The SPL-Fréjus physics potential

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An optimization of the CERN-SPL beam line has been performed which leads to better sensitivities to the θ_{13} mixing angle and to the δ_{CP} violating phase than those advocated considering baseline scenario.

1. Introduction

New user requirements had been asked at MMW04 [1] to set up new CERN-SPL [2] maximum energy keeping fixed at 4 MW the beam power. Then, an optimization of the energy as well as the secondary particle focusing and decay tunnel has been undertaken in the context of a Super Beam [3] searching for $\nu_\mu \to \nu_e$ ($\bar{\nu}_\mu \to \bar{\nu}_e$) appearance channels in a 440 kT fiducial volume water Cerenkov detector [4] located in an possible new underground laboratory at the Fréjus tunnel, 130 km from the CERN complex.

2. Fluxes

The secondary particle rates are given in table 1. One can appreciate the growing importance of the kaon rates and needless to emphasize the need of an experimental confirmation [5,6] of such numbers.

The focusing system optimized in the context of a Neutrino Factory [7,8] has been redesigned considering the specific requirements of a Super Beam. The most important point is that the pions to be focused should have an energy of the order of $p_\pi(\mathrm{MeV})/3 \approx E_\nu \gtrsim 2L(\mathrm{km})$ to obtain a maximum oscillation probability. In practice, this means that one should collect 800 MeV/c pions. The resulting fluxes for the positive (ν_μ beam) and the negative focusing ($\bar{\nu}_\mu$ beam) are show on figure 1. The total number of ν_μ ($\bar{\nu}_\mu$) in positive (negative) focusing is about $1.18(0.97)10^{12}/\mathrm{m}^2/\mathrm{yr}$ with an average energy of 300 MeV. The ν_e ($\bar{\nu}_\mu$) contamination in the ν_μ beam is around 0.7% (6.0%). Compared to the fluxes used in references [9,10] the gain is at least a factor 2.5. Using neutrino cross-sections on water [11], the number of expected ν_μ charged current is about 95 per kT.yr.

Table 1
Average numbers of the most relevant secondary particles exiting the 30 cm long, 1.5 cm diameter mercury target per incident proton (FLUKA).

E_k (GeV)	p.o.t/y $\times 10^{23}$	π^+	π^-	K^+ $\times 10^{-4}$	K^0 $\times 10^{-4}$
2.2	1.10	0.24	0.18	7	6
3.5	0.69	0.41	0.37	35	30
4.5	0.54	0.57	0.39	93	68
8.0	0.30	1.00	0.85	413	340

3. Physics potential

The physics potential of the new optimized SPL may be determined using GLoBES software [12]. Both the appearance and the disappearance channels have been used, and also five bins of 200 MeV each have been introduced. The π^o background have been rejected using a tighter PID cut compared to standard SuperK analysis [9]. The Michel electron has been required for the μ identification. As ultimate goal suggested by [13] a 2% systematical error is used both for signal and background.

The 90% CL sensitivity contour in the (Δm^2_{31},$\sin^2 2\theta_{13}$) plane after 5 years running with a positive focusing is shown on figure 2. With the new optimized setup, one expects to reach a limit on θ_{13} of 0.7^o. One may also appreciate on figure 3 the improvement on the combined sensitivity

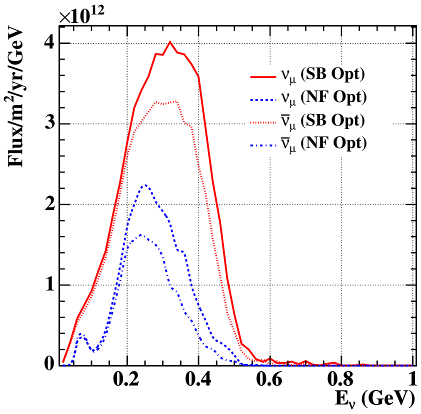

Figure 1. The ν_μ and the $\bar{\nu}_\mu$ fluxes obtained by optimizing the SPL for a Super Beam case ("SB Opt.") are compared to those obtained with a focusing system designed for a Neutrino Factory ("NF Opt.").

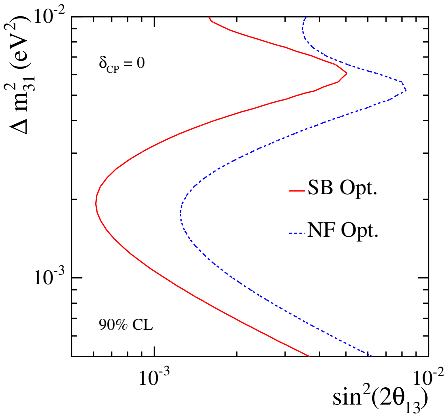

Figure 2. Comparison of the sensitivity contours with the new optimized setup and the original SPL design after 5 years of running with positive focusing.

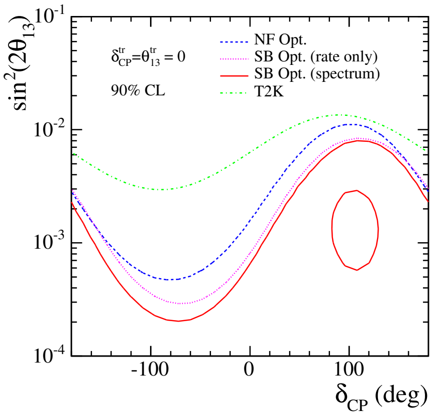

Figure 3. Comparison of the sensitivity on combined θ_{13} and δ_{CP} after 5 years of positive focusing. The T2K sensitivity contour has been derived from reference [13]. No mass hierarchy nor octant hierarchy ambiguity has been considered.

of $\sin^2 2\theta_{13}$ and δ_{CP} with the new optimization compared for instance to the T2K project [13]. One may also notice the impact of the analysis of the spectrum shape.

So, the optimized SPL beam line operating a Super Beam towards a megaton scale detector at the Fréjus tunnel has a great potential contrary to the strong statement advocated at the last SPSC/PSC Villars meeting [14]. Moreover using Beta Beam [15] and atmospheric neutrinos [16], the CERN-Fréjus project may leads to an unique physics case in Europe.

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