The Gran Sasso Underground Laboratory
a Status Report

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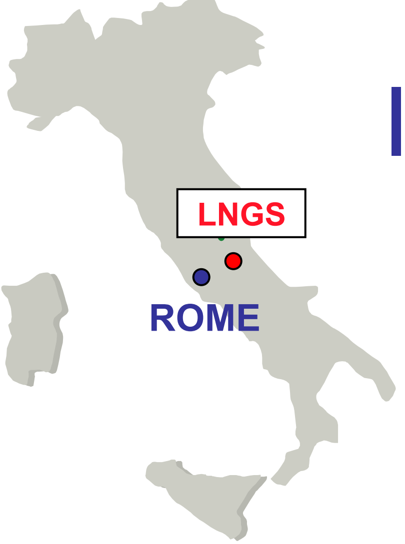
INFN Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali del Gran Sasso

Les Rencontres de Physique de la vallee d’Aoste
La Thuile - March 1, 2005

INFN Gran Sasso National Laboratory



QuickTime™ and a
Photo - JPEG decompressor
are needed to see this picture.

L'AQUILA

Tunnel of 10.4 km

TERAMO

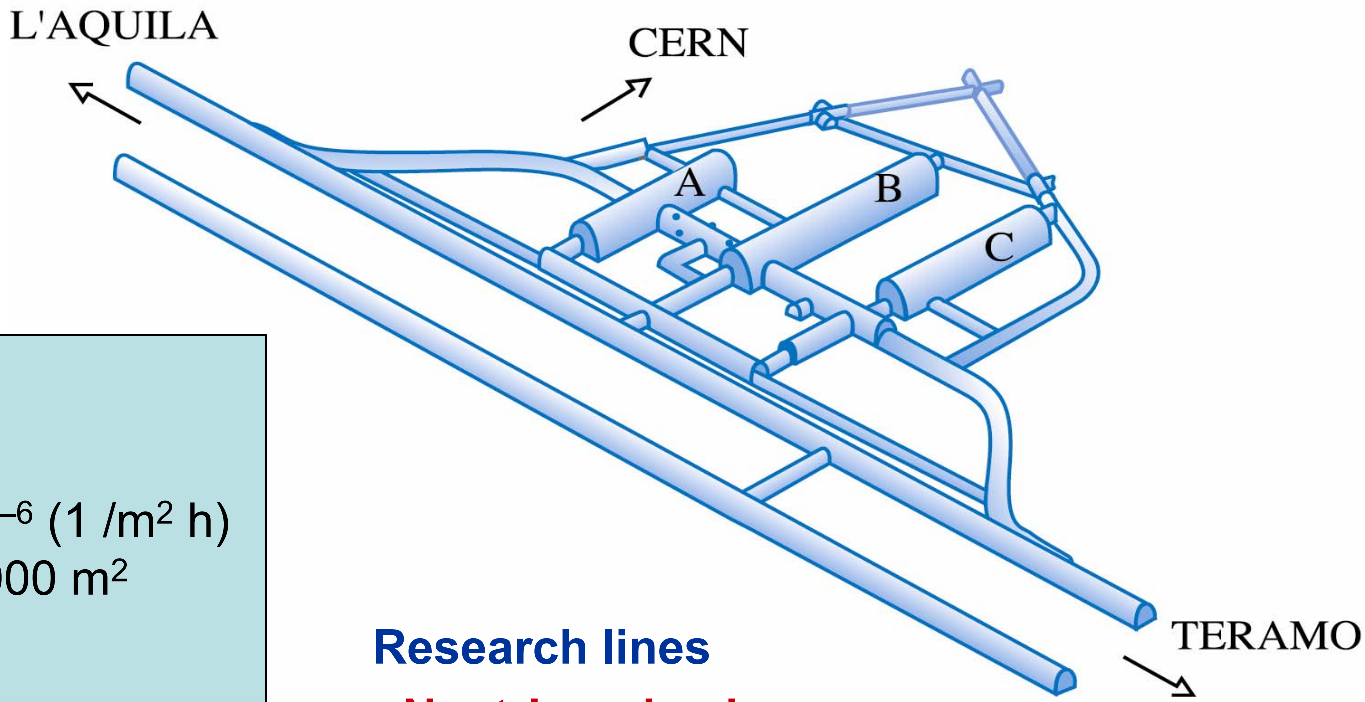
In 1979 A. Zichichi proposed to the Parliament the project of a large underground laboratory close to the Gran Sasso highway tunnel, then under construction

In 1982 the Parliament approved the construction, finished in 1987

In 1989 the first experiment, MACRO, started taking data

LABORATORI NAZIONALI DEL GRAN SASSO - INFN

Largest underground laboratory for astroparticle physics

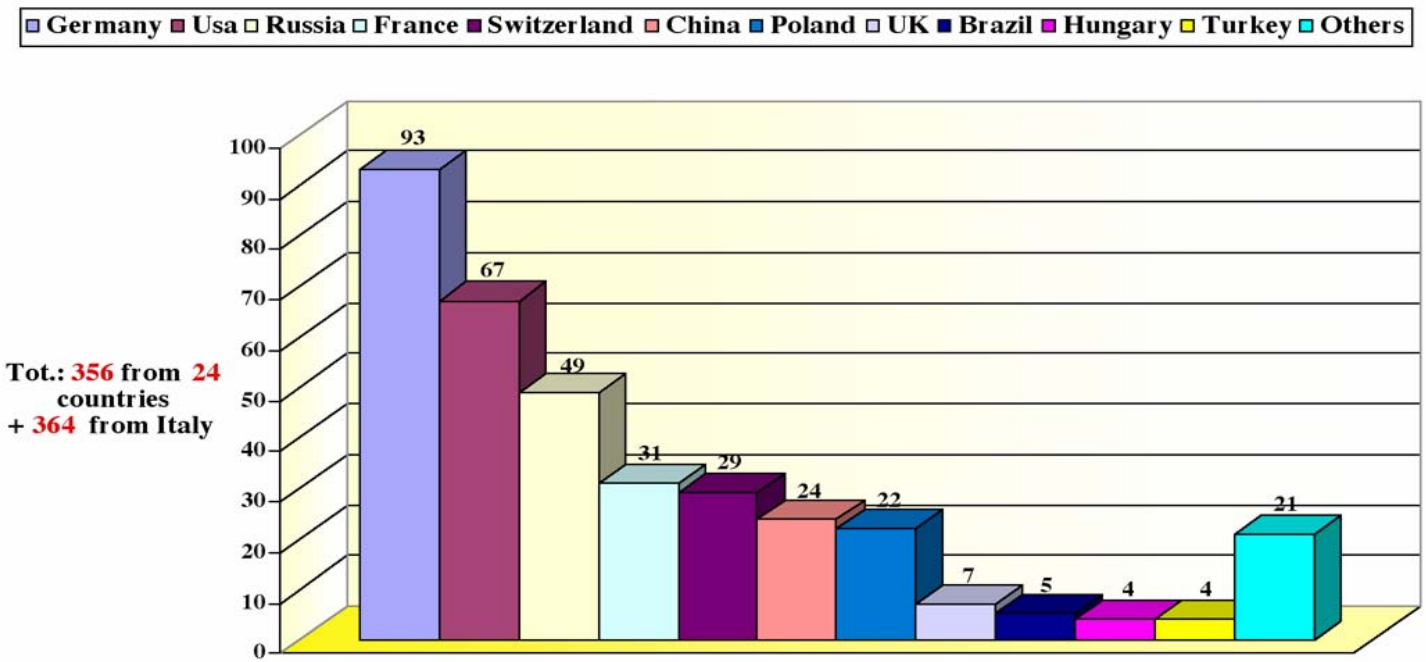


1400 m rock coverage
cosmic μ reduction= 10^{-6} (1 /m^2 h)
underground area: 18 000 m^2
external facilities
easy access
756 scientists from 25 countries
Permanent staff = 66 positions

Research lines

- **Neutrino physics**
  (mass, oscillations, stellar physics)
- **Dark matter**
- **Nuclear reactions of astrophysics interest**
- **Gravitational waves**
- **Geophysics**
- **Biology**

LNGS Users



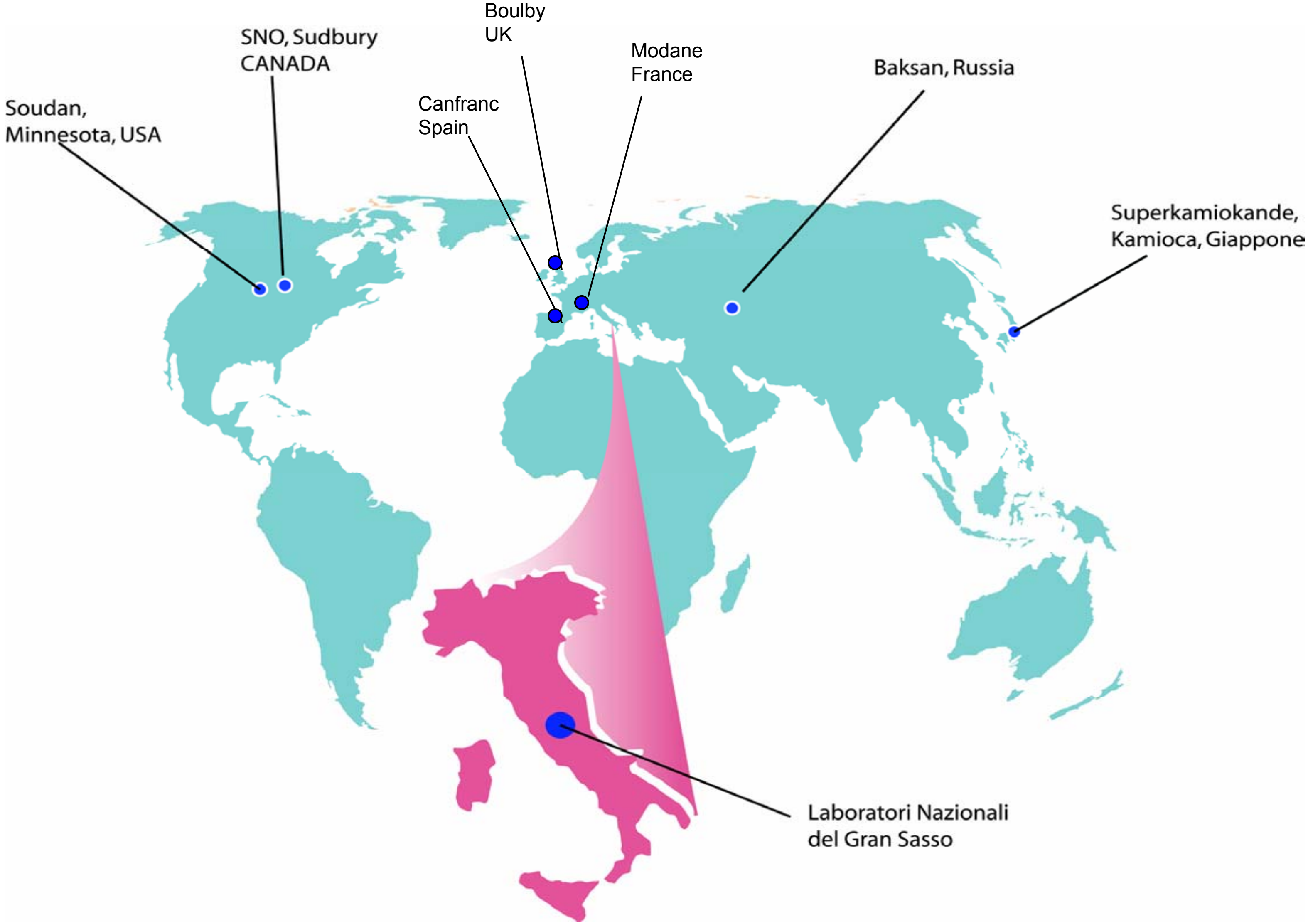
Foreigners: 356 from 24 countries

Italians: 364

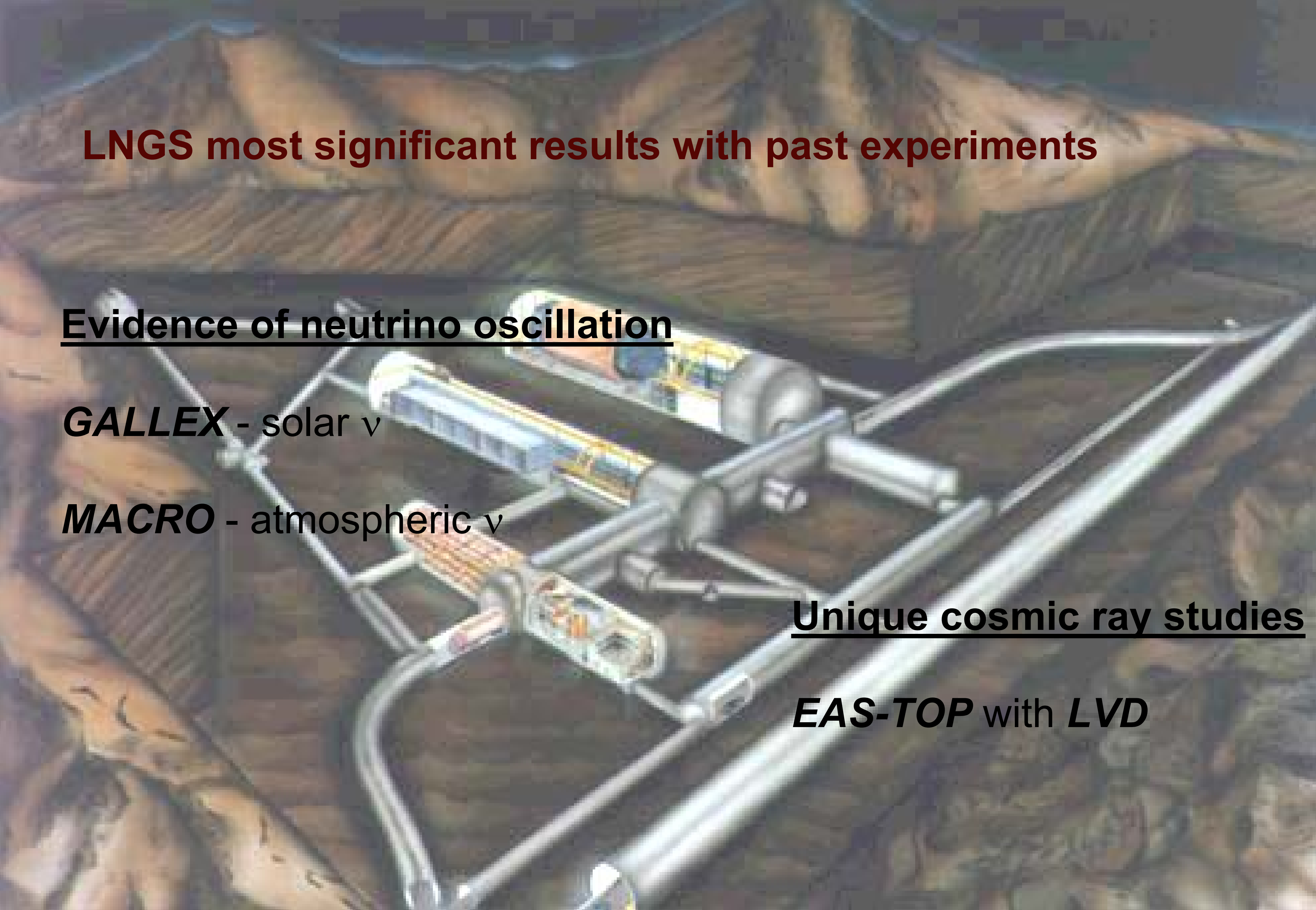
Permanent Staff: 64 people


External facilities
Administration
Public relationships support
Secretariats (visa, work permissions)
Outreach
Environmental issues
Prevention, safety, security
General, safety, electrical plants
Civil works
Chemistry
Cryogenics
Mechanical shop
Electronics
Computing and networks
Offices
Assembly halls
Lab & storage spaces
Library
Conference rooms
Canteen

Underground Laboratories



LNGS most significant results with past experiments



Evidence of neutrino oscillation

GALLEX - solar ν

MACRO - atmospheric ν

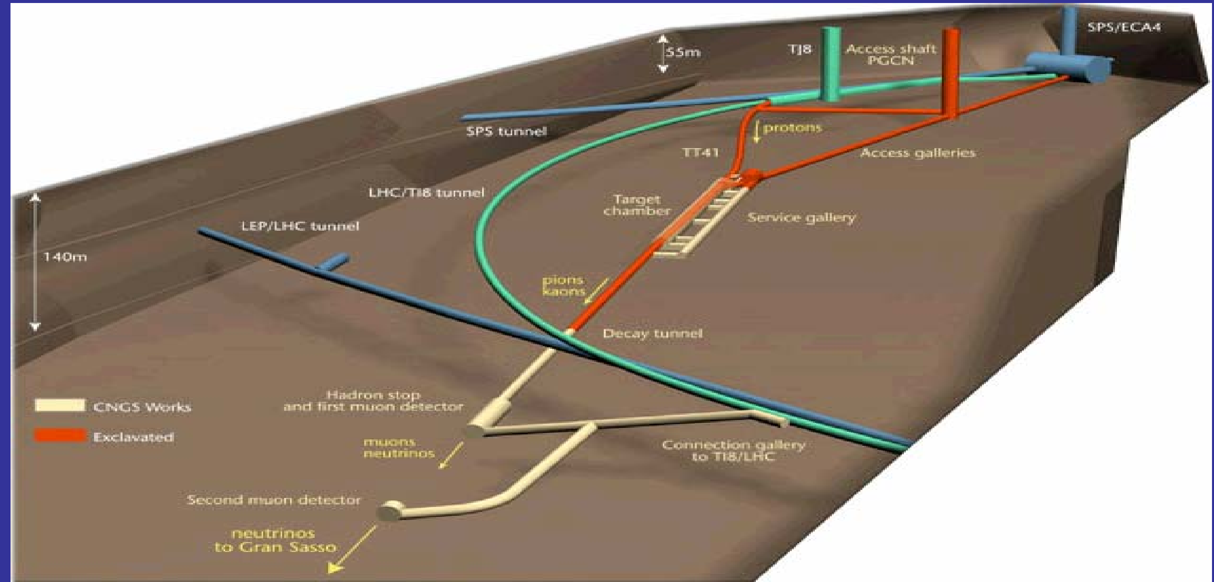
Unique cosmic ray studies

EAS-TOP with ***LVD***

ν beam from CERN:

ICARUS

OPERA



EXPERIMENTS

ββ decay and rare events

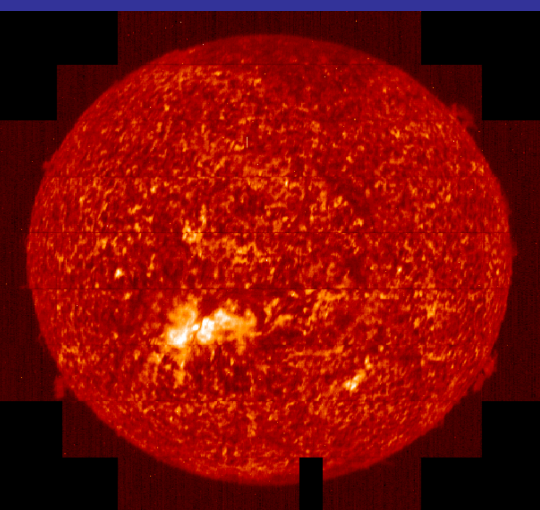
Cuoricino; HDMS; GENIUS-TF

CUORE; GERDA

Dark Matter

DAMA/LIBRA; CRESST

WARP; XENON



Solar ν

GNO

Luna

Borexino

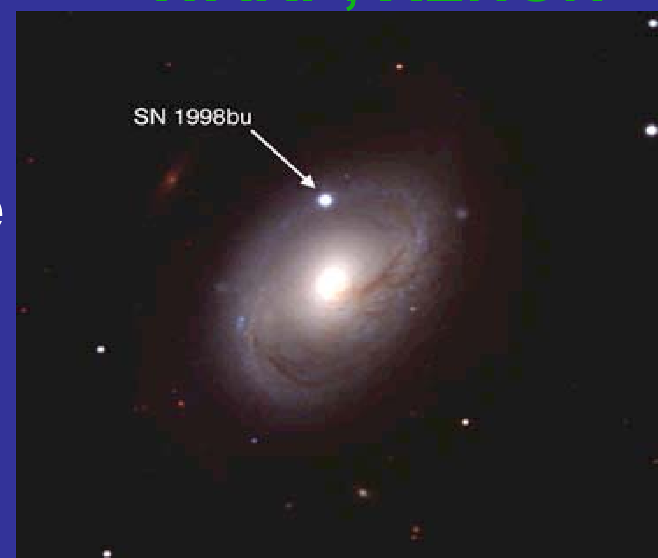
ICARUS

ν from Supernovae

LVD

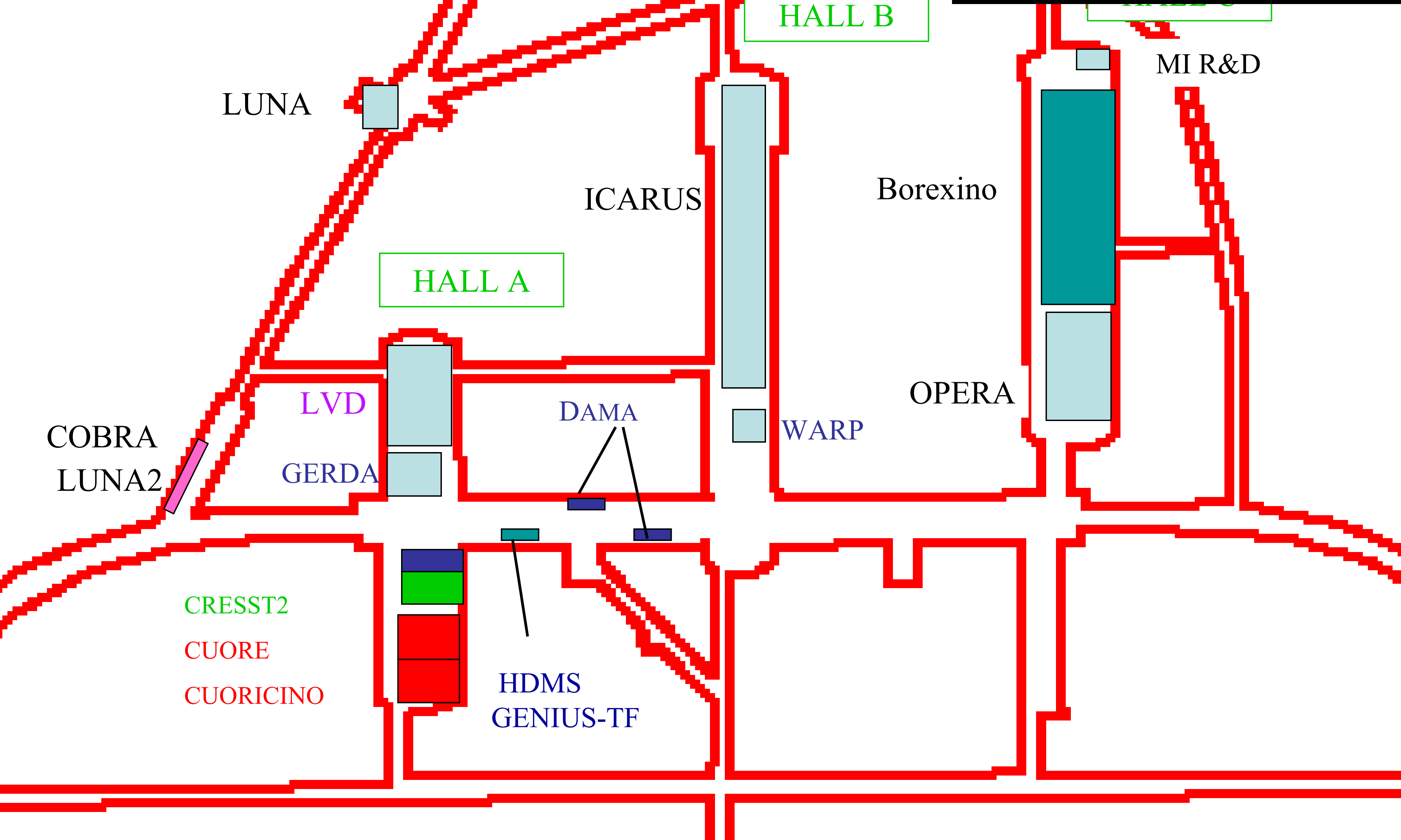
Borexino

ICARUS

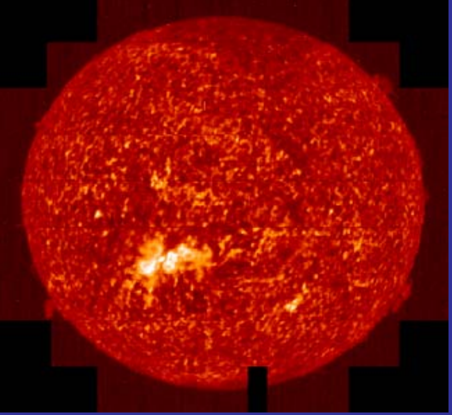


Occupancy

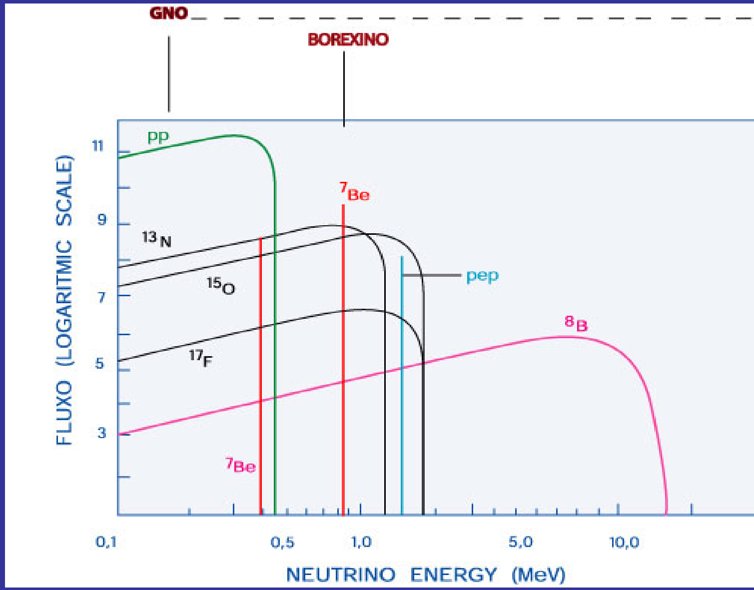
[redacted]



Gallex/GNO



GNO Goals: measurement of the interaction rate with an accuracy of 4-5% and monitoring the neutrino flux over a complete solar cycle.



101 tons Gallium Cloride solution

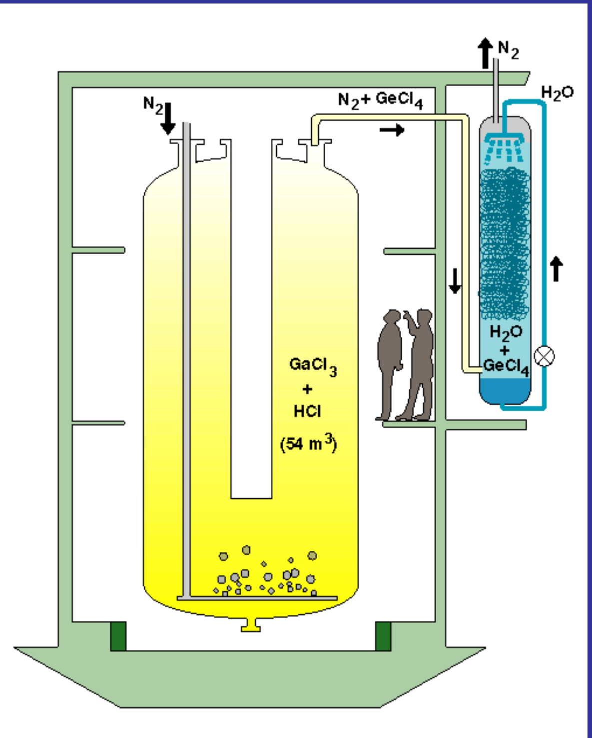
$^{71}Ge(\nu_e,e)^{71}Ge$

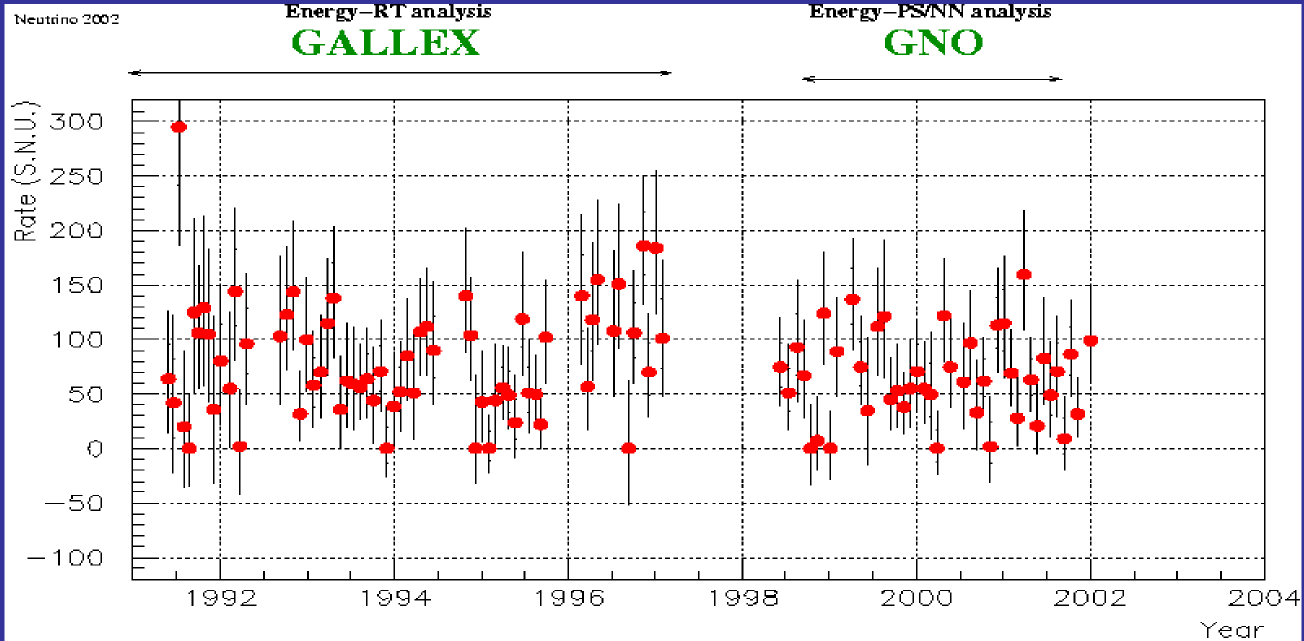
Energy threshold > 233 keV

Sensitive mainly to pp -neutrinos

Collab.:
Italy, France, Germany

SSM ⇒ 115 -135 SNU





GALLEX	65 SR	77.5 +– 6.2 (stat) +– 4.5 (sys) SNU
GNO	43 SR	65.2 +– 6.4 (stat) +– 3.0 (sys) SNU
GNO+GALLEX	108 SR	70.8 +– 4.5 (stat) +– 3.8 (sys) SNU

Why to perform low-energy solar neutrino experiments? [pp, ^{7}Be, pep]

Physics and astrophysics point of view:

- ❑Test how the Sun shines. Input parameters (Z/X, opacity, …) of SSM are correct? How much energy from CNO (1.6% from SSM)? Any other energy source?

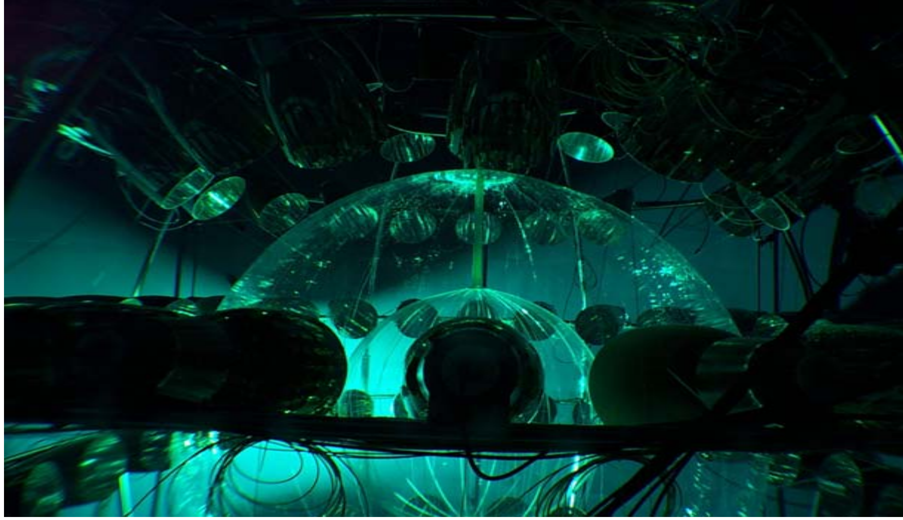
- ❑High precision neutrino flux and annual modulation determination. High precision mixing angle (θ_{12}) determination [with pp].

- ❑Test of vacuum-matter transition (energy dependence of ν oscillations). Search for new physics.

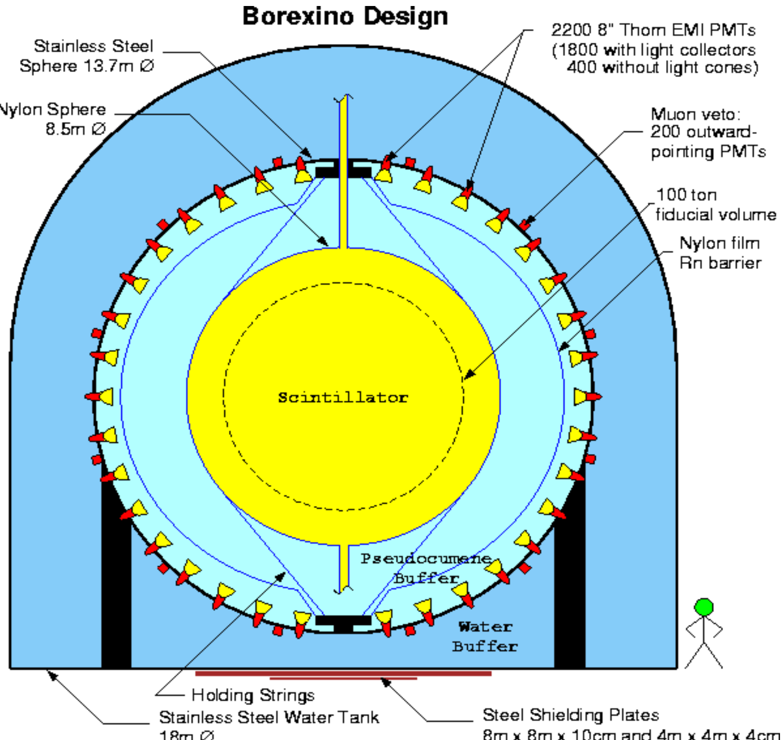
- ❑ CPT test by comparison with KamLAND

BOREXINO

300 tons liquid scintillator in a nylon bag
2200 photomultipliers
2500 tons ultrapure water
Energy threshold 0.25 MeV
Real time neutrino (all flavours) detector
Measure mono-energetic (0.86 MeV) ^{7}**Be** neutrino flux through the detection of ν-e.
40 ev/d if SSM



18 m diam., 16.9 m height



Sphere 13.7 m diam. Supports the P□Ms & optical concentrators
Space inside the sphere contains purified PC
Purified water outside the sphere

running in 2006

Collab.:
Italy, France, USA, Germany, Hungary, Russia, Belgium Poland, Canada

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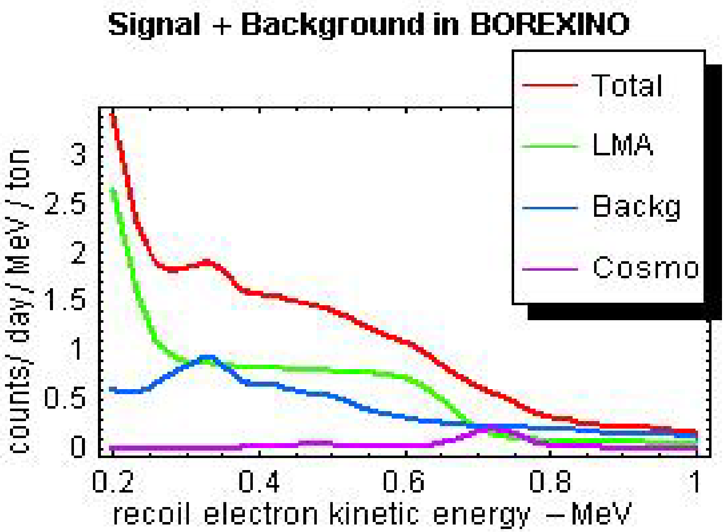
Borexino: how LNGS can search for low-energy solar neutrinos (only ^{7}Be and pep)

❑ **The possibility worldwide to measure low-energy solar neutrinos in the next 2-4 yr relies on Borexino (^{7}Be and pep) and KamLAND (only ^{7}Be)**

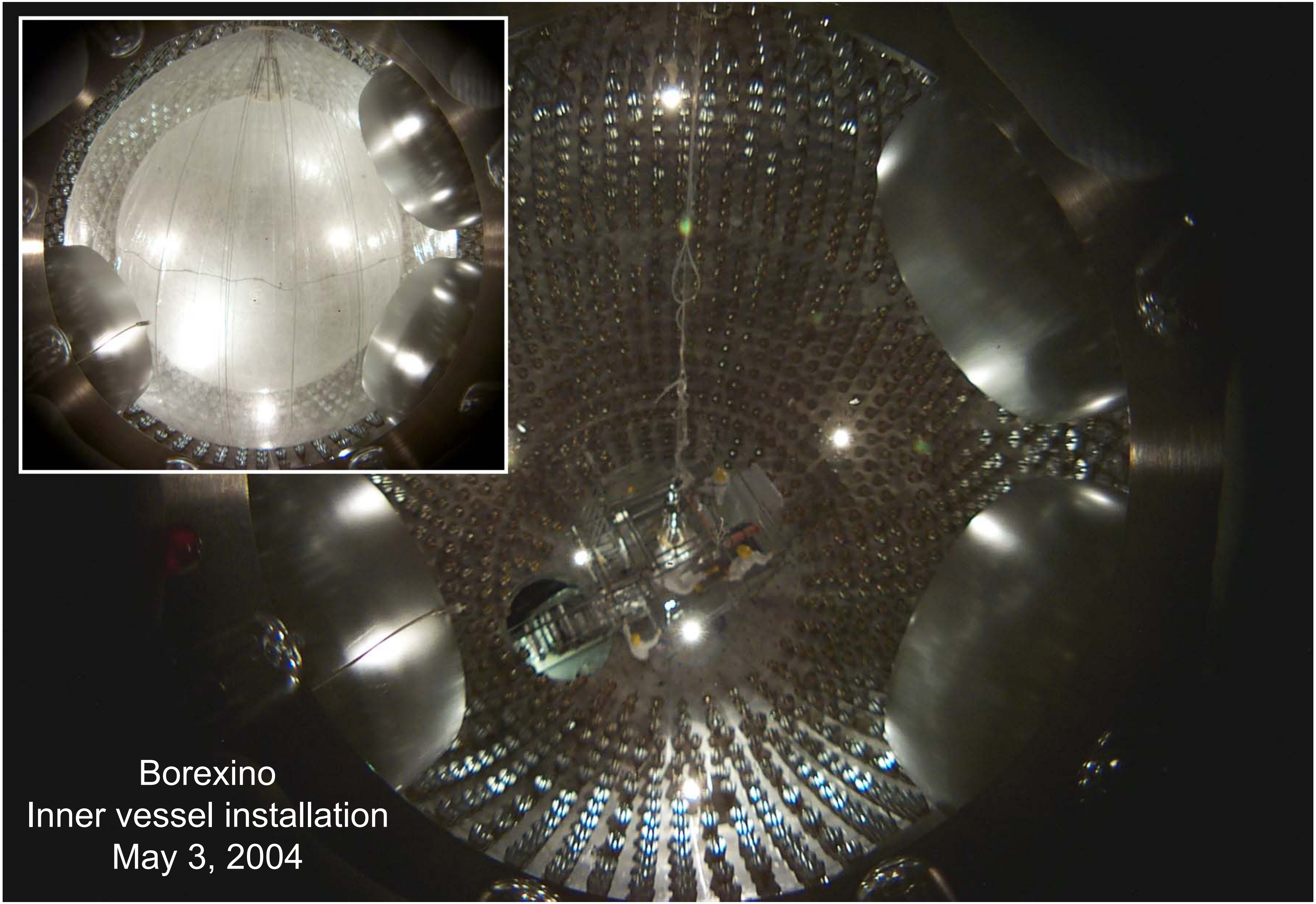
Assuming secular equilibrium for internal background

signatures and rates in Borexino:

- ✓ **$1/R^2$ signature due to the eccentricity of the Earth**
- ✓ **Compton-like edge for recoil electrons from ^{7}Be**
- ✓ **expected ~35(54) cpd in the LMA(SSM)**
- ✓ **expected ~1(2) cpd from pep neutrinos**



❑**With a 10% measu. of ^{7}Be the pp flux will be known at the level of 1%!**



Borexino
Inner vessel installation
May 3, 2004

LUNA **Laboratory for Underground Nuclear Astrophysics**

Study of the cross section of nuclear reactions at stellar energies

in particular for pp chain

2 accelerators: 50kV - 400kV

400 kV accelerator

$^{14}N(p,\gamma)^{15}O$ (CNO cycle)

Collab.:
Italy, Germany, Hungary
Portugal

pp chain

$p + p \rightarrow d + e^+ + \nu_e$

$d + p \rightarrow {}^3He + \gamma$

84.7 % — 13.8 %

$^3He + {}^3He \rightarrow \alpha + 2p$

$^3He + {}^4He \rightarrow {}^7Be + \gamma$

13.78 % — 0.02 %

$^7Be + e^- \rightarrow {}^7Li + \gamma + \nu_e$

$^7Be + p \rightarrow {}^8B + \gamma$

$^7Li + p \rightarrow \alpha + \alpha$

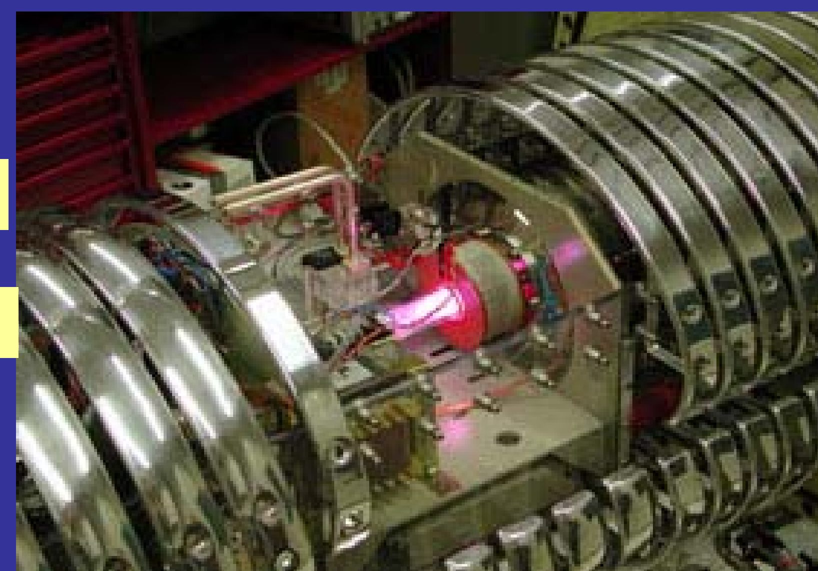
$^8B \rightarrow 2\alpha + e^+ + \nu_e$

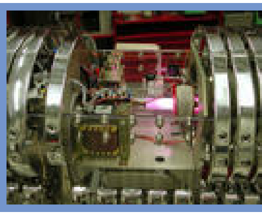
50 kV accelerator
3He(3He,2p)4He - $D(p,\gamma)^3He$

done

in 2003

INFN





The Universe, seen under the Gran Sasso mountain, seems to be older than expected

2004 May 13

Press release n. 42

Istituto Nazionale di Fisica Nucleare

2004 May 13

The Universe, seen under the Gran Sasso mountain, seems to be older than expected

Some nuclear fusion reactions inside stars occur more slowly than we thought and, as a consequence, stars themselves, as well as galaxies and the entire universe are a bit older than expected. This is what comes out from the last results of Luna experiment (Laboratory for Underground Nuclear astrophysics), settled by National Laboratories of Gran Sasso and realized in cooperation by Infn and Ruhr University in Bochum (Germany). The study, that will be published on the review Physics Letters B next June 17, has been published today on the website of the review. A second article has been accepted by the review Astronomy and Astrophysics.

LVD Large Volume Detector

Collab.:
Italy, Brazil, Russia, USA, Japan

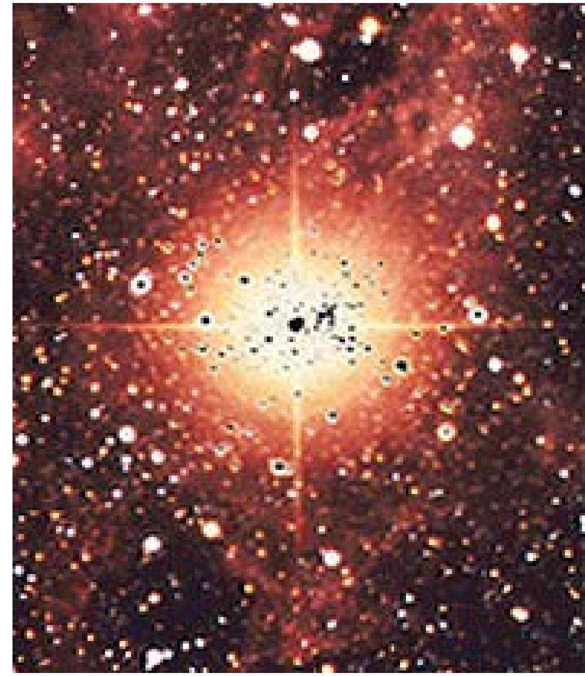
Running since 1992

1000 billions ν in 20s from the SN core
Measurement of neutrinos spectra and time evolution provides important information on ν physics and on SN evolution.
Neutrino signal detectable from SN in our Galaxy or Magellanic Clouds

2 - 4 SN/century expected in our Galaxy.
Plan for multidecennial observations

1000 tons liquid scintillator + layers of streamer tubes

300 ν from a SN in the center of Galaxy (8.5 kpc)



SN1987A

Early warning of neutrino burst important for astronomical observations with different messengers (Gravitational Waves)
SNEWS = Supernova Early Warning System
LVD, SNO, SuperK
in future: Kamland, BOREXINO

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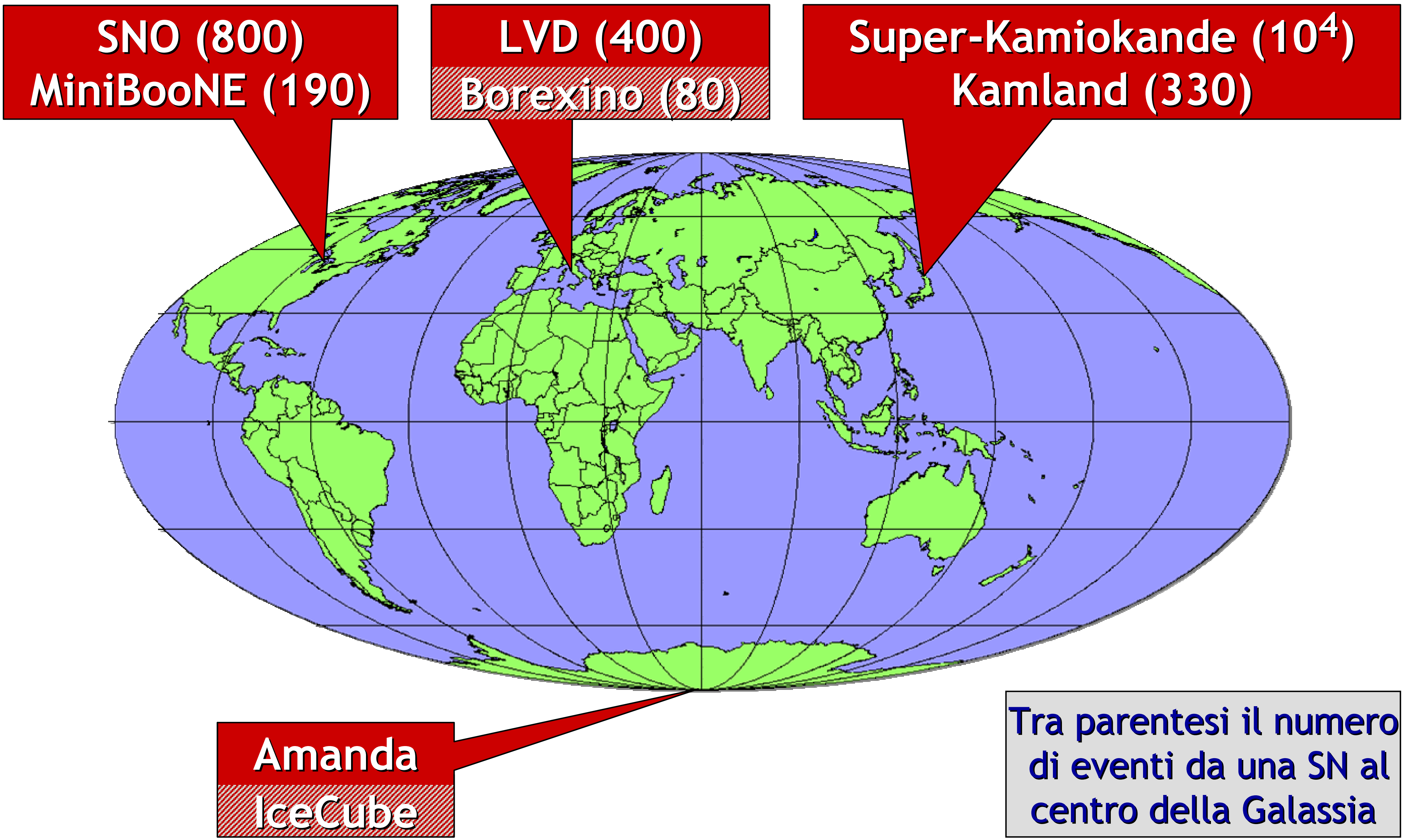
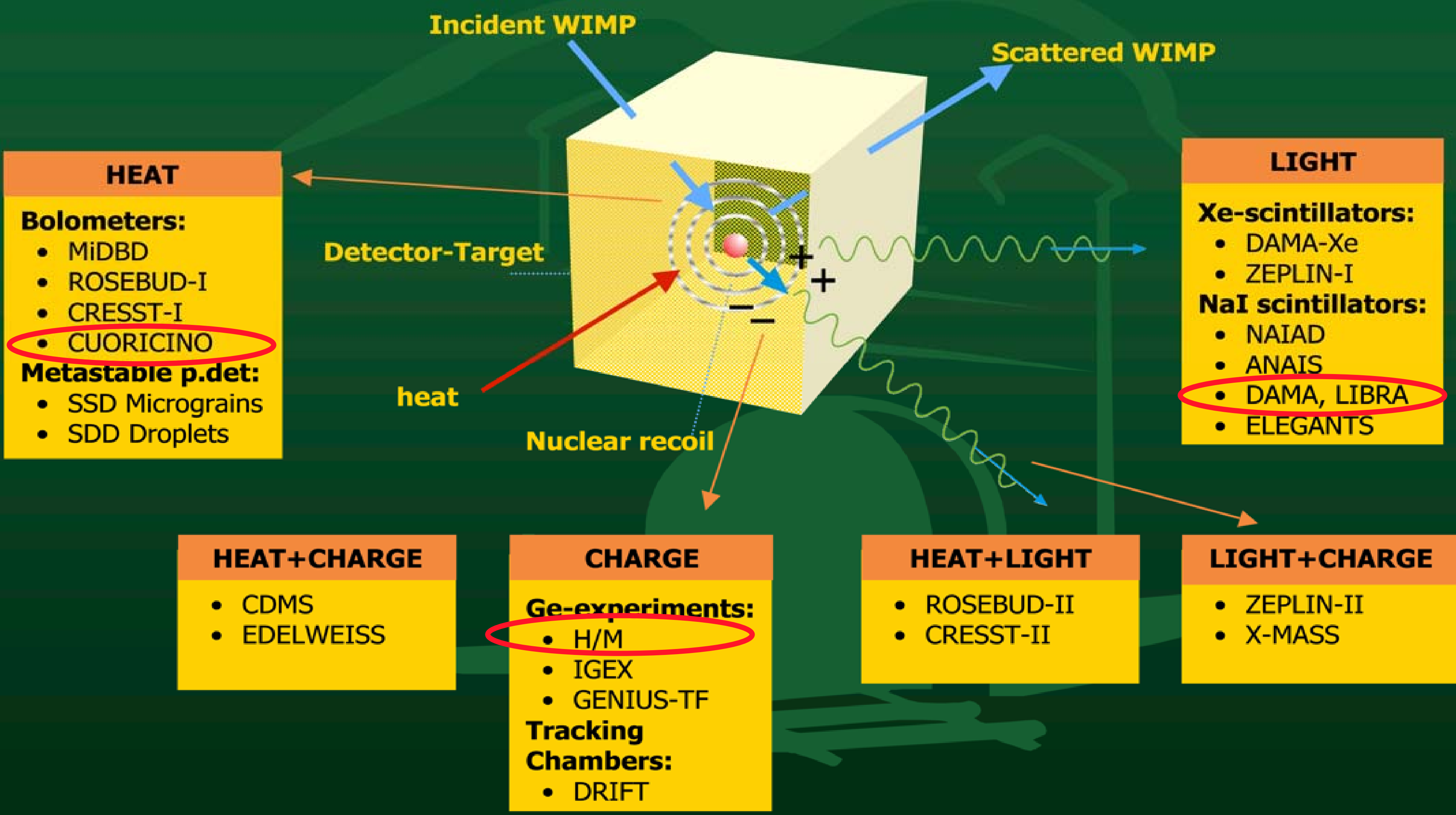


Tra parentesi il numero di eventi da una SN al centro della Galassia

Direct Detection Methods



DAMA

Dark Matter Search

Collab.:
Italy, China, Ukraine

Detection of WIMPs (Weakly Interacting Massive Particle) through the flash of light produced by a Iodine nucleus recoiling after having been hit by the WIMP.

DAMA looking for annual modulation with 100 kg NaI(Tl)

DAMA/NaI-1 to -7

107731 kg · d

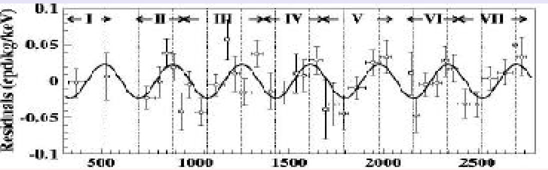
Annual modulation of the rate: the model independent result

Residuals of the rate vs time and energy

Riv. N. Cim. 26 n.1. (2003) 1-73

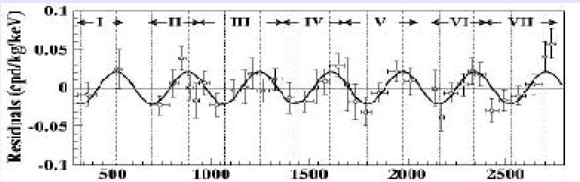
Acos[ω(t-t_0)] ; continuous lines: t_0 = 152.5 d, T = 1.00 y

2-4 keV



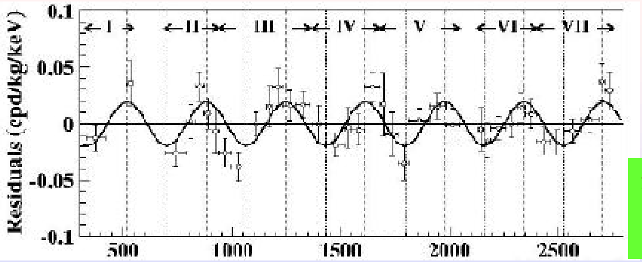
fitted: A = (0.0233 ± 0.0047) cpd/kg/keV

2-5 keV



fitted: A = (0.0210 ± 0.0038) cpd/kg/keV

2-6 keV



P(A=0)=$7\cdot10^{-4}$
χ^2/dof=71/37
fitted: A = (0.0192 ± 0.0031) cpd/kg/keV

fitted (all parameters free):
A = (0.0200 ± 0.0032) cpd/kg/keV ;
t_0 = (140 ± 22) d ; T = (1.00 ± 0.01) y

The data favor the presence of a modulated behavior with proper features at 6.3σ C.L.

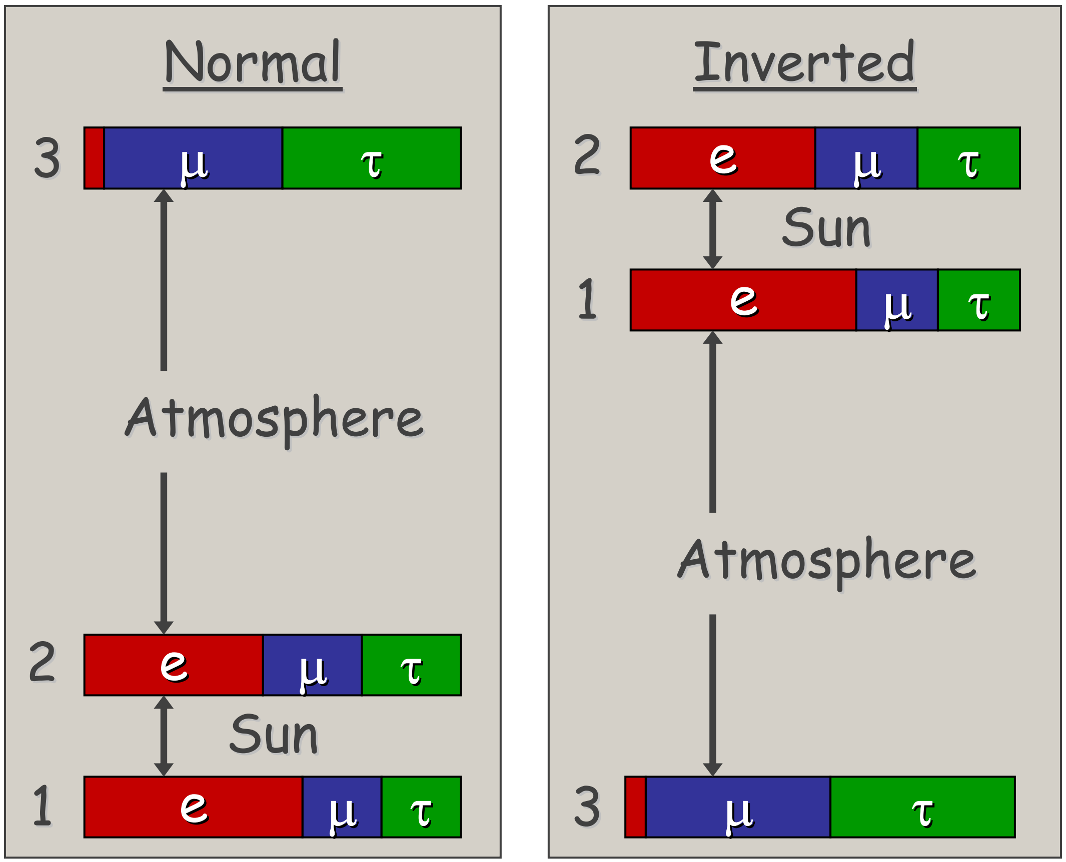
Present:

DAMA/LIBRA

250 kg NaI(Tl)

R&D in progress towards a possible 1 ton set up

Emerging picture

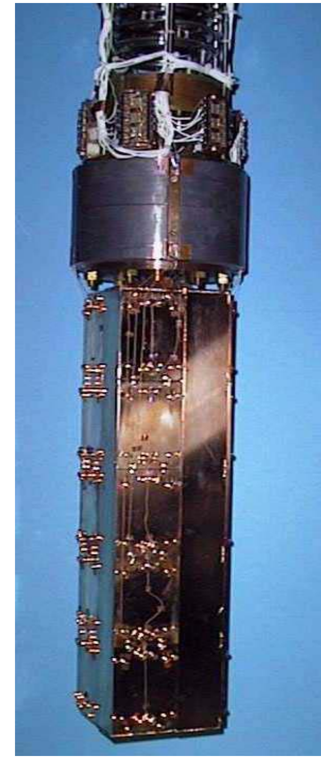


Tasks and Open Questions

- Precision for θ_{12} and θ_{23} ($\theta_{12} < 45°$ and $\theta_{23} = 45°$?)
- How large is θ_{13}?
- CP-violating phase?
- Mass ordering? (normal vs inverted)
- Absolute masses? (hierarchical vs degenerate)
- Dirac or Majorana?

- Anything beyond?

$\beta\beta$ decay neutrinoless experiments



β decay n --> p + e- + $\bar{\nu}$

$2\beta0\nu$ is a very rare decay: T(half life) ≥ 10^{-25} years)

$\nu = \bar{\nu}$

→Upper limit on the mass of ν_e 0,39 eV

Majorana neutrino

Heidelberg-Moscow
11 kg of enriched ^{76}Ge detect.
The most sensitive experiment in the world
$^{76}Ge \rightarrow {}^{76}Se + 2e^-$

Collab.:
Germany, Russia

GENIUS-TF
Test facility for GENIUS
40 kg HM Ge

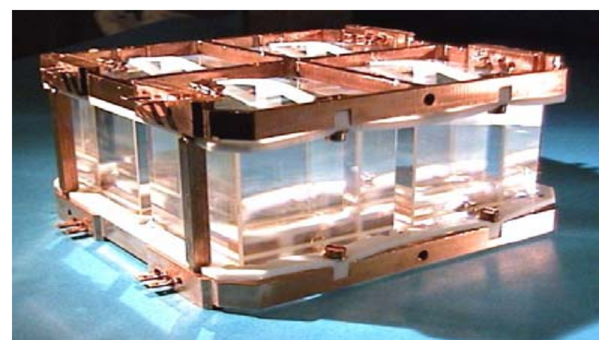
Proposed: GERDA
Sensitive mass: 1 ton enriched Ge crystals in Liquid N_2

MIBETA (Milan)
20 detectors of natural TeO_2 crystals
^{130}Te mass = 2.3 kg

CUORICINO
Sensitive ^{130}Te mass = 40 kg
Status: running

CUORE
proposal presented in 2003
^{130}Te mass = 250 kg

Collab.:
Italy, Netherland, Spain, USA



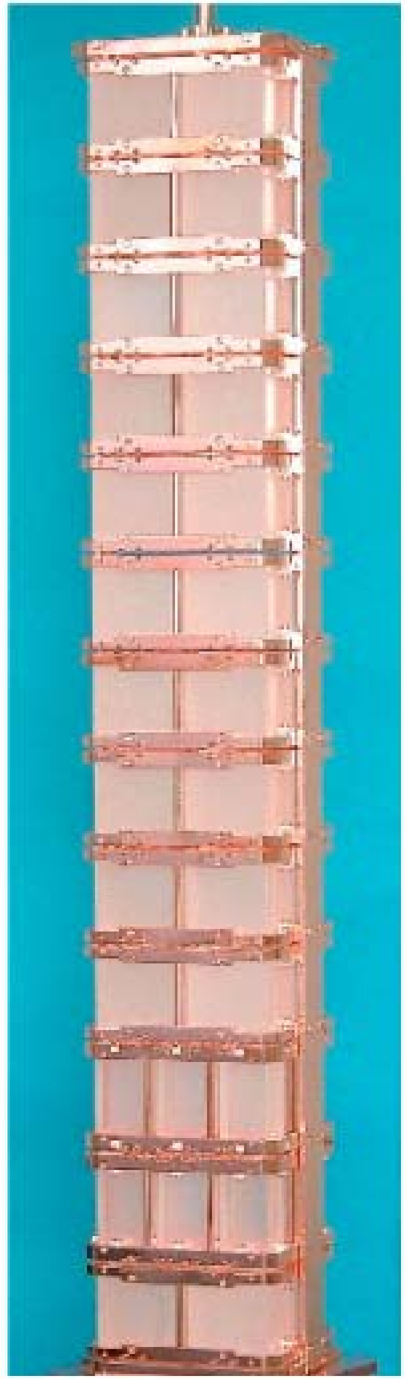
Cuoricino

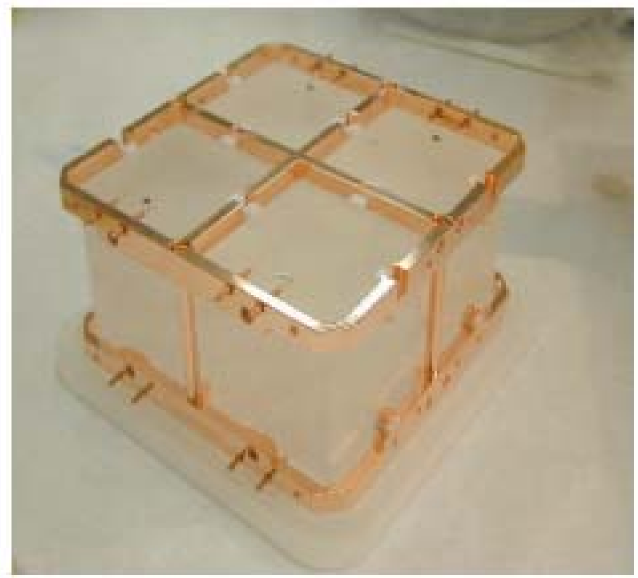
The CUORICINO set-up, 11 planes of 4 cristals 5x5x5 cm^3 and 2 planes having 9 cristals 3x3x6 cm^3 of TeO_2 . The total mass is 40 kilograms, one order of magnitude bigger than other cryogenic detector

The experiment is in data taking at Gran Sasso

With Cuore neutrino mass sensitivity $< 10^{-2}$ eV
(dependent from the model)

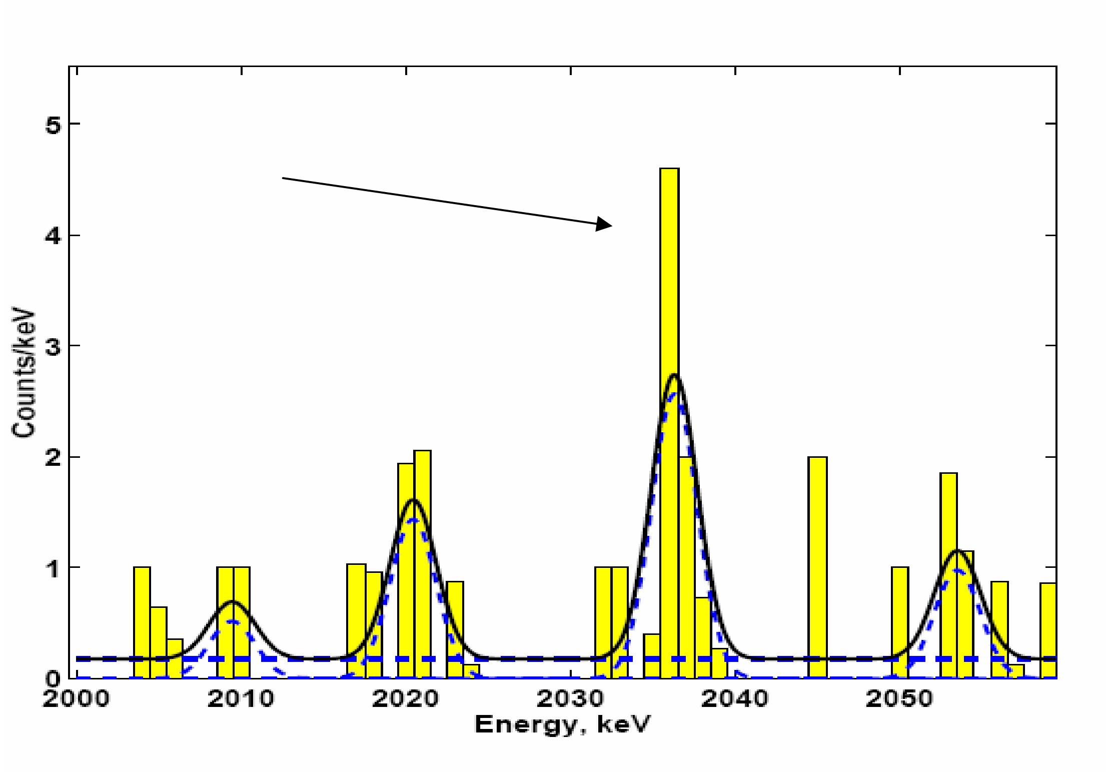
Now m < 0.4-2 eV





Neutrino masses and 0ν2β decay Heidelberg Moscow experiment

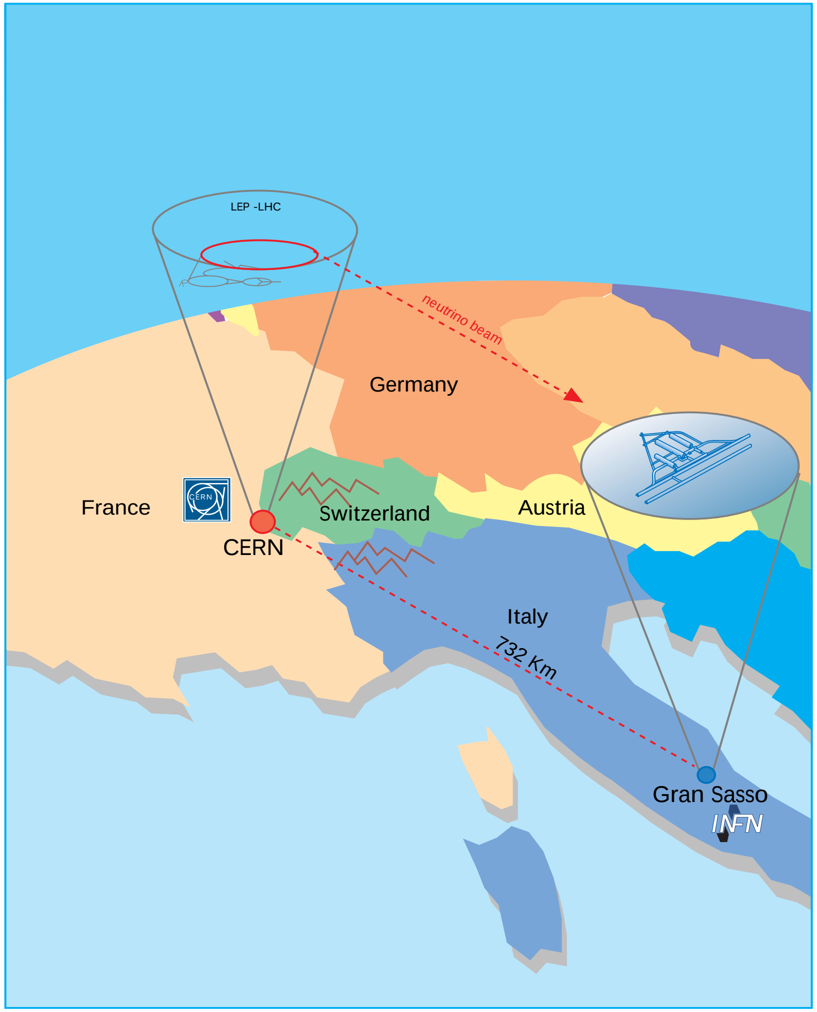
0.1< mν (0.4) <0.6 eV
4 sigma



HV Klapdor et al, NIMA: Data Acquisition and Analysis of the 76-Ge Double Beta experiment in Gran Sasso 1990-2003

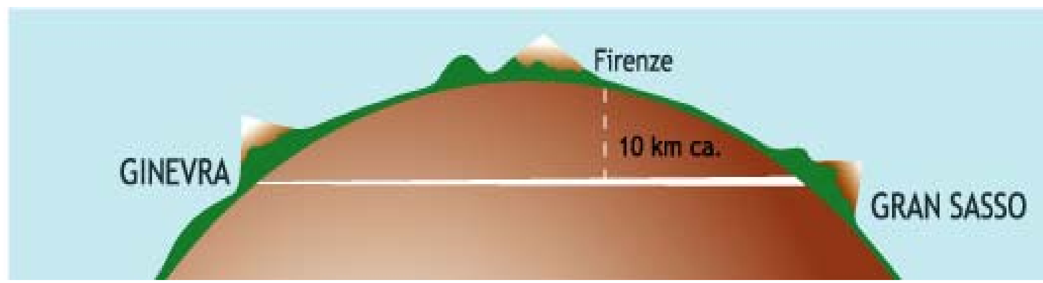
CNGS CERN to Gran Sasso Neutrino Project

A ν_τ appearance program



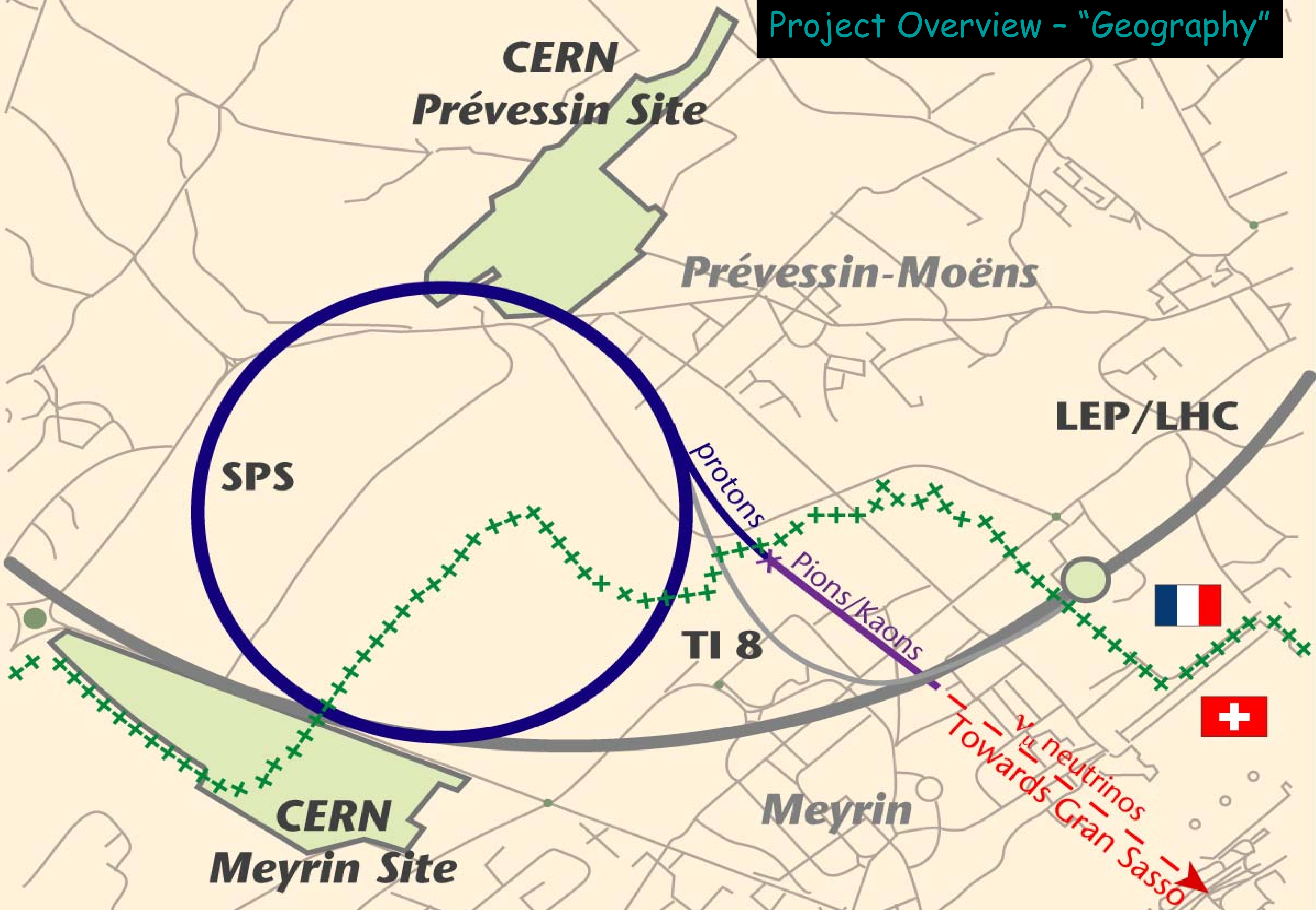
ν_μ beam produced at CERN and detected at LNGS after a travel of 730 km

Approved by CERN and INFN in 1999, ready in 2006

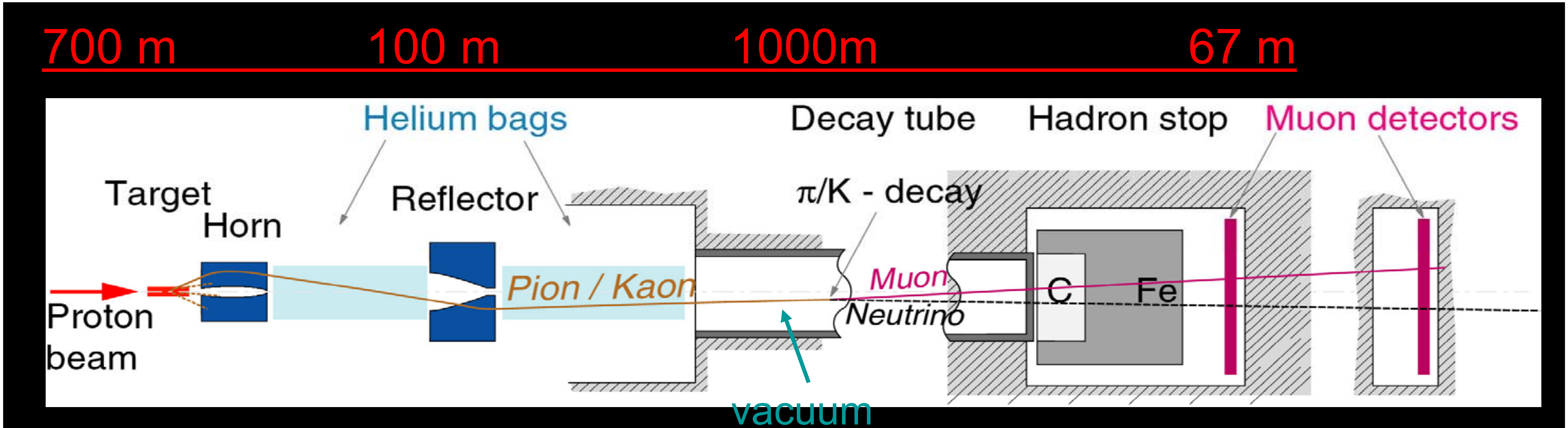


INFN

Project Overview – "Geography"



2. CNGS: the main components



p + C → (interactions) → π^+, K^+, (μ^+) → (decay in flight) → $\mu^+ + \nu_\mu$

Expected number of protons delivered on CNGS target:

For <u>1 year of CNGS operation</u> (200 days) :

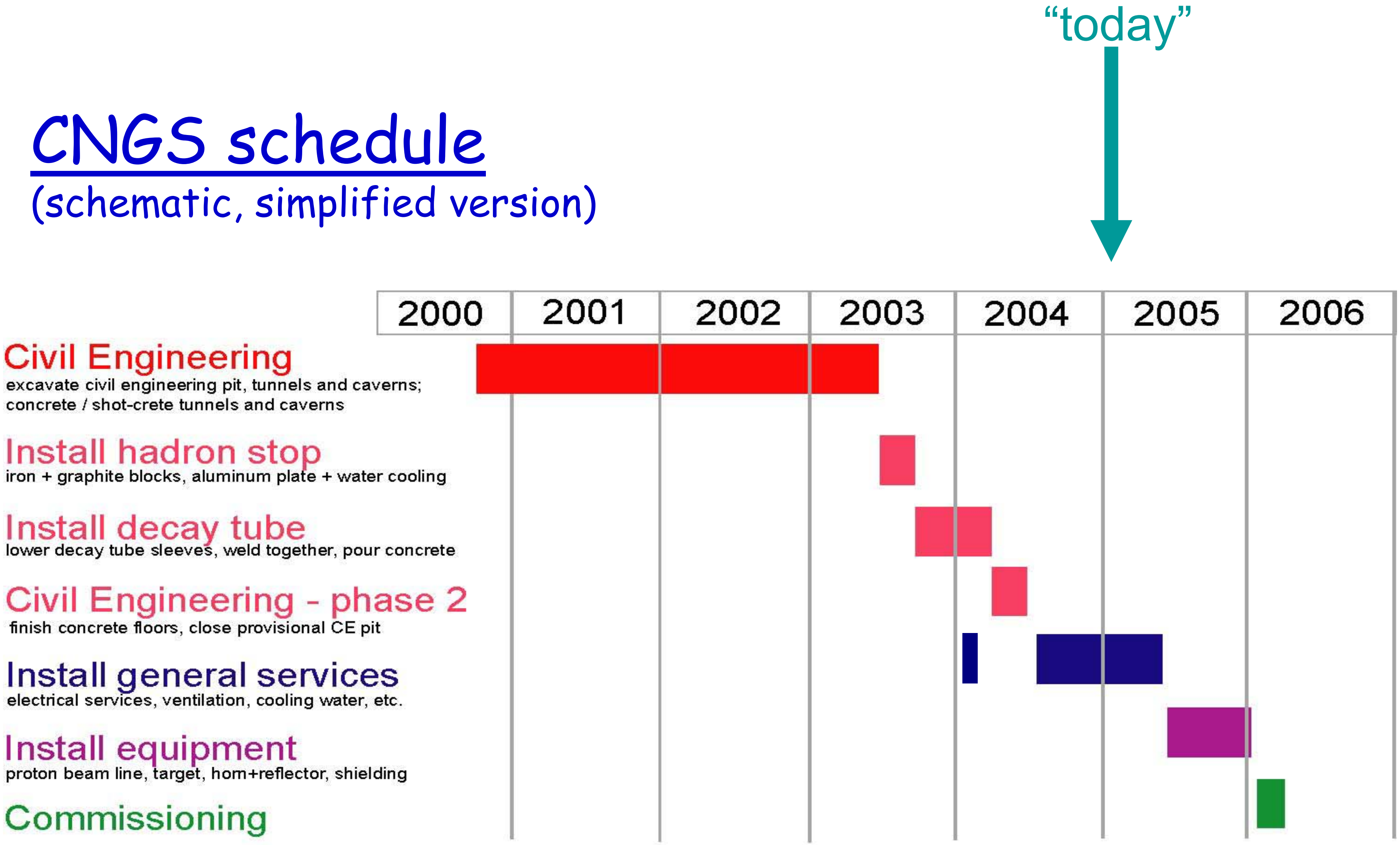
protons on target / year (“nominal”): 4.5×10^{19}

Studies towards higher proton intensities in the SPS

⇩

A factor 1.5 in intensity must to be reached

CNGS schedule
(schematic, simplified version)



First beam to Gran Sasso: May 2006

The 2 ways of detecting τ appearance @GRAN SASSO

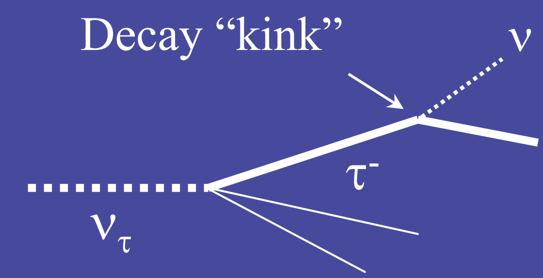
ν_μ ….. ν_τ $\rightarrow$ $\tau^- + X$

oscillation — CC interaction

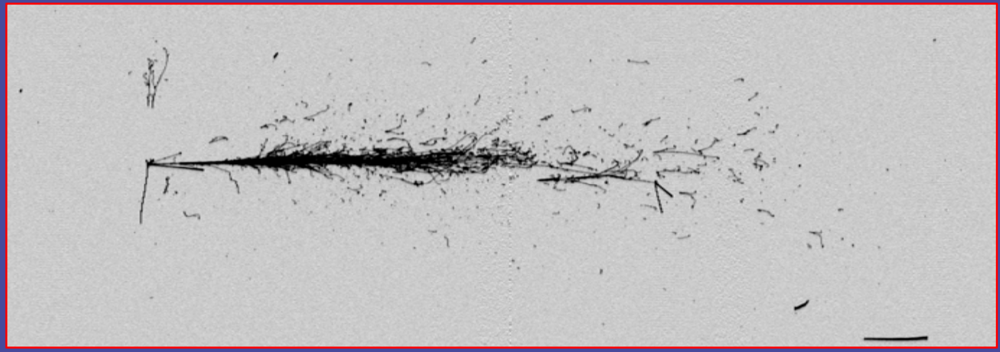
$\mu^-\ \nu_\tau\ \nu_\mu$	BR 18 %
$h^-\ \nu_\tau\ n\pi^o$	50 %
$e^-\ \nu_\tau\ \nu_e$	18 %
$\pi^+\ \pi^-\ \pi^-\ \nu_\tau\ n\pi^o$	14%

<u>OPERA</u>: Observation of the decay topology of τ in photographic emulsion

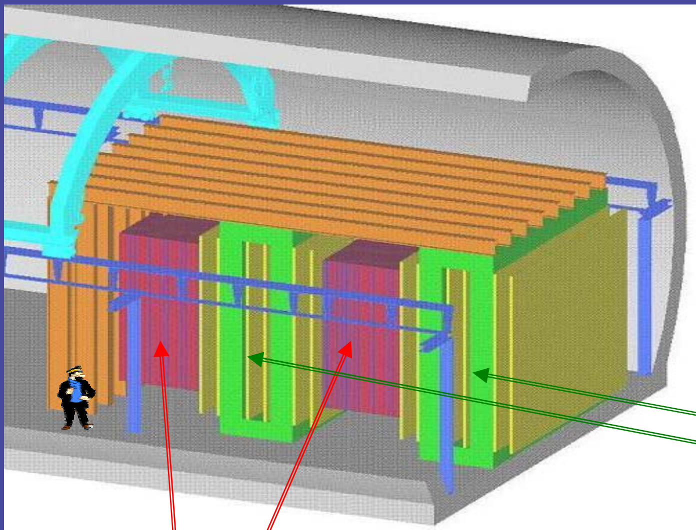
(~ µm granularity)



<u>ICARUS</u>: detailed TPC image in liquid argon and kinematic criteria (~ mm granularity)



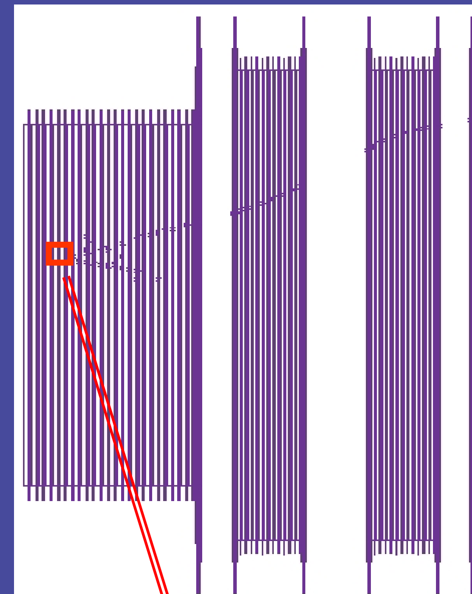
OPERA: an hybrid detector



ν interaction

Spectrometer
(drift tubes-RPCs)

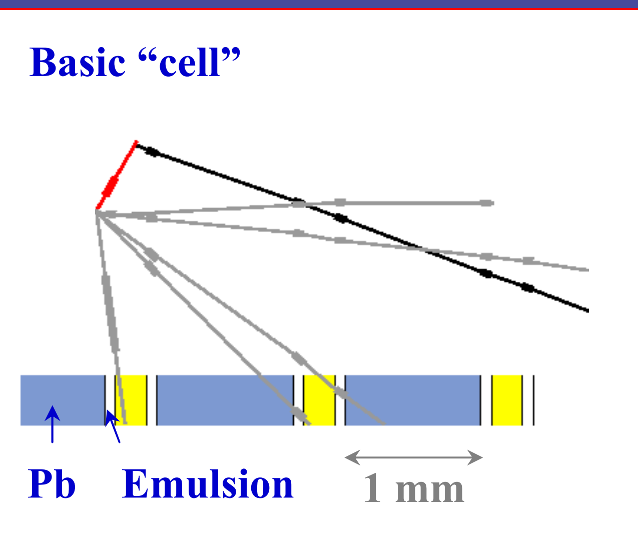
Emulsions+lead + target tracker
(scintillator strips)



Electronic detector

→ finds the brick of ν interaction

→ μ ID, charge and p



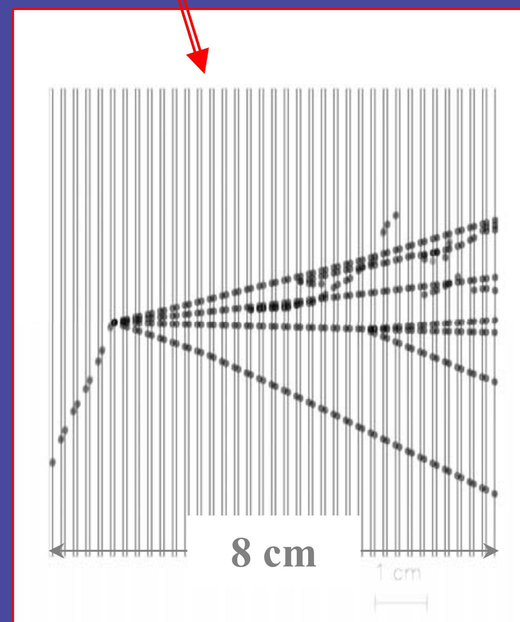
Emulsion analysis:

✓Vertex

✓Decay kink

✓e/gamma ID

✓Multiple scattering, kinematics



OPERA

OPERA CNGS (6.76 10^{19} pot/year in shared mode)

N_τ events 5 years data taking

	$\Delta m^2 = 1.8 \times 10^{-3}$	$\Delta m^2 = 2.5 \times 10^{-3}$	$\Delta m^2 = 4.0 \times 10^{-3}$	Back
Final Design	9.0	17.2	43.8	1.06
With improvements	10.3	19.8	50.4	0.67

Better efficiencies due changeable sheets

Better charm background rejection with μ id. from dE/dx

$\Delta m^2 (eV^2)$	3 years (20.3x 10^{19} pot)		5 years (33.8x 10^{19} pot)	
	$P_{3\sigma}$(%)	$P_{4\sigma}$	$P_{3\sigma}$(%)	$P_{4\sigma}$
1.8x 10^{-3}	77.2(91.1)	46.8(68.2)	97.2(99.5)	87.4(96.2)
2.2x 10^{-3}	94.9(98.9)	80.5(93.0)	99.9(100)	99.0(99.9)
2.5x 10^{-3}	98.9(99.9)	93.9(98.6)	100(100)	99.9(100)
3.0x 10^{-3}	100(100)	99.6(100)	100(100)	100(100)
4.0x 10^{-3}	100(100)	100(100)	100(100)	100(100)

Hall C 14 July 2003

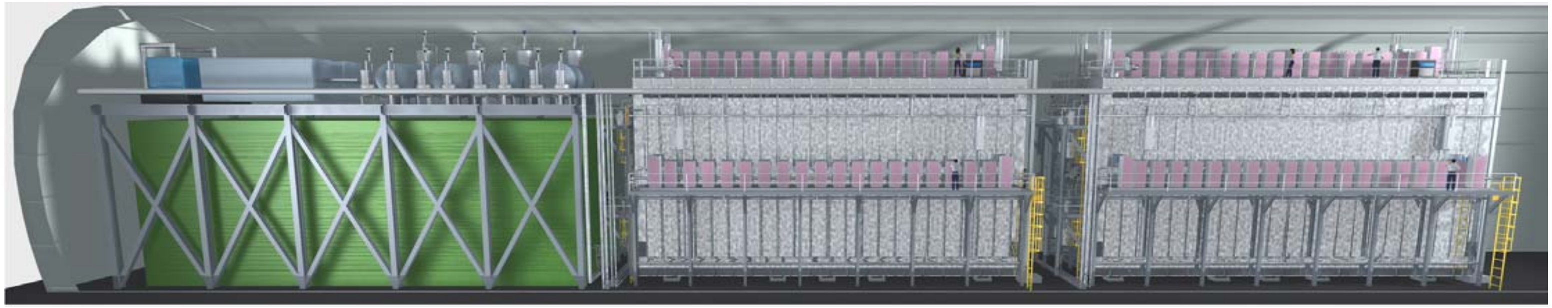

14 October 2003


OPERA Film by NAGOYA Univ. JAPAN
Produced by Fuji Photo Film & Refreshed by NAGOYA Univ.
名古屋大学OPERAフィルム初荷


Refreshed films for OPERA experiment
Radiation sensitive films, Don't expose to X-ray!!
Refreshed films for OPERA experiment
INFN

ICARUS Imaging Cosmic and Rare Underground Signals

First Unit T600 | T1200 | T1200

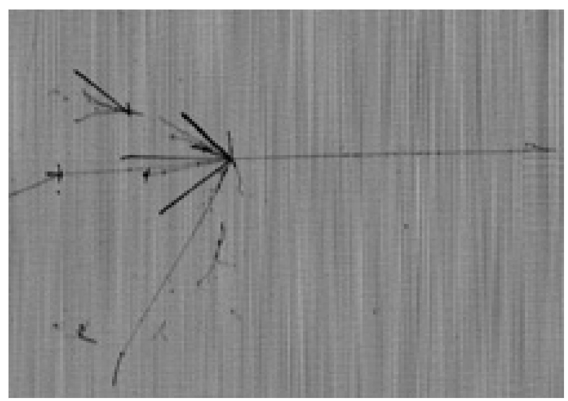


Liquid Argon (-176 °C)

First half of T600 module successfully operated in Pavia
T600 underground end 2004
T1800 funded

Collaboration:
Italy, Poland, China
Spain, Switzerland, USA

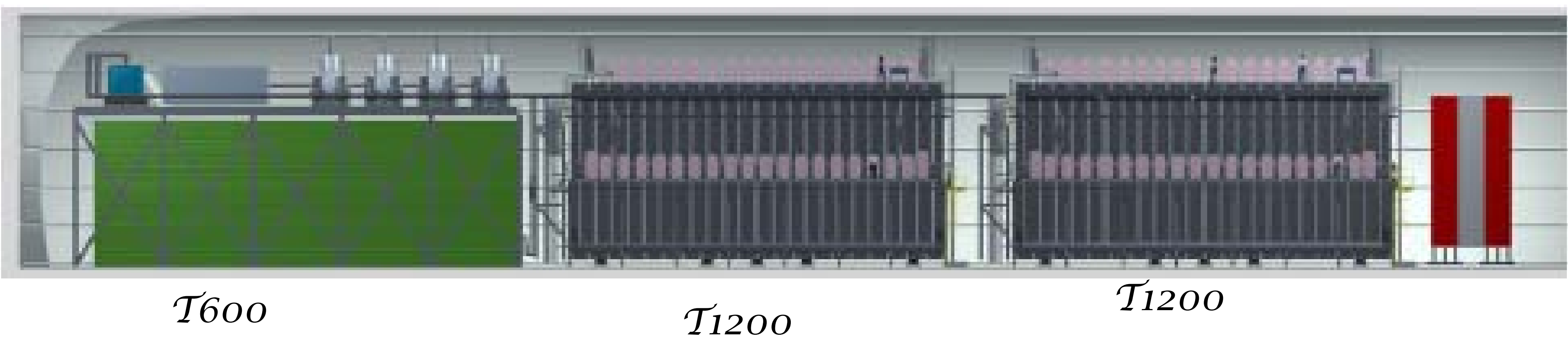
- Wide physics program
  - ν_τ and ν_e appearance on CNGS
  - atmospheric neutrinos
  - supernova neutrinos
  - solar neutrinos
  - proton decay



17 m

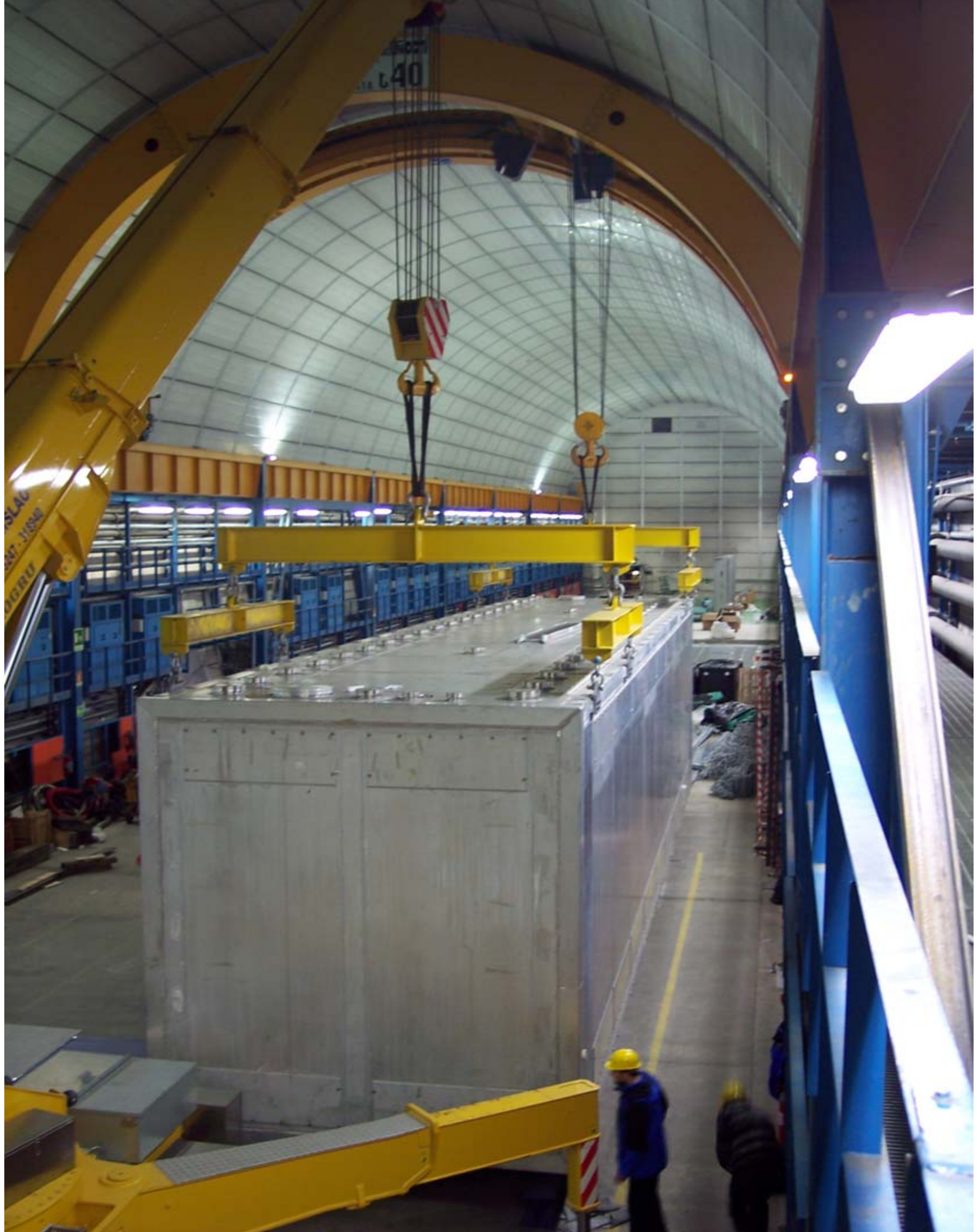
T3000 5 years 6.76 x 10^{19} prot/year

τ Decay	Signal ($\Delta m^2 = \Delta\Delta \times 10^{-3}$ eV^2)			BG
	ΔΔ = 1.6	ΔΔ = 2.5	ΔΔ = 4.0	
τ → e	5.5	13.5	35	1
τ → ρ DIS	1	2.5	6	<0.5
τ → ρ QE	1	2.5	5.5	<0.5
Total	**7.5**	**18.5**	**46.5**	**≤ 2**



L’uscita dalla Sala in Pavia

ICARUS T600
Dicember 3, 2004

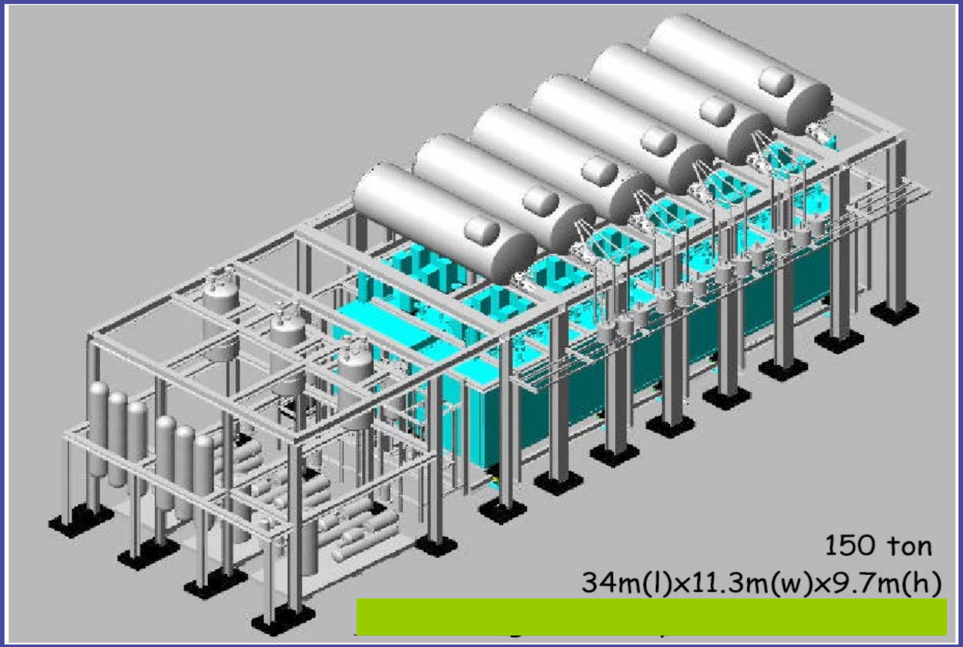


Due criostati in Sala B

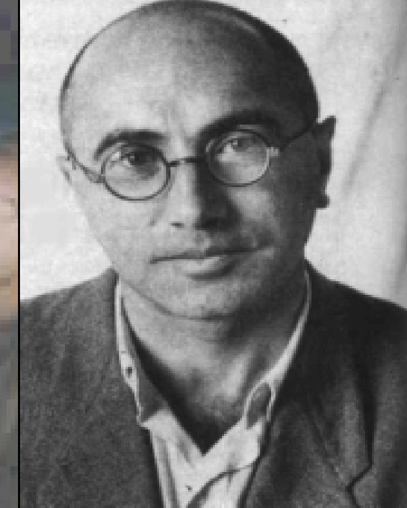
Installation of the first T600 unit at Gran Sasso

- **T600 installation has started**
- **The technical staff is working on the infrastructures in Hall B (electrical power supply system, ventilation, heat dissipation…)**
- **T600 will be operated in Gran Sasso at the beginning of 2006**

The T600 auxiliary system supporting structure



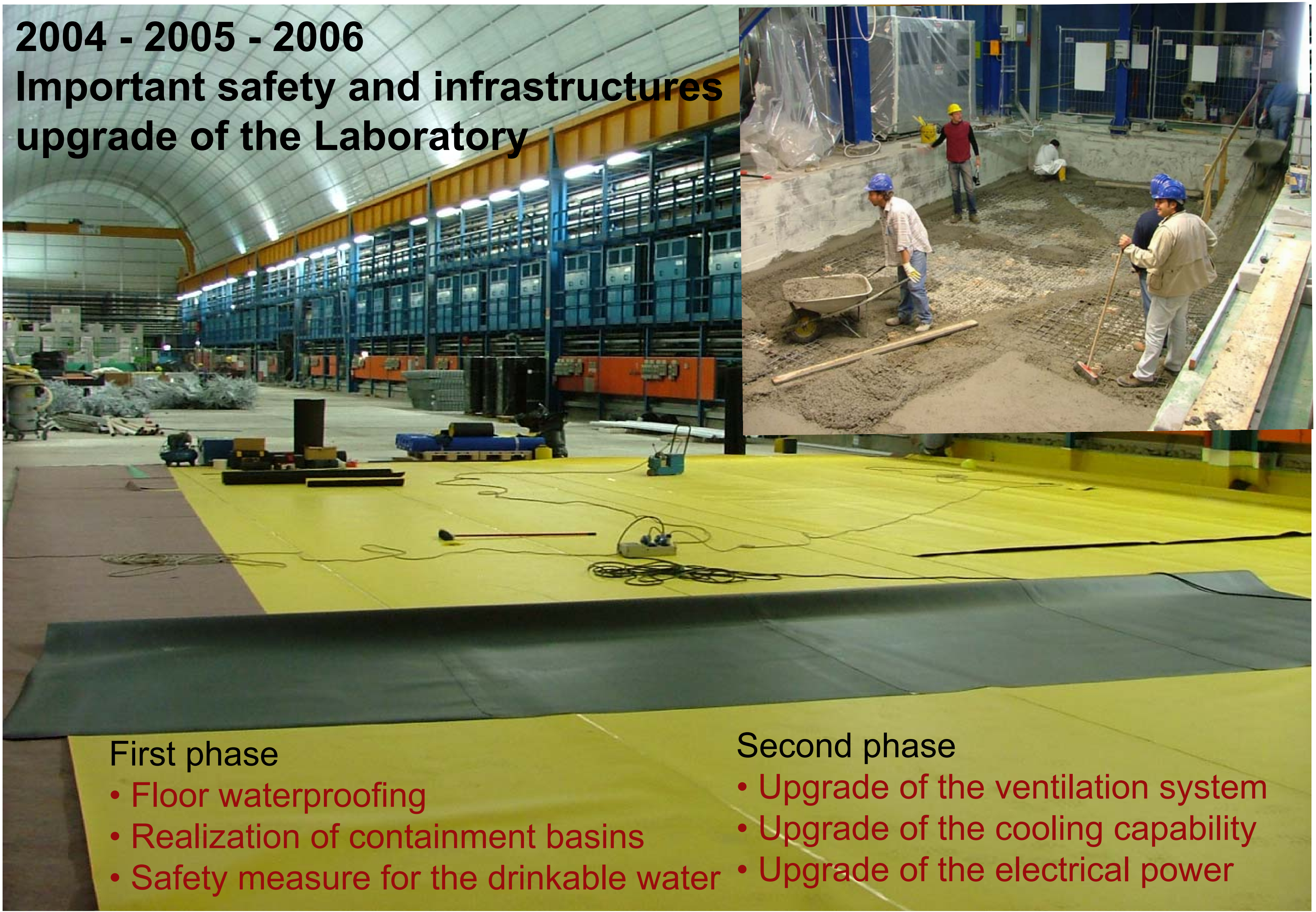
Theoretical activity in LNGS



the first suggestion of concept of Superheavy Dark Matter and its connection with Ultra High Energy Cosmic Rays (absence of GZK cutoff).
Group of people working in UHECR under the drive of Veniamin Berezinsky

More: Neutrino physics, extensions of SM

2004 - 2005 - 2006
Important safety and infrastructures upgrade of the Laboratory



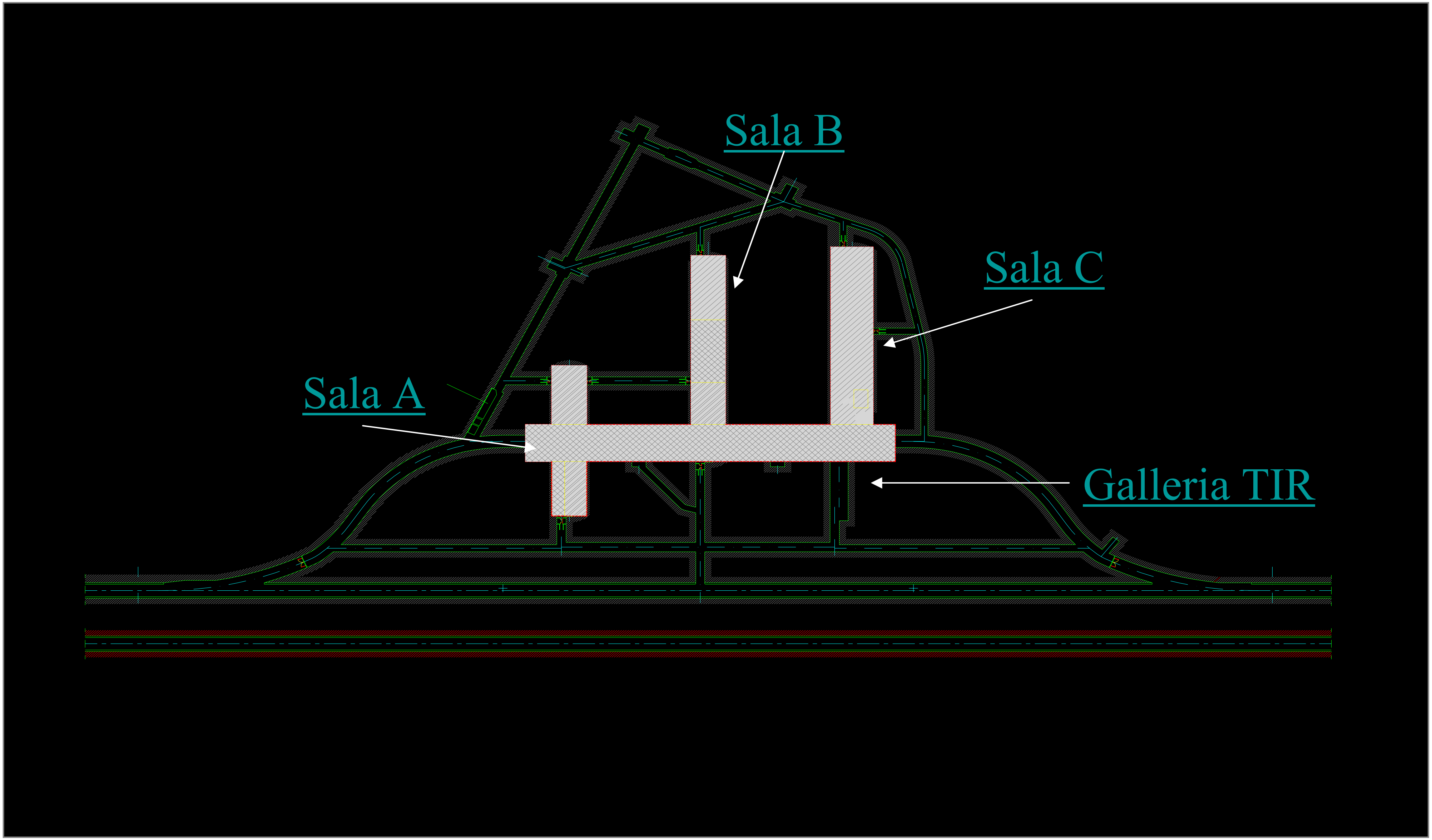
First phase

- Floor waterproofing
- Realization of containment basins
- Safety measure for the drinkable water

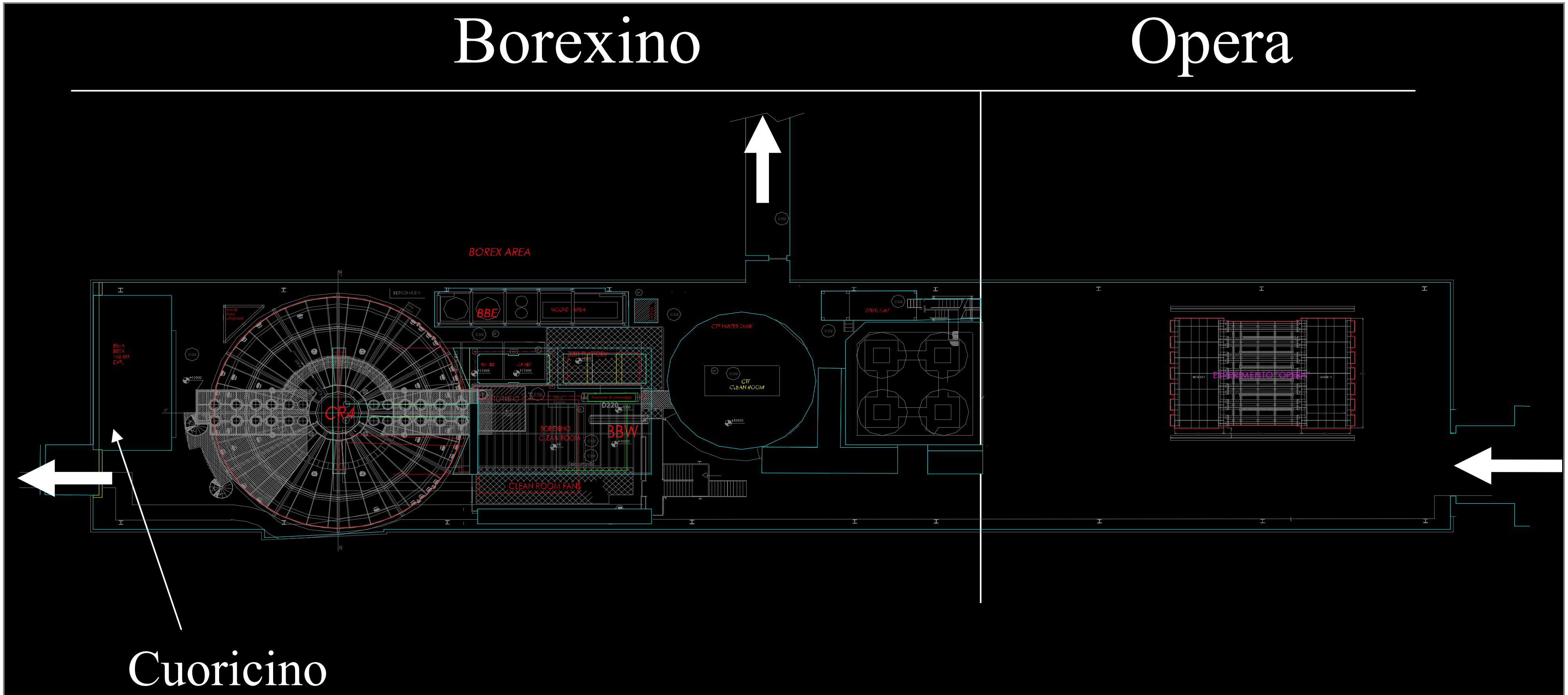
Second phase

- Upgrade of the ventilation system
- Upgrade of the cooling capability
- Upgrade of the electrical power

Planimetria generale Progetto Mosco



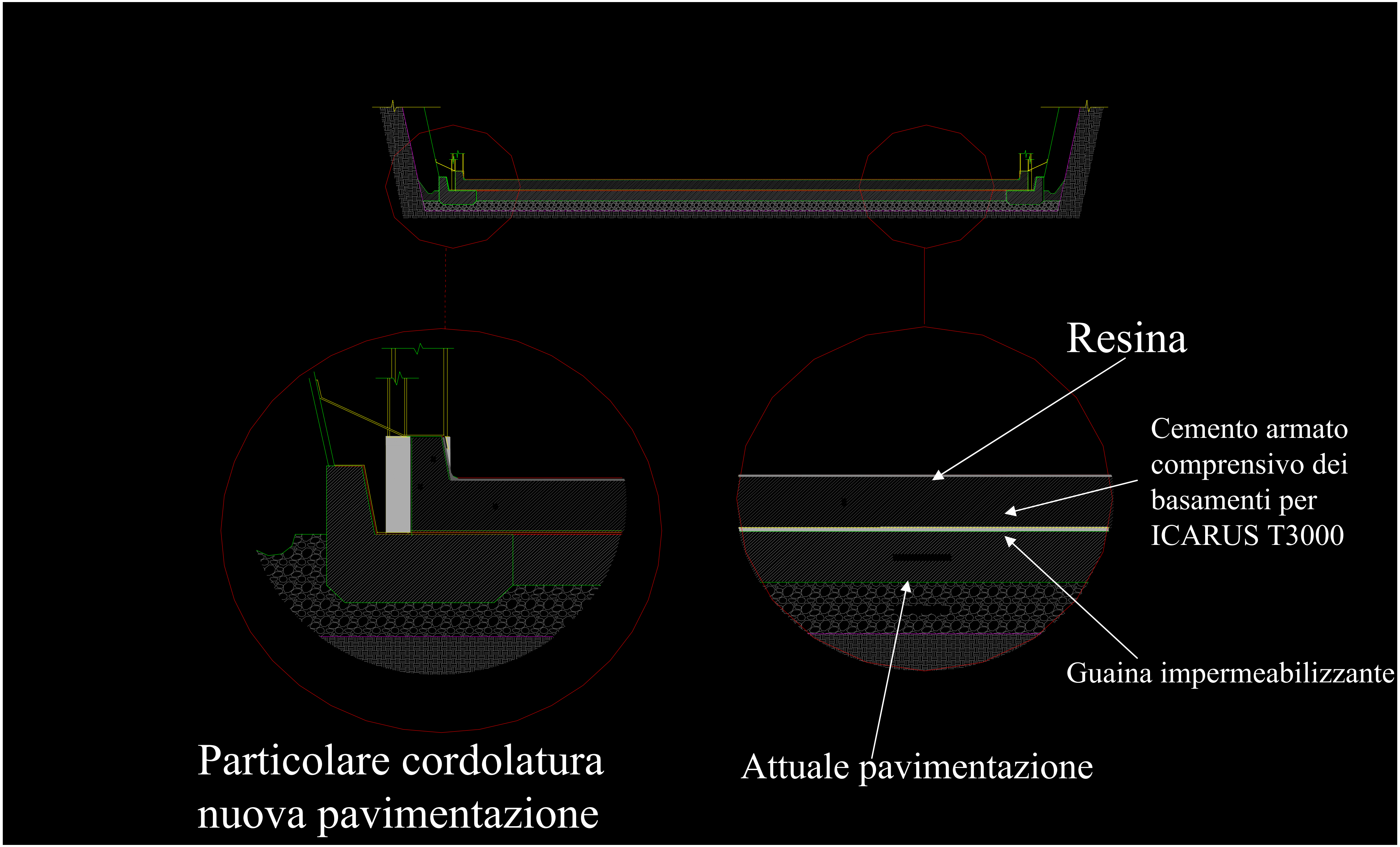
Sala C



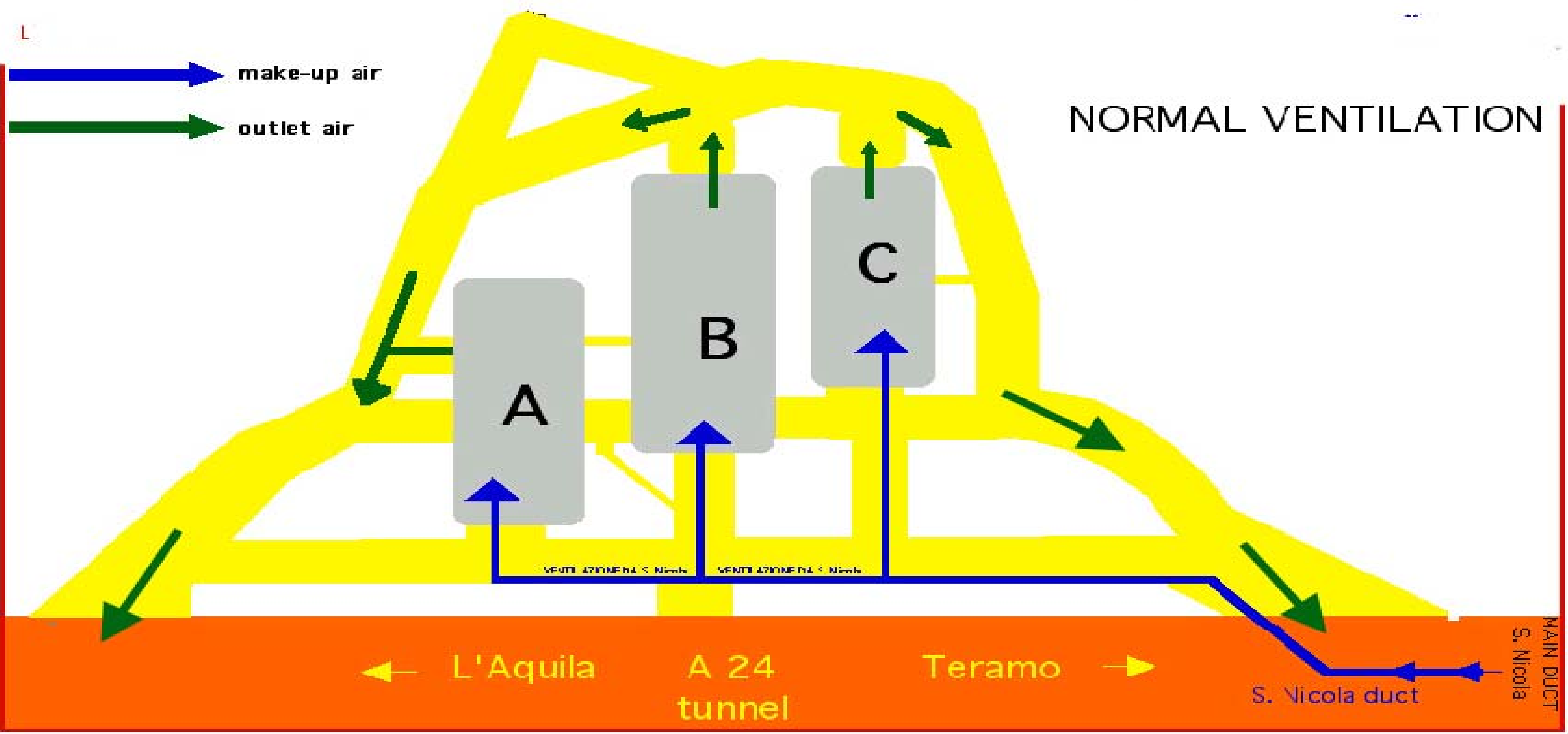
Cronoprogramma interventi in Sala C

Impermeabilizzazione della pavimentazione della Sala a mezzo di resine

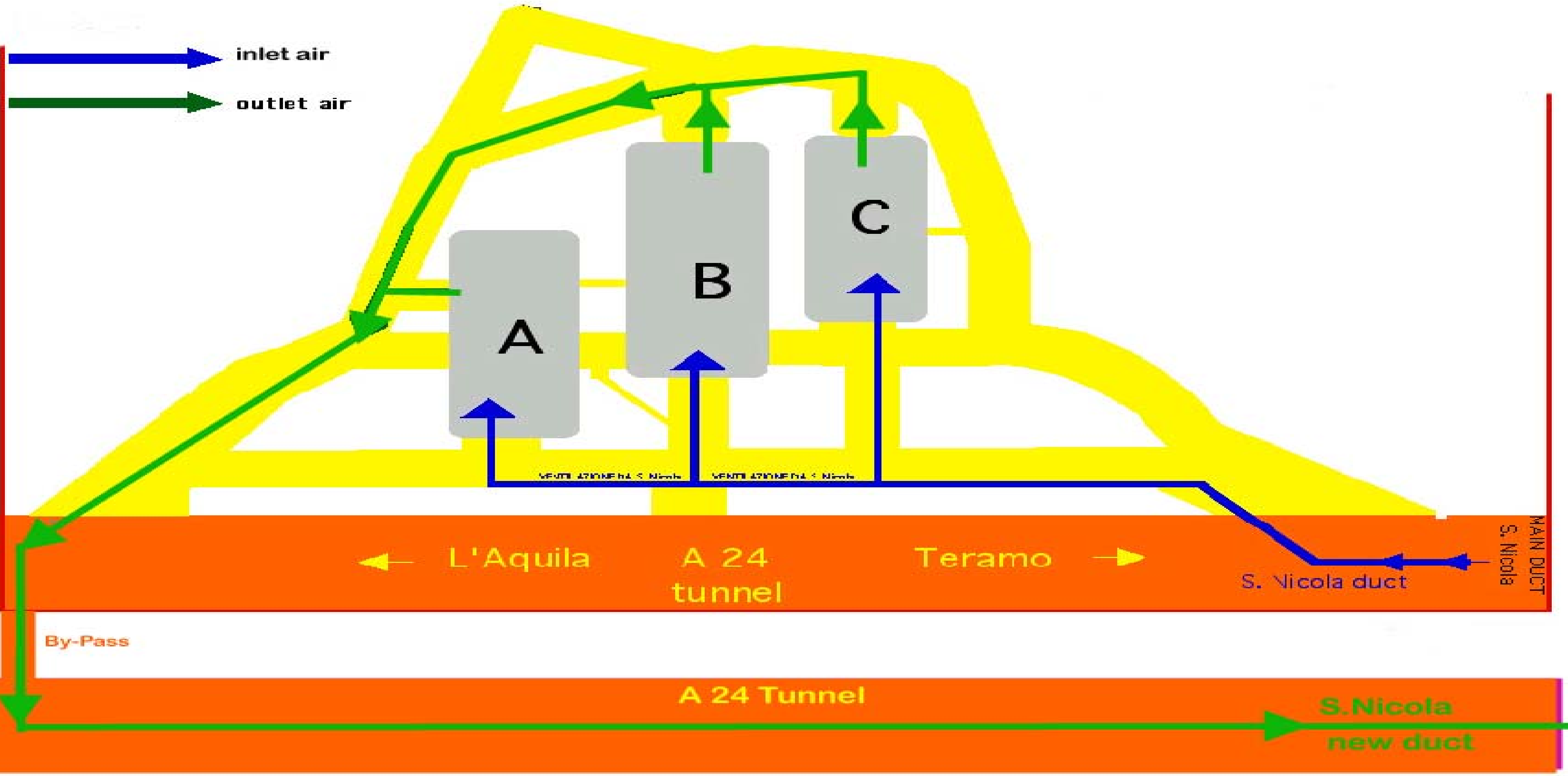
Sala B - Nuova Pavimentazione (h=0.30 m)



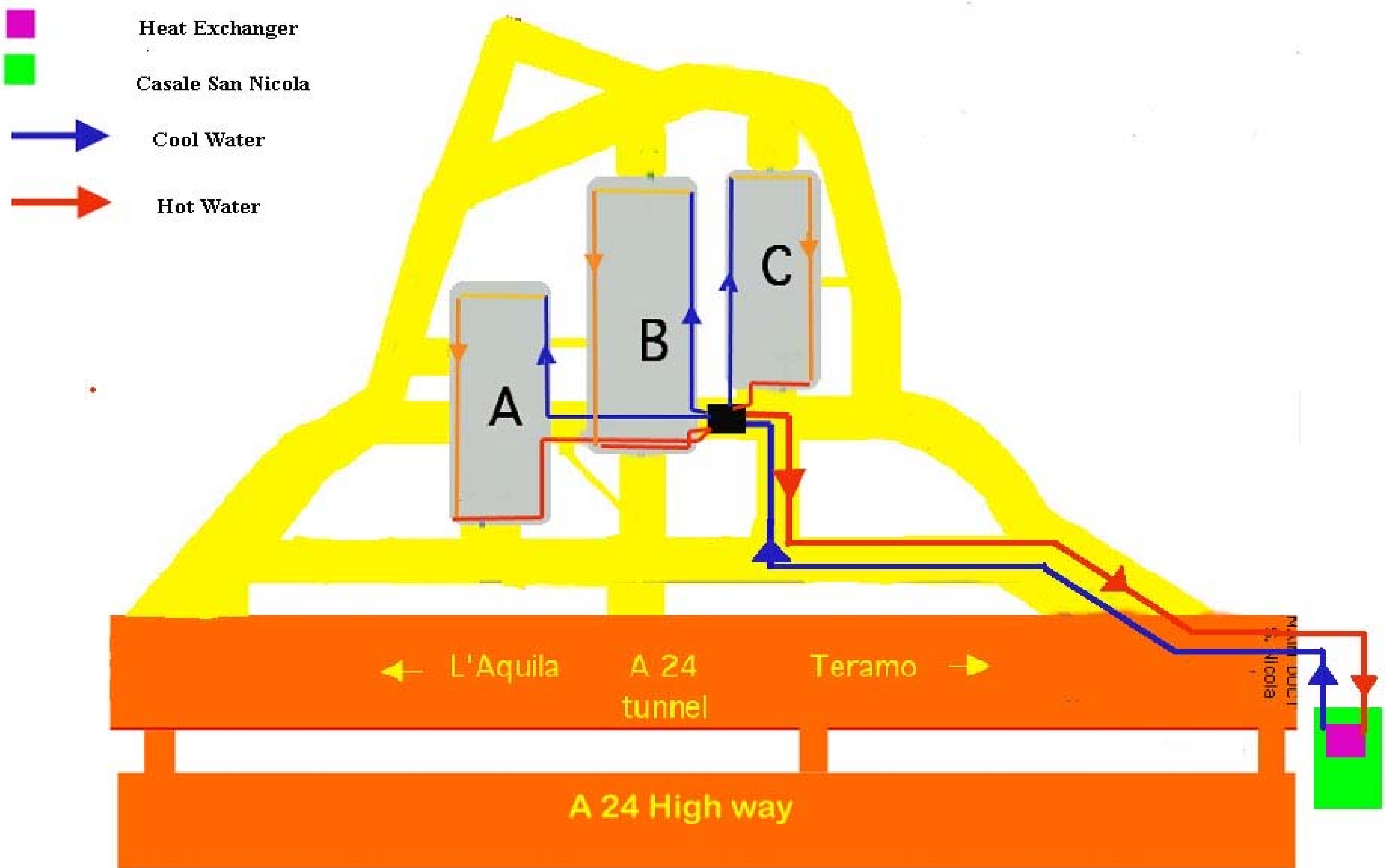
LNGS Sistema attuale di ventilazione

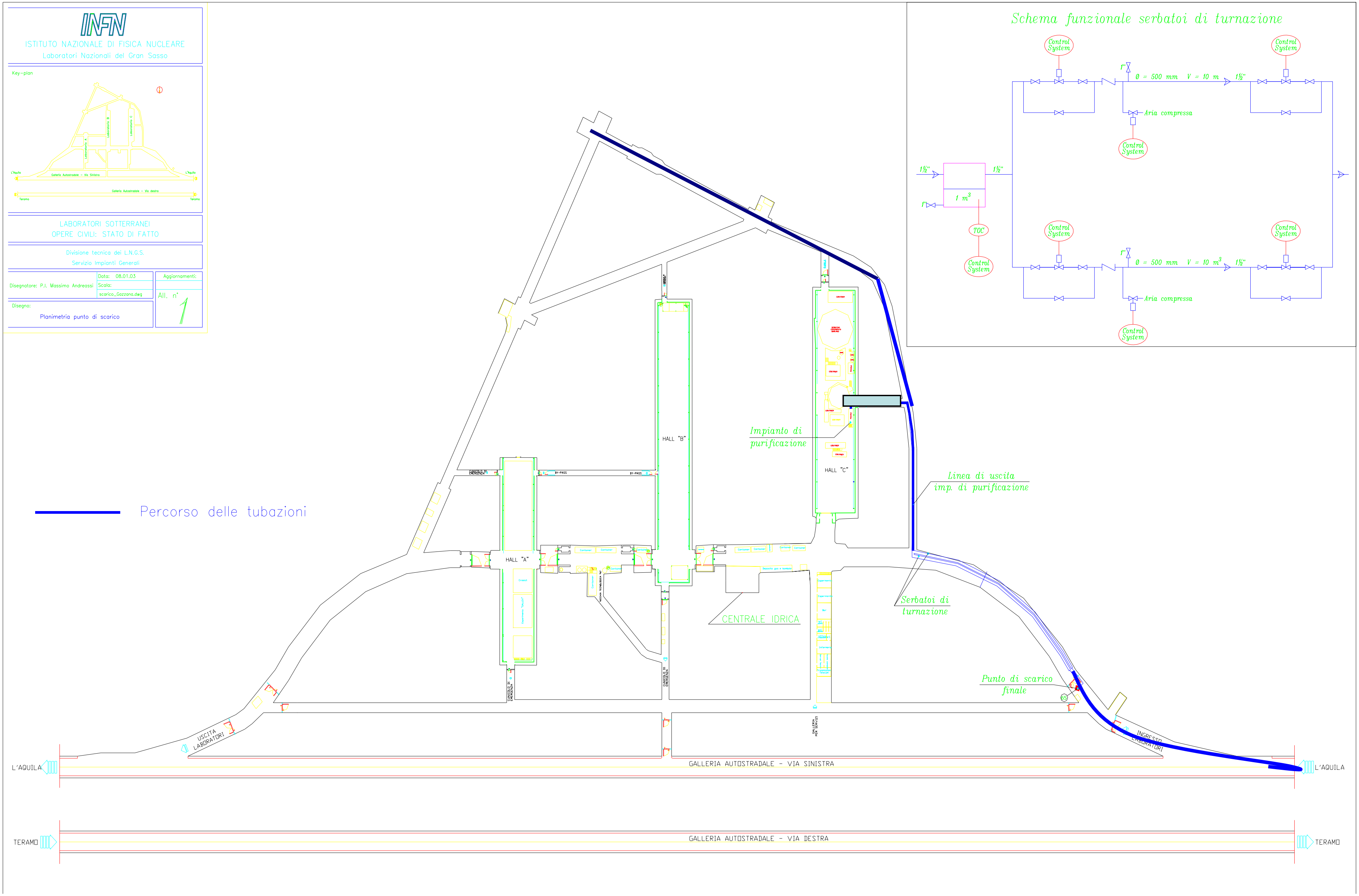


LNGS New Normal Ventilation



LNGS New cooling plant





INFN
ISTITUTO NAZIONALE DI FISICA NUCLEARE
Laboratori Nazionali del Gran Sasso
Key-plan
LABORATORI SOTTERRANEI
OPERE CIVILI: STATO DI FATTO
Divisione tecnica dei L.N.G.S.
Servizio Impianti Generali
Disegnatore: P.I. Massimo Andreassi
Data: 08.01.03
Scala:
scarico_Gozzano.dwg
Aggiornamenti:
All. n° 1
Disegno:
Planimetria punto di scarico
Schema funzionale serbatoi di turnazione
Control System
Ø = 500 mm V = 10 m³
Aria compressa
1 m³
TOC
Percorso delle tubazioni
Impianto di purificazione
Linea di uscita imp. di purificazione
Serbatoi di turnazione
Punto di scarico finale
CENTRALE IDRICA
HALL "A"
HALL "B"
HALL "C"
BY-PASS
USCITA LABORATORI
INGRESSO LABORATORI
L'AQUILA
GALLERIA AUTOSTRADALE - VIA SINISTRA
TERAMO
GALLERIA AUTOSTRADALE - VIA DESTRA

il Centro
L'Aquila e provincia

LA SICUREZZA COME OBIETTIVO COMUNE

Laboratori, segnali di pace

Il direttore Coccia e Ruffini: «Lavoreremo insieme»

CONVEGNO

L'AQUILA. Stretta di mano tra il presidente della Provincia di Teramo, Claudio Ruffini, e il neo direttore dell'Infn, Eugenio Coccia, durante il convegno sull'acqua promosso dal Parco Gran Sasso Laga. «In futuro si lavorerà insieme».

Insieme il direttore dei laboratori Coccia, Mazzitti e Ruffini

Un futuro quanto mai vicino, visto che la messa in sicurezza del sistema delle acque reflue dei laboratori di fisica nucleare del Gran Sasso è l'intervento più immediato che il direttore Coccia si appresta a realizzare. «Un'opera che può essere portata a termine in tempi brevi e a costi limitati», ha sottolineato Coccia, «e per la quale si stanno già individuando i finanziamenti. In tre mesi vorrei risolvere il problema e programmare così il rilancio delle attività dei nostri laboratori».

E' stata una giornata all'insegna dei buoni propositi, quella di ieri, in occasione del convegno dedicato alla presentazione della Carta per la valorizzazione e la tutela dell'acqua nelle aree protette, messa a punto da Federparchi e presentata in anteprima ritrovato clima di serenità», dopo gli aspri contrasti che hanno visto opposti, negli ultimi mesi, gli amministratori teramani e i rappresentanti dell'Infn. La vicenda è quella nota, con l'incidente del 16 agosto ai laboratori, lo sversamento del trimetilbenzene nelle reti idriche e il recente sequestro della sala C della struttura. «La nostra azione non è stata rivolta contro qualcuno», ha spiegato Ruffini: ho salutato con piacere il nuovo direttore dei laboratori, con cui divido le origini picene. Credo che attraverso un'iniziativa comune, coordinata dalla Regione, riusciremo a trovare la soluzione che accontenta tutti». La strada, il governo regionale, la sta già tracciando: «Non bisogna dimenticare», ha sottolineato l'assessore alle opere pubbliche Giorgio De Matteis, «che il Gran Sasso è un patrimo-

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il Centro
Teramo e provincia
GIOVEDI' 10 luglio 2003

«Acqua potabile, niente allarmi»

La commissione ambiente incontra il direttore dei laboratori

COMUNE

Ma la falda è sempre a rischio

TERAMO. «La potabilità dell'acqua teramana non è stata mai in pericolo. L'acqua che bevono i teramani è sicura». E' questo il passaggio principale dell'intervento del presidente della Ruzzo servizi (ex Acar) Pino Casalena, che ha partecipato ieri alla riunione della commissione ambiente del Comune, nella sala San Carlo. L'incontro, voluto dal presidente della commissione Roberto Zilli, doveva servire

Il direttore dei laboratori di fisica del Gran Sasso Eugenio Coccia

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IL CENTRO ABRUZZO
VENERDI' 4 luglio 2003

Laboratori più trasparenti

L'impegno del nuovo direttore dell'Infn

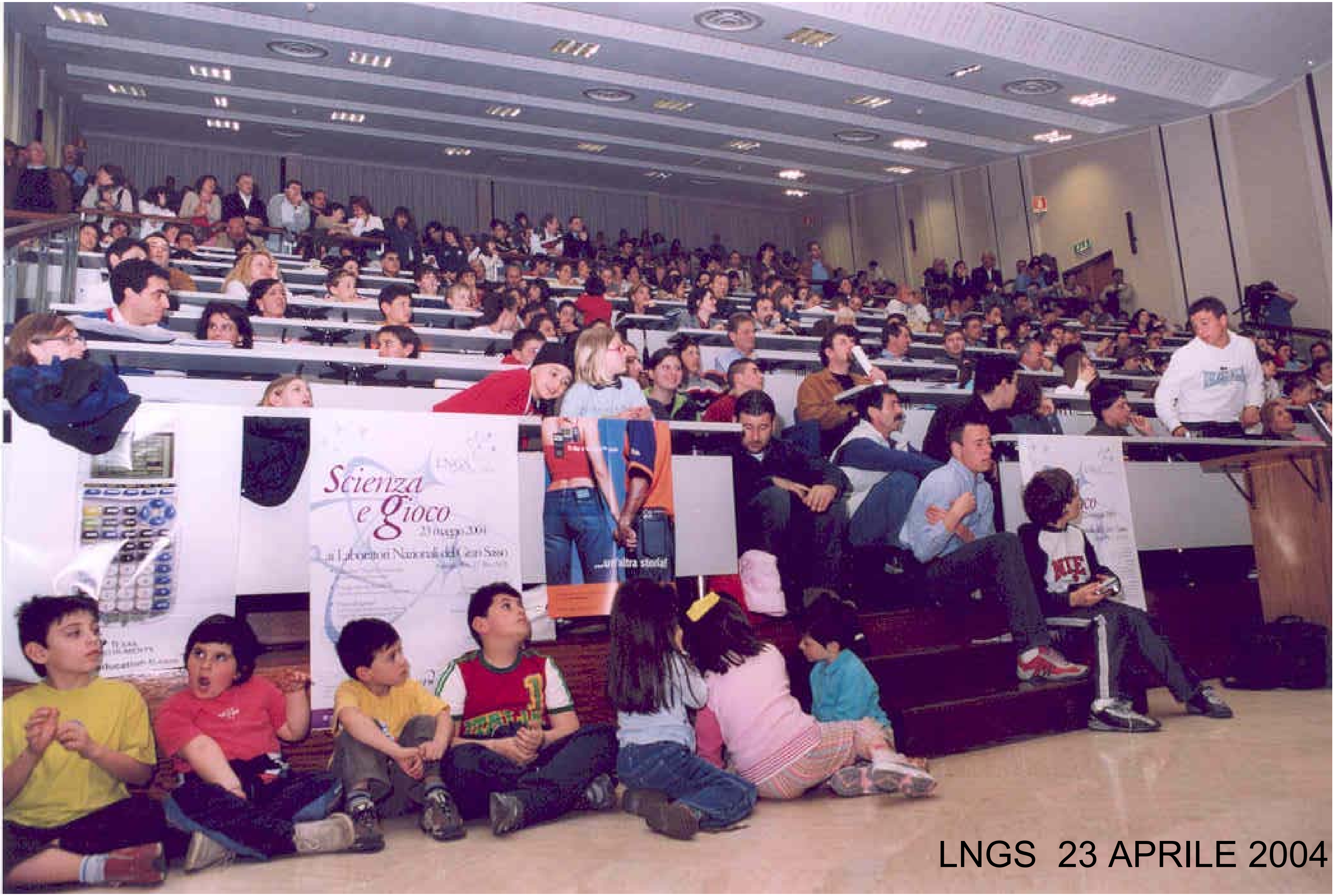
TERAMO. «Il laboratorio vuole essere trasparente». E' stata questa l'affermazione di Eugenio Coccia, neodirettore del Laboratorio del Gran Sasso, presente ieri a Teramo, in un incontro-dibattito sulla sicurezza dei laboratori organizzato dal Wwf. «Abbiamo voluto realizzare questo incontro pubblico» spiega Dante Caserta, presidente regionale del Wwf.

WWF SUL GRAN SASSO

«Per fare il punto della situazione sui laboratori del Gran Sasso. Abbiamo, infatti, costatato che, anche al nostro interno non c'è molta chiarezza su quanto è accaduto finora. La presenza del nuovo direttore è senza dubbio un primo passo ma vogliamo poter vedere dei fatti concreti». Al termine di una lunga relazione, che ha ripercorso le diverse tappe dell'intricata vicenda legata agli incidenti avve-

c'erano sostanze pericolose. E anche la questione del 3° tunnel ha esasperato gli animi. Proprio per questo stiamo facendo uno sforzo maggiore per avere un rapporto più diretto con il territorio, perché i cittadini hanno diritto di sapere cosa viene fatto con i loro soldi. E noi saremo ben lieti di spiegarglielo».

Anche sulla questione della sicurezza Coccia va spedito. «Dobbiamo essere in grado di garantire degli standard tali da non costituire un pericolo per la salute del cittadino. L'incidente dello scorso anno ha dimostrato che c'era una debolezza. Ma la sicurezza rimane il primo punto del nostro programma e i lavori previsti saranno completati nei prossimi mesi».



LNGS 23 APRILE 2004

Summary of the news

Borexino is back to work
Icarus T600 is underground
Opera is on schedule
New $\beta\beta$ and DM experiments: Cuore, Gerda, Warp, Xenon
GNO concluded

Upgrade of the Lab. infrastructures is in progress
Relationship with local people and authorities improved

2006 crucial year