CERN/2300/Rev.
Original: anglais
16 décembre 1999

ORGANISATION EUROPÉENNE POUR LA RECHERCHE NUCLÉAIRE
CERN EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

POUR APPROBATION

PROCEDURE DE VOTE:
Majorité des deux tiers de tous les Etats membres

CONSEIL
Cent quatorzième session
Genève - 17 décembre 1999

L'INSTALLATION NEUTRINOS DU CERN VERS LE GRAN SASSO (CNGS)

Le présent document décrit l'installation "Neutrinos du CERN vers le Gran Sasso" (CNGS) qui a fait l'objet de discussions au Comité des directives scientifiques et au Comité du Conseil de puis mai 1999. Les deux comités appuie la présente proposition.

Le Conseil est invité à approuver :

a) la *construction du CNGS,* décrit dans le présent document, et son *intégration dans le programme de base* de l'Organisation, en adoptant le projet de résolution joint en *annexe VI;*

en application de l'article II. 5-6 de la Convention du CERN, cette décision doit être prise à la majorité des deux tiers de tous les Etats membres;

b) le *projet de convention entre le CERN et l'INFN concernant l'installation Neutrinos du CERN vers le Gran Sasso (CNGS) (annexe III);*

en application de l'article VIII de la Convention du CERN, cette décision doit être prise à la majorité des deux tiers de tous les Etats membres.

L'INSTALLATION NEUTRINOS DU CERN VERS LE GRAN SASSO (CNGS)

I. LE PROJET CNGS ET LA COOPERATION CERN-INFN

1. Lors de leurs réunions respectives, les 14 et 17 juin 1999, le Comité des directives scientifiques et le Comité du Conseil ont examiné une proposition du Directeur général concernant la réalisation au CERN d'un projet appelé "L'installation Neutrinos du CERN vers le Gran Sasso (CNGS)" dont il a été admis qu'il permettrait une riche et prometteuse activité scientifique. Tant le Comité des directives scientifiques (CERN/SPC/767) que le Comité du Conseil (CERN/CC/2290) ont appuyé cette proposition.

2. Cet appui a été confirmé par le Comité du Conseil à sa réunion du 22 septembre 1999 (CERN/CC/2294).

Le projet

3. Il s'agirait de construire au CERN une source de faisceaux de neutrinos pointés vers le Laboratoire du Gran Sasso où des détecteurs appropriés seraient construits par des collaborations internationales pour l'étude des oscillations neutrino. Au départ, le programme serait axé sur l'expérience d'apparition du ν_τ . Le projet a été décrit pour la première fois dans le document CERN /SPC/765-CERN/CC/2278, en date du 27 mai 1999, et est défini dans le présent document.

4. Le projet de construction est présenté dans l'*annexe I*. Depuis mai 1999, l'optimisation des caractéristiques de la source de neutrinos s'est poursuivie et deux expériences, ICANOE et OPERA, sont prévues et maintenant bien définies. Leur état d'avancement actuel est décrit dans l'*annexe II*.

La coopération CERN-INFN

5. La cohérence du programme d'expérimentation repose sur la coopération entre le CERN et l'Istituto Nazionale di Fisica Nucleare (INFN, Italie). Le CERN construirait la source de neutrinos sur son domaine, tandis que les "Laboratori Nazionali del Gran Sasso" abriteraient les détecteurs et fourniraient l'infrastructure nécessaire à l'exploitation de la source et à la réalisation des expériences.

6. Le partage des tâches entre le CERN et l'INFN pour la mise en œuvre du programme d'expériences serait déterminé par une *Convention* entre le CERN et l'INFN définissant leurs droits et obligations respectifs. Le projet de Convention est présenté dans l'*annexe III* et son contenu est examiné dans la section III ci-dessous.

7. L'INFN a officiellement donné son assentiment à cette coopération en acceptant le projet de convention entre le CERN et l'INFN, comme le manifeste l'*annexe IV*.

Propositions au Conseil

8. Pour ce qui est du CERN, le projet est maintenant soumis au Conseil. Deux aspects principaux doivent être considérés: une proposition portant sur la *réalisation* de la source de neutrinos (CNGS) dans le cadre du programme du CERN et la *Convention* entre le CERN et l'INFN relative à leur coopération pour la mise en œuvre du programme d'expérimentation correspondant.

II. REALISATION DE LA SOURCE DE NEUTRINOS AU CERN

9. Comme indiqué au paragraphe 5, il incombera au CERN de construire la source du faisceau de neutrinos sur son domaine.

Le CNGS au sein du Programme de base

10. Conformément à l'avis exprimé par le Comité du Conseil le 22 septembre 1999, le CNGS serait réalisé en tant que projet spécifique du CERN dans le cadre du programme de base de l'Organisation, qui comprend actuellement le PS, le SPS, le LEP et le LHC.

11. Plus précisément, le CNGS, en tant qu'activité nouvelle et de relativement faible ampleur, serait intégré dans le programme avec cibles fixes du CERN, lequel fait partie intégrante du programme de base.

12. L'intégration du CNGS dans le programme de base permettrait d'utiliser les structures existantes, d'éviter des tâches superflues, d'alléger la gestion et de réaliser des économies non négligeables. Une totale transparence de toutes les ressources consacrées au projet serait ainsi assurée.

13. La présente proposition s'appuie sur les précédents du LEP II et du LEP 2000, qui ont été réalisés dans le cadre du programme de base et dans l'enveloppe budgétaire de l'Organisation.

Coût du CNGS

14. Les équipements et investissements existants pour le LHC représentent une valeur estimée à 22 MCHF pour le CNGS. Le coût différentiel est estimé à 71 MCHF. Le coût annuel de la construction serait inclus dans les chapitres budgétaires annuels pertinents.

15. Le coût différentiel de l'exploitation du CNGS est estimé à 1,6 MCHF.

Contributions des Etats membres et d'Etats non-membres

16. Comme dans le cas du LEP II et du LEP 2000, le projet serait financé principalement par les contributions volontaires en espèces et/ou en nature d'Etats membres. Quelques-uns d'entre eux ont indiqué qu'ils étaient disposés à participer au financement: Allemagne, Belgique, Espagne, France et Italie. D'autres Etats membres sont invités à les rejoindre. En outre la "Compagnia di San Paolo" contribuera également au projet.

17. Les contributions volontaires suivantes ont été annoncées:

- Allemagne:	5 MCHF[a]
- Belgique:	1 MCHF
- Espagne:	4 MCHF
- France:	1 MCHF[b]
- Italie:	47 MCHF[c]
- Compagnia di San Paolo :	1,6 MCHF

18. Des contributions d'Etats non-membres seraient bienvenues et déterminées au cas par cas.

19. En cas de besoin, le solde du financement nécessaire serait imputé sur le budget du programme avec cibles fixes du CERN.

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[a] en collaboration via DESY

[b] plus une contribution, à chiffrer, à la construction de cerains éléments, en collaboration via CEA, IN2P3

[c] en collaboration via INFN

Durée et étapes

20. La réalisation du projet commencerait le 1er janvier 2000 et prendrait fin avec l'achèvement de la construction du CNGS en mai 2005, selon les prévisions.

21. Une série d'échéances est présentée à l'*annexe V*.

Approbation et procédure

22. L'intégration du CNGS dans le programme de base nécessite une modification de ce programme, comme dans le cas du LEP et du LHC. En application de l'article II. 5-6 de la Convention du CERN, la décision doit être prise par le Conseil et, selon la pratique de l'Organisation, sous la forme d'une résolution dont un projet figure à l'*annexe VI*.

23. Le CNGS serait inclus dans le plan à moyen terme (MTP) pour les années 2000-2004 qui sera soumis au Conseil en juin 2000.

24. Le budget du CERN pour 2000 serait également modifié en conséquence, après son approbation par le Conseil (voir *annexe I*, tableau 8). La décision pourrait être prise dans le cadre du pouvoir que donne chaque année le Conseil au Comité des finances d'approuver le budget indexé, en mars de l'année suivante.

III. Le projet de convention CERN-INFN

25. Comme indiqué précédemment (paragraphes 5, 6 et 7), la réalisation du CNGS suppose une coopération entre le CERN et l'INFN régie par une convention, dont le projet est joint en *annexe III*.

26. Le projet de convention définit les buts de la coopération et les obligations de chaque Partie, crée un comité de coordination bilatérale et prévoit le choix des expériences et le partages des dépenses. Il fixe une période de validité de dix ans, assortie de la possibilité pour les Parties de la prolonger ou de l'abréger. Le projet de convention souligne aussi que l'exploitation scientifique et la réalisation des expériences obéiront au principe du libre accès pour les physiciens, conformément aux directives du Comité international pour les futurs accélérateurs (ICFA).

27. L'INFN a donné son assentiment à ce projet de convention, comme indiqué dans l'*annexe IV*. Pour ce qui est du CERN, il appartient maintenant au Conseil de l'examiner et le Directeur général en recommande l'approbation.

IV. CONCLUSION

Le Conseil est invité à approuver:

c) la *construction du CNGS*, décrit dans le présent document, et son *intégration dans le programme de base* de l'Organisation, en adoptant le projet de résolution joint en *annexe VI);*

en application de l'article II. 5-6 de la Convention du CERN, cette décision doit être prise à la majorité des deux tiers de tous les Etats membres;

d) le *projet de convention entre le CERN et l'INFN concernant l'installation Neutrinos du CERN vers le Gran Sasso (CNGS) (annexe III);*

en application de l'article VIII de la Convention du CERN, cette décision doit être prise à la majorité des deux tiers de tous les Etats membres.

CERN/2300
ANNEX I

CNGS CONSTRUCTION PROJECT

1 Introduction

This Annex describes the conceptual design of the CERN Neutrino to Gran Sasso Facility (CNGS) to be constructed at CERN. Performance estimates are given and the operation of the facility is described with particular attention to the constraints imposed by the operation of LHC which has priority. It is shown that the operation mode proposed provides sufficient protons for a possible fixed-target programme in addition to CNGS.

The construction would comprise a new tunnel branching off from the beam transfer tunnel linking the CERN Proton Super Synchrotron (SPS) with the Large Hadron Collider (LHC). The latter transfer tunnel is under construction. The new tunnel of about 1.5 km length would point towards the Gran Sasso Laboratory (LNGS) of the National Institute for Nuclear Physics (INFN) in Italy.

The tunnel would be equipped for the transport of a high energy proton beam from the SPS to a target where secondary particles are produced which eventually decay in flight into the neutrinos. In order to reduce particle losses and to improve the resulting neutrino beam, the elements focusing the secondary beam after the target are followed by an 1 km long evacuated steel decay tube.

The remaining secondary particles which have not decayed in this tube are stopped after it by a beam dump. Only higher energy muons and the very weakly interacting neutrinos can traverse the beam dump. Two stations monitoring the beam through the muon flux are foreseen after the beam dump which can be accessed from the LHC tunnel. The beam then continues through the earth towards Gran Sasso about 730 km away resulting in a pure neutrino beam after a few kilometers when also the muons have been absorbed completely. Since the beam will have a width of about two kilometers at Gran Sasso, aiming the beam at the detectors in Gran Sasso is rather easy.

The project includes the construction of a civil engineering shaft to decouple CNGS from the LHC project and of auxiliary tunnels with the appropriate infrastructure. Apart from the proton beam line to the target, CERN has to construct the target, the elements focusing the secondary beam, and the monitoring and control equipment. A maximum of components of the West Area Neutrino Beam (WANF) will be used in order to reduce cost.

The technical services will be provided from the existing auxiliary buildings at point 4 of the SPS in France. The only civil engineering work on the surface will concern the civil engineering shaft next to point 4 of the SPS. The shaft and all teh tunnels in France will be on land already leased by France to CERN. The shaft will be covered once the civil engineering is terminated.

A more detailed outline of the layout of this new Facility facility is given under point 2 of this report and further details can be found in reference [1]. The layout is the same as described in an earlier document submitted in June 1999 to SPC and CC (ref. [2]).

The performance of this new facility and how it will be integrated in the LHC and SPS operation is described under point 3. The work by the CNGS CERN-INFN Technical Committee has lead to improved performance figures so that the relevant neutrino flux at Gran Sasso is now 3 times higher than estimated in the initial report (ref. [1]). Further details concerning operation and performance can be found in ref. [3].

Radiological aspects are treated in point 4. A more detailed report on these issues is in preparation in view of the authorisation procedures in the Host States.

The schedule of construction is given in point 5 of this Annex. In order to complete construction and commissioning in May 2005, it is imperative to adjudicate the civil engineering contracts in the Finance Committee in June 2000, which implies that the call for tenders can be issued at the beginning of January 2000.

The estimate of the marginal cost for construction is presented in point 6 of this Annex. The estimates are based on offers obtained for LHC construction which provides the most reliable basis. The marginal cost of operation is also given; it will covered by the budget line foreseen for the Fixed-Target Programme of CERN.

The required manpower for construction and operation is also given under point 6. It will be covered from the complement foreseen for the CERN Fixed-Target Programme.

Discussions are going on concerning voluntary in-kind contributions by the Member States. The result of these discussions may influence the cost estimates and the man power requirements. The CERN Council will be kept informed about all significant changes.

2 Overview of the New Facility

2.1 Layout of the CNGS

Accelerator driven neutrino beams are generated from the decay of mesons, mostly π and K,

$$\begin{aligned}\pi^{+(-)} &\rightarrow \mu^{+(-)} + \nu_\mu(\overline{\nu}_\mu)\\ \mathrm{K}^{+(-)} &\rightarrow \mu^{+(-)} + \nu_\mu(\overline{\nu}_\mu).\end{aligned}$$

These mesons are produced from a high-energy, high-intensity proton beam hitting a suitable target. The main ingredients of the proposed CNGS are shown schematically in Fig. 1 and listed below. The layout is shown in Fig. 2 and Fig. 3.

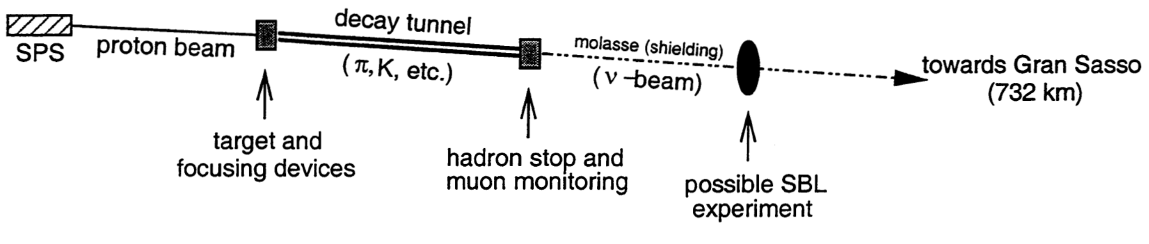

Figure 1: *Schematic layout of the new CERN neutrino facility.*

- A proton beam with an energy up to 450 GeV (400 GeV nominal) extracted from the CERN SPS accelerator, transported and focused onto a small spot at the target.

- A target station consisting of a segmented graphite target, in which the secondary particles, π and K, *etc.*, are produced.
- A two-stage focusing system, horn and reflector, which focuses a range of chosen π and K momenta into a parallel beam, pointing towards the Gran Sasso Laboratory.
- A 1000 m long decay tunnel, which allows a fraction of the π, K to decay in flight, producing a high-intensity ν_μ beam.
- A hadron stop, which absorbs the non-interacting primary protons as well as those secondary hadrons which have not decayed.
- A muon monitoring system, permitting on-line monitoring, tuning and control of the beam and its alignment.
- The natural shielding provided by a long stretch of molasse (about 730 m) to absorb the muons from hadron decay upstream of the SBL detector.

The different components of the neutrino beam are briefly described in the following sections.

2.2 Implementation at and around CERN

The geographical layout of the CNGS facility is shown in Fig. 2 and Fig. 3. The guiding principles for the implementation are the following:

- There should be no additional, permanent surface buildings other than for the possible future SBL experimental area. This leads to the need for an 800 m long access tunnel from point 4 of the SPS to the CNGS target cavern.
- The LHC project should not be hampered by the CNGS implementation — a separate neutrino civil engineering shaft (PGCN) near point 4 of the SPS is thus required. This will be a temporary shaft to be closed once the construction is completed.
- The target cavern should be large enough to allow the possible installation, after a first generation of experiments, of a new target and/or a different focusing system, *e.g.* for a low-energy or a narrow-band neutrino beam.
- In order to protect equipment and to provide acceptable working conditions, a service gallery parallel to the target cavern, an enlargement of the cavern around the target and a well shielded radioactive storage are foreseen.
- Access to two muon monitoring stations downstream of the hadron stop should be from the LEP/LHC tunnel.
- The minimal distance between the LEP/LHC tunnel and any other civil engineering should be about 10 m, to avoid disturbances to LEP/LHC.

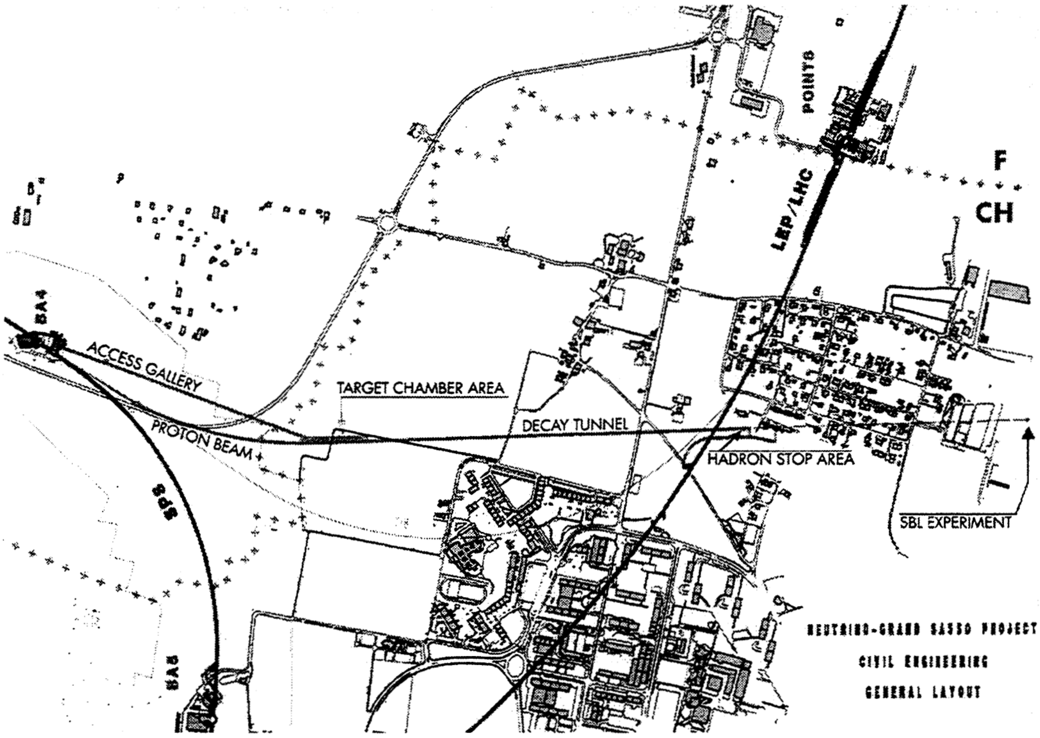

Figure 2: *Layout of the CNGS at and around CERN.*

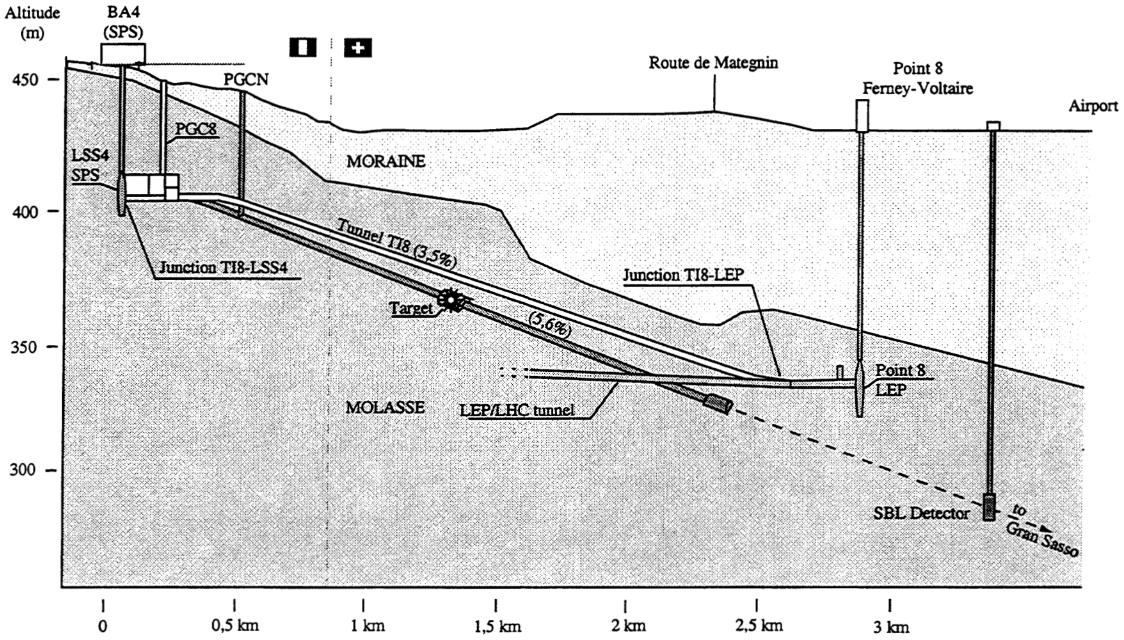

Figure 3: *Vertical cut showing the SPS and the main components of the CNGS.*

2.3 Proton Extraction from the SPS

The SPS accelerator is gradually being upgraded and modified for its new role as the LHC injector after the end of LEP operation, while continuing to deliver protons and ions for fixed target physics. For the purpose of the CNGS, it is important that one of the extractions from the SPS towards the LHC, from LSS4, points roughly in a southern direction. It was therefore envisaged, already in earlier reports, to provide protons for a neutrino beam towards Gran Sasso. The extraction system foreseen for the LHC allows fast-extracted pulses (up to 20 μs) to be sent to the TI8 transfer line towards the LHC. With some modifications to allow two fast extractions per cycle, this system can also be used to extract protons on to the CNGS target. The nominal cycle provides 4.5×10^{19} protons/year on target.

Note that the layout of the LSS4 extraction is designed such that it would in principle, though at substantial extra cost and only during a long shutdown of the SPS, allow the installation of a 'fast-slow' (resonant) extraction system, similar to the one used for the WANF (West Area Neutrino Facility). Such an extraction system would allow to increase the duration of the extracted beam spill from 10 μs to some milliseconds, thus lowering the thermo-mechanical stresses induced by the beam in the target. Potentially, this 'fast-slow' extraction could therefore allow much higher beam intensities without changes to the target technology.

2.4 Transport of the Primary Protons

The total length of the proton beam line from the SPS to the CNGS target is 830 m, and its maximum design momentum is 450 GeV/c, which is the maximum the SPS can provide. The beam branches off the TI8 beam after 110 m. The necessary deflection (horizontal and vertical) to reach the direction towards Gran Sasso is achieved by 73 conventional bending magnets.

2.5 Production Target

The target foreseen for the CNGS is based on the successful design of the T9 target in the present WANF. In a cast aluminum target container 13 rods of graphite, 10 cm long and 4 mm diameter each, form a 2 m long target array. The rods are cooled by a forced helium flow. The change from a beryllium target in the WANF to a graphite target has been mainly motivated by the change from fast-slow (6 ms) to fast (10 μs) proton beam extraction and by the better thermomechanical properties expected of graphite.

2.6 Secondary Particle Focusing System

The WANF experience is the origin of the choice for the focusing elements, namely horn and reflector which are two coaxial lenses, similar in shape but different in size. Their characteristics are not very different from those used in the WANF. The distances of horn and reflector from the target and the shape of the magnetic field provided by them are chosen to optimise a wide-band medium-energy ν_μ beam for ν_τ appearance.

2.7 Decay Tunnel

In order to obtain a neutrino beam pointing towards Gran Sasso, the parent hadrons have to decay in flight while travelling in that direction. To avoid that they interact before they can decay, an evacuated decay path is necessary. Typical π decay lengths, 2.2 km at 40 GeV, imply that a long decay pipe is desirable; given the angular distribution of the parent hadrons which can produce neutrinos, a longer decay tunnel should also have a bigger diameter. For the CNGS, a pipe of 2.45 m diameter and 1000 m length has been chosen.

2.8 Hadron Absorber and Muon Shield

At the exit of the decay tunnel, a massive iron beam dump is needed to absorb the non-interacting primary protons as well as all secondary hadrons.

It is foreseen to build a $18 \times 4 \times 4\,\mathrm{m}^3$ dump, assembled from iron blocks which can be recuperated from the WANF. A 3 m long graphite insert at the upstream end provides a better distribution of the deposited heat. Under the most extreme assumptions (dedicated operation of the SPS at 450 GeV with 4.8×10^{13} protons on target every 6 s), a heat dissipation of about 50 kW has been estimated. A modest cooling system is thus sufficient to assure stable and relatively low temperatures in the hadron stop cavern.

2.9 Muon Monitoring Station

Most of the hadron decays produce a neutrino and a muon. Measuring the muon intensity and profile provides information on the intensity and profile of the neutrino beam. Measuring the muon signals induced in a set of thin silicon detectors allows an 'on-line' monitoring and tuning of the beam (steering of the proton beam on target, horn and reflector alignment, *etc.*).

The muon monitoring system consists of two arrays of silicon detectors measuring the intensity and profile of the muon flux penetrating (a) the hadron stop and (b) the hadron stop plus a 67 m thick region of molasse. The separation of the two planes, equivalent to 25 m of iron, allows a rough measurement of the muon energy spectrum. Moreover, some angular information on the beam is also available by using the information from the two measurement planes.

3 Performance

3.1 Proton beam

In order to explore the full potential of the CNGS long-baseline experiments, a maximum number of protons on CNGS target (pot) per year is required. The SPS limitations and CNGS target constraints have to be taken into account. For a realistic scenario of SPS operation, the impact from LHC operation as well as the requests for slow extracted (SE) beam for the fixed-target physics community and test beam users have to be anticipated.

The boundary conditions for SPS running were carefully studied. After publication of the CNGS report [1], it was found that the RF acceleration programme could be shortened by 0.2 s. This allows to reduce the length of CNGS cycles with two fast extractions at 400 GeV/c from

6.2 to 6.0 s. The gain for CNGS is much more striking: a rhythm of 1.2 s is imposed by the PS injector complex, hence the SPS cycle time for CNGS is reduced from 7.2 s [1] to 6.0 s. This has a considerable impact on the pot/year for CNGS.

Since the energy of the proton beam for the slow extraction users is to be restricted to 400 GeV/c in the future for budgetary reasons, the power dissipation in the SPS magnets is no longer a relevant limitation and longer supercycles leading to larger numbers of pot/year for CNGS can be envisaged. On the other hand, the running-in and operation of the LHC will have an impact on the SPS availability for CNGS and other fixed target users. Taking all these factors into account, the expected number of protons on the CNGS target is

$$4.5 \times 10^{19}\ \text{pot/year}$$

when operating in parallel with LHC. In order to provide an idea of the reduction in performance by sharing time with LHC and protons with other fixed-target users, this number is compared with the upper limit, namely the performance in dedicated operation for CNGS which would provide 7.6×10^{19} pot/year assuming 200 days of operation per year. This indicates a significant but unavoidable loss (40 %) due to sharing. Details are described in the following sections.

3.1.1 SPS operation in the past years

The length of typical SPS runs, the maximum intensity achieved per cycle as well as the overall efficiency (protons delivered on target vs. protons expected) is well documented. For the year 1997, for example, there was a peak intensity of 4.8×10^{13} per cycle, and for a scheduled run of 137 days of proton running a total number of 2.2×10^{19} protons on target, implying that an efficiency of 55% has been achieved. This efficiency includes downtimes as well as non-optimal operation periods of the machines in the proton acceleration chain at CERN.

Therefore, it is considered realistic to assume future SPS running with the already achieved performances, i.e. peak intensity of 4.8×10^{13} protons per cycle with an overall efficiency of 55%.

3.1.2 Operation modes of the SPS

When LHC is filled and the beams are coasting, the SPS is available for fixed-target physics. Two modes are possible: i) the shared mode where CNGS and other fixed-target users get protons from different cycles within one supercycle; ii) the dedicated mode where CNGS gets all the protons.

Once LHC is getting towards the end of a coast which is estimated to last about ten hours, the injector chain and the transfer lines are being set up with low-intensity pilot beams, which may take hours, in particular in the first years of LHC operation. In order not to disrupt completely CNGS operation, it is proposed to interleave the LHC pilot cycle with CNGS cycles in one supercycle. When it comes to the actual filling of LHC, the injector chain is fully dedicated to LHC and both rings are filled in 8 min in total.

Further examination may reveal that switching from the interleaved supercycle to the dedicated LHC cycle does not provide the required reproducibility, and that it might be better to work always with a supercycle comprising the LHC fill cycle plus the CNGS cycles. This would lengthen the LHC fill by about a factor two but would provide very stable conditions.

Since the real filling of LHC takes only a few times a quarter of an hour or less per day its impact on CNGS is negligible, independent of the choice of the supercycle for the LHC fill. Also the choice of the interleaved supercycle for the pilot pulses has little effect on CNGS - both of these supercycles provide nearly the same average proton current to CNGS. Hence, no immediate decision has to be taken, leaving time for a thorough study of the two alternatives. In all cases, it is indispensable that the SPS control system be modified allowing for rapid and reproducible switching between supercycles. It is planned to implement this feature by 2003 for the first LHC injection tests. The PS complex was upgraded in this respect a few years ago.

In order to make an estimate of the expected pot/year for CNGS, assumptions on the SPS supercycles have to be made and a scenario of a possible symbiosis between LHC operation and SPS fixed-target physics has to be conceived.

For comparison of the average proton current provided by these various cycles, the number of protons on target is given which would be obtained if one used the considered cycle exclusively for 200 days. This number of days is chosen as it is close to the scheduled duration of the physics runs with protons and ions in the last ten years (as a matter of fact, about 190 days were often reached with a record of 217 days in 1998).

Protons are injected into the SPS from the PS, operating at a cycle time of 1.2 s. Therefore, SPS operation has to follow this 'clock', i.e. any SPS supercycle has to be a multiple of 1.2 s. Typically, two PS injections per SPS cycle are used (as is the case in the present SPS operation for fixed target proton physics). This is the basis for all the supercycles presented below.

Injecting three pulses from the PS and extracting three pulses for CNGS would increase the average proton current per CNGS cycle by only 25%. The target limit which is around 2.4×10^{13} protons per pulse would be respected. However, the presently known beam stability limits in the SPS would be exceeded resulting in intolerable beam loss and low transmission. Furthermore, the injection of three pulses has been tried out in machine development runs without positive results. Further studies are needed to understand these limitations. For all these reasons, only the injection of two PS pulses is considered further.

Expected protons on target in shared operation

While the beams are coasting in LHC, various scenarios can be imagined for an SPS operation serving CNGS as well as other users who are typically requiring a slow extracted beam on target. It can be anticipated that a certain amount of test beam time will be required in 2005 and beyond, particularly by the LHC experiments, but also for R&D or fixed target experiments. For budgetary reasons, the present policy of CERN foresees to run the SPS at 400 GeV/c (or lower) from 2002 onwards. This is taken as a basis assumption for the following considerations. It has been shown that this allows various SPS supercycles with 2, 3 or 4 CNGS cycles, all of which respect the power dissipation limits given for the SPS magnets. Table 1 gives a (non-exhaustive) list of possible SPS supercycles for shared operation between CNGS and users of slow-extracted (SE) beams.

As an example, the supercycle with 27.6 s duration (cf. Fig. 4) is considered to be the nominal one throughout this report. It provides a relatively high average proton current for CNGS leading to 5×10^{19} pot/year with a reasonable length of the supercycle and a duty cycle of the slow extraction of 13% (to be compared to 16% in present operation and for the nominal shared supercycle assumed in ref. [1]).

Table 1: *SPS shared operation, assuming 400 GeV/c pot for all users.*

Number of CNGS cycles per supercycle	supercycle T_{sc} [s]	slow extraction T_{FT} [s]	CNGS pot/year [10^{19} / 200 d]
2	21.6	3.5	4.22
2	22.8	4.7	4.00
3	27.6	3.5	4.96
3	28.8	4.7	4.75
4	33.6	3.5	5.43
4	34.8	4.7	5.24

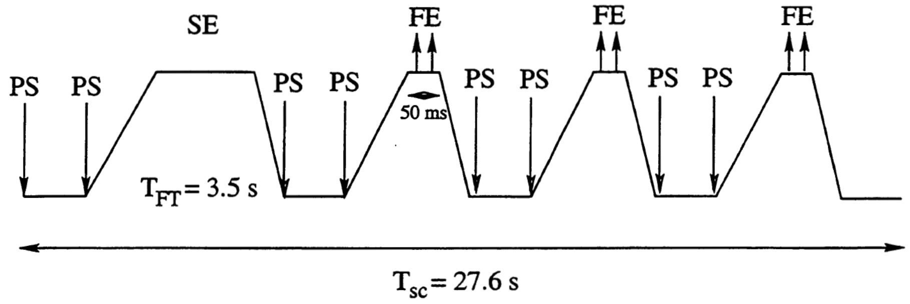

Figure 4: *Schematic view of a possible SPS supercycle for shared operation. A 3.5 s flat-top for slow extraction (SE) at 400 GeV/c is followed by three CNGS cycles, also at 400 GeV/c.*

Expected protons on target in dedicated operation

A close look at the time needed for an CNGS cycle with two fast extractions at 400 GeV/c shows that 6.0 s are sufficient. With this shortened cycle time (cf. Fig. 5), and using the SPS intensity per cycle and efficiency as mentioned above, one finds that 7.6×10^{19} pot/year can be achieved for CNGS in 200 days of dedicated operation. This gives the upper performance limit.

Supercycle with interleaved LHC pilot cycle and CNGS cycles

A low-intensity pilot beam consisting of only one bunch will be used for setting-up the injector chain of LHC, the transfer lines, injection into LHC, and the energy ramping in LHC. Fig. 6 shows an example of such a cycle combined with 2 cycles for CNGS.

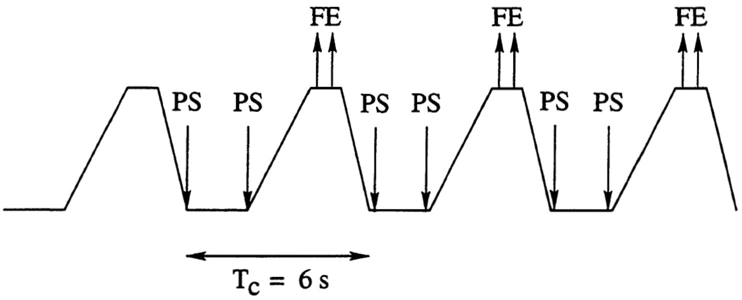

Figure 5: *Schematic view of SPS cycles for dedicated CNGS running at 400 GeV/c.*

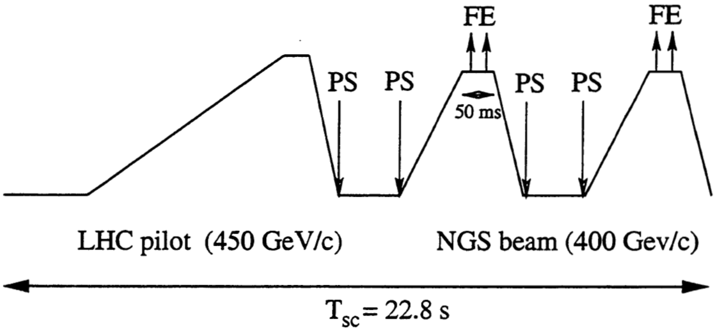

Figure 6: *Schematic view of a possible SPS supercycle with interleaved LHC pilot cycle at 450 GeV/c and CNGS cycles at 400 GeV/c.*

Supercycle with interleaved LHC cycle and CNGS cycles

Once all the adjustments for LHC are made using the supercycle with the pilot cycle, LHC can be filled with a dedicated cycle within somewhat less than 4 min for each of the counter-rotating beams. However, this introduces the risk that the settings are influenced by this change in supercycle and that the injected beam does not fulfill the stringent requirements of LHC, though filling is very rapid and the risk of drifts, especially due the persistent currents in the LHC superconducting magnets, is minimized.

Another strategy would be to use the same supercycle for the pilot beams and the LHC filling. An example of such a supercycle is shown in Fig. 7 below. The drawback of this supercycle is its length making observations and tuning a bit more tedious as well as doubling the actual filling time of LHC. However, it provides maximum reproducibility between setting-up with pilot beams and filling. There is no strong reason for choosing three CNGS cycles, eventually two or four CNGS cycles might be chosen.

3.1.3 Expected number of protons on target per year

Table 2 gives the average proton currents for CNGS for the four examples of supercycles expressed in terms of pot in 200 days.

In order to estimate the effective pot/year, a model of the operation of LHC from 2005 onwards is required. It seems to be appropriate to distinguish between the year 2005 where the

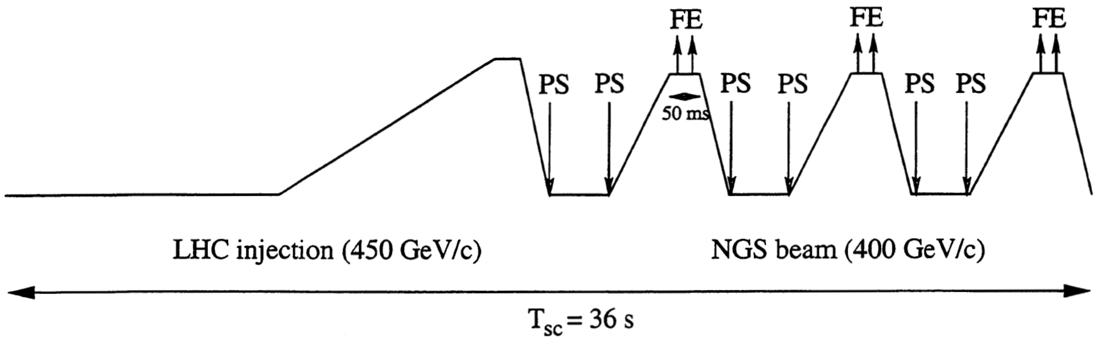

Figure 7: *Schematic view of a possible SPS supercycle with interleaved LHC filling cycle at 450 GeV/c and CNGS cycles at 400 GeV/c.*

Table 2: *Average proton current for CNGS.*

Supercycle	T_{sc} [s]	CNGS [10^{19} pot / 200 d]
Shared SE / CNGS	27.6	5.0
Dedicated CNGS	6.0	7.6
Interleaved LHC pilot / CNGS	22.8	4.1
Interleaved LHC fill / CNGS	36.0	3.9

running-in of LHC will start in July, and the following years when LHC is running though a considerable fraction of the time is still spent on improving its performance.

Operation in 2005

The following scenario is proposed as example assuming that LHC will be commissioned and have its first physics runs with protons in July to October:

March-April:	CNGS commissioning with shared SE/CNGS supercycle
May-June:	shared SE/CNGS
July-August:	50% LHC commissioning, 50% shared SE/CNGS
September-October:	for 3/4 of the week per day: 2 × 4 h interleaved LHC pilot/CNGS 16 h shared SE/CNGS for 1/4 of the week: LHC machine development with interleaved LHC/CNGS supercycles.
November:	50% LHC commissioning with ions, 50% shared SE/CNGS.

Note that the LHC filling is neglected since it takes each time only a small fraction of an hour. Also choosing the other interleaved supercycle (see 2.2.4) instead of the one described under 2.2.3 for the setting-up of LHC will not change the result as their average proton currents are virtually the same (cf. Table 2).

Table 3 gives the expected pot/year for CNGS and for the users of the slow-extraction (SE) for different possible schedules. The first line illustrates the impact of LHC which would reduce the pot/year to 72% of the value expected for shared operation without LHC. The other lines demonstrate that a number of scheduling options exist to nearly or completely reach the pot/year expected from unperturbed shared operation for 200 days. Thus, it seems reasonable to assume that 4.5×10^{19} pot can be achieved for the CNGS facility in 2005.

Table 3: *Expected pot/year in 2005 for CNGS and SE for various scheduling options.*

May-Oct.	Add Nov.	May/June no SE	July no SE	CNGS 10^{19} pot / year	SE 10^{19} pot / year
yes				3.6	1.5
yes	yes			4.0	1.6
yes		yes		4.4	1.0
yes	yes	yes		4.7	1.1
yes	yes	yes	yes	5.2	1.0

The total number of protons for SE was calculated assuming, as for CNGS, 4.8×10^{13} protons per SE cycle and an efficiency of 55%. The result is best put into perspective by comparing it with the requirements of COMPASS in phase I (0.4×10^{19} per year) and the present number of protons on target for detector tests in the North and West halls (0.14×10^{19} in 1998). Obviously, the approved phase I of COMPASS will be terminated by 2005 but comparison shows that there will be no lack of protons either for a possible phase II of COMPASS or other new fixed-target experiments.

Operation after 2005

A possible scenario is that LHC operates with protons in April to October with the same sharing between LHC, CNGS and SE as in September and October 2005. One may argue that the machine development time will decrease in later years leading to some increase of availability for CNGS. On the other hand, the steadily growing LHC luminosity will reduce the length of the LHC coast requiring more frequent LHC filling. To first order, the same conditions will prevail as in 2005.

Table 4 shows that a fairly good performance can be expected for the fixed-target programme. Two options are also shown to indicate the flexibility in the scheduling. The first option is to continue proton-fixed target operation in November using the time when LHC is filled with ions and the beams are coasting. It is assumed that 50% of the time is available for proton fixed-target operation and the SPS operates with the supercycle sharing protons between SE and CNGS (see 2.2.1). The other option shown in the third line assumes that for 40 days all the time when LHC has coasting proton beams is dedicated to CNGS.

Since our model of operation in the years after 2005 is rather crude and not all implications of the interleaved cycles for LHC performance have been studied thoroughly, it seems to be prudent to assume as nominal performance not being the maximum offered by the options but only 90% leading to 4.5×10^{19} pot/year for CNGS. Concerning the pot/year available for SE users, the same comments as for 2005 apply.

Table 4: *Expected pot/year after 2005 for CNGS and SE for various scheduling options.*

April-Oct.	Add Nov.	no SE for 40 d	CNGS 10^{19} pot/year	SE 10^{19} pot/year
yes			4.7	0.87
yes	yes		5.1	1.0
yes		yes	5.0	0.70

3.2 Neutrino beam

3.2.1 Introduction

The beam presented in the CNGS report [1] provided a stable framework on which to base the detailed studies of the civil engineering, infrastructure and radiological issues. The CNGS has to be considered as a long-term facility: choosing the parameters of a high energy, wide-band beam as a 'reference' ensured that a wide range of possible beam variants could be accomodated within the established civil engineering constraints. The high energy design was based on previous beams in the WANF and used similar material thicknesses and pulsed currents. The design was also significantly influenced by the requirements for a short-baseline facility.

The more specific design goal for the new beam, i.e. optimisation for long-baseline ν_τ appearance, has led to a revised beam optics layout to maximize the secondary beam acceptance in the desired momentum range. At the same time, modern construction methods for the magnetic horns will lead to much reduced material in the beam aperture.

3.2.2 Conditions for optimum ν_τ appearance

The criterion for ν_μ - ν_τ appearance experiments is the number of observable ν_τ charged current (CC) events. According to the latest results from the Super-Kamiokande experiment, the neutrino mass difference Δm^2 where such an oscillation is thought to occur is in the range of 10^{-3} to 10^{-2} eV^2 for full mixing. The rate of ν_τ CC events [1] from the ν_μ beam is given by:

$$R_\tau = A \int \phi_{\nu_\mu}(E) \times P_{osc}(E) \times \sigma_\tau(E) \times \epsilon(E) \times \mathrm{d}E$$

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[1] Note that, in general, we refer to CC events as the total probability for charged current interactions, i.e. the sum of deep inelastic, quasi elastic and resonance contributions.

where A is the number of nucleons in the effective detector mass, $\phi_{\nu_\mu}(E)$ is the ν_μ fluence at Gran Sasso, $\epsilon(E)$ represents the (detector-dependent) detection efficiency of the ν_τ events, $\sigma_\tau(E)$ is the ν_τ CC cross section and P_{osc}, the oscillation probability. For two flavour mixing, the latter can be expressed as

$$P_{osc} = \sin^2(2\theta) \times \sin^2(1.27 \times \Delta m^2 \times L \,/\, E).$$

Neglecting the detection efficiency $\epsilon(E)$, the neutrino spectrum $\phi_{\nu_\mu}(E)$ should match the product $P_{osc} \times \sigma_\tau(E)$. For the values Δm^2 of interest here the neutrino energy E at which this product has a maximum hardly depends on the neutrino mass difference.

Whilst the cross sections for ν_μ CC events compare well with experimental data at high energy, there is still a considerable uncertainty in the cross sections for ν_τ, in particular in the region near the τ production threshold. In the following evaluations of CC event rates, the cross section tables given on the CNGS WWW page [4] are used.

3.2.3 The new CNGS reference beam

Compared to the 1998 report [1], the civil engineering design of the CNGS facility remains unchanged. Optimizing the probability for ν_τ appearance at Gran Sasso implies maximizing the ν_μ fluence in the range of 10 to 30 GeV. The horn and the reflector are therefore designed to focus 35 GeV and 50 GeV secondary particles. In order to achieve a much higher acceptance at these energies, the two lenses are much closer to the target than in the 1998 beam. A schematic overview of the new CNGS reference beam for appearance experiments is shown in Fig. 8. Note that the target cavern is longer than required for the new beam, in view of a possible future installation of a higher energy or narrow-band neutrino beam.

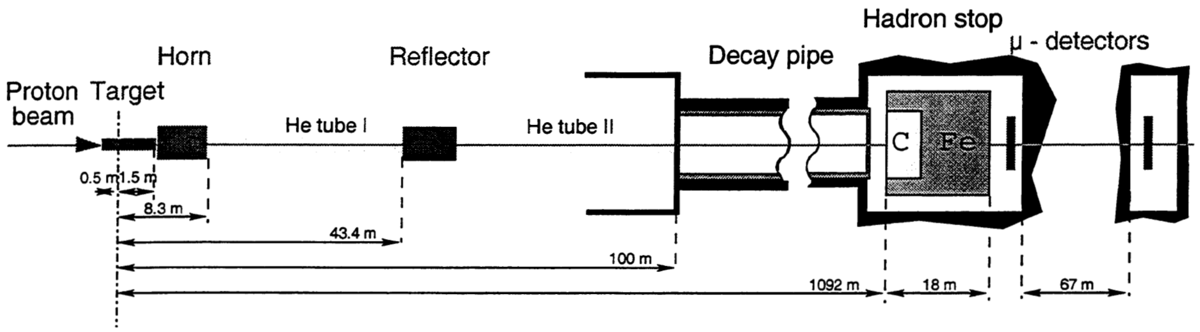

Figure 8: *Schematic overview showing the components of the new CNGS reference beam. The coordinate origin is the focus of the proton beam.*

In the compact new design the target box position and dimensions remain unchanged. Additional graphite rods are added, while keeping the overall target length at 2 m. The target rod diameter has been increased from 3 mm to 4 mm so that the proton beam is better contained within the target: this reduces spurious background from residual protons interacting later in the beam line, without significant change to the ν_μ flux and energy spectrum. The thermo-mechanical properties of the target rods under shock from the proton beam impact is slightly improved by the increased rod diameter.

The first coaxial lens, the horn, now starts at 1.7 m from the focal point of the system, just after the end of the target, and the reflector is also moved upstream, to 43.4 m. With these changes, and using a higher current in the horn and the reflector (150 kA instead of 120 kA), the nominal acceptance for pions and kaons between 20-50 GeV has been increased by 50%.

Prototype tests have demonstrated the feasibility of using electron beam welding to assemble the inner conductor elements, rather than the bolted flanges previously used. Many details of the horn and reflector construction have been re-examined. Apart from a small, local increase in the horn inner conductor thickness because of the higher current, the net result is a significant reduction of the total amount of material within the beam aperture.

Similarly to the 1998 design, helium tubes are foreseen in the free spaces of the target chamber in order to reduce the interaction probability for the secondary hadrons. In the new layout, a first He tube is located between the horn and reflector, while a second one fills the gap between the reflector and the decay tunnel.

In order to move the horn close to the target, the collimators installed after the target in the 1998 CNGS beam have been removed. A more general shielding around the target, horn and helium tubes is now used. An overview of the target cavern layout can be found in Fig. 9 with a more detailed view of the target/horn region shown in Fig. 10. The parameter list for the new CNGS reference beam is given in the Appendix.

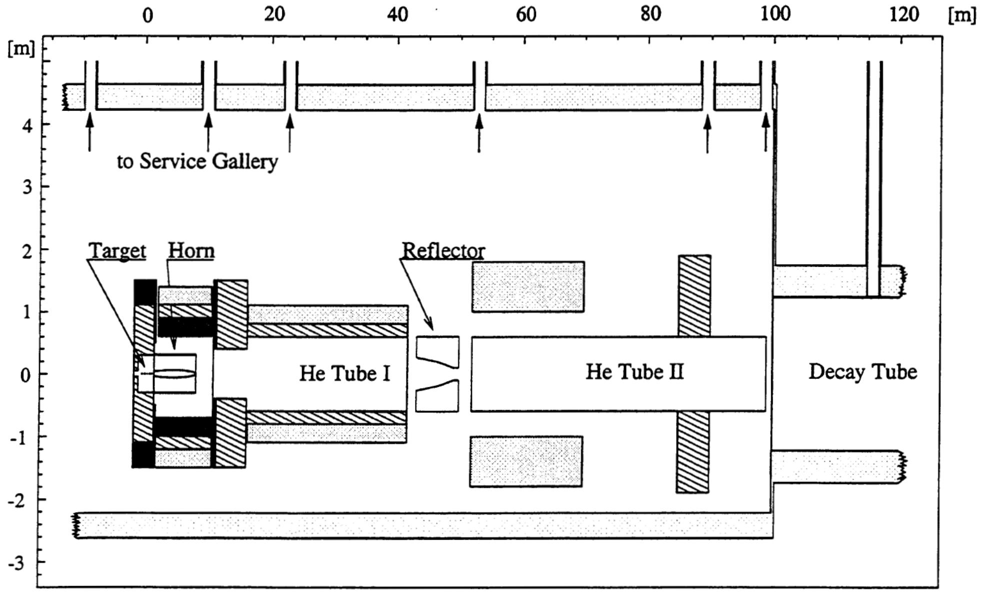

Figure 9: *The layout of the new CNGS reference beam. (Note that, in order to make the important items of the beam more visible, the scale on the two axes is very different).*

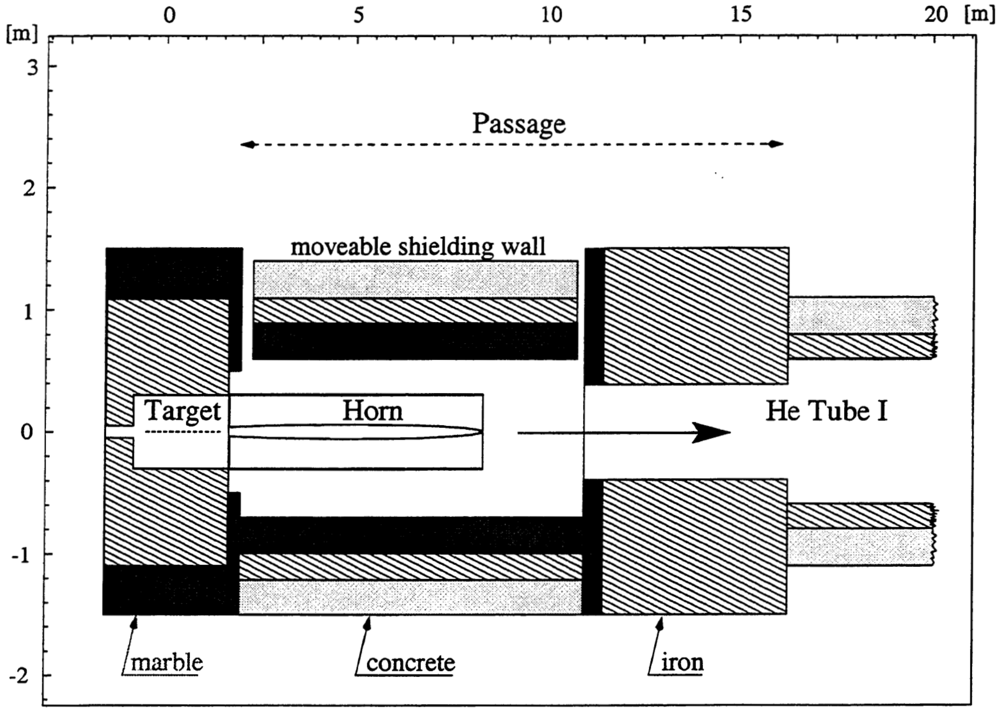

Figure 10: *Close-up on the region around target and horn.*

ν_μ Performance

Two independent simulations were performed for transport and decay of the secondary particles. In one approach, hadron spectra from the 400 GeV/c protons impinging on the graphite target are generated by the FLUKA98 programme, and GEANT3.21 is used for the transport and decay of the particles emerging from the target. The other approach is a FLUKA98 stand-alone simulation, starting from protons on target and ending with neutrinos at Gran-Sasso. There is good agreement between the two simulations.

The resulting CNGS beam performance for the new reference beam is summarized in Table 5. The values given for the ν_μ beam have been obtained by averaging over a hypothetical detector with radius 100 m at Gran Sasso[2]. In order to get reasonable statistical accuracy, this radius has been set to 400 m for ν_e, $\overline{\nu}_e$ and $\overline{\nu}_\mu$.

The expected numbers of detectable ν_τ for $sin^2 2\theta = 1$ and a few typical values of Δm^2 are shown in Table 6. When compared to the 1998 report [1], a substantial increase of about a factor of two in the expected ν_τ events per proton is found, This leads to an improved performance by a factor of three in ν_τ per kiloton and per year, taking into account that the estimated number of protons on target has increased from 3.0×10^{19} to 4.5×10^{19} per year.

The ν_μ fluence and expected CC event spectra at Gran Sasso are shown in Fig. 11. Fig. 12 shows a comparison with a hypothetical perfect beam of the same nominal acceptance: no

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[2] The neutrino beam size at Gran Sasso is 1.37 km (rms. radius of the ν_μ CC event distribution).

Table 5: *Predicted performance of the new CNGS reference beam. The statistical accuracy of the Monte-Carlo simulations is 1 % for the ν_μ component of the beam, somewhat larger for the other neutrino species.*

Energy region E_{ν_μ} [GeV]	1 - 30	1 - 100
ν_μ [m^{-2}/pot]	7.1×10^{-9}	7.45×10^{-9}
ν_μ CC events/pot/kt	4.70×10^{-17}	5.44×10^{-17}
$\langle E \rangle_{\nu_\mu \, fluence}$ [GeV]		17
fraction of other neutrino events:		
ν_e/ν_μ	0.8 %	
$\overline{\nu}_\mu/\nu_\mu$	2.0 %	
$\overline{\nu}_e/\nu_\mu$	0.05 %	

Table 6: *Expected number of ν_τ CC events at Gran Sasso per kt per year. Results of simulations for different values of Δm^2 and for $sin^2(2\theta) = 1$ are given for 4.5×10^{19} pot/year. These event numbers do not take detector efficiencies into account.*

Energy region E_{ν_τ} [GeV]	1 - 30	1 - 100
$\Delta m^2 = 1 \times 10^{-3}\,\mathrm{eV}^2$	2.34	2.48
$\Delta m^2 = 3 \times 10^{-3}\,\mathrm{eV}^2$	20.7	21.4
$\Delta m^2 = 5 \times 10^{-3}\,\mathrm{eV}^2$	55.9	57.7
$\Delta m^2 = 1 \times 10^{-2}\,\mathrm{eV}^2$	195	202

absorption, and parent particles of all energies focused parallel to the beam axis.

The appropriate matching of the new CNGS reference beam with the function $P_{osc}(E) \times \sigma_\tau(E)$ is demonstrated in Fig. 13. It should be pointed out that appearance experiments at Gran Sasso typically do not want the ν_μ spectrum to extend much beyond 30 GeV; as at higher energies, background channels open up which could be difficult to separate from the ν_τ events.

The more compact layout and larger angular acceptance for secondary particles from the target leads to a bigger diameter of the horn and reflector, thus to a beam with a larger diameter. It is therefore instructive to investigate the neutrino beam losses at Gran Sasso due to the limited diameter of the CNGS decay tunnel. For the new CNGS reference beam, the cumulative radial distribution of decaying hadrons which yield a neutrino at Gran Sasso is shown in Fig. 14. For completeness, the longitudinal distribution is also shown.

The fluence spectra for the beam contaminations in the new CNGS reference beam can be found on the CNGS WWW page [4], the fraction of background CC events (integrated up to 100 GeV/c) are given in Table 5.

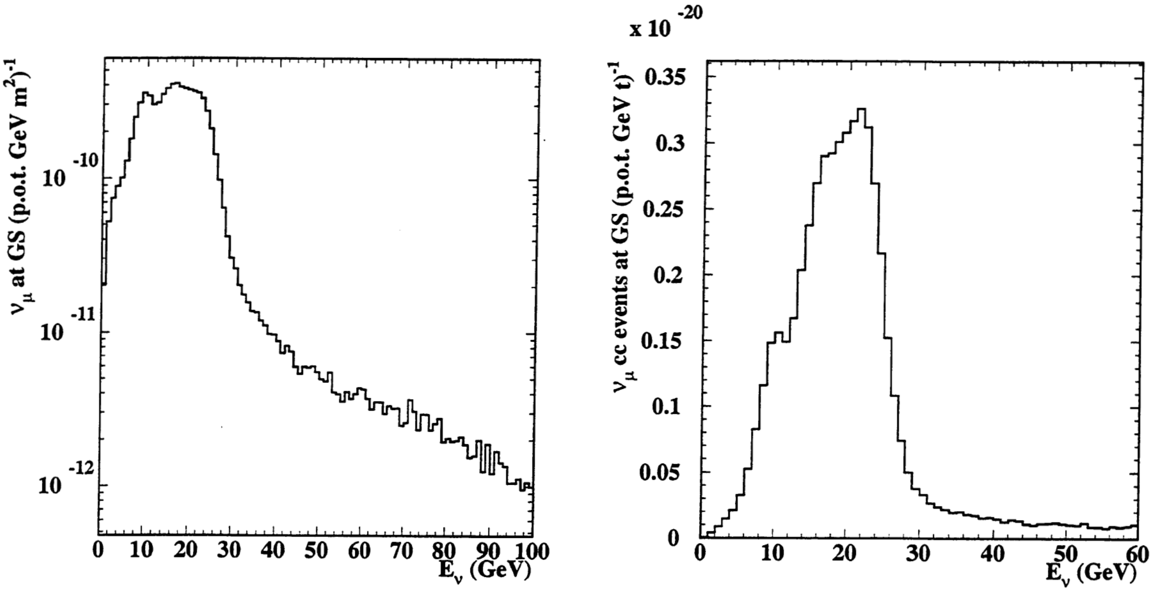

Figure 11: *Energy distribution of the ν_μ fluence (left) and of the CC ν_μ interactions (right) at Gran Sasso.*

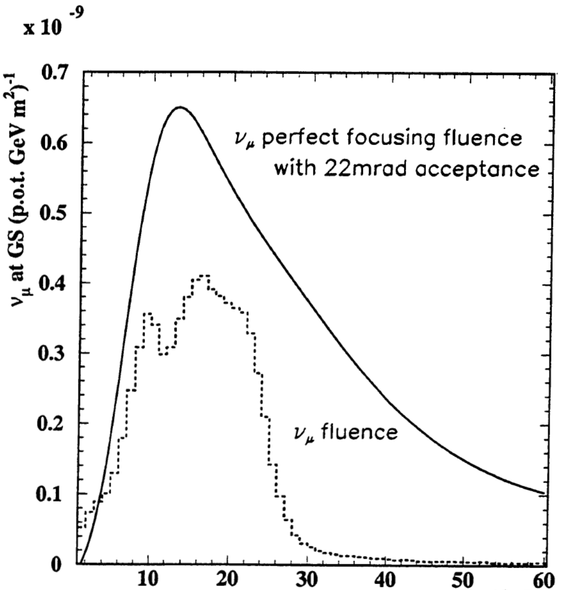

Figure 12: *Comparison of 'perfect focusing' with the ν_μ fluence at Gran Sasso.*

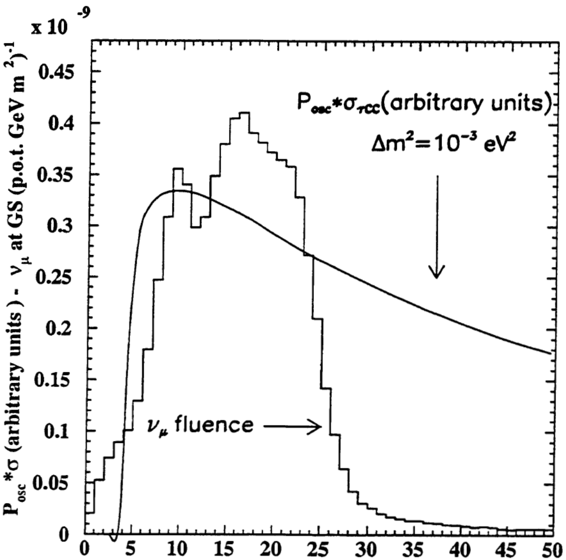

Figure 13: *ν_τ CC cross section times oscillation probability for small Δm^2 and full mixing, compared to the ν_μ fluence.*

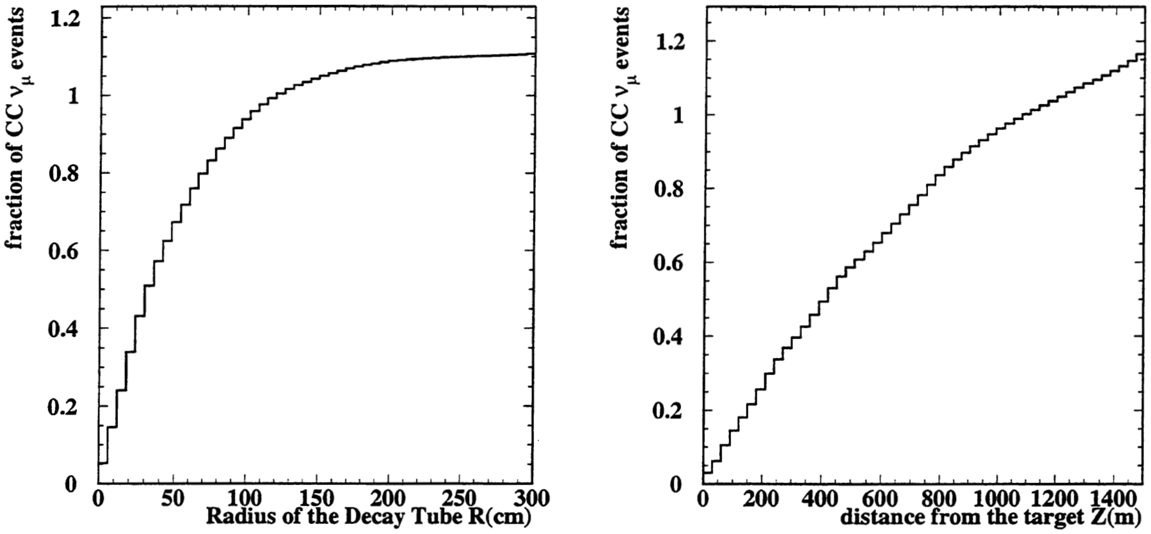

Figure 14: *Cumulative radial (left) and longitudinal (right) distribution of the decay points of parent hadrons which produce* ν_μ *events at Gran Sasso, normalised to the CNGS design values* $R = 122.5\,cm$ *and* $Z = 1100\,m$.

A possible $\overline{\nu}_\mu$ beam

Even though the first goal of CNGS is to perform a $\nu_\mu \rightarrow \nu_\tau$ appearance search, the availability of such a facility will offer other very interesting possibilities, for instance in the comparison between neutrino and antineutrino beams.

In the case of vacuum oscillations, the combined study of oscillations of neutrinos and antineutrinos could, in principle, allow the detection of possible CP violation effects in the neutrino sector ($P(\nu_\alpha \rightarrow \nu_\beta) \neq P(\overline{\nu}_\alpha \rightarrow \overline{\nu}_\beta)$). However, these effects are expected to be very small, vanishing in the limit when two neutrinos are degenerate in mass.

Larger differences in the oscillation probability could stem from a C violating effect due to the presence of matter. In that case ν_e's and $\overline{\nu}_e$'s behave differently because matter is not made of an equal amount of electrons and positrons. In matter, resonance effects can occur with neutrinos if the hierarchy is as expected ($m_{\nu_\mu} > m_{\nu_e}$). If it were the opposite, then resonance in matter could only occur with antineutrinos. Matter effects are advocated to be at work in the MSW mechanism as a possible explanation for the solar neutrino problem.

In the general case, in which all three neutrino families mix to some extent, the probabilities for ν's and $\overline{\nu}$'s oscillation will definitively differ because of matter effects. This difference is present even in the absence of CP–violating effects and could be detected at CNGS. The study of the difference between $P(\nu_\mu \rightarrow \nu_e)$ and $P(\overline{\nu}_\mu \rightarrow \overline{\nu}_e)$ oscillations would allow to gain additional information about the neutrino mass matrix and in particular it could solve the ambiguity on the sign of Δm.

For all the above reasons it is very important to compare the behaviour of neutrinos and antineutrinos. The use of neutrino and antineutrino beams can help in reducing the effect of the theoretical uncertainties (on the non–oscillated flux and on neutrino cross sections) in the determination of the oscillation parameters.

The currents in the CNGS horn and reflector can easily be inversed to focus the negatively charged parent mesons, and defocus the positive, so as to produce an $\overline{\nu}_\mu$ beam. The neutrino channel is favoured both in production and in interaction cross section at the detector. The $\overline{\nu}_\mu$ flux obtained is therefore some 75% of that in the ν_μ beam, and the CC event rate is about 35%: in a preliminary simulation, 200 $\overline{\nu}_\mu$ CC events per kiloton of detector and per 10^{19} pot have been obtained in the energy interval 0-100 GeV.

More significantly, the ν_μ and ν_e backgrounds in the $\overline{\nu}_\mu$ beam are a factor of 10 higher in the anti-neutrino beam than the equivalent backgrounds in the neutrino beam. It should be possible to reduce these backgrounds by some 30%, at the expense of a small loss in $\overline{\nu}_\mu$ flux, by installing an axial absorber after the target: parameters of such an absorber are under study.

4 Radiological Aspects

4.1 Introduction

The most important items in the present proposals for a neutrino beam to Gran Sasso from a radiological viewpoint are the target chamber, the decay tunnel and the hadron stop. Estimates must be made of possible dose rates to which maintenance personnel could be exposed, the total induced radioactivity in the structure and its surroundings and the magnitude of any release to the environment via air or water pathways. Some of these quantities of interest have been estimated from simulations of the cascades induced by the interactions of the primary protons from the SPS in the neutrino production target and the hadron stop.

Simulations of these cascades were carried out using the 1997 version of the Monte-Carlo cascade program FLUKA. Only a preliminary attempt has been made to optimise the design with respect to minimising the radiological quantities of interest. Thus the studies completed so far represent upper bounds of these quantities serving to show that the project is feasible without undue adverse effects on the environment.

4.2 Remanent Dose Rates due to Induced Radioactivity

The latest version of the present WANF has proved successful in keeping the doses to maintenance personnel to acceptable levels. It has been possible to make repairs to components in the vicinity of the target, horn and reflector. The design of the new facility allows for the increase in proton intensity by increasing the shielding around the target and collimators. Thus dose rates due to induced radioactivity should not increase over present levels in the WANF.

The situation in the new facility has been significantly improved by the provision of a service side-gallery which gives access to the target chamber without exposing people to the most radioactive items in the chamber. This allows necessary equipment to be installed close to the beam-line components and for this equipment to be maintained without radiation exposure. In addition, people making repairs to the beam-line components themselves can make their preparations in the service gallery and spend the minimum amount of time in the highest radiation environment. Such a side-gallery is a feature of both SPS target stations in the North Area.

They were included in these projects as a result of adverse criticism of the WANF Target Area design, where the civil engineering plans were completed at a very early stage in preparation for the SPS construction.

Another improvement has been the provision of a simple stub-tunnel as a storage area for radioactive items close to the target chamber. This means that a horn or reflector which has been in service and become faulty can be stored easily, reducing the dose to transport personnel.

These provisions ensure that the new facility does not increase the global exposure to personnel, despite the increased intensity of protons being targeted in the area. In fact the area has been designed rather to reduce the current level of exposure.

4.3 Radioactivity in the Structure and Components of the Facility

Assuming, as an example, that the facility will run for ten years at the reference intensities, the radioactivity induced in the molasse around the underground structures and in the concrete of the structures themselves will decay to insignificant levels within 50 – 70 years after the end of target operation.

The iron shielding around the target and helium tubes and the collimator at the front of the decay tunnel, with a assumed mass of the order of 1500 t, will have average specific activities at the end of target operation between 10^4 and a few times 10^6 Bq/g. The decay of the isotopes in this iron will be relatively slow, only reaching insignificant levels after several hundred years. Disposal of these items as radioactive waste must therefore be foreseen.

The iron of the hadron stopper will have an average specific activity of a few times 10^3 Bq/g. Parts of this, about 200 t, will also need special disposal facilities.

The iron of the decay tunnel and the iron reinforcements in the concrete of the target chamber will probably stay in place at the end of the target operation. The reinforcements will reach insignificant levels of radioactivity within 50 years, but the time for the decay tunnel to reach similar levels will be of the order of 500 years.

The horn, the reflector and the two helium-pipes in the target cave, total mass about 2 – 3 t, will have specific activities which are of the order of 10^6 Bq/g, assuming as an example 10 years of operation and a further ten years of decay. Disposal of these items as radioactive waste must also be foreseen.

However the activity in the graphite core of the hadron stop will probably reach levels where normal disposal will be possible after ten years of decay.

Demineralised water in the cooling circuits of the horn, reflector, collimators and hadron stop will be kept in closed circuits. Emptying of these circuits will only take place after measurements have been made of the radioactivity contained. It is to be expected that the tritium concentrations will allow immediate emptying to the drains, but before that the water must pass through a demineralising resin where any ^{7}Be and other radioisotopes will be removed.

4.4 Release of Radioactivity via the Air of the Ventilation System and the Drains

The air of the target chamber will be contained within a closed circuit during operation. After targeting stops, a cooling-down period of several hours will be imposed before flushing of the target chamber with fresh air is started. It will take at least several hours to flush all the original air from the target chamber. Control of the radioactivity by careful determination of the delay time, the flushing time and the transit time for the air to reach the exhaust stack from the target chamber will ensure that any radioactivity vented will be less than the relevant CERN Reference Release Constraints. Continuous monitoring of the radioactivity in the released air will be provided.

The radioactivity contained in the residual air of the decay tunnel and in the front part of the hadron stop area is significantly lower than the radioactivity in the target chamber.

Estimates have been made of the quantity of tritium that will be created in the closed helium-gas cooling circuit for the target and the helium containers in between the horn and reflector and the reflector and the end of the target chamber. It has been shown that the production is similar to that of tritium in the air of the target chamber. Since the release of tritium from this latter source is not of radiological importance, the regular flushing of one of the helium circuits will not create a significant release of tritium.

The drains in the target chamber and the LHC tunnel will collect any ground-water that might seep into the excavation as well as any spillage water. The radioactivity in the ground-water, even though at a low level, is such that it is prudent to impose controls on the release of the drain-water. In addition to routine controls on drain-water leaving the facility, water will not be released unless point controls have shown that the radioactivity in the water meets CERN Release Standards. Only then will the drain water be released. If the radioactivity exceeds such levels, then the drain-water must be evaporated, as is done in some present CERN facilities, and the residue disposed of as solid radioactive waste.

5 Schedule

The schedule shown in Fig. 15 assumes that the approval of the CNGS facility is granted no later than December '99. Then the call for tender for civil engineering work can be launched immediately - drawings are readily available -, so that the civil works can start effectively in August 2000. The first half of the year 2000 will also be used to obtain all necessary authorisations from the CERN Host States.

Thirty months are needed for completing all civil engineering works shown in the first part of the schedule. It should be stressed that this time span is a bare minimum and that there is no margin for unforeseen problems. Moreover, the assumed speed for the tunnel boring machine is higher than the one anticipated for boring TI8, although the negative slope is larger for CNGS. If such a speed can be met, interference with LHC work and SPS winter shutdowns can be avoided.

The second step concerns the construction of the hadron stop and of the decay tunnel pipe, as well as the setting up of general services, for an overall time span of 18 months. The last step concerns the installations in the target cave and of the proton beam line, for which 9 months are a strict minimum. These two steps are somewhat longer than in the CNGS report citengsreport: more detailed studies have shown that some installation work cannot be done in parallel and that more time in the target cave is needed.

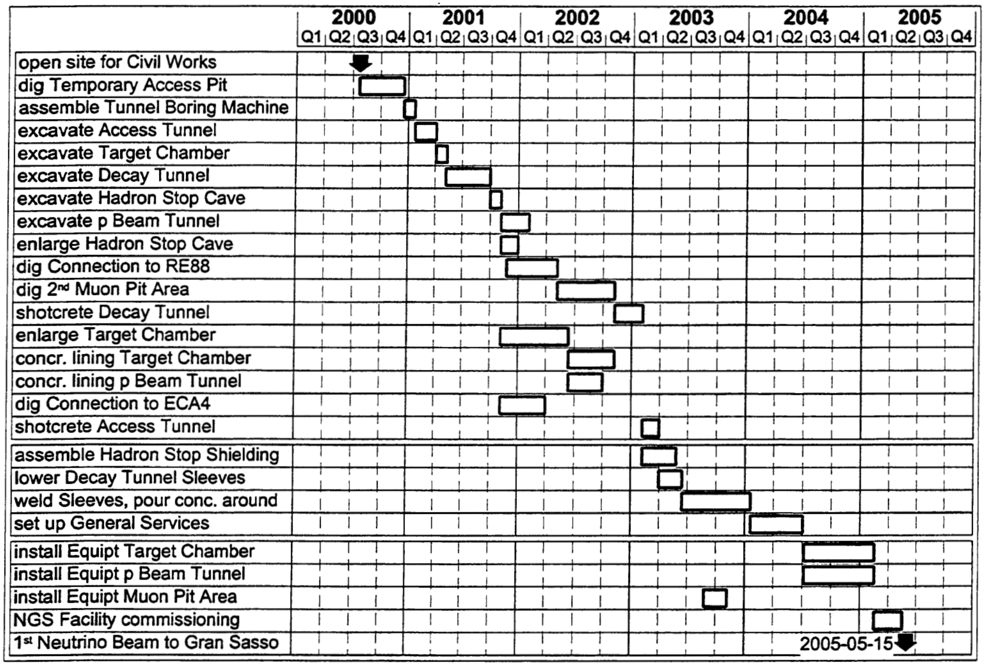

Figure 15: *Present construction schedule of the CNGS beam project.*

As a final remark, it must be recalled that the time between CNGS approval and CNGS commissioning is not constant but may have to be increased if the CNGS approval is delayed, as some operations must be done during accelerator winter shutdowns and constraints by the LHC schedule have to be respected.

6 Cost and manpower

Table 7 gives the cost estimate and the man-power per item. Possible in-kind contributions of components and man-power are not yet taken into account. Table 8 shows the expenditure and man-power profile for construction.

The operation cost (electricity cost included) is **1.6 MCHF per year**. The manpower needed to operate and maintain the facility is **4 man-years per year**. The additional effort in the operation of the accelerator chain is not included as usual.

Table 7: **Cost estimate and required man-power for CNGS construction**

	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**

$^{a)}$ includes industrial support

Table 8: **Expenditure and man-power profile for CNGS construction**

Year	**Expenditure** (MCHF)	**Man-years** (FTE)
2000	5.8	8
2001	14.0	9
2002	18.8	11
2003	17.1	15
2004	11.5	13
2005	1.3	3
Contingency	2.5	
Total	**71.0**	**59**

References

[1] G. Acquistapace et al. The CERN Neutrino Beam to Gran Sasso, Report CERN 98-02 and INFN/AE-98/05.

[2] NGS: A long base-line neutrino beam from CERN to Gran Sasso, CERN/SPC/765, CERN/CC/2278, 27 May 1999.

[3] R. Bailey et al. The CERN Neutrino Beam to Gran Sasso (Addendum to report CERN 98-02, INFN/AE-98/05), Report CERN-SL/99-034(DI) and INFN/AE-99/05.

[4] The CNGS WWW page: http://www.cern.ch/NGS/

A Reference Parameter List - May 1999

Proton Beam

Maximum proton beam momentum (design)	450 GeV/c
Proton beam momentum (assumed for operation)	400 GeV/c
Proton beam normalised emittance (1σ)	12π mm mrad
β^* at the focus (H and V)	2.5 m
$\rightarrow$ minimum beam size / maximum divergence (1σ)	0.27 mm, 0.1 mrad
Minimum repetition time (dedicated operation at 400 GeV/c)	6 s
Time between bursts	50 ms
Proton intensity (for hadron stop considerations)	6×10^{12} protons/second, 200 days/year
Proton intensity (for environmental considerations)	7.6×10^{19} protons/year
Expected integrated number of protons per year at 400 GeV/c	4.5×10^{19} protons

Target Chamber

Length of target chamber	115 m
Diameter of target chamber	6.5 m (int.)
Floor width of target chamber	5.6 m
Enlargement at target (optional)	7.4 m
Crane capacity	10 t
Free height under crane hook	3.7 m
Beam height in target chamber	1.6 m
Diameter of neutrino service gallery	3.4 m (int.)
Distance of service gallery from cavern	6.0 m
Length of junction tunnel to target chamber	8 m
Distance of proton focus to entrance of decay tunnel	100 m

Target

Start coordinate (w.r.t. proton focus)	-0.5 m
End coordinate (w.r.t. proton focus)	$+1.5$ m
Target material	carbon, density 1.81 g/cm^3
Target rod length	10 cm
Diameter of rods	4 mm
Number of rods	13
Distance between rods	first 8 rods with 9 cm distance, last 5 rods minimal possible distance

Note: the exact configuration of the 13 target rods is under investigation.

Helium tubes

Helium tube I

Start coordinate (w.r.t. proton focus)	11.00 m
End coordinate (w.r.t. proton focus)	42.00 m
Diameter first 6 m	0.80 m
Diameter remaining length	1.20 m

Helium tube II

Start coordinate (w.r.t. proton focus)	52.00 m
End coordinate (w.r.t. proton focus)	99.00 m
Diameter	1.20 m

Shielding / Collimation

Shielding 1 (around the target, cf. Fig 10)

Material	iron / marble
Start coordinate (w.r.t. proton focus)	-1.5 m
End coordinate (w.r.t. proton focus)	$+1.7$ m
Cross-section	rectangular
Opening for target box	60 × 60 cm^2

30 cm of marble added at downstream end of target

Shielding 2 (around the horn, cf. Fig 10)

Shielding underneath the horn	40 cm concrete
Side walls of 30 cm marble / 20 cm iron / 30 cm concrete	
Height of walls	3.20 m
Left wall, start coordinate (w.r.t. proton focus)	2.30 m
Left wall, end coordinate	10.80 m
Right wall, start coordinate	2.00 m
Right wall, end coordinate	11.00 m

Shielding 3 (around helium tube I, cf. Fig 9)

Upstream shielding	0.50 m marble
Shielding collar, first 5 m	iron, 3 × 3 m^2 opening 0.80 × 0.80 m^2
Shielding collar, remaining 25.5 m	0.20 m iron, 0.30 m concrete opening 1.20 × 1.20 m^2

(Height of collar 2.70 m)

Shielding 4 (along helium tube II, cf. Fig 9)

Shielding underneath the tube	0.40 m concrete
Side walls height	3.20 m

Left wall distance to axis	1.00 m
Left wall thickness	0.80 m
Right wall distance to axis	1.00 m
Right wall thickness	0.80 m

Shielding 5 (collimator around helium tube II, cf. Fig 9)

Start of shielding	85 m
Length of shielding	5 m
Inner diameter	1.20 m
Outer diameter	3.80 m (exception: downwards)

Horn and Reflector (dimensions referring to **magnetic length**):

Distance proton beam focus - horn entrance	1.7 m
Length of horn	6.65 m
Current in horn	150 kA
Distance proton beam focus - reflector entrance	43.35 m
Length of reflector	6.65 m
Current in reflector	150 kA

Note: for the beam calculations, it is assumed that all spaces outside the horn and reflector are filled with helium at 1 atm.

Decay Tunnel

Upstream end of decay tunnel (w.r.t. focus)	100 m
Length of decay tunnel	992 m
Diameter of decay tunnel (TBM)	3.50 m (ext.)
Length of decay pipe	994.5 m
Diameter of decay pipe (inner diam. steel pipe)	2.45 m (96 inch)
Wall thickness decay pipe	16 - 19 - 22 mm
Concrete filling around pipe	ca. 53 cm
Entrance window decay pipe	diameter 1.40 m, 2 mm titanium T40
Protecting shutter (thickness)	3 cm steel
Exit window decay pipe	5 cm steel
Pressure in decay pipe (min.)	1-2 Torr
Pumping down time (max.)	2 weeks

Hadron Stop and Muon Chambers

Upstream end of hadron stop cavern (w.r.t. proton focus)	$100 + 992$ m
Length of hadron stop cavern	26 m
Diameter of hadron stop cavern	6 m (int.)
Length of hadron stop	18.2 m
Cross-section of hadron stop	$4 \times 4\,\mathrm{m}^2$
Length of graphite insert	3 m
Cross-section of graphite insert	$2.6 \times 2.6\,\mathrm{m}^2$
Wall thickness of aluminium box around graphite	0.1 m
Length of airgap upstream of hadron stop	0.25 m
Length of airgap downstream of hadron stop (= length of first muon chamber)	5 m
Length of "muon filter": Molasse	67 m
Length of 2nd muon chamber	3.5 m
Muon pit "service alcove" surface	$10 \times 4\,\mathrm{m}^2$
Access gallery to hadron stop: diameter	3.1 m (int.)
Access gallery to 2nd muon pit: diameter	2.5 m (int.)

CERN/2300
ANNEX II

EXPERIMENTS AT GRAN SASSO WITH THE CERN NEUTRINO BEAM (CNGS)

Experiments at Gran Sasso with the CERN neutrino beam (CNGS)

II.1 Summary of the History of Experimental Projects

In parallel with the study of a neutrino beam produced at CERN and aiming at Gran Sasso, several experimental proposals were elaborated to study neutrino oscillations, more precisely appearance of ν_τ particles, the key phenomenon expected to be observable on a long base line in a ν_μ beam.

During 1998, five major experiments were proposed: ICARUS, NICE, Aqua-RICH, NOE and OPERA, while at least two less elaborated suggestions were made, one for the study of ν_μ $\bar{\nu}_\mu$ oscillations and one for the development of a liquid scintillation detector.

The advisory SPS and PS Committee (SPSC) held a joint meeting with the Gran Sasso Scientific Committee on 3-4 November 1998 to study the prospects opened by these various proposals. They concluded that the programme *was extremely appealing and realistic, and they urged to proceed with the construction of the* ν *beam.* They recommended that *collaborations proceed with the preparation of proposals for experiments to be submitted in the Autumn of 1999."*

The CERN Research Board, on 23 November 1998, encouraged the collaborations to *"develop one experimental proposal for a high sensitivity, low-background,* ν_τ *appearance LBL experiment."*

In turn, the SPC took to examine the proposed experiments in its June 1999 meeting. After reiterating its recommendation to build the CERN-Grand Sasso neutrino beam, it stressed that, in order to understand the nature of the apparent disappearance of ν_μ, *it is extremely important to establish what the* ν_μ *disappears into.* Thus it recommended that *the first experiment in this "facility" should be a* ν_τ *appearance experiment.*

In the meantime, the proposed experiments evolved markedly. The difficulty of the task of unambiguously identifying a few ν_τ particles over several years led to an intense R&D work and Monte-Carlo simulations. The dispersed groups tended to join forces. Eventually, two more elaborate projects emerged, ICANOE and OPERA. They were reviewed and evaluated by SPSC in its meeting of 14 September 1999, the conclusions of which were brought to the attention of the Research Board and SPC, hence indirectly to the Committee of Council of 23 November.

The SPSC conclusions were as follows:

"ICANOE

The Committee considers that the ICANOE detector has a large discovery potential to observe a ν_τ appearance signal resulting from $\nu_\mu \rightarrow \nu_\tau$ oscillation in the neutrino beam from CERN to Gran Sasso (CNGS), as well as being capable of investigating oscillations to ν_e. Moreover, the proposed detector has the potential of studying atmospheric neutrinos and proton decay.

The Committtee requests a written report to the December 1999 session of the SPSC, providing details on the schedule with a list of milestones for the construction and running of the experiment, and including the experiment's funding and manpower profiles.

The Committee is impressed by the quality and amount of work presented and encourages the collaboration to continue their experimental design, emphasising further studies of integrating the ICARUS technique with a spectrometer and realising the T600 module in order to prove the viability of the ICARUS technique.

OPERA

The Committee considers that the experiment has the potential to explore the parameter space of neutrino oscillation indicated by the Kamiokande and SuperKamiokande experiments. Using well-proven techniques and in a reasonable time, OPERA offers the possibility to observe a ν_τ appearance signal in the neutrino beam from CERN to Gran Sasso (CNGS) resulting from $\nu_\mu \rightarrow \nu_\tau$ oscillation.

In order to monitor the progress leading up to the submission of the proposal, the Committee requests a written report to the December 1999 session of the SPSC, providing details on the schedule with a list of milestones for the construction and running of the experiment, and including the experiment's funding and manpower profiles.

The Committee is impressed by the quality and amount of work presented and encourages the collaboration to continue their experimental design, emphasising further studies with test beams and simulations. A proposal is expected early in the year 2000."

II.2 ICANOE

This proposal stems from the regrouping of a liquid-argon detector of high performances to track and identify particles (ICARUS) and of a magnetized spectrometer (NOE). The development of a liquid-argon detector offers remarkable prospects for unequaled efficiency and precision in particle detection. Sizable prototypes have successfully established this novel technique. INFN has fully funded a large size (600 tons) detector (T600) fabricated in industry. It is anticipated that tests, expected to demonstrate the effectiveness of that detector, will be made in July-August 2000. The dismantling, transportation and re-installation of T600 in Gran Sasso will occur starting in the Autumn of 2000. This move was part of the plan approved for T600 by INFN.

The ICANOE proposal builds on that technique to propose a large detector of 9.3 kt of liquid argon, distributed in four modules interspaced by NOE spectrometers. Based on the experience gained in the construction of T600, the new ICARUS modules are shorter, lighter, more compact while using a longer drift length. The smaller volume contributes to improve safety aspects. The NOE calorimeter modules consist of read-out scintillation fibres imbedded in an iron matrix. This calorimeter could be magnetized to determine the charge of the detected muon. The quality of fibres allows the modules to be as wide as 9m, matching the 8mx8m cross section of ICARUS modules. One of the attractive features of the project is that it should be able to address other scientific issues as well: atmospheric neutrinos (like those studied at Kamiokande), solar neutrinos and hadron decay. The size of the collaboration is extending with significant contributions from Switzerland, China and Russia.

With the final parameters of the ν beam presented in Annex I, ICANOE would observe, for the favored $\Delta m^2=3.5\times10^{-3}$ eV^2 parameter, 35 ν_τ events over 4 years of operation, with a 5 background events.

The collaboration considers that the target of having the full ICANOE detector in operation at Gran Sasso when the CNGS beam is available in May 2005, is realistic. The committee has underlined the crucial importance of a successful demonstration of the first large-scale liquid-argon detector (T600) in the summer of 2000 as planned. In any case, the high potential of this novel technique has been widely recognized by the scientific committees of CERN and LNGS.

II.3 OPERA

This proposed design is based upon the use of emulsions for a precise identification and tracking of the particles produced from a ν_τ interaction. The detector is highly modular, consisting of about 150000 elementary bricks regrouped within five large modules. Each brick is a sandwich of passive material plates interspaced with nuclear emulsion layers used as high precision tracking devices.

The passive material chosen is made of thin lead sheets where the ν_τ would interact to produce the τ particles whose decay will unambiguously sign the occurence of ν_τ charged current interactions.

This technique has been developed at length in the course of the CHORUS experiment, and is further refined in the DONUT experiment at Fermilab. The expertise of the Japanese group from Nagoya, which plays a major role in OPERA, is recognized worldwide while significant contributions to the automated scanning of emulsions have also been made in Europe (Naples, CERN). However there is a large increase in size from CHORUS (700 kg) to OPERA (about 200 t of emulsion plates out of a total 1,5 kt weight), i.e. more than two orders of magnitude. Although the technique has been thoroughly tested and established, this calls for a full evaluation of the processes of production, handling and scanning of the plates. For the production, good progress by Fuji in industrial R&D has been reported. As for scanning, the concept of OPERA allows for regular (on a monthly basis for instance) removal and analysis of only those emulsion plates which have been identified by the associated electronic trackers to have recorded prospective candidates for ν_τ events, at variance with CHORUS for which the scanning came after two full years of data-taking. It is anticipated to remove the basic bricks at a daily rate of about 10. As a result about 1000 m^2 of emulsion plates, out of a total of 160 000 m^2, would need to be scanned every year.

The main asset of this detector is that, through the direct observation of the characteristic pattern of a τ decay, it is nearly background-free.

The major challenge of the final design of the detector is to retain sufficient detection efficiency while insuring the remarkable asset of near-zero background. That latter feature was highly recommended in the conclusions of successive committees and should indeed be considered as essential to provide unambiguous claims as to the appearance of a new kind of neutrino in a ν_μ beam. In the recent months, much progress has been accomplished to make reliable predictions of the efficency of the various possible configurations of elementary bricks.

In the September 1999 meeting of SPSC , efficiency and background estimation were presented for a combination of the two alternative brick configurations still under study. The estimate of efficiency was smaller than in initial proposals, as a result of analysis of previous CHORUS performances and of more extensive and detailed Monte-Carlo simulation. These new estimates were considered as reliable by the SPSC. They correspond to the observation of 18 events over five years with a background below 0.5 count, for the favored value of the Δm^2 parameter (i.e. 3.5×10^{-3} eV^2).

One asset of OPERA is that the collaboration contains those groups, from Europe and Japan, which have already acquired a solid experience of these techniques in the CHORUS experiment. Furthermore, the collaboration has been extending within the last 6 months so as to associate sizable research groups from other member states.

II.4 Preliminary Conclusion

At this stage, the CERN Management concurs with the SPSC that the potential to detect in Gran Sasso the occurrence of ν_τ events in the ν_μ beam from CERN is established.

Obviously the cost of the detector(s) available in 2005, in terms of funding and manpower, must be compatible with the abilities of the participating laboratories. Although one must wait for the cost estimates which have been requested from the collaborations, an appropriate staging of the detector(s) construction might be necessary. One might note that an experiment with a very low background could claim a discovery from only few events. However, the measurement of the crucial Δm^2 mass parameter would obviously necessitate an efficiency which calls for a full detector.

CERN/2300/Rév.
Annexe III

Projet

de

Convention

entre

l'Organisation européenne pour la Recherche nucléaire (CERN)

et

l'Istituto Nazionale di Fisica Nucleare (INFN)

concernant

la coopération pour l'installation "Neutrinos du CERN vers le Gran Sasso"

1999

L'Organisation européenne pour la Recherche nucléaire, ci-dessous dénommée **CERN,**

d'une part,

et

l'Istituto Nazionale di Fisica Nucleare, ci-dessous dénommé **INFN,**

d'autre part,

Attendu que

le CERN et l'INFN, reconnaissant l'importance scientifique et les riches perspectives de la physique des neutrinos, ont décidé de coopérer pour le lancement d'un projet de recherche aux fins duquel le CERN construira une source de neutrinos et l'INFN les infrastructures nécessaires à l'exploitation de cette source;

à cette fin, une installation, ci-dessous dénommée *"Neutrinos du CERN vers le Gran Sasso"* (CNGS), destinée à produire, à partir du faisceau de protons du SPS du CERN, des faisceaux de neutrinos qui seront dirigés vers le Laboratoire national du Gran Sasso (LNGS), de l'INFN, a été conçue et fera l'objet d'une demande d'approbation qui sera soumise au Conseil du CERN;

le financement de la construction du CNGS sera assuré pour l'essentiel par des contributions spéciales de plusieurs Etats membres du CERN, dont une contribution de 47 MCHF de l'Italie;

l'objectif scientifique des premières expériences envisagées avec le faisceau de neutrinos est l'étude des oscillations des neutrinos par des collaborations internationales qui construiront et exploiteront des détecteurs au LNGS;

Considérant

la Convention du CERN en date du 1er juillet 1953, telle qu'elle a été modifiée le 17 janvier 1971;

la Charte de l'INFN en date du 8 août 1951 ;

les directives émises par le Comité international pour les futurs accélérateurs (ICFA) en matière de libre accès aux grandes installations d'expérimentation régionales (9 juillet 1980/réaffirmées le 13 janvier 1993);

Sont convenus de ce qui suit:

Article 1
But de la Convention

Le CERN et l'INFN coopéreront à un projet neutrino. A cette fin, le CERN se chargera de la production d'un faisceau de neutrinos qui sera dirigé vers le LNGS. L'INFN, par l'intermédiaire de son Laboratoire du Gran Sasso, fournira l'infrastructure nécessaire à l'exploitation des détecteurs de neutrinos provenant de cette source. Les ressources correspondantes seront détaillées dans un document pertinent qui sera avalisé par les Parties lors de l'approbation du programme d'expérimentation au Gran Sasso.

Le projet de construction au CERN est défini dans le document CERN/2300/Rév. annexé à la présente convention (***annexe 1***).

Le document susmentionné relatif aux ressources afférentes à l'infrastructure fournie par l'INFN sera joint à la présente Convention en ***annexe 2***.

Article 2
Comité de coordination bilatérale

Il est créé un comité de coordination bilatérale entre le CERN et l'INFN, composé comme suit:

- pour le CERN, le Directeur de la recherche chargé du CNGS, le Directeur des accélérateurs et un membre nommé par CERN;
- pour l'INFN, le membre du Comité exécutif chargé du LNGS, le Directeur du LNGS et un membre nommé par l'INFN.

Il se réunira au moins une fois par an pour examiner des rapports sur l'état d'avancement et les perspectives du CNGS et sur les expériences, et pour faciliter l'harmonisation des programmes pertinents au CERN et au LNGS.

Article 3
Choix des expériences

Le CERN et l'INFN participeront l'un et l'autre au choix des expériences utilisant le faisceau de neutrinos du CNGS qui seront montées au LNGS, dans le respect des directives de l'ICFA.

Il sera demandé à toute collaboration souhaitant proposer une expérience de soumettre au CERN et à l'INFN une proposition qui sera évaluée par les comités scientifiques compétents. Les présidents des comités rédigeront une recommandation commune. En cas de désaccord, le Comité de coordination bilatérale sera saisi. Le CERN et l'INFN statueront en dernier ressort sur la proposition.

Article 4
Coût

Le financement de l'exploitation du CNGS et des expériences utilisant le faisceau de neutrinos sera partagé comme suit:

i) le CERN prendra à sa charge les dépenses liées à la production des faisceaux de neutrinos;

ii) le LNGS prendra à sa charge les dépenses liées à l'infrastructure de base nécessaire aux expériences;

iii) les collaborations utilisant le CNGS prendront à leur charge le coût de la construction, de la mise en service, de l'exploitation et du démantèlement des détecteurs.

Article 5
Coordination

Les Parties prendront toutes mesures nécessaires pour coordonner efficacement leurs activités respectives dans le cadre de ce projet de recherche. En particulier, toute interruption importante ou modification majeure par l'une des Parties des installations à sa charge, ou en rapport avec l'exécution de la présente convention, nécessitera l'accord écrit préalable de l'autre Partie.

Toute divergence de vues sera examinée par le Comité de coordination bilatérale.

Article 6
Dispositions administratives

Les Parties arrêteront en commun les dispositions administratives afférentes à la mise en œuvre de leur coopération, en particulier celles qui concernent le personnel et le matériel mis à disposition par le CERN et l'INFN.

Article 7
Modification

La présente convention peut être modifiée par accord entre les Parties.

Article 8
Durée de la convention

La présente Convention restera en vigueur pendant une période de dix ans. Sa durée pourra être abrégée ou prolongée d'entente entre les Parties.

Article 9
Entrée en vigueur

La Convention entrera en vigueur à la plus tardive des deux dates suivantes: celle de sa signature par la moins diligente des deux Parties ou celle de l'approbation du programme CNGS par le Conseil du CERN.

Article 10
Différends

Toute divergence de vues concernant l'application ou l'interprétation de la présente convention, qui n'a pas été réglée par la négociation directe entre les Parties, peut être soumise par l'une ou l'autre des Parties à un arbitrage international, conformément aux dispositions de l'***annexe 3*** à la présente Convention.

Fait à Genève en langue anglaise, seule version faisant foi, le ....

Pour le CERN: Pour l'INFN:

Annexe 1

DOCUMENT CERN/2300/Rev.

(á annexer à la Convention)

Document mentionné dans l'Article 1, paragraphe 3 de la Convention

ARBITRAGE

ORGANISATION EUROPÉENNE POUR LA RECHERCHE NUCLÉAIRE
EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

Laboratoire Européen pour la Physique des Particules
European Laboratory for Particle Physics

Adresse postale / Mailing address*:
CERN
CH - 1211 GENEVA 23
Switzerland

AJ/5167 - 10 July 1996

ARBITRATION

1. Should any dispute fail to be settled amicably, the Parties concerned shall, under the following conditions, resort to the statutory arbitration procedure drawn up by CERN pursuant to its international legal status.

2. Each Party shall appoint an arbitrator within ninety days after notice has been given, by registered letter with acknowledgement of receipt, by either Party to the other of his intention to resort to arbitration.

3. The two arbitrators shall, by joint agreement and within ninety days of the appointment of the second arbitrator, appoint a third arbitrator, who may in no case be drawn from amongst persons who are or have been in any way in the service of CERN or xxx or of any subsidiary or affiliated company of the latter. The third arbitrator thus selected shall preside over the arbitration tribunal.

4. Should one of the arbitrators, after accepting the task, be prevented for any reason from fulfilling it, a replacement shall be selected within a period of sixty days, in accordance with the above conditions.

5. Should one of the Parties fail to appoint an arbitrator and/or the two arbitrators fail to agree on the selection of a third, the choice shall be made by the President of the Administrative Tribunal of the International Labour Organization, at the request of the first Party to do so.

6. The arbitration proceedings shall take place in Geneva, unless otherwise agreed by the Parties. The arbitration tribunal and the two

Parties shall draw up and agree on the terms of reference for the arbitration. For procedural matters, the tribunal shall apply the general principles of civil procedure.

7. The arbitrators shall be entitled to be assisted by advisers, experts or other persons of their choice, to undertake investigations, to hear the Parties either separately or in each other's presence, assisted if they so desire by legal advisers and/or experts, and generally to carry out any enquiries, investigations and hearings which may provide them with information for the performance of their task.

8. The Parties at dispute shall spontaneously provide the arbitrators with such assistance as they are able to give.

9. The arbitrators' award shall faithfully interpret the terms of the contract and shall set out the legal grounds for the decision.

10. The award shall be final and binding upon the Parties, who shall undertake in advance not to resort to any form of appeal, whether ordinary or extraordinary.

11. Nevertheless, either Party at dispute may, within fifteen days of the arbitration tribunal's announcement of its award, request the latter to provide an interpretation of it. This interpretation shall be given within sixty days of the date on which the request is made.

12. During this time execution of the award shall be suspended.

13. The costs and fees of the arbitration shall be determined and apportioned by the arbitration tribunal.

14. This arbitration clause shall automatically apply to all amendments, modifications and addenda to a contract, even if not specifically mentioned therein, provided that they contain no formal provision to the contrary.

15. With the agreement of the arbitration tribunal, the arbitration award may be published at the request of one of the Parties.

INFN AGREEMENT TO CERN-INFN CONVENTION

STITUTO NAZIONALE DI FISICA NUCLEARE

IL PRESIDENTE

ROMA (Italy) 04.11.99 023498
Piazza dei Caprettari, 70 (00186)
Tel. 06-6840031
Fax 06-68307924

Prof. L. Maiani
Director General
CERN
CH-1211 Geneva 23
Switzerland

Dear Luciano,

I wish to inform you that, in the framework of the overall Project for the "CERN Neutrinos to Gran Sasso" facility, on October 29th, the Board of Directors of INFN approved the text of the Convention between CERN and INFN in the version enclosed therein (Annex 1).

Best regards,

pp President I.N.F.N.
(Prof. E. Iarocci)

CERN/2300
ANNEX V

MILESTONES FOR
CNGS AND EXPERIMENTS

Milestones for CNGS and Experiments

December 17, 1999: Approval of CNGS

January 2000: Call for tenders of the civil engineering

Spring 2000: Signature of the MoUs between CERN and Agencies concerning CNGS funding

June 2000: Submission of final documents for approval of experiment(s)

June 2000: Adjudication of civil engineering contracts in Finance Committee

Beginning July 2000: Contracts signed for civil engineering

August 2000: Installation of civil engineering work site

September 2000: Approval of the experiment(s)

January 2002: Start of detector(s) installation in Gran Sasso

April 2003: Completion of civil engineering

July 2004: Start of equipment installation in CNGS tunnel

May 2005: First neutrino beam to Gran Sasso and start of data taking

PROJET DE RESOLUTION

PROJET DE RESOLUTION

LE CONSEIL,

Considérant

le souhait du CERN et de l'INFN de réaliser un projet scientifique de grande importance portant sur l'étude des oscillations neutrino;

que le CERN et l'Istituto Nazionale di Fisica Nucleare (INFN, Italie) coopéreront pour la réalisation de ce projet, le CERN fournissant le faisceau de neutrinos et construisant à cette fin "l'installation Neutrinos du CERN vers le Gran Sasso (CNGS)", et l'INFN, dans les "Laboratori Nazionali del Gran Sasso", l'infrastructure nécessaire au développement des installations d'expérimentation associées et à l'exploitation de la source de faisceau CNGS;

le document CERN/2300/Rév. qui définit le projet de construction par le CERN de"l'installation Neutrinos du CERN vers le Gran Sasso (CNGS)";

les avis positifs émis par le Comité des directives scientifiques le 14 décembre 1999 et le Comité du Conseil le 16 décembre 1999;

l'assentiment donné par l'INFN, le 4 novembre 1999, au projet de convention qui sera conclue entre le CERN et l'INFN "concernant la coopération pour l'installation Neutrinos du CERN vers le Gran Sasso (CNGS)";

Considérant aussi

la Convention du CERN en date du 1^{er} juillet 1953, telle qu'elle a été modifiée le 17 janvier 1971, en particulier ses articles II et V;

DECIDE:

1. d'approuver le projet CNGS tel qu'il est défini dans le document CERN/2300/Rév. et de l'intégrer dans le programme de base de l'Organisation;
2. d'approuver le programme de base ainsi modifié.