IMPACT OF CAVITY RF FIELD PHASE AND AMPLITUDE CONTROL UNCERTAINTIES ON THE SNS LINAC*

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Abstract

There is an accuracy limit of LLRF control over cavity rf phase and amplitude. This limited accuracy of control gives rise to beam energy and phase jitter, emittance growth, and beam loss. In the case of the SNS linac [1], there are a few limiting factors such as minimizing injection foil miss, acceptable ring injection painting, and beam loss in the linac which are related with the LLRF control errors. We studied the impact of ±1° / ±1% and ±0.5° / ±0.5% rf phase and amplitude uncertainties to the linac using the Ltrace and Parmila codes.

BEAM CENTROID ENERGY AND PHASE JITTER

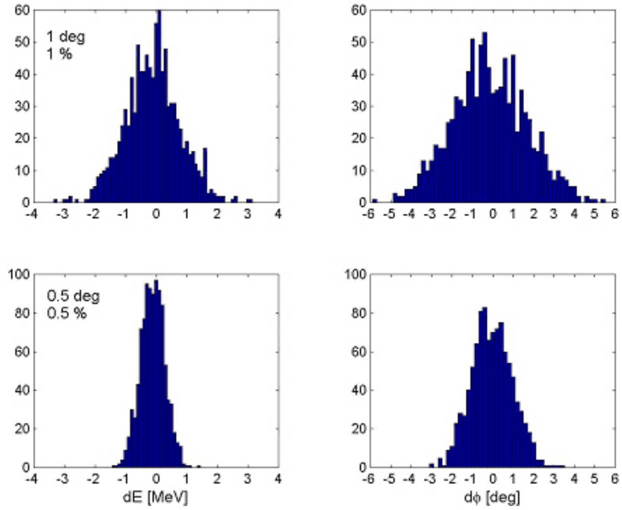

Figure 1: Histograms of beam centroid energy and phase jitters at the SCL end for ±1° and ±1% rf phase and amplitude control (upper plots) and for ±0.5° and ±0.5% rf phase and amplitude control.

As a direct consequence of cavity rf phase and amplitude control uncertainties, the beam energy and phase jitters are induced. If these jitters exceed a certain limit, it may lead to ring injection problem. The injection beam energy and phase jitters are assumed to be zero. Figure 1 shows histograms of beam centroid energy and phase jitters at the SCL end for ±1° and ±1% rf phase and amplitude uncertainties (upper plots) and for ±0.5° and ±0.5% rf phase and amplitude uncertainties. These are the results of 1000 linac runs using the Ltrace code. When the LLRF control uncertainties increase by factor two, the centroid energy and phase jitters almost doubles.

There is an energy corrector cavity (ECC) in the HEBT just before the achromat bend to reduce the beam energy jitter to facilitate the ring injection painting. What really counts is the beam centroid energy jitter after the ECC. Figure 2 shows the beam centroid energy jitters at the SCL end (left column) and after the ECC (right column) for the two sets of rf control uncertainties. As is shown, beam centroid energy jitter after the ECC degrades from ±0.2MeV to ±0.4MeV. 99 (90)% of beam is within ±0.2MeV for the ±0.5° / ±0.5% [±1.0° / ±1.0%] rf control uncertainties. This is a minor degradation. So from the viewpoint of beam centroid energy and phase jitters, ±1.0° and ±1.0% rf control uncertainties make little difference after the energy corrector cavity.

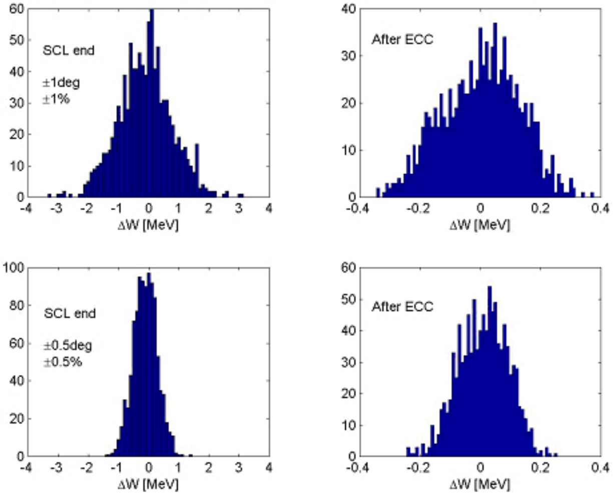

FIG. 2: Histograms of beam centroid energy at the end of SCL and after the ECC for the two sets of rf control.

BEAM EMITTANCE GROWTH IN THE LINAC

Beam emittances grow due to the rf control errors. This is important because it affects the injection foil miss and beam loss in the linac. To see the impact, 1000 Parmila [2] runs were made with 10 000 macro particles. The injected beam to DTL is an ideal water bag beam with a 0.22 (0.30) πmm-mrad transverse (longitudinal) rms emittance. So attention should be paid to the relative difference between emittance values for the two sets of rf control uncertainties.

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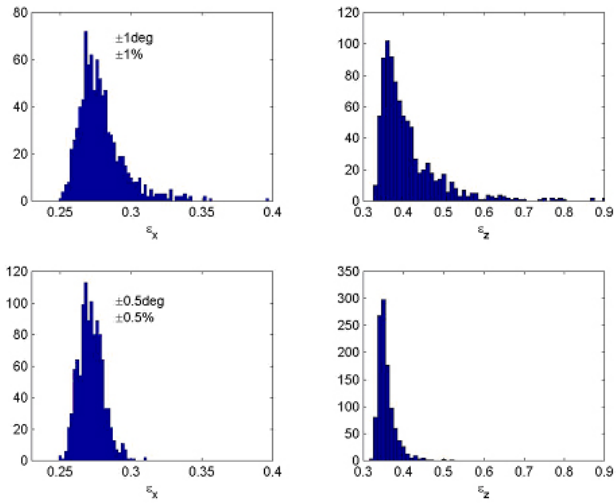

Figure 3: Histograms of x and z rms emittances [πmm-mrad] at the SCL end for the two sets of rf control errors.

Figure 3 shows the histograms of x and z rms emittances [πmm-mrad] at the end of SCL for the two sets of rf control errors. Clearly the transverse emittance ε_x degrades modestly even though the longitudinal rms emittance ε_z significantly degrades. So the injection foil miss and beam loss due to the transverse emittance growth will increase only modestly compared with the ±0.5° and ±0.5% rf phase and amplitude uncertainties. This is a result of the weak space charge coupling between transverse and longitudinal dimension of the SNS linac design. For some of the beams, the transverse emittance increases by more than 15%. This is an indication of the increase of beam loss when the rf control uncertainties increase. Even though this is acceptable for the current CD-4 commissioning goal, ±0.5° and ±0.5% rf phase and amplitude uncertainties are recommended for the post CD-4 operation.

CONCLUSION

We can commission the SNS linac with ±1.0° rf phase and ±1.0% rf amplitude control uncertainties. However ±0.5° rf phase and ±0.5% rf amplitude control uncertainties are required for routine operation after the commissioning.

REFERENCES

[1] J. Stovall et al, Proc. of 2001 Particle Accelerator Conference (Chicago, 2001) p. 446.

[2] H. Takeda, Parmila code.