Particle and Nuclear Physics at the MeV scale in Australia

Presenting Martin Sevior[a] , Lindsey Bignell [b], Tibor Kibédi[b], David Jamieson[a], Andrew Stuchbery[b], and Andrea Thamm[a]

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Determining the nature of New Physics extensions to the Standard Model is one of the most pressing issues for Particle Physics. Well-motivated theories employ New Physics to solve the strong CP, hierarchy or axion quality problems by introducing new pseudoscalar particles which are weakly coupled to the standard model. These axion-like particles can have MeV-GeV masses and predominantly decay to photons and leptons [1, 2]. Recently, the ATOMKI group found evidence [3,4] for a new fundamental boson, named the X17, observed via $p+^{7}Li \rightarrow ^{8}Be + (X17 \rightarrow (e^{+}e^{-}))$ and $p+^{3}H \rightarrow ^{4}He + (X17 \rightarrow (e^{+}e^{-}))$ reactions with a mass of 17 MeV and significance $\approx 7\sigma$. There are now numerous projects to search for weakly coupled bosons, including the X17, using particle physics experiments [5-7]. However, only the ATOMKI group have utilized nuclear reactions in a competitive way to date.

We intended to employ the Pelletron accelerator in Melbourne to initiate nuclear reactions of the kind: $p+^{Z}X \rightarrow ^{Z+1}Y + (e^{+}e^{-})$ and to build a low mass, high precision Time Projection Chamber, (TPC) with world-first capabilities. The invariant mass resolution of the TPC to the $(e^{+}e^{-})$ final state is expected to be 0.1 MeV. This provides a substantially more sensitive search for anomalous $(e^{+}e^{-})$ production than any other experiment and 200 times more sensitivity than ATOMKI. Accordingly, we will either observe the ATOMKI anomaly on the Pelletron or exclude it at very high significance. Following this we propose a program to search for anomalous $(e^{+}e^{-})$ production with world-leading sensitivity in the 5-25 MeV mass region. In addition, the very large acceptance, and excellent angular and energy resolution of the TPC enables qualitatively more sensitive investigations of Nuclear Internal Pair Conversion decays. This capability enables a range of novel Nuclear Physics investigations.

The presentation will describe the proposed TPC, its expected performance together with its application and anticipated impact in particle and nuclear physics investigations.

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[5] A. M. Baldini et al. (MEG II Collaboration), Eur. Phys. J. C 78, 380 (2018)
[6] J. Balewski et al. (DarkLight), arXiv:1412.4717
[7] C. Ahdida et al. (SHiP Collaboration), arXiv:2010.11057