

## DPF Task Force, Committee on 'Instrumentation Schools'

David Asner (PNNL), Ariella Cattai (CERN, co-chair), David MacFarlane (SLAC), Ron Lipton (Fermilab), Adam Para (Fermilab, co-chair), Gabriella Sciolla (Brandeis U.), Sally Seidel (U. of New Mexico)

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### 1. Introduction:

It is widely perceived that the level of technical experience and expertise among young experimentalists in High Energy Physics is approaching alarming levels. Such anecdotal statements were substantiated by a broad poll of the community conducted by the ICFA Instrumentation Panel in February 2010 [1,2]. The poll has evidenced that:

- A significant fraction of experimentalists is lacking good understanding of their own experiments
- The principal mode of education in the instrumentation area is 'on the job training' and instructions from peers. A particularly disturbing trend is the insignificant role of university-based training among the youngest scientists

An additional informal poll of various US universities [3] indicates that the area of detectors and instrumentation is very poorly covered by curriculum in majority of the schools, although there are several examples of cross-disciplinary courses offered at several school (Purdue, UT Austin)

### 2. Short analysis of root causes

Relative lack of experience and expertise in the detectors and instrumentation area among young physicists is only symptom and a consequence of several fundamental problems of the field of High Energy Physics. These problems are reflecting the evolution of the field itself; they include:

- A major change in the scope and nature of the experiments. Typical life cycle of an experiment extends over a decade or more thus not giving students a chance to participate and understand the various phases from the conception, thorough the R&D and construction to commissioning, data taking and analysis. The scale and technical sophistication of the experiments has increased considerably and as a result a possible role of the students and their contribution to the experiments has been reduced considerably.
- Technical education is best if acquired in the course of participation in solving of real life technical problems. It is widely reported that the technical infrastructure and the support staff, engineers and technicians, at universities has been reduced considerably over the past two decades. This erosion of the technical basis is a major obstacle in providing the education in technical matters.

A major contribution to the problems with education in technical matters is a deep cultural divide within the academic community, whereby the scientific excellence in detectors and instrumentation is not given

its proper recognition. The perceived scientific value of purely analytical skills is greatly inflated, whereas even major scientific advances in detectors and instrumentation area are not given proper recognition. These factor greatly discourage , or event prevent, young scientists from pursuing the career in technical aspects of experimental high energy physics, while at the same time sending a negative signal to the students.

This cultural biases is reflected in the major imbalance of most of the textbooks. While technology monographs and laboratory manuals are available, standard undergraduate and graduate texts on particle physics do not integrate experimental with theoretical information, typically devoting at most a chapter to the topic of experimental technique The lack of properly balanced textbooks is a major impediment in providing the well rounded education and it influences a perception of the relative importance of various subjects by the students, thus further aggravating the situation.

### **3. Existing Instrumentation Schools**

Need for better education in experimental techniques has been widely recognized and many instrumentation schools are organized around the world [4]. These schools, initiated by the ICFA Instrumentation Panel, offer introductory courses on detectors and instrumentation and they often include practical laboratory components. In addition to the ICFA-sponsored international schools there are several editions of such schools organized on national levels (Italy, Turkey, Argentina, China being the recent examples).

The laboratory component of these schools is an essential educational ingredient, as universally agreed by instructors and students, but the technical complexity of possible laboratory courses is frequently limited by logistics and other practical constraints imposed by the location of the school. To elevate the level of laboratory courses a new series of schools, EDIT, has been initiated. These schools are organized at high energy physics laboratories and they take advantage of the advanced equipment and setup available there. The first edition of EDIT school was organized in January 2011 at CERN, the next edition is planned in February 2012 at Fermilab. The survey of the participants of the CERN edition of EDIT indicates that the importance of the laboratory courses was a key factor in the overall success of the school.

Another venue for education in detector matters is provided at IEEE Nuclear Science Symposia, where several technical courses are offered, usually before the Symposium itself. Typically these are one-day courses and they are attended by ~150 students per course.

While all of these educational initiatives play an important role and they are highly appreciated by the students, they reach relatively small fraction of the young physicists and they are naturally limited in scope. In addition these schools and courses often involve a broad representation of students with varying backgrounds, thus limiting the depth of the offered courses.

Probably the most important limitation of such a remedial education is related to the brief duration of such courses. Gaining the understanding and developing an expertise in instrumentation requires long time and prolonged contact with the experimental equipment and it should be developed at universities a part of the academic education.

#### **4. Need for organized, systematic and in-depth education in detector technologies.**

While one-or-two-week-long detector schools help filling the gaps in the students' preparation, they cannot provide thorough enough education necessary to design, construct or even operate modern experiments. Much better results could be achieved with more traditional semester-long courses focusing on particle detectors. The additional time would allow the lecturer to cover the material in a more systematic way, and would give the students the time to better assimilate the concepts and apply and exercise them in the laboratory conditions.

Unfortunately, single Universities often cannot afford to offer such courses, due to the large investment of faculty time and lab equipment involved compared to the relatively small number of students who could benefit from it. A more global model has to be developed in which such courses are developed and offered by a consortium of Universities in areas where many HEP groups are concentrated, or in collaboration with National Laboratories or CERN, where students are stationed for long periods of time.

In order to make these classes worthy of academic credit even at the most demanding Graduate Schools, the curriculum must be developed to cover instrumentation in some depth, and have both a theoretical introduction to the topic and a laboratory component. Scientists with the highest qualifications should rigorously teach such courses, and students should be periodically tested on their theoretical understanding of the material as well as their ability to apply such concepts in the lab.

#### **5. Possible role of national laboratories** in the process of detectors and instrumentation education. (David Asner)

#### **6. Continuing education.**

High Energy Physics (as we like to believe) used to be at the forefront of technological advances in sensors, electronics and computing areas. This is no longer true. The rapid of progress in electronics, computing, material sciences is driven by a very broad combination of science, technology and consumer needs and it advances the limits of technology with ever increasing rate.

This process of technological acceleration renders challenges our technical expertise severely: the tools evolve rapidly changing their functionality, new tools and technologies are being developed. It is very important that some mechanism is developed to allow the 'detectors and technical experts' to keep with and to take advantage of the evolving technologies.

#### **7. A list of possible specific initiatives recommended by the committee.**

We recognize that a process of improving the level of technical skills of young scientists is very complicated, it will take time and there are several areas where major changes are necessary. Moreover the improvements must be addressed to several groups of physicist in parallel. Whereas the primary source of the education must be at the universities, some remedial forms of education are necessary for the current graduate students and post-docs, and even for the senior physicist. In the following we present a collection of possible initiatives which have been identified in our interactions with a wide circle of our colleagues.

- a. Organization and participation in the ICFA initiated and sponsored school (EDIT, ICFA Instrumentation School) should be strongly supported. Some form of the collaboration with various national schools should be developed. A development of common set of lectures and lab courses would be very beneficial.
- b. The US Particle Accelerator School provides educational programs in the field of beams and their associated accelerator technologies not otherwise available to the community of science and technology. It is a well recognized consortium providing academic-level education with a very successful organization and considerable experience in organization of academic-level courses. Broadening of the offered selection of courses to include detectors and instrumentation would be a very positive development. In a longer term it is desirable to organize a new session dedicated entirely to detectors only, perhaps held at (rotating?) national laboratories.
- c. Advanced topical schools focused on specific detection techniques or detector systems. They can be held at national laboratories or at universities where the relevant infrastructure and expertise is located. Such schools would be aimed at relatively advanced audience and they could be of potential interest for industrial collaboration: on one hand they can serve as a platform for dissemination of the knowledge latest technological advances, on the other hand they can be of interest to industry to educate the technical staff engaged in the R&D efforts.
- d. Traditional graduate-level courses on detector technologies offered at held at national laboratories or regional centers, as discussed in section 4.
- e. Internships for graduate or undergraduate students to participate in leading edge detector developments with renowned experts (at the labs or at the universities). The internships (ranging from three month to one year) would enable the students to participate in the development of new technologies and, at the same time, they would provide a mechanism for dissemination of the knowledge and experience of the detector experts.
- f. Detector-oriented series of lectures or classes (perhaps with some practical component) offered by world-class experts visiting universities.
- g. Development of a standard curriculum (program, lecture notes, transparencies, problem sets and lab component) which could be used as a starting point for the development of a detector-oriented course or for inclusion into an experimental particle physics course. Such material will be available online to the world-wide particle physics community.
- h. Development of detector technology teaching facilities. Use parts of the retired experiments: D0, CDF, BaBar, CLEO, etc.. Establish dedicated test beam facility for demonstration and examination various detection techniques. [5]

## Appendices

1. Adam Para, Reflections on Understanding of Detectors and Instrumentation, talk at the Detectors R&D Workshop, Fermilab, October 2010.
2. Ariella Cattai and Adam Para, Preliminary results from the survey on the necessity of a Detectors and Instrumentation School, April 2010
3. Informal Survey of US Universities on the education in Detectors and Instrumentation [Ron Lipton]
4. Ariella Cattai, Survey of the Instrumentation Schools.
5. Adam Para, John Hauptman and Hanna Arnold, The CDF and D0 detectors as laboratories for students