

PhD in Physics and Nanoscience (XXXV cycle) Third Year Report

Matteo Vicenzi

Supervisor: Prof. Marco Pallavicini

15 September 2022

Scientific activity

My research activity has been mainly focused on detector simulation and development for DUNE, a long-baseline neutrino oscillation experiment aimed at the precise determination of the mass hierarchy and the CP-violating phase. I am involved in the design and simulation of the SAND detector which will be part of the DUNE Near Detector complex at Fermilab.

In particular, I worked on developing an optical readout system for the scintillation light produced in GRAIN, the ~ 1 ton liquid Argon (LAr) target inside SAND, using an innovative UV lens system. Lenses are placed in front of pixelated photodetectors (arrays of SiPMs) in order to get a picture of the charged tracks through the emission of the scintillation light they generate while crossing the liquid Argon. The configuration is made of two plano-convex lenses, with a N_2 gas layer between them. The geometrical parameters are optimized in order to limit the defocusing for the possible range of expected track distances in GRAIN. Xe-doping in liquid Argon (< 10 ppm) shifts scintillation light from 128 nm to 175 nm, mitigating the typically low transmission at VUV wavelengths and making it easier to find a suitable material for the lenses.

Having defined a suitable lens configuration, I led the efforts in the development of preliminary reconstruction techniques which take as input the images coming from multiple cameras inside GRAIN to extract 3D event information. The reconstruction is based on two steps: a 2D step based on the Hough transform in which tracks are identified and fitted in each image and a 3D step in which 2D fitted tracks are propagated back into the volume and combined to build a 3D track estimate. In the end, starting from raw data, high level information on the event is extracted, such as the position of the interaction vertex, the number of tracks and their direction as well as an estimate of the energy deposited. The GRAIN output is then used in combination with the downstream tracker and calorimeter to fully reconstruct a neutrino event in SAND.

In terms of hardware, a lens prototype was manufactured by an external company using Fused Silica HPFS 8655. A prototype lens camera was then tested in a warm setup, using optical wavelengths and water as a medium. These tests allowed to validate the Monte Carlo simulations in preparation for a test in liquid Argon scheduled for the end of the year inside ARTIC, the cryostat installed at DIFILab.

In addition to my activities for DUNE, I also took part in activities for the ICARUS detector at Fermilab. In particular, I travelled to Fermilab for about a month to work on the installation and commissioning of the CRT (Cosmic Ray Taggers) modules on top of ICARUS. This activity involved testing each channel, putting the modules in place and setting up the data and timing

lines. Moreover, I also contributed in setting up and updating a SQL hardware database that recorded each component of the CRT system as well as taking regular remote monitoring shifts for the detector.

Attended courses

- *ISAPP 2021: Short Baseline (SBL) neutrino oscillations and anomalies.*
Seminar to certify the attendance to the school. (exam passed)

Attended conferences/workshops

- *NEUTRINO 2022*, May 30th - June 4th, 2022 (remote).
Poster: "A liquid argon target for SAND in the DUNE Near Detector".
- *DUNE Oscillation Analysis Workshop*, August 15-19, 2022 (CERN).
Summer workshop on neutrino oscillation analyses in DUNE.
- *108° Congresso Nazionale SIF*, September 12-16, 2021 (Milano).
Talk: "Neutrino event reconstruction with the liquid-argon target of SAND in the DUNE Near Detector".

Publications

- Andreotti, M., Bernardini, P., Bersani, A. *et al.* "Coded masks for imaging of neutrino events", *Eur. Phys. J. C* 81, 1011 (2021).
<https://doi.org/10.1140/epjc/s10052-021-09798-y>
- Vicenzi, M. "SAND, System for on-Axis Neutrino Detection, in the DUNE Near Detector Complex", *Proceedings of The 22nd International Workshop on Neutrinos from Accelerators* 402, 248 (2022).
<https://doi.org/10.22323/1.402.0248>
- Vicenzi, M. "A liquid argon target for SAND in the DUNE Near Detector", *Zenodo* (2022).
<https://doi.org/10.5281/zenodo.6781064>

Other activities

- PCTO tutor for high-school students.
February 7- 17, 2022 (40 hours).