The Superconducting Magnet and Electromagnetic Calorimeter of SAND in DUNE

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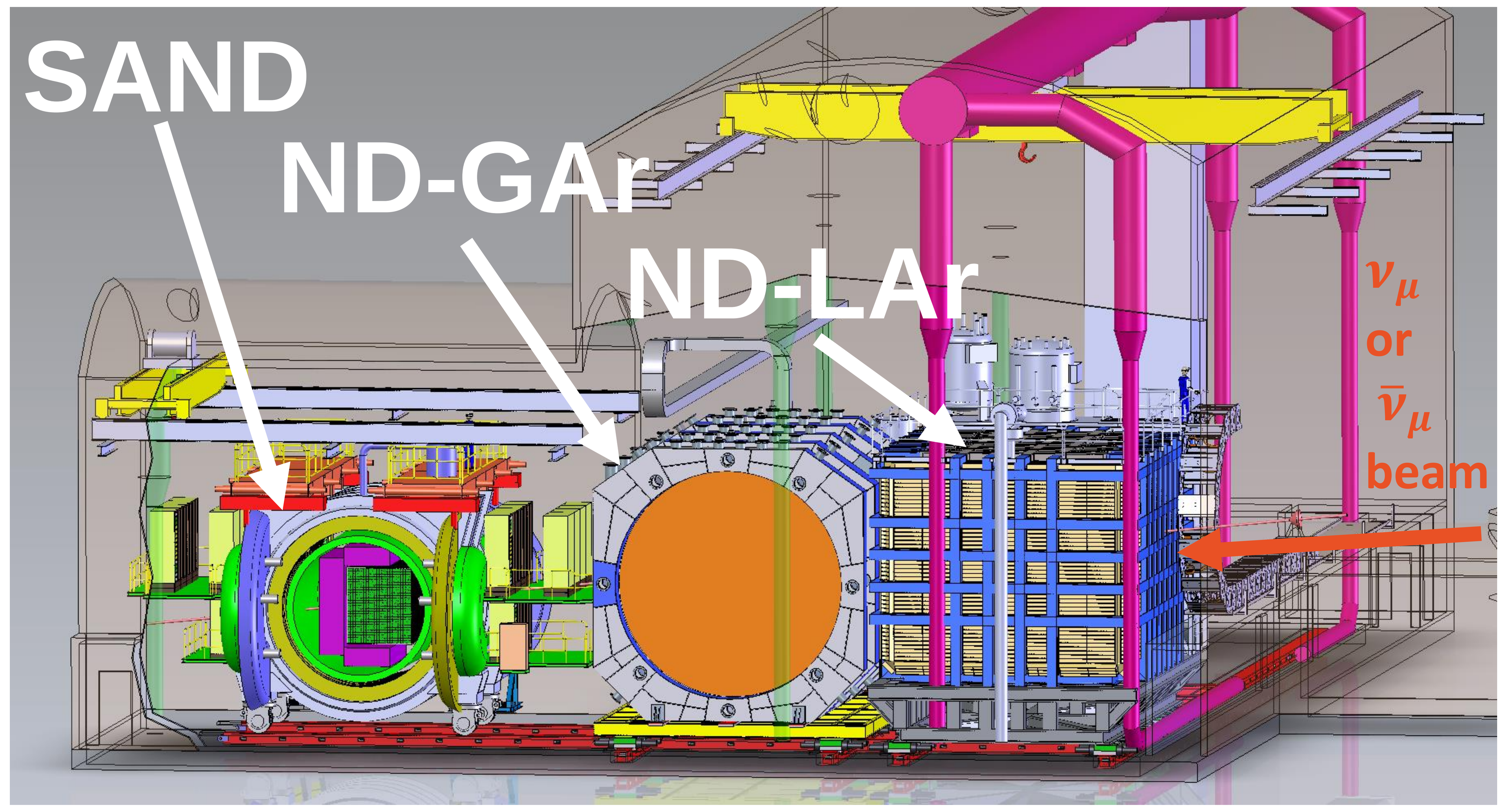
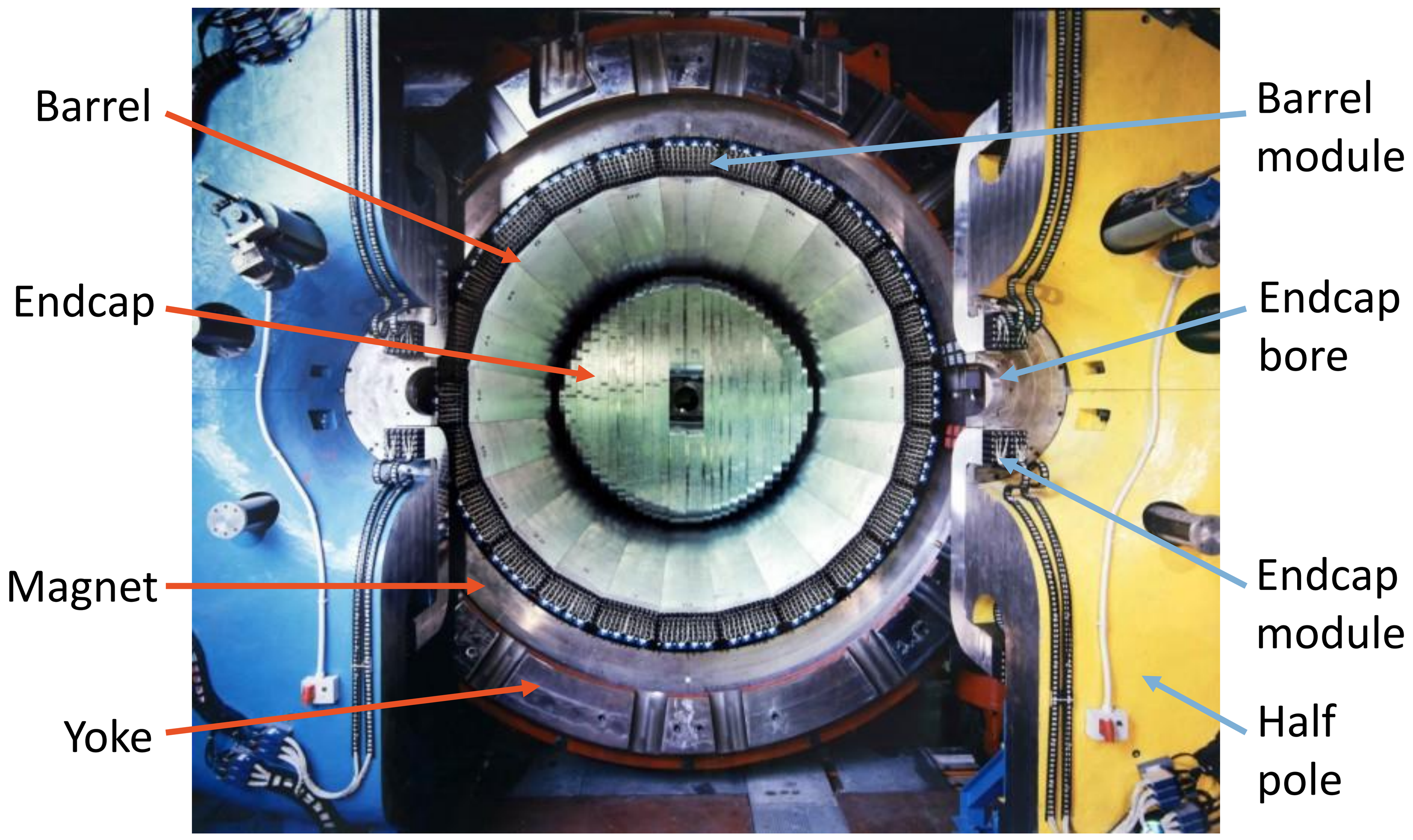
Introduction – DUNE and SAND

The **Deep Underground Neutrino Experiment (DUNE)** is a forthcoming long-baseline, on-axis neutrino oscillation experiment [1,2]. It is based on a wide-band, very intense (1.2 MW) neutrino beam produced at Fermilab, a far detector composed by large liquid argon time projection chambers and a near detector to characterize the beam and better constrain systematic uncertainties.



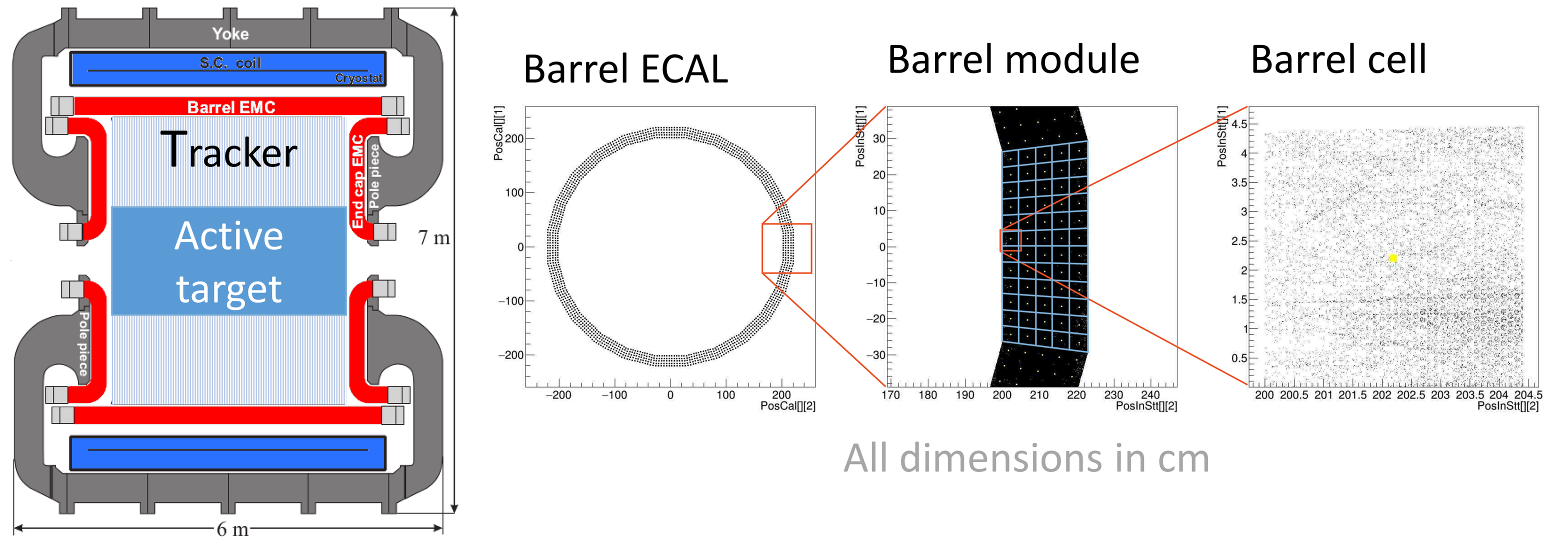
The **System for on-Axis Neutrino Detection (SAND)** [3] will be part of the DUNE near detector. It is based on a superconducting magnet and an electromagnetic calorimeter (ECAL), repurposed from KLOE (K-Long Experiment) [4].

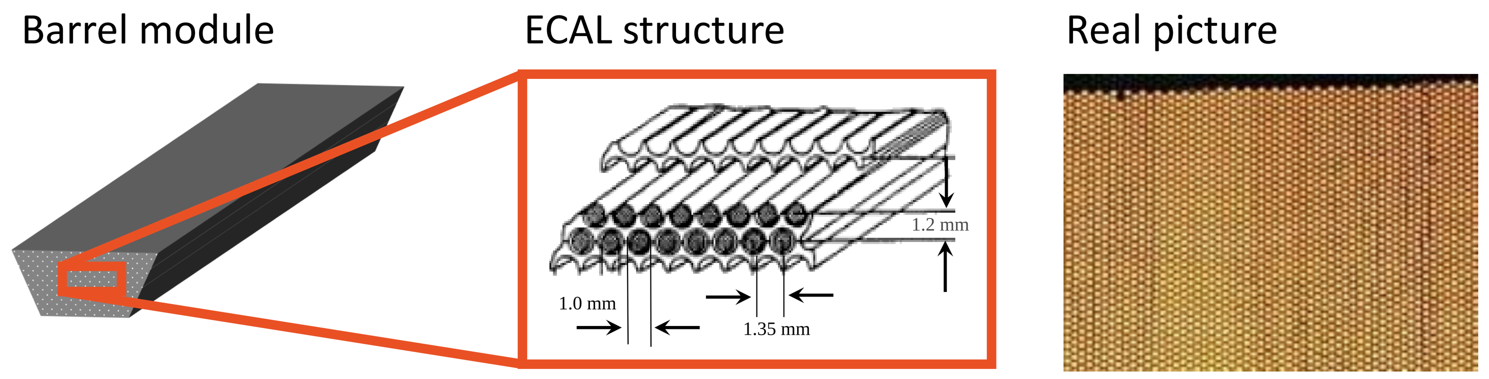


Features

The solenoidal magnet is designed in conjunction with its iron yoke to produce a field of 0.6 T over a 4.3 m long, 4.8 m diameter cylindrical volume. The coil is in a cryostat positioned inside the return yoke.

The Electromagnetic Calorimeter (ECAL) is a lead-scintillating fiber sampling calorimeter of total thickness of 23 cm, consisting of a cylindrical barrel and two endcaps. The inner volume is approximately a cylinder (3.4 m long, 4.0 m diameter).





Segmentation

Barrel: 24 modules with trapezoidal cross section.
Endcap: 32 modules with rectangular cross section.
5 planes (from the inside out): plane 1-4 are 4.4 cm thick, plane 5 is 5.2 cm thick.
12 cells every plane (barrel), 4.4 to 4.9 cm wide, depending on the plane. Similar cells for the endcap modules.
Structure: stack of ~200 grooved, 0.5 mm thick, lead foils alternating with as many layers of cladded 1 mm diameter scintillating fibers, glued together with epoxy.
Average density is 5 g/cm³. $X_0 \sim 1.5$ cm. Thickness ~ 15 X_0.
Read out: fine mesh photomultipliers (Hamamatsu R5946/01 1.5') placed at both ends of the calorimeter modules (4880 channels in total), in the cavities of the yoke, in a reduced magnetic field (0.2 T axial, 0.07 T transverse).
The signal of each PMT goes to ADC, TDC and trigger logic.
Composition by volume: 42% lead, 48% fibers, 10% epoxy.

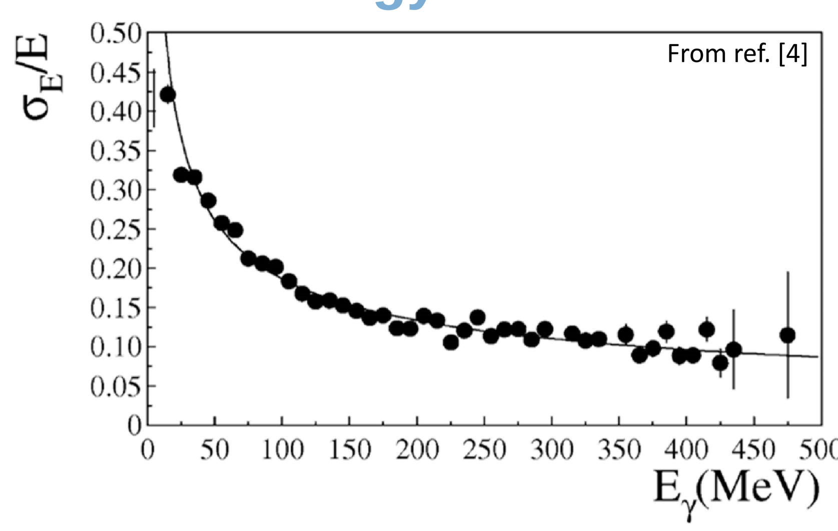
Performances

The existent segmentation of the ECAL results in a **spatial resolution of 1.3 cm** in the directions perpendicular to the fibers.

The ECAL provides particle identification and accurate reconstruction of $e^{\pm}$, γ, and π^0 as already demonstrated by KLOE.

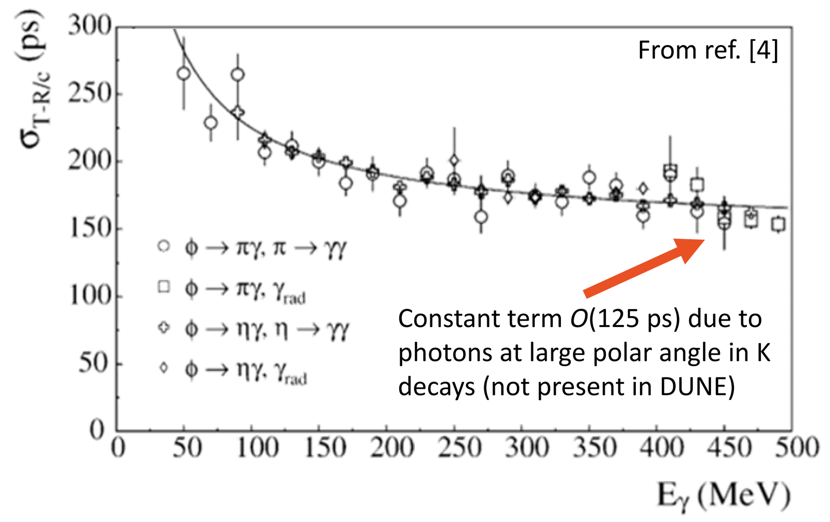
The time resolution and the fine-grained structure of the also allow the **neutron energy measurement using the time-of-flight technique** and the **distinction of incoming/outgoing muons**.

Energy resolution



$$\frac{\sigma_E}{E} = \frac{5.7\%}{\sqrt{E(\mathrm{GeV})}}$$

Time resolution



$$\sigma_t = \frac{54}{\sqrt{E(\mathrm{GeV})}}\ \mathrm{ps} \oplus 50\ \mathrm{ps}$$

The upstream part of the ECAL barrel can be used as an additional active target with a total fiducial mass of 22.8 tons (see M. Tenti's poster).

Conclusions

Different options are being considered for the active target and the tracker inside the magnetized volume (see posters by M. Tenti, B. Guo, A. Sitraka and S. Gwon).

Real data from KLOE [4] allow a fine-tuning of the Monte-Carlo simulations of the ECAL, where **actual geometry and digitization** are implemented.

References

[1] DUNE Far Detector TDR, Volume I, arXiv:2002.02967v2
[2] DUNE Far Detector TDR, Volume II, arXiv:2002.03005v2
[3] Battisti, Federico (2020) Master's Thesis, link
[4] Nucl.Instrum.Meth.A 482 (2002) 364-386, DOI