shown in Fig. 3. The implementation of some basic firmware is a little behind schedule, but should not affect the overall plan as work has already started on the hardware for the intermediate board. The DIF board contains links to the Link Data Aggregator (LDA) to other DIFs as well as having a USB interface for standalone tests.

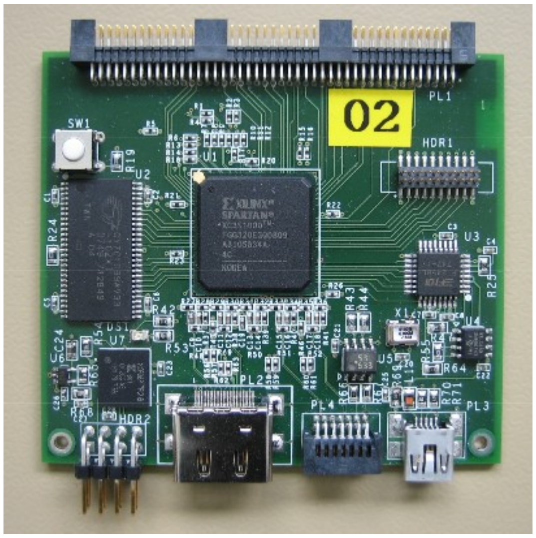

Figure 3: Prototype DIF board.

4.3 Task 2.3: Connection from on- to the off-detector receiver

Due to the revised programme, the work on the 10 Gbit switch, ID33 to ID39, has been terminated.

Work on the LDA is progressing well with ID50 and ID51 complete and ID52 on schedule. A prototype of the hardware is in-house in Manchester, however it has some problems with links not physically routed. The company is reacting to this quickly and should produce corrected boards on the timescale of a couple of weeks. This is not holding up progress on the firmware and interfaces much of which can be done without the physical board, although the faulty board has anyway been re-hashed by the Manchester group to work for our needs. Recently, the LDA links with the DIF and clock and control have been defined. Further work on integration into the full system continues.

Work on the optical switch is behind schedule (ID46), however this is not time critical and is not needed for the EUDET technological prototypes. It can therefore be done when other issues are resolved and people freed up.

4.4 Task 2.4: Transport of configuration, clock and control data

The prototype configuration, clock and control system has been designed and is a custom-made board, fulfilling ID62 and ID63 (as a commercial fan-out is not being used). The board is not yet complete as expected in ID64 as ID65 to ID67 are being performed before build. We expect the board to be complete over the summer for integration tests and a large system built on schedule for the milestone ID69. The major issue at the moment is the size of the board with many connections needed - this is currently being rationalised. Due to the revised programme, ID70 to ID72 have been terminated.

4.5 Task 2.5: Prototype off-detector receiver

This task is progressing well, with ID81 to ID84 complete and ID85 on schedule. Further work has been carried out on testing the speed of data transfer over the PCI express bus and in particular writing the data to disk. Several methods of writing were tried with a peak value reached of 90% of the data writing to memory only (the effective maximum) using the "scatter-gather" technique. The interface to the LDA has been written and needs to be tested with a "real" LDA as part of the system-integration tests. The off-detector receiver (ODR) can also be used with the DAQ software (see next section). Finally, the test software is now mature enough to be used in tests of the optical switch (Task 2.3).

4.6 Task: DAQ software

The overall structure of the DAQ software using the DOOCS package has been defined and the basic interfaces also defined. The interfacing to the hardware is progressing (ID90) with, as mentioned in the previous section, the link to the ODR already made. The software was able to measure the rate of data being passed through the ODR. The interfaces for the LDA have also been written although more testing is needed with final verification once the LDA is physically available.

4.7 Plan for completion

The work has focussed on providing the DAQ system for the EUDET technological prototypes which are part of the EU-funded programme running until December 2009. By the end of the current CALICE grant, in March 2009, we hope to have all of the components in place and DAQ system working. This will then be available for use by the respective detectors. This relies strongly on our Rolling Grant technical staff. Through use of EUDET funds, V. Bartsch (UCL) will continue until December 2009 and much will rely on her once the CALICE grant is finished. Some small extra funds will be sought for post-March 2009 which will hopefully allow us to complete our major investment in building this DAQ system.

4.8 Milestones

The recent and future milestones are listed below.

4.8.1 Milestone ID16: "Test panel 1 complete"

This milestone was completed in April 2008, delayed due to work also ongoing on the DIF.

4.8.2 Milestone ID20: "DIF completed"

This milestone will be completed in August 2008, delayed due work not yet complete on the firmware.

4.8.3 Milestone ID38: "Report on 10 Gb performance"

This milestone has been terminated.

4.8.4 Milestone ID45: "Demonstrate optically switched network"

This milestone was completed in January 2008, on schedule.

4.8.5 Milestone ID51: "LDA-DIF link operational at electrical level"

This milestone was completed in March 2008, on schedule.

4.8.6 Milestone ID64: "Demonstrate trigger and C&C fanout"

This milestone will be completed in August/September 2008, behind schedule but incorporating other features which will put the task back on track.

4.8.7 Milestone ID83: "Initial system complete"

This milestone was completed in January 2008, on schedule.

5 WP3: MAPS Development

The MAPS project has continued to make good progress since the last OsC meeting. Testing of the first round sensor has continued and significant progress on understanding its properties has been made. The second round sensor has been submitted for fabrication and is expected back around the time of the OsC meeting.

5.1 Sensor tests

Significant progress has been made in debugging and operating the first sensor. One major discovery was that a power mesh shared by the pixel monostable and comparator could droop when a large number (several hundred) of pixels fired simultaneously, which in turn caused the comparators of other pixels to fire also. This should not be an issue in normal operation but has been a significant complication in understanding data when operating at thresholds close to pedestal. Figure 4 shows the result of a typical threshold scan performed with only a single pixel enabled and for the same pixel but with all pixels enabled.

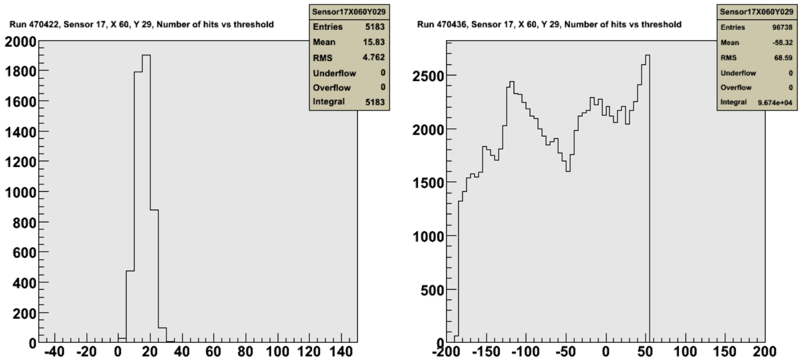

Figure 4: Threshold scan around pedestal for a pixel with (left) only the pixel enabled and (right) all pixels enabled. Note difference of the x axis scales.

It is clear the spread from crosstalk is unrelated to the pixel pedestal distribution itself but has a shape determined by the sum of the pedestals of the other pixels. This resulted in threshold scans giving an incorrect estimate of the pedestals, resulting in incorrect trim settings and hence a much larger apparent noise rate than expected.

By enabling single columns of pixels at a time, then the crosstalk does not occur and the pixel pedestals and hence trims can be determined accurately. This has allowed the sensors to be operated with a much more uniform and low noise response.

A second significant step forward was to commission a fully automated laser/stage system. The laser operates at 1064 nm, for which silicon in transparent. The laser is used to illuminate the substrate side of the sensor and is focussed on the epitaxial layer on the other side, with a spot size of less than 2 μm.

This has allowed a lot of critical measurements to be completed. In particular, the laser has been used on the bulk pixels to demonstrate the effect of the deep p-well implant developed to improve signal charge collection. Figure 5 shows measurements of the response to the laser at various positions in the pixel from sensors with and without the deep p-well implant.

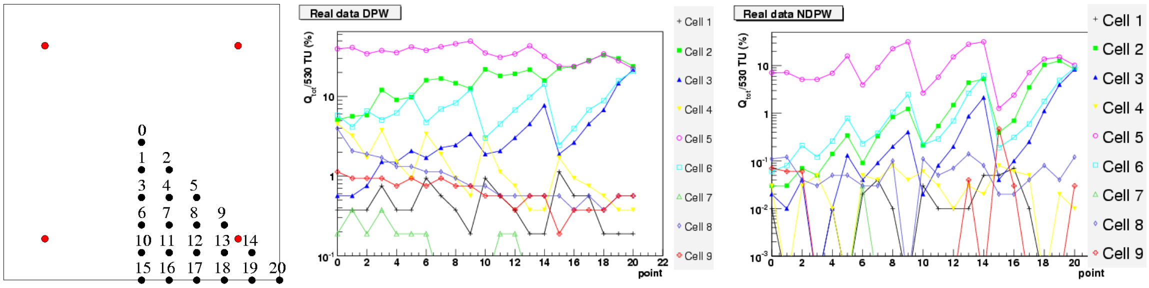

Figure 5: (Left) Definition of position numbering, with the black points being the laser positions and the red points the sense diode locations. Response of sensor to the laser as a function of the position for sensors (centre) with and (right) without the deep p-well implant. Cell 5 is the central pixel being hit by the laser and the others are the surrounding eight pixels.

The deep p-well improves the signal by a factor of three or more, with an average of 30% of the total charge being collected with deep p-well and less than 10% without. The sensor would not have been viable without this development. These results have been accepted for publication [5].

The first sensor tests will continue over the summer until the second sensor is returned from fabrication and shown to be functional (see below) so Gantt chart item ID12 is still ongoing. This will be concluded later this year with the submission of a paper detailing all the first sensor results. This is currently in preparation and a draft can be supplied to the OsC if desired.

5.2 Second round sensor

Due to the changes imposed by the STFC decision to cut the ILC grants, the scope of the second round sensor was reduced dramatically. As discussed at the last OsC meeting, we only had sufficient funds for a second shuttle run, rather than an engineering run, which limited the sensor to be the same size as the first design, i.e. $1 \times 1\,\mathrm{cm}^2$. This meant it was not possible to produce a large scale, full reticle-size sensor ($3 \times 2.5\,\mathrm{cm}^2$) suitable for a full ECAL stack test, as originally planned. Hence, the plan was to produce an iteration on the first round sensor, choosing the best pixel design to give a uniform sensor and fixing known design errors.

The second round design went through a PDR[6] (milestone ID15) and FDR[7] (milestone ID17) before submission in July. This final step concludes item ID14 and milestone ID18. It will be the same size as the current design but all pixels will be of the preShaper type, with the capacitor combination which gave a higher gain and signal/noise ratio. The pixel design itself has been modified a little in the layout to increase the size of the resistor in the RC loop of the charge amplifier, so as to improve the gain. The number of trim bits has been increased from four to six, so as to give better control over the pedestal non-uniformities. The test pixel area has been changed to have two fully functional pixels, one with the old design and one with the new. This will allow a direct comparison of the designs to check the changes had the intended effects. In addition, the known design errors have been corrected. Besides the common power supply which caused the crosstalk mentioned above, the most notable change is to the logic level of the memory write which was not sufficient to ensure the data were written without corruption, albeit at a low level of less than 1%.

The new sensor will be returned towards the end of September, completing milestone ID20. It will be tested for the six months between the end of September and the end of the grant in March 2009. As it is a relatively small iteration on the previous sensor, the design was constrained to be I/O compatible with the first sensor. This means the existing PCB used to hold the sensor is compatible with no changes and enough boards for all the foreseen tests have already been manufactured, which means item ID24 is completed. Similarly, the modifications needed to the DAQ system are minimal, only requiring a software change such that six rather than four trim bits are used. Hence item ID21 is effectively already complete.

The tests already set up should be sufficient to fully characterise the sensor (items ID22 and ID23) and allow a definitive paper on the work so far. As part of the tests, it would be possible to expose the new sensor to beam at DESY early in 2009. This would replace item ID26, which was originally planned as a beam test together with the EUDET ECAL. (Unfortunately, the new sensor, being small and with wire bonds on all four sides, cannot be used to tile a plane effectively. Hence, there is no longer any possibility of having such a combined beam test.) The stand-alone beam test at DESY would be expensive compared to the reduced travel budget available and a decision will be made when the travel budget spend is clearer.

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[5] "Monolithic Active Pixel Sensors (MAPS) in a quadruple well technology for nearly 100% fill factor and full CMOS pixels," J.A. Ballin *et al.*, accepted by Sensors, arxiv:0807.2920

[6] `http://www.hep.ph.imperial.ac.uk/calice/maps/pdr2/pdr2.html`

[7] `http://www.hep.ph.imperial.ac.uk/calice/maps/fdr2/fdr2.html`

5.3 Future prospects

Following the submission of an SoI for sensor development in June, we have recently obtained approval to proceed to a proposal. This will bid into the new £1M p.a. detector R&D fund. We are currently preparing such a proposal, together with some of the LCFI sensor groups, to continue various aspects of CMOS sensor studies, including the WP3 work. The exact shape and scope of the proposal is currently under discussion but it is hoped it will include a bid to produce the sensor originally planned for the current grant, specifically a larger sensor which would be usable in a full ECAL stack. This would allow us to construct a stack of around 15 layers, each with $\sim 10 \times 10\,\mathrm{cm}^2$ of sensors, which should then give a definitive answer to whether an digital ECAL would be a viable technique for future detectors.

5.4 Plan for completion

The last six months of the project will be completely devoted to testing the second sensor. As stated above, this will include a repeat of all tests established for the first sensor and may include a beam test in early 2009. It is unlikely we will finish all the journal articles we would like to produce within this time but these can be completed beyond the end of the grant as long as the main body of the work is done. All remaining milestones which are still current (with the exception of the beam test work) should be completed by the time of the next OsC.

The personnel to do this work who remain funded are the academic staff and M. Stanitzki at RAL/PPD. Fortunately, A.-M. Magnan, one of the PDRAs previously funded by CALICE but lost in the cuts, has succeeded in obtaining an STFC Fellowship at Imperial which will start in October 2008 and she will split her time between WP3 and CMS. She was the PDRA for whom we requested an extension (before the funding crisis) to continue on WP3 as she was considered essential to the project. Hence this will make a significant addition to the available effort in the remaining grant period.

In addition, Birmingham also have a CASE student shared with RAL/TD working full time on WP3. The remaining grant period corresponds to the first half of his third year, so he will aim to complete his thesis in around a year from now and it will clearly contain a lot of the sensor results.

5.5 Milestones

The recent and future milestones are listed below.

5.5.1 Milestone ID15: "Second sensor preliminary design review"

The second sensor PDR was held on 1 May 2008. This was four months later than planned due to the disruption caused by the uncertainty to the programme.

5.5.2 Milestone ID16: "Second sensor interim design review"

As the sensor was a relatively small iteration on the previous design and there was less than two months between the PDR and the FDR, it was decided that an interim design review was not required. Hence, this milestone was retired.

5.5.3 Milestone ID17: "Second sensor final design review"

The second sensor FDR was held on 13 June 2008, on schedule.

5.5.4 Milestone ID18: “Second sensor design to foundry”

The second sensor was submitted for fabrication on 21 July 2008, also on schedule.

5.5.5 Milestone ID20: “Second sensor fabrication complete”

This is the expected date for the sensor to be returned and is in late September 2008, around the time of the next OsC. This will be slightly ahead of schedule.

5.5.6 Milestone ID25: “Second sensor beam tests start”

If a beam test is done within this grant period, it will be a MAPS-only test at DESY in January or February 2009.

6 WP4: Thermal and Mechanical Studies

After the STFC-imposed budget cuts at the end of 2007 the scope of WP4 was reduced to concentrate on assembling the detector slabs. In particular we chose to focus on attaching the silicon wafers to the PCBs hosting the front-end readout ASICs. The requirements on the glue bond are tight - it must be mechanically robust, provide a good electrical contact between the PCB and the silicon wafer and be no more that 100μm thick. The applied glue dots must also not create shorts between neighbouring silicon pads.

Using the Manchester glue robot (which delivers a precise volume of conductive glue per dot) some preliminary investigations were carried out to assess whether the required tolerances on the glue joints could be achieved. The purpose of these tests was to determine the correct glue volume for the required separation. This was carried out by fixing a glass sheet to a baseboard that had been prepared with glue dots. The separation between the glass and baseboard could be precisely controlled with spacers of known thickness and the resultant diameter of the glue joints measured. Figure 6 shows a test baseboard before the glass sheet has been applied. It also shows the same baseboard, but now with the glass plate attached and the glue cured. The diameter of the glue dots changes with the separation between the baseboard and the glass as expected. Figure 7 shows this dependency. For a reasonable volume of glue the size of the dot becomes very large at small spearations. Furthermore the dependency steepens at small separations. This issue requires that the flatness of the two surfaces to be glued should be good, as deviations from flatness introduced during the manufactuing process may have undesirable consequences when the two are bonded with a defined overall separation. Small deviations from

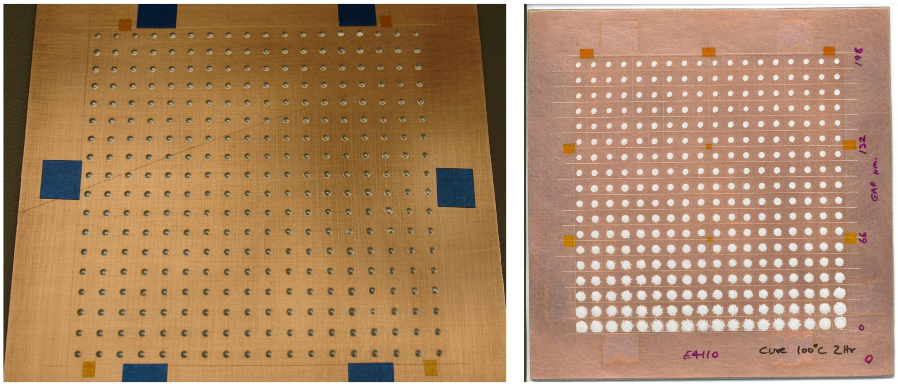

Figure 6: (Left) Baseboard with glue dots applied. (Right) Baseboard and glue dots with glass sheet after curing.

flatness may cause unacceptable spreading of the dots. It can be seen from figure 7 that a variation in separation of around 50μm results in an increase of around 0.5cm in dot diameter.

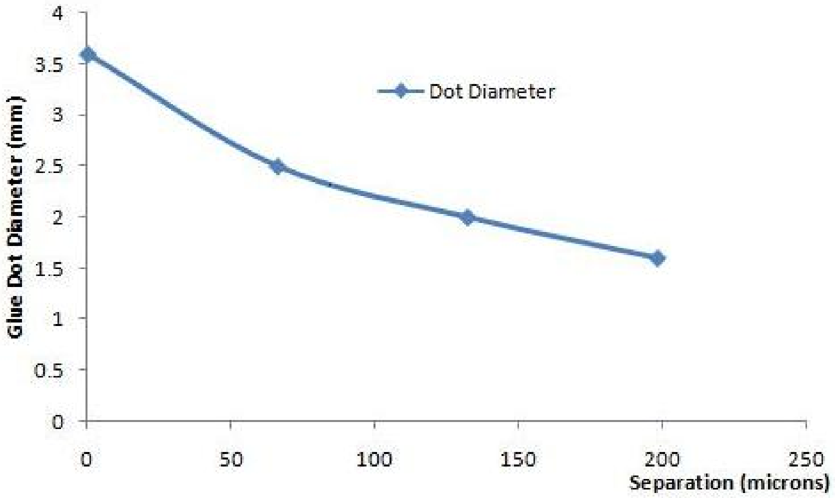

Figure 7: Dependency of glue dot diameter on the separation distance between baseboard and glass plate.

In order to determine whether the goal of 100μm was attainable, two of the PCBs used in the long-term glue stability studies were adapted so that the resistance of the glue joints between them could be measured. The two PCBs were bonded using conductive glue, separated by spacers of 100μm. Subsequent measurements showed that the resistance of the glue joints was less than 0.005Ω per pad. The bonded PCBs are shown in figure 8.

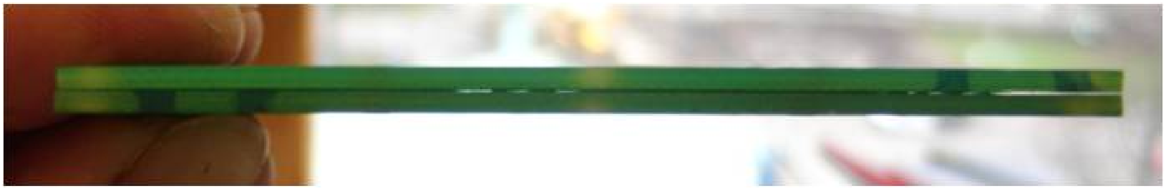

Figure 8: Side view of two glue-test PCBs bonded with conductive glue. The spacing is 100μm.

To address the potential problems with surface flatness a method for attaching the wafers to the PCB using vacuum techniques has been developed in Manchester. Both the PCB (with glue applied) and wafers are help flat in vacuum chucks on a precision stage. The vacuum holds the surfaces flat and they are then brought together to the desired separation distance and held whilst the glue cures. Figure 9 shows the vacuum jigs, that have been manufactured in Manchester, installed in the gluing enclosure. The test PCB that can be seen in figure 9 has the same pad layout as the final detector and will be used to verify the procedure. Aluminised glass sheets will be attached to a series of test PCBs in order to verify operation of the gluing rig and to carry out tests of PCB stitching schemes in conjunction with Cambridge. We also have two production wafers in hand to verify that the properties of the glued wafers meet the CALICE requirements.

6.1 Plan for Completion

In the short term (calendar year 2008) we will verify that the vacuum and glue system meets the required tolerances for the EUDET modules. We will also investigate the feasibility of reducing

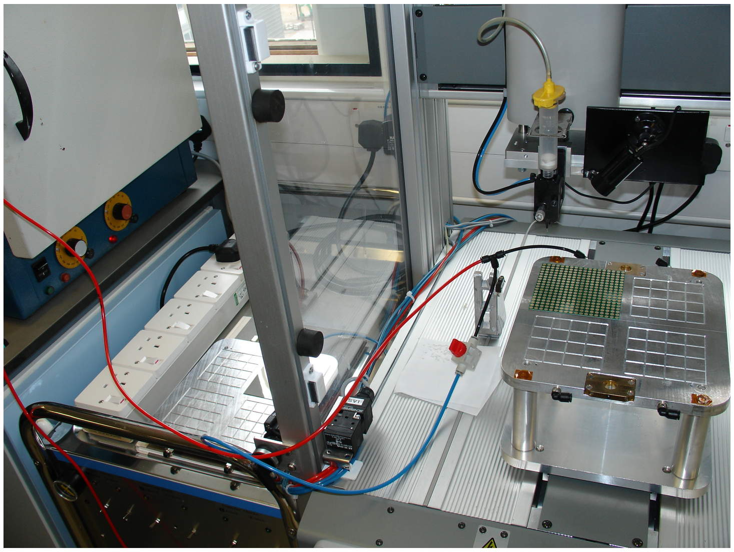

Figure 9: Vacuum jigs installed in the gluing enclosure. Also shown is a test PCB with the correct pad layout for the production silicon wafers.

the thickness of the glue dots to 60μm in order to further reduce the inactive material in the slab. This will be carried out with the existing manpower on the CALICE project.

6.2 Milestones

The recent milestones are listed below.

6.2.1 Milestone ID6: "End of module - 3D design complete"

This task was retired after the budget cuts.

6.2.2 Milestone ID11: "Module assembly - initial wafers expected"

Although it was originally envisaged to have started assembly for the EUDET module in the latter half of this year, wafer production has been delayed. We have used the opportunity to build the complete rig and are now in a position to procede with the assembly as and when silicon and production PCBs become available. This milestone has been achieved.

7 WP5: Physics and simulation studies

All direct funding for WP5 on the CALICE project grant ended at the end of March 2008 apart from three months of a PDRA at RAL. There is also a small amount of rolling grant effort at RHUL still funded together with academic effort at Cambridge; a Cambridge-funded PDRA and a RHUL PhD student are also working on this package. With such a large reduction in available effort the Gantt chart and milestones are no longer meaningful and are not included. Some comments on the work that has been carried out in the last six months on the four tasks within the workpackage follow.

7.1 Task 5.1: Particle flow algorithms

Cambridge have developed the state-of-the-art algorithm for particle flow. This work proved that the concept of particle flow calorimetry is viable at the ILC. Without further funding beyond March 2009, it is not clear if this effort can continue. Since the detector at the ILC is most likely to utilise particle flow calorimetry, this work is central to the ongoing ILC detector studies. There is also interest in this work beyond the ILC. A PRD grant application was made last year and this will be considered (again) by the PPRP this autumn. If successful, it would allow this work to continue.

7.2 Task 5.2: Global detector design

Cambridge (for ILD) and RAL (for SiD) are leading the work within the ILC detector concept groups on detector optimisation. The results from these studies were intended to provide input to detector LoIs which will be submitted to the ILC detector Research Director by April 2009. The work being performed in the UK is central to defining the baseline detector designs. Again, without further funding, it is not clear whether these highly-visible contributions from the UK will have to cease before the LoIs are written. This would result in a major lose of influence within the ILC detector community.

7.3 Task 5.3: Workpackage support

There is still a small amount of effort for support for the MAPS work in WP3. In particular, if the second sensor beam test (see Section 5) happens early next year, then simulation support will be provided.

7.4 Task 5.4: Physics studies

A RHUL PhD student (with a small contribution from a rolling grant funded PDRA) is studying the ZHH final state in order to determine how well the Higgs self-coupling can be measured using the LDC model detector. Two studies have been carried out previously but these used only particle smearing. The current approach uses full simulation and reconstruction for the first time both of the signal channel and the dominant backgrounds. The six-jet final state dominates this process with either four or six b-jets in the final state. Thus this channel, which is one of the ILC detector benchmark processes, provides good tests for both particle flow algorithms and the LCFI b-jet finding software and has therefore provided useful feedback to the authors of these software packages.

Three different approaches have been used to separate signal from background: cuts, kinematic fitting and an artificial neural network. Final results of this study are not yet available but it is clear that, while a useful measurement can be made with $500\,\mathrm{fb}^{-1}$ of data, the precision will be significantly worse than previously claimed by authors of simulations making use of particle smearing alone.

The Cambridge-funded PDRA is working on two physics channels, both of which test the jet reconstruction capabilities of particle flow calorimetry. The first is the identification and separation of the $\nu_e W^+W^-\overline{\nu}_e$ and $e^-Z^0Z^0e^+$ channels, which gives access to the potentially strong W^+W^- and ZZ scattering. The quality of the measurement can be characterised by effective anomalous quartic gauge boson couplings. The separation of these two channels, i.e. the separation of of hadronic W and Z decays, requires that the target of $\sim 30\%/\sqrt{E}$ jet energy resolution be achieved. Full detector simulation studies of signal and background have been performed at 800 GeV and 1 TeV, and the precision achieved is at least as good as that indicated by early fast simulation studies. The second study is of the ZH final state in the fully hadronic (4-jet) final state. Again, full detector simulation studies have been performed, and a neural network approach to separate signal from WW, ZZ and $q\bar{q}$ background has been studied at 250 and 350 GeV. Both jet measurements and b-tagging are important here. Kinematic fitting is then used to assess the achievable mass resolution on the Higgs boson in the hadronic channel.

Both of these studies have been carried out in the ILD framework, and will be presented at the ILD workshop in September.

7.5 Plan to completion

The rest of the grant period will be spent completing any outstanding work and presenting it to the wider community, in particular at the LCWS08 meeting in November.

8 Financial and managerial issues

The Gantt charts, financial tables, risk proforma and milestone tables are supplied separately. We continue to hold bi-monthly phone meetings of work-package managers and the project manager at which these tables and other managerial matters are discussed. Much of the discussion at these meetings has been about managing the reduced resources, especially the effort available as PDRAs has left.

8.1 The financial tables

The tables give the financial status as of the end of July 2008.

The first column shows the original approved sum, which was given with pre-FEC accounting. The actual spend in the first three years was also under this accounting regime. During this time there was an underspend of approximately £230k against the expected expenditure and this is one element of the savings made with the reduction in scope of the project.

The allocation to completion shows the amount approved following the community consultation and subsequent PPAN recommendation. This is around £220k less than the original planned spend in 2008/9 and is a second element of the savings. These therefore total £552.5k as shown at bottom right. In addition the FEC costing method adds £93k, which is included in the allocation to completion. Thus in total there is a saving of around £645k in the cost of the science being bought compared with the original proposal.

The actual spend to end July 2008 is shown in the next column and the amount that we currently anticipate spending during the rest of the financial year is simply the difference between columns (3) and (4) and is not shown.

8.2 The Gantt charts

Progress against the Gantt charts is discussed for each work package in the main body of this report. The feature to note is that where tasks have been terminated as a result of the budget cut they have been left but with the task title shown in italics.

8.3 The risk table

As we near the end of the project further risks have been retired. Because of budget cuts the UK will not deliver on some tasks, as discussed elsewhere. Changes since the last meeting are, as usual, highlighted in yellow.

8.4 The milestones tables

Comments about each milestone recently passed are contained in the report for each work package. Table 3 shows all milestones, included those that have now been deleted since the corresponding task has been terminated. Table 1 shows the status of milestones due to be reached in the period January to June 2008 and Table 2 shows those due for the remainder of the current calendar year. Changes since the last meeting are highlighted in bold.

9 Summary

The CALICE-UK groups have continued towards completion of the reduced programme, despite significant cuts and loss of personnel. There are no major problems foreseen to finish the remaining active WP tasks by March 2009.