EDITORIAL

Focus on dark matter and particle physics

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Abstract. The quest for the nature of dark matter has reached a historical point in time, with several different and complementary experiments on the verge of conclusively exploring large portions of the parameter space of the most theoretically compelling particle dark matter models. This focus issue on dark matter and particle physics brings together a broad selection of invited articles from the leading experimental and theoretical groups in the field. The \textit{leitmotif} of the collection is the need for a multi-faceted search strategy that includes complementary experimental and theoretical techniques with the common goal of a sound understanding of the fundamental particle physical nature of dark matter. These include theoretical modelling, high-energy colliders and direct and indirect searches. We are confident that the works collected here present the state of the art of this rapidly changing field and will be of interest to both experts in the topic of dark matter as well as to those new to this exciting field.
1. Introduction: The quest for the fundamental nature of particle dark matter

We are witnessing an era that is nothing short of a historical moment in the quest for the fundamental nature of particle dark matter. The energy frontier of the TeV, where new physics potentially connected to particle dark matter might lie, according to several theoretically very compelling scenarios, will be soon explored with the CERN Large Hadron Collider (LHC). Upgrades to current direct dark matter detectors, and the research and development of new and possibly complementary techniques to look for the scattering of particle dark matter off ordinary baryonic matter are at a fully mature stage. These experimental efforts carry the promise of exploring in the very near future a large and appealing portion of the parameter space of the best motivated dark matter models. Finally, a surge of excitement has recently come from the successful launches and deployments of space-based antimatter (Pamela [1]) and gamma-ray (Fermi Gamma-Ray Space Telescope, formerly known as GLAST [2]) telescopes. In particular, in the last year it is fair to say that most of the phenomenological and theoretical work in the field was driven by the puzzling results from these two payloads, in an ongoing effort to understand the instrumental systematics and to explore possible astrophysical sources of background to a dark matter signal.

This focus issue starts with the acknowledgement of the specificity of this moment in time for the discovery of the nature of dark matter, and provides novel and updated snapshots of recent results and future directions in the field. All major topics in both experimental and theoretical aspects are comprehensively treated, starting with an authoritative bird-eye review of particle dark matter candidates by Bergstrom [3].

2. Dark matter and particle physics beyond the standard model

Given the long-standing interest for supersymmetry as one of the best motivated scenarios for particle physics beyond the standard model soon to be tested with the LHC, a contribution by Cotta et al [4] specifically addresses supersymmetric dark matter candidates. In an attempt to provide a fair landscape of other compelling particle candidates, we invited specialists in the field to provide an overview and a list of what is ‘hot’ theoretically and experimentally as far as other dark matter candidates are concerned; specifically, axions [5, 6], sterile neutrinos [7], axinos [8] and MeV-scale dark matter [9]. A minimal setup, from the point of view of model building, is the interesting and exhaustive setup of ‘minimal dark matter’, here reviewed by one of its proposers in Cirelli and Strumia [10].

The complementarity of different search strategies applied to specific particle dark matter scenarios, with a special emphasis on supersymmetric dark matter, is discussed in the
contribution by Baer et al [11]; the role of a next generation electron–positron linear collider in the quest for dark matter is reviewed by Battaglia [12], while the role of direct detection in exploring the supersymmetric parameter space of models with non-universal Higgs masses is discussed by Ellis et al [13] and by Konar et al [15].

3. The universe at large and the particle nature of dark matter

The nature of dark matter as an elementary particle shapes and impacts the universe at large: in weakly interacting massive particle (WIMP) models, the density perturbations in the matter power spectrum are cut off at relatively small scale, which depend crucially on the particle model, as reviewed by Bringmann [16]. Interestingly, the smallest of those dark substructures might even be detectable if dark matter pair-annihilates, a possibility reviewed by Koushiappas [17]. The impact of the nature of dark matter on the small-scale structure of the universe is critically reviewed here by an authority in the field, Primack [18]. The relevance of this type of knowledge for next generation large-scale structure surveys cannot be overemphasized. Other cosmological probes that put important constraints on dark matter models include the impact of dark matter annihilation or decay on the synthesis of light elements in the early universe, which is here reviewed by Jedamzik and Pospelov [19].

4. Experimental aspects

The discussion of both direct and indirect dark matter search strategies and experiments is framed with an eye on the complementarities between theory and experiments: for instance, as far as direct dark matter detection is concerned, three contributions discuss theoretical topics such as how well direct detection can pinpoint the mass of the dark matter particle [20], the effect of neutrino coherent scattering on detectors [21], and new predictions for the direct detection rate in one of the best motivated corners of the supersymmetric parameter space [13]. Specific experimental aspects are presented with the comprehensive reviews of the CRESST cryogenic experiment [14], of current and next generation noble liquid experiments [22]–[24] and of future directional experiments based on gaseous detectors [25]. The class of crystal scintillator-based experiments dedicated to the detection of the annual modulation signature of particle dark matter is comprehensively reviewed in the paper by Kim et al [26].

We are excited to present in this special issue a focus on indirect dark matter detection, with in depth contributions on the status of the major experiments in the field, including Pamela [27], AMS-2 [28], GAPS [29] and IceCube [30]. Reviews of current data and prospects are here also complemented with several hot topics on the theoretical side, including the possibility of detecting dark matter fueled old stars [31], dark matter annihilation around intermediate mass black holes [32] or in the central regions of the Galaxy [33], as well as in the mentioned galactic dark substructures [17].

5. Conclusion

The hallmark of this focus issue on particle dark matter is a collection of state-of-the-art reviews of the hottest topics in a very rapidly changing field, rather than a selection of research papers. As such, the present issue stands out as an exception in the tradition of focus issues in
New Journal of Physics. We hope the works collected here will be of interest both to the experts in the field as well as to the new researchers who continue to be attracted to this wonderfully fascinating research endeavour.

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