Development of a New Concept Detector

Classification Muon and Calorimeter

Personnel and Institution requesting funding John Hauptman

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Collaborating personnel who will work on the project but are not requesting funding here.

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Project Overview

We are developing a complete and new concept detector consisting of four major subsystems: a pixel vertex detector, a single-electron sensitive TPC, a triple-readout fiber calorimeter, and a dual-solenoid muon system. The pixel and TPC developments are the work of other groups working on the ILC (mainly GLD and LDC groups, and the tracking-TPC groups), whereas the calorimeter and muon detector systems are completely new to high energy physics and their successful design and development are critical to the 4th Concept detector.

The triple-readout calorimeter measures three components of every hadronic shower: the finely spatially sampled scintillation light generated by *dE/dx* of all charged particles, the Čerenkov light generated primarily by electrons, and the MeV neutron content correlated with binding energy (BE) losses. These multiply redundant measurements result in exceptional hadronic energy resolution by virtue of event-by-event measurements of all the main fluctuations in hadronic showers: spatial, EM fraction, and binding energy (BE) losses.

The dual-solenoid for the muon system is also new in high energy physics and consists of an inner tracking solenoid to establish the TPC field, and an outer solenoid that returns the flux through the annulus between the solenoids. This geometry accomplishes many objectives: (i) muons are measured in an air volume with a momentum resolution of $\sigma_p/p^2 \sim 3 \times 10^{-4}$ $(\mathrm{GeV/c})^{-1}$; (ii) the physics acceptance for muons is greatly increased at low momenta down to 2-3 GeV/c; (iii) positive identification of muons (especially in conjunction with the triple-readout calorimeter) is enhanced; and, (iv) the cost is reduced over a conventional Fe-chamber sandwich muon system.

The main theme of the 4th Concept is multiply redundant and integrated measurements of all the bosons and fermions of the standard model.

Broader Impact The work on this project is directed from within a single-investigator group of a university professor and students, mainly undergraduate physics majors, working on a new problem and seeking new solutions. This explicity integrates teaching and research since our students have office space in our lab area in the Physics Department. It is a place where they can also do their problem sets.

More funds for undergraduate and beginning graduate students will allow us to hire more students. At this stage of work, several problems are available that are person-intensive, rather than equipment-costly: GEANT4 code for the explicitly detailed simulation of the triple-readout fibers, incorporation of the dual-solenoid into GEANT4 and analysis of the muon system capabilities, and above all, the development of "IVCRoot", the Lecce group's work on a comprehensive 4th concept simulation and physics analysis structure. All of these activities are perfect for physics majors and beginning graduate students, and as we know, these are the best recruitment tools available in physics. At Iowa State, one undergraduate (Matt Spemper) and one graduate student (Sehwook Lee) are working on this, and at Lecce three physics students (Anna Mazzacane, Emanuela Cavallo and Vito Di Benedetto) are working full time. At ISU, I have managed to keep individual students for 1-4 years (e.g., Shauna Dennis and Sam Ose) before they naturally go on.

The achievement of broad impact to enhance scientific and technological understanding and potential benefits to society at large is obtained, in these small high energy physics groups, by sending students out into the world to workshops and conferences. Already Sehwook Lee attended our 4th meeting at Fermilab, along with graduate student Efe Yazgan and postdoc John Strologas. It is the intent of this small request to be able to support these students.

Results of Prior Research

The calorimeter has substantial beam testing at CERN resulting in five publications in *Nucl. Instr. Methods*:

1. "Hadron and Jet Detection with a Dual-Readout Calorimeter", N. Akchurin, *et al.*, *Nucl. Instr. Meths.* **A 537** (2005) 537-561.
2. "Electron Detection with a Dual-Readout Calorimeter", N. Akchurin, *et al.*, *Nucl. Instr. Meths.* **A 536** (2005) 29-51.
3. "Muon Detection with a Dual-Readout Calorimeter", N. Akchurin, *et al.*, *Nucl. Instr. Meths.* **A 533** (2004) 305-321.
4. "Comparison of High-Energy Electromagnetic Shower Profiles Measured with Scintillation and Cerenkov Light", N. Akchurin, *et al.*, *Nucl. Instr. Meths.* **A 548** (2005) 336-354.
5. Separation of Scintillation and Cerenkov Light in an Optical Calorimeter", *Nucl. Instr. Meths.* **A 550** (2005) 185 - 200.

This calorimeter is thoroughly well understood. The level of detail and understanding is beyond what I am used to in other detectors: TPC calorimeters (Berkeley/SLAC), LArgon (SDC), scintillator tile (SDC), HPC (Delphi/LEP), and others.

Current and future work will center on the question of measuring the neutrons in a hadron shower, by several possible means outlined in our detector description, and the calculations and simulations for making a judgment about which method to choose.

The dual-solenoid is being calculated and simulated. This work is ideal for an undergraduate physics major (say, at ISU) coupled with a graduate student at Lecce (Emanuela Cavallo), in addition to the work done by me and Robert Wands with ANSYS at Fermilab. This work is well underway, but requires the solution of physics problems involving the measurement of muons.

Progress to date includes a detector description, several talks at Linear Collider meetings (Paris 2004, SLAC 2004, Snowmass 2005, and Vienna 2005), the development of a team of people who work on the 4th concept, and the development of a full first-principles simulation of the whole detector.

Documents describing work accomplished, all of which are accessible at the website htp://high-energy.physics.iastate.edu/ilc, are

1. "A Fourth Concept Detector", John Hauptman, Snowmass, August 2005.
2. "Fourth Concept Detector (4th)", John Hauptman, Vienna, November 2005.
3. "TPC for 4th", Sorina Popescu, Vienna, November 2005.
4. "DREAM for ILC", Aldo Penzo, Vienna, November 2005.
5. "Description of the Fourth Concept Detector (4th) for the International Linear Collider", Cavallo, it et al., version 0.2, November 2005.
6. "Dual Readout Calorimetry for the ILC", LCRD proposal, Jan. 2005
7. "Ultimate Hadron Calorimetry", LCRD proposal, Jan. 2005.

In addition, a full set of papers and figures of all aspects of the dual-readout calorimeter test is at the website http://www.phys.ttu.edu/dream.

Facilities, Equipment and Other Resources

The work is taking place in Lecce, Ames (ISU), Bucharest (IFIN-HH), Lubbock (TTU), Albuquerque (UMN), and Fermilab. These places have sufficient resources to support this design work, and we not request facilities support.

FY2006 Project Activities and Deliverables

The main deliverable is a Detector Outline document for the LCWS06 Bangalore workshop in March 2006. This will include a full calorimeter simulation, an full understanding of the capabilities of the dual-solenoid for a muon system, and an analysis of the final state in

$$e^+e^- \to HZ \to (H \to X) + e^+e^-, \mu^+\mu^-, \text{and} jj$$

and possibly an analysis of a precision measurement of the t quark mass.

FY2007 Project Activities and Deliverables

The second year will see the design and initial prototype construction of important aspects of a triple-readout calorimeter. This involves a tungsten (W) absorber, three kinds of fibers, a time-history readout of the scintillating and Čerenkov fibers, and a photoconverter selection. Separate funding has been requested for the beam test module itself, and here we only request support for design and testing.

FY2008 Project Activities and Deliverables

The third year will include the beam testing of the triple-readout module and its analysis, and the final definition of the 4th Concept detector for the ILC.

Budget justification: Iowa State University

All funds requested are for the support of people, mostly students, working on the design, physics, simulation and understanding of the 4th Concept detector. We do not request funds for senior personnel, other than travel funds to LCWS meetings, and where possible we will include students on these trips.

Three-year budget, in then-year K$

Institution: Iowa State University

Item	FY2006	FY2007	FY2008	Total
Other Professionals	0	0	0	0
Graduate Students	12.0	12.0	12.0	36.0
Undergraduate Students	6.0	6.0	6.0	18.0
Total Salaries and Wages	18.0	18.0	18.0	54.0
Fringe Benefits	0.5	0.5	0.5	1.5
Total Salaries, Wages and Fringe Benefits	18.5	18.5	18.5	55.5
Equipment	0	0	0	0
Travel	8.0	8.0	8.0	24.0
Materials and Supplies	2.0	2.0	2.0	6.0
Other direct costs	0	0	0	0
Total direct costs	28.5	28.5	28.5	85.5
Indirect costs(1)	11.4	11.4	11.4	34.2
Total direct and indirect costs	39.3	39.9	39.9	119.7