MEMPHYS: A next generation megaton water Cherenkov detector in Europe

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Abstract. MEMPHYS (MEgaton Mass PHYSics) is a proposed large-scale water Cherenkov detector to be installed deep underground. It is dedicated to nucleon decay searches, neutrinos from supernovae, solar and atmospheric neutrinos, as well as neutrinos from a future Super-Beam or Beta-Beam to measure the CP violating phase in the leptonic sector and the mass hierarchy with atmospheric neutrinos. This proceeding will show the status of the design studies concerning in particular the optical layout and the dedicated test-bench (MEMPHYNO). In addition, some results in terms of physics performances obtained by simulations will be shown.

1. Introduction
A megaton-scale water Cherenkov detector would have competitive capabilities for accelerator-based neutrino oscillation physics such as the possibility to discover the CP violation in the leptonic sector. In addition, it would reach a sensitivity on the proton lifetime close to the predictions of most supersymmetric or higher dimension grand unified theories and it would explore neutrinos from supernovae and from other astrophysical sources.

The existing Water Cherenkov Detectors are a precious source of expertise and information for MEMPHYS, which will be roughly 20 times the size of SuperKamiokande [1], so MEMPHYS will be a reasonable extension of a known, well performing detector.

2. The MEMPHYS (Megaton Mass PHYSics) detector
MEMPHYS [2] [3] is a proposed large-scale water Cherenkov detector with a fiducial mass of about 500 kt. It is composed by two tanks of 65m in diameter and 103m in height.

Each module is equipped with ~120000 12" photomultipliers (PMTs) providing 30% optical coverage. The detector could be installed at the Fréjus site, near the existing Laboratoire Souterrain de Modane (LSM laboratory) located at 130 km from CERN and with a rock overburden of 4800 m.w.e.

3. Optical layout optimization
Optimization studies to reduce the number of PMTs have been done investigating different possibilities: comparison of different photocathode diameters (8", 10" and 12"), the using of High Quantum Efficiency (HQE: 32% at 400 nm) and Normal Quantum Efficiency (NQE: 22% at 400 nm) photocathodes, different geometrical coverages (30%, 20% and 15%) and the possibility of adding Light Concentrators (LC).
As an example of the design optimization tests, in Figure 2 we show the mean number of collected PEs per MeV and the mean number of hit PMTs as a function of the electron energy considering 12” PMTs and different geometrical coverages, NQE or HQE, with or without LC.

Figure 2. Mean number of collected photoelectrons per MeV (left) and mean number of hit PMTs (right) as a function of the electron energy for different configurations. The CE is set to 0.8 and considered PMTs are 12”.

4. MEMPHYNO test-bench
One important R&D item towards the construction of MEMPHYS and other large liquid-based detectors is focused on the reduction of the number of electronics channels for power supply and signal read-out of the PMTs, which is expected to be one of the major costs of the experiment. The Pmm2 R&D programme [4] has developed an integrated readout electronics circuit (an ASIC called PARISROC [5]) for groups of PMTs (matrix of 4x4). MEMPHYNO [6] is a test bench for light sensor or electronics solutions installed at the APC Laboratory in Paris. It consists of a high-density polyethylene tank of 2x2x2 m³, filled with water and placed inside a
Muon hodoscope. A photograph of the detector and of the PMT matrix as well as an example of signal are shown in Figure 3.

![Figure 3](image)

**Figure 3.** Picture of the MEMPHYNO test-bench (left) and of the PMT matrix (center) and an example of signal recoiled on one PMT (right).

5. Simulation and Physics Studies

Realistic analysis algorithms have been developed to evaluate the detector efficiency and energy resolution, which are then used for studies on the MEMPHYS physics reach using the GLoBES package. [7]

In order to properly take into account all the effects of the reconstruction, the detector performance is conventionally described in terms of “Migration Matrices” representing the neutrino reconstructed energy versus the true one.

An example of these matrices is shown in Figure 4 (left). In the right panel of Figure 4 the coverage of the CP phase space at $3\sigma$ is shown as a function of the true value of $\sin^2 2\theta_{13}$ for different values of the systematic errors. The beam considered is the Super Beam [8] from CERN studied in the context of the EURONU project [9] We expect to cover about 55% at $3\sigma$ with 5%/10% error on signal and background.

![Figure 4](image)

**Figure 4.** “Migration Matrices” with reconstructed neutrino energy as a function of true energy for selected events ($\nu_e$ CC)

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