PREFACE

This memorial volume of *Acta Physica Polonica B* is a special tribute to the Nobel Laureate Martinus Veltman. Professor Veltman was a member of the APPB International Editorial Council, lecturer at the Cracow School of Theoretical Physics in 1977 and 1994, and the author of two the most cited articles ever published in our journal: «Second Threshold in Weak Interactions»[1] [*Acta Phys. Pol. B* **8**, 475 (1977)] and «The Infrared–Ultraviolet Connection»[2] [*Acta Phys. Pol. B* **12**, 437 (1981)].

Martinus Justinus Godefriedus Veltman passed away on January 4, 2021. The decision to prepare this book came up spontaneously, approximately one month later along with the idea to publish it on the ninetieth anniversary of Veltman's birth on June 27. With this very short deadline we addressed former students, collaborators, friends and acquaintances of Martinus Veltman asking not only for an article for this volume, but also for suggestions of other contributors. We received a very positive response, and as a result we are pleased to present to the reader a book containing 18 articles, ranging from memories, through scientific reviews, to current, innovative research articles.

Even though we did not suggest any specific topics or a special format for the submissions to this volume, most articles in one way or another provide personal summaries of the current status of the Standard Model highlighting Veltman's influence on its development and, further, various ways to move beyond the Standard Model. As put very accurately by Riccardo Barbieri *this is the relatively most uncertain time (...) in the last fifty years of Particle Physics. (...) This is due to the contrast between the impressive and steadily increasing experimental success of the Standard Model (...) and, on the opposite side, the yet unsolved "structural" problems of the Standard Model itself.*

The content of this volume is naturally divided into two parts. After this preface that includes the reprint of the already mentioned article «Second Threshold ...» by Veltman himself, you can find two personal memoirs by Andrzej Białas, chairman of the International Editorial Council of *Acta Physica Polonica B* and by Mary K. Gaillard, an outstanding scientist and a long-time friend of Tini Veltman and his family.

Although Veltman was a flesh and blood theorist, his contributions to particle physics were closely related to experiment as they allowed for precise tests of theory predictions. Veltman commented on his achievements: *I could not have done that without the knowledge of experimental physics that I had*

[1] 963 citations according to InSpire.
[2] 782 citations according to InSpire.

acquired at CERN[3]. Therefore, we begin the second part of this volume with an article by Rolf-Dieter Heuer, an experimenter and former Director General of CERN, reviewing the experimental results that form the basis of particle physics today, which proved the predictions made in Veltman's pioneering works.

Precision calculations, as pointed out by Jochum van der Bij, are considered to be *a core of Tini's work (...)*. In order to facilitate such complicated computations, Veltman developed technical tools, both theoretical and practical ones, such as the algebraic manipulation language SCHOONSCHIP. Ettore Remiddi recalls the history of SCHONSCHIP, including many anecdotes related to its implementation. He further discusses two other practical contributions of Veltman: very specific derivation of the cutting rules that Gerard 't Hooft also elaborates on in the last paper in this volume, and the method of master integrals that proved to be essential for higher-order calculations. These calculations are predictive because the Standard Model is renormalizable. The works of Martinus Veltman and Gerard 't Hooft on these issues were awarded the Nobel Prize in 1999 "for elucidating the quantum structure of electroweak interactions in physics".

Renormalizability, although technically cumbersome, results in predictions that are finite, but a direct comparison with experiment is by no means straightforward. This is at length discussed by Giampiero Passarino. He discusses the strategy to formulate an effective theory leading to calculable deviations from the Standard Model predictions. As stressed by John Ellis, present searches for extensions of the Standard Model are motivated by tensions between theory and experiment in some *precision* observables and desperately desired by cosmology. Standard Model Effective Theory has been developed to grasp the signatures of the new physics. Ellis reviews the present status of this large-scale project.

The fact that the Standard Model has to be linked with cosmology is in detail discussed by Fred Jegerlehner. He poins out that if the Higgs vacuum remains stable up to the Planck scale, the Standard Model could shape the dynamics of the early universe, explaining inflation, reheating and other phenomena. Here is the playground where particle physics meets gravity. Chris Korthals Altes recalls that Veltman had only four papers on gravity and points out that his approach to general relativity was *typical to the particle physicist he was, in heart and soul.* Korthals Altes discusses further in this spirit (parodying Volter's «Candide») so-called gauge gravity and its possible coupling to the Higgs field that would have a measurable impact on inflation.

[3] From R. Barbieri, this volume.

The next four articles focus on different, specific scenarios that extend the Standard Model.

Jochum van der Bij discusses minimalistic extensions of the Standard Model, with higher-order contributions included, that can address cosmological issues such as the baryon number asymmetry, inflation and dark matter, and even dimensionality of space-time being, however, constrained by the unprecedented consistency between the Standard Model and particle physics experiments.

Stefan Pokorski and Kazuki Sakurai emphasize a somewhat less remembered Veltman contribution related to the inconsistency of theoretical results on neutral pion decay to two photons that was resolved by the observation that axial anomaly contributed to this decay. They extend these concepts to the case of axion-like particles and their anomalous couplings, emphasising the role of axions in the beyond Standard Model scenarios.

George Zoupanos and co-workers explore the legacy of the article «The Infrared–Ultraviolet Connection» mentioned at the beginning. The naturalness condition formulated by Veltman in this paper requires vanishing of the quadratic divergences. Supersymmetry is known to have this property automatically built in. Going further, one may require that the logarithmic divergences do cancel as well. This requirement leads to Finite Unified Theories that Mondragón, Patellis and Zoupanos discuss in their contribution.

Mariano Quirós and Eugenio Megías discuss the so-called hierarchy problem. They observe that theories with wrapped extra dimensions have a potential to provide a solution that satisfies experimental constraints from the LHC.

Finally, John Iliopoulos and Emmanuel Floratos discuss an intriguing construction where d-dimensional SU(N) gauge theory can be formulated on a $d+2$ dimensional space, where the extra dimensions form a surface with non-commutative geometry.

The ideas of Veltman's «Second Threshold in Weak Interactions» are pursued by Maurizio Consoli, where a possibility of a second, heavier Higgs field excitation is discussed, both from the experimental and theoretical perspectives. In the latter case, lattice studies of the Ising model are used as a guidance.

Next, Riccardo Barbieri concentrates on flavour physics, and on the unpredictability of the masses of the Standard Model particles in particular. The solution may be delivered by physics beyond the Standard Model, but maybe also by a reformulation of the very foundations of the field theory and quantum mechanics, as discussed later in the article by Gerard 't Hooft.

As already mentioned, Veltman's approach to various physical problems relied on explicit calculations. This is best illustrated by a quote from 't Hooft's article, which gives Veltman's prescription on how to do physics:

Just consult the experimental results and do the math. The two next articles follow exactly this prescription. Frans Klinkhammer and Viacheslav Emelyanov compute elastic electron–muon scattering in the presence of the black hole and conclude that, in principle, it is possible to have information transfer from inside the black-hole horizon to outside. D.R. Timothy Jones with Ian Jack present a calculation of anomalous dimensions in O(N) theory and test semiclassical approach to this problem.

This special volume ends with an article by Gerard 't Hooft entitled «The Big Questions in Elementary Particle Physics», in which essentially all of the above issues are presented from the personal perspective of the Nobel laureate and former collaborator of Veltman. An intriguing proposal to rethink quantum mechanics is put forward.

This volume not only discusses the legacy of Martinus Veltman, but clearly shows the multitude of open puzzles in particle physics after the discovery of the Higgs boson. We would like to thank all the authors for contributing to this practical discussion and, at the same time, an intellectual challenge. Our thanks go also to those who supported us in this undertaking, as well as to those who accepted our effort with disbelief. Finally, we wish all the readers an inspiring reading.

Stanisław Jadach
Marek Jeżabek
Michał Praszałowicz

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