νIOLETA: Neutrino Interaction Observation with a Low Energy Threshold Array

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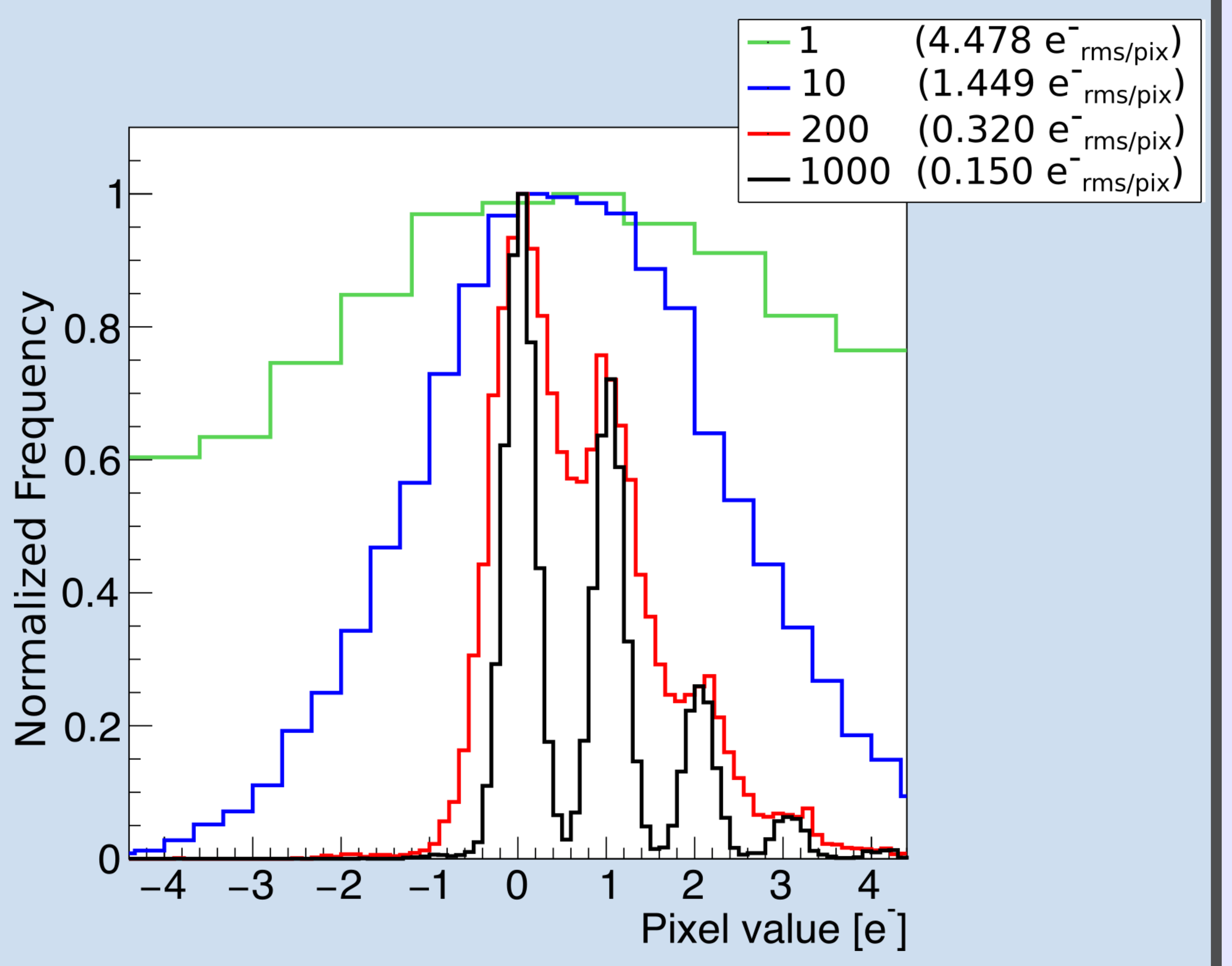
Abstract

The large number of opportunities to study non-standard neutrino interactions at low energies –below the inverse beta decay process– along with the observation of the CEνNS interaction, have witnessed a growing interest during the last years. In this context, we propose a short baseline reactor neutrino experiment to cover an unexplored energy of three orders of magnitude using 10 kg of Skipper-CCD with an energy threshold of few eV. We discuss constraints to the SM and to an extended model with a light vector mediator. In particular, we claim that our prospective for the exposure time required for observing the CEνNS at a 95% of confidence level at one of the most powerful nuclear reactors available in Argentina is less than a couple of days.

Skipper-CCD technology

The main difference between conventional scientific CCDs and Skipper-CCDs lies in the non-destructive readout system of the latter, which allows to repeatedly measure the charge in each pixel. For uncorrelated samples, this capability results in the reduction of the readout noise in a factor equal to the square root of the number of samples (arXiv:1706.00028).



This figure shows the single-pixel spectrum of an image region, which has been obtained averaging different amount of samples per pixel. For 1000 samples individual electron counting per pixel is possible.

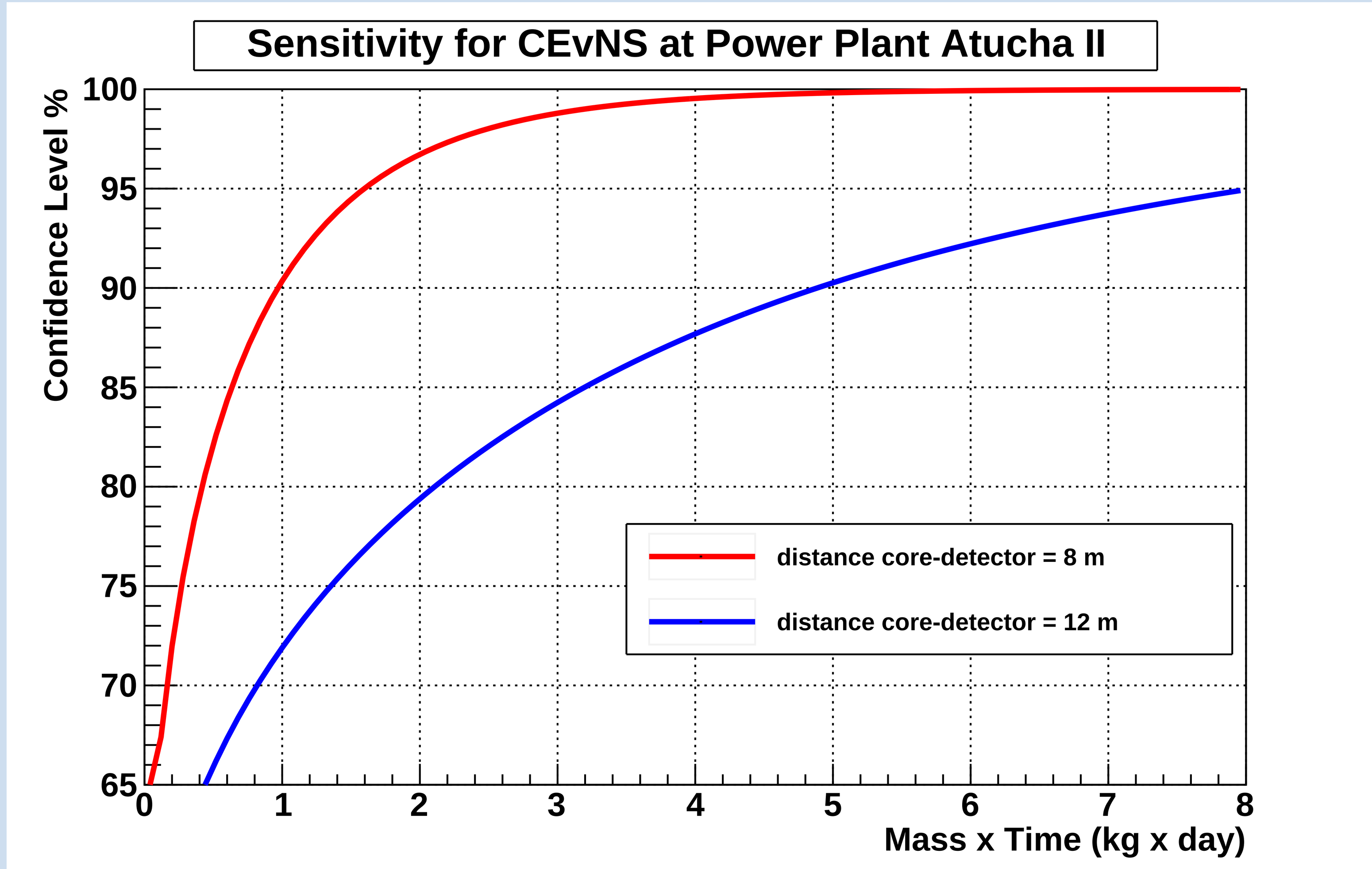
These detectors are developed by the MicroSystem Labs of Lawrence Berkeley National Laboratory and operated at Fermilab. They open a unique opportunity to detect neutrino interactions that transfer a very small quantity of energy to the Skipper-CCD silicon. A part of the transferred energy is converted in a very small amount of electron-holes pairs, which can be easily counted with a Skipper-CCD.

CNA II Nuclear Power Plant

Atucha II is a 2 GW pressurized heavy water reactor located in Argentina, ∼100 km away from Buenos Aires. The fuel elements have an active length of 5.3 m. and they are vertically allocated inside a pressure vessel of 8.44 m of diameter. Two positions are being considered, 8 m and 12 m away from the reactor core. They are shielded for most of the background radiation coming from the reactor by concrete walls. For detailed information see poster number 523.

CEνNS Sensitivity

The sensitivity curves for observing CEνNS interaction for each core-detector distance under consideration as a function of the parameter mass by time is presented. They were calculated assuming a very conservative background of 10 kdru, the Quenching factor from CONNIE-2019 (arXiv:1906.02200) and perfect efficiency above 15 eV. The time involved in reaching a 95% of CL is in the order of days per kilogram of detector.

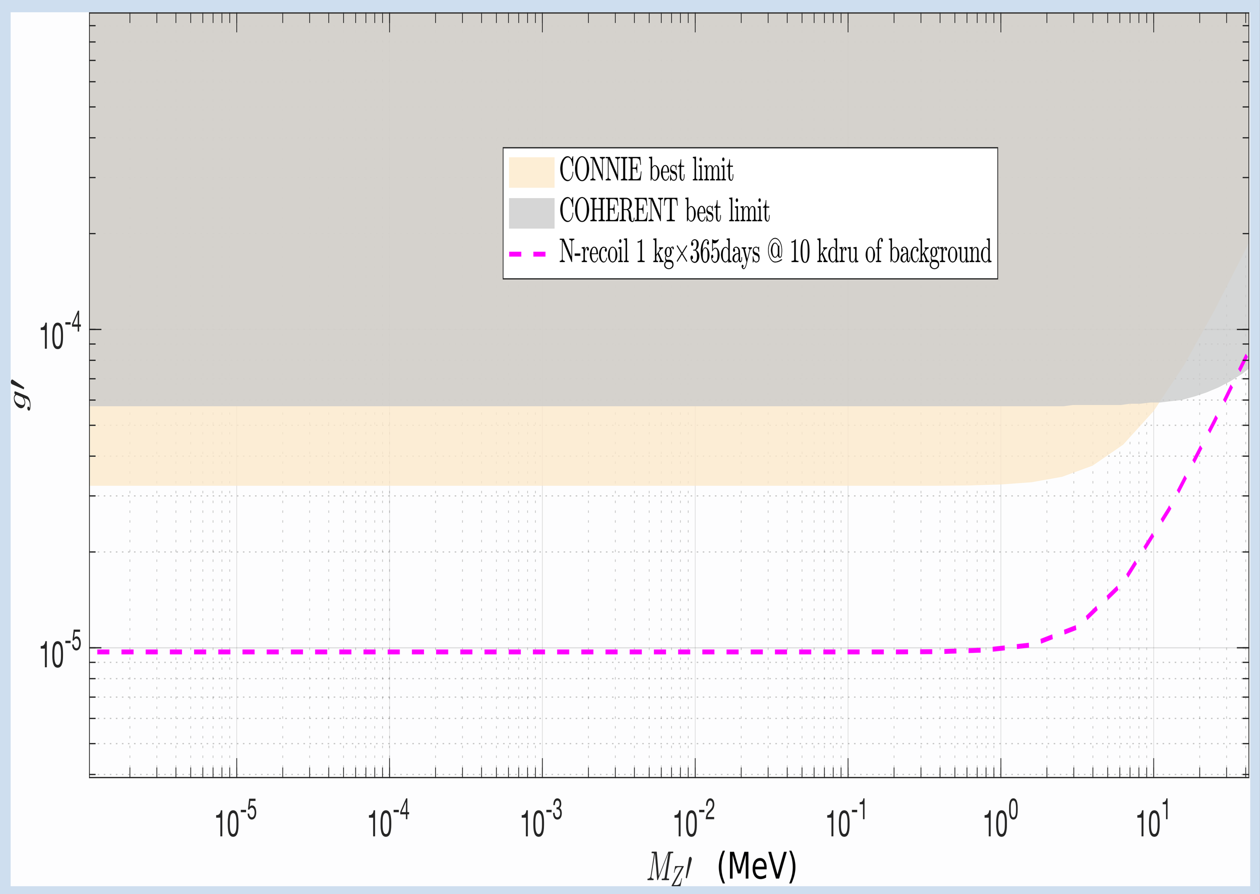


Precision measurement of SM

νIOLETA will be a perfect test bench for SM predictions at very low energy scale. Poster number 508 shows a full description of the sensitivity of the experiment to $\sin(\theta_{weak})$ parameter at very low momentum transfer. It uses the CEνNS interaction as the channel for the measurement.

Physics beyond the SM

The figure shows the exclusion region in the parameter space for an extension of the SM with an additional light, neutral vector boson Z'. To evaluate the sensitivity of the detector we have considered a counting experiment, with the expected number of events in the range 15 -100 eV assumed to be larger than the background uncertainty with 90% confidence level. As shown in the figure, there is a great improvement compared to the current limits (CONNIE:arXiv:1910.04951 , COHERENT:arXiv:1708.04255). Since the cross-section goes to the fourth power of the coupling g' there is an improvement of more than two orders of magnitude in its sensitivity. Similar constraints can be applied to other extended models with light mediators.



Overview

νIOLETA will focus on very low energy neutrino physics. It will have a great impact on models beyond the SM with new interactions that transfer small amounts of energy, in the eV to keV regimen. The experiment has a very promising scientific horizon. Its main objectives are to test the SM predictions at low energies and to search for evidence of new physics at energies not accessible to existing experiments, especially that associated with extensions of the SM, which have additional interactions mediated by light particles. The collaboration plans to install the first prototype with Skipper CCD detectors by the end of 2020 (depending on how the current global situation evolves).