Prospects

for an European Strategy for neutrino Physics

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IPN Lyon

Review of Neutrino Initiatives, Fermi Lab, june 9th 2004

- **Ongoing program: CNGS status**
- **Reactor experiment : Double CHOOZ**
- **Futur for CERN based program**
  - **Mwatt proton injector**
  - **Betabeam and Superbeam**
- **The Fréjus proposal**
- **Network for Liquid Argon detector**

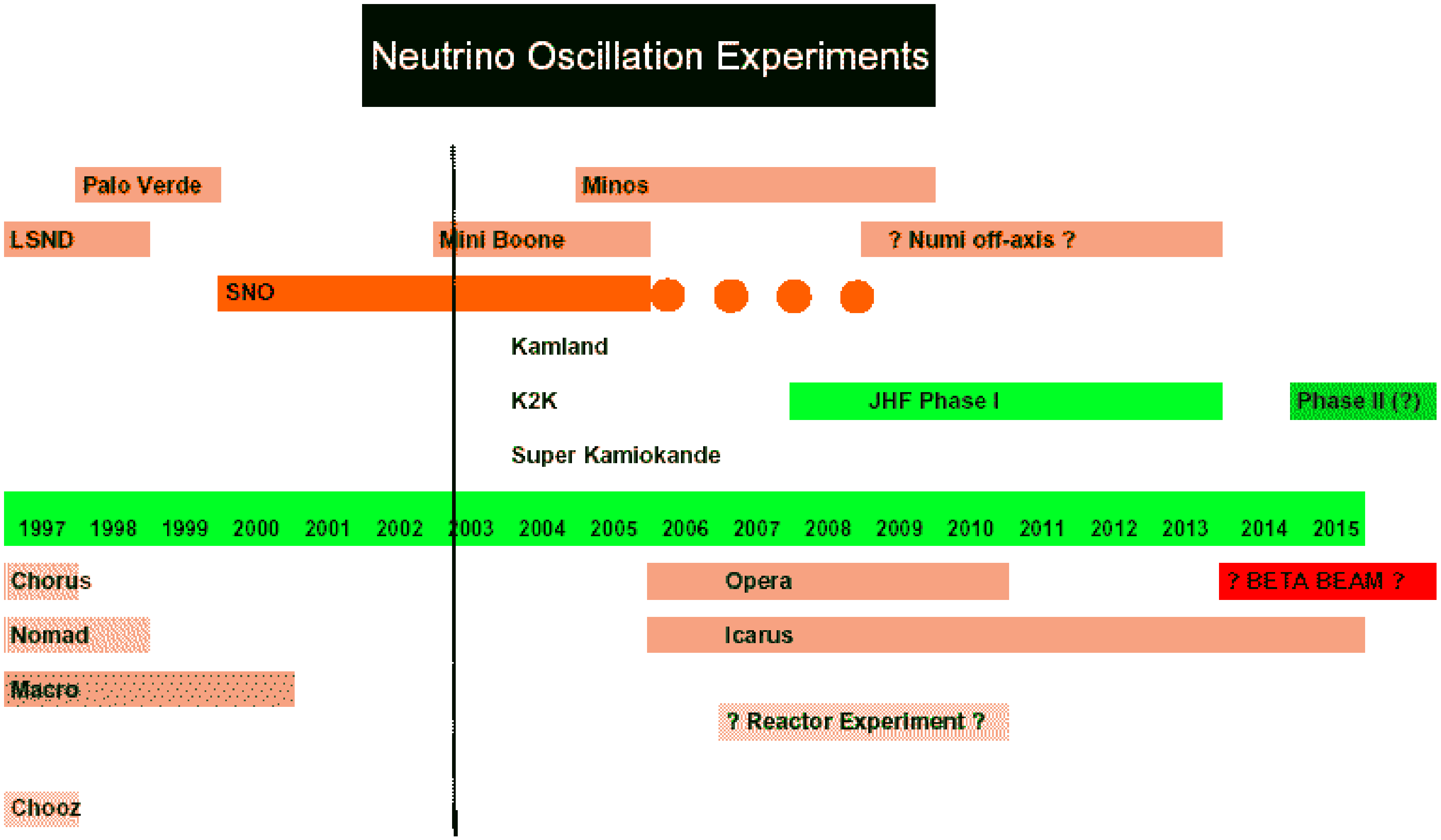
No time to discuss
R&D and Neutrino factories
This is already a world wide collaboration

See also:

- http://physicsatmwatt.web.cern.ch/physicsatmwatt
- http://axpd24.pd.infn.it/NO-VE/NO-VE.html

thanks to A. Blondel, H. De Kerret, R. Garoby, M. Mezzetto, A. Rubbia

Neutrino Mixing Matrix Study : which Road Map



CNGS : Physics Motivation

CNGS PROGRAM:

- Provide an unambiguous evidence for $\nu_\mu \rightarrow \nu_\tau$ oscillations in the region of atmospheric neutrinos by looking for ν_τ appearance in a pure ν_μ beam
- Search for the subleading $\nu_\mu \rightarrow \nu_e$ oscillations (measurement of Θ_{13})

- Beam: CNGS (1999)
- ν_τ appearance experiments

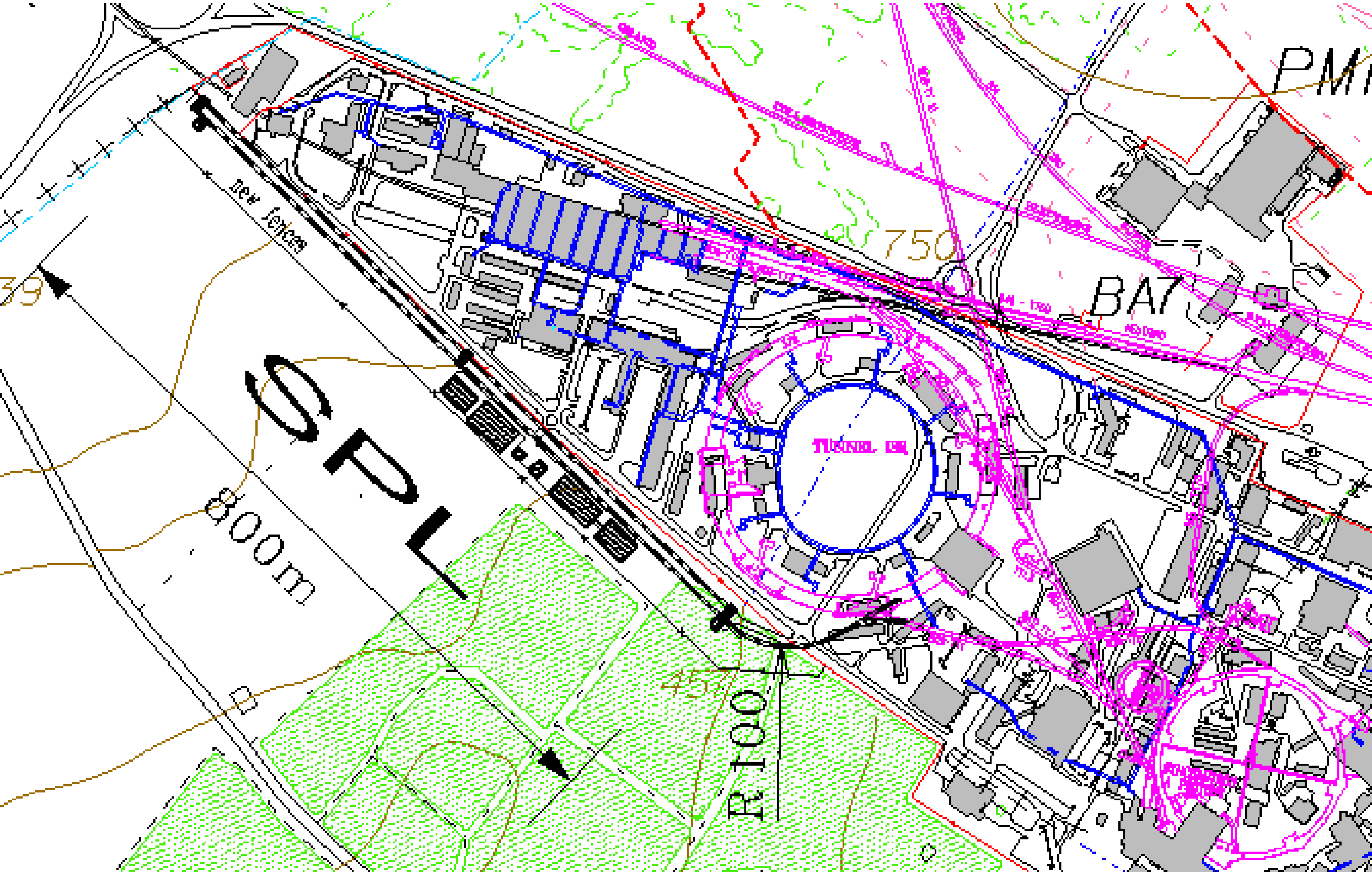
CNGS1 (2000)

OPERA

CNGS2 (2002)

ICARUS

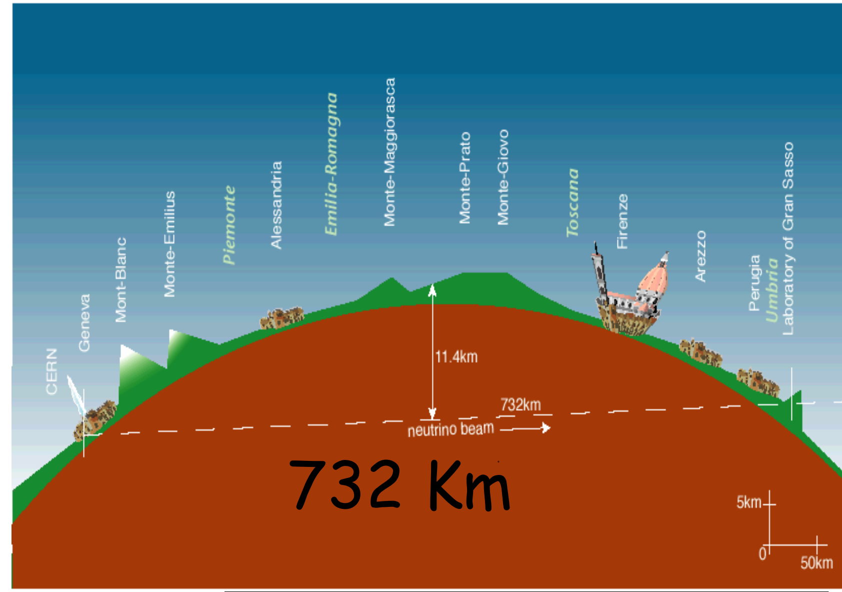
SPL on the CERN site

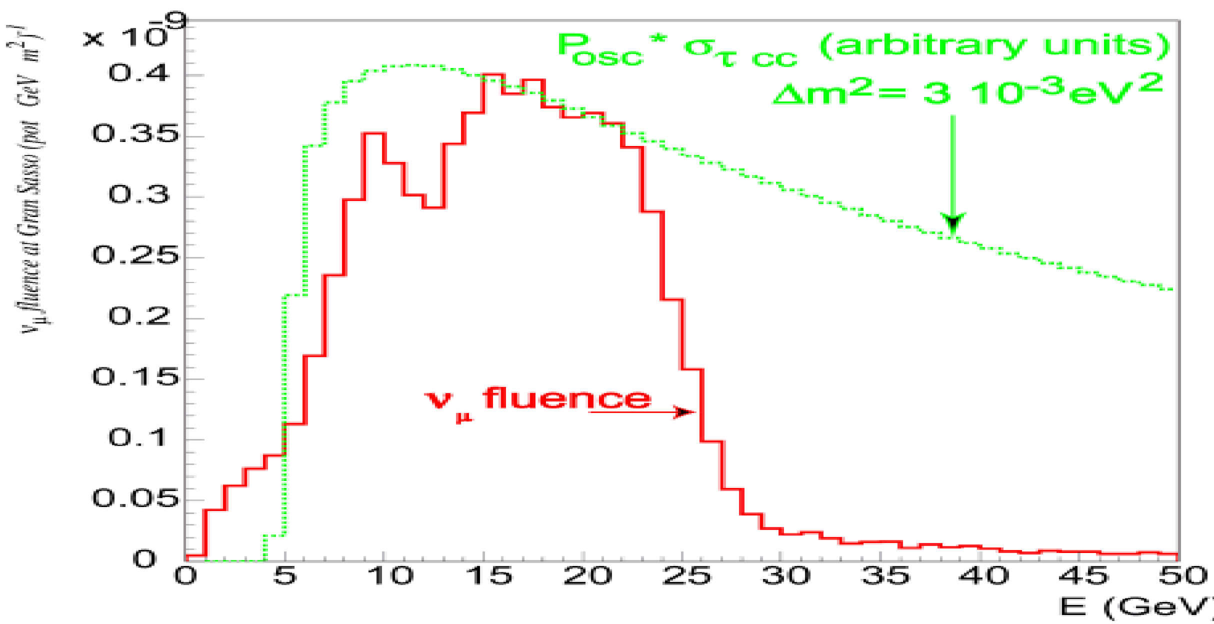


CNGS beam optimized for appearance

Given the distance: →

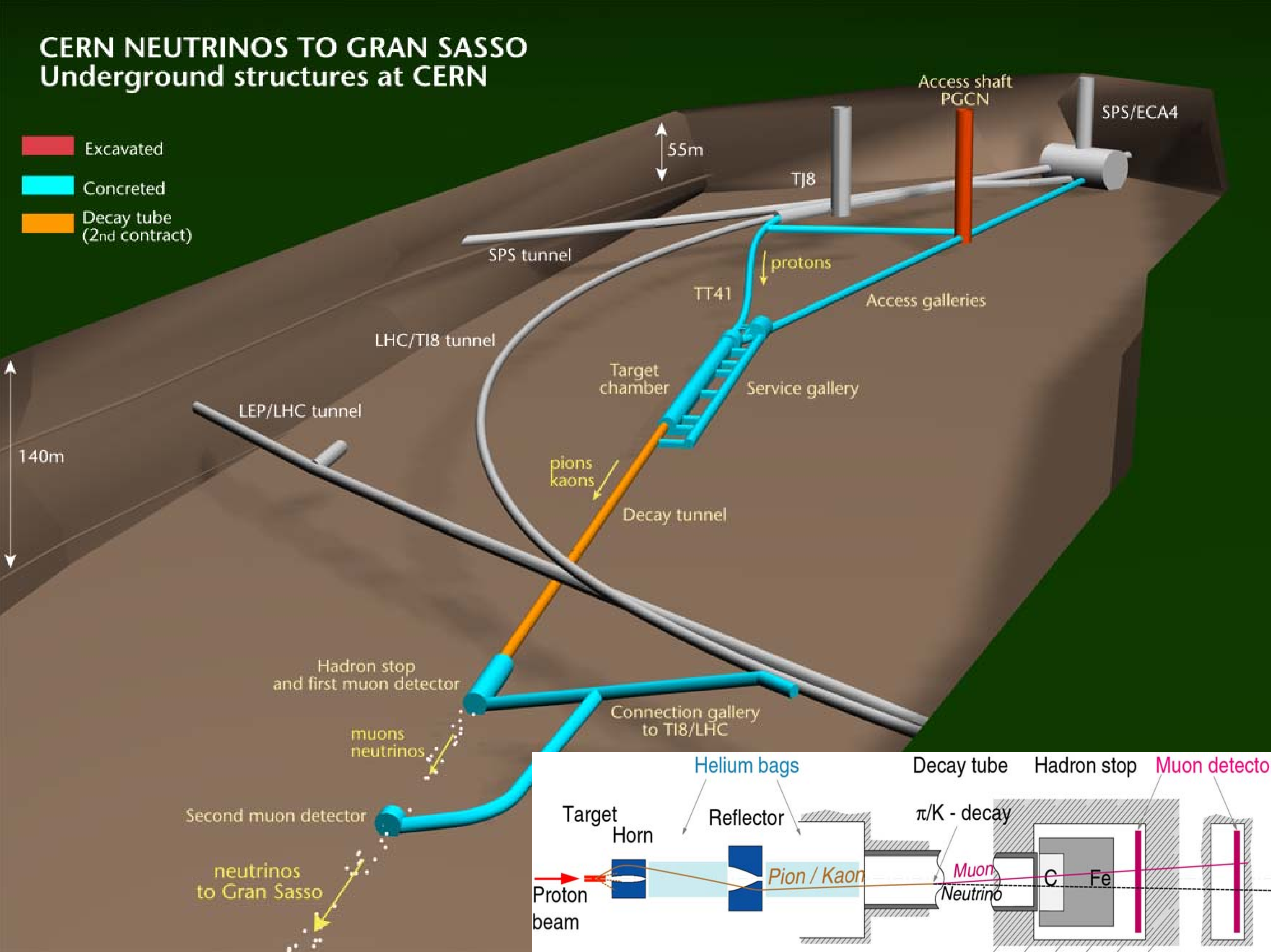
ν_μ flux optimized for the maximal number of ν_τ charged current interactions

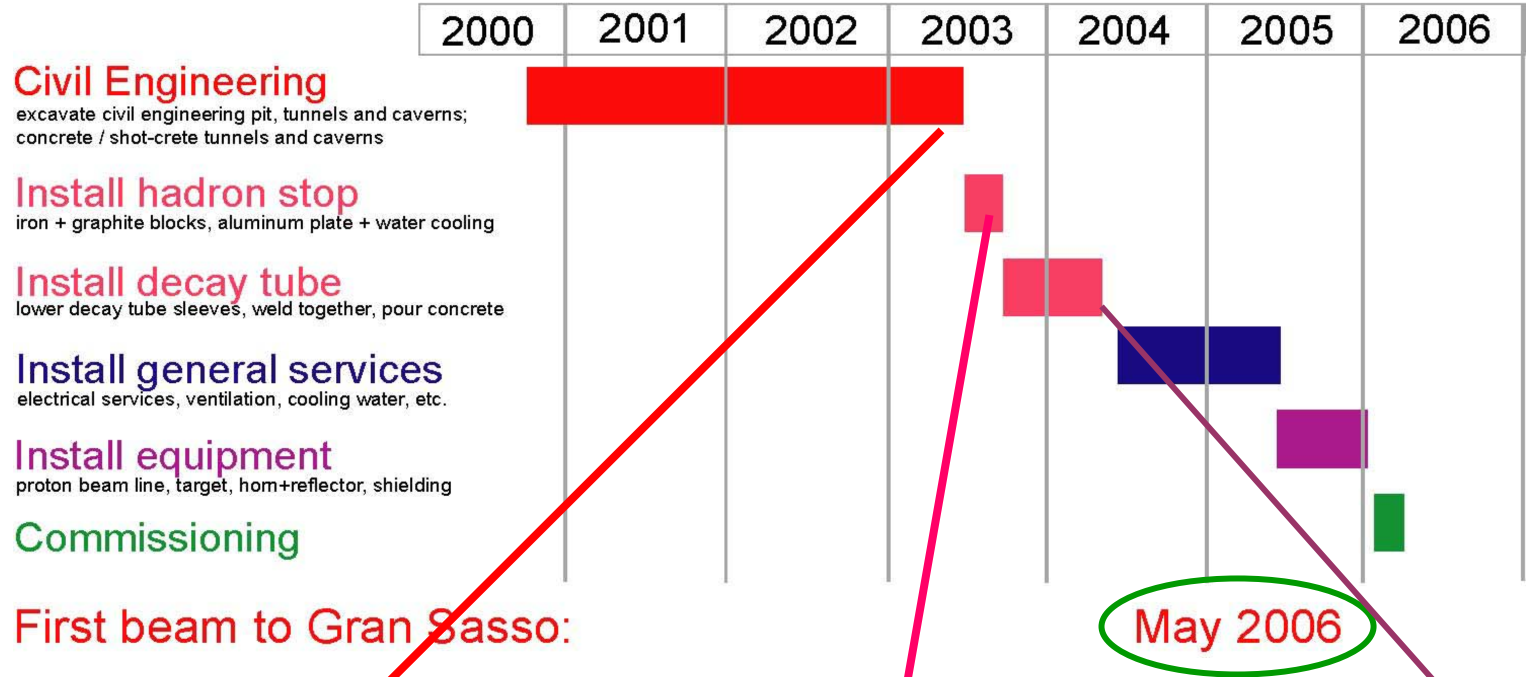




<$E\nu_\mu$>	17 GeV
$(\nu_e+\bar{\nu}_e)/\nu_\mu$	0.87%
$\bar{\nu}_\mu$ / ν_μ	2.1%
ν_τ prompt	neglegible

L/E (43 Km/GeV) not optimal: « off peak »


CERN NEUTRINOS TO GRAN SASSO
Underground structures at CERN
Excavated
Concreted
Decay tube
(2nd contract)
55m
140m
Access shaft
PGCN
SPS/ECA4
TJ8
SPS tunnel
protons
TT41
Access galleries
LHC/TI8 tunnel
Target
chamber
Service gallery
LEP/LHC tunnel
pions
kaons
Decay tunnel
Hadron stop
and first muon detector
Connection gallery
to TI8/LHC
muons
neutrinos
Second muon detector
neutrinos
to Gran Sasso
Helium bags
Decay tube
Hadron stop
Muon detecto
Target
Horn
Reflector
π/K - decay
Proton
beam
Pion / Kaon
Muon
Neutrino
C
Fe



Passed 2003 external review

Costs under control

Project on schedule

Vacuum test OK

Horns in test at CERN

CNGS Upgrade

High Intensity Protons Working Group:
Recommendations 26 February 2004

launch 3 projects (define in 2004, start in 2005):

(1) low loss extraction at the PS
(2) increase CNGS intensity
(3) 0.9 seconds for PS Booster basic period

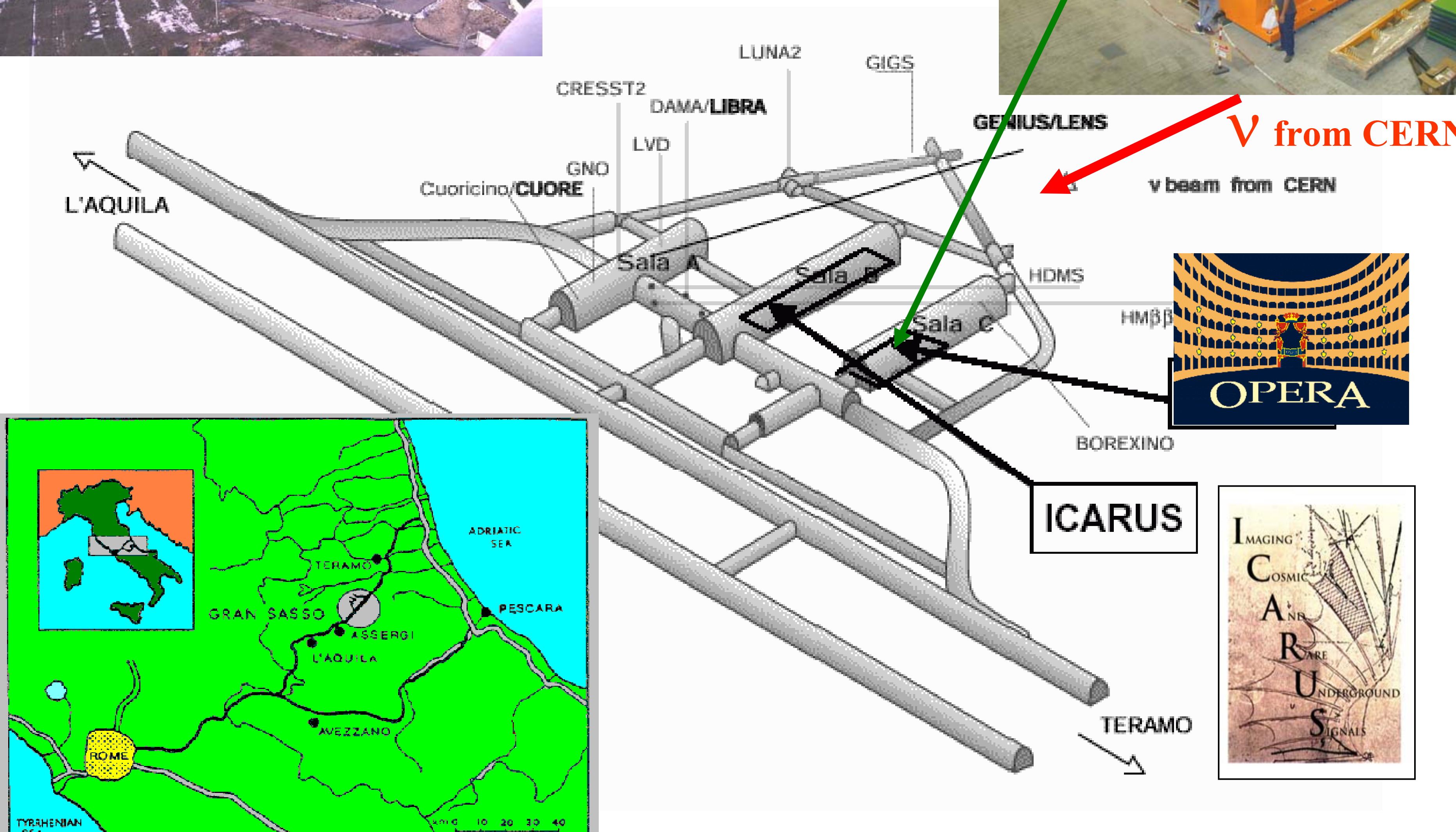
Comments by the WG:

(1) irradiation of accelerators is a major concern
(2) increase for CNGS only possible via increase per extracted beam pulse
(3) in the analysis, "other SPS fixed target expts." were given low priority

Expected proton intensity increase : 1.5 by 2007 ?

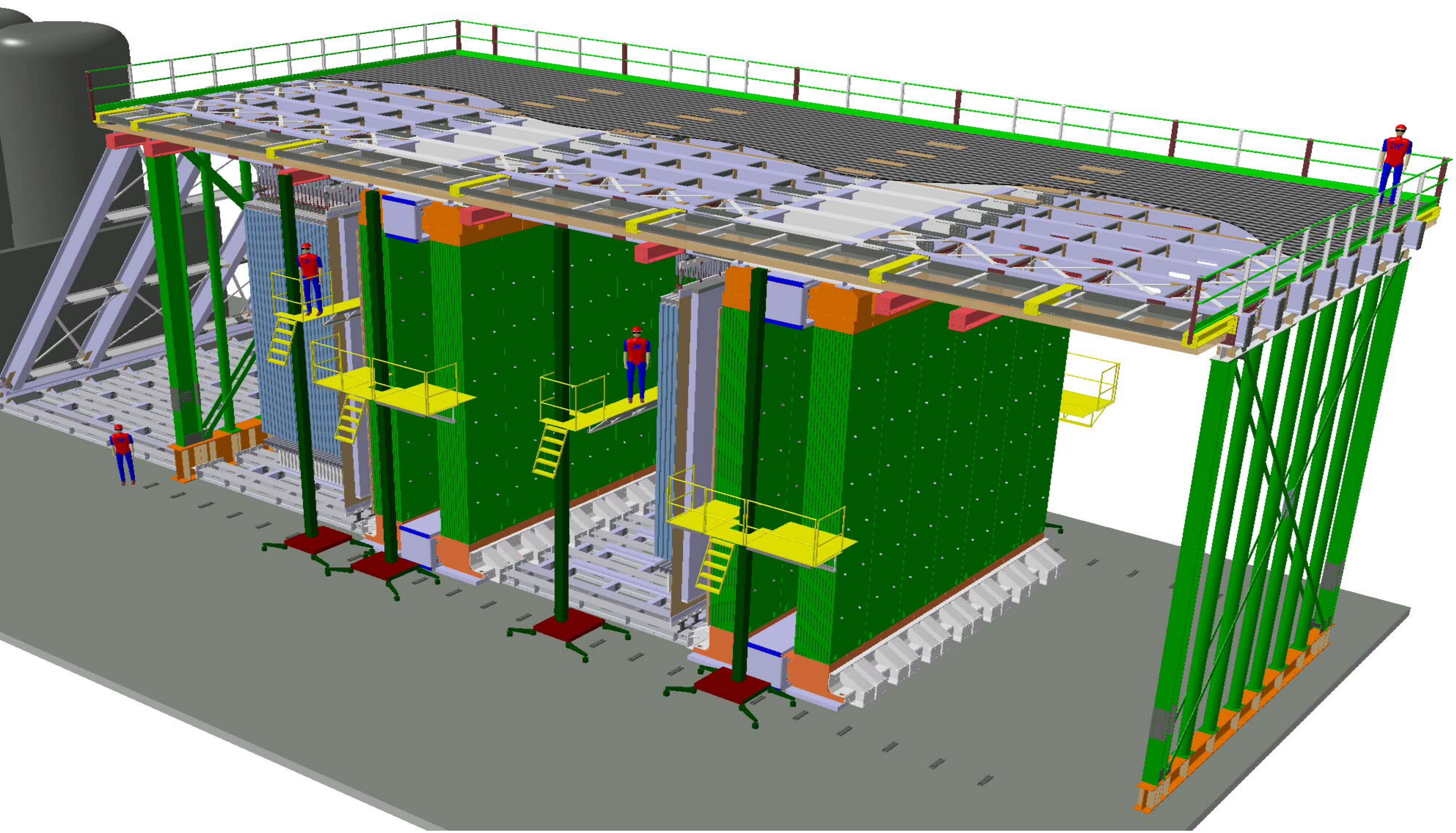
LNGS layout


Hall C


ν from CERN
ν beam from CERN
LUNA2
GIGS
CRESST2
DAMA/LIBRA
GENIUS/LENS
LVD
GNO
Cuoricino/CUORE
L'AQUILA
Sala A
Sala B
Sala C
HDMS
HMββ
OPERA
BOREXINO
ICARUS
TERAMO
ADRIATIC SEA
TERAMO
GRAN SASSO
PESCARA
ASSERGI
L'AQUILA
AVEZZANO
ROME
TYRRHENIAN SEA
10 20 30 40
Imaging
Cosmic
And
Rare
Underground
Signals

OPERA Final Design with 2 SuperModules

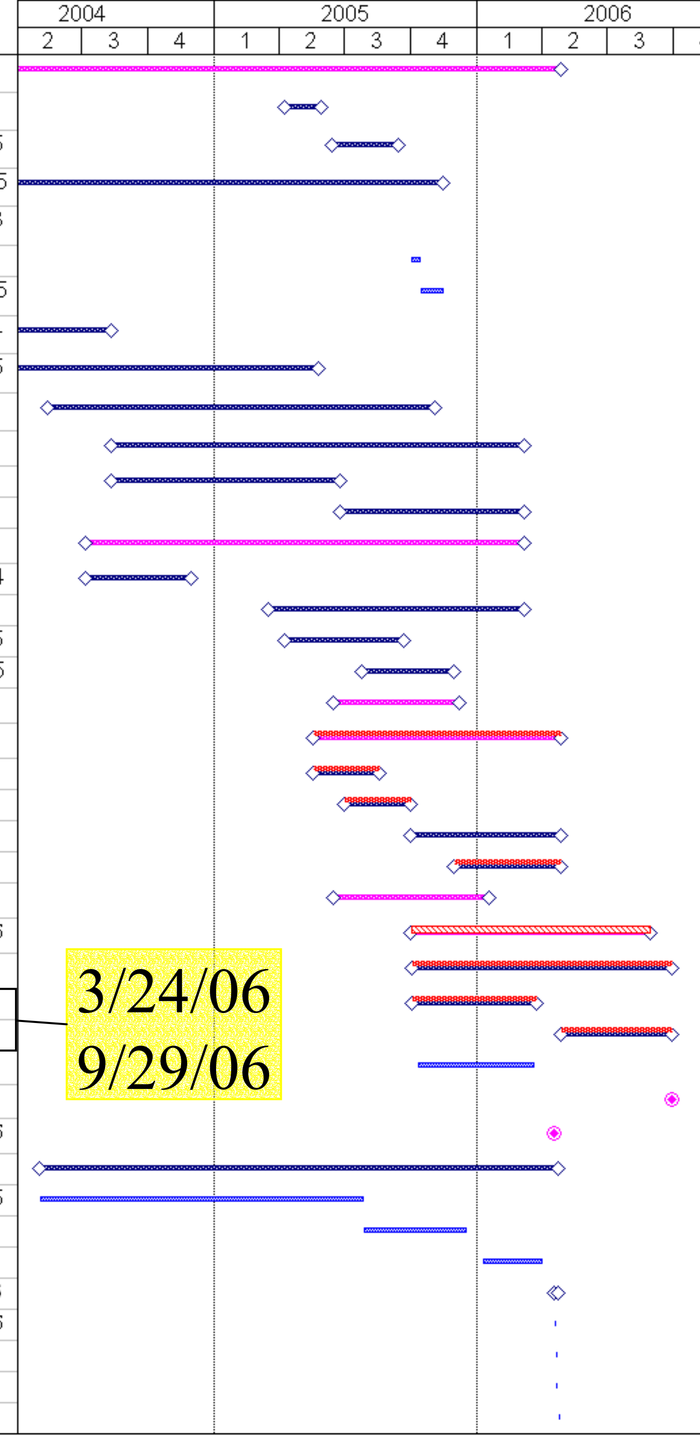
31 target planes / Super-Module (206336 bricks, 1766 tons)



. . . . in May 04

General Planning

ID	Task Name	Duration	Start	Finish
226	INSTALLATION IN GS EXPERIMENT HALL C	153.83 w	Mon 2/10/03	Thu 4/27/06
227	**C R & ELECTRONIC ROOM**	7 w	Fri 4/8/05	Mon 5/30/05
233	**BAM**	13 w	Mon 6/13/05	Wed 9/14/05
237	**SPECTROMETERS (2 MAGNETS & RPC's)**	134.03 w	Mon 2/10/03	Mon 11/14/05
238	**Preliminary working**	15 w	Mon 2/10/03	Wed 5/28/03
239	Veto plane mechanics	2 w	Fri 9/30/05	Fri 10/14/05
240	**Veto plane detector**	4 w	Fri 10/14/05	Mon 11/14/05
241	**Magnet 1**	58.35 w	Fri 5/30/03	Wed 8/11/04
274	**Magnet 2**	95.15 w	Fri 5/30/03	Wed 5/25/05
311	**TARGET TRACKERS MOUNTING**	72 w	Fri 5/14/04	Fri 11/4/05
330	**TARGET WALLS**	73.94 w	Wed 8/11/04	Tue 3/7/06
331	**SM1**	41.18 w	Wed 8/11/04	Fri 6/24/05
410	**SM2**	32.76 w	Fri 6/24/05	Tue 3/7/06
489	**XPC's & PRECISION TRACKERS**	79.34 w	Mon 7/5/04	Tue 3/7/06
490	**XPC 1**	20.88 w	Mon 7/5/04	Tue 11/30/04
496	**Precision tracker 1**	46.24 w	Wed 3/16/05	Tue 3/7/06
529	**XPC 2**	23.05 w	Fri 4/8/05	Wed 9/21/05
535	**Precision tracker 2**	18 w	Mon 7/25/05	Tue 11/29/05
568	**CABLING (detector to control room)**	24.35 w	Wed 6/15/05	Tue 12/6/05
571	**MANIPULATORS**	44.8 w	Wed 5/18/05	Thu 4/27/06
572	**SM1 cavern side**	13 w	Wed 5/18/05	Fri 8/19/05
578	**SM1 corridor side**	13 w	Thu 6/30/05	Fri 9/30/05
585	**SM2 cavern side**	25.8 w	Fri 9/30/05	Thu 4/27/06
589	**SM2 corridor side**	17.43 w	Wed 11/30/05	Thu 4/27/06
594	COMMISSIONNING WITHOUT BRICKS	27.35 w	Wed 6/15/05	Tue 1/17/06
597	ECC BRICK MANUFACTURING WITH BAM	43 w	Fri 9/30/05	Wed 8/30/06
599	WALL BRICK FILLING (2b/min 8h/day)=960 bricks)	47.2 w	Mon 10/3/05	Fri 9/29/06
600	SM1 brick filling	21.6 w	Mon 10/3/05	Fri 3/24/06
602	SM2 brick filling	21.6 w	Thu 4/27/06	Fri 9/29/06
604	COSMIC DATA TAKING WITH BRICKS	20 w	Mon 10/10/05	Tue 3/21/06
605	FULL DETECTOR COMPLETED	0 d	Fri 9/29/06	Fri 9/29/06
606	**CNGS Beam delivery**	0 d	Wed 4/19/06	Wed 4/19/06
607	OPERA RUNNING	94.6 w	Mon 5/3/04	Mon 4/24/06
608	OPERA LNGS external building	60 w	Mon 5/3/04	Wed 7/27/05
609	Emulsion processing laboratory	20 w	Thu 7/28/05	Fri 12/16/05
610	Processing tests	12 w	Mon 1/9/06	Fri 3/31/06
611	**OPERA brick processing cycle**	**0.8 w**	**Wed 4/19/06**	**Mon 4/24/06**
612	First brick extraction	1 d	Wed 4/19/06	Wed 4/19/06
613	Brick cosmic rays exposure	1 d	Thu 4/20/06	Thu 4/20/06
614	Emulsion development	1 d	Fri 4/21/06	Fri 4/21/06
615	Emulsion shipping to scanning labs	1 d	Mon 4/24/06	Mon 4/24/06



The T600 prototype

- Approved and funded in 1996
- Built between years 1997 and 2002
- Completely assembled in the INFN assembly hall in Pavia
- Full scale Demonstration test run of half-unit during first half 2001
  - Three months duration
  - Completely successful
  - Data taking with cosmic rays
  - Detector performance
  - Full scale analyses
- Full unit Assembly terminated in 2002
- Installation should start this summer

  @ LNGS , expecting to be ready by 2006 for Physics run

ICARUS detector configuration in LNGS Hall B (T3000)

The "cloning" project

≈3 kton of liquid Argon

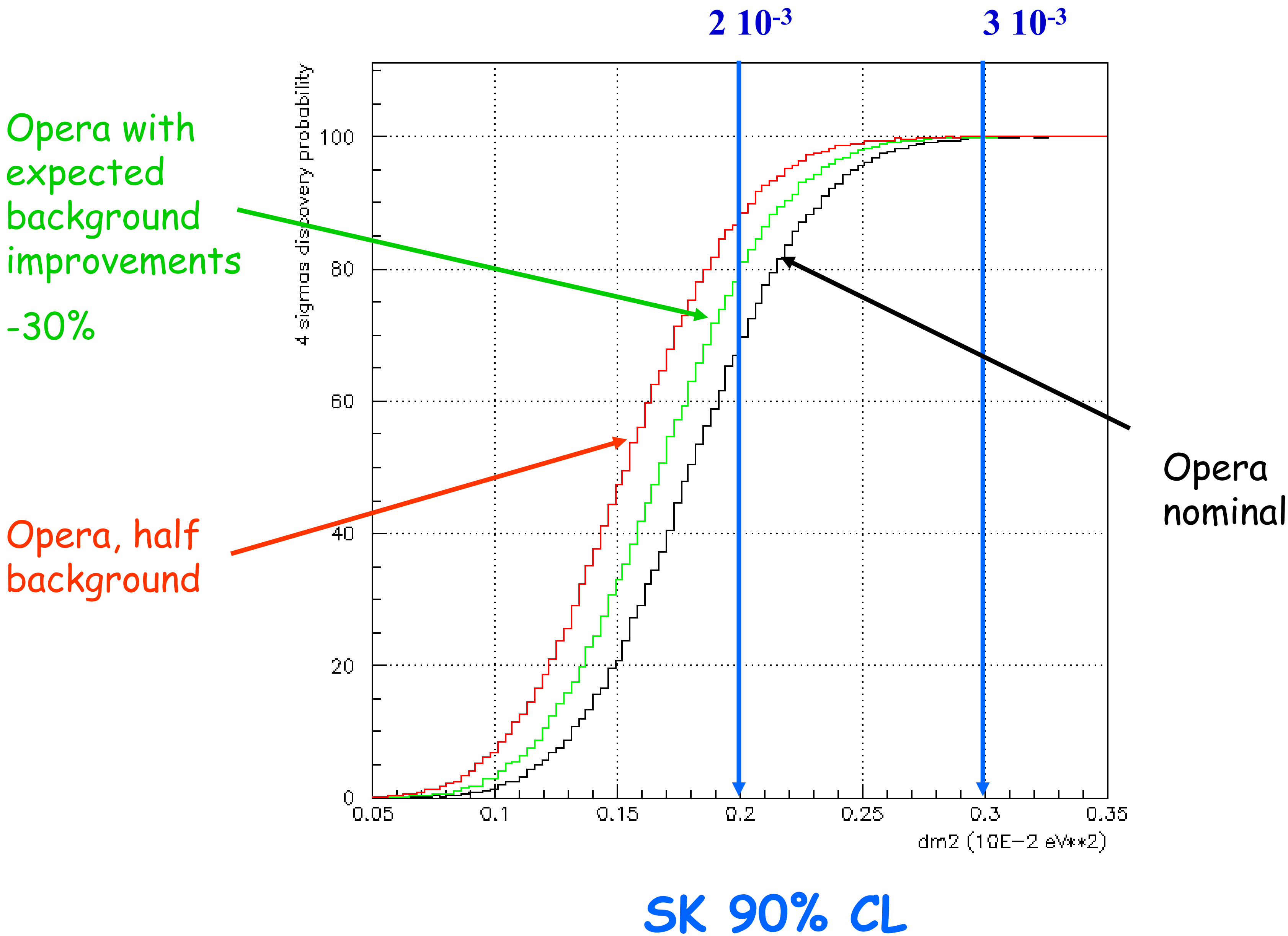
First Unit T600 + Auxiliary Equipment	T1200 Unit (two T600 superimposed)	Magnet	T1200 Unit (two T600 superimposed)

≈ 35 Metres **≈ 60 Metres**

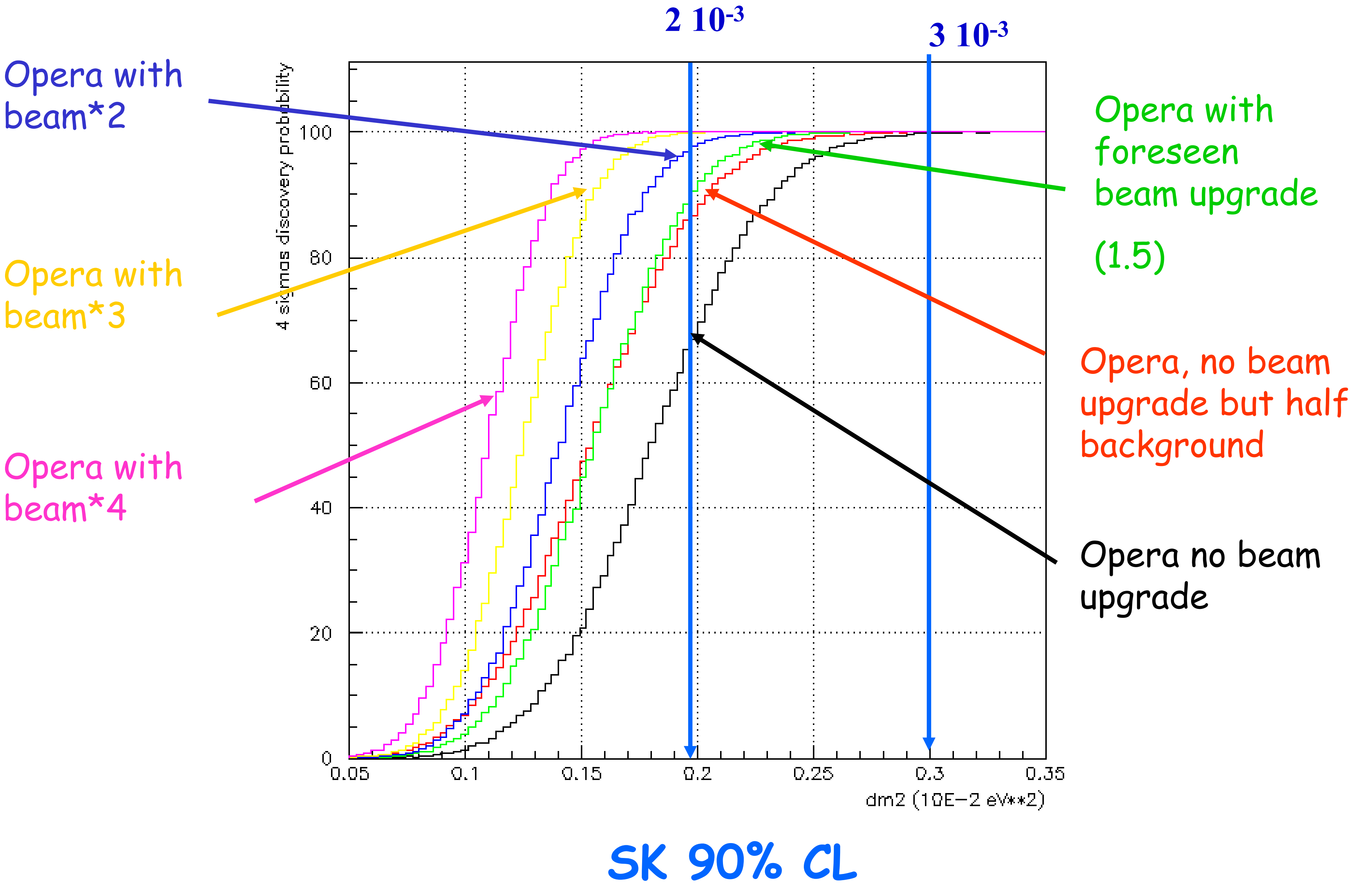
Hall B @LNGS last month

The construction of the T1200 modules is not yet granted

Sensitivity versus Background



Probability of claiming a 4σ discovery in 5 years



Comparing different scenarios in a two families scheme

Limits at 90% C.L. on $\sin^2 2\theta_{13}$ and θ_{13}
($\Delta m^2_{23}=2.5\times10^{-3}$ eV^2; $\sin^2\theta_{23}=1$)

Experiment	$\sin^2 2\theta_{13}$	θ_{13}
CHOOZ	<0.14	<11°
MINOS 2yr	<0.06	<7.1°
ICARUS 5yr	<0.04 (LI) <0.03(HI)	<5.8° <5.0°
OPERA 5yr	<0.06(LI) <0.05(HI)	<7.1° <6.4°
ICARUS+OPERA 5yr	<0.03(LI) <0.025(HI)	<5.0° <4.5°
JHF 5yr	<0.006	<2.5°

LI = nominal CNGS; HI = nominal CNGS x 1.5

Phase I exps

NB The CNGS sensitivity is limited by statistics
⇒ very important high intensity proton beam

The oscillation probability including matter effect

Migliozzi et al , Phys. Lett. B563(2003)73

$$P_{\nu_\mu \to \nu_e} \cong \sin^2 2\theta_{13} \sin^2 \theta_{23} \frac{\sin^2\left[\left(1-\hat{A}\right)\Delta\right]}{\left(1-\hat{A}\right)^2}$$

O_1 leading term

$$-\alpha \sin\theta_{13} \xi \sin\delta_{CP} \sin\Delta \frac{\sin\left(\hat{A}\Delta\right)}{\hat{A}} \frac{\sin\left[\left(1-\hat{A}\right)\Delta\right]}{\left(1-\hat{A}\right)}$$

O_2: 1 at osc. max

$$+\alpha \sin\theta_{13} \xi \cos\delta_{CP} \cos\Delta \frac{\sin\left(\hat{A}\Delta\right)}{\hat{A}} \frac{\sin\left[\left(1-\hat{A}\right)\Delta\right]}{\left(1-\hat{A}\right)}$$

O_3: 0 at osc. max

$$+\alpha^2 \cos^2\theta_{23} \sin^2 2\theta_{12} \frac{\sin^2\left(\hat{A}\Delta\right)}{\hat{A}^2}$$

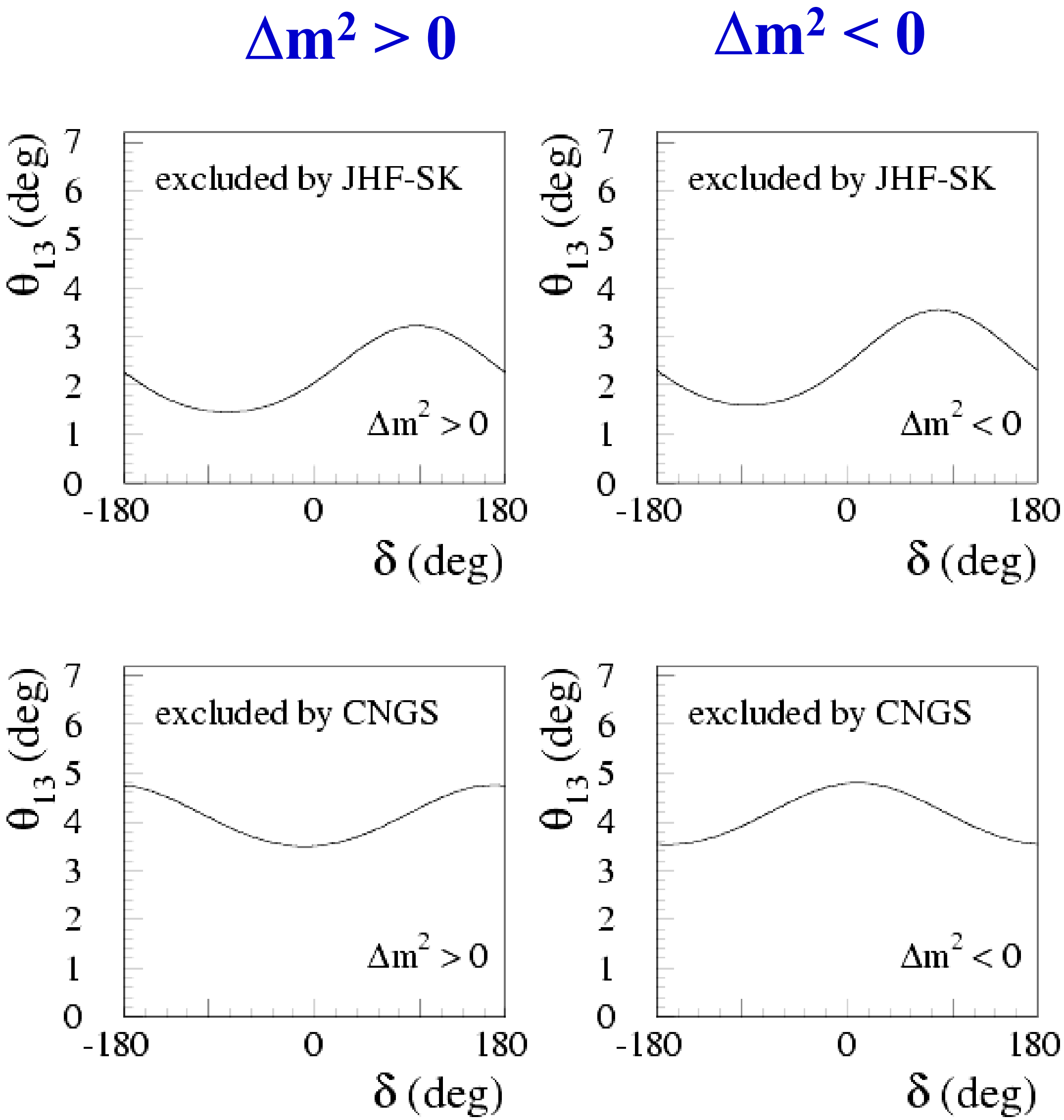
O_4: suppressed by α^2

$$\alpha \equiv \frac{\Delta m_{21}^2}{\left|\Delta m_{13}^2\right|} \qquad \xi \equiv \cos\theta_{13} \sin 2\theta_{12} \sin 2\theta_{23} \approx O(1)$$

$$\hat{A} \equiv 2\sqrt{2} G_F n_e \frac{E}{\Delta m_{13}^2} \qquad \Delta \equiv \frac{\Delta m_{13}^2 L}{4E}$$

The hierarchy among the different O terms depends on the “on peak”-“off peak” choice

Accelerator expts. sensitivity vs δ_{CP}



There are δ_{CP} values for which the sensitivity on θ_{13} is even better than the one computed in the 2-flavor approximation (δ_{CP}=0).

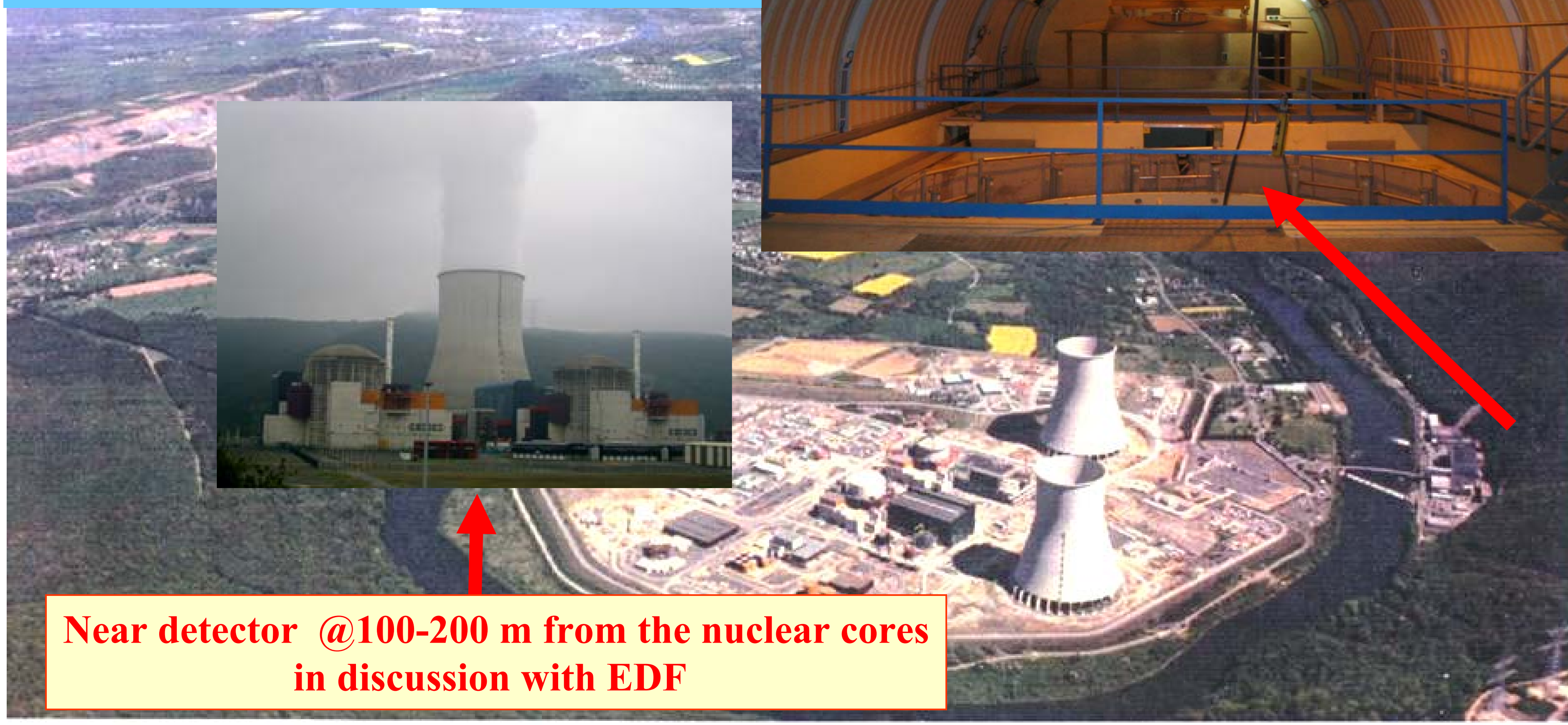
Notice the different behaviour on Δm^2 of the CNGS sensitivity
$\Rightarrow$ Possible measurement of the sign of Δm^2_{31} if Θ_{13} is large !

Double-Chooz : site

2 identical detectors ⇒goal : $\sigma_{relative} \cong 0.6\%$

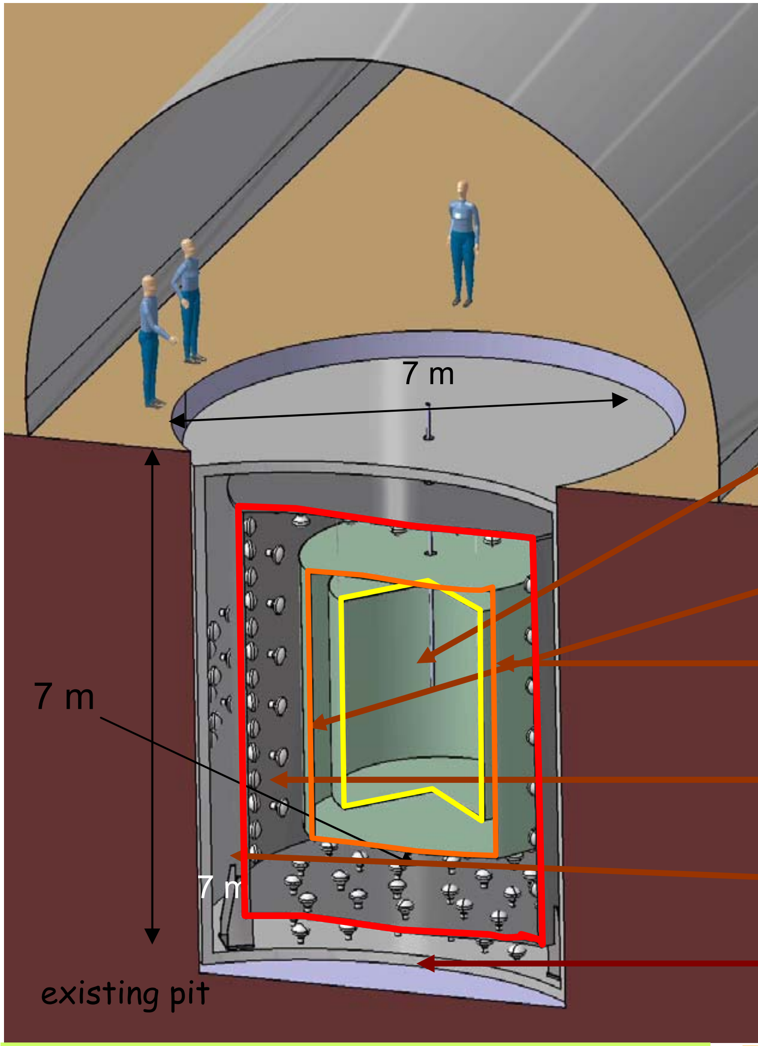
Far detector : using existing infrastructure from the previous experiment @ 1050 m

- **LOI : hep-ex/0405032**
- **detector cost 7.5 Meuros**
- **civil engineering ~5 Meuros (not studied)**
- **LOI accepted**
- **need for a proposal within 6 months**



Near detector @100-200 m from the nuclear cores in discussion with EDF

Double CHOOZ : detector structure



Same concept as CHOOZ :
the target mass is defined by
the Gd loaded scintillator mass

Target cylinder (f = 2.4m, h = 2.8m)
filled with 0.1%Gd loaded liquid scintillator (12.7 Tons)

Gamma catcher inside Acrylic Vessel, thickness : 60cm

Non scintillating buffer → new !

mechanical structure to house PMTs

Muons VETO of scintillating oil , thickness :60 cm

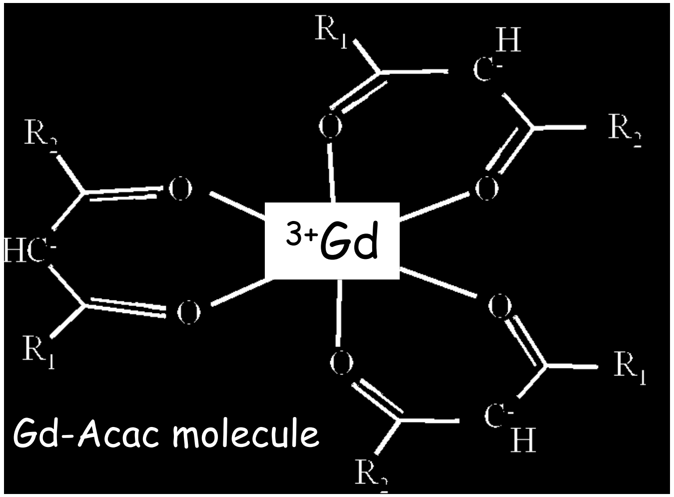
Shielding : main tank , steel thickness 15cm

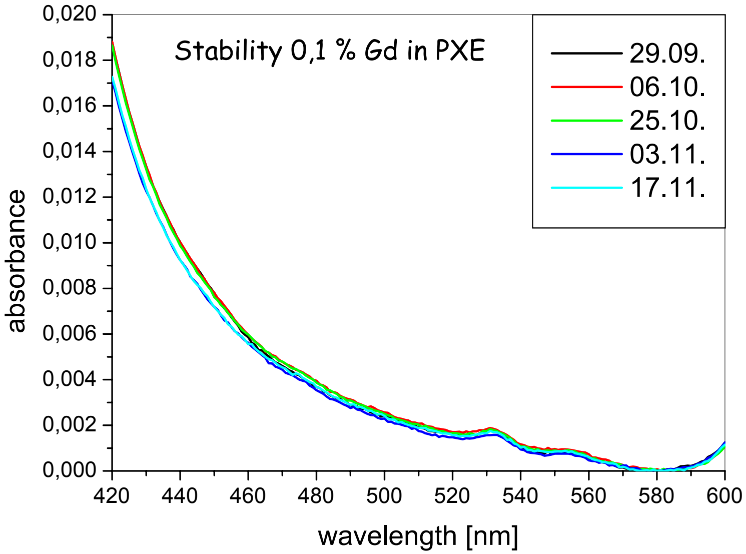
Performances (expected):
- **S/B : 10 → 100**
- **target : 5.5 → 12.7 m^3**
- **analysis errors : 1.5% → 0.2%**

But the changes would probably worsen the bkgd:
- **large increase of passive material (including high Z)**
- **active target less protected due to the increase of the target volume**

Double CHOOZ : Gd loaded scintillator

✓LENS R&D → new metal β-diketone molecule (MPIK)
✓Stable: 0.1% Gd-Acac (few months)
✓Baseline recipe **~80% mineral oil + ~20% PXE + Fluors + wavelenght shifters**
✓In-loaded scintillators (0.1 %, 5% loading) are counting @Gran Sasso
✓Spare stable recipes available (MPIK, INFN/LNGS)



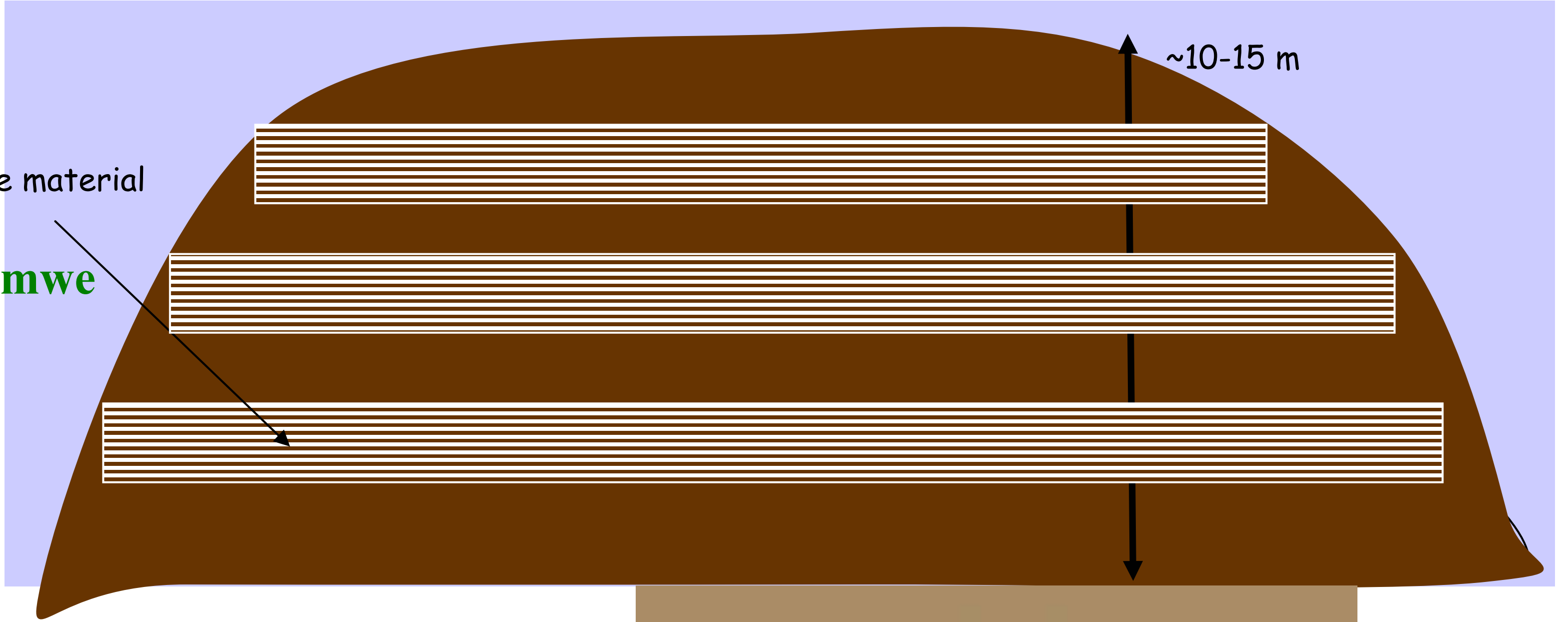


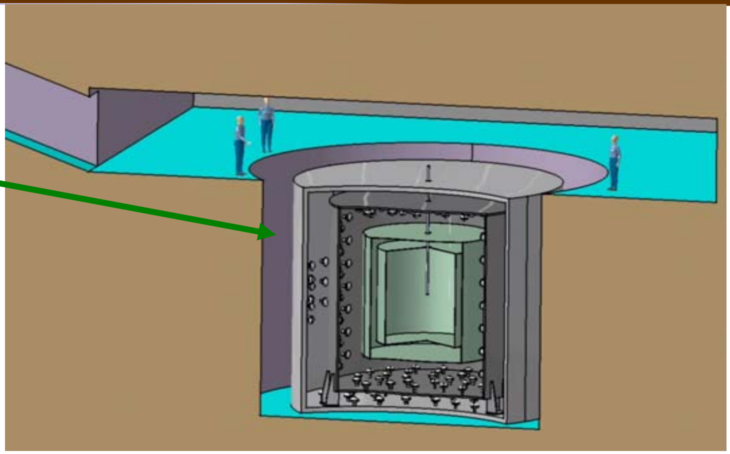
✓Completion of the R&D first half of 2004
- ✓ Choice of the final scintillator
- ✓ Stability & Material compatibility → Aging tests (MPIK, Saclay)

Warning : long term stability and acrylic vessel damage

Double CHOOZ: close detector

Overburden ~50mwe





Additional water buffer around the detector

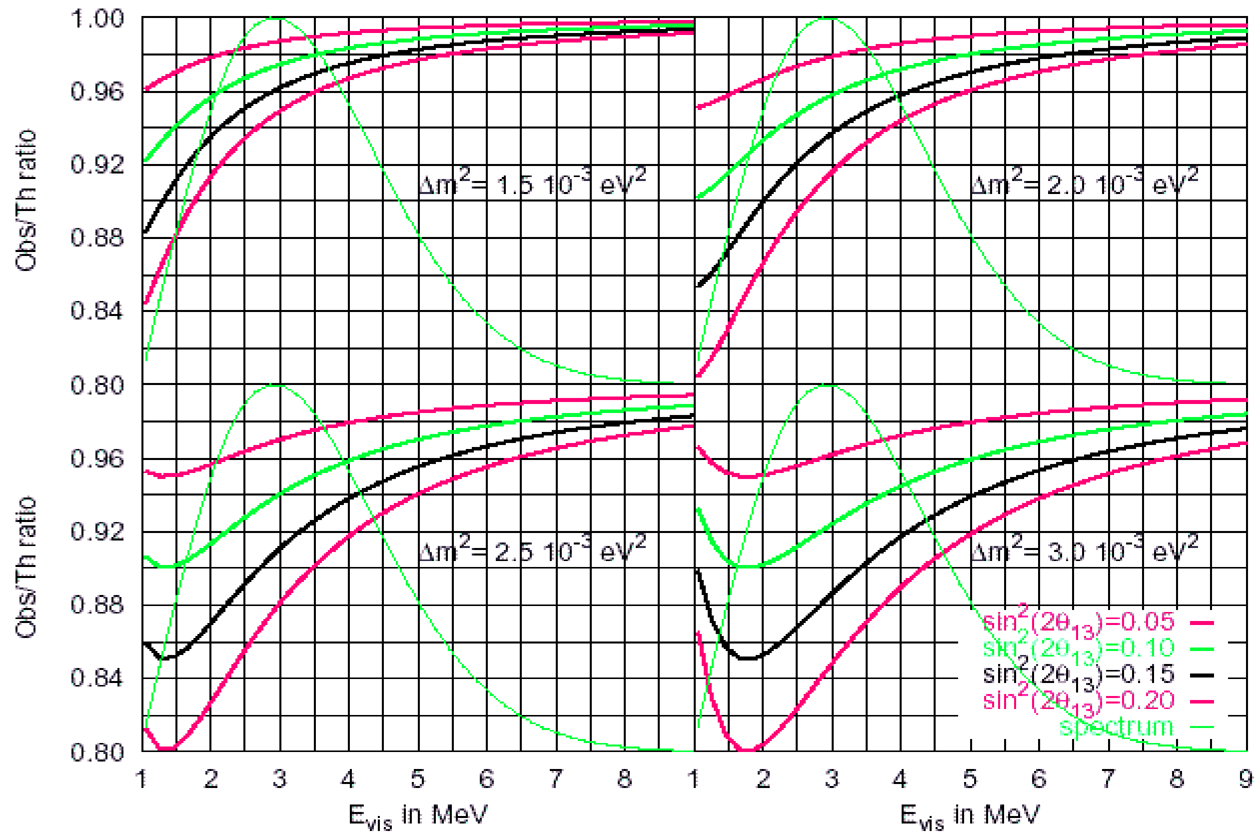
- **similar conditions to PaloVerde (46 mwe)**
- **large dead time for muon veto : 50%**
- **can a massive detector work at such a shallow depth ?**

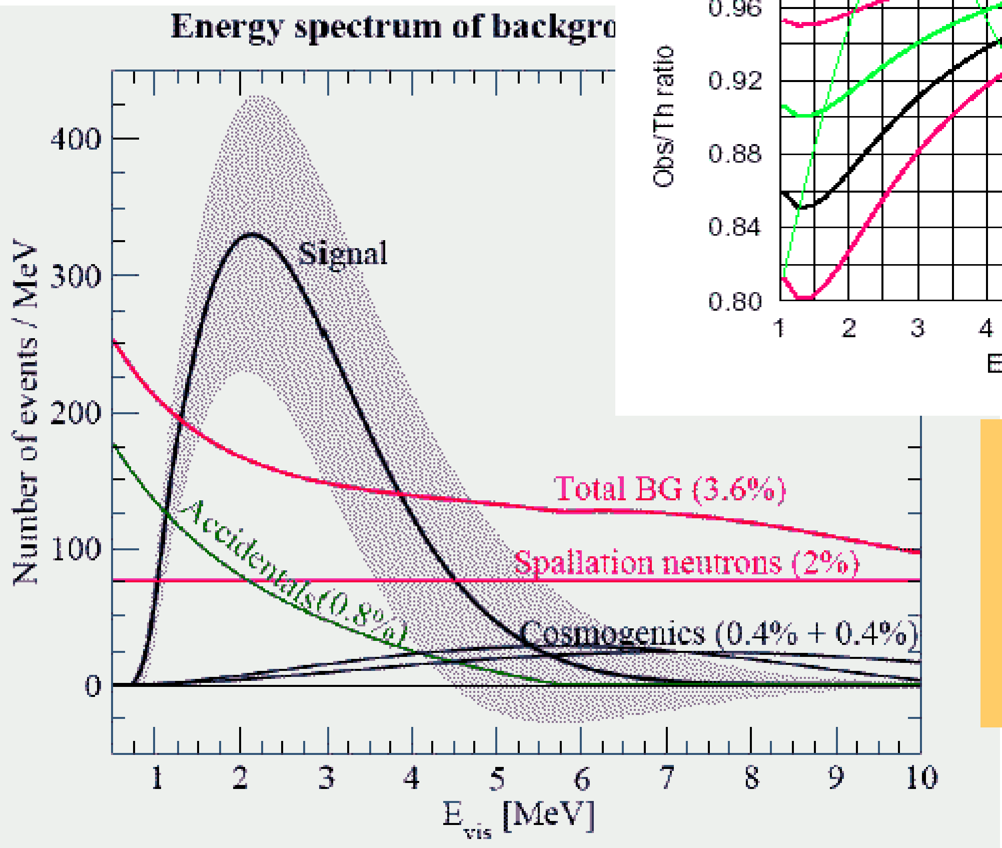
PaloVerde and Bugey was segmented and used signature for neutron and positron

Double CHOOZ : Background and signal

Ratio at the far detector

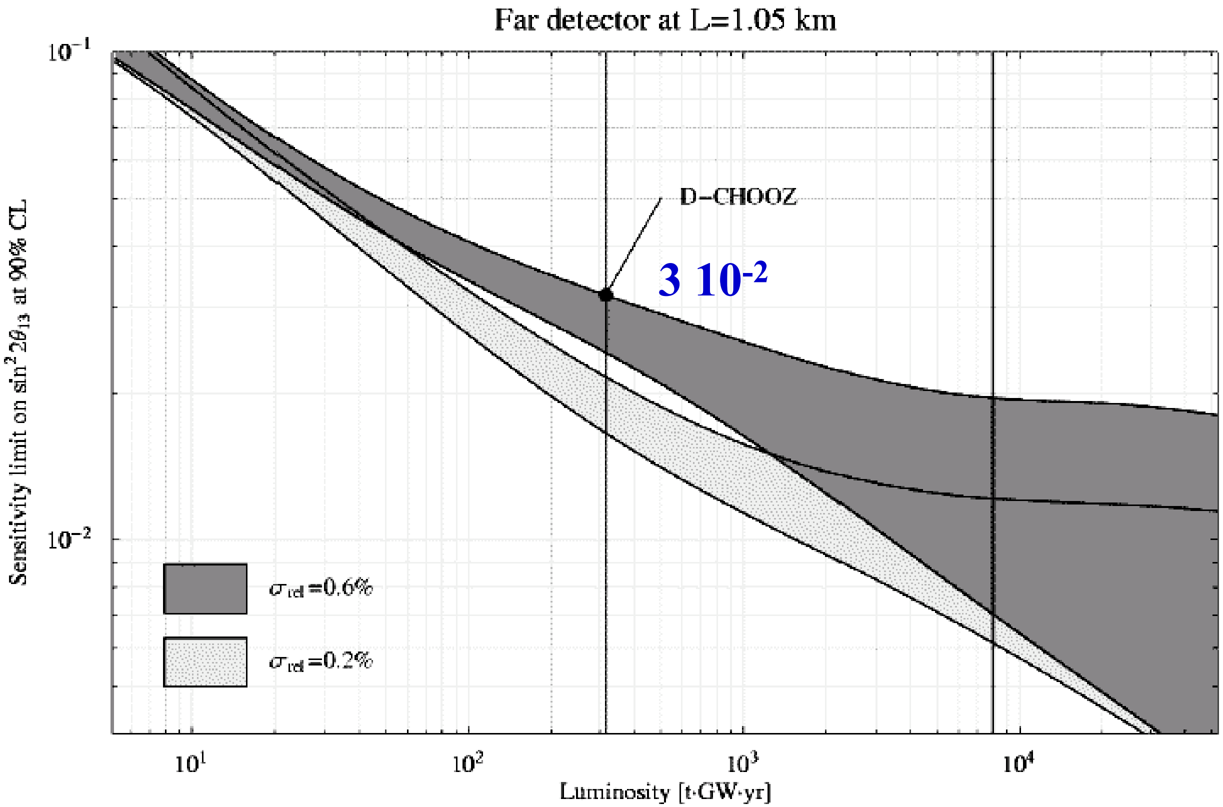
The baseline is too short to see the L/E pattern





- **no direct measurement**
- **accidental miscorrection may mimic or suppress an effect**
- **fake neutron capture signal rate underestimated**

Double CHOOZ sensitivity



To be conclusive a reactor experiment which intend to reach few 10^{-2} in $\sin^2 2\theta$ should be able to show an L/E effect according to the value of δm^2 (which will be known at a high level of accuracy) and to the disappearance rate measured

European Strategy (Venice , december 03)
4 phases program for θ_{13} and δ

1) CNGS/MINOS (2005-2010)
2) JPARC and Reactor(?) (2008-2013)
3) Superbeam/betabeam (>2014)
4) Neutrino factory (>2020)

a)Are Phase 3 (and 4) needed in case of a signal seen in JPARC
→ Complementarity with Off-axis and Reactor

b) Can we build a high gamma betabeam before

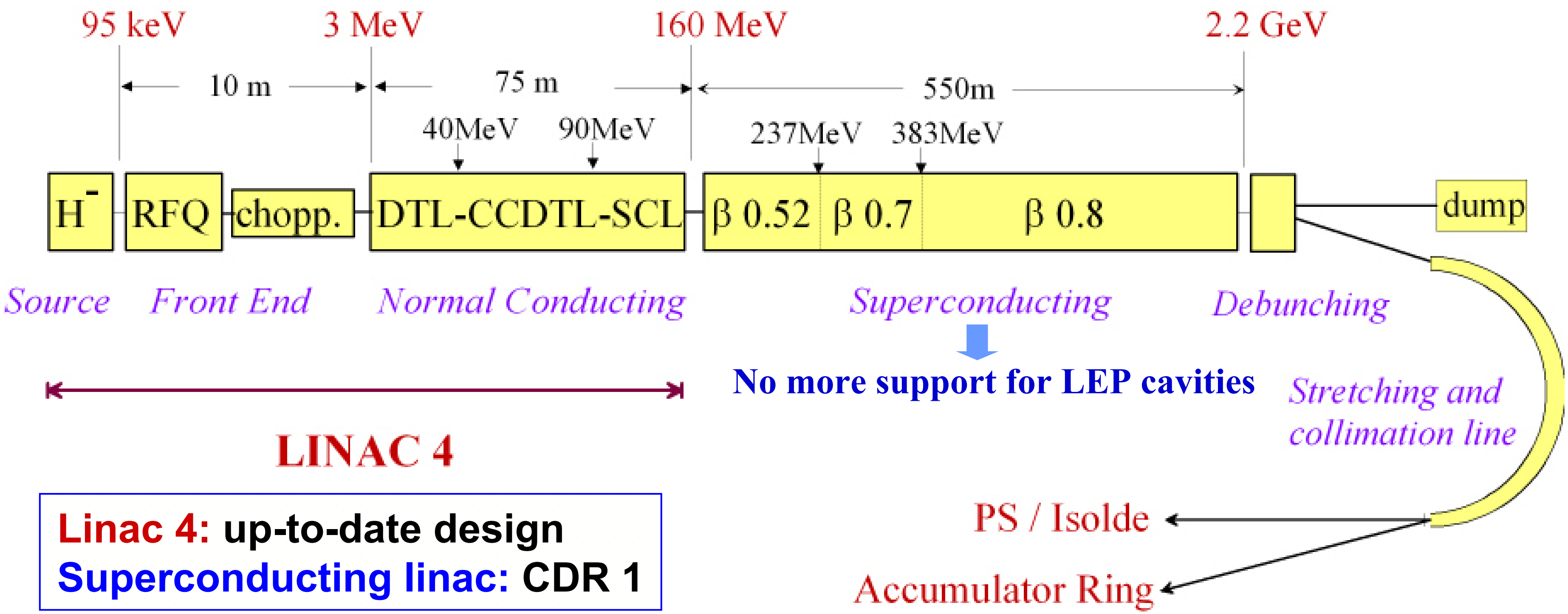
c) Shoud we go directly to phase 4 in case of no signal seen in JPARC

- shift in time for Superbeam/betabeam due to funding profile in Europe
- is the low energy the optimum choice to measure Θ_{13} , δ , sign(Δm^2)

↓

In any case a MW machine is central

SPL Block diagram (CDR1)



Linac 4: up-to-date design
Superconducting linac: CDR 1

Ion species	**H^-**	
Kinetic energy	**2.2**	**GeV**
Mean current during the pulse	**13**	**mA**
Duty cycle	**14**	**%**
Mean beam power	**4**	**MW**
Pulse repetition rate	**50**	**Hz**
Pulse duration	**2.8**	**ms**

"High Intensity Protons Pulsed Injectors"

Collaborations towards a Mwatt proton injector

HIPPI inside CARE

6th Framework Program Integrating Activities
CARE project
Coordinated Accelerator Research in Europe for Particle Physics

"Joint Research Activity" supported by the European Union in the 6th Framework programme

- **Main Objectives**

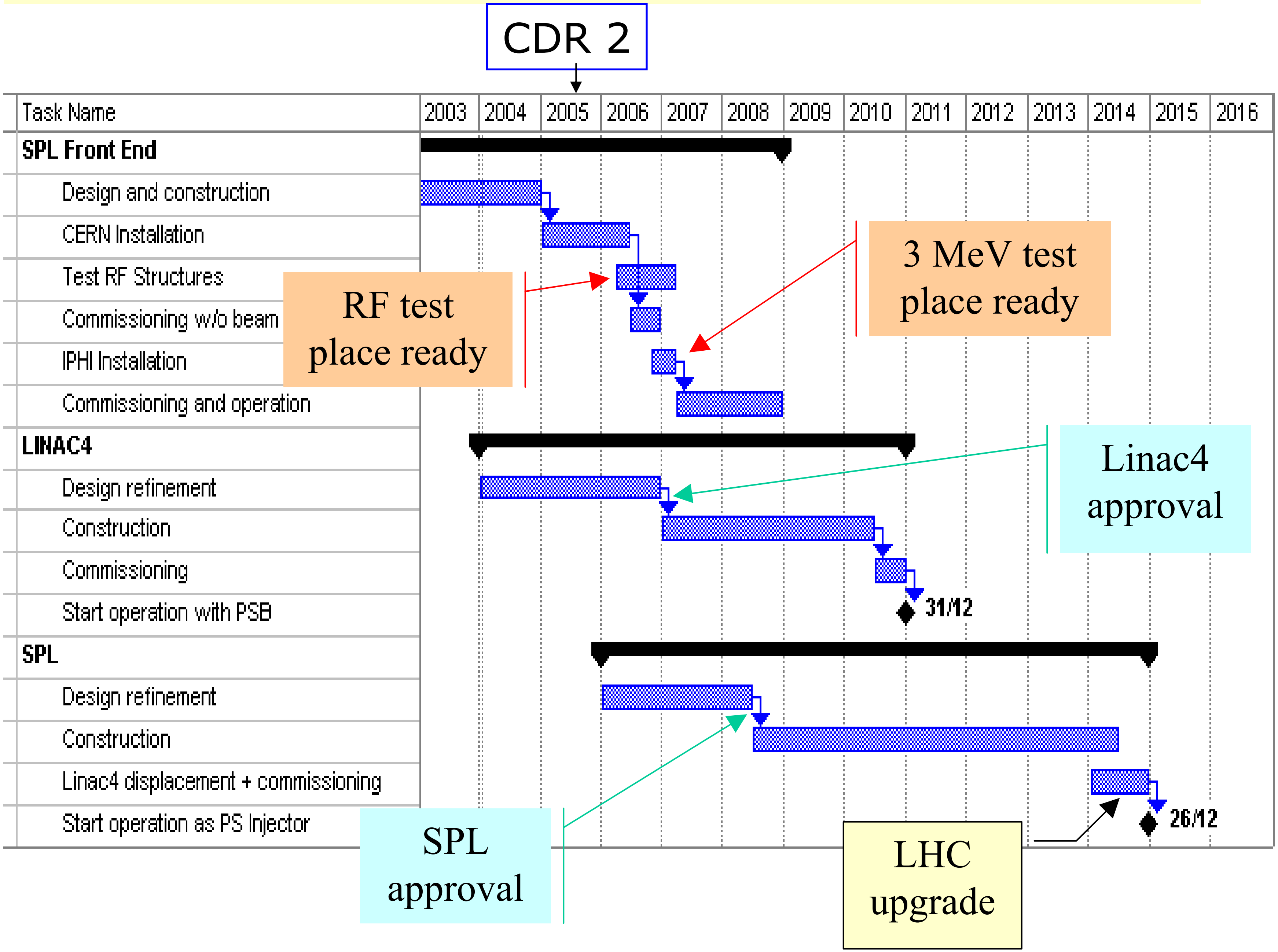
  R&D of the technology for high intensity pulsed proton linear accelerators up to an energy of 200 MeV ⇒ Improvement of existing facilities (E.U. request) at GSI, RAL and CERN

- **Means**

  9 laboratories: RAL, CEA (Saclay), CERN, FZJ, GSI, Frankfurt University, INFN-Milano, IPN (Orsay), LPSC (Grenoble).
  11.1 MEuros + 3.6 MEuros (E.U.) over 5 years (2004 – 2008)

- **Organization ⇒ 5 Work Packages**
  - **WP1 : Management & Coordination (R. Garoby – CERN)**
  - **WP2 : Normal Conducting structures (J.M. Deconto – LPSC Grenoble)**
  - **WP3 : Superconducting structures (S. Chel – CEA Saclay)**
  - **WP4 : Beam chopper (A. Lombardi – CERN)**
  - **WP5 : Beam dynamics (I. Hoffmann – GSI)**

Possible Schedule



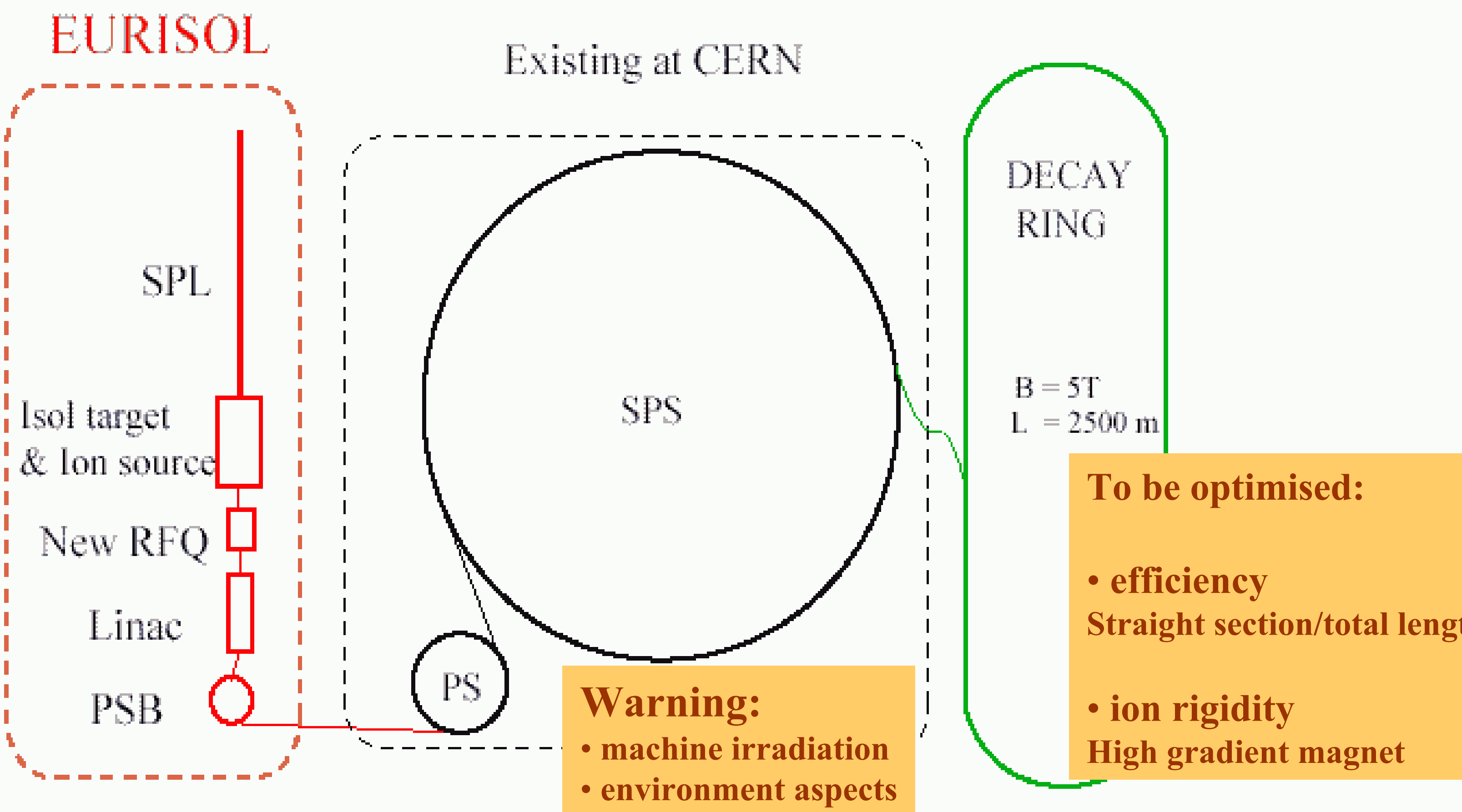
SPL long term interest

	INTEREST FOR			
	LHC upgrade	**Neutrino physics beyond CNGS**	**Radioactive ion beams (EURISOL)**	**Others**
SPL * **(>2 GeV – 50 Hz)**	**Valuable**	**Very interesting for super-beam + beta-beam**	**Ideal**	**Spare flux ⇒ possibility to serve more users**
RCS (30 GeV – 8 Hz)	**Valuable**	**Very interesting for neutrino factory**	**No**	**Valuable**
New PS (30 GeV)	**Valuable**	**No**	**No**	**Valuable**
New LHC injector (1 TeV)	**Very interesting for doubling the LHC energy**	**No**	**No**	**Potential interest for kaon physics**

* Comparison should also be made with an RCS of similar characteristics.

Beta Beam (P. Zucchelli: Phys. Lett. B532:166, 2002)

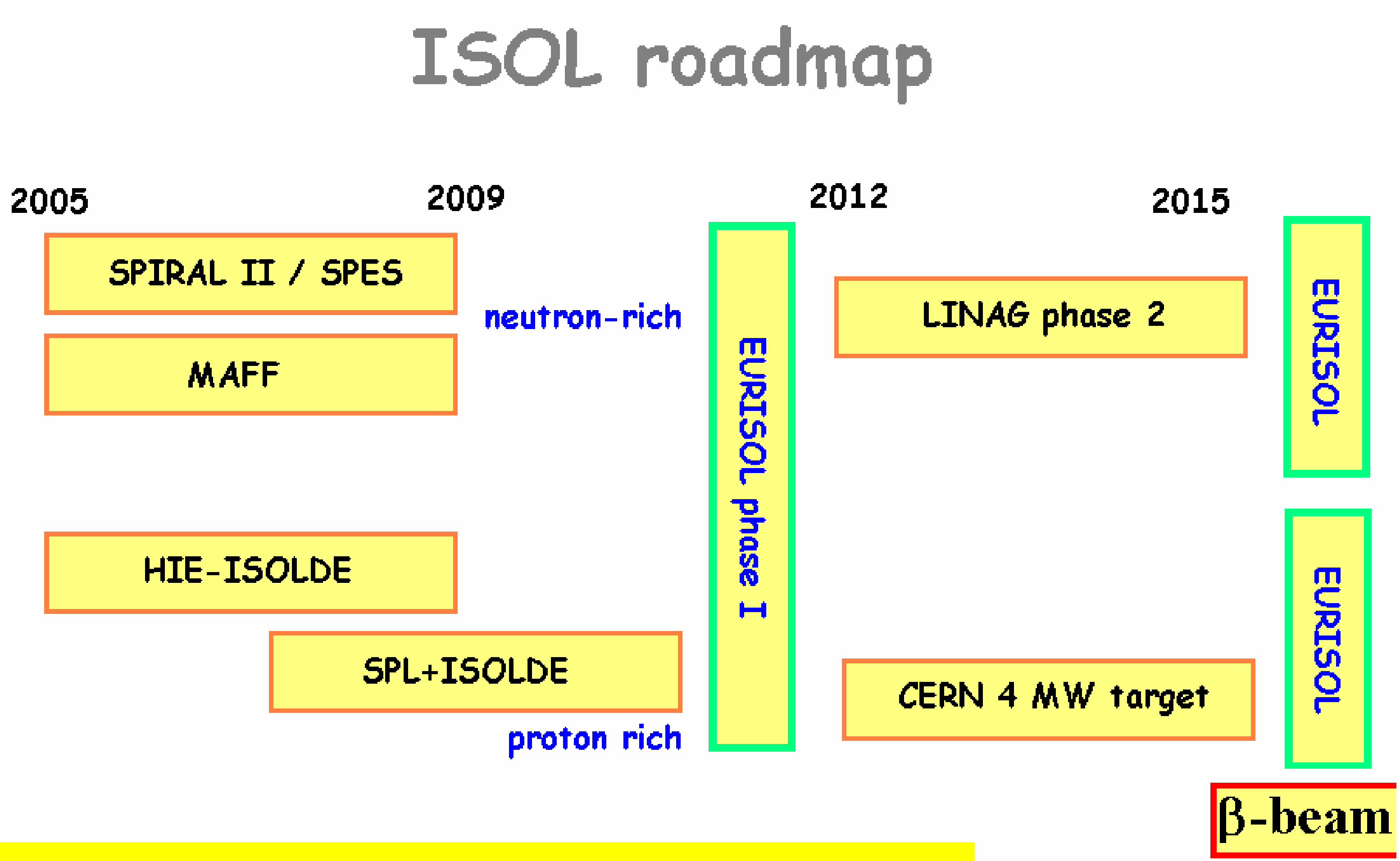
M. Lindroos and collaborators, see http://beta-beam.web.ch/beta-beam



- 1 ISOL target to produce He^6, 100 μA, $\Rightarrow 2.9 \cdot 10^{18}$ ion decays/straight session/year. $\Rightarrow \overline{\nu}_e$.
- 3 ISOL targets to produce Ne^{18}, 100 μA, $\Rightarrow 1.2 \cdot 10^{18}$ ion decays/straight session/year. $\Rightarrow \nu_e$.
- The 4 targets could run in parallel, but the decay ring optics requires:

$$\gamma(Ne^{18}) = 1.67 \cdot \gamma(He^6).$$

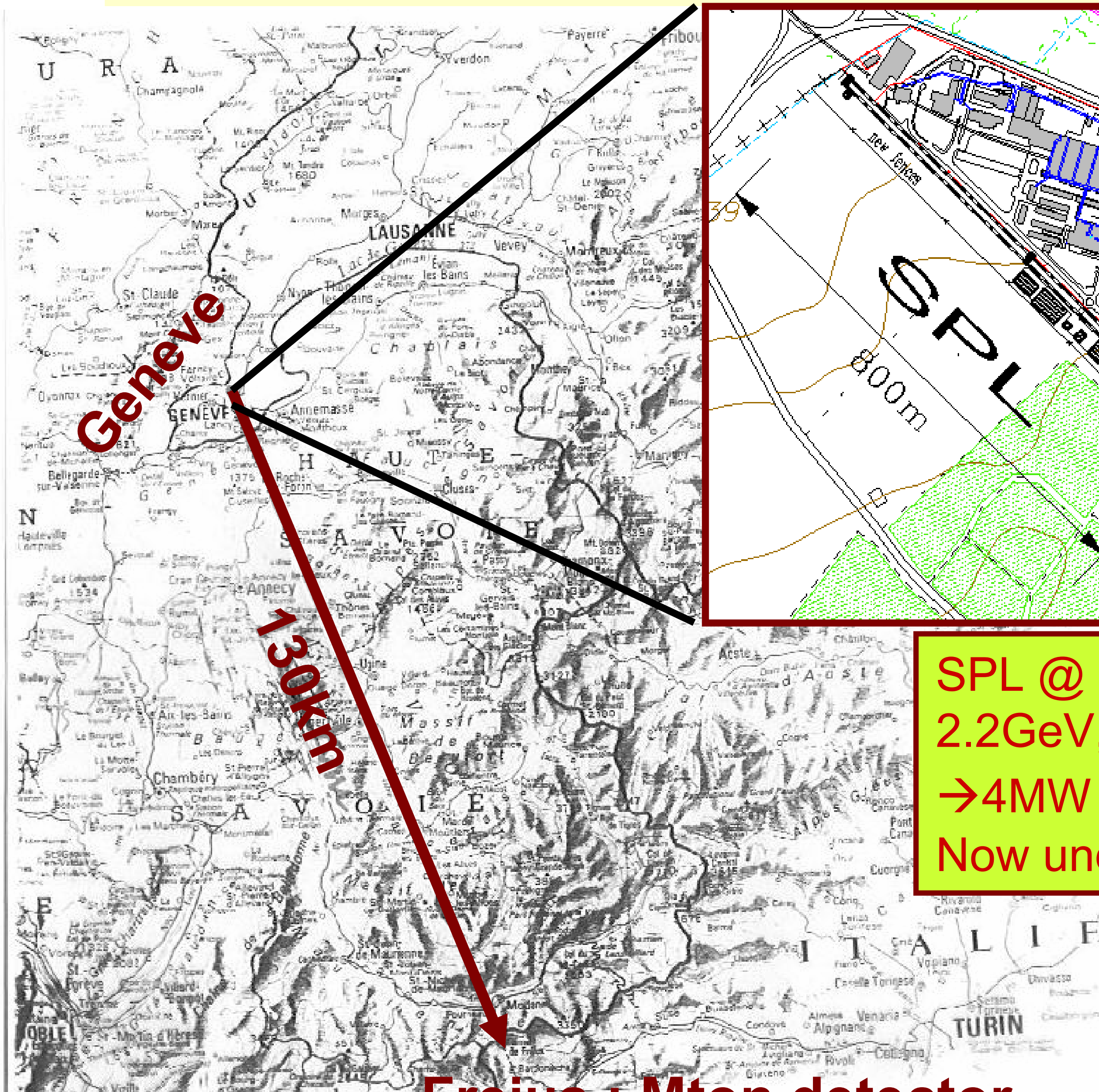
Eurisol schedule

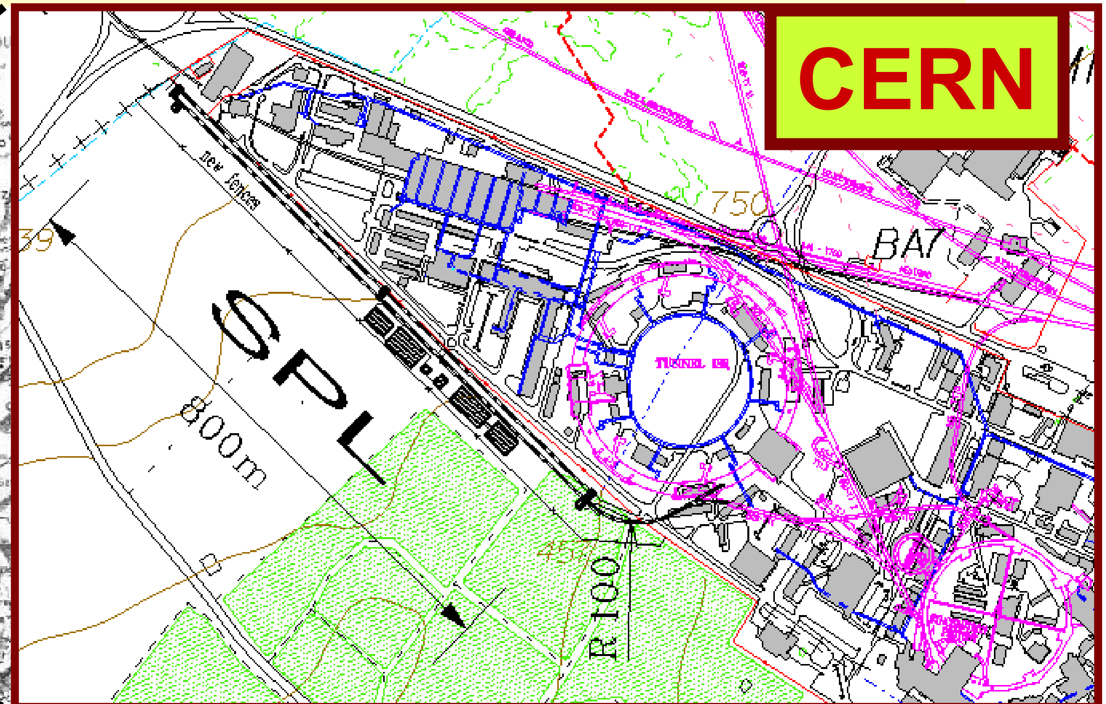


RTD and initial design 2002 – 2007

detailed design, construction 2008 – 2011

Europe: SPL→Frejus

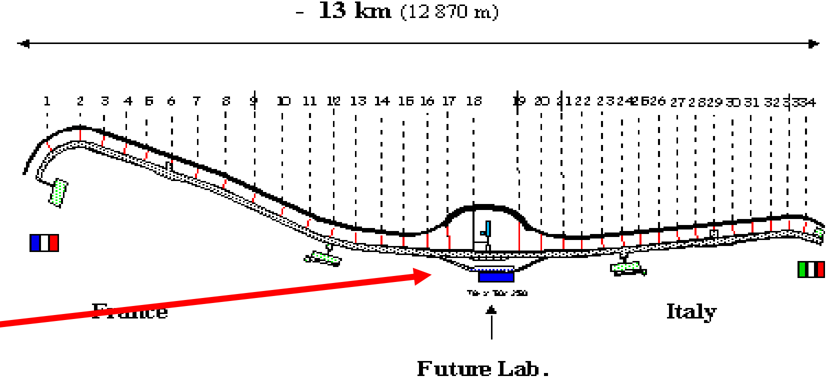




SPL @ CERN
2.2GeV, 50Hz, 2.3x10^{14} p/pulse
→4MW *superconducting*
Now under R&D phase

Frejus : Mton detector

Frejus site



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)

(latest news : not accepted since the security gallery cannot be used for excavating the new lab)

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

Very attractive for low background experiments

....

« 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.

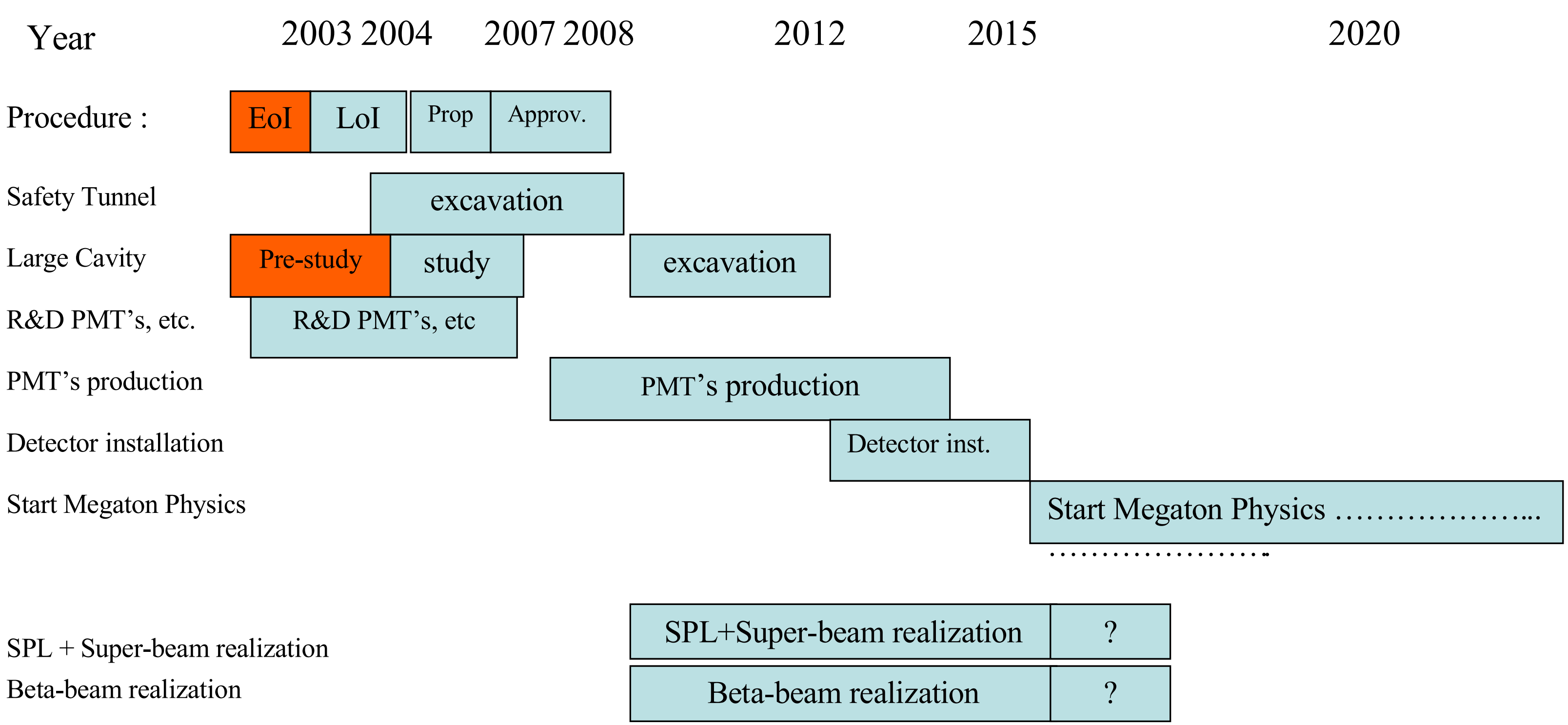
The institutions aim at associating the Fréjus and Gran Sasso laboratories in a single entity, a European Joint Laboratory, **open to the world scientific community** to carry out advanced experiments in particle, astroparticle and nuclear physics in the coming decades, on topics such as matter stability,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

The baseline option is
a megaton detector
with betabeam and superbeam
But other scenari are possible …

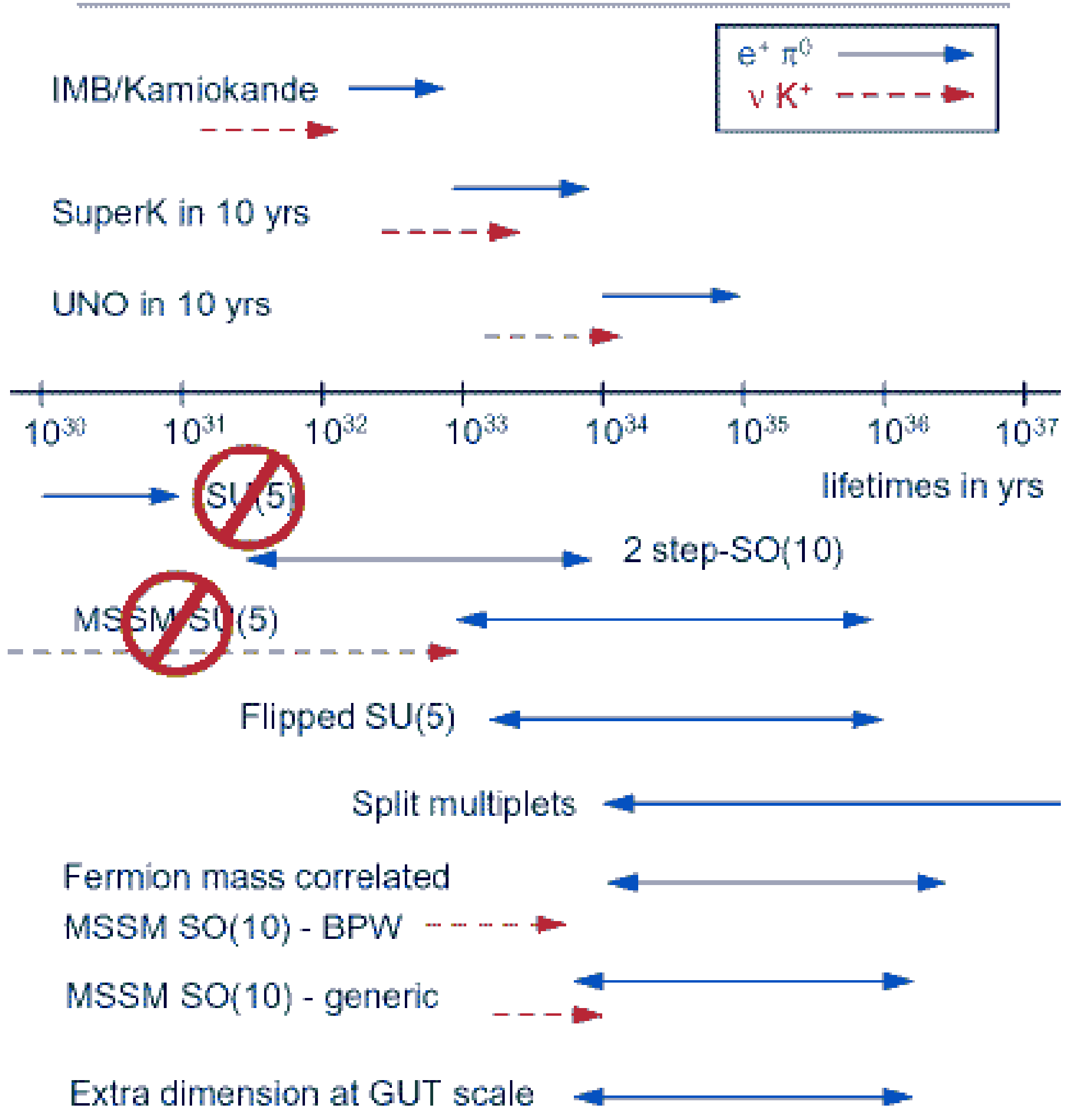
Proposed schedule for UNO like detector at Frejus

Optimistic ! ?

An « 0ptimal » schedule for a Megaton Physics Project in Europe



UNO Proton Decay Sensitivity



Comments on Organizing International Effort on Next Generation WC Detector

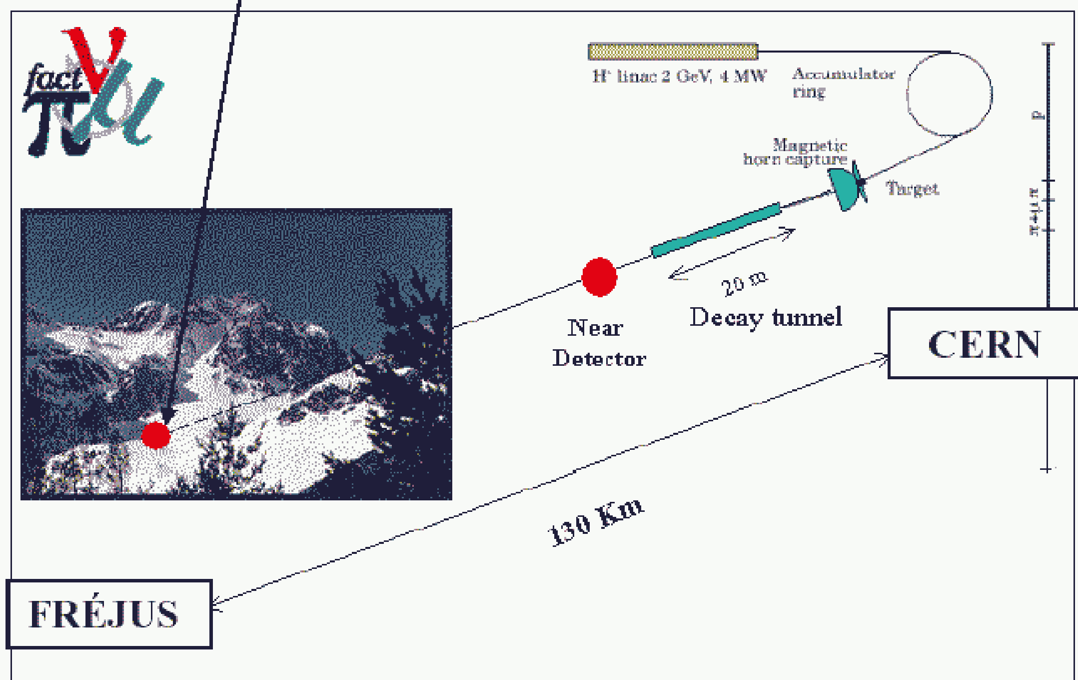
- Model 1
  - Regional Collaborations
    - ⇒ HyperK in Japan
    - ⇒ UNO in US
    - ⇒ ??? In Europe
  - Cross referencing of the collaborators
    - ⇒ mutual support for local proposals
  - Joint R&D effort for non-site specific common items
  - Formation of an International Steering Committee
  - Advantage: focused regional efforts to bring local enthusiasm
  - Disadvantages: smaller collaborations, proposals can be seen as competing with each other

Comments on Organizing International Effort on Next Generation WC Detector

- Model 2
  - Formation of a World-wide Collaboration
    - ⇒ to build one (or two) detectors somewhere in the world
    - ⇒ Frejus-UNO-HyperK

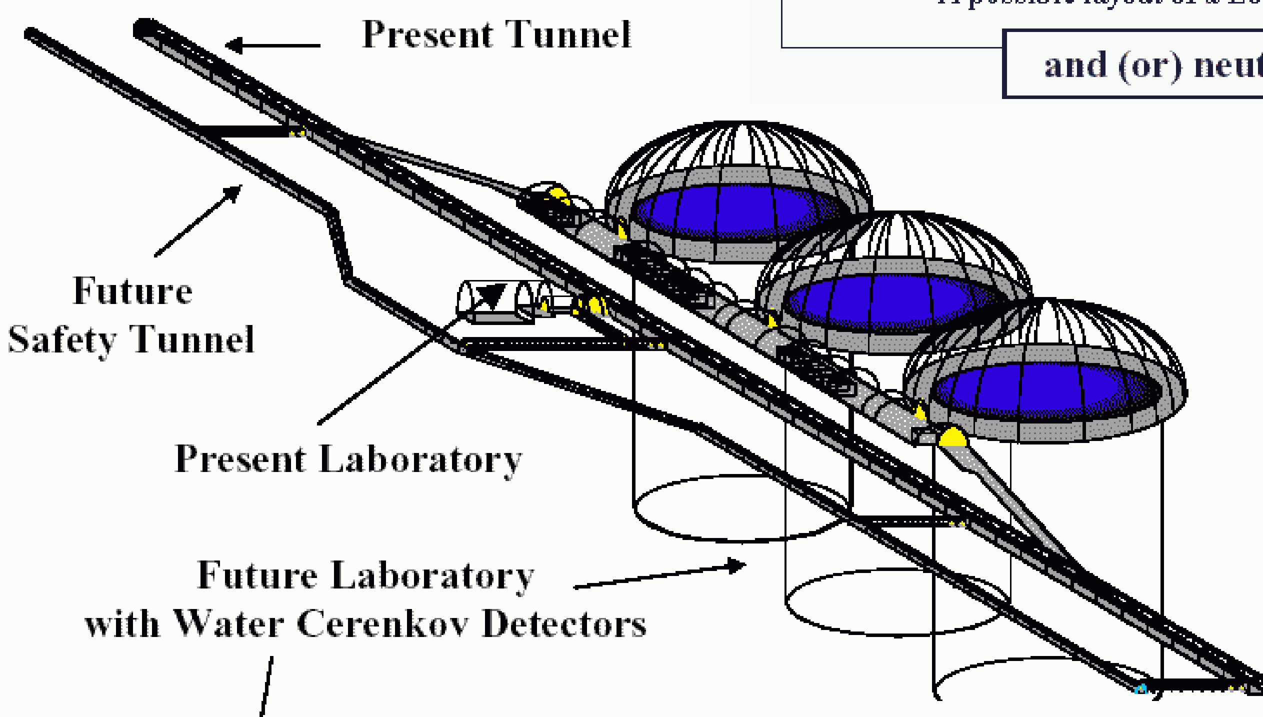
      FUHK (!) Bad name
  - Advantage: if formed, it will be a powerful collaboration
  - Disadvantage: can people truly overcome local interests?
    - ⇒ Can prioritization be done without prejudice?
    - ⇒ LC dilemma
  - "Internationalization" is a word that should be used very cautiously
    - ⇒ should avoid making foreign contributions prerequisite

Super Beam at CERN

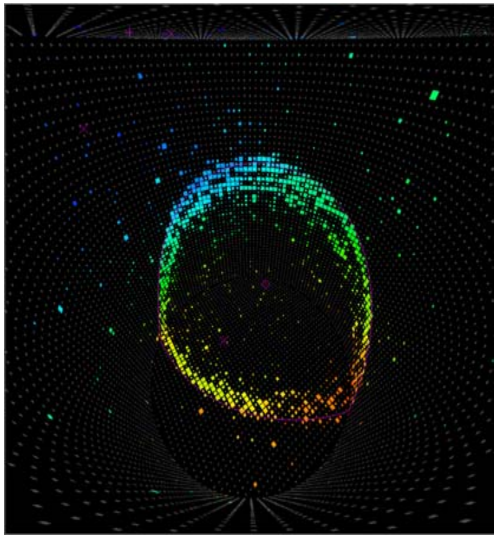


A possible layout of a Low Energy Neutrino Super Beam

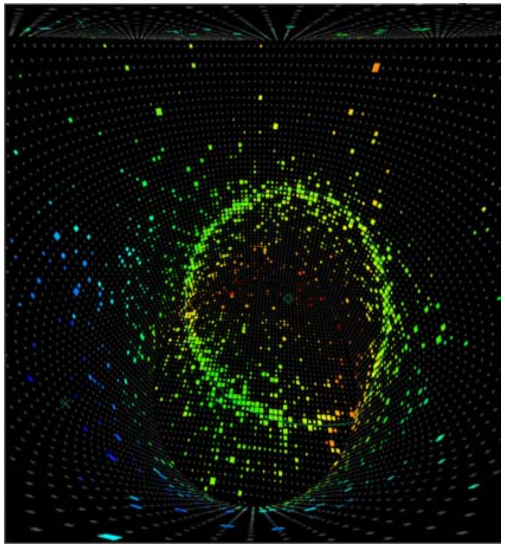
and (or) neutrino beta-beam



Combining beta beam with low energy super beam



- **Unique to CERN- based scenario :**
  SPS can accelerate ions upto $\Gamma \cong 100$
- **muon identification is much more easy**
- **betabeam is background free**
- **combines CP and T violation tests**



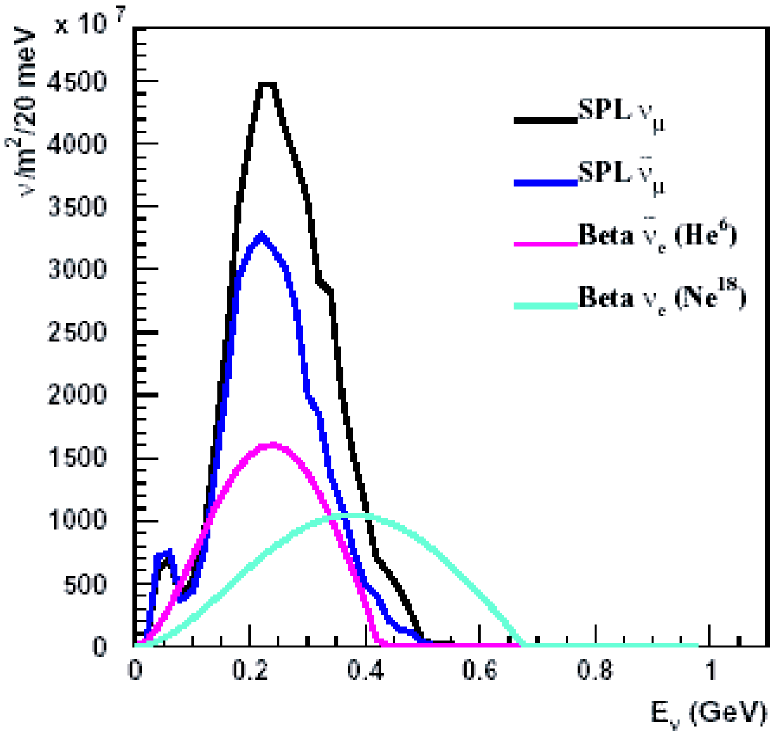
$$\nu_e \rightarrow \nu_\mu \quad (\beta+) \quad \textbf{(T)} \quad \nu_\mu \rightarrow \nu_e \quad (\pi^+)$$

(CP)

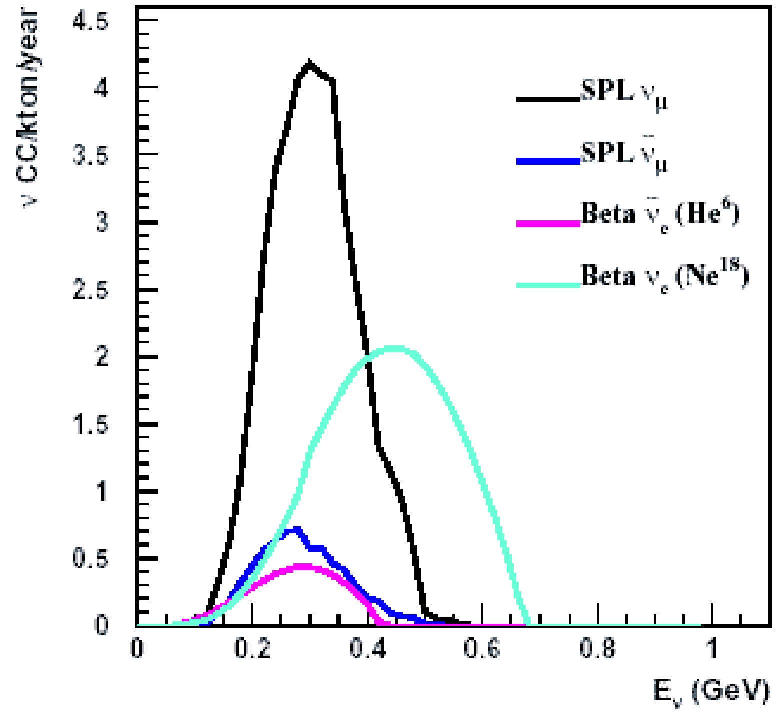
$$\bar{\nu}_e \rightarrow \bar{\nu}_\mu \quad (\beta-) \quad \textbf{(T)} \quad \bar{\nu}_\mu \rightarrow \bar{\nu}_e \quad (\pi^-)$$

Flux and rates at Frejus

Fluxes



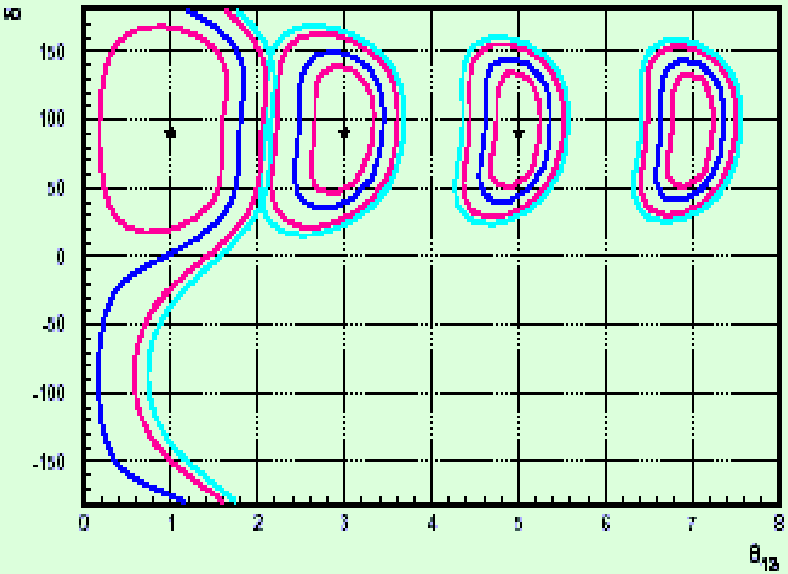
CC Rates



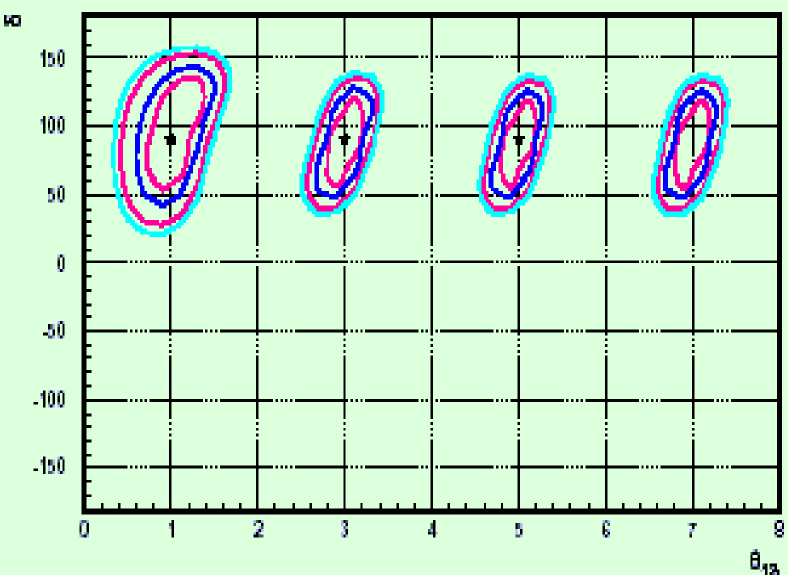
	Fluxes @ 130 km $\nu/m^2/yr$	$< E_\nu >$ (GeV)	CC rate (no osc) events/kton/yr	$< E_\nu >$ (GeV)	Years	Integrated events (440 kton $\times$ 10 years)
SPL Super Beam						
ν_μ	$4.78 \cdot 10^{11}$	0.27	41.7	0.32	2	36698
$\overline{\nu}_\mu$	$3.33 \cdot 10^{11}$	0.25	6.6	0.30	8	23320
Beta Beam						
$\overline{\nu}_e\ (\gamma = 60)$	$1.97 \cdot 10^{11}$	0.24	4.5	0.28	10	19709
$\nu_e\ (\gamma = 100)$	$1.88 \cdot 10^{11}$	0.36	32.9	0.43	10	144783

Beta Beam - Super Beam synergy: CP sensitivity

SUPER BEAM ONLY



SUPER BEAM + BETA BEAM



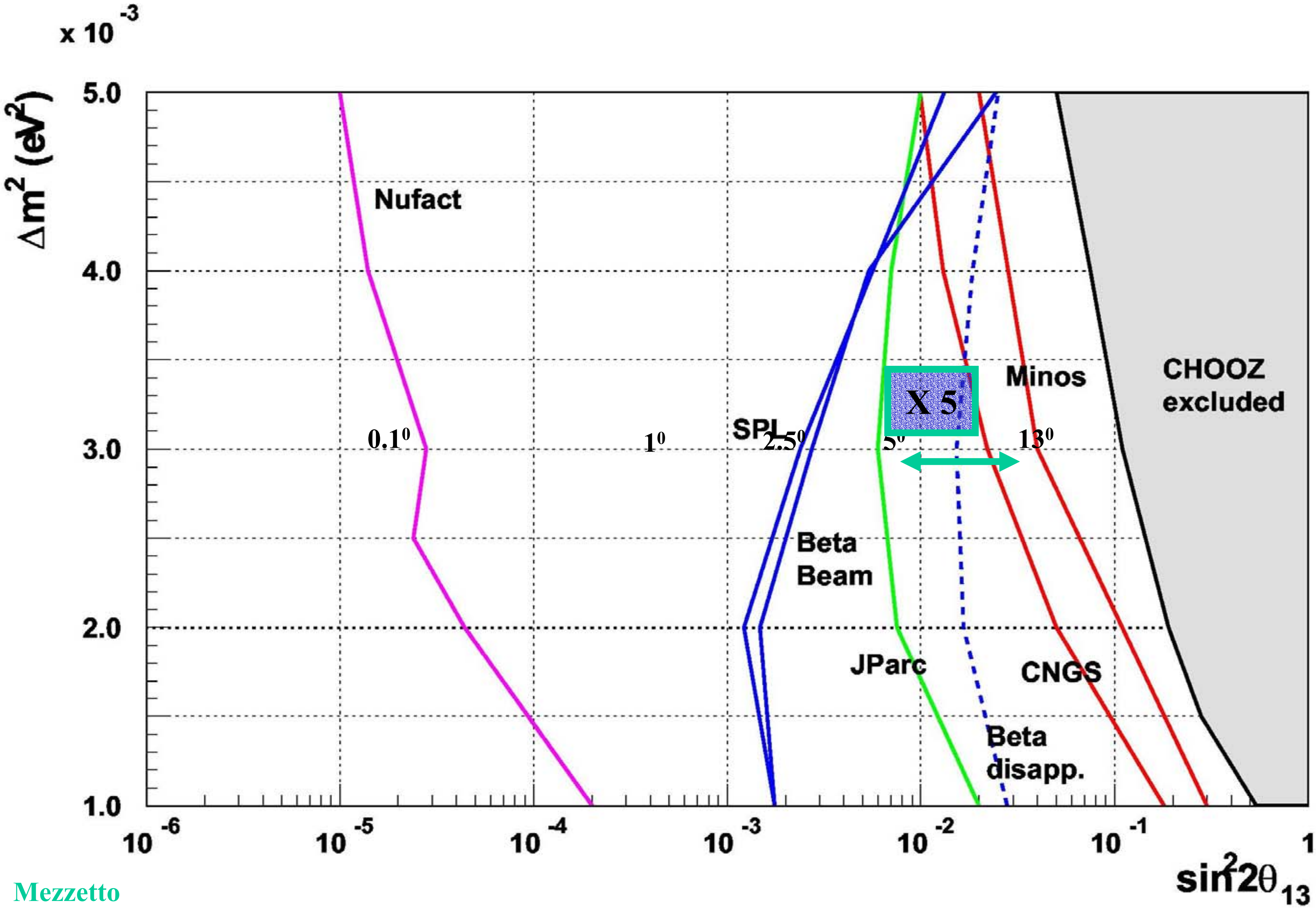
$\delta m^2_{12} = 7 \cdot 10^{-5}\ eV^2$, $\theta_{13} = 3^\circ$, $\delta_{CP} = \pi/2$, sign$(\Delta m^2) = +1$

	Beta Beam		SPL-SB	
	^6He	^{18}Ne	ν_μ	$\overline{\nu}_\mu$
	$(\gamma = 60)$	$(\gamma = 100)$	(2 yrs)	(8 yrs)
CC events (no osc, no cut)	19710	144784	36698	23320
Oscillated at the Chooz limit	612	5130	1279	774
Oscillated	44	529	93	82
δ oscillated	-9	57	-20	12
Beam background	0	0	140	101
Detector backgrounds	1	397	37	50

δ-oscillated events indicates the difference between the oscillated events computed with $\delta = 90^\circ$ and with $\delta = 0$.

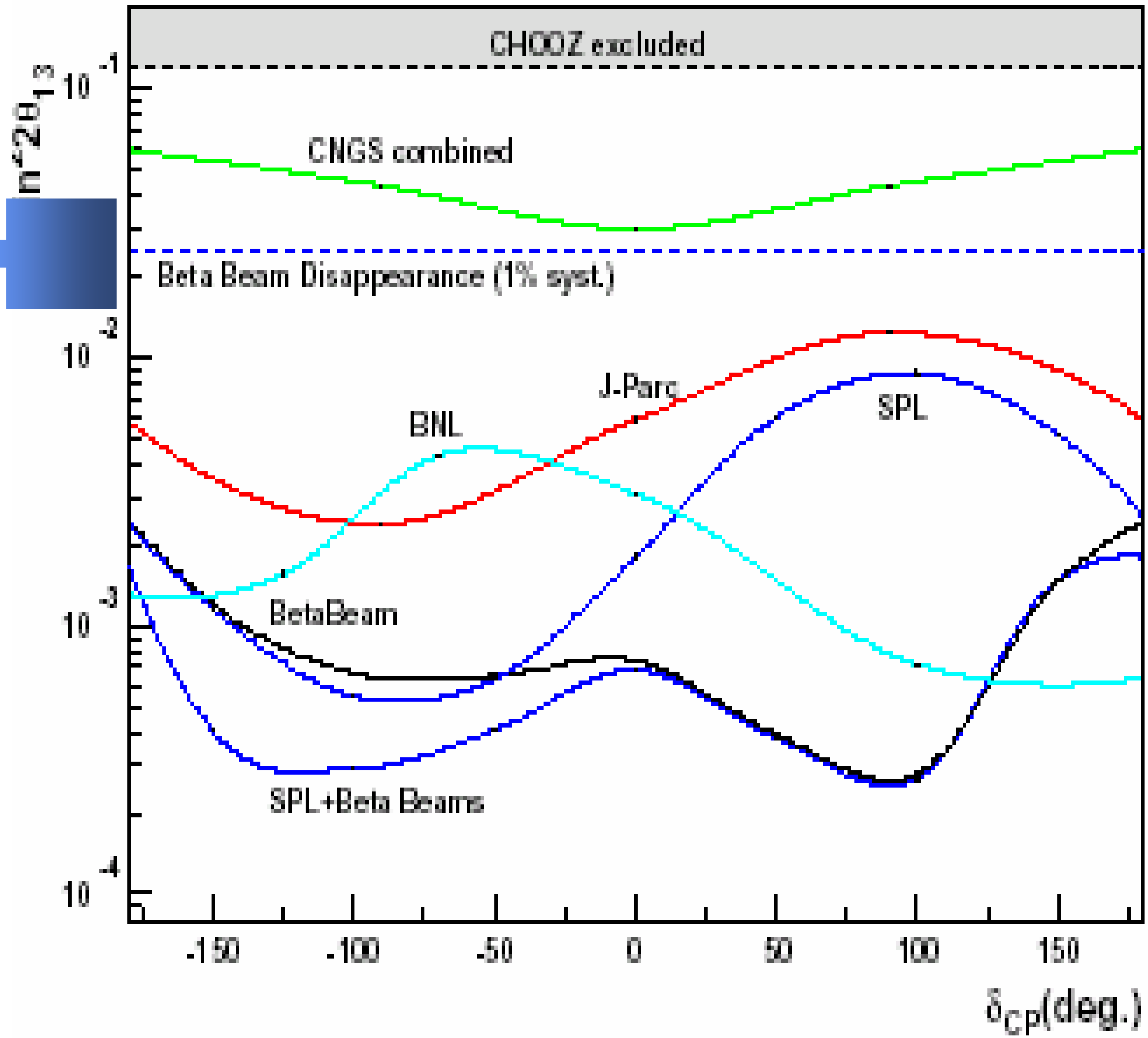
Assuming UNO like detector

Where will this get us…



Mezzetto

Reactor experiment sensitivity



High gamma betabeam simulation

Increasing the energy for fixed L/E

(as in a Neutrino factory) :

- **statistics increases linearly with E**

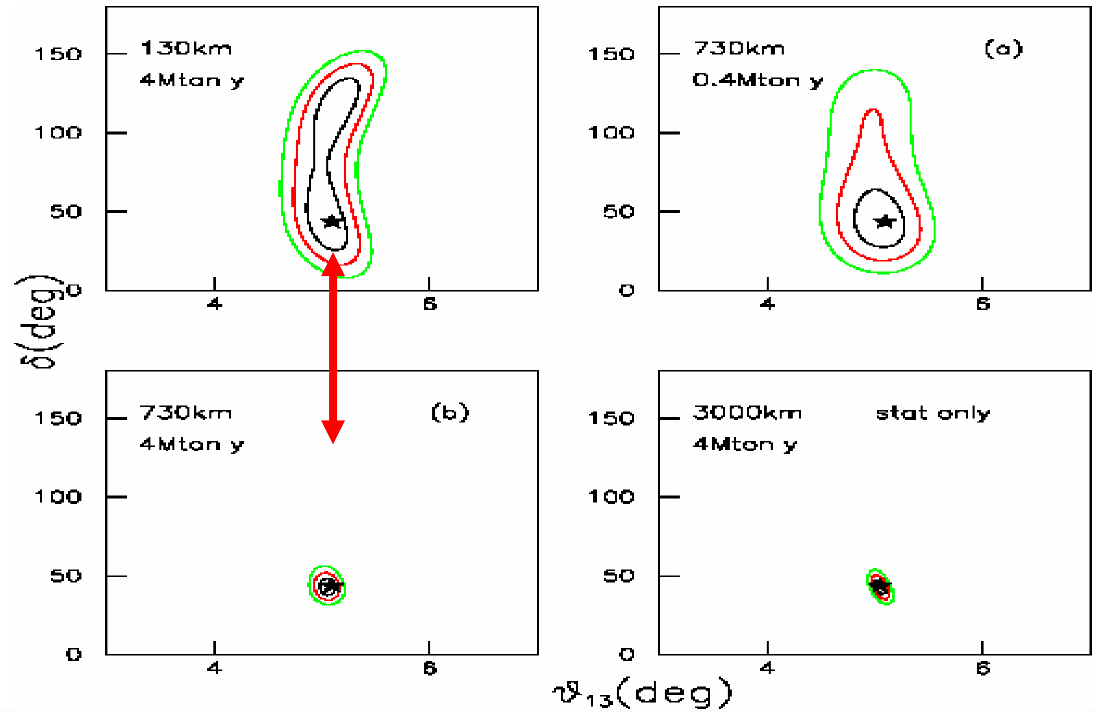
  cross section + focusing

- **longer baseline → enhance matter effect**

  accessing neutrino mass hierarchy

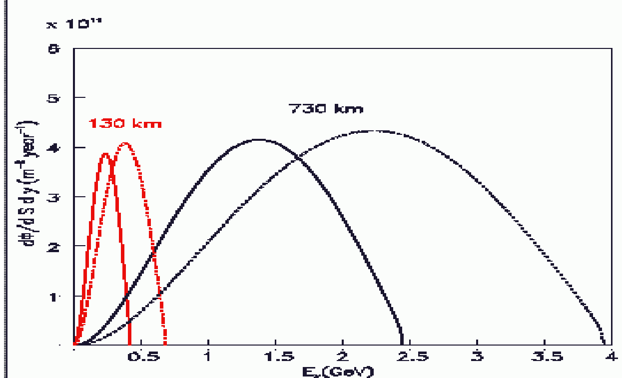
- **at high energy easier to measure spectral information in the oscillation signal**

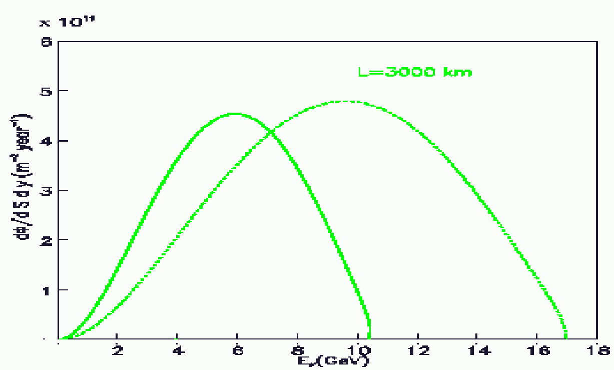
  reduce intrinsic degeneracies



Burguet-Castell:
hep-ph/0312068

γ	$L(km)$	$\bar{\nu}_e$ CC (KTon y)	ν_e CC (KTon y)	$\langle E_\nu \rangle (GeV)$
60/100	130	4.7	32.8	0.23/0.37
350/580	730	57.5	224.7	1.35/2.18
1500/2500	3000	282.7	993.1	5.80/9.39

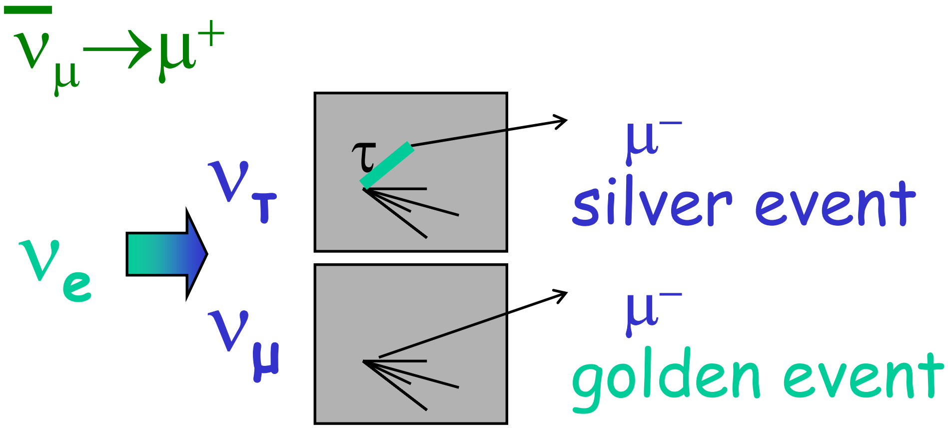




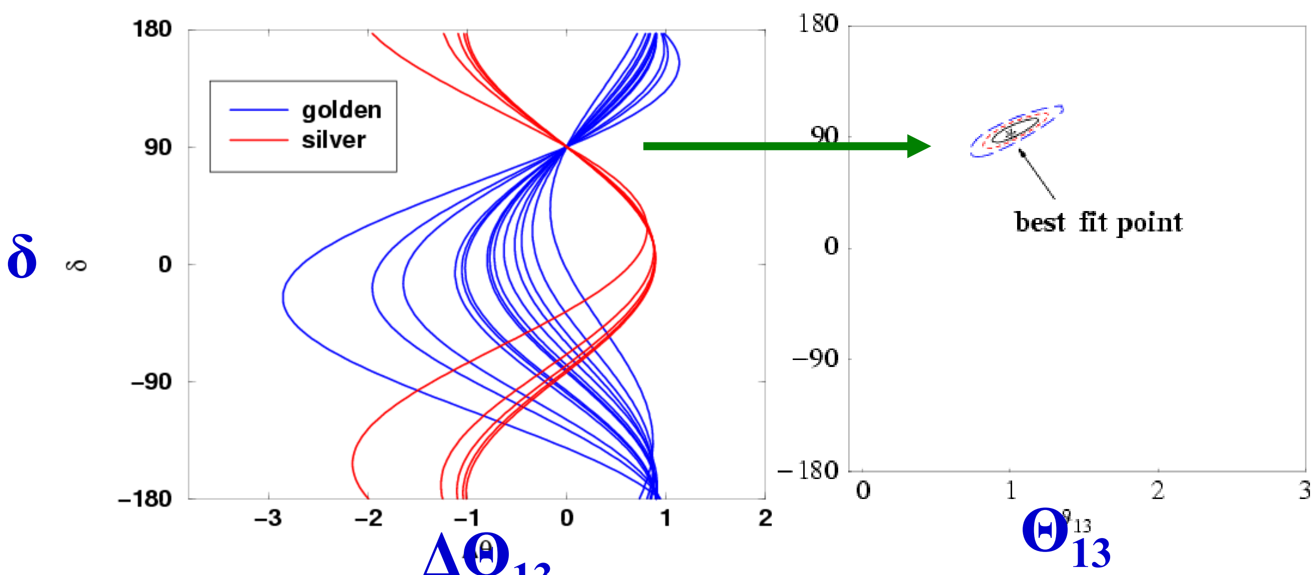
See also Terranova :
hep-ph/0405081

Optimal baseline and energy for solving degeneracies and Dm2 sign

Neutrino factory case (A. Donini) hep-ph/0305185



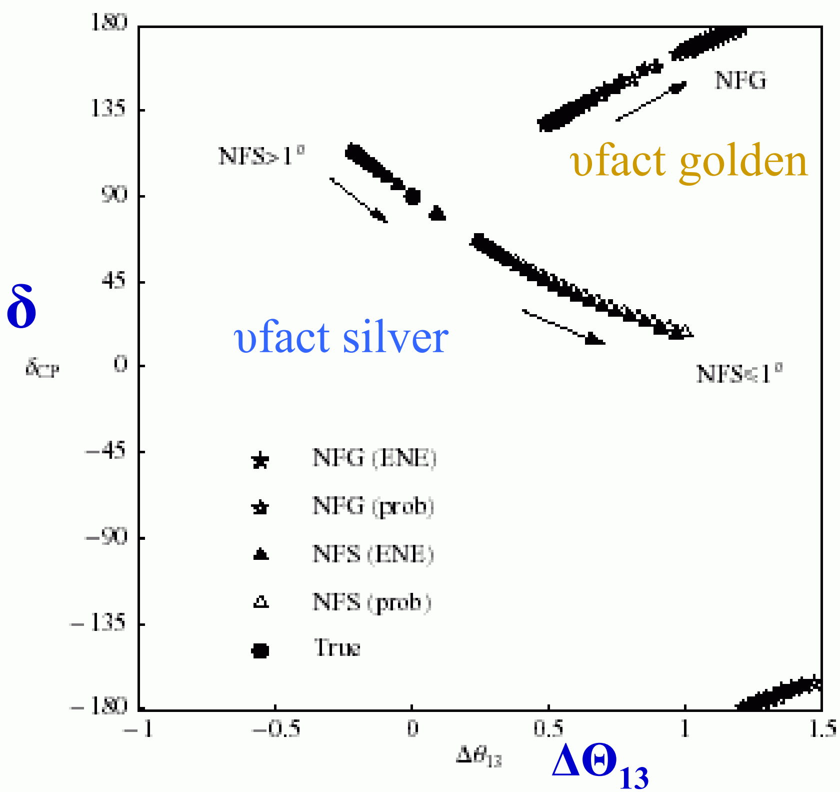
The oscillation $\nu_e \rightarrow \nu_\tau$ has a nice dependence on δ_{CP} and θ_{13} which, in combination with the golden channel, eliminates the clone regions resolving the δ_{CP},- θ_{13} degeneracy



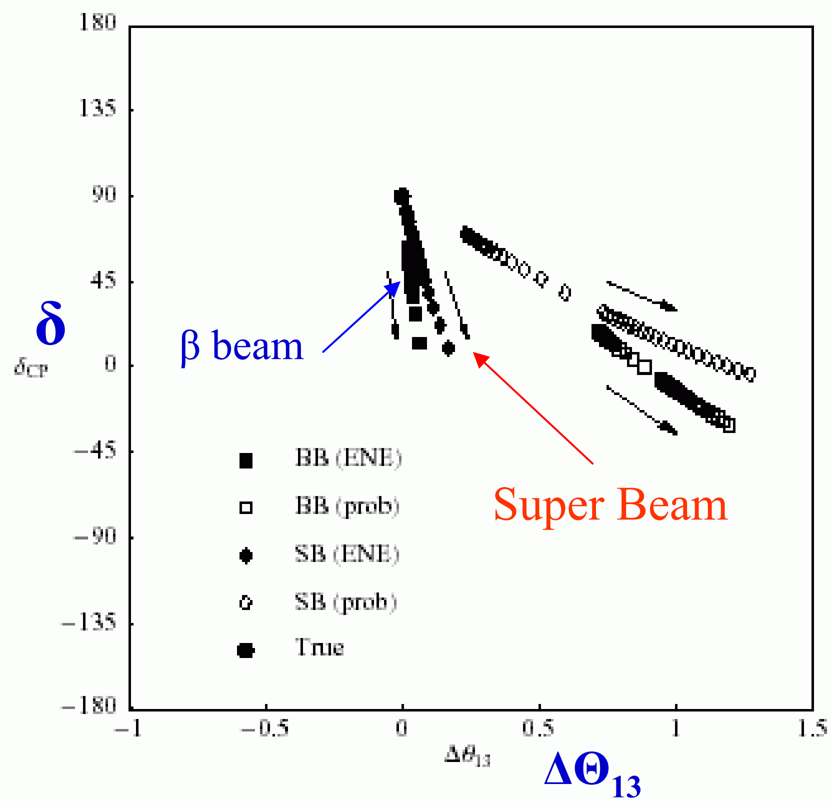
Optimal baseline and energy for solving degeneracies and Dm2 sign

Beta Beam and Super beam versus Neutrino factory (A. Donini)

hep-ph/0312072

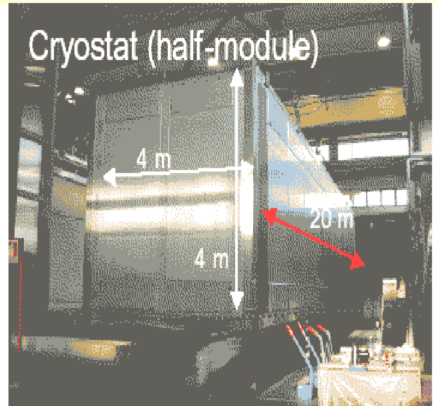


Neutrino Factory

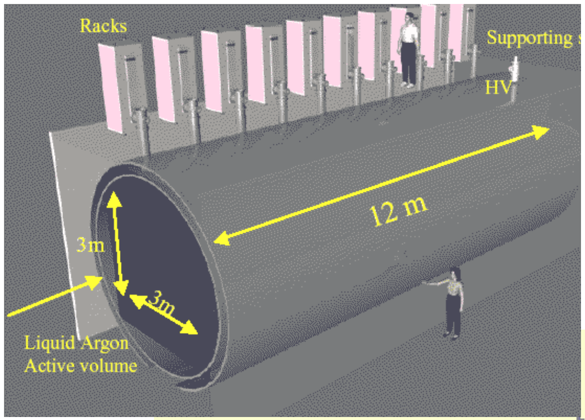


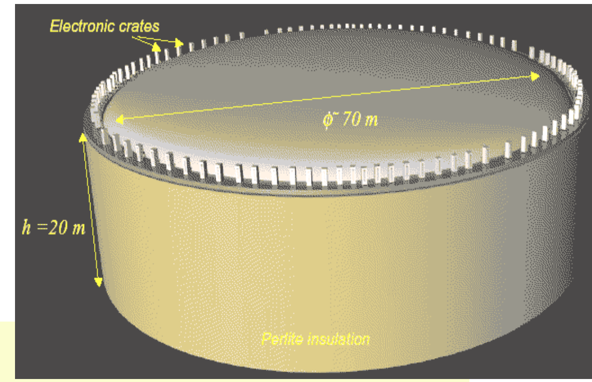
Super / Beta Beams

Liquid Argon TPC : cloning ICARUS



T600 @LNGS
Physics demonstrator





100 ton

- Precision studies of ν interactions
- Calorimetry
- Near station in LBL facilities

100 kton

- Ultimate nucleon decay searches
- Astroparticle physics
- CP violation in neutrino mixing

Strong synergy and high degree of interplay

Need to coherently develop conceptual ideas within the international community

International coordination

Argon-Net

- The further developments of the LAr TPC technique, eventually finalized to the proposal and to the realization of actual experiments, could only be accomplished by an international community of colleagues able to identify and conduct the required local R&D work and to effectively contribute, with their own experience and ideas, to the achievement of ambitious global physics goals. In particular, this is true for a large 100 kton LAr TPC detector that would exploit next generation neutrino facilities and perform ultimate non-accelerator neutrino experiments.

- We are convinced that, given the technical and financial challenges of the envisioned projects, the creation of a Network of people and institutions willing to share the responsibility of the future R&D initiatives, of the experiment's design and to propose solutions to the still open questions is mandatory.

- The actions within the Network might include the organization of meetings and workshops where the different ideas could be confronted, the R&D work could be organized and the physics issues as well as possible experiments could be discussed. One can think of coherent actions towards laboratories, institutions and funding agencies to favor the mobility of researchers, to support R&D studies, and to promote the visibility of the activities and the dissemination of the results.

So far colleagues from 21 institutions have already expressed their Interest in joining Argon-Net, to act as 'nodes' of the network

Liquid Argon medium properties

But no free protons

	Water	Liquid Argon
Density (g/cm³)	1	1.4
Radiation length (cm)	36.1	14.0
Interaction length (cm)	83.6	83.6
dE/dx (MeV/cm)	1.9	2.1
Refractive index (visible)	1.33	1.24
Cerenkov angle	42°	36°
Cerenkov $d^2N/dEdx$ (β=1)	~ 160 $eV^{-1} cm^{-1}$	~ 130 $eV^{-1} cm^{-1}$
Muon Cerenkov threshold (p in MeV/c)	120	140
Scintillation (E=0 V/cm)	No	Yes (~ 50000 γ/MeV @ λ=128nm)
Long electron drift	Not possible	Possible (μ = 500 cm^2/Vs)
Boiling point @ 1 bar	373 K	87 K

When a charged particle traverses LAr:

1) Ionization process

W_e = 23.6 ± 0.3 eV

2) Scintillation (luminescence)

W_γ = 19.5 eV

UV "line" (λ=128 nm ⇔ 9.7 eV)

No more ionization: Argon is transparent

Only Rayleigh-scattering

3) Cerenkov light (if relativistic particle)

☞ **Charge**

☞ **Scintillation light (VUV)**

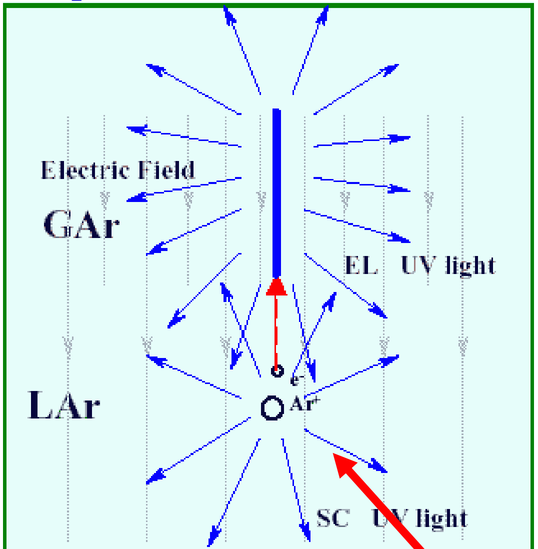
☞ **Cerenkov light (if β>1/n)**

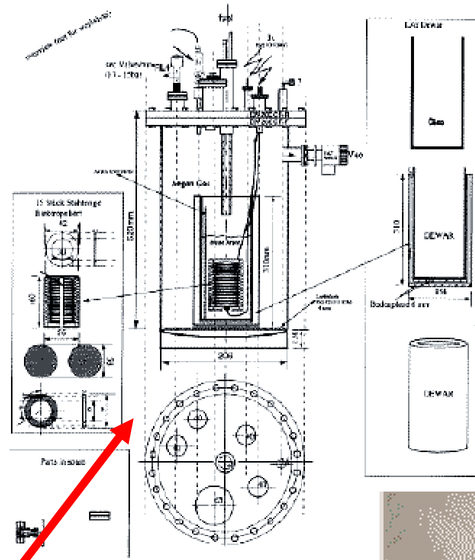
Non accelerator physics : H2O versus LAr

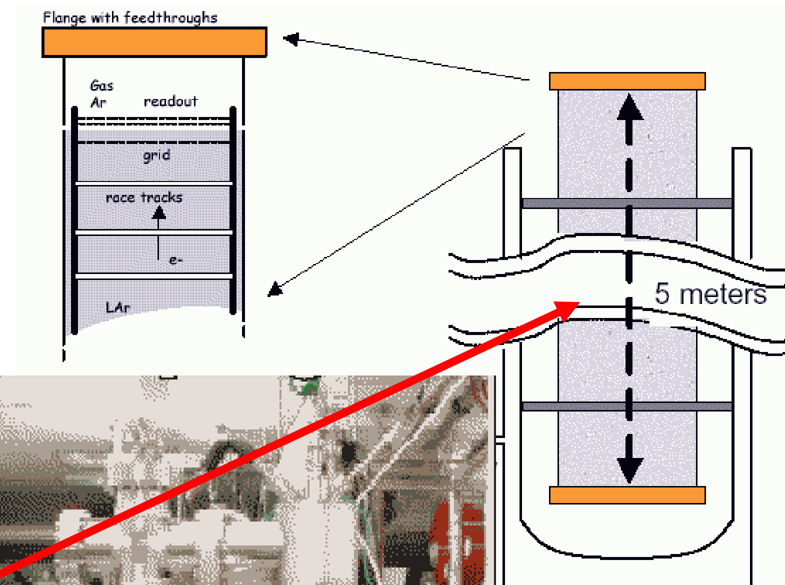
	Water Cerenkov (UNO)	Liquid Argon TPC
Total mass	650 kton	100 kton
Cost	˜ 500 M$	Under evaluation
$p \rightarrow e\,\pi^0$ in 10 years	10^{35} years ε = 43%, ˜ 30 BG events	3×10^{34} years ε = 45%, 1 BG event
$p \rightarrow \nu\,K$ in 10 years	2×10^{34} years ε = 8.6%, ˜ 57 BG events	8×10^{34} years ε = 97%, 1 BG event
$p \rightarrow \mu\,\pi\,K$ in 10 years	No	8×10^{34} years ε = 98%, 1 BG event
SN cool off @ 10 kpc	194000 (mostly $\overline{\nu}_e p \rightarrow e^+ n$)	38500 (all flavors) (64000 if NH-L mixing)
SN in Andromeda	40 events	7 (12 if NH-L mixing)
SN burst @ 10 kpc	˜ 330 ν-e elastic scattering	380 ν_e CC (flavor sensitive)
SN relic	Yes	Yes
Atmospheric neutrinos	60000 events/year	10000 events/year
Solar neutrinos	E_e > 7 MeV (central module)	324000 events/year E_e > 5 MeV

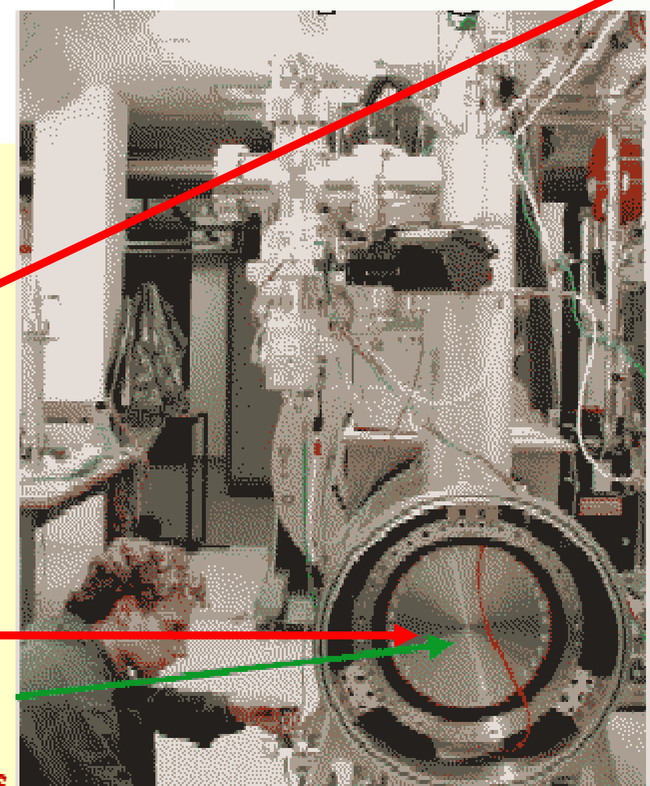
Ongoing studies and R&D

Proposed for Dark Matter search









1) Study of suitable charge extraction, amplification and imaging devices

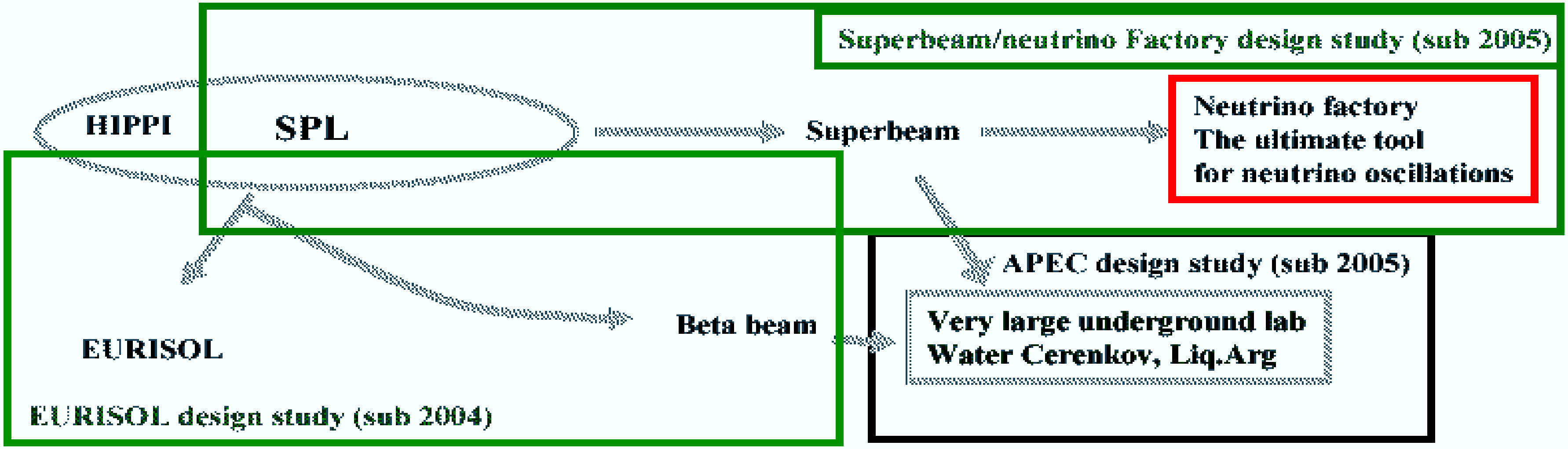
2) Understanding of charge collection under high pressure

3) Realization and test of a 5 m long detector column-like prototype

4) Study of LAr TPC prototypes immersed in a magnetic field

5) Study of logistics, infrastructure and safety issues for underground sites

Concluding on european activities (and dreams …)



SPL	330
EURISOL	200
PS/SPS upgrade	70
Decay Ring	340
Super beam	70
UNO like detector	500
Grand total	1510

Cost in Meuros
no manpower, no contingencies

could be provided by Nuclear physics

Concluding remarks by CERN management at MMW

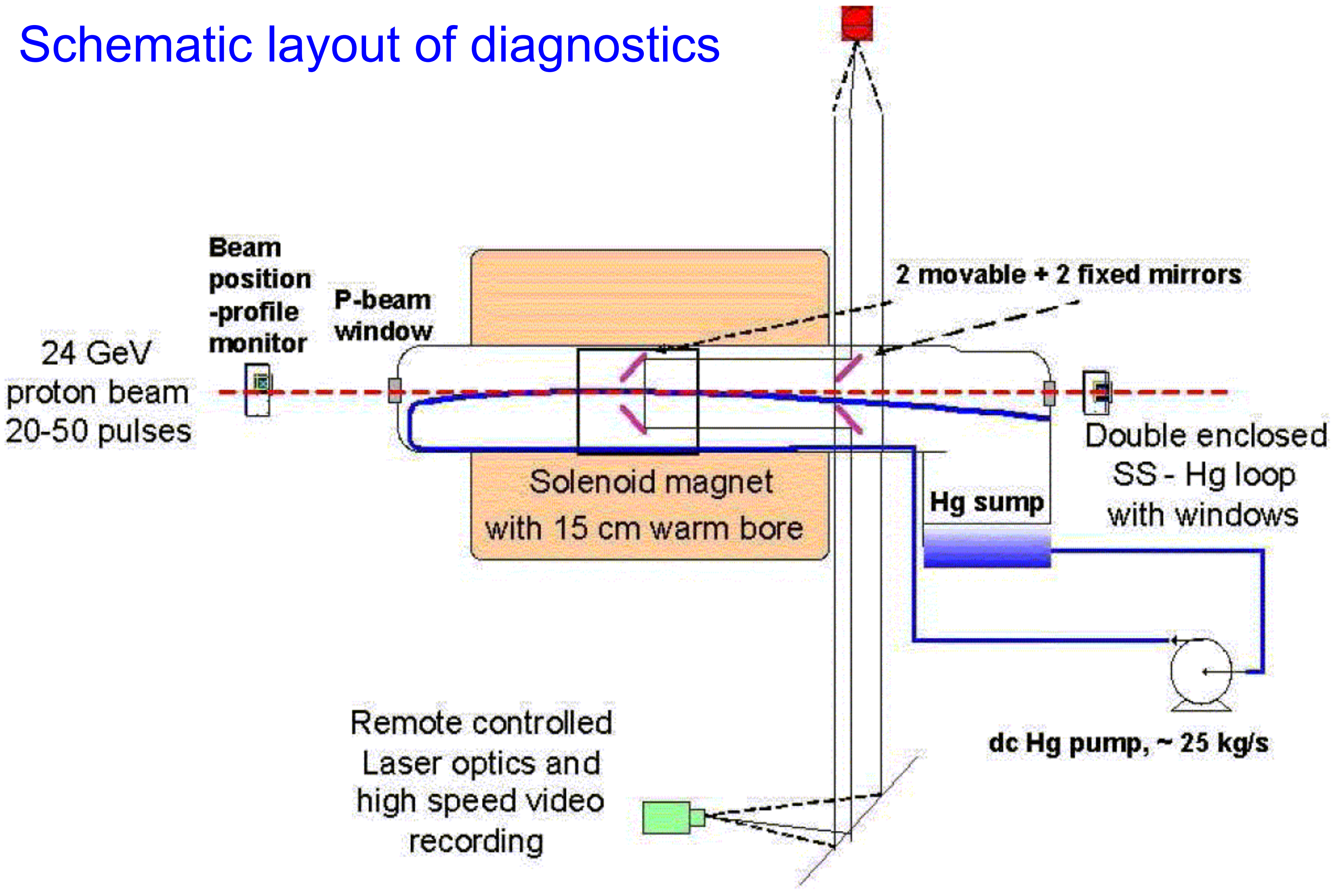
- **CERN will reimburse LHC loan up to 2011**
- **in 2008 new round of negotiations with members state for support for new R&D (not only neutrinos …)**
- **CERN machines (quite old) upgrade will cost**
- **Staff number will decrease from 2500 → 2000 in 5 years**

More international coordination is mandatory

The choice will imply consequences on Machines AND Detectors R&D

High power target R&D

Schematic layout of diagnostics



Horn focusing system R&D