Particle Focusing Optimization and Stress Analysis of a Magnetic Horn

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Abstract

A neutrino oscillation experiment aims to the observation of the transformation (oscillation) of a neutrino of a given flavour (i.e.: family) into a neutrino of a different flavour. The study of such oscillations is a powerful tool in the understanding of the fundamental interactions in particle physics. A beam of neutrinos is produced through the decay of charged pions which in turn are produced in the collision of high energy accelerated protons impinging on a thick target. Neutrinos are detected hundreds of kilometres away from the target (this enhances the oscillation probability) it is therefore necessary to create a beam of highly collimated pions in order to maximize the fraction of neutrinos emitted in the detector solid angle acceptance. A series of magnetic horns is the device used to focus charged particles produced off the target (Figure 1). Each horn consists of two coaxial conductors which encompass a closed volume. Every few ms, synchronized with the proton beam pulse, a current of about 300 kA is injected in the conductor so as to produce a toroidal magnetic field varying as 1/r where r is the distance from the horn axis (the maximum field value is about 2 T). The choice of the focusing system is a key task of the experiment design since it affects directly the physics potential of the whole experiment [1]. A COMSOL Multiphysics® study (AC/DC and Particle Tracing) is performed in order to optimize the inner conductor shape to obtain a high focusing over a wide range of both the pion energy and emission angle. The current pulse creates a magnetic pressure on the horns wall. The assessment of the stress levels are important information in the device project phase. A multiphysics analysis is performed to calculate the total displacement and von Mises stress along with the thermal deformation and temperature distribution. COMSOL Multiphysics® will be used for the first time systematically as a simulation tool for the design of a neutrino beam for the proposal of the LAGUNA-LBNO experiment [2]. LAGUNA-LBNO is a world-class experiment which will increase the discovery potential of the already successful accelerator based neutrino oscillation experiment like T2K which has recently confirmed the discovery of the muon-neutrino to electron-neutrino oscillation [3].

Reference

[1] Phys. Rev. D87 (2013) 012001.
http://arxiv.org/abs/arXiv:1211.0469
[2] www.laguna-science.eu
A. Rubbia, J.Phys.Conf.Ser. 408 (2013) 012006
[3] http://t2k-experiment.org.

Figures used in the abstract

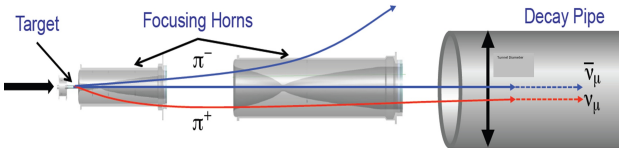

Figure 1: Neutrino production beam line layout. From left to right it is visible the proton beam, the target, the two horns system and the decay tunnel where focused positive pions decay into neutrinos. At the same time negative pions are defocused so that the emitted neutrinos do not contribute to the beam.