Proposal 317 - CALICE Update and Status Report

Birmingham, Cambridge, Imperial, Manchester, UCL

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1 Introduction

The CALICE-UK collaboration proposes to study calorimetry for a future linear collider (LC). Over the past four months, the collaboration has been strengthened in a number of respects in order to address the issues raised at the PPRP meeting of 1 July 2002. In particular, there has been a substantial increase in effort on the project (particularly amoung the academic members), a simulation work plan has been defined, and the proposal for new RA effort has been focussed. These changes are all discussed in detail below.

The CALICE collaboration aims to be at the forefront of LC calorimetry development by the time any detector collaboration is formed. It is the only collaboration within the LC community studying both electromagnetic (ECAL) and hadronic (HCAL) calorimeters in an integrated way. We believe this overall calorimetry approach is the only way to obtain a calorimeter system which will be capable of meeting the demanding physics requirements of a high energy LC detector. The CALICE program covers beam tests of several technologies and simulation studies based on the results of these tests to design a LC calorimeter optimised for both performance and cost. The CALICE-UK groups regard joining this collaboration as an ideal way to gain entry to the LC studies. The breadth of the project ensures that CALICE cannot be ignored in a future LC detector collaboration and we believe membership will give us significant influence in the design of any LC calorimeter.

This document is an update of the CALICE-UK proposal to the PPRP [1]. Section 2 outlines the current status of the CALICE collaboration and CALICE-UK groups. Section 3 outlines the status of the electronics part of the project. Section 4 gives details of the simulation work and presents a work plan and schedule as well as the status of the studies so far. The Appendix gives updated details of the effort and costs.

2 The CALICE collaboration

The CALICE collaboration as a whole has expanded both in terms of people and also in terms of the scope of the project.

In recent months, four new institutes have been accepted into the collaboration (Seoul, U. Texas at Arlington, Northern Illinois, Dubna), three more (Boston, Chicago and Illinois) are currently applying to join and there has been an initial approach from another (Fermilab). The collaboration now has 138 members from 24 institutes in 8 countries; most importantly, it has membership from all three regions (Europe, US and Asia) involved in the LC program. It is the largest LC calorimetry group by around an order of magnitude [2] and will clearly have a large influence on calorimetry design in a future LC detector collaboration.

These new institutes have allowed new technologies to be considered within CALICE. There are now three options for the digital HCAL being actively considered; RPCs, GEMs and small scintillating tiles. These are in addition to the scintillating tile analogue HCAL. The ECAL work remains concentrated on silicon-tungsten.

The beam test continues to be the major focus of the collaboration work. The aim is for the ECAL to be tested with all four HCAL options so that a meaningful comparison of their performances can be made. All four HCALs will be housed within a common mechanical structure containing iron plates, between which the various active layers can be inserted. The ECAL is still on schedule to be completed early in 2004. The different HCAL options are in different stages of maturity; the analogue tile and digital RPC HCALs are likely to be ready by mid 2004, while the other options may be available by the end of 2004. The beam test program has therefore been pushed back but extended in scope and length with these new options; rather than the original six months around mid 2004, it now looks likely it will continue for around one year, from mid 2004 to mid 2005. With the subsequent analysis of these data, the project will therefore continue into FY05/06.

The location of the beam tests is still not fixed although, given the change in schedule, it is less likely to be at CERN. Fermilab and/or Protvino should both be able to provide beams on this timescale. With regard to the latter, it has now been clarified that there will be no charge for setting up the beam line; hence the £10k budgeted for this possibility in the original proposal is no longer required. As shown below, the importance of studying proton showers is becoming apparent and so this will need to be factored into the site choice.

CALICE recently submitted an annual report [3] and gave a presentation to the DESY PRC. This gives a summary of the overall project status. The report was well received and the referee recommended that CALICE proceed to the full beam test as proposed [4].

2.1 The CALICE-UK collaboration

The UK institutes involved have had several changes in personnel since the PPRP meeting and various people have increased their time on CALICE. N.Watson will take up a joint appointment between RAL PPD and Birmingham in January 2003, which means not only that he will be able to spend 60% of his research time on CALICE but also that he will remain for the duration of the project. A large fraction of his remaining time will also be devoted to other LC-related studies. Manchester have recently appointed to a lectureship S.Söldner-Rembold, who has a strong background in LC physics studies, particularly for the TESLA TDR. He will be working 50% on CALICE after he arrives at Manchester next year. D.Miller has significantly increased his time on CALICE; although he is due to retire in 2005, UCL are expected to replace him with a new lecturer full-time on LC work. He has also brought in a UCL postdoc, S.Boogert, who is now splitting his time equally between CALICE and another LC project. This postdoc position will run out before the end of CALICE and we request a one-year extension to this post from the PPRP. D.Ward has obtained a sabbatical for 2003-4 and so can increase his time on CALICE and will also lead the simulation work. Our original proposal to the PPRP included a request for contributions to RA posts at several institutes. In response to the PPRP's comments we now propose a single RA post, to be based at Cambridge, to work on simulation and energy flow algorithms. Because of these changes, every institute will soon have an academic spending at least 50% of their research time on CALICE. More details of the proposed effort can be found in the Appendix.

We believe the UK people have already had an important impact within the LC community internationally. D. Miller has been well-known for his LC work for many years and chairs several international committees in this area, in particular the ECFA/DESY LC study [5]. M.Thomson is a convenor of the detector performance working group for these EFCA/DESY studies. P.Dauncey is a convenor of the calorimetry sessions for the international LC workshop meetings [6]. He also presented the CALICE annual progress report to the DESY PRC in October [3].

3 Status of the electronics development

The electronics design has continued over the summer and details of the current status can be found at [7].

The ECAL readout electronics went through a conceptual design review (CDR) [8] on 11 October, where the design, schedule, cost, etc., were presented in detail to four external reviewers. This was very productive and there was agreement that the proposed design was sound. Several minor technical issues were raised and solutions found [9].

The cost, effort and schedule estimates were also thought reasonable. These have been re-evaluated for this update, taking into account the suggestions from the CDR, and there have been changes at the 10% level. In this area, the main issue raised by the reviewers from RAL ID concerned the layout of the prototype readout board in the RAL ID drawing office. Due to LHC work, the office is heavily booked for the period early in 2003 when it would be needed.

The delay in approval of the electronics project, with the resulting lack of RAL ID effort, has caused a three month schedule slip relative to the original proposal. However, given the overall change in schedule of CALICE, it would be possible to delay the project by yet another three months. This would result in the readout boards being finished around mid 2004, which is still in time for the first beam test. This corresponds to the schedule which would result from delaying the layout until later in 2003, when the RAL drawing office is less busy. However, it was thought prudent to investigate possibilities which might allow the project to finish earlier and so allow some schedule contingency.

One way to do this is to reduce the layout effort required. The RAL ID reviewers proposed taking an existing board with a similar architecture and redoing the layout only for the parts which need to be CALICE-specific. The CMS Tracker Front End Driver (FED) [10] was identified as a possible starting point. This 9U VME64 board has been developed over several years by groups at Imperial and RAL and first full-specification prototypes are due to be available in December this year.

The architecture of the FED is very similar to the CALICE readout board; it has several Front End (FE) FPGAs, each handling an (optical) input cable, and these are controlled and read out using a Back End (BE) FPGA. These have effectively identical roles to the readout board slave and master FPGAs, respectively. The FED layout up to the FE FPGAs would be usable directly in CALICE. However, the input stage of the FED is completely different and this front 10cm strip of the board would need to be redesigned. It would be feasible for this smaller amount of work to be done in the RAL drawing office early in 2003.

The FED has several features which are different from the original CALICE readout board. It is somewhat overengineered for the CALICE application; around 500 will be built for CMS and they will have to operate continuously for many years. Hence, there is an emphasis on reliability and operational efficiency, with hot-swap capability, software-loadable firmware updates, resettable fuses, temperature-sensitive, multi-level power-downs, etc. These would not normally be considered as necessary for a beam test application and some of the components may not be mounted for CALICE use to save on cost. The FED has more functionality than needed for the readout board, so the FPGAs are larger and more performant (and hence more expensive) than needed. Furthermore, the FED is 9U rather than the previously proposed 6U boards. Hence, more connectors could be put on the front panel, so increasing the number of channels per board and so decreasing the number of boards and crates required.

3.1 Schedule, effort and cost

We have not yet found any critical items which would prevent the use of the FED layout although this evaluation is continuing. When this is complete, a decision on how to proceed will be made;

there are few implications for the resources required either way. Using the FED would save on schedule but not on engineering effort or cost since much of the engineering effort is required for the FPGA firmware and little of this would be common between the two boards.

The cost of using the FED is estimated to be close to the original; using 9U rather than 6U puts up the board and crate cost, as does using the more expensive FED FPGAs. However, only 6 readout boards would now be required, compared to 15 previously, and only one, not two, VME crates will be needed; both these give substantial savings. The total cost is now estimated at £111k, compared to £103k previously.

Layout effort needed would be reduced from 4 to 3 months by not having to layout the common part of the readout board. The engineering design effort needed from RAL is now estimated at 15 months, rather than the original 12 months, which mainly reflects the extended schedule and the need for a project engineer throughout this period. An additional 2 months for board testing at RAL is also requested by the project engineer. Hence, the total RAL ID effort needed is now estimated at 20 months.

By using the FED, then compared with the original schedule, the electronics schedule will be shifted by only the three month delay which we have already incurred. This means the electronics project would be completed in Mar 2004, three months before the beam tests are due to start. Some equipment costs originally needed in this FY will now slip into FY03/04, but there is still no need for equipment funds in FY04/05.

4 Status of the simulation work

At their meeting in July, the PPRP indicated the need for a detailed work plan for the simulation studies in the UK; we outline our plans here. We also report briefly on progress to date as we believe this progress indicates that we now have sufficient effort for the core studies of this project.

4.1 Plans and timescale

Software activities are taking place at many of the institutes in CALICE as a whole, so in the UK we have endeavoured to identify a program of work which complements these existing activities, and matches the effort at our disposal.

The most detailed Monte Carlo for LC calorimetry is `Mokka`, based on `Geant4`. Many studies have also been performed using `Brahms`, based on `Geant3`. Our aim in the UK (Cambridge and Birmingham, at present) is to conduct a critical comparison of the physics content of various Monte Carlo programs, particularly the response to hadrons, and to assess the impact of any differences seen on the design and expected performance of LC calorimeters. In this way we expect to identify key areas in which results from the CALICE test beam will be essential to test the expected performance of the calorimetry for a future LC experiment.

4.1.1 Core simulation work

We envisage the following core areas of work for the UK, with the approximate timescales given:

- Start with the design presented in the TESLA TDR, i.e. a silicon-tungsten ECAL and an iron-scintillator or iron-RPC HCAL, as coded in `Mokka`. Examine the response of the calorimeter to single particles ($e^{\pm}$, $\mu^{\pm}$, $\pi^{\pm}$ etc.), initially at normal incidence. Compare the standard `Mokka` simulation with alternatives, e.g. `Geant3` (for a recent presentation on this work, see [11]), `Fluka` (for a recent presentation on this work, see [12]) and the several alternative hadronic interaction models implemented in `Geant4`. In addition the dependence of the results on tracking cutoffs is being considered. *[Summer/Autumn 2002.]*

- Extend these studies using the geometry envisaged for the test beam prototype, to confirm whether effects seen in the TDR design would also be reflected in the test beam data. *[Winter 2002/Spring 2003]*

- Investigate the impact which differences between models would have on the performance of energy flow algorithms for jet energy reconstruction. This work would cover existing algorithms, as used in previous studies, and hopefully also new energy flow ideas being developed in the UK. It is important to understand in detail how realistic algorithms would be affected by uncertainties in various aspects of detector response (energy scale and resolution, spatial resolution, two-particle separation etc.) for different particle types. *[Spring/Summer 2003.]*

- Quantify the relative performance of alternative detector designs, e.g. different longitudinal sampling and transverse segmentation, dead cells. In particular, evaluate the dependence on the Monte Carlo simulation used. *[Summer 2003.]*

- Devise a data-taking strategy for the test beam (choice of particle types, energies, angles) that will yield the most valuable information about the reliability of the Monte Carlo simulations. *[Autumn 2003.]*

- Prepare software tools for test beam running and ensure that suitable Monte Carlo samples are in hand, so that the UK physicists can play a leading rôle in the interpretation of the data. *[Autumn 2003/Spring 2004.]*

In parallel, work on physics studies and on energy flow algorithms will proceed as manpower is available. Use has already been made of undergraduate projects, this is continuing and we expect the recruitment of research students and fellows to allow growth in this area.

The development and evaluation of new energy flow algorithms in the UK, and the integration of this work with the direct simulation studies, would greatly benefit from the provision of an RA at Cambridge. We view this as a critical area in which the UK is not heavily involved at present. Without this RA post, then the UK would be less strongly placed to bring together the results of the beam test studies into the optimisation of the physics capabilities of a LC detector.

4.1.2 Luminosity spectrum measurement

The UCL group are studying the ECAL requirements for the luminosity measurement. Members of the group had previously proposed [13] the only known method for determining the luminosity spectrum at a LC with the precision required for a number of physics processes which are central to the physics programme. These include measuring the top-quark mass at threshold to better than 100 MeV, the mass of the W to 6 MeV, sparticle mass measurements and, with the GigaZ option, improving the Z lineshape. The extraction of the luminosity spectrum relies on a high precision determination of the distribution of the acollinearity angle of Bhabha scattering events in the electromagnetic endcap [14]. This angle is a surrogate variable whose sensitivity to beamstrahlung and other effects should enable the true $\sqrt{s}$ distribution to be unfolded with the required precision, if the performance of the calorimeter in the inner endcap region is good enough.

UCL is using the `Brahms` and `Mokka` simulation software to develop optimised clustering algorithms for this measurement. The programme will closely overlap with the tasks given above for the optimisation of the energy flow and jet reconstruction. The tools are identical and the test beam results on high energy electrons will be used to validate the modelling of the resolution on shower energies and angles. The goal within the period of this project is be to establish a firmly realistic prediction of the precision which can be achieved on the luminosity spectrum and to give input to the ECAL optimisation work to be sure it can achieve the desired physics results. This will be done in close co-ordination with the optimisation for energy flow in jets. It is important to connect this work with the core simulation work above; we ask for an extension of the RA post to cover the final year of the project so as to ensure this will happen effectively.

4.1.3 Integrated detector design

The aim of the CALICE project is to provide information which will provide guidance in the design of a LC detector. In the measurement of jets, as well as many other topics, it will certainly be necessary to take an integrated view of the whole detector in considering its overall performance. To this end, the ECFA/DESY series of workshops have recently established a working group addressing these issues, with a member of CALICE-UK, M.Thomson, as a convenor. The CALICE-UK groups will have a good understanding of these issues and be in a strong position to influence the detector design by the time an experimental collaboration is formed for a LC. This would be aided by the proposed RA at Cambridge, who would provide the connection between this area and the core work outlined above.

4.2 Status of Geant3/Geant4 comparisons

These studies have started using the TESLA TDR calorimeter design implemented in `Mokka` (`Geant4`). We have generated samples of e^-, μ^-, $\pi^\pm$, $K^\pm$, K^0_L, protons and neutrons at kinetic energy 2, 5 and 15 GeV, impinging at normal incidence on the barrel calorimeter. `Mokka` provides a facility whereby `Geant3` FORTRAN code describing the geometry can be written out. We have taken this code and implemented it in a `Geant3` Monte Carlo (using the `Brahms` framework), and generated corresponding samples of events. The two programs have been harmonised by the use of a common output format. The digitization process is not simulated – our comparisons are based on “hits”, corresponding to the ionization deposited in the sensitive detector volumes; in this way we are making a direct comparison of the physics content of the simulations.

First results from these comparisons, using the purely electromagnetic processes induced by e^- and μ^-, showed many more hits in the `Geant4` simulation than in `Geant3`. This was readily attributable to the different (higher) tracking cutoffs implemented by default in `Geant3`, and a lack of δ-ray creation. When δ-ray production was enabled and the tracking thresholds were reduced to ~ 10 keV, reasonable agreement between `Geant4` and `Geant3` was achieved. Fig. 1(a-b) show that the longitudinal and transverse energy profiles of e^--induced showers agree well between the two models. There is a discrepancy of $\sim 6\%$ in the overall energy scale, which seems quite sensitive to the treatment of the low energy cutoffs, which are implemented in different ways in the two versions of `Geant`. The energy resolution shows good agreement.

Hadronic interactions are notoriously more difficult to simulate correctly, and hence the comparison of hadronic showers is likely to be more interesting. A typical comparison is shown in Fig. 1(c-f) for the case of 5 GeV π^+. The longitudinal shower profiles in the ECAL and HCAL show quite good agreement, as does the energy sharing between the two parts of the calorimeter. The transverse shower profiles exhibit some differences, with `Geant3` predicting slightly broader showers, especially in the HCAL. Results for π^-, $K^\pm$ and K^0_L show similar levels of agreement. However, substantial differences were revealed when examining the showers induced by protons or neutrons – the energy deposition in the ECAL and HCAL being greater in `Geant3`. This is illustrated in Fig. 2, which shows, for $\pi^\pm$ and protons the deposited energy in each calorimeter (in Mips, divided by the kinetic energy) for three energies. The discrepancy between `Geant3` and `Geant4` becomes proportionally greater at lower energies, and seems to be largely associated with the low energy baryonic component of the shower. The shower widths are also wider for baryons in `Geant3`.

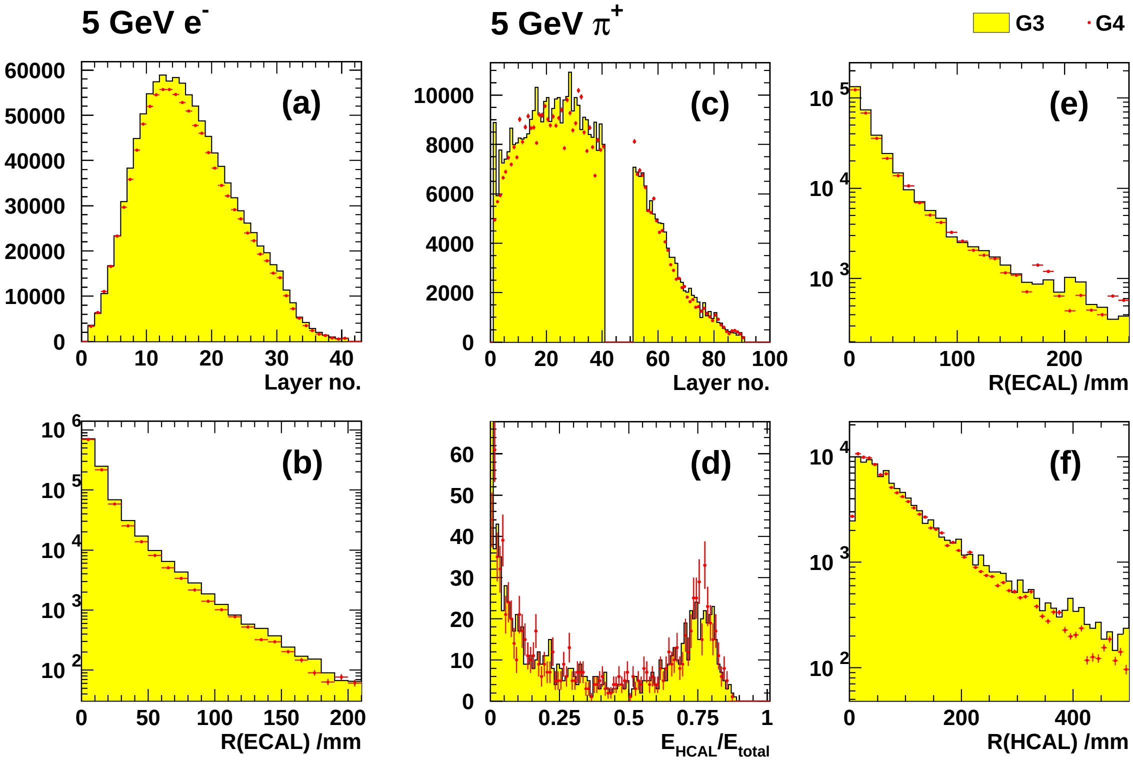

Figure 1: *(a) Longitudinal shower profile (plane number), weighted by energy, for 5 GeV* e^- *in the ECAL, (b) Transverse shower profile (radius), weighted by energy, for 5 GeV* e^- *in the ECAL, (c) Longitudinal shower profile (plane number; +50 for HCAL), weighted by energy, for 5 GeV* π^+*, (d) Fraction of energy deposited in the HCAL, for 5 GeV* π^+*, (e) Transverse shower profile (radius), weighted by energy, for 5 GeV* π^+ *in the ECAL, (f) Transverse shower profile (radius), weighted by energy, for 5 GeV* π^+ *in the HCAL. In all cases the points are* `Geant4` *and the solid histogram* `Geant3`*.*

`Geant4` provides an extensive "toolkit" of possible hadronic interaction models. The `Geant4` authors have recently made available several standard packages of these, to fit standard "use cases". We have started to compare these standard groups, for example one called "LHEP" which provides a parametrized model, and models known as "QGSP" and "QGSC" which implement more detailed descriptions of microscopic low energy cross-sections including resonances. First studies indicate differences between these models for hadronic showers at typically the $\sim 10\%$ level.

We have also recently started to compare the behaviour of hadronic showers in two of the possible technologies for the HCAL, in which the detection medium could be scintillator or RPCs. First indications are that the detected showers in the HCAL are narrower when RPCs are used, in both `Geant3` and `Geant4`, though there are other significant differences between the two programs. This clearly needs further investigation, and probably evaluation in a test beam, since it could have a significant impact on energy flow performance.

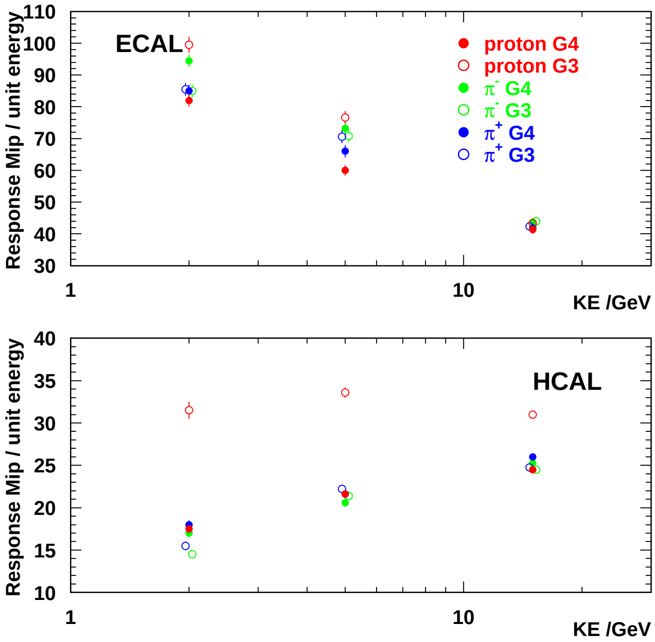

Figure 2: *Average response (in Mips) divided by kinetic energy for* $\pi^{\pm}$ *and protons at three energies, comparing* `Geant3` *and* `Geant4`*.*

4.3 Status of Fluka/Geant comparisons

The `Fluka` Monte Carlo system is reputed to have the most detailed microscopic model of hadronic interactions on nuclei, and is regarded favourably by some LHC experiments. It would therefore be highly desirable to compare `Fluka` with `Geant3` and `Geant4`. An old version of `Fluka` was interfaced to `Geant3`, but this version is now deprecated by the `Fluka` authors. The new version of `Fluka` cannot straightforwardly be interfaced to `Geant`, because of differences in philosophy in handling the geometry description as well as differences of programming language.

This difficult issue has been addressed by the LHC experiments in three ways. The first of these is to define the geometry and materials directly in `Fluka`. However, this is potentially inefficient when considering several variations on the detector design. The second approach consists of a "virtual Monte Carlo" system implemented in the ROOT framework and being developed by members of the ALICE collaboration. We chose not to adopt this as it entailed the integration of our existing `Geant3` and `Geant4` simulations with this package in addition to `Fluka`. We chose the third method, which is a direct interface between `Fluka` and the geometry of the detector as described by `Geant4`. This package, called `FLUGG`, has been developed between the `Fluka` authors and ATLAS, and used e.g. by the ATLAS barrel calorimeter group. This method seems to offer the greatest flexibility in terms of ability to study alternative detector configurations. The "hits" information is being output in the same format as the `Geant3` and `Geant4` simulations to facilitate comparisons.

At present, we have just finished testing that the `FLUGG` package faithfully describes the `Geant4` geometry using a lead-scintillator calorimeter configuration [15]. As an example of this, Fig. 3 shows the trajectory of neutrons in the plane transverse to the direction of a 10 GeV π^- entering at normal incidence to the calorimeter. We are now integrating the more complicated TESLA TDR geometry of `Mokka` with `FLUGG` for direct comparison with the `Geant3` and `Geant4` studies.

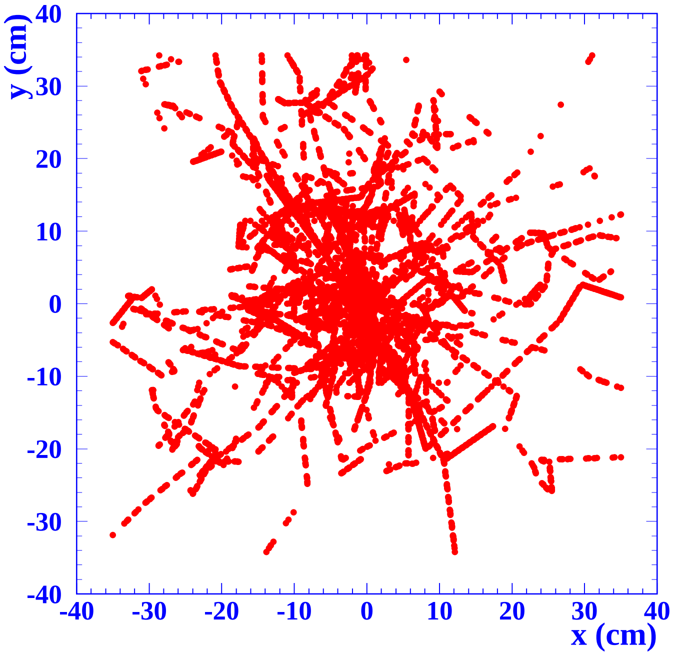

Figure 3: *Neutron trajectories from* `FLUGG` *transverse to an incident 10 GeV* π^- *entering at normal incidence to a lead-scintillator calorimeter.*

5 Summary

The CALICE collaboration continues to attract more collaborators and its scope is broadening. The UK has continued to be an active part of the collaboration and would like to put our involvement onto a firmer footing.

The electronics work has made good progress. The CMS tracker FED is being investigated as the basis of the readout board layout to prevent schedule delay. The project appears to be feasible on the new schedule without any major increases in cost or effort.

Simulation studies of differences between `Geant3`, `Geant4` and `Fluka` are being actively pursued and first results have been presented to the collaboration.

References

[1] C.M. Hawkes et al., "Proposal 317 - The CALICE collaboration: calorimeter studies for a future linear collider", submitted to the PPRP meeting, 13 May 2002.

[2] For an overview of LC R&D worldwide, see `http://blueox.uoregon.edu/~lc/randd.ps`.

[3] See `http://www.hep.ph.ic.ac.uk/calice/calice/021030prc/docu.ps.gz`

[4] See `http://www.hep.ph.ic.ac.uk/calice/calice/021030prc/referee.ps`

[5] See `http://www.desy.de/conferences/ecfa-desy-lcext.html`

[6] See `http://lcws2002.korea.ac.kr/`

[7] See `http://www.hep.ph.ic.ac.uk/calice/electronics/electronics.html`

[8] See `http://www.hep.ph.ic.ac.uk/calice/elecCDR/`

[9] See `http://www.hep.ph.ic.ac.uk/calice/elecCDR/report.ps`

[10] See `http://www.te.rl.ac.uk/esdg/cms-fed/`

[11] See `http://www.hep.phy.cam.ac.uk/drw/talk_sep24.ps.gz`

[12] See `http://www.ep.ph.bham.ac.uk/user/watson/calice_sim2_24_09_2002.pdf`

[13] M.N.Frary and D.J.Miller, “Monitoring the Luminosity Spectrum”, in proceedings of the Linear Collider workhops, Munich, Annecy Hamburg 1991, ed P.M.Zerwas, DESY92-123A and `http://www.hep.ucl.ac.uk/lc/documents/frarymiller.pdf`

[14] S.T.Boogert and D.J.Miller, “Questions about the Meaurement of the e^+e^- Luminosity Spectrum at a future Linear Collider”, proceedings of the Linear Collider Workshop, Jeju Island, Korea August 2002; ed J-S Kang, and hep-ex/0211021.

[15] M. Campanella, A. Ferrari, P.R. Sala and S. Vanini, “First calorimeter simulation with the FLUGG prototype”, ATL-SOFT-99-004.

A Appendix

Tables detailing individual effort and costs are given below.

A.1 Individual effort

The fractions of research effort for each person involved are shown in Table 1. For funding, H means HEFCE, P means PPARC and F means Fellow.

Institute and Tasks	Name	Funding	FY02/03	FY03/04	FY04/05	FY05/06
Birmingham	C. M. Hawkes	H	0.1	0.1	0.1	0.1
Simulation studies	N. K. Watson*	H/P	0.5	0.6	0.6	0.6
Cambridge	C. G. Ainsley	F	0.2	0.5	0.5	0.3
Online software	M. A. Thomson	H	0.2	0.3	0.3	0.3
Simulation studies	D. R. Ward	H	0.4	0.7	0.6	0.6
	New RA	P	0.0	1.0	1.0	1.0
Imperial	D. A. Bowerman	F	0.1	0.2	0.2	0.1
Electronics	W. Cameron	P	0.2	0.2	0.1	0.1
Data acquisition	P. D. Dauncey	H	0.6	0.6	0.6	0.6
	D. R. Price	P	0.2	0.2	0.0	0.0
	O. Zorba	P	0.2	0.2	0.0	0.0
Manchester	R. J. Barlow	H	0.1	0.2	0.3	0.3
Electronics	I. P. Duerdoth	H	0.1	0.1	0.1	0.1
Simulation studies	N. M. Malden	P	0.1	0.1	0.1	0.1
	D. Mercer	P	0.1	0.1	0.0	0.0
	S. Söldner-Rembold	H	0.0	0.3	0.5	0.5
	R. J. Thompson	P	0.0	0.0	0.1	0.1
UCL	S. Boogert	P	0.3	0.5	0.9	0.2
Electronics	J. M. Butterworth	H	0.1	0.1	0.1	0.1
Simulation studies	D. J. Miller	H	0.6	0.6	0.6	0.3
	M. Postranecky	P	0.1	0.1	0.0	0.0
	M. Warren	P	0.1	0.1	0.0	0.0
RAL ID	Engineering	P	0.5	0.9	0.0	0.0
Electronics	Drawing office	P	0.2	0.1	0.0	0.0

Table 1: Fraction of research effort per year. *Joint appointment with RAL. All University groups will be involved in analysis of the beam test data, so this task is not listed explicitly here.

The line labelled "New RA" is the post being requested from the PPRP to reinforce the existing simulation effort and, if granted, will be part of the Cambridge group. The new post would enable us to take full advantage of the simulation expertise already in the CALICE-UK group and would place the UK in a strong position to play a leading role in the simulation of calorimetry within CALICE and for a future linear collider. At Cambridge the RA would work with D.Ward, who is leading the UK simulation effort, and with M.Thomson who is coordinating efforts on energy flow and global detector performance. In particular, this RA would be able to work on new and old energy flow algorithms, to integrate these with the simulation work and to ensure that the results from the test beam are fully exploited in these studies. This is regarded as a very important area but one in which the UK has barely sufficient effort at present. It is assumed that a candidate would not be in post before April 2003, and that they will need to be employed throughout the period of test beam running and analysis.

UCL has devoted a rolling grant RA post to LC work for two years from June 2002. The incumbent, S.Boogert, is making rapid progress both on CALICE modelling for the luminosity spectrum measurement and on laser-based beam monitoring, working with the RHUL group. The post will be needed for CDF from June 2004 when their present responsive RA position ends and their need for analysis effort reaches its peak. However, this is also when the CALICE test beam results will need analysis so we are asking for a 1-year RA position at UCL to allow the present RA to stay on, concentrating on the test beam results and using them - among other things - to give firm predictions of the resolution on the luminosity spectrum.

A.2 Costs to PPRP and PPARC

The funds requested from the PPRP for each of the four FYs covered by this proposal are shown in Table 2. The new RA is costed at £35k per FTE. RAL ID effort is costed at £68k per FTE.

The travel costs are now estimated at £45k per year. This is a small increase over the original proposal as there has been a substantial increase in effort on the project. The £45k is divided as £15k for UK travel, £20k for general CALICE collaboration meetings (every three months) and £10k for CALICE meetings at the LC workshops. In addition, for the beam tests themselves, we have budgeted £30k for FY04/05 and £10k for FY05/06, reflecting the longer time for which the tests will run.

Because of the redefinition of what is counted as PPRP funding, this table now includes more than just the equipment and new RA costs. Besides several minor changes, the meaningful differences from the original proposal arise from several sources; the project continues to FY05/06 rather than FY04/05 due to lengthening the beam test schedule, the RA post is now a full post rather than several pieces at different institutes (and it is now known it will not be funded by the rolling grant) and we now know there will be no “common fund” expenses for setting up the beam line.

	FY02/03	FY03/04	FY04/05	FY05/06	Total
Equipment	19	92	0	0	111
New RA post	0	35	35	35	105
Extension to S.Boogert	0	0	33	8	41
RAL ID effort	45	68	0	0	113
Travel	17	45	75	55	192
Total cost to PPRP	81	240	143	98	**562**

Table 2: Requested funding from PPRP per year. Units are FY02/03 £k.

The total cost to PPARC for each of the four FYs covered by this proposal are shown in Table 3. University PPARC personnel are costed using their actual salaries, including all overheads. The main change in the staff line compared to the original proposal is the higher rolling grant personnel costs, due to putting more effort into the project as requested.

	FY02/03	FY03/04	FY04/05	FY05/06	Total
PPRP cost (above)	81	240	143	98	562
PPARC funded effort	67	88	42	37	234
Total cost to PPARC	148	328	185	135	**796**

Table 3: Total estimated PPARC cost per year. Units are FY02/03 £k.