The CNGS physics program

- The τ appearance program
- Sensitivity to the θ_{13} angle
- Status of construction
- Opportunities for ICARUS T600
- Conclusions

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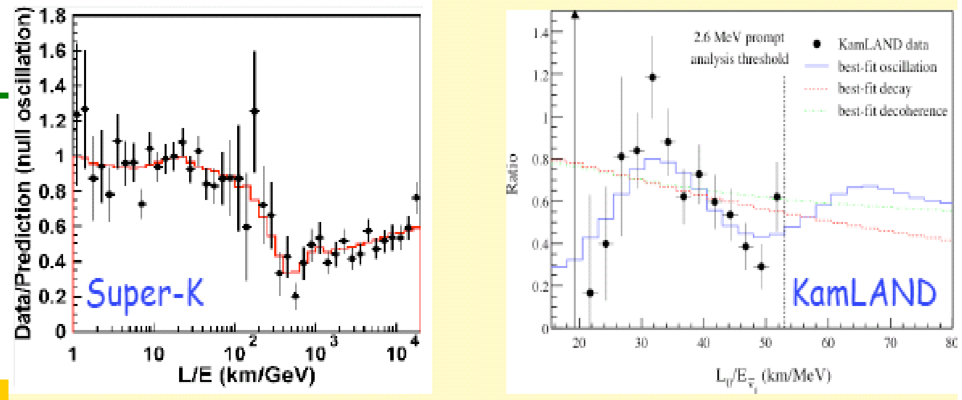
The strength of the experimental evidence

Resides in the overall consistency of

- highly non-trivial tests both in the solar and in the atmospheric sector: NC/CC (SNO), matter vs non matter dominated oscillations (Solar+Kamland), natural vs artificial sources (SK+K2K)
- some direct tests (L/E pattern)



Nobody has observed unambiguously the appearance of new flavours

You can't do it at the solar scale (E too small to produce muons)

At the atmospheric scale oscillations are very likely

$$P(\nu_\mu \to \nu_\tau) \approx \cos^4 \vartheta_{13} \sin^2 2\vartheta_{23} \sin^2 [1.27\, \Delta m^2_{23}\, L(km)/E(GeV)]$$

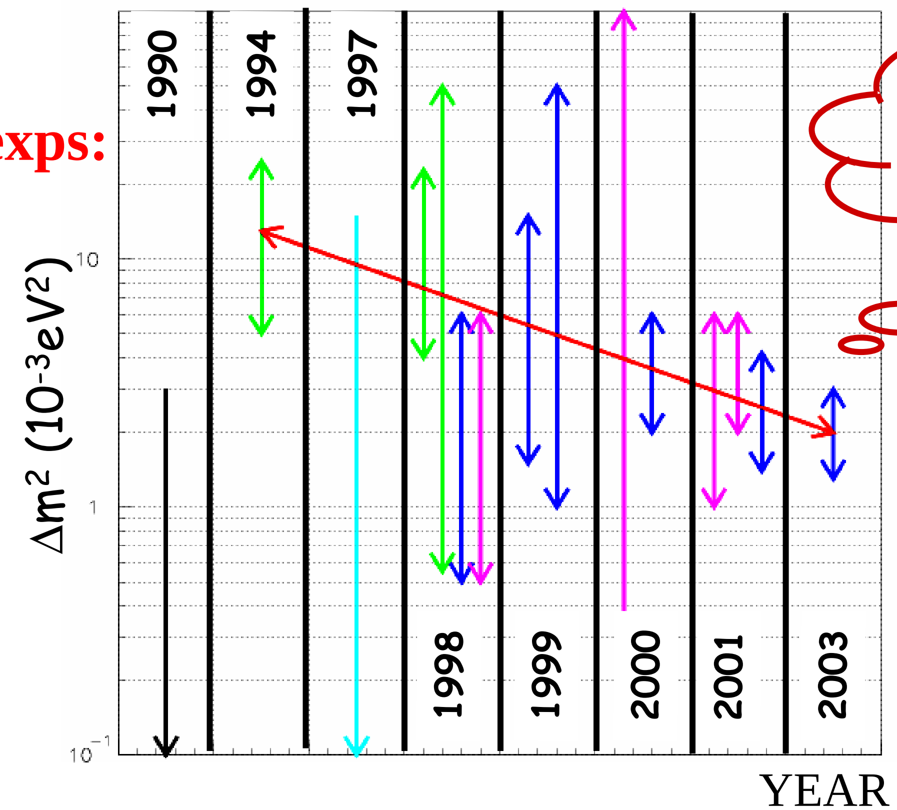
Hence, you must be able to identify unambiguously τ leptons

The CNGS experiments have been designed for it

The Δm^2_{23} saga

Atmospheric exps:

Frejus
Kamiokande
IMB
Super-K
Macro



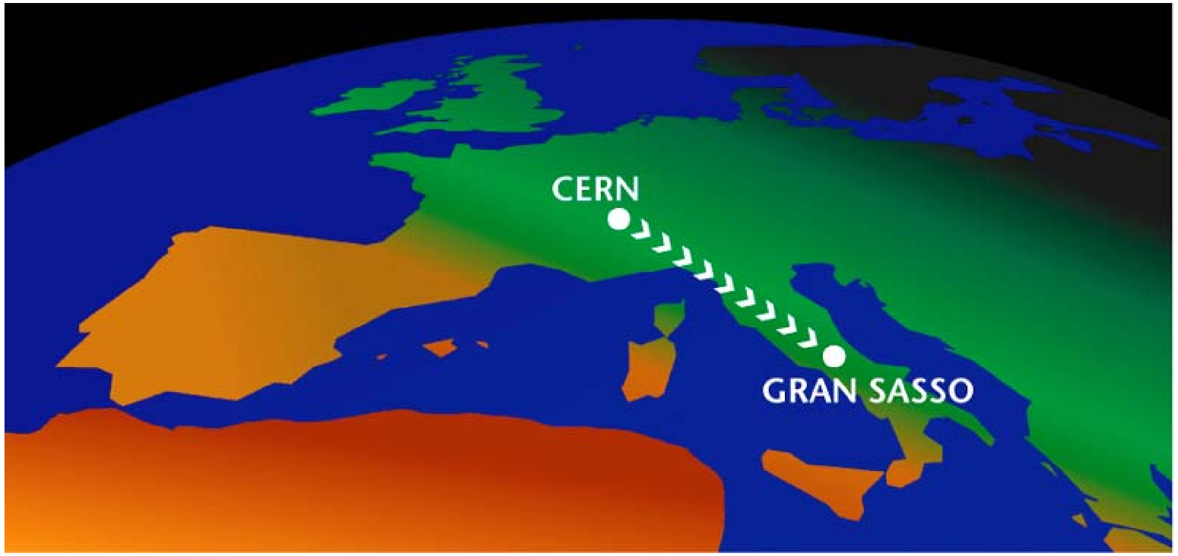
90% allowed regions for different exps as a function of the time

Nota Bene
P_{osc} goes like $(\Delta m^2)^2$
From '94 to '03 it decreased by a factor of 100 !!

It made our experiment challenging:

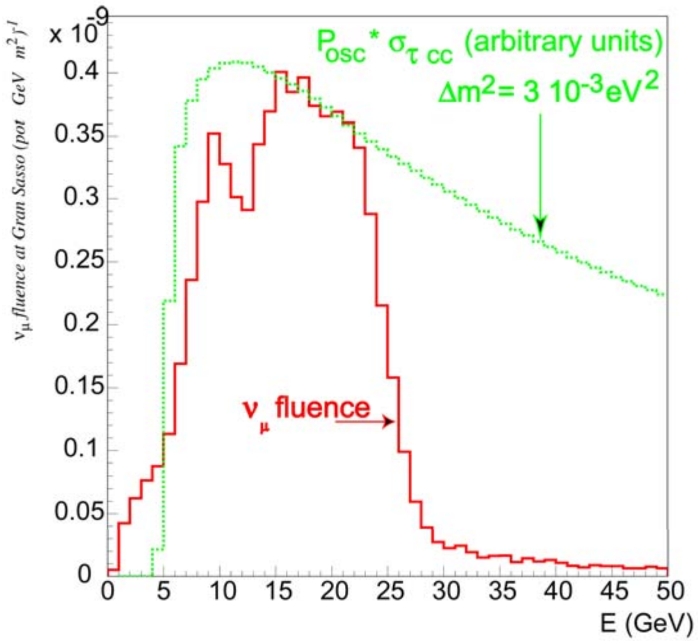
- Maximise efficiency
- Precise control of contamination to preserve the outstanding S/N of OPERA
- Possibly, increase of intensity for CNGS

Cern Neutrinos to Gran Sasso (CNGS)



Optimized for τ appearance

ν_μ CC / kton	**2900**
ν_μ NC / kton	**875**
$< E >_\nu$ (GeV)	**17**
$(\bar{\nu}_e + \nu_e)$ / ν_μ	**0.85 %**
ν_μ / ν_μ	**2.1 %**
ν_τ prompt	**negligible**

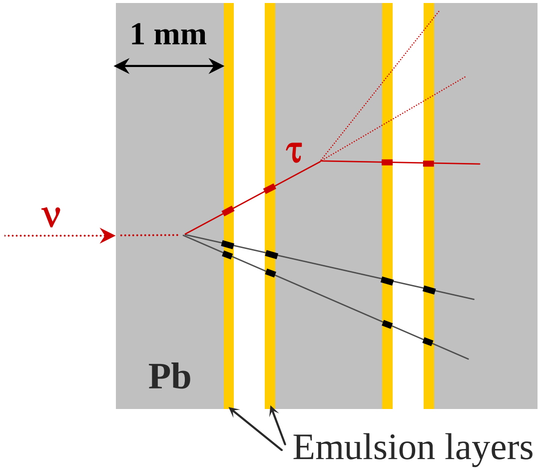


First Horn delivered to CERN – April 2004

Proton beam tunnel Feb. 2005

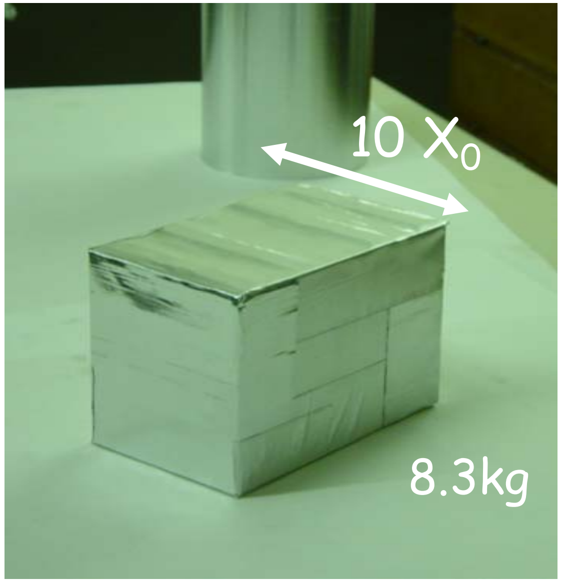
First quadrupole installed, July 2005

The OPERA experimental design



- Target based on the Emulsion Cloud Chamber (ECC) concept
- 56 1mm Pb sheets and 57 (300 μm thick) emulsion films
- At the same time capable of large mass (1.8 kton) and high spatial resolution (<1μm) in a modular structure

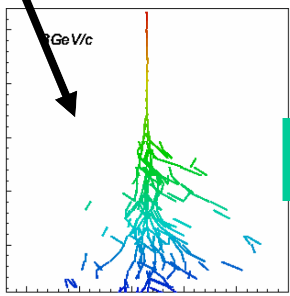
The basic unit : the « brick »



$10.2 \times 12.7 \times 7.5\ cm^3$

ECC topological and kinematical measurements

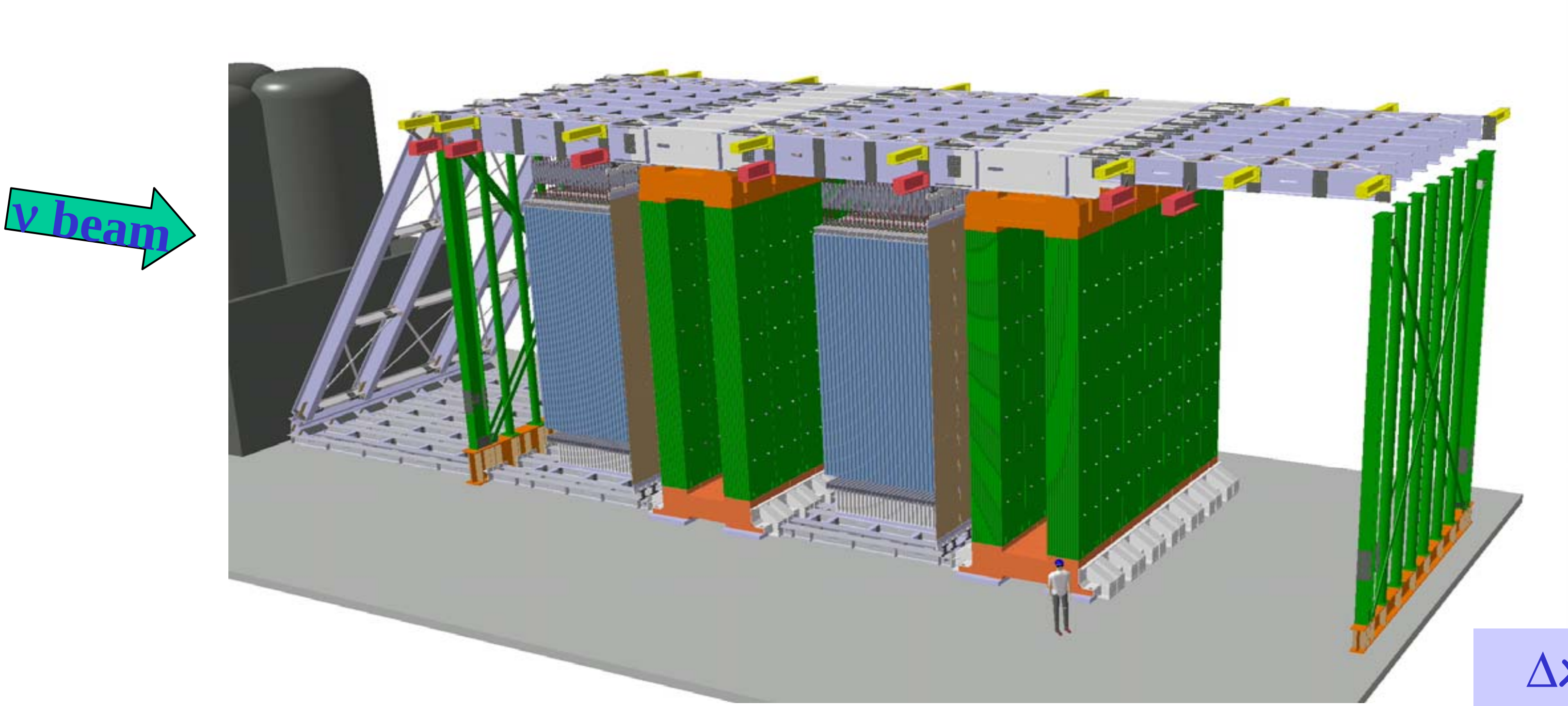
- Neutrino interaction vertex and decay topology reconstruction
- Measurement of hadron momenta by Multiple scattering
- dE/dx for **π**/μ separation at the end of their range
- Electron identification and energy measurement
- Visual inspection at microscope replaced by kinematical measurements in emulsion



8 GeV

ECC technique successfully used by DONUT for the ν_τ direct observation

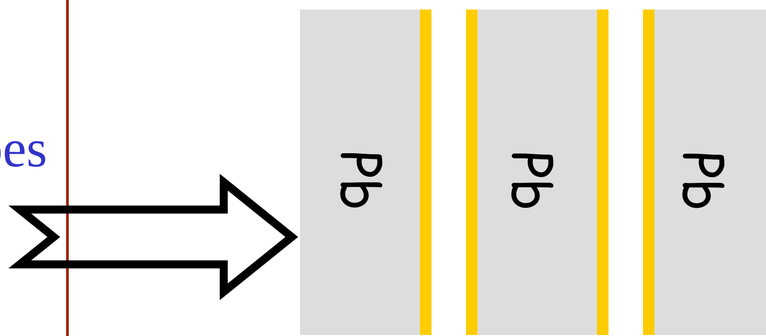
Detector concept



Δx<1μm
Δθ~2mrad

Hybrid Detector:

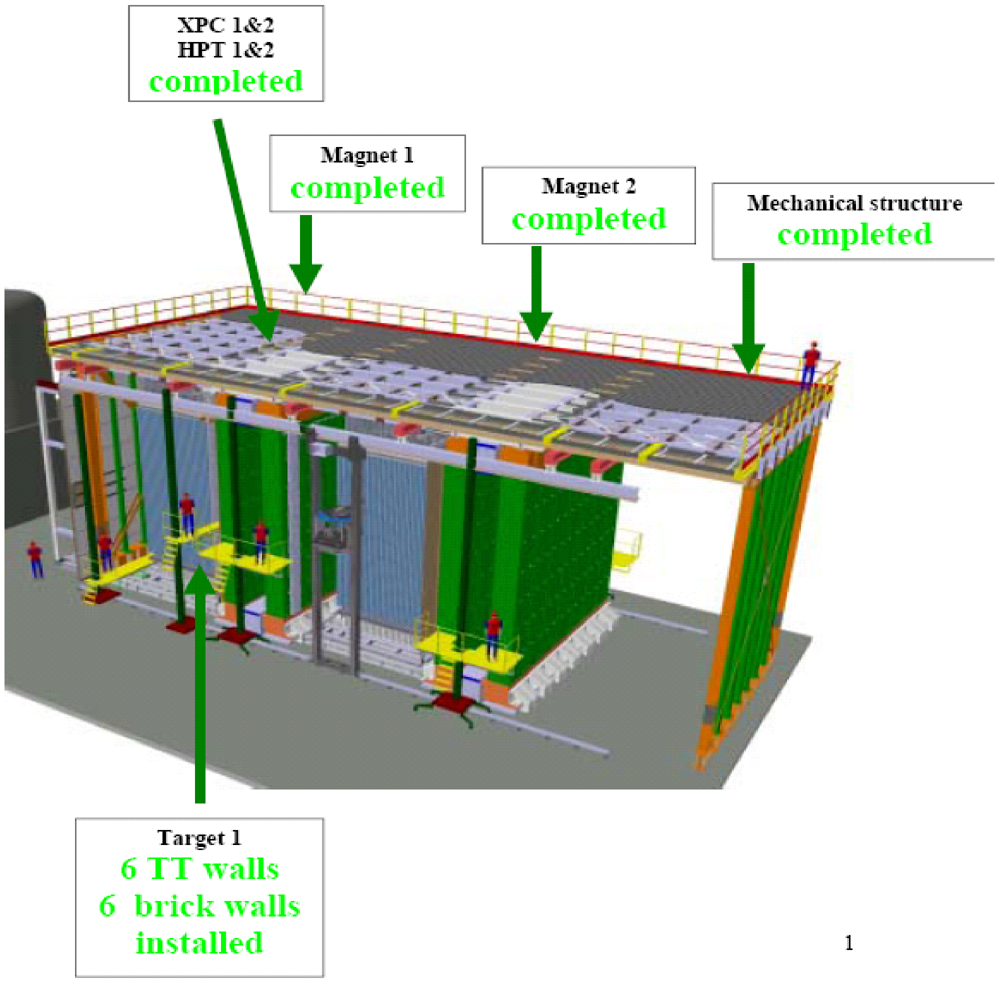
- Two supermodules – Target Mass 1766 tons
- 2 Magnetic spectrometers with RPC & Drift tubes
- 2 x [31 Target Tracker and Target Walls]
- 206,336 “ECC bricks” (56 Pb/Emulsion layers)
- 12 M Emulsion plates (thin double-coated)



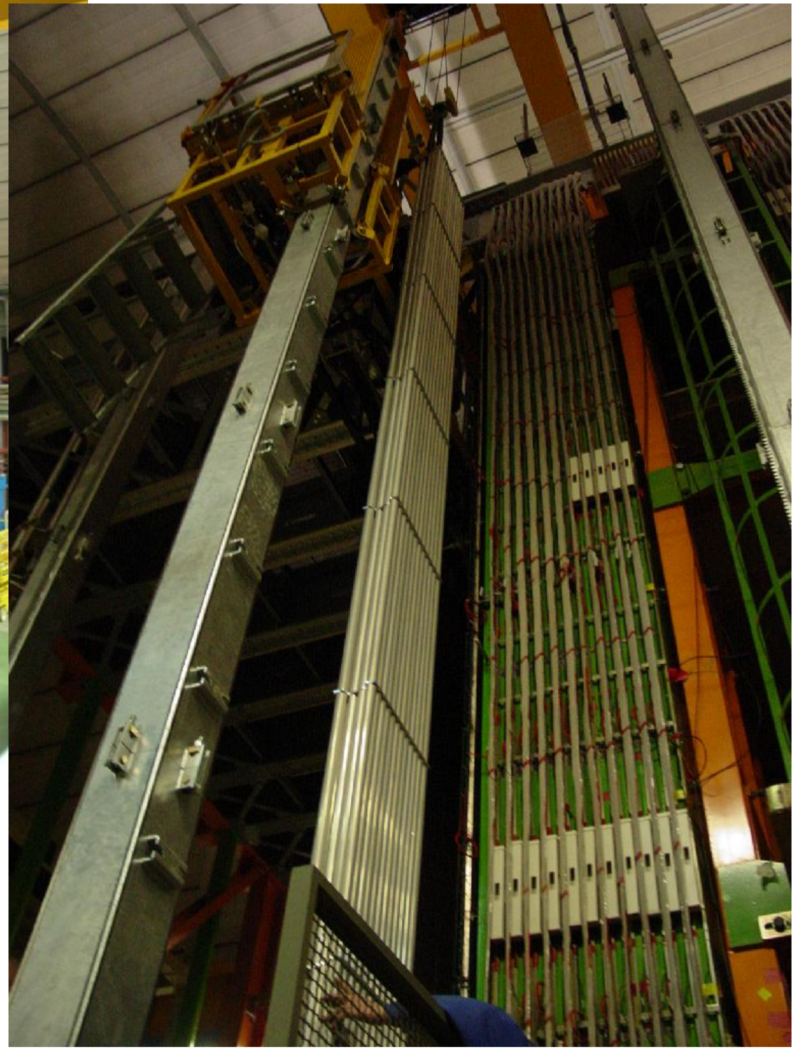
Status of the LNGS laboratory and OPERA

- After the Borexino accident, the underground labs underwent a major upgrade in order to improve safety
- A lot of work has been done (with some impact on the experiment schedule)
- A lot of work (highway pipe, truck gallery, Hall B and Hall A) still has to be done
  - Interference with underground activities still possible

In spite of this…




ASCOM

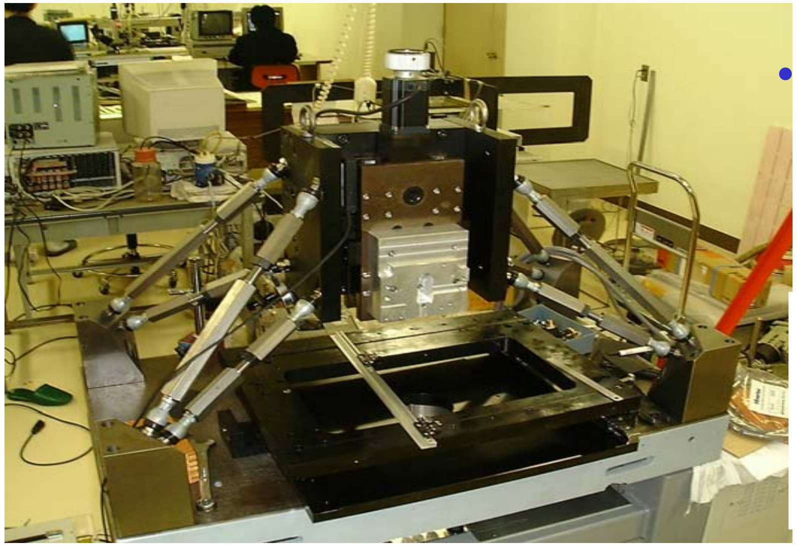


Nuclear emulsions

- Emulsions produced by Fuji-film (78% already produced in June 05)
- Stored at the Tono mine (Japan) and treated to reduce the background ("refreshing" procedure)
- Delivery at Gran Sasso after treatment
- First batch of 1.5 million films (~13%) arrived at Gran Sasso in January 2005
- 3 additional deliveries since then: about 50% of the emulsions already in Gran Sasso
- Brick filling will start on March 06 and last till Jul06

Emulsion scanning

- Real time analysis: several tens of bricks extracted/day
- About 1500 cm^2 to be scanned/day
- High speed (20 cm^2/h) fully automatic scanning systems (one order of magnitude faster than previous generation)
- independent R&D in Europe and Japan based on different approaches
- First prototype developed and tuned in Europe
- Successfully running since Summer 2004 with high efficiency (>90%), high purity (~2 tracks/ cm^2 /angle) and design speed
- 2 mrad accuracy at small incident angles

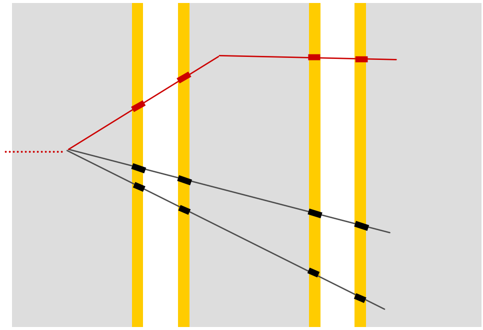


- Fast CCD camera (3 k frames/sec)
- Continuous movement of the X-Y stage

$\nu_\mu \rightarrow \nu_\tau$ search

Several τ decay channels exploited

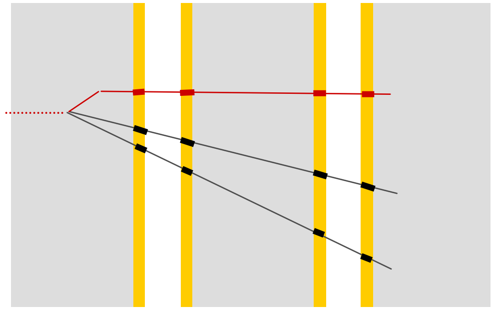
$\tau \rightarrow e\nu_\tau\nu_e$ " long decays "
$\tau \rightarrow \mu\nu_\tau\nu_\mu$ " long decays "
$\tau \rightarrow h$ " long decays "
ε.BR = 2.8-3.5%



kink angle θ_{kink} > 20 mrad

Fiducial volume

$\tau \rightarrow e\nu_\tau\nu_e$ " short decays "
$\tau \rightarrow \mu\nu_\tau\nu_\mu$ " short decays "
ε.BR = 0.7-1%



impact parameter I.P. > 5 to 20 μm

Recently added: **$\tau \rightarrow$ 3h long and short decays**

Main backgrounds:

- charm decays
- large angle μ scattering
- hadron reinteractions

$\nu_\mu \rightarrow \nu_\tau$ sensitivity

Full mixing, 5 years run @ 4.5 x10^{19} (6.7x10^{19}) pot / year

	signal (Δm^2 = 1.9 x 10^{-3} eV^2)	signal (Δm^2 = 2.4 x 10^{-3} eV^2)	signal (Δm^2 = 3.0x 10^{-3} eV^2)	BKGD
OPERA 1.8 kton fiducial	**6.6 (10)**	**10.5 (15.8)**	**16.4 (24.6)**	**0.7 (1.1)**
+ brick finding + 3 prong decay	**8.0 (12.1)**	**12.8 (19.2)**	**19.9 (29.9)**	**1.0 (1.5)**

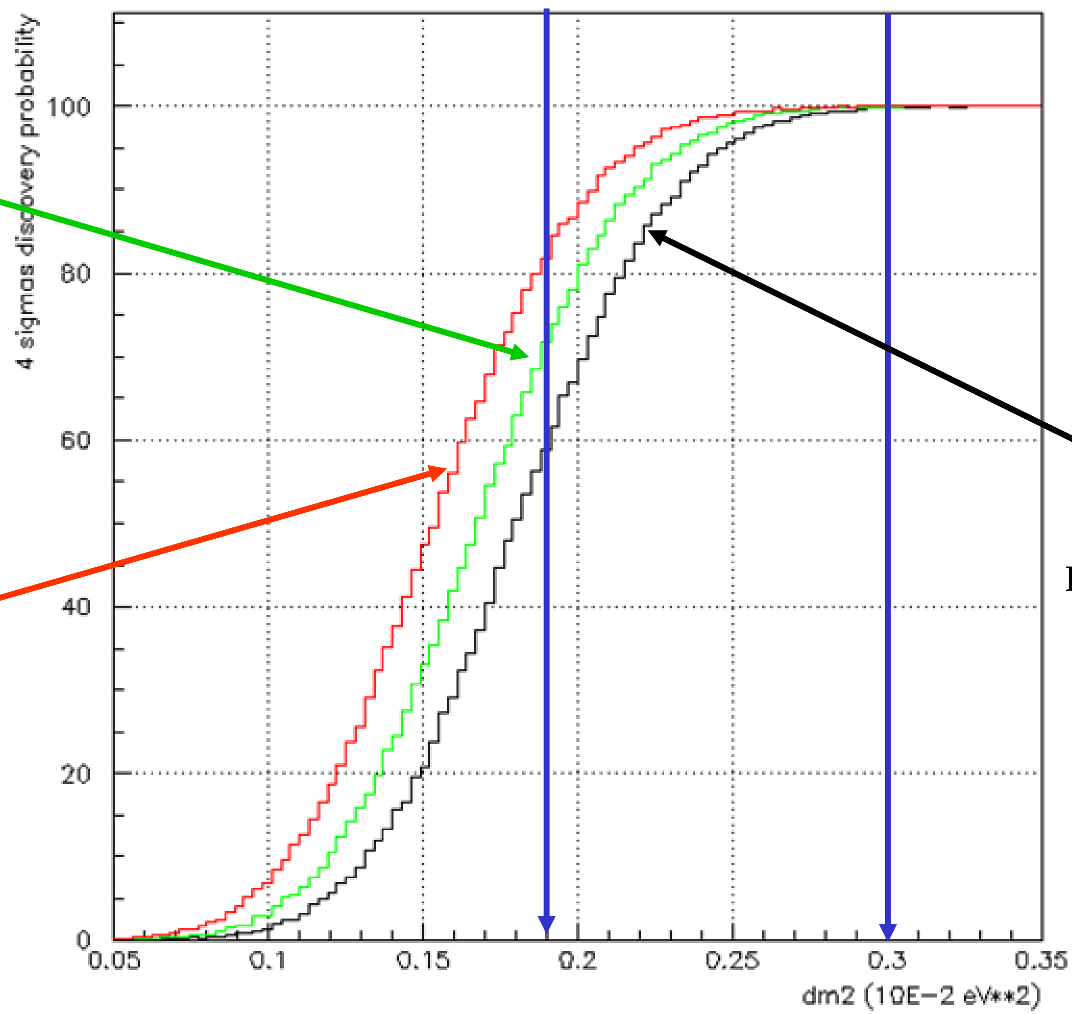
Background, 5 years run @ 4.5 x10^{19} pot / year

	$\tau \rightarrow e$	$\tau \rightarrow \mu$	$\tau \rightarrow h$	**total**
Charm background	.210	.011	.162	.382
Large angle μ scattering		.116		.116
Hadronic background		.093	.116	.209
Total per channel	.210	.219	.278	.707

OPERA 4σ discovery probability

(the prob that the observed signal is due to a back fluctuation is smaller than $6.3x10^{-5}$)

Opera with expected background improvements -30%



Opera, nominal background but $6.7x10^{19}$ pot / year

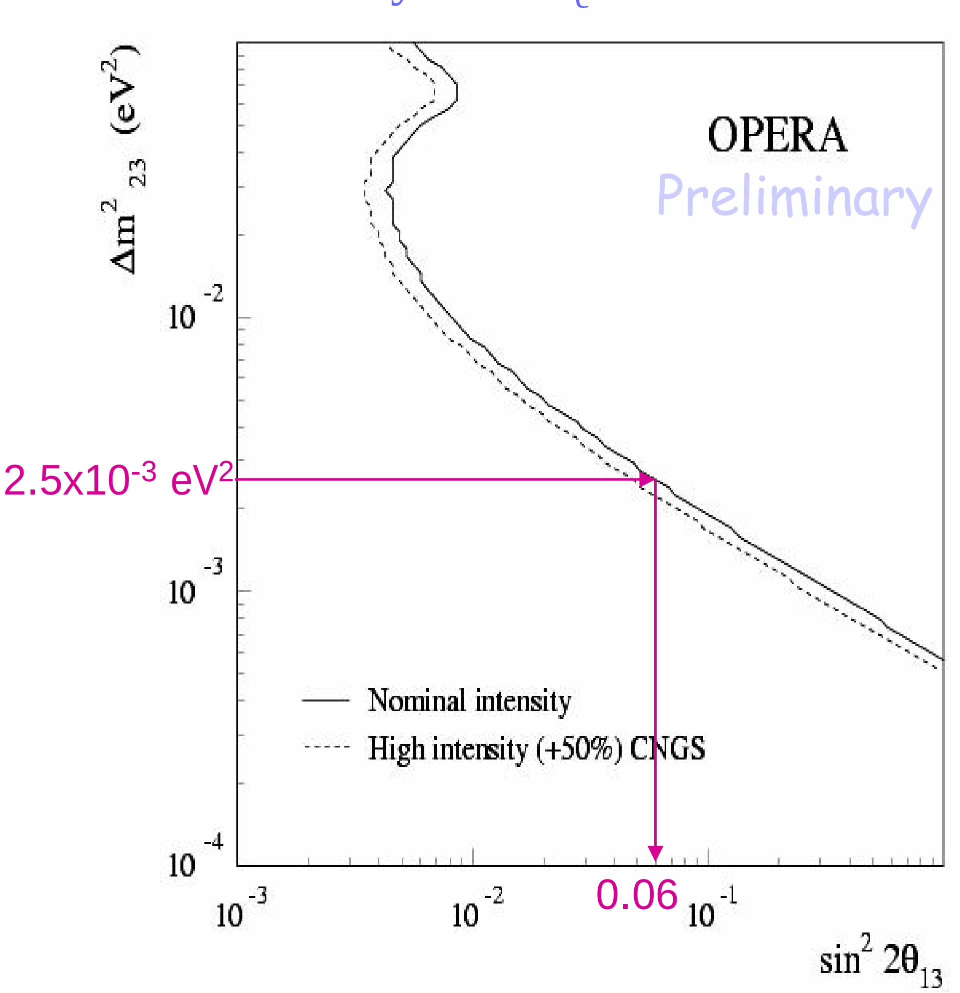
Opera nominal

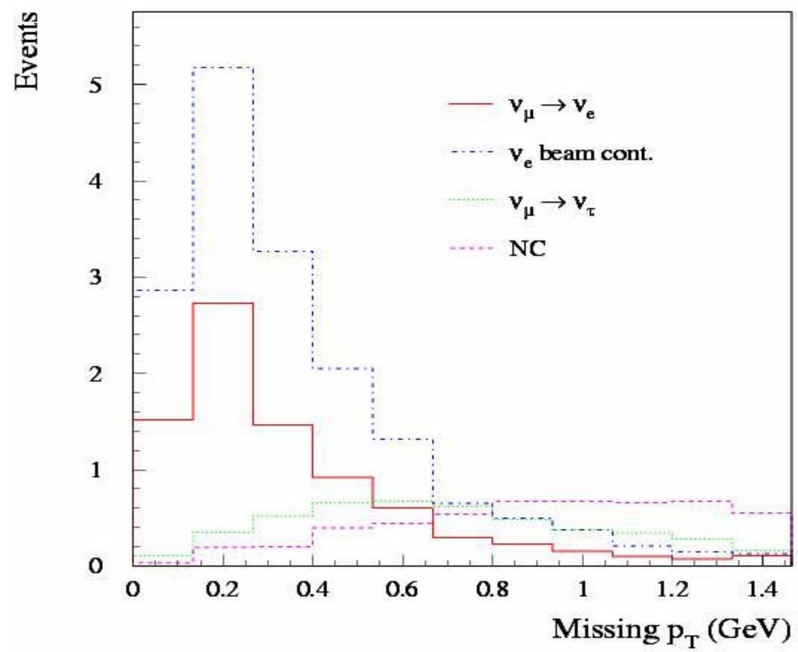
90% CL allowed region

OPERA sensitivity to θ_{13}

Simultaneous fit of E_e, missing p_T and E_{vis} distributions

10% syst. in ν_e contamination

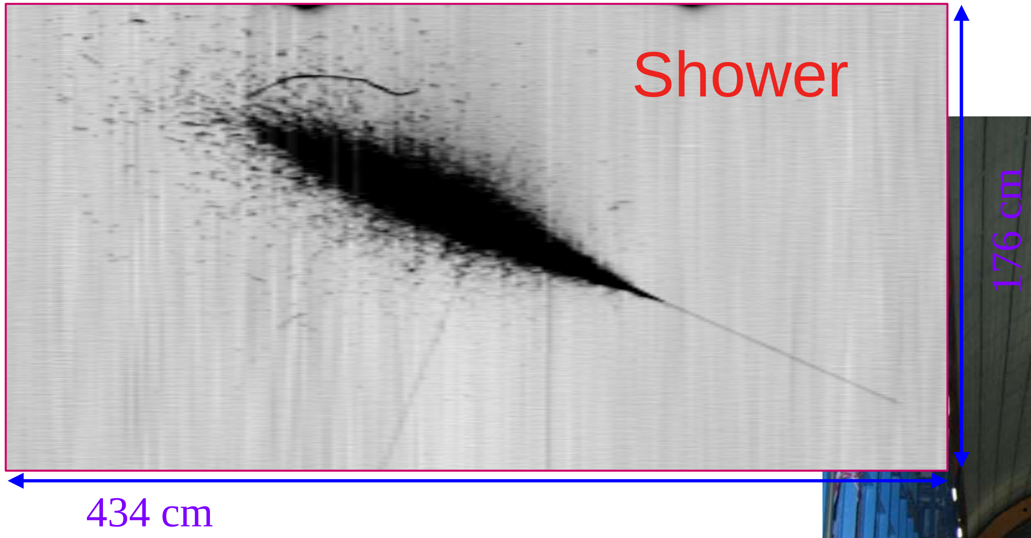


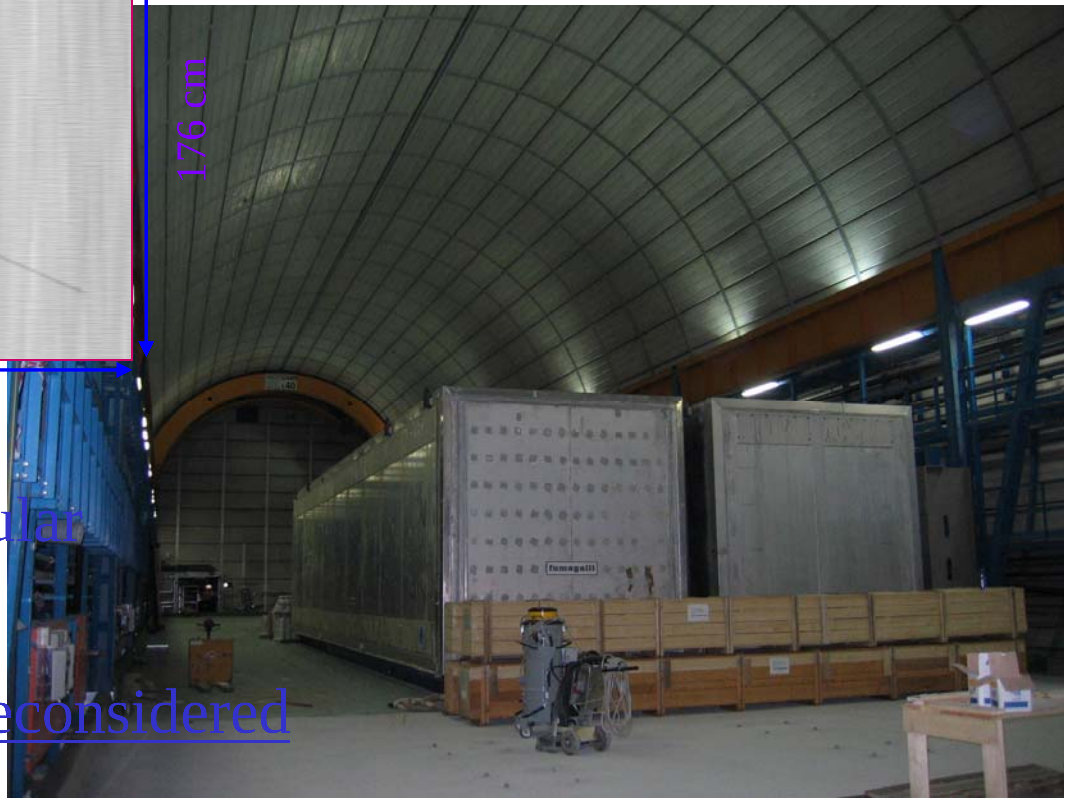


Limits at 90% CL for
$\Delta m^2 = 2.5\times10^{-3}$ eV^2 full mixing

	$\sin^2 2\theta_{13}$	θ_{13}
CHOOZ	**<0.14**	**11^0**
OPERA	**<0.06**	**7.1^0**

ICARUS T600 in Hall B at LNGS





Originally foreseen 3kt in modular structure

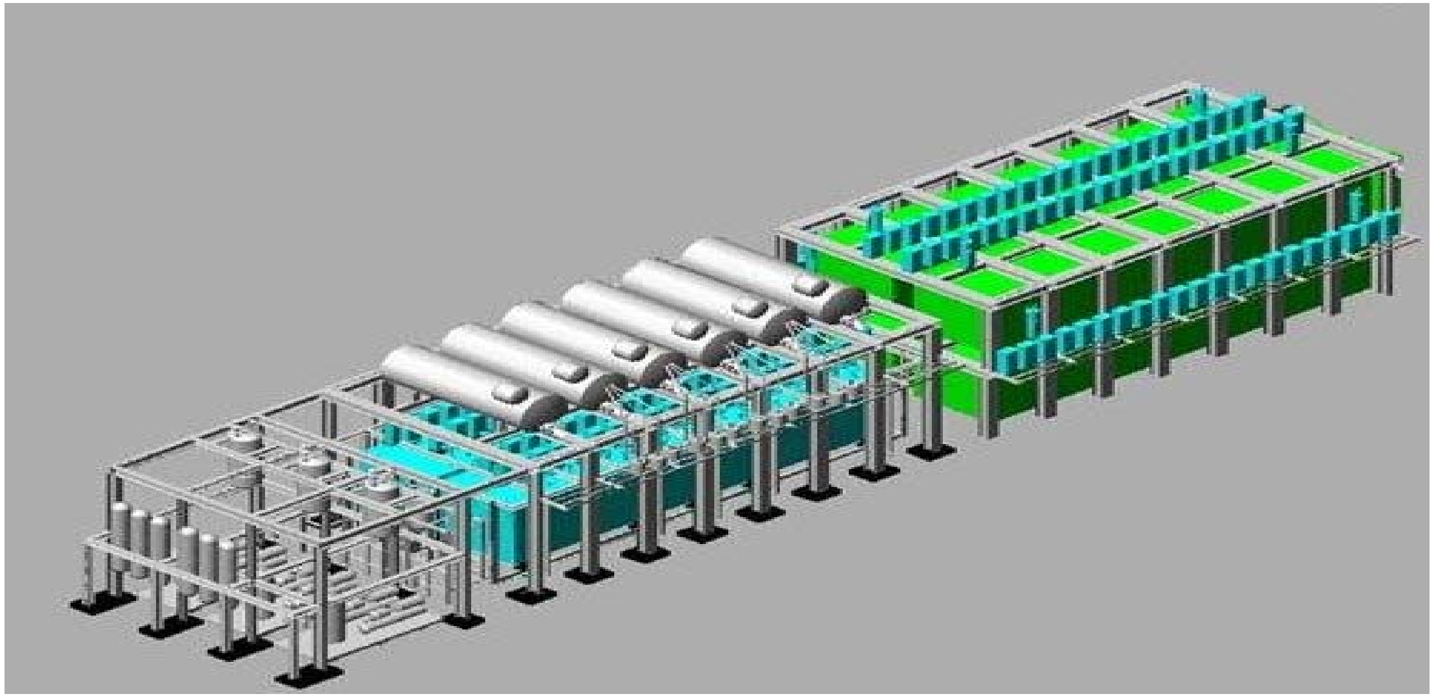
This option has been recently reconsidered

Even if T600 has a limited sensitivity (small mass) the operation of T600 at CNGS is a major step in the development of the Lar technology

T1800 detector

(1 year 0.47 kton+4 years 1.4 kton active LAr)

channel	Signal (Δm^2 (eV^2))			ε.BR	Background
	$1.6\ 10^{-3}$	$2.5\ 10^{-3}$	$3.0\ 10^{-3}$		
e	1.9	4.7	6.8	4.4%	0.3
ρ DIS	0.3	0.8	1.1	0.8%	<0.1
ρ QE	0.3	0.7	1.0	0.7%	<0.1
total	2.5	6.2	8.9	5.9%	0.3



Conclusions

- A large experimental effort is in progress to provide evidence of flavor appearance in neutrino oscillations
- The construction of CNGS and OPERA is in good shape, despite the difficulties experienced at LNGS after the 2002 accident
  - ✓ both spectrometers have been installed
  - ✓ the target of SM1 is being installed (no brick insertion)
  - ✓ one SM is expected to be ready by august 2006 (w/o interference with the LNGS works), while the second will be filled while data taking
- OPERA will start data taking in 2006 (half mass) and 2007 (full mass)
- ICARUS T600 operational during CNGS data taking
- We expect 4σ coverage of the SK allowed region in 5 years of data taking and to half the Chooz limit on θ_{13}