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The LHC experiments are the result of a coordinated effort of hundreds of labs worldwide, with multiple technologies that are not unique to CERN. To be precise, CERN has provided the locale and opportunity to catalyze a wide supranational community of researchers in engineering and experimental physics, each of whom has found in this ambitious project their own scientific purpose for more than a decade.

Mankind's largest machine is a measuring instrument. LHC is a precision multifunctional measurement machine unsurpassed in many of its key components. LHC has led us to the frontiers of a new physics after the Higgs boson discovery. In our Galilean approach, the horizons of new knowledge arise only at the frontiers of instrumentation and measurement technology.

Moreover, the largest machine ever built by humans is not an instrument for war, nor economic profit, but of knowledge. This powerful tool is aimed at basic research, i.e. it has a cultural purpose. The LHC is a machine to rethink such basic concepts as the structure of matter, mass, and the composition of the universe. This new frontier of technology is not available to individuals or even nations, not even the most visionary or most wealthy, wishing to reduce technological research to mere product innovation and private market-driven development. For all of these reasons, we accepted an invitation to realize a Special Issue on the "Instrumentation and Measurement Technologies for the CERN Large Hadron Collider" for the *I&M Magazine*.

The first tutorial of the Special Issue arises from **ATLAS (A Toroidal LHC Apparatus)**, the largest physics experiment at LHC. Measuring 46 m long, 25 m high and 25 m wide, the 7000 metric ton ATLAS detector is the largest volume particle detector ever constructed. More than 3000 scientists from 174 institutes in 38 countries work on the ATLAS experiment to investigate a wide range of physics, from the search for the Higgs boson to extra dimensions and particles that could make up dark matter. Particle beams collide at the center of the ATLAS detector, making collision debris in the form of new particles which fly out from the collision point in all directions. Six different detecting subsystems arranged in layers around the collision point record the paths, momentum, and energy of the particles, allowing them to be individually identified. A huge magnet system bends the paths of charged particles so that their momenta can be measured. The paper written by Philippe Farthouat goes through the architecture choices for the most important parts of the detector, as well as some specific developments in analog and digital signal processing.

The second tutorial concerns **LHCb (LHC beauty experiment)**, which is set up to explore what happened after the Big Bang to allow matter to survive and build the universe we inhabit today. The LHCb's mission is to record the decay of particles containing *b* and anti-*b* quarks, collectively known as *B mesons*. The experiment's 4,500 metric ton detector is specifically designed to filter out these particles and the products of their decay. About 670 scientists representing 65 different universities and laboratories (including five associated institutions) from sixteen countries are involved in the project, with support from about 250 technicians and engineers. The authoritative paper of its spokesperson, Pierluigi Campana, provides meaningful insight not only into the detector and data processing technologies for the LHCb experiment but also its main physics.

Another paper comes out from the **most recent, smallest, but smart experiment of LHC: UA9**. The UA9 experimental equipment was installed in March 2009, in anticipation of future ultra-high luminosity operation. This experiment will assess the use of bent silicon crystals as primary collimators to coherently direct the beam halo onto the secondary absorber, thus reducing out-scattering, beam losses in critical regions, and radiation load. Note that the energy in the two LHC beams is sufficient to melt almost one ton of copper! Particles with reduced energy or nuclear debris are prone to depart from stable orbits in the dispersive area of the accelerator, thus producing radiation damage in such sensitive devices as the superconducting magnets. The tutorial of UA9's spokesperson, Walter Scandale, describes how UA9 detectors produced unprecedented evidence of this beneficial crystal-based collimation by highlighting the method used to measure the reduced flux of nuclear debris generated by channeled particles.

The Sources, Targets, and Interactions Group led by Roberto Losito studies particle generation and interception and other beam interactions with matter. The paper by Alessandro Masi reports research of the Section of Equipment Controls and Electronics to provide **low-uncertainty position transducers for the LHC Collimators**. Achieving measurement uncertainty of a few micrometers over a measurement range of tens of mm is extremely challenging in the LHC environment. The collimators experience a high level of ionizing radiation on the order of MGy/year; thus, no electronics can be embedded in the sensors which must be radiation resistant. Radiation-safe alcoves for electronics can be one km removed from the collimator itself, reducing the signal–to-noise ratio at the conditioning electronics input and presenting a complex matching problem because of the cable length. Moreover, some collimators are affected by interfering magnetic fields produced by nearby high current cables.

Indisputably, one of most important I&M technologies in particle accelerators is beam instrumentation. Rhodri Jones is leader of the **Beam Instrumentation Group** within Paul Collier's Beams Department. Beam instruments are the *ears* and *eyes* of the accelerator, and they provide the unique way *watch* the beam, by allowing its properties and quality to be characterized. Rhodri's tutorial describes the exceptional metrological and technological challenges of measuring the LHC's beam position with a resolution better than ten micrometers, at a rate of up to 40 MHz and a dynamic range from 1 bunch of $\sim 2\times10^9$ charges to 2808 bunches of $\sim 2\times10^{11}$ charges, using ultra-high vacuum sensors operating near 2 K, with the requirement for radiation tolerant electronics located up to 3 km from the sensors.

The LHC doubled world-wide superconducting technology production during its construction. Amalia Ballarino's **Superconducting Cables and Devices Section**, inside the Magnets, Superconductors, and Cryostats (MSC) Group led by Luca Bottura, is developing new I&M technologies for superconducting applications. Co-authored by Guiseppe Montenero Ballarino's paper reports recent advancements in the measurement of *critical current*, the capacity of a device to carry electrical current and a key design parameter for any large-scale superconductivity application.

Superconduction requires effective measurement of the cryogenic temperature. LHC superconducting magnet temperature measurements are used in feedback closed control loops to adjust the cooling power; thus, measurement uncertainty has a direct impact on the temperature control range that must be as wide as possible to maintain operating conditions that allow particle beams to circulate around the LHC accelerator. Measurement uncertainty results from the intrinsic quality of the temperature sensor, the conditioning electronics, and the calibration; the **LHC design target was ± 0.01 K in the range 1.6 to 2.2 K**. The paper by Juan Casas of the MSC Group's Cryolab & Instrumentation Section shows how the LHC requirements were satisfied for more than 5,000 cryogenic temperature sensors operating in a high radiation environment.

According to the opinion of LHC project Leader Lyn Evans, **power conversion and the metrology for its quality assessment**, is one key factor for LHC achievement. Individual LHC sector currents must be controlled with very high accuracy in amplitude and time to ensure that the beam of particles sees the same magnetic field in all sectors of the machine: ± 5 ppm of tracking among all sectors and better than ± 2 ppm of short-term stability at 13 kA. Miguel Cerqueira Bastos, head of the High Precision Measurements Section of Jean Paul Burnet's Electronic Power Converters Group, describes the technical choices and compromises made in the design, evaluation, integration, and operation of the current transducers and ADCs at the heart of the current measurement chain of the LHC main power converters.

This Issue cannot highlight all of the impressive I&M technologies of the LHC machine. It is our hope that this modest insight will reveal the most important result of LHC: the experiences and **enthusiasm** that motivated all of the authors during these years of hard work. This enthusiasm also infected the **reviewers** of the papers of this Issue, whom we warmly thank for their patience and professionalism: Francisco Alegria, Aldo Baccigalupi, Salvo Baglio, Matteo Bertocco, Luca Bottura, Mauro D'Arco, Alessandro Danisi, Luca De Vito, Steve Dyer, Kim Fowler, Nicola Giaquinto, Pedro Girao, Francesco La Monaca, Philippe Lebrun, Giuseppe Iacobucci, Claudio Narduzzi, Roberto Ottoboni, Nicola Pasquino, Pedro Ramos, Mario Savino, Rosario Schiano lo Moriello, Ezio Todesco, and Wendy Van Moer.