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Editorial

Theoretical and experimental physics meet metrology engineering at the particle accelerators frontiers for new knowledge: the METROPAW viewpoint at the IMEKO TC-4 2014 Conference

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Nowadays, physics is facing several key problems, such as having the ability to produce small quantities of anti-matter in physics laboratories despite not having a proven explanation why in this Universe it seems to be virtually absent. We have discovered neutrinos, but we have not yet understood if they are possibly their own antiparticles.

At CERN, perhaps we are approaching an understanding of how mass is generated for all the elementary particles, but a more in-depth and wider comprehension is still needed. The Universe is expanding, and the expansion is accelerating; what generates all this if normally gravity is attractive? The speed of stars with respect to the centres of galaxies increases according to their radius more than would be expected given the effect of gravity generated by the mass of the innermost objects: why?

The answers to these and to other important questions can come not only from high-energy, but also from high-precision and well-conceivable experiments. As a matter of fact, in a very intuitive and effective way, the trends of the technological efforts in particle accelerators can be synthesised according to the view of Lucio Rossi from CERN (figure 1). However, even if in the high-precision frontier the importance of metrology seems to be prominent, the other approach of high-energy metrology also plays a determining role.

In such a context, the definition of measurement techniques, metrological chains and instruments of unprecedented precision plays a crucial role. This is an activity that has always been a harbinger of great progress for humanity: it is not just new knowledge about the world that leads to positive changes in society that were otherwise unimaginable before, but even more striking is the fact that in an attempt to attain new research objectives, new technologies are adapted, developed or invented. These innovative technologies, when properly used, are able to improve the lives of all individuals. For these reasons, any fruitful research should always recruit all the players who take part in the work equally.

A first effort in this direction of integrating the viewpoints of the main players of this scenario was made at the IMEKO TC-4 2014 Conference in Benevento (Italy) (figure 2, left) by the Special Track 'Theoretical and experimental physics meet metrology engineering at the particle accelerators frontiers for new knowledge' (Metrology for Particle Accelerators Workshop: METROPAW 2014, figure 2, right). Within this framework, theoretical and experimental physicists met engineering metrologists with the specific aim of focusing the main contribution that metrology is called to make to particle accelerator physics and engineering. The Special Track expresses clearly in the title the intentions of looking at a mutually-beneficial exchange of knowledge and experience among the instrumentation and measurement engineers and the physicists working in highly challenging scientific environments. A special contribution was made both by CERN and INFN in this direction.

In short, in many areas there is a clear feeling that the long-awaited answers can be found experimentally, but current technological limits require huge efforts to design and implement more and more refined experiments.

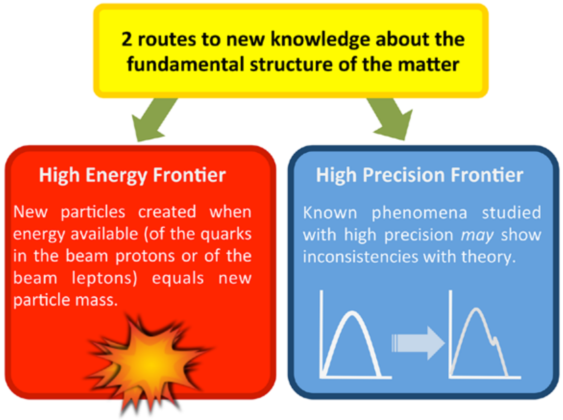

Figure 1. The main two routes to new knowledge about the fundamental structure of matter (courtesy of Lucio Rossi, CERN).

Figure 2. Logos of (left) the XX IMEKO TC-4 Symposium on 'Research on Electrical and Electronic Measurements for the Economic Upturn', and (right) Special Track 'Theoretical and experimental physics meet metrology engineering at the particle accelerators frontiers for new knowledge' (Metrology for Particle Accelerators Workshop: METROPAW 2014) held in Benevento (Italy) on September 15–17 and 16, respectively, 2014.

In an extreme synthesis, the leading concept of Stephan Russenschuck from CERN about the so-called '*C*3' [1] for establishing coherence in the specific case of magnetic measurements, acted as a paradigm for the experimental activity in particle accelerators as a whole, from the theory, to the machine physics and engineering up to the experiment. According to the *C*3 paradigm, magnetic measurements are necessary for establishing a suitable experimental coherence among machine requirements, beam physics simulations and magnet development. Beam physicists allocate a suitable budget for magnet misalignment and require experimental magnetic field maps pointing out the field errors. Analogous examples can be found in all the experimental activity, from the experiment detectors up to the other vital components of the machine. In the METROPAW paradigm, this coherence was also extended to the physics theory, for establishing a wider consistency between theory and experiment.

To this end, *Measurement Science and Technology* is paying special attention to the topics of METROPAW 2014, by hosting a number of scientific articles that address both the fundamental aspects of high-quality experiments and their consequences in particle accelerator physics and engineering. A collection of 6 of the most significant papers of METROPAW 2014, extended significantly for journal publication, is introduced here and complements a broader collection of past and future efforts published by *Measurement Science and Technology* on these topics.

De Lellis *et al* [2] tackle the limitations of the use of carbon beams, arising from poor knowledge about the effects of secondary fragments on irradiated tissues. The knowledge of the flux of secondary particles plays a key role in the real-time monitoring of the dose profile in hadron therapy. This paper presents a detector based on the technology of the emulsion cloud chamber (ECC) for fragmentation measurements performing a sub-micrometric 3D spatial resolution, excellent multi-particle separation and large angle track recognition. The reported experimental results were obtained by exposing two ECC detectors to the fragments produced by a 400 MeV n^{1} ^{12}C beam on a composite target at the GSI laboratory in Germany. The ECC was exposed inside a more complex detector, named

FIRST, in order to collect fragments with a continuous angular distribution in the range $(47,81)^\circ$ with respect to the beam axis.

Danisi *et al* [3] are working on an ironless inductive position sensor (I2PS) for the challenging task of measuring the apertures of the large hadron collider (LHC) collimators, as well as the positions of their axes. I2PS keeps the advantages of the linear variable differential transformers, by improving their accuracy limited by the peculiar parasitic effect. The aim of this paper is to give a complete and exhaustive impact evaluation, from the metrological viewpoint, of these parasitic effects on these two fundamental sensor solutions.

Drago *et al* [4] are working on improving the diagnostics of the latest generation of storage rings, both light sources and colliders, in order to achieve the most challenging design parameters. In particular, a technique aimed at improving the existing luminosity diagnostics for the collider DAΦNE (double annular-factory for nice experiments), at the e+/e Φ factory of the Laboratori Nazionali di Frascati (Italy), is presented and discussed.

D'Elia *et al* [5] propose a method for analysing coupled resonators for the generation of structure modes (resonant frequencies) and predicting structural behaviour in a variety of cases. The frequency of a single resonator in the chain is varied in order to produce a change in the frequencies of all the structure modes. It is possible to find certain invariants linearly dependent on all the unchanged parameters of the circuit. These invariants have an algebraic representation that allows the extraction of the structure parameter values with extremely high accuracy. A case study on the characterisation of a side-coupled linac completes the paper.

Zorzetti *et al* [6] are engaged in the route of the high-precision frontier (figure 1), and namely on the CERN study for the compact linear collider (CLIC) [7]. Within the PACMAN (particle accelerator components metrology and alignment to the nanometer scale) PhD training action [8], the objective of pre-aligning the electrical centre of a 15 GHz cavity BPM to the magnetic centre of the main beam quadrupole is pursued. The paper focuses on the the aspects of microwave signal excitation, transmission and impedance-matching, as well as the mechanical setup and reproducibility of the measurement method of a specific test bench to study the stretched-wire setup for the CLIC Test Facility BPM.

Auger *et al* [9] present the experience at the Bern University Hospital (Inselspital) in operating a medical cyclotron with H+ ions to 18 MeV, equipped with a custom 6 m long external beam line for routine radioisotope production for PET diagnostics, in parallel with multidisciplinary research activities. In particular, results on the low current performance of a PET medical cyclotron obtained by ion source, radio-frequency and main coil tuning are reported. Stable beam currents down to 1.5 ± 0.5 pA were obtained and measured with a high-sensitivity Faraday cup located at the end of the beam transport line.

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References

[1] Russenschuck S and Boine-Frankenheim O 2014 Establishing *C*3, the coherence between accelerator physics requirements, magnet manufacture, and magnetic measurements *Proc. of 20th IMEKO TC4 Symp. (Benevento, Italy, 15–17 September 2014)*

[2] De Lellis G, Di Crescenzo A, Lauria A, Montesi M C, Patera V, Sirignano C and Tioukov V 2015 Measurement of large angle fragments induced by 400 MeV n^1 carbon ion beams *Meas. Sci. Technol.* **26** 094001

[3] Danisi A, Losito R and Masi A 2015 Impact evaluation of environmental and geometrical parasitic effects on high-precision position measurement of the LHC collimator jaws *Meas. Sci. Technol.* **26** 094002

[4] Drago A, Bocci A, Cestelli Guidi M, De Sio A, Pace E and Marcelli A 2015 Bunch-by-bunch profile diagnostics in storage rings by infrared array detection *Meas. Sci. Technol.* **26** 094003

[5] D'Elia A, Masullo M R and Vaccaro V G 2015 High-accuracy measurements on biperiodical circuits *Meas. Sci. Technol.* **26** 094004

[6] Zorzetti S, Fanucci L, Galindo Mu N and Wendt M 2015 Design of the 15 GHz BPM test bench for the CLIC test facility to perform precise stretched-wire RF measurements *Meas. Sci. Technol.* **26** 094005

[7] Aicheler M 2012 *A Multi-TeV Linear Collider Based on CLIC Technology: CLIC Conceptual Design Report* (Geneva: CERN)

[8] PACMAN: a study on particle accelerator components metrology and alignment to the nanometre scale. Marie Curie program supported by the European Commission (FP7 Program) http://pacman.web.cern.ch/pacman/

[9] Auger M, Braccini S, Ereditato A, Nesteruk K P and Scampoli P 2015 Low current performance of the Bern medical cyclotron down to the pA range *Meas. Sci. Technol.* **26** 094006