LONGITUDINAL TUNE-UP OF SNS NORMAL CONDUCTING LINAC *

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Abstract

DTL of SNS linac accelerates the 2.5MeV H^- beam to 86 MeV and CCL to 186 MeV. Phase scan and acceptance scan will be used for DTL rf set-point. Phase scan, Delta T scan, and phase scan signature matching will be used for CCL rf set-point. Three BSMs in series will be used to get the longitudinal matching between DTL and CCL experimentally without resorting to the beam dynamics model [1].

1 INTRODUCTION

Commissioning of DTL and CCL of SNS Linac comprises rf set-point (rf amplitude and phase setting), transverse matching, emittance measurement, and orbit correction using dipole correctors. In an accompanying paper [2], the general plan for the commissioning is described. In this paper, we describe the detailed techniques which will be used for rf set-point such as phase scan using BPMs, acceptance scan using Energy Degrader and Faraday Cup (ED/FC), Delta T scan, and phase scan signature matching technique. Acceptance scan is also called phase scan with ED/FC. Simulations are performed to assess the feasibility of these techniques for SNS normal conducting linac using the PARMILA code [3].

2 DTL RF SET-POINT

2.1 phase scan with two downstream BPMS

Using two down-stream BPMs, beam bunch phases are measured. Comparing simulation and measurements, rf set-point can be obtained. Schematic plot of this scheme is in Fig. 1. The two down-stream BPMs of DTL tank 1 is inside DTL tank 2 (or D-plate). They are $6\beta\lambda$ apart (a complete period).

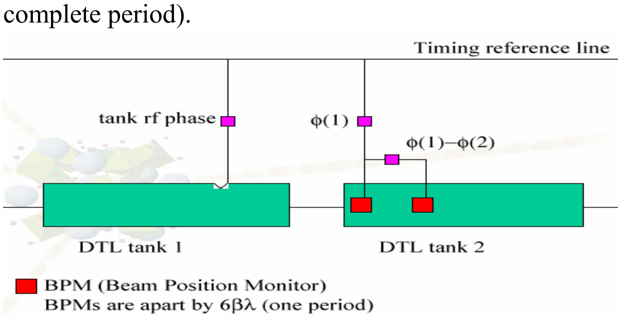

Figure 1: Schematic plot of phase scan with two down-stream BPMs.

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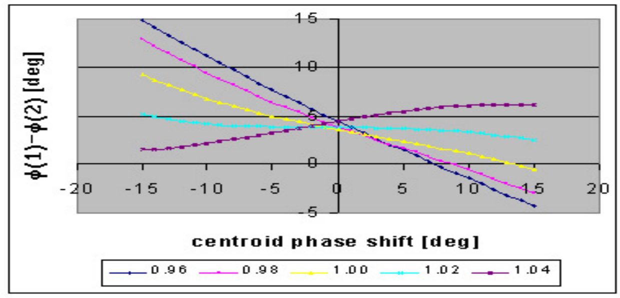

Figure 2: phase difference between two BPM signals vs. centroid phase shift for five different tank rf amplitudes. This plot is for DTL tank 1.

Phase advance plays an important role in this technique and is a function of tank rf amplitude and the offset from the design rf phase. In Fig. 2, x-axis is the deviation from the design bunch phase and y-axis is for the phase difference between two detected BPM signals. Different curves stand for different tank rf amplitude. For the rf amplitude of 1.02 (meaning 102% of design rf amplitude), phase difference becomes almost independent of bunch injection phase. From this, the rf amplitude can be determined. After rf amplitude is determined, rf phase can be easily determined from the crossing point of two different rf amplitudes.

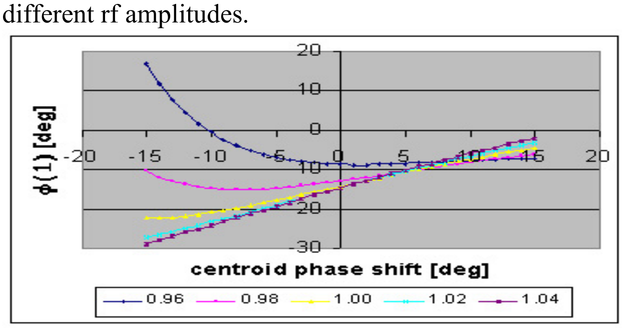

Figure 3: Beam phase of BPM 1 signal for five different tank rf amplitudes. This is for DTL tank 3.

In the case of DTL tank 3 and 4, phase from the BPM 1 turns out useful rather than the phase difference. For DTL tank 3, with an rf amplitude 0.96, part of the BPM phase becomes independent of bunch injection phase shift. After rf amplitude is determined, rf phase can be easily determined from the crossing point of two different rf amplitudes.

In the case of DTL tank 6, neither the phase difference nor the phase of one BPM is effective. So an alternative method should be used, called acceptance scan with the absorber and collector.

2.2 Acceptance scan with ED/FC

Another widely used method for rf set-point is the acceptance scan with the Energy Degrader and Faraday Cup (ED/FC). This is also called phase scan. The absorber removes low energy tail of beam bunch and the surviving beam is collected using the Faraday Cup. A schematic plot of this scheme is shown in Fig. 4.

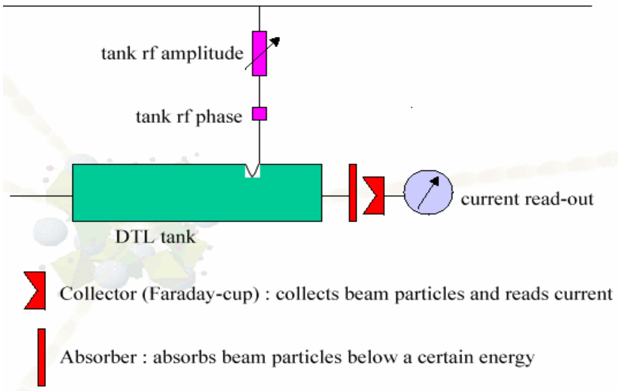

Figure 4: Schematic drawing of acceptance scan with the absorber and collector.

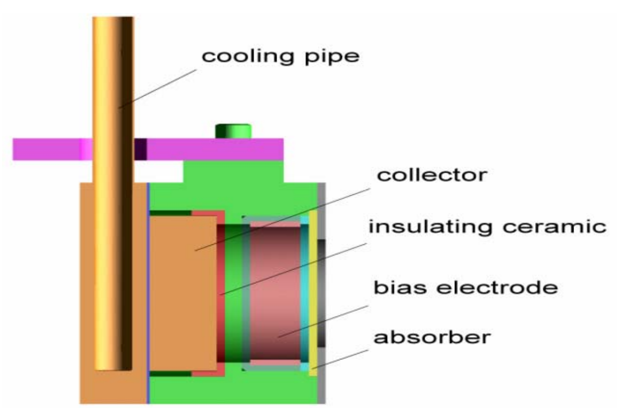

Figure 5: Plot of the absorber and collector assembly. Beam is incident from the right.

Figure 5 is the plot of the absorber and collector assembly. The absorber and collector is an in-line device mounted on actuators. The collector can take up to 50μs full current beam pulse at 1Hz at 185 MeV, which corresponds to 300W maximum.

The success of this method depends heavily on the proper choice of the threshold energy of an absorber. In order to determine the threshold energy, the acceptance plot and the energy spectrum plot of the beam are utilized. In Fig. 6, acceptance plots of DTL tank 3 are shown for three different rf amplitudes, 0.9, 1.0, and 1.1. This shows that tail has energy below 38 MeV. Figure 7 shows the energy spectrum of beam vs. beam centroid phase offset Δϕ from the design with the nominal tank rf amplitude. From Figs. 6 and 7, threshold energy of the absorber can be chosen to be 38MeV for DTL tank 3.

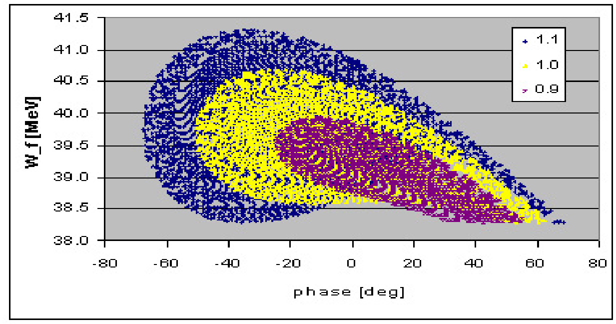

Figure 6: Acceptance plot at the output of DTL tank 3.

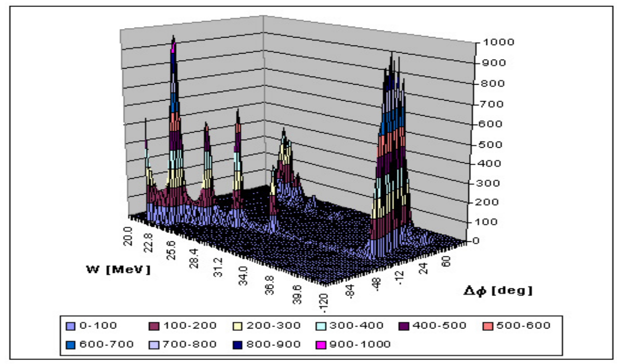

Figure 7: Energy spectrum of beam vs. beam centroid offset Δϕ from the design. Z-axis is proportional to current.

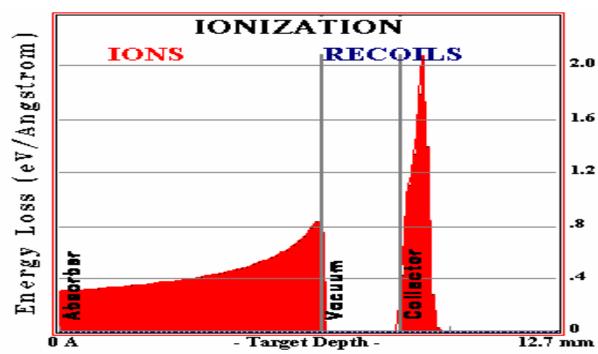

Figure 8: Trim simulation of 38MeV absorber and collector. Nominal beam energy is 39.8MeV from DTL tank 3. Most of beam stops in the collector.

Figure 8 shows the Trim simulation of 39.8MeV beam out of DTL tank 3 through a 38MeV Carbon absorber (6.72mm thickness) and a collector. As is expected, most of beam stops in the collector.

Now multiparticle simulations are done with an absorber and collector assembly at the end of a DTL tank. Top plot of Fig. 9 shows the normalized current read from the collector after DTL tank 3. By comparing the Full-Width-Half-Maximum width of experiment and simulation, tank rf amplitude can be determined. The red dot is the design value. Also from the points of half maximum, phase can be determined.

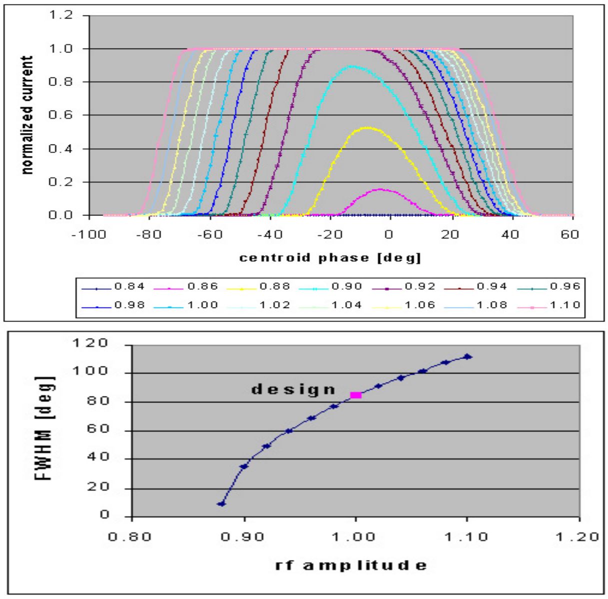

Figure 9: Normalized beam current read from the collector for a few tank rf amplitude (top) and the corresponding Full-Width-Half-Maximum width of DTL tank 3.

3 CCL RF SET-POINT

3.1 Delta T scan

Delta T scan technique was developed by Crandall [4] and has been widely used since then. This is a powerful technique for the fine-tuning of rf set-point. This technique requires two downstream BPMs. The following are measured and compared with the model:

$dTB=(T_{B\ RF\ Off}-T_{B\ RF\ On}) - (T_{B\ RF\ Off}-T_{B\ RF\ On})_{design}$

$dTC=(T_{C\ RF\ Off}-T_{C\ RF\ On}) - (T_{C\ RF\ Off}-T_{C\ RF\ On})_{design}$

and the schematic drawing is in Fig. 10.

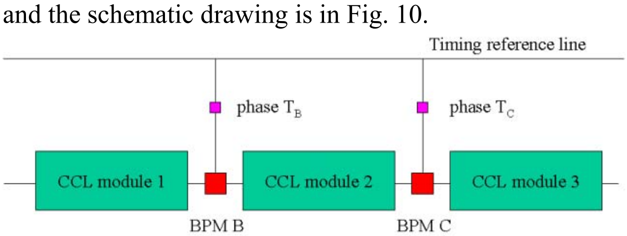

Figure 10: Schematic drawing of Delta T scan.

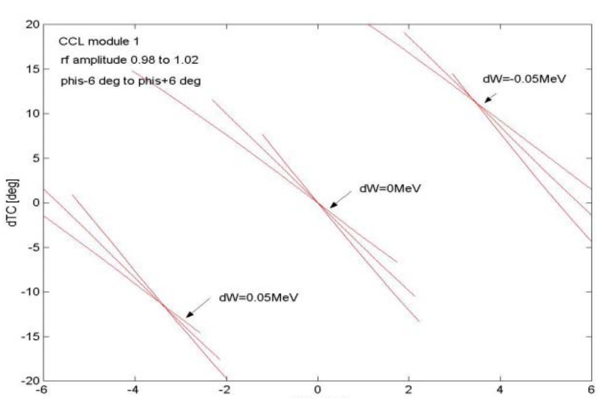

Figure 11: Simulation of Delta T scan of CCL module 1.

Figure 11 shows simulated Delta T scan for three different injection energy of CCL module 1.

3.2 Phase scan signature matching

This technique is developed in FNAL and has been successfully used there [5]. This technique can be used for coarse tuning. The basic idea is to measure $\Delta T=(T_{RF\ Off} - T_{RF\ On})$ using a downstream BPM for an entire 360 degree span and compare with the model. Figure 12 is the simulation result of CCL module 1, where blue curve represents nominal rf amplitude and red curve with rf amplitude offset.

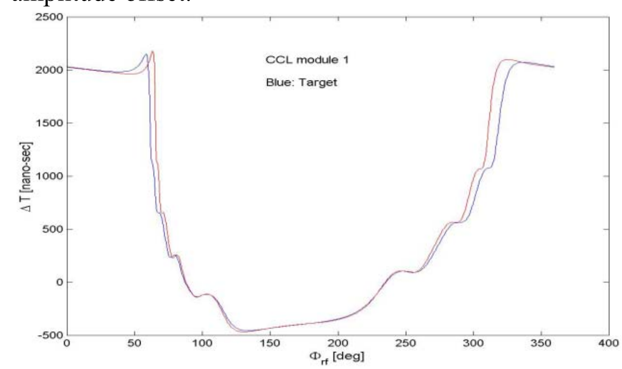

Figure 12: Simulation of PSSM technique.

3.3 Bunch Shape Monitors

One has to rely completely on the beam dynamics model to determine the rf set-point. Three Bunch Shape Monitors installed in series in CCL module 1 will provide a unique opportunity to establish the longitudinal matching between DTL and CCL experimentally without resorting to the model [1]. Through BSM measurements, we can validate the dynamics model. Setting rf set-point without relying on the model has never been done before.

4 SUMMARY

Through numerical simulations using the PARMILA code, it has been demonstrated that rf set-point can be determined using various techniques. And applicable techniques for each sections of SNS normal conducting linac have been identified and programs to be used for the commisioning are under development.

5 REFERENCES

[1] D. Jeon, et al, “Proposal for BSM and CCL in-line emittance device”, SNS/ASD-NOTE-AP-0073.

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[3] H. Takeda and J. Stovall, “Modified PARMILA code for new accelerating structures”, Proceedings of the 1995 Particle Accelerator Conference, p.2364 (Dallas, Texas).

[4] K. Crandall and D. Swenson, “Side Coupled Linac Turn-on Problem”, MP-3-98, February 9, 1970.

[5] T. Ownes et al, Particle Accelerators **48**, 169, 19.