PROCEEDINGS OF SCIENCE

PoS(NuFact08)053

Optimisation of a neutrino factory

Patrick Huber[*]
CERN
E-mail: `pahuber@vt.edu`

Michael S. Zisman[†‡]
Lawrence Berkeley National Laboratory
One Cyclotron Road, Mail Stop 71R0259, Berkeley, CA 94720 U.S.A.
E-mail: `mszisman@lbl.gov`

We review the open issues in the optimization of a neutrino factory experiment. While the general features and parameters of a neutrino factory are well understood, there are some details that have significant impact on the physics optimization.

10th International Workshop on Neutrino Factories, Super beams and Beta beams
June 30 - July 5 2008
Valencia, Spain

---

[*] Speaker.

[†] Speaker.

[‡] Supported by the Director, Office of Science, Office of High Energy Physics, of the U.S. Department of Energy under Contract No. DE-AC02-05CH11231.

The specifications of a neutrino factory have recently undergone a major revision as a result of the International Scoping Study (ISS) and can be now regarded as quite well defined [1]. Most notably, the final muon energy in the storage ring has been reduced from 50 GeV to 25 GeV. The current setup includes two storage rings serving two baselines independently, where each baseline receives one half of the available muons. The total available number of useful muon decays of μ^- and μ^+ combined is planned to be $10^{21}\,\mathrm{y}^{-1}$. However, there remain some open issues that may change the physics reach and optimization discussion. Our goal here is to review these questions, the rationale behind them, and the corresponding answers.

1. How does the total number of available muon decays change depending on the decay ring geometry? Will there be a significant difference between operation with one or two baselines? This question arises from the attempt to fine tune the optimization of a two baseline setup. The obvious way to control the relative statistical weight of data samples at the two baselines is to adjust the relative detector masses. This adjustment, however, has to be done in an *a priori* fashion and will be very difficult to change in response to the acquired data. The ability to change the fraction of beam sent to one baseline would allow control of the event sample size on line.

   The current figure of 10^{21} useful muon decays per year is mainly governed by the assumptions on the maximum allowable target power, which currently is taken to be 4 MW. The decay ring geometry changes the number of useful decays only in the range of 10 – 15%, which is related to the ratio of the length of the arcs and the straight sections of the storage ring. In a configuration with two racetrack-shaped storage rings, there is a considerable level of flexibility to allocate a different fraction of muons to the two baselines, *e.g.*, in case one detector is turned off during maintenance the other baseline could receive all muons. Obviously, in cases with only one storage ring this flexibility would be lost.

2. Is the ratio of muons to anti-muons fixed at 1 : 1? In the literature, see, *e.g.*, [2], there have been initial attempts to determine the optimal neutrino to anti-neutrino running fraction to measure CP violation for non-neutrino-factory experiments. Most of these attempts seem to indicate that a true optimization would require knowing the mass hierarchy and whether δ_{CP} is within either the interval $[0,\pi]$ or $[\pi,2\pi]$. However, no detailed study has been presented so far.

   The actual ratio will be not precisely one muon for one anti-muon, but this ratio is not a parameter that can be changed at will. On the other hand, it will be very well known. Current simulations indicate a ratio of around 1.1 : 1.

3. How feasible is muon polarization? In principle, detailed control of the muon polarization allows changing the $\bar{\nu}_e/\nu_\mu$-ratio in the beam over a wide range with possible implications for detection technologies [3]. On the other hand, a complete lack of control would, for the same reason, lead to large systematic errors.

   In the baseline design, muons are produced with a small natural polarization that varies along the bunch train. Simulation results on how well this polarization is preserved are not clearcut, which probably is related to the fact that this was not considered to be a major issue. It can be ensured that the net polarization is zero to a very high precision, making this a negligible source of systematic error.

4. Is 10^{21} useful decays per year the maximal flux? Obviously, most measurements at a neutrino factory, at least within the context of oscillations, are not yet systematics limited and thus would profit from increased luminosity.

   Currently, there are no known, realistic ways to increase that number without a corresponding increase in target power. The running time per year (10^7 s) was specified somewhat conservatively, so favorable operational experience could give a modest gain in annual intensity, perhaps a factor of two.

References

[1] J. S. Berg *et al.* [ISS Accelerator Working Group], arXiv:0802.4023 [physics.acc-ph]. T. Abe *et al.* [ISS Detector Working Group], arXiv:0712.4129 [physics.ins-det]. A. Bandyopadhyay *et al.* [ISS Physics Working Group], arXiv:0710.4947 [hep-ph].

[2] P. Huber, M. Lindner, M. Rolinec and W. Winter, Phys. Rev. D **73** (2006) 053002 [arXiv:hep-ph/0506237].

[3] A. Blondel, Nucl. Instrum. Meth. A **451** (2000) 131.