Review of the R&D for Calorimetry

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On behalf of the ILC Detector R&D Panel
(a Panel of the World-Wide Study Organising Committee)

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WWS-OC asked the Detector R&D panel to organize global reviews of the ongoing Detector R&D

These reviews will be held in conjunction with the Linear Collider Workshops – Review on Calorimetry in Hamburg

The Panel formed a review Committee inviting experts from outside the ILC community

The mission of the review committee is
- enhance the communication within the community
- a critical examination of the R&D status, the goals and the plans
- to give guidance for the future R&D
- help to complete the R&D program on the time-scale of ILC construction
- write a report

The report, after endorsement by WWS, will be published. FALC will take note.

The Committee

Experts from outside the ILC community

Marcella Diemoz	Univ. di Roma I "La Sapienza"
Andrey Golutvin	ITEP Moscow
Kazuhiko Hara	University of Tsukuba
Robert Klanner	Univ. of Hamburg
Peter Loch	University of Arizona
Pierre Petroff	LAL Orsay
Jim Pilcher	University of Chicago
Daniel Pitzl	DESY
Peter Schacht	MPI Munich
Chris Tully	Princeton University

Regional Representatives

Junji Haba	KEK for Asia
Michael Rijssenbeek	Stony Brook Univ. for Americas
Jan Timmermans	NIKHEF for Europe

ILC R&D Board

Bill Willis	Columbia Nevis Labs

R&D Panel

J.C. Brient, Ch. Damerell, W. Lohmann, R. Frey

Secretaries: M. Mende, N. Nagahashi

The Review, plan and strategy

Almost all collaborations delivered the reports in time (2 weeks before the review)

Here we had:
- 1 and ½ day presentations in open sessions
- One day closed sessions
- Executive sessions to draft our conclusions

The Draft of the Conclusions of the Review Committee was available in about a month. After several iterations it is published now on the R&D panel web-page

The Committee's spirit:

- Consider R&D primarily under scientific criteria
- Consider structure and organisation of the collaboration
- Consider resources, goals and future plans

Remember the goals from Physics

- Precision of the jet energy measurement in multi-jet final states:

  $\Delta E \approx 30\% \sqrt{E}$

- Electron, Photon, Pion, Muon identification
- π^0 reconstruction
- τ Lepton decay identification
- Hermeticity
- Precision Luminosity Measurement

The Collaborations and Groups Reviewed

Kansas Group:	Simulation studies for a PFA based ECAL G. Wilson and a group of students from Kansas Univ.
Fermilab Group:	Simulation studies for a dual readout calorimeter 6 physicists from Fermilab and Univ. of Washington
FCAL:	Calorimeters in the very forward region, luminosity measurement 15 groups from US and Europe
DREAM:	Dual readout Calorimeters (4-th concept) 8 groups from US and Europe
SiDCAL:	ECAL and HCAL R&D, PFA based 17 groups, mainly US, HCAL groups are also part of CALICE
CALICE:	ECAL and HCAL R&D, PFA based 41 groups, worldwide

Comments and Recommendations

Kansas University Group

- The simulation studies presented are of excellent quality and the ideas for the calibration of sampling calorimeters are of high interest.
- joining one of the larger collaborations using PFA would result in benefit both for this collaboration and the Kansas group.

Fermilab Group

- Several original and interesting ideas for dual radout calorimetry are investigated by simulations to approach the limits in energy resolution given by physics.
- joining the DREAM collaboration would be the natural way to continue.

Comments and Recommendations

FCAL

- Impressing report on the activities; physics requirements and technical implications were clearly presented.
- High quality of coordination.
- Relatively advanced design for BeamCal and LumiCal, GamCal design studies need still effort.
- Sensor development is ongoing, positive is the close collaboration with several groups working on radiation hard sensors for experiments on hadron machines.
- FE electronics chip design just started. Radiation tolerances and the need of precise timing information should be adressed.
- Enhanced funding of the participating US institutions is necessary and recommended.
- Additional engineering support is needed for proof-of-principle studies at the system level
- Additional support is needed for the exchange of personnel. In view of the breadth of the collaboration among 12 countries, some of which are not provided with high levels of support for HEP, the major participating labs or funding agencies should consider the possiblities to provide such support.

Comments and Recommendations

DREAM

- The novel technology of the DREAM calorimeter is extremely interesting
- The promising results from both test beam measurements and simulations are appreciated
- The ongoing test beam activities are fully supported
- The transition from the current test beam module to a larger scale module needs a list of concerns to be clarified. This list contains e.g.
  - The influence of inert upstream material on the performance of the calorimeter
  - The performance for benchmark physics processes including processes with tau lepton decays
  - Optimisation of the granularity for benchmark processes
  - , Identification for key parameters to control a large scale calorimeter.
  - Calibration and monitoring. Methods currently used in the test beam will not be applicable.
  - Long-term stability of fibres and photo-sensors

- The committee is concerned about the limited recources of the DREAM collaboration and strongly supports a significant strenghtening, in particular to perform the simulation studies to clarify the concerns mentioned above.

Comments and Recommendations

SiDCAL

- Well structured group with clear responsibilities, having provided an excellent report.
- Active in PFA simulation for the design optimisation of the calorimeters in the SiD concept. The committee supports the strenthening of the simulation effort and its integration in the PFA working group.
- Key element of the finely segmented and dense Si/W ECAL is a CMOS readout chip (KPiX) bump-bonded to the sensor pads. Larger scale tests on sensors to quantify effects of stray-capacitances, control signals, cross talk and stability are considered to be mandatory.
- The plan of a full depth prototype equipped with sensor planes is fully supported. However, several technological steps must be validated before, starting with the functioning of a full KPiX chip up to a sensor plane with bump-bonded KPiX chips.
- The HCAL activities within SiDCAL are part of CALICE. The committee fully supports the construction of the chambers to instrument 1 m^3 prototypes of the digital HCAL in the planned test-beam program. For this purpose the necessary funding of the responsible institutions is needed.

Comments and Recommendations

CALICE

- CALICE is a world-wide Collaboration.
- The committee appreciated the excellent quality of the report, the clear structure and responsibilities, the high level of collaboration and the successful use of common infrastructure.
- Physics prototypes of ECAL (SiW, Scin.W) and HCAL (analog, digital) are designed, several are now in beam-tests to demonstrate the feasiability of fine-grained and extremely dense calorimeters with imaging capabilities and
- to collect data using several particle beams and energies for comparison with and refinement of GEANT shower models.
  These data will be essential for a better understanding of the potential of PFA for the jet energy measurment

The committee recommends:

- To complete the construction of the physics prototypes for all technologies sufficiently advanced (need of $1m^3$ digital HCAL prototypes).
- To complete the ongoing test-beam program with electron, muon and hadron beams at CERN and, extended to lower energies, at Fermilab.
- To strengthen the existing feedback with the PFA working group to include the test-beam results in the performance optimisation.
- To define a procedure and goals of the test-beam program in order to aid in the convergence on final detector choices.

Comments and Recommendations

CALICE, cont.

- To Keep the door open for new technologies.
- To develop technical prototypes for ECAL and HCAL.
- To address the issues of a large scale calorimeter operational performance, e.g. calibration, monitoring, long term stability, uniformity, robustness, rate capabilities.

Comments and Recommendations

PFA based Calorimeter, Summary

The committee recommends:

- Together with the GEANT group a plan must be formulated on how best to proceed to feed back ILC test-beam results into the GEANT shower simulation. Also data taken with the upgraded MIPP facility will be of crucial importance to improve the hadron shower simulation.
- The simulation of neutral hadron showers at low energies may suffer by in principle uncertainties, resulting in a bias of the PFA based jet energy measurement. The need of neutral hadron beams data should be considered.
- Comparison of the performances for physics benchmark processes between the PFA approach and a jet energy algorithm based on energy-weighting (H1 @HERA).

- The SiD ECAL group is encouraged to work closer with CALICE to agree e.g. on a procedure for testing their ECAL with CALICE HCAL prototypes.
- FE chip developments on different technologies (CMOS KPiX and GaAs SKIROC) are considered as being reasonable for the time being to reduce technological risks.
- Large scale production issues like quality control, tolerances and cost relevant production options should be considered in future.
- The US funding is considered to be inadequate, including the risk that ideas from the US groups are not sufficiently developed to influence final designs.

Comments and Recommendations

General Conclusions

- With limited resources an impressive body of R&D work has been done towards calorimeter concepts with heretofore-unmatched resolutions
- The test-beam program initiated by CALICE using different sensor technologies for ECAL and HCAL is of highest relevance for the design and construction of ILC detectors. The completion of the program is fully supported. Funding for the completion of the $1m^3$ physics prototypes is stronly recommended.
- The construction of a prototype of the ECAL proposed by SiD is fully supported. The beam tests should be prepared and performed in close collaboration with CALICE on the basis of common standards for the performance.
- The development of technical prototypes by CALICE is fully supported to prepare the engineering of full scale detectors.
- The DREAM Collaboration should enhance the effort in design studies with more realistic assumptions on a detector built with their technology to ensure that such a calorimeter will match the physics requirements. Support is needed to improve the person-power situation for simulation studies.
- FCAL has worked out relatively advanced design for the forward calorimeters. The activities in future should focus on sensor and FE design and prototyping. Just now the most urgent requirement is an improved funding of the US institutions. For future engineering, prototyping and system tests enhanced funding is necessary.

Comments and Recommendations

General Conclusions, cont.

- To prepare the detector EDRs planned for 2010 additional engineering support in all regions is necessary.
- . The committee recognised a continuing imbalance in funding between the three regions. In particular the funding in the Americas and Asia is falling behind the European level, which is itself tight and will need an enhancement in future to face the engineering challenges. This funding situation does not adequantely reflect the physicists talents and interests involved in preparation for the ILC, and should be improved and balanced.

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