CALICE Questions and Answers for the OsC

1. Section 3.1. Task 1.1: Support for beam tests.
   (a) Is there an ongoing need for travel funds?

   Yes, not so much for operating test beams, since the last run in the present grant period is nearly finished, but for attending meetings and conferences, to make sure that our contribution has a high profile.

   (b) Do you see the UK maintaining its leadership roles in the analysis having lost PDRAs?

   The loss of PDRAs has severely prejudiced our ability to actually *do* analysis, so our leadership and coordination rôles are all we have left. We hope we can maintain this, so long as the academics involved are still able to travel. If we can't do this, then our rôle becomes very questionable.

2. Section 3.2. Task 1.2: DESY test beam. (See also Sections 3.5 and 3.6.6).
   (a) How will you maximise the gain to the UK from analysis from Fermilab data?

   By focussing on a niche which is important, and in which we currently have a lead on our collaborators (hadronic showers in the ECAL), we hope we can be seen to be making a distinctive contribution. But it will be difficult to compete, because of lack of effort.

   (b) What is likely to be inferior in the DESY analysis and how does FNAL data help supersede it?

   The DESY data only covered electrons, not pions. At the time of the DESY run, the ECAL was only equipped with 24 of its 30 layers, and 3×2 of the intended 3×3 wafers. At FNAL the calorimeter was fully populated. This means that the DESY data are less straightforward to compare with the high energy CERN data – one needs to rely on simulation to assess the uncertainties associated with the different geometries.

   (c) Are they at least compatible?

   Provisionally yes, but it is really too early to answer this question.

3. Section 3.3. Task 1.3: CERN test beam.
   (a) Foot of p3 "discriminate between different hadronic shower models in GEANT4". What kind of feature of events are you looking to get right?

   Shower energy scale, linearity and resolution; correlation between ECAL and HCAL energies; longitudinal and transverse shower shapes; detailed shower substructure (e.g. track segments, electromagnetic showers within the shower, which can have different energy scales). Ultimately the aim is to test the performance of realistic particle flow algorithms on the data, and compare with simulation.

(b) Are you confident that GEANT4 attempts realistic simulation of these features? (e.g. in low energy shower terminators GEANT3 does not try for complete realism.)

We are keeping an open mind – the aim of our R&D is to answer this question.

(c) Do you have good contact with the GEANT4 authors?

Yes, sufficiently good.

(d) Also foot of p3, you say "task of calibrating…proved to be more complex". Does this mean that we have not yet built a realistic particle flow calorimetry event reconstruction procedure?

Yes. The particle flow has been designed with robustness in mind, so we are fairly confident, but until the CALICE work on understanding digitisation in the Monte Carlo is finished, this cannot be proven.

(e) You state that the gains for the 6480 cells of the prototype are uniform but Fig.1 Right seems to show a slowly rising trend with increasing pad index. Please comment on this.

Overall the gains show a r.m.s. variation of ~5%, which is already quite good. However, the figure separates the wafers into three separate production batches/manufacturers (indicated by different colours), and there is clearly a small but systematic difference between these batches. So the apparent trend seems to be largely a consequence of the differences between these productions.

(f) Can you also please expand on the statement about the SiPM saturation effects?

There are two independent response curve measurements available for the SiPMs.The first was made at ITEP before mounting the SiPMs on tiles, while the second was repeatedly performed during data taking utilizing an LED calibration system. In both cases, the SiPM signal is gauged to pixel, i.e. the distance between single photo-electron-peaks at low light amplitudes, thus providing a comparable scale despite different setups, conditions, and data acquisitions. The test-bench measurements have the advantage of good control and monitoring of the light source over the full dynamic range, whereas the in-situ measurements suffer from the non-linear light output w.r.t. supply voltage of the LEDs. Measurements of the emitted light signal with PIN diodes are not sufficient for corrections over the entire dynamic range. However, the in-situ measurements are taken with the same readout and under identical conditions as the data. Reconciling these two sets of measurements has exercised the DESY group for a long time.

4. Section 3.6 (Milestones) and WP1 Gantt chart.
   (a) On the Gantt charts, please could you explain the meaning of the ID25 and 26 lines – horizontal bars only partly filled in?

   It means that we have some generated samples in hand, but more will be required, and more tuning of the digitisation code (especially for the HCAL) will be needed.

5. Section 4.3. Task 2.3, ID46 (Work on the Optical switch).
   (a) What depends on this?

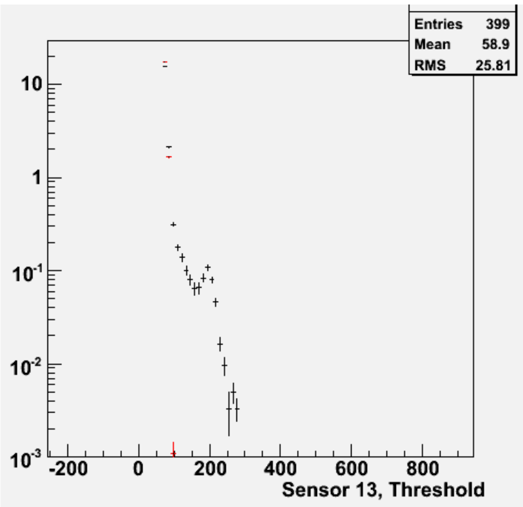
   Nothing directly; the task on the optical switch is a self-contained task.

   (b) Can we just cancel it?

   Cancellation would not impact other parts of the programme but this task could also bring benefits for future experiments including the CALICE DAQ. It is a generic piece of DAQ which could lead to a positive evaluation of such switches to be used for any future experiments to increase the efficiency of data transferred off the detector. It is not essential for the current CALICE DAQ programme, but could be beneficial. Also, having spent about £25k on such a switch and having set it up in our lab, we think it sensible to continue with this.

6. Section 5.1. (First sensor tests).
   (a) Given the lack of any calibration data with a source, is it possible to compare aspects of the device performance with the specifications and simulations?

   We have calibrated the sensor using ^{55}Fe on both the bulk and test pixels. This source gives a 5.9keV photon and on the (rare) occasions when it interacts within one of the signal diodes, all the charge ($1640e^{-}$) is collected in one pixel. When the photon interacts in the epitaxial layer, the charge diffuses to several pixels so a smaller signal is seen. Hence, observing the end point of the signal spectrum gives a calibration point. This source is used as the signal size is close to the value of $1200e^{-}$ induced by a MIP at normal incidence. The plot below shows the observed spectrum (obtained from a threshold scan by taking a derivative of the rate as a function of threshold) from an example single pixel using the GBq source available at RAL.



(b) How is the improved signal due to the deep p-well demonstrated from the data presented?

Fig. 5 in the report shows in the centre ("deep p-well") and right ("no deep p-well") plots the signal seen in each of the nine pixels in a 3×3 array around the pixel being illuminated by the laser. The x axis corresponds to the laser position within the middle pixel, as show in the left plot of this figure. Consider for example the pink line which is uppermost in the centre and right plots. This corresponds to the signal seen in the middle pixel. For the "deep p-well" case, this varies between 24% and 51% (which for a MIP would correspond to 290 to $610e^{-}$), with an average over the pixel surface of 35% ($420e^{-}$). In contrast, for the "no deep p-well" case, then the signal seen varies between 1% and 41%, with an average of 10%. Similar degradations are seen for the other coloured lines, corresponding to the neighbouring pixels. Given the observed noise of $45e^{-}$, the "deep p-well" values are perfectly acceptable (see below), while the "no deep p-well" ones would be unusable.

(c) Draft paper on first sensor results – it would be good to hear a little about this draft paper in your presentation.

We can certainly discuss the status of this draft in the OsC meeting. Although the paper is in a rough form, we could make a copy available to the OsC if they wanted to see it beforehand.

7. Section 5.2 Second round sensor.
   (a) Will you publish your results on tests?

We certainly intend to publish the results on the second sensor but this is unlikely to be within the time of the current grant, i.e. before April. If the proposal currently being considered by the PPRP is approved, then there will be continuity of the expertise beyond March and we could aim to publish by the summer. However, if it is not approved, then the second round sensor paper will take significantly longer, relying mainly on academic effort and some RAL/PPD staff at a low effort level.

(b) Is it possible to more fully evaluate the devices already delivered and to then to show how any new device can benefit from these studies (for example in terms of helping to cross-check simulations)?

We have evaluated the current device in some detail; not all of the results were reported in the OsC document due to lack of space. The most critical issues for the simulation of a full ECAL are the noise, charge spread and the hit density in EM showers. For the preShaper pixel design, the noise has been measured to be $45e^{-}$ on average, which gives an average S/N of 9. This level will make the noise a small contribution to the expected ECAL resolution and so is perfectly acceptable. The charge diffusion measurements are shown in Fig. 5 of the report and (although not shown in that figure) agree quite well with the device-level simulation. Hence, we have now verified the charge diffusion is at the expected level and, as shown previously[1], the effect of this on the ECAL resolution should therefore be small. Hence, the crucial remaining issue relates to the properties of hits in real EM showers; GEANT4 has not been verified at a granularity of 50μm. This is the main motivation for fabricating the second sensor. It will have a uniform array of pixels using the best design from the first sensor and so we are confident it will be able to take good data in a beam test. Although it is a small sensor and so cannot be used for a shower resolution measurement, it would allow us to see hit densities at various depths of EM showers if exposed to an electron beam with a tungsten converter. This would be a most important step towards evaluating the viability of the digital ECAL technique. To go further and actually measure the resolution would require a full-depth calorimeter stack and that is the main aim of the future proposal currently being considered.

(c) How can the expertise gained be retained and used to maximum advantage?

We hope the expertise can be retained through the approval of the new proposal mentioned in Sec. 5.3. This would allow us to design and fabricate the larger sensor (originally included in the current grant, before it was dropped as part of the ILC cuts) and then to do a measurement of the realistic EM resolution of a digital ECAL device. A copy of the proposal containing this bid could be made available to the OsC if desired. As far as we are aware, we are currently the only group working towards a digital ECAL; this is certainly true within the LC community. Therefore, if we can show the technique is viable and hence worth pursuing further, then we would be in a leading position worldwide. Such a calorimeter could be applied to an ILC, CLIC or muon collider detector, all of which would need good jet energy resolution and hence PFA abilities. Hence, the DECAL work could give the UK a major role in detectors for these accelerators if any of these are ever built.

8. Section 6. WP4 (Thermal and Mechanical Studies).

(a) Will you publish your results on mechanics?

Yes. It will all be written up in the EUDET report due at the end of this month.

(b) What would you argue you have learnt that has genuine novelty?

Two points: Firstly, this is the first long-term test of conductive glue that has been carried out. Secondly, we have begun to integrate the various parts of the assembly system with a view to complete automation. Sadly this has been cut short by the STFC funding problems, but would have lead to valuable insights into “industrialising” the assembly of the detector components.

(c) How can the expertise gained be retained and used to maximum advantage?

---

[1] J. A. Ballin *et al.*, “A MAPS-based Digital Electromagnetic Calorimeter for the ILC”, proceedings of the 2007 *International Collider Workshop (LCWS07 and ILC07)*, Hamburg, Germany, May 2007, arXiv:0709.1346.

We are well placed to use the existing expertise in other construction projects. It will be directly applicable to future silicon/precision detector assembly and, as such, places us in a good position for LHC upgrade detector construction.