

Accelerators for the PS neutrino beam

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Abstract. A recent memorandum for an experimental proposal [1] was discussed during the CERN PS and SPS experimental committee (SPSC) of April 2011 and at the Research Board of June 2011. The proposed experiment, with objective to investigate the anomalous $\nu_\mu \rightarrow \nu_e$ oscillations, aims at re-using the discontinued CERN PS Neutrino Facility (PSNF) and experimental zones to install a 150 ton liquid argon time projection chamber (LArTPC) as near detector and a 600 ton LArTPC as far detector. This article will summarize the experimental needs, the proposed facility layout, a primary beam production scheme and the requirements for the reconstruction of the PSNF.

1. Introduction

The proposed experiment aims at re-using the discontinued CERN PSNF. It foresees to install a 150 ton liquid argon time projection chamber (LArTPC) as near detector at 127 m from the production target and the 600 ton ICARUS LArTPC [2] that is presently operational at the Gran Sasso National Laboratory in Italy, as far detector at 850 m distance from the production target, as illustrated in figure 1. The CERN-PS will have to produce the required number of protons.

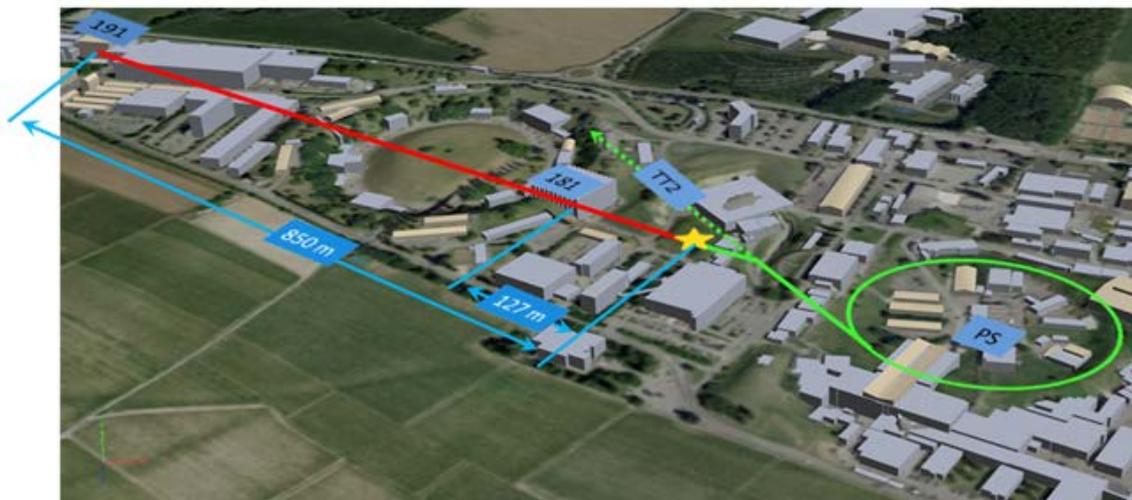


Figure 1. The foreseen layout for the neutrino production and the neutrino beam path on the CERN Meyrin site.

2. The principal experimental requirements

The proposed experiment requires 2.5×10^{20} protons at 20 GeV/c on target to produce the required number of events in the far detector in 2 years time, resulting in 1.25×10^{20} protons per year. This amount is based on the neutrino flux as produced by the target and horn configuration used in 1983.

The required neutrino beam is a low energy ν_μ beam, centred around ~ 1.5 GeV.

3. The PS neutrino facility

The initial PS TT7 tunnel and beam line were designed and constructed in the late 70's, early 80's and exploited for 2 years, starting in 1983, to provide beam to different neutrino experiments (PS169 [3], PS181 [4] and PS180 [5]) in the neutrino pit of building 181 and in the buildings 191 and 36, all situated on the CERN Meyrin site.

Protons were provided by the CERN-PS and extracted via the TT2 line through part of the TT1 line¹, into the TT7 line that directed them towards the 80 cm long beryllium target, which was followed by a magnetic horn, designed to focus the secondary mesons of a momentum around 2 GeV/c. Figure 2 and figure 3 provide an overview of the tunnels that could house the new PSNF.

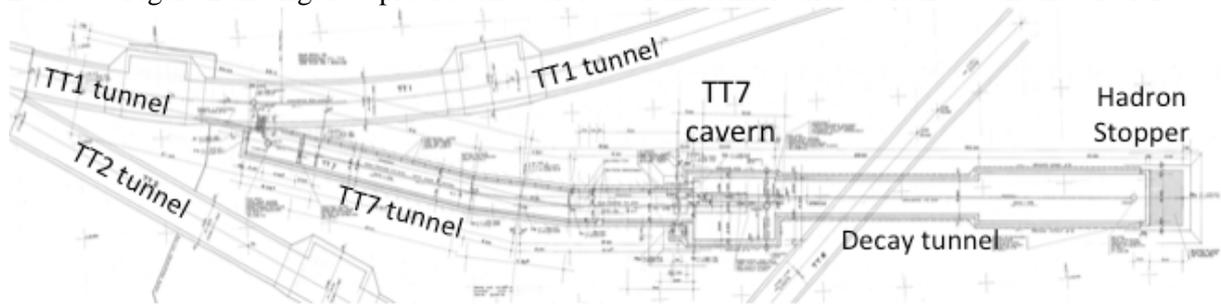


Figure 2. Top view of the transfer tunnels, target cavern, decay tunnel and hadron stopper.

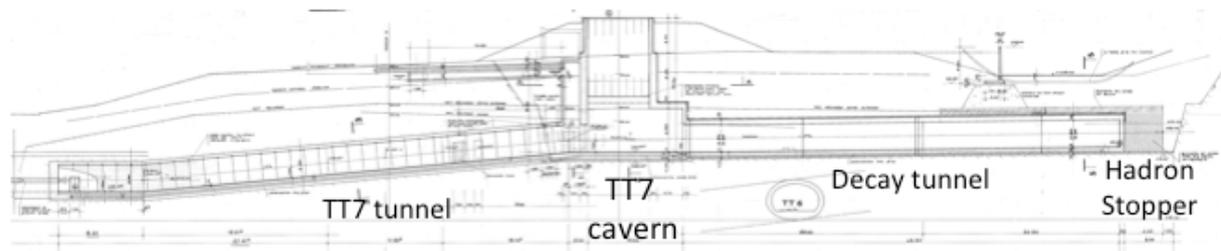


Figure 3. Side view of the TT7 tunnel, target cavern, decay tunnel, and hadron stopper.

4. PS proton beam production

The first experiments (PS169 and PS181) received during the first two months of the 1983 run (February and March) pulses of 1.25×10^{13} protons from the PS at a momentum of 19.2 GeV/c every 1.2 s, representing an average beam power of 32 kW. These experiments integrated in these two months slightly more than 10^{19} protons on target. Later that same year the BEBC experiment (PS180) received the same instantaneous intensity, but at a much lower duty cycle of about 1 pulse every 14.4 s on average, representing an average beam power of slightly more than 2.5 kW. These values together with the potentially maximum CERN-PS production capabilities today are summarized in Table 1.

The CERN-PS provides beam to different experiments by means of time-sharing. A dedicated cycle is allocated to each user and a series of these different cycles compose a super cycle, which is repeated continuously outside the 2 hours per day of dedicated filling of the LHC. Presently the CERN-PS can provide a beam with 3×10^{13} protons/pulse at 20 GeV/c with a maximum repetition rate of 1.2 s,

¹ At that time the TT1 line was supplying beam to ring II of ISR

provided the beam losses can be kept within defined limits. Assuming the above quoted beam together with a yearly physics run of 200 days of 22 hours per day and an average beam availability of 85%, a 37% duty cycle in the super cycle would be required to provide the required 1.25×10^{20} protons per year on the PSNF target. At present this required share of duty cycle in the super cycle is not available.

Table 1. Summary of past and potential PS beam production capabilities.

		Old Neutrino Facility		New Neutrino Facility	
		PS dedicated Feb-Mar 1983	PS parallel 1983 - 1984	PS dedicated	PS parasitic ¹⁾
Proton Momentum	[GeV/c]	19.2	19.2	20	20
Protons per pulse	[x 10 ¹³]	1.2	1.2	3	2.6
Maximum rep. rate	[s]	1.2	14.4	1.2	1.2
Beam energy	[kJ]	38	38	96	84
Average Beam Power	[kW]	32	2.5	80 ²⁾	70 ²⁾

¹⁾ The parasitic beam is in case the PSNF beam and the n_TOF beam will be produced on a single cycle.

²⁾ This average beam power is potentially available from the PS provided the losses are within the specified limits and that no other users are present in the PS super cycle.

However, combining the beam production of different experiments on a single cycle and thus making more efficient use of the CERN-PS, could alleviate the situation. The primary proton beam for the CERN neutron Time Of Flight (n_TOF) [6] experiments consists of a single bunch that is accelerated using an RF frequency for the accelerating cavities that is the 8th harmonic of the revolution frequency, resulting in a single bucket occupied by 1 proton bunch and 7 empty buckets that are potentially available to accelerate additional protons for the PSNF. Accelerating 3×10^{13} protons, using the 8th harmonic RF system results in a bunch intensity of 3.75×10^{12} protons. Provided the necessary systems are in place, 7 bunches, with a total intensity of 2.63×10^{13} protons, can be extracted and transferred to the PSNF target and the remaining single bunch, with 3.75×10^{12} protons can be extracted to n_TOF. Based on assumed super cycles, 200 days of 22 hours per day physics run per year and a machine availability of 85%, an estimate of the possible yearly proton production was made recently [7] and is summarized in table 2. About 73% of the yearly requested amount of protons could be accumulated on the target, providing the total requested amount of protons, 2.5×10^{20} , within less than 3 years.

Table 2: Overview of achievable PS primary proton beam intensity and beam power for the PSNF, taking 2 hours per 24 hours into account for dedicated LHC filling.

		Day time	Night time	Average	Total
Duration	[hrs/day]	9.2	12.8	-	22
Super cycle length	[s]	38.4	28.2	32.5	-
PSNF/TOF duty cycle in super cycle	[%]	28.1	33.3	33.1	-
Repetition rate	[s]	4.3	3.6	3.9	-
Beam Power	[kW]	19.7	23.3	21.8	-
Integrated proton intensity per day	[x10 ¹⁷]	1.73	2.86	-	4.6
Integrated proton intensity per run	[x10 ¹⁹]	-	-	-	9.2¹⁾

¹⁾ This figure is subject to changes depending on the final super cycle configuration.

5. (Re-)Construction of the PS neutrino facility

The existing tunnels and cavern can, after consolidation and some adaptations, be re-used to house the new facility. Since the facility is relatively close to the surface, simulations, addressing the radiological situation for the proposed beam power as given in table 1 and table 2, as well as the energy deposition in the various elements of the secondary beam production zone have been and are still being made [8]. The 150 m long primary proton beam line, the target and the focusing horn will have to be designed and constructed. The activation of the air in the decay tunnel is also an important point that needs to be addressed. A choice between a high performance ventilation system, running at lower than atmospheric pressure, or a helium filled or partial vacuum decay tube needs to be made. Further studies are required to estimate possible dose rates to which maintenance personnel could be exposed as well as the total induced radioactivity in the structure and its surroundings together with the releases to the environment via air and water pathways. The exact composition and status of the present hadron stopper are not known, apart from that it is made of steel blocks, positioned on a concrete slab, extending from the tunnel floor. It is unknown if the steel blocks are sealed to avoid infiltration of water. Putting back into operation the PSNF would require replacing the existing hadron stopper with a new design, taking into account the proposed beam power, radiological aspects and its efficiency stop charged particles and thus minimize the background for the near detector. At the same time it should be investigated if muon detectors could be integrated so that the target/horn and beam alignment can be done independently from the experimental detectors.

6. Present status and concluding remarks

CERN has expressed a genuine interest in the proposed experiment and the experimental collaboration is editing a concrete proposal for the CERN experimental committee. A preliminary feasibility identifying areas that deserve more detailed study has been made [9]. However, in order to address all items, to obtain a detailed cost estimate and a realistic project planning, a full design study must be undertaken. It is worth noting that the PSNF can also be used for other experiment and/or studies, such as neutrino cross-section measurements at very low energies, target R&D and detector studies.

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