LINAC SUMMARY

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Goals

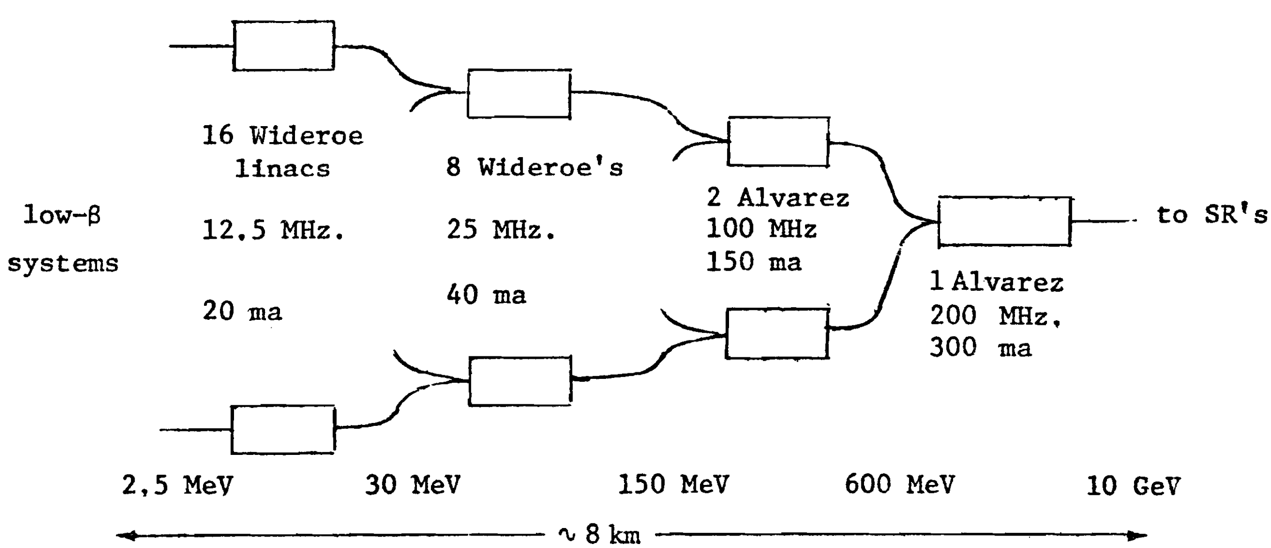
To define the problem areas for both the rf and induction linac scenarios. We are not addressing engineering or cost considerations. We also did not consider the test beds.

Scenarios

Since new target parameters were presented at the beginning of the Workshop, detailed designs to match these parameters were not available. Thus, we did not do a detailed analysis of any specific design. The specific designs presented are not optimized.

RF Linacs

The problem is to take the beams available from the ion source and low-β systems (analyzed separately) with realistic current and emittance and accelerate them to the final energy, meeting the current and emittance requirements of the storage rings. An example of how this might be done is illustrated below



Remarks

1) Since the beams are merged by frequency multiplying, the normalized transverse emittance and the longitudinal emittance per bucket could both, in principle, be conserved. In practice, some emittance growth at injection and at each merge is anticipated.

2) The design is based on limiting the space-charge tune depression to a conservative 25% ($\mu \geqslant 0.75\ \mu_o$) in both transverse and longitudinal space.

3) The basic design can be varied to meet parameter changes of the low-β section, the storage rings, or target requirements.

Questions that remain to be answered

1) Calculate the emittance growth all along the system especially at the low-β end and at each merging. Numerical tools for doing this almost exist [PARMILA can correctly predict performance of existing proton linacs "for 95% of the beam" and can be applied to heavy ions as well[1]]. Other work reported in these proceedings, by Jorna and Randa treats the problem of heavy ion emittance growth and beam envelope behavior with space charge at the low energy end of the linac, but without merging.

2) Study the impedance coupling of the beam with the structure. The concensus is that transverse beam blowup is not expected at these currents, and longitudinal blowup is rather unlikely, but must be calculated.

Induction Linac

Here one takes a single high-current beam from the injector and low-β sections (12A @ 2 MV) accelerates it to final energy (~ 10 GeV) in a single accelerator (6 - 10 km long). The beam current is kept fairly close to the transverse space charge limit ($\mu > 24°$, $\mu_o \simeq 60°$) throughout the accelerator.

This implies a gradual compression (shortening) of the beam pulse which is accomplished by shaping the accelerating voltage pulses so that the back end of the pulse has slightly higher velocity than the front end. Conceptually, the difference from an rf linac is that a very large accelerating bucket is formed instead of many (2×10^5) small ones. But in the induction case, the shape of the bucket is adjusted to optimize longitudinal motion, which isn't done in the rf case.

Remarks

1) In a sense, this system is "simpler" than the rf case because there is no need to merge beams from parallel linacs, and there are no storage rings.

2) High current electron induction linacs provide some technology base, but the applications to ions is new so there are new problems. Thus, there are more questions that remain to be answered than in the rf case.

3) The number of synchrotron oscillations in the full length of the machine is of order one. The number of transverse oscillations is of order 100; very different from the rf case.

Questions that remain to be answered

1) Longtudinal dynamics - Optimization of bunch and acceleration profiles (A start on this problem is reported by S. Chattoopadhay, et al., in these proceedings. Also in these proceedings, M. Foss presents a computer design for bunching and acceleration in a high current proton induction linac, which might be applied to a heavy ion linac.).

- Study of tolerances (preliminary work is reported in these proceedings in papers by S. Chattoopadhay et al. and by A. Faltens).

- Effect of wall impedance and feedback control of beam (discussed also in the paper by A. Faltens, these proceedings).

- How do the ends of the bunch behave (erode)? (See the paper by D. Neuffer, these proceedings for more on this question.)

2) Transverse dynamics - the understanding of this in the absence of coupling to the longitudinal motion is in relatively good shape.

3) Longitudinal-transverse coupling - some of the longitudinal dynamics questions can't be adequately addressed without considering the couplings. Unlike rf linacs, the large aspect ratio of the beam bunch in an induction linac makes the full 3-dimensional particle simulation very difficult. Some proposed approaches include: two dimensional (x-z) simulation, "2-½" dimension (R-Z), full 3-D simulation of the beam ends with a simplified model for the relatively uniform central 80-90% of the beam.

Recommendations

1) Develop numerical simulation techniques which can describe the full 3-D behavior of the beams in both rf and induction linac cases. This would not be a single program for all problems.

2) Study the interaction of the structure with the beam, i.e., beam instabilities driven by the beam-structure coupling impedances. The transverse effects appear to be negligible, but the longitudinal ones need to be calculated.

3) Experimental verfications of the results of theory and numerical simulation are needed. The proposed test beds should provide the data for at least some of the effects of interest. Since the numerical work is already quite sophisticated, "crude" comparisons with experiment won't help. Very good diagnostic tools will have to be developed.

4) Alternate methods of high current transport, such as charge-neutral transport employed in the Pulselac experiments at Sandia Labs, should continue to be investigated.

Conclusions

No fatal flaws in either rf or induction linacs have been found. The concensus from preliminary simulation and analytic studies is that there probably aren't any, but more work in the areas discussed is needed.

References

1. R. Jameson, D. Swenson, LASL Private Communication.