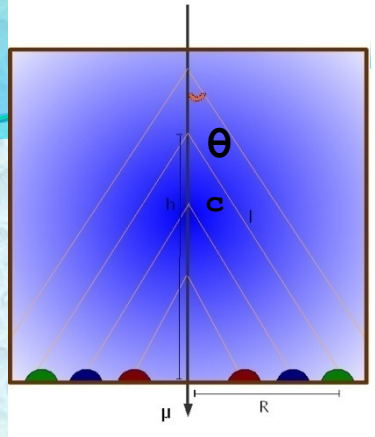
7th International Workshop on Ring Imaging Cherenkov Detectors
RICH2010 - Cassis, Provence, France, 3-7 May 2010

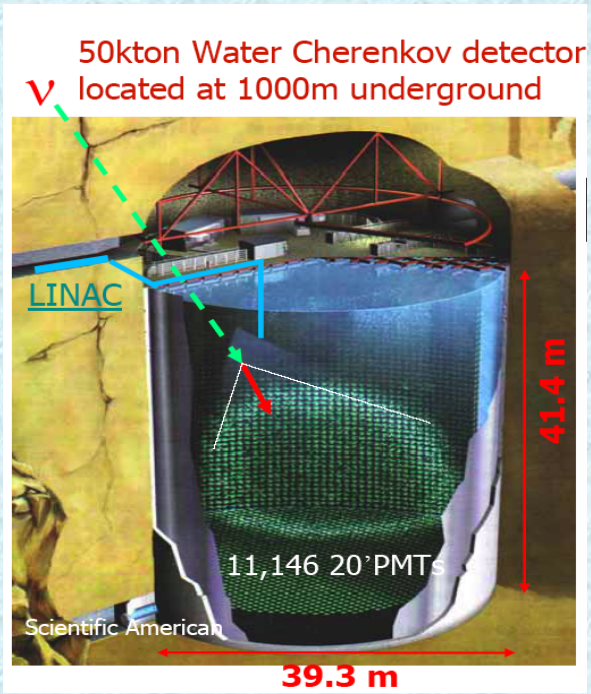


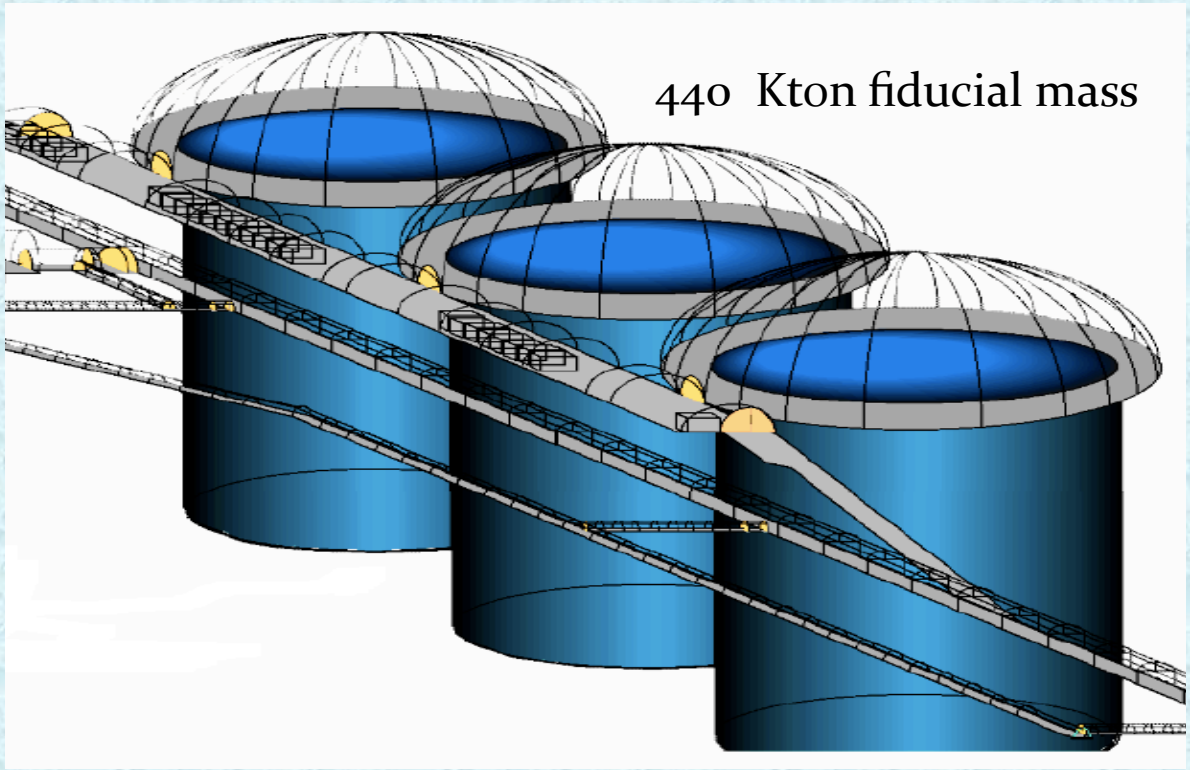
The Memphys Project

Thomas Patzak
APC, Paris
University Paris Diderot Paris 7

Studies towards a large scale Water Cherenkov detector in Europe

SuperKamiokande → ***MEMPHYS***





MEMPHYS: A large scale water Čerenkov detector at Fréjus

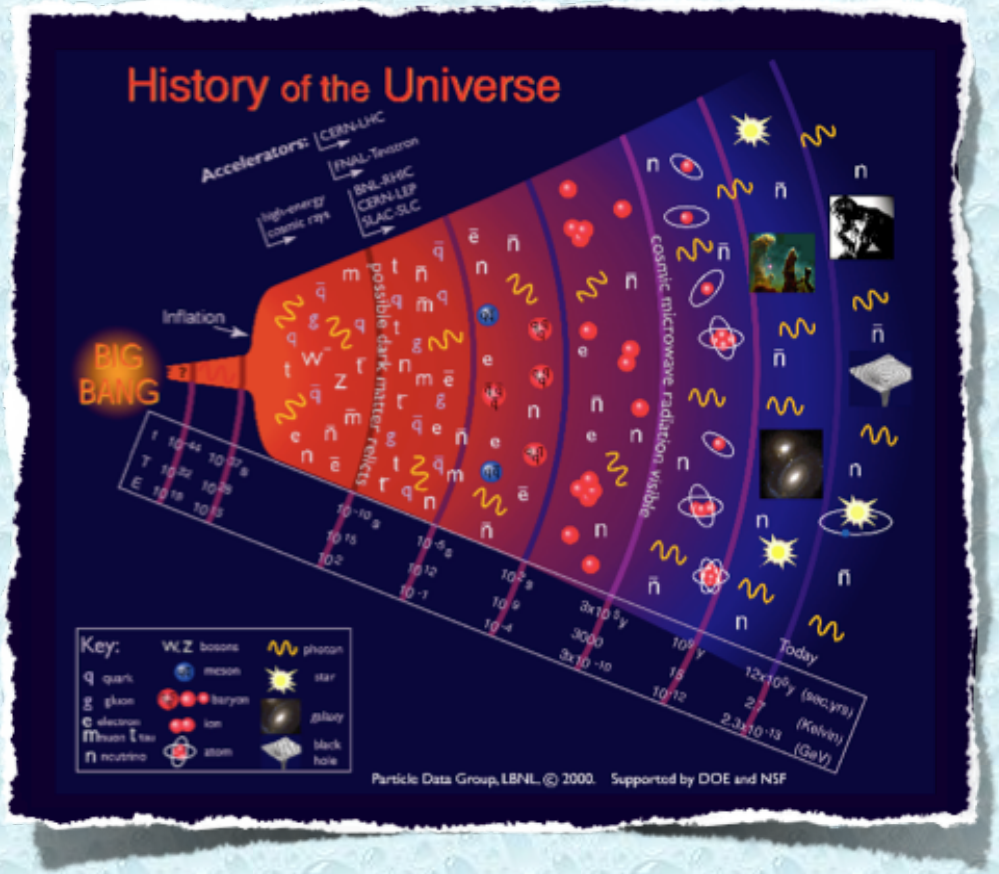
A. de Bellefon[1], J. Bouchez[1,2], J. Busto[3], J.-E. Campagne[4], C. Cavata[2], J. Dolbeau[1], J. Dumarchez[5], P. Gorodetzky[1], S. Katsanevas[1], M. Mezzetto[6], L. Mosca[2], T. Patzak[1], P. Salin[1], A. Tonazzo[1], C. Volpe[7]

[1] *APC Paris*
[2] *DAPNIA-CEA Saclay*
[3] *CPP Marseille*
[4] *LAL Orsay*
[5] *LPNHE Paris*
[6] *INFN Padova*
[7] *IPN Orsay*

Abstract

A water Čerenkov detector project, of megaton scale, to be installed in the Fréjus underground site and dedicated to nucleon decay, neutrinos from supernovae, solar and atmospheric neutrinos, as well as neutrinos from a super-beam and/or a beta-beam coming from CERN, is presented and compared with competitor projects in Japan and in the USA. The performances of the European project are discussed, including the possibility to measure the mixing angle θ_{13} and the CP-violating phase δ.

..WHY? HOW?..



The Big Bang origin of the Universe requires **matter and antimatter to be equally abundant** at the very hot beginning.

The Great Annihilation

1 particle out of 10 billion pairs of particles and anti-particles left over…

$$\eta = \frac{n_b - n_{\bar{b}}}{n_\gamma} \sim 10^{-10}$$

Baryogengesis

The **GUT** need a measure of **proton decay** to be proofen

Lepto-Baryongenesis

Measured CP baryonic violation is not enough
=> need a knew type: Lepton CP violation

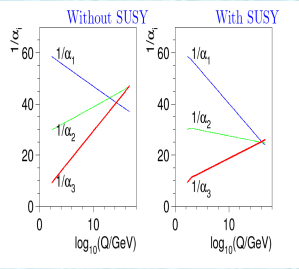
Interaction conservation of B+L

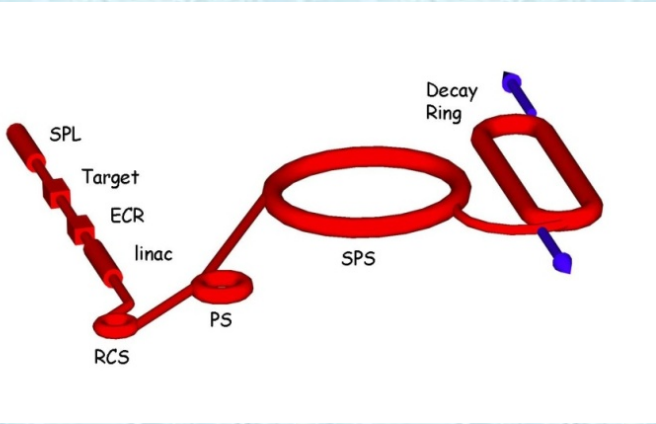
Laguna: Large Apparatus for Grand Unification and Neutrino Astrophysics

New megatonne class, multipurpose detectors will allow to study these fundamental questions

Particle physics

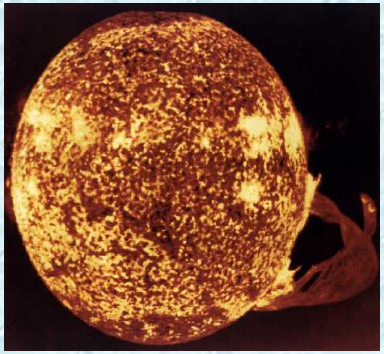
Proton decay
θ13
CP-violation
Atmospheric Neutrinos

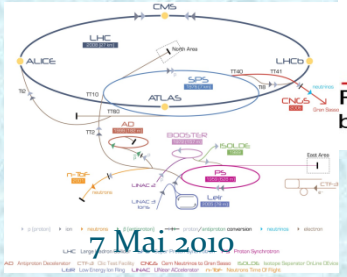


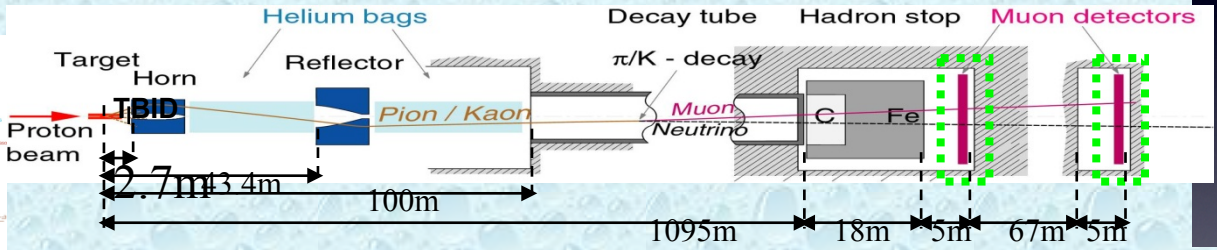


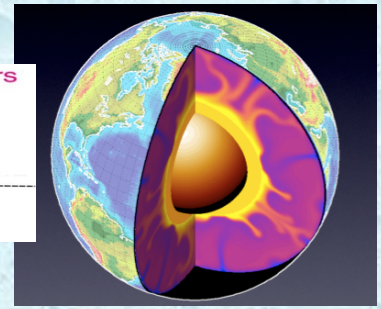
Neutrino astronomy

Supernova neutrinos
Diffuse SN neutrinos
Solar neutrinos
Dark matter annihilation
Geo-neutrinos









... In a

LAGUNA

Large Apparatus for Grand Unification and Neutrino Astrophysics

1,7 M€ from EU

Proton Decay:

- limit up to 10^{35} y

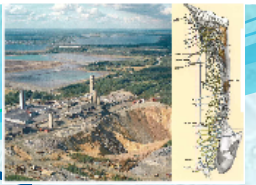
Neutrino Physics:

- supernovae neutrinos (explosion and relic)
- atmospheric neutrinos
- solar neutrinos
- accelerator neutrinos (Superbeam, BetaBeam, NeutrinoFactory)
- geo-neutrinos

Boulby mine
1050 Km

130 Km

630 Km



2300 Km
Pyhhäsalmi

SUNLAB
950 Km

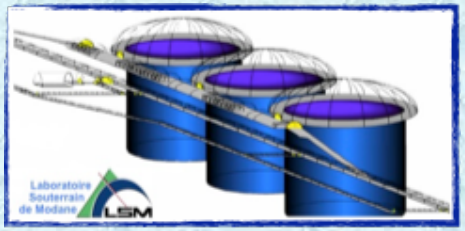
CASO
659 Km

http://laguna.ethz.ch

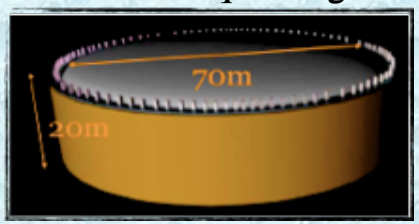
= > 7 canditate sites:

- Boulby
- Fréjus
- Caso
- LSC
- Pyhäsalmi
- Sunlab
- IFIN-HH

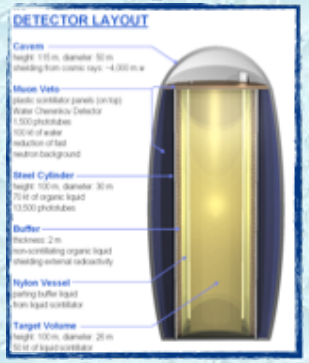
MEMPHYS: Water Čerenkov



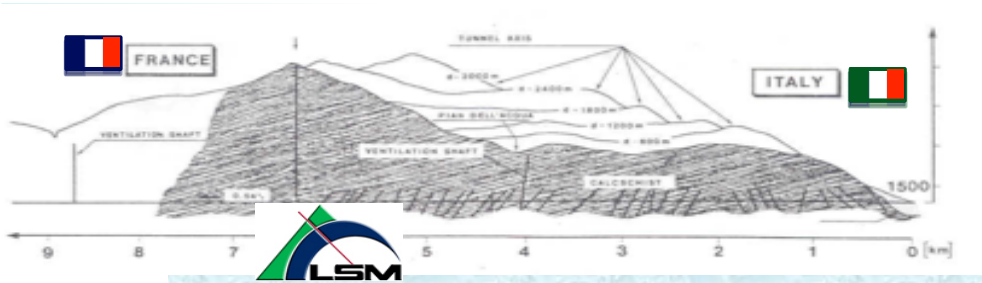
GLACIER: Liquid Argon

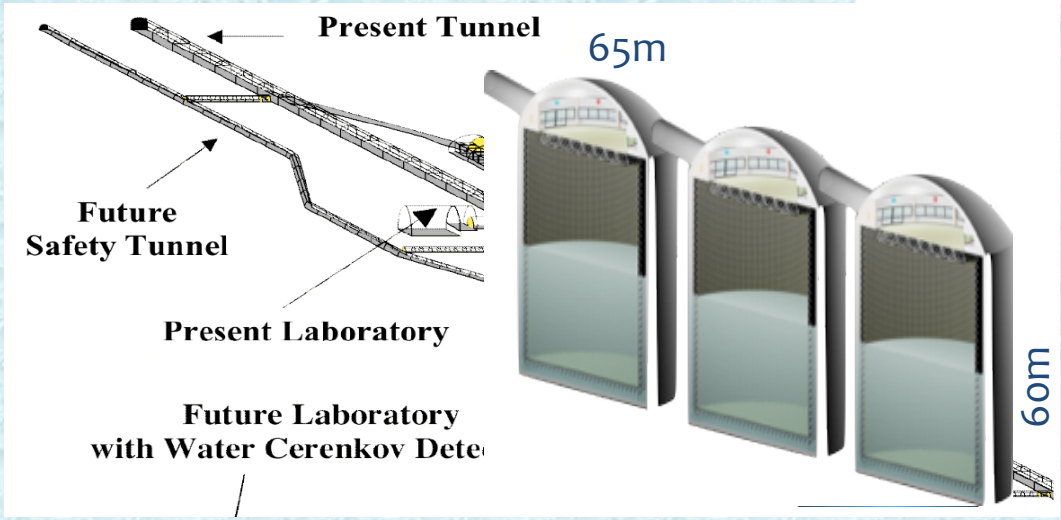


LENA: Liquid Scint.



MEMPHYS





- 130 Km from CERN
- 4800 m.w.e.

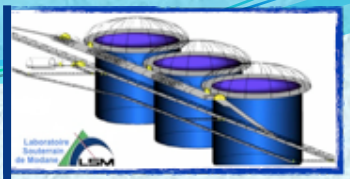
Detector	Overall size (ktons)	Fiducial volume (ktons)	Ratio
SK	47,8	28,7	60%
Memphys H= 60m	211	153	72%
Memphys H= 80m	282	208	74%

- Water Cherenkov ("cheap and stable")
- total fiducial mass: 440 kt
- 3 cylindrical modules 65 x 65 m
  - size limited by light attenuation length (λ~80m) and pressure on PMTs
  - readout : ~3 x 81k 12" PMTs, 30% geom. cover
  - PMT R&D + detailed study on excavation @Fréjus existing & ongoing

http://www.apc.univ-paris7.fr/APC_CS/Experiences/MEMPHYS/

MEMPHYS

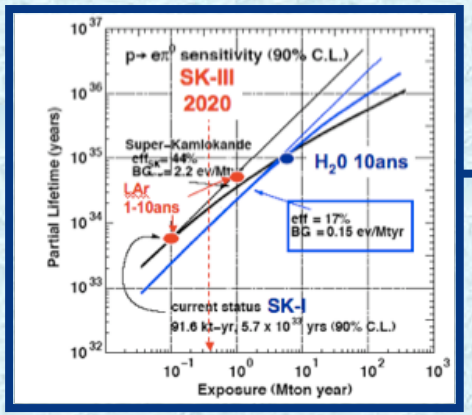
Physics channels@



$$p \rightarrow e^+ + \pi^0$$

"Golden channels"

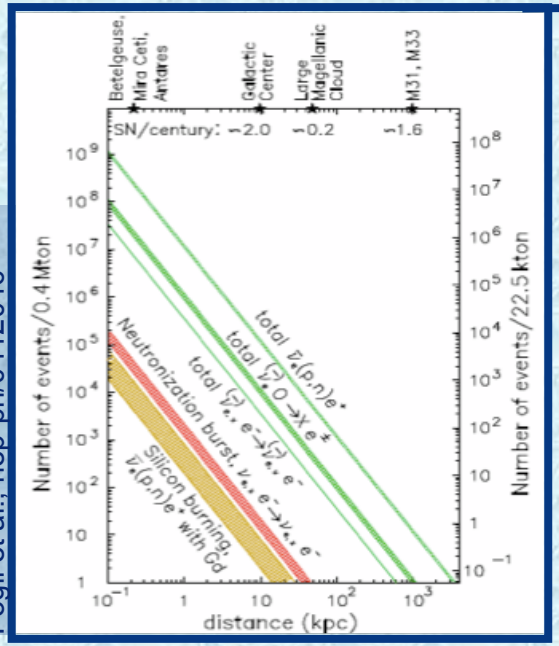
H_2O better then LAr, Scint.



PROTON DECAY

arXiv:hep-ex/0005046v1

SUPERNOVA COLLAPSE NEUTRINOS



Fogli et al., hep-ph/0412046

Evidence up to ~ 1Mpc

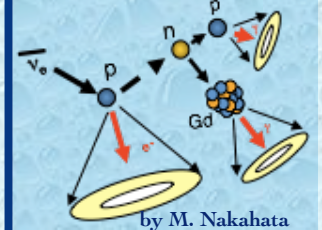
Galactic SN: Huge statistics

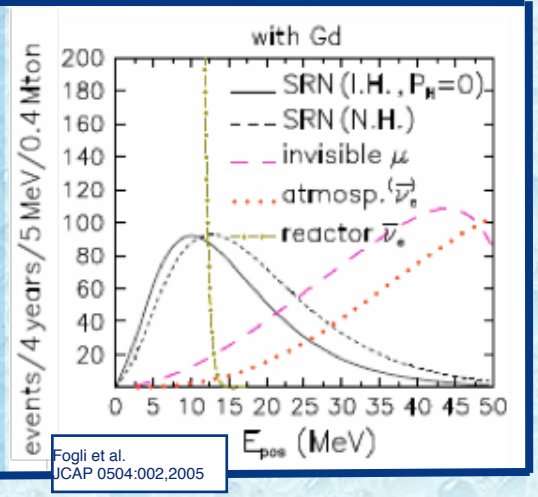
- SN explosion mechanism: shock waves, neutronization burst
- Neutrino production parameters:

rate, spectra

- Neutrino properties

DIFFUSE SUPERNOVA NEUTRINOS





Fogli et al. JCAP 0504:002,2005

ATMOSPHERIC, SOLAR (ES) NEUTRINOS

According to Lombardi we can get 30% more volume @ Frejus.

Example Proton decay: Channel p → $e^+\pi^0$, 17 % efficiency, 10 years running:

440 kton (base line design):

1,47 x 10^{35} protons

90% CL limit for life time = 1 x 10^{35} years

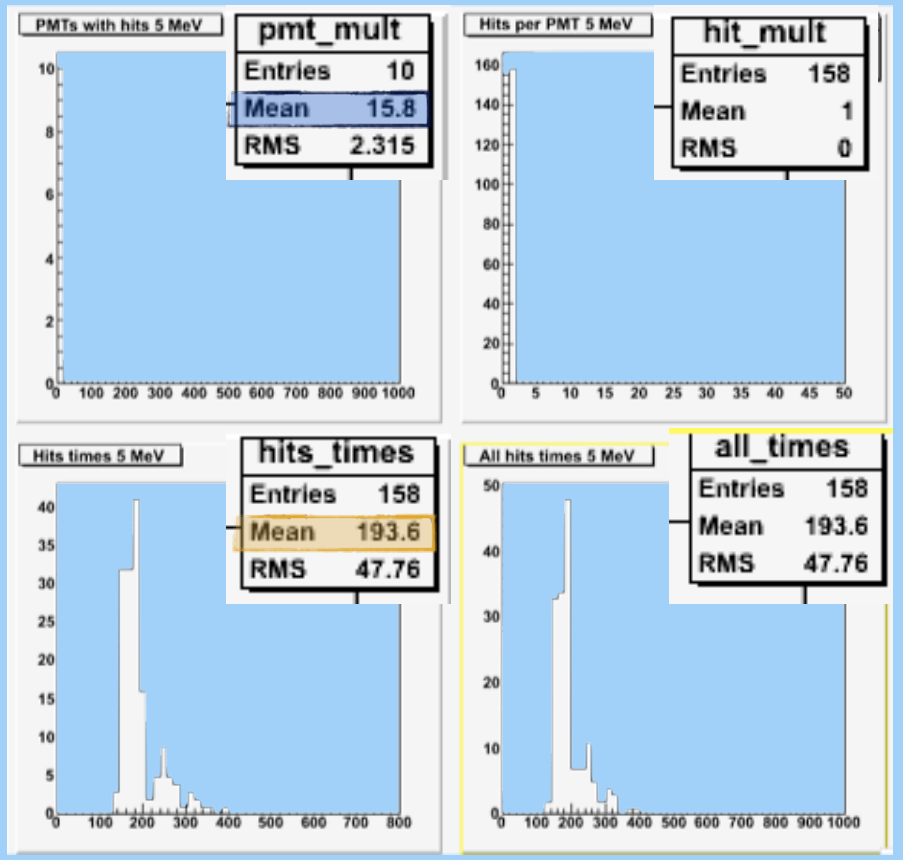
30% more fiducial volume = 572 ktons:

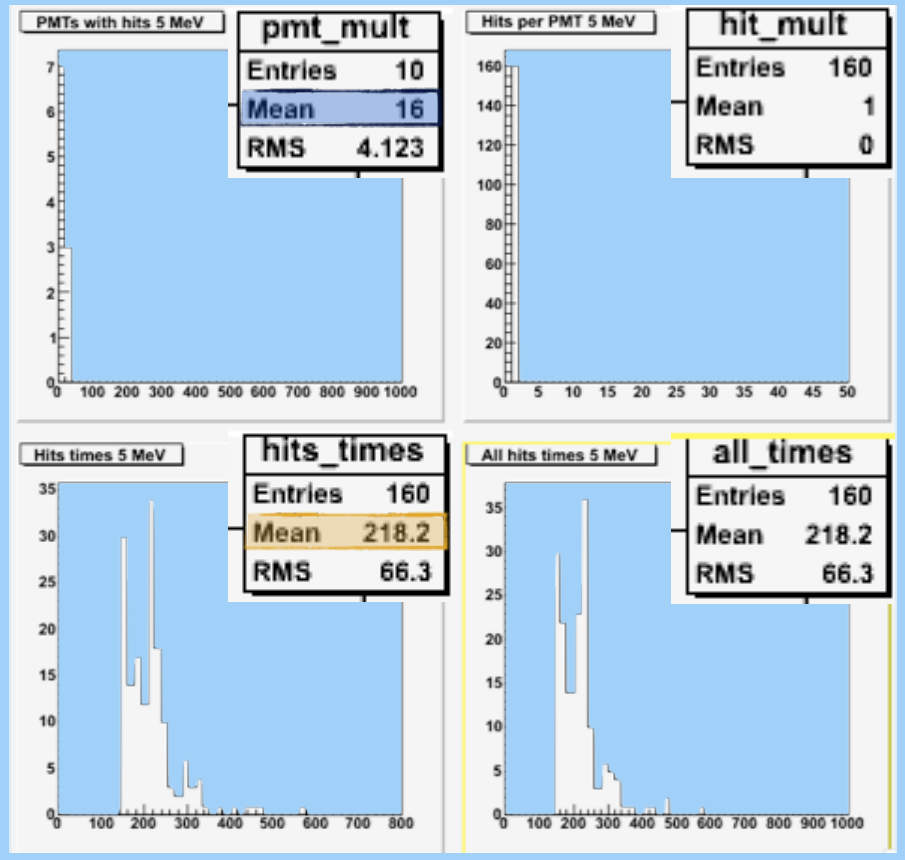
1,9 x 10^{35} protons

90% CL limit for life time = 1,4 x 10^{35} years

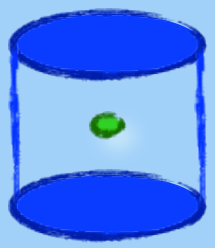
Model	Decay modes	Prediction
Georgi-Glashow model	-	ruled out
Minimal realistic non-SUSY $SU(5)$	all channels	$\tau_p^{upper} = 1.4 \times 10^{36}$
Two Step Non-SUSY $SO(10)$	$p \to e^+\pi^0$	$\approx 10^{33-38}$
Minimal SUSY $SU(5)$	$p \to \bar{\nu}K^+$	$\approx 10^{32-34}$
SUSY $SO(10)$ with 10_H, and 126_H	$p \to \bar{\nu}K^+$	$\approx 10^{33-36}$
M-Theory(G_2)	$p \to e^+\pi^0$	$\approx 10^{33-37}$
$SU(5)$ with 24_F	$p \to \pi^0 e^+$	$\approx 10^{35-36}$
Renormalizable Adjoint $SU(5)$	$p \to \pi^0 e^+$	$\approx 10^{35-36}$

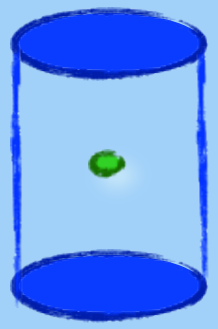
Impact of 30% enhanced Memphys





5 MeV electron in the center of the detector

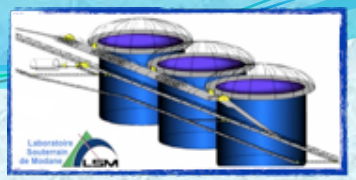


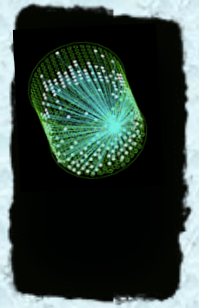


MEMPHYS

MEgaton Mass PHYSics

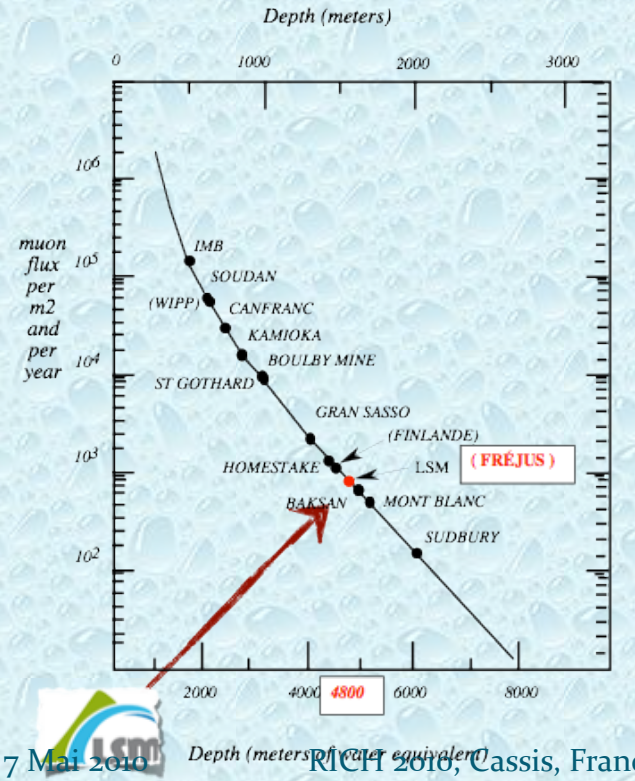
SIMULATIONS & STUDIES



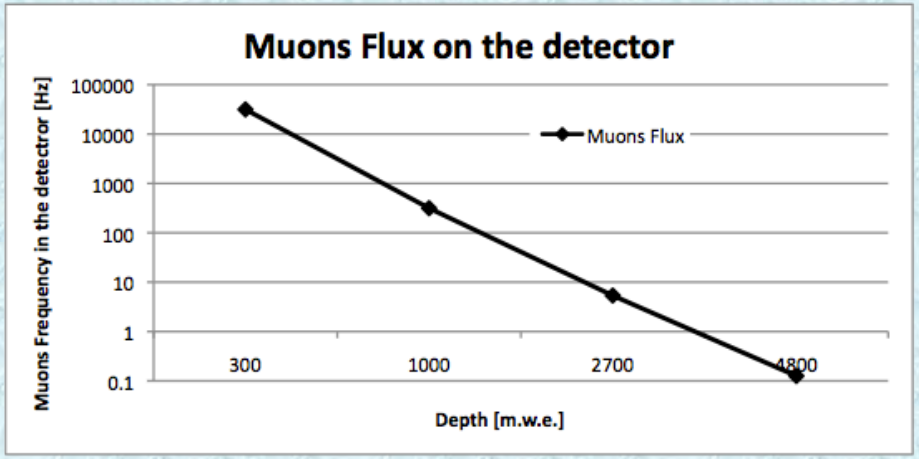


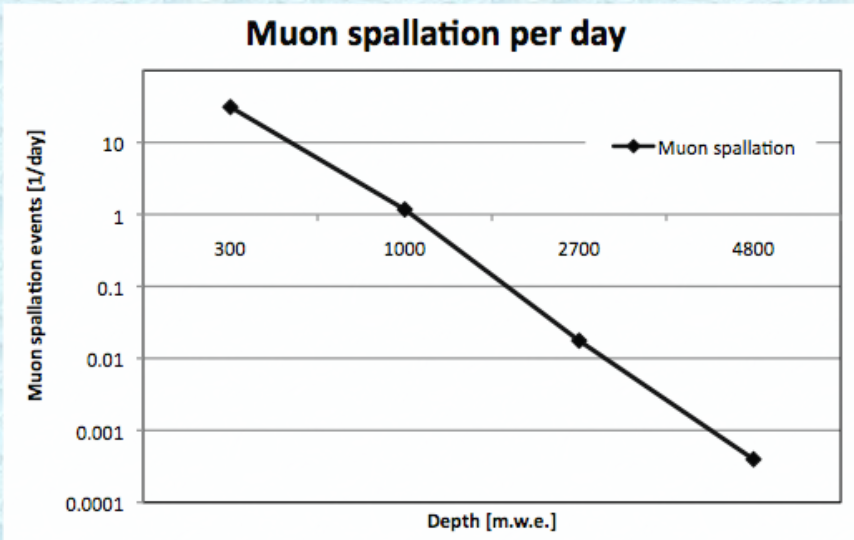
Memphys simulation in Geant4: NUANCE for ν beam, ν Atmospheric & Proton Decay.

Future developments: work in progress at APC, LAL, LAPP.



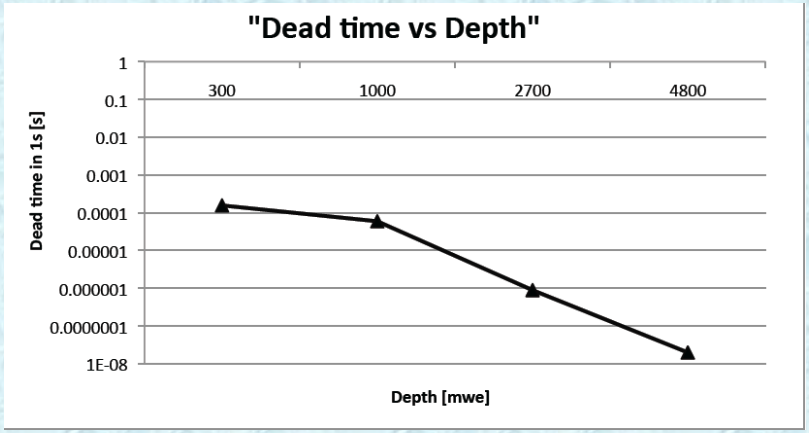
Work in progress for muon interactions in the rock, multiples backgrounds, depth and latitude studies.

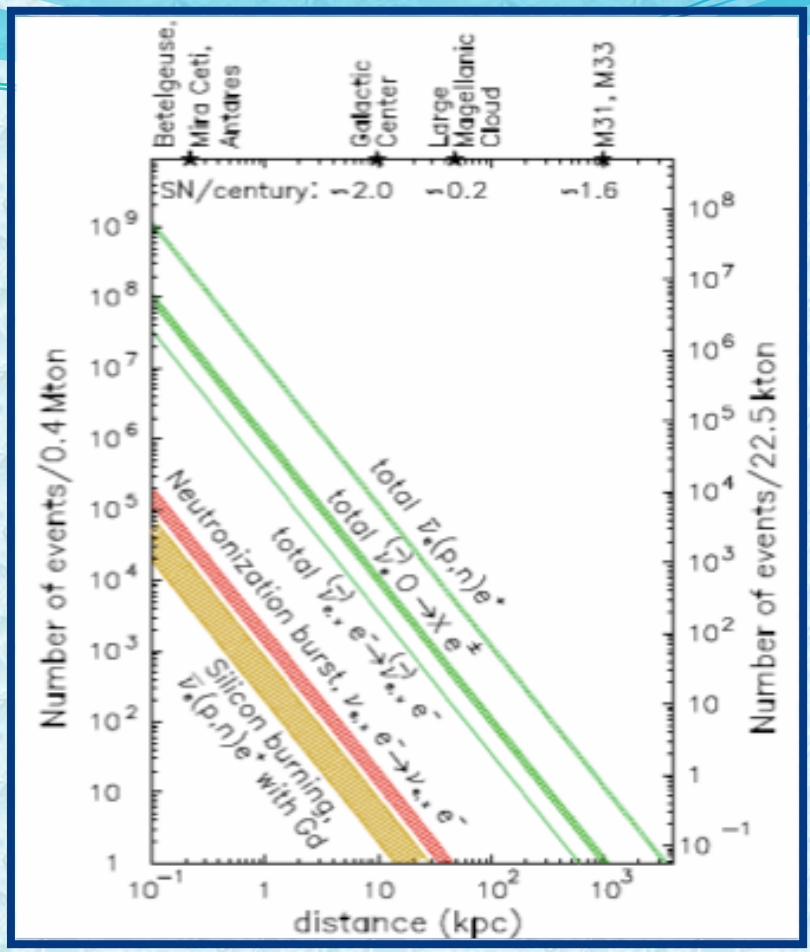


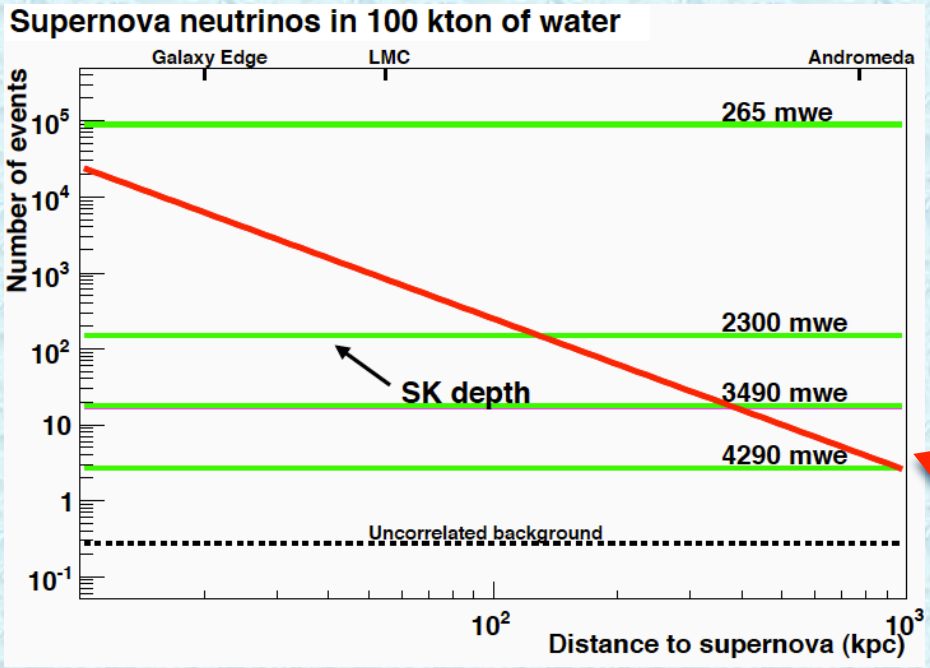


MEMPHYS

Depth is very important for SN Neutrinos





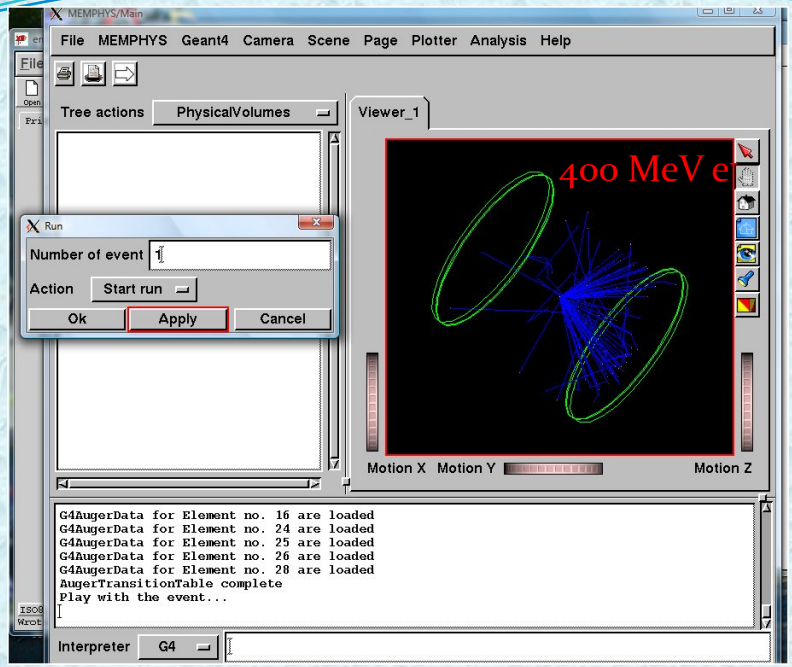


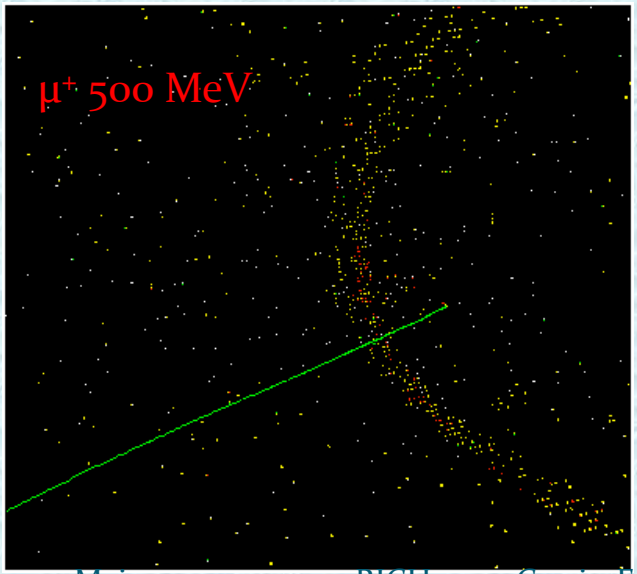
At Frejus one could get O 10 events in a 30 sec time window for an explosion at 1 Mpc

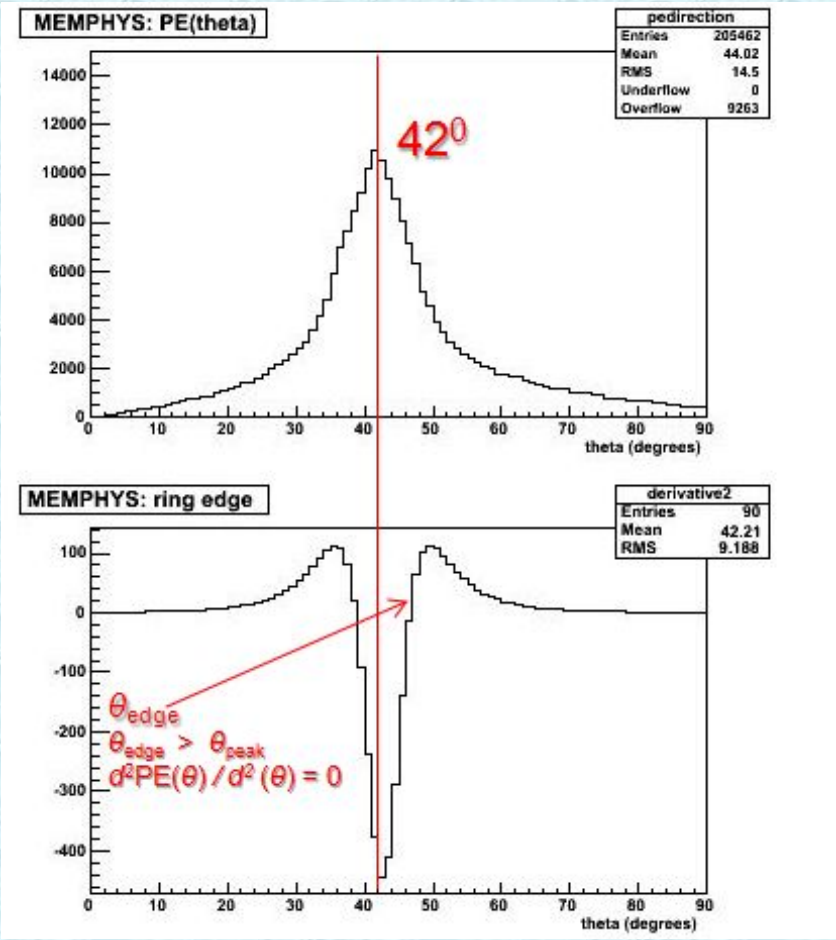
From DUSEL: Report on the Depth Requirements for a Massive Detector at Homestake (Fermilab-TM-2424-E)

Memphys event reconstruction:

from Nikolaos VASSILOPOULOS





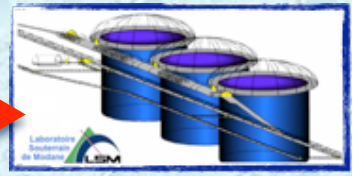


Physics channels@

MEMPHYS

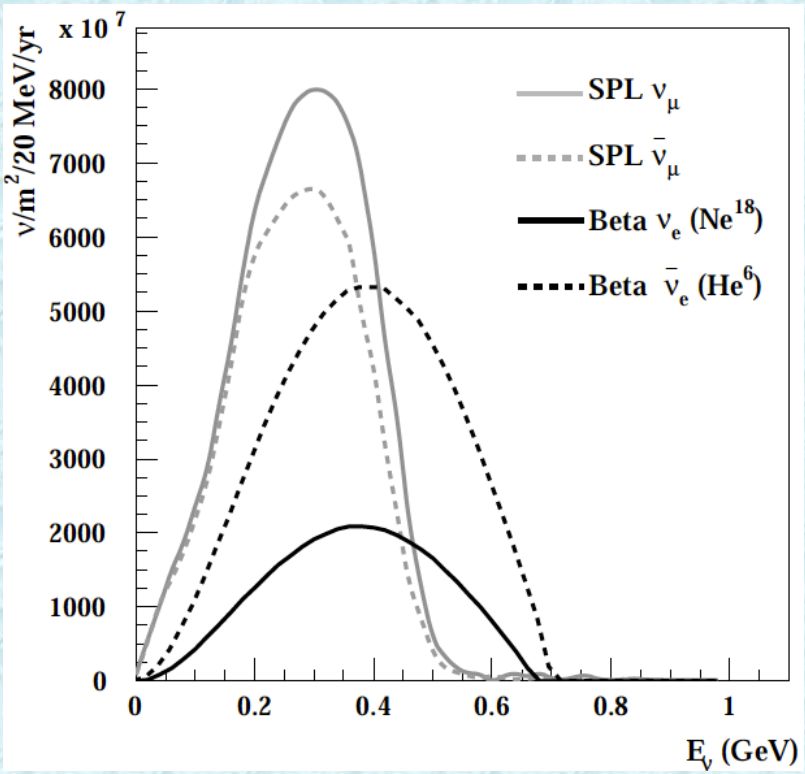
NEUTRINO BEAMS

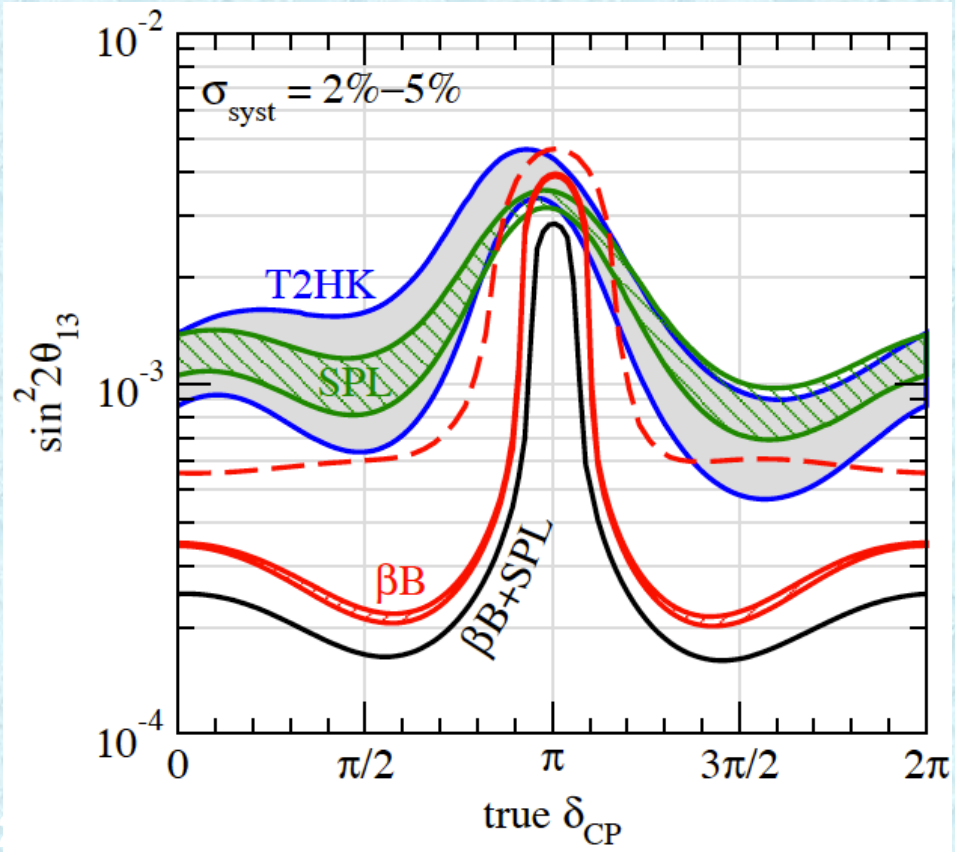
130 Km CERN-LSM



SUPER-BEAMS BETA-BEAMS

The main goals: search of a non-zero θ_{13} angle or its measurement; searching for possible leptonic ***CP violation***; determining the **mass hierarchy** and the θ_{23} ***octant***.





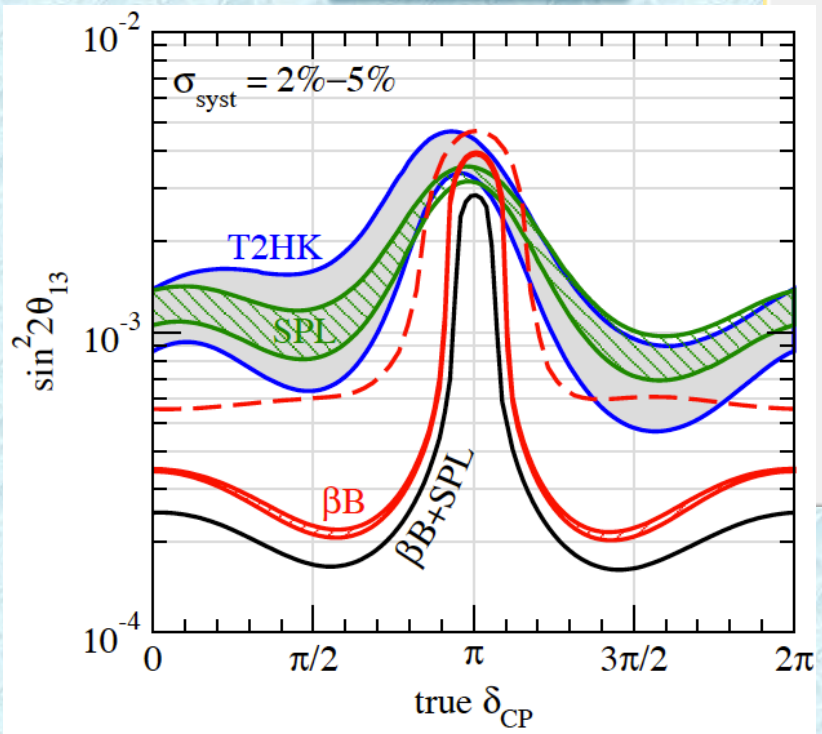
arXiv:hep-ph/0603172v3

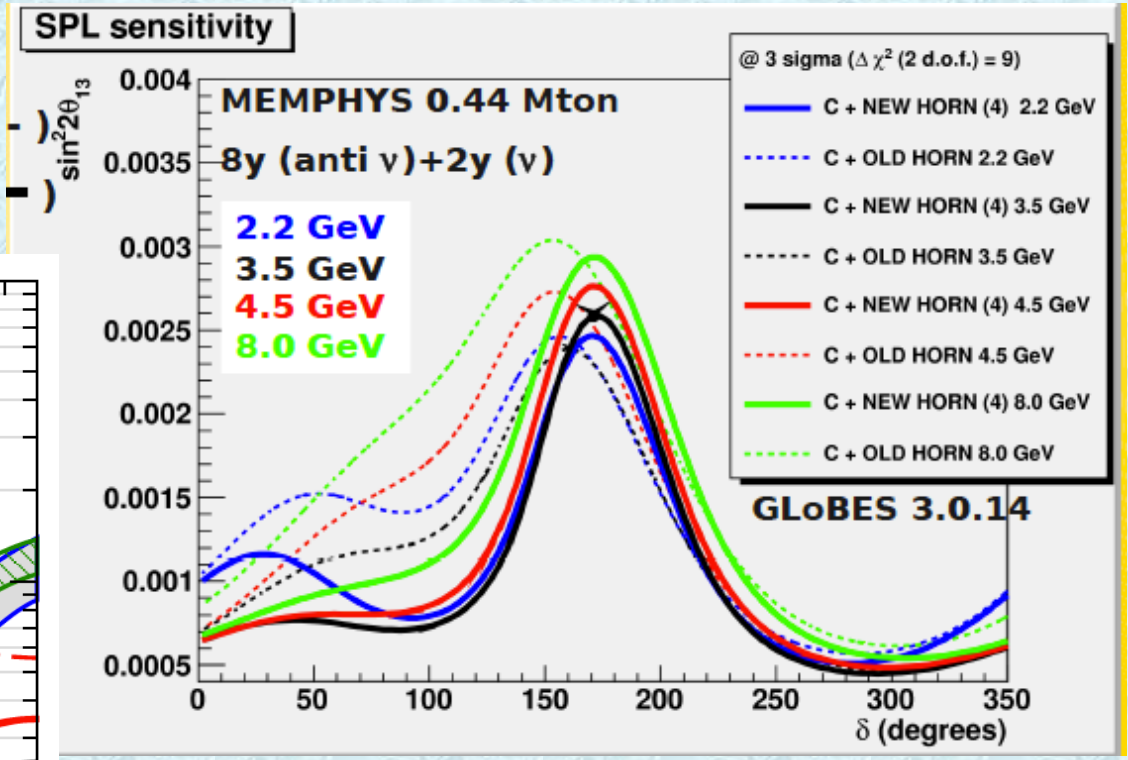
New result from EUROnu:

SPL: New horn design proposed by A. Longhin (CEA)

http://indico.in2p3.fr/conferenceDisplay.py?confId=2455

β−beam





β−beam still better than SPL

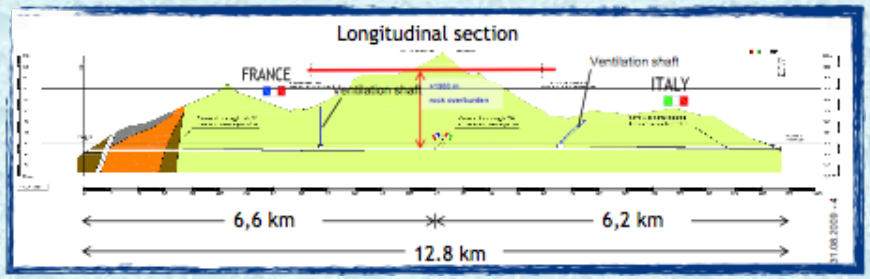
EUROnu should give the answer which is the most realistic approach

Number of events neutrinos/antineutrinos per year in 440 ktons WC:

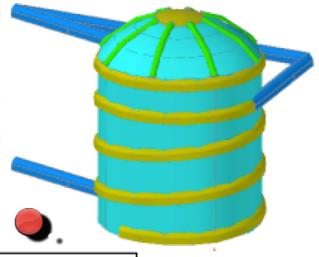
	For a β-beam:	Fréjus		Canfranc		Pyhäsalmi	
	θ_{13}/δ_{CP}	$\delta_{cp} = 0$	$\delta_{cp}=\pi/2$	$\delta_{cp} = 0$	$\delta_{cp}=\pi/2$	$\delta_{cp} = 0$	$\delta_{cp}=\pi/2$
Neutrino	$\sin^2 2\theta_{13} = 10^{-2}$	60	70	13	16	10	11
	$\sin^2 2\theta_{13} = 10^{-3}$	20	20	12	13	9	10
	bkg $(\pi^{+/-})+\nu_{atm}$	~ 29		~ 15		~ 14	
Anti-neutrino	$\sin^2 2\theta_{13} = 10^{-2}$	62	27	15	10	11	11
	$\sin^2 2\theta_{13} = 10^{-3}$	20	9	13	12	11	11
	bkg $(\pi^{+/-})+\nu_{atm}$	~ 31		~ 17		~ 16	

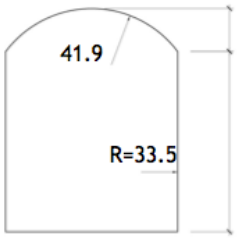
MEMPHYS

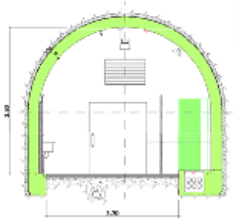
Possibles Layouts and design at Fréjus



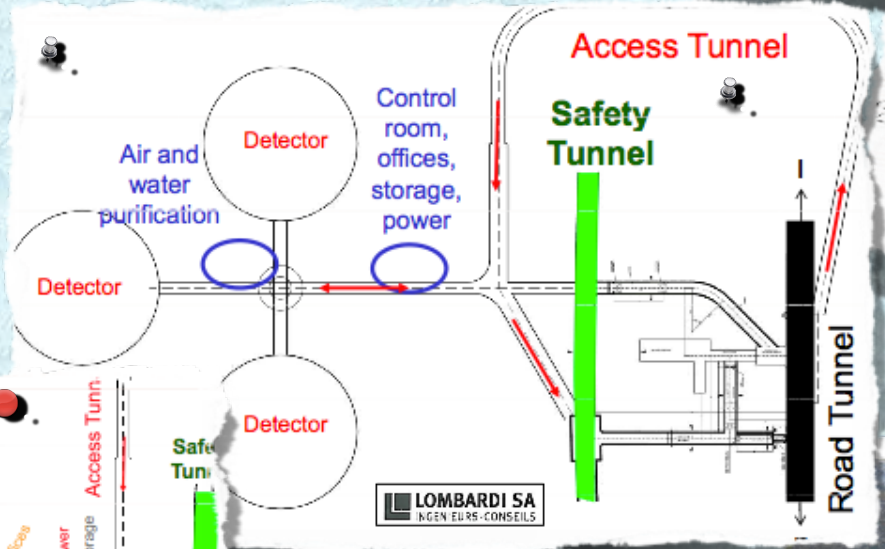
Proposed cavern excavation and layout for the LAGUNA

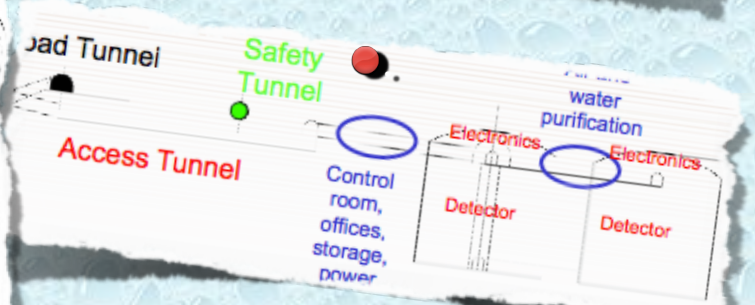


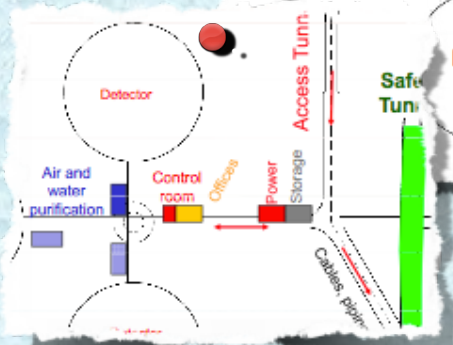




LOMBARDI SA
INGENIEURS-CONSEILS



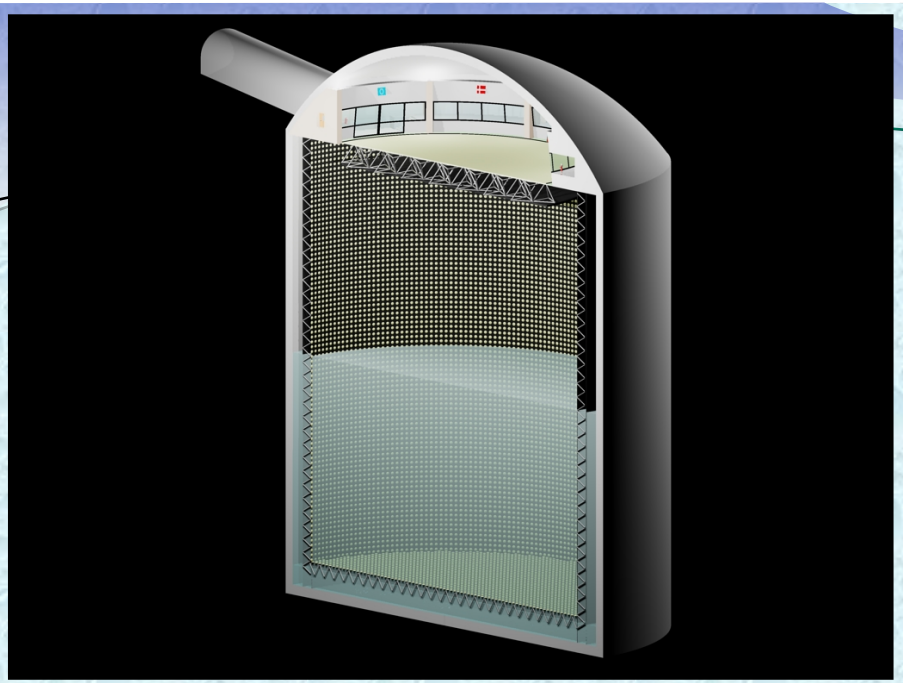


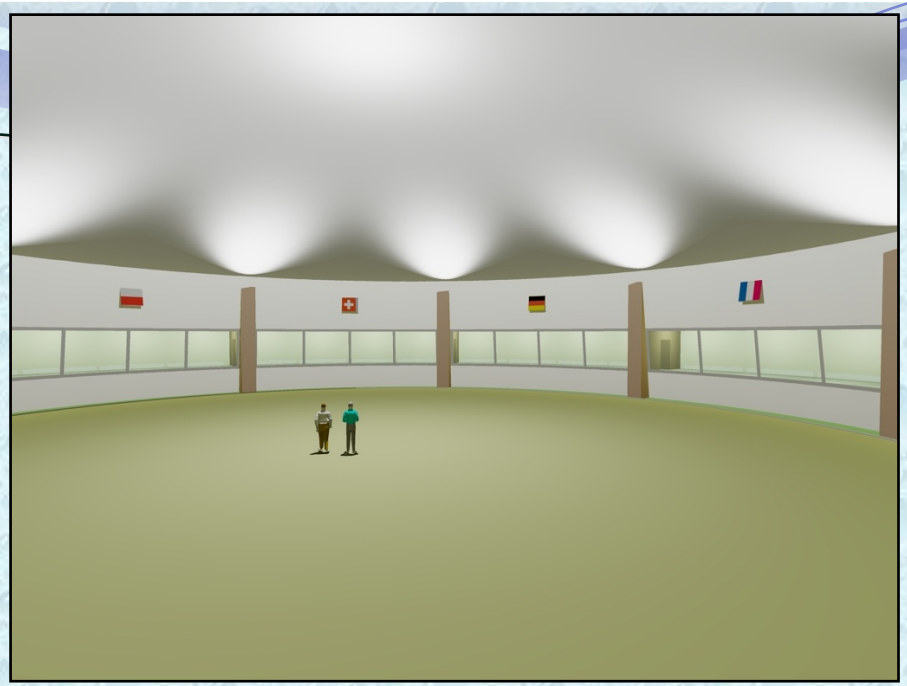


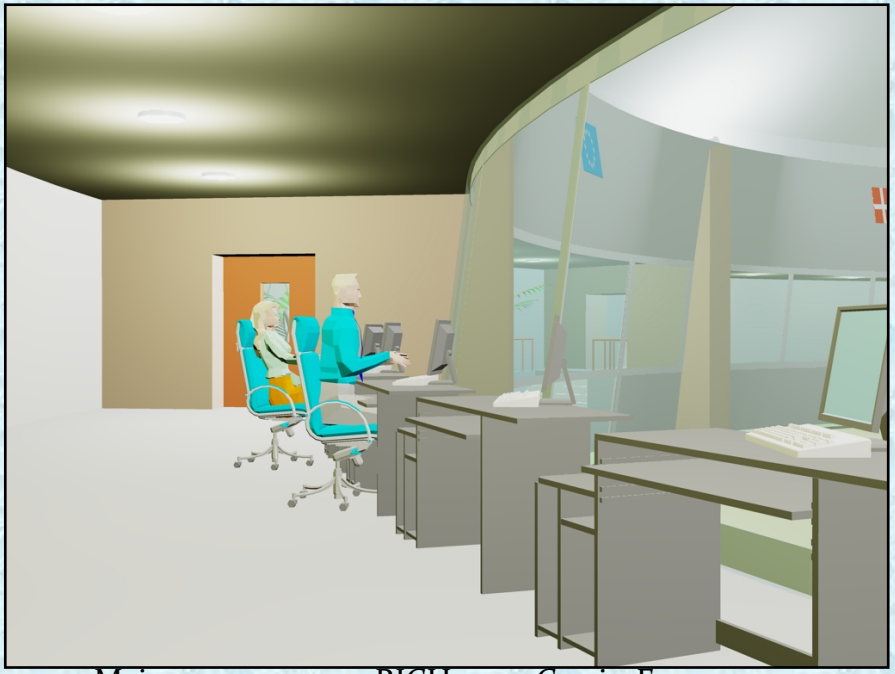
Draft version.. study in progress

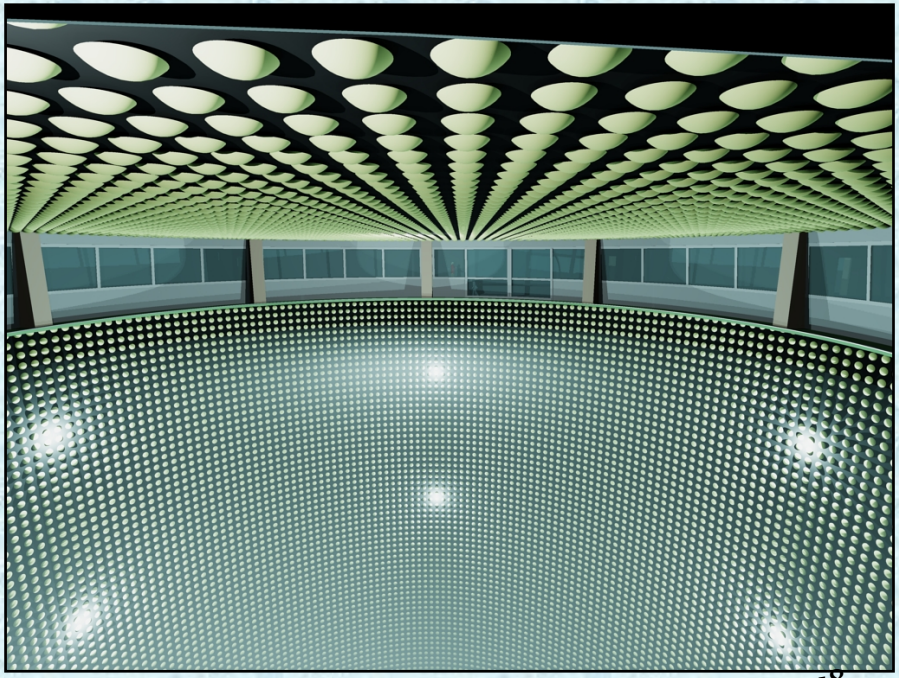
Fresh water

Shaft access



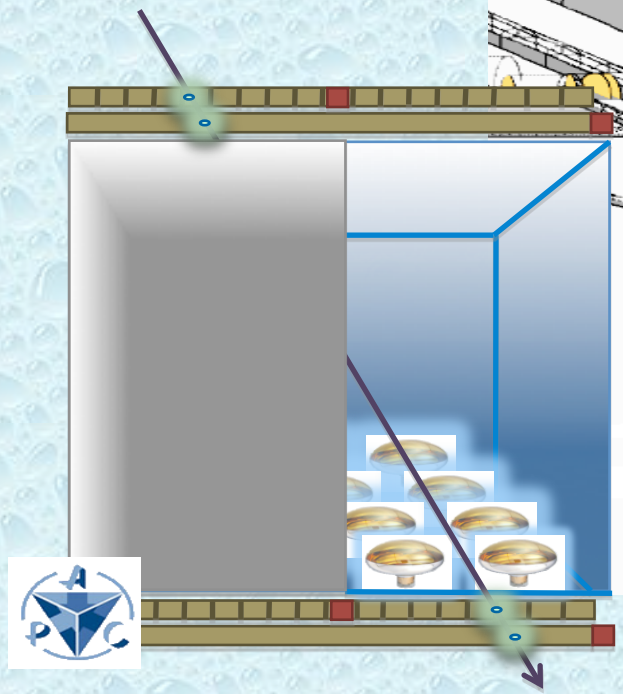




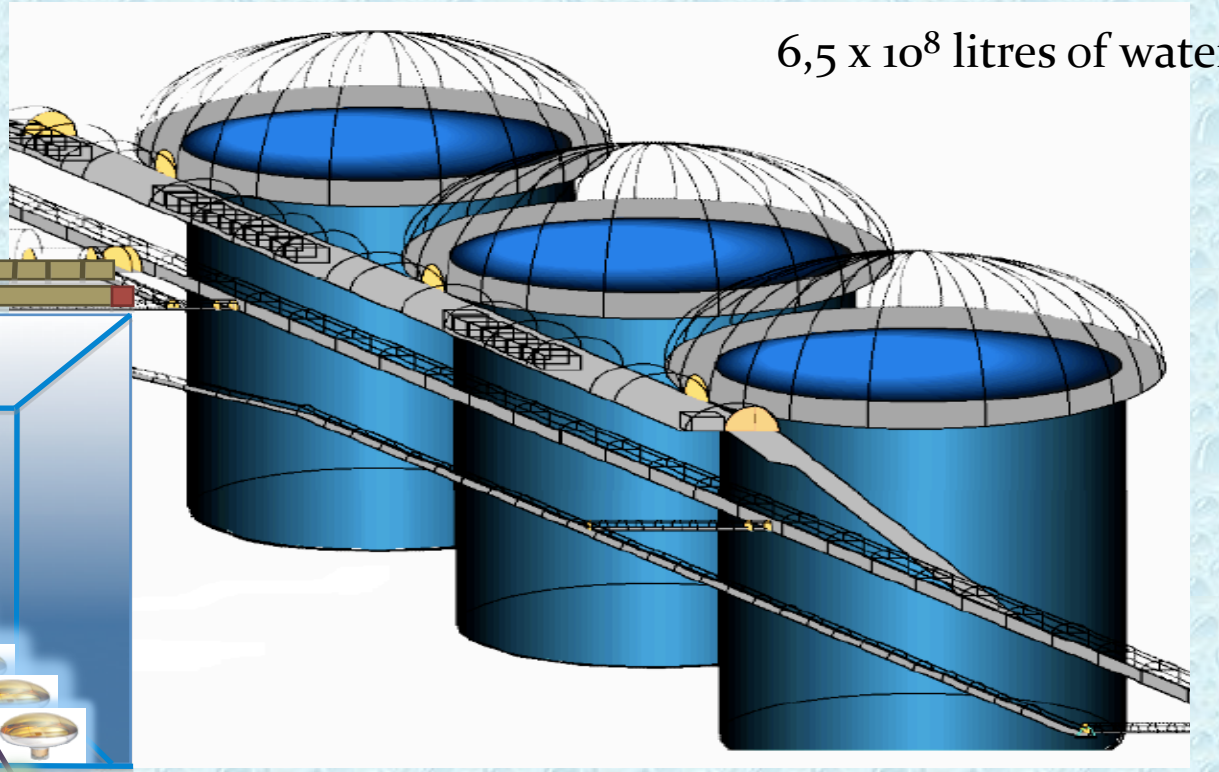


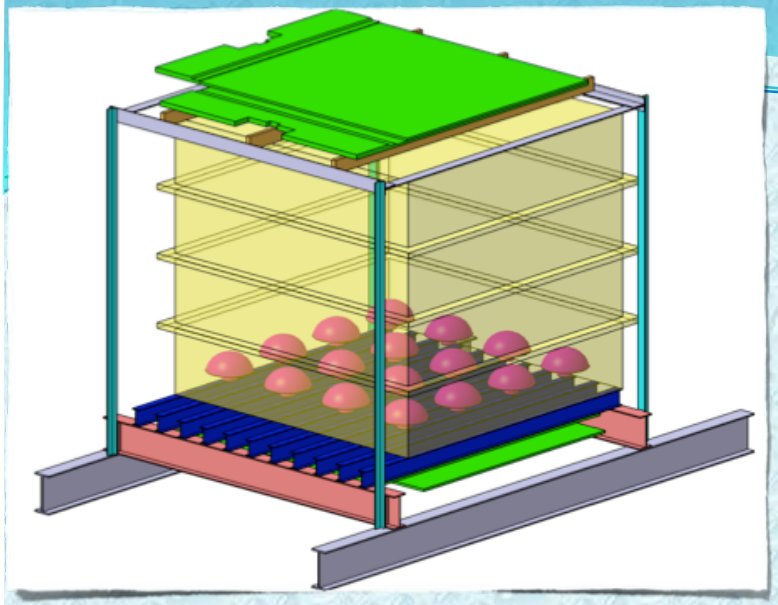
MEMPHYNO THE R&D FOR MEMPHYS

8 x 10^3 litres of water



6,5 x 10^8 litres of water





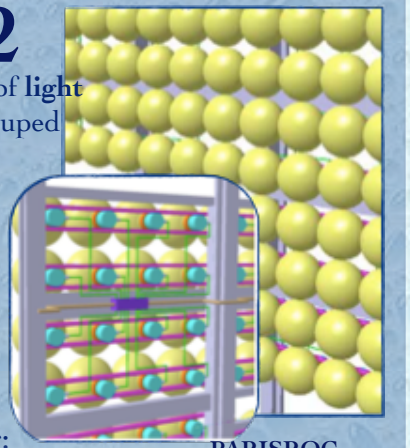
TEST BENCH for photodetection and electronic solutions for LARGE detectors

PMm2

http://pmm2.in2p3.fr

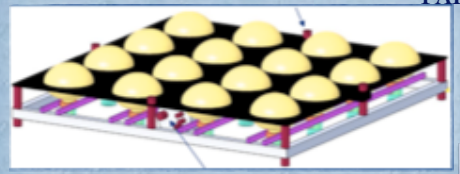
- Hight number of **light sensor**: need grouped acquisition;

- Common HV
- Common readout
- Common signal digitization



Demonstrator:

PARISROC



~8t of water (+Gd?): 2x2x2m^3 HDPE tank

- Matrix of 16 PMTs and/or other photodetectors (e.g.: X-HPX)

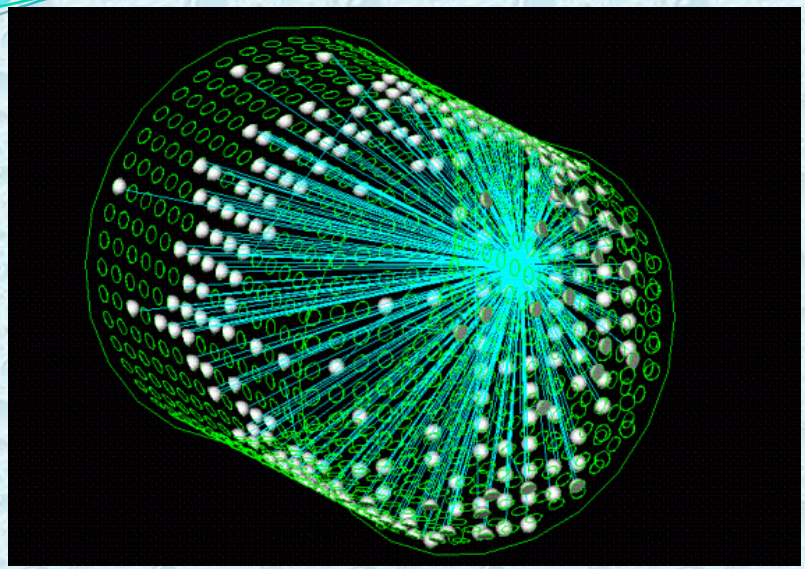
- **Muon hodoscope:**
- 2+2 planes of OPERA scintillator bars
- 4 Pmt multi anodes (64 channels)

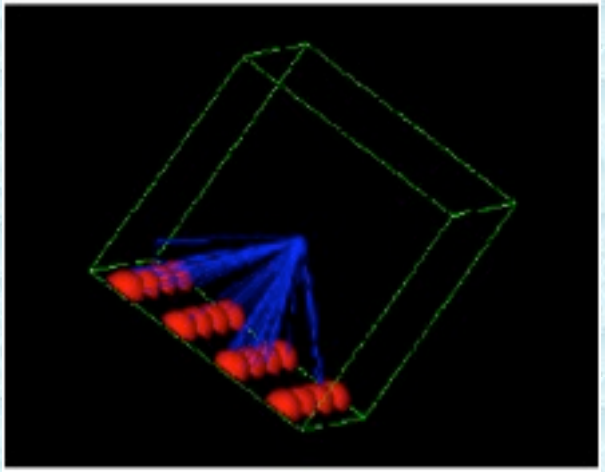
- Full test of the "**electronic and acquisition**" chain;
- Trigger **threshold** study
- Self-trigger mode
- **Track reconstruction** performances;
- Gd doping: flexibility and performance.

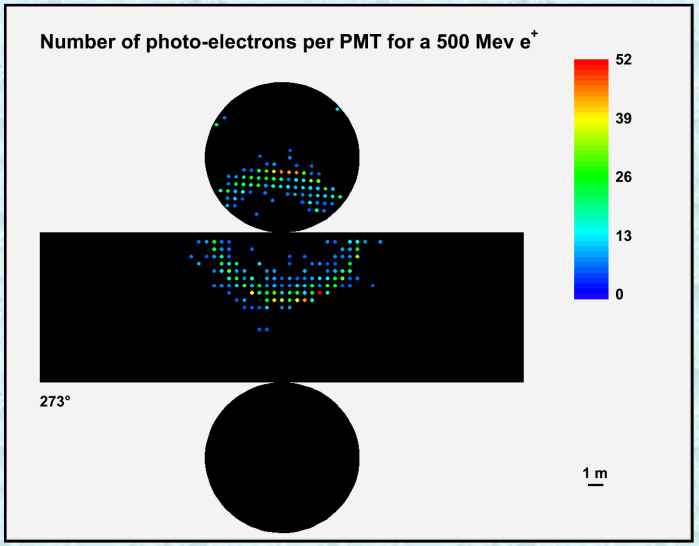
Plots by E.Richard
Stagiaire @APC

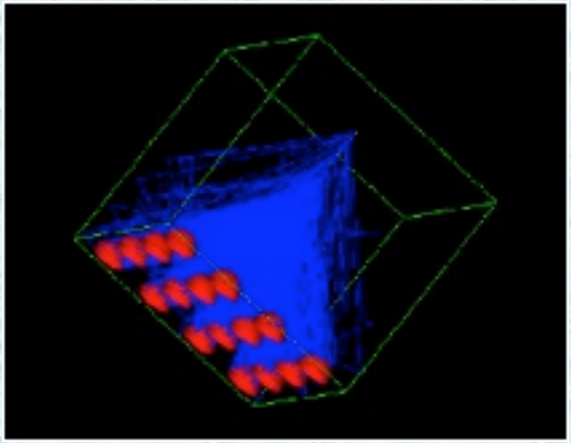
MEMPHYNO

detector analysis tools for MEMPHYS/MEMPHYNO



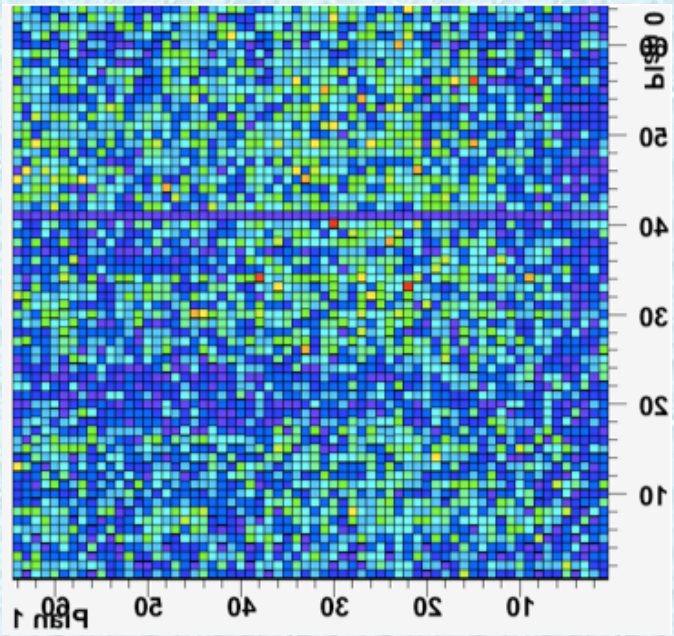


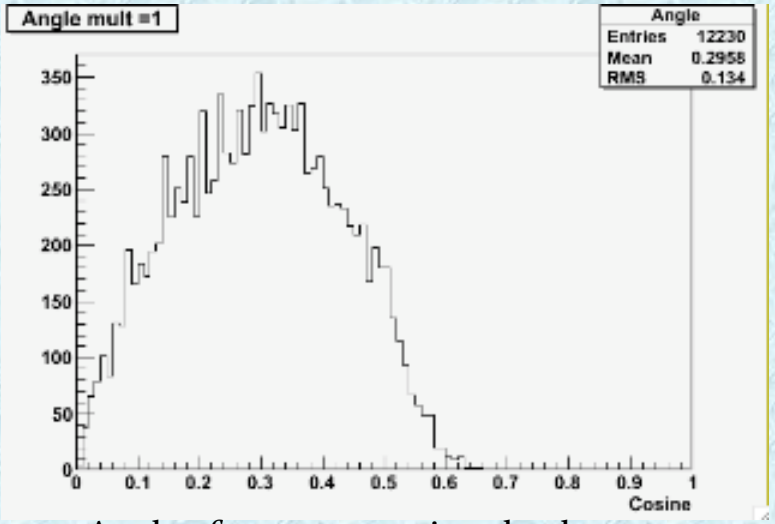




MEMPHYNO

STATUS AT PRESENT TIME





Angle of muons crossing the detector

Summary and outlook

- work on simulation, mechanical design, PMT R&D is ongoing
- 1 PhD thesis @APC (2008-2011) is funded by IN2P3-P2I (Michela Marafini)
- 1 Postdoc funded by EURONU @ APC

- Europe is active towards a megaton-scale Water-Cherenkov detector: MEMPHYS
- Envisaged installation site: @ Fréjus
  Excavation feasibility pre-study done
- Participation in European D.S.: LAGUNA, EUROnu
- Ongoing activity on simulation and analysis tools
- Ongoing R&D 1 : PMm2 development of PMTs and their readout
- Ongoing R&D 2 : MEMPHYNO small-scale prototype

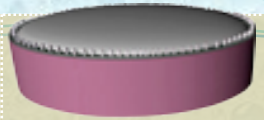
➔ **MEMPHYS welcomes new people**

➔ **We hope to start new fruitful collaborations**

http://www.apc.univ-paris7.fr/APC_CS/Experiences/MEMPHYS/

Backup slides

Outstanding physics goals

	 GLACIER	 LENA	 MEMPHYS
Total mass	100 Kton	50 kton	500 Kton
p -> $e\pi^0$ in 10 y	0.5 x 10^{35} y ε = 45%, ~1 BG event	?	1.2 x 10^{35} y ε = 17%, ~1 BG event
p -> ν K in 10 y	1.1 x 10^{35} y ε = 97%, ~1 BG event	0.4 x 10^{35} y ε = 65%, <1 BG event	0.15 x 10^{35} y ε = 8.6%, ~30 BG events
SN cool off at 10 Kpc	38·500 (all flavors) (64·000 if NH-L mixing)	20·000 (all flavors)	194·000 (mostly $\nu_e p \rightarrow e^+ n$)
Sn in Andromeda	7 - (12 if NH-L mixing)	4 events	40 events
SN burst at 10 Kpc	380 ν_e CC (flavor sensitive)	~ 30 events	~ 250 ν-e elastic scattering
DSN	50	20-40	250 (2500 with Gd)
Atm. neutirnos	~1·100 events/y	5600/y	56·000 events/y
Solar neutrinos	324·000 events/y	?	91·250·000/y
Geo-neutirnos	0	~ 3·000 events/y	0