TWEPP-07 Executive Summary

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I) Some Statistics

The Topical Workshop on Electronics for Particle Physics (TWEPP-07) took place in Prague, Czech Republic, from 3 Sep to 7 Sep 2007. Nine invited and 89 contributed papers (61 oral and 28 poster) were presented in 7 plenary and 13 parallel sessions to an audience of approximately 160 participants. Sixteen of these participants came from the United States and nine from Japan, while the rest originated from Europe. Of all presented papers, 58% referred to the LHC project, 9% to the SLHC upgrade and 33% to ILC and other experiments.

II) Session summaries

Of the twenty sessions of the workshop, seven were dedicated to **Systems, Installation and Commissioning**, three to **ASICs** and three to **Trigger**. In addition, three sessions were devoted to **Power Supply and Distribution**, one to **Optical Links** and the **Poster Session** regrouped 28 posters. Some of the main conclusions from these sessions are summarized in Sections A to F below.

A. Systems, Installation and Commissioning

Significant progress was reported on the installation and commissioning of LHC detector systems. Many sub-detectors have actively started their final full commissioning tests with cosmics and the operational performance obtained is, in general, in good agreement with expectations. The installation and commissioning of the associated electronic systems, with all related software and firmware for controls monitoring and readout, has required an enormous effort from the collaborations.

A large variety of practical difficulties have been encountered to finalize the installation of the electronic systems of the LHC experiments. The installation and verification of the complicated services for the front-end electronics (power, cooling, cables, etc.) have often turned out to be more difficult than anticipated and have required a significant manpower investment. The sequential nature of installing such services for the concentric layers of detectors has implied that some problems encountered at the local sub-system level have affected the global installation schedule. The fragility and insufficient reliability of some of the produced electronics have in some cases posed significant problems as an efficient quality assurance programme for advanced, highly integrated and minimal mass electronics is difficult to implement across a large community of many institutes and companies, with different expertise and under tight time pressure. The widespread use of high density kapton hybrids and kapton cables has in several cases caused serious reliability problems that had to be resolved with specific emergency programmes. The installation and commissioning of global electronic infrastructure covering mains power distribution, cooling systems for racks and crates, and a large base of low voltage and high voltage power supplies have also turned out to be more complicated than initially expected, even though these services are to a large extent based on commercially available equipment.

Extensive Research and Development (R&D) work in electronics for ILC and first initial R&D plans to prepare for SLHC were presented. The very large channel count needed for future particle physics detectors poses a major challenge for the appropriate powering and cooling of the front-end electronics. Very low power front-ends are vital to assure that the material budget for delivering power and cooling will not significantly degrade the physics performance of such detectors. For instance, the use of pulsed power for ILC and other future linear collider experiments was presented.

For tracking detectors a multitude of different pixel detector schemes are being extensively studied within the community. The use of fully integrated pixel detector and electronics (MAPS, DEPFET, SOI) is attractive for some applications whereas separate electronics chips and detectors connected via bump bonding or 3D packaging will be needed for other applications. The final choice of pixel detector and electronics for a given application depends strongly on the radiation environment, occupancy, and finally system size and related costs. For SLHC tracking the use of short silicon strips will pose new challenges to low power front-ends and hybrid and inter-connection schemes needed to connect readout chips and detectors. The development of dedicated front-end electronics for micro pattern gas detectors is emerging in the community for use in general tracking systems, for ILC TPC applications, and for high-rate SLHC muon detectors.

The proposed use of highly segmented 'tracking' calorimeters for ILC has triggered the development of appropriate front-end electronics. The use of large channel count, limited resolution, and low power electronics is new to this field and several detector and readout electronic developments for this were presented.

B. ASICs

Three ASIC sessions were organized: the first describing front-end ASICs for tracking detectors (silicon or gas), the second presenting ASICs for the ILC detectors, and the third looking at developments for the future (except ILC).

The first ASIC session showed the increasing complexity and performance of chips that continually reach higher levels of integration and versatility. Several designs demonstrated the excellent performance and density achieved with 130-nm technologies, in particular for LHC upgrade proposals. Also, a few designs were presented using 0.35 µm technology or SiGe processes for high voltage or large dynamic range applications.

The second ASIC session was dominated by designs for ILC, from pixel detectors to trackers and calorimeters. In addition to the normal requirements of ASICs for HEP, most ILC designs emphasize techniques aimed at lowering the power consumption of the circuits. While this is facilitated by the presence of a beam with a very low duty cycle, considerations on low in-detector mass are extremely important for ILC and demand a system design approach where this aspect is taken into account from the very early stage of design.

The third session looked into future directions such as ADC developments or high bandwidth optical transmission of data, control and timing (GBT). The large-scale use of integrated front-end electronics and optical links in highly radioactive environments will be a major challenge for SLHC. The use of standardized radiation-hard optical links to carry controls, monitoring, timing and readout information is considered an attractive solution. It is acknowledged that the use of standardized optical links will require extensive discussions on appropriate system architectures and standardized front-end chip interfaces.

A large variety of IC technologies are currently used for R&D activities. The use of a common technology base would allow sharing of building blocks and the reduction of the radiation-hardness qualification load in the community. The appropriate technology choice will, however, depend strongly on the specific time-scale of the different projects and on the cost of accessing such technologies. It is clear that the increasing complexity of chips, making them real 'systems on chips', will require more and more expertise from larger and larger teams. These teams should be encouraged to collaborate on a few (well) selected technologies.

Following the ASIC sessions, a *Microelectronics User's Group* meeting was organized to spread information about progress in making the new deep sub-micron technologies available to the HEP community.

CERN has completed the detailed negotiation with the foundry for making the 130 and 90 nm technologies available to the community following the same model applied in the past years for the ¼ micron technology. The new contract has been in place since May 2007 and pricing information is available on demand to users in the community.

The technical support for designs in 130 nm has also been significantly improved through the delivery of a number of digital design kits to various Institutes. The new design kit significantly facilitates the assembly of fully digital and mixed signal chips. The kit incorporates a commercial digital library, the foundry kit constraint files, and the Cadence Encounter design flow into a coherent package.

The number of Institutes requiring the design kit is expected to rise in the coming months as a new series of SLHC and ILC oriented projects are about to start.

Users have been urged to plan sufficiently in advance for the submission of a common MPW run in early 2008, as the price of an internally organized MPW can be very competitive with respect to a standard commercial run if sufficient users are synchronized in time.

C. Trigger

Impressive progress is being made in commissioning the trigger electronics for LHC experiments and there is growing confidence that these systems will deliver to specification.

Manufacturing problems with the high density circuit boards have been largely overcome through close cooperation with the manufacturers and ongoing attention to detail.

Commissioning has highlighted issues such as cooling problems and power supply oscillation, illustrating the need to work with the real infrastructure as early as possible in the testing process.

The resulting trigger systems include a significant number of different boards, many with more than one FPGA on them, representing a large burden for support of firmware, diagnostic software, and engineering expertise for the duration of the lifetime of these systems.

A number of designers have identified that their task would have been easier if they had used the latest, larger FPGA parts. Designing for ‘advanced’ parts early on will cost more at the prototype stage but will deliver benefits in reduced design effort and production costs.

D. Power Supply and Distribution

Since the availability of suitable COTS power supplies is limited, considerable effort has been invested in the design and production of the power supply and distribution systems of detectors in the LHC experiments. Depending on the technical requirements and the constraints of specific detectors, either custom solutions or commercial systems have been selected. The production and installation of custom components is now largely completed, having required much effort for their production and extensive quality control, sometimes hindered by fluctuating personnel resources. For some of the commercial components, the construction and qualification of prototypes has required more time than anticipated, and production is currently still on-going.

In general, the overall efficiency of the present LHC power distribution systems is low, with large power dissipation in long cables and often with sizeable power supply inefficiencies. New approaches are needed to address these issues for the next generation of systems. Given the pulsed nature of the ILC, power cycling is under consideration for relevant parts of the detectors, which could lead to a 99% reduction in the power required for the very front-end electronics, whereas for SLHC, either on-detector DC–DC conversion or serial powering are strong candidates. Studies on both approaches have started and the initial results look promising. In the domain of DC–DC conversion, developments based on piezo ceramic transformers, switched capacitor converters, and inductor-based switching DC–DC converters were described, as was an exploration of commercial buck converters using air-cored inductors. A feasibility study of serial powering, as applied to ATLAS SCT modules, was presented.

The topical day on power supply and distribution was concluded by a *discussion session* which is summarized below.

Power management for detectors is a complex engineering issue and encompasses several disciplines -electrical and electronic engineering, detector design as well as systems engineering.

Too often, the design of a specific power supply has been tackled in relative isolation from the conception of the overall power management of the detector. There is a need for overall coordination, but such a task, for an LHC-sized experiment, is too large to be carried out by the ‘Electronics Coordinator’ alone, and requires adequate manpower and resources.

An engineering office is needed from the early stages of the design of a detector or detector upgrade to coordinate the design of the power management and distribution. This office should have a complete view and control over the power system, end to end, as well as over issues of electro-magnetic compatibility and the integration of associated services.

For new detectors, there is an urgent need to address the trend for on-detector power distribution to bring the power source closer to the detector in order to avoid costly and wasteful installations, to improve the efficiency of power conversion as well as to minimize the amount of material in the detector. ATLAS has made proposals for developments (radiation tolerant DC–DC converters and serial powering). CMS has yet to formalize its needs, pending studies of the power requirements of a revised tracker, but is closely following the approach being investigated by ATLAS.

Current discussions in the ILC are concentrated around power pulsing techniques, although on-detector DC–DC conversion may be needed to manage peak loads and to limit cable volumes. It is worth noting that the use of pulsed power systems in high magnetic field environments might pose new challenges.

There is a need to coordinate the procurement of COTS power supplies (typically as bulk power sources) to avoid too large a diversity of equipment with attendant support problems, and to ensure that the simplest, cheapest and most reliable solutions are chosen.

The availability of radiation-tolerant voltage regulators for local front-end regulation also needs to be assured for the next generation of applications.

In conclusion, **it was agreed** that to avoid the duplication of effort and the a posteriori systems engineering often seen in the LHC experiments, it is desirable to adopt a coordinated approach to the power management and distribution for large experiments. It is recommended that **a working group** be set up to assess power-related issues, including:

– A summary of lessons to be learned from the LHC detectors;

– Developments likely to be required by future upgrades and experiments (e.g. SLHC & ILC), such as on-detector power distribution, electrical and energy management systems;

– Methodologies for the quality control and qualification of power systems (safety, electro-magnetic compatibility, basic electrical and environmental measurements including tolerance to radiation and magnetic fields).

E. Optical Links

The transmission of signals between the detectors and the readout, trigger, timing and control modules in the counting rooms of LHC experiments has been the subject of intensive development efforts over the years. In nearly all present configurations, electrical signals from the detectors are transmitted via radiation-resistant, high bandwidth optical fibres to the back-ends of the system. The production, assembly, integration and commissioning of these optical links were in some cases tracked by very large scale QA programmes. In particular, optical link quality control tools for system integration and commissioning phases were presented. These tools provide powerful means to localize and identify faults in the field in a short time. Time is an issue as testing must proceed in parallel with several concurrent activities, each with their own pressing schedule. So far, the number of unrecoverable faulty connections has been kept to a minimum and the quality of the installed systems was shown to be very high.

Development efforts recently initiated are investigating the possibility of using similar optical systems at SLHC. Thanks to the rapid evolution of technology, increasing the link bandwidth does not seem to be a major issue. More critical is the radiation hardness of some of the optical fibres, lasers and pin photodiodes. In the long wavelength region (1310–1550 nm), commercial radiation-hard optical fibres exist. For instance, extended tests for the LHC accelerator have allowed the identification of a single mode fibre with a radiation-induced attenuation not exceeding a few dB/km even at the highest radiation doses expected at SLHC. On the laser transmitter front, however, edge emitting lasers operating in the 1310 nm wavelength range show large threshold shifts when exposed to the fluences expected in SLHC. Vertical Cavity Surface Emitting Lasers (VCSELs) operating at 850 nm do not show such pronounced degradation and first candidates have recently been tested. The radiation resistance of the corresponding high bandwidth multi-mode fibres still needs to be validated. Further R&D is required to address these open issues and converge on a few technologies deserving full qualification.

The joint ATLAS-CMS Opto-Electronics Working Group meeting which followed the optical link session groups together in a collaboration framework several teams active in the optical link field. Three sub-groups summarized their progress on lessons learned from LHC, procedures for radiation testing, and functional evaluation of optical links for SLHC. Common project proposals were presented, targeting optical link development as well as evaluation benches.

F. Posters

The poster session was an important part of the workshop. It provided an opportunity for a large number of diverse discussions to take place that could not be accommodated in a regular session. The session provided individuals with the opportunity to seek out presenters with similar interests and to talk to them in an informal setting which provides an opportunity for extended questions. It was clear that the poster authors had made a significant effort in preparing their posters.

III) CONCLUSION

The TWEPP-07 workshop was an excellent forum to discuss progress of running projects and discover new developments in the field of electronics for particle physics.

The large fraction (42%) of non-LHC papers which were presented reinforces our conviction that a workshop mixing communities working on different experiments at different stages of development is extremely useful. It will contribute to disseminating knowledge and know-how in the field, and will eventually improve the quality and reliability of the systems built.