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**KSETA Annual Report 2023**
**Melih Kara** **13.02.2023**

## Introduction

I started my Ph.D. thesis in March 2021, my planned finishing date is February 2024.
The project titled "Astrophysical Neutrino Detection Sensitivities of the XENONnT and DARWIN experiments" is supervised by Prof. Kathrin Valerius and Prof. Guido Drexlin, and mentored by Dr. Klaus Eitel.

## Progress on the doctorate

I work within the XENON, DARWIN, and SNEWS collaborations. The main purpose of my project is to study the detection mechanisms of supernova neutrinos within dark matter detectors that utilize two-phase Xenon technology. Furthermore, I also study the detection sensitivities for such experiments and build an analysis framework for such events in their data stream. I also develop the algorithm and the software needed for SNEWS.

SNEWS, short for SuperNova Early Warning System, is a global network connecting neutrino and dark matter observatories around the world to form an early coincidence alert based on the detected signals in different experiments. I take part in the implementation team of SNEWS and developed the publication tools and coincidence system as two separate (front-end and back-end) software packages which are publicly available on GitHub. These tools are used on the users' end to publish their data-taking status and, if any, their supernova-like observations. The software on the back end then tracks and compares all the messages, and as soon as more than one detector forms a time-coincidence with their submitted observation messages, the algorithm triggers an alert back to the users. This allows us to increase our sensitivity to fainter neutrino observation and also increase our confidence in the observed supernova signal.

I contributed to SNEWS by developing these tools and demonstrating them to the rest of the collaboration to train them last year. I also gave several talks at various SNEWS meetings and presented the tools at the SNEWS collaboration meeting. We are also drafting a paper about our software tools.

In the past year, I also supervised a bachelor's student with his thesis. His task was to use the tools we developed for such neutrino signal analysis and study the characteristics of different models. He also studied the possibility of discriminating different models given a detector-like signal.

For the Xenon collaboration, I implemented a low-level correction for our waveform simulation tool. This enhancement provides a proper optical time delay for the second light signal (S2) in our detector already at the raw records level and also splits the timing information between the top and bottom photo-multiplier tubes for the simulations. Furthermore, I also helped with the gas-gap corrections for our simulations, which were needed to account for the variable gas gap between our liquid and gaseous xenon phases in our detector.

The software, I started developing to analyze coherent elastic neutrino-nucleus scattering (CEvNS) is also improved and upgraded over the past year. This package is also publicly available at GitHub. In the current version, different supernova models can be studied, any given atom or a mixture of different isotopes can be used and investigated as a target, and the interactions of the neutrinos from a selected model and the target can be studied at any given distance and for any target volume. Using this software, I have been studying the projection sensitivities for XENON and DARWIN-like dark matter detectors. These studies still need to be improved.

In the context of the analysis framework, on top of the CEvNS studies, I also simulate the signal from such supernova interactions using our waveform simulator software. These simulations are then used to study the characteristic signal shape and develop dedicated cuts. These studies, in collaboration with another colleague, are in a good shape and we are about to draft a publication.

We also developed another package to establish the connection between XENONnT and the SNEWS. We are aiming to become the first-ever dark matter detector connected to SNEWS. This software uses the SNEWS tools I developed and connects XENONnT to the network. Currently, we refer to the developed version as beta, and it can subscribe to SNEWS alerts at the XENON site computers, and forward the alerts to the on-site shifters as well as relevant XENONnT members through slack notifications and e-mails. It can also check the detector status and provide heartbeats to the SNEWS at a given frequency. Lastly, it has a basic version of a monitoring tool, which continuously searches our data stream for supernova-like signals and triggers observation messages to SNEWS.

In the past year, I advanced my research, supervised a student, tutored a nuclear physics laboratory course, and attended many online and in-person events, workshops, summer school, and collaboration meetings. On some of these occasions, I gave talks or presented posters. Below, these events are listed.

**List of Activities;**

- 7th-23rd May 2022; Taking a shift at LNGS[1].
- 30th May-4th June; Poster presentation at Neutrino 2022.
- 27-29th June; Co-organization of the XLZD[2] meeting at KIT.
- 4-8th July; Talk at the Torino XENONnT collaboration meeting.
- 24-29th July; Research visit at Purdue University.
- 1-5th August; Two talks at the SNEWS Hackathon at Purdue.
- 4-17th September; Attended and gave a talk at CERN Computing School in Krakow. (Partly covered by KSETA, and partly by PUNCH4NFDI).
- 12-13th December, Gave a talk at the Dark-Matter Lab (DMLab) at DESY/Hamburg.
- Winter semester 22/23, mentored a bachelor student on his thesis.
- Winter semester 22/23, Tutored for Praktikum Moderne Physik und Physikalisches Fortgeschrittenenpraktikum für Masterstudenten (Advanced nuclear and particle physics lab course).

Sincerely,

Melih Kara,
Department of Physics, KIT



[1]Laboratori Nazionali del Gran Sasso - INFN

[2]XENON-LUX-ZEPPLIN-DARWIN