Future Sub-GeV Dark Matter Searches with Proton Fixed Targets at FNAL

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The search for sub-GeV dark matter with proton beams has been well motivated by recent theoretical work as described in [1-5]. These scenarios constitute a cosmologically and phenomenologically viable possibility to account for the dark matter of the universe. Such sub-GeV Dark Matter (DM) particles are difficult to probe using traditional methods of dark matter detection, but can be copiously produced and then detected with neutrino beam experiments such as MiniBooNE, SBN, NOvA, and DUNE. This represents a new experimental approach to the search for dark matter and is highly complementary to other approaches.

In 2014 the MiniBooNE neutrino experiment at FNAL successfully ran in a special beam-dump configuration to minimize neutrino backgrounds and maximize sensitivity to sub-GeV DM searches. In the standard beam on target configuration of MiniBooNE, a large flux of neutrinos emerges out of the proton-beryllium target collisions and are then detected through a charged or neutral current scattering signature in the large-volume electromagnetically-sensitive detector located 540m downstream. Slightly modifying the beam configuration allows the protons to be steered past the target and onto the fixed 50 m absorber at the end of the decay volume. The results of this search produced relevant limits and demonstrated that proton beam dump dark matter searches can work [6].

Near term improved searches can be done with the SBN program. In the next two years the 8 GeV Booster Neutrino Beamline (BNB) will see the installation of a 112 ton near detector (SBND) at 110 m, and at 600 m the far detector with 476 ton fiducial mass (as comparison, MiniBooNE is 450 ton fiducial mass at 540 m). Both detectors are Liquid Argon TPC's (LArTPC) and will search for sterile neutrinos. However, by running the BNB again in beam-dump mode, the detectors can search for sub-GeV DM. The sensitivity of the SBND near detector will be the best, and with a one year run of 2×10^{20} POT, would be about an order of magnitude better than MiniBooNE due to its close proximity to the beam stop. However, best sensitivity is achieved by replacing the Be target/horn, designed for neutrino production, with a dense material (Fe, W, etc) beam stop at the end of the beam pipe. This would reduce neutrino backgrounds by three orders of magnitude. The cost of the beam stop upgrade is about $1M. The detectors will be commissioned and running by 2019. After an initial three year neutrino run to perform sterile neutrino oscillation measurements, the beamline could be re-configured for a one year beam dump run to collected at least 2×10^{20} POT. Figure 1 shows the sensitivity that can be achieved with the upgraded beam stop and SBND detector. A futher improvement that would allow simultaneous neutrino and dark matter running is a new target station and beam switch yard for $5M.

With modest investment to the beam stop, timely and sensitive searches for sub-GeV dark matter that explore the relic density limits can be performed leveraging the existing neutrino facility SBN at FNAL.

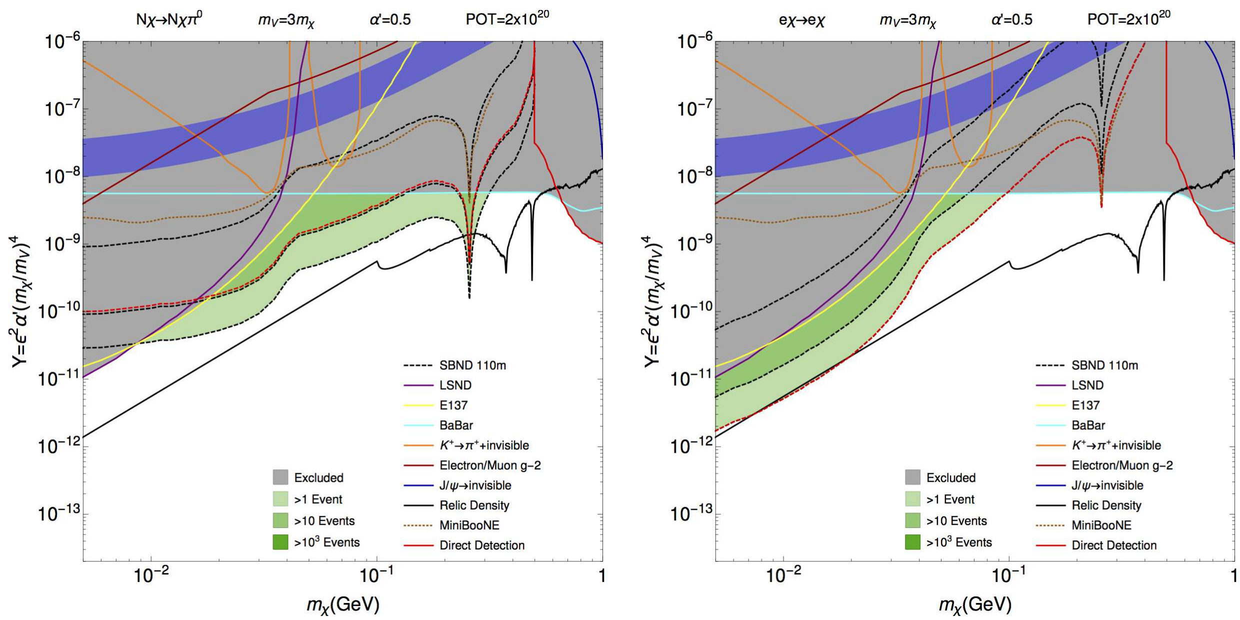

Figure 1: Regions of dimensionless cross section parameter Y vs dark matter mass m_χ. On the left is shown the sensitivity for SBND π^0 scattering channel, on the right for SBND electron scattering channel. The red dotted line shows the projected sensitivity for SBND with the improved beam stop and full systematic errors developed from the MiniBooNE dark matter search (dotted brown line).

References

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