On a new light-particle candidate for Dark Matter observed in high-energy nuclear transitions

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Dark Matter is currently one of the greatest unsolved mysteries in physics. Recently, we used the $^{7}Li(p,e^{+}e^{-})^{8}Be$ reaction to excite an 18.15 MeV excited state in ^{8}Be and observed its internal pair ($e^{+}e^{-}$) decay to the ground state. An anomaly in the form of peak-like enhancement relative to the internal pair creation was observed at large angles in the angular correlation [1]. It turned out [2] that this could be a first hint for a 17 MeV X-boson (X17), which may connect our visible world with Dark Matter. The possible relation of the X17 to the Dark Matter problem, as well as the fact that it might explain the $(g-2)_\mu$ puzzle, triggered great theoretical and experimental interest in the particle, hadron and atomic physics communities. Zhang and Miller discussed in detail whether a possible explanation of nuclear physics origin could be found but without any success [3].

Using a significantly modified and improved experimental setup, we reinvestigated the anomaly observed in the $e^{+}e^{-}$ angular correlation by using the new tandetron accelerator of our institute. This setup has different efficiency curve as a function of the correlation angle, and different sensitivity to cosmic rays yielding practically independent experimental results. In this experiment, the previous data were reproduced within the error bars.

To confirm the ^{8}Be signal, a similar approach would be to look for other nuclear states that decay by discrete gamma rays with energies above 17 MeV through M1 electromagnetic transitions. Unfortunately, the ^{8}Be system is quite special and the ^{8}Be excited states decay by gamma rays that are among the most energetic compared to decay of all the nuclear states.

Recently, we investigated high-energy transitions in ^{4}He. In order to excite the first two excited states located at E_x=20.21 MeV ($J^{\pi}=0^{+}$) and 21.1 MeV ($J^{\pi}=0^{-}$), we used the $^{3}H(p,e^{+}e^{-})^{4}He$ reaction at E_p= 1.0 MeV. In this way, we excited both of the above overlapping states. We observed $e^{+}e^{-}$ pairs with an angular correlation dominated by the E0 transition, which was expected from the $0^{+} \rightarrow 0^{+}$ transition, but on top of that a small peak at $\Theta \approx 115°$ is also visible. This would correspond to the decay of the X17 boson created in the $0^{-} \rightarrow 0^{+}$ transition.

The $\gamma\gamma$-decay of X17 boson was also studied in order to distinguish between the vector and pseudo-scalar scenarios suggested recently by theoretical groups in interpreting our experimental results [4,5]. According to the Landau-Yang theorem, the decay of a vector boson is forbidden by double γ-emission, however, a pseudo-scalar one is allowed. The analysis of the data is in progress.

There are also myriad other opportunities to test and confirm this explanation, including re-analysis of old datasets, ongoing experiments, and many planned and future experiments. The latter include the PADME experiment in Frascati, the DarkLight and HPS experiments at JLAB, the LHCb and NA64 experiments at CERN, the MESA experiment in Mainz, the Mu3e experiment at PSI Villigen and the VEPP-3 experiment in Novosibirsk.

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