SAND - System for on-Axis Neutrino Detection - in the DUNE Near Detector Complex

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DEEP UNDERGROUND NEUTRINO EXPERIMENT

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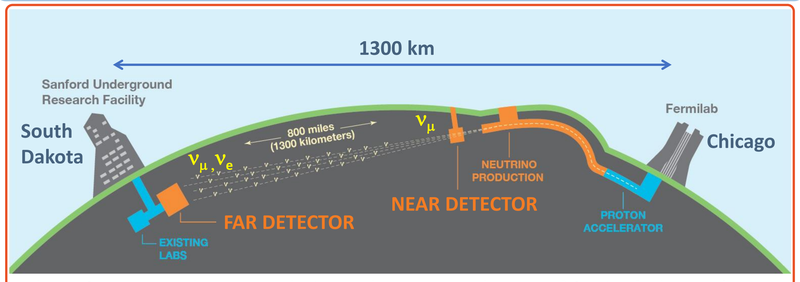
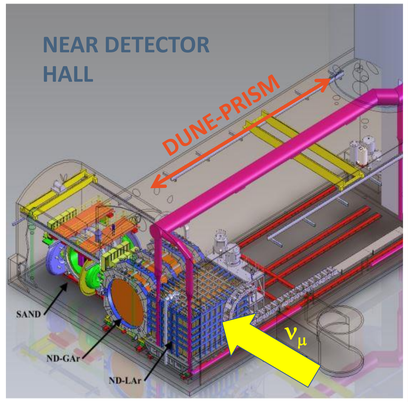
DUNE Near Detector



The Deep Underground Neutrino Experiment **(DUNE)** is a long-baseline neutrino oscillation experiment that aims to reach percent-level uncertainty on the determination of neutrino oscillation parameters, using a 1.2 MW neutrino beam produced at Fermilab (Illinois, USA) and a Far Detector of liquid argon detectors at SURF (South Dakota, USA) for a total mass of 68k tons.

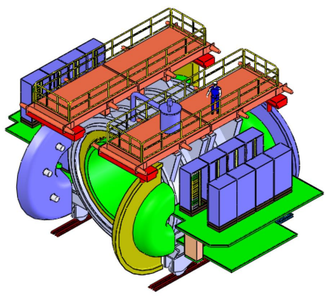
Robust **Near Detector** needed to constrain systematic uncertainties:

- **ND-LAr:** a «modular» LAr TPC optimized for the high-rate environment
- **ND-GAr:** a magnetized high-pressure GAr TPC + calorimeter
- **SAND:** a magnetized on-axis beam monitor
- **DUNE-PRISM:** capability for ND-GAr and ND-LAr to collect data up to 30m off-axis



SAND

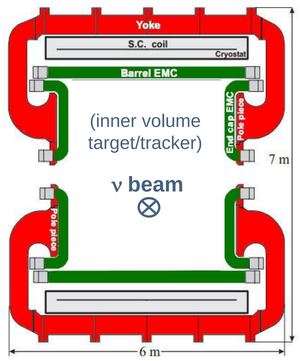
SAND (System for on-Axis Neutrino Detection) is the permanently on-axis component of the Near Detector:

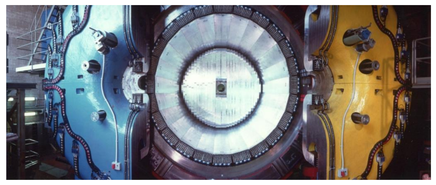


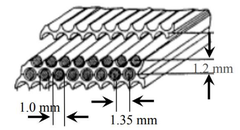
- Monitor and detect relevant **beam changes** within a week of data taking
- Perform independent $\boldsymbol{\nu/\bar{\nu}}$ **flux** and **flavor content measurements**
- Constrain nuclear effects by using different **nuclear targets** (Ar, CH_2, C) and selecting a $\boldsymbol{\nu}$**-H sample**
- Tag **neutrons** and measure their energy on an event-by-event basis
- Add robustness against “unknown unknowns”

Magnet and EM Calorimeter

SAND will be using the repurposed **superconducting magnet** (0.6 T, 5 m bore) and the electromagnetic sampling calorimeter (ECAL) previously of the **KLOE experiment** at LNF in Frascati, Italy.

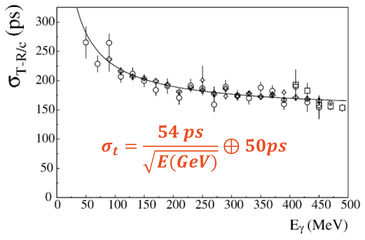


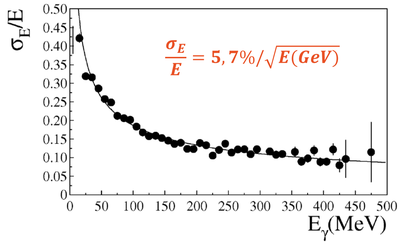




Sampling EM calorimeter: lead + 1mm scintillating fibers

The **ECAL** is divided in a cylindrical barrel section, made of 24 trapezoidal 4.3 m long modules, and two endcaps, each with 32 differently-sized “C”-shaped modules, to achieve a $\boldsymbol{4\pi}$ **total acceptance**. The fibers are grouped in cells and read on both sides. The ECAL combines a fine-structure and **excellent energy and time resolution**.

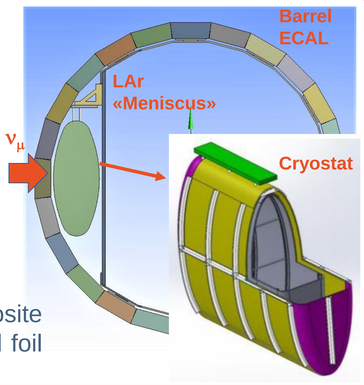




LAr Meniscus

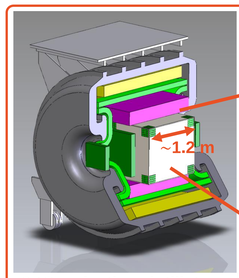
A 1-ton liquid Argon **active target** is placed upstream:

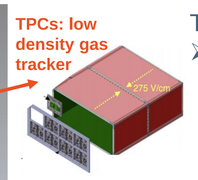
- It provides inclusive Ar interactions for nuclear effects studies and cross-calibration
- It will be instrumented with an **optical system** for VUV scintillation light to localize and reconstruct the event in combination with the ECAL and tracker
- The cryostat is made with a C-composite material reinforced with an internal Al foil (overall radiation length $\sim 1X_0$)

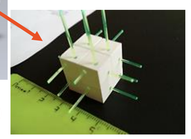


Inner Tracker

SAND will be equipped by an **inner tracker** system, providing also additional mass and nuclear targets. There are currently two options being considered (3DST+TPC and STT), both of which satisfy SAND primary beam monitoring requirements. The final design choice is currently in the process of being finalized.







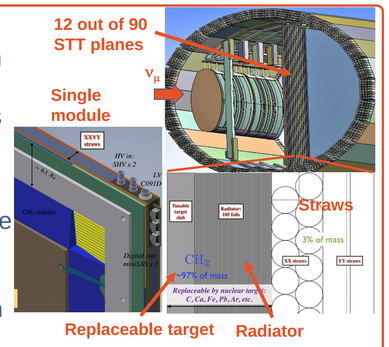
The 3DST+TPC option:

- **3DST**: a three-dimensional projection scintillator tracker, made of plastic scintillator cubes read by three orthogonal WLS fibers
- **TPCs**: low-density trackers placed around the 3DST, filled with an optimized gas mixture and using resistive Micromegas detectors as readout

- **Fully-active** target/tracker
- Momentum reconstruction by range, precise momentum reconstruction of particles leaving 3DST by TPCs
- Event-by-event **neutron detection** and kinetic energy measurement from time-of-flight

The STT option:

- **STT**: straw tube trackers, with orthogonal planes of 5 mm straws, radiators and replaceable target foils (CH_2,C,…) dispersed between them. Filling all available inner volume



- **Modular layout** with tunable average density and availability for new targets
- Particle ID capabilities via **transition radiation** (e/π), dE/dx and range
- Accurate reconstruction of transverse plane kinematics.
- **«Solid» hydrogen concept**: model independent subtraction between CH_2 and C data and kinematic selection to extract H sample

References

- DUNE Collaboration, *Deep Underground Neutrino Experiment (DUNE) Near Detector Conceptual Design Report*, arXiv:2103.13910
- D.E. Andrews et al., *Progress in the Design and Manufacture of the KLOE Solenoid for the DAΦNE ring at Frascati*, Proceedings of the 1997 Particle Accelerator Conference, May 1997;
- M. Adinolfi et al., *The KLOE electromagnetic calorimeter*, Nucl. Instrum. Meth. A482 (2002), 364