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Plan B for particle physics: finding long lived particles at CERN

Bondarenko, K.

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Stellingen

Behorend bij het proefschrift

Plan B for particle physics: finding long lived particles at CERN

1. The Standard Model of Particle Physics provides a closed, complete and self-consistent description of all phenomena observed so far at accelerator experiments. This model can be valid up to a very high energy scale. Nevertheless, this theory is incomplete, as it does not explain several observed phenomena, such as Dark Matter, the neutrino masses and the matter-antimatter asymmetry of the Universe.

(Chapter 1)

2. After the discovery of the Higgs boson, for the first time in many decades, we do not have any concrete prediction where to look for new physics. As a result new types of experiments, such as "intensity frontier" experiments and/or "non-collider experiments" and model-independent searches for new physics become more and more important.

(Chapters 1 and 5)

3. Among the proposed experiments at the intensity frontier, SHiP has a unique potential to find new particles by probing a significant and cosmologically interesting part of the parameter space of the nuMSM model.

(Chapters 1, 3 and 5)

4. In view of the constraints coming from other experiments, it will be difficult to find light fermionic dark matter particles or light axions directly at SHiP. However, SHiP has very good sensitivity to e.g. GeV-mass scalar particles that can connect the Dark Sector to the Standard Model. In this way, important information about dark matter can be obtained, albeit indirectly.

(Chapters 2, 5 and 6)

5. Cosmological and astrophysical observations are as important for our understanding of the Universe at the fundamental level, as direct accelerator searches.

A. BOYARSKY, O. RUCHAYSKIY AND M. SHAPOSHNIKOV, "THE ROLE OF STERILE NEUTRINOS IN COSMOLOGY AND ASTROPHYSICS", ANN. REV. NUCL. PART. SCI. **59**, 191 (2009).

6. Although new particles may interact with ordinary matter much more weakly than neutrinos, they have the potential to drastically affect the state of the Universe in the early stages of its evolution.

S. ALEKHIN *et al.*, "A FACILITY TO SEARCH FOR HIDDEN PARTICLES AT THE CERN SPS: THE SHiP PHYSICS CASE", REPT. PROG. PHYS. **79**, NO. 12, 124201 (2016).

7. It is quite probable that we have already seen a Warm Dark Matter signal in two different types of observations.
A. BOYARSKY, M. DREWES, T. LASSERRE, S. MERTENS AND O. RUCHAYSKIY, “STERILE NEUTRINO DARK MATTER”, [arXiv:1807.07938].
8. Dark Matter particles with a mass smaller than the Lee-Weinberg bound (Light Dark Matter) are accessible to direct detection.
S. KNAPEN, T. LIN AND K. M. ZUREK, “LIGHT DARK MATTER: MODELS AND CONSTRAINTS”, PHYS. REV. D **96**, NO. 11, 115021 (2017).
9. Contrary to the assertion of the author, the naturalness of the hierarchy of mass scales in physics does not provide sufficient reason to anticipate the existence of physics beyond the Standard Model.
J. ELLIS, “WHERE IS PARTICLE PHYSICS GOING?”, INT. J. MOD. PHYS. A **32** (2017) NO.34, 1746001.
10. The complexity of modern physics resulted in very strong specialization, in particular in methodological, sociological and even cultural boundaries between theoretical and experimental physics. Still, physics is an experimental science and it is both possible and necessary to penetrate through these boundaries and establish efficient knowledge exchange and conscious collaboration between both sides. Neglecting this may result in catastrophic consequences for physics. Modern information management technologies may be of help here.

Kyrylo Bondarenko
Leiden, 15 November 2018