The recent observation of an excess of low-energy electron recoils by the XENON1T Collaboration [1] has generated a strong interest in the particle physics community, since it may be interpreted as a signal from new physics beyond the standard model (BSM). Two of the leading hypotheses, solar axions and solar neutrino scattering with an anomalously large neutrino magnetic moment ($\nu$MM), would be expected to produce very similar excesses that rise rapidly as the electron recoil energy decreases, particularly below 5 keV. Given the energy smearing and threshold effects at around 2 keV, their signatures are essentially indistinguishable in the XENON1T detector. So the question arises: how do you tell solar neutrinos from solar axions when you can’t shut off the sun? The answer comes from the GALLEX [2] and SAGE [3] gallium detector solar neutrino experiments, which used mega-Curie (MCi) scale electron capture sources—mostly $^{51}$Cr [2–5] but also $^{37}$Ar [6]—as an “artificial sun” to test their full-system neutrino detection efficiency. The use of a $^{51}$Cr source with XENON1T would definitely show if the excess is due to neutrinos, or if some other interpretation, like axions, dark matter or tritium decay, is required. It’s worth noting that both the axion [7] and $\nu$MM [8] interpretations are in strong tension with astrophysical constraints.

In 2014, we conducted a study on the physics potential of combining a liquid Xe (LXe) dark matter detector with a MCi-scale $^{51}$Cr source [9], and computed the expected sensitivity to $\nu$MM. A simple scaling from that result shows that a single exposure of the XENON1T detector to a MCi-scale $^{51}$Cr source would exceed the neutrino event count observed by XENON1T, in just a fraction of the 226.9 days used in their study. In other words: this source run would have a larger signal and just a fraction of the background events compared to their data set with the reported excess. While the background rate in XENON1T is higher than we assumed in our original analysis, our present proposal relies only on improving upon the sensitivity of the current XENON1T result in order to disambiguate the two BSM hypotheses which are correlated with the solar power. We surmise that the sensitivity to an anomalously large $\nu$MM would exceed that required to rule out a $\nu$MM compatible with the excess. A result compatible with the SM expectation would aid in the interpretation of the XENON1T results by rejecting all neutrino hypotheses. At the same time it may well be able to improve upon the best terrestrial limits on $\nu$MM [10]. On the other hand, if the anomaly were to persist in the source data, that would strongly support the $\nu$MM hypothesis or any suitable explanation of the excess due to novel interactions of solar neutrinos [11–15].

As a specific example, we consider a $^{51}$Cr source with an initial strength of 3 MCi, which is comparable to, and even slightly smaller than, the source from Ref. [5]. It is assumed to be located with its center 1 meter below the bottom edge of the detector’s fiducial volume (see Fig. 1). Unlike our original study which assumed...
Events / keV

Background only
\( \mu_{\nu} = 2.9 \times 10^{-11} \mu_B \)
\( \mu_{\nu} = 1.4 \times 10^{-11} \mu_B \)
\( \mu_{\nu} = 0 \)

FIG. 2. The expected counts over a 50 day run with an initial source strength of 3 MCi. The background (below the dashed line) is scaled from Ref. [1] and includes solar neutrinos; the dark blue histogram shows the total events with source in the standard model (\( \mu_{\nu} = 0 \)); the medium blue shows the additional events with \( m_{\nu_e} = 1.4 \times 10^{-11} \mu_B \), the XENON1T lower limit; and the light blue is the expected signal for \( \mu_{\nu_e} = 2.9 \times 10^{-11} \mu_B \) the XENON1T upper limit.

In conclusion, we propose a simple test to distinguish between the two solar correlated BSM explanations for the XENON1T anomaly by using existing technology for a MCI-scale \(^{51}\text{Cr} \) source combined with the existing XENON1T detector. A positive detection of an excess would be tantamount to the discovery of new physics. Beyond a test of the \( \nu\text{-MM} \) hypothesis, combining large LXe dark matter detectors with MCI-scale electron capture sources enables a broad range of BSM physics searches including sterile neutrinos [9], non-standard interactions, and light \( Z' \) [17]. A detailed study of the experimental feasibility and sensitivity would be best conducted by the XENON1T collaboration.

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