The Design of the LENA Detector

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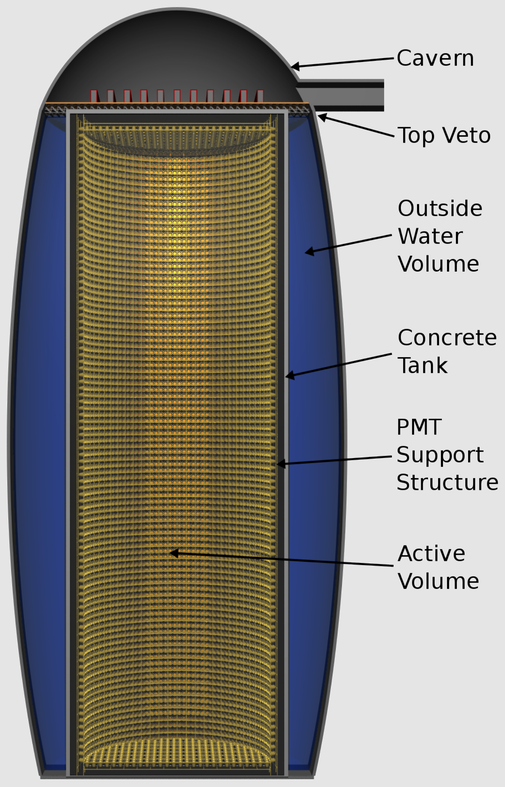
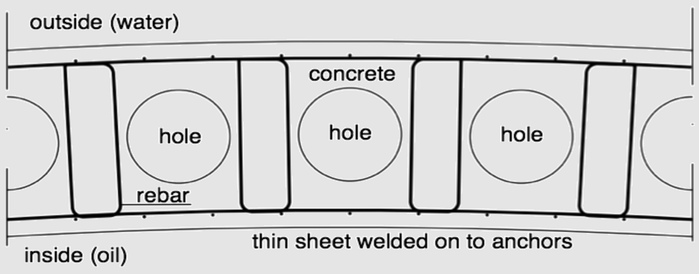
Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

Detector Design



LENA Tank

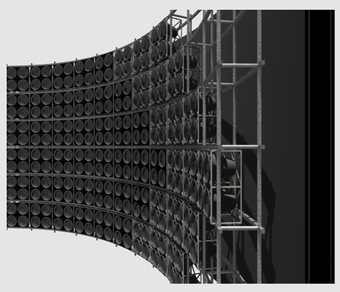
The **Hollow-Core Concrete Tank** features a sandwich structure of a 600 mm wide concrete layer covered on both sides by thin steel sheets for compatibility with the scintillator. Cylindrical cavities of 300 mm diameter and 500 mm interspacing are kept open to reduce the needed amount of material, at the same time leaving space for installations (e.g. cooling or active leak proving).
Design from Rockplan Ltd.:



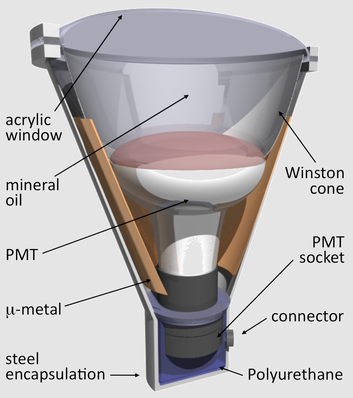
PMT Support Structure

- Scaffolding 2 m from tank wall
- Optical separation of inner volume by non-reflective plastic sheets

⇒ Reduces impact of γ activity from concrete tank wall
⇒ Mitigates Rn convection
⇒ No nylon vessel needed



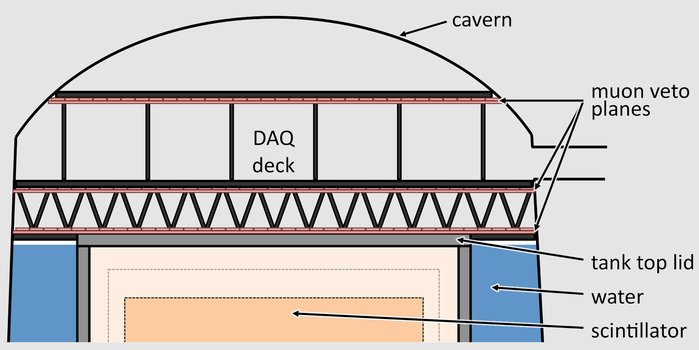
Optical Modules



The PMTs will be enclosed in optical modules

- Winston cones to increase light collection
- 32000 12" PMTs
- 2 kV HV
- 30% optical coverage
- Front diameter: 450 mm
- OM length: 700 mm
- Pressure encapsulation
- Non-scintillating buffer volume included in front of the PMT
- Total weight: 30 kg
- Contained within PSS

Muon Veto



Top Veto
On top of the detector three layers of muon detectors will be installed. The following options are under consideration:

- Plastic Scintillator
- RPCs
- Limited Streamer Tubes

Cherenkov Veto
The cavern outside the tank will be filled with water and equipped with 2000 12" PMTs

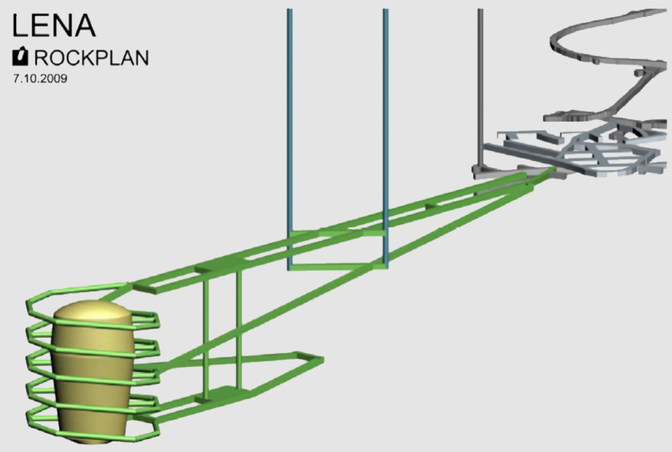
The LENA Detector

LENA (Low Energy Neutrino Astronomy) is a future detector for the observation of neutrinos from terrestrial and astrophysical sources. The design foresees the use of 50 kt of liquid scintillator for neutrino detection. LENA is one of the options currently under investigation in the European LAGUNA/LBNO design study for the next generation, very large volume, deep underground neutrino observatory.

LENA Sites

Pyhäsalmi Site

The Pyhäsalmi mine is located close to the geographic center of Finland, near the town of Pyhäjärvi. The mine is the deepest in Europe, the bottom level at $\sim$ 1450 m. The mine already hosts a small underground laboratory, the Finnish Center for Underground Physics in Pyhäsalmi (CUPP). The feasibility study for LENA at Pyhäsalmi was carried out by the Finnish company Rockplan Ltd..
The cavern will be constructed adjacent to the deepest level of the mine, about 500 m from the central mine shaft. At this depth, the rock will be very hard, dry and at 23°C. The seismic activity in the region is very low.



Depth	4000 m.w.e
μ flux	$1.1 \times 10^{-4}/\mathrm{m^2 s}$
Reactor $\bar{\nu}_e$ flux	$1.9 \times 10^{5}/\mathrm{m^2 s}$

The distance from CERN is 2288 km. This corresponds to the 1st oscillation maximum of a 4.65 GeV ν_μ beam.

Fréjus Site

The Laboratoire Souterrain de Modane (LSM) is located adjacent to the Fréjus road tunnel in the French-Italian Alps, connecting Modane (F) and Bardonecchia (I). A new laboratory nearby is discussed in the context of the MEMPHYS detector. However, the FP7 LAGUNA design study shows that Fréjus will suit well the requirements of LENA. The feasibility study was carried out by the Swiss company Lombardi Ltd.

Depth	4800 m.w.e
μ flux	$5 \times 10^{-5}/\mathrm{m^2 s}$
Reactor $\bar{\nu}_e$ flux	$1.6 \times 10^{6}/\mathrm{m^2 s}$

Radiopurity Requirements

Isotope	Concrete	PSS Steel	OM-PMTs	OS Sheets	Scintillator
^{232}Th	14 Bq/kg	0.2 Bq/kg	0.3 Bq/OM	150 Bq/kg	10^{-8} Bq/kg
^{238}U	62 Bq/kg	0.5 Bq/kg	3.2 Bq/OM	600 Bq/kg	10^{-8} Bq/kg
^{40}K	17 Bq/kg	0.03 Bq/kg	0.2 Bq/OM	200 Bq/kg	10^{-8} Bq/kg
^{60}Co	–	0.03 Bq/kg	–	–	–

Estimated trigger rate: 13 kHz (PMTs: 8.5 kHz, tank: 4.5 kHz)

Contact Information

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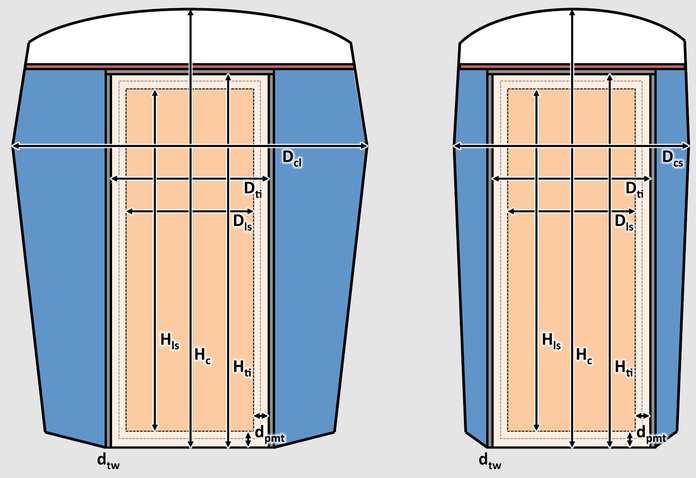
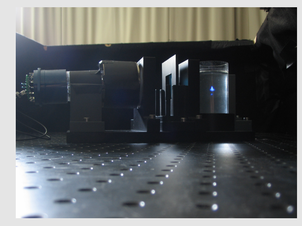
Detector Dimensions



cavern: short axis D_{cs}	44600 mm
cavern: long axis D_{cl}	71200 mm
cavern: height H_c	120000 mm
concrete tank: inner diameter D_{ti}	32000 mm
concrete tank: inner height H_{ti}	100000 mm
concrete tank: wall thickness d_{tw}	600 mm
scintillator: total volume	80.3×10^3 m^3
scintillator: total mass	69.1 kt
active volume: diameter D_{ls}	28000 mm
active volume: height H_{ls}	96000 mm
scintillator: active volume	59.1×10^3 m^3
scintillator: active mass	50.8 kt
ratio: active/total	74%
cavern volume (bottom to tank height)	219.6×10^3 m^3
tank volume	86.6×10^3 m^3
outer water volume	133.0×10^3 m^3

LENA Scintillator

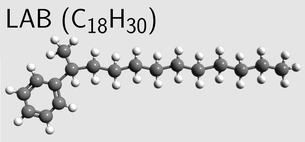
- linear-alkyl-benzene as solvent
- PPO + bisMSB as wavelength shifters
- Emission @ 430 nm
- Time response: < 5.2 ns
- High light yield $\sim$ 10000 γ per MeV
- $>$ 200 photelectrons per MeV
- High transparency $\sim$ 20 m
- Low cost (< 1.30 €/ℓ)



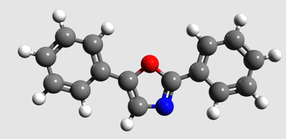
Properties of LAB:

Molecular weight	241
Density	0.863 kg/ℓ
Viscosity	4.2 cps
Flash Point	140°C
HMIS ratings	
Health	1
Flammability	1
Reactivity	0
Index of refraction	1.49
Attenuation length	$\sim$ 15 m
Absorption length	40 m
Abs.-reemission length	60 m
Rayleigh scattering length	40 m

LAB ($C_{18}H_{30}$)



+3 g/ℓ PPO ($C_{15}H_{11}NO$)



+20 mg/ℓ bisMSB ($C_{24}H_{22}$)

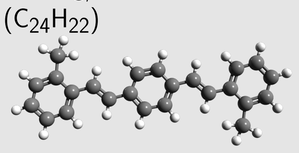
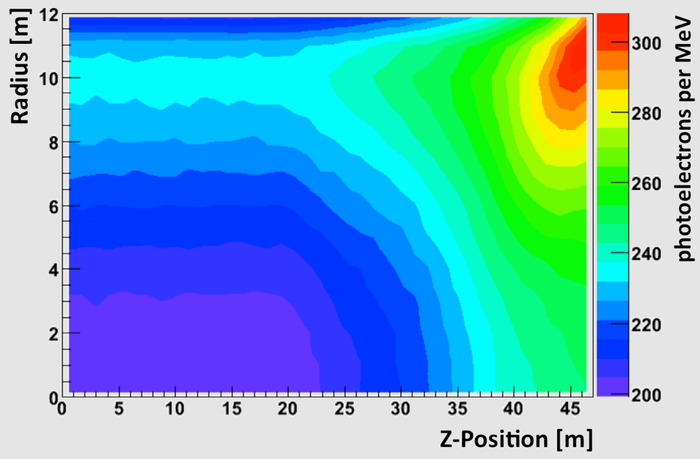


Photo Electron Yield



Liquid Handling

- Detector filling time 1 year (50 weeks $\times$ 5 days)
- Water and LS filled in parallel (individual systems)
- Entire liquid volume can not be stored ⇒ arrival, processing, filling in parallel
- LAB stored and handled under nitrogen atmosphere ⇒ N_2-supply system needed above and underground
- Option for LAB purification plant

Scintillator production line