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ST IMPLICATIONS IN THE CNGS PROJECT

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Abstract

The CNGS project concerns the construction of a neutrino beam facility (CNGS = CERN Neutrino beam to Gran Sasso). A 450 GeV proton beam will be extracted from the SPS accelerator. This proton beam will hit a target a few hundred metres downstream from the extraction point (BA4). In the debris of the proton beam we will find pions which continue down a 1000 m, evacuated tunnel and a fraction of which decay into a neutrino beam. After this decay tunnel (1.1 km), a 'hadron stop' will separate the neutrinos, after which they will resume their journey down to a detector pit, outside Rome (Gran Sasso). The CERN facility has a total length of approximately 3 km. The ST division has an important share in the construction work, both of the above-mentioned tunnels as well as of all other infrastructure services, and this work concerns most of the groups in the division. This report will outline the technical design of the facility and explain how we, in the ST division, are involved in the project. The CERN council approved the project on 17 December 1999 for a scheduled commissioning in 2005.

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1 INTRODUCTION

The description of matter and force particles known as the Standard Model has been challenged by the perceived deficit of mass in our universe.

A possible clue to this intriguing issue is the property of the neutrino (a fundamental, charge-less particle in the lepton family) and especially the question of whether the neutrino has mass. The answer to this question is, hopefully, one outcome of the CNGS project, a project hosted at CERN but funded mainly by INFN (Istituto Nazionale di Fisica Nucleare) and other national sources. If the neutrino has mass, it is likely to be out of reach of direct measurement. Therefore the key method is to search for neutrino oscillations, the transformation of one kind of neutrino into another, which can occur only for massive neutrinos. Experiments proposed in the INFN Gran Sasso Laboratory aim, with various methods, to detect and measure these oscillations.

Apart from the CERN–INFN effort, described in this report, research is in progress in other parts of the world on the subject, for example,

- at the SuperKamiokande experiment in Japan, using a neutrino beam from the KEK accelerator outside Tokyo, where some experiences already has been reported, indicating positive results;
- at Fermilab in the USA, where a facility is under construction that will send a neutrino beam to a detector 730 km away in à mine cavern (MINOS).

The CNGS project was approved by the CERN Council on 17 December 1999.

2 GENERAL DESCRIPTION OF THE FACILITY

For a complete description of the facility, see Ref. [1].

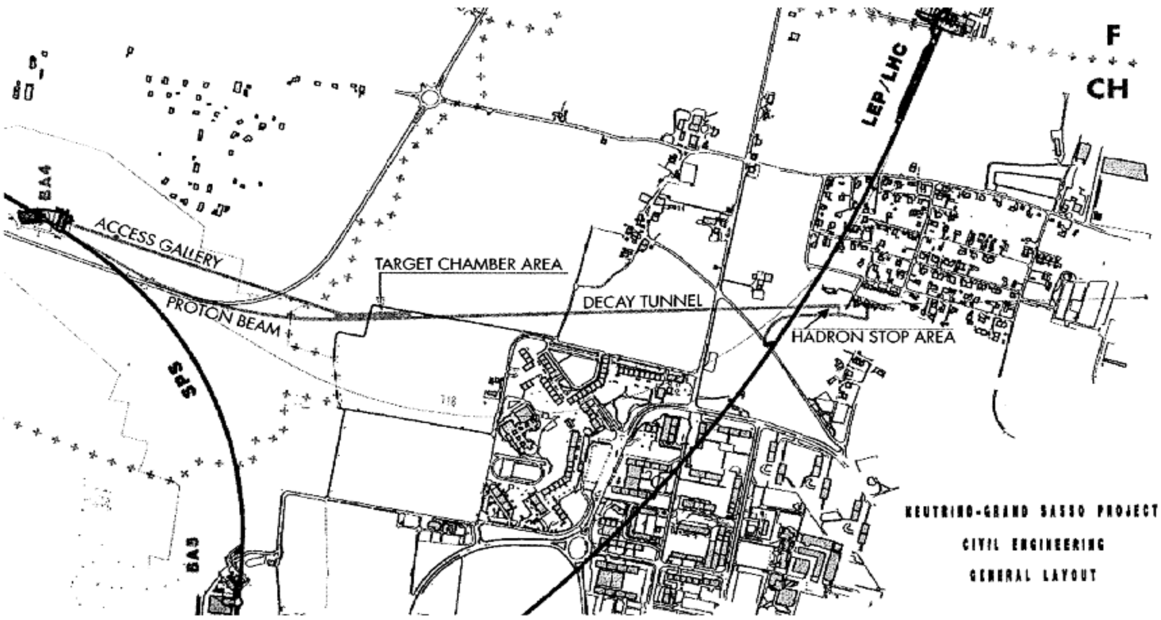

Figure 1: General layout of the CNGS facility.

The underground structure for the CNGS facility links to the existing SPS (BA4) structure. The five main parts of the facility are listed below and illustrated in Fig. 1:

- proton-beam tunnel – the beam-link with the SPS accelerator from an extraction point at TT40 (where the LHC-TI8 also reaches the SPS);
- target chamber with associated services structure;
- access gallery to the target chamber from the SPS (ECA 4);
- decay tunnel;
- 'hadron-stop' chamber with connecting link-tunnels to the LEP/LHC structure at octant 8-1, and associated muon monitoring detectors.

The extraction point from SPS (LSS4) is, after the upgrade, used as proton injector for the LHC via the TI8. 110 m after the extraction point the 450 GeV proton beam branches off, and continues 830 m through 73 bending magnets where it hits a target. In the debris of the proton beam we will find pions (π), which continue down a 1000 m, evacuated tunnel and a fraction of which decay into a neutrino (ν) beam.

This neutrino beam meets at the end of the facility a 'hadron stop', which filters the hadrons which have not decayed, and leaves the pure ν-beam on it’s flight through earth down to the Gran Sasso experiment outside Rome.

3 SCHEDULE

The present schedule, see Fig. 2, for the construction of the facility is for a first proton on target in April 2005, thus very close to the commissioning of the LHC. In order to meet this schedule, the civil engineering study had to start in advance of the formal approval, and the call for tender is now ready to be issued. The construction will start by the end of 2000.

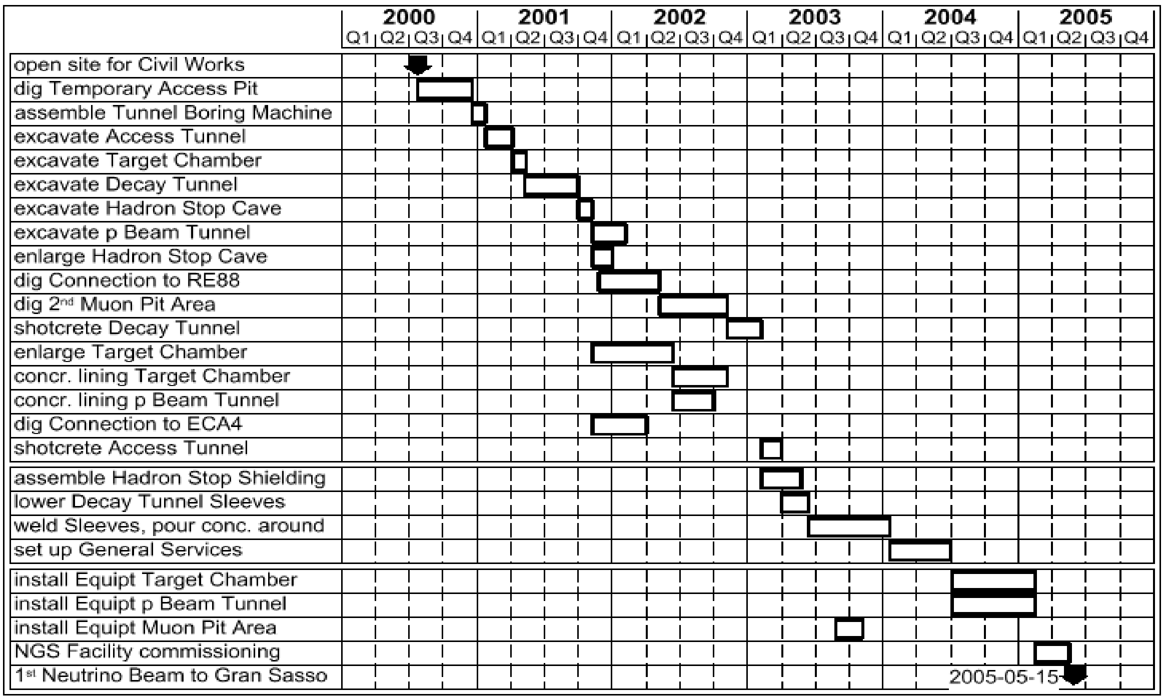

Figure 2: Installation schedule for the CNGS project.

4 SPECIFIC GROUP DESIGNS

4.1 Civil engineering construction

The description of the civil engineering structure follows the five main parts listed above.

4.1.1 Proton-beam tunnel

The tunnel, from the junction with TJ8, is 590 m long with a diameter of 3.10 m, except for a slight widening over the last 20 m.

4.1.2 Target chamber and ancillary structures
(See Schematic top view of the structure in Annex 1)

The target chamber itself is a 115 m long cylindrical cavern with a diameter of 6.50 m. It widens on one side for the junctions of proton-beam and access tunnels. Upstream from this junction towards the access gallery is a cavern with length 15 m and a diameter 9 m to house mainly ventilation equipment, as well as a 20 m long and 3.10 m wide storage chamber. Parallel to the target chamber, there is a 3.40 m diameter service tunnel for vacuum and ventilation installations.

4.1.3 Access tunnel

The access tunnel from the SPS–ECA4 to the target chamber area is 769 m long and 3.10 m in diameter. A 57 m deep shaft will be located 130 m along this tunnel for access with construction tools, e.g. TBM (Tunnel Boring Machine).

4.1.4 Decay tunnel

The 994 m long decay tunnel runs between the target area and the hadron stop. The tunnel, bored to a diameter of 3.10 m, is lined with a 2.45 m steel pipe and the space between the pipe and the tunnel wall is filled with concrete. The steel pipe will be welded in 6 m sections so that it can contain a vacuum of 1 mbar.

4.1.5 Hadron-stop and muon-detector area
(See schematic top view in Annex 1)

The cavern that houses the hadron stop and the first muon detector is a 26 m long cylindrical cavern with a diameter of 6 m. A tunnel link from the LEP/LHC structure RE88 has a total length of 224 m and a diameter of 3.10 m. The second muon detector is located in a small cavern 67 m from the first on the same beam axis. A chamber for electronic and cooling equipment is situated 10 m perpendicular to the muon chamber; it is 20 m long and 3.10 m in diameter.

4.1.6 Sequence of civil engineering work

The civil engineering work will most likely commence with the excavation of an access shaft and a suitable chamber at the foot of the access gallery. A TBM can from then onwards bore all of the underground structure, with a diameter of actual head of the TBM of about 3.5 m. The final dimensions will successively be excavated by roadheader, and finished by various types of concrete lining, construction-steel elements for the crane, flat floors with embedded drain pipes, and especially the non-shrink concrete filling around the decay-tunnel steel pipe and around the hadron stop.

4.2 Electrical-power distribution

The main part of the facility (target and access areas as well as the proton-beam tunnel) is powered from the BA4, SPS.

It is proposed to install an 18 kV cable from BA4 to an 18 kV/400 V transformer close to the target area, to minimize transfer losses and thus optimize cost. For the hadron-stop and muon-detector area, the power is distributed from the LEP stub tunnel RE88; as the power is modest, a 400 V link should be sufficient. The lighting and safety systems (emergency stops, 48 V supplies, anti-panic light and safe power) follow the same approved concepts as LEP200 installations, which basically will be continued over the LHC period. The cabling in the underground structure will be very carefully studied, as space is very limited in the narrow tunnels and galleries.

4.3 Heavy handling

An overhead crane with a capacity of 10 t will be installed in the target chamber.

The heavy-handling team will (as can be seen in the resource plan, see Annex 2) be in heavy demand during the installation period.

4.4 Access and machine-interlock system

The CNGS underground structures are considered as 'CERN Primary Beam Area' and the equipment related to the safety of personnel and equipment must be implemented accordingly.

Two access points will be available to the area, duly equipped with access control and interlock systems:

- Access to the target chamber area from point 4 of the SPS. The access point is situated in the underground cavern ECA4.
- Access to the hadron stop and the muon detector is provided through LEP/LHC structure RE88. Access to this area requires that both the neutrino and the LHC beams be switched off.

4.5 Fire detection system

Although no fire detection system has for the time being been foreseen in the CNGS underground areas, it should not be excluded in the final concept. The difficulties, pointed out during the conceptual design, of the long distance between sampling points and the smoke detectors could possibly be overcome with a general implementation in the LHC underground structure.

4.6 Ventilation

4.6.1 Target chamber and service gallery

The air for this area is treated by an AHU (Air Handling Unit) placed in the second level of the tunnel junction reserved for ventilation equipment. The unit operates entirely on recirculated air, except during access periods, to avoid any unwanted release of radioactive air to the outside atmosphere. With the experienced corrosion problem from the previous West Area Neutrino Facility, the dew point is chosen as very low.

4.6.2 Proton-beam tunnel

The proton-beam tunnel is also supplied from a recirculating AHU located in the ventilation cavern. During access periods fresh air is also injected.

4.6.3 Access gallery

The access gallery is ventilated by an AHU located in a surface building attached to BA4, named SUI4. This unit operates only during access periods.

4.6.4 Hadron-stop and muon-detector area

This area is ventilated from sector 8-1 of the LHC tunnel. A duct and fans ensure that the air reaches the whole area as far as the muon chambers.

The components for air handling will be designed to provide the conditions shown in Table 1.

Table 1: Parameters for the ventilation of the different areas.

	Dry temperature	Dew point	Air flow rate	Smoke extraction
Target area and service gallery	19°C	–15°C	16 000 m^3/h	Yes
Proton-beam tunnel	19°C	10°C	12 000 m^3/h	Yes
Access gallery	19°C	10°C	16 000 m^3/h	Yes
Hadron-stop and muon-detector area	19°C	12°C	2 300 m^3/h	Yes

The smoke-removal equipment is designed for cold smoke at a maximum temperature of 100°C. Before access can be authorized after a run period, the fresh air ventilation will be started and the whole area aerated for a certain time. This air release is monitored in relation to radioactivity.

4.7 Cooling

The cooling requirements for different purposes are shown in Table 2.

Table 2: Parameters for cooling.

	Cooling load	Temperature	Water flow rate
Target	50 kW	27/42°C	3 m^3/h
Proton-beam tunnel	2000 kW	27/42°C	115 m^3/h
Hadron stop	50 kW	27/42°C	3 m^3/h
Air-conditioning target area, service and access gallery	600 kW	6/12°C	86 m^3h

4.7.1 Proton-beam tunnel and target chamber

The primary cooling system at the SPS BA4 provides the cooling of the demineralized water for the proton-beam magnets by a separate cooling station in BA4. A small closed circuit, also of demineralized water, is provided for the equipment in the target chamber. The air-conditioning units in the ventilation cavern are supplied with chilled water from a refrigeration unit located, again, in BA4. The chilled-water pipes are installed in the access gallery.

4.7.2 Hadron stop

The hadron stop is cooled by a closed demineralized-water circuit, for which the cooling station is preliminarily located in the LEP RE88. This cooling station is supplied from the LHC primary water in octant 8-1.

4.7.3 Fire extinguishing system

In accordance with other underground structures, a fire extinguishing circuit is installed. The target-chamber area is supplied from the SPS primary water system, through the proton-beam tunnel, whereas the supply for the hadron-stop area comes from the LHC tunnel.

5 COST ESTIMATE

The cost estimate for the construction of the CNGS is in the order of 71 MCHF. The breakdown of this sum and a careful analysis of manpower needed for the realization of the facility are shown in Annex 2.

6 CONCLUDING REMARKS

The estimate for services related to our division counts for 48 MCHF, thus 67% of the total, which shows the importance of the performance within ST division for the success of the project. What cannot be seen in this report of the final design is the long list of alternatives needed to convince the management (and others) of the convergence and optimization of chosen solutions. As an example, at least three technical solutions were discussed, analysed and estimated, before the final steel-pipe design was chosen for the decay tunnel. After the exciting decision by CERN council on 17 December 1999 to approve the project, we can look back and see that the effort made by ST, and of course by others, has been fruitful. This is also a solid preparation for the engineering work, which now will continue.

REFERENCES

[1] R. Bailey et al., The CERN Neutrino beam to Gran Sasso (NGS), CERN 98–02 (1998).

ANNEX 1: CIVIL ENGINEERING DETAILS

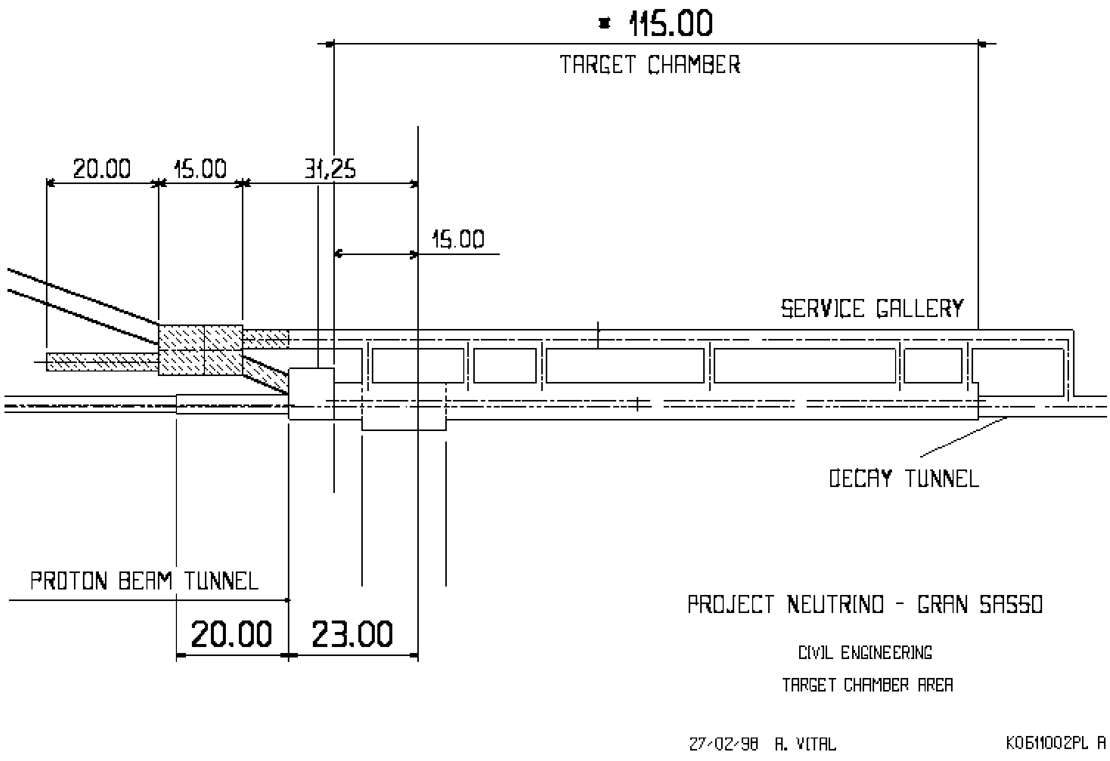

Figure 1: Target chamber and ancillary structures.

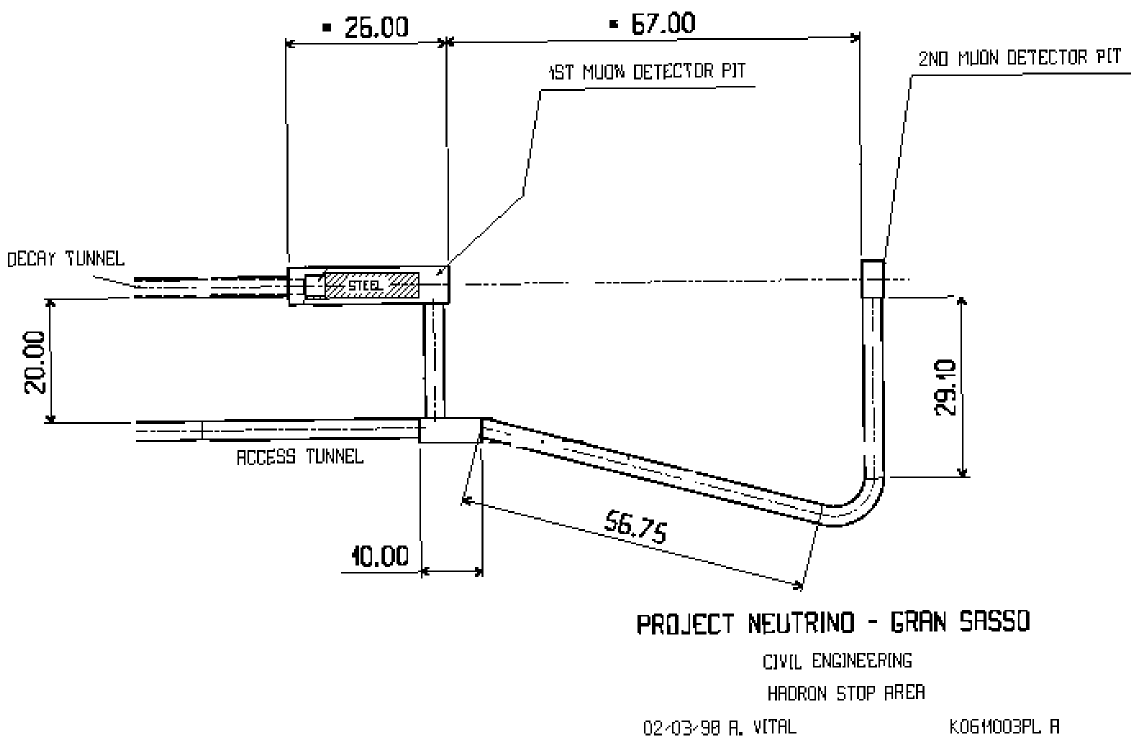

Figure 2: Hadron-stop and muon-detector area.

ANNEX 2: RESOURCES FOR THE CNGS PROJECT

Table 1: Cost and manpower estimate for the CNGS project.

	Cost (MCHF)	**Man-years** (FTE)
Civil engineering	**41.6**	**11**
Equipment	**19.6**	**35**
Proton beam and target	12.5	21
Secondary beam and hadron stop	6.8	15
Infrastructure	**7.3**	**13**
Cooling and ventilation	3.8	3
Electrical infrastructure	1.3	2
Handling equipment, safety, survey, access, alarms	2.3	8
Contingency	**2.5**	
Total	**71.0**[a)]	**59**

Table 2: Manpower profile in ST for the CNGS project.

CNGS (man-years)	Civil engineering	Cooling & ventilation	Safety alarms (ST)	Heavy handling, transport	Electricity	Coordination (ST)	**Total**
year 1	2.9	0.7			0.1	0.3	**4.0**
year 2	3.3	0.8		1.1	0.1	0.3	**5.6**
year 3	2.5	0.8	0.5	1.1	0.8	0.2	**5.9**
year 4	2.0	0.8	0.5	0.8	0.4	0.2	**4.7**
year 5	0.1	0.3	0.2		0.1	0.1	**0.8**
Total	10.8	3.4	1.2	3.0	1.5	1.1	**21**