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MUON TRANSPORT CHANNELS WITH LONGITUDINAL MAGNETIC FIELD

I.Bogdanov, S.Kozub, V.Pleskach, P.Shcherbakov, V.Sytnik, L.Tkachenko, V.Zubko
Institute for High Energy Physics (IHEP), Protvino, Moscow region, 142284 Russia
N.Holtkamp, I.Terechkine
Fermi National Accelerator Laboratory (Fermilab), P.O. Box 500, Batavia, Illinois 60510, USA

INTRODUCTION

The Neutrino Factory (NF) concept includes several channels that treat muon beam to allow its capture into the accelerating part of the complex [1]. There must be a "drift" channel where pions decay generating muons. In this channel a correlation develops between muon energy and its position (mass separation). Due to a very high beam emittance and energy spread after the target, a high magnetic field and large channel bore are required to have a satisfactory beam transport efficiency. There must be a "phase rotation" channel, where the correlation developed in the "drift" channel is used to reduce muon beam energy spread. Electrical field of low-frequency RF cavities or induction sections accelerates or decelerates different parts of the beam changing its energy distribution. Both RF and LIA channels require longitudinal magnetic fields similar to that in the drift channel. Because the action principle of the induction section is similar to that of a Linear Induction Accelerator (LIA), we will call the channel with the induction sections a LIA channel. After the "phase rotation" channels reduce the energy spread, an additional "cooling" channel is needed to reduce the beam emittance. The ionization-cooling scheme is not finalized yet, but it is developed to the extent that allows a preliminary analysis of the channel magnetic system. One of the approaches to the cooling system makes use of an alternating magnetic field of high strength. This report discusses main features of the magnetic systems for the decay, phase rotating, and cooling channels of the NF version developed at FNAL.

1 DRIFT CHANNEL

The length of the drift channel is 50 m. A preliminary study has shown that even if the magnet bore is getting smaller when the magnetic field increases (in accordance with the equation $Br^2 = 0.1125\ T{\cdot}m^2$), the cost of magnets in the channel grows. A reasonable compromise between magnetic field strength and bore size was achieved by choosing B=1.25 T and R=0.3 m for the first channel. The length of solenoids in the drift channel was chosen to be 4.7 m, so ten magnets are used in the channel with 0.2-m gaps between them. The solenoid coil is placed in a cryostat that provides needed mechanical support to the coil structure with thermal insulation allowing the use of NbTi wire at 4.2 K. The axial force on the magnet in the middle of the string is 170 kN. For the first and the last magnets in the string this force is 230 kN. Radial pressure developed at the coil location is ~0.6 MPa, that makes the magnet design quite straightforward. The solenoid has a two-layer coil wound using NbTi cable. Dimensions of superconducting (SC) cable, quantity of copper for stabilization, and nominal-to-critical current ratio were determined taking into account safe evacuation of 11 MJ energy stored in the magnet.

The coil is cooled by liquid helium flowing through copper piping soldered to copper shells. A copper thermal shield cooled by liquid nitrogen is used to reduce heat leaks to the inner and outer surfaces of the SC coil. Space inside the cryostat is pumped out to further improve thermal insulation. All the magnets are connected in series. One 180-kW power supply is used to power the chain of the solenoids; it takes 200 seconds to reach the nominal current of 6 kA.

The quench protection system uses an external dump resistor to extract the stored energy. Simulation of quench spreading through the coil was made for the case when the quench was provoked on the outer boundary of the inner layer. With a quench detector threshold of 1 V and a time delay of 100 ms, ~97% of stored energy was dissipated outside the cryostat. The amount of energy dissipated in the coil was sufficient for adiabatic heating of the coil up to 180 K in the hottest point.

2 LIA-BASED PHASE ROTATION CHANNEL

The main difference between the drift channel and the LIA channel is that magnets in the LIA channel are placed inside the accelerating structure of the LIA. This puts a strict limitation on the magnet length that cannot exceed the length of the LIA section. Moreover, the LIA accelerating gap is formed by surfaces of the two neighboring magnet cryostats [2]. For this study, 1-m LIA section length was chosen with bore diameter of 0.6 m and a longitudinal magnetic field of 1.25 T. The total number of magnets in the channel is 100. The length of each magnet is 0.85 m, and the gap between cryostats is 0.15 m. The coil design is very similar to that of the coil in the first channel. The radial pressure at the coil location is ~0.6 MPa. For a magnet in the middle of the channel, the axial compressive force is ~150 kN; for the magnets at the ends, it is ~200 kN. The total energy

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