Conference
In memory of
Veniamin Sergeyevich Berezinsky

1-3 October 2024, GSSI, L'Aquila

A historical perspective on the Gran Sasso National Laboratory

A. Bettini

G. Galilei Physics and Astronomy Dept. Padua University; INFN Padova. Italy

The cosmic radiation

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Measurements of specific ionisation of air
300 m offshore on surface and 3 m deep
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Source of new physics
Source of background for rare events

Gressonay la Trinité. December 1932

Antonio Rostagni, Gleb Wataghin, Enrico Persico, Enrico Fermi, Matilde Rostagni

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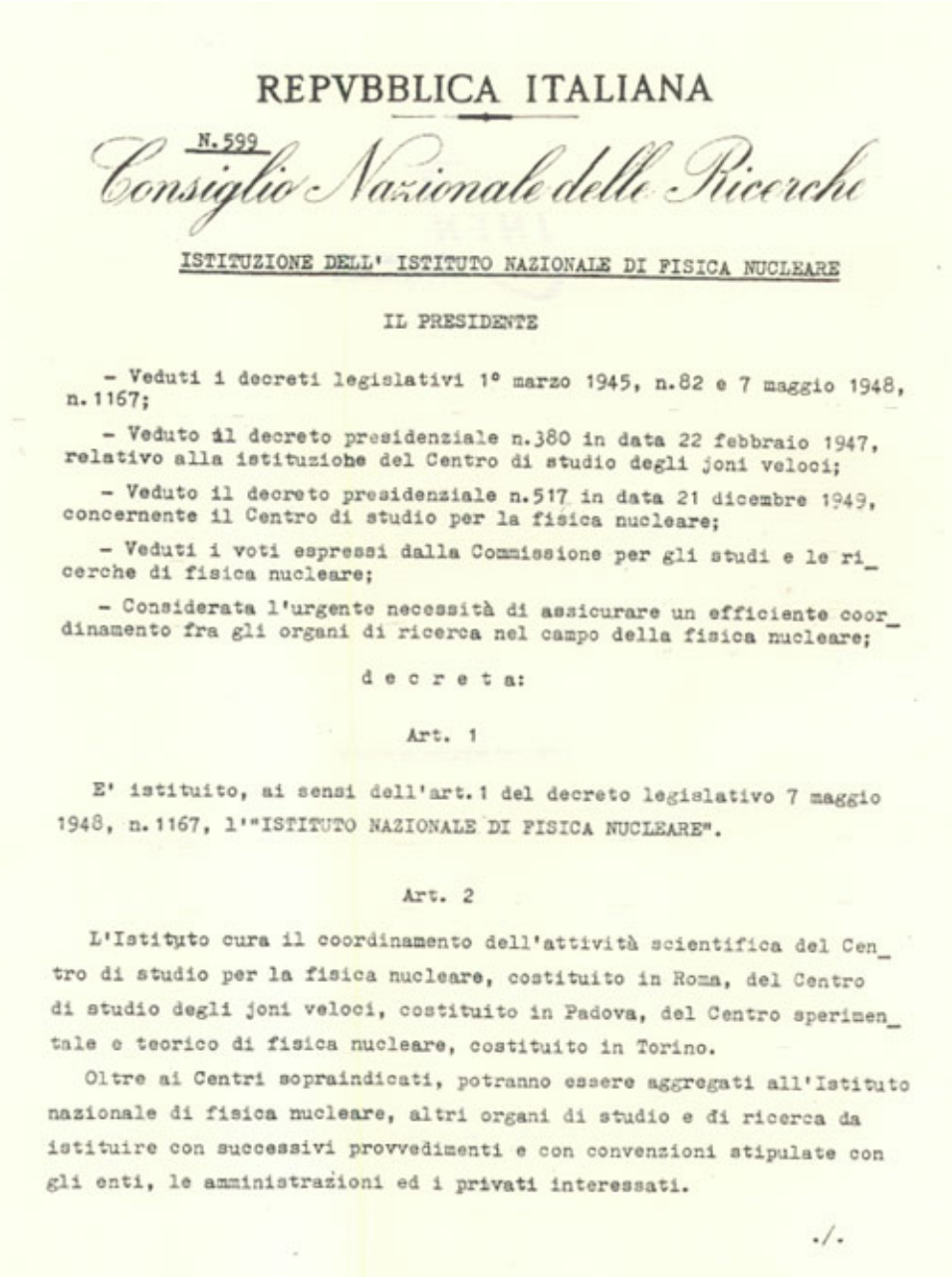
Modest but regular funding was assured by the approval by CNR of research centres

1945. Centro di studio per la fisica nucleare. Roma (Bernardinii)
1947. Centro degli ioni veloci. Padova (Rostagni)
1948. Centro sperimentale e teorico di fisica nucleare . Torino (Wataghin)

INFN is born 8. 8. 1951



REPVBBLICA ITALIANA

N.599

Consiglio Nazionale delle Ricerche

ISTITUZIONE DELL' ISTITUTO NAZIONALE DI FISICA NUCLEARE

IL PRESIDENTE

- Veduti i decreti legislativi 1° marzo 1945, n.82 e 7 maggio 1948, n.1167;

- Veduto il decreto presidenziale n.380 in data 22 febbraio 1947, relativo alla istituzione del Centro di studio degli joni veloci;

- Veduto il decreto presidenziale n.517 in data 21 dicembre 1949, concernente il Centro di studio per la fisica nucleare;

- Veduti i voti espressi dalla Commissione per gli studi e le ricerche di fisica nucleare;

- Considerata l'urgente necessità di assicurare un efficiente coordinamento fra gli organi di ricerca nel campo della fisica nucleare;

d e c r e t a:

Art. 1

E' istituito, ai sensi dell'art.1 del decreto legislativo 7 maggio 1948, n.1167, l'"ISTITUTO NAZIONALE DI FISICA NUCLEARE".

Art. 2

L'Istituto cura il coordinamento dell'attività scientifica del Centro di studio per la fisica nucleare, costituito in Roma, del Centro di studio degli joni veloci, costituito in Padova, del Centro sperimentale e teorico di fisica nucleare, costituito in Torino.

Oltre ai Centri sopraindicati, potranno essere aggregati all'Istituto nazionale di fisica nucleare, altri organi di studio e di ricerca da istituire con successivi provvedimenti e con convenzioni stipulate con gli enti, le amministrazioni ed i privati interessati.

./.

The Institute coordinates the scientific activity of the Centre for the study of Nuclear Physics, existing in Rome, the Centre for the study of the fast ions, existing in Padua, the Centre for experimental and theoretical nuclear physics, existing in Torino.

Beyond the mentioned Centres, other study and research bodies may be added to the National Institute of Nuclear Physics, to be established with subsequent provisions and agreements stipulated with interested bodies, administrations and private institutions

Immediately after Milano was added
The 4 sites, with their universities, become "Sezioni dell'INFN"

1950s. Experiments go underground

1960s. Kolar Gold Field Mine. Discovery of atmospheric neutrinos

Early 1960s. UG Lab in Italy by C. Castagnoli. Monte dei Cappuccini (To).
In an air-raid shelter 70 m. w. e. deep
1969. E. Fiorini, A. Pullia et al. double-beta decay

1968. Homestake mine. Ray Davis Solar neutrinos

About 1974. SU(5) proton decay at $10^{31} - 10^{32}$ yr (exp limit 10^{30})

Experiments employ parasitically existing underground facilities
Mines

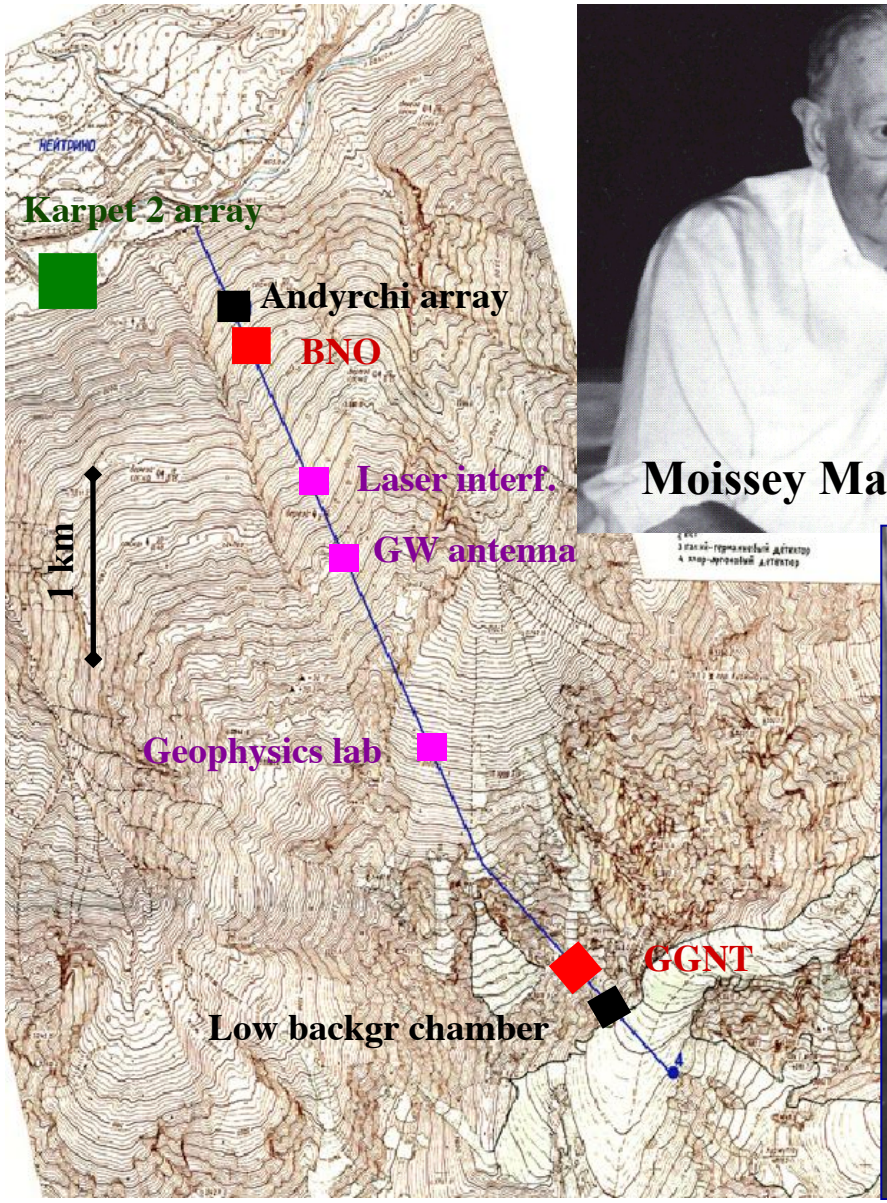
Kolar Gold Field (1984 on)
Soudan (1981 on)
KamiokaNDE (1983 on)

The background of today will be the signal of tomorrow (Masatoshi Koshiba)

Road tunnels

NUSEX (1982 on)
FREJUS (1984 on)

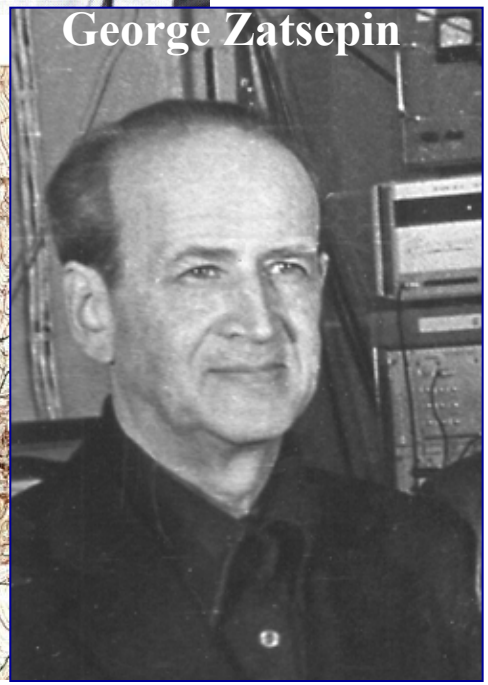
The first Underground Laboratory. Baksan



Moissey Markov

1966. Under the action of M. Markov, Head of the Physics Division, the Academy of Sciences of the USSR obtains a Decree of the Soviet Government for the construction of the underground and surface facilities (Neutrino village)

Scientific activity started under the leadership of

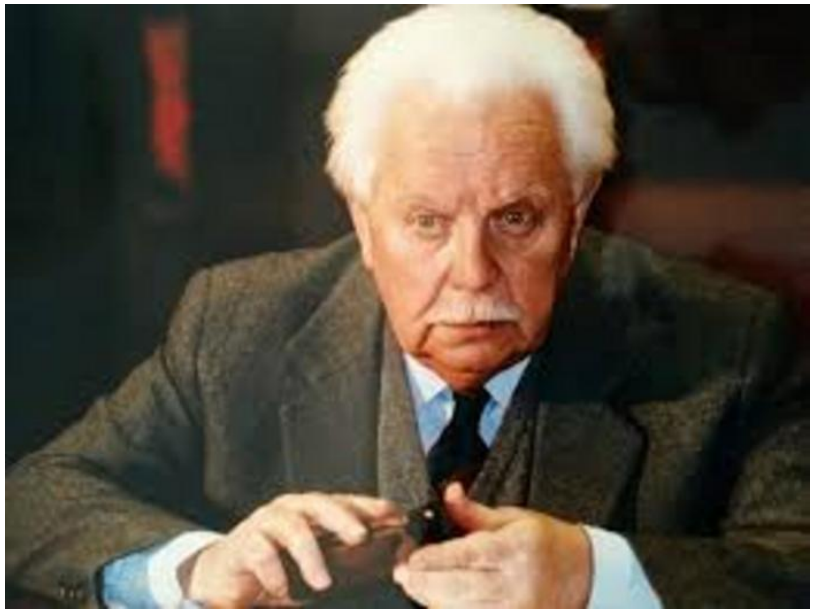

George Zatsepin

and


Alexander Chudakov

1971. The reform of the INFN

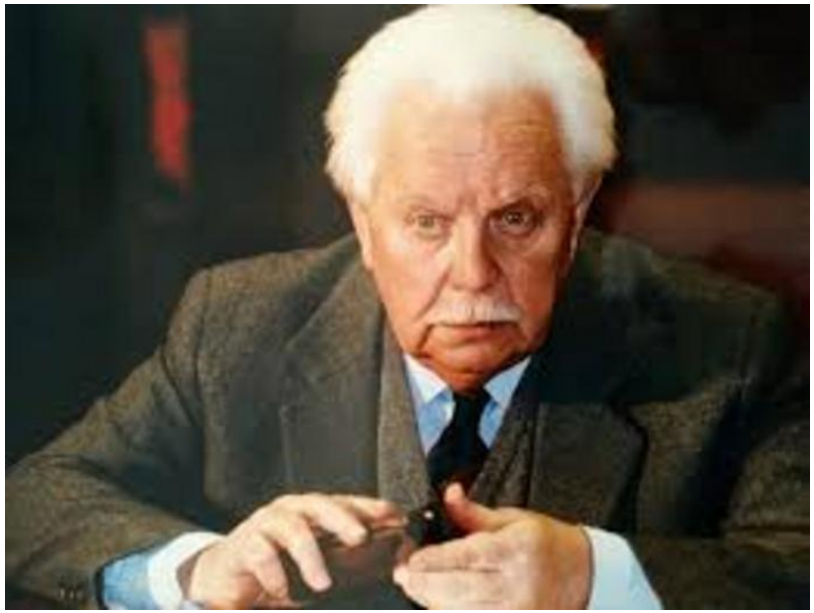
Claudio Villi. President of INFN **1971-1975**, laid down the **structure of INFN** still existing today



Operational units
- Sections (in University Physics Departments)
- National Laboratories
  - LNF 1957
  - LNL 1968 pre-exist 1961
  - LNS 1976
  - LNGS 1987

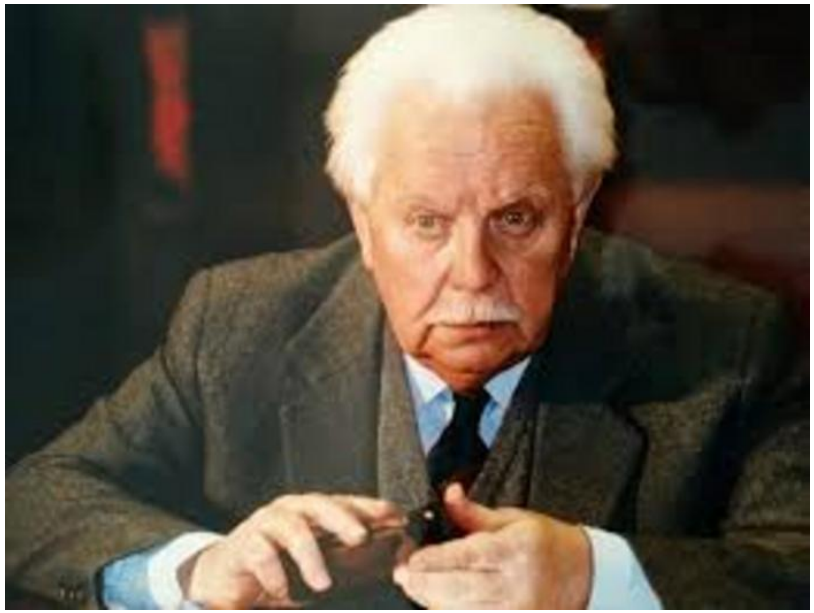
- Decisional bodies
  - Directive Council
    - with Sections and Lab Directors
  - Executive Council
  - President
- Consultant bodies. National Scientific Committees
  - 1. Elem. Part. with electronic techniques
  - 2. Elem. Part. with visual techniques
  - 3. Experimental Nuclear Physics
  - 4. Theory
  - 5. Techniques

Five-year planning and International Agreements



15 dec. 1971 INFN structures defined by law charged INFN to present to the Government for approval multi-annual budget plans
1st 5-year plan (Villi). 1974-1978

Five-year planning and International Agreements



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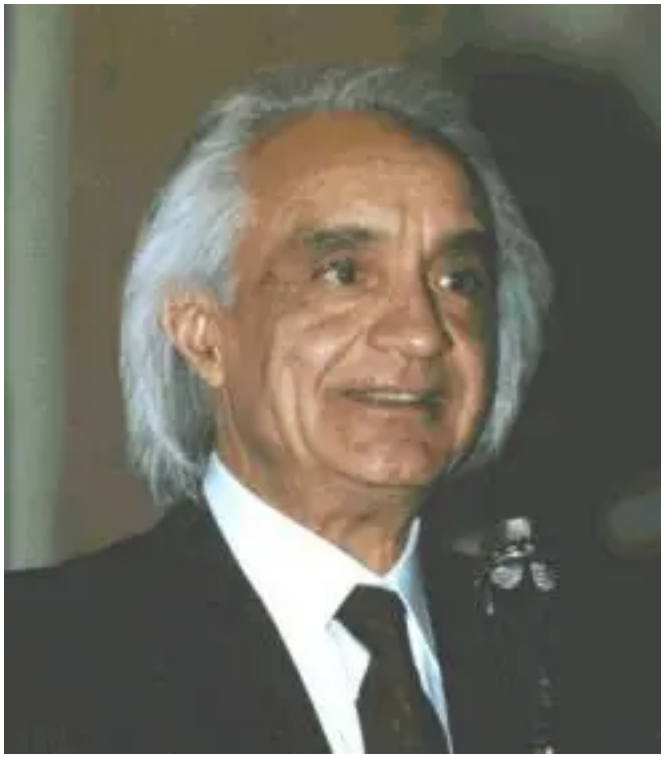
International agreements scientific collaboration

- USA 1972
- Japan 1973
- Russian Academy of Sciences 1973
- JINR 1975

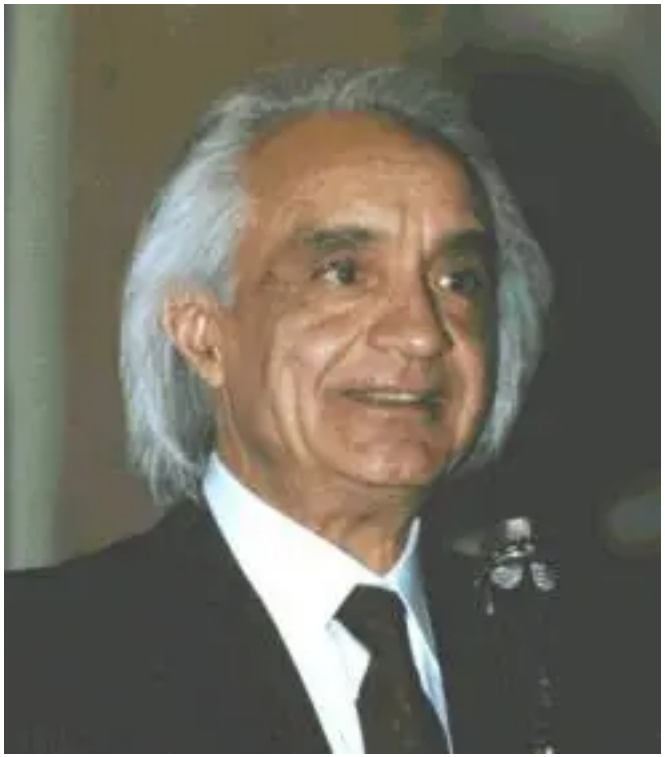
Antonino Zichichi INFN President 1976-1982



2nd 5-year plan 1979-1983

Substantial increase of the budget

Antonino Zichichi INFN President 1976-1982



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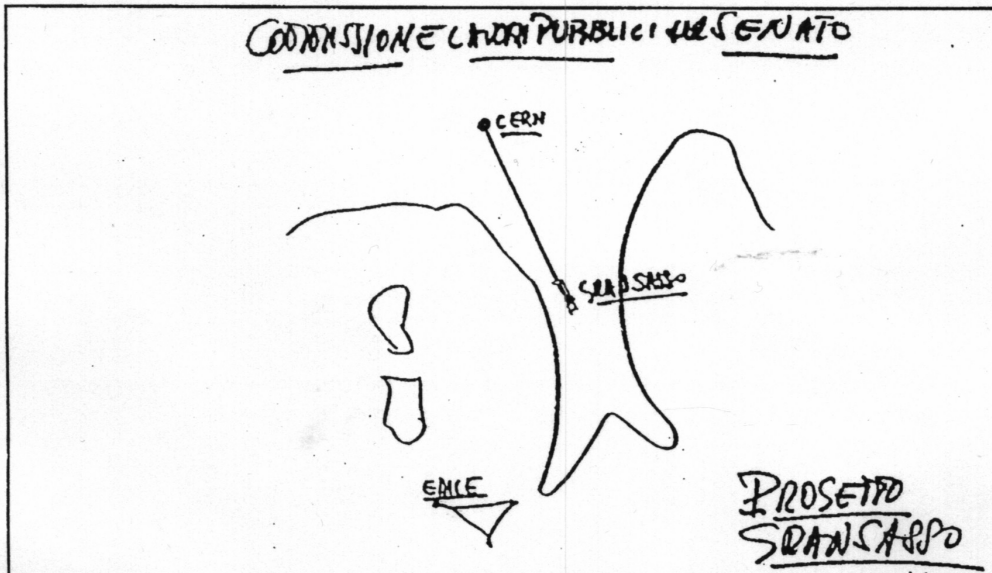
2000. Five-year budget planning and approval cancelled by Minister Luigi Belinguer

1979 The Gran Sasso project
Sketch by AZ in his presentation to the Italian Senate



Note manoscritte di A. Zichichi presentate nella Seduta della Commissione Lavori Pubblici del Senato convocata con urgenza dal Presidente del Senato per discutere la proposta del Progetto Gran Sasso (1979).

To summarize, the scientific aims of the "Gran Sasso" laboratory are the study of:

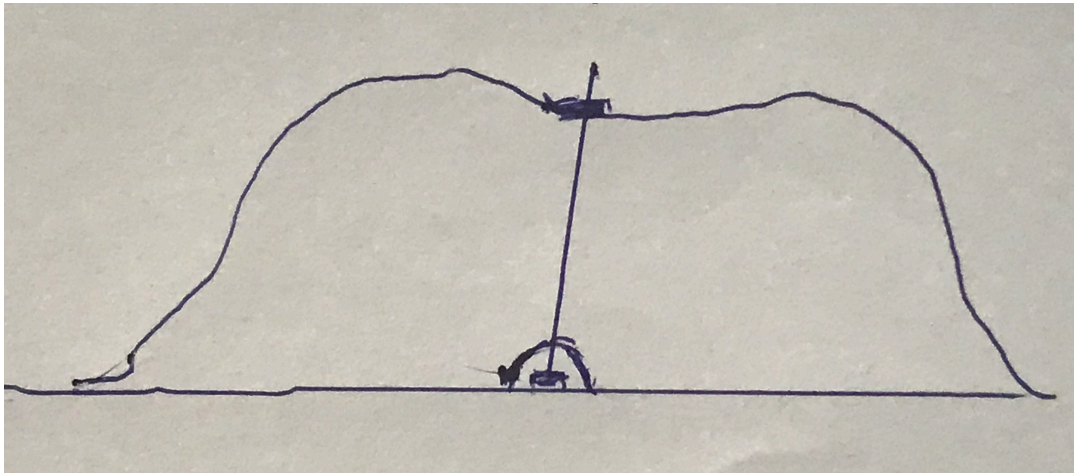
1) nuclear stability;
2) neutrino astrophysics;
3) new cosmic phenomenology;
4) neutrino oscillations;
5) biologically active matter;
6) ground stability.

NOT only $\tau_p \neq \infty$

Fig. I.1.1: (Figure from Reference 5). In the upper part, a detail of the Gran Sasso project presented by A. Zichichi in the Public Work Committee of the Italian Senate. In the lower part the reproduction of page 13 of the original project [6ª].

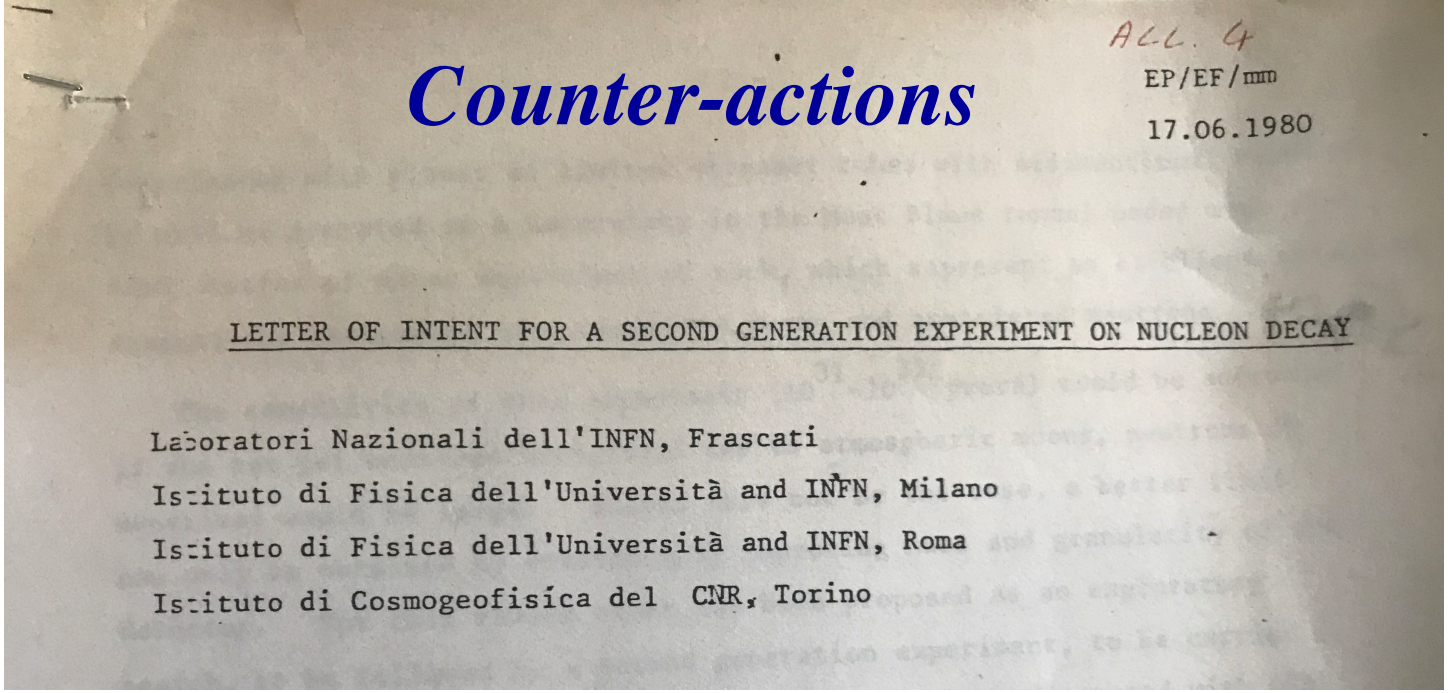
Top-bottom coincidences for cosmic rays

Did not find the original sketch
Drafted by heart



Will be
EAS-TOP at Campo Imperatore
LVD (Hall A) and MACRO (Hall B)

Counter-actions



ACC. 4
EP/EF/mm
17.06.1980

LETTER OF INTENT FOR A SECOND GENERATION EXPERIMENT ON NUCLEON DECAY

Laboratori Nazionali dell'INFN, Frascati
Istituto di Fisica dell'Università and INFN, Milano
Istituto di Fisica dell'Università and INFN, Roma
Istituto di Cosmogeofisica del CNR, Torino

Muon flux calculated (no other background considered) in 5 existing tunnels
Simplon (railway, operational)
Mont Blanc (road, operational)
Fréjus (railway, completed, to become operational in 1980)
Gottard (railway, operational)
Gran Sasso (freeway, under construction)

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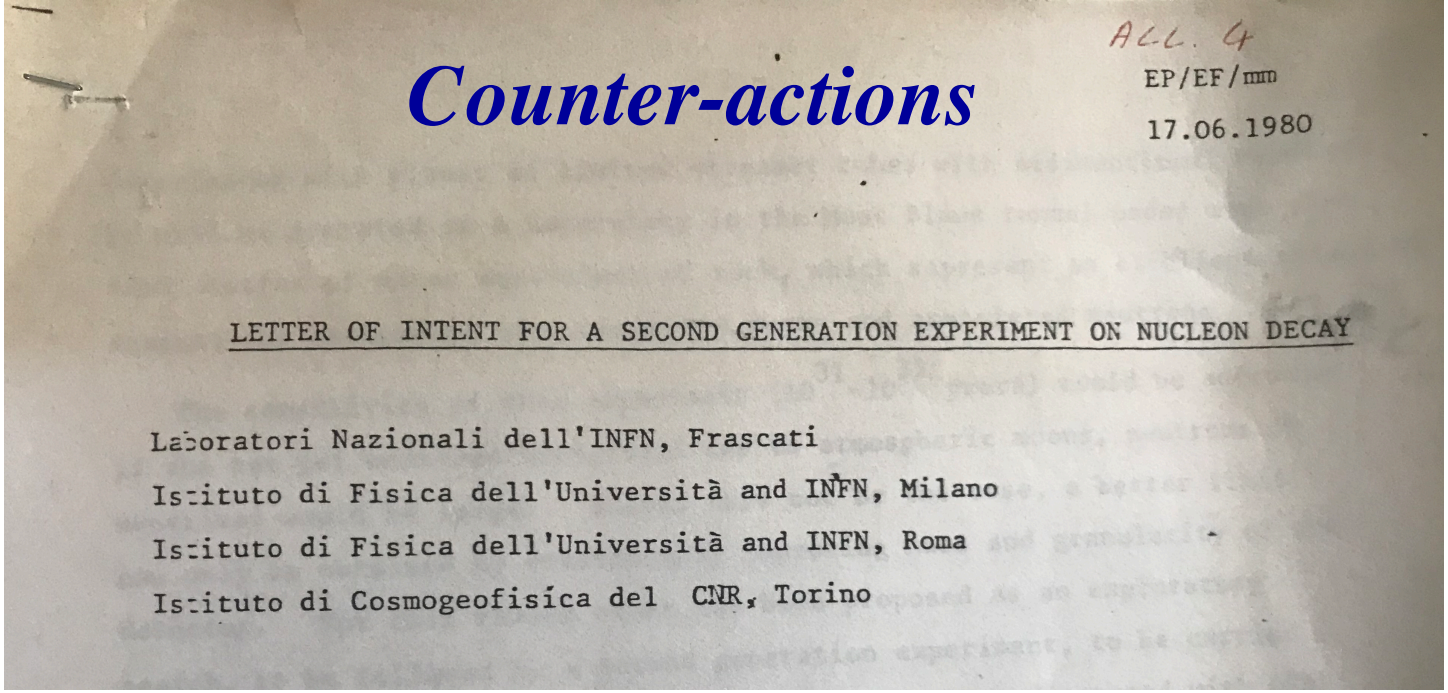

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One can see from the Table that the Mont Blanc tunnel is the best in Europe, immediately followed by the Simplon tunnel. The other three european sites are worse, but still much better than those going to be used for large underground experiment in the USA.

"Underground lobbying"

Lobbying against the Gran Sasso project originated in Italy. Zichichi writes

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Apparently, underground lobbying had produced effects. For instance, the CERN-Director-General (DG) Leon Van Hove, during a CERN Council meeting declared that the Zichichi's Gran Sasso project was invented to stop the new collaboration between Italy and France for a joint venture in underground physics using the Fréjus tunnel. After this unprecedented attack against a very important initiative in Italy, the other CERN DG, John Adams, called the author into his office, to tell him "do not worry". This ended all attacks from CERN against the project.

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During the visit, a journalist asked: "Professor Pontecorvo, what do you think of the Gran Sasso project proposed by Professor Zichichi? Many physicists consider it a useless Napoleonic venture with weak scientific content"
After a few seconds of thinking, in the usual Pontecorvo style of soft and slow answering, he said: "I regret not to be young enough to participate in this extraordinary project. Its scientific content looks to me extremely interesting."
This declaration of Pontecorvo came as a surprise, since we were on opposite political sides and every journalist was expecting a strong negative statement from Pontecorvo. But physics prevailed. And this put an end to all – open as well as underground – lobbying against the Gran Sasso project

1983. INFN National Scientific Committees reform

End of bubble chambers

On my proposal as President of the CSN2
CSN1 Particle physics with electronic techniques -> Particle physics with accelerators
CSN2 Particle physics with visual techniques -> Particle phys. without accelerators + neutrinos

The term ‘astroparticle physics’ did not yet exist

A large fraction of the community was not in agreement

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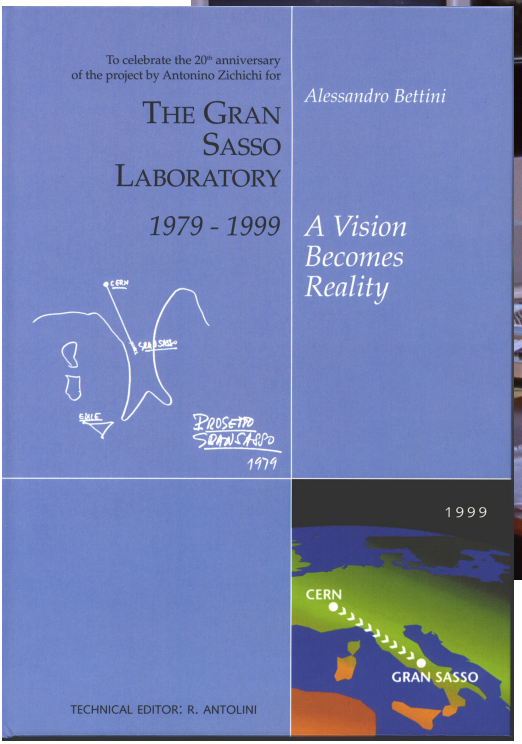
Reporting to Cabibbo, INFN President, the answer was
“you have my vote, that is more than enough”

20 years later. Recollections



From a recollection of Zichichi

By the late 1970s, the idea of providing the INFN of large underground laboratory had taken shape in my mind. A laboratory with the most advanced technological facilities, aimed at studying the new frontiers of Physics, which, as it seemed to me, were becoming clearly defined. In Italy, there had never been a scientific endeavour capable of being the world's leader that able to attract physicists from all continents.

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The new frontiers that were unfolding allowed us to think of something new and complementary to the great laboratories of Modern Physics: those scientific-technical realities centred around accelerator machines. Physics had made great strides on this front. However, the message now emerging from studies aimed at understanding how to attempt to unify the fundamental forces of nature carried us something extraordinarily new. All the discovered particles were extremely light, but the truth lies at the Planck Mass. To study these new frontiers, it would be necessary to build a particle accelerator as large as the entire Solar System. Unless new acceleration methods are invented. Or taking another path

Where to build an UG Lab?

The ideal shielding was a mountain, not like the Matterhorn, but flat, to provide the longest possible horizontal shielding. Digging a tunnel through a mountain costs billions of liras. I thought we should find an existing highway tunnel and excavate a laboratory. However, this would require shutting down traffic for at least a year

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A frontier laboratory cannot be built near an operational tunnel (Mont Blanc, Gottard, Simplon)

Only a road tunnel allows easy access of large pieces of apparatus

Ideal opportunity: the Gran Sasso freeway tunnel under construction

The shape of the mountain is flat

What about the radioactivity of the rocks?

Zichichi launches a campaign of measurement in the tunnel being excavated

Very low level of radioactivity found

Hints of a scientific programme

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If we could establish that the neutrino flux from the sun is one-third of what it should be, then the suspicion that they have mass becomes a certainty.

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At the heart of our laboratory, there are the lowest levels of environmental and cosmic radioactivity. It will therefore be possible to study living matter under conditions of 'cosmic silence.'

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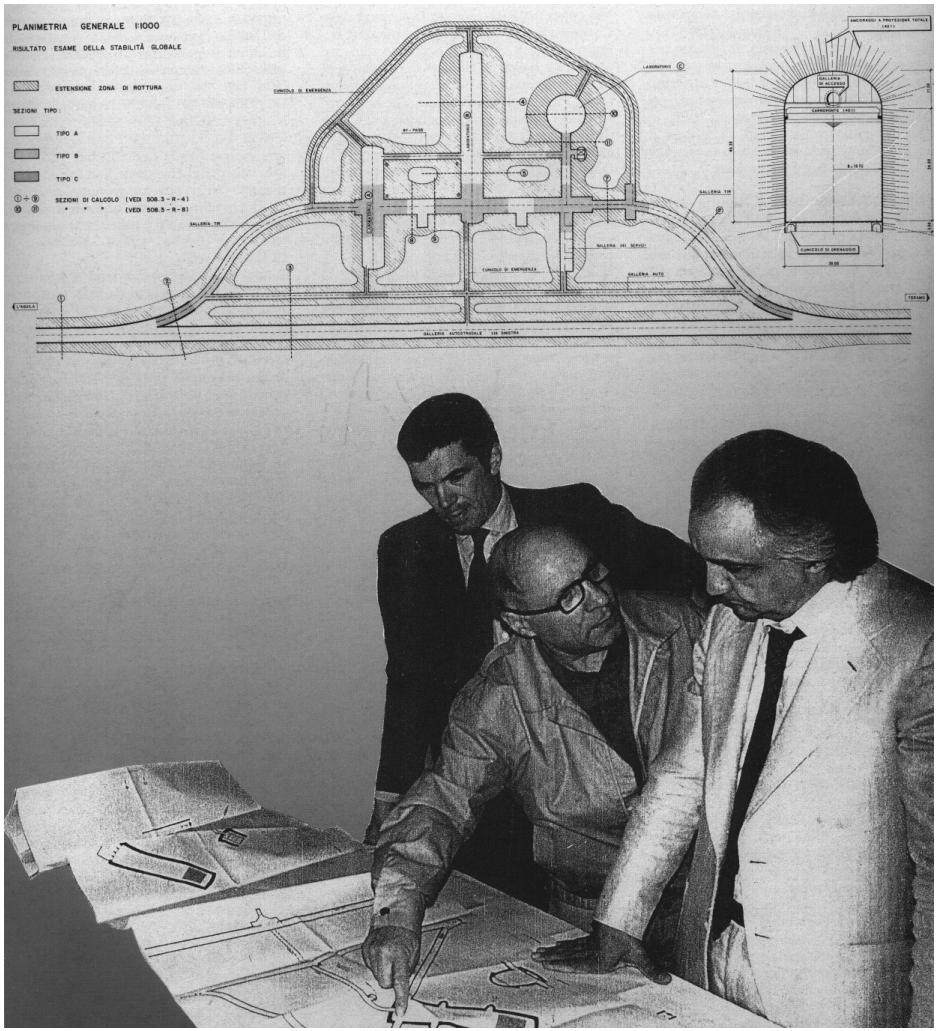
At the heart of our laboratory, there are the lowest levels of environmental and cosmic radioactivity. It will therefore be possible to study living matter under conditions of 'cosmic silence.'

Experiments will also be possible that allow studies on the structure of the mountain and the Earth's crust.

The Gran Sasso Project



1979. A. Zichichi launches the Gran Sasso Project

1982 and 1984. Appropriations to ANAS (the Government Road department) including surface campus (vecchi edifici)

Tot. 77.159 Glit = 39.85 M€

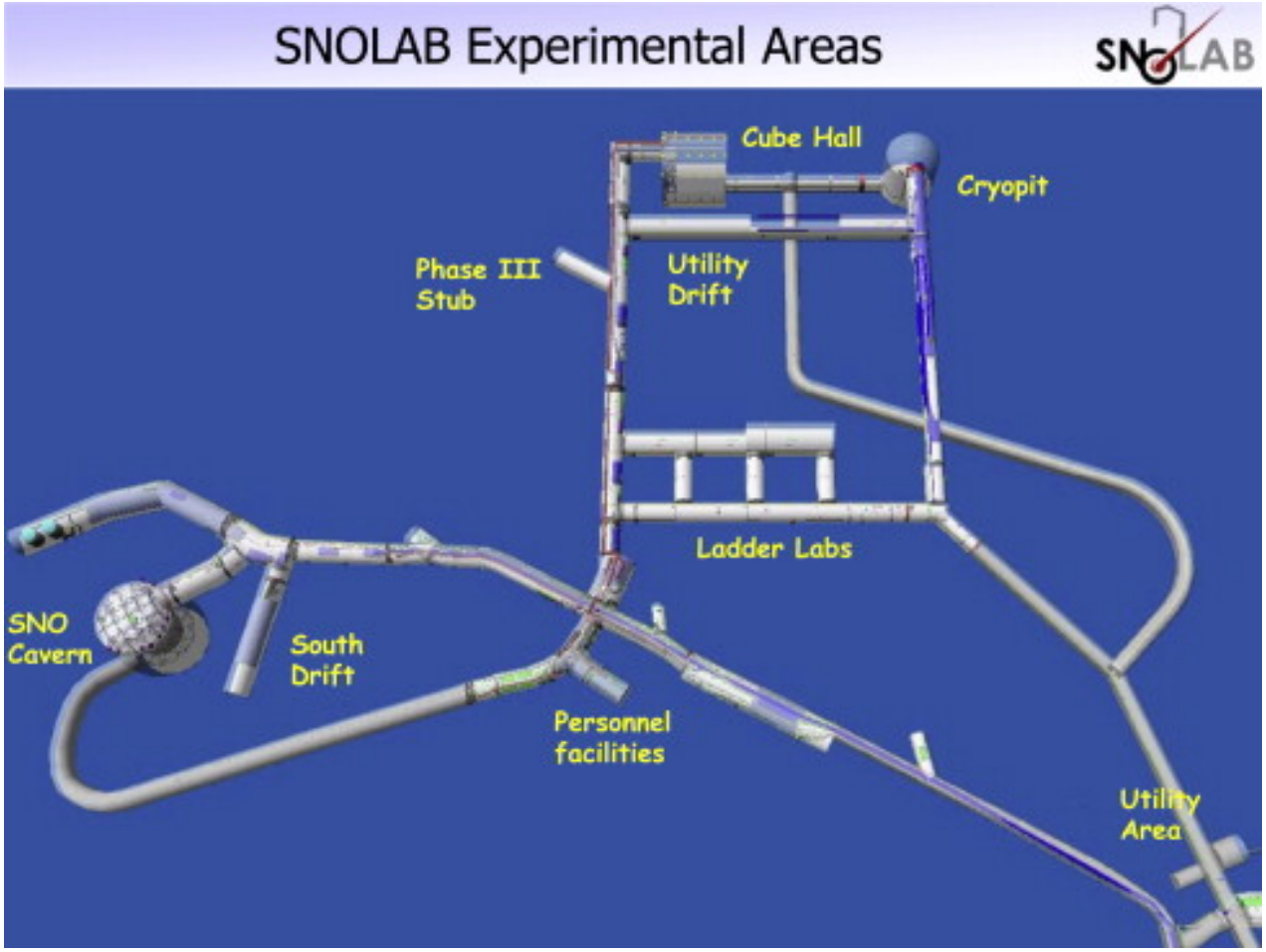
1987. Completion of the civil works

1990. Third appropriation to ANAS 90 GLit

Zichichi with Eng. Lunardi and Eng. Marini
The design of Hall C was modified to cope to the ICARUS proposal

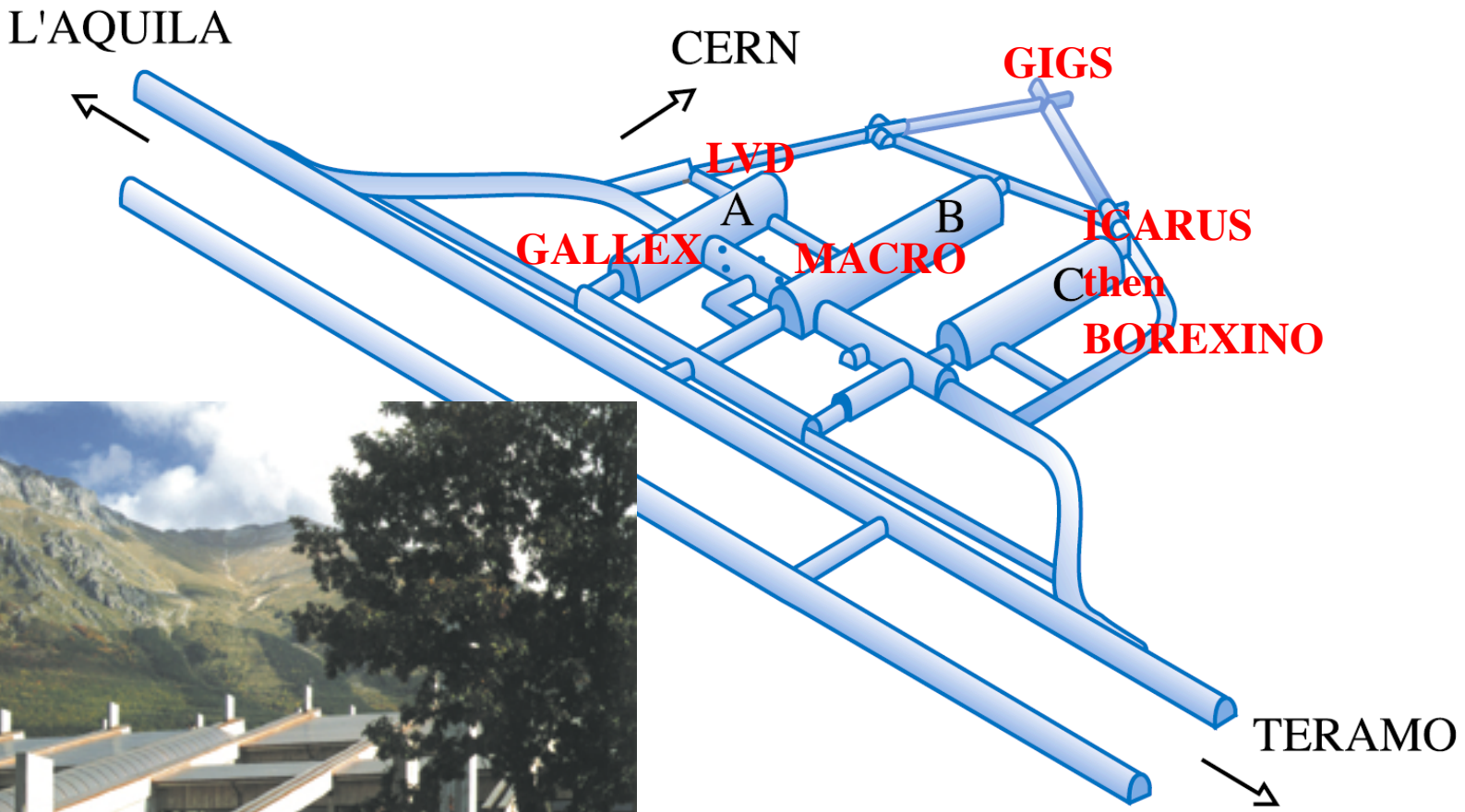
Hall C

Lab in a working mine SNOLab



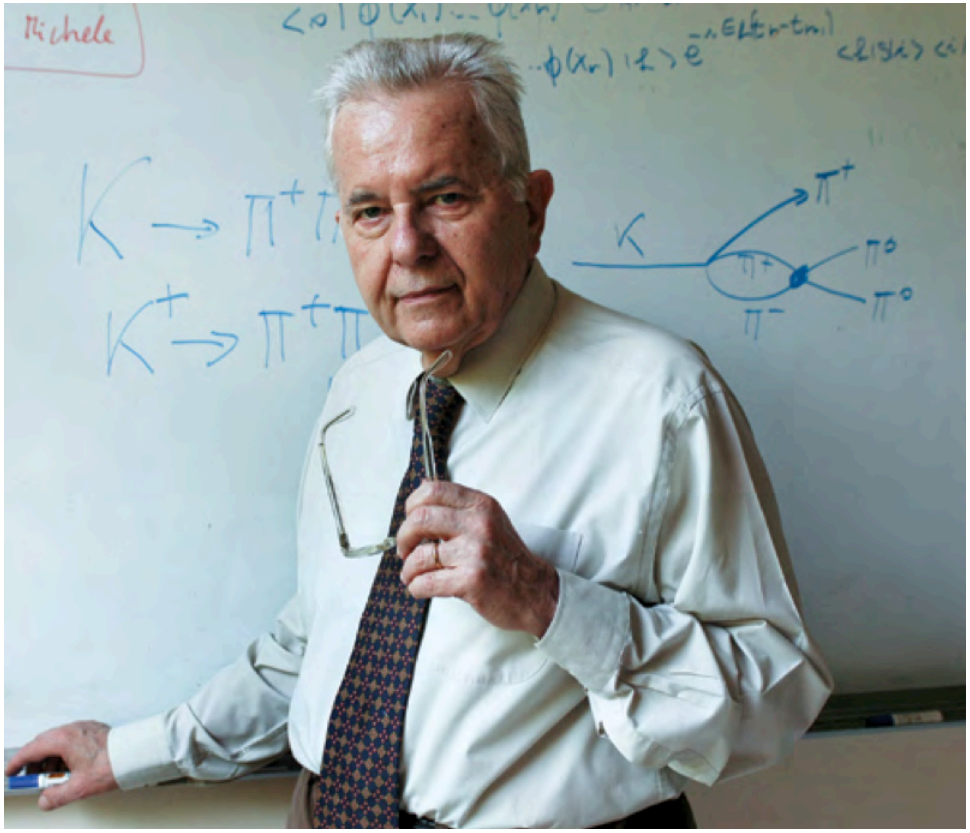
In a mine access is usually vertical via shafts a few metres diameter (Kamioka horizontal)
Interference with mine activity has an impact (in construction and operational phases)
Need relatively long drifts to reach regions with rock quality suitable for digging experimental halls

1987. Science starts



The main actors

The INFN President Nicola Cabibbo
1983 - 1992



The 1st LNGS Director Enrico Bellotti
1987(6) - 1992

Structuring LNGS. Science

Define the fine structure of the first phase scientific programme

Appoint an international Scientific Committee at the highest scientific level (by INFN Council)

Meets twice a year

Proactive actions to attract top level international collaborations

BOREXINO R. Raghavan, F. Calaprice, M. Deutsch, F. von Feiltzsch,...

GALLEX T. Kirsten, R. Moessbauer, M. Cribier, M. Spiro,..

LVD O. G. Ryazhskaya, G. T. Zatzepin, I. Pless

MACRO B. Barish,...

MIBETA > CUORE. F.Avignone, G. Frossati, S. Feedman,..

Not only subnuclear physics

LUNA. Cross sections of reaction of astrophysical interest down to the Gamow peak

GIGS. Unique interferometer, Earth crust movements down to 0 Hz

Seismic Array

PULEX. Low radioactive background biology

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PULEX. Low radioactive background biology

The LNGS culture fruitfully developed thanks to the presence of scientific communities with different backgrounds: from Italy, Germany, Russia, USA, France, China, UK, Israel, ...

The theory group at LNGS

Nicola Cabibbo: in a laboratory, conditions differ from those in a university. At LNGS, theoretical research had to be closely linked to experimental research. Lead by an internationally recognised top scientist.
Nicola proposed that to Venya, who accepted to move to Gran Sasso for the rest of his life.
No permanent positions were foreseen, but Venya would have funding to invite collaborators for certain periods and possibly students from the University of L'Aquila.
Financial resources were always limited, partly provided by the INFN, in the frame of the general agreement with INR, and partly by the countries of origin of the invitees

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Financial resources were always limited, partly provided by the INFN, in the frame of the general agreement with INR, and partly by the countries of origin of the invitees

Venya created a very active theoretical group, with visiting researchers staying for several months, coming from Russia (which at the time included Belarus, Ukraine, Georgia,...), France, the USA (particularly A. Vilenkin from Tufts University), and Brazil, as well as students, including Pasquale Blasi, Michael Kachelriess, and Roberto Aloisio.
Each year, Venya organized an *'International Topical LNGS Workshop*' with discussions attended by the world's leading specialists.

The theory group at LNGS

Nicola Cabibbo: in a laboratory, conditions differ from those in a university. At LNGS, theoretical research had to be closely linked to experimental research. Lead by an internationally recognised top scientist.
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Due to Venya, the theoretical activity at LNGS was a great success, internationally recognized as a frontier group and substantially contributing to the development of the multicultural characteristic of LNGS

Structuring LNGS. Infrastructures

New buildings for offices on the surface campus securing EU “structural funds”

Hire personnel

Design and develop technical services to support the experiments as in a full-fledged lab

- Administration
- Secretariat
- Prevention and protection service
- External relationships and outreach
- Low radioactivity assay (unique at LNGS, developed by Bellotti))
- Mechanical service and shop
- Electronic service and shop
- Computers and telecom
- Chemical service and shop
- Civil engineering service
- Electric plants service
- Library
- Cafeteria
- Few hostel rooms
- Infirmary

Other facilities will “copy” the LNGS structure

Double-beta decay

The three presently most sensitive techniques in double-beta decay, the search for the neutrino-less, measurement of the two-neutrino ones, were developed in the first-generation LNGS experiments

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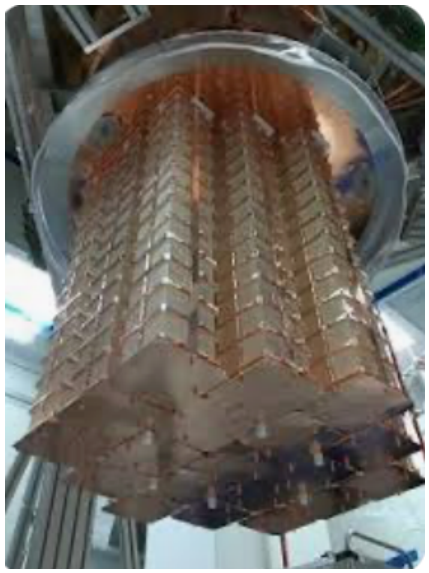
MIBETA. **Bolometric techniques** -> CUORE -> CUPID



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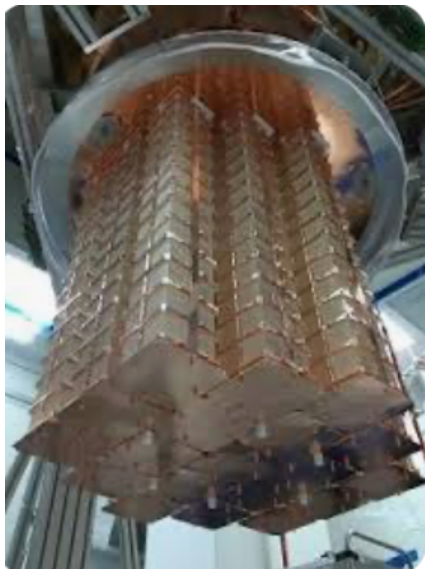
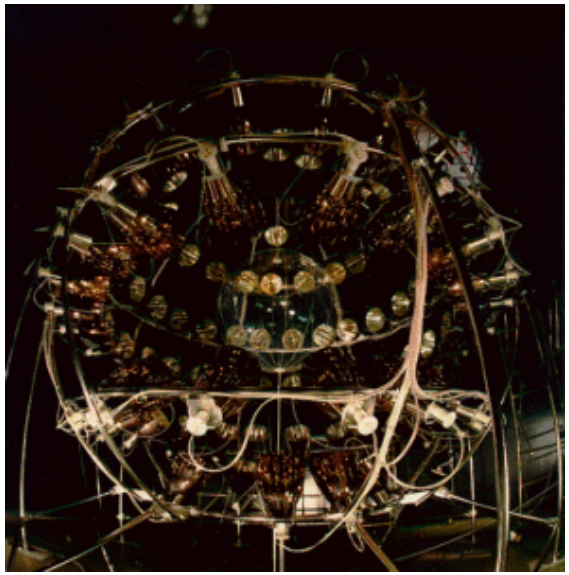
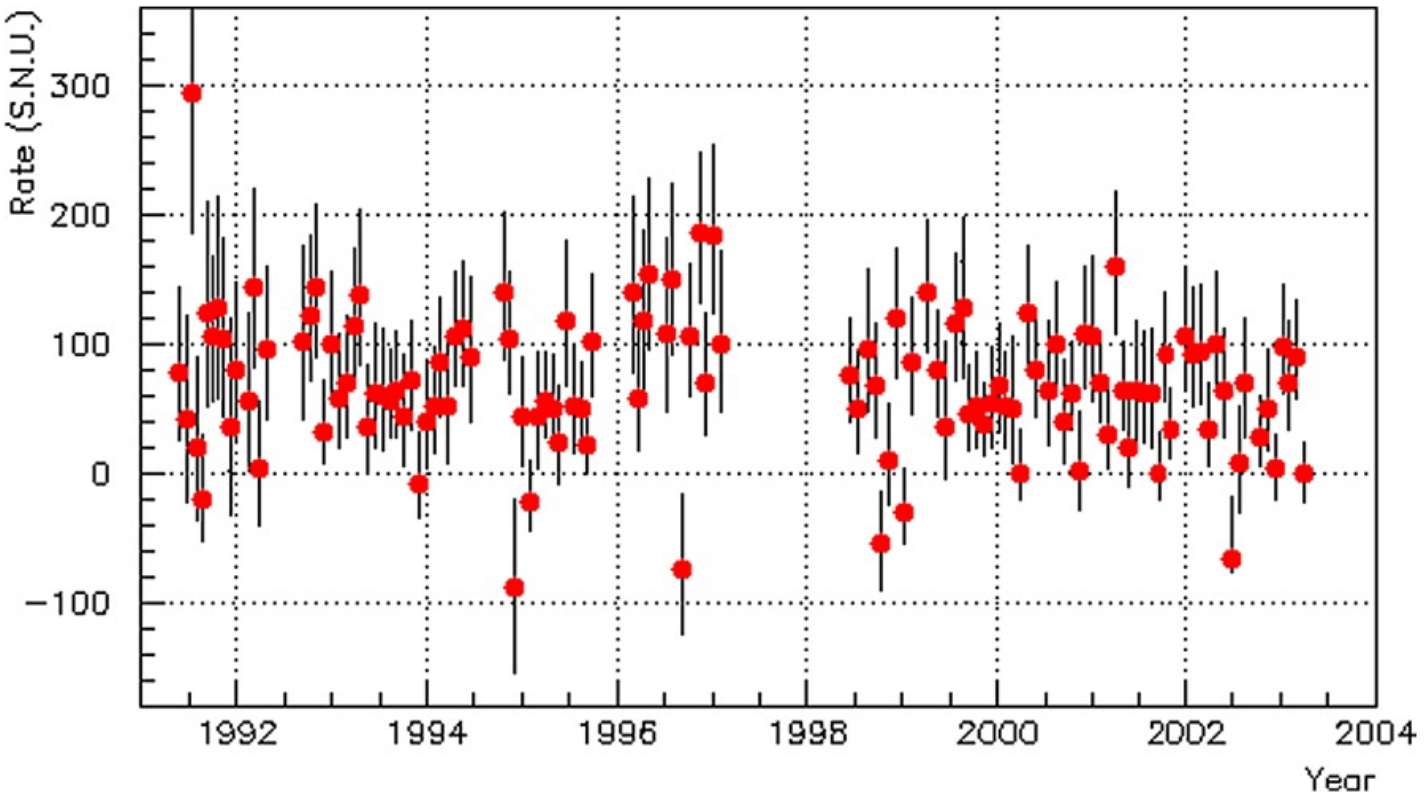
Raghavan proposal for CTF. **Enriched Xe doped of liquid scintillator** -> KamLAND-Zen





GALLEX (and GNO)



1995 "^{7}Be-^{8}B puzzle" emerges. GALLEX measures the sum of pp ($p+p \rightarrow d+e^{+}+\nu_e$), ^{7}Be ($^{7}Be+e^{-} \rightarrow {}^{7}Li+\gamma+\nu_e$) and ^{8}B ($^{8}B \rightarrow 2\,^{4}He+e^{+}+\nu_e$).

Subtracting the pp, which is well determined by the sun luminosity, and the ^{8}B flux, measured by Kamiokande one should find the ^{7}Be flux. The result was negative, but it must be positive, independently of the details of the model, because the observed ^{8}B comes from the ^{7}Be through the reaction $^{7}Be+p \rightarrow {}^{8}B+\gamma$. This argument excluded the astrophysical solution

BOREXINO

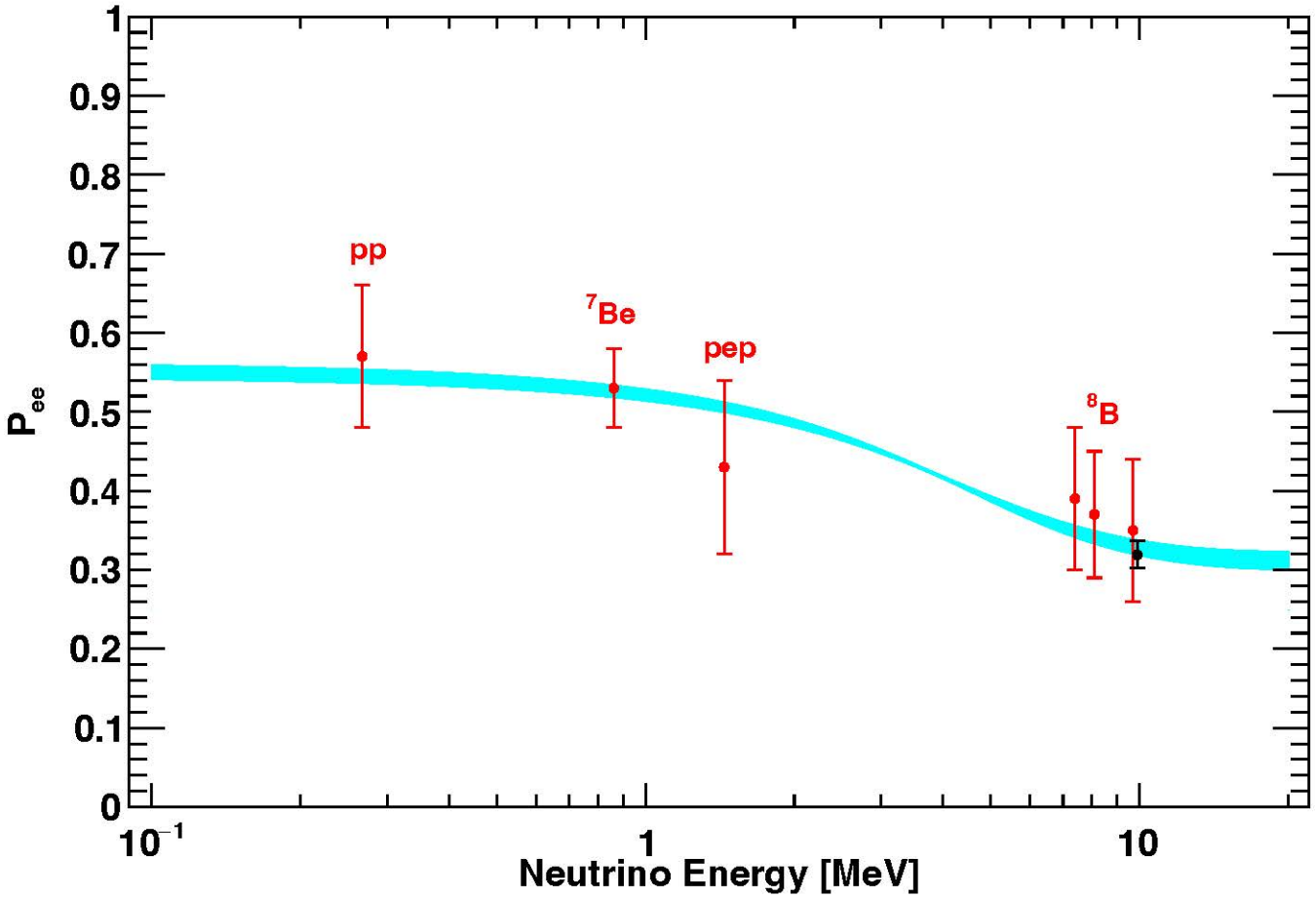
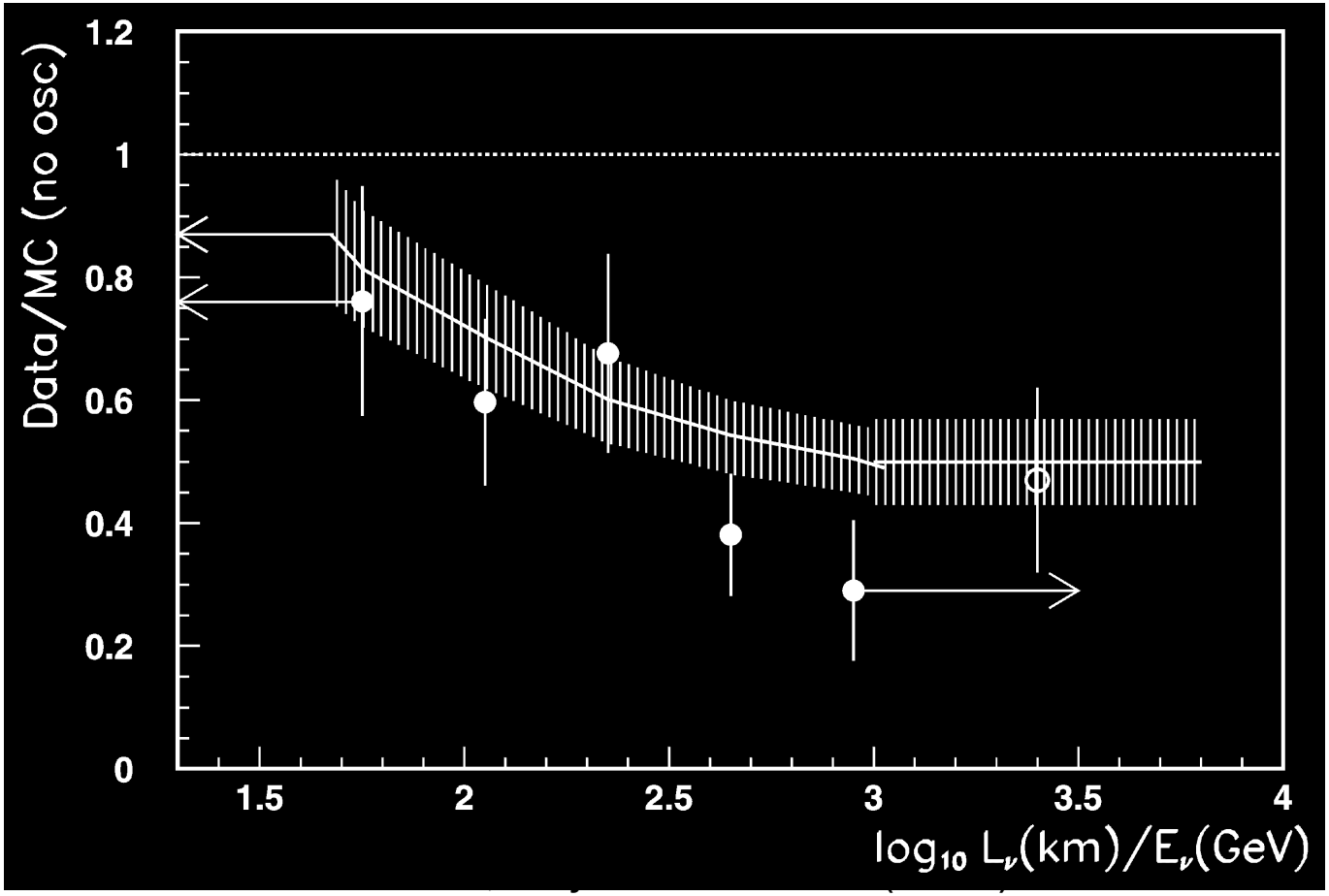


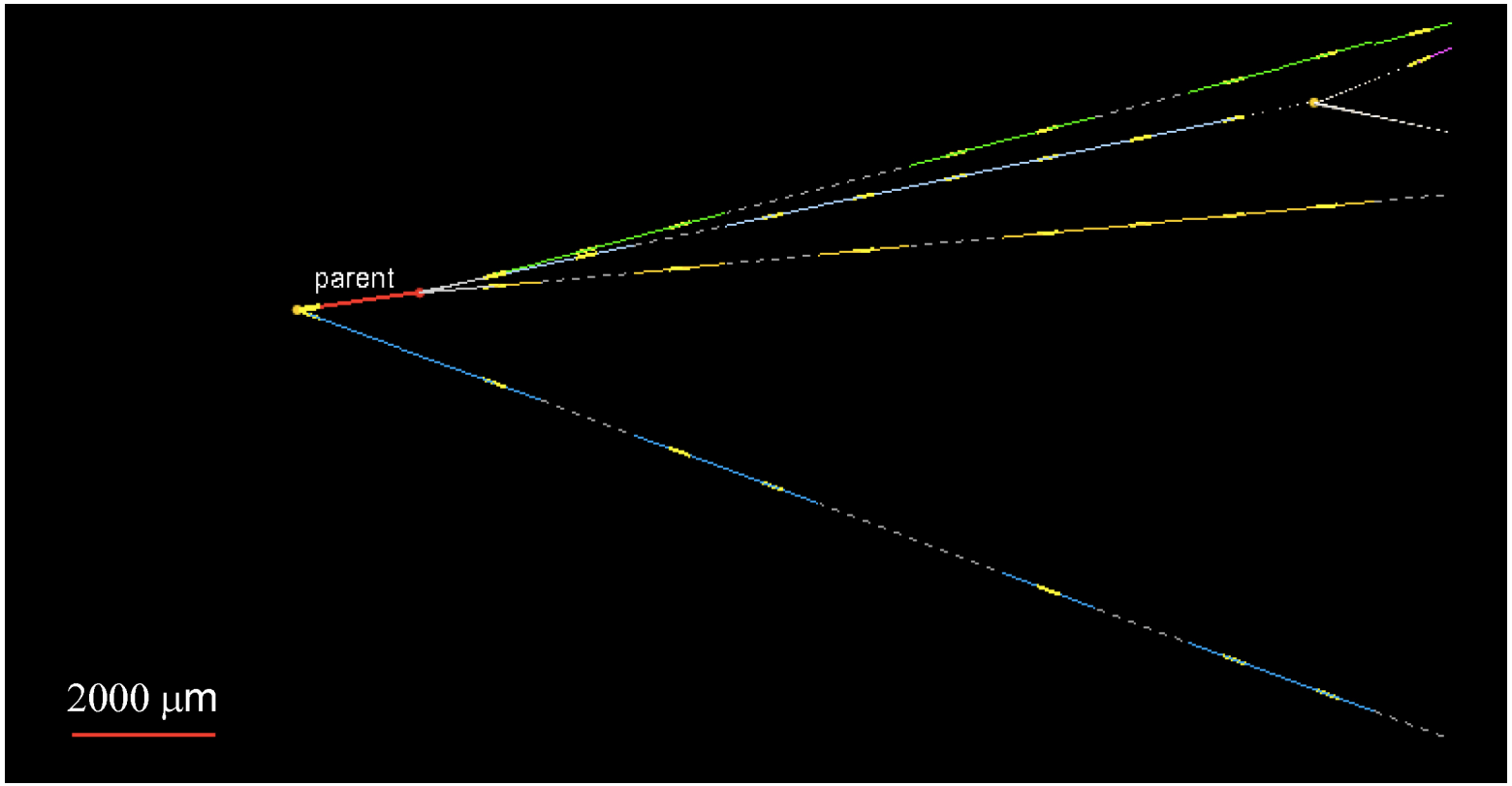
Figure by A. Ianni

MACRO



Muon neutrino disappearance vs *L*/*E* (energy from multiple scattering of the muon)

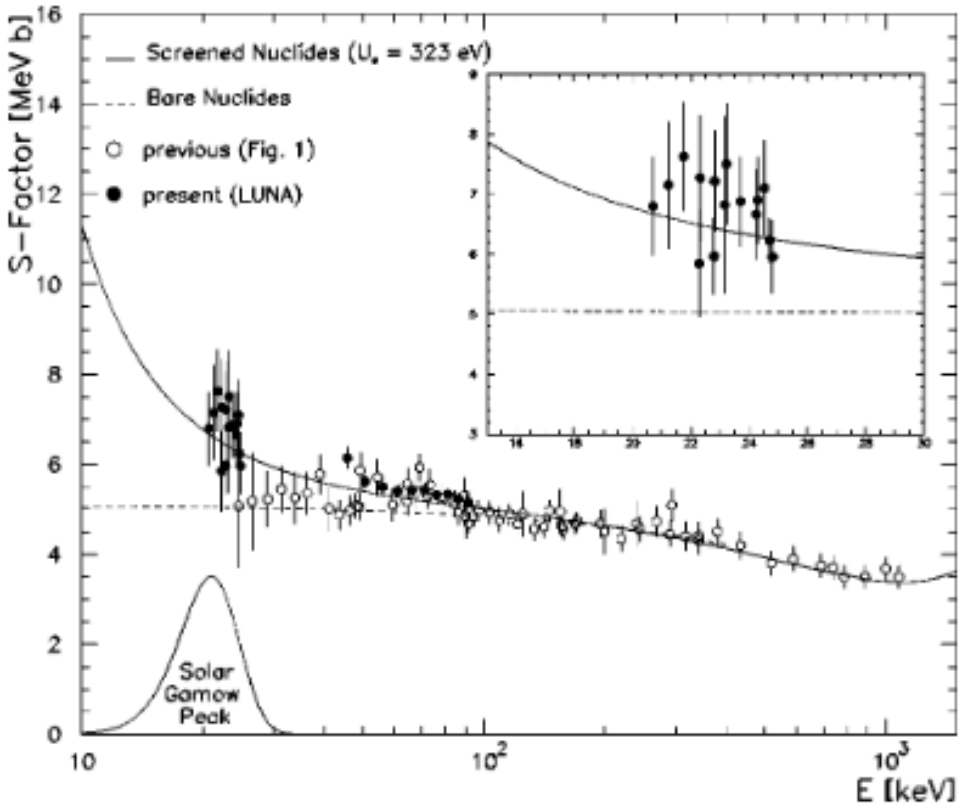
OPERA



LUNA

Excluding the "nuclear solution" of the solar neutrino puzzle

If the $^3He+^3He \rightarrow ^4He+2p$ cross section would be larger than assumed in the solar models, the flux at high energy would be smaller (^7Be + ^8B neutrinos/ pp neutrinos), as experimentally observed

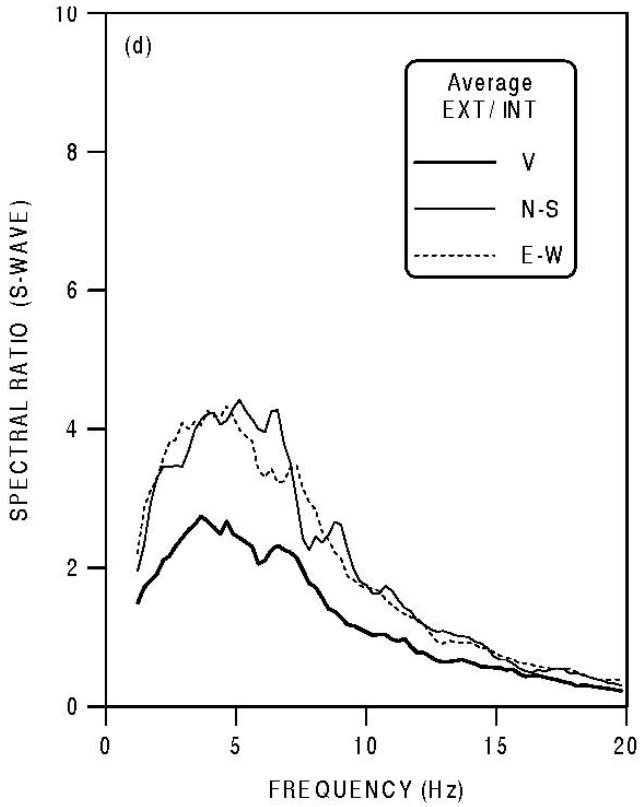


No anomalous behaviour down to the Gamow peak

This excluded the "nuclear solution" of the solar neutrino puzzle

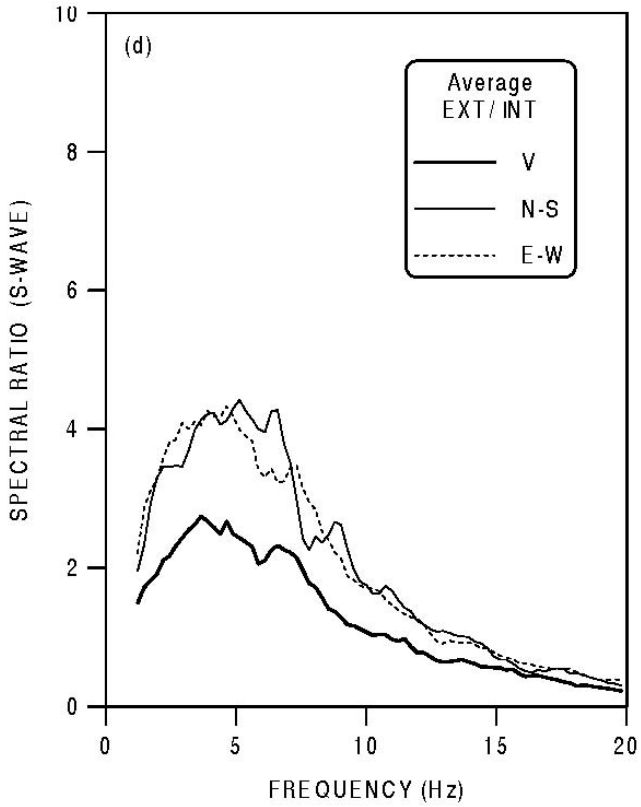
Phys Rev C **57** (1998), 57

Seismic Array



Time averaged spectra ratios external/ underground
for seismic events at distances < 50 km

Seismic Array



Time averaged spectra ratios external/ underground
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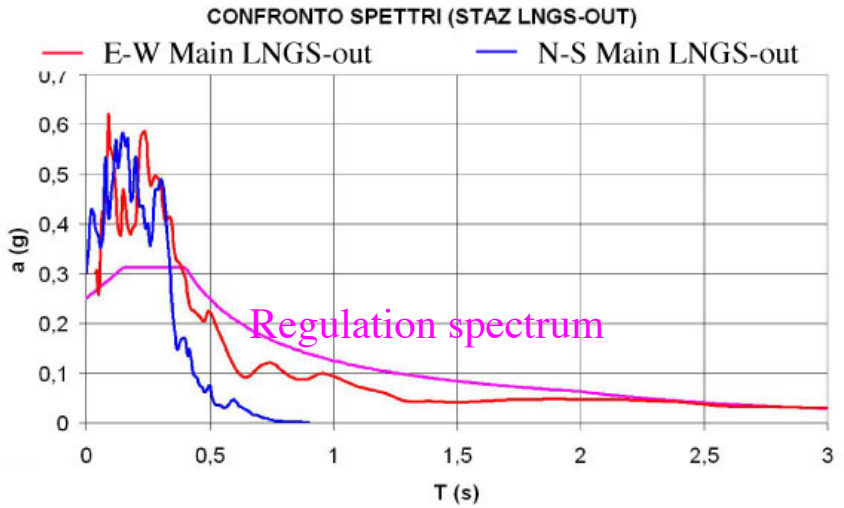
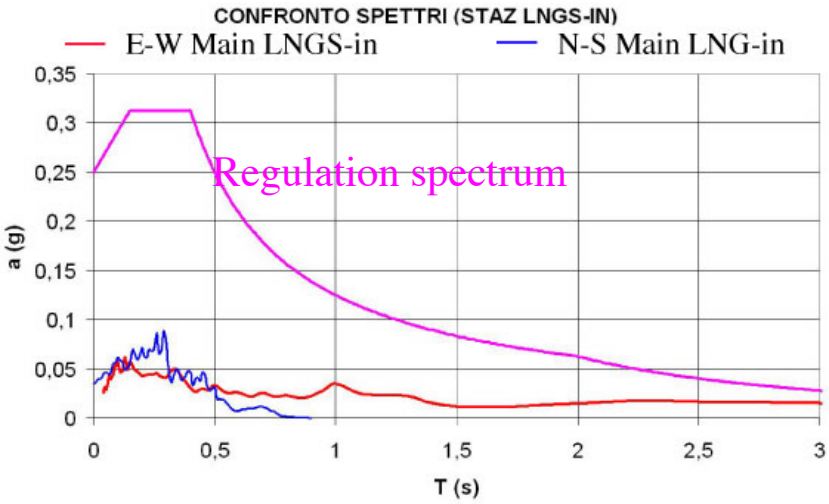
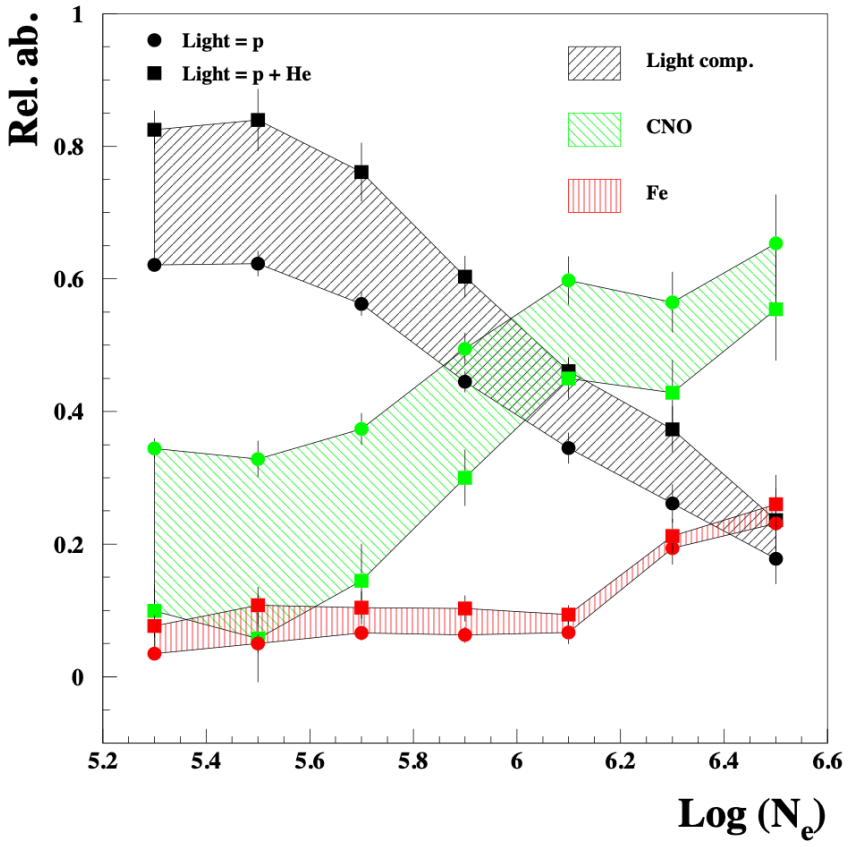
6 April 2009 event.
Outside and inside horizontal (2 components) acceleration spectra





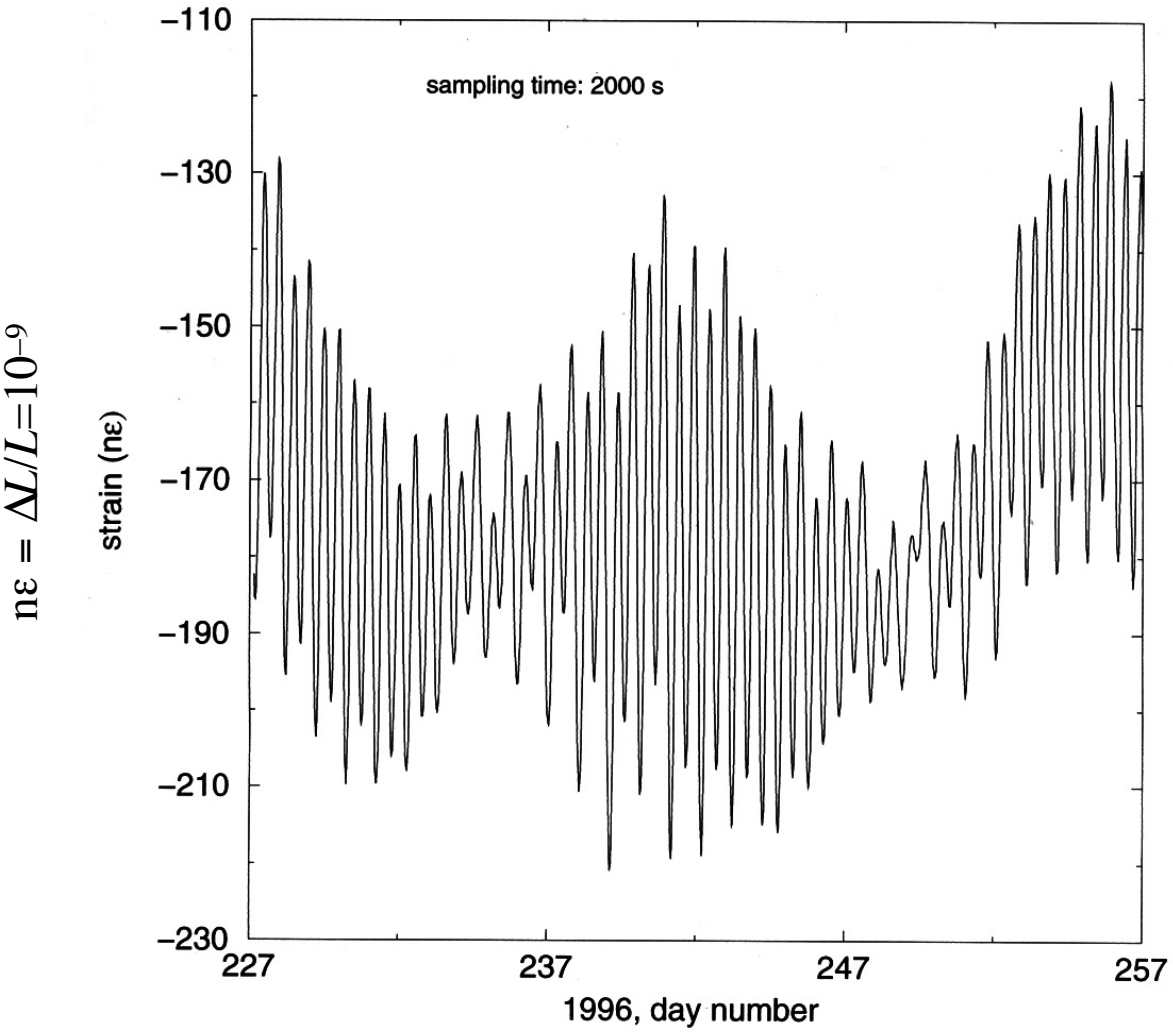
EAS TOP



Relative abundances of the three mass groups in different intervals of shower sizes.

GIGS

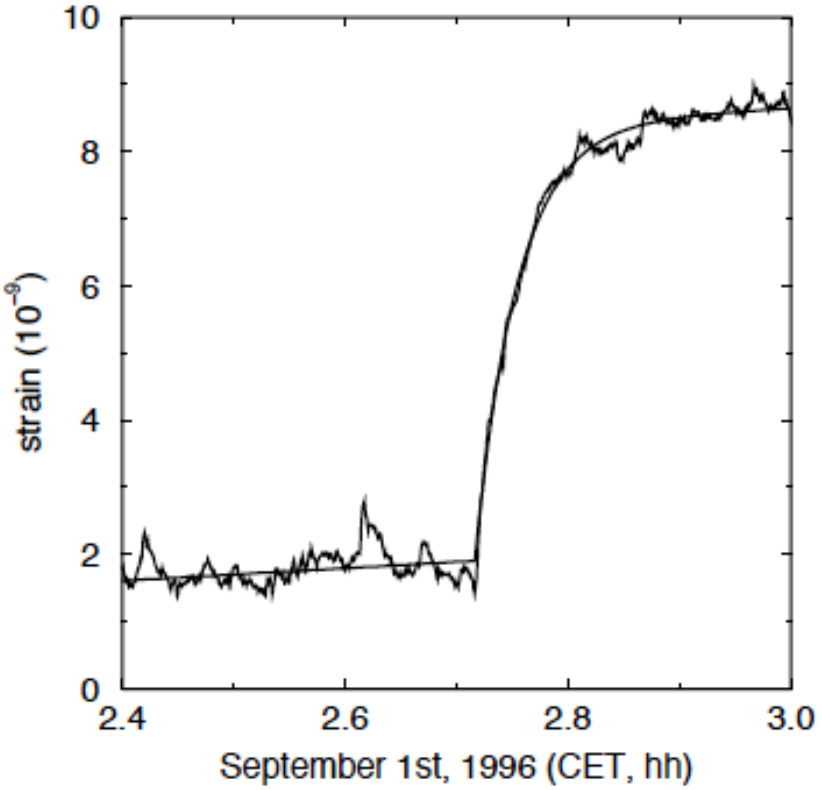
Operational since Spring 1994



GIGS

Operational since Spring 1994

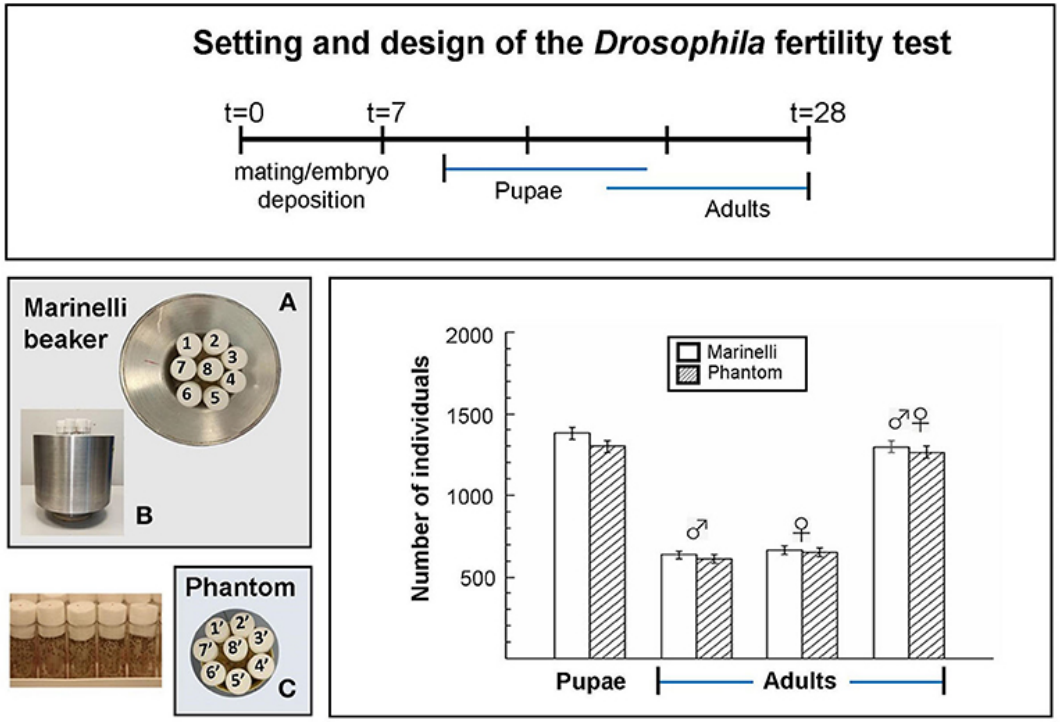
$\Delta L/L = 10^{-12}$



"Missing momentum" puzzle

Slow quakes?

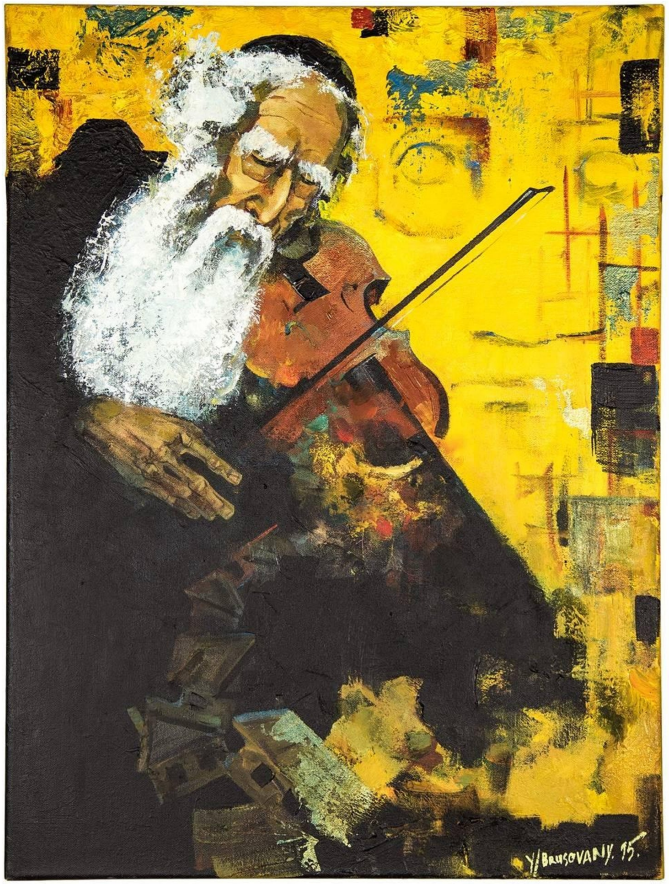
Deep Underground Radiobiology



Experiments conducted in DULs have shown changes compared to above ground laboratories in the responses of bacteria, protozoa and mammalian cells, as well as in more complex organisms, i.e., flies, fishes and worms

The violinist

A painter, poor, wanted to include a violinist in a painting he was working on, and went to a second-hand dealer in Moscow who was known to have second hand musical instruments. He asked for a violin, saying he could spend little money but didn't need it to sound good; it just had to look beautiful.



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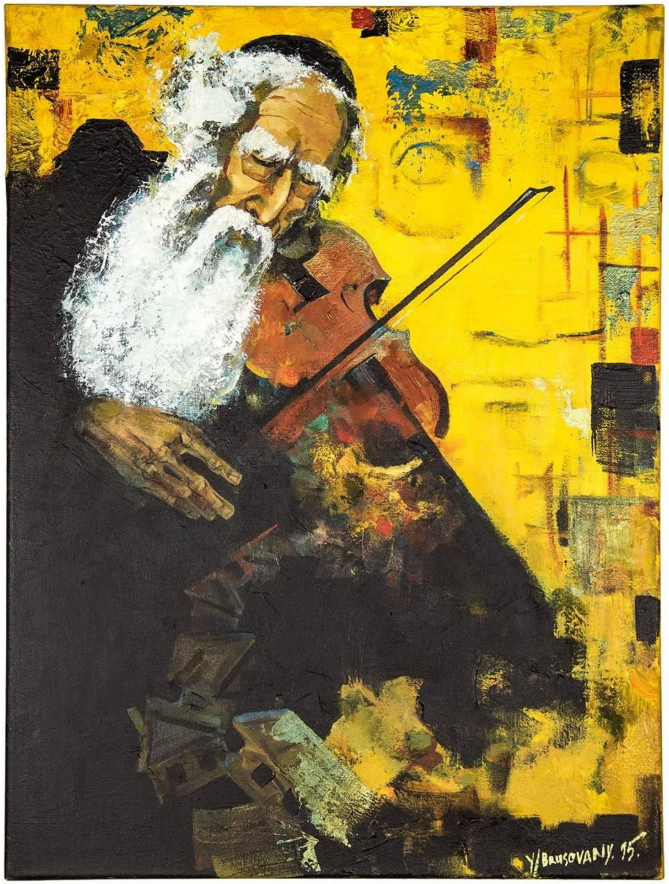

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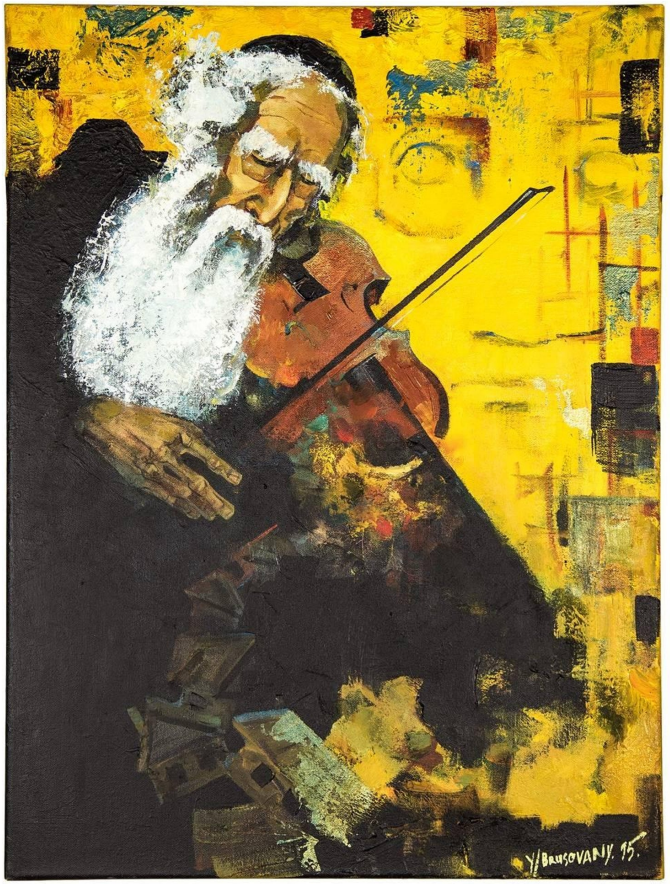

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Beauty of thought was one of the Venya's gifts

THANKS FOR YOUR ATTENTION


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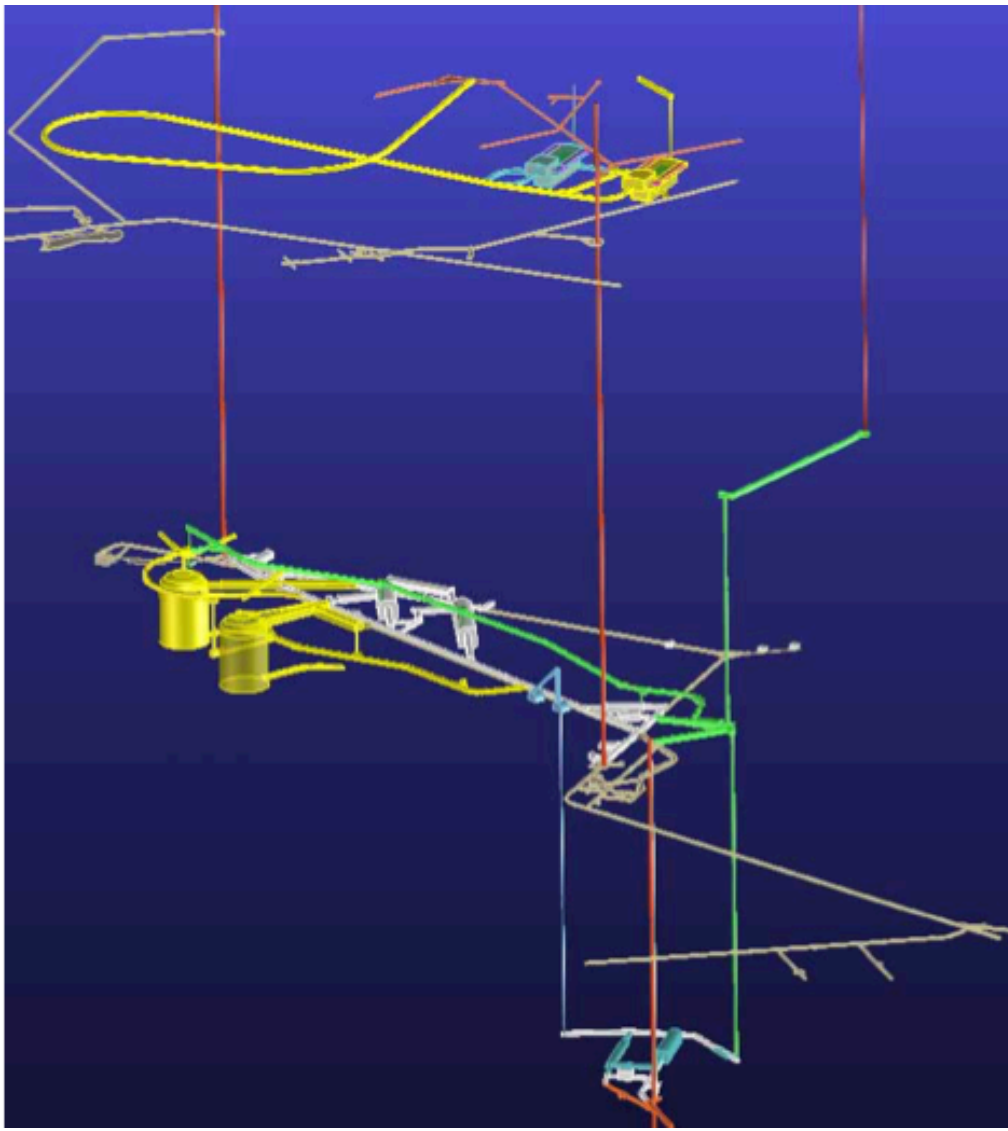
Lab in an abandoned mine DUSEL

Old access shafts needs complete refurbishing
Yates shaft had wood furnishing
Ross shat had steel furnishing
Costs estimate needs large safety factor.
2011 estimate 140 M$



4850L
25000 m^2 (total)/ 6200 m^2 (science)

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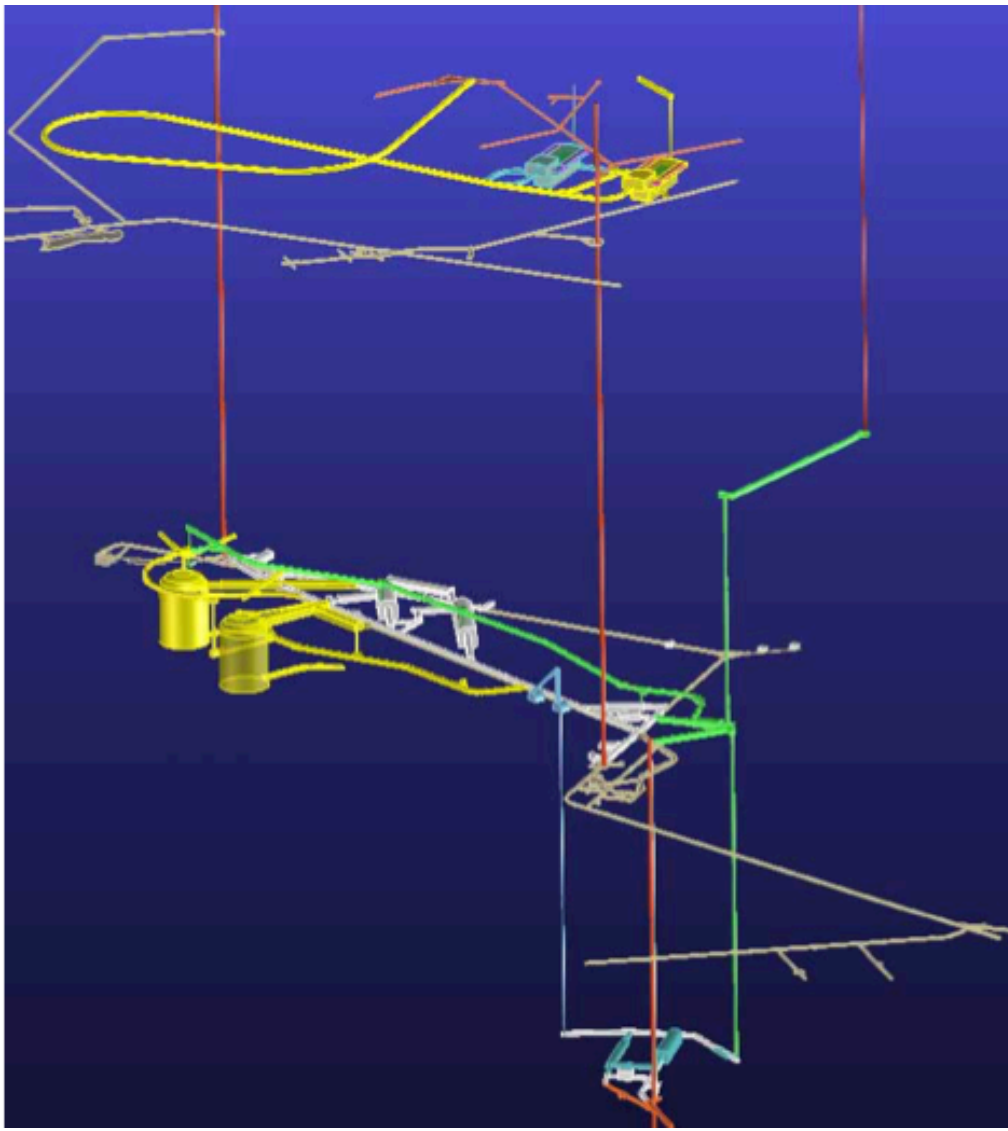

4850L
25000 m^2 (total)/ 6200 m^2 (science)

LNGS
190 000 m^3 (total)/ 153 000 m^3 (science).
85% useful
Estimated extrapolated cost **96 M€(2011)**