PHYSICS WITH THE MEMPHYS DETECTOR*

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MEMPHYS is a proposed 0.5 Mton scale water Čerenkov experiment to be performed deep underground. Possible sites are under study in the European FP7 design study LAGUNA. It is dedicated to nucleon decay, neutrinos from supernovæ, solar and atmospheric neutrinos, as well as neutrinos from a future Super-Beam or β-Beam. Its performance with neutrino beams includes the possibility of measuring the mixing angle θ_{13}, the CP-violating phase δ and the mass hierarchy. One R&D item currently being carried out is MEMPHYNO, a small-scale prototype with the main purpose of serving as a test bench for new photodetection and data acquisition solutions, such as grouped readout system. We review here the MEMPHYS physics reach and present the status of the MEMPHYNO prototype.

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1. Introduction

Neutrinos are messengers from astrophysical objects as well as from the early Universe and can give us information on processes, which cannot be studied otherwise. Underground experiments, like Super-Kamiokande (SK) [1], have made important discoveries. Next-generation very large volume underground experiments will answer fundamental questions on particle and astroparticle physics. They will search for a possible finite lifetime for the proton with a sensitivity one order of magnitude better then the current limit. With a neutrino beam they will measure with unprecedented sensitivity the last unknown mixing angle (θ_{13}) of neutrinos and unveil through neutrino oscillations the existence of CP violation in the leptonic sector, which in turn could provide an explanation of the matter–antimatter asymmetry in the Universe. Moreover, they will study astrophysical objects, in particular the Sun and Supernovæ [2].

The construction of a large scale detector devoted to particle and astroparticle physics in Europe is one of the priorities of the ASPERA[1] roadmap (2008).

The FP7 Design Study LAGUNA (Large Apparatus studying Grand Unification and Neutrino Astrophysics) [3] support studies of European research infrastructures in deep underground cavities able to host a very large multipurpose next-generation neutrino observatory — GLACIER (Liquid Argon) [4], LENA (Liquid Scintillator) [5], MEMPHYS (Water Čerenkov) [6]. One of the possible sites is near the LSM (Laboratoire Souterrain de Modane) underground site at Fréjus, the deepest in Europe (4800 m.w.e.). The very good quality of the rock and its distance from CERN adapted for “low energy” neutrino beams (130 km) made this site one of the best candidates for the MEMPHYS experiment.

Moreover, the European Program called EUROnu[2] investigates the possibility of constructing a neutrino beam in Europe. Particular interest is devoted to the CERN–Fréjus option of neutrino Super-Beam (SB) and/or β-Beam (βB), associated with a MEMPHYS detector in the Fréjus site.

In this paper we will overview the MEMPHYS detector describing in more detail the potentials in non-accelerator (Section 2.2) and accelerator (Section 2.3) physics. In Section 2.4 we present some studies made for MEMPHYS in different possible locations. Then in Section 3 we will introduce the MEMPHYNO R&D program and we briefly describe the importance of such a prototype in the context of the future development of new electronics and photodetection systems.

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[1] ASPERA: `http://www.aspera-eu.org`

[2] EUROnu: `http://www.euronu.org` (Design Study EU-FP7 EUROnu).

2. MEMPHYS

One of the most reliable techniques for neutrino detection is based on Čerenkov light emission in water by the final state particles resulting from neutrino interactions. This is why the possibility of building a water Čerenkov detector with a fiducial mass of about 20 times larger than SK is currently being investigated by different groups around the world, and for different underground sites.

The MEMPHYS project [7] is discussed here with particular interest in the physics potential of a such detector.

2.1. MEMPHYS design

The project aims at a fiducial mass around half a megaton obtained with 3 cylindrical detector modules (see Fig. 1). The original project [6] envisaged cylinders of 65 meters in diameter and 60 meters in height. At the Fréjus site the characteristics of the rock excavations allows for a higher detector: 80 meters (vertical). With this new design the fiducial volume increases up to 572 kilotons (30% bigger) without worsening the performance of the detector.

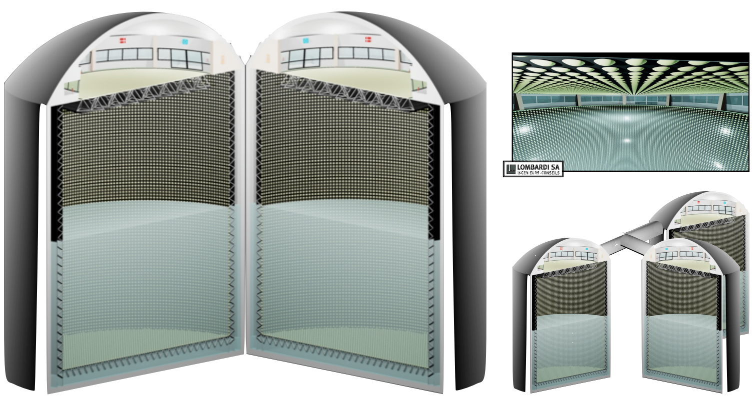

Fig. 1. Draft version of one possible MEMPHYS configuration at LSM (by Lombardi SA Ingenieurs–Conseils).

The design of each MEMPHYS module is a rather mild extrapolation of the SK detector and relies on the expertise acquired after 20 years of operation. It takes into account the need to have a veto volume, 1.5 m thick, plus a minimal distance of about 2 meters between photodetectors and interaction vertices, leaving a sufficient space for ring development and to protect from γ from the PMTs natural radioactivity. The light sensors choice is to instrument the detector with photomultipliers tubes (PMTs) with a geometrical coverage of 30%.

The coverage of large area with PMTs at a "low" cost implies a readout integrated electronics circuit (called ASIC) for groups of PMT. The development of such electronics is the aim of a dedicated French R&D program, called PMm^2 [8]. The circuit under development allows to integrate for each group of PMTs: a high-speed discriminator on the signal photoelectron (ph.e), the digitization of the charge (on 12 bits ADC) to provide numerical signals, the digitization of time (on 12 bits TDC) to provide time information, a channel-to-channel gain adjustment and a common high voltage. All the electronic and acquisition developed in the PMm^2 program is going to be fully tested with the MEMPHYNO prototype (more details in Section 3).

2.2. Non-accelerator physics goals

We describe here the physics goals of the MEMPHYS experiment [3] for neutrino measurements and its proton decay discovery potential.

2.2.1. Proton decay

Most of the GUT models predict a proton decay lifetime between 10^{33} and 10^{37} years. The best signature for a water Čerenkov detector is the $p \to e^+\pi^0$ channel (*golden channel*) with the detection of the Čerenkov ring of the positron and the two rings produced by the gammas due to the pion decay (back-to-back with respect to the positron). The channel $p \to \nu K^+$ is more complicated because the K is under Čerenkov threshold in this interaction (the decay products are detected).

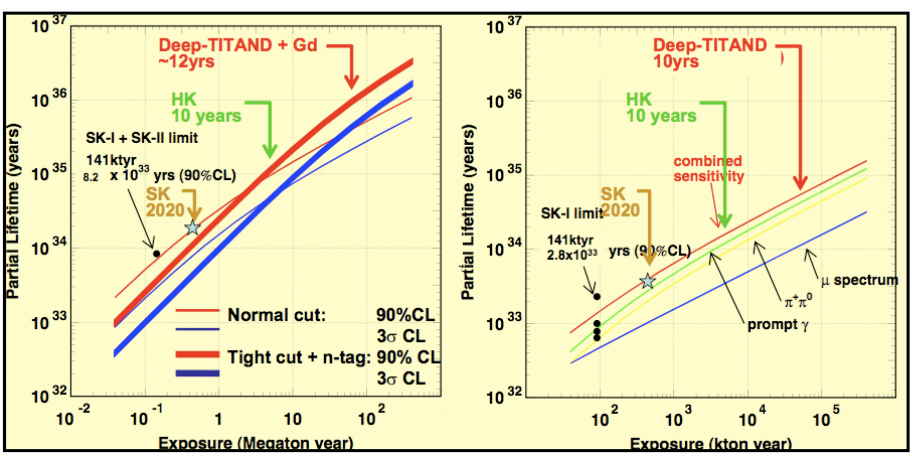

Fig. 2. Proton decay potential discovery in channel $p \to e^+\pi^0$ (*golden channel*) on the left and the $p \to \nu K^+$ channel on the right for SK and Hyper-Kamiokande detectors (MEMPHYS can have the same fiducial mass as HK) [9].

Recently SK has improved considerably the results in this channel by increasing the efficiency in vertex reconstruction of the kaon: the overall $K^+ \to \nu\mu^+$ efficiency increased by 20% [9]. We can expect to reach better limits in next years even in this second channel. With MEMPHYS we can achieve the limit of 10^{35} years in the golden channel and the limit of 2.6×10^{34} years for the second one assuming a total exposure of 10 years (90% C.L.) as shown in Fig. 2.

2.2.2. Supernova burst

A supernova (SN) explosion is one of the most spectacular and, at the same time, least understood phenomena of our Universe. Although more than 99% of energy of the burst is emitted via neutrinos it was only in 1987 that for the first time three experiments, Kamiokande, IMB and Baksan, detected such neutrinos emitted during the explosion of the supernova SN1987A [10]. A total of $\sim$ 24 events was detected in less then 13 seconds but the low statistics does not allow the reconstruction of the neutrino spectra and the time structure. As shown in Fig. 3 (left) the huge size of MEMPHYS gives a high number of events if a supernova explosion occurs. Most of the neutrinos interact via CC (charge current) exchange, but there is a small fraction of neutrinos that can interact via ES (electron scattering) yielding directional information on their source. MEMPHYS could detect

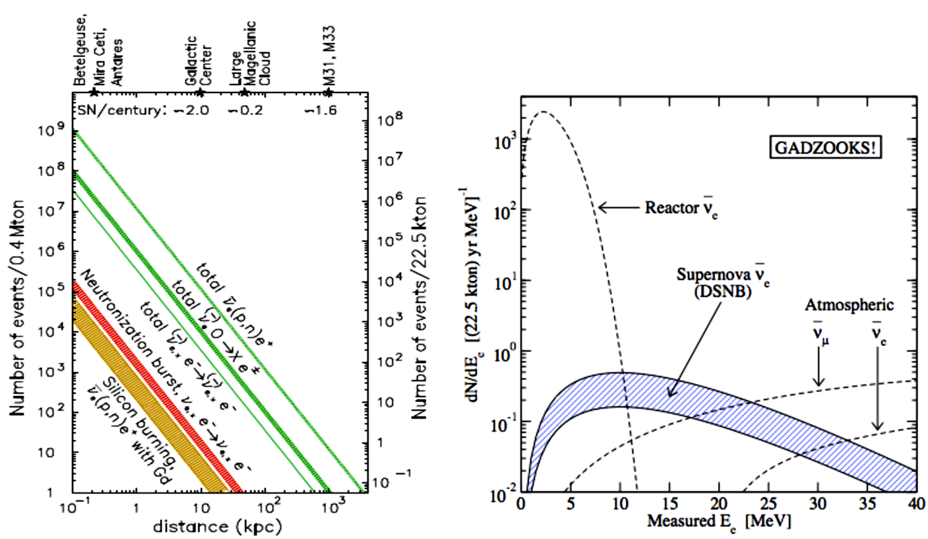

Fig. 3. Left: The number of events in the detector for a supernova explosion as a function of the distance from the Earth [11]. Right: Spectrum for low-energy $\bar{\nu}_e + p \to e^+ + n$ events for Diffuse Supernova Neutrinos together with selected backgrounds spectra [15].

SN up to 1 Mpc by looking for electron antineutrinos interacting with the free protons of the detector medium. Moreover, the high statistics give the possibility to perform spectral analysis (in time, energy and flavor composition) therefore to access the SN explosion mechanism. The measurement of such neutrinos would also allow the study of the neutrino production parameters and the study of the neutrino properties in general. As neutrinos arrive to the Earth before the photons (photon diffuse in the Universe while neutrinos travel without interacting) it is possible to use the early SN neutrinos as a trigger for events in the visible energy (photons) up to ~ 5 Mpc [12].

2.2.3. Diffuse supernova neutrinos

The number of supernova explosions which have occurred is so high that they must have emitted a huge amount of neutrinos [13]. Those neutrinos now are a diffuse background: diffuse supernova neutrinos (DSN). The easiest way of detecting the DSN is the detection of the $\bar{\nu}_e$ via the inverse-β decay.

A stringent upper limit on DSN flux was obtained by the SK Collaboration [14]: they searched for electronic anti-neutrinos that produced a positron with an energy greater then 18 MeV. For several theoretical models, in the absence of signal, upper limits at 90% C.L. on the total flux had been set; their limits ranged from 20 to 130 $\bar{\nu}_e$ cm^{-2} s^{-1}. An additional upper bound of 1.2 $\bar{\nu}_e$ cm^{-2} s^{-1} was set for the flux in the energy region $E_{\bar{\nu}} > 19.3$ MeV. Up to now the most interesting energy range is 11.3 MeV $< E_{\bar{\nu}} <$ 19.3 MeV because the background events are less critical (Fig. 3 (right)) and the reaction cross-section increases as $\sim E_{\bar{\nu}}^2$.

In order to make relic neutrino detection more likely Beacom and Vagins [15] proposed to dissolve 0.2% of gadolinium trichloride ($GdCl_3$) in pure water. Since Gd has an extremely high cross-section for radiative neutron capture this would allow antineutrino tagging by the coincidence reaction $\bar{\nu}_e + p \to e^+ + n$ and neutron capture with a clear signature: 8 MeV from the neutron capture and two gammas from the positron annihilation. In that way the background events due to atmospheric muonic neutrinos is greatly reduced.

With Gd dissolved in the water MEMPHYS in 5 years can reach a signal *versus* background ratio of 43–109/47 events.

We summarize in Table I the non-accelerator physics reach for two geometries of the MEMPHYS detector (see Section 2.1. The discovery potential of MEMPHYS for proton decay (90% C.L. in 10 years), the number of events for a supernova explosion at 10 kpc, the ratio signal over background for DSN neutrinos and the rate of solar, atmospheric and reactor neutrinos in the detector per year (not discussed in this paper). We assume an energy threshold of 5 MeV.

TABLE I

Summary of non-accelerator physics in MEMPHYS. The ($\star$) stands for the case where Gd salt is added to the water. The values on the right column are an extrapolation of the left ones.

TOPIC	MEMPHYS (440 ktons)	($\sim$ 572 ktons)
Proton decay:	in 10 years	in 10 years
$e^+\pi^0$	$< 1.0 \times 10^{35}$ [y] 90% C.L.	$\lesssim 1.4 \times 10^{35}$ [y] 90% C.L.
$\bar{\nu}K^+$	$< 2 \times 10^{34}$ [y] 90% C.L.	$\lesssim 2.6 \times 10^{34}$ [y] 90% C.L.
SN ν (10 kpc):		
CC	2.0×10^5 ($\bar{\nu}_e$)	$\sim 2.6 \times 10^5$ ($\bar{\nu}_e$)
ES	1.0×10^3 (e)	$\sim 1.3 \times 10^3$ (e)
DSN ν (S/B 5 y)	(43–109)/47 ($\star$)	(56–142)/61 ($\star$)
Solar ν		
^{8}B ES	1.1×10^6 per y	$\sim 1.3 \times 10^6$ per y
Atm. ν (per y)	4.0×10^4	$\sim 5.2 \times 10^4$
Geo ν	need 2 MeV thr.	need 2 MeV thr.
Reactor ν (per y)	6.0×10^4 ($\star$)	$\sim 7.8 \times 10^4$ ($\star$)

2.3. Physics with beams: Super-Beam and β-Beam

Concerning accelerator-based neutrino oscillations studies, there are two possible solutions for a future neutrino beam that could be studied with MEMPHYS: a Super-Beam and/or a β-Beam from CERN to the detector [16]. In particular, we are considering here a βB with $\gamma = 100$ for the stored ions and a SB based on an optimized Supercondacting Proton Linac (SPL) with a proton beam energy of 3.5 GeV and a proton beam power on the target of 4 MW.

For a MEMPHYS detector at the Fréjus site, situated at 130 km from CERN and considering the energy of the beam between 0.2–0.4 GeV, the neutrino oscillation probability corresponds to the first peak. Using both βB and SB we obtain a discovery potential of $\sin^2 2\theta_{13} \sim 5 \times 10^{-3}$–$3 \times 10^{-4}$ (lower–upper limits) at 3σ, irrespective of the actual value of $\delta_{\rm CP}$ phase. For certain values of $\delta_{\rm CP}$ the sensitivity is significantly improved. For a βB (SPL) alone, discovery limits around $\sin^2 2\theta_{13} \sim 3\ (10) \times 10^{-4}$ are obtained for a large fraction of possible values of the $\delta_{\rm CP}$ phase. Another important point is the understanding of the neutrino mass hierarchy: MEMPHYS could also determine this parameter with a sensitivity at 2σ C.L. (with 5 years data) for $\sin^2 2\theta_{13} > 0.025$. This result could be obtained — in a MEMPHYS at Fréjus configuration — combining βB and SB with the measurement of atmospheric neutrinos. There is also the possibility to determine the octant of θ_{23} with the combination of SB with atmospheric data (Fig. 4 (left)).

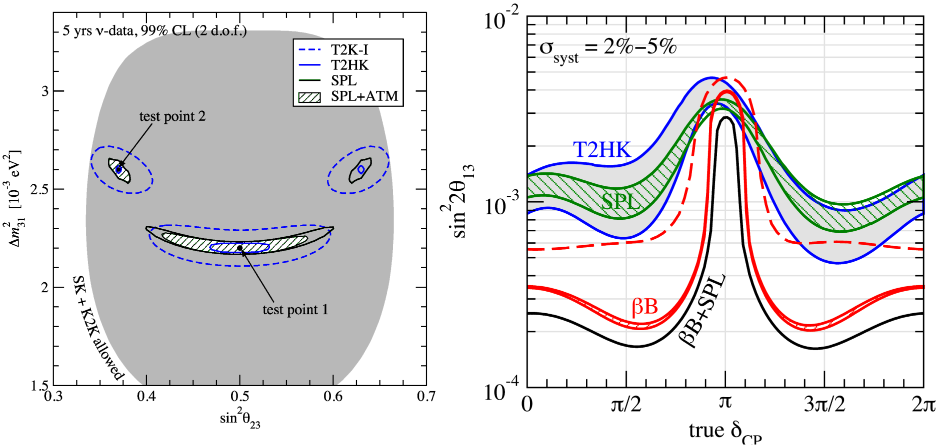

Fig. 4. Left: Allowed regions after 5 years neutrino data taking for SPL and ATM+SPL compared to T2HK and ATM+T2HK data. Right: CP violation discovery potential for β-Beam, SPL and T2HK. The width of the bands corresponds to values for the systematic errors from 2% to 5%.

In the EUROnu design-study many efforts are concentrated on a European beam directed at a MEMPHYS detector located in LSM (Fréjus) because of the convenient distance: a distance of 130 km implies a lower energy beam that is easier to construct, as well as less expensive [17].

If we consider the performance of a *standard* β-Beam [16] we obtain as a function of distance from CERN a different number of events detectable in the detector (see Fig. 5). We point out three possible location of MEMPHYS

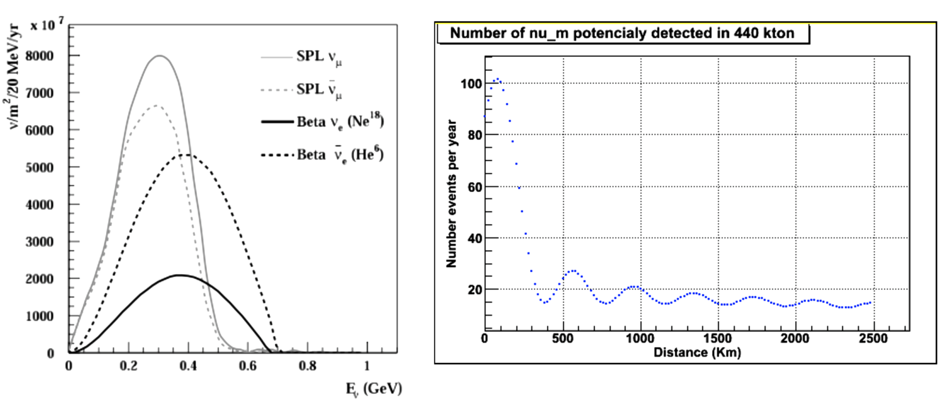

Fig. 5. Left: Comparison of the flux from SPL and β-Beam [16]. Right: with the β-Beam neutrino flux discussed in [16] number of neutrinos potentially detected in MEMPHYS as a function of the distance from CERN.

(Fréjus, Canfranc, Pyhäsalmi) and we summarize in Table II the results. In particular, we show for two values of θ_{13} and for two values of the CP phase the number of neutrinos potentially detected in one year.

TABLE II

Number of muonic neutrinos (antineutrinos) per year potentially detected in MEMPHYS in three different location (obtained taking in account a β-Beam of ν_e that oscillates in muonic neutrinos following the three flavors probability formula, matter effect included).

For a β-Beam	θ_{13}/ $\delta_{\rm CP}$	$\sin^2 2\theta_{13} = 10^{-2}$	$\sin^2 2\theta_{13} = 10^{-3}$
Fréjus (130km)	$\delta_{\rm CP} = 0$	60 (62)	20 (20)
	$\delta_{\rm CP} = \pi/2$	70 (27)	20 (9)
	bkg $(\pi^{+/-}) + \nu_{\rm atm}$	$\sim$ 29 (31)	$\sim$ 29 (31)
Canfranc (630km)	$\delta_{\rm CP} = 0$	13 (15)	12 (13)
	$\delta_{\rm CP} = \pi/2$	16 (10)	13 (12)
	bkg $(\pi^{+/-}) + \nu_{\rm atm}$	$\sim$ 15 (17)	$\sim$ 15 (17)
Pyhäsalmi (2300km)	$\delta_{\rm CP} = 0$	10 (11)	9 (11)
	$\delta_{\rm CP} = \pi/2$	10 (11)	11 (11)
	bkg $(\pi^{+/-}) + \nu_{\rm atm}$	$\sim$ 14 (16)	$\sim$ 14 (16)

We can conclude that for a neutrino beam produced at CERN of a mean energy of ~ 0.4 GeV the first peak is at LSM distance. Both for SPL and β-Beam the sensitivity is of the order of $\sin^2 2\theta_{13} \sim 10^{-3}$ for a large range of CP phase values.

2.4. Depth and latitude studies

We discuss here briefly a study on the muon flux in the detector as a function of depth and a latitude study concerning matter effects in supernova explosion neutrino measurement.

2.4.1. Depth studies

We want to evaluate the muon flux in a MEMPHYS type experiment in order to evaluate the background induced by muons crossing the Čerenkov detector as a function of the underground site location. The geometry taken in account is a 65×60 m high cylinder.

The muon flux as a function of depth is plotted in Fig. 6 (left). We consider four particular depths: 300, 1000, 2700 and 4800 m.w.e. — where 2700 m.w.e. corresponds to the Super-Kamiokande site, 4800 m.w.e. is the Fréjus site depth (LSM) and the others are two general depths useful for comparisons.

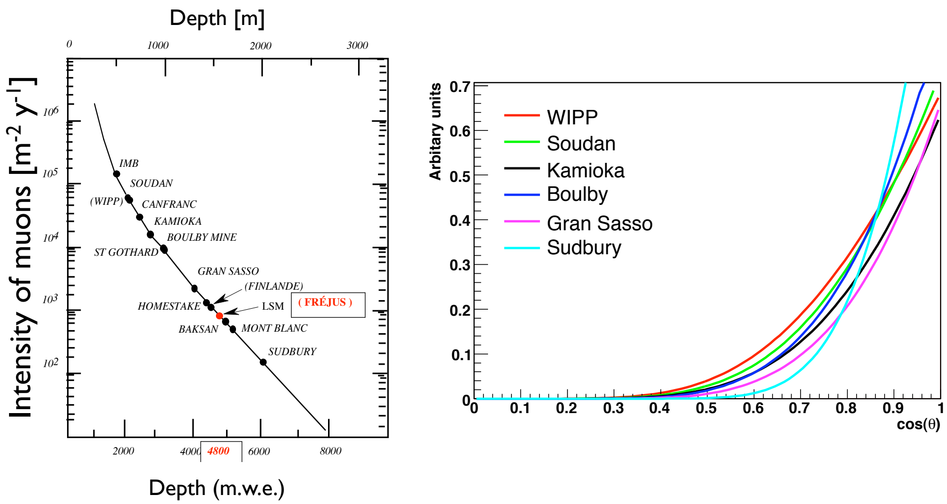

Fig. 6. Left: Muons flux as a function of crossed rock [18]. Right: The muon angular distribution local to the various underground sites based on the parameterization described in [20]. All curves have been normalised to the total muon intensity for comparison purposes.

To calculate the muon flux in the detector we must know the muons angular distribution at the given site. The angular distribution at the sea level is proportional to $\cos^2\theta$ where θ is the azimuthal angle and the average muon energy is about 4 GeV. The paper [20] shows this muon distribution local to the various underground sites based on the muon intensity ($I_{\rm th}$) parameterization (Eq. (1)):

$$I_{\rm th}(h,\theta) = (I_1 \exp\left(-h_0 \sec 0/\lambda_i\right) + I_2 \exp\left(-h_0 \sec 0/\lambda_2\right)) \sec\theta \,. \quad (1)$$

The angular distribution is shown in Fig. 6 (right). There is no data for the depths between Gran Sasso (3600 m.w.e.) and Sudbury (6000 m.w.e.), but the shape distribution does not seem to change dramatically so we assume a cosine distribution with an average of $\cos\theta \sim 0.7$ corresponding to $\sim 45°$. In order to evaluate the muon flux in the detector, for each depth we took the muon flux multiplied by an effective surface that is the sum of top surface and the half-area of the walls of the detector (to take in account the muons coming with a vertical angle between $[-45°, 45°]$).For the four studied depths we obtain the muon flux shown in Table III.

The dead time due to a crossing muon in the detector can be calculated. Each muon will produce Čerenkov light over a period that induces a dead time in the detector of around 1 μs. We can conclude that in the LSM underground site the muon flux on the MEMPHYS detector will be of ~ 0.6 muons per second giving a corresponding dead time of 6.2 s per year per cylinder which is not a problem for the experiment.

TABLE III

Left: Muon flux in the detector as a function of depth. Center: Invisible muon rate in the detector. Right: number of spallation events due to a invisible muon in a day. (All calculations are made for 1 cylinder).

DEPTH m.w.e.	Muon rate s^{-1}	Invisible muon rate y^{-1}	Spallation event due to invisible muons
300	1.56×10^3	2.5×10^2	2.46×10^2
1000	5.9×10^2	1.4×10^{-1}	1.39×10^{-1}
2700	8.9	2×10^{-5}	1.95×10^{-5}
4800	0.2	3.8×10^{-7}	3.78×10^{-7}

We evaluated the background induced from muon spallation knowing that in water the main spallation source is the "muon–oxygen" interaction: radioactive isotopes, such as ^{6}He, ^{8}Li, ^{8}B ..., are produced and decay emitting beta electrons with a mean lifetime of 0.15 s. There are two different cases: the products of the muons that can be seen in the muon veto and the ones that are produced by the muons that cannot be detected in the veto because they are below water Čerenkov threshold (*invisible muons*). The first background can be predicted for each cylinder knowing the rate of spallation products due to crossing muons (the muon veto efficiency is more the 99% for muons more energetic than ~ 0.1 GeV). The calculation with an extrapolation of SK measurements [19] yields the following rates: $\sim 9 \times 10^4$, 3×10^4, 5×10^3, 12 per day at 300, 1000, 2700, 4800 m.w.e., respectively. At 4800 m.w.e. the rate is so low that an off-line cut-off of 0.20 s after each muon could be considered. Instead, the second case is an intrinsic source of background because here the products came from the muons below Čerenkov threshold that have spallation in the tank. This muons cannot be detected in the muon veto (the muon veto works with Čerenkov detection too). The muon flux below Čerenkov threshold for a MEMPHYS (one cylinder) type detector is showed in the third column of Table III (calculated studying the energy spectra of the muon flux in different underground sites [20]). We calculated the ratio of invisible muons, at the different sites, and obtained the number of muon spallation events. The number of event for an effective day run (24 hours) is reported in the last column of Table III. The number of spallation events due to invisible muons of 4×10^{-3} events per one effective year (365 days) of run at the Fréjus site.

More background calculations must be performed, like fast neutrons from muon spallation in the rock and more background site dependent studies, but these preliminary studies confirm the need for an underground site at least at the present depth of SK.

2.4.2. Latitude study

A useful experimental signature for model-independent flavor oscillations in the neutrino signal from the next Galactic Supernova explosion would be the observation of Earth matter effects. This effect is a powerful tool to probe the *neutrino mass hierarchy*. Experiments like the next-generation large volume detectors with high energy resolution (like liquid scintillator detectors) may measure directly the energy-dependent modulation of the neutrino flux. However, even with detectors less accurate in energy measurements but with a huge statistic (like water Čerenkov detectors) it would be possible to detect Earth matter effects using a comparison of the neutrino signal form Supernova when the neutrinos arrive after crossing the Earth (*shadowed* detector) and when the neutrinos coming from the Universe do not traverse the Earth when the neutrinos coming from the Universe do not traverse the Earth (*not-shadowed* detector).

The neutrino detectors considered are mainly sensitive to $\bar{\nu}_e$ in the SN energy range, so we can concentrate on this specific case. The detector is *shadowed* when the neutrinos arrive after crossing the Earth while the detector is *not-shadowed* when the neutrinos coming from the Universe do not traverse the Earth.

One detector

As a function of the detector's location the probability to observe a shadowed neutrino flux changes. Knowing that most of the Milky Way is in the southern sky, a detector in the northern hemisphere would be preferred. The probability for each site can be calculated as shown in [21]. For any location in the world it is possible to obtain the values using the website application developed by the authors[3].

For one detector we obtain the values shown in Table IV. The shadowing probabilities for the different considered locations are very close each other (~ 0.56 to ~ 0.58).

Two detectors

As said before, a single detector can observe Earth matter effects only if its energy resolution is very good (and/or it has high statistics), nevertheless an important option is the combination of one detector results with the data of a *non-shadowed* detector (typically the Ice-Cube at South Pole).

[3] `www.mppmu.mpg.de/supernova/shadowing`

TABLE IV

Representative locations of proposed or existing SN neutrino detectors and neutrino shadowing probabilities.

LOCATION	Latitude	Longitude	Sh. prob. Earth
Pyhäsalmi, Finland	63.66° N	26.04° E	0.581
Fréjus, France	43.43° N	6.73° E	0.568
Boulby, England	54.56° N	−0.083° W	0.577
Kamioka, Japan	36.27° N	137.3° E	0.560
Canfranc, Spain	42.7° N	−0.52° W	0.568
South Pole	90° S	—	0.414

This method can provide a valuable cross-check on systematic errors for MEMPHYS as well as for LENA (liquid scintillator). In Table V we show the probability of detecting the SN neutrinos shadowed or not in some pairs of experimental sites.

TABLE V

Shadowing probability for two detectors. Probability that a detector in the first column is not shadowed while the one in the first row is shadowed. The most "interesting" row is the last one: not-shadowed South Pole and a shadowed "MEMPHYS" in different sites.

LOCATION	Pyhäsalmi	Fréjus	Boulby	Kamioka	Canfranc	South Pole
Pyhäsalmi	—	0.052	0.038	0.157	0.059	0.353
Fréjus	0.065	—	0.036	0.220	0.013	0.307
Boulby	0.042	0.028	—	0.198	0.027	0.332
Kamioka	0.179	0.230	0.216	—	0.238	0.290
Canfranc	0.073	0.014	0.036	0.229	—	0.305
South Pole	0.519	0.461	0.495	0.435	0.458	—

The special location of IceCube makes the comparison with Norther experiments particularly interesting: obviously the more northerly locations are the best. The value for the Fréjus–South-Pole pair ($\sim$ 46%) can be compared with the maximum possible value of 58.5% obtained with an experiment at the South and one at the North Pole.

3. R&D: MEMPHYNO prototype

The huge size of MEMPHYS and the cost of the light sensors for such an experiment require a careful choice concerning the detection technique and the data acquisition system.

As we mentioned before, the project PMm^2 intends to realize a new electronics board dedicated to a grouped acquisition of a matrix of 16 PMTs. In the MEMPHYS detector, each matrix of PMTs will have a common board (PARISROC) for the distribution of high voltage and for the signal readout. Such system should be tested with real physical signals and with the same detection technique as MEMPHYS. For this, a small prototype of MEMPHYS, MEMPHYNO, is presently under construction at the APC Laboratory (AstroParticules et Cosmologie — Paris) in order to make a full test of the complete chain "electronics and acquisition". Moreover, MEMPHYNO is going to measure the trigger threshold, the track reconstruction performance and the properties of the PMTs.

MEMPHYNO is a test bench for any kind of light sensor or electronics solution for next generation megaton size experiments. This prototype is realized with a PEHD (Polyethylene) tank of $2 \times 2 \times 2$ m fill with water and a hodoscope made by 4 scintillator planes (kindly donated by the OPERA Collaboration) [22] — 2 on the top and 2 on the bottom — for the trigger of the incoming cosmic muons (see Fig. 7). The first 16 PMTs matrix of PMm^2 will be placed in the tank and studied first with cosmic muons. Then, MEMPHYNO will be moved to LSM for a background test in the same environment as MEMPHYS, then at CERN for electron, pion and kaon beam measurements (an electron beam from the LAL is also possible). The test with electrons will be used to study the collection efficiency of the Čerenkov light from a point-like source and to check the single photoelectron range with the new electronics system.

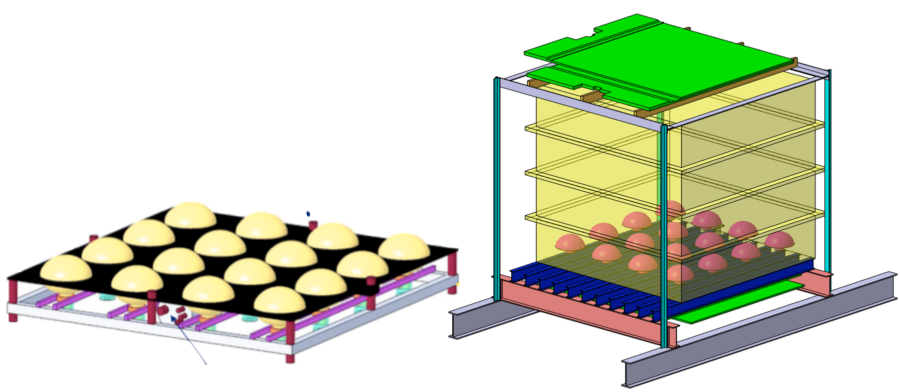

Fig. 7. On the left the demonstrator of the PMm^2 R&D program that is going to be tested with its electronics system in the MEMPHYNO prototype (right).

At present time, MEMPHYNO is being built at APC and the hodoscope is going to be operational soon. Waiting for the PMm^2 demonstrator (16 8" PMTs of Hamamatsu), the tank will be cleaned and filled and tests of the acquisition system will start with four 8" PMTs (ETL-Electron Tubes Limited) from Borexino [23]. The aim is to have a running prototype as soon as possible to start the tests of the 16 PMTs matrix and have results for the end of the year. The DAQ system, the trigger and the mechanical integration of the 16 PMTs matrix from PMm^2 is currently under development in a joint effort from teams of LAL[4], IPNO[5] and APC.

4. Conclusion

We presented here a brief review of the physics potential of MEMPHYS: a water Čerenkov detector mainly dedicated to neutrinos unknown parameters, Supernova neutrinos and proton decay. Europe is active in the study of a megaton scale water Čerenkov detector and studies are being carried out on potential neutrinos physics potentials in each sites and it is also investigating for a neutrino beam in Europe in the near future (LAGUNA and EUROnu). The present MEMPHYS Collaboration is considering an installation close to LSM site, where sufficiently large cavities appear feasible with an interesting synergy with CERN to Fréjus neutrino beam. Anyway more complete studies are performed in the LAGUNA and EUROnu context as well as more sophisticated simulation and background studies.

In France there are two R&D programs ongoing: the realization of a grouped electronics and acquisition system for a matrix of 16 PMTs (PMm2[6]) and the construction of the MEMPHYNO prototype. MEMPHYNO will be a test bench for photodetection and electronic solutions for large scale detectors. It is being built and the first tests will start soon; in the summer 2010 we will start the measurements of the PMm^2's demonstrator. We also intend to move the prototype in an underground site for background tests and to a beam facility to perform trigger threshold test and to study the collection efficiency of the Čerenkov light from a point-like source with the new electronics system.

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