Status of a magnetic horn for a neutrino factory

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Abstract. After the proposal during Nufact99 to use a horn as pion collection device, a first prototype has been designed and built. This paper reviews the current status of the Neutrino Factory horn studies at CERN.

1. Introduction

Since Nufact99[1] an intense study about the possibility of using a horn instead of a solenoid to collect pions has been launched at CERN. After 3 years the first prototype of the horn has been produced and together with a prototype of 30 kA, 1 Hz power supply, is ready for mechanical and electric tests.

2. Horn beam dynamics and new horn design

A horn consists of two coaxial conductors which encompass a closed volume. The nominal current of 300 kA, pulsed at 50 Hz, generates in that volume a toroidal magnetic field whose intensity varies as the inverse of the distance from the horn axis. Pions entering the magnetic volume are bent by the field and focused in the direction of the decay channel section. The particular horn shape is chosen to maximize the pion flux in the transverse acceptance of the 1.8 T solenoidal decay channel and to maximize the muon flux around 200 MeV kinetic energy. The matching between the horn and the decay section is optimized by varying the relative distance between the two elements and adjusting the horn shape to take into account the superposition between the solenoid fringe field and the horn field. For the latest horn design the minimum neck radius is increased to better accommodate the piping for the target and to leave enough free space for the mercury explosion. To recuperate the magnetic field volume lost by increasing the inner radius, the horn running at 300 kA is enclosed in another 600 kA horn (Fig. 1) which acts as a reflector. The pion yield obtained is 0.0013 π's per proton on target counted in a transverse normalized acceptance of 1.5 $cm\,rad$ and in an energy (total energy) range of $0.3\,GeV < E < 0.6\,GeV$. The best horn shape is still under study and strongly depends on the primary pion spectrum. The present shape is optimized for the pion spectrum produced by MARS[2] with a 2.2 GeV proton beam impinging on a 26 cm long mercury target sitting inside the horn

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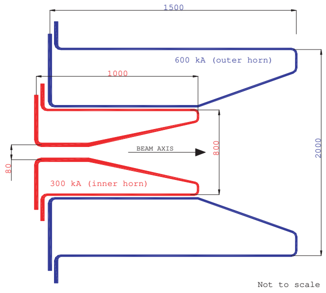

Figure 1: Double horn scheme. The reflector at 600 kA encloses the inner horn at 300 kA.

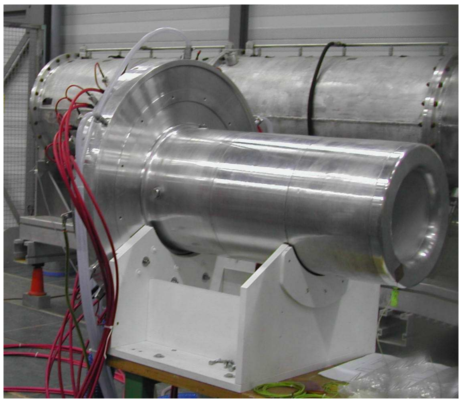

Figure 2: Inner horn first prototype.

neck. For low proton energy (few GeV) the error on the differential pion production cross section is quite large; the HARP measurements will provide the answer needed to have the final horn shape.

3. Mechanical and electric tests

The two horns operate at 50 Hz with a current pulse length of $100\mu sec$, the inner horn at 300 kA, the reflector at 600 kA. The maximum mechanical and thermal stresses are concentrated in the neck of the inner horn. From past experience the horn life-time is estimated to $2 * 10^8$ pulses at 95 C.L. which, at 50 Hz repetition rate, corresponds to about 6 weeks. A campaign of tests has been launched to check the final inner horn life-time. The original planning was the following:

- Inner horn prototype construction (Fig. 2 and 3)
- Construction of a discharge power supply of 30 kA, 1 Hz, pulse length of 100μs
- Measurement of horn mechanical vibration eigenfrequencies

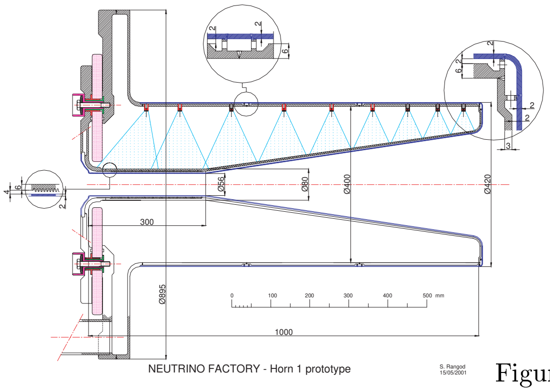

Figure 3: Inner horn first prototype technical drawing

Figure 4: The horn neck internal surface with screw shape.

- Construction of a discharge power supply of 300 kA, 1 Hz, pulse length of 100μs
- Construction of a discharge power supply of 300 kA, 50 Hz, pulse length of 100μs

Unfortunately, due to the CERN budget reduction, the program has been consistently reduced and limited to the first three points plus a small upgrade of the existing power supply which is still under study.

3.1. Horn mechanical design and construction

The horn material has been shaped and assembled entirely in the CERN Workshop. The aluminium alloy AA 6082-T6 for the conductors is the same used the CNGS horn. This particular alloy should warrant the life-time of at least 6 weeks for a maximum allowed mechanical stress of 14.5 MPa. To simplify the construction, the horn is entirely welded. The electron beam welding method reduces the mechanical characteristics in the welded areas by only 20% and respects the required geometry precision. In addition to the usual water spray system for cooling, a layer of water flows on the external surface of the inner conductor in a closed circuit, parallel to the horn conductor (Fig. 3) to evacuate the 39 kW due to joule losses in the conductor. Moreover the internal horn neck surface has been increased by a factor of two by shaping it like a screw (Fig. 4).

3.2. Effect of radiations on the horn life-time

The evaluation of the radiations on the horn life-time has started. Preliminary results suggest that the integrated neutron flux over a period of 6 weeks will cause approximately 10 dpa (displacements per atom), which seems to be the limit before an important variation of the material mechanical properties takes place. Unfortunately it doesn't exist a good experience about the behavior of the chosen alloy after irradiation. Some conclusions can be drawn from a similar alloy, the 6061-T6[3], which is largely used in nuclear reactors. For 10 dpa, this alloy shows a few percent variation of the mechanical properties and less than 1% variation of the density due to the formation of helium and hydrogen (swelling). To finalize the study it is necessary to irradiate some samples of the 6062-T6 and to measure the mechanical properties until at least 100 dpa.

4. Conclusion

The first neutrino factory horn prototype has been built. The mechanical response to an excitation of 30 kA at 1 Hz will soon be determined.

References

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