Muon phase rotation with magnetic compression

Jaroslaw Pasternak † ‡§

† CERN, 1211 Genève 23, Switzerland

‡ Institute of Theoretical Physics, University of Wroclaw, Poland

Abstract. Combining RF phase rotation with magnetic compression is proposed to improve the longitudinal collection in the front end of a neutrino factory. After phase rotation, the bunch traverses a magnetic chicane made of alternating gradient magnets in which the beam dynamics is discussed.

1. Introduction

At the exit of the pion decay channel, the muon beam has a vary large energy spread. Various schemes have been developed to accept a large fraction of muons in the longitudinal phase space. In the CERN neutrino factory reference scenario [1], the bunch to bucket principle is adopted and the time structure is the same for the proton, pion and muon beams. The proton driver delivers a beam with a 44 MHz bunch frequency and the RF frequency applied to the muons is either 44 MHz [1] or 88 MHz solution [2]. If the muon beam line is straight, the length of the muon bunch at the end of the phase rotation section exceeds the RF period in the cooling section or in the downstream accelerator and particles are lost. To improve the transmission, phase rotation may be followed by magnetic compression so as to force particles of different momenta to arrive at about the same time in the RF field. The same idea is discussed for a different lattice in [3].

2. Phase rotation

Solenoidal focusing in a phase rotation channel has been proposed in conjunction with a magnetic compression in [4]. However, recently, a system of beam combination has been developed to reduce the beam power in the target and the pion collector [5] using a lattice of alternating gradient magnets all along the decay channel. It is then interesting to explore the possibility of extending the AG structure to the phase rotation section. The line has a 2 π cm rad physical acceptance. An RF packing factor equal to 1/2 is obtained with a triplet cell which offers to the RF cavities long drift spaces with small β values in both transverse planes. The field is assumed to be 2 MV/m and the energy spread can be reduced by 64 MeV. In such a configuration, the magnetic and RF fields are fully decoupled, the design is simple and the magnetic energy is stored in a smaller volume than in solenoids wrapping the cavities. The phase rotation channel consists of eight triplet cells matched to the upstream FODO

---

§ To whom correspondence should be addressed (Jaroslaw.Pasternak@cern.ch, jarpast@ift.uni.wroc.pl)

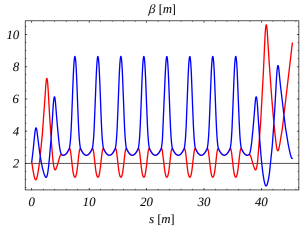

Figure 1. Optical β variations in the phase rotation channel.

Table 1. Magnet parameters for a 2 π cm acceptance.

	k $[m^{-2}]$	β [m]	g [T/m]	r [m]	B [T]
Upstream section	1.94	7	1.65	0.37	0.62
Triplet F-quadrupole	2.25	4.5	1.91	0.3	0.57
Triplet D-quadrupole	-1.79	8.5	1.52	0.41	0.63
Downstream section	1.4	10.5	1.34	0.45	0.61
Compressor quadrupoles	0.7	3.9	0.74	0.88	0.66
Compressor dipoles	-	-	-	-	0.55

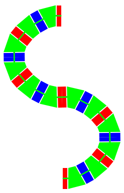

Figure 2. Layout of the compressor.

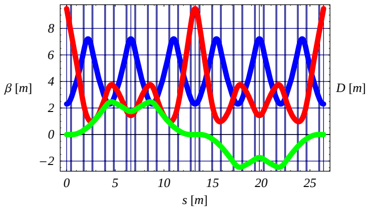

Figure 3. β_h (dark gray),β_v (black) and orbit dispersion (light gray) in the compressor.

decay channel and to the downstream magnetic chicane. The optical functions are plotted in Fig.1 for the central muon momentum of 260 MeV/c.

The magnet parameters based on the linear optics are listed in Table 1. The apertures are large and the detailed behavior of the beam in the fringe field has not yet been analyzed. The pole tip field is modest and conventional magnets can be used.

3. Magnetic compression

Magnetic compression minimizes the momentum dependence of particle transit time by balancing the momentum variations of particle velocity and trajectory length. In other terms, the beam line is isochronous. The γ-transition γ_T of the line is related to the orbit lengths and has been determined by longitudinal tracking. It was found optimum at 1.76. Due to the change of sign of the deflections, the latice of a compressor is often called a "chicane". The present chicane consists of two periods (Fig. 2). Each period is an achromat of three FODO cells whose optical functions are plotted in Fig.3 and magnet parameters given in Table 1.

The bunch compression is manifest when the longitudinal phase portraits at the

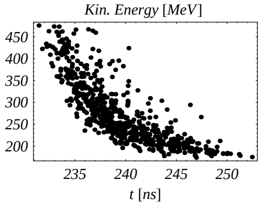

Figure 4. Longitudinal distribution after phase rotation.

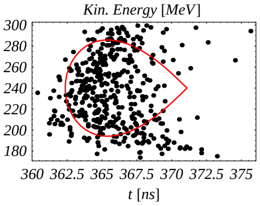

Figure 5. Longitudinal distribution at compressor end.

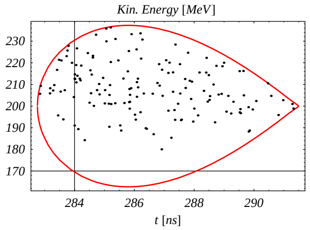

Figure 6. Bucket population after RF rotation.

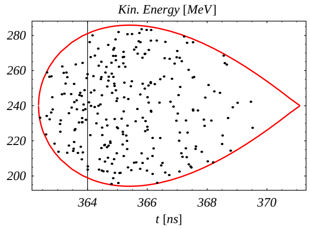

Figure 7. Bucket population after compression.

end of the phase rotation channel (Fig. 4) and at the end of the compressor (Fig. 5) are compared. The increase of population of the RF bucket due to magnetic compression is shown in Figs. 6 and 7.

4. Summary

An alternating gradient lattice has been described for both phase rotation and bunch compression. The interest of bunch compression has been shown since the increase of RF bucket population by a factor 1.8 largely exceeds the extra particle losses due to muon decay along the 30 meters of the chicane. However, a full measure of the transmission has yet to be done taking into account the aperture restrictions imposed by curved structures. Sextupolar schemes especially are under study. Last, a careful comparison with solenoidal channels has to be performed both in terms of performance and engineering aspects.

References

[1] B. Autin at al., The CERN Neutrino Factory Working Group. Status Report and Work Plan, CERN-NUFACT Note Nr 28.
[2] K. Hanke, Simulation work at CERN, *These Proceedings.*
[3] G.H. Rees, Muon front end chicane and acceleration, *These Proceedings.*
[4] B. Autin, K. Bongardt, J. Pasternak, A. Verdier, Longitudinal capture of muons using bunch compression, CERN-NUFACT Note Nr 98.
[5] B. Autin, F. Meot and A. Verdier, Four pion beam recombination, *These Proceedings.*