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SPL accumulator and compressor scenarios for neutrino factory

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A new scenario of the proton driver based on the CERN SPL is discussed, providing two operational modes of 3-bunches and 1-bunch, in addition to the 6-bunches scenario proposed in NuFact'06. The H^- beam accelerated up to 5 GeV with the SPL is stored in an accumulator and is compressed to ~2 ns bunch length in a compressor with phase rotation. Possible lattices of the accumulator and compressor for the new scenario have been found. The 1-bunch mode is rather challenging due to the large bunch intensity of 10^{14} protons. Though a difficulty in the accumulation of the fewer number of bunches using the charge exchange method is identified, the H^- injection scheme proposed here will make it possible. The bunch compression is also studied, and it is found that the space charge effect would not be a serious issue. The 3-bunches and 1-bunch scenario have been proven feasible.

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1. Introduction

The number of bunches in a neutrino factory proton driver is relevant to the muon accelerators and storage ring. We discuss a new scenario of fewer number of bunches in the proton driver based on the CERN SPL (Superconducting Proton Linac), in addition to the 6-bunches scenario proposed in NuFact'06 [1] and followed by the accumulator and compressor lattice design studies [2,3]. The ISS set the requirement ranging in 1 to 5 or 6 bunches, and the recent IDS proposed three bunches as the base line. The one bunch option would also be interesting. The H^- beams accelerated up to 5 GeV with the SPL are stored in an accumulator and are compressed to ~2 ns bunch length in a compressor with phase rotation. The minimum accumulator circumference is a key factor for a scenario of fewer number of bunches. It is estimated to be about 180 m for 5 GeV beam including rather long straight section for the charge exchange injection method. On the other hand, when the bunch length in the accumulator is 120 ns as selected in the 6-bunches scenario, the length needed for one bunch is about 50 m with some space for the extraction kicker rise time. It is, however, shorter than the minimum circumference by a factor of ~3. Therefore a reasonable scenario would be to retain 3-bunches and 1-bunch operation modes using the same accumulator and compressor.

2. SPL beam for accumulation

The number of accumulation turns depends on the bunch length, the SPL peak current and the accumulator circumference. The bunch length in the accumulator is assumed to be 120 ns in any option as taking into account the energy spread in the compressor at the end of phase rotation.

Table 1. SPL beam for accumulation.

The bunch profile is assumed to be flat but with slopes at the both ends for 3- and 6-bunches accumulation. It will be parabolic for 1-bunch accumulation to adopt an rf compensation for the longitudinal space charge force. A dedicated research and development to achieve the peak current for 1-bunch accumulation is necessary. The total intensity accumulated in one cycle is 10^{14}protons.

No. of accum. bunches	6	3	1
Peak / Average current (mA)	60/40	72/35	105/13
Pulse duration (ms)	400	460	1200

3. Accumulator and compressor

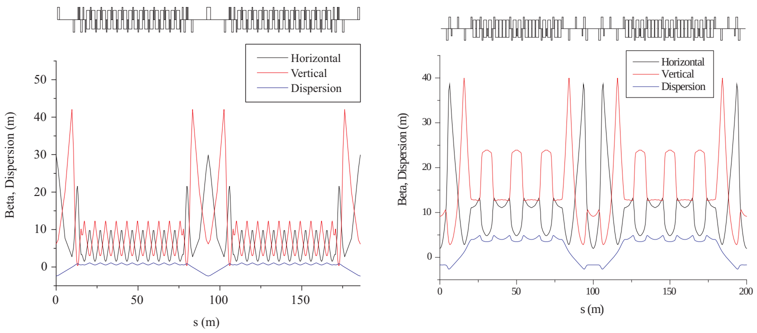
Possible accumulator and compressor lattices for the new scenario has been found and shown in Fig. 1. The lattices for 6-bunches scenario can be found in Ref [2,3]. The accumulator is assumed to be isochronous to conserve the energy spread (0.1%) during the accumulation, which is relevant to the bunch length after phase rotation. However, an isochronous ring would not be robust against instabilities such as transverse microwave instability. Thus an accumulator having non-zero slippage factor and equipped with barrier rf cavities would be an altenative.

H^- beam injection, the most delicate issue in the accumulator, has closely been studied, investigating two dimensional transverse painting to reduce the number of particle hits to the foil. It was found that for the 6-bunches scenario, the maximum foil temperature could be about

2,000 K with the transverse emittances of 3 πmm-mrad (r.m.s. physical), while the criterion coming from the evaporation is about 2,500 K. On the other hand, for the fewer number of bunches especially for 1-bunch, the beam emittance should be increased and becomes too large for the final required focusing onto a production target.

To overcome this difficulty, a scheme shown in Fig. 2 has been contrived and studied. In this scheme, the injection spot of H^- beam moves vertically in accordance with a vertical orbit bump, while the horizontal painting is retained. The foil hits with H^- beam and circulating protons are then spread over the foil. The amplitude of the vertical orbit bump is set to be larger than the movement of H^- beam and the vertical foil size, so as to reduce the total number of foil hits. The beam emittances could be 5 πmm-mrad with this scheme.

The bunch compression is simulated with the ORBIT tracking code. It is concluded that the space charge effect is not harmful even in the 1-bunch mode as far as the direct space charge in free space is concerned. The space charge effect is effectively weaken because the horizontal beam size is expanded due to the dispersion term [2,3].



(a) accumulator (b) compressor

Figure 1. Lattice functions for accumulator and compressor.

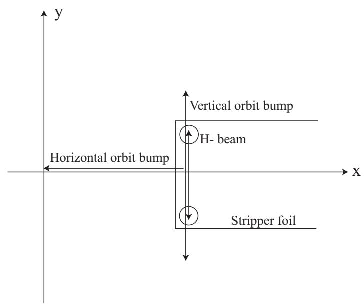


Figure 2. Charge exchange injection with “moving H^- beam”.

4. Summary

The 3-bunches and 1-bunch scenario in the SPL based proton driver is discussed. Possible lattices for the new scenario have been found. The 1-bunch mode is rather challenging due to the large bunch intensity, but the difficulty in the accumulator injection could be overcome with the H^- injection scheme proposed here. The bunch compression is also studied, and it is found that the space charge effect would not be serious issue. The basic feasibility of the 3-bunches and 1-bunch scenario has been demonstrated.

5. Acknowledgement

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References

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