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EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH
European Laboratory for Particle Physics

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GENERAL DESCRIPTION OF THE CERN PROJECT FOR A NEUTRINO BEAM TO GRAN SASSO (CNGS)

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Editor:	K. Elsener
Authors:	M. Buhler-Broglin, K. Elsener, L.A. Lopez Hernandez, G.R. Stevenson, M. Wilhelmsson
Prepared by:	D. Lajust, H.H. Vincke
Illustrations:	J.-L. Caron (Figures 3 and 4 are published with the agreement of the Italian Gran Sasso National Laboratory)

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1 The scientific basis of the CNGS project

1.1 CERN and neutrino physics

CERN's purpose is to study the foundations of the structure of matter. Its sphere of activity is high energy physics, also known as elementary particle physics.

Specifically, CERN designs, builds and operates high-energy accelerators and detectors, which are the tools needed for its research. Together with thousands of scientists from across the world studying the sub-microscopic make-up of matter and the fundamental forces, CERN has contributed much to the development of what we know as the standard model (c.f. Figure 1).

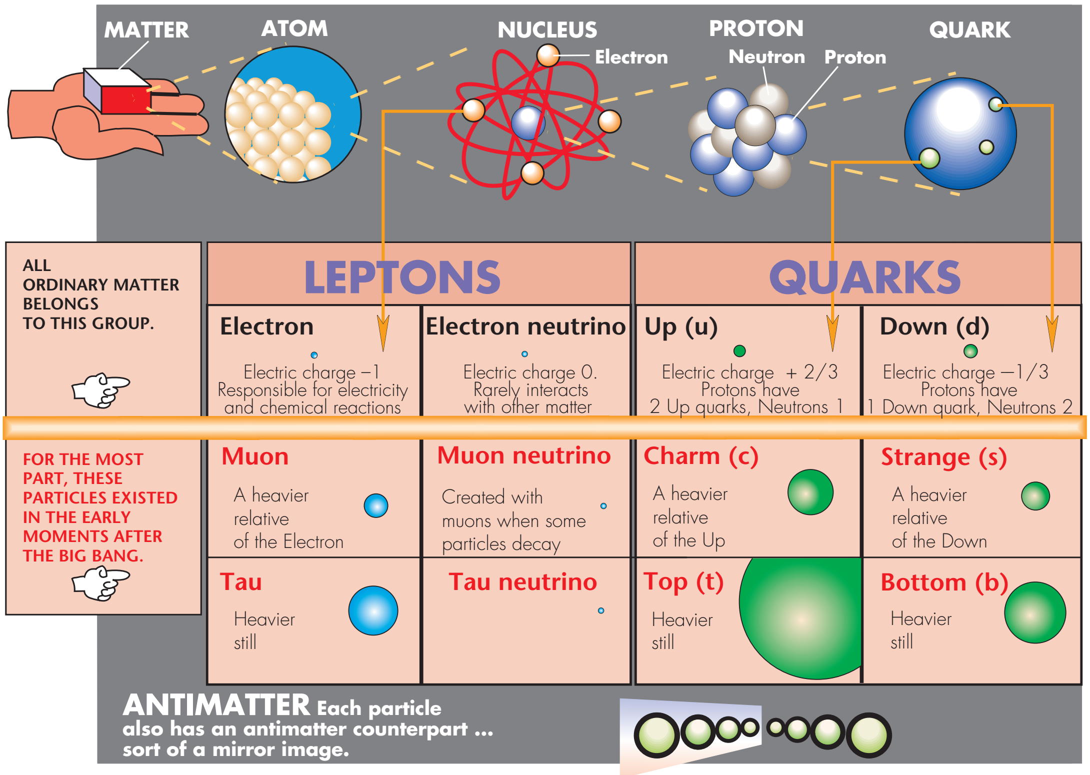

Figure 1: The standard model

The standard model explains the composition of ordinary matter, that is atoms and their constituents: the electron, a fundamental particle, the proton and the neutron, both consisting of three elementary particles, called quarks. Moreover, the standard model contains all the necessary ingredients for explaining on the one hand particles discovered in the cosmic rays and, on the other, the particles produced by accelerators, which were also present in the Universe during the first few minutes after its birth in “the Big Bang”.

Neutrinos are the hardest of the sub-atomic particles to study. They are produced by the decay of other particles, for example neutrons in a radioactive nucleus:

neutron $\Rightarrow$ proton + electron + (anti)neutrino

They are neutral (i.e. they carry no electrical charge) and the probability that they will interact with matter is extremely low. This is clearly illustrated by the fact that everyone on earth is traversed by the enormous quantity of 400,000 billion neutrinos from the sun every second. Neutrinos pass through our planet with a very low probability of interaction with matter, which shows both their relative harmlessness and how hard they are to capture in physics experiments.

The difficulty of detecting neutrinos partly explains the mystery still surrounding them in particle physics. It has now been established that neutrinos have either only a very small mass or no mass at all. Choosing between these two possibilities is of capital importance both for the standard model and for our understanding of the Universe. We know that the Universe contains some 100 millions of "relic" neutrinos per cubic metre (originating from the first minutes after the "Big Bang" but only 0.5 protons in the same volume of space. If neutrinos have mass, then they make up part of galactic "dark matter". In that case the Universe could have sufficient gravity for it one day to stop expanding and to start contracting.

Neutrinos are divided into three families, called ν_ε, ν_μ and ν_τ, indicating that they are associated with the three types of charged particles: the electron (e), muon (m) and tau (t) (c.f. Figure 1 on page 5). If neutrinos have a small mass, it is possible that the three neutrino types are in some way or other "mixed" (c.f. Figure 2 on page 7); for example, that a neutrino of type ν_μ could turn into a neutrino of type ν_τ. This phenomenon is what we call "neutrino oscillation".

Neutrinos of type ν_ε come from the sun and other natural sources. The second family of neutrinos, the ν_μ, are produced for example in the decay of particles resulting from collisions between two protons:

proton + proton ⇒ pion

↳ muon + ν_μ

proton + proton ⇒ kaon

↳ muon + ν_μ

These collisions between protons can occur in the earth's atmosphere (protons are among the cosmic rays) as well as in particle accelerators. The pions and kaons produced are particles from the so-called "meson" group. The pion consists of a quark u and an antiquark $\bar{d}$, the kaon also contains a quark u, but is accompanied by a heavier partner, an antiquark $\bar{s}$.

The first neutrino beam at CERN was built in the early nineteen sixties. In 1973, the "Gargamelle" bubble chamber in the PS[1] neutrino beam gave CERN one of its most important discoveries, called the «neutral current interaction»: neutrinos can interact with other particles while remaining neutrinos.

1 PS, "Proton Synchrotron", accelerator built at CERN in 1959, with a proton energy of 28 GeV, was the most powerful accelerator of its day. It still serves today for experiments and as pre-accelerator of the SPS ("Super Proton Synchrotron").

Up to now, neutrino experiments have been limited to the perimeter of CERN's Meyrin site, thus to relatively small distances. A recent discovery in Japan, however, shows that a "change in the nature" of neutrinos - oscillation between two types of neutrino - could occur if these particles had a long enough time-of-flight (i.e. trajectory). To confirm that this is really a neutrino oscillation and to investigate the phenomenon further, a particle beam (of neutrinos) from CERN would be linked to detectors located far from the Laboratory, and this for the first time in CERN's history.

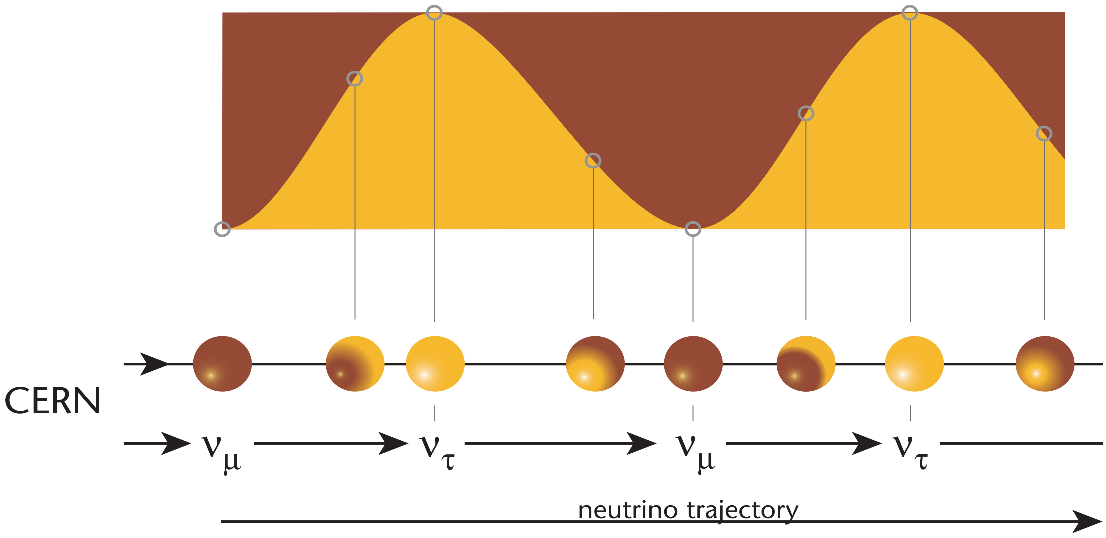

Figure 2: Illustration of ν_μ — ν_τ oscillations (a pure ν_τ beam is produced at CERN and directed towards Gran Sasso)

1.2 The underground laboratory at Gran Sasso (Italy)

The underground laboratory at Gran Sasso (LNGS), 120 kilometres from Rome, is one of the facilities belonging to the INFN, the Italian institute for research into particle physics and nuclear physics. Since its construction at the beginning of the nineteen-eighties, an impressive series of fundamental physics experiments has been carried out. Experiments on neutrinos have a prominent place in the LNGS research programme: for example the neutrinos produced by cosmic rays in the atmosphere have been studied (c.f. Figure 3 on page 8). Since they are protected from muons originating from cosmic rays by 1400 metres of rock, the three great caverns (c.f. Figure 4 on page 9) of the laboratory are ideal places for experiments looking for weak signals stemming from the passage of rare particles. In the design phase of LNGS, in 1979, the caverns were oriented towards Geneva, with a view to possible experiments with long baseline neutrino beams. Parts of the three underground halls of the LNGS are now ready for new experiments for detecting and identifying neutrinos produced at CERN and sent to LNGS over a distance of 732 kilometres.

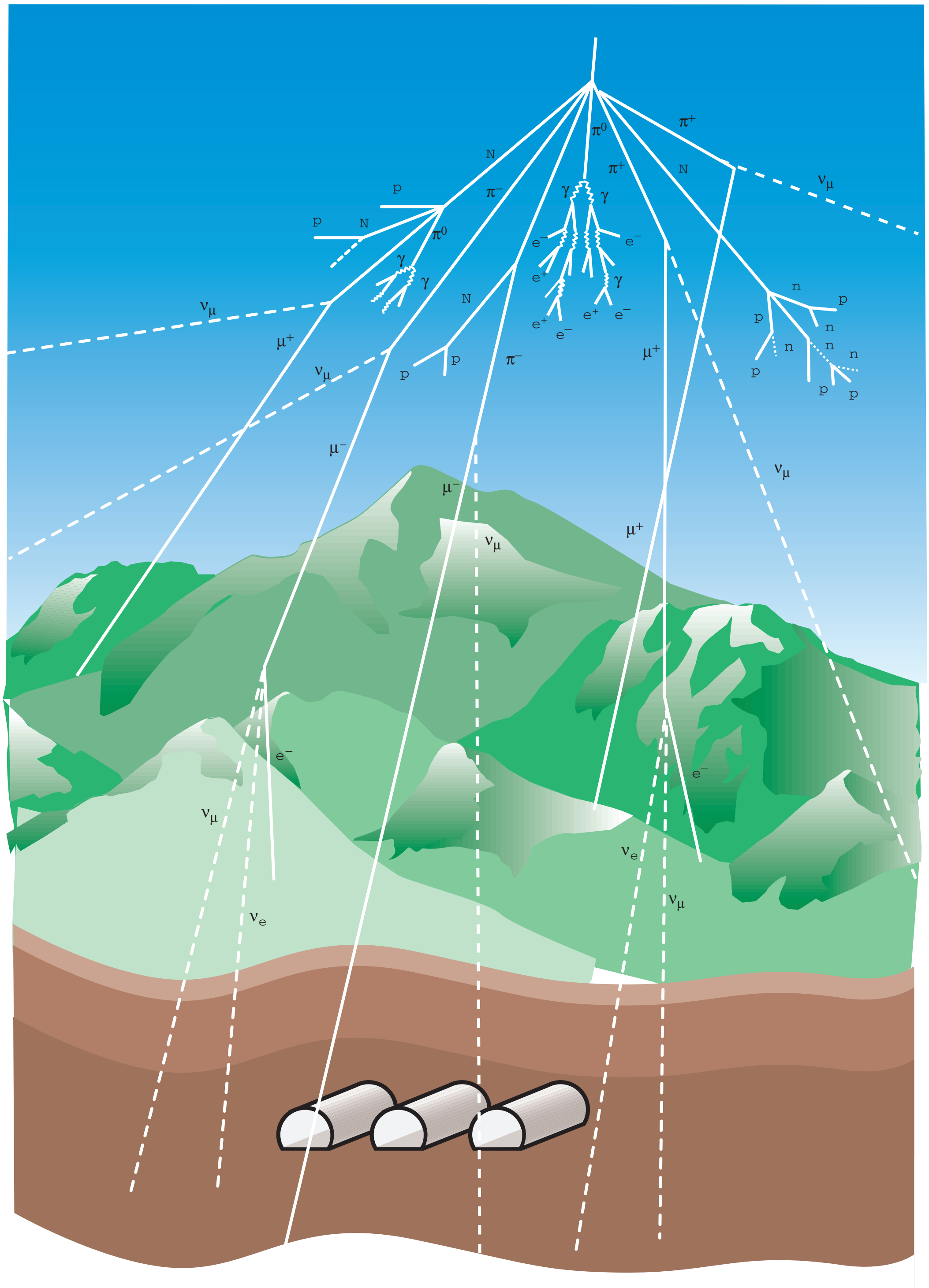

Figure 3: Simplified illustration of cosmic ray interactions producing neutrinos detected at the Gran Sasso underground laboratory

Figure 4: View inside one of the underground halls at Gran Sasso

1.3 CNGS - a long baseline neutrino beam

The CNGS project, already referred to in the LHC Impact Report (page 57), consists in producing a neutrino beam at CERN (basically of the ν_μ type) and sending it towards the Gran Sasso laboratory. A beam of this type is generated from collisions of protons in a beam with protons and neutrons in a graphite target, focussing the particles produced (pions and kaons in particular) in the desired direction. The pions and kaons, like the muons, are very short-lived particles, unlike the protons and electrons which are the stable constituents of matter surrounding us. The pions and kaons decay in flight at high energies. The products of such decay, muons and neutrinos, continue to travel in generally the same direction as the parent particles, pions or kaons.

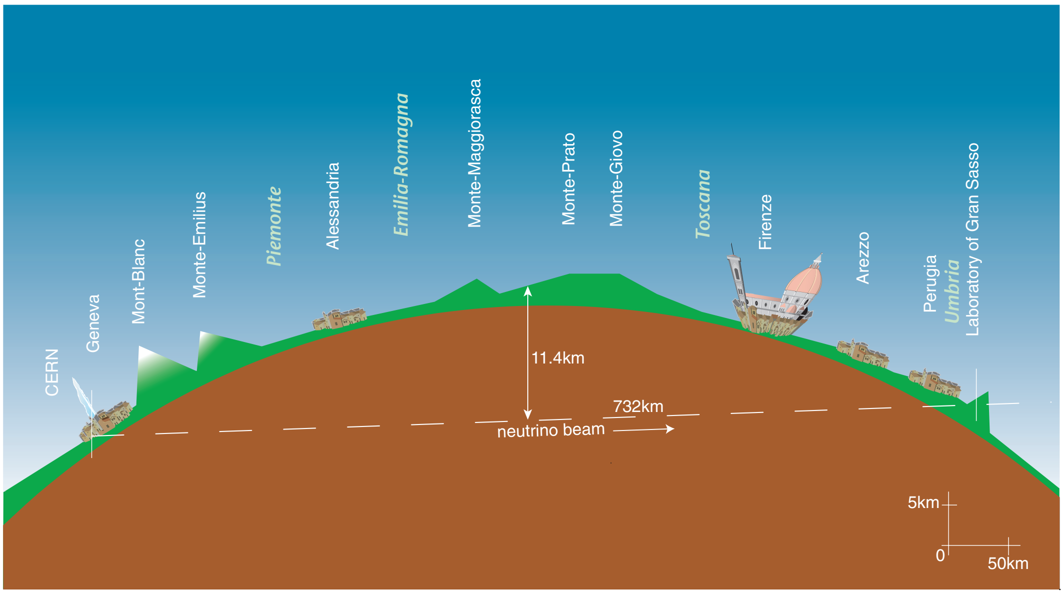

Figure 5: Route taken by neutrinos through the Earth's crust from CERN to the Gran Sasso laboratory

To direct the neutrinos towards Gran Sasso, all that need be done, therefore, is to focus the pions and kaons in that direction. The decay of these particles in a vacuum tunnel about one kilometre long creates the neutrino beam. Because of the low probability of interaction, most of these neutrinos will not be interrupted as they pass through the earth and will reach Gran Sasso. Figure 6 on page 11 shows the project set-up in map form.

Calculations show that when the neutrino beam reaches Gran Sasso, 732 km from CERN, it will have a diameter of about two kilometres.

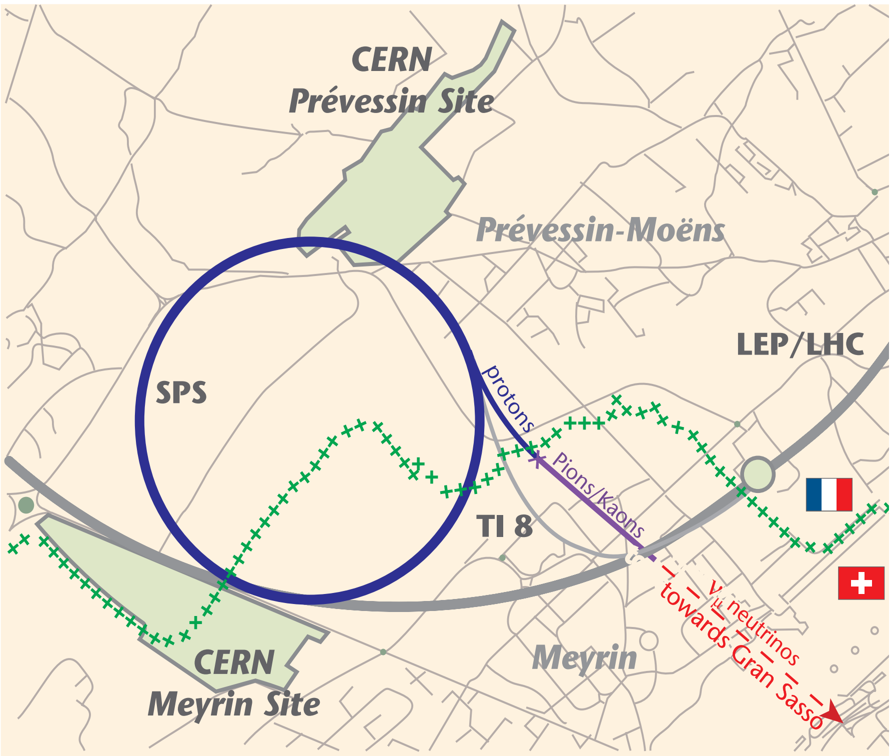

Figure 6: CNGS set-up at CERN in map form

It is proposed to install two large detectors[2] at Gran Sasso. In order to increase the probability of intercepting a neutrino, the mass of these detectors will be as large as possible, i. e. several thousand tonnes each. Very different technologies will be used in the two international collaborations in the hope of being able to record the arrival of a type ν_τ neutrino produced by such a sought-after oscillation, thus indicating that the neutrinos have small masses.

2 Though the Gran Sasso laboratory detectors are essential for the discovery of neutrino oscillations, they do not form part of the CNGS project at CERN, and are therefore not described in this document.

2 Description of the CNGS project

2.1 The objectives of the CNGS project

The aim of the CNGS project is to generate an intense neutrino beam in the direction of the Gran Sasso laboratory, making the greatest possible use of the existing CERN infrastructure. To prove the existence of neutrino oscillation, it is important for the beam produced at CERN to contain neutrinos of one type only, which in the case of the CNGS project is of the ν_μ type. The energy of the neutrinos produced is chosen in such a way that detection at Gran Sasso of neutrinos "transformed" by oscillation into ν_τ is optimised. The present plan is to provide ν_μ neutrinos with an energy between 5 and 30 GeV[3].

The most usual method of producing ν_μ neutrino beams consists of six main steps (c.f. Figure 7 on page 14):

- produce high energy protons;
- transport these protons to a target;
- collide these protons with the atomic nuclei of the target, producing a secondary beam, which partly consists of pions and kaons;
- guide the pions and kaons through a system of magnetic horns towards the experiments (in the case of CNGS in the direction of Gran Sasso);
- let the pions and kaons decay in flight in an evacuated tunnel. In most cases, the decay products are a muon and a ν_μ neutrino. The direction of flight of the neutrinos is very close to that of the parent particles, pions or kaons;
- bring the beam to a stopper, which absorbs everything except the neutrinos and muons. The neutrinos will continue on towards Gran Sasso, while the remaining muons will have been completely absorbed by the earth's crust within a kilometre.

All the components for producing the neutrino beam will be situated in the tunnels and service galleries described in Chapter 3 below. No new surface building will be needed for the CNGS project. A detailed technical presentation of the project is provided in "The CERN Neutrino Beam to Gran Sasso, Conceptual Technical Design", (ref. CERN 98-02 - INFN/AE-98/05) and its addendum (ref. CERN-SL/99-034(DI) - INFN/AE-99/05).

2.2 The main elements of the CNGS project

2.2.1 The proton beam

All the existing proton accelerators at CERN are involved in producing the CNGS beam (c.f. Figure 8 on page 14): the Linac provides 50 MeV protons for the Booster, which accelerates them to 1.4 GeV before transferring them to the PS. In the PS, the protons reach an energy of 14 GeV, then they are ejected and transferred to the Super Proton Synchrotron (SPS)[4]. In

[3] The energy of the particles is generally expressed in electronvolts (eV). One electronvolt corresponds to the energy acquired by an electron which is accelerated by a tension of 1 Volt. 1 GeV stands for a giga-electronvolt, i.e. 1 billion electronvolts.

[4] The same accelerator system will act as proton injector for the future Large Hadron Collider (LHC), which is under construction in the tunnel of the Large Electron-positron Collider (LEP) at CERN.

the SPS, the protons will be accelerated to their final energy of 400 GeV, ejected and transported in a transfer line (TN4, to be built) towards the CNGS target. The ejection point from the SPS protons will be in the sandstone molasse, 60 metres below the existing buildings of the zone BA4. All the installations in the CNGS project will be underground.

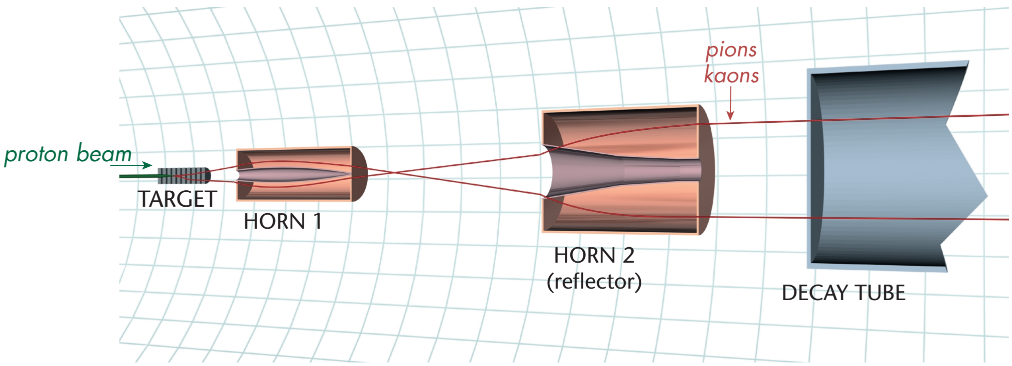

Figure 7: The production of pions and kaons (parents of the neutrinos), focussed in the direction of the Gran Sasso by two magnetic horns

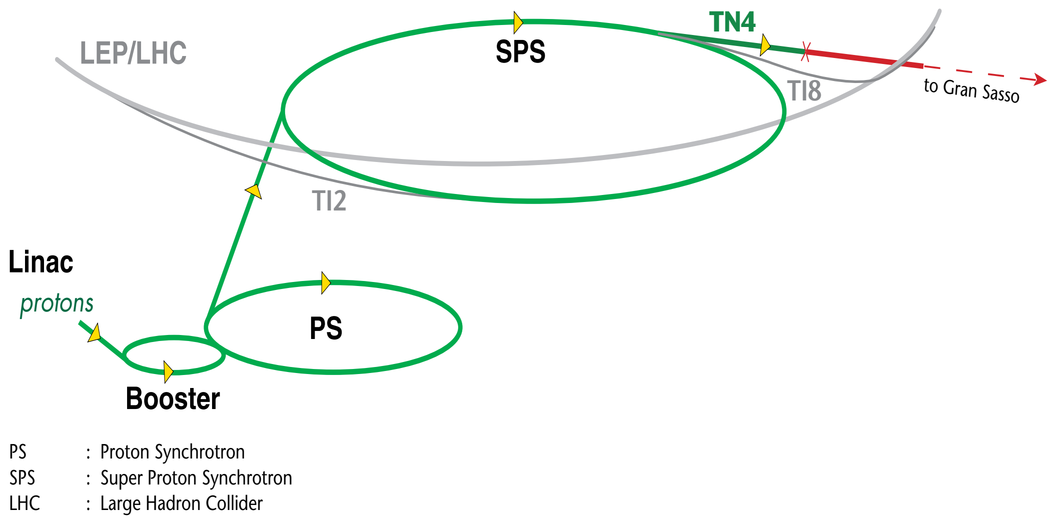

Figure 8: The CERN proton accelerators used for the CNGS

Figure 9: Dipoles (red) and quadrupoles (blue) in SPS tunnel

The TN4 transfer tunnel will be used to orient the proton beam so that even before it reaches the target it is already aimed at the Gran Sasso. This involves a horizontal deflection of 33 degrees and a vertical deflection of 3.2 degrees after the protons leave the SPS. The total length of the proton beam is 825 metres.

73 dipoles (bending magnets) and 28 quadrupoles (focussing magnets) will be needed to equip the TN4 line. All the magnets are of the same type as those used in the SPS (c.f. Figure 9 on page 15). These elements will only be powered for a very short period, while the protons are transferred towards the CNGS target, i.e. every six seconds or more; thus, they do not consume much electricity. The electricity power supply of line TN4 will be the same as that of transfer line TI8, at present under construction, which will link the SPS to the LHC.

2.2.2 The target and secondary beam

The CNGS target will consist of a series of small graphite cylinders. The size of the target has been chosen so that it will provide as many secondary particles as possible. In addition, the graphite cylinders must absorb the great heat and thermo-mechanical shock due to the energy deposited by the proton beam. The target must therefore be cooled with a jet of high-pressure helium gas in a closed circuit (helium is an inert, low density gas).

The particles produced in the target then enter a system of magnetic horns (c.f. Figure 7 on page 14), which will focus positive particles with a mean energy of 35 GeV and defocus the negative particles.

The interest lies in making the beam of pions and kaons, parents of the neutrinos, as parallel as possible. The first horn will cause excessive deflection of particles that have energies of less than 35 GeV and insufficiently deflect those with energies of over 35 GeV. To correct this a second horn known as the reflector, will be set up some 40 metres from the first. The combined focussing effect of the two horns will ensure that a maximum number of pions and kaons will be directed towards Gran Sasso.

2.2.3 The decay tunnel

Pions and kaons are not stable particles. For example, every 300 metres, some 15% of pions at 35 GeV decay. The higher the energy of the pion, the longer the mean decay length. In more than 99% of cases, the decay of pions produces a ν_μ neutrino and a muon.

To avoid any loss of pions and kaons through interactions with air, an evacuated decay tunnel is envisaged for the CNGS project. This tunnel contains a steel pipe similar to a large water main or oil pipe. The pipe, which will be one kilometre long and have a diameter of 2.45 metres, will be sealed into the rock. These dimensions are the result of a compromise between the cost of the tunnel and the number of neutrinos present in the CNGS beam. A simple vacuum pump will allow more than 99% of the air present in the pipe to be extracted within a week.

2.2.4 The hadron stop

Located at the end of the decay tunnel, the hadron stop is intended to absorb all protons not interacting in the target or the horns, together with all the pions and kaons that have not decayed before reaching this point.

The quantity of energy to be absorbed by the hadron stop is relatively high, so its construction (consisting of 3 metres of graphite followed by 15 metres of iron) must make for good heat dispersion. A closed-circuit water cooling system is also provided.

In addition to the neutrinos, muons are another group of particles that are hard to absorb in a beam stopper; they are particles which do not undergo strong nuclear interactions and only rarely react with atomic nuclei. These muons will therefore be absorbed further on in the molasse rock proper, behind the hadron stop. Within a kilometre, all the muons will have disappeared.

2.2.5 The muon detector stations

As these muons are the "sister" products of neutrinos with the same pion and kaon parents, the most practical way of checking the position, angle and intensity of a neutrino beam is to measure the trajectory of the muons. To do so, two detection stations are planned for the CNGS project: one directly behind the hadron stop and the second separated from the first by 67 metres of molasse. These sets of detectors can be used to measure the key parameters of the muon beam, hence also indirectly those of the neutrino beam towards the Gran Sasso.

2.3 Cost and planning schedule

2.3.1 Cost of the project

The estimated cost of the CNGS project is based on the experience of CERN engineers in underground civil engineering, accelerator and beam line construction and in particular in the building of equipment needed for high-performance neutrino beams.

Traditionally the construction of new beams such as that of the CNGS project, was always fully covered by the CERN budget. But the financial constraints affecting CERN due to the major collider project are such that the CNGS project will only be realizable through special contributions by several CERN Member States. Italy, first and foremost, has always been favourable, because the new project links up the Gran Sasso laboratory in a unique way to an accelerator laboratory, CERN. Italy has therefore proposed contributing 48.6 MCHF to the CNGS project. Belgium, France, Germany and Spain are also contributing.

Table 1: Cost of the project

	MCHF
Civil engineering (design, structures, steel pipe, consultants):	
in France	15
in Switzerland	26.6
Equipment (proton beam, target, secondary beam, hadron stop, muon detectors)	19.6
Infrastructure (cooling, ventilation, electricity, safety system, etc.)	9.8
Total	**71.0**

2.3.2 General scheduling

From the timetable standpoint, the CNGS project is closely linked with the LHC project. It will use the same proton extraction from the SPS and therefore, the same first 100 metres approximately of proton transfer line; the same access shafts to the SPS and LHC will also be used while installing equipment. The schedule presented here is subject to change, partly because of possible interference with the LHC project.

The general planning schedule consists of three main phases: (1) civil engineering, (2) installation of the hadron stop and the general infrastructure and (3) installation of equipment for the proton beam, target and magnetic horns.

Work has started in September 2000 near Point BA4 of the SPS. Civil engineering work will take some 32 months.

Installation of the hadron stop equipment is planned for the first six months of the year 2003. The installation of the vacuum pipe in the decay tunnel will take until the beginning of 2004. The general infrastructure should follow during the first six months of 2004. Installation of equipment in the proton transfer tunnel can be done at the same time as the installation of equipment in the target/horns zone. Beam start-up is planned for the spring of 2005. The first neutrino beam should be sent towards the Gran Sasso detectors very shortly afterwards.

3 Underground structures

All civil engineering work for the CNGS project is underground. 1000 m of the tunnels and the access shaft are to be built in France, with the remainder in Switzerland (see Figure 10 on page 20 and Figure 11 on page 21):

Table 2: Underground structures

Structures	Length or diameter (m)	Width or diameter (m)	Height (m)	Volume excavated (m3)	Volume of concrete to be poured (m3)
Temporary access shaft	8.0		57.0	3400	450
Access tunnel	769.0	3.1		8100	2250
Proton beam tunnel	590.0	3.1		6300	2300
Target chamber and annexes					
Target chamber	115.0	6.5		5500	2060
Service tunnel	148.0	3.4		2100	900
Associated structures				2700	1100
Decay tunnel	992.0	3.1		11150	1550
Hadron stopping chamber	26.0	6.0		1100	250
Connection tunnel to LEP/LHC	355.0	3.1		3950	1250
Second muon detection chamber	3.5	6.0		200	90
Total				44500	12200

3.1 The temporary access shaft

This shaft is needed so that the civil engineering work does not interfere with works for the LHC. The shaft will have a diameter of 8 m and a depth of 57 m, and will be situated 130 m from the existing cavern ECA 4. It will be used only during the construction period. The excavation will be protected by shotcrete. Once the project is completed, the shaft will be covered by a concrete slab, and then topsoil so that the surroundings revert to their initial state.

3.2 The access tunnel

This tunnel will connect the existing cavern ECA4 to the target chamber. It will allow equipment and personnel access from Point BA4 of the SPS accelerator. Its length will be 769 m with an internal diameter of 3.10 m. The walls and ceiling will be shotcreted. The general slope of the structure will be 2.2%.

3.3 The proton beam tunnel

This tunnel will link the existing cavern TJ8 to the target chamber. It will be 590 m long and it will have an internal diameter of 3.10 m. The walls and ceiling will be of concrete poured “in-situ”. The general slope will be 3.5%.

Figure 10: Work-sites connected with the CNGS project

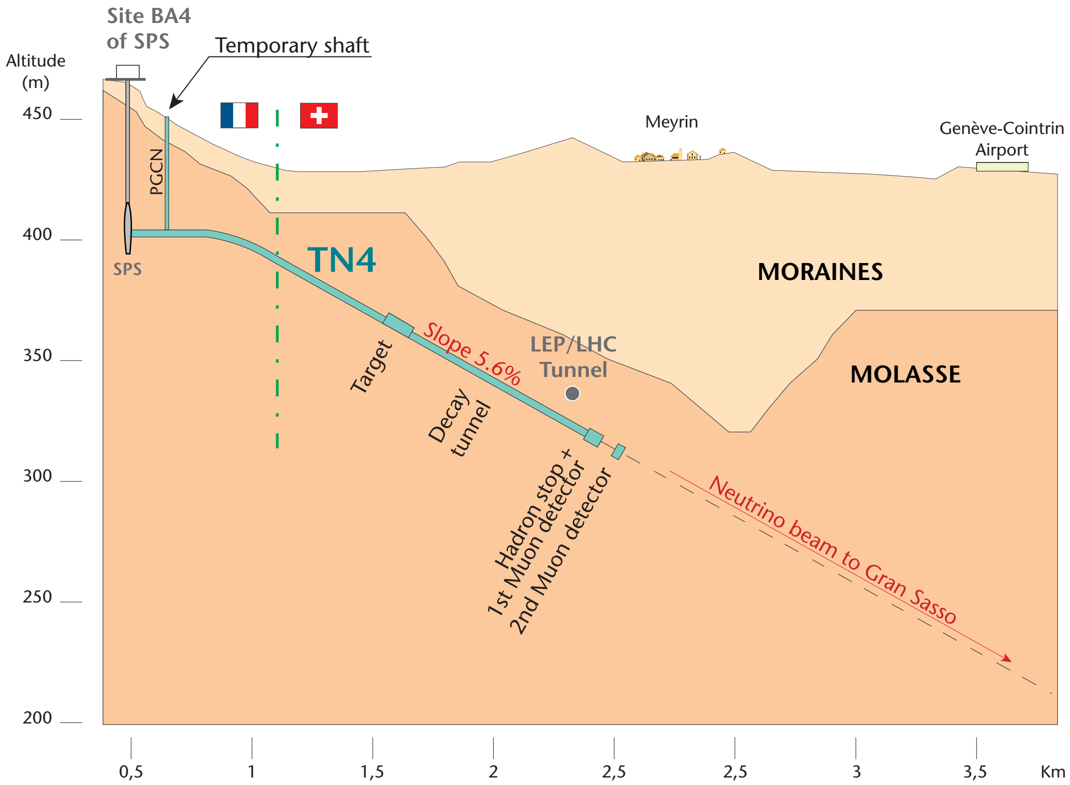

Figure 11: Works connected with the CNGS project: section

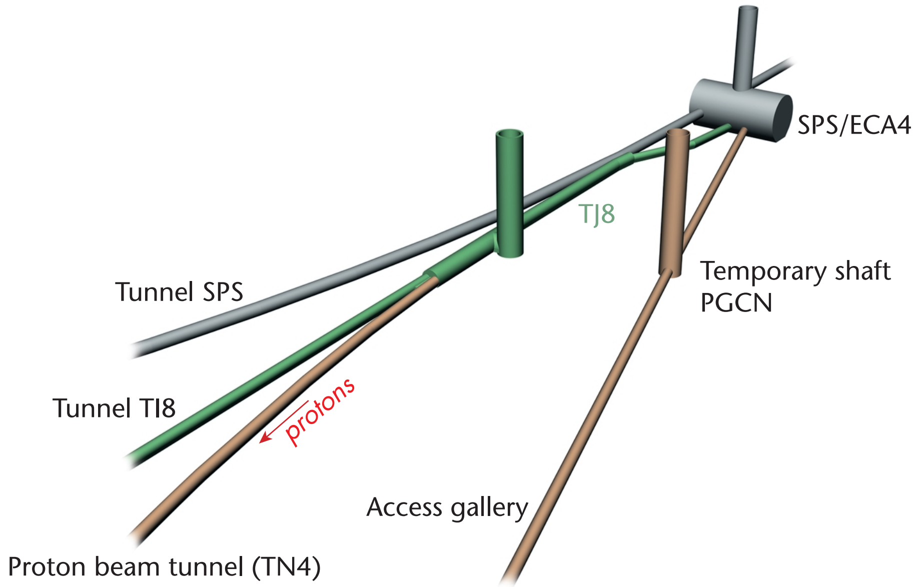

Figure 12: Underground work-sites at Point BA4 of the SPS. Tunnel TI8, under construction, will connect the SPS to the LHC.

3.4 The target chamber and the adjoining tunnels

The target chamber will be a cylindrical structure 115 m long with a diameter of 6.50 m. At the upstream end it widens out to a diameter of 8.50 m over a length of 15 m and will be linked to the proton beam tunnel by a junction tunnel 8 m long and 9 m in diameter. The access tunnel will be linked to the proton beam tunnel via the same junction.

Running parallel to the target chamber will be a service gallery 148 m long with a diameter of 3.40 m. The target chamber and the service tunnel are to be linked by six cross-passages 1.80 m in diameter allowing access to the target chamber for workers and power connections

The walls and ceilings of these structures will be of in-situ concrete except for those in the service tunnel which will be shotcreted.

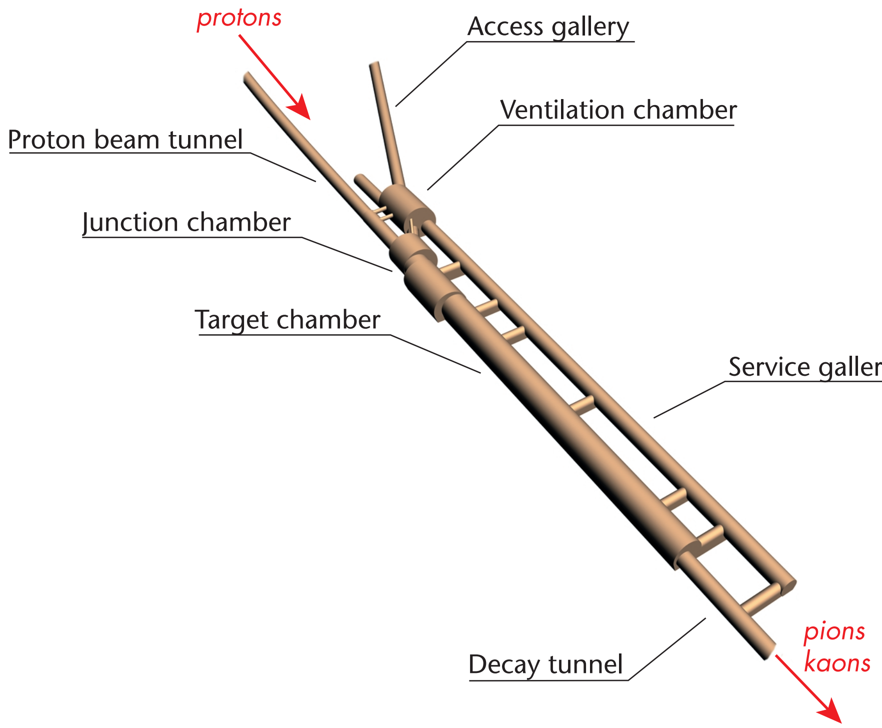

Figure 13: The target chamber and its annexes

3.5 The decay tunnel

The decay tunnel will join the lower end of the target chamber and the upper end of the chamber for the hadron stop. It will be 992 m long with an internal height and width of 3.10 m. It will house a steel pipe with an internal diameter of 2.45 m, made of 6 m long sections welded in situ. The space between the steel pipe and the tunnel wall will be filled with concrete. There will be no access for persons or equipment between the target chamber and the hadron stop chamber.

3.6 The hadron stop and the connecting tunnel to the LEP/LHC

The hadron stopper chamber will be 26 m long over all, and 6 m in diameter. The walls of this chamber will be of in-situ concrete and at its southern end will be a tunnel segment 20 m long and 3.10 m in diameter, lying perpendicular to it. At the far end of the segment will be a chamber 10 m long and 4 m in diameter. This chamber will in turn be linked to the LEP/ LHC tunnel by a connecting passage 224 m long and 3.10 m in diameter. This underground connecting passage is essential because the hadron stop chamber will not be accessible from the structures above it and CERN wishes to avoid an additional shaft from the surface. This connecting passage will pass 7 m below the level of the LHC tunnel.

The walls and ceilings of all the interconnecting passages and connection chambers will be lined in shotcrete. At its downstream end, the hadron stop chamber will house the first muon detector station.

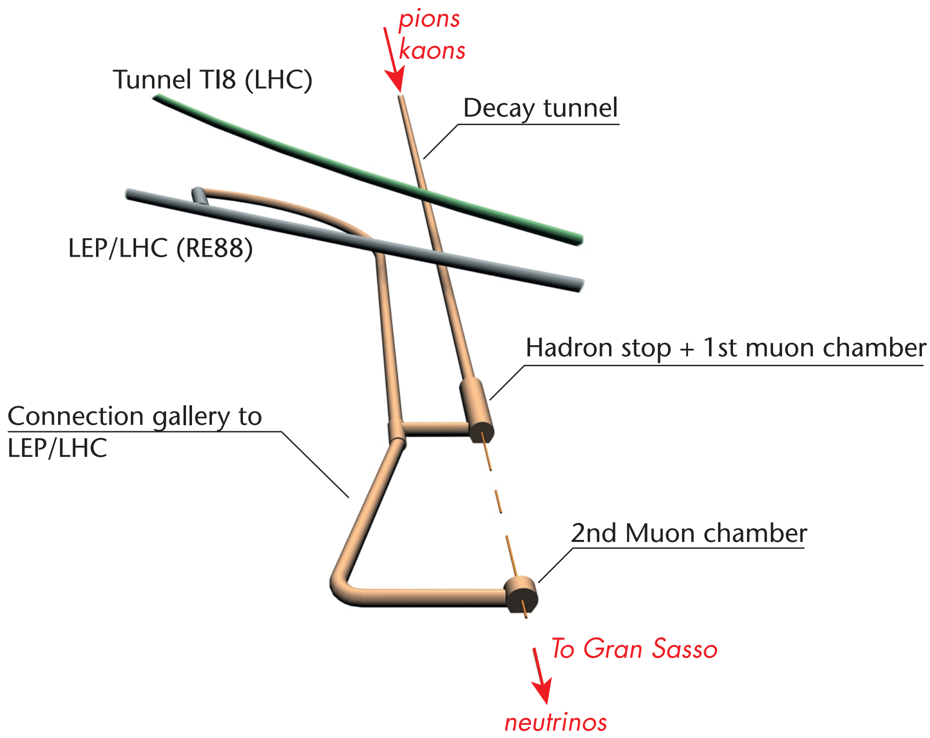

Figure 14: The hadron stop chamber and muon detection chambers and the connecting passages to the LEP/LHC

3.7 The second muon detector chamber

This second chamber, 6 m in diameter and 3.50 m long will be located 67 m from the first chamber and along the axis of the beam. It will have in-situ concrete walls and be linked to the above-mentioned connection chamber by a tunnel 3.10 m in diameter (c.f. Figure 14 on page 23). The walls and ceilings of all the interconnecting tunnels and connection chambers will be of shotcrete.

4 Civil engineering

4.1 General

All the CNGS project structures will be situated underground. Based on its experience in building the SPS, LEP and LHC accelerators, CERN is not merely taking all the precautions and measures required under the law but is also incorporating the lessons it has learned from undertaking previous projects. The aim of CERN will be to lessen significantly the impact of such a project on the surrounding environment.

4.2 Safety coordination

Design study and construction contracts are subject to international calls for tender. The conditions and limits to services provided, specifications and obligations of all kinds imposed on contractors of various types are very clearly defined. In particular, firms will be required to abide strictly by all regulations of the Host States, according to the area where the work is being done, as with the LHC at present.

In this spirit, CERN has a contract with a specialist consultant responsible for the health and safety coordination assignment on the CNGS site that meets the provisions of European Community directive 92/57/EEC of 24 June 1992 on the implementation of the health and safety requirements on construction sites.

Under the terms of its contract this firm will take part in the entire conceptual design study and development phases of the project. During the construction phase, it will be in charge of implementing the General Safety Plan.

4.3 Working hours

Working hours will conform to the relevant legislation. Work underground will generally be done in round-the-clock, five-day week shifts with possible Saturday overtime in exceptional cases to meet deadlines, safety or technical constraints.

Outside normal working hours, surface work will be kept to a minimum and applicable noise abatement legislation will be observed. Surface transport of spoil is forbidden during night-time hours.

4.4 Geological constraints

The work will be conducted entirely in the molasse of the Geneva Valley Basin. This rock is composed of many strata, typically about a metre or so thick, of variable quality ranging from relatively soft marls to very hard sandstones with intermediate elements grouped under the name sandstone marls, consisting of a soft rock that is more or less impervious to water that is scarcely ever fractured and is not very abrasive. However, it does have certain shortcomings due to its low mechanical strength and the changeable quality of the marls, sources of localized instability or swelling, and sometimes to the presence of liquid or gaseous hydrocarbons, particularly in the sandstones.

4.5 Use of explosives

The use of explosives is strictly regulated both in Switzerland and France. As in the case of the civil engineering works in the Geneva valley plain for LEP, CERN will keep the use of explosives to a strict minimum. At the same time their use cannot be completely ruled out as certain construction work cannot otherwise be carried out. Only in case of absolute necessity will CERN authorize their use on the CNGS project. In such circumstances, the blasting plans that must be drawn up by the firms will be submitted to a licensed laboratory for approval.

4.6 Construction techniques

4.6.1 Temporary access shaft

This 8 m diameter shaft is will be excavated using hydraulic rock-breaking techniques, or by blasting, if absolutely necessary. The walls of the shaft will be protected and shored up by anchoring systems and shotcrete. It will not be finished with in situ concrete. When the work is completed the shaft will be covered by a concrete cap so that it is guaranteed to be completely safe and so that it blends with its surroundings.

4.6.2 Tunnels

These can be dug by using either road header boring machines or by full-face tunnelling machines. The choice will be up to the contractor. The tunnels will be shored up provisionally as work advances by using rock bolts, whose function is to reinforce the rock mass and lock together separate rocks, in combination with shotcrete strengthened by welded mesh or fibres. For the proton beam tunnel the shoring phase will be followed by inserting an internal lining poured on site with a watertight system. As the decay tunnel will subsequently have a steel pipe inserted into it only the temporary shoring will be erected. Finally, in the remaining tunnels, once shoring work is done, a layer of shotcrete will be applied.

4.6.3 Chambers

These will either connect the different underground structures or be used to install the technical equipment. They will be dug out using road header boring machines. As the excavation progresses, the workforce will be protected and the walls consolidated by anchoring, structural steel, shotcrete or other relevant techniques. The finishing will be done by conventional methods using shuttering brought to the work-site from the surface.

Figure 15: Excavation with rotating head boring machine (roadheader)

4.7 The work-site installations

4.7.1 General

- CERN imposes certain requirements in connection with work-site installations:
- site offices shall be delivered in very good condition and properly maintained for the duration of the work;
- the work-site zone must be kept clean and in proper order;
- fencing shall be either solid steel, pre-laquered in a neutral colour, or timber;
- the work-site shall be fitted with an access gate that can be locked.

4.7.2 Location of the work-site

The civil engineering shaft work-site PGCN is alongside the work-site area for TI8 currently forming part of the LHC project. This zone is situated near SPS Access Point BA4 at Prévessin-Moëns, not far from the "Clos de Charmais" housing estate on land belonging to the French State made available to CERN when the SPS was being built. Access to the RD35 road is via the existing site entrance.

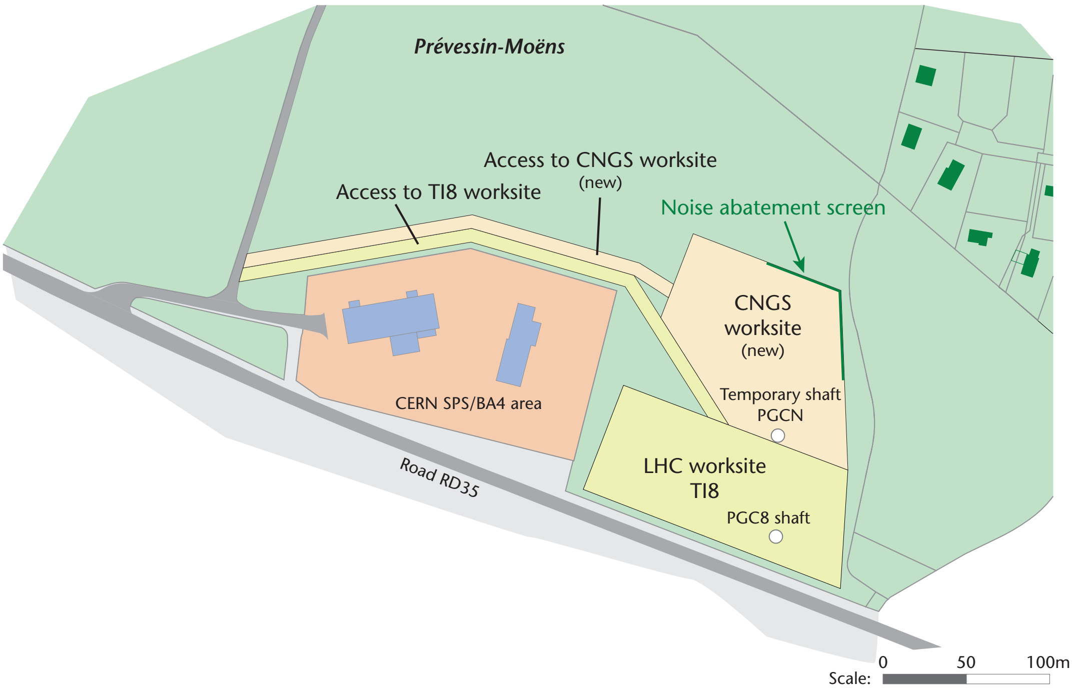

Figure 16: The CNGS work-site area near SPS Access Point BA4

Figure 17: The TI8 tunnel work-site near the SPS/BA4 area

5 CNGS and the environment

Although by their very nature underground structures have little impact on the environment, their realization nonetheless requires precautions to be taken to reduce or avoid possible nuisances due to the removal of spoil, the disposal of water on the surface, disturbances and noises from the work-site.

Once the construction work underground is finished it will no longer be a source of nuisances. Noise produced in the underground installations cannot be heard on the surface.

5.1 Spoil

5.1.1 General

The CNGS work-site will generate both natural spoil and wastes from the demolition of existing structures and work on the site itself. Three kinds of natural spoil will be produced: topsoil, which will be stored and re-used; unconsolidated material of the moraine types; and above all molasse. The two latter types of will be stockpiled.

The work of connecting up to existing underground structures will also give rise to the demolition of concrete structures. These will be dealt with in a manner that will respect the environment.

5.1.2 Spoil

The CNGS project will generate a volume of 700 m^3 of excavated moraine and 66 000 m^3 of molasse, assuming a swell factor of 1.5.

Spoil is being stockpiled in accordance with the principles applied to that originating from the LHC, i.e. by avoiding passing through built-up areas. Discussions are under way with the Prévessin-Moëns municipal authority, to increase the capacity of the Bois-des-Serves storage site established to meet the needs of the LHC.

5.2 Waste disposal

5.2.1 Concrete wastes

It is planned to break up the concrete wastes from demolition work and separate out the reinforcement so as to obtain material that can be re-used. The volume of waste from the CNGS project will be limited to 18 m^3, which will come from connections to the existing structures.

5.2.2 Other site wastes

Selective waste depositories are located on site; sorting and recovery will be made by category (drainage oil, plastics, packaging, metals, etc.) and processed appropriately.

5.3 Effect on water resources

5.3.1 Industrial water consumption

Demineralized industrial water from the SPS will be used for cooling the proton beam magnet system. This water passes through a closed circuit. It is cooled in the SPS cooling systems by means of a heat exchanger.

The SPS cooling water comes from Lake Geneva via a special pipeline. The consumption at the CNGS will be only about 1% of that of the SPS.

5.3.2 Effects on aquifers

All the underground structures of the CNGS are being built in the molasse, which is a material that is in principle impervious to water. None of the structures are located within the perimeter of a water catchment area.

Given the fact that the access shaft to the CNGS structure will not pass through any aquifers, there is no risk of polluting community water supplies either during construction or while the CNGS facility is in operation.

5.3.3 Waste water disposal

Drainage water will be collected in four underground tanks. One of these will be located in the ventilation chamber, another at the end of the service tunnel, a third in the hadron stop chamber and the fourth in the second muon detection chamber. Checks of water quality will be made before any of the water is discharged from the tanks into the SPS or LHC drainage systems.

5.4 Noise and vibration from the work-sites

These are isolated nuisances occurring from time to time that should nevertheless be taken into consideration. The different sources of possible noise during the period of engineering work on the structures are as follows:

- the movement of machinery and on-site equipment: transport of spoil is not permitted at night;
- the possible use of explosives through technical imperatives. If this is necessary it will be confined to the strict minimum. In this case, every precaution will be taken by CERN and blasting will only take place in the daytime;
- the increase in road traffic, in particular traffic connected with the transport of spoil.

Given the simultaneous existence of work-sites for CNGS and TI8, CERN is planning to install a noise abatement screen to protect nearby housing.

5.5 Transport, traffic and roads

The amount of spoil produced by work at the CNGS will total 67'000 m^3 bulked material. The excavation work will last some two years; removal will require some 15 transports per day on average.

The amount of concrete to be poured is calculated at 12’200 m^3, and the site is supposed to be supplied with this amount from the two nearby concrete mixing centres at either Thoiry or Crozet. Concreting work will last some 18 months, totalling six loads per day along roads RD35a and RD35.

Components to be installed for the project will be brought in via Point BA4 of the SPS through the access tunnel. The 500 blocks of iron for the hadron stop can be transported in loads of five at a time. The 100 magnets for the proton line must be brought in one by one. The iron blocks will be brought from CERN’s Meyrin site via road VC5 at a rate of two trucks per day during the approximately two month installation phase. The magnets will come from CERN’s Prévessin site, near SPS Point BA4.

When the CNGS is running, its beam will be controlled from the SPS-LHC control room at the Prévessin site, and there will be no major traffic during the seven months of operation each year. During shutdowns, only occasional loads of defective equipment are likely to be transported.

5.6 Land ownership aspects

For earlier CERN projects, the French State acquired and made available the necessary land to CERN. For SPS, 412 ha were acquired during the nineteen-seventies. SPS Point BA4 is located on one of these pieces of land. In Switzerland the depth of the structures is so great that they are below the useful depth level. The structures for the CNGS in France will be located in tunnels. There is therefore no land ownership impact from the CNGS project either in France, or Switzerland.

5.7 Radiation safety aspects

Although neutrinos themselves have no effect on matter or living organisms, their production by means of a proton beam generates radioactivity, which remains however confined to the tunnels. The calculations by radiation safety experts show that no ionizing radiation will reach the surface directly and that any radioactivity released via air and water will be very much lower than the natural radioactive background in the region.

In any case, the CNGS project will be formally supervised by the French and Swiss authorities. The project will be included as part of the Basic Nuclear Installation (INB [5]) Convention for the LHC and the SPS between CERN and the French government. Before obtaining the requisite permission for operation CERN will first submit its project and safety arrangements to the French national Directorate of Safety in Nuclear Installations (DSIN[6]) which manages the INB’s and to the Federal Swiss Public Health Office (OPRI[7]).

5.8 Safety

Like LEP and the LHC, the CNGS will be subject to the provisions governing basic nuclear installations (INB). In particular, the INB procedure includes in its initial phase a hazard study, identifying possible risks and identifying the principles of prevention.

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[5] “Installation Nucléaire de Base”

[6] “Direction de la Sûreté des Installations Nucléaires”

[7] “Office de Protection contre les Rayonnements Ionisants”

5.9 Socio-economic aspects

CERN's importance to the overall economy was demonstrated when the LHC was proposed. The CNGS project is much less demanding in manpower and materials than the LHC. It is not directly going to create a significant number of new employment opportunities. On the other hand, it does go together with the other scientific projects that have made CERN one of the world's greatest centres of excellence in particle physics. The new project will ensure that the study of neutrino physics continues in Europe. It will strengthen the scientific and technological image of CERN and it will attract research workers from all round the world, thereby assisting in the economic expansion of the region.

List of figures