SNS Linac Configurations for the 4-MW Upgrade

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A. J. Jason LANL

D. K. Olsen ORNL

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Spallation Neutron Source Project
Oak Ridge National laboratory
PO Box 2009 MS 8218
Oak Ridge TN 37831

SNS Linac Options for the 4MW Upgrade

INTRODUCTION

The Spallation Neutron Source, SNS, Project is a collaboration between five DOE National Laboratories to build the next U.S. spallation source for neutron science. The requirements from the scientific community for this next generation neutron source are well understood and listed below:

- Short pulse (~1 microsecond) operation
- Initial operation at ~1 megawatt beam power
- The capability of being upgraded "to significantly higher power" in the future
- An initial target station operating at 60 Hz with a second target operating at 10-20 Hz
- Rapid completion, high reliability, and high availability to the users
- A design that preserves a long pulse (1 millisecond) option

To meet these requirements the SNS collaboration has chosen a full energy linac and accumulator ring with an initial beam power on target of 1.0 MW. This baseline design has a straightforward cost-effective upgrade path to 2.0 MW of beam power by doubling the peak H^- ion source current from 35 mA to 70 mA. Most components of the baseline design will be built for this full upgraded 2 MW of beam power. The parameters of this baseline design are listed in the CDR and Table 1.

Table 1. National Spallation Neutron Source performance parameters.

Reference design parameter	Initial 1.0 MW	Upgrade to 2.0 MW
Pulse repetition rate	60 Hz	
Peak ion source H –	35 mA	70 mA
RFQ capture-bunching factor	>80%	
Linac length	493 m	
Linac beam duty factor	6.2%	
Linac final beam energy	1.0 GeV	
Accumulator ring circumference	220.7 m	
Ring orbit rotation time	841 ns	
Ring filling fraction	65%	
Number of injected turns	1225	
Ring filling time	1.03 ms	
Protons per pulse on target	1.04E+14	2.08E+14
Protons per second on target	6.3E+15	1.25E+16
Time average beam current on target	1.0 mA	2.0 mA
Beam power on target	1.0 MW	2.0 MW

The linac configuration chosen to meet these requirements for up to 2 MW of beam power is shown in Fig. 1. The structure and frequency choices for this linac have been chosen on strong physics bases and are believed near optimal. Both the RFQ and DTL operate at 402.5 MHz. A single frequency jump of a factor of two occurs at 20 MeV; both the CCDTL and CCL operate at 805 MHz. The frequency range around 800 MHz is used by all present linacs, including LANSCE, GTA, and Fermilab. Both APT and ESS will use 700 MHz. The choice of 800 MHz allows the incorporation of the considerable LANSCE experience at this frequency, and in particular experience with the robust LANSCE rf system. Both higher and lower frequencies and also larger frequency jumps were considered for the linac and discarded in favor of the above baseline design.

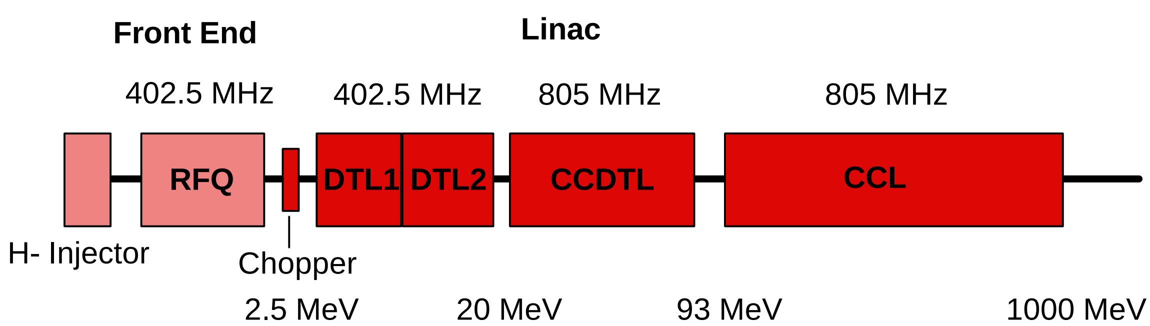

Fig. 1. Systematic of linac layout.

The upgrade from 2 MW to 4 MW of short-pulse beam power is more costly and less straightforward than the upgrade from 1 to 2 MW since several hard and soft limits are reached with the baseline 2-MW configuration. In particular: (1) The RFQ efficiency decreases rapidly above the 70-mA input level required for the 2-MW upgrade. The 4-MW upgrade requires a 140-mA input current for the RFQ and this current level is not possible with a single RFQ operating at 402 MHz. (2) At the present time it is not at all obvious that an H^- ion source with a peak current of a 140 mA at a 6% duty factor can be developed. Assuming that such an ion source will be developed over the next decade is a considerable risk. (3) The space-charge limit of the accumulator ring at 60 Hz corresponds to 2 MW of beam power. Any upgrade to 4 MW will require a second accumulator ring or synchrotron. Because of these limits, an upgrade scenario from 2 to 4 MW was developed which includes a second accumulator ring and a 4-MW linac at a 6% beam duty factor with a second front end and DTL. The two beams from the two DTLs are merged with funneling at the 20-MeV frequency jump. This upgraded 4-MW linac configuration is shown in Fig. 2 and has been discussed in detail.

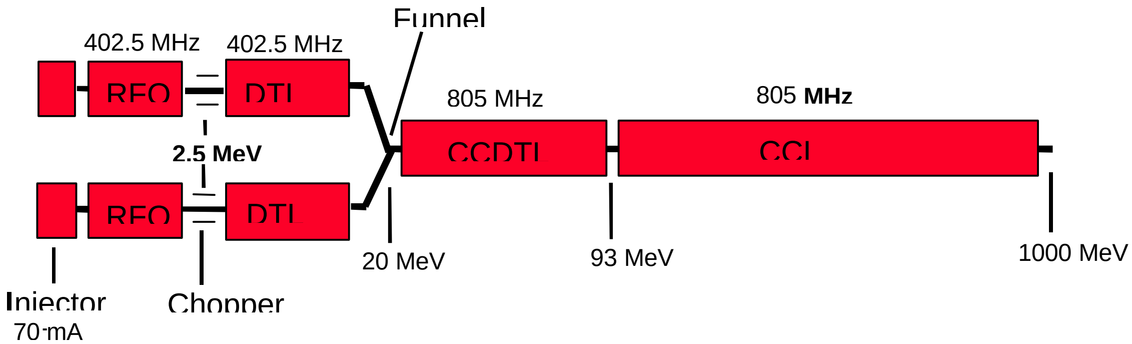

Fig. 2. Schematic of 4-MW upgrade modifications to the linac.

These short-pulse configurations require a 6.2 % beam duty factor for the linac. The user community also has a requirement not to exclude a long pulse mode, particularly if this option does not appreciable increase the cost and complexity of the accelerator system. Many people doubt the need for this requirement since the facility is designed to eventually produce 4 MW of beam in a short pulse mode. Nevertheless, this option could be exercised, be extending the linac beam duty factor. The linac will be fabricated with cooling channels to accommodate up to a 12% beam duty factor. The additional 6% beam duty factor could be used, without an accumulator ring, for an additional long-pulse beam.

This baseline design and upgrade paths were extensively reviewed during the June 1997 CDR Review. One important evaluation from the review was to “Investigate alternative routes to 4 MW besides funneling." Because of this evaluation and because a major change in the baseline would need to be incorporated now, the Collaboration felt it was timely to reevaluate funneling and the basic strategy to upgrade from 2 MW to 4 MW. This white paper reevaluates this strategy, and gathers together, organizes, and hardens the requirements for the 4-MW upgrade, particularly for the linac since the bulk of the linac will not be changed for the upgrade.

Rapid cycling synchrotron upgrades to 4 MW and higher are surely possible, beyond the scope of this paper, and are not considered here in detail. The linac beam requirements for a RCS depend on the pulse rate, energy gain, injection system, and other details. In general, optimal injection into a RCS requires short intense linac macropulses.

LINAC UPGRADE OPTIONS FOR 4 MW

Without funneling, upgrading the linac beam power from 2 to 4 MW requires either doubling the macropulse length from 1 to 2 ms, with a corresponding doubling of the ring fill times, or doubling the peak H^- ion-source current from 70 to 140 mA, with a corresponding doubling of the RFQ output current from 54 to 108 mA. The present 402-MHz RFQ simply cannot transmit the 108 mA needed to fill the ring in 1 ms; consequently, the frequency of the RFQ must be lowered in order to inject the full current into the linac.

Table 2 lists the possible linac configurations to be considered for the 4-MW upgrade. The corresponding peak H^- ion source current, ring fill time, additional rf requirements, and the number of H^- ions per micropulse are also listed. There are two possibilities using the existing 402/805-MHz frequencies: either employing funneling as described in the CDR or extending the beam duty factor to 12%. Another possibility is to replace the 402-MHz front end and DTL with a 268-MHz front end and DTL, which could accelerate the additional current. At some energy this front end and DTL could be merged with a frequency jump of a factor of three into the 805-MHz CCDTL and CCL. An intermediate configuration could have two frequency changes with a 201-MHz RFQ, a 402-MHz DTL and a 805-MHz CCDTL/CCL. The final possibility to directly accelerate 140mA from the ion source is to simply decrease all the linac frequencies maintaining a factor of two frequency jump. This would require a 700-MHz CCL.

All of these linac configurations require a second accumulator ring, a second target hall, and corresponding beam transport lines. It is assumed that the proton pulses from both rings would be used for either separate parallel neutron pulses in both target stations or combined in series to produce one intense 1-μs-wide neutron pulse in one target station.

An important limitation is the maximum fill or storage time of the beam in the accumulator rings. This latter case of a single neutron pulse from a double proton pulse requires the two rings to be filled either simultaneously by switching the linac beam between the two rings, perhaps using the 295-ns chopper spacing, or filling the rings sequentially. If the rings are filled simultaneously, then the ring fill times will be double that of a single ring. If the rings are filled sequentially, then the one ring will need to store full beam for an additional fill time. In either case a ring fill or storage time is increased.

Table 2. Linac configurations for the 4-MW upgrade.

Configuration	Peak H^- IS current	Ring fill time	Additional rf requirements	H^- per macropulse
402/805 MHz				
Funneling	70 mA	1.0 ms	2 MW for beam and second RFQ-DTL	$5.3x10^8$
12% duty factor	70 mA	2.0 ms	Extend duty factor by 6 %	$5.3x10^8$
268/805 MHz	140 mA	1.0 ms	2 MW for beam	$1.6x10^9$
201/402/805 MHz	140 mA	1.0 ms	2 MW for beam	$2.1x10^9$
350/700 MHz	140 mA	1.0 ms	2 MW for beam	$1.2x10^9$

402/805-MHZ LINAC CONFIGURATION WITH FUNNELING

A detailed description of the SNS funneling system is given in Section 3.8.4 of NSNS/CDR-2/V1 pages 3-129 to 3-135. These seven pages from the CDR are attached in the Appendix. The main points of this system will be reviewed and additional information and a cost estimate for funneling will also be given.

Although a funneling scheme has never been implemented on an operating system, experiments have been done that demonstrate the feasibility of a funneling, particularly for the GTA project. We note in particular Johnson et al. (1992) who did a careful experiment using one leg of a funnel. The leg contained the critical deflector cavity that places the beam from both legs on axis. They found that a high-intensity beam could be transported and placed on axis with little emittance growth. McDonnell Douglas (1991) did a two-leg experiment. Although we do not have detailed performance results from the latter work, the experiment confirmed that the cavity engineering is feasible, particularly in terms of the tight region where the two beams merge. Some of these design considerations are discussed in the Appendix. Some questions about funnel performance have not been definitively addressed by these experiments are discussed below. The primary remaining issues and corresponding theoretical response are:

<u>Control of final deflector to maintain beam on axis</u>. The dc fields are adjustable to any desired degree of precision. The final buncher cavity (a well-developed and tested device for a single harmonic) deflects the beams by one degree. Control of the rf fields would then need to be done to ~0.1% which is believed easily feasible for the single cavity system. Phase stability requirements are modest since the deflector is phased to the rf-wave crest.

<u>Interaction of the two beams as they are merged</u>. This interaction has been theoretically studied. An internal report places the mutual deflection of the two beams at < 10 microradians, with a readily tolerable emittance growth.

<u>The beam deflection in the final deflector is nonlinear</u>. Since the beam extends over a finite longitudinal distance and hence will experience a longitudinal distortion (~100 microradians for the extreme particles). Focusing to a high divergence will minimize emittance growth to a few percent and the addition of a second harmonic, which has been studied for APT, will decrease this effect further.

Implementation of funneling will require appreciable development and demonstration. It is recommended that a test bed consisting of a complete funnel system with two ion sources, RFQs, MEBTS, and DTLs be implemented in the funnel R&D.

Table 3 lists estimated linac upgrade costs in FY97 dollars and corresponding schedules from the baseline initial 1-MW facility. The additional cost of initially installing a 2-MW linac is also included. The 2-MW upgrade would only require a 2-month shutdown, whereas the 4-MW upgrade would require a 12-month shut down.

Table 3. Linac upgrade costs (FY97) from the 1-MW baseline.

	Unburdened cost (k$)	Contingency	Schedule
2-MW initially	15638	20%	Same as 1 MW
2-MW upgrade	22512	20%	~22 m + 2 m shutdown
4-MW upgrade	92789	23%	~51 m + 12 m shutdown

A breakdown of the costs for the 2 to 4-MW upgrade is given in Table 4. These costs are unburdened, unescalated, with zero contingency and are in FY97 k$. The additional R&D associated with constructing the funneling test stand cost 28 M$. However, the schedule risk in initial funnel commissioning may make the funnel test program worthwhile. In addition, the front-end concept may change after several years of operation, making a redesigned front end very desirable.

Table 4. Breakdown of 4-MW upgrade cost.

1. New 805-MHz rf Systems	37519
2. Two new 402.5-MHz rf Systems	10160
3. Additional rf windows	740
4. Additional Controls (water & rf only)	997
5. Fab coupling cavities & covers	550
6. Install (#5), tune linac, reconfigure water and rf waveguide	810
7. Fab / Install two New Choppers	1258
8. Fab / Install two New DTL's	12694
9. Fab Funnel Hardware (see details above)	2705
10. Funnel rf Systems (21 @ 10kW)	5250
11. Funnel Design Program	6252
12. Funnel Test & Validation Program	11424
13. Funnel Installation & Functional C/O	2430
TOTAL	92789

402/805-MHZ LINAC CONFIGURATION WITH A 12% DUTY FACTOR

In terms of additional linac hardware this is the simplest option to produce a 4-MW facility. The linac duty factor of 6% for a 2-MW short-pulse beam could be extended to 12% for a 4-MW short-pulse beam. This upgrade would probably exclude an additional long-pulse capability. There are several issues with this configuration including ion-source needs, power and rf requirements, ring fill and storage times, and utility needs.

The ion source peak current requirement for 1 MW is 35 mA at a 6% duty factor and the upgrade to 2 MW is based on increasing this ion source current to 70 mA with the same duty factor. There is considerable confidence that with substantial R&D these requirements can be met. For this 4-MW upgrade the peak ion source current would remain at 70 mA and the duty factor would be increased to 12%. It is surely possible that this more difficult requirement could also be met with R&D, but presently the possibility of meeting this requirement with a single ion source is speculative. One possible solution is to feed a single 12%-duty-factor RFQ with two 6%-duty-factor ion sources switching between them on a macropulse-to-macropulse basis.

The linac would use significantly more ac wall power to operate with a 12 % beam duty factor. The present 2-MW design requires about 9 MW of average rf power from about 27 MW of AC wall power to operate the linac with a 6% beam duty factor and a 7% rf duty factor. Extending both the beam and rf duty factors by an additional 6% would require and additional 23 MW of AC wall power. On an annual basis this is a substantial amount of energy. There is also the question of the klystron duty factor. The klystrons will be able to run at a 12% beam duty factor with somewhat reduced, but still acceptable lifetime. The additional cost for this capability is expected to be small. This upgrade would also eventually require additional capacitors and power supplies and the corresponding building space for this equipment.

Increasing the beam duty factor from 6% to 12% requires either increasing the ring fill times from 1 ms to 2 ms, or increasing the full-beam storage time in one ring for an additional 1 ms. A major concern for beam stability in the ring is the possibility of a fast transverse coherent instability for the n = 6 mode, and maybe the n = 7 mode. For the n = 6 mode the growth time is presently calculated to be 110 μs with no damping for the design betatron tunes of 5.8 with a full 2-MW beam. The largest contributions to the real part of the transverse coupling impedance comes from the kicker magnets, the vacuum chamber ports, the rf cavities, and the active damper system. Careful design of these components could increase the growth time of the instability to 0.8 ms. In order to control this possible instability for these modes, an active feedback damper system will be installed in the ring.

Finally it is important to assure that the linac mechanical structures be initially designed to cool a 12 % duty factor. Depending on cost, some of the remainder of the increased cooling system could be incorporated in the initial design.

268/805- AND 201/402/805-MHZ LINAC CONFIGURATIONS

Both configurations would allow a single RFQ to transmit the 4-MW beam current. The 268/805 configuration requires a frequency jump of a factor of three at some energy with the linac. A preferable approach may be to stage the frequency jump with a 201-MHz DTL, a 402-MHz CCDTL and an 805-MHz CCL. The charge per micropulse in the CCL is however increased by factors of 3 and 4 respectively. From a beam dynamics point of view this may be undesirable since these upgrades increase the beam micropulse current into a region not approached by operating linacs. Either option presents difficulties in matching beam at the frequency shift and would require a lower gradient, a large less-efficient RFQ, and a longer linac. The single frequency change is large and difficulty will be encountered in longitudinal matching; a matching section would likely have to be constructed at extra cost and risk. The three-frequency option would require an additional structure with additional engineering costs. We do not consider either option desirable from a beam dynamics viewpoint and would expect higher beam loss. A change to either option would require additional R&D and involve higher risk.

350/700-MHZ LINAC CONFIGURATION

Decreasing the frequencies by a factor of 7/8 would allow a single RFQ to marginally transmit the required current for the 4-MW upgrade. If the accelerating gradient were kept constant (linac length unchanged), the linac structure cost, we estimate, would decrease by about 6% while the rf system cost would increase by about 3%. The power consumption would be similar.

One would likely want to decrease the accelerating gradient to maintain the same Kilpatrick factor as in the baseline design. In this case the costs of both the structures and the rf systems would decrease by about 2% and operating costs for ac power would decrease by about 3%. The length of the linac would however increase by nearly 29 m with increased tunnel costs.

In summary, there are small decreases in the construction costs and, in the constant Kilpatrick case, an appreciable reduction in the operating costs by the decreased frequency. These costs are likely offset to within the accuracy of the estimate by other costs. The lower frequency has, however, some attractive features such as higher pumping speed for a better vacuum, slightly increased chopper-rise time and simpler cooling, but we do not see these as compelling reasons for a change.

The initial requirements for the baseline design for these various linac configurations are summarized in Table 5.

Table 5. Initial requirements for 4-MW linac upgrade configurations.

LINAC CONFIGURATION	INITIAL REQUIREMENTS
402/805 MHz with funneling	Provide front end building space
402/805 MHz with 12% duty factor	Provide linac cooling for 12% duty factor Specify 12% duty factor klystrons
268/805 MHz	Replace front end and DTL design
201/402/805 MHz	Replace front end design
350/700 MHz	Replace linac design Increase tunnel length by 29 m

CONCLUSIONS

The funneling concept is believed viable and the best option at this time for the eventual upgrade to 4 MW of beam power. A half-funnel demonstration has been successfully completed; however, full funneling has never been demonstrated and hence requires substantial engineering as well as prototyping and testing. A full test stand, consisting of the entire upgraded front end is advocated as a future R&D activity. This effort is not required for the construction of the initial 1-MW linac or for the upgrade from 1 to 2 MW. A lower frequency has been considered to obviate the need for funneling. However, the present structure frequencies are considered near optimum from the viewpoint of beam dynamics, cost and risk. A change in linac frequency would require substantial additional development and would likely affect project schedule adversely.

It is important to appreciate that the present 402/805-MHz linac frequencies allow a further alternative to funneling. The linac macropulse could be extended from one millisecond, a 6% duty factor, to two milliseconds, a 12% duty factor, with the 2-MW beam current. This second option to achieve a 4-MW beam is not precluded by the specification of the klystrons for the 1-MW linac. Other up-front requirements for the 12% duty factor option should be understood and, if these requirements do not significantly effect the cost and schedule, be incorporated in the baseline design.

REFERENCES

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Chan, K. C. D., ed. 1994. *Accelerator Performance Demonstration Facility (APDF) Conceptual Design*, LA-UR-94-4063, Los Alamos National Laboratory, October 31.

APPENDIX Section 3.8.4 of NSNS/CDR-2/V1 pages 3-129 to 3-125

3.8.4 Funneling

3.8.4.1 Overview

Substantial work has been done to confirm the possibilities of funneling, including demonstration experiments. This section discusses the concepts and designs of components for funneling, drawing heavily on previous work.

In a funnel section, two beams from two separate low-energy legs are combined to form a single collinear beam. The two legs carry bunched beams that are phased 180° apart from frequency f_0; these two beams are then merged, forming a single beam of frequency $2f_0$. The beams are interlaced as shown in Fig. 3.8-4. The interlacing is done in a deflector cavity by alternating rf transverse deflecting fields operating at frequency f_0 to form a single collinear beam with a frequency $2f_0$.

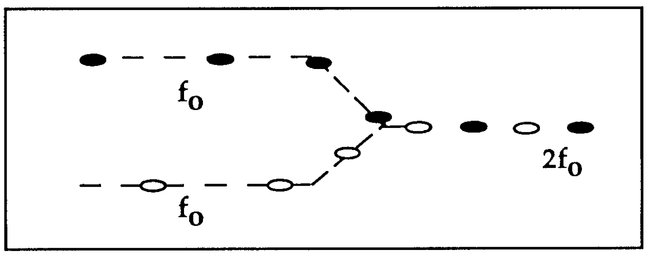

Fig. 3.8-4. Interlacing of bunches in a funnel.

It should be noted that funneling doubles the effective current of the beam but does not increase the charge per bunch.

The energy of funneling was chosen to be 20 MeV for this design. The choice of energy is a compromise between several conflicting requirements. This energy level was chosen (over a lesser energy) to keep space charge forces relatively small and to supply high enough velocity that the 805-MHz linac would accept the funneled beam. In addition, a relatively high energy is necessary to maintain interquad distances large enough to meet engineering and diagnostic constraints. The 20-MeV energy is still low enough to result in a beam that is not too rigid for deflection in the rf deflector.

3.8.4.2 Layout

The schematic arrangement of components in the 20-MeV funnel is shown in Fig. 3.8-5. Each leg of the transport region consists of 14 EMQs and eight conventional two-gap 805-MHz bunchers . These elements transport the beam with about the same transverse and longitudinal focusing strengths as that at the exit of the DTL. The funnel legs are designed with 805-MHz bunchers operating at the second harmonic of the beam, resulting in smaller cavities and savings of power and space in a fairly tight configuration. The last of the two-gap buncher cavities in each leg has a special tapered geometry to enable the bunchers in the two adjacent legs to fit together. The last quadrupole in each leg that precedes the tapered buncher cavity is made of permanent magnet material for compactness, while the final quadrupole in the merge section in front of the deflector cavity is a large-bore EMQ with both beams entering off-axis. The beam from each DTL enters the funnel section at an angle of 2.5°. The first four bending magnets bend the beam further toward the common axis by an additional angle of 26.17°, making the total angle of approach 28.67°. The second set of four dipole magnets bends the beam in the opposite direction by 26.17°. The common large-bore EMQ (where the beams enter off-axis) deflects the beam an additional 1.5°. The remaining 1° of bend to merge the beams on-axis is done in the rf deflector cavity. A detail layout near the merge section is shown in Fig. 3.8-6. The parameters that specify the funnel components are given in Table 3.8-3.

The engineering issues that are important in the design of a funnel mainly involve providing adequate space for components. A complete design and beam dynamics through the funnel have not been completed. However, the feasibility of funnels is supported by previous experiments (Johnson 1992; McDonnell Douglas 1991) and designs. A design at 20 MeV for proton beam (Chan 1994) completed in 1994 for the Accelerator Performance Demonstration Facility project is a good example of a similar design.

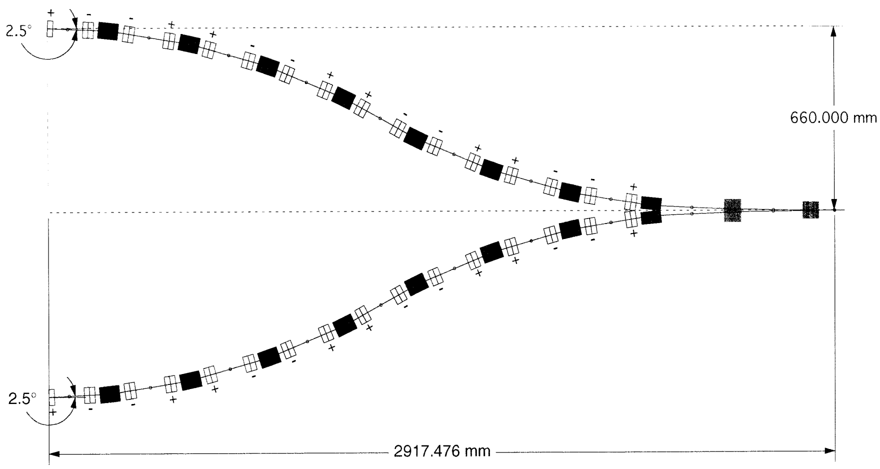

Fig. 3.8-5. Layout of the 20-MeV funnel.

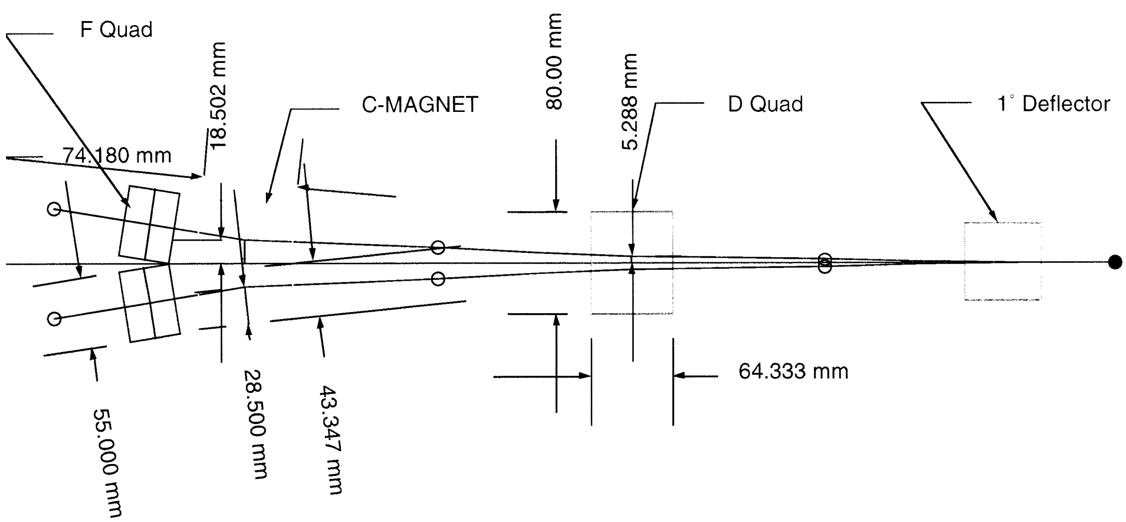

Fig. 3.8-6. Detail layout near the merge section of the funnel.

Table 3.8-3. Funnel general parameters

Energy (MeV)	20.0
Frequency (MHz)	402.5/805.0
Length (m)	2.9
No. of EMQs	$2 \times 14 + 1 = 29$
No. of PMQs	$2 \times 1 = 2$
Total no. of quadrupoles	31
No. of dipoles	$8 \times 2 = 16$
No. of bunchers	$9 \times 2 + 2 = 20$
No. of deflectors	1
Initial beam approach angle (deg)	2.5
Initial separation of beams (cm)	132.0
Quadrupole lattice	FOFODODO
Quadrupole lengths (cm)	4.0

3.8.4.3 Rf Buncher

The buncher cavities that would be used in the NSNS funnel are two-gap cavities with drift tubes. The bunch frequency of the beam on each leg of the funnel is 402.5 MHz; however, the bunchers operate at 805 MHz. The higher frequency allows for a smaller structure that fits into the drift space between the quadrupole focusing magnets and the space where the two legs of the funnel come close together. This constraint eliminates consideration of a single-gap, 402.5-MHz buncher in the funnel. Note that there is no difference in the beam dynamics between a 402.5-MHz and a805-MHz buncher. Therefore, in the present design, we have used only 805-MHz bunchers. Three distinct rf buncher cavity designs are to be incorporated into the funnel. Sketches of all three geometries are shown in Figs. 3.8-7 and 3.8-8.

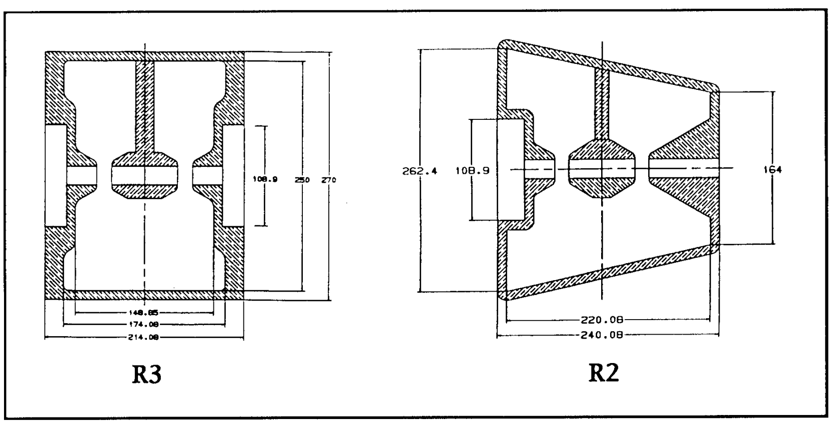

Fig. 3.8-7. Normal and tapered two-gap funnel-buncher cavity geometries.

Normal Geometry　　Tapered Geometry

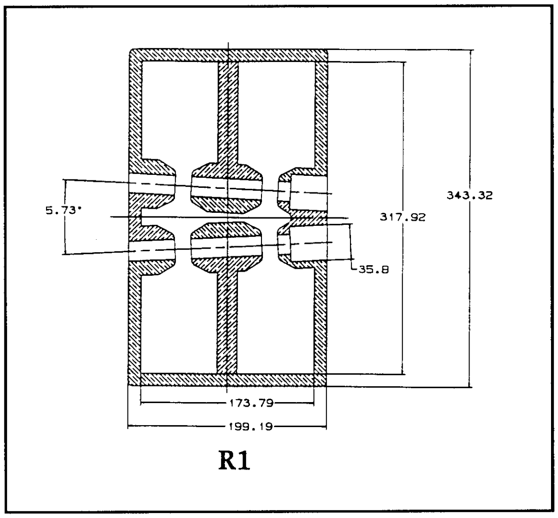

Fig. 3.8-8. Two-hole, two-gap special geometry buncher-cavity.

Figure 3.8-9 shows a SUPERFISH eld line plot of the untapered two-gap buncher, and Fig. 3.8-10 shows the same for the tapered two-gap buncher. Although the code indicates that the maximum power dissipation per unit area for the bunchers occurs on the walls of the drift tube, in the actual structure, the maximum power dissipation will occur at the joint of the drift tube and its support stem (not included in the SUPERFISH calculation). The peak power dissipation at this joint, averaged around the stem, will be approximately double the maximum value of that at the boundary.

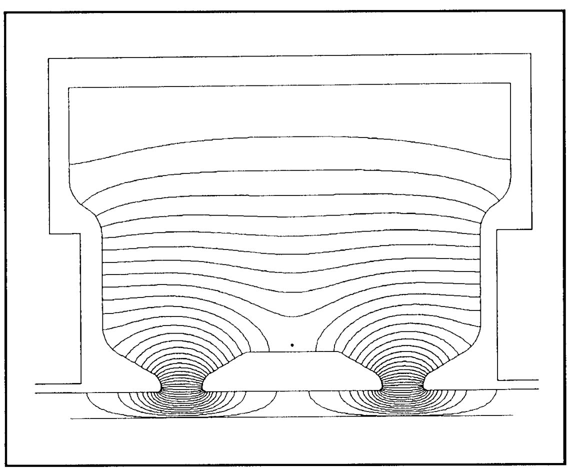

Fig. 3.8-9. SUPERFISH computed field lines for untapered, two-gap, 805-MHz buncher-cavity.

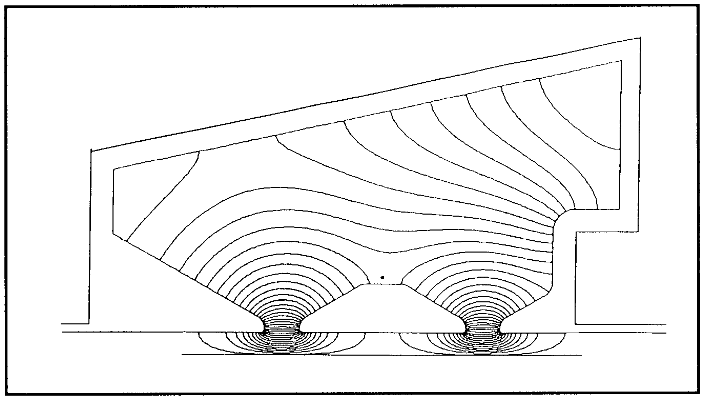

Fig. 3.8-10. SUPERFISH computed field lines for tapered, two-gap, 805-MHz buncher-cavity.

The tapered buncher is used where the two legs of the funnel are so close together that the normal geometry will not fit. Because the two legs of the funnel are mirror images of each other, no element may extend past the centerline—hence the need for the tapered buncher geometry.

Both Figs. 3.8-9 and 3.8-10 show the cross section of cylindrically symmetric cavities. The axis of rotation is at the bottoms of the figures. The SUPERFISH output indicates that the power consumption and peak power dissipation of the tapered buncher are approximately double that of the untapered buncher. The power is higher for this buncher since the gap voltage required is higher.

The two-hole, two-gap buncher shown in Fig.3.8-8 is located where the two legs of the funnel are very close together. In this case, a common cavity is used as the buncher on both legs. This buncher cavity has two beamlines through it and may be best described as a DTL with two beamlines. Since this cavity is not cylindrically symmetric, SUPERFISH cannot calculate its exact properties. Using SUPERFISH on an equivalent cavity that has cylindrical symmetry, however, we can calculate some properties. The equivalent cavity is one that has the same capacitance as the two-beamline cavity. It also has the same cross sectional area of the drift tubes. The SUPERFISH output lists the properties of the equivalent cavity, which can be compared with the 3-D MAFIA code calculation.

The power loss densities were also calculated using MAFIA (3-D). The 2-hole buncher geometry as modeled in MAFIA is shown in Fig.3.8-11. For this analysis, the cavity is aligned with the grid, and the drift tubes are tilted from their actual orientation so that each drift tube also aligns with the grid.

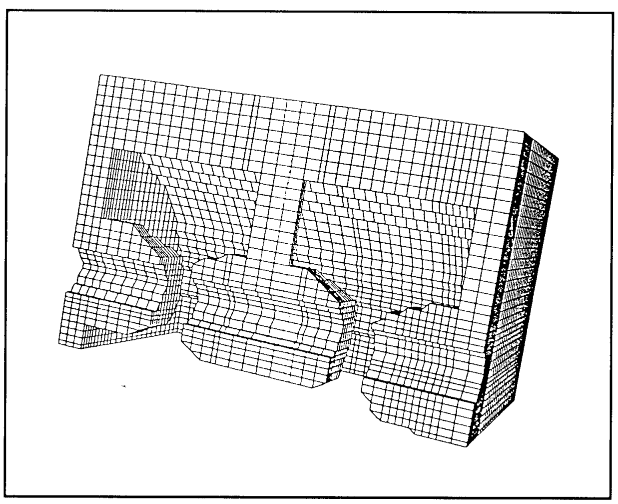

Fig. 3.8-11. MAFIA 3-D plot for one-fourth of the two-hole buncher-cavity.

The results of such analysis should be reasonably good for estimating power densities in the areas where they are expected to be highest. Electric fields near the beamline, however, are not expected to be accurate using the approximations made here. Detail analysis of such a structure needs to be performed using a different set of approximations that will give better accuracy near the beamline. Because of its symmetry, only one-fourth of the structure was modeled. Fig. 3.8-11 is a 3-D plot of the model with the gridlines shown on the surfaces.