MEMPHYS Safety at the Fréjus site

Jean-Luc Borne – June 2011

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Summary of MEMPHYS Studies

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From the geo-technical point of view, the different caverns for the three detectors types (MEMPHYS, LENA and GLACIER) can be safely excavated in the Fréjus site.

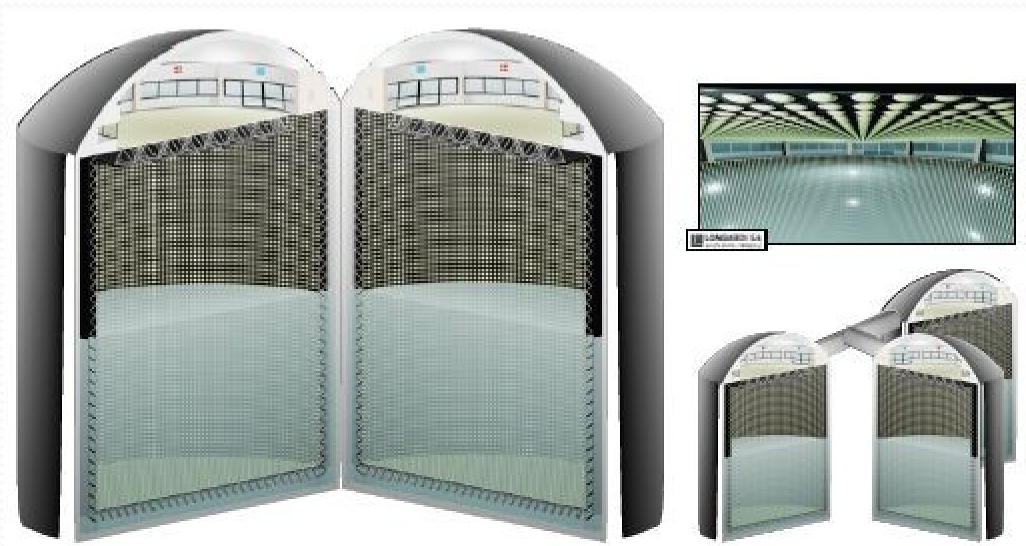
This talk is dedicated to the safety for MEMPHYS in the Fréjus site

MEMPHYS: Underground Laboratory and Detector

- underground water Cherenkov at Laboratoire Souterrain de Modane Fréjus at 4800 m.w.e.

- total fiducial volume: up to 400 kton: 3 x 65mX60 modules could be designed up to 572kton: 3 x 65mX80m (or 2 larger modules)
  - size, shape limited by light attenuation length (λ~80m) and pressure on PMTs
  - readout : ~3 x 81k 12″ (alternatively 8″, 10″) PMTs, 30% cover

- PMT R&D + detailed study on excavation existing & ongoing + prototype Cherenkov detector MEMPHYNO



one possible design at LSM
(by Lombardi SA Inagenieurs – Conseils)

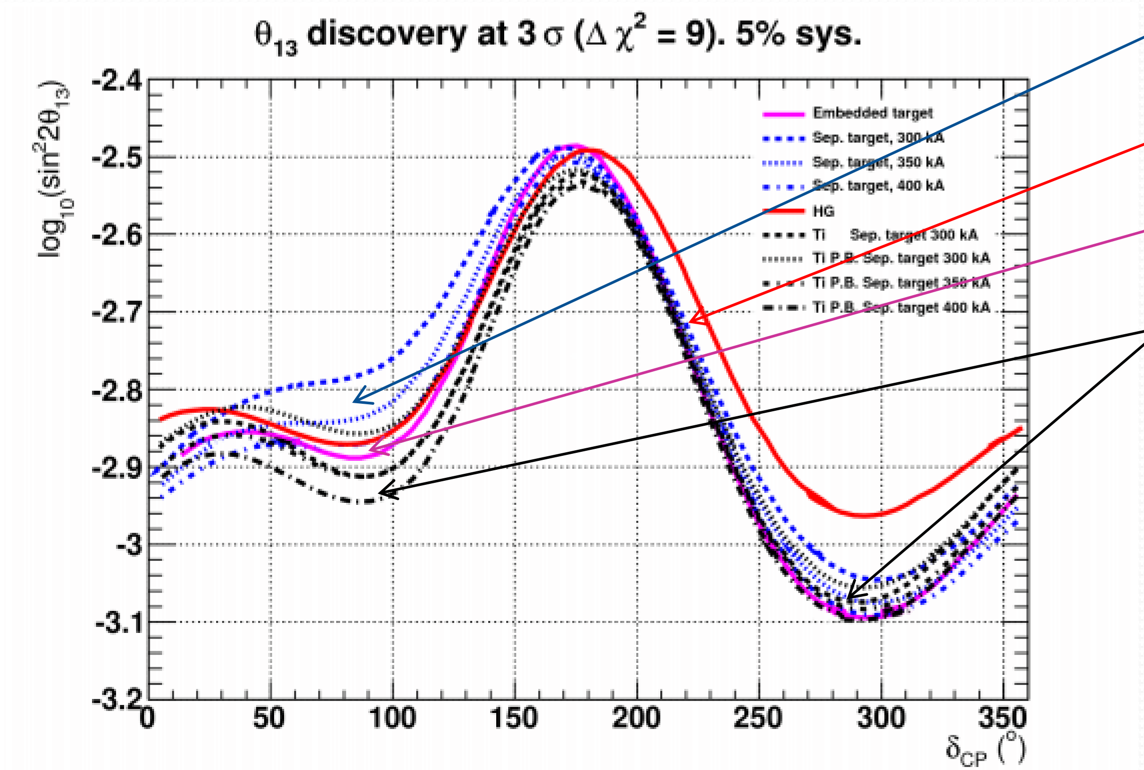
MEMPHYS physics goals

- Proton decay sensitivity:
  - up to 10^{35}yrs in 10y from the "golden" channel: $p \rightarrow e^+ \pi^0$
  - up to $2x10^{34}$yrs in 10y from $p \rightarrow K^+$ + anti-ν
- SuperNova core collapse:
  - huge statistics from galactic SN => spectral analysis in E,t, flavour -> access SN collapse mechanism / neutrino oscillation parameters
  - sensitivity up to ~1 Mpc
  - possibility of early SN trigger (from event coincidence) up to ~5 Mpc
- SuperNova relic neutrinos:
  - observable in few years with significant statistics, according to most of existing models
  - direct measurement of ν emission parameters possible

TOPIC	MEMPHYS (440 ktons)	(~ 572 ktons)
Proton decay:	in 10 years	in 10 years
$e^+\pi^0$	$< 1.0 \times 10^{35}$ [y] 90% CL	$\lesssim 1.4 \times 10^{35}$ [y] 90% CL
$\bar{\nu}K^+$	$< 2 \times 10^{34}$ [y] 90% CL	$\lesssim 2.6 \times 10^{34}$ [y] 90% CL
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		
^8B 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 ($\star$)	$\sim 7.8 \times 10^4$ ($\star$)

- and, of course… NEUTRINO BEAMS *(EUROnu WP2, WP4)*

Latest Results from WP2 SuperBeam Studies

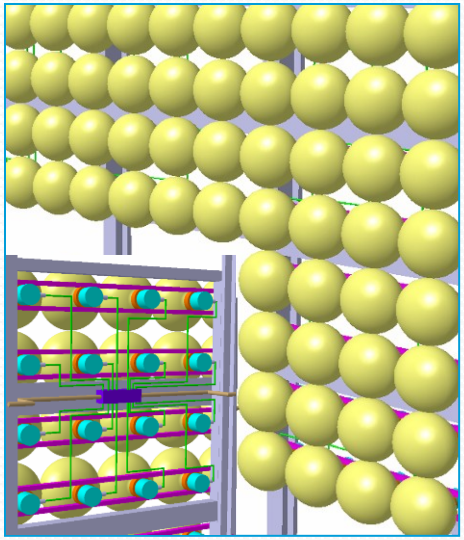


- Graphite Solid target, $2\lambda_I$
- Hg, $2\lambda_I$
- Integrated target, $2\lambda_I$
- excellent performance of packed bed Ti, d= 74%d_{Ti}

any density reduction of packed could be recuperated increasing the horn current by 50, 100 kA

R&D towards MEMPHYS : PMm2:

installed at APC, Paris



“*Innovative electronics for array of photodetectors used in High Energy Physics and Astroparticles”.*

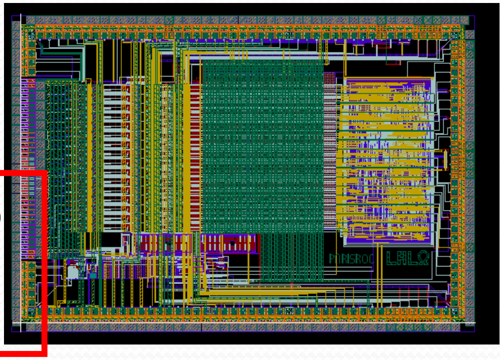
R&D program funded by French national agency for research (LAL, IPNO, LAPP and ~~Photonis~~) (2007-2010)

detailed description of the R&D: pmm2.in2p3.fr

Basic concept: very large photodetection surface → macropixels of PMTs connected to an autonomous front-end electronics.

Replace large PMTs (20”) by groups of 16 smaller ones (~~12~~”, 8”) with central ASIC :

- Independent channels
- charge and time measurement
- water-tight, common High Voltage
- Only one wire out (DATA + VCC)



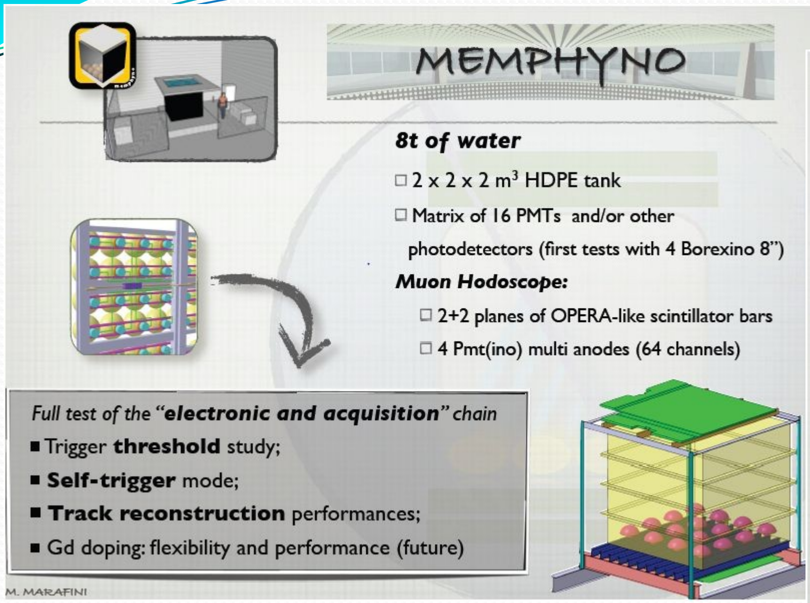
I. studies on ~~12~~" 8" PMTs design
- parameter correlation
- potting
- pressure resistance

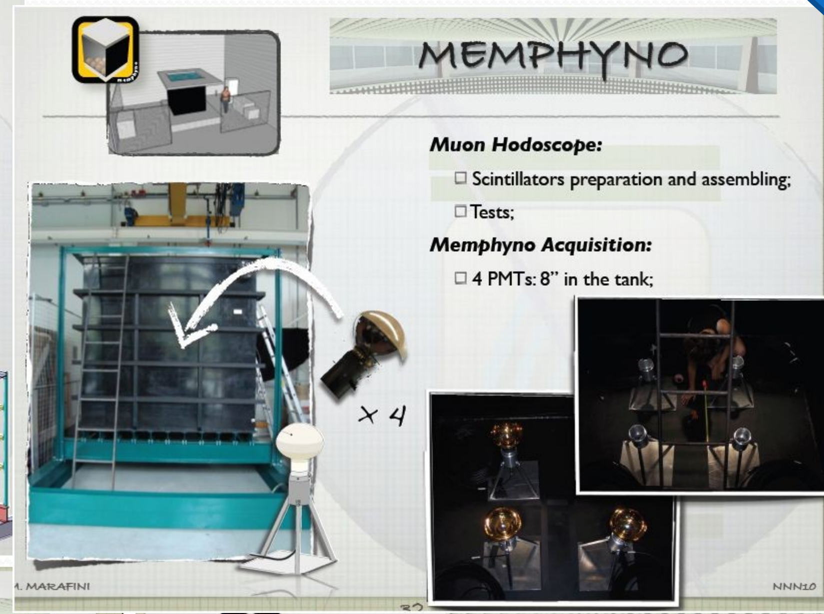
(collaboration with BNL since NNN07)

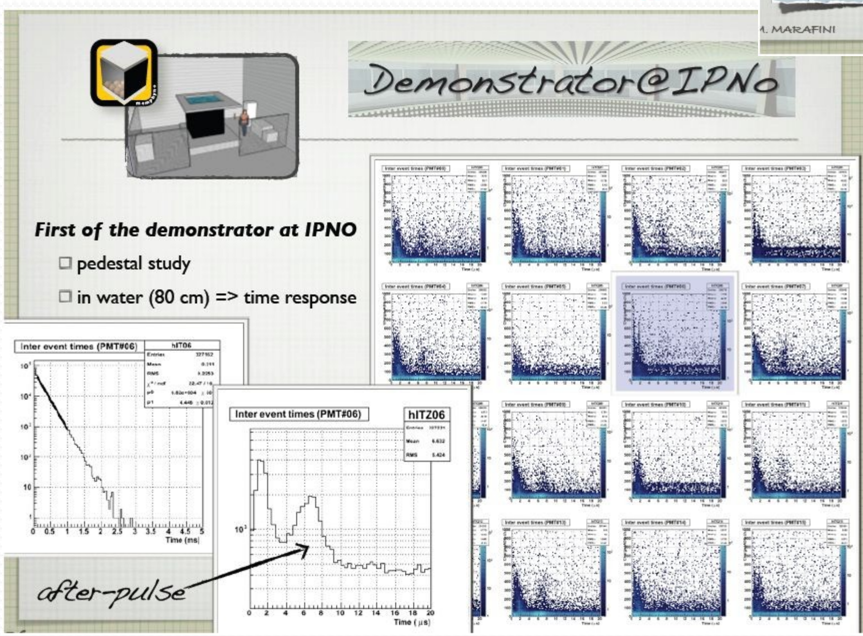
II. PArISROC readout chip
- complete front-end chip with 16 channels

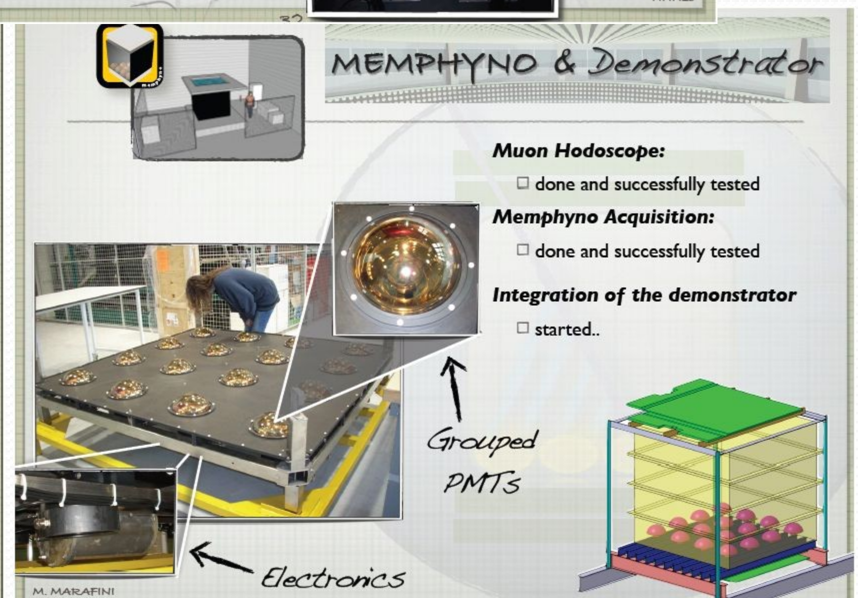
MEMPHYNO at APC & Demonstrator

M. Marafini's talk at NNN10

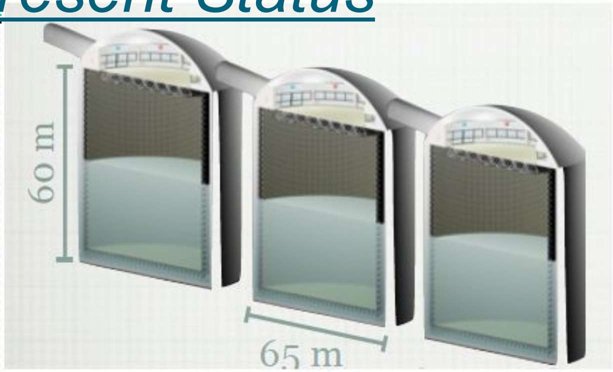






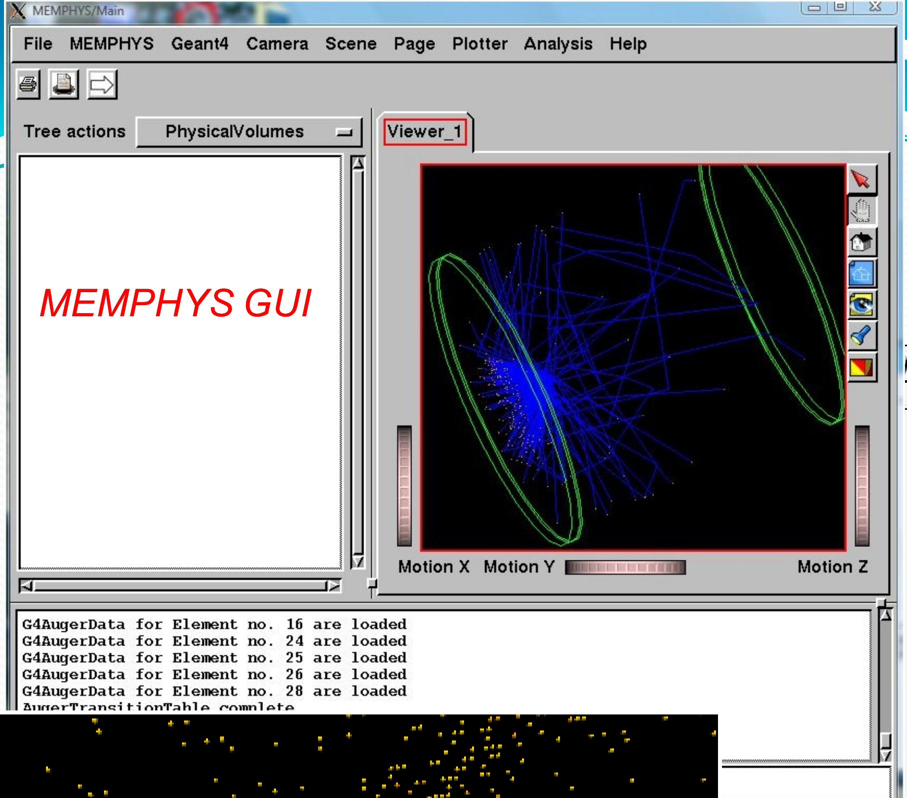


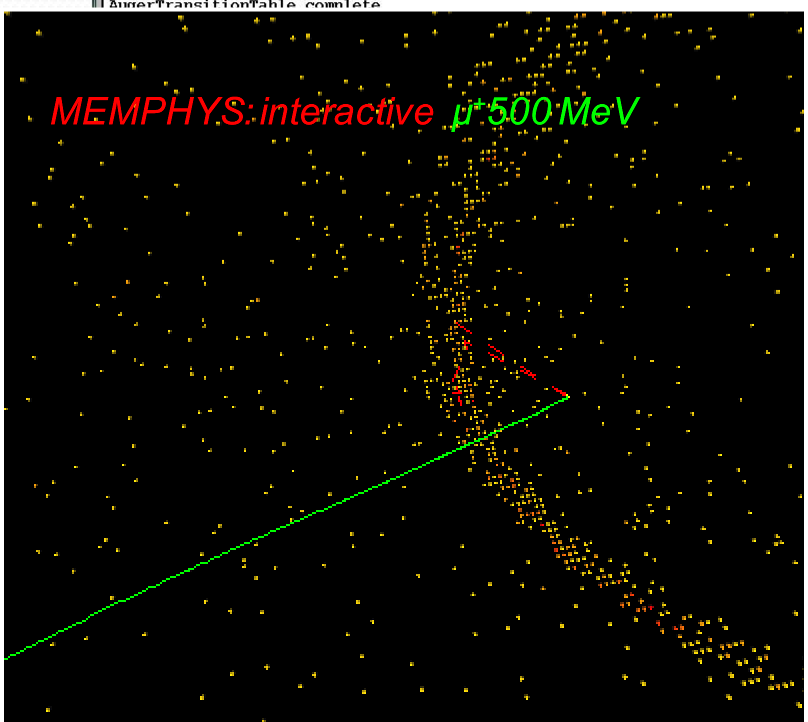
MEMPHYS: Full Simulation Present Status

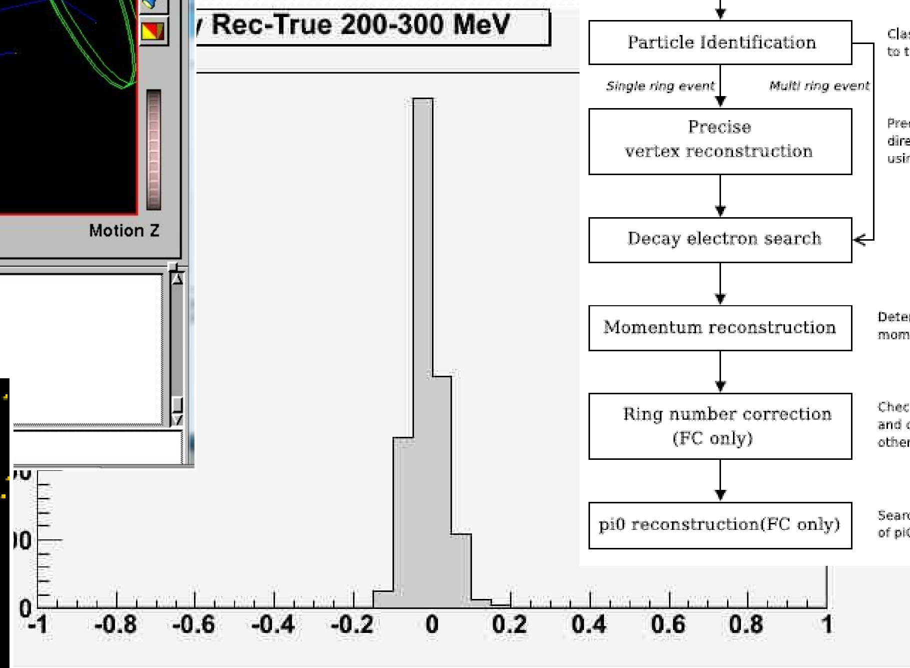


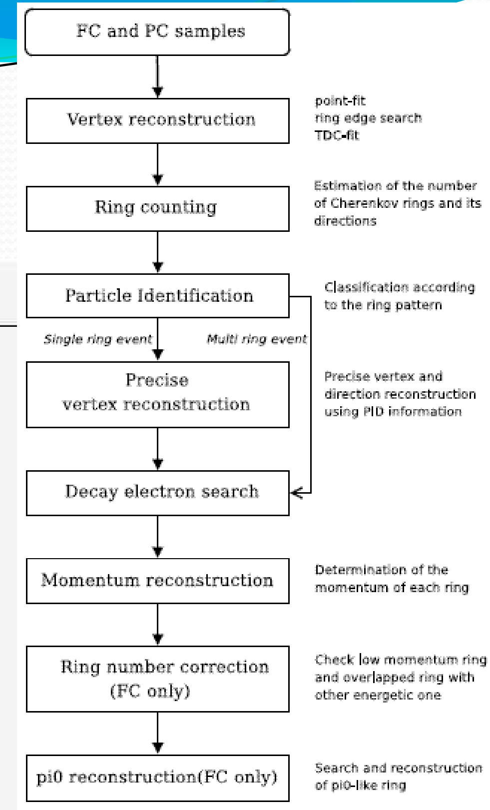
- Event Generator:
  - GENIE for ν beam *new*
- MEMPHYS Full Simulation (M. Fechner , J.E. Campagne, N. Vassilopoulos) :
  - Interface with the OpenScientist v16r0 framework (G. Barrand/LAL) using distribution kits as Geant4 & CLHEP & AIDA-IO implementation to Rio (also HDF5, XML)
  - 3 modes of running in the same framework:
    - Interactive Viewing, Batch processing, AIDA_ROOT analysis
  - primary + secondary + Optical Photon info, modular detector geometry, ntuples' storage, etc…
- MEMPHYS Event Reconstruction, Analyses (N. Vassilopoulos, A. Tonazzo):
  - interactive ROOT- cint
  - Solo C++ for complex/high stats using ROOT + AIDA libraries

MEMPHYS: GUI / Event Reconstruction





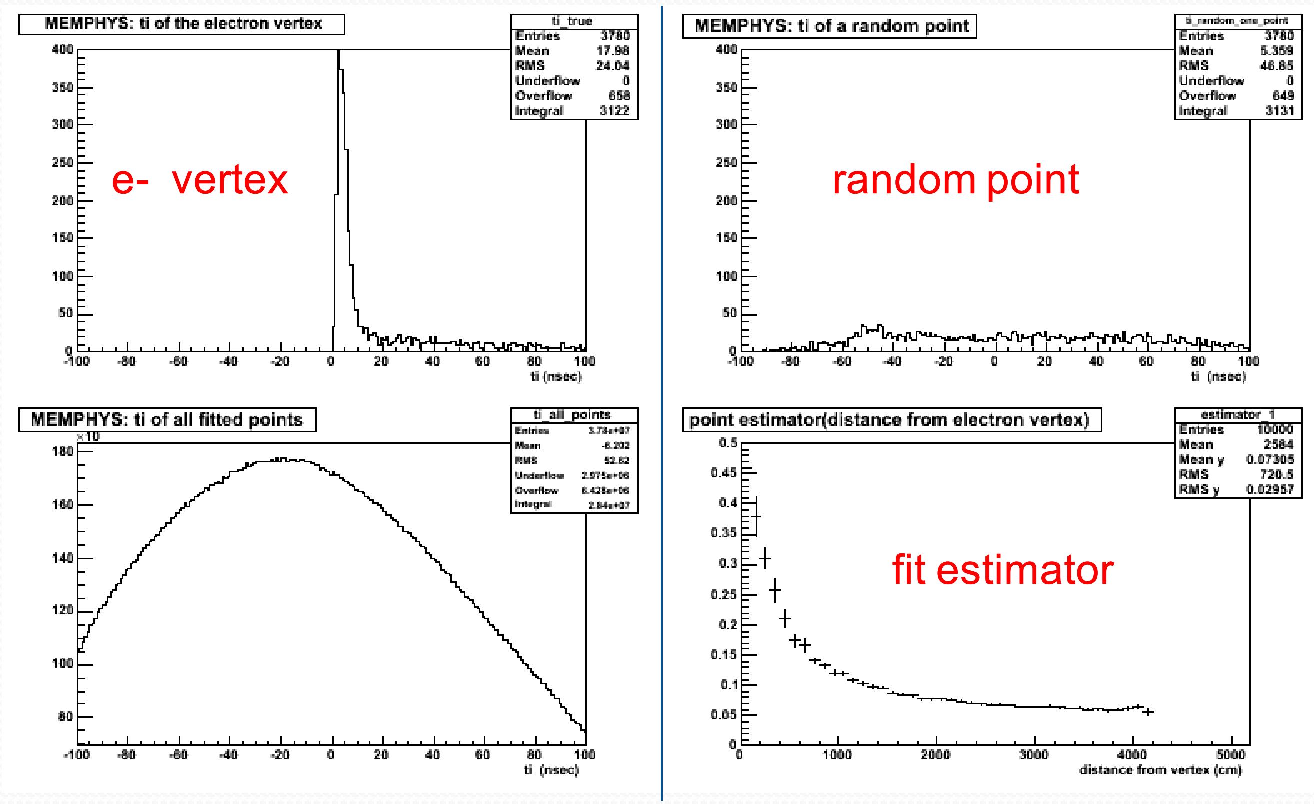




- main task using all the available tools
  - ✓evaluate detector performance
  - ✓extract energy resolutions and lepton efficiencies ⟶ migration matrices

Single rings: electrons primary vertex fit

- pick up a 400 MeV electron (FC), assume point like track length
- primary vertex fit based only on each PMT's timing info: $t_{i\,PMT} = t_i + TOF_i \Rightarrow t_i = t_{i\,PMT} - TOF_i$, where $TOF_i = (n / c) \times D$. D = distance between each PMT and grid's coordinates
- maximize estimator E a la SK $G_p = \frac{1}{N}\sum_i \exp\left(-\frac{(t_i - t_0)^2}{2\,(1.5\times\sigma)^2}\right)$ find the true vertex of electron :

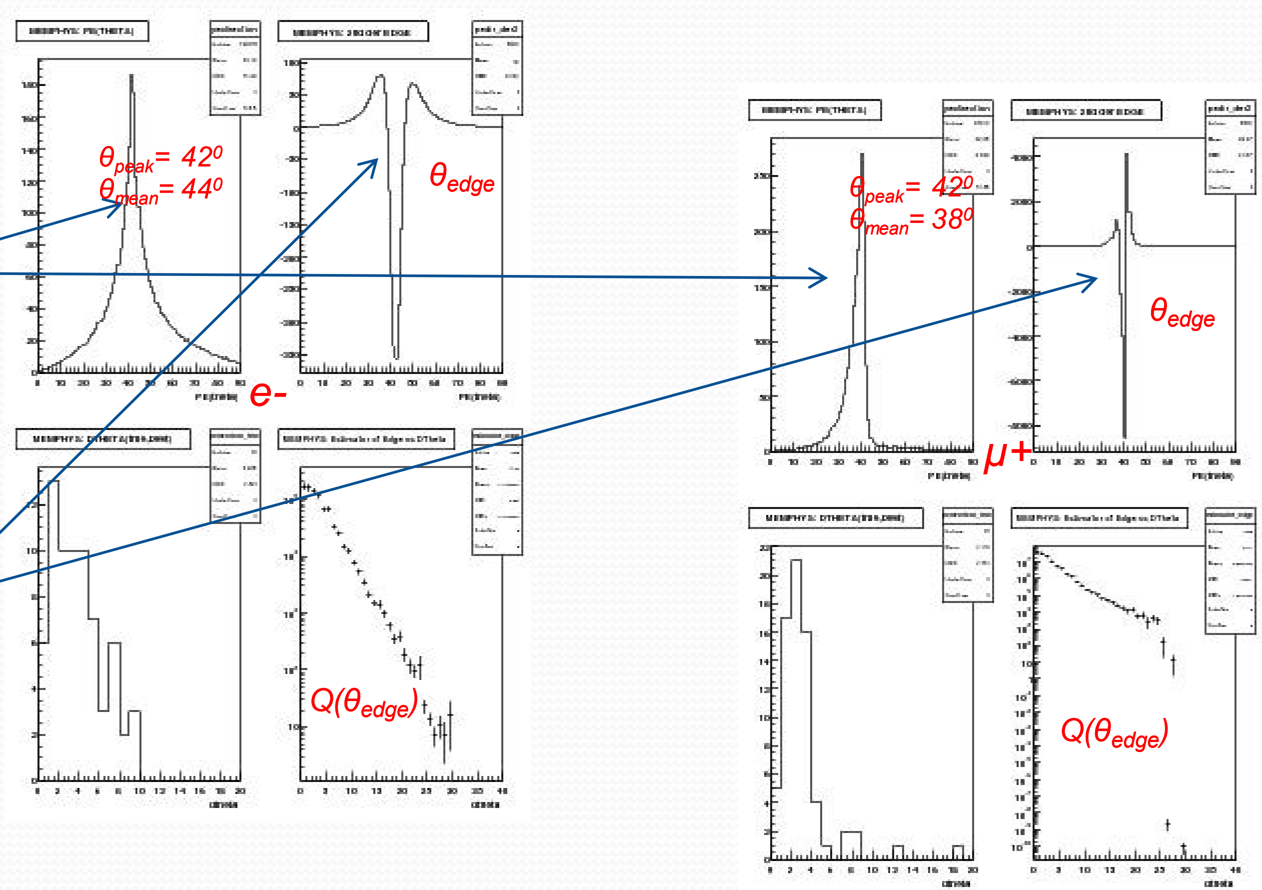


Single rings (FC): e-, μ+ 200MeV to 1000MeV ring direction

- find the best direction maximizing :

$$Q(\theta_{\rm edge}) = \frac{\int_0^{\theta_{\rm edge}} {\rm PE}(\theta)d\theta}{\sin\theta_{\rm edge}} \times \left(\frac{d{\rm PE}(\theta)}{d\theta}\bigg|_{\theta=\theta_{\rm edge}} \right)^2 \times \exp\left(-\frac{(\theta_{\rm edge}-\theta_{\rm exp})^2}{2\sigma_\theta^2} \right)$$

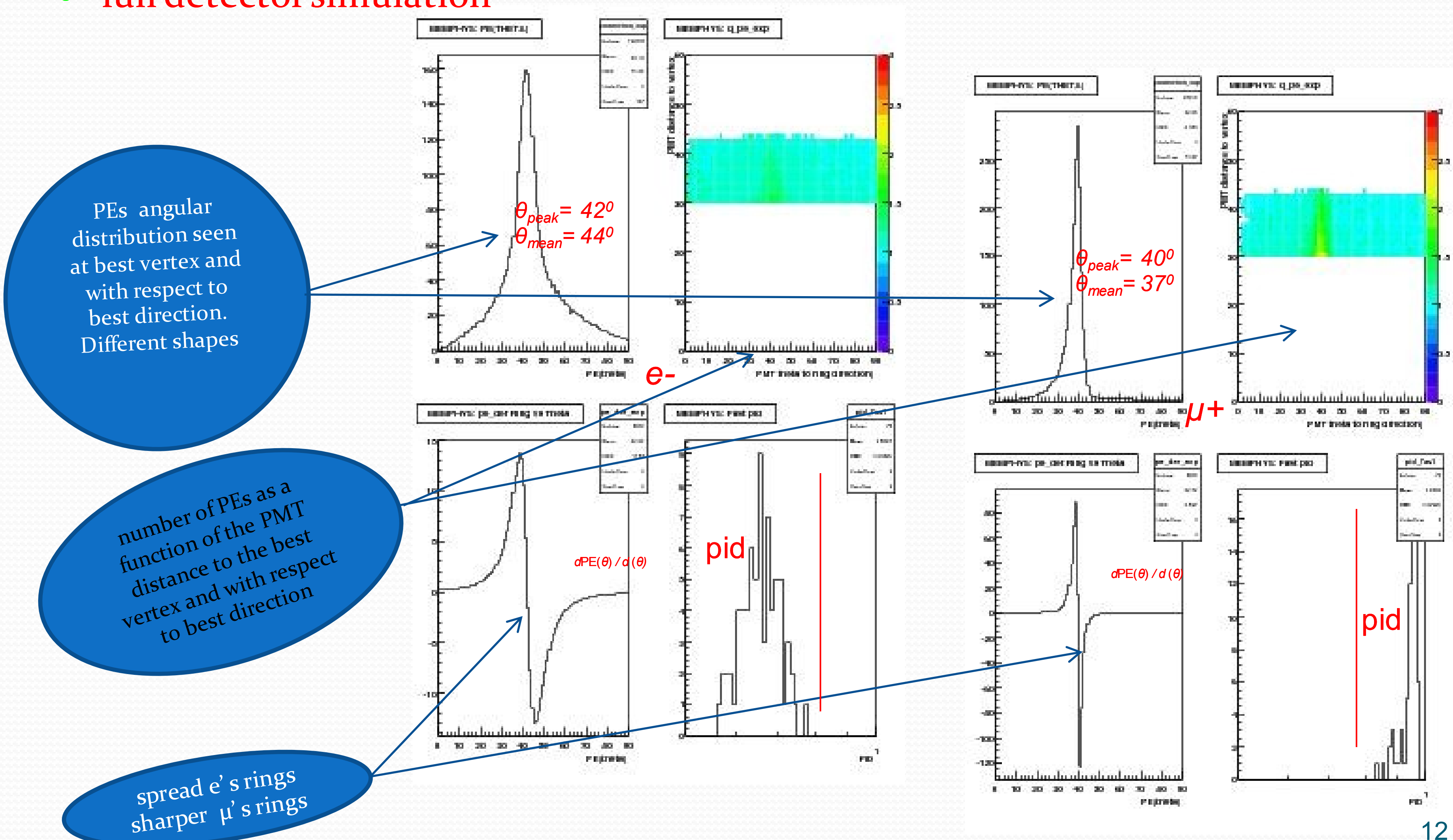
PEs angular distribution seen at best vertex and with respect to true direction. Different shapes



spread e' s rings
sharper μ' s rings

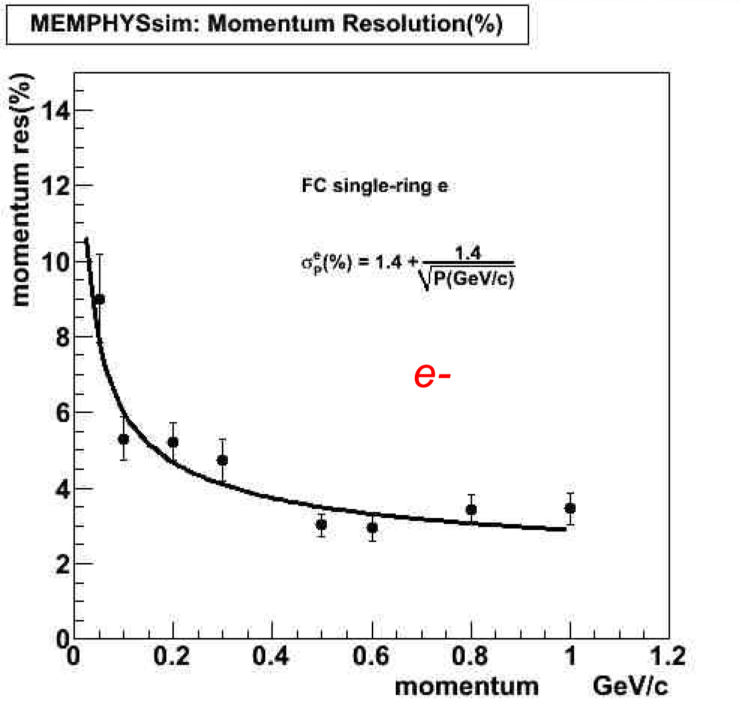
Single rings: e-, μ+ 200MeV to 1000MeV, PID

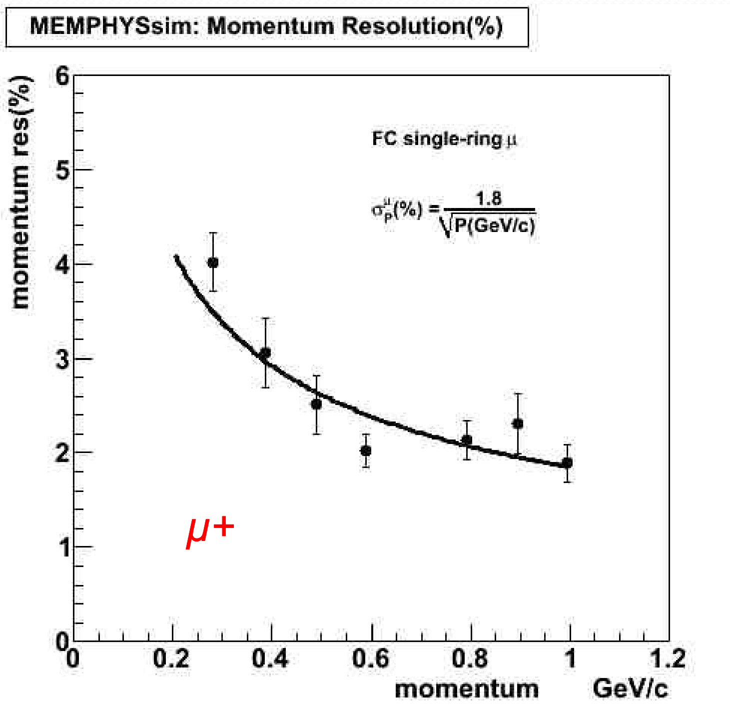
- use PEs (PMT) angular distribution from best reconstructed vertex and best direction as fast pid variable
- full detector simulation



Single rings: e-, μ+ up to 1 GeV/c momentum resolution (magnitude)

- R_{tot} , to correlate momentum with measured charged
- full detector simulation but low statistics

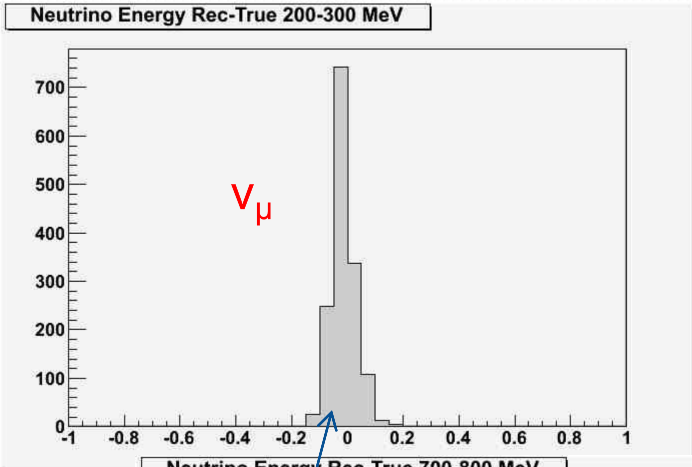


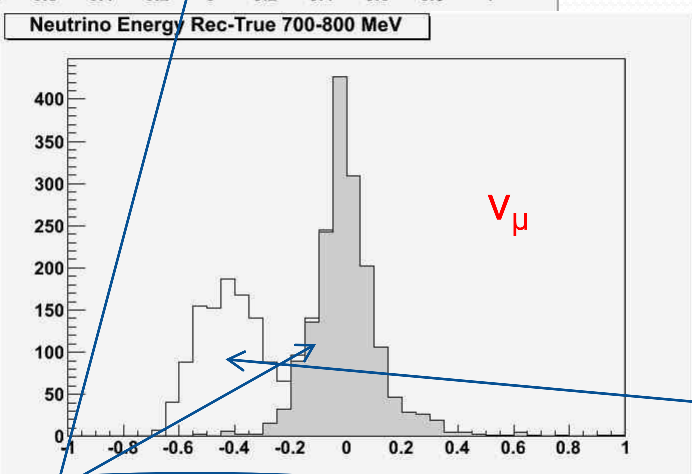


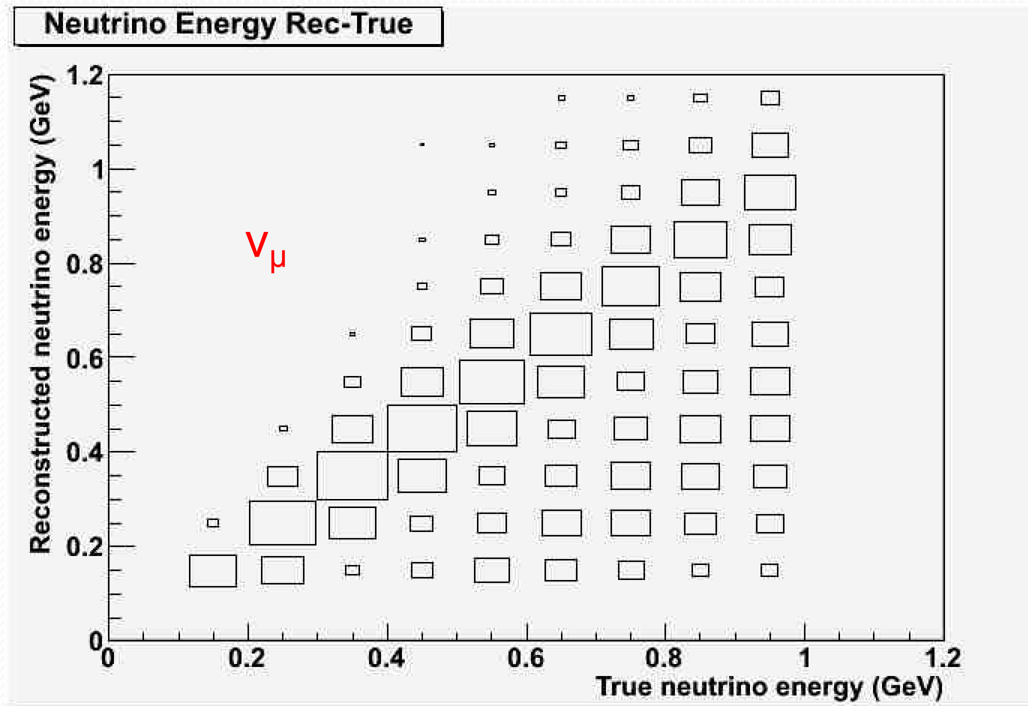
resolutions in between to SK-I, SK-II:
higher energies higher statistics of collected charge
lower energies small degradation due to detector size

MEMPHYS energy reconstruction

- momentum resolution could be be applied to any beam design to derive efficiencies, bdg. contamination and migration matrices
- e.g. true versus reconstructed
- uniform neutrino, antinuetrino samples up to 1 GeV, interactions in water simulated with GENIE



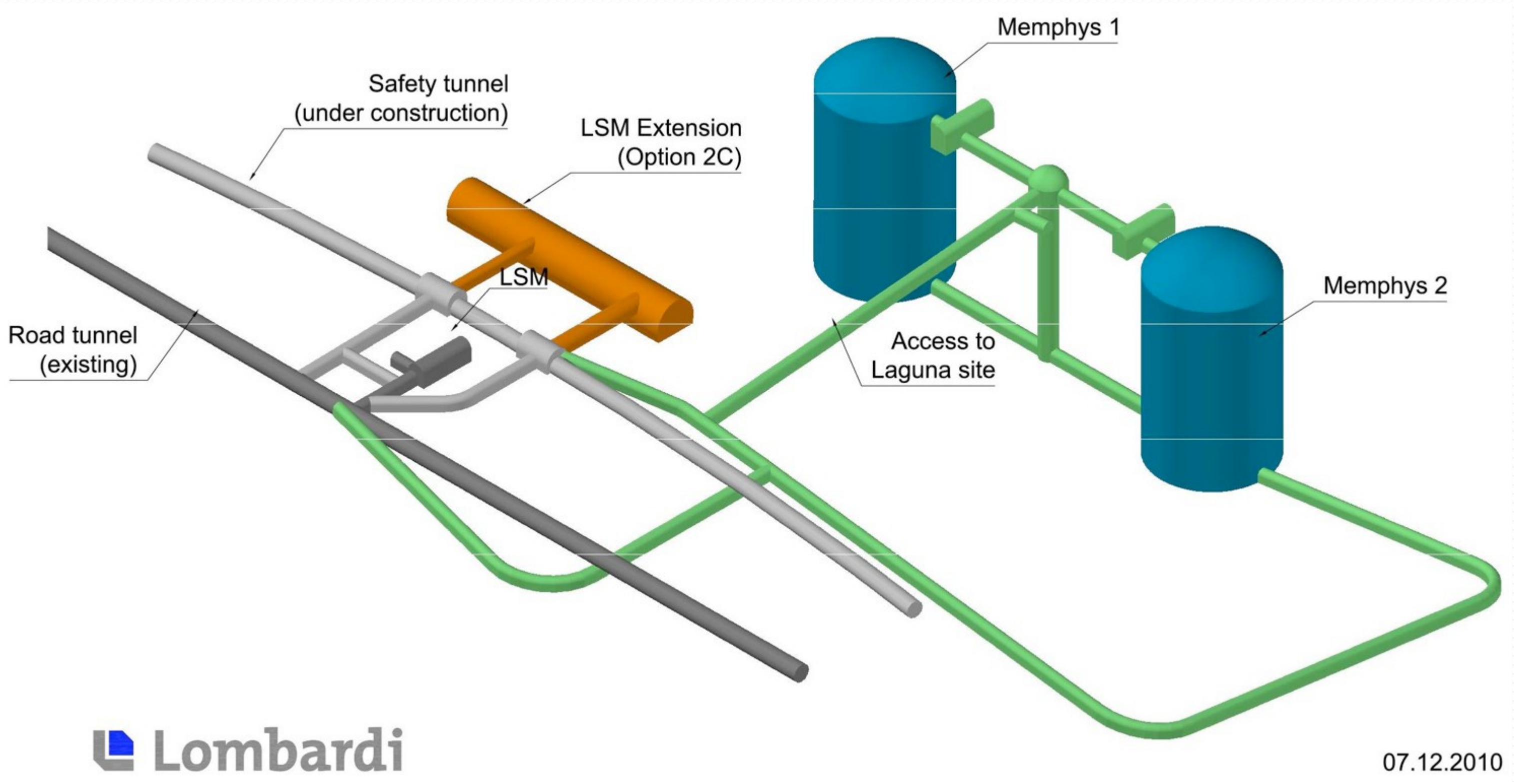




tail due to no-QE events, increasing with ν 's energy

gaussian peak due to QE's smearing of Fermi motion and experimental resolution

Schematic view for installation and infrastructure at Frejus site



Laboratory general information relevant to safety

The underground laboratory LSM “Laboratoire Souterrain de Modane” (CNRS and CEA) is located along the Fréjus road tunnel between France and Italy. The Fréjus road tunnel is a two lane 13 km long tunnel connecting Modane, France to Bardonecchia, Italy, in operation since 1978.

The present laboratory, in operation since 1982, and shielded by 1700 m of rock, is currently the deepest laboratory in operation in Europe.

In 2006 it was decided by French and Italian governments to dig a safety tunnel running parallel to main tunnel. Its excavation started in 2010 and should be completed in 2012.

Overview health and safety culture and management

The existing laboratory (and also a possible LAGUNA megaton-scale underground laboratory close by) benefits from the entire safety infrastructure settled-up by the operator of the road tunnel.

The safety management is the responsibility of the GEF (Groupement d'Expoiltation du Frejus) which is a common operator resulting from the two Fréjus tunnel companies: SFTRF (French) and SITAF (Italian).

The road tunnel safety teams are operational 24/24 hours and 7/7 days.

The existence, in a near future, of the safety tunnel (8 meters in diameter) will provide a very safe horizontal and independent access to the laboratories.

The goal is to have zero accidents in all these infrastructures. For that, the relevant equipment is at the top level and the rules of safety to respect are very stern and have as objective to protect both people and facilities.

Construction phase I: rock excavation

All risks must be assessed, tested, and efficiently mitigated.

Excavation operations will be achieved by competent enterprises that will respect all norms and rules for underground works.

A particular attention will be carried to the reinforcement of the rocks with the progression of the excavation.

For each detector module, the excavation of the cavern dome is performed in successive steps by drill and blast. During the excavation, a preliminary support is installed (shot concrete and systematic rock bolts).

The deepening of the cavern can thus start by proceeding from top to bottom. The stability is improved with systematic pre-stressed strand anchors.

Construction phase I: rock excavation (continued)

The access to the site will be possible without crossing of the trucks by using the road tunnel to enter and the safety tunnel to leave. This will permit a better safety of the staffs in case of emergency evacuation.

The ventilation of the site will be done by the safety tunnel himself, estimated fresh air flow at present is of 35 to 50 m^3/s. It will be planned an independent sheath for the extraction of the spoiled air (2 to 2.5 meters of diameter)

Construction phase II: tank construction and outfitting.

The water upper level in the tank will be lower than all the access and technical installations.

For the moment only Technodyne Ltd has studied the tank, while the Lombardi Company investigated the interface between the tank and the rock.

Special attention should be paid to the transport and handling underground of bulky items.

Concerning the seismic risk, the Fréjus site is located in a region classified with a low seismic hazard.

Operation phase I: running of LAGUNA

Health and safety Management

The chain of command will follow a clear path governed by the requirements of the Fréjus tunnel operator to the Lab's director assisted by safety engineer(s). A system of incident reporting and feedback will be in place, to ensure all incidents of any sort are logged and reported so that lessons can be learnt.

All the laboratory staffs will have safety training, fire prevention with regular exercises for evacuation. All safety documents will be archived and available for inspection. These documents will be continuous update to improve safety.

Operation phase I: running of LAGUNA (continued)

Health and Safety Infrastructure

Different dedicated sensors for identified potential risks will be installed in adequate positions. All the laboratory staffs will have personal protection equipments.

First aid is provided in the laboratory, and if necessary the evacuation by tunnel firemen to local hospital.

All the main alarm sensors signals are transmitted to the Fréjus tunnel control room. Air-flow is constantly provided by the tunnel infrastructure.

Fresh air is coming through the relevant safety tunnel equipment and stale air is extracted via a dedicated line.

The Fréjus tunnel has two independent power supplies (respectively from the French and Italian sides) to prevent electrical power failure in the different infrastructures.

Operation phase I: running of LAGUNA (continued).

Health and safety for tank operation:

This area will be covered mainly by the tank experts.

The tank conception and fabrication are essential: the critical point is to have no liquid leakage.

Adequate sensors and detectors will be disposed to early detect defaults.

Operation phase I: running of LAGUNA (continued).

Fire procedures and emergency evacuation and procedures:

Fire prevention is a key aspect very well supported by the Frejus tunnel teams. Firemen are operational in the tunnel 24/24 hours and 7/7 days with vehicles and special equipment.

To mitigate the fire risk the tunnel is equipped with a lot of fire detection sensors and a multitude of special equipment to fight and extinguish fire.

The laboratory will be included in the tunnel safety chain. In the tunnel, it already exist several protection zones (shelters) for people and evacuation circuits. All the equipments and procedures are tested periodically.

Of course the safety tunnel, presently under excavation, will provide a major improvement in this respect.

In addition the MEMPHYS experiment could even significantly contribute to the fire safety of the tunnel itself by simply installing a relatively small (≈ 1 Kton) additional water tank, permanently available to the firemen in the central region of the tunnel. This possibility is of course particularly welcome by the tunnel's direction.

Thanks