Chapter 2

The CERN – Gran Sasso LBL Project

2.1 SPS Neutrino Beam Project at CERN.

The decays of pions and kaons produce essentially μ and ν_μ. Then it is possible to generate a neutrino beam from the decay of secondaries (π and K) produced by the interactions of a primary proton beam on a target. The secondary particles are focused towards a detector and left to decay in a vacuum tunnel. A beam dump at the end of the tunnel stops muons and all remaining hadrons. It is important to remind that a small contamination of ν_e is present in the neutrino beam due to π, K and μ decay.

The feasibility of a ν_μ beam from CERN to LNGS has been considered in the framework of the LHC project [1]. New transfer lines are required in order to bring the SPS beam to LHC. The project proposes to derive the primary proton beam from one of these lines; this beam may be deflected and directed to Gran Sasso in a 550 m transfer line, followed by a target and a focusing station (25 m). A possible design of the ν beam facility is shown in Fig. 2.1. The decay tunnel is about 1 km long, with a diameter of few meters.

Tab. 2.1 shows absolute and relative coordinates of the two sites [2]. The ν beam from CERN to LNGS will enter the present underground halls with an angle of 93.3° with respect to the vertical and an azimuthal angle of 4.95° with respect to the gallery axis.

The project foresees two different extraction cycles. During LHC construction it is possible to have a neutrino beam dedicated cycle of 7.2 s with 3 fast extractions of 6μs at 50 ms interval. When LHC is operating, the

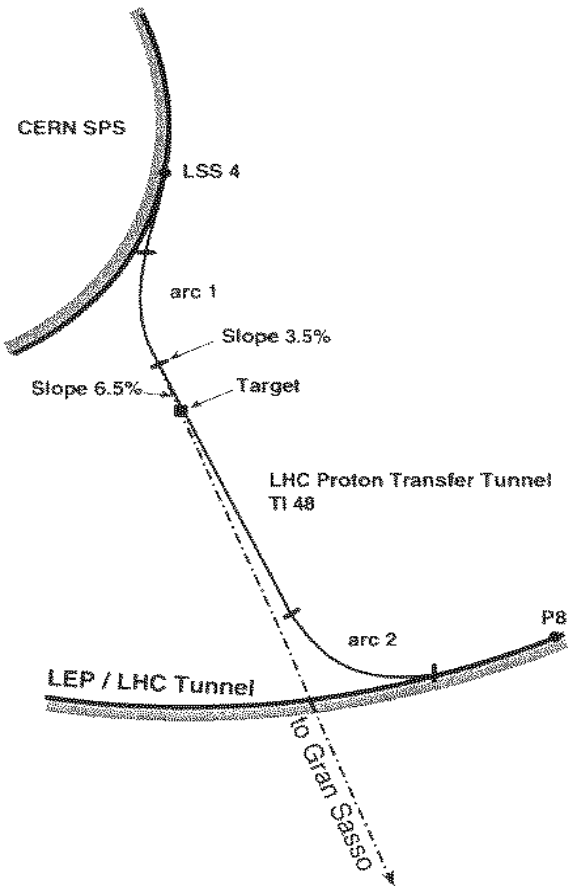

Figure 2.1: ν beam facility at CERN.

beam has to be shared. Then a cycle of 14.4 s with 2 fast extractions of 10μs at 50 ms interval for the neutrino beam can be used. Table 2.2 shows the performances of the machine in these two cases. Total number of protons on target is given for a run of 100 days ($\sim 10^7$ s) at 70% efficiency, wich corresponds to about one year of operation. At present SPS works in shared mode.

Two detailed simulations of the transport of the beam and of the decay of secondaries have been carried out independently [1],[3],[4]. For the production target both simulations assume the same configuration now used for the short baseline experiments at CERN, i.e. a segmented beryllium rod (1.2 m

Site	λ	ϕ	Λ	α	Distance
CERN	6.073°	46.24°	122.5°	3.283°	731 km
LNGS	13.57°	42.45°			

Table 2.1: Absolute coordinates (λ,ϕ) and azimuth and declination angles (Λ,α) of the direction Gran Sasso-CERN.

Operating mode	Energy (GeV)	Cycle length (s)	Proton on target per cycle	Proton on target per run
dedicated	450	7.2	$3 \times 0.8 \times 10^{13}$	2.0×10^{19}
shared	450	14.4	$2 \times 0.9 \times 10^{13}$	0.75×10^{19}

Table 2.2: Performances of the SPS machine for dedicated and shared mode.

long, with a radius of 1.5 mm). No attempt has been made up to now to optimize the target layout for given focusing configurations. Furthermore target is compatible with fluxes lower than 1.5×10^{13} protons per fast extraction. Different types of target are under study for higher fluxes.

Two different possibilities have been analyzed for the magnetic lenses: a horn-reflector system is used in Ref. 2, a single-horn system in Ref. 3. For the horn-reflector system, different configurations of the magnets, tuned to focalize different monochromatic beams, have been studied. Both simulations are based on FLUKA [5] for the model of the hadronic interactions in the target; beam transport is simulated by using GEANT [6]. They differ for the treatement of the secondary beam [4].

Reliability of the two methods has been tested by simulating the present CERN short-baseline beam configuration. Event and background rates were predicted correctly within 10 %. Compatibility between them was also tested by assuming a 'perfect focusing' of secondaries, i.e. forcing them to be parallel to the axis of the decay tunnel.

Results from the two simulations are reported in Tab. 2.3. Event rate, neutrino mean energy and ν_e contamination are reported assuming a 450 GeV/c primary beam and, in the case of Ref. 2, for two different focusing

Focusing	Events/10^{19}pot/kton	$< E_\nu^{-2} >^{-1/2}$(GeV)	ν_e/ν_μ (%)
H20R40 [1]	473	10.5	1.4
H40R70 [1]	722	14.2	1.1
Single horn [3]	1040	22.8	0.65

Table 2.3: Event rate, neutrino mean energy and ν_e contamination for a 450 GeV/c proton beam , a flux of 10^{19} protons on target and a perfectly efficient detector at Gran Sasso.

systems.

In Fig. 2.2 the neutrino energy distributions for CC interactions are shown for the different cases. In Fig. 2.3 the radial distribution of the ν beam at Gran Sasso is shown.

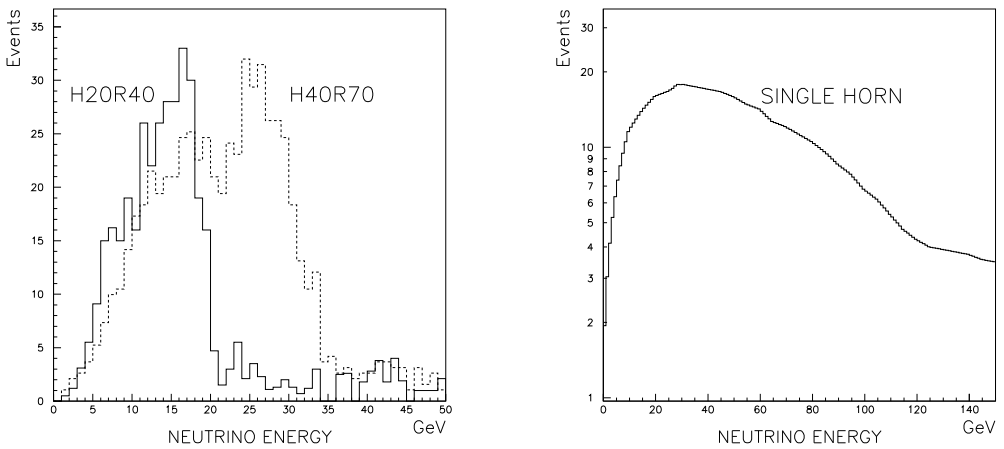

Figure 2.2: ν_μ energy distributions for CC interactions. The number of events is given for a 1 kton detector operating 1 year at Gran Sasso.

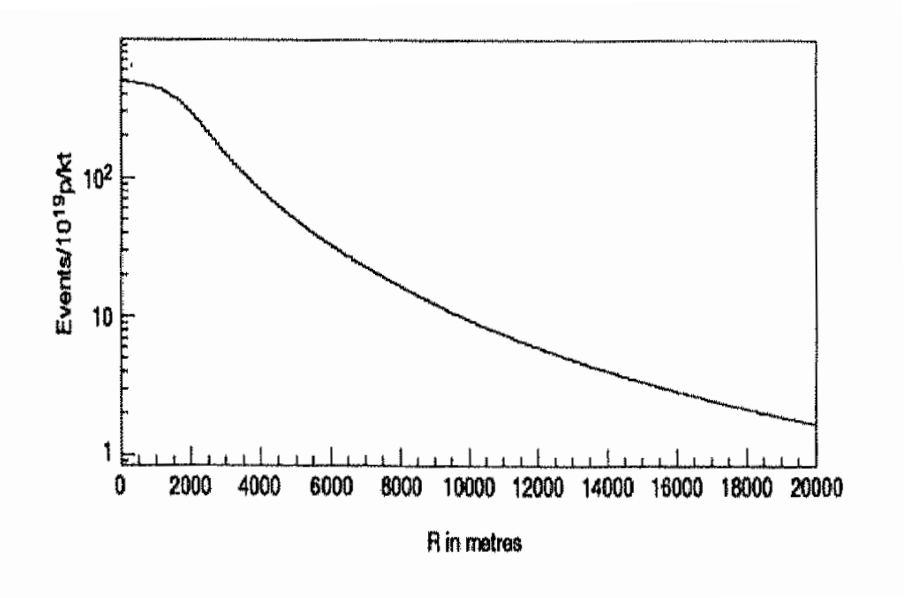

Figure 2.3: ν_μ beam radial distribution at Gran Sasso.

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