Linac issues and working topics – personal understanding & collection
(October 4, 2000)

(1) **Key challenge**
The key challenge is whether one can preserve the emittance through the linac (hence ring injection foil miss/foil hit/activation). Our design requires a maximum growth of about a factor of 2 from LEBT to HEBT with more than 90% transmission. According to information that Deepak compiled, among existing linac of energy above 100 MeV, the typical emittance growth is 5 to 15 times for machines of transmission higher that 50% (We may need to verify definition/measurement method/calculation comparison. Also, the part that we have not looked at is the perhaps equally stringent momentum spread growth.) As Jim mentioned, we probably need to check the validity of these data, find out sources that lead to the growth (RFQ? Diagnostics? …)

(2) **Beam-based alignments**
Nobody knows whether this is applicable to SNS but the idea is the following. SNS is the first SCL proton linac requiring such stringent performance at high intensity. We don't know what can go wrong, so we need to explore possible physics and be open to any useful ideas. Techniques like beam-based alignment are just examples – frequently used on electron rings and linacs. It may or may not be applicable to us but it does not hurt to evaluate.
It seems that the logic for beam based alignment is the following: BPMs usually have very good resolution (e.g. 0.15 mm for taking difference orbits) but poor accuracy (fiducial position + electronic center for absolute position, e.g. 0.5 – 1 mm). On the other hand, accuracy for quad alignment can be good (e.g. 0.2 mm). Therefore, beam-based alignment relies is relying on pulsing the quads, taking difference orbits with good resolution, and do subsequent steering/realignment until the orbit be frozen upon quad strength variation.
We probably need to evaluate our case starting from diagnostics performance. In Dick Witkover's PAC99 SNS diagnostics paper, he quote SNS BPM accuracy as 1 mm, and resolution as 0.15 mm (see the table that Sasha/Tom/myself made up). It may not hurt, as Jim suggests, to install BPMs on every quad/doublet (except space-limiting sections like DTL) and to leave possibility for future; we may also import some SLAC algorithms and evaluate some models.

(3) **DTL tuning flexibility: PMQ vs. EMQ**
Several of us did research on this topic. According to what Sig Martin collected, among existing linacs using PMQ, the highest energy is the one for SSC of 35 MeV which is never built. (SNS DTL reaches 90 MeV without tuning.) On the other hand, Deepak reviewed BNL linac operation data and found that during the past 5 years, there is not a single retuning of the quad strength needed (though the setting is different from the original design). It seems that tuning is ever done only when switching from proton to H- operation. Now Jim suggested the attractive idea of FFfDDd layout (instead of FFODDO) implementing trim EM quads of 1% strength at empty tanks. Some practical issues include tanks 5-6 already taken for dipole corrector+BPMs, and tank 1 first half length too short – only a few open cells available in tank 3 – 4?

(4) **Impact of system errors (Lorentz detuning, microphonics, …)**
The present assumption is 0.5%, 0.5 degree for the RF control. The question is what are the impact of system errors like Lorentz detuning and microphonics and whether they are covered by the assumption. Most of the information is probably already worked out by Mike Lynch (frequency shift, amplitude and phase error) and under 1-on-1 probably the issues becomes how much overhead reserve is needed.

(5) **Simulation code assumption verification & code benchmarking**
Assumptions used by PARMILA needs to be verified and reconfirmed, especially at the level of predicting beam halo at 1e-6 per meter level. There are several codes available and a detailed bench marking is probably needed and presented. (For the ring part, extensive benchmarking has been an on-going process and we keep on finding surprises.) Probably benchmarking should be done step by step under several subjects: linear optics, cavity model, space charge, errors, and steering … The other feature that one may need to put in PARMILA may be --

(6) **Analysis and modeling of 4-die asymmetric SCL cavity/cell**
Detailed 4-die geometry needs to be modeled to evaluate the difference in transit time factor, as Jim mentioned. This feature was not supported by the earlier version of the codes.

(7) **2D vs 3D space charge**
Again, several codes are available, some using 2D (PARMILA, LINAC) and some using 3D (INFN SCDyn; IMPACT; CEA codes) space charge model. Probably we need to search through other's comparison results (INFN claims a noticeable difference?) and find out whether it is generic. Jim once mentioned the large transverse-longitudinal aspect ratio of a SCL beam. Is this still an issue in 2D modeling (probably not)?

(8) **Field integral comparison**
INFN study indicates that due to SC cavity geometry, a detailed field integral gives noticeably different result than conventional methods. LANL result probably is already confirming this. Again, a cross check and

(9) **Integrated simulation from RFQ to Ring injection foil**
Harunori is in a good position to merge John Staples' and Deepak's work and to perform a consistent simulation. He probably should fully proceed. Deepak has given his codes to Harunori.

(10) **Alignment error and steering study**
John Galambos plus student did some DTL study and Sabrata did CCL part. Jim has done a good job listing error sources. A more realistic distribution (as opposed to uniform) may be needed and the study needs to continue to SCL including fault modes of BPMs.

(11) **HOM/BBU study**
The complication seems to be caused by the ac beam structure generating spectrum lines overlapping with trapped HOM modes. Ron has a nice list of summary on the working directions. According to Ron, the topics include (a) dipole mode away from ac spectrum lines causing instability (b) dipole mode near ac lines causing deflection (c) mono mode away from ac lines causing longitudinal instability (d) mono mode near ac lines causing power dissipation.

Sang-ho/Marc are working on (d) showing that HOM damper is necessary. Dong-o has been working on (b). Ron just wrote codes for (a) and (c) with simple model not including HOM frequency spread. Given the tight schedule for determining HOM damper design, probably Ron need to do as much study as he can while Dong-o trying to bench mark Ron's codes and consider missing factors.
Jim proposed to correlate the study with Harunori's simulation yielding final prediction on foil performance. The final figure of merit is the effective increase of transverse emittance (transverse) and the phase/amplitude jitter (longitudinal).
It seems that (d) is trivial; (b) can be done piece-wise and merged with PARMILA. How about (a) and (c)?

(12) **Double check beam fringe stripping at quad & cavity**

Sabrata has done it before and it is not believed to be a problem. It may be worth verifying for the entire halo region, also taking into account both cavity upgradeable E field and maximum quad B field and also taking into account stripping uncertainty.

(13) **Ground settlement and restoration**

Weishi has collected ground settlement data and it looks serious (at +/- cm level). Weishi is collecting SLAC work to see whether there is anything relevant e.g. on ground vibration.

(14) **Missing cavity rematching/retuning**

We need to evaluate the available RF headroom for possibly rematching/retuning back output energy in case of missing cavities. The bottom line is to evaluate the impact on output energy and the impact on ring.

(15) **Comparison of different transverse phase laws**

Especially on equipatitioning law violation and dispute. Recent work by I. Hofmann, R. Ryan, J. Qiang can be useful and probably need to be applied to our case to shed light on top of our own simulation results.