Physics with a Multi-MW Proton Source
CERN, Geneva, May 25-27, 2004

Project of a Large International Underground Laboratory at Fréjus

L. Mosca (CEA-Saclay)

Plan of the talk :

1) Motivations of the project

2) A cavity (or few cavities) of $\approx 10^6$ m^3 total volume

3) Possible sites in the Fréjus region :
opportunities and unknowns

4) The envisaged strategy

5) Preliminary studies (laboratory feasibility)

6) An "optimal" schedule

7) Summary and outlook

1) Motivations

"Non-Accelerator Physics" :

- Proton Decay ($\mathbf{p \to e^+ \pi^0}$, $\mathbf{p \to K^+ \bar{\nu}}$, …)
- Neutrinos from Natural Sources → Supernovae Watch
  Atmospheric Neutrinos
  Solar Neutrinos

"Accelerator Physics" :

- Neutrinos from Accelerators → Long baselines (Superbeams,
  and Betabeams)
  for Neutrinos Oscillation studies

“Non-Accelerator Physics” ….

- One possibility : a Megaton-scale Cerenkov Detector

-> No serious technical challenge, but two well known practical limitations :

1) water depth (pressure) limited to ≈ 60 m for current 20” PMTs
2) finite attenuation length of Cerenkov light ≈ 80 m in pure water at λ = 400 nm, as in Super-Kamiokande

-> Examples of expected performances :

a) for proton decay :

PMTs covering	Energy threshold	Exposure for a ($p \to e^+ \pi^0$) sensitivity of 10^{35} Years
10%	10 MeV	4 Mt.Years
20%	7 MeV	3 Mt.Years
40%	5 MeV	2 Mt.Years

b) for Supernovae neutrinos :

-> for a Supernova explosion at 10 kpc -> ≈ 140 000 events
-> for a Supernova explosion at Andromeda -> ≈ 30 events

“Accelerator Physics” ….

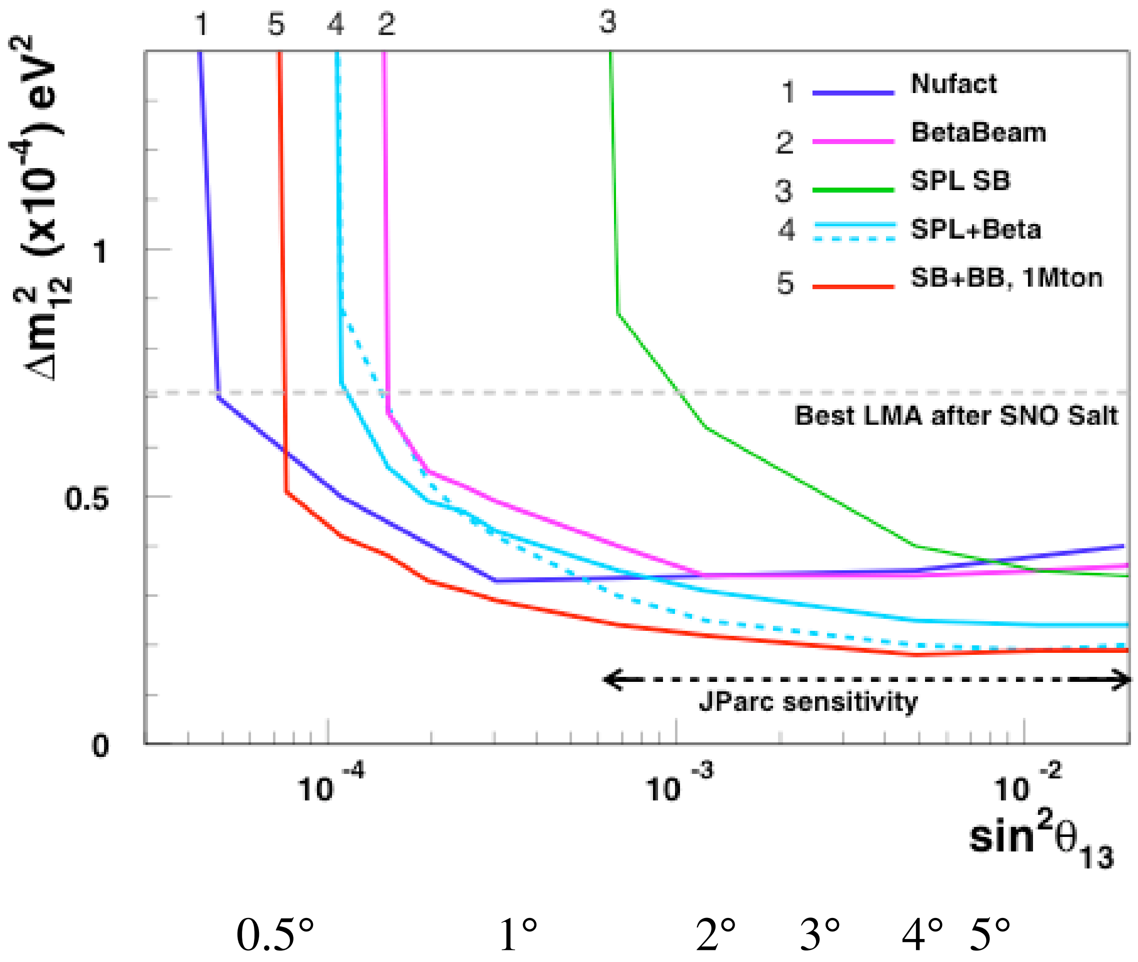
10 years running

A comparison of CP sensitivities: Beta Beam vs. Nufact

CP sensitivity, defined as the capacity to separate at 99%CL max CP ($\delta = \pi/2$) from no CP ($\delta = 0$).

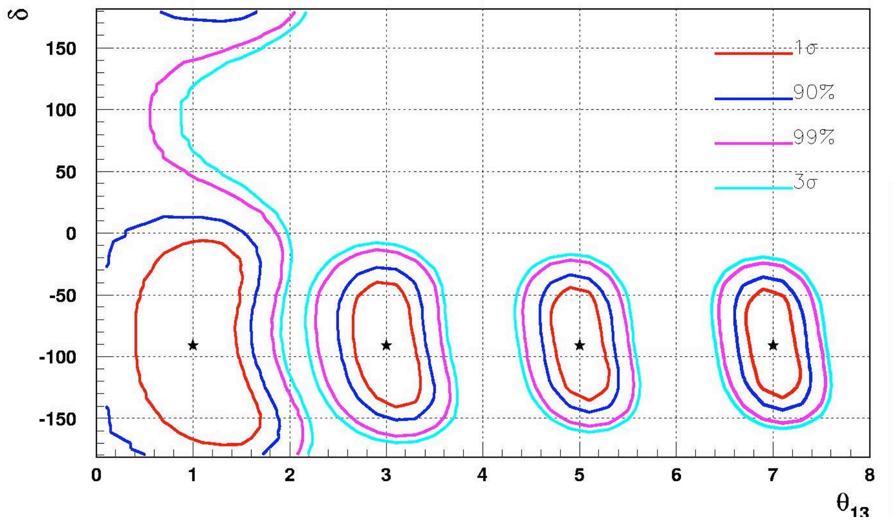
Nufact sensitivity as computed in J. Burguet-Castell et al., Nucl. Phys. B **608** (2001) 301:

- 50 GeV/c μ.
- $2 \cdot 10^{20}$ useful μ decays/year.
- 5+5 years.
- 2 iron magnetized detectors, 40 kton, at 3000 and 7000 km.
- Full detector simulation, including backgrounds and systematics.

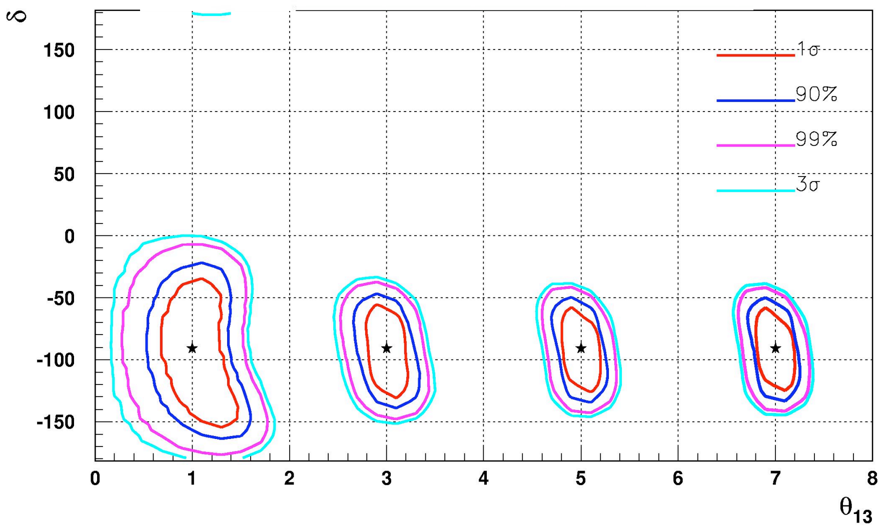


θ_{13} and δ measurements using Super-Beam and Beta-Beam

SUPER BEAM ONLY



SUPER BEAM + BETA BEAM



$\delta m^2_{12} = 7 \cdot 10^{-5}\ eV^2, \quad \theta_{13} = 4^\circ, \quad \delta_{CP} = -\pi/2$

10 yrs (4400 kton/yr)	SuperBeam		Beta Beam	
	ν_μ	$\overline{\nu}_\mu$	$\overline{\nu}_e$ (He^6)	ν_e (Ne^{18})
	(2 yrs)	(8 yrs)	$\gamma = 60$	$\gamma = 96$
CC events (no osc, no cut)	36698	23320	28880	140073
Total oscillated	314	67	147	168
CP-Odd oscillated	102	-64	47	-132
Beam background	141	113	/	/
Detector bkg.	37	50	1	299

Super-Beam :

2 years in ν_μ + 8 years in anti-ν_μ

Beta-Beam :

10 years of ^{6}He AND ^{18}Ne

(Mauro Mezzetto)

A GOLDEN Experiment !

The SuperBeam - BetaBeam synergy: CP, T and CPT

No other realistic scenario can offer CP, T and CPT searches at the same time in the same detector!!!!

CP Searches

- SuperBeam running with ν_μ and $\overline{\nu}_\mu$.
- Beta Beam running with ^{6}He ($\overline{\nu}_e$) and ^{18}Ne (ν_e).

T searches

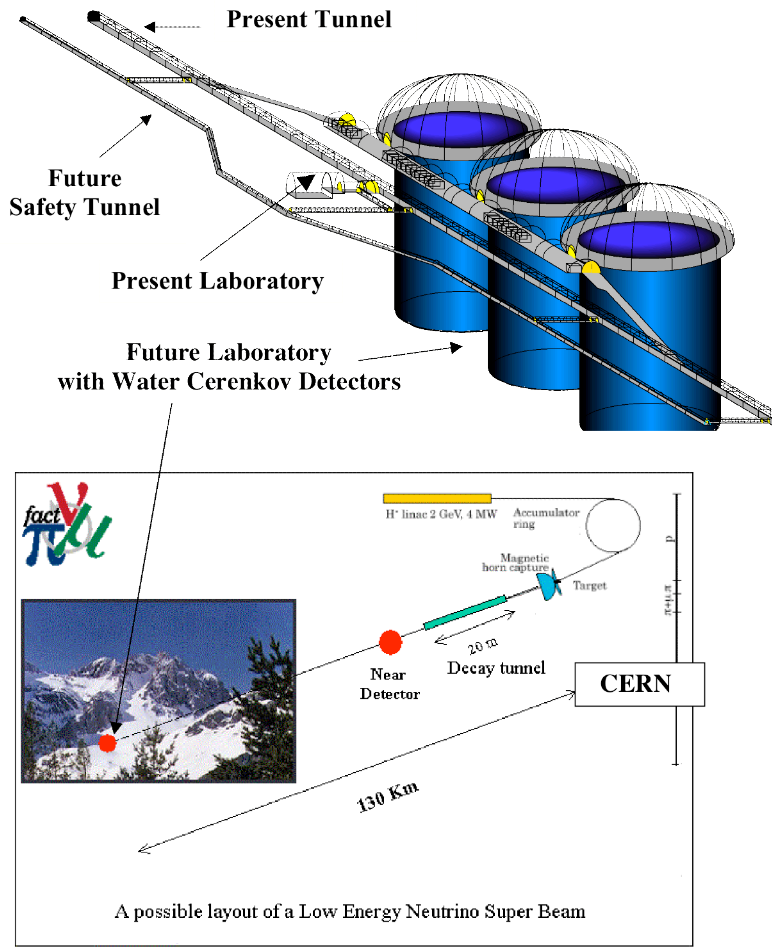
- Compare Super Beam $p(\nu_\mu \rightarrow \nu_e)$ with Beta Beam ^{18}Ne $p(\nu_e \rightarrow \nu_\mu)$
- Compare Super Beam $p(\overline{\nu}_\mu \rightarrow \overline{\nu}_e)$ with Beta Beam ^{6}He $p(\overline{\nu}_e \rightarrow \overline{\nu}_\mu)$.

CPT searches

- Compare Super Beam $p(\nu_\mu \rightarrow \nu_e)$ with Beta Beam ^{6}He $p(\overline{\nu}_e \rightarrow \overline{\nu}_\mu)$.
- Compare Super Beam p($\overline{\nu}_\mu \rightarrow \overline{\nu}_e$) with Beta Beam ^{18}Ne $p(\nu_e \rightarrow \nu_\mu)$

Components of the Project

-> a **very large Laboratory** to allow the installation of a **Megaton**-scale **Cerenkov** Detector (≈ 10^6 m^3) and/or a **Liquid-Argon** Detector



A possible layout of a Low Energy Neutrino Super Beam

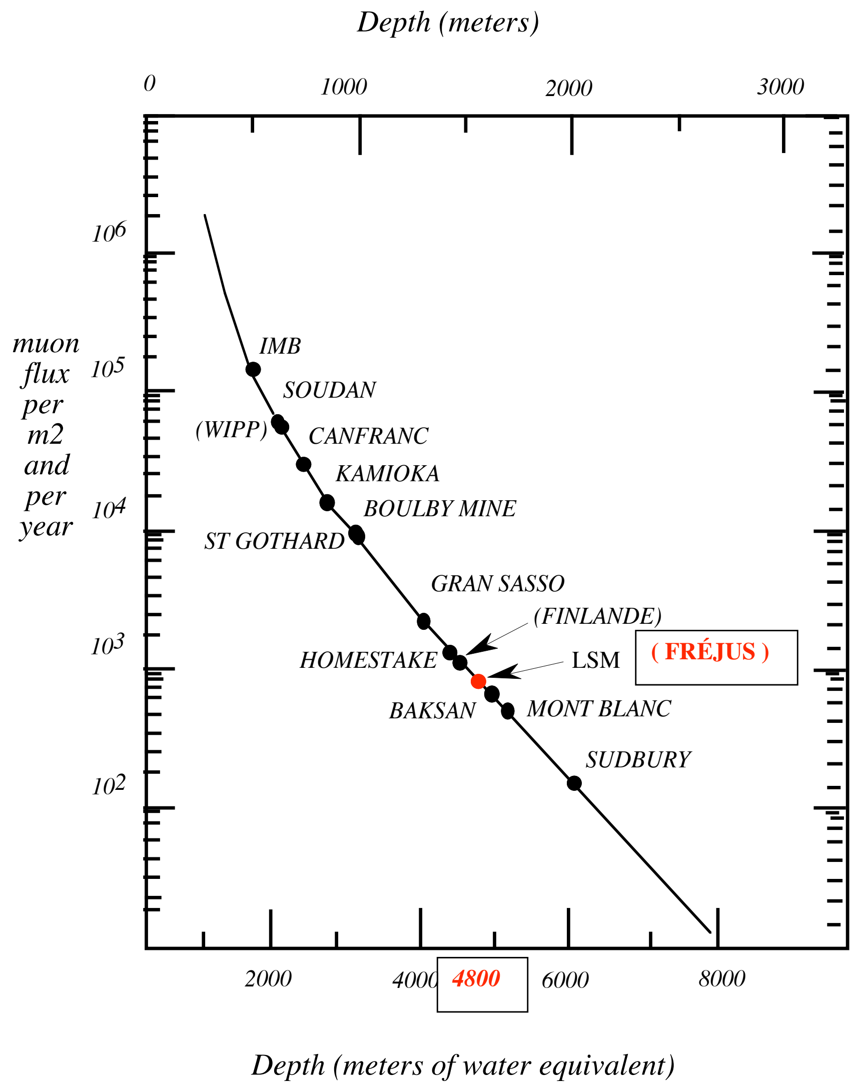
and (or) neutrino beta-beam

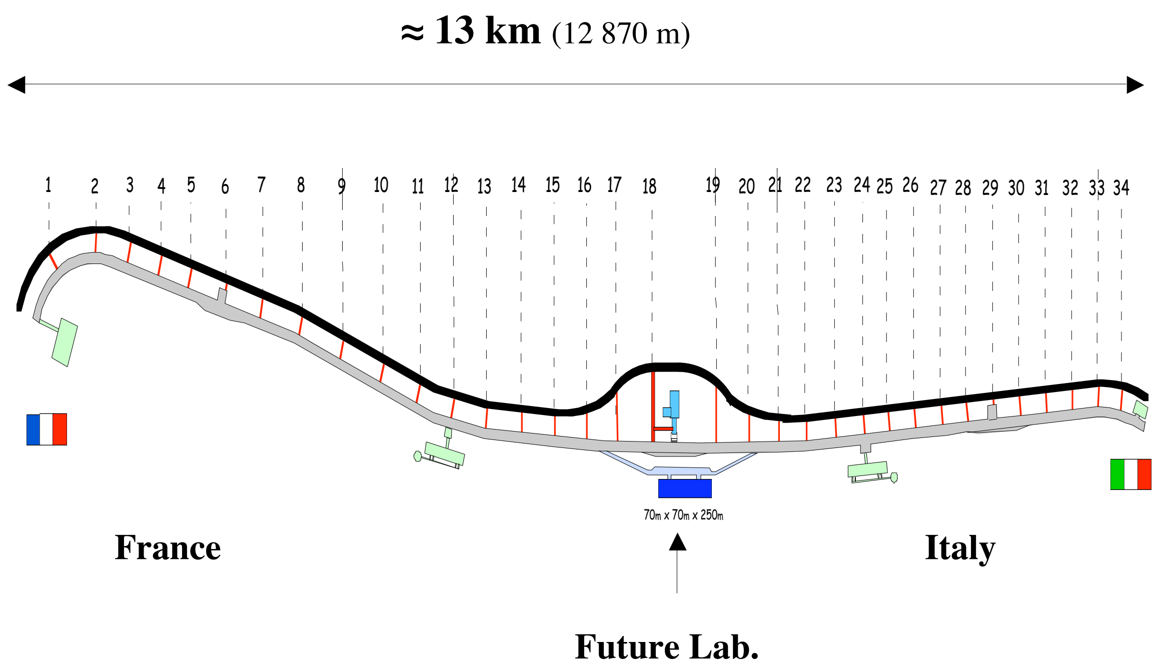
Two possible **sites** are proposed **in the Fréjus region** :

a) "**Fréjus I**" site : near the present Fréjus Laboratory (LSM),
in the central region of the road Tunnel
with a good rock covering of **4800 mwe**
The rock is very dry, of good quality and rather
well known

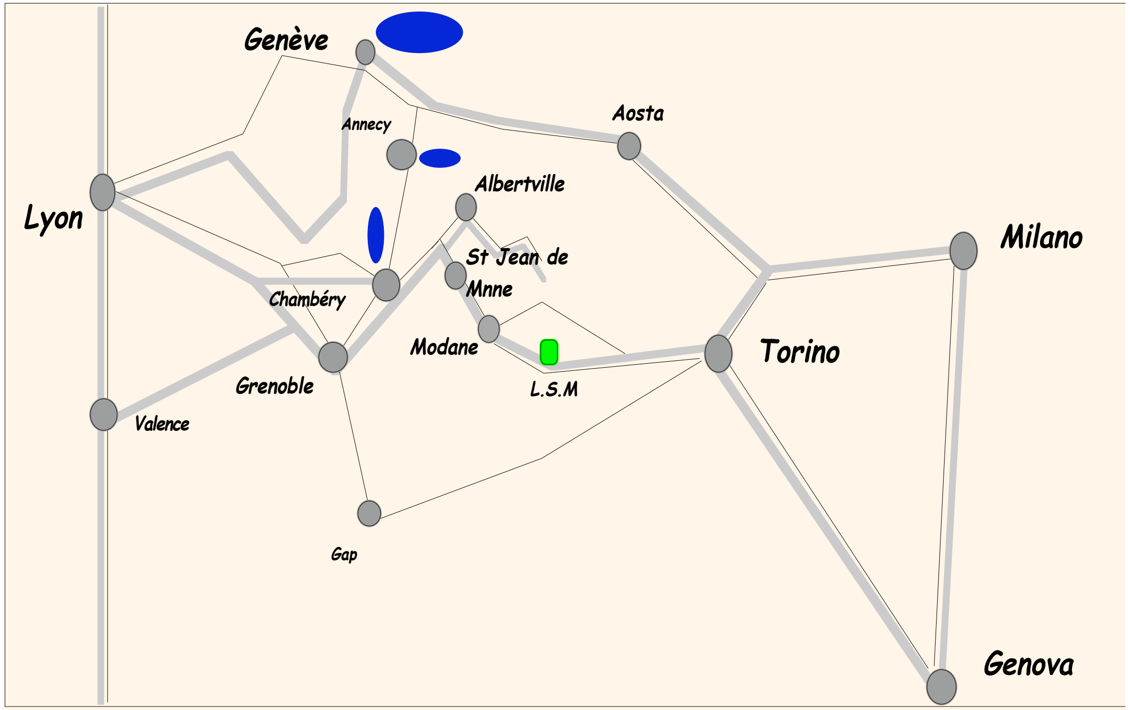
b) "**Fréjus II (Mont d'Ambin)**" site, at about 15 Km in the East
direction from Fréjus I, in a future access tunnel
to the "Lyon Turin Ferrovière" long Tunnel,
with an excellent rock covering **up to 7000 mwe** !
The rock is expected to be hard, but not yet studied
and with some possible water problems (glaciers above)

Both sites are at about the **same distance** from CERN
(130-135 Km)


Depth (meters)
0
1000
2000
3000
muon flux per m2 and per year
10^6
10^5
10^4
10^3
10^2
IMB
SOUDAN
(WIPP)
CANFRANC
KAMIOKA
BOULBY MINE
ST GOTHARD
GRAN SASSO
(FINLANDE)
HOMESTAKE
LSM
(FRÉJUS)
BAKSAN
MONT BLANC
SUDBURY
2000
4000
4800
6000
8000
Depth (meters of water equivalent)

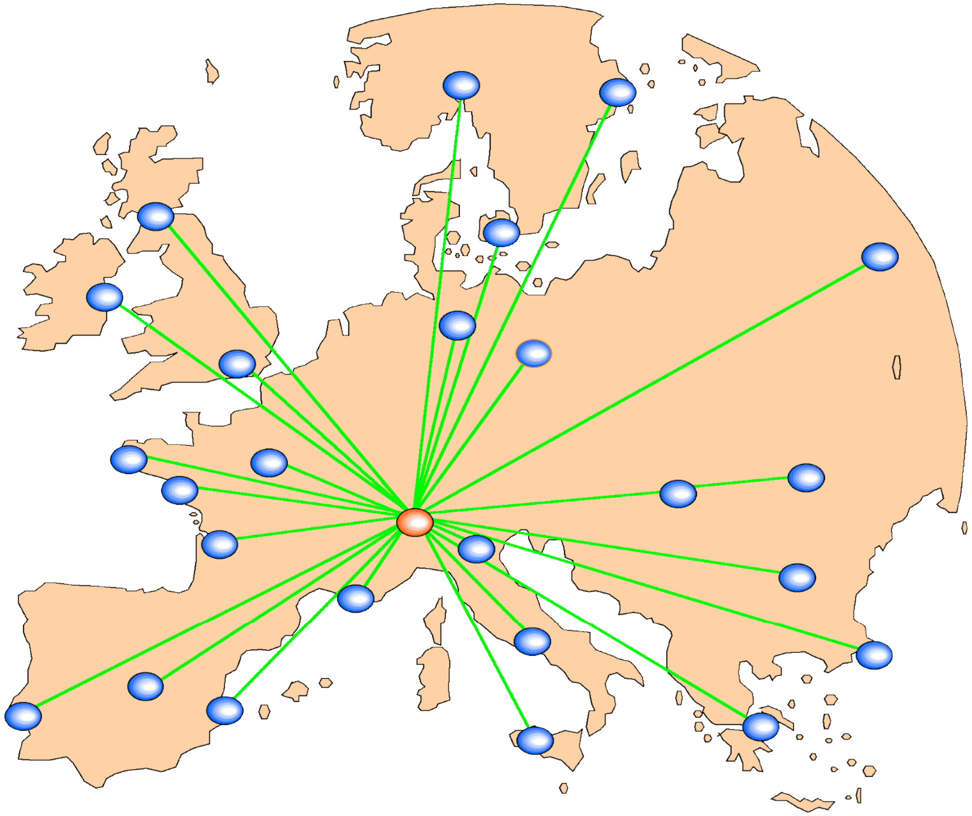


Present road Tunnel at Fréjus (grey)
and
future Tunnel (black) for safety with 34 bypasses (shelters)
connecting the two Tunnels



The Fréjus site (green) is at the junction between the Regions of

RHÔNE-ALPES (FRANCE)
and
PIEMONTE (ITALY)



Position of the Fréjus site in Europe

A very massive Detector

-Water Cerenkov : 1 Megaton of UNO or HyperK type

"MEMPHYS" *project (MEgaton Mass PHYSics)*

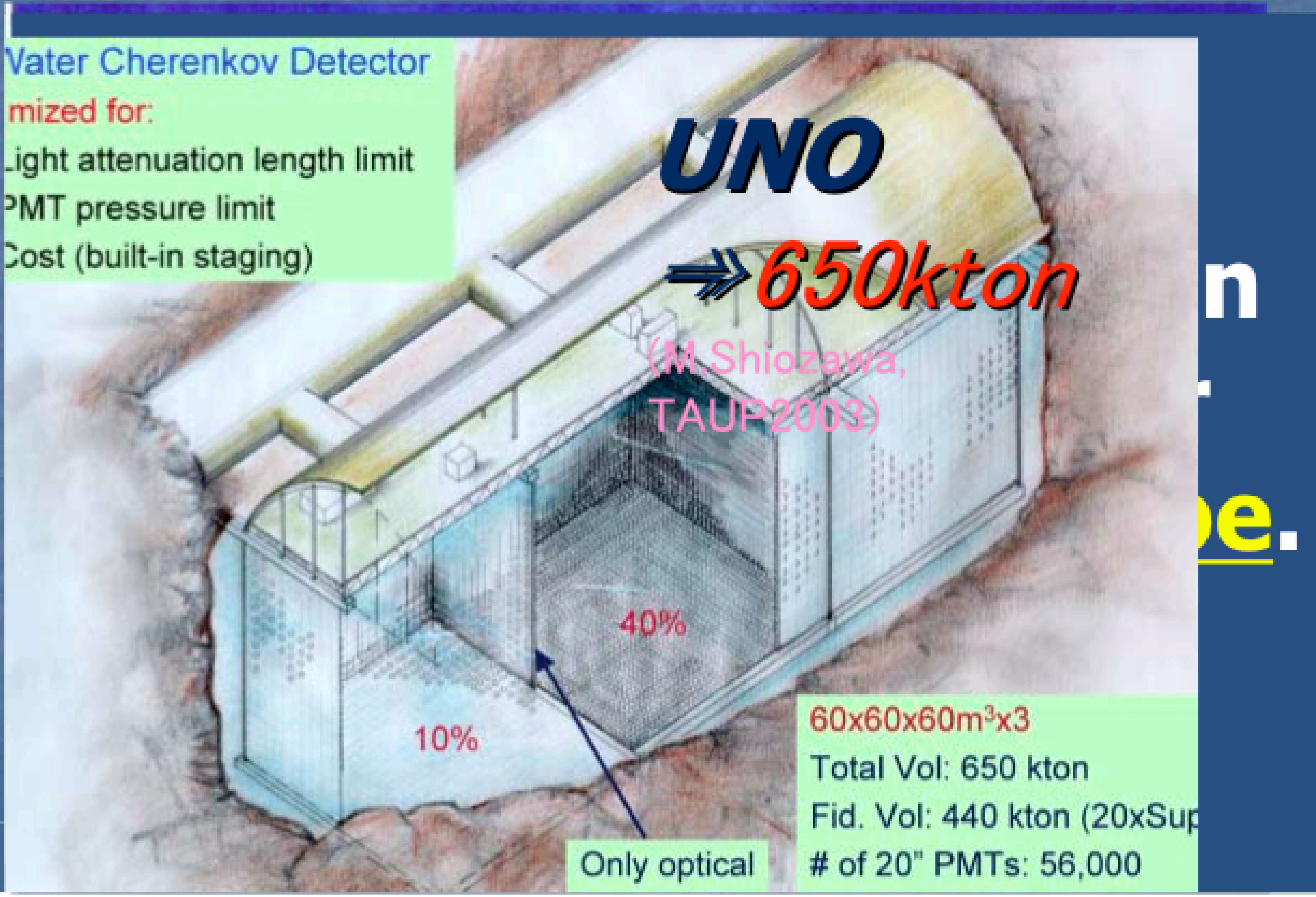
or/and

-Liquid Argon : 100 Ktons ("Glacier" Expt.)

A. Ereditato & A. Rubbia, "Physics with a Multi-MW Proton Source"(this Conf. at CERN, 25-27 May 2004)

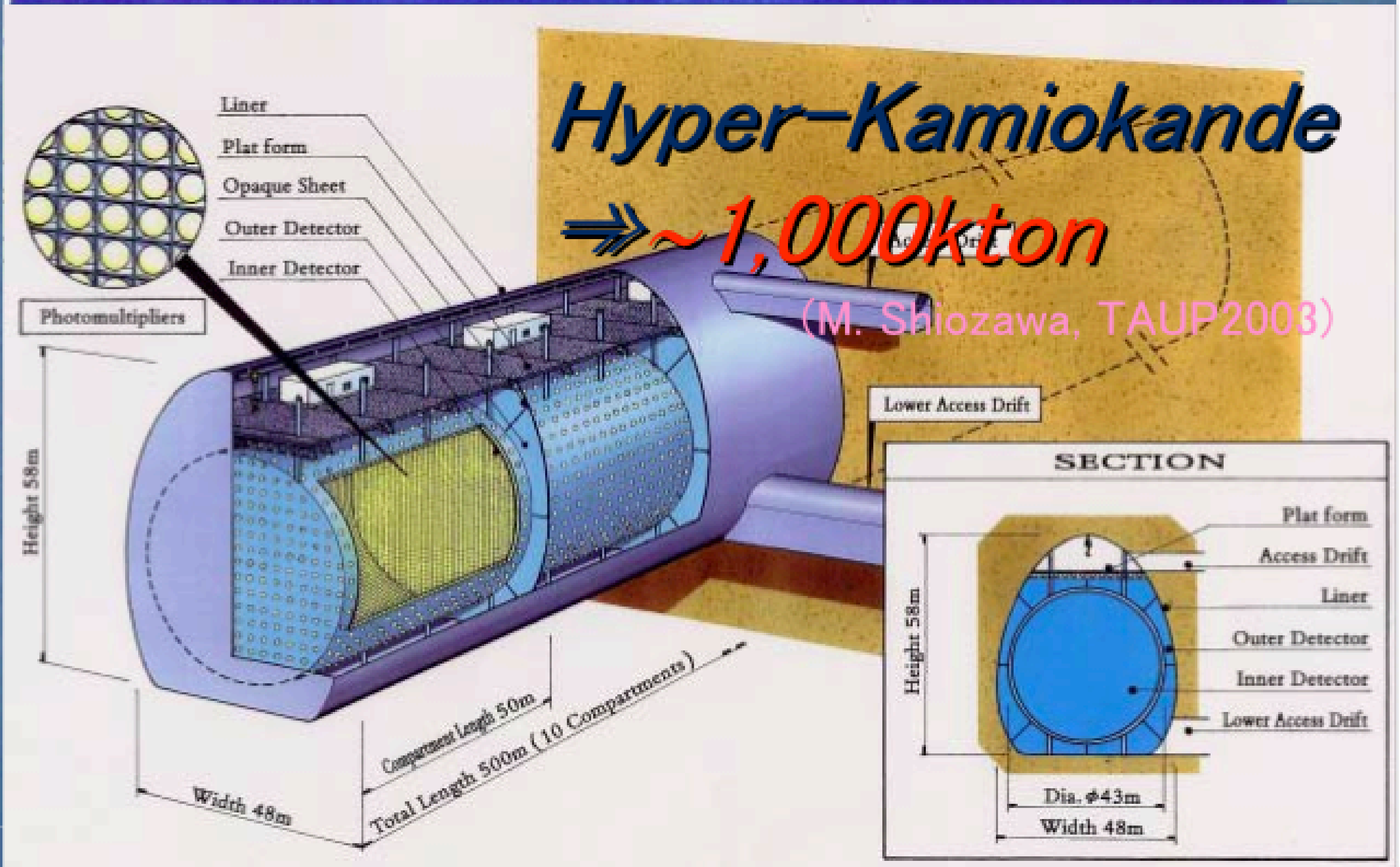
- aim: $\tau_p \sim 10^{35}$ years

  ⇒ need $>10^{35}$ protons (~300 ktons H_2O)



- aim: $\tau_p \sim 10^{35}$years

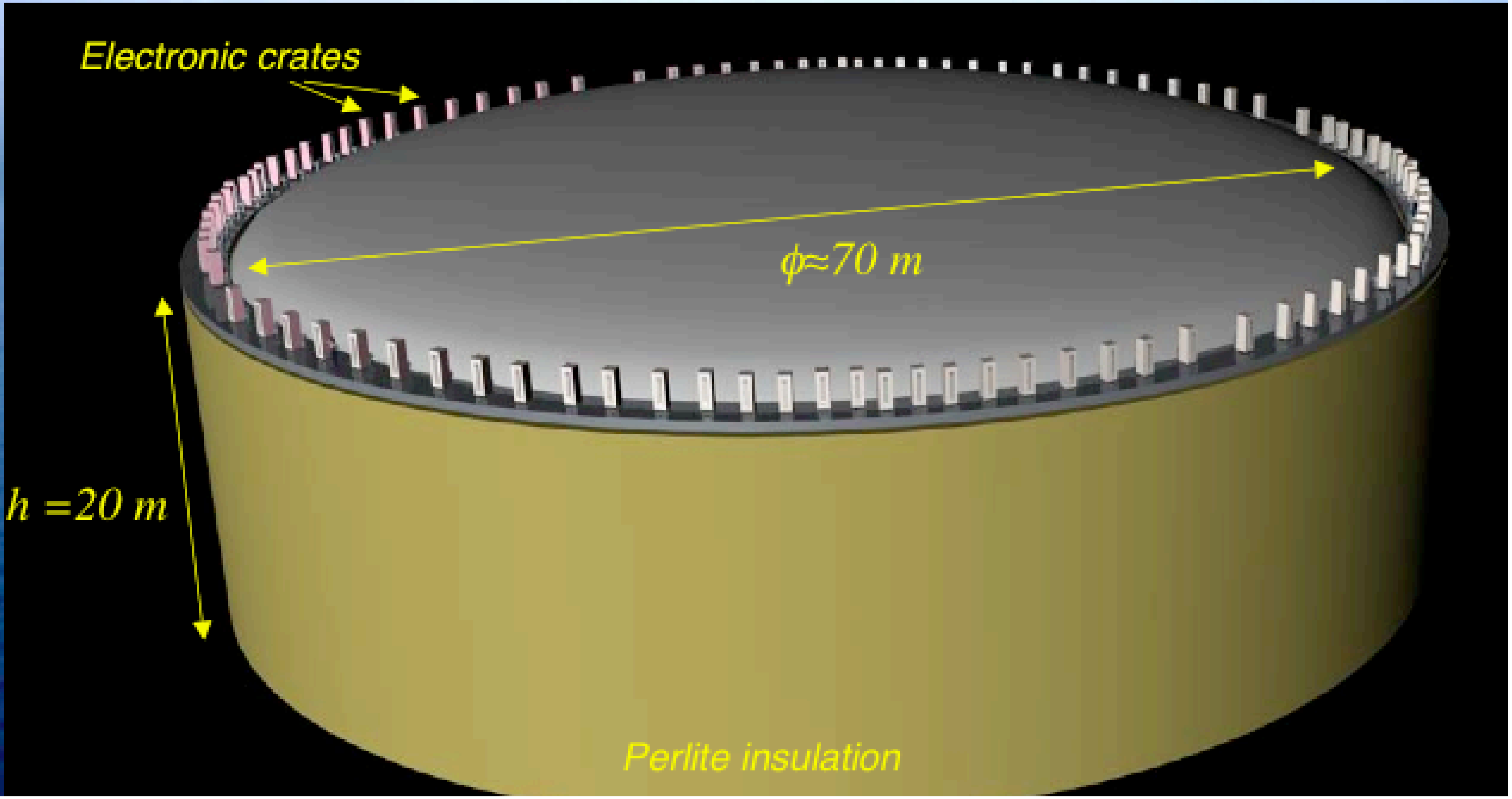
  ⇒ need >10^{35} protons (~300 ktons H_2O)



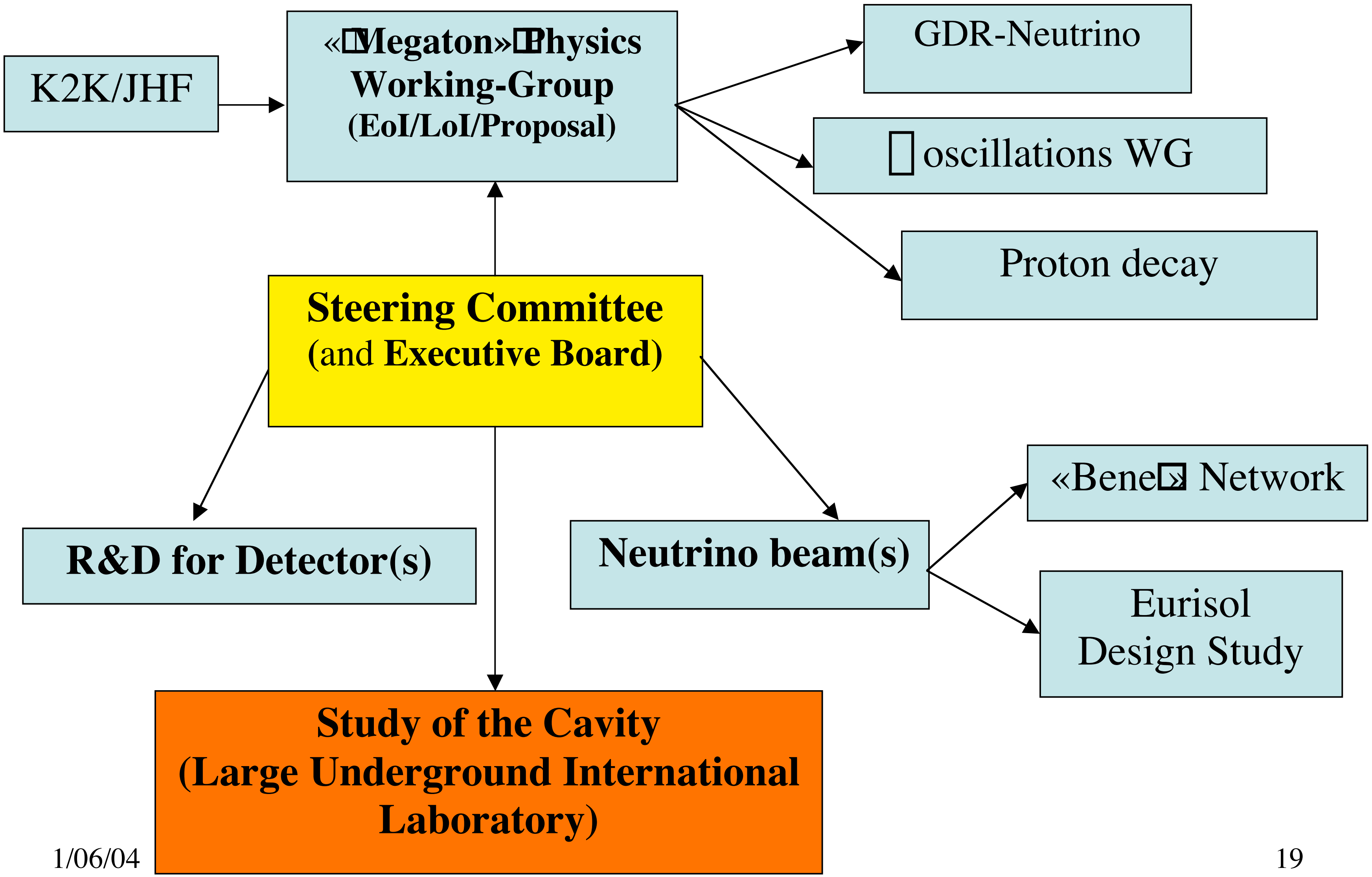
100 kton liquid Argon detector

Basic "novelties":

1. Charge imaging + scintillation + Cerenkov light readout for complete information
2. Charge amplification to allow for extremely long drifts
3. Single 100 kton "boiling" cryogenic tanker with Argon refrigeration



A Strategy for a «Megaton» Physics Project in Europe



Preliminary studies

The "Megaton Project Working-Group" has prepared a draft of an "Expression of Interest"(EoI) on the Fréjus project, as a first step towards a "Letter of Intention"

Megaton Project Working-Group

Present participants :

Jacques BOUCHEZ (Saclay) ---> Coordinator
Luigi MOSCA(Saclay et LSM/Fréjus)
Christian CAVATA (Saclay)
Alain de BELLEFON (Collège de France)
Stephan LAVIGNAC (CERN/Spht-CEA)
Alain BLONDEL (Université de GENEVE / CERN)
Vittorio PALLADINO (INFN/Napoli)
Mauro MEZZETTO (INFN/Padova)
Joan José GOMEZ-CADENAS (Barcelona/CERN)
Pilar HERNANDEZ (Barcelona/CERN)

Expression of Interest (EoI) --> Letter of Intention (LoI)

Megaton Mass detector Physics

Contents

Preliminary study for a very large cavity ($\approx 10^6$ m^3) at the two Fréjus sites

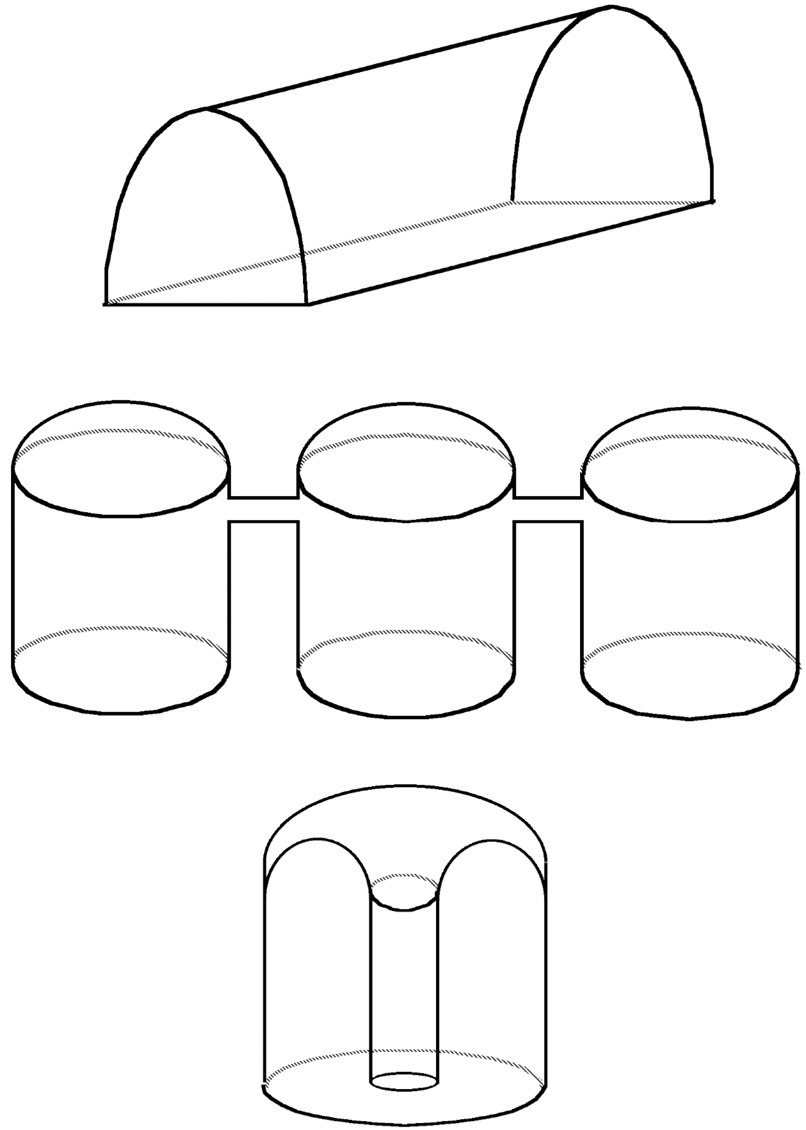
Objectives :

1) Feasibility -> determine the maximum possible size of the cavity for each type of considered geometry (see the next transparency)

2) Estimate (roughly) the cost and the time of the excavation

-> Then a more detailed ad extensive study (design study) will be performed with (hopefully) a contribution from the European Community (EC)

Three types of geometry that will be considered in the preliminary study for the future Lab.



An «Optimal» schedule for a Megaton Physics Project in Europe

Year	2003 2004	2007 2008	2012	2015	2020
Procedure :	EoI, LoI	Prop, Approv.			
Safety Tunnel	excavation				
Large Cavity	Pre-study, study	excavation			
R&D PMT's, etc.	R&D PMT's, etc				
PMT's production		PMT's production			
Detector installation			Detector inst.		
Start Megaton Physics				Start Megaton Physics ………………...	
SPL + Super-beam realization		SPL+Super-beam realization		?	
Beta-beam realization		Beta-beam realization		?	

To summarize …..

- The "seven virtues" of the two Fréjus sites :

1) **great depth** (at least 4 800 mwe)
2) (probably) good quality of the rock
3) independent horizontal access
4) central geographical position in Europe
5) "**magic distance**" from CERN (130 km) :
   Neutrino Super-beams and Betabeams
6) strong support from the local authorities
7) Recent "**Cooperation agreement (MoU)**" between French (IN2P3/CNRS, DSM/CEA) and Italian (INFN) Institutions

“Memorandum of Understanding”
between
French (IN2P3/CNRS, DSM/CEA)
and Italian (INFN) Institutions

………………….

« The DSM, IN2P3 and the INFN agree to **prepare the design of a very Large Underground Laboratory in the new Fréjus tunnel**, with complementary features with respect to the Gran Sasso laboratory, to be submitted as a joint proposal to the French and Italian governements.

The institutions aim at associating the Fréjus and Gran Sasso laboratories in a single entity, a European Joint Laboratory, **open to the world scientific community** to carry out advanced experiments in particle, astroparticle and nuclear physics in the coming decades, on topics such as matter stability, neutrino mixing and mass, stellar collapses and nuclear astrophysics »

……………………………………..

Conclusions and outlook

Both **Fréjus sites** seem well adapted for a Megaton Cerenkov and/or Liquid-Argon Detectors Facility both for "non accelerator" and "accelerator" Physics

Both sites are at about the **same distance from CERN** (130-135 Km)

A **feasibility study** is now necessary and will be done, as soon as possible, on both sites, in particular with the help of the french organism CETU (Centre d'Etudes pour les Tunnels)

In the frame of an "**optimal schedule**", the **"non accelerator" sector** of the Physics Program **can start as soon as the laboratory and the detector are ready (2012 -2014?),** while the **"accelerator" sector** can join the game later, as soon as also the **neutrino beam(s)** will be completed **(2015-2017 ?)**