40-80 MHz MUON FRONT-END FOR THE NEUTRINO FACTORY DESIGN STUDY*

G.Prior, S.S. Gilardoni, CERN, Geneva, Switzerland
A.E. Alexandri, University of Patras, Rio, Greece

INTRODUCTION

A Neutrino Factory is a machine able to produce ~10^{21} neutrinos per year. Its main objective is to do precision measurements of the neutrino oscillation parameters and probe physics beyond the Standard Model such as CP-invariance violation.

The basic concept of the Neutrino Factory is to produce a high-intensity, high-energy neutrino beam with a very well-known energy spectrum and without the contamination of unwanted neutrino flavours. For this purpose a pulsed proton beam of 4 MW will collide with a liquid mercury (Hg) target, after being accelerated in a FFAG/synchrotron. The outcome of the collision will be the production of pions and kaons, which then enter in the muon front-end. The muon front-end consists of a pion decay channel and longitudinal drift, followed by an adiabatic buncher, a phase-rotation system and an ionisation-cooling channel. The produced muons from pions decay are accelerated by being sent into two Recirculating Linac Accelerators (RLAs) and a FFAG ring. Then they are injected in two decay rings and remaining there for the time that is needed for them to decay into the neutrino beam.

DRIFT

Drifts of 10 m, 20 m and 30 m before the rotator were considered in the simulation in order to see the percentage of remaining pions that decay into useful muons. The input beam consists of the 1000 first entries (1989 μ^- and 1760 π^-) and a reference particle was set in the centre of the beam, using the beam mean time as calculated <t> = 50.7 ns. The muons number as a function of their z position for different momentum and acceptance cuts (see Table 1) are given in Fig. 1 and 2.

Cuts	n	n0	n1	n2
$100 < p_z < 300$ MeV/c	N	Y	Y	Y
A_L = 150 mm	N	N	Y	Y
A_T = 150 mm	N	N	Y	N
A_T = 30 mm	N	N	N	Y

Table 1: Momentum and acceptance cuts used in the simulation, Y (cut used) and N (cut not used).

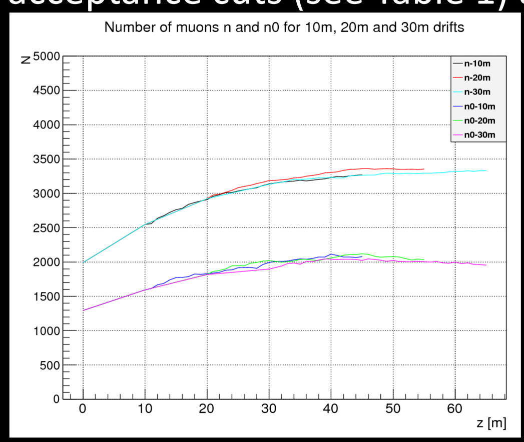

Figure 1: Total number of muons n and n0 as a function of z for three drift lengths.

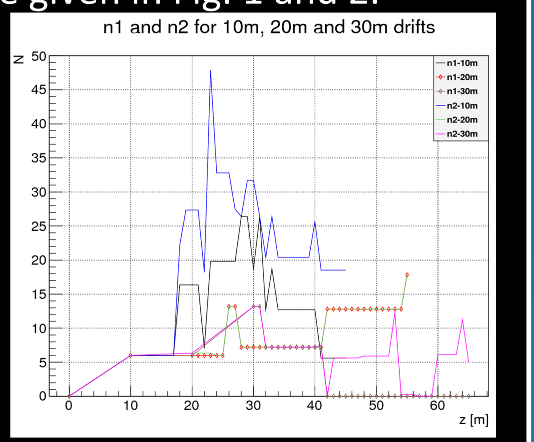

Figure 2: Total number of muons n1 and n2 as a function of z for three drift lengths.

The number of muons falling in the acceptance cuts of n1 and n2 is not increasing for a change of drift before the rotator from 10 m to 20 m, but it is doubled using the 30 m drift.
The number of muons falling in the acceptance cuts of n1 and n2, after entering the rotator is:

-> multiplied by 3 for a 20 m drift
-> bigger for a 10 m drift but falling after 20 m of rotator
-> very small for a 30 m drift

As a consequence, the rotator RF phase needs to be adjusted and future studies are needed.

MAGNETIC FIELD & CAVITIES LAYOUT

In ICOOL, a coil geometry configuration using a model made of current sheets was used for the computation of the magnetic field. The simulation included one (or several depending on the drift length) 10 m long coil, and a series of 0.5 m long coils of 60 cm radius and 10 cm thickness at a current setting of 14.24 A/mm², providing a field on axis of 1.78 T (see Fig. 5).

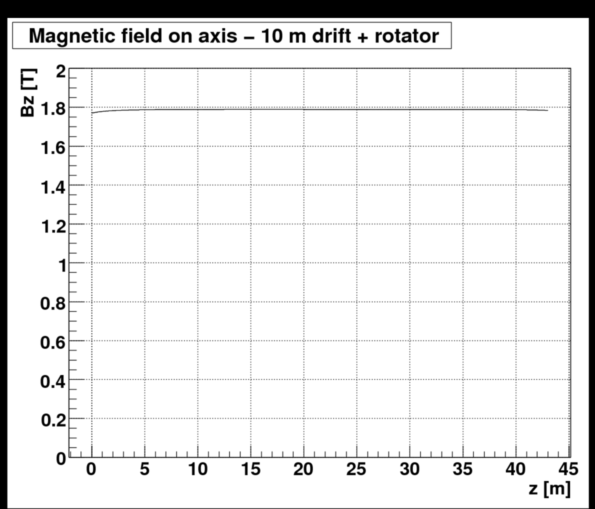

Figure 5: magnetic field on axis for a 10 m drift and 30 m rotator configuration.

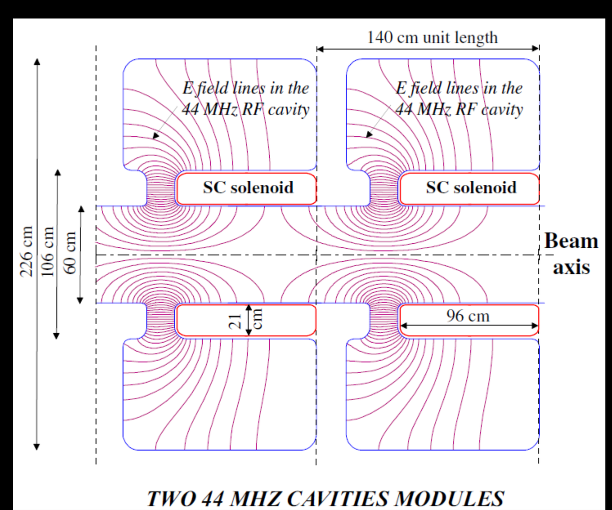

Figure 6: 44 MHz cavity dimensions and electric field lines.

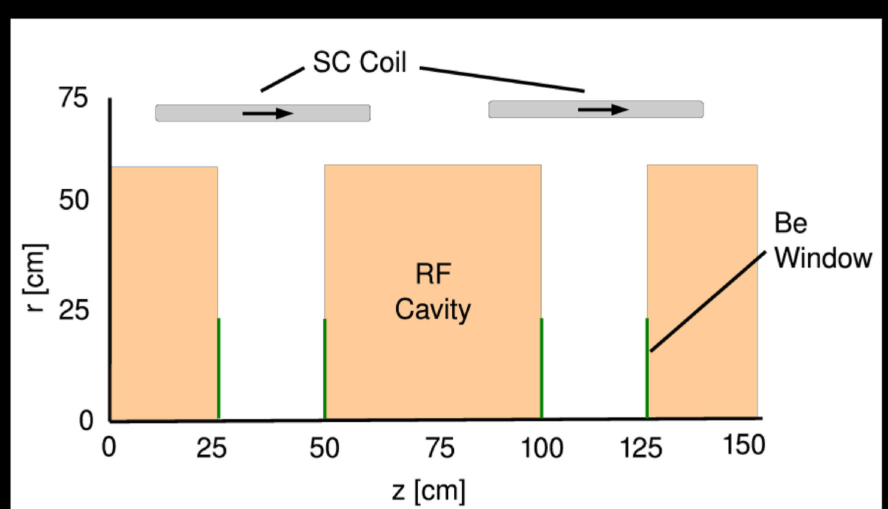

Figure 7: Schematic of the IDS-NF rotator cell .

In Figure 6 the 44 MHz cavity dimension and electric field lines are shown.
A schematic of the cavity layout for the rotator in the IDS-NF configuration (200-231MHz) is given in Figure 7 for comparison.

CONCLUSION

The 44-88 MHz lattice configuration has been studied for the rotator section using the IDS-NF baseline beam and ICOOL code. Different drift lengths (without change of the lattice configuration in comparison with previous studies) have been studied showing a very low performance in the IDS-NF acceptance and in comparison with past studies. By increasing the space between the RF cavities, a gain in the number of the muons captured in the acceptance cuts was shown. Future optimization studies with an increased RF bucket height, different RF cavities spacing, re-adjustment of the phase and reference particle time, will be done.

THE 44- 88 MHz FRONT-END

This project is presenting a revision of an alternative, muon front-end scenario which was working in a single bunch-to-bucket mode, using lower RF frequencies, in comparison with the International Design Study for a Neutrino Factory (IDS-NF) [1]. In past simulations [2,3,4] the beam was produced in FLUKA [5] using a 2 GeV proton beam on a 26 mm long Hg target immersed in a 20 T solenoid field.
The front-end was made of:

- a 30 m long decay channel in 1.8 T solenoid field
- a 30 m long rotator in 1.8T solenoid field, containing thirty 1 m long 44 MHz cavities, operating at -90° phase and 2MV/m gradient
- a cooling section with 44 MHz cavities and hydrogen absorbers
- an accelerating section with 44 MHz cavities
- an additional cooling section with 88 MHz cavities

SIMULATION

The study of the tracking in the rotator part was done using ICOOL [6] version 3.20 and ROOT [7] as a graphical interface. The beam was produced in MARS [8] using a proton beam of kinetic energy 8 GeV on a Hg-jet target in a solenoid field tapering down from 20 T at target to 1.75 T, 12.2 m downstream. The output negative pions, muons and kaons were taken 12.2 m downstream of the target and served as input to ICOOL.

SPACING BETWEEN THE CAVITIES

No spacing between the RF cavities was considered at first. 1 m long cells containing each 1 m long cavity were used. The rotator consisted of seven cells triplets, followed by one cell and finally seven cells. The cavities had 44 MHz frequency, a phase of 180° and a 2 MV/m gradient.
An additional study was done using spacing between the cavities. Here a cell was made of 0.5 m drift, plus 1 m cavity, 0.5 drift and 1 m cavity, while the frequency, the RF phase and the gradient were unchanged. Results from the simulation with a spacing between cavities is given in Fig. 3 and 4.

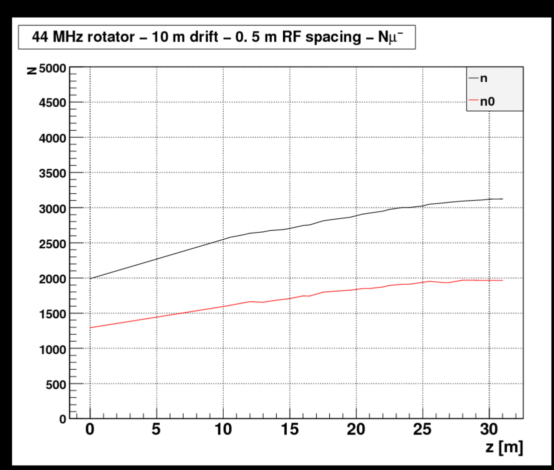

Figure 3: Total number of muons n and n0 as a function of z for a configuration with 0.5 m spacing between cavities.

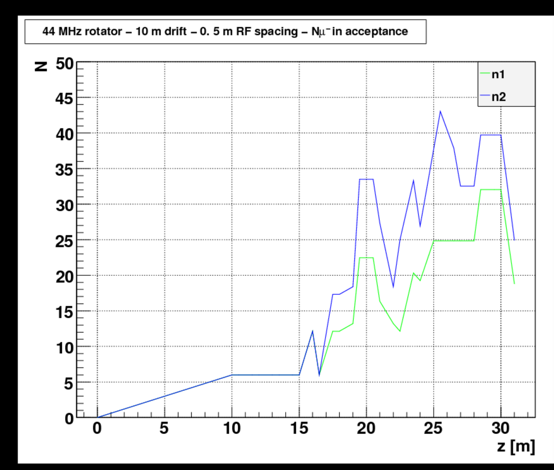

Figure 4: Total number of muons n1 and n2 as a function of z for a configuration with 0.5 m spacing between cavities.

By using a 0.5 m spacing between the RF cavities:

-> 1/50 muons are falling in the n2 acceptance cuts (1/100 are accepted for the lattice with no space between cavities)
-> the momentum spread is reduced from 11% to 1%
-> the total number of cavities is 14 (instead of 30 for the lattice with no space between cavities)

MUON MOMENTUM SPREAD

Figures 8 and 9 are showing the muon momentum spread for a 10 m drift and 30 m rotator, with spacing between the cavities, before the drift and at the end of the rotator.

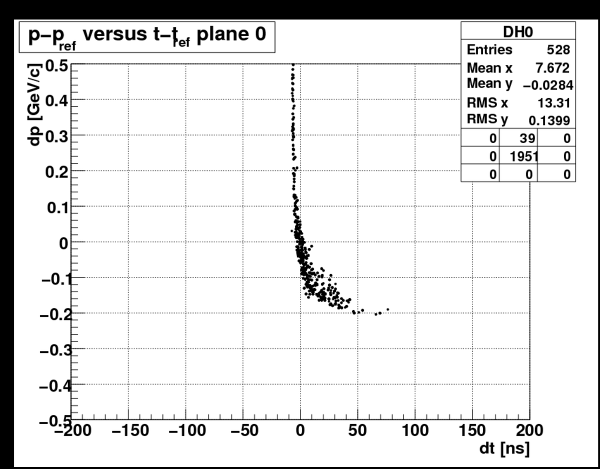

Figure 8: Muon momentum spread before the drift (11%).

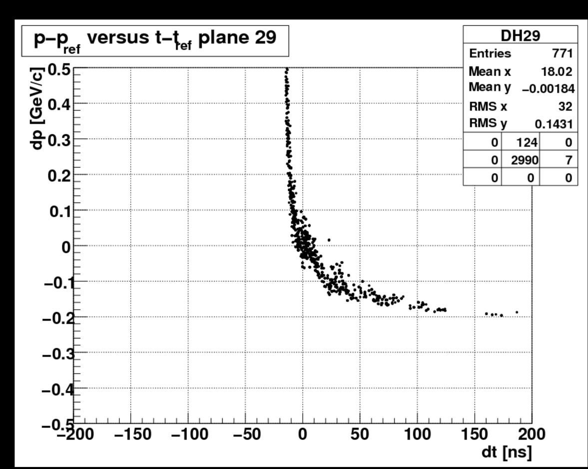

Figure 9: Muon momentum spread after the rotator (1%).

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