The Gran Sasso Underground Laboratory

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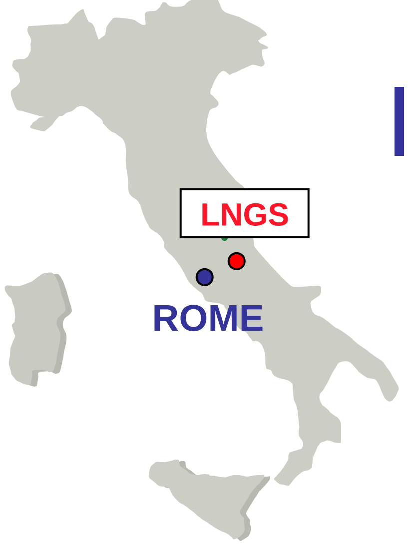
LIGO-G050033-00-Z

INFN
Istituto Nazionale
di Fisica Nucleare
Laboratori Nazionali del Gran Sasso

Aspen - GWADW
January 17, 2005



INFN Gran Sasso National Laboratory

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

L'AQUILA

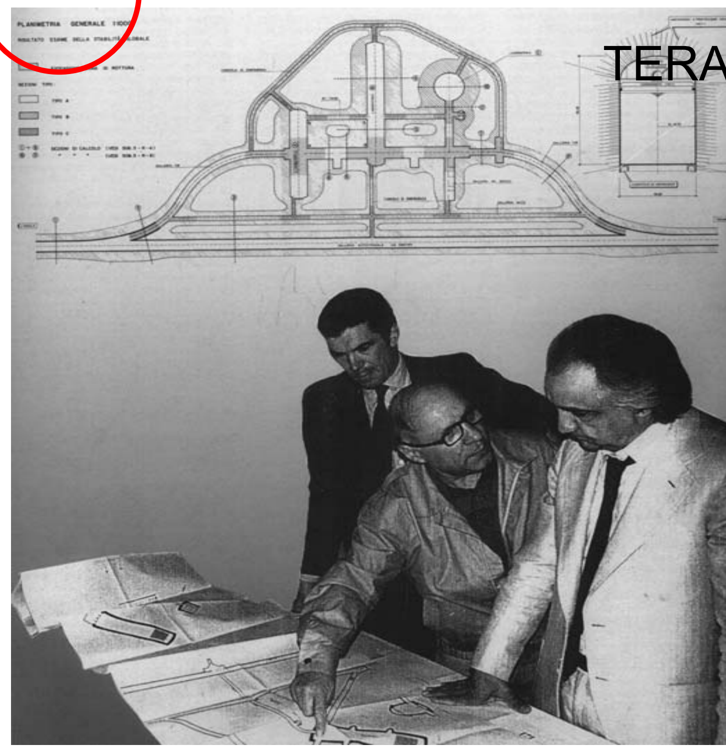
Tunnel of 10.4 km

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

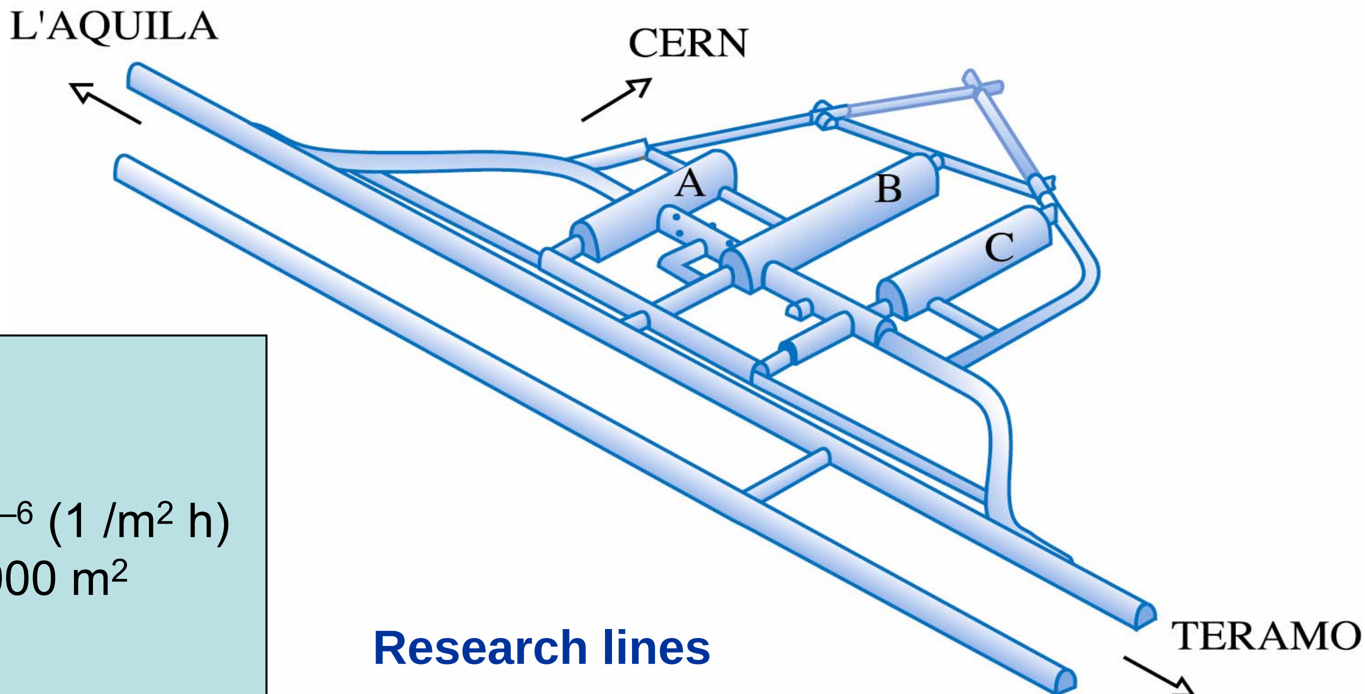
In 1982 the Parliament approved the construction, finished in 1987

In 1989 the first experiment, MACRO, started taking data




LABORATORI NAZIONALI DEL GRAN SASSO - INFN

Largest underground laboratory for astroparticle physics

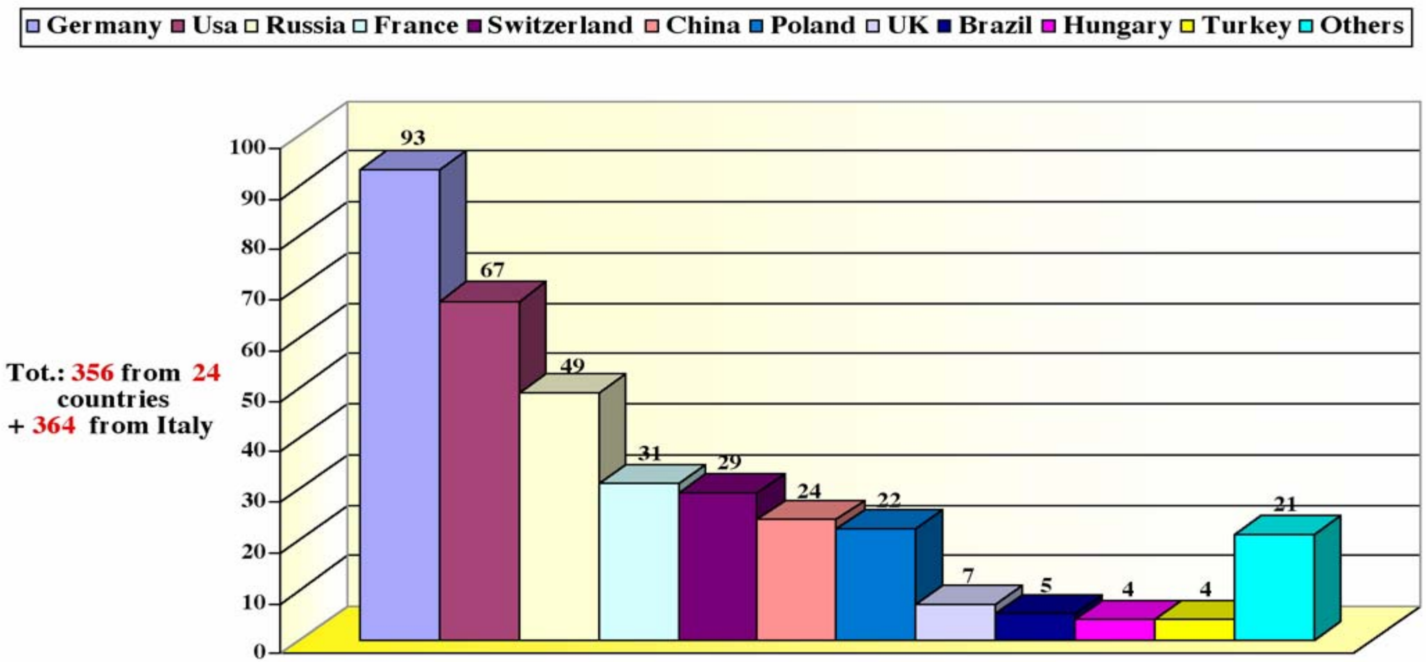


1400 m rock coverage
cosmic μ reduction= 10^{-6} (1 /m^2 h)
underground area: 18 000 m^2
external facilities
easy access
756 scientists from 25 countries
Permanent staff = 66 positions

Research lines

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

LNGS Users

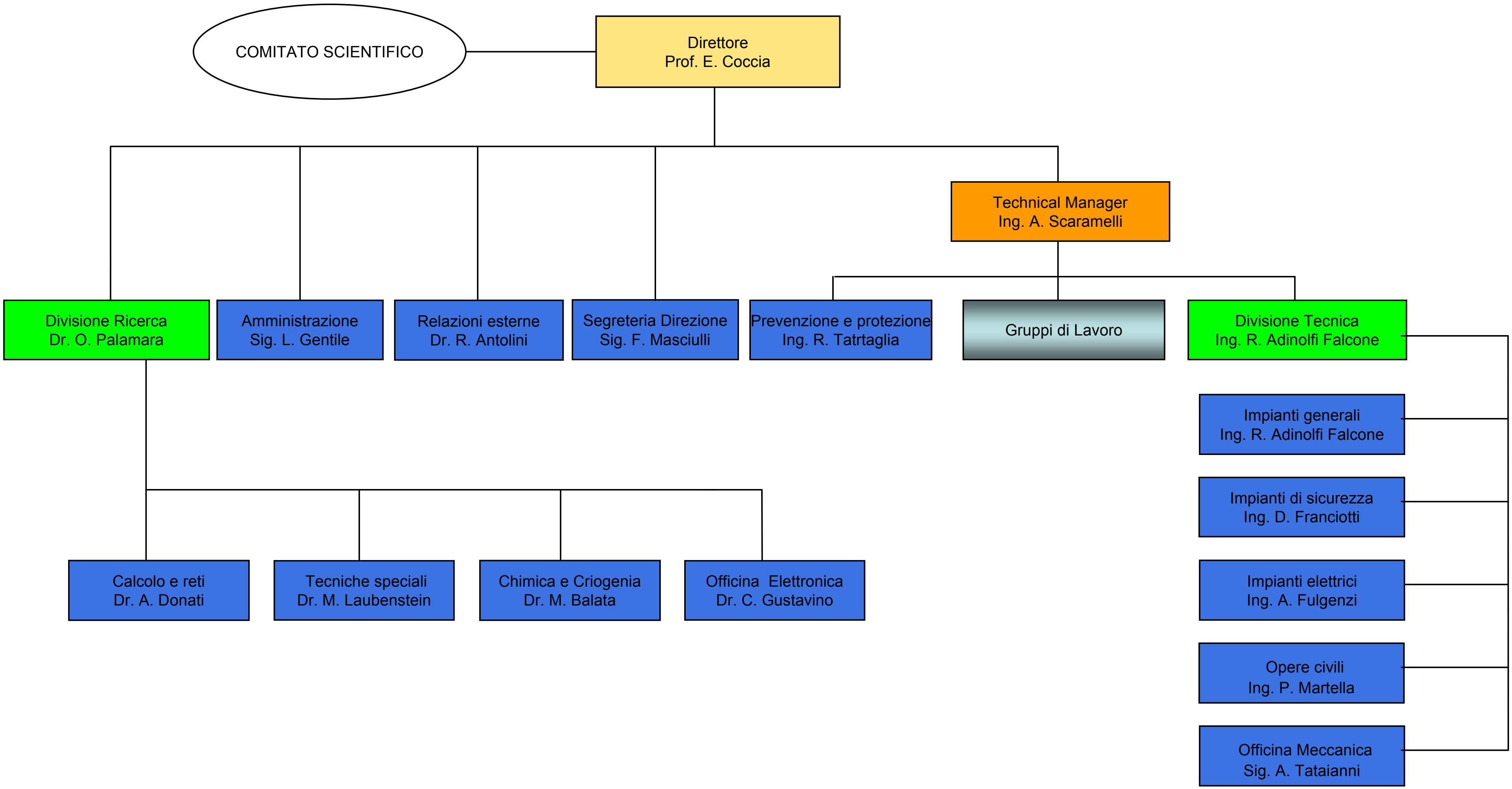


Foreigners: 356 from 24 countries

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



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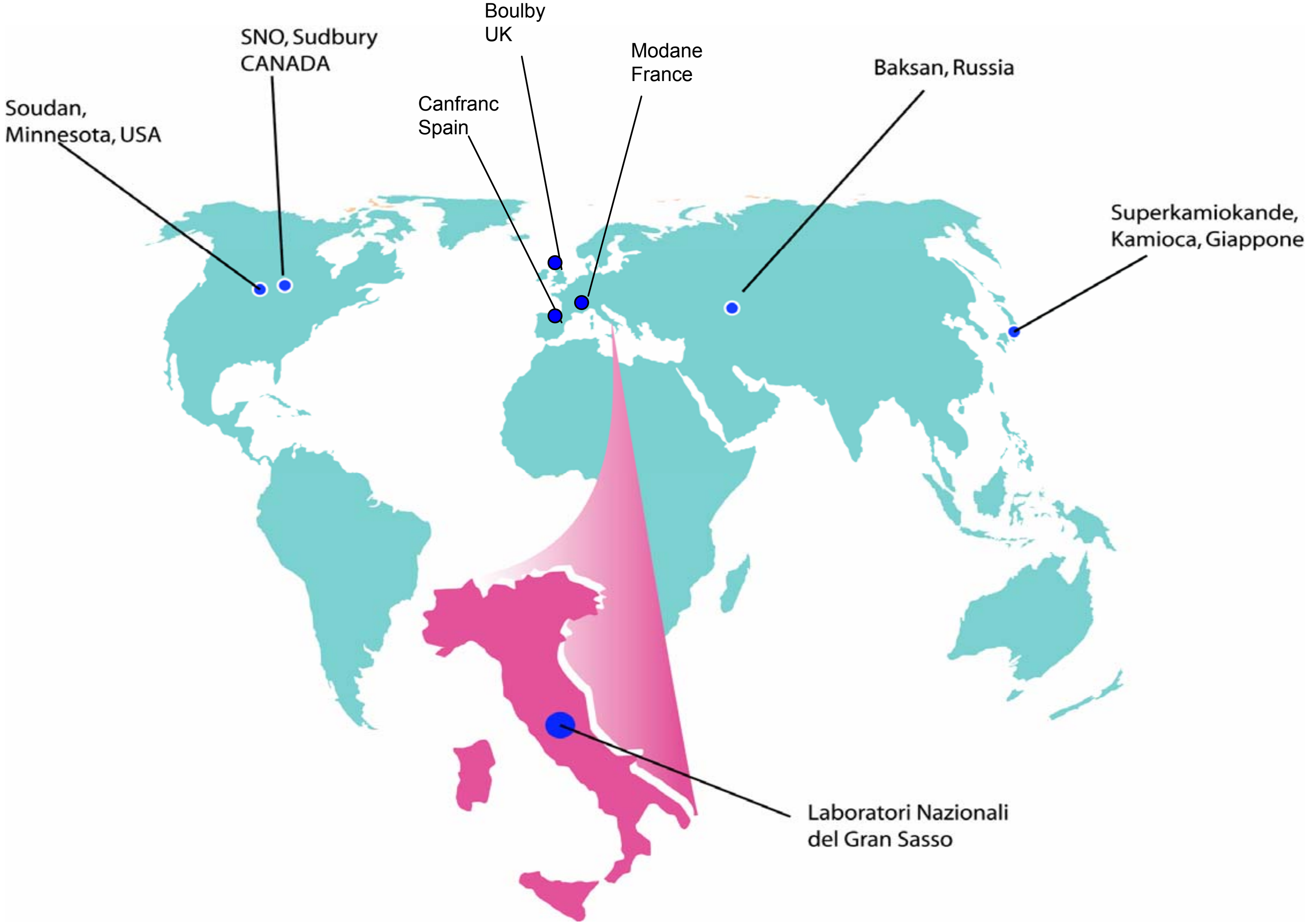
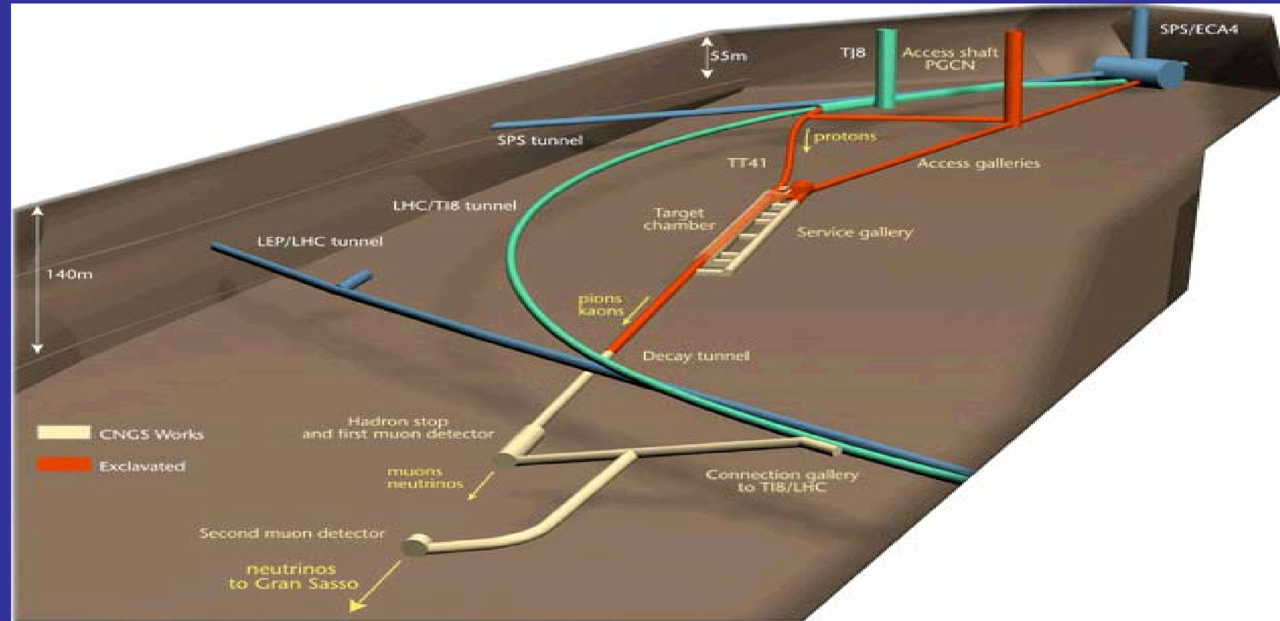
Underground Laboratories



ν beam from CERN:

ICARUS

OPERA



$\beta\beta$ decay and rare events

Cuoricino; HDMS; GENIUS-TF

CUORE; GERDA

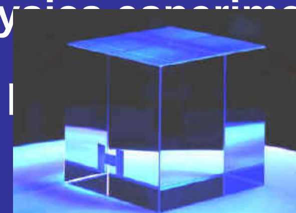
10 astroparticle phy... nts:

7 in operation, 3 in ...

4 exp. geophysics

1 exp. biology

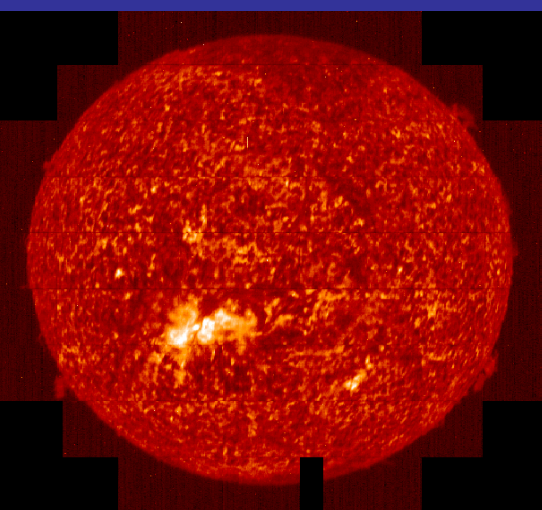
4 new experiments approved in 2004



Dark Matter

DAMA/LIBRA; CRESST

WARP; XENON



Solar ν

GNO

Luna

Borexino

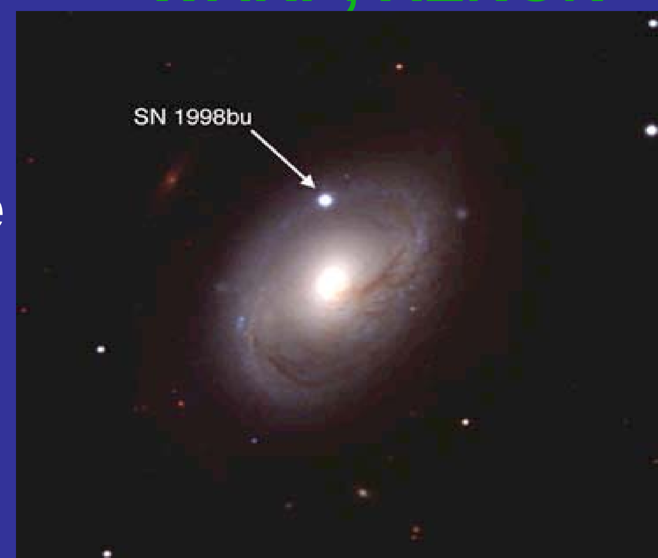
ICARUS

ν from Supernovae

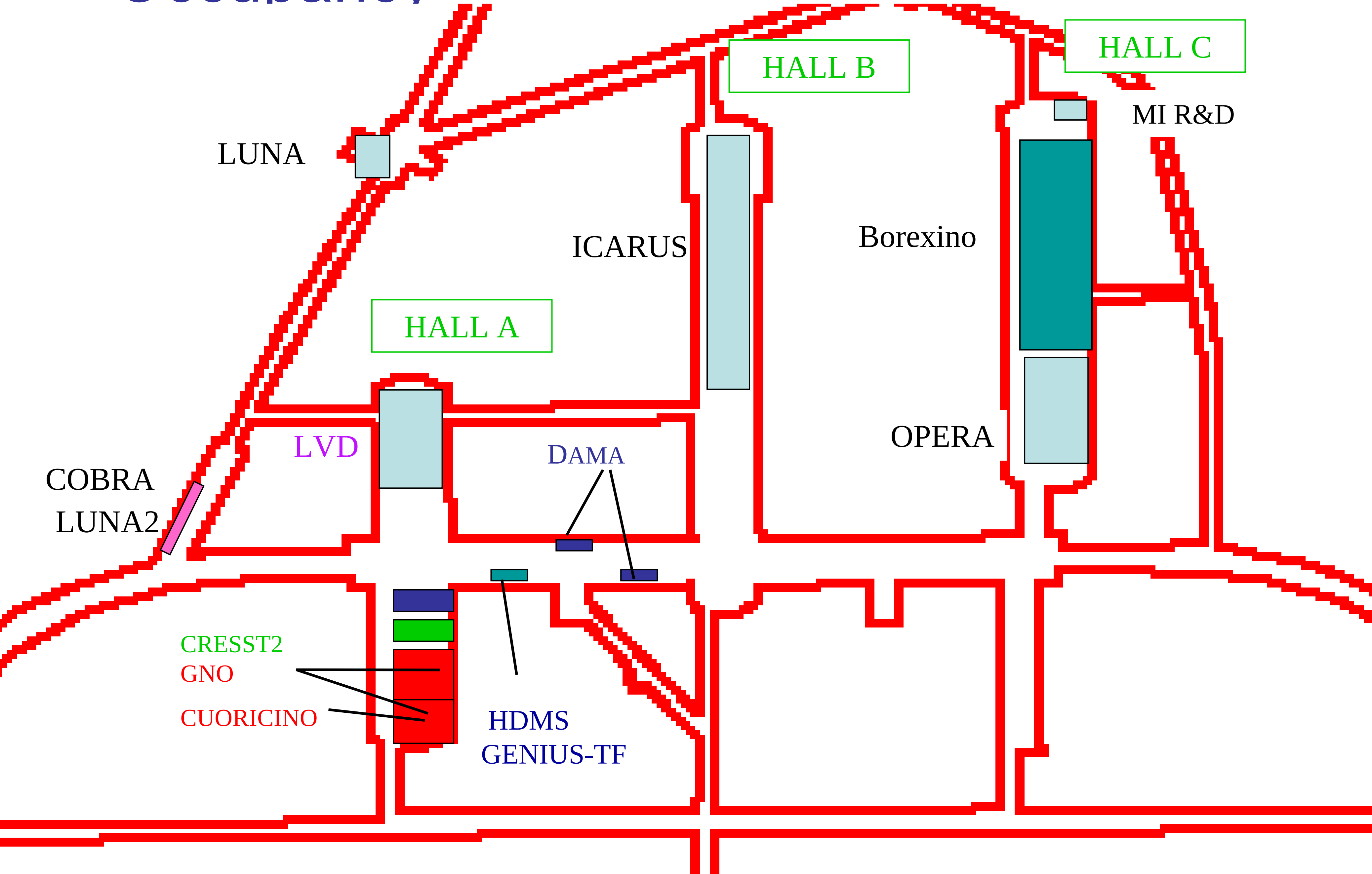
LVD

Borexino

ICARUS

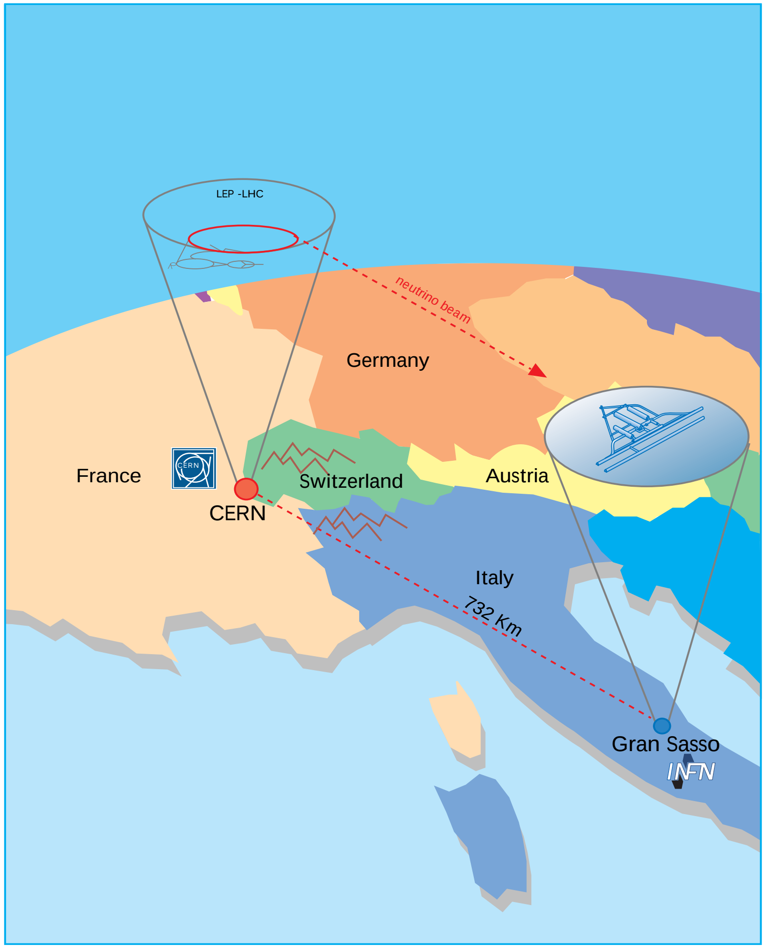


Occupancy



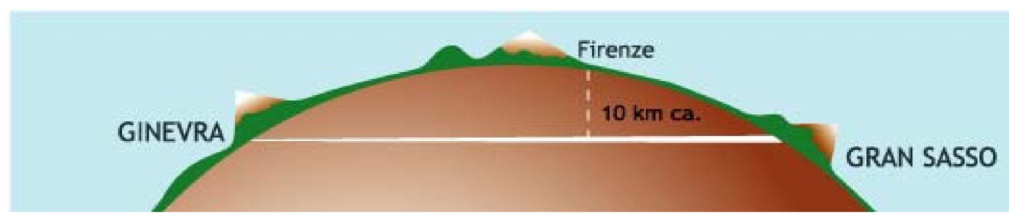
LUNA
HALL B
HALL C
MI R&D
ICARUS
Borexino
HALL A
LVD
DAMA
OPERA
COBRA
LUNA2
CRESST2
GNO
CUORICINO
HDMS
GENIUS-TF

CNGS CERN to Gran Sasso Neutrino Project



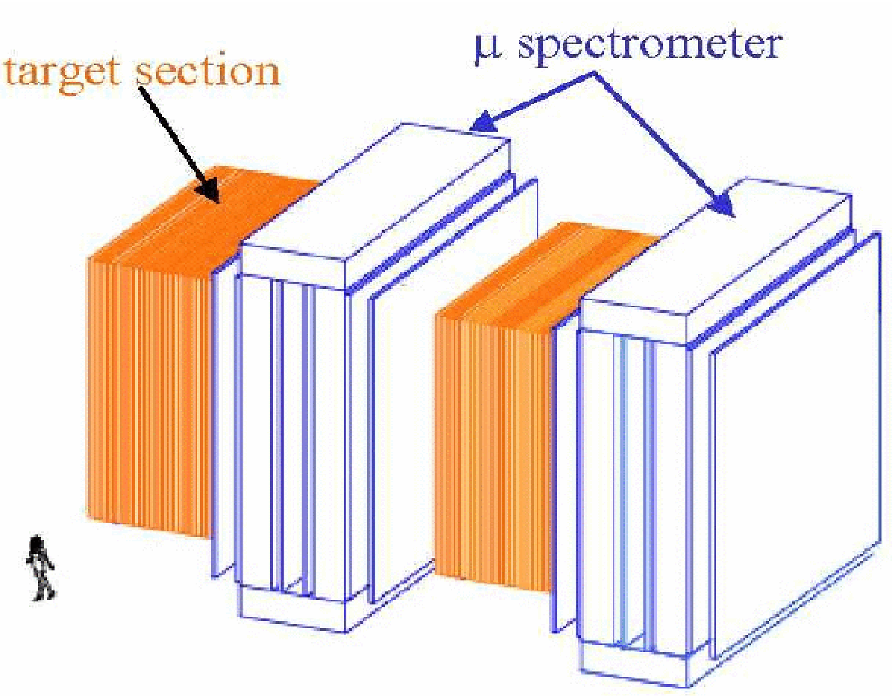
ν_μ beam produced at CERN and detected at LNGS after a travel of 730 km

Approved by CERN and INFN in 1999, ready in 2006

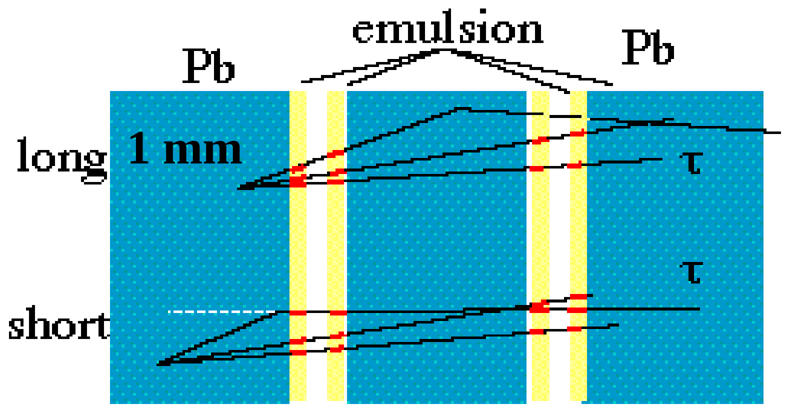


OPERA

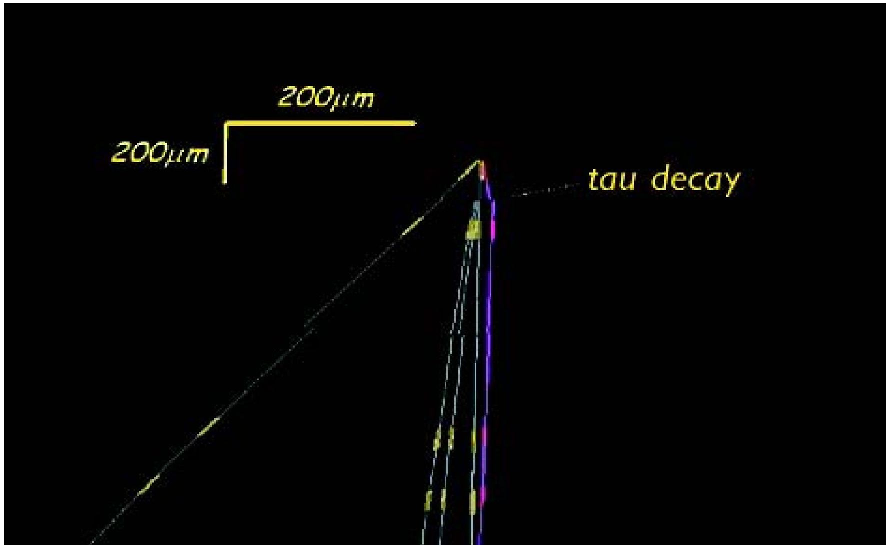
Collab.:
Italy, France, China, Germany, Belgium, Turkey, Switzerland, Russia, Japan, Israel, Croatia



Layers of emulsions and Lead

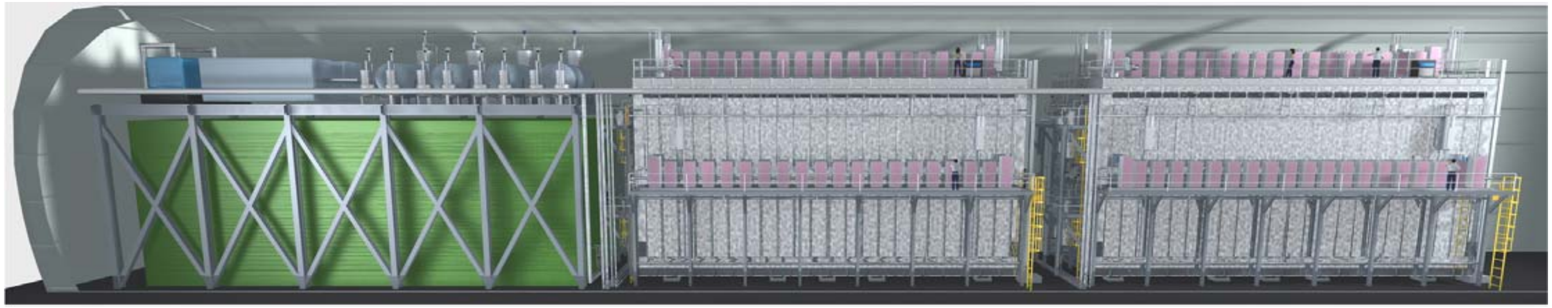


2 super-modules
1800 t sensitive mass
To detect τ is necessary a μm resolution because the τ decays in a really short time



ICARUS Imaging Cosmic and Rare Underground Signals

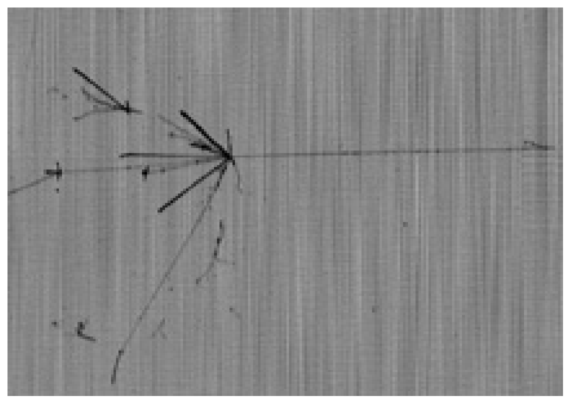
First Unit T600 | T1200 | T1200



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

Liquid Argon (-176 °C)

First half of T600 module successfully operated in Pavia
Expect to install T600 in 2004
T3000 detector proposed as a series of five T600 modules

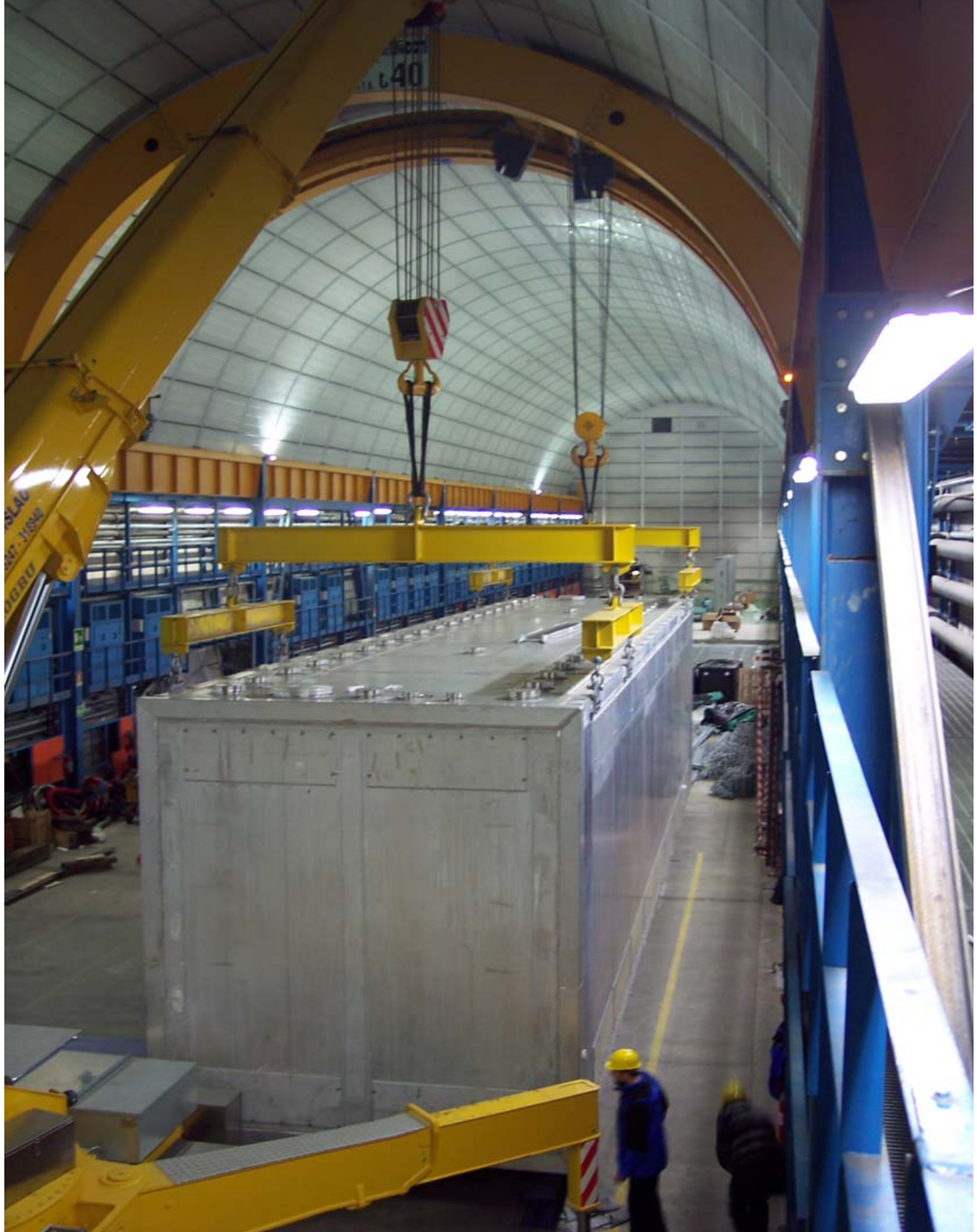


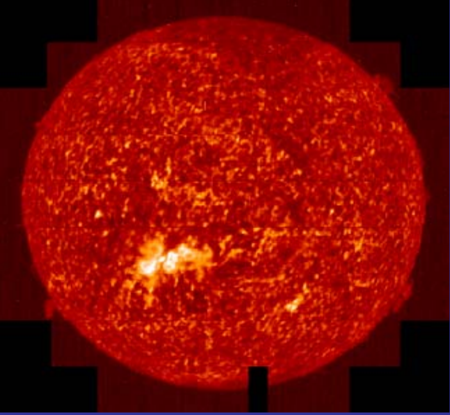
17 m

INFN

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

ICARUS T600
Dicember 3, 2004

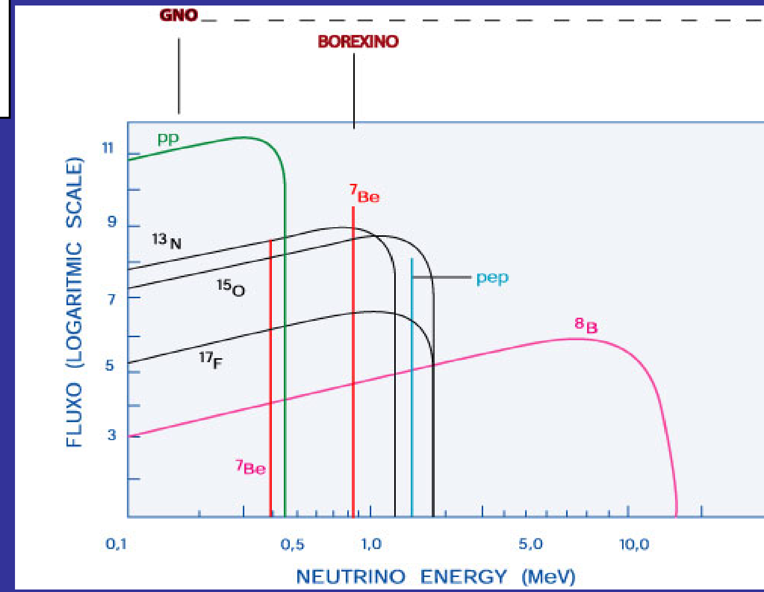




GNO

Collab.:
Italy, France, Germany

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



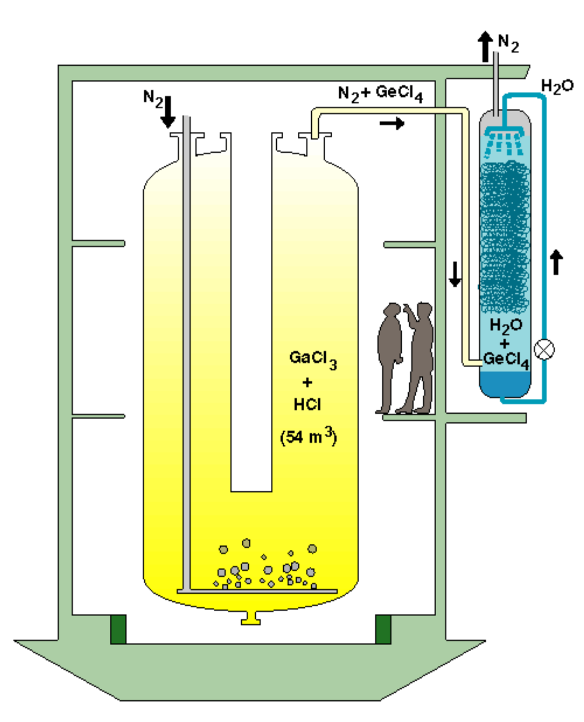
101 tons Gallium Cloride solution

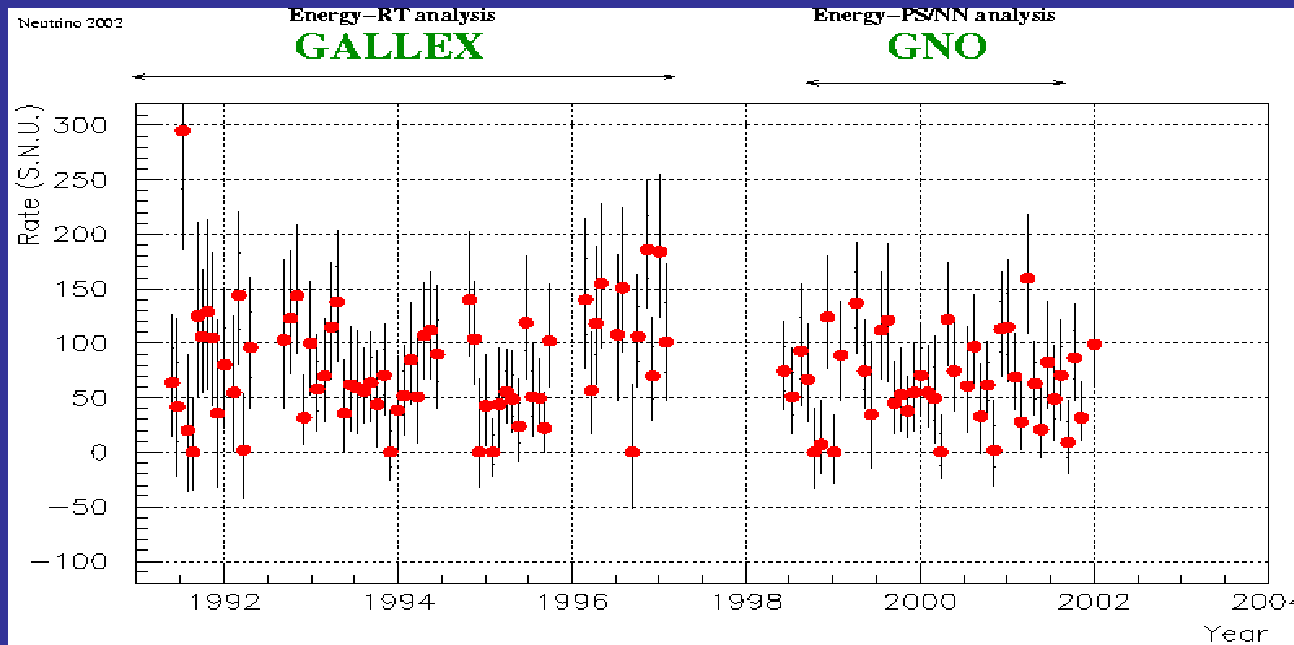
$^{71}Ge(\nu_e,e)^{71}Ge$

Energy threshold > 233 keV

Sensitive mainly to pp -neutrinos

SSM → 115 -135 SNU

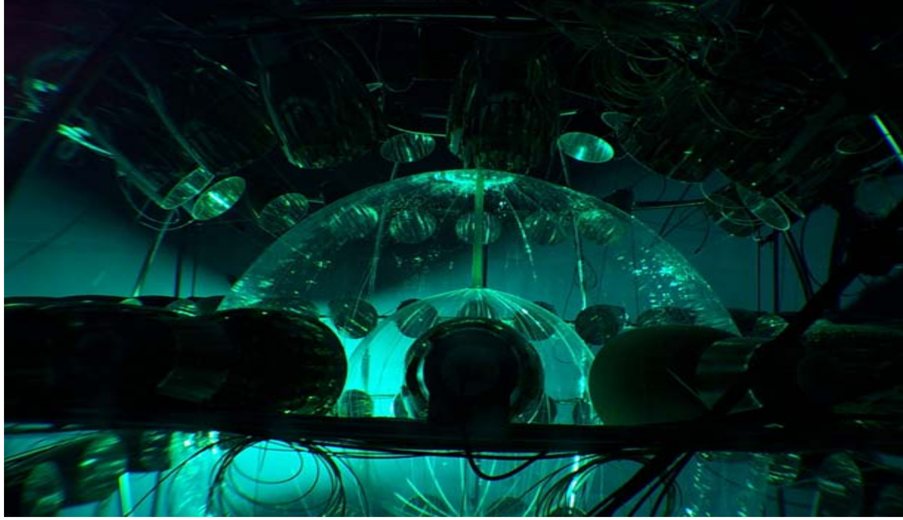




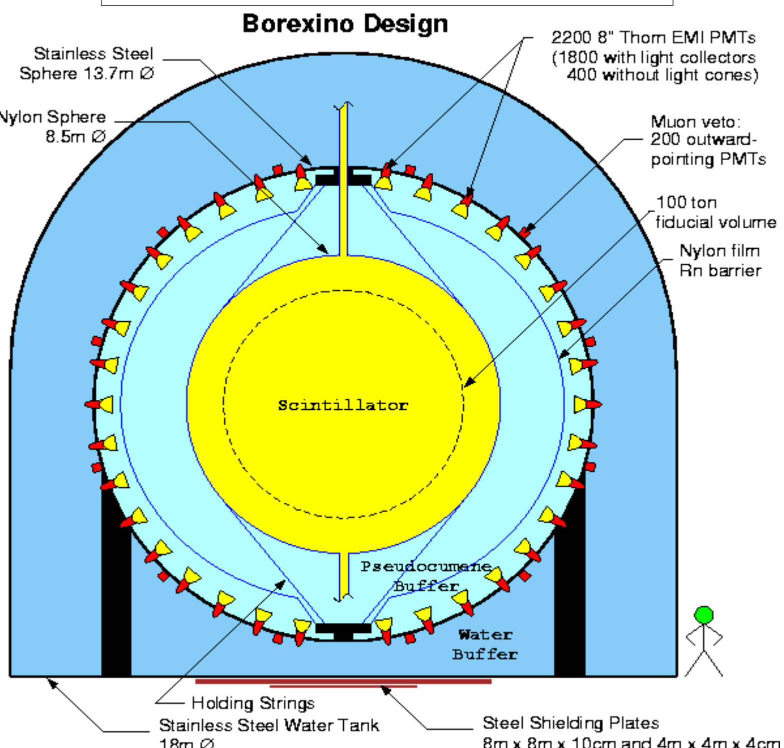
GALLEX	65 SR	77.5 +– 6.2 (stat) +– 4.5 (sys) SNU
GNO	43 SR	65.2 +– 6.4 (stat) +– 3.0 (sys) SNU
GNO+GALLEX	108 SR	70.8 +– 4.5 (stat) +– 3.8 (sys) SNU

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

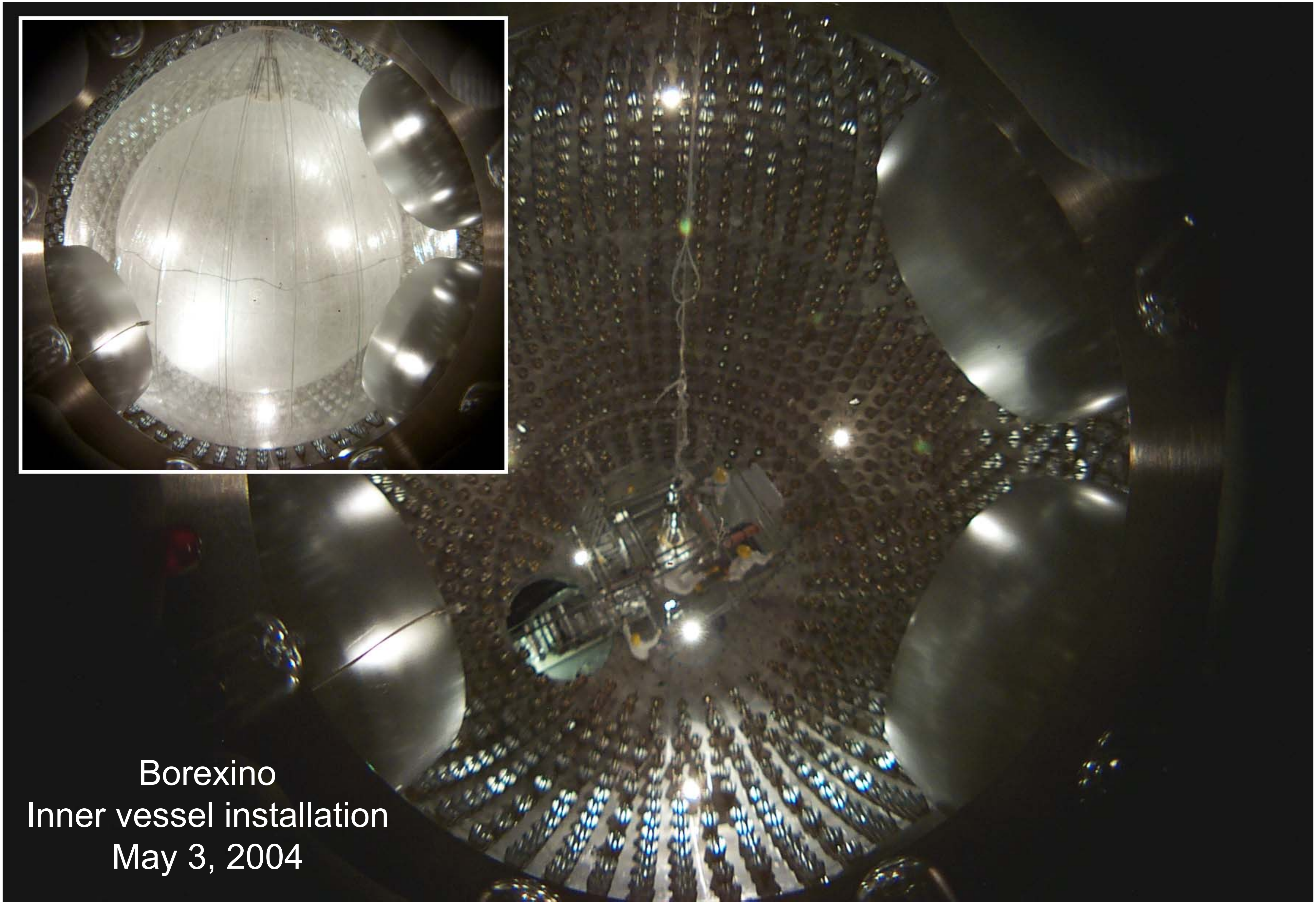


Sphere 13.7 m diam. Supports the P□Ms & optical concentrators
Space inside the sphere contains purified PC
Purified water outside the sphere

running in 2005

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

INFN



Borexino
Inner vessel installation
May 3, 2004

LUNA Laboratory for Underground Nuclear Astrophysics

Study of the cross section of nuclear reactions at stellar energies

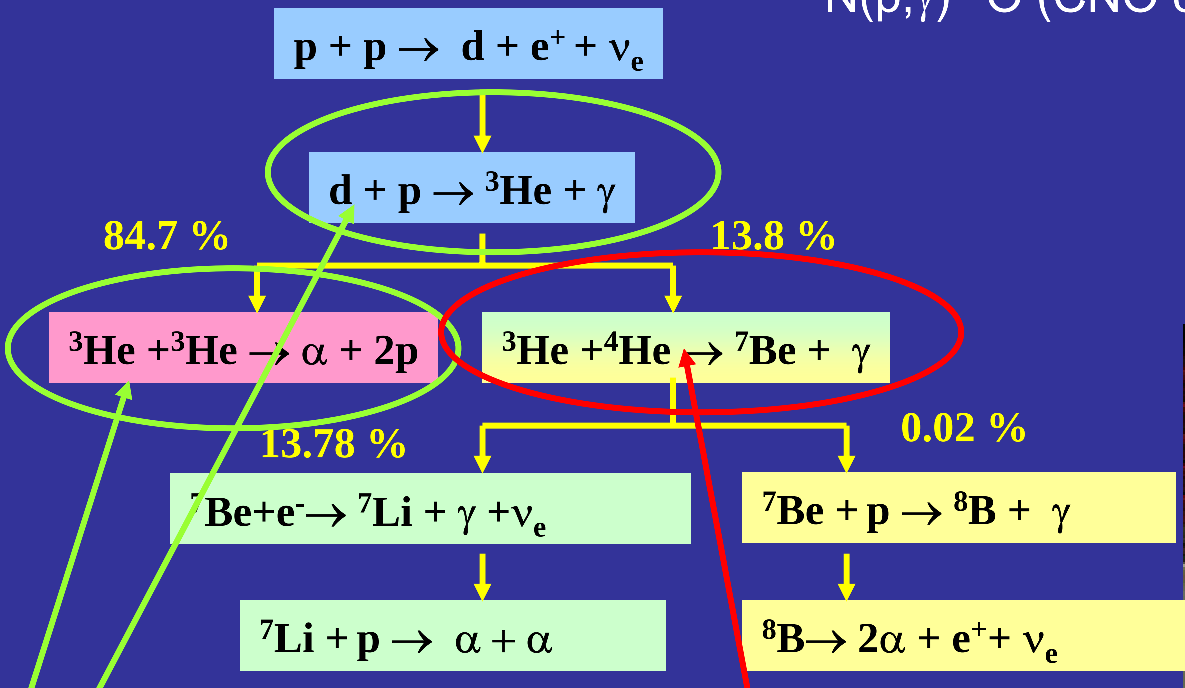
in particular for pp chain

2 accelerators: 50kV - 400kV

400 kV accelerator

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

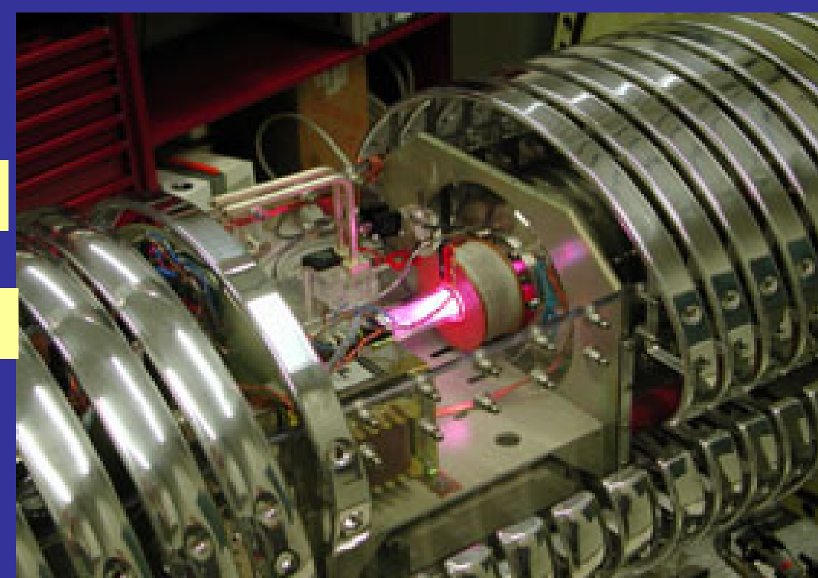
Collab.:
Italy, Germany, Hungary
Portugal

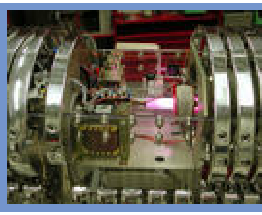


50 kV accelerator
3He(3He,2p)4He - D(p,γ)^{3}He

done

in 2003





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

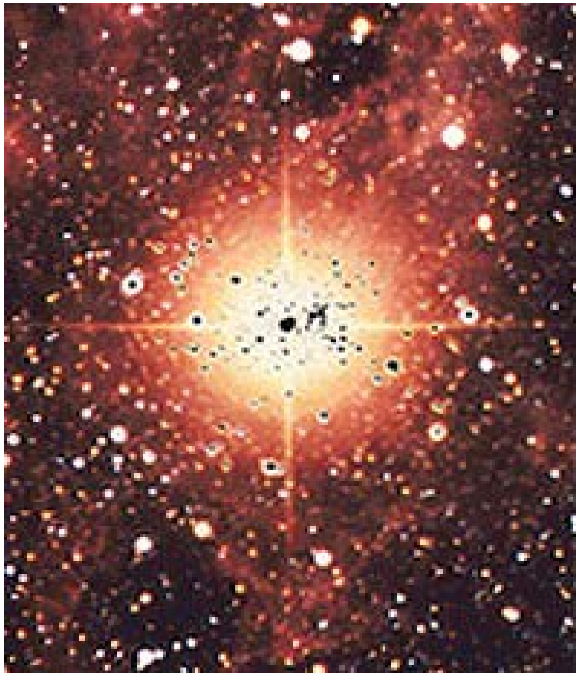
Running since 1992

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

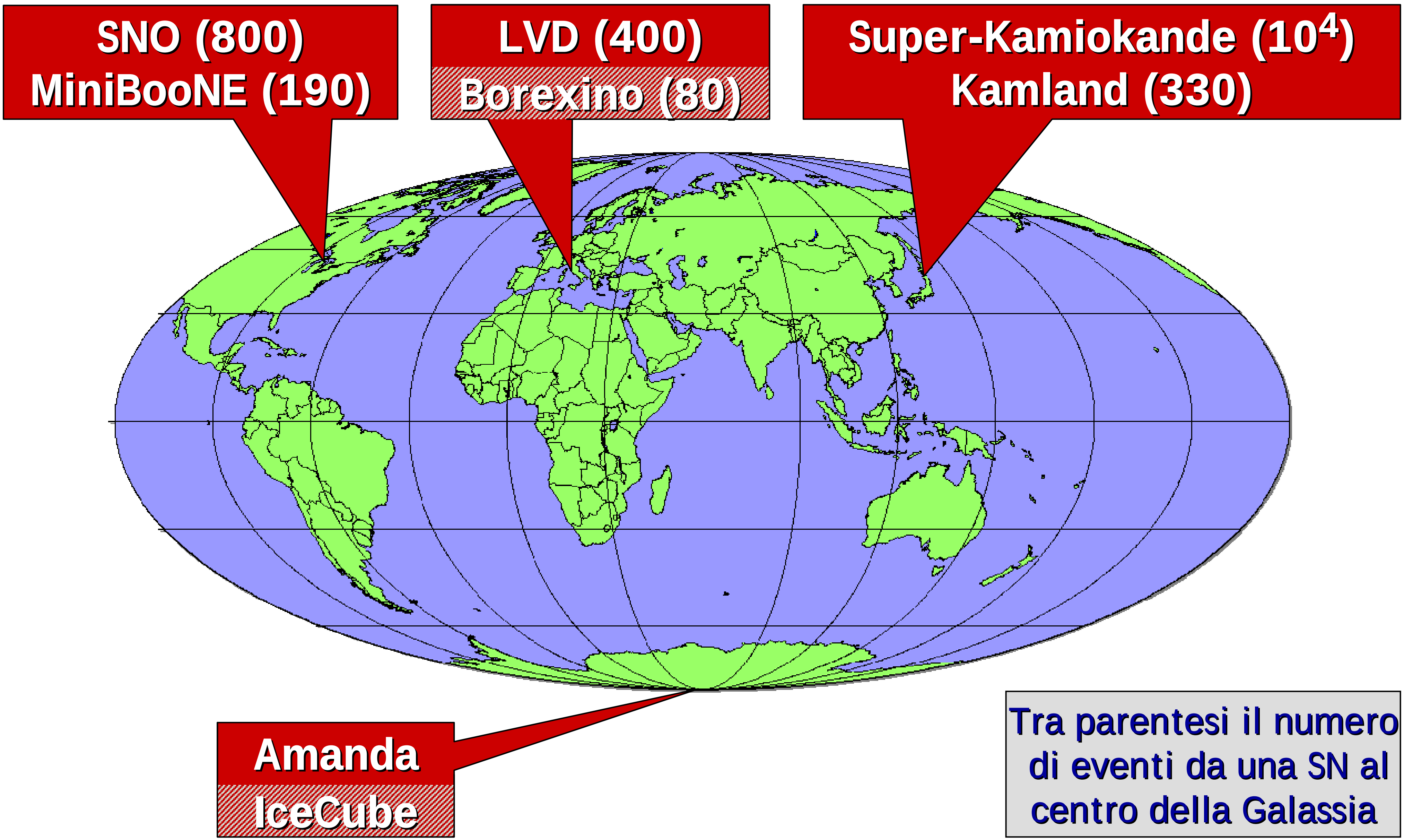
1000 tons liquid scintillator + layers of streamer tubes

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

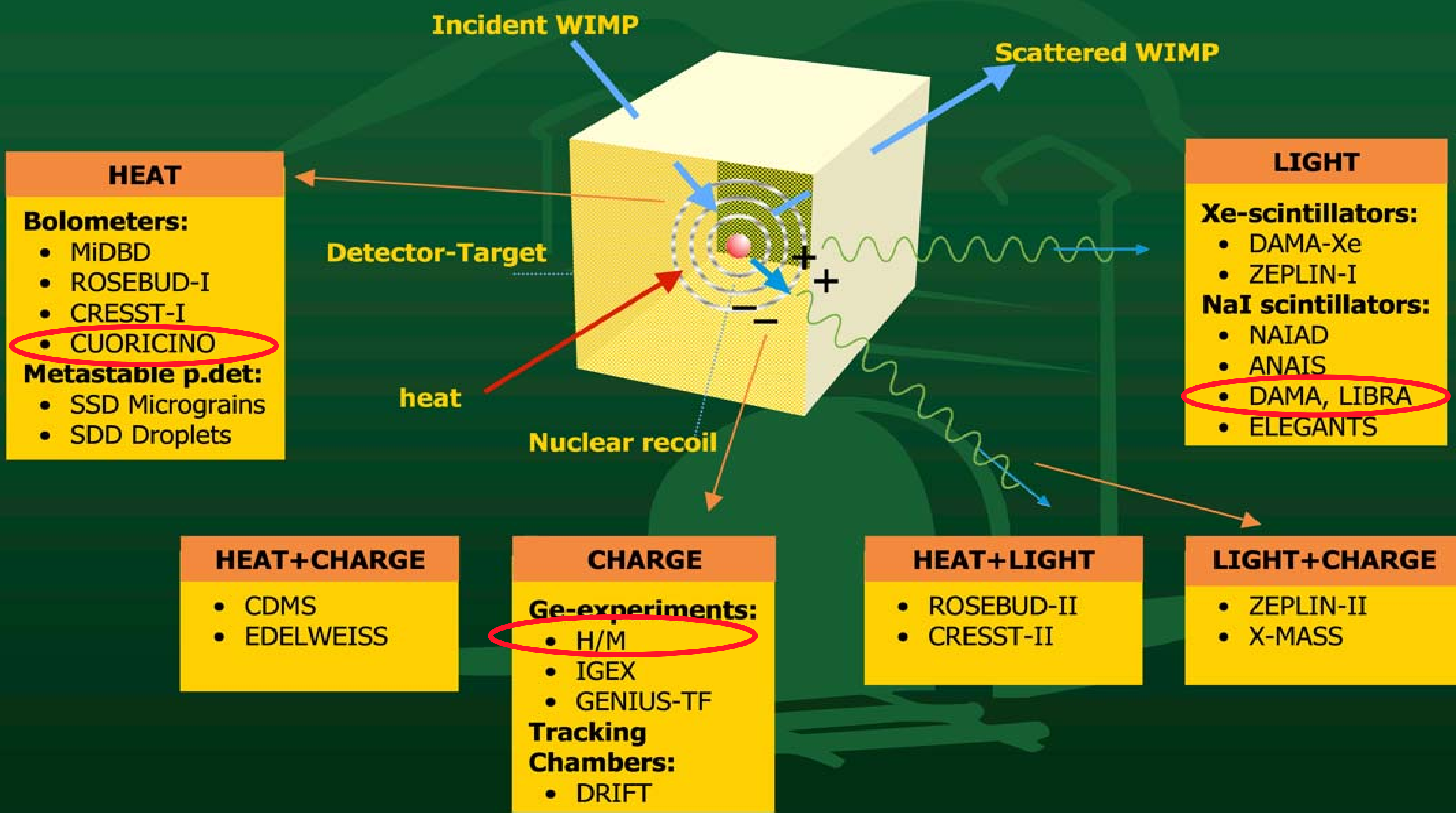


SN1987A

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


SNO (800)
MiniBooNE (190)
LVD (400)
Borexino (80)
Super-Kamiokande (10^4)
Kamland (330)
Amanda
IceCube
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(TI)

DAMA/NaI-1 to -7

107731 kg · d

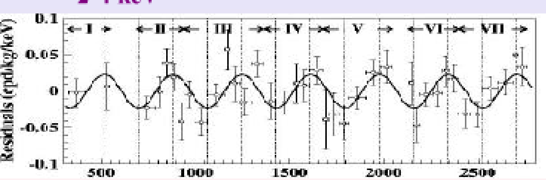
Annual modulation of the rate: the model independent result

Residuals of the rate vs time and energy

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

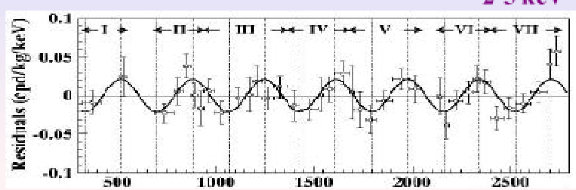
$A\cos[\omega(t-t_0)]$; continuous lines: t_0 = 152.5 d, T = 1.00 y

2-4 keV



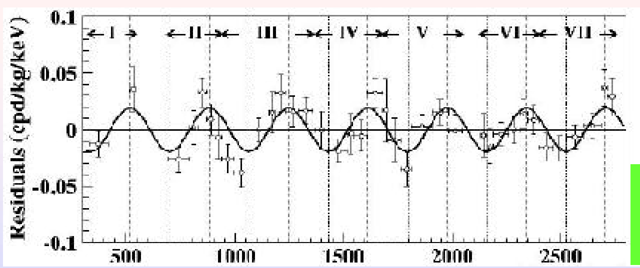
fitted: A = (0.0233 ± 0.0047) cpd/kg/keV

2-5 keV



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

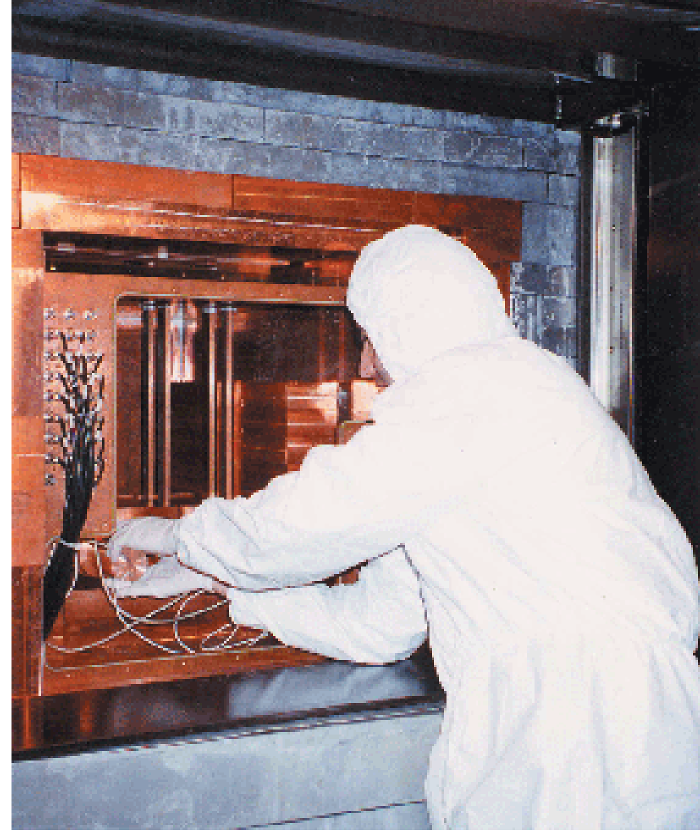
2-6 keV



P(A=0)=7·10^{-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.



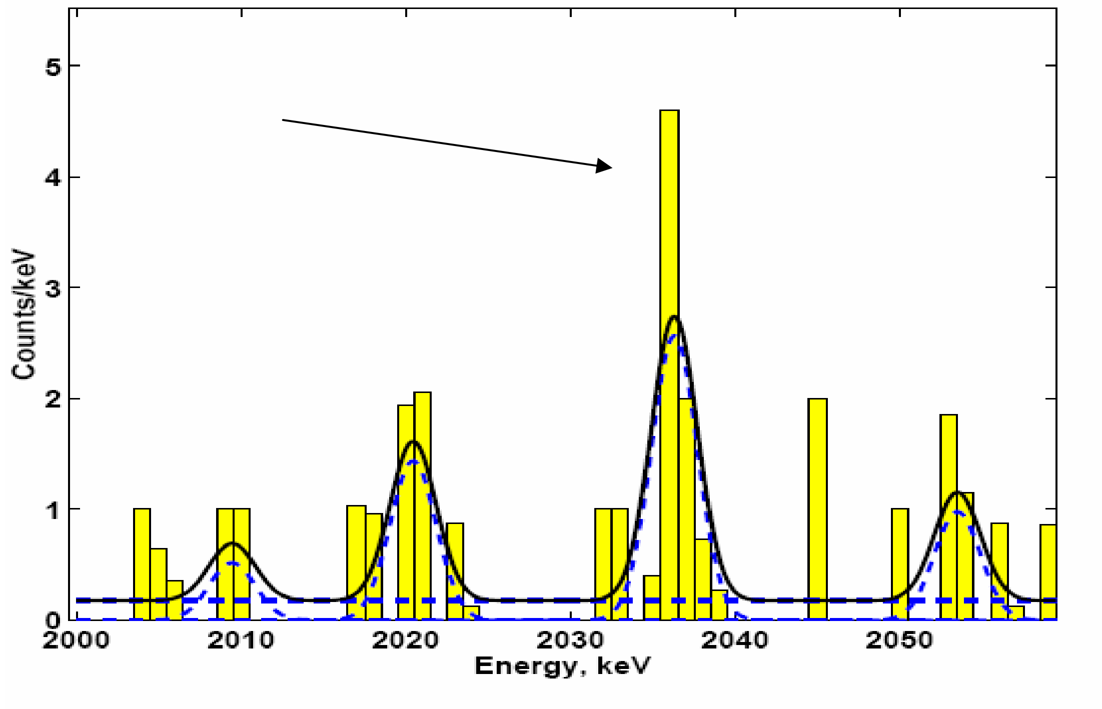
Present:

LIBRA

250 kg NaI(TI)

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

New proposals

LISA
Cuore
Warp
Xenon
Gerda

INSTITUTE OF PHYSICS PUBLISHING CLASSICAL AND QUANTUM GRAVITY

Class. Quantum Grav. **20** (2003) 317–329 PII: S0264-9381(03)56410-3

Atmospheric gravity perturbations measured by a ground-based interferometer with suspended mirrors

V N Rudenko[1], A V Serdobolski[1] and K Tsubono[2]

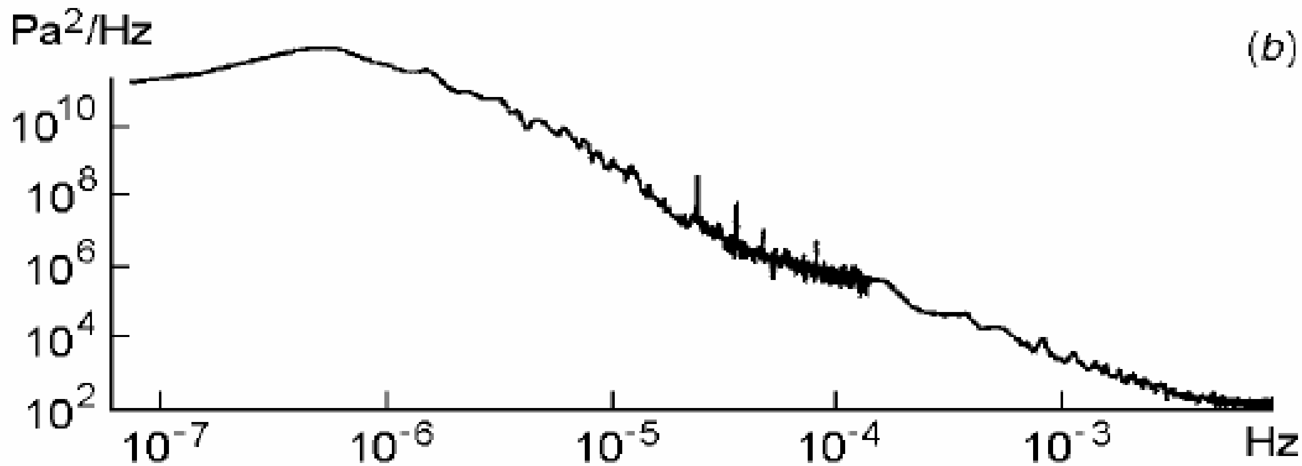
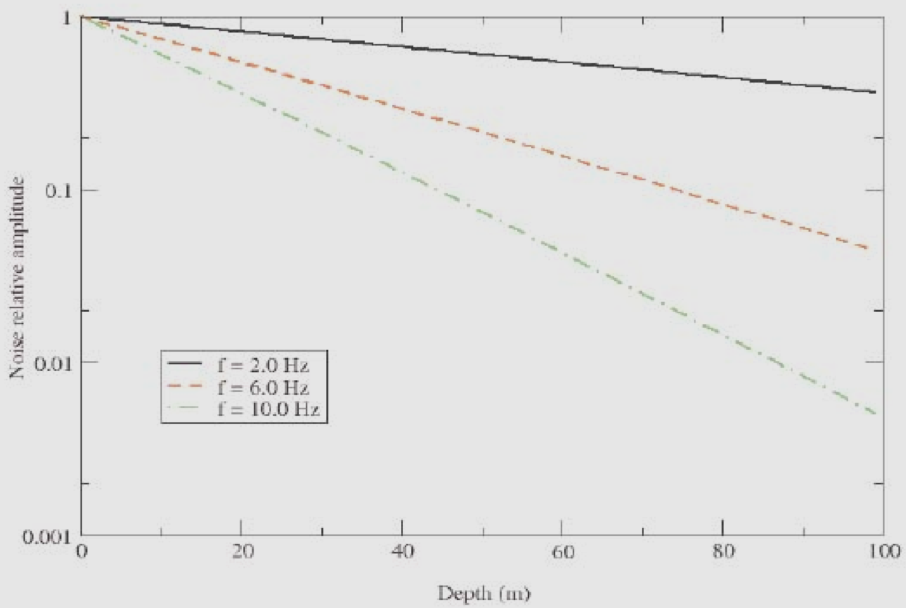


Figure 3. The pressure spectrum on the Earth's surface. Calculated curve with $h = 18$ km, $V = 3$ m s^{-1} and $\rho = 0.55$ kg m^{-3} (*a*) and experimental data (*b*).

Going underground: seismic NN reduction

A simple fact: surface waves die exponentially with the depth



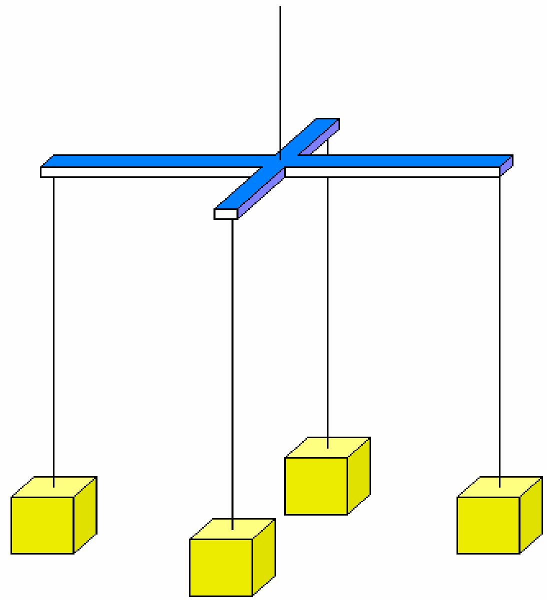
- Surface waves are probably the most important excitations for NN
- Surface movement dominate the bulk compression effect

Cella et al.

Going underground has more advantages:

- Atmospheric NN reduction
- Collective atmospheric effects damped
- Higher temperature stability

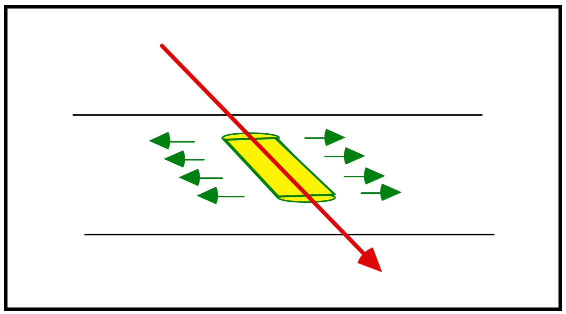
Two-degrees of freedom roto-translational pendulum



Cosmic ray interaction in the bar

Thermo-Acoustic Model:

the ***energy deposited*** by the particle is converted in a ***local heating*** of the medium:



$$\delta T = \frac{\delta E}{\rho C V_0}$$

$$\delta p = \gamma \frac{\delta E}{V_0} \qquad \gamma = \frac{\alpha Y}{\rho C}$$

Excitation of the longitudinal modes of a cylindrical bar

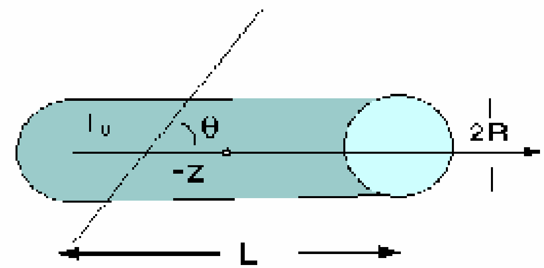
$$E_n = \frac{1}{2}\frac{l^2}{V}\frac{G_n^2}{\rho v^2}\gamma^2\left(\frac{dE}{dX}\right)^2$$

Allega A.M. & Cabibbo N. Lett Nuovo Cim 38 (1983) 263-

A. De Rujula & B. Lautrup, Nucl Phys. B242 (1984) 93-144

G_n form factor

A resonant gw detector used as a particle detector is different from any other particle detector

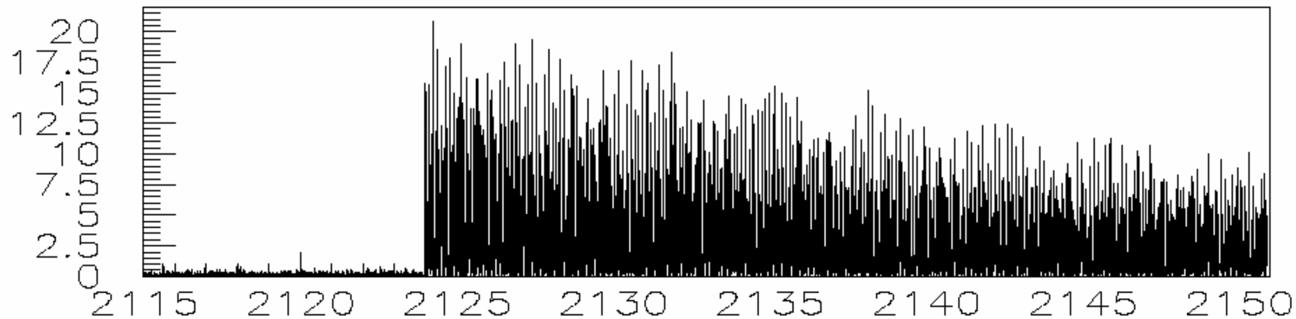


γ Gruneisen constant

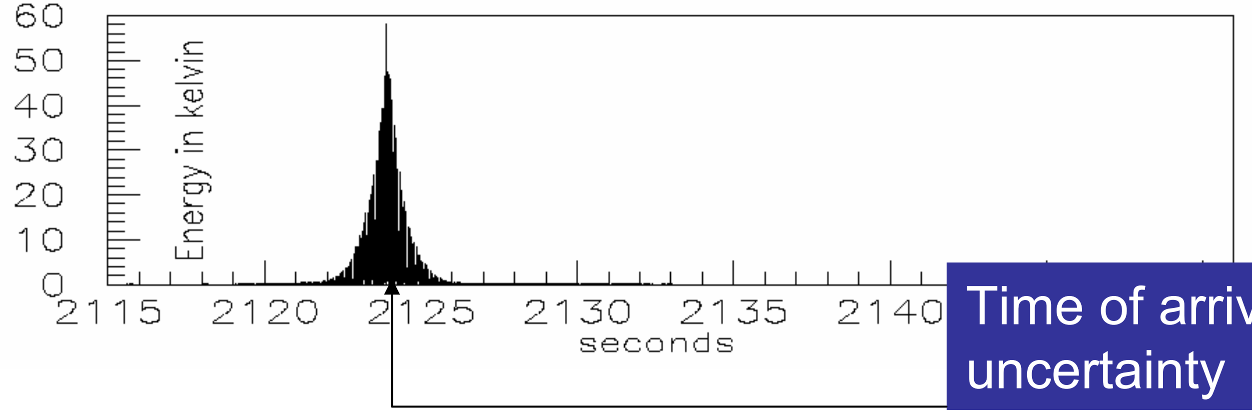
Burst event for a present bar: a millisecond pulse, a signal made by a few millisecond cycles, or a signal sweeping in frequency through the detector resonances. The burst search with bars is therefore sensitive to different kinds of gw sources such as a stellar gravitational collapse, the last stable orbits of an inspiraling NS or BH binary, its merging, and its final ringdown.

Real data: the arrival of a cosmic ray shower on NAUTILUS

Unfiltered signal (V^2)



The signal after filtering (kelvin)

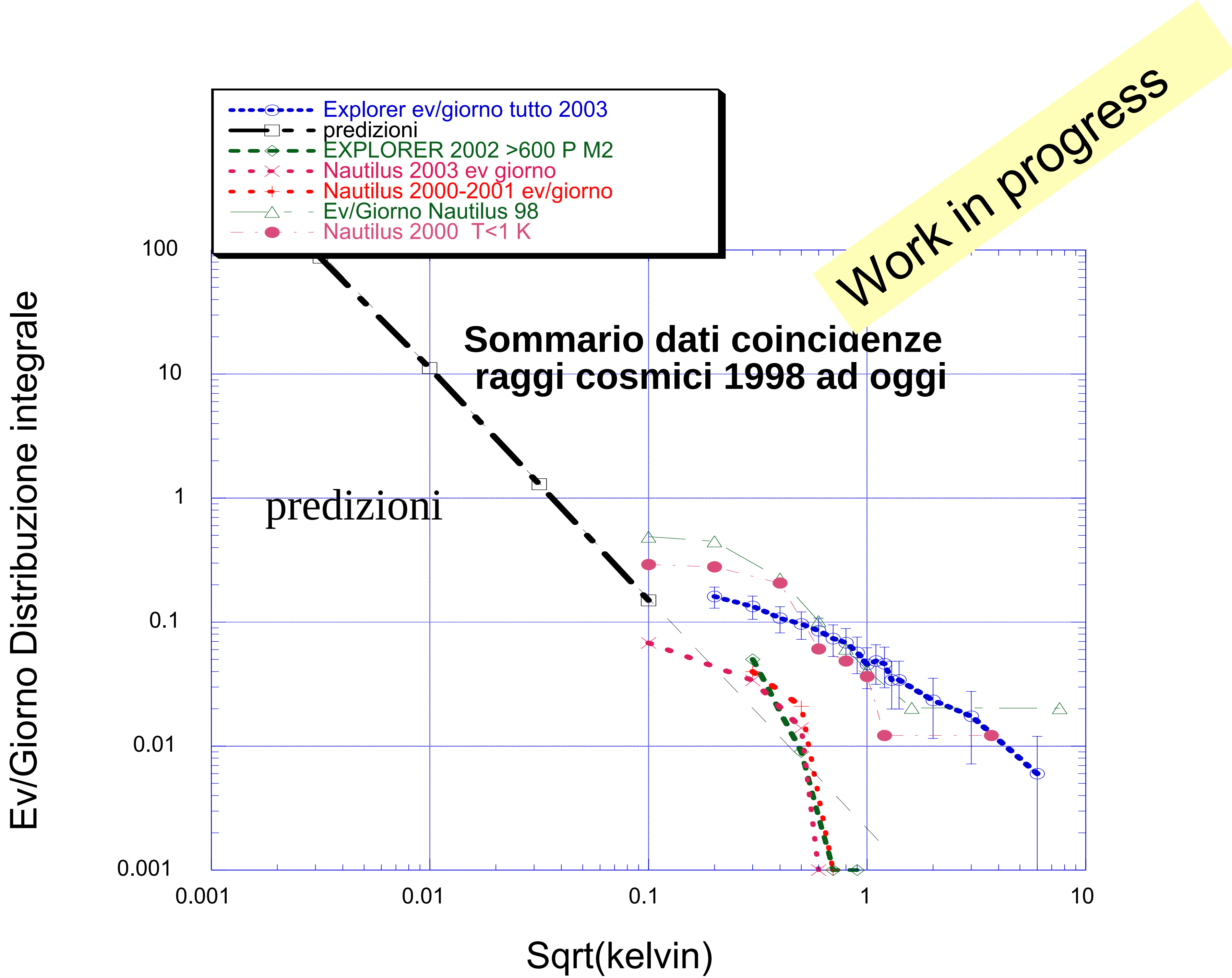


Time of arrival uncertainty ~ 1 ms

Cosmic ray:

rates in the bar (events/day)

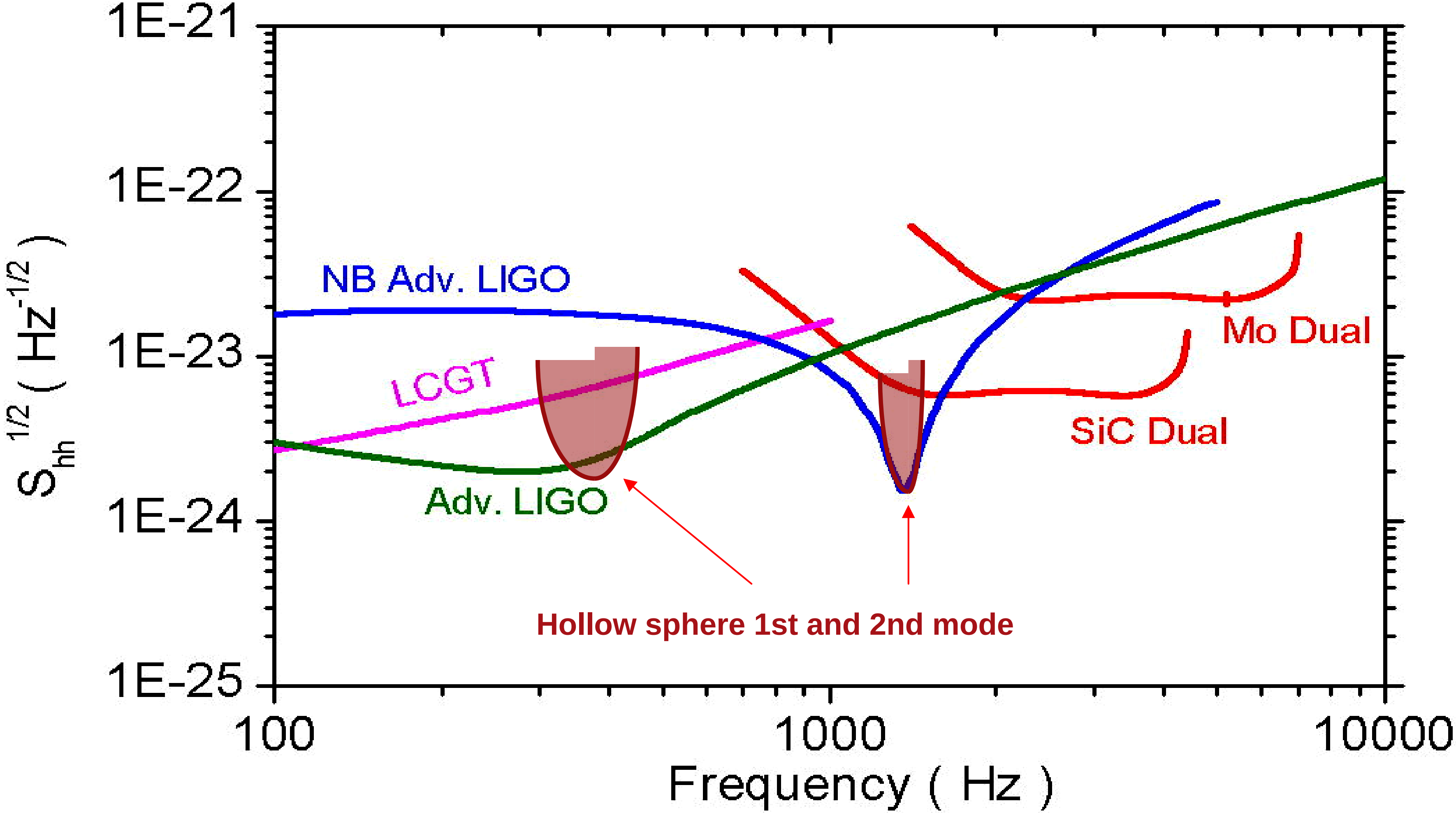
E (K)	Muon	EAS	Hadro.	Total
10^{-7}	1540	1890	-	8630
10^{-6}	155	323	-	941
10^{-5}	12.7	50	24.2	87
10^{-4}	1.2	7	3.0	11.2
10^{-3}	0.18	0.8	0.33	1.3
10^{-2}	0.002	0.1	0.05	0.15



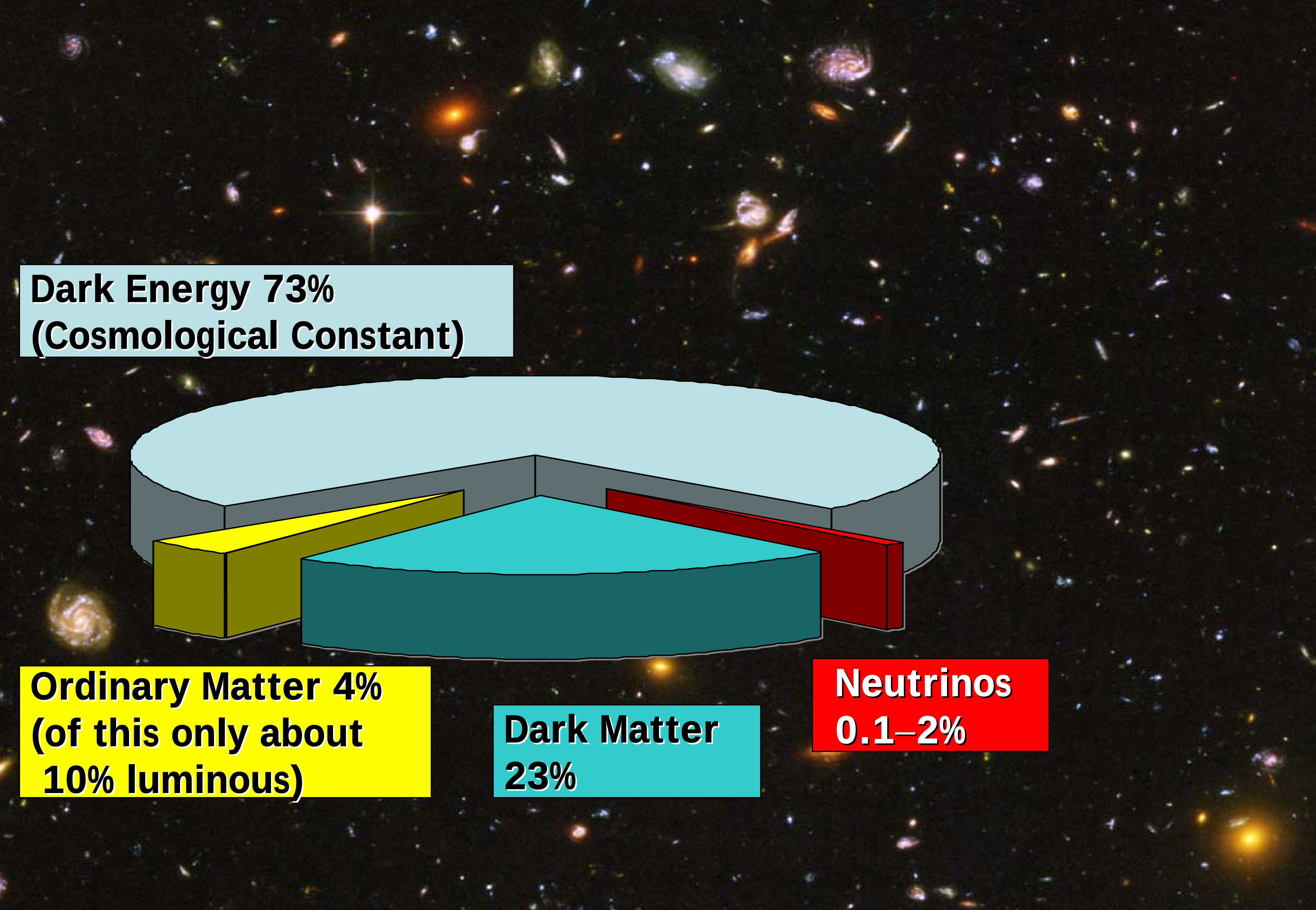
Explorer ev/giorno tutto 2003
predizioni
EXPLORER 2002 >600 P M2
Nautilus 2003 ev giorno
Nautilus 2000-2001 ev/giorno
Ev/Giorno Nautilus 98
Nautilus 2000 T<1 K
Work in progress
Sommario dati coincidenze
raggi cosmici 1998 ad oggi
predizioni
Ev/Giorno Distribuzione integrale
Sqrt(kelvin)
100
10
1
0.1
0.01
0.001
0.001
0.01
0.1
1
10

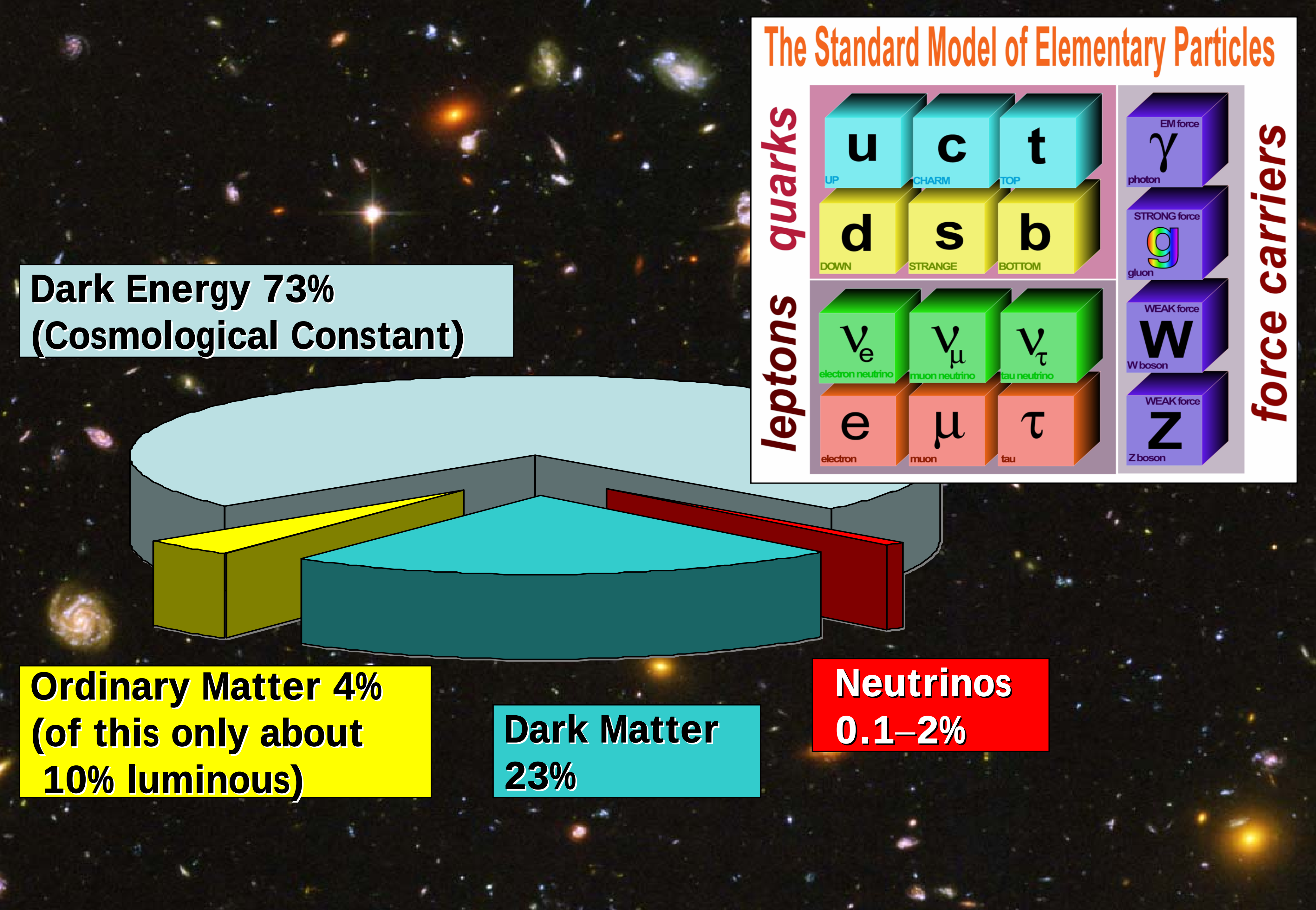
D = 4.0 m;
f_1=380 Hz;
f_2=1200 Hz;
SQL

Large Hollow Sphere

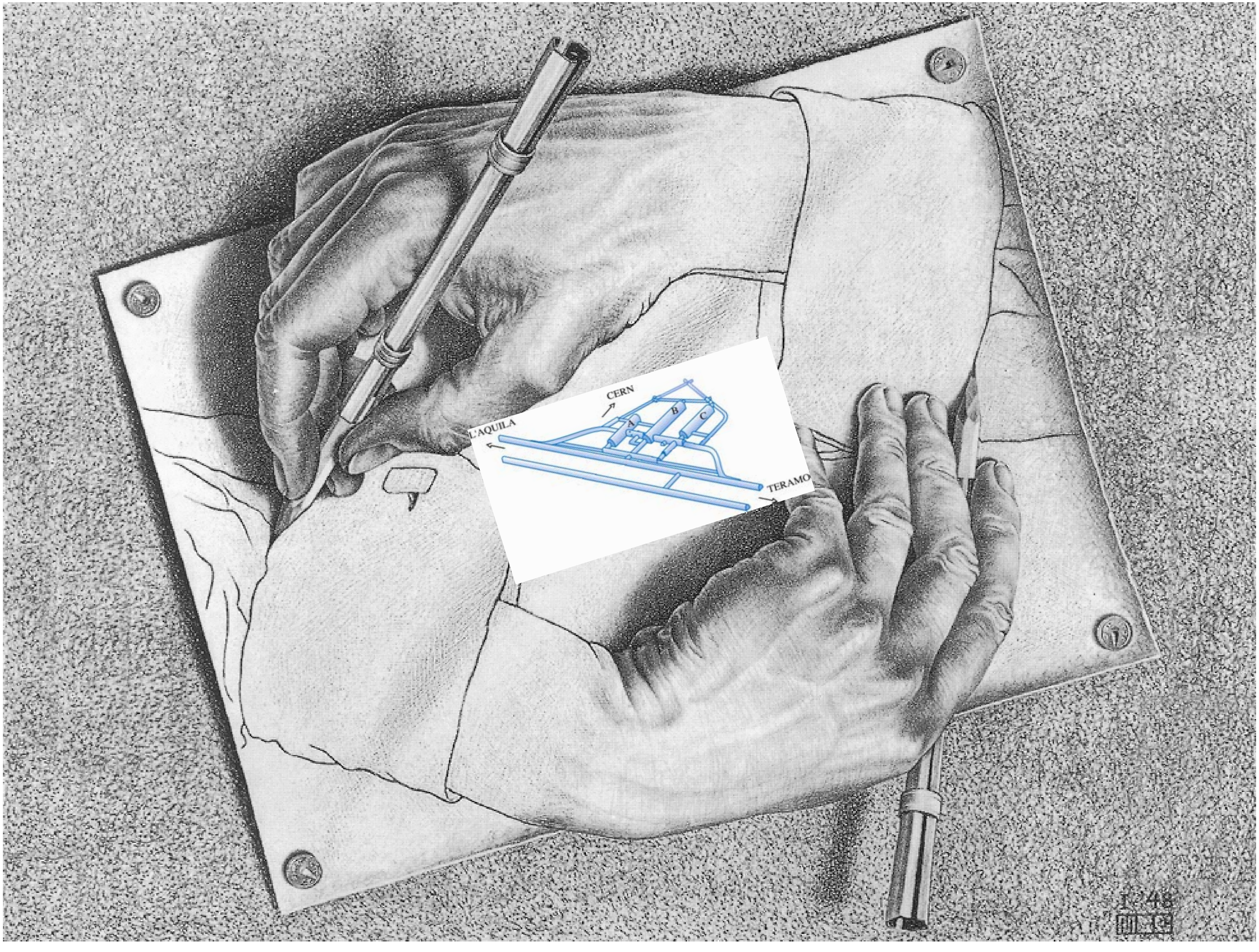


LNGS 23 APRILE 2004


Dark Energy 73%
(Cosmological Constant)
Ordinary Matter 4%
(of this only about
10% luminous)
Dark Matter
23%
Neutrinos
0.1–2%



Dark Energy 73%
(Cosmological Constant)
Ordinary Matter 4%
(of this only about
10% luminous)
Dark Matter
23%
Neutrinos
0.1–2%
The Standard Model of Elementary Particles
quarks
u
UP
c
CHARM
t
TOP
d
DOWN
s
STRANGE
b
BOTTOM
leptons
ν_e
electron neutrino
ν_μ
muon neutrino
ν_τ
tau neutrino
e
electron
μ
muon
τ
tau
force carriers
EM force
γ
photon
STRONG force
g
gluon
WEAK force
W
W boson
WEAK force
Z
Z boson


CERN
A
B
C
L'AQUILA
TERAMO
I '48